UK ARGO PROGRAMME

REPORT FOR ARGO STEERING TEAM 8TH MEETING, MARCH 2007

Background and present status

The UK Argo programme is undertaken by a partnership which was developed following discussions between the NOAA Administrator and the Chief Scientific Advisor (CSA) in 1999. It has been funded by UK government through the Department for Environment, Food and Rural Affairs (Defra) (www.defra.gov.uk), the Ministry of Defence (MoD) (www.mod.uk) and the Natural Environment Research Council (NERC) (www.nerc.ac.uk) and is carried out in collaboration between the Met Office (who manage the programme), the National Oceanography Centre Southampton (NOCS), the British Oceanographic Data Centre (BODC) and the UK Hydrographic Office (UKHO). The UK programme was initiated in 2000, with our first Argo floats being deployed in January 2001, and is presently in the process of transitioning to a sustained (or operational) basis.

Floats deployed

Since 2001, over 200 UK floats (including 5 donated to Mauritius) have been deployed in a number of different geographic areas, where deployments have focused on meeting specific UK requirements, while also contributing to the global array.

Year	*UK Argo floats*	*Argo equivalent floats*
2001	*27*	*2*
2002	*34*	*4*
2003	*22 (1)*	*15*
2004	*45 (2)*	*0*
2005	*28*	*0*
2006	*24 (2)*	*0*
2007	*45*	*2*

Table 1. Numbers of UK floats contributing to Argo deployed by year, figures in brackets are floats donated to and deployed by Mauritius. Estimated figures are given for 2007 (for which 12 floats have been deployed so far).

The interests of the UK are global but with special interests in the Atlantic and Southern Ocean. However, because other countries have committed a sufficient number of floats to the North Atlantic, UK Argo has only deployed a relatively small number of floats in that region. In particular UK Argo has taken a lead in deploying floats in other regions (e.g. North west Indian Ocean, South Indian Ocean, South Atlantic and Southern Ocean), as shown in Fig. 1, to help in establishing the global array. This has involved developing partnerships with other countries to assist in deploying UK floats, including South Africa, Mauritius, Norway, Mozambique, Iceland as well as US and France

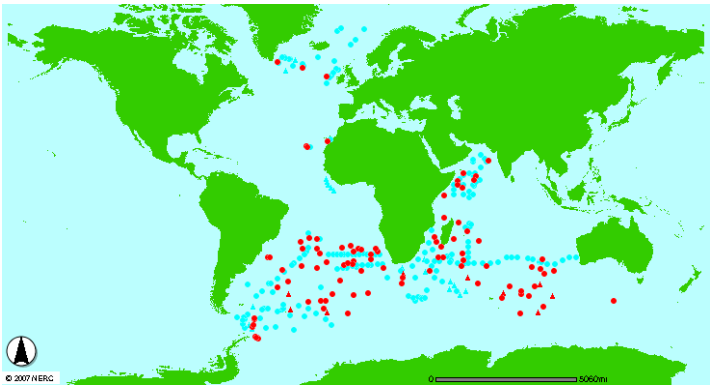

Figure 1. Locations of UK floats (•) when deployed and (•) those currently operating.

