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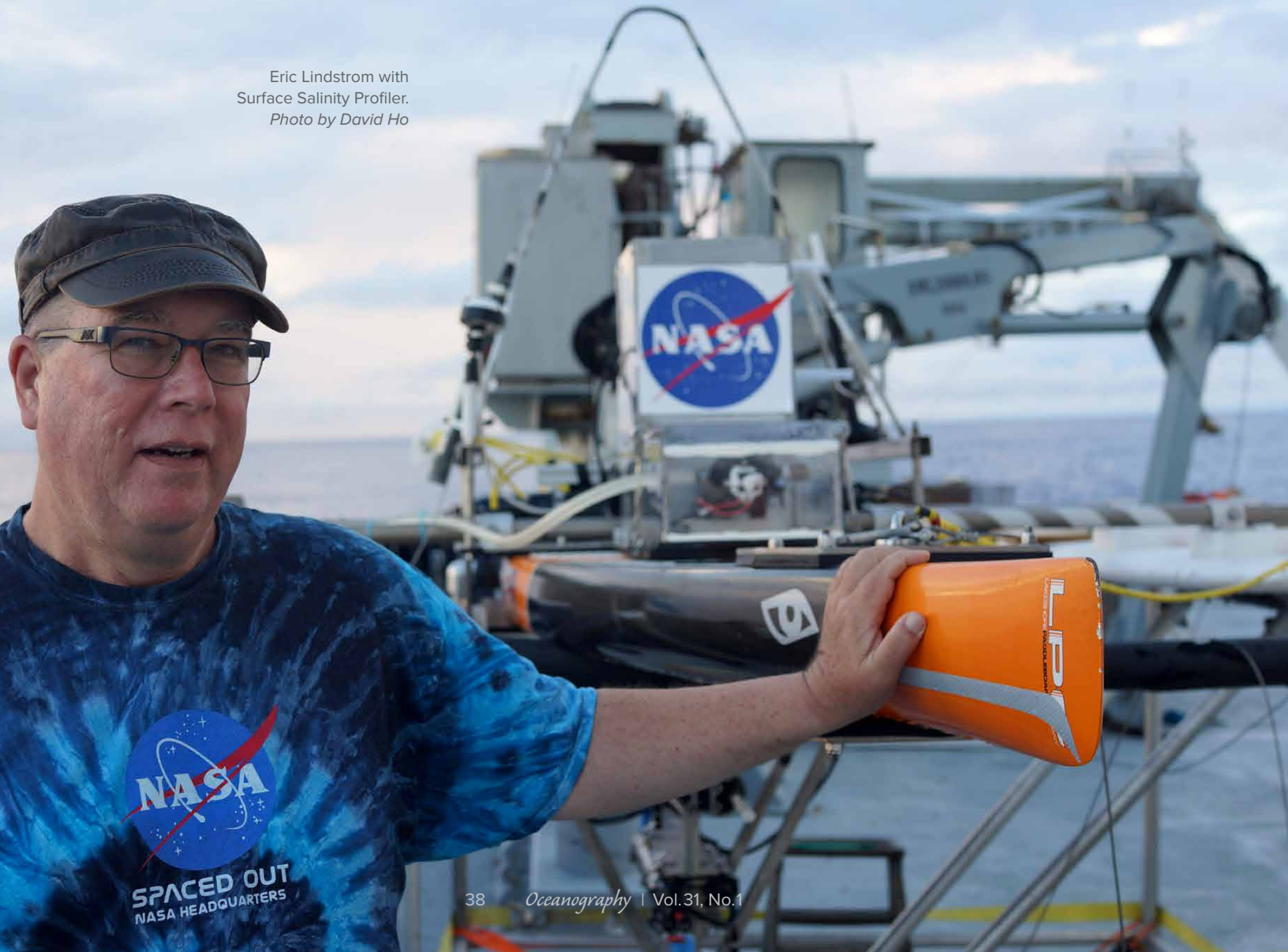
ON THE RELATIONSHIP BETWEEN THE

Global Ocean Observing System AND THE Ocean Observatories Initiative

By Eric Lindstrom



Eric Lindstrom with Surface Salinity Profiler. *Photo by David Ho*

The Global Ocean Observing System (GOOS; http://www.goosocean.org) is an international framework for supporting and sustaining the geographically distributed collection of ocean observations designed to benefit science and society. Observations required to guide an evidentiary-based response by society to environmental change are determined by various international conventions (e.g., United Nations Framework Convention on Climate Change). GOOS, under the Intergovernmental Oceanographic Commission of UNESCO, seeks to respond to the high-level requirement for ocean observations by managing a suite of global networks that collect observations. These networks include, for example, the global array of nearly 4,000 Argo profiling floats, arrays of about 1,250 surface drifters and 300 precision tide gauges, moorings at dozens of key sites around the planet, and repeat hydrographic lines that replicate the sampling of the World Ocean Circulation Experiment about every 10 years (Figure 1).

