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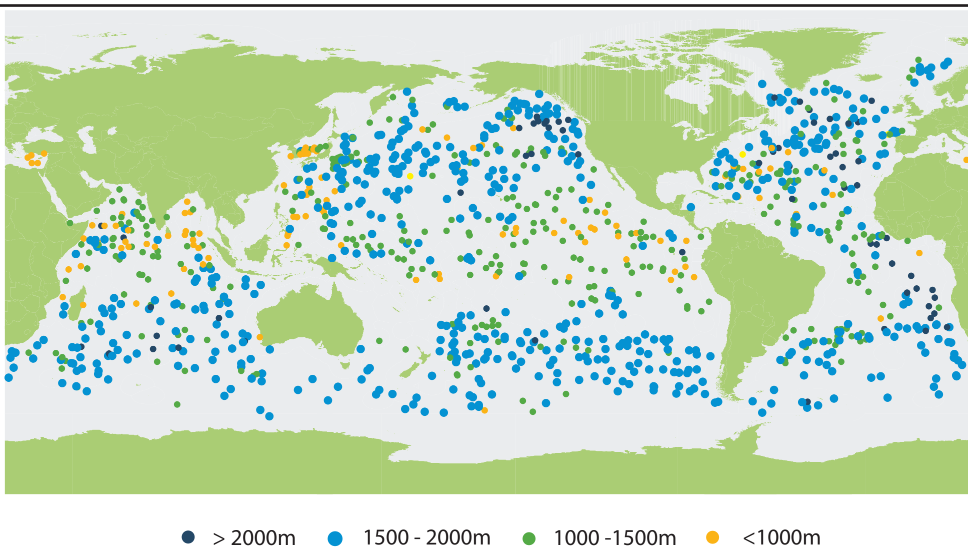
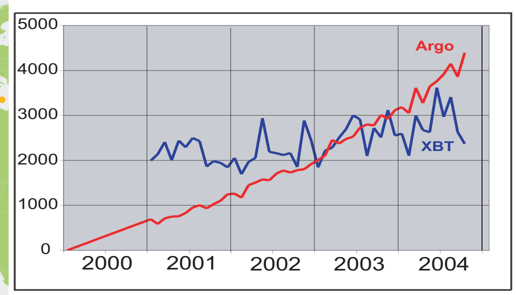
Argonautics

Newsletter of the international Argo project





Left. *Depth of Argo profiles (Prepared by the Argo Information Centre).*

Right. *The growth of monthly real-time Argo profile numbers.*

Editorial

Important target reached

The first thing to note is that at the end of November Argo passed the important milestone of 1500 operating floats. This is half way to the original target, set in 2000 of 3000 floats. Reaching that target is testament to the contributions of all the national programmes, to groups that have assisted in float deployments, to the float and sensor manufacturers. - Well done everyone! Here's to the next 1500!

Uses of Argo data

Perhaps the most important feature is that the array is now global and this permits us to start to address important scientific issues and to make the data useful to operational centres. In this issue we are starting a series of articles on how Argo data are being used. The first is from the UK Met Office that uses Argo data in both its Atlantic and global analyses and forecasts. We will be listening to feedback from these centres. They are important Argo customers and we need to make sure we are meeting their needs in terms of data quality and timeliness

Delayed-mode quality control

Ensuring the high quality of the final delayed-mode data set is receiving a great deal of attention from the Argo Data Centres and from Argo scientists. The issues that are involved in this process are outlined in an article by Lars Böhme on page 2. Lars has worked extensively with data in the North Atlantic where the high spatial and temporal variability pose particular challenges. These will be discussed in the coming months and at a workshop on the topic to be held in April 2005.

