UK ARGO PROGRAMME

REPORT FOR ARGO STEERING TEAM 13TH MEETING, MARCH 2012

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.

The most pressing issue for the UK programme remains on securing continuing and ongoing funding for UK Argo, and internationally on ensuring the long-term delivery of data from the global Argo float array.

Floats deployed and their performance

Floats deployed. Since 2001, over 315 floats have been deployed (including 5 floats donated to Mauritius) in support of the Argo array. As can be seen from Figure 1 below the number of floats purchased each year has been very variable, often due to funding being supplemented by end-of-year under-spend monies. As a result, the number of deployments each year has also been variable. In 2011 we deployed 43 floats which is a distinct improvement on recent years, being the most we have managed since 2004. So far 7 floats have been deployed in 2012. At the present we have 132 active floats (including 4 that were provided to and deployed by Mauritius in 2011) contributing to the global Argo array, see Figure 2.

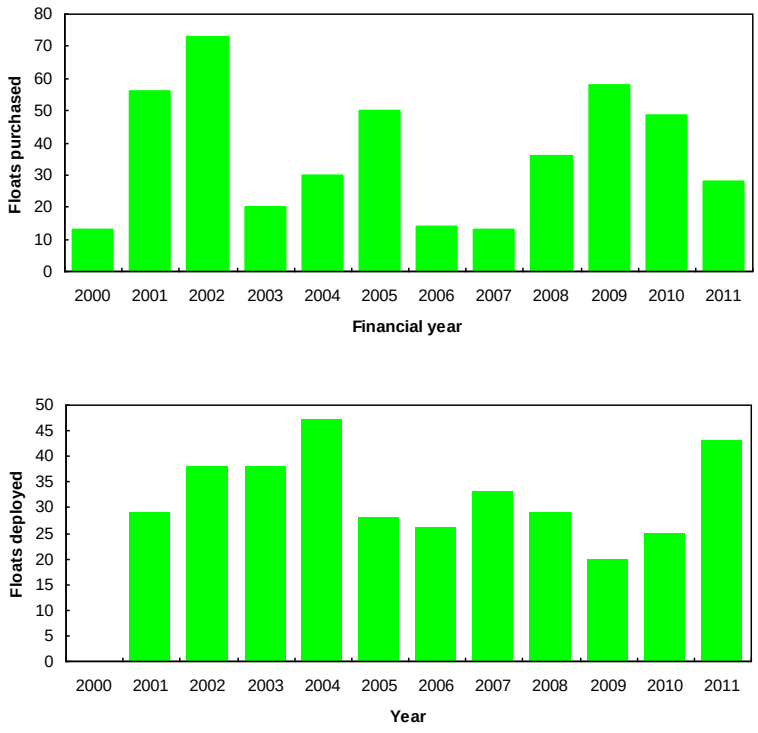

Figure 1. Showing (top) the number of floats procured each financial year (Apr-Mar) and (bottom) deployed in each calendar year.

