Best practices for Core Argo floats: Getting started, physical handling, metadata, and data considerations

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Abstract

Argo floats have been deployed in the global ocean for over 20 years. The Core mission of the Argo program (Core Argo) has contributed well over 2 million profiles of salinity and temperature of the upper 2000 m for a variety of operational and scientific applications. Core Argo floats have evolved such that the program currently consists of more than eight types of Core Argo float, some of which belong to second or third generation developments, three unique satellite communication systems and two types of Conductivity, Temperature and Depth (CTD) sensor systems. Coupled with a well-established data management system, with delayed mode quality control, makes for a very successful ocean observing network.
Here we present the Best Practices for Core Argo floats in terms of float types, physical handling and deployments, recommended metadata parameters and the data management system. The objective is to encourage new and developing scientists, research teams and institutions to contribute to the OneArgo Program, specifically to the Core Argo mission. Only by leveraging sustained contributions of current Core Argo float groups with new and emerging Argo teams and users, can the OneArgo initiative be realised. This paper makes involvement with the Core Argo mission smoother by providing a framework endorsed by a wide community for these observations.

Community Review

The Core Argo Best Practice was drafted by twelve authors, who are themselves part of the Argo Steering Team and / or the Argo Data Management Team, with support from key role players in the Argo community.
The document was reviewed by thirteen members of the Argo Steering and Argo Data Management Teams over a period of two months and all comments and changes were used to improve the document.
Finally, the Core Argo Best Practice was submitted to the co-chairs of the Argo Steering and Argo Data Management Teams for input.

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A. Introduction

1. The Argo Program and the difference between the Core, Biogeochemical and Deep Argo missions

The Argo Program was developed in the late 1990’s after the highly successful World Ocean Circulation Experiment (WOCE) project, which had a primary aim of collecting large numbers of profile data through the global oceans (Argo Steering Team, 1998). In addition, several neutrally buoyant subsurface floats had been in development over the preceding four decades, including the Swallow float (Swallow, 1955), named for the float developer Dr John Swallow, the Sound Fixing and Ranging Float (SOFAR, Rossby and Webb, 1970) and the RAFOS float, which is SOFAR spelt backwards (Rossby et al, 1986). Autonomous floats were developed in the late 1980’s and early 1990’s and did not require the acoustic tracking of a vessel close by to follow its trajectory, instead relying on satellite communications at the surface to relay data (Davis et al, 2001). The first of these was the Autonomous Lagrangian Circulation Explorer (ALACE; Davis et al. 1992), with over 290 Profiling-ALACE’s deployed as part of the WOCE experiments in the 1990’s. These earlier technologies provided the blueprint of what would become the Argo float, which we deploy today.

The primary objective of the Argo Program, established with the first Argo float deployments in 1999, was to uniformly deploy Argo floats in all the ocean basins, acquiring data from the upper 2000 db of the world’s ocean every 10 days (Roemmich et al, 2019). To do this, an array of 3000 Argo floats had to be deployed and maintained globally by the Argo Steering Team and the countries affiliated therewith (Roemmich et al, 2019). Data from the Argo floats were made available in a near-real time format (within 24 hours of upload from the Argo float) for forecasting purposes, and in a delayed-mode quality-controlled format (within 12 months of the profile being taken) for state of the ocean assessments and research purposes (Roemmich et al, 2019). This primary objective of the Argo Program focused on Core Argo float parameters, such as pressure, temperature, and conductivity, used to determine salinity through post-processing algorithms. By November 2018, over 2 million profiles from Argo floats had been acquired within the global Argo databases (or Global Data Acquisition Centres, GDACs), far exceeding the profiling capabilities of other ocean profiling instrumentation, such as Conductivity, Temperature and Depth (CTD) surveys undertaken through the WOCE and later the GO-SHIP programs (Riser et al, 2016).

The Core Argo Mission has significantly advanced our understanding of the upper 2000 db of the global oceans. Many questions however remain unanswered, such as how the ocean is changing below 2000 db in terms of heat and salt content, and questions around the carbon and production cycles of the oceans and the impacts associated with a changing climate. Two additional missions have been initiated to complement the Core Argo mission, namely the Deep Argo and Biogeochemical, or BGC, Argo missions. https://argo.ucsd.edu/expansion/deep-argo-mission/, https://argo.ucsd.edu/expansion/biogeochemical-argo-mission/

Deep Argo floats are designed either as the standard cylindrical shape able to withstand deeper pressures, or as spherical floats like the glass “hard-hat” buoyancy floats used for

subsurface ocean moorings. In addition, a CTD sensor had to be manufactured and tested that could not only withstand pressures greater than 2000 db but also return high-quality scientific data. Thus far, at least three types of Deep Argo floats are available commercially, capable of acquiring data to 4000 or 6000 db, depending on the float type. For further information around the Deep Argo mission, please refer to the dedicated page on the Argo website: https://argo.ucsd.edu/expansion/deep-argo-mission/
Fairly early in the Argo Program, when the value of profiling instruments for temperature and salinity measurements was established, additional sensors were developed to be coupled onto Argo floats for BGC sampling. This has developed into its own mission, endorsed by the Intergovernmental Oceanographic Commission (IOC), with six additional parameters making up a full BGC Argo float: dissolved oxygen, pH, nitrate, chlorophyll, suspended sediments and downwelling irradiance (Bittig et al, 2019). For further information around the BGC Argo mission, please refer to the dedicated website: https://biogeochemical-argo.org/index.php, https://argo.ucsd.edu/expansion/biogeochemical-argo-mission/

The Argo Program has developed a new strategy to meet the ongoing requirements and technological advances to ensure even greater success at sampling the global oceans. The two additional missions, Deep and BGC, add new parameters that the Argo Program had not anticipated when it was first established. However, to ensure global coverage of all parameters at sufficient scale, a great deal more of these specialised Argo floats are needed to be deployed. In addition, several key regions with important physical oceanography phenomena, such as the equatorial regions, western boundary currents, marginal seas, and the polar oceans, are understudied. Thus, OneArgo has been established to enhance deployments in key regions two-fold (green shaded blocks on Figure 1), with a split between Core Argo (2500), Deep (1200) and BGC (1000) in terms of the ideal total number (4700) of Argo floats operational at any given time in the world's oceans (Fig. 1). An important consideration of this design is that both BGC and Deep Argo contribute Core Argo data (i.e., temperature and salinity in the upper 2000 db) to the Core Argo mission.

Several challenges exist in fully implementing the OneArgo design, including funding challenges with a fivefold of current investment required, logistical and manufacturer challenges to produce more Argo floats, national and international partnerships and very critically, data management challenges. The OneArgo initiative has been endorsed by the UN Decade of Ocean Sciences as a project and attached to the program, "Observing Together: Meeting stakeholder needs and making every observation count".

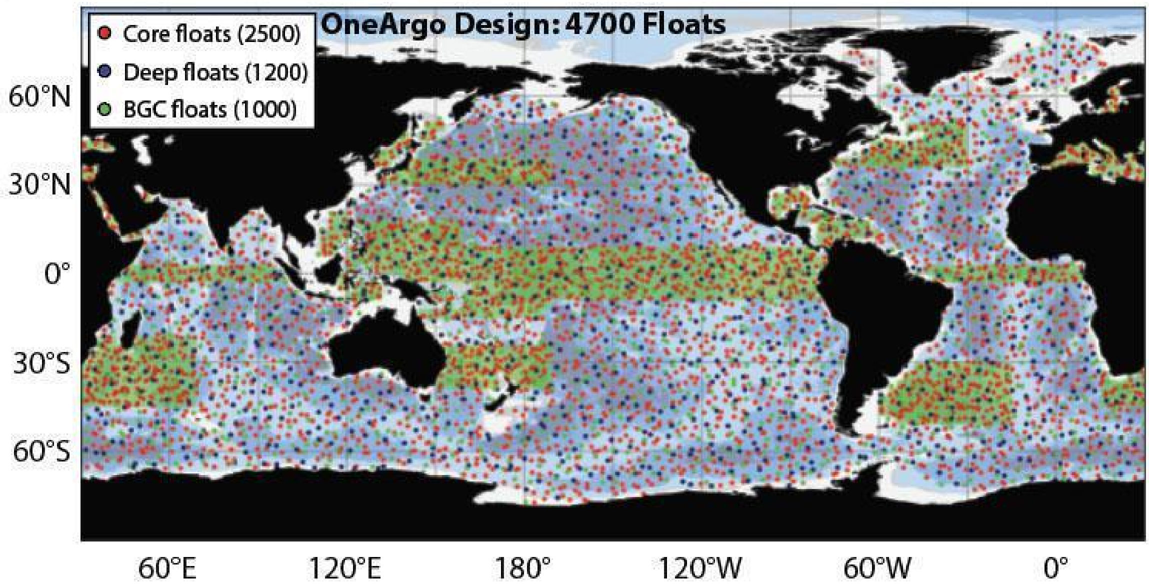

Figure 1: Enhancement of the Argo deployment design, named OneArgo, to increase resolution of Argo profiles in understudied and key regions (courtesy OceanOPS).

2. The value of Core Argo data

As stated already, Core Argo data has been acquired since 1999, when the first Argo floats were deployed. The initial design conceptualised by the Argo Science Team (1998) called for the deployment of 3000 Argo floats in a 3° x 3° array of open ocean between 60° S and 60° N, and thus mostly free of sea ice. This design was achieved by November 2007, eight years after the Argo programs' inception (Wong et al, 2020). By 2012, 1 million temperature-salinity profiles of the global ocean were acquired, with 2 million profiles by 2018 (Wong et al, 2020). Argo profiles of temperature and salinity greater than 1000db tripled in 15 years what had been acquired by shipboard observations, and archived within the World Ocean Database, over the preceding 100 years (Riser et al, 2016).

From the beginning of the Argo Program, to increase engagement with global deployment teams and to comply with the Global Ocean Observing System (GOOS) criteria, Argo data was made publicly and freely available to anyone wanting to make use of it. Each individual profile is available within 12-24 hours as a near-real time data set, after an automated quality control procedure has taken place. The data is ingested into the Global Telecommunications System (GTS) and used for operational ocean and atmosphere forecasting. Profiles of Argo data are further quality controlled as delayed mode profiles typically within one year of receiving those data from the Core Argo float itself, and periodically afterwards. All data, raw and quality controlled, are made available to users through two Global Data Acquisition Centres (GDACs) and associated repositories and services. These processes, and how to access these data, are described in the data sections below.

The value of releasing data as efficiently and openly as possible, results in the data being used very widely. Core Argo data are used extensively for State of the Ocean reports (IOC-UNESCO, 2022) and assimilated within coupled-climate models used by the Intergovernmental Panel on Climate Change (IPCC) for forecasting and predicting the impacts of climate change on our Earth (IPCC, 2019). As of February 2023, over 5779 peer-reviewed research articles have been produced using Argo data, an average of one per day, with more than 435 PhD-level students using Argo data as part of their dissertations. A link to the list of Argo publications is available here: https://argo.ucsd.edu/outreach/publications/

The Core Argo dataset over the first 20 years of the program is described by Wong et al (2020). Within the article, accuracies of the delayed-mode pressure, temperature and salinity datasets are described, along with challenges experienced and subsequent solutions. One of the key challenges the Argo Program still faces, as highlighted by Wong et al (2020), is that Argo floats do not always reach the goal lifetime of four years. One reason for early failures (i.e., within the first year or two of deployment) is the lack of pre-deployment checks of Core Argo floats being undertaken, including checks related to sensor quality where possible. Sensor quality over time (after deployment) is an ongoing issue for the Argo Program and something Argo teams continue to engage with manufacturers around. This paper looks to discuss and suggest best practices of pre-deployment checks for deployment teams to use going forwards.

