The Argo Program

7th Summer School on Theory, Mechanisms and Hierarchical Modelling of Climate Dynamics - Estimating Ocean Transports: Single Sections, Box Models and Reanalysis Products

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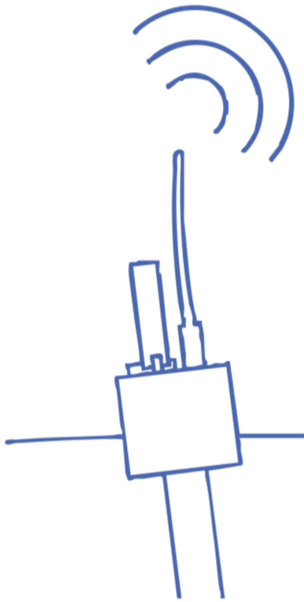
Although Argo is publicly and freely available, it is a complex data set,..

Learning Objectives

- Overview of the Argo program, including its main objectives and key characteristics
- Structure and operation of Argo floats in the open ocean
- Data quality control procedures and how they are implemented
- Organization, management, and accessibility of Argo data for users – *hands on.*



Part I: General introduction

Part II: The Argo Data set

Part III: Using the Data

Argo online School

An introduction to the Argo data

https://www.euro-argo.eu/argo-online-school

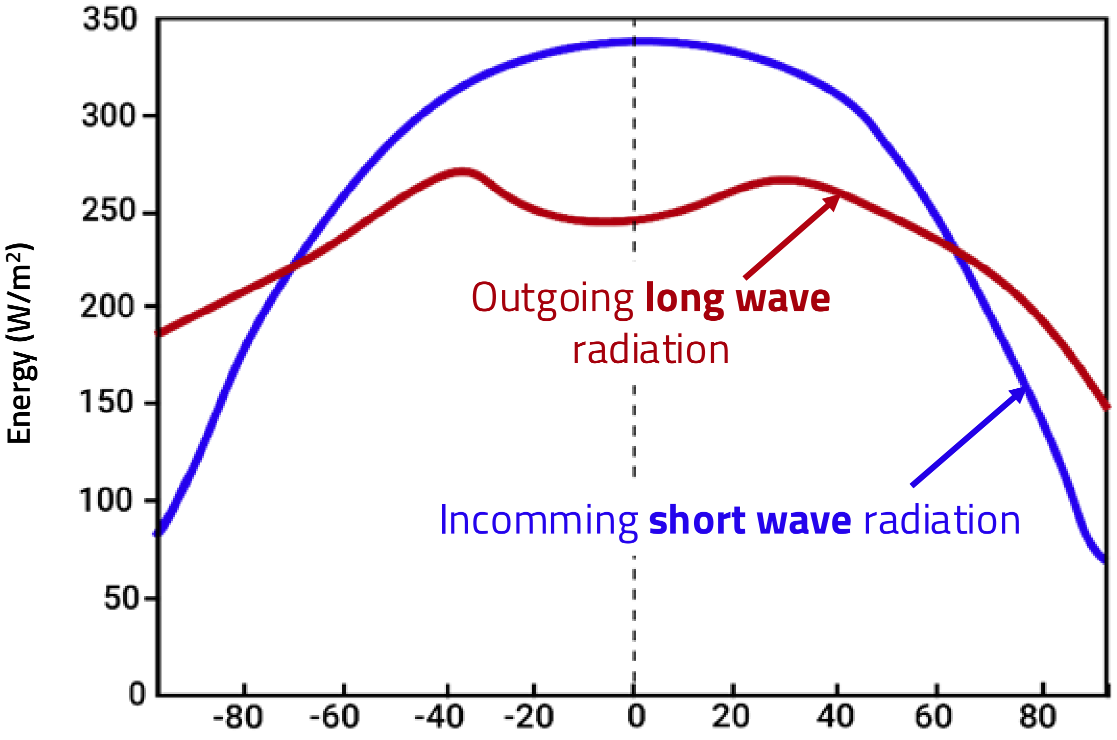
González-Santana et al., (2024). The Argo Online School: An e-learning tool to get started with Argo. Journal of Open Source Education, 7(80), 193, https://doi.org/10.21105/jose.00193

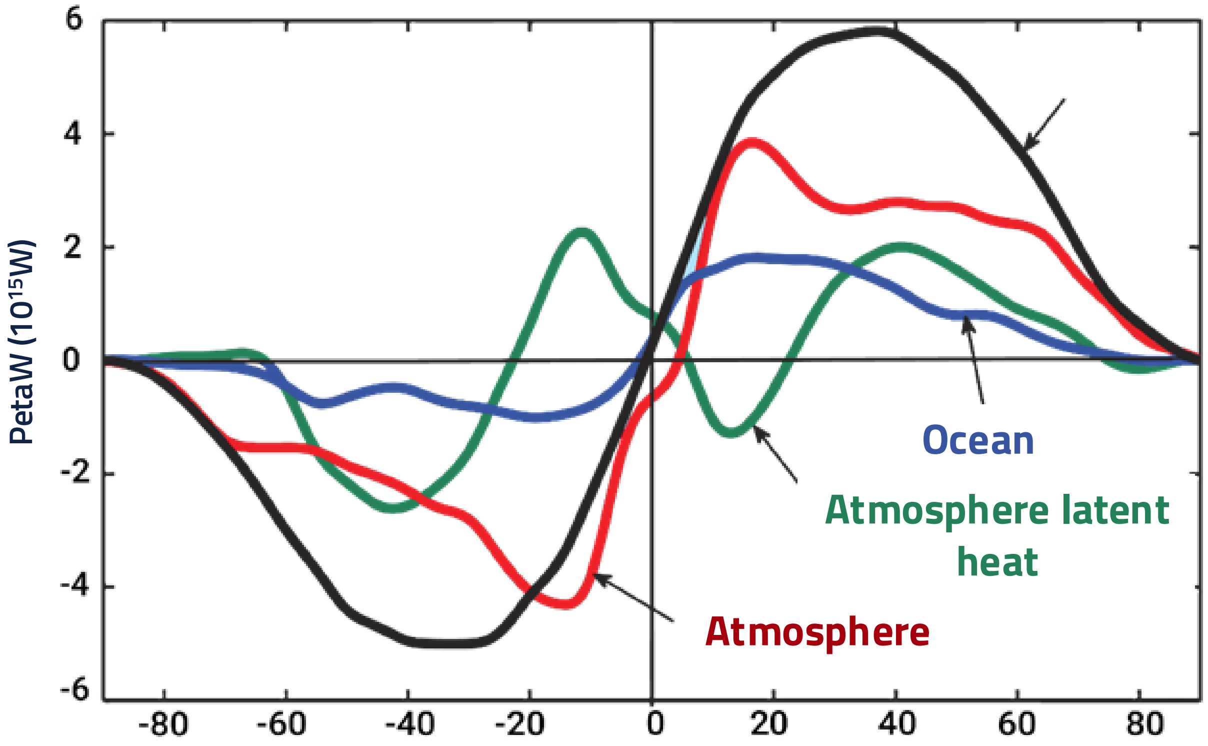
Part I: General Introduction

- Why Argo
- The Birth of Argo
- The sampling strategy
- The float cycle
- Expansion: One Argo
- Governance

Why Argo

Motivation





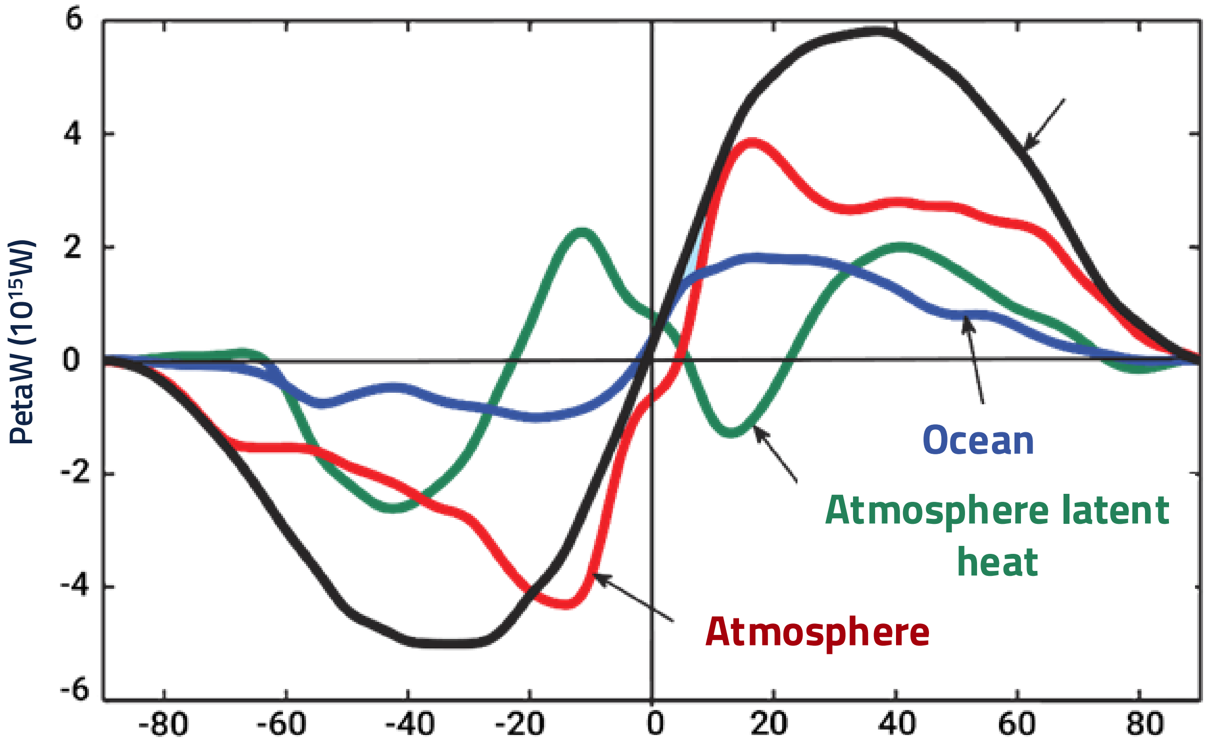
Schmitt, 2018. The ocean's role in climate. *Oceanography* 31(2):32–40

Motivation

In the 90s, climate initiatives, specifically **TOGA** and **WOCE**, highlighted the ocean's active and dominant role in the global climate system through heat and water storage, redistribution, and gas sequestration:

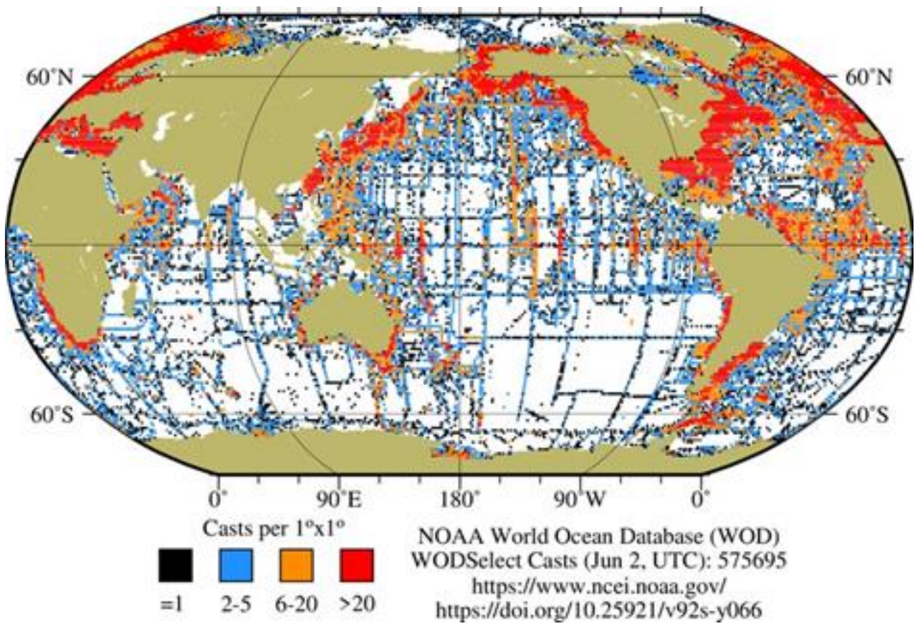
WOCE (World Ocean Circulation Experiment)
Revealed that ocean currents transport massive amounts of excess heat from the tropics to mid-latitudes (e.g., 2×10^{15} W in the Northern Hemisphere), matching atmospheric heat transport.
Showed significant interannual fluctuations in this "heat engine," such as a 30% yearly variation in North Pacific heat transport.

TOGA (Tropical Ocean Global Atmosphere)
Proved that equatorial ocean dynamics actively drive El Niño.
Deployed an in-situ observing system in the tropical Pacific, enabling the first successful El Niño forecasts.



Limitations of Pre-Argo Methods

CTDs 1900-2000



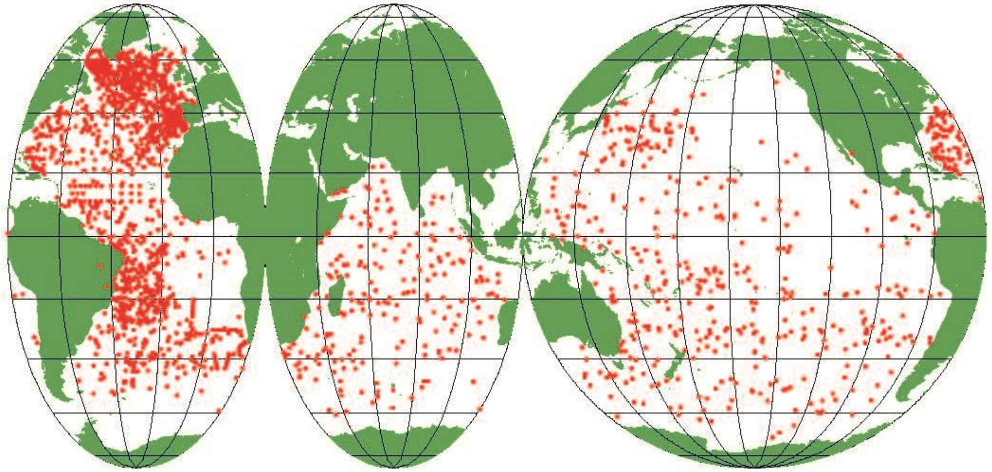
Severe Seasonal Biases AND Spatial Constraints

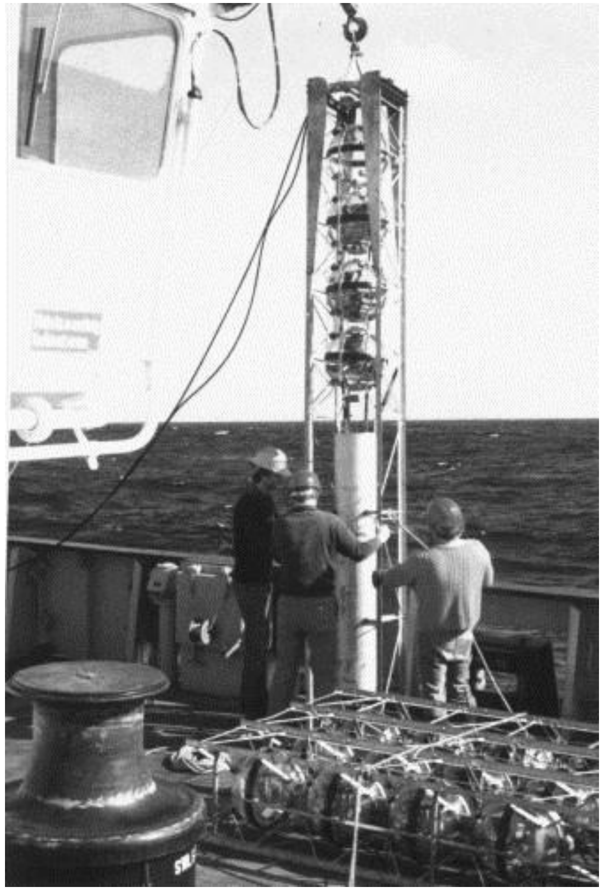
CTD: Historic measurements relied heavily on Research Vessels (R/Vs). High latitudes, particularly the Southern Ocean, had almost no winter observations due to dangerous navigation conditions during storms. Low temporal frequency.

XBT: Observations were largely confined to commercial shipping lanes. Massive ocean gyres and remote basins remained completely unmonitored for decades, masking real thermodynamic trends.

Appropriate cost-effective technology.

- Autonomous Lagrangian Circulation Explorer (ALACE). (Davis, 1991, Davis et al. 1992), that used the principle of neutral buoyancy invented by John Swallow in the mid 1950s to follow the currents at a particular pressure level. (Swallow, 1955)
- Each ALACE float rose to the sea surface at regular intervals to allow its position to be fixed by satellite.
- About 1000 ALACE-type floats were deployed by WOCE. It was soon realized that as they rose to the surface, the ALACEs could also measure the temperature and salinity of the water through which they rose and towards the end of WOCE, most of the ALACEs carried temperature/salinity/pressure sensors. They became Profiling ALACE (PALACE) floats.





Deep SOFAR float using glass spheres. (photograph, John Gould).

A statement of requirements

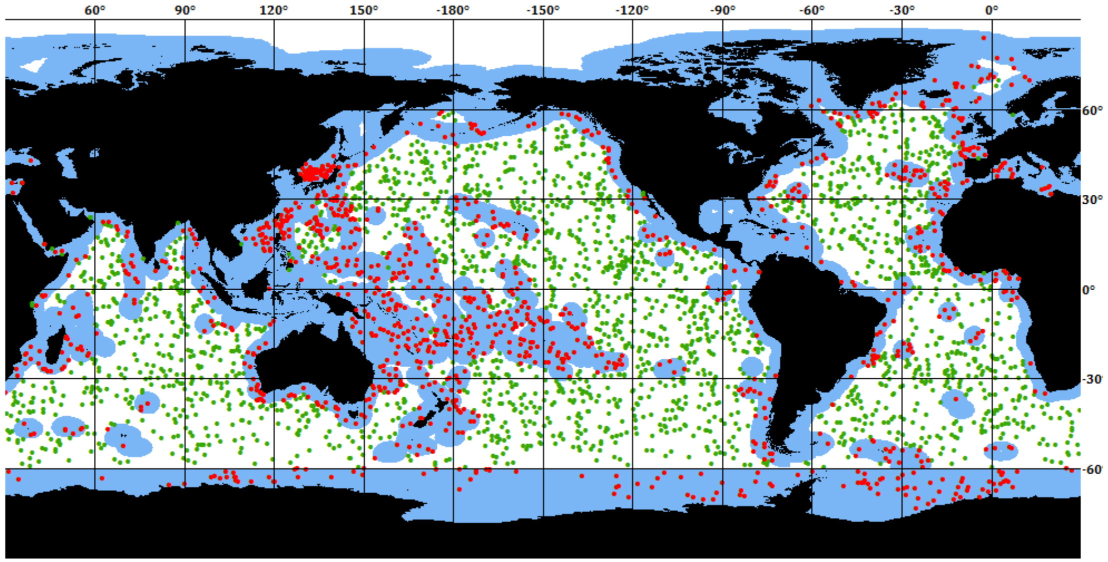
October 1997 – A global ocean array of profiling floats is discussed over lunch in the NCAR cafeteria (D. Roemmich, B. Owens, E. Lindstrom).

Late 1997 – “The ARGO White Paper”. (1 page)

Early 1998 – “A Proposal for Global Ocean Observations for Climate: the Array for Real-time Geostrophic Oceanography (ARGO)“ by D. Roemmich; and, “A Program for Global Ocean Salinity Monitoring (GOSAMOR)” by R. Schmitt.

1999 – “On the Design and Implementation of Argo”, **Argo Science Team**

Intergovernmental coordination



About 30% of Argo floats are operating inside an EEZ

1999: IOC Resolution XX-6 Accepts the Argo project as an important contribution to the operational ocean observing system of GOOS and GCOS, as well as a major contribution to CLIVAR and other scientific research programmes. (+ EC XLI.4 in

2001: Argo Information Center established to fulfill requirements of XX-6 with regard to informing coastal states of float deployments.

2008: providing guidelines for implementation of XX-6; relabels *Argo Programme*)

United Nations
Educational, Scientific and
Cultural Organization

International scientific collaboration

There is no intergovernmental funding

Argo succeeded and continues to progress because many individuals understood the value of the program and have made large and original contributions.

All national programs have agreed that building and sustaining the global array is the highest priority.

All, The Argo Steering Team, Argo Data Management Team, Argo Science Workshops, and Argo Technical and Training workshops are volunteered and have been critically important for coordinating national priorities in order to produce a global array.

