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Best practice summary Report: Report summarizing the relevant best practices available in the GEOSS (AtlantOS) best practices registry.

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Note to the reader: Inclusion of proceedings of the Best Practices workshops as appendices would make the document size too large for transmission and these documents are provided in the references for access.

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2 Introduction and Summary

As the oceans are key determinants affecting global sustainability issues such as climate change, food security and human health, the need to understand the marine environment and ocean dynamics is essential. However the scale of oceans, their transnational character, three-dimensional nature and strong attenuation of light (causing limitations of satellite observations (Yan, 2013) and electromagnetic radiation such as GPS signals (Clark, et al., 2016) introduce enduring challenges. The path to sustainable global ecosystems, as framed by the Sustainable Development Goals (SDGs) (UNSDG 2018, Wackernagel, 2017) and prioritized through essential ocean variables (EOV) (GOOS, 2018), engages a broad range of disciplines, not all conversant with each other's language, techniques and best practices. Ocean observing experts have recognized these multi-disciplinary challenges (Kulcarni, 2015, Olson, 1988) and the need to address them.

Given the complexity of these issues and the need for globalization of ocean science and applications, a crosscutting vision for broad interoperability and sustainable observations is “to have agreed methods for every activity in ocean observing research, operations and applications that are broadly adopted.” This is a vision that may not be achievable in the next decade, but offers a stretch goal that could have significant impacts. Best practices are an important element in supporting this vision, but the diversity of stakeholders makes discovering relevant best practices (BP) more difficult. Addressing this challenge rests upon: a) the creation of a basic resource for efficient discovery and access of documented best practices; and b) the acquisition and management of sufficient best practice documentation within this resource. A trusted and stable archive is needed as a focal point including harmonizing the formats of best practice documents and ensuring their contents are accessible through the Web. Further, the discoverability of content should be augmented using granular indexing and documented provenance.

The creation and use of best practices supports high priority objectives of AtlantOS and global ocean observing capabilities. Furthering of interoperability within and across disciplines allows measurements to be better understood and compared. The sustained documentation of measurement methodologies allows replication of historical observations. The best practices being addressed here are not only those for observations, but are considering the full value chain from observations to products in the user's hands and ultimately the impact on society.

Task 6.4 under AtlantOS “Innovation” WP 6, drew together a team representing major organizations interested in creating and propagating ocean best practices. The development of an Ocean Best Practice System (OBPS) also included support and collaboration from the Horizon 2020 Ocean Data Interoperability Platform (ODIP) and the NSF sponsored OceanObs Research Coordination Network. The OBPS includes a repository and advanced user interface at UNESCO/IOC/IODE; a Frontiers in Marine Science Research Topic “Best Practices in Ocean Observing” facilitating peer review and BP visibility; processes for identifying best practices working with IOC/GOOS and an incipient training capability. These are further described later in this document. The task

team has completed the plans for this task. The last major effort is now to transition the outcomes of this task for long-term sustainment of the OBPS. This is underway.

3 Requirements for an Ocean Best Practices System (OBPS)

The requirements for an Ocean Best Practices System (OBPS) come from the ocean observation and application communities. It was recognized early in the development that the overriding principle for an OBPS is that it is *community driven, based on community needs, and providing value to the community*. The word “community” is broadly constructed; it is often recognized that ocean research and applications involve a multitude of communities that must interact to provide the value of information across the value chain leading to information products that support societal decisions. Thus, the underlying principles for the system need to provide a foundation for support across heterogeneous communities.

The initial work on requirements drew upon the AtlantOS partners during a meeting of AtlantOS/AORA held in Las Palmas November 2016. A breakout session was held on best practices during which the following needs were identified:

- Document in writing best practices being used (but not necessarily created) in each network. Outputs from networks may be a good starting place as these may be more easily adopted;
- There should be an organization that can be a home for best practices;
- Have peer review processes for community practices - should a journal of best practices be created? This would encompass peer review opportunities and citations;
- Documents should be publicly available so that could then be reviewed by a “panel of experts” - which implies the creation of such panels;
- Training and presentations to the community for best practices should be provided;
- For sensors, there should be a library of factory and other calibrations - develop best practices for calibration and deployment as well as for cross-calibrations of different sensor types to ensure interoperability;
- Encourage manufacturers to track feedback from field operations;
- Adapt procedures from industry to science – expensive procedures may be overkill;
- Best practices are part of addressing the challenge to produce good data - how do we define the optimum steps for best practice engagement in data management; and
- Cost and staff time needs to be identified so there is adequate allocation of resources for implementation of best practices.

Outcomes/recommendations from the AtlantOS 2016 meeting in Las Palmas stated that each network had clearly identified the need for **best practices documents** – with respect to deployments as well as data dissemination, some already have best-practice document

(see Figure 1).



Figure 1: Best practice documents from the observation community

These recommendations from the Las Palmas meeting became part of the discussion topics considered by the Ocean Best Practices Working Group (OBPWG) in 2017. The OBPWG formulated an initial system concept for best practice support – including discovery, access and training – that would form the cornerstone for an operational system. It was clear that this concept would benefit from further inputs and review by the ocean community, which led to a user and requirements-focused workshop in November 2017 that included experts from sensors, data, applications and observing systems (Simpson, et al 2017). This workshop recommended that the following set of principles guide the system development/implementation. (1) There is a clear need for a consolidated open access repository for ocean observation best practices that would provide consistent access to a wide range of such practices. (2) With the expanding observation community, traditional mentoring approaches, particularly in developing countries, need to be complemented by documentation of practices that are discoverable by granular search capabilities and easy to access. Benefits of the system will include improved consistency and interoperability among measurements on a local to global scale, increased dialog and cooperation among experts and a reliable base to make comparisons addressing evolution of the ocean ecosystem. Best practices benefit day-to-day operations by reducing duplication of efforts (and therefore costs) and unneeded repetition of learning processes. They create a knowledge base to speed development and improve efficiency. By improving operational consistency and documenting measurement procedures, they provide a better reference foundation for reaching back to historical data.

