

DuneFront

Deliverable 6.3

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Environmental influences

Acronym – 6.3 (D6.3)

Deliverable information

	Environmental influences
	D6.3
	6
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	Report
	Public
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Version 0.1	01/04/2025	Oliver Lojek (TUB-E)	Draft created by Beneficiary A
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Cover page

The overall objective of WP6 is to quantify a range of physical processes, including sediment dynamics, vegetation coverage, and metocean conditions, across 12 hybrid dune-dike demonstrator sites distributed throughout Europe (Fig.1). These 12 demonstrator sites, located in six different countries (Fig.1), encompass a range of functionalities and are subject to diverse boundary conditions and governance structures. Nine demonstrators are dune-in-front-of-dike, two are dune only and one is a dune on a dike. Each of the demonstrators represents a hybrid natural and structural solution (NbS), combining dunes and hard infrastructure (such as dikes) with the primary objective of coastal protection and biodiversity restoration. Additionally, these solutions can facilitate recreation and mitigate aeolian sand nuisance.

The aim of this report is, assess environmental influences stemming from vegetation coverage and potential human interference (D6.3). For this purpose, a novel model has been developed to detect vegetation coverage on white dunes using a convoluted-neural-network (CNN). The model has been calibrated on a different field site and was successfully applied to Digital Orthophotos (DOP) of a EU Dune Front demonstrator site spanning two decades of vegetation development. Furthermore, corresponding digital elevation models (DEM) were analyzed for morphodynamic changes ensuring temporal alignment with the CNN results for DOP analysis. Results show a very strong trend for the occurrence of vegetation on dunes, which accrete sediment. Whereas dune areas that eroded show little to no vegetation coverage.

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List of abbreviations

	Explanation
NbS	Nature-based Solutions
DiFoD	dune-in-front-of-dike
DiD	dune-in-dike
DD-NbS	Dune-Dike hybrid Nature-Based Solutions
MSL	Mean Sea Level
CNN	Convolutated neural network
DOP	Digital orthophoto
DEM	Digital elevation model

1 Introduction

The aim of the DuneFront project is to enhance the efficiency of dune-dike hybrid Nature-based Solutions (NbS) as a new generation of blue-grey coastal infrastructure in developing innovative strategies for the sustainable protection of European coastlines that are vulnerable to the impacts of climate change. The objective of this project is to enhance coastal protection and biodiversity conservation at both local and regional scales, by considering the geographic, climatic and socio-economic boundary conditions.

In Europe, the 'dune-in-front-of-dike' (DiFoD) or 'dune-in-dike' (DiD) are being developed as Dune-Dike hybrid Nature-Based Solutions (DD-NBS) with the objective of improving the resistance of coastlines to erosion while simultaneously providing sufficient coastal protection from flooding during storms and delivering multiple other services to the public. Both DiFoD and DiD are hybrid solutions that involve the deposition of a body of sand in front of existing or on newly constructed hard infrastructures. This sand body is then typically planted with vegetation to further promote its development and enhance its resistance against erosion and resilience to sea level rise. The construction of sand bodies in front of hard structures, or covering hard structures, has been demonstrated to reduce the impact of waves, mitigate sand losses from the system, and enhance recreational values. The objective of this project will be achieved by utilizing a series of demonstrator sites along the European coastlines.

12 DuneFront demonstrator sites, located in six different countries (Figure 1), encompass a range of functionalities and are subject to diverse boundary conditions and governance structures. Each of the demonstrators represents a hybrid natural and structural solution (NbS), combining dunes and hard infrastructure (such as dikes and groynes) with the primary objectives of coastal protection and biodiversity restoration. Additionally, these solutions can facilitate recreation and mitigate aeolian sand nuisance.

The demonstrators have been selected based on their potential for cost-effectiveness, climate and structural adaptability, and the ecosystem services they provide to both human communities and the environment. The demonstrator research targeted DiFoD systems but also included structural variants (dike-in-dune) as a reference for alternative designs under anticipated different boundary conditions. Such hybrid NbS also form the basis of marine infrastructure, including the construction of artificial islands that serve as renewable energy hubs or as marine barriers for coastal protection. An analysis of the physical, morphodynamical, ecological and socio-economic data available from these demonstrators will lead to the first comprehensive and novel overview of well-known NbS available along the European coastline.



Figure 1 - Location of the 12 selected Demonstrators

Table 1: Coordinates of the 12 selected Demonstrators

1	Douro estuary sand spit	Portugal	41° 8.453'N - 8° 40.055'W
2	Soulac	France	45°31'0.16"N - 1° 7'35.35"W
3	Dunkerque	France	51° 3.014'N - 2° 22.524'E
4	Sainte-Marie La Mer	France	42° 44.094'N - 3° 2.256'E
5	Living Lab Raversijde	Belgium	51° 12.659'N - 2° 51.991'E
6	Middelkerke grass dike	Belgium	51° 10.154'N - 2° 46.145'E
7	Delflandse kust	The Netherlands	52° 2.801'N - 4° 11.097'E
8	Hondsbosche Duinen	The Netherlands	52° 45.925'N - 4° 39.151'E
9	Katwijk	The Netherlands	52° 12.298'N - 4° 23.580'E

10	Texel Hondiusdijk	Prins	The Netherlands	53° 1.593'N - 4° 49.010'E
11	Sankt Peter-Ording		Germany	54°19'11.8"N - 8°36'23.2"E
12	Ystad		Sweden	55° 25.720'N - 13° 51.546'E

1.1 Overview of work package 6 (WP6 Demonstrator morphodynamics)

The overall objective of WP6 is to quantify a range of physical processes, including sediment dynamics, vegetation coverage, and metocean conditions, across 12 hybrid dune-dike demonstrator sites distributed throughout Europe. This effort will compile a valuable spatio-temporal database that captures the variations in these processes across space and time, enabling a deeper understanding of how hybrid coastal defense structure's function and integrate across diverse European contexts.

The analysis of existing data from the demonstrators, with available data on dunes and dikes individually, will serve as the primary foundation for designing DiD (Dunes in Dikes) or DiFoD (Dikes for Dunes) systems. This analysis will include studies of erosion and accretion dynamics, vegetation development, and their interactions with various governance-related factors, such as recreation and beach nourishment. Quantifying sediment dynamics across all demonstrators is essential, linking these dynamics to local boundary conditions and assessing the subsequent maintenance actions required. This analysis will also address how sediment dynamics are influenced by recreational pressures and vegetation development, recognizing vegetation as a key driver of aeolian dynamics, which will vary across the sites. Finally, it will be necessary to quantify both the average responses of these systems and their behavior under extreme conditions.

