Planning and Implementation for GOOS

A Consultant Study prepared for
the Intergovernmental Oceanographic Commission and
the World Meteorological Organization[1]

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Contents:

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Summary

The goal of this study is to examine the cooperation and interactions between the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the World Meteorological Organization (WMO) with a view towards improving, streamlining, and making the planning, implementation, and governance of the Global Ocean Observing System (GOOS) more cost-effective. The study has been sponsored by IOC and the WMO and the specific terms of reference are provided in the Annexes to the report. The study identifies issues and questions relating to both the open ocean component and the coastal component of GOOS, the Intergovernmental Committee for GOOS (I-GOOS), and the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).

The study is not a formal review of any of these bodies. Rather, it raises issues and questions that should be addressed and is offered as input to any future review. The intent of the study process was not to reach or form consensus, but rather to provide a user-driven effort to provide additional insights into how the international organizations could be improved. It is now up to those organizations to use this advice as they see fit.

The study is timely because just as information about the ocean is becoming more and more important to society, both components of the Global Ocean Observing System – coastal ocean and global ocean – are stalled in their progress toward full implementation of sustained observations. Funding is limited, the existing set of governance bodies is not ideal for implementation of an operational global ocean observing system and there is confusion in the minds of many participants about responsibilities and roles and how the different groups can work together for a common goal.

If progress is to be made in dealing with these impediments, the existing set of intergovernmental and international bodies for planning and implementation of GOOS will need to have clear definitions of roles and responsibilities. Each of the governing and advisory bodies needs to examine how it can operate most effectively to provide GOOS with what it needs and restructure as appropriate. It is time to build on the base of existing planning and implementation work to complete a full business plan for both coastal and global GOOS. The business plan will help to engage a broader community of oceanographic and other end users of data from sustained observations who can help bring pressure for the support that is needed.

The report provides recommendations in three categories: (1) the development of a business plan to connect to end users, (2) the examination and possible restructuring of the governing and advisory bodies to be more effective in providing advice, and (3) streamlining the process for more cost-effective operations.

1. Oceans and Society: Overarching Issues for GOOS, IOC, and WMO

1.1 Society needs better ocean information

The ocean, its resources, and its impact on human society have never been more important. Society needs warnings and forecasts of impending disasters; it needs to understand and deal with the impacts of a changing climate; and it needs to manage marine resources. Increasing societal vulnerability to environmental change means that it is very possible that changes in ocean temperatures, chemistry, and currents caused by climate or by the competition for marine resources will lead to regional political instability.

The reports of the Intergovernmental Panel on Climate Change (IPCC), most recently with the IPCC 4th Assessment, reiterate the importance of better understanding of the ocean for climate. It is clear that the IPCC will want more information as the next global climate assessment is developed. There is some evidence, for example, that the "drift" of climate models away from accurate long-term forecasts is due to the lack of inclusion of information about the deep ocean – which must come from sustained observations.

It appears inevitable that climate will change to some extent, perhaps drastically, through anthropogenic influences. Both mitigation and adaptation will be required, and certainly ocean information is required to help society make the informed decisions that effectively anticipate changes and enable adaptive responses. Oceans are also important as society looks to ways to mitigate and adapt to climate change through carbon-free sources of energy and geo-engineering. Ocean fertilization may promise coastal states a way to participate in carbon sequestration for compliance to international treaties and in the carbon markets, but much remains unknown about the processes involved. Regulated research and experimentation is required. If governments decide to proceed with geo-engineering solutions, the impacts of these methods must be monitored and assessed in as close to real time as possible. Sustained ocean observations will provide the information base for understanding the ocean and its role in warnings, forecasts, climate change, and sustainable use of resources.

Perhaps the most comprehensive list of ways in which oceans affect society and where better ocean information will be enormously helpful comes from the UN Secretary-General's Report of 13 March 2009 to the 64th session of the UN on "Oceans and Law of the Sea." The report covers the topics of marine science and technology, marine fishery resources, new sustainable uses of the ocean, marine biological diversity and marine biological diversity beyond areas of national jurisdiction, and a comprehensive list of marine-related topics (see section 2.2.7). To deal effectively with most of these issues will require better ocean information, much of which will come from sustained coastal and global ocean observations.

For all of these reasons, ocean scientists have been working for the past two decades to establish a system of sustained ocean observations under the name of the Global Ocean Observing System. The goal of GOOS is to build a permanent global system covering the open ocean, coasts and estuaries for sustained observations to provide the basis for modeling and the provision of information and services that benefit society. It is also important to include land-based inputs to the coastal ocean because just as ocean-atmosphere interactions must be considered for climate change, ocean-terrestrial interaction must be considered for predicting the effects of climate change and human activities on coastal ecosystem goods and services.

Today many of the components of GOOS are operating and providing critical and fundamental information for society. Under the guidance of IOC sponsored committees, strategic and implementation plans have been developed for open ocean GOOS (a recent summary is provided in "Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008" (GOOS Report No. 173 (2009), available at http://gcos.wmo.int)). Nearly 60 per cent of the initial specification for the global component has been completed. In addition, an implementation strategy for Coastal GOOS has been approved by the Intergovernmental Oceanographic Commission (see, e.g. "An Implementation Strategy for the Coastal Module of the Global Ocean Observing System," (GOOS Report No. 148 (2005), at http://ioc.unesco.org/goos/docs/doclist.htm), and "Implementing the Coastal Module of GOOS", a Report of the Joint JCOMM-GSSC-GRA ad hoc Task Team (2006, at http://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=373). The Global Climate Observing System (GCOS) Implementation Plan provides an additional climate heritage and context for GOOS (see The Second Report on the Adequacy of the Global Observing System for Climate in Support of the UNFCCC and the Implementation Plan for the GCOS in support of the UNFCCC (GCOS-92) which included GOOS as the ocean component of GCOS-92).

An important start for GOOS has been made with moored buoys with the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON), the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) and the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) program in the Indian Ocean. The Argo float program and the operationalization of sea surface temperature and surface wave measurements add to this success which now needs to be repeated with other platforms and variables. It is important to understand that modeling is required to translate the observations into an understanding of processes, leading to analyses and forecasts of the future state of the ocean. Thus the efficient evolution of an effective GOOS will require synergy between observations and models. The timely use of observations to provide input to models is important - if the data from GOOS are not analyzed until several years after the fact, the goals of GOOS will not be achieved.

For both the global and the coastal modules of GOOS, funding has come primarily from research programs; a situation that is not sustainable in the long term. For example, the Argo float program has still not made the transition to operational funding. Ironically, achieving the global array on research funding has to some extent removed the sense of urgency of making the step. In most countries, Argo is still perceived to be driven by the research scientists rather than meeting policy needs. The key point is that sustained observations will meet a wide spectrum of user needs from academic research through strategic research to monitoring for compliance with national and international legislation/conventions and therefore needs an appropriate mix of funding sources instead of just coming from the research funders.

The Global Data Assimilation Experiment (GODAE) provides a good example of a program designed to help make the transition from research to operations for sustained observations. W. Stanley Wilson has pointed out that "When GODAE was organized a decade ago, one of the basic motivations was to demonstrate in an operational setting the impact of having timely access to data from global ocean observing systems funded by research agencies, and depending on that impact, to develop a rationale to justify the transition of funding for those systems from the research to the operational agencies. Ideally, once the utility of observations had been demonstrated, the operational agencies would incorporate support for those observing systems into their ongoing program, thereby providing an avenue to sustain their support and make them operational." One of the key actions needed now is to help the operational agencies find the support necessary for making this happen on a global scale, and to create a coastal equivalent of GODAE, or an expansion of GODAE to address coastal issues. The paper provided in the appendix (7.4) shows how GODAE can help build sustained in situ and satellite observations for GOOS.

To summarize, there are some aspects of ocean observations, such as ocean surface temperatures and surface waves, which have entered the operational phase. But, despite the progress that has been made, we do not yet have a fully implemented and sustained system. We still have inadequate warning and response mechanisms. Our existing observing systems for physical variables are too few and far between; modeling and prediction capabilities need improvement and delivery to users expanded. Long-term biological measurements are in an even more limited state of development. There are gaps in satellite and in situ coverage, and data sharing issues loom, especially for developing countries and the coastal ocean. Resources for sustained and routine maintenance of both in situ and remote sensing, data management, and modeling have not been allocated and should be better coordinated internationally. Finally, funding commitments are inadequate and mostly short-term, a problem which is particularly challenging for implementation of coastal GOOS since most of the global coastal ocean is in the Exclusive Economic Zones of developing countries.

1.2 Institutional Oversight

The Intergovernmental Oceanographic Commission (IOC) was formed as an intergovernmental body within UNESCO in 1960, when there was a sense of important priority for the study of the largely unknown ocean. ICSU's Scientific Committee on Oceanic Research (SCOR) was formed at the same time. Since then there has been a enormous increase in the amount of research, operations, ships at sea, satellites, and associated services for the ocean. IOC today has a long track record of accomplishments in intergovernmental cooperation for oceanography, and has taken on GOOS as a high priority program. IOC has formed the GOOS Science Steering Committee (GSSC) and the Intergovernmental Committee for GOOS (I-GOOS) and related panels. The World Meteorological Organization (WMO) has a strong track record for supporting the infrastructure for marine meteorology and has joined with IOC in forming the intergovernmental WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM).

With support from these international bodies, our understanding of the ocean has grown rapidly, and the role of the ocean in societal affairs has become apparent in many ways. In more recent years, the international institutional Partnership for Observations of the Global Ocean (POGO), and the intergovernmental Group on Earth Observations (GEO) have been added to provide additional coordination and outreach.

All of these bodies have been successful in promoting and persuading nations to fund both coastal and global GOOS, but only up to a point. Just as information about the ocean is becoming more and more important to society, GOOS is stalled in its progress toward full implementation of sustained observations. Funding is limited, the existing set of governance bodies is not ideal for implementation of an operational global ocean observing system and there is confusion in the minds of many participants about responsibilities and roles and how the different groups can work together for a common goal. It is very clear that the needs of the research community, the operational community, and the public have grown faster and larger than the ability of the current organizational structure to accommodate and meet them.