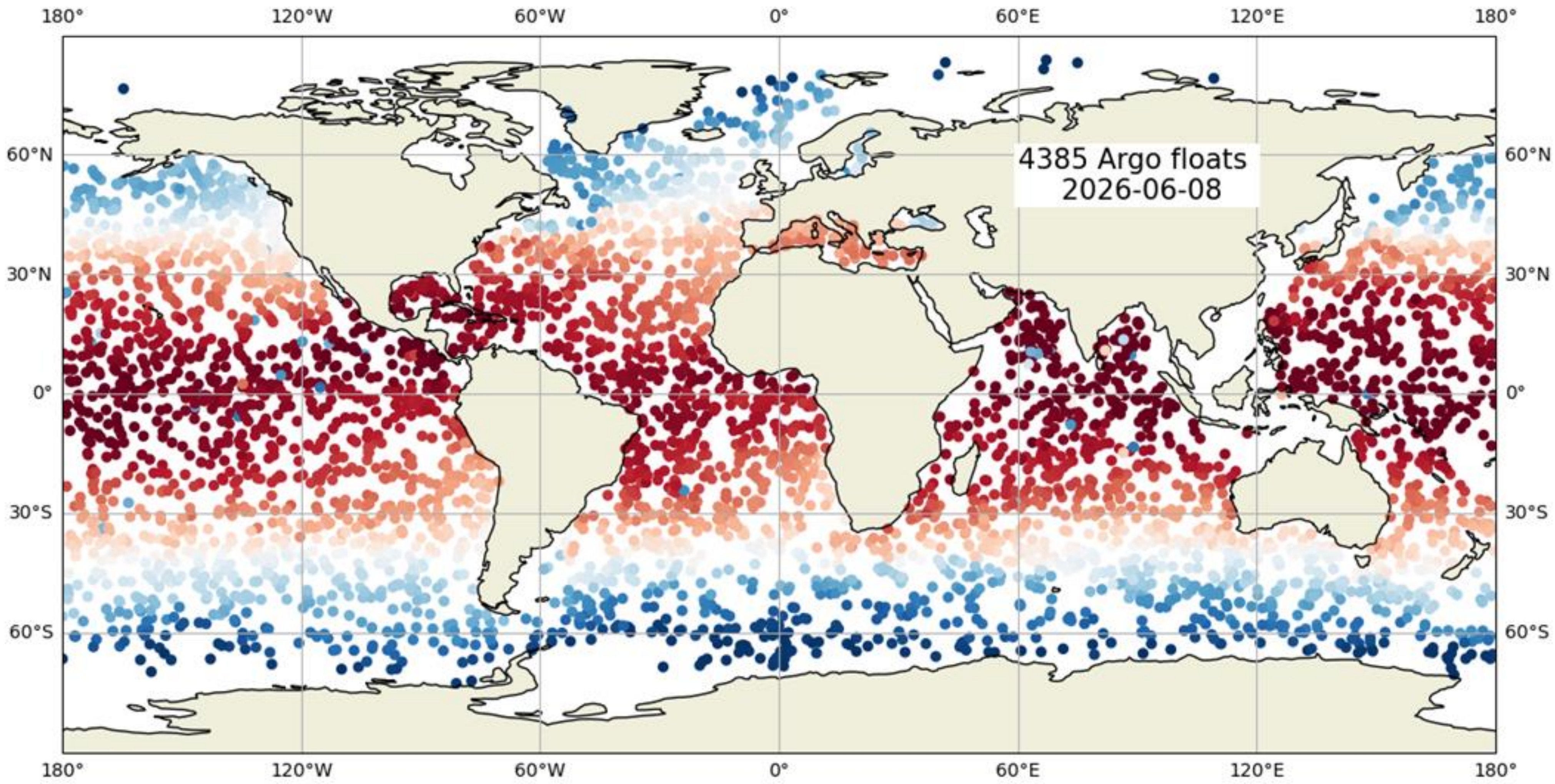
Example of international cooperation

The Birth of Argo

Argo does not replace ship-based CTD work, but it changes the scale of sampling.

A fleet of robotic instruments

that drift with the ocean currents and move up and down between the surface and a mid-water level.



Objectives

Provide a quantitative description of the changing state of the upper ocean and the patterns of ocean climate variability from months to decades, including heat and freshwater storage and transport.

A primary focus of Argo is to document seasonal to decadal climate variability and to aid our understanding of its predictability.

Provide information to initializing ocean and coupled ocean-atmosphere forecast models, for data assimilation and for model testing.

Enhance the value of satellite altimeter data

The Three Pillars of Argo

Global Coverage

Creating a uniform, high-resolution global grid to monitor heat, salt, and *biogeochemistry* across all ocean basins.

Autonomous Action

Deploying profiling floats that function independently of ships or human control for up to five years.

Open Data Policy

Providing global public access to calibrated profiles within 12 hours of telemetry

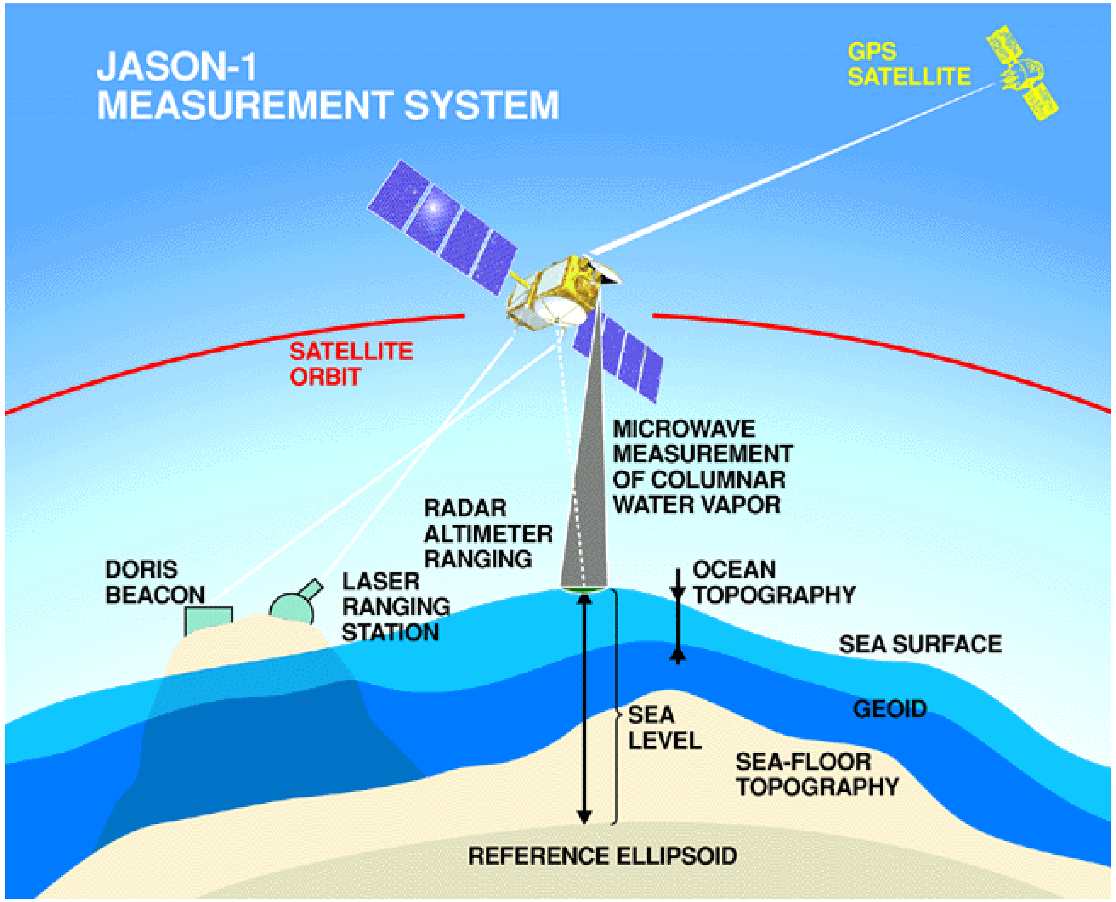
The Argo-Jason Synergy

In Greek mythology, Argo was the ship of Jason and the Argonauts in their quest for the Golden Fleece

The program is named after the mythological Greek ship Argo, sailed by Jason. This reflects its modern relationship with the Jason Satellite Altimeter Missions.

In early **1998 proposal** – "A Proposal for Global Ocean Observations for Climate: the **A**rray for **R**eal-time **G**eostrophic **O**ceanography (ARGO)" by D. Roemmich, ARGO was an acronym . However nowadays is just used in reference to the Greek mythology

The Argo-Jason Synergy



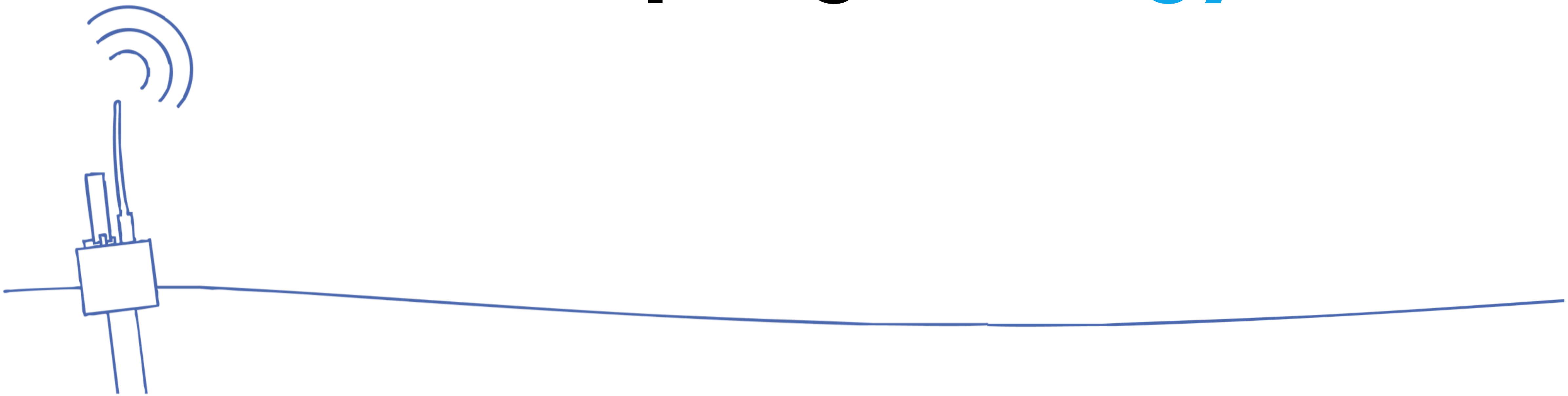
Interpreting Sea Surface Height (SSH): Satellite altimeters measure the total height of the sea surface from space

Height is a combination of density changes due to temperature and salinity (steric change) and changes in mass or pressure (reference pressure variability) Argo provides the vertical profiles of temperature and salinity needed to calculate the steric portion.

Altimeters measure temporal variability in sea level but lack an accurate geoid (a reference of the Earth's gravity field), meaning they cannot measure the temporal mean height Argo floats measure the temporal mean but cannot provide a global spatial average

The combination of Jason's surface observations and Argo’s subsurface data provides a comprehensive framework for data assimilation.

The sampling strategy



The sampling strategy

3°×3°

Nominal Grid Spacing Target

1000 dbar

Parking Depth

10 days

Nominal sampling interval

60° N – 60° S

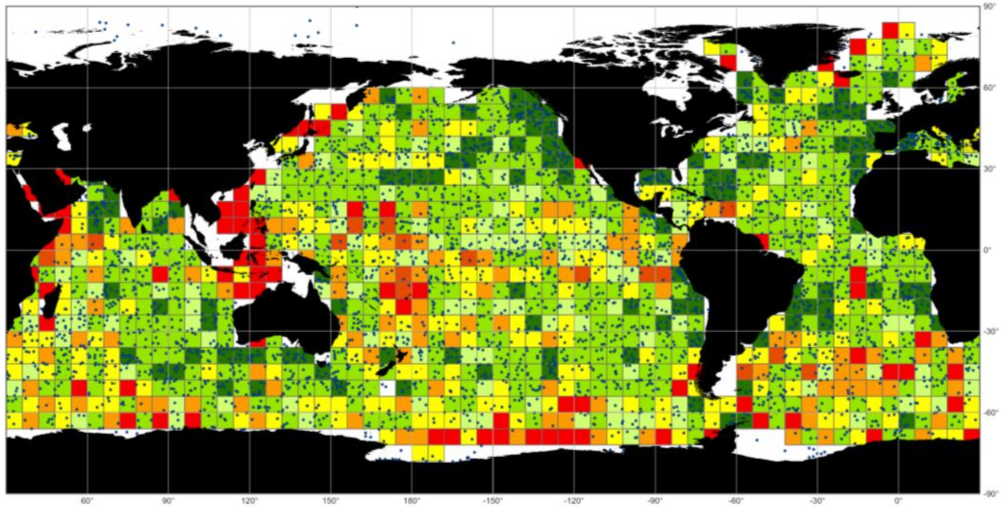
Geographical coverage

These parameters were chosen to balance the scientific need to resolve global climate signals with the practicalities of battery life and global logistical feasibility

The sampling strategy

3°×3°

Nominal Grid Spacing Target



Spectral analysis of data from the TOPEX/POSEIDON satellite altimeter showed that nearly half of the ocean's sea-level variance occurs at wavelengths longer than 1000 km. While a 500 km spacing would have provided a 1:1 **signal-to-analysis** error ratio for these signals, the 250–300 km spacing (the 3° target) improved this ratio by more than a factor of three

Complementarity with Altimetry: The 3° spacing capture approximately 90% of the variance in seasonal heat and freshwater storage, and distinguish between steric (density-driven) and mass-driven sea-level changes

Latitudinal Density Adjustments: By setting the grid in degrees rather than fixed kilometers, the physical density of floats doubles from the equator to 60° latitude. This was appropriate because the scales of ocean motion naturally decrease at higher latitudes

Practical Array Size: At this resolution, the global ocean deeper than 2000 meters could be covered by approximately 3,000 floats.
This number was seen as an ambitious but achievable target for an international partnership

Fleet Spacing Specifications

10 days

Nominal sampling interval

Suppressing Mesoscale Noise: Mesoscale features like eddies and fronts have short decorrelation times of 10–20 days

Synergy with Satellites: A 10-day cycle is consistent with the 10-day repeat cycle of satellite altimeters like Jason, providing a synchronized view of surface and subsurface conditions

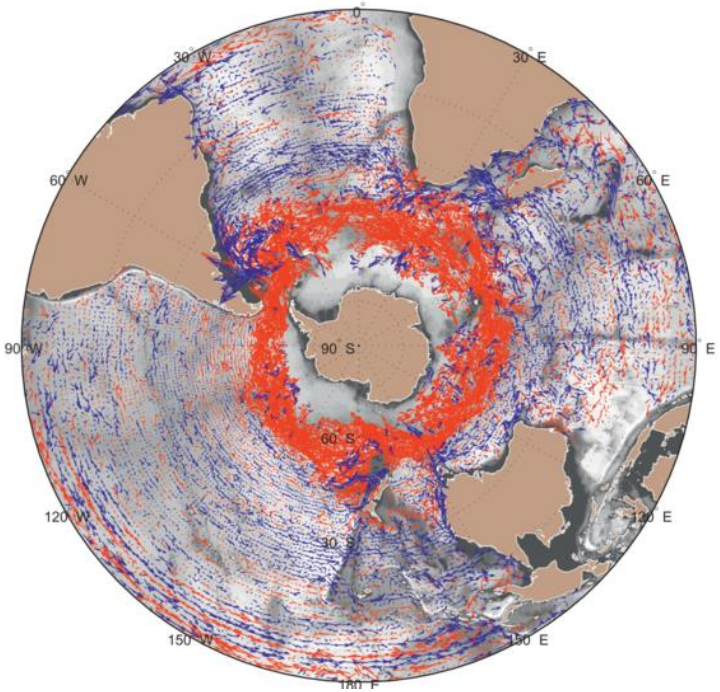
Optimizing Float Lifetime: Sampling frequency is a major driver of energy consumption. A 10-day interval was determined to be the optimal frequency that could satisfy climate monitoring requirements while allowing floats to reach their target lifetime of 4–5 years (roughly 150 cycles) on a single battery pack

Data Latency for Modelers: While climate research focuses on long scales, the 10-day cycle also provides data frequently enough to be useful for operational ocean forecasting and model initialization, provided the data is delivered within 12 hours of surfacing

Fleet Spacing Specifications

1000 dbar

Parking Depth



1000 dbar deep currents from the ANDRO dataset (Ollitrault and Rannou, 2013)

Trade-off between keeping the array in its intended positions and filling gaps in the network:

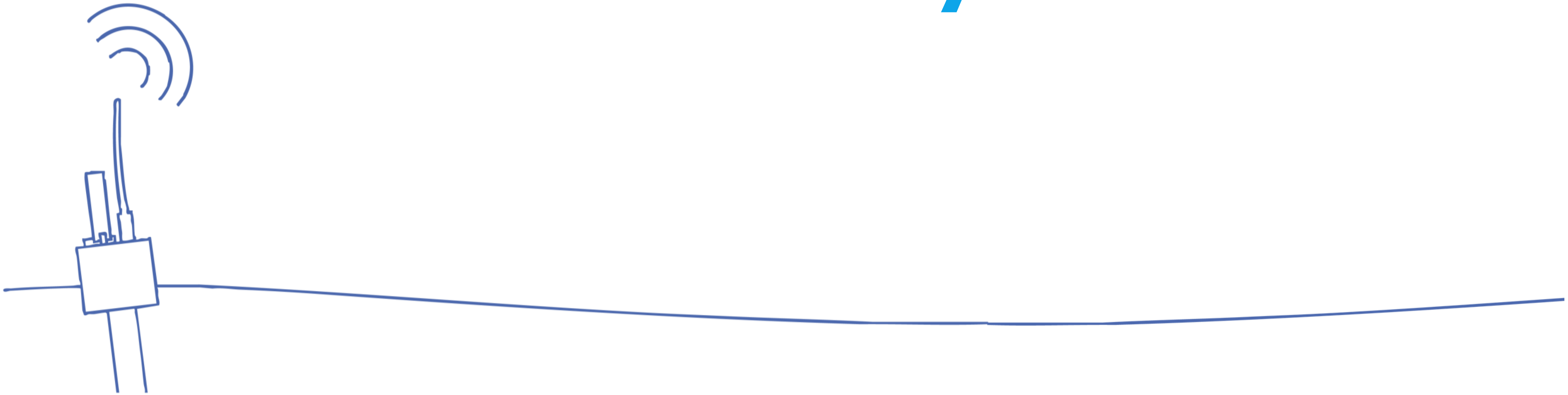
Minimizing Eddy "Noise"
This depth typically has the <u>**smallest eddy-to-mean flow ratio in the ocean.**</u> This consistency allows subsurface displacements to be used as a direct measure of absolute ocean motion.

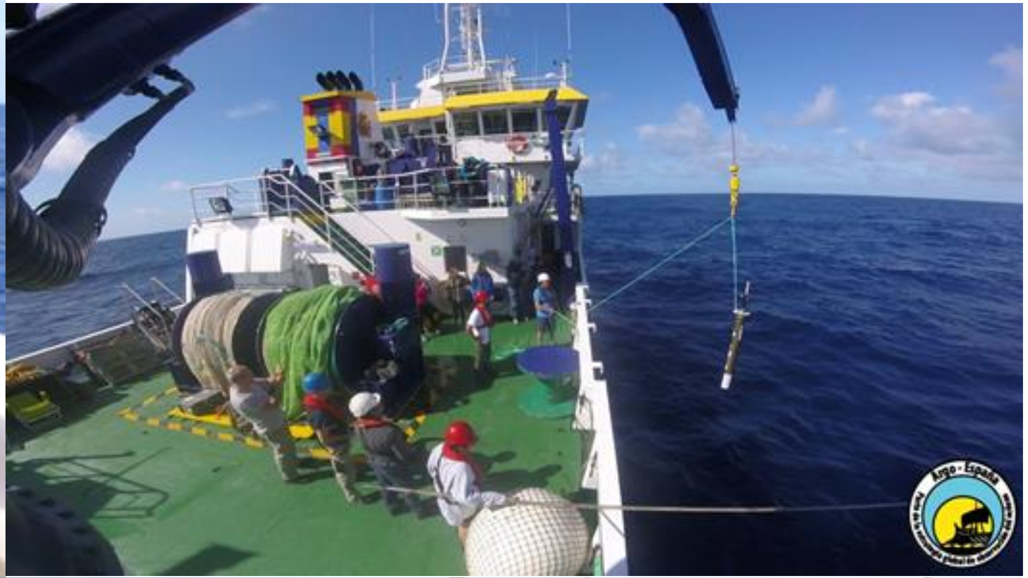
Consistency with Legacy Data (WOCE)
The 1000-dbar standard was established to ensure that Argo's velocity data would be directly comparable to the data collected during the World Ocean Circulation Experiment (WOCE).

