

Sustainability of the Argo Program: Issues and Actions

The Argo Program was conceived in late 1997 as a global array of autonomous profiling floats, and began to gain international endorsements soon thereafter. Following the deployment of the first Argo floats in late 1999, the global Argo array of over 3000 instruments, including its data management system, was in place by 2007. Since the successful installation of Argo, the program has been sustained for nearly another decade. The high value of Argo and the need to continue and improve it for many decades into the future have been recognized by the scientific community, by supporting national agencies, and in many international forums. Here, challenges are considered for continuing “Core Argo” into future decades, even while adding new Argo missions. Some of the future challenges will grow out of those already experienced by Argo, while some of the multi-decadal issues will be new. While looking back on Argo’s first 20 years, the time is right to anticipate the needs for sustaining the program for the next 30 to 50 years. The progress of Argo has been a highlight of community discussion in both OceanObs’99 and OceanObs’09. Argo will again be in the spotlight in OceanObs’19 and a strong focus should be the long-term sustainability of this critical global program. Argo will continue to be a bellwether for all of the ocean observation system. Many of the challenges for sustaining Argo long into the future do not have immediate or clear pathways to solution, but recognizing and articulating them while weighing possible actions, are important first steps.

Issues of management, leadership, and funding

Can Argo attract new scientific and technical leadership? The Argo dataset is freely and immediately available to anyone in the world, so there is limited incentive for scientists to actively engage in Argo implementation. The great breadth of Argo’s user community is evident in the 2600 publications of the Argo bibliography, but only a quarter of the publications have authorship that includes an Argo PI. The new generation of oceanographers and climate scientists has a diminishing role in developing new instrumentation and in implementing observing systems, while modeling and analysis studies using Argo and other global datasets have blossomed. The experience of multi-decadal observing systems other than Argo is that recruitment of a new generation of leaders becomes increasingly difficult with time. How can "creating Argo" become as attractive a career option for young scientists as “analyzing Argo data” has already become? How widely are academic review criteria now beginning to recognize dataset creation?

Can Argo preserve its essential nature while renewing its leadership team? Core Argo is a broadscale global upper-ocean array focused on seasonal and longer term variability in the ocean’s physical state. At present, many members of Argo’s original team are still active in the program, providing important linkage to Argo’s roots and Argo’s essence. This will change in the coming decade as new leaders come onboard, bringing exciting ideas and different directions. The “corporate memory” of the program’s founding generation will gradually fade. Can Argo National Programs engage new personnel while preserving the fundamental character

of Argo and avoiding having to re-learn past lessons? What is the appropriate balance of new Argo leaders and long-time participants?

Can Argo take on new missions without endangering Core Argo? Many new Argo missions are made possible by advances in platform and sensor technologies. These include simple mission modifications and increments in coverage (e.g. surface layer sampling, diurnal variability, tropical cyclone studies, sampling under ice and on the Equator) as well as the major enhancements of Deep Argo (<http://www.argo.ucsd.edu/DAIW1report.pdf>) and BGC Argo (http://www.biogeochemical-argo.org/cloud/document/science-implementation-plan/BGC-Argo_Science_Implementation_Plan.pdf) that require wholly new platforms and sensors. In an era of mostly flat budgets, can enhancements to the Argo Program be implemented without damaging Core Argo? There is a danger that new and exciting missions will eclipse the need to sustain Core Argo. The Argo Steering Team has made clear statements that preserving Core Argo is the highest priority, but can this internal prioritization be managed? It is essential for Argo to remain open to new ideas and new missions, but how should these be implemented in order to balance scientific innovation, agency funding priorities and resources, and technical readiness of new floats and sensors, together with the needs of sustaining Core Argo?

The flat funding issue: Is Argo best framed as research or Operational Oceanography?

Clearly, Argo serves both of these purposes. Most National Argo Programs continue to be funded as research, and often with flat or declining budgets. The number of Argo floats deployed annually has decreased over the past decade. Does the “research” label cause vulnerability for the overall Argo Program and for individual National Argo Programs? On the other hand, “Operational Oceanography” has starkly different meanings in different nations, and depending on the specific nature of research-to-operations transitions, these transitions may pose hazards to the quality and health of observing systems. Among Argo’s user groups, research has the strongest needs for high data quality and excellent coverage, and however Argo is labelled going forward, the research community must remain strongly engaged in implementation of the program. Can Argo preserve and gain advantage from its dual nature of providing a valuable dataset for basic research and Operational Oceanography?

Can the integrated observing system be sustained along with Argo? The Argo Program is complementary and interdependent with many other elements of the ocean (and atmosphere) observing system. For example, GO-SHIP repeat hydrography is the primary source of highest quality CTD reference data that is critical for validation of the accuracy and detection of drift in Argo CTDs. Other complementary programs include satellite altimetric height and sea level networks, satellite gravity, satellite wind stress, boundary current observations by XBTs and gliders, moored arrays, air-sea flux observations, surface drifters, and more. Elements of the observing system, including Argo, are often evaluated and supported as though they were stand-alone programs, but the greatest value is through their integration. The prospects of sustaining the Argo Program are closely linked to that of the integrated system.

