OceanPrediction Decade Collaborative Center: Connecting the world around ocean forecasting

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Abstract. Operational Ocean Forecasting Systems (OOFS) have proven to be immensely valuable today. Numerous successful and inspiring services are operating in various regions of the world, contributing to cutting-edge applications within the marine community. This success lays a strong foundation for building a global community around ocean forecasting. However, the development and enhancement of existing forecasting systems remain challenging due to the absence of best practices, standards, and community-endorsed architectures. The OceanPrediction Decade Collaborative Center (DCC) and its associated Decade actions aim to address these challenges by leveraging the UN Decade of Ocean Science for Sustainable Development (2021-2030) and the concept of digital twinning. This paper introduces the OceanPrediction DCC and outlines the forward-looking strategies to achieve these ambitious goals. The special issue introduced by this paper is part of this broader effort.

1 Introduction

The United Nations Decade of Ocean Science for Sustainable Development (2021-2030), also referred to as 'the Decade,' was proclaimed by the 72nd session of the UN General Assembly on December 5, 2017. Coordinated by the IOC-UNESCO, the Decade seeks to promote large-scale, transformative change to shift from the 'ocean we have' to the 'ocean we want.' The Decade supports the development of ocean data, information, and knowledge systems, driving them toward higher levels of readiness, accessibility, and interoperability. The scale of this effort must be exponentially greater than anything previously undertaken.

To guide the Decade's implementation, the IOC (Intergovernmental Oceanographic Commission) has developed an Implementation Plan (IOC-UNESCO, 2021), supported by contributions from member states, UN agencies, intergovernmental organizations, non-governmental organizations, and relevant stakeholders. The OceanPrediction Decade Collaborative Center (DCC) is a cross-cutting structure within this plan that operates globally, fostering collaboration among the Decade actions related to ocean prediction.

Mercator Ocean International has been entrusted by the IOC-UNESCO to coordinate the OceanPrediction DCC, with the mission: "to achieve a predicted ocean through a shared and coordinated global effort within the framework of the UN Ocean

Decade." The Centre implements a community-driven agenda that allows the ocean prediction community to collaborate on activities such as communication, outreach, training, cost-sharing, joint workshops, and the standardization of language and outputs. Additionally, it facilitates the co-design of an architecture necessary for developing a Global Ocean Prediction System.

The Centre acts as a global convener of multidisciplinary ocean prediction expertise, collaborating with intergovernmental programs (e.g., GOOS, ETOOFS, IODE, OBPS) to establish agreements on operational infrastructure, terminology, and standards needed to deliver unified services from multiple geographic and thematic nodes

2 OceanPrediction DCC objectives

The objectives of the OceanPrediction DCC (https://www.unoceanprediction.org/en) are as follows:

- To provide a collaborative backbone structure and a collective voice for the ocean prediction community, supporting the Decade's implementation, focusing on:
  - Creating a global, inclusive forum (spanning coastal to deep sea, nowcasting to climate, biology to physics, public to private, users to scientists) and other tools to facilitate dialogue and information exchange.
  - Implementing capacity development and ocean literacy initiatives.
  - Promoting Operational Ocean Forecasting Systems (OOFS) as a crucial tool for the Blue Economy and ocean policy.
- To develop a global technical and organizational structure centered on:
  - Co-designing, in collaboration with Ocean Decade actions and other key stakeholders, a new scenario for ocean forecasting that facilitates data sharing and interoperability while leveraging digital twin technologies.
  - Identifying needs and coordinating the development of new tools, standards, and best practices for the implementation and improvement of Ocean Forecasting Services and its applications, with a focus on a science-to-service framework and promoting interoperability and integration.
  - Aligning Decade actions with the objectives of ocean forecasting and fostering collaboration between Decade initiatives and other relevant actors.
- To support the Decade Coordination Unit (head of the Decade) by collaborating with other Decade Collaborative Centers and Coordination Offices, ensuring alignment and monitoring of Decade actions to secure their long-term legacy.

3 OceanPrediction DCC in the UN "decade ecosystem"

OceanPrediction DCC will closely coordinate with the Data Sharing DCO (led by IODE) and the Observations DCO (led by GOOS) to establish a framework for developing ocean monitoring and forecasting services throughout the Decade.

OceanPrediction DCC shall be responsible for promoting collaboration between Decade Programmes, and their relevant decade projects, as well as decade contributors when these fall under the scope of work, all done in coordination with the mentioned DCOs.

