UK ARGO PROGRAMME

REPORT FOR ARGO STEERING TEAM 15TH MEETING, MARCH 2014

The UK Argo programme is undertaken by a partnership between the Met Office, the National Oceanography Centre Southampton (NOCS) and the British Oceanographic Data Centre (BODC). The Met Office are responsible for programme management and coordination, organizing float deployments, preparation of floats for deployment, telecommunications (costs) and international contributions. NOCS and BODC have responsibility for Argo science and data management. With the recent expansion of the UK programme into bio-Argo, Plymouth Marine Laboratory (PML) is now also involved.

The most pressing issue for the UK programme remains on securing ongoing funding for UK Argo after March 2015 and, internationally, on continued delivery of data from the core Argo array. It is important that the core Argo array is complemented by the Argo extensions into deeper profiling, bio-geochemistry and high latitudes and that these do not lead to a reduction in core Argo below its target density.

A second issue is ensuring that the GTS data stream, that delivers data to operational users, is successfully migrated to the BUFR format by November 2014 (when the use of TESAC on GTS should cease) without degrading the timeliness of delivery. Also it will be important to ensure that the BUFR format(s) used evolve in parallel to the Argo NetCDF to allow for the exchange of additional profiles (e.g. near-surface and bio-geochemistry).

Floats deployed and their performance

Floats deployed. Since 2001, over 430 UK floats have been deployed (including 7 floats donated to Mauritius) in support of the Argo array. As can be seen from Figure 1, the number of floats purchased each year has been variable as it has often been reliant on the release of end-year under-spend funding. As a result, the number of deployments each year has also been variable, but with an increase over the last 3 years where 119 floats have been deployed, with 38 floats deployed in 2013.

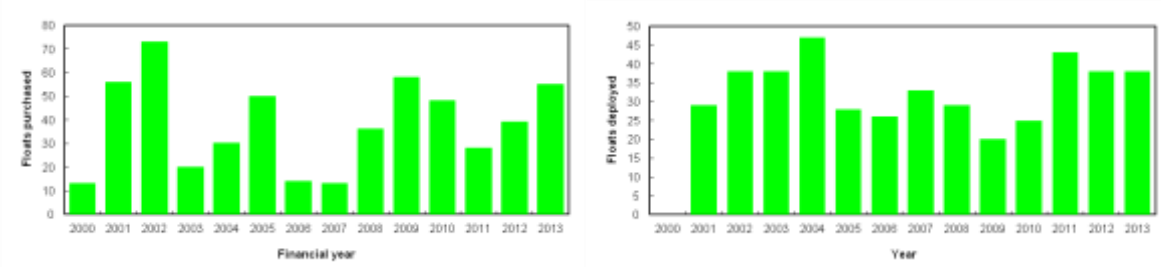

Figure 1. Showing (left) the number of floats procured each financial year (Apr-Mar) and (right) the number deployed in each calendar year.

With the increase in the number of floats deployed in the last 3 years the number of UK floats contributing to Argo (including 6 Apex that were provided to and deployed by Mauritius) has increased from around 100 to around 130, as shown in Figure 2. There are a few active floats for which data processing has not yet been set up, these are not included in Figures 2 and 3.

Figure 2. Number of UK (including Mauritius) floats reporting data to Argo by month.

