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THE EVER GROWING USE OF COPERNICUS ACROSS EUROPE'S REGIONS

A selection of 99 user stories by local and regional authorities



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Europe's eyes on Earth

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Copernicus
Europe's eyes on Earth

Dear Reader,

We, the European Commission, the European Space Agency and NEREUS – the Network of European Regions Using Space Technologies, are pleased to present the publication "*The Ever Growing Use of Copernicus across Europe's Regions*", a collection of articles which document, for a non-specialist audience, **the growing capabilities of European regions to benefit from Copernicus Sentinel data and information**.

This edition builds upon the 2012 publication "*The Growing Use of GMES across Europe's Regions*" and provides an updated snapshot of how Copernicus is being used, primarily by public authorities at local and regional levels, six years on. Since 2012, the system has significantly evolved and, with seven Copernicus Sentinel satellites and six Copernicus Services in operation and with planning for the future well underway, data availability has expanded tremendously. Awareness and understanding about the Programme have also increased and a refined set of activities has been put in place to stimulate the emergence of new Copernicus-based services and products.

The current publication portrays 99 Copernicus user stories submitted by authors from almost all of the Copernicus Participating Countries. The geographical and structural diversity of the examples collected here demonstrate that, from brownfield mapping in Wallonia to afforestation monitoring in Thuringia, from public utility management in Milan to farmland monitoring in Lithuania, Copernicus is truly a shared system producing common benefits across Europe. These articles also show that, in parallel to its global and EU-wide dimension, Copernicus is increasingly bringing concrete benefits to the daily lives of our citizens. With respect to the 2012 edition, local and regional administrations form a much larger group, pursuant to their responsibilities in key public policy domains and mandatory EU directives for which Copernicus provides relevant information, e.g. agriculture, regional development and environmental management. Their stories collectively testify to the **Programme's contribution in modernising the public sector and enabling it to deliver more efficient public services, thereby contributing to an increased quality of life and level of satisfaction for European citizens.**

In June, we celebrated the 20th anniversary of the Baveno Manifesto, which called for a long-term commitment for the development of a space-based system to support EU policies and Europe's international endeavours in protecting the environment, adapting to global climate change, enforcing sustainable development and ensuring civil security. Putting European public users in the driving seat, and recognising their pivotal role in stimulating and shaping the downstream market, the Programme is a clear example of European cooperation at its best.

Copernicus is achieving its operational maturity. The European Commission, the European Space Agency and NEREUS will continue to improve its uptake within Europe's regions, yet the Programme is now speaking for itself as a decision-making tool in a broad range of application domains. **The public officers, private companies and researchers who contributed to this collection provide tangible accounts that the Copernicus-based information is now diffusing into society**. In doing so, they are amongst the best testimonials of the Programme: We are confident you will recognise this whilst going through the pages of "*The Ever Growing Use of Copernicus across Europe's Regions*".

We wish you a pleasant reading,

Philippe Brunet

Director of Copernicus, Space Policy and Defence

European Commission (DG-GROW)



Dr. Josef Aschbacher

Director of Earth Observation Programmes

European Space Agency



Michele Emiliano

NEREUS President





Cloud-free Europe

This OLCI mosaic of cloud-free images from the Copernicus Sentinel-3A satellite spans the entire continent of Europe, and more. The 3 main instruments on board the Sentinel-3 satellite support global monitoring of the environment over land and oceans, providing regular measurements of surface temperatures, sea-surface and land-ice topography, sea and land colour data.

Credit: Contains modified Copernicus Sentinel data (2017), processed by Sinergise/ESA

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Copernicus in a nutshell

Previously called GMES (Global Monitoring for Environment and Security), Copernicus is the EU-led programme looking at our planet in support of the environment and emergency management for the ultimate benefit of all European citizens.

Copernicus supports a broad range of environmental and security applications, including climate change monitoring, sustainable development, transport and mobility, regional and local planning, maritime surveillance, agriculture and health.

Copernicus places a world of insight about our planet at the disposal of citizens, public authorities and policy makers, scientists, entrepreneurs and businesses. Copernicus data and information are made available on a full, free and open basis.

Learn more at www.copernicus.eu

Copernicus builds on Earth observations from space (both from dedicated and contributing missions) and from terrestrial and aerial sensors (in situ measurements).

Six Copernicus Services transform this wealth of observations into value-added information in different thematic areas by analysing the data, integrating it with other sources, processing it and validating the results.

Learn more at www.copernicus.eu/main/services

Emergency Management
www.emergency.copernicus.eu

Climate Change
www.climate.copernicus.eu

Land Monitoring
www.land.copernicus.eu

Marine Environment Monitoring
www.marine.copernicus.eu

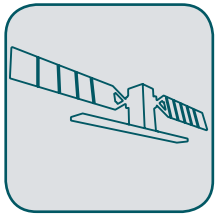
Atmosphere Monitoring
www.atmosphere.copernicus.eu

Security
www.copernicus.eu/main/security

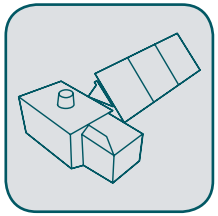
Copernicus Sentinels in a nutshell

The Copernicus Sentinel satellites are a family of Earth Observation space missions specifically developed by ESA for the Copernicus Programme. Since April 2014, 7 satellites have been launched and have started delivering data to support various applications. Additional satellites of the family are being progressively launched, targeting the full operational deployment by 2020.

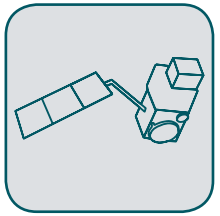
Learn more at https://sentinels.copernicus.eu



sentinel-1
carries a radar to provide all-weather, day-and-night imagery to monitor oceans, ice and land, and to aid emergency response.



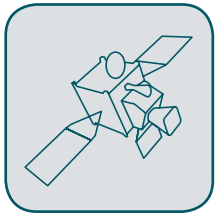
sentinel-2
carries a high-resolution multispectral imager to monitor land and vegetation cover.



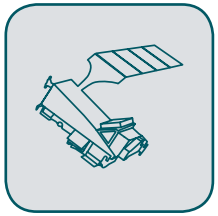
sentinel-3
carries an instrument package including a radar altimeter, an infrared radiometer and an imaging spectrometer, to monitor oceans and land.



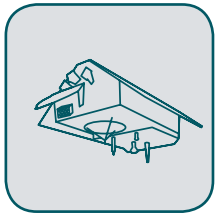
sentinel-5p
carries a spectrometer, primarily to monitor global atmospheric pollution.



sentinel-4
is a spectrometer carried on the Meteosat Third Generation Sounder satellites. It is dedicated to monitoring air quality over Europe.



sentinel-5
is a spectrometer carried on the MetOp Second Generation satellites. It is dedicated to monitoring global air quality.



sentinel-6
carries a radar altimeter to measure global sea-surface height for operational oceanography and for climate studies.

The Copernicus Contributing Missions provide complementary data within the Copernicus Space Component.

Learn more at https://spacedata.copernicus.eu

Copernicus progress since the 2012 edition



2012

Land Monitoring

Emergency Management

2013

sentinel-1a

2014

Copernicus Regulation

Marine Environment Monitoring

Atmosphere Monitoring

2015

2015

sentinel-2a

#Sentinels4regions

sentinel-1b

sentinel-3a

2016

EU space strategy
EC-ESA shared vision

Security

Copernicus Relays

Copernicus Academy

2017

sentinel-2b

sentinel-5p

DIAS

sentinel-3b

2018

BAVENO + 20

Climate Change

The Ever Growing Use of Copernicus across Europe's Regions showcases 99 user stories that describe how public administrations across Europe are using Copernicus data and information to address their challenges and how this is positively impacting the lives of citizens.

The Publication provides an update of the situation with respect to the 2012 publication "*The Growing Use of Copernicus across Europe's Regions*"[1], which portrayed 67 contributions in the Copernicus pre-operational era. The rationale behind these initiatives is that although public authorities (PAs) at national, local and regional level are recognised amongst the key potential users of Copernicus[2], they are not always aware or ready to exploit the programme's potential. Roadblocks in this respect are manifold and include insufficient awareness, lack of specific technical skills and/or of infrastructure as well as difficulties to modify the internal workflows of the administration to integrate new solutions that are not backed-up by law[3]. The Copernicus User Stories collected in this publication facilitate an interesting analysis of how and to what extent these challenges are being addressed in many regions.

"Copernicus core users <include> Union institutions and bodies, European, national, regional or local authorities entrusted with the definition, implementation, enforcement or monitoring of a public service or policy in the areas of atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security."

Copernicus Regulation (EU No 377/2014), Extract from Articles 2 and 3

1 https://esamultimedia.esa.int/multimedia/publications/NEREUS

2 See Copernicus Regulation (EU No 377/2014), Articles 2 and 3

3 The roadblocks to the full deployment of Copernicus amongst LRAs were comprehensively analysed in a previous collaboration between the ESA and NEREUS. See http://www.nereus-regions.eu/wp-content/uploads/2017/11/Brochure.pdf and http://www.nereus-regions.eu/wp-content/uploads/2017/11/Analysis.pdf

The user stories have been submitted by authors in response to a call for papers open to all Copernicus Contributing Countries[4]. The stories are grouped according to eight application domains that are closely related to the competences of local and regional authorities (LRAs)[5]:

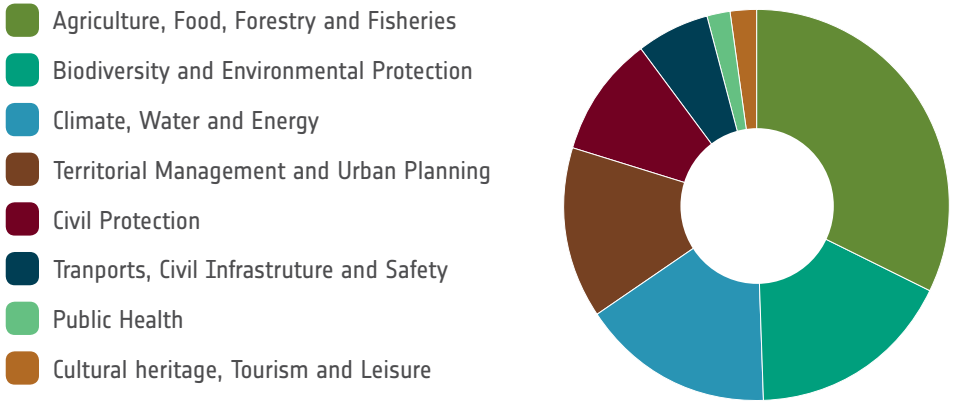


Figure 1: Distribution of the Copernicus User Stories by thematic area.

As shown in Figure 1, the number of stories per thematic area is different: around one third of the papers describe applications in the fields of "Agriculture, Food, Forestry and Fisheries" (32), followed by "Biodiversity and Environmental Protection" (17) and "Climate, Water and Energy" (16). Conversely, there are only a few papers addressing "Public Health" (2) and "Cultural Heritage, Tourism and Leisure" (2) that are in fact less mature fields of application for satellite Earth observations and not within the original objectives of the Copernicus Programme. These numbers clearly reflect the environmental vocation of Copernicus as well as the progressive availability of the related data streams whereby e.g. Copernicus Sentinel-3 and Copernicus Sentinel-5P have been launched only recently. However one can also see that some strategic areas of application, such as water and energy management, seem somehow under-represented.

This also affects the kind of Copernicus data and/or information used in the different user stories so it is not surprising, for instance, to see that the vast majority refers to data from Sentinel-1 (mentioned in 44 user stories) and Sentinel-2 (74) whilst only a few of them (3)

4 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

5 Other thematic areas such as global climate change (e.g. greenhouse gases) and security were not included because they are mostly tackled at global or national scale and fall into different governance schemes.

refer to the recently launched Sentinel-5P. Nevertheless, the overwhelming use of Copernicus Sentinel-2 is noticeable, and this can be attributed to the relative ease of use of the high-resolution optical imagery and its attractiveness for the LRAs' institutional mandate especially in relation to the management of land. Many of the stories refer to the use of products from the Copernicus Land, Atmosphere, Marine and Emergency Management Services, and a few of them address the integrated use of both, particularly for applications relating to civil protection (see for example pages 216, 220, 234).

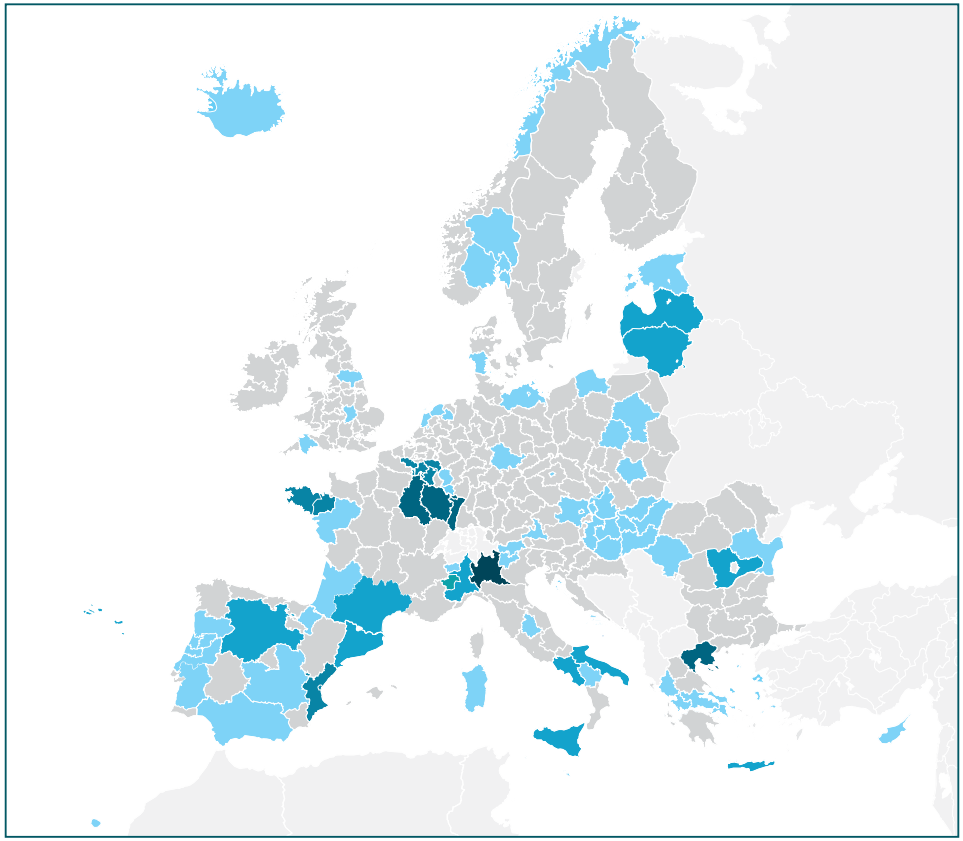


Figure 2: Graphic representation of the regional dimension of the Copernicus User Stories within the Copernicus Contributing Countries as declared by the Authors. The different shades of blue represent the number of stories associated to each region, with municipalities (NUTS3 levels) represented through their corresponding regions (NUTS2 levels) for the sake of readability. Note that only stories at NUTS2/NUTS3 level are represented in this map: national levels (NUTS1) are not represented, except for countries where corresponding NUTS2 levels do not exist (e.g. Iceland, Latvia, Malta...).

In line with the Call core objective, the majority of the stories contained in this publication are related to applications deployed at sub-national level (i.e. at NUTS2/NUTS3[6] administrative levels) within Copernicus Contributing Countries: these stories span over 72 different regions and/or municipalities across 24 countries. Their geographic distribution, illustrated in Figure 2, depicts an irregular pattern which generally reflects the maturity of the local EO community. It is interesting to notice, alongside regions having a lasting experience in the field (e.g. Grand Est and Brittany in France, Lombardy in Italy, Wallonia in Belgium), the dynamism of emerging ones (e.g. Central Macedonia in Greece, Valencia in Spain). An increasing penetration at the regional level can also be observed in Eastern Europe and Scandinavia together with a set of newcomer regions reporting successful trials with the use of Copernicus-based information (e.g. in Estonia, Lithuania, Latvia, Croatia, Slovakia, Iceland). Some of the user stories are at national level, especially when addressing the management of agricultural subsidies (see pages 42 to 59) or wide range air quality forecasts (see p. 256). It is also worth highlighting that many challenges are not confined within administrative borders: satellites provide valuable tools to address these cross-border aspects as it appears in some of the user stories, typically related to nature reserves or disasters management (see e.g. pages 120, 130, 134, 220, 222, 256). Finally, one can figure out the corresponding geography of the expertise in developing and handling Copernicus-based solutions by considering the distribution of the affiliations of the Authors: these come from 28 Copernicus Contributing Countries[7], possibly suggesting an increasing spread of skills across Europe.

The publication mainly targeted cases of mature use. Yet, many of the stories are far from this stage. As already mentioned, the integration of innovative technologies within the routine processes of a public administration is not straightforward. Even when provided by external entities (e.g. commercial companies) the new solutions must be customised and validated prior to integration into the administrative processes and this frequently requires gradual adoption through testing and ramp-up activities. Practical accounts from these experiences are considered valuable contributions to the development of best practices in the PAs and that is why, in the end, non-operational solutions were also included in this publication. However, in order to provide a comprehensive overview of the maturity of use of the described solutions, a **Usage Maturity Level (UML)** has been defined to be

6 The Nomenclature of territorial units for statistics (NUTS) is a classification providing a harmonised hierarchy of regions: it subdivides each Member State into regions at three different levels, covering NUTS 1, 2 and 3 from larger to smaller areas. See http://ec.europa.eu/eurostat/web/regions/background.

7 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and United Kingdom.

self-assessed by all contributors. The results, graphically displayed in Figure 3, are encouraging: about 15% of the use cases have been reported as mature (UML=5), whilst less than 10% were classified in the exploration phase (UML=1). The vast majority (43%) are declared to be in the pilot / testing phase in view of further integration (UML=3). These "pre-operational" solutions may possibly be incorporated within the workflow of LRAs and grow in the near future, however in the current phase their sustainability and road to the market remains vital. These figures can be considered a net improvement with respect to the situation in 2012[8], when many articles described outcomes from research projects fuelled by space-related funds.

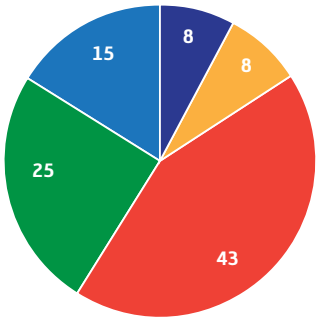


Figure 3: Distribution of the Copernicus User Stories by Usage Maturity Levels

The Usage Maturity Levels	
UML 1 Explorer	The LRA has never really made use of the Copernicus-based solution but it has planned ad-hoc tests to assess its potential benefits (e.g. as a project user).
UML 2 Ad-hoc user	The LRA has used the Copernicus-based solution ad hoc in some specific cases but without an explicit interest to trial repeated usage (e.g. the test followed the initiative of single individuals within the organisation).
UML 3 Pilot/ Experimental tester	The LRA has already used the Copernicus-based solution in one or more trials and is concretely considering its integration within its standard practices.
UML 4 Early Adopter	The LRA has confidently used the Copernicus-based solution and is working to incorporate it as part of its processes (e.g. update of internal procedures, staffing, training...).
UML 5 Operational user	The LRA is using the Copernicus-based solution and it has integrated it within its standard processes. The related resources (i.e. staff, budget, facilities) are allocated or readily deployable.

8 In the 2012 edition, no Usage Maturity Level was defined.

A total of 177 entities from 32 different countries have contributed to the stories presented in this Publication (see p. 270). These are mostly PAs (57) but also private companies (39), academia (39) and research institutes (35) that develop solutions for the PAs. When outsourcing to external entities, the administrations' competences evidently shape the research and the market for EO and, by being proactive customers, administrations concretely help to design more effective solutions (e.g. see the example in p. 92). The collection also outlines that some commercial Copernicus-based solutions are finally making it to the market, and this can be largely attributed to the Copernicus open and free data policy as well as to the guarantee of its long-term availability. Noticeably, the know-how matured in the European context also helps European companies to export their services outside the continent: a few examples are included e.g. see pages 68 and 118.

Overall, the comparison with respect to the 2012 edition shows that, six years on, the use of Copernicus across Europe's regions is truly "ever growing". The enhanced number of stories and the enlarged geographic spread evidently reflect Copernicus evolutions and the corresponding growth in the number of stakeholders and companies. Such a leap is evident not so much in terms of the increased number of articles, but especially in that the new stories, on average, show **a much stronger engagement from public authorities**. The manifest involvement of PAs in most Copernicus User Stories of the current publication demonstrates the importance of the political will as well as of the motivation of civil servants to overcome any technical roadblock. An important indicator in this respect can be taken from the increase in the number of experiences that are funded outside of the space sector, which is now significant (more than half) when compared to the 2012 publication in which about two thirds of the cases were financed by Copernicus, the EU Framework Programme or by the ESA. Another important aspect is represented by the closer link with respect to the EU Directives: **across the publication, nine different EU Directives[9] are addressed**. A note is due to highlight the case of the Common Agriculture Policy: nine user stories describe early stages of use of Copernicus by paying agencies (see pages 42-63). This can be attributed to the recent reform of the Common Agriculture Policy for 2021-2027 which allows satellite imagery to replace the physical visits necessary to check and issue payments to farmers[10]. It can be forecasted that such stories will soon become a recurring pattern.

9 EU Marine and Water Strategy Directive, EU Water Framework Directive, INSPIRE Directive, EU Nitrates Directive, Ambient air Quality Directive, Cleaner Air for Europe Directive, Habitats Directive, Fauna Flora Habitat directive, and the Floods Directive.

10 https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en

The Copernicus User Stories contained in this publication collectively show that the uptake of Copernicus is not a solitary endeavour: it inexorably relies on collaborative joint efforts across sectors, disciplines and political orientations. Indeed, the publication portrays a mosaic of relations – between regional directors, CEOs, researchers, mayors, engineers, developers, farmers, etc. – where Copernicus data and information stimulates the exchange amongst professional user communities across application domains, offering tailored solutions to global challenges tweaked at local level. In this respect, the emergence of grassroots initiatives and bottom-up approaches to the use of Copernicus data and information amongst public users provides an interesting element which accompanies the panorama of regulatory and support measures implemented by the European Commission to improve Copernicus user uptake: the example of volunteering civil servants creating working groups which operate across departments (p. 192) is a valuable mechanism in terms of internal public sector innovation.

In conclusion, *The Ever Growing Use of Copernicus across Europe's Regions* intends to serve as a practical handbook illustrating the variety of Copernicus uses as well as the processes that lead a public administration to develop and use a space-based product and/or service. The descriptions of how public authorities are starting (or trying to) to rely on services and solutions derived from Copernicus data and information can be helpful to tackle challenges that are common across different administrations and provide valuable accounts hopefully paving the way towards an ever growing community of Copernicus users.

The editorial committee: Roya Ayazi[a], Ilaria d'Auria[a], Alessandra Tassa[b] and Julien Turpin[c]

[a] NEREUS

[b] European Space Agency

[c] European Commission

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Antarctica Peninsula from Sentinel-1A

Acquired on 13 April 2014 at 23:57 GMT (14 April at 01:57 CEST) by Sentinel-1A, this image shows a transect over the northern part of the Antarctica Peninsula. The colours indicate how the land, ice and water reflect the radar signal differently. The Antarctica region with its mountainous peninsula has been experiencing warming over recent decades. Polar ice melting is one of the most visible demonstrations of the effects of climate change and it is thus critical that it is monitored comprehensively and in a sustained manner. Earth Observation satellites, including Copernicus Sentinels, are monitoring the changes in this remote area of the world.

Credit: Contains modified Copernicus Sentinel data (2014), processed by ESA



Avezzano, Italy
Cultivated fields in Avezzano (Italy) as captured from Copernicus Sentinel-2A on July 07, 2015. The varying shades of red and other colours indicate differences in vegetation cover and chlorophyll content.

Credit: Copernicus Sentinel data (2015)/ESA, CC BY-SA 3.0 IGO

AGRICULTURE, FOOD, FORESTRY AND FISHERIES

Agriculture and fisheries form the basis of our food supply. Agriculture, fisheries and forestry are key components of our biosphere and constitute key economic sectors for most European regions. Taken together, agricultural land and forests represent around 85% of land cover in the European Union. When it comes to fisheries and aquaculture production, the European Union is the fifth largest producer worldwide. These sectors also play a crucial role in employment: for example, in certain European coastal communities as many as half of the local jobs are in the fishing sector. However, sustainable food production and resources exploitation are increasingly being subject to various threats, linked to anthropogenic pressure, climate change and intensive exploitation practices. As population increases and climatic patterns change, so does the spatial distribution of ecological zones, habitats, plant diseases and pests, with significant impacts on agriculture and food production. Innovative solutions are needed to help tackle these increasingly global challenges and Copernicus can support these in manifold ways. For instance, data from Sentinel-2 and from the Copernicus Land Monitoring Service can help to monitor the health status of forests and highlight clearcuts, whilst the Marine Environment Monitoring Service forecasts can help in modelling fish habitats to support both wild fishery and aquaculture. An example of significant strategic importance is reflected by the Common Agriculture Policy (CAP), one of the most prominent and oldest EU policies, with the biggest share of EU spending (about 40% in 2016). In many countries, the "second pillar" of the CAP (rural development programme) is implemented at regional level and, because of the impact on their territory, almost all regional administrations have this competence in their scope. Data from the Sentinel-1 and Sentinel-2 satellites can support the setup of more efficient and environment-friendly agricultural practices for public authorities, companies and farmers alike. Thus, with the aim of simplifying and modernising the CAP, the European Commission has adopted new rules for the next CAP that, for the first time, will expressly allow these data to be used to replace on-farm checks for determining the area-based CAP payments. This move is expected to contribute in reaping the full potential of Copernicus' deployment, and is a good example of how policy-making can impact the adoption of new technologies and foster innovation within the public sector.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
AGRICULTURE CAP SUBSIDIES CONTROL	Vilinus	Lithuania	S1, S2	3
AGRICULTURE DAMAGE MAPPING IN HUNGARY	Central Hungary (Közép-Magyarország)	Northern Hungary	S1, S2	3
AGRICULTURE MONITORING USING SENTINEL IMAGES	Wallonia (Wallonie)	Wallonia	S1, S2	4/5
COPERNICUS DATA AND CAP MONITORING IN ROMANIA	Bucharest (Bucharest – Ilfov)	South Muntenia, West, North-East, South-East	S2	4
EARTH OBSERVATION DATA TO DETECT IRRIGATED AREAS: AN APPLICATION IN SOUTHERN ITALY	Campania (Campania)	Campania	S2	5
EARTH OBSERVATION FOR SMART FARMING AND CAP PERFORMANCE	Attica (Περιφέρεια Αττικής)	Central Greece Central Macedonia	S2	3
REINFORCING THE COMMON AGRICULTURE POLICY	Europe	Navarre	S2	4
SENTINELS FOR FLOOD AND YIELD LOSS MAPPING	Latvia - Riga (Latvija - Riga)	Latvia - Latgale	S1, S2	5
SENTINELS VERIFY AGRICULTURAL SUBSIDIES	Lääne-Viru County (Lääne-Virumaa)	Estonia	S2	3
A FARMSOURCING PLATFORM FOR A SMART NITROGEN MANAGEMENT	Wallonia (Wallonie)	Belgium	S2	3/4
A NEW DETAILED CROP AND NATURAL LAND MAP	Castilla Y Leon	Castilla Y Leon	S1, S2	4
CLOSING THE YIELD GAP WITH CALIBRATED CROP MAPS FROM GERMANY	Bavaria (Bayern)	Mecklenburg-Western Pomerania (Demmin)	S1, S2, S3	3
COPERNICUS SUPPORTS THE PRECISION FARMING AN APULIAN VINEYARD	Apulia (Puglia)	Apulia	S2	3
COPERNICUS FOR EFFICIENT FARMING IN THE WESTERN CAPE OF SOUTH AFRICA	Wageningen (Wageningen)	Western Cape of South Africa	S2	5
CROP CONDITION MONITORING AT FIELD LEVEL	North Rhine-Westphalia (Nordrhein-Westfalen)	Bela Tserkva	S1, S2	1
EO-BASED AGRO MONITORING SYSTEM TO SUPPORT REGIONAL DECISION MAKING	Europe	Valencian Community Lombardy Central Macedonia (Thessaloniki, Serres)	S1, S2	3
FREE INTERNET PROGRAM FOR FARMERS	Denmark (Danmark)	Denmark, Norway, Sweden	S2	5
PRECISION FARMING: MANAGEMENT OF GRASSLANDS	Brittany (Bretagne)	Pays de la Loire	S2	3
THE CHALLENGE OF IRRIGATION MANAGEMENT IN CYPRUS USING COPERNICUS	Cyprus (Κύπρος)	Cyprus	S2	1
USING SATELLITE MAPS TO SUPPORT VARIABLE RATE FERTILIZATION	Lombardy - Milan (Lombardia - Milano)	Lombardy Central Macedonia Valencian Community	S1, S2	3
MARITIME MONITORING FOR THE CONSERVATION OF THE UK MARINE RESOURCES	Central Bedfordshire	North Sea	S1	3
COPERNICUS SUPPORTS FOREST MONITORING FOR SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES	Occitanie (Occitanie)	Occitania	S2	3
EARTH OBSERVATION SERVING REGIONAL FORESTERS	Alsace (Alsace)	Alsace	S2	4/5
EO BASED SERVICE FOR FOREST MANAGNMENT	Mazovia (Mazowieckie District Region)	Mazowieckie District Malopolskie District Lodzkie District	S1, S2	3

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
FOREST HEALTH MONITORING: AN APPLICATION IN PORTUGAL		Continente, Norte, Centro, Alentejo Sor-Ostlandet, Nord-Norge	S2	4
FOREST MONITORING SERVICE FOR SOUTH TYROL	Autonome Provinz Bozen - Südtirol (Provincia autonoma di Bolzano - Alto Adige) (Provinzia autonoma de Bulsan - Südtirol)	South Tyrol	CLMS, S2	4
FORESTLAND DECAY IN MARESME USING SENTINEL-2 IMAGERY	Catalonia (Catalunya)	Catalonia	S2	4
OPERATIONAL AFFORESTATION MONITORING	Free State of Thuringia (Thüringen)	Free State of Thuringia	CLMS, S2	5
REMOTE SENSING FOR GARAJONAY NATIONAL PARK MANAGEMENT	Madrid	La Gomera	S2	3
SATELLITES MONITOR FOREST CHANGES IN FINLAND	Uusimaa Nyland	Finland	S2	4
SENTINEL-BASED AZORES REGIONAL FOREST INVENTORY	Azores Archipelago	Azores Archipelago	S1, S2	3
UNIQUE SATELLITE-DERIVED FORESTRY INSIGHT FOR DEFRA, UK GOVERNMENT	Berkshire, Buckinghamshire and Oxfordshire	Devon	S1, S2	5

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2; S3: Sentinel-3; S5P: Sentinel-5P; CLMS: Copernicus Land Monitoring Service.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to Fig. 3 in p. 26.*

Regions of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

AGRICULTURE CAP SUBSIDIES CONTROL

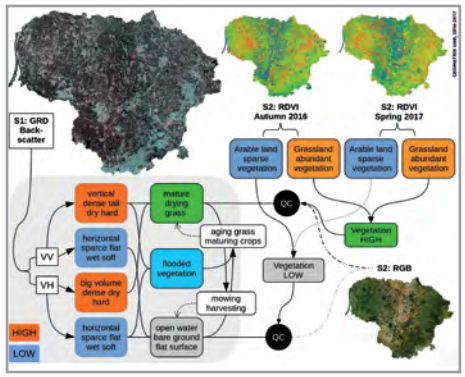
CAPCON is a Copernicus downstream service of farmland monitoring and CAP subsidies control, provided to the National Paying Agency of Lithuania since 2017.

The challenge

The Lithuanian Paying Agency (NPA) has set a strategic target to implement a CAP subsidies control system based on operational monitoring of farming activities in all declared parcels, integration of information available in several institutional registers, active use of technologically most relevant and cost-efficient remote sensing services and proactive cooperation with rural communities and farmers. Limited availability of multi-spectral satellite data, variability of natural conditions and farming practices is very high in the countries dominated by small households, therefore reliable detection of certain farming activities and major crops can only be achieved with iterative machine learning algorithms and reliable reference data samples. Artificial intelligence algorithms have to be sensitive to seasonal variation of crops and climatic conditions.

The space based solution

In 2017 NPA signed a service contract with GEOMATRIX UAB for a Sentinels-based CAP subsidies control service with per-parcel monitoring and assessment of farming activities. The service elements were (1) separation of arable land from grassland to confirm the arable land status and (2)

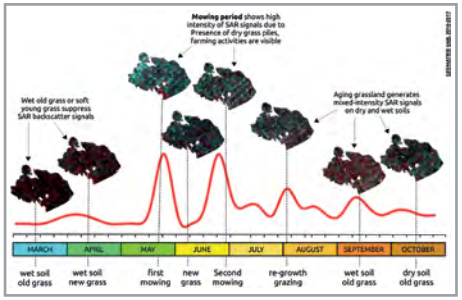


CAPCON service concept, based on per-parcel statistical analysis of polarimetric SAR data and validation with multi-spectral imagery.

operational monitoring of farming activities on grassland to detect grass mowing period(-s) and/or confirm the fact of livestock grazing. The operational monitoring service was carried out on ~1 mln. parcels larger than 0.25 ha during the entire farming season (May September) and processed a full stack of up to 100 Sentinel images per parcel. The Lithuanian CAPCON service developed and successfully implemented a series of innovative solutions adapted to unstable climate, environmental conditions and farming practices typical for the northern and eastern European countries. The CAPCON service is primarily based on pol-SAR data. Sentinel-1 active sensor provided a continuous supply of pol-SAR data despite clouded or even rainy weather conditions, whilst multispectral Sentinel-2 imagery whenever available was used for validation of SAR-based parcel status detection. The service developed automated software components for building satellite data cubes and temporal analysis of large image stacks, production of dynamic composite SAR maps and extraction of per-parcel pol-SAR signal statistics and trends. The CAPCON Big data analytic engine is based on automated machine learning algorithms, which were developed and tested using

> "With Copernicus satellite data, farmers will no longer spend time on declarations, but will receive fair payments for their hard work."
>
> ***Erikas Bėrnotas,***
> ***Lithuanian Paying Agency Director***

thousands of confirmed field data samples, reaching 90% accuracy. Satellite data used operationally? Any solution described here must be fully operational or pre-operational. No research results, only applications should be presented. Use plain language, aim at the general public. Avoid acronyms or technical jargon.



Seasonal dynamics of grassland parcel farming status with detected 2 mowing periods in 2017, as seen on Sentinel-1 time series.

Benefits to Citizens

The CAPCON service would reveal the actual farming practices and enable operational assessments of the overall farming success under challenging climatic conditions, minimize the risks of false claims for subsidies, streamline the operational control and prevention process and reduce the overall cost of CAP control considerably by switching from the manual on-site checks to automated and continuous per-parcel monitoring of farming activities. It

will increase publicity and transparency of the whole process, exposing most of the cases of inappropriate farming and fraud.

Outlook to the future

The CAPCON service is focused on automated detection of the dominating crops using customised machine learning algorithms, adjustments of classification algorithms and training samples corresponding to seasonal changes in climatic conditions, automated reporting on parcels not complying to their declared farming activities, as well as web application with thematic satellite maps and ancillary information made available for the personnel involved in field checks. Operational set-up of the system will enable a complete reprocessing of the entire parcels database and updating the current status records for all parcels over 10 days intervals, based on aggregated backscatter signal statistics retrieved from all Sentinel-1 products and calibrated with cloud-free Sentinel-2 images. Regular parcel status updates will enable automated detection of parcels possibly not complying with their declarations and trigger standard follow-up procedures implemented by the controlling authority.

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AGRICULTURAL DAMAGE MAPPING IN HUNGARY

Earth Observation based damage maps have been integrated into a central framework and have been used in an operational manner for several years now, leading to substantial cost reductions for authorities and clients alike.

The challenge

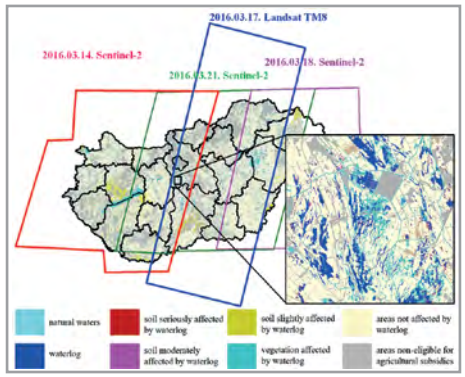
The agriculture of Hungary – as numerous cases of the last five years have demonstrated – is facing an increasing number of extreme weather conditions. The increasing rate and length of these events often result in substantial damage and loss in the Hungarian agricultural sector. Increasing risk factors, their implications on the area-based agricultural subsidies, and the large extent of agricultural territories affected all give reason for continuous monitoring via remote sensing techniques, measuring the damages in both space and time.

The space based solution

In the period February-March 2016, extreme precipitation events took place, which resulted in the appearance of inland excess water as well as water logging in several Hungarian counties.

Surveying the extent of water-affected surfaces was carried out by the use of optical satellite imagery from Sentinel-2 and Landsat. The map in Figure 1 shows the results of our analysis: altogether 131,245 hectares of water-affected areas were detected countrywide.

With free and easy access to Sentinel-1 SAR data and to the open-source Sentinel toolboxes, users can now benefit from this technology. Thus, operative inland water mapping by radar imagery becomes possible. Hence, a survey of the whole country was successfully done in a few days based on Sentinel-1 imagery for the period from 01–04 March 2016. Open inland excess water surfaces (see an example on Figure 2) were detected with high accuracies, leading to a result of 88 960 hectares as a lower estimate.



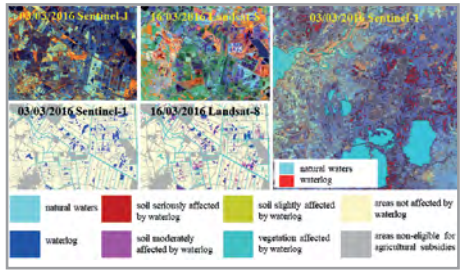
Inland excess water map of Hungary based on Sentinel-2 and Landsat-8 optical images between 14/03/2016 and 21/03/2016.

Benefits to Citizens

Countrywide appearance of inland excess water, waterlogging, spring-frost damages and summer drought events collectively can affect 30-40,000 farmers in Hungary. Obviously, it is impossible to provide operational real-time ground-based observations for the assessment of loss compensation claims. Thanks to the good spatial and temporal resolution of Sentinel satellite images not only does the affected territory becomes measureable, but the temporal evolution of the events can be monitored as well.

The Government Office of the Capital City Budapest, Department of Geodesy, Remote Sensing and Land Offices, Remote Sensing Unit produces thematic maps of land surfaces affected by extreme water conditions and drought, derived from satellite products. The final maps are uploaded to the database of the so-called Agricultural Risk Management System. Via this framework, the maps of the affected territories are available to all members of the project: the Hungarian Paying Agency, the Research Institute of Agricultural Economics, the Hungarian Meteorological Service, the General Directorate of Water Management, and the Ministry of Rural Development. Thus, the need for on-the-spot controls decreases, official administration is reduced, and procedure deadlines are shortened.

> *"Damage maps can substitute a large number of on-the-spot checks, leading to substantial cost reductions for authorities and clients likewise."*
>
> ***Hungarian Paying Agency***



Map of water-affected land surfaces around Lake Tisza on radar composite (VV, VH, VV/VH) (right). Optical (NIR, SWIR, RED) and radar (VV, VH, VV/VH) composites (left upper) and the derived waterlog maps (left down).

Outlook to the future

The success of the current system provides a solid basis for its further extensions. On the one hand, damage mapping is planned to be extended to storm and hailstorm effects, with preliminary studies already being carried out. Furthermore, measures are being taken to integrate yield loss estimations into the systems of risk management and loss compensation. In addition, the possibility of including grasslands is under consideration. Nevertheless, these topics require further investigations in order to establish robust methodologies for the estimation of crop yields and grassland productivity, in which remote sensing is likely to play a major role.

Acknowledgements

The work presented in this showcase was funded from the Agricultural Risk Management Fund by the Ministry of Agriculture. All Sentinel data were provided free of charge by ESA in the frame of the Copernicus Programme. Free Landsat data were obtained from USGS/NASA. The authors are grateful for the contribution of all experts involved.

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AGRICULTURE MONITORING USING SENTINEL IMAGES

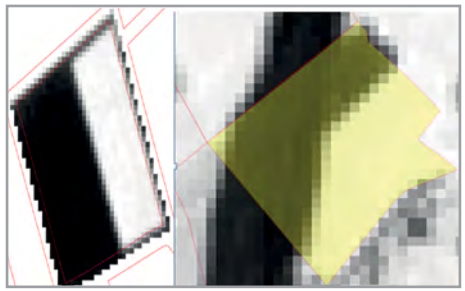
The general aim is to provide objective and timely information to the Walloon authorities to help farmers as well as to protect CAP funds.

The challenge

The Walloon Paying Agency, managing different schemes relating to the Common Agricultural Policy (CAP), is in charge of maintaining up-to-date the Land Parcel Identification System (LPIS). The LPIS is the main tool allowing farmers to annually declare areas of cultivated fields and eventually the ecological focus areas via Geo Spatial Aid Application – (GSAA). Starting with the 2018 campaign, the GSAA will be mandatorily web based, which will increase the quality of the LPIS in terms of updating. The update is the LPIS upkeep process that deals with the changes to the land.

The space based solution

Remote Sensing (RS) is one of the ways to update the LPIS. In Wallonia Region, each year, a complete aerial images cover is available and, being compliant with LPIS quality requirements, is used for LPIS updates. These orthophotos are very useful for the farmers and for the update of the LPIS thanks to their very high spatial resolution (25 cm), the principal issue of these images is their delivery time, usually the aerial imagery is only available six months after their acquisition. In this context, the use of other images, with a high temporal resolution



Two examples of change detections inside of agricultural parcels based on NDVI standard deviation (two crops on left side, a new road on the right side)

seems to be a good solution for an operational system.

Since June 2017, the EU Copernicus Programme provides high temporal resolution Sentinel 1 (S1) & Sentinel 2 (S2) satellite imagery. The Walloon Region is covered by a 3 day revisit period for S2 sensors and a 2 day revisit period for S1 sensors.

The research aims to find the optimal way for the implementation of derived product and results from high resolution Sentinel 1 & 2 satellite images in the operational chain used by the Walloon administration. This research is done by the Walloon Agronomical Research Centre (CRA-W).

Different vegetation indices are derived from S2 images and used for both:

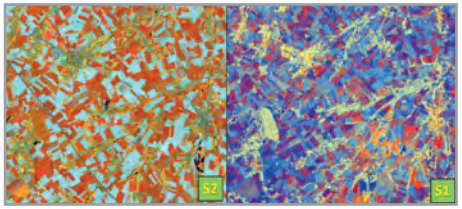
- object based classification in order to identify the crop type at parcel level
- change detection in order to roughly spot the parcels where the boundary have to be updated and/or where land use is changed.

Benefits to Citizens

The main benefit for the farmers is the reduction of their administrative burden when they have to declare their agricultural parcels in order to receive CAP aids. Indeed, they would receive pre-filled declarations based on what is For the Walloon administration, the automation of the LPIS update would limit the number of field visits to the minimum necessary, i.e. what is not controllable with remote sensing data and new technologies. Moreover, the results would lead to better assurance on activities on declared parcels throughout the Walloon region which would increase compliance with the regulation and focus on prevention.

The results of change detection of agricultural parcels borders are already operational and implemented for the Walloon administration.

> "This application of Copernicus Sentinels will significantly improve the way which farmers are doing online aid applications and, for the Walloon Paying Agency, will help to keep the Land Parcel Identification System up-to-date and to move to the new checks by monitoring."
>
> ***Alain Istasse***
> ***General Inspector of Aids Departement***
> ***General Direction of Agriculture, Natural Resources and Environment Public Service of Wallonia***



Example of optical and SAR images used for crop type classifications (S2 image acquired on 26 May 2017 – RGB:4, 3, 2, S1 image acquired on 6th of May 2017 - RGB:VH, VV, VH/VV)

Starting with the 2019 campaign, the results will be also available and implemented for the farmers.

The crop identification results will be implemented in test phase during the second half of 2018.

Outlook to the future

In spite of a theoretical short revisit time of Sentinel 2 satellites, due to very frequent cloud cover in Belgium, for an operational system the effective availability of images is very often a problem.

The Sentinel 1 satellites, as active sensors, acquire radar images independent of meteorological conditions (cloud free). Using directly radar images and some derived products (as polarimetric indices and coherence) crop type identification gives similar results as when using S2 optical images. By using both optical and radar images, the results of crop types classification are improved. Different scenarios are being developed to answer different real conditions for the Walloon administration.

Acknowledgements

The research is included in the framework of the SAGRIWASENT project founded by the Walloon region. The scientific partners of the project are the CRA-W and UCL-ELIE, with the collaboration of the DGO3 (SPW).

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COPERNICUS DATA AND CAP MONITORING IN ROMANIA

A case study on agriculture monitoring using Copernicus Sentinel-2 time series.



Copernicus Sentinel-2 image on June 2017 showing agricultural land fragmentation in South Western Romania.
Credit :Contains Copernicus Sentinel data [2017]/ESA

The challenge

The Common Agricultural Policy (CAP) supports the implementation of sustainable models for the agricultural economy Europe-wide. It also creates the premise for a new challenge – the control and monitoring of the rigorous usage of subsidies over large areas of agricultural land.

Every year, more than 700,000 farmers access the EU subsidy mechanisms through the Romanian Agency for Payments and Intervention in Agriculture (APIA). The 2016 Eurostat Yearbook indicates that 71% of agricultural holdings with areas smaller than 2 hectares encompass 17% of the utilised agricultural area (UAA). This creates tremendous pressure on the resources allocated by APIA for compliance verification.

Earth Observation (EO) data provide wide and repetitive homogenous coverage, translated into an unprecedented amount of information referred generally as "Big Data". The technologies benefitting from the data volumes represent a solid solution for a continuous monitoring of CAP compliance.

The space based solution

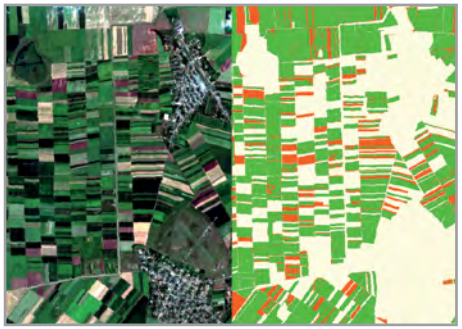
The Sentinel-2 satellites, part of the EU Copernicus data stream, hold an enhanced 5 day revisiting time. They deliver regular coverage over large areas, allowing a uniform observation of agricultural plots larger than 1.5 hectares. Historical data is also available for retrospective baselines. The superior spectral resolution allows the identification of the phenological growth stages and the distinction between various crops or crop classes.

Terrasigna developed and enhanced a technology based on automatic processing of multi-temporal series of open EO data, with the focus on Sentinel- 2. The work was developed under the framework of the DataBio project using the Land Parcel Identification Scheme (LPIS) provided by APIA. The Agency issued a consistent set of user requirements matching the CAP implementation priorities. The research is in line with the current European initiatives focussing on the increased usage of Copernicus data for the monitoring and evaluation of CAP effectiveness.

Benefits to Citizens

A continuous agricultural monitoring service based on the analysis of Copernicus satellite time series is not just a CAP compliance tool but it can also offer supplementary information for both public authorities and citizens. The service can provide an extensive picture of the overall dynamics of agriculture at both pixel and parcel level. The paying agencies will be able to simplify the CAP compliance checks whilst benefitting from homogenous data regarding the crop areas and potential mismatches between the farmers' declarations and the situation in-situ. In addition, a broad portfolio of information can be added: summer- and winter-crop assessment, crop rotation, identification of degraded land, areas affected by abnormal humidity etc. Various data layers will be provided freely as Web Map Services to the civil society: monthly satellite countrywide mosaics, early drought warnings or precise statistics regarding crops. This can be further integrated with meteorological and socio-economic data and translated into scenarios on how future changes might affect land fragmentation and agricultural productivity.

> "Geospatial services together with Copernicus data can serve as a significant tool for agricultural subsidy control, enabling easy and useful applications for farmers."
>
> ***Traian Crainic, Director IT-LPIS, APIA***



Buzau County, Romania. Example of possible mismatches (right image, in orange) between the declared and observed crop.
Credit :Contains Copernicus Sentinel data [2017]/ESA

Outlook to the future

Terrasigna aims to exploit the potential of Copernicus Sentinel-2 time series and to provide a near real-time agriculture monitoring service at national and European level, fully compliant with both Romanian and EU requirements. The farmers will benefit from modern and effective information in line with the principles of sustainable agriculture.

Acknowledgements

The "Data-driven Bio-economy" DataBio project (www.databio.eu). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 732064. LPIS sample data was received from the Romanian Agency for Payments and Intervention in Agriculture (APIA) within the framework of the project.

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EARTH OBSERVATION DATA TO DETECT IRRIGATED AREAS: AN APPLICATION IN SOUTHERN ITALY

A satellite-based service that allows to map areas irrigated without permission was implemented in two land reclamation consortia in Campania.

The challenge

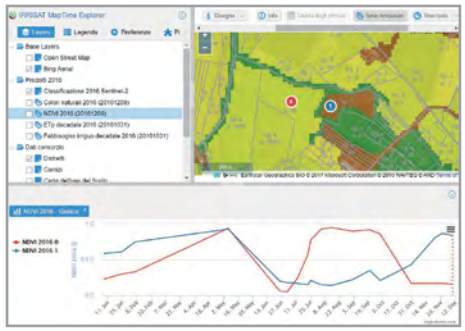
In Southern Mediterranean regions, irrigation is essential for ensuring high crop yields during late spring and summer, characterised by high temperatures and lack of rain. Indeed, irrigation allows lands to be, on average, twice as productive as rain-fed lands. Improving the efficiency of water use for irrigation is required to ensure long-term sustainability of irrigated agriculture. Current Earth Observation (EO) systems like Sentinel-2 provide multispectral imagery of crops with relatively high spatial and temporal resolutions and is free of charge.

The goal is to empower water managers to optimise the detection of non-authorised water abstractions for irrigation in two land Reclamation Consortia located in the Campania Region (Italy).

The space based solution

The mapping system for irrigated areas is based on the temporal variability of vegetative vigour. In detail, a time series of NDVI (Normalised Difference Vegetation Index) maps are computed using Sentinel-2A (S2A) and Sentinel-2B (S2B) data.

This process allows a classified map of the growth patterns to be obtained and to verify



Cadastral parcels and irrigated areas map based on time evolution of NDVI derived from satellite images.

that the growth curve is linked to the supply of established water. By overlaying the information layer of the registered cadastral parcels and the classified map, it identifies the areas without water authorisations also called water rights.

In detail, the map of the irrigated and non-irrigated areas, must be intersected with parcel boundaries with regular irrigation authorisations (Compliance parcels). For each farm, cadastral references, extension of irrigated area, irrigation period, permitted crops and water volume, are indicated.

Based on these data, it is possible to detect the irrigated areas without necessary water authorisations (Non-compliance - First type) and the irrigated areas which exceed the declared irrigated areas (Non-compliance - Second type). This methodology highlights the potential of EO data to improve water management policies and practices, especially in extreme conditions such as drought.

Benefits to Citizens

Improvement in the efficiency of water use for irrigation is required to ensure long-term sustainability of irrigated agriculture. The EU Common Agricultural Policy (CAP), combined with the Water Framework Directive, imposes

"We view it as an extremely useful tool, whilst up until recently our controls were based on random and, from a human perspective, burdensome on-site audits, today we start from satellite data to gain overall information and when things don't add up we go on site for a visual inspection."

Eng. Massimo Natalizio,
Irrigation Consorzio Sannio Alifano.
Platinum magazine - November 2017

a substantial increase in the efficiency of water use in agriculture for the next decade on farmers and irrigation managers.



Cadastral parcels with (green parcels) and without (red and orange parcels) necessary water authorizations and its location in Campania region (Italy)

Monitoring irrigated areas and the abstracted volumes on a systematic basis, and better targeting of field inspections aimed at assessing compliance with legal water

allocation, ensure the legitimacy of self-declared irrigation water abstractions and safeguard compliance with water restrictions set in special occasions such as drought.

In conclusion, it is possible to obtain an equitable redistribution of costs related to the use of water resources as well as economic and environmental benefits for the local community.

Outlook to the future

Further lines of development could be the introduction of this methodology in the context of the emerging open data "Marketplace", with the aim of using the open data and services, involving and combining individuals, businesses and public sector bodies.

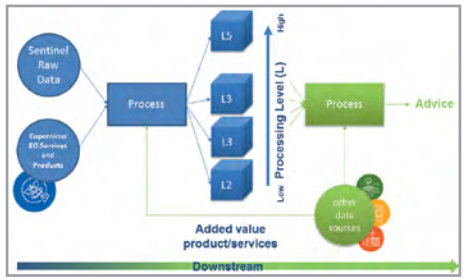
Acknowledgements

This story synthesises the works performed within the project DIANA – EU H2020 (Detection and Integrated Assessment of Non-authorized water Abstractions using by EO).

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EARTH OBSERVATION FOR SMART FARMING AND CAP PERFORMANCE

How time-series measurement of vegetation indices supports the provision of smart farming and agricultural monitoring services for Greek farmers and policymakers.



The downstream workflow of gaiasense produces a high value data chain leveraging EO Copernicus data and services.

The challenge

Greek farmers are facing a series of challenges that affect their crop yield. For example, plant defensive systems are lowered due to climate change, making them more susceptible to pest attacks. Nevertheless, farmers continue to make decisions for their farms based on their intuition, or acquired ancestral knowledge, using traditional non-sustainable practices that drain the natural resources and affect the environment.

In this context, gaiasense has arisen as a Smart Farming (SF) platform that provides data-driven environmentally friendly advisory services on fertilisation, irrigation and pest management, minimising the use of inputs (i.e. water, fertilisers and pesticides), according to the mandates of the Common Agricultural Policy (CAP). Multiple data sources, such as the Internet of Things (IoT) sensors, farm logs, and satellite imagery, are used to generate reliable advice and support the decision-making process of the farmer.

The space based solution

Gaiasense uses remote sensing methods to process and upgrade one of the main data inputs that of Copernicus raw data and services hosted on hubs. The downstream workflow aims to output high value-added products and services that may be then fused with the remaining data sources of gaiasense to generate the advice. As an example, solar radiation and IoT measurements are combined to estimate the reference evapotranspiration that is needed in the irrigation advice.

In practice, the pipeline of the platform incorporates three core modules operating independently, which in turn search for new Sentinel-2 imagery, download them and perform the required processing for optical satellite images (i.e., atmospheric correction and cloud masking). As a result, the initial data are upgraded to higher-level products, such as NDVI or LAI vegetation indices that are valuable for SF.

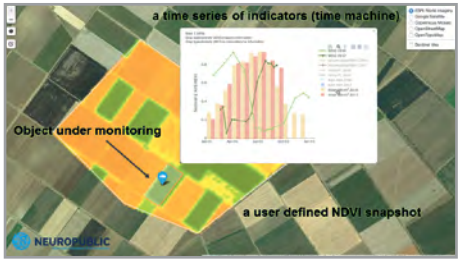
The platform automatically assigns the extracted information to the agricultural parcels or the management units belonging to the gaiasense database. Furthermore, meteorological data from the IoT telemetry stations enrich the information context. The farmer is also able to correlate the spatiotemporal conditions of his parcels with those of a larger user-defined Area of Interest (AOI).

"Gaiasense helps the producers of our regions to reduce the use of agrochemicals, leading to the production of safer food."

Mr. Kostas Apostolopoulos, Vice-Governor of Rural Economy of the Central Greece Region
Mr. Theofanis Papas, Vice-Governors of Rural Economy of the Central Macedonia Region

Benefits to Citizens

Gaiasense provides EO-based monitoring services that allow farmers to understand their crops growth and vitality, and enhance their farm management with evidence for specific action. In parallel, the extracted vegetation indices provide valuable information regarding the intrafield variability conditions of the parcel (time-series of image snapshots). The gaiasense-guided actions in the field reduce the consumption of natural resources and protect the environment by minimising the use of chemicals.



A demo view depicting fields in Central Macedonia. The end user can monitor parcels through time, either by using interactive graphs of indicators, or image snapshots.
Credit :Contains modified Copernicus Sentinel data [2016, 2017]

These services also introduce spatial analytics intelligence for CAP performance and efficiency management, which is valuable for policymakers. EO-based stream values enable crop growth analysis and crop type profiling, revealing trends and helping regional, national and EU policymakers to understand "where we are, what direction we are heading in and how far we are from where we want to be", supporting the CAP and Food Security policies.

After two years of applying the SF services, results have shown that it is possible to increase production by an average of 10% and decrease the consumption of water, fertilisers and pesticides by an average of 19%.

Outlook to the future

Agricultural monitoring and SF require a large amount of data from several sources in order to be accurate. In the future, we plan to incorporate more Sentinel missions into the workflow in order to examine data from more wavelengths and acquire the shortest revisit time that will enhance the quality of the given advice. Crop growth models and probabilistic weather forecasts powered by satellite data are another appealing extension for gaiasense.

Acknowledgements

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REINFORCING THE COMMON AGRICULTURE POLICY

Automated satellite-based Earth Observation services support the monitoring of farmers' compliance to Common Agriculture Policy (CAP) obligations.

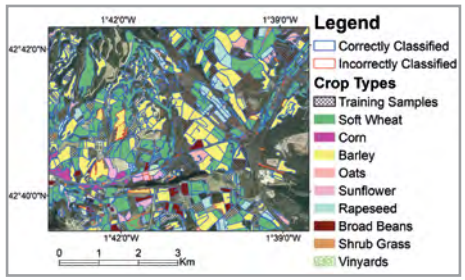
The challenge

Paying Agencies (PA), responsible for the implementation of the Common Agriculture Policy (CAP), need to monitor farmers' compliance to certain standards concerning the environment. Monitoring is performed by in-situ visits and through remote sensing. Due to the high complexity and diversity of the obligations that need to be monitored, both methods have limitations, being evidently complex processes of poor transparency and entail a high cost for public administrations.

Space technology and use of Copernicus data offer better monitoring in agriculture, also supporting the implementation of the CAP. Through its service platform, the RECAP H2020 project responds to the CAP monitoring challenges providing advanced manual and fully automatic hybrid Earth Observation (EO) techniques, contributing to cost-efficient, transparent and reliable remote CAP monitoring.

The space based solution

The introduction of the Sentinel mission enables optical and radar satellite data to be freely and systematically received on a global scale. With Sentinel-2's high temporal resolution of 5-day revisit time, consistent and timely monitoring of the agricultural land becomes feasible. Additionally, Sentinel-2's 10/20-m high spatial resolution enables the systematic provision of crop-specific biophysical parameters and accurate thematic information at parcel level. Here, we have developed and applied automated EO processing workflows, to assist the regional paying agency inspections with respect to farmers' compliance to their CAP obligations; predictably at operational level. The methodology is founded on accurate crop type classification via machine learning application on a time-series of combined Sentinel-2 imagery and vegetation indices. Effective exploitation of crop phenology enables the discrimination amongst 9 crop types, which explains 90% of the regional agricultural zone. To further assist the paying agency inspectors, the described system delivers on demand Sentinel-2 true colour composites and pertinent vegetation indices; for all cloud free acquisitions within the year of inspection. Methods have been designed and developed alongside the end-users and stakeholders, under a co-creation/co-production scheme, to offer a mutually valued outcome.

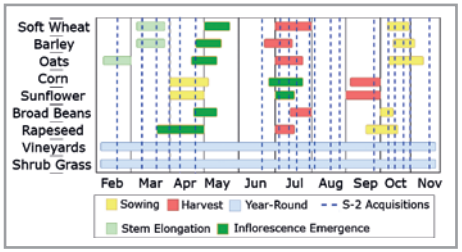


Crop type classification using time-series of Sentinel-2 imagery, Navarra, Spain 2017

Benefits to Citizens

The satellite-based RECAP solutions providing a remote compliance control system for specific rules of Cross Compliance and Greening, contribute to the reduction of the overall cost for performing the monitoring of the CAP implementation. Increased transparency and efficiency of the policy implementation is ensured alongside a simplified, personalised system of e-public services contributing to better use of public resources.

> *"Space-based services enable paying agencies to improve transparency, reduce administrative burden and efficiently monitor farmers' compliance to CAP obligations."*
>
> ***Alberto Lafarga,***
> ***Institute for Agrifood Technology and Infrastructures of Navarra INTIA***



Chronogram of key crop phenological stages and all cloud free Sentinel-2 acquisitions in 2017.

Competent authorities and service providers profit from the RECAP solution which allows them better allocation and saving of resources, enabling them to provide added value services to local farmers. Farmers profit from a system that guides and notifies them of their obligations ensuring their compliance to the rules, whilst reducing their administrative burden. Such a proactive participation of the farmers in the monitoring procedure makes them an active part of the data collection chain enhancing communication, exchange of information and cooperation with the public administration, enabling the provision of more transparent public e-services.

Outlook to the future

The system has been applied and validated in the Navarra region, currently transitioning to an early adoption level. It has also been applied in two diverse pilot sites in Greece and Lithuania (involving the respective PA); where, for the first time, there is evident agricultural land fragmentation, whilst for the latter, Sentinel-2 cloud-free imagery is scarce. The results, however, are comparable in accuracy; attributed to the unique spatial and temporal characteristics of the Sentinel-2 data. Since the methods were designed to be fully transferable, by merely utilising open access EO data, the scalability to country or even European scales is top priority. In that respect, the Copernicus Data & Information Access Services (DIAS) can act as an enabler for the operational and large-scale application of the scheme, in terms of both data and processing requirements.

Acknowledgements

RECAP is a EU project and has received funding from the EU Horizon 2020 Research and Innovation Programme under Grant Agreement No. 693171.

A. Armesto, and A. Lafarga[1], D. Petalios[2], I. Papoutsis and V. Sitokonstantinou[3].
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SENTINELS FOR FLOOD AND YIELD LOSS MAPPING

Many fields ready to harvest are flooded during severe rainfall. Sentinel satellite data was used to replace field visits and to accelerate payment of compensation.

The challenge

In August 2017, Latvia experienced extremely heavy rainfall. More than twice the monthly norm poured in two days at the very beginning of the harvesting season.

Fields were flooded and it was impossible to get agricultural machinery on them. The Government declared a state of emergency in the agriculture sector. It was clear that administrative institutions would have to check flooded fields so that farmers could receive compensations for the yield loss but many roads were impossible to drive and raining continued for more than a month.

The space based solution

For the largest flooded fields, Copernicus Sentinels became very useful. Both Sentinel-1 radar and Sentinel-2 optical satellite data were used to map the flooded areas.

Sentinel-1 radar is capable of "seeing" through clouds which allowed for the use of remote sensing data for flood mapping even though the sky was still overcast and it was raining often. Furthermore, since radar backscatter on water is completely different from vegetated areas, it makes flood mapping with radar data quite unmistakable.



Severe rain caused flood at the beginning of harvesting season in Eastern Latvia.
Image: Rural Support Service

High revisit frequency allowed for the mapping of flooded areas every week or even more often, if necessary. The possibility of obtaining data every few days allowed fields that became flooded after a while to be caught, when water flowed down the terrain.

At the end of September Sentinel-2 was able to get some optical images. Many fields were still under water. Flood mask was also generated from optical data and merged with data from previous dates.

Flood maps from Sentinel satellite data were integrated into Land Parcel Information System and used together with farmer applications for compensation.

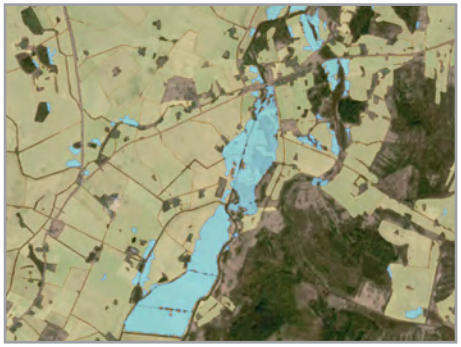
Benefits to Citizens

According to Sentinel data every parcel that was under water was considered to have lost yield and excluded from these fields that must be visited. Use of Sentinels reduced the amount of on-the-spot visits. Inspectors from the Rural Support Service could spend their time visiting only those fields whose yield loss was not clear from satellite data (small parcels and fields where crops emerge from water or the soil was too wet to harvest).

Use of Sentinels and drones shortened time for field visits by a third. Faster field visits saved plenty of administration costs (fewer working hours, less driving to visits). 3100 farmers with 82000 ha of damaged area received their compensation for yield loss in less than two-months after the first day of rainfall. That was an unprecedented speed for emergency administration - from field visits to payments.

> "Using Sentinels to check damaged fields lets us finish compensation payments in less than two months from the first drop of rain."
>
> ***Indulis Abolins,***
> ***Deputy Director of Rural Support Service***

Farmers received compensation payments faster and could start preparing for the next season.