The Decade implementation plan links each DCC and DCO to specific Decade Programmes, named “primary attachments”. In the case of OceanPrediction DCC, these are:

- FORESEA: its overarching goals are: 1; to improve the science, capacity, efficacy, use, and impact of ocean prediction systems and 2; to build a seamless ocean information value chain, from observations to end users, for economic and societal benefit. These transformative goals aim to make ocean prediction science more impactful and relevant.
- Ocean Practices: The Ocean Practices for the Decade Programme (“OceanPractices”) will support all ocean stakeholders in securing, equitably sharing, and collectively advancing this methodological heritage.
- Digital Twins of the Ocean (DITTO): it will establish and advance a digital framework on which all marine data, modeling, and simulation along with AI algorithms and specialized tools including best practices will enable shared capacity to access, manipulate, analyze, and visualize marine information.
- Global Environment Monitoring System for the Ocean and Coasts (GEMS Ocean): it is boosting its multi-stakeholder partnership convened by UNEP, bringing together experts from earth observation, monitoring, and modeling communities, together with end users and a broad range of stakeholders to provide fit-for-purpose key information for policymaking.
- Ocean Acidification Research for Sustainability (OARS): it will foster the development of the science of ocean acidification including the impacts on marine life and sustainability of marine ecosystems in estuarine-coastal-open ocean environments.
- NASA Sea Level Change Science Team: it has been conducting interdisciplinary sea level science by collecting and analyzing observational evidence of sea level change, quantifying underlying causes and driving mechanisms, and producing projections of future changes in sea level.
- France's Priority Research Program "Ocean of Solutions": aims at addressing ocean-related societal challenges through integrated research.

The collaboration with these programmes will be particularly intensive, but additional collaborations with other programmes will be established, as “secondary attachments”.

4 OceanPrediction DCC collaborative structure

To achieve its objectives, OceanPrediction DCC will establish two global collaboration structures:

- A decentralized regional structure, consisting of Regional Teams that focus on community development and capacity-building efforts
- A central structure, comprising the Ocean Forecasting Global Co-design Team (OFCT) and a central office, which will liaise with various UN, EU, and national bodies. The OFCT focuses on co-design alignment and consists of experts covering different aspects of the ocean forecasting value chain (Alvarez Fanjul et al., 2022).

Having different Teams for technical aspects and community building will allow efficient management: a smaller specialists team able to deliver technical results on time and a larger geographically based structure, able to integrate the community and catalyze the governance and organizational component.

4.1 The Regional teams

The OceanPrediction DCC Regional teams have the following objectives:

- Act as regional nodes of OceanPrediction DCC
- Contribute to the coordination and cooperation with ocean forecasting-related Decade actions in the region.
- Identify gaps and ways forward in the regional landscape of ocean forecasting.
- Support OceanPrediction DCC in the design and organization of regional events for capacity building, ocean literacy, and other purposes, such as courses, workshops, hackathons, etc.
- Advocate for regional implementation of Best Practices, Standards, and Tools derived from OceanPrediction activity.
- Collaborate with the other OceanPrediction DCC Regional Teams to support global actions
- Support OceanPrediction DCC in obtaining information for the building of an Atlas describing the situation of Ocean Forecasting around the Globe (including services, institutions, interested persons, experts, and any other relevant data).
- Promote the use of OOFS in each region for decision-making purposes, including sustainable blue economy, technical, policy, and legal aspects.

The Regional Team distribution is based both on UNEP (United Nations Environment Programme) regional seas and in GOOS Regional Alliances (GRAs), clustering some regions. The concept of the Regional Teams was announced at the OceanPrediction DCC kick-off meeting, an event that demonstrated the appetite for this initiative, with 1800 registered participants from all continents. At this moment we are building these teams, and several leaders are volunteering worldwide to chair each region:

- Region 1: West Pacific and Marginal Seas of South and East Asia. Chair: Swadhin Behera (JAMSTEC-Japan)
- Region 2: Indian seas, covering South Asian Seas and ROPME Sea Area. Chair: Sudheer Joseph (INCOIS-India)
- Region 3: African seas. Chair: Kouadio Affian (Ivory Coast - Chair of IOC Africa). For this region, we have decided to have several co-chairs and a subregional division to address the differences in technical development.

- Region 4: Mediterranean and Black Sea. Chair: Emanuela Clementi (MONGOOS/CMCC - Italy)
- Region 5: North-East Atlantic. Chairs: Ghada al Serafy and Loreta Cornacchia (EuroGOOS coastal WG, Deltares)
- Region 6: South and Central America: Chairs: Clemente Tanajura (Universidade Federal da Bahia) and Boris Dewitte (CEAZA)
- Region 7: North America: Chairs: Patrick Hogan (NOAA), and Fraser Davidson (DFO).
- Region 8: Arctic: Chair: Heather Reagan (NERSC-Norway)
- Region 9: Antarctic: Chair: Stuart Corney (UTAS - Australia)

4.2 The Ocean Forecasting Co-Design Team

Ocean Forecasting Systems (OFS) have proven invaluable for understanding the ocean and providing critical information for decision-making. However, challenges remain in areas like standardization, interoperability, and integration. Building an OFS from scratch, without guidance, is a daunting task, often resulting in isolated systems with limited integration into a larger framework.

