GODAE OCEANVIEW:
From an experiment towards a long-term International program for ocean analysis and forecasting

P.Y. Le Traon\textsuperscript{1}, M. Bell\textsuperscript{2}, E. Dombrowsky\textsuperscript{3}, A. Schiller\textsuperscript{4}, K. Wilmer-Becker\textsuperscript{2}
With contributions from the International GODAE Steering Team

\textsuperscript{1}Ifremer, Centre de Brest, Plouzané, France
\textsuperscript{2}Met Office, Exeter, UK
\textsuperscript{3}Mercator Ocean, Toulouse, France
\textsuperscript{4}CAWCR-CSIRO, Hobart, Tasmania, Australia

Abstract

Over the past 10 years, GODAE through its International GODAE Steering Team (IGST) has coordinated and facilitated the development of global and regional ocean forecasting systems and has made excellent progress. GODAE as an experiment has ended in 2008. International collaboration and coordination on both operational and research activities related to ocean analysis and forecasting should, however, continue but in a different way.

As GODAE prototype systems transition to operational status, international coordination of the standardization of products and interoperability between systems must be established. The Joint WMO/IOC technical Commission, JCOMM, has recently established an Expert Team on Operational Oceanographic Forecasting Systems (ET-OOFS) for this purpose.

The most pressing societal issues to which ocean analysis and forecasting systems can make substantial contributions have evolved over the last 10 years. Continuous improvement of these systems and the development of new capability is needed to address these issues (e.g. modeling, data assimilation, error estimates, use of new observations). This demands state-of-the-art research leadership and international collaboration and coordination. There are also important issues related to the global ocean observing system. GODAE groups should be organized to provide regular recommendation and guidance on the evolution of the global ocean observing system and to demonstrate its value and effectiveness.

In order to ensure the required long-term international collaboration and cooperation on these issues, it is proposed to set up an international program on ocean analysis and forecasting called GODAE OceanView. Through its science team, GODAE OceanView would provide coordination and leadership in:

• The consolidation and improvement of global and regional analysis and forecasting systems (physics).
• The progressive development and scientific testing of the next generation of systems covering biogeochemical and ecosystems and extending from the open ocean into the shelf sea and coastal waters.
• The exploitation of this capability in other applications (weather forecasting, seasonal and decadal prediction, climate change detection and its coastal impacts, etc).
• The assessment of the contribution of the various components of the observing system and scientific guidance for improved design and implementation of the ocean observing system.
Such an approach will need to be integrated with existing and future research activities related to ocean modeling including those within the WCRP, in IGBP and in the WMO World Weather Research Program.

This paper outlines the opportunities and challenges for operational oceanography in the next 10 years and proposes a framework for the GODAE OceanView Science Team which covers its objectives, relationships with other groups including parent bodies, main activities and task teams, terms of reference and links with international research program (e.g. CLIVAR, IMBER) and with JCOMM ET-OOFs.

Key words: analysis, forecasting, operational oceanography, organisation, international coordination

1. Introduction

GODAE was set up in 1997 with the aim of demonstrating the feasibility and utility of global ocean monitoring and forecasting and to assist in building the infrastructure for global operational oceanography (Smith and Lefebvre, 1997; GODAE Strategic Plan, 2000). Over the past 10 years, GODAE has had a major impact on the development of global operational oceanography capability. Global modeling and data assimilation systems have been progressively developed, implemented and inter-compared. In-situ and remote sensing data are now routinely assimilated in global and regional ocean models to provide an integrated description of the ocean state. Observation, analysis and forecast products are readily accessible through major data and product servers. There has been increased attention to development of products and services and the demonstration of their utility for applications such as marine environment monitoring, weather forecasting, seasonal & climate prediction, ocean research, maritime safety and pollution forecasting, national security, the oil & gas industry, fisheries management and coastal and shelf-sea forecasting.

Over the last 10 years, the International GODAE Steering Team (IGST) has been responsible for the execution of GODAE. The inescapable need for multi-national support for the required operational observing system, gave rise to a group strongly motivated to accelerate international progress through improved coordination, collaboration and sharing of real-time information, scientific knowledge and results.

