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Abstract book

LIST OF SESSIONS

- **Paleoenvironments**
- **Aerodynamics and sediment transport**
- **Anthropogenic Interactions**
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SESSION

« Paleoenvironments »

AEOLIAN DUNES OF CENTRAL SWEDEN

M. Bernhardson[1] & H. Alexanderson[1]
[1]*Lund University, Lund, Sweden*

Key words inland dunes, LiDAR, GIS, OSL dating, Holocene, Sweden

Central Sweden is home to a number of relict dune fields. They often pass unnoticed due to their considerable vegetation cover at the present day. With the help of state-of-the-art methods, such as LiDAR (light detection and ranging) based remote sensing and optically stimulated luminescence (OSL) dating, we are able to use these aeolian deposits as a palaeoenvironmental archive [1-3].

These aeolian dunes are strongly linked to the presence of glaciofluvial and glaciolacustrine deposits, with the largest dune fields in Sweden being superimposed on glaciofluvial deltas [2]. These dunes are mainly of a transverse type; some formed close to local deglaciation, whereas others formed millennia later. All in all we appear to have had a predominant dune building and dune stabilisation period in south-central Sweden around 10.5-9.0 ka; this is across an area with an age span of 4 000 years for local deglaciation [4]. This suggests that the dune formation and stabilisation of the dunes were due to regional environmental conditions.

By determining the net sediment transport directions from these inactive dunes we have inferred the general surface wind patterns that led to their formation. The transverse dunes were mainly formed by westerly and north-westerly winds, in contrast to some previous hypotheses that suggested formation of these dunes by north-easterly winds from the anticyclone over the Scandinavian Ice Sheet, e.g. [5].

Figure 1. Aeolian dune at Skattungheden, Dalarna County, Sweden.

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LAST GLACIAL AEOLIAN LANDFORMS AND DEPOSITS IN THE RHONE VALLEY (SE FRANCE): SPATIAL DISTRIBUTION AND GRAIN-SIZE CHARACTERIZATION

M. Bosq[1], P. Bertran[1,2], J.-P. Degeai[3], S. Kreutzer[4], A. Queffelec[1], O. Moine[5], E. Morin[6,7]
[1]*De la Préhistoire à l'Actuel : Culture, Environnement et Anthropologie, Pessac, France*
[2]*Institut National de Recherches Archéologiques Préventives, Bègles, France*
[3]*Archéologie des sociétés Méditerranéennes, Montpellier, France*
[4]*Institut de Recherche sur les ArchéoMATériaux – Centre de Recherche en Physique Appliquée à l'Archéologie, Pessac, France*
[5]*Laboratoire de Géographie Physique : Environnements Quaternaires et Actuels, Meudon, France*
[6]*Institut National de Recherches Archéologiques Préventives, Valence, France*
[7]*Environnement Ville Société, Lyon, France*

Key words mapping of aeolian deposits, grain-size distribution, Last Glacial, LUCAS topsoil database, loess, southeast France.

In the Rhone valley, a north-south oriented Cenozoic rift in southeast France, thick Pleistocene loess deposits have been recognized since the beginning of the last century. These loess record, which are disconnected from the North European Loess Belt (NELB), are of significant interest to document the evolution of perimediterranean landscapes and environments during the Last Glacial. To overcome the poor precision of available aeolian distribution maps, aeolian deposits were mapped using the topsoil textural database provided by the Land Use and Cover Area frame Statistical Survey project (LUCAS) [1,2]. The grain-size distribution of aeolian sand and loess was first determined using 116 samples taken from surveyed outcrops. Then, the areas showing a similar grain-size composition were extracted from the LUCAS rasters. The resulting map reproduces the conventional maps correctly but suggests a more significant extension of loess, in better agreement with the known distribution of outcrops. The map shows that the distinctive morphology of the valley dominantly controls the distribution of aeolian deposits. The deflation-related landforms, i.e. yardangs, closed depressions (pans) and desert pavements, are widespread south of narrowings of the Rhone valley between latitudes 44°N and 45°N. They indicate palaeowinds blowing from the north/northwest. Aeolian sand, loessic sand, sandy loess and loess deposits successively spread on both sides of the Rhone river. The loess is characterised by a coarse texture (main mode around 60 µm), strong local thickness (> 10 m), limited extension and abundant bioturbation (rhyzoliths). This resulted may be explained by the persistence of a shrub vegetal cover during the coldest and driest phases of the Last Glacial, capturing the saltating and suspended particles close to the alluvial sources.

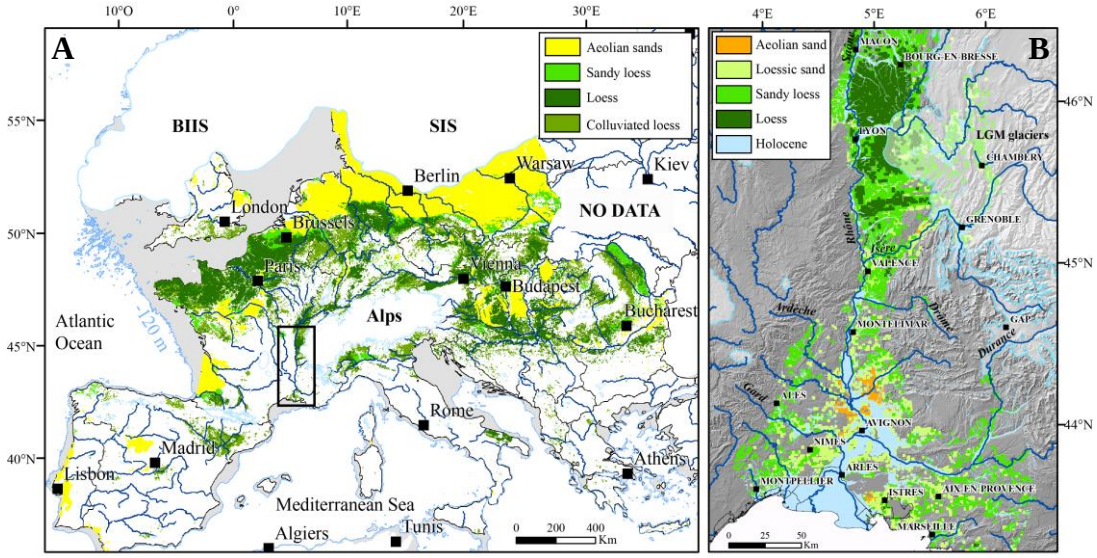

Figure 1. A) Distribution of aeolian deposits derived from the LUCAS topsoil database. B) Focus on the Rhone valley.

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Aeolian reactivation history of near-surface dune sediments at the Niobrara Valley Preserve, Nebraska Sandhills

CE. Buckland[1], RM. Bailey[1], DSG. Thomas[1]
[1]*School of Geography and the Environment, University of Oxford, Oxford, United Kingdom*

Key words Reactivation profiles, Nebraska Sandhills, OSL dating, dune sediments

Understanding the reactivation history of desert dunes is important in identifying the palaeoenvironmental drivers of change and the likelihood of future dune reactivations. Existing research in the Nebraska Sandhills has identified regional scale dune reactivations over centennial and millennial timescales during the Holocene, occurring at 9.6-6.5 ka, 3.8 ka, 2.5 ka and most recently spanning the Medieval Climatic Anomaly 1050-650 years BP [summarised in 1]. Over these timescales, episodes of aeolian reactivation, as identified in the dune sedimentary record, have been considered palaeoclimatic records of intense aridity lasting for periods of at least a decade [2]. However, the extent of shorter partial near-surface sediment reactivations over more recent timescales, during which human occupation of the Sandhills has grown, is unknown. Without a high-resolution record of historical dune system responses over these shorter timescales, it is not possible to identify and quantify the drivers of localised aeolian reactivation and environmental susceptibility to driving forces.

Recent developments in optically stimulated luminescence (OSL) methods allowing the routine dating of young sediments, coupled with the use of novel techniques to identify the geochronological structure of sediment profiles (e.g. changepoint analysis [3]), now permit the reconstruction of high-resolution aeolian reactivation histories of near-surface dune sediments. Capturing a high-chronological and spatial resolution of surface sediment movement over recent decades allows us to identify dune system response to disturbance forces in the context of a known and measured environmental history. Here we present reactivation history profiles for near-surface dune sediments in the northern limits of the Nebraska Sandhills at the Niobrara Valley Preserve. Results show peaks in surface sediment reactivation across all dunes studied during the 1890s AD and 1940s AD, with spatial heterogeneity in the luminescence results suggesting that both regional (i.e. climatic) and local (i.e. land use) forcings contribute to surface disturbance.

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THE FORMATION OF LOW-ANGLE EOLIAN STRATIFICATION THROUGH THE MIGRATION OF PROTODUNES

J. Phillips[1], R. C. Ewing[1], R. Bowling[1], B.A. Weymer[2], P. Barrineu[2], J.A. Nittrouer[3], & M.E. Everett[1]
[1]*Texas A&M University, College Station, TX, USA*
[2] *GEOMAR – Helmholtz Centre for Ocean Research Kiel, Germany*
[3]*Rice University, Houston, TX, USA*

Key words protodunes, pattern formation, emergent behavior

Protodunes are low-relief, slipfaceless migrating bed forms that represent the emergent form of eolian sand dunes. Protodunes develop as cm-scale topography out of a flat bed of sand and evolve spatially and temporally into dunes with angle-of-repose slipfaces. Protodunes at White Sands Dune Field in New Mexico form at the upwind, trailing margin of the field, on dune stoss slopes, and in interdune areas. Here we analyze protodunes at the upwind margin of White Sands by coupling 200 MHz ground penetrating radar (GPR) with time-series high-resolution topography to characterize the origin and evolution of protodune stratification and the stratigraphic transition into fully developed dunes. We surveyed a 780m transect in the resultant transport direction of the dune field from SW to NE from sand patches through protodunes and into the first dune. We used airborne lidar surveys and structure-from-motion photogrammetry from 2007, 2008, 2009, 2010, 2015, and 2016. We find that protodune stratification forms at angles between 0-10 degrees by protodune migration. Dip angles increase as protodune amplitude increases along the transect. Accumulation of low-angle stratification increases across the first ~650m and ranges from none to subcritical. Nearly aggradational accumulation of low-angle stratification occurs over the last 100m and is a precursor to angle-of-repose slipface formation. The origins of the aggradation and slipface development appear to be linked to protodune merging, dune interactions, and possibly to the development of a dune field-scale boundary layer. Protodunes and the formation of low-angle stratification at the upwind margin of White Sands are a good analog to the initiation of dune field development from sand sheets and the formation of low-angle stratification found at the base of eolian successions in the stratigraphic record.

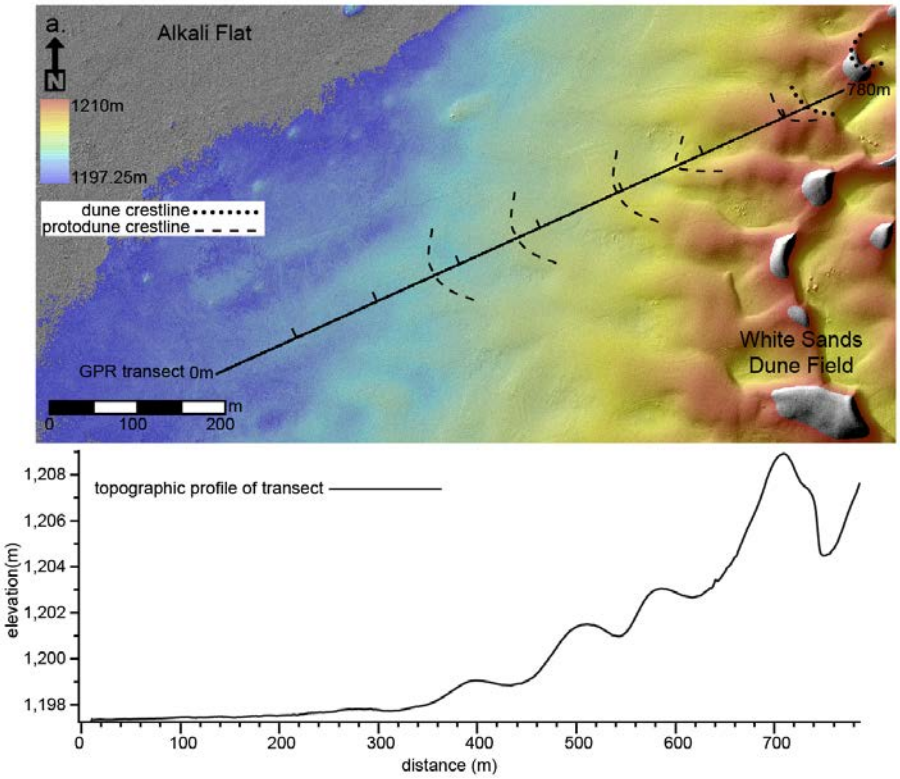

Figure 1. Spatial evolution of protodunes at the upwind margin of White Sands Dune Field, USA

THE MODERN-SAND LESSON: PROVENANCE AND ULTRALONG SEDIMENT DISPERSAL AS DOCUMENTED IN ARABIAN AND SOUTHAFRICAN SAND SEAS

E. Garzanti[1], P. Vermeesch[2], K.A. Al-Ramadan[3], P. Dinis[4], S. Andò[1], M. Limonta[1], A. Resentini[1] & G.Vezzoli[1]

[1]*Laboratory for Provenance Studies, Department of Earth and Environmental Sciences, Milano-Bicocca University, Italy*
[2]*London Geochronology Centre, Department of Earth Sciences, University College London, UK*
[3]*King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia.*
[4]*IMAR-CMA Centro do Mar e Ambiente, Departamento de Ciências da Terra, Universidade de Coimbra, Portugal*

Key words: Sand petrography; Heavy minerals; Detrital zircon geochronology; Sediment dispersal; Rub' al Khali and Namib deserts.

We used petrographic, heavy-mineral, and geochronological signatures of sand-sized grains to trace provenance, multistep dispersal pathways, and ultralong-distance sediment transport in hyper-arid tropical climatic conditions of the northern and southern hemispheres. In the Middle East, feldspatho-quartzo-lithic orogenic detritus shed by the Anatolia Plateau and Zagros Mountains - including carbonate, chert, volcanic, metabasite, and ultramafic lithic grains with a rich epidote-amphibole-pyroxene-garnet heavy-mineral suite - was carried to the Arabian-Gulf foreland basin via the Euphrates-Tigris-Karun fluvial system and other rivers draining the Zagros and blown inland by dominant Shamal winds to reach well into the Arabian foreland. Sediment dispersal over a cumulative distance of up to 4000 km took place in multiple steps, involving extensive eolian reworking of older deposits during lowstand stages of the Pleistocene before final accumulation in the Rub' al Khali sand sea.

In southern Africa, sand derived from the Orange River is dragged by swell waves and persistent southerly winds to accumulate in four successive dune fields along the Atlantic coast of Namibia and southern Angola. All four dune fields are terminated by river valleys, where aeolian sand is flushed back to the ocean. And yet sediment transport continues at sea, tracing an 1800 km-long submarine sand highway. Sand drift would extend northward to beyond the Congo if the shelf did not become progressively narrower in southern Angola, where the Orange fingerprint - characterized by basaltic rock fragments, clinopyroxene, and bimodal zircon-age spectra with peaks at ca 0.5 and 1.0 Ga - is lost abruptly, indicating that drifting sand is funneled towards oceanic depths via canyon heads connected to river mouths. Understanding the complex transfer of huge detrital masses on the Earth's surface, and mixing of sediments derived from different sources along successive tracts of a composite routing system that may cover cumulative distances of thousands of kilometers across climatic and tectonic boundaries over time periods of millions of years, is essential to enhance the resolution of source-to-sink studies and avoid gross oversimplifications in paleogeographic reconstructions.

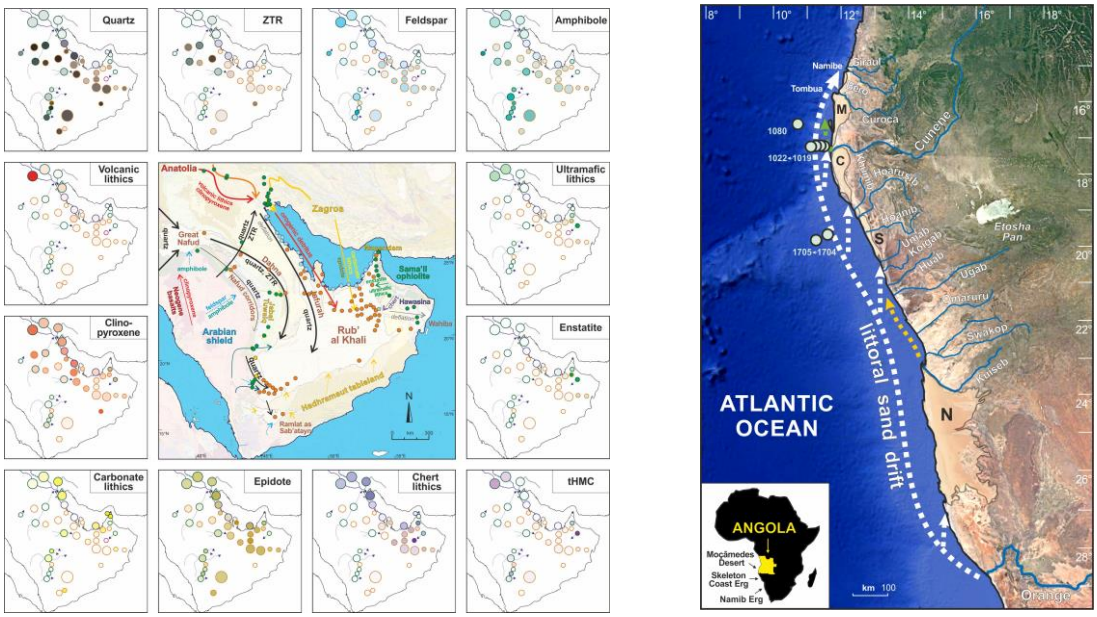

Figure 1. Sediment dispersal across Arabia and along the Atlantic coast of southern Africa (after Garzanti et al., 2017, 2018).

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Holocene coastal dune evolution in Western France: reconstruction from archaeological data

A.Gorczynska[1], P.Stéphan[2], Y. Pailler[3], B. Le Gall[1]

[1]*Laboratoire Géosciences Océan, Université de Bretagne Occidentale, Plouzané, France*
[2]*Laboratoire LETG, CNRS, Plouzané, France*
[3]*INRAP Grand Ouest, Laboratoire Trajectoires, Université Paris 1, Paris, France*

Key words: Coastal dune, Holocene, archaeology,

The long-term evolution of coastal dune barriers is controlled by variations in sediment supply, relative sea-level (RSL), wind energy, vegetation cover, anthropogenic forcing (1). Based on stratigraphical, geomorphological and chronological investigation of sand drift, numerous works highlighted the link between episodic sand invasion and changes in climate conditions (enhanced storminess) along the Atlantic coasts of Europe. While well-constrained chronologies of Holocene dune accretion were reconstructed in Portugal, Spain and Ireland, the data available for the French Atlantic coast are limited to the Aquitaine dune complex (SW France). This lack of data is mainly due to the absence of well-developed palaeosoils interbedded into the aeolian sand deposits, especially in Brittany where only thin humic layers are preserved into the coastal dune sediment records.

In this paper, we propose an alternative approach based on the use of archaeological information available in the coastal dunes of Brittany. Located in the most western part of the Atlantic coast of France, the Brittany peninsula is characterized by a limited sand supply from rivers and from soft cliff retreat. Consequently, the offshore sedimentary cover is thin and the shallow waters are dominated by rock outcrops. The coastal sediment accumulations usually form single-ridge sandy barriers, topped with a thin dune, isolating brackish lagoons, salt-marshes or small-size infilled valleys. However, some coastal dune complexes extend more than 2 km inland, consisting of foredunes and artificially stabilized dune fields where a high density of well-conserved archaeological sites were excavated from the end of the 19th century. These widely available archaeological data were used as chronological indicators to reconstruct the coastal dunes evolution during the last 7000 years at a regional scale.

From a re-evaluation of the archaeological documentation, 236 archaeological sites distributed along the Brittany coastline were selected to provide accurate information in terms of dune stratigraphy and chronology. Three main phases of aeolian activity were identified at a regional scale: Phase 1 dated from 1600 to 500 cal. BC, Phase 2 dated from 800 to 1400 cal. AD, Phase 3 dated from 1650 to 1850 cal. AD. A synchronicity is found between the North, West and South coasts of the Brittany peninsula and suggests that periods of sand dune invasion were triggered by a series of regional forcings, involving a decreasing RSL rise, significant changes in the coastal sediment budget and palaeogeography.

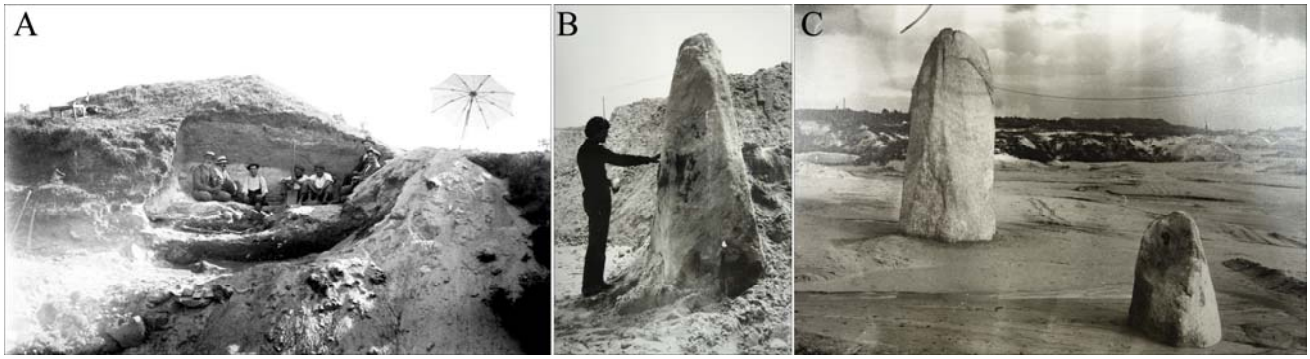

Figure 1. Examples of archaeological sites discovered in dune contexts. A. Excavations of the necropolis of Saint-Urnel (Plomeur, Finistère), 1923-1924 [3]; B. and C. Megaliths discovered in the dune field of the Bay of Audierne (Kerharo, Plomeur, Finistère) 1978-1978.

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Extended (>80ka) record of aeolian landform development in the Cady Mountains: implications for the Mojave Desert, U.S.A.

A. Hay[1], M. Powell[1], A. S. Carr[1] & I. Livingstone[2]
[1]*University of Leicester, Leicester, UK*
[2]*University of Northampton, Northampton, UK*

Key words aeolian landform development, morphological typology, luminescence dating

Observations of aeolian morphological response to an environment of complex bedrock topography within the Mojave Desert, California, identified a typology of three landforms. In many locations these aeolian sediments can be identified as landforms which coalesce into what appears to be a broadly continuous (albeit spatially variable) cover across much of the landscape. It is unknown, however, how these landforms have developed over time and thus how they relate both to each other and to the wider regional conditions under which they formed. A series of ages derived using luminescence dating indicate that the aeolian system has operated across the majority of the last 80ka. Ages range from 3ka to 80ka, but show no pattern with the three landform types. The existence of a palaeosol with carbonate accumulation along the northern boundary of the mountain block, coincident with a break in the luminescence chronology between 30-11ka, suggests a hiatus in aeolian activity and a period of stability around the time when palaeo Lake Manix reached its last high stand. These results highlight how, after deposition, such topographically-anchored aeolian deposits can be (though are not necessarily) highly persistent features within the landscape, with their preservation potential being related to their host accommodation space. Furthermore, many of these deposits incorporate locally derived sediments, sometimes forming contemporaneously with aeolian sediments within a single sedimentary unit – thus many of the landforms are best described as sand ramps. Across this time, coarse-grained sediments appear as event-based and highly localised deposits which inter-finger with the predominantly aeolian sediments, indicating that the processes operated contemporaneously rather than switching between states of aeolian and hillslope process dominance. The above observations have implications for aeolian deposits within areas of complex bedrock topography and also the wider Mojave Region. Indeed they suggest that aeolian activity has been recorded for much longer than previously understood within the region and that this activity forms a broadly continuous history, rather than operating as discrete episodes of aeolian activity.

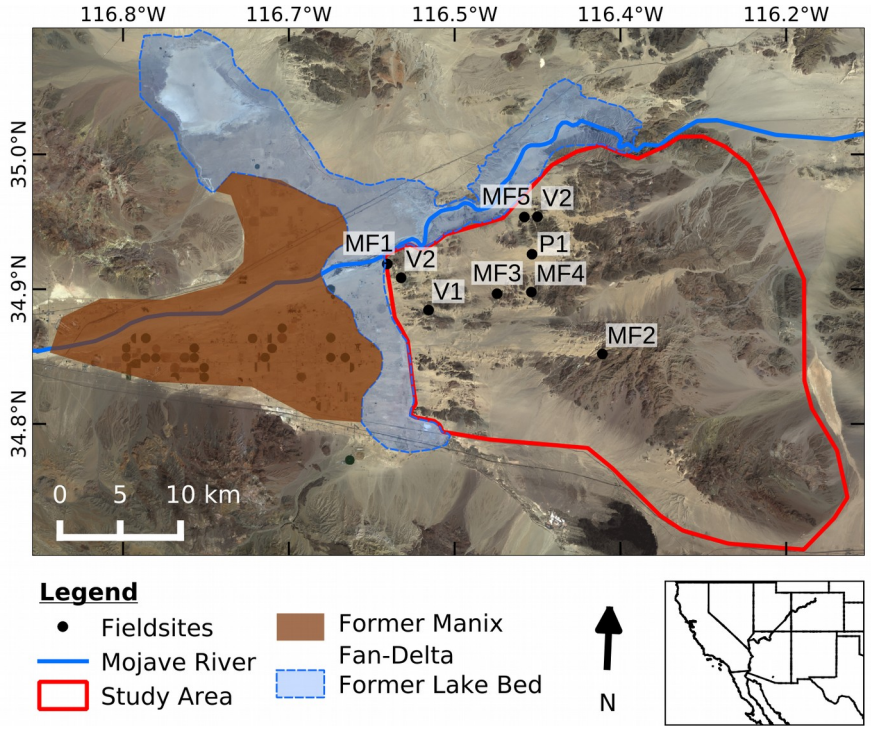

Figure 1. Map of the nine field sites discussed in this study. Landsat-8 image courtesy of the U.S. Geological Survey. Map data © OpenStreetMap contributors. Lake high stand data after Reheis and Redwine (2008).

POST-IR IRSL AND RADIOCARBON DATING OF LATE HOLOCENE VEGETATED DUNES IN THE QAIDAM BASIN, NE QINGHAI-TIBETAN PLATEAU

H. Shen, L. Yu, Z. Ding & P. An
College of Resources and environment, Linyi University, Linyi, China

Key words vegetated dunes; OSL dating method; K-feldspar; aeolian geomorphology; equivalent dose

Luminescence dating is the most important dating method for Late Quaternary aeolian sediments and has got widely application on aeolian sediments in the hyper-arid Qaidam Basin (QB). There are different types of dunes in the QB, e.g., linear dunes, barchan dunes, parabolic dunes, and vegetated dunes. These dunes are important archives for aeolian geomorphologic and palaeoenvironmental studies. These dunes were all formed during the arid late Holocene, and most of them are younger than 1 ka or even decades of years. This make it difficult to be dated with quartz, because the sensitivity of quartz on the Qinghai-Tibetan Plateau (QTP) are very low, i.e., without enough signal to get a precise age. Additionally, it's difficult to get pure quartz by SPT separation and HF etching, which might be caused by feldspar inclusion within quartz crystals. Consequently, to increase the quartz OSL signal by increasing the aliquot size will cause more feldspar contamination. The alternative method is to use the feldspar with high sensitivity. The vegetated dunes are composed of aeolian sand and vegetation residual, mainly fine branches of Tamarisk which fall during winter to spring, so the aeolian sand and vegetation residual should have the same depositional ages. This makes it possible to compare the luminescence ages with the precise ^{14}C ages and to check the reliability of luminescence ages. The aim of this study is to find a method of K-feldspar IRSL and post-IR IRSL dating to solve the problem of young dune sand dating in the QB, by comparing with their corresponding AMS ^{14}C ages.

Over 20 pairs of OSL and ^{14}C samples were taken from 12 vegetated dunes along the southern margin of the QB, including modern samples. Coarse grain (150-180 μm) K-feldspar and quartz were extracted with density liquid (SPT), and K-feldspar was not etched with HF. SAR protocol of $pIRIR_{180}$ (preheat at 210 ℃ for 60 s, stimulate with IR at 50 ℃ for 500 s, and then stimulate with IR at 180 ℃ for 500 s, without high temperature signal clear at the end of each cycle) are used to date the K-feldspar. These preheat and stimulation temperatures are chosen based on dose recovery, preheat plateau, residual dose (on modern samples) tests, recycling ratio and sensitivity change check.

The results show that: ① The vegetated dunes were accumulated since ca. 2.5 ka during the arid late Holocene when the sand supplement was adequate. ② The $IRSL_{50}$ and $pIRIR_{180}$ ages are the same after fading correction, and could be compared with ^{14}C ages within error, demonstrating the feldspar were sufficiently bleached and the dating method is reliable. ③All the BSL ages of quartz are younger than the AMS ^{14}C ages, $IRSL_{50}$ and $pIRIR_{180}$ ages by a few hundreds to over one thousand years, which might be because the BSL signals are too low to offer reliable ages.

These imply that the $pIRIR_{180}$ (including $IRSL_{50}$) dating of K-feldspar can offer reliable and accurate ages for late Holocene dune sand, and even for modern samples of decades of years. This offer the opportunity to date the young dunes and to reveal the detail dune accumulation processes for aeolian geomorphologic studies.

AEOLIAN-FLUVIAL INTERACTIONS STABILIZE DESERT IN THE QAIDAM BASIN, QINGHAI-TIBETAN PLATEAU

L. Yu
College of Resources and environment, Linyi University, Linyi, China

Key words OSL dating; dune dammed lake; ground water level; desert evolution; flood in desert

Floods are frequent in modern desert because the wadis of seasonal rivers are usually occupied by drift sands, and many cycles of dune sand and fluvial/flood-relevant sediments could be found in many deserts as well, indicating that the Aeolian-Fluvial Interactions (AFI) might have implications for desert evolution in history. The widely distributed AFI sediments were in and around the Tiekui Desert (TKD), eastern Qaidam Basin, NE Qinghai-Tibetan Plateau, and its surrounding oases indicate the former TKD has expanded to a much larger area, covered the regions where the modern towns/oases locate, and as well the river systems in these regions. These also imply that the AFIs should have severely influenced the evolution of the TKD and its surround oases.

Here we apply Optically Stimulated Luminescence (OSL) dating to establish the chronology of the AFIs in the TKD. Both quartz OSL dating and K-feldspar post-IR IRSL dating methods were used to date dune sands, dune dammed lake sediments, and dune dam breaching sediments. Over 50 OSL ages that most AFI happened during 130-1 ka, with most of the AFIs happened since the last deglaciation, and some during Marine Isotope Stage (MIS) 3b-3a and penultimate deglaciation (transition period of MIS6-5, ca. 130 ka). That is all the dated AFIs started with the beginning of deglaciation periods, i.e., transition periods from cold to warm stages.

The AFIs were caused by floods, resulting mainly from the blocked channels and increased flows. These two factors limited the periods to cold-warm transitions. During glacier or cold periods, the flows were very limited or absent, and the TKD expanded and occupied the wadis of rivers which across the TKD. When deglaciation started, the meltwater from glaciers and permafrost in the source regions of these rivers increased greatly, and precipitation also started to increase in early Holocene, however, the increased flow had no channels to cross the TKD, and alternatively, the rivers can only flow into the TKD as floods. The water from floods were trapped in the desert, forming dune dammed lakes, which can elevated ground water levels, deposited fine grain sediments, and increase vegetations. All these can reduce mobile sand source and stabilize the dunes. The migration of flood, rivers, and lakes were very slow, because the aeolian processes changed the morphology of desert constantly and blocked the new paved channels frequently, which prolonged the period of AFIs and increased the areas affected by AFIs. This is how and why AFIs can stabilize the whole TKD. Once the TKD was mostly stabilized, aeolian activities and AFIs decreased greatly. Then migration of rivers to cross the TKD became much easier and fixed channels were formed. Without the AFIs, the flows cannot stay in the desert, and the deep incised channel lower the ground water levels greatly, therefore the main effective water supply for the TKD is the limited precipitation. Worse more, the precipitation in the Qaidam Basin also decreased during the arid late Holocene, as a result, desert restarted to active.

Usually, the desert evolution is considered to be mainly controlled by palaeoclimatic changes, especially the precipitation changes, so desert evolution records could be applied to reconstruct paleoclimatic changes. However, our findings reveal that the TKD was mainly stabilized by the AFIs, which remind us to reevaluate which factor is more important for the desert stabilization. For the aeolian processes, the premise for AFIs is the wadis were occupied by the expanded desert during a long-term arid period, e.g., glacier period, which is controlled by climatic change. For the fluvial processes, the AFIs started since every deglaciation or warm period to provide enough flows, which was controlled by climatic change as well. That is the occurrence of AFIs were mainly controlled by climatic changes, e.g., glacier-inter glacier cycles. That is climatic changes provided premises for AFIs, however, the flowing AFIs controlled TKD's evolution directly. Here we emphasize the importance of geomorphology on the background of climatic changes. The climatic changes provided enough water, and the geomorphology controls redistribution of the water. The mobile 'desert dams' blocked the rivers for thousands of years, and the water contribution might be dozens or hundreds of times than its local precipitation. Consequently, desert evolution might not direct response to the climatic changes and might not suitable for paleoclimatic reconstruction in the TKD and many other deserts in the world.

SOURCES OF DUST AND DIRECTIONS OF ITS TRANSPORT ARCHIVED IN THE LOESS FROM POLAND AND UKRAINE

J. Nawrocki[1,5], A. Bogucki[2], P. Gozhik[3], M. Komar[4], M. Łanczont[5], M. Pańczyk[1], O. Rosowiecka[1], Z. Czupyt[1]
[1]*Polish Geological Institute – NRI, Warszawa, Rakowiecka 4, 00-975, Poland.*
[2]*Department of Geomorphology and Palaeogeography, Ivan Franko National University of Lviv, Lviv, P. Doroshenko 41, 79000, Ukraine.*
[3]*Institute of Geological Sciences, National Academy of Sciences of Ukraine, Kyiv, O. Gonchar 55-b, 01054, Ukraine.*
[4]*National Museum of Natural History, National Academy of Sciences of Ukraine, Kyiv, Bohdan Khmelnitsky 15, 01601, Ukraine.*
[5]*Faculty of Earth Sciences and Spatial Management, Maria Curie-Skłodowska University, , Lublin, Kraśnicka 2cd, 20-718, Poland.*

Key words: *magnetic susceptibility anisotropy, zircon isotope ages, loess, palaeogeography*

Measurements of the anisotropy of whole-rock magnetic susceptibility (AMS) and U-Pb ages of detrital zircons have been combined to define the palaeowind directions and sources of wind-blown dust in the loess-palaeosol sections in Poland and Ukraine. For the AMS studies more than 1000 geographically oriented cylindrical samples were taken from 22 loess sections located in the area between the Vistula and Dnipr rivers, and the Black Sea. The distribution of AMS axes in the different horizons of loess indicates that prevailing wind during their accumulation blew from the west and north-west, the same as the mean present-day summer wind in the studied area. In some sections, however, other directions of winds conditioned by local geomorphology were also defined. The isotope ages of zircon grains indicate that material from Carpathian and Podolian sources formed the loess from Poland, western and south-western Ukraine. In central Ukraine zircons were derived mainly from the local basement rocks. The loess material was initially transported by the rivers, then was wind-blown from their valleys.

Figure 1. Location of the studied sections on a shaded-relief map of Eastern Europe. Maximum extent of the Vistula Glaciation [1] and loess distribution [2] are presented. Relief model was adopted from [3].

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COULD LUMINESCENCE SIGNALS IN DUNE SANDS BE SUFFICIENTLY BLEACHED ?

P. An[1], L. Yu[1], R. Xu[1], Y. Wang[2], Z. Lai[3] & Z. Dong[4]
[1] *College of Resources and environment, Linyi University, Linyi, China*
[2] *Qinghai Institute of Salt Lakes, Chinese Academy of Sciences, 810008 Xining, China*
[3] *School of Earth Sciences, China University of Geosciences, 430074 Wuhan, China*
[4] *Tourism and Environment College, Shaanxi Normal University, 710119 Xi'an, China*

Key words OSL dating; k-feldspar; post-IR IRSL; grain-size; residual ages.

The choice of different dating grain-size fractions is an important question for Optically Stimulated Luminescence (OSL) dating, because different grain-size fractions might have experienced different transporting history and so as to have different bleaching extent. However, aeolian sediments are usually thought to have been well bleached before buried, and most grain-size fractions between 4 μm to 250 μm are usually used for OSL dating. The Qaidam Basin (QB) is an important region for aeolian geomorphologic studies, and OSL dating showed the linear dunes in the central QB were accumulated at 3.0-0.8 ka based on fine grain quartz [1]. To reveal the origin of these linear dunes, detailed OSL dating study were conducted with both coarse grain (150-180 μm) quartz and k-feldspar (KF). However, our BSL and fading-corrected IRSL ages based on coarse grains were all much younger than the former published fine grain BSL ages [1]. For example, some samples dated to ca. 3 ka by fine grains quartz were only dated to ca. 0.3-0.4 ka by coarse grain KF. This obvious difference might be caused by insufficient bleaching of the fine grain sediments. To reveal the bleaching (i.e., residual dose) of different grain-size fractions (4-11, 11-38, 38-63, 63-90, 90-125, 125-150, and 150-180 μm), six modern samples were taken from both linear dunes and barchan dunes in Qarhan Salt Lake region.

D_es from quartz BSL, KF $IRSL_{50}$ and post-IR_{50} $IRSL_{225}$ ($pIRIR_{225}$) were compared on each fraction of 4-11, 11-38, 38-63, 63-90, 90-125, 125-150, and 150-180 μm, respectively. The quartz BSL signals are the easiest to be bleached, while the KF $pIRIR_{225}$ signals the most difficult, so no residual $pIRIR_{225}$ signals indicate the sediments are sufficiently bleached. The results show that: ① KF ($pIRIR_{225}$) of >90 um fractions could be well bleached, and quartz of >38 um could be well bleached with ignorable residual dose; ② The fine grain (4-11 μm) sediments were poorly bleached, even the residual age of quartz could be nearly 3 ka, and residual ages of $pIRIR_{225}$ are about 5.5 ka with the highest values of over 25 ka for some aliquots.

This study indicates that even for the dune sand, OSL signals of the fine and medium grain-size fractions might be difficult to be sufficiently bleached, which could cause severely overestimation, especially for the Holocene samples. This might be because the finer grains are more likely to be transported as aggregates (or they are difficult to be deposited on dunes synchronously with coarse grains), and additionally, these fine grain aggregates were mainly eroded from the nearby old yardangs, i.e., short distance transport. As a result, the coarse grain-size sediments might be more suitable for OSL dating in most cases, and sources of sediments should be analysed as well.

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DUST DEPOSITS RULING PALEOSURFACES SEPARATING DUNE GENERATIONS ON NORTHERN FUERTEVENTURA

C.-B. Roettig & D. Faust

Dresden University of Technology

Key words Dust deposits, paleosurfaces, Canary Islands.

On the Canary Islands Pleistocene soil formation in dune sediments and colluvial layers is documented by many authors (Pomel et al., 1985; Coudé-Gaussen & Rognon, 1988; Bouab & Lamothe, 1995; Damnati et al., 1996; Menendez et al. 2007; von Suchodoletz et al. 2009; Faust et al., 2015). In different palaeo dune fields of northern Fuerteventura reddish layers (palaeosurfaces) separate several dune generations. For some decades features of these layers were always linked to soil forming processes. Albeit, in line with suggestions by Criado et al. (2012) our analytical results support the assumption of relating these red layers mainly to aggrading dust deposits. The in situ soil forming processes seem to be restricted to de- and recalcification processes and oxidation of iron and manganese. Extending Kruse & Meyer (1970) we assume the imprint of CaCO3-coated primary iron (as ingredient of dust) being leached after deposition and transformed to hematite, contributing to the reddening of the layers, finally. As a last consequence, the formation of palaeosurfaces in dune fields depends on decreasing sand supply. Therefore, periods of decreased sand supply originating from the shallow shelf to the benefit of Saharan dust imprint, have to be identified. On Fuerteventura mainly three driving forces ruling the sand supply of shelf origin have to be taken into account: 1. changing wind directions, 2. volcanic activity (cutting off dune fields from the sediments pathway), and 3. sea level changes. Hopefully, the different perspectives of aggrading soils and of dune formation on Fuerteventura (Fig. 1) will enforce the discussion about the informative content and interpretability of (unconsolidated) aeolianites in the lower latitudes, in general.

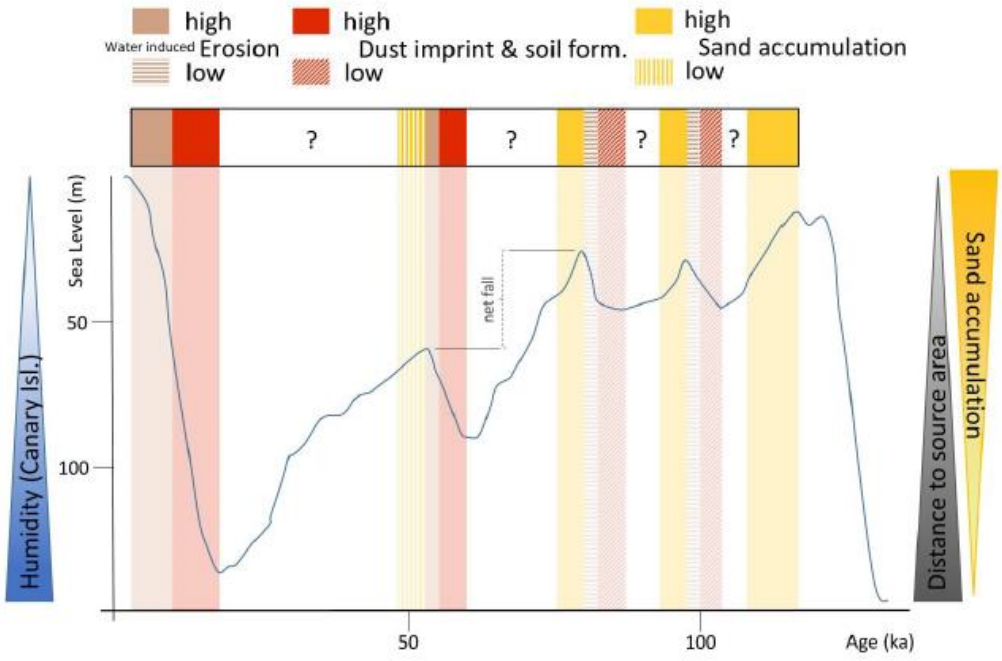

Figure 1. Conceptual approach of process relation to sea level fluctuation.

A LATE PLEISTOCENE LINEAR DUNE DAM RECORD OF AEOLIAN-FLUVIAL DYNAMICS AT THE FRINGES OF THE NORTHWESTERN NEGEV DUNEFIELD, ISRAEL

J. Roskin[1], R. Bookman[2], D. E. Friesem[3] & J. Vardi[4]

[1]*Department of Maritime Civilizations, Charney School of Marine Studies and the Leon Recanati Institute for Maritime Studies (RIMS), University of Haifa, Mt. Carmel Haifa, Israel*

[2]*Department of Marine Geosciences, Charney School of Marine Studies, University of Haifa, Mt. Carmel Haifa, Israel*

[3]*McDonald Institute for Archaeological Research, University of Cambridge, Downing Street, Cambridge CB2 3ER, UK*

[4]*Prehistory Branch, Excavations, Surveys & Research Department, Israel Antiquities Authority, Jerusalem, Israel*

Key words Aeolian-fluvial interactions; vegetated linear dune dam;; late Pleistocene-Holocene transition; Epipalaeolithic; dunefield margins

A late Pleistocene aeolian-fluvial record within a rare vegetated linear dune-like structure at the fringe of the northwestern Negev dunefield, Israel, provides direct evidence of dune-damming dynamics within the structure and its environs. Study methods included high resolution morphology and stratigraphy, micromorphology and sedimentological analyses. Chronology was based on eight archaeological sites from the structure, the INQUA Dune Atlas chronologic database and OSL ages. Low-energy fine-grained fluvial deposits (LFFDs) underlying the structure and extending from its flanks indicate deposition by low energy hyper-concentrated flows in a floodplain environment and later in water bodies that formed by dune-damming of a mid-sized drainage basin. Interbedded sand with fine-grained deposits within the linear structure indicates interchanging dominances between aeolian sand incursion and seasonal floods. Sand deposition during dune elongation led to structure growth and dune-damming of its drainage system that in turn formed water bodies and upstream fine-grained deposition following seasonal floods.

Calculations of current sediment yields indicate that fine-grained deposits accretion up to the structure's brim could possibly have rapidly occurred over a total time span of decades. However, artifacts dating to the Geometric Kebaran (~17.5-12.9 cal kyr BP) and Harifian (12.9-11.2 cal kyr BP) archaeological periods on the structure's surface indicates intermittent, repetitive, and short-term camping, utilizing adjacent water bodies over a time period of 4000-5000 years. Fluctuating high winds and precipitation during a time window of increased fluvial availability of fine-grained sediment from the hinterland generated ample fine-grained deposition. After ~11 cal kyr BP, the abundance and recurrence of dammed water bodies decreased when reduced wind power constrained dune-dam maintenance. After sediment accommodation space dissipated, fluvial flow of the drainage basin led to dune-dam destruction and partial fluvial erosion of the fine-grained deposits that continues today.

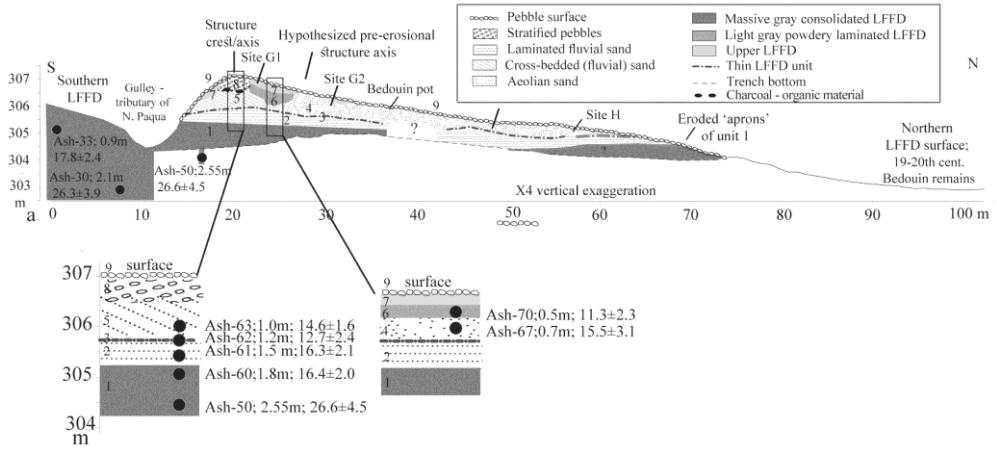

Figure 1. Cross-section of the vegetated linear dune-like structure that partly functioned as a dam. Sites G1, G2 and H revealed middle to late Epipalaeolithic remains.

TESTING PORTABLE LUMINESCENCE READER SIGNALS AGAINST LATE PLEISTOCENE TO MODERN OSL AGES OF COASTAL AND DESERT DUNEFIELD SAND IN ISRAEL

J. Roskin[1], D. Sivan[1], R. Bookman[2], N. Porat[3] & G. López[4]

[1]*Department of Maritime Civilizations, Charney School of Marine Studies and the Leon Recanati Institute for Maritime Studies (RIMS), University of Haifa, Mt. Carmel Haifa, Israel*

[2]*Department of Marine Geosciences, Charney School of Marine Studies, University of Haifa, Mt. Carmel Haifa, Israel*

[3]*Geological Survey of Israel, Jerusalem, Israel*

[4]*Luminescence Dating Laboratory, CENIEH, Burgos, Spain*

Key words Pulsed-photon portable OSL reader (PPSL); aeolian sand; OSL; Northwestern Negev dunefield, Israel coastal dunefields

Rapid assessment of luminescence signals of poly-mineral samples by a pulsed-photon portable OSL reader (PPSL) is useful for interpreting sedimentary sections during fieldwork and can assist with targeted field sampling for later full OSL dating and prioritize laboratory work. This study investigates PPSL signal intensities to assess its usefulness in obtaining relative OSL ages from linear regressions created by interpolating newly generated PPSL values of samples with existing OSL ages from two extensive Nilotic-sourced dunefields. Eighteen OSL-dated sand samples from two quartz-dominated sand systems in Israel were studied:

(1) the Mediterranean littoral-sourced coastal dunefields that formed since the middle Holocene;

(2) and (2) the inland north-western Negev desert dunefield that rapidly formed between the Last Glacial Maximum and the Holocene. Samples from three coastal dune profiles were also measured.

Results show that the PPSL signals differ by several orders of magnitude between modern and late Pleistocene sediments. The coastal and desert sand have different OSL age - PPSL signal ratios. Coastal sand shows better correlations between PPSL values and OSL ages. However, using regression curves for each dunefield to interpolate ages is less useful than expected as samples with different ages exhibit similar PPSL signals. The coastal dune profiles yielded low luminescence signal values depicting a modern profile chronology.

This study demonstrates that a rapid assessment of the relative OSL ages across different and extensive dunefields is useful and may be achieved. However, the OSL ages obtained by linear regression are only a very rough age estimate. The reasons for not obtaining more reliable ages need to be better understood, as several variables can affect the PPSL signal such as mineral provenance, intrinsic grain properties, micro-dosimetry and moisture content.

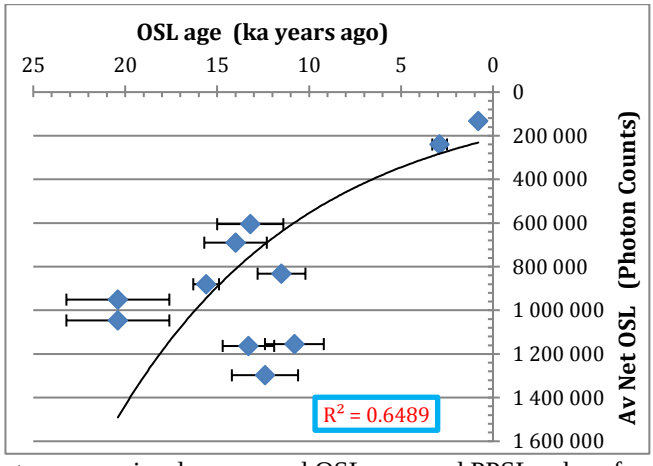

Figure 1. Exponential regression between previously measured OSL ages and PPSL values for the same subset of samples from the northwestern Negev dunefield. The dunefield does not have sand dating between 10-2 ka.

PAST and PRESENT PLOT-AND-BERM GROUNDWATER HARVESTING in AEOLIAN SAND AGROECOSYSTEMS

J. Roskin[1] and I. Taxel[2]

[1]*Department of Maritime Civilizations, Charney School of Marine Studies and the Leon Recanati Institute for Maritime Studies (RIMS), University of Haifa, Mt. Carmel Haifa, Israel*

[2]*Archaeological Research Department, Israel Antiquities Authority, P.O.B. 586, Jerusalem, 91004, Israel*

Key words aeolian sand; Early Islam period; Israel coastal dunefields; groundwater harvesting; Plot-and-berm agroecosystems

Overcoming the agricultural liabilities of the properties of loose sand is a challenge and necessity for increasing global food production. Few historical societies have tried to cultivate agriculture in aeolian sand bodies. The ones that have include interdune plantations by Arab peasants/Bedouin along the southeastern Mediterranean coastal sand in the 19th-20th century C.E. and the cultivation of maize and bean by Hopi Indian farmers in shallow vegetated sand sheets in southwest North America starting in the 16th century C.E.

"Plot-and-berm" (P&B) agroecosystems are sophisticated agricultural utilization of high-groundwater tables within loose, aeolian sand sheets that comprise agricultural hinterlands (Taxel et al., 2nd circ.). P&B agroecosystems contain earthworks of sunken agricultural plots in between 2-5 m high man-made sand berms. Such agricultural plots, which lie slightly above the groundwater table, usually make the groundwater easily accessible to crop roots and/or humans for water extraction. However, changes in the groundwater table due to climate change or anthropogenic influences can negatively affect the agricultural feasibility of P&Bs.

Plot-and-berm sand is enriched with refuse and organic material to produce productive sandy anthrosols. Berms are often also coated with anthropogenic refuse/fines and dry vegetation to protect them from aeolian erosion. It is hypothesized that surface irregularity and roughness resulting from the spatial P&B array reduces the overriding sand transport power. These factors combined enhance the preservation of such berms from aeolian erosion while protecting the sunken plots from burial by aeolian sand accumulation.

The study examines the morphometry, function, motivation, and development of archaeological to modern P&B agroecosystems around the Mediterranean basin. The earliest recognized Mediterranean agroecosystems are Early Islamic (8th-early 12th centuries C.E.) systems, located along the coastal zone of Israel. The P&B system may be an original type of mawāt (Arabic: "dead"), land reclamation, which is an important phenomenon in Islamic economic history. Known from Early Islamic juristic documents, mawāt means unowned wasteland. Islamic jurists prescribed rules for mawāt vivification and acquisition, which were typically cultivated using irrigation systems like qanats.

Some P&B agroecosystems in the Mediterranean basin date back to the Middle Ages, including: the Saharan Ghout with its multi-layered organization of date palms and fruit trees; the herbaceous crops (since the 15th century C.E.) of southeast Algeria (Boualem & Rabah, 2011); masseira or gamela on the northern coast of Portugal; Navazo in southern Spain (since the 18th century C.E) (Sánchez & Cuellar, 2016), and pre-modern mawasi in the southeastern Mediterranean coast. Ghout and mawasi agriculture, which are still practiced today, use mechanized water drilling and modification of berm and soil surface level in response to fluctuating water table levels, often inflicted by humans.

The modern agroecosystems in the Mediterranean basin may be an inherited or revived form of the possibly original Early Islamic effort found in coastal Israel, which were abandoned for reasons unclear. We can speculate whether such biocultural memories were transmitted continuously across the (mainly Islamic) Mediterranean populations from the 12th to the 19th centuries C.E. Finally, P&B agroecosystems remind us that sand bodies have potential for future agricultural exploitation.

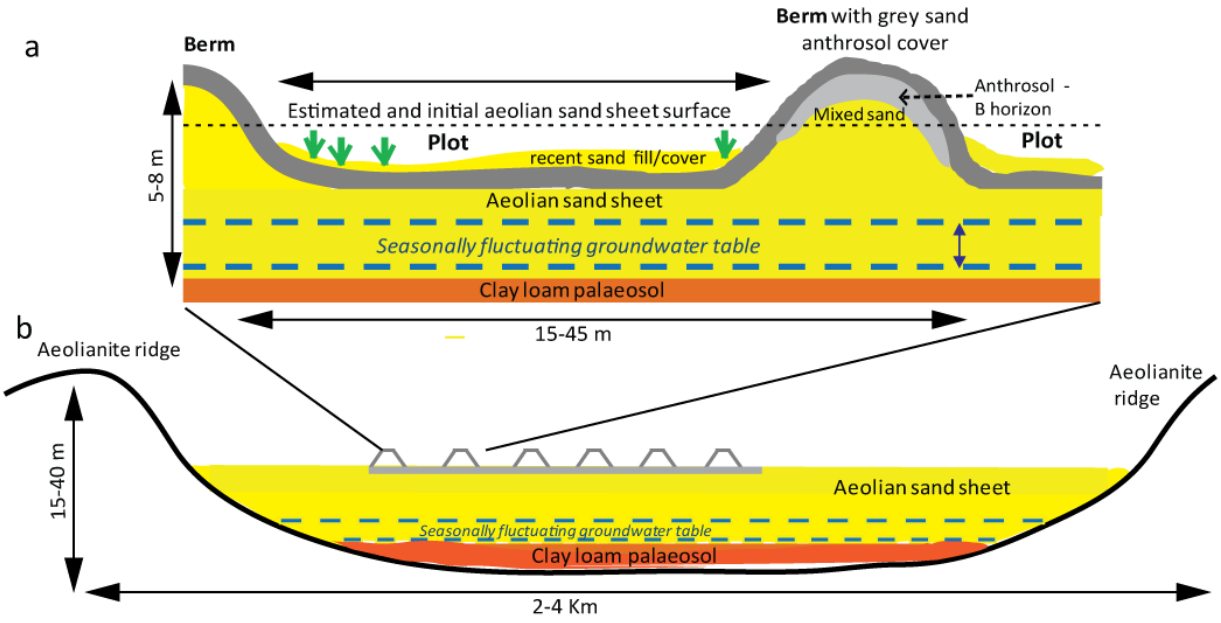

Figure 1. Schematic stratigraphic cross sections of plot and berm agroecosystems at (a) site level (modified after Porath 1975) and (b) situated in sand sheet between aeolianite ridges (Yavneh dunefield, Israel).

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TEXTURE AND STRUCTURE DIAGNOSTIC FOR EOLIANITES, EXAMPLE FROM THE ATLANTIC COAST, SOUTHERN MOROCCO

E. Niklas, J. Rotnicka
Insitute of Geology, Adam Mickiewicz University in Poznań, Poland

Key words eolianites, texture and structure, early diagenesis, southern Morocco

The term „eolianites" highly evolved in the XXth century [1] and recently they are usually defined as the rock of aeolian origin composed of carbonate grains partly or totally cemented by carbonates [2]. They are formed in coastal areas by wind-driven accumulation of carbonate debris of shallow marine origin. Contrary to their siliclastic counterparts they undergone early meteoric diagenesis that made their preservational potential relatively high. Due to their composition, eolianites have been mistaken with deposits of high energy subtidal shoals [2]. Therefore texture and structure of the eolianites are the key to distinguishe them from shallow marine deposits of similar composition.

The research focused on eolianites exposed in cliff at Aglou Beach at the Atlantic coast of southern Morocco, about 100 km south of Agadir. Studied section of eolianites was up to 6 m thick. The field work included texture and structure description, measurments of angle and azimuth of the dip of cross strata, and collection of up-down oriented samples. The composition of eolianites and their textures were further examined in thin sections under the microscope.

Studied eolianites occured in cross-laminae sets whose thickness was in the range between 1.5 and 2 m. The dip angle of cross laminae varied between 10° and 22°, whereas dip azimuths indicated that alongshore, north-easterly winds were responsible for deposition of the major part of sand preserved in studied sedimentary section. Microscope analysis showed that the grain framework of eolianites was dominated by bioclasts, such as foraminifera and fragments of bryozoans, crinoid stems, brachipods and bivalves shells. Other components included quartz and feldspar grains, peloids, lithoclasts and heavy minerals. Grains were angular to subangular and poorly sorted. The verticalization of grains, which is post-depositional features of eolianites formed by grain reorientation due to percolating meteoritic water, was poorly identifiable. The pin-stripe lamination, the other feature considered as diagnostic for eolianites [1], was not observed. It was probably due to poor sorting caused by abundant bioclasts, which had lower density than quartz grains, and therefore wind with a given speed could simultaneously transport grains of various size [1]. Studied eolianites had a high porosity. Type of cements recognized included circumgranular cement, drusy mozaic and grains mozaic cements, all indicating diagenesis in meteoric-vadose zone [3].

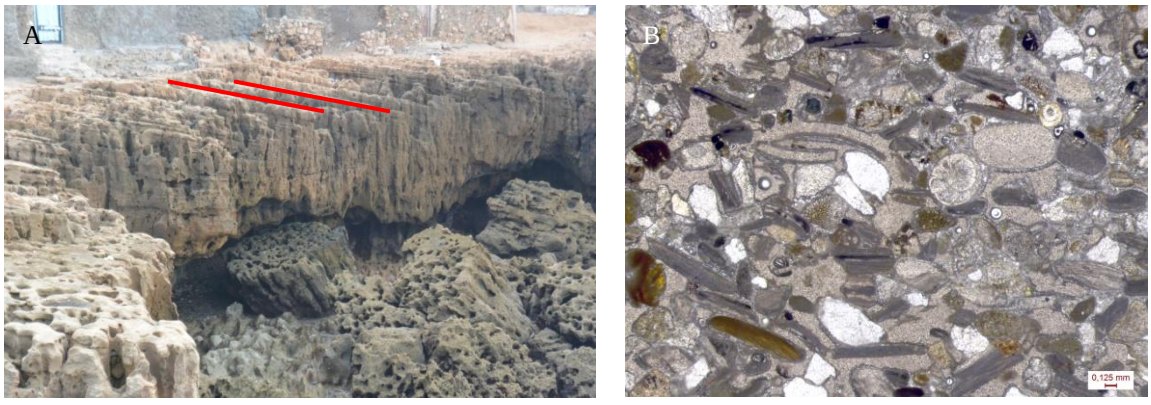

Figure 1. A – The uppermost part of the cliff built of cross-bedded eolianites, B – composition of studied eolianites under polarized light.

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Revising and Extending Late Quaternary Dune Accumulation Histories in the Thar Desert, India.

A.Srivastava[1], J.A. Durcan[1] & D.S.G. Thomas[1]
[1]*School of Geography and the Environment, University of Oxford, OX1 3QY, United Kingdom*

Key words Thar Desert; luminescence dating; late Quaternary; geomorphological change; palaeoclimate.

The Thar Desert in north-west India lies at the limit of the region receiving precipitation from the Indian monsoon. It is generally accepted that insolation driven changes in monsoon intensity have affected desert contraction and expansion during the late Quaternary, impacting on the construction and accumulation of aeolian landforms [1,2]. Observation of dune alignment using remotely sensed imagery has shown that regionally, dunes are closely aligned with the prevailing wind direction of the southwest monsoon system. Previous studies have suggested that aeolian accumulation occurs within limited time windows, when an optimal balance between wind and vegetation is reached and maintained [3]. Therefore, the Thar dune systems potentially provide a rich archive of past climatic and geomorphological change.

To investigate this, systematic sampling of dune fields was carried out in different parts of the desert. The field sites were selected considering their locations along the mean rainfall gradient and their relation to the sediment depositional styles for an optimum understanding of the resolution and duration of aridity record. Optically stimulated luminescence (OSL) dating was carried out to these samples to establish chronologies with an aim to infer the sensitivities of dunes to the changes in environment in the past, and different time scales over which they register and preserve the palaeoenvironmental record.

The results have shown that the east-central part of the Thar Desert, which previously lacked any Holocene dune record, witnessed multiple phases of dune accumulation after Last Glacial Maxima (LGM), which continued through Holocene Climatic Optimum (HCO) and Little Ice Age (LIA). The dunes in the region show records of rapid net accumulation in last 70 years, primarily due to anthropogenic reasons, with rates varying between 2m/year to 6m/year. The geochronology and field observations also show that the parabolic dune systems in the region have experienced a multi-tiered evolutionary history and are presently observed constituting configurations of barchanoids. Preliminary results from the northern margin of the desert also hint at an intensive dune activity in the Holocene. It is anticipated that the analyses of the entire datasets of luminescence ages from the desert will potentially change the interpretation of dune accumulation histories and permit the assessment of the roles of human pressure, changing sediment supply and/or monsoon intensity in the late Quaternary development of the Thar Desert.

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UTILISING A PORTABLE LUMINESCENCE READER FOR RAPID AGE ASSSESSMENT IN AEOLIAN SEDIMENTARY ENVIRONMENTS

A. Stone[1], M. Bateman[2], S. Burrough [3], E. Garzanti[4], M. Limonta[4], G. Radeff [4], M. Telfer[5]

[1]*Department of Geography, SEED, University of Manchester, Manchester, UK*
[2]*Department of Geography, University of Sheffield, Sheffield, UK*
[3]*School of Geography and the Environment, University of Oxford, Oxford, UK*
[4]*Laboratory for Provenance Studies, Department of Earth and Environmental Sciences, Universita Milano-Bicocca, Italy*
[5]*School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, UK*

Key words Portable luminescence reader (POSL); geochronology; rapid age assessment; aeolian sediment dynamics; dunefield evolution; dune accumulation; Quaternary environments; drylands

Reconstruction the accumulation of sediment at the surface requires geochronological data capturing a wide spatial area and the full temporal range of the preserved record. Collecting such datasets using traditional laboratory-based luminescence dating is extremely time and resource intensive. For example, it has taken from the late 1980s to 2016 to produce the global dataset of ~4000 luminescence ages for desert dunefields[1,]. Larger datasets, that cover a wide geographical areas to reconstruct dunefield-scale aeolian dynamics helps us to produce a temporally-constrained proxy record from which we can elucidate the mechanisms driving changes in key climate variables, such as precipitation, moisture balance and the wind. Quaternary proxy datasets are also valuable for testing the robustness of model simulations that can be used to predict future change and remobilisations[2,3].

Portable luminescence readers (POSL) have an excellent track record of producing relative age information to aid the *in situ* interpretation of sites and guide targeted field sampling, as well as assisting in informing strategies of sample selection for full-laboratory-based dating approaches. The research presented here extends the utility of the POSL approach to producing rapid age assessments, based on calibrating the POSL signals of sampled which also have published ages using full laboratory-based luminescence dating protocols[4]. This is based on 144 samples within southern Africa, and represents the first comprehensive approach to do this worldwide, following a pilot approach for contrasting age samples in the Namib Sand Sea[5].

This new approach demonstrates that there is no one regression model for all southern African aeolian sediments and that a region-specific approach to calibration is needed, with four broad regions identified: the Namib Sand Sea, northern Kalahari, western Kalahari and southern Kalahari (Figure 1). The strength of linear regressions (r^2 of 0.99, 0.93, 081 and 0.52) for samples back to ~120, ~105, ~75 and ~5ka for each region respectively, coupled with the errors on predicted ages (RMSE) generated using k-fold cross validation, demonstrates that this is an excellent approach to rapid age assessment. The main driver of these regional differences is the quartz:feldspar ratio in the bulk sediment (measured using the POSL).

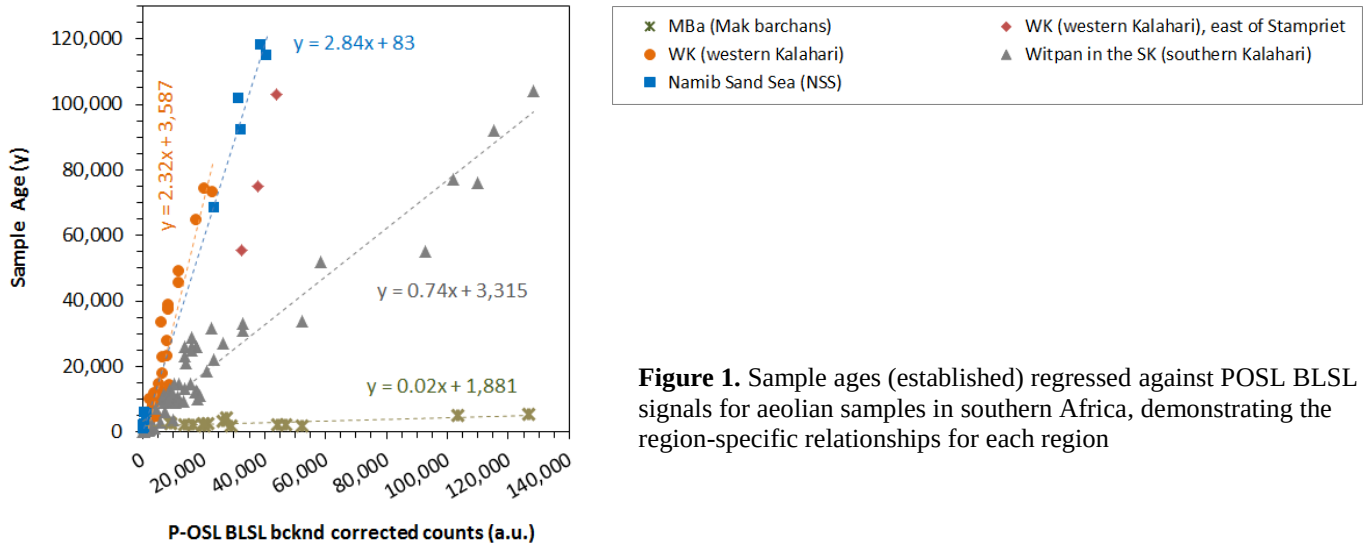

Figure 1. Sample ages (established) regressed against POSL BLSL signals for aeolian samples in southern Africa, demonstrating the region-specific relationships for each region

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QUATERNARY EOLIAN DUNES OF THE ATLANTIC COASTAL PLAIN PROVINCE, USA

C. Swezey
U.S. Geological Survey, Reston, Virginia, USA

Eolian sand dunes and sand sheets of Quaternary age are present at many inland locations throughout the Atlantic Coastal Plain province of the eastern United States. Under modern conditions, this region is not very conducive to widespread eolian sediment mobilization because of a humid and mesothermal climate, relatively low mean surface wind velocities (~1–3 m/sec), and relatively dense vegetation. LiDAR data and optically stimulated luminescence (OSL) ages, however, reveal the presence of widespread eolian sands that were active episodically from ~92–5 thousand years ago (ka), and that have subsequently been stabilized and degraded by vegetation and pedogenic processes. Most OSL ages from these sands are approximately coincident with the last glacial maximum (LGM), when conditions were much colder, drier, and windier.

These eolian sediments of the U.S. Atlantic Coastal Plain are found in the following four inland settings: (1) river valleys; (2) interfluvial upland areas of the northern coastal plain; (3) the Carolina Sandhills region; and (4) adjacent to low relief elliptical depressions known as Carolina Bays. Most of these eolian sediments are composed of fine to medium sand, although a substantial component of silt is present in the northern coastal plain, and a substantial component of coarse sand is present in the Carolina Sandhills region. Eolian sand in river valleys forms parabolic dunes that are located to the east of the modern river channels. The tails of eolian dunes in river valleys point northwest in the northern coastal plain (Delaware, Maryland), whereas the tails of eolian dunes in river valleys point west in the southern coastal plain (North Carolina, South Carolina, Georgia). This eolian sand in river valleys is thought to have been derived from fluvial sand in the nearby river channels. Eolian sand in interfluvial upland areas of the northern coastal plain (Delaware, Maryland) forms both sand sheets and parabolic dunes (with dune tails pointing to the northwest). This eolian sand in the northern upland areas was probably remobilized from any loose sediment that was available in the area, and the location near the southern margin of the LGM ice sheet is similar to extensive Quaternary eolian sand and loess deposits in Europe, China, and the central United States. Eolian sand in the Carolina Sandhills region forms mostly sand sheets and some linear dunes of short extent. This eolian sand is thought to have been derived from sand of the immediately underlying Cretaceous fluvial strata. Eolian sand associated with Carolina Bays forms arcuate ridges on the east and south sides of the depressions ("bays"). Stratigraphic relations with eolian dunes in river valleys and similar OSL ages indicate that the Carolina Bays formed during approximately the same time interval as the other eolian sands of the inland coastal plain. The Carolina Bays are therefore interpreted as thermokarst lakes that developed as a result of thaw and collapse of frozen ground, with subsequent modification by lacustrine and eolian processes.

On the basis of the OSL ages, eolian sediment mobilization appears to have occurred episodically at any given site. The presence of parabolic dunes and the abundance of sand sheets suggest that some vegetation was present when the eolian sand was mobilized. The orientations of the parabolic dunes and the locations of the Carolina Bay eolian sand ridges suggest that the winds that mobilized the sand blew from the northwest in Maryland and Delaware, and that these winds

blew from the west in North Carolina, South Carolina, and Georgia. These inferred prevailing wind directions are consistent with climate models for the LGM winter, suggesting that eolian sand mobilization may have occurred preferentially during winter. Eolian sand mobilization would have been facilitated by LGM conditions of stronger wind velocity (at least 4–6 m/sec), lower air temperature, lower air humidity, and reduced vegetation cover.

MODELLING QUATERNARY DESERT DUNE SYSTEM ACCUMULATION USING LUMINESCENCE AGE DATA

D.S.G. Thomas[1,2], & R.M. Bailey[1]
[1]*School of Geography and the Environment, University of Oxford, UK.*
[2]*University of the Witwatersrand, South Africa.*

Key words Luminescence dating, dune accumulation, accumulation modelling, Quaternary environments

Luminescence dating has since the 1980s[1] revolutionized our ability to establish the timing of desert dunefield activity and accumulation, to the point where it is regarded as a standard method in both Quaternary palaeoenvironmental studies and investigations of long-term dunefield dynamics. By 2016, almost 4000 luminescence ages from desert dunefields worldwide had bene published, as recorded in the INQUA Dune Atlas database[1,2]. Environmental and climatic interpretations of these dated dune sediment records have however proved enigmatic[3] and sometimes controversial[4], and it has remained challenging to test hypotheses of the systematic response of dunefields to changes in external forcing in the past and to make predictions of the future.

A new method of handing and modelling age data at the dunefield scale, provides an approach that addresses many of the issues associated with past age interpretations[6]. This takes account of key factors including sediment preservation, sampling bias, and dating errors that can complicate the interpretation of past accumulation records[7] (Fig. 1). The *Accumulation Intensity* method quantifies dune sediment accumulation from age datasets, rather than simply using the ages themselves as proxies of change. This allows periods of dune accumulation, over 10^2-10^5 years, to be identified from compilations of dated sand sea stratigraphic sequences.

This approach is applied to dunefield age datasets from southern Africa, Asia (China, India, Israel and UAE) and Australia, providing model outputs that allow dunefield accumulation histories to be directly compared and analysed against local, regional and global records of Quaternary environmental and climatic dynamics. This opens up the potential to test hypotheses of long term controls on dunefield development, as well as identifying significant gaps and limitations in some existing dune age archives.

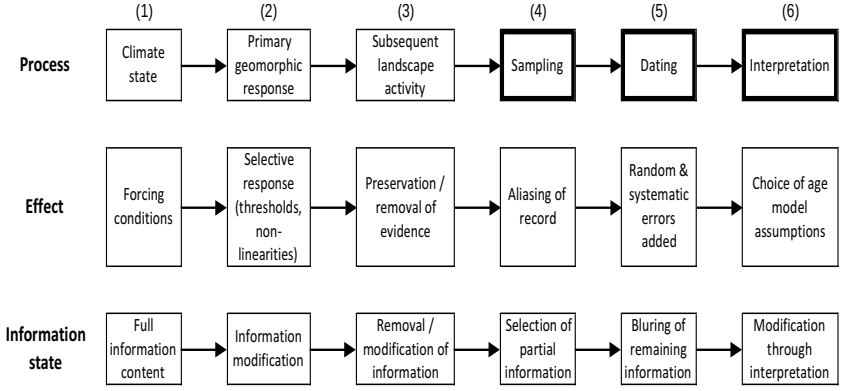

Figure 1. Factors that impact the integrity of ages derived from dune sediments[7]

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EOLIAN SEDIMENTATION IN SOUTHERN BRAZILIAN PAMPA

R. Verdum[1,4], T. C. Gomes[2], F. Laurent[3], J. Corbonnois[4]
[1] *Universidade Federal do Rio Grande do sul, Porto Alegre, Brazil*
[2] *Universidade Federal do Rio Grande do sul, Porto Alegre, Brazil*
[3] *Le Mans Université, Le Mans, France*
[4] *Le Mans Université, Le Mans, France*

Key words: Brazilian Pampa; Holocene; Quaternary surficial formations; eolian continental deposits.

The Brazilian Pampa biome presents, as a landmark, the occurrence of continental superficial eolian deposits in its landscape, which are typical of dry climate, Figure 1. Systematic studies have proven that sand deposits, *areais* in its regional denomination, has a natural origin, since its formation results from sandization process, which are erosive-depositional processes in non consolidated sandy deposits, which are reworked by water dynamic and wind. They result from Quaternary surficial formations, in which the water processes, (especially the concentrated flow, associated with torrential rains), exposed, transported and deposed sand, which in contact with the wind, tended to a constant remobilization. Given the importance and the evolution of the researches that proves both the origin and the genesis of these typical eolian morphologies (asymmetrical slopes, dry valleys barred by accumulations of sand, fields of small dunes, ripple-marks ...), mainly from the morpho-palaeoclimatic point of view, this research aims to elucidate the processes, both in past and in recent times, that culminating in the current landscape. The understanding of this complex phenomenon has its starting point in the identification and the characterization, in the field, of continental superficial eolian deposits, which are typical from dry paleoclimate, integrated to the current dynamics of the sandstone process in humid subtropical climate. Subsequently, the physical features of the sediment material collected in the field (granulometry, morphometry and texture) are characterized in laboratory. In this sense, the understanding of paleoclimatic particularities in the Pampa is significant to the interpretation of past morphologies in dry climate conditions in the recent past (between 2,000BP and 5,000BP), in the composition of the current landscape and, above all, in the association of climatic variations and the expansion or retraction processes of the sand deposits.

Figure 1. View of the sand deposits (*areais*) results from sandization process in the Brazilian Pampa biome, [1]. Monday the 31th of May 2015, we will visit the sand deposits.

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THE FORMATION AGE OF OTINDAG SANDFIELD IN NORTH CHINA

Yali Zhou*[1], Binbin Jia[1], Yuemin Zhang[1], Xiaowei Sun[1], Yuda Cuan[1], Jiyao Tu[2], Huayu Lu[3], Zhiwei Xu[3]

[1] *Shaanxi Normal University, Xi'an, China, 710062*

[2] *Peking University, Beijing, China, 100871*

[3] *Nanjing University, Nanjing, China, 210089*

Key words K-Ar age, TT-OSL, Otindag sand field, Formation age

Deserts and sand field in arid and semi-arid regions of north China are important sources of dust which influence regional or even hemispheric climate. Although there are lots of research about the climate change have been done in arid to semiarid region, the age of most desert or sand field formation still is not clear. Previous study about the boundary of Otindag sand field during the Last Glacial Maximum and Holocene Optimum revealed the oldest age of aeolian sand layer in sand dune was less than 20ka by optically stimulated luminescence (OSL) dating. This result has been acquired by the alternations of sandy loam soils, aeolian sand layers with sandy-loess in Otindag sand field, which indicate multiple intervals of dune activity and stability implying climate change processes. The stratigraphy sequences of the selected profiles consist of aeolian dune deposit overlying bright yellow (white) lacustrine sand, red-brown soil sediment and bedrock. It is well know the directly identification of desert or sand field formation or existence is aeolian sand deposition. Beside these alternation aeolian sediments, we also found the thick aeolian sand were buried by basalt with vesicular structure close to Selenhot City in the north of Otindag sand field. This implied the old sand deposits probably had not been retreated by wind force since which had been buried by the basalt rock. The age of this basalt will reveal the least formation period of Otindag Sandfield. We use the K-Ar and TT-OSL dating method to measure the basalt and sand deposits underlying respectively. The K-Ar age is 2.98±0.40Ma while the TT-OSL age is 645.43±33.88ka. The result provide reliable constraints for reconstruction of formation age to Otindag sand field which is no less than 2.98±0.40Ma as while the age of sand underlying is underestimated. The main reason of underestimate age for aeolian sand deposition in previous studies is due to no cover overlying and powerful wind was constantly eroding and moving the sand which can not be buried to accumulate the optical signal and TT-OSL signal saturated..

SESSION

« Aerodynamics and sediment transport »

MEASURING AND TESTING AEOLIAN SAND TRANSPORT MODELS ACROSS A SPATIAL GRID NETWORK

Andreas C.W. Baas[1], Irene Delgado-Fernandez[2], Derek W.T. Jackson[3], J. Andrew G. Cooper[3], Kevin Lynch[4], and J.H. Meiring Beyers[5]

[1]*King's College London, London, UK*
[2]*Edge Hill University, Ormskirk, UK*
[3]*University of Ulster, Coleraine, UK*
[4]*National University of Ireland, Galway, Ireland*
[5]*Klimaat Consulting & Innovation, Guelph, Canada*

Key words variability, field experiment, statistical techniques

Models relating wind forcing to resulting sand transport flux have been at the core of the discipline from its conception and remain an important central focus. The desired capability to accurately predict the amounts of sand that are moved in response to any given wind regime is one of the key practical applications of our scientific efforts. A plethora of predictive equations have been developed and tested over the course of many decades, with a great variety of parameter values and options, and in recent years the ever-advancing progress in deploying high-frequency wind and sand transport sensors in high-density measurement arrays has yielded a deeper understanding of the strong spatio-temporal variability in wind-blown sand transport.

Most field experiments involve measuring time-series of wind forcing and the accompanying sand transport flux in one location or along one compact array, to then analyse for statistical relationships.

In this contribution we present both an alternative measurement strategy as well as sophisticated (and unusual) statistical data analyses techniques that have not been applied to this research problem before.

A field experiment on a wide sandy beach involved the deployment of 20 pairs of 50Hz sonic anemometer and 25Hz electronic sand trap over a grid network covering a distance of 90m alongshore and 30m cross-shore. Data were collected during an event where sand transport was driven by wind blowing roughly parallel to the beach, with well-developed and typical boundary layer flow conditions. Each station of co-located sonic and sand trap thus provides the opportunity to measure and develop a transport relationship that can be independently tested on the other stations in the grid. The grid as a whole, meanwhile, provides the opportunity to quantify spatio-temporal variability in a variety of ways.

In addition to this alternative measurement strategy, a taught MSc course for physics and maths students was used to elicit the application of advanced and unusual statistical techniques to the analysis of potential relationships between the synchronous time-series from these stations. Techniques that students applied included sophisticated data-cleaning and detrending methods, stationarity testing, autoregressive-moving-average models, various types of non-linear regression, Gaussian process learning, stochastic models, k-means clustering, and Bayesian modelling. While these unusual statistical techniques by no means yield any specific superior transport model, they do introduce some interesting and useful new perspectives on our traditional lines of inquiry.

An experimental study on the influence of Plant Roots on Soil Wind Erosion

Hao Chen[1], Zhibao Dong[1], Fengjun Xiao[1]
[1] *School of Geography and Tourism, Shaanxi Normal University, Xi'an, China*

Key words plant roots; wind erosion; wind tunnel test; wind erosion rate; wind; erosion processes.

Vegetation as the main factor to control soil erosion that result from interactions between overground part and root system. Wind erosion and water erosion exist differences in physical mechanism, the effect of vegetation on soil wind and water erosion is different too. The most study of relationship between vegetation and soil erosion mainly focused on water erosion. The study of wind erosion has more focus on protective effect of plant aerial portion, the impact of plant roots on wind erosion has been ignored. The root system of plants has advantage in stabilizing soil structure and preventing soil erosion. Previous research has shown that the decrease in water erosion rates with increasing root mass is exponential [1]. The practice has proven that the plants additives in soil (similar to plant roots) can effectively increase their resistance to wind erosion. The addition of reeds in the Han Great Wall making it stand tall in the Gobi Desert in Dun huang, though it has been eroded by wind and rain for thousands of years.

Fig.1 Han Great Wall ruins in Yumenguan Pass

In this study, we use wind tunnel to test the effect of plant roots in soil, with different content and diameter (Fig. 2a). Previously, the sand soil from Mu Us Sandy Land was blended with plant roots to make wind erosion samples (75cm*75cm) (Fig. 2b). The plant roots which added to soil were divided into 3 groups with diameters (0-0.5mm, 0.5-1.0mm, 1.0-1.5mm) and 5 grades with quality. Four free-stream wind velocities (U=10, 12, 14 and 16m s^{-1}) were used in the test. During the course of the experiment, we use laser positioning and Gopro taking photos to record erosion patterns of samples (Fig. 2c). The quantity of wind erosion sample with different roots added in by weighing at a fixed interval of time, and the variations of wind erosion sample with height will be obtain by simulating on computer according to the photography (Fig. 2d, 2e).

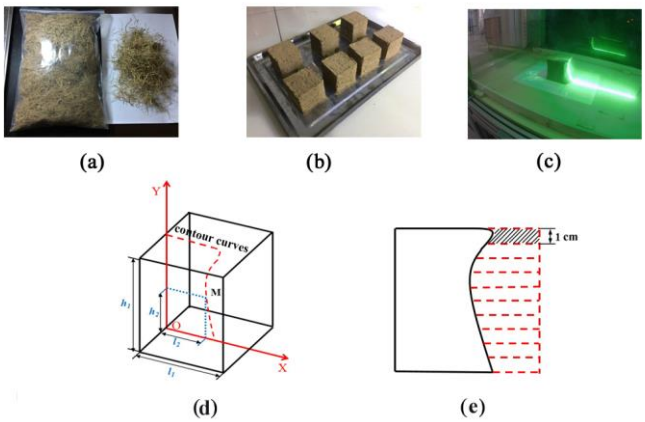

Fig.2 Sample making and the process of simulation experiment.

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VARIATIONS OF Rb/Sr RATIO FOR DIFFERENT GRAIN SIZES IN THE WIND EROSION REGION OF NORTH CHINA

Cheng Hong, Chen Tianle, Fang Yi, Zhang Kaidi, He Weiwei
State Key Laboratory of Earth Surface Processes and Resource Ecology/
MOE Engineering Center of Desertification and Blown-sand Control,
Beijing Normal University, Beijing, China

Key words Rb/Sr ratio; spatial variations; chemical weathering; eolian dust transport; grain size

Rb and Sr are trace elements with dramatic difference in geochemical behavior. The Rb/Sr ratio is an important index to represent chemical weathering intensity. In existing literature, it serves as one of the multiproxy indices preserved in the geological record, which was used to understand the temporal change of climate. In this paper, we study the spatial change of Rb/Sr ratio of sediments with eight different particle sizes by sieving 84 soil samples from the wind erosion region of north China. The main results include: 1) The Rb/Sr ratio in the eastern Helan mountain is generally obvious larger than its western part, indicating that the chemical weathering effect in the former is more intensive than the latter. Some small regions also display high value of the Rb/Sr ratio. The possible reason is the effect of river water from Alpine glacier in the mountain. 2) The spatial distributions of the Rb/Sr ratio for sediments with finer grain sizes of 0-63 and 63-100 μm are more uniform than them for coarser sediments. The main reason is that the former is transported as dust in this region. The transported dust is deposited into the study region and its provenance information would be reflected in the Rb/Sr ratio. The dust storm may change local Rb/Sr ratio for sediments with finer grain sizes. Thus, the Rb/Sr value is not only dependent on intensities of chemical weathering in local region but also on the Rb/Sr ratio of provenance for other regions. This suggests that sediments with coarser grain size, at least more than 100 μm, is suitable to analyze the environmental evolution.

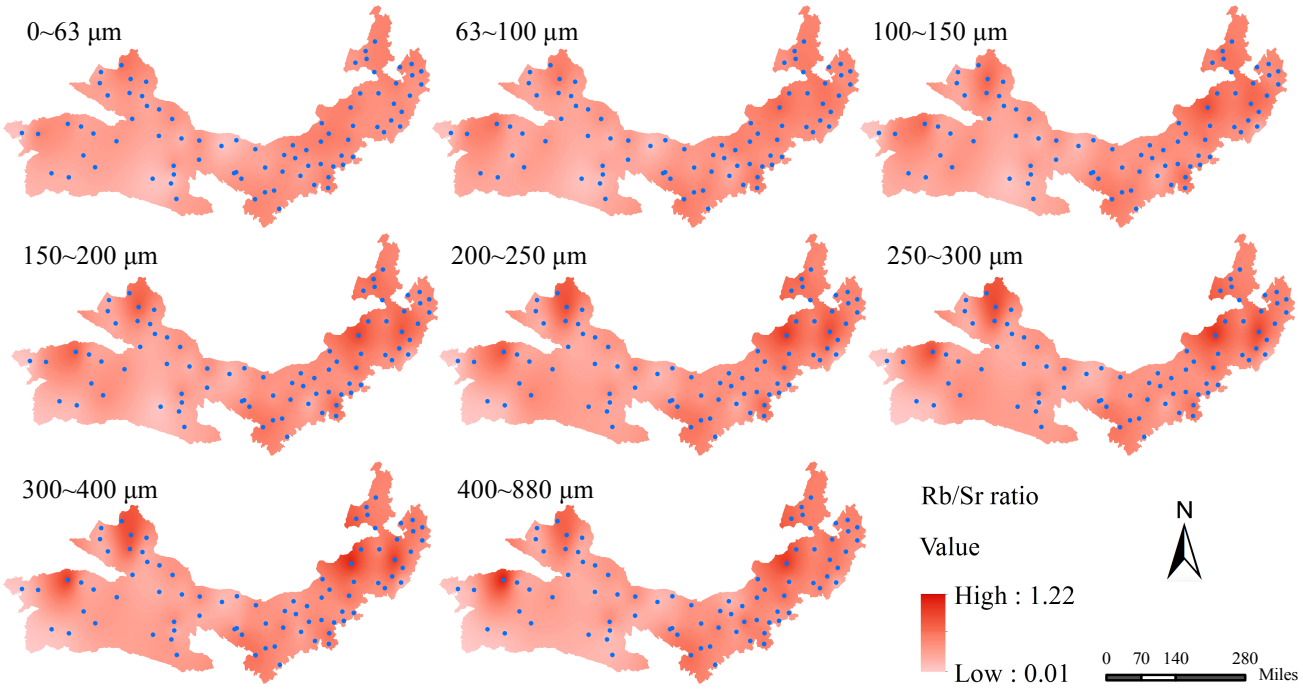

Figure 1. Spatial variations of Rb/Sr ratio in different grain size

PRESSURE MODULATION INDUCED BY A FLOW OVER AN UNDULATED BED

P. Claudin[1], M.Y. Louge[2] & B. Andreotti[3]
[1]*Physique et Mécanique des Milieux Hétérogènes, ESPCI, Paris, France*
[2]*Cornell University, Ithaca, USA*
[3]*Laboratoire de Physique Statistique, ENS, Paris, France*

Key words Basal pressure, Flow perturbation

The description and the understanding of the turbulent flow over an undulated surface is key to study the emergence and growth of bedforms, such as sand ripples and dunes [1]. Because of its relevance for sediment transport, most of studies have been concerned with the basal shear stress, showing for example its typical phase advance with respect to the topography [2]. However, the pressure is another hydrodynamical field of interest, and in this work, gathering old and more recent data available in the literature [3, 4, 5, 6], we investigate the behaviour of the modulation of the pressure in response to a turbulent flow over a sinusoidal bed of elevation $Z(x) = \zeta \cos(kx)$, where $k = 2\pi/\lambda$ is the wavenumber and ζ the amplitude, with $k\zeta \ll 1$. In particular, we extract the in-phase $\mathcal{C}$ and in-quadrature $\mathcal{D}$ components from the pressure longitudinal profiles $\delta p = \rho u_*^2 k\zeta[\mathcal{C}\cos(kx) + \mathcal{D}\sin(kx)]$, where ρ is the fluid density and u_* the shear velocity of the flow. An example with data from [4] is displayed in Fig. 1, showing that the pressure modulation is phase delayed with respect to the bed. We compare values of $\mathcal{C}$ and $\mathcal{D}$ to hydrodynamical predictions calibrated on shear stress data.