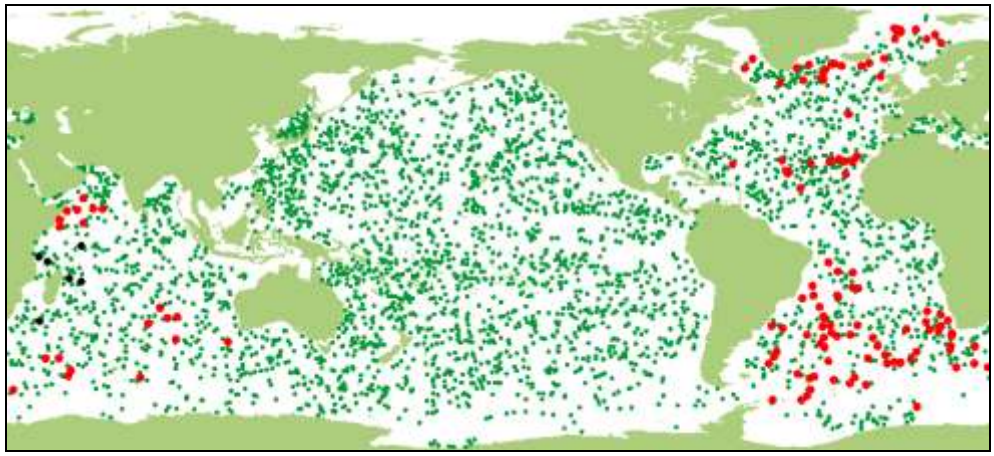

Figure 3. Showing the locations of operating UK floats (in red) and the six Mauritius floats (black) at mid-February 2014.

Float lifetime. The majority of UK floats deployed have been Webb Apex floats, which have seen a steady improvement in reliability (survival) since 2004 in terms of cycles completed, as shown in Figure 4. (Here the number of cycles has been normalised to 2,000m for floats that make shallower profiles, or only make intermittent deep profiles to 2,000m, where invalid profiles due to pressure transducer failure on pre-2004 floats have been discounted and deployment failures omitted.)

For floats deployed 2004-2006 only 66% of floats reached the target 4 year lifetime (140 profiles), whereas for 2007-2009 floats 69% reached this mark, with 8 floats still going strong after 200 profiles. For floats deployed in 2010-2012, 93% have reached the 1 year mark.

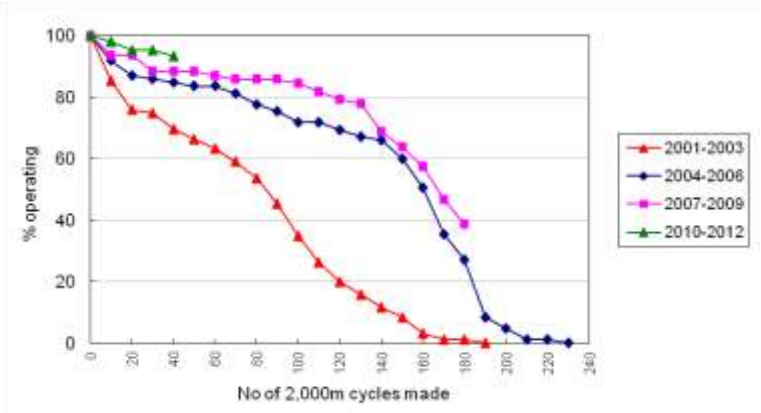

Figure 4. Number of (normalised) cycles made by UK Apex floats deployed in 2001-2003, 2004-2006, 2007-2009 and 2010-2012.

The lifetime of floats can be extended beyond the nominal 4 years by fitting lithium batteries. In 2007 we deployed our first Apex floats with lithium batteries and have since installed

lithiums in over 100 Apex floats. Figure 5 shows lifetime figures from AIC for our floats deployed since 2007. This shows that with alkaline batteries the longest living floats expire after 110 – 200 cycles, while with lithiums a significant number of floats are operating beyond 180 cycles.