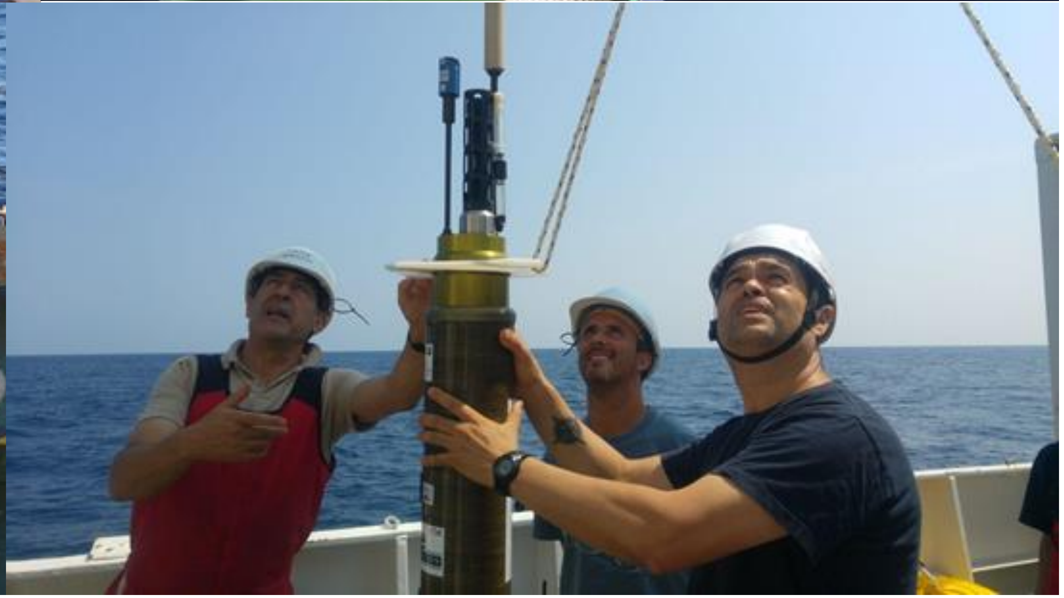
Balancing Dispersion and Stability
<u>Optimal Standard:</u> 1000 dbar was determined to be the ideal compromise, providing a stable water mass for drift while being shallow enough to avoid frequent groundings on continental shelves or ridges
<u>Salinity Stability:</u> Deeper water masses are more stable in their temperature/salinity (T/S) characteristics.
<u>Biofouling:</u> Drifting at depth reduces the risk of biofouling on sensitive sensors, which is significantly higher in the warmer, nutrient-rich waters of the upper thermocline

Avoiding Deeper "Energy Drain"

The float **cycle**





Float Structural Engineering

Key Sub-Assembly Systems

Antenna: Surfaces to transmit data and GPS coordinates and profile data via satellite.

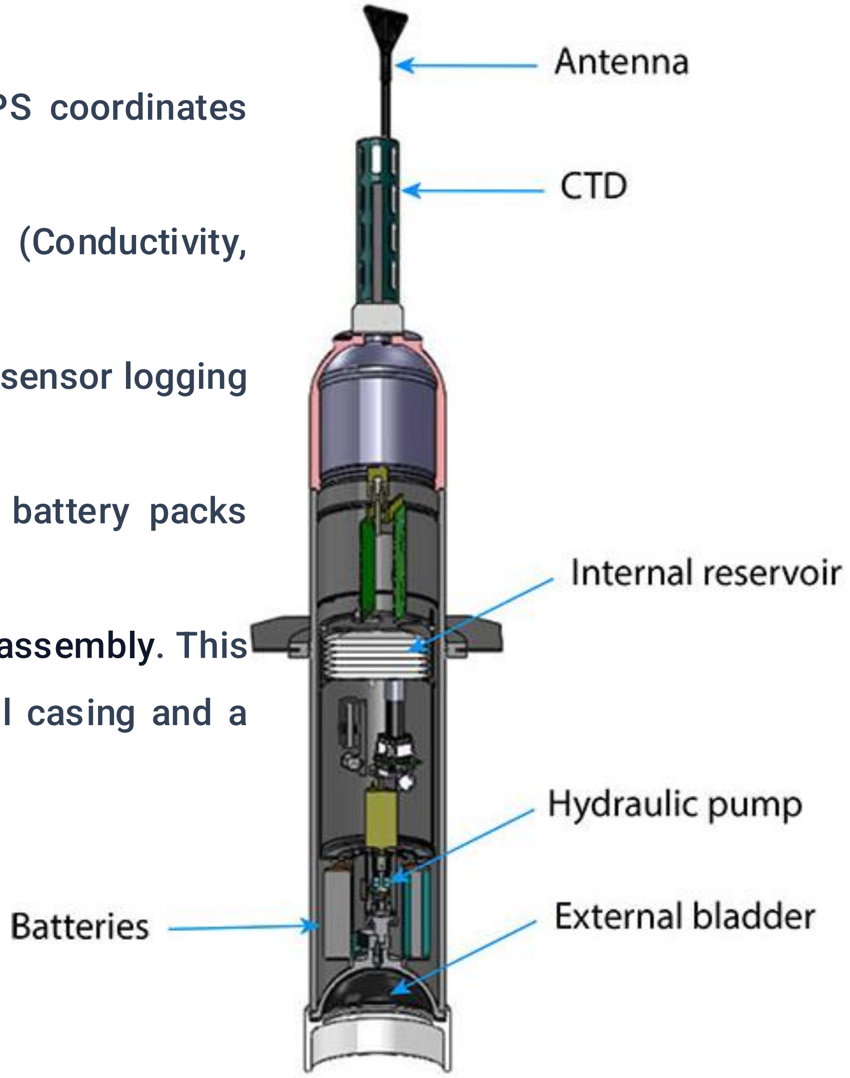
Sensors: High-precision Seabird CTD (Conductivity, Temperature, Pressure) on the upper head.

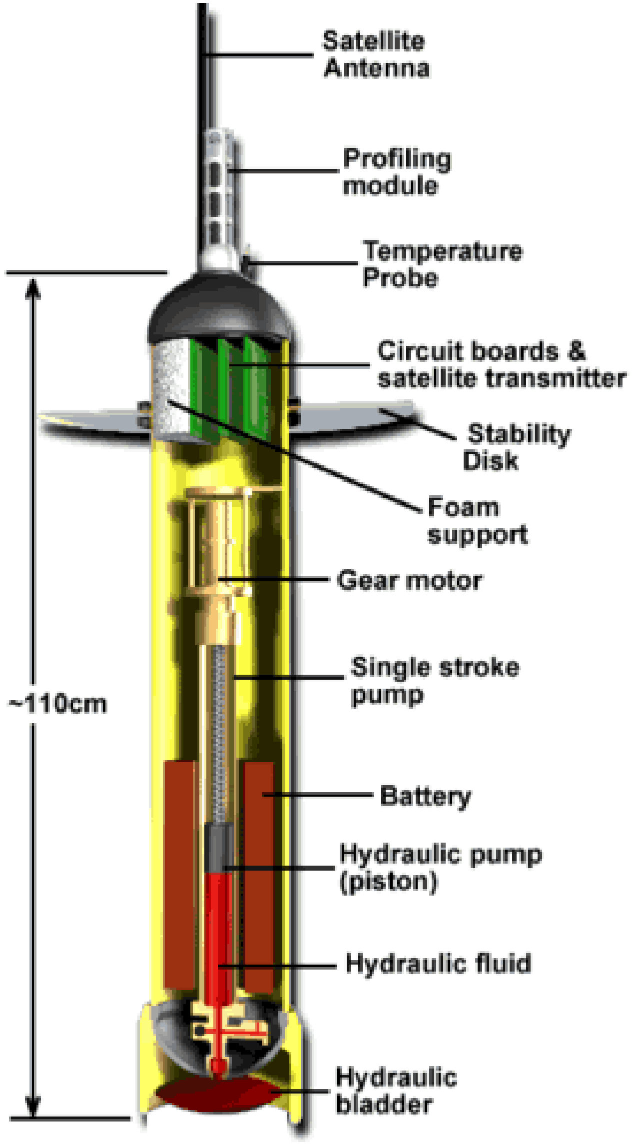
Internal Controller: Manages diving routines, sensor logging frequencies, and telemetry.

Power Supply: High-energy density lithium battery packs powering operations.

The float's core contains the **hydraulic pump assembly**. This pump transfers oil between the rigid internal casing and a flexible external bladder to control buoyancy.

An aluminum hull is typically used. This hull is engineered to compress slightly less than sea water under high pressure, maintaining stability during drift phases.





Mechanics of Buoyancy

±100

Milliliters Volume Shift

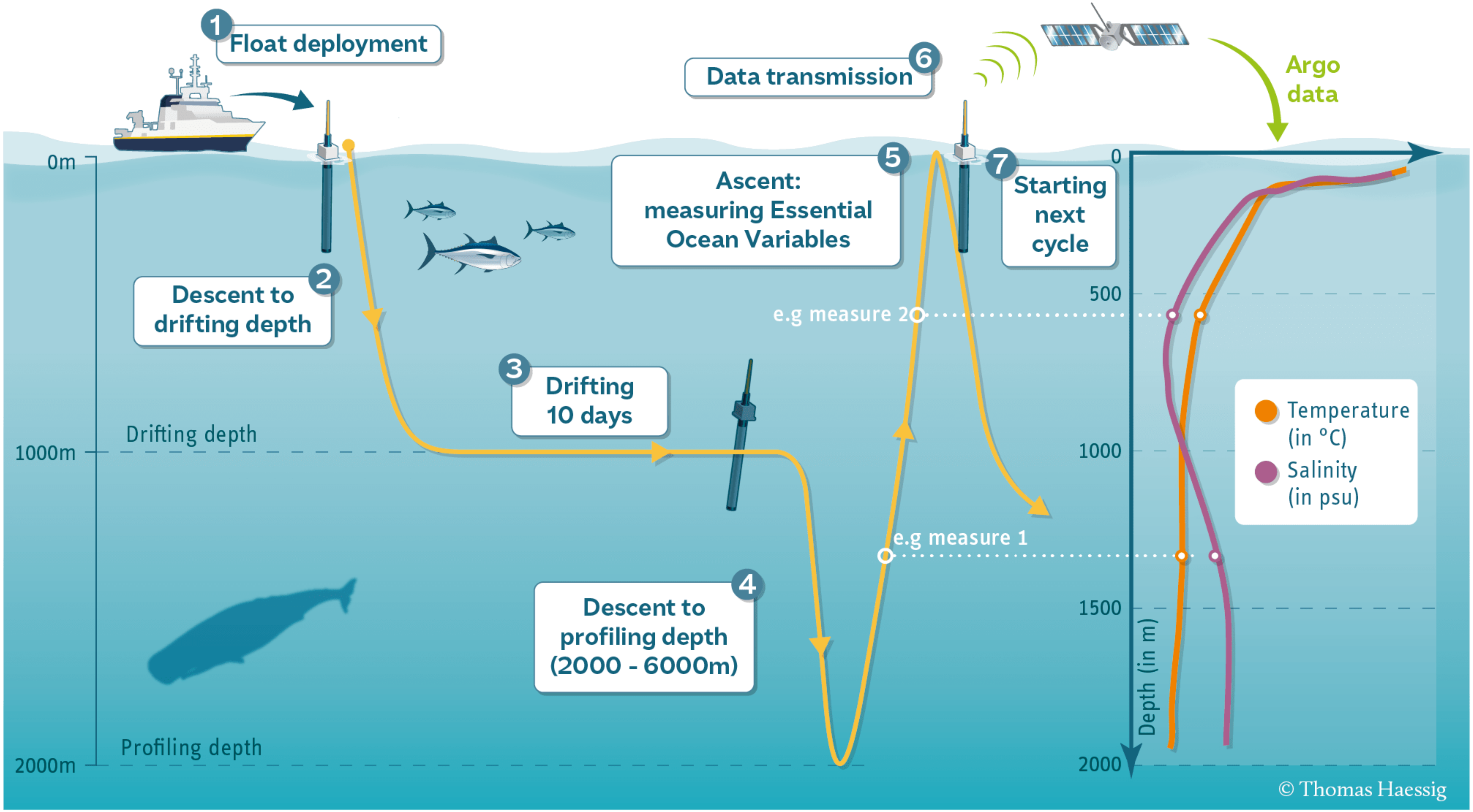
40

Kg displaced

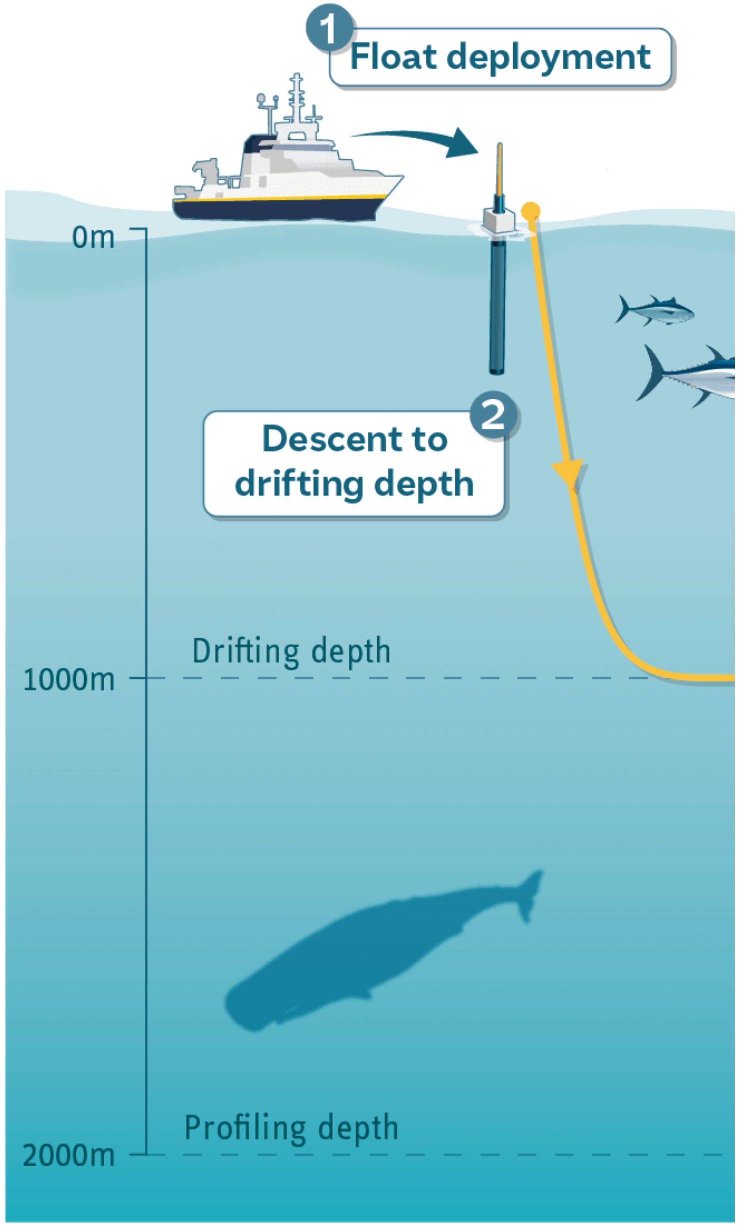
The Archimedes Principle in Action

The buoyancy engine adjusts the float's volume without changing its mass. This changes the float's density relative to surrounding sea water, allowing it to sink or rise.

To sink, the hydraulic pump withdraws oil from the external bladder, reducing the float's volume. To ascend, oil is pumped back into the bladder, expanding its volume and generating positive lift.



1 Float deployment
2 Descent to drifting depth
3 Drifting 10 days
4 Descent to profiling depth (2000 - 6000m)
5 Ascent: measuring Essential Ocean Variables
6 Data transmission
7 Starting next cycle
Argo data
0m
1000m
2000m
Drifting depth
Profiling depth
e.g measure 2
e.g measure 1
0
500
1000
1500
2000
Depth (in m)
Temperature (in °C)
Salinity (in psu)
© Thomas Haessig



Descend

The cycle begins with a controlled descent from the surface to a predetermined parking depth of approximately 1,000 meters.

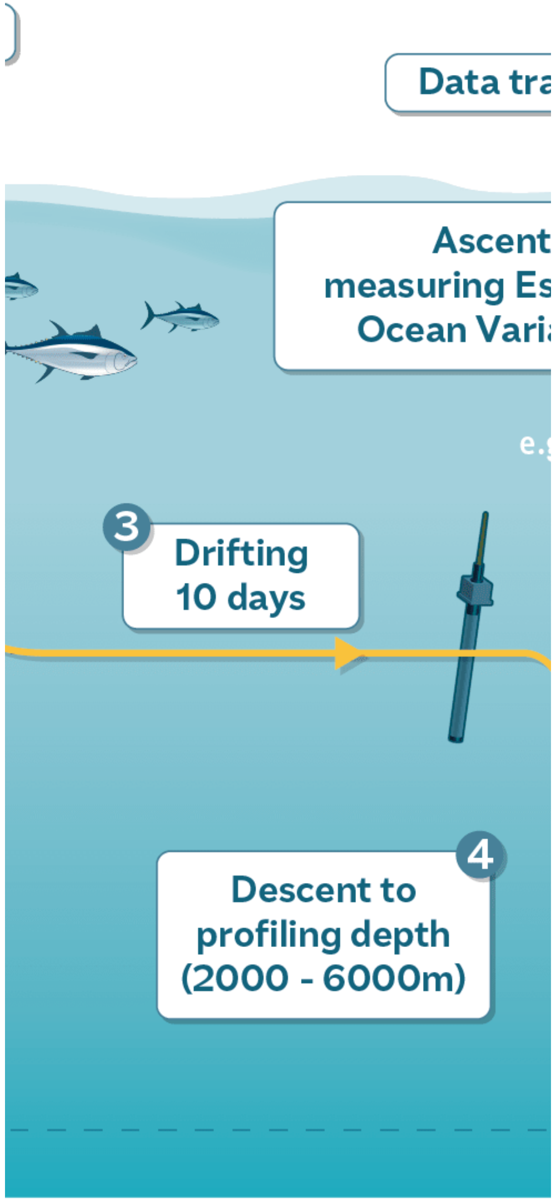
Diving speed: Approximately 2 to 4 centimeters per second. This slow descent rate minimizes power consumption and structural strain.

Passive equilibrium: The float settles at its target depth by matching its density with the surrounding ocean layer. Minimal power draw: Sensors remain off during this descent phase to conserve battery life.

9 Days of Passive Drift

The float drifts passively with deep ocean currents at its parking depth (1,000 meters) for roughly 9 days.

This phase is used to calculate deep velocity currents, which are difficult to measure using traditional satellite methods.



After drifting, the float **descends** briefly to 2,000 meters. It then pumps oil into the external bladder to begin its ascent.

During the **ascent**, the CTD sensors continuously measure conductivity, temperature, and pressure.

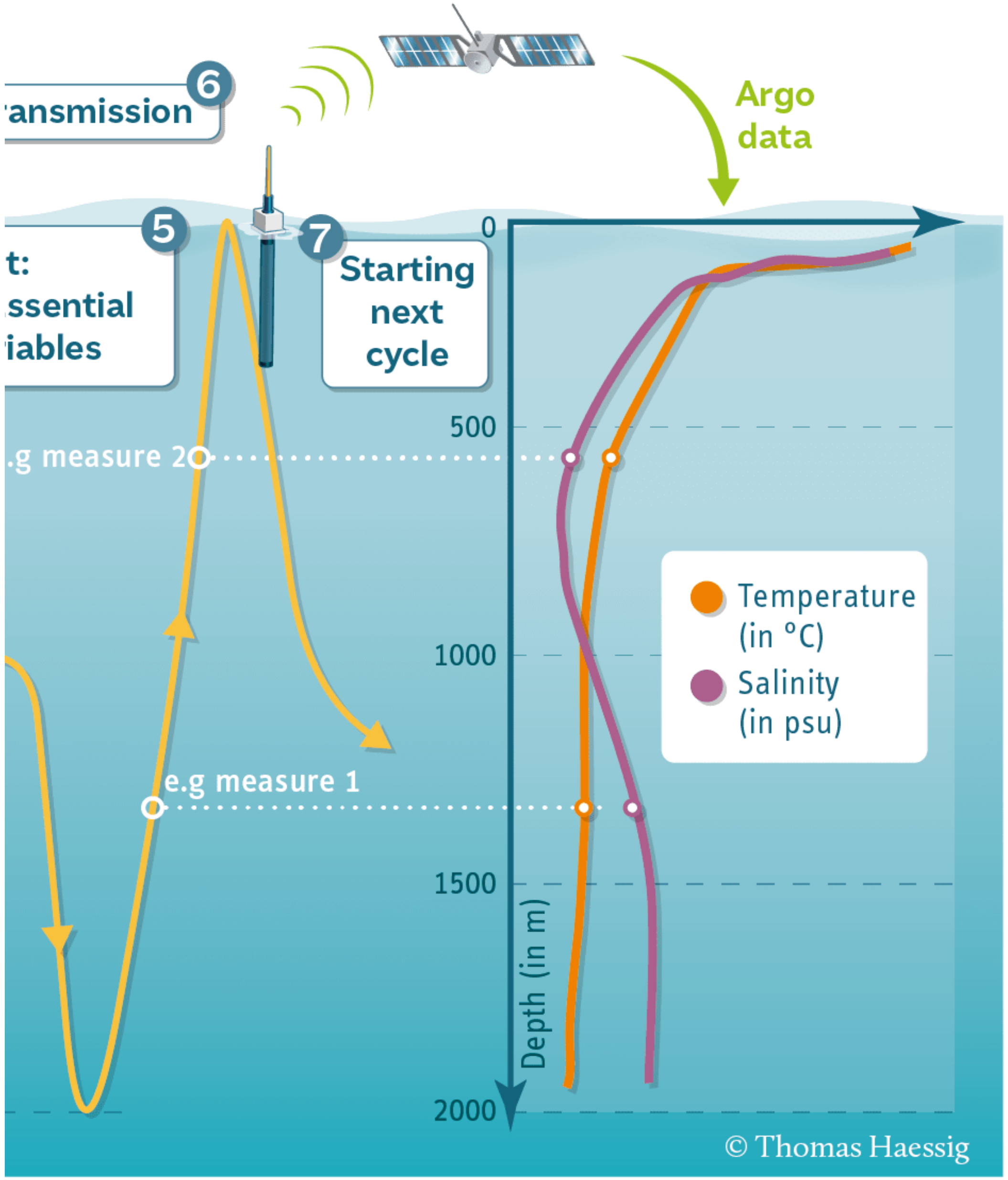
Ascent speeds average 10 cm/s, requiring about 6 hours to profile the entire 2,000-meter water column.

