PROCURING INNOVATIVE CLIMATE CHANGE SERVICES

Prospective Article: Energy and Utilities

1. Introduction

The goal of the PROTECT project is to enable public authorities to use state-of-the-art public procurement approaches in order to identify climate services based on Earth observation (EO) technologies that best fit the specific and systemic needs of the public sector. The focus of the project is on five application domains namely: Energy & Utilities, Sustainable Urban Communities, Agriculture, Forestry and other Land use, Marine and Coastal Environments and Civil Security and Protection. This article provides an overview of the first application domain, **Marine and Coastal Environment,** the key challenges within the sector, the existing market solutions, and the emerging technological developments as well as some perspectives on the future of climate services for this sector, leveraging EO.

2. Definition of the application domain

According to the taxonomy defined in the PROTECT project, marine environments are aquatic environments with high levels of dissolved salt. These include the open ocean, the deep-sea ocean, and coastal marine ecosystems, each of which have different physical and biological characteristics, and thus represent different ecosystems. Marine and coastal environments can host complex ecosystems whose fragile equilibrium and prosperity depends on numerous environmental factors influencing each other and are thus a prime example of systematic approach to tackling climate needs (and providing corresponding services), making sure that addressing a single ecosystem indicator impacts other indicators in a foreseeable and favourable manner.

The climate services in the marine and coastal domain rely on EO data for precise nowcasting and forecasting, informing ocean weather algorithms, and monitoring parameters influencing water quality (for health, tourism, reporting purposes), such as turbidity, (potentially harmful) algae blooms and others.

3. Application domain profile

Two-thirds of the Earth's surface are oceans, which form 97% of the overall water bodies. Oceans act as a climate regulator for the planet, absorbing about 25% of the overall carbon dioxide emissions and releasing half of our oxygen[1]. Oceans are crucial for the overall changes to weather patterns, storing up to 50% more carbon than atmosphere as well as, through sea ice play a vital role in the global climate system. Thanks to ocean currents, the ocean routes are estimated to carry about 90% of the global trade, with marine-related economies predicted to reach nearly 3 trillion dollars of global gross value by 2030. Furthermore, oceans also home to several species of biodiversity forming 90% of the planet's living biomass, and act as the largest source of protein ocean globally. Acknowledging the importance of oceans, the United Nations Sustainable Development Goals (SDG) dedicated one entire goal, SDG

[1] The Blue Book: Copernicus for a sustainable ocean

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14, to conserve and sustainably use the oceans, seas and marine resources[2]. The European Green Deal includes a strategy for "sustainable blue economy", which identifies key components such as offshore renewable energy, decarbonizing maritime transport and greening ports as well as developing green infrastructure in coastal areas will help preserve biodiversity and landscapes[3].

4. Value chain

The global Marine and Coastal Monitoring System (MCMS) can be generally categorised into three domains: Economy, Environment and Society. This categorisation is derived from the framework provided by the Copernicus programme as described in the Blue Book and the UN SDG 14. An example of MCMS is the Copernicus Marine Environment Monitoring Service (CMEMS)[4]. The MCMS, which includes the monitoring of all the three domains, is generally an integrated system that combines all the observations collected via satellites, drones, ocean buoys and other in-situ resources. These data products are then consumed by a first set of user groups, called "Intermediate Users", to develop products that can be used by the second group, called "End Users."

The "*Intermediate Users*" are domain experts, specifically in oceanography, marine biology and coastal monitoring, who have the competence and skills required to use data products created through the MCMS, which may not be usable by any user. Some of these users combine different sources of data to create specific solutions pertaining to the needs of the *end users*. These may include scientific institutions which carry out scientific research specifically on this application domain, researchers who are independently advancing the status quo in the understanding of the oceans and domain experts who act as representative authorities of the application domain.

The "*End Users*" user group category represents stakeholders who are indirect consumers of marine and coastal resources. These may include policy makers, companies operating in other application domains such as shipping, energy, fishing, logistics and the like as well as the general public all of whom would use the products developed by the *intermediate users*. This group of users, in general, drive the development of the MCMS by sharing the requirements with the intermediate users.

Figure 1: High-Level Value Chain of Marine and Coastal Domain

The figure above summarises the overall value chain for the application domain with the MCMS, made up of three domains along with the intermediate users and the end users.

