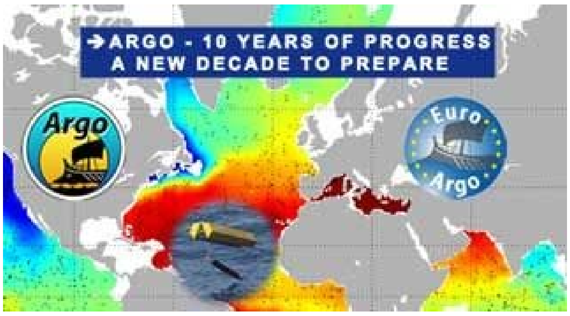
4th Argo Science Workshop
Meeting and final round table summary

P.Y. Le Traon for the ASW-4 scientific and organizing committees



The 4th Argo Science Workshop was jointly organized by Argo international and Euro-Argo. It was held in Venice, Lido together with the 20 year altimetry symposium. The altimetry symposium was held from September 24 to September 26 and the 2.5 day Argo workshop from September 27 to September 29. 234 people from 25 countries attended the Argo workshop.

The general objectives of the workshop were (i) to stimulate more research using Argo data, especially in combination with altimetry, (ii) to entrain young scientists into the Argo community (iii) to strengthen communications between the Argo and altimetry groups (iv) to further increase the visibility of the Argo Program (v) to broaden the discussion of Argo's future evolution.

The theme of the workshop was to celebrate 10 years of progress for Argo and to prepare the next decade and new challenges for Argo. The workshop included a review of Argo achievements and discussions on the development on the new phase of Argo. The oral programme was organized in six sessions: sea level and Argo, heat and salt budget, MOC and large scale circulation, mesoscale circulation, impact in models, extension of Argo to marginal seas, sea ice and biogeochemistry. 43 posters were presented during a poster session. The workshop programme, list of participants and the presentations are available at http://www.euro-argo.eu/News-Meetings/Meetings/ASW4-Venice.

Results presented confirmed the high and unique potential of Argo for ocean and climate research and operational oceanography. Compared to previous Argo science workshops, new results and new ways to analyze Argo observations jointly with the other in-situ and satellite observations and models were presented. Organizing the 4th Argo Science Workshop together with the altimeter symposium was highly valuable and the workshop demonstrated further the strong synergy between Argo and altimetry.

The final round table objective was to discuss and exchange with the workshop participants the envisioned evolution for Argo for the next decade. Vision statements for the evolution of Argo were presented and discussed with the participants. Brief presentations were given based on short position papers. The position papers were revised after the workshop to reflect the discussion. They are given hereafter. These papers will be analysed further by the AST-14 to guide the evolution of Argo for the next decade.

Final Round Table : Introduction and summary

D. Roemmich

At the OceanObs'2009 Conference (http://www.oceanobs09.net/), compelling cases were made that there is high societal value in sustaining the Argo Program, with further improvements in data coverage and quality for Argo's Global Mission, and that Argo should be enhanced to address valuable new missions. Building on OceanObs'2009, the objectives of this ASW-4 Roundtable were to articulate the international consensus on Argo's goals and priorities with respect to sustaining and enhancing the program, as well as summarizing the present status and the challenges that lie ahead. Experts were selected (i) to write a preliminary "vision" statement on each of the following topics, (ii) to present and discuss the topic at ASW-4, and (iii) to revise the statement, reflecting the community consensus, following the discussion. These brief topical statements should describe what has been achieved so far, what Argo's target requirements should be (if known), and the pathway for moving forward, including technology maturity and feasibility issues.

The final roundtable was organized with the following presentations:

- Argo expansions and enhancements:
  - Deep Argo (T. Suga)
  - Expanding Argo coverage at high latitudes (S. Wijffels)
  - Increasing Argo coverage in western boundary regions (B. Qiu)
  - Expanding Argo into the marginal seas (P.-M. Poulain)
  - Bio/BioGeoChemical Argo (E. Boss)
- Impact of expansions and enhancements on Argo Data Management (S. Pouliquen)
- Sustainability issues for Argo's evolution (P.Y. Le Traon)
- Argo evolution, GOOS, and the Framework for Ocean Observing (A. Fischer)

Following each 2 or 3 presentations, a "critiquer" had the role of asking challenging questions and stimulating audience participation. "Critiquers" were W.B. Owens, P. Oke, and S. Wijffels, and the discussions were wide-ranging and lively.

