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Ocean Forecasting at the Regional Scale: Actual Status

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Abstract. Operational ocean forecasting systems provide important information on physical and biogeochemical variables across global, regional, and coastal scales. Regional systems, with higher resolution than global models, capture small-scale processes like eddies and tides, but lack detailed land-sea interactions essential for coastal areas. These models, often nested within global systems, vary in spatial resolution (1-20 km) and may include biogeochemical components. While regional systems focus on physical parameters such as sea surface height, temperature, and currents, only a few incorporate biogeochemical processes. The growing demand for biogeochemical data has prompted advancements and more systems will include this component in the coming years.

This paper provides an overview on status of regional forecasting systems at today, discussing examples as the Copernicus Marine Service from the OceanPredict, analysing the offer in terms of covered regions, resolution and ocean variables product catalogue.

Short Summary:

This article provides an overview of the main characteristics of ocean forecast systems covering a limited region of the ocean. Their main components are described, as well as the spatial and temporal scales they resolve. The oceanic variables that these systems are able to predict are also explained. An overview of the main forecasting systems currently in operation is also provided.

1 Introduction

Numerous oceanographic systems are providing data on physical and biogeochemical variables, spanning from global, regional and coastal scale. It can be challenging to precisely define the characteristics of a regional oceanographic system versus a global or coastal system, as there may be some overlap in the information they provide and the regions they cover. Regional

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models are often more detailed than global models, having higher resolution and the capability to resolve small-scale processes such as eddies, fronts, tides, and local features, avoiding the high computational cost of running a global system at high resolution. Moreover, they can be optimized for specific areas, which may have unique oceanographic characteristics and require higher resolution or tailored parameterizations (Tonani et al., 2015). However, they do not include the processes of land-sea interaction that are important for the coastal areas, e.g. the dynamics of nearshore currents, sediment transport, the delta/estuary processes, and some biogeochemical processes, typically solved by coastal systems. In addition, the spatial scale is a factor in differentiating global, regional and coastal. Regional systems are directly nested into global and might have or not nested coastal systems.

Several regional forecasting systems have been developed across the world and are currently in operations (Tonani et al., 2015; Schiller et al., 2015; Alvarez-Fanjul et al., 2022). A brief overview of the main characteristics of these systems is presented in Sections 2 and 3. Section 4 provides details on the regional systems described by OceanPredict (Tonani et al., 2015; Bell et al., 2015), and the Copernicus Marine Service (Le Traon et al,, 2019), considered a representative overview of the systems currently in operation. Providing an exhaustive account of all the regional forecasting systems is outside the scope of this document and would require a dedicated survey.

2 General characteristics

There are several factors that determine the spatial scale of a regional ocean forecasting system, including the region's size, bathymetry, and oceanographic characteristics, as well as the system's purpose. Operational systems currently have resolutions ranging from approximately 1 to 20 kilometers. For instance, shelf sea regional systems may require a finer resolution, with smaller grid cells around 1 kilometer, while a larger region such as the North Atlantic may need coarser resolution with larger grid cells around 10 kilometers or more. The choice between a regional, global, or coastal oceanographic system will depend on a variety of factors, including the specific operational needs of the user, the oceanographic characteristics of the region of interest, and the computational resources and data availability.

Design, components, and configurations of these systems can vary widely. Most of them use an ocean general circulation model such as NEMO (Madec et al., 2022), ROMS, or HYCOM, and data assimilation components based on the Kalman filter or variational methods. Additionally, some systems include wave and biogeochemical model components. These model components can be standalone or coupled in various configurations. Most of them rely on atmospheric fields at the ocean/atmosphere boundaries because they are not coupled with an atmospheric model. Biogeochemical components are a standard feature in all the European systems of Copernicus Marine Service, but they are missing in most other systems. Some countries, such as India, are currently developing a biogeochemical component for future use.

Regional models are often nested into a global or another regional system, providing them with lateral boundary forcing. Many systems, in turn, provide lateral boundaries and initialization fields to coastal systems.

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Most systems provide deterministic forecasts, although a few already have the ability to produce ensemble forecasts. There is a growing interest in developing systems that can produce ensemble forecasts.

The forecast production is daily for most systems, although some run them twice per day. The forecast lead time is typically between 5 and 10 days (short-medium range) (WMO, 2021). The time resolution of their products varies from hours to days, with some fields delivered at a higher frequency of 15 minutes.

Ultimately, the spatial and temporal scales of a regional ocean forecasting system, as well as the selection of its components, will depend on the region's specific needs and characteristics.

3 Oceanographic information provided by regional systems

The regional oceanographic services play a crucial role in measuring the Ocean Essential Variables (EOV) defined by the Global Ocean Observing System (GOOS). EOVs are classified into four categories: physics, biology/ecosystems, biogeochemistry, and cross-disciplinary. This description is mainly focused on short term forecasting products, because most systems do not provide long climatological series of the past to understand how ocean conditions are changing over time. There are several regional reanalysis studies, but it is not easy to map the services delivering this information. Copernicus Marine Services has an operational service delivery for the reanalysis produced by all its regional systems and updated at least on a yearly basis.

