GOOS, FOO and Governance - Assessments and Strategies

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Abstract

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The Global Ocean Observing System (GOOS) and its partners have worked together over the past decade to break down barriers between open-ocean and coastal observing, between scientific disciplines, and between operational and research institutions. Here we discuss some GOOS successes and challenges from the past decade, and present ideas for moving forward, including highlights of the GOOS 2030 Strategy to be published in 2018.

The OceanObs'09 meeting in Venice in 2009 resulted in remarkable consensus that a common set of guidelines for the global ocean observing community would be useful. That resulted in development of the Framework for Ocean Observing (FOO) published in 2012 and adopted by GOOS as a foundational document that same year. The FOO provides guidelines for the setting of requirements, assessing technology readiness, and assessing the usefulness of data and products for users. Here we evaluate successes and challenges in FOO implementation and consider ways to ensure broader use of the FOO principles.

The proliferation of ocean observing activities around the world is extremely diverse and not managed, or even overseen by, any one entity. The lack of coherent governance has resulted in duplication and varying degrees of clarity, responsibility, coordination and data sharing. GOOS has shown considerable success over the past decade in encouraging voluntary collaboration across much of this broad community, including increased use of the FOO guidelines, but that is not enough to meet the world’s growing ocean information needs. Here we outline and discuss several approaches for GOOS to deliver more effective governance for the system and its stakeholders. What would a more effective and well-structured governance arrangement look like? Can the existing system be modified? Do we need to rebuild it from scratch? We consider the case for evolution vs. revolution.

Community-wide consideration of these governance issues will be timely and important before and during the OceanObs’19 meeting in November 2019.

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Abstract

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The proliferation of ocean observing activities around the world is extremely diverse and not managed, or even overseen by, any one entity. The ***lack of coherent governance*** has resulted in duplication and varying degrees of clarity, responsibility, coordination and data sharing. GOOS has shown considerable success over the past decade in encouraging voluntary collaboration across much of this broad community, including increased use of the FOO guidelines, but that is not enough to meet the world's growing ocean information needs. Here we outline and discuss several approaches for GOOS to deliver more effective governance for the system and its stakeholders. What would a more effective and well-structured governance arrangement look like? Can the existing system be modified? Do we need to rebuild it from scratch? We consider the case for evolution vs. revolution.

Community-wide consideration of these governance issues will be timely and important before and during the OceanObs'19 meeting in November 2019.

1 The need for action

The ocean affects all humans in many ways, regardless of where we live. It continues to produce most of the oxygen we breathe, and is the primary controller of the global climate that makes this planet habitable for humankind. It provides us with food, materials, energy, transportation, and recreation. Over 40% of the global population lives within 200 km of the ocean, and 12 of the world's 15 largest cities are coastal.

The ocean is also the source of many hazards, including increasingly strong hurricanes and severe coastal flooding, tsunamis, storm surges, sea level rise, toxic algal blooms and other pollution. An ability to observe and forecast the ocean and its links to weather, climate and biogeochemical phenomena are required to mitigate risks via improved early warning systems.

The international community has identified global goals related to sustainable development, climate change, and disaster risk reduction that all require systematic ocean observations:

Assessing progress of the United Nations (UN) Agenda 2030 and its Sustainable Development Goal 14 to: "conserve and sustainably use the oceans, seas and marine resources for sustainable development." and many of the other 17 Sustainable Development Goals will require more ocean data.

- At the June 2017 UN Ocean Conference, governments called for dedication of greater resources to sustained ocean and coastal observation, "in order to increase our knowledge of the ocean, to better understand the relationship between climate and the health and productivity of the ocean, to strengthen the development of coordinated early warning systems on extreme weather events and phenomena, and to promote decision-making based on the best available science."

- Improved monitoring of marine ecosystems also supports global goals under the Convention for Biodiversity, regional frameworks such as Europe's Marine Strategy Framework Directive, and assessments like those produced by the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services and the World Ocean Assessment.

- The UN Framework Convention on Climate Change and the Paris Agreement (2015) note the importance of ensuring the integrity of all ecosystems, including those in the ocean, and call on countries to strengthen, "systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making." Ocean observations are also essential to validation of climate projections assessed by the Intergovernmental Panel for Climate Change.

There will be a profound need for essential ocean information to guide policy and progress towards both local public safety needs as well as the range of internationally-agreed goals. Governments and policymakers are increasingly facing complex decisions that require evidence from sustained ocean observations. We lack both the essential observations and the integration necessary to meet these needs. In many important areas, observations are simply too infrequent, sparse, inadequate, or imprecise. A step-change is required in worldwide investment in and management of efforts to observe, analyze, understand and predict the ocean.

2 Successes, challenges and plans of the Global Ocean Observing System (GOOS)

GOOS is looking forward to the coming decade by assessing its unique role in ocean observing to date, reviewing remaining challenges, and considering how it can best improve its contributions in the future. The 2030 vision, mission, goals, and strategic objectives are presented in draft form in this paper. Responses before and during the OceanObs'19 Conference in September 2019 (Honolulu, USA) will inform and refine the GOOS Strategy for the next decade.

2.1 Historical perspective

GOOS was established in 1991 by the Member States of the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), with the World Meteorological Organization, UN Environment, and the International Science Council later joining as sponsors.

Over the past quarter-century, the GOOS community and partners have worked well in coordinating global ocean climate observing and information products and in supporting observations for operational forecast systems. Over the past decade, GOOS has had a growing focus on an integrated global observing system including a wider range of data types and serving a broader range of users.

It is important to note that the 2012 IOC endorsement of the expanded GOOS focus has not resulted in increased IOC budgetary support. Indeed, in real terms core budgetary support for GOOS has declined. Operations of the significantly expanded work plans for GOOS have been funded through short term grants and financial support from various institutions and regional funding programs. This has driven a significant and decentralization of GOOS efforts.

2.2 Elements of the GOOS

The GOOS is comprised of several key elements, see Figure 1.

2.2.1 GOOS Steering Committee

GOOS is guided by a Steering Committee, with ten expert members appointed by the IOC Executive Secretary in consultation with sponsors, and five members selected by IOC regional electoral groups. The Steering Committee reports to the IOC Assembly and other sponsors, defines the GOOS work plan, and manages the structures that report to it.

2.2.2 GOOS Office

The GOOS Office, headquartered at the IOC, consists of a small core team with in-kind contributions from several supporting agencies. The Office supports the work and actions of the Steering Committee, panels, and implementation structures of GOOS, serving as a hub of communication, and point of contact for partners.

2.2.3 Expert panels

Three panels for global ocean observing are focused on developing essential ocean variables (EOVs), evaluating success of the system, and synthesizing across the climate, operational services and ocean ecosystem health requirements. The three panels are: Physics (the co-sponsored Ocean Observations Panel for Climate), Biogeochemistry (building on the International Ocean Carbon Coordination Project), and the Biology and Ecosystems Panel.

2.2.4 The Observations Coordination Group

The IOC/World Meteorological Organization (WMO) Joint Technical Commission for Oceanography and Marine Meteorology has an Observations Coordination Group charged with reviewing, advising on, and coordinating the effective operation of the ocean and marine observing networks and related activities. Notable progress has been made in several areas: engaging networks to address new requirements; developing metrics to assess observing system performance; advancing exchange of international data and metadata, encouraging system-wide standards and best practices, data management standards and integration pilot projects.

The Observations Coordination Group monitors and reports on progress of, and risks to, the ocean observing networks. Increasing the use of metrics throughout the ocean observing value chain allows for more robust evaluations of the system, and eventually will enable monitoring of its performance and provision of feedback into improved requirements and value. The Observations Coordination Group monitors and coordinates testing and assessments of ocean observing technologies as they mature and approach readiness for sustained operation, and it will support assessments that consider the mix of platforms and /or technologies to best meet requirements.

2.2.5 GOOS Regional Alliances

GOOS oversees 13 GOOS Regional Alliances (GRAs) that have organized themselves over the past two decades covering most regions of the globe (Figure 2). GRAs enable regional cooperation in ocean observing and in some cases in ocean forecasting and services. There is great variability among the GRAs in terms of the scope and maturity of activity in each region. GRA attitudes to data sharing also vary widely, from full open access in some regions to restrictions on data sharing and use in others. The regional level of governance of GOOS is therefore ripe for evolution and adaptation, a process that will need to take stock of the regional structures that organize both science and policy.

2.2.6 GOOS Projects

GOOS Projects inform the community on how to develop, and/or mature technologies and programs, and provide architectural patterns or best practices. These GOOS Projects are finite-term endeavors focused on common challenges that span scientific or geographic boundaries.

A key benefit to the adoption of system engineering and architecture practices is the reuse of knowledge. By taking advantage of what is known or has worked successfully in the past and making required adjustments, a Project can be a mechanism for demonstrating and/or bringing best practices into the mainstream.

2.2.7 GOOS partners

In response to the requirements of a wide range of users, GOOS has developed a strategy to drive and guide implementation of a global ocean observing system. GOOS alone cannot deliver across the huge suite of challenges involved. Meeting these challenges will require concerted efforts to strengthen a suite of committed and funded international partnerships.

A generalized list of partnerships that must be formed or strengthened includes:

- A range of partnerships within the UN system, including the WMO whose members increasingly recognize the importance of ocean observations for weekly-to-seasonal weather prediction, and the UN Environment with their strong mandate to monitor ecosystem health and pollution.

- Executive bodies for international conventions and agreements that require ocean information to assess progress toward their agreed objectives.

- Groups in the marine science, management and policy communities, such as international modelling communities in climate, operational oceanography, ocean carbon, and marine ecosystems and fisheries, marine ecosystem health assessment communities, and national and regional bodies charged with evaluation of risk and management of marine systems

- National and regional agencies responsible for funding and running the ocean observing systems, many of whom are research-based, rather than operational, and without whom the global ocean observing system would not be possible.

- Industry sectors for whom ocean data and information are critical for sustainable, efficient and safe operations, such as shipping, tourism, offshore oil and gas, offshore wind power, seabed mining, fisheries, ocean services.

- Marine/ocean research and development sector, such as the Partnership for Observations of the Global Ocean, who often provide the innovation engine for advancing ocean observations, the proof-of-concept processes for many new observation programs, and many of the ongoing ocean observation programs.

- The data innovation and technical services sector, including the International Oceanographic Data and Information Exchange, the national ocean data centers, and other ocean data centers and data integrators.

- Finally, funders and educational partners to enable development of technical capacity in ocean observation across the globe.

2.3 GOOS successes

Over the past decade, GOOS has shown some success in organizing and expanding the global observing system.

2.3.1 An expanding user base

Over the past five years, GOOS has expanded to include ocean observations across physical, chemical, biological and ecological properties, supporting not just the Intergovernmental Panel on Climate Change and the Global Climate Observing System, but also the Intergovernmental Platform for Biodiversity and Ecosystem Services, the Convention for Biological Diversity, the UN Environment Program, the Committee on Fisheries of the Food and Agriculture Organization, the International Council for the Exploration of the Sea and the Regional Fisheries Management Organizations among others.

2.3.2 Increased cooperation across elements of the observing community

GOOS has long emphasized the link between observations and end-user products in its system design and implementation but has also been encouraging GRAs and IOC member nations to make observations to support marine ecosystem health and climate issues where the link to end-users is often less obvious. This dual focus has encouraged the transfer of know-how among the physics, biology and biogeochemistry domains which has been a welcome development at the regional level.