3. Environmental impact

Fairly early in the Argo Program's existence, questions were raised around the longevity of Argo floats and the resultant environmental impact when Argo floats come to an end of their lifetime. This has been assessed and detailed information is available at the following links:
https://argo.ucsd.edu/about/argos-environmental-impact/
https://argo.ucsd.edu/wp-content/uploads/sites/361/2020/05/final.Argo_Environmental_Impact.2020.05.10-1.pdf
The Euro-Argo team, representing the European Community engaged with Argo activities, have also summarised the key information with graphics for users to explain the impact to the public, within education forums, or to deployment teams. These are available as a folder brochure:
https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/06/Environmental_impact_Argo_floats_Euro-Argo_TO-BE-FOLDED-2.pdf
A poster:
https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/06/Environmental_Impact_Euro-Argo_POSTER.pdf
Or to show on screen:
https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/06/Environmental_impact_Argo_floats_Euro-Argo_ON-SCREEN-DISPLAY-2.pdf

In summary, the following key messages relate to the environmental impact of Argo floats:

- If all Argo floats deployed thus far were laid side-by-side, they would take up the space of only two football fields.
- When considering the maximum value of 900 floats dying and requiring replacement each year, the following chemical inputs to the ocean are noted (https://argo.ucsd.edu/about/argos-environmental-impact/):
    - It would take over 176,000 years of Argo operations to introduce the same amount of aluminium into the ocean that is employed annually to produce drinking cans (200 billion per year at 15 grams/can).

    - A single year of the human contribution of plastic to the ocean is equivalent to 4.4 million years of plastic input from Argo floats.
    - One year of the natural flux of lead into the ocean is equivalent to 83 million years of Argo operations.
- In addition, given the large spatial range of Argo floats (approximately 300 km apart), and mixing processes within the water column, it is highly unlikely that a concentration of chemicals will accrue in any given region when an Argo float sinks.
- It would take many vessels travelling across ocean basins and polluting the atmosphere to recover all Argo floats deployed before they sink, cancelling out any environmental value the Argo Program has brought to global ocean observations and the understanding of Earth's climatic system.
- By design, Argo floats are autonomous instruments meant to survive maximum lifetimes after they are deployed. They have been designed and manufactured with state-of-the-art technologies and could be considered as models of low energy consumption, providing outstanding information and ocean interior knowledge that few other devices could bring with such battery capacity.

B. Getting started in the Argo Program

1. International context and linking to OceanOPS

The Argo Program contributes to both the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS). Both organisations are co-sponsored by the World Meteorological Organisation (WMO), the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation (IOC-UNESCO), the United Nations Environment Programme (UN Environment), and the International Science Council (ISC). GCOS is primarily concerned with global climate observations, ensuring they are accurate and sustained, and are freely available for use. GOOS is primarily concerned with sustained ocean observations, from surface to seafloor, with the Argo Program considered as one of its networks.

Under the GOOS steering committee leadership, exists several panels and groups to ensure ocean observations are sustained. These include the expert panels on Physics and Climate, Biogeochemistry, and Biology and Ecosystems, the GOOS Regional Alliances (GRAs) and the Expert Team on Operational Ocean Forecast Systems (ETOOFS). The Observations Coordination Group (OCG) oversees the implementation of sustained ocean observations through the ocean observing networks and the Argo Program is one of eleven such networks (https://www.goosocean.org/index.php?option=com_content&view=article&id=291&Itemid=439). The OceanOPS group is a small, dedicated team of technical coordinators based in Brest, France, who provide support to the ocean observing networks. Each technical coordinator works with a minimum of two ocean observing networks to monitor observations from platforms, ensure high quality metadata is being received, assist new deployment teams to ensure platforms are accurately recorded and metadata is being transmitted. For this purpose, they have designed a dashboard where users are able to track and monitor observations by means of their metadata for further interrogation via data services. The dashboard is available here: https://www.ocean-ops.org/board, with a YouTube recording on the background of OceanOPS and how to navigate the dashboard available here: https://youtu.be/teEMbvd0ezk

The five goals of OceanOPS are:

- Monitoring to improve the global ocean observing system performance.
- Leading metadata standardisation and integration across the global ocean observing networks.
- Supporting and enhancing the operations of the global ocean observing system.
- Enabling new data streams and networks.
- Shaping the OceanOPS infrastructure for the future.

2. Exclusive Economic Zone (EEZ) considerations

Countries that have a coastline are considered coastal states and have sovereign rights and jurisdiction over waters extending no more than 200 nautical miles offshore. This is known as a coastal states' Exclusive Economic Zone (EEZ). The ocean beyond coastal states EEZ is considered High Seas, which are open for common scientific research purposes.

Coastal states need to give consent to allow marine scientific research activities to take place within their EEZ, and implementers need to request this clearance six months in advance, following article 24 of the United Nations Convention on the Law of the Sea (UNCLOS). While the requirement is clear, how to do it in practice is more challenging, and depends on each coastal state.
However, there are some exceptions, some Member States have concurred with the deployment of Argo profiling floats within their EEZs, provided the free and unrestricted data exchange and the transparent implementation through OceanOPS monitoring and Argo notification regime. These agreements were communicated to OceanOPS through letters that can be obtained on demand.
While the UNCLOS does not clearly define marine scientific research, some Member States consider that some marine data collection activities are not marine scientific research, including Argo.
Please consult with OceanOPS, by emailing support@ocean-ops.org, for latest updates on the countries, regions and territories where caution should be taken, and which of these freely allow the collection of scientific data. More information about Argo and EEZ can be found here:
https://www.euro-argo.eu/content/download/163515/file/D8.2_VF_underEC_review.pdf

3. The Argo Steering Team (AST) and the Argo Data Management Team (ADMT)

The AST and ADMT encourages new participants into the Argo Program and have developed a set of guidelines to help interested groups learn more about what is required to be part of Argo. These are described on a series of webpages: https://argo.ucsd.edu/expansion/framework-for-entering-argo/ and https://argo.ucsd.edu/expansion/framework-for-entering-argo/guidelines-for-argo-floats/table-of-guidelines-for-argo-floats/, but will be summarized below.

Argo is an operational program that relies on National Programs to contribute and maintain the Argo float array and data system. To keep it functioning as designed and delivering high quality data in a timely manner, there are a few requirements that each Argo float must meet:

- Argo floats must follow the Argo governance rules for pre-deployment notification and timely data delivery of both real-time and delayed-mode quality-controlled data.
- Argo floats must have a clear plan for long term data stewardship through a National Argo Data Assembly Centre.
- Argo floats should target the Core Argo profiling depth and cycle time, 2000 db and 10 days, respectively. However, data that contributes to the estimation of the state of the ocean on the scales of the Core Argo mission are also desirable.

As the Argo Program has expanded its design target to accommodate the improving technology, its governance structure has also expanded. There are now three main missions, Core, BGC and Deep (as noted above). Each of these missions reports to both the AST and the ADMT who oversee the entire OneArgo design structure. The co-chairs of the BGC and Deep Missions are part of the AST. The Core Argo mission is the new name given to the previous Argo array design and so it is well represented on the AST. All three missions contribute profiles to the Core Argo mission. In terms of the Data Management Team, it was determined that BGC ADMT co-chairs are needed to help manage the complexity of the new parameters, meta and technical data as well as the new quality control processes that need to be developed. Currently, the Deep Argo Mission's data needs are similar enough to the Core Argo mission's data needs that additional Deep Argo ADMT co-chairs are not necessary.

Each nation that contributes to the Argo Program is encouraged to nominate an Argo Steering Team member. If you are the first person from your country to deploy Core Argo floats, please consider joining the AST by notifying OceanOPS (support@ocean-ops.org) and the Argo Program Office (argo@ucsd.edu). If your country already deploys Core Argo floats, please contact your national AST member (https://argo.ucsd.edu/organization/ast-and-ast-executive-members/) and let them know of your desire to deploy Core Argo floats.

The Terms of Reference and membership of the AST are available here: https://argo.ucsd.edu/organization/argo-steering-team/
The ADMT team and executive committee details are available here: http://www.argodatamgt.org/Data-Mgt-Team/ADMT-team-and-Executive-Committee

4. Internal communication

To function well, there needs to be good lines of communication from the AST and ADMT to the various Core Argo float deployers. This starts with the national AST and ADMT members communicating information from the AST and ADMT to each of the Core Argo float deployers within their nation. It continues with email lists maintained by OceanOPS that target different communities within Argo. It is critical that a group or nation join the appropriate email lists so that they are aware of upcoming meetings, data announcements and more. To join the lists, contact OceanOPS (support@ocean-ops.org) or visit (https://argo.ucsd.edu/stay-connected/. Here is a brief description of each list:

1. argo@groups.wmo.int: this is a general email list for Argo announcements such as upcoming meetings, jobs, awards, news, etc. All are encouraged to join.
2. argo-st@groups.wmo.int: this is a list for AST members only.
3. argo-dm@groups.wmo.int: this is for the ADMT community and is used for announcements about upcoming meetings as well as communicating information about the data stream. Anyone working with Argo data is encouraged to join.
4. argo-dm-dm@groups.wmo.int: this list is for the Argo Delayed Mode quality control community and is used to discuss issues around delayed mode quality control. All delayed mode quality control operators are encouraged to join as well as anyone else interested in the topic.
5. argo-bio@groups.wmo.int: this list is for the BGC Argo community and covers both general BGC Argo announcements as well as issues related to data management of BGC Argo data. All are encouraged to join.
6. argo-deep@groups.wmo.int: this list is for Argo deep community to discuss issues around Deep floats only.

7. argo-deep-dm@groups.wmo.int: this list is for Argo deep community to discuss issues around data management of Deep floats.
8. argo-tech@groups.wmo.int: this list is for the Argo community to discuss technological issues.

Finally, it is suggested that users keep an eye on the AST and ADMT website for announcements. The AST website (https://argo.ucsd.edu/) has three different news feeds at the bottom of the homepage: news, meetings, and technical updates to keep you informed about the latest on the Argo Program. The ADMT website (Argo Data Management (argodatamgt.org)) has a news section on the left side of the page which is updated less frequently with only data related announcements.

5. Core Argo float design, types and manufacturer descriptions

Since the inception of the Argo Program, several manufacturers have developed their own versions of the Core Argo float. Regardless of Argo float design however, the fundamentals for Argo floats remain similar.

