U.S. Argo National Report to AST-23, March 2023

Organization of U.S. Argo:
The U.S. Argo Program is supported with major funding provided by the National Oceanic and Atmospheric Administration (NOAA), and additional participation of the U.S. Navy. It is implemented by a U.S. Float Consortium that includes principal investigators from six institutions: Scripps Institution of Oceanography (SIO), Woods Hole Oceanographic Institution (WHOI), the University of Washington (UW), the Atlantic Oceanographic and Meteorological Laboratory (AOML), the Pacific Marine Environmental Laboratory (PMEL), and the Naval Research Laboratory (NRL/Monterey). Float technology development, production, acquisition, logistics, deployment, array monitoring, and data management functions are distributed among these institutions on a collaborative basis.

In addition to the float-providing and data management activities, U.S. Argo works collaboratively with closely related programs including:
- Argo New Zealand is the largest deployer of U.S. Argo floats through designed deployment voyages of RV Kaharoa (jointly supported by Argo USA, New Zealand, and Australia) and deployment opportunities on RV Tangaroa.
- Global Ocean Biogeochemistry array (GO-BGC), supported by NSF to establish the baseline rates of photosynthetic production, respiration, and nutrient supply in present ocean ecosystems.
- Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM), a regional pilot array of BGC Argo floats supported by NSF and NOAA.
- A NOPP project for validation and improvement of the Deep Argo SBE-61 CTD.
- A NOPP project for development of a BGC SOLO float.
- A NOPP project for the development of new BGC sensors and improvement of the SBE Navis platform.
- A partnership of NOAA/PMEL and the Paul G Allen Family Foundation that provided 33 Deep Argo floats and carried out deployment of 29 of those in the Brazil Basin.
- National Academy of Sciences Gulf Research Program's support for 25 Argo floats in the Gulf of Mexico.
- A cooperatively funded and dedicated Atlantic charter to help ameliorate COVID impacts on vessel access during 2020/2021. Euro-Argo, Argo Canada and US Argo supported the charter, which has deployed ~ 90 floats, mostly into the Southeastern Atlantic.

The contributions of these and other Argo partner projects are gratefully acknowledged.

Another 5-year cycle of U.S. Argo implementation began in July 2020, and extends through June 2024. The Work Plan for this cycle of U.S. Argo includes milestones and growth of the U.S. contribution toward a unified Core/BGC/Deep international Argo Program termed *OneArgo*.

Objectives:
The U.S. Argo Program is funded by NOAA on a year-to-year basis. There is uncertainty in the level of funding that will be available to support the 5-year Work Plan. The projections included

in the Plan are optimistic. The assumptions guiding Work Plan scenarios were that (i) Core Argo budgets should increase by 10% per year above the FY2019 institutional funding levels, and (ii) incremental funding of $1M per year will be available for each of the U.S. Consortium Deep and BGC Argo Programs. The increases for Core Argo are meant first to restore a healthy number of deployments for sustaining the Core Argo array, and second to fund coverage increases, beginning with those proposed for high latitudes and the equatorial Pacific. A distribution of institutional effort between the Deep and BGC programs has been planned by the U.S. Argo institutional partners. All float-providing institutions will participate in both Deep and BGC Programs, and the U.S. Argo DAC will carry out the corresponding data management. Actual funding levels are likely to be less than the ideal scenarios, in which case the highest priority will be sustaining the Core Argo array.

