A National Oceanographic Partnership Program Award

The Argo Project: Global Ocean Observations for Understanding and Prediction of Climate Variability

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Most relevant web sites: http://www-argo.ucsd.edu, http://argo.jcommops.org, http://sio-argo.ucsd.edu, http://ursa.whoi.edu/~argo/, http://flux.ocean.washington.edu/argo/, http://floats.pmel.noaa.gov/argo, http://www.aoml.noaa.gov/phod/ARGO/HomePage/

Long-term goals

The U.S. component of the international Argo Project (http://www.argo.ucsd.edu) is implemented through this award. The present report covers Year 1 of the 5-year project, plus cumulative progress from previous awards (Phases 1 and 2) for pilot float arrays and data system development. By 2006, Argo will deploy a global array of 3000 profiling CTD floats (Argo Science Team, 1998, Roemmich and Owens, 2000, Roemmich et al, 2002), and establish a data system to meet the needs of both operational and scientific users. The Argo array will provide unprecedented real-time views of the evolving physical state of the ocean. It will reveal the physical processes that balance the large-scale heat and freshwater budgets of the ocean and will provide a crucial dataset for initialization and assimilation in seasonal-to-decadal forecast

models. Argo is a major initiative in oceanography, with research and operational objectives, providing a global dataset for climate science and other applications.

Objectives

Phase 1 (9/99 – 9/02) and Phase 2 (7/00 – 6/02) of US Argo provided a total of 187 CTD profiling floats in the Pacific, Atlantic and Indian Oceans. Objectives were to demonstrate technological capabilities for fabrication and deployment of float arrays in remote ocean locations (Phase 1) and to demonstrate the capability for manufacture and deployment of large float arrays (Phase 2). Recent technology developments in profiling floats were also implemented, including new generation salinity sensors, improved depth capability, and deployment techniques using fast ships and aircraft.

Development of the U.S. Argo Data System was part of Phase 1, on a collaborative basis with international partners. Objectives are to make all Argo data publicly available within a day of collection, applying automated quality control procedures consistent with international Argo practices. Data appropriate for research applications will be available within a few months of collection, with quality control by salinity experts.

Phase 3 is a 5-year project (8/01 – 6/06) including full implementation of the US component of Argo. This report includes Phase 3/Year 1, which provided 174 CTD profiling floats plus support for float deployment and data management activities and for national and international coordination roles in Argo. Float deployments target the Atlantic, Pacific, Indian, and Southern Oceans.

Approach and work plan

Float production and float deployment are equally distributed among three facilities – SIO (D. Roemmich and R. Davis), WHOI (W.B. Owens – float production)/AOML (S. Garzoli – float deployment), and UW (S. Riser). Philosophically, this distribution is designed to ensure the continuity of the Argo project. It makes Argo success independent of the participation of any individual PI and institution or of any single float design. It allows the large amount of effort to be shared. It encourages individual technical innovation and enhancement. It focuses the attention of multiple PIs on maximizing the scientific value of Argo as well as on problem-solving. Priorities for US float deployment are set by the US Argo Advisory Panel.

The data system is also distributed, but by function rather than for load-sharing. AOML (R Molinari) is the national Argo data center, responsible for acquiring the float data received by satellite communications, for carrying out real-time quality control, and for distribution of data via the GTS and to the Global Argo Data Assembly Centers. The second step in data management is a semi-automated recalibration of the salinity sensor carried out by PMEL (G. Johnson), using a high quality temperature/salinity climatology for comparison with float temperature/salinity data (Wong et al, 2003). The final step is individual examination of all profiles by the float-providing PIs, in order to provide high-quality data suitable for research applications. All Argo data are freely available within about 24 hours of collection, and can be accessed from the GTS or internet (http://www.usgodae.org/, or http://www.ifremer.fr/coriolis/cdc/argo.htm).

Work Completed

Based on the performance of the pilot arrays deployed in Phases 1 and 2, it was determined that design and production problems in both SOLO and APEX floats were leading to shortened instrument lifetimes. Extensive technical analysis and redesign was carried out over approximately the first 9 months of 2002, leading to substantial improvements in float pumping and control subsystems. Large-scale float deployments were resumed in the 4th quarter, and by year's end about 1/3 of the Phase 3/Year 1 floats were deployed. Results from these modified instruments are promising. Deployment of the remaining Year 1 instruments plus all 315 Year 2 instruments is scheduled for 2003.

Final elements of the Data Management system are now being implemented. All Argo profiles are subjected to the internationally-agreed automated quality control procedures and are distributed via the GTS. The US Argo Data Center (AOML) provides all US data to the Global Argo Data Assembly Centers in Monterey, California and Brest, France in standardized Argo NETCDF format. The US delayed-mode data center (PMEL) provides suggested salinity recalibration information for US floats. As soon as international Argo agrees (March 2003) on protocols for incorporating delayed-mode quality control in the standard data files, including PI examination, this final step will be implemented.