Float survivability

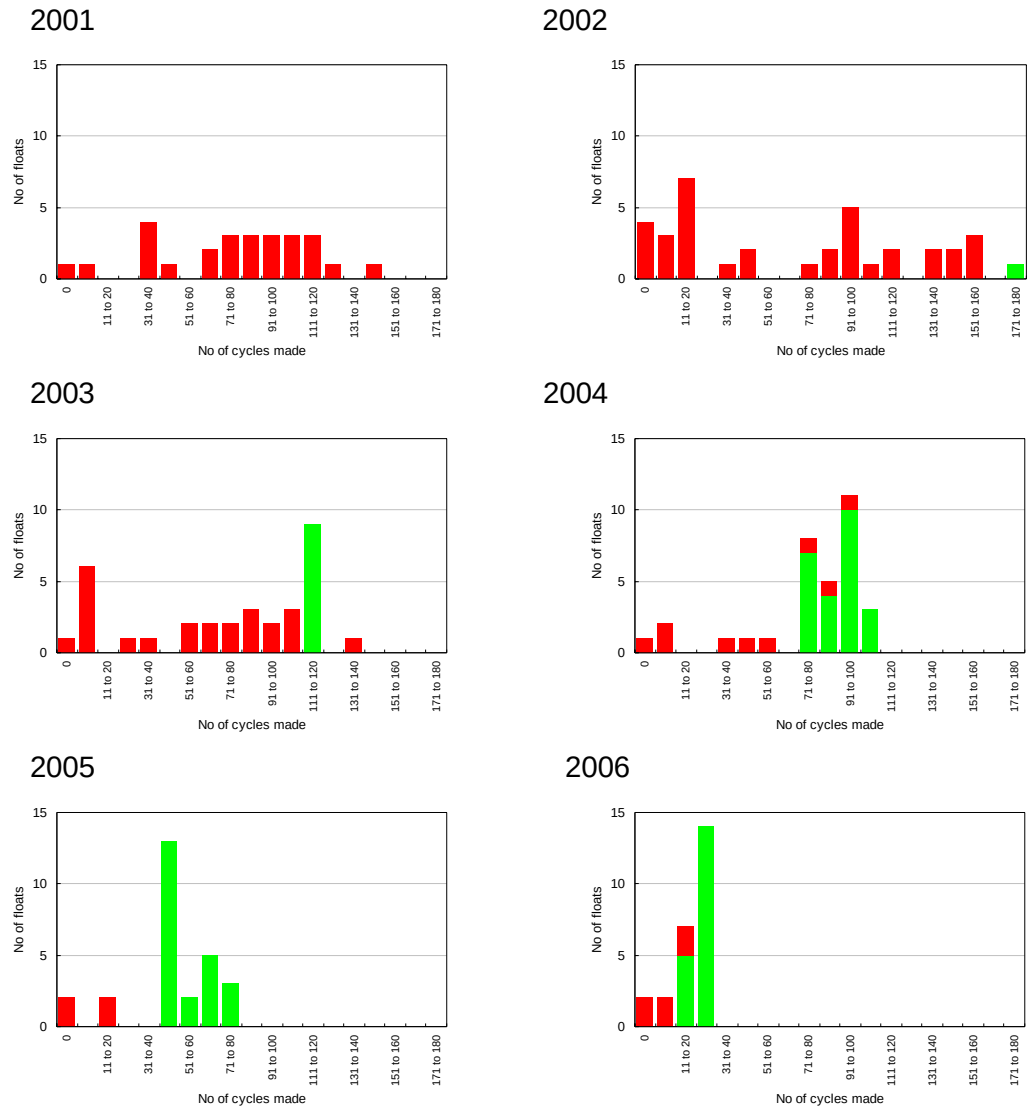

Figure 2. Showing the numbers of full-depth profiles completed for active (green) and dead (red) Apex floats grouped against year of deployment. Figures exclude floats where deployment failure has been confirmed. The number of cycles is adjusted for those floats that have shallower profiles or only profile deep intermittently.

The figures above, for Webb Apex floats, clearly show the relatively high number of early failures for floats deployed in 2002 (motor backspin) and 2003 (pressure transducer), with a

reduction in early failures for floats deployed from 2004. The oldest surviving float (from 2002) has now made 177 cycles (nearly 5 years of operation).

Of the 26 floats (all Apex) deployed in 2006, 3 failed very early (2 failed to report any profiles and 1 stopped after 2 profiles) – initial transmissions were received from these 3 floats and the failures may be due to failed air bladders (problem identified during January 2007).

The figures below shows similar statistics for the MARTEC Provor floats. As fewer of these have been deployed the figures are grouped for floats deployed in 2001 to 2003 and 2004/2005. The more recent (2004/05) Provors have demonstrated greater reliability than the earlier Provors.

