U.S. Argo National Report to AST-20, March 2019

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, deployment, array monitoring, and data system functions are distributed among these institutions on a collaborative basis.

In addition to U.S. Argo floats, Argo-equivalent floats have been provided from a number of U.S. float groups, programs, and principal investigators. A notable U.S. Argo-equivalent program is Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM). See "BGC Argo" below. The contributions of all Argo-equivalent partners are gratefully acknowledged.

The present 5-year cycle of U.S. Argo implementation began in July 2015, and extends through June 2020. A new 5-year cycle of U.S. Argo, to begin in July 2020, is presently being planned, and will include milestones and growth of the U.S. contribution toward a unified Core/BGC/Deep Argo Program (Argo 2020).

Objectives:

During the present 5-year cycle, U.S. Argo will sustain its contribution of half of the Core Argo array, while enhancing coverage on a regional basis (high latitudes, western boundary and equatorial regions, marginal seas) as recommended through sustained ocean observing system community activities and endorsed by the AST. These coverage enhancements will only be implemented if sufficient resources are available to maintain the original Argo coverage and the data quality of the Argo array. Further improvements in data quality, timeliness, and resolution are planned, along with ongoing extensions to float lifetimes and cost-effectiveness.

A major enhancement to Argo is the implementation of Deep Argo to extend sampling to the ocean bottom (to pressures as high as 6000 dbar). As a key component of the Deep Ocean Observing Strategy (DOOS), Deep Argo is needed to close regional and global budgets of heat, freshwater, and steric sea level, and for exploration of deep ocean circulation. Deployment of several regional Deep Argo pilot arrays is being undertaken to test floats and sensors, to aid in global array design, and to demonstrate the capability to deploy on a regional basis. U.S. Deep Argo deployments are integrated with planned contributions of international partners.

Status of implementation:

The support level for U.S. Argo is determined on a year-to-year basis. 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, so the number of operational U.S. Argo Program floats remains approximately 2000, equal to the high levels achieved since 2008. 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.