GODAE as an experiment will has ended in 2008 having achieved most of its goals. It has been demonstrated that global ocean data assimilation is feasible and GODAE has made important contributions to the establishment of an effective and efficient infrastructure for global operational oceanography that includes the required observing systems, data assembly and processing centers, modeling and data assimilation centers and data and product servers.

Although there are still major challenges to face (sustaining the global ocean observing system being an obvious one), global operational oceanography now needs to transition from a demonstration to a permanent and sustained capability. Operational\(^1\) data and products are needed for most applications as well as for climate research. This is critical for applications which cannot develop without operational services. In parallel, continuous improvements of operational oceanography systems are needed to better serve applications and to satisfy new requirements (e.g. for coastal zone and ecosystem monitoring and forecasting, climate monitoring).

Most GODAE groups have or are now transitioning towards operational or pre-operational status. GODAE systems are also evolving to satisfy new requirements just mentioned and must benefit from scientific advances in ocean modeling and data assimilation. International collaboration and coordination of both operational and research activities related to ocean analysis and forecasting must continue during this sustained operational phase. The challenges and expectations are very demanding and can only be achieved through international collaboration.

\(^1\) Following the GODAE Strategic Plan (2000), “operational” is used here “\textit{whenever the processing is done in a routine and regular way, with a pre-determined systematic approach and constant monitoring of performance. With this terminology, regular re-analyses may be considered as operational systems, as may be organized analyses and assessment of climate data}”.
A proposed international organization for this new, sustained phase of GODAE, so called GODAE Ocean View, is given hereafter. This paper outlines the opportunities and challenges for operational oceanography in the next 10 years and proposes a framework for the GODAE OceanView Science Team which covers its objectives, relationships with other groups including parent bodies, main activities and task teams, terms of reference and links with JCOMM ET-OOF.

2. Operational oceanography: challenges for the next decade

While most operational oceanography systems developed during GODAE are transitioning to pre-operational or operational status, they are facing new expectations and requirements and are extending or will have to extend their capabilities. There are also important issues related to ocean observing system (sustainability, evaluation and evolution). These main challenges and opportunities for the next decade are summarized below:

2.1 New societal needs

During the last decade new pressing societal issues to which ocean analysis and forecasting can make substantial contributions have evolved. They are now quite diverse and are not limited to open ocean forecasts (although open ocean forecasts will continue to serve major applications areas). The most important are:

- The use of data assimilation to provide integrated descriptions of the global ocean state (reanalyses) and to characterize and detect climate change in the ocean;
- The application of ocean prediction techniques to the prediction of climate change (so-called decadal prediction);
- The assessment and characterization of specific sources of uncertainty in down-scaling of climate and climate-change scenario simulations and predictions in studies of the impact of climate change in coastal regions (e.g. extreme events, flooding, ecosystems, …);
- The development of improved atmospheric and climate forecasts (near coastal, hurricanes/tropical cyclones, monsoons, seasonal);
- Real-time forecasting in near-shore / coastal waters (physics, biogeochemical and ecosystems…) and coupling between open ocean and coastal areas;
- Ecosystem modelling and the development of ecosystem based management of marine resources (influence of physical transports and processes on marine life, modeling up to high trophic levels);
- Marine environment monitoring in support of policies (e.g. European Marine Strategy).

2.2 Improving and extending capabilities of operational oceanography systems

Continuous improvement of operational oceanography systems and the development of new capability is needed to address these new societal needs. This demands state-of-the art research leadership and calls for dedicated cooperation with international WCRP, IGBP and SCOR research programs such as CLIVAR, GEOTRACE, SOLAS and IMBER.