Flooded area mapped (blue) using Sentinel-1&2. Overlap with reference parcels (yellow) show the lost yield in Eastern Latvia.
Credit: Contains modified Copernicus Sentinel data 2017

Outlook to the future

Every emergency or, in this case, loss of yield, leaves people with hope that it will not happen again or, at least, it will not happen soon. Still, emergencies happen and it is essential for government institutions to respond as soon as possible, to estimate damage rapidly, and to administer support payments in a short space of time.

The Sentinel constellation proved its worth in helping to administer compensation for flood damage. This was also the first example in Latvia of the joint use of both Sentinel-1 and 2.

If flooding strikes again, we will be experienced at mapping flooded parcels even faster. Also, we could extend flooded areas over digital terrain model, if available.

There are always things to improve with every solution. But it would not be possible without the Copernicus Sentinel satellites' data and its short revisit time.

Acknowledgements

Thanks to the Copernicus programme for Sentinel missions and data, ESA for training courses and tutorials for data processing, and Riga Technical University for academic support.

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SENTINELS VERIFY AGRICULTURAL SUBSIDIES

Estonia uses Copernicus Sentinel-1 and -2 time series in a country wide system to verify the mowing requirement of the agricultural subsidies under Common Agricultural Policy.

The challenge

The Estonian Agricultural Registers and Information Board (ARIB), like other European paying agencies (PAs), is responsible for the honest sharing of the subsidies to farmers and the verification of the subsidy claims.

The European Common Agricultural Policy (CAP) sets the rules for the farmers to keep the land in good condition in order to qualify for the subsidy payments. Although the fraction of non-compliances is tiny, the total economic impact on an EU level is huge given the €50 billion annual budget of CAP.

In the verification of the subsidy checks PAs have so far mainly relied on inspectors' field visits. Given the rising labour costs in Europe it gets more and more expensive every year.

The space based solution

ARIB, in cooperation with Tartu Observatory and CGI Estonia, has built an automated satellite based infosystem SATIKAS.

SATIKAS uses Sentinel-1 (S1) radar and Sentinel-2 (S2) optical satellite imagery to check whether the farmers follow the mowing requirement, which is one of the most common under CAP and is often violated on lands which are not in intens



Mowing detection results are presented on a public web map of Lääne-Viru County. Green represents mowed area, red not mowed area and orange late mowed area.

agricultural use. The system operates from May to October every year to cover the entire growing season and detects all mowing on agricultural grasslands in Estonia.

Sentinel satellite images are pre-processed and dense time series are formed. In each season more than 100 S1 radar images and more than 50 S2 optical images are used. For each parcel its characteristic S1 and S2 parameters' signatures are built, where the mowing events are detected using state of the art deep learning technology.

Benefits to Citizens

The results are published in virtual real time throughout the season in an open web map for the general public and in detailed reports for the ARIB specialists. It helps to reduce the need for expensive field visits, saves the time of inspectors – sending them directly to the right fields without wasting time on areas which are OK anyway. It also has a significant prophylactic effect – publishing the results on the web map works as a reminder for the farmers who have not yet fulfilled the mowing requirements.

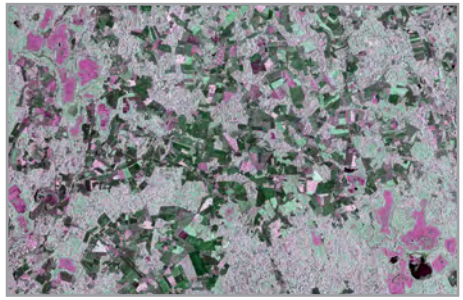
By detecting more episodes of non-compliance,

> "We are gradually increasing satellite based monitoring and reducing field visits. Building the satellite based mowing detection system is the first step in this development."
>
> ***Ahti Bleive, Estonian Agricultural Registers and Information Board***

SATIKAS helps to reduce false payments – the economic impact in Estonia alone is estimated at close to € 500,000 every year. The total economic impact of similar systems at EU level is at least two orders of magnitude greater.

As the system is new the accuracy is still improving every year. As of 2018 it is already used as the risk analysis tool with gradual movement to the ultimate goal of totally replacing field visits and making the payment decisions based on SATIKAS satellite based results.

Ultimately, SATIKAS helps to reduce the spending of the European Union and to direct the freed resources for future developments through technological progress.



Lääne-Viru County on a false colour composite. SATIKAS uses dense time series of Sentinel-1 radar images as its main data source. Red represents vv-polarization, green vh-polarization, blue vv+vh-polarization.

Outlook to the future

Mowing checks using Sentinel-1 and -2 data is the first step for ARIB in its future path towards automated satellite based monitoring and reducing the need for inspectors' field visits. It is planned to further extend the functionality of SATIKAS with grazing detection, harvesting detection, crop classification and flooded fields mapping. The accuracy of SATIKAS will be developed to the level such that it is possible to make payment decisions without field visits. Next generation Sentinels and other high resolution sensors will be used to improve the accuracy and precision of the subsidy checks and to support the farmers with satellite derived information in their work.

Acknowledgements

The project was funded by the European Regional Development Fund under the "Development of public services" programme using information and communication technologies".

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A FARMSOURCING PLATFORM FOR A SMART NITROGEN MANAGEMENT

BELCAM is an EO-based collaborative platform designed for public authorities and farmers for crop monitoring based on the joint use of field observations and Copernicus satellite data.

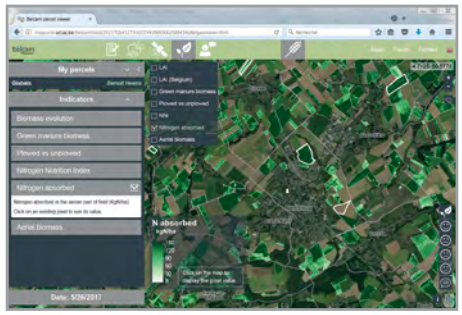
The challenge

Producers in European countries are under increasing pressure to maintain profitability within environmental constraints and the increases in N fertilisers' prices that should encourage more rational and environmentally responsible management of inputs.

The high spatial and temporal resolution provided by Sentinel missions (mainly Sentinel-1 and -2) paving the way for new local applications on a smaller scale than in agricultural regions or in very large fields has motivated the development of the collaborative farm sourcing platform BELCAM optimising nitrogen management at parcel level based on the joint use of satellite (Copernicus) data, field observations and crop growth models.

The space based solution

Nitrogen (N) is a major element of chlorophyll and enzymes implied in photosynthesis, a shortage results in lower yields whilst an excess has negative environmental consequences (e.g. groundwater pollution). Thus, providing the right doses in the right places and at the right time is crucial. The BELCAM collaborative platform contributes to smart nitrogen management of wheat, potato and maize in Belgium by providing to users satellite-based N recommendations at parcel level. It includes a total N-recommendation at the start of the season but also, throughout the growing season, the crop nitrogen status, the Nitrogen Nutrition Index (NNI) determining the crop N nutrition level and, considering the crop N requirements, the amount of fertilisers to apply. These products are built from surface reflectances (of bands at 10 and 20m) and vegetation indices derived from Sentinel-2 (available every 3-5 days over Belgium) which are used to estimate the nitrogen absorbed by the crops, the crop and green manure aboveground biomass and leaf area index (LAI). With a spatial resolution of 10m, sentinel-2 data can also be used in the delineation of management zones for variable nitrogen application. The collaborative ("farmsourcing") approach of the platform speeds up the critical learning process for the remote sensing providers, thanks to input and near real time feedback from the users.



Snapshot of the BELCAM collaborative ("farmsourcing") platform - The displayed product is the nitrogen absorbed (kg N ha-1) of winter wheat parcels in the vicinity of Gembloux on the 26th of May 2017 – parcels with border limits in white are those encoded in the platform.
Source: BELCAM project
Credit: Contains modified Copernicus Sentinel data [2017]

> "The BELCAM platform innovates management of fields."
>
> ***Engr. Pierre Lebrun, Filière wallonne de la pomme de terre, FIWAP***

Benefits to Citizens

The adequacy between the nitrogen supplies and the crop needs allows public authorities to meet European regulations e.g. Nitrates directive). It also meets the societal expectations in terms of good agricultural practices and product quality. Consumers are increasingly concerned about agricultural production that allows farmers to get fair incomes whilst preserving the environment and consumer health. This adequacy allows the minimisation of the risks of groundwater pollution by nitrates and the subsequent reduction in costs linked to the sanitation of water used for human consumption but also allows a reduction of greenhouse gas emission. Avoiding the spread of more nitrogen than is required allows farmers to reduce the cost of nitrogen fertiliser and subsequently helps them to produce at lower cost in the context of price volatility.



Nitrogen Nutrition index (NNI) describing the crop nitrogen status (in May 2017) of some winter wheat fields in Belgium (source: UCL – Louvain, Belgium).
Credit: Contains modified Copernicus Sentinel data [2017]

Outlook to the future

The BELCAM platform aims at providing EO-based products and services to regional authorities, farmers and also agricultural extension services (e.g. FIWAP) providing technical and economic support to farmers. The products and services which have been made available concern recommendations on nitrogen, crop status and estimations of yield. Other products/services valorising the sentinels constellations (mainly Sentinel-1 and -2) are currently developed in permanent interaction with end users through the collaborative platform (e.g. dry matter proportion in maize). The BELCAM platform aims at being a non-profit platform meeting a public service role. Reaching this objective is made possible by the Copernicus free and open data policy.

Acknowledgements

The BELCAM project is funded by the Belgian Science Policy Office (BELSPO) in the frame of the research programme for earth observation STEREO III. The development of the BELCAM platform and the definition of targeted products were only made possible through constant interaction with end-users (farmers, technical and pilot centres and regional authorities).

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A NEW DETAILED CROP AND NATURAL LAND MAP

Crop and forest species identification with unprecedented resolution as a tool for land monitoring in Castile and León (Spain).

The challenge

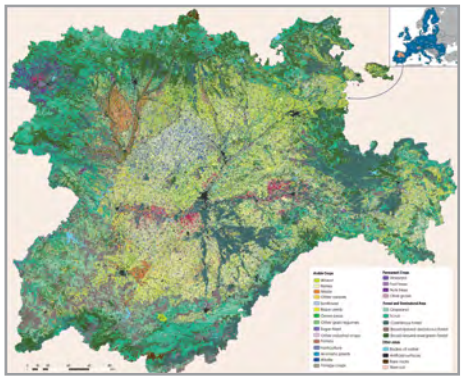
Castile and León is a very large region (94,224 km2) dominated by vast areas of cropland (mainly grain crops on arable land) surrounded by natural landscapes. Existing land cover projects at European and National level consider arable land as a single class that groups all crops in an individual legend item without giving information about the heterogeneity of the agricultural landscapes in such a big area nor their annual evolution. Moreover, forest and semi natural areas are not characterised well enough for land planning and assessment.

The challenge was to create a very detailed land cover map, updated annually with crop and forest identification at species level by means of remote sensing and ancillary data available within the regional government.

The project is conceived as a concerted and coordinated effort by the Agricultural and Livestock Department, and the Environmental Department, with the common objective of monitoring agricultural and natural land simultaneously.

The space based solution

Sentinel-2 and Sentinel-1 satellites provide an incredible tool for assessing land cover due its spatial accuracy, frequency of acquisition and ease of access.



Crop and natural land classification map over the region of Castile and León for 2017.
Credit: Contains modified Copernicus Sentinel data [2016]

Land cover classification is performed using machine learning techniques based on year long time series of images together with ancillary data such as elevation, slope, average precipitation, vegetation height taken from LIDAR flights, etc.

In order to implement the machine-learning algorithm, high-quality training cases are required, which are selected from different sources of information available in the Regional Government such as the Integrated Administration and Control System (IACS) from Common Agricultural Policy and Forest Inventories.

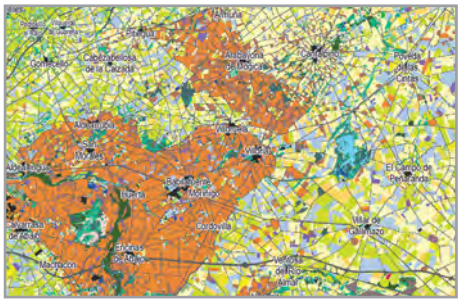
Following this methodology, detailed crop and natural land maps have been produced every year since 2011. Before the appearance of Sentinel-2, the product was based on Landsat-8 and mainly on Deimos-1 images at a considerable cost.

Since 2017, the product has been based solely on Copernicus images, providing an increase in the spatial resolution up to 10m as well as a significant cost reduction.

> "This crop map will allow us to monitor agricultural activities as well as improve the effectiveness of the CAP controls and reduce the farmer's paperwork."
>
> ***Juan Pedro Medina Rebollo, D. G. Regional Paying Agency***

Benefits to Citizens

The land cover maps are easily accessible through the Internet http://www.mcsncyl.itacyl.es]. Users with a technical background can download the entire product in order to develop their own projects and analysis; meanwhile basic users can access the information through a web interface that includes the cadastral information. The availability of yearly layers allows users to check crop rotations and land cover changes.



Example of crop and natural land classification map over a mixed area with irrigated and rainfed crops in Salamanca province.
Credit: Contains modified Copernicus Sentinel data [2017]

From a government perspective, the land cover map also enables the monitoring of land changes and the assessment of the fulfilment of different requirements of land owners in a very efficient and cost effective way. The map allows for the control of protected areas included in the Habitats Directive and for the monitoring of the use of water in agricultural land by the River Basin Authority. Moreover, the land cover map is an invaluable tool for monitoring the agricultural activities for CAP subsidies, in particular, to control crop diversity and coupled aids (crop specific payments).

Outlook to the future

The production of such a detailed land cover map requires the availability of one to three (cloud free) satellite images per month of the whole territory with adequate spatial resolution. Sentinel-1 and Sentinel-2 satellites represent the only available operational constellation that can guarantee the production of the map on an annual basis with reliability.

The use of data science techniques based on the integration of earth observation datasets, with other sources of data will produce a change in the way land is monitored all over Europe with important implications for the citizens.

Acknowledgements

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CLOSING THE YIELD GAP WITH CALIBRATED CROP MAPS FROM GERMANY

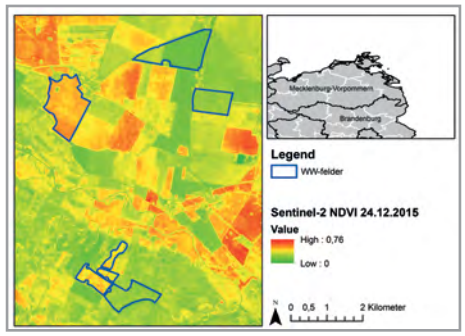
Biomass maps from Copernicus data help accounting crop yield information in the Demmin region in Germany.

The challenge

Crop yield monitoring is a major challenge in agricultural production. The knowledge of the yield condition is key for the sustainable management of agricultural lands and an important source of information for economic planning and price development in Northern Germany. The challenge is to overcome existing yield gaps by using operational space-based monitoring services as provided by the Copernicus Missions. Up-to-date spatial information and indicators on the ecological status of managed ecosystems provide knowledge for increasing cropping yields on existing agricultural systems. Despite limited land resources, efficient farming practices and the wise use of water resources for irrigation is a major challenge for land managers on a regional scale.

The space based solution

Satellite-based remote sensing enables an objective and repeated assessment of the agricultural landscape. It offers a perspective that is not influenced by property or administrative boundaries and thus helps to understand the processes in a coherent environmental system such as an agricultural landscape. The Earth Observations of the Copernicus Programme are free of charge



Illustrates how NDVI maps derived from Sentinel-2 can be used as indicators to determine high and low productive parts of a crop field.

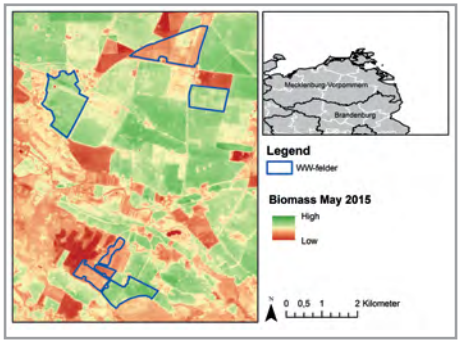
and provide high-resolution, high-frequency, detailed information about the land surface to everyone. The richness of remote sensing data helps to obtain up-to-date information on farmland and agricultural processes. Vegetation indices such as the NDVI, in combination with land use and empirical models, using in-situ data are used to estimate high and low productive areas in a field. In combination with the high frequency of remote sensing observations, this information is used to assess the effectiveness of agricultural management steps.

Benefits to Citizens

Satellite-based agricultural monitoring provides information on the condition of agricultural land. Despite the detection of areas with limited productivity, satellite data analyses provide a holistic picture on the environmental condition of managed landscapes. Examples are drought monitoring and soil moisture maps as well as maps indicating the health status of the crops for each specific field. The satellite data provide key information for adapting fertilisation practices, crop cycles, and show the success of agricultural practices. Existing archives of satellite-based agricultural conditions also help to understand slow environmental processes like soil degradation

> "Field-specific maps on biomass and vegetation productivity from satellites provide a better planning horizon for field applications and developments on the wheat markets."
>
> **Freiherr von Maltzahn, Daberkower Landhof AG**

and effects of soil erosion. These maps are very useful to understand deficits in land management and provide decision making support for on-site applications and adaptions to changing conditions. Agricultural map products on biomass, crop health and yield estimates support traditional management practices since they provide spatially



Shows a result of a light use efficiency model. The model is using high frequent remote sensing data to estimate the generation of biomass per pixel by connecting the spectral information of a remote sensing time series with the real world biophysical information like biomass.

consistent and cost-effective information for land managers. Consequences are better use of fertilisers and increased productivity by reducing the uncertainty of crop damage events and crop risks. The benefits can be scaled from farm level by supporting better crop yields resulting in stable profits for local wheat producers in the administrative region.

Spatial information on wheat conditions are good indicators for the regional wheat markets in Northern Germany. Wise land management practices further foster biodiversity, human health and well-being in the administrative region of Demmin.

Outlook to the future

Crop production is the main industry in Northern Germany. Local farmers will intensify the collaboration with the scientific network of the Durable Environmental Multidisciplinary Monitoring Information Network (DEMMIN) to generate calibrated Earth observation data for agricultural monitoring. Biomass maps will be evaluated by farmers and researchers and integrated into farm management tools.

Acknowledgements

The Authors would like to thank the networks of DLR, GFZ and the Universities of Jena, Würzburg and Halle, as well as the collaborating network of Farmers in the DEMMIN network of the Demmin region.

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COPERNICUS SUPPORTS PRECISION FARMING FOR AN APULIAN VINEYARD

EUGENIUS is a SME network for the provision of Copernicus based services for end users.
The first pilot was done in Apulia for vineyard management.

The challenge

Wine production in Apulia for 2016 is extraordinarily positive with a significant progression from 6 million hectolitres in 2014 to almost 10 million hectolitres in 2016. Apulia wine production represents 14% of the national production. According to ISTAT (Italian National Institute for Statistics), the vine surface grows by 1% each year, to reach, in 2016, 85,000 hectares. With only 3% of wine production with a Protected Designation of Origin (PDO), this significant increase mainly concerns wine without quality labels. Improving and optimising wine-making practices is therefore a major challenge for this business sector in Apulia to cope with economic and environmental constraints. Improving wine quality and quantity whilst reducing environmental impacts and the use of chemical inputs is a key issue for the sustainability of Apulia vineyards. That makes Apulia a very promising market for EUGENIUS solutions and particularly for Earth observation services for vine monitoring.

The space based solution

The EUGENIUS solution for vineyard precision farming is Œnoview®, operated by Terranis and proposed in Apulia by Planetek, thanks to the Eugenius platforms network implemented



Œnoview® products to monitor Tormaresca Bocca di Lupo Vineyard in Minervino Murge (Apulia).

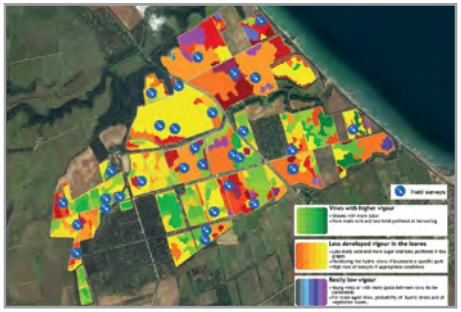
in the framework of the Eugenius H2020 Copernicus project as well as to the Copernicus images. Œnoview® uses multispectral satellite imagery to generate added value products. Biophysical parameters such as the Green leaf cover fraction (GLCV) are extracted from these images to provide a clear status on the vigour and the heterogeneity of the vine. This information is ultimately analysed and formatted in order to help users make the right decisions.

In 2017, the first experimental pilot service was conducted for the Tormaresca vineyard in Salento (Apulia), an Apulian vinery property of the Antinori family. More than 200 ha were monitored combining high frequency of acquisition and free of charge Sentinel 2 with very high resolution satellite images and agronomical in-situ datasets (grape variety, cultural practices, etc.). Œnoview® supported Tormaresca wine-growers in managing sub-field and inter-field variability of the vine vigour. Several critical stages of the grape development are monitored, with a special focus during the veraison stage (a few weeks before harvesting). Zoned maps are also produced to define homogeneous areas on which specific agricultural practices such as fertilisation, water monitoring, pruning and bunch thinning can be implemented.

> "We found satellite monitoring the most accurate and affordable survey method to support the production of high quality wine."
>
> ***Giuseppe Palumbo, Tormaresca***

Benefits to Citizens

The benefits of the Œenoview® service are threefold: decrease production costs by optimising farming practices, reduce environmental impact by limiting chemical inputs and improve the quality and productivity of the vineyard. Moreover, public authorities, such as innovation agencies can include this service in the agronomical practices support to small farmers promoting the digital innovation. This is also supported by EU policies promoting innovation in farming & food processing through EU research projects to increase productivity and reduce environmental impact.



Œnoview® provides accurate information to define homogeneous areas for harvest optimization and wine quality improvement.
Credit: Contains modified Copernicus Sentinel data [2017]

To winegrowers, Œnoview® offers the opportunity to improve the profitability of the vineyard thanks to accurate mapping of each plot. Image processing algorithms combined with oenological know-how

make it possible to extract useful indicators for a better management of the harvest and optimisation of agricultural practices (fertilisation, irrigation, health protection). Areas with anomalies (diseases or nutrient deficiencies for instance) can be detected early so that appropriate decisions can be made. Œnoview® provides wine cooperatives with an instantaneous and large scale characterisation of the qualitative potential of the vineyard parcels. This improves the efficiency of vine parcel selection to achieve production goals.

Outlook to the future

This first experimentation in the Apulia region was successful and demonstrated that the Œenoview® service now being proposed for French vineyards can be fully operational even in a new climate and soil environment. New pilots are foreseen in 2018 as well as a quantification of the economical benefit.

Acknowledgements

This project has received funding from the EU H2020 research and innovation programme under grant agreement No 730150 EUGENIUSTM H2020-EO-2016. The Œenoview product has been developed by Airbus Defence and Space.

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COPERNICUS FOR EFFICIENT FARMING IN THE WESTERN CAPE OF SOUTH AFRICA

The Western Cape of South Africa, including Cape Town, is experiencing a severe drought. With local farmers needing to become water-wise, FruitLook is the tool being used to aid this.



200,000ha of vineyards and orchards are monitored by FruitLook on a weekly basis

The challenge

Droughts are making agriculture increasingly vulnerable and it is expected that the impact of droughts will increase due to climate change. In the Western Cape of South Africa a severe drought is currently affecting two of its biggest industries: fruit and wine production. These industries are of huge fiscal importance—representing almost a third of the province's exports – so optimizing their production whilst minimizing the ecological impact is both an economic and environmental gain. The Western Cape Department of Agriculture (WCDoA) stimulates the efficient use of (water) resources in farming via an innovative approach. In cooperation with the Dutch company eLEAF, FruitLook was created. www.fruitlook.co.za is an online platform to monitor vineyards and orchards, building on frequently updated satellite imagery and weather information.

The space based solution

The starting point to improve water use efficiency is knowing how much water is actually consumed through crop production. In agriculture, this is described as actual Evapotranspiration (ETact). Reliable information on ETact is difficult to obtain since in situ measurements are complicated, expensive and do not show any spatial variation. This is where FruitLook comes in.

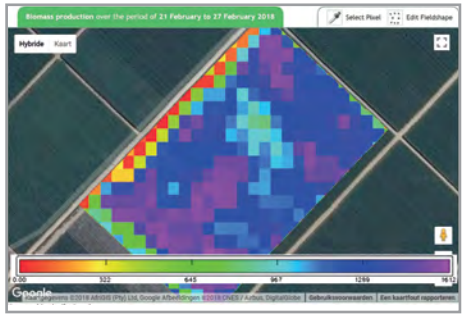
Via FruitLook, available since 2010, farmers have access to the latest satellite information technologies to analyse crop growth and water consumption over time and space. The use of Sentinel-2 satellite data is pivotal for the production of FruitLook's weekly data products. FruitLook services an area of 9 million ha, including 200,000 ha of fruit crops. The data is available via the web portal and can be accessed on a field-by-field basis. Local partners support farmers in the successful uptake of the service. FruitLook offers nine different information data sets, from biomass production showing how well the crop is growing to an evapotranspiration deficit parameter indicating whether crops are experiencing stress.

Farmers access the data at no cost, as the service is fully funded by the WCDoA. As such, WCDoA provides the information infrastructure to move the local agricultural sector forward.

Benefits to Citizens

The current drought in the Western Cape is deemed the worst in more than 100 years.

> "FruitLook helps farmers understand their water use efficiency on and between their orchards and how they respond to irrigation and climate changes throughout the season by giving the grower a visual presentation and record."
>
> ***Anton Muller, Technical Manager KROMCO, one of the largest deciduous fruit packing facilities, Western Cape Province of South Africa***



Variation in crop growth captured in a table grape block

Under these circumstances every drop literally counts. With FruitLook farmers are empowered to make better management decisions which are reflected in the efficiency and productivity of their water use. Farmers use FruitLook to monitor crop development, detect and locate growth problems, evaluate and improve water management and generally optimize resource use. And with success: the water use efficiency of FruitLook users has already increased by between 10% and 30%!

Making better informed decisions not only saves water, but can have other beneficial environmental impacts as well. It enables producers to understand what is needed when and where. For example, with FruitLook farmers can identify disease infected parts of a block quite accurately. By spraying only infected parts of a block, pesticide application is substantially reduced, saving costs and reducing environmental impact.

The agricultural sector is an indispensable component of the local economy in terms of employment opportunities and general livelihood. FruitLook provides crucial information services to make this sector more sustainable and robust. It is therefore no wonder that FruitLook is a flagship project for the Western Cape Government.

Outlook to the future

A changing climate, increased competition for water and rising input costs means farmers worldwide need to attain higher yields with fewer means to do so. Information from advanced technology is necessary to address this challenge. Pixel Intelligence Mapping technology, which forms the backbone of FruitLook in creating smart data products, is applicable on any land surface on the planet. This technology provides a huge potential aid to agriculture and water management worldwide.

Acknowledgements

The Western Cape Department of Agriculture is acknowledged for their funding of the FruitLook service.

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CROP CONDITION MONITORING AT FIELD LEVEL

Accurate and spatially explicit information on crop condition is essential for food security.

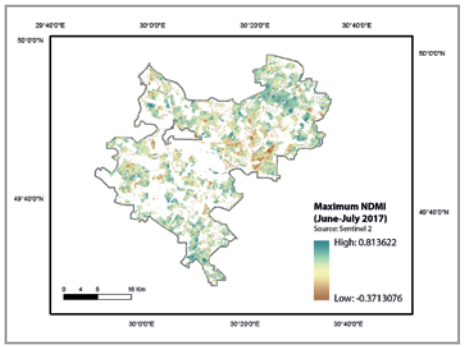
The challenge

Accurate and timely agricultural monitoring is essential for operational tasks such as yield prediction and crop condition monitoring. An improved understanding of the factors that can reduce agricultural yields and the overall production capacity of agro-ecosystems is crucial, especially at local and regional levels. This place-based crop condition information can be further used for decision making in the geographical areas which are more vulnerable to climate extremes, such as droughts. The complexity of these extreme events challenges its characterisation and spatially explicit representation of the drought impact over large areas.

The space based solution

Even though in situ observations and statistical data can be used to monitor the condition of the crop, such data acquisition is time-consuming, labour-intensive and often costly. Earth Observation (EO) provides unprecedented opportunities for cost-effective crop condition monitoring over large areas.

Crop condition can be tracked by comparing the dynamic behaviour of time series for drought and non-drought years. The dissimilarity of time series can be a sign



Maximum NDMI derived from Sentinel-2 imagery from June-July 2017 in Bila Tserkva region (Ukraine).
Credit: Contains modified Copernicus Sentinel data [2017]

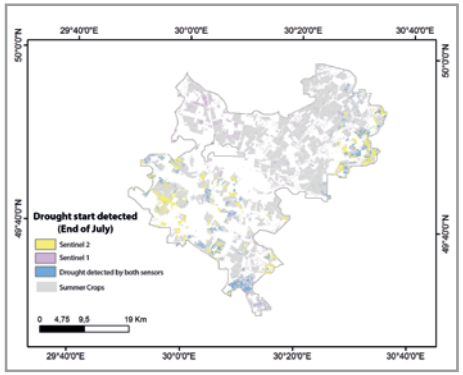
of drought-based changes in Vegetation Indices (VI). Furthermore, crop parameters such as maximum, minimum, amplitudes of VIs and backscattering intensity can be derived both for the overall growing season and during specific times of growth (e.g. the amplitudes within 20 days during vegetative and reproductive stages). One of the primary variables derived for our study area in the Ukraine were NDVI (Normalised Difference Vegetation Index) and NDMI (Normalised Difference Moisture Index). The combined use of freely distributed Sentinel-1 SAR series and multispectral Sentinel-2 observations (10-20 m spatial resolution) along with available Landsat-8 time series can give detailed information about crop condition.

Benefits to Citizens

The increasing number of freely distributed Copernicus satellite data offers opportunities to monitor intra-seasonal changes in croplands and track subtle changes in time series, which can be induced by drought. Spatially explicit drought information can be useful for the government to monitor yields, subsidy, and to support decision making such as the implementation of water management technologies in vulnerable areas. Overall, the

> "The integration of satellite-based vegetation condition information especially with a higher spatial resolution will support the monitoring of the drought stress, and can facilitate further decision making."
>
> ***Tatyana Adamenko, Ukrainian Hydrometeorological Center***

evidence-based quantitative crop condition estimates can provide accurately estimated drought characteristics (such as start, duration, intensity) and impact to different stakeholders. Along with the remotely sensed derived Land Surface Temperature (LST) and with the integration of meteorological data, we can acquire a holistic view of the drought impact. High resolution data, derived from Sentinel-1 and Sentinel-2 sensors give valuable opportunities for cost-effective crop condition monitoring over large areas, such as in the Ukraine, where an increase in frequency



Start of the drought Detected in July 2017 derived from time series of Sentinel-1 and Sentinel-2 n Bila Tserkva region (Ukraine).
Credit: Contains modified Copernicus Sentinel data [2017]

and intensity of drought in recent years was reported. This was especially advantageous, as with the use of Sentinel-1 it was possible to acquire dense time series independent of atmospheric conditions.

Outlook to the future

To make the results accessible for a wide range of users a web application has been developed, where users can derive Copernicus based data products such as vegetation indices, SAR backscatter time series without coding or image processing for a defined area of interest and a preferred period. The computation is running on Google Cloud servers (using Google Earth Engine) and the results are returned to the user in an interactive interface. This will further contribute to the use of the data and will simplify data access for users with limited remote sensing experience, or with limited processing power.

Acknowledgements

This study was conducted within the scope of the EvIDENz project which is supported by the German Federal Ministry for Economic Affairs and Energy (BMWi; grant No 50EE1541).

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EO-BASED AGRO MONITORING SYSTEM TO SUPPORT REGIONAL DECISION-MAKING

The ERMES FP7 project's downstream services provide decision and policy makers with high-quality, large-scale information on crop evolution and yield forecasting.

The challenge

There is an increasing demand for systems able to provide Near Real Time (NRT) information on crop condition and timely yield forecasts, given the potential interest for a variety of authorities within the agricultural sector, including private companies and institutional stakeholders. Such operational agro-monitoring systems, able to deliver timely early warnings and yield forecasting maps over large areas, may provide decision makers with information on seasonal dynamics and potential crop production shortages, useful to monitor agro policies, coordinate relief initiatives and control food prices' volatility. Nevertheless, they form a major technological challenge, as they require the gathering and integrating of huge amounts of information derived from remote sensing, weather and modelling data, and then the presenting of this processed, multi-scale, temporary variable data as actionable information to the end users in a useful, understandable and user friendly way.

The space based solution

Our focus was on developing a platform able to create, manage and disseminate NRT spatialised maps derived from the integration of remote sensing images, weather data and crop modelling solutions. We used free-of-charge satellite imagery and EO products from the European Copernicus Programme (e.g. Sentinel-1/2A data, SPOT/VEGETATION - PROBA-V (GEOV1) LAI) and NASA (e.g. MODIS and OLI data) to: i) assess the seasonal extent of rice cultivated area and agro-practices, ii) estimate occurrence of phenological stages, and iii) retrieve crop leaf area index to highlight anomalous conditions of rice development in the on-going season. Customised regional products from the Water Accounting Rice Modelling (WARM) solution were current and forecasted biotic risks for rice cultivations and yield forecasts obtained from the assimilation of EO data and statistical post-processing of model simulations.



ERMES regional geoportal interface showing the rice map for the Spanish Mediterranean area. Users get access to a variety of products from crop monitoring from the eye icon on the left side.

Timely and user-friendly dissemination and delivery of these products to stakeholders were as relevant and fundamental as the products themselves to accomplish the expected benefits and impacts. A regional geoportal was specifically developed to allow efficient access to the rice-monitoring information produced for regional services.

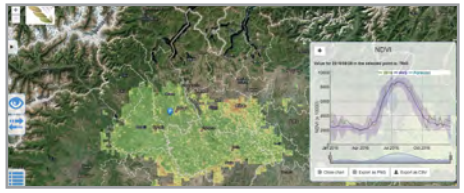
Benefits to Citizens

Adoption of the ERMES regional products can surely be beneficial for many distinct European stakeholders, including public authorities

> "The ERMES product of blast infection risk is more useful than others, such as the estimation of blast risk occurrence derived from in-situ measurements."
>
> ***Regione Lombardia***

(e.g. regions, provinces, environmental protection agencies, etc.) with the mandate of i) monitoring cultivated surface and yield, ii) implementing agro-policies, and iii) providing information to farmers concerning potential risks of biotic/a-biotic injuries or suggesting best-practices for cultivation.

For example, the ERMES regional geoportal provided spatially explicit NRT information on rice season development together with biotic/abiotic risk at regional/district scale. Rice crop maps allow regional authorities to understand the spatial distribution of rice cultivation practices and their inter-annual variations, obtaining initial estimates of the total area earlier than official statistics obtained from CAP subsidies declaration.



ERMES regional geoportal showing Normalized Difference Vegetation Index (NDVI) map and temporal trends for the Regione Lombardia (Italy).

Outlook to the future

The regional geoportal offers downloadable products and charts to support both additional analysis and production of crop monitoring bulletins. For example, a public agency of the Lombardy Region produces daily bulletins of current and forecasted risk of rice blast infection aggregated at municipality scale (www.ersaf.lombardia.it/servizi/bollettini/index.aspx).

Private insurance companies in the agricultural sector, traders/millers or large cooperatives of farmers could also benefit from ERMES products and tools to deliver added-value services. A major Italian insurance company, for example, delivers risk information derived from the ERMES agro-monitoring regional service to its customer pool as a support to reduce the risk of yield losses.

Acknowledgements

This work was supported by the EU 7th Framework Programme (FP7/2007-2013) under Grant 606983 - ERMES project.

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FREE INTERNET PROGRAMME FOR FARMERS

CropSAT enables the farmer to monitor the biomass on his field every time Sentinel-2 passes by. Furthermore, it can allow variable rate application maps for plant protection.

The challenge

The challenge is to apply the right amount of fertiliser and pesticides based on crop density and vigour, which determines the crops ability to utilise the fertiliser and pesticides. This will secure a higher yield for the farmer and less nitrogen leaching to the environment. It will also help bring down pesticide consumption, as we only have to apply pesticides to the areas where it is needed.

The space based solution

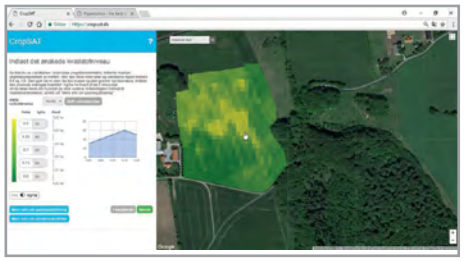
CropSAT is a user-friendly internet programme for farmers. It is free of charge and has no log-in requirements.

In CropSAT the farmer can see the changes in biomass on his fields every time the Sentinel-2 satellite passes Denmark.

He can use it for monitoring his fields and to learn from his previous crop management, and he can create variable rate application maps for fertiliser and plant protection.

The biomass map is based on data from Sentinel-2 where the NDVI vegetation index is calculated.

All the Danish fields (600,000 field polygons 2.6 mill hectares) are shown in CropSAT. The farmer only needs to type in his farm-ID and



Field in CropSAT. The yellow colour shows areas with low biomass and the dark green areas with the highest biomass.
Credit: Contains modified Copernicus Sentinel data

all his fields will appear. He can then select one field and request data from a particular day with no clouds where Sentinel-2 was passing by.

The farmer will see his fields in yellow and green colours. Yellow means lower biomass and very green means high biomass – see picture 1.

Afterwards, the farmer can type in kilo nitrogen per hectare in the five levels – see left side in picture 1. The next step in the programme will show the variable rate application map for the field according to the fertiliser input.

If the farmer is satisfied with the application map he can export the application file (shape file), download it to a USB stick and transfer it to the tractor terminal. The fertiliser will be spread according to the application map. The same procedure is used for pesticides.

Benefits to Citizens

CropSAT provides benefits for better crop quality and for the environment.

In Europe, we place a high focus on nitrogen loss from fields to the aquatic environment. CropSAT enables a significantly higher degree of precision minimising local leaching. More precise fertiliser and pesticide application will also improve food quality and safety to the benefit of the consumers. CropSAT contributes to better quality crops, especially a higher protein content. In Denmark, we strive to produce as much protein as possible rather than importing soya from America.

> "I started using CropSAT in 2017. My crops are now more uniform. It is good for the environment and the protein percentage in the grain seems to rise."
>
> ***Lars Bonde, farmer***

In addition to this, CropSAT helps bring down pesticide consumption, as pesticides and growth regulation will only be applied to the areas where it is needed.



Tractor spreading fertiliser according to a variable rate application map made in CropSAT.

Outlook to the future

The use of CropSAT is growing rapidly. In 2017 the programme had 7,300 unique users in Denmark and 4,100 in Sweden. The number of users is expected to increase rapidly since CropSAT has now been translated into English. A new feature in 2018 is an automatic nitrogen model for winter wheat and winter rape. In the long term, the use of satellites in crop production will increase and only the "sky" is the limit as to their future use.

Acknowledgements

SEGES wants to thank the Danish Ministry of Agriculture for being part of CropSAT for the last three years.

CropSAT is developed by the Swedish University of Agricultural Sciences (SLU), Hushållningssällskapet and Dataväxt.

Organisations from Denmark, Sweden and Norway are developing CropSAT further within the joint project "Innovationer för hållbar växtodling" funded by Interreg-ØKS.

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PRECISION FARMING: MANAGEMENT OF GRASSLANDS

Optimised grassland management requires accurate knowledge of grassland availability and growth. The use of remote sensing can provide an operational solution.

The challenge

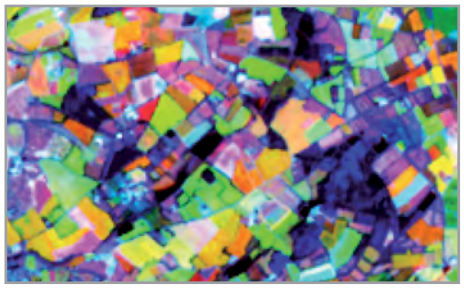
Grazed grass is the cheapest feed in a ration of livestock systems. Good grassland management, amongst other things, requires knowledge of the amount of grass available.

The objective of this study is to provide users (agricultural organisations, farmers) with information on the quantity of grass available per agricultural plot, at a weekly rate. The full development of the operational service will be effective in the short term. It will be based on easy access to data for users

This will help to reduce managerial observations on the ground and increase the accuracy of pasture management based on biomass parcel data.

The space based solution

The current space-based method relies on the ability of remote sensing data to estimate grassland biomass. It must take into account the wide variability of conditions encountered in grassland management that depend on operator's needs, grassland type, soil and climate conditions. Under these circumstances, high spatial and temporal resolution of remote sensing data are required. Sentinel missions make it possible to satisfy these new requirements, in contrast to previous missions, which are more limited in terms of spatial and spectral resolution and revisit frequency.



Variability of grassland management methods using a temporal coloured composition, Sentinel-2 images acquired at three dates along the growth season (Region Pays de Loire, France).
Credit: Contains modified Copernicus Sentinel data [2017]

The Sentinel missions make it possible to consider new perspectives in precision farming by providing accurate and regular monitoring of grassland biomass on a regional scale.

This procedure will be extended into a space-based operational solution.

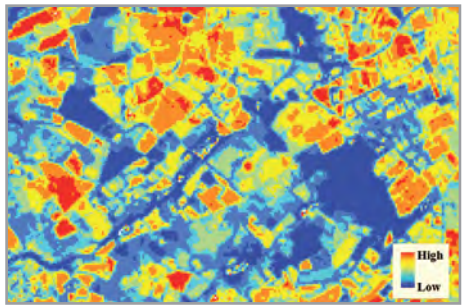
The time between the acquisition of Sentinel images and the availability of data is brief and compatible with the users' needs. These data are available in near-real time and can be immediately exploited as they are pre-processed in geometry and corrected for atmospheric effects. The estimate of grassland biomass then becomes available at the scale of an agricultural field within a timeframe suitable for agricultural activity.

If clouds are present in some areas, several devices can be used to ensure continuity of information such as the use of a grass development model, multispectral drone image acquisition and ground measurements of grass height.

> "This service will significantly change the way grasslands are managed."
>
> ***Marc Fougere***
> ***French Chamber of Agriculture, Department of Loire-Atlantique***

Benefits to Citizens

Remotely sensed grassland biomass data can optimise agricultural practices on grasslands and improve agronomic performance and yields. Easy access to spatialised data by farmers and managers allows for a measurable diagnosis of grassland conditions and provides access to plant growth assessment and on-farm yield simulation. The methods that are available today to assess grass supply are based on in situ measurements, which take time and are not very accurate. The remote sensing method will provide access to relevant information at low human and logistical costs. Finally, the access to this management support tool allows farmers to be involved and comforted in the implementation of their daily practices with the assurance of a management consistent with the state of the vegetation.



Remotely sensed grassland biomass over a set of agricultural parcels (Region Pays de Loire, France) (Source Agrocampus-Ouest).
Credit: Contains modified Copernicus Sentinel data [2017]

At national level, this decision-support and diagnostic tool makes it possible to quantify the evolution of grass production on a large scale in various soil and climate contexts, such as in relation to a particular climatic event.

Outlook to the future

The main challenge for the future is to increase the robustness of the methodology by ensuring the continuity of the digital service offered to farmers and managers on a weekly basis. The cloudiness constraint will be analysed using Sentinel-2 time series data, Sentinel-1 radar images and vegetation development models.

Acknowledgements

This research is part of the CASDAR Herdect project, funded by the Ministry of Agriculture, Agri-Food and Forestry. The Loire Atlantique Chamber of Agriculture and AGROCAMPUS OUEST supported this work.

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THE CHALLENGE OF IRRIGATION MANAGEMENT IN CYPRUS USING COPERNICUS

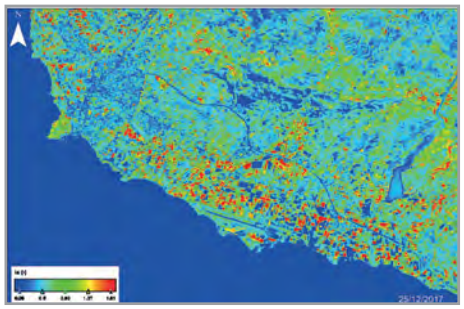
Copernicus can contribute to the rational management of the limited available water resources and assist farmers and stakeholders.

The challenge

Climate scenarios for the Eastern Mediterranean, based on large-scale climate models, predict further aridification and increasing variability of regional precipitation. One of the most important challenges in the Eastern Mediterranean region is the adaptation to climate change in the water sector linked to water stress and water scarcity. According to the European Environment Agency, the problem of irrigation in Europe is mostly concentrated along the region of the Mediterranean where some countries use more than 80% of total freshwater abstraction for agricultural purposes. The need for water management at regional level, combined with the development and use of technological tools, can contribute to the rational management of the limited available water resources.

The space based solution

A novel method for estimating crop evapotranspiration (ETc) on a systematic basis using remote sensing techniques has been established by the ERATOSTHENES Research Centre (ERC). To reach this goal, ground truth data consisting of meteorological and remotely sensed data, modelling techniques and energy balance algorithms were employed

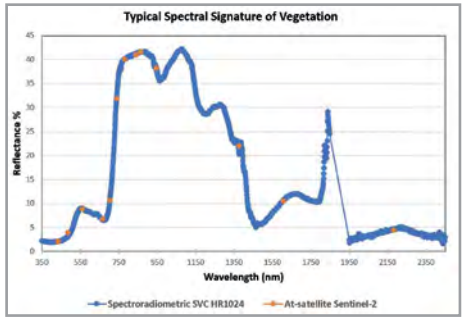


Map of Leaf Area Index (LAI) using Sentinel-2 satellite image for the area of Pafos in Cyprus.
Credit: Contains modified Copernicus Sentinel data [2018]

and combined. Spectral signatures of selected local crop types were acquired during each of the phenological stages. Subsequently, semi-empirical models were developed regarding crop canopy factors of each crop, following its phenological stages. Vegetation Indices were created from spectroradiometric measurements during crops' phenological stages. These indices were used to describe the crop canopy factors, namely, Leaf Area Index (LAI) and Crop Height (CH). The developed semi-empirical models were found to yield strong correlation coefficients.

The models were evaluated with very satisfactory results. The models were finally used to modify the algorithms decided to be adopted in this project, namely, SEBAL and Penman-Monteith, adapted to satellite data. When employing the semi-empirical models for modifying the two algorithms, the results were even more accurate and without any significant difference (Papadavid et al., 2013). Maps of crop evapotranspiration were created from the satellite images and the corresponding values were retrieved using Landsat-5 TM and Landsat-7 ETM+ images. Based on existing knowledge, researchers from the ERC, are working on adapting the existing methodology to retrieve ETc values using Sentinel-2 data.

> "The EXCELSIOR project envisions the establishment of a Centre of Excellence in Earth Observation and Remote Sensing in the Eastern Mediterranean."
>
> ***Professor Diofantos G. Hadjimitsis***
> ***EXCELSIOR Project Coordinator***



Spectral signature of vegetation presenting the reflectance values using both field spectroradiometric measurements and at-satellite reflectance for Sentinel-2.

Benefits to Citizens

The retrieved information can be distributed to agricultural producers, water management authorities, and other end-users, for more cost-effective farming. Furthermore, data products provide visual mapping and time-series information allowing end-users to obtain information on spatial and temporal patterns of crop canopy development and water requirements which can offer benefits to water resource management and strategies on water allocation priorities.

Outlook to the future

In the near future, the major goal is to be able to provide potential end-users

and stakeholders (farmers and water managers) with accurate estimations of crop irrigation needs through the estimation of evapotranspiration by combining Landsat-OLI, Sentinel-2 and Sentinel-3 data. This can increase the temporal and spatial resolution of the available data and provide information on a systematic basis with high frequency and accuracy. The Copernicus Programme through its Sentinel missions can provide freely available satellite data with high spatial and temporal resolution which can be used to support the effective use of water resources for irrigation purposes. The EXCELSIOR project envisions upgrading the existing ERC into a Centre of Excellence (ECoE) for creating an inspiring environment for conducting basic and applied research and innovation through the integrated use of remote sensing and space-based techniques for monitoring the environment. One of the priorities of the ECoE is to provide a comprehensive solution to farmers through the development of smart irrigation systems.

Acknowledgements

The EXCELSIOR project is funded under Horizon 2020 Widespread-04-2017: Teaming Phase 1 Coordination and support action. Grant agreement no.763643.

Papoutsa, C., Kouta, G., Nisantzi, A., Mammouri, R., Prodromou, M., Loulli, E., Neocleous, K., Themistocleous, K., Tzouvaras, M., Christofe, A., Mettas, C., Evagorou, E., Miltiadous, M., Michaelides, S., Hadjimitsis
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USING SATELLITE MAPS TO SUPPORT VARIABLE RATE FERTILISATION

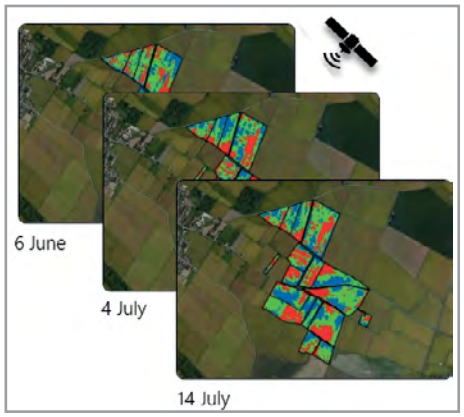
Services developed in the ERMES FP7 project can provide farmers with high quality information for performing Variable Rate Fertilisation practices.

The challenge

Availability of high-quality information concerning spatial and temporal variability of crops' distribution and status is of paramount importance to support precision agriculture solutions for improving productivity and reducing costs, whilst minimising environmental impacts. Multi temporal satellite images, in fact, enable the variability of crop status to be depicted in key periods of the crop growth cycle over large areas. This may facilitate the improvement of existing agricultural management practices through a more rational application of fertilisers, with both environmental and economic (due to the reduction of costs) advantages. In this context, within the ERMES FP7 project (An Earth obseRvation Model based RicE information Service - www.ermes-fp7space.eu), we aimed at developing operational workflows for the creation of prescription maps to be used for Variable Rate nitrogen fertilisation over rice fields, based on the analysis of High Resolution satellite imagery.

The space based solution

We used archive decametric/sub-decametric satellite imagery to characterise spatial variability related to soil properties and Very High Resolution imagery acquired in key stages



Images acquired in critical moments of the season highlight the internal variability of single rice parcels, in different moments.
Credit: Contains modified Copernicus Sentinel data [2016]

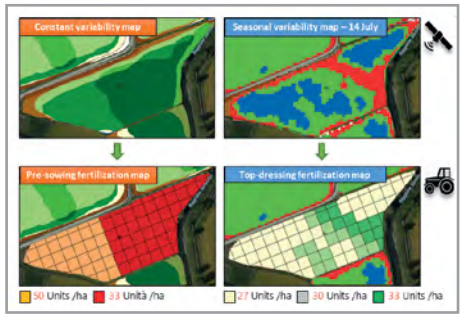
(both optical and SAR) to characterise within-field crop status variability in the ongoing growing season. Images were processed using statistical methods in order to be able to identify homogeneous areas characterised by different soil properties or crop conditions, for each field. Starting from these within-field variability maps, farmers in the ERMES study areas, with the assistance of ERMES personnel, were able to derive accurate prescription maps for nitrogen fertilisation, for both the pre-sowing and the top-dressing phases to be used in variable rate technology (VRT) cultivation practices. Full-field experiments conducted between 2014–2016 in Italy, Greece and Spain demonstrated that these prescription maps allowed for better farm management, leading to yield homogenisation and optimisation of the use of fertilisers.

Benefits to Citizens

Adoption of the services for precision agriculture developed within ERMES could surely benefit European farmers. For example, it is worth highlighting that the need for nitrogen fertilisation is a major expense in

> "A potential reduction in production costs of about 70 €/ha can be achieved using ERMES services."
>
> ***Dimitrios Katsantonis, Researcher at Hellenic Agricultural Organization – Cereal institute***

modern rice production, typically accounting for 15% to 30% of total production costs. Experiments conducted during the ERMES project demonstrated in fact the usefulness of satellite-based solutions for optimisation of production costs through a more economical use of fertilizers, and improving yield through the better management of intra-field variability. For example, the Hellenic Agricultural Organization (DEMETER) estimated that adoption of the proposed services could lead to a potential reduction in production costs of 70 €/ha in Greece. Besides, demonstration in the Italian context proved that when VRT technologies are adopted a rise in production is possible, leading to a potential increase in income of around 72 €/ha. Proper management of nitrogen fertilisation is also essential to avoid negative environmental impacts, and to help farmers comply with European agricultural and food safety policies focused on promoting



ERMES spatial variability maps were used to derive prescription maps for nitrogen fertilization.
Credit: Contains modified Copernicus Sentinel data [2016]

more environmentally friendly and safe farming practices.

Outlook to the future

The ERMES system is currently being further developed through several follow-up projects, including a demonstration project framed in the "Rural development Programme" initiative to support adoption of precision farming in Italy. IT solutions and remote sensing products are also being used by Italy's largest agricultural group, Bonifiche Ferraresi, and by Italian insurers aiming to include EO data in operational workflows for crop monitoring and damage assessment.

Acknowledgements

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MARITIME MONITORING FOR THE CONSERVATION OF UK MARINE RESOURCES

Through maps of ship density, Sentinel-1 provides the means for sustainable management and protection of UK waters and its fisheries.

The challenge

The Centre for Environment, Fisheries and Aquaculture Science (Cefas), with its mission to protect the seas and ensure safe and sustainable seafood, is collaborating with Cranfield University to establish an operational maritime monitoring system based on Sentinel-1 imagery and data from the Automatic Identification System (AIS). This solution responds to the need for a long-term and cost-effective system to protect marine ecosystems and food security from threats such as overfishing and pollution.

The monitoring system takes advantage of the Sentinel-1 constellation which generates an unprecedented volume of high-quality radar images capable of providing actionable intelligence about maritime activities in critical fishing regions.

The space based solution

Radar images like those produced by Sentinel-1 are operationally used to detect ships as small as 20 m, even in cloudy conditions. In particular, Sentinel-1 can detect the ships which broadcast identification messages using their onboard AIS, but also those which do not use or have AIS, also referred to as dark ships.



Maritime traffic in the Strait of Dover highlighted by a mosaic of all the Sentinel-1 images acquired in 2017.
Credit: Contains modified Copernicus Sentinel data [2017]

Whilst Sentinel-1 predominantly provides positional information (longitude and latitude of the ships) and some indication on ship size, AIS messages have more detailed information (ship position, type, speed, destination ...). The system developed by Cefas and Cranfield University uses Machine Learning techniques and a large database of AIS messages to enrich the information provided by Sentinel-1. In practice, after detecting all the ships in a Sentinel-1 image, the system attributes the most probable ship type (for e.g. cargo, tanker, fishing ship) to each detected ship based on its estimated position and size.

Ultimately, the system provides maps of ship density (number of ships per month in a given area) for different ship types which can be further analyzed for trends and patterns.

Benefits to Citizens

This Sentinel-1-based system improves maritime monitoring both in terms of cost and quality. In the past, Cefas mainly used commercial AIS data as a source of information. With this new monitoring method, AIS data are only needed initially to teach the system how to automatically recognize ship types based on their geographical position and size. Beyond this initial phase, the system relies solely on the free Sentinel-1 images, hence the long term reduction in cost.

> "This work has many useful applications across departments, agencies and administrations. At Cefas, we have seen immediate uptake for monitoring and observing UK waters."
>
> ***Lauren Biermann, Cefas***

Quality wise, Sentinel-1 also provides a more complete maritime picture by revealing even the dark ships. The continuation of the Sentinel-1 mission over the next decade will allow generating time series of ship density maps which reflect trends in fishing effort and potential pollution. With these maps, Cefas has access to reliable intelligence to sustainably manage and protect the UK waters and its fisheries which significantly contribute to food security, livelihoods, and the economy.



Distribution of AIS messages which are used to teach the system how to automatically recognize different ship types.

AGRICULTURE, FOOD, FORESTRY AND FISHERIES

Outlook to the future

The next step will be to adapt the system to monitor the waters surrounding the UK overseas territories which host globally significant biodiversity. Defining Marine Protected Areas for these territories is relatively straightforward, but monitoring and policing them is a challenge because of their large extent, remoteness, and the limited resources available. As Sentinel-1 reaches full operational capacity, routine images are becoming available over the overseas territories for which very little information was available in the past. Although the number of images is smaller than that over UK areas, the Sentinel-1 maritime monitoring system is anticipated to periodically enable the assessment sea compliance.

Acknowledgements

This project was funded by the Department for Environment, Food & Rural Affairs Earth Observation Centre of Excellence and the Marine Monitoring Organisation.

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COPERNICUS SUPPORTS FOREST MONITORING FOR SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES

EUGENIUS is the SME network for the provision of Copernicus-based services for end users in various European regions.

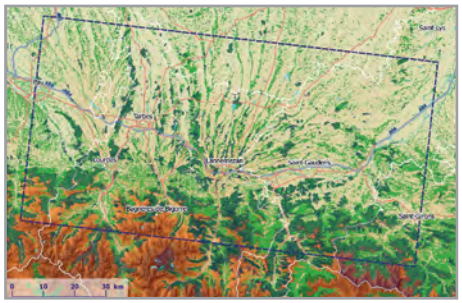
The challenge

The management and exploitation of Pyrenean forests are real challenges for local public authorities to ensure the sustainability and the economic development of their territory. Most of the Pyrenean forests belong to small private owners making it difficult to monitor and manage forests at a regional level. This natural resource is thus difficult to assess and mobilise, preventing the development of industrial and economical activities.

Earth observation applications referenced as Eugenius services aim to provide accurate indicators on more than 300,000 ha of forest to update environmental and economic indicators used by the Region. Tree species identification, logging detection and parcel accessibility assessment are key indicators used to estimate the economic value of forest areas. These indicators are used by public authorities to define land planning policy, to promote sustainable forest exploitation activities and to attract new financial authorities.

The space based solution

Eugenius Earth Observation products developed for forest monitoring make massive use of Copernicus Sentinel data and products.



Area of interest (8 250 km²) for the Forestry Earth Observation Application delivered to local public authorities and located in the south-west of Occitanie region (France).
Credit: Contains modified Copernicus Sentinel data [2017]

Tree species identification is based on the use of a Sentinel-2 image time series composed of ten dates. Biophysical parameters are extracted from these multispectral images to describe forest canopy; the evolution of these indicators makes the differentiation of tree species possible giving precise information at specific phenological stages. Forest areas are located using the Copernicus High Resolution Layer Forest Type. For logging identification, change detection algorithms are used to compare Sentinel-2 images acquired in 2015 and 2017.

Benefits to Citizens

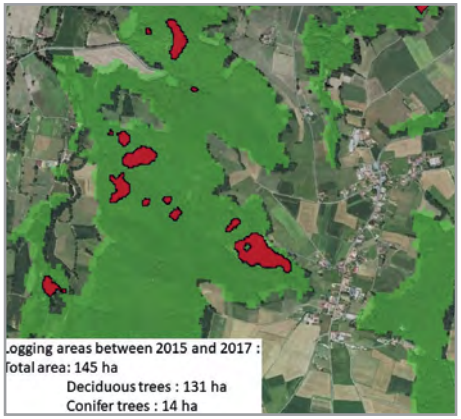
Because most private Pyrenean forest parcels are underexploited, forests are getting older with low profitability and a low rate of resource renewal. Having a better knowledge of the forest at a regional scale is mandatory to define a coherent planning policy to favour a sustainable forest exploitation and to attract industrials and economic activities (ex.: creation of forest roads, territorial projects development or forestry sector support).

Eugenius forestry products are mainly delivered to local public authorities to be used for better management of their territory.

> "Earth Observation services provide accurate indicators to monitor Pyrenean forests and to promote economic activity development in the territory."
>
> ***J.M Noisette, Project Manager, Regional Direction for Agriculture and Forestry of Occitanie***

Thematic indicators are extracted from these products to describe, compare and monitor heterogeneous situations (different tree species, various soil and climatic conditions and various forestry practices).

Amongst these indicators, we can mention the "Forest Value Indicator" which groups information such as the parcel accessibility and the tree species to estimate the economic value of the parcel. Logging detection products provide land managers with indicators such as the "Annual Exploited Forest Area".



Logging areas detected with Sentinel-2 images in a forest region of the Pyrenees.
Credit: Copernicus Service information 2017

These indicators are used by public authorities to define regional strategies in terms of environmental policy, territorial planning and economic development. For example, the benefit of creating new forest tracks to access isolated parcels can be evaluated from these products.

Outlook to the future

Forest monitoring services developed as part of the Eugenius project make sense for public local authorities if they are integrated into a single "thematic service package" with interoperable and complementary products. Additional products will be included into this package using other Copernicus data and products such as Sentinel-1 images and their complementarity with optical sensors. Thanks to the Eugenius network, the complementary skills of 3 European companies (Terranis, Spacebel, Sertit) can be gathered for proposing the best use of Copernicus images by several regional authorities in Europe.

Acknowledgements

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EARTH OBSERVATION SERVING REGIONAL FORESTERS

Operational satellite-based Earth Observation services support the regional forestry sector to valorise a forgotten resource, Chestnut groves, providing fruit and rot-resistant wood.

The challenge

The chestnut species is considered promising as it acclimatises to global warming. The rot-resistant chestnut wood was used in German and French vineyards on the eastern flanks of the Vosges Mountains. No longer used, knowledge of this resource has dwindled. Furthermore, these forest stands are under attack by a canker.

Today, it is thought that its wood could be better exploited. Hence, an international Interreg IV project focused on conservation and on wood and fruit use was set-up. At the request of regional foresters, namely, the Lorraine-Alsace Regional Centre for Forest Owners (Centre Régional de la Propriété Forestière or CRPF), ICube-SERTIT's challenge was to map this species in Alsace.

The space based solution

Specialised in satellite image processing and operational service development, ICube-SERTIT is very active providing services to regional foresters, covering forest inventory and resource monitoring within the Grand-Est Region of France. Furthermore, it provides customised windfall damage and tree die-off mapping services. All services are developed using satellite data and validated by the client. Here, ICube-SERTIT developed a method to precisely map chestnut stands throughout Alsace using multi-date satellite imagery and field samples.



Chestnut tree flowering in early summer *© SERTIT.*

The challenge was to distinguish chestnut trees from other species. Thankfully, chestnut trees bloom in early summer facilitating the task to distinguish them from other species that flower earlier or later. Hence, by acquiring images at several times during the same growing season, SERTIT has determined the percentage of the main tree species in the Upper Rhine region focussing on chestnut trees. The Earth Observation derived mapping results were validated during field campaigns. A partial validation was carried out by the Lorraine-Alsace CRPF. Concerning mature chestnut stands it shows an accuracy of 85%. The results highly convinced the foresters who are now exploiting the results.

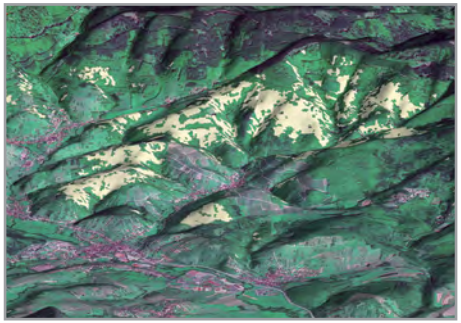
Benefits to Citizens

The chestnut grove is a defining feature of these piedmont landscapes, once punctuated by vineyards and orchards, inducing the agricultural use of wood, in addition to its use in traditional houses Local authorities are promoting and hence increasing the awareness of the socio-economic benefits of the chestnut groves by properly valorising them.

> "Really small chestnut groves, not represented on our initial maps were detected by satellite."
>
> ***Maren Baumeister, CRPF Lorraine-Alsace***

Environmentally, with global warming, climate forecasts show an increase in typical West France tree species including the chestnut tree. Conversely, beech which densely populates the region is vulnerable to climate change. Hence, the need to focus on the chestnut tree. The knowledge of the geo-location of chestnut groves, often managed within small private forest estates, was not well known and will help preserve and enhance this species in forestry practices.

Economically, abandoned in viticulture, chestnut wood is presently under-exploited in Alsace, being often used for firewood. Comparable to exotic woods, German foresters are now producing quality timber. Quality trunks are abundant in Alsace groves but marketed volumes are small. The project's forestry guide and promotional activities have helped an emerging market of chestnut wood, i.e. avalanche barriers.



3D view of Chestnut grove mapping (beige areas) in the Vosges, Alsace, France. *SPOT5 image ©CNES (2009), processing ©ICube-SERTIT*

Outlook to the future

Using a multi-temporal optical satellite image coverage, covering different phases of the annual chestnut development cycle and combining ALOS AVNIR-2 with SPOT 5 images, and geo-localised field data, a methodology to differentiate and map them was developed in collaboration with the CRPF Lorraine-Alsace. Exploiting Sentinel-2 with its high-resolution, high-frequency revisits, covering the entire vegetation cycle should help account for the window fluctuating from year to year depending on meteorological conditions making this service even more generic and operational. In conclusion, this operational service, which was awarded an Innovation Trophy by the NE French Forestry sector, can be applied to other regions and diversified to map other tree species.