The need for more systematic and sustained observational programs will require the international institutions that oversee and manage oceanography to change with the times to provide the institutional support for this new kind of operation. If progress is to be made, the bodies responsible for planning and implementation of GOOS will have to examine their effectiveness and look to restructuring consistent with clear definitions of roles and responsibilities. Each of the governing bodies needs to examine how it can operate most effectively to provide GOOS with what it needs. All of this should be done within the context of a business plan that has a focus on users. A full business plan with organization, customers, and funding is required. Parts of this business plan have been developed. Now it is necessary to complete the business plan and engage a broader community of oceanographic and other end users of data from sustained observations who can help bring pressure for the support that is needed.

2. *GOOS Products, End Users, and the Completion of the Business Plan*

2.1 Completion of a GOOS Business Plan

GOOS has moved from the planning stage into the first stages of implementation. These first steps have been impressive; today the overall open ocean surface coverage is over 60% of what has been recommended. But the long-term commitments for sustained observations for that 60% are still weak, and there is a need to both increase the 60% to 100%, and to grow an adequate system for sustainably monitoring the deeper ocean, especially important for climate and resource development.

Although much has been done to develop documentation for GOOS implementation, the overall program still lacks a complete and realistic business plan; one that combines goals and objectives with steps toward implementation and identification of products, users, benefits gained, and costs. Much of the work and material for a GOOS business plan currently exists, but the whole has not been put together. Without a business plan, it will be difficult to identify users who in the end will help provide the needs and awareness that will lead to more governmental commitments and funding. The completion of the development of a realistic business plan and links to users should have high priority for GOOS at this point.

To reach the 60% funding, the GOOS community has used a formula that has worked well in the past – a heavy reliance on research funding and close ties with the research agencies. And in fact, research must continue to be a key part of both coastal and open ocean GOOS – the long-term sustained observations are key to understanding climate. The observation not taken today is lost forever for understanding climate. In most of the respondent's views, the community will have to continue to rely on the research mode of support for the near, and possibly long-term, future. But this only gets us part way. How can we find the support for enhancement and sustainability of GOOS? This requires finding additional customers – a "user pull" for ocean services based on sustained observations.

Just as the community undertook a major effort to develop the GOOS strategic plan, now the community needs to develop a GOOS business plan – a plan with a careful analysis of the products, the customers and how these are to be brought together. Although various attempts have been made, no comprehensive business plan has been developed. It will require a close connection with users and a change of mindset from the research-driven programs of the past.

The focus on development of a business plan means that the structure and representation on the various governing and advisory bodies needs to be rethought. There must be a heavy involvement of users without losing the key element of research. There must be a focus on near-term actions and outreach. The series of recommendations below address the elements of completing the business plan for GOOS.

Recommendation 2.1 IOC and its partners should complete the development of and implement a business plan for the operations and delivery of services of GOOS as a whole (coastal and global).

2.2 Elements of the Business Plan

2.2.1 Building a User Pull

In the end, it is the users who will demand the products from an operational coastal and global GOOS. It is incumbent on IOC and its partners to make the case to these users about what a new observational system can do. For example, there is interest in most coastal countries about coastal water quality, and in many countries there is funding specifically for monitoring coastal water quality. The full set of organizations, from IOC and WMO to the GSSC panels to the associated partners POGO, GEO, and others (see section 2.2.8) all need to be involved with projects to identify user pull, get industry involved, and show what can be done. There is a special opportunity now with IOC's 50th anniversary coming up for IOC to show how these observations and services can benefit society. In addition, IOC should try to show how a successful GOOS can enhance UNESCO's role in the UN. IOC can also use I-GOOS (or a new body as proposed in section 3.2), JCOMM, and its partnership with POGO to make mutually beneficial alliances with the private sector for creation of value-added services from GOOS data and information.

Several countries and regions have developed plans for ocean observations that are driven by research needs and by local and regional user needs and that have a good emphasis on user pull. Examples are the US Integrated Ocean Observing System, The European Commission's Global Monitoring for Environment and Security (GMES) Marine Services program, and Australia's Integrated Marine Observing System (IMOS). The US IOOS program guides policy for coastal observing systems; the GMES Marine Services program has great influence over how member state country funds are spent; and Australia's Ocean Policy report: A Marine Nation: National Framework for Marine Research and Innovation (March 2009) provides a basis for IMOS national planning for ocean observational programs. Australia's success in comprehensive planning and implementing ocean research and linking to national needs is particularly impressive; they have just announced new funding of more than $50M AUS for the IMOS program. These programs demonstrate how user pull can be used to make the case for sustainable observational systems for the oceans. The GOOS business plan should draw on these examples.

Recommendation 2.2.1 The business plan for GOOS implementation should have an emphasis on the "user pull," drawing examples from successful country and regional implementation such as the US IOOS, European Commission's GMES Marine Services, and Australia's IMOS.

2.2.2 Products and Services

The Business Plan should have a clear focus on products and services to be delivered. IOC has for many years provided a sea level service through GLOSS, and these and other IOC ocean services should be highlighted. There is also a clear role for JCOMM here with its operational product and services focus. The JCOMM Services Programme Area is designed to facilitate and support the delivery of the outputs of the world's marine meteorological and oceanographic organizations, including warnings of gales, storms, severe tropical weather systems such as typhoons, hurricanes and tropical cyclones and other hazardous phenomena, and information on sea ice conditions and other products. Since the continuing provision and development of safety-related weather and oceanographic services is a fundamental priority of JCOMM and of its Services Programme, and the coordination of GLOSS and other observing networks within the JCOMM Observations Programme Area, JCOMM would be a logical group to lead the development of this part of the business plan, with the advice of GSSC.

Important input on developing products will come from the follow-on to the Global Ocean Data Assimilation Experiment (GODAE) through GODAE OceanView and the new JCOMM Expert Team on Operational Ocean Forecasting Systems. GODAE OceanView is aimed at providing the basis of products through the 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 program will exploit this capability in other applications (weather forecasting, seasonal and decadal prediction, climate change detection and its coastal impacts, etc), thus contributing to the success of both open ocean GOOS and coastal GOOS. At the same time, JCOMM is working to support the operational implementation of the ocean forecast systems, parallel to Numerical Weather Forecasting (NWP).

Tsunami warning and mitigation systems deserve a note here. Probably because of the many agencies involved and different needs, tsunami warning and mitigation systems are being developed in parallel with rather than being integrated into GOOS/JCOMM. But in fact, such systems are just one part of what a global ocean observing system is needed for. This is an example of where the different strengths of WMO and IOC could be harnessed together in a better way. IOC and WMO need to find a way to work together more closely on tsunami warning and mitigation systems.

Recommendation 2.2.2 The business plan should clearly identify products and services to be delivered, drawing heavily on the experience and capability of existing IOC services such as GLOSS in JCOMM's Observations Programme Area and JCOMM's Services Programme Area. An important input for building products and services will come from development and support of GODAE OceanView.

2.2.3 Marketing

Marketing is important, with a targeted approach. This is true even for the science programs – for example, both Argo and GODAE did market research in advance to demonstrate the need for the programs. There are many good examples of ocean impact that can be used for marketing. The soft drink sector wants to know the air temperature a few weeks ahead for stocking decisions – but usually this long term forecast depends on ocean conditions. It may be possible to use such examples to show how new information can reduce costs and provide new services. The information from the Argo float array contributes directly to seasonal forecasts. It is becoming increasingly evident that there is a direct impact of sea surface temperature and ice on short term weather forecasts in the Arctic – without the right ocean temperatures, the forecasts are not accurate. Climate change and the ocean's impact on climate change can be a driver for marketing, and should be pushed for this reason. Fisheries and coastal erosion in the past have not been seen as a high priority, but this may be changing. GSSC has a strong effort in marketing and outreach, and should play a key role in this part of the business plan. This is also an area where the GOOS Regional Alliances may be helpful because they understand their local and regional priorities better than groups more removed.

Recommendation 2.2.3 The Business Plan should have a strong outreach and marketing program to show what GOOS and GOOS services can bring to coastal states and to climate and fisheries forecasts. GSSC could lead this effort with help from JCOMM and the GRAs.

2.2.4 Capacity Building

Capacity building is also essential. An important aspect of the role of facilitator is building the capacity necessary to implement the brokered agreements. Lack of capacity is a major obstacle to the implementation of a comprehensive and sustained global observing system. IOC is currently engaged in capacity building work, but it needs to do more. For example, an important recommendation made by the Coastal Ocean Observations Panel (COOP) is that capacity building be achieved by funding pilot projects that are partnerships between developed and developing countries where developing countries determine their priorities and developed countries provide sustainable resources (expertise, technologies, funds) to achieve them. It was also recommended that Capacity Building Centers be established within each GOOS Regional Alliance (GRA) as needed. Such Centers would be hosted by a university, government research facility, or other existing organization as appropriate. They could be funded by the World Bank (GEF) and/or by developed countries. IOC could also partner with other groups like POGO in capacity building.

Recommendation 2.2.4 The Business Plan should show how IOC and WMO/JCOMM plan to broaden their activities in capacity building, and to partner with marine groups deeply involved in capacity building.

2.2.5 Data Access

Data accessibility, archiving, and exchange are all part of a sustained GOOS. IOC is positioned well with its existing data policies and IODE program, and the same is true for WMO/JCOMM. But free and open exchange of data, especially in real time, is always a challenge. IOC and WMO must continue to ensure that they have adequate funding from member states to carry out its data mandate. This will be especially challenging for coastal GOOS and should be made a high priority. The GRAs should have a role here.

Recommendation 2.2.5 IOC and WMO should continue to ensure the free and open exchange of ocean and related data through IODE and national centers. This is a particularly high priority for coastal GOOS. The strong efforts of GEO to ensure a free and open data policy for satellite information can help IOC and WMO in providing data for GOOS.

2.2.6 The role of IOC and its Sister Intergovernmental Agencies

The roles and responsibilities of the various governing and advisory bodies for GOOS are discussed in Section 3 of this report. These are the issues that must be included in the business plan; as they are resolved they will be part of the implementation of GOOS.

