#52

QUARTERLY

Newsletter

MERCATOR OCEAN

OCEAN FORECASTERS

SPECIAL ISSUE with Coriolis

While most Argo floats are deployed by research vessels, some are also deployed by the sailing community, through ship-based non-governmental organization or trans-oceanic races. It allows poorly sampled areas with no regular shipping to be sampled. Sailors got also involved in oceanographic science activities. An example of float deployment is given here (see Poffa et al., this issue) in the case of the 2015 Barcelona World Race where eight floats were successfully deployed in the Atlantic Ocean between 24° and 44° south.

Credits: © Barcelona World Race

Editorial – May 2015 – Special Issue jointly coordinated by Mercator Ocean and Coriolis focusing on Ocean Observations

Greetings all,

Once a year in April, the Mercator Ocean Forecasting Center in Toulouse and the Coriolis Infrastructure in Brest publish a common newsletter. Papers are dedicated to observations only.

- **The first paper** introducing this issue is presenting the Coriolis 2014-2020 framework which was renewed in 2014 in order to go on integrating in-situ ocean observation infrastructure for operational oceanography and ocean/climate research.
- **Next paper by Poffa** et al. describes how some Argo floats are deployed by the sailing community, through ship-based non-governmental organization or trans-oceanic races. It allows Argo floats to be deployed in poorly sampled areas where there is no regular shipping. Sailors got also involved in oceanographic science activities. An example of float deployment is given in the case of the Barcelona World Race.
- **Next paper by Pouliquen** et al. describes the EURO-ARGO ERIC infrastructure which is now officially set-up since May 2014. The objective of the Euro-Argo ERIC is to organize a long term European contribution to the international Argo array of profiling floats.
- **Le Traon et al.** are then presenting how the assessment of the impact of ARGO in Ocean models and satellite validation is conducted in the context of E-AIMS (Euro-Argo improvements for the GMES/Copernicus Marine Service) FP7 project. Observing System Evaluations and Observing System Simulation Experiments have been conducted to quantify the contribution of Argo to constrain global and regional monitoring and forecasting centers and validate satellite observations. Recommendations for the new phase of Argo are also elaborated.
- **Kolodziejczyk et al.** follow with the presentation of the complementarity of ARGO and SMOS Sea Surface Salinity (SSS) observations to help monitoring SSS variability from basin to meso scale. Using a 4-year time-series of SMOS SSS data and the global Argo array of in situ measurements, a statistical approach and an optimal interpolation method are used to characterize biases and reduce noises. Results are promising and show strong complementarity between SMOS and Argo data.
- **Herbert et al.** then describe Shipboard Acoustic Doppler Current Profilers (SADCP) observations which are carried out in the Tropical Atlantic during yearly cruises in the framework of the PIRATA program. The present note displays the SADCP data processing methodology applied for 8 PIRATA cruises by using CASCADE software.
- **Cravatte et al.** follow with a paper presenting the new international TPOS2020 project (2014-2020). The project objective is to build a renewed, integrated, internationally-coordinated and sustainable observing system in the Tropical Pacific, meeting both the needs of climate research and operational forecasting systems and learning lessons from the great success-and finally partial collapse- of the TAO/TRITON array.
- **Saout-Grit et al.** next present an updated procedure for CTD-oxygen calibration along with new data processing that was applied to hydrographic cruise “BIFURCATION” (September 2012) in the Coral Sea. They describe the content and acquisition models of hydrological and chemical data that are used for the calibration, the post-cruise calibration method and the calibration results.
- **Dussurget et al.** is showing the recent improvement in surface current estimation from satellite altimetry, contributing to a better understanding of the Sea Surface Salinity processes in the Subtropical North Atlantic in the context of the SPURS experiment.
- **Finally, Mortier et al.** are presenting the GROOM project and the Glider European Research Infrastructure. During the last three years, the GROOM community has studied the feasibility and advantages of a European Research Infrastructure for gliders. The design study has proposed operational contours for a future distributed Glider (dedicated) European Research Infrastructure (GERI).

We will meet again soon with an issue dedicated to the various achievements of the MyOcean projects now handing over to the EU Copernicus Marine Service. Moreover, we will meet again next year in April 2016 for a new jointly coordinated Newsletter between Mercator Ocean and Coriolis. We wish you a pleasant reading,

Laurence Crosnier and Sylvie Pouliquen, Editors.

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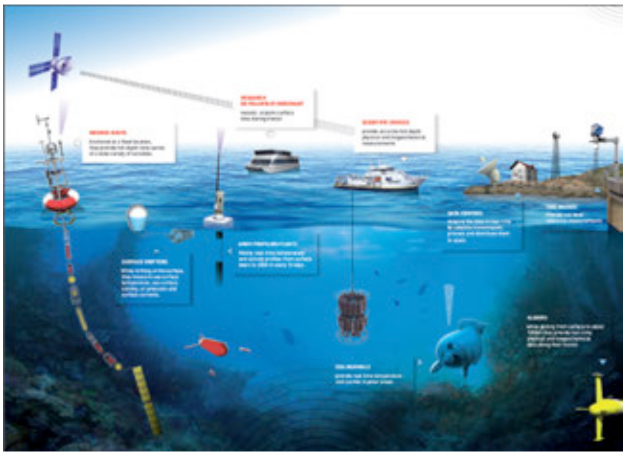
CORIOLIS 2014-2020: AN INTEGRATED IN-SITU OCEAN OBSERVATION INFRASTRUCTURE FOR OPERATIONAL OCEANOGRAPHY AND OCEAN/CLIMATE RESEARCH

P.Y. Le Traon, Ifremer and Mercator Océan
Executive Secretary of the Coriolis 2014-2020 governing board



The Coriolis structure gathers efforts of seven French institutes (CNES, CNRS, IFREMER, IPEV, IRD, Météo-France, SHOM) to organize the in-situ component of the French operational oceanography infrastructure. The objective is to organize the data acquisition and real-time/delayed mode data processing of in-situ measurements required for operational oceanography and ocean/climate research. Coriolis is focused on a limited number of physical and biogeochemical parameters that are acquired systematically and in real time or slightly delayed mode. Coriolis follows a fully open data policy.

The framework of collaboration for Coriolis was renewed in 2014 and now covers the time period of 2014 up to 2020. By signing this new agreement, the seven directors of French institutes have clearly stated their willingness to sustain and consolidate further the Coriolis in-situ infrastructure. The new framework agreement strengthens the links between research and operational oceanography. The scope is also extended to integrate the main French contributions to the global and regional in-situ observing systems: Argo, gliders, research vessels, ship of opportunities, drifting buoys, marine mammals, tidal networks and high frequency coastal observatories. These networks are organized by the different institutes with a pooling of resources for at sea operation, data processing and data dissemination and R&D activities. This new framework agreement provides a better integration of the French contributions to the Global Ocean Observing System (GOOS/JCOMM). It also confirms and extends the European mission of Coriolis, in particular, in the framework of Euro-Argo, Emodnet and the Copernicus Marine Service.

Coriolis 2014-2020 also features a strengthened organization and governance. A Steering Committee with representatives of all networks and of the three transverse components (at sea operation, data center, R&D) is in charge of the scientific and technical management. It reports to a Governing Board (directors of institutes). A Scientific Council (shared with Mercator Ocean) provides the required scientific guidance, in particular, for issues related to the integration with modelling and data assimilation.

DEPLOYING ARGO FLOATS IN THE BARCELONA WORLD RACE

By N. Poffa [(1)], N. Lebreton [(2)], M. Kramp [(3)]

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[2] SHOM, Brest, France
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Abstract

While most Argo floats are naturally deployed by research vessels, a growing number of float operations has been allocated to the sailing community, through ship-based non-governmental organization NGOs or trans-oceanic races in the last few years. The aim is to establish win-win partnerships, with Argo floats being deployed in poorly sampled areas without regular shipping, and to get sailors genuinely involved in oceanographic science activities. In the case of big events, it is also an opportunity for Argo to benefit from broad media coverage, and for the organizers, a chance to display a scientific impact of their projects. Thanks to joint forces of The Coriolis Deployment Team and the IOC-UNESCO/WMO support centre JCOMMOPS, both hosted by Ifremer in Brest, the beginning of 2015 saw probably the so far largest event of that kind, with the deployment of one Argo float by all of the eight crews participating in the Barcelona World Race. In coordination with Coriolis and JCOMMOPS, the race management gave the green light for "Argo day" on the 23rd of January, and eight floats were successfully deployed in the Atlantic Ocean between 24° and 44° south.