Schiller et al. (this issue) lists the main research topics that operational oceanography faces: high resolution physical modeling, downscaling, biogeochemical and ecosystem modelling, ocean/wave/atmosphere coupling, data assimilation and coupled data assimilation, error estimates, long-term reanalyses, use of new observations. What major developments can we expect to see in the next ten years? Current trends suggest advances in physical oceanography associated with a maturing of the eddy-resolving data-assimilating models, and a stronger integration into coupled NWP and climate modelling. There are still some significant challenges in the data-assimilation techniques themselves, and one can expect to see significant improvement there. At the same time, the user community is looking to extend these models inshore, across the shelf, and even into bays and estuaries. Better methods for nesting models, or for variable resolution and adaptive model grids, are likely to emerge. We can expect to see improved integration of wave models into coastal coupled atmospheric-hydrodynamic models, and improved sediment model predictions of turbidity and coastal geomorphology. This will be partly driven by concern about effects of increased sea level and
storm frequency / intensity. The extension of data-assimilating models inshore assumes that we can develop coastal observing systems to support them. The challenge will be to develop cost-effective in-situ coastal observing systems. Physical observing systems at basin scale are likely to face the challenge to maintain the current density of Argo and satellite altimeters. It is also likely that deployment of smart tags on pelagic animals will increase. For chemistry and biology, there do seem to be prospects for significant advances in observations at the basin scale over the next five years. We can expect to see further integration of biogeochemical models with ecosystem models, one of the very objectives of the IMBER research program.

2.3 Global and regional ocean observing system

Over the last 10 years, a global ocean observing system (in situ and remote sensing) has been progressively implemented. The system, primarily designed to serve climate research, is used as a backbone for most operational oceanography applications. Although significant progress has been made (e.g. Argo and Jason are outstanding successes), sustaining the global ocean observing system remains a challenging task. There is also a pressing need to develop further regional and coastal components and, as discussed above, to extend the measurement capabilities to biogeochemical parameters. This endeavor is clearly beyond the scope of ocean analysis and forecasting teams and involves major international or intergovernmental organizations (e.g. WMO and IOC through ICOMM, GOOS and GCOS, GEO, CEOS) and research programs (e.g. WCRP and IGBP). Ocean analysis and forecasting systems are, however, an appropriate and powerful means to assess the impact of the observing system, to identify gaps and to improve the efficiency/effectiveness of the observing system. Through the development of applications and identification of users, these systems are also essential to contribute to the long-term sustainability of the ocean observing system. Collaboration between ocean analysis and forecasting teams on ocean observing system issues is thus highly desirable. It would organize the feedback towards ocean observing system agencies (space, in-situ) and would provide sound and robust recommendations and guidance for the evolution of the global ocean observing system. It would also help to better demonstrate its value and effectiveness.

3. GODAE OceanView: objectives and international organization

3.1 Objectives

The GODAE OceanView science team is created, with the mission to define, monitor, and promote actions aimed at coordinating and integrating research associated with multi-scale and multidisciplinary ocean analysis and forecasting systems, thus enhancing the value of GODAE OceanView outputs for research and applications. Over the next decade, the science team will provide international coordination and leadership in:

- The consolidation and improvement of global and regional analysis and forecasting systems (physics).
- The progressive development and scientific testing of the next generation of ocean analysis and forecasting systems, covering bio-geochemical and eco-systems as well as physical oceanography, and extending from the open ocean into the shelf sea and coastal waters.
- The exploitation of this capability in other applications (weather forecasting, seasonal and decadal prediction, climate change detection and its coastal impacts, etc).
- The assessment of the contribution of the various components of the observing system and scientific guidance for improved design and implementation of the ocean observing system.

It is envisaged that GODAE OceanView science team will coordinate a program of activities implemented through the nationally funded activities of its members.

3.2 Internal organisation and relationships with other groups

The GODAE OceanView Science Team (GOVST) will provide a forum where the main operational and research institutions (national groups) involved in global ocean analysis and forecasting can develop collaborations and international coordination of their activities. The primary purpose of the team is to
accelerate the improvement and exploitation of these systems through exchange of information and expertise and the coordination of joint assessments. The scientists leading the scientific development of the major systems for generating ocean hindcasts and real-time operational ocean forecasts will constitute an inner core of the GOVST. The GODAE OceanView Science Team will also include scientists from the main operational systems as well as scientific experts on specific fields (e.g. observation, modeling, data assimilation) and representatives of key observing systems (e.g. from the Argo, GHRSSST and OST science teams).

