WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (OF UNESCO)

JOINT WMO / IOC TECHNICAL COMMISSION FOR OCEANOGRAPHY AND MARINE METEOROLOGY (JCOMM)

SHIP OBSERVATIONS TEAM

FIFTH SESSION

GENEVA, SWITZERLAND, 18-22 MAY 2009

SOT-V/Doc. IV-2.6
(24.04.2009)

ITEM IV-2.6

Original: ENGLISH

REPORT ON THE ARGO PROGRAMME

(Submitted by D. Roemmich, H. Freeland, M. Belbeoch)

Summary and purpose of the document

This document provides for an overview of the current, status of the Argo Pilot Project and the challenges it faces.

ACTION PROPOSED

The Team will review the information contained in this report, and comment and make decisions or recommendations as appropriate. See part A for the details of recommended actions.

Appendices: A. Argo Status

References:

Owens, W.B. and Wong, A.P.S. 2008. An Improved Calibration Method for the Drift of the Conductivity Sensor on Autonomous CTD Profiling Floats by θ-S Climatology. Deep-Sea Research, In press.

Roemmich, D. and 11 others (the Argo Science Team), 1999. On the design and implementation of Argo: An initial plan for a global array of profiling floats. International CLIVAR Project Office Report 21, GODAE Report 5. GODAE International Project Office, Melbourne, Australia, 32 pp.

- A - DRAFT TEXT FOR INCLUSION IN THE FINAL REPORT

IV-2.6.1 Mr Mathieu Belbéoch reported on Argo developments since the last SOT Session. He explained that while Argo had achieved the 3000 float milestone, it nevertheless fell short of requirements in the southern hemisphere by about 600 floats. Global deployment and replacement of the Argo array is a challenging issue and at a significant expense. The Panel agreed that more cooperation was required under JCOMM to maintain the global arrays.

IV-2.6.2 The Panel noted that ninety percent of Argo profiles reached the GTS and the GDACs within 24 hours of collection, and that the data distribution was closely monitored by the AIC to ensure that every float deployed distributed its data as appropriate.

IV-2.6.3 Operational centers are reporting positive impacts from the early years of Argo implementation, and have stressed their requirement for long-term continuation of the array for adequate evaluation. The Team noted that the research community has rapidly adopted Argo and were using the data widely.

IV-2.6.4 Mr Belbéoch explained that the Argo Steering team made efforts to promote an educational use of Argo. In particular, Argo status and products will be included in the Google Ocean offer content. Other elements of the GOOS will follow.

IV-2.6.5 The panel noted the constant progress in the support provided by the AIC to the Argo community and welcomed the idea of developing further the synergies between Argo and the SOT. The panel recognized the need to contribute properly to the technical coordination of the SOT though the existing AIC trust fund with support from IOC and WMO. The Panel invited its members as well as SOT members to contribute to the AIC funding to reflect the change of role within JCOMMOPS with the Argo TC working also on SOT coordination (***action; SOT members; SOT-VI***).

IV-2.6.6 The Panel noted that Global deployment and replacement of the Argo array remained a challenging issue and a significant expense. Transiting research vessels and commercial ships are used for float deployment wherever possible. However, in remote ocean regions, particularly in the South Pacific and Indian Oceans, opportunistic traffic is not sufficient. Through a collaboration of U.S. and New Zealand Argo programs, a series of dedicated deployment cruises has been carried out using Research Vessel Kaharoa. The Panel invited SOT members to cooperate as much as practicable with Argo in terms of logistical support for the deployment of floats and to, routinely provide the Argo/SOT TC with information on VOS and SOOP implementation plans (***action; SOT members; SOT-VI***).

IV-2.6.7 The Panel invited its members to contribute jointly with Argo and DBCP to relevant regional training workshops, platform donor programmes, and other capacity building initiatives (***action; SOOPIP members; ongoing***).

- B - BACKGROUND INFORMATION

1. Performance measured against requirements

1.1 By design (Roemmich et al., 1999) the Argo array should consist of a profiling float every 3^o latitude by 3^o longitude in the deep ice-free regions of the oceans. This distribution leads to a total requirement of about 3200 floats between 60^oS and 60^oN. The present distribution of floats by latitude, including only those providing good quality profile data, is shown in Fig 1 (black line). This is compared to the 3^o requirement (red line). Although Argo has achieved the 3000 float milestone, presently it falls short of requirements in the southern hemisphere by about 600 floats. This is because:

- Some floats are deployed in marginal seas by “Argo equivalent” programs, and are therefore in addition to the core Argo array.

- Some floats are operating at high latitudes, additional to the core array.
- Floats deployed by Argo-equivalent programs are sometimes at greater areal density, additional to Argo requirements.
- Some (grey listed) floats are not providing good profile data.

1.2 Objectives for the Argo Program in the coming years related to array performance are:

- Achieve mean float lifetimes of 4 years or longer, needed to sustain the core Argo array with 800 floats deployed per year.
- Deploy more floats in the southern hemisphere to achieve the array's design requirements.
- Extend instrument capabilities for profiling to 2000 m everywhere in the oceans. At present, 2427 out of 3292 active floats are profiling to depths greater than 1500 m.

The Argo Steering Team, co-chaired by D. Roemmich (USA/SIO) and Howard Freeland (Canada/IOS) are responsible for the International coordination and management of the Argo Program.