[2] https://sdgs.un.org/goals/goal14

[3] https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/sustainable-blue-economy_en

[4] https://insitu.copernicus.eu/FactSheets/CMEMS/

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- The '*Economy*' domain is predominantly made up of segments including food, trade and energy. Aquaculture and fisheries are fundamental to human lives with the oceans providing 20% average per capita animal protein intake for 3 billion people, whereas increasing global trade and investment in renewable energy is crucial for the sustainability of the marine and coastal environment.

- The '*Environment*' domain includes segments dealing with ocean health and biodiversity. Ocean health relates to monitoring the ocean's state and vital health signs, essential for the well-being of life, while the biodiversity segment comprises key datasets to monitor marine biodiversity and to protect protected areas and preserve at-risk ecosystems.

- The '*Society*' domain consists of two main segments: safety and governance. Safety includes services providing oceanic parameters for extreme situations at sea to support recreation and tourism efforts as well as pollutant drift forecasts for hazardous materials floating on the surface, such as marine plastic pollution. The governance segment deals with the current and upcoming legal frameworks that exist to conduct marine and coastal planning and operations as well as to regulate the activities on the oceans and coasts.

5. Key challenges

Oceans act as the planet's most important carbon sink, absorbing excess heat and energy released from rising greenhouse gas emissions trapped in the atmosphere. The warming oceans are expected to contribute to cascading effects such as ice-melting, sea-level rise, marine heatwaves, and ocean acidification[5]. Climate change will, thus, have significant effects on all the three domains of marine and coastal monitoring. The major challenges, per domain, are highlighted below.

- **Economy:** One of the biggest challenges for this domain are continuous monitoring of the impact of fishing activities and identification of illegal fishing vessels, especially in cases where vessel tracking signals are not available[6]. Tracking the movements of containers in ports is crucial for understanding global trade impacts. The energy sector is a significant part of the marine and coastal domain, both for tidal and offshore winds. The challenges across all of these applications stem from the need for continuous monitoring irrespective of time and weather conditions as well as the ability to offer insights for the stakeholders.

- **Environment:** Monitoring the marine and coastal environment is a crucial aspect of understanding the Earth system, while also being paramount to several commercial applications. Observing the state of ocean health, for instance, by acquiring data regarding sea ice and sea surface temperature is essential, however this is not always easy given the difficulty in accessing the remote locations in the open ocean. Similarly, monitoring the state of marine biodiversity is crucial to understanding the impact of human activities on ocean life. Detecting and tracking marine pollution is also an important element of protecting the environment, but this is not straightforward given the challenges in identifying toxic materials like plastic[7].

[5] https://www.un.org/en/climatechange/science/climate-issues/ocean-impacts

[6] https://globalfishingwatch.org/faqs/can-fishing-vessels-turn-off-their-ais/

[7] https://marine.copernicus.eu/services/public-policies/plastic-pollution

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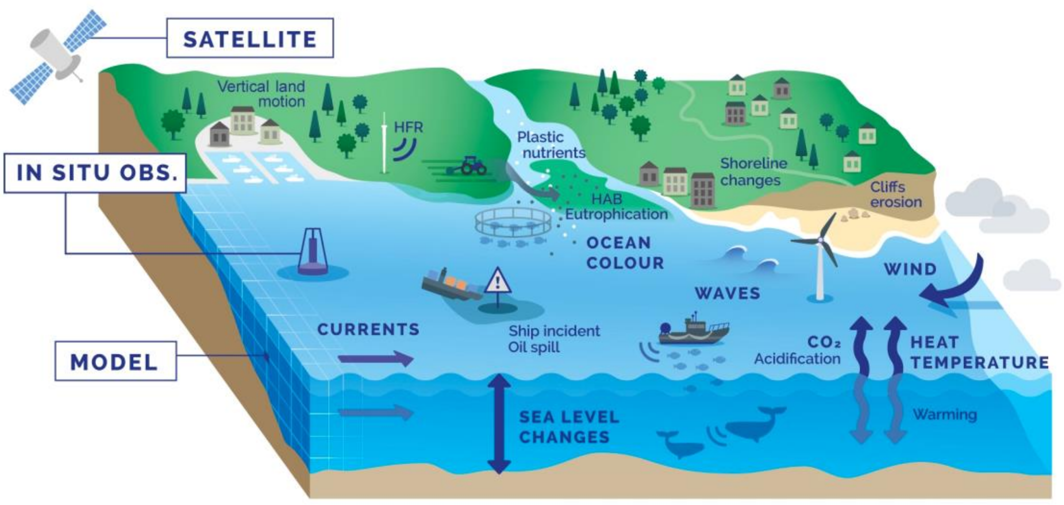
- **Society:** The importance of the marine and coastal environment for society is well-known[8]. As such, continuous monitoring of the oceans and the coastal areas is a fundamental part of keeping society safe and healthy. Support in driving regulation is also a challenge given that the ocean system is dynamic and with climate change. Coastal flooding is an example - the annual damages due to coastal erosion and flooding is estimated to be 239 €billion under a high emissions scenario[9]. This has, thus, become a major challenge for the sector, especially given that about one third of the EU population lives within 50 km of the coast.