It is clear that enhancing investment, for example in ocean observations, requires augmenting the awareness of citizens and governments to ocean-related issues. It is good to see that IOC is now beginning to strengthen its efforts in outreach for GOOS, especially through the efforts of the GSSC. The same should be happening with JCOMM, which has a growing outreach program. IOC and its sister organizations must together establish the added value of ocean services to national member states.

Recommendation 2.2.6 The Business Plan should include a clear explanation of the roles and responsibilities of the intergovernmental groups with direct responsibility for both management and outreach: I-GOOS (or a new group as recommended), JCOMM, and GSSC.

2.2.7 IOC and the UN Law of the Sea

In considering identifying users for GOOS information, a comprehensive list of relevant ocean issues is provided in the 13 March 2009 Report of the Secretary-General to the 64th session of the UN on “Oceans and Law of the Sea.” The report covers the topics of marine science and technology, marine fishery resources, new sustainable uses of the ocean, marine biological diversity and marine biological diversity beyond areas of national jurisdiction, research on and improved understanding of marine biodiversity. area-based management, marine genetic resources, marine environment, sustainable development and preparations for the World Summit on Sustainable Development, pollution from land-based activities, marine debris, maritime safety, enhancing the safety of navigation and flag State implementation and enforcement, hydrographic services and the production of nautical charts, people at sea, maritime security, piracy and armed robbery against ships, and other threats to maritime security.

To deal effectively with most of these issues will require better ocean information, much of which will come from coastal and global GOOS. But the links between UNESCO/IOC and the UN Law of the Sea (LOS) activities have not been as strong as they might be.

There needs to be more work here – the awareness raised by LOS issues could help GOOS.

Recommendation 2.2.7 The Business Plan should incorporate the ways in which GOOS will contribute to providing the data needed for the issues raised by the Secretary General in his March 09 Law of the Sea report to the UN.

2.2.8 The Role of Related Intergovernmental and Non-Governmental Groups

In addition to WMO and ICSU/SCOR, there are several groups now on the scene with which IOC needs to work closely. On the fully international level these include the Partnership for Observations of the Global Ocean (POGO) and the Group on Earth Observations/Global Earth Observations System of Systems (GEO/GEOSS); regional bodies include US IOOS, the European EuroGOOS and Global Monitoring for Environment and Security (GMES), and several other regional and national GOOS bodies. POGO is an organization of about 40 members, all of whom are directors of major oceanographic institutes around the world; much of the global capacity for ocean research and monitoring lies within these institutes. GEO/GEOSS is a body with governmental representation that is endeavoring to link societal benefit areas with observational programs, both in situ and from space, and GOOS has been designated the oceanographic component of GEOSS. GEO/GEOSS will be the way to make contact on a broad level with the space agency programs of the world. IOC, GOOS, and JCOMM are linking with the marine component of GEO/GEOSS in a variety of ways, for example through the GEO Coastal Zone Community of Practice and the GEO Biodiversity Observation Network, but much more could be done. The business plan should identify the roles of SCOR, POGO, GEO/GEOSS, regional and national observing systems, and other related bodies.

Recommendation 2.2.8 The Business Plan should include identification of the roles of SCOR, POGO, the marine component of GEO/GEOSS and other related groups to ensure their full engagement in GOOS implementation.

2.3 Responsibility for Completing the Business Plan

GOOS is sponsored by IOC, WMO, ICSU, and UNEP and therefore all four of these bodies should be formally involved in the completion of the business plan. IOC should lead the process since GOOS is a central program of IOC; this should be done by the GOOS Project Office with the assistance of the GSSC and the GOOS Regional Alliances. JCOMM has a critical role in both developing products and services and in helping to make the observations sustainable and therefore should have a substantial part of the responsibility for the plan. Since GOOS is the oceanographic component of the Global Earth Observing System of Systems (GEOSS), the input of the Group on Earth Observations (GEO) should be sought. Given the need for continuance of the research base, ICSU/SCOR and the international group of oceanographic institutions as represented by POGO will have substantial interest in the development of the plan and should be invited to participate, and given the importance of ocean observations to environmental sustainability, UNEP should also be invited to participate. Input to the plan should also be sought from other ocean-related parts of the UN family and the private sector. Member States, both developed and developing, and regional organizations such as GMES should be asked to contribute their expertise.

Recommendation 2.3 Completion of the Business Plan should be the direct responsibility of the GOOS Project Office, working in conjunction with JCOMM and the GRAs. Other sponsoring bodies ICSU and UNEP should be invited to participate. Input should be solicited from POGO, GEO, the private sector, other ocean-related parts of the UN family, regional organizations and appropriate Member States, both developed and developing.

3. *Examination and Restructuring the Governing Bodies*

3.1 IOC and WMO

The governing structure of GOOS is comprised of several UNESCO/IOC/WMO/ICSU/UNEP sanctioned bodies which coordinate together to advance the GOOS objectives of a comprehensive and sustained d international ocean observing system. Below, each of the main bodies is considered in turn with issues raised and recommendations made as appropriate.

WMO is an independent UN organization with a long history of supporting marine observations, and is a partner in JCOMM. WMO brings extensive experience in maintaining sustained observations in the atmosphere and at the sea surface. Its member states are represented by the heads of the National Meteorological and Hydrological Services, making it an effective body for making decisions and commitments. WMO, like all UN agencies, faces continual budget constraints, and is currently reorganizing under a results-based management scheme. It will be critical for the future that WMO ontinue and enhance its support of sustained ocean observations and JCOMM.

IOC is a program of UNESCO and has 136 member states with a strong interest in ocean sciences issues. It has played an important role in fostering GOOS from the beginning, particularly through providing international backing for ocean science and observing plans and international ocean services, and it is helping with capacity development and technology transfer. IOC also can and has played an important role as a facilitator and broker of intergovernmental agreements and is expected to negotiate at the intergovernmental level to ensure that the ways and means are provided to take concrete action on the agreements it brokers.

IOC, like all programs of UNESCO, faces continual budget limitations and an additional problem not faced by WMO. UNESCO, as a science and educational agency, is not a compatible home for routine and operational activities. IOC must deal with the fact that the push to sustained, operational oceanography and timely delivery is not a good fit with the science-oriented UNESCO. Some thought has been given to whether IOC might be able operate outside of UNESCO, but for the near-term, that idea has been tabled. Now

the important point will be to see how IOC can use its home in UNESCO to promote GOOS, and to make it clear how better ocean understanding and monitoring can help UNESCO meet its science and educational commitments.
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In addition, IOC the representatives of member states to IOC vary widely in their understanding and appreciation of the routine and managerial aspects of operational programs, and many of them lack the ability to commit to resolutions or resources. The fact is that facilitating and brokering agreements are of limited value if they are not backed up by commitments by Member States to implement the agreements. IOC has considered new funding mechanisms including extrabudgetary contributions from Member States through a voluntary pledging system (see, for example, (http://unesdoc.unesco.org/images/0013/001393/139345e.pdf FINANCING AND OWNERSHIP OF IOC'S PROGRAMMES: "WE HAVE A PROBLEM" (SC-2005/CONF.208/CLD.8)). It may be that the heightened awareness of oceans issues and needs for sustained observations can help support such new funding mechanisms – for both IOC and WMO. Finally, it is important to note that an important aspect of the role of facilitator is building the capacity necessary to implement the brokered agreements. Lack of capacity is seen as a major obstacle to the implementation of a comprehensive and sustained global observing system. IOC is currently engaged in capacity building work, but it needs to do more.

Since GOOS has two main thrusts: coastal and shelf monitoring and modeling and global open-ocean monitoring and modeling, the GOOS governing structure must cover both aspects. A committee of IOC has been formed to oversee GOOS, the Intergovernmental Committee for GOOS (I-GOOS), which is a subset of the member states of IOC. The Joint WMO-IOC Technical Commission on Oceanography and Marine Meteorology (JCOMM) was formed with an initial focus on the global issues. For science and technical guidance, the GOOS Science Steering Committee relies on panels for the open ocean (OOPC) and the coastal ocean (PICO), and this has worked well in the planning stages for GOOS. A set of GOOS Regional Alliances (GRAs) have been established to help implement coastal GOOS. The IOC GOOS Project Office (GPO) oversees all of these activities.

Recommendation 3.1 IOC and WMO must continue and enhance their support of sustained ocean observations. IOC needs to work with UNESCO to make the case for GOOS, make its membership more aware and responsive to GOOS needs, and to enhance capacity building.

3.2 I-GOOS

The Intergovernmental Committee for GOOS (I-GOOS), functioning under the IOC of UNESCO with co-sponsorship from WMO and UNEP, was set up to have the overall responsibility for formulation of policy, principles and strategy, and for planning and coordination of GOOS. The nations represented in I-GOOS perform a wide range of tasks in support of the GOOS effort, including the installation and maintenance of *in situ* observing networks, the launching of ocean satellites, maintenance of real-time data streams and data archives, and the provision of ocean forecasts and other ocean information products. The nations also contribute to coordination and capacity-building activities supporting GOOS, including the provision of personnel and the donation of funds**.**

I-GOOS was intended to be the body responsible for encouraging IOC member states to commit to sustainable support. However, the consultant's interviews have shown that there is a broad perception among many ocean observation experts that I-GOOS has not fulfilled that intention. In recent years I-GOOS has served primarily as an information forum, and few actions have been taken. In many cases, the I-GOOS representatives are not aware of GOOS issues and not prepared to take binding action. At this point and with the current structure, I-GOOS is a failed experiment and should be dissolved. The IOC Assembly should either take on I-GOOS functions itself or consider the following proposals for a new oversight group.

First, it seems clear that a new oversight group should consider its membership and try to ensure that the most effective people are engaged. For example, it would be very helpful to have some representatives who are responsible for compliance-type monitoring. This would help dispel the notion that GOOS is a system designed by the research community for the research community. The Global Marine Assessment process may be one way of bridging this gap

Second, an identification of roles and responsibilities for members of a new oversight group would be a very valuable step. For example, it would be useful if governments could appoint delegates to the new group that have engagement with ocean observations and the power to convey back home the decisions taken at the meetings. The new group should help IOC to use its home in UNESCO to promote GOOS, and to make it clear how better ocean understanding and monitoring can help UNESCO meet its commitments.