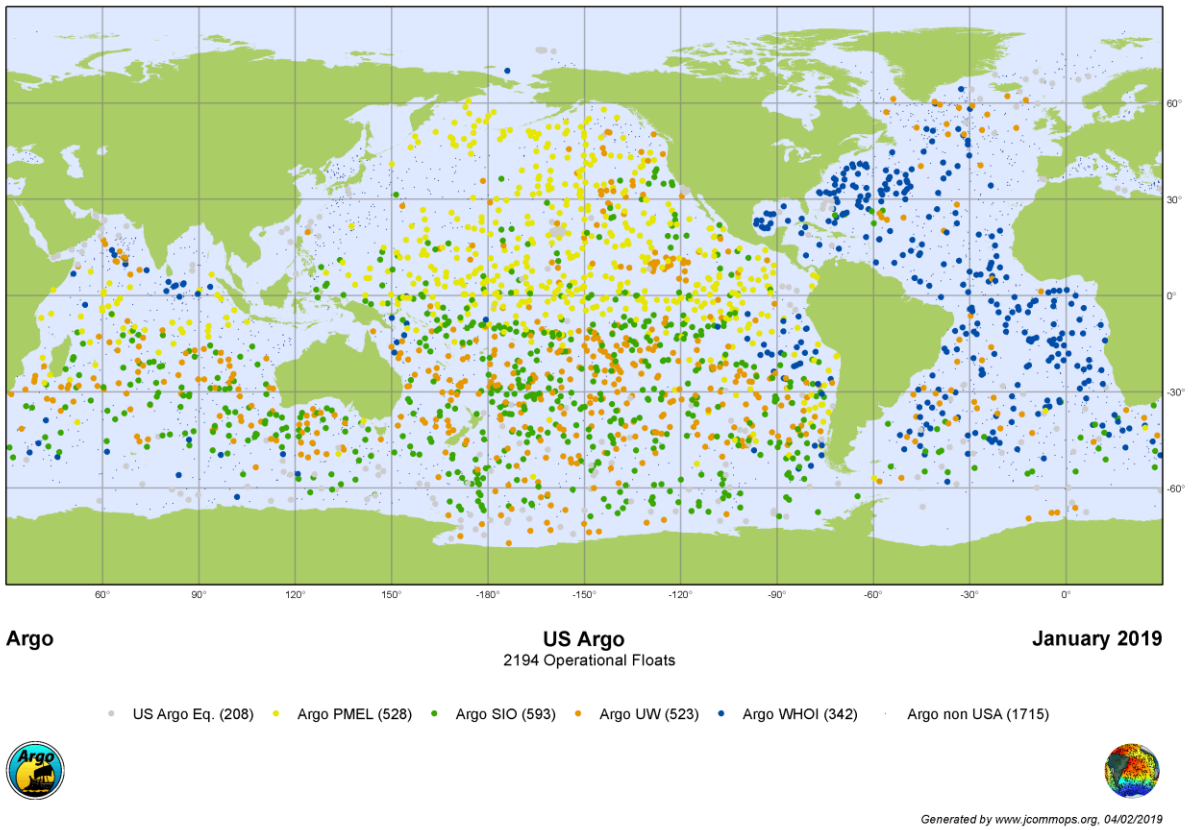


Fig. 1*: Location of 2194 operational U.S. Argo Program and U.S. Argo Equivalent floats as of January 2019. (Source: AIC)*

There are presently 1986 operational U.S. Argo Program floats (Fig. 1) as of January 2019. A timeline of the number of operational U.S. Argo Program floats is shown in Fig. 2. Table 1 indicates the number of U.S. Argo Program floats deployed and operational for each year since 2012 (Source: AIC).