Meeting the challenges of float deployments in a round-the-world race

The history of Coriolis Argo floats with sailing races goes back to 2011-2012 when Stève Ravussin and Michel Desjoyeaux deployed Argo floats from their racing yachts on the way to the departure of the Krys Ocean Race from New York to Brest. Four floats were also deployed the same year by a racing yacht between the Caribbean and Europe. It has now however been a world's first with all participants of the 2015 Barcelona World Race taking a float onboard per official racing instructions, with a strong cooperation put into place between the race organizer (Barcelona Foundation for Ocean Sailing, FNOB) and IOC-UNESCO/JCOMMOPS, supported by a number of scientific research institutions. It is a very strong commitment from the race and hopefully marks a milestone in "sailing and science" partnerships. Beyond operational needs, it offers the Argo program also an unprecedented outreach potential.

After first successful onboard tests, the project was presented at an international press conference at United Nations UN headquarters in New York in summer 2014, and training was given to the skippers in Barcelona before the departure in December 2014. Most sailors were happy to contribute to an oceanographic science program, but they were less keen to embark almost 20kg of additional weight on their yachts; for fair conditions in terms of competition, it was thus agreed to deploy all floats on a carefully chosen "Argo day" (instead of giving a deployment area), allowing for deployments in data sparse areas of the South Atlantic.

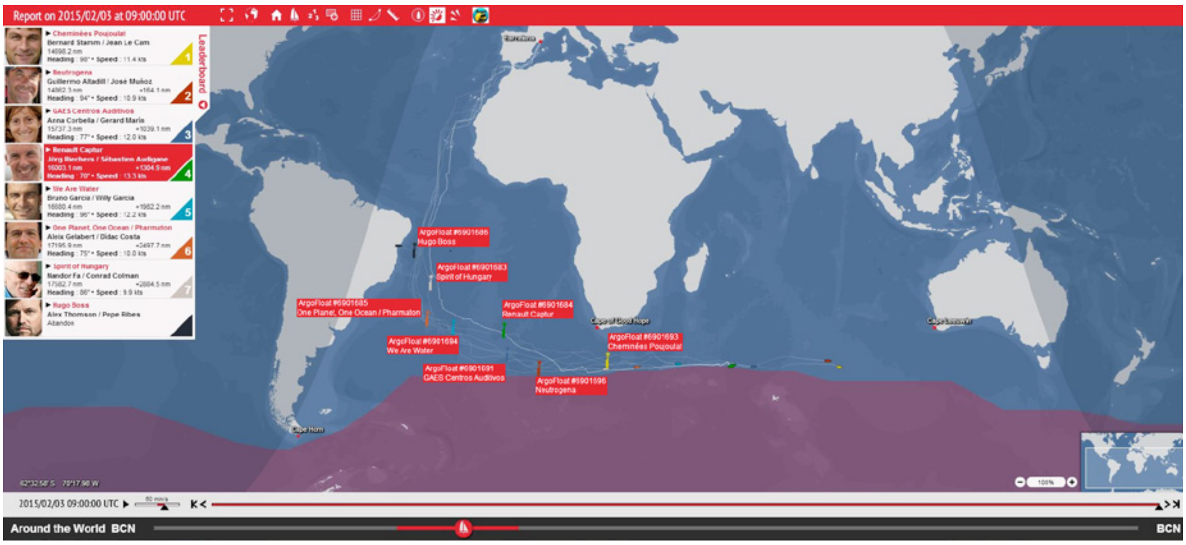

Figure 1: Boat and float positions at Argo day (courtesy of Geovoile and www.barcelonaworldrace.org)

Apart from one yacht which dismasted after 15 days, abandoned the race and released the float therefore earlier (as per agreement for such a scenario), the other competitors were given the go-ahead 23 days after the departure from Barcelona, when the weather conditions allowed a safe launch and the leading boats were hitting the 40°S latitude. During those 23 days, the floats (as the crews!) were exposed to some intense sailing, meaning a quite rough treatment in terms of shocks and vibrations. The deployment itself was also challenging for some instruments and skippers, who did not reduce the boat speed to the recommended 2 knots to put the floats at sea and instead deployed at impressive 16 knots of boat speed. Despite all that, all floats have entered the operational mode shortly after the deployment and at the time of writing, the eight floats, all of the NKE Arvor Light type, have successfully accomplished at least eight 10-day cycles and performed eight 2000m CTD profiles.

Argo visibility through supportive projects

As global climate change has become a vastly discussed topic, public awareness has led to a significant interest in the ways of climate monitoring related systems such as Argo floats. The sailing community being at the forefront of anything that has to do with meteorology and ocean is usually very concerned about research and applied science in those fields. Both sailors and followers of an event such as a round-the-world race are thus a very appreciative audience for a science program linked with the sportive event. Conrad Colman, skipper on Spirit of Hungary put it that way: “As sailors we are naturally hugely affected by the changes in the weather so it feels great to be able to contribute to its greater understanding during our race”, and Anna Corbella, skipper of GAES Centros Auditivos with Gerard Marín, added that “it means a lot to us both to do what we can to help the scientific community while we are sailing this race. [...] It makes us happy to help. We will make a little ceremony to throw the beacon in the water”. The crews did good jobs by posting pictures, videos and comments of their float launch shortly after the operation.

Figure 2: Floats deployments on Argo day onboard (from left to right) One Planet,One Ocean/Pharmaton, GAES Centros Auditivos and Spirit Of Hungary

Apart from Argo, Coriolis, UNESCO and race websites, the related press release was largely quoted and dozens of articles were published following Argo day, not only in the sailing and the science related press, but also in mainstream media and social networks. It is probably appropriate to state that such a level of communication on Argo, including explanation of the program, the network and the floats themselves was never achieved in such a short period of time. This is largely due to the characteristics of modern ocean racing, where communication is part of the challenge, and where skippers have almost become public relations PR professionals, being able to deliver quality images or video footage as well as live comments in real time. The race website has also proven to be particularly efficient, providing a lot of quality material for the press and the public. As part of the Argo project in the 2015 Barcelona World Race, a partnership between JCOMMOPS and the provider of the mapping tool, Geovoile, was set up in order to display the latest information on these particular Argo floats directly on the race-tracker, together with the yachts **(Fig. 1)**. A simple click on a float gives the user direct access to the corresponding float information from the JCOMMOPS web portal. On the other hand, a special page was set up on the Coriolis Data Center website to follow the floats deployed during the race and to access data. All those efforts coordinated at different levels (Skippers, Coriolis Deployment Team and Data Center, JCOMMOPS, Race Management, Euro Argo...) allowed for a successful operation that will be repeated, and also represents an interesting link to the next edition in 4 years. Follow-up operations have already started, and the Volvo Ocean Race has in March also deployed autonomous oceanographic instruments on the difficult Cape Horn leg from all participating yachts, showing the potential of such partnerships across different ocean observing programs.

Figure 3: One Planet,One Ocean/Pharmaton skipped by Spaniards Aleix Gelabert and Didac Costa in BWR 2015

Beside the racing community, JCOMMOPS and Coriolis also organize deployments with other sailing ships operating in undersampled zones, including traditional tall ships and expedition vessels, but also smaller pleasure yachts if they are organized in NGOs. Without such a NGO framework, efforts for logistics mostly exceed human resources on the science side. Those collaborations help informing the broader public on operational oceanography in general, and on Argo in particular. In this perspective, the Barcelona World Race was also a perfect way to kick off an educational project with 9-year old children from a school in Brest, who met the local skipper Bernard Stamm together with coordinators from Coriolis and JCOMMOPS before his departure to Barcelona. The children then "adopted" his float, and a relationship was maintained during the entire race and beyond in a one year long "sailing and science" project, including a visit of the Ifremer center in Brest during a week of Argo qualification tests, and a meeting with Bernard Stamm back from winning the 2015 edition.

Figure 4: Bernard Stamm and Jean Le Cam with their Argo float signed by pupils from Jacques Prévert School in Brest (photo left: Yvon Jezequel / right: Team Poujoulat)

Conclusion

The deployment of Argo floats in the 2015 Barcelona World Race was challenging in terms of technical constraints on the instrumentation side, but also in terms of logistics for the coordinators, and eventually the deployment operation itself for the skippers, who at the same time participated in a 90 days nonstop -and only double-handed- circumnavigation. It proved to be very successful in all aspects; all floats were deployed and work correctly, and in addition to the operational point of view, it was also an outstanding way for Argo to send a message to the outside world. The feedback from the involved crews is very positive. Given that in many data sparse areas, in particular in the Southern Ocean, racing yachts are often the only available and recurrent volunteer ships, a sound partnership with this community is considered to be of high value and thus continuously enhanced by the operational teams on the scientific side.

