Accessing Existing and Emerging Best Practices for Ocean Observation

a new approach for end-to-end management of Best Practices

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***Abstract*— There is an ever-present need for the identification and dissemination of best practices in the multidisciplinary field of ocean observation. However, the complexity of this domain and the diversity of its stakeholders make discovering relevant best practices (BP) a considerable challenge. Addressing this challenge rests upon a) the creation of a basic resource for the efficient discovery and access of documented best practices and b) the acquisition and management of sufficient best practice documentation. A trusted and stable archive location is needed as a focal point for the community, harmonizing the formats of best practice documents and ensuring their contents are exposed to the Web. Further, the discoverability of content must be augmented using granular indexing while its provenance (including any certification) and value must be exposed to support scientists in their search for appropriate methods.**

This paper presents our efforts in creating a centralized and well-indexed OceanBestPractices repository, implemented to provide sustained access to community-endorsed methodologies for ocean observation. The repository is being built to expose documents to the Web and semantically index these for improved discovery using established and emerging ontologies. The repository's design will leverage persistent identifiers - such as "Open Researcher and Contributor IDs" (ORCIDs) for human agents and "International Geo Sample Numbers" (IGSNs) for samples - to facilitate distributed and stable searches across repositories. The initial results are described of semantically indexing best practice documents that have been transferred to granular, web-accessible formats, allowing comparison of related methods from multiple communities. The first two focus areas for a pilot demonstration are sensor design and data management and specific examples in each area are selected for presentation.

Keywords—best practices, ontologies, peer review, sustainability, digital repositories, ocean observations, data, sensor, knowledgebase, permanent identifiers, semantic technology, data management

I. Introduction (*Heading 1*)

Oceanography has rapidly evolved over the last century with the investment of nations for defense and science. The need for continuing investment is driven, in part, by the significant changes that have occurred as the human population has expanded and pressures on ocean resources mount, making imperative the understanding of the ocean as part of a linked, sustainable global ecosystem. This has engaged a broad range of disciplines, not all conversant with each other's techniques and best practices. These best practices (BP) may apply across sensors and platforms where the same practice can be used for different observational objectives and science teams. In addition, the tradition of academic mentoring based on tight networks of scientists and their students is not as effective in this era of expanded globalization of science. Combine these with the networked, data and information-rich environment of the age of globally interconnected science and significant challenges in the ability to survey and identify best practices emerge.

These trends suggest that the effective transmission of best practices is an increasing and pressing concern of global science. The *Guide to best practices for ocean acidification research and data reporting* [1] describes the environment that drives this need: "Over the past few years, several high profile reports have highlighted the urgent need to better understand the effects of changes in carbonate chemistry on marine organisms and ecosystems. Research in this field was limited to a few groups around the world until recently but the number of scientists involved in ocean acidification research has been rapidly rising over the past few years. New coordinated national programs are being initiated and will further augment the research efforts in this area. Students, young researchers, and established scientists inexperienced with the intricacies of the seawater carbonate chemistry will enter the field."

To address these challenges, BP need to be accessible, reliably archived, searchable and comparable. Unfortunately, BP are typically created and used in projects while they are funded, only to be lost to most of the community once such projects close and their dissemination channels are shut down. Eventually the knowledge base atrophies and is often reinvented at a later date, usually at considerable cost.

In this context, we hold that processes for sustaining BP are necessary to provide an enduring resource for ocean observations throughout their value chain from sensors and samples to processed data in the hands of users. This paper describes initial concepts and efforts based on the FAIR principles to create and operate a platform for sustainable BP management. It is based on experiences in institutions such as IOC/IODE, projects such as FixO3 and JERICO in Europe and IOOS in the US and the many technical panels that debate and guide the directions of ocean research. The emphasis is not on the creation of BP themselves, but on having a permanent, web-accessible, and granularly indexed archive for such practices so they can be sustained, effectively discovered, compared and used for both research and training. In short, our work attempts to raise BP documentation into the age of advanced globally networked science.

