

A word cloud centered around the main title 'Framework for Global Ocean Observing System'. The words are arranged in various orientations and colors. The largest words are 'Framework', 'Global', 'Ocean', and 'Observing'. Other prominent words include 'Sustained', 'System', 'Requirements', 'Data and Information products', 'Observations', 'Integrated', 'Essential Ocean Variables EOVs', 'Governing', 'Concept', 'Readiness levels', 'Pilot', and 'Mature'.

Framework  
Global  
Ocean  
Observing  
System  
Requirements  
Data and Information products  
Observations  
Sustained  
Integrated  
Essential Ocean Variables EOVs  
Governing  
Concept  
Readiness levels  
Pilot  
Mature

# A Framework for Ocean Observing

## ***Prepared for the Task Team for an Integrated Framework for Sustained Ocean Observing (IFSOU)***

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## EXECUTIVE SUMMARY

The ocean is critical to the earth's global systems, regulating weather and climate, the concentration of gases in the atmosphere, the cycling of nutrients, and providing important food resources. As ocean scientists deploy new technologies to observe these dynamic processes, the impacts of human activity are becoming increasingly obvious and of growing concern. Rising sea level, melting ice sheets, ocean acidification, dead zones, harmful algal blooms, coral bleaching, fish population and ecosystem declines are all being experienced at local and global scales. There is also a rising likelihood of major changes in ocean circulation, weather and climate. The well-being of humankind is dependent on the health and function of the world ocean.

Ocean scientists are increasingly called upon to provide data and impartial scientific information to support all levels of governance and management, a challenge that requires more and better-coordinated efforts in observing and understanding the ocean and coastal seas around the globe. These will allow us to meet the challenge of delivering ocean information for societal benefit. To date, largely independent observing systems have evolved to meet the needs of particular disciplines and end users – the majority of these measuring ocean physics. It is now critical to extend the scope of observing networks to include ocean geochemistry and biology, and to integrate efforts across these scientific disciplines, because: 1) many of the problems facing the world today are interdisciplinary in nature; and 2) the limited resources available for ocean observing systems requires strong cooperation and leveraging.

A key recommendation from the OceanObs'09 ([www.oceanobs09.net](http://www.oceanobs09.net)) Conference held in Venice in September 2009 was for international integration and coordination of interdisciplinary ocean observations. The Conference was sponsored by many international and national ocean agencies, and attended by representatives of ocean observation programs worldwide. Based on impressive agreement among the many groups at the Conference and their strong desire to work collectively, the sponsors commissioned a Task Team to develop an integrated framework for sustained ocean observing.

The Task Team's objective was to use lessons learned from the successes of existing ocean observing efforts and outline a Framework that can guide the ocean observing community as a whole to establish an integrated and sustained global observing system – one that includes ocean physics, biogeochemistry, and ocean biology and ecosystems, and addresses the variables to be measured, the approach to measuring them, and how their data and products will be managed and made widely available to modeling efforts and a wide range of users. Achieving this step-change in ocean observing will require internationally accepted processes and expanded collaboration.

The Task Team agreed that the Framework and its coordination processes should be organized around “essential ocean variables (EOVs),” rather than by specific observing system, platform, program, or region. The group also agreed that implementing new EOVs will be carried out according to their readiness levels, allowing timely implementation of components that are already mature, while encouraging innovation and formal efforts to improve readiness and build capacity. Systems engineering approaches provide a common language and consistent handling of requirements, observing technologies, and information flow among different, largely autonomous observing elements linked in a collaborative Framework.

The Task Team recommends establishment of a governance model to optimize collaboration and integration across the many observing system elements and communities; it will include:

- A Framework Steering Group, made up of representatives of the international sponsors of OceanObs'09 and leaders of Ocean Observing System Panels (i.e. representatives of Physics, Biogeochemistry and Biology communities delivering the core elements of the Observing System). It will promote alignment of existing structures and oversee creation of any new committees/bodies required to support new elements of the observing system. The Steering Group will also support effective links across elements of the Framework, to ensure that in concert they deliver much more than the sum of their parts, and in so doing drive the desired integration.<sup>1</sup>
- Three Ocean Observing Panels -- for Physics, Biogeochemistry and Biology -- will be responsible for articulation of requirements for EOVs, documentation and sharing of best practices, assessment of readiness levels, development of implementation strategies and coordination of activities across local, national, regional and international communities. They will assess the fitness-of-purpose of data and information streams resulting from observations to improve their recommendations. These panels will build on the work of the

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<sup>1</sup> Building on a draft of this report, the Intergovernmental Oceanographic Commission and co-sponsors of the Global Ocean Observing System (GOOS) (WMO, UNEP, and ICSU) have reformed the governance model of GOOS with a new Steering Committee. The Task Team recommends that this new GOOS Steering Committee, with the participation of a wide range of partners, play the role of the Framework Steering Group. .

Ocean Observations Panel for Climate (OOPC), the GOOS Panel for Integrated Coastal Observations (PICO), and the International Ocean Carbon Coordination Project (IOCCP) where appropriate, and seek a growing set of partners.

- Ocean Observing System Implementation Teams are the core of the observing system. They will support specific activities articulated by the Panels, and be the core drivers of community commitment and contributions to the Framework. Many of these teams exist already, as independent observing networks or regional efforts. The Framework seeks to help them coordinate their efforts and to sustain or grow investment in them by increasing their linkages to other ocean observations, and to scientific and societal benefits of the observations they provide.

The Task Team strongly recommends that the ocean observing community adopt, adapt to, and fully support the way ahead quickly, recognizing that additional changes can be made, in a stepwise manner, as needed through Framework collaboration and negotiation processes.

A Framework based on broad community collaboration will improve communications and data sharing across the community; result in faster and better-coordinated information to support both research and societal needs; contribute to capacity building and enhancement of ocean observations in developing countries; increase confidence and support among sponsoring and funding entities; and foster innovation and scientific discovery.

## KEY FRAMEWORK CONCEPTS

1. Deliver an observing system that is fit for purpose:
  - Focused on both scientific inquiry and societal issues
  - Expanded to include physical, biogeochemical, and biological data
  - Operated in collaborative fashion based on set principles and best practices
  - Balancing research and innovation with the need for stability
  - Promoting alignment of independent groups, communities and networks
  - Building on existing structures as much as possible
  - Providing maximum benefit to all users from each observation
2. Apply a systems approach for sustained global ocean observing:
  - Use “Essential Ocean Variables” (EOVs) as the common focus
  - Define a system based on Requirements, Observations, and data and Information,
  - Use “readiness levels”, based on assessment of feasibility, capacity, and impact, for each of these system components,
  - Incorporate both coastal and open ocean observations
3. Recognize and develop interfaces among all actors in the Framework for their mutual benefit.
4. Provide the basis for and promote transformation of observational data organized in EOVs into information (syntheses, analyses, assessments, forecasts, projections, and scenarios) that serve a wide range of science and societal needs, and enable good management of the human relationship with the ocean.

## 1 INTRODUCTION

More than 600 representatives of ocean observation programs and the ocean science and ocean services communities from 36 countries met in Venice from 21-25 September 2009, in the OceanObs'09 Conference ([www.oceanobs09.net](http://www.oceanobs09.net)), sponsored by a number of international and national coordinating and implementing agencies. The assembly made significant progress in building bridges between research and operational observing efforts; between open-ocean and coastal observing; among various ocean science disciplines; and among groups that focus on particular ocean phenomena and observing platforms.

Based on a collective call from participants, the Conference's international sponsors commissioned a Task Team for an integrated framework for sustained ocean observing to recommend a way forward for ocean observations in the next decade. The Task Team has endorsed this document proposing a Framework and processes—using lessons learned from existing successful ocean observing systems—for sustaining present observing systems and integrating new physical, biogeochemical and ecosystem observations required to support increasing scientific and societal needs.

The Task Team has not attempted to design or re-design ocean observing, as this is the challenge for participants in the new Framework processes. The objective of the Task Team was to outline a Framework that will guide the various ocean observing communities in establishing requirements for a sustained global ocean observing system, the essential variables to be measured, the approach to measuring them, and how their data and products will be managed and made widely available.

The goal of the Framework and its coordination and processes is to encourage voluntary participation among existing and new ocean observing networks and activities – a collaborative system, not one under central control – and to enhance scientific and societal investment in these systems by clearly linking requirements, observations, data, and ocean information, including syntheses, analyses, assessments, forecasts, projections and scenarios.

This report describes the Framework, provides an overview of how it can be applied, presents specific recommendations for next steps, and highlights the benefits to be derived.

## 2 THE NEED FOR OCEAN OBSERVATIONS

Covering more than 70% of the earth's surface, the global ocean is under-sampled and poorly understood. But the ocean plays a pivotal role in the earth's physical, geochemical and biological systems and as such affects us all in pervasive and profound ways.

The ocean influences our weather and climate through its capacity to absorb, transport, and emit heat, carbon and radiation. Through evaporation to cloud formation to rain, the ocean rejuvenates the Earth's drinking water. Ocean life recycles nutrients and is the basis of the planet's largest habitat. Through fisheries, aquaculture, transport, energy, tourism and recreation, the ocean contributes directly to the economic wealth and security of a majority of nations.

The degradation of coastal habitats, pollution, over-exploitation of fisheries, biodiversity decline, bleached and dying coral reefs, receding polar ice sheets, sea level rise, and ocean acidification are all raising awareness and concern among the public and policymakers, and threaten the well-being of the great numbers of the human population (over 40%) that live in coastal areas worldwide. There is a growing need for more systematic ocean information at local, national, regional, and global scales to support efforts to manage our relationship with the ocean.

## 3 THE NEED FOR A FRAMEWORK

The ocean research community and its funding base cannot alone meet the growing requirements for ocean information, particularly the long-term, sustained efforts needed to show changes over time and to provide ocean-related services, both critical to addressing societal concerns. These will require significant, well-coordinated, additional resources from national governments. Addressing these information needs is an enormous challenge, as the global ocean is a complex and highly connected system at all scales and across all the scientific disciplines. A basic premise of the Framework, however, is that we cannot measure everything, nor do we need to.

