

# **Observing the Ocean – A Changing Paradigm A Future Vision of Operational Oceanography**

A joint paper by

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## **1. Summary**

Over the past twenty years, the paradigm for observing the oceans has evolved from a set of loosely associated research programs and experimental satellite missions towards a coordinated system of coastal and global operational activities. In this talk we will identify some of the issues that arise in the context of developing an operational ocean system like those that have evolved for the atmosphere such as the World Weather Watch. Our vision of the future is a fully operational Global Ocean Observing System with an end-to-end data system that both draws from the 150-year history of the WMO and is fully cooperative and mutually enhancing with the other global observing systems on the planet.

## **2. Introduction**

The very nature of the ocean with its turbulent surface and opaqueness in depth to electromagnetic radiation has meant that global ocean measurements have lagged those in the atmosphere. Moreover, the economic and social interest in the oceans is focused as much on the coastal regions as globally. As a consequence, the ocean community lacks the 150-year history driven by the immediacy of weather forecasting and the need for global observations that the national weather services, guided by the World Meteorological Organization (WMO) and its predecessor organizations, have used to develop the comprehensive system now in place for global atmospheric monitoring.

But today, increasing demands on the ocean for fisheries, better forecasting of coastal hazards, and impacts on human health coupled with a better understanding of how the ocean interacts with the atmosphere that comes from such global research programs as the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS) have raised the profile of the need for better and operational coastal and global observations. New technology from experimental satellites such as TOPEX/POSEIDON and autonomous floats, and greatly expanded modeling and data assimilation have laid the basis for an operational global ocean observing system.

Overall planning for such a system lies with the international IOC/WMO/ICSU/UNEP Global Ocean Observing System (GOOS) planning and implementation process, along with the development of regional and national programs that focus on coastal areas. Globally, we are making progress with the development of data assimilation techniques that use global measurements such as Argo floats in global pre-operational experiments with an emphasis on forecasting including the Global Ocean Data Assimilation Experiment GODAE and the EuroGOOS pilot project MERCATOR. The emphasis is on forecasting. The GOOS Coastal Ocean Observations Panel has developed a unified plan that addresses safe and efficient marine operations, coastal hazards, the health of marine and estuarine ecosystems and their relation to human health, and living marine resources. The plan for the Coastal Ocean Observations Module of GOOS addresses a critical aspect of ocean observations, and may well be the driving force for implementation. All of this requires close cooperation between oceanographers and meteorologists overseen by the WMO/IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM). We will discuss each of these in turn.

### **3. Current planning for the Global Ocean Observing System (GOOS)**

The GOOS Strategic Plan ([http://ioc.unesco.org/GOOS/docs/GOOS\\_str\\_pl.htm](http://ioc.unesco.org/GOOS/docs/GOOS_str_pl.htm)) conceives of GOOS as a new, internationally organized system for the gathering, coordination, quality control and distribution of many types of marine and oceanographic data and derived products of common worldwide importance and utility, as defined by the requirements of the broadest possible spectrum of user groups. GOOS will resemble the global meteorological observation and prediction network, supported by national governments and implemented through the contributions of national agencies, organizations and industries, with the assistance of national and international data management and distribution bodies.

The plan makes it clear that GOOS is an ambitious undertaking which will include diverse marine observations many of which have not been systematically or routinely assembled before. Nevertheless, maximum use will be made of existing systems and organizations, and encouragement will be given for these to modify and enhance their activities to include observations and products contributing to a coordinated GOOS plan. It is also clear that that the coastal module of GOOS, since that is where the most visible benefits of GOOS occur, will be a critical part of the implementation of GOOS.

The strategic plan goes on to note that as with meteorology, the initial impetus for ocean observations has come from operational requirements to meet customer demands, for instance to improve current analyses and forecasts of ocean conditions, including the information needed to improve weather forecasts. In meteorology however the benefits arising from better description and prediction are more clearly self-evident to the world at large.

The difficulty that oceanographers face is more clearly understood when we note that most of atmospheric science has developed in response to the need for weather forecasts.

In ocean science the needs are multiple, and most visible near the coast; as a consequence, the capacity of an observing system to assist in meeting them is less well developed. Over the last decade scientific technologies such as computing have become capable of combining marine data with numerical models to describe the complexities of the marine environment. The opportunity now exists to provide to users ocean data and products that are as beneficial as those provided by the meteorological networks.

#### **4. The Key Role of Modeling**

Because of the sparseness of ocean data, the GOOS Strategic Plan notes that a key element of ocean forecasting must involve numerical simulation in advanced ocean models nested at different levels from global to local. These models are themselves a technology in need of development; since high resolution is required, their power in turn depends on advances in the power of computing systems. Meteorological forcing is required for operational ocean models; a key source is and will be operational weather prediction models assimilating atmospheric and surface marine data. Research is needed in the development of the global scale models needed to provide boundary conditions for prediction at the local level.

The Strategic Plan also identifies the need for research into the assimilation of data into models to enable accurate forecasts to be made. We expect that the way forward here will be to assemble expertise in a few centers around the world to process data in the most appropriate way through advanced numerical modeling for the production of forecasts of ocean conditions. A model for such a center might be the **ECMWF**, focused on mid range forecasting and staffed by representatives of different contributing nations. The success of the ECMWF could usefully be applied to ocean forecasting.