Acknowledgements

These activities have mostly occurred within the Interreg IV - Upper Rhine Chestnut project, benefiting from the European Regional Development Fund. Equally, thanks are owed to the Grand Est region (especially the Alsace territory) for its support in the above-mentioned project.

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EO BASED SERVICE FOR FOREST MANAGEMENT

SAT4EST is a pre-operational web-based service dedicated to the management of privately-owned forest in Poland. This service improves the forest monitoring processes at regional level.

The challenge

The forest in Poland covers 9215 thousand hectares, which is 29.5% of the country. More than 80% of the forest is publicly-owned, including those administered by the State Forests (77%). Privately-owned forest accounts for around 20% of the total forest. Forest is managed according to the forest management plan, taking into account the sustainable forest economy. The privately-owned forest is managed by the local administration - district governor (at the second administrative level, NUTS 4). The governor acts as the controlling body for the private owners. The governor is responsible for preparation and verification of the simplified forest management plans and for continuous monitoring of the forest areas. Up to now, there has been a lack of an operational tool to support local administration in monitoring of forest cover and forest changes at regional level.

The space based solution

Satellites provide a cost-effective way to obtain systematic information on the forest status and properties. The SAT4EST offers to the users a large spectrum of satellite-based products. A time series of the European satellites Sentinel-2 and Sentinel-1 data is used to derive a set of EO products which meet the user requirements and obligations. For example, these products are forest and woodlands cover, forest change mapping on the regular bases, forest type, canopy coverage and forest condition. There are also products available on demand like assessment of forest damage due to windstorms, fires, insect infestations or estimation of forest aboveground biomass.



Forest clear cuts detected between 2015 and 2017 using Sentinel-2 data over the mountain forest in the Nowy Targ District, Poland.
Credit: Contains modified Copernicus Sentinel data [2015, 2017]

The EO based products are integrated into the SAT4EST system. The system consists of the remote sensed data component, ancillary data component, data processing and map server components. The web architecture and user-friendly interface running on the internet browser makes the service intuitive and ease to understand and navigate. The users are able to view current and archived satellite images (i.e. Sentinel-2 and Landsat), to compare various EO products with existing ancillary data, to upload own datasets, calculate statistics and generate reports.

> "This satellite-based application can help us to manage the remote forest in the mountains."
>
> ***Local administration in Nowy Targ, Poland***

The service is at the pre-operational stage. It is currently being tested in three pilot districts in Poland. The pilot districts vary in terms of geographical location: mountains (Nowy Targ), lowland (Sieradz) and suburban (Legionowo), anthropogenic pressure, and level of forest management maturity.

Benefits to Citizens

The local administration tends to rely on the cadastral land records that show large discrepancies between the official records and forest on the ground. The traditional method of surveying is time consuming, expensive and challenging, particularly, in the remote mountain areas. The proposed EO based service serves the needs of local administration for a) preparation of tender for simplified forest management plans, b) verification and acceptance of those plans and c) control of the execution of the forest management tasks. Additionally, it can serve private forest companies dealing with preparation of the forest inventories private.



A tree cover mask derived base on the analysis of multi-temporal Sentinel-2 data; fragment of the Legionowo District.
Credit: Contains modified Copernicus Sentinel data [2017]

Generally, the proposed service will make administrative processes more efficient and transparent. It may also help to reduce the overall cost of the forest management at regional level. The project also involves training and promotion of the Copernicus data to the large community of end users.

Outlook to the future

The Remote Sensing Centre of the Institute of Geodesy and Cartography will continue its successful collaboration with the Taxus.IT company in the system and service development. The ambition of the project consortium is to benefit from the constellation of Sentinels and to develop the fully operational service. The service is designed to be easily transferable to other regions and districts. More details on the SAT4EST system and service is available at www.sat4est.pl.

Acknowledgements

The SAT4EST project is founded by the European Space Agency (ESA) in the framework of the Polish Incentive Scheme programme. The EO based service is a joint effort of the Remote Sensing Centre of IGIK and Taxus.IT.

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FOREST HEALTH MONITORING: AN APPLICATION IN PORTUGAL

Silvisense is a state-of-the-art service offering timely detection of disturbance outbreaks within forest resources.

The challenge

Today the forestry sector is struggling to capture the disturbance outbreaks in a timely manner to limit the corresponding damage to their forest. Substantial values are lost if the disease spread is not contained in due time. In Europe, as of 2005, forest disturbance affected over 6.4% of the total forested area, with a production turnover estimated (in 2011) of 485 billion euro. Thus, forest disturbances cost Europe 31 billion euro annually. The disturbances are reducing the volume of healthy and viable forest for wood products, timber industries hence threatening the global bioeconomy.

The space based solution

Manual identification of disturbance outbreaks in a tree is not only time consuming but also does not give accurate results. Providing a fast, automated and accurate solution using image processing techniques offers significant added value. Some of the benefits of remotely sensed, multispectral imaging are that this technology gives consistent results, is simple to use, allows for rapid assessments, is non-destructive, highly accurate, and has a broad range of applications.

The Silvisense service uses the latest



The red polygons show automated change detections in region of Sertã, Portugal (large: forest fire, small: disease outbreaks).
Credit: Contains modified Copernicus Sentinel data [2017]

technology innovations to offer a cost-efficient monitoring service for a wide range of customers. We combine Sentinel-2 imagery with state-of-the-art algorithms to perform scalable and fully automated data analyses. The customers can choose from a range of products available for subscription through the Silvisense API:

- Pine disturbance maps
- Clear-cut validation maps
- Land classification maps
- Updated, tailored satellite imagery over select regions
- Forest fire mapping
- Drought mapping

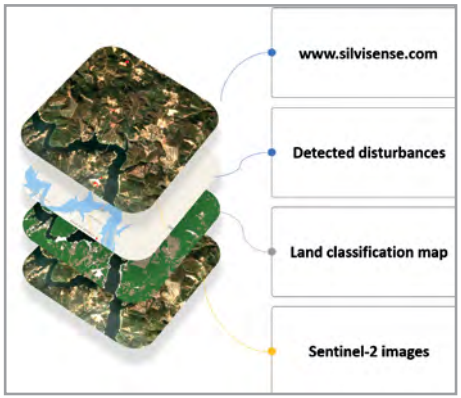
A Silvisense user will have the capacity to detect disturbance outbreak and clear-cut the declining trees at an earlier stage, resulting in a 60% reduction in corresponding disease outbreak during the following season. Thus, increasing 4% of the total forest value.

Benefits for citizens

We offer annual monitoring for forest ownership associations to provide input on

> "This is the perfect tool to get an affordable overview of our properties, providing important information. It makes our lives easier and allows us to focus on other topics."
>
> ***Jorge Freire, AproFlora, a national association of forest owners of Portugal***

volume estimates of forest area per forest stand. By incorporating the Silvisense service into their production chain, our customers are able to improve the planning, containment and removal of disturbances at a lower cost, and With improved forest management, society gains an increased capacity for capturing global carbon emissions through the securing of a larger volume of standing viable forest. Ecological damage is reduced with access to more timely disturbance detections, and this results in improved water and air quality, wildlife habitats and genetic diversity.



Silvisense is a service that provides automated forest monitoring using Copernicus satellite data.
Credit: Contains modified Copernicus Sentinel data [2017]

Our industrial partners occupied with timber and wood production are happy to have

available tools for mitigating the effects of forest disturbances and thereby keeping an improved overall forest resource quality, leading to higher priced values for re-sales and further production.

The Silvisense service is already rolled out in two different European countries, with differently sized pilot customers operating and providing feedback. Amongst them there are representatives of the national associations of forest owners such as AproFlora and Unimadeiras of Portugal and Allskog and Viken Skog of Norway.

Outlook to the future

We are currently busy setting up an infrastructure as a part of the operationalisation. Moreover, together with our Partners we are focused on demonstrating a new set of products through the EU FOCUS project. This will be achieved by extracting biophysical parameters from Sentinel-2 data and hyperspectral data acquired with airborne systems.

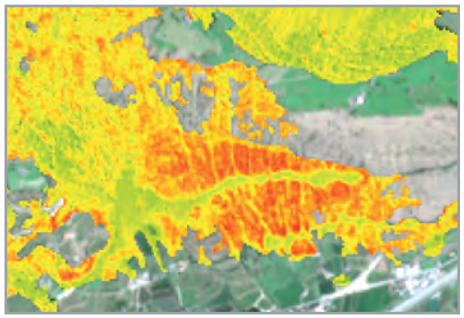
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FOREST MONITORING SERVICE FOR SOUTH TYROL

Providing information on changes of forest extent and conditions tailored to the needs of a regional Forest Service to support management and planning.



Monitoring of forest conditions using vegetation indices to identify and map vitality loss.

The challenge

Vast areas totalling 800 ha of dried up pines dominated the slopes of the Vinschgau Valley in South Tyrol (Italy) in spring 2017. These were largely the result of the severe drought of the previous two years combined with an increased vulnerability towards pest infestations. This is only one example where the Forest Service of the regional administration needs specific information about forest conditions to define and adapt site-specific management strategies and to control their effects on the forest ecosystems. Due to the i) large dimension of forest, ii) the importance of protecting the forest and iii) the remoteness and inaccessibility of mountain areas, Earth Observation is often the only means to monitor the extent and conditions of mountain forests and efficiently alert and inform about forest changes in a timely, accurately and spatially explicit way.

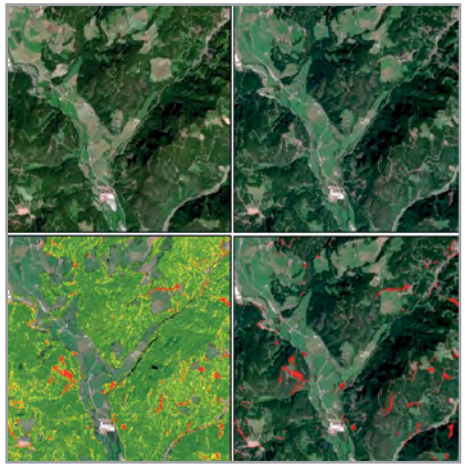
The space based solution

At Eurac Research, we developed a pre-operational Forest Monitoring Service that is tailored to the needs of the regional administration and adapted to the IT of the Forest Service. The service is entirely based on the Copernicus programme and makes use of all available high-resolution optical imagery provided by the Sentinel-2 satellite constellation as well as the geographical information by the Copernicus land monitoring service, which makes it scalable to any other region. The Forest Monitoring Service offers a set of accurate, timely and area-wide information on forest ecosystems. This set comprises annual information such as cloud-free image mosaics and information on forest extent, loss or partially damaged areas. This is complemented by a near real-time mapping service that identifies potentially damaged areas with each new satellite image acquisition and continuously tracks forest stand vitality as well as recovery based on vegetation indices. We provide all information (images, maps, quality measures and metadata) via a Web Map Service to allow the direct integration into the Forest Information System for supporting the work of a total of 300 foresters. To foster the acceptance of our maps, we regularly meet with the Forest Service and provide information and training sessions to foresters.

Benefits to Citizens

Mountain forests cover nearly half of the area of South Tyrol and provide a wide range of benefits: provision of wood and natural resources, conservation of biodiversity, recreation opportunities for tourists and residents but most importantly the effective protection against soil erosion and natural hazards such as avalanches, landslides and debris flows. The Forest Service's mission is to sustain the forests in providing the lasting benefits to citizens and forest owners who rely on them. The Forest Monitoring Service strongly supports the Forest Service in developing tools and generating datasets to achieve this objective. The continuous provision of high quality, timely, area-wide and digital information on forest conditions is crucial to plan and evaluate management measures now and with a view on climate change. The ongoing conversion of pine forest stands in lower elevation zones to hardwood dominated near-natural mixed forests across South Tyrol is only one example. The Forest Service estimates its direct annual monetary benefits of around € 50,000 coming from the assessment of 1,200 forest damage locations by 1.5 person/year.

> "Earth Observation and change products suitable for a mountain region like South Tyrol is revolutionizing our forest monitoring."
>
> ***Günther Unterthiner, Forest Service of Bolzano***



Near-real time identification of forest changes to support the management of protection forests.

Outlook to the future

The strategy for the future is to improve and enhance the Forest Monitoring Service according to the requirements and priorities of the Forest Service. We plan to map the actual distribution of tree species to evaluate their site-specific suitability in the face of climate change projections to better adapt forest management decisions. This mapping attempt will benefit significantly from the synergies of the fully operational Sentinel constellations. As an institution which is primarily regionally funded, we can ensure the long-term sustainability of our service and plan to extent it on an alpine level as part of our Sentinel Alpine Observatory initiative (www.sao.eurac.edu).

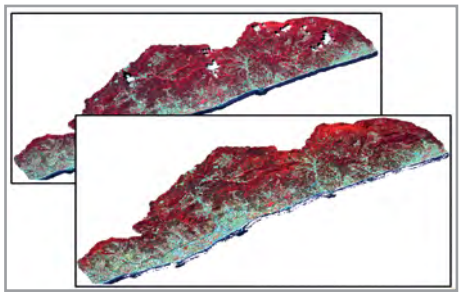
Acknowledgements

We acknowledge past funding (EU-FP 7 project EUFODOS: European Forest Downstream Services - Improved Information on Forest Structure and Damages) which allowed us to develop the service for South Tyrol.

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FORESTLAND DECAY IN MARESME USING SENTINEL-2 IMAGERY

Recent available SENTINEL 2 data represents a new key to providing a feasible monitoring of decay of forest mass on a regional scale.



SENTINEL-2 imagery over the study area taken at 02/08/2015 and 26/08/2016

The challenge

A significant portion of the forests of the Maresme region (Catalunya, Spain) is affected by a severe decaying of the trees, in particular, the stone pine (*Pinus pinea*), due to different factors like drought, the infestation by a wood boring insect (*Thomicus destruens*) and by several fungi.



Partial affected Pinus pinea forestland in Maresme

In order to be able to delimit the areas with affected trees, Institut Cartogràfic i Geològic de Catalunya (ICGC), at the request of Diputació de Barcelona (DIBA), has carried out a complete detection based on the study of Sentinel-2A imagery of Copernicus (The European Earth Observation Programme). The study focused on the detection of affected forestland in summer between 2015 and 2016, based on vegetation indices, especially from the Improved Vegetation Index (EVI) and the subsequent analysis of the changes and tendencies toward decay.

This article describes the methodology used in the study and the first results obtained. DIBA technical services are charged with the task of validating the results *in situ*.

The space based solution

The images captured by the MSI sensor of the Sentinel-2A satellite, with public and free access, were used as a basic material to detect the decline of the forest masses for one year, between the summers of 2015 and 2016.

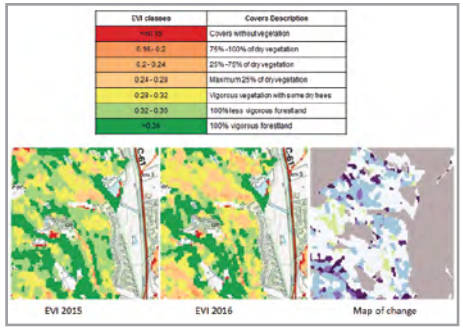
In total, 11 images were obtained along the different weather stations. The first image was taken on 2 August 2015 and the last one on 24 November 2016. With this set of images, the phonological cycle of trees could be interpreted from summer to winter of 2015 and in the same seasonal period for 2016.

One of the techniques most used in Earth Observation to detect vegetation and assess its state is the use of vegetation indices, which are based on the arithmetic combination of two or more spectral bands sensitive to characteristic behaviours of vegetation.

The vegetation index chosen was the Enhanced Vegetation Index (EVI), since it incorporates the radiation of the blue spectral zone (B2) that helps to correct the signal associated with the soil and the atmospheric effects.

> "This application of Copernicus Sentinel-2 has transformed Earth Observation Data into a decision support information."
>
> ***Ramon Riera,***
> ***Diputació de Barcelona***

Indices calculation was carried out without previous fieldwork, so the images of infrared photogrammetric flights from 2015 and 2016 of the ICGC ortoXpres free service (25 cm of spatial resolution) were consulted, to relate the results of the index to the different degrees of decay of the forest masses.



Legend and decay map from EVI between 2015 and 2016 on local scale and changes by using SENTINEL-2 imagery

The changes show the areas of expansion of decay according to EVI resulting maps from 2015 and 2016.

Benefits to Citizens

EVI enables the clear detection of the affected areas in the summer images with good spectral signatures thanks to well illuminated areas. Mountainous areas with shadow effects were not as well detected.

The results, published as official maps by the DIBA, are used by the Department of Agriculture of Catalonia (DARP) as a decision support tool for the forest management of affected areas during the 2017 campaign.

Outlook to the future

The resulting maps show some areas of maximum affectation and expansion that will be consolidated (corroborated) by a new study of the EVI including the 2017 data.

DIBA and ICGC work together in a coordinated way to enlarge and improve the analysis moving towards 2017. The new areas aimed at for the project will be to increase the area of study, to foster whole fieldwork measurements and validation in the forestland during the summer of 2017 (closer to data acquisition of Sentinel-2 images) and to improve the distinction between forest and shrub cover introducing Lidar dataset.

Acknowledgements

The authors thank both institutions DIBA-ICGC for the cross-fertilisation of experiences.

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OPERATIONAL AFFORESTATION MONITORING

An operational afforestation monitoring system has been developed in the Free State of Thuringia in Germany using Copernicus and auxiliary GIS data.

The challenge

In Germany the federal states are responsible for the monitoring, controlling and planning of local forest areas. Depending on the state's regulations, the relevant authorities are in charge of the recognition and the designation of new potential areas covered by trees as the land use type "forest".

Without precise knowledge of the position and extent of new forest areas, the local forestry authorities are facing difficulties. Since cost-effective methods are favourable, a procedure for monitoring afforestation using open access Copernicus data has been developed. The procedure does not cover the regular deforestation, as clear-cutting requires authorisation. Therefore its position and extent are well known.

The space based solution

The monitoring of afforestation is conducted with the help of Copernicus High Resolution Layers (HRLs) Forests i.e. Tree Cover Density and Forest Type as well as a priori information.

Remote sensing products, such as Copernicus, depict all types of land use dominated by trees. This also means surfaces covered by short-time rotation plantations, fruit trees and parks which do not represent "forest"



Monitoring of afforestation for a test site in the forest district Hainich-Werratal (from the left to the right): forest mask in green, areas already recognised as forest in light green, new forest areas in orange, orthophotos in the background.

according to the Thuringian forest law. In order to eliminate those areas and to improve the accuracy of the final product, the Copernicus HRLs are combined with auxiliary data. For this purpose, additional Thuringian GIS information provided by the Agency for Surveying and Geodata (Federal State Thuringia) and the Thuringian Agriculture Administration representing land use and land cover classes as well as a normalised Digital Surface Model (nDOM) have been implemented. In the first step, the spatial accuracy is improved by combining the Copernicus HRLs with the nDom. Only areas classified as "forest" and those with vegetation higher than two metres are considered for further work. Afterwards, the areas covered by trees but not representing "forest" are eliminated using the GIS information.

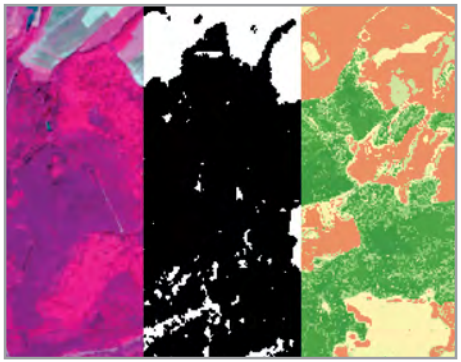
As a result, an accurate forest afforestation map is generated. The map together with a work card listing all potential afforested areas is made available to the local forestry officers, who are responsible for the verification and classification of the new forest areas.

> "The successfully implemented afforestation monitoring system is a timesaving tool for foresters."
>
> ***Sergej Chmara, ThüringenForst Institute under Public Law***

Benefits to Citizens

Forests play an important role in the regulation of ecosystems. In addition to multi-faceted range of services, forests are important for the well-being of the human population. Forests fulfill many functions such as the protection of groundwater, against floods, noise protection, provide places for recreation and etc. These are reasons why forest areas are particularly protected by law. In Germany, forests cannot be transferred to other forms of use such as for building development.

The proposed monitoring system significantly improves the ability of efficiently detecting afforestation areas and thus supporting public forestry authorities in forest inventory and planning.



Forest mask and tree density generated for a test site in the forest district Heldburg with the use of up-to-date Sentinel data (from the left to the right): Sentinel-2 (false color composite), forest mask and tree density. Copernicus Sentinel Data 2016 / FFK Gotha

Outlook to the future

ThüringenForst will continue to implement this method to monitor and verify afforestation areas in a ten-year inventory and planning cycle, which is the normal practice in Germany. This means that the afforestation product is delivered annually for one tenth of the federal state. In the future, the Copernicus High Resolution Layers will be replaced by a forest mask and tree density generated layers using up-to-date Sentinel data (as shown in the image on the bottom left of this page) because of their higher spatial and temporal resolution. Moreover, new monitoring services using Sentinel data are being developed. These services particularly focus on rapid mapping of biotic and abiotic changes in forests as well as the classification of tree species.

Acknowledgements

The authors would like to thank the Agency for Surveying and Geodata (Federal State Thuringia) and the Thuringian Agriculture Administration for providing the auxiliary data as well as the German Ministry of Transport and Digital Infrastructure for financial support of the project, 'Sentinels for Thuringian Information Systems'.

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REMOTE SENSING FOR GARAJONAY NATIONAL PARK MANAGEMENT

Understanding the Laurisilva forest dynamics has been crucial for the management of Garajonay. In the last decade this has been made possible thanks to the historical series of Landsat images.

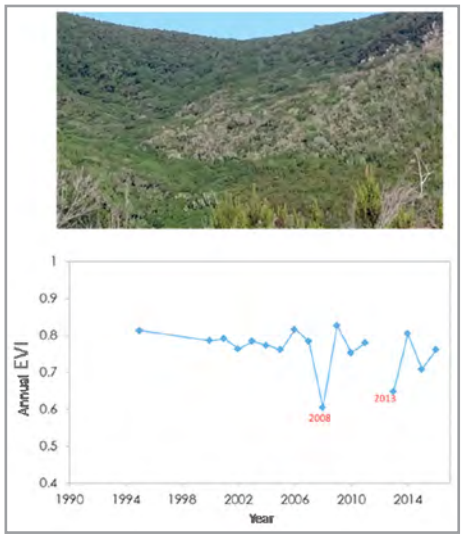
The challenge

Laurisilva forest in Garajonay National Park (GNP) (La Gomera, Canary Island) is the best preserved sample of this type of vegetation throughout the Canary Islands. It has a mature state of conservation but presents signs of decay in some areas. Understanding the possible causes is crucial and analysis of forest evolution through images over the last decade is the main tool for a complete overview of the problem.

The space based solution

The historical series of Landsat imagery allowed the analysis of annual variability of different vegetation indices between 1995 and 2016. We aimed to identify areas showing a devitalisation tendency during the studied period.

The temporal resolution obtained with Landsat enabled the provision of enough images to build mosaics free of clouds. For the devitalised areas detection we created annual mosaics and tested various vegetation indices together with an algorithm called "greenbrown". This algorithm is used to analyse trend changes in gridded time series such as from satellite observations or climate model simulation. In this case vegetation



Evolution of EVI for an area with devitalisation symptoms, mainly in years of severe drought.

indices were computed from historical series of Landsat images. The Enhanced Vegetation Index (EVI) showed the...It shoud be: The Enhanced Vegetation Index (EVI) showed the best performance. The figure shows the mean tendency of an area labelled as devitalised (see next figure). It is normal to observe the lowest values in years of severe drought. However, this kind of vegetation recovers quickly with the presence of clouds.

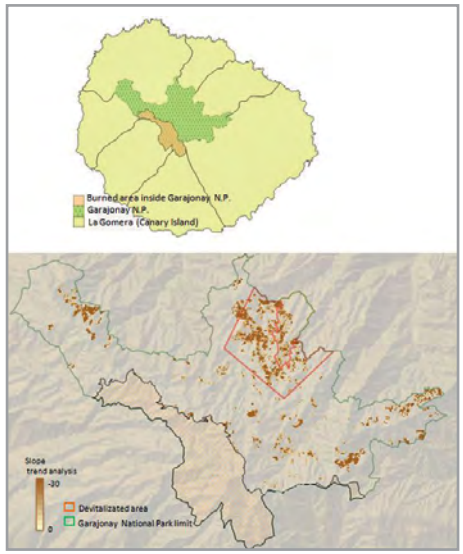
We also used Sentinel-2 images to evaluate the current state of Laurisilva forest in GNP. We located devitalised and healthy areas during a summer field campaign in 2017 and used the data, first, to train a classification model applied on Sentinel images and then to validate results.

Benefits to Citizens

Updated maps of the state of Laurisilva forest and location of devitalisation hot spots are useful tools for decision-making in forest management.

> "This application is revolutionary in the forestry sector and is a great advance in the way that decision-making can be carried out in forest management."
>
> ***Ángel Fernandez, Garajonay N. P. Director***

Free availability of images together with open source image processing software like QGIS or SNAP (Sentinel Application Platform) allows high quality spatio-temporal studies, at low cost. It enables the study of large areas and the analysis of landscape dynamics that help explain current forest state and processes. Easy access to these tools also brings this technology closer to citizens. This also provides greater understanding and awareness for the care of the environment.



Mapping of areas showing a negative slope in trend analysis (1995-2016) in Laurisilva forest in Garajonay National Park

In addition, Agresta S.Coop. has automated all the processing chain from image to products, making the work more efficient.

Outlook to the future

Finer spatial and spectral resolution of Sentinel-2 compared to Landsat helped improve the identification of devitalised areas in Laurisilva forest. Sentinel-2 opens up a wide range of possibilities for detailed studies in the forestry sector. For Agresta S.Coop, the Copernicus Programme is essential for many of its current work and future strategies. For example, current efforts focused on forestry species identification will certainly be improved by the possibility of combining different sources of imagery like optical Sentinel-2 and radar Sentinel-1.

Acknowledgements

We are grateful to Ángel B. Fernández López who supplied the terrain information and all the knowledge about Laurisilva in Garajonay National Park. This study is part of a more comprehensive research study developed by Garajonay National Park whose aim is to have a deep comprehension of vegetation inside the Park.

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SATELLITES MONITOR FOREST CHANGES IN FINLAND

The space data based cloud service monitors Finnish forests and provides up-to-date information about the changes for Finnish forest authorities.

The challenge

Satellio has developed a forest monitoring service based on Sentinel-2-data in the Finnish Government led project. The forest authorities had need for new methods to collect up-to-date information about forest inventories and loggings.

The efficient monitoring and controlling large forest areas has been challenging and resource consuming. Previously the forest authorities have mainly relied on field sampling based on required forest user notifications.

The project aimed to develop a tool for forest law enforcement. The operational use of Earth Observation and GNSS data is crucial to ensure updatable and scalable information for large territorial areas.

The space based solution

The developed solution has approval from the Finnish Ministry of Agriculture and Forestry. It is space based and utilises earth observation and satellite navigation which are used for monitoring and accurate positioning. The solution consists of three parts: data acquisition, processing and analysis.

First step is to go through all data from Sentinel-2-satellites using automated



Automatic process classifies forest biomass changes between clear cuts (red) and thinnings (yellow).

machine learning methods and artificial intelligence. As a result, the process produces a coherent time series of the desired geographic areas. Sentinel-2-satellite constellation has a good revisit time providing several images from area of interest.

Next the automatic process analyses image series, detects and classifies forest biomass changes between clear cuts and thinnings. The service interprets types of change, time frame and geometry. Generated information is enriched with forest inventory data to estimate biomass volume change.

The results can be viewed and integrated to existing geographic information systems (GIS) using Satellio's web cloud service. The technology can be scaled anywhere and anytime in the world.

Benefits to Citizens

The space-based solution is an efficient tool to monitor and detect changes in forest areas. The technology is suitable from small to large forest areas and they can be located anywhere from nearby to remote areas as Sentinel-2-images are available anywhere on Earth.

The automatic processing chain ensures up-to-date and accurate information about

> "Effective law enforcement is beneficial to the entire forest industry."
>
> ***Aki Hostikka,***
> ***Head of Financing and Inspections***
> ***Finnish Forest Centre***

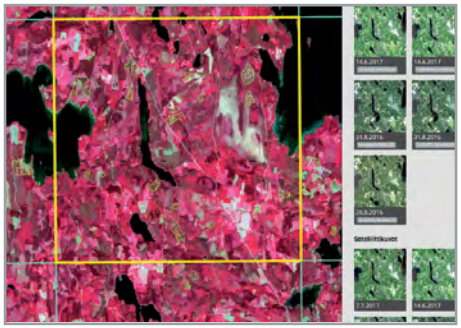
environmental changes. This helps to react faster and make relevant decisions concerning the changed forest area.

The technique has a significant positive operational, ecological and financial benefits.

Law enforcement is improved as the changes are recognised efficiently and more accurate analysis can be made to predict direct and indirect impacts of forest use.

The solution enables monitoring to ensure forest management duties are conducted on the correct areas and in the time period as informed. Furthermore, the control of conservation areas is easier as the automatic detection can reveal unexpected or illegal actions in the areas.

Financial benefits are achieved thanks to improved and optimised forest inspections. The field work can be targeted and performed on areas needing attention more efficiently.



Web service user interface.

Outlook to the future

The service has been developed in a three-year project which ends in 2019. The last year of the project is for operational piloting. The initial service has approval from the Finnish Ministry of Agriculture and Forestry. The forest authorities intend to put the technology into full operational use throughout Finland.

In the future, satellite technology can provide new applications for defining forest management needs and monitoring overall forest condition.

Acknowledgements

The Finnish Government head project has been carried out in co-operation with Satellio Oy (Ltd), VTT technical Research of Finland, Finnish Forest Centre, National Resource Institute Finland, Finnish Environment Institute and Ministry of Agriculture and Forestry.

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SENTINEL-BASED AZORES REGIONAL FOREST INVENTORY

The Azores Regional Forest Inventory is a fundamental regional tool for supporting forest management and spatial planning policies in the Azores.

The challenge

The Azorean Regional Forest Inventory constitutes the core tool for forest planning and management and also the most accurate and reliable official Land Use / Land Cover map in the Azores Autonomous Region (Portugal), being widely used by local and regional authorities for supporting both spatial planning and forestry policies purposes.

The current Azorean Regional Forest Inventory was produced in 2007 by the DRRF (Forest Regional Department) staff through the combination of Geographical Information Systems (GIS) based on-screen photointerpretation of high spatial resolution aerial imagery (with a minimum spatial unit of 1 hectare) and exhaustive field campaigns for survey and validation. As the overall cost of this methodological procedure is very high (in both human, logistics and data resources) and time consuming, the periodic update of this cartographic product is not performed as frequently as needed for spatial planning and forest management purposes.

The space based solution

Satellite remote sensing has shown to be an appropriate tool to assess and monitor large-area forest attributes with reasonable



The woody invasive species *Pittosporum undulatum* is a major threat for nature conservation in the Azores and requires appropriate management (about 24 thousand hectares). *Source: DRRF*

accuracy levels. The use, integration and combination in the current Forest Inventory's methodological procedure of free-of-charge USGS/NASA (Landsat 8 multispectral data) and Copernicus remote sensing data provided by Sentinel-1 (C-band SAR) and Sentinel-2 (multispectral) sensors will significantly improve the regional decision-support system and successfully contribute to develop a more suitable and cost-effective operational system for mapping, inventorying, monitoring, assessing and managing natural (both native and invaded) and production forest areas in the Azores. For this purpose, a remote sensing-based operational framework is being developed in order to: (1) accurately map Azorean forest areas through semi-automatic supervised classification; (2) detect changes in forest cover (by applying change detection algorithms); and (3) assess vegetation greenness and moisture status by computing and comparing several spectral indices (e.g. NDVI, SAVI, EVI, NDWI).

Benefits to Citizens

The development and implementation of a Remote Sensing-based forest monitoring operational framework able to support

> "The systematic use of Copernicus Sentinel data will improve significantly the canopy classification accuracy and update frequency of the Azores Regional Forest Inventory."
>
> ***Anabela Isidoro,***
> ***Regional Director at DRRF***

decision-making in spatial planning and to strengthen law enforcement by public authorities, will constitute an important step towards an effective promotion of cost-effective forest management and land use sustainability awareness amongst decision-makers, landowners/managers, further stakeholders and the general public. In fact, the development of a forest management approach strongly supported by an effective assessment of current resources, by the detection and monitoring of the most relevant forest changes and land-use trade-offs might be able to mitigate the main negative ecological (e.g. loss or degradation of native vegetation areas, increase of areas invaded by alien plant species) and socio-economic impacts (e.g. loss or degradation of production forest; increase of bare soil and impervious



Cryptomeria japonica is the most relevant man-planted forest species in the Azores with approximately 12,400 hectares. *Source: DRRF*

areas). This operational framework will be fully aligned with multisectorial regional, national and EU policies related to Forestry Planning and Management, Land-use Management, Invasive Alien Species control, and Nature Conservation. It will also strongly contribute for all 3 strategic priorities of the first pillar of the Azores Research and Innovation Strategy for Smart Specialization: "Agriculture, Livestock and Agroindustry".

Outlook to the future

With the expected increase of available data, there will be a growing need for cloud-based data storage and processing services. The Copernicus Data and Information Access Services (DIAS) might be in the future the most suitable platform to implement this operational framework, in order to combine this information with further valuable data produced by DRRF (namely field surveys and UAV campaigns), therefore, fostering the implementation of a powerful multi-source decision-support system.

Acknowledgements

The authors thank the University of the Azores (Regional Copernicus Academy) and the FRCT – Regional Fund for Science and Technology (Regional Copernicus Relay) for supporting the development of this initiative.

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UNIQUE SATELLITE-DERIVED FORESTRY INSIGHT FOR DEFRA

To support Defra in managing an outbreak of Sweet Chestnut blight, Rezatec was invited to develop an interactive map capable of identifying species and stress using Earth Observation.

The challenge

An outbreak of sweet chestnut blight, a plant disease caused by the fungus Cryphonectria parasitica, has recently been discovered in the South West of England. The client for this project - Defra, the UK Government's Department for Environment, Food & Rural Affairs - is managing the outbreak and wanted to explore how Earth Observation data could be deployed in outbreak situations, Rezatec was invited to develop an interactive map capable of locating Sweet Chestnut trees in the outbreak area and identifying stressed trees. This map could potentially be used to aid the deployment of ground-team resources to assess the extent of the outbreak and potential mitigation measures.

The space based solution

Rezatec provided Defra with access to unique, satellite data products derived from Sentinel 1 and 2 satellites that allowed them to...

Identify tree locations: The map provided Sweet Chestnut and Oak trees layers on top of satellite imagery. Rezatec's tree species classification data product was used to model the presence of both Sweet Chestnut or Oak trees, based on the unique spectral signature of these target species within the input Earth



Extract from Rezatec's interactive web GIS Portal depicting the entire area of interest in the study for species identification of Sweet Chestnut and Oak derived from Sentinel data.

Observation datasets.

Detect change: Copernicus Earth Observation data was used to identify stressed Sweet Chestnut. Although tree stress can be caused by a large number of factors, analyses like these could be used to prioritise areas for ground inspections to determine the presence of pests & diseases. Rezatec's forestry change detection data product was adopted to measure any anomalous phenological behaviour in the Sweet Chestnut presence map output. Specifically, annual time-series were analysed for all of the detected pixels in the study area, to identify significant deviations (temporal and spatial) in phenological behaviour, assumed to be an indicator of canopy stress.

Benefits to Citizens

With an easy-to-use interface and visualised geospatial data layers, Rezatec's web portal provides an opportunity for Defra to analyse and interrogate the information and make informed decisions based on up-to-date geo-spatial data. This is a powerful outcome, supporting Defra's challenge to understand

> "Their ability to map a range of tree species at remarkably high-levels of accuracy has supported our response to outbreaks and could potentially revolutionise Defra's response to quarantine pests and diseases in the wider environment."
>
> ***Willem Roelofs,***
> ***Plant Health Team, Defra***

and manage this outbreak as well as potential future ones.

Defra can now:

- Understand the fine scale distribution of Sweet Chestnut and Oak trees in a target area
- Detect signs of tree stress, a potential indicator of tree health issues caused by pests and diseases
- Monitor for early-warning signs of plant pest spread
- Explore how Earth Observations can be used to inform tactical responses, e.g. by ground truthing data developing time-series in areas of interest

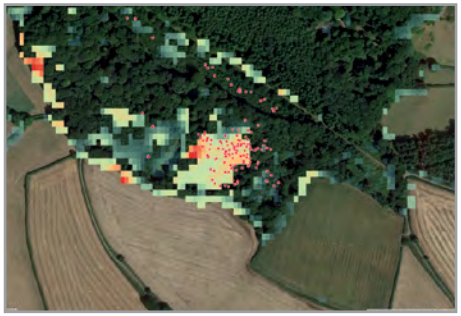
The data product layers that enable these new capabilities include:

- Spatial distribution and extent of target tree species
- Analysis of tree health, with a graded indication of stress levels.

Outlook to the future

Rezatec are very pleased to support Defra in its mission to understand the development of this tree pathogen problem, and the hope

is that it will also help their future ability to detect, treat and prevent the spread of pathogens in monitored forested areas.



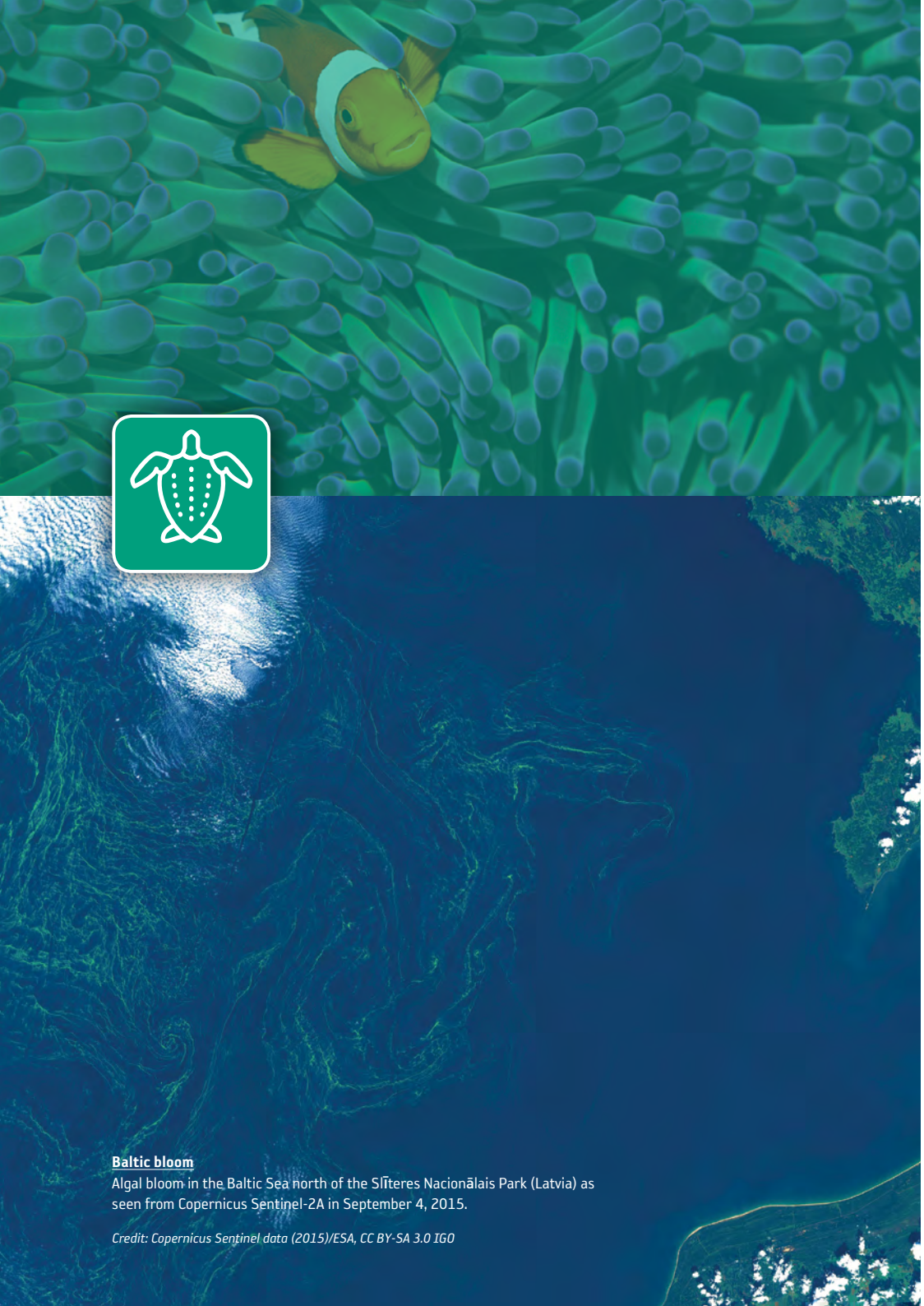
Extract from Rezatec's interactive web GIS Portal depicting a small section of the results in the study for evidence of Sweet Chestnut stress derived from Sentinel data.

Rezatec's suite of products within the Forestry industry allows for comprehensive monitoring and mensuration so this is a really exciting time to be involved at Government level in the identification and safeguarding of the UK's trees and forests.

Acknowledgements

Rezatec would like to mention that it would not have been possible to get to this point so quickly without the initial support it received from the UK Space Agency's 'Space for Smarter Government' Programme (SSGP) and the collaborative working with Forest Research. The funding has resulted in an end-user product that is now commercially available.

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Baltic bloom
Algal bloom in the Baltic Sea north of the Slīteres Nacionālais Park (Latvia) as seen from Copernicus Sentinel-2A in September 4, 2015.

Credit: Copernicus Sentinel data (2015)/ESA, CC BY-SA 3.0 IGO

BIODIVERSITY AND ENVIRONMENTAL PROTECTION

The preservation of our natural environment is essential to have clean water and air, maintain our soil, regulate the climate, recycle nutrients and provide us with food. However, this is progressively being degraded, sometimes permanently. Human activities put enormous strain on the environment: factors such as population growth, pollution, invasive species, urbanisation, and climate change are causing deterioration to ecosystems. A key indicator of this is represented by the increasing decline in biodiversity: today, almost half of Europe's mammals and a third of reptile, fish and bird species are considered endangered. The European Union environmental policy dates back to the 1970s, and with its extensive environmental legislation (about 500 Directives, Regulations and Decisions) provides some of the world's highest environmental standards: it aims at making the EU economy greener, protecting nature, and safeguarding the health and quality of life of EU citizens. The Habitats Directive is an example of such legislation, implemented through the Natura 2000 programme covering about 30,000 sites throughout Europe. But, the environment can actually only be protected if these policies are properly implemented. Local and regional authorities are crucial players in environmental protection as they are often responsible for rule-making and undertaking investments and can also have inspection and oversight functions. EU Cohesion Policy and related funds play an important role in boosting the implementation of EU environmental standards and sustainable growth, e.g. during the programming of the 2014-2020 Cohesion Policy, a strong emphasis was placed on supporting green infrastructure (e.g. flood plains, green walls and roofs), especially in cities. Environmental protection is a core objective for Copernicus. The Programme provides data and information useful to monitor a variety of environmental parameters over land, the atmosphere and the oceans. For instance, dynamic maps of vegetation health and land cover can be derived from Sentinel-2 data with unprecedented frequency, whilst chlorophyll content estimations derived from the Sentinel-3 satellite can be related to the eutrophication of the marine environment. Copernicus Land and Marine Environment Monitoring Services provide extended sets of relevant geophysical parameters such as, for example, very high-resolution maps of Natura 2000 areas (derived from Copernicus Contributing Missions) and various key physical and biogeochemical ocean parameters like currents, temperature and chlorophyll.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
ACTIONABLE GEOINFORMATION ON BURNT AREAS	Apulia (Puglia)	Apulia	S2	5
ANALYSIS OF FOREST FIRE EFFECTS WITH SENTINEL	Castilla Leon (Castilla y León)	Castilla Leon	S2	2
A SPACE-BASED SOLUTION FOR OIL SPILL DETECTION	Central Macedonia (Κεντρική Μακεδονία) (Kentrikí Makedonía)	North Aegean	CMEMS, S1	3
COPERNICUS SENTINEL DATA FOR LOCAL SCALE CONSERVATION ACTIVITIES	Crete (Κρήτη)	Crete	S1, S2	3
EARTH OBSERVATION AND PARTNERSHIPS TO SUPPORT LAND USE MANAGEMENT	Bonn (Bonn)	Kilombero, Tanzania	S2	3
ENABLING EARTH OBSERVATIONS FOR PROTECTED AREAS	Dyfed County	Europe	S2	3
EO FOR BIOTOPE-TYPE MAPPING IN THE ALPINE ZONE IN AUSTRIA	Salzburg	Salzburg	S2	3/4
HOW COULD COPERNICUS DATA SUPPORT GRASSLAND CONSERVATION?	Vidzeme (Vidzeme)	Latvia Vidzeme Region	S1, S2	2/3
IMPROVING COASTAL ECOSYSTEM BENEFITS UNDER INCREASING PRESSURES	South Holland (Zuid-Holland)	Friesland Groningen	S1, S3	4
MAKING SEAGRASSES GREAT AGAIN	Berlin (Berlin)	Samaria National Park, Crete	S2	1
MAPPING BURNED AREAS USING SENTINEL-2 IMAGES	Central Macedonia (Κεντρική Μακεδονία) (Kentrikí Makedonía)	Greece	S2	4
MONITORING COASTAL WATERS IN NEAR REAL TIME	Attica (Περιφέρεια Αττικής)"	Epirus Region	S3	4
MONITORING MOUNTAIN GRASSLANDS TO SUSTAIN WILD HERBIVORES	Tuscany (Toscana)	Piedmont Aosta Valley	S2	4
REGIONAL FLOOD MONITORING WITH SENTINELS DATA	Alsace (Alsace)	Grand-Est	S1, S2	4
THE POTENTIAL OF A PRE-COMMERCIAL PROCUREMENT APPROACH IN EARTH OBSERVATIONS	Azores Archipelago	Azores Archipelago	CMEMS, Security	1
TREE SPECIES MAPPING WITH MULTITEMPORAL SENTINEL-2 DATA	Vienna (Wien)	Northern Austria Vienna	S2	4
WETLAND FUNCTIONAL ASSESSMENT	Brittany (Bretagne)	Brittany	S2	3

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2; S3: Sentinel-3; CMEMS: Copernicus Marine Environment Monitoring Service; Security: Copernicus Security Service.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

ACTIONABLE GEOINFORMATION ON BURNT AREAS

Rheticus® Wildfires provided the Alta Murgia National Park with weekly actionable information on wildfires, overcoming the lack of data for post-fire assessments.

The challenge

2017 will be remembered as another year of significant wildfire activity across Italy, especially within national parks and protected areas. Wildfires represent a major threat to environmental resources, with hundreds of thousands of hectares of burnt areas and invaluable loss of woods and biodiversity every year. Over the 2017 summer season, the Alta Murgia National Park (Apulia Region, Southern Italy) faced the lack of actionable information on wildfires for post-fire assessments.

According to the Italian law on wildfires (L. n. 353/2000), the Forest Police are in charge of in situ detection of burnt scars whilst municipalities are in charge of keeping burnt area database up-to-date. Those activities require great effort in terms of money and time. Moreover, it is difficult to perform accurate field surveys over inaccessible areas. As a result, stakeholders such as national parks, protected areas and natural reserves entities quite often face the lack of actionable information for fire management and recovery planning, which are essential aspects also at European level (e.g. Council Regulation (EEC) No. 2158/92 and further modifications). Relevant satellite data are now freely available with high temporal and



Rheticus® Wildfires User Interface for the Alta Murgia National Park.

spatial resolutions, thus benefits of using Earth Observation are significant especially for post-fire assessments, as EO by Remote Sensing enables automatic and continual monitoring, regardless of the dimension and morphology of the area of interest. Rheticus® Wildfires is where the Alta Murgia National Park satisfied its needs.

The space based solution

In order to better monitor burnt areas after fire events, the Park activated Rheticus® Wildfires service in July 2017.

Rheticus® Wildfires by Planetek Italia is a high-performing and cloud-based geo-information service for post-fire monitoring. It provides the end-user with key information retrieved from Sentinel-2 imagery together with other open data sources through extensively tested models and algorithms. Every time new Sentinel-2 data is available over the area of interest, the service automatically downloads the image, performs some processing and generates thematic maps, dynamic geo-analytics and pre-set reports.

Thanks to the high revisit time of Sentinel-2 over the same area (up to 5-6 days) and the high spectral and spatial resolutions of those data, Rheticus® Wildfires provided the Alta Murgia National Park with burnt area detection, and fire severity classification on a weekly basis, vegetation regrowth monitoring (1/year) and detection of potential illegal

> "Rheticus® Wildfires has helped us to oversee and report fire activity, support our fire management and recovery planning through actionable knowledge on burnt areas."
>
> ***Fabio Modesti, Alta Murgia National Park***

infrastructure activities within past-burnt areas (4 times/year). Moreover, it helped to prioritise response teams. Data were available via the Rheticus® geo-portal www.rheticus.eu and through pre-set reports.

All in all, Rheticus® Wildfires was where the Alta Murgia National Park obtained the required information from to develop and support its management strategies and recovery planning, fulfil its reporting duties and management strategies and overcome the lack of actionable information.



Wildfires automatically retrieved from Sentinel-2 data acquired on 14/07/2017 over the Alta Murgia National Park.
Credit: Contains modified Copernicus Sentinel data [2017]

BIODIVERSITY AND ENVIRONMENTAL PROTECTION

Benefits to Citizens

Rheticus® Wildfires simplifies burnt areas detection and contouring from various open data sources into an interactive and comprehensive dashboard, to achieve insightful and purpose-built contents from many different perspectives. Public authorities gain immediate and reliable geo-information, including weekly and summary information over wide areas, based on continual Sentinel-2 monitoring, overcoming the difficulties and costs of field measurement campaigns. Rheticus® Wildfires generates reports, thematic maps and geo-analytics based on Sentinel-2 data, meeting local to national content requirements in the field of burnt area detection and illegal building prevention. It also helps to prioritise response teams. Furthermore, better management of precious vegetation resources is well worth the ecological advantages it gives to the environment and citizens.

Outlook to the future

The Copernicus Sentinels will ensure continuity of the service. This case history is expected to serve as a good example for the further promotion of the service at European and global scale. The integration of Sentinel-3 data will also be explored for further improvements.

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ANALYSIS OF FOREST FIRES EFFECTS WITH SENTINEL

Sentinel images help us analyse forest fires and manage the subsequent works more efficiently.

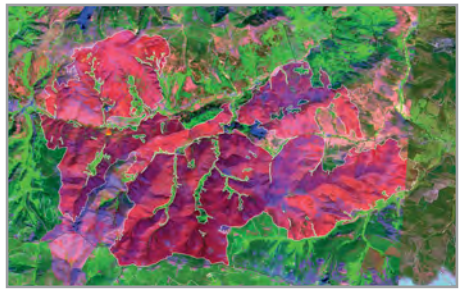
The challenge

In Spain, approximately 100,000 hectares are burnt annually by forest fires, of which about 60% of the surface constitutes the northwest area, which includes the regions of Galicia, Asturias, and the provinces of León and Zamora in Castile y Leon. León, and specifically the region of El Bierzo, is an area in which there are numerous fires during the year. In 2017, the largest fire in Spain occurred in León, extending for almost 10,000 hectares. The management of extinction is required and it is fundamental to know what has burnt and how much has burnt for post-fire analysis. Sentinel data are used to calculate the surface and analyse the severity of it.

The space based solution

Sentinel data can help us identify and learn the extent of the burnt areas, as well as define the degree of severity produced by the forest fire on a very detailed scale, since Sentinel data reaches a resolution of 10 metres of information as a minimum unit. This is possible thanks to a combination of the 13 bands on board of the Sentinel-2 satellites.

The bands that perceive the reflection of the



Map of scar burn in La Cabrera, Leon, Spain. It burned 10,000 hectares. Satellite Sentinel image Sensing in the shortwave infrared (SWIR).

chlorophyll in vegetation help us identify burnt areas, since they do not reflect the wave of light. The most appropriate light bands are those of the near infrared because they show the photosynthetic activity of the vegetation. In turn, if we compare the photosynthetic activity of the vegetation, before and after the fire, we can graduate its severity; if there is a bigger difference, the severity will be greater.

Benefits to Citizens

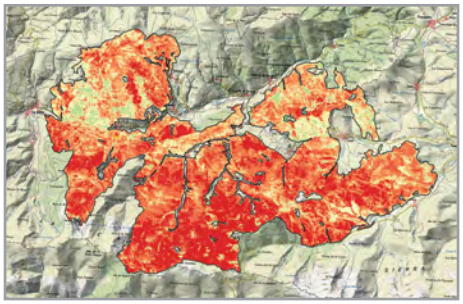
There are many benefits: Being able to perform burnt surface analysis as well as a gravity one, with data that is freely available, and more importantly it helps to improve and make more effective management decisions. The public administrations in charge of restoring the burnt-out spaces, can prioritise the most urgent actions. The measures to be carried out can improve the filtration level of runoff water which reduces soil losses and fertility. If we are able to reduce the loss of soil we can improve water quality and conserve forests. We improve the biodiversity and the habitat of the species. The economic savings are substantial.

"This application of Copernicus Sentinels helps us to manage better and more efficiently actions against forest fires."

Celso Coco, CIFP Almázcara

Outlook to the future

The fact of having images with a periodicity of less than 5 days would help managers to have updated information. This is very interesting for decision making during large forest fires and especially in the necessary work required after these fires. If we had a larger number of Sentinel-2 satellites, we could be more efficient in the decisions that need to be made during the extinction of forest fires.



Severity Map of Forest Fire in La Cabrera, Leon, Spain.

Acknowledgements

Thanks to all the forest firemen, pilots, forest rangers, technical team... without them it is possible that we would have been talking about an even bigger fire. Thanks to all the forestry engineers who do a great job for the environment.

Thanks to Copernicus for the opportunity and for the satellite information.

Celso Coco
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A SPACE-BASED SOLUTION FOR OIL SPILL DETECTION

An innovative application to collect satellite images of the sea and detect areas polluted from oil releases in order to notify the national authorities and coast guards.

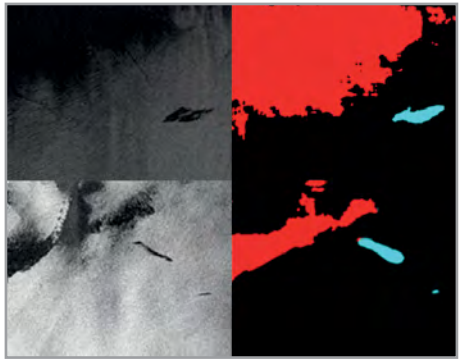
The challenge

Countries with large seawater areas or extended coastlines have to deal with the challenging issue of promptly detecting marine pollution, in order to minimise the environmental effects. Aquatic pollution may originate from oil spills, plastics, or debris from natural disasters and it can be caused either deliberately or accidentally. The large number of oil-based products on the market entails the increase of shipping routes that eventually raises the possibility of slicks occurring. Remote sensing, within the Copernicus Programme, can act as a beneficial monitoring tool that will allow early detection of slicks, provide size estimations, and predict the slick motion.

The space based solution

The solution involves a web application that tackles oil spill identification in EU maritime areas, aimed at triggering the awareness of the relevant authorities.

The application processes Synthetic Aperture Radar (SAR) images are acquired from Sentinel satellites provided by the Copernicus Open Access Hub. SAR images provide independence regarding the operational time and the environmental conditions, enhancing



Original satellite SAR images from the Mediterranean Sea (left) and detection masks (right) with oil spills and lookalikes.

the functionalities of the Copernicus Marine Environment Monitoring Service (CMEMS). On the backend, SAR images are downloaded daily from the Copernicus services, noise is suppressed and semantic segmentation algorithms are applied to identify the oil spills. Contrary to current solutions, our service not only provides a wider-area detection scheme, but also annotates each pixel with a valid classification state. Analysed images are presented as detection masks, where turquoise areas define an oil spill, whilst red areas mark lookalikes. The service can identify pollutant areas with an accuracy of 91%, thus, the frequency of in situ verification by the authorities could be significantly limited. In case of a verified oil slick, users instantly receive an alert with the position and the size of the oil slick to act accordingly.

Benefits to Citizens

By exploiting Copernicus data, the proposed application aims to rapidly identify oil related events, mitigate the positive false alerts from the end-user side and thus trigger all the necessary mechanisms that are involved during such events, e.g. the coastguard. In this way, the application primarily contributes

> "I strongly support that such an application could significantly transform the way that we respond in such events like oil spills whether they come from a single ship or an oil rig or other similar human action."
>
> ***Spyridon Kintzios, Commander HN, MSc***

to avoiding the extension of ecological disasters and, consequently, benefits both the environment and the public health.



A comparison between produced detection masks (left) and ground truth images (right).

Moreover, by providing estimates of the size and the movement of the slick, the application can be invaluable in aiding clean-up operations or helping the authorities to identify the polluters. With regards to the latter, the application can be easily integrated into existing systems that concern maritime surveillance. No additional human contribution is required in the identification process since the model is trained to identify the oil spills based on its natural attributes. Finally, it can significantly reduce the workload of the human operators of the agencies concerned due to the high accuracy identification, since this task is currently addressed manually (ships have to report pollution incidents), and, thus, it can optimise the utilisation of the personnel by assigning more complicated tasks.

Outlook to the future

Currently, the application supports the detection of oil spills, but the main objective is to extend its capability in identifying more pollution factors, i.e. debris from natural disasters. It is also expected that any evolution of the EO Copernicus solution will result in improvements of our system, e.g. enhanced detection or wider area covering. A more accurate discrimination of the phenomena that are currently denoted as "lookalikes" could constrain the false positive alerts as well as the identification of ships. Merging the latter with data from a ship's Automatic Identification System (AIS), the root of the pollution could be particularised.

Acknowledgements

The development of the application was supported by the EU's Horizon 2020 programme under grant agreements H2020-776019 EOPEN and H2020-740593 ROBORDER.

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COPERNICUS SENTINEL DATA FOR LOCAL SCALE CONSERVATION ACTIVITIES

The use of Sentinel-2 data, combined with landscape factors provides insights of the distribution of the endemic lizard Podarcis cretensis.



The endemic Cretan lizard, *Podarcis cretensis* is found mainly in West Crete

The challenge

Local scale processes shape species distributions. Mountainous areas provide a multifarious terrain where microclimate refugia shape ecological niches at local scales for animals and plants. Also, mountainous areas host endemic and rare elements of biodiversity, acting as islands of biodiversity. These processes can be identified by using high resolution data, based either on satellite or airborne observations. Both approaches have their limitations; satellite data have high frequency but low spatial resolution, whilst airborne data have high spatial resolution but costly high temporal data collection.

The space based solution

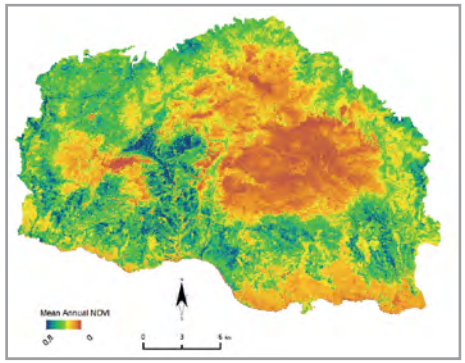
Copernicus Sentinel-2 constellation (Sentinel-2A/B) fills this gap, by providing data of high spatial resolution with an adequate temporal resolution (10 m pixel size every 5 days). In addition, Sentinel-1 constellation (Sentinel-1A/B) can provide terrain data (e.g. Digital Elevation Model) and related topographic parameters describing the geodiversity after the analysis within the open access ESA SNAP toolbox.

Products from Sentinel-1 and -2, combined with species observations in the framework of species distribution modelling, are a powerful tool in the arsenal of conservation ecology and planning. The high temporal frequency data of Sentinel-2 provide information on landscape dynamics, such as the vegetation growth and changes in landcover, whilst Sentinel-1 data give access to extracted information like elevation, aspect, and slope but also information relating to the incoming solar radiation and the terrain openness (e.g. Sky View Factor parameter). Lizards are dependent on the availability of sun for their needs, thus terrain parameters as well as vegetation dynamics are related to their ecophysiological demands.

Benefits to Citizens

The conservation and protection of biodiversity is a fundamental activity of protected areas like Samaria National Park, where the endemic lizard *Podarcis cretensis* is found. The conservation of the habitat provides a valuable cultural ecosystem service, appreciated by tourists. The use of Copernicus Sentinel data has great potential as it reduces costs for planned fieldwork activities which can be focused on targeted areas whilst the use of Sentinel-2 data makes the monitoring of certain areas easier, even without spending resources for fieldwork campaigns. Sentinel-2 data are also used for monitoring illegal activities (e.g. lodging, illegal fires) within the protected area, thus optimising the Park's management resources and supporting law enforcement. Open access satellite data allow the reduction of the cost of surveys in remote areas, which are abundant inside the national park, reducing the costs of public administrations (municipality, forest police, park authorities) and thus benefitting citizens.

> "The use of Copernicus Sentinels for conservation and environmental monitoring provide us with new ways of working."
>
> ***Antonis Tsakirakis, Samaria National Park***



Mean annual NDVI for 2017, calculated using Sentinel-2A and -2B data over Samaria National Park. *Credit: Contains modified Copernicus Sentinel data [2017]*

Outlook to the future

Protected areas require multiple tools for their daily activities. Sentinel-2 data as Analysis Ready Data (ARD) via online platforms for use by non-experts in Remote Sensing are more than welcome. A fully operational online Sentinel 1/2 system which will provide data-ready-to-use will benefit the technical staff of local authorities and parks as they will be able to use updated information without having the technical expertise to process remote sensing data. To this end, the H2020 ECOPOTENTIAL works side-by-side with 24 protected areas across Europe and beyond in providing the tools and models that make use of Sentinel data for addressing this specific monitoring need (amongst others).

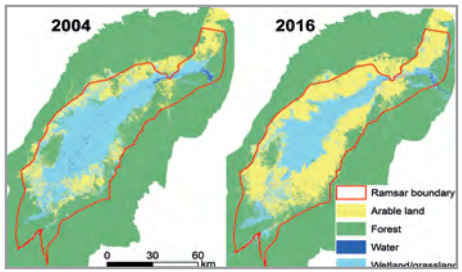
Acknowledgements

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EARTH OBSERVATION AND PARTNERSHIPS TO SUPPORT LAND USE MANAGEMENT

The cooperation of three European projects has shown how collaboration supports local authorities in wetland management.



Agricultural expansion in the Ramsar site between 2004 and 2016.

The challenge

The Kilombero Ramsar site in Tanzania is one of Africa's largest wetlands. The Ramsar convention encourages sustainable and wise use of wetlands for economic activities. However, during the last decade the area has experienced an exponential increase in immigration. Combined with a lack of property rights and low resources for management, farm encroachment and deforestation have grown uncontrolled dramatically reducing its natural habitats. Its vast area and difficult access make it challenging to obtain information on the current situation and develop land management plans that fit national and local needs.

The space based solution

In this context, the Belgian project KILOWREMP (Kilombero and Lower Rufiji Wetlands Ecosystem Management Project), the EU project SWOS (Satellite-based Wetlands Observation Service) and the German GlobE project have joined in a partnership to provide the government of Tanzania with the tools necessary to overcome the spatial challenges presented. This partnership directly contributes to the GEO-Wetlands initiative that was recently established as part of the 2017–2019 Work Programme of the Group on Earth Observations (GEO). Using satellite imagery from the Copernicus programme and NASA, the partnership provided the Tanzanian authorities with maps, models and science-based recommendations for land planning.

The products delivered show the spatio-temporal patterns and trends undergone in the floodplain during the last decades. Human activities such as deforestation and agricultural expansion have caused changes in the biophysical properties of the landscape. These changes impact the water regimes, land surface temperature and vegetation cover affecting all flora, fauna and local human populations. The land cover changes and the biophysical properties are traceable from space using different sensors and ancillary ground data provided by local users.

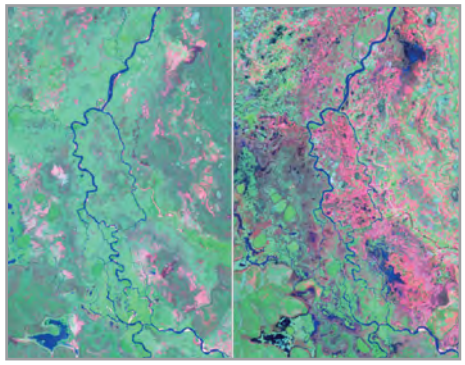
Benefits to Citizens

The area is undergoing a development phase to modernise the farming practices that aim to improve food security and sustainability. The results are being used to develop strategies that will allow economic progress with a better knowledge of the natural resources available in the floodplain and the impact that human activities cause upon them.

