Coriolis

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Coriolis and Europe : the way forward

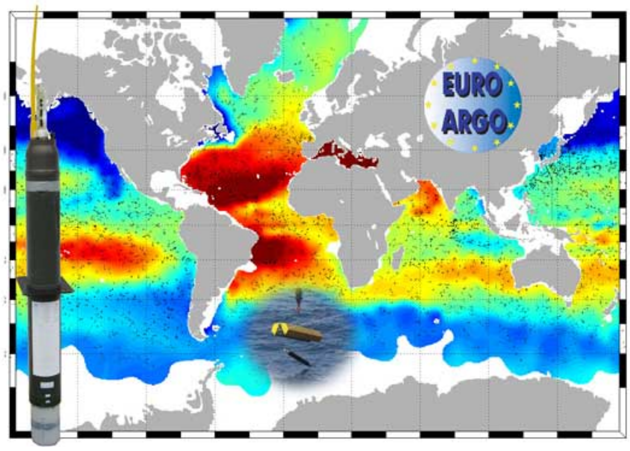
S. Pouliquen & P.Y. Le Traon, Ifremer, Brest

Since its early beginning, Coriolis has been actively involved in European and international projects and partnerships. Coriolis will develop further its European capacity with the start of two major projects: Euro-Argo and My Ocean (GMES Marine Core Services). The two projects are strong interrelated. They deal with the in-situ systems required by GMES for climate research, environment monitoring and operational oceanography. Euro Argo will work on the development of a sustained European contribution to Argo, an essential component of the global ocean observing system. As part of My Ocean, Coriolis will consolidate and improve its in-situ data services to provide the best data and products required by global and regional data assimilation systems and applications. An overview of these new projects is provided hereafter.

1. Euro-Argo : towards a sustained European contribution to the global Argo array

Argo is an essential component of the global in-situ ocean observing system. It provides, for the first time, a continuous monitoring of the temperature, salinity, and velocity of the upper ocean, with all data being relayed and made publicly available within hours after collection. This observing programme has strong complementarities to satellite observations (particularly altimetry). The development of Argo over the past 5 years is outstanding. For the first time, there is a now a truly global, real-time in-situ observing system. Data are used to develop an improved understanding of the role of the ocean in the earth climate; there are also systematically used by ocean analysis and forecasting centres and climate and seasonal forecasting centres. They are critically required by GMES Marine Core Services (see GMES Marine Core Service implementation group report).

The main issue for Argo now is to sustain the array on the long term. This is needed to realize the full potential of Argo both for climate research and applications. In agreement with its European and international partners, Ifremer/Coriolis prepared a preproposal to ESFRI (European Strategic Forum for Research Infrastructure) to sustain Argo in Europe.



The proposal was well received and Euro-Argo was selected among 35 other large research infrastructures of pan-European interest in seven key research sectors including environmental science. This allowed the participation to an FP7 call for proposal for research infrastructure preparatory phase (PP). The PP proposal was submitted in May 2007 and was recently selected. Euro Argo PP will start in January 2008 for a 30-month duration. The main objective of the Euro-Argo PP is to undertake the work needed to ensure that by 2010 Europe will be able to:

- Deploy, maintain and operate an array of 800 floats. Given the average float life time (presently

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below 4 years), the maintenance of such an array would require Europe to deploy about 250 floats per year. The European contribution is estimated to be of the order of a quarter of the global array. Specific European interest also requires a somewhat increased sampling in regional seas (Nordic, Mediterranean and Black seas).

- Provide a world-class service to the research (climate) and environment monitoring (e.g. GMES) communities. Two broad classes of users of Euro-Argo are, in particular, identified: the scientific community and the operational services for ocean monitoring (e.g. ocean and climate forecasting centres). While the former require uniform validated data sets of the highest quality, the latter place the emphasis on the efficient real time delivery of quality controlled data.

The preparatory phase proposal will focus on:

- The consolidation and strengthening of existing national contributions to the infrastructure.
- The development of a direct EC-wide contribution through GMES.
- The development of legal and governance arrangements for the Euro-Argo infrastructure.
- Evaluation and improvement of the European contribution to the Argo data management and delivery system.
- Enhancing European float technological capabilities (performances, sensors, communication systems) and working towards using Argo to study aspects of ocean biogeochemistry
- The development of a vigorous European Argo user community.
- Exploiting the open access to Argo data as an educational "window" on the oceans and their role in climate.
- Developing new partnerships between European Argo nations, new European countries and nations outside Europe.
- Integrating the European observing array into the international system.
- Developing a ten year implementation plan.

The proposal is coordinated by Ifremer and gathers 15 partners and 11 countries. The project consortium includes all the institutions in Europe (France, United Kingdom, Germany, Ireland, Italy, Spain, Netherlands, Norway) involved in the Argo international programme. Some potential new actors have already been identified and are included in the consortium (Greece, Portugal, Poland and Bulgaria). Most of these major institutions have a direct link with their funding agencies (ministerial level) and will work with them to define and agree on a long term contribution to the infrastructure.

As Argo is the main in-situ data set that is used now by European monitoring and forecasting centres, there are strong interactions between Euro Argo and the GMES Marine Core Services that will be developed further through the My Ocean project.

2. The Coriolis data centre, My Ocean and the GMES Marine Core Services

The Coriolis data centre is a major European facility to provide in-situ data sets required by operational oceanography centres and their applications, and by research users. In the coming years, the Coriolis centre will consolidate its operational and R&D activities as part of the GMES Marine Core Services (MCS) (My Ocean).

My Ocean will transition MERSEA towards a sustained and operational system fully interfaced with a series of downstream and user services. Coriolis will coordinate the in-situ thematic assembly centre (TAC). The role of the in-Situ TAC for MCS is to assemble high quality data sets, and to provide to the MCS Monitoring and Forecasting Centres (MFC) the "best" in-situ products for data assimilation both in real-time and delayed mode. This implies timely data flows from observing systems to MFC, clearly defined and homogeneous quality control procedures, validation processes with error characterization as well as reprocessing capabilities for re-analysis purposes. It will contribute to long-term monitoring of the ocean at global and regional scales

The In-Situ TAC aims to build the in-situ Pan European service for ocean monitoring, upon the national and international providers. The In-situ TAC will be composed of three entities (see figure 2):

- A coordination group, led by Ifremer, that will include a representative of the global and each region centres that will steer the In-Situ Tac activities.
- The global In-Situ centre, that will integrate, quality control and distribute in-situ data for the global ocean and connect to MyOcean Information management system to provide an integrated access to all in-Situ data to MyOcean users (internal and external)
- 6 Regional in-situ centres that will integrate and quality control in-situ data for the regional seas (Arctic, Baltic, North-West Shelves, Iberia-Biscay-Ireland (IBI), Mediterranean and Black seas) and distribute them to the regional MFC. They are connected to as well as to the Global in-situ centre.

In order to improve the quality of the In-Situ data additional R&D activities will be carried out on in three fields: improvement of bio-geochemical data quality control procedures, development of tools to check the T and S data consistency, elaboration of value added products such as climatologies, ocean state indicators and data syntheses. The methods developed will be transferred to operation within the My Ocean project.

Each global and regional centres will collect, quality control in-situ data (mainly temperature, salinity, current, sea level, Chl, O_2, nutrients) in a coherent way at European scale according to requirements defined by MFC and Services. In addition to providing an integrated access to a set of variables to MFCs and external users, one main contribution of the in-situ Tac will be the validation of the consistency of in-situ dataset at global and regional scales which was impossible to achieve when the data were distributed by individual data providers. Moreover in-situ value added products will be generated when methods developed in R&D mode are transferred.

Within this in-Situ TAC Coriolis will coordinate the overall activities and also provide the in-situ services for the Global Ocean and the IBI area (in cooperation with Puertos Del Estado/Spain). It will also contribute to the Mediterranean service. A major challenge will be to set up the appropriate collaborations with the relevant international and national entities/projects that collect in-situ data at global and regional level and to sustain these data streams on the longer term.

3. Concluding remarks

With GMES, we are contributing to GEOSS (Global Earth Observation System of Systems) for the European part. This means that interoperability (in terms of data format, data exchange, discovery/Viewing and downloading services) with other key contributors to GEOSS is a real challenge. As an example, interoperability between IOOS/USA and GMES/Europe is to be addressed.

An in-situ TAC will be useless without a well developed and sustained in-situ observing system. This is why we have, in parallel, to be proactive at national and European (GMES) levels to sustain the in-situ ocean observing system. This is what will be done for floats with EURO-ARGO and with the European projects EMSO and EuroSITES for the deep water and seafloor ocean observatories.

GMES is a new major undertaking for Coriolis and its European partners. We will move from national to truly integrated European in-situ observing systems and services. It is a major opportunity and a major challenge. We need to make it successful in order to sustain the in-situ systems and services we need for climate research and operational oceanography.