This report offers a clear, focused approach – a Framework based on systems engineering approaches – for identifying the requirements and their priorities, testing new technologies, endorsing implementation plans, and setting data sharing standards for the highest-priority global ocean observations required for both scientific and societal needs.

### 3.1 BACKGROUND

Over the last century, the research community was largely responsible for collecting and disseminating information on the physical, chemical, and biological state of the ocean. Ocean satellite missions were flown experimentally starting more than 30 years ago, and drifting and profiling floats, instrumented moorings, and ship-based observations most often began as scientific experiments. As societal demand for more information about the physical ocean environment increased, along with a growing concern about climate change, the research community began to transform some of their observing platforms into elements of a sustained global system supporting both research needs and broader societal concerns. A few operational agencies are now supporting some portions of a sustained ocean observing system, but the comprehensive transfer from research to broader societal data collection once envisioned has not taken place.

As the Task Team began its work, it became obvious there were significant lessons to be learned from the way some research communities have successfully evolved their efforts into sustained global observing programs. Partly because of the cost of satellite programs and major ocean-wide observing arrays, many in the physical oceanography community were forced years ago to adopt a global focus and a “systems” approach to doing business. The Framework concepts draw on some of the best practices of the ocean observing networks whose requirements are identified by the Global Climate Observing System (GCOS), including the Global Ocean Observing System (GOOS)-World Climate Research Project (WCRP) Ocean Observations Panel for Climate (OOPC) and work through the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) Observations Programme Area Coordination Group. For many in the ocean observing community, the concepts promoted in this report will require few behavioral or organizational changes, but will simply codify and strengthen existing successful practices.

Given the local or regional nature of most ocean biological studies until recently, however, there has not been a major focus in that community on coordinated, global observing programs. The Task Team has addressed the importance and benefits of integrating biological observations, through a Framework approach, into the global ocean observing system. For these groups, aligning with a Framework for Ocean Observing offers a new mechanism to support development of viable global observing programs integrated with sustained oceanographic and climate observations. As the ocean observing community strives to build on the significant accomplishments of the last decade (highlighted at OceanObs’09), the Task Team recommends an approach that will result in more integrated thinking across all parts of the community.

### 3.2 GUIDING PRINCIPLES

- The Framework’s requirements processes must address both ocean research and societal needs. These include the growing concerns of national and international decision-makers, and the public at large, regarding reliable sources of factual and unbiased information on the state of the ocean to inform needed decisions and services.
- Alignment with the Framework will help balance continued research innovation against the need for stability in the global ocean observing system to establish baselines, detect change, and underpin ongoing services. It is critical to involve the research community, but innovative new elements must be evaluated through community-wide Framework processes before being endorsed for inclusion in the sustained global system.
- Use of the Framework will reduce duplication among ocean observation elements, and promote data standards and broad accessibility, to support a principle of “measure once/use many times.”

- Framework activities will promote free and open exchange of data and products, with robust mechanisms to apply user feedback and community-wide assessments to the output of all observing elements.
- Framework processes will include strong efforts in education, outreach, and capacity building to create a much broader understanding of ocean influences, and to foster an improved culture of public decision-making in climate and ocean issues based on impartial scientific data.

Advocacy (influencing national or global policies, laws or conventions) will not be a goal or activity within the Framework, although the data from sustained ocean observing systems will support this sort of policy development as a result of better ocean information being made available.

The Framework does not prescribe a plan for ocean observing, or the ocean variables to be measured, or any specific observing system plans – all of these will be outcomes of collaborative Framework processes.



**Figure 1. Boundaries of the Framework.** The box highlights issues that will be addressed within the Framework for Ocean Observing. The complex activities external to the box will be directly or indirectly influenced by ocean observing activities, but will not be addressed through the Framework.

## 4 FRAMEWORK CONCEPT AND DEFINITION

The Task Team has defined a Framework based upon a collection of processes for organization, communication, best practices, and systems thinking that will foster improved interfaces and integration of ocean observing efforts into an optimal global system. It is not intended to replace or supersede existing systems, but will provide a mechanism for bringing them together.

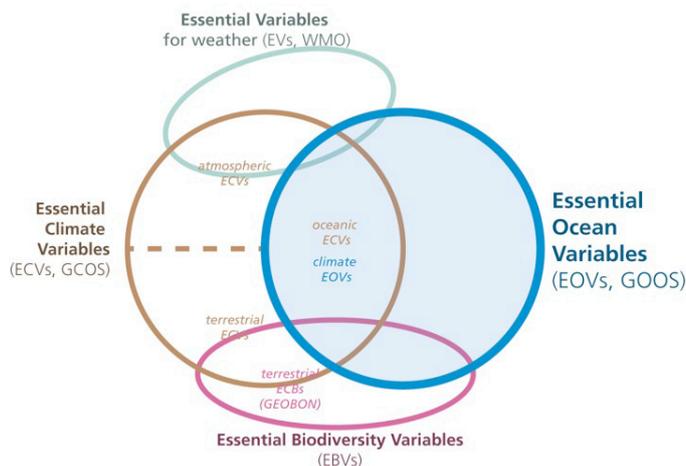
### 4.1 DEFINING THE FRAMEWORK

From a systems engineering approach, the inputs (requirements) of the system will be best described in terms of the environmental or ecosystem information needed to address a specific scientific problem or societal issue. The societal issues may include a short-timescale need such as hazard warning, or a long-timescale need for information such as knowledge of ecosystem limits required to set sustainable uses of ocean resources.

The processes (observation elements) will be the technology and networks used to collect the data needed to address these requirements. The outputs (data and information products) will be the best syntheses of ocean observations to provide services and inform scientific problems or decisions about societal issues.

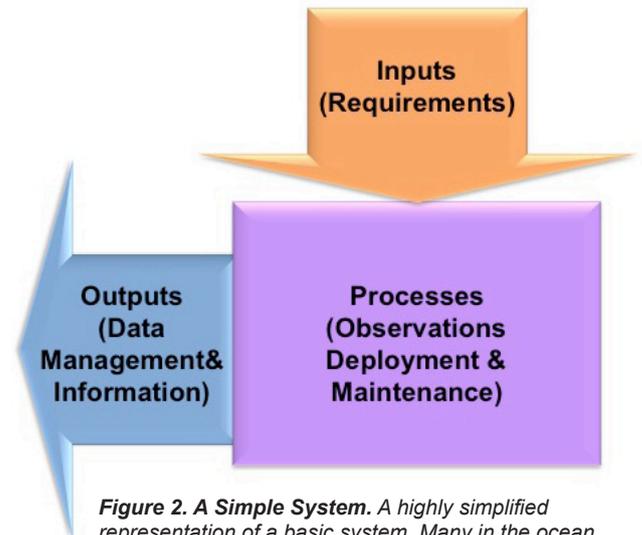
To maintain an ocean observing system that is fit-for-purpose, the outputs of the system must properly address the issues that drove the original requirements, and a feedback loop of assessment must be maintained by Framework processes.

The Task Team recommends that activities within the Framework be organized around community-defined Essential Ocean Variables (EOVs).



**Figure 3. Conceptual Overlap of Essential Ocean Variables in a Venn diagram.** Essential Variables defined by the WMO for weather forecasting inspired the Essential Climate Variables later defined by GCOS. The concept has been adopted for Essential Biodiversity Variables on land by GEOBON. The Framework for Ocean Observing processes will define ocean observing EOVs. Overlap among these groups is shown, which argues for the need to adopt a consistent approach.

duplication across observing platforms and networks, and to adopt common standards for data collection and dissemination to maximize the utility of data. To address these concerns, the Framework is designed to approach ocean observations with a focus on EOVs; this will ensure assessments that cut across platforms and recommend the best, most cost-effective plan to provide an optimal global view for each essential ocean variable.



**Figure 2. A Simple System.** A highly simplified representation of a basic system. Many in the ocean observing community have naturally aligned their activities according to this principle of organization and coordination.

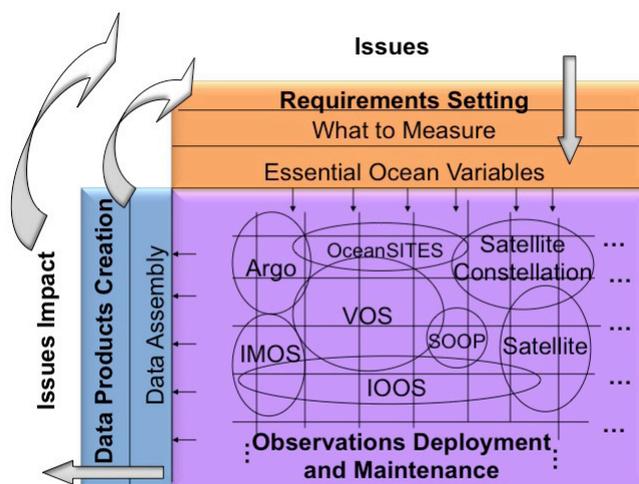
The processes of this Framework are based on lessons learned from the global climate observing community, which met with great success after organizing its efforts around essential climate variables (ECVs), which allowed them to break down barriers to cooperation among funding agencies and observing networks.

Applying this concept to ocean observations yields the Essential Ocean Variables introduced here. There are considerable conceptual overlaps among the Essential Climate Variables (ECVs) introduced by GCOS, the Essential Variables defined for meteorological services by WMO Resolution 40 (Cg-XII), emerging Essential Biodiversity Variables (EBVs) being defined in the global biodiversity observing system GEOBON, and the EOVs of this Framework for Ocean Observations, as shown in Figure 3.

