http://dx.doi.org/10.32360/78513
ISSN 0374-5686
e-ISSN 2526-7639

Labomar
Arquivos de Ciências do Mar

THE DATA WE NEED FOR THE OCEAN WE WANT TO PREDICT: A BRAZILIAN PERSPECTIVE

Os dados que precisamos para o oceano que queremos prever: uma perspectiva brasileira

Carlos Eduardo Peres Teixeira[1,2]

[1] Instituto de Ciências do Mar, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil.
E-mail: carlos.teixeira@ufc.br
[2] Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Barcelona, Spain

ABSTRACT

A Predicted Ocean is one of the UN Ocean Decade goals. Ocean observations and numerical simulations of the ocean circulation are at the heart of this outcome. Numerical models are used to understand the present and predict future ocean states, but also the human impact on it, among many other uses. However, its results are only a representation of reality, and we need to validate the numerical model outputs with observational data before using them. Considering its coast extension and the marine economic importance, Brazil does not collect enough physical ocean data and we have only a few real-time observation systems. Unfortunately, due to the COVID and the current national science budget crisis, the number of real-time observations has been further reduced. From a positive perspective, I must believe that this situation will change. We need to be prepared to convince the stakeholders of the importance of observing systems to our society and secure a budget in that regard. This is the way to better predict our oceans.

Keywords: ocean modeling, observation systems, Ocean Decade, numerical model validation.

RESUMO

Um "Oceano Previsível" é um dos objetivos da Década dos Oceanos da ONU. As observações e as simulações numéricas da circulação dos oceanos estão no centro desse resultado. Modelos numéricos são usados para entender o presente e prever o estado futuro dos oceanos, mas também o impacto humano sobre ele, entre muitos outros usos. No entanto, seus resultados são apenas uma representação da realidade, e precisamos validá-los com dados observacionais antes de usá-los. Considerando a extensão de sua costa e a importância dos mares para sua economia, o Brasil não coleta dados físicos oceânicos suficientes, tendo apenas alguns sistemas de observação em tempo real. Infelizmen-

te, devido à covid e à atual crise do orçamento nacional da ciência, o número de observações em tempo real foi reduzido ainda mais. Numa perspectiva positiva, devemos acreditar que essa situação vai mudar. Precisamos estar preparados para convencer as partes interessadas da importância de sistemas de observação para nossa sociedade e garantir um orçamento para isso. Essa é a saída para prever os nossos oceanos de forma correta.

Palavras-chave: *modelagem oceânica, sistemas de observação, Década dos Oceanos, validação de modelos numéricos.*

INTRODUCTION

In 2017, the United Nations declared that a Decade of Ocean Science for Sustainable Development would be held from 2021 to 2030 (IOC-UNESCO, 2020). The Ocean Decade intends to provide a common framework to ensure that ocean science can fully support countries to achieve the 2030 Agenda for Sustainable Development Goals (SDG)_in particular, the SDG14 "Conserve and sustainably use the oceans, seas and marine resources for sustainable development". During the 1st Global Planning Meeting of the Decade, seven societal goals were defined: 1) A safe Ocean, 2) A Sustainable and Productive Ocean, 3) A Transparent and Accessible Ocean, 4) A Clean Ocean, 5) A Healthy and Resilient Ocean, 6) A Predicted Ocean, 7) An inspiring and engaging ocean.

The outcome "A Predicted Ocean" was defined as the ocean where society has the capacity to understand current and future ocean conditions and forecast their change and impact on human well-being and livelihoods, thereby ensuring a sustainable future. Understanding present and future conditions is a prerequisite to the development of sustainable ocean economic policies and ecosystem-based management (Ryabinin *et al.*, 2019).