Third, the new group could be particularly helpful with the GRAs. Coastal states have different resources and capabilities, so need to coordinate their efforts. However, there are within GRAs and among GRAs differences that have to be overcome. Some regional alliances are very 'bureaucratic', in a sense that a decision cannot be taken without ample previous consultation. It has been hard to get a fully coordinated system in place, although there are some regional successes: US IOOS, EuroGOOS, MedGOOS, NearGOOS, IOGOOS, WAGOOS, IMOS, etc. There are a number of plans in place, but these have not yet been implemented. The system of regional alliances needs help, and this would be a good focus for a new group in collaboration with the GOOS Regional Council. In this sense a new group could play a particularly important role in helping coastal GOOS to happen globally, especially for those waters off the coasts of developing countries, by helping to obtain the needed funding, especially for those GRAs composed of developing countries.

The GOOS Regional Council has been established to coordinate implementation of coastal GOOS through the coordinated efforts of individual nations and GOOS Regional

Alliances (GRAs). This body needs to be empowered to coordinate implementation of the coastal module. The challenges are obvious: lack of funding for the Council and GRAs and the resistance to more bureaucracy. It is also important to recognize that we need to be moving toward a GOOS that does not distinguish between coastal and global GOOS. Thus in the longer term the GRAs might encompass both coastal and open ocean. This is already the case for EuroGOOS, US GOOS, IO GOOS, and the Australia IMOS. In the end, it is necessary to clarify the relationship between JCOMM, the GRAs, and the new group recognizing their different roles and governance (e.g. JCOMM involving both WMO and IOC; some GRAs being inter-institutional, some inter-governmental).

Recommendation 3.2 At this point and with the current structure, I-GOOS is a failed experiment. I-GOOS should be dissolved and replaced with a body that could truly help make IOC member states aware of its role in implementing both coastal and global GOOS. The new body should seek member state representatives who represent relevant national agencies or otherwise play a significant role in coastal or global observations and to the extent possible can make binding funding commitments. The new body needs to be responsible for GOOS (both open ocean and coastal components) and its implementation in these domains and able to take up advice from OOPC, PICO etc.

3.3 JCOMM

JCOMM as a joint technical commission between IOC and WMO coordinates, regulates and manages a fully integrated marine observing, data management and services system that uses state-of-the-art technologies and capabilities, is responsive to the evolving needs of all users of marine data and products, and includes an outreach programme to enhance the national capacity of all maritime countries. It works closely with partners including: the International Oceanographic Data and Information Exchange (IODE), the Global Ocean Observing System (GOOS), and the Global Climate Observing System (GCOS). It is also forming an important link with GODAE Ocean View.

JCOMM has been an effective body in bringing together the global ocean aspects of GOOS, but it has been underfunded and understaffed in relation to its goals and needs. Moreover, it suffers from lack of national commitment. There is also a perception that IOC member states are not fully aware of the activities or importance of JCOMM. JCOMM, as it approaches JCOMM III in fall 2009, is considering a restructuring in order to be more efficient and cost-effective. In order to JCOMM to meet its mandate, it will need full support and commitment for its restructured arrangement from both IOC and WMO.

It will be important also for JCOMM to make the right links with GEO/GEOSS and the regional international programs that are becoming operational like the GMES program in Europe. Google and other information technology companies can offer valuable capacity for data storage and modeling, and this should be pursued. JCOMM can also play an important role for coastal GOOS and the Global Coastal Network (GCN). The report of the Joint JCOMM-GSSC-GRA ad hoc Task Team recommends that: "JCOMM should coordinate the integration of all of the common variables to be measured as part of the

GCN as their data streams become pre-operational and responsible bodies have been established to sustain them. This should be a step-wise process based on recommendations from the GSSC that have been agreed to in collaboration with the GOOS Regional Council." But the question arises about whether JCOMM is structured to coordinate the implementation of sustained/operational elements of coastal GOOS and whether it can take this on with limited resources. The JCOMM restructuring needs to address this issue of coastal GOOS. If JCOMM cannot take on the common variables of the GCN then consideration should be given to having the GOOS Regional Council be empowered to do this.

Recommendation 3.3 JCOMM is playing a key role in the implementation of GOOS and the proposed restructuring needs support by both IOC and WMO. JCOMM could take on the responsibility for coordinating the Global Coastal Network (GCN). JCOMM should examine its roles and responsibilities for GOOS particularly with an eye towards identifying its role in implementing coastal GOOS, and help make both IOC and WMO member states aware of its role in implementing GOOS overall.

3.4 GSSC

The GOOS Scientific Steering Committee (GSSC) advises I-GOOS (or a new body as recommended) on scientific and technical matters including strategy, implementation and pilot projects. The committee meets annually and is comprised of members appointed by the GOOS sponsoring organizations, representatives of these sponsors, representatives of partner organizations and invited scientific experts. It currently has two panels: the Ocean Observations Panel for Climate (OOPC) and the Panel for Integrated Coastal Observations (PICO).

The Ocean Observations Panel for Climate (OOPC) is a scientific expert advisory group charged with strategic guidance for the open ocean module of GOOS. The Panel also helps to develop strategies for evaluation, evolution, and phased implementation of the system. The Panel supports global ocean observing activities by interested parties through liaison and advocacy for the agreed observing plans. The panel meets about once a year, and has about 10 members from North America, Europe and Japan. The OOPC is sponsored by the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the World Climate Research Programme (WCRP).

The Panel for Integrated Coastal Observations (PICO) is a scientific expert advisory group established to provide technical and scientific advice to the GSSC on the implementation and further development of the coastal module of GOOS. To this end, PICO collaborates with the GRAs, the OOPC and Coastal GTOS to formulate 5-year plans for building the Global Coastal Network that are updated periodically. The PICO also advises the GSSC regarding capacity building needs of nations and regions and approaches to address such needs for sustained coastal observations, analysis and modeling. At this point, PICO is viewed by its founders as a placeholder, the first step towards a joint PICO with GTOS that would address these issues across the land-sea interface just as OOPC addresses issues across the air-sea interface. PICO will help the

GSSC have a more constructive interaction with the GRAs via the GOOS Regional Forum. This collaboration will help drive the agenda of the forum.

Although the terms of reference for GSSC and its Panels are clear, in practice the Panels of GSSC are more active and effective than the parent body itself. At the outset, for the planning stages of GOOS, the role of GSSC was clear and strong community-based plans were developed. Now that GOOS is in the sustained operational phase, a new GSSC is needed. The experience of the past several years shows that the existing body lacks direction, and the consultant interviews revealed that many of the GSSC members are not clear about their responsibilities and roles. At present, the only effective part of the GSSC itself is the outreach activity being driven by the Chair. The real action is in the Panels – OOPC and PICO, which have been active and effective. Part of the reason for that is that the Panel members know what they want and are active in pursuing their needs. The GSSC should be dissolved and replaced with a joint body of OOPC and PICO.

Recommendation 3.4 In recent years, GSSC has lacked direction and focus. Members are not clear about their roles and responsibilities, whereas the GSSC Panels are active and effective. GSSC should be dissolved in its current form and reformed based on the Panels. One possible arrangement would be a joint body made up of the two panels with a governing tripartite executive committee: the current Chair representing outreach, the Chair of PICO, and the Chair of OOPC. To save funds, a single 3-4 day joint annual meeting that includes PICO and OOPC should be convened; the executive committee could meet during the joint meeting.

3.5 Related Bodies: POGO and GEO

Related bodies can help with the implementation of GOOS, particularly through outreach. IOC through the GPO should lead the effort to strengthen and clarify the relations between IOC, I-GOOS, JCOMM, POGO and the marine component of GEO/GEOSS, as well as UNCLOS, IMO, the Small Island States, and other related organizations.. POGO has offered to work with IOC on this, building on its leadership experience in coordinating ocean efforts in GEO through the informal Ocean United consortium. There is a particular opportunity here in capacity building, where POGO has suggested that IOC should broaden its activities in capacity building by partnering with marine groups deeply involved in capacity building, for example, by re-establishing participation in the POGO-SCOR Fellowship program.

Recommendation 3.5 IOC through the GPO should lead the effort to strengthen and clarify the relations between IOC, I-GOOS, JCOMM, POGO and the marine component of GEO/GEOSS, as well as UNCLOS, IMO, the Small Island States, and other organizations so that coastal ocean GOOS and open ocean GOOS are made more visible to the public and decision-makers.

4. *Streamlining, Implementation and Resources*

4.1 Prioritize and reallocate

In order for IOC and WMO/JCOMM to be able to carry out their mission to implement a sustained GOOS and associated ocean services, it will be necessary for both organizations to focus and prioritize. Internal infrastructure should be minimized, and meetings and reports should be aimed at providing information in the most efficient way. IOC and WMO/JCOMM need to do a regular review of their priorities as new ideas and techniques arise. The "user pull" is very important, and, as mentioned above, will be a key part of the business plan. For coastal GOOS, close collaboration is needed between GSSC-PICO that provides scientific and technical guidance for implementing GOOS and the GEO Coastal Zone Community of Practice that provides input on user needs. Several questions arise: Resources are always limited, but are the existing resources being used to have the maximum impact? The Argo program has operated with limited administrative oversight, and has been successful in using funds efficiently. Can that model be used for other systems? Is it possible to have fewer, or more targeted meetings? Can the number of reports be reduced? Any steps in these directions would allow funds to be reallocated to planning and coordination by expert individuals.

POGO has recommended to the IOC the appointment of an independent body to review the recommendations that have been made in IOC bodies over the past years. The body should determine how these have been followed up, and what should be done now. The planning process should give consideration to this process. This recommendation should be considered carefully.

Recommendation 4.1: IOC and WMO/JCOMM management of GOOS should be streamlined, starting with a careful consideration of what meetings and reports are really required, and a review of recommendations that have been made in the past and whether these are being followed up. IOC and WMO/JCOMM need to do a regular review of their priorities as new ideas and techniques arise, and should consider reallocating internal resources to meet planning and coordination needs.