Status of U.S. Core Argo implementation:
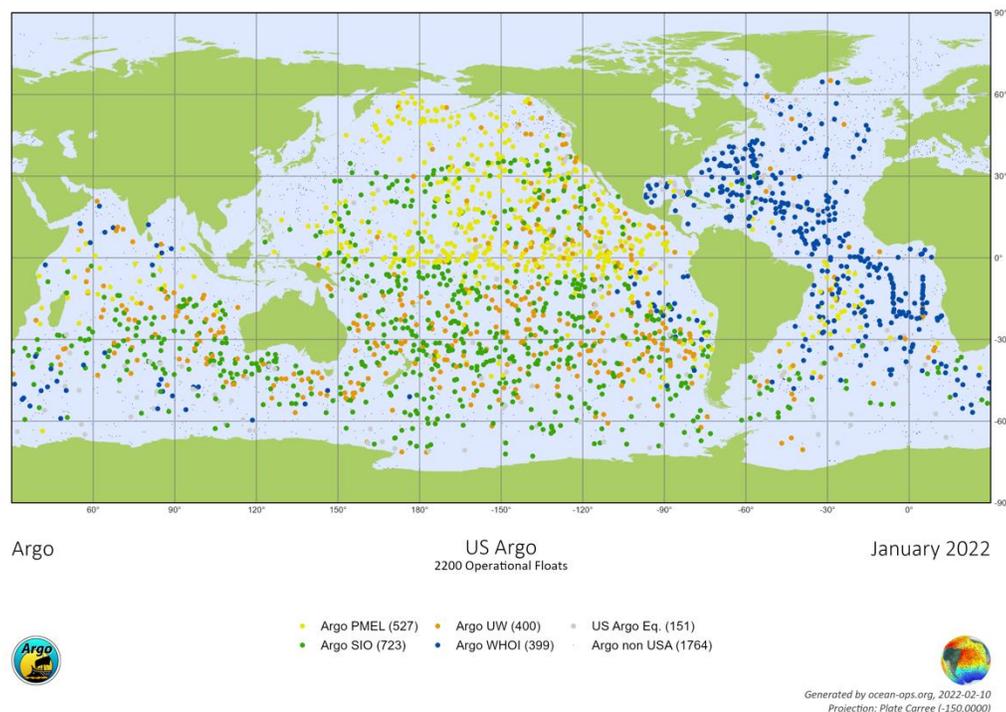
Fig. 1*: Location of operational U.S. Argo Program and U.S. Argo Equivalent floats as of January 2022 (Source: OceanOPS).*

There were 2049 operational U.S. Argo Program floats (Fig. 1) provided by the U.S. Argo Consortium as of January 2022. An additional 152 U.S. Argo equivalent floats were operational at that time, mostly SOCCOM and GO-BGC instruments. Support levels for Core U.S. Argo have remained relatively flat since 2004, with some recent augmentations. Inflationary losses have been offset by increases in float lifetime, with over 80% of floats deployed as far back as 2016 still operational as of 2/022 (Table 1). Hence the number of operational U.S. Argo Program floats has been relatively steady, oscillating around approximately 2000 since about 2016 (Fig. 2).

Further increases in lifetime are expected through continuing identification of short-term and long-term failure modes and improved battery technologies. However, the present number of yearly deployments may not be sufficient to sustain the level of U.S. Argo floats.
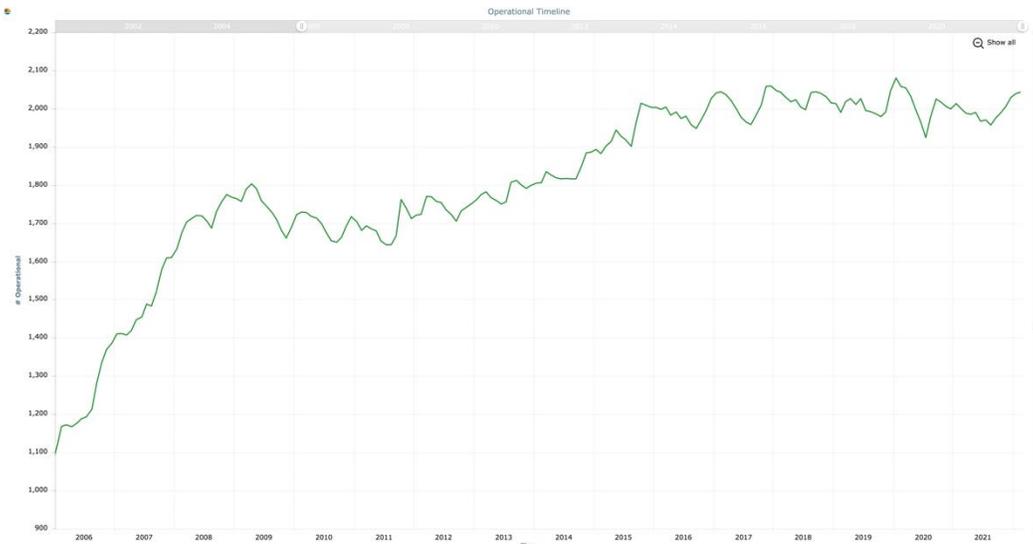

Fig. 2: Timeline of the number of operational U.S. Argo Program floats (Source: OceanOPS).