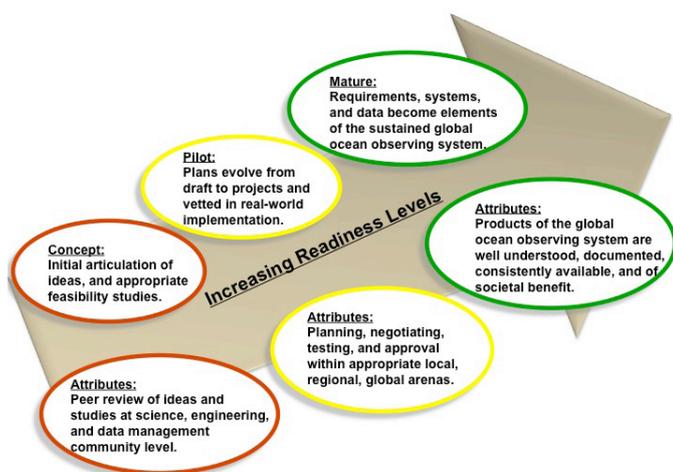
Because of the vastness, remoteness, and harshness of the ocean environment—and the costs involved in collecting any observations over, on or beneath the sea surface—many ocean observing systems have been, and will continue to be, designed to measure as many variables as possible. There is a need to avoid

Under the Framework, an “observing element” will be defined as any ocean sensing system – based on a specific platform, region, or ocean characteristic – that is driven by agreed requirements, has broad scientific support and adheres to global, common standards for data sharing. There are many examples in the ocean observing community as seen in Figure 4.

Within the Framework, the approach for evaluating new components for possible inclusion in the global ocean observing system will be in terms of their “readiness level.” These levels, as shown in Figure 5, are addressed in three broad categories: concept, pilot and mature.



**Figure 4. Structure of the Framework for Ocean Observing.** How ocean observing activities fit into the systems model of the Framework. The critical feedback loop between observing system outputs and science-driven requirements is shown. (Observation system examples are illustrative only, not comprehensive.)



**Figure 5. The Concept of Readiness Levels.** How ocean observing activities will be assessed for inclusion in the Framework for Ocean Observing. The scale and scope of activities at each readiness level will vary according to the needs of a particular EOVS.

During the concept phase, ideas are articulated and peer-reviewed. During the pilot phase, aspects of the system are tested and made ready for large-scale implementation. At maturity, they become a sustained part of the global ocean observing system.

Using the Framework approach will encourage increased partnerships across the ocean research and operational communities to assess and improve the readiness levels of requirements, observation elements, and data systems proposed to measure each EOVS. Alignment with the Framework will also enhance collaboration among developed and developing regions, and promote the use of common standards and best practices around the world.

## 4.2 GOVERNING THE FRAMEWORK

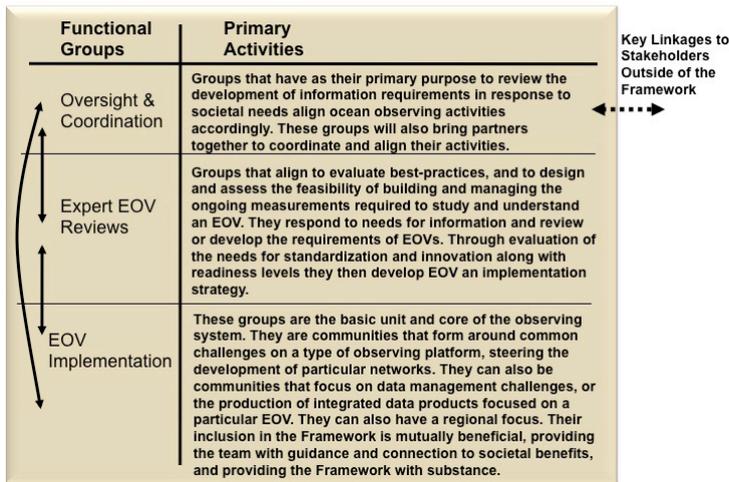
The ocean observing community is segmented according to the information required to fulfill their functions. The ocean observing community is defined here as any person or organization that has a vested interest in the input, processes, or outputs addressed through the Framework.

For addressing Framework processes, the overall ocean observing community can be aligned into three broad tiers: oversight groups, EOVS expert teams, and implementation communities. The basic functions of each tier are shown in Figure 6 Working within the Framework will facilitate the necessary, and often complex, negotiations across these three tiers as the community assesses the needs for sustaining or improving observations of each EOVS, and linking observations to societal drivers.

Within the Framework, any new Essential Ocean Variable (EOVS), or any major upgrade to observing systems, will develop and mature through a series of negotiations. As is the case today, these negotiations will require interactions among often highly distributed groups, including high-level international oversight bodies; EOVS-oriented expert teams to match new requirements to the best possible solutions; implementation groups that deal with the realities of making the observation elements and data systems work; and funding and sponsoring organizations.

It will not be uncommon to see the same individuals, organizations, and panels performing multiple functions within this construct. Implementation of the Framework relies on the continued efforts of many existing organizations, but in some cases will encourage the collapsing or merging of overlapping groups.

The Task Team recognizes the need for some group or organized body to facilitate and “steer” the transition toward collaborative alignment of the ocean observing community and its stakeholders along Framework



**Figure 6. Ocean Observing Community Roles within the Framework.** Functional tiers within the ocean observing community that will align to address scientific, organizational, and technology issues within the Framework. Arrows represent communications among groups.

principles. The Task Team recommends this activity be conducted by a Framework Steering Group (Framework SG) that can promote community alignment of existing structures and creation of any new committees and/or bodies that may be required to support new elements of the observing system. A critical role of the Framework SG will be to support effective linkages across the various elements of the Framework and with the external stakeholder community.

The Task Team recommends the Framework SG be highly flexible, characterized by simplicity, based primarily on functional needs, focused on bringing together stakeholders throughout the community, and operating with nominal associated costs. The Framework SG should be regularly self-reviewed, periodically externally reviewed, and its terms dictated by the remaining progress required to reach a governance process endorsed by the broad international ocean observing community.

In some cases – such as in addressing the needs of the ocean biology and ecosystems communities – implementing the Framework almost certainly requires the establishment of bodies that do not yet exist. The Task Team recommends that three expert Ocean Observing Panels be charged with providing guidance in the areas of physical ocean variables, biogeochemical ocean variables, and a panel dedicated to biological and ecosystem variables.

The first two of these panels can be built on the existing structures of the OOPC and IOCCP. The final panel on biology and ecosystem variables does not exist and will need to draw on the experience gained in the past decade in research ocean observations in this domain. It will be able to draw on the PICO plan which links a number of specific societal issues with the variables and observing systems needed to address them.

These panels will work with observing element teams to guide collaboration and the proliferation of best practices. It is envisioned that many of the best practices drawn from the physical ocean variables arena can be used as tools to guide the adoption and refinement of best practices by other communities. A viable structure to guide this sort of organizational change and to optimize implementation of the Framework requires coordination with many observing system elements and sponsoring organizations.

The work of these panels will be in oversight of the Framework processes described in the next section.

**Governance Structure for Sustained Global Ocean Observing**

**Framework Steering Group Members / Appointed by Sponsors**

- |                          |  |
|--------------------------|--|
| Oversight & Coordination | <ul style="list-style-type: none"> <li>• Management</li> <li>• Review/Development of Requirements</li> <li>• Convention Negotiation</li> <li>• Facilitate Community-wide Coordination and Alignment</li> <li>• Endorsement of Mature Elements</li> </ul> |
|--------------------------|--|

**Ocean Observing Panels / Appointed by Steering Group**

- |                                   |   |   |
|-----------------------------------|---|---|
| Physical Panel<br>• Build on OOPC | BioGeoChem Panel<br>• Build on IOCCP and related projects   | Bio/Ecological Panel<br>• Could draw on PICO Plan |
| Expert Reviews                    | <ul style="list-style-type: none"> <li>• Develop new EOVS</li> <li>• Articulate Best-practices</li> <li>• Assess Readiness Levels</li> <li>• Review and ensure fit-for-purpose system outputs among EOVS</li> <li>• Develop Implementation Strategies</li> <li>• Coordinate National, Regional, Local Activities</li> </ul> |   |

**EOVS Expert and Implementation Teams / Identified by Steering Group & Panels**

- EOVs: SST / Sea Level / pCO<sub>2</sub>\* / Plankton\*/ Alkalinity\* / Transport\* / Other\* (\*-potential)
- |  |   |
|--|---|
| Observing Element Implementation Teams | <ul style="list-style-type: none"> <li>• Improve Readiness Levels (Design Pilots, New Products)</li> <li>• Develop Implementation Plans</li> <li>• Improve Literacy (Train experts, Educate Users, Facilitate Integration)</li> <li>• Coordination</li> </ul> |
|--|---|

**Figure 7. A Potential Governance Structure.** The Task Team recommends alignment of existing structures and engagement of sponsors in creating new needed bodies. The structure will be negotiated by all the stakeholders, and will evolve over time. This potential structure assumes the expansion of many already existing groups and the formation of some new ones.

## 5. PROCESSES OF THE FRAMEWORK

Using the Framework processes will provide a vehicle for organizing the ocean community’s approach to justifying, planning, and funding observations and analyses at a global scale while maximizing the use of already existing local and regional organizations.

In practice, activities of individuals and organizations within the Framework will be to gauge the readiness of requirements, observation elements, and data and information products. Those seeking to incorporate a new observation into the sustained global observing system will need first to mature the associated requirements for acceptance, mature their measurement technology for inclusion, and mature their data and information products for appropriate accessibility and application to a range of scientific and societal issues.