4.2 Decentralize

Decentralization or moving functions from IOC headquarters in Paris to other countries who have committed resources to support those functions is a good way to operate with limited central funds. The successful move of IODE to Ostende has provided a good home for the data function. GOOS has two regional offices, one in Rio de Janeiro and one in Perth, and each leverages a substantial amount of funds for the program. The Perth office is active in working with GRAs to promote GOOS activities throughout the Indian Ocean and SW Pacific, and is a good model of a value-added activity. The JCOMM *in situ* Observing Platform Support centre (JCOMMOPS) has had similar success in France. It would be valuable to explore whether other functions could be moved to countries willing to commit resources.

Recommendation 4.2: Following the successful move of IODE and the establishment of the regional GOOS offices, IOC should carefully explore moving other central functions from Paris to countries willing to commit resources and help leverage funds.

4.3 Support for Planning and Coordination

In Section 2, we discussed the important role for IOC and WMO/JCOMM in the planning and coordination of GOOS. Internally, programs need management support and externally there are many partners to be coordinated. Much hard work being done by the permanent staff, and this is a crucial piece. The permanent staff must be fully supported and augmented as possible, both with permanent appointments and secondments. But the permanent staff is limited, and much of the necessary planning and coordination work is carried out by practicing scientists, engineers, and other experts who must give higher priority to their regular ("day") jobs. JCOMM has noted this problem (JCOMM MAN-VII/Doc. 6.1(17.XI.2008)) by pointing out that the ever reducing regular budget allocations in both parent Organizations makes the existing structure and meeting schedule unsustainable. JCOMM goes on to note that this situation is even worsened by the limited workforce available, as many members of the Management Committee receive little support from their home institutions. The same is true for GSSC and its Panels.

Sometimes the people who are most effective have the least time to spare in volunteer efforts. In order to get the most skilled people for the planning and coordination work, there will have to be both salary and travel support, and therefore more resources would have to be allocated for this function. This could come from extra-budgetary member state contributions, or from a reduction in the number of meetings. Since sometimes as little as $10-20K per person can make a big difference, this should have careful consideration.

Recommendation 4.3 IOC and WMO/JCOMM should make every effort to find additional support for planning and coordination in order to ensure day-to-day attention to these critical issues.

4.4 Funding

It must be recognized that implementation of GOOS as a fully operational system will be a slow, methodical and one-step-at-a-time process. Funding for the full system will come only slowly. Resources can be found by reallocating as noted above, being more entrepreneurial about getting outside grants and contracts, pushing UNESCO – and the rest of the UN system – more aggressively, looking for overseas development aid to developing countries for coastal planning and programs, and increasing IOC extra-budgetary support from Member States.

4.4.1. Becoming more proactive and entrepreneurial about finding funding is going to be critical for success. As society becomes more aware of oceans issues, there will be more opportunities for outside support (foundations, private sector, regional groups such as the European Commission,etc.). The GPO should be very active here in helping the secretariat reallocate according to priorities and in looking for new funds. Contracting with outside groups for specific management functions may reduce costs and should be considered for some functions.

Recommendation 4.4.1 IOC/GPO and WMO/JCOMM should be active and entrepreneurial in seeking outside funding from the private sector, foundations, and regional governmental groups and consider other ways of doing business, such as contracting with outside organizations if this reduces costs.

4.4.2 . IOC should task I-GOOS to establish a process for helping developing countries customize the plans for coastal GOOS that are sustainable and develop sustainable coastal plans clearly coordinated with the development of GOOS as a whole for possible funding from the developed world. IOC should also explore how developed countries might transfer funds to developing countries to meet the needs of coastal planning – if a planning process were established by the GRAs, perhaps developed countries would be willing to allocate funds to implement the plans. In addition, efforts should be put into helping developing countries to develop plans for coastal observing systems that underpin sustainable ocean management and to find funding support from developed countries for these plans.

Recommendation 4.4.2 IOC should task I-GOOS to develop a process for helping developing countries develop sustainable coastal plans for possible funding from the developed world.

4.4.3. Increasing IOC and WMO/JCOMM support from member states. This can best be done with the fully developed business plan that shows how sustained observations can be maintained. The plan, when developed will include market research, the user pull, the coordination necessary, and the products to be delivered, along with a timeline of expected accomplishments.

Recommendation 4.4.3 IOC and WMO/JCOMM should use the business plan to help increase support from member states for the operations of GOOS and delivery of services.

5. *Looking Forward*

The importance of ocean issues for society has given new impetus to IOC and WMO for improving their coordination and governance of sustained coastal and global ocean observations. At the same time there have been new organizations created that bring in wider communities and involve the private sector. As IOC and WMO move forward they need to be aware of how these new organizations can support sustained observations and bring to bear new resources. Since GOOS is a central program of IOC, the IOC Secretariat could take the lead in convening a series of strategic coordination meetings that would involve existing bodies and new institutions to help GOOS meet the many issues that have been discussed above. Such institutions and bodies include I-GOOS (or the new body recommended), JCOMM, other parts of the UN family, GEO, POGO, SCOR, IMO, IHO, and the private sector.

Such a set of strategic coordination meetings could also help IOC and WMO build awareness of ocean issues in the broader community. As of the time of this report a World Ocean Conference 2009 is being held in Indonesia, with a focus on building commitment for sustainable management of marine resources, and in urging the UNFCCC to make a commitment to put oceans on the COP-15 agenda and be aware of the ocean dimension in the post 2012 framework. Some groups have urged that there be regular world ocean conferences, building on the analogy of the World Economic Forum held annually in Davos, Switzerland. The broad economics community has been served well by that meeting, and it may well be time for the ocean community to follow suit with a regular "Oceans Davos" conference. But much thought needs to be given to such a large enterprise. A series of smaller meetings with principals, led by IOC, could be a good way to start thinking about this.

Recommendation 5 The IOC Secretariat should consider convening a series of strategic coordination meetings that would involve existing bodies and new institutions to help GOOS meet the many issues that have been discussed above. Such institutions and bodies include I-GOOS (or the new body recommended), JCOMM, other parts of the UN family, GEO, POGO, SCOR, IMO, IHO, and the private sector. These meetings could form the basis for consideration of a larger regular "Oceans Davos" conference to bring together all the constituencies of the ocean community.

6. Acknowledgements

The consultant thanks all of the reviewers and interviewees. .

7. *Appendices*

7.1 Terms of Reference and Timing for the Study

Appendix 1. Terms of Reference:

(i) Examine the modalities of cooperation between the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO) with a view to improving planning and implementation for the Global Ocean Observing System and associated ocean observation, services, and data management, including those activities coordinated through the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM), specifically:

(a) Review, analyse and comment on current governance, planning, and implementation coordination mechanisms for ocean observations and related ocean services and data management, as well as the resources available to support the work;
(b) As appropriate, recommend measures to improve the efficiency and effectiveness of and coordination among these mechanisms in the short to medium term;
(c) Recommend measures to improve, streamline and make more cost-effective the planning and governance of future GOOS and JCOMM activities;
(d) Recommend potential sources and levels for the resources appropriate to the requirements of the coordination mechanisms;

(ii) Meet with IOC and WMO Secretariat personnel and attend meetings of scientific and operational governing bodies as appropriate to gather material and discuss modalities;

(iii) Submit to UNESCO/IOC a final report at the conclusion of the work.

Timing:

Questionnaire distributed during January and February, 2009
Interviews carried out during January – March, 2009
First draft review by respondents: Mar 09
First draft review by sponsors: April 09
Second review: April 09
Study delivered to sponsors: 1 May 09

7.2. The Questionnaire and Process for Improving Planning and Implementation for GOOS

January 2009

This report for IOC and WMO, being put together by Jim Baker, is aiming at an analysis of the governance, planning, and implementation mechanisms for ocean observations and related ocean services and data management. There will be a special focus on issues of resource availability and how to improve effectiveness and efficiency.

Some basic questions to consider overall:

What's the biggest impediment to implementing a global ocean observing system?
What's the best way to overcome that impediment?
How do you see the value of IOC, I-GOOS, JCOMM, and WMO in this process?
How can we get the resources we need for a full system?

For your own programs:

What's the biggest impediment to getting your work done?
What funding issues do you see for your programs?
What are your views about the value and effectiveness of IOC, I-GOOS, JCOMM, and WMO for your work?

Organizational issues:

What international organizations do you see as really effective?
Are there changes in IOC, I-GOOS, JCOMM, and WMO that you would like to see?

Process:

The basis for this study came from a series of interviews based on the questionnaire above. Interviewees were a group of experts in ocean observations, services, and data management. The information from the interviews was collated into a summary, text and series of recommendations that was reviewed by the original interviewees. The consultant then met with IOC and WMO leadership and staff for comment and advice. The final report presented here is the result of the interviews and the various reviews, and is the sole responsibility of the consultant, Dr. D. James Baker.

7.3. Biography of consultant

Dr. D. James Baker is currently the Director of the Global Carbon Measurement Program of the William J. Clinton Foundation. He is also a science and management consultant with the Intergovernmental Oceanographic Commission of UNESCO in Paris and the H. John Heinz III Center for Science, Economics and the Environment in Washington, D.C., and a member of the international Science Steering Committee for the Census of Marine Life. He is a Visiting Senior Fellow at the London School of Economics and Political Science, and is an adjunct professor at the University of Pennsylvania and at the University of Delaware. During the 1990s he was Administrator of the National Oceanic and Atmospheric Administration (NOAA) and Under Secretary of Commerce for Oceans and Atmosphere.

7.4 An Overview of Global Observing Systems Relevant to GODAE

(note: figures can be found at: ftp://dossier.ogp.noaa.gov/OCO/GODAE/ under the "GODAE figures" file.)