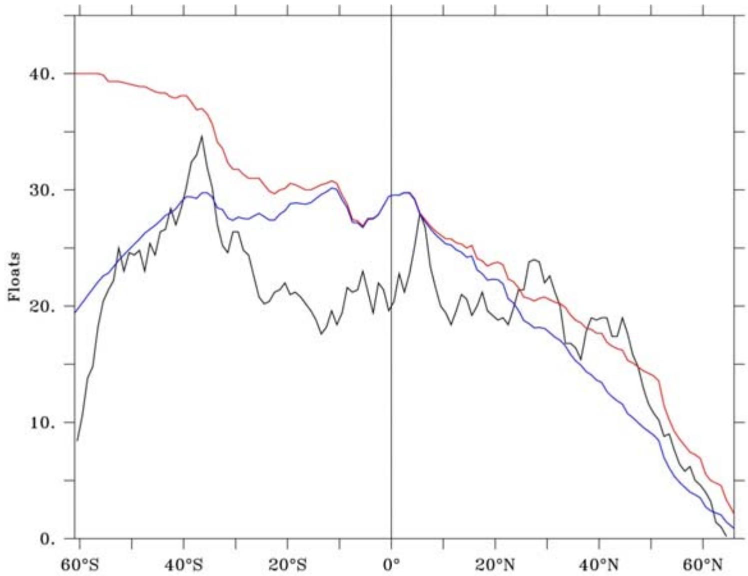


Figure 1: The number of Argo floats per degree of latitude providing good profile data, excluding those in marginal seas, is shown by the black line. Argo's design requirement for 3^o x 3^o open ocean sampling is shown in red. The blue line indicates what would be required for equal area sampling, multiplying the red line by the cosine of latitude.

2. Delivery of raw data

2.1 Argo Data Management activities are coordinated at the international level by the The Argo Data Management Team, co-chaired by S. Pouliquen (France/IFREMER) and M. Ignaszewski (US/FNMOC).

2.2 All raw Argo data are subjected to uniform, automated quality control procedures by national Data Assembly Centres (DACs). They are uniformly formatted (in NetCDF), and transmitted to one of two global DACs that maintain complete mirror-image datasets. They are also transmitted by the DACs via the GTS.

2.3 Approximately 90% of Argo profiles reach the GTS and the GDACs within 24 hours of collection. All Argo data are freely available without restriction.

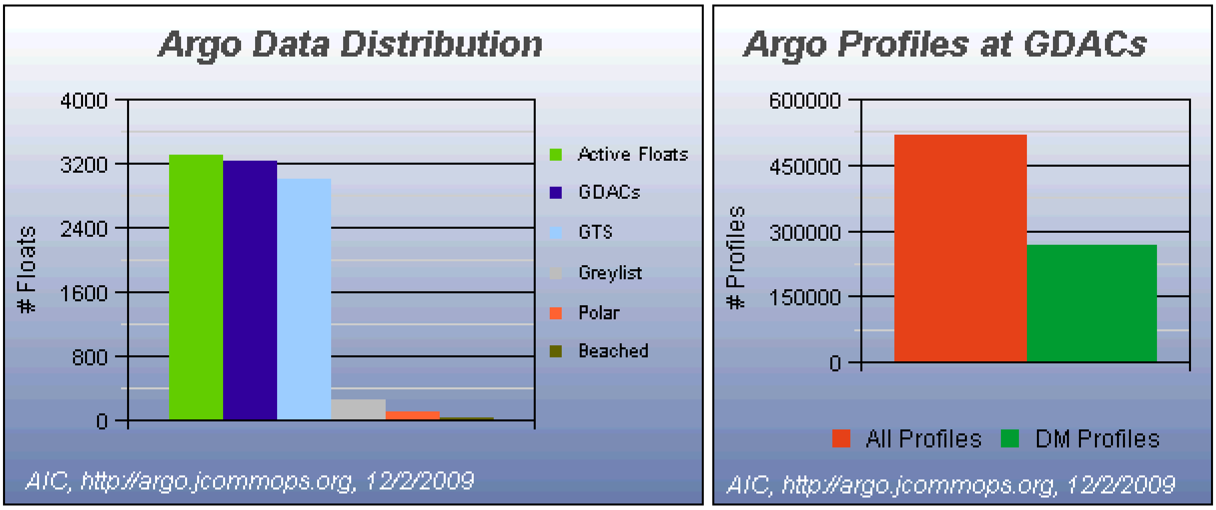


Figure 2: Data distribution by presently active Argo floats (left) and Argo profiles at the GDACs (right). Source: Argo Information Centre.

3. Measurement standards and quality control issues

3.1 Salinity drift: Salinity drift in Argo floats, due to bio-fouling and other causes, is detected by comparison of profiles to nearby high-quality shipboard CTD data and to nearby float data through a delayed-mode quality control (DMQC) process (Owens and Wong, 2008) carried out within one year of data collection. There is presently a backlog in DMQC (Fig 2; about 100,000 of "All Profiles" are too recent for DMQC) that is expected to be removed by later this year.

3.2 Accuracy of temperature versus pressure: Applications of Argo data in global change research, including ocean heat content and steric sea level change, require the highest possible quality in temperature and pressure measurements. Since most floats are not recovered, the primary means of assessing data quality is by comparison to nearby shipboard CTD data. Such comparisons can be used to identify and correct small instrumental biases, but require some years for accumulation of data and analyses. This is a highest priority objective for the Argo Program. Since Argo data are freely and immediately available, an issue is the competitive need for rapid publication of results versus the need for highest-quality data in global change applications. Further education of Argo users is needed to encourage appropriate usage.

4. Logistics and resources

4.1 Global deployment and replacement of the Argo array is a challenging issue and a significant expense. Transiting research vessels and commercial ships are used for float deployment wherever possible. However, in remote ocean regions, particularly in the South Pacific and Indian Oceans, opportunistic traffic is not sufficient. Through a collaboration of U.S. and New Zealand Argo programs, a series of dedicated deployment cruises have been carried out, including 9 voyages by RV Kaharoa since 2004 and over 600 floats deployed (Fig 3, surface drifters are also deployed). This vessel is cost effective due to its small size (28 m length, crew of 5) but large capability. Without this or a comparable program, a global Argo array would not be possible. The future of this collaboration is uncertain due to funding limitations.