> "This analysis has opened the eyes of the many stakeholders of this valley over its environmental change."
>
> ***Pellage Kauzeni, Ministry of Natural Resources and Tourism of Tanzania***

Conflicts between local farmers, authorities and itinerant herders took place in the past due to weak land management systems. Mapping of historical trends of agricultural expansion and the current situation will provide a solid framework that will facilitate negotiations and planning between stakeholders.

The creation of this partnership has allowed the maximisation of the resources invested, preventing duplication of work. The use of freely available satellite imagery and cartographic products has also contributed to a cost reduction.



Changes in the wetland between 2004 and 2016 due to farming in the Ngapemba swamp. Healthy vegetation features in green and bare soil in pink. RGB: SWIR, NIR, G

Besides the products delivered, local users were trained in how Earth Observation can be used for monitoring. This will provide continuity for the monitoring tasks needed for the Ramsar reporting obligations once the projects end, and the process can be replicated in other areas.

Outlook to the future

The GEO-Wetlands initiative facilitates cooperation between different projects and institutions under the common goal of improving the monitoring and assessment of global wetland extent, status and trends. Collaboration between multidisciplinary teams is crucial to achieve the ambitious targets set by international conventions and frameworks. Enabling stakeholders to continue monitoring after the lifetime of projects is therefore an essential goal.

Acknowledgements

The projects forming this partnership have received funding from the EU H2020 program, EU and Belgian Development Cooperation, the German Federal Ministry of Education and Research and the German Federal Ministry for Economic Cooperation and Development.

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ENABLING EARTH OBSERVATION FOR PROTECTED AREAS

Providing land managers with an easy and accessible tool to address land cover change in Europe's protected areas.

The challenge

For many years, the uptake of Earth observation (EO) data for managing Europe's protected areas has been relatively limited, with this leading to missed opportunities for conserving landscapes and the ecosystem services they provide.

Nowadays, the public availability of satellite data makes it possible to significantly increase our understanding of Europe's changing landscapes. However, the sheer volume of data involved and the steps required for their processing is overwhelming for many and hence not often undertaken. The challenge therefore was to provide a tool that converted these data into useable and standardised products that could be easily generated and accessed by a wide range of users.

The space based solution

The Horizon 2020 ECOPOTENTIAL project has developed a Virtual Laboratory (VL) to host data and software to support protected area management using EO data. Within the VL, the EO Data for EcoSystem Monitoring (EODESM) stores environmental variables extracted from EO data and uses these to automatically generate classifications of land cover and change according to the Food and



EODESM classification of land covers in Gran Paradiso National Park (NP), Italy.

Agriculture Organisation's (FAO) Land Cover Classification System (LCCS; Fig. 1). Whilst some variables (e.g., vegetation canopy cover and height, water turbidity) are used directly as input to the classification of land covers, others (e.g., sea surface temperature, plant species, snow depth) provide additional information on their states and dynamics. The EODESM system also generates historical and near real time alerts through daily to annual comparison of land covers and environmental variables (Fig. 2). These change alerts are described on the basis of accumulated evidence from EO data and other sources. The resulting classifications are comprehensive and detailed. Mobile applications have also been developed to support calibration of variable retrieval algorithms or validation of classifications.

Benefits to Citizens

The VL and the EODESM system are open to users, allowing the retrieval of environmental variables and EO data, including Copernicus datasets. A particular advantage for those charged with protecting landscapes is that consistent land cover and change classifications can be generated for landscapes across Europe. This allows better comparison of area estimates and impacts of change

"The EODESM system provides timely information on wetland conditions and dynamics that determine the distribution of flora and fauna species. This can assist in efforts to ensure planning of conservation management."

Ricardo Díaz-Delgado (Doñana NP) and Loïc Willm (Camargue NP)

events (e.g., storms, fire) and processes (e.g., forest succession) between sites, including protected areas. The tools have already been applied to classify over 15 large national parks in Europe and are being increasingly adopted, as the approach to generating relevant classifications is easy to understand. The EODESM system is also scalable to any country or region worldwide and, because of its robustness and versatility, is adaptable to use data from a diverse range of present and future airborne and spaceborne sensors regardless of their spatial resolution.



Annual hydroperiods for Doñana NP provide input to the EODESM change detection and alert system.
Credit: Contains modified Copernicus Sentinel-2 data [2015, 2016, 2017]

Outlook to the future

The land cover classifications generated by the EODESM system can be translated to different habitat taxonomies, which is anticipated to increase uptake by a wide range of conservationists and ecologists. Furthermore, environmental variables predicted from process (e.g., forest growth, hydrology) can be used to generate classifications of future landscapes. This significantly increases the potential use of EODESM as a planning tool. This will assist in better planning of environmental resource use and may contribute to reverse losses of biodiversity and degradation of landscapes, in Europe and beyond. To assist EODESM users, training workshops and material are being developed and delivered to interested parties.

Acknowledgements

Thanks to the Horizon 2020 project ECOPOTENTIAL and the FP7 BIO_SOS (Grant Agreements n. 641762 and 263435), the European Regional Development Fund and Welsh Government Sêr Cymru Programme and to scientists and managers of protected areas for contributing to the development of the VL and EODESM system.

R. Lucas [1], P. Blonda [1], J. Bustamante [1], R. Diaz-Delgado [1], S. Giamberini [1], G. Kordelas [1], J. Gonçalves [1], I. Manakos [1], M. Santoro [1], R. Sonnenschein [1], F. Weiser [1], L. Willm [1] and R. Viterbi [2]
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EO FOR BIOTOPE-TYPE MAPPING IN THE ALPINE ZONE IN AUSTRIA

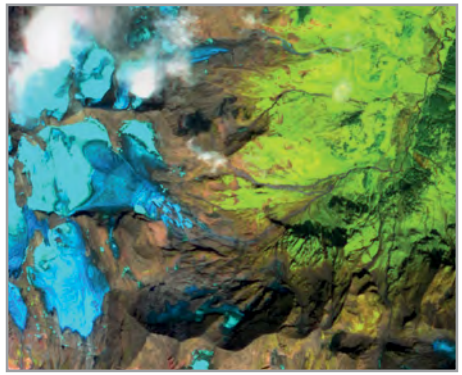
Sentinel-2 time series analysis supports alpine habitat assessment (1) by indicating changes in sensitive areas and (2) as a planning tool for designing in-field mapping.

The challenge

The alpine zone above the closed forest line hosts habitats for numerous ecological sensitive plant and animal communities in natural to near natural conditions. As a consequence of the tough environmental characteristics of alpine regions (large area, undulating to steep topography, fast changing weather conditions, short snow free period) field mapping of biotope- and habitat-types is cost- and time intensive. However, nature conservation legislation of Austrian federal states demands area wide biotope-mapping, whereas habitat assessment is required within the EU-wide Fauna-Flora-Habitat Directive (Natura 2000 network).

The space based solution

In order to monitor alpine habitats at the fine level of biotope-types and group of biotopes a stratified habitat mapping strategy was developed based on the usage of recent remote sensing (RS) sources and earth observation (EO) techniques. First Sentinel 2 time series analysis supports decision making on alpine habitat mapping strategies (vegetation period, snow coverage, seasons of cloud free satellite imagery, etc.) and provides rough information on areas with a high degree of potential changes, as well as areas with than



Sentinel-2 image (band combination 11, 8a, 2), Fuschertal valley, at mapping season (August) revealing: vegetation (green), rocks (brown), glacier (dark blue), snow (light blue), clouds (white).
Credit: Contains modified Copernicus Sentinel data [2017]

stable conditions. This knowledge is then used for tasking VHR (very high resolution, < 1 x 1 m pixel size) satellite imagery, ideally cloud free and within the vegetation period, to derive biotopes with a high spatial resolution and thus meeting the legal regulations for conservation management needs. Lastly, in-field mapping is coordinated based on the HR & VHR satellite derived information, assessing biotopes, which are hard to uncover with RS techniques or even unclear, and and is also used for validating the satellite derived information.

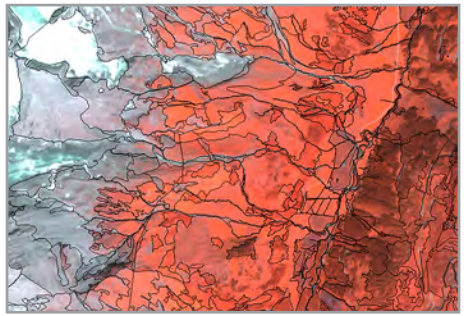
Benefits to Citizens

Biodiversity loss threatens the provision of ecosystem services to human society. With respect to alpine ecosystems the society benefits from services like natural resources, the supply of fresh water, carbon sequestration, tourism and recreation, amongst others. Thus, several national and international programmes aim to monitor the decline of biodiversity and try to halt or at least slow down these adverse effects by specific nature protection practices.

"We currently explore satellite data to accelerate the procedure of biotope mapping taking into account the goals of EU Biodiversity Strategy COM(2011)244 final and of EU Directive 92/43/EWG."

H. Hinterstoisser,
Prov. Govt. of Salzburg, Austria – Dept. 5/06

Remote or inaccessible areas, such as alpine areas, are challenging for nature conservation authorities since the ambitions of regularly monitoring and realising nature conservation management activities increase both efforts and costs, whilst the available resources are getting more and more limited.



Traditional in-field biotope map (glaciers to valley floor), Fuschertal valley (AUT), uncovering biotope structures on false colour Sentinel-2 satellite imagery (band combination 8, 4, 3).
Credit: Contains modified Copernicus Sentinel data [2017]

Use of recent RS imagery and EO analysis techniques foster a more standardised, transferable and economically viable solution for biotope- / habitat-mapping, which are less biased towards human perception than traditional in-field mapping. Moreover, high temporal and adequate spatial resolution

of Sentinel-2 facilitates regular updating of habitat changes and establishes timely, continuous and region wide comparable monitoring, which e. g. is required every six years by the European Habitat Directive. Thus, the Prov. Govt. of Salzburg – Dept. 5/06 explores EO-based solutions for biotope mapping to improve the efficiency of the monitoring procedure in alpine areas.

Outlook to the future

The implementation of EO based biotope/ habitat-mapping techniques into existing monitoring systems becomes more feasible with an increased availability of adequate RS data meeting the temporal and spatial resolution of nature conservation monitoring needs. However, forthcoming big EO data challenges have to be tackled with elaborated strategies whilst the existing regional to international monitoring systems need to be adapted to include RS derived information.

Acknowledgements

The presented work is supported by the 25th BRIDGE programme of the Austrian Research Promotion Agency (FFG), the Prov. Govt. Salzburg, Dept. 5/06, and the LE 14-20 programme.

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HOW COULD COPERNICUS DATA SUPPORT GRASSLAND CONSERVATION?

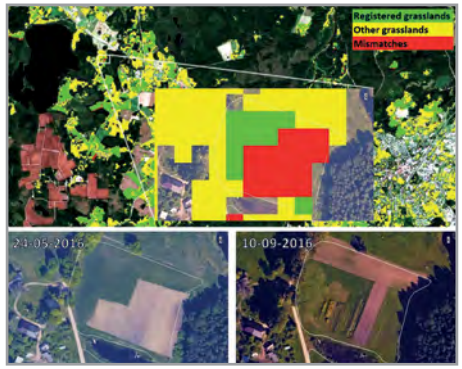
Grassland is not just a feed base for livestock but also serves as a habitat for plants and animals. Proper management of these semi-natural habitats is critical to maintain their biological value.

The challenge

The lack of appropriate management risks the long-term preservation of grasslands. As grasslands are semi-natural habitats they are exposed to a variety of risks, such as land use change, conversion to arable lands, invasive species, overgrazing or overgrowing (caused by depopulation and abandonment). The deterioration of grassland quality reduces the quality of ecosystem services and functions provided, leads to a loss of biodiversity, opens up the possibility of EU sanctions and decreases the quality of rural life. The existing monitoring practice of physical visits to grasslands is time- and labour-intensive, therefore cost-effective solutions are necessary that provide information on a large spatial scale.

The space based solution

The joint use of Copernicus Sentinel-1 optical and Sentinel-2 radar satellite data provides such benefits as the ability to discriminate spectral optical data, operation of radar data in all weathers as well as repeated image acquisition every 5 - 6 days. Therefore, testing of Copernicus Sentinel data capabilities for mapping of grasslands and monitoring of their management activities in Vidzeme region, in Latvia was performed within the



Mapping of grasslands near Cesis in Vidzeme region. Example of the mismatch where ploughed grassland is identified.
Credit: Contain modified Copernicus Sentinel data [2016]

SentiGrass project.

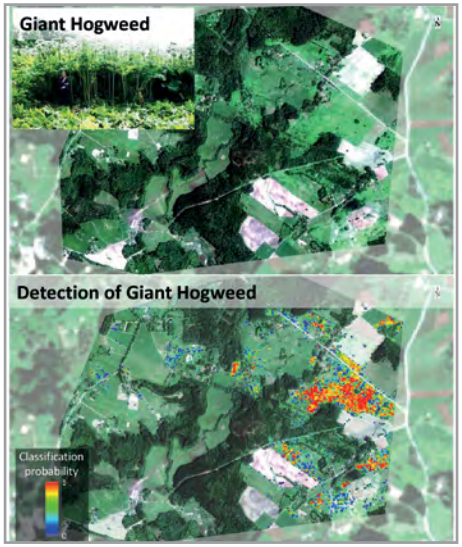
Mapping of grasslands was performed using all available Sentinel-2 optical data scenes and automatically analysed spectral signature of each image pixel to determine whether grassland was present or not. The obtained accuracy was above 90%. Whilst investigating the misclassifications, it was found that the ploughed grasslands are not classified as grasslands, thus showing potential for detecting disturbances in grassland cover.

Sentinel-2 optical data has also shown potential in the assessment of grass biomass and spread detection of invasive species (e.g. Giant Hogweed), whilst Sentinel-1 radar data is able to fill observation gaps (due to cloudy sky) and has shown potential for tracking grassland management events (e.g. ploughing and mowing).

Benefits to Citizens

Nature is not only an environmental resource, but also a cultural value. Current generations should preserve and improve their natural "inheritances" from their ancestors for the benefit of their descendants. Thus, appropriate management approaches are crucial. Field visits to sites are necessary but they are resource (time, labour, etc.) intensive. The free of charge data provided for the whole world by Copernicus enables methods that improve resource management to be developed whilst also increasing cost-effectiveness.

> *"Copernicus data could be considered as a complementary approach to standard ones in the assessment of grasslands due to the possibility of frequent observation of large areas."*
>
> ***Inga Racinska, the Latvian Fund of Nature***



Detection of Giant Hogweed in grasslands near Cesis in Vidzeme region.
Credit: Contain modified Copernicus Sentinel data [2016]

Mapping of grasslands and tracking management practices using Copernicus data allows monitoring of these habitats at a scale that would be practically impossible to do with traditional methods. Satellite data cannot fully replace habitat experts but can serve as a valuable complementary tool for remote evaluation of grassland status and targeted planning of field visits.

EU Member States have to report on the status of the natural habitats of EU importance every six years. Copernicus provides regular data that not only enables regulatory commitments to be fulfilled, but also enables real-time activities to be supported, for example, monitoring of biologically valuable grasslands that should be mowed or grazed but cannot be ploughed in order to maintain biodiversity.

Outlook to the future

It is planned to apply the developed approach to a larger scale and map grasslands over the whole Latvian territory for further development of the grassland connectivity model within the GrassLIFE.

Acknowledgements

This work was carried out within the framework of the SentiGrass project funded by the PECS programme of ESA.

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IMPROVING COASTAL ECOSYSTEM BENEFITS UNDER INCREASING PRESSURE

Modelling bird food sources, habitats and ecosystem services is possible by using Earth Observation.

The challenge

The Wadden Sea is an internationally relevant, highly productive estuarine area, and globally, one of the largest coastal wetlands in existence. Its diverse characteristics provide fertile feeding, nursery and breeding grounds for various species. Numerous ecosystem services are provided to humans through its diversity, functionality and aesthetics. However, in recent years increasing pressures have led to multiple changes in the area, for example the number of migratory bird species has decreased, and the area of spawning grounds for critical fishery species has been impacted. Earth observations help to monitor these issues and determine trends and potential pressure impact zones, particularly through the use of the new Sentinel series of satellite imagery, with the aim of nature conservation and monitoring ecosystem functioning.

The space based solution

Models such as 3D-biogeophyiscal process-based and Bayesian Networks help to investigate ecological structures behind shifting trends and provide a foundation to evaluate and forecast the impact of potential management strategies. Direct outputs such as maps of indicators generated by Delft-3D modelling suite and impact assessments



Composite optical remote sensing image of the Dutch Wadden Sea, highlighting the intertidal mud flats.
© Rijkswaterstaat

developed through expert analysis are used by municipalities, and government agencies to evaluate regional productivity and species habitability throughout the Wadden Sea. Satellite images can be processed to detect areas with high mussel and cockle abundance, or the algae and phytoplankton which they feed upon; this can be used in the validation or support of modelling efforts or as stand-alone monitoring products as provided by the COPERNICUS platform. When these images are included in 3D models through the use of data assimilation methodologies (either automated calibration or state-updating), enhanced predictions on system trends and the dynamics within the Wadden Sea can be made. By incorporating the policy and management strategies into the modelling regime, impacts of the strategies on various ecosystem services and functions can be deduced by interpreting the resulting indicators. Additionally, Earth observations used by national and regional monitoring agencies can be used in conjunction with statistical modelling activities, such as Bayesian Networks, which are able to describe ecosystem services and highlight their potential trade-offs through probabilistic impact relationships. These networks are trained with a combination of remote sensing data and an ensemble

"Copernicus products provide us with vital marine ecosystem information which allows us to enhance our models and monitor ecologically relevant proxy variables in order to inform and advise policy directives and management."

Deltares

of model outputs which aim to capture the impacts of management scenarios. This generates relationships between proposed policy and expected outcomes based on data.



One of the many nesting avian species residing in the Wadden Sea.

Benefits to Citizens

Without data from satellite missions and complimentary in-situ measurements, model development is limited; these data sets are critical for the foundation of Bayesian Networks. Satellite images provide information on vital proxies to quantity ecosystem services, trade-offs, and management strategies' impacts over time, helping inform on the decrease of birds whilst simultaneously providing data on key ecological indicators. Earth observation is much more cost-effective and less time consuming than monitoring programmes which require expensive vessels to conduct missions. Satellite images record

near real-time observations; resulting maps are used to visualise and explain trends to policymakers. Moreover, space-based observation allows users to acquire continuous spatio-temporal data, improving the overall monitoring practices in the Wadden Sea. Earth observations, derived products and models used for the Wadden Sea support decision making and inform measures to protect and conserve this unique ecosystem.

Outlook to the future

The development of ecological models based on satellite observation assists in the development and verification of the suitability and optimisation of managerial strategies. More accurate predictions will be possible thanks to higher data availability and the coupling of said data with predictive modelling techniques. More on this work can be found at http://www.ecopotential-project.eu/

Acknowledgements

The development of Earth observation based models of the Wadden Sea has been supported by the H2020 project ECOPOTENTIAL (Grant Agreement number 641762). In 2009, the Dutch-German Wadden Sea was inscribed on the UNESCO World Heritage List and extended with the Danish Wadden Sea in 2014.

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MAKING SEAGRASSES GREAT AGAIN

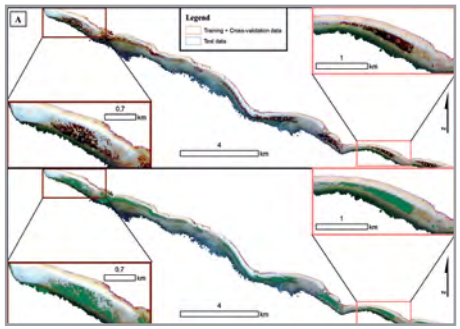
Mediterranean seagrasses are overlooked and regressed, yet they comprise the largest ocean carbon sinks. Here, we present how we are exploiting Sentinel-2 imagery to monitor Mediterranean seagrasses.

The challenge

In the era of human-induced climate change, Mediterranean seagrasses – underwater flowering plants – absorb and store carbon dioxide, the so-called "blue carbon". Posidonia oceanica which is iconic and endemic in the Mediterranean, is indeed the species with the largest stocks of blue carbon amongst all seagrasses. It could therefore act as a natural carbon capture technology, mitigating climate change. Despite being protected by EU legislation, Mediterranean seagrasses are declining. The unprecedented growth of Earth Observation is deemed necessary to resolve their existing trends, unravel data issues and allow for their better management and conservation in a time- and cost-efficient fashion.

The space based solution

Recent advances in Earth Observation in terms of optical satellite technology, cloud computing and machine learning algorithms have created the perfect storm which could aid high spatio-temporal, large-scale mapping and monitoring of Mediterranean seagrasses. More specifically, DLR and FORTH join forces towards a large-scale P. oceanica seagrass mapping and monitoring approach using Copernicus Sentinel-2 data and existing extensive field data in the entire extent of the Greek Seas (Figure 1). The enhancement of the Sentinel-2 coastal aerosol band from 60-m/ to 10-m/pixel (Figure 2) is integral in our methodology due to the resulting greater spatial information and depth range. In fact, employing this enhanced band, we mapped P. oceanica seagrass beds up to depths of 32 m in the south of Crete.



Machine learning-based classification of Posidonia oceanica seagrass meadows integrating Sentinel-2 and field data, NW Aegean Sea.
Credit: Contain modified Copernicus Sentinel data [2017]

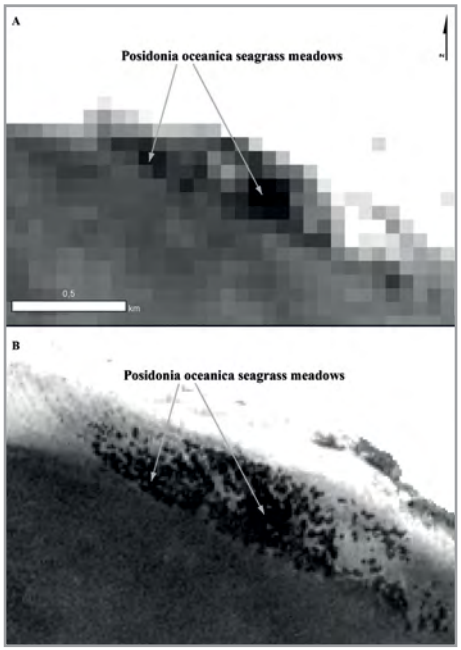
We also apply a series of corrections to decrease the interferences of the atmosphere, water surface and water column on the Sentinel-2 data, hence increasing the accuracy of the machine learning classifications.

Benefits to Citizens

Our recent satellite-based interranual change detection in the Thermaikos Gulf (NW Aegean Sea) revealed a decreasing trend in the area of P. oceanica seagrass habitat. Based on its ecological value, this translates into a financial loss of 19,264 €/yr and a further impact on the fishery grounds of the Thermaikos which exhibit the second largest fishing catch quantity in all Greek Seas. The degradation observed could be attributed to coastal development, eutrophication, but also to climate change in the broader area of the Gulf.

> *"Sentinel data can support scientists and decision makers with coastal habitat monitoring and conservation."*
>
> ***Antonis Barnias, Samaria National Park***

Generally, the twin Sentinel-2 satellites could mitigate Mediterranean seagrass degradation in a time- and cost-efficient fashion by identifying problematic areas. This would in turn lead to the successful protection of the plethora of important ecosystem services that these underwater habitats provide – carbon capture, coastal erosion protection, nursery and fishing grounds – through the creation of Marine Protected Areas.



Enhancement of Sentinel-2 coastal aerosol band 1 from 60m/pixel (A) to 10m/pixel (B) with indicated location of P. oceanica seagrass.
Credit: Contain modified Copernicus Sentinel data [2017]

Outlook to the future

In the near future, we envisage integrating our algorithms with the recently launched Google Earth Engine and the soon-to-be-launched DIAS (Copernicus Data and Information Access Services) – both cloud computing platforms – and develop workflows which we could adjust both in space and time to map and monitor seagrasses basin-wide (e.g. Mediterranean Sea) but also globally. As we are moving from Big Data to Big Indicators – where highly accurate, continuously produced, global-scale indicators monitor the health of the most vital ecosystems on Earth – we hope that our workflows will galvanise the incorporation of seagrasses to this era during which, every physical change will be indexed and related biophysical parameters, including carbon sequestration of seagrasses, will be accurately mapped, naturally, given the availability of relevant field data.

Acknowledgements

We thank the European Commission and ESA for providing Sentinel-2 data through the Copernicus Open Access Hub.

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MAPPING BURNED AREAS USING SENTINEL-2 IMAGES

An operational semi-automated burned area mapping service was developed within the context of the NOFFi project in Greece.

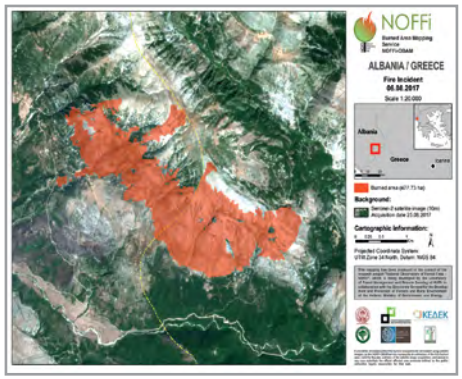
The challenge

Wildfires constitute an important environmental pressure in Mediterranean countries, with significant consequent impacts both in forested ecosystems and urban areas (e.g., increased risk of floods due to loss of vegetation cover in the wildland-urban interface). Timely burned area mapping is essential in post-fire management. However, the high number of fires, the extensiveness of the areas affected and—in many cases—the difficulty in approaching steep or remote areas render the official fire perimeter delineation, typically performed through fieldwork, a very challenging task.

Operational high-resolution satellite images constitute a cost-effective alternative in mapping wildfires, also offering much higher accuracy and timeliness than fieldwork.

The space based solution

Within the National Observatory of Forest Fires (NOFFi – http://epadap.web.auth.gr), we developed a semi-automated burned area mapping service (so-called NOFFi-OBAM), exploiting Copernicus Sentinel-2 satellite data for mapping burned areas shortly after the fire and with the highest possible accuracy. NOFFi-OBAM has been deployed and



Burned area mapping performed using Sentinel-2 imagery for a transboundary wildfire between Albania and Greece in 2017.

operationally used in Greece, on a national level. The service (implemented as a plugin in the free and open-source GIS software QGIS), was first employed on a pre-operational basis during the 2016 fire season, mapping 30 large wildfires in Greece (25,683.72 ha in total), two in Cyprus and one between Greece and FYROM.

During the 2017 fire season the service was employed systematically, mapping burned areas from 97 wildfires in Greece (20,709.67 ha in total) and two between Albania and Greece. In addition, a network with representatives from all local forestry offices was created, in order to establish a direct line of communication between the providers of the service and the primary stakeholders. As a result, in certain cases even burned areas less than a hectare were mapped, if the local forestry office believed it was important.

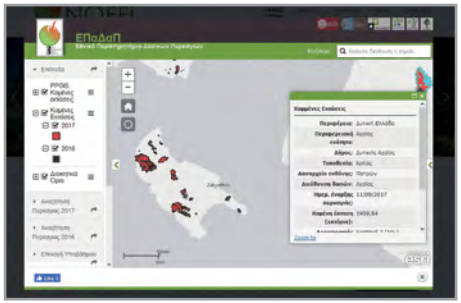
Although the methodology allows the use of other high-resolution satellite data, we almost only used Sentinel-2 images in both fire seasons, because they have an almost optimal spatial resolution for burned area mapping and – most importantly – high image acquisition frequency. In 2017 in particular, when Sentinel-2B had also been delivering images, the average time to

> *"The Sentinel-2 based NOFFi-OBAM service constitutes a new invaluable tool in post-fire management."*
>
> ***Antonios Kapetanios, Directorate General of Forests and Forest Environment, Hellenic Ministry of Environment and Energy***

produce a mapping was 6 to 7 days after the start of the fire.

Benefits to Citizens

Accurate and timely burned area mapping is essential for designing both short-term ecosystem restoration measures and direct pre-emptive measures that can mitigate the possible impacts of the fire/heavy rainfall combination (soil erosion, increased debris flow, floods, etc.). Hence, the results were also used by the General Secretariat for Civil Protection, as well as NGOs. Timely burned area mapping is also important for monitoring and safeguarding against illegal activities within the affected area. We also found a few cases where a Sentinel-2 image was acquired just after the start of the fire, highlighting the exact starting location. These



WebGIS platform developed to disseminate the results of the project, which also incorporates a burned area viewing service, open to the public (http://epadap.web.auth.gr/?lang=en).

cases were communicated to the authorities responsible for investigating the causes of the fire.

Outlook to the future

NOFFi-OBAM has received very positive feedback from all stakeholders that used the service. The service will be further developed through a follow-up project due to begin shortly, which will also evaluate the possibility of exploiting the active fire products of Sentinel-3 for automatically initiating the mapping process. Moreover, additional funding is currently being pursued for securing the observatory's uninterrupted operation. NOFFi also includes two other services related to fire prevention and risk assessment (a fuel type mapping service and a midterm fire danger index), which are also plans to exploit Copernicus Sentinel data in the future.

Acknowledgements

This work was supported by the NOFFi project, which is implemented in collaboration with the Directorate General of Forests and Forest Environment of the Hellenic Ministry of Environment and Energy and funded by Greece's Green Fund.

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MONITORING COASTAL WATERS IN NEAR REAL TIME

SAIMON is a Near Real Time satellite network for monitoring the Eutrophication Risk in the Coastal waters of the province of Thesprotia (Region of Epirus, Greece).

The challenge

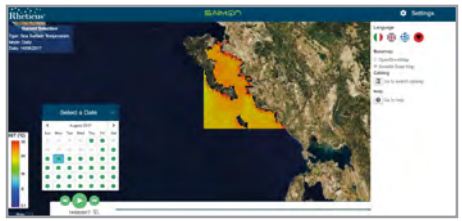
In order to monitor the Eutrophication risk in the Coastal Waters of the Epirus Region, a service has been developed for the Water Directorate of the Decentralised Administration of Epirus and Western Macedonia.

The most accurate method of measuring water quality in coastal areas is the collection of data on the field. These parameters that define the status of water quality are described in the EC Water Framework Directive (WFD) of 2000 and the Marine Strategy Directive (MSFD) of 2008.

The challenge SAIMON (SAtellite Near Real Time Monitoring Network) had to meet was to provide accurate measurements of the data needed for defining the risk of Eutrophication in near real-time without having to have daily on-site measurements. With this solution, the region would be able to provide directly to its users (fish farmers, scientific community, citizens) accurate data with much lower operational costs and with a wider area coverage.

The space based solution

A space-based solution was the key in order to meet the challenge described above.



SAIMON user interface for the monitoring of Eutrophication Risk in the Coastal area of Epirus region.

SAIMON, a cloud-based geoinformation service, was developed for monitoring Eutrophication Risk in the wider Coastal Area of Epirus Region.

Sentinel-3 data were used for extracting information about important parameters such as: Chlorophyll, Sea Surface Temperature and Water Transparency.

These parameters are being inserted automatically into the SAIMON service. Every time new Sentinel-3 Imagery is available over the area of interest, the service downloads it automatically, performs all the measurements for the parameters needed and produces the results for the specific day. These results are thematic maps with a range bar legend for each of the measured parameter.

The service is provided using Rheticus®, an automatic cloud-based geoinformation service platform and is available through http://saimon.rheticus.eu/saimon

It is worth mentioning that the Water Quality monitoring service was initially designed and developed within the framework of the ESA funded MarCoast project.

With SAIMON, the Water Directorate is able to have a reliable tool that covers a wide area and works in all weather conditions.

"Thanks to the SAIMON, we are able to provide to our citizens accurate and reliable information about the Eutrophication risk in our regions coastal area on a daily basis."

Serafim Tsipelis, Director of Water Directorate of Decentralized Administration of Epirus and Western Macedonia



Chlorophyll measurements in SAIMON service for Water Directorate of Decentralized Administration of Epirus and Western Macedonia

Benefits to Citizens

One of the important duties that the water directorate of the Decentralised Administrations of Greece has to do is to provide to its users, who are fishermen, fish farms, scientific community or even the citizens, all the information needed concerning the quality of the water in the coastal areas they live and/or work in.

With SAIMON, this information is provided reliably, accurately and directly to people who can have an easy access to the service. This makes SAIMON a valuable tool for fishermen and fish farms for monitoring changes in the fish population and provides them with all the necessary information to make decisions regarding their production.

Furthermore, it is a great tool for the scientific community to monitor the Epirus Coastal area in near real time, watch the tendencies over a period of time and predict or even prevent the consequences of the Eutrophication Phenomenon.

Outlook to the future

The Water Directorate of Decentralised Administration of Epirus and Western Macedonia had faith in developing and adopting innovative technologies in order to improve their environmental monitoring services they provide to their citizens whilst reducing the costs of using traditional on-site measurement methods.

With the increasing availability of satellite data through the Copernicus programme and the successful practices and examples that have already been deployed in several sectors, a great range of opportunities in environmental monitoring is presented.

Solutions to citizens' everyday problems should always be the lead objective in designing new innovative technologies for improving their lives. SAIMON is a great example of how to approach the problem and finally develop a successful service for solving it.

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MONITORING MOUNTAIN GRASSLAND TO SUSTAIN WILD HERBIVORES

Combined use of Earth observation data and empirical models support the management of wild herbivores and biodiversity of the Gran Paradiso National Park, in Italy.

The challenge

High-altitude grasslands, essential for the sustainment of mountain herbivores, are semi-natural habitats resulting from agro-pastoral activities and represent more than 30% of the surface in Gran Paradiso National Park.

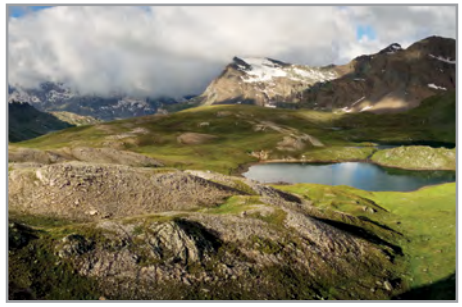
The abandonment of traditional management practices, together with climate change, are altering their plant composition and growth, leading to tree encroachment, affecting the net ecosystem CO_2 exchange and causing a decrease in biodiversity.

All such changes can seriously affect both the traditional landscapes and wild animal populations, also reducing the attractiveness of the park for sustainable tourism.

Detailed surveys are necessary but extremely difficult in remote areas covered with snow for a large part of the year.

The space based solution

The H2020 project ECOPOTENTIAL assessed the status of mountain grasslands in Gran Paradiso National Park by investigating the ongoing and expected changes in rainfall, plant productivity, biodiversity and carbon cycling in meadows under different climatic, environmental and land-use regimes, using



High altitude grasslands at the Nivolet Plain (Gran Paradiso National Park).
© Antonello Provenzale

in situ data, models and climatic projections, and deriving plant productivity, snow cover, surface temperature, as well as changes in land cover from MODIS, Landsat and Copernicus Sentinel 2 data.

The park managers and the scientific staff can now rely on Earth observation derived data, elaborated using several models and algorithms, to programme and optimise field surveys and management actions.

Remote sensing derived data like vegetal biomass growth, weekly updated snow cover maps and identification of anticipation of green-up inform empirical models on the dynamics of large herbivore populations that can be used by the park technical staff to understand criticalities affecting population trends.

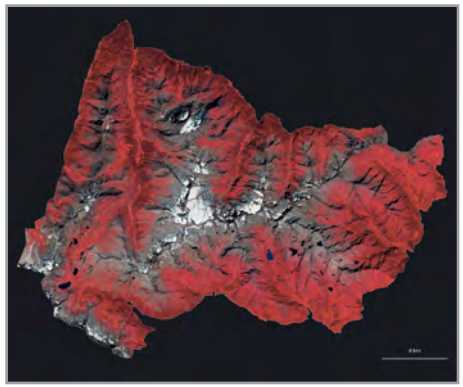
Benefits to Citizens

The use of Earth observation products has led to a deeper knowledge of the park's territory, enabling better management of the park and the optimisation of its resources. This has also resulted in a reduction in the cost of on-site monitoring and targeting management intervention, resulting in a more efficient use of public economical resources.

In particular, maps of land use change can

> *"The use of Sentinel data has improved the control and management of high altitude grasslands providing plenty of information for remote areas."*
>
> *Ramona Viterbi, Gran Paradiso National Park*

be used for planning interventions in the management of forest encroachment as well as in informing the management plan of the park and taking decisions regarding permitting.



Copernicus Sentinel-2 false colour image of Gran Paradiso National Park. Red and brown areas correspond to forest and prairies (acquired *on 23/07/2016). © CREAF for ECOPOTENTIAL Consortium. Credit: Contains modified Copernicus Sentinel data [2016]*

The array of available data, also combined with population dynamics and distribution models, allows more effective monitoring of the park's biodiversity and herbivores' survival. Overall, more effective knowledge-informed decisions can be taken, allowing an improvement of conservation of the natural landscape and animal populations that also sustain ecological tourism in the Park, whose mission is to protect species and habitats, contributing to the implementation of the EU biodiversity strategy, and to preserve

important ecosystem services such as water and climate regulation.

Outlook to the future

Protected areas need multiple monitoring tools, combined with ecological and biogeochemical modelling and data analysis. The ECOPOTENTIAL project is currently working with 24 protected areas across Europe and beyond in improving the use of Earth observation for the management of protected areas. ECOPOTENTIAL is developing an open on-line platform linked to the information system of the international Group on Earth Observations, which will host remote sensing derived data, ecological models and tools targeted to protected areas, that can also be used by non-experts in remote sensing technologies.

Acknowledgements

The ECOPOTENTIAL project is funded by the European Union's Horizon 2020 research and innovation programme (grant agreement No 641762).

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REGIONAL FLOOD MONITORING WITH SENTINELS DATA

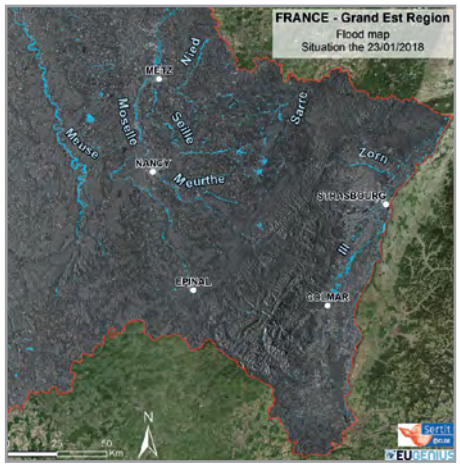
Complementary to the Copernicus Emergency Management Service, a dedicated service for local flood monitoring is also available at regional level for small and mid-size events.

The challenge

The importance of water resources and the increasing frequency of flood events around the world over the last few decades, emphasise the need for timely and cost-effective monitoring. Earth Observation technique has already demonstrated its capacity in detecting and monitoring flooded areas. For flood emergency situations, geo-information and maps related to large scale catastrophic events are provided to Civil Protection organisations or NGOs within the framework of the Copernicus Emergency Mapping Service (EMS Rapid Mapping).

In the case of regional (local) small and mid-size flood events, until now, no service has been available for systematic observation and monitoring of flood footprint evolution in space and time. This requested information should support application domains such as environment, biotopes, wetland and water management, flood prevention plan and flood modelling, land planning or the insurance sector.

The Sentinels constellation constitutes a milestone in the spatial and temporal improvements of satellite systematic observations, which is of special interest for flood information collection. These satellites are able to ensure efficient routine



Main rivers of the French Grand Est Region: flooding situation, the 23 January 2018.

surveillance mission, which has opened the door to the setting up of a regional systematic Flood Monitoring Service, filling the gap in flood related geo-information user demand at local level.

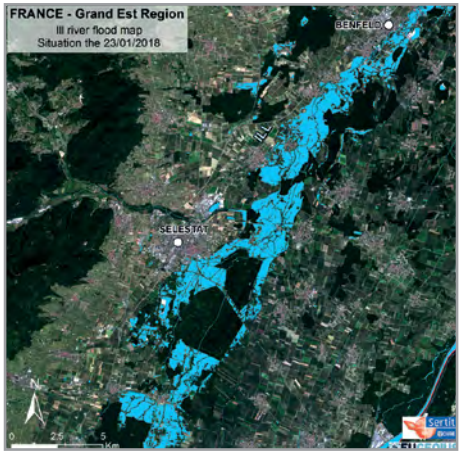
The space based solution

Within the framework of the EUGENIUS H2020, an European network of service providers is delivering geo-information services to the regional and local European market; based on the combined exploitation of Copernicus satellite data (especially Sentinel-1 and Sentinel-2) and local data, a common catalogue of thematic services has been set up, amongst which, the regional flood monitoring service delivered by SERTIT.

This service allows for the collection of geo-information related to ongoing regional plain floods. During the event, thanks to the high revisit frequency of the Sentinels satellites, the flood extent, observed at the time of acquisition, and its evolution, can be delivered shortly after EO data reception. After the event, flood maximum extent, impact, or duration, are also proposed. Geo-information related to

> *"My colleagues from the environment and the flood departments are very interested; this information would complement the theoretical models very well."*
>
> ***Frank Pouvreau, Direction départementale des territoires du Bas-Rhin, French Ministry of Ecological and Solidarity Transition***

past events may also be provided through the exploitation of archive satellite data.



Ill river flood extent, upstream of Strasbourg city, observed by Sentinel-1A satellite on 23 January 2018

Benefits to Citizens

Deployed in the French Grand Est Region during the first year of the project, the flood mapping service demonstrated its usefulness during the large flood events which have affected France in January 2018. Whereas Copernicus EMS, activated over the Northern part of France, and the surrounding areas of Paris, was in charge of the rapid mapping of the Seine river flooding, and its main tributaries (EMSR265), the regional

flood mapping service was monitoring the evolution of the situation of the main rivers in the North East (e.g. Ill, Meuse, Meurthe, Sarre, Zorn), thanks to the 20 successive Sentinel-1 radar acquisitions (in ascending and descending modes) with an average of one observation every 1.5 days over the month. Maps were made available to the public through SERTIT's website and geo-information products provided through the EUGENIUS regional hub which is using INSPIRE standards and allows products to be downloaded by the users' community (local authorities, 10 departments of the Grand Est Region) for further analyses (e.g. situation management, flood model tuning, flood prevention action).

Outlook to the future

Within EUGENIUS, the flood service is foreseen to be deployed in other European regions which are regularly subject to flooding (e.g. Occitania in France or Northern Greece). This downstream service illustrates the whole Copernicus value-chain benefits for the territory planning community, for flood risk prevention and management authorities as well as for individual citizens.

Acknowledgements

This project has received funding from the EU H2020 research and innovation programme under grant agreement No 730150 EUGENIUS H2020-EO-2016.

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THE POTENTIAL OF A PRE-COMMERCIAL PROCUREMENT APPROACH IN EARTH OBSERVATION

A Horizon 2020 funded project aimed at developing customised solutions based on Copernicus Downstream Services for Marine Monitoring and Security.

The challenge

The Marine-EO project teams up a group of five maritime authorities (the Buyers Group) and four scientific and technical organisations with significant experience in Earth Observation and maritime matters. These institutions face a common challenge which is to develop, test and validate a bundle of innovative EO downstream services, bringing incremental or radical innovations in the field of maritime awareness, leveraging on the existing Copernicus Services (i.e. CMEMS, Security) and other products from the Copernicus portfolio. At the end of the PCP process, the services that will be procured are expected to contribute to the Common Information Sharing Environment (CISE) and other relevant frameworks related to maritime awareness.

The space based solution

The Marine-EO project seeks to establish EO-based services, covering sea-basins of the Mediterranean, Atlantic, and Arctic, by adapting Copernicus data and information regarding the Marine Environment, to meet the demand of the procurers.

The innovative services are divided into two thematic areas:

- Thematic Area 1 – Copernicus Marine Environment Monitoring and Climate Change: The SATOCEAN service provides information about ocean parameters variability in time and space, best probable fishing areas, fish farm locations, and water quality. It also incorporates sea ice extent for safe navigation and maritime operations in the Arctic.
- Thematic Area 2 – Copernicus Security: The SATSURVEILLANCE service contributes to the development of EUROSUR regulation, by providing services in response to Europe's security challenges in the domains of Border Security, as the monitoring of unusual/irregular activity around a Critical Infrastructure and the enhanced change detection for evidence of embarking or disembarking of irregular immigrants.

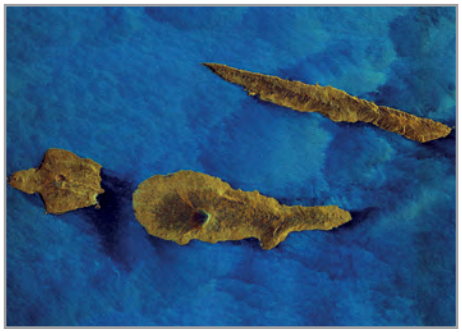


The map shows the coastal erosion susceptibility status in Santa Maria Island (Azores) and aims to provide comprehensive knowledge of the potential impact on Azores islands of different natural disasters as well as identify assets at risk. The map was produced on 22/12/2015 by GEOAPINOKISIS (EL) – NOA (EL) –CIMA (IT)-ALTAMIRA (ES) under the service contract nr. 259811 of the EC.
Credit: Contain Copernicus Sentinel data [2015]

Benefits to Citizens

Overall, the project will contribute to European society by meeting the objectives defined in the Commission Communication on Space Industrial Policy whilst simultaneously increasing the visibility of one of the main EU space flagships: Earth Observation. Marine-EO will ensure that Europe's investment in space infrastructure is exploited to the benefit of citizens and supported by European space science. Furthermore, the Marine-EO project will promote the development of innovative products and services based on remote sensing, geo-positioning or other types of satellite-enabled data as well as geo-information already generated by services such as authorities to pursue a shared and comprehensive approach to maritime security risk analysis and to make informed decisions in operationally relevant timelines by increasingly supplying them with diverse imagery, intelligence products, and services.

> *"Marine-EO will provide relevant new tools for monitoring one of the biggest EEZ in Europe: The Azores archipelago."*
>
> ***Filipe Porteiro, Regional Director of Maritime Affairs***



This Sentinel-1A radar image was processed to depict water in blue and land in earthen colours. It features some of the Azores islands and highlights the differences in the relief of the islands, with volcanoes and mountains clearly standing out.
Credit: Contain Copernicus Sentinel data [2015]/ESA, CC BY-SA 3.0 IGO released on 09/10/2015

BIODIVERSITY AND ENVIRONMENTAL PROTECTION

A more effective marine monitoring service will be beneficial for the Portuguese, Spanish, Norwegian and Greek citizens in regards to some of their more precious natural resources. The Mediterranean Sea based Public Authorities, working on security, will be able to access new services and subsequently take more accurate action as well as protect their assets.

Outlook to the future

After a successful implementation of the Pre-Commercial Procurement, the buyers' group will apply a dedicated plan to support large-scale deployment of innovative solutions. This process will link to the use of European Structural and Investment Funds (ESIF). Several "High-Level Scenarios," which will primarily form the EU cooperation umbrella in the EO services for maritime surveillance, will be prepared for the post Marine-EO period. The potential continuation of Marine-EO activities through a Public Procurement of Innovative Solutions (PPI), the reinforcement of EU cooperation and the interaction with the Copernicus services about future initiatives, will be addressed.

Acknowledgements

This project received funding from the EU Horizon 2020 R&I programme under grant agreement nº. 730098.

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1. Fundo Regional para a Ciencia e Tecnologia, Portugal
2. NCRS Demokritos, Greece

TREE SPECIES MAPPING WITH MULTITEMPORAL SENTINEL-2 DATA

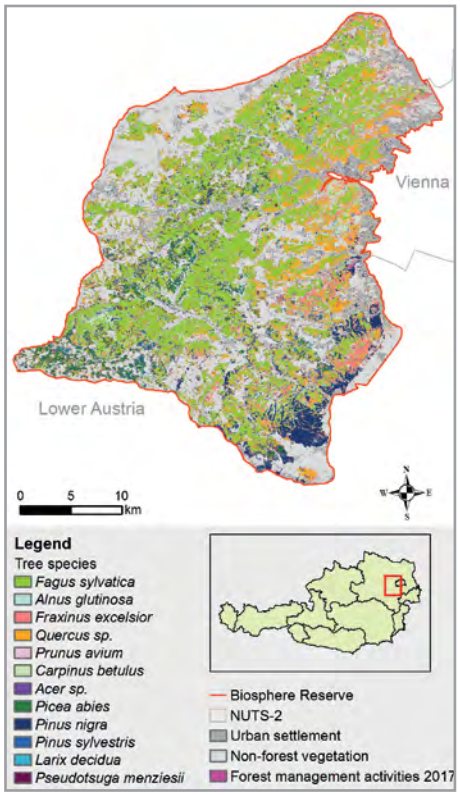
Derivation of main land cover classes and a detailed tree species distribution map from Copernicus datasets in UNESCO's Biosphere Reserve Wienerwald.

The challenge

UNESCO's biosphere reserves are model regions for promoting and developing sustainability. Ecological balance, economic security and social equity are the three pillars. In biosphere reserves, stakeholders aim to develop, implement and evaluate models of sustainable use. This requires detailed and up-to-date information about the biosphere including its natural assets. The biosphere reserve Wienerwald (BPWW), founded by the federal States of Lower Austria and Vienna, covers an area of 105,645 hectares (of which 60% is forest) and extends across 51 communities in Lower Austria and seven municipal districts of Vienna. Some 815,000 people live in the region of BPWW which incorporates 15 nature preserves. Unfortunately, the current information about the forest ecosystem is based on a patchwork of different data sources and is not up-to-date.

The space based solution

We demonstrate how Sentinel-2 (S2) satellite data can be used to support land administrations such as biosphere reserves to achieve their goals by providing detailed land cover and tree species related information. With its high spatial, spectral and temporal resolution, the twin constellation of S2



Cumulated tree species and land cover product from the Biosphere Reserve Wienerwald derived from Copernicus S2-data.

satellites delivers earth observation data of unprecedented quality. The sensors on board of S2 capture 13 spectral bands at 10, 20 and 60 m spatial resolution and pass every point on Earth at least every five days (even more frequently in areas of overlapping orbits). Using advanced image processing tools and machine learning techniques, it is possible to produce highly accurate and up-to-date tree species maps from time series of S2 images. In our case study, we used 18 cloud-free S2 scenes acquired between August 2015 and October 2017 for the classification of 12 tree species (seven broad-leaved and five coniferous species) and four non-forest classes (grassland, agriculture, built-up and water). The developed semi-automated workflow includes feature selection and model optimization. In addition, we implemented a change-detection application to monitor forest management activities. Copernicus data enables us to achieve consistent and spatially accurate mapping of tree species.

> "Land cover and tree distribution are main interests of the biosphere reserve management. With the aid of these two products we have a solid database for monitoring and know where to focus, for instance, when it comes to the topic of green corridors."
>
> ***Dr. Herbert Greisberger, Director, Biosphere Reserve Wienerwald***

Benefits to Citizens

The derived product represents the first tree species distribution map of the BPWW and now constitutes an important basis for the sustainable development of the reserve. The established workflow serves as an efficient tool to detect the high variety of tree species which is crucial for the maintenance of current ecosystem services in one of Europe's largest contiguous broad-leaved forests. Furthermore, the product can be used to derive parameters which are directly related to the recent utilization of forest resources in the biosphere reserve. Forest enterprises, forest authorities and administrations, as well as site managers, benefit from such detailed tree species and timely forest change mapping. The tool and methodology can be applied globally for similar classification tasks. Additionally, the proposed space based solution contributes to several projects initiated by the University of Natural Resources and Life Sciences Vienna (BOKU) and the BPWW Management. Furthermore, students of various master programmes at BOKU can directly benefit from the gathered knowledge on effective exploitation of S2 data for tree species mapping.

Outlook to the future

The potential value of other Copernicus missions is well recognized. We work on approaches to combine S2 imagery with remotely sensed data from other sensors (e.g. of the Sentinels constellation) to further increase classification accuracy, class depth and the spatial resolution of our product. Application of our method in other forested areas and/or other biosphere reserves would be highly appreciated.

Acknowledgements

We thank our project partners Austrian Federal Forests (ÖBf), Forestry Office and Urban Agriculture of Vienna (MA 49) and forest enterprise of Heiligenkreuz Abbey for providing reference information. The research was partly supported by the Austrian Research Promotion Agency through the ASAP project 854027 EO4Forest.

Markus Immitzer [1], Martin Neuwirth [1], Sebastian Böck [1], Francesco Vuolo [1], Clement Atzberger [1], Harald Brenner [2] and Herbert Greisberger [2]
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2. Biosphärenpark Wienerwald Management GmbH, Austria
Email: markus.immitzer@boku.ac.at

WETLAND FUNCTIONAL ASSESSMENT

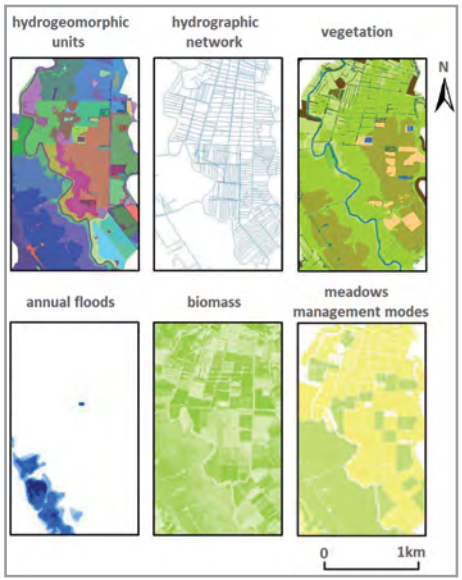
Hydrological, biogeochemical and ecological wetland functions can be assessed using Earth Observation data and multi-criteria analysis to meet the challenges of wetland management and conservation.

The challenge

Wetlands have hydrological, biogeochemical, and ecological functions that are widely recognised. Traditionally, functional assessment approaches have been based on field observations, and therefore, have been limited to sites of a few hectares. However, some processes, such as nutrient fluxes that influence water quality, need to be considered on a catchment scale. Earth observation data represent a potentially practical and economically suitable tool for extracting functional descriptors of wetlands.

The space based solution

Wetland functions are differentiated into spatial units accounting for multiple criteria extracted from various spatial data source. These wetland-related geographic information system layers are derived from Earth observation data available on a fine and large-scale making this method reproducible on any other study sites. The spatially-explicit criteria used to map these functional indicators are the following: a map of the hydrogeomorphic units, a hydrographic network map, a vegetation map, a map of annual floods duration, a map of biomass production, a map of the meadows management modes and finally a map of the external limits of the



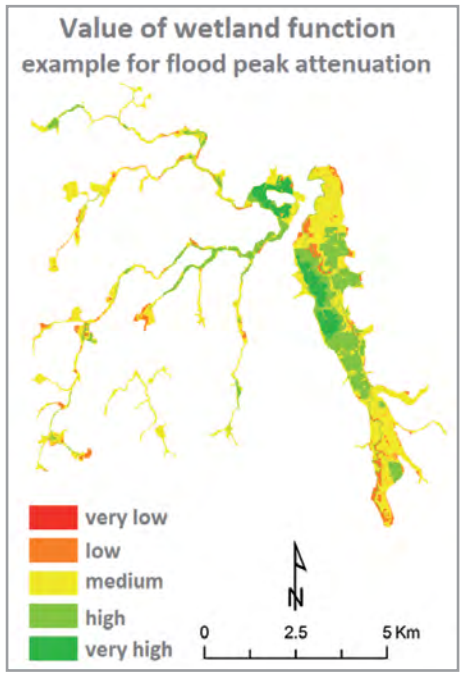
GIS layers derived from Earth observation data that were used to characterize the wetlands examined; Couesnon marshes, Brittany, France.

wetlands All these maps can be derived from airborne-based and/or space-based solutions such as Lidar and stereoscopic data, optical and radar time-series from which vegetation indices are extracted for instance. All these maps express the controlling variables that determine the functional performances of the wetlands for various ecosystems services. They are then combined using multi-criteria analysis to evaluate the overall functional assessment of wetlands.

Benefits to Citizens

Most of the described data are freely available, which is of great interest for managers. Mapping of hydrological, biogeochemical, and ecological wetland functions over large areas is an efficient tool for policymakers and other stakeholders including water authorities, nature conservation agencies, and farmers. To date, the feedback received from managers highlights the usefulness

> "This application has transformed the way we manage the public land of Sougéal marshes for biodiversity and conservation issues."
>
> *Aurélien Bellanger, Communauté de Communes du Pays de Dol et de la Baie du Mont-Saint-Michel*



Map of wetland functions at the catchment scale. Example for the Flood peak attenuation; Couesnon marshes, Brittany, France.

of European Functional Assessment Procedures (PROTOWET, EVALUWET) in mapping and simulating ecosystem functions across different scenarios; this facilitates compromises amongst the stakeholders. Furthermore, these maps have enabled a characterisation of the functional connections that are present at catchment level, and this has led to the objective identification of sites that qualify for restoration or compensation

measures under the Habitats and Water Framework Directives of the European Union. Specifically, this tool has the potential to provide a mapping of ecosystem services, conservation management priorities, and possible improvements in water resources management.

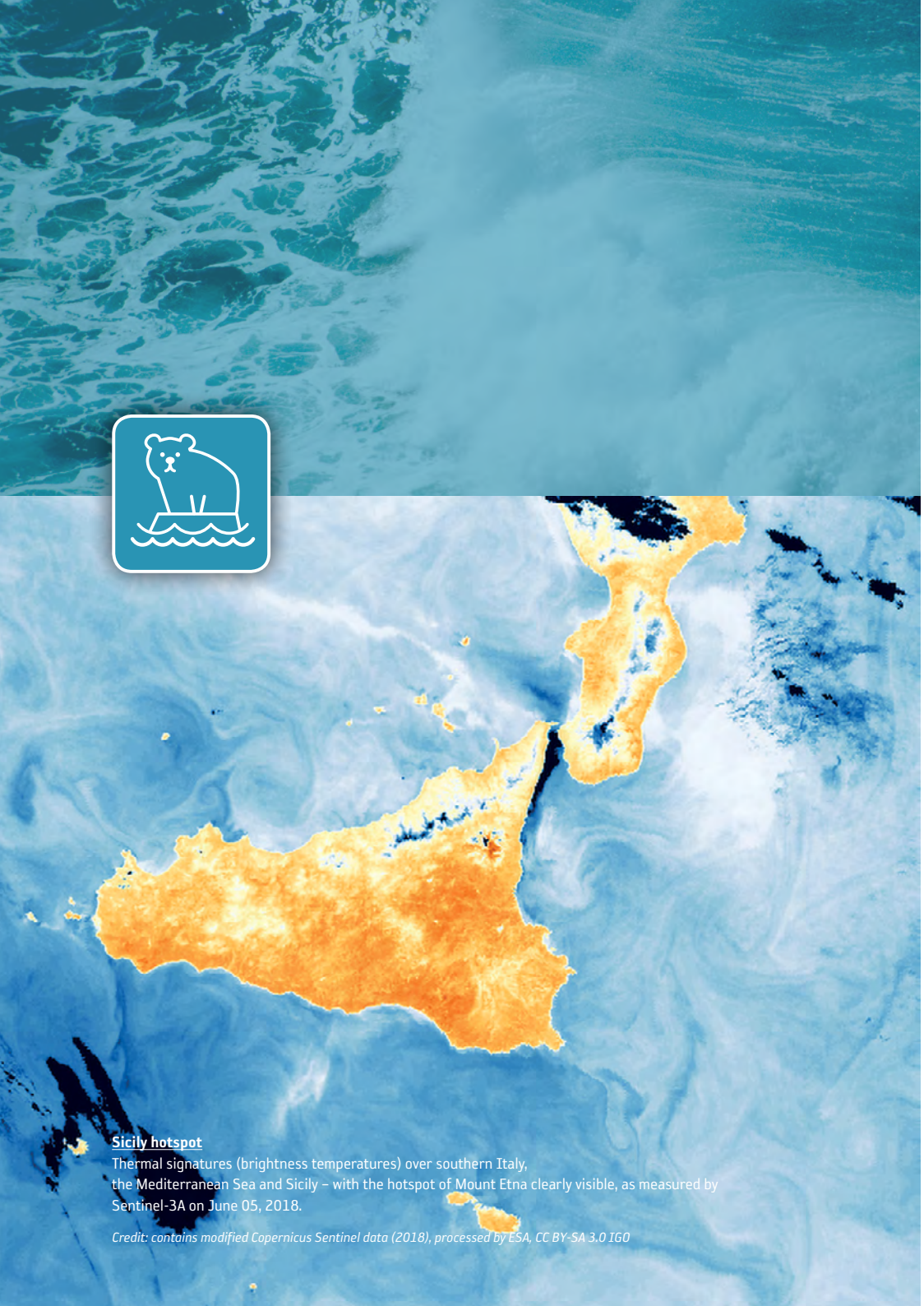
Outlook to the future

Lately, preliminary tests using cost-free Sentinel-1/2 time series pointed out that this data could improve the result. Specifically, multispectral Sentinel-2 data provide a more detailed characterisation of vegetation at the level of plant associations, whilst SAR Sentinel-1 time-series are relevant to accurately monitor surface water extent. Thus, Sentinel data should lead to the development of finer descriptors related to soil properties, such as moisture content or nutrient concentrations.

Acknowledgements

This study was supported by the Zone Atelier Armorique programme (CNRS), KALIDEOS Bretagne (CNES). We are also grateful to local authorities (Communauté de Communes du Pays de Dol et de la Baie du Mont-Saint-Michel) and water managers (SAGE Couesnon).

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Sicily hotspot
Thermal signatures (brightness temperatures) over southern Italy, the Mediterranean Sea and Sicily – with the hotspot of Mount Etna clearly visible, as measured by Sentinel-3A on June 05, 2018.

Credit: contains modified Copernicus Sentinel data (2018), processed by ESA, CC BY-SA 3.0 IGO

CLIMATE, WATER AND ENERGY

Water is life. In too many regions in Europe and worldwide, this precious resource is coming under increasing pressure, in particular from economic activities. In parallel, demands for energy are ever increasing, calling for secure, affordable and sustainable production practices. Climate change affects the availability of water and energy in multiple ways. Effective mitigation and adaptation measures need to be taken to reduce exposure and vulnerability to shortages of water and energy and to many other aspects induced by climatic changes. However, it is apparent that with demands for energy, water, and food growing around the world, there are many opportunities for the needs in one area to produce unintended outcomes in another, with unexpected broader economic, environmental, and security consequences. Understanding the implications of these linkages is indispensable to the development of sound policies. In this respect, the EU and its Member States agreed to a global action plan for climate to put the world on track to limit global warming to well below 2°C. In parallel, other relevant policies provide for "good quality" rivers, lakes, ground and coastal waters (e.g. EU Water Framework Directive) and for ensuring progress towards a carbon-free economy by 2020 (e.g. EU Renewable Energy Directive). Well-informed action must be taken at all levels: global, regional, national, and local solutions are needed to tackle systemic problems facing the Earth and its interactions with society. At regional level, mitigation and adaptation to climatic changes will occur most efficiently where local water and energy agencies can pool resources and competences to address issues that will inevitably cross local boundaries. Through its dedicated Climate Change Service, Copernicus provides authoritative, quality-assured information to help our understanding of climate change and inform the development of policies addressing mitigation and adaptation measures. This leverages on all relevant Earth observations data and on information available from the other Copernicus Services. Data from all Copernicus Sentinel satellites are relevant in this respect, being related to e.g. glaciers and ice-sheets (Sentinel-1), sea surface temperature and ocean surface height (Sentinel-3), methane, ozone and cloud/aerosol (Sentinel-5P). Copernicus data and products can support the development of sustainable practices related to water and energy management through e.g. monitoring of inland water basins and snow/glaciers or performance forecasting for renewable energy sources such as solar, wind and hydropower.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
EARTH OBSERVATION AND THE COASTAL ZONE: FROM GLOBAL IMAGES TO LOCAL INFORMATION	South Holland (Zuid-Holland)	European coasts (UK, Spain, Romania, Netherlands)	S1, S2	3
KEEPING TRACK OF RETREATING GLACIERS IN ICELAND	Iceland (Ísland)	Landsbyggð	S2	5
NEW LEVEL OF BALTIC SEA MONITORING USING SENTINEL-3 DATA	Lesser Poland Voivodeship (Małopolska)	Pomeranian Voivodeship	S3	3
SATELLITE IMAGERY FOR AN IMPROVED COASTAL MANAGEMENT	Nouvelle-Aquitaine	Nouvelle-Aquitaine	S2	3/4
SATELLITE MONITORING OF SUSPENDED PARTICULATE MATTER	Basilicata	Basilicata	S2, S3	2
SENTINEL-2 MISSION SUPPORTS COASTAL MANAGEMENT FOR OPTIMISED DECISION MAKING	Cádiz (Cádiz)	Andalusia - Cádiz	S2	3
SPACE-BASED APPROACH TO MONITORING PEATLAND RESTORATION	North Yorkshire	North Yorkshire	S1, S2	3
TRACKING ALGAL BLOOMS ON THE CURONIAN LAGOON	Klaipeda County	Lithuania	S2, S3	3
TRACKING STORMS AND HURRICANES USING SAR IMAGES	Brittany (Bretagne)	Europe + Tropical areas, including French Overseas Departments	S1	3
A VIEW OF YOUR INLAND WATER BODIES FROM SPACE	Lombardy (Lombardia)	Lombardy Umbria United Kingdom The Netherlands Estonia Lithuania	S2, S3	4
DON'T POUR MONEY DOWN THE DRAIN -FIX IT!	Midtjylland	Midtjylland - Vestjylland	S1	4
GLOBAL REAL TIME ONLINE WATER QUALITY MAPPING	Central Transdanubia	Central Transdanubia Western Transdanubia Southern Transdanubia	S2, S3	3
INFORMING WATER RESOURCES MANAGERS IN SARDINIA	Attica (Περιφέρεια Αττικής)	Sardinia	S2	3
MONITORING GROUNDWATER FLOODING IN IRELAND USING SENTINEL-1 SAR	Dublin Region	Ireland	S1	3
WATER BODIES DETECTION ON A PORTAL	Slovenia	Slovenia	S1	4/5
HOW COPERNICUS SUPPORTS THE ENERGY TRANSITION	Oberbayern	Trier	S1, S2	3

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2; S3: Sentinel-3.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

EARTH OBSERVATION AND THE COASTAL ZONE: FROM GLOBAL IMAGES TO LOCAL INFORMATION

Copernicus helps to harness the potential of foreshores to be used as part of nature-based solutions towards reducing coastal flood and erosion risk.

