Coriolis

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The Coriolis project

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In 2001, the seven French institutes (Cnes, Cnrs, Ifremer, Ird, Ipev, Météo-France, Shom) involved in operational oceanography have decided to join their efforts to build together a capacity to collect, control and distribute in real-time in-situ data needed by the Mercator and the French Navy operational ocean models.

Five years later, Coriolis team has set up an in-situ service for ocean modelling activities that is now used by the main ocean operational services in Europe such as MFS in Italy, Topaz in Norway and soon NCOF in UK. Within the Mersea Integrated Project, funded by the European Commission, the project is upgrading its services to comply with the European requirements to build the structure that should be sustained under GMES (Global Monitoring and Environment Security)

Coriolis includes four main components:

- **Float deployment unit** that coordinates the French contribution to ARGO. Within five years, 300 floats will be prepared by the team, and provided to the scientific teams selected to deploy them
- **Research vessels activities**: this multi-institute team defines protocols to transmit on a regular basis, within 24h, data acquired on board and coordinates the transmission set-up with the vessels operators.
- **Coriolis Data centre:** this centre collects, controls and distributes within 24h the data acquired by the previous components. It gathers data from the main in-situ data sources such as GTS (Global Telecommunication System), Argo, Gosud (Global Ocean surface underway Data)… These data are controlled before integration in our database. They are then distributed in a uniform format and quality flags through internet http://www.coriolis.eu.org
- **Coriolis R&D**: A scientific advisory group has been set up. It is composed of physical oceanographers involved in *in-situ* ocean observations. It works in close association with the data service group to define procedures for data validation, quality control, formats and products.

Coriolis in some figures:

- 7 institutes collaborating together
- About 20 persons involved in Coriolis development and operations
- Nearly 2000 active floats processed
- About 14 vessels transmit data in real time
- Floats from 25 Argo national projects in 10 countries are processed at Coriolis Data center
- More than 6500 profiles transmitted each week to ocean forecasting models…

The Coriolis Project team from Brest, France.

International Collaborations

One strength of the Coriolis project is its close connection with the European and International programs involved in the Godae experiment. Coriolis has set up Global Data Centres for the Argo and Gosud projects creating a one stop shopping point competitive with GTS for operational centres.

It coordinates in-situ data management activities for major European projects such as MFS/MFSTEP, Gyroscope, Mersea and Carbo-ocean. It provides the In-Situ reference dataset for satellite SST monitoring for the GHRSST (Global High Res SST) project.

The data management team is involved in normalization groups such as MarineXML and collaborates with the US.Ocean team for format and metadata definition.

Link with Research Community

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The main goal of the Coriolis project is to provide the Mercator project with real-time in-situ data of the best quality. Therefore it draws on the French expertise in oceanography either through the scientific advisory team,or with the help of scientists recruited on fixed-term contract (so-called “Réseau Bleu”) or through a yearly joint-Mercator/Coriolis call to the scientific community. Until now the science team has been working on the validation of three data types:

1) The salinity and temperature profiles measured by the ARGO floats. In order to control these profiles the Coriolis data Centre has implemented the method developed by A. Wong, modified by L. Böhme. This method already adopted by the Global Data Centers is currently under validation.

2) The sea surface salinity collected underway from research vessels or ships of opportunity. Procedures to qualify real-time and delayed mode data are under development.

3) The current profiles made by research vessels with Acoustic Doppler Current Profiler (ADCP). Data are processed using the “Cascade” software developed by Ifremer. Velocity profiles are not used yet in assimilation schemes but provide very useful information for the validation of numerical models.

Furthermore the Science Group helps in defining the deployment strategy of ARGO floats and XBT probes.

Coriolis New Letter:
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Coriolis Data Centre

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Coriolis is also a French operational oceanography data center. Quality-controlled in-situ data are collected, controlled and distributed in real-time and delayed modes (see fig. 1).

Managed data sets are mainly temperature, salinity and current measurements from profiling floats, XBT's, CTD's, thermo-salinographs, drifting and moored buoys. Data from experimental "platforms" such as gliders or sea-elephants are also handled by this center. The Coriolis data center size and structure is designed to fulfill operational oceanography needs from global ocean to regional scale (see fig. 3).

Coriolis architecture, centered on a database and web services, enables to deal with both historical and recent data with immediate access. The development of Coriolis data center was built on the expertise gained over time by the French national data center SISMER. However, additional issues were taken into consideration such as open standards (Internet XML/Soap protocols, LAS and OpenDAP data distribution services), need to manage incoming and outgoing data in real-time, need to provide data to a wide community not always clearly identified, need to include diverse data sources (see fig. 2).