1.1.1 Tasks of work package 6

Firstly, sediment dynamics will be derived from a spatiotemporal analysis of high-resolution digital elevation models (DEMs) for all demonstrator sites. This analysis will be supplemented with meteorological data sourced from on-site or nearby weather stations. The resulting dataset will be compared against a reference site that lacks dikes or dunes in proximity to the DD-hybrid NbS (Nature-based Solutions) infrastructure. This comparison will facilitate the evaluation of the relative effectiveness of the DD-hybrid NbS system at the demonstrator sites. Validation will be carried out by hindcasting sedimentary evolution within the demonstrators. To enhance accuracy, a recently developed root mapping function will be further refined for integration into the XBeach dune erosion model. This adaptation will enable the modeling of erosion dynamics and resistance even in cases where site and plant-specific root trait data are unavailable. Considering the significant spatiotemporal variability of sand and vegetation drivers, the objective is to quantify the average impacts and estimate associated uncertainties using sensitivity analyses. The DEM data will also be utilized to train numerical process-based models XBeach (for dune erosion) and AeoliS (for dune growth) for conducting kilometer-scale morphodynamic evaluations that extend beyond the DuneFront project's lifetime. Projections of potential future changes in sedimentation and erosion within the demonstrator sites will be generated using Representative Concentration Pathway (RCP) scenarios 3, 4.5, 6, and 8.5.

1.1.2 Milestones and deliverables of work package 6

Task 6.1 Morphodynamic patterns (Lead: TUB-E; Involved partners KULEUVEN, UPORTO, UPVD, ULOC, M1-M12) - Analysis and quantification of sediment dynamics deduced from collected DTM data for multiple years per Demonstrator (D6.1).

Task 6.2 Vegetation-sediment interactions (Lead: KULEUVEN; Involved partners TUB-E: M6-M15) - TUB-E and UGENT-B will use data from D5.2 and D6.1 to conduct spatiotemporal regression analyses on sedimentation/erosion budgets and vegetation cover data under various physical boundary conditions to assess vegetation cover impact and improve an existing root mapping function for XBeach to consider dune erosion resistance impacts of vegetation (D6.2).

Task 6.3 (this report) Environmental influences (Lead: TUB-E; involved partners KULEUVEN, UGENT-B, M1-18) - KULEUVEN and TUB-E assess boundary conditions from WP5 and correlate these boundary conditions with quantified morphodynamic patterns (D6.1) as well as vegetation coverage (D6.2) to deduce potential influences from abiotic as well as anthropogenic conditions at each site on observed sediment and vegetation dynamics (D6.3).

2 Environmental influences

The aim of this report is to develop a methodology to relate vegetation coverage and morphodynamic responses expressed in net accumulation or erosion.

2.1 Methodology

2.1.1 CNN Model – Vegetation segmentation map

The morphodynamics of white dunes and foredunes are strongly influenced by vegetation and its characteristics. Consequently, dune vegetation is a crucial factor as it determines the effectiveness of a dune as a Nature-based Solution (NbS) mitigating flooding of the hinterland and coastal erosion (Ahrenbeck et al., 2025). To gain a deeper insight into the condition of dunes, vegetation maps indicating spatial dune vegetation patterns like the distribution and the coverage of vegetation are essential for dune management and conservation. The use of Artificial Intelligence (AI) for vegetation classification from remote sensing data has become popular in recent years due to various advantages. Convolutional Neural Networks (CNN) have proven to be particularly promising in this context, achieving high accuracy in vegetation mapping across various ecosystems. However, to date, no CNN with high accuracy have been developed for vegetation mapping of coastal dunes. In order to create a link between research and practice, a novel CNN model has been developed. As part of the development, multiple vegetation surveys were conducted revealing the predominance of marram grass (*Calamagrostis arenaria*, formerly *Ammophila arenaria*) on a particular white dune used as calibration/validation and training data set. Consequently, vegetation for this CNN currently corresponds to marram grass and therefore vegetation mapping to the detection of marram grass. The developed CNN has a U-net architecture and was trained using a Red-Green-Blue-Alpha (RGBA) Digital Orthophoto (DOP) featuring a spatial resolution of 0.2 m. To generate the reference data for training the CNN, a total of 35700 m² of the study site was manually mapped. The CNN has an accuracy of 92 % and shows a high transferability to comparable use cases. To provide further insights into the morphodynamics of the studied dune, a novel method was developed, establishing a correlation between estimated vegetation densities via remote sensing and on-site measured vegetation densities. To estimate vegetation densities, the emission characteristics of reference pixels representing categories of different vegetation densities were analyzed within a Red-Green-Blue-Infrared (RGBI) DOP see *Figure 1*. Based on this analysis, a custom Vegetation Index (VI) was developed for the studied dune, enabling the classification of detected vegetation into predefined Vegetation Density Categories (VDC) see *Figure 2*. By processing the measured vegetation densities into the same VDCs, the established correlation was used to assign ranges

for actual vegetation densities to detected vegetation. A comparison of the result with the corresponding DOP and on-site impressions confirmed the principal correctness of the method. Due to its underlying functionality, the method is generally transferable to other white dunes for estimating their vegetation densities (Kosmalla et al., 2024). However, this requires case-specific modifications of its parameters related to the vegetation’s reflectance properties. Furthermore, the measured vegetation densities cannot be considered universally representative for other white dunes. As a result, on-site impressions of each investigated dunes are necessary to establish the correlation.

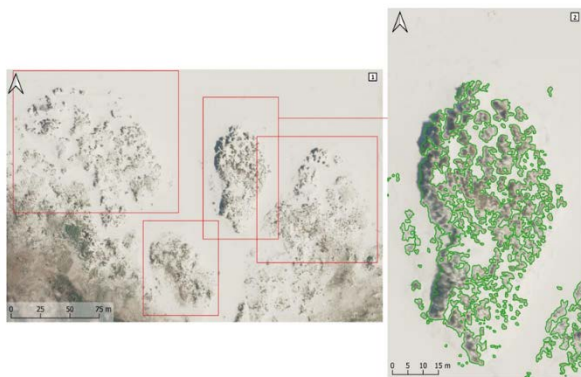


Figure 1: Training data sets and exemplary detection result for white dunes.