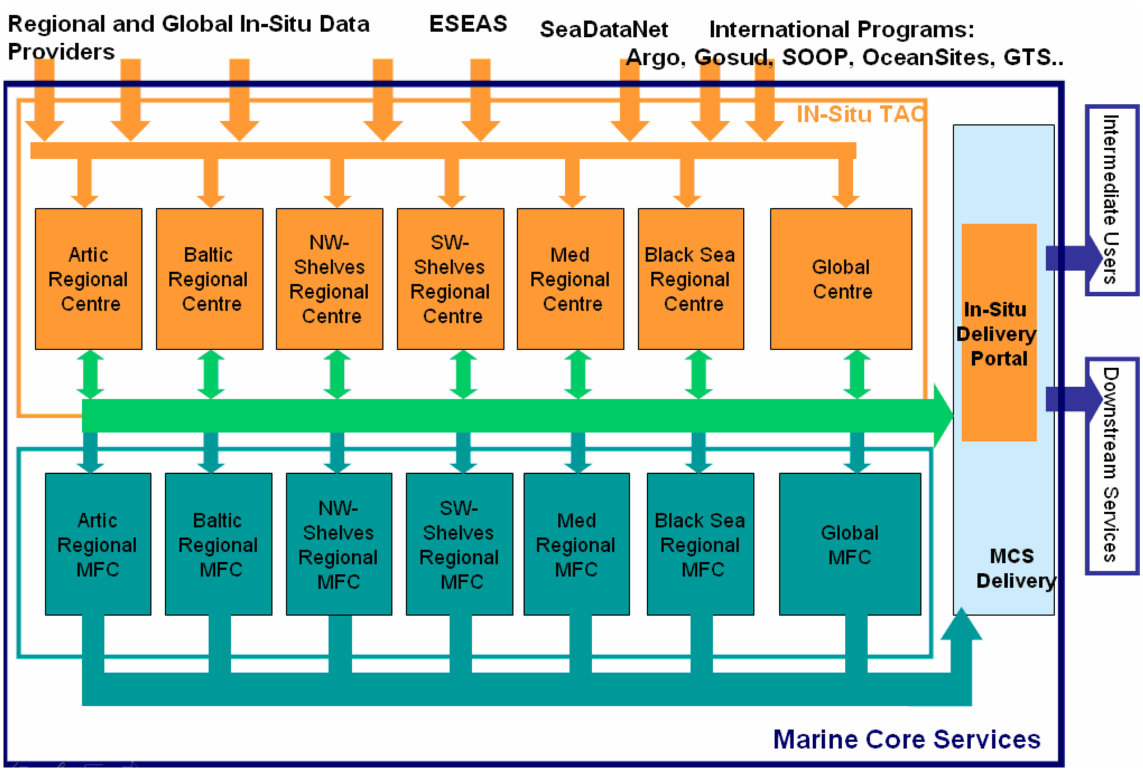


Figure 3: The Future MyOcean In Situ TAC (in orange) prepares datasets from outside data providers for the MFCs and MyOcean users.

Moving form Global to Regional

S. Pouliquen, L. Petit de la Villéon, T. Carval, Ifremer, Brest

The Coriolis data centre is now a major European facility that has been initially designed to provide integrated in-situ services for the Global Ocean. Originally settled to serve the French operational oceanography and research communities, it has evolved with MERSEA to provide services to the major operational centres in Europe and, within EuroGOOS, to set up links between regional ROOSes and global initiatives in order to build together the European in-situ facility for operational oceanography.
Designing an efficient data management structure for a project of Operational Oceanography is a real challenge at 2 different levels:

- In real-time where the challenge is to be able to provide a timely access to data, information and products in due time for daily runs of the models,
- In delayed mode to be able to deliver the most comprehensive data set for validation of the models outputs and for re-analyses purposes

Different categories of Observing system; depending on the area and the phenomena to be sampled, the observing systems to be set up could be very different. We usually sort them into 3 categories:

- Global: System designed to provide data all over the ocean (e.g altimetry, Argo for general circulation). Such a system can only be developed and maintained at the international level. It is built to resolve climate scale phenomena with sufficient resolution and accuracy and provides systematic upper ocean observations of a limited number of parameters (Temperature, salinity, SSH, SST, currents) on a time scale from 1 day to 1 month;
- Regional: System designed to provide data in a specific area to monitor specific phenomena (e.g. TAO/TRITON array for El Nino detection, Arctic buoy network for ice monitoring, etc). For satellite products, it is often required to combine data from different satellites to achieve the appropriate resolution both in time and space. Collaboration with several countries (usually less than 10) is needed and the number of parameters is larger (between 10 and 20), including ocean (both physical and bio-chemical) and meteorological measurements. The temporal sampling is often higher rate: from hours to days;
- Coastal: These observing systems are usually set up at the national level to answer very specific questions such as coastal monitoring of the water quality or wind/wave/tide monitoring in harbour areas, oil spill monitoring with satellite radar image, etc. There is little collaboration among countries and these data are often used exclusively by the coastal models that have led to setting up the system.

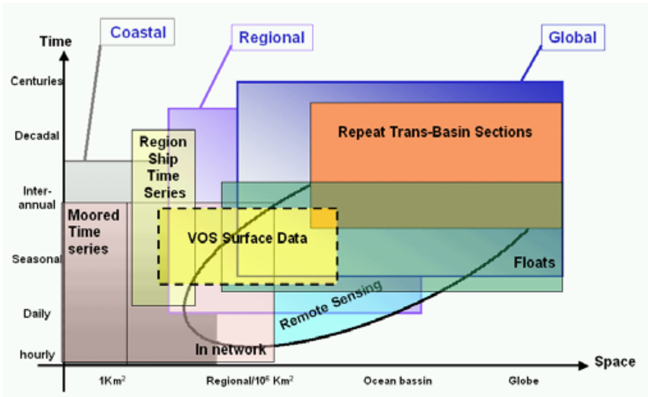


Figure 1: Platforms to use according applications (Global, Regional, Coastal).

How to improve Data access?

Access to data appears as a plate of spaghettis where you never know how long the way will be to reach the data you need. This is clearly not a way of distributing data to operational applications. What these operational users need are portals that build for them the connection to all the relevant datasets and provide access to these data as if it was all in a single place.

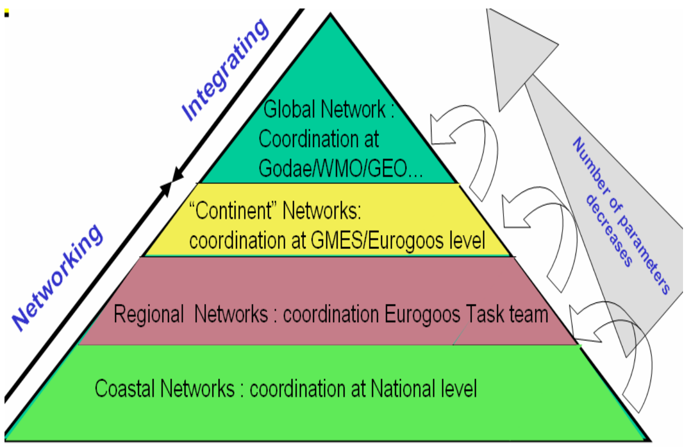


Figure 2: Global integration of observing systems.

Data are acquired at coastal, regional, pan-continent, global levels and all together they contribute to the observing system needed by operational systems. The more one goes from the coast to open-ocean, the less variables one usually needs. Therefore no need to share all the data but only a subset of variables on which we will agree on common practises in term of data access, data format and quality control procedures so that a coherent integrated dataset is provided in real-time and delayed mode to users. This is not a trivial issue and in the past 5 years data exchange both in Europe and internationally has been improved with complementary initiatives like SeaDataNet for European data infrastructure, DMAC/IOOS in USA, Argo or GHRSST for Godae, etc…Within Eurogoos, we started, through task teams, to coordinate data exchange between coastal and regional activities.

Coriolis and data exchange within EuroGOOS Rooses

The implication of Coriolis in the processing and distribution of regional data has started in the Mediterranean sea within the MFS/MFSTEP EU projects. Based on the expertise gained by Ifremer /SISMER within the MEDAR/MEDATLAS projects, Coriolis first acted as an archival centre for the MFS project before evolving to a processing and distribution centre within MFSTEP in collaboration with thematic centres managed by ENEA, OGS and HCMR.

One additional service that Coriolis has provided to the Mediterranean community was the provision of in-situ data acquired outside the MFSTEP community (fig. 3) and the capability to integrate them into a coherent Mediterranean dataset available to the operational and scientific community. This is the data flow that has been pursued within MERSEA for the Mediterranean Sea.

The second involvement of Coriolis into regional data exchange has been within the SEPRISE project (Sustained, Efficient Production of Required information Services) lead by the EUROGOOS project office. Coriolis has collaborated with the Eurogoos project office to gather in real-time the freely available data into a single port and provide visibility to the data within the Mersea Integrated Project funded by EC. This work contributed to demonstrate the feasibility of a joint pan-European data exchange and forecasting operated in an operational mode.

Despite the fact that the Seprise project ended end of March 2007, the data exchange process is still active and it will be improved within the ongoing FP6 ECOOP and the future FP7 MyOcean projects.

The third regional activity that Coriolis started is the design, in collaboration with ESEOO/Spain, of the data management system for the IBI-ROOS network (http://www.ibi-roos.eu/) that covers an area from the North of Ireland to the Canaries islands. It is based on two portals hosted by Coriolis and ESEOO(Puertos Del Estado) that will synchronize themselves for security purposes and will share the task of checking the consistency of the dataset . The data exchange has already started for real-time application between France, Spain and Ireland and will be extended to the other partner of the IBI-ROOS network within the coming year and then to delayed mode datasets.

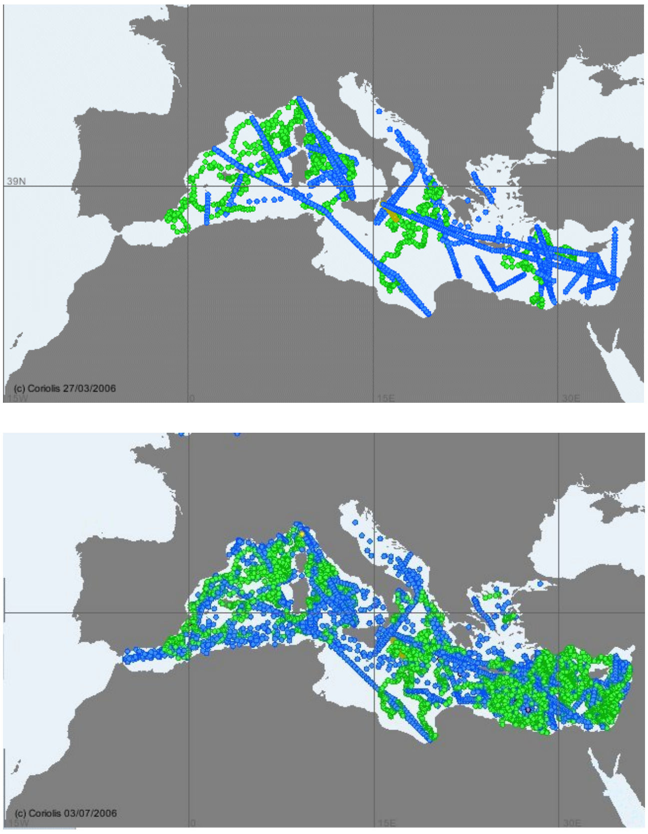


Figure 3: Monitoring the Mediterranean Network (left MFSTEP data ; right: all freely available data)

The Future

Next step will be implemented within MyOcean GLMES project where Coriolis will coordinate the setting up of a distributed architecture that will connect on a common backbone global and regional centres. Theses centres will be in charge of collecting from various outside data providers the data required by the Forecasting Centres and of qualifying and distributing them in a common way. (see next article) .