An important Argo science meeting

At the IAPSO assembly in Cairns, Australia in August I will be co-chairing with Neville Smith (the GODAE chairman) a science session entitled *"Argo and GODAE - global and regional partners"*. The session description reads *"The Convenors invite papers on research and application of Argo profile and velocity data and on related ocean model assimilation and prediction systems. Examples are invited from any region but it is expected that many will relate to the Pacific and Southern Hemisphere oceans*. Neville and I look forward to receiving your abstracts. For the URL see page 3.

Thank you Kensuke

Kensuke Takeuchi has stepped down as leader of the Japanese Argo project. He will be replaced by Nobuo Suginohara. I would like to take this opportunity to thank Kensuke for all the hard work he has done (particularly in organising the 2003 First Argo Science Workshop) and to welcome Nobuo as his successor.

Cover pictures

The cover map in this Newsletter shows the maximum depth to which floats were profiling at the end of November 2004. A few floats do a deep profile only every third cycle in order to save energy. The shallowest profiling floats are at low latidudes where they still capture most of the variability. The deepest profiles are mostly at high latitudes where winter mixing has the deepest penetration.

The right hand panel shows how monthly Argo data delivery has grown since the programme's start compared to XBT data.

John Gould (Editor)

Argo Quality Control in Highly Variable Enviroments

Lars Böhme, IFM-GEOMAR, Kiel, Germany, (lboehme@ifm-geomar.de)

To check the quality of Argo profiling floats, different methods are used to produce comparison salinities. However, the existing methods do not provide well constrained salinities in regions where the water column is weakly stratified, highly variable or exhibiting multiple temperature inversions (e.g. subpolar North Atlantic). In such areas the resultant corrections have high uncertainites of the order of up to 0.1 in salinity, frequently making corrections too doubtful to justify. In these cases an improved method is needed.

We use a similar two step mapping procedure as already employed in Wong et al. (2003) to resolve features of dfferent scales. But we modified the mapping schemes as the rich bathymetry in the North Atlantic strongly controls the flow patterns and thus the distribution of the water masses. A 'generalized' distance is included into the mapping scheme (Davis, 1998) and reduces the influence of historical profiles inside the basin when mapping to a location in a boundary current and vice versa (Fig.1). As result of this two step objective mapping procedure reference salinities with uncertainties for the float salinities (i.e. at the selected depth levels) are calculated and are used to determine a correction for each float profile.

The scaling parameters used in the objective mapping are as important as the method itself. As they represent the hydrographic structure of the ocean they change with the position of the float. These parameters are calculated on a 1° x 1° grid. The reassuring result is that the geometric distance scales are uniform even into the boundary current regimes confirming that cross-isobath gradients are now taken into account. For the North Atlantic the large spatial scales are approximately 1000km and

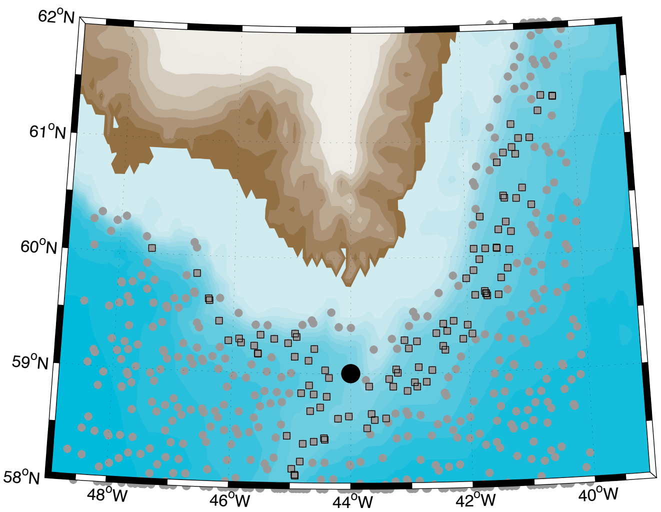


Figure 1: *Example of historical profile selection using a 'generalized' distance. Profiles (squares) are chosen from historical data (grey dots) for objective mapping to the float profile location (black dot).*

the cross-isobath scale about 0.5. This means that a factor of two in the difference in the planetary vorticity and the water depth contributes to the distance approximately like 1000km seperation in space. The small scales for the North Atlantic are ~100km and 0.1 for the cross- isobath scale. The calculation of the time scale yields to 252 days, which shows that recent reference data are of major importance for this method and was found to be typical for most regions of the North Atlantic. A detailed description of this method can be found in Böhme and Send (2004).