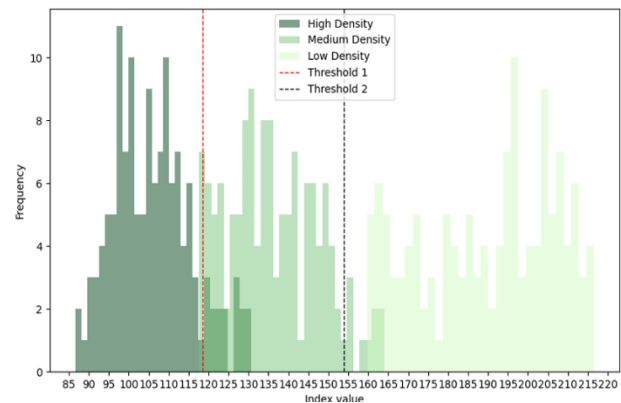


Figure 2: CNN result for training data set regarding vegetation density classes (VI)

The key outcome is a novel CNN method, which demonstrates the effectiveness of utilizing AI for analyzing the coastal protection function of dunes, while maintaining high accessibility. Additionally, it can be demonstrated for the first time that determining vegetation densities on dunes using remote sensing is fundamentally feasible. Both are important steps towards a more sustainable coastal management capable of addressing the growing challenges ahead.

After successful calibration of the CNN it was applied to the demonstrator site in DuneFronts, here Sankt-Peter Ording on federal DOPs with a ground resolution of 0,2 m per pixel (Figure 3).



Figure 3: CNN output regarding vegetation coverage on the white dune area

2.1.2 DEM analysis – Cumulative sedimentation/erosion, slope-based dune detection

In order to correlate vegetation coverage detected with the developed CNN to potential morphodynamic changes (cum. Sedimentation/erosion) in matching years, federal survey data was procured and previously assessed in D6.1. The same data base was used for carrying out two major aspects within D6.3: Firstly, the DEM data was analyzed for terrain slope using the inherent resolution of the raster equal to 10 m. Previous studies showed a good detection threshold for white dunes to reside around 5° slope for the dune toe area. Using this threshold, white dune areas were detected within the DEMs (see Figure 3 and Figure 4).

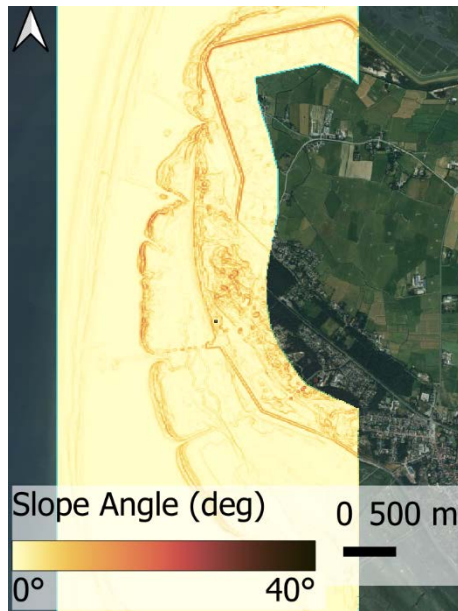


Figure 4: Slope analysis of the DEM for the German Demonstrator SPO for 2011

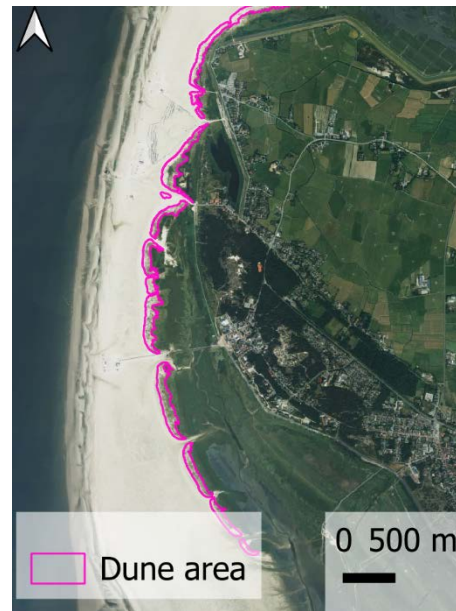


Figure 5: Slope-based white dune area detected for the DEM 2011

Similarly, to the slope analysis, DEM data sets from adjacent years were used to quantify terrain changes due to morphodynamic elevation modulations. These delta-elevation maps have been systematically generated through subtracting the previous/pre-dated DEM from the more up to date one e.g., 2011 – 2010 shows the elevation changes in 2011 since 2010 (cf. Figure 6). This ensures that all negative changes can be attributed to erosion and positive net increases equal accumulation of sediments.