THE EURO-ARGO ERIC OFFICIALLY SET UP

By S. Pouliquen(1), P-Y. Le Traon(2) and Euro-Argo Members and Observers(3),

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Abstract
In May 2014, the Euro-Argo research infrastructure became a new European legal entity (Euro-Argo ERIC). The objective of the Euro-Argo ERIC is to organize a long term European contribution to the international Argo array of profiling floats. Argo is now the most important global in-situ observing system required to observe and understand the role of the ocean on the earth climate. Euro-Argo is also an essential component of the in-situ infrastructure required for the Copernicus Marine Environmental Monitoring Service (operational oceanography). Euro-Argo will thus develop European contribution to the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS).

INTRODUCTION
The Argo system (Freeland et al. 2010) is based on an array of profiling floats which measure every 10 days temperature and salinity throughout the deep global oceans, down to 2,000 meters and deliver data both in real time for operational users and, after careful scientific quality control, for climate change research and monitoring. Argo data policy is fully open and guarantees a free access of the data to all interested users. Argo is now the major, and only systematic, source of information and data over the ocean's interior. Argo aims to establish a global array of in-situ measurements integrated with other elements of the climate observing system (in particular satellite observations) to:

- detect climate variability from seasonal to decadal scales and provide long-term observations of climate change in the oceans.
- provide data to constrain global and regional ocean analysis and forecasting models
- provide data to initialize seasonal and decadal forecasting ocean/atmosphere coupled models and to validate climate models.
- provide information necessary for the calibration and validation of satellite data.

The EURO-ARGO ERIC
The Euro-Argo research infrastructure organizes and federates European contribution to Argo (www.euro-argo.eu); it is part of the European ESFRI roadmap on large research infrastructures. Euro-Argo carried out from January 2008 to June 2011 a preparatory phase project, funded through the EU 7th Framework Research Program, whose main outcome was to agree on the legal and governance framework (Euro-Argo ERIC) under which to establish the research infrastructure. Ministries from 9 European countries (Finland, France, Germany, Italy, Netherlands, Greece, UK, Norway, Poland) have agreed to form this new legal European entity to organize a long-term European contribution to Argo. It was set up by the Commission Implementing Decision (2014/261/EU) of May 5, 2014.

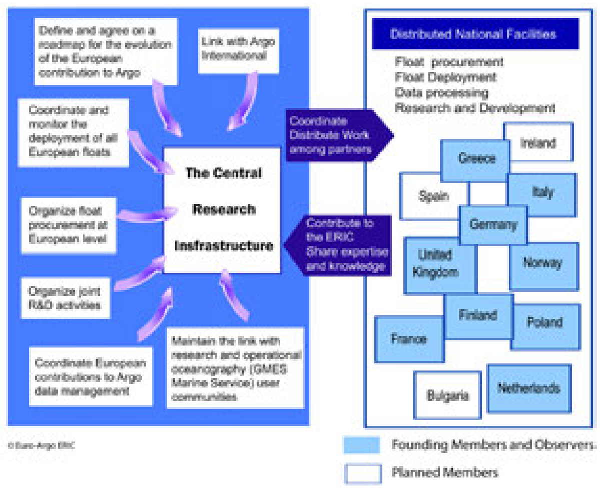

Figure 1: The EURO-ARGO distributed Research Infrastructure

The distributed national facilities operate with direct national resources. As part of the Euro-Argo research infrastructure, they agree to a multi-annual commitment of resources (in particular in terms of floats to be deployed and for the data system), and to coordinate their activities through the Euro-Argo ERIC. The Euro Argo ERIC may subcontract some of its activities to the national facilities who have the relevant expertise (e.g. data management and quality control, float deployment), and according to their areas of responsibility.

The Euro-Argo Research Infrastructure (RI) is a distributed facility (see http://www.euro-argo.eu). The Euro-Argo infrastructure is made up of a central infrastructure (C-RI) based in France (Ifremer, Brest) which is owned and controlled by the Euro-Argo ERIC and distributed national facilities. The Euro-Argo ERIC and its governance structure (Council, Management Board and Science and Technological Advisory Group) was set up at the creation of the ERIC. It was inaugurated on the 17th July in Brussels, hosted by the French Permanent Representation in Brussels, in presence of representatives of the European Commission and the Ministries of the signatory nations as well as the European institutes involved in Argo.

Figure 2: Inauguration

EURO-ARGO ERIC role and development

The Euro-Argo ERIC priorities are first to maintain and consolidate the global array and regional coverage for European seas by increasing European contribution from 150-200 floats to 250 floats/year and consolidating the data processing system. Secondly the Euro-Argo ERIC will prepare the evolution of Argo to address new scientific and operational challenges and in particular start implementing the new phase of Argo (biogeochemistry, deep ocean, Arctic).

The overall objectives of the Euro-Argo ERIC are:

- to provide, deploy and operate an array of around 800 floats contributing to the global array (a European contribution of ¼ of the global array);
- to provide enhanced coverage in the European regional seas;
- to provide quality controlled data and access to the data sets and data products to the research (climate and oceanography) and operational oceanography (e.g. Copernicus Marine Environmental Monitoring Service (CMEMS)) communities;
- to prepare the next phase of Argo with an extension to biogeochemical variables, to the deep ocean and the polar regions.

These data will be made freely available as a European contribution to the international Argo program. The Euro-Argo ERIC will organize interfaces with operational users and, in particular, with the Copernicus Marine Environmental Monitoring Service and with the ocean and climate change research communities.

The Euro-Argo ERIC is developing in two phases. In the ramping up phase (2014-mid 2015) the central entity (i.e. the Euro-Argo ERIC) works with a reduced budget funded by the Members and Observers. This budget allows to fund a programme manager a project assistant at 25% and one full time position (project scientist), and to provide basic support to the Euro-Argo RI (e.g. organization of workshops, maintenance of WWW sites including educational WWW site).

In the second phase (mid-2015-onwards) we expect a significant development of the Euro-Argo ERIC up to five persons. In line with the European nature of the infrastructure, a direct EU funding will be set up through the EMFF (European Maritime and Fisheries Fund) to complement national contributions and to ensure that Euro-Argo fulfils its objectives: deploying 250 floats/year (i.e. 25% of the overall international effort), providing high quality observations for ocean and climate research and the Copernicus Marine Environmental Monitoring Service, preparing the European contribution to the next phase of Argo.

Benefit for the European community

Thanks to a stronger European coordination of float deployments EURO-ARGO ERIC will ensure that certain areas are not overpopulated at the expense of other regions or the global array. Euro-Argo will deliver a stronger and more coherent European contribution to float technology development, with particular emphasis on European needs (e.g. sampling under ice, bio-geochemical sensors) leading to improved capability, performance and lifetime.

Figure 3: In blue: Euro-Argo RI contribution to Argo (Jan 2015)

The two European Argo data processing centres (Coriolis and BODC) will be strengthen to (i) ensure they are able to process all European floats and deliver the data to users, and (ii) ensure that Europe is able to fulfil its data processing commitments to the global programme (Coriolis GDAC, North Atlantic and Southern Ocean Regional Centres).

Euro-Argo will provide a mechanism for developing consistent inputs and a more concerted European voice into the international Argo programme, resulting in a stronger European influence on how Argo develops in the future. It will also provide the means to sustain important outreach activities (web-site, brochures, educational materials etc.) needed to explain to school children and the general public the importance of observations from the oceans towards dealing with climate change and other environmental issues.

Figure 4: About one hundred scientists met at Centre Ifremer Bretagne from 16th to 20th March 2015 for an "Argo week".

Dual Use: Research and Operational Oceanography

The oceans have a fundamental influence on our climate and weather, both of which are affected by changes in the currents and heat content of the ocean. Argo is a unique system to monitor heat and salt transport and storage, ocean circulation and global overturning changes and to understand the ability of the ocean to absorb excess CO2 from the atmosphere. Long term, global and high quality ocean observations are needed to understand the role of the ocean on the earth's climate and to predict the evolution of our weather and climate. Concerns about the lack of observations of the key factors that influence the earth's climate led governments to form the Global Earth Observation System of Systems (GEOSS) and, in Europe, the Earth observation program Copernicus and the European Marine Observation and Data Network (EMODnet) marine data initiative.

Argo is the first-ever global, in-situ ocean-observing network in the history of oceanography, providing an essential complement to satellite systems. Argo is a unique system to monitor heat and salt transport and storage, ocean circulation and global overturning changes and to understand the ability of the ocean to absorb excess heat from the atmosphere. One of Argo's most important contributions so far is a huge improvement in the estimation of heat stored by the oceans - a key factor to gauge global warming and gain a better understanding of the mechanisms behind rising sea level. Argo will be critical for developing reliable seasonal to decadal climate predictions. Argo has brought remarkable advances in ocean forecasting capability and is the single most important in-situ observing system for the Copernicus Marine Environmental Monitoring Service. It provides essential data in near real time to constrain global and regional CMEMS monitoring and forecasting centers. Without Argo, these centers will not be sufficiently constrained and will not be able to serve several key applications.