The challenge

Achieving fully integrated and sustainable coastal zone management is one of the greatest challenges facing European Union Member States. Sea level rise, climate change and increasing coastal pressures, intensify this challenge, demanding innovative approaches towards coastal management, including flood and erosion risk reduction. This increased risk will necessitate increased investment in flood defence infrastructures. To reduce costs and to limit negative impacts on ecosystems, interventions that integrate natural vegetated foreshores within flood defence schemes are now being actively explored. However, to advance in such flood management approaches a better understanding of natural flood/erosion protection and robust scientific observations are needed.

The space based solution

A way forward is to use a combination of remote sensing and field data from foreshores to map vegetated foreshores and how their specific characteristics affect wave energy and erosion. This will result in novel ways of extracting relevant information from satellite images and thus to help predict the shoreline protection provided by those foreshores.



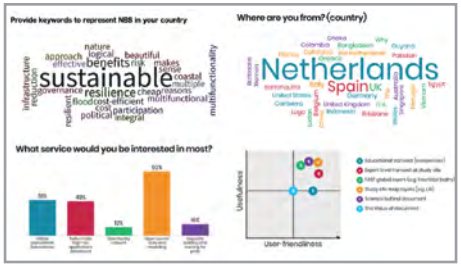
"The intricate network of channels and creeks contrasts with the regular shapes of transformed saltmarsh (right of picture)," writes Edward P. Morris, Sentinel-2 'Colour vision' photo competition.
Credit: Contains modified Copernicus Sentinel data [2017]

This approach thus makes use of scientific innovations to derive evidence and actionable information from Earth Observation (EO) resources, with a particular focus on the capabilities of the European Copernicus programme. By aligning a wide range of disciplines, this approach resulted in the generation of the MI-SAFE platform of services. On a global scale, we produce brand new open source and unique EO-based information on coastal status and flood risk parameters filling in gaps in existing datasets. At local level we deliver tailor-made highest resolution information and training relevant for coastal managers and engineers who want to integrate natural features in cost-effective Nature Based Solutions.

To generate and demonstrate MI-SAFE services, we have gathered, reclassified and produced open format layers of information on elevation, vegetation, water level and wave statistics; using EO resources (Sentinel satellite images), numerical models, but also data collected in situ. To obtain this information, enormously large datasets were digested that are open for public use. All continents are included, highest level of detail is generated for European saltmarshes. See http://fast.openearth.eu

> "This tool provides very relevant information on the coastal status and delivers this in a format beneficial for use by managers and coastal engineers helping them to design cost-effective sustainable flood safety solutions."

Prof. Dr. Ir. Stefan Aarninkhof, Delft University of Technology



Characteristics of MI-SAFE platform end-users

Benefits to Citizens

Worldwide coastal coverage allows citizens to become informed on the importance of their natural coastline for reducing flood risk. The comprehensive dataset and modelling tool is contributing to the assessment of the status of regional coastal zones for managers and policymakers. For managers and engineers, the interface is a way forward towards utilising the vastly increasing quantities of high resolution data for producing information relevant for finding nature-based flood safety solutions. The platform's shared information provides input for effective communication around nature-based coastal management options between stakeholders around possible managed realignment projects or coastal wetland restoration schemes. Its open data approach offers opportunities for 'data-collaboration' within existing open source communities. This was tested in four different European countries, hands-on training sessions and during webinars.

Outlook to the future

The MI-SAFE platform is unique in its combination of modelling and EO capability. We believe that we have created a flexible platform to further evolve and adapt to accommodating new developments in data-availability and requests from users for adapted functionalities in advanced modalities through training and cooperation.

Increasing the temporal resolution (seasonal and annual) is a valuable next step that exploits the new high-resolution sensors for the detection of coastal changes that are impacting flood safety. This requires progress on data fusion with other sensor platforms, image mining and algorithm improvements that deliver high quality information on coastal status. Together with engineers and coastal managers, the platform could be developed into a management tool that keeps observing and quantifying coastal safety and threats for whole regions of coasts in relation to increasing the impact of climate change and sea level rise.

M.B de Vries [1], I. Möller [2], G. Peralta [3], E. Morris, A. Stanica [4], A. Scrieciu, D. Van der Wal [5] and B. Van Wesenbeeck
1. Deltares, The Netherlands,
2. University of Cambridge, UK
3. Universidad de Cadiz, Spain
4. Geoecomar, Romania
5. Nioz, The Netherlands
Elaborated from the FP7 FAST project.
Grant agreement number 607131.

KEEPING TRACK OF RETREATING GLACIERS IN ICELAND

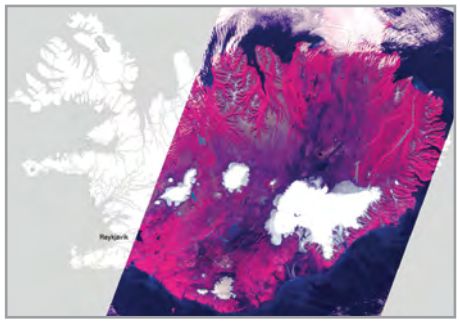
In Iceland maps and spatial data around glaciers are being updated with Sentinel-2 data, a novel way to document rapid changes due to climate change.

The challenge

The largest glaciers in Europe are in Iceland and glacial rivers flow from these to sea, crossing the road system in various places. The glaciers are generally retreating inland due to climate change and the glacial river pattern in front of the glaciers is therefore changing. The river flow tends to fluctuate from year to year, thus affecting the road system. Also, glacial outbursts are not uncommon due to volcanism beneath glacier ice. Large scale melting of ice under such conditions causes „jökulhlaup", or the sudden release of meltwater that may amount to 50.000 m3/sec, e.g. the Gjálp eruption in 1996. With a population of less than 340,000, and a total land area of 103,000 km2, Iceland is the seventh least densely populated country in the world. This means that traditional and recurrent monitoring of land from airplanes is much too expensive for glaciers in remote areas. Monitoring from space with the Sentinels is therefore a good option due to no cost, high revisit time and large area coverage, which is very important when monitoring the rapidly changing glacial landscape.

The space based solution

The National Land Survey of Iceland is responsible for maintaining a free and open



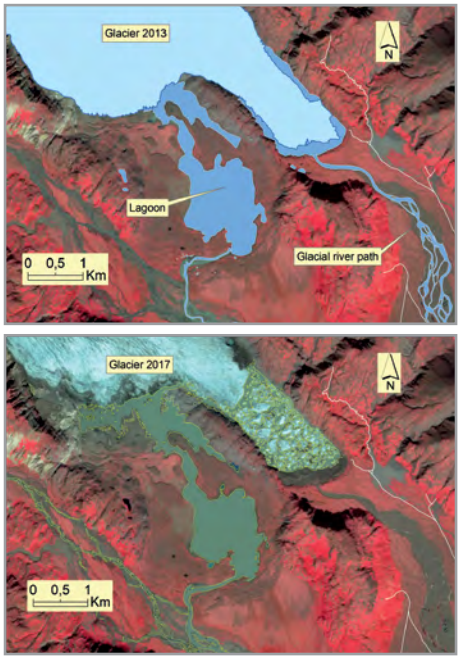
Cloud-free Sentinel image obtained August 30th, 2017 roughly covers 2/3 of Iceland.
Credit: Contains modified Copernicus Sentinel data [2017]

base map database in Iceland. A regular update of data around the glaciers has not been possible due to lack of uniform data and high cost, resulting in outdated information about the glacial river pattern and the glacier extent. The optimal solution to that problem came when the Sentinel-2A satellite crossed Iceland on 30 August 2017 and imaged nearly 2/3 of the country. This timing, i.e. late summer, enabled extraction of exact glacier outlines for almost all of Iceland`s glaciers. Thus, the Late Summer Snow Line (LSSL) is established which is an approximate for the Equilibrium Line as an indicator for the minimum annual glacier extent. Sentinel-1 and Sentinel-2 dense time series can also be used to estimate the glaciers' velocities. This image has since been used to extract the glacial river pattern in front of glaciers as well as the glacier extent. Manually, the results are cleaned by visual comparison of ground truth as seen in the Sentinel imagery.

Benefits to Citizens

Using Sentinel imagery to update the datasets around the glaciers of Iceland has many benefits. The first and most obvious is to monitor glacier retreat resulting from climate change. Also important is how this work aids the monitoring of hazardous

> "Using the Sentinel images to update our map database has not only improved our data but also our productivity."
>
> ***Magnús Guðmundsson, General Director NLSI***



Hoffellsjökull glacier extent and river pattern in 2013 (above) and in 2017 (below) showing 1-2 km retreat.
Credit: Contains modified Copernicus Sentinel data [2017]

proglacial environment, where glacial river flow paths need to be upgraded frequently to update maps and map services. This updated data makes travelling around the glaciers safer, especially for tourists with little knowledge of the glacier environment. It can also be mentioned that about 87% of the energy used in Iceland is from renewable sources of which 80% is from hydropower,

largely from glacial rivers. Monitoring the glacier environment is therefore important to secure the future of these power plants. The cost related to updating this data with Sentinel imagery is marginal in comparison to aerial, or very high-resolution satellite imagery. Compared with aerial photography the use of Sentinel imagery has the benefit of large simultaneous area coverage. For these reasons Sentinel imagery was used by the National Land Survey as the basis for feature extraction of glacial rivers and glacier extent.

Outlook to the future

The Sentinel-2 large image size and frequent revisit time, will provide the basis for monitoring future changes in glacier extent and glacial river pattern detection in Iceland. It will be possible to monitor these changes more frequently and with more precision than before. In Iceland, the largest volcanoes lie underneath the glaciers. Sentinel imagery can also be used to reveal changes in the glacier surface, such as sink depressions caused by geothermal melting of ice, that may indicate potential volcanic activity. Such rapid melting by subglacial volcanism may cause immense transport of volcanic debris/ash that can partially fill up hydro dam reservoir, thus seriously diminishing their annual capacity.

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NEW LEVEL OF BALTIC SEA MONITORING USING SENTINEL-3 DATA

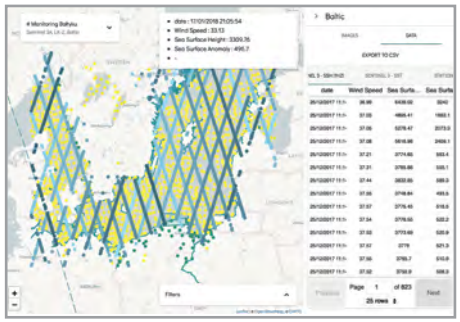
Maritime Spectator is a web-based application simplifying process of gathering satellite data and helping understand sea surface behaviour.

The challenge

Monitoring Baltic Sea levels is a very important task which ensures safe shipping and investments in coastal regions, environment protection and foremost safety for urban areas vulnerable to rapid changes in this large water body. Unfortunately, constant measurement at such a large scale is a costly and dangerous process. Very often, this makes it impossible, as even with sufficient funds this type of monitoring is difficult to carry out due to continuously varying conditions of the sea's surface. Therefore, a more technologically advanced solution was needed which could tackle this problem at much lower operational cost and without the need to directly involve humans.

The space based solution

Maritime Spectator is a web-based software solution developed for the Maritime Institute in Gdansk. It is fuelled on a daily basis by a stream of data continuously delivered by Sentinel-3. Maritime monitoring received a big boost in terms of technological capabilities thanks to the Copernicus Programme. The first two satellites allowed improvements of applications such as vessel tracking and sea pollution detection. But the biggest help came after the successful launch of the Sentinel-3



Full coverage of Baltic Sea with Sentinel-3 satellite. Sea level and temperature measurements in Maritime Spectator.
Credit: Contains modified Copernicus Sentinel data [2018]

satellite which takes maritime monitoring to another level. Sentinel-3 on its own allows monitoring sea temperature, surface height, wind speed, ice thickness and more. Maritime Spectator visualises data on the map and enables easy processing and tracking of new measurements, giving specialists access to new information just hours after the satellite passes over Baltic. This enables the analysis of the state of the sea surface, with unprecedented temporal and spatial resolution which physically would not be possible without Sentinel 3 being in orbit.

Benefits to Citizens

Maritime Spectator enables coastal authorities and institutions such as the Maritime Institute to increase the frequency of measurement and its coverage to complement their earth-based data. Thanks to Sentinel-3 data they are able to produce better and more complete products for their clients and for citizens. Better awareness of a number of parameters of the large water body opens up new possibilities for their domain. In many cases this directly translates into ensuring the safety and wellbeing of citizens spending their time at the coast in the Baltic region.

> "Possibility to retrieve and use satellite data is an invaluable addition to our analysis which allows to expand and improve its temporal and spatial extent."
>
> ***Maciej Kałas, PhD, Maritime Institute in Gdańsk***

Furthermore, through much better understanding of sea surface behaviour it provides the opportunity to optimise solutions for the shipping industry, improving the safety of vessels and transport management. Thanks to frequent data updates Maritime Spectator can fuel early warning systems for areas endangered by rising sea levels, potentially saving lives and allowing for a much more effective response in critical situations.



Sentinel-3 tracked in real time in Spectator. It allows to provide up -to-date information on overpass and data acquisition over Baltic Sea area.
Credit: Contains modified Copernicus Sentinel data [2018]

In the future, it will be also able to share information directly with the citizens, who will always have a possibility to monitor

situations for themselves in chosen areas of interest. The solutions provides completely new opportunities for understanding this large water body whose behaviour strongly affects the economy of coastal regions. Thus, its better understanding will directly convert to citizens wellbeing.

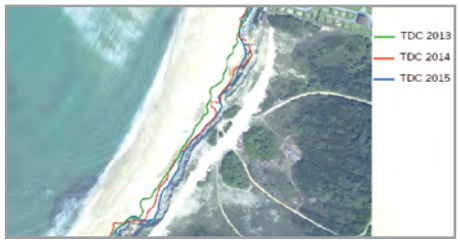
Outlook to the future

The very existence of Maritime Spectator and its increasing capabilities are directly related to what programmes, such as Copernicus, can deliver and how the European Space Sector will evolve over the coming years. That is why it is so crucial for citizens, industry and administration to fully support the development of space technologies for us all to benefit from.

Waldemar Franczak
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SATELLITE IMAGERY FOR IMPROVED COASTAL MANAGEMENT

Copernicus satellite imagery provides a new paradigm in earth observation thanks to regular, high quality imagery and accurate satellite derived products.



Coastline detection and change analysis from 2013 to 2015 in Pavillon Royal beach, Bidart, Basque country, south-west France.

The challenge

The Nouvelle-Aquitaine region features more than 700 km of coastline and presents one of the areas with the most rapid demography mostly focused on the coastal area. Coastal ecosystems are driven by complex interactions where physical processes are controlled mainly by marine forcing ranging from seconds to decades, respectively for waves to tides, winds and seasonal river discharge changes and trends over time. Therefore, nearshore and coastal environments are among the most dynamic and constantly changing on Earth. Whilst these regions play a key role at the land and ocean interface, the state of the sea surface and especially wave breaking prevent easy and safe ground observations. Whilst field observations fail to be exhaustive due to their dynamical and unsecured patterns, frequent and synoptic observations acquired by multispectral optical satellite imagery enables adaptation of coastal observation strategies and management, both for scientist and end-users.

The space based solution

Based upon ocean colour and image processing tools combined with artificial intelligence and machine learning, multi-spectral high-resolution satellite observations, including Copernicus Sentinel-2 optical sensor, allow accurate physical and biogeochemical parameters derivation. For example, they enable e.g bathymetric maps that cover the first 10 to 20 metres depth depending on the transparency of ocean waters and water constituent concentrations.

Accuracy of coastal morphological features positioning and change analysis can reach high performance achieving accurate erosional trends such as coastline change, only limited by the resolution of the space borne sensors. Lastly, in the very near future, remotely-sensed coastal indicators such as Sentinel-2 derived bathymetric charts are to be compiled by the Aquitaine Coastal Observatory in order to derive more precisely the Aquitanian erosional trends and supply recommendations for coastal management support and local strategies in order to preserve coastal zone. Integrated coastal zone management at regional scales that experience coastal erosion issues fits perfectly with the Copernicus scope as it supports sustainable marine and coastal activities, and risk mitigation strategies.

Benefits to Citizens

Coastal monitoring is supported by either time consuming field surveys, spatially limited and restricted to calm sea states to ensure human safety, or costly airborne bathymetric Lidar surveys. Conversely, satellite earth observation is identified as a cost effective solution for large and long term monitoring of coastal systems and henceforth for deriving useful environmental parameters for decision making through regular and accurate mapping to ensure the safety of people and goods. Moreover, climate change impacts have to be addressed. Thus, coastal change analysis must be based on regular and accurate surveys of key indicators in order to distinguish local and short-term processes from long-term trends dedicated to forecasting the impact of future coastal hazard. Earth observation and ocean colour tools allow water constituent concentration to be characterised thanks to relative water transparency. These indicators are of importance for coastal managers as they represent key indicators of the coastal morphology and water quality.

> "The use of satellite data to enhance our knowledge and monitoring of marine ecosystems will contribute to the regional blue growth strategy we are currently launching."
>
> ***Marie-Agnès Dupouey, Blue Growth at Région Nouvelle-Aquitaine***



Satellite derived Bathymetry of the Arcachon Lagoon, derived from Sentinel-2A imagery. Optically deep waters are represented in black.
Credit: Contains modified Copernicus Sentinel data [2016]

Outlook to the future

The next generation of Copernicus and Sentinel satellite missions planned by the European Commission and the ESA will improve ocean colour applications dedicated to strategic defence and environmental issues as they combine high space, time and radiometric resolutions, guaranteed for long-term perspectives. Coastal monitoring is also a key sector for the future of the blue growth and further sustainable worldwide economy.

Acknowledgements

Nouvelle-Aquitaine Regional council, Département des Pyrénées Atlantiques, I-Sea and Telespazio France EarthLab Aquitaine support the development of operational decision-making tools.

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SATELLITE MONITORING OF SUSPENDED PARTICULATE MATTER

Monitoring anomalous events occurred at Ionian coasts of Basilicata Region by integrating frequent and detailed multi-source satellite data.

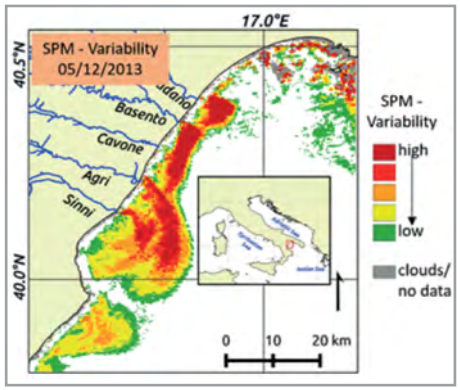
The challenge

River discharge affects Suspended Particulate Matter (SPM) dynamics and variability in coastal areas, contributing to the generation of possible environmental degradation situations. The coastal waters off the Basilicata Region (southern Italy – Ionian Sea - eastern Mediterranean) coastline are affected by the presence of five river mouths determining continuous water turbidity fluctuations that can modify the quality status of this complex coastal habitat. Only the implementation of a monitoring system able to detect the occurrence of any possible critical event, may allow a sustainable management of this region. Satellite data can be a useful tool for SPM variability monitoring, complementing traditional in-situ based methods.

The space based solution

A multi-temporal analysis of 13 years of Moderate Resolution Imaging Spectroradiometer (MODIS) data, based on the Robust Satellite Techniques approach (RST), was implemented to analyse the effect, in terms of SPM variability, of the extreme hydrological event that affected the area in December 2013.

In detail, daily visible MODIS data at 250 m



SPM variability for the Basilicata region costal water area for the MODIS image acquired on 5 December 2013.

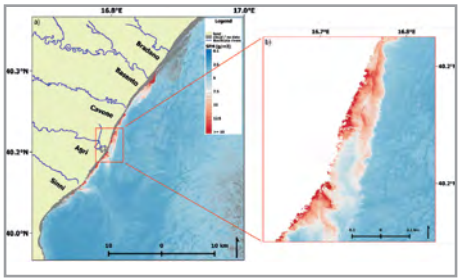
of spatial resolution, have been firstly used to compute SPM concentration by adapting a standard algorithm to the specific local conditions. Afterwards, the RST approach has been implemented enabling automatic detection of anomalous SPM concentrations in the days just after the flood wave peak. More recently, data acquired by the MultiSpectral Instrument (MSI) of Sentinel-2A at 10 m of spatial resolution have been integrated in the proposed application. Using these data allowed for an improvement in the spatial resolution of the achieved results, providing detailed information in shallow waters close to the coastlines as well as during non-extreme events, such as those recently affecting the area.

Benefits to Citizens

Besides the investigation of a single event (e.g. December 2013), the proposed approach allowed for identifying areas where the occurrence of anomalous SPM concentration was more frequent during the month of December for the whole 2003-2015 period. Such information was very helpful for the Basilicata Region authorities because it

> "The developed application allowed us to carry out effective real time monitoring of the Ionian Sea coastal water quality."
>
> ***Gerardo Colangelo, Basilicata Region officer***

provided them with information about the most critical areas that typically localised in front of the river mouths, have been affected by a water transparency reduction as well as by other phenomena, such as pollutant transport that could have affected the marine environment status. In the light of this, amongst the other possible users, aquaculture companies have found the achieved results useful in order to exclude the most vulnerable areas. Furthermore, the effect on the shoreline evolution of past dredging actions was reconsidered.



Example of application of MSI-Sentinel-2A data acquired on 30th April, 2018, for monitoring SPM in the investigated area.
Credit: Contains modified Copernicus Sentinel data [2018]

Outlook to the future

Data collected by the Ocean and Land Colour Instrument (OLCI), onboard Sentinel-3 satellite (operational since October 2016), will be used in the future in place of MODIS ones. Its spectral features specific for ocean colour applications will guarantee an improvement in results in terms of sensitivity towards the discrimination of the different in-water optical constituents. Finally, it is worth mentioning that the proposed analysis should be extended to all the other calendar months to have a clearer view of the whole area, better discriminating most critical coastal zones in terms of SPM concentration values and variability. Moreover, the proposed approach can be easily exported to other geographic regions and coastal areas, with benefits for other Local Regional Authorities managing water resources.

Acknowledgements

This work was carried out in the framework of the OP European Regional Development Fund (ERDF) Basilicata Region 2007–2013 IOSMOS (Ionian Sea water quality Monitoring by Satellite data) project, the Italian Ministry of University and Research RITMARE (Ricerca ITaliana per il MARE) Flagship project and the OP European Social Fund (ESF) Basilicata Region 2007–2013 MOMEDAS (MOnitoraggio delle acque del mar MEditerraneo mediante DAti Satellitari) project.

T. Lacava, N. Pergola, V. Satriano[1] C. Di Polito, E. Ciancia, V. Tramutoli[2] and D. Doxaran[3]
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SENTINEL-2 SUPPORTS COASTAL MANAGEMENT FOR OPTIMISED DECISION MAKING

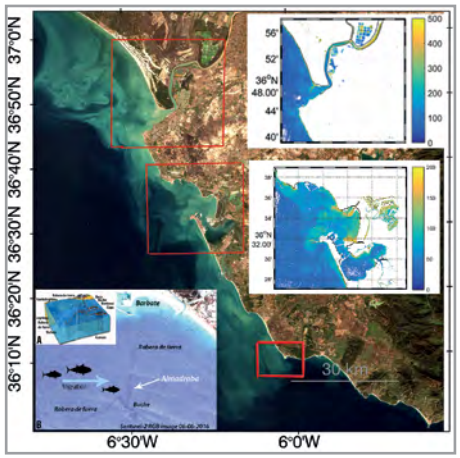
Novel applications ranging from monitoring dredged induced turbidity plumes to tuna fishing management in SW Spain

The challenge

Monitoring the complex variations in water quality and understanding the impact of environmental change on the Gulf of Cadiz ecosystem (SW Iberian Peninsula) is crucial for a broad range of local/regional authorities, stakeholders, decision-makers, and researchers. The Guadalquivir estuary, as one of the largest and most productive estuarine systems of Western Europe, and the Bay of Cadiz, are two hotspots strongly affected by human-related activities which have undergone rapid agricultural, fisheries, touristic, and anthropogenic development. Specifically, intense turbid episodes are one of the main factors altering the functioning of both regions. The essence is that nowadays this coastal zone experiences a conflict between economy and sustainable environment, and there is a need for bridging knowledge in order to ensure social and ecosystem resilience. Traditional in-situ and modelling experiments have been developed, but new insights are required to assist the cost-effective accomplishment of water quality at synoptic and transboundary scales for the implementation of the European Marine and Water Strategy Directives.

The space based solution

A semi-automatic method based on the MultiSpectral Instrument (MSI) of Sentinel-2A at 10 m resolution is implemented to estimate Total Suspended Solids (TSS). Several field campaigns are carried out to collect in-situ measurements for calibration and validation of the regional multi-conditional model, which is developed with a switching method that automatically selects the most sensitive band avoiding saturation effects. Sentinel-2 scenes are downloaded from the Data Hub and atmospheric correction is incorporated into the framework through ACOLITE processor. The semi-automatic model is routinely applied revealing improved mapping at unprecedented resolution (unachievable with traditional ocean colour sensors) along the estuary, the bay and surrounding waters (Figure 1). This methodology can robustly address small-scale monitoring due to the higher spatial resolution and band availability of Sentinel-2. In addition, it has demonstrated the feasibility to effectively estimate dredged-induced turbidity events during the periodic dredging activities of the shipping channel close to the Port of Seville



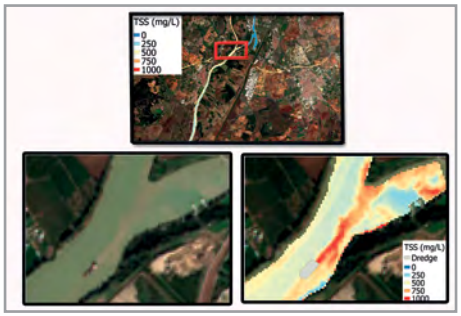
Sentinel-2 image of Cadiz coast showing Total Suspended Solids concentration (mg/L) in the Guadalquivir estuary and Cadiz Bay, and tuna fishing "almadraba" in Barbate.
Credit: Copernicus Service information [2016-2017]

> "Sentinel-2 will definitely help us to solve the challenging water quality monitoring along the coast of Cadiz, bringing new perspectives of applications into focus such as dredging-induced turbidity monitoring."
>
> ***Gregorio Gomez-Pina, National Coastal Office in Cadiz, Government of Spain.***

(Figure 2). With this ongoing semi-operational system, the National Coastal Office and the Regional Government of Andalusia will be able to take advantage of Sentinel-2 time series.

Benefits to Citizens

It is worth emphasising the benefit of assisting the services of local to regional initiatives for supporting ecosystem policymakers contributing to the challenging management of these highly sensitive regions. The findings have projections regarding other topics related to coastal management options, since the lower reaches of the estuary are adjacent to the Doñana National and Natural Park, the largest reserve in Europe. Sentinel-2



Sentinel-2 image showing the turbidity plume generated during the dredging operations in the Guadalquivir estuary and Port of Seville and map of Suspended Solids in November 2016.
Credit: Copernicus Service information [2016-2017]

has also allowed the study of the historic tuna fishing "almadraba" in Barbate (Figure 1). In particular, the increasing demand for integrated guidelines and open access techniques by end-users and water managers is being evaluated, as they need to be reinforced before being able to actively ensure upcoming policies by the agencies of the Regional Government. The proposed methodology is thought to bring significant breakthroughs in the exploitation of Copernicus data along the 1000 km of the Andalusian coast.

Outlook to the future

Overall, these results encourage additional proposals relying on both operational Sentinel-2A/B. With the 5-day revisiting of the two satellites, by integrating the data sources into the workflow we will enter a new era for time series analysis at high spatial resolution. Likewise, further insights are needed to examine other water quality parameters such as chlorophyll-a in order to contribute consolidating Sentinel-2 data to operationally and routinely assist coastal zone management as a contribution to the local and regional water quality programmes.

Acknowledgements

We acknowledge the ICMAN-CSIC Sampling Unit OPECAM and Josefa Perez dredging ship for field campaign assistance.

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SPACE-BASED APPROACH TO MONITORING PEATLAND RESTORATION

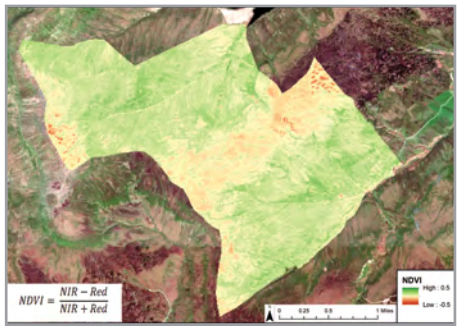
Sentinel-1 and -2 data allows Yorkshire Peat Partnership (YPP) to be a lead innovator in monitoring peatland restoration.

The challenge

The UK contains 13% of the world's peatlands. Blanket bog, one of three types of peatland in the UK, covers 70,000 hectares in Yorkshire alone. This makes the region both nationally and internationally important. Peatland conservation is crucial when considering how to address the major environmental problems faced by society today and into the future, such as climate change. This is why it is a key area of focus for both UK and EU policy makers. Our project area is vast, the fast revisit times of Sentinel 1 and 2 allow us to quickly and accurately monitor the success of restoration work. 3,464 hectares have already been analysed using this method. YPP is managed by regional charity, Yorkshire Wildlife Trust. The free to download data allows YPP to deliver effective large scale nature conservation on a tight budget.

The space based solution

With the launch of Sentinel 1 in 2014 and Sentinel 2 in 2015, YPP is able to access a plethora of retrospective data to understand the characteristics of our sites before and after restoration work. Sentinel 2 data is used to monitor vegetation productivity and moisture through the calculation of vegetation indices (such as the NDVI). The data is converted



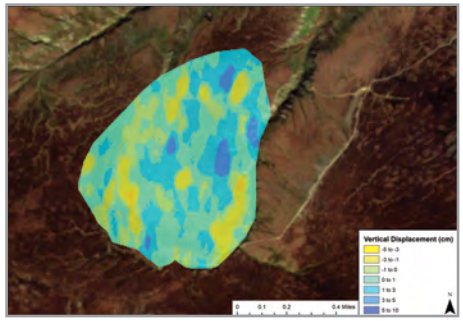
An NDVI (Normalised Difference Vegetation Index) generated from Sentinel 2 satellite data. This index shows vegetation productivity, as is particularly well suited in identifying areas of bare peat and burn scars (red and orange areas).
Credit: Contains modified Copernicus Sentinel data [2017]

to reflectance, and the reflectance bands used in the vegetation indices equation (see image inset for an example of the NDVI). Interferometry techniques that investigate the signal difference between two or more Sentinel 1 passes are analysed to create surface deformation maps. These maps can indicate the extent of peatland swelling (a characteristic of successfully restored peatlands). Bare peat and burn scar maps are generated from image classification techniques (such as Maximum Likelihood and Support Vector Machine). These classifications use both Sentinel 1 and Sentinel 2 data and help to quantify the extent of damage across our sites.

Benefits to Citizens

Functioning blanket bog, which is actively peat-forming, offers multiple benefits to wider society. UK case studies of restored peatlands suggest a reduction in flood peak of up to 33%, leading to increased attention from the UK Government's Environment Agency, who spent £24 million across Yorkshire to repair flood damage in 2016 and are starting to invest in preventative natural flood management techniques. 43% of UK drinking water comes

> "The innovation and enthusiasm the YPP team bring in terms of utilising and developing remote sensing techniques ensures that our customers get the best possible value from our peatland restoration programme."
>
> ***Andrew Walker, Yorkshire Water***



Surface deformation map showing vertical displacement (cm).
Credit: Contains modified Copernicus Sentinel data [2017]

from uplands dominated by peatlands. Acting as a natural filter to water, healthy peatlands ensure high quality water to the surrounding region. This has led to the financial support from the regional water company, Yorkshire Water, in the belief that restored peatlands will reduce the cost of expensive treatment processes that chemically remove impurities. Peat is formed by semi-decomposed plant material in a waterlogged environment. Due to the lack of normal decomposition processes, carbon from the atmosphere is locked up in these systems, estimated at 550 gigatonnes on a global scale (twice that stored by global forests). In a damaged state, this leads to the release of carbon dioxide, a significant greenhouse gas, so it is important to restore and conserve healthy peatlands to reduce this

impact. Successful peatland restoration can therefore impact on climate change, one of the most serious challenges facing humanity today.

Outlook to the future

Going forward, we will continue to use Sentinel satellite data for monitoring our sites. In particular, the higher resolution of Sentinel 2 (10m) compared to Landsat 8 (30m) will continue to improve our monitoring capabilities. As Sentinel 1's life span increases, our ability to investigate bog swelling (through surface deformation techniques) will continue to grow. Finally, the launch of Sentinel 5P in 2017 is of great interest to our future applications. The ability for Sentinel 5P to capture air pollutant data means we can investigate the effects of air pollution on peatland health and the impacts of upland burning. This growing capability will complement our ongoing unmanned aircraft monitoring to better inform peatland management plans.

Acknowledgements

YPP has run successfully since 2009 and for this, we would like to thank Yorkshire Wildlife Trust, Natural England, Yorkshire Water, IUCN UK Peatland Programme, Yorkshire Dales National Park, North York Moors National Park, Nidderdale AONB and the Environment Agency for their support.

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TRACKING ALGAL BLOOMS ON THE CURONIAN LAGOON

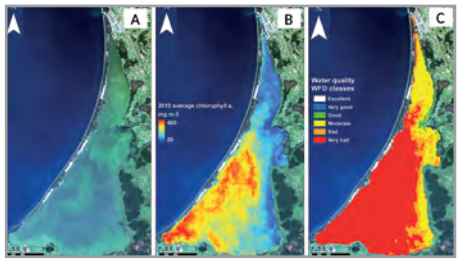
Satellite data are leading to better water management, water quality assessment and cyanobacterial bloom tracking.

The challenge

The Curonian Lagoon – the largest in Europe – is very important water body in the western region of Lithuania for recreation, tourism, fishery and industry. The Curonian Spit divides the lagoon from the Baltic Sea. This area comprises a number of protected territories including National Parks on both the Russian and Lithuanian parts of the spit (also declared a UNESCO World Heritage site), Regional Parks, and Natura 2000 territories. The freshwater lagoon is shallow (mean depth of 3.5 m), with a single and small opening to the Baltic Sea which limits water exchange and circulation. The Nemunas River entering the central part of the lagoon is the main source of nutrients. The Curonian Lagoon is a highly turbid water body and seriously threatened by high concentrations of organic material as well as by harmful blooms of cyanobacteria. Therefore, sustainable water quality and resource management of the lagoon is a priority for national and regional authorities who require regular information on its ecological status.

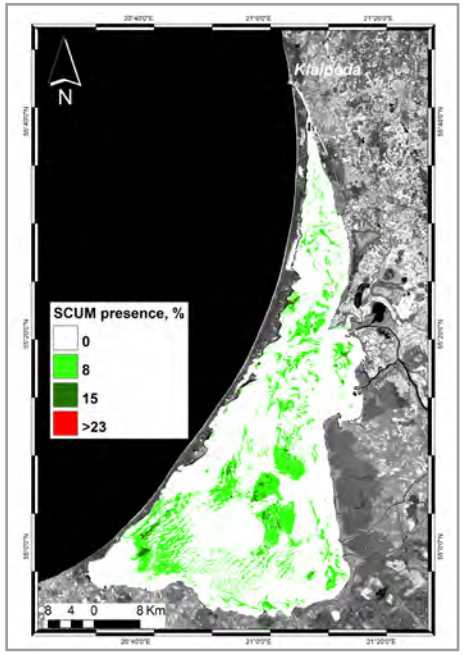
The space based solution

The Curonian Lagoon has been monitored from space since 2009, when the first attempt to map the severe summer algal blooms took place. The MEdium Resolution Imaging Spectrometer (MERIS), on-board the Envisat satellite, combined moderately high spatial resolution (300 m) with a high revisit time (2-3 days) and an appropriate spectral resolution. Using data from this sensor, comprehensive algorithms for water quality retrieval were developed. The birds-eye view from Space enabled a better understanding of the huge cyanobacterial blooms, which develop on the Curonian Lagoon, and can often cover almost its entire surface (~1500 km^2). These blooms can be extremely harmful to human, animal and plant life. Building on the legacy of Envisat (and other Earth Observation satellites), the Copernicus Sentinels have ushered in a new era of satellite Earth Observation, making huge amounts of data available on a free and open basis and guaranteeing their long-term sustainability. With both its satellites now in orbit, Sentinel-2 provides optical data at 10 m spatial resolution for the same location every 5 days. The successor of MERIS, Sentinel-3 (with two satellites in orbit) provides optical data each day with spatial resolution at 300 m. It opens the opportunity to build services for water quality. The EOMORES (H2020) and TODAY (national/ESA PECS) projects are working towards this goal.



The Curonian Lagoon: true colour view from space as seen by Landsat-8 on 04/08/2015 (A), annual summer mean Chl-a concentration during 2010 derived from MERIS images (B) and MERIS Chl-a-based water quality according to the Water Framework Directive, 2000/60/EC (C).

> "The implementation of the WFD was always challenging, relying only on in situ monitoring. We believe satellites will provide us with regular additional information about status of our lagoon, lakes and coastal waters."
>
> ***Head of the Division Eglė Šupinienė, Environment Research Department, EPA, Lithuania***



Cyanobacteria surface accumulations in the Curonian Lagoon as mapped by 13 images of Sentinel-2 and Landsat-8 during summer 2013-2016.
Credit: Contains modified Copernicus Sentinel data

Benefits to Citizens

Operational water quality monitoring services support more informed decision-making on the part of water resource managers, resulting overall in better safeguarding and stewardship of natural assets. This leads to better preservation of the ecosystem services from which citizens benefit, such as the recreational value in the lagoon and lakes. There are also some clear public health benefits from monitoring inland water quality. For example, monitoring and forecasts of potentially harmful algal blooms might result in the timely closure of bathing or fishing areas – thus decreasing the risk to public safety.

Outlook to the future

Taking a full advantage of free and open Copernicus Sentinel data, we tested and provided water quality parameters (e.g. chlorophyll-a, total suspended matter, CDOM) for the lagoon. These parameters will be adopted for other Lithuanian water bodies with different bio-optical properties (large lakes and coastal waters), whilst the approach can be reutilised in other geographical regions. Within EOMORES project, an integrated service is being developed combining in situ, Earth observation and modelling data for monitoring inland water bodies.

Acknowledgements

The work is funded by the EU's Horizon 2020 EOMORES project (No 687412) and the TODAY project funded by the Government of Lithuania through an ESA Contract under the PECS (No 4000122960/18/NL/SC).

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TRACKING STORMS AND HURRICANES USING SAR IMAGES

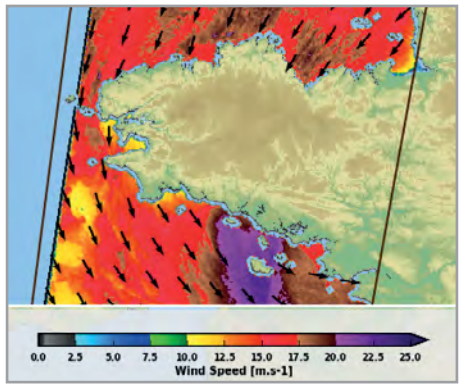
Since the launch of the constellation, Sentinel-1 keeps monitoring metocean extremes over European and worldwide seas.

The challenge

Earth Observation techniques on board the Sentinel satellites contribute to the monitoring of the marine environment. With its unique ability to observe sea surface and derive wind, wave and currents measurements in all weather and in day or night time over a wide swath image at high resolution, spaceborne Synthetic Aperture Radar (SAR) instruments are normally perfectly suited for metocean applications. The wealth of acquisitions recently allowed by Sentinel-1 constellation opens the path to imagine and build added-value services, in order to make the most of Sentinel-1 potential and provide new metocean applications.

The space based solution

The ocean products derived from Sentinel-1 mission are routinely produced and delivered by European Space Agency (ESA) core ground segments. Yet, they do not provide state-of-the-art wind measurements, especially limited for strongest events. To make the most of Sentinel-1 potential for the measurement of extreme winds, a dedicated campaign named SHOC (for Satellite Hurricane Observation Campaign) was performed in summer 2016. An unprecedent acquisition scenario was set up to trigger acquisitions

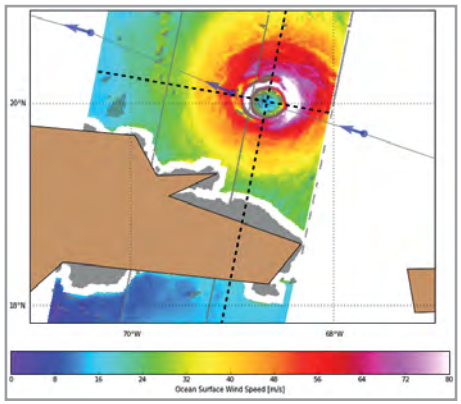


Surface wind measurement in Brittany during the Ana storm - 11/12/2017 (from Sentinel-1 - VIGISAT station).
Credit: Contains modified Copernicus Sentinel data [2017]

based on forecast urricane trajectories provided by supporting meteorological centers. More than 25 observations over hurricane eyes were acquired and Tropical Cyclones (TC) were captured at different development stages (up to category 5). Based on this unique dataset, the great relevance of Sentinel-1 dual-pol observations to measure extreme winds was demonstrated and a new methodology developed for dual SAR operating in C-band, enabling better wind measurements for wind larger than 20m/s. This is illustrated over Hurricane Irma. Based on these results, hurricane experts from the WMO (World Meteorological Organization) Hurricane Committee for USA/Caribbean region, listed in their recommendations that "Special acquisitions plans during Irma, Jose and Maria have demonstrated the high value of kilometric-scale information provided by Sentinel-1 SAR data". They thus recommend that "these data are made available to help monitor critical aspects of the TC structure (wind radii, maximum wind, eye diameter...)."

Wind maps will be produced by CLS Brest with Sentinel-1 and Radarsat-2 SAR instruments and distributed in near-real

> "Tropical cyclones represent 20% of the damage and casualties caused by natural hazards, when all phenomena are taken into consideration"
>
> ***Philippe Caroff, Head of the cyclone forecast centre at Météo-France***



Sentinel-1 derived surface wind speed over Irma on 07/09/2017 during a category-5 hurricane, showing winds greater than 80m/s
Credit: Contains modified Copernicus Sentinel data [2017]

time, after reception of the satellite data (see http://eoda.cls.fr for demonstrations) over European seas for extra-tropical storms and the Indian Ocean for hurricanes applications.

Benefits to Citizens

Extreme wind monitoring is essential for safety and emergency services. At present, SAR-derived wind measurements could already help meteorological forecasters to better estimate hurricane intensities in complex situations and improve the accuracy of weather forecast warnings. Forecasters from the RSMC, the Tropical Cyclone Center of Meteo-France at La Reunion are potential users.

Outlook to the future

This is mainly explained by the only recent increase of freely accessible satellite data provided by Sentinel-1 constellation at resolutions now approaching that of meteorological models. Pilot studies have shown the benefit of using these satellite measurements to correct wrongly estimated winds in wave models, thus improving the confidence in weather forecast warnings. The development of new assimilation methodologies adapted to such high-resolution measurements in atmospheric models is also a potential perspective. To be operationally used, a dedicated acquisition strategy over hurricane basins would be needed that enables the activation of emergency services with late-programming of Sentinel-1 acquisitions. This has already been demonstrated in pilot studies but it is not operationally implemented. Additionally, the downlink and production of the SAR extreme wind observations in Near-Real Time (NRT) would be needed, which might require using emergency framework and/or collaborative stations.

Acknowledgements

The SHOC campaign was performed in collaboration between CLS, IFREMER and ESA. This campaign also benefited from complementary acquisitions from Radarsat-2, thanks to the support of the GIS BreTel.

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A VIEW OF YOUR INLAND WATERWAYS FROM SPACE

A European innovation project aiming to develop commercial services for monitoring the quality of inland and coastal waters, using satellites, in situ sensors and ecological modelling.

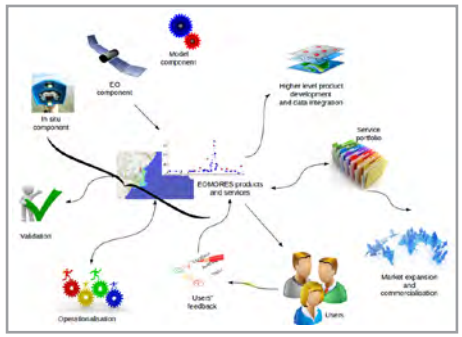
The challenge

Inland waterways are environmentally important, provide multiple ecosystem services and are vital for human consumption, irrigation, sanitation, transportation, recreation and industry.

In previous decades, these ecosystems have experienced increasing pressure from various human activities, as well as from climate change. Amongst these, the increasing eutrophication and pollution of many of these aquatic environments is a major environmental threat.

The EU Water Framework Directive (WFD) has created the need for efficient methods for monitoring the quality of inland and coastal waterways.

EOMORES (Earth Observation-Based Services for Monitoring and Reporting of Ecological Status) addresses this need whilst improving on the effectiveness of traditional methods (i.e. on-the-spot sampling and subsequent laboratory analysis). Although they are very accurate, such methods are both costly and time-consuming, and in most cases fail to capture the spatial differences which may be present within the same body of water.



Scheme of EOMORES activities in relation to users, which represent the core of the project.

The space based solution

Monitoring inland waterways from space affordably has become possible thanks to the availability of free and open satellite data from the Copernicus Sentinels. The guarantee of long-term data availability makes it feasible to build commercial operational services, whilst the improved spatial resolution (e.g. Sentinel 2 reaches 10 m) and revisit time (5-6 days for both Sentinels 1 and 2) are appropriate for discerning changes in water quality in most European lakes.

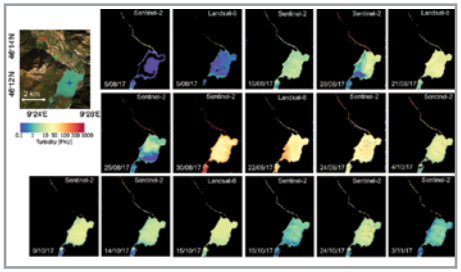
Within EOMORES, data from Sentinels 2 and 3 will be automatically acquired and processed to deliver relevant water quality parameters such as chlorophyll-a, Total Suspended Matter (TSM), turbidity, Coloured Dissolved Organic Matter (CDOM), vegetation coverage and type, cyanobacteria blooms and Water Surface Temperature (WST). Sentinel-1 data are also being investigated for their capacity to provide information on water quality (specifically cyanobacterial scum), even under cloud clover, as radar data can penetrate clouds and operate at night.

Benefits to Citizens

EOMORES aims to bring about a paradigm shift in ecological monitoring technologies for

> "The issue was that monitoring costs were old fashioned, labour intensive and data not digital. This needed to change, and we also wanted to work in real time. EO contributes to all of these."
>
> ***Regional/national organizations responsible for water quality monitoring (13 EOMORES users)***

water quality management, powered by Earth Observation (EO). EO offers great advantages for water quality monitoring, but its operational use has only really taken off in regions where traditional practices are no longer able to support monitoring requirements - due, for instance, to the large number of waterways involved (e.g. in Finland).



Monitoring the effect of turbidity in lake Mezzola (Italy), after the rock avalanche of Piz Cengalo on 23-08-2017
Credit: Contains modified Copernicus Sentinel data [2017]

EOMORES is targeted at national and regional authorities responsible for monitoring water quality management and environmental reporting, as well as private entities dealing with water quality. Thirteen users from multiple regions of six countries (e.g. Lombardy and Umbria regions in Italy) have already committed to collaborate with the consortium to define and evaluate the

EOMORES services. The waterways under investigation represent a variety of different water types and trophic levels, with most of them being (hyper)eutrophic (Italy, Lithuania, Estonia, UK, Finland and the Netherlands).

Outlook to the future

EOMORES will provide national, regional, local, public and private water managers with tools for efficient monitoring of water quality for operational management and for reporting according to the requirements of the WFD and other (national) directives.

By building downstream services upon the Copernicus programme, EOMORES will help to ensure that Europe's investments in space infrastructure are exploited for the benefit of citizens, and in order to achieve the goals of the WFD. Data from the Sentinel satellites, with their high-frequency and broad spatial coverage, are an essential input to the EOMORES services. EOMORES services are expected to become a valuable tool for water managers, bringing about a better understanding of their local water systems and enabling timely decisions and actions related to public health.

Acknowledgements

This project has received funding from the EU Horizon 2020 research and innovation programme, g.a. N. 687412.

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DON'T POUR MONEY DOWN THE DRAIN - FIX IT!

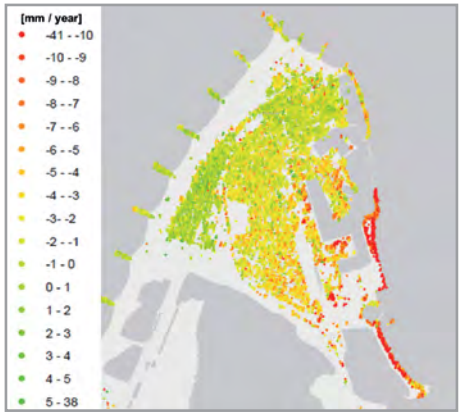
Detailed knowledge about land subsidence from Copernicus Sentinel-1 mission data changes the way the Danish utility sector guards its subsurface assets to the financial benefit of its customers.

The challenge

Well-functioning water supply and wastewater systems are crucial to the utility sector and society at large for obvious health, environmental, and economic reasons. Long term investments for sewer renewal accompany maintenance work. Additionally, climate change impacts on hydrology must be considered when addressing future investment needs and the municipal task of climate change adaptation. Approximately 95% of the utility sector's financial assets are subsurface, with only the customers i.e., citizens and industry, to pay the bill in the privatized Danish water sector. Thus, it is of the utmost importance to trim expenses and ensure cost-efficient businesses. Data on vertical land movement from Copernicus Sentinel-1 is becoming a game changer in the utility sector that links Earth Observation to the 'guys working the sewers'.

The space based solution

Knowledge of local land subsidence rates made available from the Copernicus Sentinel-1 data in a local cross-sectorial collaboration has led to behavioural changes with the Lemvig Municipality and the Lemvig Utility Company in the Central Denmark Region (CDR); and experiences are currently being



A differential pattern of vertical land motion (red colours indicate large subsidence rates) over the town of Thyborøn, Central Denmark Region. Contains modified Copernicus Sentinel-1 data.
Credit: Contains modified Copernicus Sentinel data [2017]

shared between municipalities and utilities regionally and nationally. Traditionally, broken sewer pipes led to costly replacements of entire strings based on the assumption that the pipes had degraded. Now, detailed subsidence maps often provide a causal explanation and pipe repairs can be targeted locally to optimise maintenance work. Coupled with information on local geology and maps of the sewer system in a web-based service, the Sentinel-1 based subsidence maps provide utility employees with an on-site overview of subsurface conditions to act upon.

Likewise, loss of pipeline gradients may be ascribed to local phenomena of vertical land motion and not to a generally malfunctioning system. This knowledge has led to diversion of water flow in existing pipelines and is directly incorporated into pipeline design and urban planning in new developments.

Benefits to Citizens

Copernicus Sentinel-1 based mapping reveals areas of vertical land motion. A normal life-time expectancy of sewers of 70-100

> "The use of EO data is becoming mainstreamed into our long-term strategic planning leading to a more cost-efficient water sector to the financial benefit of all citizens."
>
> *Lars N. Holmegaard, CEO, Lemvig Utility*



Corner reflector developed by DTU Space & Agency for Data Supply and Efficiency and manufactured by Lemvig Utility. Reflectors serve to link height variations in EO data to the Danish datum network (Photo by kind permission of Mr. Karsten Vognsen).

years cannot be granted in such areas, but investments can be targeted to avoid excessive costs of replacements and repairs. To the Lemvig Utility the shift n operational practices is rewarding and has already led to decreased costs for maintenance, and the use of EO data is currently being mainstreamed into the municipality and utility's strategic plans e.g. through training of local government employees. This leads to a more cost-efficient water sector to the financial benefit of all citizens and businesses within the Lemvig Municipality. Additionally, the region's resilience to climate change will

increase through cross-sectorial and shared use of Earth Observation data in mitigation and adaptation. Corner reflectors that act as unique identifiers in the satellite images have been locally developed and deployed.

The reflectors link to the Danish height system and to the bottom of sewers via traditional leveling techniques. This provides very detailed and precise determination of height changes over time and secures cross-sectorial use e.g. in the construction sector thereby making EO results applicable to the public.

Outlook to the future

The use of Copernicus Sentinel-1 for monitoring land motion provides Lemvig Utility with a very good business case in relation to pipeline maintenance and renewal, and climate change adaptation. In the future, the use of EO data will become one cornerstone to secure a cost-efficient and knowledge-driven water sector and where much potential is still to be unveiled in climate change adaptation.

Acknowledgements

CDR, DTU Space, VIA University, Port of Thyboroen, Geo, Agency for Data Supply and Efficiency, PPO.Labs and NORUT are acknowledged for contributions to the presented collaborative work. Co-funding is kindly provided through the EU Life c2ccc.eu project.

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GLOBAL REAL TIME ONLINE WATER QUALITY MAPPING

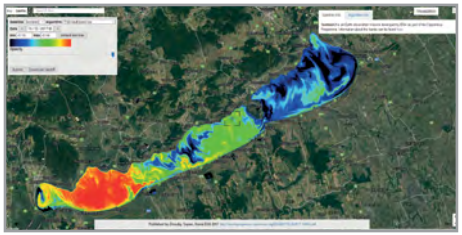
Satellite-based water quality mapping is now available from everywhere, to everyone!

The challenge

Understanding hydrodynamic and ecological processes in lakes and coastal seas is essential for ensuring clean drinking and bathing water and sustainable fisheries. Satellite imagery has been used by scientists for decades to visualise the most important properties of water: chlorophyll content, which tells us about the amount of algae and nutrients in the water and suspended sediment, which informs about the transparency. However, these data have only so far been available at selected locations and to remote sensing experts, but not to authorities or NGOs interested in water quality protection and management. Citizens interested in the quality or status of lakes and rivers had no direct access to up-to-date maps, limiting their awareness of and engagement with water quality processes.

The space based solution

A recently released massive data processing platform, Google Earth Engine, allows on-demand access and server-side processing on the full archive of Sentinel 2 and 3 satellites, which is regularly updated as new images are collected. We have implemented a set of widely used simple algorithms for mapping chlorophyll, suspended sediment,



Sentinel-2 based suspended sediment map of Lake Balaton, showing dramatic differences in water transparency.
Credit: Contains modified Copernicus Sentinel data [2017]

and temperature on these datasets and other satellite sources (Landsat, MODIS). The resulting images are shown over an easy to use Google Maps interface. Sentinel-2 provides high resolution imagery at lower repetition rates whilst Sentinel-3 imagery delivers lower spatial resolution but higher accuracy maps up to every second day. Whilst these images are not calibrated against local water samples, the algorithms themselves are robust and therefore the patterns and processes observed in the imagery can be used for monitoring.

Benefits to Citizens

Information on water quality used to be the privilege of water authorities, whilst spatially explicit maps were hardly ever produced for the public or even for the managers themselves. Globallakewatch.org democratises water quality data by delivering regularly updated maps free of charge to any user globally. This means that any internet user concerned about the status of a certain lake or coastal sea can directly access a time series of information with a spatial and temporal resolution they can understand. Interested citizens can thus provide early warnings: water quality maps can be used to identify pollution sources, inform authorities and hold polluters responsible. In the case of bodies of water in conflict

> "Satellite imagery has been essential for understanding the limitations of our water quality models."
>
> **Márk Honti, General Directorate of Water Management, Hungary**

zones or remote areas, globallakewatch.org may well be the only source of up-to-date information on water quality. The high detail and frequent acquisition of the images allows understanding of processes such as algae blooms or sediment resuspension, and will raise awareness of the importance of water quality amongst the public. Specifically on Lake Balaton, Hungary, images and maps generated by globallakewatch.org have already been widely shared in online news and social media. Additionally, water quality of many small lakes that are not regularly monitored by authorities can now be followed by the local angling communities. By boosting the availability of satellite water quality data, globallakewatch.org will foster the development of locally calibrated, high accuracy water quality monitoring from satellite imagery in many regions worldwide.



RGB image of ice breaking up on Lake Balaton, obtained via globallakewatch.org. This image has been very popular in Hungarian social media.
Credit: Contains modified Copernicus Sentinel data [2017]

Outlook to the future

The next steps currently being tested are time series graphs and data export functions that support user-generated local calibration based on water sample data. By enabling non-specialists such as schools or NGO's to perform their own calibration, the number of lakes with regular water quality monitoring worldwide is expected to grow rapidly. The improving revisit times resulting from new satellite launches will further increase the potential of globallakewatch.org for education, monitoring and management.

Acknowledgements

Google Earth Engine is the backbone of the system and is provided by Google. The development was supported by the Foundation for Lake Balaton Research.

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INFORMING WATER RESOURCE MANAGERS IN SARDINIA

SPACE-O services provide satellite data and water quality forecasts like weather data. The case of the Mulargia reservoir shows the added value of developed tools for water resource protection.



General view of Mulargia reservoir in Sardinia.
Source: Ente acque della Sardegna (ENAS)

The challenge

There is a growing need to monitor and reduce the effects of pollution and climate change on our global water cycle. On the Italian island of Sardinia, the Mulargia dam is one of two pilot cases where the SPACE-O (www.space-o.eu) project demonstrates the value of Earth Observation technology in forecasting water flows and water quality. Mulargia is the most important reservoir in a large and complex network comprising three river basins, serving as a drinking water source for 700,000 people. Ente acque della Sardegna (hereinafter ENAS), the local multisector water network manager, is the public authority responsible for operational monitoring and daily planning –such as informing the local drinking water supplier of any changes in the raw water quantity and quality– as well as strategic planning. A complex system like this is threatened by a wide variety of challenges like droughts, floods, diffuse pollution and deforestation that affect water quality and demand managers to constantly balance levels and swift flows where needed to guarantee local supply. Timely and detailed information is crucial to the efficiency of treatment processes, strategic planning and emergency responses but often challenges local capacities.

The space based solution

In order to address these challenges, the EU funded SPACE-O project combines state-of the-art satellite technology with hydrological and water quality models, integrating local knowledge and datasets so as to improve the information base used for decision making. Indicators for water quality and quantity that cannot be covered in a spatial scale by ground-based systems are now possible to obtain from Copernicus satellite missions Sentinel-2A/B and Landsat 8. These indicators include:

- Chlorophyll-a, turbidity and harmful algae blooms
- Water surface temperature and evaporation
- Floating materials (e.g. oil or scum)

Information from satellite images for the above mentioned indicators are combined with existing datasets to improve water forecasts. Models are generally as good as the data used to force those models. Systematic analysis of satellite data was used to fine-tune models by complementing missing measurements. ECMWF forecasting and coupled hydrological, hydrodynamic and ecological modelling together with near real-time data from automated image analysis, allow for forecasting of river flows and critical water quality parameters like algae and turbidity for up to 10 days.

> "With SPACE-O water quality forecast service we can now be proactive and mitigate challenging water quality threats to the benefit of our water users."
>
> **Maria Antonietta Dessena, Ente acque della Sardegna (ENAS)**

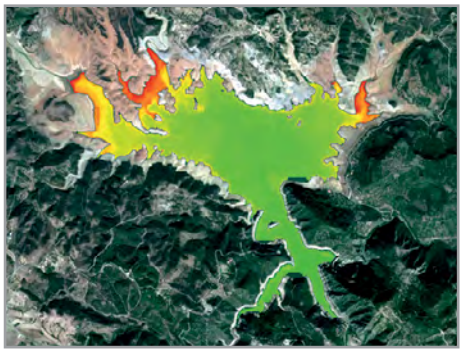
Benefits to Citizens

Based on the forecasts derived from combining Earth Observation data, a set of end-user driven functionalities have been designed and translated into a Decision Support IT tool, including the modules:

1. Environmental/water information system, supporting reservoir management specifically on short to medium term water quantity and quality forecasts.
2. Early warning system, which uses modelled (forecasted) data to provide early warning of threats to the water sources.
3. Water treatment plant optimisation.

Outlook to the future

SPACE-O is designed to be adaptive to new science allowing a dynamic upgrade of the information fluxes that it receives. It is fully aligned with newly developed Copernicus services and will provide products on a long-term time basis, assuring the future sustainability of the service. As demonstrated in Sardinia, space-based monitoring technology is greatly appreciated by water managers and brings valuable tools to the table. Lessons from Mulargia allow for further fine-tune decision support systems which can be rolled out to a broad range of water operators all over the world. SPACE-O will keep closing the knowledge gap for informed and sustainable water resources governance and optimized water services provision thanks to the open access data from Copernicus.



Turbidity concentrations in Mulargia reservoir from S2. *Source: EOMAP*
Credit: Contains modified Copernicus Sentinel data [2017]

Acknowledgements

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MONITORING GROUNDWATER FLOODING IN IRELAND USING SENTINEL-1 SAR

The winter of 2015/2016 saw unprecedented groundwater flooding across western Ireland. Sentinel-1 SAR was used to map regional flooding.

The challenge

Mapping how floodwaters develop and recede accurately and on a large spatial scale is critical for flood risk management. However, this posed a major challenge to regional authorities across the western region of Ireland following the extensive groundwater floods of 2015/2016. Little or no hydrometric data was recorded during the flood event. Earth Observation imagery collected by the EU Copernicus Programme provided a solution to this otherwise insurmountable problem.

The space based solution

Earth Observation satellites represent a growing data source for environmental monitoring. The Synthetic Aperture Radar (SAR) capability of the Sentinel-1 constellation is particularly valuable because of its ability to detect differences in land cover and provide an all-weather, day-and-night supply of imagery.

SAR systems emit radar pulses and record the return signal at the satellite. Flat surfaces such as water operate as specular reflectors for the radar pulses, giving a clear contrast between dry and flooded areas. This makes Sentinel-1 SAR data a powerful tool for flood delineation.

In this context, Geological Survey Ireland used imagery from the Copernicus Sentinel-1 mission to map the extent of the 2015/2016 extreme flood event, which would otherwise not have been possible by conventional means.



Groundwater flooding in County Galway, Western Ireland, 2016.

An additional benefit of Sentinel-1 is the frequency of image capture; the satellites have been collecting imagery over Ireland at a 3-4 day revisit time since late 2014. Whilst this revisit time may be inadequate for observing flash floods, which appear and dissipate within hours, it is suitable for monitoring groundwater flooding which occurs at a much slower rate.

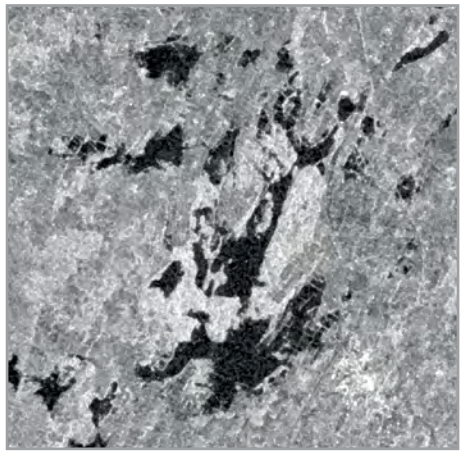
Groundwater floods typically appear and recede over a timescale of weeks to months. The considerable catalogue of Sentinel-1 imagery available has allowed us to track groundwater flood development through time, increasing our understanding of this complex flood form and help identify vulnerable areas and communities.

Benefits to Citizens

Groundwater flooding was not traditionally recognised as posing a significant flood risk in Ireland, and so historically authorities saw little benefit in routinely recording groundwater flooding. Attitude has changed dramatically in the last decade, driven in part by the introduction of the EU Floods Directive, but also by two major groundwater flood events in 2009 and 2016.