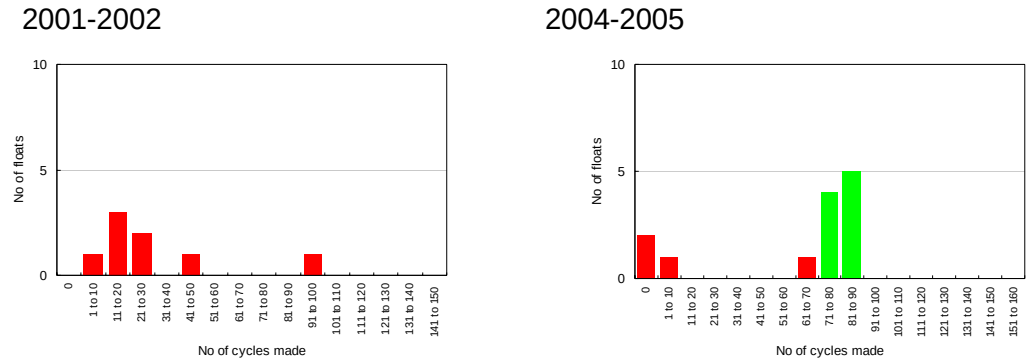

Figure 3. Showing the numbers of full-depth profiles completed for active (green) and dead (red) Provor floats grouped against years of deployment. Figures exclude floats where deployment failure has been confirmed.

Apex float monitoring

In addition we have established a partnership with Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) to monitor the performance of deployed UK (and Australian) Apex floats where an engineering web-site for UK and Australian Apex floats has been established (see http://www.cmar.csiro.au/argo/tech/). This work helps to identify areas where further improvements to the float technology can be made.

Deployment plans

As at end February 2007, we have deployed 12 floats in 2007 and have another 39 floats available for deployment, as shown in Table 2 (over).

Data management

The UK Argo Data Centre, which is established at BODC, processes all our float data. New floats are added into the system as they are deployed and metadata compiled; a metadata netCDF file is generated for each float and forwarded to the 2 Argo Global Data Assembly Centres (GDACS) in France (Coriolis) and the US (USGODAE).

Real-time data processing

An automatic real-time processing system has been developed and is operational. This downloads, twice daily, the raw (hexadecimal) data from CLS, decodes the data stream, carries out an agreed suite of automatic quality control tests (adding quality flags to the data as necessary), and generates profile and trajectory data files in the internationally agreed

12 floats deployed so far in 2007	
South-east Indian Ocean	*4 Apex floats with lithium batteries deployed from MSC Didem in January.*
Weddell Sea	*4 Apex floats to be deployed by UEA from RRS James Clark Ross in February – with ice avoidance capability - includes 2 NERC-funded Argo-equivalent floats*
Southern Ocean	*4 Apex floats (with lithium batteries) deployed from RRS James Clark Ross in February*
Floats for which deployments are scheduled (4 floats)	
South-east Atlantic (40S)	*4 Apex floats to be deployed from SA Agulhas in September*
Floats for which deployments have not yet been scheduled (35 floats)	
South Indian Ocean	*6 Apex floats*
North-east Atlantic (Iceland Basin)	*5 Apex floats (NOCS to deploy)*
North-east Atlantic (26N)	*2 Apex floats (NOCS to deploy)*
Southern Ocean	*7 Apex floats*
Arabian Sea	*5 Apex floats (VOS)*
Somali Basin	*5 Apex floats (VOS)*
tbd	*5 refurbished Provor floats*

Table 2. Floats deployed and available for deployment in 2007.

formats. The UK Argo Data Centre web-site is automatically updated daily with UK float status information, a map of current float positions and temperature and salinity profile plots.

The automatic real-time system generates the float data in both WMO TESAC and Argo netcdf formats. The TESAC messages are automatically emailed to the Met Office where they are then disseminated on the GTS via Exeter (EGGR) – this system was tested during summer 2006 and implemented operationally from September (from when TESAC messages for our floats were no longer issued through Toulouse). GTS (and in the future the WMO Weather Information System) will remain the primary mechanism for receipt by National Meteorological Services of real-time data (float, buoys and ship data etc.) needed for meteorological and ocean forecasting.