Key features of GOOS that make it unique are the ambition to sustain the observing system indefinitely, to make the data freely available to all users, to report data in real time for operational applications where feasible, and to expand the system through promulgation of best practices. To date, GOOS has been successful in providing for a baseline suite of physical measurements of the ocean as a follow-on from the World Ocean Circulation Experiment of the 1990s. It is recognized, however, that science and

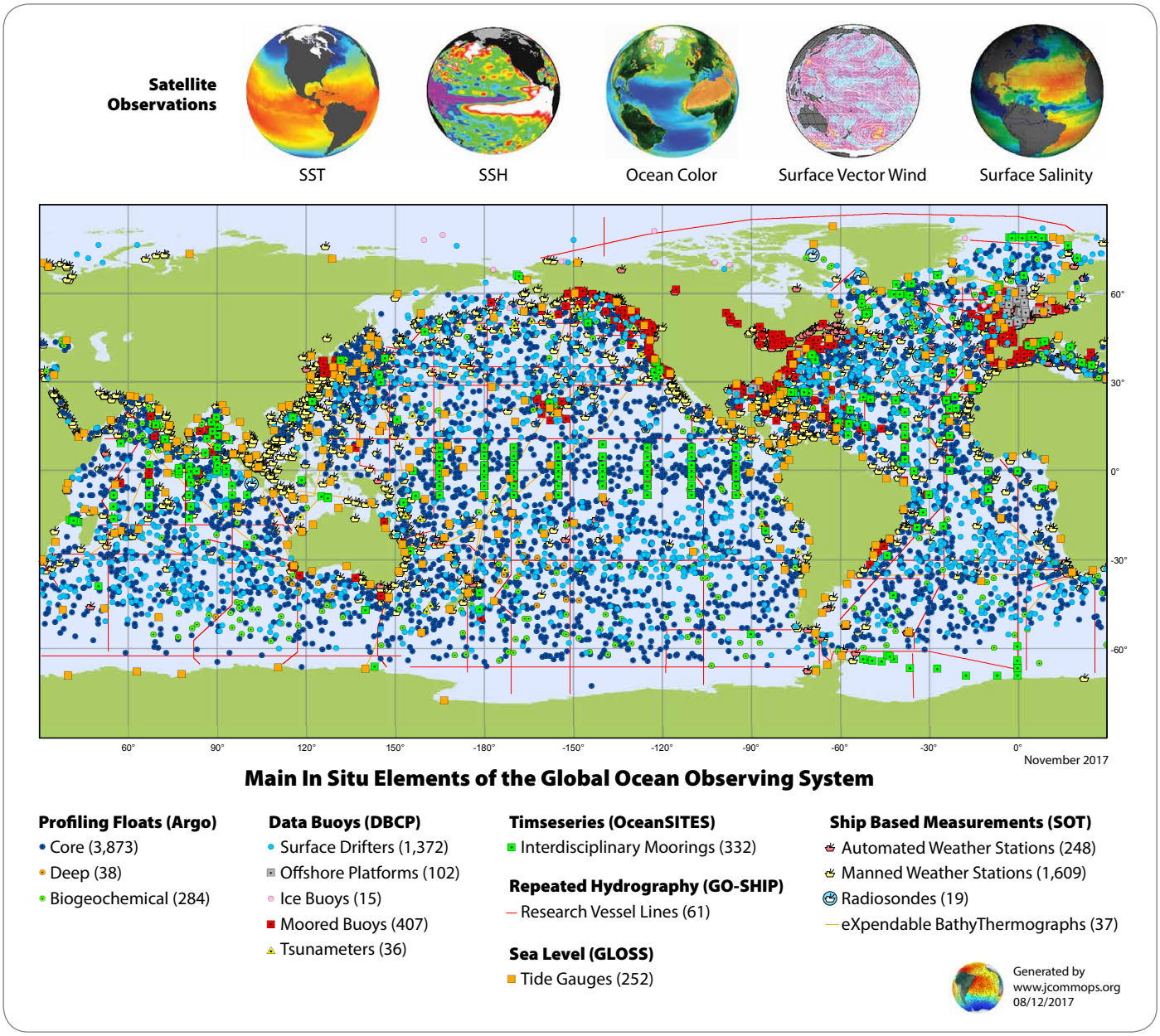


FIGURE 1. Satellite and in situ elements of the Global Ocean Observing System (GOOS).