Members of GODAE OceanView will adhere to the same principles of free, open and timely exchange of data and products, sharing of scientific results and experience developing applications which were important factors in the success of GODAE.

The societal benefits from these systems will only be realised through joint work with other teams of experts. Potential benefits include improvements in the day-to-day management of coastal waters, the management of marine ecosystems, weather prediction from hours to decades ahead, and the expected impacts of climate change on the oceans and coastal waters.

These benefits and the GODAE OceanView systems themselves are critically dependent on both the satellite and in situ components of the Global Ocean Observing System (GOOS). Through the development of improved Observing System Evaluations (OSEs) GODAE OceanView contributes to coherent, effective and scientifically robust advocacy of the case for and prioritisation of the components of the GOOS.

The hindcast and forecast systems developed by the GOVST members both require inputs from and should be a valuable resource for the oceanographic research community. Support for cooperation between research and operational groups is a key element of GODAE OceanView.

GODAE OceanView science team will need to develop linkages with other groups and report on its progresses, achievements and recommendations. GODAE OceanView will informally report to JCOMM and will have strong links with JCOMM ET-OOFS. It will develop linkages with GOOS, OOPC, IOC, WCRP and CEOS.

Some of the GODAE OceanView objectives will be pursued through a number of Task Teams. These teams will address specific topics of particular importance to GODAE OceanView in collaboration with other groups and international research programs (e.g. OOPC, CLIVAR, IMBER).

Operational aspects related to product harmonization and standardization and formal links with JCOMM will be carried out by the JCOMM ET-OOFS.

A GODAE OceanView program office with one permanent member of staff will provide assistance to the science team. In addition, a Patrons group consisting of individuals who are well placed to commit resources to support the GODAE OceanView program will be set up to provide advice and guidance to the science team. This group will include program managers from the national operational systems and representatives from the space agencies and the institutions to which GODAE OceanView reports. The members of this group will be expected to provide regular subscriptions to support the funding of the GODAE OceanView program office.

3.3 Main activities and task teams
GODAE OceanView will undertake activities which:

- foster and coordinate the development of new ocean monitoring, modeling and assimilation systems for ocean forecasting both for operational and for research applications with the goal of improved accuracy and utility of ocean analysis and forecasting products;
• promote access to data and information products and enhanced uptake of ocean analysis and forecasting products with governments, the public and private sectors;
• support the transition from the demonstration of new services based on ocean forecasting to the provision of timely, robust and reliable operational services. The Science Team will report to JCOMM ET-OOFS on relevant scientific developments whilst JCOMM ET-OOFS will make recommendations to the Science Team on what improvements would be most useful to users.
• demonstrate the value of ocean observing systems, in order to ensure access to a sustained real-time and high-quality ocean observing system, and liaise with major observing system programs (e.g. OOPC, CEOS, GOOS, GCOS) and science teams (e.g. Argo, Ocean Surface Topography, GHRSSST) on observing system issues. In particular, the science team will collaborate with the Argo Science Team on the evolution of the global Argo array (e.g. sampling, data & products, biogeochemical measurements, deeper measurements).
• coordinate the development of new capabilities, in cooperation with other relevant international research programs, through a number of task teams.

The initial list of GODAE OceanView Task Teams will include:

• **Intercomparison and Validation Task Team.** The team will pursue activities developed during GODAE. It will coordinate and promote the development of scientific validation and intercomparison of operational oceanography systems. Activities will include the definition of metrics to assess the quality of analyses and forecasts (e.g. forecast skills) both for physical and biogeochemical parameters and the setting up of specific global and regional intercomparison experiments. Metrics related to specific applications will also be defined. The team will liaise with the JCOMM ET-OOFS team for operational implementation. It will develop cooperation with CLIVAR/GSOP for climate issues.