All Argo floats are cylindrical in shape but vary slightly in height and circumference. Figure 2 shows a basic schematic of a Core Argo float. A brief description of each part follows:

- The antenna, used to communicate with passing satellites, sits proud at the top of the Argo float, allowing clear access for communications above the water line. The different satellite communication types used within the Argo Program are described in the Satellite communication systems section.
- The Conductivity, Temperature and Depth (CTD) sensor package is positioned at the top of the Argo float (refer to the CTD sensors section for further details), to acquire data relatively free of water turbulence as the Argo float ascends through the water column (refer to the Mission Configuration section for further details).
- All workings of the Argo float, including communications, data acquisition and descent and ascent of the instrument, is controlled by specialist firmware on a main electronic circuit board situated within the float manifold (not labelled on Fig. 2).
- The internal reservoir stores the hydraulic oil when it is not being used to inflate the external bladder.
- The hydraulic system is used to pump the hydraulic oil between the internal reservoir and the external bladder. Argo floats either used a pump or piston system, depending on their design. This controls the buoyancy of the Argo float.
- The batteries are what power the internal communication system, sensors, hydraulic system, and controller and are the primary limiting factor for Argo float longevity. To get around this to some degree, Argo floats are (where possible) fitted with lithium-ion batteries instead of alkaline batteries. Further discussion on this is available in the Batteries section.
- The external bladder, where the hydraulic oil from the internal reservoir is pumped to, helps control the buoyancy of the Argo float. When the oil is pumped into the external bladder it increases the volume of the Argo float, decreasing the density and allows the Argo float to rise. Pumping the oil out of the external bladder decreases the volume of the Argo float, increasing the density and allows the Argo float to sink. A controller determines exactly how much hydraulic oil needs to be shifted to allow the Argo float to drift at a particular depth.

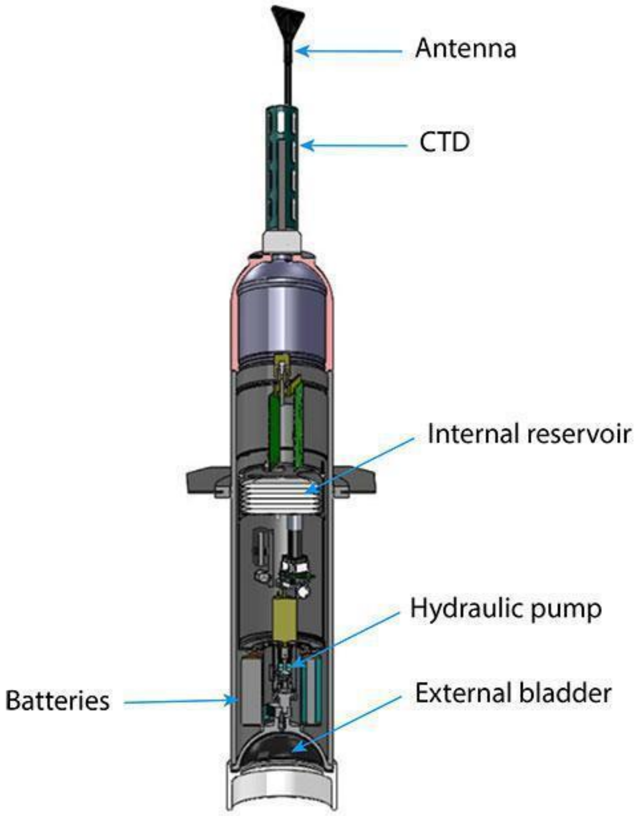

Figure 2: Schematic of a basic Core Argo float, courtesy of the Argo Program (https://argo.ucsd.edu/how-do-floats-work/) and Michael McClune of Scripps Institute of Oceanography.

A description of each available Core Argo float, along with the manufacturers and web addresses and considerations or comments around purchasing that need to be considered when procuring Core Argo floats are detailed in Table 1.

Table 1: Core Argo float types, manufacturers and considerations to bear in mind when purchasing Argo floats.

Float Model	**Manufacture**	**Considerations / Comments**
ALTO	MRV Systems, Wood Dale, IL, USA https://www.mrvsys.com/products/mrvalto	
ARVOR	NKE Instrumentation, France https://nke-instrumentation.com/standard-profiling-floats/	
APEX	Teledyne Webb Research Falmouth, MA, USA http://www.teledynemarine.c	Ballasting required to a specified region.

	om/profiling-floats	
APEX-UW	University of Washington, Seattle, WA, USA	Not commercially available.
HM2000	Qingdao Hisun Ocean Equipment Corporation, China	Commercially available in China
NAVIS	Sea-Bird, Seattle, WA, USA https://www.seabird.com/navis-autonomous-profiling-float/product?id=54627925751	
PROVOR	NKE Instrumentation, France https://nke-instrumentation.com/standard-profiling-floats/	
SOLO-II	Scripps Institution of Oceanography, La Jolla, CA, USA	Not commercially available.
S2A	MRV Systems, Wood Dale, IL, USA https://www.mrvsys.com/products/mrvs2a	

6. Argo mission configuration

The standard Argo profiling scheme is to sample every 10 days (240 hours) from 2000 db to the surface and to drift at 1000 db (Fig. 3). To avoid bias in the profile sampling time, it is suggested that Argo floats cycle every 10 days, plus several hours. This allows Argo floats to come up to the surface at random times to help ensure that as many profiles as possible can be used to help determine diurnal cycles. Some Argo float types come from the manufacturer with a default time of day set for the Argo float to end its profile. If that is the case, it is recommended to try to change this so that the Argo float samples randomly (e.g., every 245 hours, thus 10.2 days).

During the drift phase of the profiling scheme (#3 on Fig. 3), it is suggested to measure temperature and pressure throughout. This can be done hourly, 3-hourly, 12-hourly, or daily, provided the software and battery life support these additional measurements. Upon ascent (#5 on Fig. 3), it is suggested that Argo floats sample at as high a resolution as possible, such as every 2 db, if battery life still supports a 4–5-year mission. If sampling every 2 db is not possible, less frequent sampling at deeper depths is acceptable.

Argo floats deployed close to marginal sea ice zones or could possibly be drifting towards these regions in a winter period, can be procured with ice avoidance firmware installed. This algorithm is designed in such a way to calculate whether the surface will be ice-free or not, based on the upper water column temperatures. If the algorithm “senses” sea-ice above, the

Argo float will abort its ascent and return to park depth. At the next ascent to reach the surface, all acquired data in the previous ascents not able to reach the surface are then uploaded to the satellite. For more information on this process, please refer to this page: https://argo.ucsd.edu/expansion/polar-argo/polar-argo-technical-challenges/

Floats should target the Argo profiling depth and cycle time, 2000 db and 10.08 days, respectively as well as the drift depth of 1000 db. However, data that contributes to the estimation of the state of the ocean on the scales of the Core Argo Program are also desirable. This means that Argo floats that sample shallower or more rapidly can be included in the Argo Program if the data can be sufficiently quality controlled to be as accurate as needed for sensitive ocean studies.

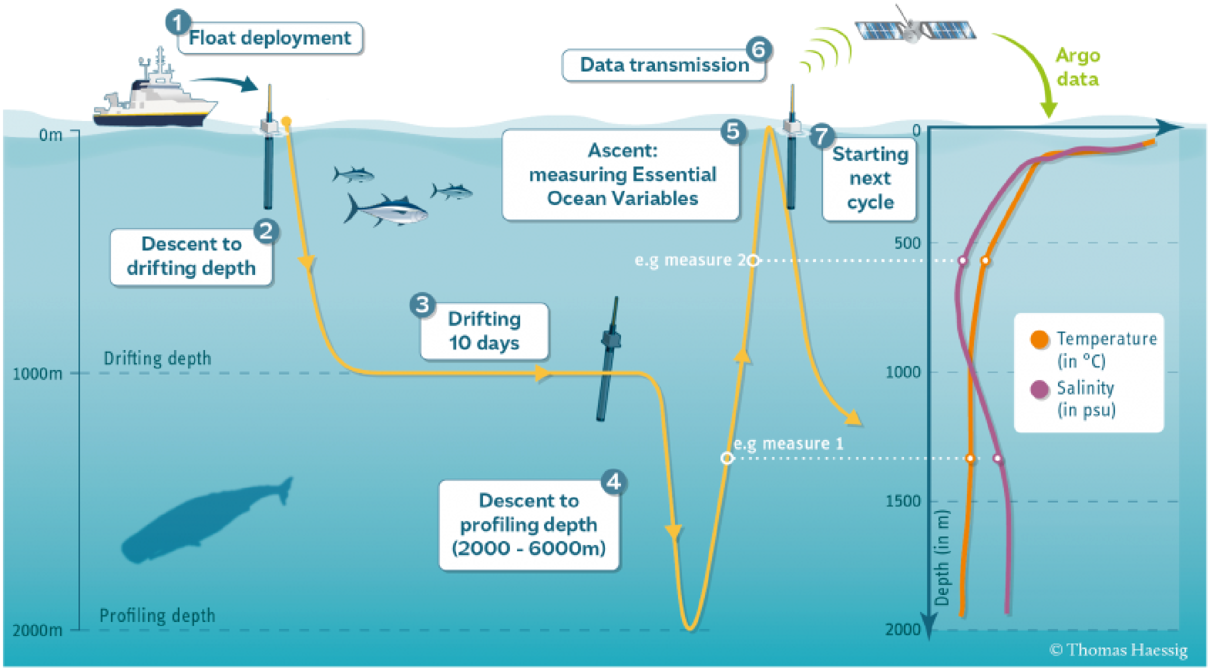

Figure 3: Standard Argo profiling mission. Schematic by Thomas Haessig.

7. Satellite communication systems

Within the Argo Program, there are currently three types of satellite communication systems used:

- GPS positioning and Iridium transmission. Most Argo floats currently deployed (~ 77%) make use of the Global Positioning System (GPS) satellites to determine their position, and upload data via the Iridium array of satellites to a base station. Surface time to upload data is also far quicker than the older Argos system and additionally allows two-way communication with the Argo float, which can be used to alter mission parameters.
- Argos. Older Argo floats still make use of the Argos satellite system to determine their positions and upload data for transmission to a ground station. Given the poor coverage of satellites however, the Argo float would need to spend between 6 and 12 hours on the surface to upload data effectively, which puts the instrument at risk of collisions with ships and floating sea ice.
- Beidou satellite (BDS) is a navigation system developed by China. It has similar positioning accuracy as GPS. Besides positioning, BDS also provides the service of

message transmission (~ 100 bytes/minute), enabling two-way communication like the Iridium satellite system. From the second half of 2022, BDS-3 will be made available which will provide global coverage of data transmission with enhanced coverage over the Asia-Pacific region.

8. Data configuration

The way in which Argo floats are setup to transmit data depends on the satellite communications systems used on the Argo float itself. It is advised that when procuring new Argo floats, that these two considerations be dealt with simultaneously. Consideration should also be given as to whether the user will want to change the Argo float mission parameters in any way, thus requiring a two-way communications system, or whether the Argo float will be set up with the manufacturer on the standard Argo float mission and left to acquire data regardless of where it drifts.

Several data configuration settings are available:

- RUDICS (Router-Based Unrestricted Digital Internetworking Connectivity Solutions) - this allows large datasets to be transferred via multi-protocol circuit switched data across the Iridium network of satellites. This requires a server setup, or rental of server space through a service provider which is always available. RUDICS has higher bandwidth and allows for more data transfer, but also needs a continuous connection.
- SBD (Short burst data) - this allows short burst transmissions of data over the Iridium network of satellites between the Argo float and the host computer. It does not require a server, only the decoding of email messages. Using SBD requires the data to be broken into smaller packets which then need to be reassembled. Sending SBD messages does not require a continuous connection and may have a high transmission success rate in high sea states.
- Argos - Argos Argo floats send the data in packets of 32-bit messages, which must be reassembled. Argos is unidirectional and cycles through the messages while at the surface. Surface times can be long, ~ 10 hours, and there is no confirmation that all the messages were received.