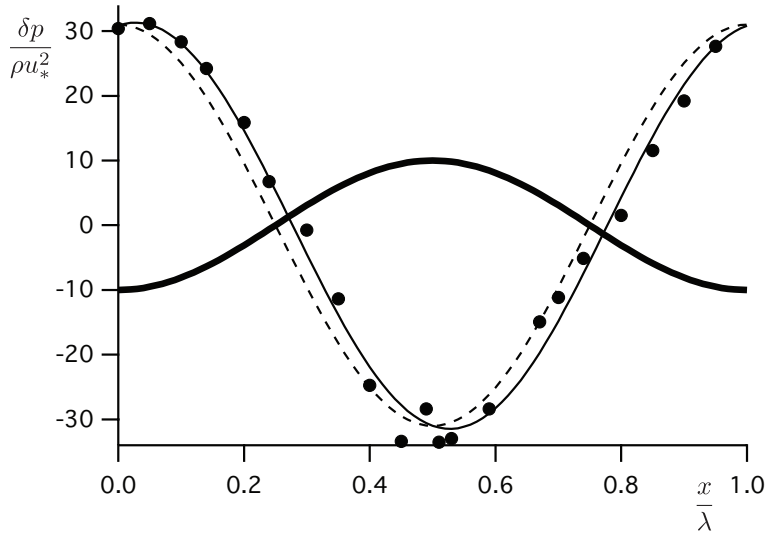

Figure 1. Symbols: pressure modulation along the bed measured by Zilker et al. [4]. Thin solid line: best sinusoidal fit of these data. Thick line: sketch of the bed profile, here displayed with an exaggerated amplitude ($x = 0$ in the troughs). Dashed line: opposite of bed profile, with same amplitude as the pressure in order to show the phase difference. Flow is from left to right.

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TEMPORAL PATTERNS OF AEOLIAN SALTATION FROM FIELD DEPLOYMENT OF A VERTICAL ARRAY OF HIGH FREQUENCY LASER PARTICLE COUNTERS

Robin Davidson-Arnott[1], Eugene Farrell[2], Jean Ellis[3] and Doug Sherman[4]
[1]*Department of Geography, University of Guelph, Guelph, ON, Canada*
[2]*Discipline of Geography , National University Ireland Galway, Ireland*
[3]*Department of Geography, University of South Carolina, Columbia, SC, USA*
[4]*Department of Geography, University of Alabama, Tuscaloosa, Alabama, USA*

Key words Aeolian sand transport; vertical saltation profile; temporal profile variation

During a larger field experiment in October 2011 at Jericoacoara National Park, Ceará, Brazil, a vertical array of 5 Wenglor 80 mm path-length, laser particle counters (LPC) was deployed within the floor of an old blowout. The LPCs were arranged at heights of 25, 45, 75, 125 and 230 mm above the bed and a 2-D sonic anemometer was positioned at a height of 200 mm, at a distance of 0.50 m to one side of the array. Particle counts, and wind speed and direction were recorded at 1Hz for 91 minutes. Short-term transport rates were obtained five times during the run using a vertically integrated 50 mm high hose trap. Wind direction was steady with 10 minute means fluctuating over a range of 8º. Mean wind speed ranged from about 5.8 ms^{-1} at the start of recording to about 6.4 ms^{-1} near the end, with gusts ranging from 7 to 8 ms^{-1}. Median grain size is 0.27-0.33mm (Barrineau and Ellis, 2013).

Sand transport during the monitoring period can be divided into two periods. During the first 40 minutes there was an increase in the continuity of transport, with the Activity Parameter (AP) calculated for 10 minute periods increasing from about 0.5 to over 0.95 at the lowermost two sensors. There were appreciable intervals with low, or no particle counts, where transport was largely confined to the elevation of the lowermost three sensors (Figure 1a). During periods of faster winds associated with gusts, particle counts at all elevations increased to a peak and then decreased to low or zero values over a period of tens of seconds similar to the described by Bauer and Davidson-Arnott (2014). Over the remainder of the monitoring period there was a trend of increasing continuity and magnitude of transport with AP values at the lowermost three sensors of 0.97-1.0 and values of 0.95 and 0.90 for sensors at 125 and 230 mm respectively. While there were continuing fluctuations in transport intensity the distinct pattern associated with flurries is not as evident in the record.

Particle counts at the two lower sensors were similar over the whole period. Over the first 50 minutes the magnitude of total counts and AP were slightly higher at 45 mm than at 25 mm with the difference decreasing slowly until the magnitude of counts became greater at the lower sensor over the last portion of the monitoring period. This may reflect a slow change in the form of the bed over time, perhaps due to the migration of a low ripple. Counts at 75mm were less than half those at 45mm and the resulting vertical profile was characterized by a marked inflection at 75 mm. The LPC dataset was compared with the vertical flux distributions collected by the hose trap in order to (i) calibrate the LPC data and (ii) provide information on the vertical saltation flux profile.

a) b)

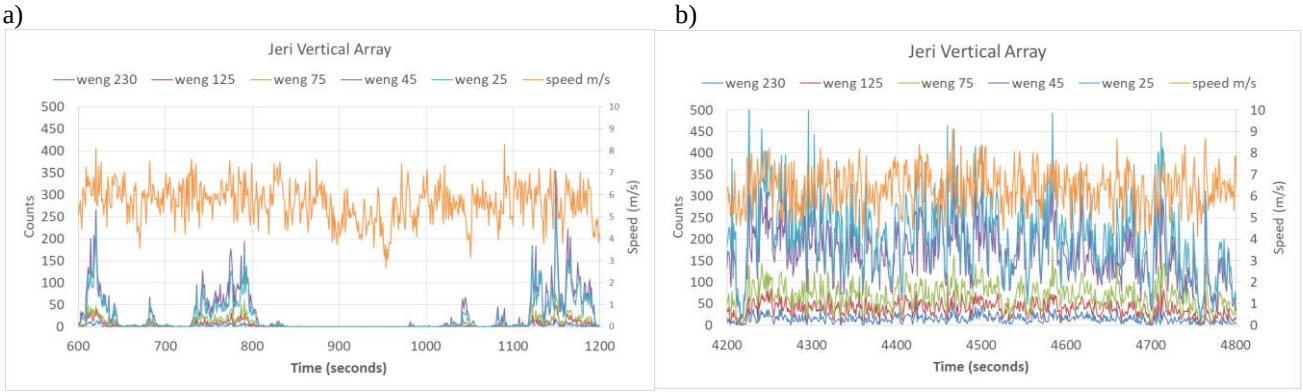

Figure 1: Ten minute plots of particle counts and wind speed: a) near the beginning of the record with intermittent transport; and b) near the end with continuous transport. Sensor names correspond to elevation above the bed in mm.

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Experimental study of saltated sand cloud over erodible and rigid bed conditions

P. Dupont[1,3], A. Ould El Moctar[2], A. Valance[1] and T. D. Ho[1]
[1] *Institut de Physique de Rennes, UMR UR1-CNRS 6251, Univ Rennes , 35000 Rennes cedex,France.*
[2] *Laboratoire de Thermique et Energie de Nantes, Polytech. Nantes, CNRS UMR 6607, 44300 Nantes,France*
[3] *LGCGM, EA3913 INSA Rennes-Univ Rennes, 35000 Rennes, France..*

Key words wind tunnel experiment, saltation, boundary conditions, particle cloud

We report extensive wind-tunnel experiments on saltation transport over two different bottom boundary conditions: an erodible bed and a rigid non-erodible bed (shortly presented by Ho et al. [1]). Our aim is to emphasize the crucial role of the boundary conditions on saltation transport regarding both the wind profile and the transported particle dynamics.
First of all the threshold wind condition and the global particle flux are characterized. The main difference between erodible and rigid case is that, for rigid bed, the mass flux of saltated particles is no longer imposed by the wind Shields number $S = {}^{\tau}/_{\rho g d}$, but by the incoming flux Q_{in} as long as it is smaller than the capacity of transport at the given S.
Then the dynamics of the cloud of saltated particle is studied statistically through measurements based on particle velocimetry tracking technique (PTV). We provide a complete description of the particle cloud above the bed, including the vertical profiles of the particle concentration, of the mean and fluctuation particle velocity, but also the vertical profiles of the particle velocity distribution.
In figure 1 for example, the particle horizontal velocity profiles are plotted for the erodible and rigid cases and it clearly exhibits the fundamental discrepancy between the two: particle velocity is managed by the splash mechanism on the erodible bed while it is roughly in equilibrium with the wind for the rigid bed case.

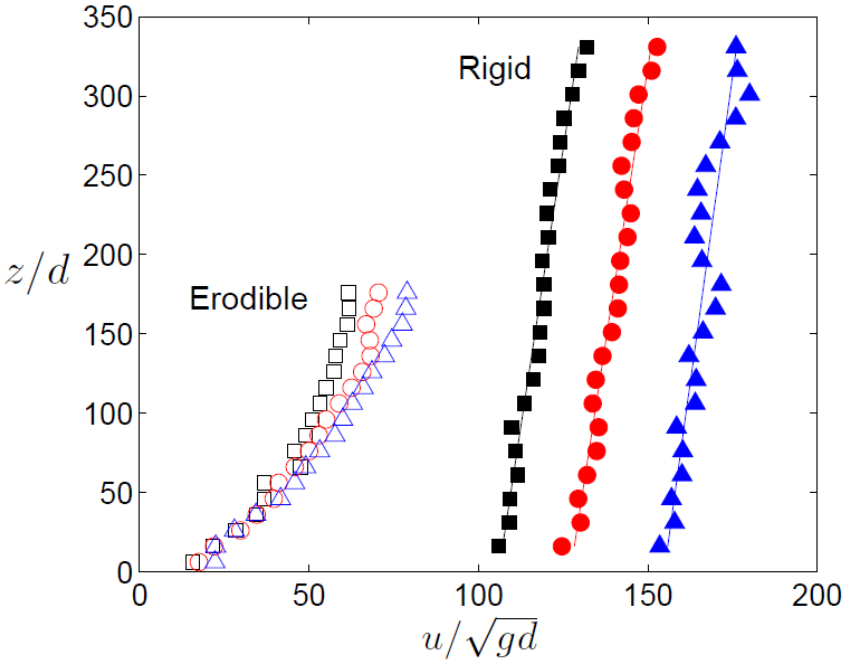

Figure 1. Horizontal particle velocity profiles obtained respectively over erodible (open symbols) and rigid bed (filled symbols) for various Shields number S:. Erodible S = 0:041 (□), S = 0:076(○), S = 0:113 (△).
Rigid bed: S = 0:0215 (■),S = 0:0267 (●), S = 0:0340 (▲).
For rigid bed, the incoming mass flow rate was set to Q_{in} = 120 g.m^{-1}.s^{-}

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Dissimilarity between dust, heat, and momentum turbulent transports during aeolian soil erosion

S. Dupont[1], J-L. Rajot[2,3,4], M. Labiadh[3], G. Bergametti[4], E. Lamaud[1], M. R. Irvine[1], S.C. Alfaro[4], C. Bouet[2,4], R. Fernandes[1], B. Khalfallah[4], B. Marticorena[4], J.M. Bonnefond[1], S. Chevaillier[4], D. Garrigou[1], T. Henry-des-Tureaux[2], S. Sekrafi[3], P. Zapf[4]

[1]*ISPA, INRA, Bordeaux Sciences Agro, F-33140 Villenave d'Ornon, France*

[2]*iEES Paris (Institut d'Ecologie et des Sciences de l'Environnement de Paris), UMR IRD 242, Université Paris Est Créteil - Sorbonne Université - CNRS - INRA - Université Paris Diderot, Bondy, France*

[3]*IRA-Médenine, Médenine, Tunisia*

[4]*LISA (Laboratoire Interuniversitaire des Systèmes Atmosphériques), UMR CNRS 7583, Universités Paris Est Créteil et Paris Diderot, IPSL, Créteil, France*

Key words Wind erosion, Size-resolved dust flux, Eddy-Covariance, Turbulence

Measuring accurately size-resolved dust flux near the surface is crucial for better quantifying dust losses by semi-arid soils. Dust fluxes have been usually estimated from the flux-gradient approach, assuming similarity between dust and momentum turbulent transport. This similarity has, however, never been verified. Here, we investigate the similarity between dust, momentum and heat fluxes during aeolian erosion events. These three fluxes were measured from the Eddy-Covariance technique during the WIND-O-V's 2017 field experiment over an isolated bare plot in South Tunisia. Our measurements confirm the prevalence of ejection and sweep motions in transporting dust as for heat and momentum. However, for this isolated erodible plot, our measurements also reveal a different partition of the dust flux between ejection and sweep motions and between eddy time-scale compared to that of momentum and heat fluxes. This dissimilarity results from the intermittency of the dust emission compared to the more continuous emission (absorption) of heat (momentum) at the surface. Conversely to heat emission and momentum absorption, dust release is conditioned by the wind intensity to initiate sandblasting. Consequently, ejection motions do not carry dust as often as heat and low momentum from the surface. This dissimilarity diminishes with increasing wind intensity as saltation patterns, and thus dust emission through sandblasting, become spatially more frequent. Overall, these findings may have implications on the evaluation of dust flux from techniques based on similarity with momentum or heat turbulent transport.

Aerodynamic parameters over an eroding bare surface: reconciliation of the Law-of-the-Wall and Eddy-Covariance determinations

S. Dupont[1], J-L. Rajot[2,3,4], M. Labiadh[3], G. Bergametti[4], S.C. Alfaro[4], C. Bouet[2,4], R. Fernandes[1], B. Khalfallah[4], E. Lamaud[1], B. Marticorena[4], J.M. Bonnefond[1], S. Chevaillier[4], D. Garrigou[1], T. Henry-des-Tureaux[2], S. Sekrafi[3], P. Zapf[4]

[1]*ISPA, INRA, Bordeaux Sciences Agro, F-33140 Villenave d'Ornon, France*

[2]*iEES Paris (Institut d'Ecologie et des Sciences de l'Environnement de Paris), UMR IRD 242, Université Paris Est Créteil - Sorbonne Université - CNRS - INRA - Université Paris Diderot, Bondy, France*

[3]*IRA-Médenine, Médenine, Tunisia*

[4]*LISA (Laboratoire Interuniversitaire des Systèmes Atmosphériques), UMR CNRS 7583, Universités Paris Est Créteil et Paris Diderot, IPSL, Créteil, France*

Key words Wind erosion, Law-of-the-Wall, Friction velocity, von Karman's constant, Eddy-Covariance, Constant flux layer

Assessing accurately the surface friction velocity is a key issue for predicting and quantifying aeolian soil erosion. This is usually done either indirectly from the Law-of-the-Wall (LoW) of the mean wind velocity profile or directly from Eddy-Covariance (EC) of the streamwise and vertical wind velocity fluctuations. However, several recent experiments have reported inconsistency between friction velocities deduced from both methods. Here, we reinvestigate the determination of aerodynamic parameters (friction velocity and surface roughness length) over an eroding bare surface and look at the possible reasons for observing differences on these parameters following the method. To that purpose a novel field experiment was performed in South Tunisia under the research program WIND-O-V. We find no significant difference between friction velocities obtained from both LoW and EC approaches when the friction velocity deduced from the EC method was extrapolated to the surface. Surface roughness lengths show a clear increase with wind erosion, with more scattered values when deduced from the EC friction velocity. Our measurements further suggest an average value of the von Karman's constant of 0.407 ± 0.002, although individual wind events lead to different average values due probably to the definition of the ground level or to the stability correction. Importantly, the von Karman's constant was found independent of the wind intensity and thus of the wind soil erosion intensity. Finally, our results lead to several recommendations for estimating the aerodynamic parameters over bare surface in order to evaluate saltation and dust fluxes.

TRAPPING OF SAND-SIZED PARTICLES EXTERIOR AND INTERIOR TO LARGE POROUS ROUGHNESS FORMS IN THE ATMOSPHERIC SURFACE LAYER

J.A. Gillies[1], V. Etyemezian[2], G. Nikolich[2]
[1]*Division of Atmospheric Sciences, Desert Research Institute, Reno, NV, USA*
[2] *Division of Atmospheric Sciences, Desert Research Institute, Las Vegas, NV, USA*

Key words Porous roughness, saltation, sand trapping effectiveness.

Six same-sized, double-walled, porous cubes constructed of plastic mesh material of different porosity (ε) were deployed at a field site where they interacted with wind-driven saltation to evaluate their relative potential for sand sequestration (internal and external). The data for the internal mass collected and external deposit mass and length characteristics demonstrated that for large 3-dimensional porous forms with a well-defined geometric shape and well-defined dimensional properties of the permeable walls, sequestration of saltating sand is largely controlled by the form characteristic 3-dimensional permeability (K′, cm^2) and the porous barrier material property hydraulic diameter (H_d, cm) and not simply ε of the walls of the forms. These two properties could collapse the relationships that quantified particle sequestration effectiveness (i.e., (internal) trapping efficiency, normalized (external) deposit length, and normalized (external) deposit mass) for the five forms with geometrically similar square/rhomboid-shaped pores. The form with rounded-rectangular holes and very thin walls did not fit on the same continuum of data. This suggests that pore geometry plays a key role in the magnitude of the amount of sand sequestered, as the data from the form with the differently-shaped pores consistently were outliers compared to the other five forms with similarly shaped pores. This is due to the physical properties of the form, the shape of pore and the shape of the solid material around the pore, as the change in flow speed between the exterior and interior scaled continually as a function of K′, with no apparent effect related to pore geometry.

Figure 1. The porous forms deployed on the eastern shore of Mono Lake, CA.

A WIND TUNNEL INVESTIGATION OF THE EFFICACY OF RAISED ROUGHNESS ELEMENT ARRAYS ON SURFACE PROTECTION FROM WIND EROSION

C. von Bulow[1], J. Gillies[2], W. G. Nickling[3] and C. McKenna-Neuman[1]

[1]*Trent Environmental Wind Tunnel Laboratory, Trent University, Peterborough ON, Canada*
[2]*Desert Research Institute, University of Nevada, Reno NV, USA*
[3] *Department of Geography, University of Guelph, Guelph ON, Canada*

Key words Roughness density, Wind tunnel experiment, Laser Doppler Anemometry

Numerous studies have investigated the role of roughness element arrays in reducing the bed surface shear stress (τ_s) relative to that required for the entrainment of particles by wind (e.g., Marshall, 1971; Crawley and Nickling, 2003). Both the roughness density (λ) and the element shape (represented in the drag coefficient, β) strongly govern the stress partitioning. However, vortical systems (i.e., horseshoe, arch, trailing and tip vortices) that develop around isolated, surface-mounted roughness elements have recently been demonstrated to cause substantial scour immediately adjacent to the geometric form at low wind speeds near the threshold for particle entrainment (e.g., McKenna Neuman and Bédard, 2015; Sutton and McKenna Neuman, 2008). Upon removing the condition that the array is surface-mounted, we hypothesize that elevating the roughness elements will alter the flow structure so as to increase turbulent energy dissipation within the wake flow and decrease τ_s, while either suppressing or eliminating the coherent flow structures responsible for enhancing sediment entrainment. Tree plantations, for example, are a direct analogue to the idealized, elevated roughness array investigated in this study. This paper reports on a pilot wind tunnel study in which this hypothesis was tested in a controlled setting.

Four roughness element arrays of varied density were constructed (λ= 0.04, 0.1, 0.2 and 0.4, where $\lambda = nbh/S$ and n is the number of elements located within an given area, S). Each element consisted of a Styrofoam cube of a standardized breadth (b = 2.54 cm) and height (h = 2.54 cm) which was mounted at a fixed horizontal position on a steel wire that stretched across the tunnel working section, perpendicular to the mean wind (Fig. 1). Each wire was secured to a frame that could be adjusted to place the roughness element array at any one of four normalized elevations (z/h = 0, 0.17, 0.25, and 0.5). A Dantec 2D Laser Doppler Anemometer (LDA) was used to measure selected airflow characteristics (e.g., wind velocity, Reynolds stress, turbulence intensity) sampled in sequence within transects running through the array. These measurements were complemented by a simple visualization technique in which erosion patterns were photographed for well-sorted medium sand (d50 = 290 μm) sprinkled evenly over the underlying tunnel floor, beneath the array.

Our visualization results suggest that arrays positioned at z/h = 0.5 are associated with both the worst (λ = 0.04) and optimal (λ = 0.2) solution for reducing sand entrainment (Fig. 1). The proportionate area affected by deflation is calculated as 0.096 and 0.006 at this elevation for λ = 0.04 and 0.2 respectively, as compared to 0.035 and 0.032 for z/h = 0 where the array is surface mounted. The full range of such observations, in concert with our detailed LDA measurements, confirm that elevating a roughness array can provide a substantial advantage with regard to the degree of surface protection provided, but only for intermediate roughness densities ($0.1 < \lambda < 0.2$).

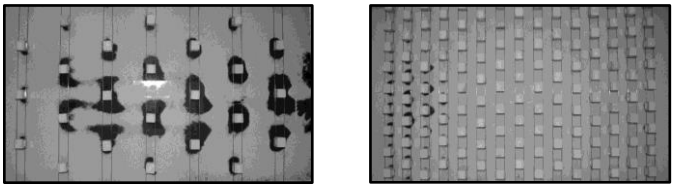

Figure 1. Comparison of erosion patterns in sand underlying roughness arrays of λ = 0.04, z/h = 0.5 (left) and λ = 0.2, z/h = 0.5 (right).

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A NEW LEESIDE AIRFLOW PATTERN IN A TRANSVERSE DUNEFIELD DURING HIGH WIND EVENTS

Guang Han, Yong Wang, Tao Xiao, Lin Yang, Gui-Fang Zhang, Li You, Xue-Yong Zou

Key words transverse dunefield, windflow veering, Ekman effect, topographic forcing, reverse flow

Transverse dunefields are distributed widely in drylands worldwide, and are generally considered products of a unidirectional wind regime. Nevertheless, their interdune corridors are subjected to complicated flow regimes and sediment dynamics, the latter of which vary with a variety of regional physiographic backgrounds. The paper presents a new leeside airflow pattern by analyzing implemental observations in a small-scale transverse dunefield on the extensive Xiliaohe Plain, Northeast China. The near-surface airflows of interdune corridor deflect startlingly towards NE or N away from the prevailing NW with a large angle of up to 180° during high wind events. The peculiar behavior of windflows in the lee of dune seems scarcely to be revealed by means of field observations and tunnel experiments as well as numerical simulations. The essentially stable secondary windflows can be primarily ascribed to the following three intertwisting processes: 1) extraordinary Ekman effect due to much larger surface roughness in the transverse dunefield; 2) local topographic forcing owing to the NE-SW trending dunefield pattern and significant relief of about 20-25m; 3) active leeside reverse flows. As a result, the dominant due south and south-southeast winds come into existence as outputs of vectorial resultant of the SW and SE winds, the latter of which eventually become rather weak and infrequent. Consequently, the unique secondary windflow can necessarily engender noticeable ripples either on the slipface or corridor bottom, resulting in lateral transport of sand. Accordingly, the leeside southerly winds play significant roles in two aspects to generate and maintain the spatial pattern of a transverse dunefield: 1) promoting the formation of coherent interdune corridor by deflation, transportation and deposition laterally; 2) inducing and directing the recovering/recovered flows to widen and deepen the interdune blowouts, thereby synchronizing the extension of interdune corridor with dune advance.

FROM GEOSTROPHIC TO GRAIN: MOMENTUM TRANSFER IN AEOLIAN SYSTEMS

A. Gunn[1], M. Wanker[2], D. A. Edmonds[2], R. C. Ewing[3] & D. J. Jerolmack[1]
[1]*University of Pennsylvania, Philadelphia, U.S.A.*
[2]*Indiana University, Bloomington, U.S.A.*
[3]*Texas A&M University, College Station, U.S.A.*

Key words Fieldwork, Atmospheric Boundary Layer, Doppler lidar.

Aeolian sand dunes grow to 100s or 1000s of meters in wavelength by sand saltation, which also produces dust plumes that feed cloud formation and may spread around the world. The relations among sediment transport, landscape dynamics and wind are typically observed at the limiting ends of the relevant range: highly resolved and localized ground observations of turbulence and relevant fluxes; or regional and synoptic-scale meteorology and satellite imagery. Between the geostrophic winds aloft and shearing stress on the Earth's surface is the boundary layer, whose stability and structure determines how momentum is transferred and ultimately entrains sediment. Although the literature on atmospheric boundary layer flows is mature, this understanding is rarely applied to aeolian landscape dynamics. Moreover, there are few vertically and time-resolved datasets of atmospheric boundary layer flows in desert sand seas, where buoyancy effects are most pronounced. Here we employ a ground-based upward-looking Doppler lidar to examine atmospheric boundary layer flow at the upwind margin of the White Sands (New Mexico) dune field, providing continuous 3D wind velocity data from the surface to 300m aloft over 70 days of the characteristically windy spring season. Data show highly resolved daily cycles of convective instability due to daytime heating and stable stratification due to nighttime cooling which act to enhance or depress, respectively, the surface wind stresses for a given free-stream velocity (Figure 1). Our data implicate convective instability in driving strong saltation and dust emission, because enhanced mixing flattens the vertical velocity profile (raising surface wind speed) while upward advection helps to deliver dust to the high atmosphere. We also find evidence for Ekman spiraling, with a magnitude that depends on atmospheric stability. This spiraling gives rise to a deflection in the direction between geostrophic and surface winds, that is significant for the orientation of dunes.

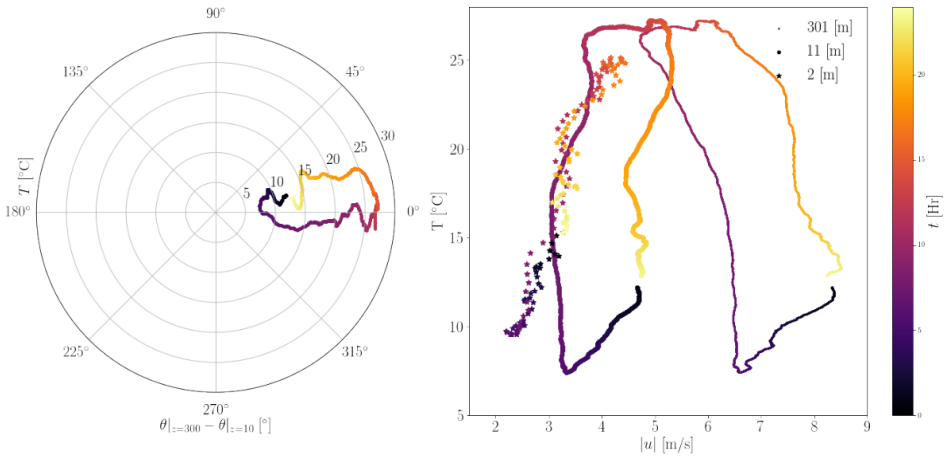

Figure 1. Boundary layer dynamics at White Sands during the 2017 deployment. On each plot, mean daily trajectories lie on a space of interest, with color along the line representing time, from early (dark) onward to late (light) hours. On the left, the space is spanned by; how much further clockwise the horizontal wind direction at 10m is from at 300m (angular coordinate), and the surface temperature (radial coordinate). On the right, the space is spanned by the horizontal wind speed (x coordinate) at some (see the legend) elevation and the surface temperature (y coordinate). All variables are smoothed over the characteristic timescale of the largest turbulent structure permissible by the boundary layer. Points (appear as lines due to high temporal resolution) are by the Doppler lidar, and stars by the MET Tower.

AIR DENSITY EFFECTS ON AEOLIAN SAND MOVEMENT: IMPLICATIONS FOR SEDIMENT TRANSPORT AND SAND CONTROL IN REGIONS WITH EXTREME ALTITUDES OR TEMPERATURES

Qingjie Han, Ruiping Zu, Kecun Zhang
[1]*Key Laboratory of Desert and Desertification, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences. Lanzhou 730000, Gansu Province, China.*

Key words Aeolian sand transport, air density, altitude, flux profile, Qinghai–Tibet Railway, temperature, threshold wind velocity.

Aeolian sand transport results from interactions between the ground surface and airflow. Previous research has focused on the effects on sand entrainment and mass transport of surface features and wind velocity, but the influence of air density, which strongly constrains airflow characteristics and the resulting sand flow, has not been widely considered. In the present study, entrainment, saltation characteristics and transport rates were examined at nine experimental sites ranging in elevation from -154 m below sea-level (Aiding Lake) to 5076 m above sea-level (Tanggula Mountain pass on the Qinghai–Tibetan plateau). At each site, a portable wind tunnel and high-speed camera system were set up, and the friction wind velocity, threshold friction velocity and sand flow structure were observed systematically. For a given volumetric airflow, lower air density increases the wind velocity. Low air density also creates a high threshold friction velocity. The Bagnold wind erosion threshold model remains valid, but the value of empirical parameter A decreased with decreasing air density and ranged from 0.10 to 0.07, the smallest values reported in the literature. For a given wind velocity, increased altitude reduced total sand transport and creeping, but the saltation rate and saltation height increased. The present results provide insights into the fundamental mechanisms of the initiation and transport of sand by wind in regions with an extreme temperature or altitude (for example, alpine deserts and low-lying lake basins) or on other planets, including Mars. These results also provide theoretical support for improved sand-control engineering measures. The data and empirical equations provided in this paper improve the ability to estimate threshold and transport conditions for wind-blown sand.

DISTINCT THRESHOLDS FOR THE INITIATION AND CESSATION OF AEOLIAN SALTATION FROM FIELD MEASUREMENTS

Raleigh L. Martin[1] & Jasper F. Kok[1]
[1]*Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, USA.*

Key words Aeolian processes, saltation, sediment transport thresholds, wind erosion, boundary layer flows

Wind-blown sand and dust models depend sensitively on the threshold wind stress. However, laboratory and numerical experiments suggest the coexistence of distinct "fluid" and "impact" thresholds for the initiation and cessation of aeolian saltation, respectively [1, 2]. Because aeolian transport models typically use only a single threshold [3-6], the existence of separate higher fluid and lower impact thresholds complicates the prediction of wind-driven transport.

Here, we extend the statistical "Time Frequency Equivalence Method" [7] to derive the first field-based estimates of distinct fluid and impact thresholds from high-frequency wind and saltation measurements at three field sites [8, 9]. Our measurements show that, when saltation is mostly inactive, its instantaneous occurrence is governed primarily by wind exceedance of the fluid threshold (left side of Fig. 1). As saltation activity increases, so too does the relative importance of the impact threshold, until it dominates under near-continuous transport conditions (right side of Fig. 1). Although both thresholds are thus important for high-frequency saltation prediction, our results suggest that the time-averaged saltation flux is primarily governed by the impact threshold.

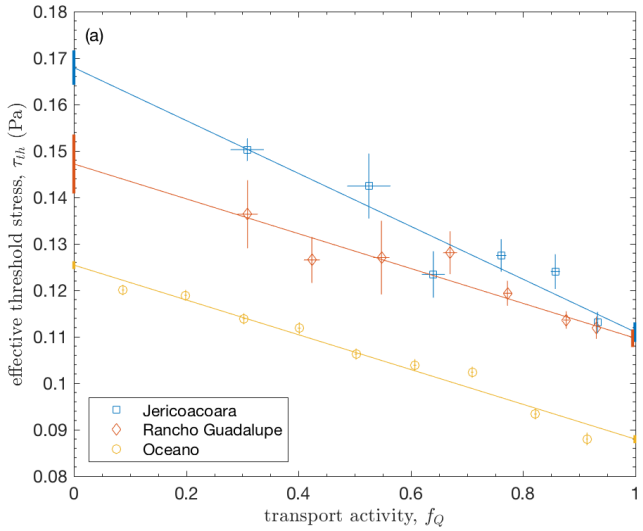

Figure 1. Effective threshold stress (τ_{th}) versus the fraction of time that saltation is active (f_Q). Color-coded lines show least-squares fits at each field site. Colored vertical bars at $f_Q = 0$ and $f_Q = 1$ denote respective estimates of the fluid threshold τ_{ft} and impact threshold τ_{it} from the linear fit.

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EQUAL SUSCEPTIBILITY AND SIZE-SELECTIVE MOBILITY IN AEOLIAN SALTATION

Raleigh L. Martin[1] & Jasper F. Kok[1]
[1]*Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, USA.*

Key words Aeolian processes, Saltation, Particle size distribution, wind erosion, sediment transport, dust emission.

Natural wind-eroded soils generally contain a mixture of particle sizes. However, models for aeolian saltation are typically derived for sediment bed surfaces containing only a single particle size [1-3]. To treat natural mixed beds, models for saltation and associated dust aerosol emission have typically simplified aeolian transport either as a series of non-interacting single particle size beds [4, 5] or as a bed containing only the median or mean particle size [6].

Here, we test these common assumptions underpinning aeolian transport models using measurements of size-resolved saltation fluxes at three natural field sites [7, 8]. We find that a wide range of sand size classes experience "equal susceptibility" to saltation at a single common threshold wind shear stress, contrary to the "selective susceptibility" expected for treatment of a mixed bed as multiple single particle size beds. Furthermore, we observe strong size-selectivity in the mobility of different particle sizes, which is not adequately accounted for in current models (Fig. 1a). At all field sites, mobility is enhanced for particles that are 0.4-0.8 times the median bed particle diameter, while mobility declines rapidly with increasing particle size above this range. We further observe that the most mobile particles also experience the largest saltation heights, which helps to explain variations in size-selective mobility (Fig. 1b).

These observations refute the common simplification of saltation as a series of non-interacting single particle sizes. Sand transport and dust emission models that use this incorrect assumption can be both simplified and improved by instead using a single particle size representative of the mixed bed.

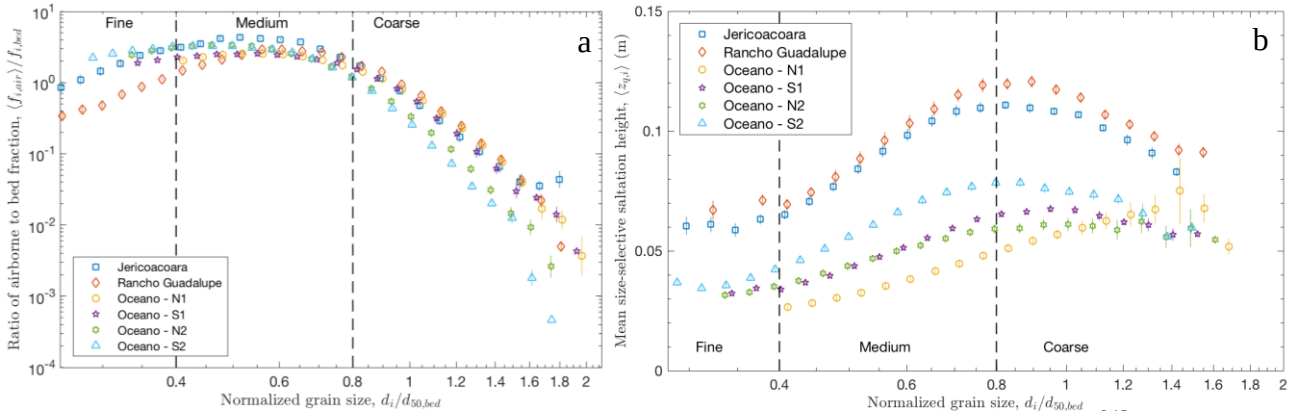

Figure 1. (a) Size-selective mobility at each site, as denoted by the ratio of mean airborne and bed surface particle volume fractions, $\langle f_{air,i}\rangle / f_{bed,i}$, versus the particle size normalized by the sand bed's median particle size. (b) Size-selective saltation layer height versus normalized particle size.

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Influence of Sand Buried on the Windbreak and Sand Fixation Benefits of Sand Barrier

YUAN Li-min, YAN De-ren, HUANG Hai-guang
Inner Mongolia Academy of Forestry Science, Hohhot, China

Key words Sand buried; wind velocity flow field; wind profile; Sand fixation; Sand barrier

Sand barrier is a prerequisite and guarantee for vegetation restoration in areas with strong wind and sand activity, which could control the wind velocity in the near field effectively, stop the cross-boundary sandstorm and restrain wind erosion. Different types of sand barriers have different protective effects, such as high vertical sand barrier is mainly to intercept the transit wind and sand flow, and low vertical sand barrier is mainly to control soil surface wind erosion. Field observations found that sand barriers were buried in the sand during the protection process, and bareness height of sand barrier decreased accordingly, thereby its protective function changed. In this study, the effect of windbreak and sand fixation benefits of low vertical sand barriers that were different levels of sand buried was investigated, the results show that in the process of sand burial, (1) there was a significant change in near-surface wind profile before and after the sand barrier, the curve gradually obeyed the logarithmic distribution, and the effective protective height and distance of the sand barrier decreased; (2) on the sand barrier leeward side the sand transport rate showed an increasing trend, 0-30cm height sediment distribution curve gradually obeyed logarithm equation; (3) on the sand barrier leeward side distribution height of sediment transport was significantly lower ($p < 0.01$), when barrier height of 10cm, the height of sediment transport was up to 42cm, which was 1.75 times that of CK, when barrier height of 5cm, the height of sediment had been reduced to 20cm; (4) Wind erosion showed a decreasing trend, especially on the leeward side wind erosion control was remarkable, When the sand barrier height dropped to 1cm, the leeward side of 20cm had been the accumulated sand; (5) Wind velocity flow chart can be seen, the higher sand barrier had greater disturbance to the transit air flow, and a large amount of turbulent flow was easy to form before and after the sand barrier, As we all know, turbulent flow could accelerate soil erosion than smooth airflow. And so if only to control wind erosion of mobile sand surface, The authors proposed that minimizing the height of sand barrier.

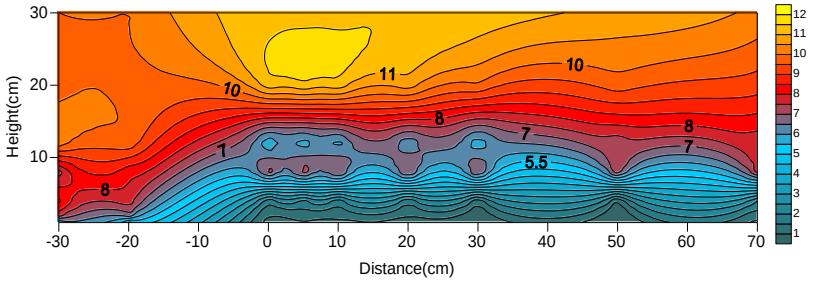

Figure 1. The contour map of the flow field in near-surface of a high 10cm sand barrier
Note: the sandbag sand barrier were set at the 0 position, the left side was the windward side of the sand barrier, the right side was the leeward side, and the sandbag sand barrier was 20cm wide and 10cm height

ANOMALOUS SHEAR VELOCITY AT THE BRINK OF A BARCHAN DUNE

M. Y. Louge[1], A. Valance[2], J. Fang[3], S. Harnett[1], & F. Porte-Agel[3]
[1]*Cornell University, Ithaca, NY 14853 (USA)*
[2]*Institut de Physique, Université de Rennes 1, France*
[3]*École Polytechnique Fédérale de Lausanne, Switzerland*

Key words Field anemometry, shear velocity transects, mobile dune, large-eddy-simulations

We report transects of aerodynamic roughness z_0 and shear velocity u^* relative to an upwind reference $u^\star_\infty$ on and around a crescent-shaped barchan dune at $25°\,00'\,30''\mathrm{N}, 51°\,20'\,27''\mathrm{E}$ with $60\,\mathrm{m}$ toe-to-brink distance, $80\,\mathrm{m}$ horn-to-horn, and $4.5\,\mathrm{m}$ crest elevation above a relatively rough Qatar desert ground, using triads of ultrasonic anemometers positioned within the inner turbulent boundary layer [1] at altitudes $z = 29\,\mathrm{cm}$, $73\,\mathrm{cm}$, and $115\,\mathrm{cm}$ above the sand surface, yielding vertical profiles of mean speed averaged during $> 15\,\mathrm{min}$ intervals and fitted to the log-law $u = (u^*/\kappa)\,\ln(z/z_0)$, where $\kappa \simeq 0.41$ is Von Kármán's constant. Here, wind blew toward a bearing of $141\,°$ close to the $159\,°$ historical direction of this mobile dune [2].

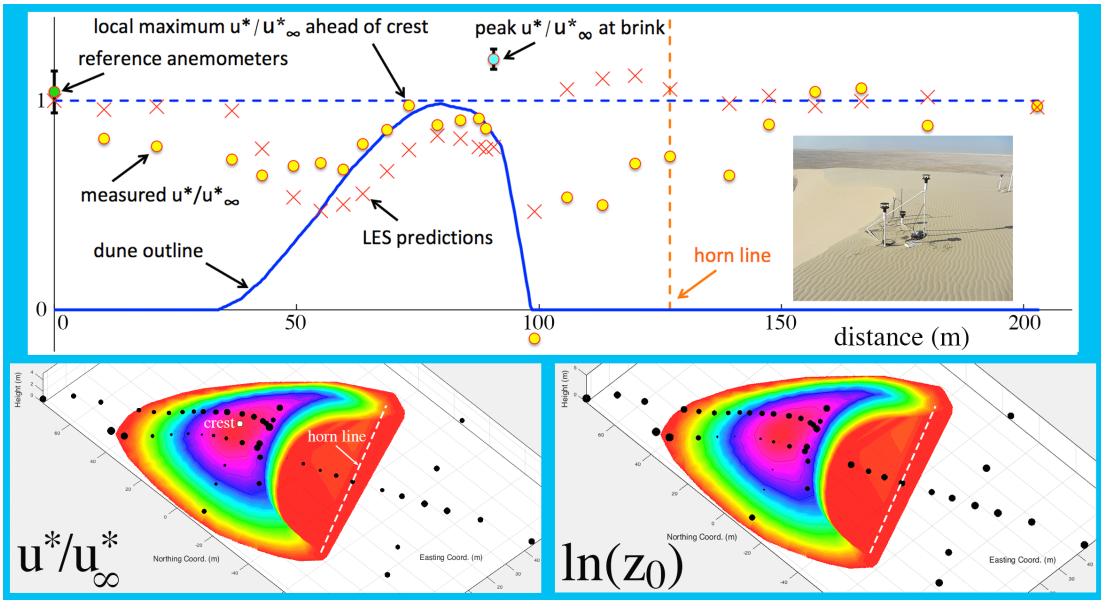

Figure 1. Top: longitudinal transect of u^* (yellow circles) and LES predictions (red crosses) relative to $u^\star_\infty$ at the green circle. Blue line: dune profile at the transect. Dashed lines join horn tips. $u^*/u^\star_\infty$ at the brink (cyan circle) is a factor 1.20 ± 0.05 higher than the local maximum at a distance $L_{\mathrm{sat}} \simeq 6\,\mathrm{m}$ ahead of the crest. Inset: roving anemometer triad near the brink line. Bottom: on the dune surface colored for altitude, the size of black dots grows with $u^*/u^\star_\infty$ (left) and $\ln[z_0(m)]$ (right).

As Fig. 1 shows, z_0 progressively adjusted from its relatively high $z_{0_\infty} = 5.3 \pm 0.5\,\mathrm{mm}$ on hard ground to $z_0 = 0.16 \pm 0.02\,\mathrm{mm}$ at the crest, while u^* first decreased, then progressively recovered as air climbed on the dune. Contrary to earlier models [3], a peak of $u^*/u^\star_\infty$ arose at the brink on the dune centerline. Large-eddy numerical simulations (LES) showed similar trends. However, $u^*/u^\star_\infty$ in the LES recovered closer downstream of the slip face than field measurements, which asymptoted back to 1 twice as far as the line joining horn tips. To the exception of a single wind reversal at the base of the avalanche, all profiles closely conformed to the log-law, and u from all three anemometers in the roving triad rose and fell in unison without discernable mutual lag along the transect [1].

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What is the ideal roughness element shape for wind erosion control?

C. McKenna Neuman & C. von Bulow
Trent Environmental Wind Tunnel Laboratory, Trent University, Peterborough ON, Canada

Key words morphodynamic adjustment, aeolian transport, roughness element, wind tunnel simulation, LDA

The flow structures surrounding idealized, wall-mounted roughness elements have been extensively studied by fluid dynamists. In geophysical systems, however, self-regulation occurs with the adjacent bed surface undergoing rapid modification with sediment entrainment and deposition. A steady state is eventually attained in which the vortex system becomes morphodynamically adjusted, so that particle entrainment by fluid drag in the vicinity of the element is arrested. A series of wind tunnel experiments was conducted to extend the earlier work of McKenna Neuman and Bedard (2015) on a wall mounted cylinder in order to address two general questions: 1) What is the most effective roughness element shape with regard to wind erosion suppression, and 2) How might morphodynamic adjustment lead to the development of a more streamlined bedform? Listed in descending order with regard to the expected degree of flow perturbation they initiate, the bluff body forms considered in this study included a cube, orientated face-on into the wind and then edge-on, a hemisphere, and a streamlined reference form or 'yardang'.

All experiments were conducted at a fixed friction velocity of 0.34 m s^{-1} in the absence of an approaching particle cloud. The topography of each sand bed surface (d_{50} =290μm) and roughness element configuration was scanned, both before and after (Fig. 1), a wind erosion event. This provided a pair of Digital Elevation Models (DEMs) from which the change in elevation was used to calculate the volume of sand lost. The associated change in the airflow structure was measured with a Dantec™ 2-D Laser Doppler Anemometer.

The edge-on cube initiated the greatest erosion along the windward edge and sidewalls, followed by the face-on cube, the hemisphere, and finally the yardang, which as hypothesized produced no measurable erosion. Similar to the findings of McKenna Neuman and Bédard (2015) in their work with cylinders, the formation of a keel immediately to the rear of any given element is dependent on the development of a strong upwash out of the windward deflation well and annihilation of the arch vortex (as observed for the edge-on cube). In the presence of either a downwash or weak recirculating eddy immediately to the lee of the element, as in the case of either a face-on cube or hemisphere, the underlying bed surface appears to be well protected and a keel is not observed to form in the absence of an upwind sediment supply. As a general rule, the turbulence intensity is reduced over morphodynamically adjusted surfaces, except in the case of the edge-on cube (i.e. worst case, least protection).

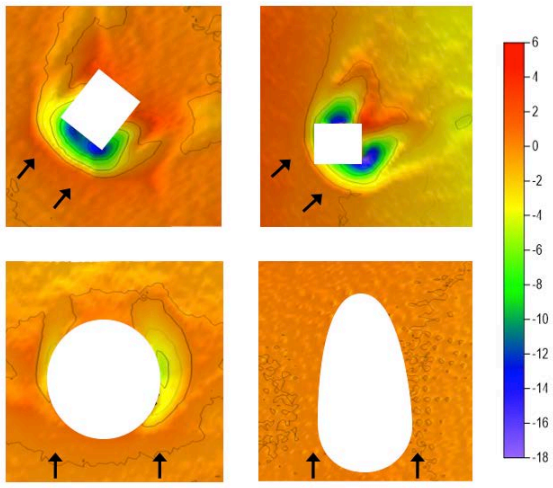

Figure 1. Morphodynamic surface adjustments (mm) surrounding selected roughness elements.

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Estimation of aerodynamic entrainment of sand particles during initial morphs of sand ripples formationA

F. Mei, Y. Xi, N. Zhang, X. Liu

Key words aerodynamic entrainment, Aeolian sand particle, sand ripples formation, high-speed photography.

Abstract: As a basic topography of aeolian environments, aeolian sand ripples are distributed on sand dunes and flat surfaces in arid, semiarid areas and sandy beach areas. Beautiful regular patterns-identical space and elevation of aeolian sand ripples have been arousing many scientists' interest for exploring what and how factors control the pattern since 1884. An grains/bed collisions hypothesis seems reliable for explaining Aeolian sand ripples formation compared to turbulent vortices hypothesis. The former has been being supported by empirical observations or adopted by numeric computations. Nevertheless, the collisions hypothesis may not cover effect of aerodynamic entrainment to sand particles on ripples formation. The initial morphs of sand ripples blown in a wind tunnel have small humps and hollows with one millimeter scale which may origin from collisions without the slope effect and removals of sand particles from the sand surface by turbulent wind. To validate the stated above estimation, an inventory of grains/bed collisions under lower and higher concentrations were established by tracking individual sand particles recorded by a high speed camera during the initial morphs formation of sand ripples. The physical constraints such as momentum conservation law and horizontal displacement relation, plus empirical spatial and temporal relationships among incidence, rebound and ejection, were used to identify aerodynamic entrainment from rebounds and ejections based on the inventory of grains/bed collisions. Two cases of sand particles in lower and higher concentration indicates that aerodynamic entrainment results in losses of sand particles which can be comparable with losses of sand particles by collision. The abstract should typically be 1 page long, possibly with a figure. The underlined author name is that of the person who is going to present the work at the conference (talk or poster).

Particle Size Analysis of Atmospheric Dust(2008-2015) in Spring of Beijing

Mengcui Zhang[1]. Ruxing Wang[2].Xueyong Zou[1]
[1] *State Key Laboratory of Earth Surface Processes and Resource Ecology, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China*
[2] *Department of Tourism, Hefei University, Hefei 230000, China*

Key words: Particle size analysis; Atmospheric dust fall; Spatial distribution characteristics

Abstract: Atmospheric dust is product of dust release, transportation and sedimentation in source areas. Its formation process has a significant impact on atmosphere and surface environment. The particle size distribution of dust is closely related to dynamic environment during atmospheric transportation. In order to monitor the amount of atmospheric dust and classify its particle characteristics in Beijing, the authors deployed 20 sampling sites for monitoring atmospheric dustfall.Based on collecting dust samples during spring of 2008-2015 to analyze the particle size of dust particles using scanning electron microscopy, we find that: 1) The average amount of dustfall is 33.54 $t \cdot km^{-2}$. The spatial distribution of dustfall shows the ring structure and the amount of dustfall in urban and the suburbs areas was significantly higher than that in the outer suburbs and mountains.The main reason is that urban dust caused by human activities contributes most to the total dustfall. 2) The average dust particle size is 32.9μm and the median particle size is 29.6μm. The particles of 10-50μm are the main body of atmospheric dustfall, accounting for 82.1% of the total dustfall. The average particle dust content above 25μm accounts for 57.4% of the total dustfall. Dustfall of mean grain size and median grain size have a significantly positive correlation with wind speed in spring, with R^2 values of 0.66 and 0.51 ($P < 0.05$), respectively. This indicates that Beijing has a large amount of dustfall, which is dominated by local sources in spring.

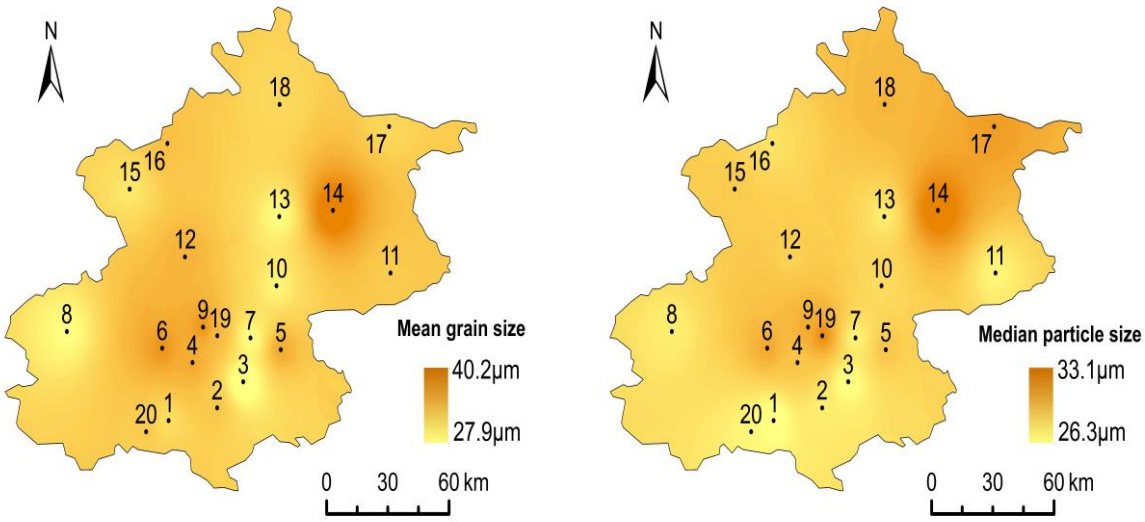

Figure 1. Spatial distribution of mean dust particle size and median particle size for 20 sampling sites in Beijing during spring of 2008-2015

Direct PTV Measurement of the particle-borne stress during steady-state saltation

P. O'Brien and C. McKenna Neuman

Trent University Environmental Wind Tunnel Laboratory, Peterborough, Canada

Key Words: *Wind Tunnel Simulation, Particle Tracking Velocimetry, Saltation, Particle Borne Stress*

Much emphasis within aeolian transport studies has been placed on understanding the feedback of the particle cloud on the boundary layer flow, which forces this geophysical system toward steady-state/saturation. Owen (1964) first suggested that near the bed surface the total fluid stress (τ) is partitioned between the air-borne (τ_a) and particle-borne (τ_p) stresses, so that at the bed surface τ_a drops to the impact threshold. Owing to many technical challenges associated with measuring particle motion at high speed (10^{-3} s) and small scale (10^{-6} to 10^{-3} m) within dense particle clouds, experimental validation of Owen's hypothesis has lagged well behind advances in numerical modeling. Using Laser Doppler Anemometry in a set of wind tunnel experiments, Li and McKenna Neuman (2012) measured the vertical profile of the fluid stress within a particle cloud that was saturated. To this date, however, no direct observations have been obtained for the corresponding particle-borne stress (τ_p). This paper reports on a subsequent companion experiment aimed at measuring: i) the near surface (0.5 mm < z < 500 mm) profile of the particle transport rate over a range of friction velocities, and ii) the vertical profile of τ_p in relation to τ_a.

All experiments were carried out in the Trent University Environmental Wind Tunnel Laboratory. In replicating exactly the earlier study by Li and McKenna Neuman (2012), the entire working section was filled with a bed of sand (median diameter 550 µm) and steady-state saltation was established across a range of friction velocities (u_*). Measurements of the diameter and corresponding velocity components (u_i and v_i) for each of 10^5 particles sampled within the dense cloud were carried out using the Trent Particle Tracking Velocimetry system (O'Brien and McKenna Neuman 2016, and 2017). This technology can identify discrete particle trajectories and sample to within 1 particle diameter of the bed surface, so that both saltating and splashed particles are included in the analysis.

The near bed, vertical decay of the particle transport rate is best described by a power function below 1 cm, and appears to be a consistent relation independent of u_* when normalized. At an elevation of approximately 3 mm, the median streamwise particle impact and ejection velocities converge to values of 0.5 and 0.3 m s^{-1}, respectively. These focal points also do not appear to be affected by u_*. The vertical profile of the sampled particle-borne stress also attains a maximum value around 3 mm, with τ_p scaling positively with the friction velocity. In general terms, the particle borne and air borne stresses are confirmed to be inversely related, although their vertical distributions bear unique and dissimilar trends.

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SCALING LAWS OF SALTATION TRANSPORT RATE AND DYNAMIC TRANSPORT THRESHOLD ARE UNRELATED TO SPLASH ENTRAINMENT

T. Pähtz[1] & O. Durán[2]
[1]*Institute of Port, Coastal and Offshore Engineering, Ocean College, Zhejiang University, 866 Yu Hang Tang Road, 310058 Hangzhou, China*
[2]*Department of Ocean Engineering, Texas A&M University, College Station, Texas 77843-3136, USA*

Key words Saltation, bedload, dynamic threshold, splash, entrainment, continuous rebounds.

The Bagnoldian transport law $Q \propto \rho_p d(\Theta - \Theta_t^r)V$ is known to predict the rate Q at which non-suspended particles of density ρ_p and size d are transported by viscous or turbulent shearing flows of Newtonian fluid, where V is the average velocity of transported particles and (Θ_t^r) Θ is the (threshold) Shields number, which is proportional to the square of the (threshold) friction velocity. It is currently a widely-accepted paradigm that this scaling of Q and the inherent scalings of Θ_t^r and V with environmental parameters are associated with bed sediment entrainment. For example, it is believed that Θ_t^r is an entrainment threshold, and that the mode of entrainment controls whether or not V increases with Θ: when entrainment by particle-bed impacts ('splash') dominates, V is constant with Θ, whereas V increases with Θ when direct fluid entrainment dominates. However, we [1] (and others) recently showed that impact entrainment does not only dominate aeolian saltation, but also fluvial bedload transport (for which V increases with Θ), which causes doubt on the potential role that entrainment plays for the Bagnoldian transport law. Here we summarize evidence from our recent studies [1, 2, 3] that strongly indicate that none of the elements of the Bagnoldian transport law is associated with bed sediment entrainment. We find that Θ_t^r is a rebound threshold [2]: the minimal fluid shear stress needed to compensate the average energy loss of transport particles during an average rebound at the bed surface, which can be predicted by a relatively simple universal analytical model in agreement with available measurements in air and viscous and turbulent liquids (Fig. 1). The scaling of V also follows from this continuous rebound picture when combined with insights from granular flow rheology. Furthermore, the impact entrainment threshold $\Theta_t^e > \Theta_t^r$ (which we find is associated with a critical creeping motion of the bed surface) controls the transition from intermittent to continuous transport, whereas fluid entrainment by turbulent sweep events is needed to maintain the intermittent regime below Θ_t^e.

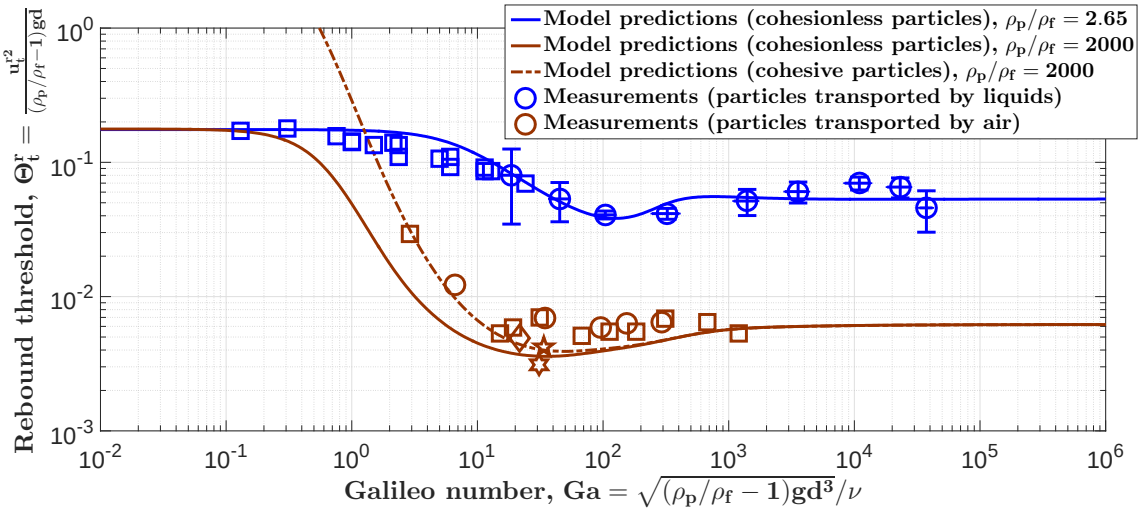

Figure 1. Threshold model predictions versus measurements in air and viscous and turbulent liquids.

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THE EFFECT OF WIND AVERAGING TIME ON SAND RTANSPORT ESTIMATION

Yaping SHEN, Chunlai ZHANG, Xuesong WANG, Xueyong ZOU, Liqiang KANG

State Key Laboratory of Earth Surface Processes and Resource Ecology,
MOE Engineering Research Center of Desertification and Blown-sand Control,
Faculty of Geographical Science, Beijing Normal University,
No. 19 Xinjiekouwai Street, Beijing 100875, China

Key words wind speed; averaging time; wind erosion; sand transport.

Wind is the primary and direct dynamic force responsible for near-surface soil erosion and transport of sand and dust in semiarid and arid regions [1-3]. Sand transport is the most direct reflection of wind effects on soil erosion. In this study, the amount of sand transport was calculated using the equation of Lettau and Lettau [4] to investigate the effect of averaging time on wind erosion estimation based on observed wind data. We compare the total sand transport during the observed period calculated from 1, 2, 5, 10, 30, and 60 minutes average wind speed data. The results of comparisons indicate that averaging wind speed can significantly influence estimates of wind erosion. Compared with the sand transport calculated from one minute average wind speed data, all values calculated from 2, 5, 10, 30, and 60 minute averaged wind speeds tend to be significantly lower than values calculated from one minute values. In general, longer averaging times tend to produce smaller values of the total sand transport, which may lead to an under-estimation of wind erosion. Further studies are needed to extend and apply the findings obtained in this study to actual wind erosion predictions.

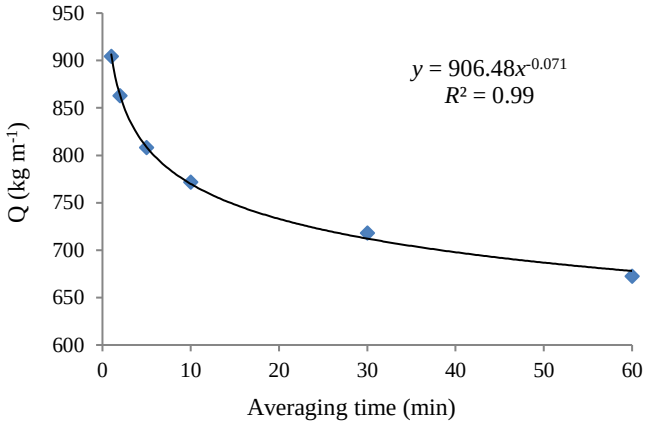

Figure 1. The amount of sand transport calculated from 1, 2, 5, 10, 30, and 60 minutes average wind speed data.

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A TWO-PHASE CONTINUUM MODEL FOR WINDBLOWN SAND

A. Valance[1], & J.T. Jenkins .[2]
[1]*Institut de Physique de Rennes, UMR 6251, CNRS, Univ Rennes, 35 042, France*
[2] *School of Civil and Environmental Engineering, Cornell University, Ithaca, NY 14853, USA*

Key words Continuum modeling, unsteady and inhomgeoneous flows, relaxation process.

We outline the derivation of a two-phase continuum theory for grains, jumping above a bed of sand, while accelerated by a turbulent shearing flow, colliding with the bed, rebounding and, perhaps, generating other grains. We follow the template established in the continuum modeling of Sauermann, et al. [1]. They formulated a depth-averaged, two-dimensional phenomenological model to predict the evolution in space and time of the average particle density and velocity, driven by a turbulent shearing flow over a horizontal particle bed. The model contained parameters that in the absence of better information were evaluated in comparisons with experiments and numerical simulations. The model predicted the dependence of the saturation flux on the strength of the steady, uniform, turbulent shearing flow and the times and distances necessary to reach saturation after changes in the strength of the flow or conditions at the bed, these mechanisms included both the drag of the wind and the collisional flux of particles from the bed. Here, we take advantage of progress made in characterizing the interactions of particles with the bed and in the development of local continuum relations for the particle shear and normal stress above the bed to phrase a more detailed continuum model. It involves a system of partial differential equations and boundary conditions for the values above the bed of particle concentration, particle velocity parallel and perpendicular to the bed, and wind velocity.

We solve the resulting system of equations subject to the derived boundary conditions for steady, uniform flows over both particle and rigid beds, and obtain unsteady uniform solutions and steady, non-uniform solutions that provide information regarding saturation times and lengths, respectively [2]. In steady, uniform situations, we calculate profiles of particle concentration and particle and gas velocities for flows that interact with a particle bed over a range of wind strengths and flows that interact with a rigid bed for a single wind strength and a range of particle holdups. Then, we consider a uniform, unsteady situation, associated with a change in the strength of the wind over a particle bed, and determine the change in profiles and particle flux with time (see Figure 1). Next, we calculate the evolution with distance of steady profiles over a rigid bed and determine that some of these steady solutions are unstable. Finally, taking as an upstream boundary condition the profiles associated with the flow of maximum particle flux over a rigid bed at a given wind speed, we determine their evolution with distance over a particle bed.

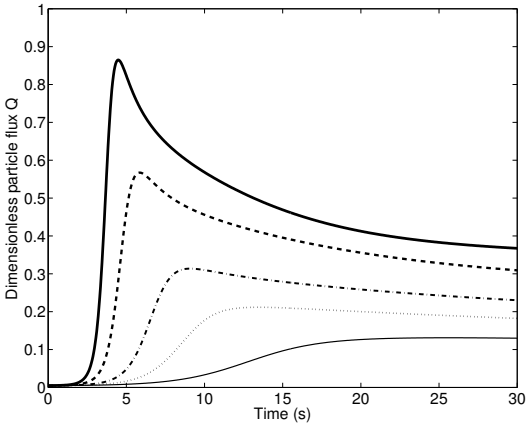

Figure 1. Dimensionless particle flux versus time in seconds showing the evolution with time on a particle bed from a very small initial value (Q = 0.005 at S* = 0.009) for increases in Shields numbers of 0.002, 0.003, 0.004, 0.006 and 0.008, indicated by increasing line weights (here the sand grain diameter is $d = 0.25mm$)

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Fetch effect on mixed sand tranport in a wind tunnel

XIAO Fengjun[1], CHEN Zongyan[1],CHEN Hao[1], DONG Zhibao[1]
[1] *School of Geography and Tourism, Shaanxi Normal University, No. 620, West Chang'an Avenue, Xi'an, Shaanxi 710119, China*

Key words Aeolian sand transport; size grading; flux profile; saltation

Introduction

The fetch effect is an increase of the sand transport rate with distance downwind from a zone of no transport, such as a leading edge of a sand sheet or a wind tunnel without a sand feeder[1-3]. The movement of grains in a mixed sand bed is different to the grain movement in a uniform sand bed due to the different response to the wind and the interaction among each size groups. However, little attention has been given to the relationship among each size groups especially in this fetch zone.

In this study, the fetch effect on the size frequency distributions in successive elevations and the mass flux profile of each grain size groups were investigated in a wind tunnel.

Materials and methods

The experiment was carried out in the wind tunnel at Shaanxi Normal University, China. The working section of non-circulating blow-type wind tunnel is 5.0m long, and has a cross-sectional area of 0.5m×0.6m. The sand used was typical dune sand from the Shapotou area, southeast of the Tengger Desert of China. The mean diameter was 0.18mm, and the standard deviation was 0.40.

The mass flux was measured by a WITSEG sampler at six fetch length locations. The fetch lengths tested were: 0.5, 1.2, 1.9, 2.6, 3.4 and 4.1m (Locations A-F). Sand samples collected at the sampler chambers were weighed and then the size distributions were analyzed using a particle size analyzer (Microtrac-S3500.)

Results

Figure 1(a) shows the variation of total mass flux profile with fetch length. The mass flux profiles above 0.05m show an exponential curve ($q = a\exp(bh)$) and are all straight lines in a log-linear plot. We can see that the Coefficient b increases with the fetch length, which means the mass flux decays less rapidly with height. The mass flux profile of Locations E and F are almost the same, this may imply that the sand transport have reached the saturated state.

Figure 1(b) shows the Mass flux profiles of each grain size groups at location F. We can see that the relative slope rates b decrease with the increasing of grain size. The mass flux profile of larger grain size group decays with height more quickly than that of smaller grain size groups. This results are very different with other results [4, 5].

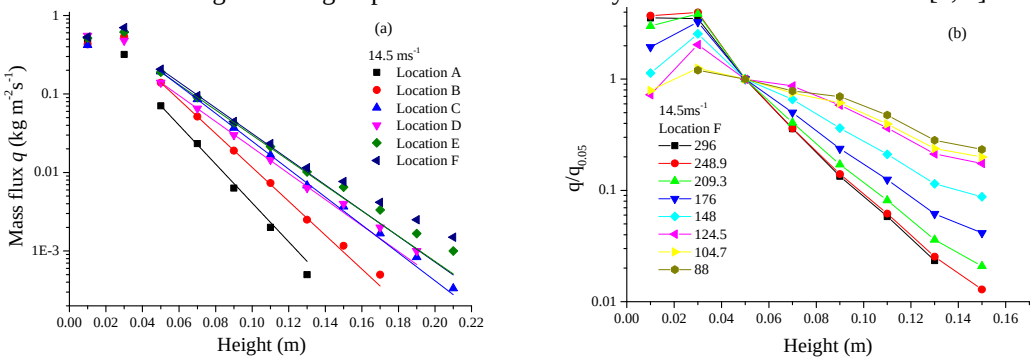

Figure 1. (a) Variation of total mass flux profile with fetch length ; (b) Mass flux profiles of each grain size groups at location F.

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Aerodynamic grain size distribution of blown sand

Yanyan Yang, Lianyou Liu, Mingxin Tao, Guoming Zhang, Mengdi Zhao, Jiadong Dai

Beijing Normal University

Key words Aeolian saltation, Erosive selectivity by wind, Grain size fractions, Sand transport flux, Vertical distribution.

Aeolian sand entrainment, saltation, and deposition are closely related near–surface processes. Learning how grains move and are sorted by wind within the vertical profile could improve our understanding of the aerodynamic sand transport process. The mass, concentration, velocity and grain size distribution (GSD) of sand are important parameters of blown sand flux structure. Most studies have been conducted on the vertical distributions of the mass, concentration and velocity of blown sand grains. The GSD of saltating sand has been investigated within 20 cm above the ground. The variations in the GSD throughout the whole saltation layer and sand transport flux of different gain size with changes in wind velocity are unclear. In this study, a blowdown wind tunnel with a 50–cm boundary layer was used to investigate saltating sand grains along a 50–cm vertical profile. The weight percentage and transport flux of different grain size fractions and the mean grain size at different wind velocities were analyzed. It was found that the mean grain size decreased with height above the sand bed before undergoing a reversal. The height of the reversal point ranged from 4 cm to 25 cm, increased with wind velocity and was not observed at wind velocities > 18 m s-1, implying that wind velocity might be the factor explaining the decreasing and reversing grain size distributions in previous studies. The contents of the finer fractions (very fine sand and fine sand) first increased above the sand bed and then decreased slightly with height, while those of the coarse fractions (medium and coarse sand) exhibited the opposite trend. The contents of coarser grains and the mean size of sand in the saltation layer increased with wind velocity, indicating wind had erosive selectivity with respect to grains in multi–size sand beds and the level of this size selectivity decreased with increasing of wind velocity. The vertical mass flux structure of fine sand and very fine sand did not obey a general exponential decay pattern under strong wind conditions. The coarser the sand grains, the greater the decrease rates of their transport mass with height. The increase rates of the transport flux of different grain sizes with wind velocity were determined by their contents in sand beds. The grain size selectivity by wind needs to be considered in future studies of sediment transport.

A NEW SCHEME FOR PARTICLE DEPOSITION TO VEGETATION CANOPY

X. Yin [1], J. Zhang[2], N. Huang[2] and Y. Shao[1]

[1]*Institute for Geophysics and Meteorology, Koeln, Germany*
[2]*Key laboratory of Mechanics on Disaster and Environment in Western China*
The Ministry of Education of China, Lanzhou, China

Key words Canyon vortex, scalar transfer, drag partition, turbulence.

Existing dust deposition schemes have major limitations in parameterizing dust deposition over rough surfaces. In this study, a new scheme for dust deposition to vegetation canopy is presented. In this scheme, roughness elements are assumed to be uniform in size, and the surface layer is divided into an inertial layer and a collection layer. In the inertial layer, particle transfer is mainly caused by turbulent diffusion for which roughness generated eddies play an important role. In the collection layer, particle transfer is dominated by molecular diffusion, impaction and interception. We first present the theoretical derivation of particle deposition velocity and then describe a conceptual model for vegetative canopy flow and estimate particle deposition velocity by means of an aerodynamic resistance network. The resistances are determined based on drag partition and vortex advection. This study takes into consideration the impact of vegetation canopy on vortex scalar transfer and surface particle collection. By analyzing deposition flux partition and drag partition, a new formulation for surface collection is proposed. The sensitivity of the scheme to input parameters is analyzed.
Finally, the scheme is tested against large eddy simulations.

Wind-water erosion on sloping fields in the wind-water erosion crisscross region on the Chinese Loess Plateau

Jiaqiong Zhang, Mingyi Yang, Fengbao Zhang, Xinxin Deng
State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, Yangling, Shaanxi 712100, China

Key words: sheet erosion; wind-water erosion; beryllium-7 measurements; temporal and spatial variation

Abstract: Soil erosion is complex in the wind-water erosion crisscross region of the Chinese Loess Plateau, as interleaving of wind and water erosion occurs on both temporal and spatial scales. It is difficult to distinguish wind and water erosion from the total erosion due to the untraceable of aeolian particles and the limitation of feasible methods and techniques. This study used beryllium-7 measurements to study wind and water erosion (in the form of sheet erosion) in the wind-water erosion crisscross region on the Chinese Loess Plateau arms to delineate distribution of wind and water erosion on plots (1.5×5 m) with different slope gradient (0°, 5°, 10°, 15°, 20°, and 25°), to determine correlations between erosion rates and slope gradients, and to analyze influence factors of erosion patterns in the multiple agency induced erosion processes. Results obtained using beryllium-7 measurements were verified with saltating particle collection in windy season and sediment collection in rainy season. Two years (from October 2014 to October 2016) continuous study results indicated that water erosion increased in a top-down direction and achieved maximum values at the mid- or lower-mid sections of slopes, while wind erosion changed complex on the observation plots. Both wind and water erosion intensified with the increasing of slope gradients fitting to linear or exponential functions. The contribution of wind and water erosion to the total erosion dramaticly changed with slope gradient. Wind was the primary agency induced erosion on flat ground (appximately 97.6%), and its relative influence continus decrease with increasing of slope gradinent, while water erosion keeping increased and accounting for half of the total erosion on 15° slopes, and reached 68.7% on 25° sloping fields. As a whole, in the study duration, the average wind erosion to sheet erosion ratio was approxinately 1.7:1, which significantly different from the restults of Zhang et al. (2017) obtained by cesium-137 on decades scale (approxinately 1:2.6). This study validates the feasibility of beryllium-7 measurements for soil wind-water erosion in field experiments, which will be helpful for the study of complex erosion induced by multiple erosion agencies.

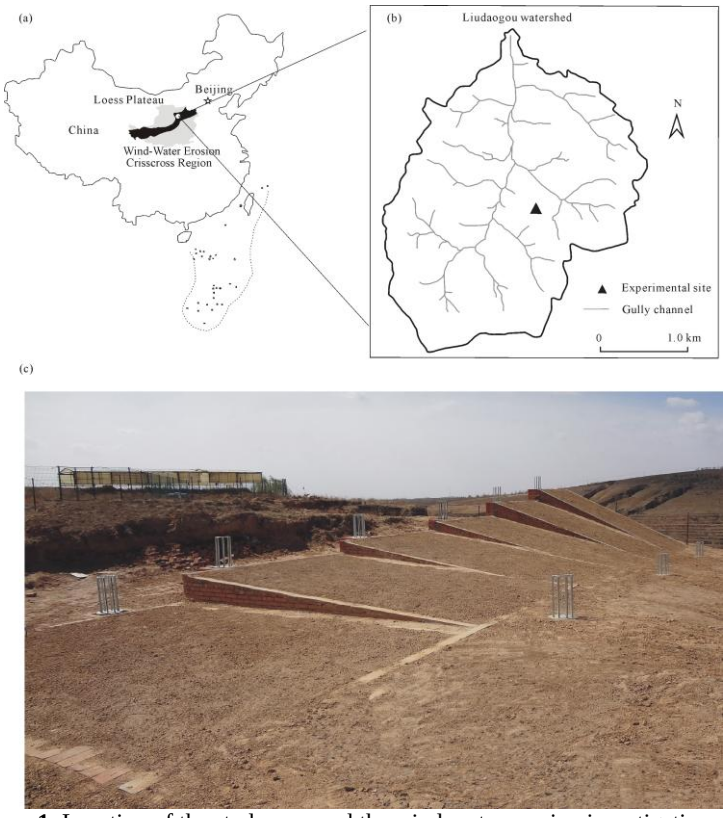

Figure 1. Location of the study area and the wind-water erosion investigation plots

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WIND TUNNEL MEASUREMENTS OF THE SALTATION REBOUND THRESHOLD

W. Zhu[1], X. Huo[2], N. Huang[2] & T. Pähtz[1]

[1]*Institute of Port, Coastal and Offshore Engineering, Ocean College, Zhejiang University, 866 Yu Hang Tang Road, 310058 Hangzhou, China*

[2]*Key Laboratory of Mechanics on Disaster and Environment in Western China, the Ministry of Education of China, College of Civil Engineering and Mechanics, Lanzhou University, Lanzhou 730050, China*

Key words Saltation, dynamic threshold, continuous rebounds, wind tunnel.

Pähtz & Durán [1] recently put forward the notion that the threshold value u_t of the friction velocity u_* associated with the saltation flux law $Q \sim u_*^2 - u_t^2$ is not a splash entrainment, but a 'rebound threshold': the minimal fluid shear stress needed to compensate the average energy loss of transport particles during an average rebound at the bed surface. They also put forward that this flux law only describes continuous, but not intermittent transport, which means precisely measuring u_t requires extrapolation of continuous transport regimes to vanishing transport. Here we present measurements of u_t, carried out in a 50 m long wind tunnel in Lanzhou University, as a function of the median particle diameter d of several sieved sand samples using the inspiring method outlined in the PhD thesis by Ho [2]: For each sand sample, we measured the proportionality between the free stream velocity U and u_* for the absence of transport (nearly) and the linear relationship between U and u_* for the presence of continuous transport. The value of u_* at which these two relationships intersect constitutes an estimate of u_t that can be determined with high accuracy. Our measurements confirm the theoretical predictions by Pähtz & Durán [1] and indicate that the old measurements by Bagnold [3] and Chepil [4] significantly overestimated the value of u_t.

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SESSION

« Anthropogenic interactions »

IMPACT OF LAND USE AND LANDSCAPE VARIABILITY ON WIND EROSION OCCURING ON SANDY DUNES IN THE SAHEL

A. Abdourhamane Touré[1], A.D. Tidjani[1], J.L. Rajot[2,3], B. Marticorena[2]C., Bouet[2,3], G. Bergametti[2], Z. Garba[1], K.J.M. Ambouta[1]

[1]*JEAI ADE, Université Abdou Moumouni, Niamey, Niger*
[2]*Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*
[3]*Institut d'Ecologie et des Sciences de l'Environnement de Paris, Bondy, France*

Key words Sahel, saltation flux, land use.

In the Sahel, wind erosion increases the vulnerability of sandy soil by the removal of the finest and most fertile fraction of the soil, including nutrients, which limits vegetation development. The aim of this work is thus to provide experimental evidences of the role of different land uses on wind erosion in order to better quantify their impact on wind erosion. Measurements have been performed during four years in Kilakina (south-east of Niger) where large rangeland surfaces co-exist with cultivated surfaces and moving dunes in a typical Sahelian semi-arid regime (± 300 mm yr^{-1}). The horizontal sand fluxes were monitored with the same instrumentation on the three surfaces. The sand catcher used in this study was the BSNE (Big Spring Number Eight). In addition, a meteorological station was installed to monitor the wind speed and direction, and rainfall.

The mobile dunes resulting from an intensive land-use produced erosion fluxes 4 to 40 times more intense than the cultivated fields and the rangeland. Erosion flux on the bare mobile dune is an excellent proxy of wind erosivity in this region. The annual fluxes on the dune varied from 2000 to 6000 kg m^{-1}, due to the variability of the winds from year to year. The erosion fluxes measured on the rangeland were much lower than on the cultivated fields during the Monsoon season and extremely low during the Harmattan season. Indeed, on the field and on the rangeland, the amount of green vegetation is largely dependent on rainfall and is subject to the same variability as precipitation. However, litter and residue cover are more dependent on agricultural practices and their covers during the Harmattan season is very low (less than 2%). Vegetation is lower on the field, but the specific arrangement of the millet plant is susceptible to favor wind erosion by the presence of large fraction of bare surface compared to the homogeneous grass cover existing on the pastured sandy surface.

AN INTRODUCTION AND PRELIMINARY RESULTS FROM THE SOUTH AFRICAN CROPLAND DUST EMISSION RISK PROJECT (SACDER)

F.D. Eckardt[1], D. Cowen[2], N.J. Kuhn[3], A.N. Palmer[4]
[1]*EGS Department, University of Cape Town, South Africa*
[2]*Centre for Microbial Ecology and Genomics, Genomics Research Institute, University of Pretoria, South Africa*
[3] *Physical Geography and Environmental Change, University of Basel, Switzerland*.
[4] *Agricultural Research Council - Animal Production Institute, Grahamstown, South Africa*

Key words Agricultural dust, South Africa.

This is an introduction to the South African cropland dust emission risks (SACDER) project. The project is a bilateral Swiss/South African funded effort aimed at identifying the major South African dust sources, establishing boundary conditions of dust emission in relation to land management practices, and determining dust dispersal patterns, compositions and impact. An 11 year, Meteosat Second Generation observation record suggests that most of South Africa's dust originates from 3% of its surface area, mostly in the central Free State province, where the land cover comprises native grasslands and dryland cultivation (maize, sorghum, sunflower, ground nuts). Dust emission peaks in the August to September period and may be triggered by both winter and summer synoptic but appears to have been on the increase with the prevailing drought over the last 5 year.

An assessment of the management practices of several land parcels suggests that the source of dust plumes may be associated with unusually long (> 2 year) fallow periods brought about by late rains, and a need to recharge groundwater in arenosols. Current process studies focus on the formation and development of crusts, their resistance to wind erosion, dust emissions, and contribution to dust quality. Laboratory and wind tunnel observations will be complemented by field measurements and experiments, and will include the use of a Piswerl.

Further work will involve the impact of stubble and straw cover, as well as grazing of harvested fields, on dust emissions and quality. The dust microbiome will be analysed using modern phylogenetic and Next Generation sequencing methods, and will allow us to compare dust samples to the source-soil microbiome and other soils samples from across the region. Given that dust plumes identifiable in satellite imagery extend as far as Johannesburg and beyond, the objective of this subsidiary study is to assess whether the dust microbiome might be a usable diagnostic for identifying the source region.

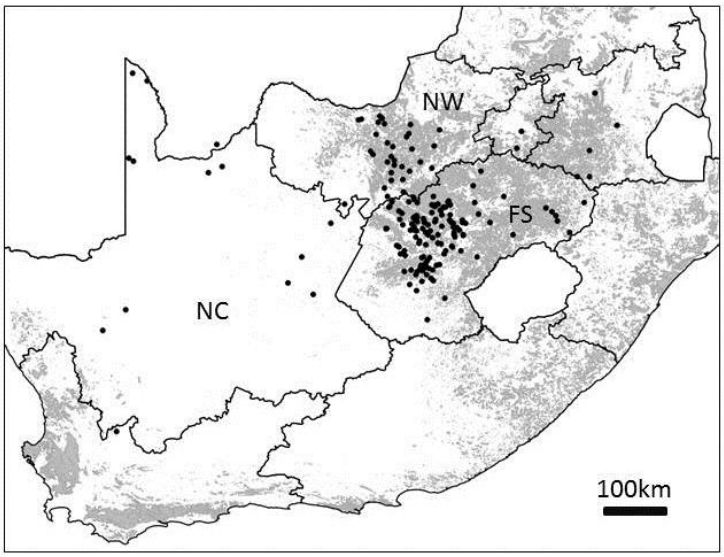

Figure 1. South Africa's major dust source points, cultivated land and provinces (Northern Cape, Northwest and Free State)

DEVELOPMENT AND VALIDATION OF A METHOD TO ESTIMATE THE WIND EROSION RISK IN GERMANY

R. Funk, Detlef Deumlich & Lidia Völker

Leibniz Centre for Agricultural Landscape Research (ZALF),
Eberswalder Str. 84, 15374 Müncheberg, Germany

Key words Cross Compliance, erosion risk, landscape structure, laser scan

The introduction of the European Cross Compliance (CC) regulations for soil protection in 2008 resulted in the demand to classify annually the wind erosion risk on agriculturally used areas in Germany. A spatial highly resolved method was needed based on uniform data sets and validation principles, and according a fair and equivalent procedure for all affected farmers. A GIS-procedure was developed, which derives the site specific wind erosion risk from the main influencing factors: soil texture, wind velocity, wind direction and landscape structure, following the German standard DIN 19706. The procedure enables different approaches in the Federal States, but comparable classification results are provided. Here, we present the approach for the 29.654 km² of the Federal State of Brandenburg.

In the first step a complete soil data map was composed in a grid size of 10 x 10 m. Data were taken from 1.) the Soil quality Appraisal (scale 1:10.000), 2.) the Medium-scale Soil Mapping (MMK, 1:25.000), 3.) extrapolating the MMK, 4.) new Soil quality Appraisal (new areas after coal-mining). Based on the texture and carbon content of a soil mapping unit the wind erosion susceptibility was derived in 6 classes. This map was combined with data of the annual average wind velocity resulting in an increase of the risk classes for wind velocities > 5 ms^{-1} and a decrease for < 3 ms^{-1}. The structure elements of the landscape are taken from the "Biotope and Land Use Map", the "Digital Field Block Cadaster" and field surveying, including all obstacles which have influence on the wind field. A height was allocated to each landscape element, corresponding to the described features in the maps or the measured values. In ArcGIS the "hill shade" procedure was used to set virtual shadows in front and behind each landscape element for five distance-depending protection zones and for eight directions. The relative frequency of wind from each direction was used as a weighting factor and multiplied with the numerical values of the shadowed cells. Depending on the distance to the landscape element the shadowing effect was combined with the risk classes for each grid cell. The results show that the wind erosion risk is obviously reduced by integrating landscape structures into the risk assessment. After the renewed classification for the entire Federal State, about 60% of the area in the highest, and 40% in the medium risk classes changed into lower classes. The area of the highest potential risk class decreased from 40% to 17% relative to the total area.

A validation of this approach was made with data of the Digital Surface Model (DSM, so-called first pulse) from laser scanning of an area of 144 km² with a grid resolution of 1 x 1 m. All landscape elements are measured with a height accuracy of < ± 0.3 m [2]. Because the structures of the allocated elements are like blocks or walls, the question was what the differences to the real heights and structures are. It could be shown that the allocated height values of the landscape elements were correct in 75% per cent, too low in 15% and too high in 12% off all cases. The differences are mainly caused by missing elements or wrong allocations, by example single bushes as a continuous hedge. At the time computing capacities do not allow to apply the DSM for the entire area, but it can be currently used in the case of disputes and will replace the landscape elements map in the near future.

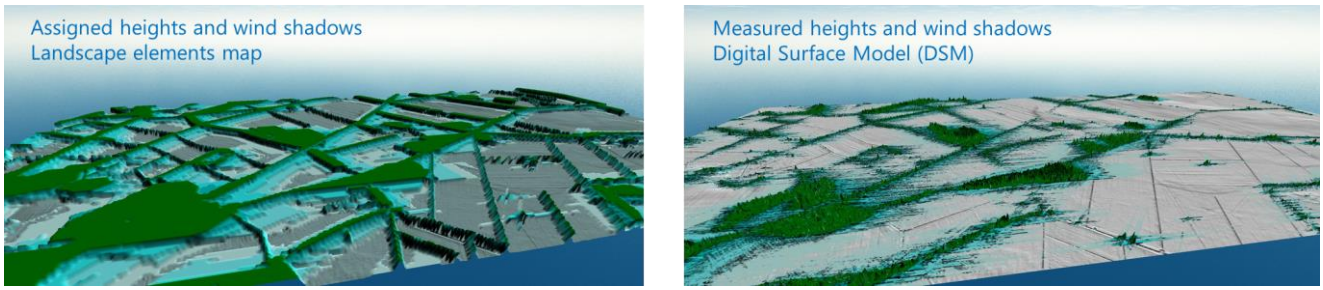

Figure 1. Landscape elements (green) and its wind shadowing effects (cyan) derived from height allocation (left) and laser scanning (right)

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Evaluation of the effect of climate change and human activities on aeolian desertification in Xilingol Grassland, Inner Mongolia

J. Wu[1], Y. Kurosaki[1], C. Du[2], T. Wang[3]
[1]*Arid Land Research Center, Tottori University, Tottori, Japan*
[2]*School of Economics and Management, Inner Mongolia Agricultural University, Hohhot, China*
[3]*Northwest Institute of Eco-Environment and Resources, CAS, Lanzhou, China*

Key words desertification, precipitation, temperature, livestock

Xilingol Grassland, which is located in Inner Mongolia may act as a potential dust source, linked with aeolian desertification. A series of policies and projects (e.g. livestock reduction, grazing prohibition) have been implemented to combat aeolian desertification since 2000 in Inner Mongolia. The effectiveness of those restoration programs is controversial and still uncertain. Therefore, the current study is aimed to evaluate the effect of livestock reduction, as well as climatic variables (precipitation and temperature) at Abaga-Qi, a typical rangeland in Xilingol.

We proposed an erodibility index (DOR), which is calculated as a ratio of the frequency of dust occurrence and strong wind, to represent the condition of aeolian desertification. From 1974 to 2013, there appeared a breaking point of the inter-annual variation in DOR at the year 2000 at Abaga-Qi. The DORs dramatically increased and showed high values in 2001-2002 and 2005-2006. Great fluctuations in the DORs during the period of 2001-2013 indicate that land surface condition has become more vulnerable to wind erosion. To understand the relative climatic and anthropogenic impacts on the DOR variations, the annual DOR was regressed on precipitation, temperature and livestock population. According to the comparison of simple and multiple regression models, the restoration of aeolian desertification (namely, a decline in DOR) was associated with abundant precipitation in May-September of the previous year, low monthly maximum temperature of the previous year, and low livestock population from the previous year's July to the current year's June. Livestock reduction made the greatest contribution to improve the land surface condition from 2001 to 2013. We predict that a reduction of 10 thousand livestock population result in a 1.23% decrease in the DOR. Our results suggest that the control of grazing activities is an effective way for aeolian desertification restoration in Xilingol Grassland. We expect to conduct similar analysis in a wide region and to support sustainable rangeland management in the future.

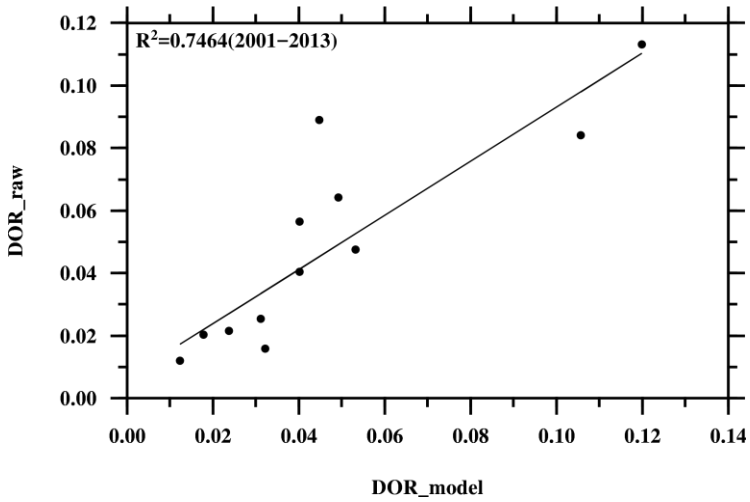

Figure 1. Scatter plots of the multiple regression modeling output of DOR and the original DOR.

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CONSTRAINING SOIL DUST EMISSIONS FROM NATURAL AND ANTHROPOGENIC SOURCES

M. Klose[1], C. Pérez García-Pando[1], A. Deroubaix[2], P. Ginoux[2] & R. Miller[3]
[1] *Barcelona Supercomputing Center (BSC), Barcelona, Spain*
[2] *NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, USA*
[3] *NASA Goddard Institute for Space Studies, New York, NY, USA*

Key words dust emission, anthropogenic dust sources, drag partition, global modeling, NMMB-MONARCH

The contribution of anthropogenic sources to the global soil dust load has been under debate over more than two decades with estimates ranging from 10 – 50% [e.g. 1,2,3,4]. Reasons for this large uncertainty include (1) deficits in the representation of small-scale anthropogenic dust sources (cropland and pasture); (2) a lack of data available to constrain the global dust load; (3) deficits in the model representation of parameters affecting dust emissions as well as of the dust emission process itself. In light of these issues, *Ginoux et al.* [5,6] utilized MODIS Deep Blue 2 satellite data to estimate the frequency of occurrence (FoO) of dust optical depth (DOD) > 0.2 globally at a high resolution (0.1° × 0.1°). The identified areas were interpreted as dust sources and were attributed to source type using a land use data set [7]. For the identified source regions, dust emission rates were estimated based on a simple expression [8] and a uniform threshold wind speed below which no dust is emitted. This threshold was set to be higher for anthropogenic sources than for natural sources: a heuristic representation of elements that inhibit wind erosion in cultivated environments, including higher soil moisture and more extensive vegetation shielding the soil from wind forces. Combining the so obtained dust emission rates with the calculated FoO (used as a "preferential source" scaling factor), *Ginoux et al.* estimated that 25% of global dust emissions originate from anthropogenic sources.