Readiness Level	Requirements	Observations	Data & Information
<b>Highest Readiness Level</b>			
<b>Mature</b>	Measurement validated through peer review, implemented at regional and/or global scales and capable of being sustained.	Following validation of observation via peer review of specifications and documentation, system is in place globally and indefinitely.	Validation of data policy via routinely available and relevant information products.
<b>Pilot</b>	Measurement and sampling strategy verified at sea. Autonomous deployment in an operational environment.	Establishment of international governance mechanism, international commitments, and sustaining components. Maintenance and servicing logistics negotiated.	Data management Practices determined and tested for quality and accuracy throughout the system. Creation of draft data policy.
<b>Concept</b>	Need for information identified and characteristics determined. Feasibility study of measurement strategy and technology.	The system is articulated, capability is documented and tested. Proof of concept validated by a basin scale feasibility test.	Data model is articulated, expert review of interoperability strategy. Verification of model with actual observational unit.
<b>Lowest Readiness Level</b>			

**Figure 8. Framework Processes and Readiness Levels.**

*Requirements, Observations, and Data & Information products move through readiness levels within the Framework. Each component will experience rigorous review, vetting, and approval by the community before reaching the highest level of readiness. This process will allow for innovation while protecting the system from inadequate or duplicative solutions.*

This process will part of a repeating cycle that starts with examining the requirements for a particular societal benefit, developing implementation plans (which implies assessing the readiness of observing networks, including the feasibility and usefulness of a measurement approach), assessing the data management efforts, and assessing the fitness of the products in meeting the original requirements.

For each EOVS, the Framework processes will provide for the public record a fully-vetted set of requirements, including measurements to be made, an assessment of various observing options to address

the requirements, the feasibility/maturity of the sampling approaches, and associated sampling costs.

A more detailed description of these processes is provided in Figure 9.

## FRAMEWORK PROCESSES BY READINESS LEVELS

Readiness Levels	Requirements Processes	Coordination of Observational Elements	Data Management & Information Products
<b>Mature</b>			
Level 9 "Sustained"	Essential Ocean Variable: <ul style="list-style-type: none"> <li>Adequate sampling specifications</li> <li>Quality specifications</li> </ul>	System in Place: <ul style="list-style-type: none"> <li>Globally</li> <li>Sustained indefinitely</li> <li>Periodic review</li> </ul>	Information Products Routinely Available: <ul style="list-style-type: none"> <li>Product generation standardized</li> <li>User groups routinely consulted</li> </ul>
Level 8 "Mission qualified"	Requirements "Mission Qualified:" <ul style="list-style-type: none"> <li>Longevity/stability</li> <li>Fully scalable</li> </ul>	System "Mission Qualified:" <ul style="list-style-type: none"> <li>Regional implementation</li> <li>Fully scalable</li> <li>Available specifications and documentation</li> </ul>	Data Availability: <ul style="list-style-type: none"> <li>Globally available</li> <li>Evaluation of utility</li> </ul>
Level 7 "Fitness for purpose"	Validation of Requirements: <ul style="list-style-type: none"> <li>Consensus on observation impact</li> <li>Satisfaction of multiple user needs</li> <li>Ongoing international community support</li> </ul>	Fitness-for-Purpose of Observation: <ul style="list-style-type: none"> <li>Full-range of operational environments</li> <li>Meet quality specifications</li> <li>Peer review certified</li> </ul>	Validation of Data Policy <ul style="list-style-type: none"> <li>Management</li> <li>Distribution</li> </ul>
<b>Pilot</b>			
Level 6 "Proven capacity"	Requirement Refined: <ul style="list-style-type: none"> <li>Operational environment</li> <li>Platform and sensor constraints</li> </ul>	Implementation Plans Developed: <ul style="list-style-type: none"> <li>Maintenance schedule</li> <li>Servicing logistics</li> </ul>	Demonstrate: <ul style="list-style-type: none"> <li>System-wide availability</li> <li>System-wide use</li> <li>Interoperability</li> </ul>
Level 5 "Verification"	Sampling Strategy Verified: <ul style="list-style-type: none"> <li>Spatial</li> <li>Temporal</li> </ul>	Establish: <ul style="list-style-type: none"> <li>International commitments and governance</li> <li>Define standardized components</li> </ul>	Verify and Validate Management Practices: <ul style="list-style-type: none"> <li>Draft data policy</li> <li>Archival plan</li> </ul>
Level 4 "Trial"	Measurement Strategy Verified at Sea	Pilot project in an operational environment	Agree to Management Practices: <ul style="list-style-type: none"> <li>Quality control</li> <li>Quality assurance</li> <li>Calibration</li> <li>Provenance</li> </ul>
<b>Concept</b>			
Level 3 "Proof of concept"	Proof of Concept via Feasibility Study: <ul style="list-style-type: none"> <li>Measurement strategy</li> <li>Technology</li> </ul>	Proof of Concept Validated: <ul style="list-style-type: none"> <li>Technical review</li> <li>Concept of operations</li> <li>Scalability (ocean basin)</li> </ul>	Verification of Data Model with Actual Observational Unit
Level 2 "Documentation"	Measurement Strategy Described <ul style="list-style-type: none"> <li>Sensors</li> <li>Sensitivity</li> <li>Dependencies</li> </ul>	Proof of Concept: <ul style="list-style-type: none"> <li>Technical capability</li> <li>Feasibility testing</li> <li>Documentation</li> <li>Preliminary design</li> </ul>	Socialization of Data Model <ul style="list-style-type: none"> <li>Interoperability strategy</li> <li>Expert review</li> </ul>
Level 1 "Idea"	Environment Information Need and Characteristics Identified: <ul style="list-style-type: none"> <li>Physical</li> <li>Chemical</li> <li>Biological</li> </ul>	System Formulation: <ul style="list-style-type: none"> <li>Sensors</li> <li>Platforms</li> <li>Candidate technologies</li> <li>Innovative approaches</li> </ul>	Specify Data Model <ul style="list-style-type: none"> <li>Entities, Standards</li> <li>Delivery latency</li> <li>Processing flow</li> </ul>

Figure 9. A Detailed View of Framework Processes for Varying Levels of Readiness.

## 5.1 REQUIREMENTS PROCESSES

By reviewing requirements according to EOVs, rather than within individual observing elements, the Framework allows for innovation in observing technology, encourages tradeoffs where possible, and focuses the observing system on sustaining quality observations of the natural system, regardless of how the underlying observing techniques and programs may change over time. This focus on EOVs will improve continuity of the data stream required to detect and understand long-term trends.

For an observation requirement to drive a sustained global observing effort, it must be reviewed within the Framework according to several criteria: an impact assessment of its contribution to scientific knowledge and/or societal issues; the feasibility, maturity and sustainability (readiness) of the observing technology (refined by individual scientists, national programs, and international pilot projects); and the costs.

To justify a global observation, a requirement must be quite broadly accepted and the need articulated at the international level. To justify observing over a sustained period, a requirement must be defined in a manner independent of specific technologies or implementation approach. Proponents of new requirements will need to engage in discussions with stakeholders of existing observation elements to ensure any case for creating a new observation element will include an evaluation of its added value. This will be an iterative and adaptive process involving regular re-evaluation informed by new knowledge, technologies, issues and priorities.

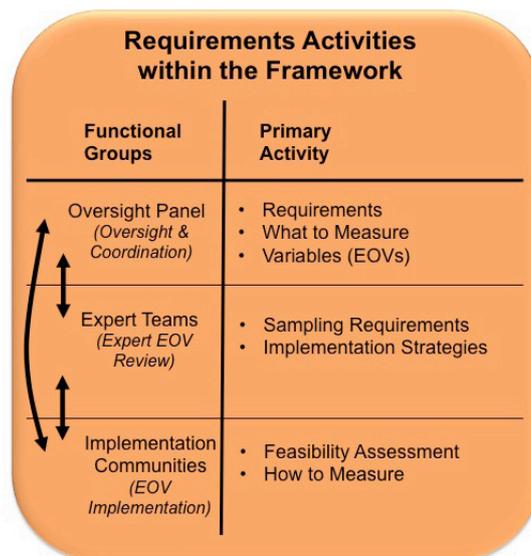
Once a requirement for a new EOV is widely accepted through the Framework processes, maturation of the observation approach for that EOV can be initiated. This will include limited deployment to determine technology feasibility, proposal of a realistic management structure to deploy, sustain and upgrade the observation element, and an assessment of the resources required versus the benefits gained.

Regional requirements will be driven by regional priorities. Setting these at a regional level while remaining mindful of the Framework concepts and broader global context will maximize connections between global and regional observations, and in so doing will support the broader assessment of ocean processes and health. Aligning with the Framework’s best practices will bring benefit to both global and regional levels.

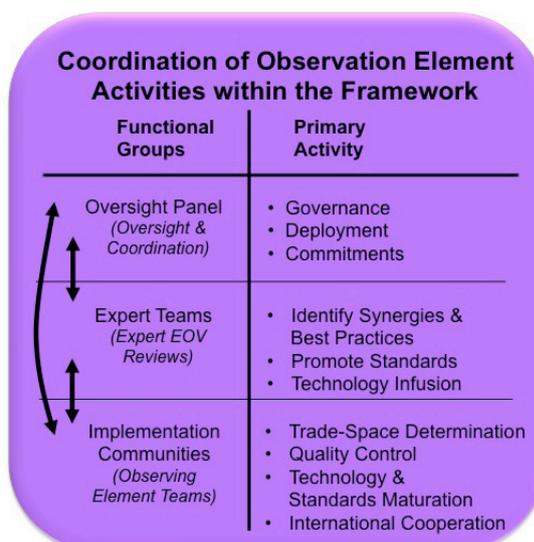
## 5.2 COORDINATION OF OBSERVATION ELEMENTS

Ocean observations are the core of the Framework. Major elements of physical, chemical, geological, biological and ecological observing already exist. Use of the Framework will better connect all these observational elements into a broad requirements process and into assessments of the design and delivery of data and products. It will also promote feasibility testing of new observation technologies, the integration of new observing approaches, the coordination of observing element deployments, and the use of common standards and best practices,

An alignment with an EOV (or EOVs) within the Framework is the mechanism through which feasibility and impact of proposals for new or upgraded observation elements will be assessed. Operating within the Framework becomes a



**Figure 10. Requirements Setting within the Framework.** The types of ocean observing groups that need to align to define requirements for a given EOV. Arrows represent communications among groups; often the same individuals will perform multiple roles at various levels. The spatial and temporal scales required will be agreed and articulated through the Framework processes.