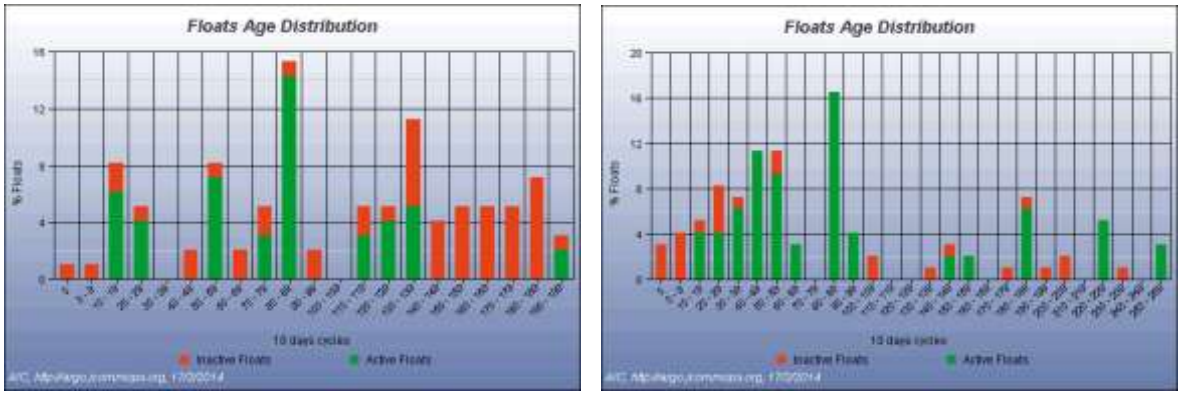

Figure 5. Number of cycles made by UK Apex floats deployed since 2007 with (left) alkaline and (right) lithium batteries. Note the horizontal scales are different.

Float enhancements. Following some early float losses in 2007 to ice damage, since 2008 all Southern Ocean floats considered at risk of ice have been specified with ice-avoidance capability. In 2008 our first 2 Apex Argos floats with near surface temperature measurement capability (un-pumped measurements) were deployed. All our Apex Argos floats (other than those with ice-avoidance) are now ordered with near surface temperature capability.

In 2012 we deployed 13 Webb Apex floats with Iridium communications in the Nordic Seas, 4 of these also carried sensors for dissolved oxygen and chlorophyll fluorescence. In 2013 we deployed (in addition to 27 standard Webb Apex Argos floats) 2 Webb Apex (Iridium) floats, 4 SeaBird Navis floats, 1 MetOcean Nova float (provided free-of-charge by MetOcean), 2 NKE E-AIMS BGC floats and 2 SeaBird Navis (E-AIMS equivalent) BGCi floats. The Navis, Nova and NKE floats all have Iridium communications. During the year the 13 Webb Apex Iridium floats in the Nordic Seas were all switched, using the 2-way communications, to report full (2m) resolution CTD profiles to 2,000m depth.

Deployment plans for 2014

At mid Feb 2014 we have around 45 Apex floats available for deployment, with a further 50 floats expected to be delivered by end March. This should include 2 deep Apex (6,000m depth capability) equipped with SBE61 and oxygen sensors and 2 deep ARVOR (expected depth capability 3,500 – 4,000m) equipped with ruggedized SBE41 and oxygen sensors.

At present, outline deployments in 2014 include:

- 8 floats Southern Ocean/Drake Passage (March/April)
- 6 floats Western Indian Ocean south of Madagascar (May/June)
- 4-8 floats Rockall Trough/Iceland basin (Ragnarroc cruise, June/July)
- 4-6 floats SE Atlantic (SA Agulhas, Sept)
- 4-10 floats S Atlantic (AMT cruise, autumn)
- 2-4 floats for Mauritius

Other deployments will be arranged as opportunities arise. The aim is to deploy around 40 floats during the year, including floats provided to Mauritius. We expect to deploy the deep floats in the North Atlantic later in 2014, on a suitable research cruise with full-depth CTDO.

In addition PML have successfully bid for NERC funding for bio-geochemical floats, and have 11 NKE E-AIMS BGC floats presently on order that. It is expected that these will be deployed from the AMT cruise in the autumn, classed as Argo-equivalents and handled through UK Argo (telecoms and data management).

Data management

The UK Argo Data Centre, established at BODC, processes all our float data (including the floats donated to Mauritius) and also Irish and Portuguese floats. In December 2013 Clare Davis moved on to a post-doc and she has been replaced with 2 members of staff (Charlotte Williams and Katherine Gowers) to provide more resilience when staff change.