In addition, the following guidelines were reflected in the recommendations:

- The repository should abide by the FAIR principles Findable, Accessible, Interoperability, Reusable (Wilkinson et al 2016). This includes open access approach that permits the retention of the best practice documentation in multiple, linked repositories.
- With the submission of best practices to the OBPS Repository, the control of technical content of a best practice and the intellectual property remain with the BP creator.

- The documents accepted by the OBPS Repository may be formatted in many ways (e.g. best practices, standard operating procedures, manuals, etc.) when they are offered by a provider as a community best practice. The important concept is that the person or entity making the entry into the repository has successfully used and documented the practice.
- There are recognizable benefits from peer review of best practices as a means to refine and propagate the use of such practices. Such review also motivates academic experts to publish best practices. Both expert panels (internal to a project) or a journal of best practices would provide opportunities for such peer review and a journal can offer a forum for community discussion.

These guidelines and other inputs from the user workshop were used in refining both the OBPS strategy and the concept from which the system was implemented.

4 System Strategy and Concept

The guidelines of Section 3 above need to be translated into system characteristics to allow for practical implementation. The Task addressed this in two ways: 1) the creation of a system level strategy and 2) a robust operations concept that both embodies the principles and is flexible to support evolution. Vision and mission statements provide the framework for the strategy.

A cross-cutting vision that will serve the needs for broad interoperability and sustainable observations is *“to have agreed methods for every activity in ocean observing research, operations and applications that are broadly adopted.”*

Thus, with the above statement, the vision is to increase efficiency, reproducibility, and interoperability of the entire ocean observing value chain by providing the ocean observing community with a unified, sustained, and readily accessible knowledge base of interdisciplinary best practices.

To achieve this vision, the mission for the OBPS is *“to provide a sustained system which fosters collaboration, consensus building, and innovation by providing coordinated and global access to best practices across ocean sciences.”*

Consistent with this mission, the objective is to provide coordinated and sustained global access to best practices in the end-to-end value chain to foster innovation and excellence.

4.1 OBPS Strategy

An essential element of the OBPS is the definition of a best practice (Pearlman, et al., 2017). This definition has been further refined at the Best Practices workshop (Simpson et al 2017). The operating definition is: *A community best practice is a methodology that*

has repeatedly produced superior results relative to other methodologies with the same objective.

To be fully elevated to a best practice, a promising method will have been adopted and employed by multiple organizations. Best Practices may come in any of a number of format types mentioned in section 2. This allows ready inclusion of historical BPs curated within the repository to enable better understanding of past processes in use at the time. This is consistent with the strategy for creating a useful and sustainable Ocean Best Practices System by leveraging existing capabilities whenever possible, both in the repository infrastructure and the community networks for observations and applications. Then expand the infrastructure with new search mechanisms based on ontologies that can service the different disciplines of ocean research from physical observations to chemistry, biology and ecosystems.

The best practices cover a diverse set of methods including those for sensors, calibration, platforms and platform integration to communication of observed data, data management and products and services for the benefit of society (Figure 2). These facets combine to form what is called the value chain from observing to users.



Figure 2. Value chain for ocean applications and products

An example of a use case that covers such ocean observing value chain was developed in AtlantOS WP 8 and is one of several that reflect the processes and best practices that are envisioned for the applications across the value chain feeding information to end users. As part of the collaboration between WP6 and WP8, the best practice documentation for the HABs (see Figure 3) was submitted to the OBPS <http://dx.doi.org/10.25607/OBP-13>, (Leadbetter et al 2018). This led to a further discussion relating to processes for HABs bulletins, which are issued in regions around the globe, but are not consistent in the practices used for their creation. It is anticipated that further contributions of practices

will be offered to the OBPS Repository for documenting the various approaches for HABs assessments.