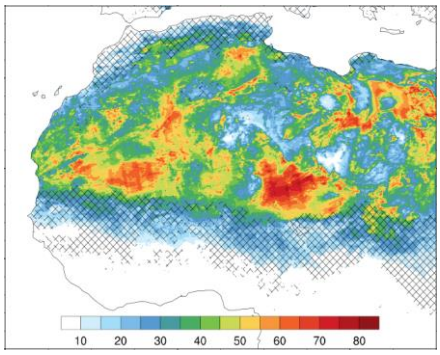

Figure 1. Frequency of occurrence that dust optical depth exceeds a threshold of 0.2 for natural and anthropogenic (dash pattern) dust sources [6] in northern Africa.

Here we aim to further constrain dust emissions from natural and anthropogenic sources. For this purpose, we make use of the recent advances by *Ginoux et al.*, and combine the advantages of direct source identification and attribution with the benefits of using a state-of-the-art integrated numerical modeling system containing a fully-coupled online dust component. These benefits include: (1) a physics-based threshold friction velocity for saltation varying in time and space; (2) a satellite-based representation of aerodynamic roughness length, an important parameter for sediment flux estimates; (3) a physics-based dust emission parameterization; and (3) a 4D dust concentration field allowing for in-depth model evaluation.

We conduct and thoroughly evaluate global model simulations for one year using NMMB-MONARCH, the Multiscale Online Nonhydrostatic AtmospheRe CHemistry model [8,9] using multiple combinations of source, emission, and drag partition parameters. Based on these simulations, we quantify the present-day relative contributions of natural and anthropogenic sources to global dust emission and deposition together with their uncertainties. We discuss the challenges of constraining the anthropogenic fraction of dust, anticipating that it heavily depends on variables that are poorly constrained at global scale. In addition, we use the simulation to identify model deficits which we are going to address in the future.

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THREAT TO AUSTRALIAN NATIONAL SOIL ASSET BY REMOVAL OF SOIL NUTRIENT BY WIND EROSION IN AUSTRALIA 2000-2010

J. Leys[1], A. Chappell[2], J. Mewett[3]
[1]*NSW Environnent and Heritage, Gunnedah Australia*
[2]*Earth and Ocean Science, Cardiff University, Cardiff, United Kingdom*
[3]*Australian Bureau of Agricultural and Resource Economics and Sciences, Braddon, Australia.*

Key words Soil nutrients; soil asset, wind erosion; Australia

Soil underpins Australia's agricultural production, biodiversity and provides ecosystem services that benefit the entire community. The condition of the soil describes the balance between exploitation and preservation. One-way soil is exploited is via erosion of soil nutrients. Dry seasonal conditions and land management practices that lead to low ground cover increase erosion rates. But how do we describe the condition of the soil and the services it provides? For this study, we assume that the soil organic carbon (SOC) and fertility of the soil represents the asset condition of the soil. Wind erosion threatens the soil asset by removing soil and nutrients, leading to a decrease in the soil's capacity to produce food and fiber and ecosystem services. We acknowledge that nutrient and SOC inputs protect the soil asset; however, no national data set is available and so is not included in this study.

For a national assessment of Australia's soil condition, we quantified the threat of wind erosion to the soil asset by modelling and mapping the loss of SOC, total phosphorous (TP) and total nitrogen (TN). We use an nutrient enrichment ratio of one as we are dealing with horizontal and not vertical (dust) fluxes. We compare the nutrient losses to established stock maps to establish the relative loss (SOC and soil nutrient stocks (t ha^{-1}) divided by the eroded SOC and nutrients) of SOC, TP and TN. These three relative losses, expressed as percentages, were averaged to produce a nutrient loss index map for Australia for the 2000-2010 period (Figure 1).

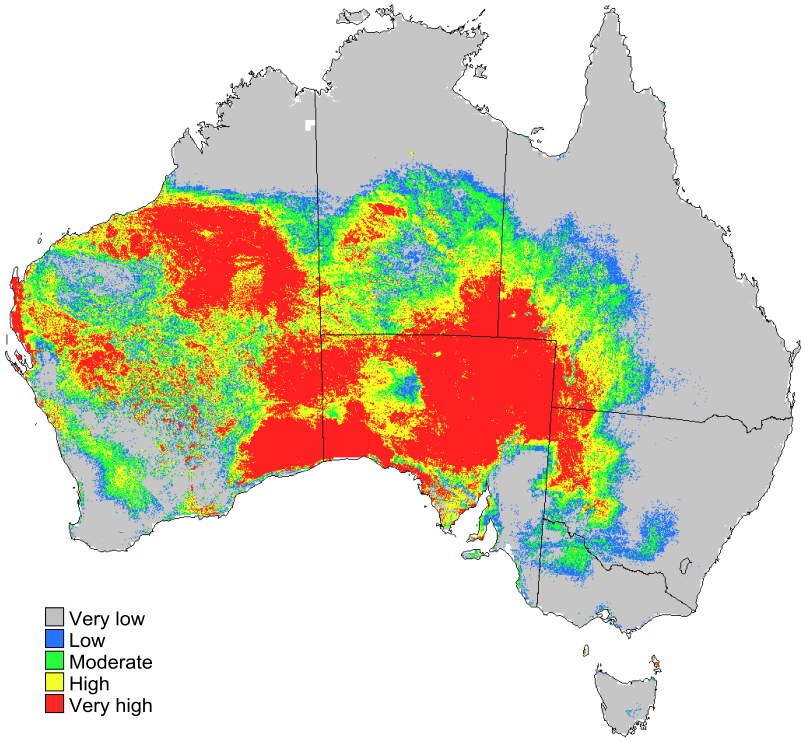

Figure 1. Nutrient loss index map for Australia

The largest impact of wind erosion on the soil asset (nutrient stock) is in the more arid parts of Australia. This is because erosion rates are high and nutrient stocks low. These results imply that ground cover management to control wind erosion in the arid areas is a high priority for protecting the current and future soil asset of Australia. These results also provide a 10-year benchmark, against which to measure future climate and land management impacts.

Spatial distribution and zoning of aeolian desertified land on the Qinghai-Tibet Plateau

LI Qing[1], ZHOU Na[2], ZHANG Chun-Lai[3], WU Yong-Qiu[3], ZOU Xue-Yong[3] & WANG Ren-De[1]

1. Hebei Engineering Research Center of Geographic Information Application, Institute of Geographical Sciences, Hebei Academy of Sciences, Shijiazhuang, China

2.College of Management Science and Engineering, Hebei University of Economics and Business, Shijiazhuang , China

3. State Key Laboratory of Earth Surface Processes and Resource Ecology, MOE Engineering Research Center of Desertification and Blown-sand Control, Faculty of Geographical Science, Beijing Normal University, Beijing, China

Key words Aeolian desertified land, spatial distribution, factors that control desertification, spatial zones, Qinghai-Tibet Plateau.

Using field investigations in the Qinghai-Tibet Plateau to develop a desertification attribute set, we established an interpretation index system for Landsat TM remote sensing images to identify the distribution and severity of aeolian desertified land (ADL). Using this system, we obtained current data on the area of ADL and its spatial distribution through visual interpretation and supervised classification of the Landsat data. We found that 15.1% of the plateau (392 914 km^2) suffered from aeolian desertification; this was mostly sandy ADL, gravel ADL, and aeolian yardangs. Most ADL was slight to moderate, but severe and extremely severe desertification occupied 12.2% of the plateau (48 272 km^2). ADL was scattered throughout the plateau, but concentrated mostly in the western and northern parts. From the southeast to the northwest, the distribution of ADL changed gradually from a sporadic distribution with small areas to a continuous distribution over large areas, and the severity of desertification tended to increase. Regional differences in climate, landforms, Quaternary deposit type, and human activities accounted for the spatial distribution. We divided the plateau into five sub-regions based on the ADL characteristics (area, type, severity, spatial distribution, and cause): the Qaidam Basin arid desertification sub-region, high and cold northern Tibet and southern Qinghai desertification sub-region, semi-arid mountainous desertification sub-region of the Yarlung Zangbo River watershed, the semi-arid desertification sub-region of the upper reaches of the Huanghe River watershed, and the humid mountainous desertification sub-region of the Nujiang River, Lancang River, and Yangtze River watersheds.

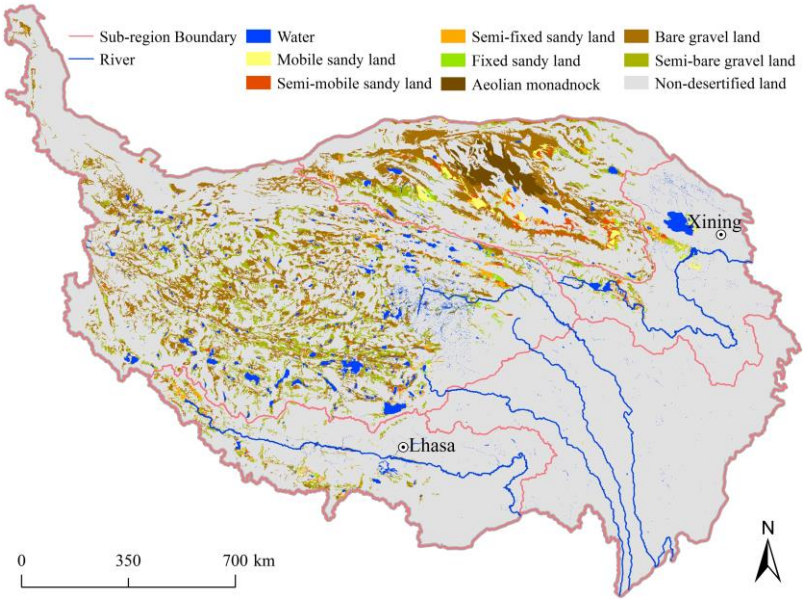

Figure 1. Spatial distribution and zoning of aeolian desertified land on the Qinghai-Tibet Plateau.

Impact of land use on wind erosion and dust emission in the Sahel: a regional modelling approach

Marticorena B.[1], Siour G.[1], Pierre C.[1,2], Bouet C.[1,2], Bergametti G.[1], Abdourhamane Touré A. [6], Baron C.[4], Bouniol D.[5], Couvreux F.[5], Guichard F.[5], Grippa M.[3], Hiernaux P.[3], Kergoat L.[3], Largeron Y.[5], Lebel T.[7], Mougin E.[3], Quantin G.[7], Rajot J.L.[1,2], Roussillon J. [1], Tidjani A.D.[6], Valentin C.[2], Vischel T.[7]

[1]*LISA, UMR CNRS 7583, UPEC, UPD, IPSL, Créteil, France*

[2]*iESS-Paris, UMR IRD 242, CNRS, INRA, UPMC, UPEC, UPD, Bondy, France*

[3]*GET, UMR CNRS 5563, Toulouse, France*

[4]*CIRAD, Montpellier, France*

[5]*CNRM-GAME, UMR CNRS 3589,Météo-France,Toulouse, France*

[6]*JEAI ADE, Université Abdou Moumouni, Niamey, Niger*

[7]*LTHE, UMR CNRS 5564, Grenoble, France*

Key words Wind erosion; Dust emission; Land use; Vegetation; Sahel.

The semi-arid Sahelian region is particularly prone to wind erosion due to low and variable annual precipitation producing low vegetation cover with a high interannual variability. Surfaces traditionally devoted to livestock grazing are more and more used as croplands, increasing the proportion of bare surface unprotected from wind erosion. Wind erosion could significantly evolve in the future with climate change and the changes in land use and agropastoral management practices expected from the persistent demographic growth.

To estimate the wind erosion and dust emission in the Sahel, we have developed a regional modelling approach in the framework of the CAVIARS project (Climate, Agriculture and Vegetation: Impacts on Aeolian eRosion in the Sahel). The approach is based on existing models that were adapted and coupled to represent the main processes involved in the wind erosion and their dependence to climate parameters and agropastoral practices. Natural vegetation (herbaceous) and cropped vegetation (millet) are respectively modelled with the STEP vegetation model [1] and the SARRA-H agronomic model [2]. Both models have been improved to reproduce the dynamics of dry vegetation and to produce multi-annual simulations [3]. The wind erosion model [4] has been tested and adapted to represent the erosion fluxes over typical Sahelian vegetated surfaces [5, 6]. Surface crusting and its dynamics is represented as a function of soil texture, precipitation and vegetation cover. A main limitation was to represent the very strong surface winds associated to the convective activity that are not reproduced by the large scale meteorological wind fields [7]. A specific parameterization of the distribution of the surface wind speeds has been developed based on high resolution simulations (CASCADE exercise) and applied to the ERA-I reanalyses from the European meteorological center (European Centre for Medium-range Weather Forecast). The application of the models at the regional scale required dedicated data sets, established for this purpose. Daily precipitation fields were produced based on local measurements. Grazing pressure maps were established based on national data and/or agro-poastoral census. The proportion of croplands and rangelands are derived from the Sahelian land use map of the AGRHYMET [8].

The spatial and temporal distribution of the simulated dust emissions computed for the period 2000-2014 will be presented. The parameterization of the wind speed distribution associated with the convective activity allows to better capture the seasonal pattern of local wind erosion [9]. The relative weight of climatic parameters and agropastoral management will be estimated by reference to a simulation with no vegetation and no land use.

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The relevance for dust emissions from agricultural operations on arable lands for the spread of pathogenic bacteria

Steffen Münch[1], Nadine Thiel[2], Paul Siller[3], Oliver Biniasch[4], Matthias Faust[5], Kerstin Schepanski[5], Thomas Amon[4], Uwe Rösler[3], Ulrich Nübel[2] & Roger Funk[1]

[1] *Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany*
[2] *Leibniz-Institute DSMZ, Braunschweig, Germany*
[3] *Institute for Animal Hygiene and Environmental Health, Freie Universität Berlin, Germany*
[4] *Leibniz-Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany*
[5] *Leibniz-Institute for Tropospheric Research (TROPOS), Leipzig, Germany*

Key words Agriculture, dust emission, pathogenic bacteria

The use of contaminated farmyard manure on agricultural fields could have an impact on human health, when agricultural operations (application, incorporation, tillage) take place. In this case, dispersing particles, spread by the wind, might act as a carrier for pathogenic bacteria. The investigation for the dust-associated release of such bacteria over manure-fertilized fields is operated in the frame of the project SOARiAL (Spread of Antibiotic Resistance in an Agrarian Landscape).

There are three processes, where dust is released on agricultural fields: Application of manure, tillage activities and wind erosion. In this study, we concentrate on dust emissions, which are caused by tillage. In Germany, tillage tends to equivalent dust emissions, when tillage operation tools disturb the soil, comparing to wind erosion events [1] and leads to a loss of fine material and organic matter. Shortly after farmyard manure application, the organic matter proportion in the soil will increase (2 % → 2.14 %, 3 t/ha, 15 cm incorporation) and the potential for dust release will increase, too. Because of no formation of soil aggregates with manure during incorporation, pathogenic bacteria could release directly via dust manure. During tillage, dispersing soil particles over fertilized field could also act as a carrier for pathogenic bacteria. Therefore, the objective of this study is to investigate the composition of particulate matter and particle size distribution near the dust source, with a special focus on bacteria-associated aerosol particle properties.

The experiments took place on two experimental field sites (loamy sand soil) in spring/early summer 2017 in Brandenburg/Germany. Four tillage events were investigated: Incorporating manure with a disk harrow, incorporating nitrogen fertilizer with a chisel, sowing maize with a harrow and again incorporating manure with a chisel on a second experimental site, comparing all events with the pre-process of manure application. To determine the properties of fine particles, dust fraction was measured in two different heights by two environmental dust monitors (GRIMM EDM107 Spectrometer).

Figure 1. Measurement of dust emissions during tillage.

Finally, these measurements will provide data for modelling of dust fluxes and microbial emission fluxes on a larger scale to get a better understanding into the dynamics of atmospheric microbial dispersal and to develop strategies to mitigate microbial dispersal.

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BEST MANAGEMENT PRACTICES TO MITIGATE WIND EROSION AND PARTICULATE EMISSIONS FROM AGRICULTURAL SOILS

B. Sharratt[1]
[1]*USDA-ARS Northwest Sustainable Agroecosystem Research Unit, Pullman, Washington, USA*

Key words Air quality; Crop residue; Sustainable agriculture; Tillage.

According the Food and Agriculture Organization, 48.5 million km^{-2} or 37% of the Earth's land mass is used to support agricultural production. Tillage, water, and wind erosion can deteriorate the soil resource, therefore farm management practices imposed upon these lands are important for ensuring an adequate food supply for future generations. In addition, wind erosion of agricultural land in some regions of the world can elevate particulate matter concentrations above national ambient air quality standards. For these reasons, it is important to identify or develop economically-viable crop and soil management strategies to mitigate wind erosion. In the United States, for example, reduced tillage practices have been advocated for reducing wind erosion and particulate emissions from dryland and irrigated soils in the Pacific Northwest. More recently, green manure and surface application of biosolids (Fig. 1) have been examined as alternative strategies to reduce wind erosion. Similarly, in the southern Great Plains, reduced or directional tillage are viable strategies for controlling wind erosion. However, where little crop residue remains after harvest of locally-important crops such as cotton, clod-forming tillage implements such as a rotary hoe or sand fighter might be used to roughen the surface to protect the soil from stresses associated with wind shear. In the Red River Valley of the northern Great Plains, reduced tillage after harvest of small grains or the use of cover crops after harvest of sugar beets have been promoted for reducing wind erosion. In Australia, managing grazing pressure is a viable strategy to control wind erosion from rangelands while reduced or zero tillage has been recommended for reducing wind erosion from cultivated lands. This presentation will also highlight land management strategies used in other parts of the world as well as novel strategies that have been recently examined for mitigating wind erosion of agricultural lands.

Figure 1. Biosolids applied to the soil surface during the fallow phase of a winter wheat-summer fallow rotation in the Pacific Northwest.

HOW TO DETECT CHANGE IN AEOLIAN SEDIMENT TRANSPORT

N.P. Webb[1], A. Chappell[2], J.W. Van Zee[1], B. Edwards[1], D. James[1]
[1] *USDA-ARS Jornada Experimental Range, Las Cruces, NM, United States*
[2] *School of Earth and Ocean Sciences, Cardiff University, United Kingdom*

Key words wind erosion, aeolian sediment transport, sampling, uncertainty, dust emission, land use land cover change (LULCC)

The detection of change in aeolian sediment transport is key to explaining cause. For example, anthropogenic land use and land cover change (LULCC) influence global rates of wind erosion and dust emission. However, current approaches to measuring wind erosion and dust emission are typically highly uncertain, because they inadequately account for the large spatial and temporal variation in aeolian sediment transport. Field measurements need to reduce uncertainty sufficiently to enable change to be detected at some specified confidence level. Here, we use field measurements of aeolian sediment transport to show (Figure 1) that: i) the spatial variance in aeolian sediment transport may be many times larger than the temporal variance depending on the land surface aerodynamics and sediment supply; and ii) too few samplers, or poorly positioned (biased, e.g., by avoiding vegetation) samplers inflate uncertainty causing change in aeolian sediment transport to be undetectable. The straightforward application of an unbiased sampling design combined with a rigorous statistical framework enables minimum detectable change over time in aeolian sediment transport responding to e.g., land use and management across land cover types. We examine how robust field measurements can be combined with new modelling approaches that resolve the spatial variation in transport controls to improve dust model sensitivity and reduce uncertainty in assessments of the impacts of LULCC.

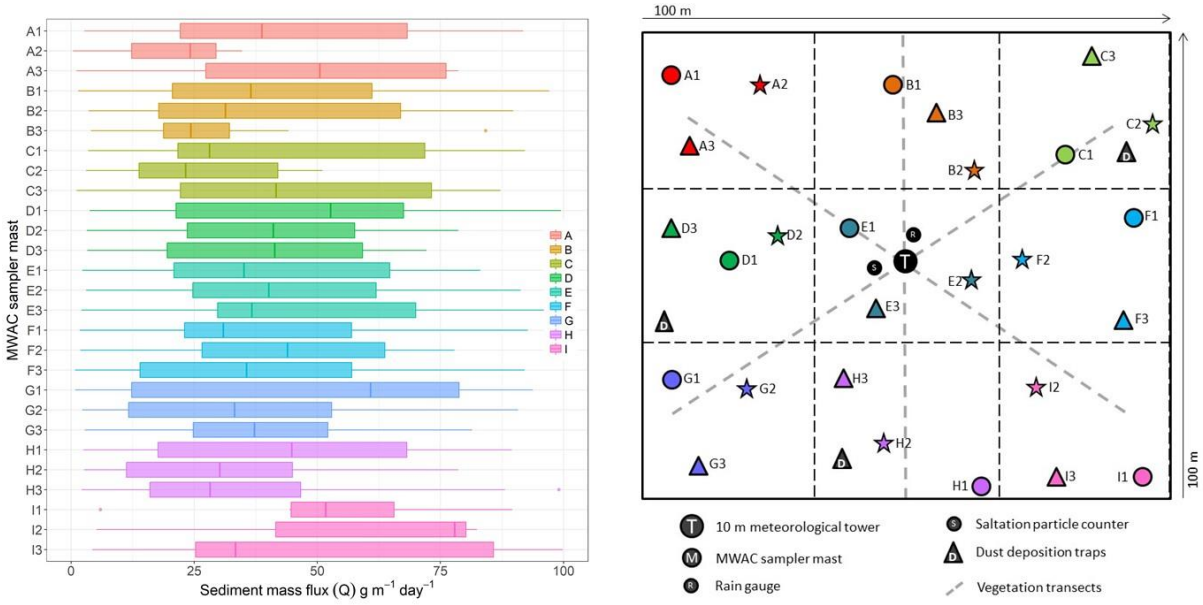

Figure 1. Vertically-integrated sediment mass fluxes (left) summarized for 27 Modified Wilson and Cooke (MWAC) sampler masts. Data were collected monthly from May 2015 to December 2017 at the National Wind Erosion Research Network site (right) located at the USDA-ARS Jornada Experimental Range in south-central New Mexico, USA [1].

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SESSION

« Dust dynamics and processes: emission, dispersal, and deposition »

Size-resolved deposition fluxes and deposition velocities over a sandy surface: In-situ experimental determination and comparison with existing parameterizations

G. Bergametti[1], B. Marticorena[1], J.L. Rajot[1,2], G. Forêt[1], S.C. Alfaro[1], and B. Laurent[1]
[1]*Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*
[2]*Institut d'Ecologie et des Sciences de l'Environnement de Paris, Bondy, France*

Key words dust dry deposition, measurements, test of parameterizations

An intense dust deposition event occurred in June 2006 in Niger. It was the consequence of the turn-back of a dust cloud resulting from a large wind erosion event that occurred the day before due to the passage of a mesoscale convective system. Bulk and size resolved particle concentrations were measured at 2.1 and 6.5 m over an agricultural field. At the date of the experiment (mid-June), almost all the vegetative residues from the previous year were decomposed or grazed and the sandy surface was almost bare, with only few per-cents of residues remaining. In the wind direction, the fetch was greater than 500 m. Bulk concentrations measurements were performed using two TEOM instruments and size resolved particle concentrations in 15 channels (from 0.3 µm to 20 µm) using two Optical Particle Counters (OPC, GRIMM instruments). These instruments have been carefully cross-calibrated before the campaign. At each level, the particle concentrations from TEOM and the particle volume from OPC were highly correlated with a slope 2.265 (+/- 0.02) which is the apparent mass density of the particles. In complement wind and temperature profiles were measured at 5 and 4 different heights, respectively. The stability conditions remained near-neutral ($-0.05<1/L<0.01$) for the 10h duration of the deposition period. The dust deposition event was so huge that the difference in particles concentrations over a $\Delta H = 4.4$ m reached 100 µg m^{-3}. All these observations allowed to compute size-resolved dust deposition fluxes and dry deposition velocities with a good confidence level. The deposition fluxes and velocities were computed using a 20-min sliding average and a 5-min time step. Size-resolved dry deposition velocities were computed only if the difference in concentrations for the considered channel between the two levels was greater than 5%.
Deposition fluxes derived from bulk particle concentrations measured by TEOM instruments and those derived from size-resolved concentration measurements performed by OPC are in very good agreement. The evolution of the dust deposition fluxes during the day follows the dust concentration: higher deposition fluxes being recorded when the concentrations were maximal. This is not the case of the dry deposition velocities that are mainly controlled by the sensible heat flux in the early morning and by the wind friction velocity the rest of the day. Dry deposition velocities exhibit a maximum around noon as frequently reported in the literature.
Size-resolved dry deposition velocities were compared with the rare existing data of dust deposition over bare sandy soils. A very good agreement was found with the data obtained by Lamaud et al. (1994) in Niger for submicron particles and with those obtained in wind tunnel for deposition of dust particles (1 to 40 µm) over sand and sandy loam by Zhang et al. (2014). Then, our in situ measurements were confronted to exiting parameterizations of deposition velocity (Slinn, 1982; Zhang et al., 2001; Zhang and Shao, 2014). The parameterization of Zhang and Shao (2014) is the only one that reproduces with a good confidence level the dry deposition velocities on sandy soils for particles in the size range 1-10 µm. This good agreement is mainly because, unlike the others, this model considers the bare sandy surfaces as rough surfaces allowing the interception of dust particles by the sand grains and small roughness elements present at the surface.

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DO SAHARA DUNE SANDS MAKE DUST ?

C. S. Bristow[1], & T. H. Moller[1],
[1]*Department of Earth and Planetary Sciences,Birkbeck University of London, Malet Street, London WC1E 7HX, UK, Europe.*

Key words Sahara, dune, sand, dust.

The Sahara desert produces around half of the atmospheric mineral dust on Earth. While most of the Sahara has the potential to produce dust some areas have been identified using remote sensing as especially prolific sources such as the Bodélé Depression in Chad which is described as the dustiest place on Earth (Giles 2005). Geomorphological analysis indicates that these areas are usually topographic lows, such as the Bodélé, as well as regions on the flanks of topographic highs (Prospero et al. 2002). Many of the topographic depressions are the sites of former lakes. The lakes which were full of water during the African Humid Period have subsequently dried out leaving fine grained sediments on the surface that are subject to deflation. Alternatively, it has been suggested that active sand dunes are the most frequent dust sources (Crouvi et al. 2010). In this paper we use an aeolian abrasion chamber to reproduce the physical processes of aeolian abrasion and test the hypothesis that desert dune sands produce dust. We use dune sediment samples collected from active sand dunes across the Sahara including samples from the Bodélé Depression, as well as dune sands from Algeria, Egypt, Libya, Morocco and Mauritania. The experiments produced results that range across three orders of magnitude, indicating that some dune sands, including those from the Bodélé produce much more dust than others. In addition we test the production of dust from sands over time. The results show that dust production from red desert dune sands declines over time, probably due to the removal of resident fine particles and grain coatings (Bullard et al. 2004). However, dust production from grey dune sands composed of aggregate particles does not decline as much over time (Figure 1). This means that the dust potential of red dune sands could be rapidly depleted, while potential for dunes composed of aggregate particles will persist.

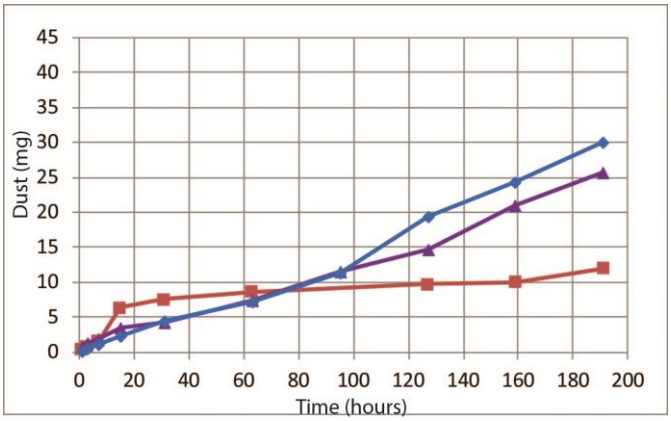

Figure 1. Cumulative dust production from a Sahara dune sand (PV2, (Red)) showing rates of dust production tending to decrease over time while samples that include aggregate (CH56 (Blue), and WP10 (Purple)) continue to produce dust at similar rates.

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SPATIAL AND TEMPORAL VARIABILITY OF DUST DEPOSITION RATES IN SW GREENLAND

J.E. Bullard, M. Van-Soest, N.J. Anderson, M.C. Baddock
Department of Geography, Loughborough University, Leicestershire, LE11 3TU UK.

Key words dust, deposition, seasonality, Arctic, Holocene

Estimates from field studies, remote sensing and modelling all suggest around 5% of global dust emissions originate in the high latitudes (≥50°N and ≥40°S), but there have been few studies of the deposition rates and impacts of locally-sourced dust within the Arctic and sub-Arctic. In proglacial areas, such as SW Greenland, aeolian sediment systems (sand and dust) not only respond directly to climate, but are also affected by ice dynamics and the magnitude, frequency and timing of meltwater sediment delivery to floodplains. This paper reports measurements of contemporary dust deposition along a 30 km transect extending seawards from the margin of the Greenland Ice Sheet to the head of Kangerlussuaq fjord. Deposition rates of locally-sourced dust are highest within 10 km of the ice margin (50-100 g m^{-2} yr^{-1}) and decrease to 20-50 g m^{-2} yr^{-1} 20-40 km from the ice. Deposition rates are also seasonally very variable and highest during spring months (0.5-1 g m^{-2} day^{-1}), coinciding with high sediment supply, strong winds and low surface moisture. Lake sediment core records suggest regional dust deposition rates have varied considerably during the past 7500 years (from 20 g m^{-2} yr^{-1} to >80 g m^{-2} yr^{-1}) and that modern regional dust deposition rates are comparable with those during the Little Ice Age (c. 70 g m^{-2} yr^{-1}). Within this part of Greenland locally-redistributed dust is an important source of minerogenic matter and nutrients to soils and lakes.

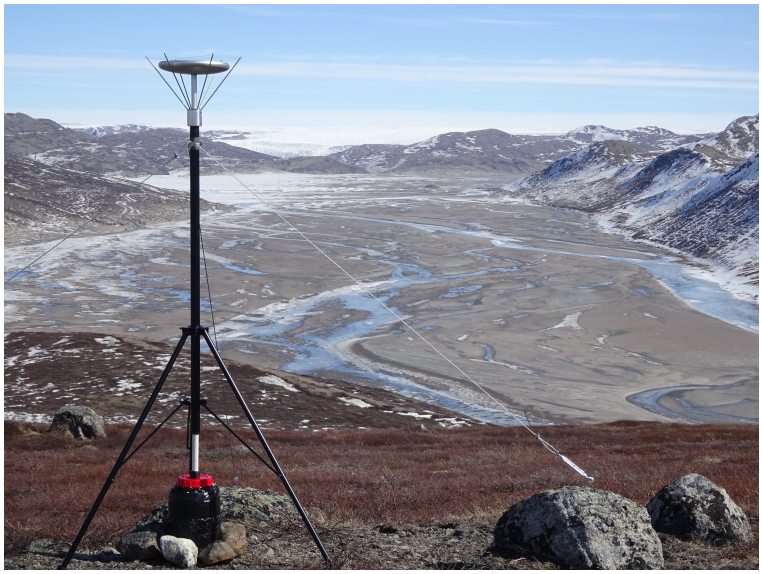

Figure 1. Dust deposition trap located c. 10 km west of the Greenland ice margin near Kangerlussuaq.

SIGNIFICANCE FOR DUST EMISSION MODELLING OF OMITTING CHANGING AERODYNAMIC ROUGHNESS

A. Chappell[1] & N. Webb[2]
[1] *School of Earth and Ocean Sciences, Cardiff University, United Kingdom*
[2] *USDA-ARS Jornada Experimental Range, Las Cruces, NM, United States*

Key words Land surface aerodynamic roughness; Wind stilling; Dust emission; west African Sahel; Drylands.

Experiments of dust emission processes have informed the development and evolution of dust emission schemes that underpin global dust emission models (GDEMs) [1, 2]. Despite these improvements, many GDEMs retain only crude approximations of the emission processes because they do not adequately balance upscaling, parameterisation parsimony and process fidelity [3]. The GDEMs focus on static and homogeneous land surface aerodynamic roughness (and soil characteristics, not tackled here). This approach omits the spatio-temporal dynamics of soil surface shear stress due to land use / land management change, CO_2-fertilisation and drought amplification. Consequently, observed reduction in dust emission in e.g., the west African Sahel cannot be replicated by GDEMs [4, 5]. The same omission very likely causes modelled wind speed outputs to be much more uncertain than currently recognized. For example, observed wind stilling is absent in modelled wind speed outputs [6]. To establish the significance of these omissions, we improve shear stress dynamics using an albedo-based parameterization of the aerodynamic roughness normalized by wind speed (u_{S*}/U_f) [7]. We use MODIS albedo (MCD43A1 8-daily, 500 m) and GLDAS modelled wind speed data and other global datasets to investigate the spatio-temporal dynamics of global u_{S*}/U_f and dust emission. Global drylands show distinct and opposing trends of u_{S*}/U_f (Fig. 1). Modelled winds dominate dust emission inconsistent with trends in u_{S*}/U_f. Omitting changing aerodynamic roughness in wind data and dust emission will render GDEM outputs ineffective and interpretations unreliable. A solution is to use u_{S*}/U_f and embed GDEMs in to LSMs coupled to GCMs. Improved modelling of dust emission spatio-temporal dynamics will likely reduce uncertainty in radiative forcing and biogeochemical cycling for climate change projections.

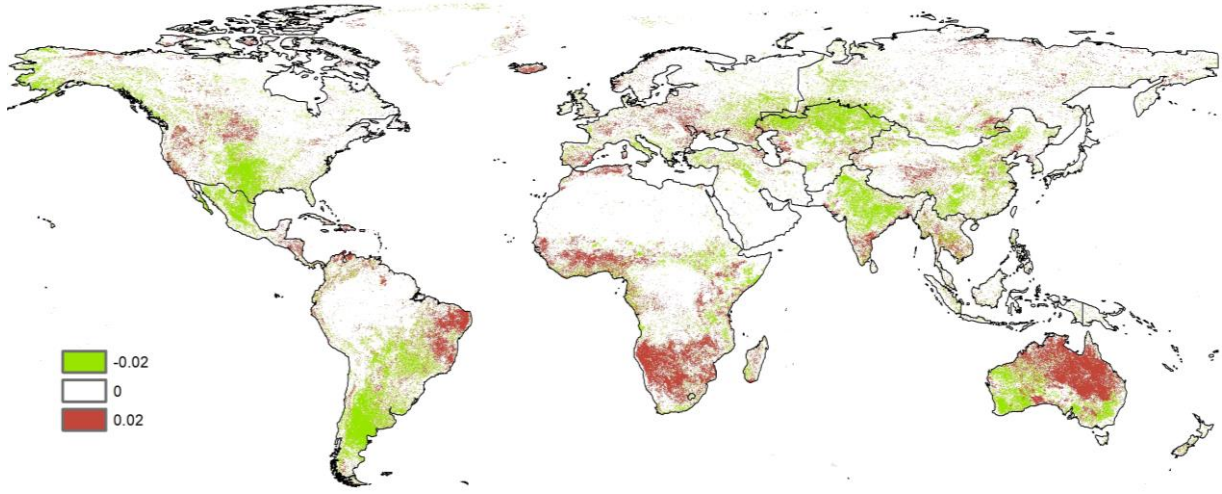

Figure 1. Robust estimator [8] of trend for land surface aerodynamic roughness (u_{S*}/U_f) during April-September 2010-2016 (green=increasing roughness, white=no change, red=decreasing roughness).

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EXPLAINING THE DISTRIBUTION OF NUTRIENTS BY WIND PARTITIONING IN THE COAST OF THE NAMIBIAN DESERT

A. Chaput, J. King, P. Formenti, P. Gauvin-Bourdon

LÉÉ Laboratory: Université de Montréal

Key words Aeolian, Dust dynamics, climate change, radiation balance, modelisation, granulometry, nutrients.

Diffusion and absorption of radiation are directly impacted by mineral dust aerosols, which currently represents the greatest uncertainty of the radiative forcing in the global climate models. Currently, dust production models in global circulation models are based on corrected theoretical models and idealized laboratory or field experiments. Consequently, this can lead to a misrepresentation of the size and composition of dust particles when evaluating their distribution. This project is part of a series of campaigns trying to better understand the influence of mineral aerosols in the southeast Atlantic. The results from these projects will improve the knowledge and precision already obtained during the operational campaigns performed in this region.

Figure 1 : Location of the study sites (red dots) in Namibia (Google Earth, 2016)

Based on the coast of the Namibia, this project's objective is to quantify the enrichment of soils from dust particles locally transported to better assess the biological cycling and the radiative effects related to the parent soil material. Three valleys (figure 1) have been selected considering their importance in potential fertilisation derived from dust particles and their active aeolian transport, all with a currently an unknown net transport direction between the consistent southwesterly trade wind and episodic easterlies. For each valley, data was collected in August-September 2017 from: surface soil samples throughout the valley deposited behind vegetation, horizontal transport traps, and vertical PM10 flux filters. The analyses performed on these samples include: particle size distribution, composition, physical, element and chemical properties as determined by the XRF and XRD. Coupled with climatology measured at the mouth of each valley, these results show that the majority of winds are from the southwesterly direction (i.e., the main direction in the Huab is south, of which 20% is oriented at an angle of 150°), yet the net sediment transport is from the east, suggesting that there is a substantial component of transport onshore that plays an important biological and radiative role. These results will be compared with several dust production models to compare the relative radiative effects for transport in the two principal directions. In addition experiments with a resuspension chamber has been performed to compare the impact of sediment derived from several transport modes on their radiative and chemical properties, which aims to improve the performance and the standard procedures for measuring dust particles.

Effect of salt mineralogy on dust emissions: a laboratory experiment

Dai Jiadong[1,2,3,4], Zhang Guoming[1,2,3,4], Han Xujiao[1,2,3,4], Liu Lianyou[1,2,3,4], Yan Ping[1,2,3,4], Yang Yanyan[1,2,3,4],
[1]Key Laboratory of Environmental Change and Natural Disaster of Ministry of Education, Beijing Normal University, Beijing，China
2 State Key Laboratory of Earth Surface Process and Resources Ecology, Beijing Normal University, Beijing，China
3 Academy of Disaster Reduction and Emergency Management Ministry of Civil Affairs & Ministry of Education, Beijing Normal University, Beijing，China
4 Faculty of Geographical Science , Beijing Normal University, Beijing，China

Key words playa, dust emission, salt mineralogy, salt crust, wind tunnel

Playas are considered as significant sources of salt dust, leading to severe ecological hazards. Salt crusts can come into formation at surface of playas derived from residual salt, evaporation of underground water and rock weathering. It is well known that salt crusts affect the susceptibility of surface particles to be entrained by wind. However, there is little known about effect of salt mineralogy on dust emission potential. A laboratory experiment including wind tunnel test has been conducted to get the understanding of effect of typical salt mineralogy on dust emissions.
Seven types of salt mineralogy are chosen to create salt crust samples by sub-irrigating the soil samples with silty clay loam and natural evaporation, containing sodium chloride, potassium chloride, magnesium chloride, sodium sulphate, potassium sulphate, magnesium sulphate and sodium carbonate. We undertook a series of tests with wind tunnel and TSI DustTrak aerosol monitor to obtain dust emission flux at high wind velocity. Properties of salt crusts were also tested including crust thickness and hardness. The results show that crusts rich in sodium chloride, potassium chloride and magnesium chloride are found to be less emissive than crusts formed from the other types of salt mineralogy while sodium sulphate and sodium carbonate are more emissive. Salt crust hardness plays a more important role than crust thickness in influencing dust emission and resistance to wind erosion as the hardness of salt crust with lower emissive characteristic is large. The results from this study is in agreement with other scientific researches in some ways. However, there are many types of salt mineralogy coexisting in the field and exists interaction between them. More work need to be done to understand the effect of salt crust created by multiple types of salt mineralogy on dust emission.

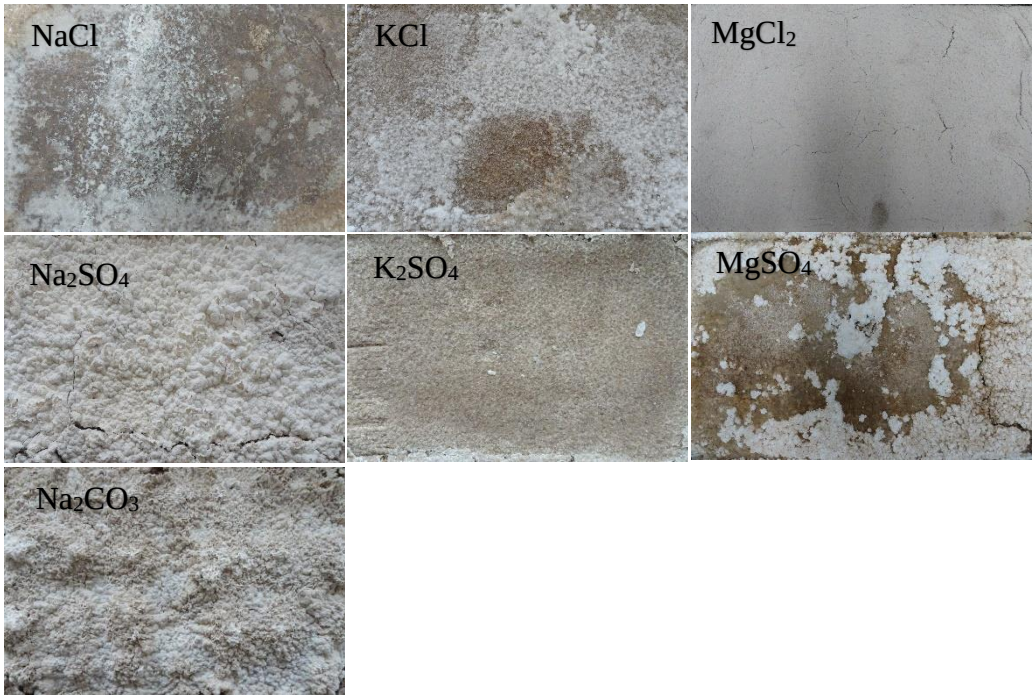

Figure 1. Different types of salt crusts

CLIMATIC AND EUSTATIC SIGNIFICATION OF QUATERNARY WIND MOBILIZATION IN MARITIME JEFFARA IN THE SOUTHEASTERN OF TUNISIA

A. Essid[1], M. Mansoura[1, 2], M. Ouaja[3], K. Regaya[1, 4] and J.Y. Reynaud[5]
[1]*Research unit: geodynamics of geosystems, Tunisia*
[2]*The National Office of Mines, Tunisia*
[3]*University of Gabes, Tunisia*
[4]*University of Carthage,Tunisia*
[5]*University of Lille 1, France*

Key words: Quaternary, plain of Jeffara, climate change, fluvio-lacustrine deposits, desert deposits, tectonics, incised valley.

In the maritime Jeffara, particularly in the Ben Guerdane depression situated in the far southeastern part of Tunisia, the phenomena of desertification were quite active during the late Pleistocene and Holocene. The mobilization of a large amount of sand, require an important source which were eroded during these periods. Separated from the plain of Jeffara by the Mesozoic relief of the Dahar plateau, the dune fields of the Grand Erg Oriental can not constitute the principal source of sediments. The study of the terraces in the incised valleys of many rivers that crisscross the Jeffara plain, allowed a fine analysis of the Quaternary continental sedimentary facies and a reconstitution of the history of the Aeolian sands and their origin.

In the southeastern Tunisia, Quaternary series begin with thick layers of silt clay and conglomerates. Attributed to the early to medium Pleistocene, this series represents a fluvio-lacustrine sedimentation deposited in a warm and relatively humid climate with contrasting seasons as evidenced by the abundance of carbonate concretions.

Largely distributed in maritime Jeffara, these fluvio-lacustrine deposits are cut by many and wide valleys in which the late Pleistocene and Holocene deposits are nested. These deposits are mainly made of fine aeolian sands and silty-gypse clays of coastal plains and their associated sebkha. A fluvio-lacustrine deposit interbedded within a hot and arid sediment facies shows the occurrence of short humid periods.

At least three climatic sedimentary sequences, corresponding to orbital cycles, made of the superposition of heterogeneous fluvio-lacustrine sediments and homogeneous fine sands deposited by marine winds. The degradation and preservation of these sequences are tightly controlled by tectonic uplifts and piezometric fluctuations of the groundwater. In the lower coastal plains, the latter depends much more on variations of the base level than precipitation.

In agreement with Swezey's work (2001) which reveals an overall trend towards widespread wind mobilization of sediments during late Pleistocene, stabilization of early Holocene aeolian sediments and the return to the generalized mobilization of wind sediments during late Holocene, the late Pleistocene and Holocene deposit model in Maritime Jeffara shows the same climatic sedimentary sequences. The possibility of correlation with the equivalent marine formations, allow us to integrate quaternary desert deposits into the overall framework of climate changes and sea level variation.

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Resuspension Potential of Volcanic Ash

V. Etyemezian[1], J. Gillies[2], & G. Nikolich[5]
[1,2]Desert Research Institute, Las Vegas[1] and Reno[2], Nevada, USA

Key words tephra, PM10, dust

There have been few direct studies that have quantified the magnitude of ash resuspension by wind following a volcanic eruption. Close to a volcano post-eruptive erosion and remobilization of pyroclastic deposits by wind are maximized by large erupted volumes, abundant unconsolidated ash-sized material, destruction of the vegetation cover, and inhibition of vegetation regrowth. Further from the source volcano, at distances of tens to hundreds of kilometers, the potential for resuspension of the deposited ash by wind will be controlled by the depth of the deposit, the particle size distribution of the ash, the moisture conditions during and subsequent to deposition, and the nature of the surface onto which it deposits. Resuspension events are observed to occur immediately after the deposition of ash as well as recurrently for months after deposition.

An understanding of the potential for ash resuspension from a landscape first requires information on the inherent tendency of the ash to mobilize under conditions of varying shear stress, information that is scarce in the literature. Samples of volcanic ash were collected from two sources in North America, Mount Saint Helens in Washington and the Valley of Ten Thousand Smokes in Alaska. Ash deposits were oven-dried in a laboratory and placed in an environmental chamber where they were subjected to conditions of constant relative humidity (Figure 1). A sample of sand from the Oceano Dunes in California was included in the testing protocol for reference.

Experiments were conducted to assess the impact of varying the relative humidity in the environmental chamber on wind erodibility from 25% to 75%, with limited tests at 10% and 90%. The potential for wind erosion was measured with a modified PI-SWERL® instrument. In a subset of tests, liquid water was added to the ash sample to mimic the effect of rainfall on ash resuspension.

Results of testing indicate that volcanic ash is much more prone to resuspension than other natural surfaces that have been tested with the PI-SWERL previously, either in-situ or in the laboratory. As expected, the potential for resuspension decreases somewhat at relative humidity above 75%. Some data suggest a decrease in resuspension at very low humidities as well, perhaps due to the influence of static electricity. The presence of liquid water a few centimeters beneath the surface had a small impact on the potential for resuspension from the surface.

To our knowledge, this is the first time that resuspension from volcanic ash has been directly measured under controlled conditions.

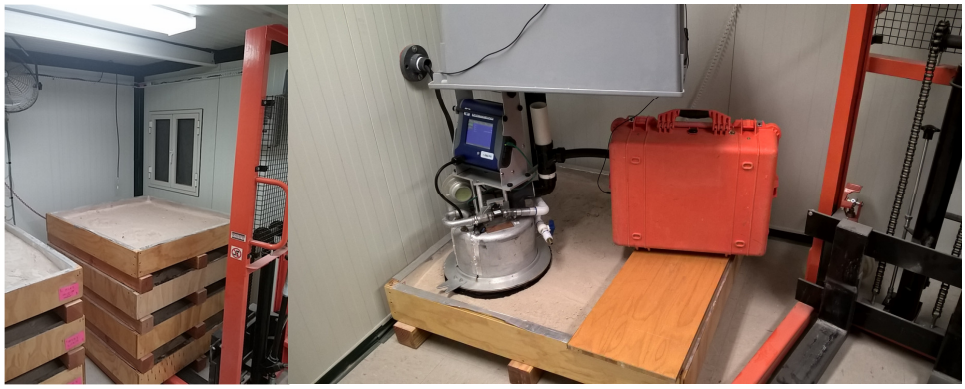

Figure 1. Ash samples in condition chamber (left) and ash sample undergoing PI-SWERL tests (right).

Dust Emissions from the Oceano Dunes, San Luis Obispo County, California, USA

V. Etyemezian[1], J.A. Gillies[2], G. Nikolich[1], R. Glick[3]
[1]*Division of Atmospheric Sciences, Desert Research Institute, Las Vegas, NV, USA*
[2]*Division of Atmospheric Sciences, Desert Research Institute, Reno, NV, USA*
[3]*California Department of Parks and Recreation, Oceano Dunes District, Pismo Beach, CA, USA*

Key words Sand dunes, dust emissions, air quality degradation, PM_{10}, off highway vehicles

The active Oceano Dunes on the Central Coast of California in San Luis Obispo County formed approximately 12,000 to 15,000 years ago. Earlier dune building episodes extend back in time even further, perhaps as early as 750,000 years ago. A large portion of the dunes (≈500 ha) serves as the setting for a State Park where the public is allowed to ride off-road recreational vehicles (ATVs). Frontal systems during spring and portions of summer result in consistent west-northwesterly winds that move sand to drive the dust emission system. Under conditions of high winds, mineral dust is emitted in quantities that result in the exceedance of air quality standards for mass concentration of particulate matter (PM_{10}). This dust is transported downwind to residential and commercial areas of the nearby Nipomo Mesa. Complaints from impacted residents and concerns from the regulatory agency for air quality have prompted a long-term effort to understand and reduce dust emissions from the Oceano Dunes.

A focus of the work has been to determine the portion of air quality degradation in excess of what would occur naturally that is a consequence of allowing recreational vehicles to use the dunes. Studies have included multiple field measurements of wind erosion potential with the PI-SWERL® instrument, field measurements of ambient wind and dust particle concentrations, modeling studies, and implementation of water-free dust control techniques. With emphasis on the spatial emissions patterns estimated from PI-SWERL testing over several years, an overview of what has been learned to date will be presented.

Figure 1. Oblique view of the Oceano Dunes.

WHAT INFLUENCES THE SIZE DISTRIBUTION OF THE NEAR-SURFACE DUST FLUX?

R. Fernandes[1], S. Dupont[1] & E. Lamaud[1]
[1]*ISPA, INRA, Bordeaux Sciences Agro, F-33140, Villenave-d'Ornon, France*

Key words Dust flux size distribution, dust emission, dust dispersion, dust deposition, particle entrainment, inter-particle cohesive bond, aggregate distribution, wind intensity

Identifying the main factors influencing the size distribution of near-surface dust flux is essential given its impacts on the micro-climate, human health, and human activities. A comparison of existing dust schemes demonstrates disagreements on the dependence of the dust-flux size distribution to various factors such as the wind intensity, the surface aggregate distribution, the surface inter-particle cohesive bond strength, or the erosion duration. Here, we evaluate the importance of each of these factors onto the size distribution of the near-surface dust flux. To this effect, we developed a simple 1D dust-dispersal model accounting for (1) dust emission through sandblasting, based on an energy budget linking the surface cohesive forces to the dust particle size, (2) dust turbulent transport within the surface boundary layer through an Eulerian approach, and (3) dust deposition at the surface. The model is first evaluated against published results to gauge its ability to predict accurately the dust concentration and dust-flux size distribution as a function of time and space. Then, the impact of the above factors onto the dust-flux size distribution is investigated using the 1D model applied on a simple academic soil erosion configuration with constant wind condition, and starting from an air clean of dust. Our analysis suggests that the surface cohesive bond represents one of the main factors influencing the dust size distribution. More interestingly, the temporal variation of the dust-flux size distribution depends on the difference of distribution with particle size between the cohesive bond and the deposition velocity.

MODELLING NAMIBIAN DUST EMISSION IN THE FRAMEWORK OF AEROCLOSA

S. Feuerstein[1], K. Schepanski[1], C. Flamant[2], F. Waquet[3], B. Laurent[4], P. Chazette[5], B.N. Holben[6], E.J. Welton[6], and P. Formenti[4]

[1]*Leibniz Institute for Tropospheric Research, Leipzig, Germany*
[2] *Laboratoire Atmosphères, Milieux, Observations Spatiales, Paris, France*
[3] *Laboratoire d'Optique Atmospherique, Université de Lille, Lille, France*
[4] *Laboratoire Inter-Universitaire des Systèmes Atmosphériques, Cretail Cedex, France*
[5] *Laboratoire des sciences du climat et de l'environement, Cedex, France*
[6] *NASA, Goddard Space Flight Center, Greenbelt, USA*

Key words dust sources, dust modelling, remote sensing, southern Africa.

The southwestern coast of southern Africa is one of the driest regions in the world. It is not surprising that the arid to hyperarid conditions there lead to a very low expanse in vegetation cover and to a huge amount of barren sediments that are prone to wind erosion. In fact, a number of studies have already proven the importance of southern African dust sources for the atmospheric dust load from both, large scale features like salt pans as well as small geomorphologic features like ephemeral river basins along the coastline.

Adjoined to the AEROCLO-sA campaign, the EUFAR funded project ALLDUST-SA (Alluvial Dust Sources – a Sub-Basin Analysis) took place in Namibia in August and September 2017, which focused on the precise localization of dust sources in Namibia using LIDAR measurements.

The study consists of two parts: The first part makes use of different LIDAR systems operating onboard the SAFIRE F20 aircraft during the campaign and at ground-based sites in Namibia, as well as satellite dust and AOD products. We will present first results on the spatio-temporal variability of active dust sources and the vertical distribution of dust in the atmospheric column.

In the second part, we will show how the gained knowledge on the localization and characteristic of dust sources in Namibia can be implemented in dust-emission-models: As a first attempt, an offline dust emission model is used to reproduce the activity of Namibian dust sources by determining and including surface characteristics that are responsible for the variability in dust emission. Like this, the study provides a first step towards a better representation of southern African dust sources in dust emission models and for a better estimation of the total atmospheric aerosol load in the region.

NUTRIENT AND ELEMENT EXPORT IS AFFECTED BY WIND SORTING IN DIFFERENT TEXTURED AGRICULTURAL SOILS

L.A. Iturri[1,2]; R. Funk[3]; M. Sommer[3] ; D.E. Buschiazzo[1,2,4]

[1]*Institute for Earth and Environmental Sciences of La Pampa, National Council for Research and Technology (INCITAP, CONICET-UNLPam), cc 186, 6300, Santa Rosa, Argentina.*

[2] *National University of La Pampa (UNLPam), cc 300, 6300, Santa Rosa, Argentina.*

[3]*Leibniz Centre for Agricultural Landscape Research (ZALF), 15374, Müncheberg, Germany.*

[4]*National Institute for Agricultural Technology (INTA), Anguil Experimental Station, 6326, Anguil, Argentina.*

Key words soil fertility; wind erosion; soil degradation; semiarid environments

The element concentration in the sediments transported during a wind erosion event show different distributions in height, affecting the export either at the field or regional scale. The nutrients and elements that are present in coarse aggregates are transported by saltation, at low heights and across short distances. On the other hand, those in low-density compounds, including the particulate matter with an aerodynamic diameter smaller than 10 µm (PM10), by suspension, at great heights and long distances. In different textured soils, these trends can be affected by wind sorting, as sandy soils yield more eroded sand at lower heights while finer soils more silt and clay [1].

The aim of this study was to evaluate how sorting caused by the wind could influence the nutrient and element export in different textured soils from the Semiarid Pampean Region of Argentina. For that reason, the 2.5 uppermost-cm of both a sandy and a loamy soil were used for wind tunnel simulations. The sediments transported by saltation were collected with BSNE samplers at heights of 0.05, 0.17, 0.32 and 0.48 m. The PM10 were obtained with a laboratory method [2]. All samples were investigated for C, N, P and S content, by dry combustion using an elemental analyzer, and Ca, Mg, K, Na, Fe, Al, Mn, Ba, Cu, Zn, Ag, Be, Cd, Cu, Cr content, by ICP-OES.

All the elements were more abundant in the bulk of soil, the saltating and particulate materials of the loamy compared to the sandy soil. In both soils, C and N contents were associated mainly with low dense organic particles and compounds, while P, Al and Zn contents were linked to clays. S content as well, but only in the sandy soil. P, Ca, Mg, K and Na were present in high-density coarse particles and aggregates, as they constitute the apatite and feldspars minerals dominating coarse silt and fine sand. Ba and Mn showed opposite trends, increasing their concentration at greater heights in the sandy soil, but decreasing in the loamy. Cu did not show a define accumulation pattern in variable density and size particles. Ag, Be, Cd, Cu and Cr were not detected even at trace levels.

In conclusion, the nutrients and elements transported mainly by saltation in high-density particles or aggregates could be lost at the field scale, being deposited in adjacent ecosystems. Those transported by suspension in low-density compounds could be exported at longer distances influencing regional or global scale process, like C sequestration. Moreover, as the sandy soils experience a more intensive separation between mineral and organic particles in height than the finer soils [1], the nutrient export by suspension would be of higher magnitude in the sandy than in the loamy studied soils.

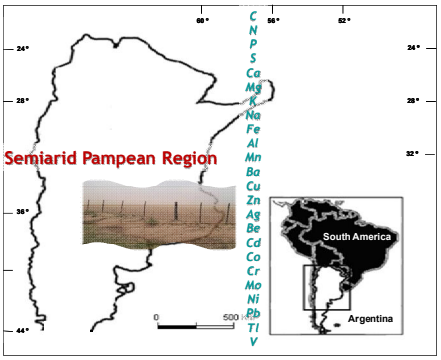

Figure 1. Schematic representation of the studied sites and the nutrients, majority and minority elements concentration investigated in the saltating and particulate materials of the studied soils.

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WIND TUNNEL TESTS TO ESTIMATE PM_{10} AND $PM_{2.5}$ - EMISSIONS OF SUBSTRATES FROM OPEN-CAST LIGNITE MINES IN LUSATIA, GERMANY

R. Funk & N. Papke
Leibniz Centre for Agricultural Landscape Research (ZALF),
Eberswalder Str. 84, 15374 Müncheberg, Germany

Key words open-cast mines, PM_{10}, $PM_{2.5}$, emission potential, wind erosion

Despite decreasing reputation, lignite is still one of the most important energy resources in Germany, with a share of 22.6 % of the total electricity generation in 2017. One of the main lignite mining regions is located in the southern part of Brandenburg, where four open-cast mines are operated (Fig. 1). Claiming huge areas with bare surfaces for years and moving overburdens permanently are the main sources of fugitive dust emissions [1]. Possible air quality problems arise in the surrounding settlements, if the working level moves into a windward position. The PM- emissions within the mines have two causes; all emissions associated with the mining processes as digging or dumping, and wind erosion as natural origin. Dispersion models are used to predict the additional PM- loads from the mining areas to initiate countermeasures in advance, but distinct differences between measured and modelled emissions resulted in the necessity to re-determine the PM_{10}- and $PM_{2.5}$- emission factors.
The experimental approach to estimate the PM- emissions included the separated consideration of the releasing processes. Samples for wind tunnel investigations were taken from the overburdens and the main working levels, the latter represent mixtures of all layers above. PM- emission potentials of the materials were estimated by using the wind tunnel as cross-flow gravitational separator, supplying the materials at the beginning and from the top of the wind tunnel. Particles > 40 µm in diameter will deposit in the tunnel whereas the PM can be measured at the outlet. Results are mass-related PM- emissions in µg per g, used to describe the mining activities. The PM- emissions caused by wind erosion were also determined by wind tunnel experiments and related to the affected area in µg per m² and to the total eroded amounts in µg per g. Finally, the PM- emissions by wind erosion were compared to the PM- emission potentials, to detect a correlation between properties of the materials and wind-induced PM- emissions and to validate the used methodology. So, beyond the task to derive PM- emissivity of the affected materials, the applicability of the used methodology to estimate the PM- emission potentials was tested for predictions of PM- emissions in the case of wind erosion.
The use of the new PM- emission factors resulted in very good agreements between measurements of air quality observations and predicted PM- emissions.

Figure 1. The four active mines in Lusatia (left, Source: LEAG); different layers of overburden in the mine Nochten (right).

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DYNAMIC VARIATION OF EVAPORATED SALT AND ITS RESPONSE TO WIND EROSION IN THE PLAYA OF EBINUR LAKE, ARID NORTHWEST CHINA

GE Yongxiao[1,2], Jilili ABUDUWAILI[1,2],MA long[1,2], Wu Na[1,2]
[1]*State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, NO.818 South Beijing Road, Urumqi, P.R.China*.
[2] *CAS Research Center for Ecology and Environment of Central Asia, NO.818 South Beijing Road, Urumqi, P.R.China*.

Key words Playa; evaporated salt; wind erosion; Ebinur Lake; arid land

In order to understand the salinity variation characteristic in the process of wind erosion, lacustrine sediment samples were sampled from three typical positions of the Ebinur Lake（S1, intermittently dry lake bed; S2, lakeside; S3, permanently dry lake bed）to reveal changes of salt content and response characteristics to wind erosion, which dominated by bare desert, Phragmites australis, Haloxylon ammodendron and Halocnemum strobilaceum, respectively. The results showed that evaporated salt content in different locations of Ebinur Lake dry lakebed were quite different. The highest content among the three study areas appeared in S1 at the northwest intermittent dry lakebed, up to 101.00g/kg, followed by S2, which salt content was 47.3g/kg, the S2 had the lowest 40.0g/kg at the surface. Evaporated salt content varied in time and space at different locations of dry lakebed, and the highest content occurred in June and gradually reduced with the seasonal changes from June to October; salt content showed a decreasing trend in different seasons with increasing depth, that is, evaporated salt content of five layers from 0cm to 50cm showed a downward trend at different times and different locations. Take wind erosion into consideration, the response characteristics of salt content to wind erosion showed significant regional differences. Salt content of sediment that was not covered inS1 was significantly higher than the coverage area. The relationship of the covered and uncovered sediment in S2 was complex. However, response characteristic of S3 to wind erosion was just the reverse of that of S1. All above information indicated the regional difference and complexity of variation and response to wind erosion of evaporated salt content.

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Very-High Resolution (20m) Flow and Dust Dispersion Modeling: Oceano Dunes, Oceano, CA

J.F. Mejia[1], J. Gillies[1], and V. Etyemezian[2]
[1]*Division of Atmospheric Sciences, Desert Research Institute DRI, Reno, NV, USA*
[2] *Division of Atmospheric Sciences, Desert Research Institute DRI, Las Vegas, NV, USA*

Key words Oceano Dunes, Dust Dispersion Modeling, Mitigation Strategies.

This presentation shows results from a series of very high-resolution (20 m) dust emissions and transport simulations for the Oceano Dunes State Vehicular Recreation Area (ODSVRA), a coastal sand dune complex located in San Luis Obispo County, California. Field data from an enhanced observation period carried out in May-July 2013 helped estimate the particulate matter (PM) emissions and flow conditions over the dune field. Emissions of PM are based on a comprehensive emissions grid developed from in-situ measurements using the PI-SWERL®. PI-SWERL estimates the potential for a soil surface to produce PM_{10} (PM ≤10 µm aerodynamic diameter) dust emissions for a range of wind speeds. This approach provided a well-determined PM_{10} emissions field as a function of time and space. Wind and turbulence fields were estimated using the CALMET diagnostic meteorological model constrained with surface stations, upper air soundings, buoys, and North American Reanalysis data. Hourly, 3-dimensional wind flow and instability objective analysis fields were developed at 20 m resolution in order to consider the complex flow pathways over realistic dune morphology, land use/land cover and terrain characteristics of the dunes and surrounding area. The dust dispersion simulations were performed using a computationally efficient and vectorized Lagrangian Stochastic Particle Dispersion Model driven by the CALMET output and the PI-SWERL time-space variable emissions. The dispersion model is based on the Langevin formulation and includes turbulent diffusion and stochastic particle (hundreds of thousands) motion in the inertial sub-range, assuming particles act as discrete units and neglecting deposition. The model estimates diffusion of particles from an initial particle releases (thousands) that scales using the PI-SWERL time-variable emissions estimate. Modeled PM_{10} mass concentrations were compared with measured concentrations at two independent downwind locations, with very positive correlations for flow conditions, i.e., wind speed (r^2=0.89), and receptor PM_{10} concentrations (r^2=0.85). Evaluations against observations during mean flow conditions as well as for high dust events suggest that the model framework is capable of capturing spatial and temporal characteristics of dust mean diurnal variability and outbreaks. In this presentation, we outline the details of the model framework and its performance, including the model implementation to locate those dust sources that have the strongest impact in the receptor sites. We further evaluate the impact of different dust reduction strategies based on controls within the Park to mitigate high PM_{10} at downwind receptors.

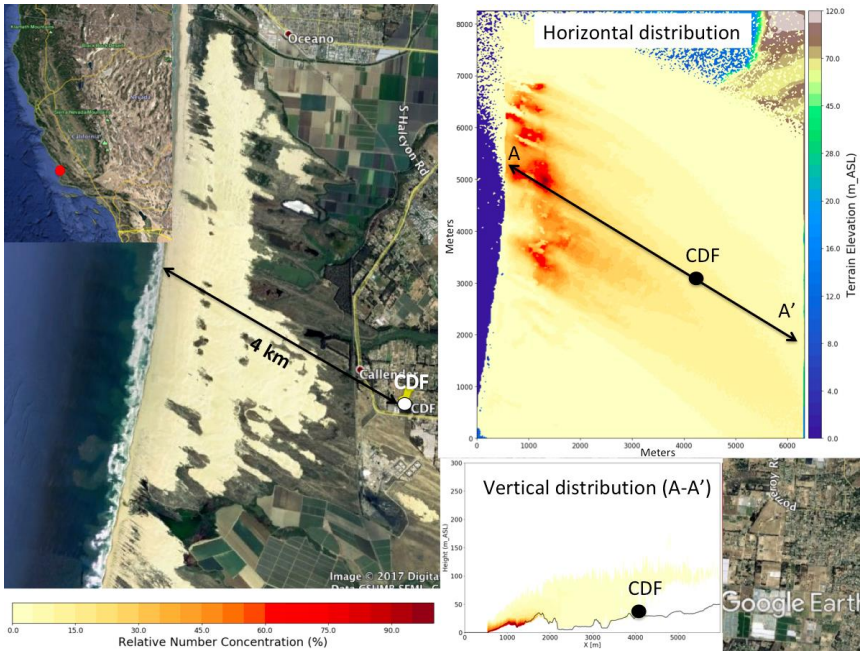

Figure 1. Google Earth satellite canvas showing location of the Oceano Dunes, CA. Insets show the simulated (right-top) horizontal and (right-bottom) vertical dust dispersion distribution during May-July, 2013, and relative location of an independent emissions receptors site (CDF) used for model evaluation.

DUST OBSERVATIONS IN TOPOGRAPHICALLY DEPRESSED VALLEY, GOBI DESERT, MONGOLIA

M. Ishizuka[1], B. Gantsetseg[2], Y. Kurosaki[3] & B. Buyantogtokh[2,3]
[1]*Faculty of Engineering, Kagawa University, Takamatsu, Kagawa, Japan*
[2]*Information and Research Institute of Meteorology Hydrology and Environment, Ulaanbaatar, Mongolia*
[3]*Arid Land Research Center, Tottori University, Tottori, Tottori, Japan*

Key words PM_{10}, $PM_{2.5}$, topographic depression, KOSA (Asian dust), dryland, soil crust, desert steppe

Gobi Desert in Mongolia is one of the major source of Asian dust (KOSA). In Gobi Desert, precipitation is very small, less than 100 mm per one year, and this area is categorized as desert steppe. Vegetation mount is very small but it varies year by year even in the desert steppe. Gantsetseg et al. (2017) found that the topography is very important for vegetation growth in desert steppe. The high NDVI (up to 0.56), as well as the high aboveground biomass, in the valley bottom was measured resulted from the overland flow after relatively heavy precipitation events. This process also makes the soil particle size difference between in the valley bottom and the slope. The water flow causes the soil crustiness and gravel distribution. The topographically depressed valley is a hotspot area for dust supply and the dust observation is necessary to understand the local and global atmospheric environment under such various ground surface conditions.

Dust observation started since the end of March 2012 in Tsogt-Ovoo, which is located in the northern Gobi Desert (Ishizuka et al., 2012). Dust and hydro-meteorological measurement instruments were set on a gentle slope and bottom of small valley. A dust event, which was accompanied by a synoptic front, occurred during April 30 – May 01 in 2016. The maximum wind speed reaches to 16.6 m/s, and wind speed over 12 m/s continued for about 7 hours. During this event, PM_{10} concentration increased to 0.8 mg/m^3 at 0.9 m height on the gentle slope. However, the PM_{10} concentration in the bottom of valley, where it was no gravel surface, increased to 4 mg/m^3. Average PM_{10} concentration at the gravel surface on gentle slope during dust event was about 50% smaller than that at the no gravel surface in the valley bottom. This result suggests that local topography is important as a dust source in Gobi desert.

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Atmospheric deposition of iron from mineral aerosols to ocean ecosystem model

A. Ito[1], J.-B. W. Stuut [2], A. Yamamoto[1], M. Watanabe[1], M. N. Aita[1], L. Chuxian[3], S. Arcusa[4], N. Sagoo[5], Z. Hoseini[6], C. Gonzales[7] & F. De Vleeschouwer[3]

[1]*Yokohama Institute for Earth Sciences, JAMSTEC, Yokohama, Japan*
[2]*NIOZ, Utrecht University, Utrecht, the Netherlands*
[3] *EcoLab, Castanet-Tolosan, France.*
[4]*Northern Arizona University, Flagstaff, USA*
[5]*Yale University, New Haven, USA.*
[6]*Shahid Beheshti University, Tehran, Iran.*
[7]*University of Chili, Santiago, Chili.*

Key words Dust deposition; labile iron; dissolved iron; environmental changes.

Atmospheric deposition of labile iron (Fe) to the ocean has been suggested to modulate primary ocean productivity and thus indirectly affect the climate. Significant progress has been made in our understanding of atmospheric inputs of labile Fe from natural and anthropogenic sources to the oceans. Different emission sources and transformation processes affect aerosol Fe solubility. Mineral dust contains a small amount of labile Fe (e.g., ferrihydrite) on the surface (about 1% of Fe solubility) and thus may deliver insignificant labile Fe fluxes to the polar oceans in present days [1]. However, about 10% of mean Fe solubility is measured for the Last Glacial Maximum (LGM) aerosols in Antarctica [2]. If this value is applied to mineral dust during the LGM, the atmospheric input of labile Fe could be comparable to that provided by upwelling in present days. However, there are still large uncertainties regarding the relative importance of different sources of Fe and the effects of atmospheric aerosols on dissolved Fe in the ocean. Here, we use atmospheric chemistry transport model [3] and ocean ecosystem model [4] to investigate the effects of atmospheric deposition of Fe from mineral aerosols to dissolved Fe in the ocean, based on measurements in the North Atlantic [5].

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FINE DUST EMISSIONS FROM OCEANO SAND DUNES

Y. Huang[1], J. F. Kok[1], R. L. Martin[1], L. S. Freire[2], N. Swet[3], I. Katra[3], T. E. Gill[4], R. L. Reynolds[5] & F. A. Turney[1]
[1]*Department of Atmospheric & Oceanic Sciences, University of California, Los Angeles, USA*
[2]*Department of Meteorology and Atmospheric Science, Pennsylvania State University, University Park, USA.*
[3]*Department of Geography and Environmental Protection, Ben Gurion University of the Negev, Be'er-Sheva, Israel*
[4]*Department of Geological Sciences, University of Texas, El Paso, USA*
[5]*Geosciences and Environmental Change Science Center, Denver, USA*

Key words Sand dunes, fine dust emission, field measurements, aeolian abrasion, feldspar, and clay coating

Sand dunes generally have a small content of fine grains, and therefore are generally not considered to be important dust sources [1]. However, recent studies have proposed that under saltation bombardment of dune sands, several processes could contribute to dust emissions from sand dunes, including chipping and spalling of sand grains, removal of clay minerals coated on dune sands, and release of loose fine particles trapped in between dune sands [2, 3].

To help understand the dust emission potential of active sand dunes, we present field measurements of dust emissions under natural saltation from the coastal Oceano Dunes in California. We find that saltation drives substantial dust emissions from these sand dunes, which laboratory analysis of sand samples suggest could be driven by aeolian abrasion of extensive feldspars and the removal of coatings of clay minerals on sand grains. We further find that this emitted dust is substantially finer than dust emitted from both non-sandy soils and from North African dust sources [4]. As such, dust emitted from Oceano Dunes, and potentially from other dune systems affected by similar emission processes, could have potent impacts on human health, weather, and climate [5]. Furthermore, our measurements support the hypothesis that reactivation of currently inactive dunes, which can have accumulated substantial clay minerals, could produce considerable emissions of fine dust [6]. This raises the possibility that sand dunes might have been important dust sources in past climates, and could become important sources under future land management and climate change.

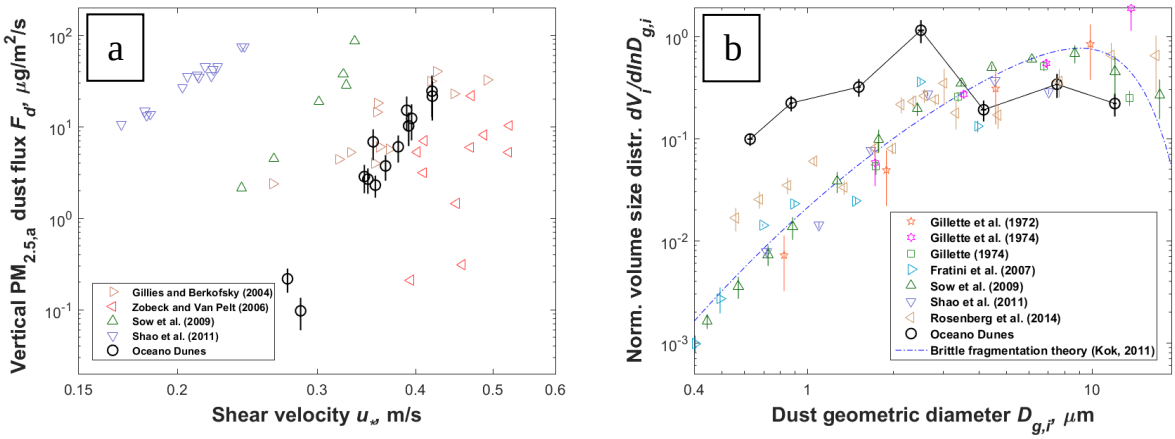

Figure 1. (a) The vertical flux of dust with diameter less than 2.5 mm, as a function of shear velocity. Plotted for comparison are previously published field studies of natural dust emissions from non-sandy soils. (b) Normalized volume size distribution of emitted dust as a function of dust aerosol geometric diameter averaged over all measurements at Oceano Dunes. Plotted for comparison are measurements of the size distribution of dust emitted from non-sandy soils.

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DUST MINERALOGICAL COMPOSITION AND IRON SOLUBILITY OF AEROSOLS GENERATED IN LABORATORY FROM VARIOUS SOURCE SOILS

S. Lafon[1] , E. Journet[1], B. Laurent[1], S. Nowak[2] , P. Ausset[1] & S. Chevaillier[1]
[1]*Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*
[2] *Plateforme Rayons X, UFR de Chimie, Université Paris Diderot, Paris, France*

Key words dust aerosol composition, mineralogy, iron solubility, laboratory aerosol generation

Mineral dust aerosols emitted by wind erosion in arid areas and semi-arid areas are composed of a complex mixture of various minerals. This mineralogical composition presents a high spatiotemporal variability due to the diversity of soil nature and to size dependence of processes occurring during the dust cycle. The type and the relative abundance of the mineralogical species as well as the way they are mixed together have been shown to be factors controlling dust environmental impacts. In particular, large uncertainties on the quantification of dust biogeochemical and chemical impacts are due to the remaining misunderstanding on dust aerosol intrinsic properties and notably their mineralogical composition. Nonetheless, the mineralogical composition of dust is currently poorly documented and its quantification remains challenging.

The aim of this work is to improve the consideration of mineralogical composition of dust aerosols and its variability as recommended in literature [1]. In this aim, a study was carried out in the framework of FerATMO project from various aerosol samples generated in laboratory. African and Asian aerosols, as well as pure reference mineral aerosols were generated with a specific device developed in our lab ("Générateur d'Aérosol Minéral En Laboratoire", GAMEL [2]). Such samples generated from soil are considered to be representative source-aerosol, that is to say fresh aerosol at emission.

An extensive mineralogical characterization was performed on these samples, using a combination of adequate analytical methods to quantify their size-resolved mineralogy. Elemental composition and iron oxide quantification were obtained by X-ray fluorescence spectrometry and chemical extraction treatments (CBD), size-resolution was obtained by analytical scanning electron microcopy and clay species quantification was obtained by X-ray-diffraction. These analyses required new and appropriate analytical developments [3]. The solubility of the iron in dust, which conditions its bioavailability for oceanic biota, was also measured on these samples.

First results of this dataset are presented and discussed in order to illustrate potential variability of mineralogical composition of source-aerosols and effects on iron the solubility.

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DUST EMISSION OVER SALT CRUST SURFACE IN THE QAIDAM BASIN, NORTHEASTERN TIBETAN PLATEAU

J. Lu[1], Z. Dong[1,3], G. Qian[1], W. Luo[1], Z. Zhang[1] & Y. Shao[2]
[1]*Key Laboratory of Desert and Desertification, Chinese Academy of Sciences, Lanzhou, China*
[2]*Institute for Geophysics and Meteorology, University of Cologne, Germany*
[3]*School of Geography and Tourism, Shaanxi Normal University, Xi'an, China*

Key words salt crust, dust emission, dust flux, grain-size, PM10

Qaidam Basin is the biggest area of scattered salt crust in China, which has become a major mineral dust source due to the abounce of salt-rich sediment and frequent erosion activities. However, little is known about the processes of salt dust emission and transport in this area. In this paper, we present the results of field experiments carried out in the Qaidam Basin. Dust samplers were mounted at four heights (0.25, 0.5, 1.0 and 2.0 m) at several monitoring stations to measure horizontal dust fluxes from different salt crust surfaces (flat, polygonal, ridged, irregular and degraded salt crust). We analyze the grain-size characteristics of salt dust and surface sediment samples. The results suggest that significant differences in temporal and spatial variation of dust flux exist among the different salt crust surfaces. The highest and lowest annual dust flux were found on degraded salt crust and flat salt crust, respectively. The horizontal dust flux decayed rapidly with increasing height following a power function. The content of PM10 and PM20 in dust samplers increased with increasing height, and reached 24.7 and 37.7%, respectively. These are much higher than for sand and gravel surfaces. Dust emission from salt crust surface depends primarily on the micro-geomorphological characteristics of salt curst and wind conditions. Our results indicate the Qaidam Basin is a main dust source for long distance-transport dust because there are large areas of loose salt-rich sediment which emits more fine dust than other areas.

BEHAVIOR ASSESSMENT OF SOIL UNDER NATURAL VEGETATION IN ALGERIAN STEPPIC RANGELAND (CASE AT LAGHOUAT REGION)

H.Mallem [1,*], Z. Houyou [1], A.Benrima[2], R.A.Wesselingh[3], M.Kouidri[1], H. Chaar [4]

[1]Desertification and climate team, laboratory of Mechanics, Laghouat University Bp37, Algeria .
[2]Saad Dahleb university , Blida- Algeria.
[3]Biodiversity Research Centre, Earth & Life Institute, UCL, Belgium.
[4]National Agricultural Institute , 43 Avenue Charles Nicolle. 1083 Tunis-Mahrajène.

ABSTRACT

Land clearing combined with eolian activity cause degradation of many areas in the Algerian steppe. That is why knowledge of natural steppic vegetation could be useful to control wind erosion. In order to investigate the behavior of soil, this work was conducted in a site highly exposed to sandstorms in the Algerian steppe. Accumulated sediment height has been measured under all the plant species inventoried in the site after the field slope correction. Under three perennial plant species (*Retama raetam, Aristida pungens*, and *Astragalus armatus*); particle size distribution, physico-chemical and microbiological soil characteristics have been analyzed and compared to those of a soil without vegetation. The accumulated sediment height fixed by the plant species was between 28 and 63 cm and was lower than that of the soil without vegetation ,which was between 36 and 97 cm. Regarding the three perennial plant species, accumulated sediment heights have not registered significant differences; noting *A. pungens* showed the lowest values up to 29 cm. Soil characteristics showed differences; the soil under *A. pungens* does not contain silt and clay . Sediment fixed by *A. armatus* contained more silt and clay respectively 9%, 10%. Accumulated sediments under *R. raetam* showed the highest contents of nitrogen, carbon and bacterial richness respectively (0.08%, 0.82%, $12.1x10^5$cfu/g). The soil under *A. pungens* presented high content of $CaCO_3$, EC and fungal richness respectively (2.37%, 0.92 ms/cm, 6.3×10^4 cfu/g). The principal component analysis (PCA) allowed assessing associate effect of the three plant species sediment fixer on soil characteristics.

Key words *: Steppic rangeland; accumulated sediment height*; *soil characteristics; psammophile vegetation ; wind erosion control.*

*Correspondence to : Hamida Mallem, Equipe désertification et climat. Laboratoire de mécanique, BP 37- Université de Laghouat 03000 Algeria. Tel : ++213 665 878 686. Fax : ++213 29 137 520. Email: hamida.mallem@gmail.com

The INDAAF dust monitoring in Sahel : an opportunity to constrain the dust mass budget in regional simulations

B. Marticorena[1], A. Féron[1], C. Gaimoz[1], F. Maisonneuve[1], J.L. Rajot[1,2], G. Siour[1]
M. Coulibaly[3], A. Diallo[4], S. Der Ba[5], S. G. Dorego[5], I. Koné[3], A. Maman[6], T. NDiaye[4], M. Sene[5] and A. Zakou[6].
[1] LISA, UMR CNRS 7583, UPEC,UPD; IPSL, Créteil, France ; [2] iEES Paris, UMR IRD 242, Bondy, France;
[3]IER Cinzana, Mali; [4]IRD M'Bour, Senegal; [5]CNRA Bambey, Senegal, [6]IRD Niamey, Niger.

Key words Sahel; Dust monitoring; Dust deposition; Mass budget; Regional modelling.

The Sahel is a semi-arid region located south of the largest arid region of the world, the Sahara desert. During the last century, aeolian erosion in the Sahel has fluctuated significantly, in connection with irregular precipitation and variability of the vegetation cover. The Sahelian region is also subject an anthropogenic pressure that leads to an increase of the cultivated surfaces, more susceptible to Aeolian erosion than rangelands and fallows. The climate is characterized by two contrasted seasons: a dry season with a dominant northeasterly flow called the Harmattan, and a wet season associated with the southwesterly monsoon flow that brings precipitation to the Sahel. In the dry season, the Harmattan flow transports in the Sahelian region large amounts of mineral dust emitted further North from the different dust sources located in the Sahara desert. In the wet season, due to the moist air brought by the monsoon, convective cells develop in the Sahel. The very high surface wind speeds that developed in the front of the convective systems or in the cold pool associated with their passage, are responsible for intense local dust emissions. But convective systems also bring precipitation that can wash out the locally emitted dust. The Sahel region is thus a region of emission and deposition of mineral dust. A precise estimation of the net mass budget of mineral dust requires to account for the strong inter-annual variability of the dust atmospheric load in this region.

Since 2006, a set of stations (M'Bour and Bambey, Senegal; Cinzana, Mali; and Banizoumbou, Niger) dedicated to the monitoring of mineral dust are operating in the Sahel as part of a national long-term observation network INDAAF (International Network to study Deposition and Atmospheric composition in Africa). The main objective is to provide quantitative information to constrain the dust mass budget at the regional scale. Simple and robust instrumentation allows to monitor simultaneously the atmospheric dust load (Aerosol Optical Depth (AOD), Sunphotometers of the AERONET/Photons network), the concentration of particles smaller than 10 µm (PM_{10}) (TEOM instruments), the total and wet deposition fluxes (Frisbee and MTX collectors).

A multiannual analysis of the data shows that the dust concentrations, the AODs and the deposition fluxes all exhibit persistent seasonal cycles but they differ in terms of timing. This is due to the fact that they are modulated by different processes. Dust concentrations are driven by the variability of the dust transport in the Harmattan season and by local dust emissions in the Monsson season [1]. The seasonal cycle of the dust AODs is impacted by the variability of the dust layers thickness and altitude [2,3]. The seasonal cycle of the deposition fluxes is very sensitive to the contribution of the wet deposition [4]. This one being controlled by the very high concentrations due to local dust emissions and the occurrence of precipitation associated.

From these results, it is clear that reproducing simultaneously the dust concentrations, AODs and deposition fluxes in the Sahel is a challenge for regional models. The data from the Sahelian INDAAF stations will be used as validation data sets in the frame of the European DUSTCLIM project (ERA4CS) to evaluate long-term regional dust simulations and to estimate the benefit brought by the assimilation of satellite data.

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MODELING ANALYSIS AND SATELLITE OBSERVATIONS OF MINERAL DUST EVENT IN THE SISTAN REGION.

F. Minvielle[1], I. Chiapello[1], C. Bouet[2,3], D. Kaskaoutis[5], B. Laurent[2], M. Legrand[1], B. Marticorena[2] & A. Rashki[4].

[3]*Institut d'Ecologie et des Sciences de l'Environnement de Paris, Bondy, France*

[1]*Laboratoire d'Optique Atmosphérique, Lille, France*

[4]*Natural Ressources and Environnement College, Mashhad, Iran*

[2]*Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*

[5]*Institute for Environmental Research and Sustainable Development, Athens, Greece*

Key words Mineral dust, Sistan region, meso-scale modeling, satellite, dynamic transport, emission.

The Sistan, located in the Iran-Afghanistan-Pakistan region belongs to the "desert dust belt" that extends from the west coast of North Africa, over the Middle east, Central and South Asia, to China [1]. It is considered as one of the most active dust source regions in South west Asia.

The specificity of the Sistan region is its limited spatial extent, its intense satellite signal and its complexity resulting from its rough topography, at the junction of basins and deserts. Thus, the region is associated with a complex wind pattern, strongly constrained by this topography, which controls the dust emission and transport. In spite of the local but intense signature in satellite observations of dust emissions and frequent dust storms, this dust source zone is relatively unknown. A consequence of the complex geographic situation of the Sistan region is the poorly available ground-based measurements of aerosols properties, except those provided by meteorological stations (especially visibility and wind measurements available in Zabol and other stations in Iran and Pakistan). The nearest AERONET station is the one of Karachi in Pakistan. So, satellites observations and modeling are complementary tools to study and to understand dust emission and transport from Sistan sources.

In this work, we present two components: first part is a climatological analysis of satellite observations over the 2007-2016 period based on AOD derived from MODIS (Deep Blue combined to Dark Target product) and Aerosol Index from OMI; the second part is the RAMS (Regional atmospheric modeling system) analysis of desert dust emission and transport from the Sistan region. Our objectives are to identify the most intense dust events during the time period of the last ten years; to study their seasonal and inter-annual variability; to validate numerical simulations of dust events from meso-scale model in understanding emission and transport of dust processes in the specific Sistan region. Complementary dust observations from MSG/IDDI will help to characterize specific dust events that will be investigated in details. This analysis is part of a LEFE/INSU project [2] that combines model simulations with ground-based and satellite measurements to study desert dust emission and transport from the Sistan.

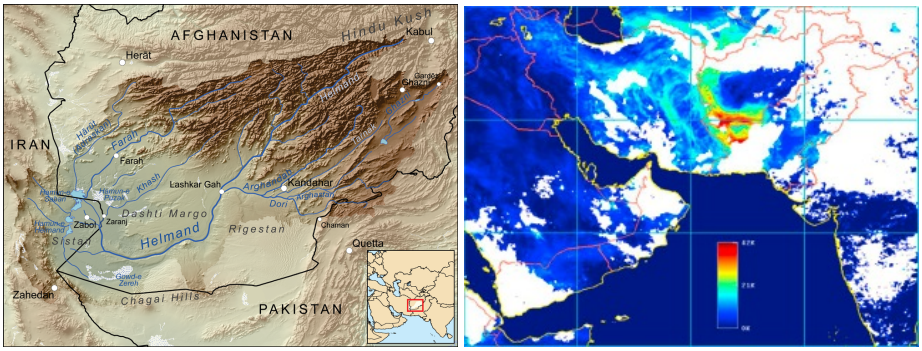

Figure 1. Topography of the Sistan region (left figure) and IDDI METEOSAT dust product for july 14, 2016, illustrating dust emission and regional dust plume transport (right figure).

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Experimental study of aeolian dust emission from active sands under natural processes

Nitzan Swet[1], Tov Elperin[2], Jasper F. Kok[3], Raleigh L. Martin[3], Hezi Yizhaq[4], Itzhak Katra[1]

[1]*Department of Geography and Environmental Development, Ben Gurion University of the Negev, Be'er-Sheva, Israel.*
[2]*Department of Mechanical Engineering, The Pearlstone Center for Aeronautical Engineering Studies, Ben-Gurion University of the Negev, Beer-Sheva, Israel.*
[3]*Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, USA.*
[4]*Department of Solar Energy and Environmental Physics, BIDR, Ben-Gurion University of the Negev, Israel.*

Keywords: Aeolian processes; Dust sources; PM_{10}; Wind tunnel; Saltation.

Surfaces composed of active sand grains (dunes, sand sheets) have been identified as dust sources in northern Africa, China, and elsewhere [1,2]. This dust is apparently generated by different aeolian mechanisms that are related to settled dust particles, removal of clay coating, and abrasion of the sand grains [3,4,5]. However, only limited empirical evidence of dust emission from active sands under natural conditions of saltation has yet been reported. The aim of this study is to explore aeolian dust emission from active sands by integration of laboratory analyses of sand samples and wind tunnel experiments with conditions simulating the natural processes of saltation. Three sand samples were selected to represent different sand compositions. The sands have modal diameters ranging from 250 µm to 450 µm with an initial content of dust-sized particles (< 63 µm) of 0.8-8 % by mass. The aeolian experiments were conducted under various wind velocities, above and below the saltation threshold. No dust emission was recorded for shear velocities below the saltation threshold. Increasing the velocity above the saltation fluid threshold (> 0.29 m s^{-1}) resulted in increasing PM_{10} emission, the magnitude of which depended on the specific shear velocity and likely the initial content of dust-sized particles in the sand. Higher PM_{10} concentrations were recorded from sand samples initially containing more than 2 % of dust-sized particles. The results indicate that in typical sand dunes the dominant mechanism is most likely the re-emission of loose-settled dust with some clay coatings removal. Future experiments and field studies will enable a better understanding on the specific mechanisms of dust generation and emission from active sands.

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EOLIAN DUST DISPERSAL PATTERNS REFLECTED BY THE PARTICLE SIZE CHARACTERISTICS OF CHINESE LOESS

Maarten A. Prins
Vrije Universiteit Amsterdam, Faculty of Science, Department of Earth Sciences
De Boelelaan 1085, 1081 HV Amsterdam, the Netherlands (m.a.prins@vu.nl)

Key words Loess, particle size, mixing model, end-member modelling

One of the outstanding problems of dust flux reconstruction from physico-chemical properties of terrigenous sediments stems from the fact that most sediments are mixtures of sediment populations derived from different sources and transported by different mechanisms. We have formulated a 'holistic approach' to tackle the mixing problem which combines (i) laser-diffraction grain size analysis of the siliciclastic sediment fraction [1], (ii) decomposition of sets of grain-size distributions with the end-member modelling algorithm EMMA [2-4] to characterise dust transport processes, and (iii) geochemical fingerprinting of the modelled sedimentary components to trace the dust source. Here we report on several dust grain-size records extracted from Late Quaternary Chinese loess-paleosol sequences [5-7]. The mixing model of the Mangshan loess-paleosol sequence [8-10] will be tested by U-Pb dating of detrital zircons extracted from narrow size fractions belonging to specific modelled end-members [9]. Such analyses provide transport-invariant measures of sediment composition in which effects of selective transport due to variations of grain size, shape [10] and density can be ignored, and therefore allow the provenance determination of the modelled end-members.