This new method was tested by application to more than 100 floats deployed in the North Atlantic as part of Argo and yielded in strongly reduced errors for the mapped reference salinities by up to a factor of five compared to Wong et al. (2003) (Fig. 2). It was also tested in regions with a similar challenging hydrographic structure to the North Atlantic, e.g. the Southern Ocean. Again the uncertainties were reduced comparing to other methods resulting in a useable correction. An other result is, that about 70% to 80% of the floats perform well within ±0.01 in salinity for the first two years.

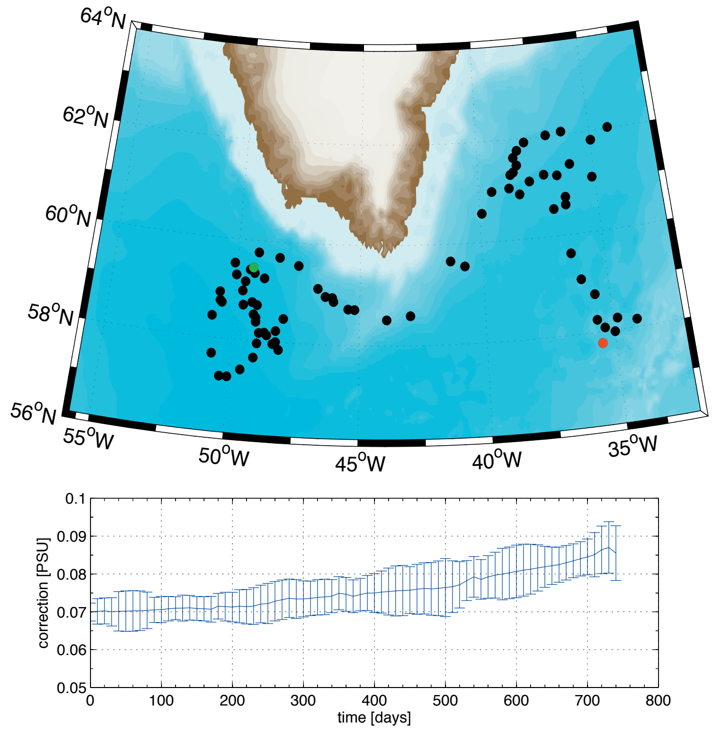


Figure 2: *Top: Profile locations of float 4900223. This Provor float is equipped with a FSI sensor and was deployed in the Irminger Sea (red dot) and drifted into the Labrador Sea (green dot). Bottom: Proposed corrections with uncertainties. Pre-deployment calibration showed an offset of 0.072.*

Applying the method to float data obtained in regions with very sparse historical data (like the Southern Ocean) results in huge errors or even no estimated correction. However, the Southern Ocean is now filled with Argo floats, which need to be checked. One possible way to increase the historical dataset is to use raw float data itself assuming that most of this data is well within the desired accuracy. For example, the method using a historical dataset gave no results for six floats drifting in the southern Pacific between 54°S to 62°S and 168°E to 180°E. Using float data as the historical database (without the one, which is checked) showed that one float is offset. The corrected data were again used as a database for a second run, assuring that all floats except one are working within the accuracy (Fig. 3).

This way, it is possible to check the quality of float salinities in areas of absent historical data. Care should be taken, because the salinity measurements of floats with the same kind of conductivity sensor tend to drift in the same direction. This will affect the calculated correction.