This situation hampers the proliferation of forecasting services, especially in technologically less advanced countries, and hinders the growth of the ocean forecasting community and collective knowledge. The Ocean Forecasting Co-Design Team (https://www.unoceanprediction.org/en/about/technical) is an international group of experts working under OceanPrediction DCC coordination, collaborating to overcome these limitations by developing a new ocean forecasting architecture. This team comprises worldwide specialists whose collective expertise covers the whole value chain. It will leverage existing technologies and initiatives, such as the digital twins, and the IPCC activities on standardization, interoperability, and integration.

As an initial step, the team assembled the current special issue and evaluated the status of operational ocean forecasting systems from both user and expert perspectives (Ciliberti et al., 2023). The team's primary objective is to design a unified ocean forecasting architecture that leverages the concept of digital twinning (Tzachor et al., 2023). This architecture aims to facilitate simpler, modular, and more robust system development in the future. A key aspect of this development will be the establishment of well-defined building blocks, which will take the form of standards, tools, and best practices. While this new framework will benefit all forecasting services, it will be especially impactful for organizations that are just beginning their activities.

The Ocean Forecasting Co-Design Team's role is to identify this architecture and define the essential building blocks needed for its expansion. This effort will support the various Decade Programmes by providing clear development targets. However, the team's role is not to "code" these components directly, but rather to inspire and guide the implementation of these targets by Decade Programmes.

5 Next Steps

The OFCT will continue its activities, and, in the future, it is planned to address the identification of gaps in ocean forecasting and the priorities for further development. The results of these works will be published in subsequent special issues. These efforts form part of a wider strategy to promote ocean forecasting worldwide, which is summarized in the virtuous loop shown in **Figure 1**.

The Ocean Prediction DCC's community, organized around the regional teams and integrating the Decade Programmes related to Ocean Forecasting, will be at the center of all the developments. This community will be articulated through the OceanPrediction DCC web page (https://www.unoceanprediction.org/en) and, more specifically, around a Forum, where the community will share experiences and address doubts, and an Atlas, that will serve to identify who is who.

Figure 1: OceanPrediction DCC's Virtuous loop towards the promotion of Ocean Forecasting

The description of the virtuous loop can start with the knowledge required to understand ocean forecasting techniques and their degree of development and implementation. The publications presented in this special issue, and the future gap analysis mentioned above are part of this effort, which is centralized around the ETOOFS guide (Alvarez-Fanjul et al., 2022). This is a GOOS publication that compiles the basic knowledge related to the different aspects of Ocean Forecasting. Now the Guide has been transformed into a wiki site under the OceanPrediction DCC website. This will permit the update of content by the addition of community contributions.

This compilation of common knowledge will serve as a valuable tool for capacity development, and therefore it will facilitate the construction of new operational services and the improvement of existing ones. To additionally facilitate this task, the OFCT has delivered the so-called "Architecture Guide", available at the resource center of OceanPrediction DCC website. This document describes all the components, and "internal wiring" required to implement a robust forecasting service. The architecture is based on "building blocks", which will take the form of Data Standards and Tools.

Once a system is implemented, it is required to operate it properly. To facilitate this task, the OFCT has developed the Operational Readiness Level (ORL), (Alvarez Fanjul et at, 2024). This is a new tool to promote the adoption and implementation of best practices in ocean forecasting. Thanks to its application, system developers will be able to assess the operational status of an ocean forecasting system. Improving the ORL qualification of a service is a means to implement best practices and standards in ocean forecasting, improving the system.

The ORL comprises three independent digits designed to certify the operational status of an ocean forecasting system. Each digit ranges from 0 (minimum) to 5 (maximum), with decimal numbers being allowed. These digits correspond to distinct aspects related to operationality: the First Digit reflects the reliability of the service, the Second monitors the level of validation for the service, and the Third assesses the various degrees of product dissemination achievable by the system.

In the last conceptual step of the virtuous loop, the data will be integrated into interoperable frameworks, such as Digital Twins of the Ocean. This will allow a richer exploitation of the data, extracting more information useful for science and decision-making. The knowledge generated in this way will be incorporated into our common, closing the loop.

We intend that this compilation becomes a relevant part of the shared knowledge that forms part of this loop, describing where ocean forecasting stands today. By examining current methods and new developments, we highlight how important ocean forecasting is for keeping our marine environment healthy and productive for future generations.

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Competing interests

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

Data and/or code availability

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