GOOS has demonstrated some success in facilitating closer collaboration between the *in situ* and satellite observing communities, and the ocean modelling and forecasting communities. In EuroGOOS, for instance, the recent establishment of a cross-cutting coastal working group that considers the link between satellite, in-situ and modeling data across scientific domains and different user groups is an impressive result of GOOS influence.

2.4 GOOS challenges

GOOS faces many challenges to further success in addressing the entire value chain (Figure 3).

2.4.1 Funding the observing system

There have been two major funding sources to date for ocean observing. The global research community has provided the bulk of funding for global, basin-wide and regional scientific discovery, which created and maintained many of the ocean observing networks that have also supported other users. Nations have traditionally funded observing networks in their own waters to support marine transportation and public safety needs. Expansion of the scope and requirements into ocean health and environmental concerns has greatly increased the demand for observations without a commensurate increase in funding, which is putting enormous pressure on the system. To build the expanded system needed will require more cooperation and more funding across the ocean research, operations and policy communities worldwide.

2.4.2 Capacity development

Building an operational system that is truly global requires expanding participation to include a far broader representation of developing and less-resourced countries. Significant global efforts to support capacity-building have been sponsored through a variety of organizations including the IOC, but the truth is these have not been sufficiently effective. To succeed, capacity development strategy must be sustained, and stronger partnerships, new funding models, innovative technologies, and new training approaches will be required (Miloslavich et al., *2018*). The goal is to have more countries actively participating in GOOS observing and benefiting from its information products.

2.4.3 Data sharing

GOOS is a strong supporter of the principle "measure once/use many times." As an IOC program, GOOS also adheres to the IOC oceanographic data exchange policy (Resolution IOC-XXII-6, 2003), which stipulates that Member States shall provide timely, free and unrestricted access to all data, associated metadata and products generated under the auspices of IOC programs[1].

On 21 March 2018, *Nature* published the results of a large survey on the practical challenges of scientific data sharing[2]. It showed that 76% of respondents highly rated the importance of data being discoverable, but the main challenge to data sharing is organizing data in a presentable and useful way (46%), followed by confusion around copyright (37%) and not knowing where to share data (33%). This confirms that there is still a strong need to improve capacity in data management, promote best practices in global common data standards, data exchange protocols, and expert-controlled vocabularies to ensure interoperability between datasets.

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[1] www.iode.org/policy

[2] http://go.nature.com/ResearchDataWhitepaper

The FAIR (Findable, Accessible, Interoperable, and Reusable) Guiding Principles (Wilkinson et al, 2016) now enjoy broad recognition through the data community, and several oceanographic organizations/projects, such as the *AtlantOS Blueprint - Data flow (*Tanhua, Pouliquen and Muelbert, 2017), are already embracing the FAIR Principles alongside the consideration of EOVs and requirements, so it makes sense to bring them into GOOS.

2.4.4 GOOS major issues and concerns

In planning for the next decade of GOOS operations, the following major issues were raised.

- There is a fundamental lack of connection across the value chain from observations to end use, and in the ability to ensure fit-for-purpose delivery of information.

- The current system is funded mainly through national investments, frequently fragmented across different funding mechanisms and dependent on short-term research projects. Ocean observing must be moved further up the political agenda internationally, and there is a fundamental need for long-term funding mechanisms to support ocean observing.

- The *Framework for Ocean Observing* identifies the need for regular cycles of evaluation to ensure the data products meet designated requirements, and to ensure the information generated is having impact on the societal issues the observing system is designed to address, but this process is not as active as needed.

- Except for weather forecast systems, there is no collective knowledge base for assessing the value of ocean data products and services.

- Requirements for the ocean observing system are expanding rapidly and exponentially. It is challenging to determine where and why investment should be made for maximum utility.

- GOOS's observations come from many different observing sensors, platforms, techniques and communities, which can all benefit from increased sharing of best practices and integration.

- The ocean data system architecture is incomplete and fragmented. And the cultural revolution of free and open data sharing achieved for most open-ocean physical variables is not universal to biogeochemical and biological variables, or to certain ocean areas under national jurisdiction.

- While observing technology evolves rapidly, the sustained observing system must balance responsiveness and continuity.

- There are profound gaps in ocean observing coverage.

- The ocean observing capacity to monitor human impacts on the global ocean and climate must be engaged and improved.

- As the system grows to serve a broader suite of users across operational services and marine ecosystem health -- encompassing open ocean and coastal applications -- complexity of the environment is increasing. A global and inclusive governance architecture is needed to enable direction setting and coordination of ocean observing.

2.5 The GOOS way ahead

The new GOOS vision, mission, goals and strategic objectives, to be published in late 2018 or early 2019, are all presented here.

2.5.1 The GOOS vision

A fully integrated global ocean observing system that delivers the essential information needed for our sustainable development, safety, wellbeing and prosperity. By 2030 we envision an ocean observing system with greatly expanded coverage, delivering a wider variety of essential information to a broader range of end users.

2.5.2 The GOOS mission

To lead the ocean observing community and create the partnerships to grow an integrated, responsive and sustained global observing system. Our aim is to provide one integrated system that can deliver ocean information across three key areas: operational services, climate, and ocean health.

A fully implemented global ocean observing system will provide the critical ocean information needed to address climate change, generate forecasts, and protect ocean health. By 2030, GOOS will engage a greatly expanded level of partnership and participation from more countries, other observing organizations, and users of the data and products.

2.5.3 GOOS goals and strategic objectives

GOOS will work with its partners over the next decade to address these issues and achieve its vision through 11 Strategic Objectives, grouped under Three Overarching Goals shown in Figure 4.

- <u>Goal 1: Deepening Engagement & Impact</u>
  Strengthen partnerships, to improve delivery to end users from observations through forecasts, services, and scientific assessments
  1. Build advocacy and visibility for the sustained observing system with stakeholders, communicating with key users and national funders
  2. Regularly evaluate system impact, to assess fitness-for-purpose
  3. Strengthen knowledge and exchange around value creation from ocean observation, empowering the spread of end user applications at a local level

- <u>Goal 2: Supporting Integration & Delivery</u>
  Deliver an integrated observing system that is fit-for-purpose, built on a systems approach as outlined in the Framework for Ocean Observing

  5. Provide authoritative guidance on implementation for integrated observing, synthesizing across evolving requirements
  6. Sustain, strengthen and expand observations through GOOS and partner communities, promoting standards and best practices, and developing metrics to measure success
  7. Ensure GOOS ocean observing data and information are findable, accessible, interoperable, and reusable, with appropriate quality and latency.

- <u>Goal 3: Building for the Future</u>
  Building for the future through innovation, capacity development, and evolving good governance

  8. Support innovation in observing technologies and networks
  9. Develop capacity to ensure a broader range of stakeholders participate in, and benefit from, GOOS
  10. Extend systematic observations to understand human impacts on the ocean
  11. Play a leading role in establishing effective governance for global in situ and satellite observing, together with partners and stakeholders.

3 Successes and challenges of the Framework for Ocean Observing (FOO)

3.1 Origin and early accomplishments of the FOO

The OceanObs'09 Conference in Venice, Italy achieved broad agreement on the need for interdisciplinary, internationally integrated ocean observations. Based on general consensus at the meeting, its 18 sponsors commissioned a working group of international program representatives to create a systematic approach for defining requirements for ocean observations, deciding appropriate technology for measurements, and assessing data standards and dissemination. The resulting ***Framework for Ocean Observing,*** published in 2012, has been widely endorsed by the ocean observing community, and adopted formally by GOOS as a guiding document, Figure 5.

In addition to its extensive recommendations on the design of an enhanced ocean observing system, the FOO made two recommendations on governance:

- To simplify and strengthen the high-level governance of GOOS, establish a single, expertise-based Steering Committee reporting directly to the IOC officers and members.

- Establish two new GOOS Panels – for Biogeochemistry, and for Biology and Ecosystems, to complement the existing Observations of Ocean Physics and Climate Panel.

In 2012, the IOC General Assembly unanimously endorsed all the FOO recommendations. A new GOOS Steering Committee was established to replace the IOC Intergovernmental Committee on GOOS and its supporting GOOS Scientific Steering Committee. The three recommended expert panels were formed, and the GRA Council was reinvigorated.

From the start, the FOO has argued it is essential that governance of the global ocean observing system reflect the needs and contributions of ***both*** the broad ocean observing system community (scientists, institutions, observing system managers), and the IOC member states who represent their national and collectively the international community's interests. The changes to the GOOS Program governance made in 2012 were a step-change towards providing a balance between the interests of these two communities. However, since OceanObs'09 and the FOO the proliferation of consortia/organizations (the "acronym soup") that now share the broad ocean observing mission makes the governance challenge even more complex.

3.2 Elements of the FOO

The FOO provides a structure that allows ocean observing providers and users to engage in the system at various points. It traces the path from Inputs (essential ocean variables) to Processes (observations and maintenance), to Outputs (data and products). It has helped form an understanding of the elements of the system as a whole and has facilitated the activities of GOOS in many areas (Figure 6).

The common language and system design principles introduced by the FOO are:

- Essential Ocean Variables (EOVs)
- Requirements
- Observing system elements
- Data management and information products
- Readiness levels (for requirements, observations, and data and information)
- Incorporation of both coastal and open ocean observations addressing science challenges and societal needs

3.3 FOO successes

The FOO has provided a rigorous, standardized way for the ocean observing enterprise to be understood and advanced. It provides a framework of processes, best practices for requirements-setting based on societal needs, identification of common EOVs to be observed, technology readiness assessments, data sharing, product development and information delivery. As the global ocean is a complex and highly connected system, addressing these information needs is an enormous challenge that has benefited from the engineering approach of the FOO.

3.3.1 Essential Ocean Variables (EOVs)

Much of the implementation effort to date has focused on EOVs and requirements, and it is here that we can most clearly see its demonstrated value. The new GOOS Biology and Ecosystems Panel was able to start its requirements-setting process from the outset using FOO principles, as well as a thorough analysis using the Driver Pressure State Impact Response framework commonly used in ecosystem management. The panel developed a list of new, priority EOVs (Table 1), with clear societal benefit for developed and developing nations. Implementation planning is now underway.

The GOOS Biogeochemistry Panel used the FOO to evolve from its singular focus on carbon under the International Ocean Carbon Coordination Project and identify a new, broader set of priority EOVs (Table 2), with relevance to the United Nation’s Sustainable Development Goals. The goal is for some of these EOV observations to be established as “indicators” that can be used internationally as monitors of progress toward the SDG goals, and those of related intergovernmental conventions. It would be useful to establish a demonstration project for this in one or two nations and then expand it globally.

The FOO has also influenced priorities under the most recent review of the Global Climate Observing System, enabling better linkages across ocean physics, biogeochemistry, and biology and ecosystems. It has enabled the GOOS Physics Panel, whose EOVs are shown in Table 3, to begin responding to requirements in continental shelf and coastal systems through a focus on boundary currents.

A number of the EOVs identified by the three panels are clearly interdisciplinary, such as ocean sound, which is physical measurement but is often measured to assess its effects on ocean mammals and fish. Lead responsibility for these cross-disciplinary EOVs has been assigned to the Panel which is deemed most in need of the data. The EOVs identified by the three panels are continuously evaluated and evolved by interaction with their scientific and operational user communities.