Ocean observations and numerical simulations of its circulation are at the heart of this outcome. Ocean observations are naturally the best option to characterize the current state of the ocean. Satellites play a critical role in this sense providing real-time, global high space and time resolution observations of key ocean variables including sea level, sea surface water temperature, ocean color, sea surface salinity, waves, and winds (e.g. Lentini & Mendonça, 2021). Satellite products are also free most of the time, however, the information provided is largely restricted to the ocean's surface. *In situ* observations - from moorings, a ship (including opportunity vessels), a drifting (e.g., Argo profiling floats and surface drifting buoys) and mobile platforms (e.g., gliders or tagged animals) give us information on the ocean interior and are certainly also essential. However, only a limited portion of the ocean can be characterized through observations alone, as the spatial and temporal distribution of observational efforts is inevitably sparse.

Numerical models are used to predict future ocean states (e.g. Marta-Almeida, 2021; Fox-Kemper *et al.*, 2019), but models can be also used to connect and interpret sparse coastal observations (De Mey-Frémaux *et al.*, 2019) helping to understand the current state of the oceans and its dynamics. Since the first ocean models were proposed in the 60s, significant advances have occurred in time-stepping techniques, advection schemes, physical parameterizations, and vertical and horizontal discretization and due to the substantial increase in high-performance computational resources, today, the use of high-resolution numerical grids are possible. Numerical models have now been used in decision-making support under a sustainable ecosystem approach, marine search and rescue, understanding transport and fate of pollutants, connectivity studies, maritime and coastal port operations, etc.

While numerical models have significantly evolved in this century and developed to be an almost ready-to-use tool in some cases, their results are only a representation of reality. Due to the incomplete understanding of some physical processes, poorly representation of some forcing fields of the simulations (e.g. water and heat fluxes, winds, and riverine coastal discharge) and the ocean bathymetry, we need to validate the numerical model results with observational data before using its results for management purpose or prediction studies. Data assimilation, which is a technique to minimize the misfit of model results with the use of observations, is also essential in forecast systems to have proper results (e.g. Davidson *et al.*, 2019).

The oil spill that occurred in early September 2019, which affected more than 3.000 km of the South Atlantic Ocean and around 1.000 Brazilian beaches (Soares *et al.*, 2020), is a vivid example of the difficulties predicting and understanding our oceans and the reason we need more data. During this event, many attempts were made to predict the destination of the oil on the Brazilian coast. I tried to use two of the most employed global ocean models (Hycom/Ncoda and Glorys-Mercator) to do that. The results could not be worst, since one model predicted the oil transport northwards of the city of Salvador coast, while the other model predicted the transport southward. Which forecast was correct? During the event, was impossible to say, because no real-time observing system was available to validate these models along all the coast affected by the oil. After many days, a mooring deployed by the Universidade Federal da Bahia close to Salvador city, but unfortunately not provided with a real-time system, was recovered and we were able to show that the Glorys-Mercator was the best forecast at that time (Lessa *et al.*, 2021). Thanks to this deployment we were also able to learn the mechanism responsible to bring the oil from the open ocean towards the east coast of the northeast region of Brazil. Unfortunately, we did not have such a system at the north coast of the northeast region, and we do not know how the oil was transported into this shelf during the event.

Initiatives and perspectives on data observation

As part of the Global Ocean Observing System (GOOS) (IOC, 2019), the GOOS-Brazil initiative is responsible for important monitoring programs and public data distribution. An updated overview of some of these initiatives and other modeling and data collection efforts is presented by Franz *et al.* (2021). Among these initiatives, the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA[1]) program, is a successful cooperation between Brazil, France, and the US that has collected upper ocean and atmospheric near real-time data over the Tropical Atlantic for more than 20 years including. PIRATA operated twenty-one moorings including five buoys adjacent to the Brazilian waters. The National Buoy Program (PNBoia[2]) is also an important national program that has provided near real-time data from eleven moored buoys and almost 300 drifters buoys since 1998. The national initiative of the Global Sea Level Observing System (GLOSS-Brazil[3])

1 http://www.goosbrasil.org/pirata/
2 http://www.goosbrasil.org/pnboia/
3 http://www.goosbrasil.org/gloss/

is a network of sea level sensors that has provided near real-time sea level data from thirteen different locations along the Brazilian coast in the last 30 years. It is worth mentioning that all the initiatives above are managed or have assistance from the Brazilian Navy.