• **Observing System Evaluation Task Team.** One of the aims of GODAE OceanView is to formulate more specific requirements for observations on the basis of improved understanding of data utility. The team is jointly formed by GODAE OceanView and OOPC. Through the task team, GODAE OceanView, in collaboration with, e.g., OOPC partners and CLIVAR/GSOP, will get organized at the international level to provide consistent and scientifically justified responses to agencies and organizations in charge of sustaining the global and regional ocean observing systems used for ocean monitoring and forecasting at short-range, seasonal and decadal time-scales. This activity will require harmonized protocols for observation impact assessment [e.g. Observing System Evaluation (OSEs) and Observing System Simulation Experiments (OSSE)], tools for routine production of appropriate diagnostics using NWP-derived methods, common sets of metrics for intercomparison of results, and objective methodologies which can be used to provide recommendations to the appropriate agencies and organizations. In the longer term consideration will need to be given to an evaluation strategy for identifying observing system requirements for different, possibly user-specific, applications. The Task Team will develop its international collaboration through regular meetings and workshops.

• **Coastal Ocean and Shelf Seas Task Team.** This task team would deal with scientific issues in support of multidisciplinary analysis and forecasting of the coastal transition zone and shelf/open ocean exchanges in relation with the larger-scale efforts. The specific objectives would include: (1) In the continuation of the GODAE CSSWG, discuss and promote the uses of GODAE OceanView products and results for coastal ocean forecasting systems and for coastal applications in a wider community. (2) Discuss and foster integration of the varied routine sources of information in coastal ocean forecasting systems: large-scale forecasts, satellite observations, coastal observatories, etc.; discuss and support the development of coastal observing systems in terms of science and technology. (3) Discuss the key physical and biogeochemical processes which have the greatest impact on modeling and forecasting quality and their utility for applications; this includes validation and forecast verification. (4) Discuss and promote state-of-the-art methodology such as two-way coupling, unstructured-grid modeling, downscaling, data assimilation, array design.

• **Marine Ecosystem Monitoring and Prediction Task Team.** The integration of new models and assimilation components for ocean biogeochemistry and marine ecosystem monitoring and prediction
will be required to bridge the gap between the current status of the GODAE capabilities and new applications in areas such as fisheries management, marine pollution and carbon cycle monitoring. Following the outcome of a first IMBER-GODAE working group established in 2007, the Task Team will be set up with the goal to define, promote and coordinate actions between developers of operational systems and ecosystem modeling experts, in tight connection with IMBER. The objectives of the task team will be (i) to design appropriate ecosystem modeling and assimilation strategies that will be compatible with the functionalities of operational systems; (ii) to develop numerical experiments aimed at improving, assessing and demonstrating the value of operational products for marine ecosystem monitoring and prediction; (iii) to expand the concept of the “GODAE metrics” to biogeochemical variables and to coordinate intercomparison exercises across international groups to assess implementation progress and performances; (iv) to identify the essential sets of physical and biogeochemical observations required to constrain the coupled models and to formulate relevant recommendations to further develop the global ocean observing system; (v) to promote and organize educational activities (summer schools, training workshops, etc.) aimed at sharing experience between young scientists, operational oceanographers and marine ecosystem experts. In addition to the link with IMBER, the task team will articulate its activities with other relevant international programs such as GEOTRACES and SOLAS.

In addition, GODAE OceanView will continue and strengthen its collaboration with CLIVAR/GSOP on global ocean synthesis activities. Other task teams may be formed during the course of GODAE OceanView (e.g. links with NWP through CAS).

Working groups may also be formed to address specific issues over a limited duration.

### 3.4 Terms of reference

The specific roles of the GODAE OceanView Science Team, the GODAE OceanView Program Office and the Program Managers group are as follows:

#### GODAE OceanView Science Team

The GODAE Ocean Science Team membership should reflect all major activities supported by GODAE Ocean View but be limited to 30 members to allow for an efficient and effective operation of the team. The GODAE OceanView science team will initially be co-chaired by two of its members. New members will be proposed by the chair or co-chairs and are subject to approval by the Science Team itself. The term of membership will normally be 5 years but can be extended with the agreement of the chair or co-chairs. The chair of ET-OOFS and the chairs of the Task Teams are members of GODAE Ocean View Science Team. Representatives from Argo, GHRSSST, OSTST are also ex officio members of the science team.