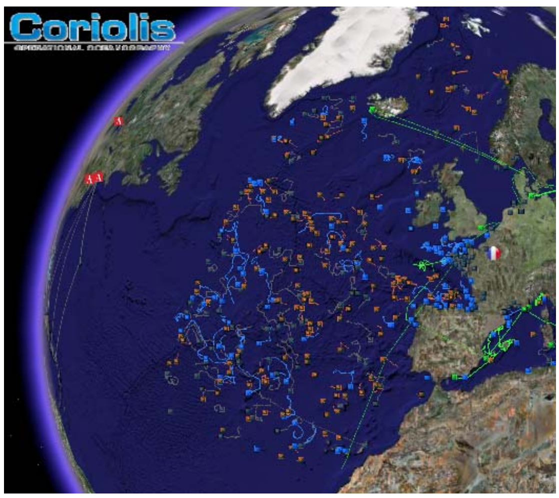


Figure 4: One month of European data available from a single portal ftp://ftp.ifremer.fr/ifremer/coriolis/seprise/*,*
in round blue Drifters, in red Argo, in blue squares moorings, in green vessels, in yellow gliders.

Coriolis and Argo Profilers

L. Gourmelen, EPSHOM, Brest

Coriolis activities at sea are managed both by the *profiler deployment unit* and the *cruise measurement unit*. Directed by personal from SHOM (Service Hydrographique et Océanographique de la Marine), the deployment team unit is composed of persons from Ifremer, INSU (Institut National des Sciences de l'Univers), IRD and SHOM. Up to now, more than 400 profilers have been tested, prepared and deployed by this team. It represents the french contribution of the Argo International project.

Acceptance tests at Ifremer tank.

How does Coriolis Deployment unit work ?

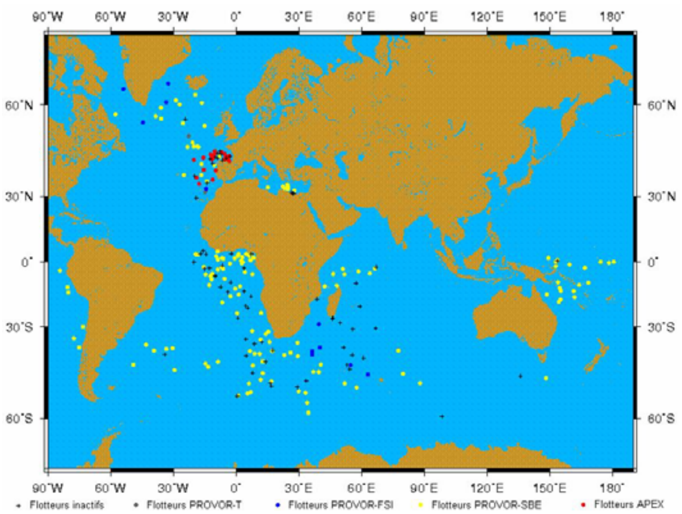
Each year, a schedule is established from both float delivery and float deployment plans. The four institutes contribute quite at the same level in the Coriolis deployment unit activities. Bought by Ifremer, SHOM and INSU/DT, profilers are checked by this team. Apex floats are verified and their Argos module is tested systematically. As the technology allows it, Provor floats are tested in the 20 meter depth pool at Ifremer Brest during one week-end. Both the hydraulic system and the sensors are checked that way. As their argos module is tested by Martec prior to delivery, only a small percentage of floats is tested in an hyperbare tank. As technology evolves (new sensors (O2, transmissiometer,…), new type of floats), the trial procedure must be adapted frequently. Profilers are stamped "ready to deploy" if they succeed all trails. They join the float stock in a warehouse at Brest. When profilers must be sent, they are programmed (PROVOR, because APEX are pre-programmed by Webb R.C.) and packed for expedition. The appropriate deployment system is also choosen for each mission. Of course we maintain a hotline link with the teams at sea for any problem or question that may occur during float deployment activities.

Towards a better supervision

AIC is the main contact to gather information on the float status. Nevertheless, at Coriolis we have defined statistics to analyse the "at sea behaviour of the Coriolis fleet. An easy-to-use and accurate web tool is going to be set up beginning of 2008. The main goal is to allow Principal Investigators to analyse statistical details during floats life and supervise the status of their fleet on a monthly basis. For sure, this tool will be very useful to the team to adjust float set up or identify anomalies early enough. We will write an article on this activity in next Coriolis issue.

What about reaching the 3000 floats ?

In coming months, profilers are going to be deployed in Canarian bassin, in North-East Atlantic, from Cape-Town to Antarctica, ana from Europe to Greenland . A doozen of floats are also planned to be deployed in North Atlantic during an opportunity cruise. Of course, the question is: with about 80 floats deployed this year, what is the probability for Coriolis project to deploy the 3000^{th} Argo profiler ?



French contribution to ARGO

New float developments at Coriolis

S. Le Reste & S. Le Bras, Ifremer, Brest

ARVOR : the Provor New Generation

The development of this new profiler ended in 2006. Lighter and easier to deploy (P <20Kg), this new float is exclusively dedicated for T and C measurements and can perform more than 150 cycles.

A first prototype has been cycling in the Bay of Biscay since the beginning December 2006. It has been programmed to realise a cycle at 2000 m every two days and has already transmitted 132 profiles. The industrialisation of this new product is now in progress at MARTEC firm and we plan to deploy the first ARVOR before end 2007.

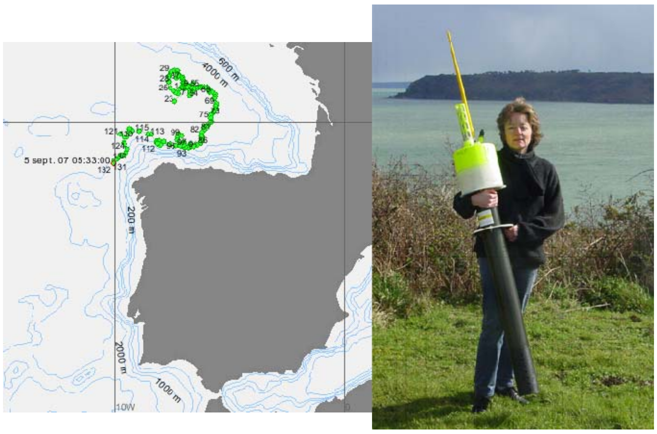


Figure 1: First ARVOR trajectory

PROVOR : an extended range of versions

In order to answer to scientists' requirements, new PROVOR versions have been developed fitted with traditional CTD and new optical sensors. This new range is derived from a common base, the Provor CTS3, which is now widely used within Argo. These new versions (apart from ProvDO) use the Iridium Satellite System. The antenna has been redesigned to improve reliability at pressure.

ProvBio:

This float is developed for biogeochemical applications. It is fitted with a transmissometer (Wetlabs) and an irradiance sensor (3 wavelengths radiometer Satlantic). The prototype was successfully tested in the Mediterranean Sea (Nov. 2006) from the ship Tethys2. The second version, called ProvBio2 is still under development and will be fitted with a transmissometer (Wetlabs), a radiometer (Satlantic) and an ECO-triplet (backscattering, chla, CDOM).

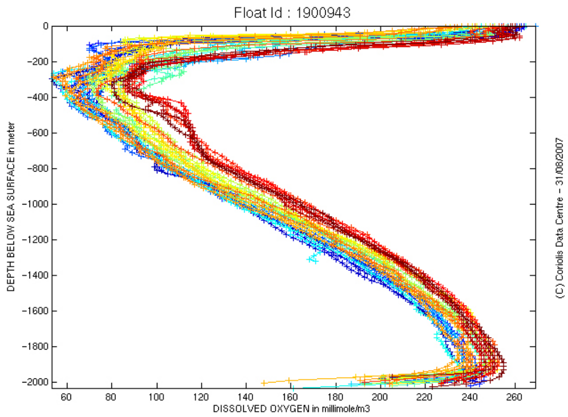


Figure 2: Oxygen profiles from ProvDO

ProvDo:

This Provor is fitted with an optode Anderaa to measure dissolved oxygen. The transmission uses the Argos system. A prototype deployed in February 2007 by IFM Geomar (Carbo-Ocean EU project) has performed 40 profiles at 2000 m and is still cycling. Eight floats will be shortly deployed by IRD, by Chili.

In parallel, qualification tests were performed in basin to check the optodes and improve their calibration.

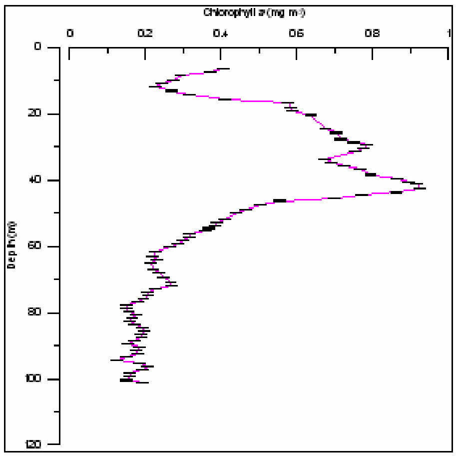


Figure 3: Chlorophyl profiles from ProvDO

ProvCarbon:

Developed in the frame of the European program Carbo-Ocean, this float is fitted with an optode Anderaa and a transmissometer Wetlabs. Two prototypes are now in a final test phase and will be deployed by IFM in the beginning of 2008.