The development of the Euro-Argo ERIC, we will strengthen European contribution to Argo and contribute to a better coverage of the Global Ocean, Atlantic Ocean and European Seas. Argo float deployed and processed by Euro-Argo will directly feed the EMODnet data portals, the Copernicus Marine Environment Monitoring Service and their users. Thanks to the EU funding, the Euro-Argo ERIC jointly with its partners will be able to demonstrate that it:

- is able to manage a European Contribution to Argo and coordinate its implementation in coherence with the Euro-Argo and international partners. This It will ensure that certain areas are not overpopulated at the expense of others or the global array,
- provides a central capability for float testing and preparation (e.g. mission programming, installation of lithium batteries) and storage,
- provides enhanced at sea monitoring of the European fleet that will lead to an improvement of the fleet behavior with earlier detection of anomalies,
- strengthens the European Argo data processing centers so that they are (i) able to process all European floats and ensure the data are delivered to users, and (ii) ensure that Europe is able to fulfil its data processing commitments to the global program,
- improves the data management system and in particular the delayed mode data for research community,
- provides the means to outreach activities (web-site, brochures) needed to explain the importance of observations from the oceans towards dealing with climate change and other environmental issues,
- is able to extend float coverage into the marginal seas such as Mediterranean and Black Seas and also Nordic Seas and Arctic Ocean, regions which have a significant impact on the Atlantic circulation and climate change impacting Western Europe.

Maintaining observations in international waters over the long term is challenging. Frequently monitoring begins as part of a research project but once the concept is proven it can no longer be considered as research and be supported by national or EU research budgets. Furthermore, it is difficult to justify one Member State bearing the costs of an infrastructure that does not principally benefit its own citizens but rather serves the interests of all Member States. The Euro-Argo ERIC will demonstrate in the coming years that it is able to manage a direct EU contribution to the international Argo.

Future extensions

Finally, Euro-Argo has set up the following priorities for the next five years

- Contribute to the global array and sampling of European regional seas. and Improve European coordination.
- Work with DG MARE, Copernicus and Emodnet to set up a long term (7-year) EU funding for Euro-Argo
- Maximise the relevant knowledge of the Seas and Oceans, e.g. their role in a changing climate (towards deeper measurements).
- Continue working with the user communities Develop /extend the user base. Education and outreach
- Maintain strong links with Copernicus and Emodnet.
- Prepare high quality delayed mode data sets required by ocean and climate change research.
- Improving float technology (e.g. extend life time, new sensors) and interactions with float manufacturers.
- Prepare the implementation of the new phase of Argo at European level:
  deep ocean, biogeochemistry and Arctic.
  Pilot projects, evolution of national roadmaps and new agreements at European level.
- Integration of Euro-Argo with other marine research infrastructures: towards an European Ocean Observing

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ASSESSESMENT OF THE IMPACT OF ARGO IN OCEAN MODELS AND SATELLITE VALIDATION FROM E-AIMS PROJECT

By P.Y. Le Traon [(1)]***, E. Remy*** [(2),] ***J. Ballabrera-Poy*** [(3)]***,***

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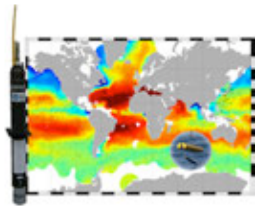


Abstract

The main objective of the E-AIMS (Euro-Argo improvements for the GMES/Copernicus Marine Service) FP7 project is to conduct R&D activities on Argo float technology, Argo data centers and the design of the new phase of Argo (improved coverage, deep ocean, biogeochemical sensors, polar regions) to better answer existing and future needs of the Copernicus Marine Service. Observing System Evaluations and Observing System Simulation Experiments have been, in particular, conducted to quantify the contribution of Argo to constrain global and regional monitoring and forecasting centers and validate satellite observations. Recommendations for the new phase of Argo are also elaborated. A summary of these results is provided here.

Context: the Copernicus Marine Service, Argo and Euro-Argo

The Copernicus Marine Service through its MyOcean projects has set up a pan-European service for ocean monitoring and forecasting over the global ocean and European seas. In-situ and satellite observations are routinely assimilated in ocean models to provide in real time or in delayed mode (reanalyses) integrated descriptions and short-term forecasts of the ocean physical and biogeochemical state. These core products serve a wide range of applications and users. The delivery of the Copernicus Marine Service strongly relies on the timely provision of both satellite and in-situ observations. While satellites provide a global view of the surface of the oceans, in-situ systems provide complementary data primarily by monitoring their interior. In the context of the Copernicus Marine Service, global to regional scale in-situ observations are required to constrain the models at depth & provide calibration and verification data. The Marine Service has thus a very high dependency on in-situ observations.

The international Argo programme is a major element of the global in-situ ocean observing system. More than 3500 floats are now globally measuring temperature and salinity throughout the deep global oceans, down to 2,000 metres and delivering data both in real time for operational users and after careful scientific quality control for climate change research and monitoring. Argo is the single most important in-situ observing system for the Copernicus Marine Service. It provides essential/critical data in near real time to constrain global and regional data monitoring and forecasting centers and to validate satellite observations. Techniques are also mature and fully demonstrated. Float technology will also evolve in the coming years to include new sensors (e.g. oxygen, biology) and new capabilities (e.g. deep ocean, under ice measurements) that are essential for climate change research and for the Copernicus Marine Service.

The Euro-Argo research infrastructure organizes and federates European contribution to Argo (www.euro-argo.eu); it is part of the European ESFRI roadmap on large research infrastructures. Euro-Argo carried out a preparatory phase project, funded through the EU 7th Framework Research Programme, whose main outcome was to agree on the legal and governance framework (Euro-Argo ERIC) under which to establish the research infrastructure. The Euro-Argo ERIC was set up in May 2014; it will allow European countries to consolidate and improve their contribution to Argo international. The main challenges for Argo and Euro-Argo are 1/ to maintain the global array and ensure its long term sustainability and 2/ prepare the next phase of Argo with an extension towards biogeochemistry, the polar oceans, the marginal seas and the deep ocean. Meeting such challenges is essential for the long term sustainability and evolution of the Copernicus Marine Service. This requires major improvements in Argo float technology. New floats with improved capabilities are or will be soon available from float manufacturers. They require, however, extensive testing at sea before they can be used for operational monitoring. The Euro-Argo data centres need also to be upgraded so that they can handle these new floats.

The FP7 E-AIMS project

E-AIMS (Euro-Argo Improvements for the GMES/Copernicus Marine Service) is an FP7 Space R&D project dealing with the in-situ component of Copernicus (see www.euro-argo.eu/E-AIMS). E-AIMS is led by Ifremer and gathers 16 institutions from 9 different countries. E-AIMS will organize an end-to-end evaluation of new Argo floats (from float design down to the use by GMES/Copernicus). Observing System Evaluations and Sensitivity Experiments will also be conducted to provide robust recommendations for the next phase of Argo that take into account GMES/Copernicus Marine Service, seasonal/decadal climate forecasting and satellite validation requirements. E-AIMS will thus demonstrate the capability of the Euro-Argo infrastructure to conduct R&D driven by GMES/Copernicus needs and demonstrate that procurement, deployment and processing of floats for GMES/Copernicus can be organized at European level. These are key aspects for the long term sustainability of GMES/Copernicus in-situ component. At the end of E-AIMS, Euro-Argo should agree on and start implementing the new phase of Argo. This requires demonstrating feasibility and utility which is the very objective of E-AIMS.

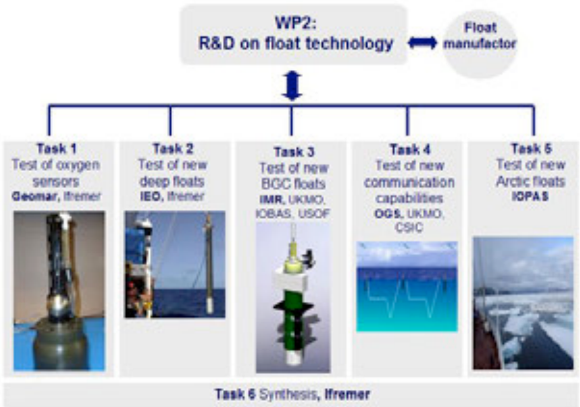
• Ifremer, France, UKMO, U.K OGS, Italy, NERC/BODC, U.K. KNMI, Netherlands, IEO, Spain, IMR, Norway, USOF, Bulgaria, IOPAS, Poland, Geomar, Germany, Mercator Océan, France, INGV, Italy, CLS, France, ACRI-ST, France, CSIC, Spain, IOBAS, Bulgaria.