**Figure 11. Deployment/ Maintenance of Observing Elements within the Framework.** The types of ocean observing groups that need to align to assess/implement a new capability that meets the measurement requirements of an EOV. Arrows represent communications among groups; often the same individuals will perform multiple roles at various levels. Observations will be provided to the data management community based on agreed-upon archival and dissemination standards and formats.

function of gauging the readiness of an observation element relative to its potential to improve the knowledge or understanding of an EOV, with clear support to both research and societal concerns. This will help individual observing networks argue for sustained funding, while allowing for system innovation across the global Framework.

### 5.3 DATA MANAGEMENT AND INFORMATION PRODUCTS

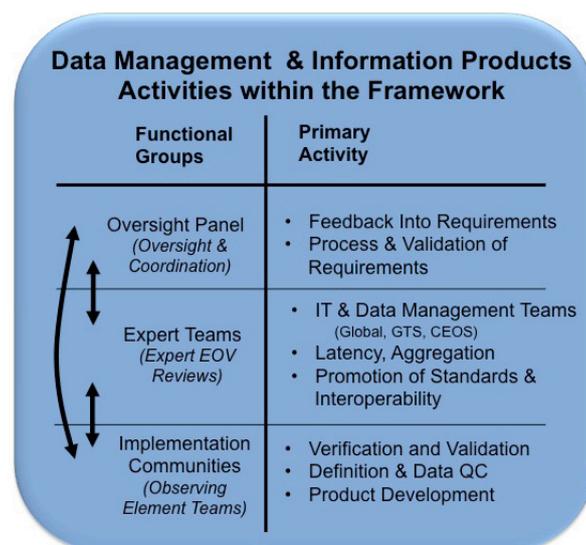
As the outputs of the Framework, data and information products will be the interface for most users. Ocean information products are required to support both research and decision-making in diverse areas such as climate studies and adaptation, disaster warning and mitigation, commerce, and ecosystem-based management. Beyond the observation elements there are many modeling, data assimilation, synthesis, and assessment activities that will provide added value to observations and meet specific user requirements for information. Broad dialog among Framework participants will assist in identifying what partnerships are required to create the information needed to support scientific discovery and address societal decisions.

Using the Framework will promote widespread stakeholder input into the best approaches for data management and dissemination, including global data availability, open/modular information platforms that enable optimal user access, and technologies that enable the development of third-party access tools. It will also provide a robust forum for user feedback to assess how clearly and completely all EOV data sets in the global ocean observing system are identified, described, and documented. In addition, Framework processes will include publicly-available data usage metrics to reflect the level of demand for and breadth of uses for different data types, and the need for improvements in data access, quality, and products.

Data management groups within the Framework will be recognized for their successes in all of these important areas. Traditionally, information about and recognition for the providers of sustained global observations are often lost in the process of collating information from multiple sources, so ensuring recognition for data providers will be a difficult but important challenge. The Task Team recommends the use of Digital Object Identifiers (DOI) for data publication and identification, so the source of critical observations can be made clear in information products.

There are also strong communities developing ocean data syntheses, models, and assessments—processed information of broader utility. There is a broad range of such activities, at the edge of the system the Framework covers. Their readiness should also be promoted, and their feedback to the setting of observing requirements of the Framework is critical. These activities are part of the continuing cycle of assessing and updating the requirements, the measurement approaches, and the data and information products addressed by the Framework.

Wide participation in the Framework will facilitate the important work being done to collaborate across disparate observing systems and to foster more wide-spread awareness and coordination of available data products across a broadening user base, including the assimilation and modeling communities. It will enable increased understanding and articulation of linkages among various EOV observations, supporting wider use and stronger justification for their data collection efforts. And while not all data collected will become a part of the global sustained observing system, consideration should be given to the potential for this eventual outcome. All of these activities are also important mechanisms to narrow the gap between developed and developing countries with respect to ocean observations.



**Figure 12. Managing Data and Information Products within the Framework.** The types of ocean observing groups that need to align to acquire, disseminate, and manage data received from the observing infrastructure. Arrows represent communications among groups; often the same individuals will perform multiple roles at various levels. The aggregation, quality control, dissemination, and/or product design will be measured against end user needs to address both societal and scientific concerns.

## 6 APPLYING THE FRAMEWORK PROCESSES

With the growing societal need for long-term data records, especially given the threats to ocean ecosystems, the need for coordinated global observing efforts has never been more critical. Three global ocean observation communities are reviewed below—spanning the fields of ocean physics to biology, and ranging from mature to early stages of development for a global ocean observing capability – to illustrate how the Framework’s principles and processes will be applied.

### Sea Surface Temperature

Sea Surface Temperature (SST) is a key variable that supports weather prediction, ocean forecasting, and coupled ocean-atmosphere variability leading to understanding and forecasting short- and long-term climate variability. The historical record of ocean surface temperature is the longest of any ocean variable, and because of its multiple uses, is measured by many different observing elements.

**REQUIREMENTS** The Ocean Observations Panel for Climate (OOPC) has negotiated requirements for the observation of SST for climate monitoring, research, and forecasting and reported them to the United Nations Framework Convention on Climate Change (UNFCCC) through GCOS. The World Meteorological Organization (WMO) maintains a database of observational user requirements - including SST in particular - for WMO Applications (e.g. numerical weather prediction, marine services, climate monitoring and applications, seasonal to inter-annual climate forecasting, and hydrology) as a part of its “Rolling Review of Requirements.” The Group for High Resolution Sea Surface Temperature (GHRSSST) Working Group has also identified requirements from a number of different user communities for high resolution SST products. Global requirements for SST, and the processes for adjudicating them, are thus quite mature.

**OBSERVATIONS** SST is measured by numerous satellite platforms and sensors, calibrated primarily by observations from drifting buoys, and platforms such as moorings, Argo profiling floats, volunteer and research ship observations. OOPC, GHRSSST, satellite teams, the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) Observations Programme Area, and the larger research community all have a role to play in the process of negotiating which observing elements measure SST, and evaluating their spatial resolution, accuracy, and feasibility.

**DATA AND PRODUCTS** GHRSSST plays an important role in the generation and evaluation of high resolution SST products, in cooperation with research groups, weather services worldwide, and data management systems for individual observing elements. The data are widely available for use in models and other information-generation tools as well as to individuals.

Sea Surface Temperature is an EOVS with a mature set of processes already aligned with principles of the Framework, and can serve as a model for other EOVS. There is room for improvement, however, with some overlap and duplication of functions for which use of the Framework can help facilitate improved communications and negotiations.

### Ocean Carbon/Ocean Acidification

The ocean functions as a key element of the global carbon cycle. It is a carbon sink, and has absorbed about half of the historical anthropogenic (human-produced) emissions of carbon, significantly dampening climate warming in the atmosphere. As a consequence, however, the ocean has become about 30% more acidic since the start of the industrial revolution, with some demonstrated but complex consequences for ocean ecosystems.

**REQUIREMENTS** The OOPC, with the International Ocean Carbon Cooperation Project (IOCCP) and various other observing networks, has negotiated the requirements for measurement of ocean carbon variables in response to the UNFCCC. While ocean carbon requirements are relatively mature today, further requirements related to ocean acidification will be needed to support the Convention on Biological Diversity and the just-formed Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), to answer societal questions about how ocean ecosystem changes might impact them.

**OBSERVATIONS** Sustained ocean carbon system observations are made up of surface flux observations, repeat ocean hydrography, and time-series stations, and are driven by long-term research funding.

Hydrographic surveys have lacked a formal global organization since the end of the World Ocean Circulation Experiment (WOCE), leading to a decrease in the number of trans-basin sections, duplication

of some sections, no consistent suite of core variables, inconsistent data analysis procedures, variable data quality, and disparate data sharing policies. Responding to the increased need for both surface and sub-surface measurement, an initiative was proposed at the OceanObs'09 meeting in Venice to develop a coordinated program for hydrographic cruise coordination called the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP). An integrated observing system is important for the ocean carbon cycle: for example research-quality hydrographic and carbon data from ships can be used to calibrate Argo float data, and the ships can be used for deployment of drifter and profiling floats, providing potential cost-sharing opportunities.

Observations of the impact of ocean acidification on ocean ecosystems are research-driven, regional, and often focused on processes. The observing requirements for ocean acidification are starting to be discussed broadly in the community.

**DATA AND PRODUCTS** Several ocean carbon observing networks have made varying arrangements for the quality control and management of data, which are not uniformly available to the wider community. Modeling and synthesis efforts are firmly within the research domain and not always accessible to those outside the effort. A larger role for IOCCP through the Framework can coordinate a review of ocean carbon data systems and products, including additional partners in international research programmes as new requirements for biogeochemical EOVs are examined.

The ocean carbon community is already using many of the Framework concepts, and has elements already functioning at a fairly high readiness level, but additional emphasis on coordination and negotiation through the Framework will provide added benefits, in particular linking their findings to those of other disciplines.

## Zooplankton

Zooplankton are a critical component at the base of the food web of ocean ecosystems. Changes in their abundance can be linked to changes in the abundance of both phytoplankton and commercially-exploited fish species, and their distributions often respond to changes in ocean temperature, stratification, circulation, and seasonality.

**REQUIREMENTS** While there are many research efforts being conducted, there is currently no international group responsible for setting requirements for the global measurement of zooplankton abundance and composition. Requirements for these observations are currently set by national or regional groups for their own needs in limited areas, but there is a growing need to develop global observation requirements to support international agreements such as the Convention on Biological Diversity (CBD), the UN Commission on Sustainable Development (CSD) and now the UNFCCC, since zooplankton change with the climate impacts of warming/stratification, acidification, and de-oxygenation. The Task Team recommends that zooplankton variables such as abundance, size, and taxonomic composition be addressed through Framework processes as EOVs for sustained global observation.