Candyce Clark[2], U.S. National Oceanic and Atmospheric Administration (NOAA), Climate Program Office; and the *in situ* Observing System Authors[3]
Stan Wilson, NOAA, Satellite & Information Service; and the Satellite Observing System Authors[4]

Abstract. Comprising both *in situ* and satellite components, a global ocean observing system for the physical climate system was conceived largely at the Ocean Observations conference in St. Raphael in September 1999. It was recognized that society did not have adequate information about the state of the world ocean or its regional variations to address a range of important societal needs, and the subsequent work by the marine carbon community and others in the ocean science and operational communities led to an agreed international plan that was described in the GCOS Implementation Plan (GCOS-92, 2004). This foundation observing system was designed to meet climate requirements, but also supports weather prediction, global and coastal ocean prediction, marine hazard warning systems, transportation, marine environment and ecosystem monitoring, and naval applications. We here describe the efforts that have been made to reach these goals. Thanks to these efforts, most of the ice free ocean above 2000m is now being observed systematically for the first time, and a global repeat hydrographic survey and selected transport measurements supplement these networks.

The system is both integrated and composite. It depends upon *in situ* and satellite networks with observations of the same variable from different sensors. In this way optimum use is made of all available platforms and sensors to maximize coverage and attain maximum accuracy. Wherever feasible, observations are transmitted in real time or near-real time in order to maximize their utility, from short term ocean forecasting to estimation of century-long trends. Because our historical knowledge of oceanic

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variability is limited, we are learning about the sampling requirements and needed accuracies as the system is implemented and exploited, and the system will evolve as technology and knowledge improve. The biggest challenge for the greater oceanographic community – including both research and operational components – will be the demonstration of impacts and benefits sufficient to justify the funds needed to complete the observing system, as well as sustain its funding for the long term.

Introduction. The delivery of ocean services to society depends upon operation of an observing system adequate to support the services desired; analysis systems to integrate all available observations and permit the extraction of ocean information; and appropriate assimilation/analysis/ forecast systems to deliver forecasts of the desired extent into the future. An effective observing system – *in situ* and/or satellite – depends upon many data system elements. In particular, measurements must be made from sensors whose characteristics are understood and acceptable; the observations from the sensor must be transported to a facility where they can be assembled and given preliminary quality control; provision for access by the wide range of potential users must be made, including that for near-term operational purposes; and integration with other observations must also occur in order that delayed-mode quality control can be done for more exacting research applications.

This paper will discuss the current status of those global ocean observing systems that are relevant to, and whose data have been used by, GODAE. It will conclude with a discussion of some of the challenges facing these observing systems, in our effort to establish their funding on a sustained basis.

Global Observing Systems. The Global Climate Observing System (GCOS) Implementation Plan (GCOS-92, 2004) serves as a useful starting point. It calls for the phased implementation of an integrated and composite satellite and *in situ* observing system, with related data management and analysis activities. The ten-year implementation ramps are shown in Figure 1, which also shows the year-by-year progress in reaching the ten-year goals and the status to date.

***In situ* Observing Networks.** Successful operation of a global *in situ* observing system requires that there be coordination of activities on a number of levels. Sensors and best practices need to be agreed. Deployment opportunities need to be identified and instruments delivered to take advantage of them; where no opportunistic deployment is feasible, timely provision of special deployment efforts needs to be made. The data coverage of the system needs to be monitored along with sensor lifetimes and provision made to anticipate where gaps will appear so that deployment can be arranged. Successful implementation depends fundamentally upon near-real time transmission of both observations and relevant metadata. Given that a number of nations participate in each of the observing networks and both 'operational' and 'research' programs are involved, this monitoring/system management function is non-trivial and critical.

There are two different classes of observing activities underway *in situ* – those from fixed points and those whose location varies with time. Fixed point observations are made either from moorings or from repeated occupation of stations. Observations whose location vary with time are made from platforms that move as a result of the motion of the ocean or of a moving vessel. Some moving platforms are thought to follow the motion of water parcels fairly well ("Lagrangian").

Figure 1. Status of the in situ Global Ocean Observing System against targets defined by the GCOS Implementation Plan and accepted by JCOMM.

Fixed-Point Observing Networks**.** The networks of this type are the Global Tropical Moored Array, the OceanSITES program, the Global Sea Level Observing System (GLOSS), and some station-keeping repeat hydrographic surveys.

Global Tropical Moored Array. The Earth's tropics are the ocean's major capacity for heat exchange with the atmosphere. The near-equatorial upper ocean with its strong and quite variable currents poses many observational challenges and arrays on fixed mooring are the fundamental observing system building block in each of the oceans. In the tropical Pacific the TAO/TRITON array was fully deployed by 1999, while in the Atlantic the PIRATA (Prediction and Research Moored Array in the Atlantic) array has expanded to nearly double in size from 10 moorings in 1999 to the current 20). The Indian Ocean RAMA array (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction) was begun during the GODAE period and is about 50% complete (Figure 2). See http://www.pmel.noaa.gov/tao/global/global.html.

Figure 2: Global Tropical Moored Buoy Array in October 1999 (top) and October 2008 (bottom).

Ocean Sustained Interdisciplinary Timeseries Environment Observation System (OceanSITES). A global network of ocean reference station moored buoys is being implemented to provide the most accurate long-term climate data records of oceanic and near-surface atmospheric variables in key ocean regimes. OceanSITES is one of the most challenging because of the expense of maintaining highly accurate instruments in remote ocean regions, yet the network is essential for evaluation of climate model outputs. OceanSITES has plans to deploy and maintain 89 ocean reference stations (including transport, flex and multi-sensor platforms) that will sample as comprehensively as is feasible. There are currently 43 references stations. See http://www.oceansites.org/.

Global Sea Level Observing System (GLOSS). This is one of the oldest networks of the global ocean observing system, with some tide gauges having been maintained since the 19th century. Tide gauges are necessary for accurately measuring long-term trends in sea level change and for calibration and validation of the measurements from satellite altimeters, which are assimilated into global climate models for predicting climate variability and change. Important improvements in the number of gauges reporting high frequency data and in real time have taken place since 1999 (Figure 3). In support of GODAE, Fast Delivery mode (available within 1 month of collection) and real time (available 15 minutes to 3 hours) GLOSS data are assembled and provided by the University Hawaii Sea Level Center (UHSLC). The British Oceanographic Data Centre (BODC) provides final delayed mode data. See http://www.gloss-sealevel.org/. The status of real time reporting stations and recently collected time series are available at the Sea Level Station Monitoring Facility, maintained by the Flanders Marine Institute (VLIZ). See http://www.vliz.be/gauges/.

Figure 3: Configuration of the GLOSS/GCOS Core Network in 1999 (left) and 2008 (right). Important improvements in the number of tide gauges reporting high frequency data in real time have taken place during the GODAE period.

Repeat Hydrographic Surveys. The global repeat hydrographic survey is an essential observing system element for understanding the controls and distribution of natural and anthropogenic carbon, circulation tracers, and a large suite of biogeochemically and ecologically important chemicals in the ocean interior, including nutrients and oxygen. The surveys also remain critical for understanding ocean changes below 2 km (52% of global ocean volume), and their contributions to global freshwater, heat and sea-level budgets. See http://www.ioccp.org/.

Moving Observing Networks. The networks of this type are the Argo profiling float program, the surface drifting buoy network, the Arctic and Antarctic buoy programs, the XBT network and the Volunteer Observing Ship (VOS) scheme.

Surface Drifting Buoy Program. Planning for this array was begun in 1967 as part of the First GARP (Global Atmospheric Research Programme) Experiment, designed to provide ocean surface information from regions not sampled by the volunteer observing ships. It plays a fundamental role in providing accurate 'bulk' SST observations and surface pressure observations to the integrated observing system. Standard global SST analyses are derived from satellite retrievals, but the satellite measurements must be continuously tuned using surface *in situ* measurements. The network, coordinated by the Data Buoy Cooperation Panel (DBCP), reached its initial number goal of 1250 drifters in 2005, but has not yet achieved the desired geographical coverage of a drifter per 5x5 degree area of the ice-free ocean (see Figure 4).
See http://www.jcommops.org/dbcp/ and http://www.aoml.noaa.gov/phod/dac/gdp.html.

Figure 4: The configuration of the surface drifting buoy network on 13 September 1999 (left) and on 27 October 2008 (right). The network reached its initial implementation goal of 1250 in 2005.

Argo Profiling Float Program. This array was developed as a GODAE observing system initiative to understand upper ocean temperature variability and heat content and attained its initial implementation goal of 3000 operating floats, distributed relatively homogeneously throughout the world's ocean basins between 60^{o} N and 60^{o} S, in November 2007 (Figure 5). Although it has not yet reached its desired geographical coverage of a float per $3^{o} \times 3^{o}$ region, the Argo array is providing a nearly global picture of the world's oceans every ten days, and the development of instruments capable of operating in ice-covered regions is extending this into higher latitudes in both hemispheres. See paper on the Argo network by Roemich et al. in this volume; also http://www.argo.ucsd.edu/.

Figure 5: Global distribution of Argo profiling has grown to its initial implementation goal of 3000 floats during GODAE.

International Arctic Buoy Program. This network of buoys is used to monitor synoptic-scale fields of sea level pressure, surface air temperature, and ice motion throughout the Arctic Ocean. The Arctic ocean observing buoys have more than doubled during GODAE (24 in 1999 and 54 in 2008).

Voluntary Observing Ship (VOS) scheme. In this effort, research, private and commercial crews report a variety of air-sea variables, either from automated sensors or by direct measurement. This is perhaps the oldest of the global marine observing system and has its roots in the observations recorded routinely in ship logs. This network is maintained primarily for weather observations at sea, but the observational data are used extensively for climate studies as well, particularly for assessment of long-term trends. It uniquely is capable of providing information about marine surface atmospheric pressure, air temperature and humidity and clouds. See http://www.bom.gov.au/jcomm/vos/.

Ship of Opportunity Programme (SOOP). The ship of opportunity program is similar to the VOS scheme, but rather than atmospheric measurements, is focused on oceanographic observations. The primary sensors employed by Ships of Opportunity are eXpendable BathyThermographs (XBT), Thermosalinographs (TSG), and sensors equipped to measure the partial pressure of Carbon Dioxide (pCO2). In this program ships either deploy sensors (XBTs or XCTDs) or pump water to laboratory sensors. The global atmospheric and oceanic data from SOOP have been the foundation for understanding long-term changes in marine climate and are essential input to climate and weather forecast models. Over the past decade there has been an effort to focus on repeat sections in order to explore systematically space- and time-scales of oceanic variability (Figure 6). The total number of XBT profiles from SOOP decreased during the GODAE period as the Argo array was implemented. See http://www.jcommops.org/soopip/.