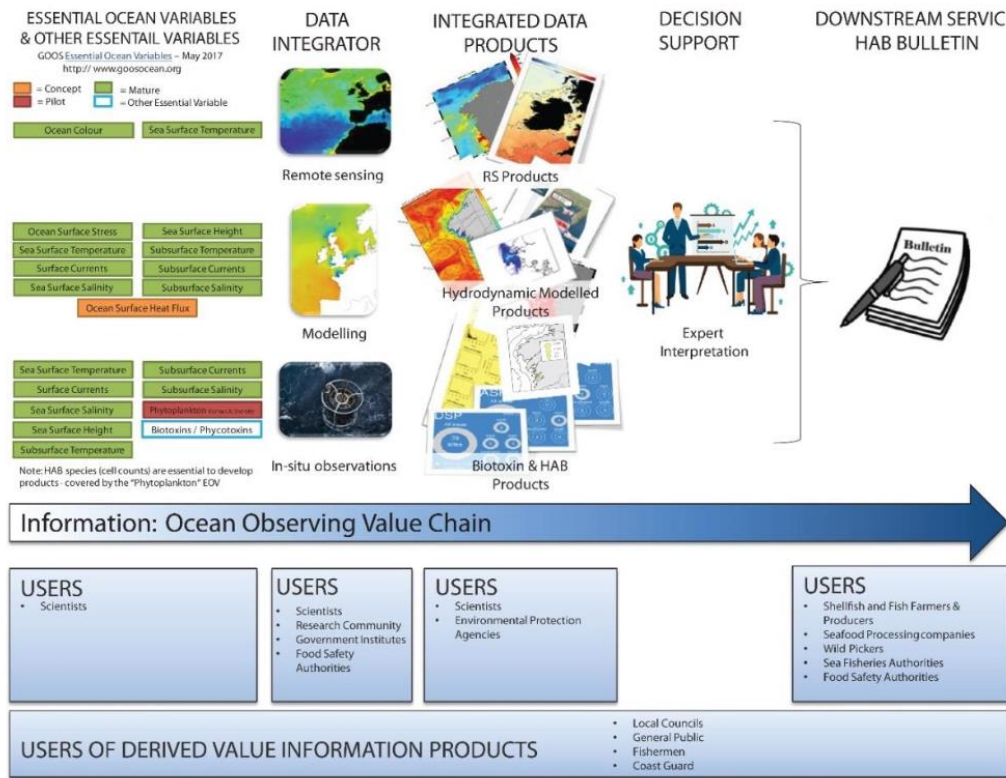


Figure 3. Harmful Algal Bloom Bulletin Production: application of knowledge along the value chain from In-situ , satellite and modeled data, integrated data information products through to the knowledge targeted product i.e. HAB bulletin production. Some of the current “Users” of the products along the chain are identified. The development of a HAB bulleting follows the method outlined in “A Framework for Ocean Observing ” (Lindstrom et al. 2012).

4.2 OBPS Concept

There are four essential capabilities, as mentioned earlier, to serve the community needs for expanded use of best practices. These are:

1. A sustained repository supporting easy discovery and access through semantic technology and natural language processes and machine-to-machine interoperability
2. A process for community peer review and identification of preferred or recognized practices
3. A capability to facilitate capacity building and uptake of best practices
4. A procedure for tracking and monitoring of best practices use and a means of uniquely identifying best practices and provenance.

The system concept is shown in Figure 4.

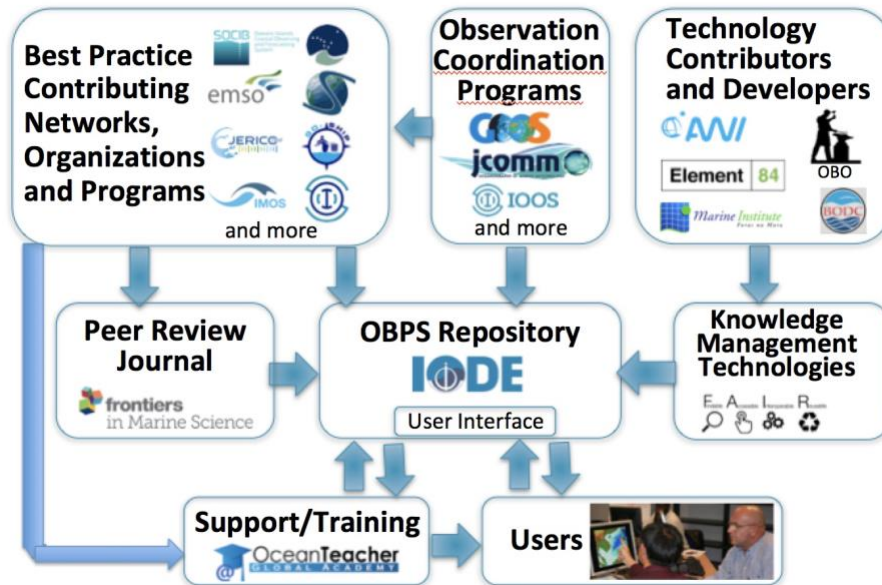


Figure 4. Block diagram of OBPS elements and their linkages

Building upon the OBPS concept, the system has four strategic objectives:

- 1) Enhance the functionality and search capabilities of the existing IODE OBPS repository and provide tools to promote and increase the BP content.
- 2) Establish the *Frontiers in Marine Science* “Best Practices in Ocean Observing” research topic as the medium to describe and understand robust, high quality methodologies over the entire range of ocean observing including addressing the challenges of improving observation capabilities (including data management and user applications) and interoperability.
- 3) Ensure visibility and relevance of the repository/system through community engagement activities.
- 4) Establish sustainability of the BP system by the global and regional ocean observation and information organizations as well as community practitioners.

The outcomes of the best practices workshop in 2017 highlighted some underlying principles that define the relations between the system and the user community. These include that the OBPS support open access based on the FAIR principles of “Findable, Accessible, Interoperable and Reusable”. Various of the observation networks provide access to their best practices on their project website. Recognizing that project websites are very often not permanent, multiple locations for documents (e.g. in the project website and the OBPS repository) are encouraged with linked web-based connectivity. Importantly, BP developers retain control of their content within the repository. This is consistent with the fact that the networks have the experts to create, assess and update best practices relevant to their missions.

The question of peer review was raised. Peer review is supported within the major global observing networks such as GO-SHIP or projects such as the European FixO3. However, not all best practices come from global networks and if they come from a university research environment, peer review may need to draw on an external community. Thus, a peer review process is important. The next section, which describes the Ocean Best Practice System (OBPS), reflects this guidance for OBPS implementation.

5 OBPS Implementation

The first best practices workshop identified key attributes of the Ocean Best Practices System described in the previous section. These attributes are the high level requirements for implementation. The more detailed requirements for implementation were defined in early 2018 at a meeting of the OBPWG hosted by SOCIB. Each of the major attributes was considered and characteristics were defined to frame the implementation.