9. CTD sensors

Two types of CTD sensors are now available for use on Argo floats. Historically, only the Sea-Bird Scientific model SBE41 has been accepted by the community to ensure consistent high-quality temperature and salinity data for Argo profiles. In 2018, RBR requested the Argo Program to allow their CTD sensors to enter a pilot study whereby RBR and SBE41 sensors were deployed side-by-side and robustly tested against one another over a period. In 2022, RBR sensors were accepted as part of the sensor set for Argo floats.

- The SBE 41/41CP is a 3-electrode conductivity cell with zero external field, because the outer electrodes are connected. The conductivity is measured by the voltage produced in response to the flow of a known electrical current. The Seabird SBE41 are pumped sensors, using similar technology as the 911+ TC duct system found on shipboard CTD sensors. This allows for the Argo float to ascend at varying rates as per mission requirements. Temperatures higher than 45° C can cause the SBE 41/41CP thermistor to drift from calibration. In addition, the anti-foulant (TBTO) can become liquid and leak into the conductivity cell. This will cause the salinity data to be fresher until the TBTO has washed out of the cell (Sea-Bird Scientific, 2017).

- The RBR CTD requires less energy to operate as it is not a pumped CTD system. The Argo float should be set to a constant ascent rate for best quality measurements, preferably at 20 cm s^{-1}. RBR's conductivity cell contains two toroidal coils: a generating coil and a receiving coil. An AC signal is applied to the generating coil, producing a magnetic flux and a resultant electric field, and, finally, a current is induced in the seawater present in the centre of the cell. The current in the seawater passes through the centre of the receiving coil and induces a secondary current to flow in the receiving coil. The current in the receiving coil is proportional to the resistance of the water, which is inversely proportional to conductivity (Halverson and Johnson 2020). The electric field around the RBR CTD has a radius of 15 cm. It is advised to avoid any scratches on the hard anodized Argo float head within 15 cm of the conductivity cell as this will impact measurements.

It is advised to **never** carry any Argo float by their CTD sensors.

New sensor development is a critical part of continuing technological advancements to improve the data delivered by Argo floats. However, using sensors of high quality and stability is crucial for Argo's success and adding sensors to the Argo Data Management System is time consuming. Therefore, the AST and ADMT developed a set of sensor development stages to help researchers and manufacturers understand how to navigate the process of bringing a new sensor to be an accepted Argo Program sensor. These steps are outlined on this webpage: https://argo.ucsd.edu/expansion/framework-for-entering-argo/guidelines-for-argo-floats/, and summarised here.

- Stage III - Accepted: Sensors are distributed globally, and the performance and accuracy of the sensors is fully characterised. The sensors have a well-developed path of quality control from real time to delayed mode and all metadata and parameters are well defined in the Argo data stream. Sensors should be expected to last 4-5 years while following the accepted Argo sampling scheme of making profile measurements from 2000 db every 10 days and drifting at 1000 db. Data is distributed in the accepted Argo netCDF format.
- Stage II - Pilot: A sensor has been developed either for an accepted or non-accepted parameter within Argo and this sensor 1) is expected to be deployed on a significant fraction of Argo floats, 2) has the potential to meet Argo's accuracy and stability requirements, 3) has quality control procedures being developed, and 4) has all the metadata and technical data well described in the Argo data system. Data from this sensor will be distributed in the accepted Argo netCDF format with associated metadata and technical data, but with quality control (QC) flags of 2 or 3. QC flags are further described in the Data section.

- Stage I - Experimental: A sensor has been deployed on an Argo float along with an accepted Argo Program sensor. This sensor's performance and accuracy have not been characterised and it is not expected that many of these sensors will be deployed on Argo floats. Data from this sensor will be distributed in the Auxiliary directory to comply with IOC XX-6 (https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/09/IOC-ASSEMBLY-RESOLUTION-XX-6.pdf) which states that all observations from an Argo float must be available. If, over time, the sensor's performance is characterised and looks as if it could be accepted into the Argo Program, the manufacturer can apply to the AST for a Stage II Pilot study and the IOC for parameter acceptance.

10. Batteries

To extend the lifetime of Argo floats, it has been advised by the AST that wherever possible, Argo floats should be procured fitted with lithium battery packs. Lithium batteries are more expensive than alkaline ones, and new Argo teams, or those struggling with funding issues, may choose to procure alkaline fitted systems instead. Lithium batteries are also considered dangerous goods for airline shipping (please refer to the Shipping section) and thus may impact if Argo teams are able to procure these systems.

Argo floats can also be fitted with additional battery packs to extend the lifetime. In this case, the final ballasting of the Argo float for the ocean basin in which it is eventually deployed needs to be carefully undertaken to ensure the Argo float operates optimally.

In terms of lithium batteries, three manufacturers are used - Electrochem (https://electrochemsolutions.com/products/default.aspx), Tadiran (https://tadiranbat.com/) and Saft (https://www.saftbatteries.com/). It is advised that when Argo teams are procuring Argo floats, they should make enquiries with the float manufacturer about which of these lithium battery types work most efficiently with the Argo float they are looking to purchase.

11. Core Argo float purchasing considerations

Core Argo floats can be ordered in several ways. They will usually be ordered and delivered ready to deploy (Fantail ready). Some organisations will order Argo floats and perform full functionality testing including ballasting themselves. Please refer to Section C on ballast adjustments and pre-deployment testing.

Some manufacturers will request the proposed deployment position for the Argo float order. When these details are provided to the manufacturer, they can make sure the float will profile for the full specified depth. For example, if an Argo float is deployed near the tropics and was not ballasted for that region, it may not profile to its full potential depth.

It is recommended that Argo teams ordering Argo floats discuss these considerations during their procurement phase. There are many experienced Argo teams that are willing to share information and tips to ensure successful bids from vendors.

12. Production Testing (at the manufacturer)

Manufacturers will perform functionality testing of discrete parts of the Argo float including the buoyancy engine, communications and CTD. They should also perform a full functionality test when the Argo float is fully assembled.

13. Data quality and management requirements

As mentioned in Section 3 *(The Argo Steering Team (AST) and the Argo Data Management Team (ADMT))*, contributors to the Argo Program must have a long-term plan for data stewardship and distribution through a Data Assembly Centre (DAC). The AST and the ADMT established a set of data quality and management requirements which are listed in these tables on the AST website: https://argo.ucsd.edu/expansion/framework-for-entering-argo/guidelines-for-argo-floats/table-of-guidelines-for-argo-floats/

The general requirements state that the Argo float and its data must be consistent with Argo governance and IOC XX-6 (https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/09/IOC-ASSEMBLY-RESOLUTION-XX-6.pdf) and IOC EC_XLI.4 (https://argo.ucsd.edu/wp-content/uploads/sites/361/2021/09/EC-XLI.4.pdf). In practice, this means that the Argo float owner (Principal Investigator (PI)) needs to notify the Argo float with OceanOPS prior to deployment. Upon registering, a contact is required for the Argo float which must be maintained during the Argo float's lifetime. There is also a contact required for the data processing during its lifetime and after the Argo float has died. It is possible to transfer this contact requirement, but OceanOPS should be notified. If you are not sure the Technical Coordinator at OceanOPS, please email: support@ocean-ops.org. A demonstration video on how to notify an Argo float on the OceanOPS system is being developed and will be made available to the community through the mailing addresses provided above and the Argo website.

The data requirements include: the need for an established pathway for the Argo float data from telemetry; preparation of real time files and real time quality control; delayed mode quality control for all parameters on the Argo float; and the ability to continue the long-term curation of data including responding to changing requirements of the ADMT.

DACs receive the data from Argo floats, decode it, create real time files, apply agreed upon real time quality control tests and submit the data to the Global Data Assembly Centres (GDACs) and the GTS to make it publicly available. In addition, when a delayed mode quality control operator produces a delayed mode ('D') Argo data file, they submit these 'D' files to their DAC who will then upload the files to the GDAC, making them publicly available. Therefore, Argo teams must find a DAC willing to take on this role for their Argo floats. If there is an existing DAC in your country (Argo Data System components - Argo Data Management (argodatamgt.org)), it is suggested that you contact them first (ADMT team and Executive Committee - Argo Data Management (argodatamgt.org)) to see if they can take on the processing of your Argo float data. Their response may depend on whether they already process similar Argo float types and if they have the capacity to take on additional work. If there is no DAC in your country, you should consider contacting the Argo Technical Coordinator (support@ocean-ops.org) for suggestions on which DAC might be best suited to help.

In terms of the delayed mode quality control, it is the responsibility of the Argo float owner or PI to perform delayed mode quality control on all approved parameters measured on the Argo float. Please refer to the Data Section for further details around data submission and making these available. If your group does not have the expertise to perform delayed mode quality control on all parameters, you may reach out to other groups, preferably before purchasing of Argo floats, to ask if they will take on the responsibility of delayed mode quality control either for the entire Argo float or for particular parameters. If you have a desire to develop delayed mode quality control expertise, there are occasional delayed mode quality control workshops (every few years) as well as a mentor program to help provide more one-on-one interactions between established experts and those wishing to learn more about the process. To find out about possible upcoming delayed mode quality control workshops plus a list of reports from previous workshops, visit the following webpage: https://argo.ucsd.edu/organization/argo-meetings/delayed-mode-quality-control-workshops/. A brief description of the mentor program and a list of experts is available here: Mentors for Argo CTD - Argo Data Management (argodatamgt.org). There are some tools that have been developed to help with the delayed mode quality control process (Tools for DMQC - Argo Data Management (argodatamgt.org), https://github.com/ArgoDMQC and https://argo.ucsd.edu/data/argo-software-tools/

C. Physical handling of Core Argo floats at pre-deployment facilities

It must be noted that this section pertains to the physical handling and testing of Core Argo floats once they have been received from the manufacturers, but before the Argo floats are loaded onto vessels (or shipped to waiting vessels). While not all Argo teams will have ballasting facilities or water tanks to do tests, it is advised that all groups purchasing and receiving Argo floats should undertake some basic tests prior to deployment of their floats. All information noted are helpful in understanding the operations of Argo floats and could help with problem solving with the manufacturers should problems be encountered.

1. Core Argo float testing prior to shipping of floats

a) Ballast Adjustments

Argo floats profile to 2000 db and need to be neutrally buoyant at this depth. Argo floats are ballasted by determining the volume, and the required weight of the Argo float to be neutrally buoyant at depth. As the density of the ocean varies around the world, Argo floats need to be ballasted according to the ocean basin in which they will be deployed. This is not the case for ARVOR and PROVOR Argo floats, which are ready to deploy in any ocean basin once shipped from NKE, and for Argo Navis floats, shipped from Seabird. The Argo floats may be ballasted by placing the instrument in a pressure tank or determining the volume at surface pressure. A weight change in an Argo float of 1 g can make approximately a 10 m parking depth difference (Izawa, 2001). Ballasting using the pressure tank is more accurate, however pressure tanks are not always available. Several manufacturers provide surface ballasting and should be consulted when purchasing an Argo float. A method for ballasting floats in a pressure tank is described in Izawa (2001). Many Argo floats can overcome slight ballasting deficiencies. However, with an insufficient bladder volume, surfacing can become a problem in some ocean basins.

b) Check list upon receiving Core Argo floats at facilities

It is advised that when receiving Core Argo floats from the manufacturer, the following checks are done. This is not an exhaustive list and can be adjusted for each Argo facilities' needs.