Operational issues

What are Argo's future requirements for dedicated deployment vessels? Most Argo floats are deployed on an opportunistic basis, by transiting research vessels (RVs), RVs engaged in non-Argo work, and commercial ships. However, in the remotest expanses of the oceans, especially in the South Pacific and South Indian Oceans, passages by RVs and commercial vessels are too rare. A global Argo array cannot be maintained today solely with opportunistic ship traffic. Of the present 952 Argo floats operating in the South Pacific Ocean, 446 were deployed by New Zealand's RV Kaharoa on dedicated Argo charter voyages, through a partnership of the N.Z., U.S., and Australian Argo Programs. Overall, RV Kaharoa has deployed more than 1600 Argo floats since 2004, and without this contribution Argo would not have achieved global coverage. Moreover, the needs for dedicated deployment vessels may increase in the future as large research vessels and ocean-spanning commercial shipping routes are both diminishing. Can the use of dedicated deployment vessels be continued, with increased international participation, and without becoming a major burden on Argo resources?

Can Argo achieve and maintain adequate access to EEZs for float deployment? A global array can only be sustained through practical international governance procedures that enable deployment within, as well as drift into, Exclusive Economic Zones (EEZs). IOC Resolution EC-XLI/3 provided a set of guidelines for the drift of Argo floats into EEZs, but no international consensus has been achieved on the issue of EEZ deployment. Are the *ad hoc* measures in use at present (bi-lateral and multi-lateral partnerships that include deployment by coastal nations; concurrences by many nations on EEZ deployments; reliance on drift into EEZs) sufficient for Argo's future? Are there new approaches to the EEZ deployment issue that could be tried? To what extent will the new biogeochemical sensors complicate the issues of EEZ deployment and drift?

Can the Argo array be sustained in the seasonally ice-covered oceans? The seasonally ice-covered Arctic and Southern Ocean are especially valuable regions for Argo sampling, but are problematic for sustaining coverage on both technical and logistical grounds. Between 2010 and 2016, 353 Argo floats were deployed south of 60°S, and 163 of these (46%) are presently classified by JCOMMOPS as operational. In comparison, for the latitude range 60S to 40S, 640 out of 1143 (56%) of floats deployed since 2010 are operational. Coverage remains poor poleward of 60°N and S due to low deployment rates and high attrition. The expected lifetime of high-latitude floats having ice-avoidance software is not yet accurately known (half-life of 25 months for the sample above). Deployment opportunities have not been sufficient to achieve and sustain required Argo coverage at high latitudes. What is the level of resources needed to deploy and sustain Argo coverage in these regions and are Argo National Programs able to invest toward this objective?

Is the Argo Program too dependent on single sources of float components? Sensor failures and an interruption in the manufacture of Druck pressure sensors led to supply problems for Argo SeaBird CTDs in 2009, causing substantial reductions in float deployments, Argo

coverage, and data quality. Other components of Argo floats are similarly limited to one or two suppliers. For example, Argo is becoming increasingly dependent on Iridium communication, as it was previously on System Argos. How should the existential risks to Argo that are inherent in single sources be weighed against possible decreases in data quality, uniformity, and technical capability from diversified sources? Does Argo need to increase efforts to encourage and qualify new sources of float components?

Can Argo continue to deliver a comprehensive dataset without over-complexity? In recent years, new requirements for Argo data have included additional sensors, multiple pressure axes, and substantial increases in meta- and technical data. New data formats have required re-processing of large volumes of data, for which Argo DACs may not be prepared. All Argo data, including any “additional sensors”, must be made publicly available, but most Argo DACs are supported only for managing the Core Argo temperature/salinity dataset. Can a comprehensive Argo dataset be improved and maintained, and new sensors or sampling modifications introduced, without overwhelming the Argo data system with increased complexity and repeating requirements for file reconstruction?

What can be done? Consider the following:

What are key practical actions for sustaining Argo?

The Argo Steering Team suggests that the multi-decadal sustainability of the Argo Program can be substantially advanced through the following actions:

1. Argo float lifetimes should be extended beyond 6 years to increase cost-effectiveness of the program and to stretch the array’s refresh time. This can be accomplished through technology improvements and effective commercial partnerships.
2. Argo should work with its user community to articulate more effectively and broadly the high value of the Argo Program and its critical importance in the integrated Global Ocean Observing System and Global Climate Observing System.
3. In order to encourage participation in ”doing” Argo, Argo should document individual and group contributions to the implementation and improvement of the Argo array and its dataset.
4. A more systematic approach should be taken to the problems of global Argo deployment, including both the logistical issue of reaching remote ocean regions and the problems of international governance.