**OBSERVATIONS** Zooplankton are collected routinely in regional fishery organization surveys, and in Continuous Plankton Recorder (CPR) surveys. Acoustic and optical measurements are increasing—from ships, gliders, and moorings—but not in a coordinated way. The Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which has been conducting long-term CPR studies in the North Atlantic, launched a Global Alliance of CPR Surveys (GACS) in September 2011. Framework processes will support this community in further developing standards for global sampling frequency, method(s), size range(s) and depth(s).

**DATA AND PRODUCTS** Framework processes will also assist this community in resolving global policies for analysis resolution, and data management to support ecosystem-based management and broad policies related to fishing and ocean acidification.

Zooplankton EOVs for a sustained global ocean observing system are increasingly needed and have great potential to move to a higher readiness level. The groups involved in zooplankton observations are currently in the concept and pilot phases. The use of Framework processes will support maturation and integration of these efforts into the broader suite of ocean observations, which will provide profound opportunities for new discovery and decision-making.

	SST	Ocean Carbon/ Ocean Acidification	Zooplankton
<b>Requirements Setting</b>			
Oversight & Coordination	GCOS WMO (rolling review)	Origin UNFCCC Biodiversity Conv IOCCP -4 carbon species pH, TC, Alk, pCO <sub>2</sub>	Individual observing groups Fisheries research; ICES
Expert Reviews	Climate Community CAL/VAL Team GHRSSST Meteorological Community	OCB/EPOCA/IOCCP	Fisheries and Oceanography Survey Programs; GACS, M&CM, IMARPE, IFREMER, AZTI, DFO, CalCOFI
Observing Element Teams	Proposed Constellation • Satellite • in situ Sensor Platform Mix	In situ Sensor and Platform mix Go-SHIP SOCAT OceanSITES Round Robin cal/val	(a) biomass of zooplankton of specific size range, (b) number of species or diversity index and (c) slope of size spectrum
<b>Observation Deployment &amp; Maintenance</b>			
Oversight & Coordination	JCOMM-OCG Bodies	IOCCP and sub-panels	Needs a global governance structure
Expert Reviews	GHRSSST Science Team Research Community • Scripps • NOAA AOML Many Satellite Teams	Intercalibration Common Reference Standards (gases and Seawater)	<ul style="list-style-type: none"> <li>• Fisheries surveys (nets, acoustics)</li> <li>• Optical imaging developing</li> <li>• Some common standards and practices</li> </ul>
Observing Element Teams	NOAA Climate Observation Met Services DBCP, VOS, SST VC, Argo Sea Mammals	Go-SHIP SOCAT OceanSITES OCB/EPOCA	<ul style="list-style-type: none"> <li>• Ship-based sampling floats and gliders, moorings</li> <li>• Implementation communities (programs): include GACS, CalCOFI, M&amp;CM, IMARPE, IFREMER, AZTI, NOAA NMFS, DFO, ICES</li> </ul>
<b>Data &amp; Information Creation</b>			
Oversight & Coordination	GHRSSST GDAC	CDIAC assembly QC by implementation bodies	
Expert Reviews	Research Groups Met Services MISST, OI STT Reynolds SST New products: ongoing	IOCCP	<ul style="list-style-type: none"> <li>• Time series of zooplankton abundance, composition, and size structure, e.g., SCOR WG125 on zooplankton time series</li> </ul>
Observing Element Teams	OOPC WMO GHRSSST ISDM (archive)	IOCCP/GCP	

**Figure 13. Examples of Applying the Framework.** Specifics of how activities of three potential EOVs might align under Framework processes.

The SST example highlights the benefits to be realized by regular, concerted efforts targeted toward common, well-articulated, global goals. Participation in the Framework processes will continue this community's mature activities, but will also improve interfaces with other ocean observation communities.

The Ocean Carbon example illustrates how a common Framework may assist in a more integrated evolution of observing requirements and technologies. Alignment with the Framework will assist this community in identifying key areas where focus is required, and can assist with the allocation of resources.

The Zooplankton example demonstrates how a community at relatively low levels of maturation will benefit from aligning with the Framework to determine what standardization is required for a global system, and to facilitate the communication and negotiations needed for their definition and adoption.

These examples illustrate the need for establishment of, and communications among, bodies such as oversight panels, EOv expert teams, and implementation groups for observing elements. Within a Framework aligned according to EOVs, the optimal role for each of these bodies will be more readily identifiable. Alignment with the Framework will allow for a transitioning of many ocean observing groups to more streamlined organizational structures, fit for the task.

## 7 IMPLEMENTATION – RECOMMENDED NEXT STEPS

Through numerous Consultative Drafts, the Task Team has made a number of specific recommendations regarding suggested next steps for the sponsoring bodies toward alignment with the Framework. The Task Team's recommendations are shown here in full, though many of the organizations cited are already evolving to address the Framework.

### 7.1 FRAMEWORK STEERING GROUP

*The Task Team recommends:*

- **Creation of a Framework Steering Group**

In response to consultative drafts of this Framework for Ocean Observing report, as well as other reviews of the GOOS governing structures, a year-long effort by the Board of the Intergovernmental Committee for GOOS (I-GOOS) led to the proposal of a streamlined and strengthened GOOS, enacted by the 26th session of the International Oceanographic Commission (IOC) Assembly in Resolution XXVI-8 (adopted 5 July 2011). The Resolution focuses GOOS as a holistic system encompassing global, regional and coastal observations and products, and aligned with a Framework for Ocean Observing using an EOVS approach. It directs GOOS to set requirements based on the needs of global conventions and agreements in climate, natural hazards, biodiversity, safety of life at sea, marine assessment, and regional conventions, and to reinforce global participation through capacity development.

Former IOC bodies responsible for the governance of GOOS, including I-GOOS, the GOOS Scientific Steering Committee (GSSC), and its subsidiary panels, were dissolved on 31 December 2011. Replacing these, a new GOOS Steering Committee was created on 1 January 2012. Its membership includes: five experts appointed by IOC Member State electoral groups; up to 10 scientific and technical experts appointed by the IOC Executive Secretary in consultation with the IOC Officers and co-sponsors of GOOS; and the chairs of appropriate coordinating and implementing bodies as ex officio members. The first meeting of the GSC is planned for June 2012.

The goal of the IOC Secretariat is to offer and position the GOOS Steering Committee (GSC) as the Framework Steering Group. In this capacity it will:

- Work in the widest way practicable to include international initiatives that are stakeholders in the ocean observing system (including all of the sponsors of this document)
- Clarify and streamline GOOS management and functions modeled on the Framework
- Build on the achievements and strengths of existing bodies formally under GOOS and, in partnership with others, recommend changes in management in a stepwise and stable manner
- Ensure that Framework processes are in place to identify requirements based on scientific and societal needs; coordinate observing networks with a focus on encouraging integration; and encourage coordination of data systems and products
- Assess the readiness of requirements, observing systems, data systems and products through subsidiary Ocean Observing Panels based on existing groups such as OOPC and IOCCP, and the joint creation of new ones as needed
- Assess the overall fitness-for-purpose of GOOS to meet societal needs, engaging with key stakeholders outside the Framework
- Work with partners to assess regional requirements and capacity, with the goal of identifying tractable capacity-development projects.
- Foster an adherence by ocean observing communities to Framework principles

The success of this positioning will depend on the wide engagement and entrainment of ocean observing communities at the international and regional levels into a common Framework for Ocean Observing, and the avoidance of duplicative efforts through this wide cooperation. High-level efforts to engage with external stakeholders led by POGO and GEO must be effectively linked with the work of the GSC. The initial GSC will be an evolving body, with its terms dictated by the progress required to reach an agreed-to and functional governance structure.

## 7.2 FRAMEWORK ELEMENTS

There are 12 international sponsors of the Task Team and all will have a role to play in building the Framework, along with many other international, regional, national and local groups. Following are some recommended next steps, based on existing stable structures, that can move the global ocean observing community toward a more inclusive, more integrated, and more capable state, by aligning with the Framework.

### 7.2.1 REQUIREMENTS

Requirements for the sustained global ocean observing system come generally from two sources. Both society at large and science in particular will need to organize in order to set and prioritize requirements within the Framework and align requirements documents and implementation plans with data products.

#### Societal Needs

Requirements are placed on the system by societal needs from various conventions, such as the reports on Essential Climate Variables (ECVs) developed by GCOS. This example, where GCOS developed the concept of ECVs for the UNFCCC as an infrastructure for organizing and reporting on requirements and adequacy of measurements, is a well-known and strong example for the Framework. GCOS works with GOOS and WCRP through their joint OOPC to ensure that requirements respond to climate science needs, as well as addressing policy needs. Similarly, the Scientific Committee on Oceanic Research (SCOR)-IOC International Ocean Carbon Coordination Project (IOCCP) works with OOPC to develop requirements for ocean carbon variables.

*The Task Team recommends:*

- **Framework partners extend their dialogue on requirements to other conventions such as the Convention on Biological Diversity (building on the experience of the Census of Marine Life), or emerging assessments such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), and a UN World Ocean Assessment (the ‘Regular Process’).**
- **Evolve requirements for the UNFCCC to support climate adaptation as well as mitigation agendas, and strengthen requirements dialogues for ocean-related services.**
- **Continue engagement with JCOMM to negotiate improved implementation against requirements for real-time services, including the emerging Global Framework for Climate Services (GFCS).**
- **Strengthen engagement at the regional level with Large Marine Ecosystems, Regional Seas conventions and action plans, and other regional ocean environmental management bodies to identify specific observing requirements and capacity.**

#### Science Needs

The existing structures described in Figure 13 serve the purpose of identifying scientific requirements for sustained observations, but thus far they are focused primarily on physical ocean variables required to better understand climate.

