Report of the Argo Science Team 2nd Meeting (AST-2)

March 7-9, 2000, Southampton Oceanography Centre, Southampton U.K.

1. Introduction

The meeting is intended to accomplish the following objectives:

- Review national plans, priorities and commitments - to measure progress toward achieving resource requirements for Argo and to continue formulation of a strategy for global coverage (Sections 3 and 6).

- Examine and compare data management prototypes of those countries having begun to design and implement an Argo Data System (Section 4). The intention is to ensure that the data system is in place to enable data throughput from floats to be deployed in the near future. It must meet the requirements of users for dual real-time (operational quality) and delayed mode (scientific quality) T,S data streams. It must be country-to-country compatible to facilitate easy exchange and maximum usefulness.

- Review the technical issues relevant to Argo (Section 5). Are the evolving technical capabilities of floats able to satisfy user requirements? What are the performance standards needed to ensure the value of the Argo array composed of intermingled floats from multiple float providers?

- Initiate a forum for discussion of scientific results relevant to Argo (Section 7).

Argo must continue to balance the requirements of operational analysis and prediction centers and of scientific users in an appropriate manner. Section 2 consists of a brief review of the requirements of CLIVAR and GODAE, the parent bodies of the Argo Science Team, for the global profiling float array.

2. CLIVAR and GODAE requirements for Argo

2.1 CLIVAR

John Gould reminded the meeting that CLIVAR was the most recent and broadest of the component projects of the World Climate Research Programme. The overall objectives of CLIVAR are:

- To describe and understand the physical processes responsible for climate variability and predictability on seasonal, interannual, decadal, and centennial time-scales, through the collection and analysis of observations and the development and application of models of the coupled climate system, in cooperation with other relevant climate-research and observing programmes.
- To extend the record of climate variability over the time-scales of interest through the assembly of quality-controlled paleoclimatic and instrumental data sets.

- To extend the range and accuracy of seasonal to interannual climate prediction through the development of global coupled predictive models.
- To understand and predict the response of the climate system to increases of radiatively active gases and aerosols and to compare these predictions to the observed climate record in order to detect the anthropogenic modification of the natural climate signal.

CLIVAR has identified a series of Principal Research Areas focussed on identifiable elements of the physical climate system in which both observations and modeling activities hold the promise of either improving existing climate prediction systems or demonstrating climate predictability. It is understood that these PRAs many of which have a regional on phenomenological focus need to be embedded in a framework of sustained observations in both the oceans and the atmosphere. Argo is a necessary but not sufficient component of these observations.

The PRAs to which Argo will be most directly applicable are:

G1. ENSO Extending and Improving predictions
G2. Variability of the Asian-Australian Monsoon System
G3. Variability of the American Monsoon system

D1. North Atlantic Oscillation
D2. Tropical Atlantic Decadal Variability
D3. Atlantic thermohaline circulation
D4. Indo-Pacific Decadal Variability
D5. Southern Oean Thermohaline Circulation

CLIVAR will require from Argo both the temperature/salinity profile data and velocity information to complement observations from satellites (SST and altimetry), XBT data (particularly from the WOCE/TOGA high density lines) and repeated hydrographic sections. While there is an obvious focus in the CLIVAR PRAs on high and low latitudes, the need for data from throughout the global ocean should be reiterated.

CLIVAR will require the data to be accessible to researchers from both real-time and delayed mode data streams. Indeed CLIVAR's need for a user-friendly data delivery system is urgent.

2.2 GODAE

P.Y. Le Traon summarized the GODAE requirements for Argo. He first reiterated the GODAE vision and objectives and gave a status of GODAE progress and planning. More details can be found in the GODAE strategic plan, which is now under revision and will be distributed soon. GODAE has entered its development and pre-operational phase where GODAE components will be developed and tested. During this phase, prototype systems will be run and pilot experiments will be conducted. From 2003 to

2005, the integrated systems (distributed among the different partners) will be in place and will provide products to the user community.

The relationships between GODAE and Argo were then described. GODAE deals with the integration of in-situ and remote sensing data with models. One of the objectives of GODAE is to maximize the benefits from the data (in particular altimetry and Argo). Argo will provide data complementary to remote sensing data (altimetry, scatterometer, SST) to constrain an ocean model. It will also provide a feedback on GODAE analyzed fields. On the other hand, GODAE will provide analyzed 4D ocean data to improve QC and help the Argo data interpretation. It will also provide a feedback on Argo data contribution (impact in models, consistency/complementarity with other data sets, testing the utility of Argo data in an integrated framework)

GODAE requirements for Argo were finally summarized. GODAE requires a global ocean observing system (remote sensing and in-situ) and Argo (a GODAE pilot project) will provide the main in-situ data for GODAE (global, complementary to remote sensing data). Data will be required both in near real-time (about 12 hours) and in delayed mode (for reanalyses). The availability of timely and high quality input data sets for GODAE will be crucial for the quality of GODAE final products.

The Argo implementation from a GODAE perspective should also take into account that:

- A global array in 2003 requires that global deployments start in 2001.
- Prototype systems will be able to use data in real time in the North Atlantic and North Pacific in mid-2001. The Data System should be ready for these prototype systems (format, distribution, QC).
- Available past profiling float data should be made available in an efficient way as soon as possible (e.g. via the Argo data centers) to develop/test data assimilation techniques.

The GODAE requirement for a truly global array was re-emphasized as most of the GODAE applications (e.g. climate, boundary conditions for regional sub-systems) will be best achieved with a global array. If Argo cannot achieve its global coverage in 2003, a global sparser array is also strongly preferred to a complete array limited to a given basin. A global sparser array (e.g. 2000 versus 3000 floats) is expected to contribute in a significant way to the global ocean description that GODAE requires. It is also the only way to achieve in 2004 and 2005 (during the GODAE operational phase) a complete global array. Argo should thus start going global as soon as possible.

3. National Reports

3.1 Australia (S. Wijffels)

Present Plans:

A 10-float pilot array is being deployed in the South Eastern Indian Ocean between Australia and Indonesia. Four floats have been operating along 12^{o}S since November 1999. Delays in deployment have arisen out of the discovery that floats available in mid-1999 could not complete an Argo mission in our region of interest due to an inadequate buoyancy range. We are therefore utilizing the older R1-PALACE design. The data is being transmitted in real time by ARGOS and broadcast on the GTS. Remaining deployments are planned from commercial ships. Negotiations are underway with Indonesian agencies to secure deployment opportunities within the Indonesian EEZ.

A web page exists where the float data and plots are published in near-real time. An interactive data explorer is also available from the site:

http://www.marine.csiro.au/~waring/cooe/

Potential for expanded participation in Argo:

Two funding routes are being explored to support further Argo activity in Australia: one will be assessed at budget time (June 2000), and the second will be assessed in late 2000. These requests are for up to AUS$1million per year between 2000 and 2005.

3.2 Canada (H. Freeland, S. Narayanan)

Any Canadian contribution to project Argo will take place through the activity of scientists within the Department of Fisheries and Oceans (DFO) through an interdepartmental program on climate change

The Climate Program has a sufficiently high profile in the Canadian Government and in the Department of Fisheries and Oceans. In 1999, the Federal Departments having a mandate to address climate issues have developed a climate monitoring program, in which Argo is given a high priority. Recently, year-end funding was made available to purchase 10 floats and additional funding is expected in the upcoming months.

The Canadian strategy that is under discussion, but has broad general support, starts with Canada purchasing 150 floats to support Argo. Canada assumes that because of the large number of interested countries surrounding the Atlantic Ocean (e.g. UK, France, Germany, U.S.A.) that are active in Argo, and the relatively small size of the Atlantic Ocean compared with the Pacific, then the Atlantic will be instrumented adequately without Canadian contributions. Thus, we reserve the first 100 instruments for a Canadian deployment in the N.E. Pacific Ocean. The remaining 50 floats are reserved to “help Argo go global”. These could be deployed in the Indian Ocean, or the Southern Ocean, or anywhere else where there is an urgent need. However, if the international array fails to meet Canadian needs in the Atlantic, then those 50 will be used there first. Canada is prepared to initiate deployments in a Pacific array in 2001.