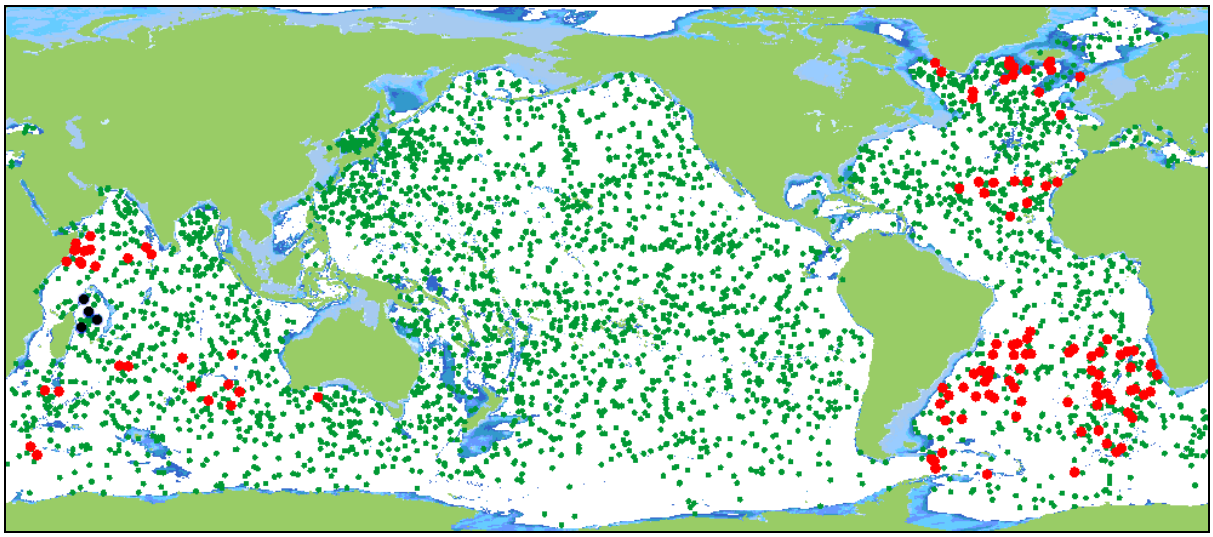

Figure 2. Showing the locations of operating UK floats (in red) and the four Mauritian floats (in black) in mid-February 2012.

With the increase in the number of floats deployed in 2011 the number of UK floats contributing to Argo has increased to over 130, as shown in Figure 3.

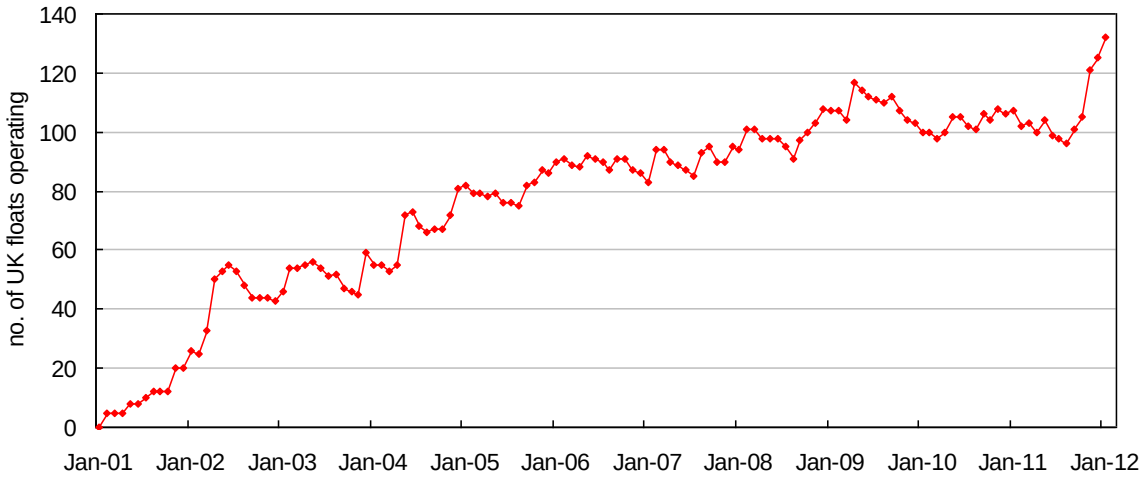

Figure 3. Number of active UK (including Mauritius) floats contributing to Argo by month.

Float performance. There has been a distinct improvement in the survival of our Apex floats deployed since 2004 compared to those deployed in the earlier years in terms of cycles completed (normalised to 2,000m for floats that make shallower profiles or only profile to 2,000m intermittently, with invalid cycles due to pressure transducer failure discounted and deployment failures omitted), as shown in Figure 4.