The data in netcdf format are also provided (by FTP) to the two GDACs, generally within 24 hours of receipt, and are also available from the UK Argo Data Centre web-site via an interactive map interface.

Delayed-mode data processing

This is carried out by BODC with support from the UKHO. In the last year a substantial number of floats have been processed. While the adjustments to the float data have been agreed, modifications are needed to the software used to generate the delayed-mode netcdf file. These should be completed shortly and the data submitted to the GDACs. The delayed-mode processing has focused on floats from the South Indian Ocean and South Atlantic with a few from the North Atlantic and Southern Ocean. A new member of staff will join BODC in March to work on the delayed-mode QC and it is anticipated that the backlog in data needing to be processed will be significantly reduced during 2007.

Southern Ocean Argo Regional Centre (SOARC)

As noted earlier, the UK has particular interest in the Southern Ocean and has taken the lead in establishing the SOARC, which is a collaborative effort between BODC and CSIRO. BODC has primary responsibility for the South Atlantic and western Indian Ocean sectors of the Southern Ocean, while CSIRO have responsibility for the eastern Indian Ocean sector and the region around Australasia. Work has concentrated on acquiring recent CTD data to improve the reference data set for the Southern Ocean needed for scientific QC of the float data. New web pages for the Southern Ocean Argo regional Centre have been launched with an interactive map which provides links to the GDACs for retrieving float data.

Operational and scientific use of Argo data

A key aspect of the UK Argo programme is to develop the capabilities to fully exploit all Argo data for operational forecasting and research applications, as summarized below. Further details are given in the UK report for Agenda Item 7.

Operational ocean forecasting

All Argo data (alongside other in-situ and remotely sensed ocean data) are routinely assimilated into the FOAM operational ocean forecasting system run by the National Centre for Ocean Forecasting (NCOF). Assessments have clearly demonstrated the positive impact of Argo data on ocean predictions, with a significant improvement in the accuracy of temperature and salinity predictions through the top 1,000m of the ocean. Argo data have also been used to improve and validate the mixed layer model used in FOAM. Within NCOF research work continues to improve the assimilation methods used.

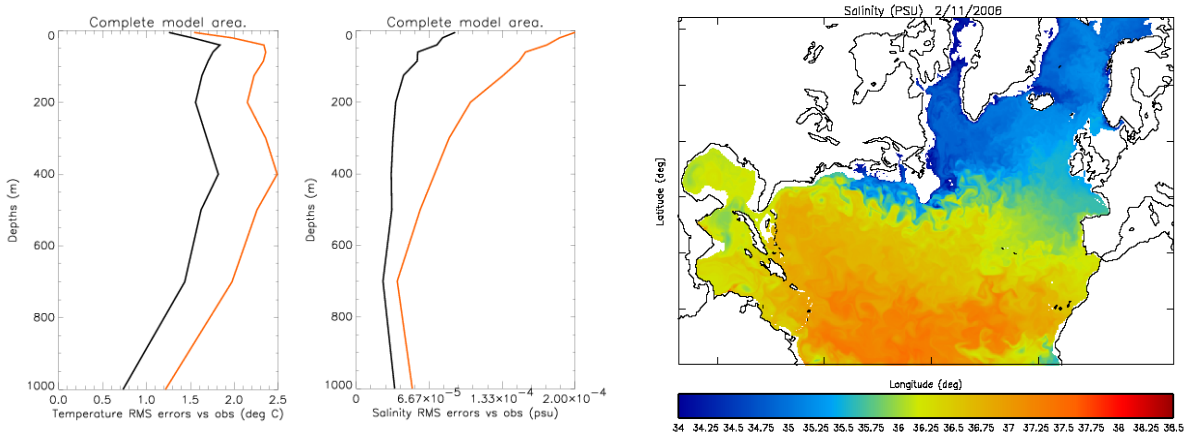

Figure 4. Left, RMS errors in temperature and salinity analyses compared to in situ profile observations, the orange curve is when Argo data are withheld. Right, example of FOAM output for the North Atlantic.