II. Considerations on Best Practices

When asked if something is a best practice, the inevitable response is "what makes it a *best* practice?" The spirit (and practicality) of BP is that they are an ever evolving and context-dependent "best", driven forward and endorsed by multiple stakeholders (academia, agencies, etc.). Observation environments are diverse and resource availability highly variable, thus a best practice that applies to an autonomous vehicle deployed by an agency of a highly industrialized nation may not be best for ship-based observations conducted by a public agency from a developing country. Similarly, measurement of near surface conditions will have divergent BP from those made at depth. Thus, there is the need to identify the "best for who" and "best for what" for every "best" that is encountered to prevent discrepancies and confusion.

A. What is a best practice?

Defining best practices is a common occurrence in many fields. A common dictionary definition for BP that applies to ocean observation is a procedure that has been shown by experience to produce optimal results [2, 3, 4, 5]. Often, considerations of cost and feasibility, which determine how suitable a practice is for widespread adoption, are also factored in to its evaluation. Not all BP are at the same level of specificity, nor with the same breadth, or always achievable by all of a community. Thus, there is a risk in trying to define the structure too rigidly, inhibiting creativity and progress.

It is important to note that the rapid and diversified development of new BP often outpaces the development cycle of stable, widely accepted standards that often form the basis for infrastructural observation practices. To maintain rigor while accommodating innovation, there needs to be some intermediary process that allows efficient propagation of promising and community-endorsed techniques for improving the consistency of observations across multiple contexts.

B. The creation of a best practice

A community best practice is formed when a methodology is repeatedly shown to produce superior results (modulo resource limitations and feasibility) relative to other methodologies with the same objective. To be fully elevated to a best practice, a promising method will be adopted and employed by more than one organization; while one organization may advocate a practice, it is the adoption by a broader community that is a true mark of generalizable value. Naturally, the practice should be well documented and openly accessible in order to promote such adoption.

Generally, practices go through some form of peer review by panels, experts or project participants. The European FixO3 project created a BP document for fixed-point ocean observatories compiled and reviewed by project experts [6]. IOCCP and PICES drew on panel expertise for a *Guide to best practices for ocean CO2 measurements* [7] and a number of SCOR groups have produced publications around BP [8]. Research and education institutions may use internal experts or peer review to create BP.

There are continuing discussions of the validity of peer review to identify and confirm a best practice. In a recent publication [9], it is noted that: "With the advent of Web technologies, we are now witnessing a phase of innovation and experimentation in our approaches to peer review". As will be discussed later in this paper, both traditional and alternative forms of peer review (open community review) are considered important in best practice formulation.

C. The documentation of best practices

As already noted, 'one size does not fit all' when discussing BP documents; for example, a BP document section required for sensors may not be required for data management BP. However, there is a suggestion that a BP document template where 'core' content headings are identified might be helpful for broad topic areas. Draft templates are being circulated for further discussion within the ocean observation community suggesting core headings that should be used. This suggested template is not intended to be overly prescriptive, but to enable easier inter-comparison between like-coverage BP and to assist emerging technologies as a guide.

D. The evolution of Best Practices

Creation of new practices and evolution of current practices are naturally driven by new technologies and techniques of measurement or computational advances. Such change also occurs as practices move from one area of science to another. The use of mobile phones for photography and environmental measurements in additional to communication is an example. LEDs created for compact disc players have evolved so that LEDs are now part of ocean fluorescence measurements.

Challenges may arise when a new best practice is updating or altering a previous best practice. Adjudicating such an evolution involves decisions on the benefits of changing a practice. Even when the improvements in outcomes are significant, these must be traded off against community re-education and risks of discontinuity in data usability. This is part of the dynamics of a vibrant research community and also of a best practice inventory and there must be processes that facilitate updating of best practices.

III. Towards a More Modern Process For Archiving and Sustaining Best Practices

Best practice archives have been envisioned for a long time and some parts of the ocean community have created repositories for specific areas. For example, a repository of data and information BP called OceanDataPractices (ODPr) was established in 2013 as part of the Ocean Data Standards and Best Practices Project. [10] The OceanDataPractices repository replaced the *JCOMM Catalogue of Best Practices* and all records were migrated into the new repository. Since ocean best practices cover many elements of the observation chain, there is a broader need to have a dynamic archive for, ideally, all of the elements of ocean observation. Working with the EU Horizon 2020 ODIP and AtlantOS projects in 2017 and through agreement of its main partners (JCOMM, WMO and ICES), the IODE is re-engineering ODPr as OceanBestPractices (OBP) repository [11] that includes recommended practices in ocean research, ocean observation and ocean data and information management. The repository already contains a wide variety of "practices", such as manuals and guides, and aims to provide new resources for discovering and accessing existing methodologies and BP. To do this more effectively, another iteration of development is envisioned to cope with the diverse manner in which BP are documented as well as with the growing complexity of methods in ocean science.