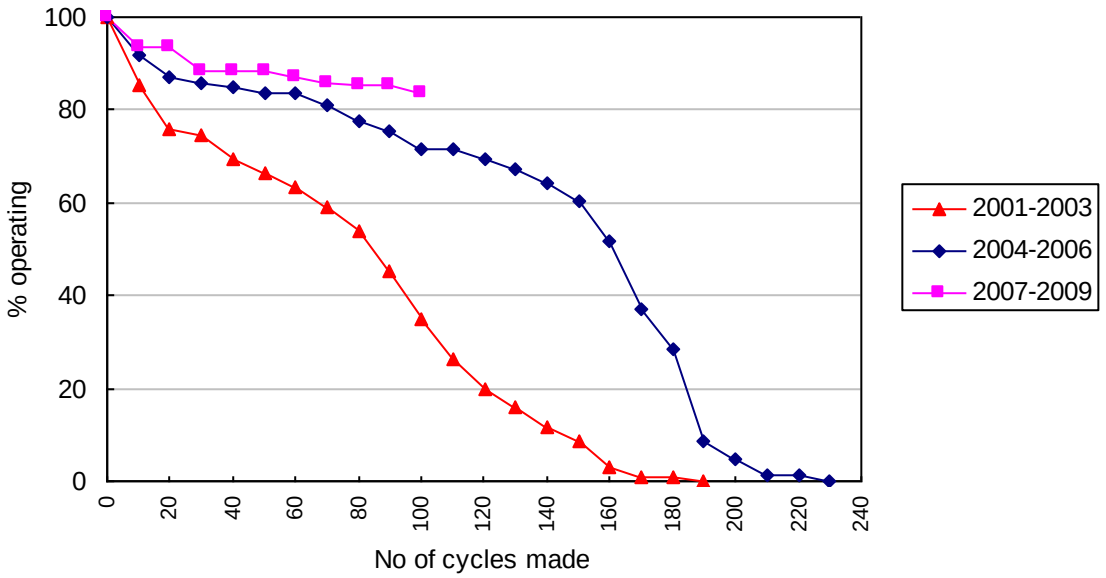

Figure 4. Number of (normalised) cycles made by UK Apex floats deployed in 2001-2003, 2004-2006 and 2007-2010.

Only 30-40% of Apex floats deployed before 2004 made more than 100 cycles, whereas for floats deployed 2004 to 2006 and 2007 to 2010, 72% and 84% of floats reached the 100 cycle mark.

Following some early float losses to ice damage in 2007, since 2008 all new Southern Ocean floats considered at risk of ice have been specified with ice-avoidance capability. So far 17 floats with ice-avoidance have been deployed and none have failed due to ice damage. In 2007 we deployed our first Apex floats with lithium batteries and have since deployed 65 floats with lithiums.

In 2008 our first 2 Apex floats with near surface temperature measurement capability (un-pumped measurements) were deployed, with 63 SST-capable floats having now been deployed.

As yet all of our floats have used Argos for communications, however 13 of the 28 Apex floats currently on order will use Iridium, 4 of these Iridium floats will also carry dissolved oxygen and chlorophyll fluorescence sensors.

Deployment plans for 2012

At the end of Feb 2012 we have around 50 Apex floats available for deployment, with a further 28 floats expected to be delivered by end March 2012. Anticipated deployments in 2012 include:

4 floats Rockall Trough/Iceland basin (Extended Ellett Line July)
13 floats Nordic Seas (summer)
5 floats N Atlantic 26N (RAPID cruise Oct/Nov)
2 (possibly more) floats SE Atlantic (SA Agulhas Sept)
2 (possibly more) floats S Atlantic (AMT cruise autumn)
6 floats Southern Ocean/Drake Passage (winter 2012/13)
2-4 floats near Mauritius

With 9 floats available for the Arabian Sea, 6 for the Somali Basin and 2 for South Indian Ocean. The expectation would be to deploy around 40 floats (including those provided to Mauritius).

Data management

The UK Argo Data Centre, established at BODC, processes all our float data (including the floats donated to Mauritius and also floats for the Irish Argo programme).

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. 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 and these files are provided to CSIRO Marine to populate the technical web-site.