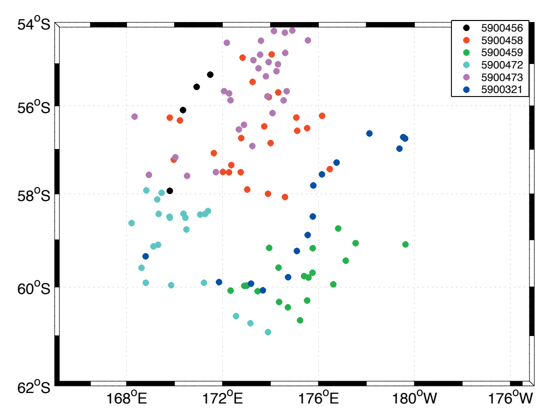


Figure 3a: *For caption see next page*

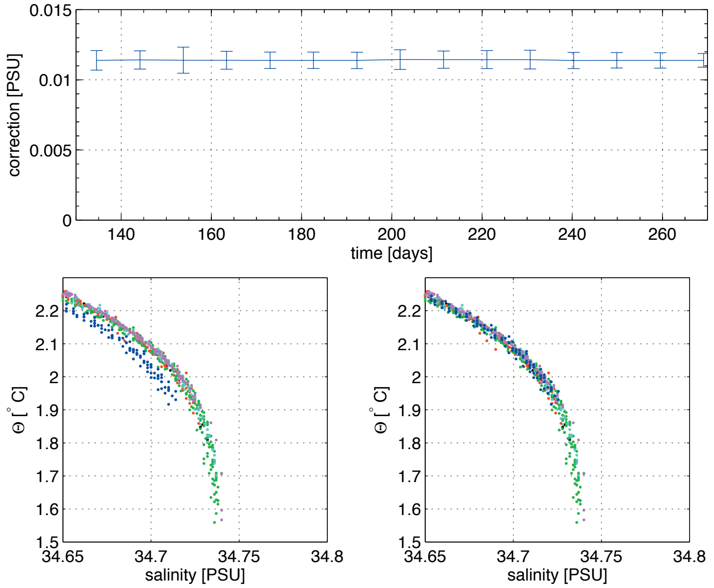


Figure 3: Previous page: *Profile locations of six floats in the region of interest.* **Top:** *Proposed corrections with uncertainties for float 5900321 using only float data as database.* **Bottom:** *T-S diagrammes of float data. The raw data are shown on the left and corrected data on the right.*

However, with this method and the possibility to check floats without a historical database we are able to check the quality of profiling floats in most of the world ocean.

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Next steps in delayed-mode quality control

In the last Argonautics we reported that 7000 Argo profiles from the Pacific Ocean had been subjected to delayed-mode quality control. By mid-December 2004 that number had increased to 17,000 out of 74,000 available profiles (23% of the total). (Remember, because of the sliding 1 year window data from the last 6 months are not available for delayed-mode quality control). There are now some delayed-mode data from all oceans.

There are now several groups carrying out the quality control process and while all are using some version of the recommended WJO (see above) method, it is vital to ensure that each group is doing that in a consistent manner.

In order to confirm this, a workshop is to be held at Scripps Institution of Oceanography in April 2005. It will be in two parts. Initially the people from the Data Assembly Centres will meet for two days to discuss the exact details of applying WJO. This will be followed by a meeting of a larger group of PIs who will discuss how to ensure spatial and temporal uniformity of data quality.

The meetings will be open only to invitees but the outcome of the meeting will be carried in *Argonautics* and on the Argo web site.

Argo actions from POGO-6

Dean Roemmich and John Gould attended the 6th Annual meeting of the Partnership for Observations of the Global Ocean, POGO in Brest, Nov 29-Dec 1. One discussion session centred on the role played by the research community in sustained global observations. POGO sent a communiqué (http://ocean-partners.org/Meetings/P6.html) to the GEO-5 meeting in Ottawa the same week that was attended by Howard Freeland.

