A new Copernicus downstream service supporting nature-based flood defence

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Abstract and scope

This popular article aims to generate interest in the Copernicus Earth Observation programme and highlight its potential for generating knowledge based services, particularly in coastal zones. The article outlines how Copernicus can aid coastal protection/risk assessment and goes on to give a practical example of how the EU project FAST (Foreshore Assessment using Space Technology) is developing down-stream services using Copernicus to support cost-effective, nature-based shoreline protection against flooding and erosion. The article is intended for a wide audience including industry experts, scientists, managers, and policy makers, from whom we wish to inspire contributions to the FAST end-user consultation process. It is also suitable as a detailed explanation for the general public. The intended outlets are a leading, global marine technical professional magazine, *Sea Technology* and a pre-publication version for posting on the FAST website.

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1. Introduction

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 has, in the past been a complicated and costly business, limiting availability. The launch in April 2014 of the first Sentinel satellite from Europe's flagship EO programme known as 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.

2. 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 socio-economic pressures (Science Communication Unit 2013). The programme includes satellites with missions observing land, atmospheric and oceanographic parameters. This space-component is comprised of ESA's five families of dedicated Sentinel (launched between 2014-2020, Malenovský et al. (2012)) and missions from other space agencies, called Contributing Missions. In common with the NASA/USGS (U. S. Geological society) Landsat missions, access to Sentinel data is open, full and free to all without restrictions. 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, whilst providing consumers with more choice and value for money.

Paramount to this strategy, 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.

2014	2015	2016	2017	2018	2019	2020
SENTINEL-1A	SENTINEL-1B	C-band Synthetic Aperture Radar (SAR) Monitoring sea ice, oil spills, marine winds & waves, land-use change, land deformation among others, and to respond to emergencies such as floods and earthquakes				
SENTINEL-2A	SENTINEL-2B	Multi Spectral Instrument (MSI) Land cover, usage and change-detection-maps. Geophysical variable maps, risk mapping. Fast images for disaster relief				
SENTINEL-3A	SENTINEL-3B	Ocean Land Colour Instrument (OLCI) – Sea and Land Surface Temperature Radiometer (SLSTR) – Sentinel-3 Ku/C Radar Altimetry (SRAL) – MicroWave Radometer (MWR) Ocean forecasting, sea-ice charting, and maritime safety services needing accurate and timely measurements of the state of the ocean surface, including surface temperature, ocean ecosystems, water quality and pollution monitoring. Land services to monitor land-use change, forest cover, photosynthetic activity, soil quality and fire detection.				
	SENTINEL-5P	UV-VIS-NIR-SWIR spectrometer. Measurements of elements of atmospheric chemistry at high temporal and spatial resolution. Information of cloud-free observations required for the study of troposphere variability.				
High Resolution Spectrometer (UVN) Continuous monitoring of the atmospheric chemistry at high temporal and spatial resolution from the geostationary orbit. Support air quality monitoring and forecast over Europe.						SENTINEL-4
UV-VIS-NIR-SWIR spectrometer. Measurements of elements of atmospheric chemistry at high temporal and spatial resolution. Information of cloud-free observations required for the study of troposphere variability.						SENTINEL-5

The planned Sentinel missions of Copernicus. Source: [ESA](http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/)

3. Towards innovative services tailored to coastal zones

The pre-operational marine service (developed by MyOcean) integrates in situ, satellite and modelling data to provide detailed, near real-time information on marine physio-chemical parameters at global, regional and local scales. Complementary marine and coastal meteorological and climate forcing data are available from the pre-operational 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).

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 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 allows 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 a real impact, is risk management and protection of coastal populations/assets. Recent extreme weather events, such as the 5th Dec. 2013 storm surge that affected eastern England, Hurricane Sandy (2012) and Katrina (2005), as well as the recent severe flooding events in southern UK 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 (Hallegatte et al. 2013). Hence, assessing the risks and providing innovative solutions to mitigate exposure is a very valuable endeavour.

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, these have been shaped by projects such as Eurosion, Micore and Theseus, to name but a few, and will continue to be developed by 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 that is, Foreshore Assessment using Space Technology (FAST, *http://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 down-stream services using Copernicus to support cost-effective, nature-based shoreline protection against flooding and erosion.

Saltmarsh vegetation providing protection against erosion of a dyke in the Netherlands. Photograph: Daphne van der Wal

4. Down-stream services to support nature-based shoreline protection

Vegetated foreshores, such as tidal marshes and mangroves, naturally defend against coastal flooding and erosion (Temmerman et al. 2013). This means natural coastal ecosystems can play an important role in reducing flood risks, and are increasingly becoming part of cost-effective flood defence 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 (Shepard, Crain, and Beck 2011). However, the critical biophysical properties of the habitats responsible for attenuation are not always clear and few have examined the protective function of these ecosystems under extreme storm conditions. Hence, although a large amount of information exists, translating this into a product that can be used in evaluating flood defence/coastal protection schemes is presently 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 defence designs".