society require more biogeochemical and biological observations of the ocean than are currently provided by GOOS platforms. The oceanographic community is quite active in sifting through all the various requirements for sustained global observations and their feasibility. Adding more components to a global, permanent, operational observing system is a daunting challenge—politically, financially, and practically. Many questions must be answered with respect to which new measurements are the highest priorities and whether there is a robust sensor technology and sampling platform with which to obtain the measurements. Eventually, nations have to agree to a plan and collect observations using common standards and practices.

The Ocean Observatories Initiative (OOI; http://oceanobservatories.org) is an important element within GOOS, despite the fact that it is NOT a global observing system. It does contribute observations to the global system via cabled observatory and moored measurement systems. If there were a weakness in the OOI for GOOS, it would be a failure to report some key data openly in near-real time for societal uses. I will not dwell here on the valuable data reporting contribution of the OOI to GOOS and science; it a complex area worthy of deeper discussion. The most important OOI contribution may be in promoting and perfecting the next generation of sensors and platforms for global sustained measurement systems, the launching pad for GOOS evolution.

In 2012, with the advent and international agreement to the Framework for Ocean Observing (FOO; http://www.oceanobs09.net/foo; Figure 2), GOOS underwent a transformation. It was recognized that GOOS was not only about the collection and use of global ocean observations, but it also had to embrace and develop the ways and means to fulfill new requirements for sustained observations. It was already recognized that much of GOOS was supplied and maintained by the research community, but GOOS had not identified the development pathways for its next generation or evolving observing systems. This outlook, in broad strokes, was the subject of the Framework for Ocean Observing, which was to provide a set of guidelines for how to mature systems from concept to reality, and globally implement them, based on the proven best practices of GOOS to date. I believe that the OOI is a critical tool for developing the next generation of integrated ocean observing platforms.

Roughly speaking, many of today's oceanography methods focus on using a measurement platform to observe a small number of variables. Most oceanographers would recognize that their tools limit the diversity of observations that they make—despite the great expense and effort to get themselves and/or their observing platforms to far reaches of the ocean. We have yet to perfect autonomous observatories that are truly fit for providing sustained global observations of the disciplinary scope required by the challenges facing society. Argo (http://www.argo.ucsd.edu) is one embryonic model for such an observatory, with its evolving subspecies of Deep Argo, Bio-Argo, and Biogeochemical Argo. The OOI represents a pathway for development of cabled observatories, cutting-edge moored observatories, and sophisticated gliders. If GOOS is to be successful and evolve to meet society's need for a comprehensive ocean observing system, the OOI will be a critical element in that evolution. Though there is not space here to enumerate all the potential developments needed to improve a GOOS, I can say that the next generation of improvements within GOOS will build on reliable measurement technologies as now attempted by the OOI. There are numerous frustrations and opportunities: power constraints for autonomous platforms (batteries), cabled platforms and sensors for observing the subtle and crushing signals in the deep ocean, high-bandwidth telemetry through seawater, samplers for the myriad gelatinous forms of life, automated taxonomic identification technology, and robust yet sensitive chemical sensors—the list goes on.

