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End User Applications for Ocean Forecasting: present status description

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Abstract. The direct benefit of developing ocean forecasting systems and in improving the accuracy of the predictions is practically demonstrated through downstream applications. These systems are considered pillars of the Blue Economy, offering potential for economy, environmental sustainability, creation of new job opportunities and actively supporting decision making. In this paper, the authors outline the main sectors currently benefiting from ocean model products, reviewing the state-of-the-art and potential use for societal activities, management and planning.

1 Introduction

The Blue Economy is an increasing sector which includes, amongst other socio-economic sectors, marine living resources, marine non-living resources, marine renewable energy, port activities, shipbuilding and repair, maritime transport and coastal tourism. The associated economic activities directly employed close to 4.45 million people and generated around €667.2 billion in turnover and €183.9 billion in gross value added (Rayner et al., 2019). These sectors offer significant potential for economic growth, sustainability transition, employment creation, as well as they ask for innovative, sound and prompt decision making support tools. A decision-making workflow needs to understand past and present ocean conditions and forecast future ocean conditions. Accurate predictive capabilities permit the implementation of services for real-time decision-making, multi-hazard warning systems, and anticipatory marine spatial planning. Once the ocean forecast model data is generated, it can be used in a variety of ways. For example, shipping companies can use the data to optimize their routes and avoid areas with dangerous weather or ocean conditions. Fisheries managers can use the data to predict fish populations and optimize their harvests. Environmental agencies can use the data to monitor water quality and detect the spread of pollution, etc. Notably, the Horizon Europe programme (2021-2027) has a budget of €95.5 billion (including €5.4 billion from the Next Generation of the EU Recovery Fund), of which at least 35 % will be devoted to support climate-related actions, supporting the transition of maritime industries to climate neutrality. Maritime Spatial Planning (MSP) is a policy framework for mediating between human activities and managing their impact on the marine environment. It is considered a key pillar of the Sustainable Blue Economy.

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Europe's coastal seas, particularly the North Sea and the Baltic Sea, host a highly competitive group of users, such as commercial and private shipping, oil and gas exploitation, pipelines, cables, sand extraction or disposal, wind farms, recreational activities, and fishing as well as nature reserves and other marine and coastal protected areas (Buck et al., 2004). The following paragraphs are presenting examples of how the blue economy is using model data and which is its overall impact.

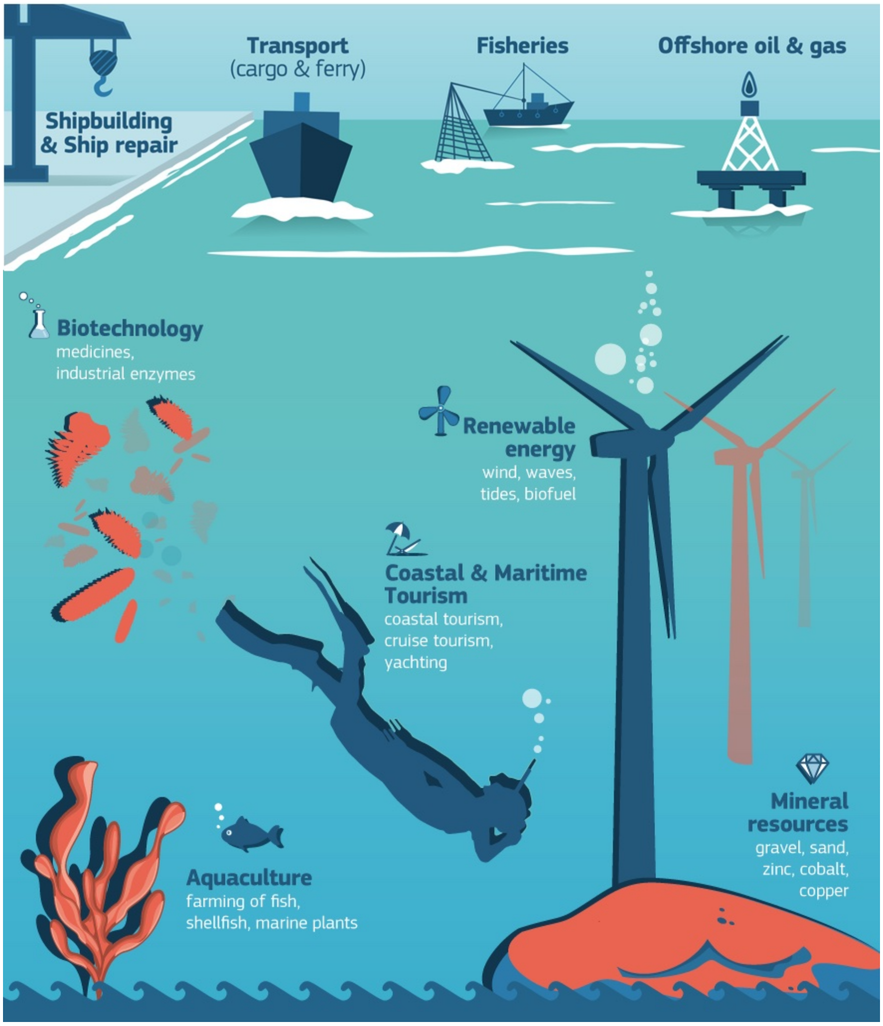

Figure 1: Blue Growth (adapted from the EC infographics on Blue Growth)

2 Model data applications in Blue Economy

A good collection of examples of application of Ocean Forecasting data in Blue Economy can be found at ETOOFS Guide. The following section describes briefly some of these application fields.