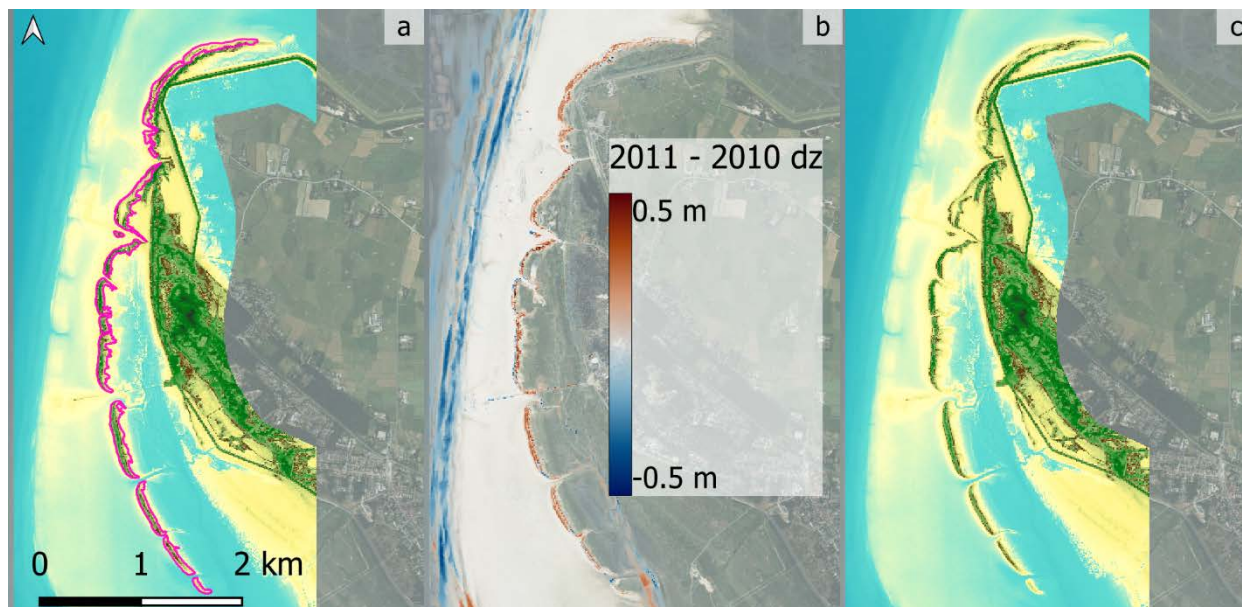


Figure 6: Generation of elevation changes map between adjacent years of DEM data. Subtracting the pre-dated year (a) from the following one (c) to create a delta DEM (b).

2.1.3 Correlation of vegetation coverage and cumulative sedimentation and erosion

Correlation of vegetation coverage detected with the developed CNN and the morphodynamic changes was achieved by extracting the vegetation coverage data per cell and the cumulative erosion/sedimentation value of the corresponding cell. Given the different spatial resolutions of the DOPs with 0,2 m per pixel and the DEMs with 10 m grid spacing, the CNN values based on the DOP data feature a much higher spatial resolution. This facilitates a better vegetation detection. Surface elevation change values were interpolated onto the vegetation grid cells, using a geospatial interpolation (inverse distance Kriging) achieving cross validation values of $R^2=0.998$.

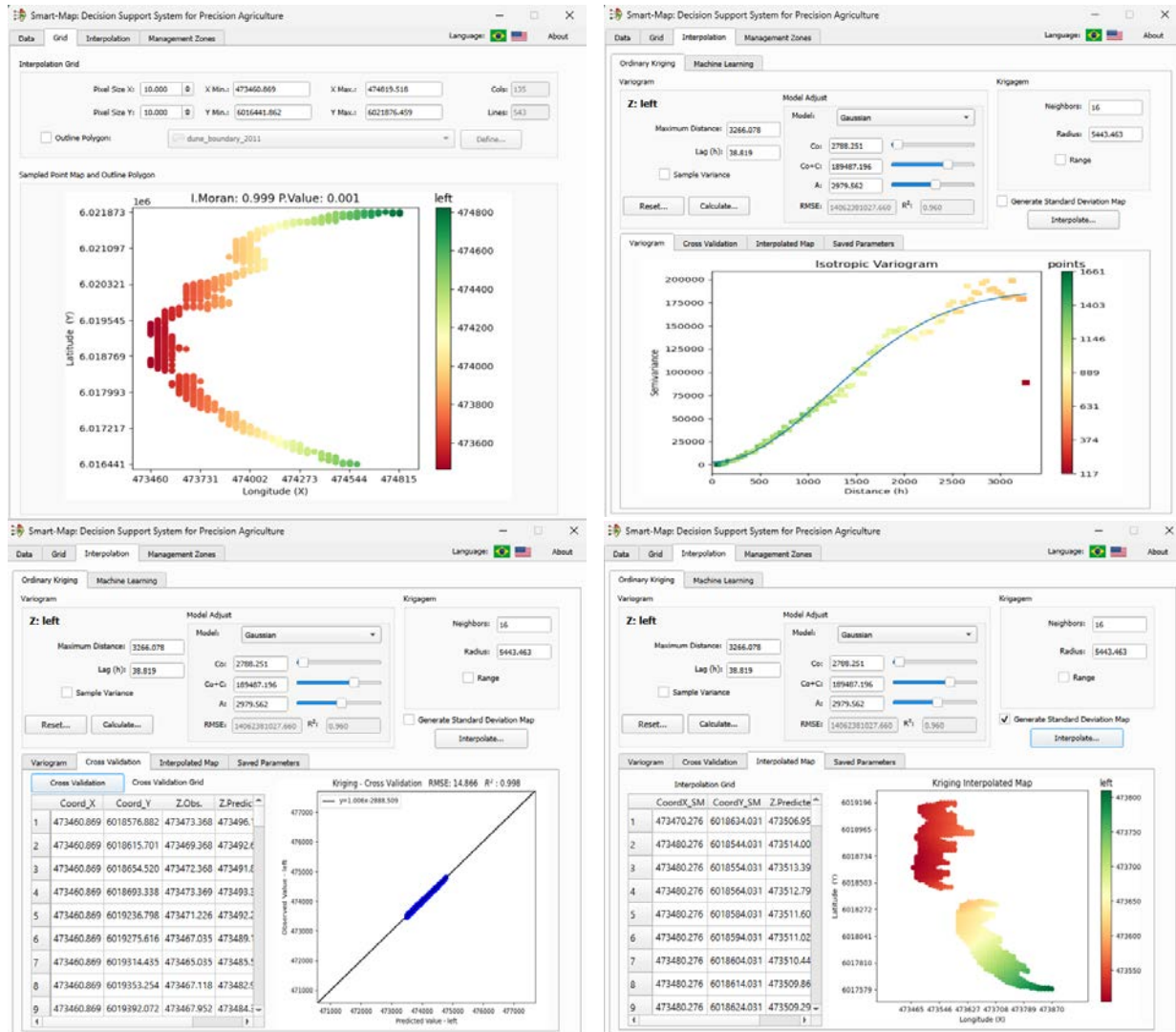


Figure 7: Snippets of the weighted inverse distance Kriging interpolation for the DEM data onto the CNN raster. Cross validation values exceeded $R^2=0.95$ for all years

The IDK allowed to extract and compare vegetation coverage and sedimentation erosion values. This was successively done for the available data. For multiple years the analysis was conducted forward and backward in time, meaning the vegetation coverage was compared with the cumulative sedimentation and erosion values stemming from the previous year and the current year for the first set and the current year and the following year for a second data set. This yields two data sets per CNN analysis allowing to check

the development of vegetation & morphodynamics in space and time, rendering the results more robust compared to a single snap-shot with only one analysis.