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Identification of high-resolution dust sources and dynamics over Hamoun ephemeral lakes using satellite image processing

Alireza Rashki[1], Dimitris Kaskaoutis[2]
[1]Department of Desert and Arid zone management, Ferdowsi University of Mashhad, Iran
[2]Institute for Environmental Research and Sustainable Development, National Observatory of Athens, Athens, Greece

Key words: Hamoun Lakes, Dust source, Dust dynamics, Satellite imagery, High resolution,

Abstract

Changes in the extension of natural inundation systems occurring on interior ephemeral lakes in arid/desert areas may lead to significant fluctuations in regional dust emissions. As the water coverage decreases, the arid-land surfaces are increasingly susceptible to wind deflation, resulting in desertification and increase in dust outbreaks [1, 2]. Identification of the dust-source emissions is a critical task for dust control planning [3]. The dynamics of the dust sources related to dryness of the lake beds in various time scales is another issue that effects the control planning. Multi-sensor satellite images have been used to identify and monitor the dynamics of dust sources over the globe [4]. Mitigation of the dust hazards at regions near to the dust source requires precise delineation of the source and its strength that varies from seasonal to inter-annual time scales due to changes in the water surface. Hamoun ephemeral lakes in Sistan Basin, southeast Iran are one of the major dust sources in Southwest Asia, where massive dust storms are often generated from the dried beds by Aeolian deflation of the strong wind called “Levar” or “120 days wind”. The Hamouns appear as point sources on high resolution satellite images. In this work, Multi-Spectral images from Moderate Resolution Imaging Spectroradiometer (MODIS) have been used and modelled by ground parameters in order to produce a high-resolution dust emission source, at grid size of 500 m. The Top of Atmosphere (TOA) reflectance and surface reflectance datasets were extracted from the MODIS images and integrated with ground data, such as digital elevation model (DEM), mean sea level pressure and surface wetness in a developed algorithm. The results are able to identify topographically small areas of dust emissions that have not been shown by previous studies over the region (Fig. 1). Time series of satellite-derived data have been used for various dust events from 2000 to 2017 in order to create a dynamic dust source. The dust-source dynamics were correlated with the dried bed surface. The results showed that the dust sources at Hamouns consequently change by changes in the water surface, allowing public authorities and policy makers to better estimate the potential dust source and the intensity of the emissions.

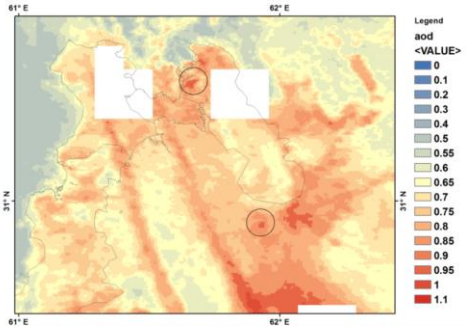

Figure 1. High resolution dust source regions at Hamoun lakes for a dust event on 9 August 2015

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FACTORS AFFECTING THE SETTLING RATE OF ICELANDIC DUST

T. Richards-Thomas, C. McKenna-Neuman,
Trent Environmental Wind Tunnel Laboratory, Trent University, Peterborough ON, Canada

Key words fall column experiment, settling velocity, Laser Doppler Anemometry (LDA), particle characteristics, humidity

There are extremely active dust sources within selected areas of Iceland that are comprised of particles supplied from both glacio-fluvial outwash systems and volcanic eruptions [1, 2]. Apart from recent collaborative efforts to measure and model Icelandic dust emission, transport and deposition [3, 4], a number of underlying physical mechanisms that are unique to cold, humid climates and the geology of Iceland are not well understood. This study specifically aims to measure the dependency of the settling rate of Icelandic dust upon the particle morphology, as well as the relative humidity of the atmosphere. The samples used to conduct this study were collected at four different site locations near the most active dust sources within Northeast and South Iceland.

The particle-size distribution and specific surface area of each sample studied were measured using a Horiba Partica PSA and a Brunauer, Emmett and Teller (BET) surface area (SA) analyzer, respectively. Particle densities were obtained from both helium and water pycnometer measurements. A Laser Doppler Anemometer was used to measure the horizontal ($\overline{u}_i$) and vertical ($\overline{v}_i$) components of particle settling velocities (U) sampled within a fall column at varied relative humidities of $20-30\%$, $50-60\%$ and $70-80\%$. Particle shape and aggregation were assessed from SEM images, spanning from micro- to nano-scales. The gravimetric moisture content (GWC) was also determined at relative humidities ranging from $40-95\%$, as it was anticipated to vary with the particle porosity and to affect the settling rate.

The BET SAs of the Icelandic dust particles were $1-2$ orders of magnitude higher than for a reference glass sphere, as a result of the particles being highly irregular in shape and porous. Particle density was found to decrease with increasing diameter in the same order as the corresponding BET SAs, which is consistent with the suggestion that Icelandic dust particles are porous. The amount of adsorbed water appears to increase with relative humidity. Higher dust concentrations were found to stimulate particle interactions and the formation of aggregates, especially at higher humidities. Under dry conditions ($20\%<RH<30\%$), the horizontal component ($\overline{u}_i$) of the fall velocity (U) measured for the angular, porous Icelandic particles well exceeded that observed for the solid glass spheres; although these measurements were an order of magnitude smaller than $\overline{v}_i$ (Figs. 1 a and b). Under progressively more humid conditions, $\overline{u}_i$ and $\overline{v}_i$ increase with particle aggregation. Calculation of the drag coefficient at Reynolds numbers below one suggests that it decreases with particle porosity.

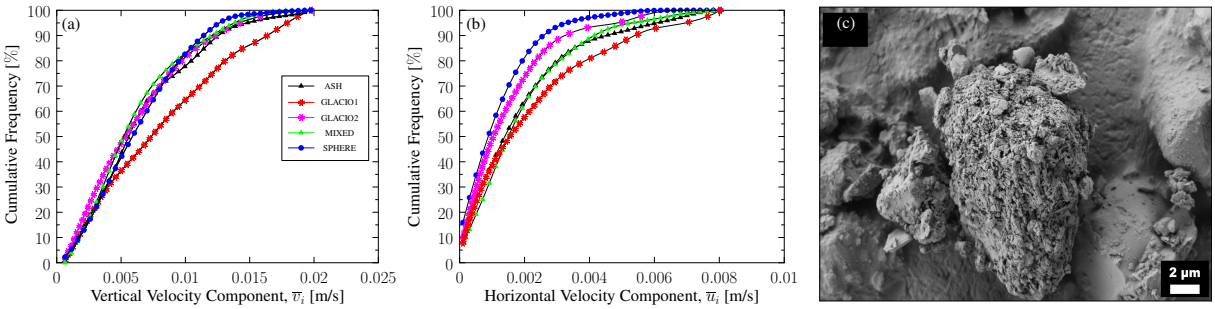

Figure 1. (a) Vertical and (b) Horizontal velocity distributions measured at $14\pm1^{\circ}$C and $20\%<RH<30\%$. (c) SEM image illustrating the high porosity and dust coatings that are typical of Icelandic particles sampled from dust emission sites.

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ICELANDIC DUST EJECTION VIA WATER DROPLET IMPACT

T. Richards-Thomas, C. McKenna-Neuman,
Trent Environmental Wind Tunnel Laboratory, Trent University, Peterborough ON, Canada

Key words Water droplet impact, High speed photography, Icelandic dust emission, Particle characteristics

Saltation bombardment is widely recognized to be a key mechanism driving the emission of dust from surfaces subjected to boundary layer flows. Similarly, water droplet impact during precipitation can significantly contribute to particle mobilization, simultaneously initializing both saltation and aerosol ejection [2]. In Iceland, field workers report that dust emission often coincides with the onset of a precipitation event. This study reports on a laboratory experiment designed to observe and measure on a micro-scale the ejection of dust in response to the impact of a single water droplet. Loose, dry, $20\,\text{mm}\times50\,\text{mm}\times15\,\text{mm}$ beds were prepared from sediments collected from four Icelandic sources, each known to emit large amounts of dust. The sediments had been wet sieved to extract subsamples of similar particle size distribution. An $18\,\text{G}$, flat-end syringe was used to create water droplets of diameter, $2.2\,\text{mm}$. The droplet release height was $360\,\text{mm}$, measured from the tip of the needle to the test surface. A high speed PCO Dimax digital camera (1 frame per millisecond) was used to record the impact of each droplet and the associated splash of particles from the bed (Figure 1). Five replicates of each experiment were performed on each of the four Icelandic dust samples.

The maximum splash height ($20<h<50\,\text{mm}$) is found to well exceed the aerodynamic roughness height (z_o=$0.7-2.8\,\text{mm}$) associated with most surfaces in Iceland [1]. However, it is less than the values ($>200\,\text{mm}$) reported by Ryzak et al. (2015) for a typical loamy soil, likely because the impact velocity in the present set of experiments ($2.55\,\text{ms}^{-1}$) was smaller than that for a typical rain drop ($7.5\,\text{ms}^{-1}$) of similar diameter. In comparison, the maximum splash widths (w $\sim$30 mm) are larger than those reported for a loamy soil ($10<w<22\,\text{mm}$). The results further indicate that h increases in the same order as the BET surface area measured for each of the Icelandic samples, which suggests that particle-scale, surface roughness influences particle splash. As expected, increasing particle diameter was found to reduce h. Particles finer than the lower limit of detection by the camera ($\sim$125 µm) may well have travelled much further than noted herein. The observed water droplet rebound (Figure 1) suggests some degree hydrophobicity. Upon impact with the bed surface, however, the water droplet undergoes a pinning rebound before being absorbed into the bed, and bears a solid coating of dust.

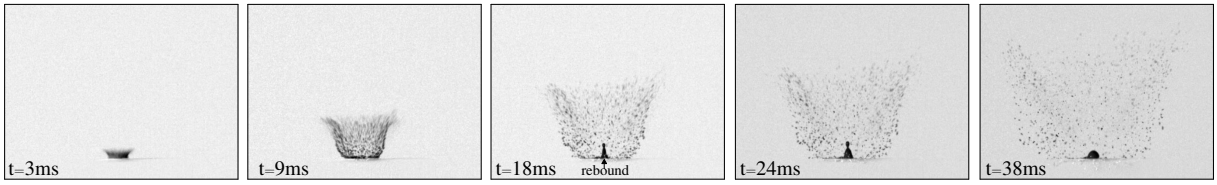

Figure 1. Time lapse images showing the particle splash and water droplet behaviour associated with a single impact on a dry, loose bed of Icelandic particles. Field workers report that this glaciogenic sediment may emit large quantities of dust with the onset of precipitation.

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Atmospheric controls on the interannual variability of dust concentration and dust transport pathways

K. Schepanski[1] and A. Kubin[1]
[1]*Leibniz Institute for Tropospheric Research, Leipzig, Germany*

Key words: dust sources, dust transport, atmospheric circulation, interannual variability, atmosphere-aerosol model, ECHAM-HAM

Dust emitted over the North African deserts is transported towards the adjacent Oceans and Europe. Thereby, the actual dust transport pathway and atmospheric dust loading are determined predominantly by emission flux and atmospheric transport capacity (i.e. wind). Both dust source activity respective dust emission flux and atmospheric circulation in concert depict the interannual variability by superposing each other resulting into a net variability. This interannual net variability is illustrated by means of temporally varying atmospheric dust concentrations as observed by ground-based and space-borne measurement.

Whereas observations reflect the current atmospheric concentration at ground level, its distribution throughout the vertical column, or the vertical integral, numerical modelling studies allow for examining the atmospheric processes resulting into the observed situation. Recent work published on the atmospheric controls fostering the variability in dust export towards the Mediterranean and Europe [Schepanski et al., 2016] and the tropical northern Atlantic [Schepanski et al., 2017] for summer 2013 highlight the relevance of superimposing major atmospheric circulation regimes such as the strength of the trade winds (Harmattan), the Saharan heat low, the position of the intertropical discontinuity (ITD), and the strength of the West African Monsoon circulation. Here, we aim for extending these studies in order to investigate the variability in atmospheric circulation fostering long-term variability in atmospheric dust loading over northern Africa, the adjacent Seas, and Europe. We used the global atmosphere-aerosol model ECHAM-HAM to simulate 39 years of atmospheric circulation and aerosol concentrations including mineral dust. The model output is examined regarding the variability in predominant atmospheric circulation patterns and associated dust concentrations over northern Africa, the northern Atlantic, the Mediterranean Sea and Europe.

Results from this study illustrate the atmospheric controls on the interannual variability in the atmospheric dust burden at climatological time scales (39-years). Ultimately, the outcome contributes to the understanding of the interplay between atmosphere and potential dust sources (soil characteristics). Lessons learned from this long-term study point towards applications for investigating future dust scenarios in a changing climate.

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Tropical rains control Saharan dust deposition and bio-availability of nutrients

M. van der Does[1], L.F. Korte[1], G-J.A. Brummer[1], C.P.D. Brussaard[2], F.C.J. van Crimpen[1,3], P. Laan[1], N.M. Mahowald[4], U. Merkel[5], F. Pausch[6], J.M. Prospero[7], S. Trimborn[6], H. Yu[8], P. Zuidema[7] & J-B. W. Stuut[1,5]

[1]*NIOZ - Royal Netherlands Institute for Sea Research, Ocean Systems, and Utrecht University, Texel, The Netherlands*
[2]*NIOZ - Royal Netherlands Institute for Sea Research, Marine Microbiology, and Utrecht University, Texel, The Netherlands*
[3]*Faculty of Science, University of Amsterdam, Amsterdam, The Netherlands*
[4]*Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY, USA*
[5]*MARUM - Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany*
[6]*Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany*
[7]*Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL, USA*
[8]*Earth Sciences Division, NASA Goddard Space Flight Center, Greenbelt, MD, USA*
www.nioz.nl/dust

Key words Sahara, Atlantic, Source-to-sink, deposition, fertilization

Mineral dust plays an important role in the ocean's carbon cycle through the input of nutrients and metals which potentially fertilise phytoplankton, and by ballasting organic matter from the surface ocean to the deep sea floor[1]. Because open-ocean dust-flux measurements are either based on shipboard[2]- or sediment-trap data[1], they are biased by interpolation and extrapolation of point observations in space and time. Alternatively, dust-flux estimations can be made using satellite observations[3], but these are often hampered by the presence of clouds. Here, we present a two-year time series of sediment-trap dust-deposition fluxes directly below the core of the Saharan dust plume along a transatlantic array at 12ºN, which shows the spatial and temporal evolution of Saharan-dust deposition across the Atlantic Ocean. We demonstrate that most of the dust deposited in the Atlantic Ocean is washed out of the atmosphere by summer rains. These field data are corroborated by comprehensive earth system model (CESM) dust-deposition data across the same transatlantic transect. In addition, nutrient-release bottle experiments in ambient sea water carried out along the same transect demonstrate how wet deposition of Saharan dust increases the release of both macro- (P, Si) and micronutrients (Fe) up to an order-of-magnitude as opposed to dry deposition. Rain-amplified bioavailability of these nutrients may well be the key to increased surface-ocean productivity in the remote and oligotrophic parts of the oceans and, potentially, also continental ecosystems[4].

Figure 1. Rain at sea; the most important supplier of dust?

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Study on dynamic process of dust deposition over solar cell surface

Wenhai Sun[1], Jie Zhang[2]
[1]*Ningxia Key Laboratory of Intelligent Sensing for the Desert Information, School of Physics & Electrical Information Engineering, Ningxia University, Yinchuan 750000, China.*
[2]*Key Laboratory of Mechanics on Disaster and Environment in Western China (Lanzhou University), Ministry of Education, Lanzhou 730000, China*.

Key words dust deposition rate; photovoltaic power generation; saltating particles; atmosphere turbulence

Solar cells are in the outdoor environment, and cells' surface is usually covered by dust, which affect the efficiency of photovoltaic power generation system. Dust deposition is considered the most important process that cause inefficiency of photovoltaic power generation system. As shown by many researchers, deposition is influenced by particle properties, including size, shape, density and composition, and also by environment condition, including wind, heat, and humidity. In this paper, a field observation was carried on in a Solar Plants and a sand storm monitoring tower near Tengger desert. The results show that with the wind speed increasing, the probability distribution of dust deposition rate over solar cell surface shows right-skewed with a single peak. The arrangements of solar cell plates also affect the dust deposition rate. Some models have been developed to study and predict the deposition of aerosol particles. But the effect of solar cell plate is not considered in these models. Based on the field observation results, we are trying to provide a new approach for the development of physical model on dust deposition over solar cell surface. This work is meaningful for development of solar technology and of significance for the study of wind-driven sand flow research.

Figure 1. Solar cells in the desert.

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Possible Mechanisms Behind the Long-Range Transport of Giant Mineral Dust Particles

Michèlle van der Does[1*], Peter Knippertz[2], Philipp Zschenderlein[2], Giles Harrison[3] & Jan-Berend Stuut[1]
[1]*NIOZ – Royal Netherlands Institute for Sea Research, Department of Ocean Systems, and Utrecht University, Texel, The Netherlands*
[2]*Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Karlsruhe, Germany*
[3]*Department of Meteorology, University of Reading, Reading, UK*
** mdoes@nioz.nl*

Keywords Giant dust particles – Atlantic Ocean – Sahara – Convection – Electrical charging

Saharan dust is transported from northern Africa over the Atlantic Ocean in great quantities. This transport occurs though different air layers, blowing at different altitudes seasonally. So-called giant mineral dust particles (>75 µm; Betzer et al., 1988) are found at large distances from the source, up to several thousands of kilometers (van der Does et al., 2016). To date, there is no known mechanism that can explain how these giant mineral dust particles are transported over such great distances. Global climate models do not consider them and are often limited to particles <10 µm (Kok et al., 2017). However, the size of dust particles affects both the radiative properties of dust suspended in the atmosphere (Ryder et al., 2013; Kok et al., 2017), as well as the environmental effects after deposition in the ocean, e.g. fertilization and ballast potential (Martin and Fitzwater, 1988; Iversen et al., 2010). Here we report individual giant Saharan-dust particles >100 µm sampled by dust-collecting surface buoys moored in the Atlantic Ocean at 2,400 and 3,500 km from the northwest-African coast, and discuss the mechanisms and requirements for long-range transport of such giant dust particles across the Atlantic Ocean. We propose a conceptual model of deep convective clouds that repeatedly carry the particles to great altitudes in the upper troposphere, in combination with turbulent and electrical forces acting on individual quartz particles keeping them aloft.

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Identifying aeolian transport mechanisms using end-member modelling of combined grain size and shape data

J.A. van Hateren[1], M.A. Prins[1], U. van Buuren[1], C.J. Beets[1], S.M. Arens, R.T. van Balen[1,3]
[1]*Vrije Universiteit Amsterdam, Faculty of Science, Department of Earth Sciences, Amsterdam, The Netherlands.*
[2]*Arens Bureau for Beach and Dune research, The Netherlands*
[3]*TNO Geologische Dienst Nederland, Utrecht, The Netherlands.*

Key words end-member modelling, grain size, grain shape, provenance, suspension, (modified) saltation

Past efforts on reconstructing transport mechanisms, dispersal pathways and provenance from sedimentary deposits have largely been based on grain-size distribution data. However, it is fall velocity, a product of grain size, shape and density [1], that determines behaviour of sediment grains during entrainment, transport and deposition. Hence, accurate inferences of above mentioned factors should be based on the combined variation in these three sediment grain properties. Here we propose a method for end-member modelling on a combination of two of these three properties: grain size and shape, giving rise to size-shape end-member distributions. We use AnalySize, the most accurate end-member modelling algorithm currently available [2] [3]. First, an artificial dataset with known size-shape end-member distributions is used to test in detail the accuracy of the method. Subsequently we apply our technique to a size-shape dataset from sediments of the Dutch coastal dunes. Unmixing results for this dataset indicate three main aeolian transport processes that that can be interpreted in terms of the dominant transport processes occurring along a beach-dune transect: saltation dominates the beach, modified saltation dominates directly land inwards of the foredune, whereas suspension dominates the hinterland. The three processes transport grains of different size and shape: the saltating load is composed of coarse equidimensional grains whereas the suspended load is composed of fine and less equidimensional grains. The modified saltation load takes in an intermediate position in size and shape (Fig. 1). End-members resulting from combined modelling of size and shape are more consistent with true sedimentological end-members because fall velocity is better approximated from these two parameters than size alone [1]. Thus, combined end-member modelling of size and shape is a promising new technique in sedimentary research which will increase insight into provenance and transport mechanisms [4].

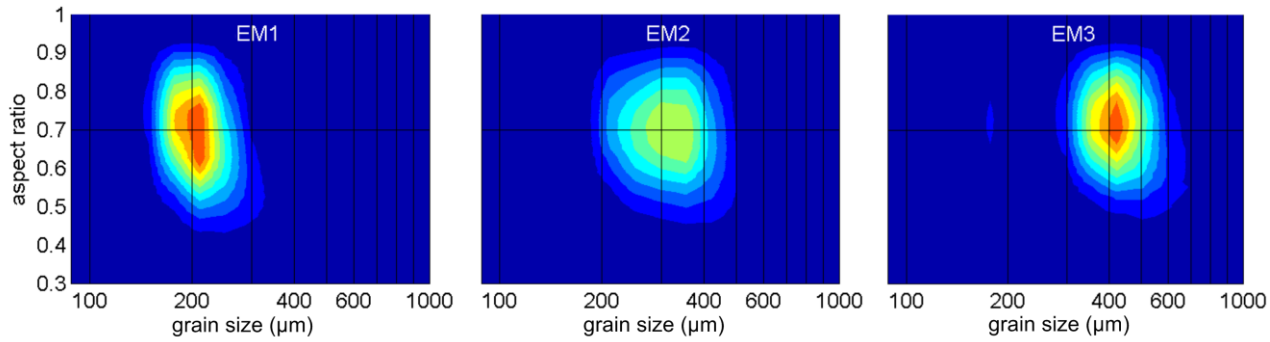

Figure 1. End-member modelling results for sediments of the Dutch coastal dunes. A 3-end-member solution is shown with a suspended (left, EM1), modified saltation (middle, EM2) and bedload component (right, EM3). Higher aspect ratios indicate more equidimensional sediment grains.

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Erodibility of and Dust Emisssions from Bare Soil Surfaces in the North American Soutwest

R.S. Van Pelt[1], J. Tatarko[2], C. Chang[3], I. Eibendingle[4] & T.E. Gill[4]
[1]*United States Department of Agriculture- Agricultural Research Service, Big Spring, Texas, USA*
[2]*United States Department of Agriculture- Agricultural Research Service, Ft. Collins, Colorado, USA*
[3]*Hebei Normal University, Shijiazhuang, China*
[4]*University of Texas at El Paso, El Paso, Texas*

Key words Natural surfaces, erodibility, dust emissions, climate change.

Native plant communities throughout the Southwestern United States are subject to increased abiotic stress due to climate change. As native grass cover is replaced by shrubs, more bare soil surface is susceptible to erosion by wind. The dust record for the last 20 years indicates that wind erosion and resultant fugitive dust emissions are increasing over broad areas of the Southwest. Furthermore, dust outbreaks in certain locations have resulted in multiple fatalities due to reduced visibility and motor vehicle accidents. We used a Portable In-Situ Wind Erosion Laboratory (PI-SWERL) and a simple pneumatic gun method to assess and compare the erodibility and dust emissions from multiple undisturbed and disturbed soil surfaces in Texas, New Mexico, and Arizona. Results of this study will be presented along with recommendations for improved management of these changing ecosystems.

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DUST EMISSION FROM CROPLANDS IN THE FREE STATE, SOUTH AFRICA

F. Eckardt[1], W. Fister[2], N.Kuhn[2], N. Ndara[1], A.R. Palmer[3], H.C. Vos[1]
[1]*Environmental and Geographical Science, University of Cape Town, South-Africa*
[2]*Physical Geography and Environmental Change, University of Basel, Switzerland*
[3]*Animal Production Institute, Agricultural Research Council, South Africa*

Key words Dust emission, South Africa, Free State, agriculture, wind and rainfall experiments, PI-SWERL, microbiome

The Free State Province is one of the regions in South Africa with the highest dust emission. Using Meteorsat Second Generation (MSG) data, we identified the source areas of dust plumes between 2006 and 2017. In contrast to most dust sources, which have a solely natural origin, the dust producing areas in the Free State are mostly located in intensively cultivated croplands. The dust emissions from the dominating Arenosols and Luvisols are likely to have a severe impact on human health, global climate, and biochemical cycles. Beside the regional or even global off-site effects of these dust emissions, there is also the direct soil degradation by the wind erosion processes at a local scale. The removal of fine, nutrient- and organic-rich particles leads to a reduction of soil fertility and crop production. The dust emissions from these croplands is driven by several processes, including crop management, local tillage practices, soil and weather conditions. This project, which is funded for three years by the Swiss National Fund and the National Research Foundation will address these different drivers. The first phase focusses on locating the points of origin of the dust and the factors that might lead to exposed and bare croplands, such as droughts or agricultural management practice. The second part of this study focusses on measuring and reproducing soil characteristics and the physical boundary conditions for dust emission on these exposed croplands. The third part of this study will address the human health issues associated with these dust plumes in cities nearby, with a focus on the microbiome that is captured with the dust.

By combining wind and rainfall experiments into one portable device and comparing the dust emission values from laboratory experiments with the wind tunnel and a Portable In-Situ Wind ERosion Lab (PI-SWERL, Desert Research Institute) device with field observations and measurements, it should be possible to create a better understanding of the situation in this dust region. Methods applied are interviews with local farmers regarding their crop management, satellite image analysis as well as field measurements on crust formation and wind erosion rates. The PI-SWERL will be used as supplement to the field measurements and to better estimate the potential dust emissions. By calibrating the PI-SWERL with the wind tunnel prior the field campaigns, we can most likely link their results together up to a certain degree. A better understanding of the combination of the different aspects of this study will enable us to develop a more profound picture of the involved erosion processes.

EFFECT OF WIND SPEED ON AGGREGATE SIZE DISTRIBUTION OF WINDBLOWN SEDIMENT

Wang Rende[1], Li Qing[1], Zhou Na[2*], Chang Chunping[3], Guo Zhongling[3], Li Jifeng[3]
[1]*Institute of Geographical Sciences, Heibei Academy Sciences/Hebei Engineering Research Center for Geographic Information Application; Shijiazhaung Hebei, 050011, China*
[2]*College of Management Science and Engineering, Hebei University of Economics and Business, 47 Xuefu Road, Shijiazhuang 050000 , Hebei Province, China*
[3] *College of Resource and Environment Sciences/Hebei Key Laboratory of Environmental Change and Ecological Construction, Hebei Normal University, Shijiazhang Hebei, 050024, China*

Key words dry aggregate size distribution; friction wind speed; windblown sediment; dust emission efficiency.

Wind speed plays a critical role in wind erosion and dust emission process, but the field measurements are so far insufficient to verify the effect of wind speed on particle size composition of windblown sediment. The change in dry aggregate size distribution of windblown sediment with friction wind speed was studied in the paper by field observation in Bashang district, north China from 2012 to 2016. The results showed that, for both loamy soil (LS) and sandy soil (SS), the geometric mean diameter of sediment increased exponentially with the increase in friction wind speed; the mass percentages of coarse particles with diameters of 0.1–0.5, 0.5–0.8, and0.8–1.0 mm and fine particles with diameters <0.05 mm in sediment increased with friction wind speed increasing, while the mass percentage of medium-sized sediments with diameters of 0.05–0.1 mm decreased with friction wind speed increasing. The dust emission efficiency increased linearly with friction wind speed increasing for LS, but the trend was not significant for SS. The similarity in aggregate size distribution between windblown sediment and erodible surface soil improved gradually with friction wind speed increasing, though the contents of fine and medium-sized particles in sediments were always higher than that in surface soil. According to this study, when determining dust emission efficiency or analysing the influence of particle size composition of soil on that of windblown sediment, the influence of wind speed should be considered.
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METHODOLOGICAL ASPECTS OF DUST DEPOSITION SAMPLING AND DUST COMPOSITION STUDY IN A DUST TRANSPORT REGION (TENERIFE): RESULTS FROM SINGLE-PARTICLE CHARACTERIZATION

A. Waza[1], K. Schneiders[1], J. May[2], K. Kandler[1]

[1]*Atmospheric Aerosol, Insitute for Applied Geosciences, Technische Universität Darmstadt, D-64287 Darmstadt,Germany*
[2]*Institute for Energy Systems & Technology, Technische Universität Darmstadt, D-64287 Darmstadt,Germany*

Key words Mineral dust particles, passive samplers, SEM-EDX, single particle analysis, size distribution

Mineral dust is dominated by particles in the supermicron range and consists to a great extent of particles larger than 10µm. Therefore, assessment of its properties can't rely only on standard PM10 instrumentation. Frequently, deposition or other passive measurement techniques are used to sample mineral dust from the atmosphere. However, there exists a multitude of different collection instruments with different, usually not well-characterized sampling efficiencies, so the resulting data might be considerably biased with respect to their size representatively. In this study, individual particle analysis by automated scanning electron microscopy (SEM) coupled with energy-dispersive X-ray (EDX) was used to characterize different, commonly used samplers (Big Spring Number Eight, Modified Wilson and Cooke, Hellmann, bucket and flat-plate geometries) with respect to their size-resolved mass deposition flux. The samples were collected on pure carbon adhesive substrate inside the different passive samplers. In addition, computational fluid dynamics modeling was used in parallel to achieve deposition velocities from a theoretical point of view. The samplers were operated in a mineral dust transport region (Izaña, Tenerife) in July – August 2017.
First results of the analysis show that there is a considerable differences in dust mass deposition flux measurements among different samplers (greater than order of magnitude 3). Generally, the Modified Wilson and Cook (MWAC) sampler obtains considerably higher deposition flux when compared to other passive samplers. In particular, it shows higher at coarser particle sizes. The maximum mass deposition flux measured is approximately 4300mg/m2day. Not surprisingly, the study also showed that there is high temporal variation in deposition flux between dust event days and non dust event days (greater than an order of magnitude of 3). The results obviously provide evidence of positive correlation between wind speed and efficiency of samplers for trapping particles [1]. From the chemical and mineralogical analysis point of view, unsurprisingly silicates are the dominant component of mineral dust particles. In addition to the silicates, the quartz particles also contribute to the composition in significant amount. The silicate composition increase with the particle size across the size distribution. Ironrich particles are found in small amounts particularly for particles less than 10µm. Clearly, this shows that there is strong dependence of the chemical composition on the particle size..

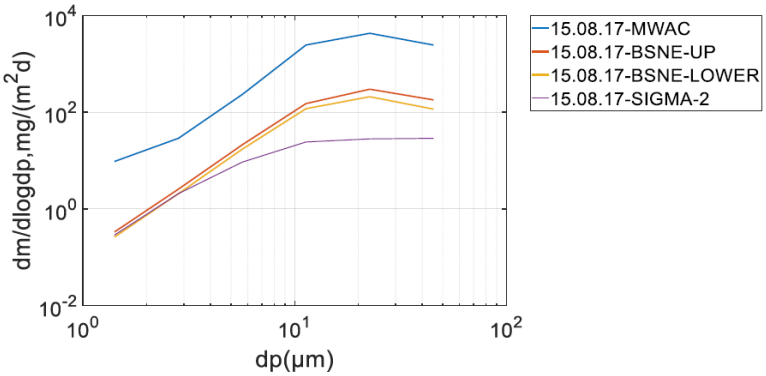

Figure 1. Size resolved mass deposition flux measured by different passive samplers.

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Combining field-based observations and remote sensing data to resolve aeolian dust dynamics at a globally significant source: Etosha Pan, Namibia

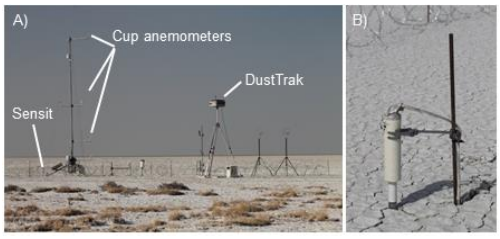
G.F.S. Wiggs[1], M.C.Baddock[2], R.G. Bryant[3], D.S.G.Thomas[1], F. Eckardt[4], R. Washington[1], S. Engelstaedter[1], J. Nield[5], M. Seely[6] & S. Kötting[7]

[1]*School of Geography and the Environment, University of Oxford, Oxford UK*
[2]*Department of Geography, Loughborough University, Loughborough, UK*
[3]*Department of Geography, University of Sheffield, Sheffield, UK*
[4]*Department of Environmental and Geographical Science, University of Cape Town, Cape Town, South Africa*
[5]*Geography and Environment, University of Southampton, Southampton, UK*
[6]*Desert Research Foundation of Namibia, Windhoek, Namibia*
[7]*Ministry of Environment and Tourism, Windhoek, Namibia.*

Key words dust emissions, dry lake bed, field measurements, remote sensing, dust flux

Windblown dust is a major global export from the world's deserts playing a critical role in the Earth's land-atmosphere-ocean-biosphere system. Yet the complex dynamics of windblown dust from source areas in deserts are poorly understood with much of our knowledge restricted to remote sensing interpretation. This lack of understanding leads to errors in models of dust emission into the atmosphere and predictions of deposition into the terrestrial and oceanic systems. Modelling of the dust cycle begins with proper representation of source areas and this is difficult without ground-based measurements of the processes of dust emission, and an understanding of the atmospheric and land surface factors that control erosion. We begin to address this data-gap by coupling coincident datasets from remote sensing analysis with ground based measurements of wind characteristics and dust emissions in order to clarify the temporal and spatial variability in dust dynamics for a globally significant dust source, Etosha Pan in Namibia (Figure 1C).

We used comprehensive ground-based measurements to characterise drivers of dust activity at both seasonal and event scales over a period of 12 months. We present data from four field sites located downwind of Etohsa Pan (Figure 1C). At each site we measured wind erosivity characteristics averaged over a 10 minute interval using 6 m high anemometer arrays. These data were combined with dust concentration measurements from DustTrak DRX aerosol monitors and saltation dynamics data measured with Sensit mass erosion monitors (Figure 1). These data were analysed to quantify the magnitude-frequency relationships of dust events to determine their individual contribution to overall seasonal dust flux. Field observations were coupled with coincident MODIS remote sensing imagery to identify emission source locations and spatial characteristics of individual dust events.



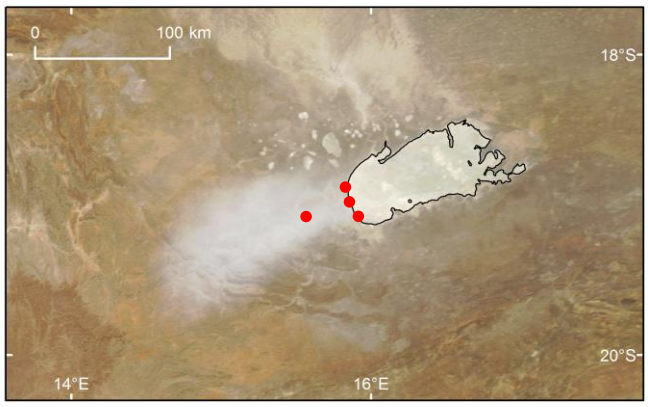


Figure 1. A) Typical field site deployment on the surface of the pan. B) Sensit erosion mass monitor. C) Etosha Pan, a 6000 km^2 dry lake bed in Namibia, during a typical SW trending dust storm. Red dots signify downwind monitoring sites.

Our data identified 51 significant dust events during the 12 month measuring period. Magnitude-frequency analysis of the measured dust events show that seasonal dust flux was dominated by just 6 large events that accounted for 41% of all the sediment eroded from Etosha Pan. The key drivers of these events are shown to differ substantially with season. In the traditional winter dust season, emission events are propelled by a low level jet which develops soon after dawn. However, our field observations also identified substantial summer emissions associated with nocturnal convective storms. Such events were not identifiable from the MODIS data which failed to identify dust events amounting to c. 28% of the annual sediment flux. However, remote sensing analysis enabled the spatial and temporal dynamics of emissions source locations to be identified. Our investigation offers a first step in demonstrating the value of combining ground-based measurements and remote sensing analysis for interpreting dust dynamics in major dust emitting regions.

Turbulent Saltation : JADE Observations and Model Considerations

Y. Shao[1], D. W. Liu[2], M. Ishizuka[3], M. Mikami[4]

[1]*Institute for Geophysics and Meteorology, University of Cologne, Germany*
[2]*School of Ecology and Environment, Inner Mongolia University, China*
[3]*Faculty of Engineering, Kagawa University, Japan*
[4]*Office of Climate and Environmental Research Promotion, Japan Meteorological Business Support Center, Japan*

We use JADE (Japan-Australian Dust Experiment) data of saltation fluxes and frictional velocity to analyze the statistical behavior of turbulent saltation and estimate the probability distribution of saltation model parameters, namely, the threshold friction velocity, u_{*t}, and saltation coefficient, c_0. Saltation flux, Q, shows rich variations on different scales. While the $Q \sim u_*^3$ relationship holds in general, it varies significantly between different erosion events. In several wind erosion events observed in JADE, saltation hysteresis occurred. We examine the probability density function of the saltation fluxes, $p(Q)$, and found that it generally behaves like $Q^{-\alpha}$, with $\alpha \sim 1$ for small Q and ~ 4 for larger Q.

Following [1], saltation intermittency, γ, is fraction of time during which saltation occurs at a given point in a given time period. In fact, as saltation is a turbulent process, intermittency describes only the behaviour of this process at $u_* \sim u_{*t}$ and is a special case of the process. We introduce several formulations of γ and estimate saltation them using the JADE data. The power spectra of saltation flux and friction velocity are computed. They are found to have qualitatively similar behavior. Both have a maximum at about 10^{-5} Hz, a minimum at about 10^{-4} Hz and another peak maximum at about 10^{-3} Hz. The maximum at 10^{-5} Hz is related to the diurnal to synoptic events that drive wind erosion episodes, the minimum at 10^{-4} Hz is due to the lack of turbulent wind fluctuations at the time scale of several hours, while the peak maximum at 10^{-3} Hz is caused by the minute-scale gusty winds/large eddies in turbulent flows.

As saltation is turbulent, saltation model parameters are probabilistic. The pdf of u_{*t} shows that it has a most frequent value close to the theoretical value, but can vary over in a range of 20% to 30%. In contrast, the pdf of c_0 shows it scatters over a wide range. It is thus unlikely that a universal c_0 exists. In a saltation model, even if the optimally estimated u_{*t} and c_0 are used, large scatter between the model and the data would remain. The likely reason for the large uncertainty in c_0 may be that this it is parameter depending on additional factors related to turbulence and particle size. It may also be that saltation in reality is never in equilibrium as [2] conceptualized, because due to turbulence, sand grains are continuously entrained at different rates into the airflow and a continuous flow- and particle-motion feedback takes place. Considerations for future saltation models will be discussed.

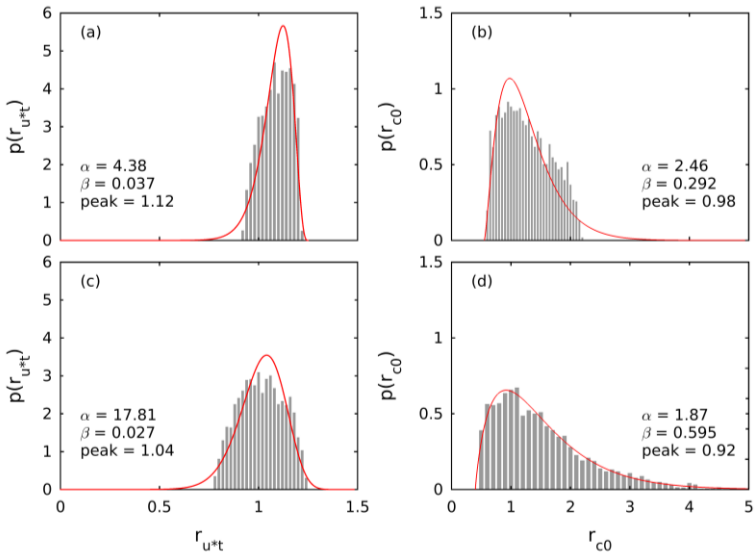


Figure 1. We define $u_{*t}=r_{u*t}u_{*t,theory}$ and $c_0=r_{c0}c_{0,theory}$. (a) Parameter pdf $p(r_{u*t})$ for 1-min averaged saltation fluxes; (b) as (a), but for $p(r_{c0})$; (c) and (d), as (a) and (b), but for 30-min averaged saltation fluxes.

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HOW TO ESTIMATE GRAIN AERODYNAMIC ENTRAINMENT THRESHOLD IN TURBULENCE?

Jie Zhang[1,2], Ning Huang[1,2], Guang Li[2] and Lei Ma[2]
[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, 222 Souther Tianshui Road, Lanzhou, 730000, China*

[2]*School of Civil Engineering and Mechanics, Lanzhou University, 730000 Lanzhou, China*

Key words: aerodynamic entrainment, turbulence, threshold, wind tunnel experiment

It is recognized that grain aerodynamic entrainment threshold is important to wind erosion research. Despite some efforts have been done, the relevant understanding is until today incomplete. The specific value of threshold shear stress (or friction velocity) is normally based on experiment measurement. In most of previous studies, the threshold shear stress τ_t is defined as the lowest mean surface shear stress at which entrainment is observed. This is an obvious questionable definition which is not only depended on surface property, but also effected by wind turbulence. We thus carried out a series of wind tunnel experiment to firstly study the entrainment regimes in turbulence flows. Intermittent and continuous entrainments are clearly identified. And then a new reasonable method to estimate threshold shear stress of aerodynamic entrainment in turbulence is proposed.

The contribution of different wind velocities on soil wind erosion mass in Qumarleb County, China

Zhang Kaidi, Cheng Hong, Chen Tianle, He Weiwei
State Key Laboratory of Earth Surface Processes and Resource Ecology,
MOE Engineering Research Center of Desertification and Blown-sand Control,
Beijing Normal University, Beijing, China

Key words Soil wind erosion mass; wind velocity; accumulative time

Soil wind erosion is a global environment issue in arid, semiarid and part of sub-humid regions. Accurately assessing soil wind erosion is an important topic. In the past several decades, scientists carried out plenty of studies about this problem. However, there is a debate about the contribution of low wind velocity with a lot of duration time and high velocity with less duration time on soil wind erosion in nature. In this paper, we calculated the soil wind erosion mass in Qumarleb County in 2016, using a model developed by Beijing Normal University, which was based on land use type, different wind velocity grades with an interval of 1 m/s, vegetation cover, surface humidity, and roughness. The main results include: 1) The relationship between each wind velocity grade (u) and its accumulative time (t) can be expressed as an exponential function (u =4822.88exp(-t/2.29)). 2) Soil wind erosion mass increases rapidly at first, then continuously decreases with increasing wind velocity. The transition wind velocity is about 8m/s. 3) Although there is plenty of accumulative time for low wind velocities, soil wind erosion mass is largely decided by the wind within the range of 7 to 15 m/s, and their contribution is about 74%. This is not consistent with previous reports, which concluded that soil wind erosion mass mainly depended on strong wind with little accumulative time. The possible reason is that previous studies focused on sand drift potential rather than actual wind erosion mass. These results would help to understand the process of wind erosion.

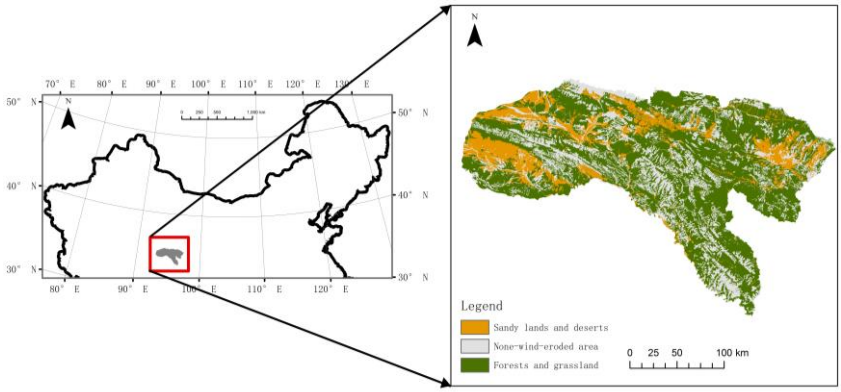

Figure 1. The location and land-use map in 2016 of Qumarleb County

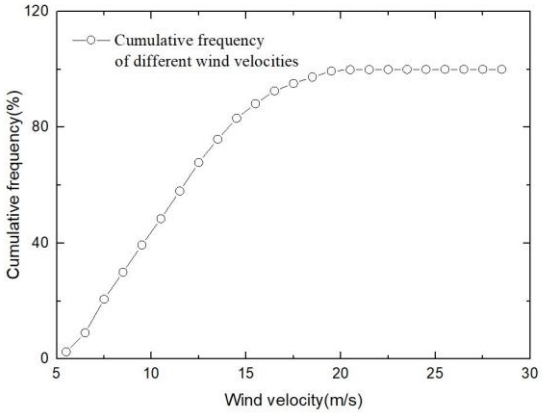

Figure 2. Cumulative probability distribution of different wind velocities

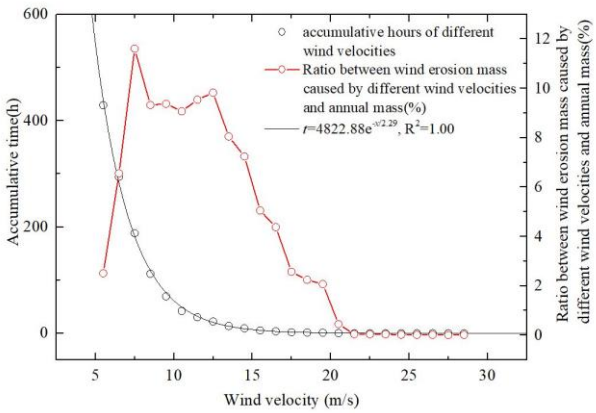

Figure 3. Accumulative hours and the contribution on annual soil wind erosion mass of different wind velocities

GRAVEL SURFACE PROPERTIES AND THEIR IMPLICATIONS TO THRESHOLD FRICTION CELOCITY

Z.C. Zhang[1], Z. B. Dong[2], G.Q. Qian[1], Z. Dong[3], X.J. Cui[2], C. Li[2]
[1]*Chinese Academy of Sciences Key Laboratory of Desert and Desertification, Lanzhou, China*
[2]*College of Tourism and Environment, Shaanxi Normal University, Xi'ans, China*
[2]*Shandong Agriculture University, Taian, China*

Key words gravel desert; threshold friction velocity; physical soil crust.

Dust emission processes are complex and directly associted with land surface properites, which makes accurate dust emission estimation are difficult. Gravel deserts are important dust sources. There are extensive areas of gravel deserts (approximately 57×10^4 km^2) in northwest China (Fig. 1). Gravel desert in the Alxa Plain, the Hexi Corridor, and the Heihe River Basin were selected to study the gravel surface properties to threshold friction velocity. A total of 120 field sites were selected and divided into 13 sections based on the geomorphological characteristics (Fig. 1).

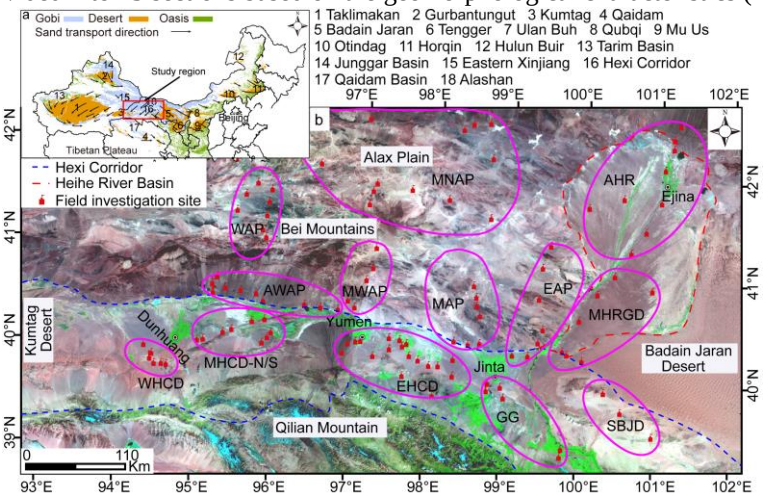

Figure 1. Study region, field investigation sites, and dust emission field measurement sites. a: study region in China; b: the 14 sub-regions used in the study, field investigation sites, and dust emission field measurement sites.

Based on detailed field investigations data of gravel weight (%, the ratio between grain size larger than 2 mm to total collected sampler), soil crust distribution, erodible sediment content, and four mathematical models (Shao et al., (1996) threshold friction calculation method, Raupach (1992) surface roughness elements calculation method, Fécan et al. (1999) soil moisture calculation method, and Vaddella (2014) surface soil crust calculation method), the effect of gravel surface properties on threshold friction velocity had been assessed. Results show that average gravel weight ranges from 6.6% to 99.5% (with a mean of 67.4%±22.3%), and approximately 81% of sites are covered by physical soil crust. Average silt content was 2.4%±2.4% in the study region, less than 2% for 52.1% of the region and the then from 2% to 4% (24.4%). The four regions where silt content is greater than regional mean are the western Alxa Plain, the alluvial fan of the western Alxa Plain, the northern Alxa Plain, and the Hexi Corridor. Threshold friction velocities, u_{*t}, range between 0.12 and 0.78 m s^{-1} (with a mean of 0.45±0.13 m s^{-1}). Soil moisture, gravel weight and soil crust all affect u_{*t}, with soil moisture being the most important (an effective could reach up to 88.5%, with an average of 81.4%±7.7%), followed by soil crust (an effective could reach up to 24.5%, with an average of 5.7%±6.4%) and gravel weight (an effective could reach up to 8.4%, with an average of 5.4%±2.1%). Analysis of variance showed obvious spatial differences in gravel weight, silt content, and u_{*t} in northwest China. Analysis of variance (ANOVA) showed that the soil moisture, soil crust distribution and gravel weight have obvious and significant spatial differences between sub-regions.

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SESSION

« Interactions with vegetation »

TEMPORAL VARIATION OF VEGETATION INDICES IN AREAS ASSOCIATED WITH SANDIZATION PROCESS IN THE BRAZILIAN PAMPA BIOME

L. C. B. da Costa[1,2], L. A. Guasselli[1], F. Laurent[2]
[1]*University Federal of Rio Grande do sul, Porto Alegre, Brazil*
[2]*University of Le Mans, Le Mans, France*

Key words Brazilian Pampa; temporal series of vegetation indices; seasonal dynamics of vegetation; sandization process

The Brazilian Pampa biome presents sandization process characterized by Suertegaray, 1987, is described as "the process of reworking sandy or non-consolidated sandy deposits, which causes a difficulty in fixing the vegetation cover in these areas due to the intense mobility of the sediments by the action of the waters and of the winds. The sand deposits (*"areais"* in its regional denomination) are the most evident form of this process. According to Suertegaray and Oliveira (2014) due to the difficulty of establishment of the vegetation in sandization areas, there is a propensity to mobilize the superficial layers of soil by water and wind erosion, contributing to the maintenance or evolution of the sand deposits. Another factor that triggers the expansion of the sand deposits is the inadequate practices of land use, mainly activities related to agriculture and livestock. The temporal series of vegetation indices (VIs), such as the Normalized Difference Vegetation Index (NDVI) and EVI (Enhanced Vegetation Index), derived from satellite images, can provide an understanding of the dynamics and processes that occur in these areas. Therefore, the objective of this work is to analyze the temporal variation of NDVI and EVI of the vegetation cover in areas related to the sandization process in the Brazilian Pampa biome. The time series of NDVI and EVI from Terra satellite, MODIS sensor are available on the internet in the web tool *SATVeg*. To compose the study were selected 8 samples (polygons), 4 in areas of reduced biomass and 4 in areas of exposed soil. Time series of temperature (satellite Terra / MODIS) and precipitation (satellite TRMM) were also available on the internet from the *series view* (LAF-INPE) web tool. With each of these data, temporal profiles of the averages of each month from 2000 to 2015 were generated. With the aid of statistical techniques, we tried to verify a seasonal behavior of the NDVI and EVI indexes, as well as their correlation with temperature and precipitation. It was verified that the vegetation indices did not present a marked seasonal dynamics, and their correlation with climatic data varied according to the location of the sample, whether in exposed soil or in areas reduced biomass.

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Effects of conservation tillage and residue management on soil carbon erosion in a corn field in northern China

Xiaohong Dang[1], Zhongju Meng[1],Yong Gao[1]

[1]*Inner Mongolia Agricultural University, Hohhot 010019, China*

Key words:Crop biomass, dry farmland, soil organic carbon, stubble retention, sustainable agriculture, wind erosion

Current interest in soil-conserving tillage in China has developed from the concern that Chinese agricultural land loses 73.8 Tg C annually. Previous research has shown that changing from conventional tillage to conservation tillage no tillage field management increases sequestration soil carbon. To investigate the effects of tillage and stubble retention on soil carbon levels Renewed interest in conservation tillage in China was derived from the concern that the national agricultural land loses 73.8 Tg C annually. However, research on the impacts of no-tillage with stubble retention on soil organic carbon is still in early developmental stage in China. We conducted a this study in northern China using treatments of no-tillage and with retention of different stubble lengths. We found that soil organic C storage (kgm^{-2}) under conservation tillage farming in the form of (no post harvest -tillage with stubble retention) significantly increased in the soil depths of 0-30 cm ($p < 0.01$) compared to the conventional tillage. The treatment of retaining post-harvest ed stubble with a height of 30 cm after harvesting and incorporating at the stubble into the soil before seeding in the next spring increased soil organic carbon (SOC) the most. Carbon storage ($kg \cdot ha^{-1}$) in above- and below-ground biomass of the corn plants in seedling and harvest stages were significantly greater ($p < 0.01$) with stubble retention treatments than with the conventional tillage. Carbon contents in root biomass in all the treatments with of stubble retention was significantly greater than with the conventional tillage. Given the complexities of agricultural systems, it is unlikely that one ideal farming practice is suitable to all soils or different climate conditions, but the stubble retention during harvesting and incorporation of the stubble into soil in the next spring appears to might be the best choice in the dry northern China where farmland suffers serious wind erosion.

Figure 1. Research site showing stubble retention and corn growth.

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Quantifying Post-Fire Aeolian Sediment Transport in a Shrub-Grass Ecotone Using Rare Earth Element Tracers

D. Dukes[1], H. Gonzales[1], S. Ravi[1], D. Grandstaff[1], R.S. Van Pelt[2], J. Li[3], G. Wang[3], and J. Sankey[4]
[1]*Department of Earth and Environmental Science, Temple University, Philadelphia, United States.*
[2]*Wind Erosion and Water Conservation Research, USDA-ARS, Big Spring, United States*
[3]*Department of Geoscience, The University of Tulsa, Tulsa, United States*
[4]*Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, US Geologic Survey, Flagstaff, USA*

Key words: Sediment tracers, land degradation, rare earth elements, wildfires, land management

Grasslands, which provide fundamental ecosystem services in many arid and semi-arid regions of the world, are undergoing rapid increases in fire activity and are highly susceptible to post-fire accelerated soil erosion by wind. A quantitative assessment of physical processes that integrates fire-wind erosion feedbacks is therefore needed relative to vegetation change, soil biogeochemical cycling, air quality, and landscape evolution. We investigated the applicability of a novel tracer technique – the use of multiple rare earth elements (REE) - to quantify soil transport by wind and to identify sources and sinks of wind-blown sediments in both a burned and unburned shrub-grass transition zone in the Chihuahuan Desert, NM, USA (Figure 1). Results indicate that the horizontal mass flux of wind-borne sediment increased approximately threefold following the fire. The REE-tracer analysis of wind-borne sediments show that the source of the horizontal mass flux in the unburned site was derived from bare microsites (88.5%), while in the burned site it was primarily sourced from shrub (42.3%) and bare (39.1%) microsites. Vegetated microsites which were predominantly sinks of aeolian sediments in the unburned areas, became sediment sources following the fire. The burned areas showed a spatial homogenization of sediment tracers, highlighting a potential negative feedback on landscape heterogeneity induced by shrub encroachment into grasslands. Though fires are known to increase aeolian sediment transport, accompanying changes in the sources and sinks of wind-borne sediments may influence biogeochemical cycling and land degradation dynamics. Furthermore, our experiment demonstrated that REEs can be used as reliable tracers for field-scale aeolian studies.

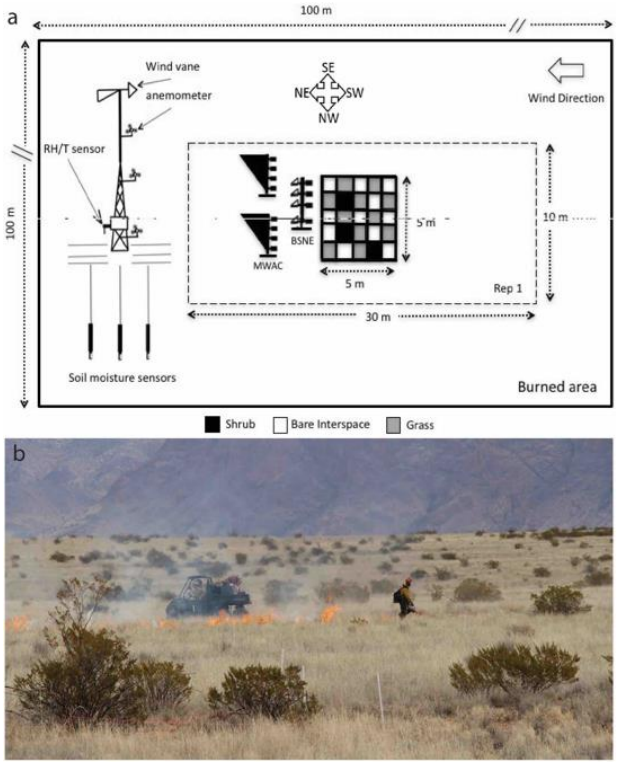

Figure 1. (a) The experimental layout of the burned treatment area. (b) The prescribed fire at the shrub-grass transition zone in the Chihuahuan Desert, New Mexico, USA.

VEGETATION EFFECTS ON SPATIOTEMPORAL VARIABILITY IN AEOLIAN MASS FLUX OVER A RANGE OF ECOLOGICAL CONDITIONS

B.L. Edwards[1], N.P. Webb[1], J.W. Van Zee[1], A. Chappell[2]
[1] *USDA-ARS Jornada Experimental Range, Las Cruces, NM, United States*
[2] *School of Earth and Ocean Sciences, Cardiff University, United Kingdom*

Key words sediment transport; sampling; regression co-kriging; wind-vegetation interaction; mapping

Issues of scale have long been a chief concern in efforts by the aeolian research community to monitor and model aeolian mass flux over spatially large areas. Observations over small sampling scales (< 1 m^2) dominate physical descriptions of aeolian transport processes and predictive mass flux equations. Consequently, those descriptions are unlikely to represent the controls of transport over space (>> 1 m^2). Loss of process fidelity is compounded as area increases because additional sources of variance are introduced and unknown synergies occur between controlling factors (Figure 1). Uncertainty is further amplified by increasing landscape heterogeneity, but because monitoring efforts are often limited in scope, few data are available to adequately describe spatial variability of transport to produce unbiased areal estimates, particularly in vegetated landscapes.

In this paper, we use transport and vegetation data from US National Wind Erosion Research Network (http://winderosionnetwork.org) sites to investigate spatiotemporal variability of transport and its controls for a range of vegetation conditions. For a given site, vegetation characteristics (e.g., canopy height, vegetative cover fraction, and gap size distribution) are recorded seasonally using standardized methods. Transport is measured using a stratified scheme of 27 MWAC collectors randomly located in groups of 3 within 9 cells in a 100 m^2 plot. We use regression co-kriging to map monthly transport and investigate how vegetation as a controlling factor drives variability in transport. Results are expected to inform future modeling efforts and improve analyses of wind erosion and dust emission responses to land use and land cover change.

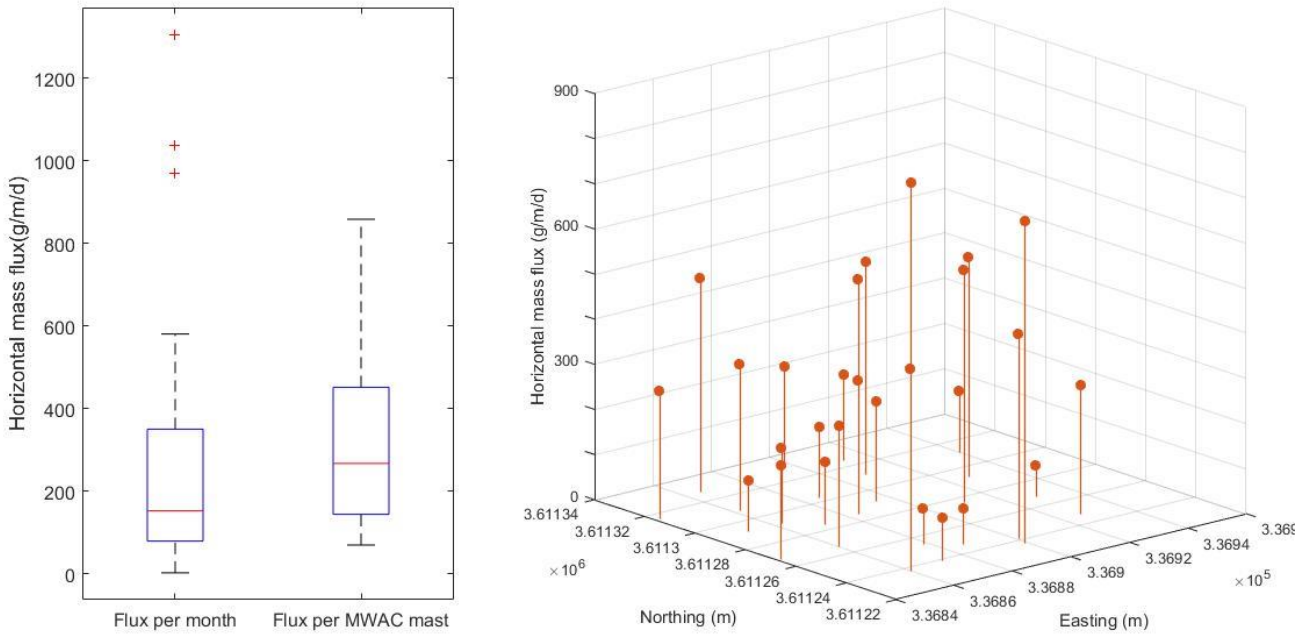

Figure 1. A) Boxplots of monthly flux averaged over an entire plot and flux averaged per MWAC sampler mast. Variability over space is of similar magnitude to variability through time. **B)** Mean monthly horizontal mass flux from 2015-2017 at 27 MWAC mast locations within one study plot.

MODELLING DUST EMISSION FROM EUROPEAN CROPLAND

Matthias Faust[1], Roger Funk[2], Steffen Münch[2], Nadine Thiel[3], Paul Siller[4], Oliver Biniasch[5], Thomas Amon[5], Uwe Rösler[4], Ulrich Nübel[3] & Kerstin Schepanski[1]

[1]*Leibniz-Institute for Tropospheric Research (TROPOS), Leipzig, Germany, faust@tropos.de*

[2]*Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany*

[3]*Leibniz-Institute DSMZ, Braunschweig, Germany*

[4]*Institute for Animal Hygiene and Environmental Health, Freie Universität Berlin, Germany*

[5]*Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany*

Key words human-induced dust source, agriculture, meso-scale modelling

Dust emission from anthropogenically disturbed soil such as arable land is a considerable contribution to the natural aerosol burden in Europe. Modelling studies estimate the global fraction of dust emitted from these soils to up to 60%. For Europe, the amount of dust emitted from agricultural land is estimated to more than 50%. Wind erosion from agricultural lands is of importance for several reasons: The loss of fertile topsoil ultimately reduces the bio-productivity and biodiversity. Furthermore, airborne dust reduces the air quality fostering negative impacts on human well-being. Soil particles dispersed through the atmosphere may act as a transport medium for pathogens and thus contribute to its spreading.

The susceptibility of agricultural land to wind erosion is strongly controlled by vegetation, in particular crop cultivation. In between harvest and sowing, bare and possibly ploughed land is in particular prone to wind erosion.

In order to fully assess the contribution of mineral dust from human-induced dust sources such as agricultural land, we apply the meso-scale dust-atmosphere model system COSMO-MUSCAT. In a first step, the dust emission module is revised in order to represent agricultural lands as temporary dust source. The soil type data set is updated now using the European Soil Database. Results from wind tunnel experiments will be used to update prescribed soil erodibilities. As dust emission from arable land is strongly controlled by vegetation, we apply the non-linear approach developed by Okin (2008) accounting for a decreasing dust emission flux for increasing vegetation cover. The actual vegetation cover is taken from the 10-daily PROBA-V satellite product FCOVER. Simulations performed using the improved COSMOMUSCAT model are validated against measurements from two field campaigns carried out in spring and early summer 2017 in eastern Germany (Brandenburg).

Ultimately, outcomes from this study contribute to the current level of knowledge on mineral dust emitted from human induced dust sources in a non-desert environment. The results further allow for an assessment on the role of dust emitted from an agrarian landscape for air quality and human well-being.

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Transition Model of Airflow Fields around Single Plants to Multiple Plants

Cheng Hong, Liu Chenchen, He Weiwei, Zhang Kaidi, Chen Tianle

State Key Laboratory of Earth Surface Processes and Resource Ecology/
MOE Engineering Center of Desertification and Blown-sand Control,
Beijing Normal University, Beijing, China

Key words: transition model, airflow, plant, wind tunnel

The biocontrol method is the most effective method for land desertification control in arid and semi-arid areas. These areas have limited water and poor soil, and thus, optimizations are needed for the existing biocontrol methods for anti-desertification and soil-erosion control so that the scope and scale of the biocontrol can be reduced. The premise for the optimization work is to reveal the distribution law of airflow fields around vegetation. Current studies lack focus on the spatial distribution of airflow speed on a 2-D surface. No research efforts have been reported on the transition of airflow fields around single plants to the patterns around multiple plants. Based on wind tunnel experiments for different airflow fields around a single plant, a single-row forest belt with different spacing intervals between plants, a multi-row forest belt with different numbers of rows, and a double-row forest belt with various arrangements, this paper comprehensively analyzed factors including air flow speed and plants' characteristic parameters (such as transmittance, crown width, height, etc.) of the horizontal and vertical air flow field partition around single plants and developed the horizontal model for the airflow fields around single plants. A transition model for airflow fields around single plants to patterns around multiple plants was also proposed, which lays the theoretical foundations for optimum biocontrol plant configurations to address anti-desertification and soil erosion control.

WATER EROSION CONTROL EXPERIMENT OF ASTRAGALUS ADSURGENS ROOTS AND CANOPY IN THE WATER–WIND CRISSCROSSED EROSION REGION OF MU US DESERT, CHINA

J.E. Gao[1,2], C.H.Zhao[1], Z.X[1] , G.G.Zhang [1], Z.Gao[1],M.J.Ji[1]

1 Northwest A&F University, Yangling,Shaanxi, P.R. China
2 Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling ,Shaanxi, P.R. China

key words: soil erosion; root and canopy; soil resistance to erosion; water–wind crisscrossed erosion region;Astragalus adsurgens

Astragalus adsurgens is a common grass widely distributed in the water–wind crisscrossed erosion zone of the Mu Us Desert and plays an important role in controlling sand and preventing windstorms. Simulated rainfall experiments were conducted to investigate the effect of Astragalus adsurgens roots and canopy on water erosion yield,erosion processes and soil resistance to erosion. Experiments were conducted on grass, root and bare slopes, with sandy soil from a water–wind crisscrossed erosion region of Mu Us Desert, China. A. adsurgens coverage on grass slopes was approximately 40%. There were three rainfall intensities of 30, 60 and 90mmh–1 and four slope gradients of 3, 6, 9 and 12 °. A. adsurgens had a significant effect on soil erosion control; soil loss was reduced by 70% on slopes with the grass compared with bare slopes. The grass roots reduced soil loss more than its canopy, particularly in high-intensity rainfall, which reduced soil loss by 82%. The presence of the grass and its roots changed the soil erosion process, reducing soil erodibility (Kr) and increasing the critical shear stress (τ c). The soil erosion rate on the bare slope increased steadily over time; on the grass and root slopes, its rate initially increased, then decreased and then finally stabilized. Kr on the grass and root slopes was reduced by 96% and 89%, respectively, compared with the bare slope, while the corresponding τ c increased by 92% and 195% respectively. These results provide insights into the mechanisms of grass on soil and water conservation and may help to improve vegetation construction in water–wind crisscrossed erosion regions of the Loess Plateau.

Figure 1. The dune of Mu Us Desert Aerial

Influence of dry-season vegetation variability on Sahelian dust during 2002–2015

L. Kergoat [1], F. Guichard [2], C. Pierre [1,3], B. Marticorena [4], G. Bergametti [4], C. Vassal [1],
[1] *Geosciences Environnement Toulouse, Toulouse, France*
[2] *Centre National de Recherches Météorologiques, Toulouse, France*
[3] *Institut d'Ecologie et des Sciences de l'Environnement de Paris, Bondy,*
[4] *Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*

Key words Non photosynthetic vegetation, Sahel, STI, dust interannual variability, MODIS.

North Africa is the largest dust source on Earth. However, the drivers of dust emission interannual variability in this region are still debated. Early studies outlined the role of previous-season rainfall and vegetation growth, while some recent studies emphasize the role of wind variability. Here we use a newly developed estimation of dry-season nonphotosynthetic vegetation cover in the Sahel to address this question [1]. This estimation is based on data from the Moderate Resolution Imaging Spectroradiometer (MODIS) short-wave infrared bands and covers the 2002–2015 period. Firstly, we showed that the annual vegetation growth anomalies caused by variability of rainfall in June–September (rainy season) translate into anomalies of dry vegetation cover that persist throughout the dry season until May, i.e. until the very end of it. Secondly, we showed that these vegetation anomalies explain 43% (50%) of the year-to-year variance in Sahelian-mean dry-season aerosol optical depth (AOD) as derived from MODIS Deep Blue (or AERONET Sun photometers). Similar explained variance is found with 10 m wind speed and dust uplift potential from the ECMWF. Wind and dry-season vegetation anomalies are not correlated and are further combined in a linear two-variable model. This model is compared to the independent dust concentration data from the Sahelian Dust Transect. The central Sahel proves more important than the western Sahel for dry-season AOD variability, but no relationship to Land Use was found. Dry-season vegetation, for which we now have large-scale observations, is being implemented in models.

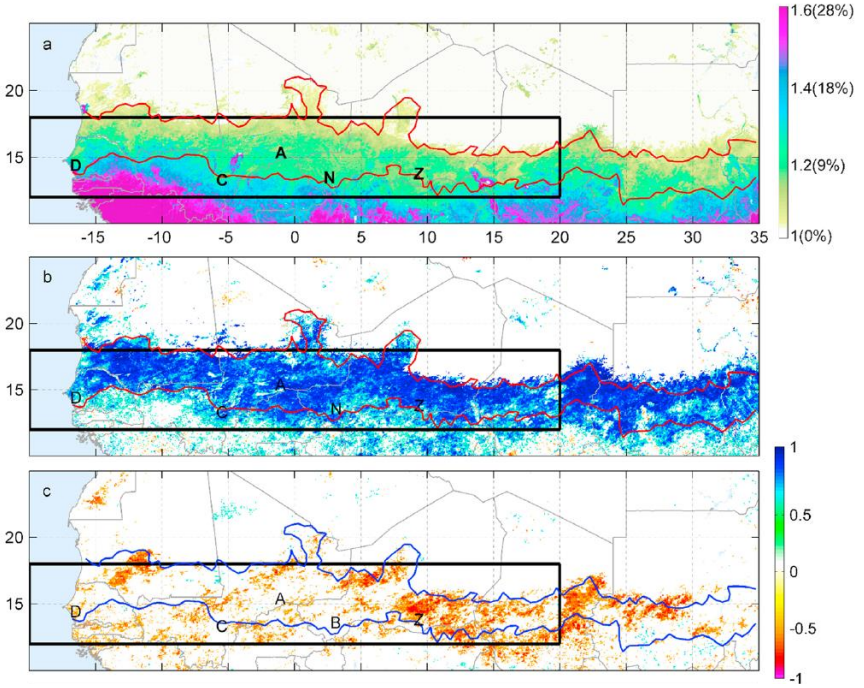

Figure: (a) Dry-season STI and corresponding dry-vegetation cover in % from MODIS. Letters mark the AERONET stations. The red lines are the 600 mm and 100 mm isohyets. (b) Map of correlation of dry-season STI (October–June) with previous growing-season NDVI (July–September). (c) Map of correlation between dry-season STI and Sahelian AOD.

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SPATIAL-TEMPORAL DISTRIBUTION OF BIOLOGICAL SOIL CRUST ON DIFFERENT TIME SCALES

Y. Li, M. Reyers, Y. Shao

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Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany

Key words Biological soil crust; Remote sensing; Spatial-temporal distribution

Biogenic Soil Crusts (BSCs) are critical components of desert ecosystems, significantly modifying the surfaces they occupy. Soil resistance to wind erosion increases as BSCs develop, especially in deserts where plant cover is low. Thus, studying BSCs interactions with aeolian processes and including the effect of BSCs in aeolian models is important. To model the interactions between aeolian processes and BSCs requires information of the spatial-temporal distribution of BSCs.

To detect and map BSCs, satellite remote sensing data can be used. First, surface reflectance is retrieved from Landsat data with radiation calibration and atmospheric correction. BSC Index (BSCI) is then calculated using the retrieved surface reflectance. Masking study area using certain slopes is also applied. Based on a BSC model, the range of BSCI is determined for the study area. In this study, this method is applied to the Gurbantunggut Desert in China. Information of the typical spectral reflectance of BSCs is taken from literatures. The BSCI is calculated for a 20 year period. The spatial-temporal variability of BSC on different time scales, including intra-annual, inter-annual and inter-decadal, is analyzed. In addition, changes of BSCs associated with severe dust events are examined.

Interactive effects of wind, vegetation and soil moisture in controlling wind erosion in a temperate desert steppe

Meng Zhongju, GaoYong ,Dang Xiaohong , Cui Xiangxin, Zhao Wenling

Inner Mongolia Agricultural University, Hohhot , China.

Key words**:** *desert steppe; soil erosion, desertification, Aeolian processes, drylands*

The rapid desertification of grassland in Inner Mongolia pose a significant ecological threat to northern China. The combined effect of anthropogenic disturbances (e.g. overgrazing) and biophysical processes (e.g. soil erosion) has led to vegetation degradation and the consequent acceleration of regional desertification. Hence, mitigating accelerated soil erosion by wind, a cause and effect of grassland desertification, is critical for the sustainable management of grasslands. Here, using a combination of mobile wind tunnel experiments and modeling, we investigated the effect of varying levels of vegetation cover and soil water content on wind erosion potential of different slope positions in the Xilamuren desert steppe of Inner Mongolia. Our results indicate a significant spatial difference in wind erosion intensities depending on the vegetation coverage, with a strong decreasing trend from the top to the base of the slope. Increase in vegetation coverage resulted in rapid decrease in wind erosion as explained by a power function correlation. Vegetation cover, by increasing the surface roughness, was found to be a dominant control on wind erosion by lowering the threshold velocity for erosion. The critical vegetation cover required for effective control of wind erosion was found to be greater than 60%. Further, the wind erosion rates were negatively correlated with surface soil moisture and the horizontal mass fluxes for sand transport increased with increasing wind velocity regimes. A mathematical model of surface wind erosion was developed based on the results of an orthogonal experiment. The results from the model simulation indicated that the standardized regression coefficients of the main effects of the three factors of the mass flux in aeolian sand transport were as follows: wind speed > vegetation coverage > soil moisture. The three factors had varying levels of interaction effects on the mass flux in aeolian transport of sand. Our results will improve the understanding of the interactive effects of wind, vegetation and soil characteristics in controlling aeolian erosion in the desert steppe and will help in the design of future desertification control programs.

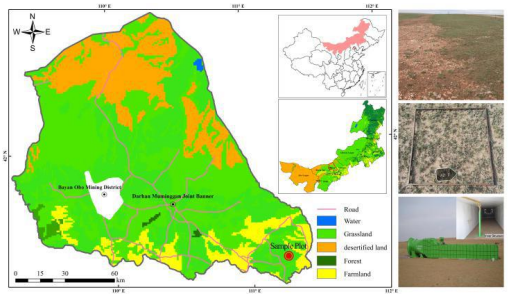

Fig. 1 Study area and sample plot

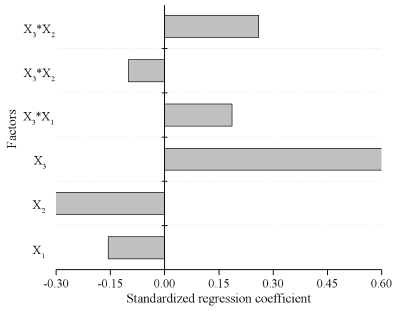

Fig. 2 Standardized regression coefficients of the main factors of sand transport via sand-free wind. where x_1 is the soil moisture content, x_2 is the vegetation coverage, and x_3 is the wind speed.

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How does agropastoral management affect wind erosion in Sahelian croplands?

C. Pierre[1,2], L. Kergoat[3], P. Hiernaux[4], C. Baron[5], G. Bergametti[2],
JL. Rajot[1,2,6], A. Abdourhamane Toure[7], G. S. Okin[8], B. Marticorena[2]
[1] *Institut d'Ecologie et des Sciences de l'Environnement, Paris, France*
[2] *Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*
[3] *Géosciences Environnement Toulouse, Toulouse, France*
[4] *Pastoralisme Conseil, Caylus, France*
[5] *Centre de coopération Internationale en Recherche Agronomique pour le Développement, Montpellier, France*
[6] *Institut des Régions Arides, Médenine, Tunisia*
[7] *Université Abdou Moumouni, Niamey, Niger*
[8] *University of California Los Angeles, Los Angeles, California, USA*

Key words: wind erosion, agropastoral practices, simulations, land use

Climate change and demographic growth raise major concerns about the ability of Sahelian crop yields to support the local population. Ii is known that agropastoral practices affect wind erosion (e.g., through crop residue management and tillage), which itself can substantially affects soil fertility and thus crop production. Thus, we need to estimate the potential impact on wind erosion of the main Sahelian cropping practices like sowing, manuring, and crop residue management. We used a modeling approach adapted to an experimental site located in southwestern Niger over a 7-year period (2006–2012). We defined scenarios that describe a set of agropastoral practices to simulate and compare the impacts of these practices on wind erosion.

As a result, horizontal fluxes differ by a factor of 10 among scenarios, with annual horizontal fluxes ranging from 121 to 1,317 kg m^{-1}. The simulated wind erosion is most sensitive to the mass of crop residues in the late dry season, but different practices dealing either with crop growth or with crop residue management may result in fluxes of the similar magnitude. It is also noted that the collection of the crop residues after grain harvest increases wind erosion. Grazing might have mixed effects, probably further mediated by the mobility of livestock as a response to forage availability. The seasonal dynamics of the monthly cumulated horizontal fluxes vary depending on practice, but the annual cumulated horizontal fluxes are closely correlated with meteorological conditions such as wind speed and rainfall in the previous year.

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The effects of vegetation on wind erosion in the West African Sahel

Geert Sterk[1], Guido Kersten[1] & Lisette Peters[1]

[1]*Dept. of Physical Geography, Utrecht University, Utrecht, The Netherlands*

Key words Sahel, wind erosion processes, wind erosion control, natural vegetation, modelling.

Wind erosion is an important soil degradation problem in the Sahelian zone of West Africa. Much research in the past has focused on wind erosion control using typical field-scale measures like mulching, ridging, strip cropping and growing shelterbelts. Despite the generally good potential in reducing wind erosion, most measures are difficult to adopt by farmers for varying reasons. Hence, there is a need for alternative measures to reduce wind erosion in the Sahel. Potentially, the characteristic dryland vegetation with scattered trees and shrubs can provide for soil erosion protection from wind erosion, but so far adequate quantification of vegetation impacts is lacking. In this study the effects of scattered natural vegetation of trees and shrubs on sediment transport in a typical Sahelian environment have been modelled. A semi-empirical model was developed that makes use of the 1) Lettau (1969) approach for assessment of aerodynamic roughness of vegetated terrain, 2) the Raupach (1992) shear stress partitioning theory, and 3) the Dong et al. (2002) sediment transport equation. The model was tested for both hypothetical and actual vegetated surfaces in the Sahel. The performance of the developed model was verified by using field measurements on sediment transport that were obtained on two farmers' fields in Burkina Faso. The characteristics of the vegetation and the density of vegetation elements differed per field. The model predictions of sediment transport were close to the measured amounts for both fields for single storms. The model was subsequently used to carry out scenario studies to test the effect of height, number, and type of vegetation elements (tree versus shrub) on Aeolian sediment transport. From these scenarios it appeared that trees reduce wind speed and sediment transport much stronger than shrubs, due to their higher aerodynamic roughness (Figure 1). However, the model also predicts an increase in sediment transport in fields with only few trees (<10 trees/ha). This effect is also present, but less pronounced, when only a few shrubs (<25 shrubs/ha) are present. Therefore it is concluded that scattered woody vegetation can be used to reduce sediment transport, but only if a substantial number of trees and/or shrubs is used. Applying scattered woody vegetation to reduce sediment transport effectively requires cooperation of farmers and management of vegetation at village level.

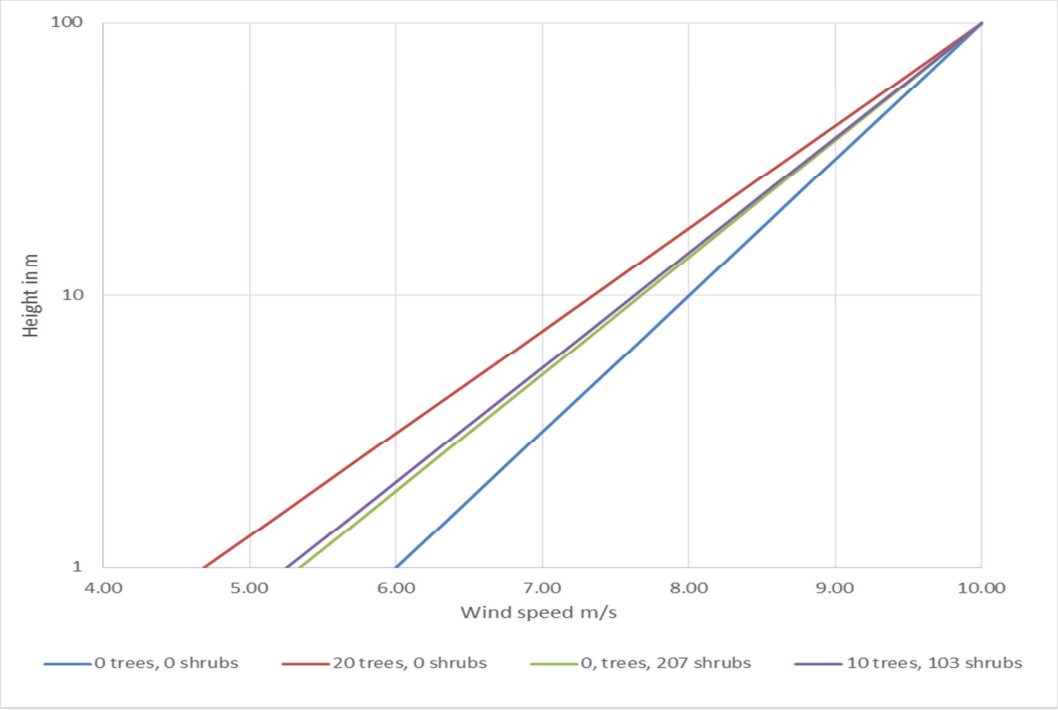

Figure 1: The influence of trees and shrubs on wind speed profiles in the Sahel.

POST-FIRE SPATIAL DISTRIBUTION AND SOURCES OF SOIL CARBON AT A GRASSLAND-SHRUBLAND TRANSITION ZONE IN THE SOUTHWESTERN US

Guan Wang[1], Junran Li[1], Sujith Ravi[2], Joel B. Sankey[3]
[1] *Department of Geosciences, The University of Tulsa, Tulsa, OK, 74104, USA.*
[2] *Department of Earth and Environmental Science, Temple University, Philadelphia, PA 19122, USA.*
[3] *Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, US Geological Survey, Flagstaff, AZ 86001, USA.*

Key words Shrub encroachment, Wildfire, Wind erosion, Soil carbon partitioning, Spatial heterogeneity, Microsites

Nearly 70% of the world's drylands, including large areas of the southwestern US, are experiencing rapid and extensive land degradation, concomitant with the woody shrub encroachment into grasslands, due to loss of vegetation cover, accelerated soil erosion, and the consequent loss of soil resources [1]. Fires are known to decrease vegetation cover and increase soil erodibility, and the shifts in wildfire regimes are currently occurring in many drylands. Several studies have suggested that periodic fire favors the homogenization of soil resources and can provide some form of reversibility for the shrub-grass transition, making prescribed burning a potential tool for reducing the abundance of the undesirable shrubs and slowing the shrub encroachment process [2]. However, the enhanced wind erosion and soil structure changes following fires may result in increased dust emission, promoted soil water repellency, reduced soil moisture retention capacity, loss of soil organic matter, and changes in C pool in the ecosystem [3]. Soil carbon (C) is of crucial importance to maintain soil quality and productivity in order to stabilize the ecosystem services. The shrub invasion adds complexity on soil C pool in grassland-shrubland transition areas than areas dominated by a single physiognomy, and the relative distribution of each vegetation type to the soil C pool and its variability after wildfires are not well-understood [4].

In this study, manipulative field experiments were used to investigate the influence of fire on the dynamics of spatial distribution and source partitioning of the soil C pool in a typical grassland-shrubland transition zone. Replicated burned and control experimental plots were set up in a desert grassland in the northern Chihuahuan Desert in March 2016. According to the aboveground vegetation cover, the soil surface was artificially divided into three types of microsites, namely, grass, shrub, and bare interspace. Soil samples were collected every March and June (before and after spring windy season). Stable carbon isotope and organic carbon content of soils and plants were utilized in the assessment in conjunction with geostatistical analysis.

Soil $\delta^{13}C$ in the burned area changed notably after the fire, especially in the shrub microsites. Soil $\delta^{13}C$ increased from -22.8‰ to -19.1‰ in soil under shrub canopies one year after the fire, and reached -17.8‰ in June 2017. In contrast, at the control site, it decreased from -19.6‰ to -21.7‰ in shrub microsites after one year, and then dropped slowly during the second windy season. Soil $\delta^{13}C$ reflects the relative contributions of soil organic matter from shrubs (C3 plants) and grasses (C4 plants) [4]. The contribution of C3 plants increased significantly in bare and grass microsites while decreased in shrub microsites after the fire at the burned site, which suggests that the islands of fertility under shrub canopies weakened and organic matter that originally gathered under shrub canopies were dispersed to other microsites. The kriging maps exhibited that the spatial distribution of soil $\delta^{13}C$ homogenized during the experiment period at the burned site. The results indicate that the fire-induced shrub mortality and increased wind erosion improved the homogeneity of the soil C spatial distribution, and the spatial pattern changes of vegetation after the fire have corresponding effects on the localized redistribution of soil $\delta^{13}C$ and soil C partitioning. These results suggest that fire can change the organic carbon interactions between soil and plants, which may further affect the shrub encroachment process as well as the dynamics of grassland-shrubland ecosystems.

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POST-FIRE SPATIAL HETEROGENEITY OF STABLE ISOTOPES OF SOIL NITROGEN AT A GRASSLAND-SHRUBLAND ECOTONE IN THE NORTHERN CHIHUAHUAN DESERT

Guan Wang[1], Junran Li[1], Sujith Ravi[2], Joel B. Sankey[3]
[1] *Department of Geosciences, The University of Tulsa, Tulsa, OK, 74104, USA.*
[2] *Department of Earth and Environmental Science, Temple University, Philadelphia, PA 19122, USA.*
[3] *Southwest Biological Science Center, Grand Canyon Monitoring and Research Center, US Geological Survey, Flagstaff, AZ 86001, USA.*

Key words Woody shrub encroachment, Soil $\delta^{15}N$, Nitrogen cycling, Wind transportation, Geostatistics

Woody plant encroachment into grasslands and the enhanced woody plant density in rangelands are well documented and rapidly occurring global phenomena [1]. Recent studies have explored the possibility of using periodic fire to provide some form of reversibility for the shrub-grass transition, pointing out a possible way to counteract the woody shrub encroachment processes [2]. Soil $\delta^{15}N$ is a natural integrator of soil nitrogen cycling processes. Its spatial distribution is a good indicator of processes that are critical to N cycling and of their controlling factors integrated both in time and space [3]. The spatial distribution of soil $\delta^{15}N$ and its underlying drivers at woody shrub encroached grasslands after wildfires are rarely investigated. This study utilized a prescribed fire to create a burned site at a grassland-shrubland ecotone in the northern Chihuahuan Desert to explore the effects of fire and subsequent vegetation and wind transportation changes on the spatial distribution patterns of soil $\delta^{15}N$. 50 soil samples were randomly collected at each 5 m × 5 m plot at the burned and control sites for analyses of $\delta^{15}N$ and TN (Total Nitrogen). At each site, the wind speed at four different heights (0.5 m, 1 m, 2 m, and 4 m), precipitation and soil water content under the three types of microsites were recorded. According to the aboveground vegetation cover, the soil surface was divided into three types of microsites, namely, grass, shrub, and bare interspace, and the microsite type of each sampling point was carefully recorded. Distinct patterns of VWC (Volumetric Water Content) were observed under different microsites between the control site and the burned site. At the control site, soil water content was always the highest at the shrub microsite and the lowest at the grass microsite. As a comparison, the shrub microsites consistently had the lowest water content even when it rained, while the bare and grass microsites occupied similar soil water content after the fire at the burned site. The average horizontal mass flux in the burned plots (75.3 g m^{-1} d^{-1}) was nearly three times higher than in the control plots (27.1 g m^{-1} d^{-1}) [4]. No significant difference of $\delta^{15}N$ existed among different microsites in March 2016, right after the prescribed fire. After one year, $\delta^{15}N$ in the bare microsites (6.06‰) became significantly higher than grass microsites (4.79‰), but they showed no significant difference with shrub microsites (5.79‰) at the burned site. The kriging maps show that soil $\delta^{15}N$ were patchily distributed in the burned and control plots. Woody shrub and grass distribution greatly determined the soil $\delta^{15}N$ spatial pattern. At both the burned and control sites, the soil in bare interspaces corresponded with patches of higher $\delta^{15}N$ values while the low $\delta^{15}N$ values were generally in agreement with the locations of grasses immediately after the fire. However, this distinct spatial pattern became less obvious and the coefficient of variation of soil $\delta^{15}N$ decreased at the burned site one year after the fire, suggesting a more homogeneous soil $\delta^{15}N$ distribution. These results indicate that the fire-induced soil moisture, wind transportation, and vegetation cover changes interactively control the spatial redistribution of soil $\delta^{15}N$ and affect the soil nitrogen cycling in the grassland-shrubland transition areas.

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SESSION

« Dunes and bedforms »

A comparison of general models of activity of sand dunes in Iran

H.R. Abbasi[1, 2], C. Opp[1], M. Groll[1] , A. Gohardoost[2]
[1]*Phillips Universität Marburg, Marburg, Germany*
[2] *Desert Research Division, Research Institute of Forests and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Tehran, Iran.*

Key words Wind energy environment, dune mobility, Iran ergs.

