# UK ARGO PROGRAMME

# REPORT FOR 23RD ARGO STEERING TEAM MEETING MARCH 2022

## 1. Status of Implementation

### Floats deployed and their performance

During 2021 we were able to deploy 18 floats; of these 15 were standard core APEX, four were APEX Deep and one Navis BGCi (bio-geochemical) float. Deployments were still impacted by the cancellation of several cruises in the autumn due to Covid.

Since the end of the year, to end February 2022, we have deployed five core APEX and our first six-parameter PROV-BIO float.

As at 1st March the UK has 152 operational floats (i.e. for which real-time data are presently being distributed), as shown in Figure 2. This does not show the recently deployed six-parameter PROV-BIO float as processing has still to be set up.

Of the 24 floats deployed between 1st January 2021 and end February 2022 we have had three float failures, two of which failed to report after being deployed, the other while still active is not transmitting sufficient information to process. This is a higher failure rate than we would normally expect.

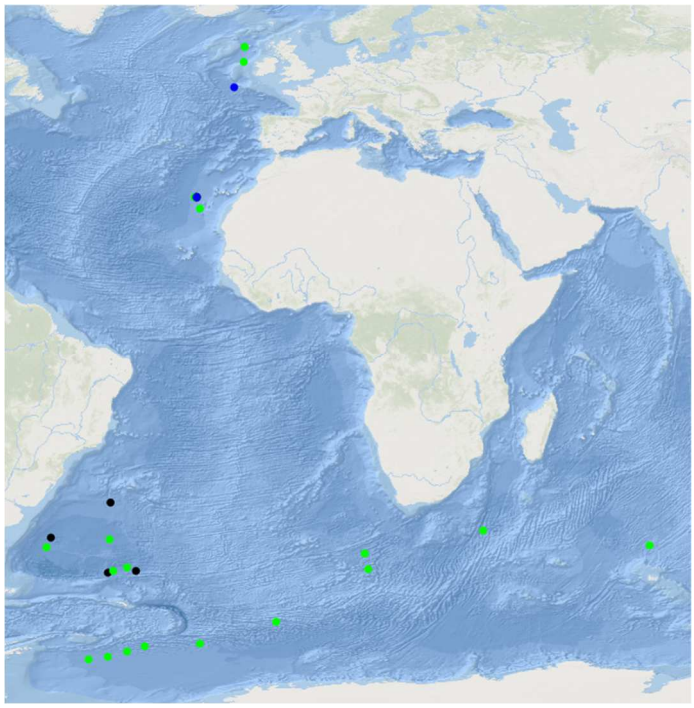

*Figure 1. Showing the latest reported locations of UK Argo floats deployed between 1st January 2021 and 28 February 2022, core APEX floats in green, APEX-Deep in black, BGC floats in blue.*

At end February 2022 the 152 operational floats returning data include:

- 124 core APEX with SBE CTDs
- 6 core APEX with the RBR sensor
- 1 core NAVIS
- 4 APEX with oxygen and pH
- 1 APEX with oxygen
- 8 NAVIS with oxygen
- 5 APEX DEEP
- 1 APEX DEEP with oxygen
- 1 NAVIS BGCi
- 1 PROV-BIO.

In addition, we have one active six-parameter PROV-BIO still to be set up for processing.