Figure 6: The global distribution of XBT observations from Ships of Opportunity in 1999 (left) and 2005 (right). The total number of XBT profiles from SOOP decreased during the GODAE period as the Argo array was implemented.

Satellite Observing Systems. The research space agencies have made great progress over the past three decades. Today spaceborne sensors have a demonstrated capability to observe a variety of variables; they include altimetry to observe ocean surface topography or sea level; scatterometry to observe ocean surface vector winds; infrared and microwave radiometry to observe sea surface temperature; microwave radiometry to observe sea ice cover; and visible and near-infrared radiometry to observe ocean color. Only several representative satellite systems will be discussed in this article, and only one of those at any length; for additional information, see Wilson et al., 2009. For a comprehensive overview of satellite capabilities prepared by the European Space Agency on behalf of the Committee on Earth Observations, see: http://www.eohandbook.com/eohb2008/earthobservation.htm.

Ocean surface topography. Precision altimetry was initiated by NASA and CNES with the launch of their *TOPEX/Poseidon (T/P*) in 1992; it is being continued by *Jason-1* and *Jason-2* (launched in 2008) today. These satellites have provided a continuous *climate* record of global sea level; and NOAA and EUMETSAT – as counterpart operational agencies – are proposing[5] a *Jason-3* for launch in 2013 as a follow-on to provide continuity of these observations in the future. See http://sealevel.jpl.nasa.gov/ and http://ibis.grdl.noaa.gov/SAT/slr/.

Why maintain the sea level record? Global sea level rise (GSLR) – the most obvious manifestation of climate change in the ocean – directly threatens coastal infrastructure through increased erosion and more frequent storm-surge flooding.

While its latest projections for GSLR over the coming century range from 28 to 79 cm, the Intergovernmental Panel for Climate Change (IPCC, 2007) states *…the upper values of the ranges given are not to be considered upper bounds…*for GSLR because existing models are unable to account for uncertainties such as changes in ice sheet flow. And regarding these changes, the U.S. Climate Change Science Program has gone on to say that *Sea level rise from glaciers and ice sheets has accelerated* (CCSP, 2008).

Given such uncertainties, it is critical that systematic observations of global sea level be maintained, and the only feasible way to resolve the spatial variability needed in an accurate determination of GSLR is by means of precision satellite altimetry – *TOPEX/Poseidon* (T/P) and the on-going *Jason* series of satellites. See for example, Figure 7. A complementary global network of GLOSS tide gauges, each with geodetic positioning to estimate vertical land motion, provides essential cross-validation for GSLR. Together, these observations suggest that GSLR is accelerating; in particular, the value of ~3.1 mm/yr from altimeters over the past 1½ decades is almost twice the estimate of ~1.7 mm/yr from tide gauges over the past century.

Figure 7. All satellite altimeters show global mean sea level to be rising. The current estimate of ~2.8 mm/yr is somewhat lower than the IPCC's ~3.1 mm/yr, most likely due to recent cooling associated with a protracted La Nina. In this figure, the high-precision T/P and Jason altimeters have provided the reference baseline, and results from each of the additional altimeters have had a bias adjustment to minimize differences with the baseline.

Courtesy of the NOAA Laboratory for Satellite Altimetry and Altimetrics LLC.

[5] On May 7, 2009 when the President's budget proposal for FY10 was submitted to the Congress for approval, funding for the U.S. portion of Jason-3 was included as a new NOAA initiative. While Jason-3 will serve a broad range of GODAE applications, as reflected in its justification by both EUMETSAT and NOAA, the most convincing rationale for its inclusion in the FY10 budget submission for NOAA concerned the issue of global sea level rise. This is why several paragraphs have been devoted to this issue, even though not a direct priority for GODAE. The target for approval of the Jason-3 budget for both NOAA and EUMETSAT is the end of CY2009.

In order to understand and improve the projections of GSLR, it is necessary to collect systematic observations of the two major contributors – thermal expansion due to the warming oceans, and the addition of melt water due to the warming of terrestrial ice sheets and glaciers. Thermal expansion estimates – previously based on sparse coverage by ship observations, especially so in the Southern Hemisphere – now principally come from the global *Argo* array of 3,000 profiling floats (see article by Roemmich in this issue).

A number of research programs are directed at estimating the addition of melt water, for example, by measuring changes in gravity of both the ice sheets and oceanic water masses, as well as changes in the topography and flow rate of glaciers and ice sheets. Together with Jason and Argo observations, these estimates can be used to infer a contribution from melting glaciers and ice sheets as a consistency check for these research efforts, as well as help assess the performance of climate models projecting sea level rise.

Oke (see article in this issue) describes how GODAE systems have used observations from different observing systems for meeting the needs of a variety of operational oceanographic applications. For example, the climate data record of sea level from *Jason*-class satellite altimetry – together with *Argo* float profiles and satellite observations of sea surface temperature (see article by Donlon) – is required to characterize decadal variability in the oceans and its relation to droughts, floods, and fishery regime shifts, as well as support seasonal forecasting (Balmaseda). These same data records, when combined with those from complementary altimeters (like that on the European Space Agency's ENVISAT and the U.S. Navy's recent GFO), enables an approximation of the oceanic mesoscale field – the ocean's *weather* – and contributes to many applications such as marine safety (Davidson), marine pollution monitoring (Hackett), hurricane intensity forecasting (Goni), and Naval applications (Jacobs), as well as provides boundary conditions for nested coastal models (DeMey), supports surface wave forecasting, and helps characterize the physical context for marine ecosystems (Brasseur). See http://www.aviso.oceanobs.com/.

Ocean surface vector winds (OSVW). For more than a decade and a half, satellite scatterometry has provided observations – although with varying degrees of spatial coverage – of the surface vector wind field over the oceans. The longest-running with the broadest coverage, NASA's QuikSCAT, was launched in 1999 and still operating today; the first fully operational scatterometer, ASCAT on EUMETSAT's *Metop-A*, was launched in 2006 with units on *MetOp-B* and *-C* to follow.

Observations of the OSVW field are needed both for operational forecasting, as well as research. For the former, they are needed in the early detection, tracking and characterization of hurricanes and tropical systems; observing and forecasting surface waves and storm surge; detection and characterization of extra-tropical, hurricane-force winter storms; and observing and forecasting localized wind events and frontal passages. See for example, Figure 8. For research, scatterometer observations provide fundamental characteristics of the wind forcing that drives the oceanic circulation. Moreover, such observations will be key in documenting extreme weather events at sea, events that are thought to become more frequent and intense with our warming climate. See http://winds.jpl.nasa.gov/missions/quikscat/ and http://www.knmi.nl/scatterometer/.

Figure 8. An extra-tropical cyclone with its center just east of Nova Scotia having peak winds of 50-60 knots, as displayed on a forecaster work station at the NOAA Ocean Prediction Center.

- *9A – 12:15 GMT, May 13, 2009 GOES visible image showing cloud patterns and surface observations collected by ships (with wind reports) and buoys (without);*
- *9B – 13:51 GMT ASCAT/MetOp surface vector wind field;*
- *9C – 09:22 GMT QuikSCAT surface vector wind field, with the edge of a 07:42 GMT pass to the east.*

These ASCAT and QuikSCAT products provide 12.5- to 25-km resolution observations of the surface vector wind field; this is in marked contrast to the relative sparsity of ship and buoy reports, and enables the accurate location of storm centers and associated fronts (such as the one extending to the southwest from the storm center. Realizing such improvements for operational forecasting is a prime motivation behind the Committee on Earth Observation Satellites encouraging every nation to provide timely access to data from its satellites for the benefit of all.
Courtesy of the NOAA Ocean Prediction Center.

Sea surface temperature (SST). For a couple of decades, continuing observations of sea surface temperature observations, to varying degrees of accuracy, have been provided by infrared radiometry (IR). In contrast to IR's relatively fine spatial resolution, but which is blocked by the presence of clouds, microwave radiometry (MR) offers an all-weather, but relatively coarse resolution. The interested reader is directed elsewhere in this issue to the article in which Donlon discusses how the Global High-Resolution SST Project combines the best attributes of IR (fine spatial resolution) and MR (all-weather) to develop improved SST products.

Sea ice cover. Continuing observations of sea ice cover have been collected using MR techniques since 1978; these results have shown in easy-to-understand terms how the Arctic permanent ice cover has visibly declined over the 30-year record of satellite observations. See for example, Figure 9. Moreover, MR has been complemented more recently by scatterometry and synthetic aperture radar to provide complementary information on ice concentration, ice age and ice temperature. See http://nsidc.org/.

Figure 9. The Arctic ice cover has been in decline over the three decades of satellite observation. Perennial Ice (blue line), defined as the area of minimum ice cover, survives melting and occurs in late summer. Multiyear Ice (green), the area of ice at least three years old and generally the thickest, is observed in February; it typically takes several summers for brine to drain from sea ice, leaving it almost salt free and with a distinctive microwave signature. Since Multiyear Ice is declining faster than Perennial Ice, the thickness of the Arctic ice cover is, on average, declining as well. This time series – based on data from SMMR/Nimbus-7, SSMI/DMSP and AMSR-E/Aqua (grey line since 2003) – demonstrates the value of being able to integrate observations from

multiple sources into a single climate record. Courtesy of Joey Comiso, NASA Goddard Space Flight Center.

Additional variables. There are several additional variables that – while important – have been of less direct relevance to GODAE, so they will only be mentioned in passing. Continuity of the ocean color climate record was initiated in 1997 and is being continued by several satellites; see http://oceancolor.gsfc.nasa.gov/. Observations of the Earth's gravity field have been provided since 2002); see http://www.csr.utexas.edu/grace/. Microwave radiometry will be used to demonstrate the feasibility of observing sea surface salinity later in 2009; see http://www.esa.int/esaLP/LPsmos.html.