3.3.2 Best practices

The use of best practices fostered by the FOO has supported many good outcomes for the ocean observing system (Figure 7):

- Identified (minimal) system attributes for multiple system components, such as sensor performance, observing, data models, data quality, and data flow
- Encouraged more complete capture of metadata, important for data quality
- Enabled more rapid capacity development through sharing of knowledge
- Encouraged more contributions of usable data and better data quality
- Enabled system-wide integration across networks around EOVs

3.3.3 User feedback

Use of the FOO has also addressed the need to involve the end user in assessing and achieving the full societal benefit of sustained ocean observing by:

- Encouraging the practice of establishing user-driven requirements around EOVs
- Requiring assessment and feedback of the effectiveness of the observing system in addressing these requirements/needs
- Encouraging and assessing synthesis-based products based on EOV observations
- Recognizing and advancing these synthesized EOV Products (e.g. Sea Surface Temperature, ocean currents, global sea level rise estimates, wave field) as a critical bridge between raw observations and user-driven needs.

3.3.4 Using the Framework

As GOOS responds to new requirements for measuring additional EOVs in coastal and open ocean environments, it must also include new observing system elements/networks. In many instances, GRAs are already operating observing networks that are potentially fit for these purposes. Examples include high frequency radar, ocean glider, and animal tracking networks. Here we have seen the networks and GRAs come together as ocean observing communities to propose expansion of GOOS in line with the FOO. The need to address requirements, measure priority EOVs, and provide data and information products is accepted by these communities. This indicates that the usefulness of guidance provided by the FOO is also being recognized from the 'bottom up'.

Argo provides a good example of how the FOO can be used to evolve an existing observing system element in response to new requirements. The Argo profiling float network, which is at a mature level of readiness for its core variables and spatial coverage, is now challenged to mature technologies and data delivery for floats measuring additional EOVs. Biogeochemical and bio-optical Argo floats (Bio-Argo) are now at a pilot level of readiness and are being trialed in the Southern Ocean and other locations. Deep Argo is at a proof-of-concept level of readiness, also within FOO guidelines, with several experiments underway.

3.3.5 GOOS Projects

The ongoing GOOS Projects are also actively using the FOO processes. The Tropical Pacific Observing System 2020 (TPOS 2020) is focused on an ocean region of high importance to global seasonal climate variability, the Deep Ocean Observing Strategy is designing and implementing an observing approach for the very under-sampled areas of the deep sea. The European-led AtlantOS project aims to engage a larger set of actors around the Atlantic Ocean with a legacy system organized on a ocean basin-wide level. These projects cut across GOOS requirements, panels and observing systems, and provide insight into observing system development and best practices for future efforts.

3.4 Case studies

Several case studies presented in text boxes address both successes and challenges in real-world application of the FOO guidelines.

A national case study--the Integrated Marine Observing System (IMOS)

The Integrated Marine Observing System (IMOS) is a national collaborative research infrastructure funded by the Australian Government, doing systematic and sustained observing of Australia's vast ocean territory, and making all its data openly accessible for science, research, and other uses. IMOS is integrated across scales (open ocean, continental shelf, and coast), and across disciplines (physics, biogeochemistry, and biology and ecosystems). Established in 2007, it has been expanded, consolidated, and sustained over the past decade.

This period overlapped with development and dissemination of the FOO, and IMOS has used the common language and system design principles of the FOO in numerous ways.

IMOS requirements were initially set through national science planning, subject to international peer review. Within a socio-economic context, major research themes and science questions were identified (requirements), leading to prioritization of variables to be measured at relevant time and space scales (EOVs), along with platforms and sensors to be utilized (observing system elements). Direct investment in information management infrastructure was a design feature from the outset.

IMOS has also used the FOO concept of readiness to assess technology investments over time. Investing mostly in mature technologies to ensure delivery of quality data for its missions, IMOS has also run pilot projects of some newer technologies, maturing them if successful, or discontinuing them if not.

Now funded to 2023, with strong prospects out to 2029, IMOS is looking to strengthen its use of FOO elements that have served it well. Based on the expectations of Australian Government, requirements will be more clearly defined based on social, environmental and economic drivers. The strategy is to move from use and impact being something that emerges from what we do, to something that is explicitly planned for and measured. Direct investment will also be made in new technology assessment, with more rigorous selection and evaluation of pilot projects. There will also be emphasis on areas where the FOO has been less influential to date: increasing effectiveness and efficiency, greater integration across EOVs, and more investment in value-added information products.

A regional case study--the European Ocean Observing System (EOOS)

European stakeholders in ocean observation are working together in the European Ocean Observing System (EOOS) under the guidance of EuroGOOS and the European Marine Board. Stakeholder events and consultations have been held to gather perspectives on how the current system can be broadened to include marine ecosystem health, climate observations and applications, as well as the traditional data collection that supports real time oceanographic services for the user community. EOOS aims to establish a mechanism for a wide range of users to formulate and convey their needs to ocean observation system implementers, where they can be transformed into data requirements and the most appropriate measurement strategies can be identified. EOOS will also provide a mechanism to track and assess the implementation of solutions to meet user needs.

The requirements feedback loop advocated in the FOO has provided a globally-adopted context for this cycle of user requirements, implementation and tracking of observing system implementation for EOOS. A future FOO should address the effectiveness of various mechanisms for gathering user feedback to inform future advances in ocean observing system design.

A basin-scale case study--TPOS 2020

The TPOS 2020 Project is evaluating all elements that contribute to ocean observing in this area, based on a modern understanding of the science and the capabilities of new sensing technologies, and recommending a redesign that will deliver enhanced effectiveness for all stakeholders, including operational climate prediction systems (Cravatte et al, 2016; Smith et al, 2019). In the context of FOO it is a regional Project, owned by regional stakeholders, but otherwise well aligned with the basic concepts of the FOO.

The First Report of TPOS 2020 (Cravatte et al, 2016) is structured according to the FOO in the following ways:

- *User requirements are expressed in terms of EOVs and characteristic scales and quality*
- *Generic, platform-agnostic recommendations are high-level responses to those requirements, which manifest as requirements on the various platforms and networks*
- *Possible platform and network solutions take account of the complementary capabilities of different approaches.*

Differentiating these distinct levels of requirements was a constant source of debate, with the ever-present temptation to immediately focus on the technology solutions. It is critical these steps are considered independently to avoid conflicts of interest. Research and societal needs must be considered together. The First Report further refined the meaning of "essential" and differentiated between experimental and sustained measurements. Process experiments and pilot studies were managed somewhat differently from FOO, but their important role was fully recognized (Smith et al, 2019).

TPOS 2020 is moving toward a regional governance model involving key stakeholders and partners; again, this differs somewhat from FOO which emphasizes global aspects. This does require further elaboration – FOO is a top-down construct, but allowance must also be made for bottom-up development and direction.

3.5 FOO challenges

Technology related to ocean observing and analysis has been evolving rapidly in recent years. Sensor systems, platforms, data transmission, archival systems, data analysis software, and user product design have all been changing at a remarkable pace. This applies both to new sensors, such as those for measuring biogeochemical properties, and to more well-established systems such as instruments for measuring sea level. It is a significant challenge to balance the incorporation of new technologies while sustaining the appropriate legacy components of the system, and ensuring the necessary calibration, verification and integration of all data sets, models, and end-user products.

Some observing networks, such as Argo or HF Radar, that focus on particular technologies are quite effective at developing and sharing best practices. Given the wide range of observing systems and end-users around the globe, however, we have learned that relying on informal processes to share best practices is inadequate. There is a critical need to increase emphasis on identifying, sharing and following lessons learned and best practices across the GOOS enterprise.

To achieve a more effective system, improved feedback loops are needed to ensure greater alignment of system output to user needs. There are many elements to this. Currently feedback from end-users to the observing system is largely ad-hoc. Development of a robust assessment component for the FOO is needed, with a wide range of questions addressed: How well are requirements being met? Do the requirements need revising? Is the mix of observing elements optimal? Are data quality and attributes acceptable? Do the products contain useful information? How well are user needs being met?

An effective system must focus on integration and optimization, which includes such questions as: Are all the data accessible and used? Can we demonstrate we are using the best mix of platforms to meet the requirements? Feedback and assessments should also track progress over time. Metrics for measuring GOOS system performance are under discussion and must be developed. An important aspect of this work is being address by the Best Practices Working Group (*Pearlman, et al, 2019*).

Use of the FOO explicitly requires an assessment of the value-chain linking the development of EOV's to how well the system is meeting the needs of its myriad users. Scientists often need the raw data; other users mostly rely on the observing system to provide the products they require. Given the evolution of user needs, the observing system and protocols for the analysis of observations, it is important that there be regular periodic reviews of the value chain to ensure that it continues to meet both scientific and societal needs.

3.6 FOO community review

A community-wide review of the FOO's usefulness was launched in August 2017. Twenty-one extensive interviews have been conducted with representatives from federal agencies, research institution, academia, and the private sector. These discussions have focused on three broad categories: technology and implementation, data and analysis, and management and governance.

This effort has resulted in several key findings that will guide changes to use and implementation of the FOO. Recommended changes so far are that there should be an increased emphasis on the multi-scale (coastal, open-ocean, local, regional, national, global) aspects of the observing system. Also, there must be improvements in assessment methods to clarify the path to new technology maturity.

A brief summary of early results from the project:

- The FOO has been helpful in the establishment of EOVs, however, the observing community could benefit from an ongoing review of the EOV setting process and its outcomes.

- While alignment with FOO did facilitate the dialog around what should be measured, it was not as useful in trade-space negotiations of what sensors should be deployed on observing platforms, or in the design or redesign of observing networks or arrays.

- There is a greater need for interaction among data managers and integrators within the system. The implementation and data management teams are often overlooked in conversations when calling for enhanced relationships with users, and the needs of these users are often not sufficiently funded or managed in a sustained manner.

- There is a need for greater awareness of the role of GOOS and other groups functioning in the international coordination arena (e.g. Group on Earth Observations BluePlanet, World Ocean Council, Global Ocean Data Assimilation Experiment OceanView). Improved understanding and strengthened partnerships can assist the international community in addressing the entire value chain of the ocean observation system.

- In addition to the expanded emphasis on building an observation and data and information infrastructure that is based on the scientific understanding generated by the EOV setting process practitioners are also challenged to develop the more direct or concerted relationships required to develop the system's feedback loops further addressing science and societal needs.

4 Improving governance of the Ocean Observing System: revolution or evolution?

4.1 The urgent need for improved ocean observing governance

The world at large is increasingly recognizing the magnitude of the ocean's impact on global, regional and local lives and livelihoods. These include the ocean's impacts on regulating climate and the increasing tendency toward local extreme storm and flooding events; global sea level rise; and the growing problems of ocean warming, acidification, plastics and other forms of pollution. Many nations are calling for improved public safety forecasts and warnings; a plethora of international conventions and regional agreements are calling for more ocean observations to support their various concerns; and ocean scientists urgently require more ocean observations to support these many needs. At the same time, there is a growing "blue economy" with many innovations in marine transportation, search/salvage, food production, underwater mining, recreational boating, and many other expanding maritime industries. The requirements for increased ocean observations to address all of these issues, and to provide products to support them is growing in number and urgency.

There is a wide and growing range of participants worldwide in ocean observing with different scopes, aims and ambitions and different geographical, thematic and technical scope. Significant expansion of new observing efforts has recently increased the community's intellectual and operational capability, which is a great outcome. And there are strong indications that this growth will continue in the coming decade.

However, there is unbridled growth in the number of groups taking on management responsibilities without coordination due to ineffective system-level management, lack of planning coordination across the system, and sub-optimal financial and management support levels for many of the efforts. This lack of awareness of and/or coordination with already existing observing systems in some areas has resulted in less positive outcomes, including duplication of observing requirements, use of less-than-optimal observing technology, and limitations in data standards and data sharing.

