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With an uncertain future that includes climate change, sea level rise and increasing coastal populations, being able to make informed policy decisions in coastal zones will be critical for ensuring the well-being of citizens, the environment and the sustainability of economic activities. Earth observation (EO) can be used to efficiently and systematically provide the key information needed to make these decisions. However, getting access to the right EO information can be a complicated and costly business, limiting availability. However, the launch in April 2014 of the first Sentinel satellite from Europe's flagship EO program, Copernicus, represents a major advance in the availability of EO data, which has great potential to benefit numerous sectors involved in marine and coastal activities.

What is Copernicus?

Copernicus (previously Global Monitoring for Environment and Security—GMES) is an EU-led initiative in partnership with the European Space Agency (ESA) that aims to aid decision making in a world facing increasing environmental and socioeconomic pressures. The program includes satellites with missions observing land, atmospheric and oceanographic parameters. This space component comprises ESA's five families of dedicated Sentinels (launched between 2014 and 2020) and contributing missions from other space agencies. In common with the NASA/USGS (U. S. Geological Survey) Landsat missions, access to Sentinel data is open, full and free to all. This decision, very much appreciated by end-users, is part of the strategy designed to ensure the long-term sustainability of Copernicus. Reuse of data will generate new businesses and jobs, while providing consumers with more choice and value for their money.

In line with this idea, Copernicus is more than just its space component. It is solidly built upon three other equally important pillars: in-situ (ground-based and airborne) measurements, data harmonization and standardization, and the provision of products and services to users. These general services address six main thematic areas: land, marine, atmosphere, emergency management, security and climate change.

Innovative Services for Coastal Zones

The preoperational marine service (developed by MyOcean) integrates in-situ, satellite and modeling data to provide detailed, near-real-time information on marine physiochemical parameters at global, regional and local scales. Complementary marine and coastal meteorological and climate data are available from the preoperational atmosphere monitoring and climate services. Also relevant for coastal zones, the land service provides detailed information on land use types, water bodies and digital elevation.

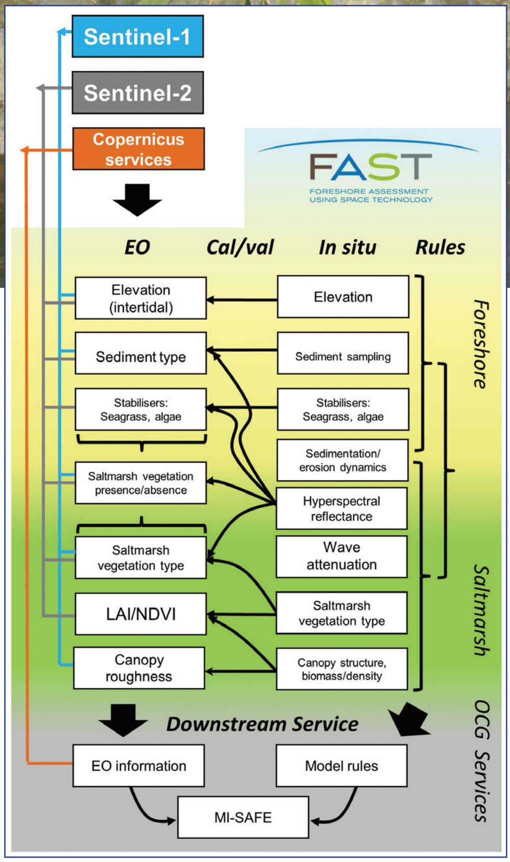
Taking advantage of these general services and including rapid tasking, the emergency management service provides support for disaster management and prevention, including, for example, flood warnings throughout Europe via the European Flood Awareness System (EFAS).

Indeed the opportunities for synergistic development of these generic services to provide value-added, user-specific downstream services in coastal zones are unlimited. For example, a system to provide early warnings of marine toxic algal blooms for the aquaculture and fisheries industries that will help contribute to food security/safety is being developed by the ASIMUTH and AQUA-USERS projects. Another example, already contributing to improvements in maritime safety and environmental protection, is radar satellite tracking of vessels and oil spills (CleanSeaNet and ARCOPOL), which enables the recognition of oil pollution, monitoring of accidental spills during emergencies and the identification of polluters.

A sector of growing interest, where Copernicus can potentially make an impact, is risk management and protection of coastal populations/assets. Recent extreme weather events, such as the December 5, 2013 storm surge that affected eastern England, Hurricane Sandy in 2012 and Hurricane Katrina in 2005, as well as the recent severe flooding events in the southern U.K. and the Danube, have firmly underlined the very real human and economic costs of coastal flooding.

Indeed, studies suggest that the future global economic impacts of sea level rise and changing climate will be substantial. Hence, assessing these risks and providing inno-

Waves breaking near the reed margin in Jurilovca, Romania. (Inset) Flow chart representing potential parameters derived from the Sentinels 1 and 2 for use in the development of the FAST downstream service. (Image Credit: van der Wal et al, 2014)



vative solutions to mitigate exposure is a very valuable endeavor.