The need for continued collection of well-calibrated CTD observations (particularly for Argo QC) was highlighted to the POGO members (Directors of the major oceanographic laboratories) and resulted in the following action item.

> *All POGO members to request their scientists who make high-quality CTD data to relay the data in real time (if possible) or at least within one month, to an appropriate regional or international data centre.*

We will be maintaining pressure on CTD groups and PIs to provide early access to ship-based CTD data. These are an integral and essential elment of the global observing system.

Calendar of Argo-relevant meetings

2005			
Feb 14 - 16	Brussels, Belgium	Earth Observation Summit	earthobservations.org/
Feb 14 - 16	Perth, Australia	Argo Exec	
Feb 14 - 18	Perth, Australia	Indian Ocean Mar. Env. Conf.	www.imarest.org/events/IOMEC2005/
Apr 8 - 13	La Jolla, CA	Argo DM QC Workshop	
April 26 - 28	Silver Spring, MD	NOAA Climate Obs Workshop	www.ogp.noaa.gov/mpe/co/
April 25 - 29	Vienna, Austria	EGU	www.copernicus.org/EGS/EGS.html
May 12 - 14	Cape Town, S Africa	Argo S Atlantic Data Workshop	
August 22 - 26	Cairns, Australia	IAPSO - IAG - IABO	www.dynamicplanet2005.com
2006			
Jan 16-18	Hyderabad, India	POGO-7	
Jan 18-20	Hyderabad, India	Argo Steering Team 7	

Use of Argo data at the Met Office

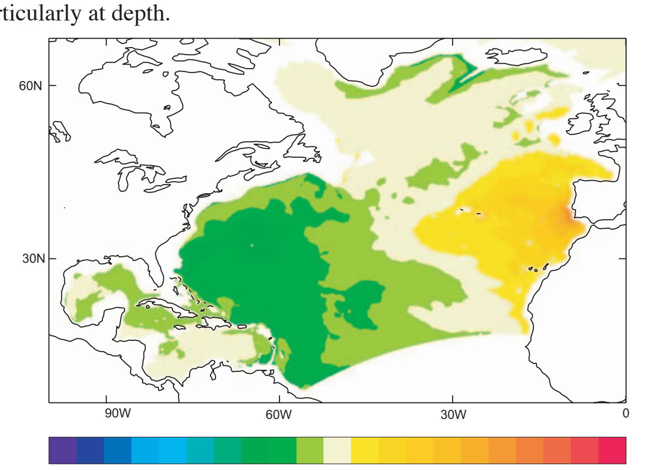
Matt Martin, Adrian Hines, Bruce Ingleby, Matt Huddleston, Doug Smith, Helene Banks, Richard Wood.
Met Office, FitzRoy Road, Exeter, Devon, EX1 3PB, UK.

The Met Office undertakes a variety of ocean modeling activities providing predictions of the ocean state on a range of timescales. All of these applications stand to benefit from the development of the Argo array. For the real-time short-range deep ocean forecasting system, FOAM, the vast improvement in the availability of real-time profile data has had immediate impacts. Other systems assimilating data are benefiting from the major improvement to the observing network provided by Argo, particularly in the sampling of the southern hemisphere and of salinity. Meanwhile, the potential for the use of Argo in other areas such as climate change monitoring is being explored.

The Forecasting Ocean Assimilation Model (FOAM) system analyses and predicts the short-term evolution of temperature, salinity, currents and sea-ice in the deep ocean. It is run daily in the operational system of the Met Office and provides information on the past, present and future state of the ocean to a range of customers. At the core of the system lies a numerical ocean circulation model which is run in various configurations ranging from a global model with a 1° grid to high resolution regional configurations. These models are forced at the surface by momentum, heat and moisture fluxes provided by the atmospheric NWP model run at the Met Office.