Upon surfacing, the float establishes a **satellite connection** to transmit its position and the recorded profile data.

Iridium Constellation: Modern floats use bidirectional Iridium links. This reduces the time spent on the surface to under 20 minutes.

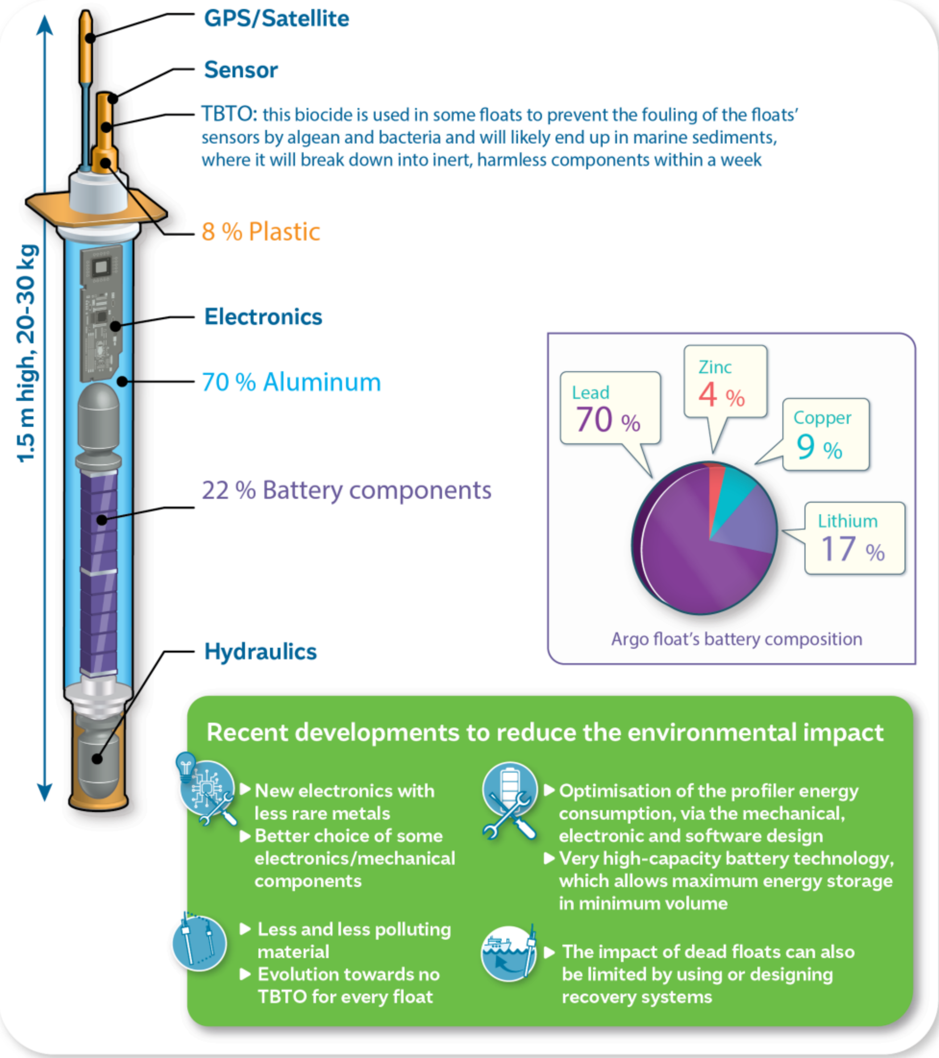
Older ARGOS System: Required up to 12 hours on the surface, increasing the risk of drift, biofouling, and ship collisions.

Bidirectional Communication.



Environmental Footprint

Deploying thousands of autonomous instruments raises valid questions about plastic and heavy metal accumulation on the seabed.



These releases are extremely small compared with natural and human-induced inputs to the ocean.

For example:

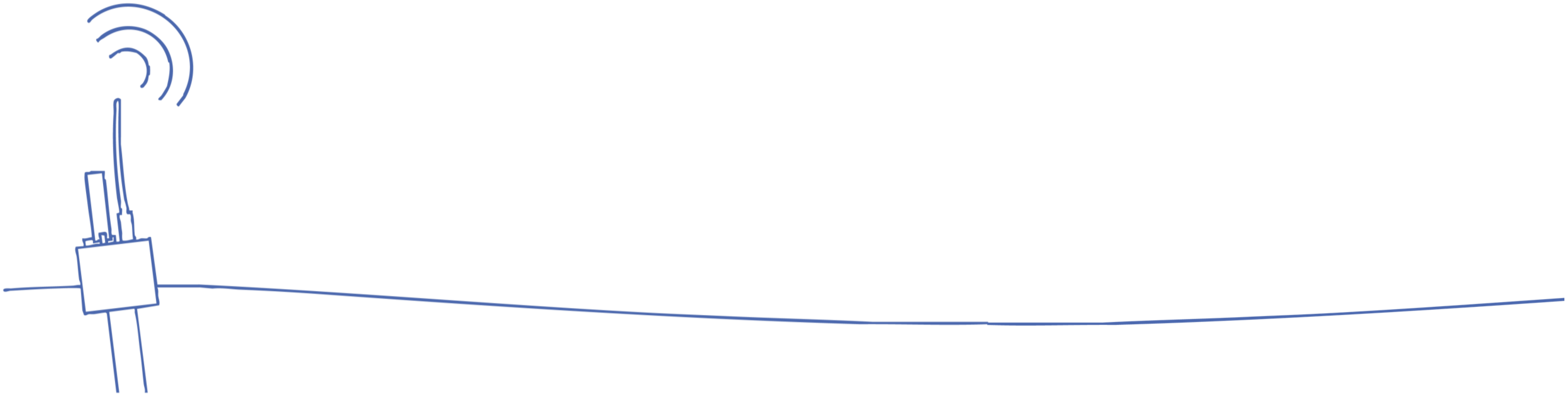
- **176,000 years** of Argo operations would be needed to release as much aluminum as is used annually to manufacture beverage cans.
- One year of global plastic pollution entering the ocean is equivalent to **4.4 million years of Argo operations**.
- One year of natural lead input to the ocean is equivalent to **83 million years of Argo operations.**

The wide spacing between floats (~300 km) and deep-ocean mixing make harmful accumulation of materials highly unlikely.

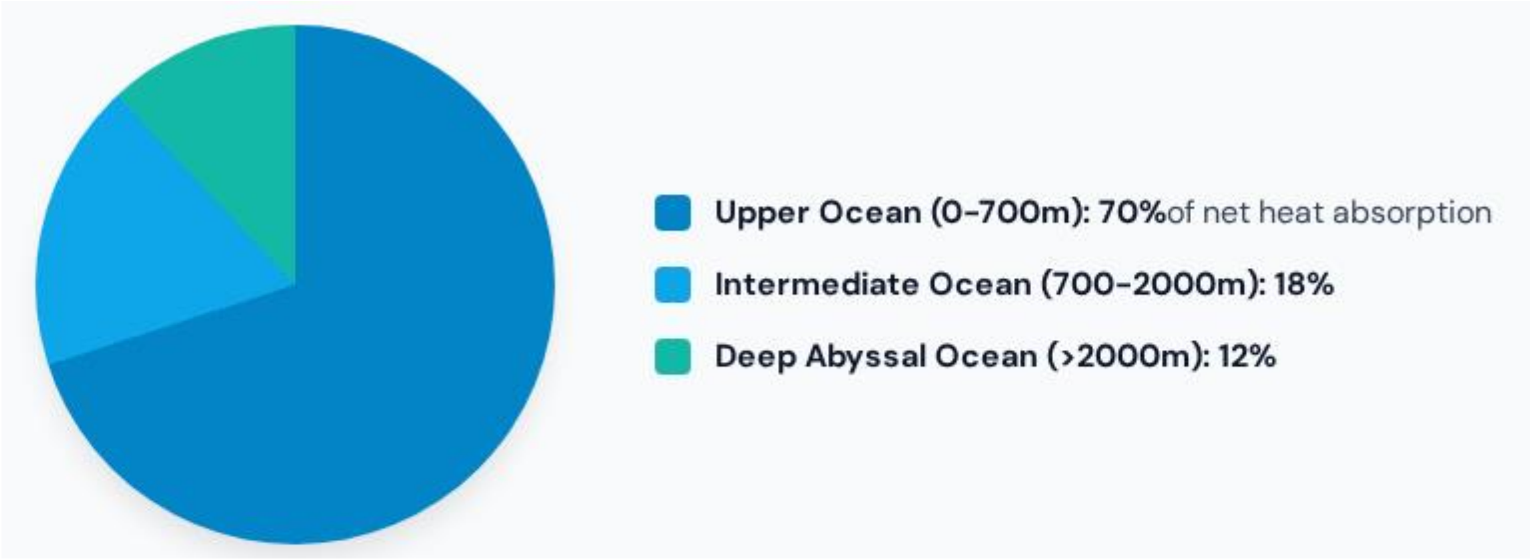
Compared with alternative ocean observing methods, Argo provides the lowest environmental footprint for global subsurface ocean observations.

Key message: The environmental impact of Argo is negligible relative to natural and anthropogenic ocean inputs, while its scientific and societal benefits are substantial.

Expansion: One Argo



Global Ocean Heating Distribution



Deep Argo floats are designed to monitor the remaining 12% of oceanic heat storage. These measurements are essential for closing Earth's planetary energy budget.

Ecosystem questions

Acidification

Direct pH measurements track the impacts of carbon absorption on calcifying marine organisms in real time.

Deoxygenation

Oxygen profiling maps oxygen minimum zones (OMZs), helping predict stress on pelagic ecosystems.

Carbon Pump

Optical sensors track organic carbon export, improving models of the biological pump's role in carbon sequestration.

Geographical extension

- Above 60ºN & 60ºS
- Marginal & closed seas
- Double-density in the intertropical belt and on western boundaries (currents)

Deep Argo mission

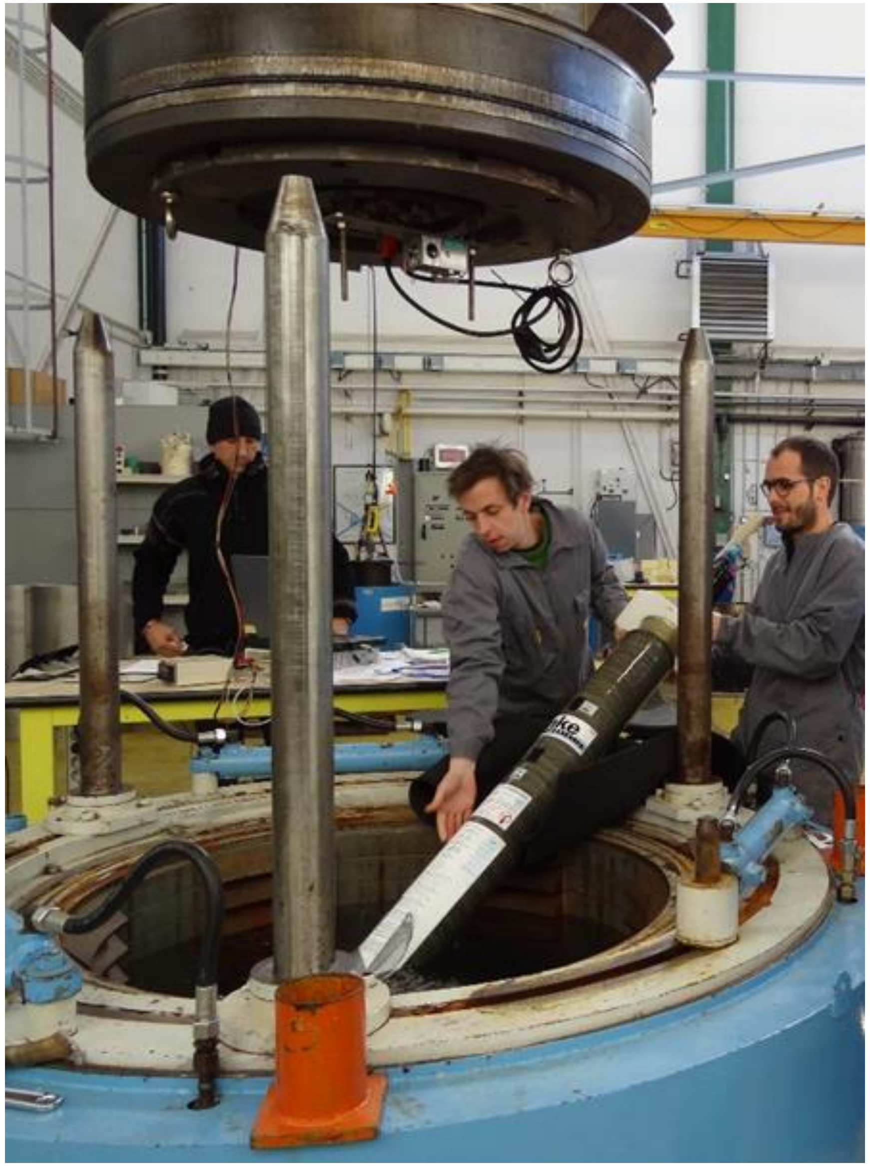
50%

The median depth of the ocean is 4000 m

4000 m (90% of the oceans)
6000 m

One of the challenges facing Deep Argo is that the CTD sensor used on standard Argo floats was not designed to go below 2000 m depth.

SeaBird has been working to develop a new CTD sensor that will be accurate down to 6000 m. This new CTD, named the SBE-61, has not yet achieved its aspirational goals of (**± .001C, ±.002 psu, and ± 3 dbar**)



BGC Mission

Major research and management topics and sensors applicable to topics. ✔ indicates direct relevance and ● indicates indirect relevance through a calibration function.

Research and management topic	O_2	NO_3	pH	Chl*a*	Suspended particles	Downwelling irradiance
Carbon cycle						
Anthropogenic carbon uptake by the ocean	●	●	✔			
Variability in the biological pump	✔	✔	✔	✔	✔	✔
Variability in NCP	✔	✔	✔	✔	✔	✔
Mesopelagic respiration	✔		✔	✔	✔	
Particulate export				✔	✔	
Ocean deoxygenation / denitrification	✔	✔	●	✔	✔	
Ocean acidification variability	●		●	✔	✔	
Effects of changing carbonate saturation state	●	●	✔		●	
Marine resource management	✔	✔	✔	✔	✔	✔
Reducing error in ocean carbon budget	●	●	✔		●	
Ocean Color validation				✔	✔	✔

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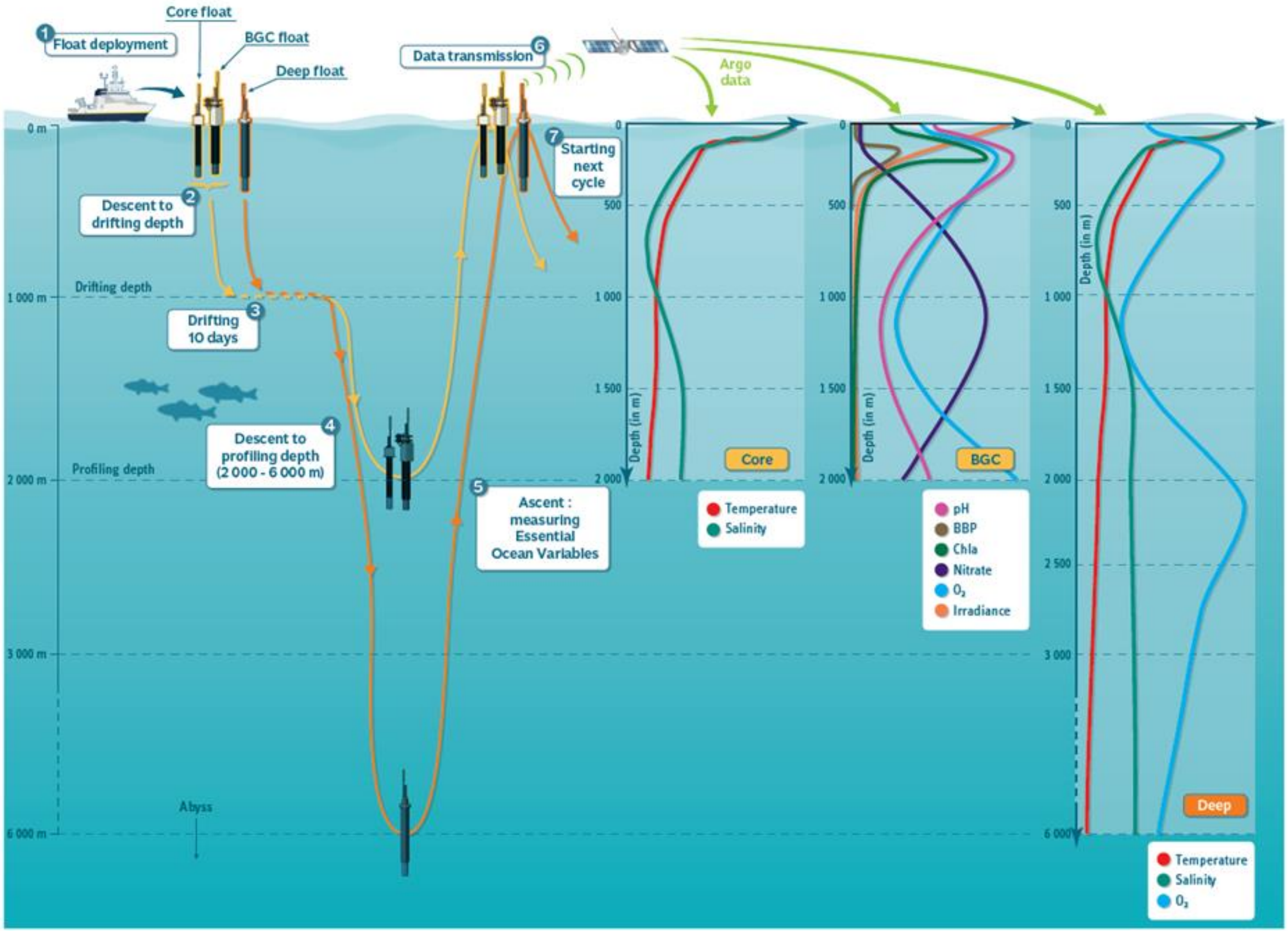
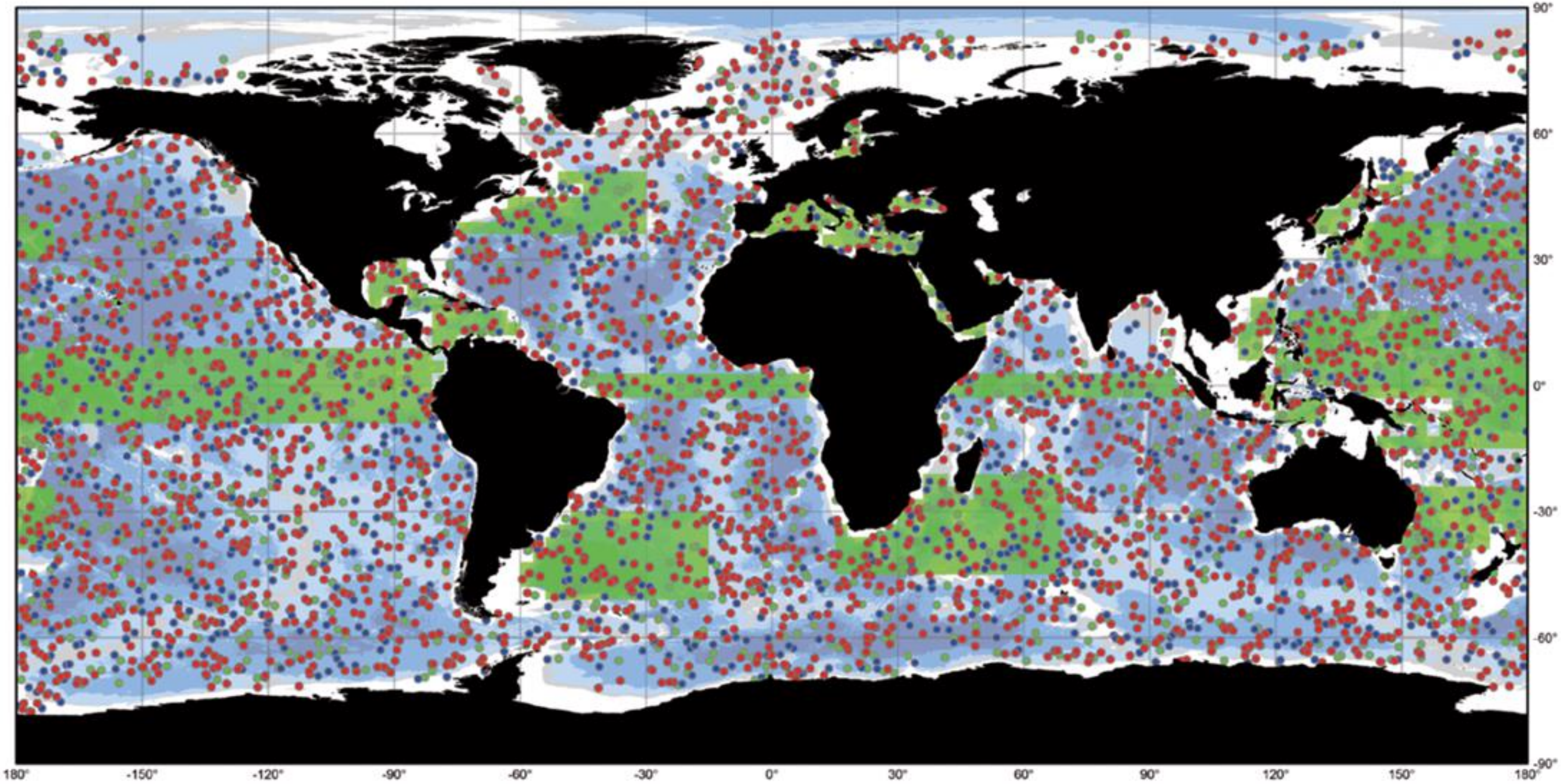