5.1 System Attributes

5.1.1 Easy Discovery and Access to Best Practices

- Semantic-based natural language search with expanded key words / granular extraction leveraging use of “Ocean Knowledge Tagger” processes
- Use of ocean-focused ontologies / links to ocean vocabulary to support semantic search for observations and applications including, for example, EOVs
- Structured, machine-actionable rich metadata (including “filling” if necessary)
- DOI assignment / version control
- Easy to use User interface (web page plus?) with user ID option

5.1.2 Robust and sustainable Repository

- Sustainable storage of BPs and related information
- Web crawling for best practice web search
- Internationally recognized and reliable facility/organization (IOC/IODE)
- Hosting, curation and maintenance by repository organization
- Simple submission process (including templates and author IDs)
- Interoperability with other BP archives and routinely tested links between archives
- Content can be harvested by search engines (Google, etc.)
- Help Desk
- Web site link verification

5.1.3 Supporting Best Practice Evolution and Maturity

- Support by expert panels and relevant peer review process
- Best Practice “Research Topic” in *Frontiers in Marine Science* (link: <https://www.frontiersin.org/research-topics/7173/best-practices-in-ocean-observing>)
- Implementation of maturity indicators (Technology Readiness Level)
- Implementation metrics
- Address aging and updating of best practices including provision of alerts/requests for updates

- Automation-based testing of links to BP locations of BP providers

5.1.4 Community Engagement and Support

- “Ocean Knowledge Tagger” Service (Automated support for BP Analysis) for new external documents
- Outreach documentation and active public relations
- Activity monitoring and metrics
- Workshops, community meetings, webinars, newsletter, listserv
- BP Templates to encourage machine readable BP format
- Automated ingest of BP (one-click upload’)

5.1.5 Capacity Building and Training

- Capacity building supports the work of both developed and developing nation scientists and other experts
- Access to information should be supported with and without internet
- Use of videos and social media should be leveraged
- Webinars
- Leveraging other organizations training programs (summer schools etc.)
- Supporting the UNESCO “Transfer of Marine Technology”

5.2 System structure

As a description of the OBPS, a high-level system block diagram was provided in Figure 3. The flow for the operational system requires more detailed interfaces and functional descriptions, which are provided in this section (see Figure 5). This will be addressed by examining each of the major elements of the OBPS.

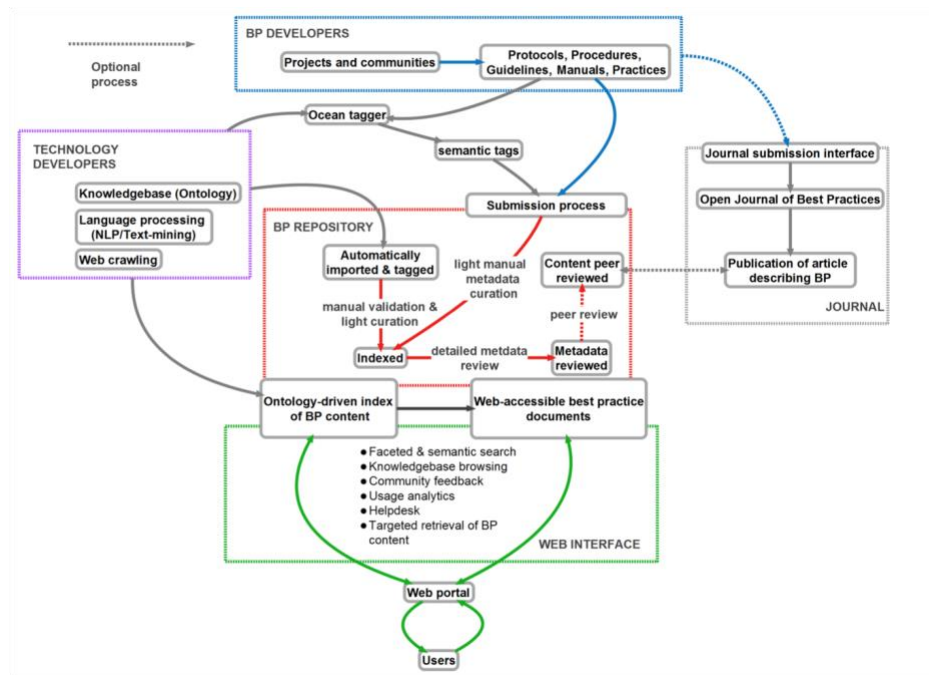


Figure 5: Elements of the OBPS and their interfaces

5.2.1 OBPS Repository

The repository originated as the Ocean Data Practices repository, part of the IODE information product profile. In defining the OBPS, it was reconfigured in a number of ways. First, it was redefined as the Ocean Best Practices System repository and expanded to include all facets of the value chain from observations to applications and a base for understanding the methodologies that support decisions and policy in society. To move toward machine readability, standardized BP templates have been created for best practices (e.g. see <https://www.oceanbestpractices.net/handle/11329/398>). Originally, a single template was designed, but in beta testing, it became apparent that template information for sensors and application best practices were different enough that multiple templates would be required. Three were developed as prototypes for three areas: sensors, ocean applications and data management. More templates will be created based on community inputs. The templates focus on both metadata and the structure of best practice documents. They also ask if the BP is relevant to Essential Ocean Variables (EOVs) and Sustainable Development Goals (SDGs). These allow users to search and examine best practices for monitoring progress in EOVs and targets for SDGs.

Another advance was the introduction of enhanced discovery and access for best practices. Two capabilities were created. One was a means of semantic tagging the contents of best practice documents. The second was a new user interface to enable improved granular search based on the tagging. The tagging process draws on ocean-related ontologies and vocabularies to offer users alternative words or concepts for finding appropriate best practices, and the ontologies themselves build on the search terms users request to identify relevant best practice documents. The repository currently uses six ontologies and this will expand with time. When best practice documents are submitted to the repository, the tagging process is initiated (see figure 6). The submitted best practice text undergoes a raw text extraction to make it accessible for tagging (indexing). This text is compared with merged knowledge base of ontologies and vocabularies and the tagging of words in the best practices text is done. The tagged best practice is then available for discovery through the semantic and Elasticsearch interface (info.elastic.co). The results from this process are fed back to the tagging module to improve the efficiency and effectiveness of the system.