6. Existing Market Solutions

Given the challenges described above, there are several solutions available in the market specifically aimed at offering climate services for the marine and coastal environment domain. As the PROTECT project is specifically aimed at identifying climate services based on EO technologies, the following section covers an overview of the key advancements that have led to the development of climate services, followed by a section presenting some key EO-enabled climate services.

Earth Observation Technologies

EO sensors provide invaluable information for monitoring and forecasting the state of the oceans and the coastal environments. Satellites can provide crucial information on variables such as sea surface height, sea surface salinity, sea surface temperature, ocean colour and ocean surface vector winds. However, satellite observations often provide a big picture view that may not always meet the precision required for specific applications. As such, a number of in-situ sensors are also used to directly monitor the marine and coastal zones. All these observations are typically then integrated into numerical models, providing a 4-dimensional (e.g., latitude, longitude, depth, and time) monitoring of the ocean and coastal areas. The following figure provides an overview of the different variables that can be observed by satellites and in-situ sensors along with the kind of applications they offer.



[8] https://environment.ec.europa.eu/topics/marine-and-coastal-environment_en

[9] https://joint-research-centre.ec.europa.eu/system/files/2020-09/06_pesetaiv_coastal_floods_sc_august2020_en.pdf

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Figure 2: Overview of Marine and Coastal Observations (Source: Copernicus)[10]

The Copernicus Programme is the world's largest producer of freely and openly available EO data and includes the Sentinel satellite component. Sentinel-1, 2 and 3 are some of the major satellites in the world for monitoring the ocean and coasts. The Copernicus Marine and Land services (also referred to as CMEMS and CLMS, respectively) form a significant part of products offered for the marine and coastal user community, leveraging data from the Sentinel missions along with other commercial and non-commercial satellites.

High-resolution optical, thermal infrared, and synthetic aperture radar images from both airborne and satellite sensors are crucial for biodiversity monitoring, for observing patterns in the land and sea which relate directly to biodiversity or for the provision of environmental data layers that are needed to build predictive models of species and habitat distributions[11]. Coastal models, developed by fusing several sources of data are vital for monitoring and managing coastal areas, specifically to protect at-risk coastal properties and perform infrastructure assessments. Observations of various oceanic parameters from satellites are important for acquiring data related to pollutant drift forecasting like oil spills, vessel identification, illegal fishing detection, coastal erosion detection, and algal blooms identification.

Climate Services for Marine and Coastal Environment

The following figure presents an overview of some examples of EO-based climate services for the marine and coastal environment domain, classified into three domains as derived from Copernicus Blue Book[12]. This section provides a brief overview of each domain and the relevant applications of the climate service.