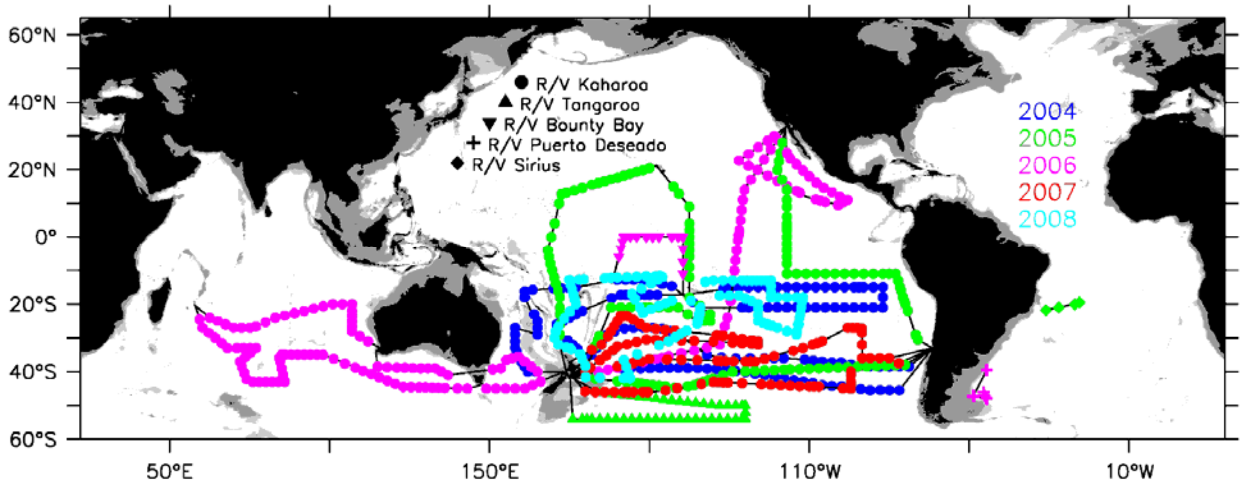


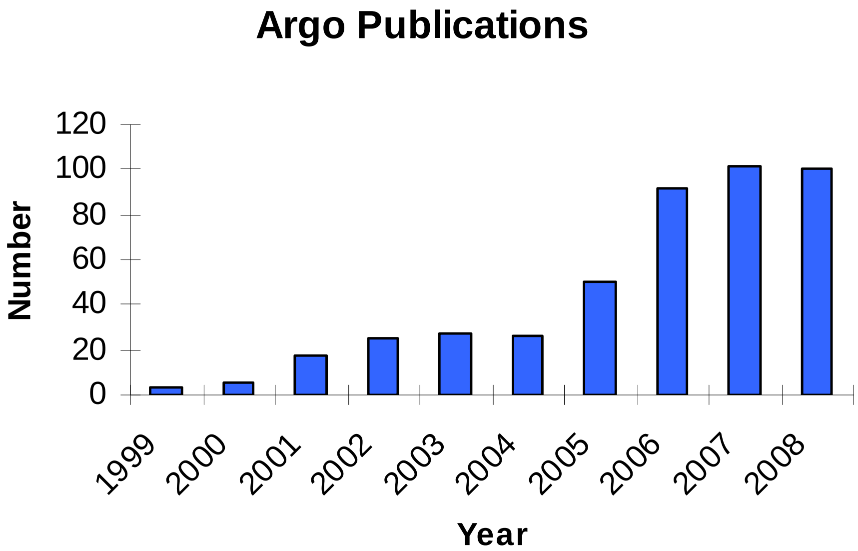
Figure 3: Deployment positions of Argo floats from dedicated RV cruises. Kaharoa's Argo-10 voyage to the South Indian Ocean (not shown) is planned for late 2009.

5. Costs of the system and benefits

5.1 Costs: Profiling floats cost about US$16,000 each. This equipment cost is approximately matched by the total cost of float shipping and deployment (including some floats by dedicated vessels, Fig 3), data transmission cost over the ~ 4-year float lifetime, data management costs including real-time and delayed-mode quality control, program management and coordination, and capacity building activities. Hence, for 800 floats per year the annual cost is approximately US$26M. Actual expenditure (extrapolating from U.S. Argo's budget) is about US$20M (budgets are not reported by national programs because, with differing scopes they are not comparable) as some activities are under-funded. In addition, some national Argo programs support research using Argo data, while others do not.

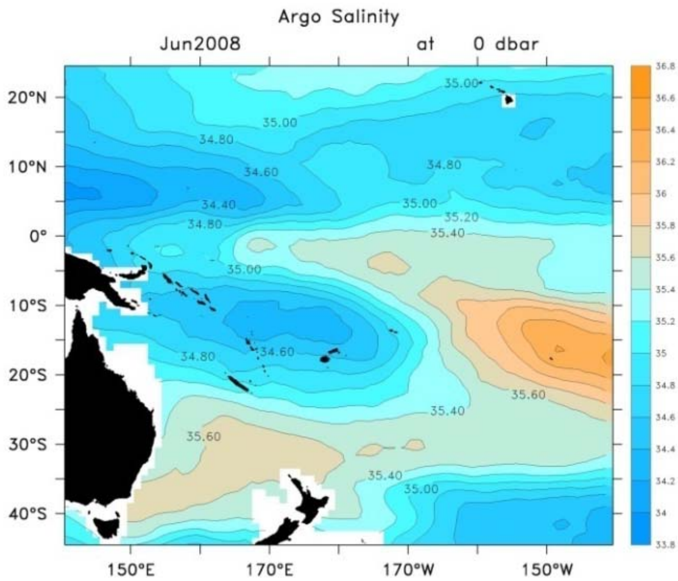
5.2 Operational uses: The Argo Program tracks, uses of Argo data by operational centers and in research. Approximately 16 operational centers (http://www-argo.ucsd.edu/FrUse_by_Operational.html) are using Argo data in ocean reanalyses and for initialization of short-term, seasonal-to-inter-annual, and decadal climate prediction models. The data are used both regionally and globally in ocean and coupled models. Argo is the dominant subsurface ocean dataset for global reanalysis and prediction. Operational centers are reporting positive impacts from the early years of Argo implementation, and have stressed their requirement for long-term continuation of the array for adequate evaluation.