Our consortium plays strong leadership roles in the international Argo project. In addition to chairing the Argo Science Team (D. Roemmich), we provide coordination for basin deployment planning in the Pacific and Southern Oceans. We have distributed the PMEL technique for salinity recalibration to international partners, along with assistance in getting it running, and it has been adopted internationally. The US is the technology leader in profiling floats, and our technical improvements have been shared with international partners. Finally, in the data management realm, AOML has provided assistance to other groups (e.g., China, South Korea and India) as they establish their real-time data management procedures.

Results

The international Argo array now includes 620 active floats (Figure 1, from http://argo.jcommops.org), over 20% of the 3000 float array planned for 2006. The ability to coordinate, deploy and maintain basin-scale float arrays has been successfully demonstrated in the North Atlantic and North Pacific. The US has derived large benefits from international collaboration in Argo because nearly 2/3 of the present floats are non-US (224 active US floats), and there is open access to the complete dataset. Float deployments will increase steeply in the coming year, especially in the remote sparsely sampled regions.

The Argo Data Management System is operating, delivering profiles in near real-time to operational and other users via the GTS and the internet. The ability to produce scientific-quality data has been demonstrated and will soon be implemented for all floats, with public internet distribution.

The Argo Project is still very young. Nevertheless, scientific studies using Argo data have begun., including the Wong and Johnson (2003) work on southeast Pacific Subtropical Mode Water, the Schmid et al. (2003) study of the intermediate depth flow in the tropical South Atlantic, and a recent investigation of Bering Sea circulation and water properties by Johnson et

al. (2003). It is clear that Argo's contributions to the ocean observing system – including the addition of salinity and extensive coverage of remote ocean areas – are a profound increment in our ability to characterize water masses and large-scale circulation, and to make accurate estimates of heat and freshwater storage and their transport by ocean currents. The optimal combination of Argo profile data with satellite altimetry (Willis et al, 2003) will provide better resolution and accuracy in estimates of the subsurface ocean than is possible from either system alone.