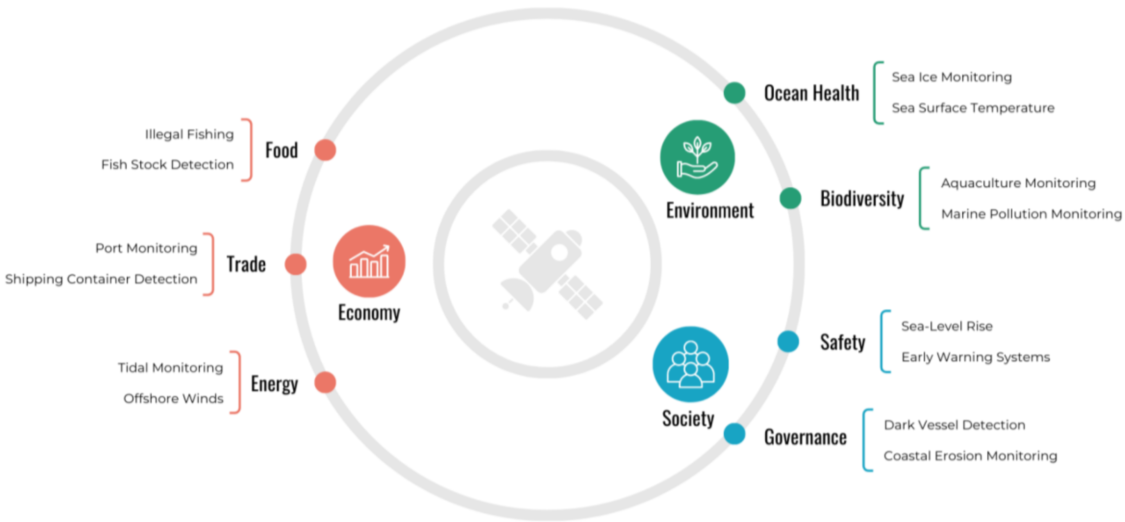

Figure 3: Marine and Coastal Environment - Climate Services

- **Economy:** The climate services included in this domain are aimed at creating a sustainable and resourceful marine and coastal economy, derived from the three segments: food, trade and energy.

[10] https://marine.copernicus.eu/news/monitoring-marine-coastal-hazards-earth-observations-and-copernicus-data

[11] https://www.cloudeo.group/blog/cloudeo-blog-space-1/earth-observation-for-marine-and-maritime-applications-24

[12] https://marine.copernicus.eu/services/user-learning-services/blue-book-copernicus-sustainable-ocean

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- Climate services related to the **food** segment include:
  - *Illegal fishing* to identify vessels involved in detecting and tracking vessels involved in unlawful and non-regulated fishing activities. Specifically, these services leverage diverse datasets from national reporting and regional fisheries management organisations, and combine these observations with satellite views of vessel behaviour, to identify discrepancies that may point to potentially suspicious activity.
  - *Fish stock detection* involves using key inputs for marine ecosystem models which are then fed into numerical models that can effectively support decision-making for fishery and environmental policies, related to assessing the status of fish stocks and habitats. For instance, sea-surface temperature, ocean colour and ocean currents allow plankton and micronekton concentrations to be derived, which can then be related to the likely health of different fish stocks[13].

- Climate services related to the **trade** segment include:
  - *Port monitoring* deals with insights on the state of the global economy by monitoring activities on the ports. This includes monitoring changes in port infrastructure, especially in case of weather events that may damage the assets.
  - *Shipping container detection* includes services that provide insights related to monitoring shipments of containers and other goods, especially during times of crisis for disaster management as well as other operations that lead to macroeconomic understanding.
- Climate services related to the **energy** segment include:
  - *Tidal monitoring* climate services provide crucial information related to safe navigation, coastal engineering and surveying, all of which are important for building energy infrastructure in the marine environment. This includes observing and deriving indicators related to maximum tidal speed, power density and tidal patterns, useful for predicting energy production activities.
  - *Offshore winds* include services that lead to understanding of the seabed dynamics, which is highly relevant when planning to reduce potential risks of exposure of cables and infrastructure, observing winds, waves and sea surface height, which is useful for wind resource estimation, as well as providing real-time updates on offshore maintenance activities.

- **Environment**: The climate services included in this domain are aimed at creating a healthy and well-maintained environment for marine and coastal domains, derived from the two segments: biodiversity and ocean health.

  - Climate services related to the **biodiversity** segment include:

13 https://www.copernicus.eu/sites/default/files/documents/Copernicus_Briefs/Copernicus_Brief_Issue34_FishMonitoring_Sep2013.pdf

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        - *Aquaculture monitoring* includes services that monitor variables such as water temperatures, nutrient levels, marine current speeds, wave patterns and levels of water transparency, all of which have a direct impact on fish, shellfish and marine plant populations[14]. It also includes early-warning alerts for common aquaculture problems like algal blooms, which can be toxic to fishes.
        - *Marine pollution monitoring* includes services to detect, monitor and track marine litter across space and time as doing so is difficult as it is impossible to see much of the ocean at one time. This applies to both toxic materials like plastic as well as services to monitor oil spills including providing spill location, spill area and length and the potential source of the spill.