> "Sentinel 1 data has transformed the way we monitor groundwater flooding in Ireland. It provides a practical method to monitor a complex problem."
>
> ***Koen Verbruggen, Geological Survey Ireland***

Remedying this lack of monitoring poses significant technical challenges. In Ireland, groundwater flooding occurs in isolated basins across the landscape. The large number and wide distribution of these basins makes them impractical to monitor using traditional field instrumentation. The availability of Copernicus EO data represents a practical and cost-effective alternative.



Sentinel-1 imagery of groundwater flooding in County Galway, Western Ireland, 2016 (flooded areas displayed in black).
Credit: Contains modified Copernicus Sentinel data [2016]

Critical flood data can now be gathered on a scale that was previously thought unachievable, and provided to relevant regional authorities and local communities in a timely manner. Flood maps derived from Sentinel-1 imagery also aid in regional planning and development and limiting future flood vulnerability.

Outlook to the future

Our intention is to incorporate near real-time Sentinel-1 SAR imagery into an operational groundwater flood forecasting scheme that will benefit those at risk of flooding. The continued work of the Copernicus programme is essential to achieve this goal. This will give local authorities and vulnerable communities valuable time before impending floods to mitigate damage o property and disturbance to economic activity.

Acknowledgements

This work was supported by the Geological Survey of Ireland and the University of Dublin Trinity College. The authors would also like to thank the Office of Public Works, Environmental Protection Agency, National Parks and Wildlife Service and County Councils of Roscommon, Galway, Longford and Mayo for their on-going assistance and support.

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WATER BODIES DETECTION ON A PORTAL

Radar Satellite Sentinel 1 products for detection and analyses of water surfaces and flood areas in Slovenia. Users are Slovenian Environment Agency and other professionals.



WhereIsWater.at portal shows Cerknica lake, Slovenia and toolbox with customized services.

The challenge

GeoCodis Ltd. and ZRC SAZU, the Slovenian Academy of Science and Arts, are working together to provide services for receiving up-to-date satellite images, for the detection and analysis of water surfaces and flood areas, and to provide the right information for users. The main challenge of the whereiswater.at portal was using the Sentinel 1 radar data for detection of water bodies in Slovenia. We succeeded in establishing an automatic processing chain by downloading raw data from the Hub, processing images in several steps, storing results into a database and delivering it to a web-based application. The main aim of the system is monitoring of bodies of water in Slovenia, providing historical statistics and supporting water related environment monitoring. The initial goal of the system was to create an additional independent source for flood prediction monitoring at Slovenian Environment Agency.

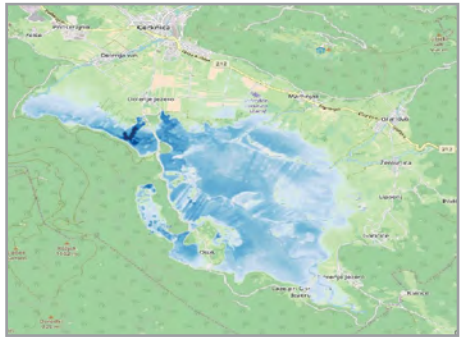
The space based solution

Sentinel 1 data are fully compliant for the detection of bodies of water but need to be carefully analysed and combined with precise terrain data and with samples of existing bodies of water on the surface. Whereiswater.at portal stores and analyses satellite data from the very start and creates its own archive of bodies of water. Users can search the observed data on the map where all acquisitions are marked. Additional functionalities help users to select data only for the specific area. More advanced users can create their own polygons and create a statistical graph with the percentage of water area in the region. It can be of special interest for flood frequency over a long-time period. The final interesting functionality is the water heatmap that shows the number of days covered by water since Sentinel 1 tandem became operational. It happens that some of the results are wrongly classified and therefore we establish the possibility to mark these data and exclude them form the further analyses. However, these data could be valuable for other purposes, e.g. for monitoring wet snow conditions in the mountains or to detect other water related phenomena, like watering golf courses or football pitches.

Benefits to Citizens

The portal is fully operational and is consulted as an information source for water specialists and for the general public. Besides the regional overview of present and past conditions of bodies of water, it also provides additional and sometimes even unexpected information such as detected wetness which remains after the watering or spreading of liquid manure on agriculture fields, or wetness on frequently watered golf courses, etc. The most valuable applicability of the portal is seen in the monitoring and evaluation of the large flood events and observing conditions of wetlands. It is also possible to monitor the extent of water inside large hydroelectrical or agricultural accumulations. Additionally, it can be used for identifying drought or dry conditions of soil on large agricultural areas. Until now, whereiswater.at service has only covered Slovenia and some nearby areas but can be extended to other areas where regular water monitoring is not established. Various professionals can derive huge advantages from using our services for their specific needs. The Slovenian Environment Agency uses this portal for analysing standing water, lakes and for monitoring flooded karst fields, as well as for evaluating the forecast on rivers. Based on satellite imagery, it can confirm or reject the alert values of the flood warning process. It has made a significant contribution to increasing knowledge about remote geographical areas.

> "The WhereIsWater portal has made a significant contribution to increasing knowledge about water conditions and has helped to improve the flood alert warning system."
>
> ***Mojca Robič, hydrologist, Slovenian Environment Agency***



Heatmap of intermittent Lake Cerknica, southern part of Slovenia, from autumn 2014 – beginning of 2018.

Outlook to the future

There are still many areas for further development including spatial statistics of water conditions, combination with ground sensors and validation of flood prediction systems. We would like to extend the use to other countries and to compare the results with other similar Sentinel 1 based applications. Whilst Sentinel 1 data are available only every 4th to 6th day we could combine data with Sentinel 2 products. There are still windows of opportunity to improve the accuracy of the provided data. The mobile app is also under development and should be available in the near future.

Acknowledgements

We would like to express our gratitude to everybody who was involved in making WhereIsWater service operational.

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HOW COPERNICUS SUPPORTS THE ENERGY TRANSITION

COP4EE uses Copernicus data to determine the potential of areas for the different renewable energy sources and supports regional administrations in defining energy transition targets.

The challenge

Energy transition is governed at European and national scale, leading to laws and regulations such as the German EEG or the French LTECV. The implementation of the energy transition in response to these acts is taking place on a regional scale. Regional administrations define their own targets adapted to the local demands and potentials. Regional administrations are often not aware of the full potential and limitations of their spatial units regarding the production of renewable energies. Earth Observation (EO) is therefore used by COP4EE to determine the potential of areas for wind power plants, photovoltaic plants, district heating or the production of biomass (www.geo-way.de).

The space based solution

Open access Copernicus data, particularly the high-resolution Sentinel satellite data, allow for continuous monitoring of land use, crop type cultivation and the use of permanent grassland. By combining these data with digital elevation models, climate data and other existing spatial information (e.g. soil data, Natura 2000 sites, other conservation areas, locations of power plants etc.) in a spatial model, the most suitable renewable energy source for an area can be determined. Regionally adapted scenarios can be computed to address regionally defined energy transition targets. Since Copernicus is providing optical multispectral satellite data (Sentinel-2) as well as cloud-penetrating SAR (Synthetic Aperture Radar) data (Sentinel-1), both with short revisit cycles, the development of renewable energy sources over time can be monitored at high spatial resolution. This includes the estimation of the biomass development of energy crops as well as the monitoring of the implementation of the energy transition. For the first time, this space-based solution allows evidence based spatial decision support to be provided for the renewable energy sector, a key sector reflected in the Paris Agreement.



Copernicus helps finding most suitable areas for an efficient and ecological production of renewables.
Photo: RSS GmbH

Benefits to Citizens

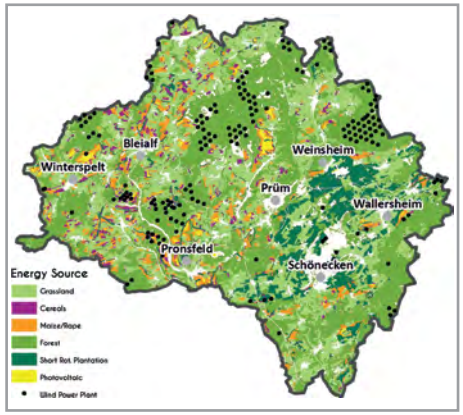
The expansion of renewable energies is driven by regulations and financial incentives such as subsidies. In some regions, this often led to a spatially unplanned expansion independent from the actual potential of an area for the production of renewable energies.

Negative land use-related side effects have been observed such as intensification of agricultural production, transformation of permanent grassland to arable land or land use competition with food crops.

> "This Copernicus-based model helps decision makers and experts to enforce the energy transition. The possibility of creating scenarios is used to find the optimal solution for the individual region."
>
> ***Achim Hill,***
> ***Energy Agency of the Region Trier***

The unique character of this space-based solution is that it considers ecological and economical aspects of renewable energy production. For example, factors such as distance from biogas plants (regarding transport costs and GHG emissions) and pollinator-friendly crop cycles are taken into account when assessing the potential for bioenergy crop production.

The spatial model is an innovative planning tool for regional decision makers and public authorities, such as governing mayors who are directly involved in the development.



Designation of the most suitable renewable energy source per area for the municipality of Prüm.
Credit: Contains modified Copernicus Sentinel data [2016]

Hence, the energy transition can be planned in direct response to the local energy demand, on sites with most efficient energy output and in an ecologically sustainable manner. Spatial planning of the energy transition is thus possible, whilst preserving the regional diversity of the landscape with direct benefits for citizens.

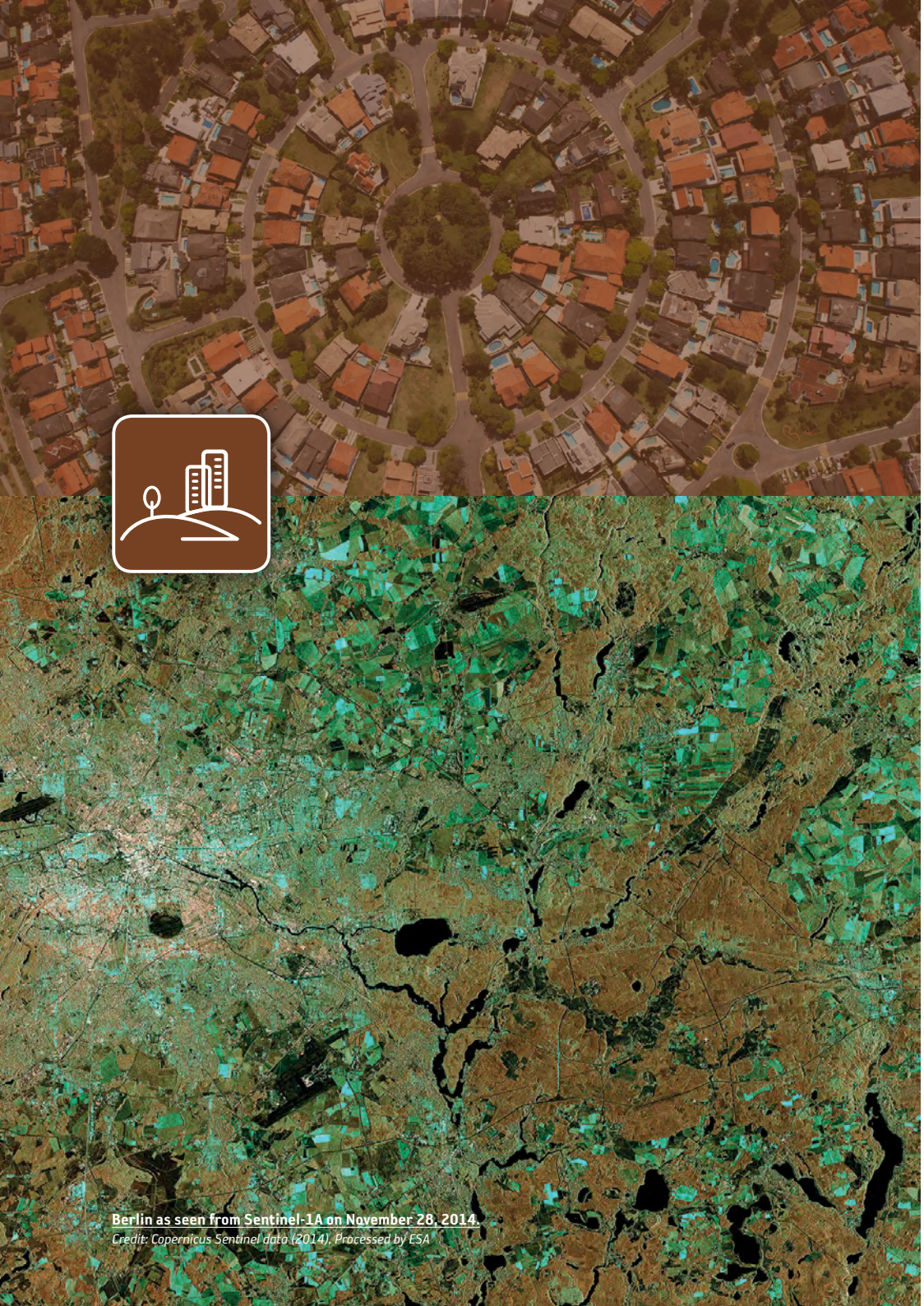
Outlook to the future

The energy transition is a major challenge for the European Union. Its territorial implementation is having more and more impact on regional development. The COP4EE approach has so far been established in the region of Trier and Bitburg-Prüm in Germany, but with the fully operational Sentinels and with modern IT infrastructure for big data processing, it is possible to scale up the approach to the EU territory. The Copernicus programme, with its long-term provision of free EO data and the upcoming Copernicus Data and Information Access Services (DIAS), is therefore fundamental.

Acknowledgements

COP4EE is funded by the Federal Ministry for Economic Affairs and Energy (BMWi) via the Space Administration of the DLR.

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Berlin as seen from Sentinel-1A on November 28, 2014.
Credit: Copernicus Sentinel data (2014), Processed by ESA

TERRITORIAL MANAGEMENT AND URBAN PLANNING

The management of rural areas and urbanisation is key for sustainable development. In Europe, urban areas account for over two-thirds of the population, use about 80% of the energy and generate up to 85% of the GDP. Greener, smarter cities, rural development and infrastructures are amongst the pillars of the EU cohesion policy. This implies a balanced approach integrating different scales of cities and human settlements, making sure that supplies and demands between urban and rural areas are smoothly flowing and territories are connected. Several challenges must be faced to ensure that sustainable practices are adopted, for instance through comprehensive soil sealing mitigation measures, regulated housing and waste management.

Urban and territorial managers globally aim at ensuring that citizens' private and social living is balanced, by carefully planning infrastructure and services that facilitate trade and productivity still safeguarding the environment and social public places. Local and regional authorities have significant responsibilities in this respect and are responsible for the successful implementation of several EU policies influencing spatial planning.

Copernicus Sentinels and the Copernicus Land Monitoring Service can help facing these challenges by providing disparate geospatial information regarding e.g. land use and land cover classification, urban growth, urban green areas, urban heat islands, imperviousness, etc. Whilst in-situ data and very high resolution data from Copernicus Contributing Missions are essential in resolving the details of e.g. urban maps and ecological corridors, Sentinel-1 and Sentinel-2 missions provide regular and consistent observations that are especially important when dealing with wide areas and shared cross-border resources.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
CHANGE DETECTION ANALYSIS ON WALLOON BROWNFIELD SITES	Wallonia (Wallonie)	Wallonia	S2	3
COPERNICUS FOR LYS BASIN WATER MANAGEMENT	Occitania (Occitanie)	Occitania Hauts de France	S1	4
DIOGNASING THE BURJASSOT URBAN DRAINAGE SYSTEM	Community of Valencia (Comunidad Valenciana)	Community of Valencia	S2	3
ENABLING PERIODIC DOWNSTREAM SERVICES VIA USER-FRIENDLY DATA GRABBING	Lombardy (Lombardia)	Lombardy	S1, S2	1
LOCAL COPERNICUS DEMONSTRATOR IN BRITTANY	Brittany (Bretagne)	Brittany	S2	1
A PLATFORM FOR MAPPING TERRITORIES BY SATELLITE IN THE INDIAN OCEAN	Reunion (Ile de la Réunion)	Madagaskar	S2	3
MEASURES OF SURFACE MOVEMENTS IN CATALONIA USING SENTINEL-1	Catalonia (Catalunya)	Catalonia	S1	4
STORYTELLING TOOL FOR A FOREST FIRE IN YESTE	Andalusia (Andalucia)	Castilla La Mancha	S2, S3	2
COPERNICUS DATA USED TO UNDERSTAND LANDSCAPE HISTORICAL TRANSFORMATIONS	Lombardy (Lombardia)	Lombardy	S2	5 2/3
COPERNICUS HELPS PRAGUE TO PLAN THE CITY OF THE FUTURE	Prague (Praha)	Prague	CLMS	3
EO FOR SUSTAINABLE URBAN PLANNING	Wallonia (Wallonie)	Wallonia	CLMS, S1, S2	3
MODELING AND FORECASTING URBAN POPULATION PATTERNS	Brussels (Région de Bruxelles Capitale)	Dakar Ouagadougou	S1, S2	2
MONITOR URBAN AREAS AND GREEN INFRASTRUCTURES	Brittany (Bretagne)	Brittany Ille-et-Vilaine	S2	3
URBAN GROWTH MONITORING WITH COPERNICUS DATA	Alsace (Alsace)	Haut-Rhin	S2	3/4

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2; S3: Sentinel-3; CLMS: Copernicus Land Monitoring Service.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

CHANGE DETECTION ANALYSIS ON WALLOON BROWNFIELD SITES

Change detection analysis based on Sentinel-2 data in order to update the inventory and quantitatively assess the evolution of brownfield sites in time and space.



Urban renovation in Seraing (West of Liège, Wallonia). Former colliery site reconverted into commercial and service area. *(Source : Walonmap – SPW)*

The challenge

After the successive industrial restructuring of the 70s and 80s, Wallonia has inherited numerous derelict and underused sites. In 2006, the European Commission required that each member state establish an inventory of these sites, known as brownfields. The Walloon inventory includes sites of economic and non-economic activities that have been abandoned, both polluted and unpolluted. It lists more than 2,000 sites previously dedicated to economic activity ranging from post offices to heavy steel industries. Due to its time-consuming nature and expansive cost, public authorities were looking for a new solution for the inventory. This solution would enable (1) frequent updating of the inventory and (2) prioritisation of the sites for urban redevelopment projects.

The space based solution

The developed decision-making tool uses Sentinel-2 data in combination with aerial orthophotos, LiDAR (light detection and ranging) and Pleiades data. The integration of these Earth Observation (EO) data with expert knowledge helps to detect and label the changes related to the rehabilitation of the inventoried sites. These include building demolition, renovation, new build and also conversion of land to recreational areas such as parks. Thanks to their high resolution multispectral data, Sentinel-2 satellites are of great interest to apply radiometric change detection methods on brownfield sites. They enable fine intra- and inter-annual change detection analysis.

The methodology uses a variety of spectral indices for detecting change in vegetation and other land covers. Indices are mathematical expressions combining different spectral bands of the electromagnetic spectrum. For instance, they quantify the strength and the vitality of the vegetation (e.g. the Normalized Difference Vegetation Index - NDVI) or the brightness of soils (e.g. the Brightness Index - BI) which is highly correlated with soil moisture and sealed surface materials (e.g. roads, parking areas or roofs). Spectral indices help to identify areas of changes, to qualify types of changes and, finally, to quantify their extension.

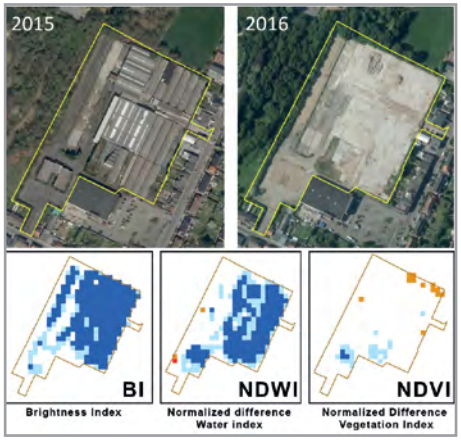
Benefits to Citizens

The identification of brownfields represents a valuable opportunity and an important potential for Wallonia. Indeed, some derelict sites have negative impacts the environment (visual impact, symbol of economic and social difficulties, environmental and health risks...).

> "This application, based on Sentinel data, will save time and reduce the costs of updating brownfield inventory."
>
> ***Christophe Rasumny, DG04, Public Service of Wallonia, Belgium***

All residents settled in the surroundings of brownfields deserve a qualitative environment.

Previously abandoned sites could then be brought back to beneficial use by pushing local entrepreneurship spirit by highlighting the regional remarkable heritage. The rehabilitation of brownfields also enables urban sprawl within agricultural lands to be limited. Limiting regional soil sealing reduces the risks of flash floods. Moreover,



Old manufacturing industries being rehabilitated. The total destruction of buildings is well identified by the spectral indices.
Sources : Walonmap - SPW Credit: Contains modified Copernicus Sentinel data [2015-2016]

brownfields of Wallonia are generally located in urban area and are thus well connected to public transport facilities. The regeneration of these areas will contribute to job creation and new developments of residential, industrial or recreational areas.

Outlook to the future

By exploiting the revisit time of Sentinel-2 data, this decision-making tool supports the public administration for a more efficient and rapid updating of the inventory of the brownfields. However, developing a fully automated change detection process remains challenging as photo-interpretation, i.e. expert knowledge, still plays an important role in the current tool. An initial outlook then consists in developing automatic steps to improve and accelerate the visual processes.

Secondly, we will develop more complex / composite indices, namely, those based on satellite time-series analysis, to enhance change detection accuracy. Testing Sentinel-1 data can overcome the issues of cloud cover on Wallonia.

In addition, the EO based method could study a further detection of non-inventoried brownfields in order to increase the completeness of the inventory.

Acknowledgements

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COPERNICUS FOR LYS BASIN WATER MANAGEMENT

The June 2016 satellite images acquired over Northern France flooding provide unprecedented information concerning the Lys basin, its hydraulic mechanisms and actions to be implemented.

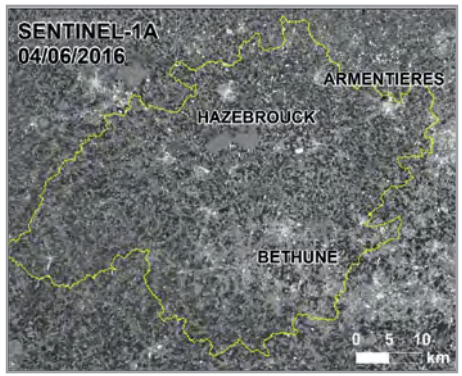
The challenge

The Lys basin in the North of France has had to cope with an increasing number of flood phenomena over the last few years. With 180,000 persons exposed the Mixed Water Management Syndicate of the Lys Basin (Symsagel) needs knowledge concerning these events to implement its Local Strategy for Flood Risk Management (SLGRI) in relation to the European Floods Directive.

Terrain surveys are practised during events but only punctually (in time and space) and essentially on urban areas. Rural areas are only poorly or not monitored at all whereas they strongly contribute to hydraulics mechanisms potentially responsible for increasing impacts. Large-scale data is necessary to cover this fairly large basin (1800 km²) and river segment at a length of 195 km. Cloud cover in this territory often prevents aerial acquisitions during flood events. Alternative solutions are necessary to obtain information at the basin scale to understand hydraulic mechanisms and propose planning actions in the context of PAPI (Action Plan and Flood Prevention), part of the SLGRI.

The space based solution

In May-June 2016, a large-scale flood event



Sentinel-1A image acquired on Lys Basin on 4 June 2016.

occurred in Northern France. Over the Lys Basin, very high precipitations occurred between 30 and 31 May 2016 causing rapid flooding of the Lys River and its tributaries, followed on the 6 and 7 of June 2016 by a second less intense rainfall episode, which also raised the water level, flooding the plain (favoured by soil saturation) causing over 27,000.000 euro of direct damage. Three Copernicus images covered the Lys Basin: Sentinel-1A images acquired on 31 May, and 4 and 7 June; a Landsat-8 image acquired on 9 June completing the dataset. Those images covered the entire basin.

Cerema (a French Public Establishment with a Department in charge of Space applications for public policies), extracted information on flooded areas from those images.

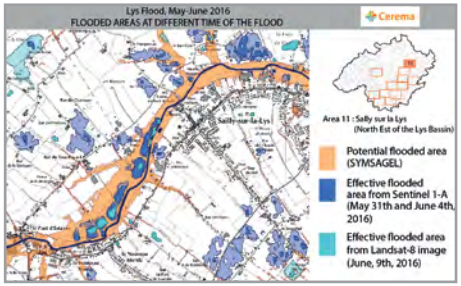
The maps produced presenting satellite-based analysis report all observed flooded areas of the basin, a result which has never been produced at this scale in this area. This exhaustivity placed emphasis on unexpected flooded areas out of the "potential flooded area". This large-scale analysis enabled the most exposed areas of flooding (overflow runoff or rising water) to be targeted and where it would be appropriate to carry out

> "These maps provide us with reliable data on rural areas, which in time will allow us to focus the manpower to help with crisis management and feedback."
>
> ***Sarah Duverney,***
> ***Flood Plan Project Manager, Symsagel***

complementary investigations to confirm or not their sensitivity to local practices.

Benefits to Citizens

Terrain surveys are performed during a crisis but provide punctual information in time (in general during the crisis) and on few selected geographical areas (in general urban areas or few selected streams). Lots of other areas are generally not monitored. Space data is one of the unique tools used to cover the whole Lys Basin and provide such information with repetitivity during and after the crisis. The images taken three days later raised the question of knowing how long it takes for water to recede.



Map of flooded areas extracted from satellite images (Sentinel-1A and Landsat-8) acquired during Lys floods. Lys Plain, Sally-sur-la-Lys area, Hauts de France, France.

TERRITORIAL MANAGEMENT AND URBAN PLANNING

Satellite-based maps are guidance documents to point out some areas to work with to reduce damages and the number of persons exposed. Symsagel uses this result as a starting point for scientific exchanges about hydraulics mechanisms involved during floods and causing damages.

Outlook to the future

In the Lys Basin, agricultural drainage is singled out as a contributing factor to flooding. Cerema and SERTIT (Regional Service of Remote sensing and Image Processing, operator of the Copernicus Emergency Management Service), will work together with Symsagel in order to exploit the results of space image analyses to enrich the hydraulic knowledge of the Lys plain and assess the impact of agricultural drainage on floods. Symsagel will exploit this information to add actions at the halfway stage of its flood prevention plan.

Acknowledgements

Thanks to the Copernicus programme for the images acquired and for putting them at our disposal for the study.

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DIAGNOSING THE BURJASSOT URBAN DRAINAGE SYSTEM

Sentinel-2B data is being used by the Climatology from Satellites Group to diagnose the current situation of the Burjassot Municipality drainage system.

The challenge

Climathon is a global 24-hour Climate Change Hackaton, organised by EIT Climate KIC, that takes place each year in different cities all over the world. The University of Valencia Climatology from Satellites Group (GCS), Valencia, Spain, organised the Burjassot Climathon 2017, focusing on Earth Observation in Support of a Sustainable Water Resources Management using Copernicus data. Burjassot Climathon 2017. It provided a clear idea to propose and hopefully achieve a Sustainable Urban Drainage System (SUDS) for Burjassot municipality. Burjassot is a small city close to Valencia where more than 70% of precipitation is concentrated in ±10 days per year, given the variability and distribution of the rain is extremely irregular. Besides, the orography and topography of the city and the massive urban growth with the so-called "hard infrastructures" have caused a significant regression of green areas, also triggering the occurrence of periodic issues of flooded streets, unusable infrastructure during and after the events and material and non-material damages.

The space based solution

In order to improve the drainage system, accurate knowledge of the current land uses is

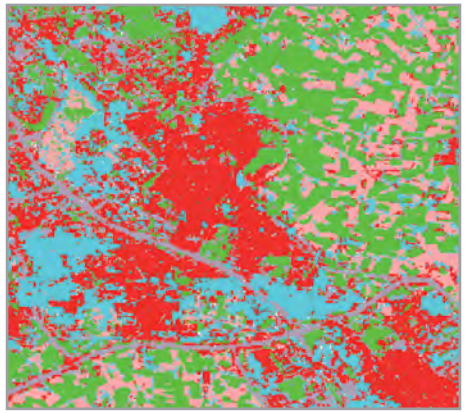


Natural colour RGB (bands 4, 3, 2) image of Burjassot Municipality (Sentinel-2B EMS Copernicus Service, 17 Dec 2017, 10-m spatial resolution)

needed to be able to identify and estimate the impervious surface areas (ISA) and propose adequate solutions to make them more sustainable and "flood resilient" through the development of green/blue infrastructures, permeable pavements, filter strips, etc. Copernicus Sentinel-2 MSI (MultiSpectral Imager) data are suitable for understanding the current situation of Burjassot. The figure below shows a supervised nearest-neighbour land use classification of the Burjassot Municipality using data from Copernicus Sentinel-2B MSI. Preprocessing begins with the combination of Maximum Noise Fraction (MNF) and Principal Components Analysis (PCA) to reduce the spectral dimensionality and selecting the bands with more information. Then, Pixel Purity Index (PPI) is applied to identify three extreme endmembers: high albedo (bright ISA and bare soil), low albedo (dark ISA, water, wet areas and shadows) and vegetation. Classifiers are applied to group both ISA classes (bright and dark) and define the sealed zones. This process is carried out with several images throughout the year to verify changes. Once the final classification is established, it is compared to high resolution images as well as to the Copernicus High

> "The proposals from the study on the Burjassot drainage system are absolutely necessary to avoid urban floods that our town undergoes quite often."
>
> ***Local Office for Sustainability, Burjassot Town Hall***

Resolution Imperviousness product, by evaluating 100 points that generate a confusion matrix, together with the overall accuracy (OA), producer's accuracy (PA) and user's accuracy (UA).



Burjassot Municipality land uses (Sentinel-2B EMS Copernicus Service, 17h Dec 2017, 10-m spatial resolution).

Benefits to Citizens

As a consequence of the Burjassot Climathon 2017, the GCS is now closely collaborating with the Burjassot City Hall in some of their significant water management issues. They jointly produced the Urban Adaptation to Climate Change report, which consists of a diagnostic study with a detailed work plan to carry out an evaluation and implementation project based on Copernicus Sentinel data and products. Implementation measures

on critical identified areas will increase the citizens' quality of life thus favouring routine displacements during risk events and reducing restoring costs after them. Water reuse will also be encouraged when channelled to green zones, thus reducing costs in irrigation waters.

Outlook to the future

The GCS has developed an innovative approach to be implemented into a pilot study to assist in future municipal water management issues consisting of a holistic methodology that puts together Copernicus EO data, a refined 3D digital elevation model and a statistic analysis of meteorological data. All this information is then inputted into an urban runoff model that will simulate different SDUS scenarios and help in the decision-making process.

Acknowledgements

The authors wish to express their gratitude to Ms Lluna Arias and her Team, D. Gomez and M.C. Exposito, at the Burjassot Town Hall Environment Department. They also acknowledge the financial support from the Climate KIC Education InnoSpace Project to carry out the Copernicus Climathon Burjassot 2017, as well as Climate KIC Spain.

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ENABLING PERIODIC DOWNSTREAM SERVICES VIA USER-FRIENDLY DATA GRABBING

GeoGrabber is a desktop tool for non-experts, periodically downloading and processing data from Sentinel sources.

The challenge

Ever since EO Copernicus Sentinel missions became operational, we have entered a new age of possibilities, an age of open development of downstream services at low cost for the most diverse application fields, such as environmental monitoring, climate change, anomaly detection and emergency prevention, preparedness and management.

Nevertheless, the feasibility of implementing a downstream service by directly using the currently available facilities offered by ESA SciHub and tools such as SNAP still require the engagement of remote sensing experts. From querying the sources, to evaluating and downloading the images, and – last but not least – to processing those images in order to generate semantic products, an expert figure is required. This statement of facts is an obstacle to the widespread diffusion of remote sensing technologies amongst civil society. Public administrations tend to regard this technology as too complex and expensive, eventually ignoring it and hosting a gap between available data and territorial challenges.

The space based solution

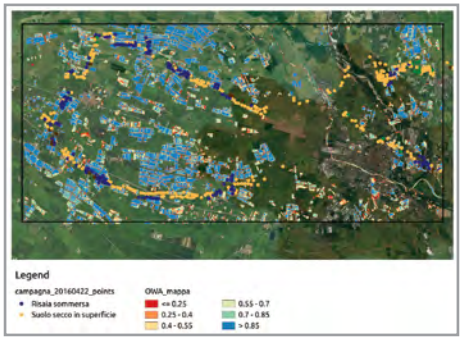
The reasons outlined above motivate our proposal for developing an easy-to-use abling desktop tool of downstream services that can be customised by non-experts to periodically generate a variety of remote sensing products. This is possible through transparent and periodic querying Sentinel sources through SciHub APIs and by providing facilities for the integrated client-side auto-computation of indicators on the downloaded data, the periodic feature being an original aspect with respect to other ESA DIAS such as Sentinel Playground or even Google Earth Engine.



GeoGrabber's graphic interface. Through a user-friendly environment, it enables any user to implement customised down-stream services of Sentinel data.

To this end, a multidisciplinary team has been working, together with end users, on the definition of requirements and architecture of GeoGrabber, a user-centred desktop tool. Running on common computers, it offers simple user interaction schemes, mainly based on selecting facilities by means of a user-experience-designed interface. It lets the user define a Region Of Interest (ROI) by specifying a toponym, a bounding box, or a vector file. Over the selected ROI, the user can choose one or more products he/she wants to generate (i.e. flooded areas, wildfires, vegetation vigor indicators), selecting them from the menu, possibly specifying the sensing date of the source data, the tolerance on the cloud coverage, and the option for the roduct to be generated periodically, at each sensor revisiting time. In this last case, once activated, the task runs automatically in the background, with no need for further user intervention, and periodically downloads and processes the desired Sentinel data from either S1 or S2, scheduling periodic tasks.

> "Change the vision that citizens have of remote sensing, by making it less remote and more sensitive."
>
> ***CNR IREA and CNR IDPA***



Map showing rice fields flood status (processed through fuzzy reasoning applying OWA) on a Sentinel-2A image. Downloaded and automatically processed by GeoGrabber.

Benefits to Citizens

Since GeoGrabber runs on a common PC with a Java Virtual Machine and an R interpreter, it can be easily installed, and at little expense – thus, being affordable for the budget of any public administration. Its design is such that any non-expert from public local authorities could use it to check the status of the environment in the municipality, monitoring burned or flooded areas in case of natural disasters and filling the "handling gap" between data and their full exploitation. Moreover, local authorities could use it to monitor crop growth and help local farmers, providing the flood status of rice fields, eventually improving the economy of rural areas by empowering the citizens with data tailored to their specific needs. Concerning existing alternatives, it can feasibly help to save on costs and make monitoring processes – currently mainly based on surveys – more efficient. The exploitation of remote-sensing-derived information for the discovery of possible anomaly-affected areas can drive in situ survey directly where needed and improve the efficiency and effectiveness of the administrative procedures by saving on costs.

Outlook to the future

GeoGrabber is an open software in its early release, funded by STRESS project (started in May 2017). It will be extended with other features, such as the computation of different products and the downloading of Sentinel data from other sources, as they become operational.

Acknowledgements

STRESS project, #2016-0766, funded by Cariplo, "Bando Fondazione Rst - Ricerca dedicata al dissesto idrogeologico 2016" and SIMULATOR-ADS project, #137287, co-funded by Regione Lombardia & FESR "Linea R&S per Aggregazioni".

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LOCAL COPERNICUS DEMONSTRATOR IN BRITTANY

A working group to democratize data and services from Copernicus and make Brittany a territory for experimentation and demonstration of space applications.



First meeting of the working group across 5 cities (Brest, Lannion, Lorient, Rennes, Vannes).

The challenge

Since 2015, the French Regions have been given additional responsibilities and must establish a regional planning and sustainable development scheme. Thus, to be fully informed about their territory and to efficiently manage its planning, local authorities need data, knowledge and tools. At the same time, earth observation data, including Copernicus and Sentinel data, remains underutilized: its use has so far been limited to specific projects, without real regional coordination. Local public authorities using geolocation data are aware of this potential and would like to take advantage of this dynamic. This results in two challenges for users: to integrate earth observation data, tools and techniques with their commonly used data and tools; and, more generally, to become active agents of these technological and technical evolutions.

The space based solution

The space based solution consists in proposing operational demonstrators available on the Breton geographic data sharing platform "GeoBretagne" that has already been used by a large community of territorial managers for 10 years. Data and products resulting from Copernicus Programme and space applications, previously unexploited in this platform, would be integrated with other data.

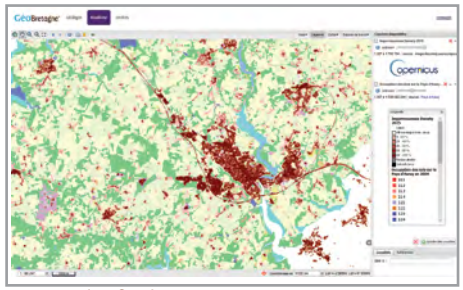
The originality of the initiative lies in the joint construction of demonstrators: a working group was set up within the GeoBretagne partnership, the Remote Sensing working group. It is currently made up of about twenty volunteers (territory managers, service managers, geomaticians) and led by GIS BreTel. The group aims at sharing knowledge and experiences, as well as co-designing space based services that respond to end-users needs. The first meeting of the Remote Sensing working group took place in January 2018 across 5 cities, and led to the proposal of an action plan.

Benefits to Citizens

The working group operates at two levels. The first is data and services dedicated to end-users access, providing them:

- Reliable and regularly updated data/ indicators/products with homogeneous acquisition methods for the region and consistent with the INSPIRE directive;
- Demonstration space to get to know and make known the space based solutions to their little-aware pairs.

> "Many public authorities still have rather low expectations for space applications because of a fast-moving landscape. They ask for a place to discuss use cases at their own pace, using their business vocabulary in order to build their own strategy that will combine remote sensing with their daily applications."
>
> ***Fabrice PHUNG (GeoBretagne)***



An example of a demonstrator on GeoBretagne showing Copernicus product (imperviousness) compare to local land-use.
Credit: Contains modified Copernicus Sentinel data [2015]

The second level relates to users' ownership, allowing them:

- To have a resource and exchange centre to share experiences and practices, be they successes or disappointments that are also instructive;
- To join a network of users, remote sensing experts and support structures (in Brittany or in national and European networks);
- For mutual needs, to share the costs and reduce risks when setting up operational services or joint pilot projects;
- To be more than just consumers of data/ products/services, to take part in their elaboration, and thus to be a voice alongside other communities of space authorities.

Outlook to the future

The aim is to propose a regional variation of Copernicus for regional managers, which will be both a data platform, providing products and services and a place for experimentation. This will give the end-users' community more ownership over these new tools and will contribute to a favourable environment for the use of Copernicus data and products, and more generally space applications in Brittany.

Acknowledgements

Project officers of GeoBretagne: Fabrice PHUNG and Stéphane MEVEL-VIANNAY

Head of territorial development department, Brittany Region: Jonathan MORICE

All people involved in the working group and in the partership GeoBretagne.

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A PLATFORM FOR MAPPING TERRITORIES BY SATELLITE IN THE INDIAN OCEAN

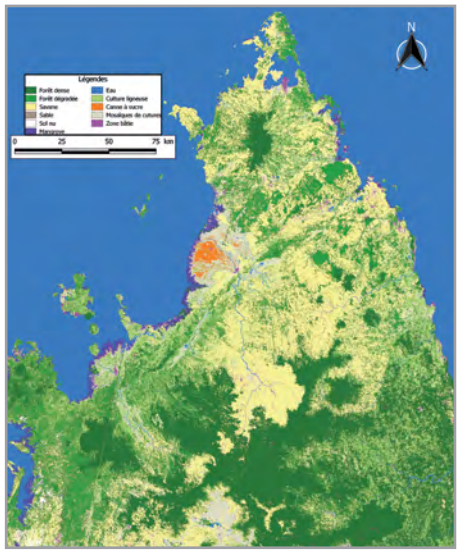
Led by the Regional Council, the programme CACAOS aims to develop an infrastructure for obtaining a reliable, shared and up-to-date cartographic database.

The challenge

The use and benefit of land-use data in Geographic Information Systems is complicated by: often limited coverage; random updating; geographical incompatibility of data due to the different repositories used; and non-compatible typology that does not allow a temporal spatial comparison of the classes. In addition, producers of this data sometimes restrict access to it, thus limiting its valorisation. The European Copernicus programme offers a new perspective for producing reliable, shared and up-to-date land use maps of the Indian Ocean territories from Sentinel-2 images and remote sensing. With a high spatial resolution (10m) and high temporal repetitively (one image every 5 days), this data is very useful for monitoring land with great responsiveness.

The space based solution

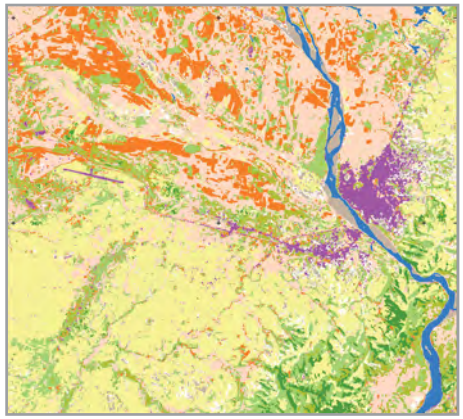
The CACAOS programme led by the Regional Council of Reunion allows for computer-assisted processing of Sentinel-2 satellite images from the Copernicus programme over large territories to obtain land use maps. The CACAOS chain is based on free software (MAJA, IOTA²) developed by the French National Centre for Space Studies (CNES) and notably by the Centre for the Spatial Studies of the



Land-use maps of the north of Madagascar produced from CACAOS in 2017.
Credit: Contains modified Copernicus Sentinel data [2017]

Biosphere from Space (CESBIO). A first pilot phase was carried out on the Diana region in Madagascar (20,000 km²) during the first half of 2017 in partnership with the Regional Council of Diana and the National Geographic and Hydrographic Institute of Madagascar (FTM) with co-financing from the French State and the Regional Council of Reunion. This area was mapped into 13 different land use classes at a scale of 1:50,000 to 1:100,000. The processing of spatial data initially requires the collection of referenced data. All data were processed at the Regional Council's data processing centre on Reunion Island within the SEAS-OI station (Survey of the Environment Assisted by Satellite in the Indian Ocean). This mapping allows the delimitation of different kinds of forest (primary, degraded, mangrove,...) and the urban areas. The second phase in progress co-financed by the French Development Agency (AFD) and the Regional Council of Reunion aims to generalise the CACAOS tool throughout Madagascar (587,000

> "The free access to satellite imagery through the Copernicus programme and the development of free and open remote sensing processing tools are opening up new perspectives in territorial mapping."
>
> ***Jean-Désiré Rajaonarison National Geographic and Hydrographic Institute of Madagascar***



Land-use maps on a scale of 1:50 000 produced from CACAOS.
Credit: Contains modified Copernicus Sentinel data [2017]

km²) in order to produce a complete land cover over the country in 2017.

Benefits to Citizens

The CACAOS programme allows free and open distribution of land use mapping products. These data make it possible to manage various problems at regional and sub-regional scales: environment (protected area, natural risks, etc.), agricultural and urban areas. In Madagascar, land use mapping is essential to establish a baseline survey and to monitor territorial planning documents. The land use indicators

(frequency at least once a year) are essential for the strategic management of territories but also for monitoring and control of public policies. This map was used by the Regional Council of Diana of Madagascar to update the regional land use and development plan.

Outlook to the future

A capacity building and skills transfer approach is planned with local authorities to avoid any digital divide and democratise access to spatial information from the Copernicus programme. In addition to the tool itself, the CACAOS programme aims to develop a strategic partnership with technical and financial operators, government departments, Non-Governmental Organisations, research organisations,... to make it a shared technical reference platform for sustainable development first in Madagascar, and then to extend it to other countries. The Regional Council of Reunion is thus planning to develop a remote sensing resource centre in Reunion Island.

Acknowledgements

This programme is the result of a collaboration between the Regional Council of Reunion, the National Geographic and Hydrographic Institute of Madagascar, the Regional Council of Diana of Madagascar with the financial contribution of the French Development Agency, the French State and the Regional Council of Reunion.

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MEASURES OF SURFACE MOVEMENTS IN CATALONIA USING SENTINEL-1 DATA

A complete monitoring of surface movements at regional scale has been implemented as a decision support tool on risk management.

The challenge

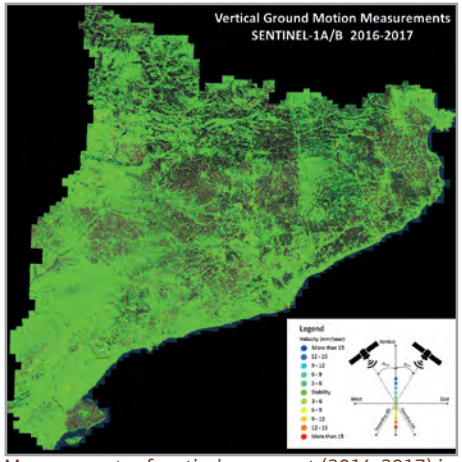
Surface movements can be caused by various phenomena, both anthropic and natural ones, such as groundwater extraction, landslides, infrastructure construction, mining or tunnelling. The techniques developed by the Cartographic and Geological Institute of Catalonia (ICGC) allow the measurement of movements with millimetre accuracy.

Using these techniques, the ICGC has generated a map of ground motion measures for the Catalan territory, using SENTINEL-1A/B radar satellites at C band throughout 2016 and 2017.

The space based solution

ICGC has created the first complete map of measures of land movement for the entire territory of Catalonia. The measurements have been obtained from radar images of the SENTINEL-1A and B satellites on ascending and descending modes. These satellites offer a maximum 6-day image acquisition frequency, and the images are free to download.

In recent months ICGC has been developing Persistent Scatterer Interferometry (PSI) methodology for processing large quantities of SENTINEL-1 images.



Measurements of vertical movement (2016-2017) in the entire territory of Catalonia obtained with ICGC's PSI processing chain using SENTINEL-1A/B data.

With regards to SENTINEL-1A/B images, the measurement points are shown on the maps with a spatial resolution of 20 x 20 metres. The points that can be measured must be surface elements that do not undergo major changes during the monitoring period, and are usually found with a high density in urban areas, infrastructures and zones with low vegetation.

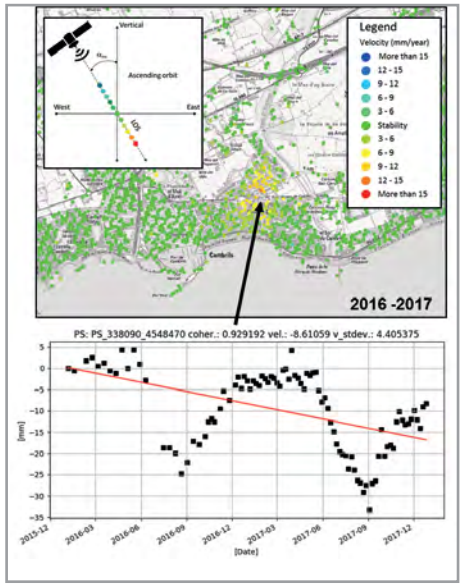
Benefits to Citizens

The different incidence angles of the satellite in the ascending and descending orbits allow the measurement of the components of the movement corresponding to the vertical and horizontal direction (East-West).

This translates into a very detailed knowledge of the characteristics of the motion, and this information combined with geological studies and in situ measurements, is transformed into a great tool to evaluate the causes and to apply solutions, for better management and monitoring of the territory.

The images that illustrate this article show motion measurements generated with a set of SENTINEL-1A/B images during 2016 and 2017, corresponding to the motion in the vertical direction and Line Of Sight (LOS) respectively. A colour scale indicating the intensity of the velocity represents the points that can be measured.

> "Copernicus Sentinel-1 data allow us to transform data into information and knowledge in a cross-fertilisation action between geologist and remote sensing professionals."
>
> ***Sr. Jordi Marturia,***
> ***ICGC-Geological Prevention Risks***



Example of measured subsidence in Cambrils urban area due to periods of groundwater extraction. During summer (2016 and 2017) groundwater is extracted and subsidence accelerates (more than 3 cm accumulated in 2017). Note that surface level does not recover fully during the winter.

TERRITORIAL MANAGEMENT AND URBAN PLANNING

Stable points are shown in green. In these measures, which cover the entire Catalan territory, several areas affected by surface movements can be distinguished.

The mentioned ICGC SENTINEL 1 added value chain has been also used in the LIFE EBRO-ADMICLIM project (ENV / ES / 001182), in the Ebro Delta (Catalonia, a zone that is very vulnerable to the rise of sea level and ground subsidence. Therefore, the interferometric SENTINEL-1 data on the current rates of subsidence of the Delta are of major importance.

Outlook to the future

Starting from the measure corresponding to 2016, the ICGC proposes to create periodic updates, generating a historical database of surface motion throughout the territory of Catalonia.

Acknowledgements

The authors would like to thank ESA and the Copernicus Open data Hub for the official open data available and the associated software and support for the management and analysis of SENTINEL-1 imagery.

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STORYTELLING TOOL FOR A FOREST FIRE IN YESTE (ALBACETE, SPAIN)

This storytelling tool shows the daily evolution of the fire based on the wind direction changes using satellite data.

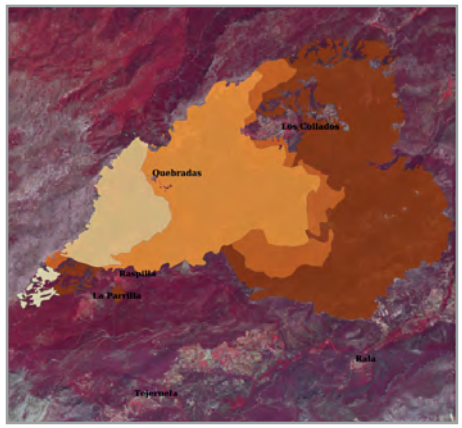
The challenge

Castilla la Mancha is a region in Spain that has been severely affected by wildfires. Large forest fires such as the one that took place in August 2017 in the municipality of Yeste (Albacete) are becoming more and more frequent in the Mediterranean and are leading to more catastrophic outcomes. Understanding how the fire growth and spread is crucial for preventing and suppressing wildfires whilst providing critical and accurate information to the pertinent authorities. This is why we developed this storyline tool for the forest fire in Yeste. This tool combines the accuracy and updated data from the Copernicus Earth Observation (EO) Programme with wind speed data to analyse how the fire spread.

The tool shows maps together with narratives explaining the fire behaviour using graphs and pictures to convey the event information in an interactive and comprehensive way for the general public.

The space based solution

Copernicus EO data offers unprecedented available amount of data and services to monitor wildfires. We used Sentinel 3A, 2A and 2B from the Copernicus Programme,



The map shows the satellite image in false colour Sentinel 2B with brownish colours showing the area affected by the fire per day.

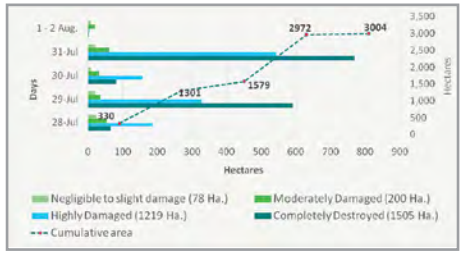
MODIS imagery aboard NASA`s Terra satellite and Landsat-ETM+ and OLI satellite images from the joint NASA/USGS programme to delimit burnt areas per day and detect active fires during the fire event. In addition to this, we used information from the Copernicus Emergency Management Service and other relevant datasets such as the boundaries of the natural park that were affected by the fire. Global wind data coming from the NOAA Operational Model Archive and Distribution System was collected on every day the event occurred. Once the layers were ready a set of web mapping services were created with the purpose of publishing the results online. A short text was prepared to explain the source of the fire. The application is available free of charge at: http://projects.randbee.com/yeste_storytelling. The tool which is based on open source software works best with Firefox or Chrome Internet browsers.

Benefits to Citizens

The service and data coming from Copernicus offer a great opportunity to democratise the use of satellite data and services beyond

> "This tool provides reliable information to the citizens whilst incorporating lessons learned that could be applied in other regions or events."
>
> ***Nicolás López Molina, Regional Government of Castille La Mancha***

academia and industry. For example, the fires generate a lot of attention from the media. The attention increases if the fire is putting people's life and goods in danger. It is estimated that over the two weeks after the start of the Yeste fire, there were about 160 news items published on the web.



The graph shows the number of hectares burned per day together with the severity index derived from satellite images.

This storytelling tool was published 10 days after the event and as soon as the images were published and processed. It was disseminated using different social media channels and shared amongst different local organisations in the area. This storytelling tool provides all authorities involved in the event with timely and accurate geospatial information derived from EO Copernicus with narrative text, multimedia and images content. The core benefit of this tool is that it makes it easy to harness the power of EO data further combined with other data sources.

TERRITORIAL MANAGEMENT AND URBAN PLANNING

This tool also facilitates the work of Local and Regional authorities (LRAs) when measuring the impact of fire damage. An assessment of burn severity can be communicated using a severity index (in order of severity level) negligible to slight damaged area, moderately damaged area, highly damaged area, and completely destroyed area as per the graph above.

Moreover, LRAs can potentially share official assessments using these type tools for informing citizens.

Outlook to the future

Storytelling tools are very engaging and informative and a great way of promoting the use of satellite imagery from the Copernicus Programme. The tool presented here is an example of how stories based on satellite data and information can be communicated. The data and services from the different Sentinels are fundamental for advancing our knowledge on climate change but also for raising environmental awareness and improving data driven decision-making.

Acknowledgements

We acknowledge the Copernicus Programme and the National Oceanic and Atmospheric Administration for the data and services provided.

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COPERNICUS DATA USED TO UNDERSTAND LANDSCAPE HISTORICAL TRANSFORMATIONS

The ENERGIC OD Virtual Hub is a point of access to Sentinel Data and other geographic information lowering the barriers to the integration of geospatial data.

The challenge

The world of geographic information (GI) is currently extremely heterogeneous. User and system requirements, too varied to be satisfied by a single system or technology, have led to an utter lack of agreement on interoperability standards, creating a barrier to the full exploitation of GI by application developers. For this reason, the integration between Copernicus data, geospatial data (GIS and crowdsourcing data) as well as unconventional GI data like historical maps, remains highly underexploited. The Pan-European Virtual Hub (PEVH) and GeoPAN application provide a solution for tracking riverbed changes by integrating heterogeneous geospatial data such as Copernicus data, information from local Spatial Data Infrastructures (SDI) and digitised historical maps.

The space based solution

The PEVH is a single point of access to both Copernicus datasets, open geospatial datasets and unconventional GI data. Through it, an end user or a developer is able to access datasets provided by remote and heterogeneous systems, as if they were provided by a unique system. In particular, the PEVH is linked with the Sentinels Open Hub to get access to Copernicus Sentinels data.



Search through the Pan-European Virtual Hub of Sentinel-2A data (www.vh.energic-od.eu) in Lombardy (Italy).

GeoPAN is an example of application developed using the PEVH APIs. Thanks to the Virtual Hub, the development of GeoPAN application did not require the resolution of complex interoperability issues, such as the transformation of the reference system or encoding the format. Moreover, the PEVH introduces value added services, such as the support of multilingual search through GEMET vocabulary. GeoPAN allows the tracking of changes of riverbeds by integrating various data sources. In particular, initially Sentinel-2A data were used to identify possible former riverbed areas considering soil moisture indexes (NDMI, NDWI). Then, GeoPAN enables access to high resolution seismic classification of land parcels provided by Lombardy region SDI. It has long been recognised that unconsolidated sediments, like the ones that can be found in former riverbed areas, are found to amplify ground motion during earthquakes more than ground with hard strata. For this reason, GeoPAN was designed in close cooperation with the Lombardy Order of Geologists (more than 1000 geologists) to help in seismic microsonation. Historical data are also analysed. Thus, in order to evaluate if a parcel of land has been traversed by a riverbed in the past, numerous heterogeneous data

> "Thanks to GeoPAN it is possible to discover that today the course of the Adda river is displaced laterally towards the left bank with respect to the XIX Century one."
>
> ***Egidio De Maron, Vice president of "Ordine dei Geologi della Lombardia***

sources are needed and these very often oversee different local, regional even national PAs. GeoPAN collects a set of these sparse information and allows visualisation and data investigation within one unique tool. The application is currently undergoing testing in other European countries.



GeoPAN APP: integration of Sentinel-2A data, historical maps and shapefiles from the local (Lombardy) SDI to track riverbed changes.
Credit: Contains modified Copernicus Sentinel data [2016]

Benefits to Citizens

The ENERGIC-OD PEVH facilitates the development of new and multidisciplinary applications based on the full exploitation of (open) GI, including INSPIRE-compliant systems, Sentinel data and Copernicus services. Such an approach is stimulating for business innovations that increasingly rely on Earth Observation information, especially for the market of geospatial open data

applications.

The GeoPAN application has been extremely well received in professional environments such as the Association of Geologists as it provides a quick and easy way to track landscape transformations that have occurred across the centuries. Monitoring of such changes enables PAs to make more informed decisions regarding environmental monitoring and risk mitigation actions.

Outlook to the future

The concrete example of GeoPAN application can be replicated in other geographical areas and during emergencies caused by geo-hazards, with potential new features. In such cases, the use of PEVH could be extremely important in order to overcome bottlenecks given by lower level of data openness or be exploited to access datasets at local level (municipalities).

Acknowledgements

The research leading to the results of this paper has been partially funded under the ICT Policy Support Programme (ICT PSP). The ENERGIC OD Pan-European Virtual Hub was developed within the ENERGIC OD European project.

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COPERNICUS HELPS PRAGUE PLAN THE CITY OF THE FUTURE

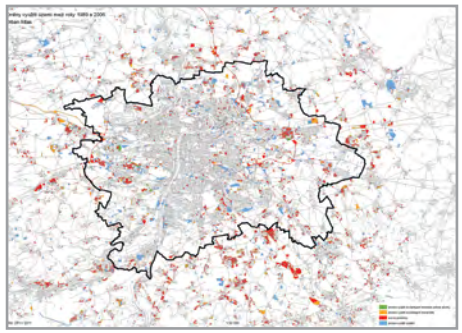
Urban and strategic planning in Prague relies on Copernicus Land Monitoring Services for land use benchmarking and monitoring change over time.

The challenge

Prague, like many European cities, suffers from a gap in data and information between the city's administrative areas and the surrounding region. Whilst Prague produces detailed, up-to-date geodata for planning and decision-making, the coverage of the wider metropolitan region with comparable data is weak. In the Prague metropolitan region, the Copernicus Urban Atlas is used in the monitoring and evaluation of various kinds of development, including: residential buildings, logistics hubs and industrial parks, and retail areas. The Urban Atlas also facilitates the comparison of the pace of new residential development between Prague and the wider metropolitan region, the locations of regional development hotspots, and other development indicators. Finally, the Urban Atlas is a convenient data source for inter-city or inter-regional comparisons and benchmarking, especially when it comes to obtaining comparable figures for the built-up area index, green spaces index, and others.

The space based solution

An integral part of urban planning is the monitoring of land use development in the city and in the wider metropolitan region over time. Temporal analysis enables



Land use changes 1989-2006, created with Urban Atlas-based retrospective data for Prague, property of IPR Praha.

planners to better understand issues such as traffic, demands on public services, housing development, property price fluctuations, and others. These issues, however, function across administrative boundaries and influence not only cities themselves, but also their relationships to other cities and areas. Taking the Urban Atlas 2006 and 2012 as the base, Prague provided additional classification for aerial imagery from 1989 and 1999 to gain a more realistic picture of land use development in the last 28 years. The comparison shows the trends in development and provides a guideline for future planning policies.

Regardless of the classification complexity and spatial resolution achieved, the Urban Atlas data still has limited use for planning at the local level due to the inconsistent classification of land uses over time, a lack of precision with regards to parcel outlines when compared with cadastral data, and other issues. Tackling these issues will be the challenge for the new, high-resolution Copernicus data products.

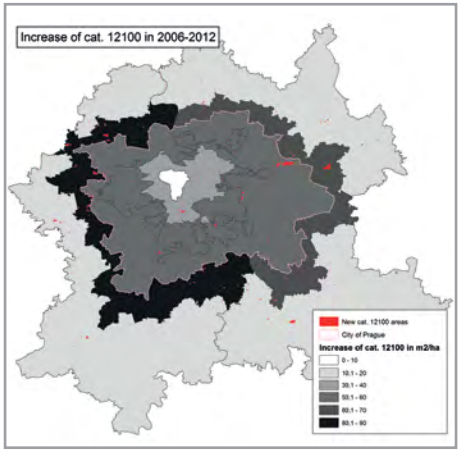
Benefits to Citizens

Copernicus data has also been used in the comprehensive, bi-annual Prague Analytical Planning Report, a binding and regularly

> "Copernicus data opens the door to smart metropolitan planning."
>
> ***Ondřej Boháč, Prague Institute of Planning and Development***

updated information source for he city which is anchored within the Czech legal framework.

In addition, the Urban Atlas was used in the preparation of Prague's new Metropolitan Plan, as well as for its Strategic Plan. The main contribution of the Urban Atlas to these documents was the identification of new development sites and more information about their character, along with the subsequent setting of expectations for future development trends.



New industrial and logistics developments from 2006-2012, Prague and the suburban region

For example, as presented in the map below, an evaluation of the increase in commercial and industrial units from 2006 to 2012 showed that most of this development took place in the outer ring of Prague and in neighbouring municipalities.

Finally, Copernicus data is also very beneficial for wider regional analyses. As there is no comparable data source which would employ the same classification system across different cities, regions, and even countries, the Urban Atlas provides a level of insight into land use which would not otherwise be possible.

Outlook to the future

The testing and development of new products with high spatial resolution and frequent updates is necessary for the management of the city and for good urban planning. The promotion of data sources with an MMU of less than 0.1 ha, along with annual updates, is crucial for replacing traditional, local data sources with new EO data products.

Acknowledgements

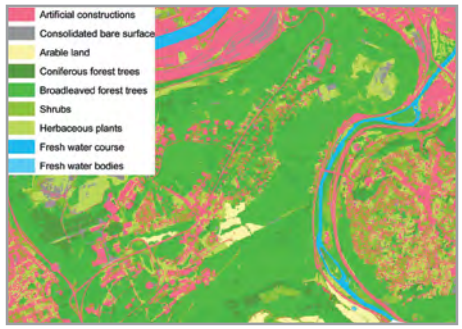
The bi-annual Prague Analytical Planning Report is available at http://uap.iprpraha.cz.

Urban Atlas-based Prague retrospective data is made up of datasets derived from historical orthophotos on the basis of Urban Atlas classification provided for the years 1989 and 1999 and is the property of the Prague Institute of Planning and Development.

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EO FOR SUSTAINABLE URBAN PLANNING

Using Earth Observation (EO) and modelling tools to spatially plan population growth. Population maps are needed to support risk management and to shape the Smart Cities of tomorrow.



RE compliant "Pure Component Land Cover" map on Sart Tilman, Seraing (2013).

The challenge

Urbanisation induces health and environmental risk-related challenges. In the context of steady urban population growth, cities and regions need to develop smart and sustainable management strategies to understand, measure, map and mitigate the increasing urban risks such as air pollution or urban heat, which are increasing in the context of climate change. In Wallonia, the current and official Land Cover (LC) and Land Use (LU) spatial database is not up to date. The LCLU map (COSW2007) does not distinguish LC from LU. Moreover, population figures are provided at the level of the statistical sectors, which have various sizes and shapes causing distortions in the spatial analysis. SmartPop develops smart spatial modelling methods combining various EO and geographical data. Derived gridded population density and risk-related maps support risk analysis, either in the assessment of hazards or in the exposure of the population, now and in the future. These tools are compliant with the EU INSPIRE directive requirements.

The space based solution

SmartPop develops two distinct LC and LU datasets integrated in a unique database. Firstly, a detailed regional urban LC mapping processing chain combines Very High Resolution (VHR) multispectral satellite imagery with aerial one as well as 3D digital height models, driven by LiDAR or photogrammetric methods. This semi-automated object-oriented chain is provided in open access. Secondly, the functional information needed in the LU map is deducted from existing thematic data and the LC map.

Using this LCLU database with the High Resolution "imperviousness" Layer (HRL) from the Copernicus land monitoring service or the Global Human Settlement Layer (GHSL), SmartPop proposes population dasymetric methods disaggregating demographic figures to fine-scale raster grid (100m). With the goal of improving the regional risk modelling, the two databases are then integrated in (i) an activity-based cellular automata model that simulates LCLU changes and population distribution until 2060 and (ii) in an urban climate model, "UrbClim", that produces outputs such as urban heat island maps and the number of heat wave days per period.