In response, a number of international and national agencies have launched specific policy initiatives related to flood risks and coastal protection, including the United Nations Environment Program, World Bank, Federal Emergency Management Agency and the European Commission. In Europe, projects such as Eurosion, Micore and Theseus, to name but a few, have contributed to flood-risk policy, as will ongoing projects such as Risc-Kit and Pearl. However, none of these projects have been specifically designed to harness the power of Copernicus—until now. Foreshore Assessment using Space Technology, or FAST (www.fast-space-project.eu), led by Mindert de Vries of the Dutch independent institute for applied research, Deltares, has the ambitious aim of developing downstream services using Copernicus to support cost-effective, nature-based shoreline protection against flooding and erosion.

Downstream Services for Shoreline Protection

Vegetated foreshores, such as tidal marshes and mangroves, naturally defend against coastal flooding and erosion. This means natural coastal ecosystems can play an important role in reducing flood risks and are increasingly becoming part of cost-effective flood defense solutions.

The water storage and friction capacity of different habitats is related to their structural properties; for example, large, woody mangrove trees have very different energy attenuation properties compared to small, sparse tidal marsh plants. The position of a habitat type in relation to tidal elevation, the low or high intertidal, is also critical to deciding its impact in different hydrodynamic scenarios. Together these factors help determine the impact of waves, as well as long-term sediment dynamics and thus shoreline erosion.

A number of studies have examined the mechanisms by which vegetation interacts with hydrodynamics, and in particular tidal marshes and wave attenuation. However, the critical biophysical properties of the habitats responsible for attenuation are not always clear. Hence, although a large amount of information exists, translating this into a product that can be used in evaluating flood defense/coastal protection schemes is complex. This is the essence of the proposed service FAST is developing, as explained by Mindert de Vries, project leader: “FAST aims to make it quantifiable and controllable for end-users to include the services provided by vegetated foreshores into nature-based flood defense designs.”

"The biophysical characteristics of coastal wetlands (such as the canopy structure and biomass) need to be linked to wave attenuation, allowing standardized generic parameters to be used to predict the attenuation properties of different vegetated habitats."

The FAST Approach

How will the FAST consortium develop this service? To facilitate the widespread implementation of nature-based flood defense, we need to: understand the mechanisms by which different vegetation types interact with waves, storm surges and sediment dynamics; map in detail coastal habitats at the appropriate spatiotemporal scales; and provide useful outputs and services to easily and accurately include this information in flood defense strategies. Hence, the FAST team, made up of experts in hydrodynamics, EO, coastal ecosystems, modeling and product development, is focusing on these three major tasks.

The biophysical characteristics of coastal wetlands (such as the canopy structure and biomass) need to be linked to wave attenuation, allowing standardized generic parameters to be used to predict the attenuation properties of different vegetated habitats. For this, measurements of wave attenuation, led by Iris Möller, Cambridge University, are being done in different marshes at case study sites in the U.K., Spain, Romania and the Netherlands.

Techniques for the classification of coastal habitats and the quantification of biophysical parameters using the Sentinel satellites need to be refined and further developed. For this, Daphne van der Wal, Royal Netherlands Institute for Sea Research, has selected Sentinel 1 (S1, C-band synthetic aperture radar) and Sentinel 2 (S2, very-high-resolution, multispectral optical) as the candidates to derive the array of habitat parameters potentially relevant to wave attenuation. The synergy of optical remote sensing (S2) and active SAR (S1) will be used to detect vegetation presence and estimate biomass and the density of the salt marsh vegetation, providing the large-scale patterns and structural properties of the vegetation needed to predict their effect on waves. Intensive ground measurements of biophysical properties for validation of S1 and S2 products are planned at each case study site.

"One of the benefits to potential end-users from participating in service development is access to cutting-edge techniques."

The modeling team of Deltares, a world leader in the development, validation and continuous expansion of software, has the task of translating the biophysical properties derived from the Copernicus Sentinels into impacts on engineering requirements for flood safety infrastructure.

Deltares, together with the business internationalization team of the University of Cádiz, also has the job of packaging all this know-how into a user-friendly, self-sustaining downstream service (MI-SAFE). Key to this development process is ensuring strong end-user involvement and a user-driven approach to product design, which is being coordinated by Jose Sanchez, who is an expert in the creation of start-ups, and Gloria Peralta from the University of Cádiz.

Getting the Most out of Copernicus

This agile development concept is fundamental to all of the Copernicus services (generic and downstream), as stated in the mission brief by the European Parliament: "Copernicus should be user-driven, thus requiring the continuous, effective involvement of users, particularly regarding the definition and validation of service requirements." Hence, to a large degree it is also up to the user community to help define and shape the services they need. To this end, FAST is in contact with a number of potential beneficiaries, ranging from small to medium enterprises (SMEs), such as consultancies and engineering firms, to environmental NGOs and governmental agencies.

The first consultations have yielded some interesting regional differences in requirements and expectations that are being introduced into the first demo version of the FAST services to be released in 2017. Organizations, particularly SMEs, interested in learning more about the development of the FAST services are encouraged to make contact with the team via the project website.

One of the benefits to potential end-users from participating in service development is access to cutting-edge techniques that can provide advantages in terms of cost reductions and efficiency due to improvements in data gathering and decision making. Overall, these benefits should be passed on to citizens as increased value for money and improved safety and well-being.

In the near future, growth in the availability of EO data is going to be exponential. Thus, the only potential limit on the vast capacity of Copernicus to stimulate knowledge-based services in coastal zones is the ingenuity of the global ocean community.

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