This scenario for deployments is still under active debate in Canada and subject to change, but it does have broad general approval. The floats that are purchased now will be put in storage until we initiate deployments for the Pacific array.

3.2 European Union GyroScope proposal (Y. Desaubies)

A proposal has been submitted to the EU by a consortium of 9 laboratories in 4 countries. These include France (LPO/Ifremer/CNRS-Brest, CMO/SHOM-Brest and Toulouse, CLS-Toulouse), the UK (SOC-Southampton, Met Office-Bracknell), Germany (IFM-Kiel), and Spain (IEO-Madrid and Santander, ICM/CSIC-Barcelona, University of Las Palmas-Gran Canaries). A funding decision should be announced in early May, for a project start in late 2000. Field work would then begin in 2001.
The objective of the GyroScope project is to develop a European component of a global in situ observing system of ocean variability in the North Atlantic. The first objective is to deploy a pilot array of 80 autonomous profiling floats, as a contribution to the Argo international programme. This array will transmit in real time data to a Data Centre, that will quality control, and distribute it on the GTS for use by National Weather Services, and operational agencies. The data will be used to estimate the time varying ocean circulation, temperature and salinity fields, and the balance of heat in the North Atlantic. Some of the estimations will be done in real time ; other will include complementary data sets (satellite altimetry) to obtain the most accurate estimates and assess the information content of the float data (resolution, accuracy). Recommendations will be made for future implementation of an in situ ocean observing system.

3.3 France (Y. Desaubies)

Several agencies (Ifremer, SHOM, IRD, Meteo-France, CNRS, CNES) are working together to develop a strong capability in operational oceanography in France. At the same time, the EU (through EuroGOOS and a number of workshops) is also taking up the topic. The focus in France is on a triad comprising: satellite (in particular the JASON altimetry mission); numerical modelling with assimilation (the MERCATOR project); and in situ data (the CORIOLIS project). The prime focus of the latter is a contribution to Argo, but other in situ data are handled as well.

THE CORIOLIS project includes instrumental developments, data management (real time and time delayed), and operational deployments.

Argo

Proposals have been submitted, and funding requested, for a study of North Atlantic variability, that would include profiling floats deployments. A total of 150 floats over 3 years has been requested, but is not approved at this date. We are confident that funding will come, if not in 2000, possibly in 2001. The initial strategy is to combine operational interests with scientific programmes (POMME and CLIVAR). The North Atlantic is chosen for the first phase of the MERCATOR runs.

The first deployments will be coordinated with other programmes (GyroScope, plans from Germany and the UK, other). The strategy is to provide the broad-scale, low resolution coverage recommended by Argo. As additional floats are funded, and other national contributions are defined, we shall strive to maintain the N-Atlantic array, and expand progressively. The goal is to ramp up for GODAE (2003), when a truly pre-operational infrastructure would be in place, allowing a global expansion of the French contribution.

POMME

This mesoscale subduction experiment will take place from Sept. 2000 through October 2001. The area is 38 to 45°N, 16 to 22°W. Fifteen profiling floats will be deployed (PROVOR type, 8 of which with FSI conductivity cells, the other T only). Data will be transmitted to the GTS in real time. In the Argo context, this is viewed as a pilot project. Very intensive measurements will provide a context in which to validate and interpret the float data (they include 65 acoustically tracked floats, several intensive CTD surveys, 5 moorings with current-meters, upward looking ADCPS, tomography). We expect that most of the floats lifetime will exceed that of POMME.

CLIVAR

Proposals have been submitted, and funding requested, for a study of North Atlantic variability. One of the goals is to map and quantify the subpolar mode water formation, transports and attendant heat release to the atmosphere. Moorings and repeat hydrography are planned.

The Argo - CORIOLIS floats will form the backbone of the observing array, but we anticipate the need for enhanced (higher resolution) in the North Atlantic Current area.

Float development

The development of the PROVOR float is progressing. A first test-deployments of 6 floats (T only) is underway since October 1999. The floats cycle every week (some every other week). The integration of conductivity cells is progressing, with comparative evaluation of the FSI (ECTP-202 package) and the SeaBird (SBE-41) sensors. After laboratory testing, the first sea trials will take place in February - March (7 floats: 3 P-T; 4 P-C).

Software development is underway to allow different data reduction schemes, grounding detection, etc.

Data centre

The CORIOLIS data Centre, is in charge of providing quality controlled data in real time, to the MERCATOR project. The data transmitted by the first test-deployment of floats, is processed, QC'd and distributed to the GTS, with minimum delay (12h). The Centre aims to become one of the gateways to global Argo data; and to process the European floats that will be deployed. It will operate in this way for the GyroScope project. The activities of CORIOLIS include other data sets (XBTS, Thermo-salinograph), and the time delay data management. A science team is working in close association with CORIOLIS and MERCATOR to recommend procedures for validation and quality control, formats, develop data products and summaries, etc.

Detailed information on the Data centre is given in Appendix II.

CORIOLIS maintains a web site (http://www.ifremer.fr/coriolis) where data can be accessed and visualized.

3.4 Germany (U. Send)

3.5 Japan (K. Takeuchi)

The MOT (Ministry of Transport) and the STA (Science and Technology Agency) are funded for a 5-year Argo related project starting form FY 2000. The main purpose of the project is to monitor the upper portion of the World Ocean with profiling floats and improve long term weather forecast using the data, with cooperation with other countries. The agencies involved in the projects are JAMSTEC/ FORSGC, Japan Meteorological Agency and Maritime Safety Agency. JAMSTEC/FORSGC are mainly responsible for actual float operation, JMA for data management and MSA for data verification using XCTDs etc.

In FY2000, most of the effort will be paid for preparation such as establishment of a system for float deployment and data processing, examination of logistics, test deployment and so on. More than 20 floats will be put in the water for testing in the northwestern Pacific near Japan. From FY 2001, actual operation will start and more than 50 floats will be put in the water in FY2001 and more than 100 floats per year from FY 2002, in the western North Pacific, Indian Ocean and Southern Ocean. A Japanese manufacturer, Tsurumi-seiki Co. Ltd. is currently developing profiling floats after the SOLO design, and is expecting to start production in 2000.

3.6 Korea (Kuh Kim)

There is a growing interest in climate research in Korea, but no action plan is yet established at the government level to participate in global programs. However, MRI (Meteorological Research Institute) of KMA (Korea Meteorological Agency) recently took an initiative to submit a multi-year proposal for Argo, beginning FY2001. The level of MRI funding is very uncertain, but its target is equivalent to US$750,000 per year - to purchase, deploy and process about 50 floats per year. Government agencies and individual scientists from universities and research institutes including KORDI are going to put resources together to form a Korean Argo program (K-Argo). Western Pacific Ocean and neighboring seas around Korea are areas of the primary interest to deploy floats. K-Argo will be the first international climate program of a global scale in Korea.

3.7 U.K. (B. King)

It has been agreed in the UK that Argo is a key international programme. The UK contribution will be at least GNP level at full deployment. The UK Met Office will be responsible for the management and co-ordination of the UK contribution to Argo.

Funding

UK funding for Argo will come from three main sponsors. Department of Environment (DETR), Ministry of Defence (MOD) and the Natural Environment Research Council (NERC). Funding for FY00/01 is expected to be about 320K pounds and is anticipated to ramp up fairly rapidly to about 700-750K pounds per year. The funding will cover all aspects of float purchase, deployment, communications, data handling and project management.