The rapidly increasing requirements, the growing landscape of actors and activities in ocean observing, and the constrained resources, require that some form of improved ocean observing governance evolve that can effectively and efficiently address the growing needs of the many users.

4.2 Strengths and weaknesses of ocean observing governance today

This diversity, energy and activity in the global ocean observing community can be seen both as a strength and a weakness of the current ocean observing system. The global ocean observing community is multi-faceted, loosely organized, and growing more so every year. We operate now with an historical accretion of organizations and networks working at different scales and focused on different parts of the value chain from observations to end users.

Structurally the community can be looked at as being aligned around three dimensions:

- A first dimension is that of ***platform-based observing***.

A core component of the observing system has long been the Observing Networks organized around particular observing platforms. Good examples are profiling floats (Argo), moored time series (OceanSites), large scale hydrography (Global Ocean Ship-Based Hydrographic Investigations Program). These Networks operate under well-defined criteria and shared best practices. They have their own governance systems, are global in ambition, promote free and open data and are meant to be sustained. These networks tend to be successfully focused on specific scientific and/or societal user needs but are not well integrated with other observing systems often in the same areas.

- A second dimension is that of ocean observing ***themes.***

Good examples are the Global Ocean Acidification Network and the Group on Earth Observations Biodiversity Observation Networks. Thematic based collaborations allow for broad, and as appropriate, multi-disciplinary engagement across geographic areas. Currently there are efforts underway to more systematically align these thematic networks with the broader GOOS structure and encourage wider use of the FOO principles and processes.

- The third, and the most complicated, is the dimension of ***scale.***

The bulk of the funding for ocean observations comes from the ***national*** level where the strongest governance also exists, although it is of course different for every nation and not well-coordinated across nations. The nations mostly oversee their own ***local*** observing networks, although in some nations there are so many that they are not really well coordinated, and in other nations, outside organizations sometimes take the lead without coordinating strongly with national agencies.

The ***regional*** level has both geopolitical and natural ocean drivers for cooperation, like regional current systems, pollution, fisheries, and other issues of resource management and protection. Yet today there is no solution for regional efforts, not just for ocean observations, but also for the broader issues of transboundary problems and regional politics. The regional scale of governance for both science and policy is ripe for improvement.

A recent positive development has been the emergence of coordination at the scale of complete ocean basins. Good examples include the Southern Ocean Observing System, AtlantOS for the Atlantic, the Indian Ocean Observing System and TPOS2020 focusing on the tropical Pacific. The ***basin-scale*** focus provides a new and effective vehicle for collaboration on ocean observation requirements, observing strategies, data sharing, capacity building, and resourcing. The European Commission has pursued this scale of cooperation for ocean science with the Galway Statement (2013) and the Belem Statement (2017), covering respectively North and South Atlantic Ocean research and observing cooperation.

The current governance system is loosely coordinated based on voluntary commitments with little of the rule and control characteristics usually associated with governance. The variety of differently focused observing systems makes it challenging to find a governance model that works, but the current model is clearly not adequate to accommodate, oversee, guide, or support all systems. And governance of ocean observing is severely underfunded. One possible reason for this is the inherently unclear structures, roles and responsibilities of the current governance system.

Perhaps most importantly, there is currently no mechanism in place to assess the effectiveness of the sum of ocean observations and data streams from the variety of networks and systems towards the goals of the scientific and societal benefit areas recognized as the underpinning purposes for the observations.

4.3 Attributes and objectives of a good ocean observing governance system

All indications are that the diversity of expertise, interests, and support for the fragmented global ocean observing community will continue to expand in the coming decade. The "next step" for high-level governance of the global ocean observing system must be to attract and involve more representatives from the community who are currently working in isolation and establish guidelines, standards and procedures for moving forward. The FOO principles will be a valuable resource toward this objective.

In a recent assessment of over 100 international agreements comprising the global ocean governance architecture for fisheries, pollution, biodiversity and climate change, Mahon et al. (2016) found two emerging network structures. The first were 'global-regional, issue-based networks' building from the siloed global agreements touching fisheries, pollution, biodiversity and climate change, which they suggested should be better integrated. At the regional level, they found 16 crosscutting regional clusters of networks, where regional agreements for several issues coincide spatially. They suggested these clusters provide the opportunity for integration, focusing broadly on ecosystem-based management of the ocean, and improving regional implementation of global agreements. Sustained ocean observations are a necessary input for all of these initiatives, as is scientific input for setting requirements and policy and in monitoring outcomes, but Mahon et al. found that many of these mechanisms to incorporate science into policy were weak. This study makes clear the requirements and the opportunities for strengthened governance at both the global and regional levels.

Required principles for an observing system governance structure are outlined below:

- Responsiveness. Governance must respond to the needs of stakeholders and participants, from local, regional to global, across all relevant sectors, and include governmental and non-governmental aspects.

- Purposeful. Governance must be purposeful for, and on behalf of the community.

- Clear objectives. Good governance relies on clear and purposeful (relevant) objectives and strategy.

- Transparency. Transparency and openness must be a priority, to ensure public access to and benefit from the system. While private networks may be warranted on the grounds of security or because of the narrowness of the target audience, in general information should be public and governance arranged accordingly.

- Efficiency and Effectiveness. Governance must ensure that maximum value is derived from invested resources and must have enough flexibility and nimbleness to ensure guidance/decisions are provided in a timely way.

- Adaptive. Governance must support innovation and openness to change, to ensure that benefits accrue for new solutions and improved practices.

- Sustainability. Governance must have a long-term orientation, taking account of the broad-range of existing and likely future drivers, and the need for dependability and robustness.

- Authoritative. The individuals and teams contributing to governance must have the appropriate capability, skills, and respect of the community to act on their behalf.

- Performance and accountability. The governance must include monitoring and measures of success and performance.

An additional principle when dealing with multiple levels of governance is that "a central authority should have a subsidiary function, performing only those tasks which cannot be performed at a more local level." This “subsidiarity” principle establishes a link of co-responsibility among different levels of governance. The central idea is that local governance will be the most responsive to local needs, increasing quality and effectiveness. Some negative aspects of this can include slowed implementation and heterogeneity based on varying capacities at the local levels. (Jachtenfuchs & Krisch, 2016). In practice though, if the “central authority” is not respected the system, or lack of authority at the national level the system will not work well.

Most of the funding for ocean observation infrastructure continues to come from national governmental funding sources, so the strongest level of governance around planning, commitments and implementation continues to be at the national level. But improved governance must demonstrate to the national players how engagement with regional and global levels can bring advantages by leveraging the best practices of others. Also, more engagement with the global level of governance will give all participants in ocean observing more access to provide input and engage in the development and implementation of intergovernmental conventions that are increasingly requiring ocean observations.

Required improvement to the governance system must focus foremost on finding common ground and building strong partnerships across the growing observing system. It is necessary to define roles and responsibilities and agree on goals and strategies including processes for setting requirements, assessing technology choices, setting standards for data management and sharing, coordinating the suite of public products, and cooperating in global capacity development on all levels.

Where do commitments take place for the observing system, and how can the governance be more effective and efficient internally while at the same time recognizing and working more closely with other partners making commitments to the observing system?

It is important to recognize the nesting from national to regional or basin-scale to global efforts; the needs and contributions of each level; and how a governance system must work with and help to coordinate the efforts of all of these levels to achieve the best system of systems for all users. We need to invest in projects to test and demonstrate the linking of the various governance levels.

4.4 Scenarios for improved ocean observing governance

The ultimate objective is a better-structured, efficient system-of-systems, with clear roles and responsibilities and a sense of ownership of all members in the overall system, where all individual parts work in concert, with observations, standards, data sharing and data product needs met in the most efficient and cost-effective ways.

How do we get there? The authors present several scenarios for improving governance of the overall ocean observing community.

4.4.1 Starting over – a revolution

If we could start over and build the ideal governance structure, what would it look like?

There would be a strong, single international organization with a clear mandate and adequate funding to direct, coordinate, integrate, monitor and assess ocean observations, data and products worldwide, and to provide and coordinate robust capacity building for nations in need of it. It would direct and oversee expanded use of the FOO, including requirement setting organized around EOVs, technology readiness assessments, increasing user feedback, and assessing the adequacy of the system in meeting societal benefits. It would establish and support strong channels for two-way communications and mechanisms for input of ideas and leadership from national and regional levels.

This organization would adhere to all the principles, objectives and attributes of governance outlined above. All other intergovernmental organizations needing ocean information would be required to coordinate their needs and efforts with the lead organization.

Every nation with an ocean coastline would have an "ocean ministry," responsible for coordination of ocean science and observations. In nations with multiple ocean agencies, one would be clearly designated as the lead for ocean observations. These national ocean ministries would coordinate their ocean observing efforts with the lead intergovernmental organization. Regional observing efforts would have clear internal governance and would be required to coordinate with and take direction from the lead intergovernmental organization. Both national and regional observing efforts would work closely together by participating in established mechanisms for their input and leadership of various aspects of the global effort. All the geographical scales of ocean observing would be linked, both "upward" and "downward" to assure engagement, ownership, consistency and cost-effectiveness of the overall system.

Clearly, starting over is not a realistic option. There is no identified mechanism to make that level of change achievable in a system with so many players, and even if possible, it would cause too much disruption to important ongoing and emerging observing efforts. Perhaps this look at the ideal, however, will inform the goals and attributes of the evolutionary approaches outlined below.

4.4.2 Top-Down model

A top-down governance system led from some part of the UN system has some strengths: it is rooted in Member State governments, it is consensual and inclusive, and conditioned to treat capacity development as a priority to bring the community of nations up to a common level of development. That leads to some of its disadvantages: a consensual drive can lead to lowest-common denominator responses to innovation.

A good example of a top-down model is the rather strongly regulated framework around meteorological observations, recognized many decades ago as vital to public safety (weather and storm forecasts), business interests (agriculture, aviation forecasts) and military needs. Governed by the WMO, members have a strong say in formulating regulations, but once promulgated the WMO regulations are largely complied with by most nations, and each nation has a designated responsible agency to ensure compliance.

The current ocean observing governance system under IOC/UNESCO is chronically underfunded. User needs are represented within different UN agencies, ranging from operational users (WMO), scientific users (IOC/UNESCO and International Science Council), and policy/regulatory users (UN Environment, UN, International Maritime Organization, others), requiring strong partnerships that are sometimes difficult to establish across agencies.

4.4.3 Bottom-Up model

A strength of the bottom-up, community-based self-organizing model is that the governance energy is naturally concentrated in the elements that see the greatest advantage in collaboration. This approach harnesses the energy, enthusiasm, and funding of self-organizing efforts. In this bottom-up model, governance of the global ocean observing system is left to the observing communities to self-organize around their own objectives and goals, often without the guidance of broader international knowledge, experience and goals. This approach could be organized around voluntary participation in an overall governing body financed by membership fees from organizations that would then have a seat at the table of their governance structure. This model could be structured as an independent legal entity and could potentially be inclusive and recognize all participants in ocean observing. An example of this approach is EuroGOOS, the European GOOS Regional Alliance (GRA), that is funded and governed by membership organizations to form a strong regional ocean observing body with well-defined mission and goals, though it does not have a direct connection to the intergovernmental influence of the UN system.