Year deployed	Number deployed	Number active as of 2/2022	% active (2/2022)
2012	341	15	4%
2013	329	17	5%
2014	376	99	31%
2015	346	225	65%
2016	346	276	80%
2017	366	301	82%
2018	284	236	83%
2019	295	252	85%
2020	284	261	92%
2021	295	264	89%

Table 1: Number of U.S. Argo Program floats deployed in each year since 2012 and the number still active as of 2/2022 (Source: OceanOPS). A major focus of U.S. Argo is extension of float lifetimes and reduction of early float failures.

Impacts of the Covid-19 pandemic have included limitations on all institutional laboratory activities for physical distancing, a substantial reduction in available deployment opportunities by the research fleet, supply chain difficulties that have adversely affected float manufacture, and sea freight delays. There were 295 US Argo Program floats deployed during 2021 (Table 1). Continuing limitations of the research fleet are limiting deployments in remote regions (Fig. 3). Nonetheless, the relatively long life of Argo floats mitigates the Covid-19 reduction in activities, as illustrated by the continuing nearly-constant number of active US Argo Program floats (Fig. 2).
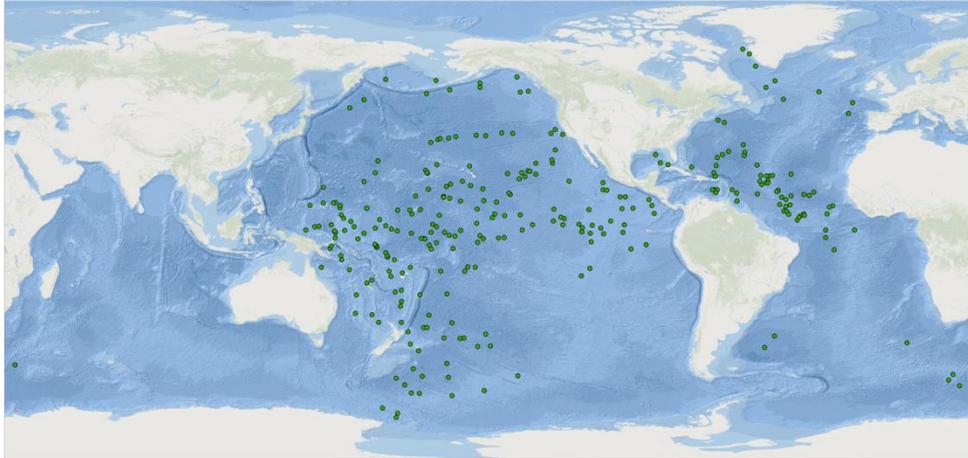
Fig. 3: Latest location of US Argo Program floats deployed during 2021 (Source: OceanOPS).

Support for U.S. Argo includes float production and deployment, technology improvement, communications, data system development and implementation for real-time and delayed-mode data streams, participation in international Argo coordination and in technical and science workshops, Regional Centers, and outreach activities. Work is ongoing to assess the accuracy of CTD data used for the core Argo mission. Salinity drift in recent cohorts of Argo floats is being closely monitored collaboratively with the CTD manufacturer. An alternative Core CTD manufacturer is entering pilot status with the intent of limiting risk to the Argo Program. US Argo is actively involved in testing, quantifying sensor biases, and contributing to the pilot array of RBR CTD equipped floats.

