Argo: An Array of Free-Drifting Profiling Floats

Progress Towards Establishing a Global Array of 3,000 Floats for Observing the World’s Oceans

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Argo will be an array of 3,000 free-drifting profiling floats that will measure the temperature and salinity of the upper 2,000 metres of the ocean. Global observations from Argo will provide significant benefits for ocean forecasting, seasonal forecasting and climate studies. This article outlines the international Argo project and progress made to date.

Use of Floats Before Argo

The idea of using neutrally buoyant floats to measure sub-surface ocean currents was first developed in the mid-1950s by Henry Stommel in the U.S. (1955) and John Swallow in the U.K. (1955). These early floats were tracked acoustically, and the SOFAR (sound fixing and ranging) and RAFOS (SOFAR spelled backwards) floats that evolved from them were used extensively in the 1970s and 1980s.

The Inception of Argo

The World Ocean Circulation Experiment (WOCE) resulted in the development by Webb Research Corp. of the first-generation Autonomous Lagrangian Circulation Explorer (ALACE) and Profiling ALACE (PALACE) floats. WOCE provided a demonstration of the viability of using autonomous profiling floats to make global ocean measurements.

In July 1998, an initial outline for Argo was developed and an Argo Science Team (AST) was formed with responsibility for the implementation plan for Argo, and to provide scientific and technical guidance on float technology and establishment of the

Argo status as of June 2003.
The aim of Argo is to have approximately 3,000 floats deployed globally, with a spacing of about 300 kilometres. To achieve a 3,000 float array, it will be necessary to deploy floats at a rate of around 825 per year (assuming that 90 percent of the floats operate for four years and 10 percent fail early). Each float costs approximately US$25,000 over its four year life, such that the annual cost of maintaining a 3,000-float array is approximately US$20 million. From the outset, it was recognised that Argo was too large for any nation to undertake individually and would require a coordinated international effort; this began in early 1999 with the initial meeting of the AST. Since then, 15 nations have developed plans to provide floats, together with a contribution from the European Commission.

Benefits from Argo

Ocean Forecasting. The Global Ocean Data Assimilation Experiment (GODAE) is bringing together real-time float data (Argo), satellite sea surface height data (e.g., from Jason) and ocean modelling to demonstrate the practicality and feasibility of routine real-time high-resolution global ocean data assimilation and prediction. The demonstration phase of GODAE will be from 2003 to 2005, with a consolidation and transition (to operational systems) phase from 2005 to 2007. A key component of GODAE is the wide availability of ocean analyses and forecasts to participants and other potential users such as the oceanographic, marine research and industry communities via the various GODAE web servers.

Argo data are expected to lead to improved predictions from ocean models by making it worthwhile to assimilate salinity data, little of which has previously been available, allowing better initialisation of the upper ocean structure and improved mixed layer prediction; allowing better representation, in combination with satellite altimeter data, of the vertical structure on the mesoscale; and permitting better verification of the accuracy of predictions from ocean forecasting models.

Seasonal Forecasting. Although it is generally not possible to predict individual weather events more than several days in advance, it is possible to provide useful information about conditions averaged over weeks to months and over large areas (e.g., the chance of above average winter rainfall over western Europe, related to the North Atlantic Oscillation, or the likelihood of an El Niño event in the Pacific).

Such long-range predictions (seasonal forecasts) depend on the existence of relatively slow changes in the upper ocean temperatures. The ocean-atmosphere link is particularly strong in the tropics, where seasonal predictions are usually more reliable than at mid-latitudes.

Seasonal forecasting with coupled ocean-atmosphere models requires information about the initial upper ocean state. Consequently, data from Argo will allow better initialisation of coupled ocean-atmosphere models, which should lead to improved long-term forecasts of wet or dry seasons and better warning of the likelihood of floods and drought for many areas of the world.

Climate Prediction. There is a constant exchange of heat, momentum and water between the ocean and the
The ocean acts as a heat sink to delay climate change, and ocean currents transport large amounts of heat and water around the world. The rate of climate change is largely determined by processes in the ocean interior.

In particular, the large thermal inertia of the oceans and the consequent long time-scales of adjustment mean that an accurate representation of ocean processes is critical for realistic climate simulation and predicting climate change.