The revised statements are collected here. This is to invite further comment from the worldwide community of present and potential Argo users, and to be passed to the Argo Steering Team for discussion at AST-14 and for action by the National Argo Programs. Just as the strong international consensus on the 1998 vision of Argo 3000 was a key factor in making Argo a reality, so we need clear and agreed goals on how Argo will evolve in the coming decade. Enhancements of areal coverage, including the high latitudes, marginal seas, and western boundary regions, represent incremental growth of the program, but they are nevertheless challenging because they cannot be done without proportional new resources and each presents unique technical issues. Expansion into the deep ocean and the addition of multi-disciplinary sensors are major changes for Argo that cannot be undertaken without substantial growth, including manpower for data management. Finally, while the present discussion is focused on Argo, the broader perspective of maximizing the value of the integrated ocean observing system is paramount.

Deep Argo

Toshio Suga

The expansion of Argo into the deep ocean below 2000 m has been widely recognized as an essential element of the truly global ocean observing system envisioned by the OceanObs'09 conference. It would allow, for the first time, broad-scale, sustained sampling of deep ocean properties, which is needed to properly understand the evolving global inventories of heat, freshwater and other properties and thereby global energy budget, sea level rise, variations in the meridional overturning circulation, etc.

While the primary objectives of Deep Argo will be to observe large-spatial scale variability and change in temperature and salinity on timescales of a decade and longer, its target and requirements are still not clear. This is quite different from the situation when the present Argo global mission was designed in late 1990s; we had better idea about target and requirements owing to experience from the upper ocean thermal network and knowledge about large-scale seasonal to interannual climate variability. We also already had a better idea about cost of global sampling because fairly large number of profiling floats had been deployed as part of WOCE and other projects.

Pilot experiments, at least for several years, are necessary for acquiring information needed both for array design and to determine the cost-feasibility of global sampling, with defining clear target and requirements of Deep Argo. Issues about the data QC process and required reference data should also be adequately addressed during the pilot experiments. Development of several types of deep ocean profiling floats is on-going and their prototypes will be available quite soon. At the same time, development of a CTD with improved depth and stability characteristics in pressure, temperature and salinity needed for deep ocean profiling is in progress. While pilot experiments using these instruments are currently planned in different countries, some degree of coordination among these activities and also with relevant Observing System Simulation Experiments (OSSE) activities will be useful for building a strategy for a global Deep Argo array.

Extending Argo into the Ice covered oceans

Esmee Van Wijk, S. Wijffels with input from S. Riser, S. Rintoul, K. Speer,
O. Klatt, O. Boebel, B. Owens, J.-C. Gascard, H. Freeland, D. Roemmich, A. Wong.

At present there are a few hundred floats already operating in the Antarctic sea ice zone and high latitude northern oceans. Recent failure rates are just slightly higher than open ocean floats, due to using high satellite bandwidth and improved ice avoidance algorithms. While some floats are acoustically tracked, most are not and thus the winter data are not real time and are not positioned well. However, more sophisticated position extrapolation could be deployed. In the Arctic, Ice Tethered Profilers have collected many tens of thousands of profiles, though snapshot spatial coverage is still very sparse and these platforms are most suited to multiyear ice. These pilot arrays are already delivering 1st order descriptions of the mean and seasonal changes in the sea ice zones. Given the changes in the polar oceans and cryospheres, there is a growing sense of urgency for realtime tracking of ocean changes that might be driving and responding to the ice changes.

What do we need to extend Argo to beyond 60˚S and 60˚N in the seasonal ice zone? At the nominal design density, we would require:

- 360 active floats would be required in the Southern Ocean (85 floats require acoustic receivers in the Weddell Gyre and 110 floats in the Ross Gyre).
- 300 active floats in the Arctic.

Calculations are based on the number of floats required to populate the area between 60˚ of latitude and the fast ice edge with an assumed profiling depth of 2000 m in the Antarctic and 900 m in the Arctic. To maintain an array of 300 floats with a 20%/year loss rate requires 100 deployments/year. A key issue is whether we live with extrapolated positions under the ice where acoustic tracking is not feasible.

Can we extend Argo to the fast ice zone? This requires consideration of alternative sampling platforms. A number of instruments have been developed for this purpose

- Ice Tethered Profilers (ITP)
- Polar Ocean Profiling System (POPS)
- Acoustically-tracked floats with ice thickness sonars.

To progress these questions a team of international experts is meeting to develop a first strategy at the Workshop – Seeing below the ice being held in October 22-25, 2012, CSIRO, Hobart. The outcomes of this workshop will be reported to the Argo Steering Team and international research and operational community.

Western Boundary Current (WBC) regions

Bo Qiu

In considering the importance of expanding Argo float measurements to the WBC regions in the coming decade, it is relevant to emphasize the pertinent scientific questions cover a broad range of spatial and temporal scales. These include frontal meandering and instability processes, mesoscale eddies and cross-frontal exchanges, upper ocean heat/salt content anomalies, recirculation gyres, ventilation/ subduction processes, and forced versus intrinsic variability of the entire WBC system.