Even though it is not part of the GOOS-Brazil, a more recent and important initiative is the Brazilian Coastal Monitoring System (SiMCosta[4]), which collects near real-time oceanographic data (including bio and chemical information) from six moorings and atmospheric and sea level data from twelve stations along the Brazilian coast since 2014.

There are other local observing efforts, but these are the national initiatives that aimed to collect near-rea-time data along the Brazilian shelf and adjacent open ocean, which is essential for ocean prediction projects. No one would say that these observational initiatives are enough for a country with almost 8,000 km of coastline and from which a large part of its economy depends on the oceans. When we look at the details of these observations, the situation is even more worrisome, since the spatial distribution of the moorings is not even along the Brazilian coast and the temporal extension of part of these observations is short. Lack of continued funding and buoy vandalism contributed to this situation. The PNBOIA program, for example, has only a few locations with continuous data collected for more than one year, mostly due to vandalism on the moorings.

If we have not observed enough in the past, the current situation is a tragedy for the Brazilian ocean observations systems. The COVID-19 pandemic made the moorings maintenance impossible in 2020 and the current national science budget crisis (e.g. Angelo, 2019) makes the acquisition of new sensors and the payment for the expensive logistics for new deployments almost impossible. As a result, from the five PIRATE buoys moored adjacent to the Brazilian shelf, only one is currently collecting data (Pirata, 2021). Only one of the eleven proposed PNBOIA moorings is currently working. No drifting buoys have been deployed since 2016 and no data from it has been collected since 2019 (PNBOIA, 2021). Only six of the twelve sea level sensors installed by the SimCosta (SimCosta, 2021) and five of the thirteen sensors installed in the context of the GLOSS-Brazil program (Gloss-Brazil, 2021) are working. Only three of the previous six moorings deployed by the SimCosta are working. It is true, unfortunately, we have been collecting less real-time oceanography data today than we use to do in the past.

The COVID pandemic will end, and we will be able to return to our sea-going activities. Each one of us has a unique idea on how to improve our ocean observation systems, but we don't need to reinvent the wheel, we can learn from and adapt the successful examples of Europe, the USA, or Australia. Franz *et al.* (2021) and De Young *et al.* (2019) presents a long perspective on this topic, however, I should highlight a few key points necessary to improve our ocean observation systems:

- The need for a central and national-level institute responsible for the deployment and maintenance of data collection systems. The proposed Brazilian Institute for the Sea (INMAR) is a path (and a dream) to be followed.
- Data needs to be FAIR (findable, accessible, interoperable, and reusable). To do that, we need a National Oceanographic Database where oceanography data is

4 https://simcosta.furg.br

stored and made available without restriction in a timely and user-friendly way for all users – and not only for researchers. There are plenty of international initiatives to follow.

- The observations systems must focus on "Essential Climate Variables" (ECV) and include biogeochemical sensors. The SimCosta moorings are an example to be followed.

We may all not agree on the best way to collect the data, where to collect it, who should be collecting or storing the data among many other academic differences. Nevertheless, if we really want to predict our oceans, we must make the mantra "we need more (FAIR) data, we need more (FAIR) data!" reality. I have been hearing this mantra since I started my academic life twenty years ago, but unfortunately, observing systems and all the deployment and maintenance logistics is very costly. Funding is vital for that, and science spending has never been a priority in Brazil and nowadays is considered a burden by our central government. From a positive perspective, I must believe that it will change one day. We need to be prepared to convince the stakeholders of the importance of observing systems to our society and secure a budget in that regard. FAIR data, among other things, is necessary for the ocean we want to predict.

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