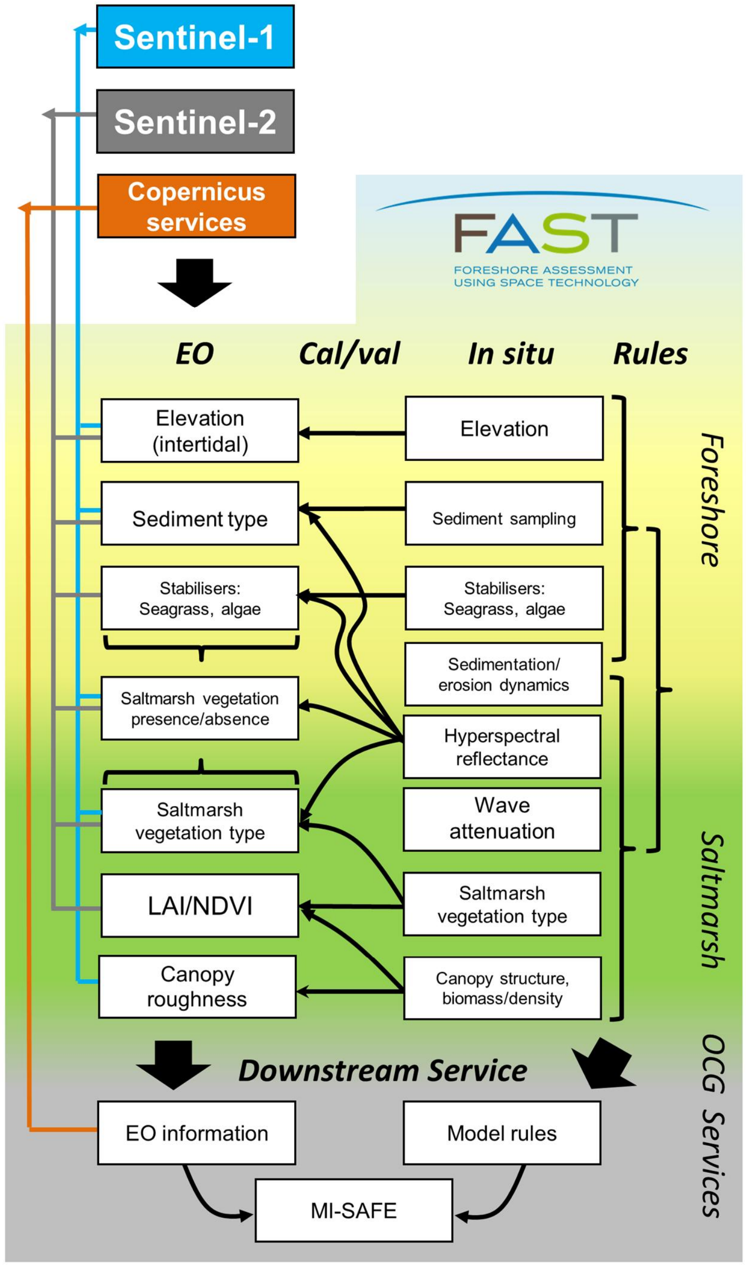
5. The FAST approach

How will the FAST consortium develop this service? To facilitate the widespread implementation of nature-based flood defence, we need to; 1) understand the mechanisms by which different vegetation types interact with waves, storm surges and sediment dynamics, 2) map in detail coastal habitats at the appropriate spatio-temporal scales, and 3) provide useful outputs (and services) in order to easily and accurately include this information in flood defence strategies. Hence, the FAST team, made up of experts in hydrodynamics, EO, coastal ecosystems, modelling and product development, are focussing 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 standardised generic parameters to be used to predict the attenuation properties of different vegetated habitats. For this measurements of wave attenuation, led by Iris Möller, Univ. Cambridge, are being made in different marshes at case-study sites throughout Europe (UK, 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, multi-spectral optical) as the perfect 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, retrieve biomass and the density of the salt marsh vegetation, providing large-scale vegetation patterns and the 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 a each of the case-study sites.

The modelling team of Deltares, world leaders in the development, validation and continuous expansion of software, have 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 internationalisation team of the Univ. Cádiz, also have the job of packaging all this know-how into a user-friendly, self-sustaining downstream service (currently code-named 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 Gloria Peralta and Jose Sanchez, Univ. Cádiz, an expert in the creation of start-ups.



Flow chart representing potential parameters derived from the Sentinels 1 and 2 for use in the development of the FAST down-stream service. Image: after [van der Wal et al. 2014] (http://rodin.uca.es/xmlui/handle/10498/16264)

6. Getting the most out of Copernicus

Indeed, 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 of Copernicus down-stream services tailored to coastal zones, 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 service to be released in 2017. Any potential end-users, particularly SMEs, interested in learning more about the development of the FAST service can make contact with the team via the project website. The rewards to potential end-users from participating in the development of Copernicus services include access to cutting-edge techniques that can bring 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 improvements in safety and well being.

In the near future, growth in the availability of EO data is going to be exponential, thus potentially the only limit on accessing the vast potential of Copernicus to stimulate knowledge-based services in coastal zones, is the ingenuity of the Global Ocean Community.

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