5.3 Research uses: The research community has rapidly adopted Argo and is using the data widely. About 100 Argo-relevant research papers are now being published each year (Fig 4). This work includes a broad range of studies of water mass properties and formation, air-sea interaction, ocean circulation, mesoscale eddies, ocean dynamics, and seasonal-to-decadal variability. Argo's open data policy has resulted in the global dataset being at the fingertips of researchers around the world. The rapid acceleration in the use of Argo data for research when the array "went global" in 2004-2005 attests to the high demand for climate-relevant global ocean data.



<u>Figure 4</u>: Argo-related publications per year (http://www-argo.ucsd.edu/FrBibliography.html)
Not all publications are reported.

5.4 Education uses: Argo data are also valuable in education. Argo and other ocean datasets can now afford students desktop explorations of the planet. The use of Argo data in secondary and tertiary education is being tested in a number of nations, but there is still a large untapped capacity. Development of display tools for easy viewing of Argo data (Fig 5) will boost this process. Subsequent releases of Google Ocean are planned to include Argo data under the “state of the oceans”. Ocean, atmosphere, and climate science must be an integral part of educational curricula, so that tomorrow’s adults have a better understanding of the world and its changing climate.



<u>Figure 5</u>: The Argo Marine Atlas (http://sio-argo.ucsd.edu/Marine_Atlas.html) provides the capability for easy display of a wide variety of maps, vertical sections, time-series plots, and line drawings of Argo data, based on user-selectable ranges.

6. Capacity-building requirements

6.1 Raising capacity in Argo national programs: Some Argo national programs have needed assistance in acquiring expertise in float technologies and data management including DMQC. Argo conducts technical workshops on these topics (3 DMQC and 1 technology workshop to date), aimed at raising capacity and at standardizing practices across the program. Also, the larger participating institutions have hosted visits by Argo scientists and data managers requesting assistance and training.

6.2 Increasing Argo's international user community: The Argo float-providing partners are mostly in the larger industrialized nations. There is a strong need to provide awareness of the global dataset and its applications in the less developed nations so that the value of global ocean observations can be widely shared. Argo user workshops have been held in the Pacific islands (twice) and Ghana, with multi-national attendance by interested scientists, students, fisheries managers and meteorological services U.S. Argo and AUSAID (http://pi-goos.org/) support a full- time Pacific Islands Global Ocean Observing System Coordinator in the region. The Coordinator is responsible for identifying applications of value in the region, for providing information on datasets and applications, and for coordinating between data providers and regional users. More initiatives of this type are needed around the world. Argo has also supplied guest speakers for regional Argo science workshops and Argo-related meetings.

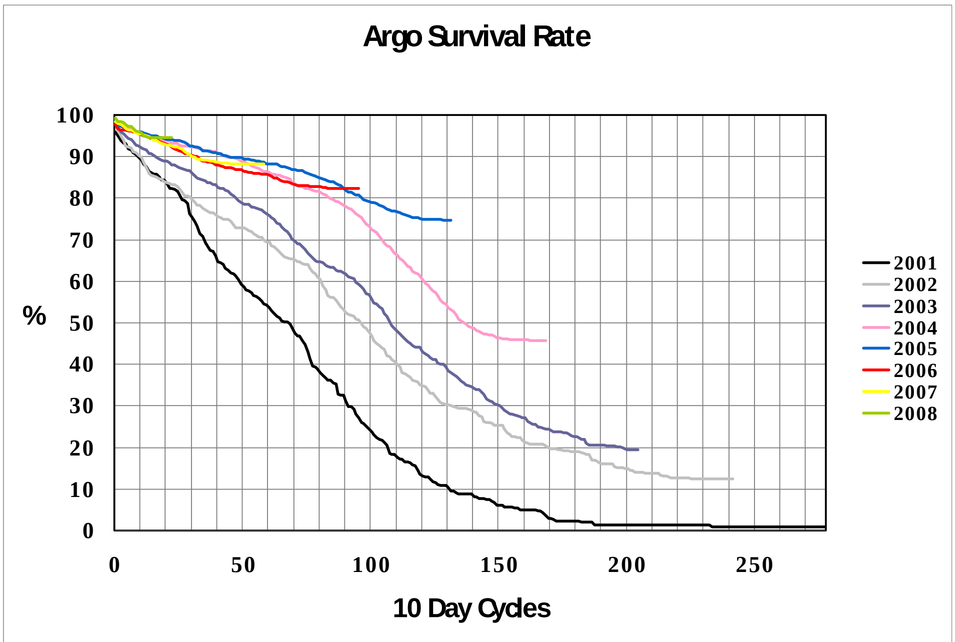
6.3 Argo data in secondary and tertiary education: (see 5 above). One example of education capacity building is the SEREAD program in Pacific island nations partially sponsored by U.S. Argo. SEREAD (see http://www.argo.ucsd.edu/FrUses_of_Argo_data.html) is developing teaching materials and holding teacher training workshops aimed at bringing ocean awareness and data into regional classrooms through curriculum-based units on climate and sea level.