Float deployment
Core float
BGC float
Deep float
Data transmission
Argo data
0 m
Descent to drifting depth
Drifting depth
1 000 m
Drifting 10 days
Profiling depth
2 000 m
Descent to profiling depth (2 000 - 6 000 m)
Ascent : measuring Essential Ocean Variables
Starting next cycle
3 000 m
Abyss
6 000 m
Depth (in m)
Core
Temperature
Salinity
BGC
pH
BBP
Chla
Nitrate
O_2
Irradiance
Deep
Temperature
Salinity
O_2

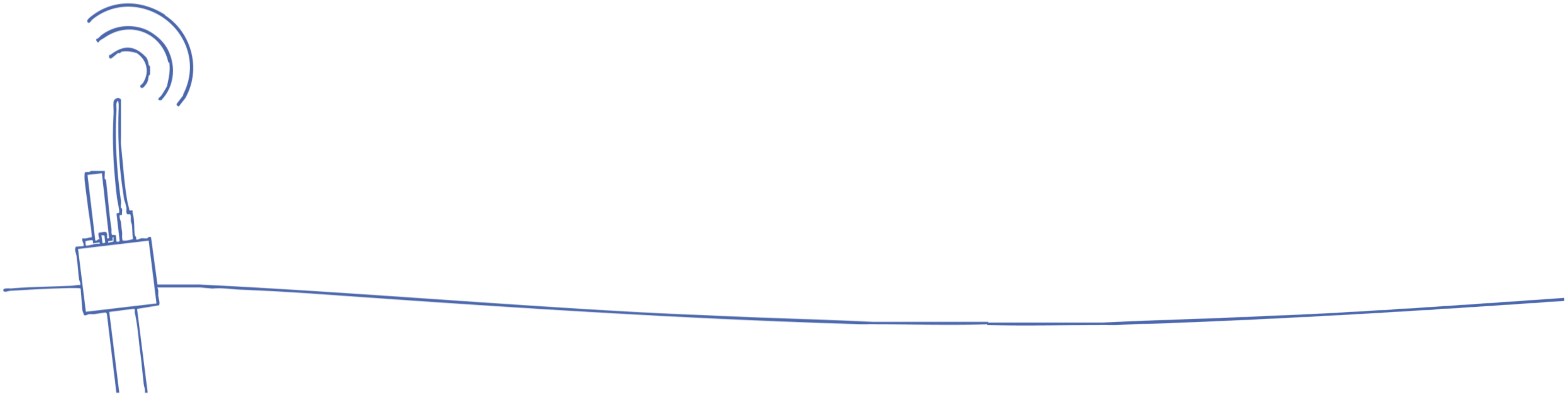
Expansion: One Argo 4700 floats



Double density

- Core 2500
- Deep 1200
- BGC 1000

Governance

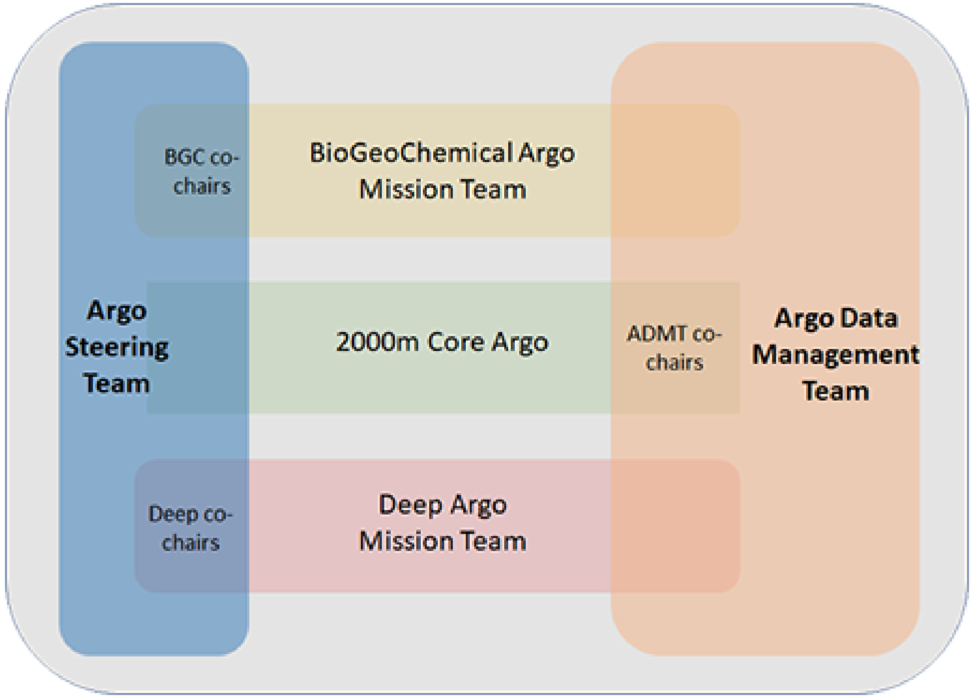


Governance

The program, including the three missions, are overseen by an **International Argo Steering Team** and a **Data Management Team** that are comprised of representatives of float-providing countries.

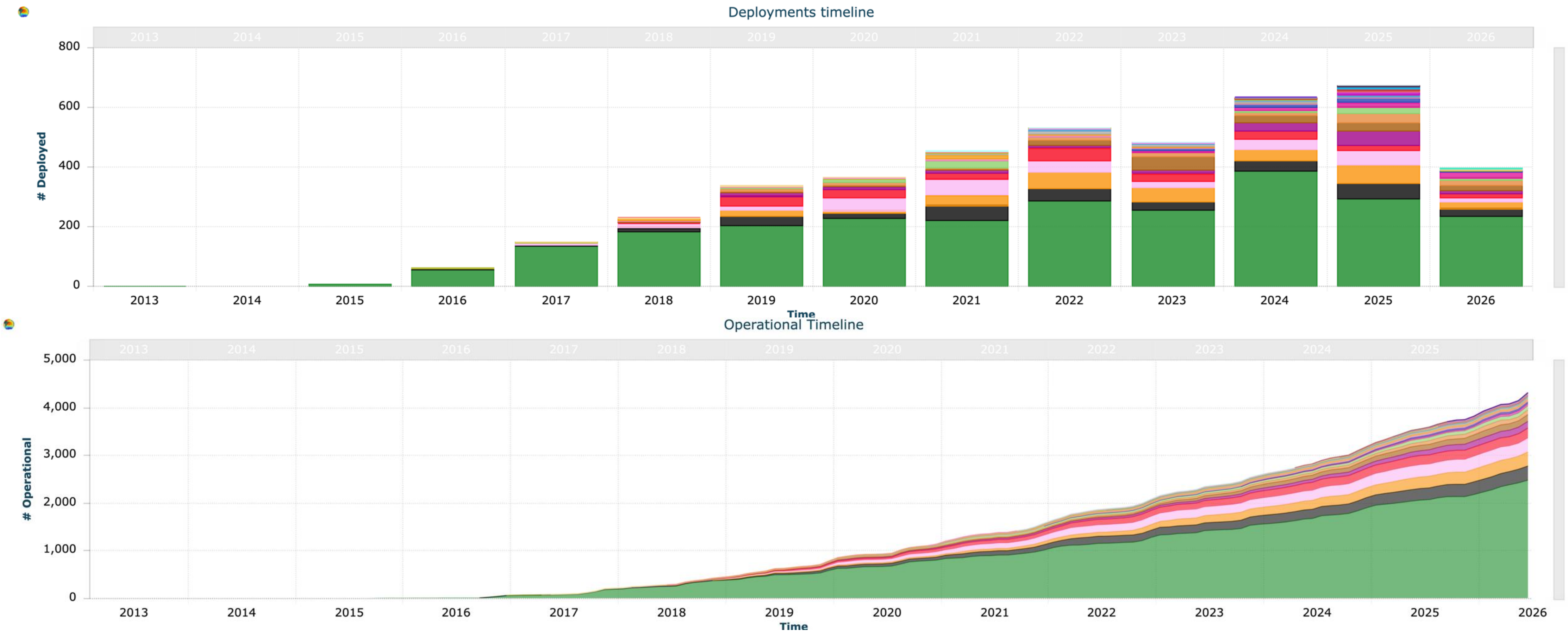
There is a framework for countries that would like to join the Argo Program.

The array's growth is monitored by the **Technical Coordinator** at OceanOPS (COI/UNESCO). OceanOPS is responsible for monitoring and coordinating system for operational ocean observations.



OceanOPS

Argo Profile Growth (2000–2026)

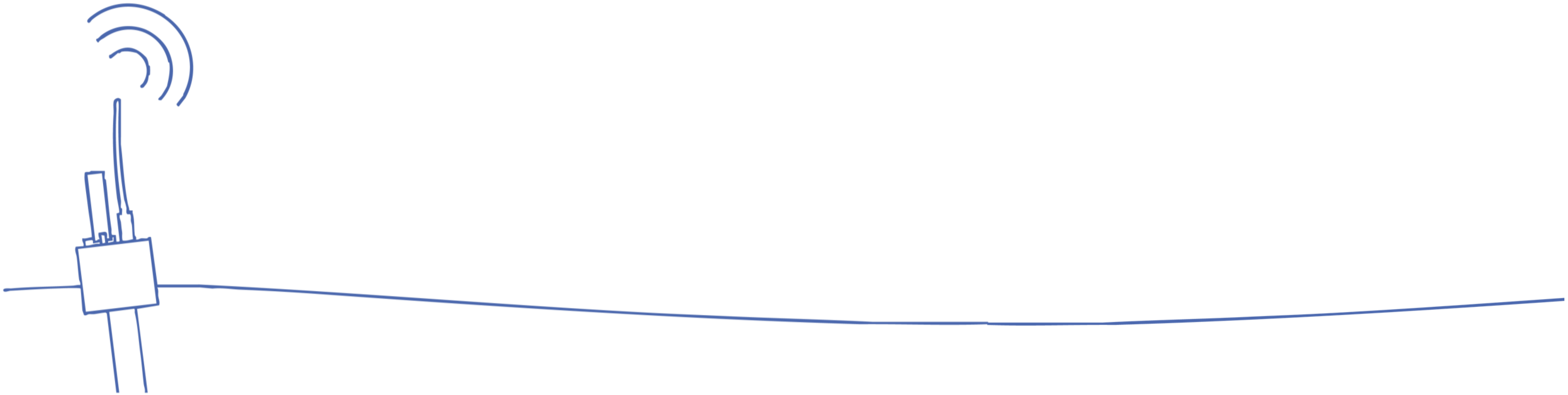


Cumulative profiles gathered by the global fleet. This continuous observation stream has transformed deep-sea climatology and thermodynamic models.

Part II: The Argo data

- Data flow
- Quality control

Data **flow**

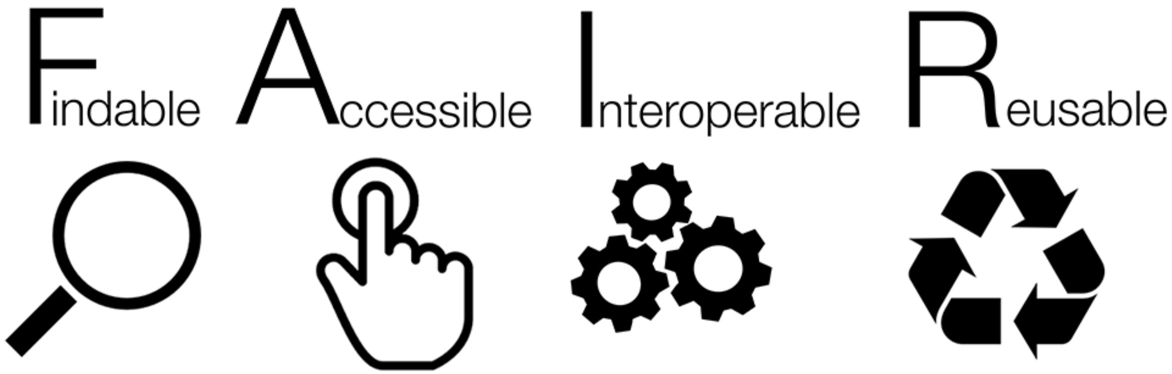


Argo Open Data Principles

The Argo program established a pioneering open data policy in global oceanography, which is now a standard for international science cooperation.

- **No Embargoes:** All profile measurements are made publicly available without delay, bypassing traditional proprietary periods.
- **Global Equality:** Students, researchers, and public weather models access the exact same dataset at the same time. **No registration**
- **Standardized Formats:** Data is structured in standardized NetCDF files to ensure cross-platform compatibility.

netCDF



... Since 1999

Argo data complies with the FAIR data principles: Findable, Accessible, Interoperable, and Reusable.

These standards ensure the dataset remains compatible with modern cloud computing pipelines and machine learning algorithms.

Unique identifier

WMO

World Meteorological Organization ID

Each one of the Argo floats has a unique identifier, known as the World Meteorological Organization float identifier, or just the WMO. The WMO identifier is assigned at the moment of the deployment of the float, but it is not hard-coded in the float.

The Argo Data system

Argo Information Centre at OceanOPS

Registration of floats (*IOC resolution XX-6*)

Array monitoring

1	2	3	4	5
Uplink	**DAC Processing**	**Real Time QC**	**GDAC**	**Delayed Mode QC**
Surfaced float transmits raw hex codes via satellites to the DACs	Data Assembly Centers convert hex signals into physical values.	Automated algorithms flag obvious anomalies in under 12 hours.	Profiles are synced to public repositories for global access.	Elaborated calibration

11 DACs

Data Assembly Centers

2 Global DACSs

Synchronized

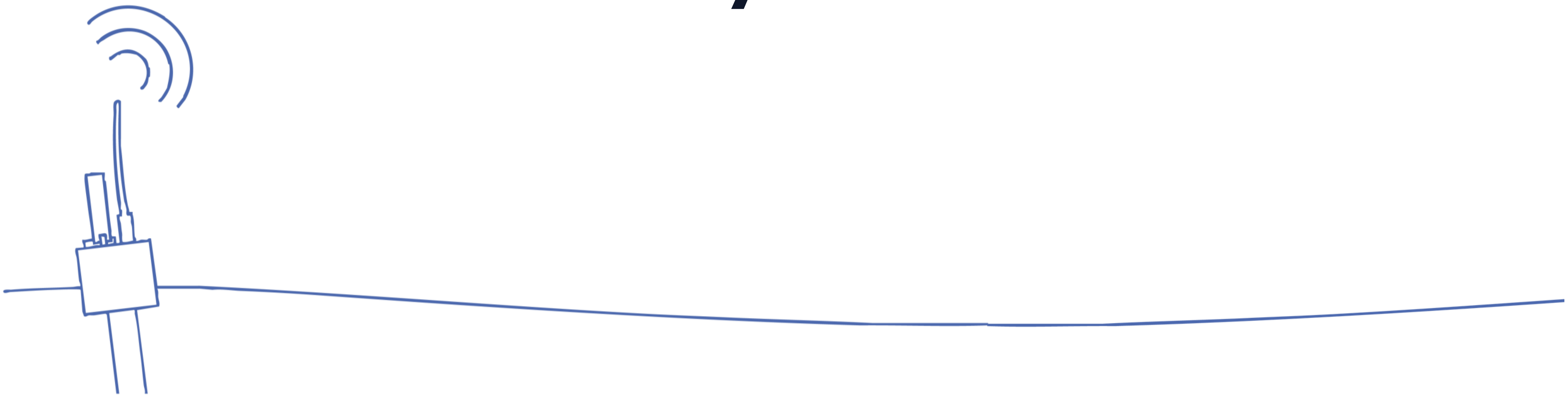
Argo Data Management Team (ADMT)

International team

Common format and procedures for Quality Control

DACs & GDACs representatives, DMQC operators, scientists/PIs, etc.

Quality control

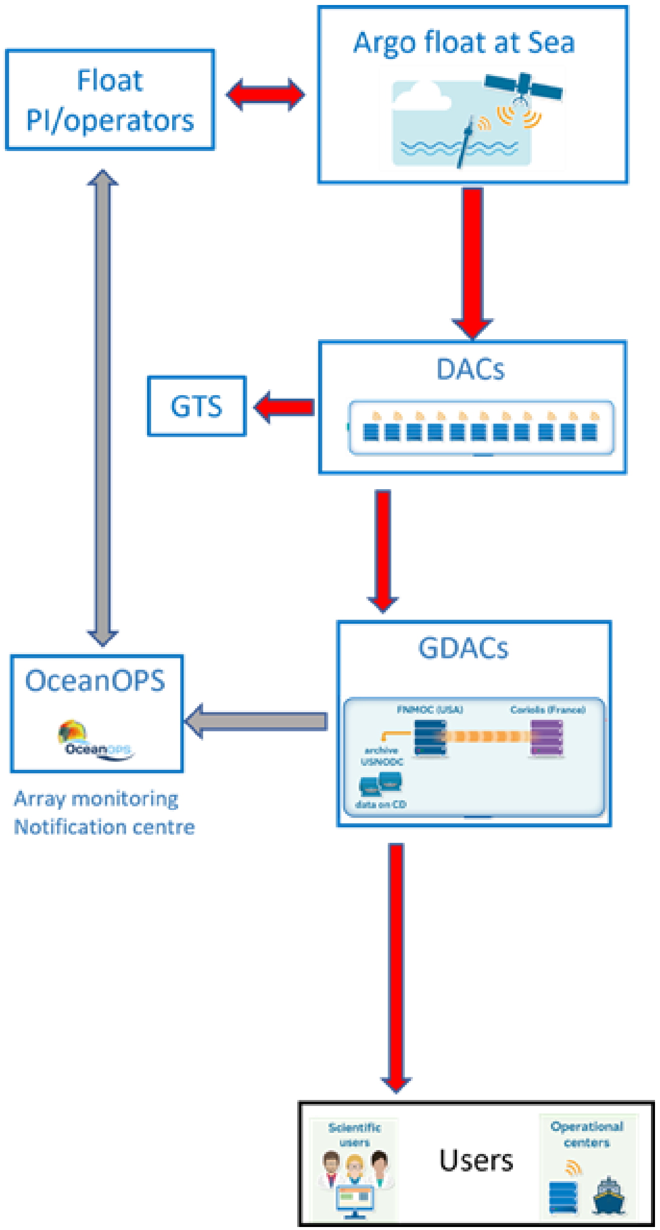


Quality control

Real Time (‘R’ mode)

- 12 hours max
- Automatic Quality Control tests
- Operational applications

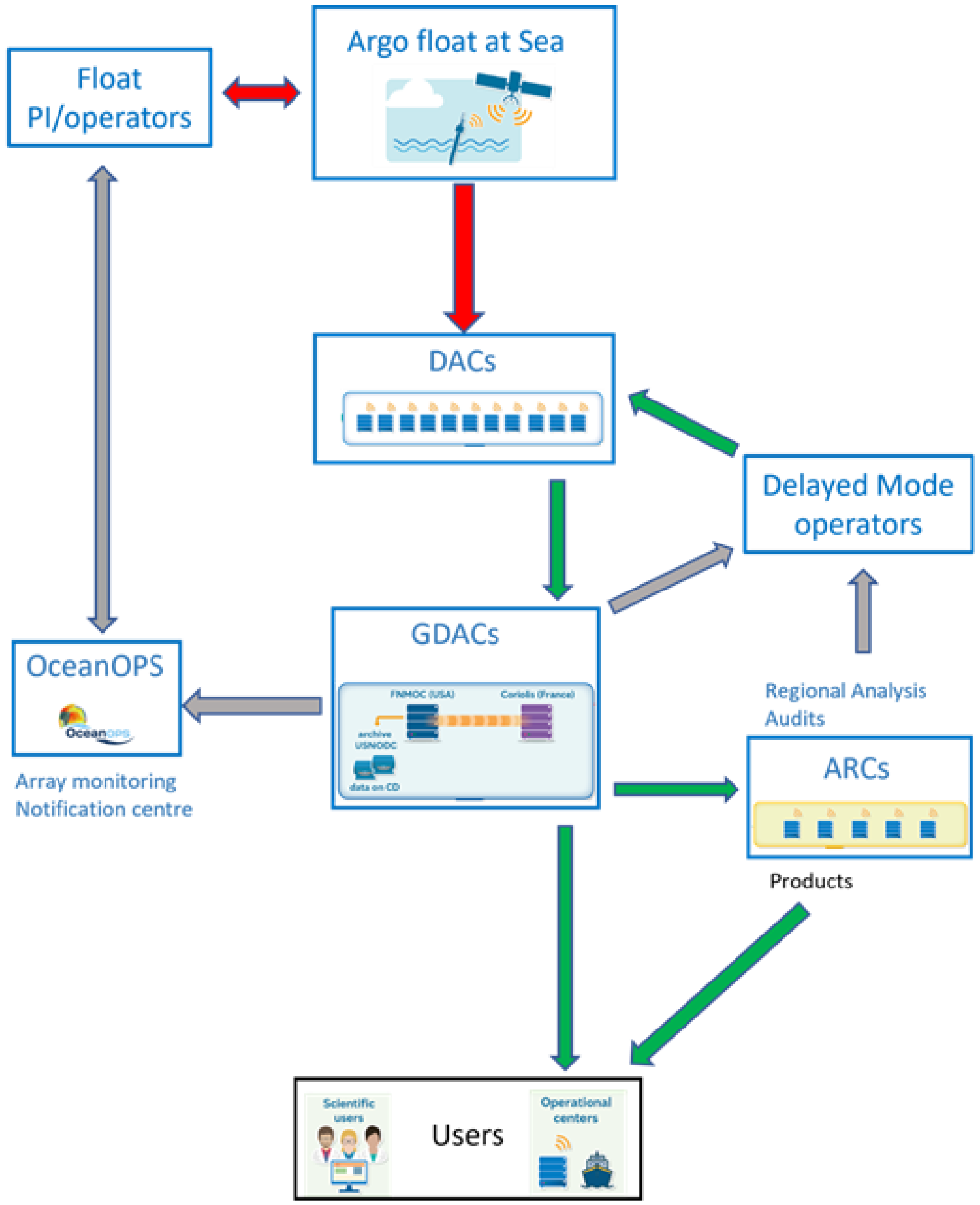
APPLICATION ORDER	TEST NUMBER (n)	TEST NAME
1	1	Platform Identification Test
2	2	Impossible Date Test
3	3	Impossible Location Test
4	4	Position on Land Test
5	5	Impossible Speed Test
6	15	Grey List Test
7	19	Deepest Pressure Test
8	6	Global Range Test
9	7	Regional Range Test
10	8	Pressure Increasing Test
11	9	Spike Test
12	25	MEDD Test
13	12	Digit Rollover Test
14	13	Stuck Value Test
15	14	Density Inversion Test
16	16	Gross Salinity or Temperature Sensor Drift Test
17	18	Frozen Profile Test
18	17	Visual QC Test



Quality control

Delayed Mode ('D' mode)

- Within 12 months
- Performed over the float profiles' time series
- Detailed time series analyses and corrections
- Suitable for Ocean & climate science applications



Calibrating Salinity Drift

OWC

Climatological Calibration Method

"*An improved calibration method for the drift of the conductivity sensor on autonomous CTD profiling floats by θ-S climatology*", by W.B. **Owens** and A.P.S. **Wong**, in Deep-Sea Research Part I: Oceanographic Research Papers, 56(3), 450-457, 2009.