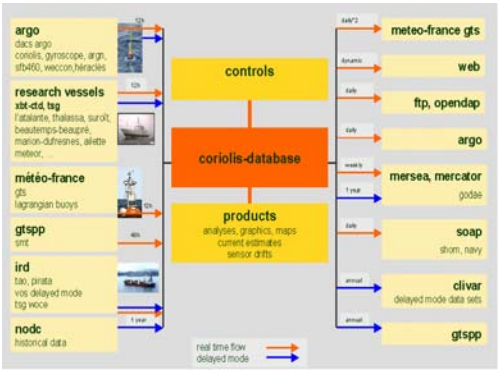

Figure 1 : Coriolis data flow

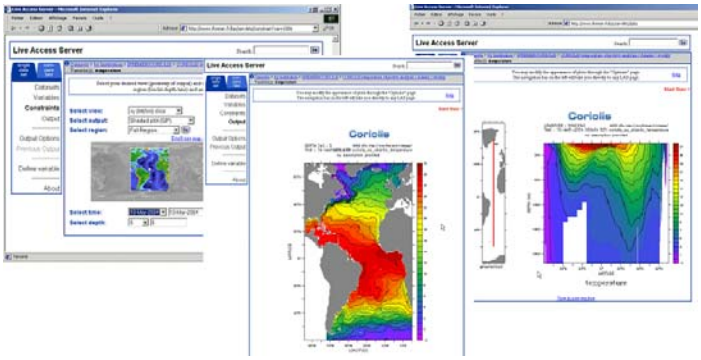

Figure 2 : Coriolis data are distributed through open standards such as Live Access Server (LAS)

Figure 3 : Coriolis data sources

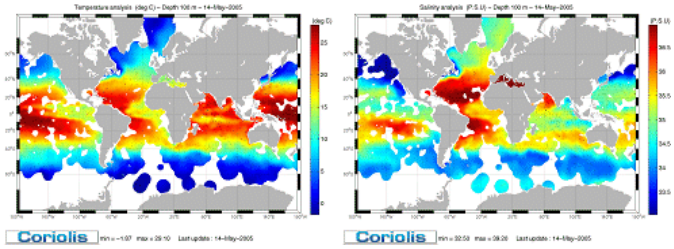

Figure 4 : example of Coriolis product : global temperature and salinity analyses performed daily, from 0 to 2000 meter deep.

Coriolis database offers to final users value added products such as dynamic charts and geographic maps, horizontal and vertical sections, temperature and salinity maps from objective analyses (see figure 4). According to the scientific user specifications, binary and Ascii dissemination formats are available (NetCDF, Medatlas, Bathy, Tesac, Trackob).

Coriolis data Center can now offer a data management structure for international projects (Argo, Gosud, MFSTEP, MERSEA). It is one of the two global Argo data centers (see fig. 5).

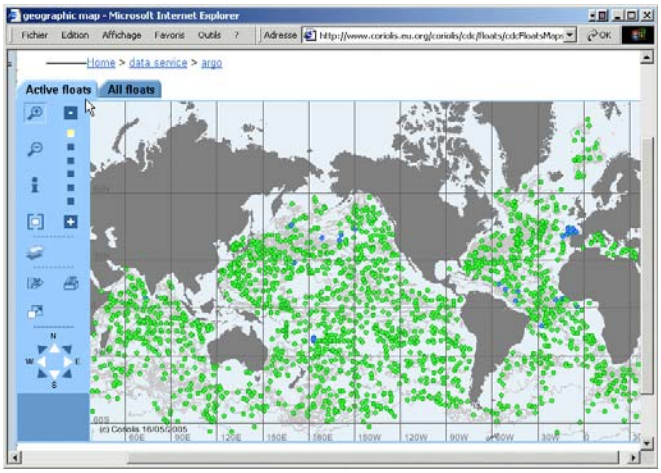

Figure 5 : Coriolis is one of the 2 global Argo data centers

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Contributing to the observing system

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Data needed by operational oceanography activities don't come by themselves. Acquiring enough data for operational oceanography is a major challenge that can only be achieved by international collaboration and free access to data. To contribute to the observing network. The Coriolis project has decided to focus on three main activities:

- Improvement of data collection from research vessels
- Coordination of French contribution to Argo program
- Improvement of the float technology

Research vessels activities;

Research vessels can be a key element of the global ocean observing system (GOOS).. First of all, research vessels areas of interest are, most of the time, far from the commercial vessels routes where there are few data. Secondly, those vessels are operated by highly specialized crew and engineers. So, the quality of the data is potentially very good. Finally some pertinent data are already collected during scientific cruises for physical oceanography purposes but are only transmitted to shore at the end of the cruises. As research vessels are equipped with high level telecommunications facilities, it is pretty easy to transmit the data in near-real time to an Operational

Oceanography data centre. Data concerned by this activity at Coriolis are mainly XBT, thermosalinograph and ADCP measurements.