Deployment of CTD loggers on Kerguelen elephant seals in 2007

Roquet F. (1), Park Y.-H. (1), Bailleul F. (2), Charrassin J.-B. (1), Guinet C. (2)

(1) MNHN, USM402, Paris, France
(2) CEBC/CNRS, Chizé, France

Introduction

To study the foraging ecology of elephant seals in relation to oceanographic conditions, the international "Southern Elephant seals as oceanographers" project has been launched since 2004, consisting in equipping elephant seals with CTD loggers (Fig. 1a) at four sub-Antarctic locations (South Georgia, Macquarie Islands, Antarctic Peninsula and Kerguelen Islands). These CTD loggers are capable of autonomously collecting and transmitting by satellite (Argos, CLS system) hydrographic data. In addition to their biological interest, the CTD profiles sampled in the remote Austral Ocean are of great interest for oceanographers. Currently, more than 8000 profiles were acquired south of 60°S (9 times more than obtained from floats and ships) and about 4500 profiles were obtained beneath the sea ice, in important regions for the deep overturning circulation study. Seals profiles were transmitted in near real-time to Coriolis from where they are distributed to the modelling and oceanographic communities, complementing data obtained from ships, satellites and floats.

During the austral summer 2007, 16 elephant seals from the Kerguelen Islands colony and 3 Weddell Seals from Adelie Land, Antarctica were equipped. This resulted in more than 4500 T/S profiles (Fig. 1b). Contrary to first deployment years where elephant seals mainly foraged close to the Antarctic continent, most 2007 seals stayed over the shallow platform of the Kerguelen Plateau or followed the Polar and Sub-Antarctic fronts eastward. On average, 2.5 profiles were transmitted daily by each logger. The logger operational lifetime ranged from 30 to 200 days (mean 90 days) and 6 loggers were still in operation on September 30th, 2007. The CTD loggers deployed in 2007 contained a newly designed CTD unit made by Valeport (UK) and were assembled at SMRU (St Andrews, UK). All the loggers were then statically calibrated in the new calibration laboratory of Valeport. The main novelty of the CTD unit consisted in the conductivity sensor being now completely pressure-housed with a titanium coat. A major step in salinity quality was therefore expected this year. In the following, we will present two calibration at-sea experiments performed prior to the deployment, before introducing the 2007 transmitted data set.

Calibration results from the at-sea experiments

Prior to the deployment of the CTD loggers, two at-sea experiments were performed. The first one was performed in the Mediterranean Sea on 12 of the 16 loggers deployed at Kerguelen on board the R/V Tethys 2 and the second one was done on the 3 loggers deployed at Adelie Land on board the R/V Astrolabe in the Antarctic coastal water. Both experiments consisted in attaching the CTD loggers to a standard calibrated CTD (Seabird SBE25) and doing several dives for comparison purpose – 7 dives at ~400 m in the first case and 3 dives between 600 and 800 m deep in the second case. The thermohaline structure of mediterranean waters is characterized by slowly varying warm and saline deep waters (13-14 °C, 38.2-38.7 psu) separated from surface waters by a very strong thermocline found between 40 m and 70 m. Antarctic waters sampled during the second experiment are colder and fresher (-2°-0 °C, 34-34.65 psu). It is noted that the mediterranean structure encountered during the first experiment is very different from the one found where loggers are deployed. Yet, we will see that valuable information can be obtained from this experiment.

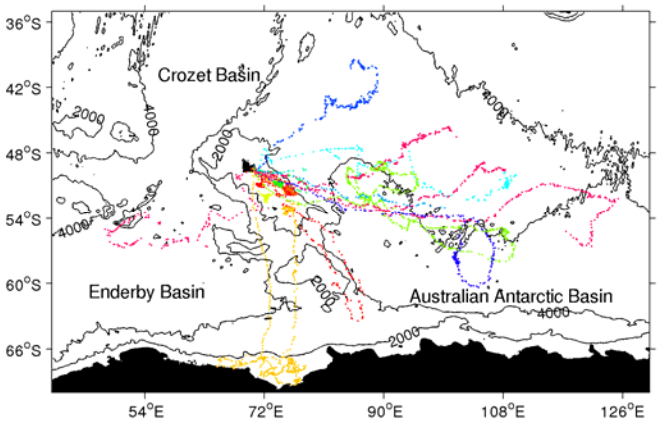


Figure 1: (a) An elephant seal equipped with a CTD logger. (b) Position of the profiles transmitted by the 16 CTD loggers deployed at Kerguelen in 2007.

The methodology was identical for both experiments. The CTD loggers sampled the water column during the ascent phase of each dive (speed: ~1 m/s) at a 1 s sampling rate and were attached upward to simulate best an elephant seal ascent. By attaching the CTD loggers to a SBE25, we aimed at referencing separately each of their sensor measurements – pressure P, temperature T and conductivity C – to reliable hydrographic measurements. To do so, we first needed to synchronize SBE25 measurements with CTD loggers one. This was done by using pressure as a proxy, because this sensor has a fast response time negligible in respect with 1 second. Once synchronized, the three sensors' responses could be analysed separately.

The comparison of the loggers' P sensor response with SBE25 provided excellent results, with the rms of the difference generally lower than 1 dbar. In some cases, a light bias was detected, which could easily be corrected using a linear function.

For T and C, we were interested in systematic biases and their relation to P. Thus we studied the difference between the CTD loggers and the SBE25 T and C series as a function of P. Firstly, we separately averaged loggers and SBE25 T (C) timeseries in 10 dbar bins. All bins where the ensemble rms was greater than an arbitrarily-chosen threshold (0.005 °C for T and 0.005 mS/cm for C) were discarded to ascertain that the difference was only considered in weakly stratified areas. Indeed, in stratified areas, characterized by strong vertical gradients of hydrological properties, time-lag differences between loggers and SBE25 sensors result in important non-systematic biases.

Two typical examples of the differences between SBE25 and CTD loggers T and C are presented, one for the Mediterranean experiment (Fig. 2, logger 10518) and the other for the Antarctic experiment (Fig. 3, logger 10555). Remarkably, T and C biases were very similar from dives to dives in both cases, which was very encouraging to further correct them. To investigate further the pressure dependance, the differences were fitted linearly. The mean standard error of the linear fit was only of 0.003 °C and 0.003 mS/cm, demonstrating the great similarity of biases from dives to dives for any given logger. The slopes for T varied from non-significant values (<0.01 °C/km) to lightly higher than 0.05 °C/km (Fig. 3). In the latter case, a correction of received data could be undertaken, consisting in removing the detected systematic bias from all T data.

While the slopes of C fits were generally weak (~0.02 mS/cm/km), C values were all negatively offseted, in both Mediterranean and Antarctic experiments. However, the magnitude of these offsets was clearly greater in the former experiment (mean -0.08 mS/cm) than in the latter one (mean -0.02 mS/cm). We are currently investigating the possible causes of this offset. We suspect problems in the calibration method used at the Valeport laboratory to scale C sensors,

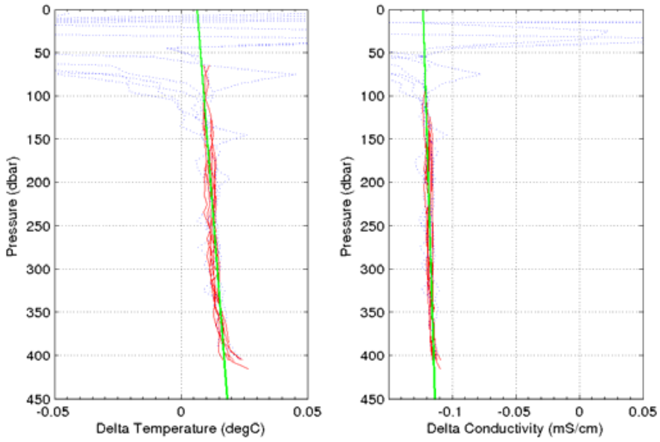


Figure 2: CTD loggers versus SBE25 differences of T and C sensors response for the 7 dives of the 10518 logger performed in the mediterranean sea (dashed blue). Values used to calculate the linear fit are shown in red, and the linear fit is superimposed in green. See the text for details on the method of calculation.

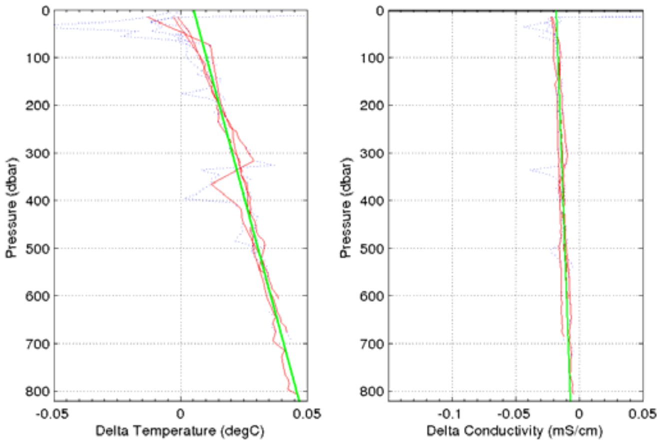


Figure 3: Same as in Fig. 2, but for the 3 dives of the 10555 logger performed in the Antarctic coastal water.

which may fail for the high C values found in the Mediterranean Sea (~45 mS/cm). Indeed, we recalibrated 4 loggers at the calibration laboratory of the SHOM and found significant discrepancies in C for values greater than 30 mS/cm, increasing with increasing conductivities. Unfortunately, the recalibrated loggers were not the same than those tested at sea, preventing us to be conclusive for the moment.

The transmitted seal data set

Due to the limited Argos system bandwidth, CTD data logged during an elephant seal dive can not be entirely transmitted. It is thus necessary to compress CTD data before transmission, which is done automatically by the logger micro-controller. Once compressed, hydrographic profiles are transmitted under the form of 18 T/S points (see Roquet et al., 2007, for a detailed description of the compression algorithm).

In Fig. 4, we show T/S profiles from the CTD logger 10518 super-imposed with historical CTD profiles from the same geographic area. The good superposition of both sources' profiles show the absence of significant offset in conductivity, in great contrast with the mediterranean experiments where the offset was greater than 0.1 mS/cm which corresponded to a salinity offset >0.1 psu. This is consistent with results of recalibration tests done at the SHOM laboratory indicating that this offset is probably conductivity dependant, increasing with increasing conductivities. Also it demonstrates the need for a post-transmission C offset estimation.