Marine Transport

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Maritime transport plays a key role in the EU economy and trade, estimated to represent between 75 % and 90 % (depending on the sources) of the EU's external trade and one third of the intra-EU trade. EU passenger ships can carry up to 1.3 million passengers, representing 40 % of the world's passenger transport capacity. The sector consumes forecasting data on weather and ocean conditions to, for example, determine the optimal route and time of departure for a vessel (Życzkowski et al., 2019; Bitner-Gregersen et al., 2014; Schnurr and Walker, 2019). These models can help improve the safety and efficiency of marine transport while minimizing fuel consumption and environmental impacts (Wan et al., 2018).

Search and Rescue

Search and rescue (SAR) operations use evidence-based methods to plan, execute, and evaluate SAR operations (Futch and Allen, 2019). SAR needs gathering and processing relevant data and information, such as weather and ocean forecasts, topography and geography of the area, and the real time information of the nature of the incident and its evolution. This information is used, for example, to minimize the search areas.

Operational Services for Ports and Cities

Port and coastal cities need ocean forecasting data for several reasons. A good example of this kind of applications can be found on the OSPAC (Operational Services for Ports and Cities) software system, consisting of an integrated set of tools and measuring instruments that provide an operational service to the city and the adjacent port in order to minimize risks and improve environmental management. In these systems there are two main service layers: the first one includes forecast models of local sea conditions and, based on these models, a second layer provides real-time alerts on extreme values of coastal variables such as water quality, currents, and sea state that are used for a variety of applications (Gaughan et al., 2019; NOAA, 2021; OECD, 2016; OECD, 2018; Rayner et al., 2019).

Offshore oil and gas

Marine non living resources have played a key role in providing access to sources of energy and raw materials necessary for the economy. Ocean forecasting services are crucial for offshore oil and gas activities, supporting oil spill trajectory modeling, data-driven approaches to forecasting production, maintenance support, and many other uses (Keramea et al., 2021).

Offshore renewable energy production

Marine renewable energy (production and transmission) sector represents an important source of green energy and, for example, can make a significant contribution to the EU's 2050 energy strategy. As with the developments in aquaculture, the energy sector has also experienced considerable transformations. Model forecasting is an important tool for offshore renewable energy production, as it enables the accurate prediction of energy and yields operational efficiency (Uihlein and Magagna, 2016).

Ocean Health

Extreme marine events are threatening marine ecosystems, resources, food security and related businesses. Forecasting services, working in combination with satellite observations are powerful tools to understand this phenomenon (Le Traon et al., 2015).

Aquaculture

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The EU has highlighted the need for a new strategy for aquaculture to become sustainable and to enable future growth in this sector (COM/2021/236) and the new approach for a sustainable blue economy (COM/2021/240). Currently, the need for blue sector food products in the EU is mostly met through imports, around 60 %, ("The EU Fish Market" EUMOFA 2020 edition), while EU aquaculture accounts for only 20 % of fish and shellfish supply. The rising population demands radical solutions towards food security, which cannot be solely met through land-based agriculture. Seaweed (macroalgae) aquaculture has the potential to supplement food supplies, enhance the maritime economy, and enable ecosystem services. In this framework, forecasting services play an important role by providing valuable information to help improve production efficiency, reduce risks, and ensure sustainable practices, such as production planning. The services are helping to determine optimal production plans, e.g. size and timing of harvests, based on factors like water temperature, nutrient levels, and fish growth rates. These services are also supporting the impact prediction of environmental factors, such as ocean extremes and pollution levels (Sangiuliano, 2018).

Coastal tourism

Coastal tourism plays an important role in many EU Member State economies, with a wide-ranging impact on economic growth, employment and social development. Coastal tourism is the largest Blue Economy sector, representing 44% of the GVA and 63 % of the employment of the total EU Blue Economy. The value of models for coastal tourisms goes from short term weather forecast to long-term including climate change, sea level rise, and tourism demand, forecasting tourism demand using machine learning algorithms, and predicting coastal tourism vulnerability to climate change and sea-level rise.

Disaster Risk Reduction

Forecasting services are key elements to enable the timely detection and prediction of dangerous weather and ocean conditions (extreme events) including sea level (storm surge) events and their relevance in inundation and coastal destruction processes.

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Competing interests

The contact author has declared that none of the authors has any competing interests.

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Data and/or code availability

This review considered the results and data listed in the references.

Authors contribution

Authors equally contributed to the design and writing

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