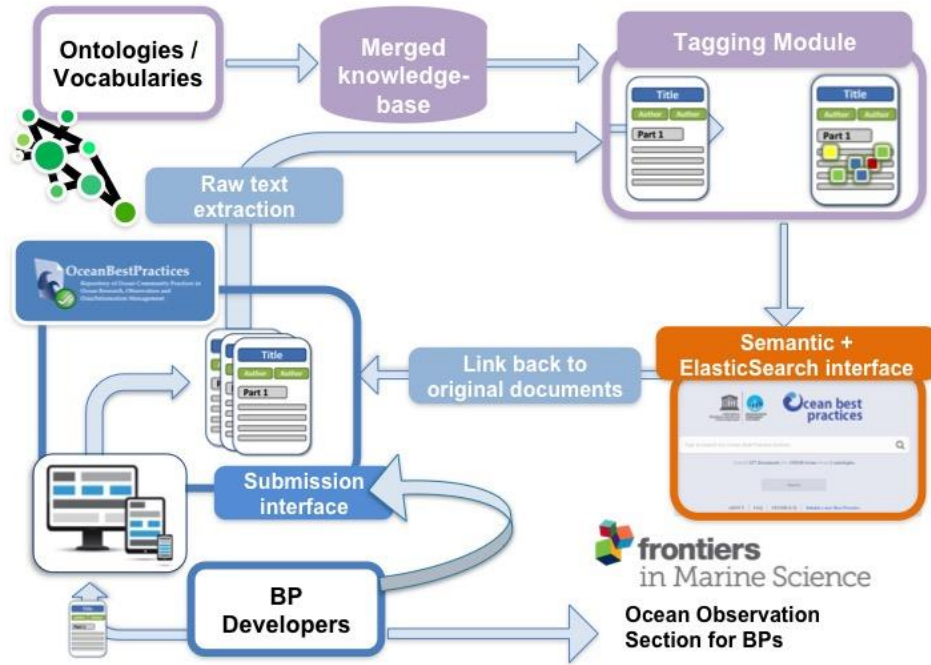


Figure 6: Semantic tagging process for Best Practice Documents

The user interface (UI) is the user-facing connection to the system for search, access and submission of best practices (see Figure 7). In addition to these functions, it provides

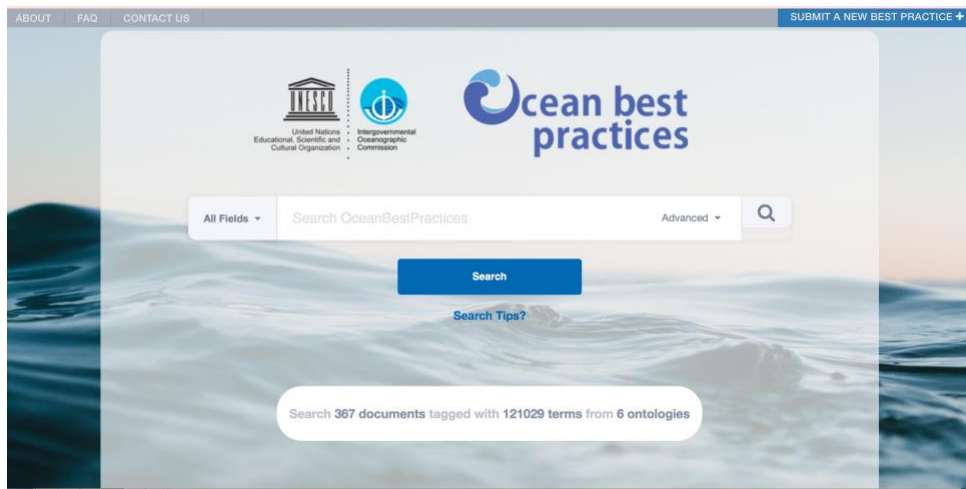


Figure 7: User Interface for the OBPS allowing BP search and access

community feedback, usage analyses, a help desk and other features. Beta testing of the user interface was done during November 2018 to January 2019 and updates have been incorporated.

Testing of a web crawler was carried out in 2018. Web crawling has the benefit of finding best practices on the web that are not part of the repository. This allows

contacting the BP authors about BP use and sustainability. The work was supported by a team led by Chris Mattman (C. Mattman, 2018) and supported by Pier Luigi Buttigieg, Pauline Simpson, Nick Roden and Ketil Koop-Jackson of our AtlantOS team. The crawler found a number of BPs that were not part of the repository (though many were journal articles behind subscription firewalls). However, there were many false positives, meaning that it picked websites that did not offer best practices. The key next steps would be reducing the labor needed for sorting by reducing the number of false positives. This can be done by improving the selection algorithms.

5.2.2 OBPS Peer Review and Community Forum

Methodologies are not generally peer reviewed and academics have not been responsive in creating documents that do not contribute to their career advancement. In addition, many best practices derive from the work of engineers and technicians that are not propagated into the archival literature. For these and other reasons, the creation of a peer reviewed journal or equivalent could have a significant impact on the creation and adoption of ocean best practices. This was an outcome of a discussion at the AtlantOS/AORA meeting in Las Palmas in November 2016.

In 2017, a number of journals (all operating as open access) were contacted to select a platform for peer review of best practice papers. A Research Topic on methodologies is new to ocean observations and, of the journals being considered, *Frontiers in Marine Science* (FMARS) and the editor of the FMARS Ocean Observations section (Herve Claustre) were interested to test this as a opportunity for expanding the Ocean Observations section of the *Frontiers in Marine Science*. They offered a number of features, for example, reduced author fees and free access for commentaries. In addition, the Best Practices Research Topic does not have a termination date, which is a change of policy and allows a sustained platform for peer review and discussion forum.