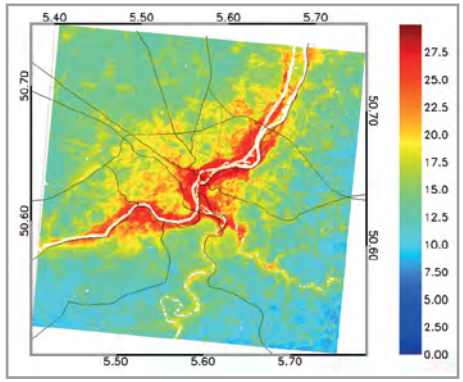
Benefits to Citizens

Local and regional authorities need comprehensive, user-driven and holistic visions of the fast changing urban territory to address the population growth challenge.

"The Walloon Operational Plan of Geomatic and the General Direction of Agriculture, Natural Resources and Environment rely on SmartPop to answer INSPIRE and create new LC and LU maps for Wallonia. We are convinced that this application covers specific Walloon needs."

Christel Baltus & Céline Delhage, Public Service of Wallonia (DG03)

With SmartPop, these authorities benefit from fine-scale, up-to-date and dynamic geoinformation that allow smart and sustainable planning of the urban territory.



Prediction of the number of heat wave days per summer for the 2081-2100 time period according to UrbClim (RCP8.5).

Outlook to the future

Thanks to the ad-hoc solution developed in Liege, a project called "Walous" and funded by public authorities has started in 2018. At regional scale, spectral indices from Sentinel-1 and 2 time series will be integrated into the current LC mapping scheme. In addition to the VHR data, these will provide useful object statistics that will help refine the level of thematic detail and increase the mapping accuracies. Sentinel data will also be primarily used for carrying out change detection analysis. By delineating the main areas of change within the LCLU database, Sentinel will help to prioritise the VHR EO data processing and hence improve the efficiency of the upgrading process.

The new Copernicus land monitoring services, such as Corine Land Cover +, HRL and GHSL, will be assessed with regards to the needs of Wallonia. Using the activity-based cellular automata model, different scenarios of population and LU change can be simulated. The outputs of this model will serve as inputs in risk analysis models such as "UrbClim" to analyse future risks. Using this modelling chain, robustness of environment policies can be tested under different outlooks for the future.

Acknowledgements

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MODELLING AND FORECASTING URBAN POPULATION PATTERNS

The MAUPP project aims at improving existing models of urban growth and population distribution for vulnerability and health assessment for a set of 48 African cities.

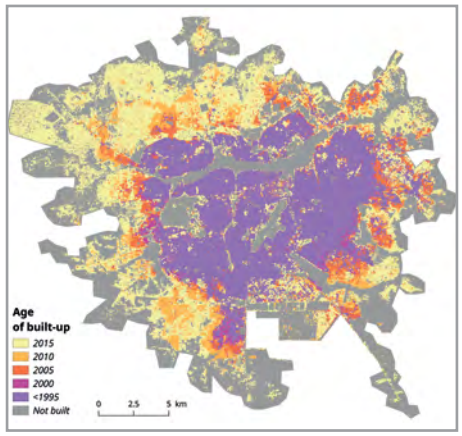
The challenge

Spatial modelling and forecasting of the human population is of primary importance for epidemiology and risk assessment, especially in Africa where the population is predicted to double over the next 40 years. At the same time, the information coming from the census is out-dated and/or only available in coarse administrative units; it therefore limits the confidence of the expansion models. The MAUPP project (maupp.ulb.ac.be) aims at taking advantage of remote sensing data to map and predict the extension of cities through time and to understand and predict intra-urban variations of population density.

The space based solution

Remote sensing offers an effective solution to map and monitor urbanisation at different spatial and temporal scales. On a local scale, they provide information on the morphology of different residential patterns that can be linked to different population densities.

On a large set of 48 cities selected to be representative of the variations in climates and urban patterns in sub-Saharan Africa, historical and recent optical and radar high resolution (~30m) remote sensing data, i.e. Landsat, Sentinel, Envisat and ERS, are fused in a highly-automated image analysis process, using open source solutions, in order to delineate their current extent and map their growth from 1995 to nowadays. This knowledge of the past is then used to build urban expansion models to forecast the urban extension until 2030. Our products achieved more than 85% of overall accuracy on independent test sets. The corresponding dataset of more than 4 Terabytes is processed on a high performing PC. Without considering the pre-processing, the processing took an average of 1 hour per city. At the same time, another part of the project focuses on the use of very-high resolution remote sensing data (~0.5m) to better capture the diversity of intra-urban patterns, and to improve the estimations of population density. For 3 African cities of different structure and size, open-source semi-automated processing chains mapped land cover and land use, at city scale, with an overall accuracy above 85%. All processes are achieved on a high performance PC.

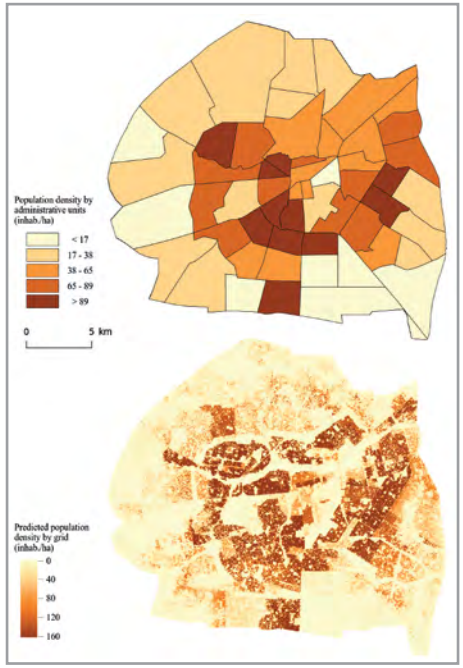


Automated classification of the built-up area for 1995 to 2015. Ouagadougou, Burkina Faso.

> *"This kind of population data would be extremely useful for improving our urban health services."*
>
> ***Olga Waigel, German Development Cooperation Agency (GIZ)***

Benefits to Citizens

Urbanisation has profound social, environmental and epidemiological implications and makes spatial and quantitative estimations of urban change and population density a valuable information source for epidemiology and vulnerability assessment. Such information is also very valuable for land management and planning, especially in developing countries facing rapid urban growth.



Example of population count reallocation from administrative units to a regular grid using land-cover information (Ouagadougou, Burkina Faso).

The methods developed, and the geographic information produced will be made available on an open and free-of-charge basis. All new maps will be available to public authorities and other users through the existing WorldPop web data portal (www.worldpop.org).

Outlook to the future

In the future, the methods could be used to monitor the urban expansion of a larger number of cities. Sentinel-1 and Sentinel-2 have already proved their capability for such a purpose. Over the next few years, they will definitely become cornerstones for the automated production of geographic information, on a regular basis and at reduced costs, especially for regions such as sub-Saharan Africa where this information is still lacking.

Acknowledgements

This work was funded by the research programme for earth observation (STEREO III) of the Belgian Federal Science Policy Office (BELSPO).

Grippa T, Forget Y., Lopez J-F., Vanhuysse S., Wolff E.a, Linard C., Gilbert M.[1], Shimoni M.[2] and Tatem A.J.[3]
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MONITOR URBAN AREAS AND GREEN INFRASTRUCTURES

Satellite imagery supports cities in filling the gap of environmental information and contributing towards the production of urban planning documents.



Urban vegetation extraction and characterisation based on very high resolution Pléiades satellite image. Application in Rennes, FRANCE.

The challenge

In 2050, 70 % of the world population will live in cities and policymakers are already engaged in providing a city capable of (1) hosting more inhabitants, (2) preserving and enhancing their health and quality of life, and (3) adapting to climate change. Green frames and green-infrastructures are obviously credible answers to new challenges that cities have to face. Local authorities and urban planning agencies currently consider vegetation as an important theme of urban master plans. They are looking for new decision-making tools to monitor ecological services such as biodiversity conservation, heat island and air pollution reduction.

The space based solution

Urban vegetation is difficult to monitor and manage. Databases on urban vegetation are primarily made from field missions, are difficult to update and limited to the public domain. Faced with these constraints, satellite imagery is a suitable tool to monitor urban areas; they have the advantages of being continuous, global and objective.

On a European scale for example, the Copernicus land services took the initiative to map urban vegetation for cities of more than 50,000 residents. However the minimal mapping unit is still limited and cannot extract the individual trees or small hedges network. Specific works are ongoing to investigate contributions of very high-resolution images such as Pléiades images to extract and characterise low and high urban vegetation (Figure 1).

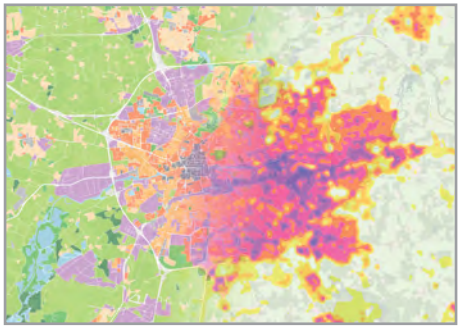
In addition, Sentinel-2 images are a very good complementary data source to monitor urban morphology at a coarser scale. With the 10m spatial resolution, it is possible to understand land-use, classify spatial arrangements of building and estimate their height. This information is crucial for climate modelling and evaluating the urban heat island effect (Figure 2).

Benefits to Citizens

The market for sustainable management of city and urban vegetation is emerging. Conversely, budgets of local authorities tend to be decreasing and consequently, it opens up new challenges for innovative solutions. Very high-resolution satellite images allow extraction of vegetation at fine scale (single tree and tree line) and provide a better understanding of vegetation in the public and private domains.

New information can be provided to local authorities to manage their city: (1) diagnoses in terms of biodiversity, and environmental health help to define new urban planning documents; (2) climate modelling to locate sensitive areas affected by urban heat islands. This phenomenon can impact the inhabitants' wellbeing; (3) land imperviousness monitoring to identify green area conversion into car parks in the private domain; (4) vegetation index to prove that urban development is not at the expense of the environment and to ensure that compensatory measures are respected.

> *"Satellite images create value-added data essential for monitoring our territory and building a sustainable city."*
>
> ***Emmanuel Bouriau, Land and Environment Division, Urban planning Agency of Rennes (AUDIAR)***



Local Climate Zones and Urban Heat Island modelling based urban vegetation data and Sentinel-2. Applications in Rennes, FRANCE.
Credit: Contains modified Copernicus Sentinel data [2017]

Outlook to the future

A first initiative to evaluate the benefit of satellite images was conducted by the an planning agency of Rennes (AUDIAR). Rennes is an urban area about 700 km² and 440,000 inhabitants. Relevant results have been achieved and the agency is now relying more and more on satellite images to carry out their diagnosis. The encouraging results have thus interested the services of the local authority, Rennes Metropole. It has commissioned a study on the implementation of environmental indicators in order to setup decision-making tools.

Kermap, a startup in earth observation, has been selected to develop innovative solutions to provide smart monitoring of land imperviousness, biodiversity, citizen comfort, urban climate and carbon stock estimates. This information will then help Rennes Metropole to renew its urban master plan.

Both in France and in Europe as a whole, these documents have to be updated regularly (every 3 to 5 years) and include an increasing need for sanitary and environmental information. In that context, satellite image is a suitable and affordable tool that is becoming more and more important in the decision-making process.

Acknowledgements

AUDIAR is the urban planning agency of Rennes. It is an association that serves public service missions. KERMAP is a startup in earth observation and a spin-off project of the public research laboratory, UMR LETG.

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URBAN GROWTH MONITORING WITH COPERNICUS DATA

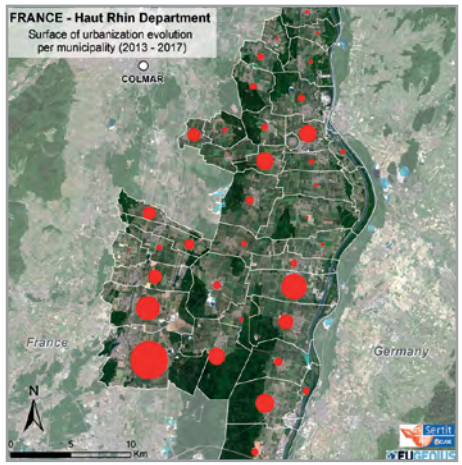
Satellite derived information provides a quantified expertise for the assessment and evaluation of territorial development policies.

The challenge

Within a climate change adaptation perspective linked to the increasing importance of sustainable management of our environment, territorial authorities involved on this subject have an increased need for geo-information providing the support to realise their missions, especially those related to the development of a territory in compliance with ecological and sustainability considerations or directives.

Amongst these needs, the regular measurement of urban zone development and the consumption of space is helpful for green and blue infrastructure assessment, for local biodiversity - green corridor preservation which is linked to the artificialisation of landscapes at local level, and more generally for the setting up of specific indicators and environment profile diagnostics, or synthetic documents at regional level allowing the monitoring of the "Grenelle de l'Environnement", French Ministry of Environment policy, especially through the setting up of sustainable development planning tools.

This information, today not available regularly (i.e. annually), is needed by Urban and Land Planning authorities in order to monitor the realisation of officially authorised urban planning directives, to forecast new urbanisation trends and needs, and to help them in their decision making process regarding the regional and local application of spatial and environmental politics (e.g. for France, PLU, SCOT, SRCE,...). This need for monitoring highlights the pertinence of the exploitation of Earth Observation techniques compared to more traditional approaches (e.g. aerial photos, administrative document collection and compilation, in–situ data and field campaign).

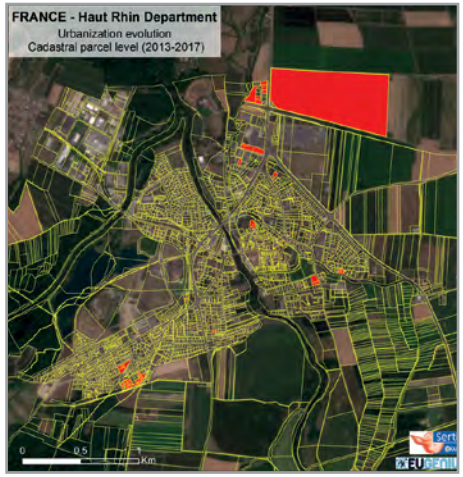


Surface of urbanization evolution per municipality between 2013 and 2017 in the East part of the Haut-Rhin department of the Grand Est region (France).

The space based solution

Based on the use of Copernicus satellite data and local information, the urban growth monitoring service, provided by SERTIT within the H2020 EUGENIUS project (European Group of Enterprises for a Network of Information Using Space), is dedicated to urban and land spatial planning users in charge of the setting up & control of local urban plans, of the monitoring of the development of new constructions within authorised built up areas, and of the assessment of remaining available spaces in urban planning documents; these geo-information are derived and mapped from multi-temporal satellite data.

> *"It is important to have an objective indicator to measure the evolution of urbanization."*
>
> ***Dominique Esnault, ADAUHR - ATD 68, Agence Technique Départementale du Haut-Rhin***



Cadastral parcels affected by urbanization evolution between 2013 and 2017.

Whereas Sentinel-2 data (10m) are used for monitoring the urban zone development at a global municipality level and in peri-urban areas, contributing missions satellite data, such as Pleiades (50 cm) or SPOT6-7 (1.50m), combined to local datasets, such as the local urban plan (PLU) or the cadastre, allow this monitoring to be refined on a more detailed scale, i.e. of the urban plan sector or at a cadastral parcel level. Thereby, on both spatial and temporal scales, this information also complements the core Copernicus products related to urban areas (e.g. Urban Atlas, HR layers, CLC).

Benefits to Citizens

Deployed in the Eastern part of the Haut-Rhin department of the French Grand Est Region during the first year of the EUGENIUS project, the urban growth monitoring service has allowed assess, for the 2013-2017 time period, to the evolution of 44 municipalities situated along the French - German border, a sector of special interest for the annual monitoring of the economic impact of the future closure of a nuclear plant.

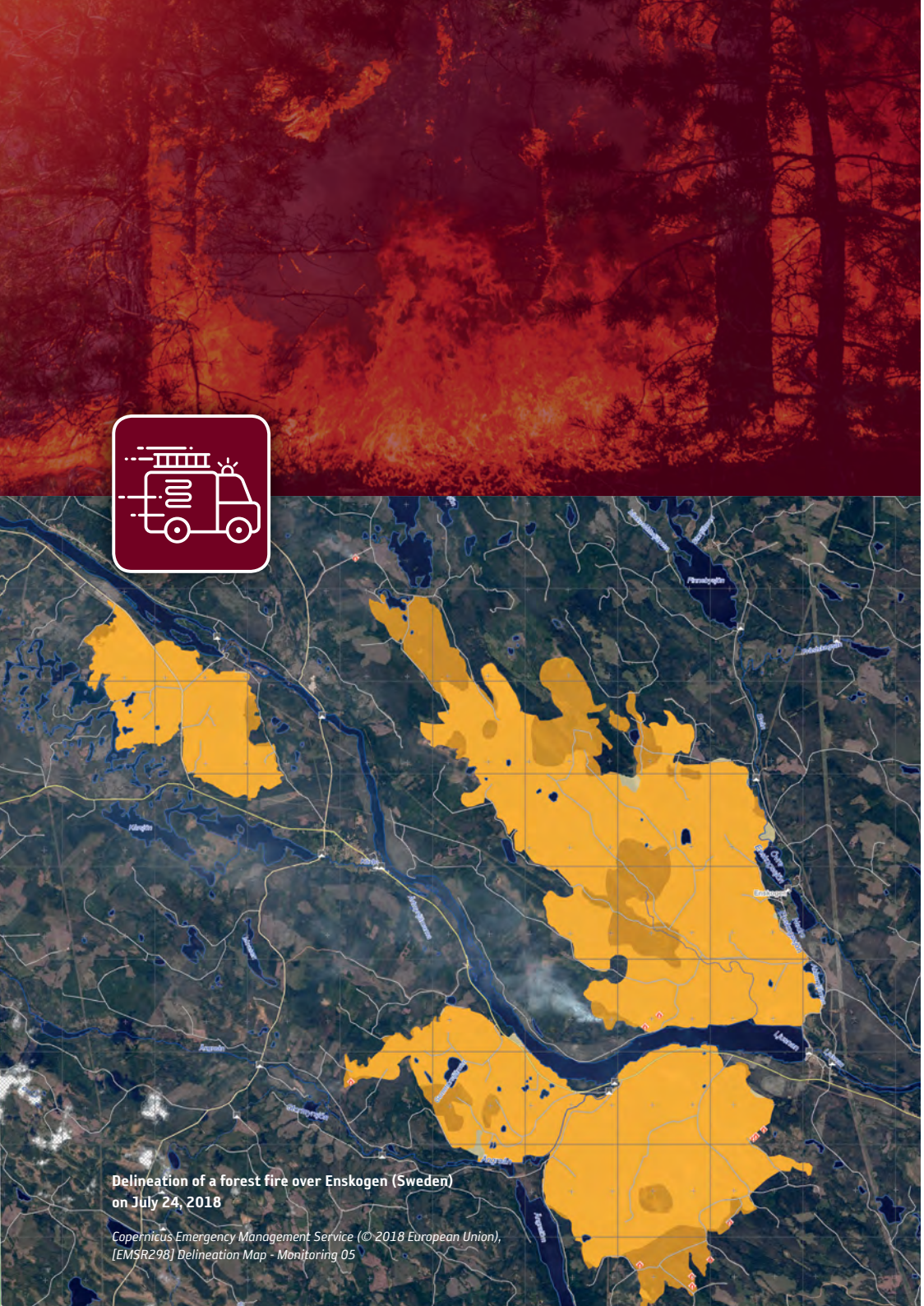
Outlook to the future

Within EUGENIUS, the service is progressively being assessed in other European regions which are also concerned by sustainable territory management and space consumption issues (e.g. Apulia region in Italy). Moreover, this information could also be of interest for the private sector, public works or building companies (e.g. updated knowledge of available areas for urbanisation) or even for the individual citizen concerned about the development of his surrounding environment.

Acknowledgements

This project has received funding from the EU H2020 research and innovation programme under grant agreement No 730150 EUGENIUS H2020-EO-2016.

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Delineation of a forest fire over Enskogen (Sweden) on July 24, 2018

Copernicus Emergency Management Service (© 2018 European Union), [EMSR298] Delineation Map - Monitoring 05

CIVIL PROTECTION

Floods, landslides, earthquakes, wild fires, volcanic eruptions: natural and man-made disasters can occur at any moment in time. They can not only cause economic and environmental damage, but more importantly threaten lives. Civil protection includes response to emergencies to be deployed in the immediate aftermath of a disaster, but also post-disaster assistance, rehabilitation and reconstruction. And, before disasters take place, prevention and preparedness are essential. As also advocated within the UN Sendai Framework for Disaster Risk Reduction, understanding disaster risk is essential to invest in preparedness and enhance resilience. This strongly leverages on the accurate knowledge of territory and population.

In general, civil protection is managed at national level, however, when it comes to implementation, cooperation and sharing of information with the EU and at regional/local level is essential: disasters know no borders and a well-coordinated response through different layers of competent authorities is needed to ensure that assistance meets the real needs of the affected areas.

Support for the management of emergencies is a core objective of Copernicus. This is mainly achieved through the Copernicus Emergency Management Service which delivers disaster maps as soon as possible after a crisis occurs. These maps are based on the Sentinels but also on data from the Copernicus Contributing Missions. By comparing post with pre-disaster maps, an overview of the impact can be gained to help directing recovery efforts and assessing the damages. The Service also helps to improve preparedness through mapping risk-prone areas and providing early warnings related to specific types of events such as floods and wild fires. Alongside the Emergency Management Service, the availability of Sentinel data can support dedicated monitoring and alerting functions for some types of disasters such as volcanic eruptions, floods and fires. This is important especially for wide, cross-border and rapidly evolving events and for remote areas.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
BURNT AREA MAPPING AT PROVINCIAL LEVEL USING SENTINEL IMAGERY	Città Metropolitana di Torino	Città Metropolitana di Torino	CEMS, S1, S2	3/4
COPERNICUS DATA GIVE PROSPECTS	Central Macedonia	Central Macedonia	S1, S2	5
COPERNICUS HELPING CIVIL PROTECTION	Intermunicipal community of Coimbra Region	Intermunicipal Community Região de Coimbra Intermunicipal Community Viseu Dão-Lafões	S1, S2, S3 and S5P CAMS, CEMS, CMEMS, CLMS	5
EO INTEGRATED APROACH FOR PLUVIAL FLOOD MANAGEMENT	Bulgaria	Bulgaria	S1, S2, S3, CLMS	3
MONITORING LANDSLIDE RISKS IN URBAN AREAS	Apulia (Puglia)	Sicily	S1	4
NEW FRONTIER FOR EMERGENCY RESPONSE: SATELLITE DATA	Italy (Italia)	Italy	S1, S2	3
SENTINEL-1 MONITORS GEOHAZARDS TO SECURE HOMES OF CITIZENS	Bratislava Region (Bratislavský kraj)	Trenčiansky kraj	S1	2
THE PHLEGREAN FIELDS CALDERA: A HISTORY OF DEFORMATION	Campania	Campania	S1	5
USE OF COPERNICUS EMERGENCY SERVICE DURING SLEET IN SLOVENIA	Central Slovenia Statistical Region (Osrednjeslovenska statistična regija)	Slovenia	CEMS	4
WILDFIRE MANAGEMENT ON THE CROATIAN TERRITORY	City of Zagreb (Grad Zagreb)	Adriatic Croatia - County of Split Dalmatia	CEMS, S2	1

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2; S3: Sentinel-3; S5P: Sentinel-5P; CLMS: Copernicus Land Monitoring Service; CMEMS: Copernicus Marine Environment Monitoring Service; CEMS: Copernicus Emergency Management Service; CAMS: Copernicus Atmosphere Monitoring Service.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

BURNT AREA MAPPING AT PROVINCIAL LEVEL USING SENTINEL IMAGERY

Sentinel-2 imagery was analysed to map the extent of burnt areas in the afftected municipalilties of "Città Metropolitana di Torino".



Burnt areas in Val di Susa, Città metropolitana di Torino after the forest fires in October 2017. *(Source: Città Metropolitana di Torino)*

The challenge

The Piemonte region in northwest Italy was affected by a series of large fires in October 2017, caused by a combination of long lasting drought conditions, high temperatures, strong winds and arsonists. Once the immediate emergency response phase ended, the main challenge was to create a comprehensive inventory of the burnt areas, as explicitly required by national regulations, in a short timeframe. Field mapping of the burnt areas is a demanding task in terms of resources and time. Satellite imagery is indeed an effective and efficient approach to speed up such a task with a sufficient degree of accuracy.

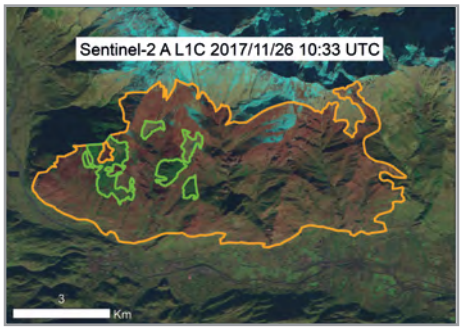
The space based solution

The efficiency and effectiveness of a space-based solution for burnt areas mapping for this specific event was already demonstrated by the Copernicus Emergency Management Service (© European Union, 2012-2018), which mapped 6 of the most affected areas in the framework of [EMSR253] forest fire in Piemonte, Italy. The Public Authority "Città metropolitana di Torino" (NUTS3 level), covering 316 municipalities grouped into 11 homogeneous areas, decided therefore to integrate an operational satellite based solution to map the burnt areas in the 60 affected municipalities of Torino [Turin], integrating and updating the 6 areas already analysed by the Copernicus EMS service. For this purpose, it collaborated with the ITHACA research centre, which has long-standing experience in emergency mapping, and with Politecnico di Torino. Multi-temporal Copernicus Sentinel-2 optical images acquired before, during and after the forest fire event (thanks to the ~3 days revisit time of the constellation at mid-latitudes) were processed. The availability of multispectral information in the Short Wave and Near infrared bands allowed burnt areas to be delineated with an adequate accuracy even in the presence of fire smoke, that would have jeopardised the analysis based only on visible data. Burnt areas have been exported in GIS-ready formats to allow further value-added analyses.

Benefits to Citizens

The main benefits of the EO space-based solution is mainly in terms of safety of citizens and infrastructures. Intersecting the burnt areas with the in-situ data of provincial authorities (e.g. urban areas strategic infrastructures, risk zones) enables to carry out timely risk analyses in the affected areas, e.g. debris flow risk, safe mobility planning, allowing preventive measures to be assessed (also in terms of costs), prioritised and planned. Furthermore, the availability of a comprehensive burnt areas database (a strict user's requirement) derived by satellite imagery efficiently supports administrative processes foreseen by national regulations in case of fires events (e.g., prohibitions prescriptions, penalties). Satellite-based analysis are indeed faster than traditional time-consuming field surveys and cheaper then aerial flights, allowing large areas (including possible inaccessible areas) to be mapped with homogeneous interpretation guidelines. Long lasting events can also be monitored thanks to the short revisiting time. For this specific event, the estimation of the impact of forest fires on ecosystem services has been also experimented by "Città metropolitana di Torino", to estimate the social costs of reactivating lost ecosystems services or to maintain their baseline conditions.

> "A comprehensive mapping of the burnt areas over the provincial territory in a short timeframe enables a more efficient response, especially in terms of protection of citizens."
>
> ***Massimo Vettoretti***
> ***Città metropolitana di Torino***



Burnt area extent (Susa, Torino) and severity (orange, completely burnt – green, partially burnt) overlaid on a post-event Sentinel-2 imagery. (Source: ITHACA)

Outlook to the future

In order to consolidate the support of the Sentinel derivative products to public authorities, dedicated ad-hoc services tailored to regional and/or provincial requirements could be further developed. In particular, the exploitation of data acquired by the Sentinel-1 radar SAR constellation would allow the limitations of optical data to be overcome. Sentinel-1 imagery can indeed also provide information in the event of cloud coverage. Furthermore, considering the increased availability of services and products based on Sentinel imagery, ad-hoc operational workflows can be developed at provincial authority level to ingest space-based data (possibly including the outputs of the European Forest Fire Information System, EFFIS) and to extract the required value-added information.

Acknowledgements

The authors would like to thank the authorities of the affected municipalities for the logistical and technical support.

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COPERNICUS DATA GIVE PROSPECTS

The purpose of this study is to upgrade the existing infrastructure of Geospatial Information (SDI) of Thessaloniki with Satellite data from Copernicus in almost real time.

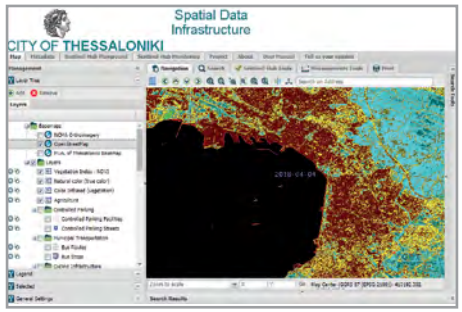
The challenge

The Municipality of Thessaloniki acknowledges the need for central management of geospatial and attributive information in order to provide quality information to the citizens. In this context, an open data portal and an enterprise Geographical Information System (GIS) were developed and have been in operation since 2008.

One of the features that was missing though was high resolution satellite data which would have allowed continuous environmental monitoring of land and sea. Although high resolution Sentinel data was freely available through the Copernicus Scientific Hub for more than 2 years, several technical limitations like size and complexity prevented the operational use of these data and their exploitation according to their value until recently.

The space based solution

The Municipality of Thessaloniki acquired a new Satellite data service from Geospatial Enabling Technologies (www.getmap.eu), integrating the Sinergise Sentinel Hub technology within the existing GET SDI Portal web portal environment. The solution provides access to near real-time Sentinel-2



Sentinel-2 data integrated to the Thessaloniki SDI platform. NDVI for the greater Thessaloniki area is automatically calculated using bands 4 and 8.
Credit: Contains modified Copernicus Sentinel data [2018]

& 3 (OLCI) satellite data via standard OGC Web Services, WMS / WMTS and WCS, in order to give to the end user (internal user, citizen, other organisations) advanced search, viewing and downloading on satellite data of Copernicus system.

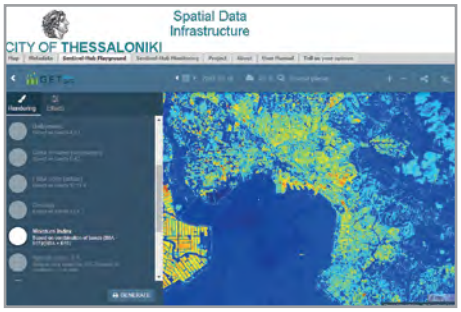
The service gives direct access with multiple selection criteria (e.g., date of capture, cloud cover) on standard multi-spectral data such as single band images, colour RGB composite spectral channels such as True Colour, False Colour, Short Wave Infrared, or remote sensing indexes like NDVI, NDWI, SAVI, LAI, and EVI. These products are available in a browser, through the Municipalities' geoportal, or in a GIS environment, without the need to download, process or transform of the data.

Finally, through a real-time alert service, the system operator of the Municipality can be notified when new data is available.

Benefits to Citizens

The Copernicus Sentinel data will support several internal needs of various departments of the Municipality (Directorate of Technical Services Department of Building and Planning Applications, Urban Environmental

> "The use of Copernicus - Sentinel data has transformed the way we understand space and has increased our capacity to manage emergency situations or monitor the environment."
>
> ***Simos Misirloglou,***
> ***City of Thessaloniki***



Interactive Browser of Sentinel data products over the Greater Thessaloniki area. Users simple select product (RGB, band, index), date and cloud cover.
Credit: Contains modified Copernicus Sentinel data [2018]

Management, Directorate of Urban Planning and Architectural Design, Independent Civil Protection Department).

The data will additionally be useful to the following programmes and actions of the Strategic Plan for Urban Resilience:

- Local risk reduction and development of a risk management system (adverse natural phenomena such as earthquakes, floods, landslides and forest fires).
- Strengthening the environmental awareness of citizens through the availability of modern satellite data to Climathon participants

CIVIL PROTECTION

- Monitoring Green areas / neighbourhoods in the city as well as Municipal properties and infrastructure.
- Strengthening the Transparency and Efficiency of the Municipality through Open Data.
- Monitoring the environmental endurance of the Thermaikos Gulf ecosystem.

Outlook to the future

With the fully operational use of the Sentinels' constellation even more data will be available to support the Municipality in the daily operations and the strategic planning. Sentinel-1 SAR data, which is already available, can be used to monitor landslides phenomena or emergency situations like floods and oil spills. Sentinel 4 and 5 data can be used to monitor emission sources and air quality, providing a continuous monitoring system of air pollution. Using that data, new added value products and services are expected to emerge and provide even more information tailored to the users' needs.

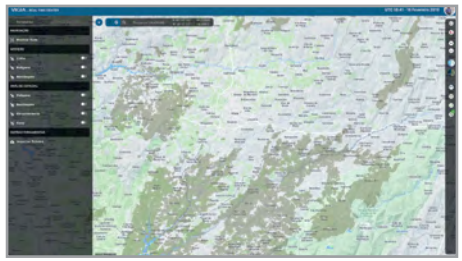
Acknowledgements

The work described in this article was supported by our collaborator GET Ltd and especially Gabriel Mavrellis and Theodoros Vakkas who, with their scientific guidance and experience, helped us develop the abovementioned platform and services.

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COPERNICUS HELPING CIVIL PROTECTION

SADGE & VIGIA decision-making platforms for civil protection based on Copernicus services and Sentinel Imagery.



Burnt area in the 2017 forest fire at CIM Viseu-Dão Lafões (Portugal) using Copernicus Emergency Management Service visualised on VIGIA. Credits: Copernicus Service information 2017.

The challenge

Fires have claimed 165 lives in Portugal over the last 17 years whilst climate change is triggering major river floods, destroying coastal infrastructures and changing agriculture cycles. The economic implications are enormous both for citizens and for public authorities, being intensified due to the specificity of the local territory. New dynamical computational tools must be used taking into consideration the heterogeneity and specificity of the territory, especially for civil protection purposes. Intermunicipal communities (CIM) "Região de Coimbra" and "Viseu-Dão Lafões" developed SADGE and VIGIA, respectively, combining Earth Observation and in-situ data with artificial intelligence for effective emergency response and pro-active daily decision-making, minimising social and economic implications on their citizens and infrastructures.

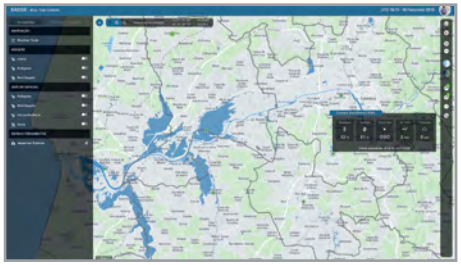
The space based solution

The multitude of environmental threats increase the need for the use of Earth Observation due to the smaller number of ground-level sensor networks required. The platforms use Copernicus services and Sentinels imagery intensively. Air quality is provided in a first layer by the Atmospheric Monitoring service that, combined with ground-measurements, are inserted into an algorithm to improve forecasts (where and when) and space resolution. It allows to identify hotspots of pollution such as, for instance, the 2016 and 2017 Sahara Desert aerosol events. In addition, it connects the notifications to local health services to minimise the implications, e.g., in asthmatics. Emergency Management Services are employed to characterise disaster areas and adapt local decision-making policies after the event. Sea tides and currents from marine service and climate change are employed together with Sentinel 2, cameras and ground information to analyse coastal erosion and near-sea infrastructures planning and mitigation. In the case of the rivers, Sentinel 1 and his radar sensors are used to effectively characterise floods, even in cloudy conditions. Finally, land service and Sentinel 2 provide detailed data for forest characterisation and biomass quantification analysing the risk of fire propagation.

Benefits to Citizens

The direct benefits of using Copernicus services by institutions and citizens are clear in these regions. Institutionally, the use of scientific-based tools and global perspectives

> "Copernicus aids daily decision-making activities, minimising the implications of environmental threats."
>
> ***Jorge Brito (CIM Região de Coimbra)***
> ***Nuno Martinho (CIM Viseu -Dão Lafões)***



Flood areas of Mondego (Coimbra, Portugal) river visualized on SADGE platform. Data obtained from Sentinel 1 imagery processed by SpaceLayer Technologies. Credits: Copernicus Sentinel data 2016.

of the territory are needed to make the right decisions, and make the best out of the low budgets available. Potential flooded areas are analysed using time-lapse satellite imagery knowing that local records are usually outdated. Vegetation can be monitored all year round and the fire hazard of the forest can be calculated. Using weather forecasts and local measurements the cone propagation is automatically anticipated. Taking proactive measures and decisions, the 2017 death toll can be minimized in the future. Nowadays, air pollution is a major issue in Europe with wellbeing implications. The forecast tools of Copernicus services and the improved algorithms anticipate harsh-events. All the deployed alerts in the platform are correlated with infrastructures (emergency services, schools, events, amongst others) so that the response can be optimised in each and every case. Both platforms have tools for creating notifications in case of major events to increase the safety of the citizens.

Outlook to the future

SADGE and VIGIA reached maturity with a full and efficient exploitation of cloud computing, big data and artificial intelligence, combing Copernicus and Earth Observation/ remote sensing automatisation. The modular architecture allows other Copernicus Services, in particular with Sentinel 4 and 5 family imagery for air quality monitoring. From the Municipality Associations, there is a strong commitment to create a two-way information pipeline, providing data from their stations to the Copernicus ecosystem helping improving the services.

Acknowledgements

The work had the support of European Union Cohesion Funds via PT2020 and POSEUR, contracts 02-1810-FC-000110 10-2016-43. The projects were co-financed by the municipalities of CIM-RC and CIM-VDL.

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EO INTEGRATED APPROACH FOR PLUVIAL FLOOD MANAGEMENT

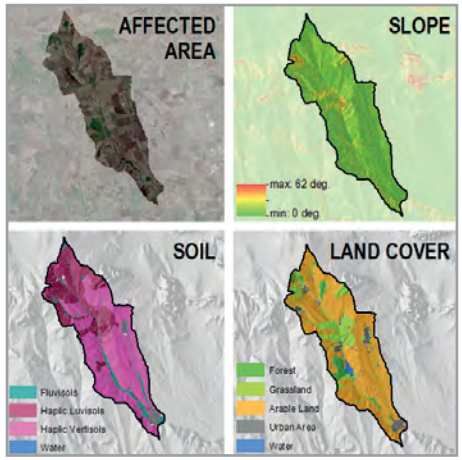
Climate change more often results in disastrous events such as flash floods. This calls for a need for detailed analyses of its cause and consequences.

The challenge

During the last two decades, flash flood events have increased their negative impact significantly in many regions in Bulgaria. They are difficult to predict, last for a short period of time, but are causing serious damage – both casualties and financial losses. Flood risk management at local, regional, national, and European (EU Floods Directive – EU FD) level calls for an integrated spatial information before, during and after the flood in order to analyse the event and to select adequate measures for flood mitigation. Copernicus provides the required EO data, the challenge is to couple these data with local information and expertise to create a standardised service to support decision-making.

The space based solution

The pluvial floods and the extent of the damage they cause are a complex balance which needs detailed information for the territory they occur as well as its state before and after the event. Thus, the proposed solution to mitigate the impact from the disaster has several modules relying on the spatial component which Copernicus data and core services provide, updated and refined using local knowledge. The climatological module relies on data from Sentinel 3,



Refined watershed related characteristics information extracted from EO data is used to describe the preconditions.

meteorological satellites, in-situ data and meteorological radars in order to describe in detail the evolution of the event. As an outcome from the module, regions with high potential of similar events to occur will be identified. The second module describes the preconditions within the affected territory. Here, the high revisit time of Sentinel 1 and 2 is of great importance. The data from the satellites, together with the Land Core Services are used to derive specific information for the land cover/use, soil moisture, orographic details, condition of the water reservoirs etc. The possibility of using data from Copernicus contributing missions should also not be neglected.

The third module is related to the post event status of the territory. The same parameters are analysed in order to identify the flood extent and damage, but also small changes in the land cover which could be later used for detailed analyses. Here, the use of the Sentinels' data is essential. The final module is the analytical one where all the data are combined in a GIS environment and every waterway subject to flooding is analysed

> "The approach is filling a significant knowledge-gap on the pluvial floods' mechanism, analysis and risk-reducing measures' planning - an important contribution to the FRMP[1] update."
>
> ***Rumeliya Petrova, Danube Region BD***
>
> *[1]Flood Risk Management Plan of the Danube river basin*

based on the hydrological characteristics and changes in the land cover. The detailed analyses allow identification of the area with high instance of surface runoff where specific measures should be undertaken in order to decrease the flood risk.



Sentinel-2 data shows not only the flooded area, but the area where the water was accumulated – thus allowing precise risk reduction measures on watershed level to be implemented.

Benefits to Citizens

The developed solution is ready to be put into operation. It provides a detailed description of the whole waterway and how its characteristics influence the effects of the flood event. This allows elaboration of a set of

small waterway measures, related to better land use/cover management, rather than expensive hydrotechnical measures. Optimal land management will directly influence the flood risk, together with water pollution, biodiversity, soil erosion etc. Thus, the solution will support not only the flood mitigation, but also activities related to Water Framework Directive, Common Agricultural Policy, Biodiversity Strategy etc. Often activities of these EU policy instruments are implemented separately at national level. Being able to use a common solution which will support cross relation between these instruments will allow more integrated implementation which will result in decreasing the flood risk, but with measures which will have positive impact on land management, environment, biodiversity, and hence human life.

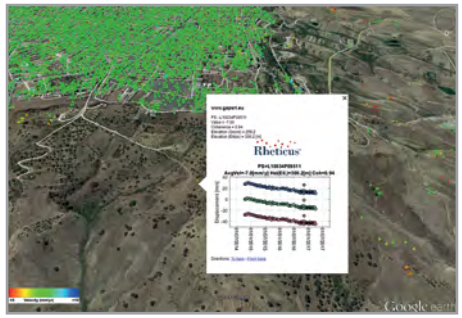
Outlook to the future

In 2016, the second planning cycle of the EU FD began. Now, when the Copernicus becomes operational the developed approach will support the River Basin Directorates in more precise implementation of the Directive in all its phases – delineation of areas with significant potential flood risk, and especially in the development of flood risk management plans, where Copernicus will provide valuable sources of information for planning risk-reducing measures at catchment level.

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MONITORING LANDSLIDE RISKS IN URBAN AREAS

Copernicus Sentinel-1 SAR data were used to detect and monitor landslides in the urban area of Niscemi, Sicily, Italy.



Niscemi, Sicily, Italy. Trends of the displacements identified over the municipality area.

The challenge

The Municipality of Niscemi, Italy, is a historic village, located in a hilly area in Sicily, affected by landslides. Amongst its institutional activities, on the theme of civil protection in case of landslides and/or subsidence phenomena, the municipality is in charge of the implementation of forecasting activities and risk prevention measures. There was a need to establish an early warning information service to support authorities in the prevention of possible risks to citizens and infrastructures and to find a cost-effective solution that does not require the installation of instruments or their maintenance which was suitable for low budget and time-restricted surveys.

Planetek Italia, with the agreement of the Municipality of Niscemi, activated the Rheticus® Displacement monitoring service over the Municipality area, to exploit Copernicus Sentinel-1 SAR data and Persistent Scatterers (PS) techniques for monitoring landslide risks in urban areas.

The space based solution

Today, satellite surveys allow: the measurement of millimetric surface deformations; the study of the evolution of displacements in time; the processing of periodic trends, based on a series of acquired data, to identify non-linear movements; the determination of horizontal and vertical displacement speed of points; the performance of multi-scale analyses; and the integration of other data sources. The Rheticus® Displacement service was able to process satellite data over the area and to provide thematic maps, dynamic geo-analytics and pre-set reports to the Municipality of Niscemi. For the assessment of the landslide trend over the Municipality, a time series of past movements was required to build a past and future trend scenario. Displacement was assessed over the subscribed area of interest by means of measurements of velocity, acceleration and coherence of Persistent Scatterers (PS). PS were identified and their velocity/acceleration measured through the extensively tested SPINUA© algorithm applied using Sentinel-1 radar data.

Satellite monitoring based on Sentinel-1 data also allowed the creation of a "Warning" service, i.e. an early warning, to alert authorities about the accumulation of instability factors in the areas of interest and thus to concentrate on these areas precise diagnostic actions and any other interventions intended to prevent or mitigate possible damage.

> "This service gives us the opportunity to monitor in real-time the dynamics of ground movements and identify the most critical points."
>
> ***Concetta Meli, Head of Environment and Public Works Dept., Municipality of Niscemi, Sicily, Italy***

The "Warning Maps" allow a more immediate understanding of the phenomena and of the potential criticalities. In fact, whilst the "Displacement maps" include all the PS obtained in the area of interest, the Warning Maps extrapolate only those that meet some established criteria of risk.



Niscemi, Sicily, Italy. Rheticus® Displacement user interface showing ground movements' velocity acceleration and trends over data retrieved from Sentinel-1.

Benefits to Citizens

Monitoring is essential for assessing and predicting landslides or ground structural weaknesses, which could affect buildings, infrastructures and citizens safety.

Using Copernicus Sentinel-1 images and PS techniques, the Rheticus® Displacement service complements traditional survey methods, providing a long-term solution to ground instability monitoring and fresh accurate information all over the world.

By subscribing to the Rheticus® Displacement service, users can log in to the Web platform and access an intuitive dashboard, gaining an immediate overview and reliable geo-information, including reports, thematic maps, indicators and geo-analytics, and a weekly update. This is possible thanks to the continuous Copernicus Sentinel monitoring information that helps to meet local and national requirements in the field of land monitoring and ground surface displacement detection.

Rheticus® Displacement guarantees the best quality-price ratio available on the market, thanks to the use of open data, automatic processing procedures and its cloud-based architecture, overcoming difficulties and costs of field measurement campaigns.

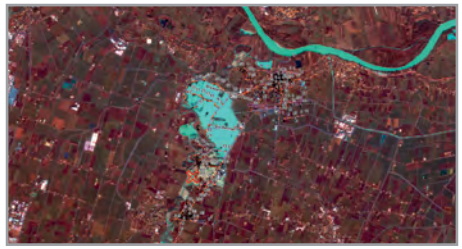
Outlook to the future

The service will include a new advanced and interactive analysis system, based on the correlation between the different PS, in order to highlight homogeneous areas in terms of displacement kinematics.

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NEW FRONTIER FOR EMERGENCY RESPONSE: SATELLITE DATA

The space-based approach gives an innovative instrument to improve rescue operations in terms of rapid mapping for identifying targets and priorities.



Italy - Reggio Emilia 2017, multispectral image (Sentinel) showing flooded areas, in light blue, near Lentigione town due to Enza river flooding.
Credit: Contains modified Copernicus Sentinel data [2017]

The challenge

The Italian National Fire and Rescue Service guarantees a 24/7 response for any type of emergency. For this purpose, the first requirement is the rapid identification of the affected area in order to define the amount of resources and minimise the time of deployment.

Consequently, a point of view not involved in the operational scenario is fundamental. A significant contribution to this approach is an optical analysis of the affected area through the Earth Observation programme.

The space based solution

Two real emergencies affecting the Italian territory are described below. Data from Sentinel-1 and Sentinel-2 were used to support the management function, and, using multispectral bands (SWIR and false colour NDVI) it was possible to represent the impact of floods and forest fires, two very different types of scenario.

During December 2017, the Emilia Romagna region was affected by flooding. The delimitation of the flooded area compared to a land use map allowed the identification of the civil and commercial buildings, streets and highways involved. In this way, it was possible to define the amount of affected people to be rescued and to be displaced in safe accommodations.

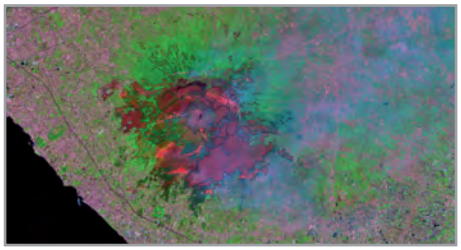
In August 2017, in the Campania region, a big forest fire occurred on the slopes of Vesuvius. The delimitation of burned areas provided data for monitoring the emergency evolution taking into account threatened infrastructures, available roads for rescues, targets for aerial forest fire fighting vehicles, etc. It was also possible to collect data for statistical purposes such as the type of affected vegetation, the extent of the event and, the number of deployed Fire and Rescue Service teams, in order to improve the planning process for future forest fire fighting operations.

These two cases aim to show how the use of satellite data, a few hours after the event, allow optimising the deployment of rescuers, reducing response times.

Benefits to Citizens

The Italian National Fire Corp operates in every regional area, coordinated by a Central Emergency Directorate, a few minutes after events. In the Central Emergency Directorate, we activate a technical team that immediately made a plan based on a cartographic survey of the affected area. The "Space-Based" approach for emergency management, using small-scale geography, allows a stronger awareness of the scenario evolution and therefore a faster and more targeted operational response which provides a more effective and efficient support to the population. Delimitation of an affected area overlapped to, for example, population density allows an estimate to be made of the number of people affected and threatened and to optimise the planning phase of the assistance in terms of the number of rescuers and resources needed.

> "The satellite data planning changes the way to prepare, plan and respond to an emergency, optimizing risk analysis and rescue operation efficiency."
>
> ***Italian National Fire Corps***



Italy - Vesuvio 2017, diachronic analysis with change detection method (Sentinel) showing burned areas, in red, due to forest fires occurring on the slopes of the volcano during last summer.
Credit: Contains modified Copernicus Sentinel data [2017]

As mentioned above, we need emergency mapping a few hours after the event, hence EO Data are necessary as soon as possible, just after the acquisition by satellite in order to create self-produced maps. The Copernicus EMService is used to compare and to verify the results of our map processing.

Outlook to the future

The objective for the future: higher spatial resolution and higher temporal incidence.

Improving the temporal incidence will give more images, resulting in a more accurate analysis of the evolution of the event and a higher possibility of analysis to be integrated with our daily data entry.

A higher spatial resolution also provides a more realistic scenario.

The Italian National Fire and Rescue Service is improving their knowledge and skills in using satellite data, optical and SAR products, in emergency and planning activities.

Giuseppe Romano, Valentina Nocente and Stefano Frittelli
Corpo Nazionale dei Vigili del Fuoco
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SENTINEL-1 MONITORS GEOHAZARDS TO SECURE CITIZENS' HOMES

Sentinel-1 enables operational monitoring of structures threatened by landslides and subsidence over the large area of the Upper Nitra region, Slovakia. Effectively, precisely and at low cost merit.

The challenge

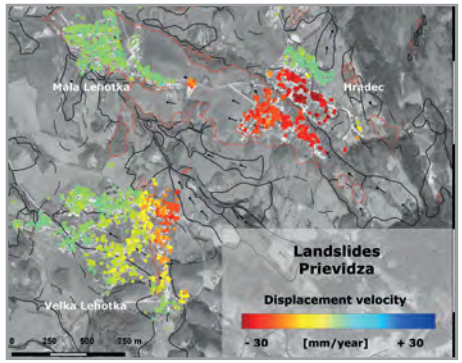
Slope deformations are the most significant geohazards in Slovakia which cause extensive economic damage on an annual basis, seriously limiting the rational use of land and in some cases also threatening property and the health of residents in the affected areas.

Especially in the region of Upper Nitra, Central Slovakia, notable for its landslide susceptibility over 60% of the territory, which is further impaired by intensive coal mining activity.

Conventional in situ monitoring techniques provide only point-wise information of the landslide's activity, however, they lack efficient and timely updates. To reduce the risks, we need to respond to emergencies faster and more accurately over the entire region.

The space based solution

Monitoring of mass-wasting geohazards like landslides and land subsidence due to under mining has been marked by the new perspective thanks to the Europe's Copernicus programme Sentinel-1 radar satellites. Extended spatial coverage of this EO mission covers the entire Upper Nitra region spanning more than thousand square kilometres in a single image.



Landslides detected over three villages in Upper Nitra region. Affected structures shown in red, stable in green.
Credit: Contains modified Copernicus Sentinel data [2018]

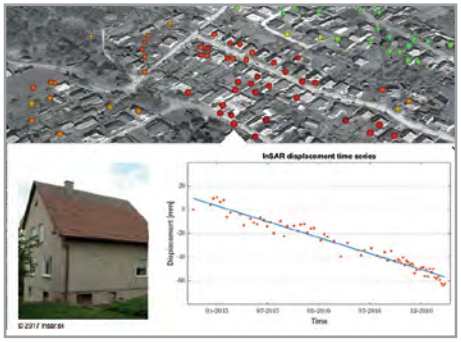
Using advanced radar interferometry technique InSAR and regularly utilising all radar images acquired by the Sentinel-1 pair over the desired area of interest, we can observe recent ground movements. As shown in an example image (above) of several villages in the Upper Nitra region, for every coloured point corresponding to the particular man-made structure or infrastructure, we derive precise displacement time series in millimetres per year, thus forming a "natural GPS network" with measurements going back to the end of 2014.

This way, we can remotely detect and monitor hundreds of objects endangered by landslide activity simultaneously, whilst being independent of cloud coverage or daylight thanks to the radar nature of the Sentinel-1 satellites. Moreover, the satellite's weekly revisit allows for frequent updates, thus empowering the operational capability of the technique.

Benefits to Citizens

Our emerging monitoring service based on Sentinel-1 EO data will provide continually updated information on the stability of individual structures and infrastructure, which can ensure advanced situation awareness during evolving and complex deformation processes like landslides, building collapses, road disruptions or land subsidence as a consequence of active under mining.

> "Thanks to Sentinel-1 we can monitor landslides threatening citizens' homes more reliably and with unprecedented detail."
>
> ***Dr. Pavel Liscak,***
> ***State Geological Institute***



Detail of village Hradec in first figure: Displacement time series showing 3 cm/year subsidence over building disrupted by landslide. Each dot represents satellite's acquisition.
Credit: Contains modified Copernicus Sentinel data [2018]

In comparison to labourious and costly in situ measurements, it brings unprecedented spatial coverage as well as guaranteed updates and may, therefore, potentially reduce operating costs by several million euro. More detailed and frequent surveillance means better safety conditions for citizens, and as such can help identify and prioritise buildings requiring field inspection or repair work. All maintained without the prior need for equipment or human presence at the area of interest.

Such operational monitoring can help prevent emergency situations and economic losses due to structural damage, help to assess remediation works of the State Geological Survey, or assist with the responsibilities of the mining companies as well as regional authorities.

Outlook to the future

Sentinel 1 InSAR complements conventional ground-based landslide monitoring techniques. Once the presented service becomes fully operational, it can further extend its regional application capability to monitor cultural heritage (e.g. Bojnice castle), to help assess the complex environmental impact of under mining or become an integral part of the regional urban planning policy.

Acknowledgements

Sentinel-1 data are provided by the European Commission and ESA under the free, full and open data policy adopted for the Copernicus programme. The authors would like to thank the State Geological Institute of Dionyz Stur and Hornonitrianske bane Prievidza, a.s.

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THE PHLEGREAN FIELDS CALDERA: A HISTORY OF DEFORMATION

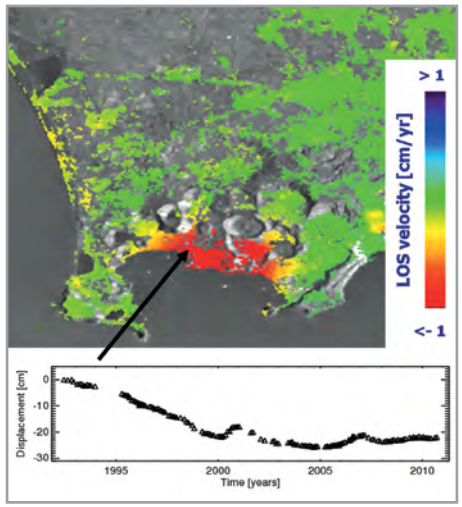
The deformation history of the Phlegrean Fields volcano imaged through ESA and Copernicus satellites.

The challenge

Located west of the densely populated city of Naples (Italy), the Phlegrean Fields caldera is one of the most dangerous volcanoes in the world. The caldera is the result of two major eruptions, which occurred approximately 37 ka and 12 ka ago, respectively. Starting from the end of the 1960's, the caldera has experienced rapid, large amplitude uplift episodes followed by long-term subsidence. In particular, during the 2012–2013 interval, the caldera has shown a rapid uplift of about 11 cm. This event led the Italian Civil Protection Department (DPC) to increase the monitoring activities to the level 2 in a range of 4 (where 4 represents the maximum alert). Accordingly, to keep one of the areas with the highest volcanic risk in the world under control, one of the greatest challenges is the continuous monitoring of several volcano parameters and, amongst others, the surface deformation.

The space based solution

Differential SAR Interferometry (DInSAR) is a well-established microwave remote sensing technique that, by exploiting two SAR images acquired at different times, allows estimation of ground deformation that has occurred between the two acquisitions with centimetre to millimetre accuracy. Therefore, by using

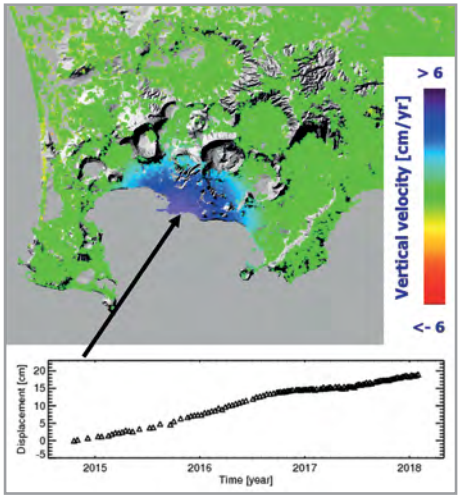


Mean deformation velocity map in satellite Line of sight (LOS) obtained by exploiting ERS/ENVISAT SAR data on Phlegrean Fields from 1992 to 2010.

DInSAR, it is possible to detect and monitor any kind of deformation on Earth surface, such as the one induced by earthquakes, landslides and volcanoes, as in the case of the Phlegrean Fields. DInSAR clearly benefits from the availability of long-time SAR archives, because of the possibility to follow the evolution of the ground deformation. The figure above shows the mean deformation velocity map generated on Phlegrean Fields by exploiting the ESA ERS and ENVISAT SAR data acquired since 1992 and 2002, respectively. The plot of the displacement time series shows the evolution of the deformation of the caldera and clearly demonstrates the importance of disposing of long-term SAR archives for monitoring high risky areas. It is indeed worth noting that the current DInSAR scenario is characterised by the huge availability of SAR data acquired by several satellite constellations. In particular, starting from 2014, the Copernicus Sentinel-1 (S1) satellites are supplying a massive SAR data flow thanks to their global coverage acquisition strategy. S1 constellation consists

> "Satellite ground deformation measurements provide a useful complement to the in-situ volcano monitoring infrastructures."
>
> ***F. Bianco, INGV-OV***

of 2 fully operational satellites and acquires new data, on land, every 6 days with the Interferometric Wide Swath mode, which guarantees a very large footprint and is specifically devoted to DInSAR applications. As an example of the S1 potential, the figure below shows the deformation in the 2014–2018 period measured at Phlegrean Fields, which experienced a resumption of the uplift.



Vertical deformation velocity map obtained by exploiting Sentinel-1 SAR data on Phlegrean Fields from 2014 to 2018.
Credit: Contains modified Copernicus Sentinel data [2018]

Benefits to Citizens

When a volcano shows new or unusual signs

of deformation activity, as for the Phlegrean Fields, monitoring data may help in the assessment and then timely communication of information about the volcanic hazards. CNR-IREA routinely provides the ground deformation measurements derived from S1 data to DPC and the volcano observatory of the National Geophisycs and Volcanology Institute (INGV-OV). Based on the history of the Phlegrean Fields and the analysis of the monitoring data from in-situ and space-borne sensors, the scientists can determine the possible ascent of magma towards the surface. This type of knowledge helps them to figure out the possible types of volcanic activity and the associated hazards to people. This information is crucial for DPC to determine which alerts and policies are needed to prevent loss of life and property.

Outlook to the future

The Copernicus Sentinel programme is a fundamental instrument for natural hazard monitoring, thanks to the free access to a data archive that is routinely acquired at global scale.

Acknowledgements

This work has been supported by the DPC-IREA agreement, the EU-H2020 EPOS-IP project (GA No. 676564), the ESA GEP project and the I-AMICA project (PONa3_00363).

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USE OF COPERNICUS EMERGENCY MANAGEMENT SERVICE DURING SLEET IN SLOVENIA

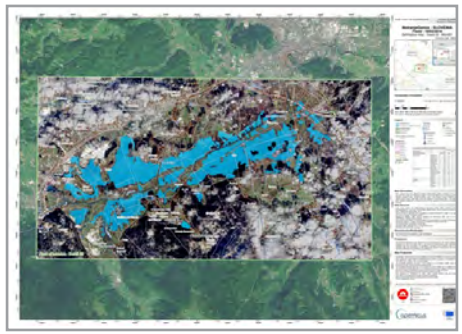
Slovenia was hit by severe sleet followed by floods in January 2014.

The challenge

The frequency and intensity of natural disasters in Slovenia is unfortunately still rising. Rapid technological development of remote sensing services enables improvement in the control and monitoring of extraordinary phenomena, thus allowing the relevant services to provide a faster and more effective disaster response whilst on the other hand supports analysts in their work. The Slovenian national contact point for Copernicus Emergency Management Service, the Administration for Civil Protection and Disaster Relief of the Republic of Slovenia, has been involved in monitoring the development of the European Commission and European Space Agency initiative for global monitoring of the environment from its beginning being aware of the benefits the solution can bring.

The space based solution

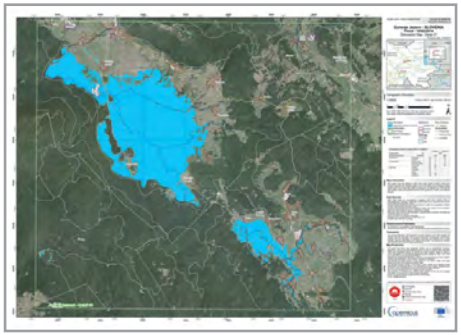
On Friday, January 31st 2014, the majority part of Slovenia was affected by extremely unfavourable weather conditions with heavy snow and sleet affecting the southwest of Slovenia the most. This situation continued until February 6, when the temperature rose above the freezing point and caused quick melting, which combined with the rain and debris of the destroyed trees in the water



Ljubljansko barje flooded on 14 February 2014 at 9.39 UTC with SPOT-6 optical satellite with a local resolution of 1.5 meters.
Source: Copernicus Emergency Management System

courses caused the flooding of Karst fields and Ljubljansko barje. Experiences from the previous Copernicus activations showed that due to the time lag between sending the request and the actual scanning, especially in the case of flash floods, it was not able to provide a satisfactory picture of the situation of the pick of the flood. Thus, the Administration of the Republic of Slovenia for Civil Protection and Disaster Relief cooperated closely with the Slovenian Environment Agency which monitored the development of the weather and assessed the likelihood of flooding. According to the Slovenian Environment Agency experts, after several days of monitoring the weather and weather forecasts and the situation on the ground, the floods of the Cerknica and Planinsko polje, the Ljubljansko barje and the surroundings of Knežak were expected to reach their peak on 12 and/or 13 March. The completed order form was sent to the Emergency Response Coordination Center in Brussels on Tuesday, 11 February, at 13.43, with the attached kml-files of the sites and in accordance with the harmonised protocol.

> "This application has contributed a small but important part to the safety of the citizens of Slovenia."
>
> ***Katja Banovec Juroš, Administration of the Republic of Slovenia for Civil Protection and Disaster Relief of the Slovenia***



Flooding of Cerknica Field, shot with COSMO-SkyMed satellite in radar spectrum, 13 February 2014 at 4.50 UTC, local resolution 3 meters; background: air digital orthophoto recordings (2009-2012) *© ARSO*

Benefits to Citizens

The first maps, which were available within two to three hours after the scan, were used by the responsible authorities for the first assessment of the situation on the ground which, in combination with data received from other sources, led to more reliable response of the teams on the ground.

Although the Copernicus licensing policy did not permit the public distribution of raw satellite imagery to users for further analysis, the vector data prepared on their basis was publicly available for use in the further processing of national public and research institutions. The results of the analysis allowed decision makers to support their

decisions. Both above mentioned uses of Copernicus data also contributed to the safety of the citizens of Slovenia in both NUTS 2 regions (Eastern and Western Slovenia).

Outlook to the future

With new Sentinel missions and other functional improvements of Copernicus Emergency Management Service the provided data will be more accurate and delivered with shorter timeframe between order of the service and scanning of the terrain. With more precise and reliable maps also the response of the rescuers and other services would be more efficient.

Acknowledgements

Copernicus has provided a valuable contribution to the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030. Also in this way, we all build a society that is more resilient to disasters and contribute to a world that is a safer place to live in.

Katja Banovec Juroš
Administration of the Republic of Slovenia for Civil Protection and Disaster Relief, Slovenia

WILDFIRE MANAGEMENT ON THE CROATIAN TERRITORY

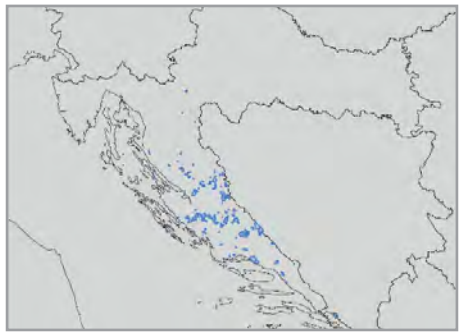
Wildfire management is one of the essential tasks for local authorities, especially those wich are in high-risk areas. Copernicus free spatial data can help manage and solve this task.