Assessement of the impact of ARGO in ocean models and satellite validation from E-AIMS project

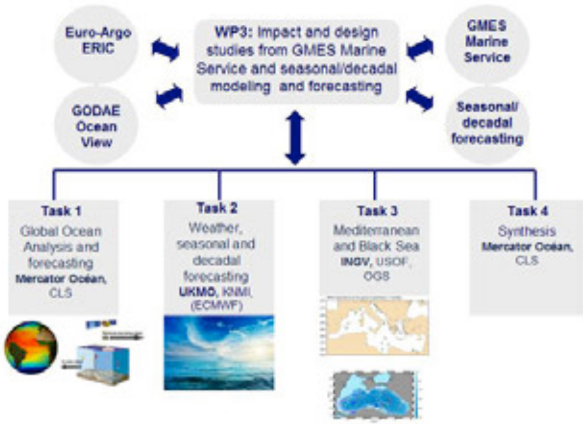
The project started in January 2013 and will end in December 2015. It is organized along the following work packages:

WP1&7, 8: Management, Coordination and Communication

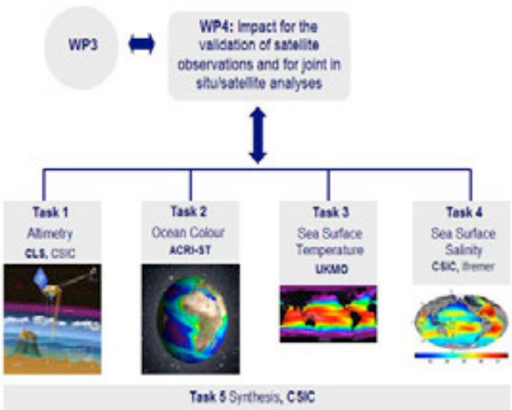
WP2: R&D on float technology. The objective of WP2 is to test several new Argo floats which have been recently developed. These new models of floats require intensive testing before they can be used for operational monitoring. WP2 will organize an end-to-end test of the following new floats: floats with oxygen and biogeochemical sensors, deep floats, floats with improved communication capabilities, Arctic floats.



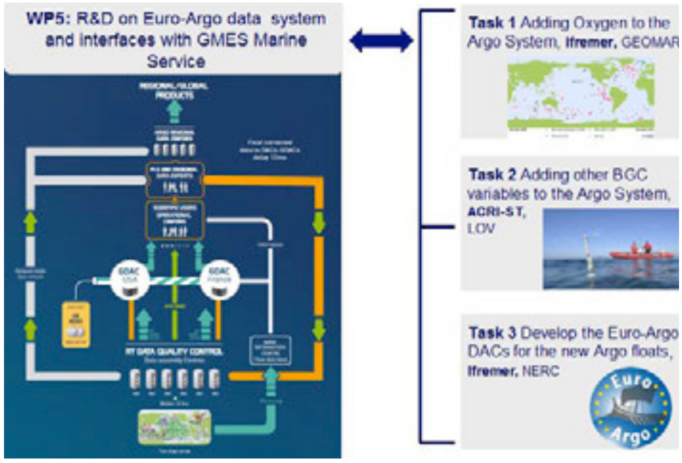
WP3: Impact and design studies from Copernicus Marine Service and seasonal/decadal modeling and forecasting. The main objective is to perform Observing System Experiments and Observing System Simulation Experiment with the Copernicus Marine Service assimilative systems to assess the potential of Argo and its extensions.



WP4: Impact for the validation of satellite observations. WP4 will analyze the use of Argo float data to calibrate, validate and monitor the long term stability of satellite observations. Present and future requirements for satellite Cal/Val activities will be given.



WP5: R&D on Euro-Argo data system and interfaces with Copernicus Marine Service. The objective is to improve the Euro-Argo data system to better serve the Copernicus Marine Service and adapt it to the future generation of Argo profiling floats.



WP6: Real time processing, impact and final assessment. The objective is to demonstrate that Euro-Argo data centers can process in real time the new floats developed and tested in WP2, distribute them to MyOcean modeling and forecasting centers and satellite Cal/Val teams as well as to show that these teams can effectively use these new data sets.

An overview of main results from WP3 and WP4 is given in the next sections focusing on aspects directly relevant to the Copernicus Marine Service. Main recommendations are also given in the final section.

Impact and design studies for Copernicus Marine Service monitoring and forecasting centers

Several impact and design studies were carried out as part of E-AIMS. Main results related to the Copernicus Marine Service monitoring and forecasting centers are given here. Impact of Argo floats have been assessed both at global and regional scales.

Global ocean

1-year Observing System Evaluations (OSEs) were carried out with the Mercator Ocean ¼° global data assimilation system. A reference run where all data (satellite altimetry, sea surface temperature, Argo and other in-situ observations) are assimilated is compared to a run without Argo data assimilation or with only half of the Argo data assimilated. A strong impact of Argo data assimilation is identified on temperature and salinity estimates at all depths, linked with an observation minus model forecast error (innovation) reduction both in term of variability and bias. Through Argo assimilation the differences between observation and forecasted fields is thus reduced by about 20% in the 0-300 m depth and from 20% to 65% in the 700-2000 m layers depth **(Figure 1)**. Argo floats are thus crucial in the system to control the model forecasted water properties, from the surface down to 2000m. Not all regions are equally impacted by the Argo observations. The performance of the system is also degraded if only half of the array is assimilated. Time series of the anomaly of heat and salt content for different depth ranges (not shown here) also reveal a strong sensitivity to the density of the Argo array.

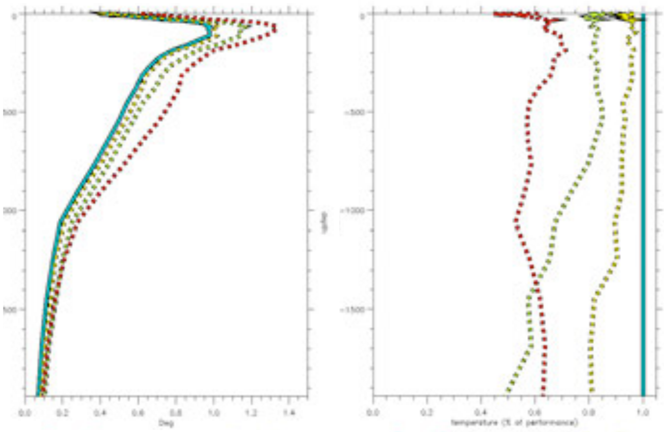


Figure 1: OSEs carried out with the Mercator Ocean global data assimilation system. Vertical structure of RMS of temperature innovations (left) and normalized RMS temperature innovations (right) from 0-2000m for Run-Ref (blue) (all observations assimilated), Run-Argo2 (yellow) (half of the Argo data assimilated), Run-NoArgo (green) (no Argo data assimilated) and Free Run (red). Innovations are defined as observation minus model forecast fields.

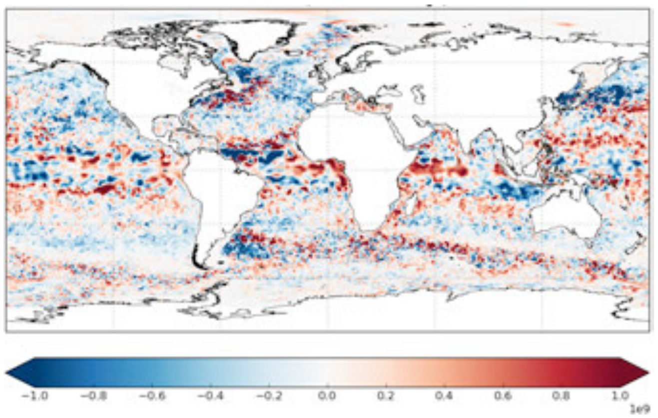


Figure 2: OSEs carried out with the Met Office ocean/atmosphere coupled system. Upper-ocean heat content difference (J, of top 300m) between the control analyses and the no-Argo analyses averaged over October 2012 (control minus no-Argo) global data assimilation system.

ARMOR3D Copernicus Multi Observations system developed by CLS has also been used to assess the impact of Argo observations to map temperature and salinity fields together with satellite observations using Degree of Freedom of Signal (DFS) diagnostics. Results show that most of the information comes from the Argo observing system, with almost no redundancy, then from the satellite dataset (altimetry and SST) and then from the other in-situ instruments (e.g. moorings, XBTs). This demonstrates, once again, the major role played by the Argo observing system.

The denial of Argo observations from the Met Office coupled global data assimilation system caused a similar large degradation in ocean temperature and salinity innovation statistics. The greatest differences in the upper ocean built slowly over 6 to 12 months and future OSEs investigating the impact of Argo and other ocean observing systems should be run for between 6-months and 1-year. **(Figure 2)**. Case study forecasts with the Met Office ocean/atmosphere coupled system of Hurricane Sandy highlighted that the assimilation of Argo profiles has an impact on the analyzed position of the Gulf Stream, with consequent impacts on forecasts. However, no systematic improvements of the atmospheric state can be determined without further case studies. A crucial aspect of the coupled model which is expected to influence forecast skill is the diurnal cycle of SST, and high vertical resolution near-surface data will be useful for the assessment of this aspect of the model. A number of Argo profiles already make this data available, and the extension of this to the whole array would be very useful for coupled forecasting, particularly as the cost of the additional measurements is minimal. High vertical resolution near-surface temperature data from all Argo floats would be required for such an application.