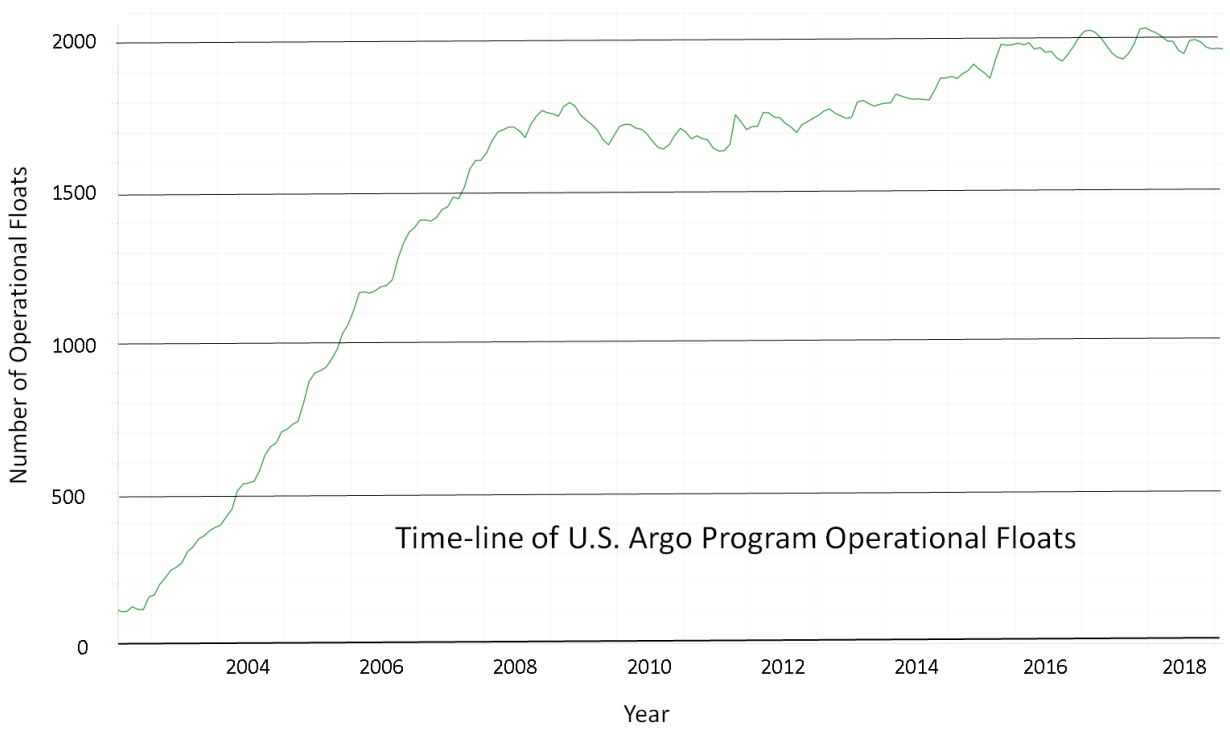


Fig. 2: *History of the number of operational U.S. Argo Program floats (Source: AIC)*

Table 1: Number of U.S. Argo Program floats deployed in each year since 2012 and the number still active as of 2/2019. A major focus of U.S. Argo is extension of float lifetimes and reduction of early float failures. (Source: AIC)

Year deployed	Number deployed	Number active	% active (2/2019)
2012	341	92	27%
2013	329	167	51%
2014	376	276	73%
2015	346	276	80%
2016	346	326	94%
2017	362	344	95%
2018	259	251	97%

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, and participation in international Argo coordination, Regional Centers, and outreach activities.

Work is also being done to bound and check errors in CTD data used for the core Argo mission. Both SBE41CP and RBR ArgoCTDs were taken to sea in November 2018 with data collected in

parallel to the ship-board system. The analysis of these data is underway, and results will be presented at the ADMT-20.

Deep Argo:

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 - 2017, in the South Australian Basin in late 2016, in the Australian Antarctic Basin in early 2018, and in the western North Atlantic in early 2017 (Fig. 3). A three year collaboration between PMEL and Paul G. Allen Philanthropies has provided resources to procure, test, and deploy a regional Deep Argo pilot array of up to 30 Deep SOLO floats in the western South Atlantic.