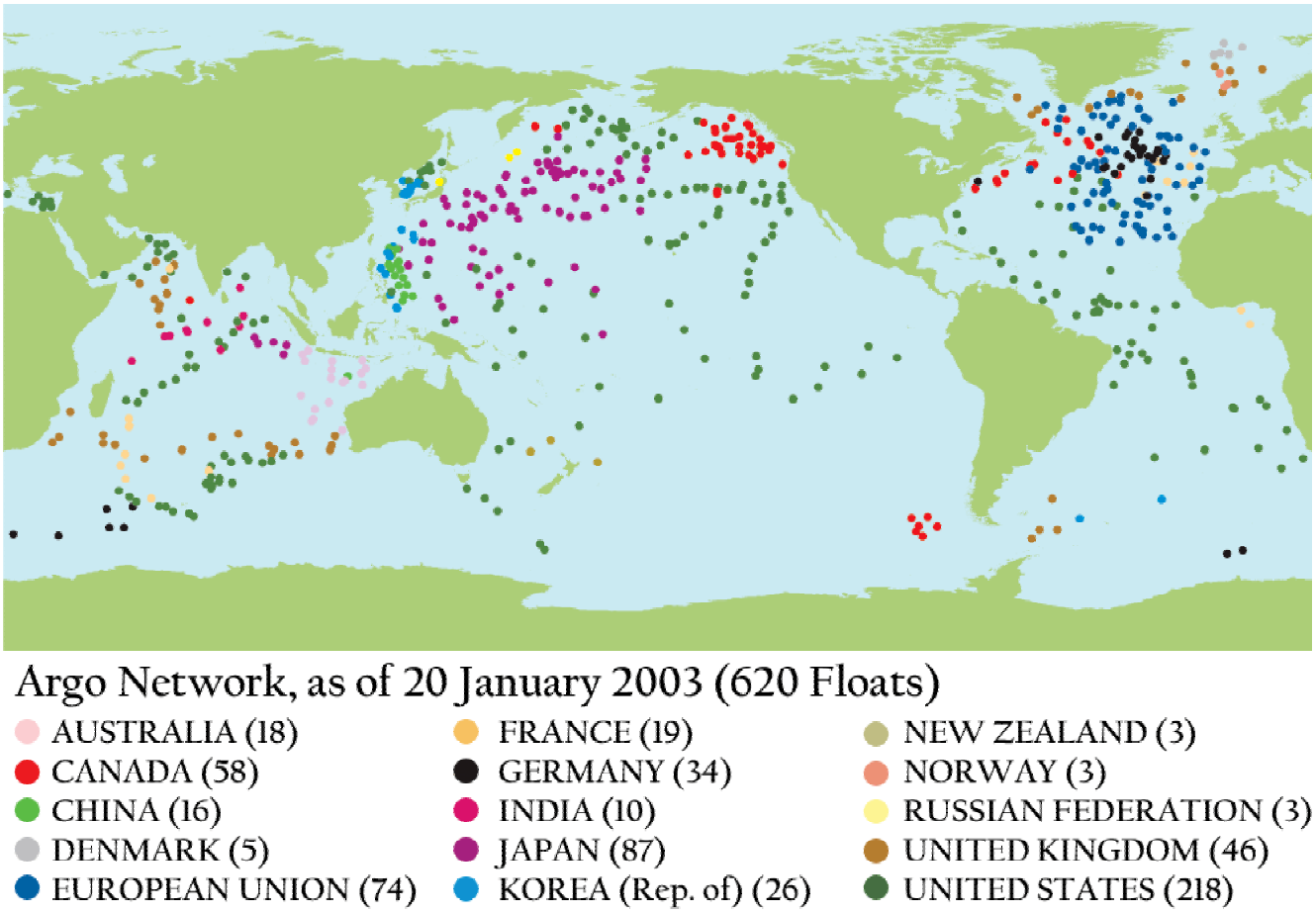

Figure 1 : Positions of 620 active Argo floats in January 2003, identified by country of origin.

Impacts, Applications, and Transitions

National Security

The US Navy has a strong interest in accurate estimates and forecasts of the physical state of the ocean and the coupled air-sea system, because of the obvious impacts of wind, waves, currents, and temperature on virtually all aspects of naval operations. The Navy has experimental ocean state estimation and forecasting efforts, using both regional and global models, for which Argo provides a central contribution for ocean data assimilation. The Navy interest is further expressed by the hosting of one of the two Global Argo Data Centers (at FNMOC, Monterey), by NAVOCEANO participation as a provider of floats for international Argo, and by

NAVOCEANO participation in air deployment of Argo floats. Phase 1 of US Argo was supported by ONR.

Economic Development

The Global Ocean Data Assimilation Experiment (GODAE) has identified a number of applications with substantial economic impacts arising from ocean observations, including improved seasonal-to-interannual forecasting, state estimation (now-casting), and coupled physical/biological modeling (e.g. for fisheries). The El Nino/Southern Oscillation (ENSO) Observing System in the tropical Pacific has demonstrated over the past decade that economic gains in energy, agriculture, and insurance sectors are possible from successful seasonal forecasts. Improvement in S-I forecasting is expected as the tropical observing system is extended and expanded to global coverage, and Argo plays a key role in that expansion.

Quality of Life

Argo is central to an unprecedented capability for global assessment of the evolving climate state of the ocean. The thermal structure of the upper ocean controls the temperature of the lower atmosphere, and is the primary variable defining the physical environment of ocean ecosystems. Over 90% of the increased heat content due to global warming of the air/sea/ice climate system in the past 40 years occurred in the oceans. Climate stresses on ocean ecosystems have serious consequences, and sometimes dramatic ones, such as coral reef bleaching. In the future, the impacts of a varying climate on the health of the seas and coastal ecosystems will become an increasingly important aspect of resource management. The unique niche of the Argo array is to provide global broadscale observations of temperature, salinity, and circulation of the upper ocean.

Science Education

Although the Argo project is still very new, it is proving to be an attractive educational asset for secondary, tertiary, and post-graduate levels. For secondary education, the web-based and real-time nature of the Argo data system, as well as Argo's strong climate-relevance, have been keys to engaging student interest in the oceans. Our consortium participates in a UNESCO and IOC-sponsored initiative called SEREAD (http://argo.jcommops.org), that uses Argo data in existing secondary science curricula in Pacific Island countries. In post-graduate education, Argo is already providing primary data for dissertation research of graduate students in the US and other countries.

Related projects

GODAE: The Global Ocean Data Assimilation Experiment uses satellite and in situ ocean datasets in data assimilation models for practical applications. Argo plays a special role in GODAE because it is the only globally repeating subsurface ocean dataset, and is strongly complementary to its satellite counterparts. GODAE's vision is "A global system of observations, communications, modeling and assimilation, that will deliver regular, comprehensive information on the state of the oceans, in a way that will promote and engender wide utility and availability of this resource for maximum benefit to the community." (http://www.bom.gov.au/bmrc/ocean/GODAE/).

CLIVAR (Climate Variability and Predictability experiment of the World Climate Research Program). Argo provides a primary ocean dataset for this experiment targeting better understanding of the climate system, including its variability and predictability. See http://www.clivar.org. CLIVAR's aim is to exploit the research value of broadscale climate observations and focused process experiments. In this context, Argo measures the storage and transport of heat and freshwater globally on broad spatial scales.

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