The Science Team is responsible for:

- Leading and managing the execution of the GODAE OceanView program;
- Promoting the development of improved capabilities in ocean analysis and forecasting;
- Developing collaborations and improved communications between the participants in GODAE OceanView;
- Evaluating scientific and technical developments to optimize the use of knowledge and technology in GODAE Ocean View implementation;
- Reporting on national activities related to GODAE Ocean View. Maintain an up-to-date description of national capabilities related to ocean analysis and forecasting (national reports);
- Liaising with other international programs of interest to, and interested in, GODAE Ocean View.
**GODAE OceanView Patrons Group**

The group will consist of representatives of those agencies or groups which are well places to provide resources for GODAE OceanView activities and wish to provide guidance to the members of the science team or be kept informed of its discussions. The specific tasks of the Patrons group are to:

- Provide visibility for and promote the value of GODAE OceanView and its activities;
- Promote the concept of GODAE OceanView at the national and international level;
- Provide a focus for national participation in GODAE OceanView;
- Obtain or provide appropriate national and international resources for GODAE OceanView; and
- Provide advice to the International GODAE OceanView Science Team on matters of resources, international coordination and funding priorities.

**GODAE OceanView Program Office**

The GODAE OceanView Program Office will provide support to the Science Team and its task teams. It is supported through contributions from the Patrons. The tasks of the Office are to:

- Facilitate and support the GODAE OceanView Science Team and its task teams in their various tasks including in the monitoring of progress and achievements;
- Maintain and update the GODAE OceanView Web site and publications;
- Prepare and publish GODAE OceanView Reports, as appropriate;
- In collaboration with the Patrons, promote the practical benefits and objectives of GODAE among the operational and research communities (e.g. brochure)

The progress made by GODAE OceanView and the case for continuation will be reviewed every 5 years and its terms of reference will be adjusted as necessary.

### 3.5 Links with the JCOMM ET-OOFS

As GODAE prototype systems transition to operational systems, international collaboration on product standardization and interoperability between systems must be maintained and developed. The joint WMO/IOC Technical Commission JCOMM provides an appropriate intergovernmental mechanism for the coordinating role and has recently established an expert team on operational oceanographic forecasting systems (ET-OOFS) within its Services Program Area for this purpose. Terms of reference of the ET-OOFS are as follows:

- Develop and maintain "The Guide to Operational Oceanographic Forecasting systems of the World"
- Provide advice to JCOMM teams and member states on the application, nomenclature, symbology and standards used by operational ocean forecasting systems;
- Develop and operate an inter-comparison framework for near real time monitoring of OOFS outputs building on the legacy of GODAE;
- Work effectively with the Scientific community developing and maintaining OOFS
- Provide observation requirements for OOFS to the JCOMM Observations Program Area;
- Provide advice to the JCOMM Data Management Program Areas;
- Provide advice to Members/Member States on operational Ocean Forecast systems.

The GODAE OceanView Science Team will report to ET-OOFS on scientific and operational developments, while ET-OOFS will provide recommendations on service provision (for instance standardization) based on users’ needs. The GODAE OceanView Task Team on intercomparison and validation will provide inputs
and recommendations to the ET-OOFS on standardization of validation activities (e.g. a minimum set of metrics that should be implemented in operational systems to monitor the quality of analyses and forecasts). We anticipate that the two groups (GODAE Ocean View Science Team and ET-OOFS) will work very closely in the coming years: the ET-OOFS chair will be de facto member of GODAE Ocean View science team; and GODAE OceanView systems will be represented in the ET-OOFS.

4. Conclusions

In summary:

- Operational Oceanography faces many challenges with time scales ranging from weather to climate
- It is inherently an international issue, requiring broad collaboration to span the global oceans; it is beyond the capability of any one country
- GODAE OceanView will promote the development of ocean modelling and assimilation in a consistent framework to optimize mutual progress and benefit
- It will promote the associated exploitation of improved ocean analyses and forecasts
- It will provide a means to assess the relative contributions of and requirements for observing systems, and their respective priorities

We believe the GODAE OceanView programme will result in the long-term international collaboration and cooperation required for the next, sustained, phase of operational oceanography. GODAE OceanView now needs to receive wide support from the international community and to better define its links with other international research programs. Based on these inputs, a work-plan for the next 5 years will be developed.

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References