The challenge

Every year, an area of 350 mill. hectares is occupied by fire, of which 90% are forest fires. In Europe, due to climatic conditions, the most endangered is the Mediterranean area. Croatia is one of the countries with a high risk of forest fires (47% of the land surface consists of forest). In 2017, 104 forest fires were recorded in Croatia causing economic damage of around € 60 million. Two large forest fires in June last year hit the area of the Makarska Riviera in only two days, covering an area of 325 hectares. Local authorities have been shown that free access to Copernicus satellite missions data and EFFIS systems (European Forest Fire Information System) can contribute to predicting fire hazards, mapping wildfires and improving wildfire management which contributes to the economic aspect as well as the human protection.

The space based solution

Free and open data Copernicus solutions which can improve wildfire management and achieve more efficiently, reliably and quickly detecting of wildfires and analysing of affected areas are presented to local authorities. The solution is based on the use of Sentinel-2 imagery and EFFIS to identify areas of land



Fire affected areas (blue) in 2017 on Croatian territory based on EFFIS data.
Credit: Contains data downloaded from EFFIS for 2017

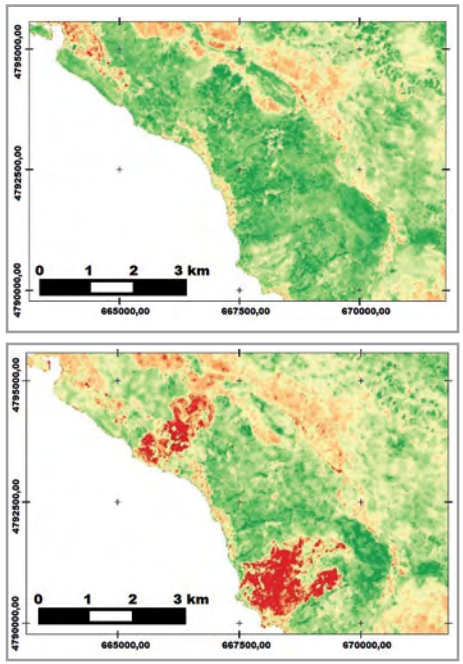
affected by wildfire scarring. The obtained data were processed using SNAP and QGIS software (open source). EFFIS was used to roughly locate the location, time, and area of the wildfire. After locating the fire, images of the area before and after the wildfire event were downloaded from the Sentinel Scientific Hub (Sentinel-2 level C – 1 products) and used for detailed analysis. Initial processing, such as, resampling, band merging and subset export was carried out in SNAP followed by the Normalized Burn Ration (NBR) technique which was applied on images to highlight the areas covered by fire. RGB true colour imaging was also used for a better view of the environment. The final product includes wildfire maps of the affected areas which can be used for better understanding, analysing and preventing fire events, as well as for improving post-fire operations.

Benefits to Citizens

Remote sensing methods play a significant role in all aspects of wildfire management. Copernicus provides free spatial data, and its images can be used for making significant maps for better risk assessment of the affected areas and the environment.

Such maps can provide a wealth of information,

> "The application of this method will greatly accelerate the fire extinguishing time and facilitate the movement of firefighters within the affected area."
>
> ***Fire Department of the Split-Dalmatia county***



Overview of processed images of wildfire in the area of the Makarska Riviera before (a) and after (b) fire, based on NBR technique and defining steps (c) towards final product of wildfire maps" should be shortened to: "Overview of processed images of wildfire in the area of the Makarska Riviera before (a) and after (b) fire, based on NBR technique.
Credit: Contains Sentinel data [2017]

especially for firefighters and other units that need to bring a fire under control as soon as possible. They can enable analysis after the

fire event and can be applied to strategies and policies for prevention, forecasting, mitigation and management of wildfire events. Besides that, the obtained data can contribute to monitoring of the environment recovery, which is extremely important for fields such as agronomy and forestry. All of this is aimed at improving the life and safety of citizens during wildfire events and for the faster recovery of the affected areas and the environment.

Outlook to the future

Products obtained using these methods can benefit both GIS and other, non-GIS users. They enable overlapping with other data depending on the interest in use. Besides fire management institutions and local authorities, these methods can also contribute to the improvement of work in other institutions such as police administration, environmental protection agencies, civil protection, agricultural and forestry agencies, national parks, insurance companies and many others.

Acknowledgements

The Croatian territory is affected with more than 100 wildfires every year and these methods will improve prevention and fire protection as well as enabling a faster and better response in areas affected by fires for local authorities.

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Oslo train station subsidence analysis as performed using data from the Sentinel-1 satellite acquired between 26 December 2014 and 28 October 2016.
Credit: Contains modified Copernicus Sentinel data (2014–16) / ESA SEOM INSARAP study / InSAR Norway project / NGU / Norut / PPO.labs, CC BY-SA 3.0 IGO

TRANSPORTS, CIVIL INFRASTRUCTURE AND SAFETY

Roads, airports, bridges, sea lanes, ports... All countries need efficient transport systems and reliable infrastructures if they are to prosper and provide a decent standard of living for their populations, and ensuring passenger safety is a priority for public authorities. Whilst safety and national assets are managed at national level, regional and local authorities in Europe frequently have competencies related to building and maintenance of local networks: ports and harbours, planning, construction and maintenance of roads and transport infrastructure, public transport typically fall into the competences of the regions.

Over land, Copernicus supports improved planning and management of civil infrastructure and the prevention of future damages through information on the topography and on instabilities of the terrain surface that may arise due to e.g. subsidence, sliding or underground natural or human induced activities (such as public utility works, gas and/or water pumping). More specifically, interferometric techniques applied to Sentinel-1 imagery allow the detection of millimetre-scale surface displacements that could threaten the integrity and safety of built infrastructures with regular and unprecedented frequency. Over sea, Copernicus data and information can support maritime safety: for example, the Copernicus Marine Environment Monitoring Service produces forecasts of oceanic currents and estimates of sea ice concentrations/drifts, whilst data from Sentinel-1 are widely used to support shipping through icy waters and for maritime surveillance activities such as the ones provided by the Copernicus Security Service.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
A VILLAGE STRICKEN BY TERRAIN MOVEMENTS	Alsace (Alsace)	Bas-Rhin	S1	4/5
COPERNICUS SENTINELS HELP VESSEL TRAFFIC MONITORING	Bucharest (Ilfov Bucaresti)	South Muntenia - Teleorman County	S1, S2	2
IMPROVING SNOW AVALANCHE FORECASTING	County of Troms (Troms Land)	Iceland Italy Switzerland	S1	4
MONITORING THE HEALTH OF WATER & SEWERAGE NETWORKS	Apulia (Puglia)	Lombardy	S1	5
SATELLITE-BASED MARITIME SURVEILLANCE SERVICES IN EUROPE	Brittany (Bretagne)	European maritime areas	S1	5
SMARTPHONE APPLICATION DELIVERING METEO-MARINE DATA TO THE PUBLIC	Malta	Malta Sicily	CMEMS	5

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2; CMEMS: Copernicus Marine Environment Monitoring Service.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to* *Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

A VILLAGE STRICKEN BY TERRAIN MOVEMENTS

The Sentinel-1 radar satellites capacities in detecting and measuring small ground surface movements allow the provision of quantified expertise to decision makers.

The challenge

Lochwiller, an Alsatian village in the Grand Est region, Northeastern France, is affected by severe land elevation movement because of the swelling of a geological layer reaching an underground water table, during a sub-surface geothermal drilling activity. Houses are cracking and families are obliged to leave their homes.

The State services need to monitor the evolution of the phenomenon that the technical services cannot stop and, with insurance companies, promote a policy of compensation for those affected. The municipality is trying to establish a plan both to prevent the growth of abandoned housing and to decide on its future urbanisation policy around the disaster area. Therefore, decision makers are seeking relevant indicators to support a strategy that will directly depend on the evolution, in space and time, of the surface instability phenomenon.

The space based solution

The EUGENIUS H2020 project combines in a common catalogue of services the expertise of several remote sensing operators for the benefit of their region. SERTIT (SErvice Régional de Traitement d'Image et de Télédétection,

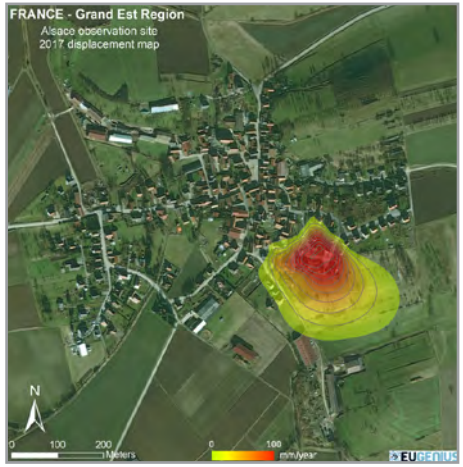


Houses affected by terrain movements in the village of Lochwiller (Alsace- France)

a technical platform of the ICube laboratory of Strasbourg University), associated with the Italian company, Planetek, has thus proposed to the deconcentrated service of the French Ministry of Environment, in the Grand Est region, a pilot project based on the exploitation of interferometric data, acquired by the Sentinel-1 radar satellites, which allow the detection of millimeteric ground displacements. With the use of Persistent Scatter Interferometry technique, regular monitoring of the behaviour of permanent reflectors over time, has been set up and performed. The height variations measured with the use of more than twenty satellite acquisitions during the first year (Sentinel-1A data), and more than fifty observations during the second year (Sentinel-1A and Sentinel-1B data), made it possible to detect the lifting of the surface related to the swelling of the anhydrite layer pierced by drilling, and also, to map and measure the extent of the phenomenon. Compared to observations and field surveys, measurements derived from spatial data were also calibrated. Maximum vertical displacement measures could reach 140 mm/year around the drilling.

> "This remote sensed technique has transformed the way we are monitoring this particular problem for which a long-term survey will be necessary."
>
> ***Frank Pouvreau, Direction départementale des territoires du Bas-Rhin, French Ministry of Ecological and Solidarity Transition***

The approach having been validated, the State services asked for the monitoring of the affected sector to be continued and also to apply it on another Alsatian village where a similar phenomenon has started.



Spatial representation of the swelling phenomenon in the Lochwiller most affected area (Alsace-France)

Benefits to Citizens

The approach presented here benefits citizen on several levels. Allowing for the monitoring and quantifying of a phenomenon causing property damage, even human ones, it contributes to the risk assessment mission of the state services, and to the drawing up of the request for compensation which is paid by the insurance guarantee fund.

Risk prevention and mitigation are major societal challenges, such as the sustainable management of resources and territories.

Therefore the EUGENIUS Association is federating skills and interoperable tools from different European partners in order to respond in the most effective way to these issues.

Outlook to the future

With these swelling phenomena having a continuous evolution, and upon user request, the monitoring of the two villages will be pursued after the H2020 project.

Through its regular observation frequency capacity, the Copernicus programme space infrastructure offers new possibilities for the monitoring of vast territories and the measurement of spatialised indicators previously inaccessible by ground-based observation means. The interferometric techniques presented here can also be applied to subsidence problems, such as the ones occurring in the mining sectors, related to karst environments or underground activities.

Acknowledgements

This project has received funding from the EU H2020 research and innovation programme under grant agreement No 730150 EUGENIUS H2020-EO-2016.

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COPERNICUS SENTINELS HELP VESSEL TRAFFIC MONITORING

Sentinel satellites imagery is used by local authorities to monitor navigation and manage traffic in Southeastern Europe, on the Romanian Danube sector.

The challenge

Navigation on the Danube river is limited by the presence of sand banks (dry summer periods) and ice banks (very cold winter time), phenomena that have an important impact on navigation safety, continuity and effectiveness of goods and passengers transport operations.

In July–August 2015, most of the European continent experienced daily temperatures above 34 - 35° C and absolute maximum values above 40° in many areas (e.g. 46.2° C in southern Romania). Combined with a significant reduction of rainfall, this led to atmospheric and soil drought and low water levels of the Danube River. The low water level advanced the narrowing of the navigation path at Zimnicea (567 kilometer), causing ships to wait in a row before crossing the area.

The space based solution

During the hot summer of 2015, the Romanian Lower Danube River Administration (AFDJ) and Romanian Space Agency (ROSA) were in contact and worked closely to find a reliable solution for characterizing the ship traffic on the Danube. Everything started from the notice sent by the authorities relating to the long time needed by the ships to cross the Romanian channel.



Ships queuing along the Danube due to low water level.
© ugal.ro 2015

With the help of the European Space Agency (ESA) experts and mission managers, the first available Sentinel 1 and Sentinel 2 (still in the commissioning phase at that time) were processed and sent to AFDJ. Image data was mainly used for identifying the crowded points and to count the ships queuing on the Danube. Thanks to the satellite images of 2nd and 9th of August, it became immediately obvious that many more ships were on the Danube than initially reported based on the AIS (Automatic Identification System) data (some 100 or more ships).

The combined use of Sentinel-1 and Sentinel-2 information allowed the Romanian Lower Danube River Administration to monitor navigation at critical points such as those close to Zimnicea until the end of the drought period.

The results have been published on the European Space Agency and Romanian Space Agency websites.

The User Maturity Level is represented by the ad-hoc use phase, where the Copernicus-based solution has been used with no explicit interest from the regional authority to trial consistent usage.

> "The main purpose was to identify the ships that are not equipped with Automatic Identification System, and the Sentinel images have proved extremely useful."
>
> ***Ion Nedelcu,***
> ***Romanian Space Agency***

Benefits to Citizens

In 2017, AFDJ reported a significant increase in the number of ships transporting goods on the Danube – 1863 ships in 2017 compared with 1771 ships in 2016, which also translates into an increase of revenues for both the administration and the commercial sector.



Ships queuing along the Danube river near the Romanian town of Zimnicea. Captured by Sentinel-1A on 2 August 2015.
Credit: Contains modified Copernicus Sentinel data [2015]/ESA

Earth Observation satellite data proved to be very useful for helping continuous monitoring of the ship traffic in order to avoid navigation problems. They can further improve the functionality of existing navigation systems, accuracy of sailing management information and dissemination of information.

Outlook to the future

Integration of Copernicus data into RIS will contribute to better vessel traffic monitoring considering the inland waterway and the main navigation operations such as, lock operation, port operation, bridge operation and others.

The integration and use of Sentinels together with inland vessel traffic services would prevent the development of dangerous vessel traffic situations by managing traffic movements, providing safety and efficient movement of vessel traffic within the VTS area.

Where appropriate, selecting SAR (Synthetic Aperture Radar) sensors take opportunities disregarding the day / night or weather conditions, reducing the effort on the delineation of navigation obstacles over the river surface. It is possible to grant multiple daily opportunities for acquisitions and in so doing widen the portfolio of higher value products available.

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Ion Nedelcu and Alina Radutu
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IMPROVING SNOW AVALANCHE FORECASTING

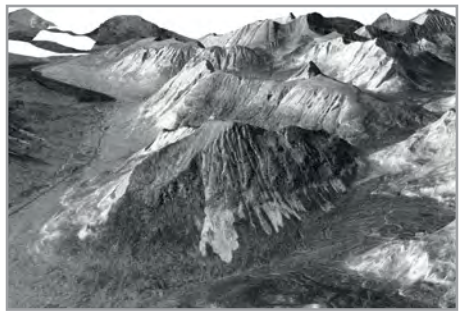
We solve the problem of complete snow avalanche activity monitoring in forecasting regions in Norway by automatically detecting snow avalanches in radar satellite data provided by Sentinel-1 satellites.

The challenge

Snow avalanches (hereinafter called avalanches) pose a threat to people and infrastructure in Norway. Daily, public risk assessments (so-called avalanche forecasts) are carried out for large forecasting regions. A defining parameter of avalanche hazard is avalanche activity, i.e. how many avalanches of which type and size release in a certain area during a certain time period? This seemingly easy question is impossible to answer with traditional, field-based observation techniques. This is where the benefit of radarsatellite data comes in, providing the opportunity to detect avalanches consistently during a winter within a forecasting region.

The space based solution

The Sentinel-1 radar satellites provide daily images over Norway. Their free availability, high spatial resolution, large ground swath and all weather, all light capabilities make them perfect observation tools of avalanches. Avalanche debris, the depositional part of avalanches is detectable in SAR images owing to their rough surface reflecting more energy and thus supplying more information back to the satellites than the surrounding, undisturbed snow.



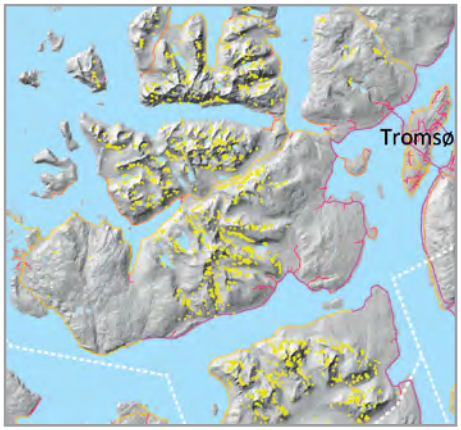
3D view of a Sentinel-1 radar backscatter image with avalanches visible in the foreground in light grey.

In our pre-operational service, we process all Sentinel-1 images over three forecasting regions in Norway and automatically detect all avalanches. About half an hour after the Sentinel images are available, the detected avalanches are stored in a geodatabase with a time stamp, location information and spatial extent. Forecasters of the Norwegian Avalanche Warning Service, who use the avalanche activity as an important information tool in their daily risk assessment, can access the database. During the winter 2016-2017, we increased the number of avalanche observations by a factor of ten, from about 900 field observations to over 12,000 satellite observations of avalanches.

Benefits to Citizens

Public, regional avalanche forecasts mainly target two user groups: Winter backcountry users, the group with the vast majority of avalanche fatalities, and public entities, responsible for infrastructure planning and road safety. Both user groups use the forecast as a risk reduction measure, depending greatly on its accuracy and predictive power. However, avalanche forecasting is inherently forecasting of uncertainty expressed in probabilities of avalanche release. Moreover, it is a complex, synoptic decision making task carried out by an expert. Our avalanche activity datasets decrease the uncertainty of the forecast, as released avalanches are the best available sign of prevailing avalanche hazard. This gives the forecasters an improved tool for their risk assessment and ultimately a higher quality avalanche forecast for the end users. The ultimate goal of an avalanche forecast is to prevent fatal avalanche accidents. Our service contributes to achieving this important goal.

> "Avalanche detections from radar satellite data decrease the uncertainty of our avalanche forecasts."
>
> ***Rune Engeset,***
> ***Norwegian Avalanche Warning Service, NVE***



Map showing detected avalanches (yellow) during winter 2016-17 on the island of Kvaløya in Northern Norway
Credit: Contains modified Copernicus Sentinel data [2015]

Outlook to the future

From winter 2018-2019, our service will be transferred to the Norwegian Avalanche Centre thus becoming fully operational. Within the next two years, we plan to expand from the current three to all 22 forecasting regions in Norway.

With the worldwide availability of Sentinel-1 data, our service can be established in any avalanche forecasting region in the world.

Besides the monitoring service described, avalanche detections could also assist in emergency response situations in remote areas struck by extreme avalanche cycles. Lastly, the long-term collection of avalanche activity offers the opportunity to conduct climate-related studies

Acknowledgements

This pre-operational service, based on Copernicus data, is a joint project between the independent research company Norut, the Norwegian Avalanche Centre at NVE and the Norwegian Public Road Administration, financed by the Norwegian Space Centre.

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MONITORING THE HEALTH OF WATER AND SEWERAGE NETWORKS

Copernicus Sentinel-1 SAR data were used to detect and monitor ground displacements near Milan's public sewerage network in Italy, to discover damage to the actual water infrastructure.



Subsidence in urban area induced by water network leakage. *Credits: meadowsaffron on flickr*

The challenge

The public sewer network of Milan runs for approximately 1500 km. MM SpA is the engineering company 100% owned by the Municipality of Milan, which manages the Integrated Water and Wastewater Services of the City of Milan, located in the Lombardy region, Italy. MM had been searching for a method to better understand the scenario of ground surface movements caused by the structural defect of its collector that could affect the area above the primary network and adjacent areas. The purpose was to prevent damage to surface structures (roads, buildings, etc.) by detecting the movements underway whose effects are not yet visible. For an assessment of the subsidence trend, a time series of past movements was required to build a past and future trend scenario. MM also aimed for a cost-effective solution that did not require the installation of instruments or their maintenance, and which was suitable for low budget and time-restricted surveys.

The space based solution

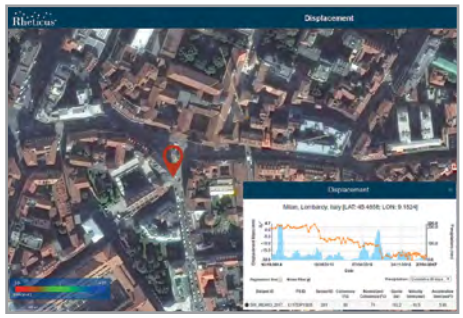
Today, satellite surveys allow: measuring millimetric surface deformations; studying the evolution of displacements in time and processing periodic trends, based on a series of acquired data, to identify non-linear movements; determining the horizontal and vertical displacement speed of points; performing multi-scale analyses; and integrating other data sources.

Satellite radar interferometry resulted in being the most accurate and affordable survey method to prevent and detect potential sewerage failures, even in relation to the high traffic volume of metropolitan cities like Milan. Displacement was assessed over the subscribed area of interest by means of measurements of velocity, acceleration and coherence of Persistent Scatterers (PS). PS were identified and their velocity/acceleration measured through the extensively tested SPINUA© algorithm applied on Sentinel-1 radar data. The Rheticus® Displacement service owned by Planetek Italia was able to process satellite data over the area and to provide thematic maps, dynamic geo-analytics and pre-set reports to MM. This service is currently used by several Integrated Water and Wastewater management companies in Italy and other EU countries, with clients like Hera, ACEA, Iren, ABC Napoli, Aquafin and MPWIK.

Benefits to Citizens

Rheticus® Displacement simplifies the detection, monitoring and analysis of subsidence phenomena from various open data sources into an interactive and comprehensive dashboard, to achieve insightful and purpose-built contents from many different perspectives. Users gain immediate and reliable geo-information, including weekly and summary information over wide areas, based on continual satellite monitoring, overcoming the difficulties and costs of field measurement campaigns. Rheticus® Displacement generates reports, thematic maps and geo-analytics based on Sentinel-1 data, meeting local to national content requirements in the field of land, buildings or infrastructures monitoring to prevent potential damage to people and properties.

> "We found satellite radar interferometry the most accurate and affordable survey method to prevent and detect potential sewer and water network failures."
>
> ***Andrea Aliscioni, MM SpA***



Milan, Italy. Screenshot of Rheticus® Displacement interface pinpointing where leaks are most likely and showing ground movements' velocity acceleration and trends.
Credit: Contains modified Copernicus Sentinel data [2014-2018]

Operators of water and sewage networks spend a lot of money maintaining their network and fighting against water leakages or structural problems. Based on Copernicus data, Rheticus® delivers an automated information service to municipal bodies, helping them pinpoint where leaks are most likely and prioritize their response teams.

Outlook to the future

The monitoring of environmental resources is taking advantage of the increased availability of satellite data from the Copernicus Programme. New satellite missions planned by ESA and the European Commission in the near future will provide further unique data sources for timely operational services.

Machine learning and deep learning are the methodologies, which will be integrated in future developments of Rheticus® services. These methodologies will allow the integration of heterogeneous data within the processing chain, collected from remote sensing, the user, the Web and social networks to improve forecast accuracy. The output will feed the decision support system of the end-user that will be able to take a decision based on accurate and predicted information.

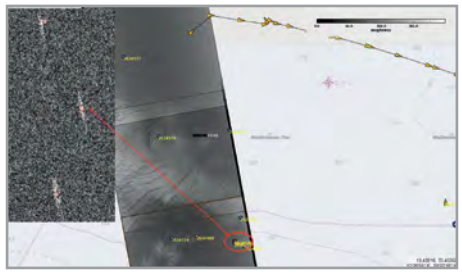
Vincenzo Massimi[1], Giuseppe Forenza[1] and Andrea Aliscioni[2]
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SATELLITE-BASED MARITIME SURVEILLANCE SERVICES IN EUROPE

Since its creation, the operational VIGISAT centre has kept reinventing maritime surveillance by satellite.

The challenge

The Region of Brittany is very sensitive to the oil spills at sea, considering its geographical unique location and past traumatic experience of oil spill disasters such as Amoco Cadiz (1978), Erika (1999) and Prestige (2002) to mention only the most important. In 2010, VIGISAT, the unique French ground receiving station of satellite radar high resolution images, was selected as one of the service provider for CleanSeaNet, the pan-European oil spill detection service implemented by EMSA. Since then, VIGISAT has kept becoming a major player of this service, not only to detect pollution, but also to identify potential source of pollution. More recently, VIGISAT also supported FRONTEX through its mission of maritime borders surveillance. Eventually, VIGISAT has extended the scope of its activities in supporting EMSA in the implementation of maritime surveillance, one of the key element of the Copernicus Security Service. In addition to the European services, VIGISAT took the lead in pioneer services such as icebergs detection in the southern seas. All these challenges turned into achievements that contributed to consolidate the strategic positioning of the regional and local authorities in the domain of marine science and technology.



On 06/10/2015, VIGISAT supported FRONTEX EUROSUR services. A SAR image acquired, processed and analysed by VIGISAT enabled to relocate and rescue 370 people aboard three rubber boats off Lybian Coast (source FRONTEX)

The space based solution

The VIGISAT satellite ground receiving station was officially opened in Brest by CLS, a French private company. Two regional projects successively supported this initiative: VIGISAT and VIGISAT-2. These projects are led by IMT Atlantique, a French Elite Graduate School specialized in digital technology, energy and environment, and supported by Europe and local authorities from the Brittany Region. They both aim at stimulating science and education activities at regional level.

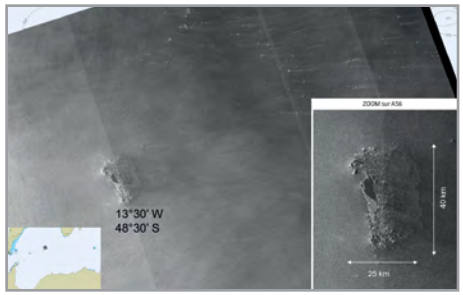
In parallel, CLS was engaged in positioning the VIGISAT infrastructure in the European network of ground stations involved in operational near real time services. VIGISAT can rely on its capacity to acquire directly the European Sentinel-1 constellation as well as the Canadian SAR (Synthetic Aperture Radar) mission Radarsat-2. In addition, most of the operational SAR missions such as TerraSAR-X, COSMO-SkyMed and some optical missions (e.g. Sentinel-2) can be processed and analysed at VIGISAT.

Benefits to Citizens

It was a great achievement when, on February 25, 2012, VIGISAT acquired, processed and analysed the first case in Europe in a maritime pollution prosecution using SAR imagery. The satellite SAR image was used as primary evidence to demonstrate that the pollution was actually released by the culprit vessel within the UK's 12 nautical mile territorial sea.

> "Forests are our planet's green lung, but oceans are its blue heart. It is now up to all of us to keep this blue heart beating."
>
> ***Karmenu Vella, European Commissioner for Environment, Maritime Affairs and Fisheries***

Another activity of great significance for the city of Brest is related to sailing races and the world tour records attempts the start of which is given off Brest. Since 2008, VIGISAT has developed and kept improving a unique iceberg detection and tracking service, that has been provided to the main round-the-world sailing races (Vendée Globe, Barcelona World Race, Volvo Ocean Race). Most of the sailors attempting since then to beat the world tour records both solo and crewed have used



The giant tabular iceberg A56 such as captured by the European Copernicus Sentinel-1 satellite on 14/11/2016, after it broke up in the southern Atlantic Ocean.
Credit: Contains modified Copernicus Sentinel data [2016]

VIGISAT services (Coville, Cammas, Joyon, Guichard, Gabart). The benefit is not only for the sailing community but also the scientific community as VIGISAT has developed a unique knowledge of icebergs generation mechanisms.

Outlook to the future

In the future, maritime surveillance services should include new applications such as the monitoring of massive stranding of sargassum algae or new technologies such as drones, big data and analytics.

Acknowledgements

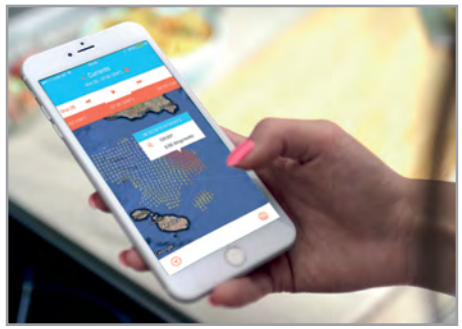
The VIGISAT station is owned and operated by CLS, a French private Company, subsidiary of CNES (the French space agency), IFREMER (the French marine institute) and ARDIAN.

VIGISAT also participates to the regional programs VIGISAT and VIGISAT2, supported by public funds (FEDER, Région Bretagne, Brest Métropole) and by Institut Mines Télécom, and managed by "Groupement Bretagne Télédétection" (BreTel - Brittany Remote Sensing).

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A SMARTPHONE APPLICATION DELIVERING METEO-MARINE DATA TO THE PUBLIC

Seafarers in the Malta-Sicily Channel are just a few clicks away from access to meteo and sea conditions for marine navigation and more.



KAPTAN is a smartphone application available on both Android and iOS platforms.

The challenge

Mariners, fishermen and leisure craft owners are always in search of the most accurate and updated information on weather and marine conditions ahead of starting their voyages at sea. Seafarers navigating across the stretch of sea between Malta and Sicily, now have an aid for planning their journeys and safer trips. KAPTAN, the Maltese word for "Captain", is supplying this data on personal smartphones, making access to data easier and more direct, based on marine and weather prediction services, with higher resolution and local data. Just a few clicks on a phone app leads users to a suite of sea and weather data in the form of interactive spatial maps providing instantaneous user friendly and user defined access to prevailing conditions at sea as well as short term past and forecast information. KAPTAN is really an on board assistant, a phone app created to serve local mariners.

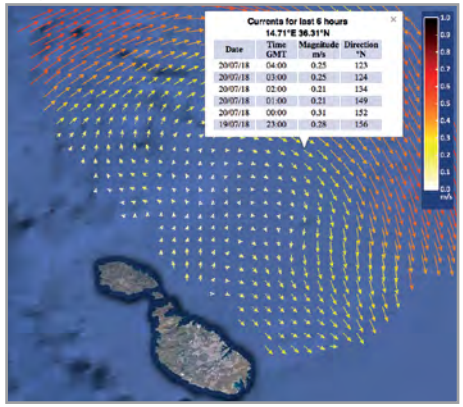
The space based solution

KAPTAN was developed within the CALYPSO project, an Italy-Malta cross-border cooperation initiative led by the Physical Oceanography Research Group (PO.Res.Grp) within the Dept. of Geosciences at the University of Malta. The service integrates real time observations with satellite data and numerical model forecasts. Sea surface current maps are provided every hour at a spatial resolution of 3 km x 3 km by the CALYPSO HF radar network consisting of four CODAR SeaSonde installations at selected sites on the northern Maltese and southern Sicilian shores. Sea surface temperature satellite observations from the COPERNICUS Marine Environment Monitoring Service (CMEMS) are added to high resolution 3-hourly maps from weather and marine numerical models specific to the Malta-Sicily Channel, providing a full suite of local scale meteo-marine reports, and complementing other weather forecasts. The big difference is that KAPTAN provides maps and point data showing how the dynamical structures of the atmosphere and the variability of sea surface currents, temperature and waves evolve in space and with time, allowing the user to zoom and to interact with a selection of specific waypoints as well as to select the viewing of sea current conditions along a user defined journey track. Most importantly the users can get the specific data they need when they need it and at no cost.

Benefits to Citizens

KAPTAN is delivered by making use of and integrating data from CMEMS to local marine observations and the high-resolution sub-regional and coastal scale operational forecasting activities of the PO.Res.Grp in Malta. It is an example of how the merging of national datasets to marine core data supplied from CMEMS is leading to a proliferation of dedicated services with downscaling to the geographical detail in demand by local communities, coastal users and national responsible entities. KAPTAN is showcasing the benefits of and need for sustained marine observations in the coastal seas to complement the data acquired at regional level. Marine data and information services delivered by operational oceanography are triggering an unprecedented leap in the economic value of met-ocean data, becoming essential for managing marine resources efficiently, and feeding benefits to the marine-related industry and the services sectors. The sharing and access to data, as a public good, is the basis for the use and re-use of data to generate a multiplier effect, and for value addition by a wide range of users, leading to the generation of knowledge, supporting service provision and economic activity.

> "Great app! Easy to navigate and excellent visuals!"
>
> ***Kristie Lormand, Android app user***



Screenshot of sea surface currents on the KAPTAN online version.

Outlook to the future

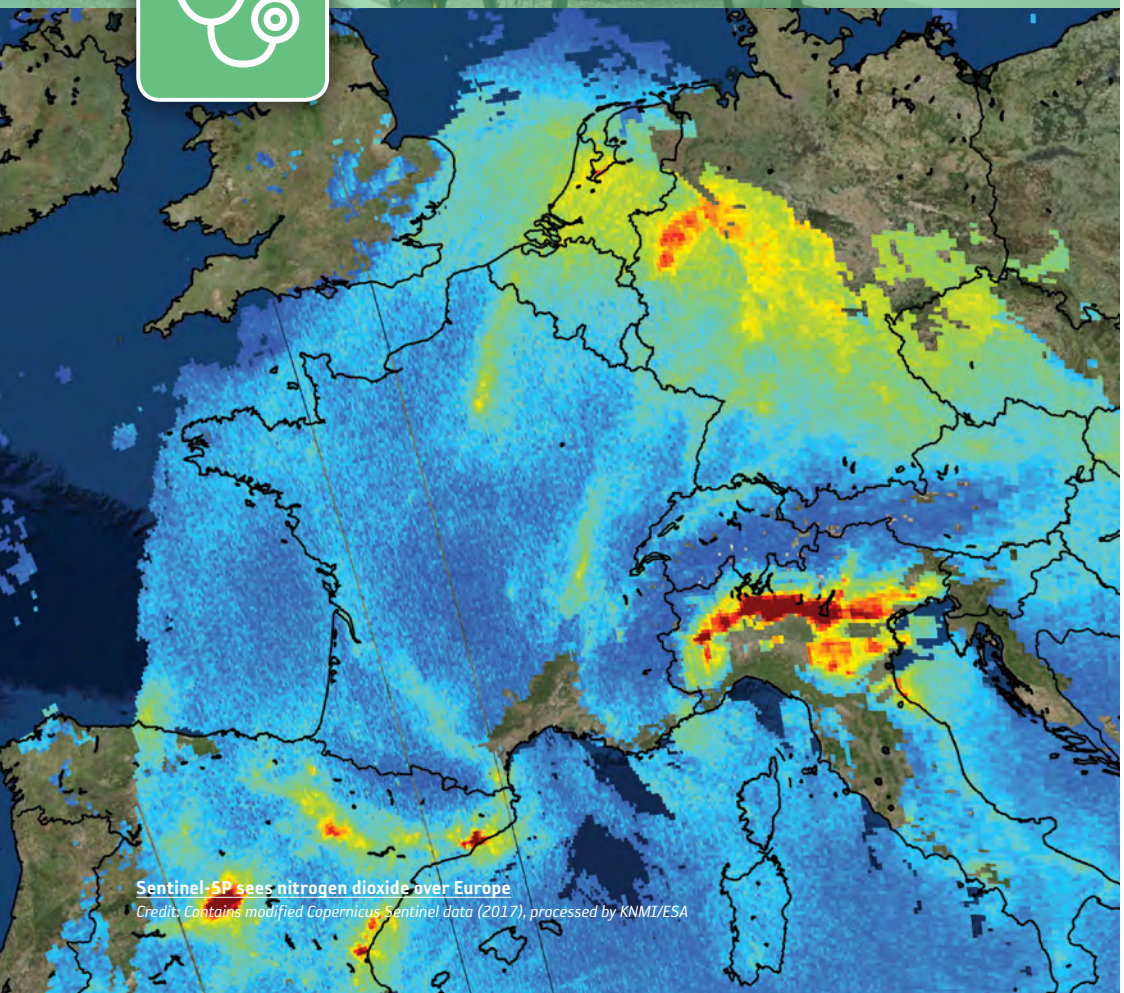
Besides fishermen and sailing enthusiasts, KAPTAN also appeals to divers, surfers, beach tourists and coastal users in general. The service is secured in the long term by the PO.Res.Grp. Data is only worth by how much it is used. Produce data once, to be used by many. This is a key added value of KAPTAN by making data easily and freely available not only to researchers, public authorities and environmental agencies, but also to the public for general consumption as a service to improve the quality of life. KAPTAN is a perfect example of such an approach, and exploits easily accessible and popular media to maximise the use of data and information about the sea and atmosphere. The phone app can be downloaded for free for both Android and iOS devices (Google Play and App Store on iTunes respectively). KAPTAN exploits the good SatCom reception in the region besides the 3G or 4G coverage up to 13 nautical miles from the coast.

Acknowledgements

KAPTAN was supported by the CALYPSO series of projects and will continue to be partially funded by the INTERREG V-A Italia-Malta programme (2014-2020) within the CALYPSO South project.

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University of Malta, Malta
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Sentinel-5P sees nitrogen dioxide over Europe
Credit: Contains modified Copernicus Sentinel data (2017), processed by KNMI/ESA

PUBLIC HEALTH

Public authorities at different levels are responsible for protecting and improving the health of people and their communities. Even before healthcare and assistance, public health is to be achieved e.g. by promoting healthy lifestyles, researching disease and injury prevention solutions, and detecting, preventing and responding to infectious diseases.

Copernicus provides disparate kinds of information useful to support public health policies, especially in relation to air quality and respiratory diseases. As poor air quality continues to prematurely claim the lives of millions of people every year, Copernicus provides an important mean for better and more accurate ways of monitoring the air we breathe. For instance, the Copernicus Sentinel-5 Precursor satellite provides information about a range of trace gases that affect air quality such as carbon monoxide, nitrogen dioxide and ozone, whilst the Copernicus Atmosphere Monitoring Service delivers regular information and forecasts about air pollutants, greenhouse gases and small particles such as dust, smoke and pollen. The Service also provides forecasts of atmospheric ozone concentrations and UV radiation that can be harmful for the skin and the eyes. Related to different policy areas, data from the Sentinel-3 mission help planners to design cooler, more comfortable cities by delineating urban areas affected by severe heat waves, whereas Sentinel-3 based water quality estimations and forecasts from the Marine Environment Monitoring Service can help identify toxic algal blooms that could potentially hit coastal areas and affect human activities such as bathing and fish farming. These data can also support the identification of areas prone to the emergence and spread of vector borne epidemics, such as malaria, which greatly depend on environmental factors such as water, sanitation, food or air quality.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
AN AIR-QUALITY-APP FOR GERMANY	Berlin Dessau	Berlin Germany	CAMS, S5P	4
MAPPING REAL-TIME AIRBORNE PARTICLE POLLUTION	Achaea (Αχαΐα)	Western Greece - Achaea	CAMS, S5P	2

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S5P: Sentinel-5 Precursor; CAMS: Copernicus Atmosphere Monitoring Service.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

AN AIR-QUALITY-APP FOR GERMANY

The German Environment Agency develops an air quality app. As of summer 2018, citizens can use the modern media to quickly and conveniently find out about the air quality.

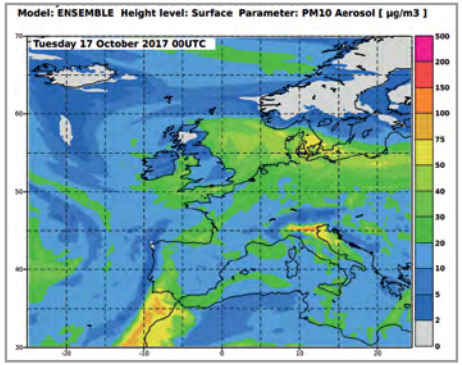
The challenge

Air quality is an important issue nowadays, especially in urban areas. It is monitored throughout Germany by the individual federal states and the German Environment Agency. Air quality is determined on the basis of the amount of air pollutants. However, this data only provides information for a single location.

The German Environment Agency provides the general public with information in all areas pertaining to the environment, including air quality. For this purpose, modern media such as, for example, the internet or apps, is used. For our app, we have used data from European modelling for the creation of an "air-quality-app", which is currently being developed and will be launched in the summer of 2018.

The space based solution

The app will be used to forecast ambient concentrations of ozone, nitrogen dioxide and particulate matter (PM10). This back-end data will be downloaded from the Copernicus Atmosphere Monitoring Service (CAMS), which indicates the daily production of near-real-time European air quality forecasts with a multi-model ensemble system. In-situ measurements of meteorology value and the forecast data, the emission sources, in-situ



Particulate matter (PM10) concentration in µg/m³ predicted for 17.10.2017 00 UTC, CAMS ensemble forecast.
Credit: Contains Copernicus Service information [2017]

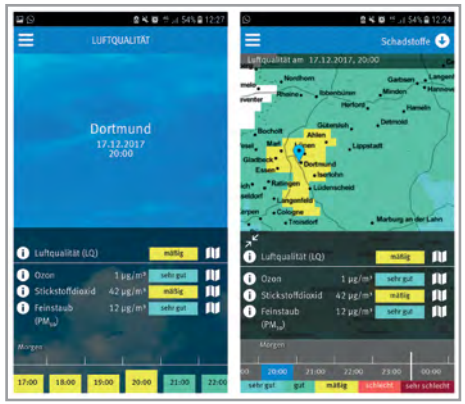
measurements of concentration of pollutants as well as satellite data are being used for the model calculations. The spatial resolution of models is set at a 15 x15 km grid. It can be concluded - the row data is suitable for background. Therefore, we have corrected the predicted concentration of pollutants. Users can find this corrected forecast on our app. The data obtained from the Copernicus Atmosphere Monitoring Service or satellite data has a great advantage (in contrast to in-situ measurements) – it is spatial information. This spatial information will support us (the German Environment Agency, Unit "Air") in our daily business, for example, in periods of high pollution concentration.

Benefits to Citizens

The air quality app will serve to inform and warn citizens. The app is free. Thus, individuals (in possession of a smartphone) at home or on the road can get information on current, location-specific air quality. This information is of particular interest to individuals belonging to higher risk groups, such as elderly people, pregnant women, children and individuals with chronic diseases (for example, asthma).

> "We hope our APP will help people plan their leisure time activities whilst raising the public awareness of air quality."
>
> ***Ute Dauert,***
> ***German Environment Agency***

Additionally, this app sets out to raise public awareness of air quality. App users will be able to compare forecasts with the limits and target values of the Directive on Ambient Air Quality and Cleaner Air for Europe as well as with recommendations of the World Health Organization. Exceedance has health and financial consequences and the EU will sue and monetary penalise the affected Member States.



Two screenshots of air-quality-app, left information about a location, right map with air quality classes.
Credit: Contains modified Copernicus Service information [2017]

The air quality information is described briefly and simply, and, thus, is easily to understand by everyone. The information can be obtained quickly and conveniently.



Outlook to the future

The app will be especially useful to inform users in case of higher pollution. Then, people can react and adjust their behaviour accordingly. For example, the ozone concentration increases under summer conditions with intensive sunlight. If you belong to a higher risk group, you can decide whether to reduce or delay any outdoor activity like doing sports. The app provides this information in the menu called "Verhaltensempfehlung" (eng. "Recommendations for behaviour").

With the development of the operational Sentinel, new air quality data becomes available. By using this data in the modelling, the model quality can be improved. The Sentinel-5 precursor was designed to provide input-data for the Copernicus Atmosphere Monitoring Service (CAMS). We, the German Environment Agency, plan to continue to use the forecast data from the CAMS in the future, not only for our app, but also for our website and our daily business.

Acknowledgements

We thank the German Aerospace Center for financial support and the promotion of our project. Our vote of thanks goes especially to Ms. Förster and Ms. Schultz-Lieckfeld, without whose support the successful implementation of our project would not have been possible.

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MAPPING REAL-TIME AIRBORNE PARTICLE POLLUTION

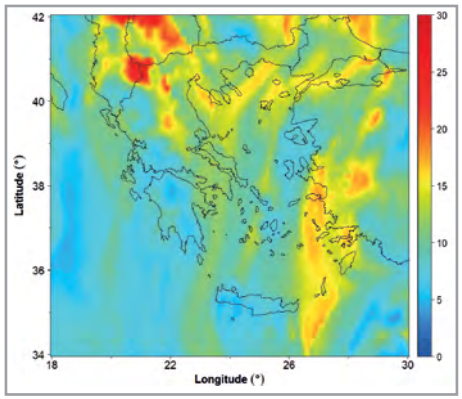
Satellite observations and in-situ particulate matter (PM) measurements are used to create maps and improve real time monitoring, modelling and forecasting performance.

The challenge

Airborne particles constitute a major atmospheric pollutant for local and regional air quality. The management of air pollution is still challenging in Greece and Patras in particular, due to lack of monitoring tools and complexity of sources (natural and anthropogenic) as well as topography. The adverse effects of aerosols on both climate and human health are of great importance to atmospheric science studies. Satellite data combined with in-situ real time aerosol concentration measurements are employed to produce a high spatio-temporal analysis of particulate matter (PM) concentrations.

The space based solution

Patrasair.gr is a real time PM concentration monitoring network of certified and regularly calibrated sensors, implemented across the city of Patras. Copernicus Atmosphere Monitoring Service (CAMS) products require certified accuracy. Quality assured in-situ measurements can be used as a basis for the evaluation of CAMS products. Analysis, modelling and forecast capabilities could eventually be improved. The greater region of Western Greece lacks high density PM monitoring stations. Verified satellite-based observations can overcome this problem



Daily mean prediction of airborne particles (μg/m3) issued from CAMS with 0.1 degree resolution over the greater area of Greece.

providing estimations of airborne particle concentrations across areas with limited measurement availability.

Moreover, the patrasair.gr network uses results from the CAMS European air quality forecast service over four days in order to provide forecasts across the city of Patras. In many cases, CAMS products are instrumental in showing if the measured air pollution by particles is caused by local or regional sources.

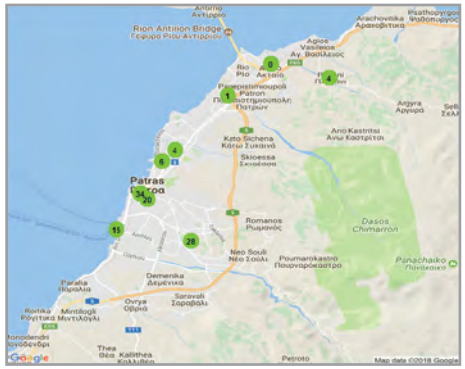
Finally, PM values are reported in near-real time, as an operational service to the citizens and stakeholders. In compliance with European Directives and the recommendations of the World Health Organisation, the air quality index values are disseminated directly to the public.

Benefits to Citizens

Patras regularly suffers from poor air quality conditions due to emissions from traffic, agricultural products/biomass burning. Air pollution is associated with adverse effects on human health. Inhaled airborne particles can provoke respiratory diseases, heart

> "The synergy of satellite-based data from Sentinels, forecasts from CAMS and in-situ measurements of airborne particulate matter make us confident we can provide air quality products at neighbourhood scale."
>
> ***Andreas Kazantzidis, University of Patras***

attacks and premature death. Although there is not a threshold below which no adverse health impacts are observed, there are guidelines aimed at reducing the reduction of PM concentrations. Studies show that



Example map of air quality index at the ground-based stations of PM across the city of Patras.

the proposed limits are exceeded both in urban and rural areas. Mapping real time PM concentrations can be used for the promotion of environmental education and awareness of the citizens. Improvement of air quality modelling and forecasting capabilities is possible through the collaboration of CAMS forecasts and in-situ data. Authorities are also expected to be involved more actively

in monitoring and air pollution management. The aforementioned tools are freely provided to policymakers to set up alerts and notifications and to take precautions to protect citizens' exposure when high PM concentrations are predicted.

Patrasair.gr is a crowd-funded project. Since its pilot operation, it has received significant attention from citizens and has been invited to many social events concerning environmental education, air quality information campaigns/programmes and the impact on the health of sensitive groups like children and the elderly.

Outlook to the future

Sentinel-5P and Sentinel-4 will provide key information for the improvement, as well as for the sustainability of this application.

In this context, operational satellite-based PM measurements with high spatial and temporal analysis will be used in synergy with CAMS forecasts and in-situ instrumentation to face future air quality challenges.

Acknowledgements

Patrasair.gr is a crowd-funded project. Special thanks are given to individual citizens, the Regional and Patras Harbour authorities and the University of Patras for their support.

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Mont Saint-Michel, France
The Bay of Mont Saint-Michel in northern France, a UNESCO world heritage site subject to some of the biggest tides in continental Europe, as observed by Sentinel-2 on May 08, 2018.

Credits: contains modified Copernicus Sentinel data (2017), processed by ESA, CC BY-SA 3.0 IGO

CULTURAL HERITAGE, TOURISM AND LEISURE

The ensemble of natural, built and archaeological sites, monuments and historic cities, all together constitute the roots of our culture and provide an immense source of leisure. Together with natural parks and marine reserves, coastal areas and ski resorts, ever year, they attract hundreds of millions of tourists from Europe and worldwide and constitute an important source of revenues and jobs for the tourist industry. They constitute an excellent conduit for promoting social inclusion and supporting cultural diversity. These sites must be maintained in the present and, very importantly, preserved for the benefit of future generations. However, threats can derive from disparate factors such as natural disasters, incautious management practices, pollution and climate change.

In almost all Member States the local and regional authorities have shared competences with the national governments for Cultural Heritage, Leisure, Tourism and Sport. The European Union mostly supports the activities of the Member States by providing financial support, coordination of joint projects and efforts, and sharing of knowledge. For instance, it has contributed to raising awareness about preservation, conservation and restoration issues, technological research (for example 3D reconstructions) and scientific progress in technological solutions through the Creative Europe Programme.

In this area, Copernicus, through the provision of information useful for the preservation of the natural environment and for the improvement of land management practices, indirectly supports tourism and leisure. The Programme was not designed to serve the specific cultural heritage needs but, when applied to cultural landscapes, different types of Copernicus-derived information can be considered potentially useful such as maps of land use changes and early warnings for potential hazards and degradation risks (e.g. from subsidence, landslides, floods but also air pollution etc.). The use of Earth observation data in the domains of tourism and cultural heritage has increased over the last few decades but is not yet established and applications are still limited to research and development projects.

OVERVIEW OF COPERNICUS USER STORIES

Title of the Copernicus User Story	Region of Affiliation of the Lead Author	Main Region of Application of the User Story	Relevant Copernicus Data and Information*	Usage Maturity Level**
MONITORING HERITAGE AT RISK WITH SENTINEL-2	Italy (Italia)	(i) Hama, Syria; and (ii) Cyrenaica, Libya	S2	1 3
PROTECTION OF EUROPEAN CULTURAL HERITAGE FROM GEO-HAZARDS	UK	Italy Cyprus Spain	S1	3

** Copernicus data sources mentioned in the user stories. Acronyms refer to: S1: Sentinel-1; S2: Sentinel-2.*

*** The Usage Maturity Level assigned to each story has been self-assessed by the Authors. Values range from 1 (Explorer) to 5 (Operational User). For the definition, please refer to* *Fig. 3 in p. 26.*

Region of affiliation of the lead Author and Main region of application of the User Story as declared by the Authors.

MONITORING HERITAGE AT RISK WITH SENTINEL-2

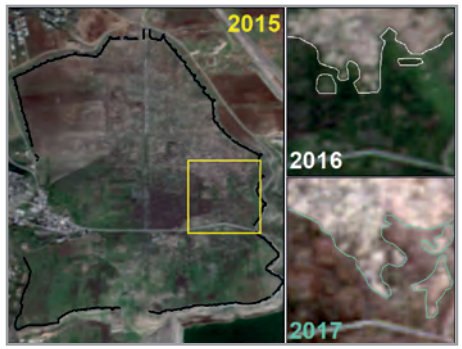
Sentinel-2 provides timely and objective information to assess the condition of heritage sites at risk in the Middle East and North Africa.

The challenge

During conflicts, cultural heritage sites are vulnerable to illegal diggings by looters searching for goods to feed the clandestine market trafficking antiquities. In ordinary times, anthropogenic modifications (e.g. urbanisation) can impact the conservation of local heritage and the surrounding cultural landscape. In both these circumstances, the challenge for heritage stakeholders such as national or regional UNESCO offices, government heritage bodies and site managers, is to be able to monitor the condition of heritage assets, and repeat the assessment on a regular basis or in case specific events of damage occur. This task requires timely data of sufficient spatial resolution that can provide objective information and allow for multi-temporal comparative measures. Common constraints for users are the costs to access very high-resolution satellite imagery (mostly provided by commercial providers) and the availability of in-house expertise for data processing and interpretation.

The space based solution

The freely accessible time series acquired by the Copernicus Sentinel-2 constellation can address this challenge. Images are acquired

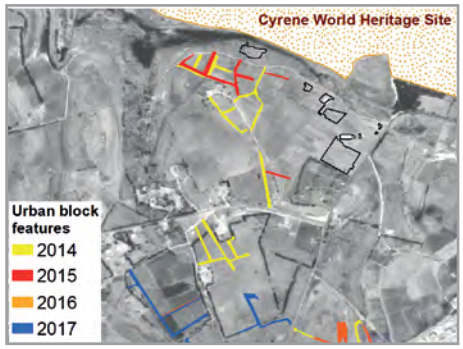


Multi-temporal mapping of new archaeological looting in the heritage site of Apamea in Syria, based on Sentinel-2 images.
Credit: Copernicus Sentinel data (2015-2017)

systematically and globally with consistent parameters, spatial resolution of 10 m in the visible bands, and every few days (e.g. 5 days over the Mediterranean countries). Our research tests of multi-temporal change detection on the archaeological site of Apamea in Syria (being looted on a massive scale since 2012) prove that Sentinel-2 data can distinctively depict clusters of several adjacent looting holes, allow for delineation of new areas of illegal digging, and estimate looting rates. Owing to a clear contrast in the reflectance of looted areas with respect to the surrounding greening land, new looting is found south-east of the theatre, west of the Cardo Maximus and the Agora and in the eastern portion of the archaeological site, along the second main Decumanus. The high temporal frequency of Sentinel-2 images increases the timeliness in recording new incidents of looting, thus bringing in an improved capability compared to satellite-based assessments based on single images acquired on demand on a monthly or yearly basis. Feature extraction analysis through long time series of Sentinel-2 can be used to capture the appearance, over time, of new manmade features due to urbanisation across the landscape, e.g. new roads, clusters

> "... using satellite imagery databases we are able to go back in time and compare the status of cultural heritage areas during different time intervals..."
>
> ***UN Institute for Training and Research (UNITAR)***

of buildings or excavation sites. Around the modern town of Shahat in Libya, this approach allowed us to map the changing degree of exposure of vulnerable heritage and to identify a hotspot south of the UNESCO World Heritage Site of Cyrene, close to the Sanctuary of Demeter and Kore.



Mapping urban block features in UNESCO World Heritage Site of Cyrene, Libya, based on Sentinel-2 time series.
Credit: Contains Copernicus Sentinel data [2017]

Benefits to Citizens

Public authorities for heritage conservation and site managers need to assess and monitor the condition of heritage at risk. Some international organisations such as UNITAR and the ASOR (American Schools of Oriental Research) Cultural Heritage Initiatives already use very high-resolution optical satellite data to monitor and document

damage at heritage sites of the Middle East and North Africa, and provide proof of concept of the value that services based on regular satellite monitoring could bring. Therefore, in an operational perspective, the condition assessment of cultural heritage sites based on Sentinel-2 time series would enable heritage stakeholders to:

- produce weekly or monthly condition reports and damage maps
- locate areas of major concern
- anticipate where concerns may arise

This Sentinel-2 space-based solution could be applied either to monitor heritage hotspots of known vulnerability or to screen wider regions.

Outlook to the future

Automatic processing chains (e.g. based on machine learning) are expected to be a technological development accelerator towards an operational use of Sentinel-2 imagery for the condition assessment and monitoring of local to wide areas of study. This automation should therefore complement the analyst-driven methods that currently represent the state-of-the-art in this field and, ideally, help to mitigate the drawbacks of manual examination (e.g. time-consumption, subjectivity). Initiatives of capacity building and training would then contribute to fill the knowledge and expertise gaps that frequently constrain the heritage user uptake of new satellite technologies.

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PROTECTION OF EUROPEAN CULTURAL HERITAGE FROM GEOHAZARDS

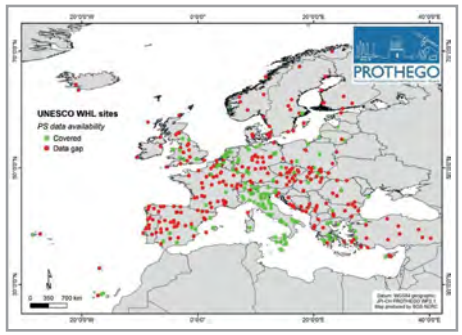
Application of innovative EO techniques for geohazards assessment in the Derwent Valley Mills (WHS).

The challenge

Tangible cultural heritage includes various categories of monuments and sites, from individual architecture to cultural landscapes, and from archaeological complexes to historic centres. Many of these sites are affected by a variety of factors, with rapid or slow onset. They include natural hazards, such as landslides, settlement, subsidence, earthquakes or extreme meteorological events, which could be worsened by climate change and/or human interaction. A comprehensive picture of cultural sites affected by geohazards is not yet available. The PROTection of European Cultural HEritage from GeOhazards, (PROTHEGO) project provides an overview of remote sensing capabilities for monitoring these threats by focusing on properties on the UNESCO World Heritage List (WHL) in Europe. These properties will serve as a reference case for all EU heritage properties.

The space based solution

PROTHEGO applies novel space technologies based on radar interferometry (InSAR) to monitor monuments and sites in Europe which are potentially unstable due to geohazards. These technologies can play a crucial role in developing site management strategies sustainable for the preservation



UNESCO WHL sites of Europe covered by PS ground motion data, derived by satellite radar interferometry. Base map data *© ESRI. World Heritage Site data Credit © 1992 - [2016] UNESCO/World Heritage Centre. All rights reserved. Map produced by BGS, © NERC/UKRI. Green dots indicate PS data available for site, red dots indicate PS data not available.*

of cultural heritage and landscape. Remotely sensed information on ground stability conditions is combined with In order to assess observed motions and understand geological processes, an analysis of remotely sensed data in conjunction with local-scale geological analysis was implemented for each test site. Advanced modelling and field surveying were also carried out. At least one site for each partner country (i.e. Italy, United Kingdom, Cyprus and Spain) was chosen to validate and calibrate the methodology.

The Derwent Valley Mills World Heritage Site (DVMWHS), managed by the Derwent Valley Mills Partnership, is one of the PROTHEGO case study sites selected for local scale monitoring, investigation and advanced modelling. The Derwent Valley, with its associated mill complexes, industrial housing and infrastructure, was inscribed on the UNESCO World Heritage List in 2001 in recognition of its importance as the birthplace of the modern factory system. In order to monitor the current state of activity of the identified geo-hazards, Sentinel-1 space-borne imagery acquired between 2015

> "The data and methods developed by PROTHEGO will contribute significantly to the development of mitigation strategies aiming to preserve the Derwent Valley's globally important cultural heritage."
>
> ***David Knight, DVM's Partnership***

and 2017 was processed using the InSAR technique. The project identified fluvial and groundwater flooding and landslides as key threats to the Valley's cultural heritage resource, for example, at Belper, where radar data identified damage possibly connected to a recent flooding event.



InSAR data identified damage in the East Mill possibly connected to the Winter 2016-17 flooding event in Belper. Sentinel-1 data were sourced from the European Space Agency. Imagery supplied through ESRI's World Imagery layer under ESRI's Master license Agreement *©ESRI. Credit: Contains modified Copernicus Sentinel data 2015-2017*

Benefits to Citizens

PROTHEGO's goal is to enhance cultural heritage management practices at the national level, reinforcing institutional support and governance through knowledge and innovation.

CULTURAL HERITAGE, TOURISM AND LEISURE

The project identifies, assesses and monitors risks with the aim of strengthening disaster preparedness for heritage properties in the future. The project promoted interdisciplinary and collaborative R&D activities, transferring the highest level of knowledge, quality and standards from space and earth sciences to cultural heritage conservation sciences.

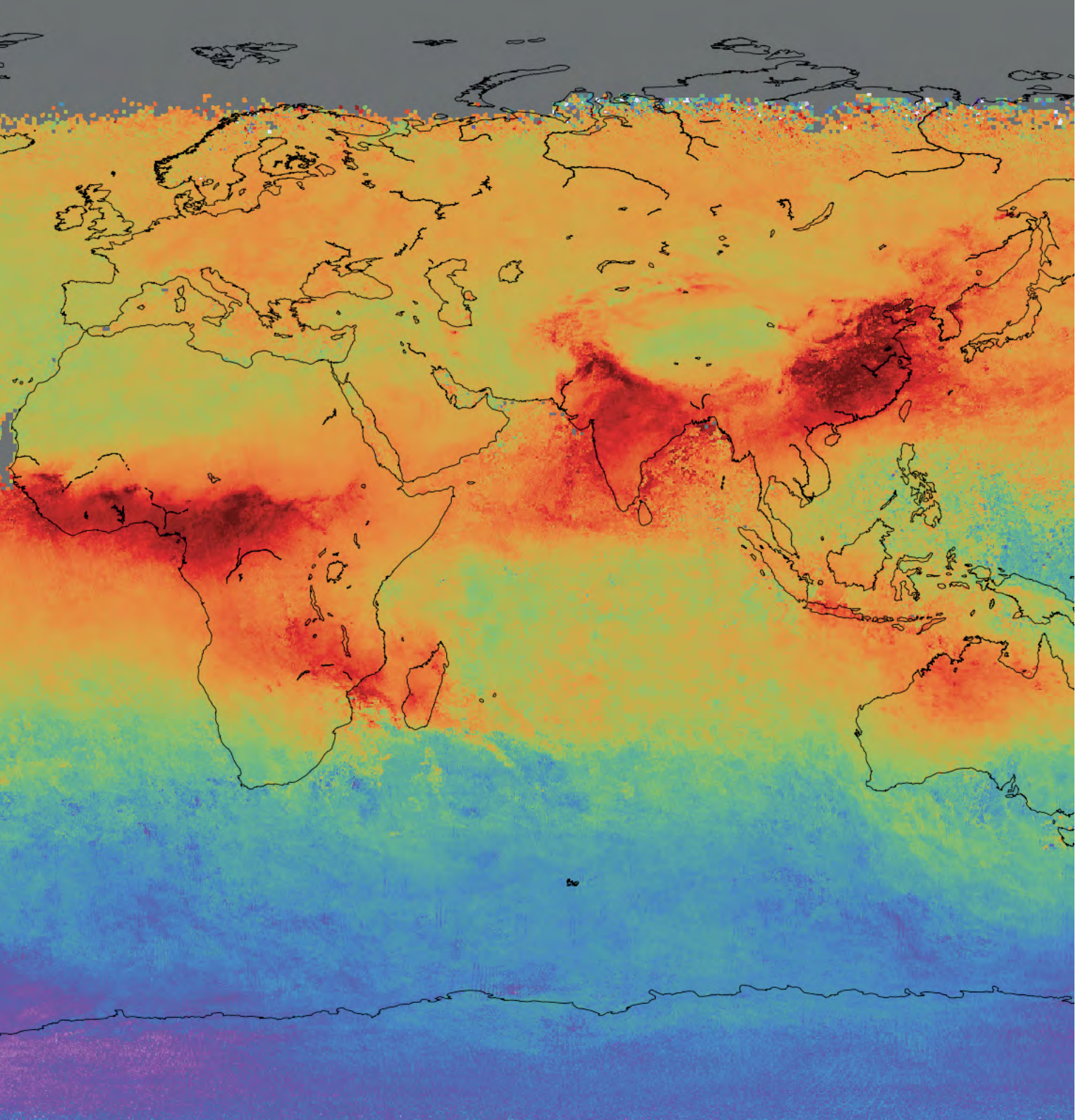
Outlook to the future

An agreement amongst EU institutions (e.g. member states, EU Commission, ESA, EEA etc.) on the use of satellite services for monitoring geohazards affecting cultural heritage would help define best practice guidelines and standard methodologies for adoption by practitioners in this field.

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Carbon monoxide measured by Sentinel-5P

Launched on 13 October 2017, the Copernicus Sentinel-5P satellite has been used to map atmospheric carbon monoxide around the globe. The image shows high levels of this air pollutant over parts of Asia, Africa and South America. The mission has a swath width of 2600 km, which allows the whole planet to be mapped every 24 hours.

Credit: Contains modified Copernicus Sentinel data (2017), processed by SRON/ESA

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