This bottom-up approach is to a large extent already happening with many organizations and structures developing around emerging ocean observing themes, networks and systems. Drawbacks of this approach are the difficulty of accessing advantages rooted in the UN system, such as global targets and global/regional development funds; the difficulty of influencing development and implementation of the intergovernmental conventions; and the difficulties in access to new technology assessments, best practices, and data sharing globally.

4.4.4 Loosely coupled hybrid model, "business as usual"

The current governance system can be described as a weak "hybrid model" with governance provided by GOOS within the UN system and working as much as possible with partners at all geographic scales. GOOS provides credibility for national and regional observing efforts through its presence within the UN system and by providing member states a voice into the intergovernmental processes.

The GOOS ocean observing governance efforts are currently inadequately funded by its sponsors (IOC, WMO, International Science Council, UN Environment) to effectively coordinate and manage the observing system. Resources are currently obtained from funders outside of the UN system for components of the governance system, such as the GOOS panels and most of the network structures. Although this provision of funds from partners outside of the UN system is currently essential to governance operations, it leads to a loosely coordinated, difficult to manage system.

4.4.5 Tightly coupled hybrid model

This approach is similar to the "business as usual" model, but with a much stronger link for partners into the governance of the observing system. This model builds on a strong UN presence but with official membership status of partners that work in concert, a hybrid of top-down and bottom-up approaches. Outside of the core activities of coordinating and implementing sustained ocean observing activity, this puts emphasis on building partnerships for delivery, advocacy and visibility with stakeholders, supporting innovation, and developing capacity. A governance approach where partners from the observing system are members and directly participate in governance would facilitate engagement, foster common solutions, and encourage sharing of best practices and data.

How could such an approach look in practice? Perhaps a lead UN agency clearly designated to provide the top-down coordination, plus an office of the lead UN agency placed outside of the UN system as a legal entity that engages the national, regional, scientific, and industry observing partners as members, working in concert with the UN system. It would empower partners to participate and facilitate co-design and management of the observing system.

This starts to define a global common observing infrastructure. Though still a small fraction of the investment in observing systems by nations, this approach would give more voice at the intergovernmental level to the national efforts. The benefits of such a global common coordinated infrastructure arguably flow to all nations, but the capacity of many countries to use data for their local purposes must be further developed. The creation of a G7 "Future of Oceans and Seas" working group has led to ongoing discussions of the establishment of a G7 sustained ocean observing coordination center, linked to GOOS. This, or a somewhat larger grouping of countries, might form part of a strong hybrid model for governing GOOS.

4.5 The case for a stronger GOOS leadership role

GOOS is a UN organization that includes involvement with *in situ* networks, satellite systems, governments, UN agencies, research organizations, and individual scientists. GOOS adopted and oversees the FOO guidelines which have been widely embraced and used throughout the ocean observing community. Through the FOO, GOOS is coordinating the assessment of ocean observing requirements, observing system implementation, and innovation through GOOS Projects. Sitting within the UN structure allows GOOS to enable a 2-way interaction with nations through many forums. Through building community consensus, GOOS enables stakeholders to engage with the system as a whole.

Since its establishment in 1990 as a program designed to observe the role of the ocean within the climate system, the GOOS mandate has grown in size and to include multiple new scientific disciplines, responding to a growing range of societal and policy drivers, and operating in an increasingly crowded environment. In 2018, the "global ocean observing system" brings together individuals and organizations from multiple inter-governmental organizations (UN Framework Convention on Climate Change, UNESCO-IOC, WMO, UN Environment, European Community), and national and academic sectors, from more than one hundred countries.

GOOS adopted and promulgated the FOO, which has been widely embraced and used by many. A stronger GOOS governance structure within the UN system, with adequate support from the intergovernmental UN sponsors of GOOS for both ocean observations and the needed governance work, and with a much stronger effort to build substantive partnerships and strongly engage nations and other stakeholders -- is seen by the authors as a viable approach for addressing the governance needs of ocean observing efforts globally.

5 Next steps in ocean observing governance

We invite all participants across the ocean observing community to consider and comment on the governance ideas laid out in this paper. Leading up to the OceanObs19 conference a concerted effort will be conducted to collect community input on the governance recommendations from across the community. This process will be designed to make input into the process as seamless as possible while providing a forum for ongoing discussion and comment.

Further, as these governance discussions will be an important part of the agenda at OceanObs19 in September 2019, to ensure the community is ready to make meaningful progress on this issue at those meetings, a workshop will be held beforehand (in early to mid-2019) with invitations to representatives of all the varied parts of the observing community. The workshop agenda will address various ways to improve communication, coordination, partnership and governance across the global ocean observing enterprise.

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Acronym List

EOOS = European Ocean Observing System
EOV = essential ocean variables
FAIR = Findable, Accessible, Interoperable, and Reusable
FOO = Framework for Ocean Observing
GOOS = Global Ocean Observing System
GRA = GOOS Regional Alliances
IMOS = Integrated Marine Observing System
IOC = Intergovernmental Oceanographic Commission
TPOS 2020 = Tropical Pacific Observing System 2020
UN = United Nations
UNESCO = United Nations Educational, Scientific and Cultural Organization
WMO = World Meteorological Organization

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Author Contributions Statement

TT, AM, AF helped to conceive the paper, coordinated author contributions, wrote text, edited and contributed tables and figures. LG, LS, AM coordinated the submission of text, completion of tables and figures, and final report editing. WA, NB, KC, BD, DD, EH, JG, KH, MI, DL, EL, PM, TM, GN, AP, SS, BS, NS, MT, MV, JW contributed manuscript ideas and text.

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Table 1: GOOS Biology and Ecosystems Panel supported EOVs (October 2018).

Biology & Ecosystem EOVs
Phytoplankton biomass and diversity
Zooplankton biomass and diversity
Fish abundance and distribution
Marine turtles, birds, mammals abundance and distribution
Hard coral cover and composition
Seagrass cover and composition
Macroalgal canopy cover and composition
Mangrove cover and composition
Ocean Sound
Microbe biomass and diversity (*emerging)
Benthic invertebrate abundance and distribution (*emerging)

Table 2: GOOS Biogeochemistry Panel supported EOVs (October 2018).

Biogechemistry EOVs
Oxygen
Nutrients
Inorganic carbon
Transient tracers
Particulate matter
Nitrous oxide
Stable carbon isotopes
Dissolved organic carbon
Ocean colour

Table 3: GOOS Physics Panel supported EOVs (October 2018).

Physics EOVs
Sea state
Ocean surface stress
Sea ice
Sea surface height
Sea surface temperature
Subsurface temperature
Surface currents
Subsurface currents
Sea surface salinity
Subsurface salinity
Ocean surface heat flux

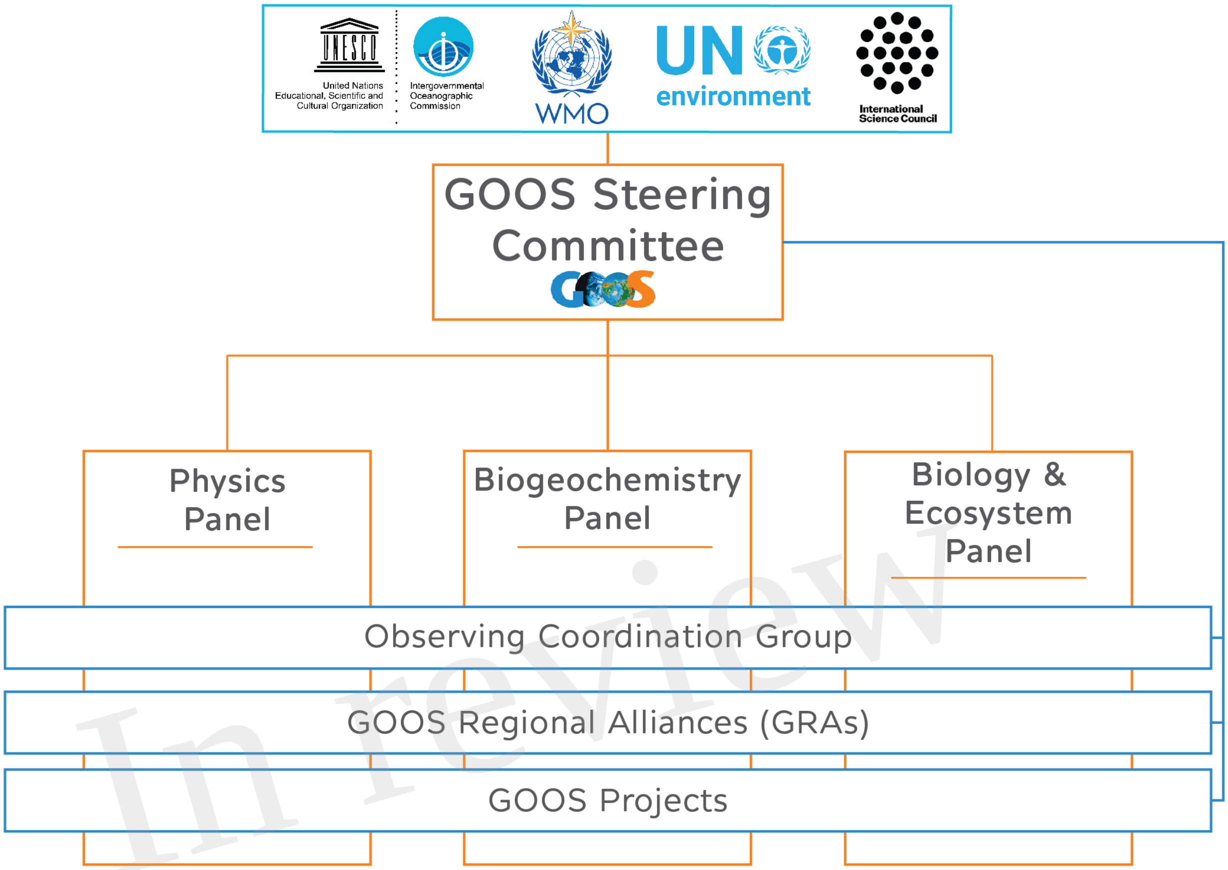

Figure 1: Simple organization chart of primary GOOS groups and activities in 2018.

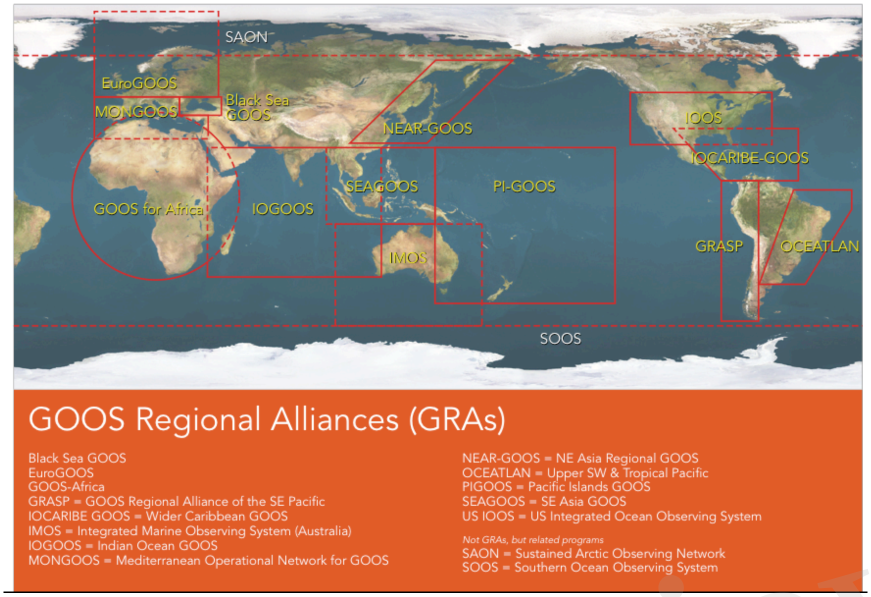

Figure 2: GOOS Regional Alliances (GRAs).