Very limited studies have been published regarding the sand dunes of Iran but none of the available English reviews in national scale for the international scientific society. For this purpose, climatic parameters such as hourly wind data and precipitation and temperature were collected at 198 meteorological stations in arid and semi-arid of Iran. Tow mobility indexes, which introduced by Lancaster [1] and Tosar [2], are calculated and mapped by geostatistical method. We also overlaid sand drift potential (DP), evapotranspiration potential and precipitation maps and classified activity dunes in Iran. Results showed that sand dunes covers near 4.8 million hectares of Iran extended into and around of the Dasht-e Kavir and Lut deserts, tow vast of Iran deserts. They formed at 9 sand seas and 84 dune fields that according our method mobility index 15 % is fully active, 48 % active except interdune areas, 2 % active only dune crests and 15 % completely stabilized. Both of models almost classified fully active dunes in same except two regions. The highest values in both of mobility indexes were 46 and 9.3 at Zabol station, respectively. The highest values of DP is 2516 and 1643 (VU) for the Zabol and Damgan stations in which have fully active dunes in Iran. The rate of mobility single barchan with 10 meter height in Sistan plain measured between 30 to 60 meters annually.

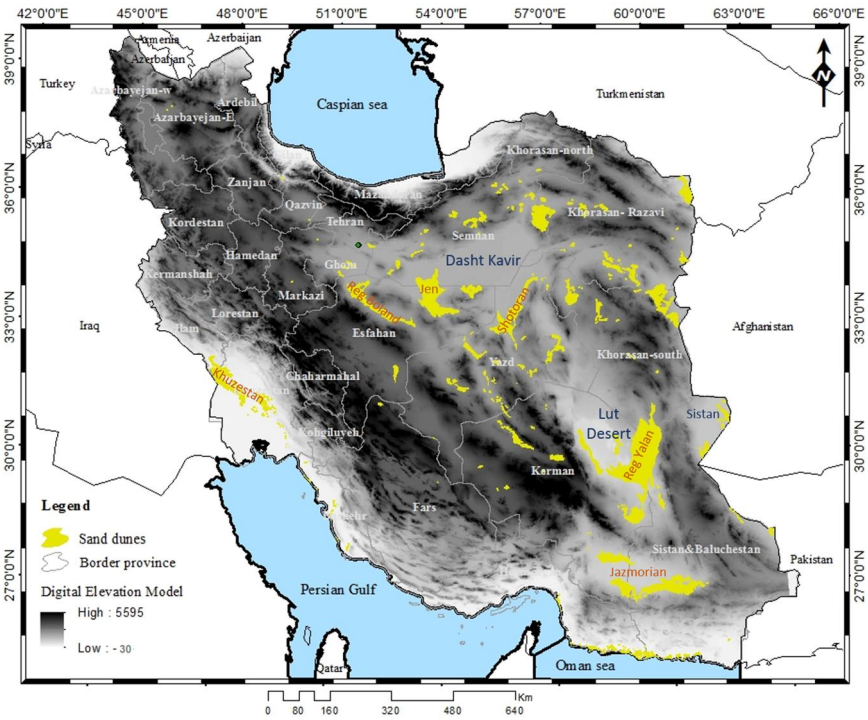

Figure 1. Distribution of Sand dunes in Iran

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YERDI SAND DUNES LOCATED NEAR TO ERFOUD CITY (TAFILALET BASIN, SE OF MOROCCO): MINERALOGY, COLOR AND ORIGIN INVESTIGATION

M. ADNANI[1], M.A. AZZAOUI[1], H. ELBELRHITI[2], M. AHMAMOU[1], L. MASMOUDI[1], M. CHIBAN[3]

1 Laboratoire d'Electronique et de Traitement du Signal/ Géomatique (LETS/Géomat) Faculté des Sciences de Rabat, Université Mohammed V-Agdal, 4 Avenue Ibn Battouta B.P. 1014 RP, Rabat, Maroc.

2 Département des Sciences Fondamentales et Appliquées. Institut Agronomique et Vétérinaire Hassan II. BP 6202, 10101 – Rabat, Maroc.

3 Département de chimie, Faculté des sciences, Université Ibn Zohr, BP 8106 Hay Dakhla, 80000, Agadir, Maroc.

Key words Dunes, Color, Origin, Mineralogy, Remote sensing, GIS.

The abundance of different types of sand dunes in the same environmental conditions is largely observed in a restricted area in Tafilalet basin, southeastern arid area of Morocco. Dunes color is one of the characteristics to highlight this variation. The present study aims to prove sand dunes color difference observed in sand dunes in Yerdi locality across both of Ziz valley sides, then to investigate sand's origin and its transport pathways. To this end, we have opted for remote sensing and GIS tools as a methodology, in addition to laboratory analyses, that included mineralogy, grains size and shape investigation of samples collected from the studied dunes.

The results reveal: i) the grain sizes of the right side are significantly different from the left. As for quartz grains shape study revealed the prevalence of the round-shiny type on the right side while the angular type predominates on the left. Mineralogical analysis results revealed a high concentration of quartz and a low amount of carbonates and iron oxide. While Fe-DCB results reveal 0.180 g / 100g of iron in the right bank and 0, 175 g / 100g in the left one. As for microscopical analyses of Heavy minerals, they have shown a similar mineralogical concentration in both of samples; yet, sand in the left side appears to be richer in Hematite and goethite than the right one. ii) Remote sensing method supported a laboratory method. Hence, Band ratios 6/4 and 5/7 of Landsat TM allowed the mineralogical distinction of mafic minerals, carbonates and quartz. While Landsat 3/1 band ratio and ASTER 2/1 band ratio were the most suitable for iron oxide distinction. The results confirm the dominance of quartz in both sides. However, iron oxide III (Fe^{3+}) concentration is much important in the left side, which explains the difference in sand color. iii) Geomorphologic map reveal that the studied dunes are potentially supplied from Quaternary, Cretaceous and Paleozoic formations.

The abundance of ferruginous conglomerate among potential formations supplying dunes, the abundance of hematite and goethite in sand from the left bank more than the right explain the red color marking these dunes. While, dunes morphodynamic explain the pal color observed in dunes located in the right bank.

A SEDIMENTARY MODEL FOR TRANSVERSE INLAND DUNES IN CENTRAL SCANDINAVIA

H. Alexanderson[1], M. Bernhardson[1], M. Henriksen[2] & E. Kalińska-Nartiša[1,3]
[1]*Lund University, Lund, Sweden*
[2]*Norwegian University of Life Sciences, Ås, Norway*
[3]*University of Tartu, Tartu, Estonia*

Key words inland dunes, transverse dunes, GPR, sedimentology, Sweden, Norway

The largest dune fields in Sweden and Norway are small in international comparison but still form distinct parts of this previously glaciated landscape. The dunes formed c.10.5-9 ka ago, shortly after the last deglaciation, when winds close to the ice sheet were strong and vegetation was largely absent [1-4]. Since then they have been more or less stable and today they are covered by forest. Most of the dunes are curvi-linear in shape and formed transverse to the wind [5].

Here we present a sedimentary model for these transverse inland dunes, based on geophysical and sedimentological investigations of dunes at Skattungheden, Bonäsheden and Starmoen in central Sweden and south-eastern Norway. Ground-penetrating radar profiles reveal the main architectural elements of the dunes, while logging of sediment exposures in the dunes provide information on sedimentary structures. Grain-size analysis and scanning electron microscope studies of individual grains give us more detail on sediment characteristics.

The main dune body, consisting of cross beds generally dipping 25-30°, makes up the largest part of the dunes; minor elements include windward side cover, dune-crest superimposed features and dune-toe apron (Fig. 1). The dominating sediment structures are planar parallel lamination, massive to vaguely stratified beds and a few types of secondary structures, such as bioturbation or physical disturbances. Few large erosional discordances are seen, and the dominating depositional processes are wind-ripple migration and some grain fall on the sloping lee sides. The sediments are well-sorted fine-to-medium sand, dominated by quartz, but with significant amounts of feldspar as well as some lithic fragments, micas and heavy minerals. Most grains are angular to subrounded and their surfaces display few traces of aeolian transport. Overall, the dune sands show large similarities to their source material (glacifluvial deposits), which suggests only short transport and brief reworking by aeolian processes.

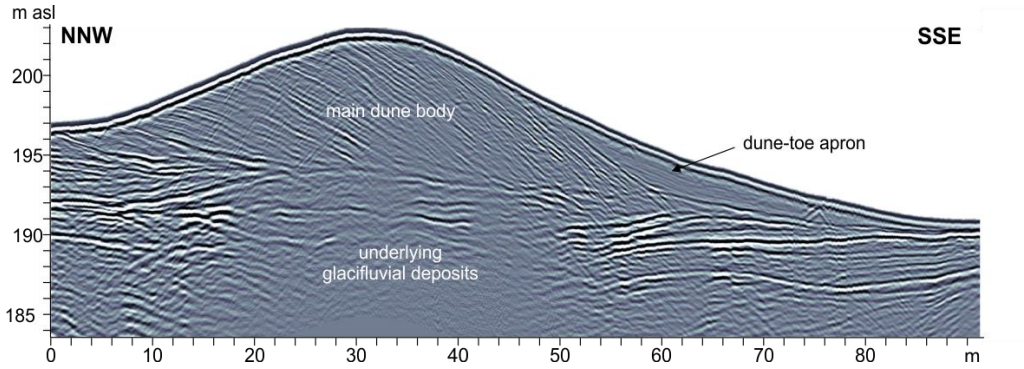

Figure 1. Example of GPR-profile (200 MHz) perpendicular to a dune crest, Bonäsheden, Sweden.

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INTERNAL STRUCTURE OF MOBILE BARCHAN DUNES

M. I. Arran[1], M. Y. Louge[2], A. G. Hay[3], A. Valance[4], & N. M. Vriend[1]
[1]*DAMTP, University of Cambridge, Cambridge, United Kingdom*
[2]*Mechanical and Aerospace Engineering, Cornell University, Ithaca, United States of America*
[3]*Microbiology, Cornell University, Ithaca, United States of America*
[4]*Institut de Physique de Rennes, Université de Rennes I, CNRS UMR 6251, Rennes, France*

Key words Internal structure, aeolian dunes, hydrology, Ground-Penetrating Radar, grain flows

The internal structure of desert dunes is a key feature determining how water penetrates into an active dune. In this work, we present results from a multi-year field campaign on Qatari barchan dunes, mapping internal structure from the scale of entire dunes to that of individual grainflow strata. Producing a high-resolution ground-penetrating radar survey, using 1200 MHz antennae along the entire midlines of two dunes, we reveal changes in water content associated with consistent grainflow cross-strata, parallel to the slip face (Fig. 1a). We make such strata directly visible, by introducing dyed water to the dune surface and excavating vertical test pits aligned with the survey transect (Fig. 1b), and we extract samples with novel apparatus, in order to measure and compare particle size distributions across individual strata. These measurements demonstrate preferential permeation of water along substrata with a high concentration of fine particles. This provides a mechanism by which water may permeate to, and reside in, the deep interior of the dune, as documented by previous work on the same field site [1].

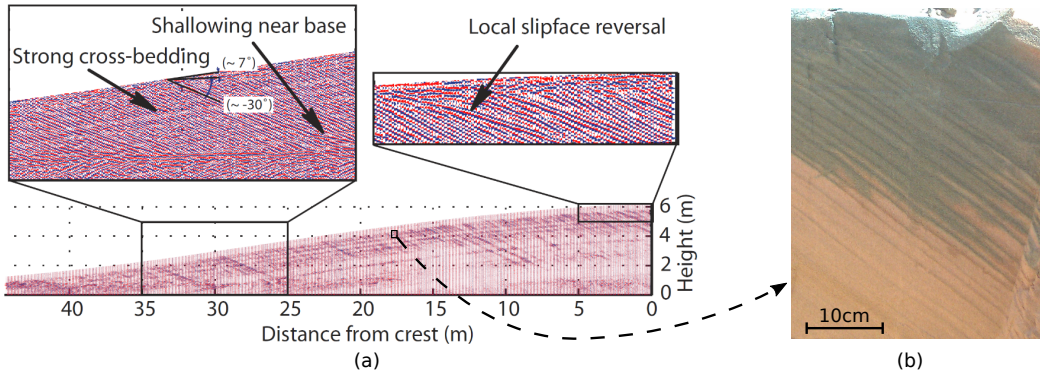

Figure 1. (a) A typical ground-penetrating radar profile, revealing grainflow cross-strata. (b) Photograph from a test pit, demonstrating preferential permeation of water along the stratification.

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The effect of vegetation and biogenic crust cover on dunes' height

Y. Ashkenazy[1]
[1]*Solar Energy and Environmental Physics, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Midreshet Ben-Gurion, Israel*

Key words Sand dunes, vegetation, biogenic crust, dune height.

Vegetation and biogenic crust play a major role in the stability of sand dunes. Their growth is affected, among other factors, by the wind and precipitation. In turn, their presence limits sand transport. It was shown before that fixed and active dunes can co-exist under similar climatic conditions where this bi-stability was attributed to processes associated with vegetation and biogenic crust [1]. Fixed vegetated dunes are less developed in comparison to active bare dunes; i.e., active dunes are higher than fixed dunes despite the similar conditions affecting them. We develop a dynamical model for dune height, vegetation and biogenic crust covers to study the relation between vegetation and biogenic crust covers and dunes' height. We also study the transitions between fixed and active dunes states under climate change and how these affect the dunes' height.

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Morphological dynamics for a continuum of aeolian bedform types

M.C. Baddock[1], G.F.S. Wiggs[2] & J.M. Nield[3]
[1]*Department of Geography, Loughborough University, Loughborough UK*
[2]*School of Geography and the Environment, University of Oxford, Oxford UK*
[3]*Geography and Environment, University of Southampton, Southampton, UK*

Key words dune, protodune, boundary layer airflow, Terrestrial Laser Scanner

The early stages of dune development remain a poorly understood aspect of aeolian bedform evolution. Flow-form feedbacks, however, are recognised to be fundamental in driving bedform growth across different stages of dune development. Specifically, the growth of aeolian bedforms has been linked theoretically with the location of the maximum windspeed at a point upwind of the bedform crest. This upwind position of maximum velocity, combined with the relaxation length scale for sand transport (L_{sat}) allows for sand deposition in the crestal region of dunes, a necessity for vertical growth of the dune body. There has, however, been only limited empirical evidence of this process on a small number of individual dunes.

We present field data from the Skeleton Coast dunefield in Namibia, quantifying the morphological change of a suite of bedforms representing the full range of dune development stages (i.e. sand patch, protodune, dome form and barchan dune). Our measurements at timescales of i) high-energy, sand transport events, and ii) a longer term, multi-annual monitoring period, provide new insights into dune development. For the event-scale focus, near-surface airflow measurements were undertaken coincident with high frequency surface change monitoring, allowing flow dynamics and morphological change to help explain dune development specific to the different bedform stages.

This work highlights the relationship of crestal flow velocity patterns to highly resolved distributions of erosion and deposition for the full range of bedform types. For example, airflow over the protodune feature demonstrates the crest-upwind velocity shift coinciding with patterns of sediment deposition and vertical growth (Figure 1). Modelling of these field data matches theoretical requirements for dune growth. At the longer timescale, observed trends of annual change for the established dunes (dome and barchan) reveal that flow patterns are responsible for these features maintaining their shape while migrating, while also exhibiting an increase in overall volume of sediment.

While flow-form measurements indicate the importance of airflow dynamics in driving dune growth as observed over the short term, multi-year change also reveals shrinkage of both the sand patch and protodune at our study site. Such long term measurements therefore demonstrate the influence of external forcings, such as sediment supply. This suggests caution when applying sand transport-based models to interpret real world environmental examples, or in the prediction of dune form change in aeolian systems.

Figure 1. The study protodune, one feature in the suite of aeolian bedform types investigated in this work.

Towards a dune celerity map of the Sahara

T. Baird,[1] & P. Vermeesch[1]
[1]*Department of Earth Sciences, Universiy College London, UCL*

Key words Dune Celerity; Remote Sensing; COSI-Corr; Big Data.

As part of a project to map dune celerity across the Sahara, we here present the initial results relating to the Grand Erg Oriental, an extensive dune field situated between Algeria and Tunisia. The application of traditional ground-based methods to measure dune migration rates can be argued to be spatially restricted and temporally inconsistent [1]. The Co-Registration of Optically Sensed Images and Correlation (COSI-Corr) algorithm [2] offers a path to overcome this issue using remotely sensed imagery. Already widely applied to dune celerity detections on Earth [3,4], the methodology has proven successful in providing celerity records across an entire dune field.

We here present an automated application of the COSI-Corr methodology and post-processing (Fig. 1) to cloudless Landsat 4/5 scenes from 1985, 1995, and 2005. The resulting raster outputs quantify dune celerity magnitudes and direction across the Grand Erg Oriental with a resolution of 60 m. Not only does this dataset facilitate a spatial analysis of dune celerity patterns across the Erg, but by using the 1995 scenes as the 'master' images from which to correlate the 1985 and 2005 imagery, the project can also quantify celerity changes seen with time. With clearly identifiable dune ridges and interdune areas, the dataset also shows a spatial gradient with increasingly more active dunes towards the South of the Grand Erg Oriental. Temporally, overall dune migration rates in the Grand Erg are found to have increased going into the 21st century. However, a spatially uniform pattern of increase is not seen, with areas bordering the Chott el Djerid, an ephemeral salt playa, showing a decrease in celerity.

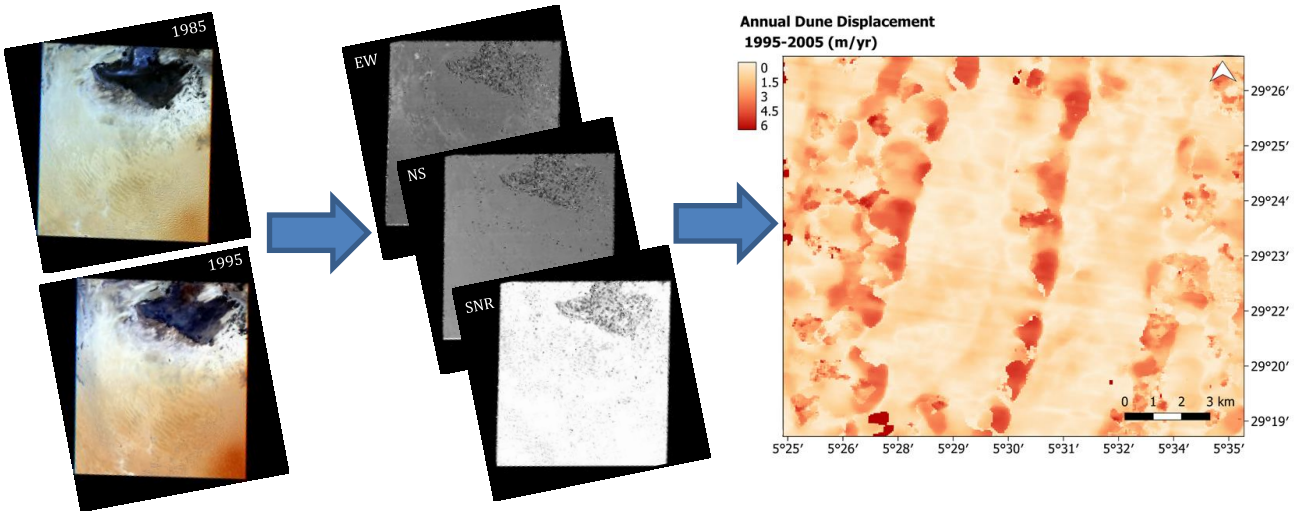

Figure 1. Example of the automated dune celerity quantifications for Landsat 4/5 TM imagery path/row 192/037, from True Colour Composites to COSI-Corr correlations outputs from which raster maps of average annual celerity (m/yr) can be produced with a resolution of 60 m.

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VARIATION IN SAND TRANSPORT INTENSITY OVER SMALL REVERSING DUNES

M. Dluzewski[1], J. Rotnicka[2]
[1]*Faculty of Geography and Regional Studies, University of Warsaw, Poland*
[2]*Institute of Geology, Adam Mickiewicz University in Poznan, Poland*

Key words reversing dunes, dune topography, sand transport rate, bimodal wind regime, southern Morocco

The aim of the work was to analyze the variation in sand transport rate over small reversing dune located in the Coude du Dra region (southern Morocco) dominated by bimodal wind regime. We investigated the impact of dune topography, wind direction variability and wind acceleration on sand transport rate and its vertical distribution. The research was made on 3 dunes in 3 different wind seasons. A set of anemometers was deployed within both windward and lee slopes at 1 m above dune surface and a reference mast was placed on the flat interdune area. The sand transport rate was measured by means of 10 passive vertical sand traps (0.5 m high) divided into 40 compartments, each 1cm wide and 1.27 cm high. The sand traps was arrange along the transect perpendicular to the dune crest. Measurements were made when effective wind was both oblique and perpendicular to the dune crest. The latter included runs when wind approached the dune from its windward as well as leeward slopes.

In the case of wind perpendicular to the dune crest, even within dunes not higher than 3 m, the wind speed at the dune crest increased about 1.5 times (measured at a high of 1m above dune surface) causing the tenfold increase of sand transport rate between dune toe and dune crest. However, this increase was only slightly dependent on wind direction. Almost the same increase of sand transport rate at the dune top was recorded when wind blew from the direction of slope with lower inclination of 10° (windward slope) or from the direction of much steeper and shorter slope inclined at 20° (former lee slope) after the wind changed direction by 180°. When wind speed was only slightly greater than the critical threshold wind velocity, the transport rate at the top of reversing dune was about 25 times greater than at the dune toe.

When the angle between the wind and the dune crest was greater than 35°, the flow separation on the lee side of the crest occurred. This was confirmed by vertical distribution of mass flux measured in consecutive sand traps located on the leeward side of the crest. In the first trap located just below the crest, the maximum sand transport rate was recorded slightly above the surface. In the second sand trap located about 0.5-0.7 m away from the crest, the greatest value of mass flux was recorded in the uppermost compartments of the trap. In the third sand trap located about 2 m away from the crest, the maximum mass flux was recorded again in the lower part of the trap and it confirmed that at this point the flow reattachment took place. It also means that the vertical profile of mass flux gradually recovered to its upwind profile characteristics. The flow separation within reversing dunes took place when the airflow came from both windward and leeward side. In our opinion it was connected with total angle of both slopes inclination which must be greater than 30°. The results also confirmed that when angle between the wind and the dune crest was less than 35°, the flow separation did not occur and in this case the highest sand flux was recorded in the lowermost part of the sand trap.

The obtained results show that morphodynamics of small reversing dunes depend mostly on wind energy. When the wind speed is much greater than the threshold value, change in wind direction to the opposite results in rapid change of dune morphology expressed by complete conversion of the lee slope into the windward slope and conversely. When the direction of the wind reverses but its speed is only slightly greater than the threshold, only the upper part of dune is modified due to wind acceleration. Therefore each of the dune slopes is divided in two segments that significantly differ in inclination. This complex dune topography imposes strong variation in sand transport rate over a small reversing dune.

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A MECHANISTIC EXPLANATION OF MARTIAN BEDFORMS

O. Duran Vinent[1], B. Andreotti[2] & P. Claudin[2]
[1]*Texas A&M University, College Station, USA*
[2]*Ecole Supérieure de Physique et Chimie Industrielle, Paris, France*

Key words sediment transport, bedforms, ripples, dunes, Mars.

Bedforms like aeolian sand dunes, found in arid regions and along shorelines, and subaqueous ripples and dunes result from the same instability mechanism, related to the lag between bed shear stress, sediment transport and bed elevation. Analogous bedforms are also observed in planetary environments as diverse as Mars, Venus, Titan or comet Churyumov-Gerasimenko. They can display, however, rather different characteristic lengths and formation time scales. In order to deduce a reliable interpretation of these atmospheric conditions from remote photos and measurements, an obstacle is to determine relevant terrestrial analogues. Martian meter scale bedforms were first understood as aeolian ripples superimposed on barchan dunes but have been recently reinterpreted as being more akin to subaqueous current ripples. But, how could aeolian-like bedforms (dunes and impact ripples) and subaqueous-like bedforms (current ripples) coexist in the same Martian environment? Similarly, so called transversal aeolian ridges (TAR), decameter scale Martian bedforms found in regions with complex grain composition, have been recently interpreted as aeolian megaripples. But again, how can impact-driven bedforms like megaripples be larger than, and still co-exist with, flow-driven bedforms like Martian meter scale ripples? We answer these questions using a new morphodynamic model that couples hydrodynamics over a modulated bed to sediment transport and relaxation laws and resolves both initial and mature bedforms. We find that planetary bedforms can be classified into 'laminar' and 'turbulent' bedforms and that the occurrence of these bedform types depends on two dimensionless numbers, the particle Reynolds number $\mathcal{R}_d$ and the transport saturation length rescaled by the viscous length $l_{\rm sat}u_*/\nu$. In particular, Martian conditions fall in the regime where laminar bedforms superimpose to turbulent bedforms, which allow us to identify all mid-size Martian bedforms, including TARs, as 'laminar' bedforms, and Martian dunes are 'turbulent' bedforms.

DUNE GROWTH UNDER MULTIDIRECTIONAL WIND REGIMES

C. Gadal[1], P. Claudin[2], S. Courrech du Pont[3], O. Rozier[1] & C. Narteau[1]
[1]*Institut de Physique du Globe, Paris, France*
[2]*Ecole Supérieure de Physique et Chimie Industrielle, Paris, France*
[3]*Université Paris Diderot, Paris, France*

Key words Instability, Dune growth, Multidirectional wind regimes

Terrestrial sand seas show a variety of dune patterns reflecting the diversity of the wind regimes that shaped them. However, despite the growing interest in dune dynamics, there is still not a formal description of the dune instability mechanism under multidirectional wind regimes. Here, we extend the linear stability analysis of a flat sand bed under a unidirectional wind [1] to multidirectional ones in order to incorporate temporal changes in wind properties (strength and orientation) into the physical modelling of dune formation. Considering the simplest case of bidirectional flow regimes, we recover that the transition from transverse to oblique or longitudinal patterns is controlled by the transport ratio N and the wind divergence angle θ between the two flow directions, in agreement with field observations and previous models that were only focused on the dune orientation [2, 3].
In addition, our analysis gives access to the most unstable wavelength, which is found to be $\simeq 20\%$ smaller when the divergence angle approaches $90°$ and the wind velocity is much larger than the transport threshold. We also emphasize the role of longitudinal and transverse slope effects, when the wind is close to the transport threshold.

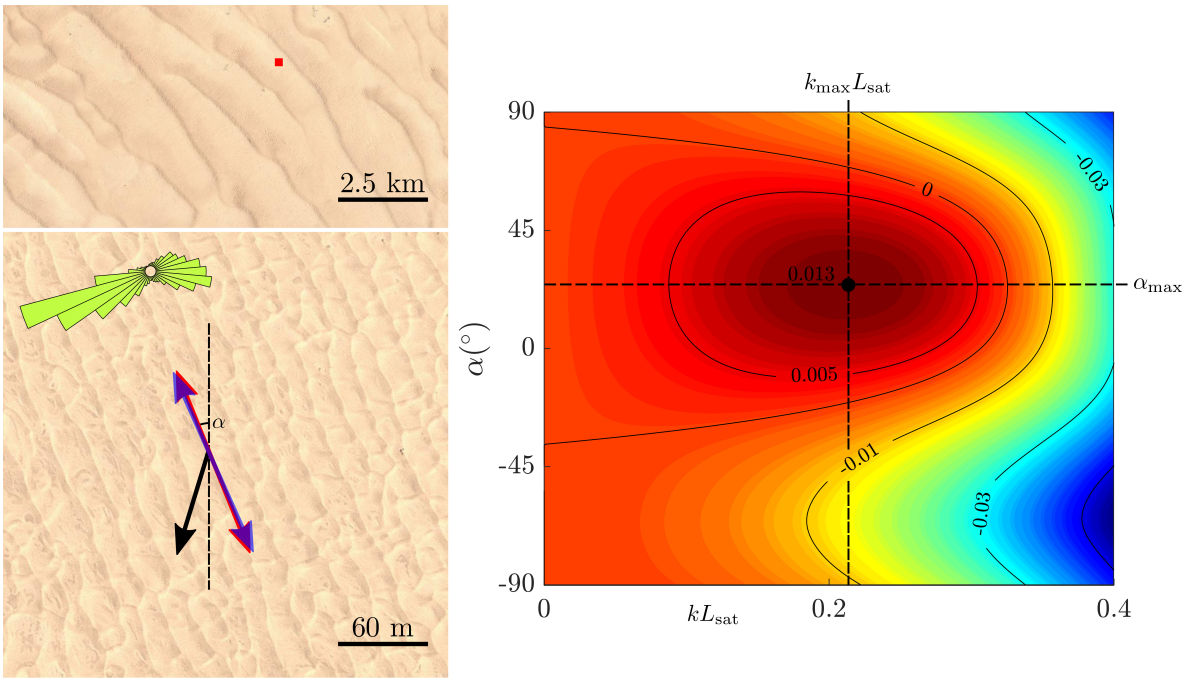

Figure 1. Dune orientation in the Taklamacan desert (China). The left panel corresponds to satellite images of the site with the large scale (top) over which the red square corresponds to the small scale (bottom). The green rose corresponds to the sand fluxes and the black single arrow to the resultant flux direction. Correlation on the small scale pattern gives an orientation of $\alpha_{\text{p}} = 22 \pm 3°$ (red arrow) and a wavelength of $\lambda_{\text{p}} = 17 \pm 2$ m. The right panel corresponds to the growth function in the plane (α, k) computed from the flux rose using the linear stability analysis. Its maximum gives a predicted orientation of $\alpha_{\text{max}} = 24 \pm 1°$ (blue arrow) and a wavelength of $\lambda_{\text{max}} = 27 \pm 5$ m taking $L_{\text{sat}} \simeq 0.9 \pm 0.2$ m.

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Determinants and dynamics of the ridges of reticulate dunes at the western fringe of the Hobq Desert, Inner Mongolia, China

C. Guan[1], E.D. Hasi[1], P. Zhang[2], Y.G. Zhou[1], X.F. Qi[1], H.Y. Li[1]
[1] *School of Natural Resources, Faculty of Geographical Science, Beijing Normal University, Beijing, 100875, China.*
[2] *School of Agriculture, Ningxia University, Yinchuan 750021, China.*

Key words Reticulate dunes; primary ridge; secondary ridge; morphological change.

Abstract Four observations of reticulate dunes at the western fringe of the Hobq Desert, Inner Mongolia, China were carried out through UAV low-altitude photogrammetry between May, 2016 and April, 2017 to obtain high-resolution orthoimages. Meanwhile, RKT-GPS was utilized to measure profile lines of primary and secondary ridges and DEM of dunes, obtaining high-accuracy morphological data. In combination with regional meteorological data, this paper discussed morphological characteristics of primary and secondary ridges of dunes in different wind regimes and modes of erosion and deposition and explained reasons for morphologic changes. Results showed that in a north-wind environment, the secondary ridge was the development model of transversal dunes, while the primary ridge was the development model of longitudinal dunes; in a west-wind environment, the secondary ridge was the development model of longitudinal dunes, while the primary ridge was the development model of transversal dunes. Different development models led to different morphological characteristics of primary and secondary ridges. The development model of transversal dunes created smooth dune crest, the ridges are not obvious, while the development model of longitudinal dunes resulted in obvious ridge lines or even small slip face. In an environment of strong north wind, there were deposition at the lower half of the stoss slope of the secondary ridge on the north side and erosion at the upper half of the stoss slope, where a sunken topography, which was similar to a blowout, was formed. This is mainly because there were short secondary ridges at adjacent reticulate dunes on the north side, where reverse airflow was formed at the lee slope of short secondary ridges after north wind passed the crest of short secondary ridges, leading to erosion between them. When the wind direction turned into west, the west wind could promote erosion in this area by the "funnelling effect", resulting in ruptures of primary and secondary ridges and a gap of adjacent reticulate dunes on the north side. As a result, sand patches, which were similar to diluvial fans, were formed by corroded sand material falling through the gap and there's large deformation of the primary ridge, which gradually turned to the lee slope. With the alternation between west and north winds, the primary ridge gradually connected to the secondary ridge of adjacent reticulate dunes on the east side, forming a long sand ridge connecting front and rear reticulate dunes. A short secondary ridge is a secondary longitudinal dune inside reticulate dunes. That is to say, it is redevelopment of a dune at the location of recovered airflow field of the lee slope of the secondary ridge, regarded as a transversal dune, in the north wind. The existence of a short secondary ridge led to changes of the local erosion and deposition of primary and secondary ridges of reticulate dunes, causing morphological changes of overall dunes.

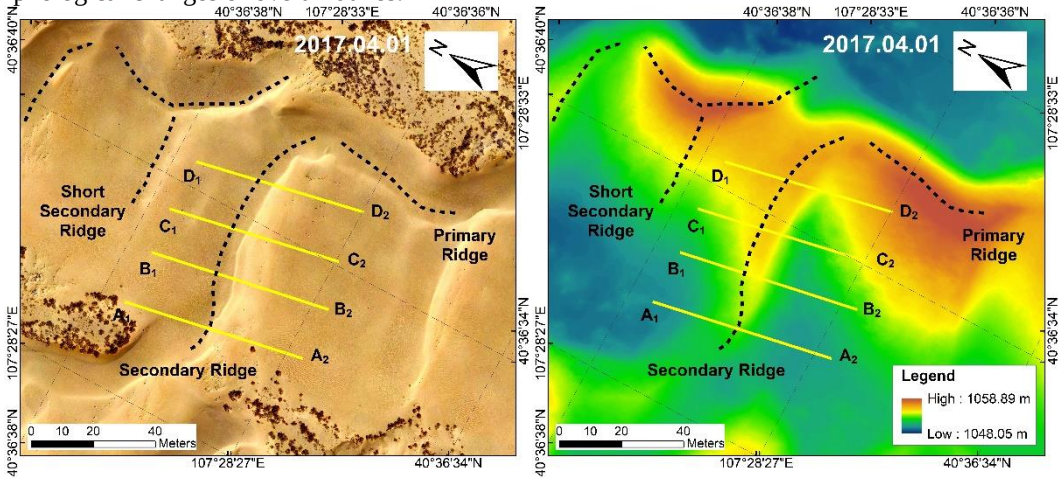

Figure 1. The orthoimage and DEM data obtained by UAV low-altitude photogrammetry on 1st April, 2017. There is a short secondary ridge in the middle of adjacent dunes on the north side. Due to the existence of the short secondary ridge, under the strong north wind environment, the reverse airflow of the lee slope of it continuously erodes the stoss slope of profile line C and D, which in turn forms a sunken topography similar to a local blowout.

MORPHOLOGIC DIVERSITY OF MARTIAN RIPPLES : IMPLICATIONS FOR LOW-INTENSITY TRANSPORT AS A MECHANISM FOR LARGE-RIPPLE FORMATION

M.G.A Lapotre[1], R.C. Ewing[2], C.M. Weitz[3], K.W. Lewis[4], M.P. Lamb[5], B.L. Ehlmann[5,6], D.M. Rubin[7] & N.T. Bridges[8*]
[1]*Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA*
[2]*Department of Geology and Geophysics, Texas A&M University, College Station, TX 77843, USA*
[3]*Planetary Science Institute, Tucson, AZ 85719-2395, USA*
[4]*Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, USA*
[5]*Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, USA*
[6]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA*
[7]*Department of Earth and Planetary Sciences, University of California in Santa Cruz, Santa Cruz, CA 95064, USA*
[8]*Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723, USA.*
[*]Deceased.

Key words Mars, Curiosity, Gale crater, impact ripples, large ripples, dunes.

Large ripples with meter-scale crest-to-crest spacings, or wavelengths, are found ubiquitously on Mars; however, eolian bedforms with similar morphologies and of similar sizes are absent from terrestrial sandy deserts [1]. The formation mechanism of large martian ripples is debated. Specifically, they were proposed to either be a larger version of the decimeter-scale impact ripples we observe on Earth [e.g., 2-3], or to be a different type of bedform altogether [1]. The recent traverse of the Bagnold Dune Field by the Mars Science Laboratory (MSL) Curiosity rover [4] revealed the morphologic diversity of large ripples (Fig. 1). Ripples with sinuous (Fig. 1A) and linear (Fig. 1B) planform crestline geometries are found both in isolated patches and on dunes. They form transversely (Fig. 1A), obliquely, or longitudinally (Fig. 1B) to the net sand-flux direction, in very fine and homogenous sand to heterogeneous sand including very coarse grains. Finally, whereas inactive ripples were covered with dust, the active ripples were dust free. Despite this wide variety of large martian ripples, no bedforms are found with wavelengths between ~20 and ~80 cm. Altogether, ground observations are inconsistent with an impact-ripple formation mechanism of the large ripples. Building on morphologic and genetic similarities among different types of bedforms, we propose that large martian ripples, instead, belong to a diverse family of bedforms that form under low-intensity sediment transport across fluids and planetary environments. Owing to their formation in concert with environmental fluid flows, these bedforms and their associated cross-stratification may prove useful environmental indicators readily found at the surface of planets or in their sedimentary record [1].

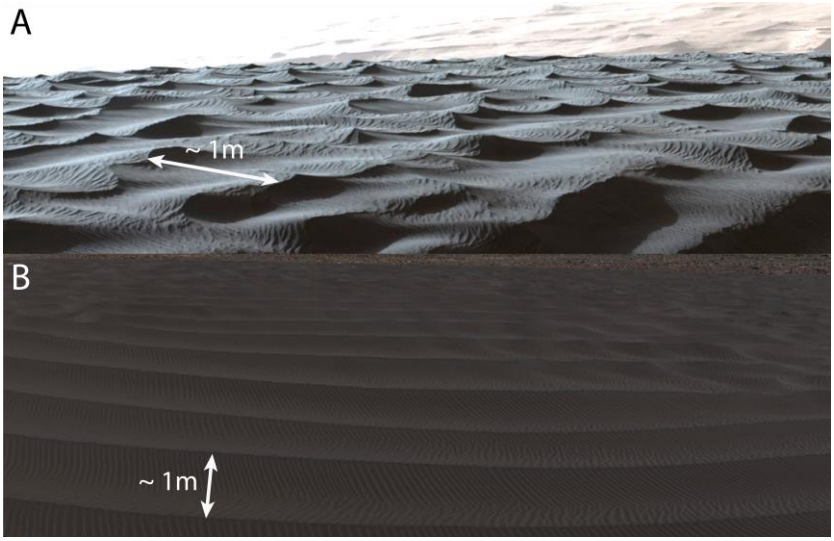

Figure 1. Mastcam images of (A) transverse and (B) longitudinal large ripples found on larger dunes of the Bagnold Dune Field. In both images, net sand flux is from left to right (Credit: NASA/JPL-Caltech).

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Dependence of Trapping Capacity on Sand Fence Height

Qingqian Ning[1,2], Bailiang Li[1], Jean T. Ellis[3]
[1]*Xi'an Jiaotong-Liverpool University, Suzhou, China*
[2]*University of Liverpool, Liverpool, UK.*
[3]*University of South Carolina, Columbia, USA.*

Key words: Porous Fences, Trapping Effect.

Fences have been widely used to reduce wind velocity and trap sand particles. Although much is known about the effect of fence configurations on wind reduction, less is known about the fence trapping effect [1]. This study investigates the effect of fence height on the sand volume trapped near the vicinity of the fences in a field-based experiment. Three fence configurations were deployed on a pre-flattened sand surface. The sand fence heights were 10, 20, and 40 cm with corresponding widths of 1.25, 2.5, and 5 cm with a porosity of 50%. Erosion pins and cameras were deployed to capture the dune-forming process. The results show a similar incipient dune formation stage for the three fences - two dunes formed upwind and one downwind of the fence. Only at the 40cm high fence did the dunes coalesce into one dune at its final stage. This study suggests that dune height scales with fence height, *h*. For the 10cm and 20cm fences, the maximum dune height occurs near the fences, but for 40 cm fence, the maximum dune height is located 10h downwind from the fence (c.f. Figure 1, top). After extrapolating linearly to the original sand surface level (c.f. Figure 1, bottom), the cross-section areas for 40cm, 20cm, and 10cm are 4.55, 0.42, and 0.22 m^2 respectively, indicating the trapping capacity of fences is approximately proportional to *h* when *h* is close to saltation layer thickness *d*. However, when h >> *d*, i.e. the 40cm fence, the trapping capacity increases dramatically to about 10 times more than 20cm fence and 20 times more than 10cm fence. Results from this study will not only inform researchers, but also coastal and environmental mangers.

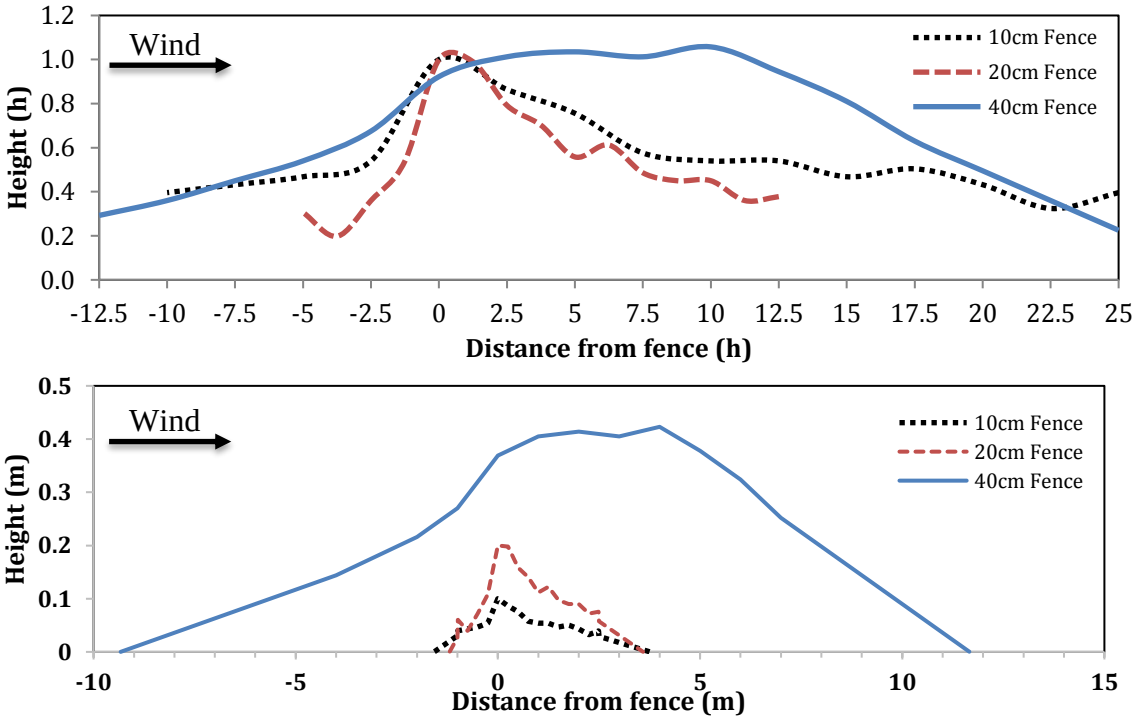

Figure 1. Topographic profiles for newly formed dunes around the 10 cm, 20 cm, and 40 cm high fences, respectively. Top: in *h*, Bottom: in meters.

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Numerical simulation of the internal structure of sand dunes using a cellular automaton (CA)

Y. Liu[1] , G. Wiggs[1] , R. Bailey[1]

[1]*School of Geography and the Environment, University of Oxford*

Key words Sand dune, Internal structure, Cellular automaton, Chronology, Collision

A CA system is built to simulate the internal sedimentary structure of aeolian sand dunes. Here we focus on simulating dune and bedform interaction cases. Initially the model system is based on the Werner, 1995 CA with incorporated rules to track properties of each single sediment unit. This initial version encountered some limitations surrounding aerodynamic issues, such as non-realistic cross profiles of dunes and the over-simplified lee side airflow pattern. Therefore at this stage, we seek for solutions from other dune dynamic models. Currently the lattice gas cellular automaton (LGCA, detailed in Narteau, et al. 2009) is implemented, and we combine the lattice gas domain to the earlier Werner model (e.g. using the shear stress to determine the erosion/deposition probability). Dynamic figures are presented to show comparisons between these models. The first aerodynamic problem: symmetrical cross profiles, can be largely solved with the fluid particle collision and bedform rebounding based lattice gas component. The lee side airflow pattern, however, cannot be solved with current versions, particularly for the case where a deflection is involved when wind blows obliquely to the crest.

Here we apply proper model versions to test recently raised scientific issues: (1) the relationship between the chronology record of dunes and pattern coarsening; (2) aeolian bedform repulsion cases and the internal architecture of repulsed dunes. For the first issue, chronology records are mapped in transverse dune fields and longitudinal dune fields. We track the age differences between the oldest and the youngest sand, associated with dune ridge number counting through the time. In modelled dune fields, coarser patterns tend to have younger sediments. This is in contrast to previously published hypotheses and dating results (e.g. Telfer, et al., 2017). For the second issue, three elemental collisions: forward merging, backward merging and ejection are identified and presented with sand sources tracked through the entire processes. More complicated aeolian bedform collisions are composed of the three cases in some ways, including between maturely developed dunes and between Y-junction arms. Some collision scenarios are run, in binary barchan domains and in the defect to Y-junction evolutions. This model approach can contributes to testing previously identified repulsion cases (e.g. Brothers, et al. 2017), as well as constructively analysing the sedimentary features of interacted aeolian bedform (e.g. the target and impactor structure presented in Day and Kocurek, 2017).

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ACCOMMODATION SPACE TYPES AS A CONTROL OVER AEOLIAN LANDFORM DEVELOPMENT IN A TOPOGRAPHICALLY COMPLEX ENVIRONMENT

A. Hay[1], M. Powell[1], A. S. Carr[1] & I. Livingstone[2]

[1]*University of Leicester, Leicester, UK*
[2]*University of Northampton, Northampton, UK*

Key words aeolian landform development, complex topography, dune morphology, topographic control.

The role of topography in controlling aeolian landform morphology is most commonly conceived as anchored dunes – where a discrete landform accumulates against some obstacle within the bedrock topography on either its windward or leeward flank. Yet, bedrock topographic control on aeolian systems has been observed well beyond the landform-scale (e.g. the positioning of sand seas). It is therefore surprising that the discipline of aeolian geomorphology contains a comparative lack of investigation into the complexity of the landscape-scale aeolian response to topographically complex environments. Indeed, no study appears to have mapped patterns of aeolian deposition within an area of complex topography and unpicked the relationship between the distribution and morphology of aeolian deposits within the landscape and their topographic setting. This study developed a novel approach which combines spectral land cover data, morphometric feature classification and field observations to describe and typify the distribution and form of aeolian deposits across a whole mountain block. The approach was designed to be applicable across a defined-range of spatial scales (appropriate for the field site), thus allowing for the scale-dependence and nesting of geomorphological features within the landscape. Using the Mojave Desert, California, as a case study, this study demonstrates a complex aeolian morphological response (distribution and morphology) which appears to be controlled by the form of the underlying bedrock topography. The outcome of this control is manifest as deposits which represent three accommodation space types, each having a characteristic morphology: sand ramps, sand sheets and valley-fills. These observed aeolian morphologies cannot necessarily be delimited into a discrete patchwork of landforms because, in many cases, they lack distinct boundaries and because of the close association of the different accommodation space types within the landscape.
The net effect is that aeolian sediments can coalesce into what appears to be a broadly continuous (albeit spatially variable) cover across much of the landscape. This typology takes our understanding of the influence of bedrock topography on aeolian landform development beyond that of single discrete landforms towards conceptions which are applicable at the landform-scale.

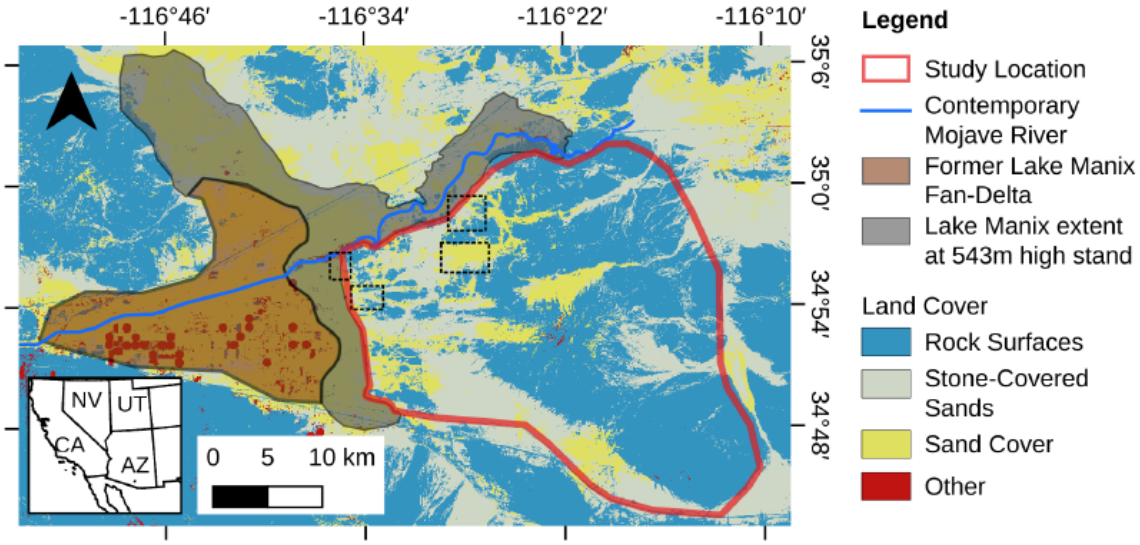

Figure 1. Land cover map for the study site – the Cady Mountains within the Mojave Desert, USA. Landsat-8 image courtesy of the U.S. Geological Survey. Map data © OpenStreetMap contributors. High stand data after Reheis and Redwine (2008).

MIGRATION RATES AND MORPHOLOGICAL EVOLUTION OF THE SALTON SEA BARCHAN DUNE FIELD AS MONITORED BY AN UNMANNED AERIAL VEHICLE

J. Moersch[1], C. Tate[1], R. Ewing[2], & C. McCarty[1]
[1]*Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, USA*
[2]*Department of Geology and Geophysics, Texas A&M University, College Station, TX, USA*

Key words Dune migration, Dune morphology, Unmanned Aerial Vehicle

Background: The barchan dune field near the southwestern shore of the Salton Sea in southern California is a classic locality that has been used for many dune investigations [e.g., 1, 2]. Recent migration rates for the Salton Sea dunes have been calculated as values ranging from ~3-43 m yr-1 [2]. To date, morphological studies of these dunes have made use of aerial photographs from manned aircraft [e.g., 1], aerial Light Detection and Ranging (LiDAR) [e.g., 2, 3], and terrestrial laser scanning (TLS) [e.g., 2, 3]. Investigations using satellite images at similar locations have been performed as well [e.g., 4]. Unmanned Aerial Vehicles (UAVs) are starting to see use in many remote sensing applications because of their low cost and logistical ease of deployment, and the high spatial resolution of the acquired data. These factors make UAVs particularly useful for acquiring high spatial and high temporal resolution data or images for detection of morphological changes [5, 6]. We have acquired a UAV image data set over the Salton Sea dunes, with images taken before and after a short, but strong wind event, and once again a year later. The closely-spaced times of acquisition of the data bracketing the strong wind event make this a unique data set for understanding the migration and evolution of dunes in response to a single wind event, and the images collected a year later show the cumulative effect of multiple wind events.

Data: Images were acquired during flights over the dune field with a DJI Phantom 4 Pro UAV. Flights were performed on March 3rd, 2017, March 6th , 2017, and February 24th, 2018. Each flight was performed at an altitude of 60m, resulting in a ground sampling distance of 1.88 cm. On each flight day, approximately 1600 images of the dune field were acquired with frame overlaps of 80% in both directions, covering an area of approximately 0.5 km^2. Between the times of the two 2017 flight days, on March 5th, 2017, nearby weather stations registered a significant wind event, with winds coming from the west at speeds exceeding the saltation threshold for a duration of approximately 16 hours.

Methods: The images for each flight were processed using structure from motion algorithms to produce orthophotomosaics and digital surface models (DSMs) of the study area for each flight day. These data products were registered to each other using fixed ground control tie points to enable change detection analysis. The registered DSMs were differenced from each other in order to identify areas of erosion and deposition and investigate morphological changes.

Results: Figure 1 shows the changes detected by differencing the two DSMs made from images acquired before and after the wind event in early March, 2017. The expected pattern of erosion on the windward side and deposition on the leeward side of the dunes is present, however there are localized amounts of deposition on windward sides near the crest of the dunes. This is consistent with deposition on the downwind side of the crest due to flow expansion before separating at the brink. The calculated average depth of erosion and deposition from the wind event is 32 cm ± 20 cm and 30 cm ± 20 cm, respectively. Average hourly rates of slip face migration during the wind event (assuming 16 hours of activity) for the four dunes labeled in Figure 1 ranged from 0.9 cm hr^{-1} (Dune D) to 5.3 cm hr^{-1} (Dune B). A similar change detection analysis using the UAV images acquired in late February, 2018, is underway. Preliminary results indicate annual migration rates for the same dunes ranging from 16 m/yr (Dune D) to 29 m/yr (Dune B). This implies that between 34 and 106 wind events of the magnitude of the one observed on March 5th, 2017, would be necessary to account for the total annual migration.

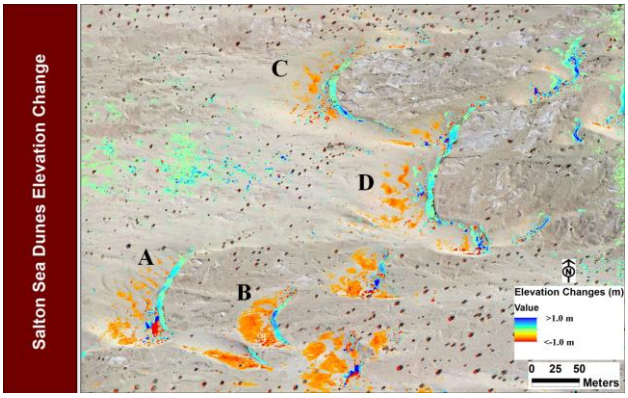

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Figure 1. Elevation changes from a single wind event on March 5th, 2017, calculated from UAV data overlaid on the March 3rd, 2017, orthophotomosaic. Values within ±20 cm of 0 cm have been masked out due to uncertainties in the analysis. Red colors indicate erosion, while blue colors indicate deposition.

USING WEATHER FORECAST REANALYSIS DATA TO ANALYZE POTENTIAL SAND TRANSPORT AND DUNE MORPHOLOGY WITHIN THE RUB' AL KHALI

K. Mulligan[1] & F. Amutlaq[2]
[1]*Department of Geosciences, Texas Tech University, Lubbock, Texas, USA.*
[2]*Department of Geography, King Saud University, Riyadh, Saudi Arabia.*

Key words wind regime, sand transport, sand dunes, Rub' al Khali.

This paper describes the use of the Global Ensemble Forecast System (GEFS) Reforecast dataset to better understand the nature of aeolian processes in a large dune field. In this case, the analysis is focused on the Rub' al Khali, the largest and perhaps most significant sand sea in the world. Located on the southern Arabian Peninsula, the dune field stretches for more than 1,200 km – with very large linear dunes in the west, mega-barchans in the east-central part of the dune field, transverse dunes in the northeast, star dunes in the southeast and smaller undifferentiated complex dunes in the center.

To analyze the relationship between the wind regime, sand transport and dune morphology, the GEFS Reforecast data are used to calculate pathways of potential sand transport through the dune field. The GEFS Reforecast includes the historical instantaneous near-surface (~10 m) *U* and *V* components of the wind. In this analysis, these data are used to analyze the spatial variability in wind speed and direction at 47 locations in the dune field using an 11-year record of daily 6-hour forecasts. In the dataset, the spatial resolution of the grid cells is 1° (~110 km) and there are 47 grid cells covering the Rub' al Kahli. In essence, each of these 47 grid cells represents a virtual weather station located within the dune field.

Using the *U* and *V* components of the wind, the total drift potential (DP), resultant drift potential (RDP) and RDP/DP ratio were calculated in a manner similar to that proposed by Fryberger [1]. The calculated values of RDP and RDP/DP at each of the 47 "stations" were then interpolated to create higher resolution RDP and RDP/DP surfaces. The results from this analysis show that the resultant drift potential (RDP) varies in magnitude and direction across the dune field, defining pathways of potential sand transport (Fig. 1). In addition, the analysis of the RDP/DP ratio shows that the directional variability in sand movement varies greatly in different parts the dune field (Fig 2).

The results from this research show that GEFS Reforecast data provides the high spatial and temporal resolution necessary to map the magnitude and direction of sand transport through a large dune field, and the variability in transport direction. In this regard, the methodology should provide a basis for understanding the relationship between wind, sand transport and the varied dune morphology in any large dune field.

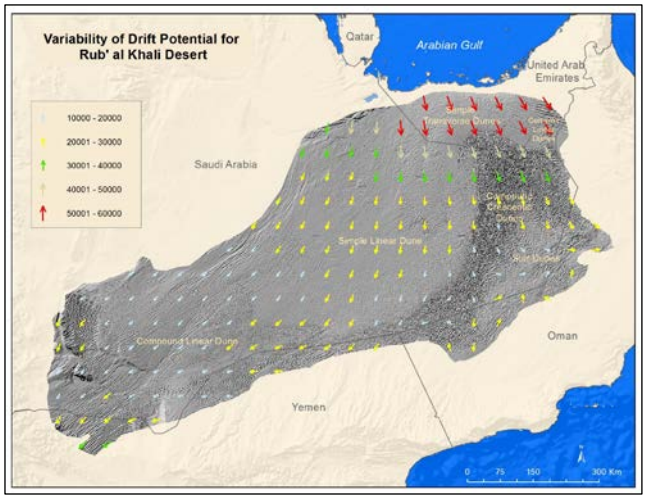

Figure 1. Pathways of sand movement in the Rub' al Khali.

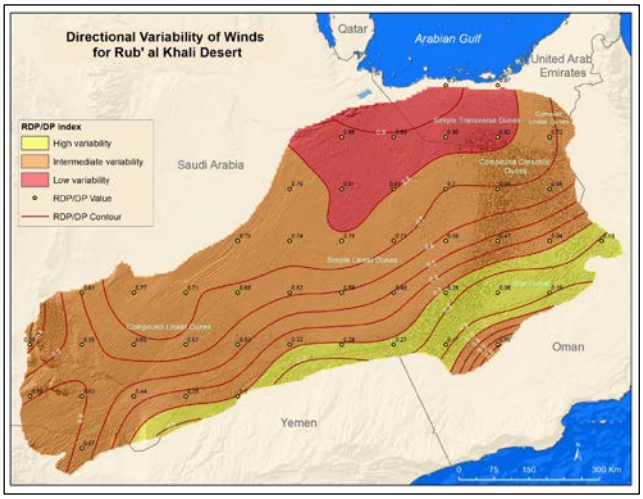

Figure 2. Directional variability in potential sand movement.

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Ground truthing high-resolution modelled wind data using field observations from the Namib desert.

C.R. Nash[1] and G.F.S. Wiggs[1]
[1]*School of Geography & the Environment, University of Oxford, U.K.*

Key words ERA5, modelled data, ground truthing, meteorology, data analysis, Namibia

Geomorphological assessment of aeolian sand transport in drylands has been hampered by a shortage of meteorological data. This lack of data hampers attempts to protect dryland infrastructure from, and predict risk of, sand encroachment because sand fluxes cannot easily be computed.

This study aims to ground-truth high spatial and temporal resolution modelled wind data in different aeolian environments (coastal, inland, dune fields, gravel plains, high-altitude) across the Namib desert. High-resolution, modelled meteorological data in the form of European Re-analysis 5 (ERA-5) data have been released recently by the European Centre for Medium-Range Weather Forecasting (ECMWF). These data offer unprecedented spatial and temporal resolution with data points every 30 km at hourly intervals. Ground truthing has been undertaken using meteorological data obtained from deployment of meteorological stations in the field (with data records from 1-5 years) and from national weather stations across the Namib desert. We compare sand drift potentials obtained using ERA-5 data with those calculated from field data with an emphasis on flux distribution and variability.

The new ERA-5 dataset is likely to more closely approximate field-observed data due to its improved spatial and temporal resolution compared to previous ERA datasets. Legacy ERA-40 data were observed to under-estimate field data obtained from the north of the Namib sand sea [1], while a moderate correlation was found between field data and newer ERA-Interim data [2]. However, these previous data were modelled every 6 hours at a relatively coarse spatial resolution (>80 km).

Currently, sand hazard assessment in drylands is implemented poorly and lacks a consistent approach. Usage of modelled wind data as part of predictive hazard assessment could reduce the time, energy, and expense involved in hazard assessment by minimising the requirement to collect field data. At present, ERA-5 data have been released only for the eight-year period 2010-2017. However, a complete dataset stretching from 1950 is expected to be released shortly [3]. Ground truthing of the existing dataset is a first step in testing its accuracy and potential for long term assessments of wind and sand flux conditions.

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UNRAVELLING RAKED LINEAR DUNES TO EXPLAIN THE COEXISTENCE OF BEDFORMS IN COMPLEX DUNEFIELDS

Ping Lü[1,2] , Clément Narteau [3] , Zhibao Dong [1,2] , Olivier Rozier [3] & Sylvain Courrech du Pont [4]

[1] *Department of Geography, Shaanxi Normal University, Xi'an, China*
[2] *Key Laboratory of Desert and Desertification, Chinese Academy of Sciences, Lanzhou, China*
[3] *Institut de Physique du Globe, Paris, France*
4 Laboratoire Matiere et Systemes Complexes, Paris, France

Key words Raked linear dunes, Sand flux, Numerical simulation.

Raked linear dunes keep a constant orientation for considerable distances with a marked asymmetry between a periodic pattern of semi-crescentic structures on one side and a continuous slope on the other. Here we show that this shape is associated with a steady-state dune type arising from the coexistence of two dune growth mechanisms. Primary ridges elongate in the direction of the resultant sand flux. Semicrescentic structures result from the development of superimposed dunes growing perpendicularly to the maximum gross bedform-normal transport. In the particular case of raked linear dunes, these two mechanisms produces primary and secondary ridges with similar height but with different orientations, which are oblique to each other. The raked pattern develops preferentially on the leeward side of the primary ridges according to the direction of propagation of the superimposed bedforms. As shown by numerical modelling, raked linear dunes occur where both these oblique orientations and dynamics are met.

MORPHOGENESIS AND STABILITY OF ELONGATING DUNES

O. Rozier[1], S. Courrech du Pont[2], C. Gadal[1], P. Claudin[3] & C. Narteau[1]
[1]*Institut de Physique du Globe, Paris, France*
[2]*Laboratiore Matière et Systèmes Complexes, Université Paris Diderot, Paris, France*
[3]*Ecole Supérieure de Physique et Chimie Industrielle, Paris, France*

Key words Elongating dunes, stable shape, sediment flux.

Under unidirectional wind and low sand supply, barchan dunes may migrate at constant velocity keeping their characteristic crescent shape [1]. These steady-state dunes have been extensively studied to investigate the physical processes that lead to the development of a bed instability. Much less is known, however, about the linear morphology of dunes that elongate under multidirectional wind regimes in the resultant transport direction. This is mainly due to the fact that this elongation growth mechanism has only recently been identified [2]. Here, by means of numerical simulation, we show that elongating dunes can reach a steady-state, from which the equilibrium profile, the sand flux on the dune flanks and the sand loss can be determined. Then, an analytical model is proposed to derive the dune morphology from a fixed source of sediment and a constant injection rate. We find that dune width and height decrease linearly downstream until the elementary dune size is reached. This is associated with a constant sand loss all along the dune. Finally, we show that the injection rate controls the dune length by setting the maximum width of the upstream dune section.

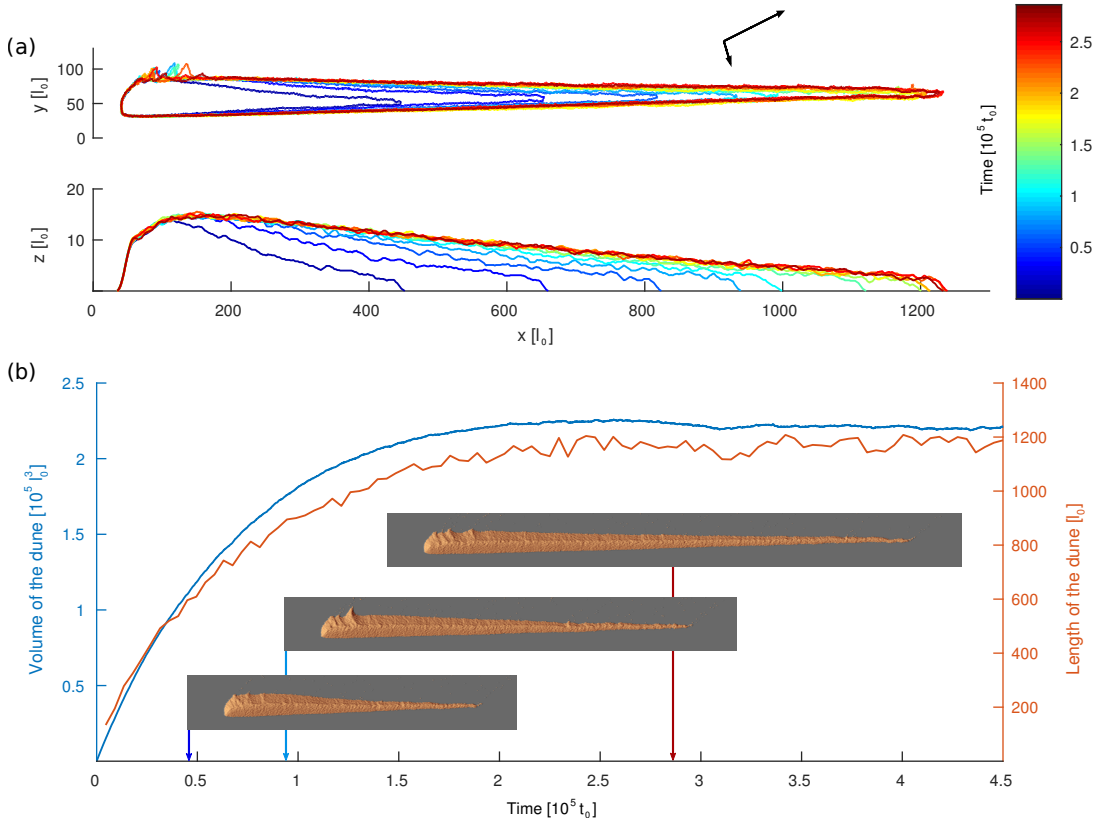

Figure 1. Morphology and stabilisation of an elongating dune under an asymmetric bidirectional wind regime. (a) Horizontal and vertical contours of the dune taken at regular time intervals. The arrows indicate the direction and intensity of the respective sand fluxes for each wind. (b) Volume and length of the dune with respect to time. Insets show the dune at three different times in the numerical simulation.

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WHY LONGITUDINAL DUNES ARE RARELY RECOGNIZED IN THE GEOLOGIC RECORD—UPDATE AFTER 3 DECADES

D. Rubin[1], & S. Courrech du Pont[2]
[1]*Department of Earth and Planetary Sciences, University of California Santa Cruz, Santa Cruz, CA USA*
[2]*Laboratoire Matière et Systèmes Complexes, Université Paris Diderot, Paris, France*

Key words dunes, cross-stratification, linear, morphology, Bagnold

Until the early 1980s, geomorphologists generally believed that aeolian dunes were oriented either longitudinal or transverse to sand transport. Bagnold [1] suggested that linear dunes reverse without migrating and therefore deposit symmetrical zigzag stratification. Rubin & Hunter [2] showed that such stratification is exceedingly rare in aeolian sandstones, and they considered two hypotheses to explain why: (a) deposits of linear dunes superficially resemble those of transverse dunes because linear dunes usually migrate laterally, or (b) longitudinal dunes don't leave deposits. Theory and experiments have shown that oblique, laterally migrating, linear dunes form under a much wider range of winds than perfectly longitudinal dunes [3], suggesting that lateral migration can explain why symmetrical zigzags are so rare. Nevertheless, the hypothesis that linear dunes do not leave deposits has remained untested for 3 decades.

In 2014, lab experiments showed that dunes have two modes [4]. On beds completely covered with sand, dunes form in the bed-instability mode and are oriented as reported in reference [3]; on beds that are partially starved, dunes form in the fingering mode [4]. Two situations can create perfectly longitudinal fingering dunes: symmetrical winds or a fixed sand source. Discovery of this second mode revives the question from 3 decades earlier: Do dunes in the fingering mode also usually migrate laterally, or do fingering dunes only leave thin traces of strata at the base of eolian sequences before deposition covers the bed—thereby eliminating the starved condition—causing dunes to change to the other mode?

We addressed this question using both lab experiments and fieldwork. In lab experiments, we found it difficult—but not impossible—to generate some relatively symmetrical zigzags (Fig. 1A). In the field (Harris Wash Member of the Page Sandstone in southern Utah) we found a starved (cemented) surface overlain by zigzags (Fig. 1B), as well as cyclic cross-beds inferred to have been deposited by seasonally reversing winds. The zigzag strata might have been deposited by either reversing dunes or by reversing spurs on the lee sides of transverse dunes. In the Stimson sandstone in Gale Crater, Mars, we also found stratification suggestive of Bagnold's zigzag structure. The stratigraphic setting and modern winds are suitable for fingering dunes, but exposures aren't sufficient to determine if the zigzags are symmetrical.

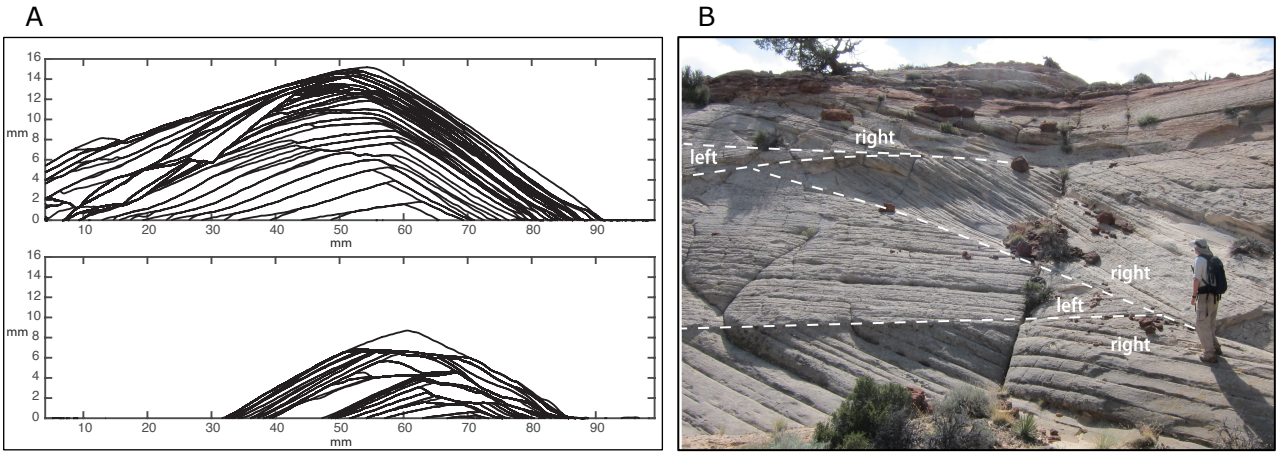

Figure 1. Stratification crudely resembling Bagnold's zigzags. (A) Synthetic stratigraphy in a fingering-mode dune in the lab. Some individual zigzags formed by reversing flow, whereas thicker packages of cross-beds formed by superimposed topographic features migrating down the length of the dune. Images were computed from sequential laser-scanned topography rather than mathematical surfaces, using code of [5]. (B) Zigzag stratification in the Harris Wash Member of the Page Sandstone, southern Utah, USA.

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FINGERPRINTING LINEAR DUNES

L. Scuderi
Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico, USA

Key words linear dune, minutiae, junctions, terminations, fingerprints.

Fingerprints contain sets of features that allow identification of individuals through a unique combination of metrics including ridges, Y-junctions, terminations and defects. Linear dunes share many of these features with closed Y-junctions where two dunes merge downwind, open Y-junctions where a dune bifurcates downwind, start and end-terminations and assorted defects. Scuderi et al. [1] noted that, since the crestline features of linear dunes have well-defined attributes, if the minutiae that define these crests could be exactly and consistently defined (rendered crisply) they could form the basis of an ontology for a *bona fide* aeolian object. Furthermore, Tefler et al. [2] suggested that spatial patterning of linear dune field minutiae could be defined by the presence, frequency, and arrangement of basic parameters. Therefore, formulation of a consistent and repeatable automated extraction process to extract these parameters could significantly augment our ability to map these features and to understand linear dune field organization and dynamics.

Unfortunately, extraction of minutiae is extremely time intensive, and manual extraction is not consistently reproducible. In this study, fingerprint minutiae extraction software [3], a mature tool set used extensively in forensic work, was evaluated to determine whether unique identifiers could be 1) easily extracted from raw and processed imagery of linear dune fields, and 2) used to quantitatively characterize these fields. The study area in the northern part of the Namib Sand Sea is dominated by large, north-south–trending, complex, linear dunes. Application of minutiae identification software [3] produced consistent and repeatable output from both imagery processed from an automated dune crest mapping approach and directly from satellite imagery with minor smoothing (Figure 1). While the results differ somewhat from manual extraction methods, the ability to automate the extraction of minutiae location, direction and type, as well as to assess the quality of each feature identified may allow improved characterization of linear dune fields.

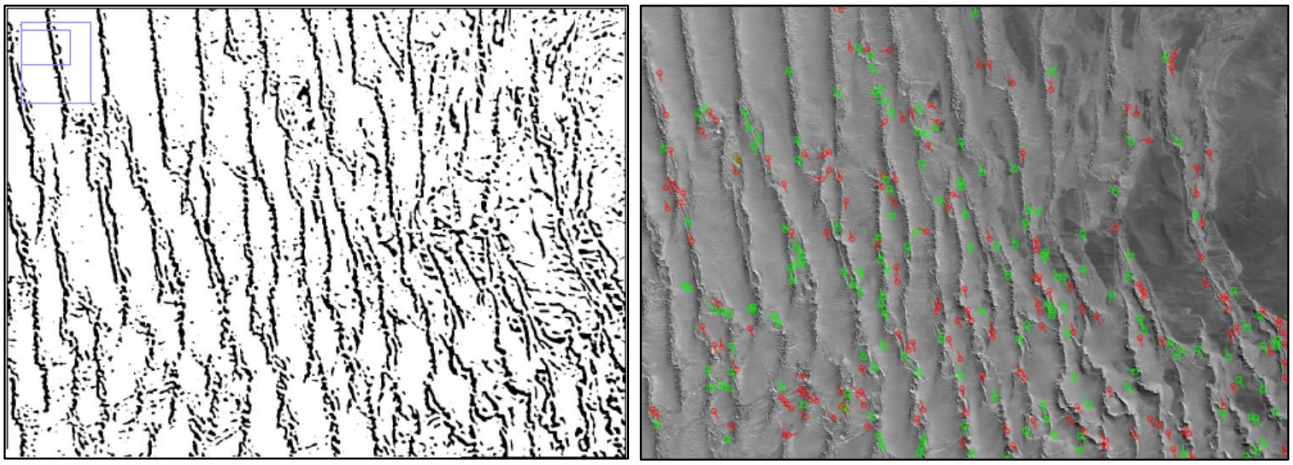

Figure 1. Linear dunes centered on 24ºS 15ºE in the northern part of the Namib Sand Sea a) Dune crests extracted using an edge detection filter. b) Minutiae extracted from a Landsat image (LC08_L1TP_179077_20170531_20170531_01_RT_B5) using fingerprint identification software. Bifurcations (green) and terminations (red) as well as the direction of the feature are shown [3].

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Dune Migration on the Navajo Nation

A. Sunda [1,2], L. Amoroso [2]
[1] *Regis University, Denver, Colorado*
[2] *Northern Arizona University, Flagstaff, Arizona*

Keywords: dune migration rate, grain size

The purpose of this project was to study the movement of two dunes fields and how that movement is influenced by different factors. The dune fields used for this study are located on the Navajo Nation, in a section of the Great Basin Desert, in the northeastern corner of Arizona. The dune fields are about 65 km apart and differ in age by 100 million years. The northernmost dunes are located at Tonelea, in eolian sandstone from the Early Jurassic period; the southernmost dunes are located at Hotevilla-Bacavi in Quaternary sediments surrounded by nearshore marine sandstone from the Cretaceous [1].

The surrounding bedrock of the two dune fields is the source of sand for the dunes and influences the grain size, dune activity, dune size, and dune density of the fields. Dunes in Tonelea have an average grain size of 0.13 mm while the dunes in Hotevilla-Bacavi have an average grain size of 0.25 mm. Grain size determines the mobility of sand grains: the rate of movement for suspended grains less than 0.25 mm is about half the velocity of the wind that transports the grains, and grains greater than 0.25 mm creep along the surface at a rate that is less than that of suspended grains [2]. Dunes at Tonelea moved a net average of 1.87 meters more per year than the dunes at Hotevilla. The field area at Tonelea (Figure 1) encompassed three dunes with measurable extents while the field area at Hotevilla (Figure 2) encompassed more than seven dunes with measurable extents. The dune regression between 2010 and 2013 correlates to a subdued wind regime during that time period. There are differences between the dune fields for every measured parameter, the only constant between the two were weather patterns, thus the differences can be related to source supply and grain size.

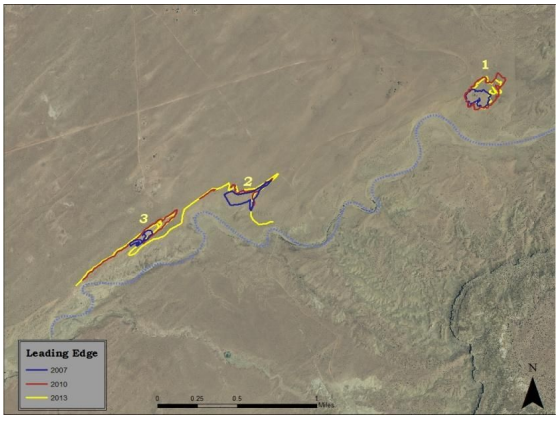

Figure 1| *Extent of dunes measured at Tonelea[3]*

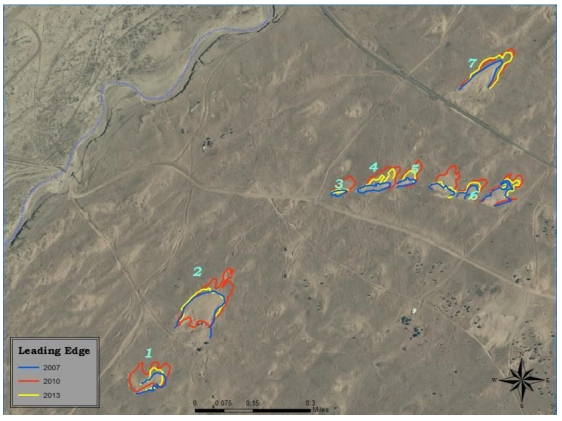

Figure 2| *Extent of dunes measured at Hotevilla-Bacavi[3]*

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DUNE AVALANCHE MODELLING AND EMERGENT BEHAVIOURS

S.L.F. Sutton and D.M. Burr
Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, USA

Key words Aeolian dune avalanche, cellular automata modelling, emergent behaviour.

Avalanche processes control dune slipfaces, which in turn strongly influence local airflow through flow separation, and the dune sediment budget through the change in capture efficiency. Cellular Automata Modelling (CAM) of dunes and dune fields have used simple, minimalist sets of controls to produced significant improvements in understanding of maturation and maintenance of these bedforms [e.g. 1-3]. However, CAM representation of avalanches typically includes arbitrary relocation of sediments on the slipface through forced relaxation in order to maintain a characteristic angle, and this simplification fails to capture the controlling parameters of the avalanche processes, and therefore does not model the system behaviour of the avalanche process well. We present a new model framework that captures the essential simplicity of system behaviour through a simple rule set, yet also resolves the critical thresholds, reservoirs and length scales that control the avalanche process. Differing from CAMs primarily through the inclusion of continuous elevation representation (Fig. 1) this model is capable of properly resolving both local angles of initial yield (angle of spontaneous failure) and of repose (angle failure relaxes to). This capability allows the model slipface to cycle through realistic capture and release phases. Application of the model under both terrestrial and planetary conditions shows three significant model behaviours:

First, under terrestrial and all planetary boundary conditions slipface formation requires a minimum brink height. Sediment transported across a dune brink is deposited onto the slipface in a topographic bulge a short distance downslope [e.g. 4]. Avalanching removes some of this sediment, redistributing it to lower reaches of the slipface. If the avalanched sediment is not transported far enough downslope to remove it from the grainfall region, the post-avalanche depositional material can impinge on the capture and release cycling, disrupting slipface maintenance and resulting in a loss of the slipface.

Second, the longer saltation trajectories on Mars [e.g. 5], a function of lower gravity and reduced drag, increases both the distance downslope from the brink that the topographic bulge forms, as well as increasing the length of the bulge. This change in location and length results in larger quantities of sediment being required to produce similar changes in surface slope in comparison to Earth. The consequence is: a) decreased avalanche frequency and increased volume per unit of sediment transport across the brink, and b) an increase in required slipface height, as described above.

Lastly, simulated transport of sediment with short trajectories, as expected on Titan and Venus with their thick atmospheres, results in avalanche behaviour approaching that of simple sandpiles. Short trajectories result in a lack of capture and release cycling at the top of the slipface. Instead the model slope exhibits stick and slip behaviour by small grainflows, creating a pulsing behaviour on the slipface itself in a manner similar to Bak *et al.* in their self-organized criticality modelling of a sand pile [6].

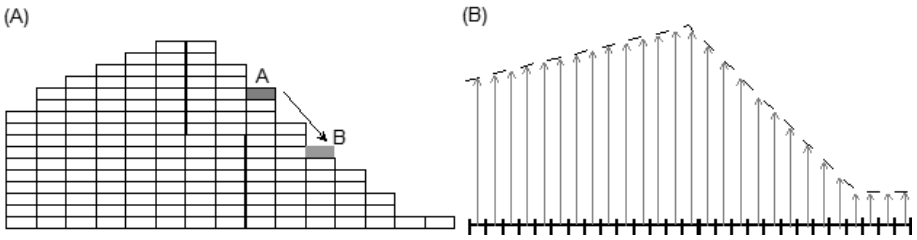

Figure 1. Comparison of two modelling frameworks: A) The Cellular Automata Model framework of discrete rectangular elements that are moved as indivisible blocks. B) The present modelling framework with near infinite vertical resolution and uniform discrete horizontal spatial resolution.

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Sedimentary Structure and Development of Mobile Sand Dune in the Mu Us Desert

Tianyang Fu[1,2,3], Yongqiu Wu [1,2,3]*, Lihua Tan[1,2,3], Yanglei Wen[1,2,3] & Dawei Li[1,2,3]
[1] *State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing, China.*
[2]*MOE Engineering Center of Desertification and Blown-sand Control, Beijing Normal University, Beijing, China.*
[3] *Faculty of Geographical Science, Beijing Normal University, Beijing, China.*

Key words: Aeolian landform; Ground penetrating radar; Sedimentary structure; Stratigraphic sequence; Development process.

Abstract
The formation mechanism and development process of aeolian landforms are significant research of aeolian geomorphology. The analysis of sedimentary structure and stratigraphic sequence of sand dunes are the key content of this study. Ground penetrating radar (GPR) is an effective technique to detect underground sediment structures, which has made a lot of achievements in aeolian landform during the past two decades. However, most studies of GPR surveys only collect data in several major geomorphologic positions of sand dunes, which obtain less sedimentary structure information. In this study, GPR technique was used to reveal sedimentary structures and reconstruct the development process of mobile sand dune in the Mu Us Desert, from the perspective of three-dimensional space through reasonable arranging GPR survey lines in a grid. The results showed that the sedimentary structure of the sand dune were mainly consists of sets of cross-bedding with low to high dip angles and second or third bounding surfaces with low dip angles. The central section of the dune was dominated by oblique bedding with high dip angle reflectors in the longitudinal section (NW-SE orientation) and trough shape reflectors in the transverse section (NE-SW orientation). The two arms of the sand dune were mainly sets of cross-bedding with low to high dip angle reflectors in the longitudinal section and convex-up, horizontal or middle dip angle reflectors in the transverse section. Second or third bounding surfaces between different sets of cross-bedding showed a gentle undulation shape. Remote sensing images of the study area showed that the development process of the sand dune had undergone two major periods. In the early stage, a parabolic dune moved over fixed sand dunes, and later was covered by the upwind barchan dune. The sedimentary structures reflected by GPR could better reveal these geomorphologic processes, which help deepen understanding of the formation mechanism and development process of sand dunes.

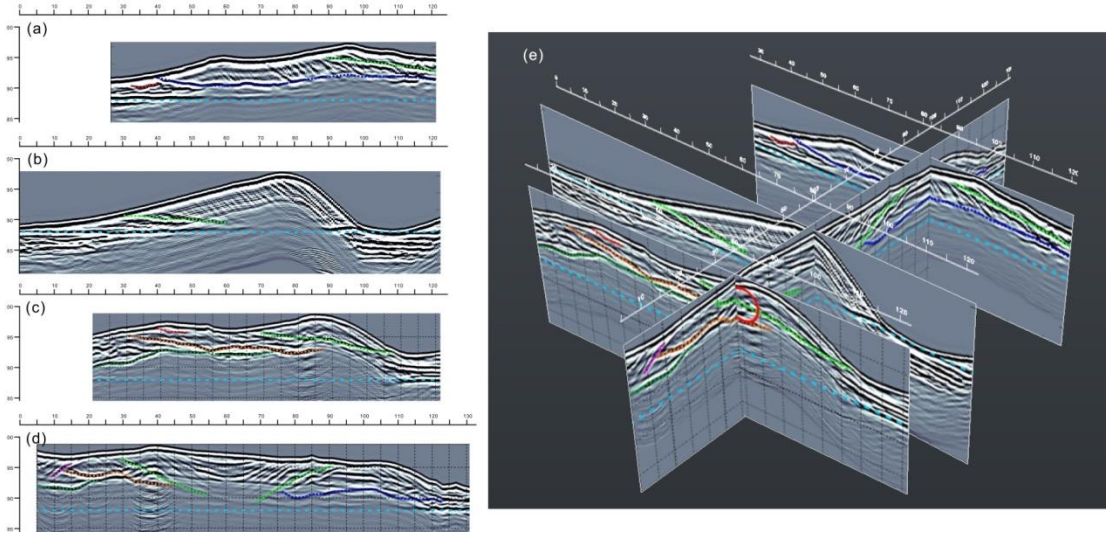

Figure 1. GPR profiles of mobile sand dune.

Aeolian sand ripples instability and grain sorting

Peng Wang[1], Ning Huang[1] & Jie Zhang[1]
[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, Lanzhou 730000, China*

A theoretical model is proposed to investigate the formation of aeolian sand ripples and the grain sorting along the bed forms over a non-uniform bed. We employ a method of linear stability analysis to study the influence of sediment heterogeneity on growth and migration rates of aeolian sand ripples. The transport of nonuniform sediment is described by formulations of both the reptation caused by impact-driven and creep caused by gravity-driven as well as wind drag-driven. The results of the model show that the grain sorting phenomena is mainly caused by a selective transport of grains with different sizes. The graded sand mixture tends to stabilize the sand bed, and longer ripples appear when the graded sand mixture is characterized by a poorly sorted. Moreover, the theoretical model successfully reproduces the observed phenomenon that the coarse sand at the crest and fining at the trough of a sand ripple.

Key words: aeolian transport sand ripples grain sorting.

LARGE EDDY SIMULATION OF WIND EROSION WITH SAND DUNE DEFORMATION

J. WU[1], C. LE RIBAULT[1], I. VINKOVIC[1] & S. SIMOËNS[1]
[1]*LMFA, UMR CNRS 5509, Ecole Centrale de Lyon, Université de Lyon I, INSA Lyon, France*

Key words Wind erosion, particle transport, dune deformation, large eddy simulation, immersed boundary method.

Wind erosion greatly contributes to the evolution of geographic topography. Our goal is to understand and analyse the mechanism of dune displacement and deformation in the turbulent atmospheric boundary layer. Models based on the mass conservation relating the height of the hill and the saltation and creeping fluxes are usually applied in literature. The erosion and deposition rates are modelled as functions of the Shields number and used to estimate the deformation. In this study, a new model of wind erosion is proposed. Large eddy simulations (LES) are performed to study the dynamics of the dune and different models are used for the particles transport and their interactions with the ground.

LES of the saltation over a Gaussian dune have already been performed by Huang [1] and compared to the experiments of Simoëns [2]. To resolve the turbulent velocity field over a deformable boundary, the LES have been coupled with an immersed boundary method (IBM). No-slip boundary conditions are imposed on the immersed deformable dune surface through a direct forcing as suggested by Lundquist [3]. An instantaneous particle entrainment model is used to initialize the particle incipient motion. Lagrangian particle tracking is applied to simulate particle transport in the atmosphere [4]. In addition, the particle/dune collision is taken into account by an empirical statistical rebound model proposed by Beladjine [5]. The net cumulative fluxes of erosion and deposition are used to estimate the temporal evolution of the dune. The local bed slope is also controlled by an avalanche model.

A first validation case of a turbulent boundary layer flow over a Gaussian dune is performed to verify the accuracy of the new IBM method. Recirculation region characteristics (Fig. 1), mean fluid velocity profiles as well as particle concentrations at different streamwise positions are analysed. Good agreement between experimental data and simulated results demonstrates the ability of the improved solver. Then, a preliminary simulation of the wind erosion over an initially sinusoidal dune is carried out and compared to the experimental results of Lopez [6]. Windward erosion and lee side deposition are observed as illustrated on Fig. 2. Moreover, the location of dune crest moves in the streamwise direction.

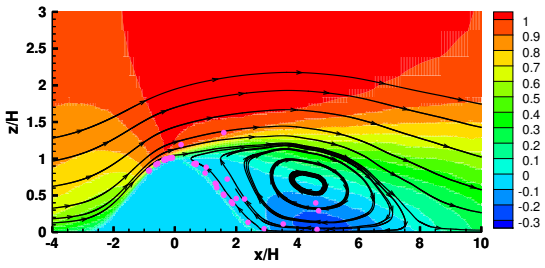

Figure 1. Velocity field and particle transport (purple points).

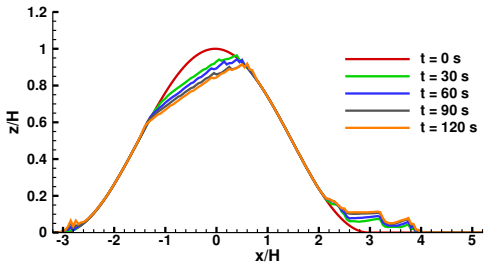

Figure 2. Temporal evolution of dune shape.

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FORMATION AND LATERAL MIGRATION OF REVERSING DUNES

Xin Gao, Qin Song, Shengyu Li, Jiaqiang Lei and Yongcheng Zhao
Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences

Key words Reversing dunes, Lateral migration, Dune growth mechanisms, Reversing winds

The dunes reverse due to seasonal changes in direction of the dominant wind. Here we use ∼12 yr of high-resolution aerial imagery of the southern margin of the Taklamakan Desert, China, to show that reversing dunes with 1-3 m heights migrated laterally on average 102.6 m without extension between 2005 and 2017. The observed seasonal wind reversals control the formation and lateral migration of these reversing dunes. Field surveys show that reversing dunes characterized by asymmetrical profiles develop on an alluvial deposit composed of a mixture of fine and coarse grains. As shown by numerical modelling, in zones of low sediment availability, the development of reversing dunes undergoes the coexistence or alternation of two dune growth mechanisms. As confirmed by observation, appearances of the crest-line sinuosities or isolated dunes in 2017 indicate that the present reversing dunes develop in the bed instability mode. Our findings provide direct evidence that reversing dunes are unstable with respect to the seasonal shift in winds, and the lateral migration may be a transient dynamic change in equilibrium with the seasonally reversing winds.