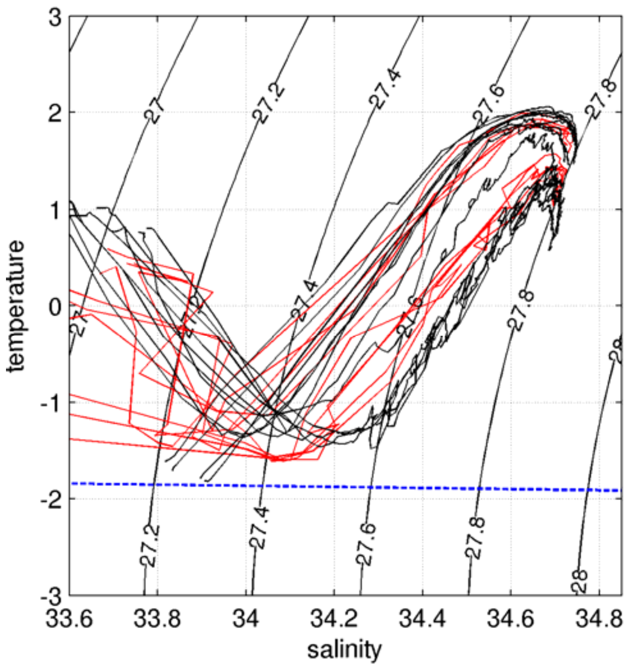


Figure 4: Superposition of historical (black) and logger 10518 (red) T/S profiles sampled in the same region (61-65°S, 70-76°E). Both data sources' measurements are consistent, particularly in deep layers (upper right corner of the diagram).

Several indirect methods to estimate the magnitude of the C offset in the transmitted data are possible. One method is to use the stable T-S relationships of deep waters to compare loggers and historical profiles as for example in Böhme and Send (2005) for Argo float salinities. This method is made more difficult for seals data than for Argo data because of the lower mean depth of seals profiles (~600 m against 2000 m for Argo) and the generally sparse distribution of historical profiles in Antarctic regions, yet it generally yields a valuable estimate (Roquet et al., in prep.). However, this method can be inadequate, particularly south of the Polar Front because deep water temperatures are almost homogeneous there and the associated T-S curves are nearly horizontal, rendering the T-S relationships highly ill-defined. Fortunately, in that case, we can benefit of the proximity of the stable and vertically homogeneous Circumpolar Deep Water from the surface to estimate roughly the magnitude of the C offset (Roquet et al., 2007).

Another way to explore is the inter-comparison of conductivities between CTD loggers when different seals crossed the same areas. In 2007, a great concentration of profiles is found over the shallow part of the Kerguelen Plateau and along 54°S in the Australian-Antarctic Basin. We may take advantage of this superposition of profiles to inter-calibrate the different CTD loggers.

Conclusion

Since the earlier developments of the CTD loggers in 2003, several critical technical improvements have been achieved, leading to better accuracy of the CTD unit and a far better reliability of the whole logger. The last modification in date is the protection of the C sensor from pressure effects with a titanium coat. No important changes in the CTD unit conception should happen now, which should permit to provide an homogeneous interannual data set from now on.

Yet, some biases still exist and necessitate a rigourous calibration work, both before and after deployment. In addition to the static calibration done by Valeport, a recalibration in a laboratory of reference like the SHOM appears necessary as long as the discrepancies between both calibrations are observed. Testing loggers on field before the deployment also appear essential to estimate the loggers' overall quality and to correct possible pressure-dependant biases like for T.

Acknowledgements

This project was supported by CNES, CORIOLIS and IPEV. We are grateful for the opportunity to use R/V Tethys and Astrolabe for the at-sea experiments. We also thank the SHOM to give us access to their calibration laboratory.

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European Gliding Observatories EGO

In behalf of the EGO group: P. Testor[1], L. Mortier[1], U. Send[2], R. Davis[2], D. Smeed[3], L. Merckelbach[3], A. Alvarez[4], J. Tintore[4], P. Lherminier[5], T. Terre[5], G. Krahmann[6], J. Karstensen[6], H. Claustre[7], J.-J. Naudin[8], V. Rigaud[9], T. Carval[10], L. Petit de la Villeon[10], C. Jones[11], J. Sherman[2]

[1] LOCEAN-IPSL, Paris, France
[2] SIO, La Jolla, CA, USA
[3] NOCS, Southampton, UK
[4] IMEDEA, Esporles, Spain
[5] LPO-IFREMER, Brest, France
[6] IFM-GEOMAR, Kiel, Germany
[6] IFM-GEOMAR, Kiel, Germany
[7] LOV, Villefranche, France
[8] OOB, Banyuls/mer, France
[9] SSM-IFREMER, La Seyne/mer, France
[10] Coriolis-IFREMER, Brest, France
[11] Webb Research Corp., Falmouth, MA, USA.

The ARGO program now provides an operational in-situ monitoring array suitable for the large-scale global circulation, with numerous but low cost, automated platforms. This array has been configured (on average one ARGO profiling float for every 10^5 km^2 of the global ocean) in order to constrain the large scale distribution of physical water properties in numerical models through data assimilation. An important advance in oceanography has been achieved with this array but it is still insufficient. If one wants to characterize the marine environment from its large scale and long-term variability for climatic aspects, down to the small scales necessary to address the management of the coastal environment, one has to go one step further.

Designed for large scale monitoring, the ARGO array is not able to resolve mesoscale (10-100km) or smaller scale (<10km) flows, which are very important for the mixing of water properties and ecosystem functioning. As a result, these aspects are not constrained properly in operational forecasting systems. Moreover, the profiling floats design does not allow to sample in a convenient way the circulation over continental shelves and margins where most of human marine activity takes place. Floats do not stay long in these regions as they drift away rapidly or go aground and end their missions prematurely. This implies a lack of data in these regions which are critical. There, energetic currents and intensive meso and submesoscale activity drive a variety of exchange processes that control water mass mixing and ecosystem functioning. The impact on forecasting is not only local as the circulation along the continental slope is generally very energetic (boundary currents) and strongly influences the circulation at the basin scale.

It has been envisaged that individual or even fleets of gliders -that are equivalent to remotely steered profiling floats- deployed at both regional and large scale could efficiently complement the ARGO array for the benefit of both operational oceanography and academic research including in particular, "green ocean" objectives. The EGO group, gathering together (http://www.locean-ipsl.upmc.fr/gliders/EGO/) together several teams of engineers and scientists, tries to demonstrate this vision through pilot projects. The objectives of the EGO group are to share the corresponding efforts and to provide support to people operating gliders. EGO also helps to coordinate deployments of enough gliders for dedicated exercises in targeted areas.

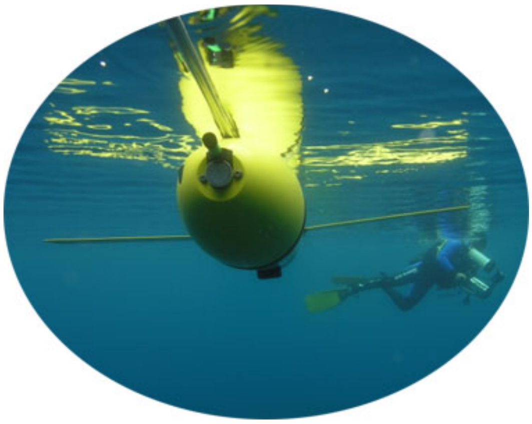

Figure 3: first glider tests in the Villefranche-sur-Mer Bay. © D. Luquet, obs. Océanologique de Villefranche, France.

The north-western Mediterranean basin is perfectly suited for this kind of demonstration: the circulation is a basin scale cyclonic gyre populated by strong mesoscale and submesoscale features, in particular during the winter when deep convection occurs. An unstable current, the so-called Northern Current, flows over the shelf break and partly controls the circulation over the shallow part of the Gulf of Lions. These patterns also strongly shape the bloom events during the winter and spring periods.

As a first EGO demonstration and in the framework the EU project MERSEA, as well as national projects, seven deep (1000m) and two shallow (200m) gliders were used between January and June 2007 to collect temperature and salinity profiles as well as oxygen, backscattering, Chlorophyll-a, and CDOM fluorescence on the gliders equipped with biogeochemical sensors. One deep glider was devoted to the large scale monitoring of the gyre in its longitudinal extension from the Balearic Islands to the Gulf of Genova while another has crossed the basin in the meridional direction. A shallow glider was deployed to cross the channels between the Balearic Islands and a deep one sampled the Ligurian Sea offshore of Villefranche s/Mer to monitor an upstream section on the Northern Current. Three deep gliders were devoted to the investigation of the deep convection area in the Gulf of Lion. Finally, a shallow glider was deployed to study mesoscale and submesoscale features associated with the Northern Current.

The gliders were deployed and recovered from small boats from the "gliderports" hosted in marine stations around the basin: Palma de Mallorca, Banyuls sur Mer, La Seyne sur Mer and Villefranche sur Mer. Some of the gliders that were equipped with alkaline batteries, were recovered to change their batteries and were immediately redeployed. Remote steering of the gliders and real time data download were allowed by Iridium bidirectional link and carried out using "groundstation" computers based in the partners institutions. Routines have been developed for real time data processing and visualization on the web in order to better control the glider missions. Moreover, forecasts of the trajectories of the fleet based on the currents produced by MERCATOR on a weekly basis, were published on the web both to help the pilots reshaping the network periodically and also to deliver the information on the glider positions to the Spanish and French marine security agencies.

Despite extremely strong wind events impeding efficient remote control of the gliders (bad communications when at surface), and several glider failures too, the network was maintained over this period with a peak of six gliders simultaneously at sea. A total of about 3200 profiles were collected and delivered in real time to the Coriolis Data Center for visualisation, archiving, and dissemination (Fig1 & 2).