2.2 Results

Combining the different aspects of the described methodology, the following steps are performed, and outlined in Figure 8, to obtain trend data for vegetation coverage and morphodynamic elevation changes:

- a) Slope analysis of DEM allowing for a slope-based detection of the white dune area
- b) Slope-based white dune area for a given DEM
- c) Application of CNN model to DOP of given year and matching DEM based white dune area
- d) DEM based cumulative sedimentation/erosion analysis for previous year
- e) Base DEM matching DOPs and CNN analysis
- f) DEM based cumulative sedimentation/erosion analysis for subsequent year
- g) Inverse distance Kriging (IDK) of morphodynamic response value onto higher resolution CNN vegetation coverage index
- h) IDK for an anthropogenically influence beach/dune area, which is dredged out every season since it resembles one of two beach access pathways for visitors.

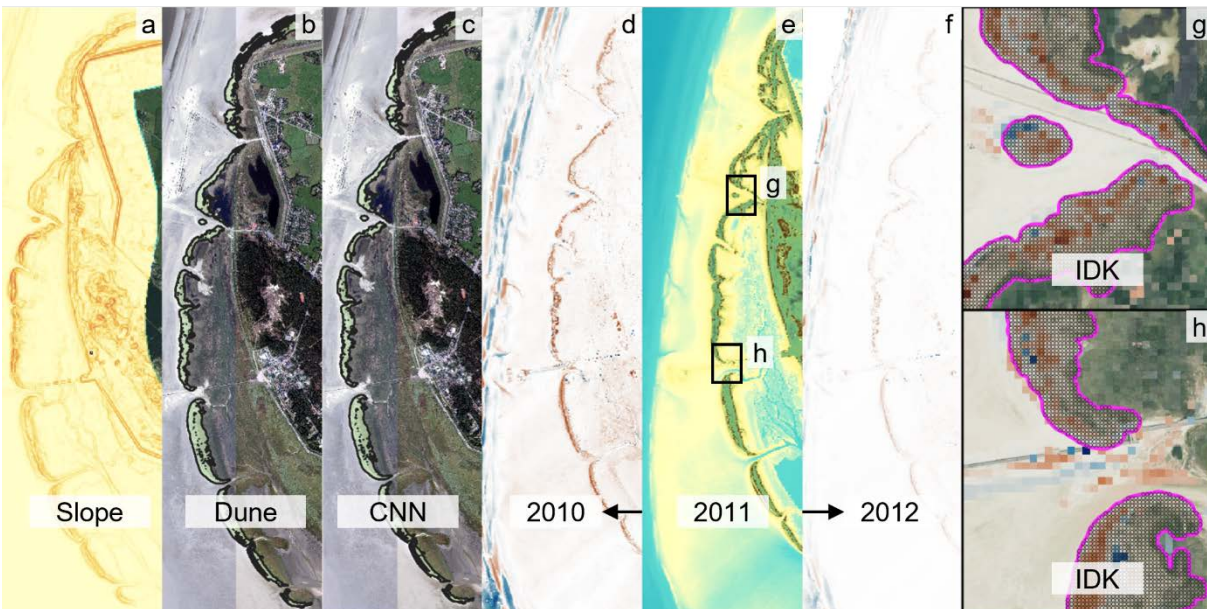


Figure 8: Method description: (a) Slope detection (b) White dune area detection slope-based (c) CNN application to DOPs within white dune area (d) morphodynamic changes 2011-2010 (e) DEM 2011 (f) morphodynamic changes (2012-2011) (g-h): Inverse distance Kriging

2.2.1 Sankt Peter Ording (Germany)

Overall DOPs were available for the years 2011, 2014, 2018, 2020 and 2022. Matching DEM data was researched and processed as outlined in the methodology section. The available data base allowed for 4 spatio-temporal analysis of CNN and matching DEM. For 2022 subsequent DEM data is not yet available. DOPs predating 2011 are available but the quality of the sensor and/or the weather conditions and lightning prevented a full analysis. An overview is given in Figure 11.

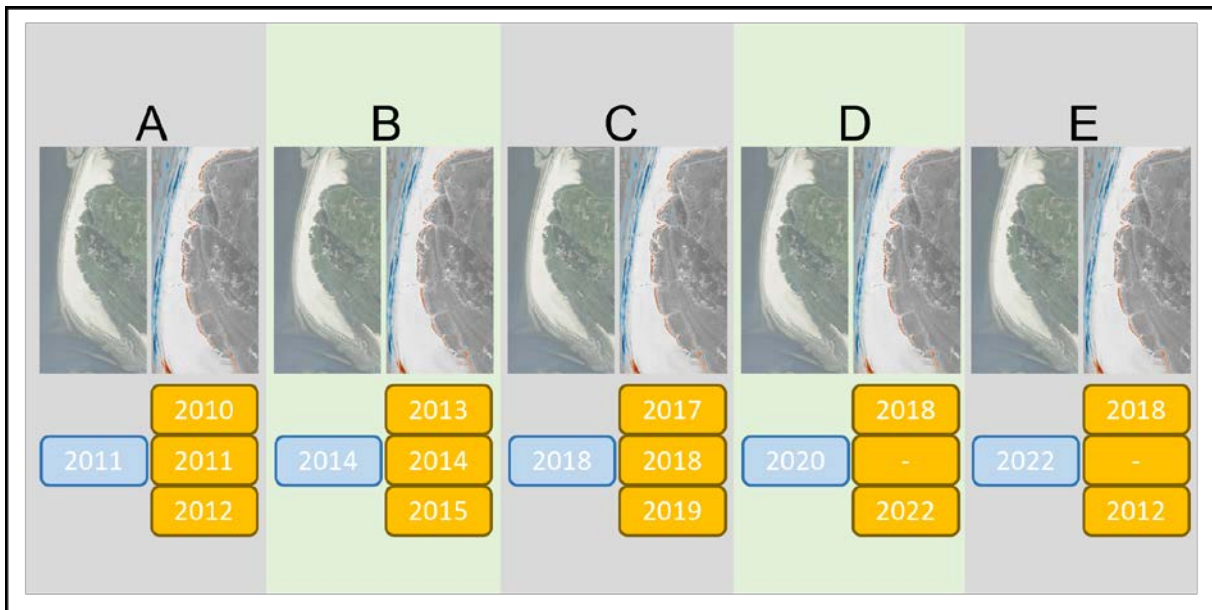


Figure 9: Data used for the CNN and DEM analysis and resulting trend data for vegetation-morphodynamic responses