    - Climate services related to the **ocean health** segment include:
        - *Sea ice monitoring* includes services that provide continuous monitoring of sea ice across locations and seasons. For example, the Copernicus Climate Service includes sea ice as a data product for the Arctic region[15].
        - *Sea surface temperature* is used as input for weather and ocean forecasting, to observe and monitor ocean current systems and ocean fronts, eddies, upwelling areas and marine ecosystems. For example, EUMETSAT provides sea surface temperature data leveraging data from the Sentinel-3 satellite[16].

- **Society:** The climate services included in this domain are aimed at creating a safe environment for the general public as well as set up governance mechanisms to regulate the activities in the marine and coastal domains. These are derived from two segments including: safety and governance.

    - Climate services related to the **safety** segment include:
        - *Sea-level rise* is caused primarily by two factors: the added water from melting ice sheets and glaciers, and the expansion of seawater as it warms. As such, data from satellites such as Sentinel-1, Sentinel-3 and Sentinel-6 are used to monitor these variables to derive a daily and monthly global, sea-level rise product[17].
        - *Early warning systems* provide alerts to policymakers, businesses and the general public related to flooding events, coastal erosion, sea-level rise and other hazardous events. Generally, this is provided via a web platform for professional use or via mobile applications and text messages.

    - Climate services related to the **governance** segment include:
        - *Dark vessel detection* is crucial for supporting policy makers and naval forces involved in identifying vessels that have switched off their automatic identification systems, for illegal fishing, trade or other unlawful activities. A

[14]https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all/satellite-data-highlights-optimal-sites-aquaculture

[15] https://climate.copernicus.eu/sea-ice

[16] https://www.eumetsat.int/sea-surface-temperature-services

[17] https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-sea-level-global

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combination of data from optical, radar and radio frequency monitoring satellites provide useful actionable insights for mitigating unregulated practices.
- Services offering *coastal erosion monitoring* support the creation of an Europe-wide coastal erosion methodological framework, in order to make sure that the same data source is used for identifying sites at risk and take actions that can be standardised across regions and countries.

7. Future Developments

The European Green Deal, which has a strategy in the domain of "sustainable blue economy" has objectives that specifically highlight the need for investing in offshore renewable energy, preserving biodiversity and landscapes and reducing marine plastic pollution[18]. Most of these objectives have applications and relevance for the use of EO-enabled climate services, of which several are already existing in the market. Some of the services are used by intermediate users such as scientific institutions and researchers in helping create awareness among the general public while also serving as key inputs for climate policies being drafted by policymakers and climate resilience solutions developed by businesses. As such, the future of climate services in the marine and coastal environment domain is bright given the existing advancements in EO, which can already serve several climate services, while upcoming developments in improving resolution, revisit and quality of EO data will grow the market even further.

The Copernicus programme is expected to see an evolution in the following years with the launch of the second generation of Sentinel satellites, which will cover hyperspectral imaging that can support biodiversity monitoring, marine litter identification and ocean colour mapping among others as well as thermal infrared and microwave sensors that can support and improve most climate services described in the section above[19]. The emergence of the so-called NewSpace era has meant that several commercial companies are also launching their own satellite constellations, which can complement data provided by public data sources, also thanks to the use of swarms of nanosatellites (e.g. CubeSats[20]). This is particularly useful for areas such as detection of illegal fishing vessels and aquaculture monitoring, especially with data such as radio frequency, automatic identification systems and multispectral imagery.

8. Conclusions

Climate change is driving sea-level rise, increasing global sea surface temperatures and intensifying coastal storms, resulting in more frequent flooding, along the coastal areas. The impacts can be felt both on the ocean with the effects on marine biodiversity, increase in algal bloom events as well as the disruptions to recreational and tourism activities. While locally deployed sensors and data collection mechanisms can work for some applications, several of them lack continuous monitoring services with the ability to identify, distinguish and provide actionable information to the stakeholders. Given the advancements in EO, the availability of climate services for protecting the marine and coastal environment is expected to grow and evolve over the coming years, making such solutions available for governments and businesses to respond to the impacts of climate change.

[18] https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/sustainable-blue-economy_en

[19] https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

[20] https://www.eoportal.org/satellite-missions/seahawk-1#seahawk-1-cubesat-ocean-color-mission

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