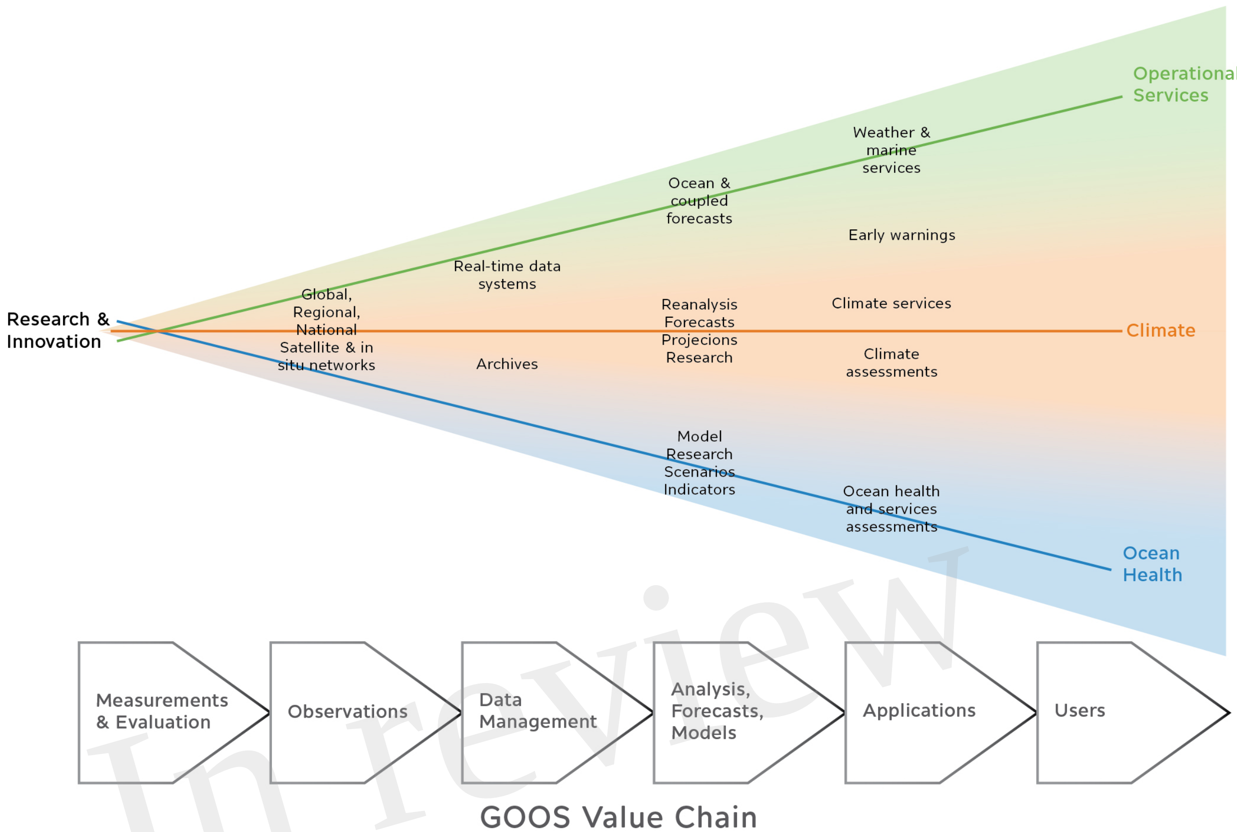

Figure 3: GOOS value chain and associated activities and outcomes.

Figure 4: GOOS 2018 Strategic Plan vision and mission statements with strategic goals and correlating objectives.

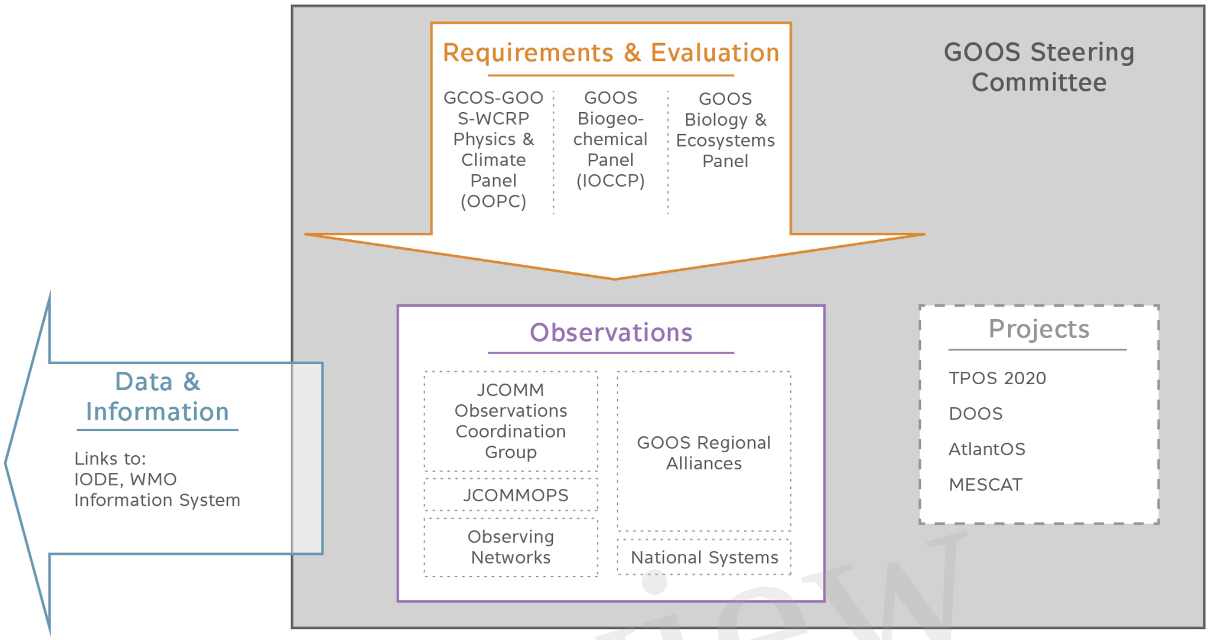

Figure 5: Primary areas of activity and influence for key GOOS elements and linkages in 2018.

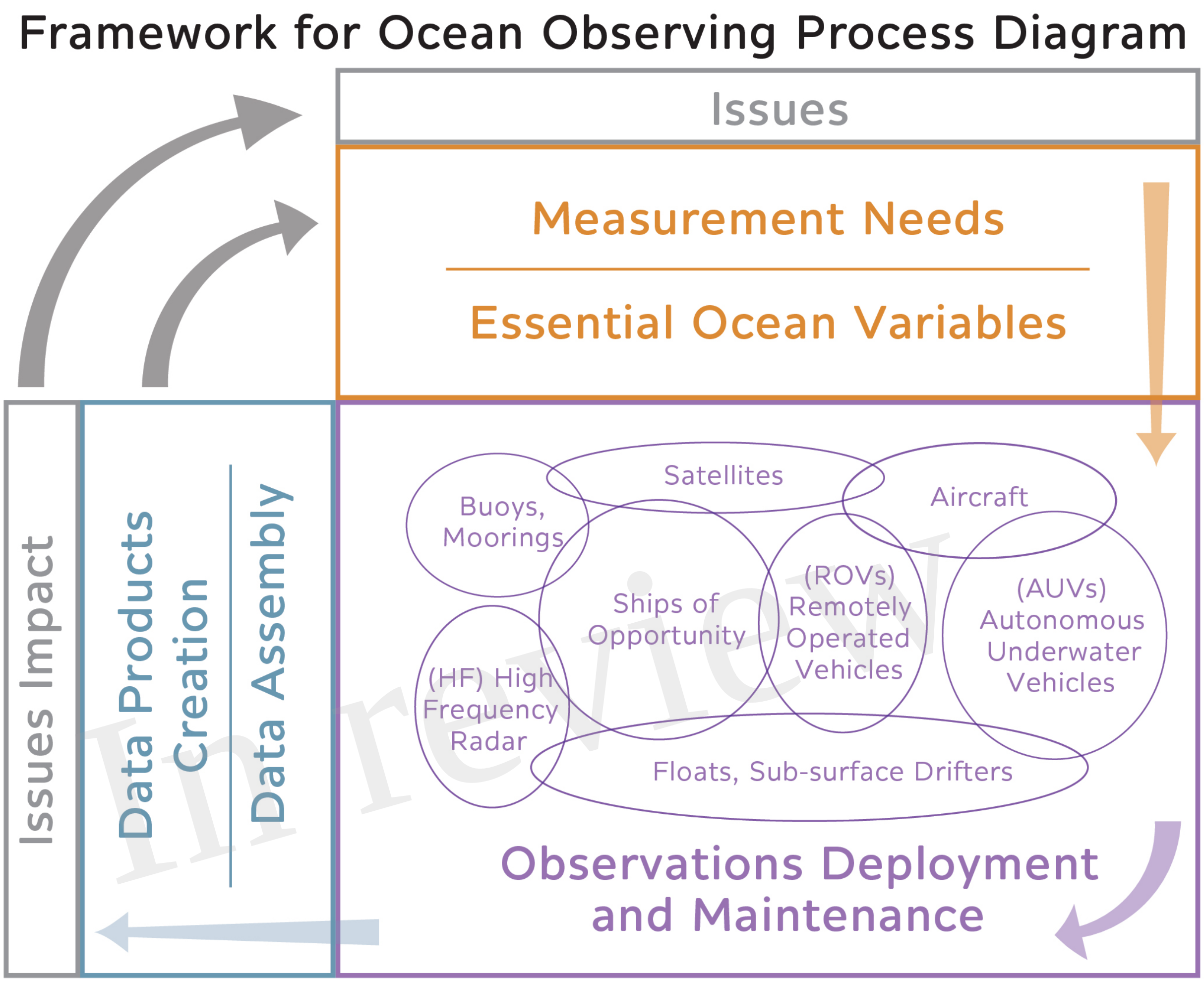

Figure 6. FOO Process Diagram.