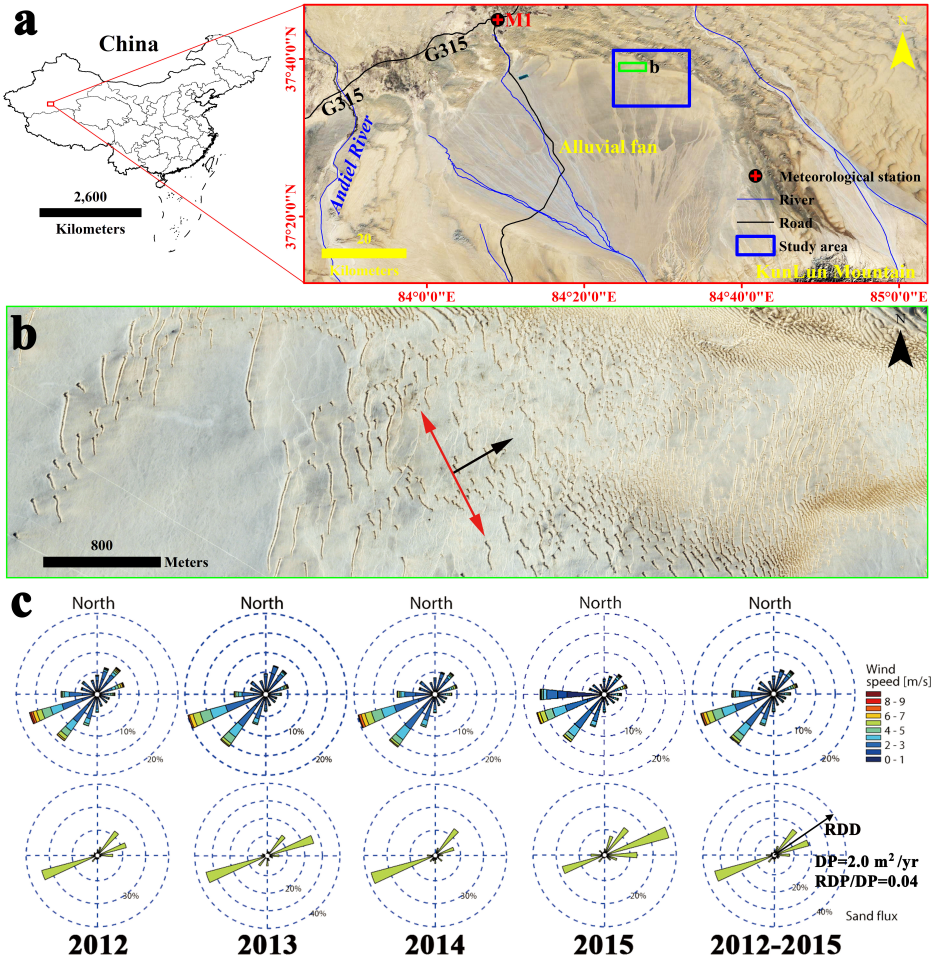

Figure 1. Reversing dunes developing on an alluvial fan in the southern margin of Taklamakan Desert, China. (a) The location of reversing dunes at the edge of an alluvial fan. (b) Enlargement of reversing dunes with different lengths and orientations in the green box of (a). The insets show the predicted dune orientations in the bed instability mode (red arrow) and fingering mode (black arrow). (c) The wind and sediment flux roses predicted by the wind data observed from the meteorological station M1 in (a) for the years 2012 - 2015. The wind regime can be approximated by a reversing bimodal wind pattern. The black arrow shows the resultant drift direction (RDD).

GRAVEL DESERT VEGETATION DUNES GEOMORPHOLOGY AND ITS IMPLICATION ON DUST EMISSION

Z.C. Zhang[1], Z. B. Dong[2], M.L. Guan[1]
[1]*Chinese Academy of Sciences Key Laboratory of Desert and Desertification, Lanzhou, China*
[2] *College of Tourism and Environment, Shaanxi Normal University, Xi'ans, China*

Key words Vegetation dunes; Gravel desert; Geomorphology; Dust emission.

Vegetation dune, also named as Nebkha, coppice and shrub-coppice dunes (Hesp and Smyth, 2017), which formed in any regions where there are strong wind regime, aeolian sand sediment and vegetation. Due to the larger distribution region in the worldwide, many researchers had studied it formation and development (Gillies et al., 2014; Hesp and Smyth, 2017), morphological properties (Yang et al., 2015) and environmental implications (Wang et al., 2006; Zou et al., 2016). However, there are little research on the vegetation dunes on the gravel desert, which is one of most important landforms in north and northwest China, and had been thank as one of most dust sources region in central Asia.

Four field regions and 50 vegetation dunes were selected to study vegetation dunes geomorphology properties in the Hexi Corridor and Heihe River Basin gravel desert in northwestern China. Vegetation length (Lv), width (Wv) and width (Hv), vegetation dune length (Ls), width (Ws) and width (Hs) were measured in the field conditions. The results indicated that there are good relationship between vegetation and dunes pattern parameters ($Y_{1,2,3}=a+bLv+cWv+dHv$, $P<0.0001$), $y_{1,2,3}$ is the dunes length, width and height, respectively. *a*, *b*, *c* and *d* are coefficients. Lvx_1 is the vegetation length, Wvx_2 is the vegetation width, Hvx_3 is the vegetation height. The significance of the fitting functions means that the vegetation dunes pattern parameter were controlled by vegetation pattern parameter. Vegetation dunes width were best related to vegetation length, width and height (R^2 = 0.887). Vegetation length controlled dunes parameters, and the contribution to the dune length, widht and height were 0.529, 0.432 and 0.715, respectively.

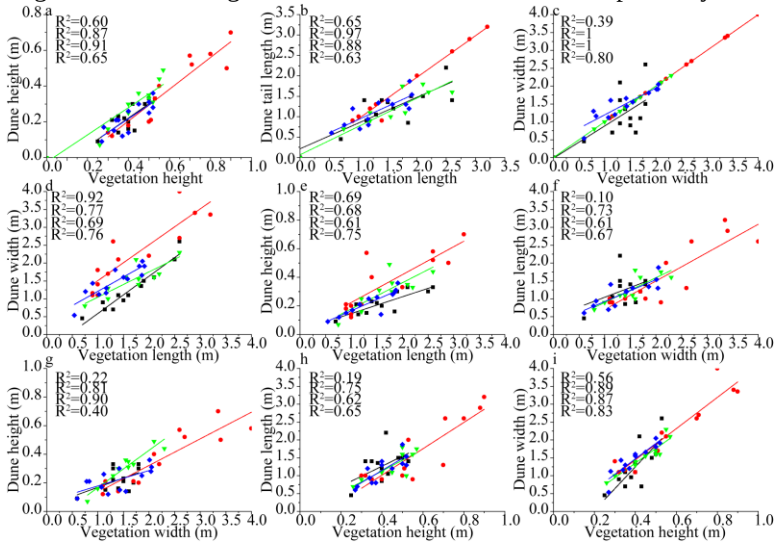

Figure 1. The relationships between vegetation pattern parameters and dunes geomorphology parameters.

Vegetation dunes geomorphology controlled by regional wind regime, air flow dynamic over vegetation, sand supply and vegetation. For the gravel vegetation dunes, there are two types : with shadow dunes and without shadow dunes. High wind energy environment caused there were not shadow dune on the most gravel desert area, however, lower air flow in the downwind of the vegetation, more sand supply in the gravel desert gullies made there are shadow dunes.

Based on our detailed field investigation, we found that vegetation dune mainly distributed in the gullies, where the erodible material were much more than other gravel surface, which means that gravel desert was one of dust source in the northwestern China, and gullies on the gravel desert can provide more dust material than other area.

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SESSION

« Planetary aeolian research »

GENERATION OF PERIODIC BEDFORMS ON EARTH AND MARS BY SUBLIMATION OF ICE UNDER TURBULENT WINDS

M. Bordiec[1], S. Carpy[1], O. Bourgeois[1], M. Massé[1], L. Perret[2] & P. Claudin[3]
[1]*Laboratoire de Planétologie et Géodynamique, Nantes*
[2] *Laboratoire de recherche en Hydrodynamique, Energétique et Environnement Atmosphérique, Nantes*
[3] *Laboratoire de Physique et Mécanique des Milieux Hétérogènes, Paris*

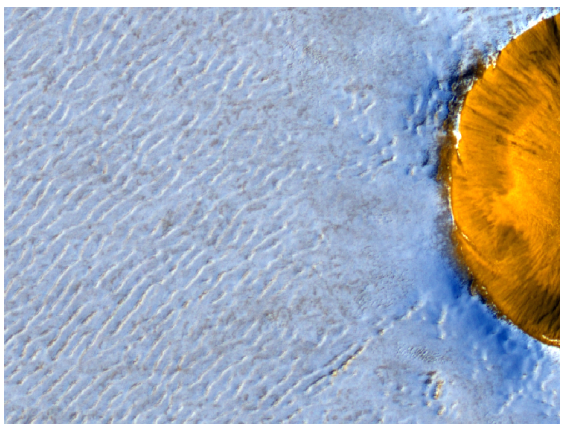
Key words Sublimation, diffusion, linear stability analysis, Mars.

The generation of bedforms does not necessarily involve solid particle transport and can be controlled by other physical processes [1] as sublimation. For instance, ice bedforms have been well described in the so-called blue-ice area in Antarctica (10 to 25 cm in wavelength [2] fig.(a)) while their equivalents on Mars appear to be larger in wavelength: about 7 m (fig.(b)). We aim to understand the mechanisms that generate and develop these periodic transverse bedforms and to evaluate the plausibility that the same processes are involved on Earth and Mars.

Sublimation induce mass transfers between icy surfaces and overlying steady boundary layer turbulent flows. These mass transfers diffuse water vapor into the atmosphere and the mixing may be responsible for the instability of transverse bedforms. To explore these mechanisms, we performed a linear stability analysis applied to a turbulent boundary layer flow perturbed by a wavy ice surface.

Our model shows that a primary linear instability related to the matter diffusion by sublimation results in a bedform growth when the hydrodynamic response related to the wavy bed (based on a Reynolds number defined by the wavenumber k and the friction velocity u_*) changes from laminar to turbulent. The most unstable wavelength of ice bedforms are found to be decimetric and metric in terrestrial and martian environments respectively, which is a good match with the observed wavelengths. Our results are in quantitative agreement with the scaling law first proposed by Thomas [3] which linearly links the wavelength to the thickness of the viscous sublayer from experimental and natural observations, as we find $\lambda \approx 9.10^2 \nu/u_*$. The friction velocity u_* is not easily measurable and is then usually computed using an extrapolation of the typical logarithmic law of the wall which involves the mean flow velocity U above the surface. This leads to another linear law $\lambda \propto 1/U$ which appears to be of great interest for wind predictions (mean velocity and orientation, as those bedforms are generally perpendicular to the main wind direction) on Mars, if the martian ice bedforms (fig.(b)) are actually equivalent to those in the blue-ice area. A good agreement is also shown between the results and the measures of Bintanja [2] for migration velocity ($\approx$ 2 cm.month^{-1}) in the downwind direction and typical time scale ($\approx$ 1month) of ice bedforms in the blue-ice area. These quantities strongly depend on the flux of matter on the bed and could then bring more information on the sublimation rates on the martian north polar cap.

(a) Ice bedforms in Antarctica (BIA), $\lambda \approx 20$ cm [2].



(b) Ice bedforms on the martian north polar cap, $\lambda \approx 7$ m [4].

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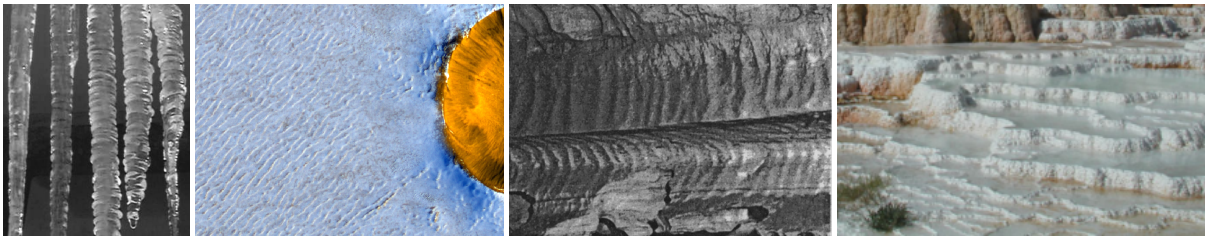
BEDFORMS FORMED ON CONSOLIDATED SUBSTRATES BY DIFFUSION IN FLUID FLOWS: INTER-PLANETARY COMPARISON

M. Bordiec[1], O. Bourgeois[1], S. Carpy[1], M. Massé[1] & S. Pochat[1]
[1]*Laboratoire de Planétologie et Géodynamique, Nantes, France*

Key words Consolidated bedforms, phase transition, chemical solubility, diffusion.

Periodic bedforms with various wavelengths, patterns and compositions are widespread at the surface of solid bodies of the Solar System. The most famous of these are dunes and ripples, which derive from transport by saltation or bed load of loose granular materials (e.g., sand, snow) by fluid flows (e.g., water, air). The origin and dynamics of this first class of planetary bedforms ("granular bedforms") have been addressed in an abundant and always updated literature. A more enigmatic class exists however ("consolidated bedforms"): this class includes periodic bedforms that develop by (1) mass transfers between consolidated substrates (e.g., massive rock, massive ice) and fluid flows (e.g., water, air) and (2) diffusion of the matter exchanged with the substrate into the fluid.

"Consolidated bedforms" comprise periodic bedforms where mass transfers between the substrate and the fluid occur by phase transitions. Ice crystallisation and melting, on one hand, are involved in the development of topographic waves on the floor of glacial meltwater channels [1], of fluted scallops in ice caves [2], and of wavy patterns on icicles [3] (fig.1(a)). Ice sublimation and condensation, on the other hand, have been proposed to control the development of periodic bedforms on terrestrial ice sheets, from centimetric bedforms [4] to kilometric megadunes [5]. Similar icy bedforms have been observed [6] and studied [7] on the Martian polar caps (fig.1(b)) and suspected on Pluto [8]. "Consolidated bedforms" also include periodic bedforms where mass transfers between the substrate and the fluid occur by chemical reactions (e.g., dissolution, precipitation). Examples include fluted scallops and wavy flowstones on the walls of limestone, gypsum and halite caves [2] (fig.1(c)), periodic travertine dams in rivers [9] (fig.1(d)), terraced siliceous deposits around hot springs [10] and bedforms in salt deposits [11]. Although the mass transfer processes differ in their details between these examples, the resulting bedforms display striking morphological and sedimentological similarities. To assess whether these similarities reflect comparable dynamic behaviours, we aim to evaluate the control parameters responsible for the dynamics and shape of those periodic patterns in order to attempt a classification based on the physical processes.



(a) Icicles [3]. (b) Ice bedforms on Mars [7]. (c) Limestone fluted scallops [2]. (d) Travertine terrace [9] .

Figure 1. Various consolidated bedforms: (a) icicles of 6 mm in wavelength, (b) ice bedforms of 7 m in wavelength on the martian north polar cap, (c) figure is 2 m height, in B & B cave, USA, (d) largest terraces of the order of 10 m in Mammoth Hot Springs, USA.

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POTENTIAL EARTH ANALOGS FOR MARS LIQUEFACTION/FLUIDIZATION FEATURES: LARGE-SCALE ZONES OF DEFORMATION IN THE NAVAJO SANDSTONE

G. Bryant

Dixie State University, St George, Utah, USA

Key words Mars; liquefaction; fluid escape; soft-sediment deformation; Navajo Sandstone

Images from the Mars rover Curiosity indicate the presence of fluid escape pipes in Gale Crater, within a sedimentary succession that includes eolian sediments. These fluidization features add to the accumulating evidence of aqueous activity during the sedimentary history of the planet and indicate both the presence of shallow water tables and impact activity or some other triggering event, at the time of pipe formation. Modern Earth analogs to the features in Gale Crater are abundant; however, subsurface components of the fluidization complex producing these features may not be well represented in modern Earth environments.

A broad range of liquefaction/fluidization features does appear in the ancient eolian record exposed on the Colorado Plateau of the southwestern United States. Within the regional pipe-bearing succession, the Navajo Sandstone provides particularly useful examples, linking fluid-escape pipes to much larger-scale processes and an array of deformation features. Some deformation features persist for kilometers across these extensive outcrops, representing liquefaction that in some instances occurred at least 40 m below the contemporary land surface.

Among the larger-scale examples, a complex located in Kanab Canyon is notable for providing a complete cross-sectional view, which displays a central zone of intense deformation that gradually attenuates in all directions. Convoluted bedding and abrupt shears define multiple zones of sediment displacement with diverse orientations. At that location, preserved primary structures also support the reconstruction of original bedding geometries, and cross-cutting surfaces establish a relative chronology between erosional/depositional processes and the deformation event. These characteristics of the Kanab Canyon study site make it an ideal case study for researchers preparing to interpret sedimentary successions on Mars that have been subject to liquefaction/fluidization processes.

Grain saltation induced by boiling – Experiments in a low pressure chamber

S. Carpy[1], S.J. Conway[1], M. Massé[1], C. Herny[2] & M.. R. Patel[3]

[1]*Laboratoire de Planétologie et Géodynamique, CNRS UMR 6112 Nantes, France*
[2]*Physikalisches Institut, Universität Bern, Sidlerstrasse 5, 3012 Bern, Switzerland*
[3] *School of Physical Sciences, Open University, Milton Keynes, UK*

Key words saltation, unstable liquid water, ripples

On Earth, the emergence of small aeolian ripples is brought about by interactions between wind, sediment transport and topography. Under an atmosphere of a few millibars and without forcing by winds, in our previous labwork we showed that seeping metastable water was also able to generate ripples by grain saltation induced by boiling (Massé et al, 2016 [1]). In these initial experiments, a frozen cylinder of pure water was melted at a temperature of 20°C on an inclined rough plane covered with 3 mm of loose sand. These experiments were compared to similar experiments under terrestrial conditions. Under terrestrial conditions the water propagated downslope by gradual infiltration through the sand, leaving no detectable surface modification after drying. Under low pressure the infiltrating water was metastable and propagated at a lower flow rate (100 $cm.h^{-1}$ vs 33 $cm.h^{-1}$) compared to terrestrial conditions. We observed the generation of small ripples, which occurred at the flow front. This is where the interstitial pressure, due to the phase change of the water, is sufficiently strong to eject dry particles ahead of the flow. They are mobilized before the advance of the water cohesively binds the particles. In contrast to what is observed on terrestrial conditions, the surface after drying shows a succession of ripples. As the flow progresses, the small ripples build up, destabilize and create small avalanches of dry sand.

In order to better understand the particle ejection mechanism, we conducted a new series of experiments using a high-speed camera to observe the ballistic trajectories of particles. It was placed on the outside of the chamber, but at the same height as the inclined plane in order to achieve a perpendicular view-point (Fig1-left). We processed the videos using an open source particle tracking code called tractrac developed by Joris Heyman (https://perso.univ-rennes1.fr/joris.heyman/trac.html). We extracted the particle trajectories (Fig1-right) and estimated the initial ejection velocity, the angle of ejection, the saltation length for tens to hundreds of particles for nine combinations of grainsize and slope angle using the 378 videos we collected. The particle paths obtained from the videos are compared to the predictions from the ballistic trajectory model of Massé et al. (2016) Fig. 1b, Xe find an average ejection velocity about 0.3 $m.s^{-1}$, which is in good agreement with our theoretical calculations. This ejection velocity is dependant on the temperature of the sand bed [2].

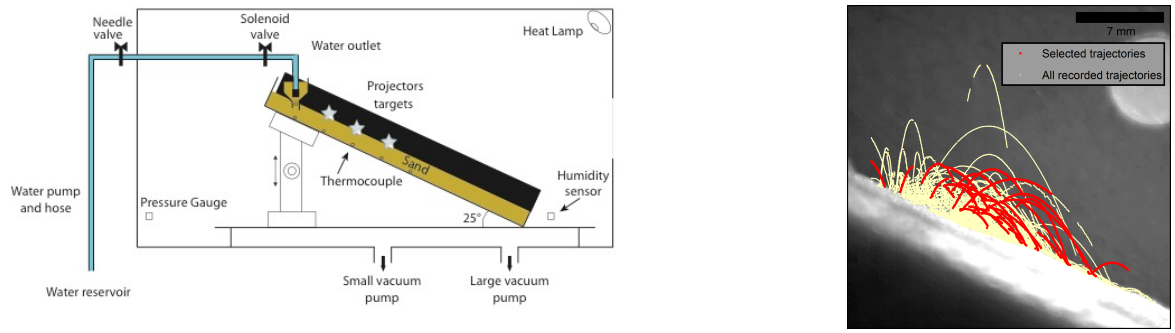

Figure 1. (Left) Diagram of set up. A vertical calibration board allowing scale to be established in the high speed videos. (Right) A screen capture of one of the high speed videos superposed with the grain trajectories extracted using tractrac..Circle in top-right is 7 mm across.

Acknolegments: This work is funded by Europlanet (Europlanet 2020 RI TA 17-EPN3-078) and Plan National de Plantéologie.

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PLANETARY BOUNDARY CONDITION CONTROL ON MARTIAN BEDFORM MOBILITY

M. Chojnacki[1]. [1]*Lunar and Planetary Lab, University of Arizona, Tucson, AZ (chojan1@pirl.lpl.arizona.edu).*

Key words Mars, bedforms, migration rates, sediment fluxes, planetary boundary conditions.

Introduction: Aeolian activity has been an enduring geomorphic process throughout Mars' history, in contrast to Earth where aqueous processes are prevalent. Recent rover and orbiter observations have revealed winds are frequently transporting fine-grained sediment across the surface of Mars today, as evidenced by migrating aeolian bedforms [for a review see 1]. On Earth, antecedent conditions like near-surface water tables and vegetation can critically influence local bedform patterns and mobility [2]. Although these factors do not play a role on modern Mars, other martian boundary conditions (e.g., wind regime, topography, sediment supply/state) play an important role in how aeolian systems evolve and persist. The objective of this investigation is to quantify bedform migration trends on Mars in the context of the aforementioned unique boundary conditions of the red planet. Related questions include: What is the spectrum of transport parameters for active bedforms on Mars and how do these compare with Earth? What might be the contributing factors (boundary conditions) for martian bedforms and how do they differ for terrestrial examples?

Data Sets and Methods: This study utilized temporal image series (resolutions ~25–50 cm/pix) and derived digital terrain models (1 m/post) from the HiRISE camera of aeolian systems across Mars (**Fig. 1**). Volumetric sand fluxes of dunes were obtained using the product of the estimated height and the dune lee front displacement over the intervening time (typically 2–3 Mars years), producing units of $m^3\ m^{-1}\ yr^{-1}$ in time units of Earth years. See [3] for full methodology.

Results: Active bedforms were detected across Mars within craters, canyons, fossae, patera, polar basins, and extracrater terrain (**Fig. 1**). Average bedform migration rates, typically barchan or barchanoid dune morphologies, across all sites was 0.5 m/yr (std. dev. +/-0.4 m/yr). These rates are for sub-meter-tall ripples (~40 cm), occasional mega-ripples (~1.5-m-tall), and ~2-120-m-tall sand dunes. Sand dune crest fluxes are in the range of 0.8-17.6 $m^3\ m^{-1}\ yr^{-1}$, while individual dunes may exceed 25 $m^3\ m^{-1}\ yr^{-1}$ (ave.+ /- std. dev. of 6.5+/-4.9 $m^3\ m^{-1}\ yr^{-1}$). These flux and migration rates are often an order of magnitude less than for similar scale terrestrial dunes, but larger than earlier reports for Mars [1, 4, 5].

Discussion: Results demonstrate substantial geographic heterogeneity in bedform transport rates across the planet and per site. Whereas migration rates are more spatially variable, dune fields with the highest fluxes tend to be concentrated in a few regions suggesting some boundary condition control. The most active aeolian region on Mars occurs with the expansive, north circumpolar erg. A critical seasonal boundary condition for that region is the martian autumn/winter CO_2/H_2O ice layers that covers the erg and restrict dune migration for roughly half of the year. Despite this sediment state limitation, the region shows extensive annual/seasonal activity with widespread ripple, dune, and megadune migration [5, 6]. Seasonal ice appears to contribute to up to 20% of the local sand movement (in the form of large slipface alcoves) [6], a factor that does not influence most terrestrial dunes. High-flux sand movement occurs with spring/summer katabatic winds that are driven by the retreat of the seasonal ice [7] and are fastest at the north polar topographic ice-cap boundary. These trends contrast the often static bedforms surrounding the more topographically-modest south polar cap, which displays limited sand supply and mobility, where the latter is attributed to a restricted sediment state related to seasonal frost and induration [5] – another process not known to occur on Earth.

High-sand flux tropical-latitude regions are also located adjacent to large topographic dichotomies (e.g. impact basins) that possess strong thermal gradients. Transport directions are broadly aligned to regional-scale slopes, but may occur downs or upslope consistent with katabatic and anabatic wind regimes, respectively. Thermally-forced topographic flow appears to play less of a role on Earth with exceptions (e.g. Antarctica plateau slope winds) [8]. Other terrestrial and martian boundary conditions will be presented and discussed at the conference.

Acknowledgments: This research was supported by NASA MDAP Grants NNH14ZDA001N and the HiRISE/MRO mission. **References:**
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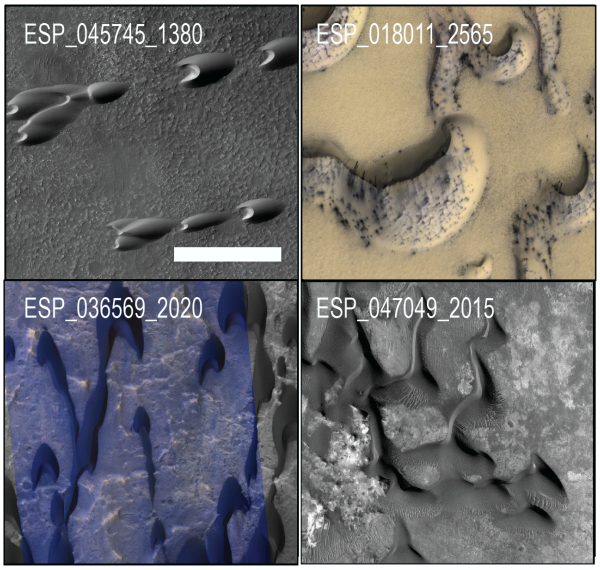

Figure 1. Examples of high-flux dunes across Mars (clockwise from upper left): Hellespontus, Olympia Undae (polar), Mawrth Vallis, and Nili Fossae. White scale bar is 500 m and all panels are at the same scale.

Remote Sensing of Wind Streaks

A. L. Cohen-Zada[1], D. G. Blumberg[1] & S. Maman[2]
[1]*Department of Geography and Environmental Development, Ben-Gurion University of the Negev, Beer-Sheva, Israel*
[2]*Homeland Security Research Institute, Ben-Gurion University of the Negev, Beer-Sheva, Israel*

Key words remote sensing, aeolian, planetary geomorphology

Wind streaks are remarkably common aeolian features observed on planetary surfaces. They occur by the thousands on Mars, Venus and Earth and they are more than likely to be formed on the moons Titan and Triton. Due to their global distribution compared to other aeolian features, wind streaks serve as a leading indicator for the prevailing wind direction near the surface. In the past four decades they were used to estimate the atmospheric circulation on Mars and Venus. Whereas the climatic perspective of wind streaks in the planetary context has been supported by recent studies on Earth, their interpretation in remote sensing images is still lacking. The geomorphological properties of wind streaks are diverse and may involve changes in surface composition, thickness, grain size or the presence of aeolian bedforms compared to their surroundings. Thus, the response of wind streaks to optic and radar sensors is significantly different. While optic images are mostly affected by the mineralogy of the surface, radar is sensitive to the surface roughness and the viewing geometry. Because Venus is constantly shrouded with clouds, its surface was imaged solely by radar. Mars, on the other hand, has been imaged only by optic sensors (visible and infrared spectrum). Therefore, the Martian and Venusian wind streaks are not comparable, and meaningful information is being unexploited on each planet. Currently, Earth is the only place where wind streaks were imaged by both optic and radar sensors and a complete set of data can be retrieved.

This study presents a wide-ranging comparison of remote sensing means, using various sensors, both optic and radar. The main goal is to examine and demonstrate how the different characteristic of the observation means affect wind streaks interpretation. Nine sites were chosen from the Earth Wind Streaks Database as case studies. Visual analysis, spatial statistics and statistical correlation were applied to determine the nature of relationships, both among the sensors and between the sensors and the surface. Results show that wind streaks identification is highly dependent on the sensor specifications. The ability to distinct its area from the surroundings rely on the relevant combination of spectral range, spatial resolution, wavelength, polarization and incidence angle (radar only). The study strongly implies that wind streaks on Mars and Venus were only partially discovered and more of them are likely to be obscured by the technology limitations. It seems that wind streaks have yet reached their full scientific potential.

Microbial mat biosignatures in a wet aeolian system

R. Ewing[1], M.M. Tice[1], H. Patel[1], C. Neal[1], K. Cheffer[1] & M. Coker[1]
[1]*Texas A&M University, College Station, TX, 77843*

Key words biosignature, microbial, wet aeolian, interdune

Wind-blown modern and ancient sedimentary environments are a recognized extreme habitable environment on Earth and are ubiquitous across modern environments on Venus, Mars, Titan, Comet 67P/ Churyumov–Gerasimenko, and putatively Pluto, and within ancient environments on Mars [1, 2]. Although, wind has clearly played a significant role in shaping the worlds within our solar system and wind-driven processes have likely interacted with any surface biosphere that exists or existed on these worlds, aeolian environments are underexplored as potential archives of life signatures [3]. Because of the limited focus on biosignatures of aeolian environments, a gap remains in our understanding of the distribution of biosignatures within aeolian environments, how organisms and sediment are eroded, transported, deposited and preserved in aeolian geomorphology and stratigraphy, and what textural and geochemical biosignatures are within aeolian stratigraphy and how to detect them.

We present initial results examining the distribution of microbial mats occurring within wind tidal flats and the interdune areas of a wet aeolian system on Padre Island, Texas.

Satellite and aerial photo examination revealed that microbial mats extensively cover the wind tidal flats and patchily cover interdune areas adjacent to active dunes. Patches of microbial mat, more extensive than those within the interdune areas, occur marginal to the active dune field (Fig. 1). Time-series image analysis shows the extent of exposed microbial mat and active sand varies seasonally within the active dune field, but less so in the wind tidal flat. Microbial mats are most exposed in fall and winter and most covered by sand during spring and summer. In situ investigation of the microbial mat showed that the best developed mats occurred within the wind tidal flats and dune-field marginal areas, and had ~0.5 cm thick mat surface, whereas the least developed mats occurred within the dune field were mm-scale. Surface microbial mat textures ranged from microscale roughness with no visible organization on the surface to structures organized into ripple-like bedforms. Trenching revealed poorly stratified deposits within the wind tidal flats and well-stratified deposits within the interdune areas (Fig. 3). Wind tidal flat deposits had a massive structure with no visible sedimentary structures. Interdune deposits had alternating light and dark, parallel, mm-scale lamination (Fig. 1). The lamination at the surface had a crinkly texture and below 10 cm was planar. X-ray flourescence will be used to examine spatial and stratigraphic variations in geochemistry.

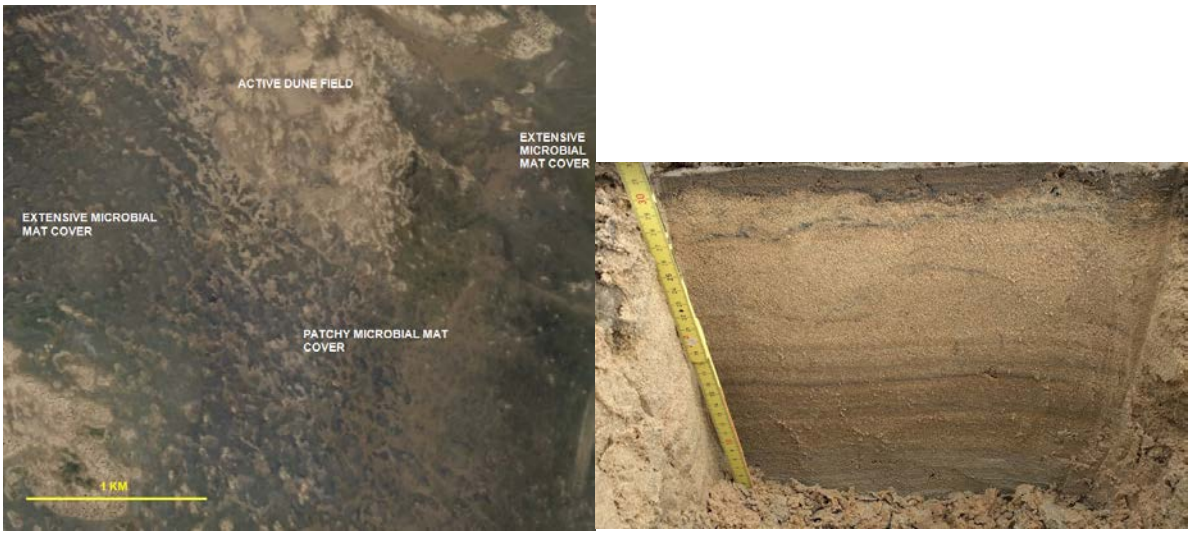

Figure 1. (left) Satellite image of dune field on Padre Island, TX. (right) Trench into interdune area showing buried microbial lamination. Dark laminations are concentrations of heavy minerals.

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Microscale Airflow Modelling of the Namib Dune, Gale Crater, Mars

C. Cornwall[1], D. Jackson[1], M. Bourke[2], M. Beyers[3] & A. Cooper[1]
[1]Ulster University, Coleraine, Northern Ireland ;[2]Trinity College, Dublin, Ireland
[3]Klimaat Consulting, Guelph, Canada

Keywords: Mars, Aeolian, Airflow Model, Sediment Transport.

This study achieves the highest resolution of airflow modelling thus far in the study of martian aeolian dynamics by employing a High Resolution Imaging Science Experiment (HiRISE) Digital Terrain Model (DTM) of the Namib dune in Gale Crater at a 1-meter resolution. At this resolution, sub-dune scale bedforms, not previously resolved by mesoscale models [1,2,3], provide a more comprehensive investigation of the complex airflow patterns affecting dune morphology [4]. In addition, we utilize in situ wind data collected by the Curiosity rover which provides more accurate airflow modelling results that reflect the near surface wind environment (Fig. 1). The local topography can significantly influence wind speed and direction, thereby also affecting surface shear stress and potentially enabling sediment transport or redistribution during seasons of low magnitude winds.

Using 3D Computational Fluid Dynamics (CFD) we present a detailed analysis of the local wind regime at the Namib dune, illustrating how and when sediment is redistributed throughout the martian year. We show how these complex seasonal airflow patterns may affect grainflow activity on the slipface and we constrain times of aeolian activity throughout the martian year using wind data collected by the Curiosity rover

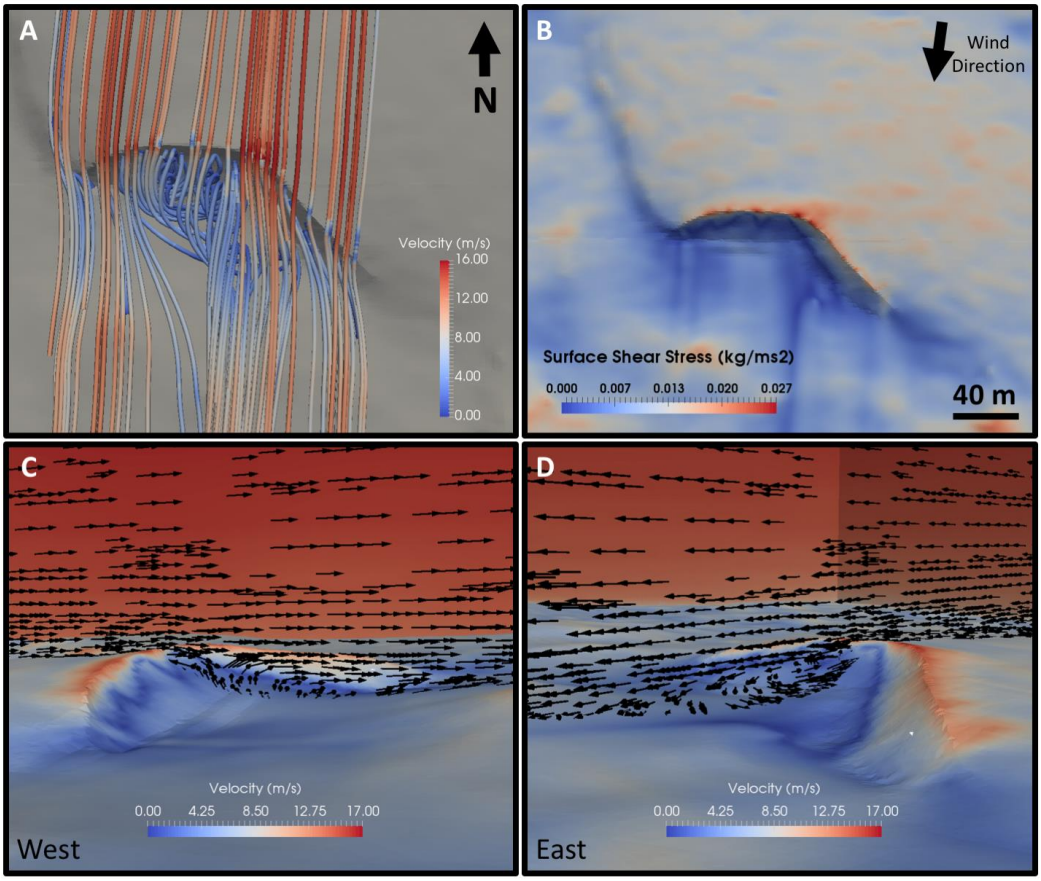

Figure 1. CFD modelling results using Curiosity wind data from the spring season on Mars of the Namib dune, Gale Crater. Boxes depict complex flow generated on the downwind side of the dune (A), surface shear stress (B), and airflow vectors showing flow reversal and flow diversion to the east (C, D)

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GIANT RIPPLES ON COMET 67P/CHURYUMOV- GERASIMENKO SCULPTED BY SUNSET THERMAL WIND

Pan Jia, B. Andreotti & P. Claudin
Laboratoire de Physique et Mécanique des Milieux Hétérogènes
PMMH UMR 7636 ESPCI – CNRS – Univ. Paris Diderot – Univ. P. M. Curie, Paris, France.

Key words Ripples; Dunes; Sediment transport; Comet; Outgassing

The recent approach of comet 67P/Churyumov-Gerasimenko by the spacecraft Rosetta has revealed the presence of astonishing dune-like patterns (Fig. 1A). How can the radial outgassing, caused by heating when passing close to the sun, produce a vapor flow along the surface of the comet dense enough to transport grains? We show that the vapor flow emitted by the comet around its perihelion spreads laterally in thermal winds, due to the strong pressure difference between zones illuminated by sunlight and those in shadow (Fig. 1B). Drawing on the physical mechanisms at work for the formation of dunes on Earth and planetary bodies, we can explain the emergence of these bedforms in such extreme cometary conditions at the observed crest-to-crest size, about 10 m. Although generated by a rarefied atmosphere, they are in fact analogous to ripples emerging on granular beds submitted to viscous shear flows (Fig. 1C).

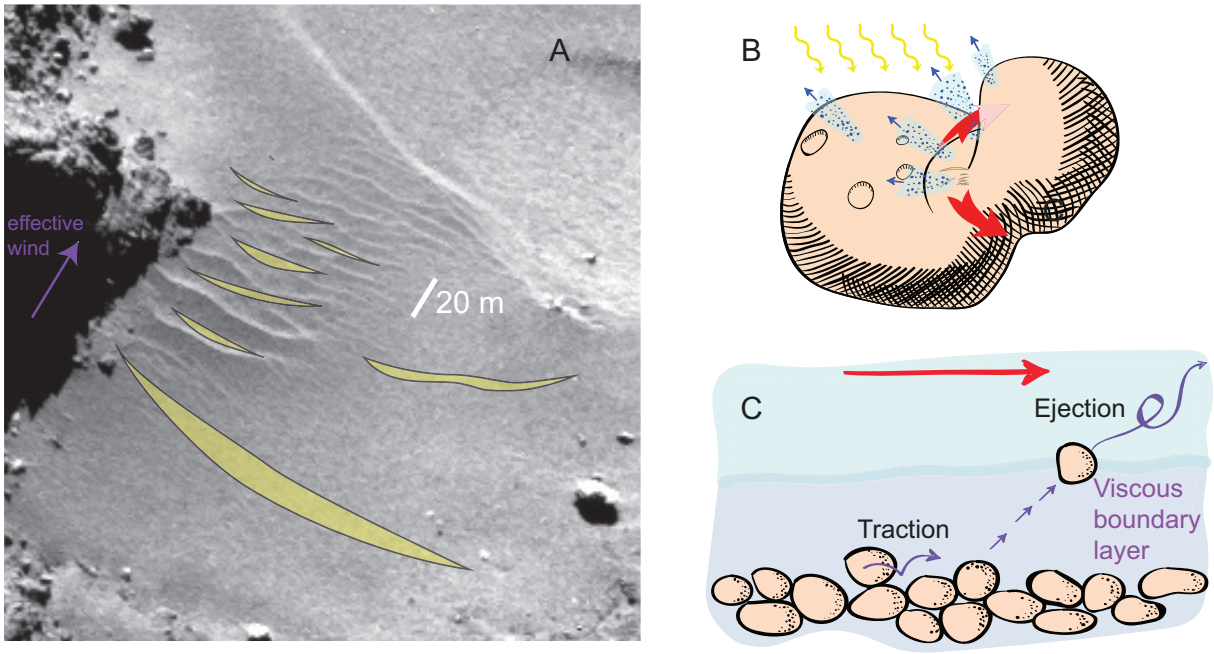

Figure 1. **A** View of the comet's bedforms in the neck (Hapi) region by OSIRIS narrow-angle camera dated 18 September 2014, i.e. before perihelion. Superimposed yellow marks: position of the ripples from a photo dated 17 January 2016, i.e. after perihelion providing evidence for their activity. Photo credits: ESA/Rosetta/MPS. **B** Schematic of the outgassing (blue) and the resulting winds (red arrows) driven by pressure gradients from illuminated to shadow areas. **C** Schematic of the vapor flow (red arrow) above the granular bed. Grains rebounding on the bed can reach the upper turbulent zone and are eventually ejected in the coma, which prevents the existence of saltation. The only mode of sediment transport along the bed is traction, in the viscous sub-layer close to the bed (Violet background), typically $10\nu/u_* \simeq 0.7$ m thick close to perihelion.

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CURIOSITY'S INVESTIGATION OF THE BAGNOLD DUNES, GALE CRATER: OVERVIEW OF A TWO-PHASE SCIENTIFIC CAMPAIGN

M.G.A. Lapotre[1] & E.B. Rampe[2]
[1]*Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138, USA*
[2]*Astromaterials Research and Exploration Science Division, NASA Johnson Space Center, Houston, TX 77058, USA.*

Key words Curiosity, rover, Mars, Gale crater, Bagnold dunes, morphology, sand composition, aeolian activity.

The Mars Science Laboratory (MSL) Curiosity rover landed at Gale crater on August, 6th 2012. On its way to its ultimate targets, the higher stratigraphic levels of Aeolis Mons (the crater's central mound), Curiosity crossed an active dune field informally named the *Bagnold Dune Field* (Fig. 1A) [1-2]. Curiosity's traverse through the Bagnold Dunes between December 2015 and April 2017 constituted the first in situ investigation of an active dune field on another planet. The scientific campaign at the dunes enabled a detailed study of martian aeolian processes at scales that are unachievable from orbiter-based imagery, from the scale of compound bedforms to that of individual sand grains. The Bagnold Dunes campaign was broadly divided into two main phases – a first-phase investigation near two barchan dunes along the northern trailing edge of the dune field (Fig. 1) [1], and a second-phase investigation further south towards Aeolis Mons near a linear dune (Fig. 1) [2]. In addition to these two phases, the Bagnold Dunes campaign included punctual investigations of isolated ripples and ripple fields between the Bagnold Dune Field and the Vera Rubin Ridge. The main goals of the scientific investigation at the Bagnold Dunes were two-fold: (I) developing a mechanistic understanding of martian aeolian processes and rates from direct in situ observations of aeolian structures and their dynamics, and (II) characterizing the physical properties and chemical, isotopic, and mineral composition of aeolian materials on Mars. Significant advances in martian aeolian science resulted from Curiosity's in situ investigation of the Bagnold Dunes [see, e.g., publication lists in 1-2]. Altogether, results from the Bagnold Dunes campaign are key to understanding how the martian environment affects aeolian processes, and thus to deciphering paleoenvironments from the martian aeolian sedimentary record.

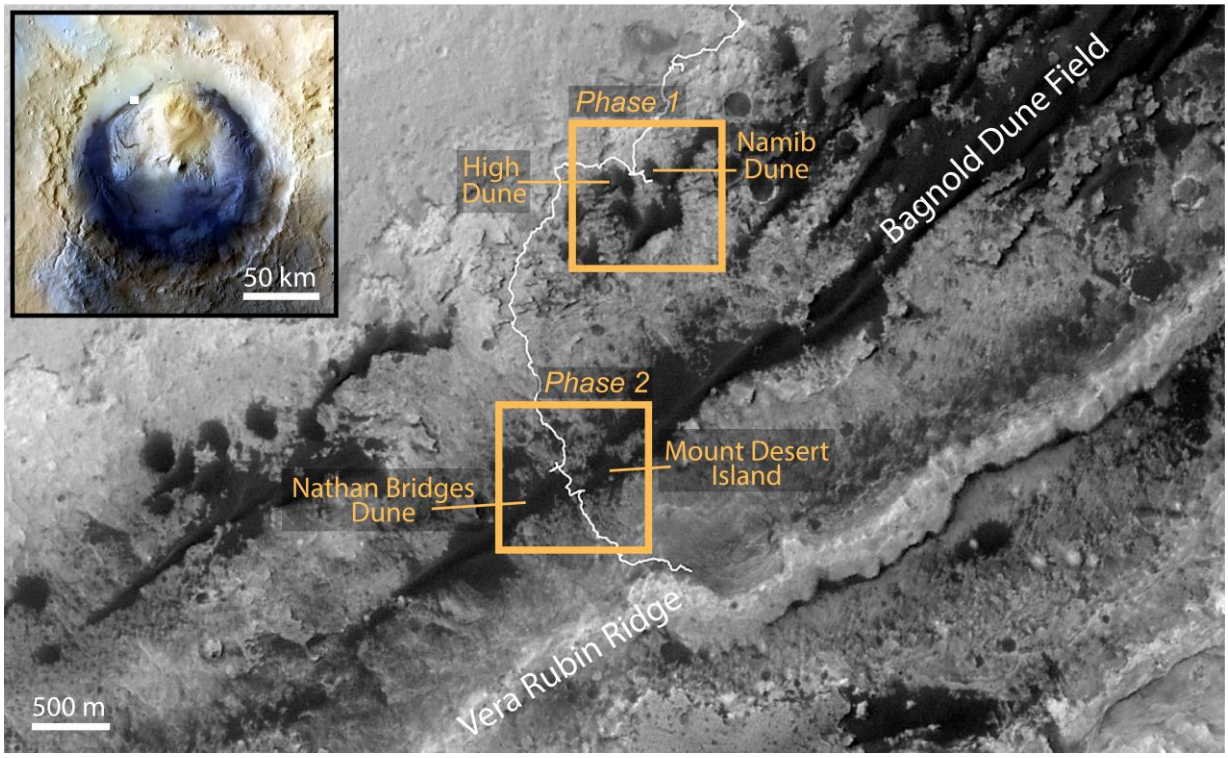

Figure 1. HiRISE mosaic of the Bagnold Dunes of Gale crater, Mars, with rover traverse and main campaign stops. Inset: Context of the Bagnold Dune Field within Gale crater (white box outlines the location of the main figure).

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INSALTATION: INSIGHT ON SALTATION AT ELYSIUM PLANUM (MARS)

A. Lucas[1], A. Spiga[2], S. Rodriguez[1], N. A. Teanby[3], D. Banfield[4], N. Murdoch[5], M. Golombek[6], C. Narteau[1] & the InSight Science Team

[1]*Institut de Physique du Globe de Paris, Université Paris-Diderot, CNRS, France* - [2]*Laboratoire de Météorologie Dynamique, Sorbonne Université Paris, France* - [3]*School of Earth Sciences, University of Bristol, Bristol, U.K.* - [4]*Cornell Center for Astrophysics and Planetary Science, Cornell University, Ithaca, NY, USA* - [5]*Institut Supérieur de l'Aéronautique et de l'Espace, Toulouse, France* - [6]*Jet Propulsion Laboratory, Caltech, Pasadena, CA, USA*

Key words Mars, InSight, Saltation, Dust.

In November 2018, the InSight lander, a dedicated geophysical station, will be deployed on the surface of Mars. While probing the internal structure of the planet is the primary scientific goal, atmospheric science remains a key objective for the mission. In addition to the geophysical package, the lander incorporates a pressure sensor, two booms measuring wind and temperature continuously, a deployment arm with scoop (IDA), and cameras on both the deck and the arm itself (IDC). Along with standard atmospheric measurements, imaging on board the InSight lander offers the opportunity to study key aspects of aeolian transport: grain size distribution, lifting velocity threshold, avalanche phase (friction angle, angle of repose), and seasonal variations of sediment flux at the landing site in Elysium Planum [1]. We will describe and discuss the motivations and the science activities that will be performed during the operating phase (Figure 1): i) the IDA will be used for building and tracking sand piles experiencing the wind regime at the surface; ii) the lifting threshold will be estimated by comparing the measured movement of dune field ripples, from both remote-sensing and *in-situ*, to predictions using GCM-derived winds [2]. These possible activities offer the opportunity to provide new constrains and hence new insight into aeolian transport on Mars.

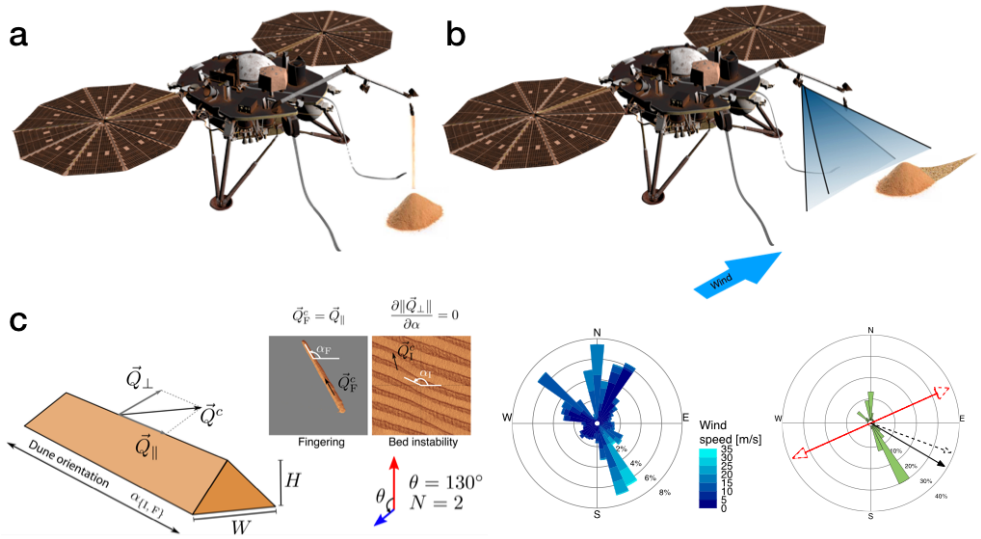

Figure 1. Science activity on sediment transport during InSight operations. (a-b) the arms and associated camera (IDA and IDC) will be used for building and tracking over time sand piles experiencing the ground wind regime at Elysium Planum. (c) Theoretical framework of new generation dune model is used for predicting the bedform evolution accounting for GCM predictions as shown on the roses [3, 4].

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FIRST QUANTIFICATION OF RELATIONSHIP BETWEEN DUNE ORIENTATION AND SEDIMENT AVAILABILITY, OLYMPIA UNDAE, MARS

L. Fernandez-Cascales[1], A. Lucas[1], S. Rodriguez[1], X. Gao[2], A. Spiga[3], C. Narteau[1]

[1] *Institut de Physique du Globe de Paris, Université Paris-Diderot, CNRS, France*
[2] *Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, China*
[3] *Laboratoire de Météorologie Dynamique, Sorbonne Université Paris, France*

Key words Mars, Dune, North Pole.

Dunes provide unique information about wind regimes on planetary bodies where there is no direct meteorological data. At the eastern margin of Olympia Undae on Mars, sediment cover and dune orientation are measured from satellite imagery using the high contrast between the dune material and the substratum. These data provide the first quantification of relationship between sediment availability and dune orientation. Abrupt and smooth dune reorientations are associated with inward and outward dynamics of dunes approaching and ejecting from major sedimentary bodies, respectively (Figure 1). These reorientation patterns along sediment transport pathways are interpreted using a new generation dune model based on the coexistence of two dune growth mechanisms. This model also permits solving of the inverse problem of predicting the wind regime from dune orientation. For bidirectional wind regimes, solutions of this inverse problem show substantial variations in the distributions of sediment flux orientation, which can be attributed to changes in albedo at the boundaries of major dune fields. Then, we conclude that relationships between sediment cover and dune orientation can now be used to constrain wind regime and dune field development on Mars and other planetary surfaces [1].

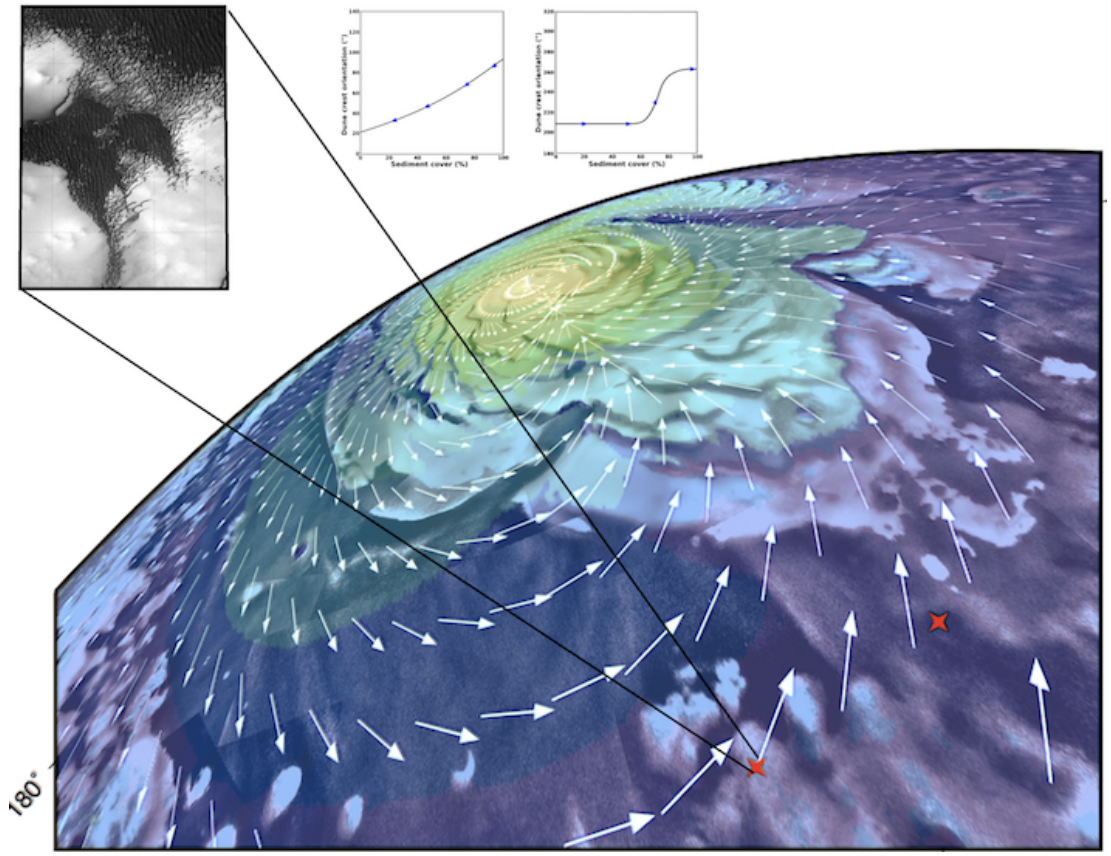

Figure 1. First quantification of relationship between sediment availability and dune orientation with sharp and smooth dune reorientations associated with inward and outward dynamics with respect to sedimentary body (see inset).

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REVISING THE EXPERIMENTALLY DERIVED AEOLIAN THRESHOLD SPEED MODEL IN HIGH PRESSURE ATMOSPHERES

E. V. Nield[1], D. M. Burr[1], J. P. Emery[1], S. L.F. Sutton[1], J. F. Kok[2] & J. K. Smith[3]
[1]*Department of Earth and Planetary Science, University of Tennessee, Knoxville, Tennessee, United States*
[2]*Department of Atmospheric and Oceanic Sciences, University of California Los Angeles, California, United States*
[3]*School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, United States*

Key words Titan Wind Tunnel, Threshold wind speed, high-pressure, density ratio

The aeolian saltation threshold is the minimum wind speed required to entrain sediment into saltation. A general expression for aeolian saltation threshold is needed for the prediction and modeling of saltation threshold speeds on Earth as well as on the myriad other planetary bodies with aeolian sand transport [1-4]. Bagnold derived the threshold friction (or shear) speed (u_{*t}) as:

$$u_{*t} = A\sqrt{\frac{\rho_p - \rho}{\rho} g D_p}, \quad (1)$$

where A is the dimensionless threshold parameter, ρ_p and ρ are the particle and atmospheric densities, D_p is the mean particle diameter, and g is the gravitational acceleration [5]. A is a function of the density ratio, the ratio of the density of the sediment or particle being entrained by the fluid (or wind) to the density of the fluid entraining the sediment (ρ_p/ρ), as well as the interparticle force and the Reynolds number (Re_{*t}). Previous work resulted in the following expression for A [1],

$$A = \frac{0.2}{\sqrt{\left(1 + 2.3\left\{1 - e^{\left[-\gamma(\rho_p/\rho - 1)^{\lambda}\right]}\right\}\right)}}, \quad (2)$$

where γ is 0.0078 and λ is 0.86. This expression was based on data from experiments in water, high-density air, and ambient air, giving density ratios that range over five orders of magnitude. The high-density data, collected in the Venus Wind Tunnel, was filtered to include only data for grain sizes greater than 200 µm and particle Reynolds numbers greater than 10, constrain the central portion of the curve. The filtering was done to mitigate the effect that the interparticle force and Reynolds number have on the A parameter. However, this transitional portion of the curve, between low (<10) and high (>1000) density ratios, does not fit recent threshold data from the Titan Wind Tunnel (TWT) [6] subject to the same filtering conditions [6]. We investigated the validity of the density ratio term and its inclusion in the *Iversen et al.* threshold model [1]. This investigation entailed running new threshold experiments in the TWT under a range of density ratios conditions. In running these experiments, we considered the different definitions of threshold used in previous planetary wind tunnel work. In the data reduction, we explored different fitting techniques for deriving the roughness heights from the boundary layer profiles. From these efforts, we derived a new expression for the density ratio curve to fit the previous and newly collected TWT threshold data (Figure 1). This new expression increases the value of A in the transitional portion of the curve. This result is consistent with the use of previous TWT threshold data that were found to be higher than predicted [2] by the *Iversen et al.* model. This new threshold curve will increase the accuracy of predicting saltation threshold friction speeds, improving planetary models and terrestrial ones as well.

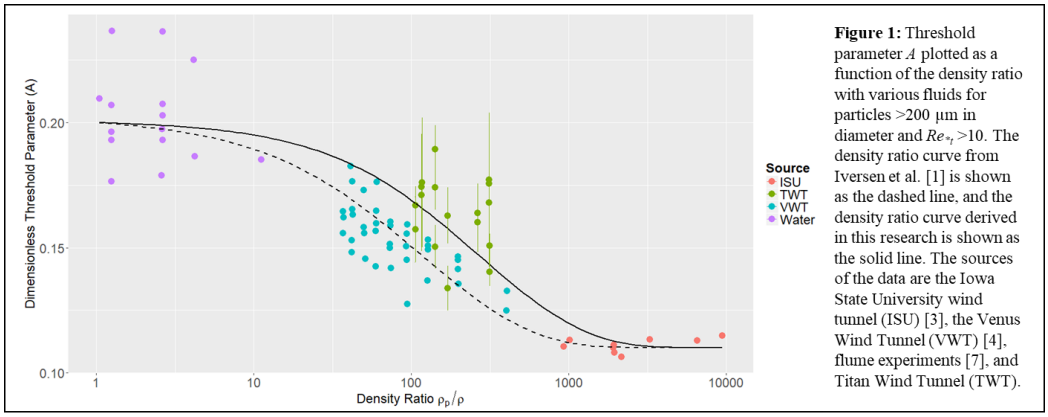

Figure 1: Threshold parameter A plotted as a function of the density ratio with various fluids for particles >200 µm in diameter and Re_{*_t} >10. The density ratio curve from Iversen et al. [1] is shown as the dashed line, and the density ratio curve derived in this research is shown as the solid line. The sources of the data are the Iowa State University wind tunnel (ISU) [3], the Venus Wind Tunnel (VWT) [4], flume experiments [7], and Titan Wind Tunnel (TWT).

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AEOLIAN THRESHOLD WINDSPEED ARCHIVE: A NEW ARCHIVE IN PDS4

E. V. Nield[1], D. M. Burr[1], & L. D. V. Neakrase[2]
[1]*Department of Earth and Planetary Science, University of Tennessee, Knoxville, Tennessee, United States*
[2]*NASA PDS Atmospheres Node, New Mexico State University, Las Cruces, New Mexico, United States*

Key words Threshold wind speed, archive, PDS4, data management, wind tunnel

Aeolian activity has been documented on Earth, Mars, Venus, Titan and has been suggested to occur on some icy bodies [1-4]. To better understand the movement of sediment on these bodies, it is critical to understand the threshold wind speeds under these disparate conditions. Beginning with Bagnold's seminal research, data obtained in wind tunnels have been used to derive models of threshold speed [5-9]. In the 1970's, the Planetary Aeolian Laboratory (PAL) was established [1]. This facility consists of wind tunnels designed to mimic specific atmospheric conditions such as density or kinematic viscosity. In the last 40 years, investigations using the facilities in PAL have yielded a wealth of information about threshold wind speed [e.g., 6-9]. This information has been dispersed to the aeolian community through a variety of journal publications, conference presentations, and technical memoranda. The threshold data published in these older papers are becoming increasingly inaccessible due to their analog nature, while data in recent publications may not be widely released due to the lack of a distribution platform. At the same time, newer planetary wind tunnels (e.g., the Aarhus Mars Simulation Facility) are generating new data. Such wind tunnel data are critical for understanding the onset of aeolian processes and calibrating threshold models.

The purpose of this work is to increase the amount and quality of aeolian threshold wind speed data available to the community. We will do this by creating a publicly available archive of threshold speed data, available through the NASA Planetary Data System (PDS) Atmospheres Node. The current work is providing a baseline by archiving past and present threshold experiment data from the wind tunnels associated with the Planetary Aeolian Laboratory (PAL) including analog wind tunnel experiments representing Venus, Mars, Earth, and Titan.

Under the new PDS4 archiving standard, data are arranged in *bundles.* Each bundle contains *collections* that organize data by type and content. Within each collection the analog data can be organized by each representative planetary body (e.g., Venus, Earth, Mars, and Titan) as *products*. Products can include tables, graphs, and videos as well as user guide resource documentation. Wind tunnel experiments can be organized by individual runs within the data collections. According to PDS archiving procedure, all data submitted are peer-reviewed and validated to ensure archival and scientific accuracy, and then made publicly available through the Atmosphere Node's website.

The threshold speed bundle is still in development and is expected to be available within the next year through the PDS. The hope of this work is to provide a template for archiving wind tunnel data officially with the PDS making it more readily available for future researchers. Providing a role model for how this type of work is done, and by providing a common place for wind tunnel data to be archived, we hope that future researchers will utilize our expertise and that of the PDS Atmospheres Node to continue what has been started, enabling better comparative science in the future. Please feel free to contact us for more information regarding the PDS and the archiving of planetary analog wind tunnel data.

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TRANSVERSE DUNES IN SPUTNIK PLANITIA, PLUTO : IMPLICATIONS FOR WIND REGIME AND PARTICLE SIZE

M. Telfer[1], E. J. R. Parteli[2], J. Radebaugh[3], R. Beyer[4,5], T. Bertrand[6], F. Forget[6], F. Nimmo[7], W. Grundy[8], J. Moore[5], A. Stern[9] & The New Horizons Team

[1]*School of Geography, Earth and Environmental Sciences, Plymouth University, UK*
[2]*Department of Geosciences, University of Cologne, Germany*
[3]*Department of Geological Sciences, Brigham Young University, Provo, Utah, USA*
[4]*Sagan Center at the SETI Institute, Mountain View, CA, USA*
[5]*NASA Ames Research Center, Moffett Field, CA, USA*
[6]*Laboratoire de Météorologie Dynamique, Université Pierre et Marie Curie, Paris, France*
[7]*University of California Santa Cruz, Santa Cruz, CA, USA*
[8]*Lowell Observatory, Flagstaff, AZ, USA*
[9]*Southwest Research Institute, Boulder, CO, USA*

Key words Pluto, dunes, New Horizons

The New Horizons LORRI instrument imaged hundreds of aligned, regularly spaced features sitting atop the nitrogen-rich Sputnik Planitia continental glacier at the base of the Al-Idrisi Montes on Pluto. These dunes are several tens of kilometers long, are spaced by 500-700 meters, are subparallel and with a slightly undulatory planform, and are best described as transverse dunes [1]. Their crests are orthogonal to wind streaks seen nearby, and therefore to the assumed regional winds. Moreover, the dunes appear from New Horizons MVIC data to have a composition enriched in methane. Their presence requires there to be particles on the surface, as well as wind that is strong enough to transport them. The aeolian particles, or "sands", are likely composed of relatively hard methane ice, possibly derived from the methane snow seen to blanket the mountain summits. While Pluto's nitrogen-rich atmosphere fluctuates in density, perhaps dramatically, current modelled conditions allow for winds that are required to transport the ice sands (<~10 m/s).

We develop a model to approximately constrain average particle size and formative wind speed from the average crest-to-crest distance (or wavelength) of the transverse dunes. This model combines a mathematical description for the distance needed for the mass flux of transported particles to adapt to a change in local flow conditions, i.e. the saturation length of the sediment flux [2], with analytical equations for the wavelength of transverse dunes as a function of this saturation length [3]. We find that the observed wavelength of the transverse dunes in Sputnik Planitia is consistent with moderate winds (<10 m/s) and particle sizes that are most probably within the range between 210 and 310 μm. Similar prediction for the range of particle sizes is obtained from the spectral response of the MVIC CH4 filter.

The transverse dunes of Sputnik Planitia are relatively fresh in appearance, especially in comparison with other features farther south that have deformation from glacier flow and textures of severe sublimation erosion. Furthermore, they occur on top of convection cell margins of Sputnik Planitia, which overturns at rates of ~500 ka. This observation indicates the dunes are relatively young, and has implications for the surface activity of other large Kuiper Belt Objects, as well as for the interaction between limited solar heating and the exotic properties of their surfaces and atmospheres.

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LINEAR DUNE MATURITY IN TITAN'S BELET SAND SEA AS REVEALED BY PARAMETRIC TRENDS

J. Radebaugh[1], R.C. Lewis[1], B. Bishop[1], E.H Christiansen[1], A. Le Gall[2], R.D. Lorenz[3], J.W. Barnes[4], S. Rodriguez[5]
[1]*Department of Geological Sciences, Brigham Young University, Provo, Utah, USA*
[2]*LATMOS/IPSL, Universite Paris-Saclay, Paris, France*
[3]*Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA*
[4]*Department of Physics, University of Idaho, Moscow, ID, USA*
[5]*IPGP, Paris, France*

Key words Titan, dunes, Cassini, linear dunes

The equatorial regions of Titan are dominated by tens of thousands of dunes organized into sand seas [1,2]. Five major sand seas exist, with minor declines in dune abundance marking the boundaries between them (with a larger break at Xanadu). However, it has been argued this is one large, global sedimentary system [3], and that dominantly westerly winds transport sand within and across the sand seas [4,5]. While dunes are visible to Cassini SAR (350 m) and in select high-resolution VIMS images, the sand sea regions are also delineated by the presence of sand as seen by VIMS (dark brown, organic unit) and ISS (dark in V-NIR) [4,6]. It is possible that regional elevation plays a role in storage of sand, as some dune fields and sand seas on Earth, such as the Namib Sand Sea, are in elevational lows or topographic traps. Sands of the Belet Sand Sea (210-300 W) are generally abundant in regional lows, as revealed by a new global topographic map [7].

Studies of sand seas on Earth, Mars, and Titan have used parametric analyses of dune length, width, and spacing to identify constraints on their formation [8]. Studies of the width and spacing of a select global sampling of Titan's dunes revealed that dunes at higher latitudes have a higher interdune:dune width, perhaps because of a decrease in sediment availability or stabilization by liquids [9]. Furthermore, it was found that dunes across Titan appear to be of the same general population, interpreted to mean that they formed and evolved under the same conditions [10].

New dune width and spacing measurements, paired with the previous ones, all systematically obtained across the Belet Sand Sea, reveal that while dune width still varies with latitude, there is no statistically significant correlation in dune width and spacing with distance from the margin or regional elevation. This may indicate that on a regional scale, sand sea boundaries are artificial and/or temporary, and do not affect dune morphologies. Furthermore, it appears that elevation differences are not strong enough to affect dune morphology (with local exceptions near obstacles). These results indicate that more important than regional geology for linear dune morphology is the existence of a sufficient supply of sand and enough time spent under given wind conditions to lead to large, organized forms. When free of constraints in growth other than those imposed by the atmosphere, dunes will grow to a size and spacing characteristic of those conditions [11]. Coupled with evidence for a single dune population, the new distributions of width and spacing reveal Titan's dunes may have reached a mature steady state. This has important implications for the growth of linear dunes on Earth and conditions for their steady-state maturation. This should encourage examination of other sand seas, such as the Olympia Undae Erg of the martian north pole [12].

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Measurement of dune and ripple sand fluxes at active dunes at Nili Patera, Mars

K. Roback[1], J.-P. Avouac[1], K. Runyon[2], and F. Ayoub[3]
[1]*California Institute of Technology, Pasadena, California, USA*
[2]*Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, USA*
[3]*Jet Propulsion Laboratory, Pasadena, California, USA*

Key words: Mars, dunes, ripples, sand flux

Aeolian sand dunes are observed across many parts of the Martian surface. Notably, Martian sand dunes are covered in meter-scale bedforms which appear to resemble ripples, but have an uncertain dynamical origin. Recent studies using observations from the Mars Reconnaissance Orbiter's HiRISE camera have documented movement of both the meter-scale bedforms and whole-dune movement. Measuring ripple-only motion is done with the COSI-Corr automated tracking algorithm, though whole-dune motion has required manually tracking the slip faces. Notably, numerous authors have shown Martian ripples to be substantially faster (~1-2 m/Earth year) than dunes (0.1-0.2 m/Earth year).

Since these early studies, the length of the timeseries of HiRISE imagery of the Martian surface has increased to 5 Mars years, enabling better discrimination of whole-dune motion for automated processes. We present measurements of whole-dune and ripple sand fluxes derived from COSI-Corr analysis of orthorectified imagery from the Mars Reconnaissance Orbiter's HiRISE camera. We find that the sand fluxes involved in whole-dune motion are much higher than previously measured ripple-only fluxes. We also find, in agreement with previous studies, large seasonal variations in ripple motion, with a maximum in activity during northern-hemisphere winter. The results of our analysis are consistent with the dynamical model of Martian ripples as aeolian impact ripples, but may be compatible with alternative, aerodynamically driven models of Martian bedform formation, if such models can reproduce observed differences between ripple and whole-dune sand fluxes.

FIRST EVIDENCE FOR BRIGHT-TONED AEOLIAN BEDFORMS MIGRATION ON MARS

S. Silvestro[1,2], D.A. Vaz[3,4], M. Chojnacki[5], H. Yizhaq[6] & F. Esposito[1]
[1]*INAF Osservatorio Astronomico di Capodimonte, Napoli, Italia*
[2]*SETI Institute Carl Sagan Center, Mountain View, CA, USA*
[3]*INAF Osservatorio Astronomico d'Abruzzo, Teramo, Italia*
[4]*Centre for Earth and Space Research of the University of Coimbra, Coimbra, Portugal*
[5]*Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA*
[6]*Department of Solar Energy and Environmental Physics, Ben-Gurion University of the Negev, Israel.*

Key words Ripples, dunes, mars, wind

In this report, we show evidence for migrating bright-toned bedforms in the North Polar Region of Mars and in the Hellaspontus region (Fig. 1). The migrating bedforms can reach wavelengths of ~10-12 meters and height of 1-1.5 meters, which are larger than typical dark-toned large ripples (LRs) (~2-4 meter wavelengths and ~40 cm) [2, 3]. These features are located in between or upwind high sand flux dunes [1] (Fig. 1a), suggesting a megaripple origin. In the study areas, the migrating megaripples are found in continuity with LRs sharing with them similar orientations. This suggests that both, bright-toned megaripples and large ripples were formed under similar wind conditions and that they share a common origin. These intermediate-sized ripples may exist on a continuum of Martian bedforms with even larger (>70 meter wavelength) Transverse Aeolian Ridges (TARs) [4, 5], which have yet to display evidence for movement.

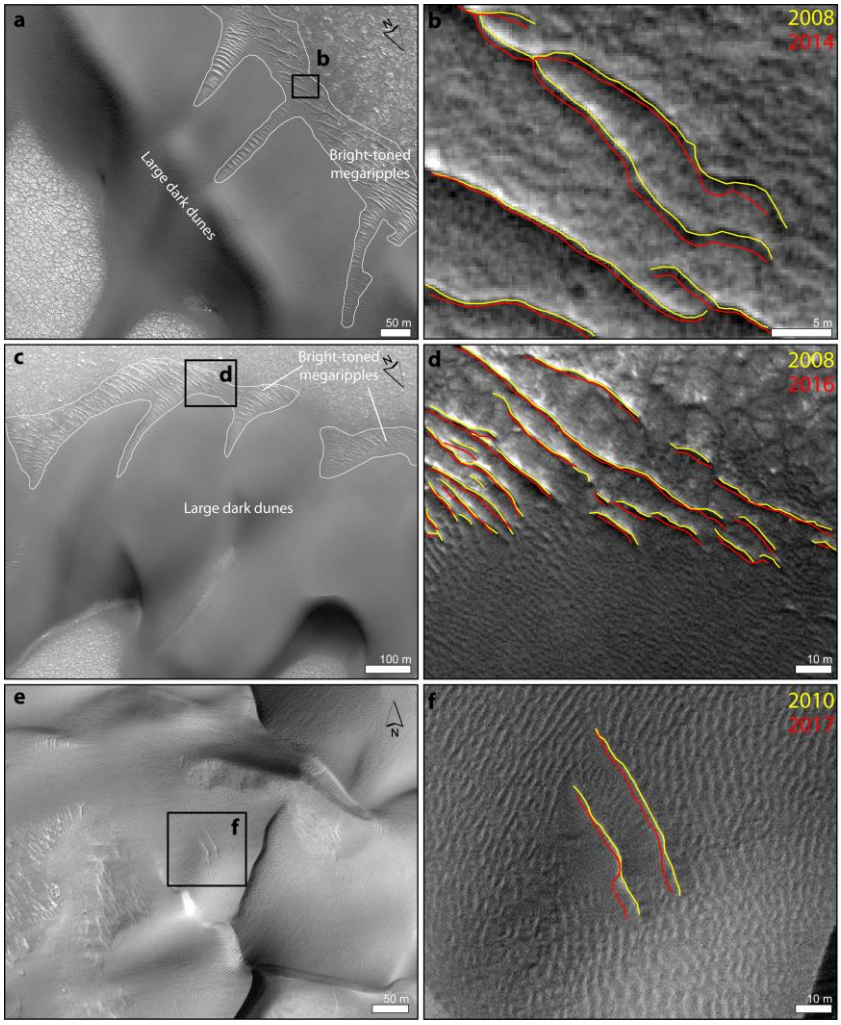

Figure 1. Active bright-toned bedforms on Mars: a-d) North Polar Region (HiRISE image PSP_009739_2580/ESP_036217_2580; PSP_009396_2590/ESP_044973_2590) **e-f)** Hellaspontus (HiRISE image ESP_051217_1380/ESP_016339_1380).

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LOW DYNAMIC WIND PRESSURES ON MARS ALLOW A BROAD CONTINUUM OF AEOLIAN RIPPLE SIZES

R. Sullivan[1], J. F. Kok[2], H. Yizhaq[3], A. Siminovich[4], T. Elperin[4], & I. Katra[5]
[1]*Cornell Center for Astrophysics and Planetary Sciences, Cornell University, Ithaca, NY, USA.*
[2]*Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, USA.*
[3]*Department of Solar Energy & Environmental Physics, BIDR, Ben-Gurion University of the Negev, Israel.*
[4]*Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel.*
[5]*Department of Geography and Environmental Development, Ben-Gurion University of the Negev, Beer-Sheva, Israel*

Key words Mars, ripple, large martian ripples, Bagnold.

Small aeolian ripples are common features in sandy settings on Earth and Mars, and form by saltation impact. On Earth, ripples of well-sorted 250 μm dune sands have heights of millimeters, and very strong winds can flatten and erase these ripples [e.g., 1,2]. On Mars, ripple-like bedforms ~20 times larger have been encountered, with ripples of smaller, more conventional sizes superimposed on their surfaces [3-5]. These characteristics have raised questions about formative mechanisms and the applicability of terrestrial aeolian physics and analogs in different planetary environments [4,6,7].

We approach this problem by evaluating factors that limit growth of aeolian impact ripples on Earth but that might be less effective on Mars. Bagnold inferred from wind tunnel experiments that terrestrial impact ripple height grows upward until wind dynamic pressure begins to reduce grain stability at ripple crests [1]. Numerical experiments accounting for this effect replicate ripple height evolution well [8]. With Bagnold's point in mind, two factors enable aeolian impact ripples to grow relatively higher (and thus larger) on Mars than on Earth. First, numerical experiments predict relatively modest impact thresholds for sand (compared with very high fluid thresholds), making saltation possible on Mars at prevailing wind speeds that are much lower than fluid threshold [9-13]. Second, low martian gravity allows low saltation flux to be initiated and sustained well below the fluid threshold required for establishing a conventional high-flux, saturated saltation cloud [14]. Together, these factors allow impact ripples to migrate (albeit slowly) entirely under prevailing conditions of relatively low wind speeds in the thin martian atmosphere. It is significant that these conditions represent relatively low wind dynamic pressures compared with Earth, therefore should allow ripples to grow higher into the martian boundary layer, and thus become larger in overall size. This concept has several implications that facilitate interpretations of complex bedform configurations encountered by rovers and observed from orbit: (a) impact ripple growth to (larger) maximum size on Mars will require much more time than on Earth; (b) during this long growth interval, wind azimuth is likely to vary even in settings where a single wind azimuth is most common, thereby leading to a dominant ripple orientation that gradually grows larger, with smaller, more transient ripples superimposed; (c) troughs between increasingly massive primary ripples become partly shielded from primary wind azimuths, and can function as conduits for redirecting oblique near-surface winds, thereby helping to establish a system of secondary ripples along trough floors; (d) settings that have no dominant wind azimuth, or shorter exposure ages, might not exhibit any ripples at the maximum possible size. These concepts could help explain the wide range of observed ripple sizes and morphologies on Mars, and indicate that even the largest martian ripples have formed by relatively conventional saltation impact mechanisms.

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GRAINSCALE MECHANICS IN THE TITAN WIND TUNNEL: OBSERVATIONS OF FLUID DOMINATED ENTRAINMENT AND TRANSPORT

S.L.F. Sutton[1], E.V. Nield[1], D.M. Burr[1], J.P. Emery[1], J.F. Kok[2], F.A. Turney[2], K.D. Runyon[3], and J.K. Smith[4].

[1]*Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, USA*

[2]*Department of Atmospheric and Oceanic Sciences, University of California, Los Angles, USA*

[3]*Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA*

[4]*Planetary Aeolian Laboratory, NASA Ames Research Center, Mountain View, California, USA*

Key words Analogue, entrainment, transport modes, Titan, wind tunnel.

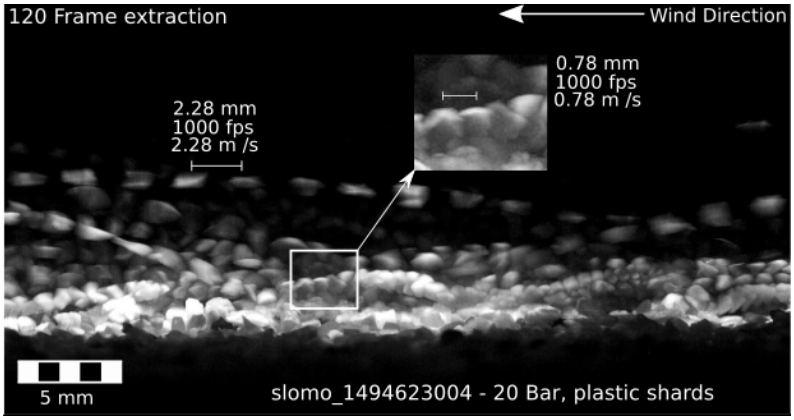

Figure 1. Transport paths of plastic chips in the Titan Wind Tunnel illuminated by a laser light sheet aligned parallel with the wind direction. Time lapse composite at 1000 Hz, 15 bar (ν = 1.02 $^{-6}$ m^2 s^{-1}, Re_{unit} = 833 000).

Recent experiments into sediment threshold have been conducted under Titan analogue conditions using kinematic viscosity as the similitude parameter in the Titan Wind Tunnel (TWT), the refurbished Venus Wind Tunnel [1] at the Planetary Aeolian Laboratory, NASA Ames Research Center, [1-4]. The results from these experiments illustrate differences in the grainscale mechanics of entrainment and transport between these and Earth ambient conditions. Observations of entrainment and transport made using high speed videos (Fig. 1) show a dominance of horizontal translational motions. These motions are similar to the wobble, rolling, saltation continuum observed under Venus analogue conditions in the Venus Wind Tunnel [5,6]. We find the grains are entrained through horizontal motions such as translation, rotation, or skipping [3], and attribute this change to an increased importance of fluid entrainment. Fluid entrainment occurs when grains are lifted from the bed primarily through fluid drag, and is distinct from impact entrainment resulting from a saltator impact. Under Earth ambient conditions, fluid entrainment is significant for the initiation of transport, but once begun transport is maintained through saltation, and fluid entrainment is of little to no importance. Under Titan conditions fluid entrainment appears to be of primary importance under at least low to moderate wind speeds [7]. Feedbacks within the terrestrial saltation cloud provide similarity that may be utilized by modellers [e.g. 8]. Without dominance of saltation impact processes, transport on Titan may scale differently than on Earth.

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Study on the processes of wind erosion

Wang Xuesong[1], Zhang Chunlai[1], Shen Yaping[1], Huang Xiaoqi[1], Li Jiao[1], Ceng Songbo[1], Zou Xueyong[1]
1. State Key Laboratory of Earth Surface Processes and Resource Ecology, MOE Engineering Research Center of Desertification and Blown-sand Control, Faculty of Geographical Science, Beijing Normal University, No. 19 Xinjiekouwai Street, Beijing 100875, China

Key words Dynamic process; wind erosion; shear velocities; aerodynamic roughness length; duration.

Aeolian sand transport is a complicated system in which many parameters like shear velocities, aerodynamic roughness length, sand transport rate, erosion rate and sand trap efficiency etc. are dynamic as erosion progresses. Whilst many aeolian studies have averaged these parameters. Using this method indeed can simplify the analysis procedure and make the results easy to understand. However, it also causes the results deviating from the true values without doubt. So, we aim to preliminarily investigate the dynamic changing process of wind erosion by measuring some parameters continuously at sufficiently high frequencies, for helping people to understand this complicated process more clearly. Results show that the shear velocities (u_*) and aerodynamic roughness length (z_0) are not fixed values but decrease with time in the process of sand transport. Functions that describe their changing trends have been attained for differing wind velocities. At two different wind speed levels (low wind level at which parts of sand particles are erodible and high level that the whole sand particles are erodible), the sand transport rate (q) also shows distinct variation tendency. The duration of an erosion event (T) has an obvious effect on erosion rate (Q_s) and sand trap efficiency (ε) which in turn will affect the establish of wind erosion model or sand transport rate model. The relationships between erosion duration and erosion mass (Q) and sand trap efficiency have been attained.

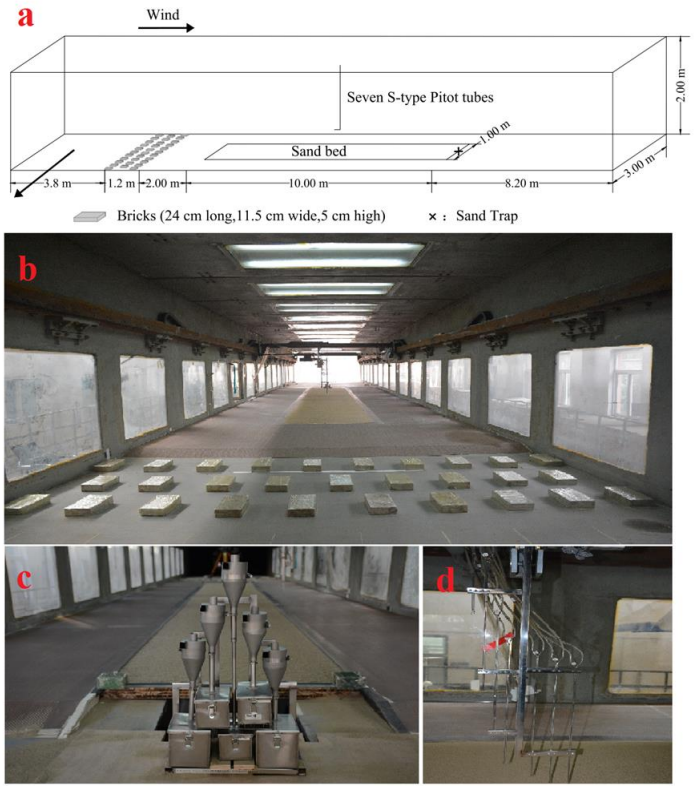

Figure 1. The experimental instruments and layout. a. Schematic diagram of the test section of the wind tunnel. b. A photo of the test section of the wind tunnel. c. A photo of the sand trap. d. The seven S-type Pitot tubes.

NUMERICAL STUDY OF SHEAR STRESS DISTRIBUTION OVER SAND RIPPLES UNDER TERRESTRIAL AND MARTIAN CONDITIONS

A. Siminovich[1], T. Elperin[1], I. Katra[2], J. F. Kok[3], R. Sullivan[4], S. Simone[5,6] & H. Yizhaq[7]
[1]*Department of Mechanical Engineering, The Pearlstone Center for Aeronautical Engineering Studies, Ben-Gurion University of the Negev, Israel*
[2]*Department of Geography and Environmental Development, Ben-Gurion University of the Negev, 8410501, Israel*
[3]*Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, California 90095, USA*
[4]*Cornell Center for Astrophysics and Planetary Sciences, Cornell University, Ithaca, NY 14853, USA*
[5]*INAF Osservatorio Astronomico di Capodimonte, Via Moiariello 16, 80131 Napoli, Italy*
[6]*SETI Institute, Carl Sagan Center, 189 North Bernardo Avenue, Mountain View, California 94043, USA*
[7]*Swiss Institutes for Dryland Environmental and Energy Research, BIDR, Ben-Gurion University of the Negev, Midreshet Ben-Gurion, Israel.*

Key words impact ripples, saltation, reptation, ANSYS Fluent, Mars, COMSALT

Ripples in a range of sizes occur on Earth and Mars. From terrestrial studies, ripple size is known to depend on grain size-frequency, wind duration, wind strength (including stronger winds that can flatten ripples), as well as fundamental environmental factors that differ between the two planets. Here, we use Computational Fluid Dynamics (CFD) experiments to model boundary layer shear stresses applied to aeolian ripple surfaces, to investigate how this might differ between Earth and Mars. CFD experiments used ANSYS Fluent, with inlet wind speeds of 10 m/s and 15 m/s for both planetary environments (Fig.1). Ripple profiles for Earth and Mars were developed using saltation and reptation properties modeled by the numerical saltation model COMSALT [1] to develop ripple profiles using the numerical technique of Yizhaq et al. [2]. Although the CFD experiments using these inputs could not include the effects of a saltation cloud, results are robust enough to indicate clearly that for similar modeled wind speeds on Earth and Mars, boundary layer shear stress applied to ripple surfaces is greater on Earth. This indicates that fluid shear stress is a more important factor for controlling ripple size on Earth than on Mars.

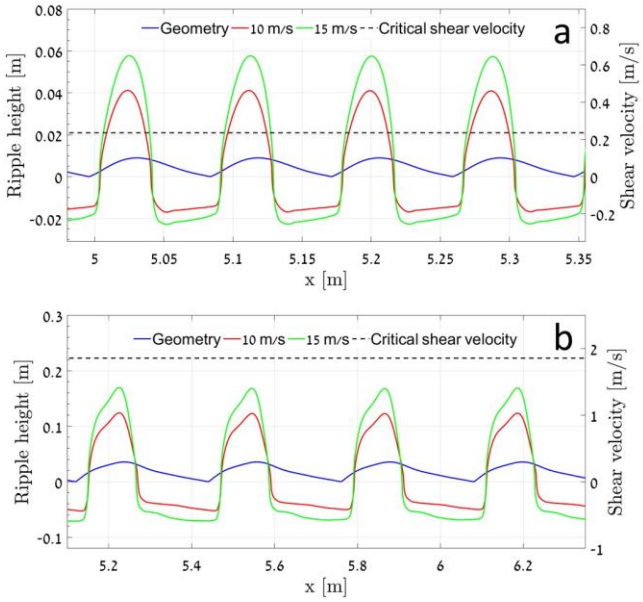

Figure 1. Shear velocity over the ripples (in blue) for two wind velocities 10 m/s (red) and 15 m/s (green) for Earth (a) and Mars (b). The dashed line shows the calculated fluid shear velocity threshold velocity based on Shao and Lu, 2000 for 100 μm particles. For Earth conditions the shear velocity is above the fluid threshold velocity at the crest and at part of the stoss slope, whereas for under Mars conditions $u_* < u_{*_t}$ for the entire ripple profile.

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Sand source, age and formation mechanism of sand dune field on the Right Bank of Middle Xiangshui River in the Xiliaohe Plain, Northeast China

Yong Wang[1], Guang Han[2], Ping Yan[1], Wei Wu[1]
[1]*Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China*
[2]*College of Resources and Environment, Hunan Normal University, Changsha 410081, China*

Keywords: Riverine dune; Aeolian-fluvial interactions; Sand source; Age; Formation mechanism

Abstract: The sand dune field of the Xiangshui river as branch of Xar Moron river is typical riverine dune, and is mainly barchan chain. A series of sample is collected along the main wind direction, and the material source, forming age and formation mechanism of riverine dune are researched by the analysis of grain size, heavy mineral and optically stimulated luminescence. The results are as follows: (1)Dune sand nearby valley mainly come from strata of the right valley slope, and dune far away from valley mainly obtain sand material from interdunes. (2)The formation time of dunes in study region are different, and on the whole, the cycle time is about 800 to 2,400 years. (3) The disturbance of the valley to airflow plays an important role during the formation of riverine dune, and the fluctuation of airflow and formation of the waveform dunes are a kind of mutually derived relationship.