Profiling floats are commonly regarded as "unsuitable" for WBC research because of their small spatial scales. In fact, the world's WBC systems (which include not only the inertial jets, but their recirculation gyres, detached eddies, and subducted water masses) span a broad geographical region. There exist no better tools than the profiling floats that are equally cost-effective, agile, and logistically manageable, for observing the WBC systems. Through recent and on-going field programs such as KESS, CLIMODE and INBOX, profiling float measurements have made significant and unique contributions in addressing the WBC scientific questions listed above.

In planning for the next decade of exploring the WBC systems with the use of Argo floats, it is important to keep in mind that mapping out the synoptic-scale, 3-dimensional field of a WBC system is likely to be highly challenging, even with the combination of other satellite and in-situ measurements. With this constraint, it may make sense to focus on longer timescale and broader spatial scale issues relating to the WBCs, such as their decadal modulations, their heat/salt content fluctuations, and their connection to the interior ocean variability.

From the viewpoint of dynamic requirement, it is recommended that the float sampling in the 5 midlatitude WBC regions be increased from the global 3 deg x 3 deg x 10 days target to 2 deg lat x 2 deg long x 10 days. In other words, double the float density in the WBC regions. To achieve this, it is desirable to maintain targeted float deployments at an inflow point of a WBC on a repeated basis. Monitoring and understanding of the WBC systems can benefit greatly by having deep Argo floats and floats with oxygen sensors deployed within their geographic domains. Rather than an independent and competing effort, the WBC floats, once dispersed, can seamlessly be merged with the floats of the "core" Argo program.

Argo in Marginal Seas

P.M. Poulain

The extension of Argo into marginal seas, presently ongoing in some seas such as the Mediterranean Sea, introduces the following issues:

(1) Specific requirements of higher concentration of float density for adequate monitoring of T/S and biochemical parameters (smaller scales with respect to the world ocean).

(2) Operational challenges related to floats stranding and being stuck in shallow waters, to floats being recovered and redeployed, and to floats being picked up by seafarers (higher mortality).

(3) Political problems related to stranding on "less friendly" shores, and in general to floats passing in territorial waters and EEZs.

Specific sampling requirements for Argo in marginal seas should mainly aim at monitoring processes in those seas relevant to the world ocean dynamics (i.e., changes in water mass properties) and pertinent to the global Argo objectives. Synergy with other observational networks (e.g., coastal platforms, moorings, gliders, HF radars) should be encouraged to resolve smaller scales and local processes. Preliminary assessments revealed that the float density in the marginal seas should typically be double with respect to the global array density and that the cycle length should be reduced to 5 days. Given the geographical extension of marginal seas worldwide, a very rough estimation calls for about 300 active floats in the marginal seas, that is about 10% of the global Argo array.

Two-way satellite communication (Iridium, Argos-3) can help the operational challenges listed in (2). Minimizing surfacing time decreases the probability of theft and drifting ashore. Modifiying the cycling and sampling characteristics interactively while floats are drifting allows optimal adaptive sampling and longer operating life.

Solutions to (3) can be obtained through a more effective use of AIC, through regional collaboration, outreach and capacity building, and with the possible ratification of ad hoc laws.

New funding initiatives, in particular at the national and regional levels, should be sought in order to maintain Argo into marginal seas without competing with the established Argo funding sources.

Bio/BGC Argo

E. Boss, H. Claustre and K. Johnson

In the next decade Argo could play an increasing role in studies of oceanic biogeochemical cycles, and detect in increasing details the ocean response to climate forcing.

Much of the interest in this endeavor comes from the ocean biogeochemical and ecosystem modeling communities, who need persistent globally representative data to further develop, constrain and assimilate to state-of-the-art biogeochemical and ecosystem models.

This role will be facilitated by an increased availability of robust, simple, low power, and (relatively) cheap sensors measuring different aspects of ocean biota, carbon pools and fluxes and by an increasingly multidisciplinary core of trained scientists and technologists.

The challenge in moving Argo to this broader mission is finding a mutually satisfactory operating space, in which the cost of additional sensors is offset by a stronger user base that leads to increased funding for the core efforts. This funding must offset reductions in float lifetime driven by greater power demands and increased data processing costs created by more complex observations. In addition, issues such as sampling time (e.g. day vs. night) should be addressed to insure potential for upper ocean sampling biases are taken into account.

In preparation for that evolution of Argo, studies will have been conducted showcasing the benefit of the specific biogeochemical measurements on profiling floats and protocols for Argo-style QA/QC will be developed (e.g. at the upcoming ADMT meeting).