Table 2: Suggested checklist for clients receiving Core Argo floats. Each Argo float manufacturer will be able to guide on how to undertake these tests as they will be specific to the Argo float. Please refer to their operational manuals. The description below if by way of explanation only.

#	Check item:	What you should have / see
1	Calibration sheets and Argo float mission setup	This must match up to what you requested the manufacturer set up for you.

2	Shock watch tube check (where fitted)	If the shock watch tube is red, the Argo float has been dropped or shipping was not ideal. The shock watch tube should be white.
3	Argo containers are intact	Are the wooden or cardboard boxes damaged in any way?
4	Perform the basic built in system self-test that most floats will have in their software/firmware (described further below).	This test can be used as a baseline for future testing and to report back to the manufacturers that the Argo float is functional.
5	Perform Communications testing and GPS functionality (described further below).	Confirm that telemetry is operational and is sending data to your designated server.
6	Buoyancy Engine Functionality (described further below).	This will confirm full functionality of the buoyancy engine to configuration.
7	CTD Functionality (described further below).	The CTD should be fully operational.

c) Testing of Core Argo floats

This will help with identifying Core Argo floats that may have small problems that could affect lifetime operation of the float after deployment.

The user will have to connect a computer to the Argo float and send commands to perform operations. It is assumed that the user has prior knowledge for these tasks and / or be guided by the float manufacturer for assistance.

The below list has been given for those Core Argo floats that are commercially available (Table 1). If Argo teams are receiving Argo floats from non-commercial entities (e.g., HM2000, APEX-UW), then it is advised that Argo teams discuss directly with these entities any tests that need to be undertaken prior to deployment.

Perform the following checks to confirm the Argo float will be fully functional when deployed. This may capture potential faults. It is recommended that this is performed as soon as practicable after receiving the floats.

- Arrival Check - usually using the built in system test command.
- Communications Check - Test the GPS and Iridium (or other) communications systems. This can also test your own servers and incoming data stream if not already done by the manufacturer.
- Air Engine / Bladder Check - can be performed with commands on the float. Various options for testing.
- Buoyancy Engine Check - Test full range of buoyancy engine to confirm satisfactory operation.

- CTD Check - Multiple Checks (SeaBird CTD)
    1. Pressure Test - Dead Weight full scale check of pressure sensor (or other options).
    2. Cracked Cell Test (TCR Command) - confirm frequency of cell is still within specification.
    3. Salt Check or Dock Test - run clean sea water through the CTD and compare it to a known reference unit.

2. Shipment and storage of Core Argo floats

a) Shipping and handling

Do not grab or bump the sensor head or antenna. The sensor head and antenna are not designed to hold the weight of the Argo float and can easily be damaged. Pick up and move the Argo float by the aluminium hull and/or the stability disk/collar. Do not drop the Argo float and generally handle it with care. Avoid scratching the hull as this could decrease the integrity of the hull by increasing the chances of corrosion. It is suggested that a specialised trolley be used to move the Argo floats around as opposed carrying them, where possible.

Argo Floats contain battery packs of lithium or electrochemical (alkaline) batteries. There are differing regulations in terms of shipping, depending on the type of battery installed.

- <u>Lithium batteries</u>: The International Air Transport Association (IATA) Dangerous Goods Regulations (DGR) must be followed when transporting lithium metal or lithium-ion batteries by air. The shipping containers or boxes must be correctly marked, labelled, and certified in accordance with IATA DGR for Class 9 Miscellaneous Dangerous Goods. All lithium metal and lithium-ion cells and batteries are prohibited for transport on passenger aircraft to, over, and from the United States. Please check your country's regulations.
- <u>Alkaline batteries</u>: There exists a small risk for alkaline cells within battery packs powering Argo floats, to emit a combustible gas mixture. When exposed to air, these gases easily dissipate to a safe level. However, building up within the hull of an Argo float can pose problems. One solution to this, developed by the manufacturer of the Apex Argo float is to add a catalyst which allows the recombination of hydrogen gas to oxygen, forming H_2O. The instrument is also designed to relieve internal pressure through the upper end cape release (Teledyne Webb, 2010).

b) Transportation types

Argo floats can be shipped either by air freight or sea freight, depending on timeline and budgets. Argo floats can be freighted in plywood crates, with sponge cut-outs to secure the Argo float safely, or ready to deploy cardboard boxes wrapped in plastic wrap. A shock watch, shaped as a shock absorber tube is fixed to the outside of the crates and cardboard boxes to notify freight companies and the receiver if the crates have received rough handling. If the shock watch has been activated (by turning red instead of its normal white colour), then careful physical observation is required of the Argo float and crate, plus follow up testing is required to confirm the Argo float is still operational. Notification to the manufacturer of rough handling is also a good idea.

Figure 4: Shock absorber glass tube. If the tube is red, the Argo float was not handled correctly.

c) Core Argo float storage

Core Argo floats are delicate instruments and require suitable storage. Below are short descriptions given for each Core Argo float from their relevant manufacturers where available.

- <u>APEX (and APEX-UW):</u> For optimum battery life, APEX Argo floats should be stored in a controlled environment in which the ambient temperature is restricted to the range +10 °C to +25 °C.
- <u>ARVOR and PROVOR</u>: These Argo floats operate in a temperature range of -20 to +50°C. The suggested storage time before expiry is one year.
- <u>NAVIS:</u> Avoid exposing Argo NAVIS floats to high temperatures during shipping, storage, and handling.
- <u>ALTO, SOLO-II and S2A:</u> It is best to store these Argo floats vertically cushioned with foam. These Argo floats are much more robust against impact when oriented vertically. This is especially important on smaller boats. The boxes use water soluble tape to keep the box closed and this is protected by a bag. But it is best to prevent the package from getting wet. Also, these Argo floats should be kept out of direct sunlight, as sunlight on the bag could cause condensation on the inside of the bag which could compromise the water-soluble tape.

The sensitivity of the CTD sensors should also be considered when storing Argo floats, especially where conditions in storerooms or onboard vessels are likely to become extreme (very warm or very cold). Argo floats equipped with a SBE41/SBE41CP CTD should be stored and shipped above freezing and less than 45 °C (Seabird, 2017). Argo floats equipped with a RBR CTD can be stored and shipped between -40 °C to 70 °C (email communication with Jean-Michel Leconte, RBR, 2022).

3. Setup of Core Argo floats

This section is related to the final checks and initiation of Core Argo floats prior to their deployment. All Argo float needs to be started outside, with a clear view of the sky, and in the vertical position with the water release end down on the ground. This is so the GPS positioning and satellites communications can be tested before deployment.

a) S2A / ALTO / SOLO-II

- The S2A or ALTO Argo floats can be started with a magnet prior to being loaded onto a vessel, and up to 180 days prior to deployment. It is helpful if this procedure is undertaken in a relatively quiet environment, so the pump initialising can be heard at the time of the magnet swipe. Please communicate with the float operator before starting up the Argo float.
- Cut a flap in the outer plastic bag and the shrink wrap to expose the RESET window that is cut into the box. Open the reset flaps on the box to show a section of the Argo float. Find the RESET decal on the pressure case. If it cannot be found, reach in and gently rotate the Argo float until it is accessible.
- Using the magnet, swipe it vertically once over the RESET label, making sure the magnet swipe extends beyond the label. If started successfully, the pump should be heard running immediately. If the pump is not heard running after 60 seconds, re-swipe the magnet until the pump is engaged. Once engaged the pump will run for 7-15 minutes and a self-diagnostic Built In Test (BIST) will be initiated. A portion of the test includes obtaining GPS position and offloading test messages to verify communications with the Iridium system.
- The instrument will send the results of the BIST to the float operator via Iridium satellite network, and this may take up to an hour to receive. The S2A or ALTO Argo float should NOT be deployed until the float operator confirms that the startup BIST messages have been sent and that the Argo float has indicated that it is ready to be deployed. If a complete startup message is not received, the float operator will request the Argo float be re-swiped.
- Once the float operator has confirmed a complete startup BIST message, the plastic flap can be taped shut and the float stored back inside.
  A video of how-to startup an ATLO/S2A/SOLO-II can be found at https://argo.whoi.edu/argo/deployment/WHOI_Argo_startup.mp4.

b) APEX and NAVIS

- APEX and NAVIS Argo floats can be deployed in two ways. Either activated before deployment with a magnet swipe over the hull in a designated point, or using a computer connected to the Argo float. The second option for deployment can be pressure activation after the Argo float has descended past 25 db.
- If activated on deck with a magnet swipe, then onshore team members can confirm the Argo float has started and has passed its self-test. Alternatively, a computer can be connected to the Argo float to initiate activation and monitor the mission prelude phase before deployment.
- Pressure activation is a good method if the deployment vessel is a ship of opportunity and therefore has limited time for the deployment due to other operations onboard, or limited capacity in terms of deployment teams.

c) HM2000

- HM2000 Argo floats need to be started outdoors with a clear view of the sky. These Argo floats can be activated with the magnet at the location of “activation”. If the HM2000 Argo float uses the BDS satellite system for data transmission, the operator must wait for a permission for deployment from the land-based stations, because the Argo float will return its test messages to the land via BDS.

d) ARVOR / PROVOR

- ARVOR Floats need to be armed (ARMED ON) prior to deployment. This is generally done at factory level or before shipping the instrument.
- These Argo floats have a magnet fixed to the hull which needs to be removed for activation of the Argo float. They need to be started outside, with a clear view of the sky, and in the vertical position. This is so the GPS positioning and Iridium satellites communications can be tested during its self test.
- After removal of the magnet, the ARVOR Argo float undergoes a self-test of all its elements (CTD, hydraulic, internal vacuum, Iridium and GPS). This test lasts for about three to five minutes and will activate a buzzer and send an SBD Iridium message upon completion. The buzzer acts as the “ready to deploy” signal and will last for 30 minutes during which the Argo float may be deployed. At any time, the magnet may be put back on its position on the hull if for any reason the deployment has to be cancelled.
- If the buzzer does not activate after 5 minutes, it is advised to restart the Argo float by putting back and removing the magnet again. After 3 failed attempts, the float should not be deployed, and advice should be sought from NKE.
- Alternatively, the Argo float can be in ARMED ON mode, and have a magnet fitted with water soluble tape. This method can be used for ships of opportunity deployments where deployment expertise is minimal. It is like pressure activation mode. ARVOR Argo floats may also be delivered without a magnet and set into pressure activation mode. It will then start its mission as soon as a pressure is detected by the CTD. Those two configurations are not however the default mode for ARVOR Argo floats, and the buzzer activation should be the preferred method considering that it should not take more than 5 minutes.

4. Deployment of Core Argo floats

Most Core Argo float deployment techniques require the ship to be moving between 0.5 - 2 knots and the deployment to take place on the leeward side of the vessel. All these deployment instructions assume that the Core Argo float has been confirmed to have been initiated. There are several deployment videos available in the Supplementary Materials section at the end of this paper which we suggest users watch and perhaps make use of in their operations.

a) Box with water release (S2A/ALTO/SOLO-II)

These Argo floats are deployed inside a biodegradable cardboard box held together with water soluble tape or release harness. The box protects the delicate parts of the Argo float from impact during deployment.