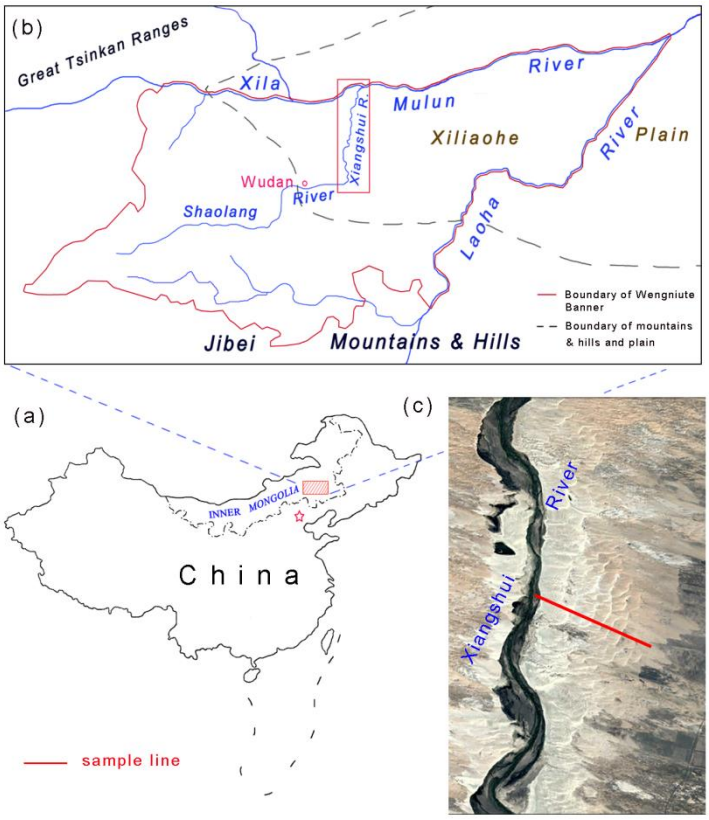

Figure 1. The location of study area

SESSION

« Coastal environments »

Transgressive Sand Dunes (TSD): Genesis and Evolution

E. Barboza[1], S. Dillenburg[1], M. Rosa[1], & F. Caron[2]
[1]*UFRGS, Instituto de Geociências, Centro de Estudos de Geologia Costeira e Oceânica (CECO), Porto Alegre, RS, Brazil*
[2]*UFRGS, Campus do Litoral, Tramandaí, RS, Brazil*

Key words Coastal evolution, Remote Sensing, climate changes.

Coastal systems dominated by waves present foredunes as the first depositional system derived from wind action. Along the Holocenic coastal barrier of the Pelotas Basin, Southern of Brazil, in addition to the presence of foredunes, transgressive sand dunes (TSD) are also found in the progradational record of this barrier. Through satellite image analysis and field observations, the formation of a modern and extensive TSD was identified over 100 km along the Holocenic coastal barrier, between the Albardão Lighthouse and the Hermenegildo Balneary. According to multitemporal analysis, this dunes transgressed 200 m during the last 15 years. The process is associated with the death of the vegetation that fixes the sands in the foredune system. This vegetation consists mainly of *Panicum racemosum* and *Spartina ciliata*, which promote this bioconstruction (foredunes). Along the stratigraphic record, related to the evolution of the Holocenic coastal system in the Pelotas Basin, several phases of occurrence of this TSD morphology are found. To the north along the progradational Holocenic barrier of Casino phases formed in the last 5 ka occur, with greater expression in the last 0.3 ka. Also, to the north in the progradational holocenic barrier of Curumim, these phases were formed in the last 7 ka. Thus, it is suggested here that the genesis of TSD is directly related to the death of the vegetation that constructs the foredunes, and that this death should be related to changes in climatic and/or oceanographic conditions along some sectors in the Pelotas Basin. It is suggested that future studies should investigate which is the main forcing factor that produces changes in physical conditions that promotes the death of the vegetation.

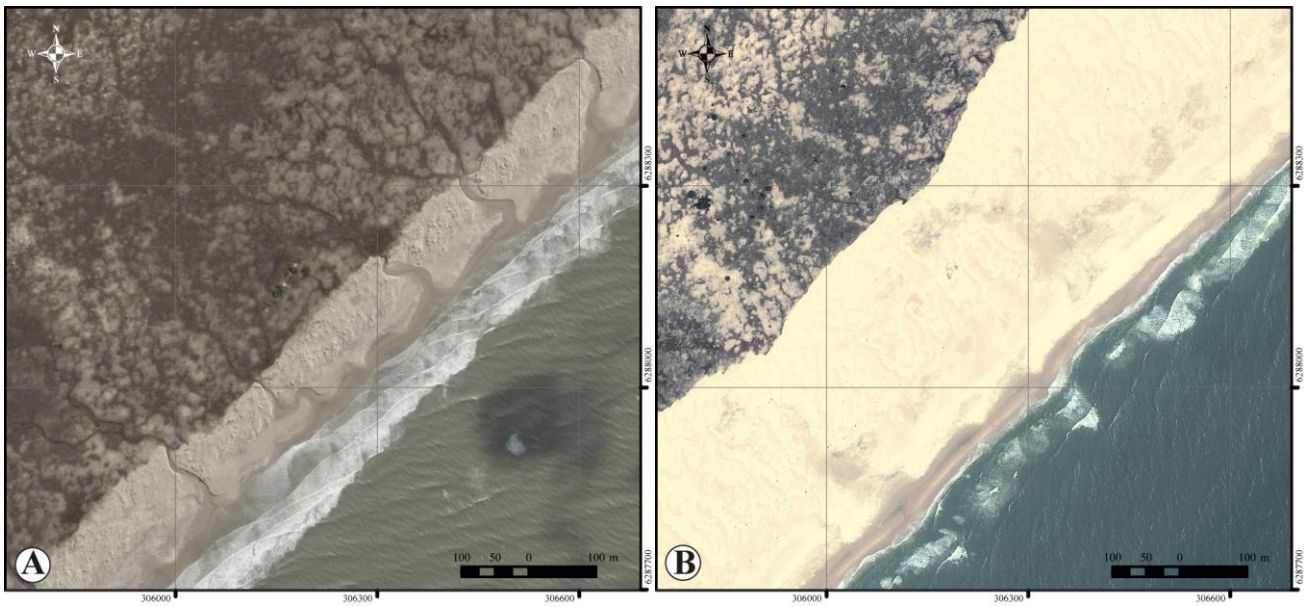

Figure 1. Satellite images [1]. A) Image of the year 2003, there is a foredune field and a small grove with two houses in the middle of the picture; B) Image of the year 2013, observe the formation of an extensive TDS, transgressing 200 m towards the mainland, and the covering the grove and houses.

References

[1] Source: Google™ Earth Pro

Linking short-term dynamics with the long-term evolution of a parabolic dune

I. Delgado-Fernandez[1] & T.A.G. Smyth[2]
[1] *Department of Geography, Edge Hill University, Ormskirk, Lancashire, L39 4QP, UK*
[2] *Department of Geography and Environmental Science, Liverpool Hope University, Hope Park, Liverpool L16 9JD, UK*

Key words Parabolics; coastal dunes; multi-scale evolution.

Multi-scale approaches in examining the evolution of aeolian landscapes at the coast are relatively rare due to the limitations imposed by a paucity of adequate environmental data. Research efforts tend to focus on short-term, process-driven dynamics (over hours) up to medium to long-term (months to years) landscape trends, with few studies actually incorporating a range of temporal/spatial scales [1, 2, 3]. A number of benefits exist in the linking of long-term landscape change analysis to the knowledge of the processes generating them, including improved modelling approaches, enhanced understanding of how the landscape functions as well as more informed science-led management. This study presents results from a multi-temporal scale approach to understanding the growth and evolution of a parabolic dune in a coastal dune field in NW England. A combination of historical (7 decades) aerial mosaics and medium-term (decadal and yearly) analysis using DEMs of Difference (DoD) enables quantification of morphological and volumetric changes from the initial stages of the parabolic to the present day. These can be compared with long-term records of potential transport events based on analysis of wind and weather records collected from nearby meteorological stations. On-site transport data measured within the parabolic allows then for the quantification of actual transport rates at the short-term (hours). The ability to combine multi-temporal scale data provides important insights into parabolic dune mobility and growth, and facilitates the identification of primary controls on landform evolution at different temporal time-scales [4].

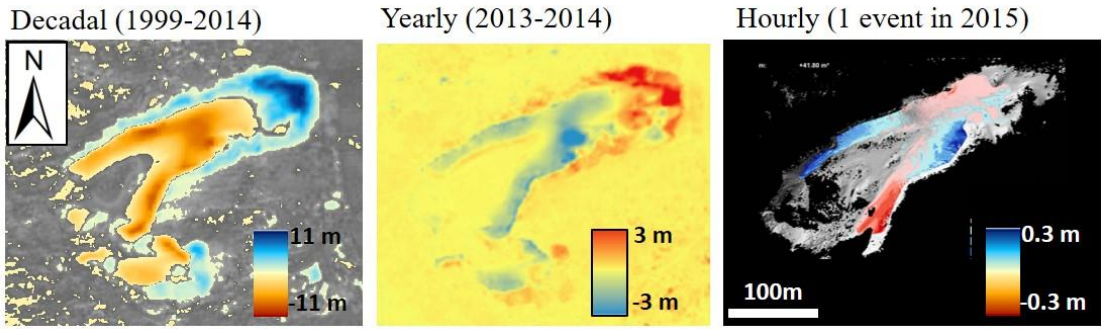

Figure 1. Morphological changes inside a parabolic dune at different temporal scales (Sefton Dunes, NW England).

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The combined role of marine and aeolian sediment transport in the formation of coastal foredunes

S. de Vries[1], B. Hoonhout[2]
[1]*Delft University of Technology, Delft, The Netherlands.*
[2]*Deltares, Delft , The Netherlands*

Key words Supply limited coastal sediment transport, conceptual model, field measurements, numerical simulation.

Coastal foredunes are aeolian features that are formed by a combination of marine and aeolian sediment transport processes. Marine sediment transports that shape the coastal dunes typically happen during storms when coastal foredunes are exposed to highly energetic marine conditions with high water levels and/or large waves in a relatively short period. Marine processes mainly have an erosive effect on the formation of foredunes. Compared to aeolian forces, marine forces are capable of transporting large amounts of sediment in a short period of time.
Aeolian sediment transports that shape coastal dunes happen when winds are sufficiently strong to transport sediment and sediment supply is available. Research has shown that limitations in sediment supply can have a dominant effect on the magnitude of sediment transport in the coastal system (De Vries *et al.*, 2014). Especially the tide can have a dominant effect on instantaneous aeolian sediment supply and aeolian sediment transport, see Figure A. However, the relative importance between marine and aeolian sediment transport on coastal foredune formation remains unclear when considering longer timescales.

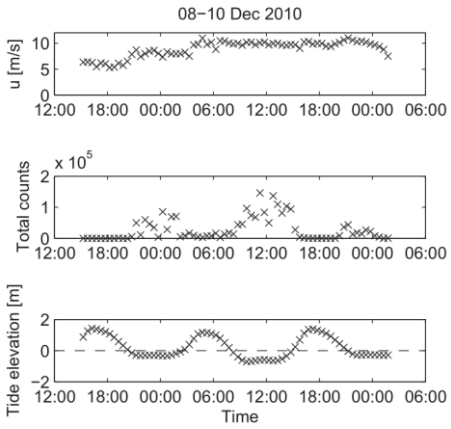

Figure A. Measured temporal variability of wind speed (top panel); Sediment transport at the upper beach (middle panel); tide (Bottom panel) during a 48 hour period. Notice the temporal correlation between tide and measured aeolian sediment transport. (de Vries et al 2014)

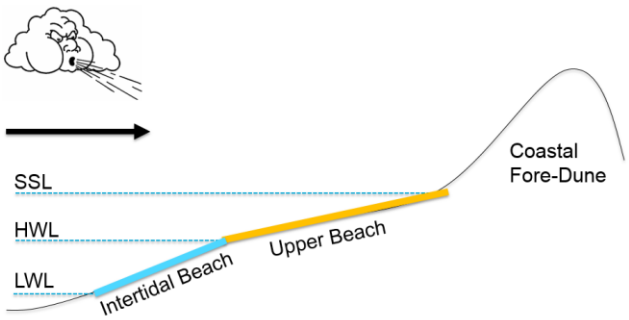

Figure B. Conceptual model of the coastal zone used to distinguish the relative importance between marine and aeolian sediment transports. LWL is low water level, HWL is high water level, SSL is storm surge water level.

In this paper we evaluate the relative importance of marine and aeolian sediment transports in the formation of coastal foredunes. We developed a conceptual model that is based on the conservation of sediment in the aeolian coastal system and the exchange of sediment with the marine coastal domain (see figure B). The conceptual model comprises 3 aeolian zones that are distinguished based on the frequency of occurrence of marine and aeolian processes. We distinguish the:

1. Intertidal zone (marine and aeolian processes alternate every tide)
2. Upper beach (marine processes occur once per month-year, aeolian processes occur daily)
3. Coastal foredunes (marine processes occur only incidentally, aeolian processes occur daily)

We have further quantified this conceptual model by using in-situ measurements of topographic changes in the three zones, in combination with numerical modelling using a grain size selective model for sediment supply and wind transport capacity (by Hoonhout and De Vries, 2016). The results highlight the role of occasional marine events in the temporal variability of aeolian sediment supply and transports. Moreover, the results support the hypothesis that coastal aeolian sediment transport can be supply-limited and sediment supply is largely governed by marine processes.

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Local wind characteristics over a beach-foredune morphology

W. de Winter[1], B.G. Ruessink[1], J.J.A. Donker[1] & G. Sterk[1]
[1] *Department of Physical Geography, Utrecht University, The Netherlands*

Key words field data, spatial variability, mean wind speed, turbulent kinetic energy, wind direction

Coastal dunes act as a primary defense against flooding of the hinterland during storms from sea. To predict dune erosion by wave action, advanced numerical models can be used in both scientific projects and policy-making. However, coastal foredunes recover in between storms by aeolian sediment transport from the (intertidal) beach. Predictive models for dune recovery are still in their infancy because of, among a number of aspects, the potentially strong spatial variability in wind characteristics on the beach. Mean wind characteristics (speed and direction) are likely to vary across the beach due to the presence of the foredune front. Furthermore, because aeolian transport is strongly intermittent, a better understanding of wind turbulence across the beach is needed to improve sediment transport predictions. In our research we examine the spatial variability of mean wind velocity and direction, and of turbulence at the beach of Egmond aan Zee, The Netherlands.

Three-dimensional wind velocities were measured at a height of 0.9 m and a frequency of 10 Hz. We used 4 to 6 ultrasonic anemometers in a cross-shore array between the waterline and the dune foot, depending on the beach width. During two 6-week field campaigns in autumn 2015 and 2017 and three additional days with strong winds (winter 2017), measurements were performed nearly every day during daytime. This resulted in an extensive dataset with mean wind speeds ranging from no wind up to 15 m/s. The velocity data were processed into a 10-minute mean velocity ($\bar{u}$), mean turbulent kinetic energy (TKE) and wind direction.

Results show that during onshore obliquely incoming winds the mean wind velocity is decreasing from the waterline towards the dune foot, while the TKE remains constant over the beach and is slightly higher at the dune foot. As a result, the gustiness increases towards the dune foot. Also, the wind direction is steered substantially in the alongshore direction, especially near the dune foot. The mean wind velocities can be 1.5 times higher at sea compared to the dune foot. During the more alongshore winds, wind speed and TKE are spatially more uniform and the wind direction is steered less in the alongshore direction.

The effect of a coastal foredune on local wind patterns has the potential to substantially reduce the aeolian sand supply to coastal foredunes, because the drop in velocity near the dune foot reduces pick up rates and promotes deposition. Our findings show that in order to accurately predict aeolian sand supply to coastal foredune systems, at least the effects of local wind patterns should be incorporated. Moreover, a quadratic relation between TKE and windspeed, a basic assumption for most sediment transport equations, was not found here. Instead, the TKE-windspeed ratio is spatially variable. Further research is needed to elucidate the role of turbulent structures and spatial variation herein on sediment pick up rates.

Figure 1. An ultrasonic anemometer in front of the high and steep foredune at Egmond aan Zee, The Netherlands.

Records of Aeolian activity potentially related with the Little Ice Age in Regressive Coastal Barriers of Southern Brazil

S. Dillenburg[1], P. Hesp[2], E. Barboza[1], M. Rosa[1], F. Caron[3], A. Sawakuchi[4], & S. Forman[5]
[1]*UFRGS, Instituto de Geociências, Centro de Estudos de Geologia Costeira e Oceânica (CECO), Porto Alegre, Brasil*
[2]*Flinders University, School of Environment, Adelaide, Australia*
[3]*UNIPAMPA, Caçapava do Sul, Brasil.*
[4]*USP, Instituto de Geociências, São Paulo, Brasil*
[5]*Baylor University, Waco, United States*

Key words OSL ages, Cassino, Pinheira.

The Little Ice Age (LIA) was active worldwide from 1300 to 1850. In the last 15 years many papers have indicated the dominance of arid and cold conditions during the LIA in southern South America. In southern Brazil two well-studied regressive barriers (Cassino and Pinheira) are marked by their complex nature, in the sense that they display two or more different dune types or landforms on the surface. Both barriers present many phases of dune formation. While at Cassino the dunes are low relief Transgressive Sand Sheets (Fig. 1A), at Pinheira they are low to medium relief Parabolic Dunes (Fig. 1B). These two barriers have in common historically modern phases of dune formation connected to the modern foredune-beach system. These phases were dated by OSL as active at least from 91 to 345 years ago. Presently these dunes are completely vegetated and stabilized as a result of an historical increase in precipitation and decrease in wind drift potential in the last few decades. The two barriers also present reworked aeolian deposits located landwards and dated at 253 (Cassino) and 365 (Pinheira) years ago. These OSL ages of the dunes of Cassino and Pinheira indicate an aeolian activity on the southern coast of Brazil contemporary to the dry climate of the last pulses of the LIA.

Figure 1. Aerial photos showing active phases of aeolian construction. (A) Transgressive dune sheets at Cassino (1947), and (B) Parabolic dunes at Pinheira (1957).

DECADAL DYNAMICS OF INCIPIENT FOREDUNES IN A TIDELESS BEACH SETTING

J. Rotnicka[1], M. Dluzewski[2]
[1]*Institute of Geology, Adam Mickiewicz University in Poznan, Poland*
[2]*Faculty of Geography and Regional Studies, University of Warsaw, Poland*

Key words incipient foredune dynamics, sand availability, fetch distance, sand transport rate, foredune sediment budget

Dynamics of foredune growth depends on aeolian sediment input resulting from wind action and sand availability. The key to analysis this process is the direction of effective wind and beach orientation and width. In the case of effective wind parallel to the coast, when the beach is dry enough to allow sand deflation, the fetch distance is unlimited and sandflow is usually saturated. In the case of effective wind oblique to the coast, the sand transport rate under given wind direction is controlled by beach width. However, when the beach is wide enough, shore normal or oblique winds generate intense sand transport toward the foredunes causing their significant growth.

The aim of the research was to study the dependence of incipient foredunes dynamics from aeolian sediment input in a decadal scale. To analyze the sediment input, following main factors were taken into account. First, the available fetch distance was analyzed on the basis of wind speed and direction data and beach width. The latter was determined on the basis of sea level and storminess data. The 10-year hourly wind data was shared by the National Meteorological Station (IMGW) in Łeba and 10-year hourly sea level data was obtained from a sea-level recorder installed in the Łeba harbor by the Institute of Meteorology and Water Management (IMGW), both situated about 18 km east of the study site. Second, potential sand flux was calculated on the basis of formulae established for: (i) alongshore saturated sand flux, (ii) onshore unsaturated sand flux, (iii) onshore saturated sand flux, and (iv) total sand flux (onshore + alongshore sand flux) [1]. In the case of onshore wind, the potential sand flux was calculated only for the available fetch distance greater than 20 m.

The incipient foredune dynamics was analyzed on the basis of more than 10-year seasonal measurements of 6 beach-foredune profiles. The profiles were located within tideless Baltic Sea coast of Łeba Barrier, Poland. The distance between the easternmost and the westernmost profiles equaled to ca. 5.5 km and the coastline orientation at this part of the barrier differed by about 20°. The sediment budget was calculated for these sections of profiles where the sand accumulation and/or erosion were related to aeolian processes only. The established foredunes were not taken into account in sediment budget calculation. The profiles were measured at every point that marked visible change in the topography (on average 3-5 points on 1 m of the profile) but the sediment budget was recalculated for every 0.5 m of the profile. The older profiles were measured using a total station and younger – using RTK differential GPS. The vertical and horizontal precision of profiling was of 1-2 cm.

The obtained results showed that in the periods of onshore wind, the 20° difference in the coast orientation resulted in 4-fold difference in the amount of potential sand input from the beach to the foredunes. In the case of alongshore wind, this difference was 2-fold. During 10 years of investigations, the calculated potential sand input caused by saturated onshore wind was about 5 times greater than sand input caused by unsaturated onshore wind, independently from the coast orientation. The rates of sand flux generated by alongshore saturated airflow was about 10 times greater than the unsaturated onshore sandflow. In all profiles analyzed within study area, in the part of incipient foredunes modified by aeolian processes only, deposition prevailed over erosion. The 20° differences in the coast orientation resulted in 2-fold difference in the average amount of sand deposited annually within incipient foredune. Independently of the coast orientation the sediment budget strongly correlated with time in which foredune dynamics is analyzed.

All results showed that, despite the rate of potential sand transport was much greater in the case of alongshore saturated sandflow than in the case of unsaturated onshore sandflow, the relationship between potential sand flux and foredune growth was statistically significant only when onshore unsaturated sand flux was taken into account. It proves that the direction of effective wind and sediment availability controlled by beach width and angle of wind attack are the most important factors in analysis of foredune dynamics.

The research was supported by grants from Polish Ministry of Science and Higher Education (2/PO4D/008/28) and National Science Center (2012/05/B/ST10/00680).

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AEOLIAN TRANSPORT AND BARRIER ISLAND RESPONSE TO SEA LEVEL RISE

O. Duran Vinent[1] & L.J. Moore[2]
[1]*Texas A&M University, College Station, USA*
[2]*University of North Carolina—Chapel Hill, Chapel Hill, USA*

Key words sediment transport, coastal dunes, barrier islands.

Barrier islands represent about 10% of the world's coastline, sustain rich ecosystems, host valuable infrastructure and protect mainland coasts from storms. We recently proposed[1] that island response to external drivers, such as storms and sea level rise, is intrinsically bistable and controlled by previously unrecognized dynamics: the competing, and quantifiable, effects of storm erosion, sea level rise, and the aeolian and biological processes that enable and drive dune recovery. When the biophysical processes driving dune recovery dominate, islands tend to be high in elevation and vulnerability to storms is minimized. Alternatively, when the effects of storm erosion dominate, islands may become trapped in a perpetual state of low elevation and maximum vulnerability to storms, even under mild storm conditions. When sea level rise dominates, islands become unstable and face possible disintegration. This suggests aeolian sand transport plays a fundamental role in the response of barrier islands to sea level rise, not so much because it controls the formation and size of coastal dunes but mainly because it drives the after-storm island recovery. Indeed, simulations show that immediately following an overwash event, island elevation is too low to sustain the growth of 'dune-building' plants. In the absence of vegetation, small non-vegetated dunes slowly nucleate at the back of the beach in response to the interaction between morphology and wind flow following the same mechanisms as the nucleation of desert dunes. Once sand elevation is sufficiently high to allow vegetation recovery, vegetated dune growth begins as plants trap sand, thereby accelerating vertical accretion and leading to rapid dune building. Consideration of the processes behind vegetation recovery, and thus dune and island recovery, shows that the vegetation recovery time increases with relative sea level rise because the rate of net surface accretion—which prevents frequent salt-water inundation of the backshore and leads to vegetation recovery—is the difference between the aeolian-driven growth rate of the non-vegetated incipient dunes and the rate of relative sea level rise. We propose that the aeolian-driven growth rate scales as the ratio of the mean aeolian sand flux at the beach, an increasing function of wind intensity and (dry-) sand supply, and the non-vegetated dune wavelength. The vegetation recovery time, and thus coastal dune recovery time, then relates the primary factors influencing vegetation and dune recovery: vegetation sensitivity to inundation, aeolian transport, and sea level rise.

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ANALYZING THE EFFECT OF BEACH WIDTH CHANGES ON COASTAL DUNE DEVELOPMENT USING A CELLULAR AUTOMATA MODEL

F. Galiforni Silva [1], K. M. Wijnberg[1], A. V. de Groot[2] & S. J. M. H. Hulscher[1]
[1] *Water Engineering & Mangement, Faculty of Engineering Technology, University of Twente, P.O.Box 2217, 7500 AE Enschede, The Netherlands*
[2]*Wageningen Marine Research, Wageningen University & Research Postbus 57, 1780 AB Den Helder, The Netherlands*

Key words: Cellular automata models, coastal dunes, beach width, sediment supply.

The cellular automata model DUBEVEG [1] is used to evaluate the effect of beach width changes on the development of coastal dune systems. The model simulates the effects of Aeolian transport, hydrodynamic erosion and accretion, groundwater and vegetation growth. Twenty different beach profiles were constructed, with beach width ranging from 50 to 1000 meters, based on topographic measurements of real beach-dune systems. Simulations were carried out for a 90-year period for both unlimited and limited sediment supply conditions which were regulated by groundwater depth. The final topographies were compared based on morphological characteristics such as dunefoot position and volume increase. Results show that the distance between dunefoot and the waterline varies according to the supply condition, being closer to the waterline for unlimited supply cases (Figure 1). Furthermore, the position of the seaward most dunerow stabilizes after the first 15-30 years of simulation, suggesting not only an initial horizontal expansion before a vertical growth dominance, but also the delimitation of space on which dunes can actually develop. Regarding dune volume, values increased proportionally with the beach width for an unlimited supply scenario. However, for a limited supply condition, the effect of beach width on dune volume only appears for beach widths larger than 300 meters, suggesting that limitation in supply due to local conditions can dominate dune growth over beach width. These results suggest that for a decadal scale, beach width controls the space available for dune formation, thus the position of the most seaward dune, but the effect of beach width on dune volume can be overruled by other supply limiting conditions such as groundwater depth.

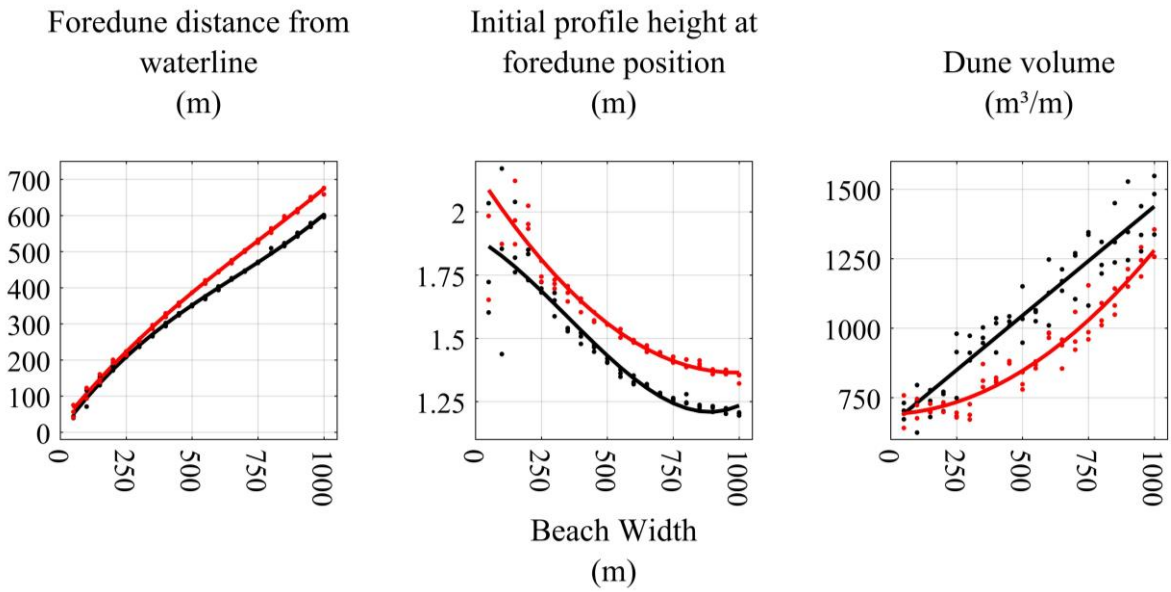

Figure 1. Beach-dune morphological characteristics after 90-year simulations. Black curves represent unlimited supply scenarios, whereas red curves represent limited supply scenarios.

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Wind Regime and Aeolian Landforms on the Eastern Shore of the Qinghai Lake, Northeastern Tibetan Plateau, China

Guangyin Hu[1], Zhengcai Zhang[1], Zhibao Dong[2], Linhai Yang[1]& Patrick Hesp[3]
[1] *Key Laboratory of Desert and Desertification, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, China*
[2] *School of Geography and Tourism, Shaanxi Normal University, Xi'an 710119, China*
[3] *School of the Environment, Flinders University, South Australia 5042, Australia*

Key words Wind Regime; Aeolian Landform; Qinghai Lake; Tibetan Plateau.

Wind regime is typically highly variable in space and in time, and the studies of aeolian geomorphology often use a single meteorological station as representative of a specific dune field due to the scarcity of meteorological stations in remote areas. For example, researchers have used the wind data recorded in Gangcha meteorological station (13 km to the north of the Qinghai Lake) to analyze the aeolian landforms of the dune field on the eastern beach of the Qinghai Lake, which is the largest lake in China covering an area of 4436 km^2, with an altitude of 3194.65 m above sea level in 2015 [1]. However, wind regime may vary greatly even between sites located just a few kilometers apart. In this study, to fully understand the relationship between wind regime and aeolian landforms of the dune field on the eastern beach of the Qinghai Lake, one year's hourly recorded wind data of 2012 from four stations, namely Gangcha Station, Eri Station, Wendu Station and Daotanghe Station was used to analyze the wind energy. According to Fryberger and Dean's [2] model, the variables of drift potential (DP), resultant drift potential (RDP) and resultant drift direction (RDD) were used to examine the correspondence between wind energy and aeolian landforms. The wind data revealed that drift potential (DP) of Gangcha, Eri, Wendu and Daotanghe stations is 144, 537, 829 and 431 VU, respectively. The resultant drift potential (RDP) of Gangcha, Eri, Wendu and Daotanghe stations is 112, 143, 544 and 125 VU, respectively. The value of the directional variability index RDP/DP is 0.78, 0.27, 0.66 and 0.29, respectively. In addition, the resultant drift direction (RDD) were 106 °, 325 °, 266 ° and 157 °. The high-energy wind environment in addition to multidirectional and locally highly variable wind regime are principal factors responsible for the coexistence of several types of aeolian landforms (eg. Transverse, star, and reversing dunes).

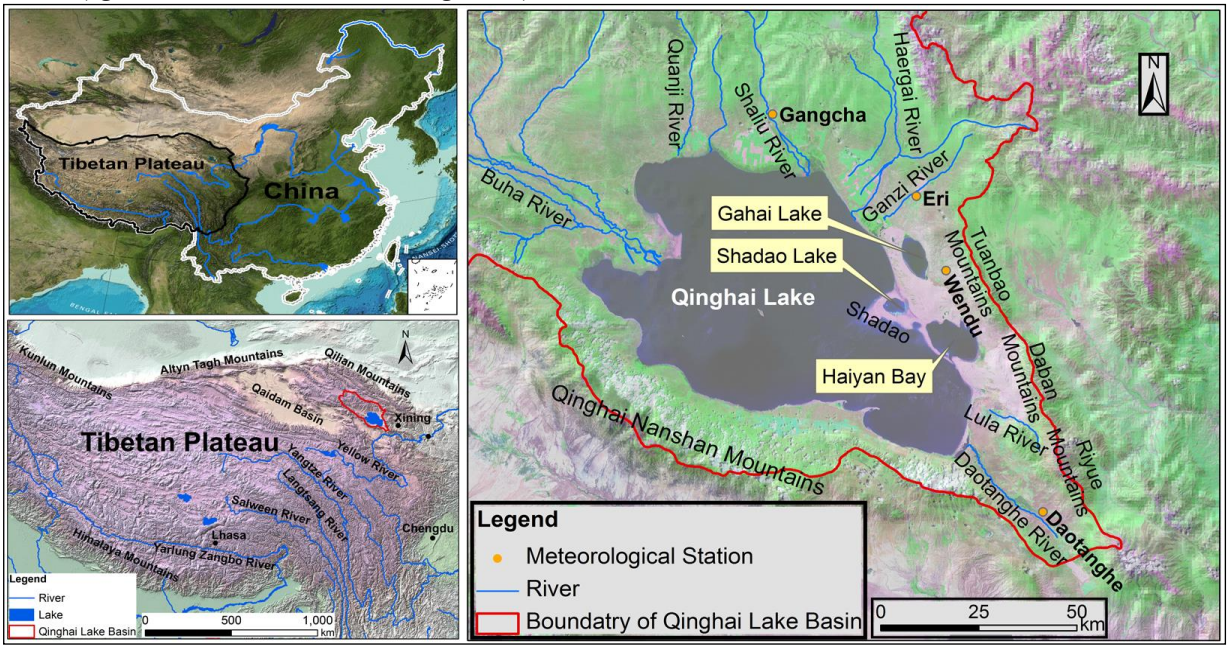

Figure 1. Location map of the Qinghai Lake and the distribution of the major dune field on the eastern beach.

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ARID AEOLIAN SEDIMENTARY SYSTEMS ON HOT-SPOT VOLCANIC ISLANDS: FROM THE SIGULARITY TO THE PARADOX. THE CASE OF THE CANARY ISLANDS

L. Hernández-Calvento
Grupo de Geografía Física y Medio Ambiente, Instituto de Oceanografía y Cambio Global, IOCAG, Universidad de Las Palmas de Gran Canaria, ULPGC, Parque Científico-Tecnológico de Taliarte, Calle Miramar, 121, 35214 Telde, Las Palmas, Spain.

Key words hot-spot volcanic islands, transgressive dunefields, arid foredune, nebkhas, human interactions.

The Canary Islands are a group of seven major islands, a minor island and five islets, located in the Atlantic Ocean (27°-30° N latitude, 13°-19° W longitude). The beginning of this volcanic archipelago dates from more than 20 mys. The volcanic activity has followed a displacement westward, generating an E-W chain. Its location on an old oceanic crust (165-176 myr), rigid and of slow displacement, determines the practical absence of tectonic subsidence. This results in periods of subaerial survival of atypical amplitude in oceanic islands, determining long term of erosional processes and the formation of aeolian coastal sedimentary systems, especially in the older eastern islands. In some cases, these systems extend along wide coastal stretches, encapsulating entire islands or parts of them. From this perspective, the aeolian sedimentary systems of the Canary Islands are singular.

These systems are conditioned by the coastal clime. The average annual temperature is around 20º C, the annual rainfall is around 100 mm and the NE trade winds are almost constant throughout the year. The arid conditions limit the development of the vegetation, by hydric stress. Plant density is low and halophilous and xerophilous shrubs predominate. As consequence, the first dunes generated by the plants (embryonic dunes) do not evolve into ridges. The nebkhas thus become characteristic landforms of both the primary stages of the dune formation and more advanced ones. All these bioclimatic conditions favor the mobility of the sediments toward inner areas all along the year, forming transgressive dune systems. Two types of these systems can be distinguished: transgressive dune sheets and transgressive dunefields, depending on the volume of sediment supply. The first ones consist of sandy plains where sand sheets and nebkhas generated by shrubby vegetation predominate. The size of the nebkhas is associated with the height of the plants that generates them, ranging from a few centimeters to 5 meters in height. Considering the degree of sand mobility, it is possible to distinguish between active and stabilized systems. The transgressive dunefields present a large mobile sedimentary volume and show a greater variety and complexity of aeolian landforms, as free dunes, erosive landforms, dunes conditioned by vegetation and by relief. There are two differentiated zones in them: active dunes and stabilized dunes. The first ones present two differentiated geomorphological and ecological units: the foredune and the mobile dunes. Due to the positive balance of sand, the moderate wind energy and the scarce vegetation, the foredune is constitute by nebkhas, mainly formed by *Traganum moquinii* shrub. This species acts as a pioneer and it is also present in the most advanced stages of plant succession. Recent studies indicate that sand burial stimulates its growth, favoring the formation of nebkhas. The nebkhas slow the sedimentary transport, forming shadow dunes. The entrance of dunes between nebkhas, and their contact with the shadow dunes, generates parabolic shape dunes that mark the transition to mobile dunes.

Changes in land use have had important implications for these aeolian sedimentary systems. We can distinguish two major stages, one historical, prior to tourism development (until 1960s-1970s) and another one recent and current (after these decades). By the eighteenth century these sandy systems lacked value on the part of society, since they were sterile spaces from the agriculture and for livestock. Mining, urbanization and the cutting of vegetation were the main activities that impacted on these systems. Since the 1960s and 1970s, there has been a change in the perception of coastal sandy systems, as a consequence of their exploitation as touristic resources. A significant part of them have become protected at different scales. In parallel, the pressure on these spaces has increasing during the last decades. Most of the changes in these systems have been motivated, directly or indirectly, by the development of tourism, the main actions being the mining and the construction of buildings and infrastructures. The human actions, continuous throughout the year, affect the natural processes, increasing the geomorphological fragility and making these systems increasingly vulnerable. A significant reduction in the surfaces occupied by most of the landforms is detected, some of which have disappeared. Given the role that it plays in the protection of these systems and in the development of their characteristic processes, the case of the foredunes is relevant. Also free dunes have been replaced by landforms of smaller volume or dynamics. On the contrary, stabilized dunes and deflation surfaces have experienced a considerable increase.

These changes imply the loss of attraction for the tourists, what becomes into a paradox. Especially if it is taken into account that the geomorphological processes that occur in the aeolian sedimentary systems of the Canary Islands are fundamental in the economic development of the archipelago. However, until now there are no management tools adapted to their functional particularities and the norm is the application of tools created to manage similar systems in temperate regions.

NEBKHA OR NOT: THE ROLE OF RAINFALL AND SEDIMENT SUPPLY IN CONTROLLING NEBKHA VS FOREDUNE RIDGE FORMATION.

Patrick Hesp[1] Luis Hernández-Calvento[2], , Antonio I. Hernández-Cordero[2], Juan B. Gallego Fernández[3] ,

Graziela Miot da Silva[1], and Marie-Helene Ruz[4]

[1]Beach and Dune Systems Lab, College of Sci and Engr., Flinders University, South Australia 5042, Australia
[2] Grupo de Geografía Física y Medio Ambiente, Instituto de Oceanografía y Cambio Global, IOCAG, Universidad de Las Palmas de Gran Canaria, ULPGC, 35214 Telde, Las Palmas, Spain.
[3] Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, P. Box 1095, 41080 Seville, Spain
[4]Laboratoire d'Océanologie et de Géosciences, UMR CNRS 8187, Université du Littoral Côte d'Opale, 32 Ave Foch, 62930 Wimereux, France.

Key words Foredunes; Nebkha; Climate; Sediment supply; NW Africa

Studies conducted on some arid coasts and coastal dunefields have noted that nebkhas are common, and continuous foredunes are absent or poorly represented While the formation of foredunes principally depends on a variety of factors including wind regime, sand supply, wave energy and surfzone-beach type, plant species present, impacts and frequencies of storms, and short to long term coastal dynamics (stability, progradation or retrogradation), we demonstrate that one principal factor determines whether continuous and semi-continuous foredunes or discrete nebkha types form. That factor is rainfall. The numbers of nebkha present was also analysed and sediment supply plays a major role in determining nebkha density.

We mapped the foredune types beach by beach along the NW coast of Africa extending from Tangier, Morocco in the north, through Western Sahara, Mauritania, to near Niodoir in Senegal near The Gambia border region, a distance of ~ 3500km and including the adjacent Canaries Islands. This coastal reach displays significant mean annual rainfall gradients ranging from ~50mm/yr to ~1200mm/year. There are also significant variations in sediment supply along this coast.

Overall, where rainfall is lower than ~340mm.year only nebkha are found, between around 340mm and 480mm discontinuous foredunes predominate, and above ~500mm/year continuous foredunes are found. Foredune type is also correlated with plant species. The dominant rhizomatous grasses species in the temperate zone of Morocco are replaced in the arid zones by halophilous shrubs, and then by shrub and stoloniferous shrubs and some grasses in the tropical regions in Senegal. The numbers of nebkha present are also correlated with sediment supply, with increasing numbers occurring as sediment supply declines.

DOES AEOLIAN SEDIMENTATION CONTRIBUTE TO CORAL CAY ACCRETION AND ISLAND DEVELOPMENT IN THE MALDIVES?

M. Hilton[1], T. Konlechner[2], D. Borrie[1], P. Kench[3], A. Ashton[4], D. Kennedy[2] & M. Aslam[5]
[1]*University of Otago, Dunedin, New Zealand*
[2]*National Centre for Coasts and Climate, School of Geography, University of Melbourne, Australia*
[3]*University of Auckland, Auckland, New Zealand*
[4]*Woods Hole Oceanographic Institute, Woods Hole, MA 02543, United States of America*
[5]*Small Island Research Station, Fares-Mathoda Island, Huvahdoo Atoll, Maldives*

Key words Coral reef island, cay, Maldives, aeolian sedimentation

The atolls of the Maldives contain over 1200 reef islands; including atoll lagoon islands and numerous sand cays on reef platforms. Sand cays are comprised entirely of biogenic sediments, primarily coral sand. Cay formation at nodal zones has been attributed to wave refraction and diffraction around and over reef platforms. They are unstable deposits that may meander within these zones. Unvegetated sand cays are low and commonly over-washed by local waves during high astronomical tides. They may also be inundated by swell waves generated in the southern Indian Ocean and tsunami. These processes are known to deposit sediment on vegetated islands, but over-wash is unlikely to contribute to cay accretion in the absence of vegetation. There remains, therefore, the conundrum of how cays transition to stable and forested islands? We hypothesize that aeolian sedimentation, in conjunction with stranded organic debris and the growth of early successional plant species, may contribute sufficient depth of sediment to allow the development of non-saline groundwater and the colonisation of islands by forest tree species.

This investigation arose from observations of ripples, shadow dunes and nabkha during a visit to the lagoon island of Maaodagalla (Huvadhoo Atoll). Maaodagalla is 28km north of the equator in the Indian Ocean. Early successional species colonised the island (by marine-stranded seed) following cay formation between 2010 and 2014. We observed wind speed and direction using Windsonic 2D anemometers mounted on a mast at 5.8, 0.53m and 0.05m. The mast was located on an unvegetated terrace at the eastern end of the island, approximately 0.10m above the level of spring high tides. Additional anemometers were positioned across the surface of this terrace. Aeolian sedimentation was observed using Wenglor laser particle counters over a period of 8 days, with swinging sand traps and erosion/accretion stakes. Samples were extracted from multiple pits dug across Maaodagalla, Maahutigalla (an adjacent forested island) and an unvegetated (and un-named) coral cay, to characterise and quantify the depth of the aeolian facies. Sediment samples were also obtained from the surface of the island and adjacent reef platform. Ground penetrating radar data was gained across multiple tracks on Maaodagalla and Maahutigalla. The pits were excavated to the water table which was intercepted 1.2-1.4m below the surface on Maaodagalla. Surface topography, nabkha and island morphology was surveyed using a laser level to a datum established by RTK-GPS and local mean sea level (derived from RBR deployments).

Incident wind direction was mainly from the north east during the period of fieldwork, consistent with the Northeast Monsoon (October to April). Incident wind speed was typically 4-6ms^{-1} at 5.8m, however, periods of wind speed in excess of 12ms^{-1} were recorded on two occasions. These events, which were characterised by periods of relatively high onshore wind speed lasting several minutes, followed by a reverse in wind direction, appear to be driven by low-level outbursts under cumulonimbus clouds. Wind speed at ground level (0.05m) during these events reached 8ms^{-1}. Saltation and ripple development occurred during these events, albeit the rates of sand flux were not high (with Wenglor counts up to 200/s). Our observations occurred during the relatively weak Northeast Monsoon. We conclude that aeolian sedimentation probably occurs frequently on Maaodagalla, particularly during the more energetic Southwest Monsoon.

The development of nabkha appears to make a significant contribution to island elevation. The elevation of Maaodagalla does not exceed 1.0m above the level of spring high tides and 0.6m above observed maximum wave run-up. Therefore, nabkha development has contributed most of the elevation (0.5m) of the island above the level of wave run-up. Of course, aeolian sedimentation may be occurring concomitant with overwash processes. The analysis of sediment texture and the GPR data is ongoing to determine the nature of the aeolian facies across the island and on Mahutigalla. A freshwater lens was found under Maaodagalla in almost all of the excavated pits, which indicates the cays do not need to accrete much to generate conditions for freshwater accumulation and the establishment of forest tree species.

TURBULENCE IN BOUNDARY LAYER FLOW OVER A SANDY BEACH SURFACE

Derek W.T. Jackson[1], Andreas C.W. Baas[2], and Alex Smith[3]

[1]*University of Ulster, Coleraine, UK*
[2]*King's College London, London, UK*
[3]*National University of Ireland, Galway, Ireland*

Key words longitudinal transect, coherent flow structures, Large Eddy Simulation

Aeolian sand transport is crucial for post-storm recovery of beach and dune systems, protodune formation and early stage embryonic dune forms that may go on to accumulate into foredune ridges. The sand transport process is driven by the momentum transfer from the local boundary layer to the surface. An important component of this process are the turbulent flow structures that are either impinging from the outer flow into the surface layer or that have been induced by the friction of the sediment surface and are advected along. The precise nature and origins of these turbulent structures in natural boundary layer flows in coastal environments is unclear. This paper reports on field measurements and CFD modelling of the boundary layer flow over a beach surface to investigate the near-surface turbulence.

Using three vertical masts equipped with 16 x 3D sonic anemometers (50Hz sampling) in an array orientated parallel to the general incipient wind flow over the beach, several runs extending over 3 hours, captured a range of wind conditions operating at a beach site in Maghera Strand, Co. Donegal in NW Ireland. Detailed Terrestrial Laser Scans of the sand surface were also made before and after sampling campaigns to give detailed topographic measurements of the beach. These surface scans provided an underlying surface for 3D Large Eddy Simulation (LES) airflow modelling using computational fluid dynamics model OpenFOAM.

The combination of CFD modelling and multiple in situ anemometer measurements allowed detailed examination of a longitudinal transect of the boundary layer and its turbulence behaviour as the boundary layer developed over the beach surface. We interrogated the measured airflow for larger scale eddy migration through the boundary layer along with smaller turbulence features near the sediment surface. The instrumented array also provided field validation of the 3D LES modelling.

We found excellent agreement between modelled (CFD) airflow modelling and 3D sonic anemometer data which provides a further validation of CFD as a tool for accurately characterising boundary layer flow over aeolian surfaces. The work also highlights the complex nature of boundary layer behaviour with a range of spatial and temporal scales shown in turbulent structures driving aeolian sediment transport on natural sandy beach environments.

THE ROLE OF SUMMER STORMS AND SEICHE IN EROSION OF FOREDUNES ALONG THE SOUTHERN SHORES OF LAKE MICHIGAN, USA

Z. Kilibarda[1] and S.G. Barajas[1]
[1]*Department of Geosciences, Indiana University Northwest, Gary, IN, USA*

Key words Lake Michigan, foredunes, blowouts, seiche, storms

There are abundant coastal dunes along the southern shores of Lake Michigan in Indiana, USA. Closest to the water are incipient foredunes, and further inland are established foredunes, blowouts, and parabolic dunes. During low levels of Lake Michigan the backshore is wide and incipient dunes develop and grow by trapping the sand, thus limiting sand accretion on established foredunes and parabolic dunes. At the times of high Lake Michigan level incipient, and sometimes established, foredunes are eroding and providing sand for parabolic dune growth. Lake Michigan level was lower than long term average from December 1998 to August 2014 allowing continuos development and growth of incipient foredunes. In January 2013 Lake Michigan level fell to 175.57 m, reaching the absolute minimum since the beginning of systematic lake level measurements in 1860. Incipient foredunes were 13 to 50 m wide, 2.5-4.5 m tall, and had some 30 to 50 m wide backshore to the water line. Lake Michigan level began rising in late 2013, surpassing the long term average in August 2014, and in July 2017 reached 177.06 m, or 1.49 m higher level than in January 2013. The backshore was shortened by 35-40 m and many incipient foredunes were partially or completely eroded, with 1-3 m high cliffs in places. Unlike the blowouts, which experience most sand transport and inland migration in the late fall to spring (October-April), most foredune erosion takes place during summer storms and seiche events. Lake Michigan levels are about 50 cm higher in summer than in winter, which shortens the backshore by about 12-13 m, allowing waves to more easily erode foredunes (Fig. 1) on stormy days when high waves (>2 m) are common. Most destruction of foredunes occurred in several seiches, the most severe of which occurred on July 20, 2017. At Indiana Harbor station five large pulses (lake level exceeded 177.3 m), and several smaller pulses of rising lake levels were recorded, with a maximum amplitude of 96.1 cm (Fig. 2).

Figure 1. Foredune erosion in Indiana Dunes State Park, August 31, 2016

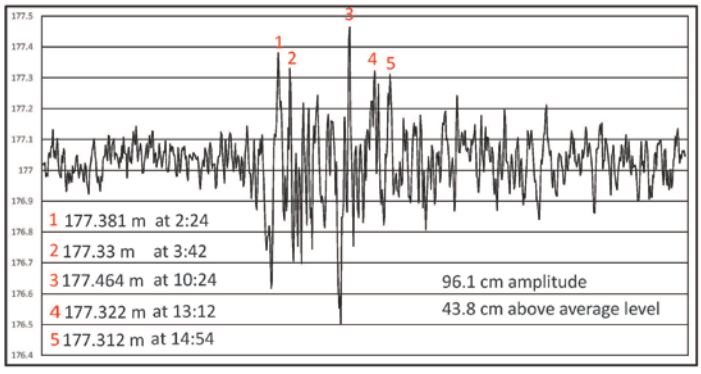

Figure 2. Indiana Harbor record of seiche on 20 July, 2017

Post-disturbance evolution of a prograded foredune barrier: the role of wind speed, wind direction and vegetation

T.M Konlechner[1]
[1]*National Centre for Coasts and Climate, School of Geography, University of Melbourne, Australia*

Key words foredune, dynamic restoration, mophodynamic readjustment, biogeomorphology

The evolution of dune landforms is influenced by wind (strength, direction) and vegetation (type, density, rates of colonization). Coastal dunes could, therefore, follow divergent evolutionary pathways in response to variation in wind or vegetation cover. Here we examine the influence of these factors on dune system evolution, during a sustained dune restoration programme at Doughboy Bay, New Zealand, over a 15-year period. Understanding how a system will respond to disturbance in relation to its unique set of constituent process–response dynamics is critical to successfully achieving restoration goals. Moreover, effective monitoring of restoration projects can contribute to our understanding the genesis and evolution of mobile dune fields in relation to the disturbance of vegetation.

The main restoration process at Doughboy Bay is the eradication of marram grass (*Ammophila arenaria*). At the commencement of the project in December 1999 marram had established a continuous canopy across two prograded bay-head foredune barriers (referred to as the 'northern' and 'southern' dunes). Complete marram necrosis was achieved after five years of herbicide application. Devegetation was followed by widespread remobilization of the dune surface; however, the development of a sand sheet was arrested following establishment of the native sand-binding species. Repeated topographic surveys along shore-normal transects show that, overall, dune forms have evolved from shore-aligned foredune ridges to nabkha, 3–5 m high, and associated shadow dunes, 20–30 m in length. The long-axes of these dunes are oriented more or less toward the south-east, reflecting the direction of the prevailing competent winds. The profiles record erosion on the seaward margin of both barriers and accretion inland. An overall increase in barrier elevation was observed. However, the spatial and temporal patterns of sand erosion and accumulation across the surface of the barrier differed with distance alongshore.

Incident winds measured over a five-hour period during an onshore wind event recorded considerable variation in alongshore wind speed and direction. Maximum wind speeds were recorded through the center of the bay, and these speeds declined by 60% towards both ends of the bay. Measured wind direction showed little variation; however, wind direction relative to the shoreline differed with distance alongshore due to the curvature of the bay. Winds across the northern dunes were oblique-alongshore in direction (9-25° relative to the foredune toe), while wind across the southern dunes were oblique-onshore to onshore in direction (47-90°). Annual topographic profiles recorded increased beach width and landward migration of the southern dunes following erosion of the first marram foredune and deposition at the rear of the barrier. In contrast, there has been no significant change in barrier position nor the width of the beach of the northern dunes. Instead Sand has largely accumulated over the pre-restoration barrier surface as shadow dunes in the lee of nabkha. Across both barriers the rate and magnitude of change decreased proportionally to relative wind speed. Changes in vegetation cover were calculated from aerial photographs. Cover declined from ~90% to ~12-40% cover within 5 years of the initial application of herbicide. Changes in vegetation cover reflect patterns of wind speed, with little decline in vegetation cover recorded towards the more sheltered sections of the dunes, and almost total loss of vegetation towards the center of the bay. Subsequent changes in vegetation cover continue to reflect wind speed patterns, with an increase in vegetation cover associated with low wind speeds and a continued decline or no change in vegetation cover across the most exposed parts of the barriers. Finally, localized sediment accumulation across both barriers is strongly correlated with the presence of dune-building species.

This case demonstrates the influence of wind speed, wind direction and vegetation on post-disturbance foredune morphologies and barrier development. Wind speed and vegetation interact to promote increased plant survival and recovery in areas of reduced wind speed; and to slow or impede the rate of post-disturbance morphological re-adjustment. Differences in wind direction, namely onshore versus oblique winds relative to the shoreline, resulted in substantially different patterns of sand erosion transport and deposition across the barrier surface. These patterns of sand movement were also altered by wind speed and vegetation cover, collectively resulting in the evolution of the Doughboy Bay dunes from a stable prograded foredune barrier to a relatively morphodynamically diverse mobile system. This morphological complexity is expected to further evolve and diverge as the Doughboy Bay dune system continues to adjust to variations in wind and vegetation cover.

What constrains incipient foredune development post-scarping?

T. Konlechner[1], D. Kennedy[1] & A. Chiaradia[2]
[1]*National Centre for Coasts and Climate, School of Geography, University of Melbourne, Australia*
[2]*Phillip Island Nature Parks, Australia*

Key words Foredune, scarping, erosion, recovery.

Foredune erosion is likely to become more frequent due to eustatic sea-level rise, changes in storminess, and modification of sediment budgets predicted with climate change. Eroded foredunes are less resistant to subsequent erosion events, with a concomitant decline in hazard mitigation values. Erosion scarps can also act as significant barriers to species that must cross the beach/dune interface to access inland breeding grounds, and limit beach access by people along urban and recreational coasts. Foredune resilience in the future will depend on the potential to recover following increasingly frequent erosion events. Here we use LiDAR and UAV data to explore the controls on dune recovery following erosion of a temperate foredune in Victoria, Australia. In particular we focus on the influence of foredune vegetation.

Summerlands Beach is a broadly south-facing bay, approximately 1.5 km in length. It provides habitat for a globally significant Little Penguin population. Recent foredune erosion has required active management to maintain penguin access to nest sites. Winds are strongly seasonal with predominantly south-west to south-east winds (onshore) during the summer and westerly to northerly (offshore). Modal wave height is 1.5-2 m and predominantly south-southwesterly in direction. Sand accumulation and changes in vegetation cover and density were measured between August 2017 and January 2018 (summer) within three 50 m sections of beach located at the eastern, center and western ends of the bay. Beach and dune morphology when the study commenced comprised of a steep recently scarped foredune with little to no recovery of the pre-erosion dune profile.

Vegetation cover and density increased over the study period by 20-100% by infilling of existing patches and colonization of new ground by vegetative growth. The seaward vegetation growth was constrained in all three study areas by the height of the spring tides. Maximum accretion of the backshore above the elevation of the spring tides varied from 0.09 m at the eastern-most study area to 0.2-0.3 m at the central and western-most study areas. Areas of accretion were usually vegetated; however, there was no strong correlation between accretion rates and vegetation cover suggesting that vegetation density plays a minor role in sand accumulation patterns during the initial stages of foredune recovery. Preliminary analysis of wind and wave data over the study period are ongoing but indicate that sand accumulation rates reflect sand transport and wave patterns throughout the bay. Examination of historic aerial images and LiDAR data suggest that past dune management practices, namely the introduction of invasive plants and stabilization, have resulted in overall shoreline progradation since 1940's. The contemporary foredune now occupies close to all the available accommodation space under current wind and wave climes. The potential for post-storm recovery is limited and occurs slowly, and erosional dune profiles at this site may now be the norm.

THE MORPHOLOGICAL CHANGES OF THE SAND DUNES ON A MOVING BARRIER ISLAND AND THEIR FUTURE CHALLENGES

T-Y. Lin[1] & J-Y. Liou[2]
[1]*Department of Geography, National Taiwan Normal University, Taipei, Taiwan*
[2]*Tainan Hydraulics Laboratory, National Cheng Kung University, Tainan, Taiwan*

Key words Coastal dune, Barrier island, Overwash process, Dune vulnerability

The morphological changes of the sand dunes located on a moving barrier island off the southwestern coast of Taiwan are analyzed through satellite images and various field surveys conducted during the past twenty years (1996-2016) in this study. The morphological developments have involved both natural factors and human interferences. The barrier island itself is a long and narrow one that extends almost parallel to the predominant winter northeasterly monsoon winds. As a result, the sand dunes at the northern part of the barrier island are mainly small shadow dunes and low transverse dunes. The barrier island becomes wider at the southern part, which starts from where the sand fences were set up to protect the artificially-planted wind-break forests. Although the dunes are separated by the forest, dunes are higher and more well-developed on both the ocean side and the lagoon side. Thus, the dune morphological changes of the northern and southern parts are following different paths.

The northern part, with the low and flat dunes, is frequently overwashed by typhoon waves, and sometimes, new tidal inlets would form at the same time. Although a new inlet that opened during the summer typhoon season could be closed in the winter due to stronger longshore drift and wind-blown sand, the positive feedback process initiated by the overwash lowers the dunes even more. The sand barrier is moving landward so fast that human interferences, such as in the form of geo-tubes and earth-dikes, were introduced to slow down the landward migration rate. Since the southern part of the barrier island has a higher and wider dune field, it is more stable for the dunes and the barrier island as a whole. Only the very northern end displays obvious shoreline retreat where the beach has been eroded, forest trees have tumbled down, and some dune cliffs have formed. With the prevailing longshore currents transporting sand from the North to the South, the barrier island also grows at the southern end. However, with the mainland side of the lagoon shoreline already fixed with the concrete sea wall, the fast moving northern part of the barrier island will eventually close part of the lagoon. The whole lagoon is expected to shrink to two-third or one half of its size in the near future. Piling up drift woods that accumulated on the beach during strong typhoon waves on the slacks of the low dunes in the northern part of the barrier island was suggested to enhance sand accumulation and to reduce the vulnerability of the dunes with the sea-level rise scenario predicted by the global climate change model.

Figure 1. Aerial view of the dune at the southern part of the barrier island

ENVIRONMENTAL STATUS OF COASTAL DUNES ON TAIWAN ISLAND

B. Liu[1] & T-Y. Lin[2]
[1]*College of the Environnement and Ecology, Xiamen University, Xiamen, China*
[2]*Department of Geography,National Taiwan Normal University,Taipei, Taiwan*

Key words Coastal dunes, Dunes Vulnerability Index, Integrated Coastal Management

Coastal dunes represent the natural barriers and play a vital role in defensing natural hazards formed by waves and tides, and also provide the venues to unique ecosystems. However, such natural system is under huge pressures due to various reasons. Although this issue is world widely recognized and studied [1], it is until recently that studies of coastal dunes conservation and restoration have been put on research agenda in China and Taiwan area. To carry out such work, it is necessary to assess the status of current coastal dune environments in advance so that proper management approaches can be decided. Assessment of such status was initially referred as dunes vulnerability which suggests the dunes ability to adapt to change. Previous studies in Europe have provided a set of coastal Dune Vulnerability Index (DVI) in order to assess the vulnerability level and identify the main source of dune system displacement at local scales [2]. In this study, such DVI was further revised considering the characteristics of local environment. Several local dune systems on Taiwan Island were selected for practical purposes. It is interesting that all sites are classified as medium vulnerability but the main sources of disturbance are different, which help to locate the weakness points in each dune system precisely and subsequently propose relevant solution approaches. Successful practice of the revised DVI could be further applied in assessing all coastal dunes in the Taiwan Strait, so that potential environmental pressures to this region can be identified and an efficient integrated coastal management could be suggested.

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Are Coastal Dune Activation Cycles in the Great Lakes (USA) Linked Across the Northern Hemisphere during the Late Holocene? If so, Why?

G. William Monaghan[1], Alan F. Arbogast[2], and William A. Lovis[2],
[1]*Indiana University, Bloomington, Indiana, USA*
[2]*Michigan State University, East Lansing, Michigan, USA*

Key Words: coastal dunes, drivers, ENSO, NAO, Great Lakes (USA), northern Europe

Probability Density Distribution (PDD) of OSL ages from dunes around Lake Michigan, USA, indicate that coastal dunes were cyclically constructed during several basin-wide millennial-scaled cycles. The cycles were identified through PDD shape—peaks in OSL ages mark times when dunes were active (e.g., building) basin-wide; PDD lows represent intervals of dune stability. We focus on intervals of dune formation in the Great Lakes during the late Holocene (~2000, 1000, and 500 ya). The first two of these (2000 and 1000 ya) are separated by the "Holland Paleosol interval," a remarkable, 500-700 year period when only a few dunes were built. We will describe how dunes, Great Lakes water levels, and soil formation fit into a regional pattern of coastal dune activation and stabilization, and discuss the regional climate and local environmental factors that most influence the pattern of dune formation and stability. ENSO cycles exhibit the greatest apparent controls on dune building in the Great Lakes; dunes are generally stable during strong El Niño events (mainly indicated by a reconstruction in southern Ecuador) and build during other (presumably La Nina) intervals. ENSO and dune formation in the Great Lakes link by increased autumn-winter storminess related to southwesterly low-pressure storm tracks during La Nina events. Intervals of dune stability and soil formation relate to milder winter weather patterns that occur in the eastern USA when El Niño events are more common. The ENSO match is only general, however, which may suggest that other factors or other climate drivers, such as the North Atlantic Oscillation (NAO), Great Lakes water level, and sand-supply intersect within the coastal zones to create the proper conditions to construct dunes.

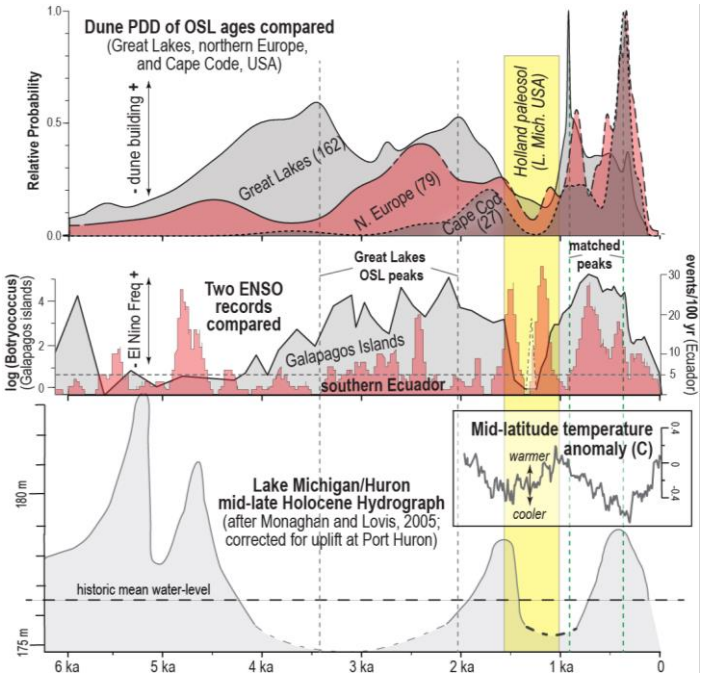

Fig. 1. Comparisons of PDD or OSL ages from dunes in the Great Lake and Cape Cod (USA) with northern Europe (upper), ENSO records from coastal South America, and the Holocene water-level record from the Great Lakes, with the Holocene temperature anomaly record (northern Europe).

After about 2 ka, the late Holocene dune cycles around Lake Michigan, including the Holland Paleosol interval, are generally coincident with coastal dune cycles at Cape Cod (northeast Atlantic coast, USA) and across coastal northern Europe. Prior to that age, dune activation intervals were mostly out of sync, which suggest that the drivers for dunes formation may have become hemispherically linked during the past few millennia. We will explored the important drivers for late Holocene dune formation by comparing coastal Great Lakes, Cape Cod, and European dune episodes with long-term records of continental and global climate drivers (i.e., El Niño-Southern Oscillation, Arctic & North Atlantic Oscillations, Pacific/North American Pattern, and Pacific Decadal Oscillation). The farther back in time these reconstructions are extended, the less definitive they become. With that caveat in mind, comparing these records may provide clues as to the factors and condition through which dunes building and stabilize are linked hemispherically.

LONG-TERM VEGETATION INCREASE AND DUNEFIELD STABILIZATION CAUSED BY CHANGES IN RAINFALL PATTERNS AND RABBIT ABUNDANCE BETWEEN 1949-2017 (YOUNGHUSBAND PENINSULA - SOUTH AUSTRALIA)

Martim A.B. Moulton, Patrick A. Hesp, Graziela Miot da Silva and Guilherme B. Fernandez.

Key words Coastal vegetation, dunefield dynamics, remote-sensing.

Studies have shown that the impact of climate variability, human and animal actions on coastal vegetation can turn stabilized dunes into active mobile dunes and vice versa. Yet, the link between these driving factors and vegetation changes in coastal dunes is far from being fully understood. This study attempts to identify the causes of the recent changes in increased vegetation cover observed in the last ~70 years on one of the most important coastal dune systems of Australia, the Younghusband Peninsula transgressive dunefields (South-east coast of South-Australia). Here we quantify these changes using the available historical aerial photography and satellite imagery of the area, and compare these results with the different factors that might have played a role in this transformation. Results show that vegetation cover has increased significantly from 1949 to 2017, from ~6% vegetation cover to ~40% in the study area. Periods of above average rainfall together with low rabbit density numbers (between 1952-1956; and then again between 2009-2013), coincide with the biggest rates of annual vegetation cover growth, and therefore were found to be the primary factors linked to the rapid vegetation growth and stabilization of the transgressive dunes. These findings can potentially explain the stabilization and vegetation growth observed in the past decades in other South Australian dune systems.

Beach-dune sediment exchange and airflow dynamics at a blowout throat during oblique onshore winds

N. O'Keeffe[1], I. Delgado-Fernandez[1], D.W.T. Jackson.[2] & P. Aplin[1]
[1]*Edge Hill University, Coastal Studies Laboratory, Ormskirk, England.*
[2]*Ulster University, Environmental Sciences Research Institute, Coleraine, Northern Ireland.*

Key words Dune blowouts, beach-dune sediment exchange, flow dynamics, sediment transport.

Coastal blowouts are acknowledged as highly effective transport pathways on dune-fringed coasts. Their morphological form is indicative of aeolian transport and the propensity of their topography to modify airflow sufficiently to support transport has been extensively researched [1, 2]. As the evolution of sandy coastlines is governed by sediment exchanges between sub-units of the cross shore profile, blowouts located at the beach-dune interface may play a significant role in dune evolution through enhancing the landward transfer of sediment into the dune field. Although there is a growing number of studies detailing blowout transport, those which encompass synchronous measurement of flow and sediment exchange from the beach into the dune field are rare [3].

Detailed measurements of airflow and sediment transport dynamics at the beach-dune interface of a trough blowout were conducted at Sefton dunes, northwest England. An array of 3D sonic anemometers, co-located with transport sensors were deployed during an oblique onshore wind event. Instantaneous flow and transport dynamics were measured on the back beach, the adjacent upwind foredune and within the throat of the blowout. The resulting morphological response of the blowout surface was captured via pre- and post-event TLS surveys.

The importance of alongshore deflected airflow in delivering sediment to the blowout throat area from the beach was highlighted by a linear trend of high magnitude transport intensity across the upwind foredune. Within the throat, levels of transport intensity displayed extremely high spatial and temporal variability across a relatively confined area. Multiple topographically-forced flow modifications were observed. Although incident wind speed remained relatively constant, a sharp 15° onshore directional shift during the experiment resulted in a step change (increase) in transport intensity within the blowout, providing insight into how sediment is first delivered to the throat area and then driven landwards through topographical funnelling (flow compression) of local winds.

Figure 1: 3D sonic anemometry deployment - those numbered in black co-located with LPC transport sensors

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Aeolian transport over wet sand beds

V. Ralaiarisoa[1], A. Valance[1], F. Naaim-Bouvet[2], A. Ould El Moctar[3] & P. Dupont[4]
[1]*Institut de Physique de Rennes, UMR 6251, CNRS, Univ. Rennes, F-35042 Rennes, France*
[2] *Unité de Recherche Erosion Torrentielle Neige et Avalanches, Irstea, Univ. Grenoble Alpes, Grenoble, France*
[3]*Laboratoire de Thermique et Energie de Nantes, UMR 6607, Univ. Nantes, F-44306 Nantes, France*
[4]*Laboratoire de Génie Civil et Génie Mécanique, EA 3913, Institut National des Sciences Appliquées Rennes, Univ. Rennes, F-35708, France*

Key words: wet granular bed, saturated transport, saturation length, threshold of transport.

The transport of particles by the wind takes place in different natural contexts: sand in deserts and coastal areas or snow in cold regions. For spherical, dry and non-cohesive sand, the physics of aeolian transport is quite well understood [1]. In contrast, much less is known about aeolian transport over wet sand beds which is relevant to sandy coastal areas. Although moisture effects have been the focus of numerous studies [2], there exist significant discrepancies in experimental or model predictions and reliable and quantitative results for aeolian sand transport in moist environments are lacking.

In this experimental work, we conducted well-controlled wind tunnel experiments with wet sand beds ranging from 0.5 to 3% of moisture content at different wind speeds. The experimental challenge is to control the homogeneity of the sand-water mixture and to minimize water evaporation during the experiments. To this end, the mixture of a 0.2mm natural sand and water was achieved in a concrete mixer and then left in a sealed container over 24 hours before it is spread evenly over the whole 7m length of the tunnel. Importantly, the air entering the tunnel is fully saturated of water vapor with the help of ultrasonic fog makers.

We investigated two different configurations of transport: (i) the first one with zero upwind particle flux and (ii) the second with a finite upwind flux. The first configuration allows us to assess the static threshold of transport while the second one provides information about the dynamic threshold. For each experiment which typically lasts one or two minutes, the mass flow rate is obtained both via sand trap measurements and particle imaging.

Preliminary results confirm that the presence of moisture within the bed increases the static threshold of transport but by a much greater factor than previously reported in the literature. For example with 3% moisture content, we found a threshold wind speed of 25m/s compared to the 8m/s given in the literature (see Fig. 1a). In contrast, the dynamic threshold is significantly lower and is close to that obtained for dry sand. Additionally, experiments with a finite upwind mass flux lead to mass flow rates comparable with those obtained for dry sand. At moderate wind speed (5m/s), the mass flow rate over 3% wet sand bed is surprisingly equivalent to that found for dry sand while at higher wind speed (7 and 9 m/s), it is smaller (see Fig. 1b). These results suggest that the saturated value of transport over a wet sand bed is the same as over dry sand but that the saturation length is much longer than that in dry conditions. We strongly suspect that with a longer tunnel, the mass flow rate would have reached the same value as for dry sand at any speed. These new results clearly rise the issues of saturated state of transport over wet sand beds and the sensitivity of the saturation length to moisture content.

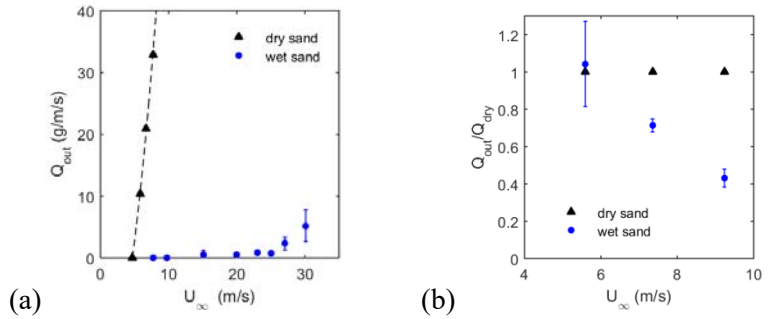

Figure 1. Transport features over a 3% wet sand bed: a) Without upwind particle flux: Downwind mass flow rate versus wind speed; (b) With upwind particle flux (Q_{upwind}=5.6 g/m.s): Downwind mass flow rate rescaled by the corresponding dry flux versus the wind speed.

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Aeolian sand transport rate on a beach in relation to the available fetch distance

J. Rotnicka
Institute of Geology, Adam Mickiewicz Univeristy in Poznan, Poland

Key words critical fetch distance, saturated and unsaturated mass flux, Baltic coast

Aeolian sand transport rate on the beach exhibits a great spatial and temporal variability as a function of the wind speed and available fetch distance, surface roughness and moisture, and air temperature and humidity. In the case of a narrow beach the most important factor is the available fetch distance that is imposed by beach geometry (its width) and the angle of wind approach and often may be shorter than the critical fetch defined as the minimum distance required to achieve equilibrium transport whose rate is relatively constant. Up to now, there is no consensus on length of the critical fetch distance. Its estimates varies from a few metres in wind tunnel conditions to more than hundred meters under natural conditions. The aim of the research was to study the variation in sand transport rate at different beach sites during wide range of wind events.

The field work has been conducted on beaches located on the Łeba Barrier on the southern Baltic coast, Poland. During field work the beach was usually between 50 and 60 m wide and only in periods of low sea level it broadened to 100 m. Beach sand was very well- and well-sorted and composed of fine to medium quartz grains with a mean grain size equal to 0.26 mm. Aeolian sand transport rate were measured along the shore normal beach profile by means of up to ten vertical passive sand traps that were 0.5 m in height. Wind speed and direction were taken by automatic meteorological stations with three-cup anemometers and vanes placed 1 m above the ground. The analysed data set contained more than 500 data.

The results showed that at wind speed lower than 8 m/s the sand transport rate generated by on- or offshore winds often achieved values comparable with that of mass flux generated by alongshore wind (Fig. 1). At higher wind speeds sand transport rate generated by alongshore winds was greater than the transport rate measured during on- and offshore winds. This difference increased with increase of wind speed and at speed of 12 m/s it reached an order of magnitude. Such big differences in mass flux were caused by the available fetch distance, which is unlimited during alongshore winds and the mass flux got saturated. During onshore or offshore winds, the mass flux reached different levels of saturation at different points of the beach, depending on the wind direction and beach width, and it rarely achieved maximum saturation. It also explains why the established relationships between mass flux and wind speed was statistically significant in the case of alongshore winds and showed weak statistical significance in the case of all other winds [1]. The obtained relationships also suggests that the stronger the wind, the longer the critical fetch distance and thus confirm the results of some wind tunnel experiments [2].

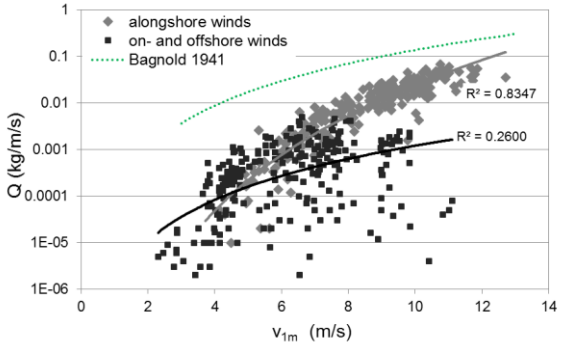

Fig. 1. The aeolian sand transport rate, Q, in relation to wind speed, v_{1m} [1].

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Spatiotemporal surface moisture dynamics on a coastal beach

Yvonne Smit[1], Jasper J.A. Donker[1] & Gerben Ruessink[1]
[1] *Department of Physical Geography, Faculty of Geosciences, Utrecht University, The Netherlands*

Key words surface moisture, groundwater depth, tide, terrestrial laser scanner, aeolian sand transport, beach, dunes

Surface moisture is a major limiting factor for aeolian sand transport on a beach and, accordingly, understanding its spatiotemporal variability will aid in developing a predictive model for the aeolian input of wind-blown beach sand into the foredune. In our earlier work (Smit et al., 2017, *Aeolian Research*) we have illustrated that the reflectance signal of a near-infrared Terrestrial Laser Scanner (TLS) corresponds well to gravimetric surface moisture content (in %) over its full range. Here, we analyze TLS-derived surface moisture maps with a 1x1 m spatial and a 15-min temporal resolution and concurrent groundwater measurements collected during a falling and rising tide at Egmond beach, the Netherlands. The maps show that the beach can be conceptualized into three surface moisture zones. First, the swash zone: 18% - 25%. Second, the intertidal zone: 5% – 25% (large fluctuations). And third, the back beach zone: 3% - 7%. During rising tide no anticipated processes by capillary forces were observed in advance of the rising tide and no hysteresis was observed over de complete tidal cycle. During falling tide surface moisture fluctuations are strongly linked to the behavior of groundwater depth. A clear 'Van Genuchten-type' retention curve can describe the relation between the two. This relationship opens up new opportunities to calculate surface moisture out of groundwater measurements but also vice versa; to calculate groundwater depth with surface moisture measurements. Preliminary results already show corresponding patterns between measured and calculated surface moisture maps and groundwater depth maps. Concluding, the TLS-derived moisture maps and groundwater measurements clearly show that groundwater depth is a key control on spatiotemporal surface moisture variations.

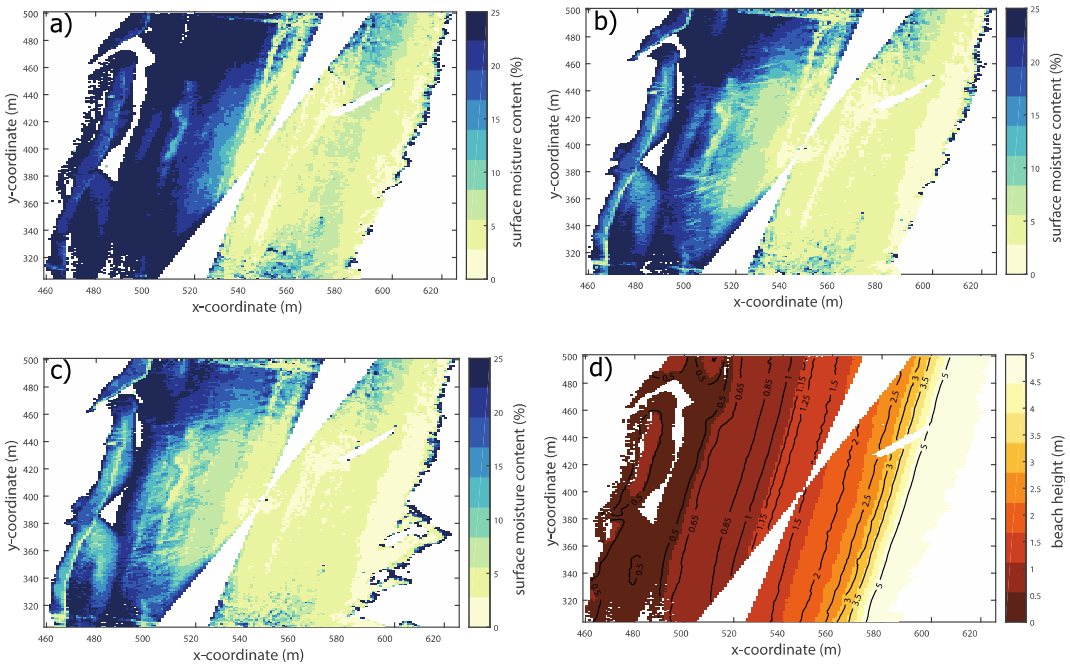

Figure 1. *Three surface moisture maps that show the surface moisture variations during falling tide on September 29, 2016 at the beach of Egmond aan Zee, with a corresponding beach height. On the right side the dunes are situated and on the left side the sea. A clear trough at approximately 480 m in the x-coordinate is visible, which dries out during the day. Also the yellow color spreads out towards the sea, which means the soil dries up during the day. Graph (a) was taken at 10:30 h, (b) at 14:00 h, (c) at 16:00 h. (d) Shows the beach height above mean sea level on September 29, 2016* [1].

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Greedy parabolics: How effectively do parabolic dunes steer incident wind flow?

T.A.G Smyth[1], I. Delgado-Fernandez[2] & D.W.T. Jackson[3]
[1] *Department of Geography and Environmental Science, Liverpool Hope University, Hope Park, Liverpool L16 9JD*
[2] *Department of Geography, Edge Hill University, Ormskirk, Lancashire, UK.*
[3] Centre for Coastal and Marine Research, School of Environmental Science, Ulster University, Northern Ireland UK

Key words Parabolic dunes; coastal dunes; computational fluid dynamics; wind flow steering; paleoclimate

Parabolic dunes are U or V shaped aeolian landforms that form on pre-existing sand deposits. Their morphology consists of an upwind deflation basin, bordered by often-vegetated trailing arms and a downwind depositional lobe. The orientation of parabolic dunes commonly aligns and is attributed to prevailing [1, 2, 3, 4, 5] or the resultant wind direction [1, 6]. As a result, the orientation of parabolic dunes stabilised by vegetation growth has been used as a proxy for wind direction during past climates in a number of studies [7, 8]. However, the effectiveness of the morphology of parabolic dunes to steer incident wind flow remains unquantified. By systematically modelling near surface wind flow using 3D Computational Fluid Dynamics over three parabolic dunes for a range of incident wind directions, we demonstrate that parabolic dunes are capable of steering incident wind flow so that it aligns with the deflation basin of the parabolic dune (Figure 1). These results thereby question the validity of using vegetated parabolic dunes as a proxy for paleo wind conditions. Quantifying the ability of parabolic dunes to steer incident wind flows is important not only for the identification of paleo-wind directions but also to better understand how the orientation of parabolic dunes and overall dune evolution is likely to change in the future.

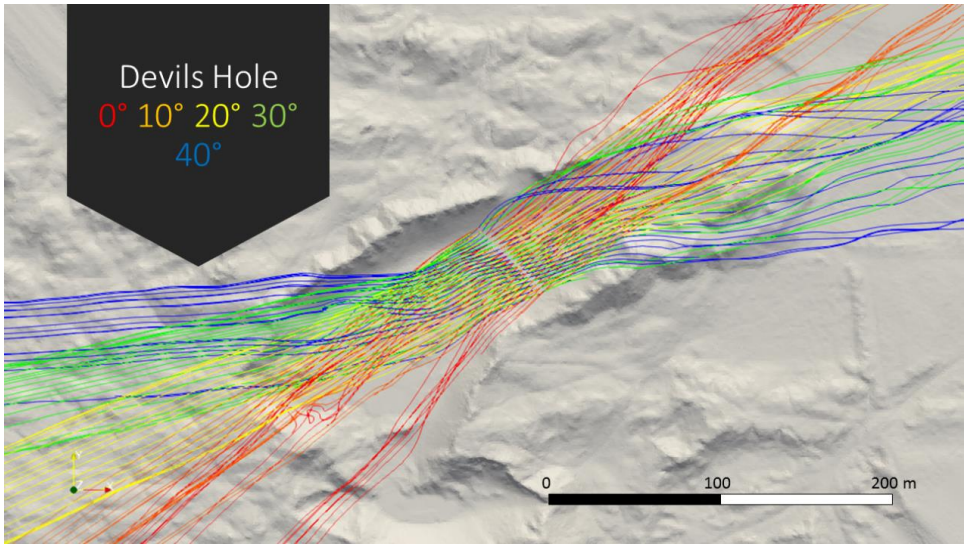

Figure 1. Incident wind direction modelled at 10° increments on the Sefton Coast (UK) demonstrate the ability of parabolic dunes to steer incident wind flow along the axis deflation of the deflation basin for a range of incident wind directions. 0° represents wind flow that is directly parallel to axis of the deflation basin.

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AEOLIAN SEDIMENT TRANSPORT ON A BELGIAN BEACH : SPATIO-TEMPORAL VARIABILITY DURING ALONGSHORE WINDS

G. Strypsteen[1] & P. Rauwoens[1]
[1]*KU Leuven, Department of Civil Engineering, Technology Cluster Construction, Bruges, Belgium*

Key words Backshore, foredune, sediment transport, sand strips, spatio-temporal variation.

Half of the Belgian coast consists of coastal dunes which acts as the primary defence against storm events. Aeolian sediment transport from the beach towards the dunes is important for coastal dune evolution. However, important factors in coastal aeolian processes, such as wind speed, wind direction and surface characteristics are characterized by a large spatial and temporal variability. These make the processes even more complex. This field study identifies the short-term (hours) behaviour of aeolian transport and surface elevation changes on the backshore and foredune at Oostduinkerke, Belgium. The region in front of the dune foot is characterized with a zone of debris and shell fragments deposited by tidal uprush. Aeolian transport studies commonly deploy a single transect parallel with the wind direction, assuming there is no variation in sediment transport lateral to this transect. In this experiment, twelve Modified Wilson And Cook (MWAC) sand traps were positioned in a cross and were exposed to alongshore winds on 29 January 2018 (Figure 1A). Wind speed 2 m above the dune foot averaged 10.82 m/s. Three sampling runs were carried out between 10h20 and 18h00. Along the backshore, large aeolian sand strips (approximately 5 m wide) were moving in the downwind direction due to high energy transport events, causing a large spatio-temporal variability in sediment transport (Figure 1B). In the alongshore trap array Z1-Z6, trapping rates varied as the sand strips moved spatially over time (see blue bars in Figure 1B). Based on photo imagery and Figure 1B, the exact location of the sand strips can be identified. A sand strip was observed between traps when there was a decrease in sediment transport. An increase in sediment transport between traps showed no sand strip. In the cross-shore transect Z7-Z3-Z12, substantial differences in transport rates over a relative short distance (6 m) are observed at the backshore (see red bars in Figure 1B). Transport rates in the dune region were lower than measured at the backshore. Moreover, variations in vertical flux profiles between traps were larger in the foredune, where vegetation influenced sediment transport. This paper presents the results of the experiment.

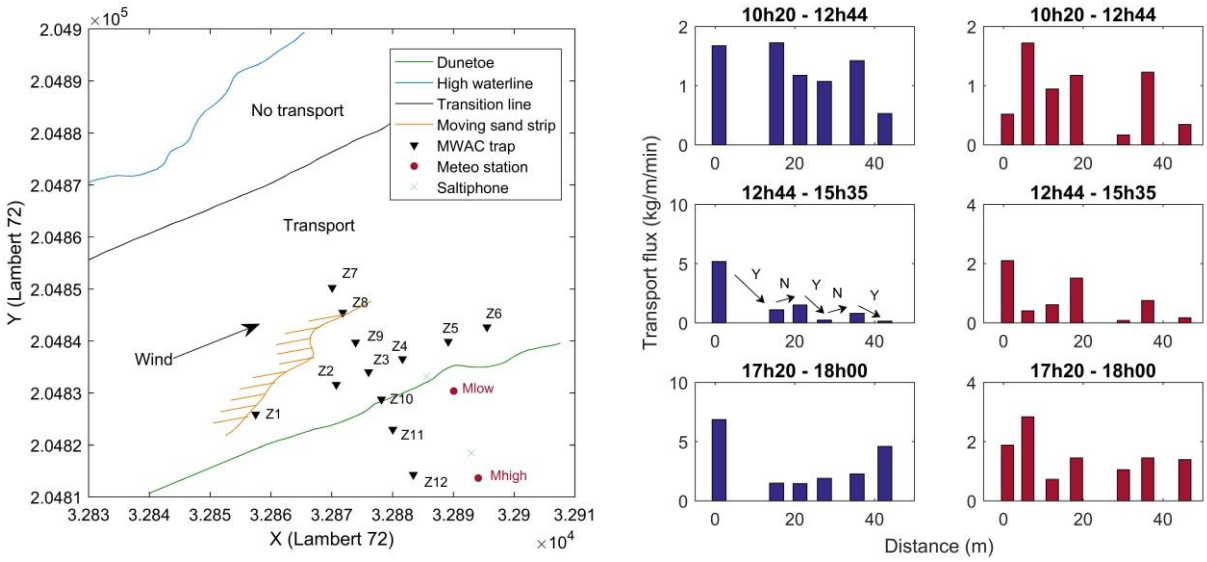

Figure 1. A) The locations of the instrumentation. One of the moving aeolian sand strips is shown. B) Spatio-temporal variability in sediment transport for three sampling runs. Blue bars represent the alongshore array Z1-Z6 (Z1 is upwind , 0 m). A sand strip was observed beteen traps when there was a decrease in sediment transport and vice versa. Red bars represent the cross-shore array Z7-Z3-Z12 (Z7 is the lower trap at the backshore, 0 m).

SESSION

« Modelling and numerical simulations »

Identifying drivers of near-surface reactivation in semi-arid landscapes using luminescence profiles and novel applications of modelling techniques

CE. Buckland[1], RM. Bailey[1], DSG. Thomas[1]
[1]*School of Geography and the Environment, University of Oxford, Oxford, United Kingdom*

Key words OSL dating, reactivation histories, machine learning, Nebraska Sandhills.

Two billion people living in drylands are affected by land degradation. Sediment erosion by wind and water removes fertile soil and destabilises landscapes. A quantified understanding of vegetation cover sensitivities and resultant surface change to forcing factors is needed if the vegetation and landscape response to future climate change and human pressure are to be better predicted.

Using quartz luminescence-dated near-surface sediment profiles and records of climate change, land use history and wildfire frequency, this study attempts to identify drivers of sediment movement and near-surface reactivation. Luminescence ages, measuring the date since deposition, of near-surface profiles produce reactivation histories of aeolian sediments across dryland geomorphological features in the Niobrara Valley Preserve of the Nebraska Sandhills. Data on natural and anthropogenic driving forces, including precipitation, wildfire history and land use pressure, are taken from a range of instrumental and archival datasets from the local region, spanning the last two hundred years. Using a range of data analytical techniques, including machine learning, the relationship between sediment reactivation ages and corresponding driving parameters is explored to help identify and quantify the level of disturbance required to induce landscape reactivation. Identifying episodes of surface deposition and comparing with records of disturbances allows us to assess the future sensitivity, stability and thresholds of the landscape to a range of forcing factors, including climate change.

AERO: AN AEOLIAN EROSION MODELING ENVIRONMENT

B.L. Edwards[1], S.E. McCord[1], N.P. Webb[1], N. Stauffer[1]
[1]*USDA-ARS Jornada Experimental Range, Las Cruces, NM, USA*

Key words sediment transport modeling; aeolian transport; dust emission; land management

The Aeolian Erosion Model (AERO) is a versatile aeolian transport and dust emission modeling environment developed to provide a robust interface for fundamental research while also acting as a decision-support tool for land managers. The model simulates size-resolved horizontal and vertical mass flux on the plot scale from user inputs of meteorological, soil and vegetation data. AERO is highly customizable; the model can be run for a single set of conditions, a time series of conditions, conditions over space, or a time series of conditions over space. Drag partitioning, vertical dust emission schemes, and horizontal transport equations are user-selectable. Key variables (e.g., vegetation cover, canopy gap distribution, soil type) can be input as scalars, defined by descriptive statistics, supplied as probability distributions, or, when run spatially, as remote sensing-derived inputs and atmospheric data from the Weather Research and Forecasting (WRF) weather prediction model. As such, the model is adaptable to many research and management applications over a range of site conditions.