Data set A

For the first data set a DOP mosaic of 2011 was processed with the CNN and a vegetation coverage obtained. For the DEM analysis, data sets from 2010, 2011 and 2012 were readily obtained and processed. The total white dune area detected based on the terrain slope equaled 638840 m² for 2011. Resulting elevation changes for vegetated cells can be seen in the two histogram plots with cumulative distribution functions of the elevation change magnitudes. Left panel shows the distribution of vertical elevation changes detected within the white dune area covered by vegetation. The dividing centerline marks the shift from erosion (left side) and accretion (right side). A clearly positive skewed distribution is obtained for the years 2010-2011 given the CNN vegetation map. Similarly, the follow-up year 2012 in comparison to 2011 shows strong accretive tendencies across the complete demonstrator site for the white dune area with vegetation. Given that there is also a small number of cells detected with vegetation and negative elevation changes (erosion) shows, that vegetation coverage is not linearly linked to dune growth. The negative values mainly occur along steep cliffs and overhangs, where the root systems alone cannot prevent cliff erosion.

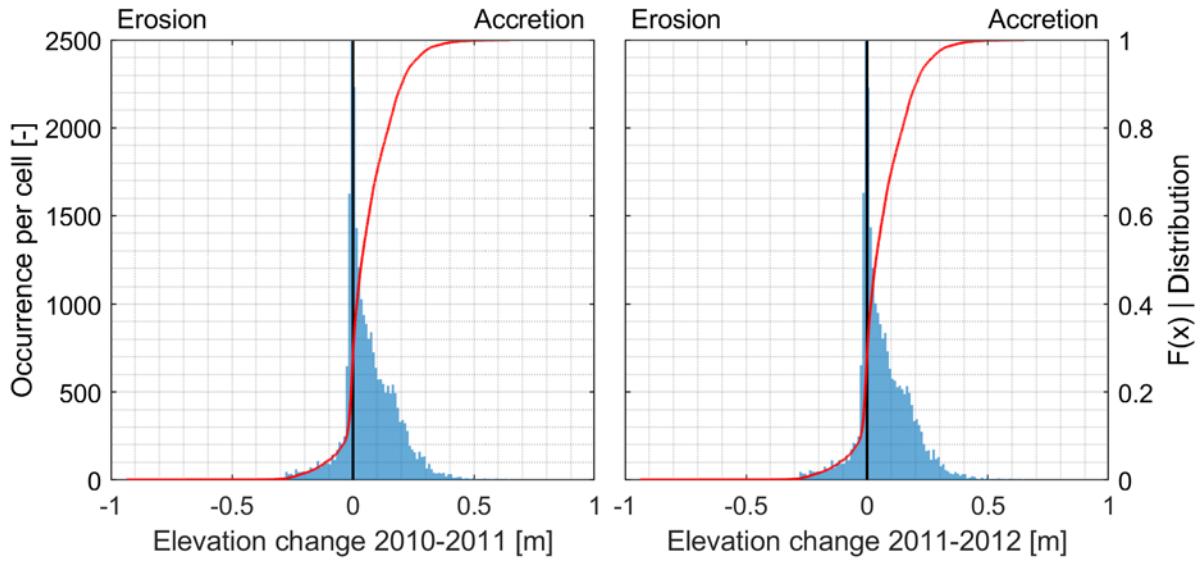


Figure 10: Distribution histogram of detected vegetated cells and corresponding cell elevation changes for 2010 - 2011 and 2011 - 2012

Data set B

Similar to A, the following data set B was analyzed based on three years of DEM data yielding morphodynamic changes and a corresponding DOP mosaic from 2014. Results are given in Figure 11. The

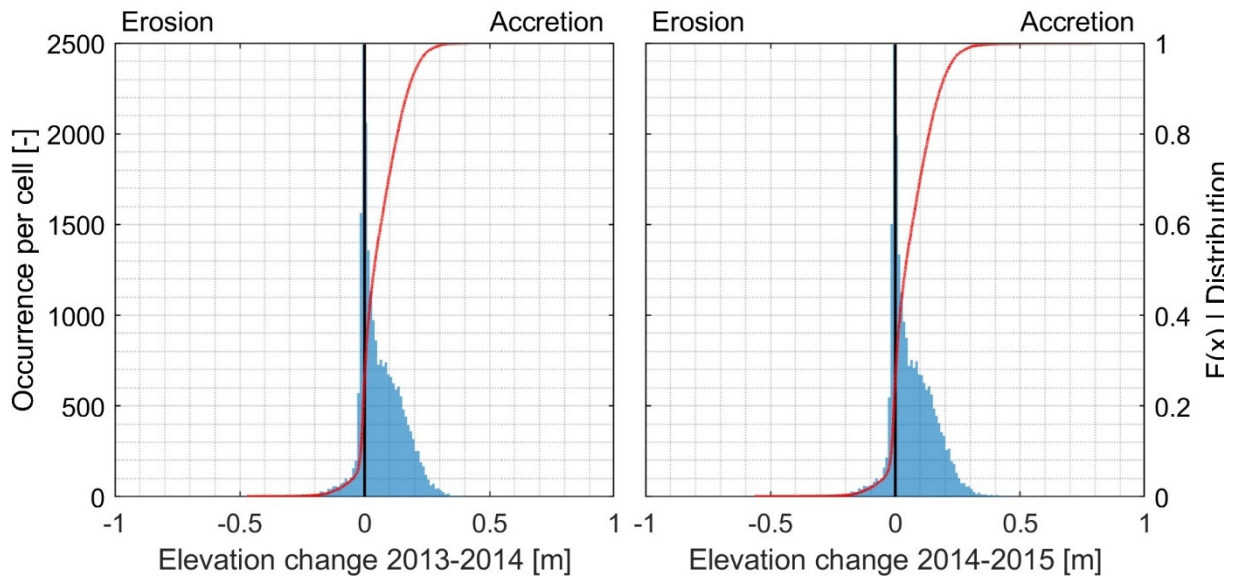


Figure 11: Distribution histogram of detected vegetated cells and corresponding cell elevation changes for 2013 - 2014 and 2014 - 2015

The slope-based detection of the white dune area yielded 558937 m² so a smaller dune area, compared to the previous data set A. Regardless, the overall trend is comparable to the previous one, with primarily accreting cells detected with the CNN inside the dune area.