The objectives of the Coriolis "research vessels activities" are:

- find new data sources and contact new research vessels able to transmit their data to the Coriolis data centre ;
- define protocols for transmitting data from vessels to the data centre;
- set up all means that could increase the quality of the collected data such as water sample analysis.

Beautemps-Beaupré vessel

On a daily basis, the Ifremer open ocean research vessels (Atalante, Le Suroît, Thalassa) send their XBT data (vertical profiles of temperature measurements) to the Coriolis data centre. This happens occasionally from some coastal vessels (Thalia, Belgica) and regularly from the Beautemps Beaupré (Hydrographic service of the French Navy) when the cruises are not classified. When Chief Scientists agree, the ships also transmit CTD data in near real time, decimated (1 measurement every 10 dbar) which is enough for operational oceanography needs. On a regular basis some of these vessels, as well as commercial vessels from IRD salinity observatory, also collect sea surface temperature and sea surface salinity measured with thermosalinometers as a contribution to the international program Gosud (http://www.gosud.org). In the future other parameters such as dissolved oxygen or fluorescence in the future may be taken into account.

The project is always looking for new sources of data. The number of vessels transmitting data in realtime has significantly increased in past years. Within the frame of the European Union funded project Mersea, a task is devoted to this objective. Soon Spanish, German, Norwegian and British research vessels will be able to transmit their data. See the Mersea web site http://www.mersea.eu.org/Insitu-Obs/1-Insitu-Vessels.html .

To improve the data quality, especially for thermosalinograph data, the project has also set up a "common calibration centre" which is able to calibrate the temperature and conductivity sensors and to analyse the sea water samples collected for further salinity adjustments. The aim is to provide a delayed-mode data set specifically for the Gosud project

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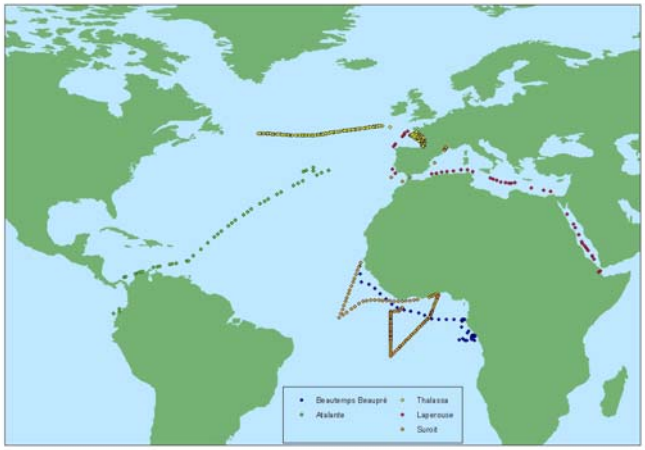


Geographic map of the XBT and CTD received in near real time at the Coriolis data centre (April-May-June 2005)

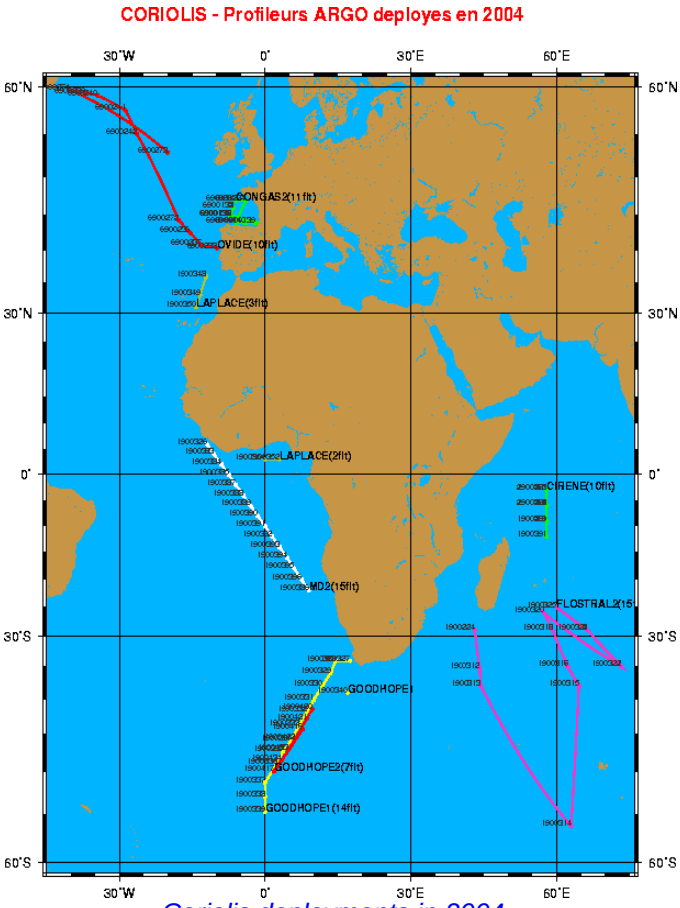
Contribution to Argo;