7. Potential new technology: instrumentation, communications, platforms

7.1 Profiling float technology continues to evolve and improve substantially. In the past few years large advances have been made in float lifetimes, and it is likely that Argo's objective of four-year mean lifetimes will be met and exceeded (Fig 6).

7.2 Ongoing efforts in float technology development are aimed at increasing float capabilities (buoyancy capacity, communications, sampling under seasonal ice) and efficiency. Future floats will be smaller and lighter, therefore easier to ship and deploy and require less energy for buoyancy adjustment. Development of an abyssal profiling float is under consideration.

7.3 New sensor development is an exciting area of work, with potential to increase Argo's future value. New sensors for biological and geochemical parameters, for wind and rainfall, and for better sampling of temperature and salinity structure in the ocean's surface layer are being tested. Sensor development and demonstration are carried out as activities separate from Argo, and are therefore not reported here. At present over 100 Argo floats carry oxygen sensors.



<u>Figure 6</u>: Percentage of Argo floats remaining active after a given number of 10-day cycles. Each line is for a different deployment year. Source: Argo Information Centre

8. Ideas for the way forward

8.1 Argo's top priorities are to meet its core objective for spatial coverage (3^o x 3^o) in the deep ocean regions from 60^oS to 60^oN and to provide the best-possible data quality through DMQC, including careful comparisons with shipboard CTD data to identify and correct systematic errors. Work on the latter goal is underway, and the former can be achieved at present levels of float deployment (800 per year) through extended float lifetime and an increased percentage of floats providing good data.

8.2 Other high priority objectives are being established through a community consultation and consensus process that began with Argo participation at the GODAE Final Symposium (Nov 2008), and will continue at Argo's 3rd Science Workshop (March 2009) and through Argo participation at OceanObs09 (Sep 2009). New objectives could include extension of Argo's core sampling domain (into marginal seas, boundary currents, high latitude regions, and abyssal oceans) or inclusion of additional sensors on Argo floats. Once identified as priorities by the community, implementation of new objectives will require that they be sponsored through new agency contributions to national Argo programs or partners.

9. Argo Information Center

9.1 Background

9.1.1 The AIC is funded on a yearly basis via voluntary contributions from Australia, Canada, China, France, Germany, India, the United Kingdom and the United States.
In 2008 **Rep. of Korea** also began providing funds for the AIC.

9.1.2 The Argo TC started to act as SOT TC (30% of working time) as of February 2009.
Current contributing countries to SOT coordination (via the DBCP trust fund), are Australia, Canada, Germany, New Zealand and USA, all invited to contribute directly to the AIC trust fund at the IOC.

9.2 TC Activities

9.2.1 The Argo Technical Coordinator supports the Argo community on a wide range of issues that could be summarized in three keywords: **Assistance**, **Monitoring**, and **Cooperation**.
Many of these issues became routine activities:

- Network status monitoring
- Data management status monitoring
- Monthly Reporting
- Assistance in deployment planning, float retrieval, data distribution
- Assistance in national programmes (ad hoc stats, maps, …)
- Support Centre (user desk, QC feedback relay)
- Information System technical maintenance
- Information System content management (float metadata, contacts, documents, news, …)
- International Cooperation, Donor Programmes
- JCOMMOPS Administration, development
- Links with SOT, DBCP, OceanSITES, IOC, WMO, JCOMM
- Media needs (photos, articles)
- Assistance in new programmes (Marine Mammals, ITP, etc)

9.2.2 The AIC monthly report continues to be enhanced and improved each month. See: http://argo.jcommops.org/FTPRoot/Argo/Doc/2009-02-AIC.pdf

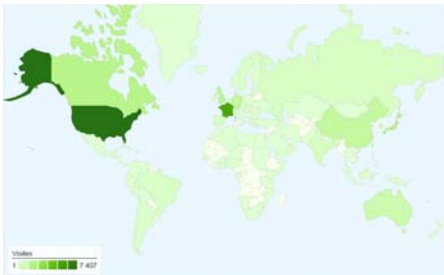
9.3 Information System

9.3.1 In 2009-2010, the JCOMMOPS web services (and in particular the AIC) will be re-designed. JCOMMOPS aims to clarify access to information and develop a web-based toolbox that will be used for many years to come, by:

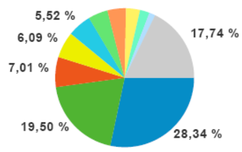
- better integration of the technical elements of the Information System
- designing a new structure for the JCOMMOPS website
- analysing, in depth, the results of the websites audience tracking set up a year ago
- using more interactivity in navigation (thanks to new technologies)
- developing a profile based service: "*My JCOMMOPS*"

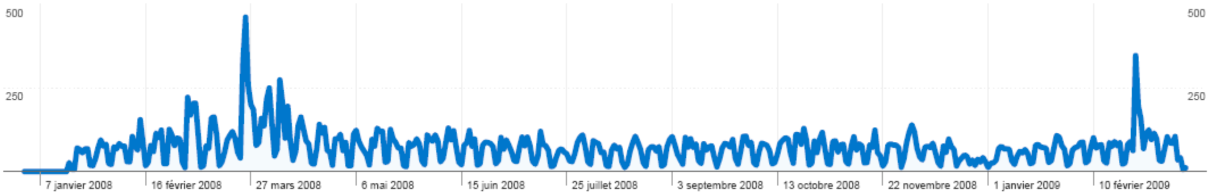
9.3.2 The AIC website seems to reach its international target and is regularly used by Argonauts. 2008 Usage Statistics:

- visits: ~100 times/day, ~500/week, ~2000/month.
- 26126 visits in 2008, from 135 countries
- ~800 pages views / day, ~10000/month, ~120 000 / year.