#### **5. Regional Alliances**

The Strategic Plan emphasizes that regional alliances are critical for the implementation of GOOS implementation, though not necessarily for all types of observations and products. Since **IOC** and the other GOOS sponsors do not have the resources for operational programs, regions will be relied upon to take the initiative and organize resources if a GOOS activity is to gain a high regional profile. Today, regional alliances are developing or emerging in Europe, the Baltic, the Mediterranean, the Black Sea, Africa, North-East and South-East Asia, the Pacific Islands, the South-East Pacific, the Indian Ocean, the U.S.A., and the Caribbean.

The GOOS plan specifies that for the initiation of the development of a GOOS regional program, the first step is an agreement between agencies or institutes from neighboring countries on regional contributions to GOOS, with the objective of getting commitments from Member States. Regional subsidiary bodies of the **IOC** (such as **WESTPAC** and **IOCARIBE**) have a part to play in facilitating GOOS, and could embrace regional GOOS activities within their purview in coordination with global GOOS (as **WESTPAC** has done with **NEAR-GOOS**, and as **IOCARIBE** has done with **IOCARIBE-GOOS**). In general, use could be made of the managerial, financial and administrative support

services available at the **IOC** regional secretariats. IOC is also helping the development of GOOS Regional Alliances through establishing regional GOOS programme offices, such as those in Rio de Janeiro and Perth.

## **6. National Programs**

National programs are essential for the implementation of GOOS because that is where national interest and funding will be focused. There are many such programs in place now, but we will summarize just two of these that we are familiar with.

In France, the national program **CORIOLIS** has proved to be very effective. CORIOLIS is a system for operational oceanography to monitor and forecast ocean behavior. It is composed of three projects: sea surface observation using satellite sensors, in situ measurements from ships, moored or drifting autonomous systems, and assimilation of in situ and satellite data in an ocean circulation model. CORIOLIS contributes to the in situ part of this system, with the objective of developing continuous, automatic, and permanent observation networks. The data collected will enable water properties, such as temperature and ocean circulation, to be mapped and made available to users.

In the U.S., the Gulf of Maine Ocean Observation System (**GoMOOS**) provides new marine information for multiple users. GoMOOS is a national pilot program designed to bring hourly oceanographic data from the Gulf of Maine to all those who need it, including commercial mariners, coastal resource managers, scientists, educators, search and rescue teams, emergency response teams, and public health officials. GoMOOS is a regional consortium of interests and disciplines. It is an important part of GOOS because it shows how a consortium can respond to user needs because users direct the organization, and it has been very effective in getting funding because of the regional focus. The cost-benefit ratio also appears to be positive. For example, a study done to identify potential economic impacts of GoMOOS concluded that potential annual benefits are US\$33M. An additional 6 lives per year could be saved during search-and-rescue missions if there is a 1% improvement (from 90% to 91%) in lives-at-risk saved, which is deemed possible with more accurate current and wind data provided by GoMOOS instrumentation.

## **7. JCOMM and GOOS**

The Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) is an intergovernmental body of experts, which provides the international, intergovernmental coordination, regulation and management mechanism for an operational oceanographic and marine meteorological observing, data management and services system. The JCOMM comes from the long experience of the meteorological community in coordinating global and regional observations.

The literature for JCOMM states that until the formation of JCOMM in 1999, the coordination of these activities was provided by two separate bodies: the WMO

Commission for Marine Meteorology (CMM) and the Joint IOC/WMO Committee for the Integrated Global Ocean Services System (IGOSS). Now, in response to an increasing need, JCOMM has been established to recognize the increasing demand for integrated marine meteorological and oceanographic data and services, and the efficiencies that may be achieved by combining the expertise and technological capabilities of the WMO and IOC systems.

JCOMM is meeting its mandate through developing observing networks and seeking commitment for global observations, implementing integrated end-to-end data systems in collaboration with the appropriate bodies, ensuring delivery of products and services required by all users, and capacity building. JCOMM is a global organization with a current membership of approximately 250 experts in marine meteorology and oceanography, with approximately equal numbers of meteorologists and oceanographers providing support to the marine community. JCOMM coordinates a global network to provide maritime services including the provision of warnings and weather and sea bulletins according to a broadcast schedule, in conformity with procedures laid down under the Global Maritime Distress and Safety System protocols, and is overseeing data input from volunteer ships, drifting and moored buoys, tidal stations, ice monitoring, and the like.

Of particular importance are the JCOMM collaborations with the satellite community, facilitating on-line acquisition and calibration/validation of satellite data, as examples, and the capacity to provide end-to-end data management support, data acquisition guidance, data management, data exchange. JCOMM is also providing information dissemination mechanisms, e.g. through the JCOMM Products Bulletin. To ensure the adequate engagement of modeling, JCOMM is coordinating several lead nations in numerical modeling/data assimilation. JCOMM also has a strong commitment to embracing and supporting new technologies. It is through the JCOMM that the ocean community can best link with the meteorological community, and benefit from the lessons learned over the 150 years of experience in delivering operational data. JCOMM is acting as the implementation mechanism for the physical oceanographic and meteorological components of GOOS at the global scale; consideration is now being given to how JCOMM can respond to the multi-disciplinary requirements for a GOOS in coastal seas.

## **8. Summary**

The ocean community is poised on the brink of having a global operational observing system with a strong coastal component, and many of the elements are in place. With continued emphasis on pre-operational data assimilation studies, regional alliances and national programs that build constituencies, and close cooperation with WMO through JCOMM, the ocean community will be able to learn from the 150-year history of operational meteorology to establish a fully operational ocean observing system.