In order to produce initial conditions for a forecast, observations are combined with a previous 1 day forecast. Various observation types are assimilated including in situ and satellite sea surface temperature (SST) data, satellite altimeter data and in situ temperature and salinity profile data, including the Argo observations.

The most direct impacts of Argo on the FOAM system arise from the fact that the floats provide information on both temperature and salinity down to 2000m. Before Argo there were very few temperature observations that reached this depth and almost no salinity observations on a routine basis. The impact of assimilating Argo data on the quality of the FOAM salinity analysis is illustrated in Figure 1 which shows annual mean differences between FOAM analyses using a 1/9° resolution North Atlantic configuration and Levitus climatology at 1000m. Differences are shown for two year-long hindcast integrations beginning June 2002, with and without assimilation of Argo salinity data. The initial state for the integrations was taken from the end of a 6 month spin-up run. Without the salinity assimilation, the model tends to drift away from climatology and over time large biases develop. Assimilation of Argo salinity data controls this drift and significantly reduces the biases in the analyses. Similar improvements are found at all depths down to 2000m and also in the temperature fields, particularly at depth.



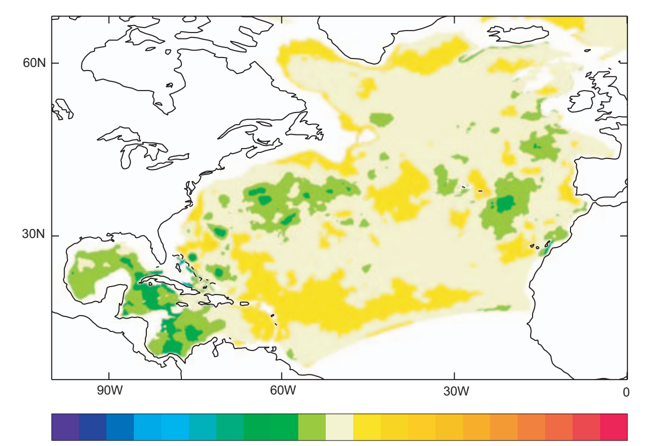


Figure 1. Annual mean salinity differences (psu) from Levitus climatology at 1000m depth for integrations (left) with no salinity assimilation (right) with Argo salinity assimilation.

Comparisons with climatology provide useful information about large scale biases in the FOAM system. For more detailed information about the quality of analyses it is necessary to compare analyses and observations. With the relative abundance of Argo salinity data, it is for the first time possible to carry out such assessments for salinity. An example of verification against salinity data is shown in Figure 2. This shows root mean square analysis (RMS) errors against observations (before they are assimilated and valid within 24 hours of the analysis) averaged over the whole year of integration for the two experiments described in the previous paragraph. The integration in which the salinity data are assimilated shows a clear improvement in the fit to independent observations at all depths in both the north-east and north-west Atlantic.

The Met Office's seasonal forecast system produces a forecast out to six-months ahead once a month using a coupled atmosphere-ocean general circulation model. In order to capture El Niño related variability in the tropical Pacific Ocean which is particularly important for seasonal forecasting, initial conditions are provided by an ocean analysis. The operational analysis system is similar to that used for FOAM, but currently only assimilates in situ temperature data. Versions being tested as part of the European Union ENACT project include in situ salinity data and also altimeter data. These will form the basis for an upgrade of the operational system in 2005. As there are only twelve forecasts a year and Argo data has only been available for a few years (especially in the Southern Hemisphere) the impact of the Argo data on the system is less immediate than that seen in the FOAM system. However, the benefits of the data should now be realised in the system, and assessments of the impact will be performed very shortly.