Here, we detail the model framework and processing options and provide an example of model application to U.S. Bureau of Land Management (BLM) Assessment, Inventory and Monitoring (AIM) plots in New Mexico, USA to assess potential implications of management actions for dust emission rates. The test case demonstrates how the AERO model can leverage emerging large-scale ecological datasets like AIM to provide new opportunities to evaluate aeolian sediment transport responses to land surface conditions, potential interactions with disturbances and ecological change, and impacts of anthropogenic land use and land cover change.

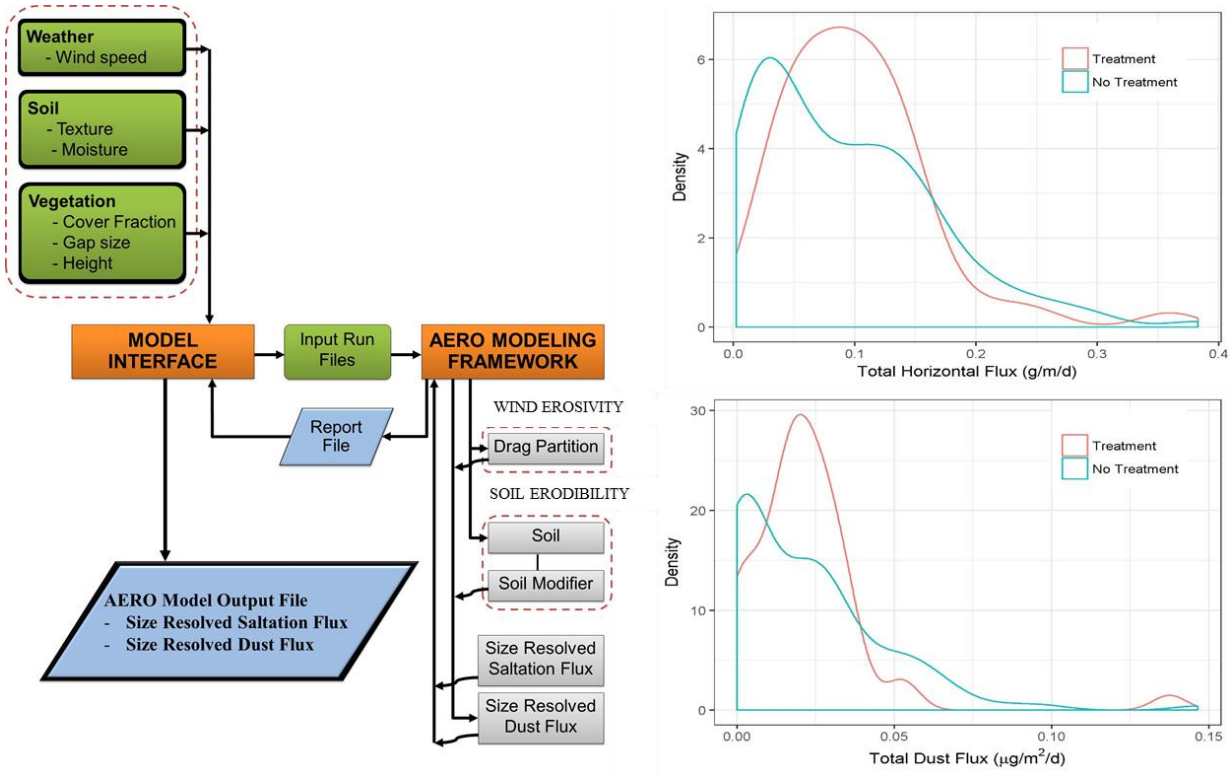

Figure 1. A) Conceptual diagram of AERO model workflow; and B) modeled mass flux given current conditions and potential impacts from vegetation removal for AIM monitoring plots in New Mexico, USA.

INVESTIGATING THE DISSIMILARITY BETWEEN DUST AND MOMENTUM TURBULENT TRANSPORTS USING LARGE EDDY SIMULATION

R. Fernandes[1], S. Dupont[1] & E. Lamaud[1]
[1]*ISPA, INRA, Bordeaux Sciences Agro, F-33140, Villenave-d'Ornon, France*

Key words Flow turbulence modeling, Large Eddy Simulation, Boundary layer processes, Mineral dust emission, Wind erosion, Saltation, Sandlasting, Momentum transport, Particle dispersion

The ability to estimate the dust exchange between the surface and the atmosphere has tremendous importance owing to mineral dust's impact on micro-climate, agriculture, human health and economic activities. This exchange involves the release of dust grains into the turbulent boundary layer through sandblasting, their dispersion by the turbulence, and their deposition back onto the surface. In order to simulate this exchange, one needs to simulate both the flow turbulence and the saltation process - which supplies energy for dust emission. To this effect, a Large Eddy Simulation (LES) airflow model capable of explicitly simulating the main turbulent eddies of the flow was used. This model was coupled with a Lagrangian model for saltation that resolves individual saltator trajectories and accounts for the two-way interaction between the saltator motions and turbulent flow. A splash scheme was employed to account for particle rebound and ejection at the surface, and to derive energy required for dust emission. A simple energy based dust emission scheme that links surface cohesive forces to dust particle size was developed. Finally, an Eulerian dust dispersal model was incorporated to simulate the transport of the dust plume. The model is evaluated against the WIND-O-V's 2017 field experiment performed in Tunisia in 2017, where wind dynamics, saltation flux and dust flux were measured. An interesting outcome of this campaign was the dissimilarity in the transport of dust and momentum, contrary to existing views. The high intermittency of dust emission compared to the more continuous momentum absorption at the surface may explain this dissimilarity. The LES model is used here to explore the sources of dissimilarity between the dust and momentum turbulent transports.

COMPUTATIONAL SIMULATIONS ON SAND ACCUMULATION OVER RAILWAY BEHIND WINDBREAK WALL

Wei He[1,2], Ning Huang[1,2], Bin Xu[1,2] & Kang Gong[1,2]

[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, 730000 Lanzhou, China*

[2] *School of Civil Engineering and Mechanics, Lanzhou University, 730000 Lanzhou, China*

Key words Windbreak wall, CFD simulation, wind tunnel experiment.

Strong crosswind is dangerous for trains running in high speed[1], as a result, windbreak walls were installed on the upwind side of the railbed built in the regions with strong crosswind. However, since the opening of high speed railways in the northwest arid areas of China, sand hazards have occurred frequently to the railway segment passing through the desert, which not only affect the safe operation of vehicle, but also increase the cost of railway maintenance. CFD simulations and wind tunnel experiments were carried out to study the characteristics of wind field and sand movement near the railway. It was found that the simulated results were in good agreement with the results of the wind tunnel experiment. Further analysis of the numerical results showed that 1) there exists a wind velocity rising region upwind the windbreak wall and a part of inlet sand particles will be transported upward in this region; 2) the total mass of sand particles which can climb up the windward slop and fly over the windbreak wall increases dramatically with inlet wind velocity, and most of vertical sand movement occurs within 0.1 m from upwind side of the windbreak wall; 3) after the sand particles fly over the windbreak wall, most of them will sequentially fly over the railbed and fall onto the ground downwind the railbed. Then part of them are blown back to the railbed because of the reversed flow region and 4) the relative position where sand particles fall on to the ground and the reversed flow region affect the total number of sand particles that can be blown back to the railbed. The results of the study may provide quantitative evidence for sand-control measures on the railways.

Figure 1. Sand hazard on the railbed downwind the windbreak wall [1].

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A dynamic model of dust emission in farmland

Hongchao Dun[1,2], Ning Huang[1,2] & Guanglei Shi[1,2]

[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, 730000 Lanzhou, China*

[2] *School of Civil Engineering and Mechanics, Lanzhou University, 730000 Lanzhou, China*

Key words dynamic model, dust emission, farmland.

Dust emission caused by human farming activities has an important influence on global dust circulation system, and the soil moisture plays a great role in both vegetation growth and soil erosion. However, most of current dust emission models do not take the effects of soil moisture change into account, neither the dust supply limit phenomenon. Here, based on soil evaporation process, we proposed a concept which presents both the influence of particle size distribution and soil moisture on dust emission process. A new dynamic model of dust emission in farmland is built through combining both soil hydrodynamic and blown sand physics (Figure 1), and then we simulated the changing law of dust emission with time in farmland. The results show that the particle size distribution is the main factor limiting the release and supply of dust particles in light wind speed situation, and the soil moisture switches to primary in high wind velocity case. In addition, wo found that as the coupling process of water evaporation and soil erosion gradually stabilizes, the moisture in soil surface will have obvious changes. It indicates that previous formula of dust emission, where the moisture is constant are not suitable.

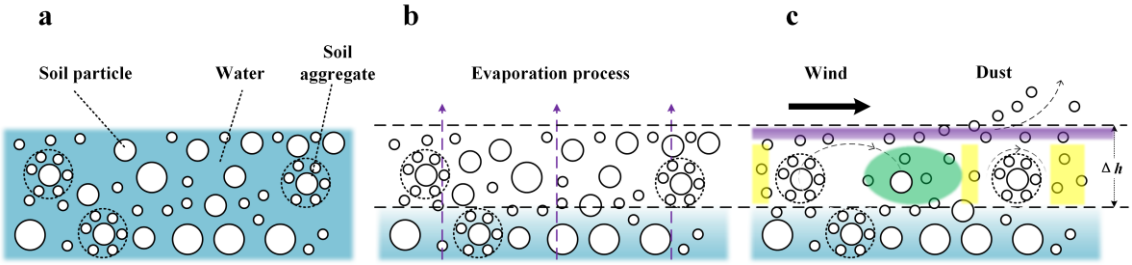

Figure 1. The new dynamic model of dust emission in farmland: a) wet soil; b) evaporation process; c) emission process.

NUMERICAL SIMULATIONS ON THE EMERGENCE OF AEOLIAN SAND RIPPLES

Xinghui Huo, & Ning Huang
Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou, China
School of Civil Engineering and Mechanics, Lanzhou University, Lanzhou, China

Key words Sand ripples, saltation, large eddy simulation, immersed boundary method.

Aeolian sand beds exhibit regular patterns of ripples resulting from the interaction between topography and sand transport. Grains entrained by the wind impact on the sand bed causes saltation and creep of other grains on bed, which are dominating ways of sand transport near the bed. Researches nowadays are usually based on experiments which provide less information about the emergence stage of sand ripples. And recent numerical simulations are always just based on 2D models. In this work, a 3D numerical model with wind-blow sand and dynamic bedform is established to simulate the generation of sand ripples. The wind field is evaluated from Large Eddy Simulation (LES). Every particle leaving the bed into air due to both aerodynamic entrainment and particle splash is tracked in the simulation. Immersed boundary method is used to simulate the topography. By coupling particle transport, wind field and dynamic boundary, the emergence of sand ripples can be obtained directly. The work also shows that grain size distribution on the sand bed takes a great part in sand ripples' emergence and development. Wavelengths of ripples are determined by the average saltation length of grains, which is proportion to the wind field friction velocity.

Regional Snow Distribution Modeling in Qilian Mountain

Guang Li[1,2], Ning Huang[1,2]
[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, 730000 Lanzhou, China*
[2]*School of Civil Engineering and Mechanics, Lanzhou University, 730000 Lanzhou, China*

Key words Snow Distribution, Wind Blowing Snow, Snow Sublimation, Regional Modeling

Snow distribution has significant impact on hydrologic process of alpine catchments, as well as local climate and ecosystem. However, the strong spatiotemporal heterogeneity of snow distribution caused by nonuniform snowfall and wind blowing snow is difficult for current hydrologic models. In this work, we introduced a drifting snow model considering the slope effect, parameterization of preferential deposition, and a simple snowmelt model into the ARPS atmospheric model, to simulate the snow distribution evolution in Qilian mountain (FIG.1(a), E100°14’28”, N38°00’58”), Qinhai Province, China.

The results show that our model is more accurate in snow depth estimation in alpine area after considering the slope effect of snow transport, shown as FIG.1(b). Scenario prediction results also show a clearer deposition patterns for drifting snow comparing to preferential deposition, and the erosion or deposition rate is sensitive to the local wind speed. This work has considerable value in improving the accuracy of snow distribution prediction in alpine area, which is important for hydrological modeling of alpine catchments.

(a) (b)

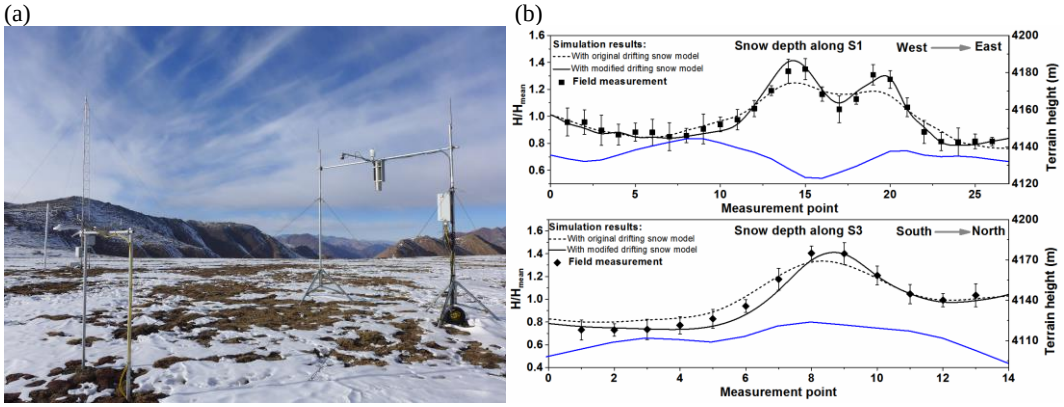

Figure 1. (a)Yakou Station, Qilian mountain, Qinhai Province, China (Photo by Li, 2013); (b) Snow depth along two lines near the station by observations and simuliations

WECON: A model to estimate wind erosion from disturbed surfaces

Benli Liu[1*], Jianjun Qu[1, 2], Duihu Ning[3], Qingjie Han[1], Daiying Yin[1], Pengfei Du[3]

[1]*Dunhuang Gobi Desert Research Station, Key Laboratory of Desert and Desertification, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, China.*

[2] *Gansu Center for Sand Hazard Reduction Engineering and Technology, Lanzhou 730000, China.*

[3] *International Research and Training Center on Erosion and Sedimentation, Beijing 100048, China.*

Corresponding author: Benli Liu (liubenli@lzb.ac.cn)

Key words wind erosion; model; disturbed surface; construction activity

We present a new wind erosion estimation model (Wind Erosion from CONstruction activities, WECON) that is designed for not only flat surfaces but also land that has been disturbed by construction or engineering activities. The core of the model is based on the maximum soil loss potential from wind erosion. The factors that were considered include wind speed, wind direction, plot dimension, particle size, soil water content, surface coverage, soil loosening, and pile height and arrangement. The model can be run in two settings: one using observation wind data and one using long-term meteorological data when observation records are absent. The model is robust in reflecting the factors influencing wind erosion when compared to field observations and wind tunnel experimental results. Portable software with a database containing information from 1781 meteorological stations across China was compiled so that users can conveniently estimate wind erosion in different locations with different (including natural or undisturbed) surface conditions.

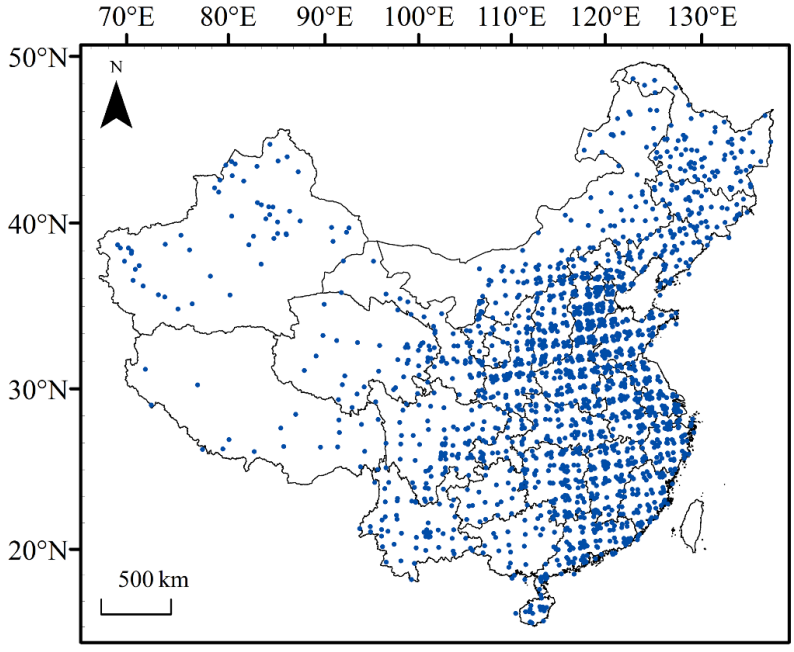

Figure 1. Distribution of long-term meteorological data stations in the built database

Coupling model and numerical simulation of high voltage insulator pollution based on LBM-LES-DEM method

Mao_Dong[1], Gao_Qiang[1]
[1] *School of Mechanical and Electric Engineering, Soochow University, Suzhou, China*

Key words Lattice Boltzmann method, Large eddy simulation, Discrete element method, Adhesion.

Insulators are an important part of high voltage transmission lines. The contamination accumulation of the insulators is a prerequisite for pollution flashover on transmission lines (Fig. 1).In recent years, fog and haze weather is frequent. In order to ensure the safe operation of the power grid, it is of great significance to study the contamination accumulation characteristic of the insulators in the fog and haze environment. The contamination accumulation process of the insulators is a typical gas-solid two-phase flow problem. Based on the LBM-LES-DEM method, the modeling of the high voltage insulator fouling process is carried out. The complicated turbulent air field around the insulator was analyzed by lattice Boltzmann method (LBM),and the 3D particle velocity model is D3Q19 (Fig. 2).Large eddy simulation (LES) is used to calculate turbulent flow, and the subgrid model uses the dynamic Smagorinsky model. The discrete element method(DEM) is used in the process of particle transport, and the Lagrange method is used to track the particle trajectory. The sedimentation model of haze particles, is modified according to the adhesion measured by the experimental results. The numerical results show that the LBM-LES-DEM method can well capture the dynamic process of insulator fouling, and get the results of external air flow field, haze particle transport trajectory and the particle deposition distribution. The sedimentation model of haze particles is corrected by experimentally measured adhesion, which makes the numerical model more fit the actual situation.

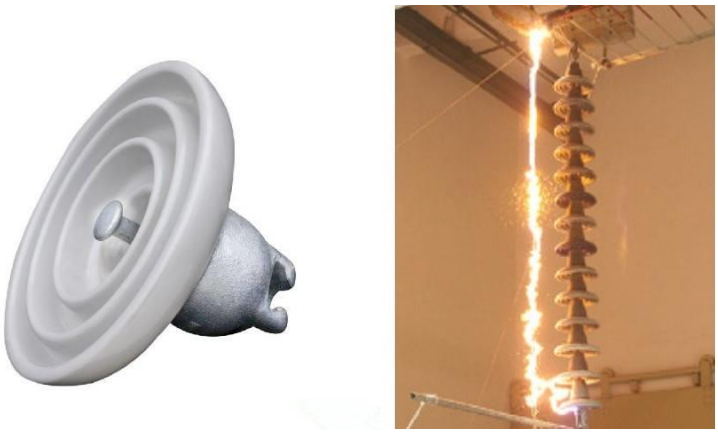

Figure 1. High-voltage insulators and insulator pollution flashover [1]

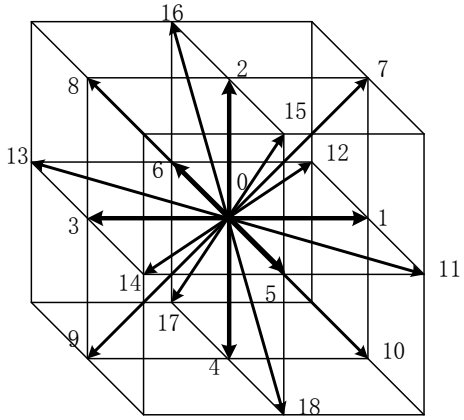

Figure 2. 3D particle velocity model D3Q19

References

[1] Source: **https://image.baidu.com/**

NUMERICAL SIMULATIONS OF THREE-DIMENSIONAL SAND TRANSPORT UNDER UNSTEADY WIND

Panli He[1,2], Yiqi Xu[1,2], Ning Huang[1,2], Li Liu[1,2]
[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, 730000 Lanzhou, China*
[2]*School of Civil Engineering and Mechanics, Lanzhou University, 730000 Lanzhou, China*

Key words Numerical simulation, 3-D wind-blown sand flow, Sinusoidal wind, Sand transport rate.

Most of current numerical simulations on sand transportation are based on the basic assumption of steady flow field, which is different from the actual situation in nature. In this paper, an unsteady flow field in atmospheric boundary layer is characterized by sinusoidal wind. The process of grain-bed collision and the coupling effect between grain and flow filed are considered together. The development process and particle motion law of 3-D wind sand flow under different amplitudes and frequencies unsteady sinusoidal wind are investigated numerically by Large Eddy Simulation (LES). Simulation results show that: the sediment transport rate represents a sine-like variation under the effect of sinusoidal gust, the sediment transport rate of unsteady incoming flow is greater than that of uniform flow under the same average wind speed, when period T<2s, the variation tendency of average sediment transport rate is similar to that of uniform flow, and with the change of wind field period, there is no regular change in average sediment transport rate. We also find that the appearance of the overshoot is related to the period of gust. Under small period, the first wave of sand transport rate is smaller than subsequent one. As period goes up, the first wave increases and finally bigger than later, that is to say, the "overshoot" appears. The sine-like characteristics of average sand transport rate have a slight hysteresis compared with the sinusoidal wind gust, and this hysteresis phenomenon become weaker as the wind field amplitude increases.

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An Integrated Simulation-Assessment Study for Optimizing Wind Barrier Design

Hui Fang[1], Xiaoxu Wu[1], Xueyong Zou[2] & Xiaofan Yang [2]

[1]*State Key Laboratory of Earth Surface Processes and Resource Ecology, College of Global Change and Earth System Science, Beijing Normal University, Beijing 100875, China*
[2]*State Key Laboratory of Earth Surface Processes and Resource Ecology, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China*

Key words wind barrier, 3D numerical simulation, structural parameter, optimal design

Abstract : Wind barriers are artificial structures that are widely built to abate wind erosion by reducing wind velocity near surface, which requires optimal design in aeolian engineering. Previous studies have shown that numerical simulation is an effective method for wind barrier optimal design. However, there still exist two challenging questions: 1) how to resolve fine-scale turbulence wind fields around barriers? and 2) how to systematically evaluate the shelter efficiency? In the current study, we have conducted high-resolution 3D computational fluid dynamics (CFD) simulations for airflow passing through wind barriers then explored optimal designs. To validate the simulation results, we compared the simulated airflow results with those from wind-tunnel measurement. Moreover, we innovatively proposed a shelter index to evaluate the shelter efficiency, which has taken wind velocity reduction, economical cost and shelter degree into account. According to the calculated shelter index, wind barriers with porosity of 0.3~0.4 could provide the longest effective shelter distance, and a 2-row-a-belt scheme with inter-row spacing of 5~7*h* (*h* as the height of wind barriers) is the most effective. The optimal inter-belt spacing is suggested as 12~15*h* depending on local wind velocity. This study is intended to provide design references for constructing wind barriers in aeolian engineering.

SESSION

« Experiments and instrumentation »

COMPARING DUNE MIGRATION MEASURED FROM REMOTE SENSING WITH SAND FLUX PREDICTION BASED ON WEATHER DATA AND MODEL, A TEST CASE IN QATAR

S. Michel[1, 2], J.-P. Avouac[2], F. Ayoub[2], R. C. Ewing[3], N. Vriend[4], E. Heggy[5, 6]

[1] *University of Cambridge, Cambridge, UK*
[2] *California Institute of Technology, Pasadena, USA*
[3] *Texas A&M University, College Station, USA*
[4] *University of Cambridge, Cambridge, UK*
[5] *University of Southern California, Los Angeles, USA*
[6] *Jet Propulsion Laboratory, Pasadena, USA*

Key words: Dunes dynamics, Wind, Remote sensing, Planetary Geomorphology, Global Circulation Model.

This study explores the possibility of validating and calibrating the wind regime predicted by Global Circulation Models (GCM) on Earth and other planets using optical remote sensing of dune dynamics. We use Landsat-8 images to track the migration of 64 Barchan dunes in Qatar using the COSI-Corr technique. We estimate the volume of the dunes using a scaling law calibrated from one particular dune, which was surveyed in the field. Using volume and migration rate, we determine the sand flux from single dune, Q_{Dunes}, and scale this estimate to the whole dune field. We compare the measured sand flux with those derived from wind velocity measurements at a local meteorological station as well as with those predicted from ERA-Interim (a Global Circulation Model). The wind velocity predicted by ERA-Interim is inappropriate to calculate the sand flux. This is due to the 6-hour sampling rate and to systematic bias revealed by a comparison with the local wind data. We describe a simple procedure that allows a correction for these effects. With the proposed correction, similar sand flux are predicted using the local and ERA-Interim data, independently of the value of the value of the shear velocity threshold, u_{*t}. The predicted sand flux is about 65% of Q_{Dunes}. The agreement is best assuming the lowest value $u_{*t} = 0.22\ m/s$ which is only slightly larger than the value of $u_{*t} = 0.2345\ m/s$ estimated based in the sand granulometry measured from a field sample. The influence of the dune topography on the wind velocity field could explain the underestimation. In any case, the study demonstrates the possibility of validating GCM model and calibrating aeolian sand transport laws using remote sensing measurements of dune dynamics and highlights the caveats associated to such an approach.

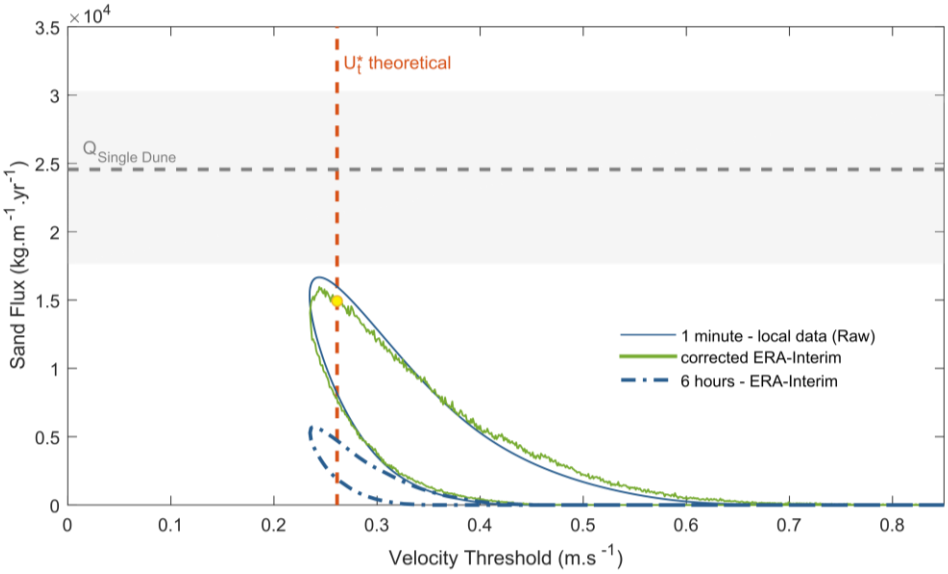

Figure 1. ERA-Interim's sand flux correction. The blue lines correspond to the initial data and the green lines correspond to the ERA-Interim's sand flux correction. The horizontal gray dashed line associated with $Q_{single\ dune}$ is the measured average sand flux for a single dune in our area. The shaded gray area represents its standard deviation. The vertical dashed orange line is Shao and Lu's (2000) [1] shear velocity threshold for a mean sand diameter of 236µm. From Michel et al., in review [2].

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Measurement of Aeolian bedforms dynamics from time series of optical images

J.-P. Avouac[1], F. Ayoub [2], S. Michel [1], K. Roback [1]
[1] *California Institute of Technology, Pasadena, California, USA*
[2] *Jet Propulsion Laboratory, Pasadena, California, USA*

Key words: remote sensing, ripples, dunes, sand flux

Abstract

The availability of high resolution optical images acquired from orbiting satellites and advances in image registration and correlation techniques [1] have open new avenues to study Aeolian processes on Earth and Mars [2,3]. In this talk we will discuss the performance and limitation of these techniques to track the migration of bedforms, dunes and ripples in particular, using time series of images. We will present a proof of concept studies focused on dune fields at Nili Patera, on Mars, and in Qatar, on Earth. We will use these examples to show how the remote sensing measurements can be used to estimate the sand flux related to the migration of bedforms of different scales and the insight gain on transport laws. We will also show how they can be used to estimate the wind field and validate predictions from weather modeling (a Mars GCM on Mars or ERA-Interim on Earth). These studies show that optical remote sensing can provide useful insight into the physics of Aeolian sand transport, information on current Mars weather, and help assess quantitatively the geomorphic impact of Aeolian processes with the possibility of extrapolating in space and time using GCM models.

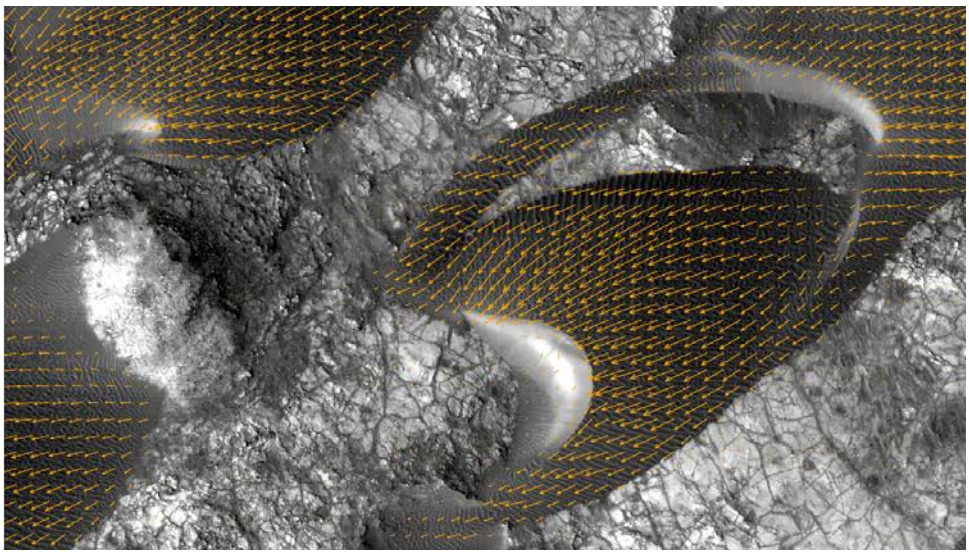

Figure 1. Ripples migration on Mars (Nili Patera) measured from optical image correlation [3].

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WIND TUNNEL INVESTIGATIONS INTO THRESHOLD WIND SPEEDS ON TITAN

D. M. Burr[1], S. L. F. Sutton[1], E. V. Nield[1], K. D. Runyon[2], J. P. Emery[1], J. K. Smith[3], J. F. Kok[4], F. Turney, C. E. Newman[5]

[1]*Department of Earth and Planetary Science, University of Tennessee, Knoxville, Tennessee, United States*

[2]*JHU/APL, 11100 Johns Hopkins Rd., Laurel, MD, USA 20723,*

[3]*School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, United States*

[4]*Department of Atmospheric and Oceanic Sciences, University of California Los Angeles, California, United States*

[5]Ashima Research, Pasadena, CA USA

Key words wind tunnel experiments, Titan, threshold wind speed

Titan, the largest satellite of Saturn, exhibits extensive linear dunes and sand seas [1 and refs therein]. The wind speeds required to entrain sand on Titan under current atmospheric conditions have been investigated using the Titan Wind Tunnel (TWT; Fig. 1) [1], a resource available at the NASA Ames Research Center, Mountain View, CA, USA [2]. The results from that work suggest that predictive models for threshold wind speeds on Titan underestimate the required speeds [1]. The inclusion of the density ratio term [3] brings the models into accord with the TWT data. On-going research is providing new values for parameters in the density ratio equation [4,5], but the reason for its corrective effect remains unclear [1].

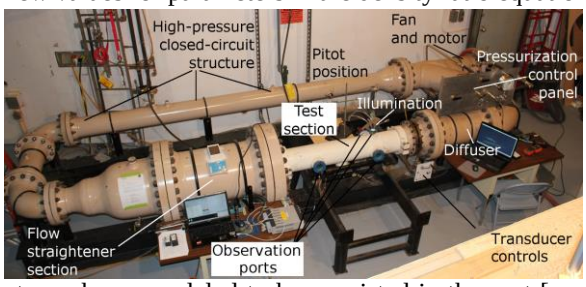

Figure 1. The Titan Wind Tunnel [1,2].

Additional research is investigating the effects on threshold wind speeds of paleoclimate conditions. In the previous work [1], we used a static pressure of 12.5 bar in the TWT to achieve the same particle Reynolds number – our similitude parameter – as at the surface of Titan. In these paleopressure investigations, we have used lower static pressures, to simulate the lower-density atmospheres modeled to have existed in the past [e.g., 6], and also higher pressures to more fully capture the effects of dense atmospheres on threshold. Our matrix is shown below (Table 1).

MATERIAL	SIZE RANGE*	DENSITY	PRESSURES (bar)
Charcoal	250-707 µm	400 kg/m^3	1, 3, 8, 12.5, 15, 20
Walnut shell	125-1000 µm	~1100 kg/m^3 [8]	1, 3, 8, 12.5, 15, 20
Beach Sand	500-1000 µm	2500 kg/m^3	3, 8, 12.5, 15, 20
Silica (Quartz)	106-600 µm	2650 kg/m^3	3, 8, 12.5, 15, 20
Basaltic cinders	150-1000 µm	3000 kg/m^3	3, 8, 12.5

Table 1. Partial experimental matrix. Other minor materials include glass spheres, chromite, and plastic chips. *Ranges aggregated to save space, but will be shown individually in presentation.

Our methodology entails: 1) collecting boundary layer profiles (BLPs) for a range of wind tunnel fan motor speeds and bed grain sizes, 2) analyzing the BLPs to derive values for roughness height (z_0) and the top BL (z), 3) collecting freestream wind speed data at threshold (u_t), 4) applying the values for z_0 (interpolating where necessary) and z to the u_t values with the Law of the Wall, to derive the threshold friction wind speed ($u*_t$). Challenges and uncertainties in this work include: 1) unexpectedly low values for z_0, and 2) collecting BLPs without sediment for applications to sediment transport conditions. Our initial results show the expected decrease in $u*_t$ with increasing pressure [7]. The finalized outcome from this experimental work will be used in conjunction with a Titan global atmospheric model [8] to quantify locations and directions of aeolian sand transport on Titan.

In a third project related to threshold wind speeds, we are conducting experiments to quantify particle trajectories near fluid entrainment. [9]. These experiments use a fixed sediment bed to limit sediment impact from upstream, with an inset trench of mobile sediment. This hybrid set-up allows us to capture on video the initial stages of saltation trajectories of fluid-lifted particles. Analysis of these trajectories will be used to guide development of a turbulence- and grain-resolving model of sand transport, with the ultimate goal of better understanding the role of intermittent sediment transport in dust emission and geomorphology. Extension of the model to Titan will widen the scope of the model to examine intermittency as a function of air-to-particle density ratio, turbulence structure, gravitational force, and cohesion.

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AVOID MAJOR 'PITFALLS' IN EXPERIMENTAL DESIGN TO IMPROVE AEOLIAN RESEARCH

A. Chappell[1] & N. Webb[2]
[1] *School of Earth and Ocean Sciences, Cardiff University, United Kingdom*
[2] *USDA-ARS Jornada Experimental Range, Las Cruces, NM, United States*

Key words Sediment transport; dust emission; field measurements; modelling; up-scaling; spatial-temporal variation; lateral cover.

We know from a vast soil erosion literature, that field measurements over a long period of time are required to represent the magnitude and frequency of events which transport sediment [1, 2]. Similarly, there are many publications which illustrate that many field measurements of sediment transport are required to reduce uncertainty sufficiently to detect change [3, 4]. On this basis it is difficult to reconcile the many studies of aeolian sediment transport which tackle neither of these challenges adequately, quantify only partial uncertainty and believe that interpretations of results are robust. More specifically, there are several major 'pitfalls' which appear to be hindering progress in field measurement and modelling of aeolian research. Here, we describe some of those pitfalls and their potential impact on the future of aeolian research (Table 1). We present the results of simulations and existing studies of aeolian research and related fields to demonstrate either how these pitfalls may be avoided or, where there is currently no satisfactory solution, to encourage the community to target these weaknesses in research. With an open and transparent approach to tackling these and other major pitfalls we encourage a more consistent and community-based approach to aeolian research. The intention is to improve reputational impact in aeolian research, raise awareness of its significance and attract a greater share of environmental funding for our community. We welcome contributions to the arising paper.

Table 1. Major pitfalls which appear to be hindering progress in aeolian research

Pitfalls	*Impact on aeolian research*
Up-scaling – the inability to adequately represent the non-linear (threshold) nature of aeolian sediment transport and dust emission for using measurements at one scale to make robust estimates over large areas.	Restricts the ability of process-based studies to generalize their impact particularly over large areas (regions, continents or globally) and hence influence large scale modelling efforts.
Point-based model and field validation – aeolian sediment transport equations which often underpin dust emission models are based on 'point' measurements and commonly applied (without up-scaling) over large areas.	Model uncertainty is incompletely quantified causing validation to be adequate which 'hides' variance and does little to improve understanding, progress research and influence modelling.
Preference for temporal variation – single towers for wind profile measurements are erected typically over highly heterogeneous land surface aerodynamic roughness (dunes, vegetation) omitting anisotropic variation of fetch, wind speed and direction and sheltering.	Measurement uncertainty of total shear stress is incompletely quantified and surface shear stress, which controls transport, is crudely estimated increasing uncertainty in transport and dust emission.
Ignoring spatial heterogeneity – few measurements of sediment transport or threshold are made over space typically with biased sampling designs.	Measurement uncertainty of sediment transport and surface shear stress is incompletely quantified with potentially misleading awareness e.g., erodibility is homogeneous and sediment supply is indefinite; areal averages for appropriate model validation are hindered.
Using vegetation indices or lateral cover – measurements or more commonly model estimates are used to approximate land surface aerodynamic roughness and its changes with wind direction and wind speed.	Estimates are at best crude and at worst flawed approximations with limited uncertainty and misleading outcomes.

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Experimental study to the take-off process of ejected particles

Youxing Chen, & Ning Huang
Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou, China
School of Civil Engineering and Mechanics, Lanzhou University, Lanzhou, China.

Key words Natural sand, the number of ejected particles, splash function.

The grain-bed collision and the splash process after the saltation collision in the sand flow are the key issues in the study of drifting sand movement. The number of ejected particles by saltating grains is an important parameter to characterize the splash process. Most of the existing experiments take substitute material of large particles to simulate sand particle-bed collision. As for numerical simulations, some assumptions have to be made to simplify the grain-bed collision. In order to obtain the take-off process of ejected particles, we use natural sand grains in the collision experiments. The results show that the number of splash particles in natural sand particles is lower than that of the numerical simulation, and our experimental results are different with the previous experiment results using substitute particles. Finally we present a splash function for the number of ejected particles.

Simulation of natural winds in a portable wind tunnel by evaluating full-depth and part-depth atmospheric boundary layer approaches for soil erosion research

C. Fabbri[1] & W. Fister[1]
[1]*Department of Environmental Sciences, Basel, Switzerland*

Key words Portable wind tunnel, atmospheric boundary layer, full-depth ABL, part-depth ABL, Irwin spires, Counihan vortex

To study the manifold aspects and impacts of wind erosion, scientists face the challenges of creating natural winds in a controllable study environment. In order to further improve the wind characteristics of an existing portable wind and rainfall simulator tunnel (PWRS, Trier University), a new and improved version of the tunnel was built at the University of Basel. The new wind tunnel consists of an electronically powered push-type fan, a four metres long transition section and a four metres long test section that follows after the air-straighter. Since atmospheric boundary layers (ABL) grow naturally over large fetch areas, the ABL needs to be artificially thickened due to the short length of the wind tunnel. Wind engineers commonly use a combination of roughness elements, barriers and mixing-devices (RBMD-Method) to accelerate the growth of the ABL.

In this study, the application of flat triangular spires (Irwin 1981) is compared to vortex generators (Counihan 1968) in terms of their potential to generate a full-depth atmospheric boundary layer in the scale ratio of 1:1000 (300 mm thick BL). LEGO™ bricks are used as roughness elements and a castellated barrier wall in front of the turbulence generators should replace the roughness effect of the natural surface by giving the growing ABL an initial momentum deficit (Cook 1978). Thus, the fetch length is kept as short as possible. In a second step, two part-depth ABL approaches are evaluated. By focusing on the simulation of the lower part of the ABL, a higher-scaled representation of natural winds is possible (in this case 1:500) to study wind-related problems in higher resolution (Kozmar 2011). Therefore, enlarged but truncated versions of the spires and vortex generators are tested in the wind tunnel on their potential to produce a 600 mm thick ABL. To our knowledge, so far no study has compared Irwin`s and Counihan`s methods in both, part- and full-depth approaches for laboratory and field testing of wind and rain erosion processes. The results will provide valuable information on the practicability and accuracy of frequently used ABL thickening devices. In addition, they could be used to further investigate the impact of the ABL scaling factors on erosion processes in wind and wind-driven rain experiments.

Figure 1. Portable Wind and Rainfall Simulator.

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SOIL CRUST PENETROMETER (SCP-200)

Jie Zhang[1], Kang Gong[1], Ning Huang[1] and Yaping Shao[2],

[1] *Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou University, 222 Souther Tianshui Road, Lanzhou, 730000, China*
[2] *The Institute for Geophysics and Meteorology, University of Cologne, Cologne, Germany*

Key words: soil crust, penetrometer, portable device

We design a portable Soil Crust Penetrometer (SCP) for puncture test of strength of soil crust. The device is separable and can be carried and operated by one person in the field. It is burly and powered by storage battery, and thus suitable for outdoor research. The assembly diagram is shown in Figure 1. The three legs can be fixed on the soil surface through dowel. A pedestal supported by the legs sustains a beam with puncture platform. The beam can revolve around the vertical axis of the pedestal and the puncture platform can move along the beam, thus different puncture positions can be selected. The puncture platform consists mainly of an impactor assembled with needle (optional sizes of millimeters) and struts, a mobile station assembled with screw rod, an electromotor to drive the screw rod, a spring to provide energy for impactor and a position-adjustable trigger locked on the strut. A high-precision dynamometer is mounted on the impactor to measure the axial force exerted on the needle. The impactor can be stuck together with the mobile station and driven by electromotor to move downward with a small and constant speed (adjustable form 0.1mm/s to 10 mm/s). The maximum force is recorded during the needle penetration into the soil to a depth of about 10 mm. This force should represent the strength of soil crust. The above measurement method is called the Quasi-static Test. A Dynamic Test is also available. If the impactor and mobile station jointly move upward, the spring will be compressed on the impactor. When the impactor approaches to the trigger position, it will be unhooked from the mobile station and accelerated by spring. Then the needle will thrust into soil with high and variable speed and the maximum force is recorded. The puncture speed can be controlled by the electromotor for the Quasi-static Test, but is dependent on the trigger position and property of spring for the Dynamic Test.

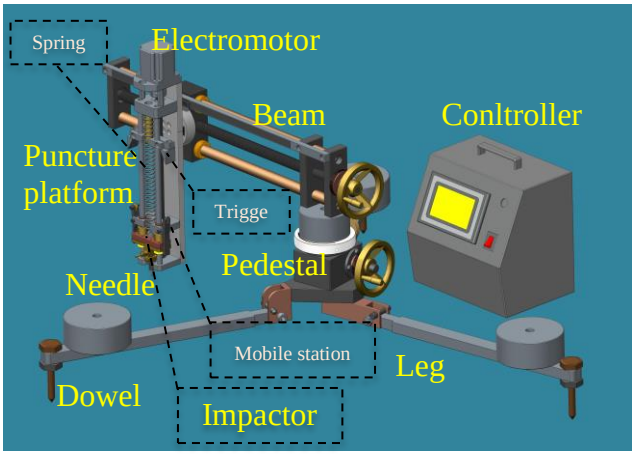

Figure 1: Structure of Soil Crust Penetrometer（SCP-200）

SIZE RESOLVED DUST EMISSION FLUXES MEASURED BY THE GRADIENT METHOD DURING 6 DUST STORMS OF THE WIND-O-V's 2017 EXPERIMENT IN SOUTHERN TUNISIA

B. Khalfallah[1], C. Bouet[1,2], M. T. Labiadh[3], S. C. Alfaro[1], J. L. Rajot[1,2,3], G. Bergametti[1], B. Marticorena[1], S. Dupont[4], S. Lafon[1], J. M. Bonnefond[4], S. Chevaillier[1], A. Féron[1], D. Garrigou[4], P. Hease[1], T. Henry des Tureaux[2], S. Sekrafi[3], P. Zapf[1]

[1]*Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*
[2]*Institut d'Ecologie et des Sciences de l'Environnement de Paris, Bondy, France*
[3]*Institut des Régions Arides de Médenine, El Fjé, Tunisia*
[4]*Institut National de la Recherche Agronomique, Villenave d'Ornon, France.*

Key words Dust emission flux, gradient method, WELAS.

Dust size distribution is a critical parameter to understand the interactions of mineral dust with its environment throughout its life cycle [1]. This is why it is important to document this characteristic of mineral dust from emission to deposition, included the atmospheric transport phase. Until recently, because of the limitation of the available instrumentation, only the total dust mass flux could be measured at emission, and this with a limited (half hourly at best) temporal resolution. The development of optical particle counters has allowed overcoming this limitation and the dust size distributions can now be measured at high frequency.

Using a dedicated experimental setup, size resolved dust emission fluxes were documented on a bare plot in southern Tunisia in the framework of the first intensive observing period of the WIND-O-V (WIND erOsion in presence of Vegetation) program (grant ANR-15-CE02-0013). The experiment was conducted from 1 March to 15 May 2017 in the Dar Dhaoui Experimental Range of the Institut des Régions Arides of Médenine. Size resolved dust emission fluxes were computed using the gradient method [2] and using for the first time WELAS optical particle counters.

During the field campaign, 6 dust storms were sampled. In the present work, the size resolved dust emission fluxes measured during the dust storms are presented and discussed in relation with the meteorological characteristics of the storms and the characteristics of the soil surface.

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High-latitude dust emissions : measurement considerations and approaches

J. King
Laboratoire d'Érosion Éolienne, Université de Montréal, Montréal, Canada

Key words high latitude, instrumentation, dust, paleoclimate, katabatic, climate change

Dust emissions from pro-glacial surfaces has been shown to produce some of the largest dust fluxes and are attributed to a soil type that can be several hundred meters thick. In the present climate, pro-glacial processes are globally reduced compared to the last glacial maximum (LGM) and concentrated at higher latitudes, but contribute a non-negligible proportion of the global dust budget albeit with large uncertainty. The estimates of dust production from high-latitudes is from a combination of few field studies, poor satellite retrieval from cloud cover, and limited knowledge on the processes that augment the timing and production of dust emissions in these regions.

It is theorized that from either the egress or ingress of glaciers that the resulting production of glacio-fluvial sediment and subsequent aeolian transport resulted in the large loess deposits globally. In the case of the northwestern Americas, these deposits are concentrated in a small region in western Yukon, Canada and Alaska, U.S.A., which is associated with an area not glaciated during the LGM. The processes that contribute to dust deposition from glacial erosion still occur today and are concentrated in fluvio-glacial valleys in where glaciers provide variable amounts of fine sediment from erosional processes that are subsequently transported by meltwater during warmer seasons and carried down the valley to either a lake or the Ocean. The dust emission process is driven by high winds that are generated by temperature gradients daily or annually, but are also a function of surface processes that can limit the availability of sediment. The river valleys containing the fine glacier-derived sediment are maximized when the ground is not frozen and the valley contains little to no meltwater. Further minor controls on dust emissions are snowfall, rainfall, grainsize, and soil water chemistry. The combination of the driving and limiting factors results in a relatively short window of transport in North America, with soils frozen in most of the valleys from November or December until April or May, and meltwater producing a pro-glacial river that can cover the valley floor from June until October. In fact, the dust emission episodes in previous studies also rely heavily on the timing and magnitude of winds in the region, which vary seasonally and could greatly limit the dust produced from these valleys even when they are unfrozen and dry, although these studies have concentrated mainly on the erodibility of the valleys.

Figure 1. Looking upstream of aeolian transported dust from Slims River Valley, Yukon, Canada

The focus herein is to demonstrate that the wind regime of a pro-glacial valley in southwestern Yukon, is a major controlling variable and that the variation in wind speed annually and from year-to-year greatly exceeds the variation in precipitation or temperature. If the glacial output of sediment and meltwater is consistent, the dust emission process should be controlled by the wind seasonality after the ground thawing and river levels. This hypothesis is tested with historical meteorological data from nearby climate stations and satellite imagery to estimate the seasonal and longterm changes in potential transport under a steady-state assumption for the glacio-fluvial system. Then using recently reconstructed glacier mass balance data a historical annual dust emission production is calculated to examine the influence of the activity of the glacial system.

A WIND TUNNEL TEST ON PREVENTATION OF SNOWPACK OF HIGH-SPEED TRAIN

Yusheng Liu[1,2,3], Jie Zhang[1,2], Ning Huang[1,2], Lei Ma[1,2] & Zhenjiao Teng [1,2]
[1]*Key Laboratory of Mechanics on Disaster and Environment in Western China, Lanzhou, China*
[2]*School of Civil Engineering and Mechanics Lanzhou University, Lanzhou, China*
[3]*School of Mathematics Lanzhou City University, Lanzhou, China*

Key words High-speed train, the bogie, prevention of snowpack, deflectors, protective effect.

It is hard to avoid packed snow particles in the bogie and the underframe, when high-speed trains run on the track around snowfield or in snowy weather. The adhered snowpack affects the movement of the bogie and its components, with potential of causing damage to the vehicle. It is believed that the installation of protective or diversion devices around the bogie is an effective way to reduce snow particles to enter in the bogie area and to subsequently decrease snowpack over the bogie area. In this paper, the shape and installation method of the skirt boards and deflectors of the train is tested by wind tunnel experiment. The transport law of three typical particulate matters (snow particles, fine wheat bran, fine sieved soil particles) through the bogie area is simulated and analyzed under 10 kinds of working conditions. Several parameters, including the relative reduction rate (snow particles), particle flux ratio (fine wheat bran), concentration ratio (fine sieve soil particles) and so on, are taken as a basis of the assessment for protective effect. The results of the comparative analysis show that the installation of short skirt boards on both sides of the train bogie, the installation of straight triangular deflectors at the front and rear ends, and the installation of the 90 degrees side deflectors have better effect in reducing the entry of the particles into the bogie and the underframe.

Interacting protodunes

J. M. Nield[1], M. C. Baddock[2] & G. F. S. Wiggs[3]
[1]*University of Southampton, UK*
[2]*Loughborough University, UK*
[3]*University of Oxford, UK*

Key words protodune, terrestrial laser scanner (TLS), beach, bedform development.

Early-stage bedforms, or protodunes, can be observed to form on sandy beaches, desert gravels or superimposed on the surfaces of larger dunes and can develop topography of 0.1 m or more over several hours. These protodunes are the precursors to embryo and eventually mature dunes, and so it is important to understand how these bedforms develop and interact. Whilst theory and conceptual models have offered some explanation for protodune existence and development, we know surprisingly little about how these bedforms initiate, migrate and interact because it is difficult to measure small changes in form (millimetres; seconds) on highly active surfaces of limited topographic expression. Here, we employ terrestrial laser scanning (TLS) to measure morphological change at the high frequency and spatial resolution (sub-millimetre) required to gain new insights into protodune behavior over a section of beach approximately 50 x 30 m during a two hour time period. During the experiment, bedforms migrated 0.5 m or more along the beach and in some instances grew vertically by >0.005 m. However, the placement of the protodunes with respect to the larger protodune field was important and protodunes in some cases reduced the sediment supply downwind, causing protodunes in the immediate downwind vicinity to shrink and accelerate. This field study shows the influence that even very small bedforms can have in the development and organisation of larger landscape patterns.

A New Laser Sheet Sensor (LASS) for Wind-blown Sand Flux Measurement

Qingqian Ning[1,2], Bailiang Li[1]
[1]*Xi'an Jiaotong-Liverpool University, Suzhou, China*
[2]*University of Liverpool, Liverpool, UK.*

Key words: Saltation sensor, sand mass flux, saturation limit.

Sand mass flux is often required to measure in many aeolian studies. The methodology has been developed from traditional mechanical traps to acoustic, photoelectric, and piezoelectric sensors with much higher spatial and temporal resolution. Among these photoelectric sensors, Wenglor Particle Counter (Wenglor YH03PCT8, 'the Wenglor') becomes very popular in recent years due to its fast response speed, small particle volume, and presumed consistency [1].
However, there are two major shortcomings: firstly, it may miss counts when multiple particles fly through the laser beam at the same time since it can only generate on-off binary signals. This ultimately leads to its low saturation limit and inapplicability for dense flux measurement. Secondly, its beam laser is too small to capture the bulk character of saltation clouds. To overcome these two shortcomings, a LAser Sheet Sensor (LASS) called Keyence LV-NH300 is proposed. A lab experiment following Baas's method [2] and a field experiment were conducted to test this sensor. The calibration results from these two experiments show that the LASS sensor has a much higher saturation limit than Wenglor, and its consistency is also better. However, lab test shows that sand particles within different diameter ranges have slightly different regression equation and that indicates on site calibration is needed (Figure 1). The field test shows that LASS might be affected by light density opaque material like foam ball or straw. LASS can be installed either vertically to capture bulk character of saltation clouds, or horizontally to acquire the saltation flux at a certain height, therefore it should have very wide applicability in aeolian research.

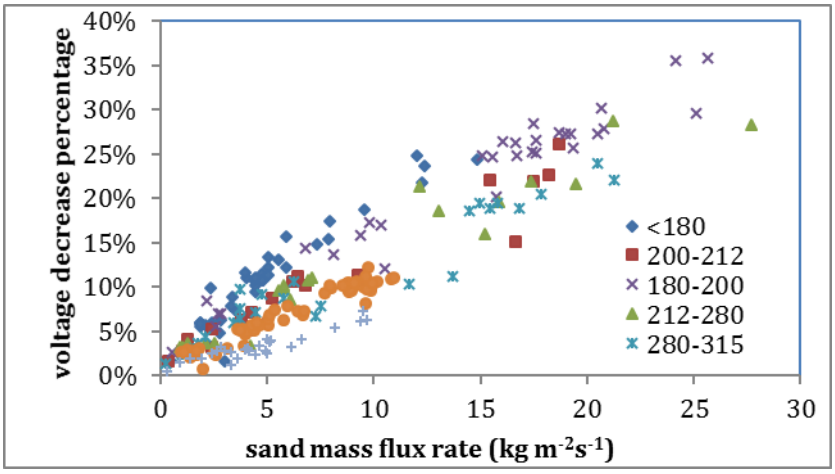

Figure 1. Relationship between sand mass flux rate and voltage decrease percentage for different grain sizes in μm. The saturation limit of Wenglor particle counter is less than 1 km m^{-2} s^{-1}.

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The WIND-O-V field experiment: WIND erOsion in presence of sparse Vegetation

Rajot J.L.[1,2,3], Bergametti G.[3], Labiadh M.T.[2], Alfaro S.C.[3], Bonnefond J.M.[4], Bouet C.[2,3], Chevaillier S.[3], Fernandes, R.[4], Féron A.[3], Garrigou D.[4], Guillet A.C.[3], Hease P.[3], Henri des Tureaux T.[1], Khalfallah B.[3], Lafon S.[3] , Lamaud E.[4], Laurent B.[3] , Ltifi M.[2], Marticorena B.[3], Pierre C.[1], Sekrafi S.[2], Zapf P.[3], Dupont S.[4]

[1]*iEES-Paris UMR IRD 242 - Institut d'Ecologie et des Sciences de l'Environnement de Paris, Bondy, France*

[2]*IRA – Institut des Régions Arides de Médenine, El Fjé, Tunisie*

[3]*LISA, UMR CNRS 7583 - Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France*

[4]*ISPA, UMR INRA 1391 – Interaction Sol Plante Atmosphère Villenave d'Ornon, France*

Key words: Saltation; Dust emission; Size-resolved fluxes; Gradient method; Eddy covariance method; Chemical composition.

Wind erosion in semiarid areas is a major threat for the soil productivity as it impoverishes soil in organic matters and nutrients. Compared to desert regions, these regions are characterized by sparse seasonal vegetation that impacts the erosion process. Semiarid areas face two major evolutions that may modify their wind soil erosion in the future: (1) climate change, with a modification of the amplitude and frequency of precipitations, affecting the surface vegetation cover, and (2) population growth, generating a considerable human pressure on the land use. Characterizing wind erosion in such complex regions is, therefore, crucial and challenging.

In order to better predict the amount and composition of emitted dust from semiarid areas, a novel field experiment named WIND-O-V (wind erosion in presence of sparse vegetation) has been performed in 2017 and 2018 in South Tunisia. The originality of this experiment is (1) to cover successively a plot without and with sparse vegetation, and (2) to combine detailed measurements of wind dynamics (including turbulence), size-resolved saltation and dust fluxes, and erosion-flux compositional fractionation along the soil-saltation-suspension continuum.

The experiment took place from March to May in the experimental range of the Institut des Régions Arides (IRA) of Médenine (Dar Dhaoui, 25 km east of Médenine). The site approximates a flat half-circle plot of 150 m radius where measurements were performed at the center of the circle in order to ensure a fetch of at least 150 m. In 2017, the surface has been tilled with a disc plough and levelled with a wood board in order to meet the conditions of an ideal flat bare soil without soil crust or ridges. In 2018, sparse vegetation consisting of barley tufts have been grown on the plot with a 3.3 m wide regular arrangement.

Three types of measures were carried out.

Meteorology: on a 9 m high mast erected at the center of the plot, turbulent velocity components and air temperature fluctuations were measured simultaneously at 1.0, 1.9, 3.0, and 4.1 m height using four 3D sonic anemometers sampling at 60, 50, 50, and 20 Hz, respectively. On the same mast, 7 cup anemometers (0.2, 0.6, 1.3, 1.8, 3.0, 4.0, 5.2 m) and 4 thermocouples (0.4, 1.6, 3.7, 5.0 m) were also installed to measure simultaneously at 0.1 Hz the mean horizontal wind velocity and temperature profiles, respectively. Three additional 2D sonic anemometers were installed in 2018 around a barley tuft to characterize the wind around the vegetation. Roughness length of the surface and friction velocity were computed on the bare plot case by comparing the Law-of-the-wall and Eddy-Covariance methods.

Saltation flux: one vertical array of 5 sediment traps like Big Spring Number Eight (BSNE) was deployed to quantify the saltation flux and its size distribution. The modified BSNE had a 5 times wider opening area to collect larger sediment quantities, allowing sequential (in time) sampling of individual erosive events and guarantying the possibility of applying size resolved analyses. Saltation flux measurements with a better temporal resolution were thus associated with more stable friction velocity conditions. In 2018, 5 MWAC masts were added to measure the spatial variability of the flux due to the sparse vegetation. A Saltiphone and a camera gave information on the beginning, end, and duration of erosive events.

Dust flux: for the first time size-resolved dust fluxes were estimated from both the traditional flux-gradient approach and the eddy covariance approach. For the first approach, mass and size resolved number concentrations were measured at two levels (2 and 4 m). To that purpose, two TEOM microbalances and two optical particle counters (WELAS Promo 2300) were used. Both sensor-types were connected to omnidirectional air sampling inlets. The WELAS monitored at 1 Hz the dust concentrations per size class (32 classes between 0.3 and 17 μm). For the second approach, a third WELAS was coupled to the 3 m high sonic anemometer in order to correlate the size-resolved dust concentration and the vertical wind velocity fluctuations. Finally, the chemical composition of dust fluxes was estimated from the sequential sampling of dust particles at two levels (2 and 4 m) with online filters equipped with inlets of different size cut-offs (20, 10, 2.5 and 1 μm).

SandFlow (SF4), a new acoustic sediment transport sensor

Michel Riksen[1] Dirk Goossens[2] Mahrooz Rezaei[3]

1) Soil Physics and Land Management Group, Wageningen University and Research, P.O. Box 47, 6700 AA Wageningen, The Netherlands

2) Geography and Tourism Research Group, KU Leuven Department of Earth and Environmental Sciences, Geo-Institute, Celestijnenlaan 200 E, 3001 Leuven, Belgium

3) Department of Soil Science, School of Agriculture, Shiraz University, Shiraz, Iran

Key words Sediment flux, Acoustic sensor, Sand transport, Field test

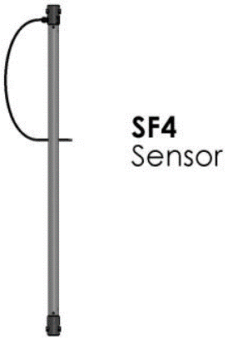

Fig. 1: The SF4 Sensor

The SandFlow (SF4) (Fig. 1), developed by IAV Technologies SARL - ISAW Products Division, is a new acoustic device to detect and measure aeolian sand transport. The SandFlow is based on the FlowCapt sensor (Chritin 1999; Cierco et al., 2007), an instrument developed to measure aeolian snow transport. Besides sediment transport the sensor also measures wind speed. The SandFlow is a robust and omnidirectional sensor, which could make it very suitable for long-time monitoring. However no field test data exist in which the sensor is compared to other equipment used for measuring aeolian sediment transport. The aim of this study is to test the capability of the SandFlow to measure aeolian sand transport by comparing the sensor to two other aeolian devices in a field experiment: the Modified Wilson and Cooke sampler (MWAC) and the Saltiphone. The test was performed from 7 till 24 August 2017 at a wide flat beach on the Dutch barrier island Terschelling. A total of 3 wind erosion events were measured during the experiment. Results indicated that the registrations of the periods of sand transport were very similar between the instruments provided sufficiently intense sand transport occurred. When sand transport was less intense, the agreement between the instruments was substantially lower although in many cases the periods of sand transport were still detected. Although differences could be observed between the SandFlows and the MWAC masts the flux values were of the same order of magnitude. This result is encouraging considering that aeolian sand transport usually occurs in streamers that create some variation in the spatial distribution of the transport flux. Identical transport fluxes are therefore not to be expected, but the fluxes should be within the same order of magnitude and this was the case for all three wind erosion events on Terschelling. The agreement between the transport fluxes measured by the SandFlow and the Saltiphone, on the contrary, was lower. Preliminary tests in the laboratory with different sand samples indicated that the sensitivity of the sensor to sand impacts is strongly dependent on particle size, which will require an adequate calibration of the instrument. We conclude that the SandFlow instrument adequately detects episodes of aeolian sand transport but that further calibration is necessary to optimize the flux readings.

Fig. 2: Comparing two Sandflow sensors with the MWAC and Saltiphone on the beach of Terschelling, The Netherlands

Constructing a Rotating Photoelectric Sensor to Quantify Aeolian Sand Transport Relative to Differing Bed Surface Compositions

P. Schmutz[1], T. Briggs[1], P. Tereszkiewicz[2]
[1]*University of West Florida, Pensacola, Florida, USA*
[2]*University of South Carolina, Columbia, South Carolina, USA*

Key words: Instrument Construction, Photoelectronic Sensors, Meso-scale Analysis, Anthropogenic

Electronic (i.e., acoustic, piezoelectric, and photoelectric) sensors have been utilized extensive and effectively for measuring aeolian transport intensity; however, these devices remain stationary during field deployments only capturing a single direction of transport. During shorter field deployments sensors can be moved or re-set in response to a change in wind direction; the reality of adjustment, however, for longer field deployments (months to years) is unrealistic. Being that transport processes are a vector function influenced by the magnitude and directional fluctuations of the wind, our current sensor deployment regimes present a limitation hampering our understanding of transport processes across meso timescales. In light of this limitation, this paper presents the development of an omnidirectional instrument to measure aeolian transport intensity across a 360-degree azimuthal range. The Rotating Wenglor Device (RWD) was deployed on Santa Rosa Island, Florida for a three-month field study. The combination of transport intensity and wind direction are graphically represented in a Wenglor Rose and compared against the theoretical Fryberger drift model for analysis and discussion. The data revealed that the general wind field produced a tri-modal pattern with the dominant direction out of the southeast; however, the prevailing transport activity was concentrated out of the northwest. This finding highlights a major advantage of utilizing the RWD to quantify transport drift compared to traditional methods, such as the Fryberger model, which is based solely on the percentage of winds greater than the threshold velocity of the sediment. The Fryberger model predicted a drastic overestimation of total transport (3 times) with a resultant drift direction towards the north-northwest compared to an observed drift direction towards northeast by the RWD (Figure 1). An additional advantage of the RWD to convention methods is that data can be collected by a sampling system that operates unattended for extended periods, yet at the same time provides high-resolution information regarding transport dynamics.

A secondary aim of this research was to evaluate the influence that intrusive gravel lag has on aeolian sediment transport activity. In aeolian systems the size and texture of sand grains can impact and alter the fluid threshold necessary for movement of sand. Therefore, intrusive sediments such as high concentrations of gravel can heavily influence the rate of sediment transport and subsequently dune development. This was accomplished by utilizing the RWD within survey plots containing differing concentrations of gravel lag. Results showed a statistically significant difference in transport activity between the plots at wind speeds up to 10.5 m/s, meaning that the gravel lag substantially inhibits aeolian sediment transport activity for winds below this value (Figure 2). Breakdown of the data demonstrated that winds occurred below 10.5 m/s 95% of the time during the 3-month study period.

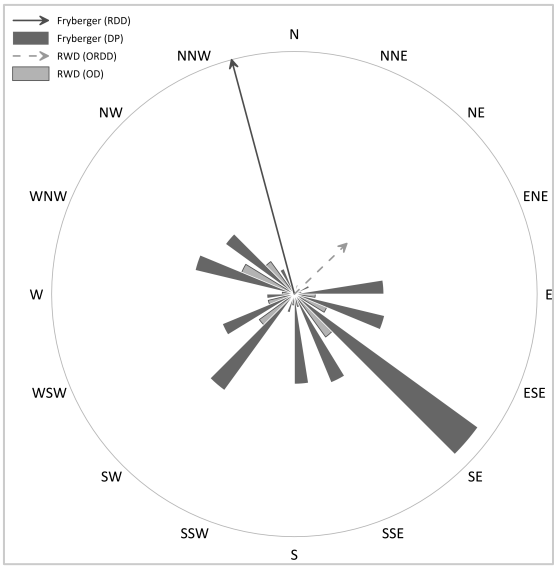

Figure 1.

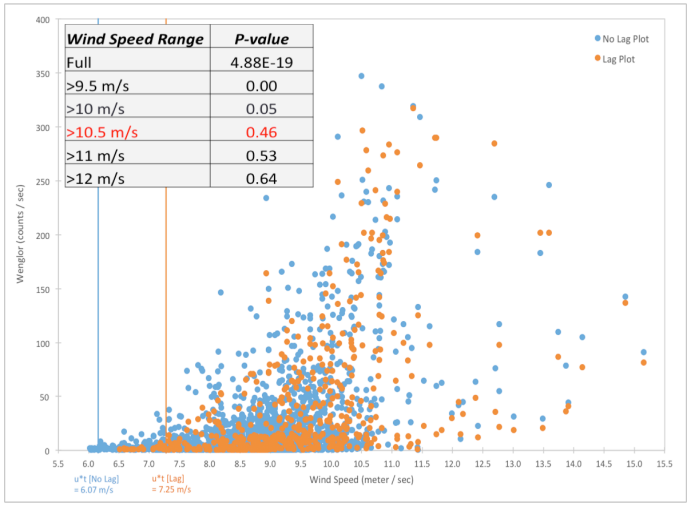

Figure 2.

EXPERIMENTAL MEASUREMENTS OF THE RELAXATION LENGTH IN AEOLIAN SAND TRANSPORT

H. Selmani[1,4], A. Valance[1], A. Ould El Moctar[2] & P. Dupont[3]
[1]*Institut de Physique de Rennes, UMR UR1-CNRS 6251, Université de Rennes, 35042 Rennes cedex, France.*
[2]*Laboratoire de Thermique et Energie de Nantes, Polytech. Nantes, CNRS UMR 6607, 44306 Nantes, France.*
[3]*LGCGM, EA3913 INSA Rennes-Univ Rennes, F35000 Rennes, France.*
[4]*Laboratoire de Mécanique de Précision Appliquée, Institut d'Optique et Mécanique de précision, Université Ferhat Abbas Sétif 1, Algérie.*

Key words
Relaxation process.
Sand mass flux.
Damped oscillation.

We investigate the relaxation process toward the equilibrium regime of saltation transport in the context of nonuniform conditions (i.e., transition from a rigid bed to a particle bed). Relaxation phenomena can be described in terms of a characteristic length scale which stands for the distance needed for the particle flux to adapt to a spatial change in flow or boundary conditions [1]. We carried out wind tunnel experiments to document the influence of the upwind mass flux on the relaxation process [2]. These experiments were conducted with various incoming sand fluxes at the upstream of the wind tunnel. In the case of zero upwind mass flux, the relaxation process is monotone and the saturation length is independent of the wind strength confirming the experimental outcomes of [3]. In contrast, for nonzero upwind flux conditions (by releasing particles in the flow from a hopper installed on the roof of the wind-tunnel and delivers a constant and prescribed upwind sand flux), the relaxation process is nonmonotone and share instead some features of a damped harmonic oscillations. Importantly, the relaxation length obtained in the last case increases with increasing air flow velocity but is almost insensitive to the magnitude of the upwind flux as shown in (Fig. 1). Our experimental outcomes clearly indicate that the relaxation of far from equilibrium transport regimes strongly deviates from a simple exponential behavior.

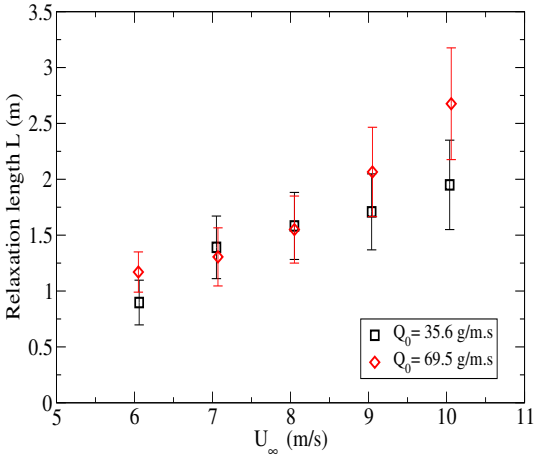

Figure 1. Relaxation length L versus the wind speed for two different upwind mass flux Q_0=35.6 and 69.5 $g/m.s$.

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Assessment of wind erosion rate affected by different soil properties in the Fars province, Iran

E. Sirjani[1], A. Sameni[1], A.A. Moosavi[1], M. Mahmoodabadi[2], M. Mirzaei Varoei[3] & B. Laurent[4]
[1]*Department of Soil Science, Agriculture Faculty, Shiraz University, Shiraz, Iran*
[2]*Department of Soil Science, Agriculture Faculty, Shahid Bahonar University of Kerman, Kerman, Iran*
[3]*Department of Natural Resources, Kurdistan University, Kurdistan, Iran*
[4]*Laboratoire Interuniversitaire des Systèmes Atmosphériques, UMR 7583, Université Paris Diderot, Université Paris-EstCréteil, IPSL, Créteil, France*

Key words: Arid and semi-arid soils, Soil erosion by wind in Fars province, Portable wind tunnel, Critical values of soil properties for soil erodibility

In this study, soil erosion by wind, estimated using a portable wind tunnel, is discussed regarding different soil properties at 60 points of 20 different arid and semi-arid regions of the Fars province, Iran. The soil erodibility can be controlled by several concomitant soil properties; one of them could be inhibiting. Extensive wind tunnel experiments were conducted at the same speed of 15 m s^{-1} and duration allowing measuring soil erosion rates by wind (E in g m^{-2} s^{-1}). The results indicated that the increase of soil surface gravel cover as well as the mean weight diameter (MWD) of soil particles could significantly reduce soil erodibility by wind (R^2=0.6, P<0.001, Fig. 1a; and R^2=0.6, P<0.001, Fig. 1b, respectively). The non-erodible elements on the soil surface protect soil against the erosive agent of wind by covering a part of the erodible surface and reducing the wind shear stress by absorbing wind momentum near the surface. Moreover, as this was indicated for other arid and semi-arid soils, our results showed the significant effect of soil clay (R^2=0.4, P<0.001) and moisture contents (R^2=0.6, P<0.001) on the decrease of soil loss rate by wind in the studied areas (Fig. 1c and 1d, respectively).Soils with high clay content have a low erodibility factor. The negative effect of soil moisture on erodibility is related to the cohesive forces of the adsorbed water film surrounding the soil particles through adhesion and capillary effects. Effects of some soil chemical properties on soil erosion by wind were also studied. Among soil chemical properties, soil organic carbon led to decrease the soil erodibility, significantly. Critical values of the soil parameters, for which soil erosion by wind is inhibited, were determined for the regions of the Fars province: 5% for the soil surface gravel cover, 0.3 mm for the soil MWD, 15% for the soil clay content, 2% for the gravimetric soil moisture content, and 0.4% for the soil organic carbon. Furthermore, the effects of the soil salinity, soil gypsum content, and calcium carbonate equivalent (CCE) on the soil erodibility by wind were also investigated. These results can definitively help us in documenting and finally preventing soil erosion by wind in the arid and semi-arid areas of the Fars province.

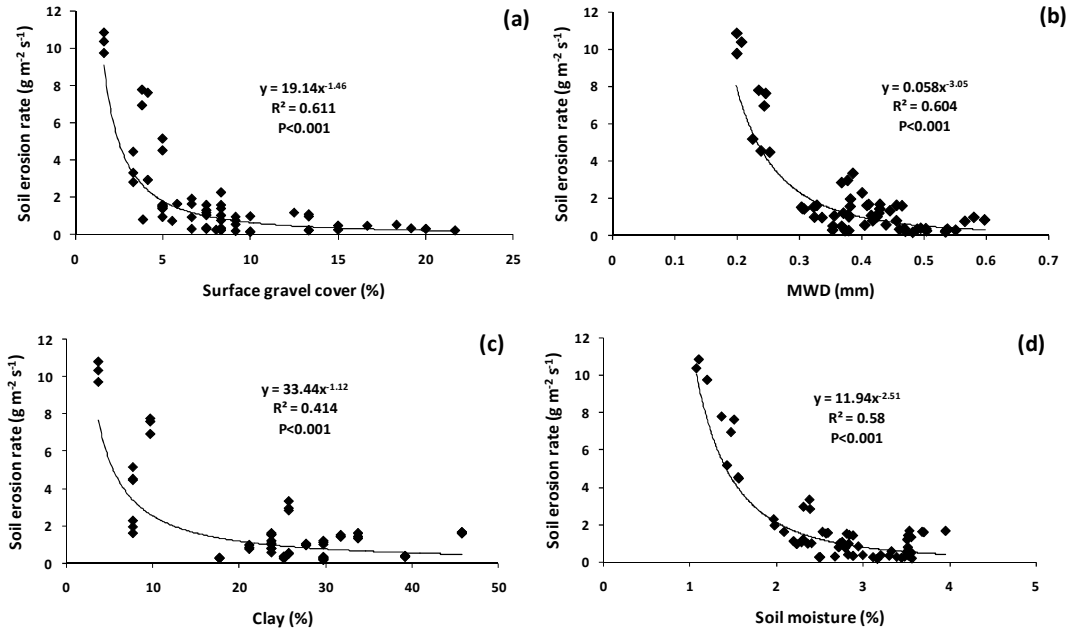

Figure 1. Dependence of wind erosion rate to (a) soil surface gravel cover, (b) soil mean weight diameter (MWD) (c) soil clay and (d) soil gravimetric moisture contents.

INFLUENCE OF SAMPLING APPROACHES ON PHYSICAL AND GEOCHEMICAL ANALYSIS OF AEOLIAN DUST IN SOURCE REGIONS

J ; Von Holdt[1], F. Eckardt[2], G. Wiggs[3], M. Baddock[4], M. Hpondoka[5],

[1] *University of Cape Town, South Africa*
[2] *University of Cape Town, South Africa*
[3] *University of Oxford, UK*
[4] *Loughborough University, UK*
[5] *University of Namibia, Namibia*

Key words Dust sources; emission potential;remote sensing

Variable erodibility and erosivity factors result in dust emission dynamics being complex in both space and time. Accounting for local-scale surface variability is critical to our understanding of dust emitting processes. This study identifies mineral dust using remote sensing, establishes emission thresholds through field measurements and identifies particle chemistry for major dust sources sampled in the Central Namib Desert. A PI-SWERL (Portable In-Situ Wind ERosion Lab) wind tunnel was used to measure the emission potential of the sub-kilometer scale point sources identified from Landsat imagery. The source point sediments were subjected to physical and geochemical analyses and compared to samples obtained from a passive collector, such as the Big Spring Number Eight (BSNE) and active PI-SWERL exhaust emissions, using an auto-SEM (QEMSCAN). This provided individual particle size, shape and mineralogy (>2 µm resolution) for up to 60000 particles per sample enabling a comparison between sampling methods.

Linking landforms with emission measurements allow for the assessment of two existing dust emission schemes: the Preferential Dust Scheme (PDS) and the Sediment Supply Map (SSM). Although these schemes represent a major advance in our representation of dust emission source areas and erodibility, this study shows that they still need to be improved to accurately depict dust emission potential. Different sampling approaches resulted in different representations of dust emitted at source, with differences in size, shape and mineralogy. The BSNE was inefficient at trapping and/or retaining the fine fractions (<20 µm), whereas the surface sediment sampling resulted in a potential underrepresentation of the <20 µm fraction. The PI-SWERL sample almost exclusively consisted of particles <63 µm. This has consequences for the interpretation of the potential impacts of the dust sampled at the emission source, such as an underrepresentation of the iron concentration in samples obtained with BSNE traps.

There is currently a disconnect between research efforts on dust emission undertaken by remote sensing identifying global transport pathways and inter-annual regional variability (>104 m) and ground based testing at grain scale (<10-2 m) studies that identify inter-particle interactions controlling surface emission. The high-resolution remote sensing, wind tunnel and auto-SEM data from this study established connections and provides an opportunity to explore dust emission processes across spatial scales.

RAINFALL EXPERIMENTS ON CRUST FORMATION ON SOILS FROM CROPLANDS IN THE FREE STATE, SOUTH AFRICA

H.C. Vos[1], A. Rzanicanin[1], W. Fister[1], N. Kuhn[1]
[1]*Physical Geography and Environmental Change, University of Basel, Switzerland*

Key words Crust formation, rainfall experiments, South Africa, Free State, cone penetrometer, dust emission

The croplands in the province of the Free State in South Africa emit large amounts of dust during periods of low crop cover and dry weather conditions, which usually occur from August to October. The predominant soils in this region are mainly Arenosols and Luvisols according to the FAO classification system. Physical soil crusts can develop quite frequently during rainfall events on these soils. Since the soil crusts significantly reduce the erodibility of these soils, it is fundamental to know the conditions under which they are formed and how resistant they are against wind erosion. The aims of this study were, therefore, to assess the dominant climatic and pedological conditions under which these crusts develop and to characterize the crusts by performing laboratory rainfall experiments on sampled soil from the study area.

The rainfall intensity, amount, duration, and the kinetic energy of the raindrops was chosen to simulate the conditions in the Free State. After the rainfall simulation the soil trays were dried in a climate chamber to simulate the relevant temperature and humidity conditions to, perhaps, stimulate growth of organic crusts as well. The analyzed crusts characteristics were the crust shear strength, the crust thickness and structure, the grainsize distribution within the crust, and the surface characteristics such as surface roughness and the presence of aggregates. The crust strength of these samples was measured by using a cone penetrometer. Through using thin sections and microscope analyses the micro-structure and characteristics of the crusts could be observed. In order to link these crust characteristics and formation conditions to actual dust emissions, future laboratory experiments using a wind tunnel in comparison with a Portable In-Situ Wind ERosion Lab (PI-SWERL, Desert Research Institute) are planned. In addition, future fieldwork will enable us to compare the dust emissions from these simulated crusts with natural crust and environmental conditions in the Free State.

Investigation of the mesoscopic features of the windblown sand creep motion with windtunnel experiment

Yang Zhang[1] & Bin Yang[2]
[1]*Department of Fluid Machinery and Engineering, Xi'an Jiaotong University, Xi'an, China*
[2]*School of Chemical Engineering, Northwest University, Xi'an, China*

Key words sand creep motion, wind tunnel experiment, particle tracking, creep trajectory, mesoscopic parameter

The characterization of aeolian sand creep motion remains incomplete. In this study, a top-view imaging system was constructed in a wind tunnel experiment to record sand creep motion on a flat sand bed, as shown in Figure 1. In addition, a set of 'mesoscopic' parameters was defined based on the creep trajectory that was reconstructed by a particle tracking algorithm. Statistical results show that the parameters representing the lifespan of the creep motion follow a lognormal distribution, whereas those representing the sideways grain motion deviate from the lognormal distribution. As the wind velocity increases, the sideways motion is strengthened and the lifespan of the creep motion is shortened, indicating a stronger transition from creep to saltation. Furthermore, under a 'pure rolling' hypothesis, the creep trajectory can be transformed into two numbers of rolling cycles from the perspectives of space and time. The ratio of the two numbers is useful in identifying the specific mode of the creep motion.

This study has two main limitations. The first limitation is related to technology: the top-view imaging system along with its image-processing algorithms only work when the sand flow density is relatively low. A dense saltating flow would cover the surface creep motion. Thus, the experiment in the current study was conducted under unsaturated conditions. Therefore, a universally applicable recording method, which is presumably difficult to achieve, is necessary in future. The second limitation is related to the transverse comparison among diameter groups. In this experiment, these groups are comparable only in terms of the 'starting point' and the 'span' of the friction velocity; the identification of a better criterion would be beneficial.

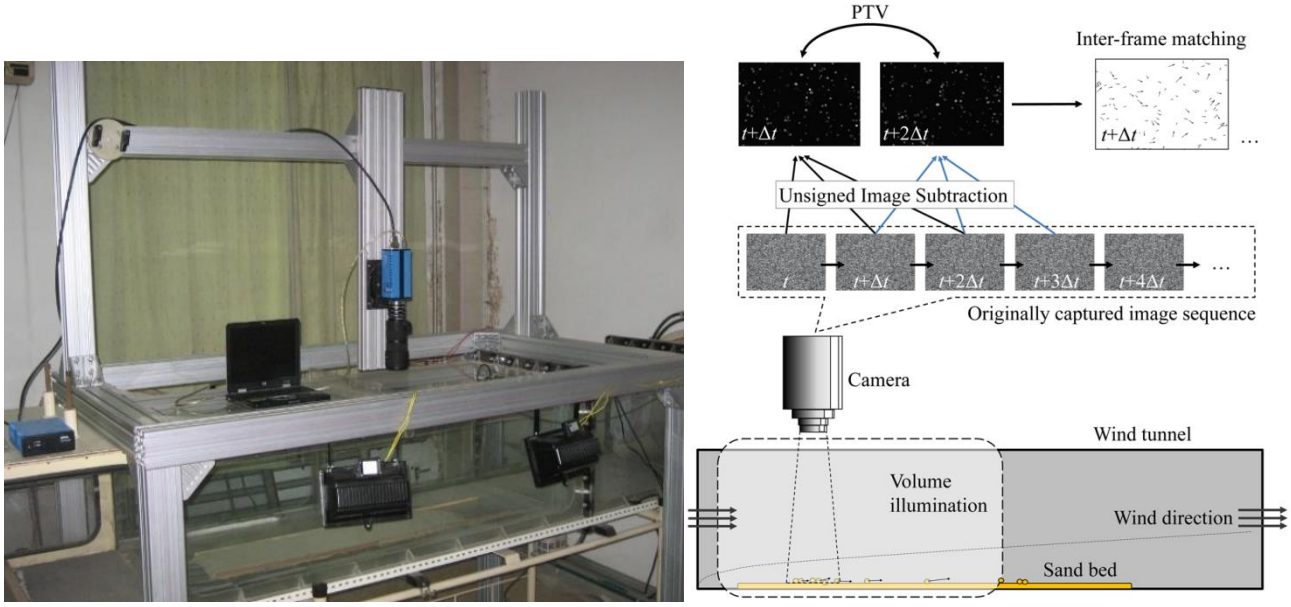

Figure 1. Experiment setup and post-processing procedure.

SIMULATION OF UNSTEADY WIND IN AN ABL WIND TUNNEL WITH DUAL AXIAL-FLOW FANS

Bin Yang[1],Bo Zhang[1],Yinghui Ren[1],Yang Zhang[2]
[1]*School of Chemical Engineering, Northwest University, Xian 710069, China*
[2]*Department of Fluid Machinery and Engineering, Xian Jiaotong University, Xian 710049, China*

Key words ABL wind tunnel; Unsteady wind; Fourier analysis; Sinusoidal wind.

Wind tunnel test plays an important role in studying the mechanism of aeolian sand transport. An ABL wind tunnel with dual axial-flow fans for simulating the unsteady wind is described in this paper. The air flows are generated by two fans arranged at both ends of the wind tunnel. During the experiment, the rotation rate of the fans were changed by varying the frequency of the inverters which can be controlled by PLC.

Through the steady wind experiment, it is verified that the airflow velocity in the wind tunnel fits logarithmic distribution law for neutral ABL flow and obtained the linear relationship between wind velocity v and current average frequency f. The correspondence relationship is Eqs1:

$$v(f,h) = \frac{f}{c1} ln \frac{h}{c2} + b(h) \tag{1}$$

Here $c1$, $c2$ are constants related to the roughness of the wind tunnel, $b(h)$ is the wind velocity loss due to negative pressure. When the frequency f is greater than 25Hz, The value of b can be negligible compared with the mainstream wind velocity. The Eqs1 is well fitted with the logarithmic law $U(z)/u_* = (1/k) \cdot ln(z/z_0)$ which is accurate in describing the near surface region of the simulated ABL.

While fans rotated with sinusoidal variation, corresponding sinusoidal wind generated in the wind tunnel. The unsteady wind is simulated in the experiment by means of dual fans running with different sinusoidal functions. Result shows that the produced unsteady wind can be regarded as superimposition of two sinusoidal winds which generated by the two fans individually. The fact is well match inverse Fourier transformation. Sinusoidal wind could be represented as Eqs2:

$$v(t) = A \sin(\frac{2\pi}{T} t + \phi) + m \tag{2}$$

here, v is the wind velocity, t is the time, A is amplitude value, T is the period, ϕ is the phase angle, m is the mean value. It could be found that the four factors A, T, ϕ and m are independent of each other. Mean value m and amplitude value A give the average velocity and the velocity variation interval of terminal composite wind respectively. Phase angle ϕ can be used to transfer the position of wind velocity history in the time axis. The most important factor is period T which decides the shape of wind velocity history. Thus the unsteady wind with complex changing can be produced in the wind tunnel by adjusting the rotation rate of dual fans as given sinusoidal variation. Figure1 shows an example wind velocity history. The unsteady wind production in the wind tunnel is under total control.

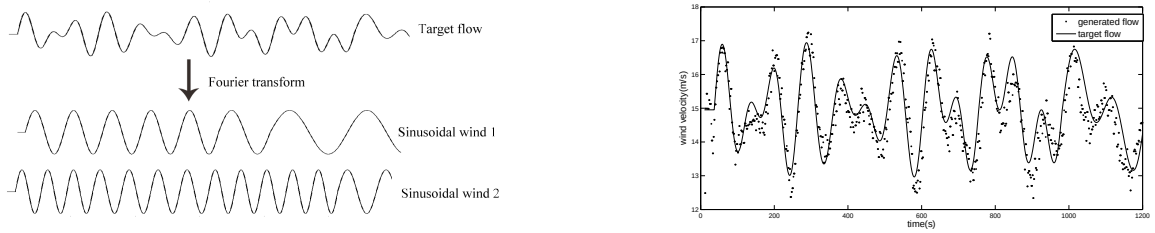

Figure 1. An example of simulation of velocity history.

Based on Fourier analysis, velocity history of field gust could be transformed to a series of sinusoidal winds. According to the experimental results as mention above, it is possible that low-frequency energetic part of the field gust could be approximately reproduced in the wind tunnel by superimposing several sinusoidal winds which is selected from the Fourier transformation result of field gust.

WIND TUNNEL OBSERVATIOM ON THE EFFECT OF A POROUS FENCE ON SHELTER OF A PRISMATIC COAL PILE WITH TRIANGULAR CROSS SECTION

G.G. Zhang[1], N. Zhang[1],J.E. Gao[2,3]

[1]*College of Water Resources and Architectural Engineering, Northwest A & F University, Yangling 712100, PR China.*

[2] *Institute of Soil and Water Conservation, Northwest A&F University, Yangling 712100, PR China.*

[3] *Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Yangling 712100, PR China.*

To investigate the shelter effect of a porous fence on wind erosion in a coal-pile storage yard, a wind fence (ε = 38.5%) was installed in front of a prismatic coal-pile with triangular cross section in a simulated atmospheric boundary layer (ABL). In the experiment, a particle image velocimetry (PIV) system was employed to visualize the instantaneous velocity of the flow around the fence and coal pile. The mean velocity, friction velocity and dust emission around the fence and coal pile were analyzed and evaluated. The results showed that 1) air flow rose gradually after encountering the coal pile. The wind speed increased and finally the vortex was formed in the leeward area behind of the top of the pile. The vortex caused the air flow reversely flew in the backwind of the coal pile, and the wind speed decreased rapidly. Therefore, dust movement mainly occurred on the surface of the windward area of coal pile, and the wind erosion was weak in the leeward area. 2) The wind fence could significantly reduce the wind speed in the windward area of coal pile downstream of the fence, but the wind-suppression effect was not obvious in the leeward area of coal pile. 3) The amount of wind erosion of coal pile was related with the normalized surface wind speed coefficient; the speed coefficient increased gradually along the surface level of the coal pile and reached the maximum value 0.8 in the top area of the pile. In the backwind area of the coal pile, the coefficient decreased rapidly, and was reduced to a negative value, so the air flow was less corrosive to the backwind area of coal pile. After setting the fence, the speed coefficient was significantly reduced to be only 0.4 at the top area of the pile, just about half of the value for no fence. 4) The efficiency of fence inhibiting the coal dust emission was decreased with the strength of wind increasing, and tended to be stable eventually. However the dust-suppression efficiency at the maximum wind strength could still surpass 75%, so it was obvious that the fence could suppress the dust emission.

key words: Porous fence; coal pile; PIV; friction velocity; dust emission.

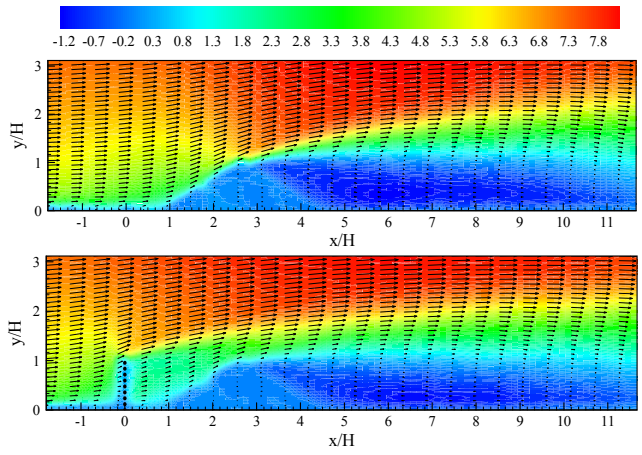

Figure 1. Comparison of the mean velocity field around a coal pile between with and without porous fence