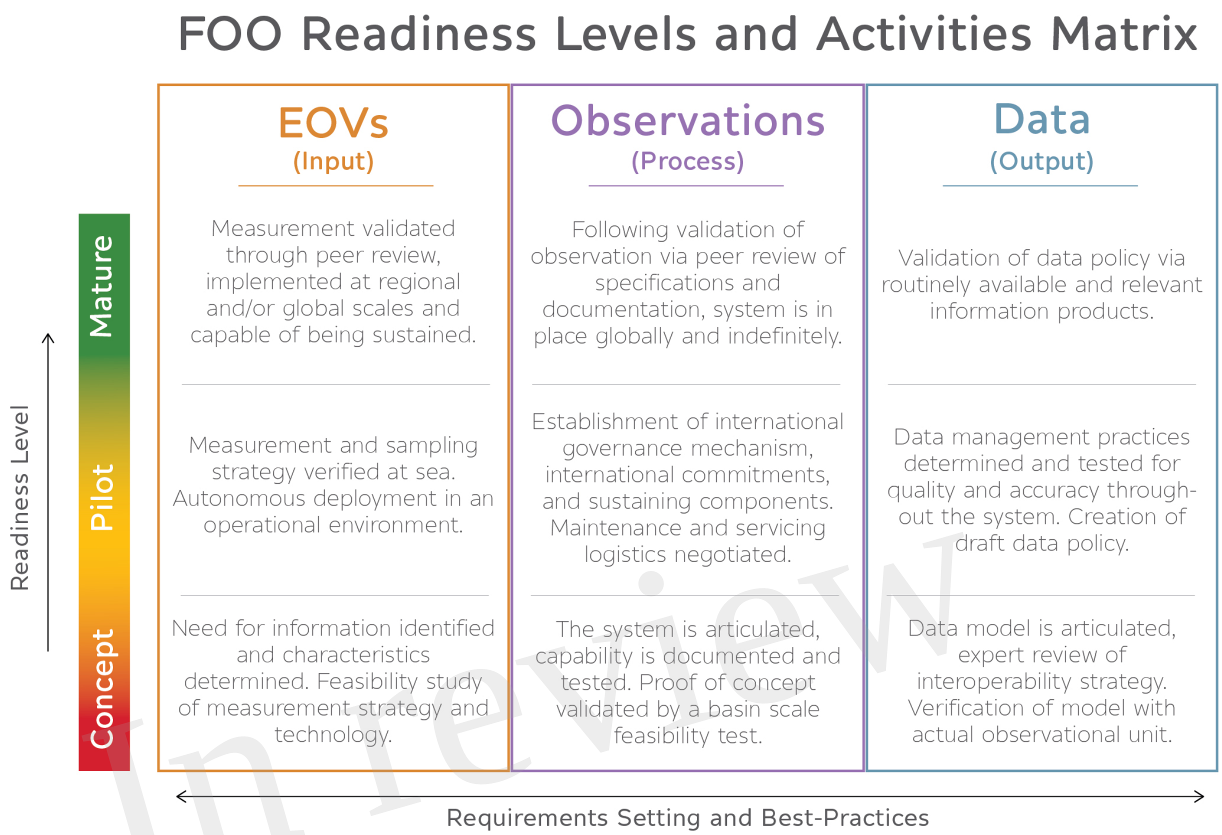

Figure 7: Matrix of FOO-element attributes at increasing readiness levels.