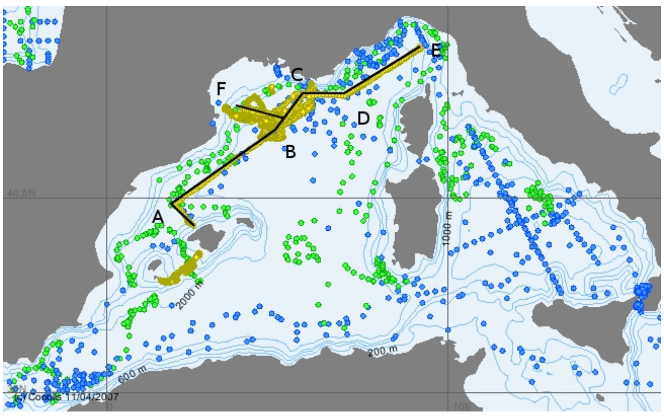

Figure 1: Glider profiles locations (in yellow) in the western Mediterranean Sea between 2007/01 and 2007/06 as displayed on the Coriolis web site, together with CTD/XBT profiles (in blue) and ARGO profiles (in green) for the same period. One glider trajectory is highlighted in black. Labels indicate waypoints.

A technological and scientific assessment is now being undertaken. A first obvious conclusion is that operating several gliders over long periods, requires multi-site coordinated facilities: operators are needed to 1) evaluate the actual trajectories of the gliders and modify them if necessary, 2) modify some parameters (speed, sampling rate, …) or correct small malfunctions of the gliders, and 3) quickly organize an emergency recovery in case of a major failure. This first EGO coordinated deployment of a glider fleet was a successful technological demonstration and the amount of data collected demonstrates how intensively one can observe the ocean interior using such platforms in a particular area. In fact, only Mother Nature itself was able to spoil the observations of deep convection by producing one of the warmest winters on record. The very mild air temperature conditions of last winter triggered a convection down to only 400m depth, which is not a proper deep convection event...

Acknowledgements:

The MERSEA project has been funded by the European Union in the framework of the 7th Framework Program under contract 502885. We are grateful for the support of the Natural Environment Research Council (UK) and Agence Nationale de la Recherche (France). We also thank captains and crews from Tethys II, Nereis II (INSU-France), IMEDEA (CSIC-Spain) and local support boats, as well as the Spanish Air Force and French Navy for their great cooperation. The glider data have been distributed to the modelling community using the Coriolis data centre facilities.

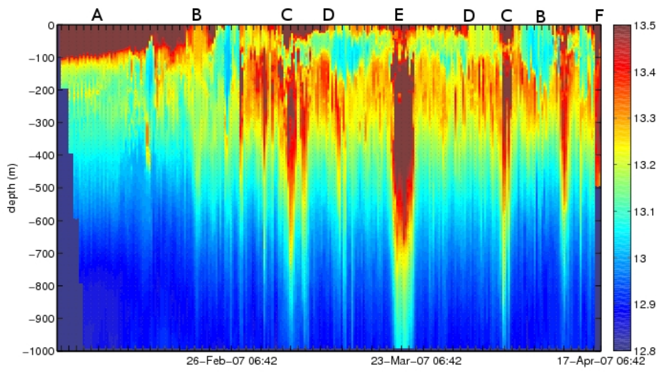

Figure 2: Example of a vertical section of potential temperature along the glider trajectory highlighted in Fig. 1. Dates when waypoints are reached by this glider are indicated on the top axis.

Thermohaline Variability of the Eastern Edge of the Western Pacific Warm Pool, as inferred from ARGO floats.

Christelle Bosc[1], Christophe Maes[2] and Thierry Delcroix[1]

[1] LEGOS, Toulouse - [2] LEGOS, Nouméa

The Western Pacific Warm Pool (WP) is one of the major driving forces of the world climate and, in particular, plays a key role in influencing features of El Nino Southern Oscillation (ENSO) events. The WP is characterized by Sea Surface Temperature (SST) warmer than 28-29°C and Sea Surface Salinity (SSS) lower than 35 reflecting heavy precipitation (>3 m/year). Previous works have identified two important quasi-permanent climatic characteristics of the WP: a zonal SSS front marking its eastern edge and the presence of rather thick barrier layer. A review of these two notable climatic features can be found in Picaut et al. (2001). A schematic diagram showing the links between the zonal SSS front, the BL and formation mechanisms is also shown in Delcroix and Maes (2006).

To better understand the time-space variability of the fine-scale thermohaline structure of this key region, ten PROVOR floats (WMO 5900901 to 5900910) were deployed along the equator between 161°E and 167°E in May 2005 during the FRONTALIS 3 cruise onboard the R/V Alis (Maes et al., 2006). The exact positions of the float deployments were chosen at sea, during the cruise, in order to sample both the western and eastern parts of the zonal SSS front and the associated vertical thermohaline structure. Following our requests, the floats were configured by the Coriolis deployment division so that to sample the 0-1500 m water column every 10 days, with a parking depth of 1000 m, and with an "unusual" enhanced 5 m depth resolution in the upper 250 m. As of today (September 2007) 9 out of the10 floats are still active (the float WMO 5900902 landed on Kapingamarangi Island, near 0.5° N-155°E, on February 2006).

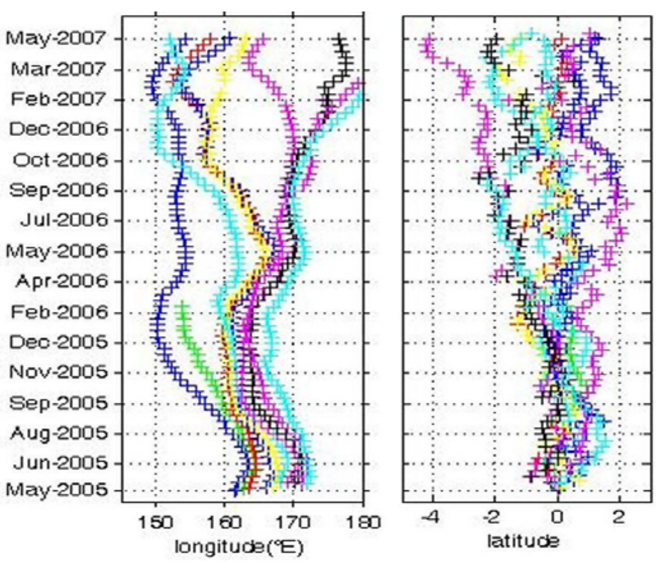

Figure 1: Zonal (left) and meridional (right) displacements of the ten PROVOR floats deployed in May 2005 along the equator in the western Pacific warm pool.

The T and S profiles of the 10 floats, downloaded from the Coriolis web site, were carefully quality controlled via various tests involving visualisation of all profiles, climatic limits, vertical stability in density, etc... About 98% of the profiles were validated by such analyses. The space-time distribution of the floats is shown in Figure 1. It indicates rather weak longitudinal and latitudinal migrations over the 2-year period of May 2005 – May 2007, with the floats remaining within about 150°E-180°E and 2°N-2°S, i.e., in the usual BL formation region.

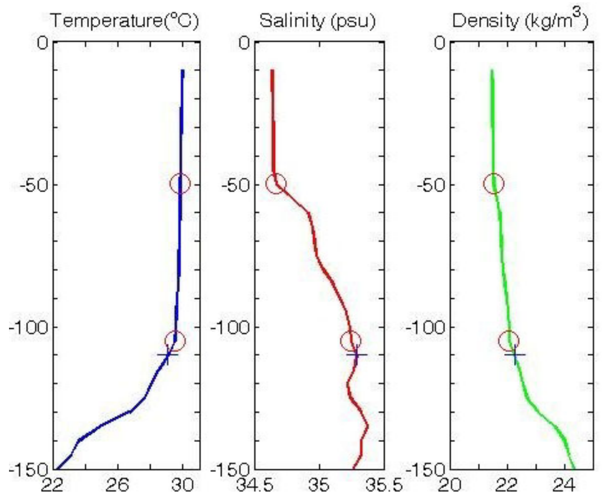

Figure 2. Vertical profiles of (left panel) temperature, (middle panel) salinity and (left panel) density obtained on May 5, 2005 at 0°-161°E. The open red circles denote the depth of mixed layers defined with the criteria of Lukas and Lindstrom (1991); the blue plus with the criteria of Levitus (1982), as detailed in the main text.

There are several ways of defining the depth of the mixed layer from T and S profiles. We chose two gradient criteria to discriminate the top of the thermocline (0.05°C/m) and the base of the density mixed layer (0.01 kg/m^4), as done by Lukas and Lindstrom (1991) in the same region. We also tested to define the top of the thermocline from a temperature difference (the depth where T=SST-0.5°C), and the base of the density mixed layer from a density difference (the depth where ρ= ρ+0.125 kg/m^3), as proposed by Levitus (1982). As an example, with the above criteria, Figure 2 reveals the occurrence of a barrier layer thickness of about 50 m at the equator and 161°E on May 4, 2005, reflecting the presence of a vertical salinity gradient within the temperature mixed layer.

To further set the stage, Figure 3 shows the longitude-depth distribution of salinity together with the corresponding thickness of the BL, as derived from 10 floats during the first half of June 2005. Noteworthy, we observe a well-marked zonal SSS front near 169°E, with a rather thick BL to the west (maximum at the front position) and a vanishing BL to the east. Similar calculations were done for all 15-day periods starting in May 2005. The ongoing analysis (not detailed here) reveals a surprisingly high frequency variability of the BL which was not detected before. It also enables us to precisely monitor the displacements of the zonal SSS front featuring the eastern edge of the WP. Most interestingly, it suggests a key role of zonal current anomalies associated with equatorial Kelvin and Rossby waves in modulating the BL formation and thickness (Bosc et al., ms in preparation). These results, presently being verified, would not have been made possible without the fine-scale horizontal and vertical resolution in both temperature and salinity of the deployed ARGO floats.