United States	7 407	28,34 %
France	5 097	19,50 %
Japan	1 832	7,01 %
Canada	1 592	6,09 %
United Kingdom	1 442	5,52 %
Germany	1 191	4,56 %
China	1 130	4,32 %
Australia	853	3,26 %
South Korea	582	2,23 %
India	375	1,43 %
Spain	363	1,39 %
Russia	334	1,28 %
Ireland	301	1,15 %





9.3.3 The AIC database is synchronized with the Argo Coriolis GDACs index files to gather more metadata on profiles (time, space, quality, delays, etc), similar to the synchronisation with Meteo-France GTS statistics.

9.3.4 The production of GIS files was reviewed to manage more metadata, export new text/Google Earth files, and create new monthly maps (see appendix).

9.3.5 WMO ids are allocated by the AIC in support of WMO for most of Argo contributing countries.

9.4 Support

9.4.1 A support/Feedback Centre was developed within the AIC website to assist the Argo data users to relay their individual feedback to data producers. Some routine feedback (comparisons with Altimetry data) is loaded quarterly in the system.

9.4.2 Argo will need to make progress to harmonize the practices on the instrumentation, in particular to help new and existing Argo groups that request support. TC proposed then to establish an inventory of "Common Practices" and share the expertise on float set-up further.

9.5 International Issues

9.5.1 The IOC Executive Council, Resolution XLI-4, recognized Argo as a "programme" to be sustained, "acknowledged" the work of the AIC (within JCOMMOPS) and adopted the "Guidelines for the Implementation of Resolution XX-6 of the IOC Assembly regarding the deployment of profiling floats in the high seas".

9.5.2 SOT is invited to contribute jointly with Argo and DBCP to the regional training workshops, platform donor programmes, and other capacity building initiatives.

9.6 Argo TC Planning for 2009 can be summarized as follow:

- Continue to produce/improve the AIC Monthly Report
- Continue to encourage/assist float operators to notify of deployment plans.

- Develop the Google Ocean Argo Layer
- Finalize specification of new AIC/JCOMMOPS website
- Migrate JCOMMOPS database on a new server
- Start developments of new web services

- Work on new GDACs metadata: delays, cycles, data formats
- Exploit detailed index files to develop appropriate monitoring tools

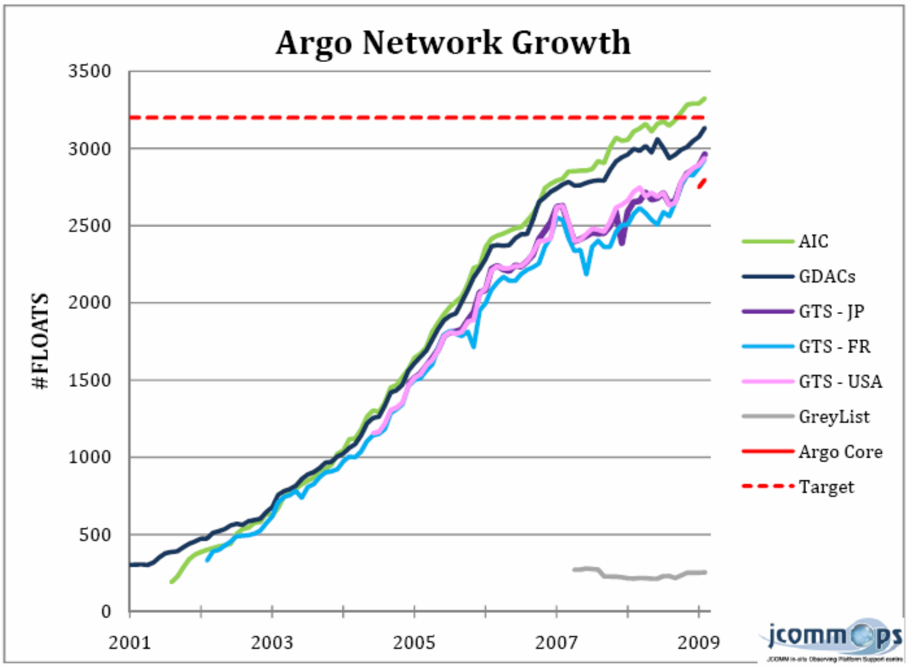
- Work on Argo Common Practices
- Update documentation for JCOMM
- Work (with AST and JCOMM) on new monitoring products demonstrating how Argo is meeting its requirements.

- Continue to assist in the float retrieval activities
- Continue to foster participation by new countries through donor programmes