- Remove the outer plastic sleeve, plastic wrap, and the cardboard that protects the water release. Keep the area where you are working dry as exposure to water will prematurely trigger the water-soluble release mechanism.
- The water release is a metal or plastic cylinder on the heavy end of the box, it may be wrapped in plastic, remove the plastic wrap. If the water release was activated and released its line, follow the instructions in Appendix A to replace the water release.
- Some boxes may have a backup line that secures the harness in case the water release is triggered accidentally. Usually, this line is red. If there is a backup line it must be cut before deploying or the harness will not release.
- If a carabiner is provided, pass the loops of the bridle through it and secure one end of the deployment line to the carabiner using a bowline knot. If no carabiner is provided, pass the deployment line through each of the 4 loops and secure it with a bowline knot. Secure the other end of the deployment line to the ship.
- With the ship underway at ~0.5 - 2 knots, deploy the instrument over the side preferably on the leeward side. With one person keeping tension on the deployment line, have one to two others lift the heavy end over the side. Gently lower the box to the water level being careful to not hit the box against the side of the ship or impact the water too hard (Figure 5). Continue lowering smoothly until the bottom of the box is in contact with the water. You can dunk the box like a tea bag to help keep the box up right. When the release mechanism gets wet, the starch ring will dissolve, and it will release the box from the bridle and the entire box will slip away. The box is sealed with water-soluble tape and is biodegradable. The water release should activate within one minute of touching the water. All parts of the harness and water release will be retrieved with the lowering line.

Figure 5: Deployment of the Argo float within a box over the side of the vessel (Photo: WHOI)

- Please save the deployment supplies. Rinse the water releases and save them along with the harnesses, deployment line, and carabiner for return to the Argo team. These supplies are custom made and returning them allows for re-use.

- Complete the metadata sheet with the appropriate serial number and record the deployment information together with any notes about deployment problems, bad weather or any other pertinent observations (see the example metadata sheet in Appendix B).
- Never stand the box on its light end, or the antenna could be damaged. Keep the Argo floats horizontal or secured vertically on the heavy end until deploying.
  A video of float deployment using a water release can be found at https://argo.whoi.edu/argo/deployment/WHOI_Argo_deployment_water_release.mp4.

b) Box without water release - sling method (S2A/ALTO/SOLO-II)

This method is much the same as the box with water release method but uses two slings to lower the Argo float. The method was developed by Christopher Berg and Kyle Grindley of SIO. It is advised that this method be used by research vessel teams, whereas the water release method is ideal for ships of opportunity.

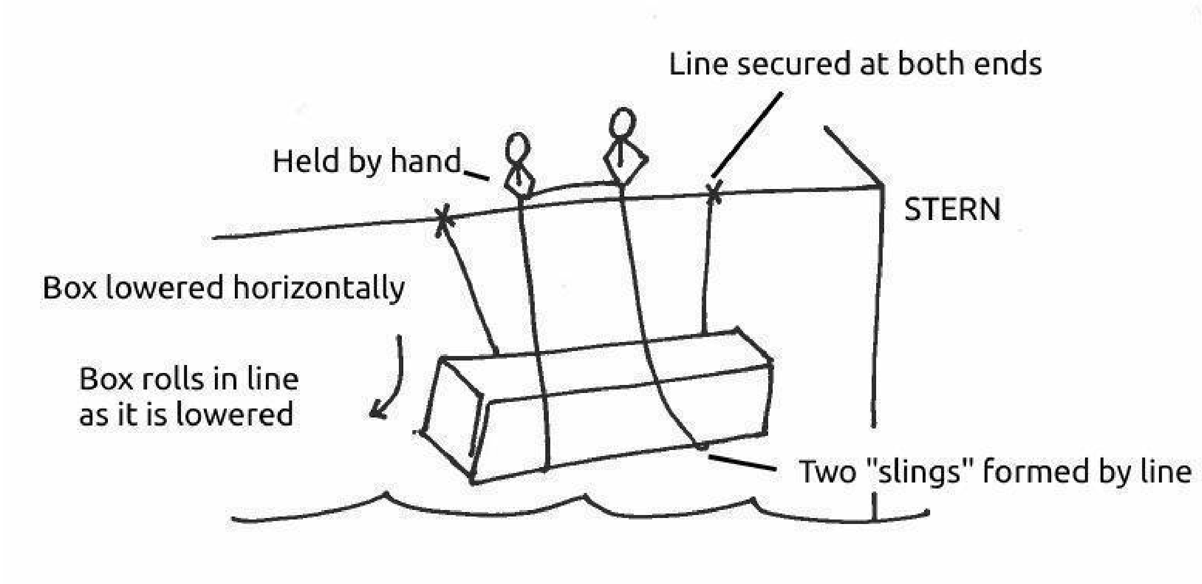

Figure 6: Schematic of Argo float box release using a sling (Schematic: WHOI)

- If the boxed Argo float is inside a bag, remove the plastic first, taking care not to cut the two PVA tape bands around the box.
- Remove the plastic packing tape from the ends of the box. The packing tape is the only link holding the ends of the box closed during shipment. It must be removed from the box before deploying or the Argo float will not release properly from the box. After removing the packing tape, be careful not to let the Argo float slip out of the box's unsecured ends.
- Rig the deployment line. Deploy the instrument over the side at the aft port or starboard quarter of the ship, preferably the leeward side (Figure 6). Use a length of line at least 4 times the distance from the top of the rail to the waterline. Secure both ends of the line to the rail ~2-3 ft (0.6 - 1 m) apart. If possible, open the railing gate or safety lines so the box can be lowered from deck level.

- Start lowering the box over the rail. With one person holding each end of the line about 1.5 m inside of each secured end, the line should form two “slings”. Hold the Argo float horizontally, manoeuvre it over the rail so that it is supported by the “slings”.
- Lower the box over the side and into the water. The ship should be underway at ~1 knot. Do not deploy when stationary or drifting to avoid a collision with the instrument. Slowly and evenly pay out the line so that the Argo float is lowered down the side. It should roll as the line is paid out. Once the box is in the water, release the centre of the line into the water, tossing it so it clears the box to avoid tangles.
- An mp4 video of the sling deployment can be found here (https://sio-argo.ucsd.edu/dplyprocedures.html).
  A video of float deployment using the sling/roll method can be found at https://argo.whoi.edu/argo/deployment/WHOI_Argo_deployment_roll.mp4.

c) Unboxed lowered (NAVIS/APEX/ARVOR)

Rope method: Deploy the Argo float on the leeward side of the vessel, to avoid bumping the vessel, with the ship moving between 0.5 and 2 knots. This method has been adapted from Teledyne (2010).

- Remove the plugs from the CTD inlet (if the Argo float is fitted with a SBE41 CTD) and outlets.
- Pass a rope through the hole in the plastic damper plate. The rope should fit easily through the hole and be capable of supporting 50 kg. Pass the rope down through the hole.
- Holding both ends of the rope bight, carefully lower the Argo float into the water. The damper plate is amply strong enough to support the weight of the Argo float. However, do not let the rope slide rapidly through the hole as this may cut the plastic disk and release the Argo float prematurely.
- Take care to not damage the CTD or the Iridium antenna against the side of the ship while lowering the Argo float.
- Do not leave the rope with the instrument. Once the float is in the water, let go of the lower end of the rope and pull on the top end slowly and carefully until the rope clears the hole and the Argo float is released.
- It may take several minutes for the cowling protecting the bladder to fully flood with water and the Argo float may drift at an angle or even rest on its side during this period. This is normal behaviour and not a cause for concern.

Quick-release hook method

The method noted above is almost the same as that that would be employed using a quick-release hook. The only difference would be to attach the rope through the quick release hook as opposed through the Argo float damper plate.

d) Unboxed by hand (ARVOR)

The ARVOR Argo float can be launched by hand from the deck on the leeward side from a maximum height of 2 m, with the ship moving forward between 0.5 - 2 knots.

- Remove the plugs from the CTD inlet and outlets (if the Argo float is fitted with a SBE41 CTD).
- Hold the ARVOR Argo float by the damper plate being careful of the ARVOR Argo float's antennae and CTD and simply drop it over the side of the ship.

5. Beached Argo floats

If an Argo float washes ashore or is beached, it is the responsibility of the deploying institution to arrange for its safe disposal. This is to secure the safety of the public and the environment. A sticker (Figure 7) is attached to all Argo floats to warn against opening the float and to facilitate the float's identification and provide the public with contact information (Via OceanOPS) to find the float 'owner'. Safe disposal usually entails removing the batteries for local disposal as hazardous waste or shipping the float back to the originating laboratory for disassembly. Since the use of high-bandwidth communication systems, and thus shorter surface times, grounding rates have markedly decreased, but this responsibility remains in place.

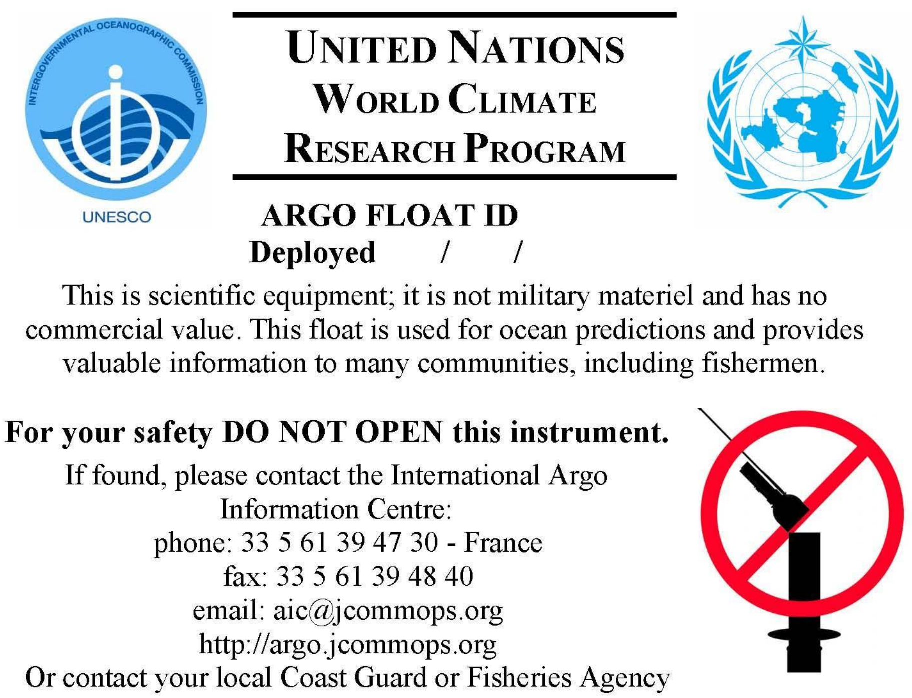

Figure 7: Sticker placed on every Argo float to warn against opening the float and how to find additional information.

D. Metadata

Metadata are crucial for understanding the Argo dataset, monitoring it and helping preserve it over time. Including lots of metadata associated with float deployments has helped Argo quality control experts identify systematic problems with data from different sensors. Metadata is also used to help inform users of subtleties of sensor sampling and resolution and allows for easy categorization of the dataset.

A template of the metadata required is given in Appendix B. This template has been designed specifically for Core Argo floats and covers all parameters required for notifying the float on OceanOps, but also for processing of the data.