The OOI is highly relevant to

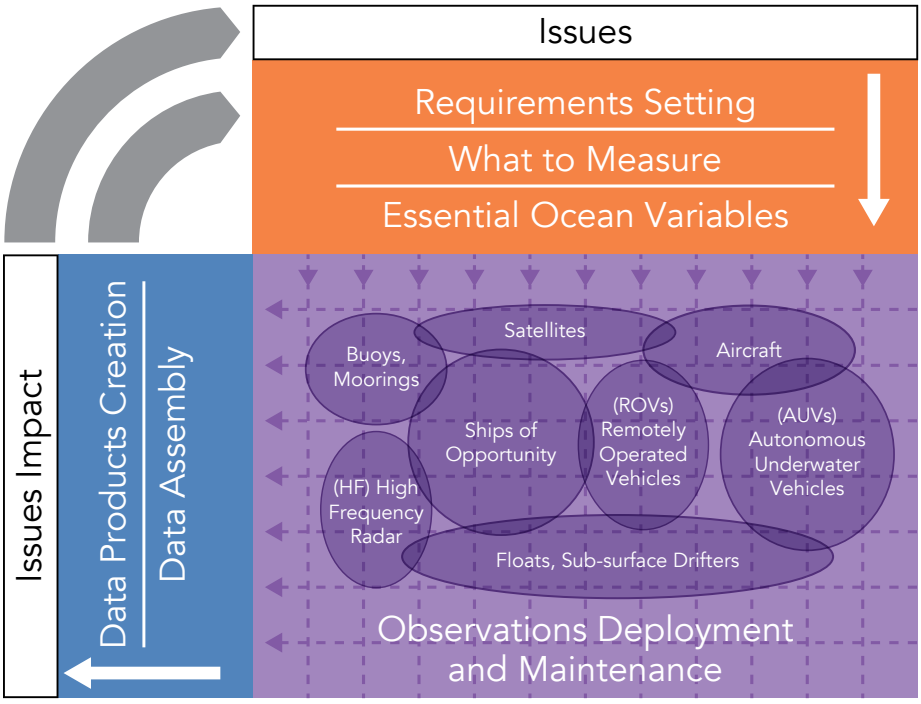


FIGURE 2. Structure of the Framework for Ocean Observing, showing how ocean observing activities fit into the systems model of the Framework and also the critical feedback loop between observing system outputs and science-driven requirements. Observation system examples are illustrative only, not comprehensive.

Box 1. Access to OOI Data from Global and Regional Repositories

In situ observatories, complex cyberinfrastructure, and the need for open access to data are now baseline components of a successful global oceanographic community. Integration and collaboration across programs are imperative. To meet these requirements, Ocean Observatories Initiative (OOI) data have been made available through several existing data repositories, and have been integrated into existing and evolving global and regional visualizations. This allows OOI data not only to be viewed in the greater context of data collected in the area by other programs but also increases its accessibility, as individuals can download through multiple avenues. Currently,

- Coastal Endurance Array mooring data can be viewed through the Northwest Association of Networked Ocean Observing Systems (NANOOS) Visualization System (http://nvs.nanoos.org).
- Coastal Pioneer Array mooring data can be viewed through the Mid-Atlantic Coastal Ocean Observing System (MARACOOS) Ocean Map (http://oceansmap.maracoos.org).
- OOI glider data have been integrated into the IOOS Glider Data Assembly Center (DAC; https://gliders.ioos.us).
- Global Array atmospheric data have been integrated into the World Meteorological Organization's (WMO) Global Telecommunication System (GTS) via the National Data Buoy Center (NDBC; http://www.ndbc.noaa.gov).
- Global Array mooring data are available through OceanSITES (http://www.oceansites.org).
- Cabled Array seismometer and bottom pressure tilt data are available through the Incorporated Research Institutions for Seismology (IRIS; http://www.iris.edu).

Our future is in sustained observations of Earth. *Photo by Julian Schanze*

such challenges as just articulated. Fundamentally, it has sought to sample a wide range of variables with its sensor platforms. It has sought to bring power to the deep sea. It has enabled long-term term sampling in remote locations through a coherent mix of technology innovations and management skills. The OOI recognized that there is need for a robust cyberinfrastructure to translate observations into usable products and services (Box 1).

It will be very important going forward to find ways for OOI and GOOS to cooperate in meaningful ways to capture OOI innovations into a regularized, internationalized, and economized system such as GOOS. For the most part, GOOS is not "high tech." It is at its best when the required technologies are easily deployable (e.g., drifter in a cardboard box) but can deliver sophisticated products consumable by all manner of user groups. As GOOS has learned, it is not just about observing the ocean. We must deliver products and services from those observations to achieve the value that society demands. The OOI is largely tailored to a sophisticated scientific audience. The extension of OOI data products and data services to a wider audience will align nicely with the GOOS objectives.

One way ahead for the synergy of the OOI and GOOS is through joint agreement to the Framework for Ocean Observing (Figure 2) and working together to evolve and improve this Framework. OceanObs'19 (http://www.oceanobs19.net) is coming up in less than two years, and it is likely the Framework will be front and center in considering community progress in ocean observing. The OOI can articulate its success to the GOOS community by showing how its developments contribute to the "readiness" of systems to participate in sustained global observations. The GOOS community can take better note of the progress and development of OOI sensors and platforms by including them in proposals to grow and expand GOOS, thus furthering the overarching GOOS objective to use ocean observations to meet the societal challenges of environmental change.

AUTHOR

Eric Lindstrom (eric.j.lindstrom@nasa.gov) manages the National Aeronautics and Space Administration's (NASA's) Physical Oceanography Research Program, NASA Headquarters, Washington, DC, USA, and is serving as co-chair of the steering committee for the Global Ocean Observing System from 2012–2017.

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