Currently, BP are primarily distributed as texts in PDF or similar formats, with highly variable internal structure and format. This is consistent with providing human readable documents with the purpose of sharing techniques for observing, calibrating, monitoring performance, etc. While this seems natural to most, such sharing of "flat files" is remarkably similar to the approaches of 100 years ago. Even with a repository to centralize these files, they are likely to be written in the "dialect" of its featured disciplines, restricting the ability of other groups to discover and avail of their content.

In the current efforts, an upgraded OBP repository will, minimally, expose its content in a web-accessible way such that it is liberated from flat files and more fully visible to search providers. Naturally, one cannot rely solely on the effectiveness of third party search solutions, and the repository will include structured, machine-actionable metadata, such as classes from relevant ontologies (e.g. for environmental systems [12, 13], protocols [14] and biodiversity [15]), to be associated with its content. Upon this basis, enhanced search and retrieval functions with high precision can be created, especially if the ocean community provides feedback to reshape such metadata resources. In addition to web-availability and granular indexing, there is considerable value in casting best practice documents into a common format, as is done by virtually all individual journals of methods or compendia of standard operating procedures. While it may not be feasible to reformat legacy documents, outreach activities should encourage future initiatives to develop their best practice documents in this format, potentially within the OBP repository itself. To tie these elements together, the repository must also have a set of policies that support sustainability of the best practice documentation, the discovery and access of practices in ways that allow inter-comparison and updating (with version control), define the life cycle support and detail how users will be supported.

To summarize, the basic functionalities of a comprehensive OBP repository provide the means for: contributions (both provider and web search inputs); use (including discovery and access); types of review (completeness and peer review); unique identification of documents and authorship, and for linking to other relevant materials. Figure 1 shows an end-to-end flow diagram indicating the central role of the repository. The repository serves as an active archive and does not create nor change BP.

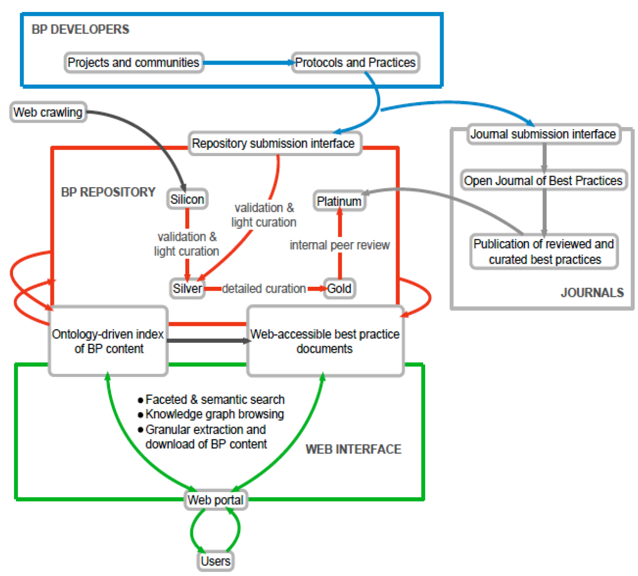

Figure 1. Conceptual structure and information flow for a BP repository.

As shown in the top of Figure 1, documents created by expert groups, agencies, or other stakeholders would be submitted to either a) the repository itself or b) a journal that coordinates its content with the repository. In both cases, the submitters would include metadata descriptors, sourced from a continually updated ontology, clarifying what each section of their document is about (e.g. which parameters, which environments, which sensors, etc.). Within the repository, the document is 'promoted' as it is more heavily curated and reviewed. Documents that have been peer reviewed and annotated by compatible journals would automatically be assigned the highest level of internal repository review after validation. All documents will be exposed as web pages, with each section indexed by the assigned metadata descriptors, and assigned a persistent URL or Handle. Users may access a web portal that would convert their requests (e.g. "Retrieve all BPs that are about measuring nitrate in coastal water") into semantic queries that would be processed using the ontology. The responses to such queries will provide the Handles of all BP sections relevant to the user's search, which will be retrieved and delivered to the user.