The decadal climate prediction system developed at the Met Office Hadley Centre also expects to realise significant benefits from the use of Argo data. The system makes forecasts using a coupled climate model (HadCM3). Initial conditions for the ocean component of the model are created by relaxing HadCM3 to monthly 3D analyses of temperature and salinity anomalies. These analyses are created by optimal interpolation of subsurface temperature and salinity data which have been quality controlled using the procedures developed by the seasonal forecasting group for the ENACT project. Initial conditions in the atmosphere are created by relaxing to ECMWF reanalyses. Hindcast experiments covering the period 1979 to 2001 show significant skill at predicting surface temperature both globally and in many regions throughout the ten years of the integrations. Future plans for the system include assessing the impact of improved subsurface ocean data coverage provided by the Argo project.

The fluxes of heat and freshwater into the ocean can undergo large changes, due both to internal variability of the climate system and to externally forced climate changes. Direct measurements of heat and freshwater fluxes are prone to large uncertainties, but by measuring changes in ocean temperature and salinity we can observe the integrated effect of surface climate changes over the ocean. At the Hadley Centre we have recently been using historical observations to evaluate coupled climate model simulations and to interpret observed changes. Variables examined

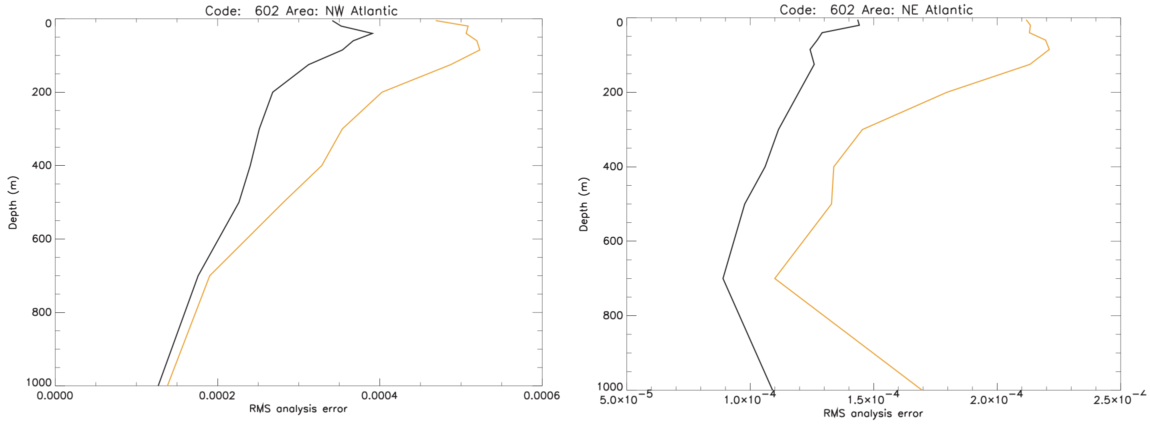


Figure 2. Annual mean salinity RMS errors (psu/1000) against independent salinity observations for an integration assimilating Argo salinity data (black) and one not assimilating salinity data (orange) for (left) north-west Atlantic and (right) north-east Atlantic.

include ocean heat content (Gregory et al. 2004), and temperature and salinity changes across specific sections (eg, South Indian Ocean, Banks et al 2000 and the Labrador Sea, Wu et al. 2004). However, in many parts of the ocean the limited sampling in the past means that it is hard to make an unambiguous attribution of any observed changes to either natural or anthropogenic causes. The increased spatial and temporal resolution of temperature and salinity data from Argo are already helping us to understand better the variability of the climate system. As we build up a continuous timeseries of observations from Argo over the coming years, we can expect a big step forward in our ability to understand contemporary climate change and to constrain our model projections of future change.

URLs

FOAM http://www.metoffice.com/research/ocean/operational/foam/
ENACT http://www.cls.fr/enact/

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Requirements for a successful Argo project

The success of Argo in reaching the half-way point towards the 3000 float target perhaps disguises the enormous amount of hard work that is being carried out. No matter what the size of each national contribution, for it to be successful it needs to contain a number of vital elements and each of these needs to be completed successfully.