*The Task Team recommends:*

- **Better engagement of International Geosphere-Biosphere Programme (IGBP) as it evolves into a ‘Future Earth’ programme of science for sustainability, SCOR, and other relevant groups to explore requirements for non-physical, non-carbon ocean variables.**
- **Regional groups such as North Pacific Marine Science Organization (PICES), the International Council for the Exploration of the Seas (ICES), and GOOS Regional Alliances provide input on requirements for sustained ocean observations in their domains of interest.**

### 7.2.2 OBSERVATIONS

Within observation elements, two very distinct activities are required. First to identify and align observing elements with EOVS requirements, and second to balance the sustained measurement needs of the observing system with the need for innovation and research. The ocean observing community is currently addressing regional, national and global needs of the observing system and providing expert scientific advice. For physical variables, the OOPC and the JCOMM Observations Coordination Group (OCG) are focal points for these activities, as is the IOCCP for ocean carbon variables.

*The Task Team recommends:*

- **Expansion of this type of EOV activity within the Framework for biogeochemical and ecosystem variables, building on the IOCCP and the work of PICO, to mediate among all the relevant observing networks and determine an agreed-to set of EOVs.**

## EOV Needs

Addressing EOV requirements within the Framework may involve working on products for a particular variable such as GHRSSST; or on a particular observing network oriented around a platform such as the Data Buoy Coordination Panel (DBCP) for surface drifting buoys; or with networks that exist at a global level and are focused around an observing platform, such as Argo. Examples of existing EOV teams include GHRSSST for SST, Ocean Surface Topography Science Team (OSTST) and GLOSS for sea level, the International Ocean Colour Coordinating Group (IOCCG) for ocean color, along with the Committee for Earth Observation Satellites (CEOS) virtual constellation teams working across ECVs. It is within these excellent examples where efforts of coordination among regional, national and global systems occurs as required to measure an ocean variable.

*The Task Team recommends:*

- **Groups in this area take the responsibility for defining EOVs, which will require a high degree of informal collaboration among these distinct disciplinary groups.**
- **Rescoping of the OOPC to address physical variables, with the added responsibility for providing advice on requirements and evaluating fitness-for-purpose of information, in cooperation with other relevant groups.**
- **Maintenance of the JCOMM OCG, with a particular focus on the development of cross-network collaboration, standards, and best practices.**
- **Broadening of the scientific disciplines of IOCCP to include biogeochemistry, and to strengthen their role in providing scientific advice on requirements, implementation, and fitness-for-purpose for related EOVs, engaging new communities and sponsors.**
- **Formation of an Ocean Observing Panel for Biology and Ecosystems Variables, potentially co-sponsored by GOOS, IGBP, SCOR, and others, with the goal of strengthening scientific advice on requirements, implementation, and fitness for purpose of biological EOVs. It should draw on the work of PICO, whose final report links observing requirements for ecosystem variables in the coastal ocean to societal drivers.**

## Research and Innovation Needs

There is no group today that considers the balance between the global, sustained, ocean observing system and the need for innovation and research. Typically this is done individually by each community involved in ocean observations. Two examples are SCOR, which has sponsored the working group OceanScope to promote innovation in commercial ship-based observations, and Argo which is exploring options for deep profilers and new telecommunications systems.

*The Task Team recommends:*

- **Groups such as WCRP, IGBP, SCOR, the Life in a Changing Ocean programme (follow-on to the Census of Marine Life), and others continue to increase the readiness levels of observing networks and components, with the goal of assessing their benefit to the sustained observing system, providing an ocean observing legacy, when required, after research projects are completed.**

### 7.2.3 DATA AND INFORMATION PRODUCTS

The data and information products arena must address both internal and external demands. The desire to “measure once and use many times” requires that standards be developed and adopted by observing components. These efforts are now loosely federated under a variety of international entities: the JCOMM Data Management Coordination Group, the IODE focus on physical and biological data, the IOCCP for ocean carbon, and the Ocean Biogeographic Information System (OBIS). Others promote development of ocean data information products, like JCOMM Services Programme Area groups, GODAE OceanView for ocean forecasting, and Climate Variability and Predictability (CLIVAR) Global Synthesis and Observations Panel (GSOP) for ocean synthesis/reanalysis.

## Data Management and Information Needs

Data and products generated within the global ocean observing system are required for a growing variety of scientific and societal uses. There is growing demand for new data quality, standards, and accessibility, as well as for new types of measurements and products.

*The Task Team recommends:*

- **The data management community develop a more concerted mechanism for identifying and implementing standardization and Quality Assurance/Quality Control (QA/QC) best practices in response to user needs to ensure these products are an increasingly valuable component of the sustained observing system.**
- **The data management, synthesis, information, and user communities increase their collaboration with and feed back into the requirements-setting mechanisms of the Framework. Expand the mandate of the OOPC, IOCCP-biogeochemical, and biology/ecosystems panels to assess data/information systems in cooperation with partners, provide advice on data/information products, and more stringently evaluate their fitness-for-purpose.**

## User Needs

Societal, scientific and operational user needs are currently being addressed by a variety of groups. For climate studies, this occurs through GCOS and WCRP activities of OOPC as it interfaces with scientific users. The importance of ocean observations is addressed in outreach efforts by GOOS, Partnership for Observation of the Global Ocean (POGO), SCOR, and the Group on Earth Observations (GEO).

*The Task Team recommends:*

- **Further efforts, through the Framework, to understand user needs for data and products in other societal benefit areas, and region-by-region.**

### 7.2.4 EDUCATION, OUTREACH AND CAPACITY BUILDING

Critical to success of the Framework is the creation of products and services that can be widely understood by members of the non-oceanographic community—policymakers, students at all levels, and the general public—as clear and intuitive visualizations or indices linked to phenomena of societal interest.

In many countries, the culture of decision-making based on scientific information is lacking. Capacity-building is needed to develop a scientific infrastructure capable of generating information of local use from a mixture of local and global data and analyses. While training related to the use of existing ocean products can generate short-term benefits, it is critical to develop a self-reliant scientific infrastructure within many countries that can translate scientific data for their local uses on an ongoing basis.

Not all nations can or will contribute to all components of the Ocean Observing System. The recommended systems approach, based on agreed EOVs, common standards and wide data sharing, allows investment in observations or information-generation at local, national and regional scales to contribute to a global system, with leveraged benefits returned to all contributors.

The Task Team recognizes that targeted capacity development in the area of local goals related to environmental management is needed to extend the benefits of the Framework to all nations and to maximize the utility of ocean information for human well-being.

*The Task Team recommends:*

- **In addition to the Ocean Obs '09 Community White Papers, develop education products to ensure both ocean and non-ocean scientists have a broader understanding of the complex interactions of the ocean with most other branches of science, as well as the major influence of the ocean in issues of societal importance.**
- **Develop outreach products that demonstrate the improvements to local decision-making on societal issues and responsible local economic development that can be realized from an investment in ocean observations.**
- **Focus on ways to support broad capacity building to: broaden the base of countries that can both benefit from and contribute to observations within the Framework; and, ultimately, to contribute to the development of an international generation of scientific leaders that can articulate the benefits of sound ocean science policies and practices.**

## 8 BENEFITS OF THE FRAMEWORK

As the Task Team developed a conceptual basis for the Framework, we received many reminders from community members in countries that currently don't invest heavily (or at all) in ocean observing that it must provide the basis for their nations to buy-in and begin to engage, even if only at small scales. Achieving this will provide both local and national as well as international benefits, and will ensure a widely useful and widely used global ocean observing system.

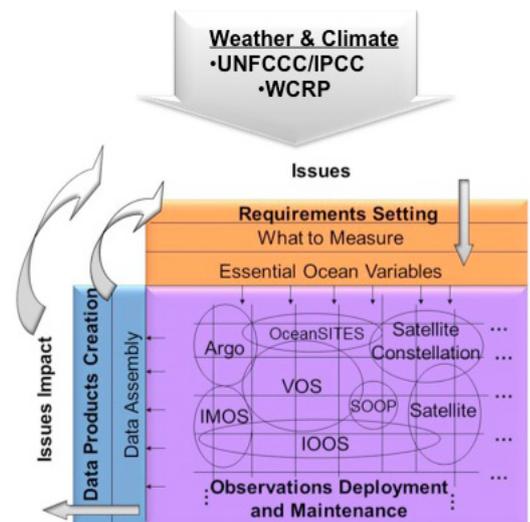
Aligning the ocean observing community's efforts within the Framework will allow for a consistent handling of requirements, assessment of readiness, implementation, and data standards for information sharing among different, largely autonomous, observing elements. Adherence to Framework processes will identify a well-defined set of requirements and goals; enable coordination within and among observing elements; streamline implementation of a sustained global ocean observing system through the use of agreed systems engineering best practices; and foster increased and more useful scientific support to an increasingly important suite of societal issues.

Through rigorous, standardized and widely agreed processes for using readiness assessments of requirements, observation plans, and data management plans, the Framework processes will create a firm foundation for promoting and vetting new initiatives. It will clarify how new observing elements can be incorporated into the observing system without compromising the success of existing elements.

Alignment with the Framework will require adjustments to the way some communities function, but these shifts will provide significant dividends. Operating within the Framework will provide widely-endorsed agreement on how well requirements are being met; joint deployment opportunities; broad exposure to cross-network progress in sensors and data management; and expanded use of each observation element through increased generation of multi-use data and information products.