Recently, the Argo Program has converted almost all its reference tables for metadata to standardised vocabularies that are both machine readable and human readable. These are maintained by the Natural Environment Research Centre (NERC) Vocabulary Server (NVS) at the British Oceanographic Data Centre (BODC). The collection of Argo reference tables can be found here: NVS Search (nerc.ac.uk)**.** All the Argo reference tables begin with 'R' and will also be linked from the Argo User Manual. This ADMT webpage explains how to access the NVS to find Argo vocabularies and also includes links for all the available reference tables: Argo vocabulary server - Argo Data Management (argodatamgt.org)**.**

Metadata contents and format are checked by the Argo File Checker (euroargodev/ArgoNetCDF: Argo NetCDF format and content (github.com)) prior to inclusion on the Argo data servers and the NVS version of the Argo reference tables makes this process less likely for error given the ability to query accepted metadata values by machine rather than by human input.

OceanOPS also monitors Core Argo metadata, especially those collected at deployment. This is important because Argo must follow IOC XX-6 (https://argo.ucsd.edu/international-oceanographic-commission-argo/) which calls for notification when Core Argo floats drift into countries EEZs (please refer to the EEZ section for further information). It is imperative that the Argo Program follow the IOC resolutions to maintain its good standing within the international community which allows for Core Argo floats to make and freely distribute these measurements, even in EEZs, with the country's permission. All Core Argo floats deployed must be registered at OceanOPS prior to deployment.

It is strongly advised that the IMEI number of the Argo float is NOT PUBLISHED on any websites or portals. Argo floats can be interrogated through telecommunications with this number and Argo teams are advised to keep these secure and for use only by the Argo float operators.

E. Data

1. Data flow - from the Core Argo float to the GDAC

Argo data are sent from the Core Argo floats upon surfacing to their respective Data Assembly Centres (DACs), where the data are decoded and put through real time quality control tests to identify gross errors due to sensor malfunctioning or transmission errors. If an adjustment has been previously made by a delayed mode quality control expert, this is applied to the data in the ‘ADJUSTED’ data fields. In this case, both the raw data and the real time adjusted data will be available in the real time data stream. Within 12 hours, the data are put into BUFR format for insertion into the Global Telecommunications System (GTS) and into NetCDF format for distribution on the Global Data Assembly Centres (GDACs). This is schematically shown in Figure 8. However, for scientific applications such as calculations of global ocean heat content or mixed layer depth, the delayed mode (D-mode) dataset is more appropriate (Wong et al, 2020, and Wong et al, 2023).

After 12 months, the data are further quality controlled by a delayed mode quality control expert (DM-operators) with global and regional oceanographic expertise and adjusted for sensor drift, if needed (Fig. 8). A longer time series is needed to identify possible sensor drift when statistically compared to nearby ocean climatology’s. If adjustments are needed, they are applied, and the data is put into the ‘ADJUSTED’ data fields. Since 2000, adjusted salinity has been estimated by comparison with a reference database (RefDB) using a process described by Wong et al (2003), Böhme and Send (2005), Owens and Wong (2009) and Cabanes et al (2016). The Argo salinity calibration package is known simply as ‘OWC’.

> Core Argo floats are delayed mode quality controlled several times throughout their lifetime and delayed mode profile files are updated on the GDACs. For this reason, if doing climate quality studies, it is important to always get the most up to date Core Argo profile files and to use the ‘ADJUSTED’ data instead of the raw data.

To help bridge the gap between real time and delayed mode files, there are a few near real time quality control checks that are run regularly.

- The first is a comparison with satellite altimetry that is run every 3 months at CLS where steric height from the Core Argo float is compared with altimetric height that is close in time and space (Guinehut et al., 2009). This comparison can help detect sensor drift or calibration errors.
- The second is a statistical comparison to identify outlier data based on residual mapping errors (Gaillard et al., 2009). It is run monthly at Coriolis.
- The third method is a Min-Max comparison run daily against a climatology of minimums and maximums from high quality, delayed mode Core Argo profiles and reference CTD profiles (refer to Section 3 below) from GO-SHIP and other sources (Gourrion et al., 2020). It is run monthly at Coriolis.

Results of all three of these tests are sent to the DACs where the appropriate action is taken to either 1) greylist the Argo float to quickly indicate there is an issue with data quality or 2) ask the delayed mode operator to look at the Argo float’s data and adjust as needed. Both actions move the Argo float to the highest priority for delayed mode quality control.

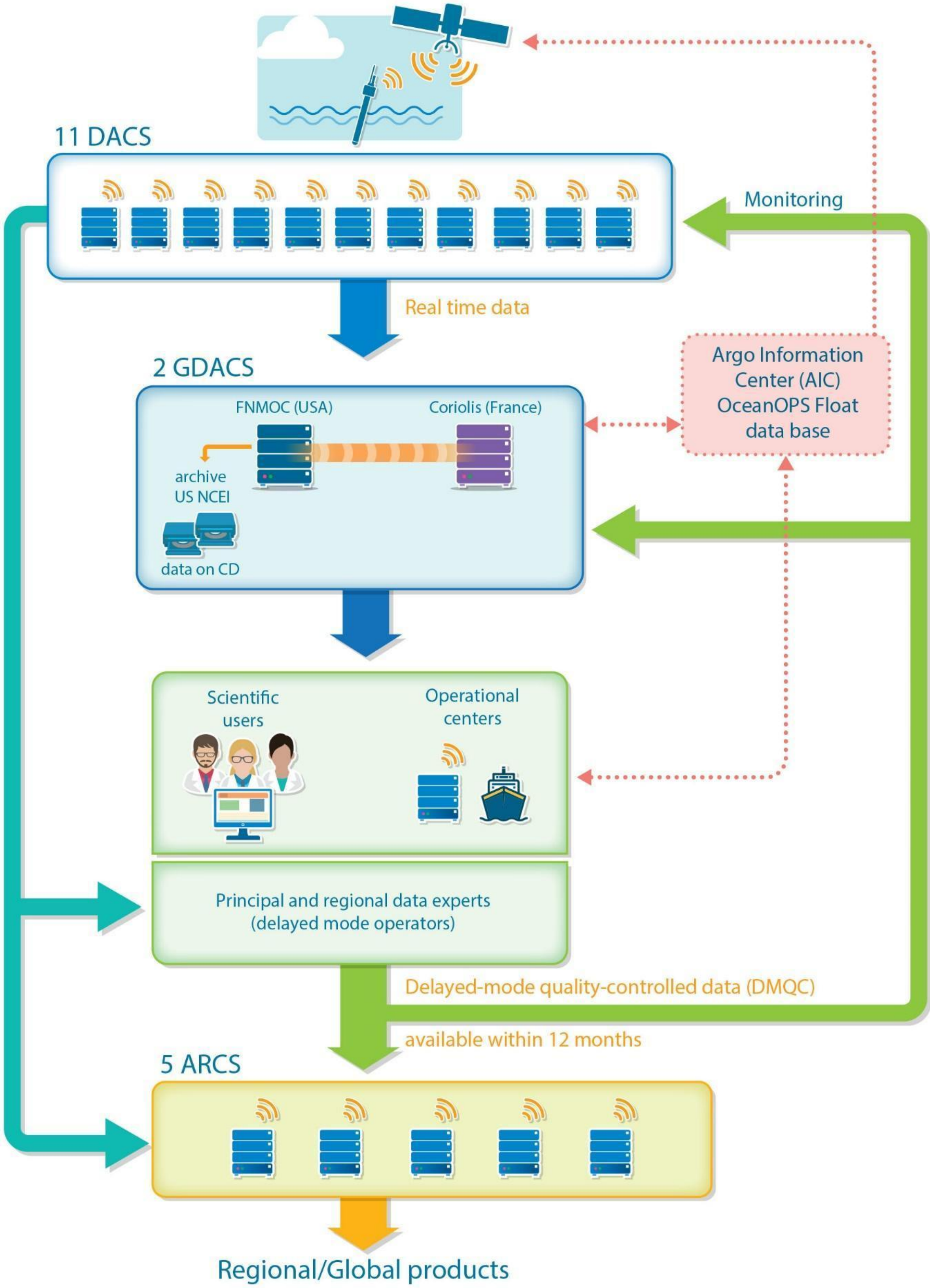

Figure 8: Schematic showing data pathways. ARC – Argo Regional Centres, DAC – Data Acquisition Centre, GDAC – Global Data Acquisition Centre, DMQC – Delayed-Mode Quality Control, AIC – Argo Information Centre, FNMOC – Fleet Numerical Meteorology and Oceanography Centre, NCEI – National Centre for Environmental Information.

2. File types, data modes and quality control flags

This section describes the different files produced by the DACs, the data modes used to indicate what type of quality control has been done, and how to use the quality control flags. Argo float providers are requested to provide allocated DACs with the necessary metadata and technical data for each Argo float for the files to be created. Some of this metadata and technical data are reported by the Argo float each cycle and some of it must be provided once, prior to deployment. If an Argo float changes its mission during its lifetime, this is recorded in the metadata and Argo float providers and DACs should agree on how this will be communicated and recorded in the files.

a) File types

There are four file types: profile, trajectory, meta and technical files.

Profile file: There is one profile file for each Core Argo float cycle which contains the P/T/S (pressure / temperature / salinity) measurements made upon ascent or descent, along with the profile location, date, and some metadata. The cycle number is included in both the name of the profile file (e.g. D5900400_020.nc is the ascending profile file for cycle 20, where e.g., D5900400_020D.nc defines the descending profile) and inside the netCDF file itself in the CYCLE_NUMBER variable. Note: this means the profile files are either real time or delayed mode and this can be determined by the file name (e.g., the 'D' at the beginning of D5900400_020.nc indicates this is a delayed mode file) and inside the netCDF file itself in the 'DATA_MODE' variable.

Trajectory file: There can be up to two trajectory files per Core Argo float: one for real time and one for delayed mode. The naming convention is 5900400_Rtraj.nc and 5900400_Dtraj.nc. Trajectory files include data from multiple cycles. The real time trajectory file contains real time trajectory data for all the float cycles and will exist until all cycles have been delayed mode quality controlled and the delayed mode trajectory file will then replace the real time trajectory file. The delayed mode trajectory file contains all the cycles that have been delayed mode quality controlled. This means that if both trajectory files exist, users may need to look in both the real time and the delayed mode file to find all the data because there may be real time cycles that have come in after the last delayed mode cycle. Trajectory files contain location, time and parameter data taken by the Argo float, outside of the 'profile'. This means all the data taken on the surface, during descent, during drift, during descent to profile depth, and on the surface again. Sometimes timing information from ascent, along with the occasional P/T/S measurement are also included. This is because the profile file is not designed to contain time, but some Argo floats return this time, so it is stored in the trajectory file.

Meta file: There is one metafile per Argo float (e.g., 5900400_meta.nc) and this contains meta information pertaining to the Argo float, its sensors and owner, as well as some configuration parameters like cycle time, drift pressure, profile pressure, etc. For Argo floats equipped with two-way communication, these configuration parameters can be changed between cycles and are recorded in the 'CONFIG_PARAMETERS' variables. For Argo floats not equipped with two-way communication, the meta file contents do not change over time and so there is only one entry in CONFIG_PARAMETERS.

Technical file: There is one technical file per Argo float (e.g., 5900400_tech.nc) and contains technical information pertaining to the Argo float like battery voltage, piston counts, surface pressure offset, etc. This information is included for each cycle.

b) Data modes

There are three data modes: real time (R), adjusted (A), and delayed mode (D).

Real time mode means that the data is available within 24 hours of profiling and has undergone basic real time quality control tests that remove gross errors from the data. All data are found in the <PARAM> variables (e.g., TEMP, PRES, PSAL).