The NERC contribution has recently been agreed by the new NERC Chief Executive, and is therefore 'firm'. The contributions from DETR and MOD have been confirmed, but have still to be signed off through formal contracts; it is expected that these will be completed soon.

The aim of the UK Argo project is to establish by Mar 2003 an operational system with the capacity to deploy about 50 floats each year, thus maintaining about 100 to 150 floats in the water at any one time. It is hoped to have about 15 UK Argo floats operating by April 2001.

Organisation

Because of the multiple funding streams, the UK has established two groups to manage the UK contribution to Argo. A Project Board, consisting of representatives of the participating bodies (The Met. Office, NERC and the Hydrographic Office), is responsible for directing the UK Argo Project. A UK Argo Expert Group has been established to provide scientific and technical advice. King is a member of the latter group, which is chaired by SOC. The first meetings of these groups were held on 29 Feb 2000. In addition the funding agencies (DETR, MOD and NERC) will be establishing a sponsors group to which the Project Board will formally report.

Science partners

The main UK science partners presently involved in planning are The Met. Office and SOC.

Data handling: delayed mode; real time.

Discussions are taking place between the UK Hydrographic Office and the British Oceanographic Data Centre about division of responsibilities in the UK for delayed mode data handling. No consensus has emerged yet. The Met. Office will be the focus for UK real-time data activities. Some float data from the GTS are already assimilated into The Met. Office's operational Forecasting-Ocean Atmosphere Model (FOAM).

Data transfer to GTS

There are four surviving UK floats from a deployment of seven in 1996. SOC has agreed with CLS/Argos that data from these will be posted automatically onto GTS. SOC is currently checking algorithms with CLS, and expects automatic posting to commence in late March 2000. These will therefore be the first UK floats to contribute to the Argo programme.

Future deployments

The UK pilot deployment is planned for the Irminger basin in late 2000. Future deployment locations will need to be agreed with the funding agencies, who will need to be convinced that deployment strategies address their areas of operational and scientific interest.

3.8 U.S.A. (D. Roemmich)

The U.S contribution to Argo is a multi-agency effort implemented through the National Oceanographic Partnership Program (NOPP). NOPP supports a variety of projects involving partnerships of academic, government and industry PIs, including ocean observations, data assimilation, and modeling. The complete implementation of U.S. Argo will take place in three phases between 2000 and 2005.

Phase 1 of U.S. Argo is a funded pilot demonstration, with 55 floats being deployed in the tropical Atlantic and southeastern tropical Pacific. The pilot phase includes instrumentation development and demonstration activities – improvements in communication, salinity sensors and air deployment capabilities. It also provides for development of the U.S. Argo Data System. Partners in the pilot are Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, University of Washington, NOAA Atlantic Oceanographic and Meteorological Laboratory, NOAA Pacific Marine Environmental Laboratory, Webb Research Corporation, and Seascan Incorporated. By the end of 2000, it is planned that all of the pilot floats will be deployed, feeding real-time and delayed-mode data through the Argo Data Center.

Phase 2 is a 1-year initial implementation phase aimed at building the inventory of Argo floats in the Atlantic and Pacific Oceans. The objective is to develop and demonstrate the capability for manufacture and deployment of large float arrays and for handling the resulting data stream. This phase will increase the size of the Argo array using the $3M of new funds for Argo in NOAA's FY2000 budget ($2M in 'base' funds and $1M from a Congressional earmark). It will include the U.S. contribution to startup funding for the international Coordinator's office in Toulouse.

Phase 3 will be a 5-year full implementation phase, beginning in FY2001, of the U.S. component of Argo. The concept of Argo as a global array of profiling floats is the primary objective. Major foci of the national effort will be the Atlantic and Pacific, but substantial contributions in the Indian and Southern Oceans are also likely. While the sustained level of multi-agency U.S. resources available for Argo is not yet known, a $4.5M increase (to the $2M in base funds) has been requested in NOAA's FY2001 budget pending before Congress. If approved, this would raise the base level to $6.5M. Multi-agency (NOAA, NSF, ONR) funding levels can likely support up to about half of the global array, including the data system needed to provide real-time and high quality delayed-mode data from these instruments. A parallel continuing effort in developing the technology of profiling floats is also planned as part of the implementation phase.

The magnitude of U.S. resources available for Argo and the spatial distribution of floats will depend on international commitments to achieve a global array. This should include agreement among the partner countries on a plan for global coverage, consistency in performance standards of floats, and consistency in delivery of Argo data.

4. The Argo Data System

Data System Prototypes

Argo Data System prototypes are under construction in the U.S. (Appendix I) and France (Appendix II). In discussions, it was noted that the two systems are evolving along remarkably parallel tracks. Both favor self-documenting, platform independent binary data formats to facilitate rapid and efficient exchange. Both are evaluating NetCDF templates, with all profiles from a particular instrument stored in a single file. This is desirable from the standpoint of storing meta-data and tracking changes in salinity calibrations. There was discussion of differing ideas for data flagging, but it is thought that adoption of a common data format is possible and is a strong requirement for Argo. Experiences with profiling float data and tentative plans for Argo data management were provided by representatives of several other nations including N. Shikama for Japan and S. Narayanan for Canada.

National requirements may result in more than one data center for some ocean basins. This will not create problems provided that (i) a common data format is adopted by all, (ii) responsibilities for flagging, recalibration, GTS transmission etc. are clearly defined and agreed by all - to minimize inconsistent copies, and (iii) full access is provided for frequent update and exchange. It is not envisioned that users would need to obtain data from multiple locations. Rather they could obtain the complete and up-to-date Argo dataset from any data center.

Real-time quality control and transmission

Float experiments during the past few years have provided a variety of experiences with regard to real-time data transmission. In Argo, it is agreed that all data will be transmitted via the GTS in real time. Real-time quality control procedures will be fully automated to allow rapid turnaround 24 hours per day, 7 days per week. In other words, the time-limiting step should be communications from float to data center rather than holding time at the center. It is expected to achieve GTS transmission within 12 hours of data collection for a high percentage of both ARGOS and ORBCOMM profiles. A presentation on GTS data transmission was provided by E. Charpentier (Appendix III). He noted that a number of different GTS formats are presently used for float profiles. While real-time Argo data will be transmitted via the GTS, the opportunity also exists to supplement the GTS dataset with a better quality real-time dataset.

Delayed-mode quality control

Following the automated real-time quality control procedures, a more careful examination of data will be undertaken to provide the best quality data for scientific analyses. Delayed-mode quality control will include comparison of profile data with all other nearby (in space and time) data and examination of profile sequences from individual instruments by float-providing principal investigators or comparable experts. The data centers will provide continuous access to data during the quality control process to ensure that data from other centers is available for comparison. Centers will undertake to complete the delayed-mode quality control within a period of 3 months following data collection.

The necessity for rapid evolution and implementation of a working, country-to-country compatible data system is recognized. To facilitate this, a data system task team led by R. Molinari was established, with a progress report due by mid-2000.

5. Technical Issues Review

5.1 Salinity Stability

For Argo, it is desirable to have conductivity sensors capable of making measurements of salinity that are stable to 0.01 PSU over the course of 4 or 5 years. No known profiling floats have yet met this standard, mainly because there have been few floats in the water for this long with high-quality conductivity sensors. However, progress is being made toward the goal of salinity accurate to 0.01 PSU. A US APEX float equipped with and SBE CTD unit has now been working well in the western N. Atlantic for nearly 3 years, with salinity repeatable to better than 0.01 PSU in the tightest portion of the T/S relation. The scatter in salinity estimates from this sensor package is considerably less than the scatter in historical data from the region, and in the most repeatable portion of the T/S relation the standard deviation of salinity at a given temperature measured by the float is about 0.007 PSU, slightly better than the Argo target. Two other APEX/SBE floats have shown similar stability over a period of about 2.5 years, and 19 more have shown the same behavior over periods of 6-9 months. Additionally, Canadian, Japanese, German and Australian groups have reported good results with SBE CTD sensors for times of up to one year. Thus, there is reason to be optimistic that the Argo salinity target can be met over missions of a few years. Whether this stability will continue for longer missions can only be assessed by continuing to monitor the performance of these floats over the next year or two.