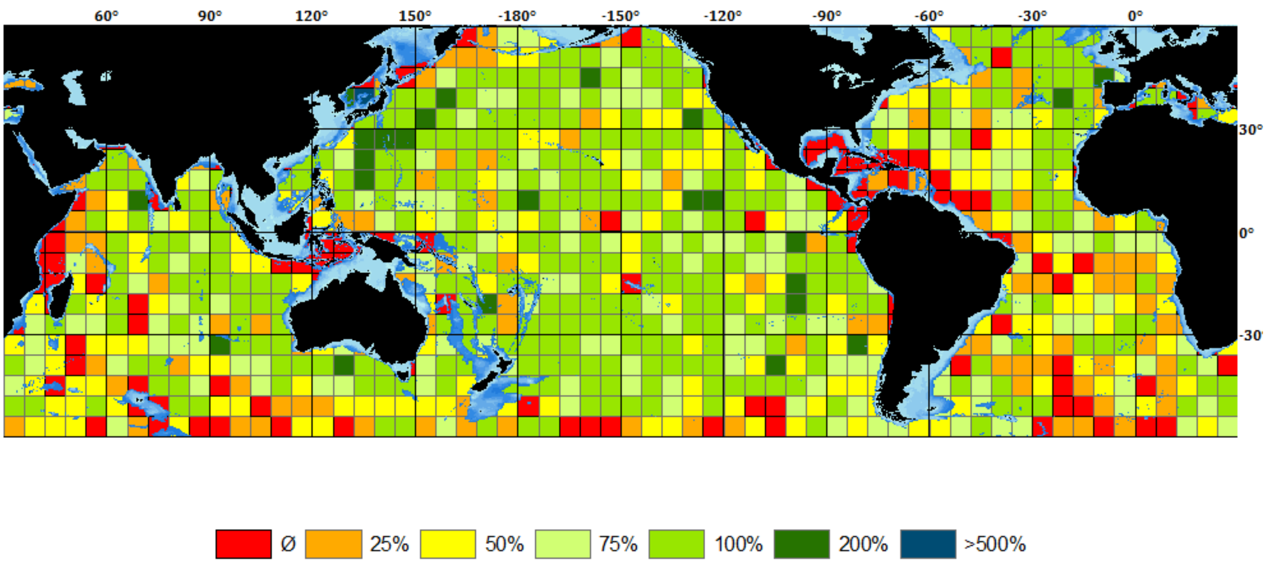
- Investigate possibilities to strengthen JCOMMOPS resources (ship coordinator)

APPENDIX A

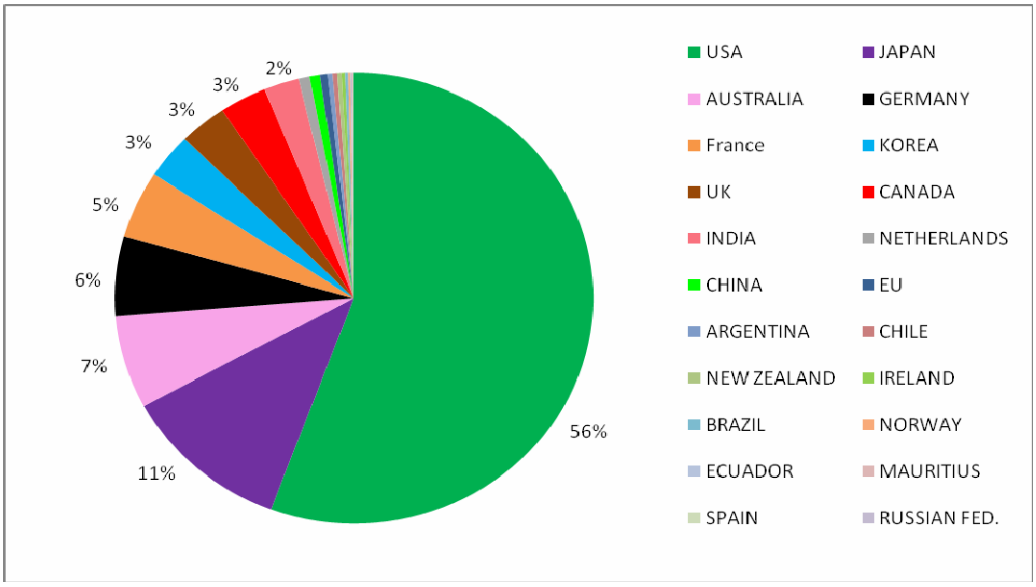
ARGO STATUS



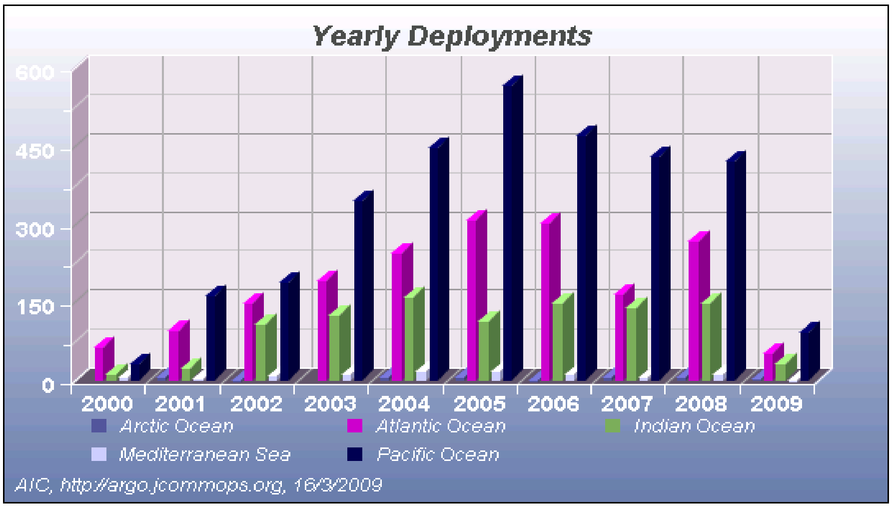
Argo core mission not fully achieved.
About 600 additional floats are required between 60N and 60S.