A. The Repository

The repository in the center of Figure 1 will be the IODE OceanBestPractices Repository, which will maintain a tagging process that enables users to know the level of review that a contributed best practice has been through. Three levels of review are envisaged with corresponding tagging of BP:

Silicon – Documents that have been identified as potential BP and automatically harvested by web-crawling software [16]. This archive will be available for users to mine themselves, but with no guarantee that the content comprises true BP. Should users or the repository curation team validate that any Silicon-grade document is a best practice, the document will be promoted to the Silver or Gold Archive, dependent on the level of curation it undergoes.

Silver – Documents that have been lightly curated with automated and semi-automated methods including checks for the completeness of mandatory metadata fields and a successful file upload

Gold – Documents that have been through detailed curation process that includes tagging of their sections with ontology classes, metadata quality check and text documentation

Platinum –BP that have undergone one of two versions of peer review, either within repository through its panel of experts or through a peer reviewed journal publication. If peer review has already been done, then it need not be repeated.

Another feature of the repository is its interface with contributors. An optimized path has been created for contributors to submit content based on a best practice document template that will be available from the repository. Completing the template will ensure that sufficient metadata will be available for the best practice to effectively expose it to potential users. Different document templates have been designed to gather input from different expert groups such as, for example, those specializing in sensors or data management. The grouping allows each community to contribute in their own vocabulary that will then be integrated into the vocabulary-agnostic ontology that serves as a cross-domain translation layer. Naturally, this process will not be rigid and will respond to community feedback.

In the future, the option for users and groups to create and edit a best practice in the repository's wiki-based system will be available, further standardizing input. BP documents deposited in the OBP repository will be made available as web accessible documents via a Wiki-like solution. Using automated or semi-automated processes each section within the document that pertains to a different best practice will be tagged with ontology classes expressing what the method targets, what sensors it uses, and what techniques it brings to bear. A search interface will be developed that will be able to search across the literal content of the repository as well as through the knowledge graph that links the ontology classes used to tag its content. In this manner, users will be able to find BP even without knowing the discipline-specific terminology, provided an initial vocabulary mapping is present or developed. In addition to faceted searches, the knowledge graph itself will be browsable, allowing users to explore content in an open-world manner. Naturally, should users encounter issues or wish to update the knowledge graph, they may report issues through the web interface.

When they are contributed to the repository, BP will be assigned a unique persistent identifier (a Handle). Should they already have such an ID, this will be mapped to the repository's Handle ID to provide a form of backup supported by long-term mandates. Author ORCID IDs will be associated with the BP as well as repository IDs (RE3data) if appropriate. At the end of the curation process, the BP repository record will contain rich metadata to enable sophisticated discovery and access.

B. Peer Review of Best Practices

Several mechanisms for peer review have been examined and are under consideration for implementation. Traditional peer review for journals uses two or more experts to comment upon a potential research publication. This is a voluntary effort on the part of reviewers coordinated by the journal management and the journal editor. This current system of peer review only became widespread in the mid-20th century. For example, Nature did not implement such a formal peer review process until 1967 (17). Peer review processes that use a single-blind review, where reviewers are anonymous but authors are not, is the most widely used because the process is comparably less onerous and less expensive to operate than the alternatives. Double-blind peer review, where both authors and reviewers are reciprocally anonymous is also used [18]. Recently, another "open" approach is evolving where community reviews have both the authors and reviewers identified. The open modality can operate through assigned expert reviews or through open community reviews where, for the latter, drafts are published and comments are requested within a certain timeframe (for a fuller description and tradeoffs, see Tenant 2017 tables 2 and 3 [19]). In examining the options, questions still must be answered. It is not year clear if the ocean community prefers open versus blind reviews for BP. It is also unclear the extent to which innovation versus solid technical base should have a higher priority in the reviews. For the sustainable best practice archiving process and peer review, a hybrid approach is being considered where both expert panels and open community review are used. For implementation, the most practical mechanism is to align with an existing journal having established mechanisms for peer review.