Seasonal forecasting

The Met Office produces a forecast out to six-months ahead once a month using a coupled atmosphere-ocean general circulation model. Data-withholding experiments have shown the benefits of using Argo data in being better able to define the initial ocean state. Argo data from the North Atlantic are now also used to monitor ocean temperature anomaly patterns in the summer, as these can be used to predict the probability of winter conditions (related to the North Atlantic Oscillation) over western Europe.

In particular Argo data were used in examining temperature anomalies for the North Atlantic during 2005 and provided observational evidence for the basis of the forecast issued in October 2005 of a two in three chance of a colder-than-average (and drier-than-average) winter for much of Europe. This forecast attracted considerable government and media attention in the UK[1] – and four out of five predicted events actually happened.

WINTER REVIEW		
	Prediction	**Outcome**
Mean temperature across Europe	Most likely colder than average	Colder than average for many areas
UK mean temperature	Most likely colder than average	Warmer than average
Southern UK mean temperature	Most likely colder than average	Colder than average
UK precipitation	Most likely drier than average	Drier than average
North Atlantic Oscillation (NAO) for the winter season	Negative	Negative

Table 3. Verification of winter forecast for 2005/06.

Since then the Met Office has been designated a Long-Range Forecasting Centre by WMO. Although other centres received this designation, the Met Office is the only centre to meet all the criteria.

Climate monitoring and prediction

Argo data are also used for ocean climate monitoring (e.g. ocean heat content) and will be used by the Hadley Centre with climate models to make decadal climate predictions. By measuring changes in ocean temperature and salinity using Argo data it is possible to observe the integrated effect of surface climate changes over the ocean. The increased spatial and temporal resolution of temperature and salinity data from Argo are already helping to understand better the variability of the climate system, as demonstrated by results from UK floats deployed in the South Indian Ocean – where the data and recent climate model simulations suggest changes between the 1960s and 2002 (previously thought to be a freshening trend) are best explained by internal variability of the climate system. Argo data will continue to be used by the Hadley Centre and NOCS to further our understanding of, and ability to predict, climate change.

The Hadley Centre are developing the HadGOA dataset (see http://hadobs.metoffice.com/hadgoa), a new ocean analysis of historical temperature and salinity suitable for climate model validation, evaluation of historical ocean heat content variability and more general climate monitoring, based on observed data (now mainly Argo). HadGOA will provide an important addition to the key global climate datasets maintained by the Hadley Centre for the climate research community.

Ocean science

Argo data are being used by many researchers in UK on improving understanding of ocean properties (e.g. circulation, heat storage and budget, and mixing) and on how they are applied in ocean models (e.g. improved salinity assimilation, mixed layer forecasting and seasonal forecasting). This includes many scientists from outside of the UK Argo community. The UK Argo Users' Group provides a forum for engagement between these scientists and the UK Argo programme.

[1] Weather, December 2006, Vol 61, No. 12. Special issue on 2005/06 winter forecasting – methodology and accuracy.

Funding

As noted earlier the UK Argo Project has been funded by Defra and MoD (through the Met Office) and by NERC (through NOCS and BODC), in addition MoD also funds UKHO support for Argo data processing.

The need for longer-term funding for UK Argo has been recognised by two important cross-government committees, the Inter Agency Committee on Marine Science and Technology (IACMST) (http://www.marine.gov.uk) and the Global Environment Change Committee (GECC) (http://www.ukgecc.org), as Argo is recognised as being a key component of the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS)[2] to which the UK has made commitments. Argo is specifically mentioned in the GEOSS Implementation Plan to which the UK made a high profile ministerial commitment (Defra minister Lord Whitty) in February 2005.