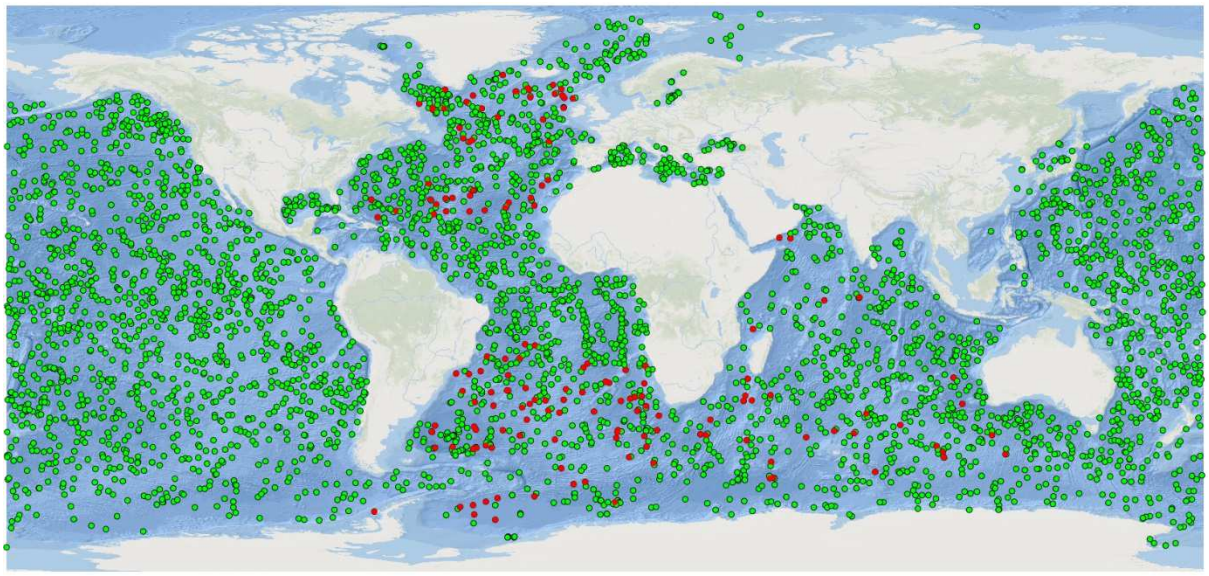

*Figure 2. Showing the locations of all UK floats delivering data in red with the global network of ~3,900 floats in green, as at 1 March 2022.*

## Technical problems encountered

APEX Core

We had deployed 16 APEX floats that are at risk of a fast salty drift, these were deployed before the problem was known. We still have five undeployed APEX floats that are at risk of the fast salty drift problem that have yet to be returned to Teledyne Webb (three of these are in South Africa).

APEX Deep

As noted above UK deployed four APEX Deep in 2021, all in the Argentine Basin. All four are presently working together with two APEX Deep deployed in 2020. We are still awaiting delivery of a Deep SOLO ordered last year. There are no plans to buy any more deep floats at present.

Bio-geochemical Argo

We presently have two active BGC floats. The Navis BGCi that was deployed in November 2020 near the Porcupine Abyssal Plain (PAP) mooring appears to be working well and the data look good. However, the NAVIS BGCi deployed near PAP in April 2021 failed to report, despite SeaBird engineers clearing the float for deployment when asked to review the lab test data. The 11 PROV-BIO floats purchased by PML in 2013 have all shown good longevity, with one that was deployed in December 2015 still active having made over 330 cycles. One of the floats from that batch has been recovered and awaiting refurbishment. As noted earlier we deployed our first 6-parameter PROV-BIO float in early 2022 with another two due to go in shortly. A further five 6-parameter BGC floats are in stock at NOC for deployment later this year.

APEX floats with RBR CTD

We procured our first six APEX-RBR floats in 2015. Five were deployed with three early failures, the other two are still operating having made over 200 cycles. Two RBR-L3 replacements for the early failures were provided in 2020 and the sixth was upgraded to L3, these were deployed in the North Atlantic in December 2020 alongside one new APEX-RBR-L3, all four APEX-RBR-L3 are presently operating normally. The data are being made available to Mat Dever at RBR, two of the floats have been put onto 1Hz sampling in the top 100 dBar. We have three other APEX-RBR-L3 available, two of which are out for deployment, with five new ones in the float order to be delivered in March.

## Status of contributions to Argo data management

Real-time data processing

At 1st March 2022 the British Oceanographic Data Centre (BODC) were processing data from 152 active UK floats, 18 Irish floats and 59 Euro-Argo MOCCA floats. Work remains to deliver the UK BGC data to the GDACs, and this will be a high priority for the coming year.

Real-time processing is run four times a day with NetCDF files distributed to the GDACs and the Met Office, where the BUFR files are generated and disseminated on the WMO Global Telecommunications System (GTS). The capability now exists to include supplementary profiles and oxygen into the BUFR files. However, we have not yet been able to progress the extension of the BUFR capability to include other biogeochemical variables. Within the Euro-Argo RISE project, UK Argo is also developing real-time tests for BBP, as well as a technique for producing uncertainty estimates for BBP.

Delayed-mode QC processing

**Core Argo**

At 1st March 2022 BODC had delivered 94,684 profiles from UK floats, of which 75,992 profiles have been subjected to delayed-mode QC. This represents 80% of all profiles, and 82% of eligible profiles (i.e. all profiles from expired floats and profiles over one-year old from active floats). From February 2021 up to 9th March 2022 BODC analysed and delivered to the GDAC in delayed mode 13,294 profiles (from 93 floats).