Figure 1.JPEG

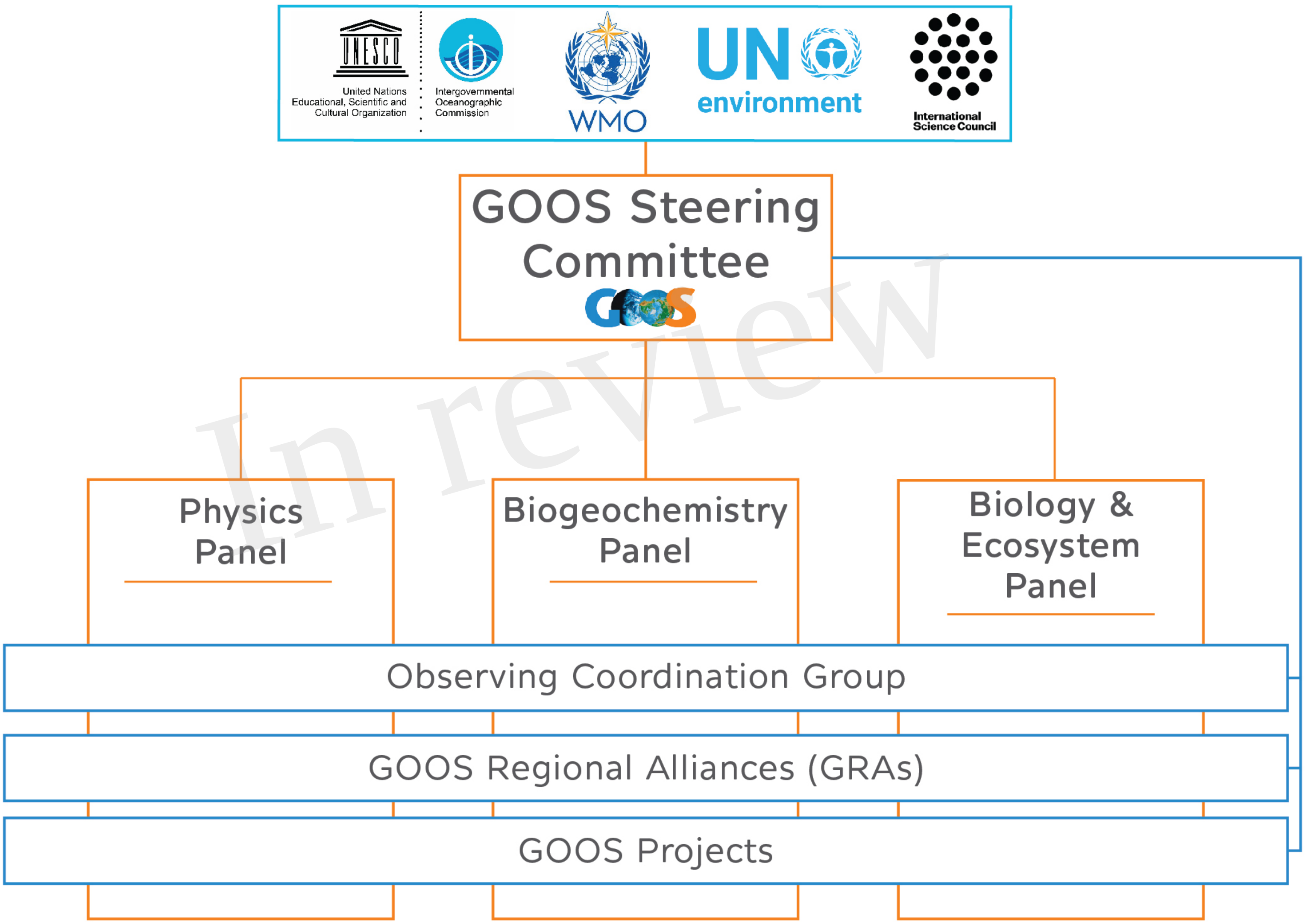

Figure 2.JPEG

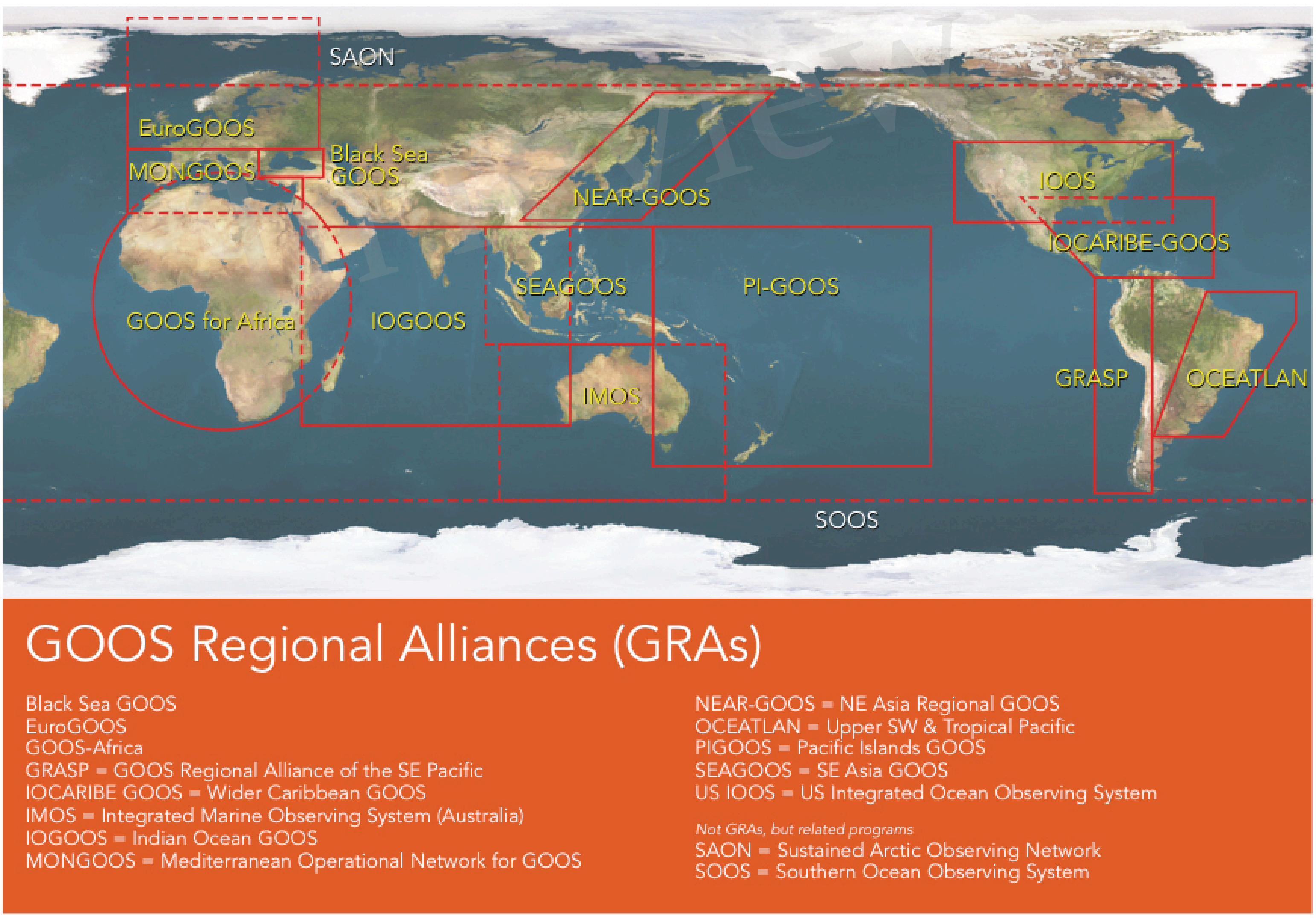

Figure 3.JPEG

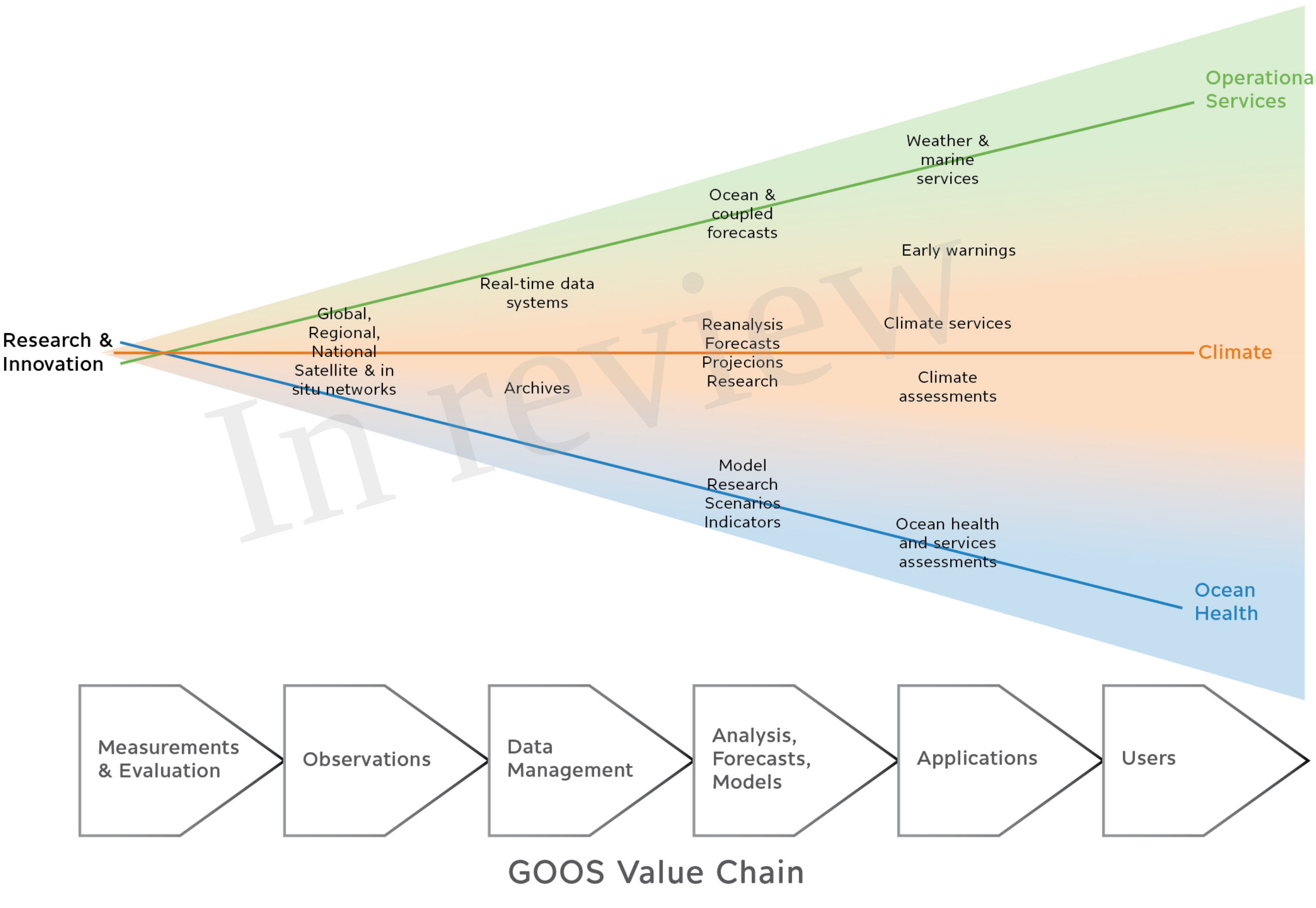

Figure 4.JPEG

Vision
A fully implemented global ocean observing system will provide the critical ocean information needed to address climate change, generate forecasts, and protect ocean health.

Mission
To lead the ocean observing community and create the partnerships to grow an integrated, responsive and sustained global observing system.

For
- Climate
- Ocean health
- Operational services

Strategic Goals & Objectives

Deepening Engagement & Impact

1 Strengthen partnerships, to improve delivery to end users from observations through forecasts, services, and scientific assessments.

2 Build advocacy and visibility for the sustained observing system with stakeholders, communicating with key users and national funders.

3 Regularly evaluate system impact, to assess fit for purpose.

4 Strengthen knowledge and exchange around services and products, empowering the spread of end user applications at a local level.

System Integration & Delivery

5 Provide authoritative guidance on integrated observing system design, synthesizing across evolving requirements.

6 Sustain, strengthen and expand observing system implementation through GOOS and partner communities, promoting standards and best practice, and developing metrics to measure success.

7 Ensure GOOS ocean observing data and information are findable, accessible, interoperable, and reusable, with appropriate quality and latency.

Building for the Future

8 Support innovation in observing technologies and networks.

9 Develop capacity to ensure a broader range of stakeholders participate in, and benefit from, GOOS.

10 Extend systematic observations to understand human impacts on the ocean.

11 Champion effective governance for global in situ and satellite observing, together with partners and stakeholders.

Figure 5.JPEG

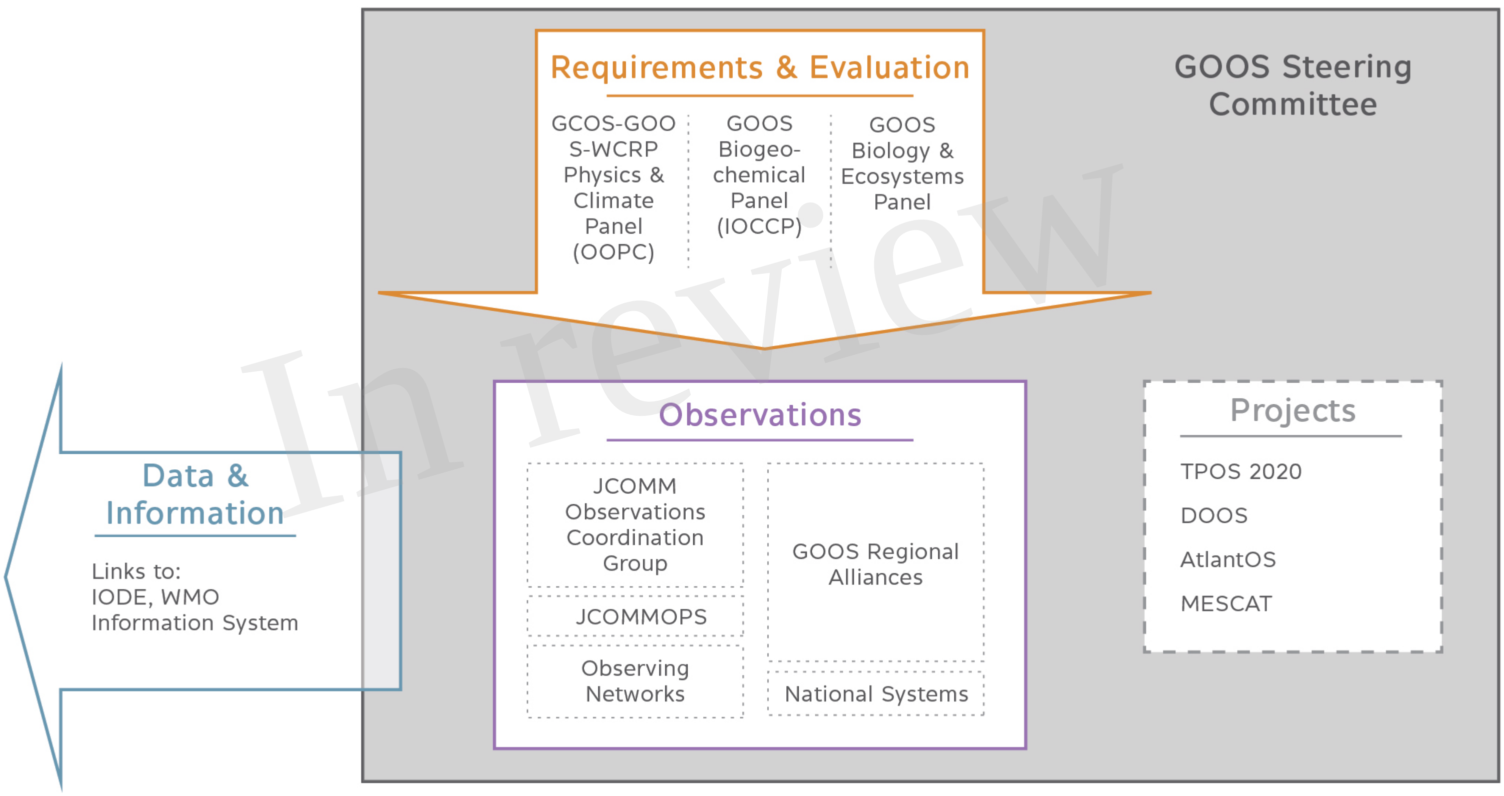

Figure 6.JPEG

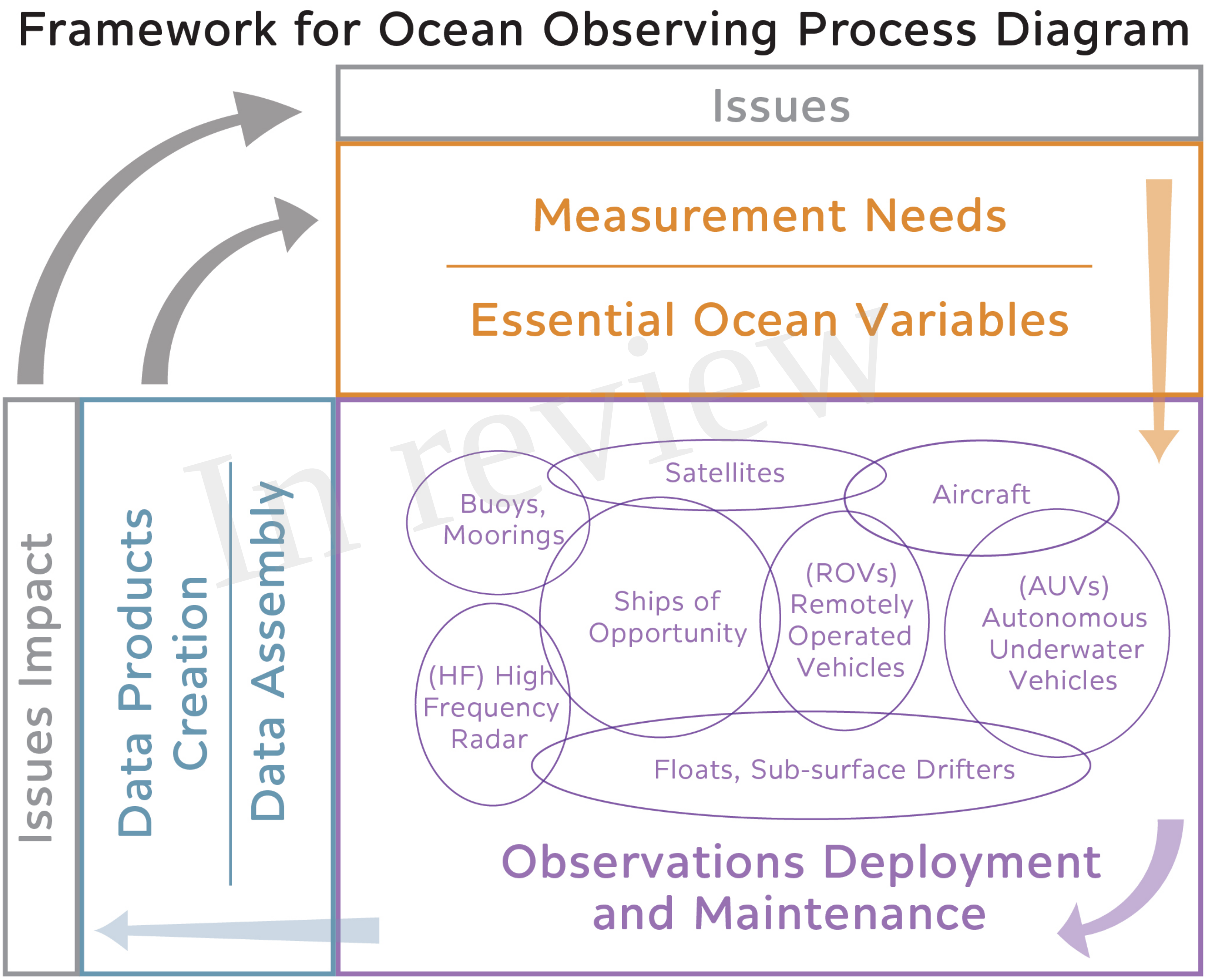

Figure 7.JPEG