Some problems with SBE sensors have been encountered in the past year. On about 16 US floats in the Japan/East Sea, the salinity was low by as much as 0.2 PSU immediately following deployment. The problem was traced to a leakage of the biocide used in the instruments into the conductivity cell, sometime between the time the instruments were shipped and the time they were deployed. Since the biocide is somewhat water soluble, it washed off the cells after deployment and, in general, the salinity was accurate to within 0.01 PSU after less than 10 profiles. A similar problem was found on SBE CTD units deployed by Australia in the western Pacific warm pool. SBE has found the cause of this problem and has fixed it in newer CTD units.

Earlier models of FSI sensors on SOLO and APEX floats had some known problems, such as faulty electronic components or drift due to problems with biocide ablation from the conductivity cell. N. Shikama reported a problem seen in 2 FSI/APEX floats in the western North Pacific. These instruments returned profiles with unrealistic (unstable) density structure. FSI determined the cause to be an operational amplifier (MAX402), and this has now been corrected. At this point, it is concluded that both FSI and SBE sensor packages can meet the target of 0.01 PSU accuracy over periods of one to a few years. We do not yet know whether this accuracy can be maintained over longer intervals.

5.2 Energy budget and instrument lifetime

Energy budgets for APEX, SOLO and PROVOR floats were provided at AST-1. There it was seen there that 4KJ (lithium) battery packs could provide sufficient energy for about 200 float cycles to 2000 m depth, including sensor power for profiling plus communications. At AST-2, discussion focused on tradeoffs between use of alkaline and lithium battery packs. Alkaline batteries have lower cost and less regulatory difficulties (e.g. as non-hazardous cargo in shipping). Lithium batteries have greater energy density and longer shelf life. They are no longer considered dangerous. It was reported that the U.S. Float Consortium is investigating both options and has not yet agreed on the suitability of alkaline batteries for achieving a 4-year mean float lifetime, or, conversely, on the necessity for lithium batteries.

5.3 Communications

System ARGOS and ORBCOMM continue to be the most likely communications systems to be used for Argo. Since Iridium is bankrupt and appears to have actually ceased to function, it can no longer be considered for Argo. Until recently, System ARGOS has been the sole means to transmit float data. For a small additional charge, it is now possible to increase ARGOS coverage to include four satellites. Using the increased ARGOS coverage German and Australian floats have been able to successfully send profiles with of order 60 samples for surface times of less than 3 hours, even in the tropics where the satellite coverage is the sparsest. Thus, even if we continue to use System ARGOS, profiles with moderate resolution can be telemetered, processed, and placed onto the GTS network within 12 hours, as required for real-time ocean analyses produced by numerical weather prediction centers such as NCEP, ECMWF, and the UK Met Office.

Use of ORBCOMM has been limited to date, but its increased effective transfer rate, error correction, and nearly continuous coverage offer great advantages. Since the data link is reliable, modest data compression methods can be used. . For Argo, we will use messages up to seven times longer than those used for System ARGOS. Tests using CTD casts from ships suggest that profiles with 2 dbar resolution to 500 dbars and 5 dbars to 2000 dbars will require less than 9 ORBCOMM messages. Even though the ORBCOMM system limits usage by an individual transmitter to 1 % of the time, the high resolution profile can be telemetered during a surface time of less than an hour. Costs for an ORBCOMM transmitter and GPS receiver should be the same or less than for a System ARGOS PTT. ORBCOMM has been used in an autonomous electric glider to transmit over 90 shallow water profiles of temperature and salinity offshore from Monterey. A SOLO float equipped with ORBCOMM is now being tested at Woods Hole. It has successfully sent data from a coastal pond and should be tested at Bermuda time series station by the end of April and then deployed permanently near Bermuda by early summer. Successful tests of ORBCOMM were made between San Diego and Honolulu from the R/V Thompson during the fall of 1999. A surface mooring deployed near the Canary Islands has also been transmitting data in real-time using ORBCOMM. These developments indicate that ORBCOMM is now viable for Argo, but that it should not be used exclusively until a significant number of floats have been deployed using this system.

Negotiations are under way with ORBCOMM for a long term agreement, of 5 years or longer, for a low monthly fee for the each float. These negotiations will be expanded to provide coverage for the entire Argo array.

5.4 Profile depth

It is desirable for Argo to have floats that can profile to depths of up to 2000 m anywhere in the World Ocean. This depth is chosen for several reasons. First, in many locations the climatological T/S relation is more variable at depths above this level; to the extent that it will be necessary to correct salinity to climatology, it is desirable to make this correction at a depth where the T/S relation shows little variation. Second, it is anticipated that the dispersion of floats will decrease with increasing depth, and a parking level of 2000 m might be desirable in regions where it is necessary to minimize float dispersion. Third, deeper profiles are is desirable for both for scientific and operational users of Argo data.

Both the APEX and SOLO instruments are potentially capable of profiling to 2000 m in the sense that their hulls can withstand this pressure. However, at present there is not enough excess buoyancy available on either float to profile from 2000 m to the sea surface in tropical regions having a very warm surface layer. If a float lacks the necessary excess buoyancy, then it will not reach the surface during its profile. A study has recently been conducted at the University of Washington to attempt to determine the maximum profiling depths of floats that are presently available. Using historical temperature and salinity data from various regions, a simple model of float buoyancy was created that takes account of the thermal expansion and compressibility of both APEX and SOLO floats. For the present generation of floats, it has been found that a high fraction (as much as 60%) of the profiles would be lost at low latitudes due to a lack of excess buoyancy for both types of floats, for parking at 2000 m. In fact, in the equatorial Pacific it was found that both types of floats presently available could reliably collect data to no more than about 800 m. At higher latitudes, where the surface waters are denser and less buoyancy is required to reach the surface, this problem is less severe. A more detailed report resulting from this study, that examines the maximum reliable profiling depth in most regions of the world ocean can be found on the web at http://compass.ocean.washington.edu/~riser/public, in the file argo-depth.pdf or argo-depth.ps.

The Science Team agreed that the depth capability of profiling floats is still an actively evolving part of the technology. Several areas of investigation are underway. These include the use of pumps with greater displacement and passive solutions for changing the effective compressibility of floats or their effective thermal expansion coefficient. The Science Team is uncertain how to achieve an appropriate balance between encouragement of float manufacturers to achieve greater profile depth versus cost effectiveness of present designs. The cost/benefit curve is not yet understood. The agreed "target" depth during the early years of Argo is 2000 m. However, this is a "target" and not a performance standard. It is achievable with PROVOR floats but not in warm/fresh tropical waters using presently tested APEX or SOLO floats. The issue should be revisited at AST-3 following testing of improved models.

5.5 Performance standards

Performance standards are needed to ensure that (i) scientific and technical requirements of Argo are met, (ii) there is a uniform metric available for quality control procedures, and (iii) so that contributions from different Argo float providers meet minimum compatibility requirements. A technical performance subcommittee has been formed to address the issue. As an interim measure, "provisional" standards for sensor accuracy are as given below. Profiles that meet these standards will satisfy design criteria discussed in the Argo Design document. Indeed, instrumental errors at the levels specified below are considerably less than mapping errors for the short time-scale (seasonal) short spatial scale (1000 km) limit of our interest. For long time-scale (decadal) and large spatial scale (global) variability, the required limits for small non-random errors will need careful consideration.