Deep Argo:
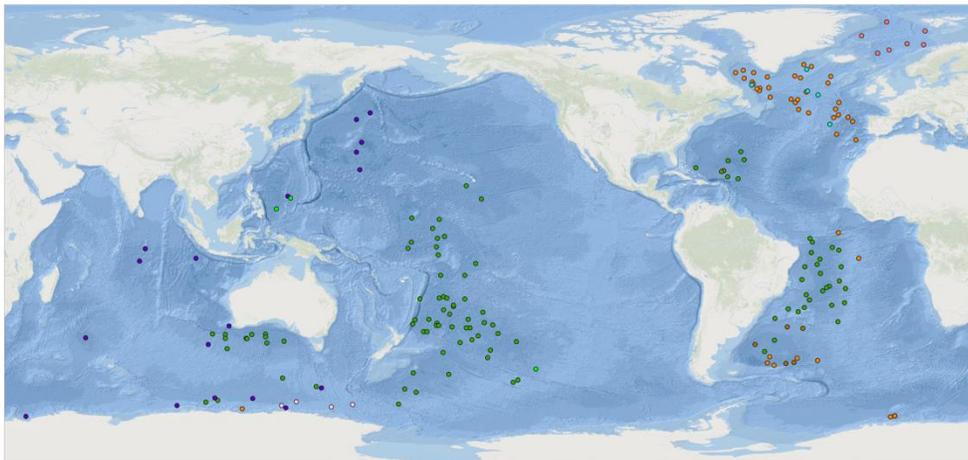
Fig. 4: Location of all 189 active Deep Argo floats, as of 2/2022, by National Program, with the 102 active U.S. Deep Argo floats indicated by dark green symbols (Source: OceanOPS).

In 2011–2015, U.S. Argo carried out development and testing of Deep Argo floats, with successful prototype float deployments in 2013–2015. U.S. Deep Argo floats profile to

pressures as great as 6000 dbar, and recent versions with hybrid lithium batteries are capable of more than 200 cycles. Deployment of U.S. Deep Argo regional pilot arrays began in the SW Pacific Basin in 2016–present, in the South Australian Basin in late 2016 and 2020, in the Australian Antarctic Basin in early 2018, and in the western North Atlantic in early 2017. In 2019–2020, in the Brazil Basin, 29 Deep Argo floats were deployed through a partnership of PMEL/U.S. Argo and the Paul G. Allen Family Foundation, with continued U.S. Argo Deep floats deployments in the Western South Atlantic thereafter (Fig. 4).

Testing of Deep Argo float models continues as well as testing of SBE-61 CTD accuracy and stability. The SBE-61 has not achieved its aspirational goals of ± .001°C, ±.002 psu, and ± 4 dbar, but is progressing relative to those goals. In partnership with U.S. Argo, a 3-year National Ocean Partnership Program award is funded for improvement of the SBE-61. A collaborative U.S./New Zealand/SeaBird Scientific cruise on RV Tangaroa took place in March 2021 for testing/validation of new SBE-61 conductivity and pressure sensors.

BGC Argo:
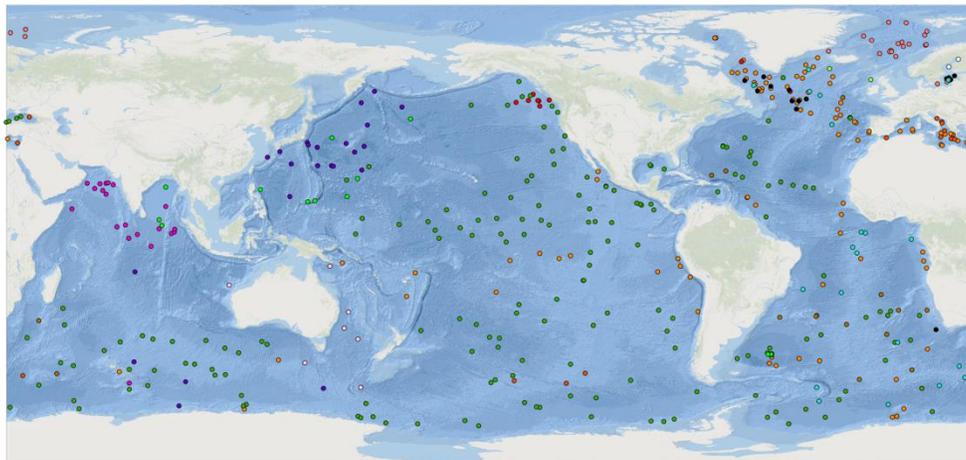
Fig. 5: *Locations of 454 active BGC-Argo floats as of 2/2022, including 177 US Argo and Argo Equivalent BGC floats (mostly from SOCCOM and GO-BGC). US BGC floats are indicated as dark green symbols (Source: OceanOPS).*