Since the beginning of the Coriolis project more than 300 floats have been deployed as the French contribution to the Argo program. They were first deployed in North-East Atlantic, then deployments moved to the Equatorial and South Atlantic, Indian Ocean and Southern Ocean. Deployments are either made by scientists during oceanographic cruises or through opportunity by collaborating with French Navy or with other countries contributing to Argo. Some deployments have also been made within European projects such as Gyroscope, Mfstep or Mersea.

As the float technology is not yet straightforward, we have set up a deployment unit that :

- Performs the acceptance tests : pressure , metrology and tanks tests are made on a subset of equipments.
- Prepares floats for deployment: definition of the float mission, attribution of a WMO and Argos identification, support for shipping.
- Trains the teams that will do the at sea activities and assists them in real time during the operations.

Finally since 2005, in collaboration with the data center team, at sea monitoring of the floats have started in order to improve the quality of the instruments.

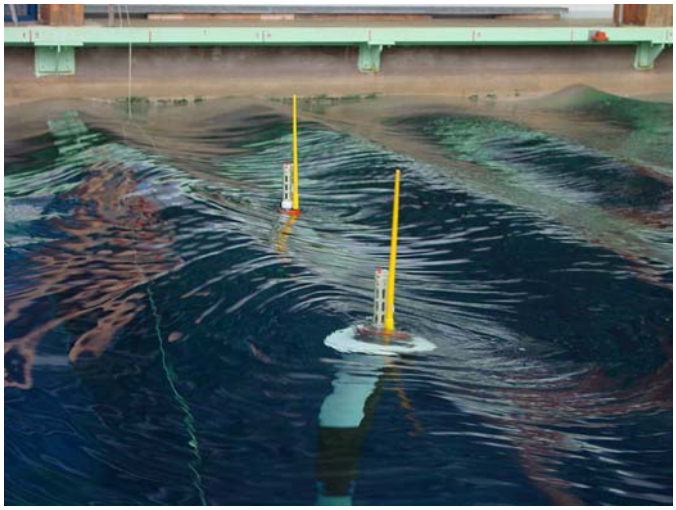


Coriolis deployments in 2004

Development of the float technology;

Within the ARGO project, Coriolis has to fulfil the needs of operational oceanography with the development of appropriate leading edge technology. These instrumental developments take into account the requirements of the Argo scientific community concerning *in situ* measurements, but they also must consider operational constraints linked to the implementation. Coriolis relies on the Ifremer project « Profiling Floats Development » to develop new technologies in order to respond to more and more extensive and varied demands.
The instrumental support mainly concerns the development and the industrialization of the PROVOR and PNG (New Generation Profiler) floats.

PROVOR refers to a range of profilers designed and finalized in the frame of a partnership between Ifremer and Martec. The current far reaching experience allowed making float more reliable. Provor is produced by series and the main coming improvements are focussed on easier deployment from ships of opportunity. All these floats are equipped with SeaBird CTD sensors.



Provor in the sea water basin at Ifremer to check the effect of the damping disk

PROVOR is now moving towards a « multi-sensors » utilization. The instrumental base has been modified in order to make the integration of new sensors easier. For example, Provor can be fitted with an Aanderaa optode (Provor-DO) or with a Rafos acoustic receiver (Provor-A), still using Argos data transmission system. On the other hand, ProvBio (CTD and optical sensors) and ProCarbon (CTD, dissolved Oxygen, Particular Organic Carbon) will use Iridium system to transmit more data, to reduce time at surface and to modify some mission parameters by remote control.

Sea trials of the PNG float

PNG aims to complete the float offer. When PROVOR leads toward a "multi-sensors" utilization, PNG tends to agree with the following criteria: performances improvement, easy deployment and costs reduction.
Prototypes have been manufactured and qualified. The weight tends to 19 kg instead of 33 kg for PROVOR technology.