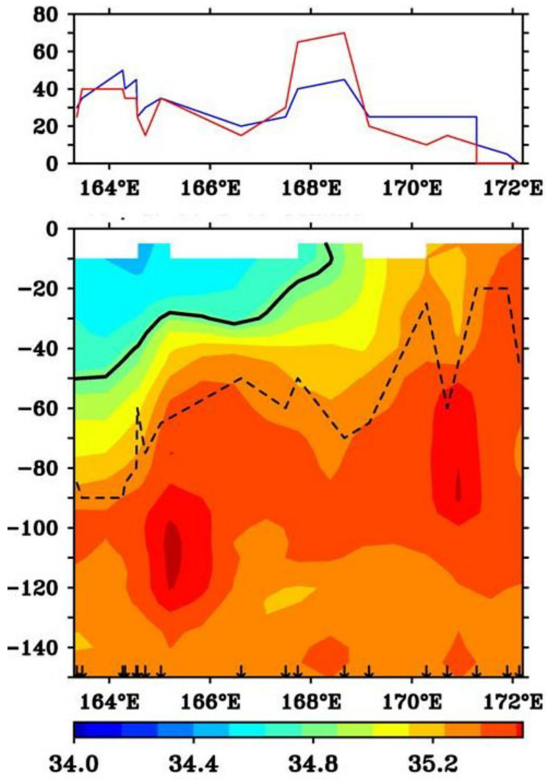

Figure 3. (bottom panel) Longitude-depth section of salinity derived from 17 PROVOR profiles present within 1.5°N-1°5°S in the first half of June 2005. The small arrows on the x-axis denote the float positions. The heavy black line represents the 34.8 isohaline, and the dashed line the 29°C isotherm. (top panel) Zonal variations of the barrier layer thickness, as estimated from the (in red) Lukas and Lindstrom (1991) and (in blue) Levitus (1982) criteria.

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ARGO floats sample vertically homogenized water in Agulhas rings

M. Arhan and S. Speich, LPO (Brest)

The international program GoodHope coordinated by Sabrina Speich (LPO/Brest) and launched in 2004 aims at studying the full-depth oceanic exchanges between the Indian and Atlantic oceans, in a latitude band which encompasses the subtropical domain between South Africa and the Subtropical Front (~35°S-40°S), and the Antarctic Circumpolar Current (ACC; ~40°S-55°S). Specific objectives are a better knowledge of the temporal variability of the ACC transport, a study of property modifications experienced by the exchanged waters, and an improved understanding of the mechanisms involved in these exchanges throughout the water column.

The field activity of the program rests on repeated and high resolution expendable bathythermograph (XBT) samplings between Cape Town and 55°S along a transect which partially follows a JASON track (NOAA/Miami, University of Cape Town), on hydrology measurements along the same line (three realizations performed by the Shirshov Institute of Moscow, and a French one planned in 2008), and on regular launchings of PROVOR/ARGO profilers (LPO/Brest).

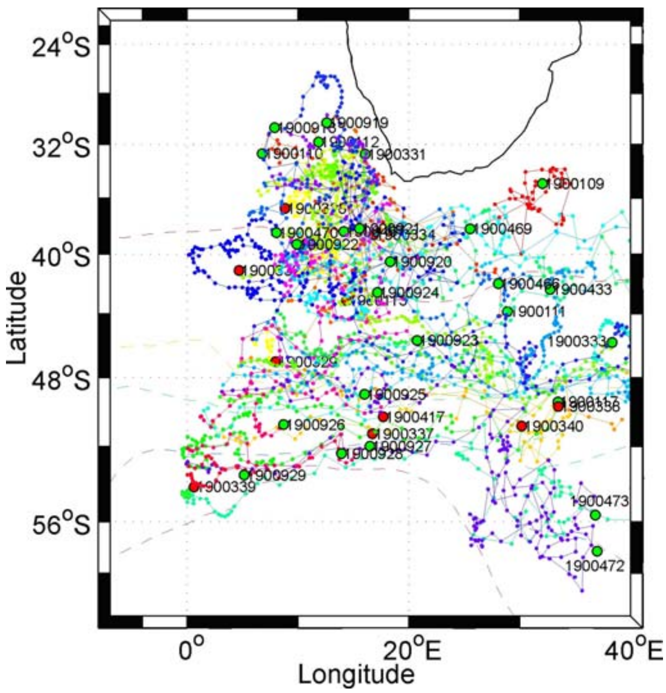

Figure 1: Trajectories and profile locations of GoodHope PROVOR floats (years 2004 to 2007, here limited to 0°W-40°W). Green (red) dots mark floats that were active (no longer active) in June 2007. Climatological ACC fronts locations are also shown.

This brief note illustrates an ongoing study on the role of winter convection in the transformation of part of the subtropical Indian Ocean waters bound for the Atlantic. The study rests on combined use of Conductivity-Temperature-Depth (CTD) data from the GoodHope project, PROVOR/ARGO profiles, and maps of absolute sea surface height (SSH) combining a multi-satellite sea surface anomaly (Ducet et al., 2000) and a mean dynamic topography (Rio and Hernandez, 2004).

Out of 48 PROVOR floats launched since early 2004 in the framework of GoodHope, 37 were still active in June 2007, and a total of about 2800 hydrology profiles down to 2000 m had been gathered through the CORIOLIS data centre (Figure 1). This data base is well-suited to the description of the surface mixed layer seasonal variations. Displayed on Figure 2 are the annual cycles of the mixed layer depth in the subtropical and subantarctic zones, at longitudes 0°W-40°W. The allotment of a profile to a given zone was done on the basis of its surface dynamic height value (referenced to 1500 m), a value of this parameter having previously been ascribed to the Subtropical Front from neighbouring historical and GoodHope CTD data.

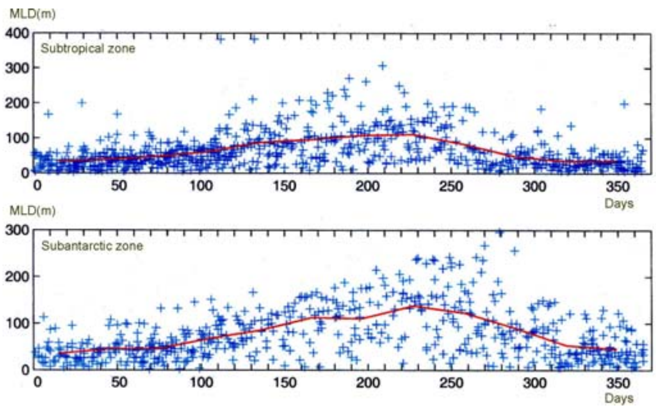

Figure 2: Depth of oceanic mixed layer from PROVOR profiles south of South Africa in the subtropical (upper) and subantarctic (lower) domains

The Southern Ocean Atlantic sector has long been known as a weak contributor of Subantarctic Mode Waters (SAMW) to lower latitudes (McCartney, 1977). Although annual cycles of the mixed layer depth stand out in both zones, low average winter values around 130 m in the subantarctic zone confirm this weak contribution. The pronounced scatter of the winter mixed layer depths around their average values reflects significant exchanges across the Subtropical Front: Parcels of relatively fresh Subantarctic Surface Water shed into the subtropical domain are associated with thin mixed layers. On the other hand, eddies of subtropical water penetrating the subantarctic zone may, owing to their saline nature, favour convection reaching downward to ~300 m.

Figure 3 illustrates an extreme case where convection reached 390 m. The lower panels showing the float locations superimposed onto concomitant maps of SSH confirm that this deep convective event occurred in an eddy of subtropical water shed in the subantarctic zone. Previous occasional samplings of eddies with a subsurface homogenized core in the Cape Basin (e.g. Arhan et al., 1999) suggested a formation of these structures in the subantarctic zone, before their northwestward propagation and subduction beneath lighter Atlantic subtropical waters. The present observation by ARGO floats in the formation region complements the previous ones. An altimetric tracking of these vortices shows that they originate in the subdivision of newly-spawned Agulhas rings encountering the Agulhas Ridge. Intense cooling and convection of the eddy core waters may occur during autumn or winter transit through the subantarctic domain, leading to the formation of vertically homogenized water with temperatures that may reach downward to about 12°C. This locally ventilated water has higher oxygen concentrations than the remotely formed SAMW (of Indian Ocean origin) present in the Agulhas retroflection (Gordon et al., 1987). Although this water might have but a limited effect on the ventilation of the South Atlantic, the ongoing study tends to better evaluate its role and understand the behaviour of the eddies that convey it.

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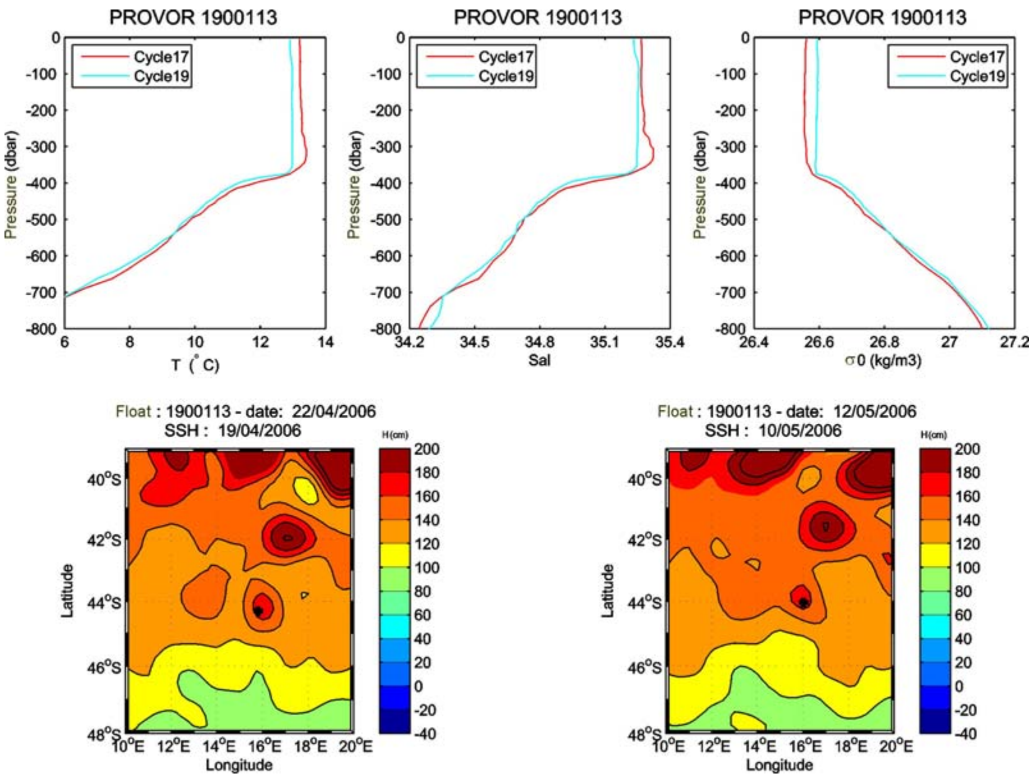


Figure 3: Upper: Deep (390 m) homogenized core water of an eddy in the ACC subantarctic zone south of South Africa. Lower: SSH maps showing the eddy and positions of the PROVOR float which was trapped in it for more than 20 days.