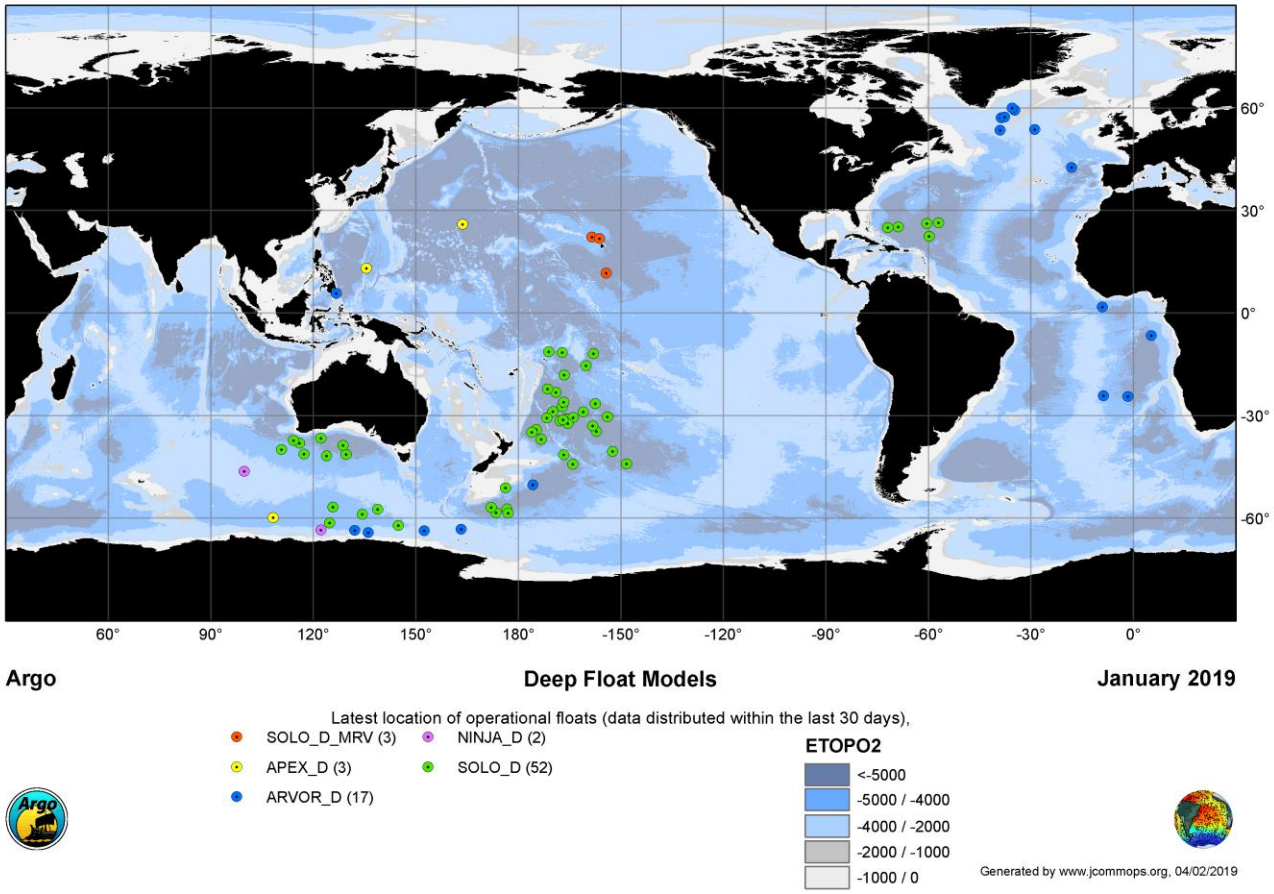
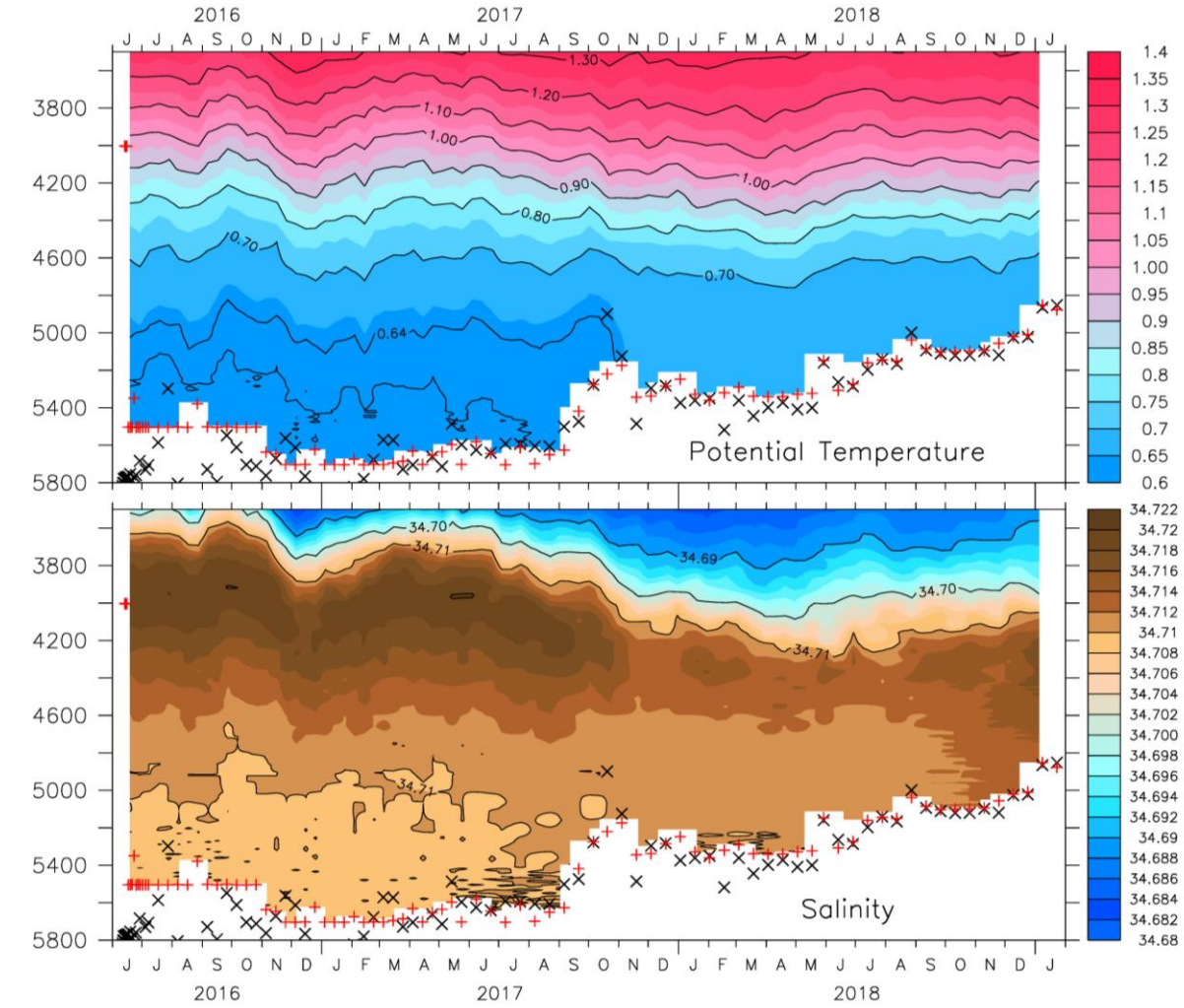