Coriolis real-time analysis system: Validation over the North Atlantic

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The analysis system

The Coriolis data centre collects and distributes in real time a great variety of in-situ observations of temperature and salinity. These data initially obtained with XBT, XCTD and CTD, are now provided in a large part by the ARGO profilers. One of Coriolis main concerns has been to define a system for the real-time data quality control that could be at the same time efficient, such as to process an increasingly large number of data, and reliable, in order to insure the detection of outliers but preventing excessive false alarms. The need for data based high level products such as gridded fields of temperature and salinity expressed by various scientific communities was another requirement.

We have developed an analysis system that answers both demands. It is based on optimal estimation techniques and combines the Coriolis data with a-priori information derived from the climatology and elementary statistics. Diagnostic tools applied to the daily analysis residuals allow to detect outliers and trigger an alarm. The results are inspected by an operator and the quality flags are manually confirmed. Once a week, a second pass analysis is performed on the cleaned data base to produce the gridded fields which are made available on the Coriolis Web site.

In order to validate the system, we have performed a re-analysis of the Atlantic basin over the period 2000-2004 with the exact operational real-time configuration. The only difference with the weekly real time analysis lies in the dataset used: in our case we have access to the data transmitted to Coriolis after the analysis date. The re-analysis are then 'centred', while the real-time analysis are slightly biased backward in time. The first results of this analysis are:

1) an inventory of the database,
2) an overview of the profilers long term drift
3) a new 'climatology' representing recent years.

This last point is presented here. We will proceed with a study of the time and space variability.

Method and configuration

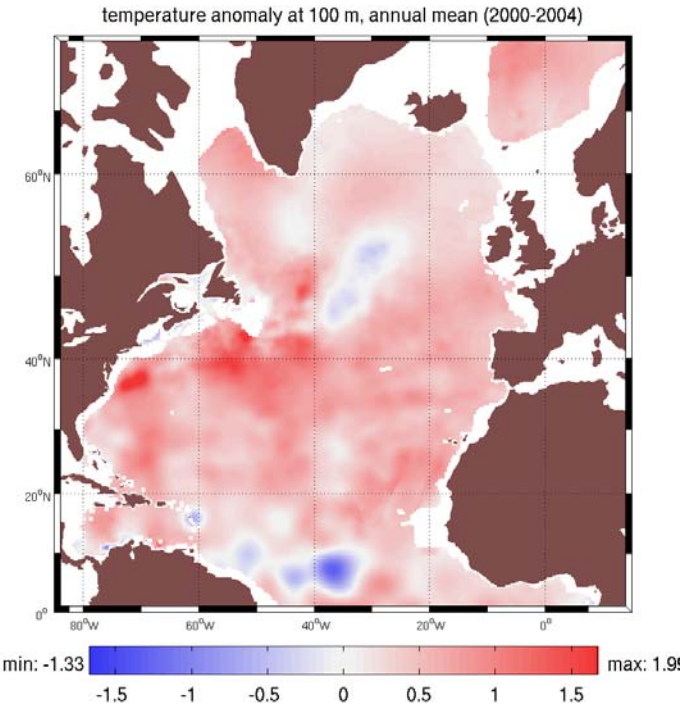
The analysis derives from optimal estimation methods as exposed by (Bretherton et al., 1976). In order to permit the data quality control, temperature and salinity are analysed separately, on horizontal levels. The solution is searched as an anomaly relative to a monthly climatology (Reynaud et al., 1998). For each analysis date, all data closest than 3 weeks in time are collected and converted to anomalies relative to the climatology to build the data vector (d). The covariance matrices involved in the solution:

$$x^a = x^f + C_{ao}\left(C_o + R\right)^{-1} d$$

are constructed using the Gaussian structure functions in time and space defined for the area considered and the data noise. The variances are deduced from the full dataset. We produce analyzed fields on 59 levels between 5 and 2000 m. The grid spacing is 1/3°.

A new climatology

The first goal of the analysis is to extract a mean seasonal cycle representing the year range 2000-2004. To construct each month of the cycle, all weekly analysis relative to this month and above an error threshold have been averaged. The annual mean fields, was obtained by averaging the monthly means. Provided a sufficiently low error level, this mean is unbiased relative to the season. The above figure shows the mean anomaly at 100 m relative to Reynaud's climatology, representative of the 1970-1980. The global warming is clear, but the anomaly exhibits spatial structure that need to be explained.



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Reynaud, T., L. G. P., et al. (1998). "A new analysis of hydrographic data in the Atlantic and its application to inverse modelling." WOCE Newsletter **32**: 29-31.