Delayed-mode
Delayed-mode processing is carried out by BODC using the OW software and the CTD_for_DMQC_V1 and ARGO_for_DMQC_V02 reference datasets. Reference data are updated when new versions are available. During the summer of 2010 the backlog in DMQC of BODC hosted (Argo UK, Ireland, Mauritius, Saudi Arabia) Argo profiles was cleared. As of October 2011, 98.9% of eligible BODC profiles (profiles older than one year) had been submitted to the GDACs in delayed mode.

Southern Ocean
BODC works with three other organizations to operate a 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.
- Development of real time quality control procedures for un-pumped near surface temperature data from APEX floats and inclusion of in profile file submitted to the GDACs

Reference CTD data
At the Argo Data Management Team meeting in 2012 the link between BODC and CCHDO was restored. This included an initial submission of ~3,500 CTD profiles in BODC holdings for use in the Argo delayed mode reference climatology. The aim is to develop the link with further submissions of CTD data in 2012 and an eventual move towards automated submission of data to CCDHO (plus NODC and ICES) when data are banked at BODC.

The delayed mode cookbook information produced by BODC in previous years has also been supplied to Steve Diggs who is using this information to identify areas where the current reference data/climatology is in need of enhancement so these areas can be

prioritised when seeking new data for inclusion in the climatology. This approach has already been fruitful in the Northwest Atlantic.

Scientific and operational use of Argo data

Argo has an open data policy which means that all Argo data are freely available without any restrictions, for both scientific research and operational applications. In recent years there have been between 100 and 120 Argo based papers per year, of which between 10 and 15% have a UK lead author or co-author.

At the Met Office Argo data are assimilated into FOAM (Forecasting Ocean Assimilation Model), 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. GODAE OceanView (https://www.godae-oceanview.org/), an international group dedicated to collaborating on research and development of ocean data assimilation systems, have been developing methods of assessing the impact of observations on ocean data assimilation systems. Last year, to test these ideas, the Met Office performed a series of experiments to assess the impact of different observing systems on its FOAM system, including the impact of excluding all Argo temperature and salinity data for 1 month (July 2011). One method to assess the model is the fit to observations before they are assimilated. The fit to both profile temperature and salinity is 5% worse without Argo as shown in Table 1. However, it should be noted that one month may not be long enough to see the full impact of removing Argo data as previous experience suggests that the subsurface can take a year or more to spin-up (or spin-down).

	Operational	No Argo
Profile T / ºC	0.680	0.728
Profile S / psu	0.132	0.139

Table 1. Summary observation minus background RMS accumulated globally over July 2011.
2011.

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. Such forecasts are more reliable for tropical regions (such as the Sahel, East Africa and north-east Brazil) than for temperate climates and 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 assessed in idealised experiments. For further information and experimental forecasts see http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal.

A recent climate model-based study, by Matt Palmer and colleagues in the Hadley Centre[1], into the relationships between sea surface temperature (SST) and ocean heat content (OHC) with the top of the atmosphere radiation balance suggests the need to measure OHC deeper than 2,000 m (ideally to 4,000 m) to reduce decadal variability in the longer-term climate change signal. The findings highlight the need to sustain the Argo observations to 2000 m and provide strong motivation for the development of a deep ocean observing array.

[1] Palmer, M. D., D. J. McNeall, and N. J. Dunstone (2011), Importance of the deep ocean for estimating decadal changes in Earth's radiation balance, Geophys. Res. Lett., 38, L13707, doi:10.1029/2011GL047835

The Hadley Centre also maintains the HadGOA (sub-surface global analysis) dataset of historical temperature and salinity. Variables are on a 2-degree grid and computed on number of fixed isotherms and fixed depths at monthly resolution. 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.

Research using Argo data at NOC is carried forward mainly, though not exclusively, through graduate students. Projects include: upper ocean circulation and variability in the North Atlantic, ocean correlation scales in the Pacific and Atlantic oceans, seasonal to decadal variations in water mass properties in the SE Pacific/Drake Passage/Atlantic sector of the Southern Ocean, decadal changes in intermediate and thermocline water properties in the subtropical South Atlantic. Also, the NOC satellite oceanography group is involved in ground truth for SMOS and is evaluating ways in which Argo near-surface data can be used for SMOS evaluation.