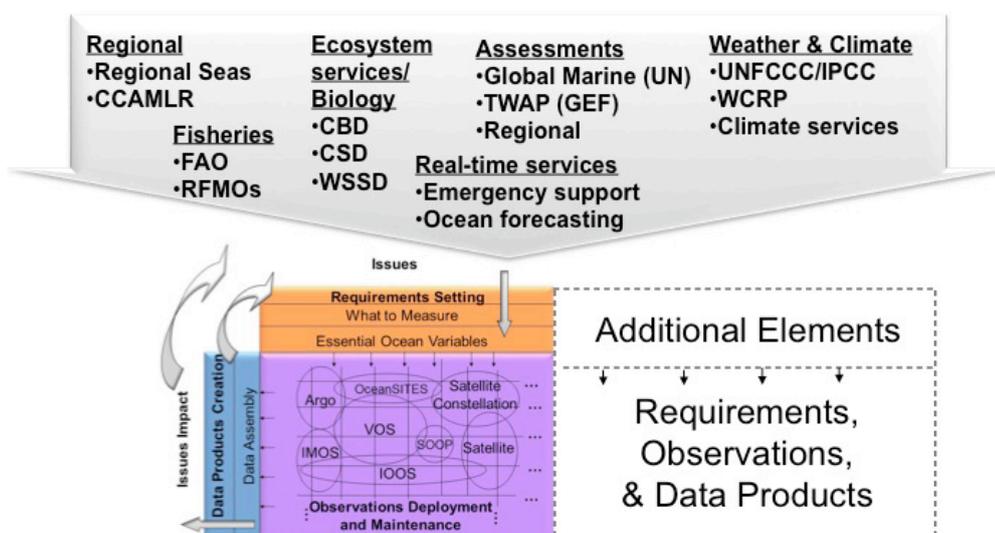
Approaching sustained ocean observations in an integrated manner will enable the development of a wide range of information products based on the data from a multifaceted observing system that are consistent and interoperable

### FRAMEWORK: SOCIETAL DRIVER 2012



**Figure 14. Benefits of Using the Framework.** Alignment of the requirement-setting processes, observing elements, and data and information systems will increase societal benefits of the ocean observing system, and generate broader support for ocean observations.

### FRAMEWORK: SOCIETAL DRIVERS NEXT DECADE



**Figure 15. Benefits of Using the Framework.** Alignment of the requirement-setting processes, observing elements, and data and information systems will generate broader support for ocean observations.

across domains and fields of application. This in turn will result in increased usage of ocean observations, and the cross-domain usage will also support quality assurance.

Using the Framework processes—with its organization based on EOVs, assessments based on readiness levels, and feedback loops between outputs and requirements – will provide the multiple benefits of promoting community-wide support for some new observation elements; designing an overall system better aligned with societal needs

and expanding applications; providing a clearer environment for deciding on design and funding of conceptual and pilot projects; and offering scientifically-vetted and broadly agreed upon plans for new observation elements to national and international funding organizations.

Through coordinated decision-making and the avoidance of duplicative efforts, the Framework will be the source of advocacy for sustained funding regionally, nationally, and internationally – to sustain and expand the physical and ocean carbon observing elements, and expand global observing of essential biological and ecological variables. It will also allow individual funding agencies to identify which observations align with their own priorities, targeting investment in what most interests them, while giving them the security of investing in an organized global system whose collective worth is greater than the sum of its parts.

Framework processes will promote ocean observing systems that provide more information “fit-for-purpose” to both science needs and societal applications. This added relevance will be a source of community unity, and the improved communications and data sharing across ocean science disciplines will allow important new scientific and societal discoveries that are not yet imagined.

## APPENDIX 1

### AFFILIATIONS OF THE TASK TEAM MEMBERS

Name	Expertise	Country	Primary sponsor link	other sponsor link
Keith Alverson	physical, observing systems	Intl.	IOC	GOOS
Bee Berx	physical oceanography for fisheries and environmental science	UK	ICES	
Peter Burkill	biology, plankton	UK	SCOR	
Francisco Chavez	biogeochemistry, ecosystems, coastal	USA	IGBP	
Dave Checkley	fisheries	USA	PICES	
Candyce Clark	observing systems	USA	JCOMM	
Victoria Fabry	acidification, plankton, biogeochemistry	USA	POGO	
Albert Fischer (secretariat)	physical, observing systems	Intl.	IOC	GOOS, JCOMM, WCRP
John Gunn*	biology, fisheries	Australia	CoML	POGO, SCOR, GOOS
Julie Hall	biology	New Zealand	IGBP	
Eric Lindstrom*	satellite oceanography	USA	GCOS	GOOS
Yukio Masumoto	physical oceanography	Japan	POGO	
David Meldrum	meteorology, physical, observing systems	UK	JCOMM	
Mike Meredith	polar regions	UK	SCAR	
Pedro Monteiro	carbon fluxes	South Africa	GOOS	
José Mulbert	biology, coastal	Brazil	GEO	GOOS
Sylvie Pouliquen	Real-time data systems	France	JCOMM	GOOS
Carolin Richter	climate observations	Intl.	GCOS	
Sun Song	marine ecosystems	China	POGO	
M. Tanner, R. Koopman, D. Cripe	climate / GEOSS	Intl.	GEO	
Martin Visbeck	physical oceanography, climate	Germany	WCRP	CLIVAR
Stan Wilson	satellite oceanography	USA	CEOS	

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### ADDITIONAL CO-AUTHOR AFFILIATIONS

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## APPENDIX 2

### ACRONYMS

Argo	Argo global profiling float array
AZTI	AZTI-Tecnalia - El Centro Tecnológico del Mar y los Alimentos
CalCOFI	California Cooperative for Oceanic Fisheries Investigations
CBD	Convention on Biological Diversity
CDIAC	Carbon Dioxide Information Analysis Center
CEOS	Committee on Earth Observation Satellites
CLIVAR	Climate Variability and Predictability (WCRP project)
CoML	Census of Marine Life
CPR	Continuous Plankton Recorder
CSD	Commission on Sustainable Development
DBCP	Data Buoy Cooperation Panel
DFO	Department of Fisheries and Oceans (Canada)
DOI	Digital Object Identifiers
EBV	Essential Biodiversity Variable
ECV	Essential Climate Variable
EOV	Essential Ocean Variable
EPOCA	European Project on Ocean Acidification
FOO	Framework for Ocean Observing
FSG	Framework Steering Group
GACS	Global Alliance of CPR Surveys
GCOS	Global Climate Observing System (WMO-IOC-UNEP-ICSU)
GCP	Global Carbon Project
GDAC	Global Data Archival Center
GEO	Group on Earth Observations
GEOBON	GEO Biodiversity Observation Network
GFCS	Global Framework for Climate Services
GHRSSST	Global High Resolution Sea Surface Temperature
GLOSS	Global Sea Level Observing System (IOC)
GODAE	Global Ocean Data Assimilation Experiment
GODAE OceanView	successor to GODAE focused on ocean forecast system research
GOOS	Global Ocean Observing System (IOC-WMO-UNEP-ICSU)
GO-SHIP	Global Ocean Ship-based Hydrographic Investigations Program
GSOP	CLIVAR Global Synthesis and Observations Panel
GSC	GOOS Steering Committee
GSSC	GOOS Scientific Steering Committee
ICES	International Council for the Exploration of the Sea
ICSU	International Council for Science (formerly, International Council of Scientific Unions)
IFREMER	French Research Institute for Exploration of the Sea
IFSOO	Integrated Framework for Sustained Ocean Observing Task Team
IGBP	International Geosphere-Biosphere Programme
I-GOOS	Intergovernmental Committed for the Global Ocean Observing System (IOC-WMO-UNEP)

IMARPE . . . . .	Instituto del Mar del Peru
IMOS . . . . .	Integrated Marine Observing System (Australia)
IOC . . . . .	Intergovernmental Oceanographic Commission of UNESCO
IOCCG. . . . .	International Ocean Colour Coordinating Group
IOCCP. . . . .	International Ocean Carbon Cooperation Project (SCOR-IOC)
IODE . . . . .	International Oceanographic Data and Information Exchange (IOC)
IOOS . . . . .	Integrated Ocean Observing System (US)
IPBES . . . . .	Intergovernmental Platform on Biodiversity and Ecosystem Services
ISDM . . . . .	Integrated Science Data Management (Canada)
JCOMM . . . . .	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
JCOMM OCG . . . . .	JCOMM Observations Coordination Group
JCOMM DMCG . . . . .	JCOMM Data Management Coordination Group
JCOMM ETOOFS . . . . .	Expert Team on Operational Ocean Forecast Systems
M&CM . . . . .	South Africa Department of Environmental and Tourism Affairs Marine & Coastal Management Branch - now the South Africa Department of Environmental Affairs Oceans and Coasts Branch
MISST . . . . .	Multi-sensor Improved SST
NOAA . . . . .	National Oceanic and Atmospheric Administration (US)
NOAA AOML . . . . .	NOAA's Atlantic Oceanic and Meteorological Laboratory
NOAA NMFS . . . . .	NOAA's National Marine Fisheries Service
OBIS . . . . .	Ocean Biogeographic Information System (IOC)
OCB. . . . .	Ocean Carbon and Biogeochemistry (US)
OCCP . . . . .	GCOS-GOOS-WCRP Ocean Observations Panel for Climate
OCG . . . . .	JCOMM Observations Programme Area Coordination Group
OOPC . . . . .	Ocean Observations Panel for Climate (GOOS-GCOS-WCRP)
OSTST. . . . .	Ocean Surface Topography Science Team
PICES . . . . .	North Pacific Marine Science Organization
PICO . . . . .	Panel for Integrated Coastal Observations (GOOS)
POGO . . . . .	Partnership for Observation of the Global Ocean
QA/QC. . . . .	Quality Assurance/Quality Control
SAHFOS . . . . .	Sir Alister Hardy Foundation for Ocean Science
SCAR . . . . .	Scientific Committee on Antarctic Research
SCOR . . . . .	Scientific Committee on Oceanic Research
SOCAT . . . . .	Surface Ocean CO2 Atlas
SOOP . . . . .	Ship of Opportunity Programme (JCOMM)
SST . . . . .	Sea Surface Temperature
UN . . . . .	United Nations
UNEP . . . . .	United Nations Environmental Programme
UNFCCC. . . . .	United Nations Framework Convention on Climate Change
VOS. . . . .	Voluntary Observing Ship
WCRP . . . . .	World Climate Research Programme (WMO-IOC-ICSU)
WMO . . . . .	World Meteorological Organization
WOCE . . . . .	World Ocean Circulation Experiment (WCRP)