The list of these elements gives some idea of what is involved :-

- float purchase - including specification of mission profile
- acceptance tests on each float when delivered
- selection of deployment locations and selection of deployment mode
- packing and transport to deployment platform
- pre-deployment checks
- briefing of float deployers
- float deployment
- report float deployments to AIC
- provision of communication costs
- monitoring of float performance
- data management and quality control
- dialogue with float and sensor manufacturers
- scientific exploitation

Each country has a different model for how these various tasks are carried out and each has a different level of success in terms of achieving long float lifetime and data quality.

As Argo matures we will have to try to assess which of the elements has the greatest impact on float performance and pass the lessons about what is the “best practice” to all national programmes.

On a lighter note

This seems to be an ideal place for Argo scientists to stay when visiting San Francisco.

The back page

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Recent papers of relevance to Argo

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Henson SA, Sanders R, Allen JT, Robinson IS, Brown L Seasonal constraints on the estimation of new production from space using temperature-nitrate relationships **Geophysical Research Letters** 30 (17): Art. No. 1912 SEP 13 2003

Papers in preparation, submitted and in press, reports and theses (e-mail addresses are contacts for more infromation)

Bo Qiu and Shuiming Chen (Accepted) Eddy-Induced Heat Transport in the Subtropical North Pacific from Argo, TMI and Altimetry Measurements. J. Phys. Oceanogr. [bo@soest.hawaii.edu, http://www.soest.hawaii.edu/oceanography/bo/QC05_inpress.pdf]

Faure, V., and K.Speer, (Sumitted) Labrador Sea Water Circulation in the Northern North Atlantic Ocean. Deep-Sea Research II.[faure@ocean.fsu.edu]

King, B.A. and E.L. McDonagh, (In Preparation). Decadal Changes in Ocean Properties revealed by ARGO floats, in preparation. [bak@soc.soton.ac.uk]

Park, Jong Jin, Kuh Kim, B.A. King and S.C. Riser, (Submitted): A simple method to estimate deep currents from Profiling Floats. *J. Atmos. and Ocean. Tech.* [jpark@ocean.snu.ac.kr]

Wirts, A. E., and G. C. Johnson. (Submitted): Interannual upper ocean variability in the deep southeast Bering Sea. *Journal of Marine Research,* [gregory.c.johnson@noaa.gov]

Wong, Annie P.S.: (Submitted); Subantarctic Mode Water and Antarctic Intermediate Water in the South Indian Ocean based on profiling float data 2000-2004. *Journal of Marine Research.* [awong@nansen.pmel.noaa.gov]

Please inform us of any papers not yet listed in *Argonautics*. or at www.argo.ucsd.edu

How to acknowledge Argo data

Argo data are available to anyone. As the project develops we expect the community of Argo data users, to include research groups and countries not directly involved in Argo float deployment or data management. The Argo Steering Team encourage the use of a standard acknowledgement in publications that use Argo data as follows :-

" These data were collected and made freely available by the International Argo Project and the national programmes that contribute to it. (www.argo.ucsd.edu, argo.jcommops.org). Argo is a pilot programme of the Global Ocean Observing System".

People using Argo float data are encouraged, as a courtesy, to contact the person responsible for the floats used and to outline the type of research or analysis that they intend to carry out.

The Argo Director is moving

At the end of 2004 I will be moving - first to Hobart Tasmania, where I will be working with colleagues there on Argo float reliability issues and Southern Ocean data and then returning to the UK.

From January 1st 2005 I can be reached at

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Please send articles for inclusion in *Argonautics* to the above address or to Mathieu Beléoch, Argo Technical Co-ordinator, (belbeoch@jcommops.org).

Information about Argo can be found at www.argo.ucsd.edu and from the Argo Information Centre argo.jcommops.org. The AIC site includes information about the present (and past) distribution of Argo floats.
Argo data may be downloaded from the Global Data Centres
www.usgodae.org/argo/argo.html and www.ifremer.fr/coriolis/cdc/argo.htm