IV. Current Status of Development

At present, the OceanBestPractices Repository exists and is ready for community deposits. A BP document template is under review by the community in mid 2017; also during

2017, the repository and journal peer review panel construct will be defined in collaboration with community experts. International projects and funding agencies will be encouraged to consider archiving and sharing their BP documents in the ODP repository.

Simultaneously, a prototype Methods and Best Practices in Environmental Sensing Ontology [MESO; 20] has been created to test semantic indexing of the OBP's content. This ontology reuses existing, interoperable ontologies covering the domains of environments [21], populations and communities [22], information artifacts [23], devices and protocols [24], chemicals [25], and qualities [26] developed using the BP of the Open Biological and Biomedical Ontologies (OBO) Foundry and Library [27]. MESO will soon integrate ontologies for sensors and sample collection and only mint new classes when needed. In addition, scope exists to explicitly link ocean BP to the United Nations Sustainable Development Goals (SDGs), their targets, and indicators through the Sustainable Development Goals Interface Ontology (SDGIO; 28). Through such reuse, the content of the OBP repository will be indexed with the same semantic resources used across many fields and communities, preparing the way for future integration and extended discoverability as new challenges emerge.

The Repository as well as the rest of the system envisaged will be guided by the FAIR principles (29) to make BP Findable, Accessible, Interoperable, and Re-usable. While FAIR is generally thought of as applying to data and associated metadata, the principles apply equally well here. These are essential in addressing and representing the knowledge of diverse communities for the purpose of improved findability and accessibility through semantic searches and an easy-to-use and web-facing solution for content, coupled with accepted norms for quality control (peer-review) as well as the capacity to enable more inclusive review and comment.

V. Summary

There is a recognized need for a trusted, permanent sustainable repository for ocean best practices. Large investments in best practices are made in ocean research through sponsoring organizations and these are many times lost when projects complete or scientists retire. A sustainable repository is thus being built within the context and the spirit of best practice documents as an ever-evolving "best", driven forward by multiple stakeholders (academia, agencies, etc.); the need to identify the "best for who" and "best for what" for every "best" we encounter. The steps forward are guided by the FAIR principles so that BP remain an open and accessible resource for the community. In this spirit, BP create opportunities for collaboration among scientists with the opportunity to mentor and learn methodologies and to facilitate cross discipline research easier and more productive.

With the evolution of archiving technology including: (1) changes in the identification of objects, authors and institutions; (2) review processes for research and practices outcomes; and (3) linking of information, there is a need to move beyond traditional approaches in order to support and archive with substantially improved discovery and access. This is particularly important where science challenges such as climate change and ecosystem response involve multiple disciplines, traditionally with their own customs and vocabularies. This paper offers background in practices and technology options and then provides a process approach using the web, advances in ontologies and peer review mechanisms for evolving and sustaining best practices in a long-term archive.

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ACRONYMS

AtlantOS	Integrated Atlantic Ocean Observing System
BP	Best Practices of the Ocean Observation Community
FAIR	Guiding rinciples to make data Findable, Accessible, Interoperable, and Re-usable
FixO3	Fixed point Open Ocean Observatory network (FixO3
GOOS	Global Ocean Observing System
ICES	International Council for the Exploration of the Sea
IGSN	International Geo Sample Number**.**
IOC	Intergovernmental Oceanographic Commission
IOCCP	International Ocean Carbon Coordination Project
IODE	International Oceanographic Data and Information Exchange
JCOMM	Joint Committee on Oceanography & Marine Meteorology
LEDs	Light Emitting Diodes
MESO	Methods and Best Practices in Environmental Sensing Ontology
OBP	Ocean Best Practices Repository
OBO	Open Biological and Biomedical Ontologies
ODPr	Ocean Data Practices Repository
ODSBP SG	Ocean Data Standards and Best Practices Project Steering Group
ORCID	Open Researcher and Contributor ID
PICES	North Pacific Marine Science Organization
PID	Persistent Identifier
SCOR	Scientific Committee on Oceanic Research
SDGIO	Sustainable Development Goal Interface Ontology 28
SDGs	Sustainable Development Goals