BODC supported the UK and Irish Argo programs, data for which are managed by the BODC Argo Data Assembly Centre (DAC) function. Recently BODC performed DMQC analysis of eight Irish Argo floats and submitted them to the GDAC.

BODC actively contributed to activities related to the Abrupt Salty Drift (ASD) group, focusing on estimating the best practices, guidance and examples of data affected by salinity sensor drift to produce optimal adjustment in delayed-mode. This involved contributing to updating the shared list of floats affected by the salty drift and reviewing documentation related to the draft version of best practices for DMQC operators of core Argo floats.

BODC continued development works related to the conversion of the DMQC software (OWC package) from Matlab to Python. The works were focused on improving the code performance, readability and fixing any remaining known issues that arrived during testing the floats. The next steps to finalize the project are to continue the User Acceptance Testing involving the broader Argo community, improve code readability and enhance functionality related to configuration and code design. The progress of works has been demonstrated at the 22nd ADMT meeting.

**Deep Argo**

NOC and BODC, have also played a key role in coordinating the development of deep Argo mission. This covers contributions in compiling the new procedures for the real-time QC flag scheme and Real-time adjustments on Deep Argo vertical profiles and procedures for DMQC of Deep Argo salinity data.

BODC has started development work on automatically applying the CpCor correction for pressure effects on conductivity data of deep Argo floats (>2000 dbar) in the real-time QC process which was recommended by the Deep Argo team earlier in 2021. This step is required to perform further analysis of deep Argo floats in delayed mode. BODC is planning to implement the delayed-mode procedures for DMQC analysis of Deep Argo floats in 2022.

BODC and NOC have been actively involved in the coordination and organisation of DMQC for deep ocean data as a part of the EuroArgo Rise WP3, Task 3.2. This involved organisation and coordination of the intermediate meeting with other European partners within the task and providing a regular update of progress to the reporting body.

BODC and NOC were strongly involved in the co-organisation of the BGC and 3rd Deep Argo workshop.

**BGC Argo**

BODC has not been able to make progress with DMQC of the UK BGC floats due to a long-term absence in the team, which has limited availability of staff working in the Argo group over a prolonged period.

BODC contributed to reviewing the report for the Euro-Argo RISE WP4 deliverable of enhancing the current oxygen QC.

A significant focus in the coming year will be to progress DMQC training in the analysis of Oxygen parameter to be able perform DMQC analysis of BGC floats. This activity is a part of the Euro-Argo RISE project WP4.

**Southern Ocean Argo Regional Centre (SOARC)**

SOARC activity has been limited to efforts that are happening towards deliverables in Euro Argo RISE WP5. BODC and NOC have been working to establish a method of regional data quality assessment in the Southern Ocean. (i) BODC reviewed and tested the currently available tools for the classification of the Argo profiles located in the Southern Ocean (SO). The classification method aims to improve the quality control analysis of Argo floats by reducing the impact of selected reference data from other zones in the SO during the quality checks of salinity data. (ii) BODC and NOC implemented and operationalized in BODC the float classification tool based on the machine learning developed in Ifremer. The method is called the PCM (Profile Classification Model) and its output is used to perform the OWC analysis. (iii) BODC and NOC are working on a quality assessment of Argo floats in d-mode, in the Southern Ocean performed by PIs and DMQC operators from various DACs. The current works aim to review the fleet from the Atlantic sector (70˚ W to 30˚E). (iv) BODC reviewed the quality assessment method of delayed mode quality control of Argo floats used in the Coriolis Argo Regional Center and implemented some of their procedures which are also appropriate for the Southern Ocean floats.

Due to the long term absence of the BODC Argo Lead, who is also a lead of the SOARC Argo group, progress on wider SOARC Partnership activities has stalled.

Research cruise CTD data

When the UK notifies float deployments with OceanOPS, we include any information about nearby or simultaneous CTD casts if the scientists on board the deploying ship provide this. It is written in the Description free text box in the notification form.

# 2. Funding and human resources

The UK Argo programme is undertaken by a partnership between the Met Office, the National Oceanography Centre (NOC, which includes BODC) and Plymouth Marine Laboratory (PML). The Met Office are responsible for programme management and coordination, procurement of core floats, organizing float deployments, preparation of floats for deployment, telecommunications (costs) and international funding contributions (OceanOPS and Euro-Argo). NOC and BODC have responsibility for Argo science and data management respectively. NOC have the lead on deep Argo and PML play a leading role in the expansion of the UK programme into BGC-Argo.