Hand-in-hand with the expansion of profiling float sensing capabilities is the expansion in the user base for float (both numbers and disciplines) and the associated expansion of funding agencies and programs willing to invest in profiling float and associated technology (e.g. in the US NASA and NOPP have been funding much of the work to integrate new sensors to Argo floats. NSF is considering funding a large regional float based observatory in the Southern Ocean). This expansion bodes well for a sustained future for Argo.

Bio/BGC Argo will not occur in isolation; Integration with ship-based measurements, remote sensing (e.g. Ocean Color) and ecosystem/biogeochemistry modeling efforts will provide added context and utility to the data.

While it is recognized that biogeochemical parameters have shorter spatial and temporal decorrelation time scale than physical variables, it is currently unrealistic to have a goal of instrumenting the whole Argo fleet with biogeochemical sensors. We have put forward as a target to instrument 20% of the Argo fleet in the next five years with biogeochemical floats. Indeed, France has adopted such a model.

Impact of Argo extensions on Argo data management

S. Pouliquen

Argo data management system has been developed in close collaboration with the scientific community with involvement of the Argo steering team members in the data management meetings and report from data management committee to the Argo steering team. For the next decade it is important to secure the Core mission data processing activities. This means maintaining:

- scientific involvement in enhancing the QC procedures and Quality monitoring to continuously improve the quality of Argo dataset. The risk is that gradually scientists consider T&S Argo processing as finalized and move to other research topics.
- involvement of the different countries in data processing according to agreed Real Time and Delay mode procedures. Presently there are 11 DACS, 2 GDACS, 12 DM Operators and 6 ARCs.
- and securing the man power dedicated to the Core mission real time and delayed mode data processing.

The Argo dataset will reach 1 000 000 profiles at the end 2012, which means that it is important to secure the capacity to reprocess this large dataset when needed and also to develop monitoring tools to detect anomalies as early as possible.

The second challenge for data management is to prepare the data system to handle new type of floats. This means develop the capability of manage new parameters especially Bio-Argo (Oxygen, Chlorophyll, Nitrate…) but also surface data and deep ocean measurements. For each new parameter, one needs:

- a definition on how to store these new parameters (agreement on units, what information should be kept, how to calculate the parameters from the measured observations…).
- a definition Real Time QC procedures for these new parameters .
- a definition Delayed Mode QC procedures for these new parameters.

This will require the involvement of new teams in the assessment of the Argo data in delayed mode and for the quality monitoring of the new parameters. The Argo data management system will also have to evolve to be able to handle the changes performed through 2-way communications. This means that:

- data format must evolve to handle mission changes.
- more technical parameters are sent to shore => enhance vocabularies to store these data.
- sampling on the vertical can be different for the different sensors and we need to be able to store them.
- reduction of the time at Surface : need to measure the impact of the Argo dataset in particular on velocity calculation as very few displacements at surface.

Sustainability issues

P.Y. Le Traon

One of the main challenges for Argo is to sustain the global array (T & S) for the next decades. This requires deploying 800 to 900 floats per year. Climate change research requires global observation over long time series (> 20 years) and the full potential of Argo will only achieved with several decades of measurements. Operational oceanography services, seasonal (and decadal) forecasting and climate services cannot be sustained without a sustained global Argo array. The following issues need to be addressed:

1. Funding. Long term commitments from nations contributing to Argo are required. We need to move to a sustained research or operational funding for the core Argo program. This remains difficult as we are still working with project (i.e. over limited time period) funding. This is the rationale for developing the research infrastructure concept in Europe that requires specific funding (and evaluation) mechanisms.
2. Float technology. Sustainability is also related to float technology issues. Reducing costs, increasing life time and reliability are important issues for the long term sustainability of Argo.
3. Data management issues. Maintaining efforts on quality control and quality monitoring over a > 10 year time frame is essential. This is an important issue as it is difficult to maintain over a long time period skill and interest in these activities. The work of teams involved in data management and quality control must be secured and recognized. We also need to favour interaction with the science community so that new QC methods continue to be developed.
4. Deployment issues. Maintaining a global array is different and more difficult that building a global array. We will have more and more to rely on dedicated deployment capabilities (e.g. Kaharoa, Lady Amber). These costs should be planned.
5. Organization issues. There will be a need to progressively transition towards stronger (e.g. committed resources) national structures and reinforced international governance.

Argo will also evolve to answer new requirements (e.g. biogeochemical observations, deep ocean, polar oceans, marginal seas) and this should be managed carefully so that the first objective of Argo (sustaining the global T & S array) is preserved. The evolution of Argo towards new and broader user community (e.g. biogeochemistry) could, however, be a good opportunity to sustain the core Argo program. Extending the user community and drivers is a good means (if carefully managed) to sustain the whole programme.