Observing System Simulation Experiments, where observations are simulated from a fully known ocean simulation, were also carried out to simulate extension of the future deep Argo network and its impact on the Mercator Ocean global ocean data assimilation system. The analysis quality at depth greatly benefits from observations deeper than 2000 m, even with a sparser spatial coverage than the surface layers. Deep ocean bias could then be corrected for (Figure 3). The oceans deeper than 2000 m are mainly unobserved as of today and they represent more than 50% of the total ocean volume. Given the role of the deep ocean on the earth climate it is essential to set up a global, long term monitoring system for depths deeper than 2000 m. E-AIMS results show that such deep measurements will be crucial to validate and constrain Copernicus Marine Service models at depth.

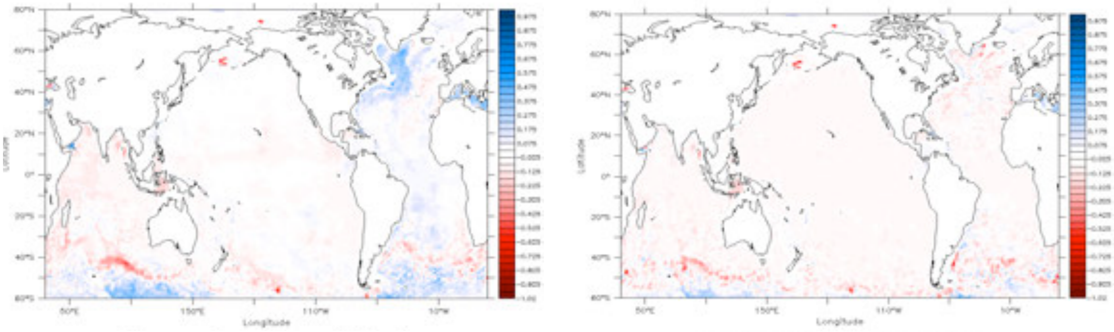


Figure 3: OSSE carried out with the Mercator Ocean global data assimilation model to analyze the sensitivity of results to the assimilation of deep (4000 m) Argo floats. Three month mean temperature difference between the analyzed and the simulated "truth" in the 2000m-4000m layer: on the left without any float diving below 2000 m and on the right with one third of the floats diving up to 4000 m every three 10-day cycle (colour scale between -1 and 1°C).

Mediterranean Sea

INGV studied the impact of the Argo horizontal and vertical/time sampling scheme through both OSEs and OSSEs on the quality of the MyOcean Monitoring and Forecasting Center analyses and forecasts. Argo observations produce a reduction of 30% on RMS of the analysis residual (observation minus model background) for temperature and salinity with respect to the free model simulation. If we use only half the Argo fleet, the mean analysis residual in salinity increases by 30% and the RMS error by 10% in the thermocline. OSSEs evidenced that the Argo sampling scheme could be modified to further improve the operational analyses quality. A positive impact has been found when probes have a drifting time of 3 days (as compared to 5 days) and vertical continuous sampling (every meter for Argo) with respect to vertical subsampling as presently done. Full profile transmission could also be considered as a major improvement for the MyOcean Mediterranean analyses. Results from OGS modelling experiments indicate that the assimilation of floats has a small but positive impact on the biological compartment as well. The improvements are located mainly in specific area (e.g. north western region of Mediterranean Sea) and specific period of the year (e.g. winter) when the vertical mixing is relevant for biogeochemical dynamics.

Black Sea

Experiments with different deployment strategies demonstrated that increasing the amount of Argo floats performs better than increasing the frequency of surfacing. Without Argo data, estimates in the upper mixed layer suffer from large errors. Profiling float measurements are very important for depths below the seasonal thermocline because the transition from thermo-to-haline-dominated stratification shows only short spatial covariance length. Another major conclusion from this research is that the present number of Argo floats operating in the Black Sea of about 10 seems optimal for operational purposes. Further increase of this number could be beneficial when addressing specific research questions.

Use of Argo for satellite validation

The satellite validation studies carried out in E-AIMS have been focused on sea level from satellite altimetry, ocean colour, sea surface temperature and sea surface salinity. It must be noticed that the development stage and maturity of the corresponding satellite missions differ from one to the other. All these satellite missions require, however, to be validated with in-situ measurements and Argo provides unique observations for such a validation. Analyses carried out as part of E-AIMS confirm the high potential of Argo observations for the validation of satellite observations. For some missions (e.g. SSS) they already are the main source of information to validate and monitor the quality of satellite observations. Main findings and results are summarized here:

- Satellite altimetry and Argo are quite complementary. Sea Level Anomalies (SLA) from altimeter measurements and dynamic height anomalies (DHA) calculated from the temperature and salinity profiles of the Argo network are strongly correlated and thus, their comparison can be used to detect drifts, anomalies or jumps in altimeter measurements, assess improvements due to altimetry data process standards, or to detect errors in the Argo float time series. Results indicate that the altimeter drift detection and the global statistics of the differences between altimetry and Argo data are only slightly affected by a reduction of the number of Argo floats and a reduced spatial coverage of the in-situ network while a reduced temporal sampling of the floats (>10 days) could prevent appropriate assessment of the impact of new altimeter standards. Detection of the altimeter drift and the quality assessment of new altimeter standards or products are, however, sensitive to the Reference Depth and would benefit from deeper Argo observations.

- Ocean colour remote sensing data (Chlorophyll-a concentration, Chl-a, and diffuse attenuation coefficient, Kd) and data derived from bio-profilers (i.e., Chl-a and Kd) are indirect measurements relying on semi-empirical models of the backscattered light at the sea surface (remote sensing) and fluorescence (bio-profilers). Direct comparison of two "indirect" sources of observation might therefore allow identifying weakness (or strengths) of both the measurement technology and their semi-empirical transformation. The development of bio-Argo profilers is timely to the calibration/validation of the future Ocean and Land Colour Instrument (OLCI) on board Sentinel 3 planned to launch late in 2015. The ability of bio-Argo floats for the verification of future ocean colour remote sensing missions has been demonstrated through matchups between Chl-a from remote sensing and Chl-a integrated over the upper layer measured by existing bio-Argo floats **(Figure 4)**.

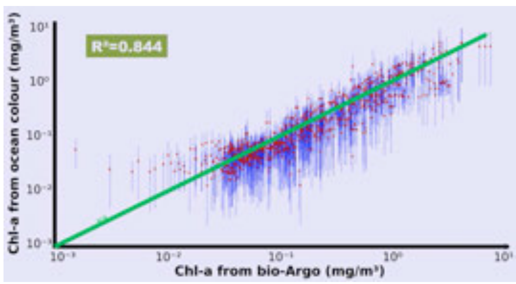
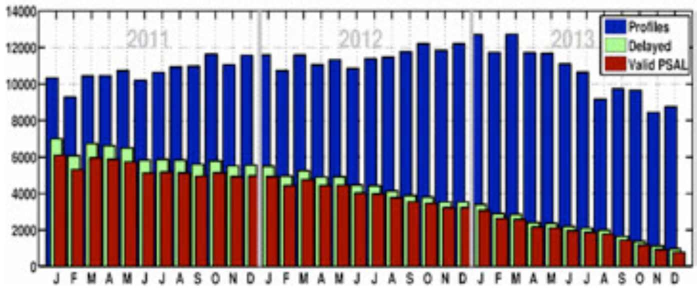


Figure 4: Matchup between bio-Argo and remotely sensed Chl-a estimates.

• Satellite sea surface temperature observations (SST) are obtained from infra-red and microwave sensors. They are generally validated with precise in-situ surface observations (in particular from surface drifters). The global coverage of Argo is now providing a very complementary mean for the validation of satellite SST measurements. Argo observations between 3-5 m have been shown to provide a good estimate of SST when compared to the OSTIA (Operational SST and Ice Analysis) gridded SST (http://ghrsst-pp.metoffice.com/). The sampling error associated with the monthly mean difference between the OSTIA analysis and near-surface Argo observations has been investigated. The monthly total number of near-surface Argo observations is suitable for a sampling error of <0.03 K for most major ocean regions. Some exceptions are western boundary current regions (0.082 K) and the Polar regions (0.2 K). The monthly total number of near-surface Argo observations currently available is sufficient to identify a statistically significant difference in standard deviation between two analyses where large differences have been found. The Pacific has enough observations to demonstrate statistical differences between the analyses. However, more floats are needed in the North and South Atlantic. Routine monthly validation of OSTIA and GMPE SST products using quality-controlled Argo observations from the EN4 database 2 has now been set up. Time series of global and regional statistics (using the MyOcean region definitions) are freely available on the web: http://ghrsst-pp.metoffice.com/pages/latest_analysis/sst_monitor/argo.