Fig. 3*: Location of all Deep Argo regional pilot array floats. U.S. 6000 dbar floats include 52 Deep SOLOs (Argo Program) in the Southwest Pacific Basin, South Australian Basin, Australian Antarctic Basin, and western North Atlantic, as well as 3 MRV Deep SOLOs near Hawaii.*

Testing of deep float models continues as well as testing of SBE-61 CTD accuracy and stability. The SBE-61 has not yet achieved it aspirational goals of (± .001C, ±.002 psu, and ± 3 dbar) but is progressing relative to those goals. A 3-year National Ocean Partnership Program award is funded for improvement of the SBE-61. An example of potential temperature and salinity data along the path of a single Deep Argo float is shown in Fig. 4



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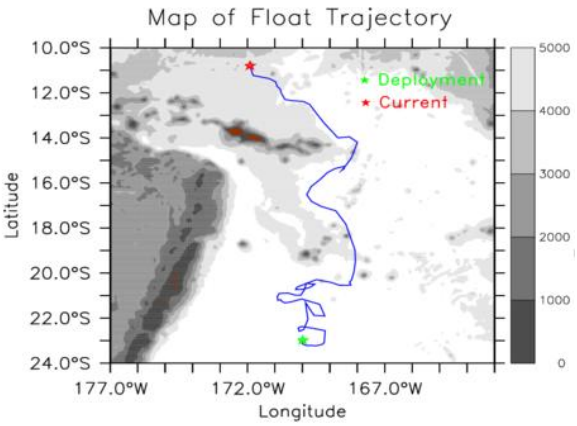

Fig. 4 *(Above) Potential temperature and salinity along the path (left) of Deep Argo float WMO ID 5902457, January 2016 to January 2019. As the float drifted northward from the Southwest Pacific Basin to the Samoa Basin, the increasing temperature of the abyssal layer and the decay of the North Atlantic Deep Water salinity maximum are clearly seen. The float's parking* pressure was 5000 dbar. The estimated bottom pressure from published bathymetry (x) and deepest pressure from the float (+) are shown.*

BGC Argo:

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, carry sensors for dissolved oxygen, nitrate, pH, chlorophyll fluorescence, and particulate backscatter. The SOCCOM BGC float array in the Southern Ocean now contains 125 operational BGC floats, pointing towards a goal of 200 floats by the end of 2021 (see Figure 5). The floats are performing well with lifetimes roughly comparable to core-Argo floats. There is now an active planning effort to expand the SOCCOM array into a global BGC-Argo array that might consist of up to 1000 BGC floats. Initial BGC-Argo expansion might proceed into the North Atlantic and Equatorial Pacific. Potential funding sources are being identified.