Real-time
An automatic system processes the data in real-time and generates the profile data in WMO TESAC and BUFR and Argo netCDF formats. Data from all UK floats are received at BODC by automatic download from the CLS database every 12 hours. The TESAC/BUFR messages are relayed to GTS via the Met Office (EGRR). Almost 100% of GTS messages are available within 24h. Occasional disruptions happen due to email server failures and server problems. Data in netCDF format are also sent (by FTP) to the two GDACs. The real-time processing system operates every 12 hours and delivers data twice daily. The data are also available from the UK Argo Data Centre web-site via an interactive map interface. In addition the technical files are updated once a week.

Delayed-mode
Delayed-mode processing is carried out by BODC using the OW software and the most recent CTD climatology and Argo climatology reference datasets. These are updated when new versions are made available. As of mid February 2014 the percentage of eligible (greater than one year old) profiles on the GDACs in delayed mode is ~80%.

Southern Ocean
BODC works with three other organizations to operate the Southern Ocean Argo Regional Centre (SOARC) covering the entire Southern Ocean. Responsibilities are: BODC - Atlantic Ocean Sector, CSIRO - 'Australian' sector, JAMSTEC - Pacific Ocean Sector and the University of Washington - Indian Ocean Sector. BODC hosts the main SOARC data and information web pages (http://www.bodc.ac.uk/projects/international/argo/southern_ocean/).

On-going development activity
In addition to maintaining progress of previous years on-going development at BODC is focusing on the following:

- Improving the quality of trajectory data distributed by BODC. This is based on the actions decided by the ADMT and output from the ANDRO Atlas.
- Implementation of real-time quality control procedures for un-pumped near surface temperature data from Apex.
- A switch to Argo V3 formats including the real time processing and distribution of data from floats with bio-geochemical sensors and near surface temperature data firmware. The deadline for this to be delivered for an EU project is June 2014. This work will help evaluate the proposal for splitting core Argo and non-core Argo data into different data files.

- Investigation into how persistent identifiers can be assigned to Argo data. This has resulted in an initial proposal that was accepted by the ADMT in 2013 and on-going development to improve this approach with NODC.

Scientific and operational use of Argo data

At the Met Office Argo data are assimilated into FOAM-NEMO (Forecasting Ocean Assimilation Model - Nucleus for European Modelling of the Ocean), see http://www.metoffice.gov.uk/research/weather/ocean-forecasting, which is the Met Office deep ocean forecasting system. It comprises a global ¼ degree model (ORCA025) and nested $^{1}/_{12}$ degree North Atlantic, Mediterranean and Indian Ocean limited area models. The system is run operationally at around 0500 UTC every day. The latest description of FOAM is given by: *Blockley, E. W., Martin, M. J., McLaren, A. J., Ryan, A. G., Waters, J., Lea, D. J., Mirouze, I., Peterson, K. A., Sellar, A., and Storkey, D.: Recent development of the Met Office operational ocean forecasting system: an overview and assessment of the new Global FOAM forecasts, Geosci. Model Dev. Discuss., 6, 6219-6278, doi:10.5194/gmdd-6-6219-2013, 2013*. Also, a paper describing the impact of Argo, and other data types, in FOAM has been accepted and is awaiting publication: *Lea, D.J., M.J. Martin, and P.R. Oke. Demonstrating complementarity of observations in an operational ocean forecasting system. Accepted for publication in Q. J. R. Meteorol. Soc*.

Argo data are also used in the GloSea (Global Seasonal) coupled model run by the Met Office to make seasonal forecasts for several months ahead. Seasonal forecasting is still an area in which the science is being developed. On longer timescales the Hadley Centre DePreSys (Decadal Prediction System) is being developed for climate predictions on decadal timescales, where the impact of Argo data on decadal climate forecasts has been demonstrated through idealised experiments. See http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal.