12 Coriolis floats documenting water masses and circulation in the Argentine Basin

Ana Cordeiro Pires, Nicolas Barré, Alice Renault and Christine Provost

LOCEAN, UMR 7159, Université Pierre et Marie Curie 75005 Paris

Twelve floats, part of the Coriolis mission, were deployed at two distinct locations from the argentinean R.V. Puerto Deseado: six in northern Drake Passage in March 16 2005 and six in the continental slope off Argentina at about 43S in July 2 2005 (Fig.1). From the six floats deployed in each area, three had a 400 db parking depth and the other three a 1000 db parking depth. Two 400-db floats and three 1000-db floats are still in the basin, two 400-db floats and three 1000-db floats are out of the basin and two 400-db floats are "dead" (Table 1). On average, the floats stayed in the basin for 18 months.

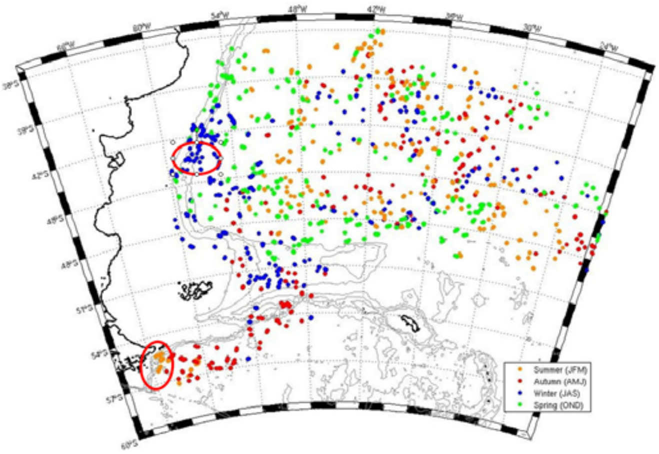


Figure 1: Seasonal distribution of the Argo floats profiles in the Argentine Basin. Grey lines represent 1000-db bathymetry lines from 1000 to 3000 db. Red circles mark deployment locations.

ID number	Deployment date	Deployment area	Parking depth	Current status*
3900386	March 16 2005	Drake Passage	400 db	In
3900387	March 16 2005	Drake Passage	400 db	Dead(Jan 07)
3900388	March 16 2005	Drake Passage	400 db	In
3900389	July 2 2005	Malvinas Talus	400 db	Out (Sep 06)
3900390	July 2 2005	Malvinas Talus	400 db	Dead(May 06)
3900391	July 2 2005	Malvinas Talus	400 db	Out (Jun 06)
3900392	March 16 2005	Drake Passage	1000 db	In
3900393	March 16 2005	Drake Passage	1000 db	In
3900394	March 16 2005	Drake Passage	1000 db	Out (Jun 06)
3900395	July 2 2005	Malvinas Talus	1000 db	Out (Apr 06)
3900396	July 2 2005	Malvinas Talus	1000 db	Out (Dec 06)
3900397	July 2 2005	Malvinas Talus	1000 db	In

Table 1: Characteristics of the Coriolis Argo floats (with respect to the Argentine Basin)*

The salinity accuracy of the Argo floats at depth was compared to recent CTDs in Drake Passage and was better than 0.01. The float provided informations about the water masses in the upper 2000 m (Fig.2) and their evolution through space and time.

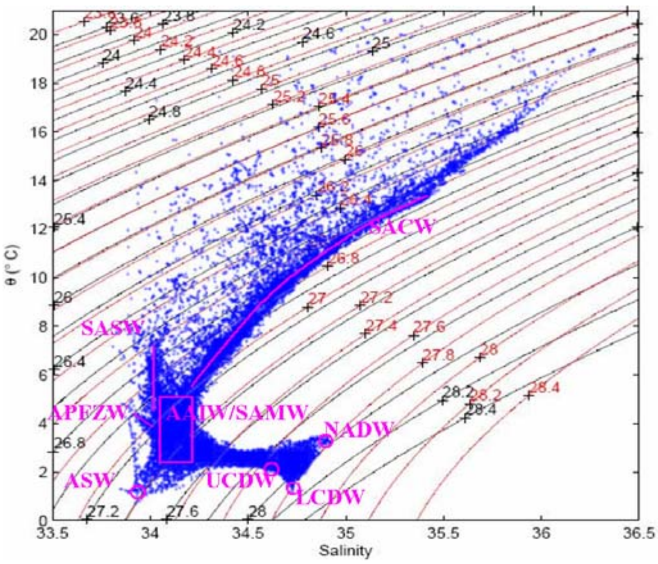
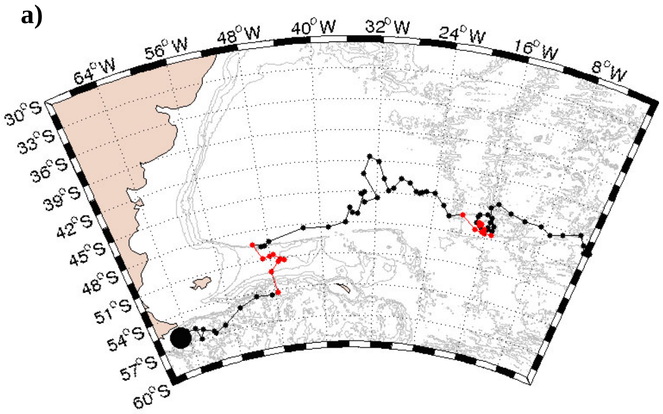


Figure 2: θ-S diagram from the float profiles in the Argentine Basin potential density lines in red and neutral density lines in black. The major water masses are identified in pink: SACW – South Atlantic Central Water; SASW – Subantarctic Surface Water; APFZW – Antartcic Polar Frontal Zone Water; AAIW – Antarctic Intermediate Water; SAMW – Subantarctic Mode Water; ASW – Antarctic Surface Water; UCDW – Upper Circumpolar Deep Water; LCDW – Lower Circumpolar Deep Water; NADW – North Atlantic Deep Water.

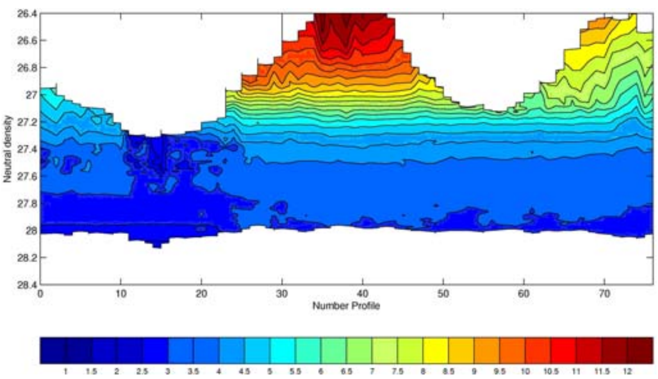
In particular they documented the evolution of the intermediate water masses, their ventilation in winter (Fig. 3) and their mixing with cold and fresh intrusions in the south of the region and with warm and salty waters in the north (not shown).

Float 394 for example spent winter 2005 over the Malvinas Plateau (first red part of the trajectory) and shows ventilation down to the 27.33 neutral density level (Fig.3). It spent the second winter (2006) further East around 16W (second red part of the trajectory) where ventilation occurs only down to the 27.2 level (Fig.3).

a)



b)



c)

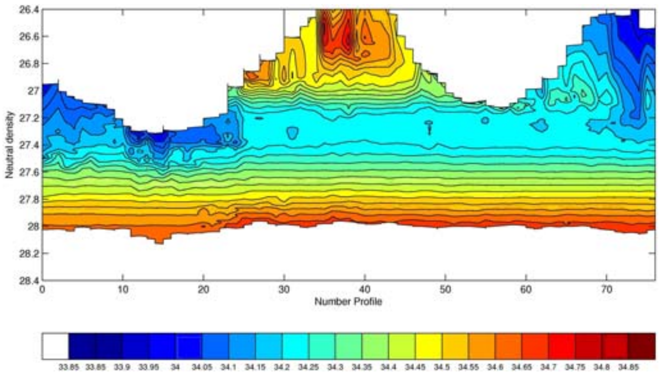


Figure 3 – Trajectory (a) and neutral density sections of potential temperature (ºC) (b) and salinity (c) for float 394. In a) grey lines represent 1000-db bathymetry lines from 1000 to 4000 db and red portions of trajectory correspond to winter time, marked in the sections below profile numbers.

Perspectives:

It is a rich data set, not easy to synthesize. The role of eddy activity in intrusions and isoycnal mixing was explored in the northern Drake Passage using satellite data. It remains to be further explored.
None of these 12 Coriolis floats managed to go north of 36S. We shall also use other Argo floats, with a 2000 db parking depth and examine whether they managed to cross 36S parallel.

Next meetings

- 8th Argo Data Management Meeting, Hobart, Australia, Nov 14-17, 2007
- Euro-Argo Project: Kick-off meeting, Brest, France, Jan 14-15,2008
- 9th Argo Steering Team Meeting, Exeter, UK, May 2008
- 5th EUROGOOS conference, Exeter, UK, May 20-22, 2008
- Final GODAE Symposium, France, Nov 2008

We would be interested in reading about the results of your work in a future Coriolis News Letter.

We welcome your contributions!