## Funding

UK funding for Argo comes through various channels – the Met Office, NOCS and PML. Both the Met Office and NERC (Natural Environment Research Council) funding originates from BEIS (Department for Business, Energy and Industrial Strategy).

Argo funding to the Met Office is presently provided directly from BEIS mainly through the Hadley Centre Climate Programme (HCCP), but with an additional contribution through the Public Weather Service Programme. The HCCP workplan and funding for 2021 to 2024, which has been approved by BEIS and Defra (Department for Environment, Food and Rural Affairs) includes UK Argo funding for the period April 2021 to March 2024. From 2020 onwards all new floats have been with Iridium telecoms. The regular funding for FY2021 has allowed for the purchase of 17 core APEX floats, however additional in-year funding has enabled the purchase of a further 39 core APEX floats which should be delivered in March 2022. This means we will have in stock enough floats to maintain the UK Argo contribution to core Argo for three years even if (in the unlikely event) future funding is curtailed. In addition, two PROV-BIO floats have been ordered through the Euro-Argo ERIC for the PICCOLO (Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning) project led by the University of East Anglia.

NERC funding for Argo is primarily directed through NOC under National Capability (NC) funding lines which cover Argo data management (through NC Environmental Data Services funding of BODC) and Argo science. In March 2021, NERC and NOC announced an investment of £3.7 million to begin building the UK Atlantic Sector BGC Argo Network (ASBAN-UK) where NOC will deploy ~30 six-parameter BGC floats in the Atlantic Ocean over the next three years as part of the UK Argo programme, the first of these was deployed in February 2022. Non-NC funding is also provided through participation in EU-funded Argo-related projects.

Our aspirations are to contribute 10% of each of the BGC and Deep Argo arrays, and to continue to provide 5% of the Core floats deployed. This could be achieved by deploying 25 BGC floats per year, with a projected lifetime of four years this would lead to a sustained fleet of 100 BGC floats. Deployment of 25 each of Deep and Core floats per year, with a five-year lifetime would ramp up to a sustained fleet of 125 of each float type. The UK would then maintain a fleet of 350 floats (100 BGC, 125 each Core and Deep), about 8% of the total anticipated global fleet. However, funding for this, at around five times the present level, is not in place and would require significant additional investment primarily from BEIS.

## Human resources

Staff members working on UK Argo, their institution and effort on Argo during 2021 are given below; this will have been remained below normal years effort due to Covid-99 lockdowns and associated home-schooling demands. BODC staffing levels have been hit with the long-term absence (Sept 21 to date) of the Argo lead staff member, which has impacted the team. They have secured some additional time from another NOC team member to help meet priority deliverables, but this has not fully filled the time or skillset gap.

Met Office – 0.56 FTE
Jon Turton, Fiona Carse, John Hankins

NOC, Southampton – 0.25 FTE (estimated)
Brian King, Nathan Briggs

NOC, BODC – 3 FTE

Primarily Matt Donnelly (part of the year), Kamila Walicka, Clare Bellingham and Violetta Paba, with others providing additional support, like Clive Neil, BODC software developer team for short, 2 weeks development works

PML – 0.1 FTE
Giorgio Dall'Olmo

# 3. Summary of deployment and data management plans

### Deployment plans

As noted earlier, at 1st March in 2022 UK Argo has deployed seven core APEX and one 6-parameter PROV-BIO float.

Other floats out for deployment presently include:
Two APEX-RBR-L3 and two 6-parameter PROV-BIO floats (March 2022)
One Navis BGCi: North Atlantic (PAP cruise April 2022)
Four APEX: South-west Atlantic (April 2022)
Two APEX: Indian Ocean (floats are with Mauritius Met Service).

At the time of writing we have 37 core APEX, one APEX-RBR-L3 and two Navis BGCi floats in stock, with a further 34 core Apex and five core APEX-RBR-L3 to be delivered in March. NOC have five 6-parameter PROV-BIO in store with another 7 to be delivered spring 2022, and PML have one older PROV-BIO float that was recovered in 2018 to be refurbished.

Other deployment opportunities later in the year will be investigated. A reasonable estimate for the year 2022 would be twenty core floats, one deep float and eight BGC floats.

# 4. Uses of Argo data in the UK

Argo data are used widely within NOC, where the science applications include:

- measurement of evolution and drivers of mixed layer processes in the (Indian Ocean);
- inventory and evolution of heat and freshwater establishing controls on budgets (both regional and global);
- deep heat content (N Atlantic).