Salinity – 0.01 psu relative to deep T/S variability. It is agreed that 0.01 psu accuracy is desirable, but that with presently tested CTDs sensor drift at this level cannot be unambiguously distinguished from deep T/S variability of similar magnitude. Testing of new generation CTDs (Section 5.2) shows promise for achieving the absolute standard.

Temperature – 0.005 ^{o}C. Temperature stability specifications for present CTDs indicate that this can be achieved over substantial float lifetimes (4 years).

Pressure – 5 db.

6. Implementation of a global profiling float array

A summary of national commitments and proposals was extracted from the national reports and is summarized in the following table. Close dashed lines (---) indicate commitments and spaced dashed lines (- - -) indicate proposals. Vertical bars indicate approximate fiscal year boundaries, which are different in different countries. Absence of continuation lines during later years indicates that the specific national plans are not yet formulated, but contributions may be made.

Table 1. Argo National Commitments and Proposals by Year

<table>
<tr><td>Date</td><td>4/ 2000…….1/ 2001…………1/ 2002…………1/ 2003…………1/ 2004</td></tr>
<tr><td>Australia</td><td>---------------10---------------||- - - - 30-50 - - - || - - - - 30-50 - - || - - - - 30-50 - -</td></tr>
<tr><td>Canada</td><td>---------------10-------------||- - - - - - 75 - - - || - - - - -75 - - - - ||</td></tr>
<tr><td>E.U.</td><td>|| - - - - - 80 - - - - ||</td></tr>
<tr><td>France</td><td>-----------20-----|| - - - - 50 - - - - -|| - - - - 50 - - - - -|| - - - - 50 - - - - -|| - - - - - -</td></tr>
<tr><td>Germany</td><td>|| - - - - 75 - - - - || - - - - 75 - - - - -||</td></tr>
<tr><td>Japan</td><td>-----------20---------------|| - - - - 50 - - - - -|| - 100 or more - || - 100 or more - ||</td></tr>
<tr><td>Korea</td><td>|| - - - 25-50 - - - || - - - 25-50 - - - || - - - 25-50 - - - || - - - - - - -</td></tr>
<tr><td>U.K.</td><td>-----------15-----------------|| - - - - 50 - - - - -|| - - - - 50 - - - - - || - - - - 50 - - - - - ||</td></tr>
<tr><td>U.S.A.</td><td>----55--------||---------130-------|| - - - 300 - - - - || - - - 375 - - - - || - - - 375 - - - -</td></tr>
</table>

It is likely that approximately half of the global array of 3000 Argo floats will be operating by the end of 2003, the first year of GODAE. The question of tradeoffs of global coverage at sparse density versus regional coverage at full Argo density (3^o spacing) was discussed. Clearly, deployments will begin regionally. It was agreed by most of the Science Team that for GODAE and CLIVAR objectives, it is preferable that Argo initially achieve global coverage at 50% density rather than sampling half of the global ocean at 100% density of instruments. A completed Argo array of 3000 instruments should be in place by the end of 2005.

6.1 Basin implementation strategies

There is not yet enough known of national contributions to Argo and national priorities to make detailed basin-by-basin implementation plans. However, planning exercises were initiated so that the process of basin planning could be better understood. Problem areas (the southern hemisphere extra-tropics) need to be identified early in order to direct attention there. Argo must be a global array of profiling floats rather than a cluster of regional arrays. Resource projections for the Atlantic, Pacific, Indian, and Southern Ocean were deemed adequate for completion of the Argo array in all except the Southern Ocean. This should not be interpreted as meaning that no further floats are required for other basins. Priority shifts will occur (preferably southward) and some planned contributions may not materialize. Additional participation by float-providing nations is needed.

First iteration maps of deployment strategy were produced for all basins except the Southern Ocean (where array dispersion will be relatively rapid from sparse supply vessel routes due to high velocity at any parking depth). The basin implementation strategy maps are not reproduced here due to their speculative nature. However, they will be provided as input for subsequent basin implementation meetings. The first of these (for the Pacific and eastern Indian Oceans) will be held in Tokyo in April, 2000. Discussion of Atlantic Ocean implementation strategy is planned for July 2000 and the Indian Ocean for November 2000.

In addition to achieving adequate density of instruments, it is desirable to avoid populating a given region with floats from a single provider or during a single deployment year. The former is to permit comparison of different instrument types and provide backup in case of systematic failures. The latter is to prevent large gaps from forming due to array aging.

6.2 Status Report on the International Coordinator

An International Coordinator will be located in Toulouse France to facilitate IOC/WMO requirements for notification of member states regarding deployment of floats that may drift into EEZs. The Coordinator will also assist the Science Team in a number of functions including coordination of float deployments, wide dissemination of Argo information via the internet, and encouragement of IOC/WMO member states to join the Argo project. It is thought that an effective vehicle for enlisting broad interest and participation is through regional action panels. Chairpersons of Basin Implementation Strategy meetings are directed to consider formation of such panels. The status report on the Coordinator (from E. Charpentier) is included as Appendix IV. The U.S. and U.K have agreed to support part of the cost of the Coordinator. Additional support is needed.

7. Argo Science

Brief presentations of Argo-related science were made by P.Y. Le Traon (Combining float data and altimetry in the gulf Stream region) and D. Roemmich (Eddy transport of heat and thermocline waters in the North Pacific). Future meetings of the Science Team should include more time set aside for presentation of scientific results from Argo.

8. Next meeting, changes to membership

The present membership of the Argo Science Team includes Dean Roemmich (chairman), Olaf Boebel, Yves Desaubies, Howard Freeland, Brian King, Pierre-Yves Le Traon, Bob Molinari, Breck Owens, Steve Riser, Uwe Send, Kensuke Takeuchi, and Susan Wijffels. The Science Team will recommend to its parent bodies (GODAE, CLIVAR UOP) that Kuh Kim (Korea) and an additional representative from Japan (to be named) should be added to the group.

The next meeting of the full Argo Science Team is tentatively scheduled for Victoria, British Columbia, Canada, in March 2001. In the interim, basin implementation meetings should have been held as discussed in Section 6.1.

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Appendix I- THE U.S. ARGO DATA SYSTEM

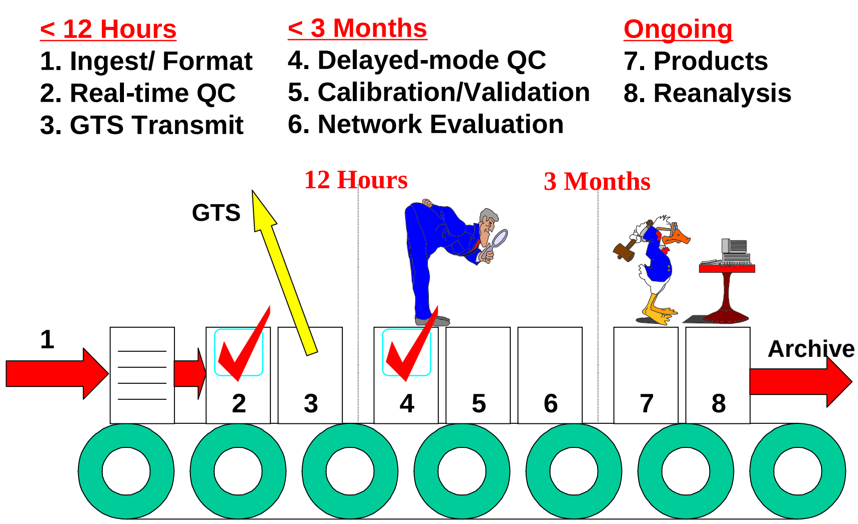
1. INTRODUCTION

The purpose of this document is to advance the planning and implementation of a data management system for the profiling float array, Argo. Many of the desirable characteristics of the data system are known, as are some of the pitfalls we wish to avoid. While the overall form of the data system is known, many of its specific attributes are not and some areas of responsibilities are still to be determined. The following is prepared to circulate among those involved in Argo data delivery in order to solicit ideas and assistance. Readers should not assume that what is written here is fixed. It is advanced as a straw man for comment. Initial steps in implementation must occur soon, so there is some urgency in the process.