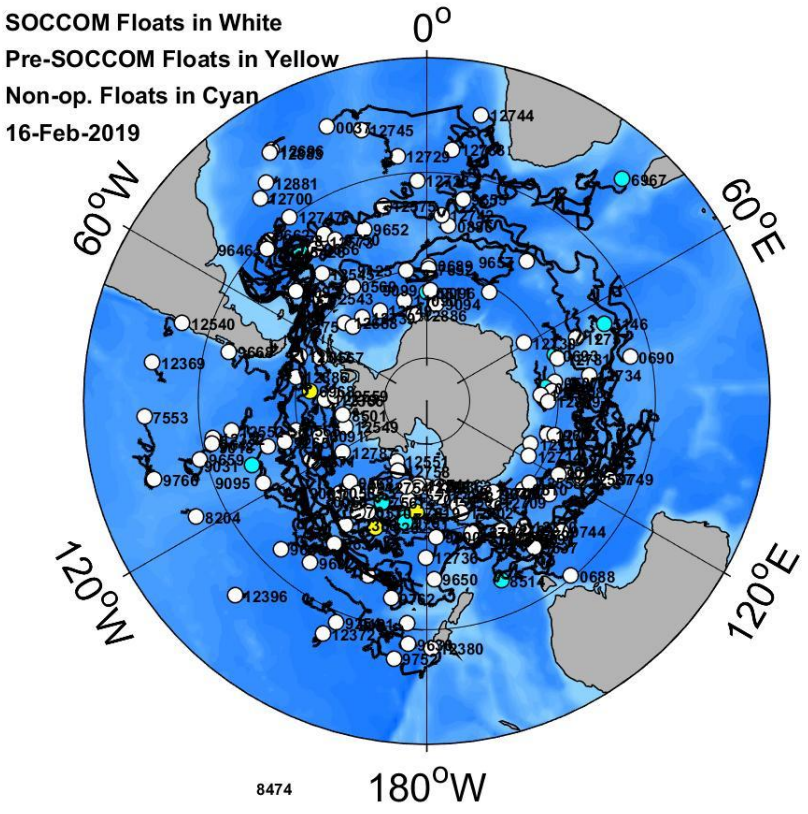

Fig. 5 *Locations of 125 BGC-Argo floats deployed as part of the SOCCOM program in the Southern Ocean.*

Plans:

The highest priority for U.S. Argo is to sustain the Core Argo array. Specific plans for float deployments in 2019, as they evolve, are posted on the AIC deployment planning links. A major U.S./New Zealand/Australia Argo deployment cruise from New Zealand to Tahiti and back on RV Kaharoa was carried out in mid-2018. This voyage deployed 96 Core Argo floats in the South Pacific Ocean plus 10 Deep Argo floats in the SW Pacific Basin, enlarging the regional pilot array there (Fig. 3). In addition, 2 Deep Argo floats with rapidly drifting salinity were recovered by Kaharoa. The CTDs were replaced onboard and the floats were re-deployed. A deployment cruise on RV Kaharoa, from New Zealand to Valparaiso, is planned in December 2019 to deploy 10 Deep Argo floats in the SW Pacific Basin, plus 94 additional Core Argo floats in the South Pacific. Over 1800 Argo floats have been deployed by RV Kaharoa since 2004 (Fig. 6).