“*Improvement of bias detection in Argo float conductivity sensors and its application in the North Atlantic*” , by C. **Cabanes**, V. Thierry and C. Lagadec, in Deep-Sea Research Part I, 114, 128-136, 2016.

Adjusting Conductivity Values

Conductivity cell drift, caused by structural changes under pressure, introduces a systematic salinity bias. The OWC method corrects this by comparing other profiles values against stable climatological baselines.

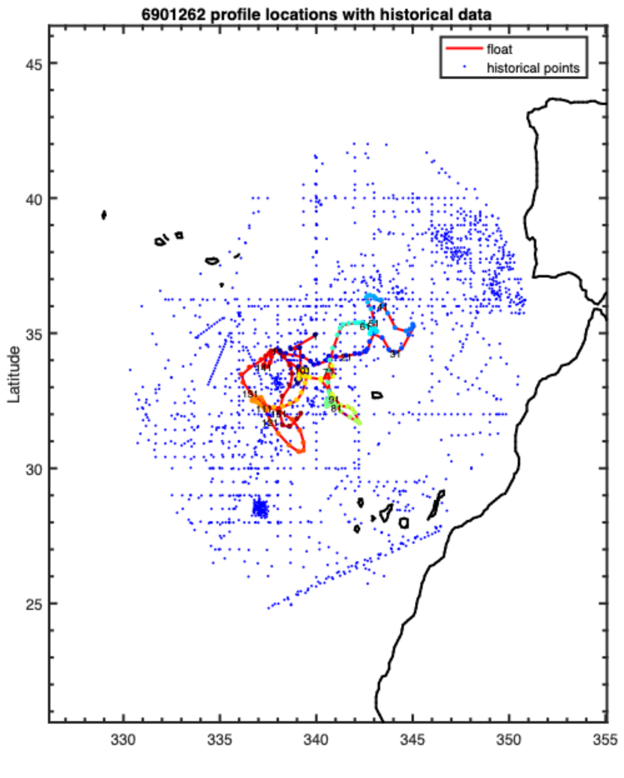
$$C_{cal}(t) = r(t) \cdot C_{measured}(t)$$

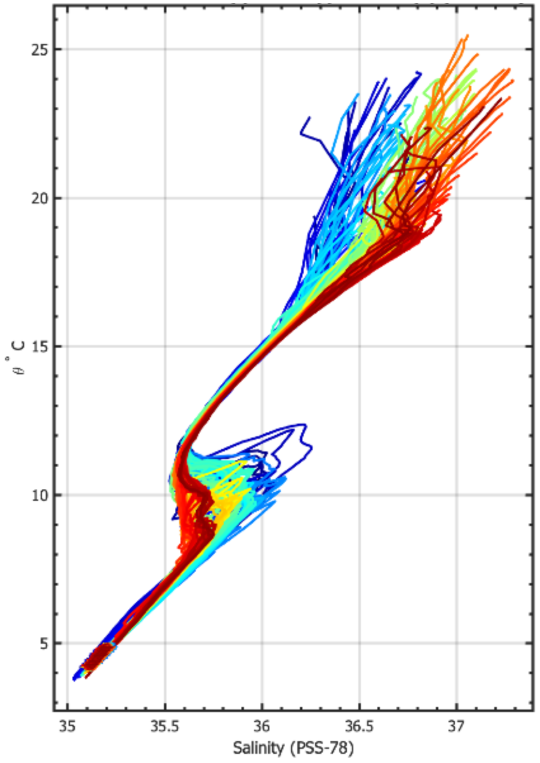
An adjustment factor, r(t) , is calculated using ocean layers where natural variability is minimal. This factor is applied to calibrate conductivity values before calculating final salinity profiles.

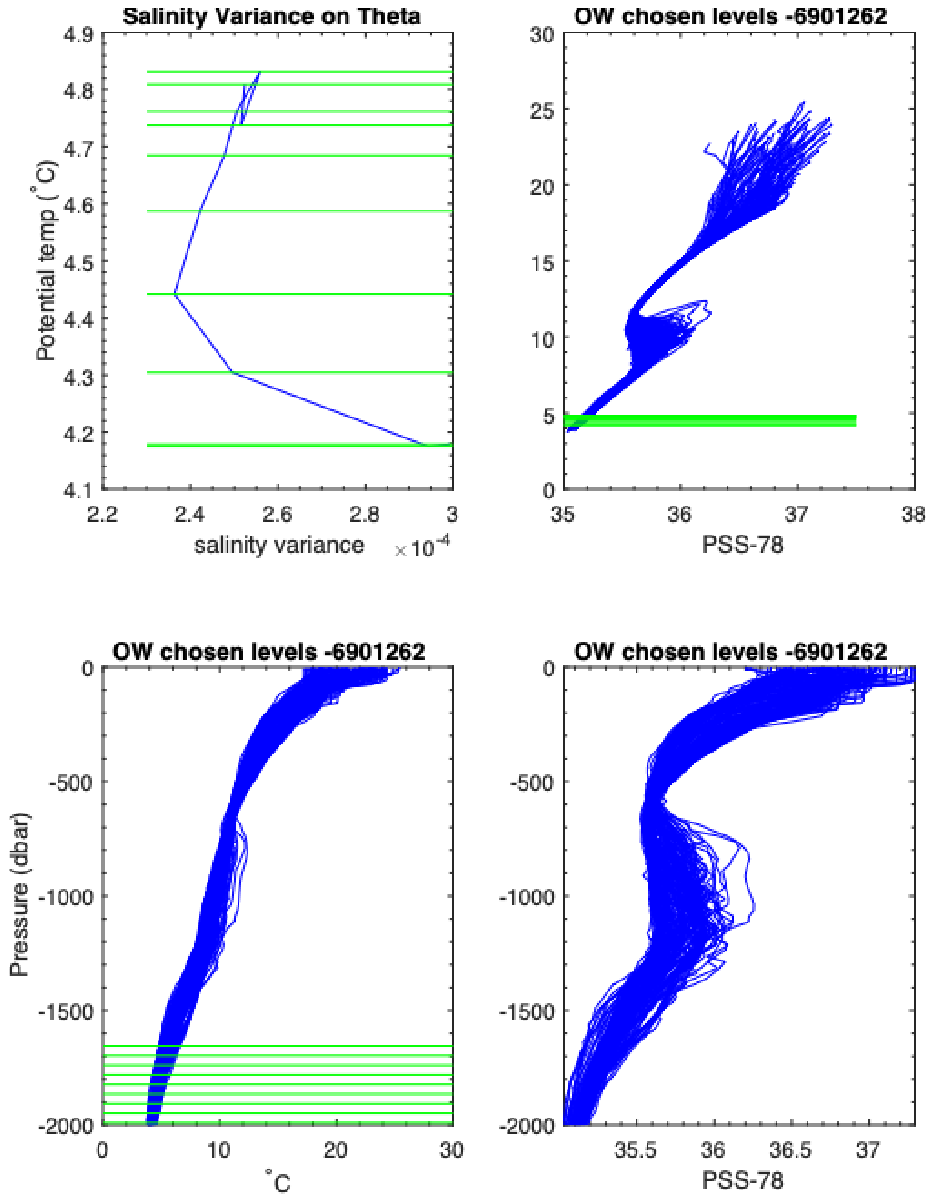
Calibrating Salinity Drift

OWC

Climatological Calibration Method



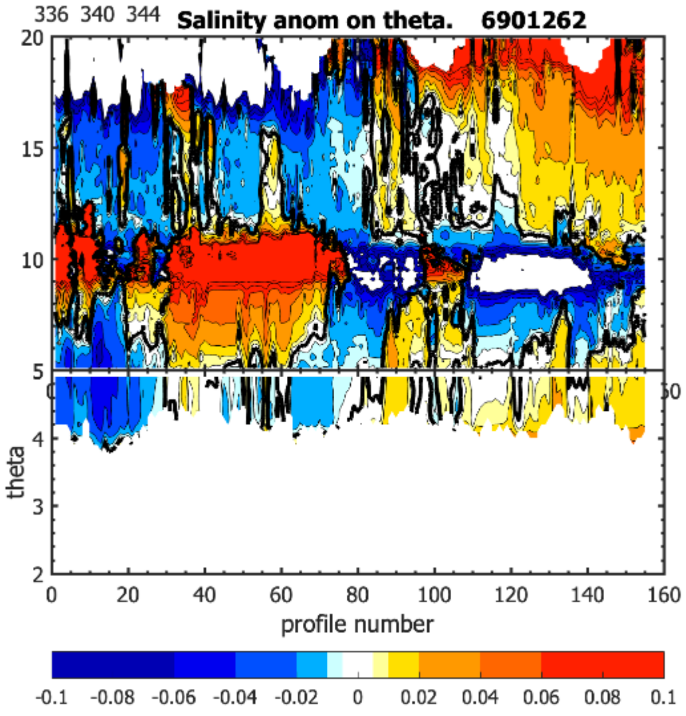


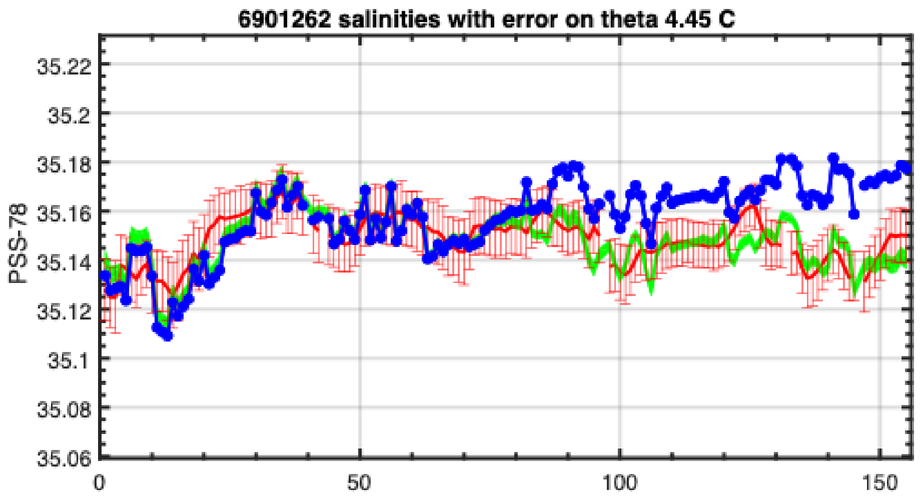


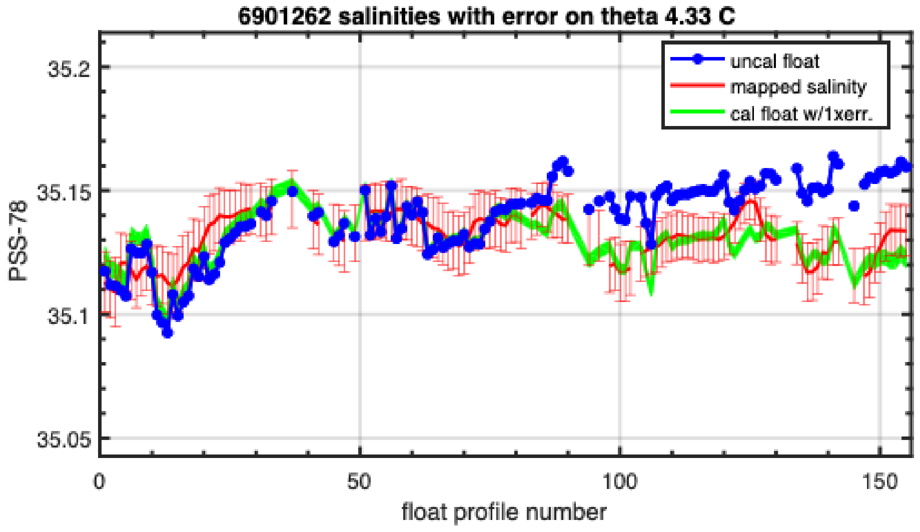
Calibrating Salinity Drift

OWC

Climatological Calibration Method



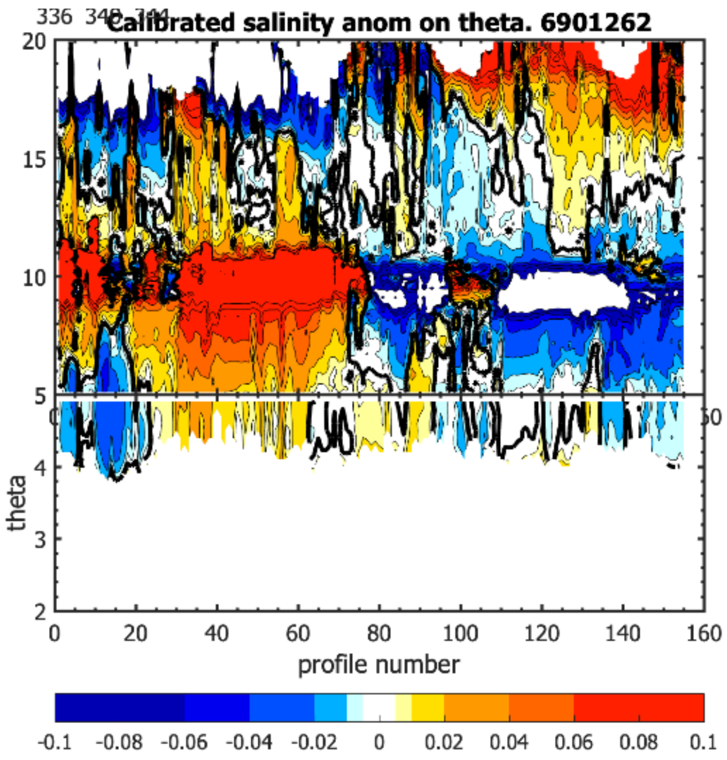


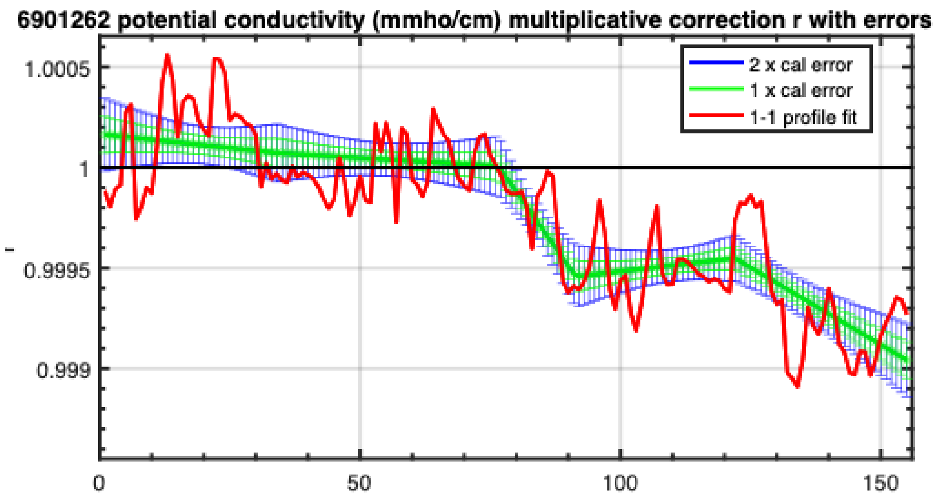


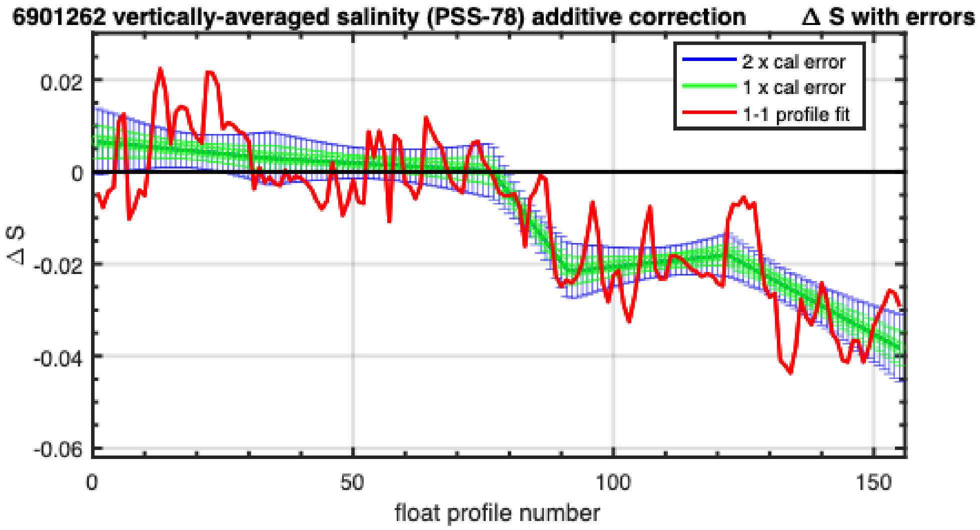
Calibrating Salinity Drift

OWC

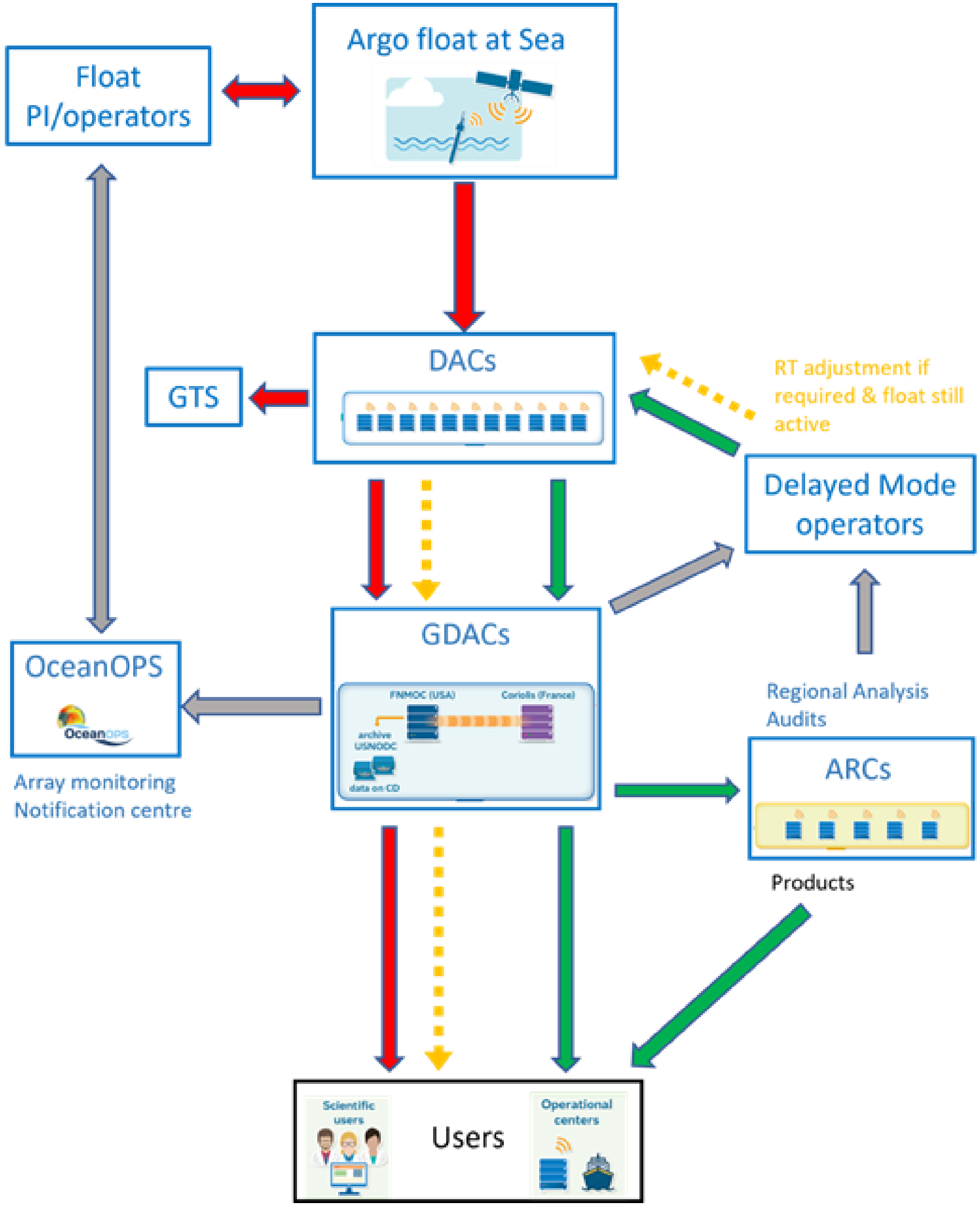
Climatological Calibration Method







Quality control



Adjusted in Real Time ('A' mode)