2. CONCEPT

Data management in Argo is planned to be step-by-step process, with all profiles being tracked through a series of procedures that add to the quality of individual profiles or of the overall dataset, with fixed time limits. Users have access to the data at any point after the initial steps (i.e. within 12 hours of collection) and are provided with information on what processing has been completed at that point in time. We characterize this system as the Argo Data Assembly Line (ADAL) and its basic structure is shown in Fig 1.

Fig. 1 The Argo Data Assembly Line



The ADAL represents the data management methodology needed to ensure timely delivery of high quality profiling float data to a large user community. Specific objectives are:

(a) Real-time quality controlled data available to the operational community within 12 hours of collection. A 24 hour, 7 day a week fully automated operation is required.

(b) A higher level of quality control, including expert inspection of profiles, applied to the data within 3 months.

(c) Continuous open access to the data after the real-time quality control.

(d) Continuous evaluation of the network to ensure that design requirements are satisfied.

(e) Generation of data products to increase the usefulness of data and for further quality assessment.

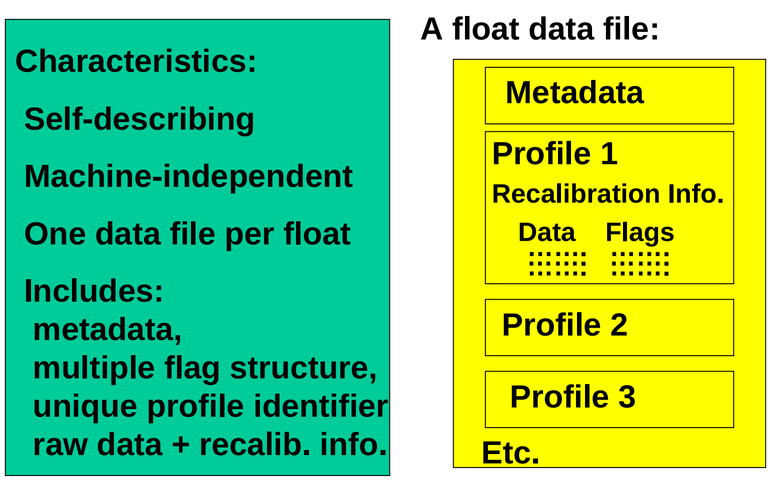
A description of the tasks to be performed on the ADAL to achieve these objectives is given next. Off-line requirements to be satisfied prior to and during the operation of the ADAL are then described.

2. DATA ASSEMBLY LINE TASKS

A schematic diagram of the ADAL is shown in Fig 1. Within each of the major steps, specific activities are as follows:

Task 1, Data ingestion: Raw data from the satellite services (presently ARGOS and ORBCOMM) are simultaneously sent to the ADAL and to float PIs. The PI copy is both for information purposes and to ensure that data are not subsequently lost from the ADAL. The data are put into a common format on the ADAL (Fig 2) and meta-data are added. The data format should be self-describing and machine independent (NetCDF is an example of such a format although no final choice has been made). Data are stored as one data file per float, with new profiles from the same float appended as they are received. This is efficient in terms of meta-data storage and

Fig. 2 ADAL Format for Argo Data



access to individual float histories. Individual profiles have a unique identification consisting of platform and sequence numbers.

Task 2, Real-time quality control (QC): The raw data are checked using automated procedures. Real-time tests include comparison of data values and gradients with climatologies, comparison with near neighbors including the float’s own recent profiles, speed and checksum tests, and some specific tests for salinity that have yet to be devised. Data formats will include a series of flags to indicate whether data records have passed or failed individual tests (as opposed to a single good/bad/questionable flag).

Task 3, Data transmission: Within 12 hours of data collection, the data are both put onto the GTS and e-mailed/ftped to designated users. The GTS data format does not allow for flags and so the GTS transmission includes only the data that are rated as "good" by the automated QC. The email/ftp route is for those operational centers desiring details of the QC procedures or wanting to make their own choice to accept or reject questionable data. The latter route uses the ADAL's internal format. Simultaneous to the transmission, the data are placed outside the ADAL firewall for open access by other users.

Task 4, Delayed-mode QC: Following the real-time QC, a higher level of QC is carried out jointly by the data center and the PI within 3 months of data collection. In delayed-mode, the data center is in possession of a more complete dataset for mapping and comparison purposes. Neighboring floats from other data centers, different data types (XBT, XCTD, TSG etc.), and subsequent profiles from a given float can all be used in identification of outlier data. The PI's role is to make a careful examination of individual profiles and to render his expert opinion on data integrity, salinity calibration changes etc. As with the data center's QC procedures, the PI attaches unique QC flags. He also attaches recalibration information that reflects the history of the float's sensors. In the internal format (Fig 2), data arrays are not altered for recalibration, but every profile has recalibration information that is changeable.

Task 5, Data validation: Changes in the mix of data types in the climate data base, and even technology changes within a data type, can result in spurious climate signals. For example, it is know that XBT data contain systematic errors (related to the DC analog circuitry) not present in floats and other high quality CTD data. It will be necessary to compare maps drawn with different data types to identify any systematic differences and ensure that spurious signals are not introduced into the long-term record.

Task 6, Network evaluation: Continuous network evaluation is needed to ensure that design requirements are being met. For example, data voids will be examined using Data Center, PI, and operational center products. Based on these reviews, appropriate actions will be taken to fill important gaps. While network evaluation can be carried out by individual data centers, network maintenance requires close cooperation between U.S. and international partners having overlapping regions of responsibility

Task 7, Product generation: A product suite is needed to evaluate the network and as a marketing tool to generate additional users. Products will use both trajectory and profile data.

Task 8, Reanalysis: Real-time and delayed-mode QC will utilize the best contemporaneous datasets and climatologies data available at the time. However, especially during the early years of Argo, climatologies will improve substantially with time (salinity everywhere and temperature in remote regions). Delayed-mode datasets will become more complete on a time-scale of years, for example as shipboard CTD surveys are added to the data mix. These improvements will be used for reanalysis of Argo data and products.

Data Tracking: An important activity that takes place across the ADAL is data tracking. This is to assure that all data are received by the ADAL and available to the users. The first step in data tracking is registration of new float information by PIs. The PI registers newly deployed floats by passing float metadata – ID, location, sensors, profile timing and other parameters - to the data center. This allows the data center to anticipate the arrival of profiles and to initiate inquiries when data are not received. The ADAL thus holds a master list of instruments, profiles, and current instrument status. After data are inserted onto the GTS, it is necessary to make data counts at various GTS nodes to determine whether all of the data are available to users. Experience in the XBT program is that substantial amounts of data sometimes disappear on the GTS and corrective action must be taken.

Appendix II - Coriolis Data Centre

Activity 1 : Data receipt at Coriolis data centre

* Raw data

Float raw data are received directly from CLS-ARGOS (ADS-mail service). Data are then decoded at the data centre to produce one "raw data file" per float cycle which is disseminated for technical purposes without quality checks to float owners via a mailing list.

This process is fully automated and triggered by full reception of float cycle data at data centre.

* Format of raw data

"Raw data files" are flat ASCII files and include all float cycle information : ascending and descending vertical profiles : (P,T) or (P,T,C,S), immersion drift : (P,T) or (P,T,C,S), surface drift : Argos latitude and longitude, localisation class, (P,T) or (P,T,C,S), float technical status.

As a consequence, the file format is very close to the PROVOR float design (example of this file in attached document #1).

Activity status : Done automatically (real time). Full reception detection has to be improved (now, it’s a time gap after last Argos transmission).