Thus, the OBPWG worked with *Frontiers in Marine Science* to create a sustained research topic “Best Practices in Ocean Observing” which began in November 2017 with initial publication of articles in May 2018. (see www.frontiersin.org/research-topics/7173). It has been encouraging to note the diversity of subjects and geographic participation in the Research Topic manuscripts. The call for papers is broad - the description on the web page (see Figure 8) notes that the following areas are invited:

- The design of observatories (and observatory networks), logistics, and operations procedures (incl. deployment/recovery, procedures for Exclusive Economic Zone, notice to mariners, and others)
- Sensor design, calibration, metrology, instrument handling and application
- Measurement methodologies
- Methods and standards for hardware interoperability
- Data and information handling, quality control, and FAIRness (Findability, Accessibility, Interoperability, and Reusability), including real-time (RT) and delayed mode (DM) data
- Guidelines (formats, procedures, documentation) for observational and model data comparison strategies (e.g. Obs4MIPs; www.earthsystemcog.org/projects/obs4mips/)
- Knowledge transfer and capacity building

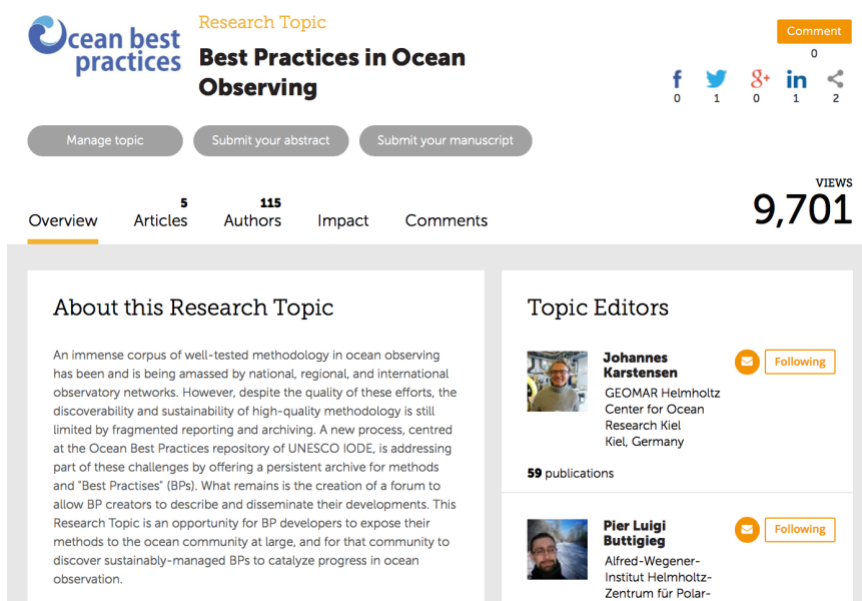


Figure 8: Research Topic "Best Practices in Ocean Observing" web page and overview

Through an agreement with Frontiers, the research topic includes a community forum for discussion of papers and, more generally, best practices. Such a platform is consistent with the emphasis on best practices as a community endeavor.

There have also been discussions of additional community platforms through GOOS, IODE and other organizations. These platforms are particularly important when working to understand the level of adoption of a practice. Since there is a reasonable assumption that “best” may vary depending on geographic location or on ecosystem type, users need to have a perspective on what has gone before and why. Thus, both a forum and the Research Topic play an important and complementary role in evolving best practices. This concept is to provide the tools and facilitate their use where BP providers indicate interest.

During the last year, there have been many discussions of how to approach a methodology (such as measuring oxygen in the ocean) with multiple best practices that have the same goal, but differ in their approach. This is the “best of the best” paradox, which does not have a simple answer. In fact, with different locations such as the Arctic and the Tropics, ‘best’ for one region may not be ‘best’ for the other. Recognizing this challenge, there is still a need for “recommended best practices” to further the monitoring and interoperability of an Essential Ocean Variable and recommended best practices should part of an EOVS documentation. Through such OBPWG discussions, GOOS is now planning, working through its panels, to identify and document recommended practices for each of the EOVS and this process may extend to other networks e.g. IMOS.

Another approach is to use community feedback to identify best practices that should be recognized for more common use. This was discussed at the second annual workshop in

December 2018. While an initial approach could be “likes” rating, no final solution has been selected but the requirement remains.

5.2.3 Capacity Building and Training

The adoption of best practices and their practical applications is a priority for the OBPS.

As more observations are planned and, ultimately, a sustained global capability emerges, there needs to be some transition from oral traditions in training to a documented best practice knowledge transfer. Modern social media, videocasting, webinars provide a new generation of tools that can be used. The IODE Ocean



Figure 9: Training is essential for effective best practices

Teacher Global Academy has offered to be a focal point for facilitating training. They would engage global experts to provide the courses and materials for training. Longer term mentoring needs to be addressed and this is still open for discussion. This area for the OBPS is being initiated and will need iterations as the training in best practices progresses (see Figure 9).

5.2.4 Outreach and Engagement

A number of approaches were used to engage the ocean and broader communities in the area of ocean best practices. These included presentations at conferences, town hall meetings, webinars, websites, help desk and others. These are listed in Table 1 below.

Part of the outreach involved working with the AtlantOS partners through the project meetings. There were a number of internal presentations to AtlantOS workpackages for collaboration, which are not noted in the table below.