While the regional forecasting systems primarily focus on physical parameters such as temperature, salinity, currents, and sea level, some also include wave and sea ice components to provide comprehensive information about the ocean's physical characteristics.

It is important to clarify that most of the regional systems forecast the Sea Level, also called Sea Surface Height. This is the distance between the ocean surface and a reference level, which is typically for these models the geoid. Different models can have a different datum associated to their Sea Level due, for example, to different physics in the global model they are nested in. This needs to be taken into consideration when inter-comparing model data to observations and or to other models (e.g. regional vs. coastal). Moreover, it's worth taking into account that the approximations done by the models and data assimilation schemes can have an impact on the accuracy of this information.

Except for the Copernicus Marine Service, most regional systems do not deliver information on biogeochemistry and biology. These models are computationally very expensive due to the high number of variables and processes they take into account, preventing them from providing in most cases the level of details and accuracy that users require. However, despite these limitations, there is a growing recognition of the importance of monitoring and understanding biogeochemical variables in the ocean as confirmed by the steady increase in the demand for the biogeochemical products at Copernicus Marine Services. Additional regional systems, i.e. the Indian INDOFOS and Australia, are currently developing a biogeochemical model that will be coupled to their systems.

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4 Operational regional systems across the world

Different countries and organizations have developed regional ocean forecasting systems. The European Copernicus Marine System (Le Traon et al., 2019), since 2015, has a set of regional systems that cover all the European seas, the Arctic ocean, and the northeastern Atlantic. Australia has a relocatable regional system for refining its global model around its own region. Other countries such as Brazil (Franz et al., 2021; Lima et al., 2013), Canada, China, India, Japan (Sakamoto et al., 2019), Korea, and the US have regional ocean forecasting systems or a set of them, covering the ocean and seas surrounding their coasts.

These systems use different data sources and modeling techniques, but they also have many similarities. Table 2.2-1 provides a non-exhaustive summary of the regional systems as described by OceanPredict and by the Copernicus Marine Service.

As described in Section 1, their geographical extension can vary from relatively small surfaces to extended areas and their horizontal grid resolution is usually of the order of 2-20 km. They do all provide the standard physical variables but only few also provide biogeochemical information.

There are also differences in the level of operational readiness in the systems described as well as in the data dissemination policy. Not all this information has an open and free access policy but all the regional systems play an important role in monitoring and forecasting the ocean.

Table 1: Summary of the region covered by the regional ocean forecasting systems based on the information available from OceanPredict and from Copernicus Marine Service. The last column describes the Ocean Essential Variables (defined by GOOS) provided by each system.

Country/ Provider	Geographical area/System	Resolution	Essential Ocean Variables
Australia - Blue Link	Relocatable regional model along Australian coast	~2km	Physics (T, S, currents, SSH, waves) Biogeochemistry under development
Brazil – REMO	• Atlantic ocean • Brazilian continental Margin (METAREA V)	• 1/12° • 1/24°	Physics (T, S, currents, SSH)
Canada-Concept RIOPS	• Arctic	• 1/4° • 1/36°	Physics (T, S, currents, SSH, sea ice)

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Government of Canada Gouvernement du Canada	• North Atlantic and Great Lakes		
China – NMEFC	• Northwest Pacific • Bohai Sea, Yellow Sea and East China Sea • South China Sea	• 1/20° (1/36°) • 1/30° • 1/30°	Physics (T, S, currents, SSH)
Europe – Copernicus Marine Service	• Arctic Sea • Baltic Sea • North West European Shelf • Iberian-Biscay-Irish sea • Mediterranean Sea • Black Sea	• 3-6 km • ~2km • ~2 and 7km • ~2-3 km • ~5-3 km • ~3km	Physics (T, S, currents, SSH, sea ice, waves) Biogeochemistry (nutrients, oxygen, carbonate system, organic carbon, optics) Biology (plankton)
India – INCOIS	• Indian Ocean (INDOFOS) • Local Indian Ocean regions (HOOFS) • Indian Ocean nested into Global (ITOPS-IO)	• 1/12° • 1/48° • 1/16°	Physics (T, S, currents, SSH) Biogeochemistry – under development
Japan – MOVE/MRI.COM	• Japanese area • North Pacific	• 1/33° x 1/50° • 1/10° x 1/11°	Physics (T, S, currents, SSH)
Republic of Korea	• North Pacific • The Yellow and East China Sea (KOOFS)	• 1/28° • 3 km	Physics (T, S, currents, SSH)

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US – NOAA	• West Coast Operational Forecast System (WCOFS)	4 km	Physics (T, S, currents, SSH)

Competing interests

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

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