Activity 2 : Storage in Coriolis data base

"Raw data files" are automatically stored in the Coriolis data base. This data base is based on Oracle 8 RDBMS and adapted from TOGA/WOCE upper layer data base.

End of decoding starts database loading.

Activity status : Done automatically (real time).

Activity 3 : Quality control

* All quality controls (automatic check, visual checks) are done with data previously stored in data base
(Quality flag set to 0-Unqualified)
* Quality control is divided in two stages (temperature and salinity are not dissociated):
* automatic checks,
* visual checks (require operator intervention)

Up to now, both automatic and visual checks are done in real time before data transmission because data centre and floats are in test phase. Float surfacing is programmed to occur in working days.

Automatic checks include :
* Gross check with average adjusted to immersion and area,
* Climatology (Levitus, Reynaud, … depending on the area). A Netcdf file format has been defined (see attached file #2). This test may include previous week's ocean analysis if available in the same format.
* Spike and vertical high gradient detection,
* Vertical instability (if salinity measured),
if salinity missing check (under construction) with climatological salinity.
* On land detection (etopo5, Sandwell topo2).

Visual checks include :
* Individual profil visualisation superposed on climatologies,
* Water fall plot (continuity with previous profiles of the same float),
* Superposed profiles of same float,
* Visual comparison to previous profiles in the same area,
* Trajectory map and speed checks for position and date,
* T/S diagram

Automatic check results are highlighted with a colour code.

c) Used flagging convention is GTSPP one (For coherence with other past experiments, it will be extremely costly for us to change it). GTSPP history codes are also used (a subset of them).

On a practical point of view, QC flags are used in this way :
- 0 : unqualified,
- 1 : all checks passed,
- 2 : different from climatology,
- 3 : spike, gradient,
- 4 : impossible value : out of scale, vertical instability, constant value, ..;
- 5 : interpolated (only on request),
- 9 : missing value.

Activity status : Implemented for temperature, salinity, time series with SCOOP software (extension of TOGA/WOCE one). On average, 300 temperature profiles are checked daily on working days (mainly XBT).

Have been tested for temperature in Argo context from September 1999.

Automatic climatology check "rejects" obviously good profiles in the POMME area (meddies).

First experiment on April for float salinity (Pommier 2 PROVOR float deployment). Have been already used for CTD for three years.

Balance between automated checks and visual checks has to be analysed in the profiling float framework (target date : November 2000).

Activity 4 : Data transmission

* Dissemination is done after quality control. Quality flags are disseminated with data. If format can not handle quality flags (example : GTS/TESAC), only "good" measurements are sent (flags = 1, 2, 5).

* .Data sets are send automatically once a day to Meteo-France (ftp procedure) which, in France, is in charge of forwarding data to GTS. Procedures presently in place at Meteo-France require operator intervention (24 h delay on working days).

Automated procedures will be developed at Meteo-France.

* Data sets are available on the WEB in real time (12h after full reception). The WEB server includes drift maps and profile visualisation.

* Quality controlled data sets are now available in CORIOLIS format. Description of this flat ASCII format is available on the Web (http://www.ifremer.fr/sismer/program/medatlas/gb/gb_format.htm).
Other formats are available on request : TSDC, GTSPP,…
(http://www.ifremer.fr/sismer/program/gsdc/formats.htm)

Most of these formats handle only vertical profiles. Coriolis format should be improved to handle drift information. A netCDF format is under development now as well as an "end-user" format (compatible with Ocean Data View and most of visualisation software : GMT, AVS, Surfer, ..;).

* Direct access to data sets through a DODS Web server will be implemented.

Activity status :

GTS transmission : needs improvement in a short real time context (Météo-France),

WEB : web server available from September 1999, first interactive version on February.

File formats : mostly under development, strong interaction with other ARGO data centres and MERCATOR project.

Activity 5 : Delayed mode analysis.

* Objective mapping of T and S (target date 2000),
* Kalman filter analysis (target date 2001),
* Salinity sensor drift estimation (various method will be tested) (target date 2001),
* Statistics, EOF, horizontal covariances and tools for building "specific" statistics (target date 2001)

Activity status :
First draft available on the Coriolis Web for temperature,
Mostly to be adressed (cf target dates)

Appendix III - Real time GTS distribution of Argo data

What follows are views expressed by the Technical Coordinator of the Data Buoy Cooperation Panel (DBCP) based upon his experience with the Global Telecommunication System (GTS), surface buoy data and XBTs. This is not a proposal and should be regarded only as elements of discussion on the subject. Argo Science Team is invited to debate and comment on the issue.

There are basically three aspects for the exchange of profiling float data:

Real time: Real time distribution, i.e. as soon as possible after data collection with only simple automatic quality control checks. Those data are assimilated by oceanographic and coupled meteorological/oceanographic models at major operational centres.

Relaxed real-time: Real time distribution in slightly delayed mode (e.g. a few days) which permits to apply more complex QC checks and therefore to distribute more reliable profiles. This permits assimilation by experimental models, re-assimilation of the data at the operational centres to replace those profiles received earlier. It also permits routine model validation and monitoring. It is understood that Argo is designing a specific scheme for that purpose (e.g. using NetCDF format, etc..).

Deferred time: Deferred time data exchange of high quality scientific data sets for basically research purposes.

This document only deals with (i) real time.

Considering that most of the centres presently running operational oceanographic models are actually meteorological centres interested in ENSO and/or climate prediction, GTS is for now a natural tool for real-time data exchange: any observation distributed on GTS in an agreed WMO format will be received by practically all centres and assimilated without having to develop specific data exchange system not writing specific decoders.

This does not prevent from designing and using other data telecommunication means and other formats which may eventually prove more efficient and reliable than the GTS. Suggesting to use the GTS as an initial solution for real time data exchange of Argo data would leave time to carefully design a new dedicated system which would meet all the requirements.

It should be noted that while the GTS might be regarded as a complex system to handle, such complexity is also related to the level of standardisation of the GTS and mechanisms in place to insure the system remains operational while changes are implemented. Standardisation and such mechanisms should be regarded as necessities. Even a new future real-time data exchange system that will be designed for Argo will need to be precisely defined, documented, monitored, and uniformity agreed upon by data producers and users. Mechanisms for updating the system will need to be defined. Some of the strengths of such standardisation are listed below:

System is perfectly documented and documentation is up to date. For the GTS, formal documentation can be obtained from WMO (manual on the GTS, manuals on codes..).

It permits uniformity of data formats (e.g. only one version of a given format actually used by everybody at a given time).

It is not possible to add new features or implement changes without suggesting them through appropriate channels. For example, this prevents from seeing non formally documented features implemented.

There are mechanisms to discuss new requirements and to make sure that proposed evolutions of the system are acceptable to all parties, bearing in mind the operational nature of the system.

There are mechanisms to inform everybody regarding changes and implementation dates well in advance so that such evolutions can occur smoothly.

System is routinely monitored in terms of performance and solutions proposed to correct problems.