Table 1: Outreach and Engagement for Ocean Best Practices

Type of Engagement	Activity	Presenter	Date
Peer Reviewed paper and Conference	IEEE Oceans2017, presentation & paper	Jay Pearlman	September 2017, Anchorage
Peer Reviewed Paper	MTS Journal	Mark Bushnell	June 2018
Peer reviewed Publication (in press)	OceanObs19 - best practices community white	Jay Pearlman et al.	October, 2018

	paper		
Peer reviewed publication	EOS Magazine	Juliet Hermes, Jay Pearlman and Pier Luigi Buttigieg	April, 2018
Workshop	OceanObs RCN) at AGU Ocean Sciences Meeting	Jay Pearlman	February 11, 2018, Portland
Workshop	Best Practice community workshop	BPWG	November 2017, Paris
Workshop	Best Practice community workshop	BPWG	December 3 – 5, 2018, Paris
Workshop	Interoperability Technologies and Best Practices in environmental monitoring	Jay Pearlman (presentation), Francoise Pearlman (poster)	October 10 – 12, 2018, Brest
Workshop	European Ocean Observing System (EOOS) /poster	Cristian Munoz	November 21-23, 2018, Brussels
AGU Town Hall meeting	Ocean Sciences Meeting	OBPWG	February 2018
Mini-Workshop	AtlantOS GA	OBPWG	November 2017
Presentation (Webinar)	GOOS Regional Associations	Juliet Hermes	May 2017
Webinar	OBPS implementation	Jay Pearlman, Pier Luigi Buttigieg, Johannes Karstensen, Juliet Hermes	May 8, 2018
Webinar	GOOS Webinar	Juliet Hermes	July 26, 2018
Conference	Blue Planet Symposium poster	Jay Pearlman	July 4-6, 2018, Toulouse
Conference	UNESCO	Jay Pearlman	September 10-11, 2018, Paris
Conference	International conference on glider data management	Cristian Munoz	September 18 – 20, 2018, Genoa
Conference	IMDIS	Cristian Munoz, Peter	November 5-7, 2018,

		Pissierssens, Pauline Simpson. Pier Luigi Buttigieg	Barcelona
Coordination Meeting	INTAROS H2020 Project	Jay Pearlman, Francoise Pearlman	June, 2018 Bergen
Coordination Meeting	ICOS	Jay Pearlman	November 2018 GEO Plenary
Coordination Meeting	EMSO	Jay Pearlman, Francoise Pearlman	October 2018, Brest
Coordination Meeting	GEO (with Doug Cripe, GEO Secretariat)	Jay Pearlman	December 2018 @RCN meeting
Technical meeting	12th OceanSITES meeting	Johannes Karstensen	July 2-6, 2018, GEOMAR, Kiel, Germany
Bi-weekly News	IOOS Newsletter	Mark Bushnell	Bi-weekly
Monthly News Letter	Good, Better and Best	Francoise Pearlman, Editor	Monthly starting 1 April, 2018
Best Practice Flyer (2 pager)		BPWG	November 2018

6 Sustainability and Partnerships

With the successful implementation of the OBPS developed through project support, the sustainability of the system was an issue in 2017 and 2018. At the first BP workshop in Nov 2017, a panel was convened to discuss options. The panel recommendation was to look at a coordinated action between IOC bodies, IODE, GOOS and JCOMM, to create a proposal for a long term IOC project to sponsor core operations of the OBPS. In mid 2018, following reviews by the Steering/Management Committees of the three organizations, a proposal was created for review by the three organizations and then, upon their approval, to be presented to the IOC Assembly in June 2019. It is anticipated that further technology development of OBPS upgrades would come from grants and the OBPWG is looking at supporting teams that are responding to grant opportunities.

In addition to financial resources, participation by the community in creating and offering best practices for the repository is essential. This participation is a combination of representation in the OBPWG and engagement with the OBPWG by ocean observing organizations. The OBPWG has 14 volunteers (see figure 8) that meet routinely. They

represent a broad range of organizations. In addition, other key members of the community contribute for advancing the OBPS.



Figure 10: Front row - R Venkatesan, Cristian Munoz-Mas*, Pier Luigi Buttigieg*, Mark Bushnell*, Pauline Simpson*, Francoise Pearlman*, Frank Muller-Karger*; Second Row – John Allen, Johannes Karstensen*, Cyndy Chandler*, Juliet Hermes*, Jay Pearlman*, Arno Lambert*, Emma Heslop*; missing are Peter Pissierssens* and Nick Roden*. * indicates OBPWG core members.

The OBPWG engages with the community in a number of ways. Two workshops have been held, the first for input to system requirements and the second for strategic planning for operations. A town hall was held at the Ocean Sciences meeting in February 2018 for inputs to the system requirements that was well attended. The OBPWG publishes a monthly newsletter with advances and activities of participating organizations. These are available at: <https://tinyurl.com/y7kwmg99>. The community engagements include beta testing for the OBPS user interface and the testing of templates. Feedback on the system has been positive and there is a general recognition that sustainability of best practices is a priority for ocean observing.

In addition to IOC organizations and panels, collaborations are emerging with the Group on Earth Observation Blue Planet and ocean focused organizations/projects such EMSO (open ocean), JERICO (coastal), ICOS (Carbon), INTAROS (Arctic), IMOS, IOOS (coastal), MBON (biodiversity), POGO (education) and Sea Floor Mapping. Technology

contributions have been provided by BODC, Ifremer, IOPAS, Marine Institute (Ireland), MARUM and PLOCAN.

7 Future Directions

There are further developments and contributions, which will make best practices more widely used and the OBPS a core contribution to advances in Ocean Observing. A paper on this subject was written for OceanObs'19 conference (Pearlman, in press) to be held in 2019 (<http://www.oceanobs19.net>). While the paper provides extensive background on technology and future needs for best practice use, a list of recommendations is:

- There needs to be an expanded open and sustained system built upon the OBPS at IOC/IODE for supporting best practice discovery, access and training. This should address the entire ocean observing value chain and be based on FAIR principles. It will need the flexibility to adapt to the changing needs and capabilities over the next decade and more;
- All EOVs and other elements of ocean observing should have associated best practices; this should be clearly articulated in the next generation Framework for Ocean Observing (FOO);
- Expanded peer review processes and expert panels will be needed to acknowledge preferred or “recognized” practices and support community building;
- The best practices for QA/QC need to become part of the ecosystem of methodologies that have wide acceptance;
- Introduction of Artificial Intelligence and machine-to-machine interfaces will lead to a new class of best practices that need to be accommodated;
- Semantic tagging for improved BP access needs further evolution of marine ontologies that should range across the value chain, e.g., from sustainable development goals monitoring to genomics to aquaculture;
- Modeled after linked data, the linking of best practice methodologies should be done (creating a methodology "fabric") and allow connections across elements of the value chain in a transparent manner;
- Transferring knowledge embedded in best practices through training will evolve through increased use of social media and, in the longer term, visual immersion techniques as well as three-dimensional CAD drawings including tools created by 3D printing to help, e.g. with training for sensors and potentially platform interfaces;
- Methodologies for technical advances are more straightforward than evolution of human factors. There are elements of trust and sustainability that have not been sufficiently addressed that will have important impacts on the future of ocean observing;
- Practices relating to citizen science are being created and evolving, but are not well documented, best practices are needed that are accessible to a non-expert audience;

- Effective governance is needed for sustainability and expansion of best practices, preferably guided by the FOO and under an international organization such as IOC.

A lot of changes can be anticipated over the next decade and the impacts of new information system capabilities, new energy storage devices, microcircuit and memory expansions allowing miniaturization and autonomous systems are but a few of the technologies that will create a new observation paradigm. Best practices and their access/sharing will need to accommodate all of these changes and more.

8 References

Clark, M.R., Consalvey, M. and Rowden, A.A. (eds) (2016). *Biological Sampling in the Deep Sea*. Wiley Blackwell. DOI:[10.1002/9781118332535](https://doi.org/10.1002/9781118332535)

Kulkarni, S. (2015). Interdisciplinary research: challenges, perceptions, and the way forward. Available at: <https://www.editage.com/insights/interdisciplinary-research-challenges-perceptions-and-the-way-forward>. (Accessed 22 October 2018)

GOOS, (2018) <http://www.goosocean.org>, viewed Dec 2018.

Leadbetter, Adam; Silke, Joe and Cusack, Caroline (2018) *Creating a weekly Harmful Algal Bloom bulletin*. Version 1. Galway, Ireland, Marine Institute, 59pp. DOI: <http://dx.doi.org/10.25607/OBP-13>

Lindstrom, E., Gunn, J., Fischer, A., McCurdy, A. and Glover, L.K. (2012). *A Framework for Ocean Observing*. By the Task Team for an Integrated Framework for Sustained Ocean Observing. Paris France, UNESCO, 25pp. (IOC/INF-1284). DOI: [10.5270/OceanObs09-FOO](https://doi.org/10.5270/OceanObs09-FOO)

Mattman, C, Khalsa, SJS, Duerr, Ruth, “National Science Foundation Grant: “Earthcube Building Blocks: Collaborative Proposal: Polar Data Insights and Search Analytics for the Deep and Scientific Web”
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1639753

Olson D. (1988). Multidisciplinary issues in marine science. *Oceanography*, 1, 42-43. <http://www.jstor.org/stable/43924422>

Pearlman, J., Luigi Buttigieg, P., Simpson, P., Muñoz, C., Heslop, E., Hermes, J. (2017). "Accessing Existing and Emerging Best Practices for Ocean Observation, a new approach for end-to-end management of best practices", in: *Oceans 2017*. (Anchorage).

Pearlman, J., Bushnell, M., Coppola, L., Buttigieg, P.L., Pearlman, F., Simpson, P., (in press,). "Evolving and Sustaining Ocean Best Practices and Standards for the Next Decade", in: *Frontiers in Science*. (submitted to *Frontiers in Science* October 2018).

Simpson, P., Pearlman, F. and Pearlman J. (eds) (2017) Evolving and Sustaining Ocean Best Practices Workshop, 15 – 17 November 2017, Intergovernmental Oceanographic Commission, Paris, France: Proceedings. AtlantOS/ODIP/OORCN Ocean Best Practices Working Group, 74pp. DOI: <http://dx.doi.org/10.25607/OBP-3>

UNSDG (2018). About the Sustainable Development Goals. Available at: <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>. (Accessed 18 October 2018)

Wackernagel, M., Hanscom, L. and Lin. D. (2017). Making the Sustainable Development Goals Consistent with Sustainability. *Frontiers in. Energy Research*, 5:18. DOI:10.3389/fenrg.2017.00018

Wilkinson, M.D. et al (2016) The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, 3, Article number: 160018

Yan, X-H. (ed.). (2013). Observing the Ocean's Interior from Satellite Remote Sensing. *Remote Sensing Journal*, Special Issue. https://www.mdpi.com/journal/remotesensing/special_issues/observing-ocean-interior

Appendix 1 AtlantOS Task summary and Stakeholder information

Stakeholder engagement information relating to this task

<p>WHO are your most important stakeholders?</p>	<p><input checked="" type="checkbox"/> Private company If yes, is it an SME <input checked="" type="checkbox"/> or a large company <input checked="" type="checkbox"/>? <input checked="" type="checkbox"/> National governmental body <input checked="" type="checkbox"/> International organization <input checked="" type="checkbox"/> NGO <input type="checkbox"/> others Please give the name(s) of the stakeholder(s): ...</p>
<p>WHERE is/are the company(ies) or organization(s) from?</p>	<p><input checked="" type="checkbox"/> Your own country <input checked="" type="checkbox"/> Another country in the EU <input checked="" type="checkbox"/> Another country outside the EU Please name the country(ies): ...</p>
<p>Is this deliverable a success story? If yes, why? If not, why?</p>	<p><input checked="" type="checkbox"/> Yes, because it created the foundation for a sustained resource in best practices for the ocean observation and ocean application communities <input type="checkbox"/> No, because</p>
<p>Will this deliverable be used? If yes, who will use it? If not, why will it not be used?</p>	<p><input checked="" type="checkbox"/> Yes, by ocean observation teams, ocean applications and policy experts. <input type="checkbox"/> No, because</p>