Data set C

The subsequent data set constitutes the years 2017 – 2018 – 2019. The slope-based dune area detection resulted in 729032 m² of white dune area, so an overall growth of the dune chain system since 2014. This is corroborated by recent literature studies (Mehrtens et al., 2023, 2025). For 2017-2018 (cf. Figure 12 left panel) a very clear net-accretion for the complete white dune system was detected, with very little to no negative values (erosion). The subsequent year 2019 shows a less pronounced but still very clear positive net-accretion of the vegetated white dune areas (cf. Figure 12 right panel).

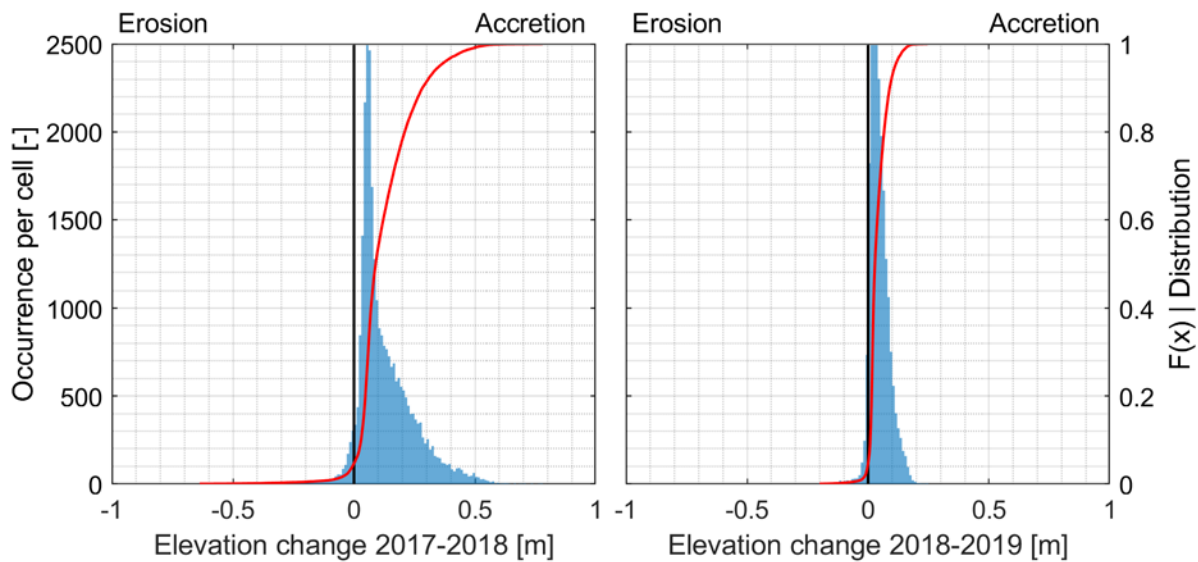


Figure 12: Distribution histogram of detected vegetated cells and corresponding cell elevation changes for 2017 - 2018 and 2018 – 2019

Data set D

For the DOP mosaic from 2020, matching DEM data was available only for the previous and matching years 2019 and 2020. For 2021 no DEM survey data is available, rendering only the backward facing analysis of the CNN-DEM possible. The result is given in Figure 13 for the elevation changes 2019 to 2020 for the vegetated white dune area. The trend remains clear positive with a net accretion. The overall white dune area detected based on terrain slope amounted to 511685 m² so comparable to the years 2011 and 2014 and not as large as the previous 2018 slice. This is connected to storm surges eroding the dune chain (cf. Figure 13).



Figure 13: Eroded white dune chain of Sankt Peter-Ording

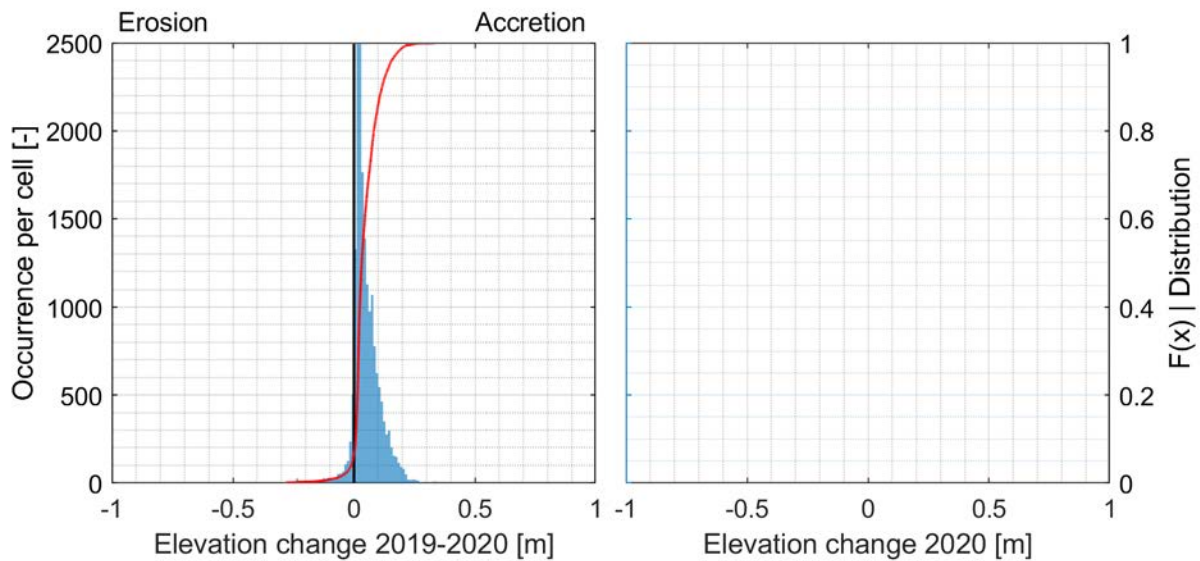


Figure 14: Distribution histogram of detected vegetated cells and corresponding cell elevation changes for 2019 - 2020

Data set E

Slope-based white dune area equals 669215 m², so the system exhibits a net-growth again after the storm surge impacts in 2018. Unfortunately, 2022 marks the most up-to date DEM and DOP data available. Therefore, a backward facing analysis was conducted with 2020 and 2022. Forward facing rendered impossible due to a lack of data at this point in time. The trend shows a clear net-accretion for 2020-2022 given the CNN analysis (Figure 14 left panel).