GTS has a number of advantages and drawbacks which could be summarised below:

Advantages	Drawbacks
Data automatically assimilated at operational centres (no development required)	Old-fashioned, complicated routing system and not 100% reliable
Decoders already exist	Complicated data formats
Many formats available including binary	Need to write encoders or specific data processing systems
Uniformity	Need to keep up to date with formal changes
Documented	Long procedures to adopt code changes
Global	Not easily accessible outside of the Meteorological/oceanographic operational community
Operational	Limited to meteorological, hydrological, and oceanographic data exchange
Evolving with technology (mainly point to point through bilateral agreements)	Global scheme evolving slowly
Monitored	Less efficient between developing countries

Regarding float data, a number of above drawbacks can be dealt with one way or another:

Drawbacks	Solution
Old-fashioned, complicated routing system And not 100% reliable	Small percentage of missing data can be re-assimilated later (relaxed real time)
Complicated data formats	Decoders exist
Need to write encoders Or specific data processing systems	See "Data processing for GTS purposes" below.
Need to keep up to date with formal changes	The number of centres responsible for processing the data and encoding them in WMO format should be minimal in order to limit impact of changes and globally to save

	resources.
Long procedures to adopt code changes	BUFR or CREX format already permit to encode almost any oceanographic data, including profiles in high accuracy plus some metadata. Adding new entries in BUFR tables (e.g. for metadata or new identifiers) is relatively simple.
Not easily accessible outside of the Meteorological/oceanographic operational community	Other applications do not necessarily require real time. Specialised archiving centres will be dedicated for delivery of data to the public.
Limited to meteorological, hydrological, And oceanographic data exchange	Argo fits into these categories.
Evolving slowly	Alternative to GTS can be designed and eventually implemented
Less efficient between developing countries	Although major operational centres which are the principal users of Argo data are not concerned, it should be emphasised to deliver the data to all countries, especially those with concerns regarding floats entering their EEZ

Data processing for GTS purposes

Several solutions are possible, e.g.

Design of one (global) or more (regional, e.g. Pacific) dedicated system at meteorological or oceanographic centre(s). Provided there is sufficient uniformity in raw data formats, data would be forwarded in raw form by the float operators to the centre(s) for data processing, Quality Control, encoding into adequate WMO code, compilation of the reports into bulletins, and effective GTS distribution.

Each float operator makes specific developments to receive and process its float data, control the quality, and format the data in adequate WMO code. Data are grouped into bulletins and forwarded to a national meteorological service for effective GTS distribution.

GTS data processing at Service Argos for data transmitted through all satellite systems (e.g. Orbcomm, Argos, etc.). For floats processed via Argos, a dedicated GTS sub-system exists which can process wide range of Argos message formats, apply simple QC checks, encode the data in relevant GTS format and forwards them to the NWS and Météo France for effective insertion on GTS. Argos message formats must be compatible with the Argos GTS sub-system so the issue must be discussed and formats agreed between float operators, manufacturers, and Service Argos. For floats processed via other systems (e.g. Orbcomm), one solution could be to forward the received raw data to Argos for GTS data-processing (negotiation and developments required in that case).

One important issue is to have a minimum number of centres responsible for GTS data processing, and GTS distribution of Argo data because:

(a) Having multiple GTS data-processing centres for sub-surface float data would make it difficult for GTS users to deal with potential problems related to specific floats. When a user detects a problem, there should be a mechanism to track it down at every step from the float down to the user via satellite, data processing system, quality control scheme, encoding system, and GTS route.

(b) Coordination of GTS distribution, including data-flow monitoring is more efficient when dealing with a limited number of data processing centres;

(c) Consistency of produced float data, and of quality control schemes, is less likely to be guaranteed when dealing with various data processing systems.

(d) It is more effective to coordinate and eventually implement code changes or encoding practice when the number of centres to deal with is small.

(e) It is globally more cost effective to implement such changes when the number of centres is small.

This might not be so crucial during the research phase of Argo but during the transition period to an operational programme, Argo could work at slowly reducing the number of GTS data processing centres.

Current practices for GTS distribution of float data:

A number of profiling sub-surface floats are presently reporting on GTS via NOAA/NWS, USA, MEDS, Canada, and Météo France.

WMO numbers:

WMO numbers have the form ABnnn (e.g. 49001). For floats "B" should be encoded with a 9. "A" designates WMO region as for other buoys. "nnn" is the buoy number to be assigned sequentially to floats deployed in area "A". Other series of WMO numbers were allocated which will continue to be used until the floats using them stop operating.

GTS bulletin headers:

SOVX10 KWBC : TESAC bulletins for US floats as inserted on GTS by NOAA.
SOVX01 LFPW : TESAC bulletins for IFREMER floats as inserted on GTS by Météo France.

Possible GTS formats to encode float data:

FM 64-IX TESAC (KKXX): The floats presently reporting on GTS are using TESAC format (temperature/salinity) which permits a resolution of 0.01 Celsius and 0.01 part per thousand.

FM 63-X Ext. BATHY (JJYY) only permits a resolution of 0.1 Celsius and 0.1 part per thousand. It is also limited to 20 points in the upper 500 meters. BATHY is used principally for XBTs.

FM 18-X BUOY (ZZYY) code permits a resolution of 0.01 Celsius and 0.01 part per thousand. This code is used for drifting and moored buoys. It could also be used for floats.

FM-94-X Ext. BUFR permits any resolution and provides for inclusion of associated data (e.g. QC flags), metadata as well as specific identification fields (e.g. Argos ID). Format is binary and permits compression, a feature which might be interesting for profile data. It is more complicated than character codes but encoders and decoders can be obtained from meteorological services.

FM-95-XI Ext. CREX permits any resolution and provides for inclusion of metadata as well as specific identification fields (e.g. Argos ID). This is a character code (i.e. a person can read it) which uses the same structure than BUFR. It also uses the same code tables than BUFR to describe the data. However, CREX does not permit compression nor associated fields (e.g. QC flags).

Appendix IV The Argo Information Center (AIC)

The AIC will be operated by the Argo Coordinator and will include a dedicated web site. The Coordinator will be located in Toulouse, will work under the supervision of the Technical Coordinator of the DBCP-SOOP, and will report to the Argo Science Team. This will be a half time position. Coordinator will be employed as a UN International Civil servant.

The Coordinator will:

- Develop and maintain a web site for float monitoring (e.g. EEZ issue).
- Propose and develop a scheme to alert member states on the status of floats entering their EEZ.
- Inform member states of the interest to keep them operational.
- Act as a clearing house for information on all aspects of float use (e.g. how to access data). Information will be available on the web site and updated regularly as required.
- Provide information regarding the status of the network.
- Advertise Argo through direct contacts, encourage participation of new partners.
- Promote flow of float data to designated archives.
- Promote an improved international dialogue between oceanographers and meteorologists, and between research and operational communities.

When requested by the Argo Science Team, the Coordinator may also work on specific issues such as:

- Assist with the development of co-operative arrangements for float deployments.
- Assist in the implementation of a global system, and in particular with regard to real time exchange of the data (contacts with float operators, data telecommunication providers, data assimilation centres).
- Assist in the implementation of real time and deferred time QC procedures.
- Act to resolve issues arising between float operators, manufacturers, data telecommunication providers, data assimilation centres, quality control and archiving agencies, WMO and IOC.

During the first year, the Coordinator will focus on the development of a web site, and address the EEZ issue.

Cost to develop and operate the AIC

To develop the Argo Information Centre, the following is required

Employment of the Argo co-ordinator half time as a UN international civil servant at the P3 grade. This is evaluated at about $35,000 per year.

Office space and logistic support for the Co-ordinator in Toulouse at Collecte-Localisation-Satellite (CLS)/Service Argos. It is here proposed that arrangements for the work be aligned along those used for the Technical Co-ordinator of the DBCP/SOOP. The DBCP/SOOP Technical Co-ordinator is a full time position. DBCP and SOOP pay FF80,000 yearly to CLS/Service Argos for office space and logistic support. 50% of that sum would be required for the Argo Co-ordinator, i.e. about $6,000 annually at the current FF exchange rate.

Provision for the Co-ordinator to travel for:

- meeting with Argo Science Team members and gain experience with regard to Argo
- meeting with representatives of countries with substantial concerns regarding floats entering their EEZ.

A provision of $10,000 is proposed for the fist year, and $7,000 for the following years.

Provision for hardware (2 computers, one for operating the center, and one for developments & backup), software, maintenance, and Internet access, for developing and then running the Argo Information Centre (web site). This is evaluated at $16,300 (investment) for the first year plus $6,400 per year (including the fist year) for Internet access and maintenance.

Hence, a total of $73,700 would be required for the first year, and $54,400 per year for the following years.