Since 2012 the US has carried out testing and deployment of Biogeochemical (BGC) Argo floats. The present versions of these floats cycle 0–2000 m at 10-day intervals and, in addition to the CTD, may carry sensors for dissolved oxygen, nitrate, pH, chlorophyll fluorescence, and particulate backscatter. A major NSF proposal (SOCCOM) started in 2014 to deploy a 200-float array of BGC floats in the Southern Ocean. A second major NSF proposal (GO-BGC) has recently been funded for global deployments of up to 500 BGC floats over a 5-year period. A funded NOPP proposal is developing a BGC SOLO float to increase the number of available BGC float models. As of 2/2022, US BGC floats, mostly from SOCCOM and GO-BGC, number 177 of the total 454 active BGC Argo floats (Fig. 5) with at least 1 BGC sensor

Plans:

The highest priority for U.S. Argo is to sustain the Core Argo array. Specific plans for float deployments in 2022, as they evolve, are posted on the AIC deployment planning web page. Funding levels for the U.S. Argo Program in FY2022 are not yet finalized but are expected to at least equal FY2021 levels.

A deployment cruise on RV Kaharoa, from New Zealand to Tahiti, and back to NZ (Fig. 6), is tentatively planned beginning about November 2022, to deploy about 8 U.S. Deep Argo floats in the SW Pacific Basin, about 100 U.S. Core Argo floats in the South Pacific, plus additional Australia Core Argo floats. Since 2004, 24 voyages on RV Kaharoa have deployed at least 2054 Argo floats (Source: OceanOPS).
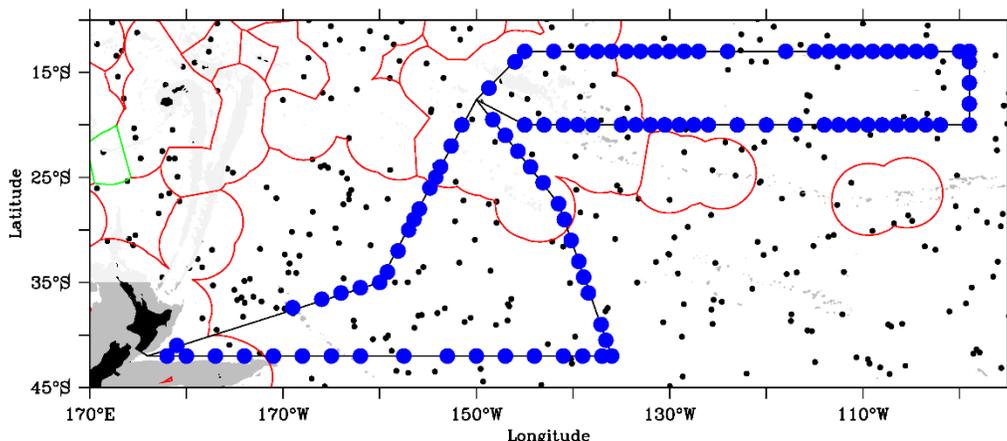
Fig. 6: *Tentative cruise track and deployment plan for the Kaharoa Argo-25 voyage. Blue dots indicate Core Argo float deployments. Deep float deployment locations are not yet determined*

Data management
The U.S. Argo Data Assembly Center (DAC) is based at NOAA/AOML. Real-time data from all U.S. Argo floats are distributed via the GTS and the Global Data Assembly Centers (GDACs). The systems developed at AOML are operational on a primary server housed at AOML and also run on AOML's Argo mirror server at a cloud service provider. These apply internationally-agreed Argo-specific quality control tests and generate data files for the user communities that comply with the Argo standards. The U.S. Argo DAC has expanded its decoding and quality control capabilities to the full suite BGC data from APEX-family Iridium floats. Currently, an expansion of this capability to NAVIS-type Iridium floats is underway. The U.S. Argo DAC also implemented adaptations necessary for the processing of core data from the first SOLO-type BGC float. The collaboration with SIO on this data stream is ongoing. The AOML data center serves as the national focus for data management and is the conduit for delayed-mode data to pass between the PIs and the GDACs. Delayed-mode quality control and some other data management functions are carried out by the float-providing institutions.

In addition to the national DAC, a GDAC is run as part of the GODAE server, located at the Naval Research Laboratory, Monterey. The two GDACs at NRL/Monterey and IFREMER/Brest are mirror images in their assemblies of Argo data from all international partners, and are

responsible for dissemination of the data. Several U.S. institutions participate in Argo Regional Center activities.