- For floats still active
- Possible adjustment defined during Delayed Mode processing (offset or drift) applied to the upcoming profiles sent in Real Time

The Argo Quality Flag System

Flag	Meaning	Real Time	Delayed Mode
0	No QC performed	No QC performed	No QC is performed.
1	**Good data**	**Good data. All Argo real-time QC tests passed. These measurements are good within the limits of the Argo real-time QC tests**	**Good data. No adjustment is needed, or the adjusted value is statistically consistent with good quality reference data. An error estimate is supplied**
2	**Probably good data**	**Probably good data. These measurements are to be used with caution**	**Probably good data. Delayed- mode evaluation is based on insufficient information. An error estimate is supplied.**
3	**Probably bad data that are potentially adjustable**	**Probably bad data. These measurements are not to be used without scientific adjustment, e.g. data affected by sensor drift but may be adjusted in delayed-mode.**	**Probably bad data. An adjustment may (or may not) have been applied, but the value may still be bad. An error estimate is supplied.**
4	Bad data	Bad data. These measurements are not to be used. A flag '4' indicates that a relevant real- time qc test has failed. A flag '4' may also be assigned for bad measurements that are known to be not adjustable, e.g. due to sensor failure.	Bad data. Not adjustable. Adjusted data are replaced by FillValue.
5	Value changed	Value changed	Value changed
8	Estimated	Estimated value (interpolated, extrapolated or other estimation)	Estimated value (interpolated, extrapolated, or other estimation)
9	Missing value	Missing value	Missing value. Data parameter will record FillValue

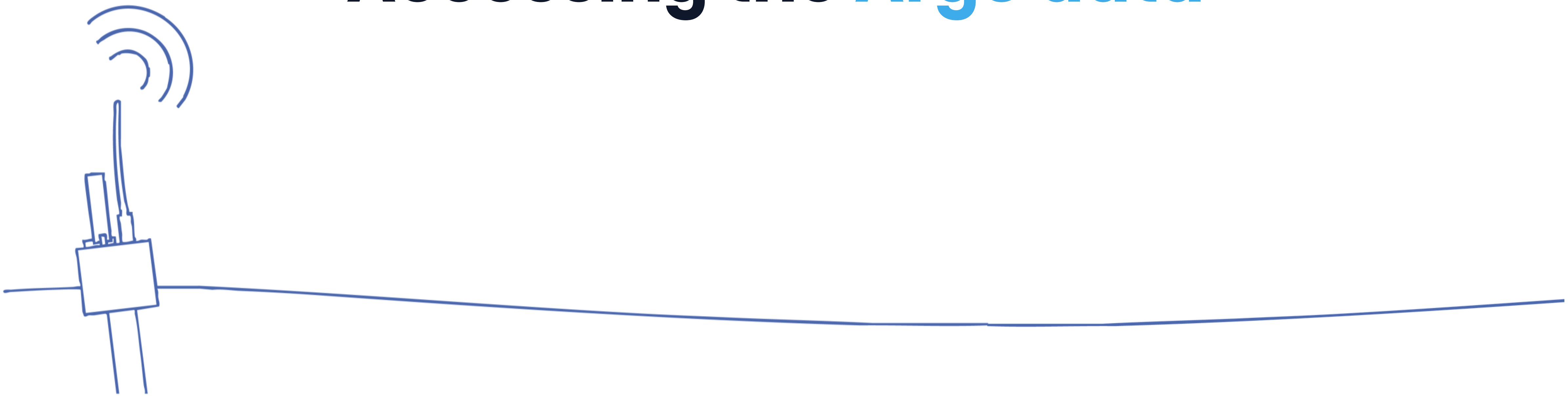
RTQC vs DMQC Profiles

Feature	Real-Time QC (R Files)	Delayed-Mode QC (D Files)
Availability	Within 12 hours of telemetry.	Nominal processing delay of ~12 months.
Processing	Automated, algorithmic tests only.	Deep scientific review and climatological calibration.
Target Application	Real-time weather and ocean forecasting.	Long-term climate research and oceanographic studies.
Accuracy	Contains uncorrected sensor drifts.	Highly calibrated, stable values.

Part III: Using the data

- Accessing the Argo data
- Data Organization
- Hands on session
- Accessing Argo data by float
- Accessing Argo data by date
- Real Time data
- Delayed Mode data
- ArgoPy

Accessing the Argo data



Argo data Access

Direct Access

ftp
ftp://ftp.ifremer.fr/ifremer/argo

https
https://data-argo.ifremer.fr/

https://nrlgodae1.nrlmry.navy.mil/pub/outgoing/argo/

Erddap
https://erddap.ifremer.fr/erddap/tabledap/ArgoFloats.html

Daily copy Cloud

https://argo-gdac-sandbox.s3.eu-west-3.amazonaws.com/pub/index.html#pub/

Monthly copy

Argo float data and metadata from GDAC

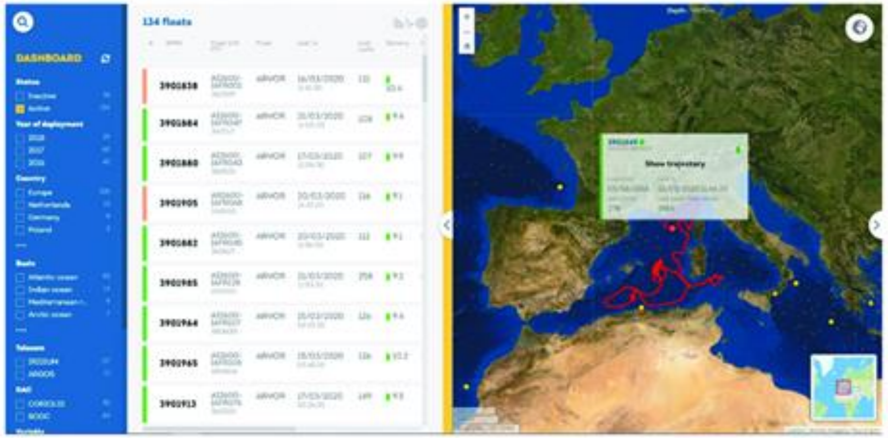
https://www.seanoe.org/data/00311/42182/
Seanoe doi 10.17882/42182

Argo data access: web interfaces

Fleetmonitoring

https://fleetmonitoring.euro-argo.eu/

Allows any user to visualise Argo profiling float metadata, ocean measurements, trajectories and technical parameters. It gives access to a fleet dashboard and also provide detailed information on a specific Argo float webpage (by WMO number).



Data selection

https://dataselection.euro-argo.eu/

Designed for users to select, visualise and download Argo scientific data (profiles files) in different formats.

Argo data Access

Gridded products

https://argo.ucsd.edu/data/argo-data-products

Other external access

Access from services & data aggregators

Copernicus Marine Service

NOAA

Blue-Cloud

ENVRI Hub

DATA TERRA

EMODnet

SeaDataNet

How to cite Argo data

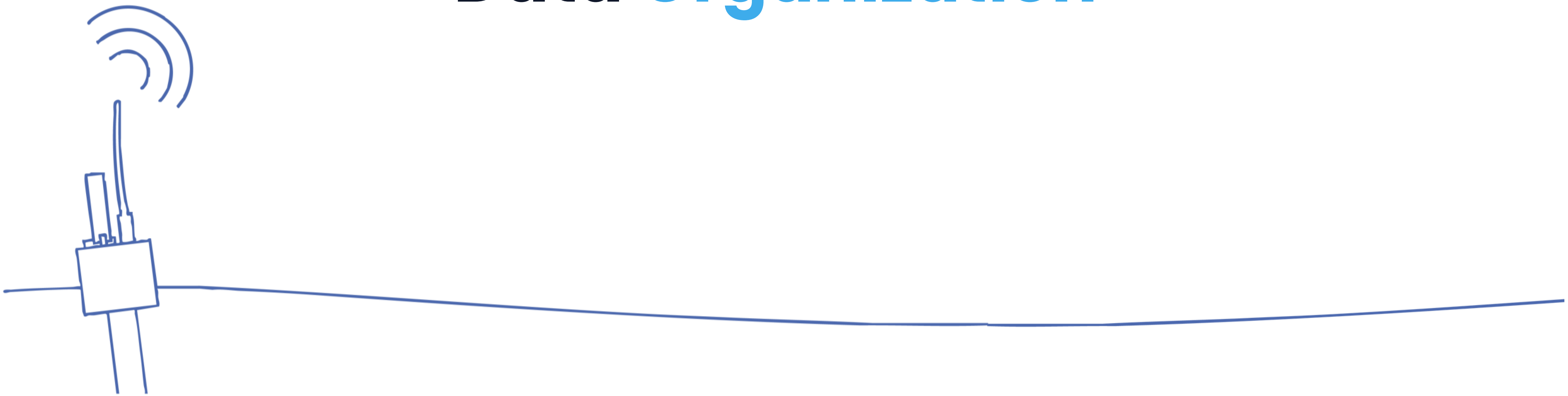
"These data were collected and made freely available by the International Argo Program and the national programs that contribute to it. (https://argo.ucsd.edu, https://www.ocean-ops.org). The Argo Program is part of the Global Ocean Observing System."

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

Argo (2020). Argo float data and metadata from Global Data Assembly Centre (Argo GDAC) – Snapshot of Argo GDAC of August 2020. SEANOE. https://doi.org/10.17882/42182#76230

Wong, A. P. S., 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*(700), doi: https://doi.org/10.3389/fmars.2020.00700

Data Organization



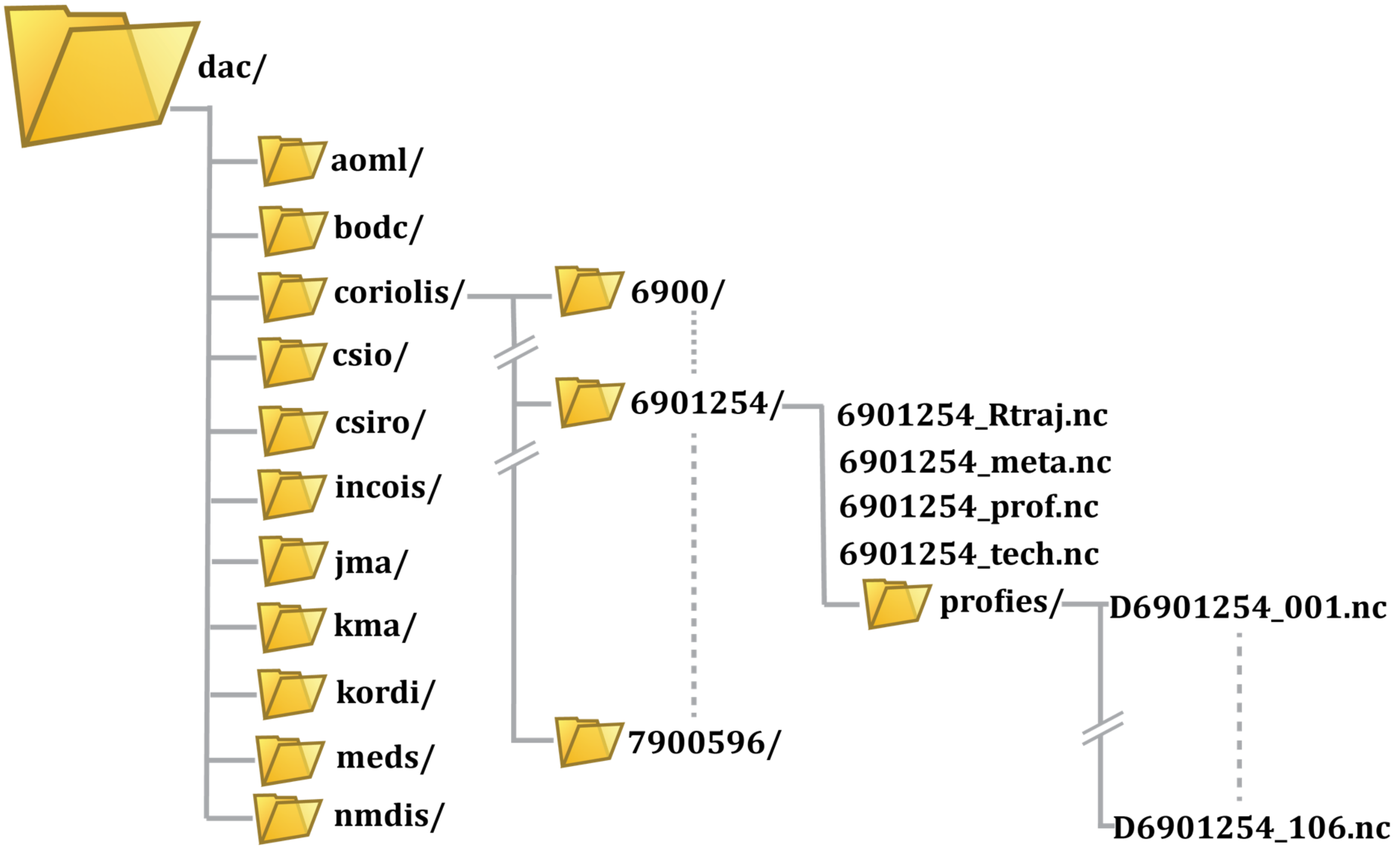
Argo data Access

gdac/

- aux/ → **aux/** contains data from experimental sensors.
- dac/ → **dac/** sorts the data by Data Assembly Centre (DAC) then by float
- etc/ → **etc/** The etc folder includes various auxiliary files and miscellaneous content.
- geo/ → **geo/** sorts the data by sorts the data by ocean basin and day
- last_data/ → **Last_data/** includes the most recent data
- ar_index_global_meta.txt
- ar_index_global_meta.txt.gz
- ar_index_global_prof.txt
- ar_index_global_prof.txt.gz
- ar_index_global_tech.txt
- ar_index_global_tech.txt.gz
- ar_index_global_traj.txt
- ar_index_global_traj.txt.gz
- ar_index_this_week_meta.txt
- ar_index_this_week_prof.txt
- argo_bio-profile_index.txt
- argo_bio-profile_index.txt.gz
- argo_bio-traj_index.txt
- argo_bio-traj_index.txt.gz
- argo_synthetic-profile_index.txt
- argo_synthetic-profile_index.txt.gz
- readme_before_using_the_data.txt

Index files containing a list of metadata on each type of Argo data file (meta, prof, tech and traj)

Argo data Access by float - DAC

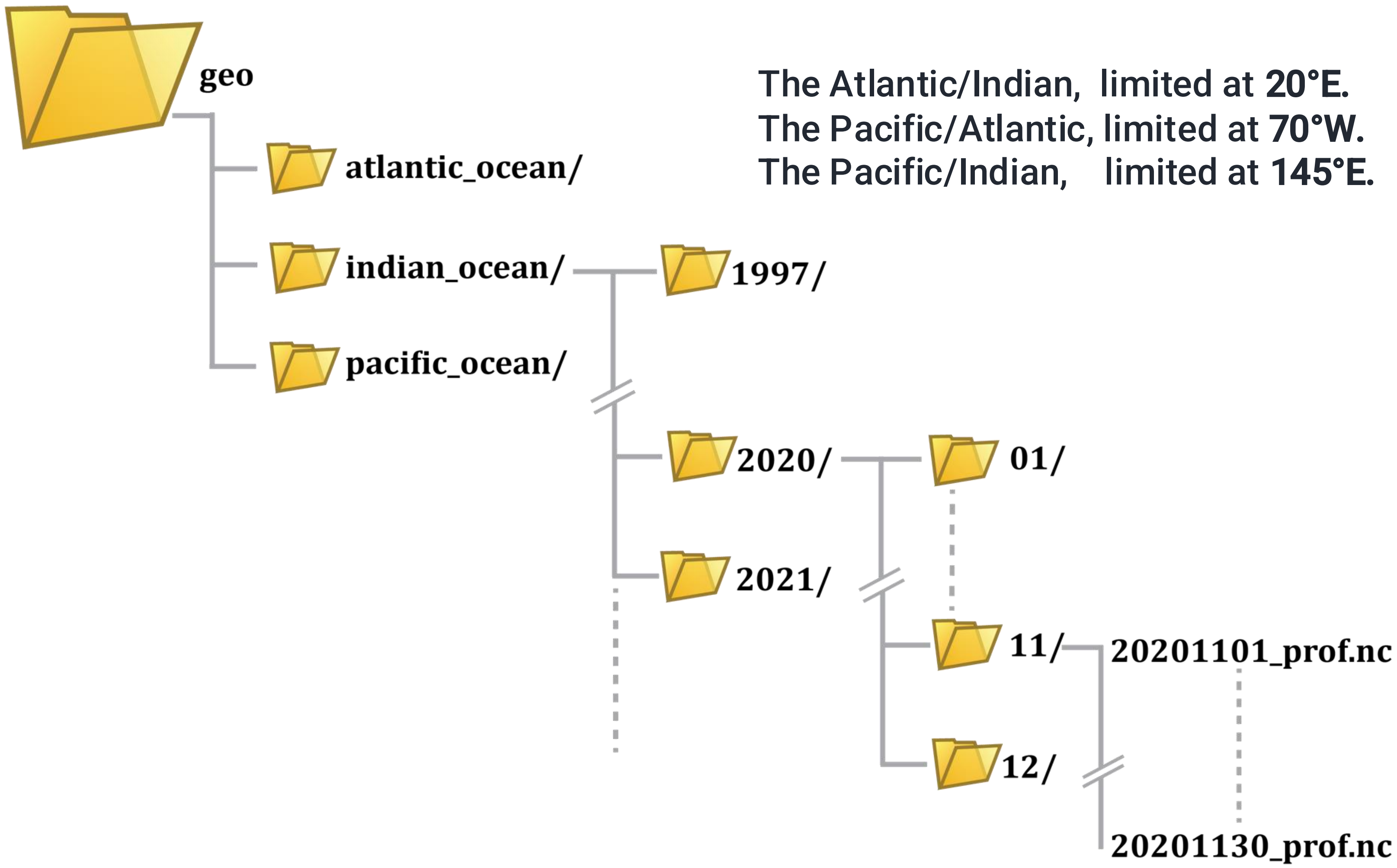


<R/D><FloatWmoID>_<XXX><D>.nc

R indicates Real-Time data
D indicates Delayed-Mode data
XXX is the cycle number
The second D indicates a descending profile, if exists, while profiles without this D are collected during ascent.

The R-files are substituted by the D-files once the data is adjusted

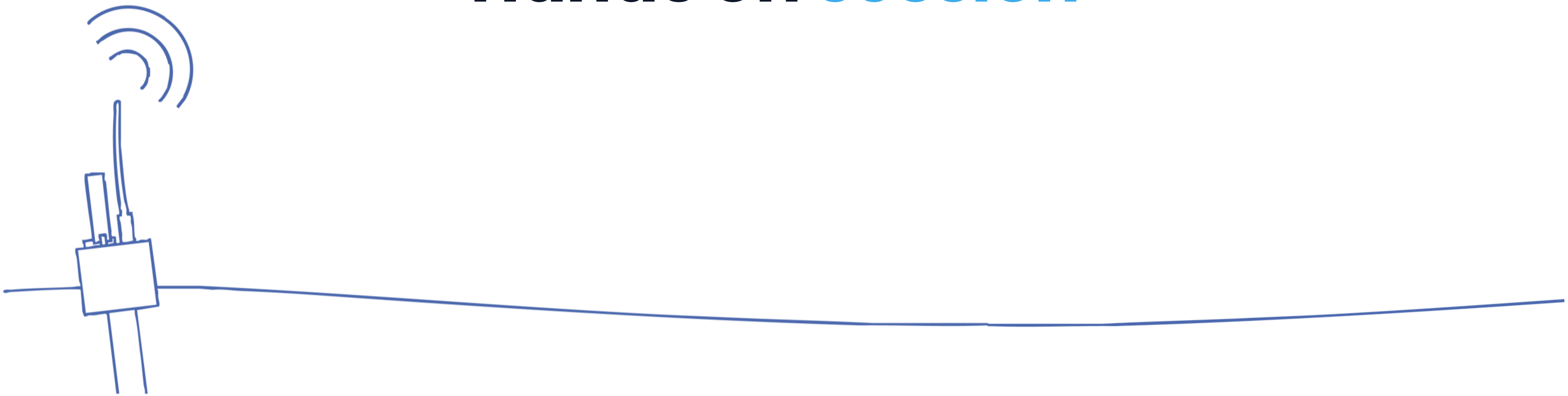
Argo data Access by date - GEO



The Atlantic/Indian, limited at **20°E.**
The Pacific/Atlantic, limited at **70°W.**
The Pacific/Indian, limited at **145°E.**

In each directory the data is organized by **year**, **month** and **day**, according to the date of the profile.