Recent climate simulations made by the Hadley Centre suggest a freshening in southern Indian Ocean and Arabian Sea intermediate waters is a signal of anthropogenic climate change. Guided by these results, Argo floats have been deployed in these regions to monitor salinity.

**Present-Day Argo Floats**

Today's second-generation floats include the Sounding Oceanographic Lagrangian Observer (SOLO), the Webb Apex and MARTEC/METEC Provor, and new designs are being tested in Japan (NINJA) and China (COPEX). The floats drift at a preset parking depth (typically 1,000 to 2,000 metres), returning to the surface every 10 days to give a temperature and salinity profile.

When at the surface, the floats relay their data and position to an orbiting Argo satellite before returning to depth and continuing another cycle. The expectation is that the floats should be capable of making as many as 100 profiles and operate autonomously for four to five years. With present communications, the floats typically spend six to 12 hours at the surface transmitting data. With increased bandwidth, it is hoped this can be reduced to about one hour, which should save battery power and minimise the likelihood of sensor biofouling.

**Float Deployment.** To date, the vast majority of floats have been deployed from ships. Usually, this is from stationary vessels, under calm conditions, where the floats are lowered into the water using ropes. Floats have also been deployed from VOS (voluntary observing ships). These deployments have taken place with the ship at speed and from deck level, typically 20 to 80 feet above the water. The float is placed inside a cardboard box for protection and lowered into the water. Once in the water, a soluble link dissolves, allowing the box to open and discharge the float. VOS deployments have also been made using a free-fall technique.

Here, the float is packaged as for air deployment and launched into the water using a slide. Apex floats (which are air-certified by the United States Department of Defense) have also been deployed by the United States Navy from C130 aircraft. For air deployment, the floats are packaged in a protective container together with a parachute.

**Availability of Argo Data**

All Argo data are openly available without proprietary restrictions. Real-time data from Argo are disseminated via the WMO GTS (World Meteorological Organization Global Telecommunications System) within a day or so of collection and are available through the two global Argo data centres (the U.S. GODAE server, Monterey, California, and Coriolis data centre, Brest, France) via the Internet. The delayed-mode float data, after quality control and evaluation against

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other data holdings (moorings, floats, XBTs, climatology, etc.), should be available after about six months. These data are lodged at the global Argo data centres and specified regional data centres, and are available on web servers for access by the public.

**Argo Information Centre**

To help coordinate Argo, the Intergovernmental Oceanographic Commission (IOC) has established an Argo Information Centre (AIC). The centre provides information about float deployments, how to track float positions and how to access float data. The AIC supports the international program in various ways.

For instance, it provides a liaison between float-providers and on float deployment opportunities, acts as a clearing house for information on all aspects of float use, and promotes an improved dialogue between oceanographers and meteorologists, and between the research and operational communities. The AIC also issues updated float lists, monthly status reports and monitors in real-time the status of Argo array (http://argo.jcom-mops.org).

**Argo: Where We Are Now**

Since its inception, Argo has developed rapidly with nearly 900 floats reporting data. Early float deployments focused on the north and tropical Atlantic and Pacific Oceans, with coverage now building in the Indian and Southern Oceans. However, to achieve a uniform global float distribution, around two-thirds of all Argo floats will need to be deployed in the southern hemisphere. This will be a major challenge for Argo, with most of its participants being northern hemisphere nations.

Profiling floats are already making a significant contribution toward the amount of profile data available in real-time. For example, in May 2003, 2,435 float profiles were available within 48 hours, compared to 1,765 XBT profiles. The full Argo array of 3,000 floats will deliver approximately 100,000 profiles per annum.

**Conclusions**

Over the past five years, Argo has developed rapidly with expectations for the full global array being in place by 2006. The implementation of Argo is unique in both its pace and scope; it offers the first genuinely global observing system for the deep oceans and is bringing together research and operational organizations with a common goal.

Although Argo currently has the status of a pilot project to establish a global float array, the expectation is that it will then enter a transition phase and become an operational (sustained) ocean observing system with longer-term commitments. However, it will be absolutely essential for Argo to demonstrate real benefits and impacts in order for this expectation to be justified.

The first Argo Science Workshop, which will be held in Tokyo, Japan, in November 2003, will provide an early demonstration of Argo achievements and results.

**References**

For a full list of references, contact the author Jon Turton at jon.turton@metoffice.com. /st/

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