• Remotely sensed estimates of sea surface salinity (SSS) can be derived from microwave radiometry at L-band. The Soil Moisture and Ocean Salinity (SMOS) and the Aquarius missions have been the first ones designed to provide operational estimates of the global SSS fields. They have been launched in 2009 and 2011 respectively. As of today, the Argo array is the only observing system able to provide global measurements of salinity, allowing validation of the retrieval algorithms in different geophysical scenarios (sea surface temperature, surface wind speed and distance to the coast). Comparison of Argo near surface salinity data with satellite SSS products generated by the SMOS Barcelona Expert Centre (http://cp34-bec.cmima.csic.es) have demonstrated this high potential of Argo. It has been noticed that the number of available Delayed Mode profiles has been decreasing during the validation period (2011-2013). If in January 2011 more than 6000 Argo salinity profiles are available, by December 2013, less than 1000 Argo salinity profiles are available **(Figure 5)**. This is due to the time required for the Argo data delayed mode quality control but it would be very important to reduce this time delay and/or to produce intermediate data sets where surface observations are validated. The results indicate that robust estimates of the difference between SMOS and Delayed Argo have been found. The standard deviation of the differences are of the order of 0.29 and 0.23 (in the practical salinity scale) depending if the comparison is done in the latitudinal band of 60S-60N or 30S-30N respectively.

Figure 5: Number of available profiles from January 2011 to December 2013: Shown are the total number of profiles, the delayed mode profiles, and the number of delayed mode profiles with salinity.



Conclusions and recommendations

Analyses carried out as part of E-AIMS confirm the very strong impact of Argo observations to constrain global and regional ocean models. The existing Argo observing system should thus be as much as possible stabilized with its actual spatial and temporal coverage and should continue to equally sample the entire world ocean (a decrease of the number of profiles will immediately lead to a degradation of the ocean analyses and forecasts). There is a strong need of deep Argo profiles (coarse resolution) for model validation and data assimilation. Deep observations are mandatory to monitor and estimate error on forced and assimilative models at large depths.The assimilation of simulated deep Argo floats shows that deep model bias could be corrected for even if the float sampling is coarse. For the upper ocean and for ocean/atmosphere coupled systems, there is a need of higher resolution close to the surface. Other requirements include the continued production of delayed-mode high quality processing of Argo data with minimal time delay (to be used for ocean reanalyses). Optimal drifting time and parking depth are still under investigation and will depend on the regions. In parallel, work should be carried out to improve data assimilation schemes to better use the present Argo profile observations and the future deep/high vertical resolution observations. Although this was not evaluated per se as part of WP3, Bio-Argo data will also be essential to validate Copernicus Marine Service global and regional biogeochemical models and, if the sampling is sufficient, to constrain them through data assimilation. There is now a critical lack of biogeochemical observations and this strongly limits our ability to validate Copernicus Marine Service biogeochemical models.

The results of the satellite validation activities suggest that current spatial and temporal coverage of Argo array is suited for validation activities of sea level, SST, Ocean Colour and SSS (especially for monthly validation). However, further improvements that will help to improve the robustness of these validations are: 1) Speeding up the scientific validation of Argo data; 2) increase the depth of the vertical sampling; 3) increase the number of measurements in the upper four meters of the ocean; 4) increase sampling in regions of high variability; 5) network coverage should be enlarged in the Atlantic Ocean and at high latitudes. Bio-Argo profilers are already a unique source of observations for the validation of ocean colour satellites. Development of this new capability will require on the longer run to: 1) Optimize the match-up strategy; 2) program high-frequency profile cycles when located in a biologically stable area; 3) Make use of additional recoverable profilers at launch and recovery times.

Acknowledgements

The authors wish to thank all the participants of the WP3 and WP4 of the FP7-SPACE E-AIMS project (grant agreement 312642). J. Ballabrera-Poy has also been founded by the Spanish Ministry of Economy through the National R&D Plan by means of MIDAS-7 project AYA2012–39356-C05-03.

ARGO AND SMOS SSS COMBINATION HELPS MONITORING SSS VARIABILITY FROM BASIN SCALE TO MESOSCALE

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Abstract

The Soil Moisture and Ocean Salinity (SMOS) mission (European Space Agency) launched in November 2009 provides with measurements of Sea Surface Salinity (SSS) over the global ocean at 45 km resolution every 3 to 5 days. For the first time, the SMOS SSS products are used to monitor and address the distribution of mesoscale feature of the SSS (larger than 50-100km, with 10 day to monthly averages). However, SMOS SSS still experience large biases and noise on various time and space scales which are not yet fully understood. Using a 4-year time-series of SMOS SSS data (mid-2010 to mid-2014) and the global Argo array of in situ measurements as reference data base, a statistical approach and Optimal Interpolation are used to characterize and to correct a large part of the biases and reduce the noise. The results are promising and it shows the strong complementarity between SMOS and Argo data.

Introduction

Changes to the global water cycle are anticipated as a consequence of the climate change. Actually, precipitation and evaporation fluxes are very difficult to monitor accurately over the global ocean. Measuring ocean salinity has been shown to be a good proxy to monitor the evolution of the water cycle (Terray et al., 2012; Durack and Wijffels, 2010). During last 50 years, the global change in the freshwater balance is responsible for a positive trend in Sea Surface Salinity (SSS) in the Subtropical Atlantic (Curry et al., 2003; Durack and Wijffels, 2010). However, SSS is controlled by various processes and is forced on all scales by: evaporation and precipitation; continental freshwater input (e.g. Dai and Trenberth, 2002); vertical mixing with subsurface water masses (e.g. Kolodziejczyk et al., 2015a); and horizontal advection of salinity at large to submesoscale (e.g. Reul et al., 2014; Kolodziejczyk et al., 2015b,c; Reverdin et al., 2015). These processes need to be well assessed to accurately monitor the freshwater flux from SSS variability.

Since the 2000's, the international Argo Program provides an unprecedented spatial and seasonal coverage of temperature and salinity in situ measurements (Gould et al., 2006) with more than 3500 active autonomous profiler floats (https//www.coriolis.eu.org) over the global ocean in 2014. The Argo floats provide profiles of temperature and salinity from 2000 m to the surface (~5 m) every 10 days, i.e. on the order of one SSS measurement every 10 days and every 3°x3°. Derived monthly gridded products such as ISAS (Gaillard et al., 2009) provide an objective mapping at spatial resolution of 300-500 km (depending on the sampling). However, this resolution is still too coarse to assess temporal and spatial mesoscale variability over which SSS is known to vary significantly.

SSS at higher spatio-temporal resolution is provided by the Soil Moisture and Ocean Salinity (SMOS) satellite mission (European Space Agency's water mission) since the beginning of 2010 (Mecklenburg et al., 2012). The targeted accuracy for averages over GODAE (Global Ocean Data Assimilation Experiment) scale (100x100 km2) is 0.1 pss. Quality assessment of the SMOS products over 100 x 100 km2 and 10 days revealed an accuracy of 0.3-0.4 pss in the tropical and subtropical regions and of 0.5 pss in the more poleward regions (Boutin et al., 2013; Reul et al., 2013). At mesoscales, the additional information brought by SMOS SSS with respect to other existing in situ networks has been locally demonstrated (Reul et al., 2014; Maes et al., 2014; Hernandez et al., 2014; and Kolodziejczyk et al., 2015b).

Nevertheless, in some regions, SMOS data are strongly affected by Radio Frequency Interferences (RFI) (Oliva et al., 2012), and suffer from large biases up to several hundreds of kilometers from coastlines (Reul et al. 2013; Boutin et al., 2013). There are also seasonal and latitudinal biases likely due to imperfect corrections of geophysical signals such as galactic noise scattered by the sea surface and antenna sun heating (Kainulainen et al., 2012). Latitudinal dependency of the satellite microwave SSS accuracy is mainly due to the change of SMOS brightness temperature sensitivity to salinity with sea surface temperature. The latter reaches a maximum in warm Sea Surface Temperature (SST) waters (0.7 K for a SSS variation of 1 at SST of 30°C) and strongly decreases in cold waters (0.2 K for a SSS variation of 1 at SST of 0°C) (Klein and Swift, 1977).

Two major goals for SMOS SSS have been identified and are tackled in this newsletter: The first one is to reduce the systematic discrepancies between SMOS and in situ SSS which results from various sources (coastal contamination, solar and galactic noise signals imperfect antenna) and which might be systematic at seasonal and large scale. The second goal is to maximize the signal to noise ratio at mesoscale.