As part of the FP7 E-AIMS project work is ongoing to assess the impact of Argo data on the predictions from weather, seasonal and decadal forecasting models. This will be done by performing Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) by withholding Argo data from the models. It is expected that the near-surface ocean is most important for short-timescales, for medium-range to monthly prediction it is likely that the upper few hundred metres of the ocean will be more important than the deeper ocean and the longer the prediction horizon becomes (from seasonal to decadal) the more important the deeper ocean becomes. Also under the E-AIMS project work will be carried out to assess the impact of Argo observations on the validation of satellite SST observations and joint in-situ/satellite SST analyses (e.g. the Met Office OSTIA product and the GHRSST Multi-Product Ensemble (GMPE)).

The Hadley Centre also maintains the HadGOA (sub-surface global analysis) dataset of historical temperature and salinity. The dataset includes available Argo data and will include near real-time updates using Argo data. The dataset is used for global ocean heat content analyses. For further information see http://www.metoffice.gov.uk/research/climate/climate-monitoring/oceans-and-sea-ice.

During the year the "EN" database was updated to EN4. This is a database of ocean temperature and salinity profiles obtained across the global oceans over the period 1900 to the present to which a series of quality control checks have been applied. Associated with this are monthly objective analyses with uncertainty estimates. See *Good, S. A., M. J. Martin and N. A. Rayner, 2013. EN4: quality controlled ocean temperature and salinity profiles and monthly objective analyses with uncertainty estimates, Journal of Geophysical Research:*

Oceans, 118, 6704-6716, doi:10.1002/2013JC009067 for details of how the dataset was constructed. The data are available from: http://www.metoffice.gov.uk/hadobs/en4/.

Funding

It was initially agreed in 1999 that MoD and DETR (then Defra and now DECC) would provide matching funding (through the Met Office) for UK Argo, and that NERC would also provide regular funding for support activities (e.g. data processing, science leadership) with additional capital funding for floats being provided on an opportunistic basis (e.g. via open calls for proposals). The matched funding agreement collapsed after MoD withdrew its funding in April 2010. Regular annual funding from DECC (ex Defra) to the Met Office has also reduced, although it has been supplemented in most years with year-end funding for floats. NERC has maintained regular, stable funding for support activities at NOCS and BODC, whilst funding for floats has remained variable relying largely on bids for NERC capital funds and year-end funds. Hence, the funding profile for UK Argo has exhibited large year-to-year variations.

For the period April 2012 to March 2015 the Met Office (Public Weather Service Programme) has agreed to co-fund UK Argo with DECC and a MoU has been signed off. NERC will continue to fund its Argo support activities at NOCS and BODC. However the committed funding is only sufficient to pay for support activities and does not include provision for procuring floats, although additional funding for float purchases has been made available in both 2012 and 2013 (as shown in Figure 1). While the current agreement provides some stability for the 3 years to March 2015, there is still a risk that by April 2015 there is no longer term agreement.

The funding outlook for data management is potentially very good. On-going national capability support from NERC has been sustained and the European E-AIMS project is supporting the development needed for Bio-Argo. In addition to this further resource at the bidding or proposal stage includes Bio-Argo support as part of the EU AtlantOS proposal and Core Argo support to host the processing of Euro-Argo floats for DG-MARE.

Euro-Argo

The Euro-Argo ERIC is expected to be formally established within the next 6 months. The Met Office, under delegated authority from BIS, has committed the UK to becoming a full member of Euro-Argo.

Work on the Euro-Argo FP7 SIDERI project continued to the end of the project in December 2013, with a number of reports prepared on legal and policy (e.g. UNCLOS, EEZ) issues, how Argo should relate to (or interface with) the emerging WIGOS (WMO Integrated Global Observing System) and with further contributions to the Euro-Argo Roadmap. Also through the Euro-Argo E-AIMS FP7 project 50% funding was provided for 2 floats with bio-geochemical sensors and 2 floats with new (Iridium) communications (all deployed during autumn 2013), developing the data processing capability at BODC (as noted above) for these floats and evaluation of the data for the bio-geochemical floats (via a contract with PML) and capability of the Iridium floats. As noted earlier, E-AIMS is also supporting work on assessing the impact of Argo data on forecasts using a coupled ocean-atmosphere model and for validation of satellite SST products and SST analyses.