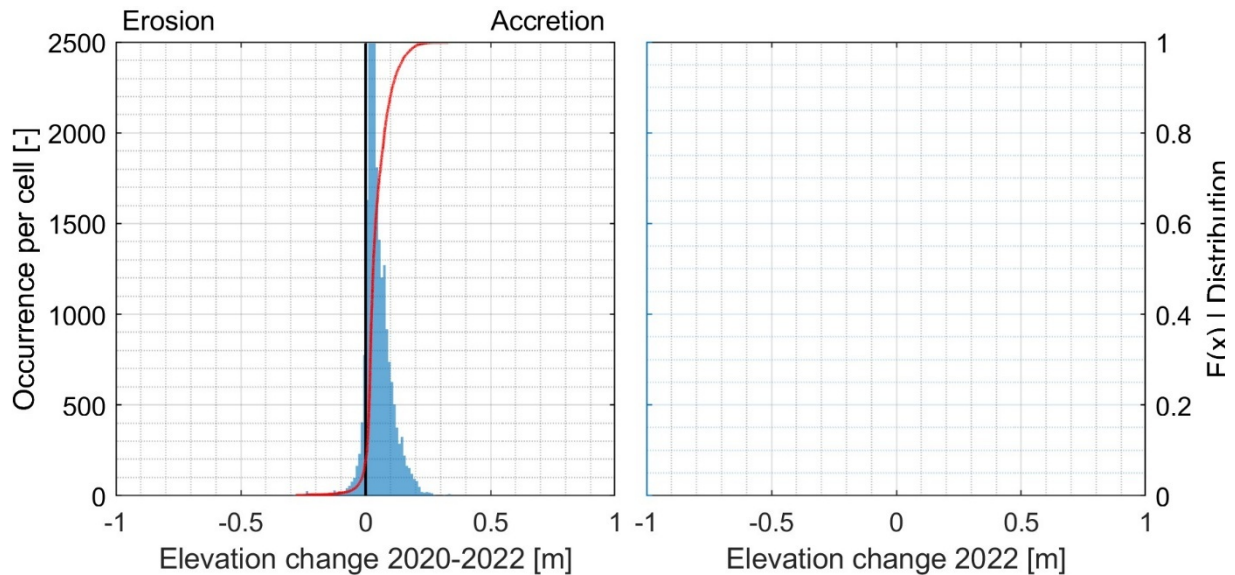


Figure 15: Distribution histogram of detected vegetated cells and corresponding cell elevation changes for 2020 - 2022

3 Conclusion

The aim of this report was to develop a suitable methodology to relate morphodynamic trends with environmental influences. This was achieved by developing a novel CNN model with extensive training data for a field site and ground truthing conducted before application of the CNN model to the demonstrator site Sankt Peter-Ording, Germany. Available federal DOP mosaics for the demonstrator site were sourced and processed to match RGBA values across two decades to make them accessible to the CNN model. The obtained vegetation coverage maps allowed for a subsequent extraction of surface elevation change data from the DEM data sets via IDK with correlation coefficients of $R^2=0.98$ and above, making this approach robust and reliable. The detected elevation changes within the delineated white dune area were extracted and analyzed for cumulative erosion/accumulation for previous and subsequent years, where available.

The overall white dune area grows over the 21 years analyzed, with one incident of reduction, which can be attributed to a storm surge impact eroding the white dune chain.

Trends are consistently showing a positive net-accretion of the vegetated white dune area for all five time-slices building a strong case for vegetation related net-sediment accretion and corresponding elevation changes.

Anthropogenic influences are omitted for this demonstrator, since the white dune system is not accessible to the public but only national park rangers, coastal authority staff and researchers, strongly limiting the overall number of people walking in this area rendering the system natural.

The developed methodology presents a novel and readily applicable approach to (1) identify white dune areas using the terrain slope (2) map vegetation coverage within these white dune areas using the developed CNN in combination with a suitable DOP (3) using DEM data to quantify elevation changes across the area

and (4) apply IDK to obtain elevation change values for the finer CNN vegetation map data to inspect erosion/accretion trends for the vegetated white dune areas.

The novel CNN is currently being further advanced and applied to different coastal dune systems to expand its application to the remainder of the Dune Front demonstrator sites.

4 References

Kosmalla, Viktoria; Lojek, Oliver; Carus, Jana; Keimer, Kara; Ahrenbeck, Lukas; Mehrtens, Björn et al. (2024): Biomechanical parameters of marram grass (Calamagrostis arenaria) for advanced modeling of dune vegetation. In Earth Surface Dynamics. DOI: 10.5194/egusphere-2024-2688.

Mehrtens, Björn; Lojek, Oliver; Kosmalla, Viktoria; Bölker, Thea; Goseberg, Nils (2023): Foredune growth and storm surge protection potential at the Eiderstedt Peninsula, Germany. In Front. Mar. Sci. 9, Article 1020351. DOI: 10.3389/fmars.2022.1020351.

Mehrtens, Björn; Vinkelau, Leon; Bölker, Thea; Lojek, Oliver; Ahrenbeck, Lukas; Schweiger, Constantin et al. (2025): Benchmarking Overview on Methods for Spatiotemporal Detection of Dune Erosion in Physical Modeling. In J. Waterway, Port, Coastal, Ocean Eng. 151 (4), Article 04025012. DOI: <https://10.1061/JWPED5.WWENG-2138>

Lukas Ahrenbeck; Oliver Lojek; Johannes Schattmann; Björn Mehrtens; Constantin Schweiger; Viktoria Kosmalla; David Schürenkamp; Nils Goseberg (2025): Surrogate root system modeling — A hybrid dune reinforcement. In: Coastal Engineering, Vol. 202, 15 DOI: <https://doi.org/10.1016/j.coastaleng.2025.104835>