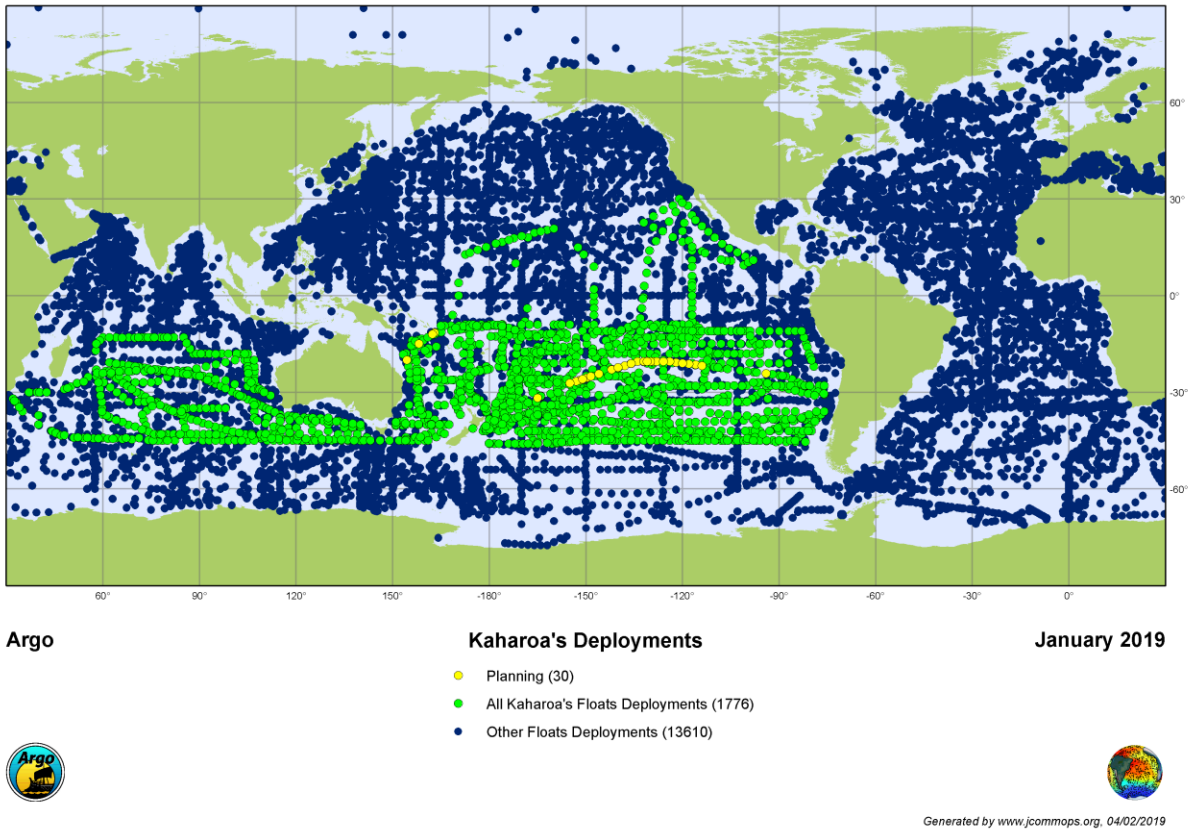

Fig. 6: *Locations of over 1800 Argo floats deployed by RV Kaharoa since 2004 (Green and yellow symbols). Deployment voyages are supported by U.S., New Zealand, and Australia Argo Programs. Argo could not have achieved and cannot sustain global coverage without dedicated deployment voyages in the South Pacific and South Indian Ocean. (Source: AIC)*

The U.S. Argo Data Assembly Center (DAC) is based at NOAA/AOML. Real-time data from all U.S. Argo floats are transmitted via the GTS. GTS transmission uses parallel systems developed at AOML and housed at AOML and at Collect Localisation Satellites (CLS), implementing internationally-agreed quality control tests. 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.

In addition to the national DAC, a Global Data Assembly Center (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, including AOML's role as focus for the South Atlantic ARC.