Adjusted mode means that an adjustment has been applied to the data in real time based on previous delayed mode quality control done on the data or other known offsets such as pressure drifts. When delayed mode quality control is done on the data and a salinity adjustment is needed, that adjustment is applied to the appropriate profile files. When new profiles arrive, in real time, that same salinity adjustment determined in delayed mode quality control is made to the salinity and filled in the PSAL_ADJUSTED variable with a DATA_MODE of 'A'.

Delayed mode data means that a regional oceanographic expert has looked at the data and has either determined it of good quality or applied an adjustment to make it of good quality. The high-quality data (whether it needs an adjustment or not), goes into the *_ADJUSTED variables. If no adjustment is needed, the real time data is copied into the adjusted parameters (e.g., TEMP is copied into TEMP_ADJUSTED). This data is typically available within 12 - 18 months of profiling.

Note: If doing a study sensitive to small errors, use only delayed mode data. Also, it is important to frequently refresh your Argo dataset as files change and the quality can improve over time.

c) Quality flags

There are two Argo reference tables describing quality flags (QC) which can range from 0 to 9 although not all numbers are in use at the moment. There is a real time QC flag table: https://vocab.nerc.ac.uk/search_nvs/RR2/ and a delayed mode QC flag table: https://vocab.nerc.ac.uk/search_nvs/RD2/

It is important to understand what the QC flags mean to know when to use the data. If the data is marked with a QC flag of '3' or '4', it means the data is likely bad or uncorrectable and it is recommended that this data should not be used. If the data is marked with a QC flag of '1' or '2', it means the data is likely good. A QC flag of '0' means no quality control was performed on that data point.

d) Data resources

For more information about the data, how it is processed and what quality control measures are taken, please visit the ADMT documentation webpage (Documentation - Argo Data Management (argodatamgt.org)). It is organised into the following categories:

1. Argo data formats: These user manuals describe each of the data file types and include lists of the various parameters, including the physical parameters as well as the meta and technical parameters.
2. Quality control documents: These describe the quality control tests and processes and are organised by Core Argo data and by BGC data parameters.
3. Cookbooks: These are documents, mainly targeted at DACs, that explain how to process raw Argo float data to create the real time files that are made publicly available. They are very technical and aim to make files consistent across the different DACs.

If you are interested in getting more involved in any part of these data management processes, please contact the ADMT co-chairs and consider attending the annual ADMT meeting (https://argo.ucsd.edu/organization/argo-meetings/argo-data-management-team-meetings/).

e) How to get started with Argo data

If you are new to Argo data, there are some tools available to help you get familiar with the format, accessing the data, and using the QC flags. A webpage with all the tools is here: https://argo.ucsd.edu/data/argo-software-tools/. In particular, the Argo Online School, https://euroargodev.github.io/argoonlineschool/intro.html, is a great introduction.

3. The CTD reference database

Argo floats use complex sensors subject to various conditions that can lead to measurements outside the initial manufacturer's accuracy. Checks for sensor drifts and offsets are necessary. Profiling floats have an expected lifespan of 4-5 years and usually yield accurate measurements of pressure and temperature during this time. However, unlike ship based CTD measurements, Argo floats have prolonged exposure to harsh environmental conditions and cannot be routinely calibrated against *in situ* bottle salinity samples.

Two reference databases are supplied to the DM-operators and are used as input into OWC for Argo delayed-mode salinity adjustment. Information about the databases and how to obtain them can be found on the ADMT website (Latest Argo Reference DB - Argo Data Management (argodatamgt.org))

- **The CTD reference database** is maintained by IFEMER/Coriolis and is comprised of historical shipboard CTD data obtained from the World Ocean Database (NOAA/NCEI) and supplemented with CTD data from GO-SHIP (CCHDO) and from the International Council for the Exploration of the Sea (ICES) and/or directly from individual investigators.

- **The Argo reference database** contains Argo profiles that have been verified in delayed mode as good and do not require any salinity adjustments.

The CTD and the Argo Reference Databases are hosted by IFREMER/Coriolis and announced by email to argo-dm@groups.wmo.int Detailed information on OWC and the Reference Databases can be found at https://doi.org/10.13155/78994

4. Data sources

Several data sources are available to all users. There are many more web portals and packages that make use of Argo data, and metadata, but of which the Argo Steering Team are not always aware of. Thus, for this best practice paper, the following links to data sets are noted for users:

- Coriolis:
  ftp://ftp.ifremer.fr/ifremer/argo,
  https://data-argo.ifremer.fr,
  rsync:
  http://www.argodatamgt.org/Access-to-data/Argo-GDAC-synchronization-service
  Data selection tool: https://dataselection.euro-argo.eu/
- US GDAC:
  https://usgodae.org/argo/argo.html
  ftp://www.usgodae.org/pub/outgoing/argo/
  USGODAE Argo GDAC Data Browser (navy.mil):
  https://usgodae.org/cgi-bin/argo_select.pl
- Argo monthly DOI snapshot:
  http://doi.org/10.17882/42182
- ERDDAP:
  http://www.ifremer.fr/erddap/index.html
- Thredds:
  http://www.ifremer.fr/thredds/catalog/CORIOLIS-ARGO-GDAC-OBS/catalog.html
- European Open Science Cloud:
  https://marketplace.eosc-portal.eu/services/argo-floats-data-discovery
- Argo float dashboard (great for reviewing meta and tech data; also has simple visualisations of profile data):
  https://fleetmonitoring.euro-argo.eu/dashboard

5. Citing Core Argo Data

When citing Core Argo data, please make note of the following description:

To cite Argo data, please use the following sentence ***and*** the appropriate Argo DOI afterwards as described below.

"***These data were collected and made freely available by the International Argo Program and the national programs that contribute to it. (https://argo.ucsd.edu, https://www.ocean-ops.org). The Argo Program is part of the Global Ocean Observing System.*** "

The general Argo DOI is below:

Argo (2000). Argo float data and metadata from Global Data Assembly Centre (Argo GDAC). SEANOE. https://doi.org/10.17882/42182

If you used data from a particular month, please add the month key to the end of the DOI URL to make it reproducible. The key is comprised of the hashtag symbol (#) and then numbers. For example, the key for August 2020 is #76230.

The citation would look like:

Argo (2020). Argo float data and metadata from Global Data Assembly Centre (Argo GDAC) – Snapshot of Argo GDAC of August 2020. SEANOE.

Alternatively, should you want to acknowledge the value of the Argo data set, without making use of the data directly within a publication, please use the following Argo data paper citation:

Wong, A. P. S., S. E. Wijffels, S. C. Riser, et al., 2020: Argo Data 1999–2019: Two Million Temperature-Salinity Profiles and Subsurface Velocity Observations From a Global Array of Profiling Floats. *Frontiers in Marine Science*, 7, https://doi.org/10.3389/fmars.2020.00700

Abbreviations

ADMT	Argo Data Management Team
ALACE	Autonomous Lagrangian Circulation Experiment
AST	Argo Steering Team
BDS	Beidou Satellite
BGC	Biogeochemical
BIST	Built In Test
BODC	British Oceanographic Data Centre
BUFR	Binary Universal Form for the Representation of meteorological data
CLS	Collecte Localisation Satellites
CTD	Conductivity Temperature and Depth
DAC	Data Acquisition Centre
DGR	Dangerous Goods Regulations
DOI	Digital Object Identifier
EEZ	Exclusive Economic Zone
ETOOFS	Expert Team on Operational Ocean Forecast System
GDAC	Global Data Acquisition Centre
GCOS	Global Climate Observing System
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GTS	Global Telecommunication System
IATA	International Air Travel Association
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
ISC	International Science Council
PI	Principle Investigator
PVA	Polyvinyl Acetate
NERC	Natural Environment Research Council
NVS	NERC Vocabulary Server
RAFOS	SOFAR spelt backwards
RUDICS	Router-based Unrestricted Internetworking Connectivity Solutions
SBD	Short Burst Data
SBE	SeaBird Electronics
SOFAR	Sound Fixing and Ranging Float
TBTO	Tributyltin oxide
WMO	World Meteorological Organisation
WOCE	World Ocean Circulation Experiment

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SUPPLEMENTARY MATERIAL

SIO ARGO floats Deployment Procedure Documents.
http://sio-argo.ucsd.edu/dplyprocedures.html

WHOI deployment videos
http://argo.whoi.edu/argo/deployment/

UW Argo float deployment
http://runt.ocean.washington.edu/rupan/Deployment/UWPalmerLong.m4v

APEX float deployment manual
http://www.coriolis.eu.org/content/download/23298/160455/file/120210_____Job1848_ApexUserManual-120210.pdf

ARVOR PROVOR Workshop
https://euroargodev.github.io/techworkshop/

Sailing Vessel Iris deploying S2A floats in boxes and ARVOR floats
https://www.youtube.com/watch?v=UJHiulkt5r4

Float deployment best practices webpage

https://argo.ucsd.edu/float-deployment-best-practices

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We would like to acknowledge Christopher Berg, Michael Cassen, and Kyle Grindley of Scripps Institution of Oceanography for the video and directions of deploying a Core Argo float using the sling method.
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APPENDIX A

Replacing the cornstarch collar in the Water Release of a SOLO II Core Argo float

In the unlikely event that the water release mechanism has released prematurely, you can replace the cornstarch collar, yellow piece shown in Figure 9. (Note: Sometimes the cornstarch collar is red.) The aluminium release mechanism can be unscrewed, and the cornstarch collar replaced. The cornstarch collar is a plastic cylinder with a solid ring of yellow (or red) on one end and a ring of fingers that leaves the white starch ring visible on the other end. The fingered ends should be closest to the spring mechanism (see Figure 9 for the correct orientation of the cornstarch collar). Insert the pointed end of the shear pin into the spring. Place the opposite end of the shear pin into the top of the starch collar. Thread on the housing to complete assembly. To hold the harness around the box, a length of line with loops on each end or a looped line is provided. The line is threaded through each of the four looped ends of the harness straps at the heavy end of the box. The loops on the water release line are captured over the shear pin of the water release as it is screwed into the housing. See another rigged box for an example of how the harness is rigged with the water release.

Figure 9. Water release used for boxed Argo float releases

APPENDIX B

Metadata deployment sheet template

Core Argo Float Deployment Metadata Template			
Pre-deployment information			
Argo Float Type	▢ ALTO ▢ ARVOR ▢ APEX ▢ APEX-UW ▢ HM2000 ▢ NAVIS ▢ SOLO-II ▢ S2A ▢ Other:		
Argo Serial #		Argo WMO #	
Cruise name		Ship	
Deployment operator			
Pre-deployment checks			
Visual check - float	▢ Yes ▢ n/a	Visual check - ballast	▢ Yes ▢ n/a
Magnet removed	▢ Yes ▢ n/a	CTD plugs removed	▢ Yes
Magnet removal (dd/mm/yy hh:mm)		Buzzer or pump activation	▢ OK ▢ n/a
Deployment			
Date		Time (GMT)	
Latitude		Longitude	
Deployment type	▢ Boxed ▢ Unboxed ▢ Lowered ▢ By hand ▢ Quick-release hook		
Vessel lee position	▢ Stern ▢ Starboard ▢ Port		
Deployment height		Ship speed (kts)	
Wind (Beaufort)		Sea State	
Bathymetry (m)			
CTD cast prior to deployment	▢ Yes ▢ No	CTD filename	
Additional comments			