Sustaining the Observing Systems. At the present time, the majority of the *in situ* ocean observations are funded by research agencies, and this is likely to continue for the foreseeable future. At some point, research agencies may look to the operational agencies to assume some responsibility for sustaining at least partial support for routine, systematic observations over the long term. GODAE recognized this when it was organized a decade ago. One of its basic motivations was to demonstrate in an operational setting the impact of having timely access to data from global ocean observing systems funded by research agencies, and depending on that impact, to develop a rationale to justify the transition of funding for those systems from the research to the operational agencies. Ideally, once the utility of observations had been demonstrated, the operational agencies would incorporate support for at least some of those observing systems into their ongoing program, thereby providing one avenue to sustain their support.

There are many challenges to be addressed in maintaining what has been achieved over the past decade. All programs face nontrivial increases in the cost of hardware and salaries. The VOS program is feeling the impact of cutbacks in national weather services support of the program, particularly reduction in the number of Port Meteorological Officers, and changes in the patterns and staffing and security concerns affecting the global merchant shipping fleet. The XBT program also strains to achieve its coverage because of changes in the routing of outfitted ships. The Argo and surface drifting buoy programs require special deployment assistance in areas remote from commercial shipping. The global hydrographic survey is strongly affected by decreases in the availability and increases in the cost of operating blue water research ships. Sustaining moored arrays requires dedicated ships and personnel able to go where and when replenishment is needed or data return suffers, and vandalism restricts effectiveness in some regions. Data sharing of tide gauge observations is problematic in some key regions.

For the satellite observing systems, the issue of transitioning support from research agencies to operational agencies is a critical one, and both the technical feasibility of observing a given variable and the scientific utility of the resulting observations needs to be demonstrated. In the transition process, the research and operational agencies share the next step, the demonstration of the operational utility of that observation, namely, that an operational agency, given timely access to such observations and the capability to utilize them, can demonstrate they can have a significant impact on meeting its mission need.

This justification entails convincing the government supporting that operational agency of the potential impact or value, in terms of societal relevance, of the data collected by a given observing system. Note that some *impact* can be expressed in more immediate and quantifiable terms: for example how much a *weather* forecast is improved where the impact is realized within hours to days of the time when a given set of observations have been collected. Other value may be expressed in terms of the variable's role in the *climate* system, for example the specific impact of the collection of a given set of observations to assess or quantify that variable's role in climate may not be realized for years to decades.

Ensuring Sustained Operations. As the operational agencies collaborate with their research counterparts to ensure sustained operations of the global observing systems, there are particular challenges to be faced.

<u>Societal relevance.</u> The operational agencies need to make the case that what is proposed to implement on a long-continuing basis is worth a corresponding continuing investment of tax dollars over the long term. This is often different than making the case within a research agency.

<u>Fiscal.</u> Operational and research agencies have, and will continue to have, a tight budget environment. For example, in the U.S. NOAA is attempting to establish elements of a new (for NOAA) operational ocean capability in a level-funding environment on top of a well-established and growing operational weather forecasting program. And in Europe, research and operational programs frequently compete within essentially the same overall envelope, so more support for operational programs can mean less for research.

<u>Climate change.</u> To the extent that political leaders recognize and appreciate climate change as an issue that must be addressed, the operational agencies could provide a valuable service to the research agencies by assuming responsibility for maintaining transitioned observing systems and thereby providing the research agencies a valuable continuing stream of climate data. But in so doing, the operational agencies must maintain a close partnership with the research community to ensure that the integrity of the climate data record is maintained. Further, oceanographers need to recognize that they are competing within the overall Earth science community for resources in the climate arena, and there is a need to clearly articulate and promote the critical role played by the global oceans.

<u>Organizational focus.</u> Some countries have, at the national level, an organizational focus for the implementation of operational oceanography such as the group of French agencies involved in oceanography. Over almost two decades, this group has recognized the need for cross-agency coordination and the establishment, as needed, of organizations such as MERCATOR and CORIOLIS to provide an integrated approach to ocean modelling and forecasting and *in situ* ocean observations, respectively. This serves as a useful example

of effective programmatic integration for other nations, although it is recognized that in other countries support for the *in situ* system will continue to come from research agencies, or a combination of operational and research entities.

Observing system support and monitoring. Sustaining the required coverage in space and time of observations requires substantial coordination and at many different levels, and the advantages of a systematic framework to support these observing systems deployment and monitoring activities is clear. JCOMMOPS (the WMO-IOC Technical Commission for Oceanography and Marine Meteorology *in situ* Observing Platform Support Centre (http://www.jcommops.org) does much of this work, and the Observing System Monitoring Center (http://www.osmc.noaa.gov/) is a useful tool for monitoring real-time status and performance of the global *in situ* ocean observing system.

Integrating *in situ* and satellite observing systems. It is essential for these communities to work together on an integrated system. The two sets of systems are complementary; for example, the satellite systems have the ability to resolve horizontal variability at the surface and the *in situ* networks can resolve variability in the vertical. The ocean is relatively opaque to electromagnetic radiation, and there is only so much that may be inferred from surface observations. Subsurface structure can deviate immensely from historical relations to the surface. Directed subsurface observations from *in situ* observing systems are a critical piece, but at the same time those observations by themselves are incomplete without the satellite observations. Ocean models can play an important role here, integrating observations from both systems. No one working on either system should be unaware of the importance of the other.

Focus and prioritize. Operational agencies typically have little budgetary flexibility, and therefore need to focus and prioritize when attempting the implementation of operational infrastructure. They need to concentrate on those variables for which there have been successful demonstrations of technical feasibility and scientific utility. If there was some degree of community consensus based, for example, on compelling issues of societal relevance, it could be used as the basis for prioritization.

Clear, concise and consistent message. Securing the resources to implement a sustained infrastructure for observing the global oceans will require a clear, concise and consistent message coming from the community at large that reflects priorities in a progression of successive steps.

Looking to the Future.

While moving an observational capability from the point of theoretical possibility to an on-going, sustained reality is a decades-long process, it is important to note that significant progress has been made. For the first time most of the ice-free ocean above 2000m is now being observed systematically for the first time. We need to concentrate on the near-term opportunities, as well as engage in a number of international activities that could have significant benefit for promoting and integrating the *in situ* and satellite observing system, including:

- The WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) coordinates the implementation of the *in situ* observing system, and offers an opportunity to strengthen the effective integration with space observation systems through its Observations Coordination Group.
- The Global Earth Observing System of Systems (GEOSS) offers an avenue for ministerial-level political visibility; this could be critical as the two communities help each other secure the resources needed to implement a shared international effort in operational oceanography.
- The Committee on Earth Observation Satellites (CEOS) Constellations represents a potentially valuable international forum to help member space agencies seek development of common data products, formats, and protocols as well as consensus data policies for timely sharing of data, since no agency or nation can afford to collect all of the data it needs.

The ocean community has demonstrated during the GODAE period that a global ocean observing system can be implemented, and can provide critical data to support global ocean forecasting and analysis. With the observations being used ever more effectively, it is hoped that the coming decade will see not only continuity, but also increased coverage including more variables. From this foundation observing system, important progress will be made in ecosystem management, sustainable fisheries, weather and climate forecasting, marine operations, and the safety of life at sea.
Impressive progress has been made in a relatively small number of years, and in many respects, much more has been achieved than was ever expected or even dreamt of; however, there is still much to be done.

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List of Acronyms

AMSR-E/Aqua	
	JAXA Advanced Microwave Scanning Radiometer on the NASA Aqua satellite
ASCAT	**Advance Scatterometer on EUMETSAT MetOp satellites**
BODC	**British Oceanographic Data Centre**
CCSP	**U.S. Climate Change Science Program**
CEOS	**Committee on Earth Observing Satellites**
CNES	***Centre National d'Etudes Spatiale (the French space agency)***
ECV	**Essential Climate Variable**
ENVISAT	**ESA Environment Satellite**
ESA	**European Space Agency**
EUMETSAT	**European Organization for the Exploitation of Meteorological Satellites**
GARP	**Global Atmospheric Research Programme**
GCOS	**Global Climate Observing System**
GCOS-92	**GCOS Implementation Plan for the Global Observing System for Climate in support of the UNFCCC**
GEOSS	**Global Earth Observation System of Systems**
GFO	**U.S. Navy Geodetic Satellite Follow-on**
GLOSS	**Global Sea Level Observing System**
GODAE	**Global Ocean Data Assimilation Experiment**
GSLR	**Global Sea Level Rise**
IPCC FAR	**Intergovernmental Panel on Climate Change Fourth Assessment Report**

IR	**Infrared radiometry**
JAXA	**Japanese Aerospace Exploration Agency**
JCOMM	**WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology**
JCOMMOPS	**JCOMM *in situ* Observing Platform Support Centre**
MetOp	**EUMETSAT Meteorological Operational satellite**
MR	**Microwave radiometry**
NASA	**National Aeronautics and Space Administration**
NOAA	**National Oceanic and Atmospheric Administration**
OSVW	**Ocean Surface Vector Winds**
PIRATA	**Pilot Research Moored Array in the Tropical Atlantic**
QuikSCAT	**NASA Quick Scatterometer satellite carrying the SeaWinds Scatterometer**
RAMA	**Research African-Asian-Australian Monsoon Array**
SMMR/Nimbus-7	**NASA Scanning Multi-frequency Microwave Radiometer on its Nimbus-7 satellite**
SOOP	**Ship of Opportunity Programme**
SSMI/DMSP	**U.S. Air Force Special Sensor Microwave Imager on its Defense Meteorological Satellite Program satellite**
SST	**Sea surface temperature**
TAO/TRITON	**Tropical Atmosphere Ocean Array/Triangle TransOcean Buoy Network**
T/P	**NASA/CNES Ocean Topography Experiment**
TSG	**Thermosalinograph**
UHSLC	**University of Hawaii Sea Level Center**
UNFCCC	**United Nations Framework Convention on Climate Change**
XBT	**Expendable Bathy-Thermograph**
VOS	**Volunteer Observing Ship**
VLIZ	Flanders Marine Institute