PML have the lead for BGC Argo in the UK, where the data are used for:

- investigating different aspects of the biological carbon pump (e.g., mixed-layer pump, fragmentation, respiration of both dissolved and particulate organic matter);
- investigating export fluxes and efficiency in hypoxic ocean regions;
- providing a description of the physical environment in the framework of biological (e.g. mapping eel migration routes) and biogeochemical studies;
- developing techniques to generate 3D fields of biogeochemical variables by merging ocean-colour and in-situ data;
- investigating mesoscale structures by combining altimetry and in-situ profiles with a special focus on Agulhas rings.

At the Met Office Argo data are used operationally:

- they are routinely assimilated into its FOAM (Forecasting Ocean Assimilation Model) suite which is run daily and produces 2 analysis days and a 7-day forecast. The FOAM suite now includes an improved resolution version of global FOAM with 1/12 degree horizontal resolution. This will continue to make use of Argo data to constrain the T/S fields in the same way as the original ¼ degree resolution system.
- fields from global FOAM are also used to initialise the ocean component of coupled monthly-to-seasonal forecasts;
- Argo data are also used in the initialisation of ocean conditions in climate models run to make decadal predictions;
- near-surface Argo data are used to validate the output from the Met Office's OSTIA (Operational Sea Surface Temperature and Sea Ice Analysis), where the OSTIA fields are used as a lower boundary condition in numerical weather prediction models run by both the Met Office and ECMWF.

- A global coupled weather forecasting system which is initialised using coupled data assimilation is now running operationally (commenced March 2022). Argo data therefore directly contribute to operational weather forecasts as well as ocean forecasts. An assessment of the impact of Argo in a lower atmospheric-resolution version of that coupled system was detailed in King et al., 2019.

Recent Met Office research & development applications (non-operational) which have made significant use of Argo data:

- a paper was published on OSSEs to investigate potential impact of expanding the Argo array (Mao et al., 2020);
- David Ford has done some OSSEs looking at the impact of the planned BGC-Argo array of floats in a global physical-biogeochemical model where he assimilates synthetic versions of the BGC Argo profiles in conjunction with satellite ocean colour data (Ford, 2021);
- one other project where we made good use of Argo data was in the assimilation of satellite sea surface salinity data from SMOS, Aquarius and SMAP. The near-surface salinity data from Argo was used to bias correct the satellite salinity data and was crucial for the performance of the assimilation of SSS data. That work is written up in Martin et al., 2019.
- Another paper was published investigating impact in FOAM and the Mercator system of satellite SSS assimilation which used Argo for assessment (Martin et al., 2020).
- An additional recent paper has been published (Dong et al., 2021) on improving ocean reanalyses (which make use of Argo data).

In the Hadley Centre for Climate Science and Services, Argo data is used to make the following products:

- EN4 contains in-situ ocean temperature and salinity profiles and objective analyses. It is updated monthly using real-time Argo profiles and GTSPP data, and annually using delayed-mode Argo profiles (and WOD, GTSPP and ASBO data). EN4 is freely available for scientific research use (see http://www.metoffice.gov.uk/hadobs/en4/). The latest version is EN.4.2.2, which includes a fresh download of all the source data and a substantial update to the XBT/MBT correction schemes. EN.4.2.2 contains four ensemble members where previously there was only two. There is also a new product user guide (based on both the Argo Users' Manual and the HadIOD user guide), including FAQs and example code. EN4 is also forming part of a GEWEX EEI project - comparing Ocean Heat Content calculated from reanalyses, in situ data and satellite products (the project website is https://sites.google.com/magellium.fr/eeiassessment/dissemination/documents?authuser=0).
- HadIOD (Hadley Centre Integrated Ocean Database) is a database of in situ surface and subsurface ocean temperature and salinity observations supplemented with additional metadata including bias corrections, uncertainties and quality flags. The dataset is global from 1850-present with monthly updates. The current version is HadIOD.1.2.0.0, the chief sources of data are ICOADS.2.5.1, EN4 and CMEMS drifting buoy data. This product has been available to the public since mid-2020 via https://www.metoffice.gov.uk/hadobs/.

Met Office science uses of the EN4 product include OHC analysis, contributions to BAMS, Ocean Obs'19 White Paper and an Earth Energy Imbalance paper (von Schuckmann et al., 2020).

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## 5. Issues from UK to be considered by AST

None.