UK government has stated that climate change is the greatest environmental challenge facing the world today. Marine issues have also been identified as one of the top 10 issues for Defra for the next three to five years as identified in the Defra Strategy Refresh initiative led by David Miliband, the Defra Secretary of State. Under the lead of Defra, a UK Marine Monitoring and Assessment Strategy (UKMMAS) is being developed, which recognises the requirement to meet the UK's marine/ocean commitments to international programmes.

The UKMMAS remit includes monitoring activities in both UK waters and the open oceans and covers ocean monitoring carried out in support of internationally agreed programmes, such as from Argo, that are commitments to the GOOS, GCOS and the GEOSS. At present there is a shortfall in UK funding for marine monitoring (as required to meet EC directives and international commitments) and through the UKMMAS a bid for additional funding is being prepared and is expected to be submitted as part of the UK Government's 2007 Comprehensive Spending Review (CSR).

The planned CSR bid includes longer-term funding for UK Argo at £850k per annum. It is expected that, if successful, the bid will provide funding for 10 years from April 2008. For 2007/08 funding from Defra, MoD and NERC has been allocated, although the level of funding cannot be confirmed as yet. Defra and MoD have indicated that they will continue to try to provide some funding for UK Argo in the event that the CSR bid is delayed or unsuccessful. Longer-term NERC funding, at the present level, has been agreed for the next 2 years with future allocations being dependent on the outcome of the CSR.

UK aspirations for Argo

Our priority is to see the complete global 3,000 float array established and maintained long enough for its full value to be demonstrated. For climate purposes (i.e. determining ocean heat content) a coarser array would not be sufficient. For climate research the full value of Argo will only be realised when multi-year or decadal time-series are available and it is recognised that this could take at least as long as 10 years. Therefore, it will be critical to maintain international support for Argo for at least this length of time, and the UK will advocate its continuation as long as there is the wider international support for Argo.

An ongoing contribution of 50 floats per year would represent ~6% of the array, which we believe is not too large a contribution for UK to make given our strong international and

[2] UK GOOS Strategic Plan Summary Report. Report of the GOOS Action Group of the Inter-Agency Committee on Marine Science and Technology. July 2006.

maritime interests, and is consistent with the initial commitment by the Governments Chief Scientific Advisor (Sir Robert May) CSA in 1999 that the UK would contribute to Argo, to at least a GNP level (presently 4.94%) of contribution at full deployment, with the expectation that Argo would be sustained in the longer term.

Although the baseline Argo array should be focused on well-established technology, there remains an important role for the research community in improvement of the technology, development of new sensors and implementation of higher resolution regional arrays for scientific research. This is an area in which NOCS would take the lead for UK.

The advantages of the free and unrestricted data policy for Argo have already been seen in that Argo data are being used by scientific researchers outside of the 'Argo community'. Wider use of the data for scientific and educational purposes will continue to be encouraged by UK Argo.

Euro-Argo

The UK Argo programme intends to engage fully with the Euro-Argo proposal, and has suggested the following contributions.

(1) Procurement, preparation and deployment of additional floats in key regions of importance for European climate. UK would procure and deploy around 30% of any EC-funded floats alongside UK funded (approx 45 per year) floats. The deployments for the EC-funded floats would be coordinated with the international Argo programme, but focused on the South Atlantic, other Atlantic regions and the Southern Ocean. Plus monitoring of all European Apex floats (building on the CSIRO collaboration).

(2) Data processing. With EC-funding we would increase resources at BODC on the existing UK Argo Data Centre and Southern Ocean Argo Regional Centre functions, focusing on the South Atlantic and Southern Ocean regions, in order to remove backlogs in the data flow and bring these centres fully up to the level of capability required.

(3) Research. Continue work on exploitation of the Argo data (for ocean forecasting, seasonal forecasting, decadal climate prediction and ocean climate monitoring), development of new Argo data products etc.

Through Euro-Argo it is advocated that Europe (through the EC and national programmes) will sustain ¼ of the global 3,000 float array, and provide additional floats to provide enhanced coverage in the European regional and marginal seas.