The data are used extensively in a wide range of research projects in UK Universities and research laboratories and is a central component of several PhD and MSc projects covering a broad range of topics including water mass properties and formation, air-sea interaction, ocean circulation, mesoscale eddies, ocean dynamics and seasonal-to-decadal variability.

The GHRSST (Group for High Resolution Sea Surface Temperature) community is now using Argo data to provide validation of various gap-free (Level 4 or L4) SST analysis products. The Argo data provide a good estimate of foundation SST (the SST free of diurnal warming). As the Argo data are not used in the L4 analyses, the data provide a high quality independent source of data for validation of the foundation SST. The GHRSST Multi-Product Ensemble (GMPE) system is run on a daily basis at the Met Office, taking various L4 analyses as inputs, transfers them onto a common grid, and produces an ensemble median and standard deviation. Validation against Argo data (at 3 to 5 m depth) has shown that the GMPE median is more accurate than any of the contributing analyses with a standard deviation error of 0.40K globally with respect to the near-surface Argo data. The results[2] will be published in a Deep Sea Research II Special Issue on Satellite Oceanography and Climate Change.

Work has continued to gather and analyze the available near-surface unpumped temperature (NST) data in collaboration with GHRSST. BODC has collected the data from UK, US, Japanese, and Indian NST capable floats. The data (to May 2011) were analyzed by Sarah Quinn (Reading University) as an MSc dissertation project in collaboration with Andrea Kaiser-Weiss (GHRSST Project Coordinator) and Prof. Keith Haines. After accounting for pressure sensor drift (required so that an accurate depth could be determined), evidence of diurnal warming (defined as a $\Delta T > 0.5°C$ between 10m and the surface) was seen in 62 profiles from 26 different floats, with a maximum ΔT of 2.4°C, diurnal mixing layers between 0.1m and 8m thick; various vertical diurnal structures were observed where in some cases the stratification probably reflects remnants of diurnal structures from the previous day(s). Some examples are shown in the following figures (showing the top ten metres).

[2] Group for High Resolution Sea Surface Temperature 1 (GHRSST) Analysis Fields Inter-Comparisons: Part 1. A GHRSST Multi-Product Ensemble (GMPE). Matthew Martina, Prasanjit Dashb, Alexander Ignatov, Viva Banzond, Helen Beggs, Bruce Brasnett, Jean-Francois Cayulag, James Cummings, Craig Donlon, Chelle Gentemann, Robert Grumbine, Shiro Ishizaki, Eileen Maturi, Richard W. Reynolds, Jonah Roberts-Jones.

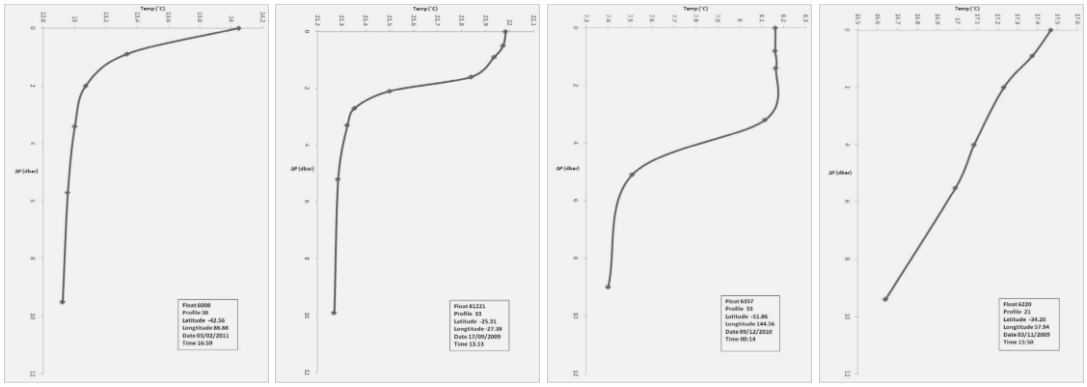

Figure 5. Examples of various diurnal mixed layer structures observed by NST capable Argo floats.