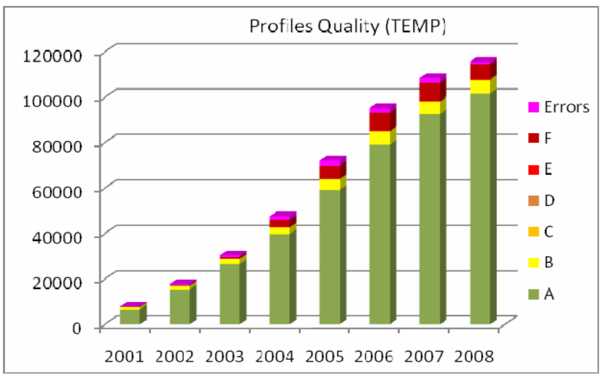
Argo density.
6x6 grid normalized on the 3x3 Argo standard.
(100% = 4 floats)

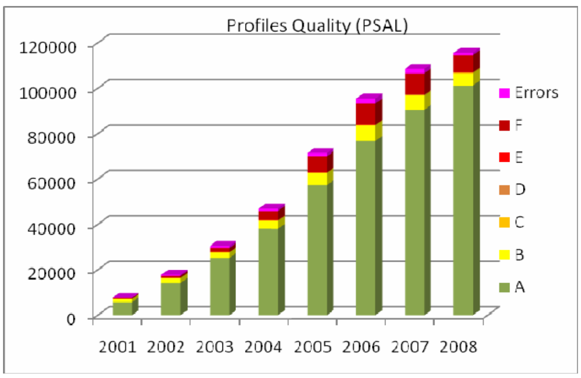


National contributions (% of active floats)
A dozen countries are sustaining the global array, and another dozen takes care of regional gaps.

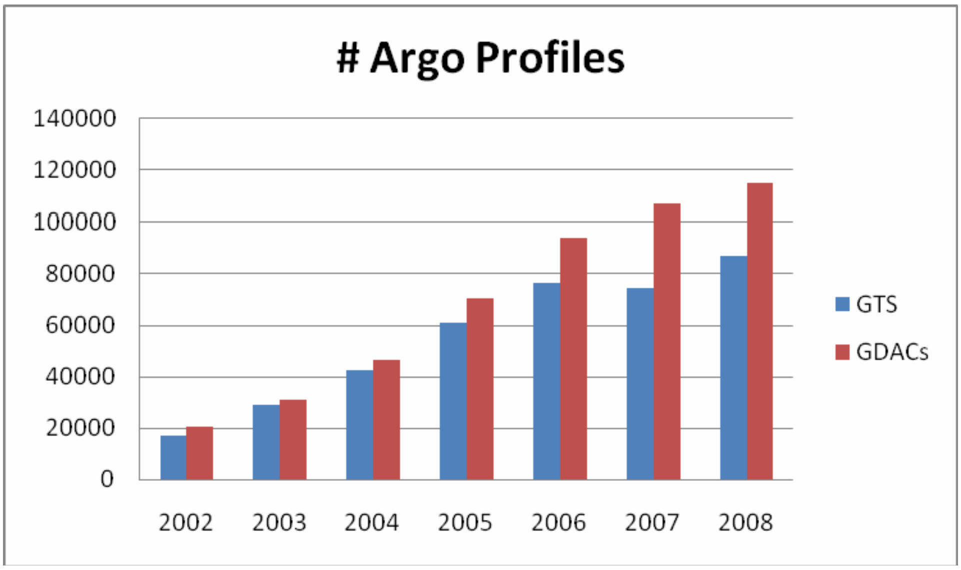


2008 is a good year for Argo, especially in the Atlantic Ocean with increased contributions from France and Germany.

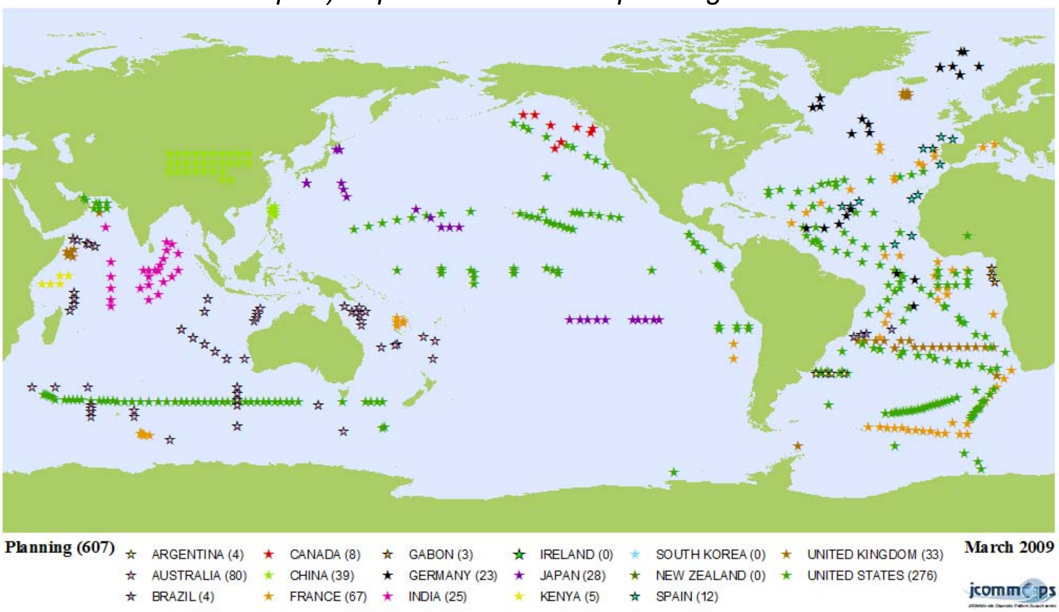




Growth and quality of T/S profiles distributed via the Argo GDACs.



At least 10% of profiles in 2008 were lost for operational users:
87079 profiles were distributed on GTS, while 97574 (high quality) were distributed at GDACs.
The AIC is monitoring this daily. In addition data managers are reminded every month (via the AIC report) to proceed the list of pending floats.



Current planning for 2009.
Float operators make substantial efforts to; routinely use the centralized deployment-planning interface

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