Hands on session



Hands on

Argo online School

An introduction to the Argo data

1. **INITIAL REQUIREMENT:** The open-source package management system CONDA (display).
2. Create the AOS-Hands-on folder in a desired location.
3. Access the AOS website. https://euroargodev.github.io/argoonlineschool
4. Access the repository (https://github.com/euroargodev/argoonlineschool) and download the zip file.
5. Use an external software to unzip the files is highly recommendable (WinRAR, WinZIP, B1, etc).
6. Access lesson 3 and open the terminal.
7. Using the terminal, navigate to the AOS-Hands-on folder.
8. Access Lessons/L03_UsingArgoData/Chapter30_UsingArgoData_intro , review it, and check the environment by executing **conda-env list** in the terminal (Jupyter Notebook is included).

9. Create and activate the AoS environment in the terminal by typing:

   cd AOS-Hands-on (go to the desired folder) and run **conda env create -n AOS -f environment.yml**.

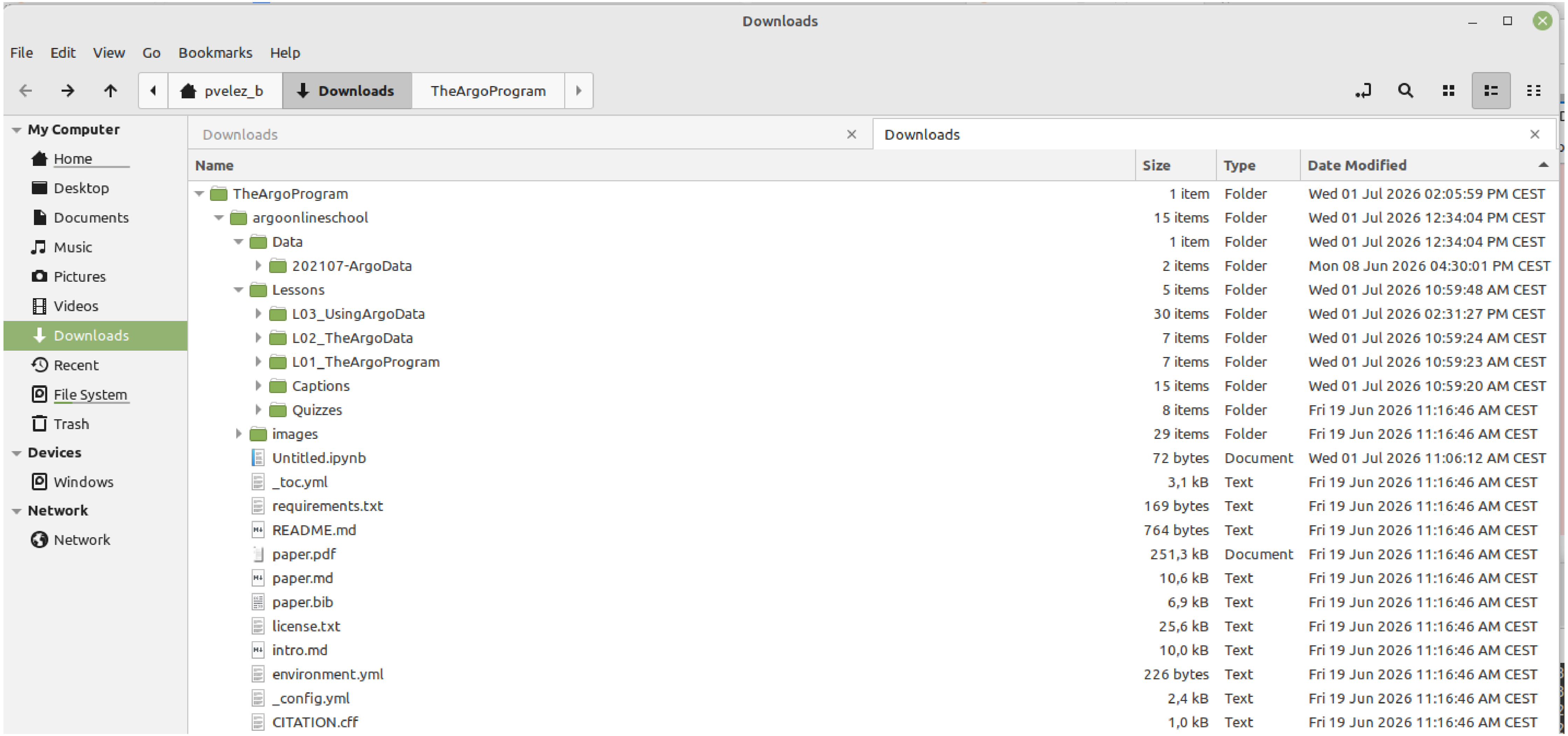
   conda activate AOS for environment activation.

10. Execute conda env list (see an asterisk* on the left side of the last line that appears in the terminal prompt for activation confirmation).
11. Download and snapshot of the Argo float data and metadata from Global Data Assembly Centre (Argo GDAC) from the Seanoe portal and place the zipped file at the same level as the Lessons folder, and unzip it with an external software. The Data folder will be created at the same level as the Lessons folder. Or, as indicate in the AoS download the same snapshot used in the school, from here:
12. Run **Jupyter-lab** in the terminal.
13. Find out the Lesson 3 and make sure you're "localhost"
14. Go to the desired chapter.

Hands on

Argo online School

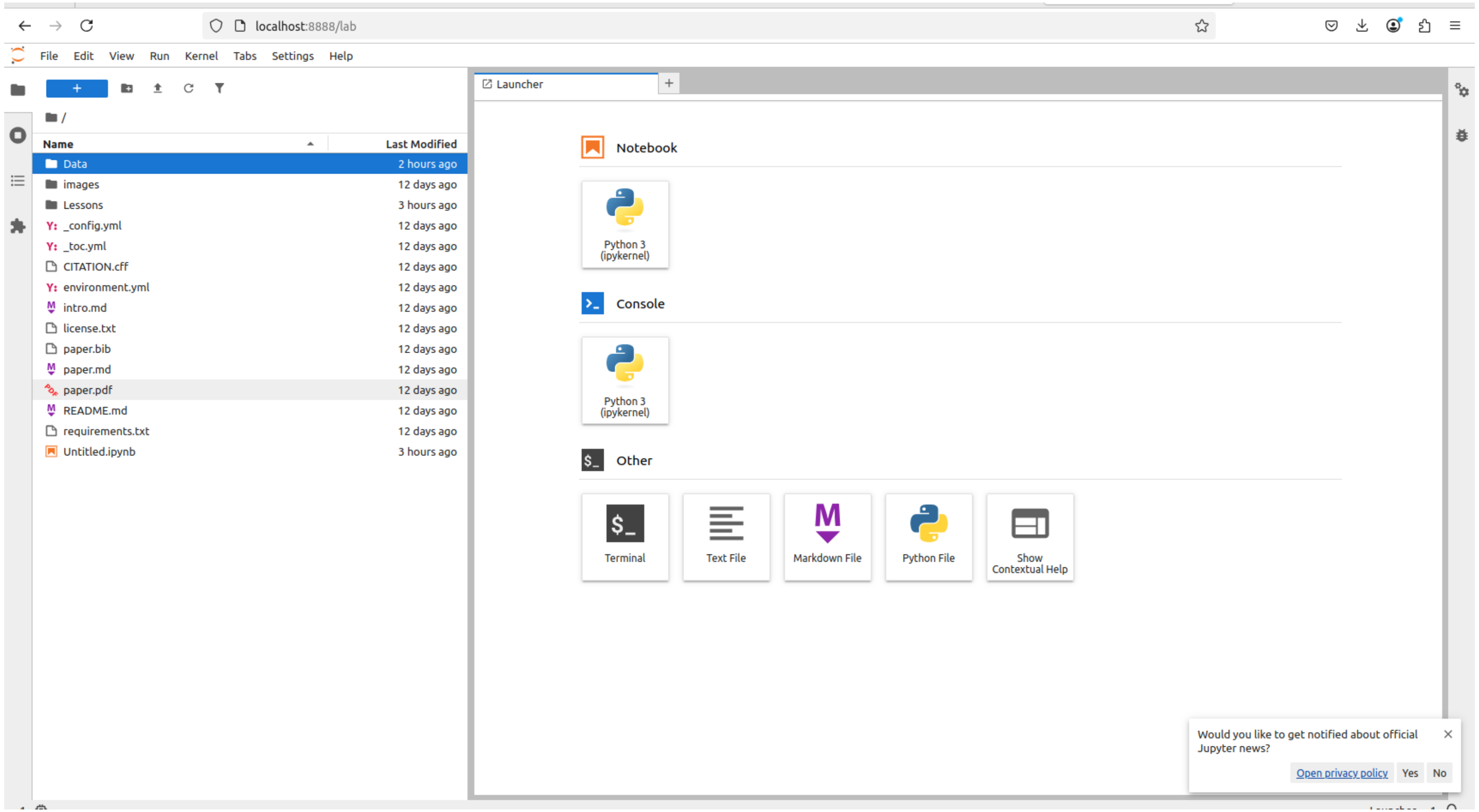
An introduction to the Argo data



Hands on

Argo online School

An introduction to the Argo data

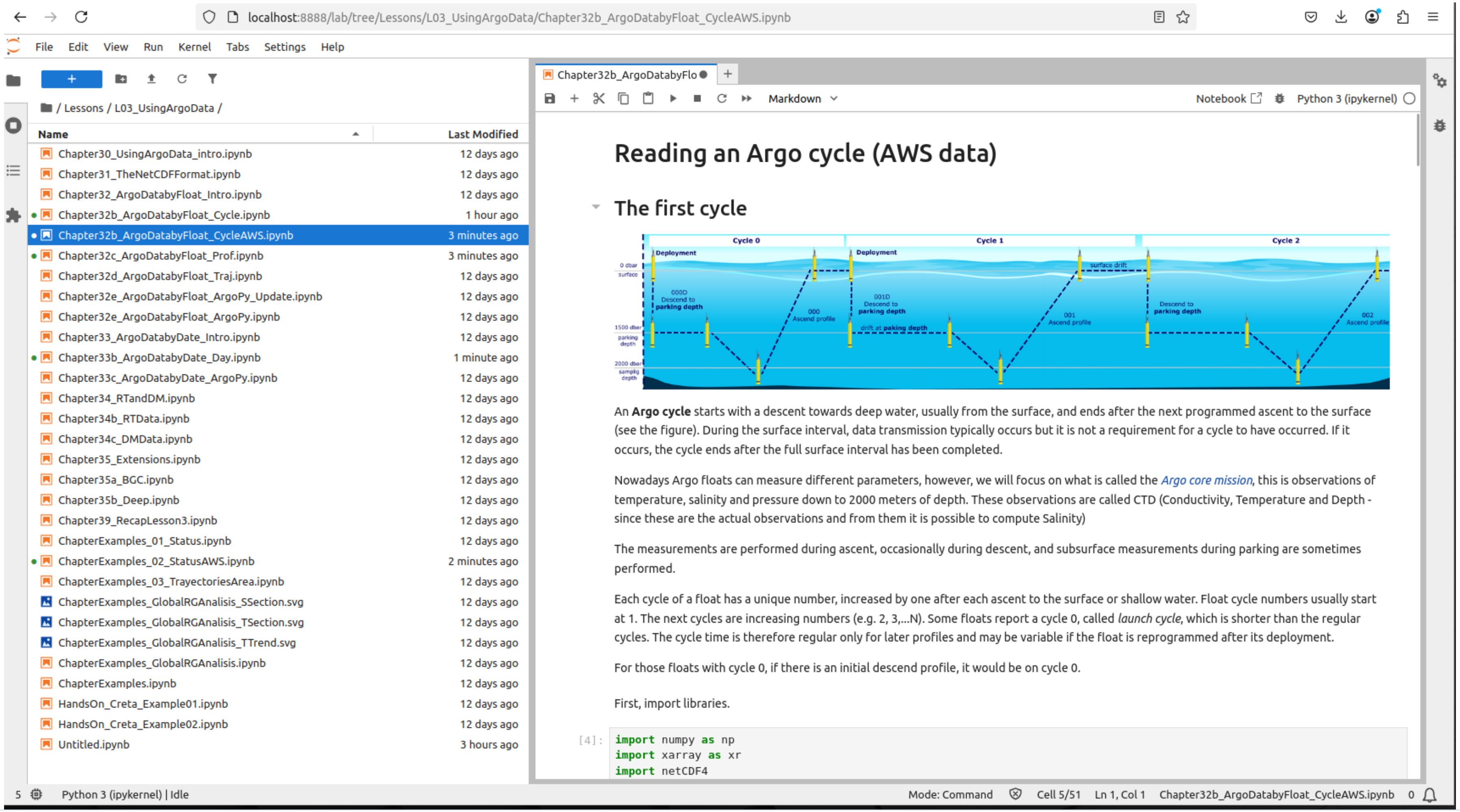


Hands on

Argo online School

An introduction to the Argo data

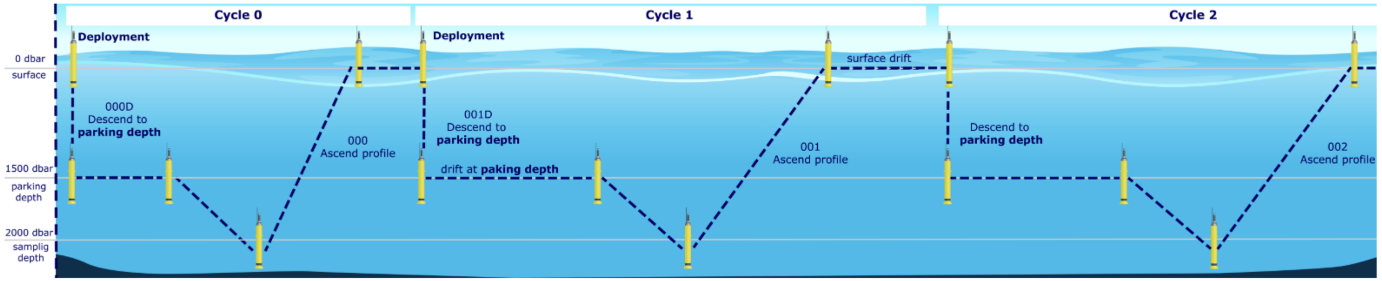
Select /Lessons/L03_UsingArgoData/Chapter32b_ArgoDatabyFloat_CycleAWS.ipynb



Accessing Argo data by float

Reading an Argo cycle

The first cycle



An **Argo cycle** starts with a descent towards deep water, usually from the surface, and ends after the next programmed ascent to the surface (see the figure). During the surface interval, data transmission typically occurs but it is not a requirement for a cycle to have occurred. If it occurs, the cycle ends after the full surface interval has been completed.

Nowadays Argo floats can measure different parameters, however, we will focus on what is called the *Argo core mission*, this is observations of temperature, salinity and pressure down to 2000 meters of depth. These observations are called CTD (Conductivity, Temperature and Depth - since these are the actual observations and from them it is

Accessing Argo data by float

Accessing all profiles at once

Conveniently, all the core mission profiles are compacted in a single file, named: `<FloatWmoID>_prof.nc`. However, some information is only in the individual profile files, but we will see it.

Let's start loading the neccesary python modules and the netCDF file **6901254/6901254_prof.nc**

```
import numpy as np
import xarray as xr
import netCDF4
from matplotlib import pyplot as plt
%matplotlib inline
```

```
prof  = xr.open_dataset('../../Data/202107-ArgoData/dac/coriolis/6901254/
```

```
prof
```

Accessing Argo data by float

Accessing trajectory data

Within the folder for each float there is also a netCDF file with the data during the time the float was drifting, this is the data not included during the profiling part of the cycle.

First, import libraries:

```
import numpy as np
import xarray as xr
import netCDF4
from matplotlib import pyplot as plt
%matplotlib inline
```

```
Rtraj = xr.open_dataset('../../Data/202107-ArgoData/dac/coriolis/6901254/
```

```
Rtraj
```

Accessing Argo data by date

Reading Argo data by date

Let's use, as an example, data in the *Atlantic for the 11th November 2020. It is pre-downloaded in the ./Data folder, but you can download it from the Coriolis GDAC [See here for instructions on how to download the data]

First, import the libraries

```
import numpy as np
import netCDF4
import xarray as xr

import cartopy.crs as ccrs
import cartopy

import matplotlib as mpl
import matplotlib.cm as cm
from matplotlib import pyplot as plt
%matplotlib inline
```

and define a colorbar that will be useful later.

Real Time data

Real Time data

Real-Time quality control is a set of automatic procedures that are performed at the National Data Acquisition Centers (DACs) to carry out the first quality control of the data. There are a total of 19 tests that aim, to say, easy to identify anomalies in the data. The subtle anomalies, that need a lot of expertise and time to discern between sensor malfunctioning and natural variability, are left for the Delayed-Mode quality control.

The results of the Real-Time tests are summarized in what is called the **quality control flags**. Quality control flags are an essential part of Argo.

Quality Control flags

Each observation after the RT quality control has a QC flag associated, described in the Table 2: quality control flag scale of the Argo user's manual) and assigned in real-time or delayed mode according to the Argo Quality Control Manual for CTD and Trajectory Data. A summary of the meaning of the QC flags, a number from 0 to 9, is described in the following table:

Delayed Mode data

Delayed mode data

What if the Real-Time (RT) quality control is not enough?, or if we need the previous data of the float and the data from its neighbors to discern between subtle sensor malfunctioning and natural variability?.

This is where the second data quality control comes in. It is called **Delayed - Mode (DM)** quality control. Principal investigators and regional data experts are in charge of this meticulous task since it requires a more elaborate specific data analysis of every float and oceanographic expertise in the region where the float was deployed.

Delayed mode files

Delayed mode profile files are the same as the Real-Time profile files, except their file names on the GDACs all contain a "D" before the WMO number (e.g. D5900400_001.nc, BD5904179_001.nc). These profile files contain delayed mode - also called adjusted-data, which are recorded in the variable `<PARAM>_ADJUSTED`. The variable `DATA_MODE` will record 'D'. Two other variables are also filled in delayed mode, which are

ArgoPy

Argopy is a python library dedicated to Argo data access, manipulation and visualisation for standard users as well as Argo experts.

https://argopy.readthedocs.io

Maze et al., (2020). argopy: A Python library for Argo ocean data analysis. Journal of Open Source Software, 5(53), 2425, https://doi.org/10.21105/joss.02425

ArgoPy

```
In [1]: import argopy

In [2]: f = argopy.DataFetcher()

In [3]: f
Out[3]:
<datafetcher.erddap> 'No access point initialised'
Available access points: float, profile, region
User mode: standard
Dataset: phy
Performances: cache=False, parallel=True [thread]
```

```
In [4]: f = f.region([-75, -45, 20, 30, 0, 10, '2011-01', '2011-06'])

In [5]: f.data
Out[5]:
<xarray.Dataset> Size: 120kB
Dimensions:          (N_POINTS: 998)
Coordinates:
    LATITUDE         (N_POINTS) float64 8kB 21.48 21.48 28.59 ... 24.96 2
    LONGITUDE        (N_POINTS) float64 8kB -60.82 -60.82 -69.98 ... -50.
    TIME             (N_POINTS) datetime64[ns] 8kB 2011-01-02T10:23:10 ..
  * N_POINTS         (N_POINTS) int64 8kB 0 1 2 3 4 5 ... 993 994 995 996
Data variables: (12/15)
    CYCLE_NUMBER     (N_POINTS) int64 8kB 135 135 160 160 157 ... 1 1 2 3
    DATA_MODE        (N_POINTS) <U1 4kB 'D' 'D' 'D' 'D' 'D' ... 'D' 'D' '
    DIRECTION        (N_POINTS) <U1 4kB 'A' 'A' 'A' 'A' 'A' ... 'A' 'A' '
    PLATFORM_NUMBER  (N_POINTS) int64 8kB 4900818 4900818 ... 1901463 190
    POSITION_QC      (N_POINTS) int64 8kB 1 1 1 1 1 1 1 1 ... 1 1 1 1 1
    PRES             (N_POINTS) float32 4kB 5.0 10.0 5.0 10.0 ... 6.3 5.0
    ...               ...
    PSAL_ERROR       (N_POINTS) float32 4kB 0.01 0.01 0.01 ... 0.01091 0.
```

The Argo Program

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Argo online School

An introduction to the Argo data

https://www.euro-argo.eu/argo-online-school

González-Santana et al., (2024). The Argo Online School: An e-learning tool to get started with Argo. Journal of Open Source Education, 7(80), 193, https://doi.org/10.21105/jose.00193