At this stage the accuracy of the un-pumped Argo measurements has not been verified and it is not known whether they are less accurate (or by how much), compared to the standard Argo pumped measurements, nevertheless the results do demonstrate the ability of such floats to record significant near-surface stratification that would otherwise be missed and provide information of value to the GHRSST community. The data from all the NST-capable floats, including Scripp's Iridium floats that sample (with the pump running) at 1db (with 1m bins above 10m). At present (late February) there are over 200 un-pumped Apex floats deployed plus 75 (or more) NST capable Iridium floats. It is proposed to analyze the now much larger data set ahead of the Argo Science Workshop in September 2012.

Funding

It was initially agreed in 1999 that MoD and DETR (then Defra, Dept of Environment, Fisheries and Rural Affairs and now DECC, Dept of Energy and Climate Change) would provide matching funding (through the Met Office) for UK Argo, and that NERC would also provide funding and support through NOCS and BODC. This agreement collapsed after MoD withdrew its funding to the Met Office in April 2010. Regular funding from DECC (ex Defra) to the Met Office has also reduced, although it has been supplemented in most years with year-end under-spend funding for floats. Hence the funding profile has exhibited large year-to-year variations. Securing an adequate level of regular funding for UK Argo activities at the Met Office remains an issue, particularly with the cessation of the MoD funding in 2010. In the last few years, funding for personnel (programme management, coordination and technical support) has been at a minimal level and has not kept up with the funding for floats.

NERC funding has also been variable due to funding for floats relying largely on bids to thematic programmes and end-of-year under-spends, although the regular NERC funding for support activities (e.g. data processing, science leadership) has been relatively stable. In its review of National Capability NERC has prioritised resource spend on Argo highly and the NERC asset management strategy (capital funding for floats) has Argo high on the list. This is based on the assumption that the Met Office will continue to be funded to manage and operate the programme and also procure floats.

During 2011 various meeting were held with DECC and other government departments to try and identify those departments who benefit from Argo and could contribute to costs. However, these approaches have not yielded any additional funding. The Argo funding issue has also been raised to the cross government Marine Science Coordination Committee (http://www.defra.gov.uk/mscc/) and in February 2012 a meeting was arranged by the Government's Chief Scientific Advisor to discuss funding and governance arrangements for core long term observational programmes (such as Argo).

However, in order to try and resolve the funding problems for the next few years the Met Office is in discussion with DECC on the possibility of part-funding the programme management costs (staff, communications, international subscriptions) from the Public Weather Service programme (http://www.metoffice.gov.uk/services/public/about). These discussions are ongoing and it is expected that additional DECC and/or NERC funding for floats will continue to be made available.

Euro-Argo

Both the Met Office and NERC were involved in the Euro-Argo project (completed June 2011) to develop and establish a longer-term European infrastructure for Argo – the Euro-Argo ERIC (European Research Infrastructure Consortium). The expected timescale for establishing the Euro-Argo ERIC is summer 2012. DECC had previously indicated that UK should become full members of the ERIC, however in June 2011 they decided they were not able to put forward a Minister who could sign up to the ERIC on behalf of the UK, as the funding issues needed to be resolved. At present (late-February) UK is still unable to commit to becoming a member of the Euro-Argo ERIC.

Both the Met Office and NERC are partners in the FP7 SIDERI (Strengthening the International Dimension of Euro-Argo Research Infrastructure) project (December 2011 to November 2013) and the FP7 E-AIMS (Euro-Argo Improvements for the Marine Service) proposal which has been submitted to the EC. SIDERI will provide funding for studies on legal and policy (e.g. EEZ) issues, how the Argo data system links into the emerging WMO Integrated Global Observing System (WIGOS), enhancing data management capability (at BODC), while maintaining outreach activities (the Euro-Argo educational web-site hosted by NOCS) and supporting international engagement.