Retrieving SSS mesoscale features from SMOS

Reul et al. (2014) and Kolodziejczyk et al., (2015b) have respectively shown the SMOS capability at detecting 2D mesoscale SSS features in the region of Gulf Stream and the Azores Front/Current in the North Atlantic. Here, we further present the results of Kolodziejczyk et al. (2015b) in the region of the eastward Azores Current. This region located at the northern edge of the Subtropical North Atlantic SSS maximum (Fig. 1) presents a meridional front which separates salty and oligotrophic, poor in organic matter like chlorophyll-a, water to the south from fresher and eutrophic water masses to the north **(Fig. 1)**. Furthermore, the Azores frontal current is baroclinicaly instable creating mesoscale frontal eddies and meanders of hundred kilometers scales with propagation velocities of about 2.5 cm.s-1 (Alves and Colin de Verdière, 1999).

The monthly situation of July 2011 is presented **(Fig. 1)**. The Azores front is still identified with a significant gain of details from SMOS SSS over ISAS. It is not identified from satellite SST **(Fig. 1a-d; black and magenta curve),** as a result of the summer heating of the ocean surface. In order to further illustrate the SMOS mesoscale features, the high resolution monthly ocean color data have been considered **(Fig. 1e)**. The meandering front and associated eddies seen on altimetric currents and salinity are consistently seen from the ocean color data. The current advection appears to shape mesoscale features of tracers (SSS, Chlorophyll-a). In particular, west of 30°W, a series of high (low) salinity and low (high) chlorophyll-a signed anticyclonic (cyclonic) eddies are observed **(Fig. 1a,e)**. They characterize the intrusion of surface waters masses at mesoscale from the both part of the Azores front.

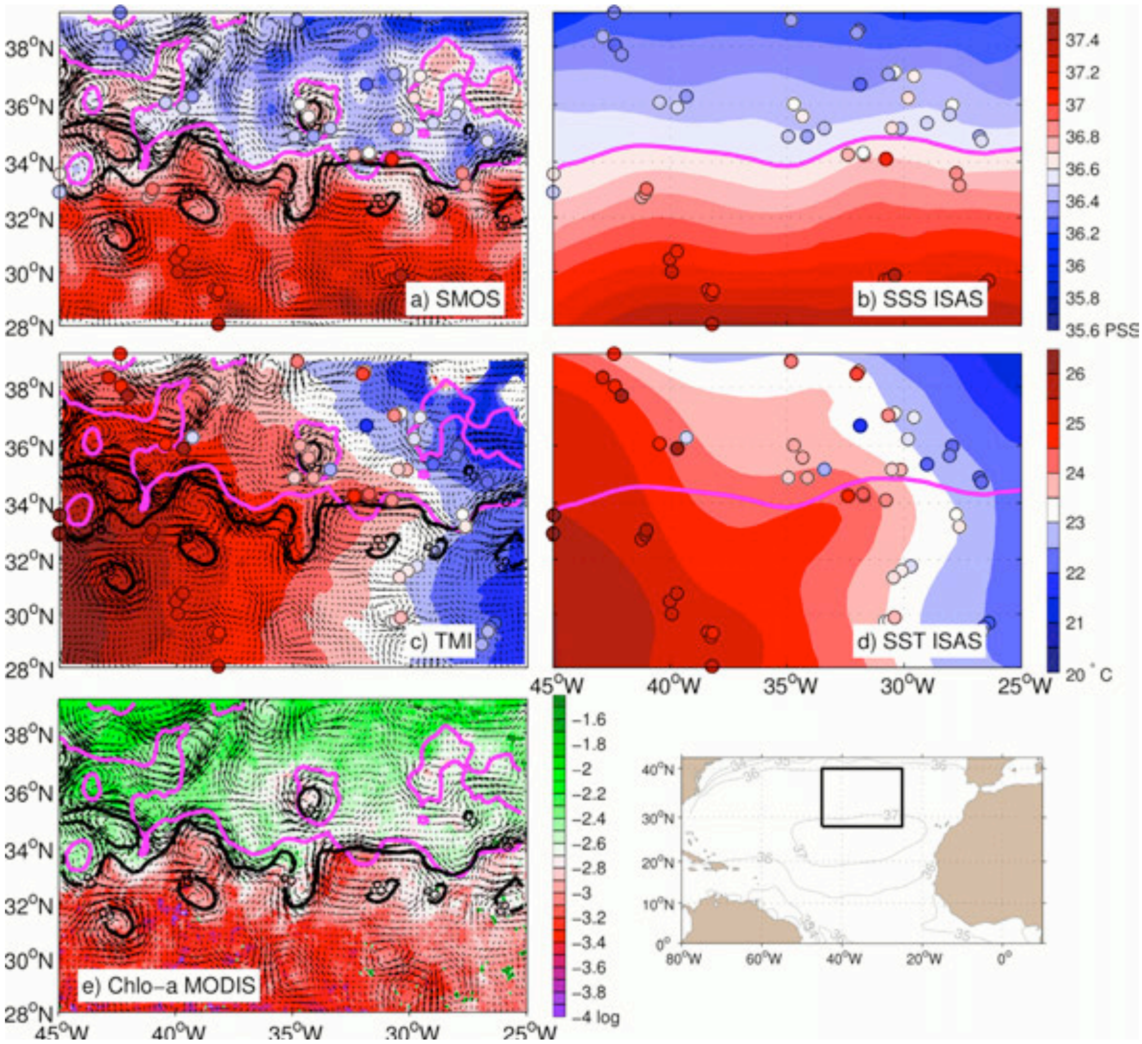

Figure 1: July 2011 monthly mean surface salinity from (a) monthly SMOS L3 and (b) ISAS, surface temperature in °C from (c) TMI and (d) ISAS, (e) MODIS sea surface Chlorophyll-a concentration in log(kg.m-3). Arrows are the monthly mean geostrophic surface velocities from AVISO Ssalto-DUACS product (in m.s^{-1}). The thick black contour corresponding to the 8 10-^{5} s-^{5} vorticity isoline identifies the Azores Front/Current (vort = f+ξ; where f is the planetary vorticity and ξ is the relative vorticity computed as ξ=∂v/∂x-∂u/∂y). The thick magenta (blue) contours corresponding to the 36.6 isohaline (19 °C isotherm) identify the thermohaline front associated with the Azores front. Colored circles are at the Argo float position and the corresponding near-surface (~5 m depth) salinity and temperature values . The figures correspond to the black square region on the lower corner map (after Kolodziejczyk et al., 2015b)

The mesoscale resolution of SMOS SSS data helps interpreting individual Argo measurements (see for instance Argo SSS within an anticyclonic eddy around 36°N-35°W) **(Fig. 1a)**. From Argo measurements, this eddy is suggested by two slightly saltier SSS measurements surrounded by fresher ones (Fig. 1b). This eddy probably detached from the Azores Current front, as suggested by its positive relative vorticity signature, higher salinity and higher chlorophyll-a than the surrounding environment **(Fig. 1e)**. On the other hand, during boreal summer the surface heating of the upper ocean totally masks the frontal and eddy signatures in SST fields. This feature is of course not resolved by the smoothed interpolated ISAS Argo product.

Although the SSS monthly mesoscale features seen by SMOS qualitatively compare well with *in situ* and ancillary satellite data sources, the quantitative agreements are often poor. For example, the previously documented AC is about 0.1-0.2 pss saltier than the in situ measurement (Fig. 1a). In spite of the different nature of in situ (instantaneous at ~5 m depth) and satellite measurements (averaged over 100km, one month? and in the top centimeter) which may introduce discrepancies sensitive to upper stratification and intermittent precipitations, Hernandez et al. (2014), have shown in the Subtropical North Atlantic that SMOS measurement are subject to strong seasonal and large scale biases up to as large as 0.5 pss during winter months. Furthermore, SMOS SSS individual retrievals at 43 km resolution present small signal over noise ratio (much smaller than 1) which can be minimized only by spatial and temporal averages. Thus, the accuracy of 0.15 pss could only be obtained on SMOS SSS retrieved with ESA version 5 processing at the price of a 100x100 km^2 spatial filtering and monthly averaging far from coastal regions where biases are dramatically large (±1.5 pss) (Hernandez et al., 2014).

SMOS mapping using Argo data

We have chosen a statistical approach to tackle these issues taking advantage of the 4 years of available SMOS data. The SMOS SSS data from ESA L2 version 5 processing has been preliminarily processed following three main steps: i) Estimation and removal of systematic bias near the coast and from some RFI sources. ii) Estimation and removal of large scale and seasonal biases. iii) Smoothing and mapping of corrected SMOS data at mesoscale. The first step uses a statistical approach to estimate climatological SMOS SSS bias based on an internal consistency check between SMOS SSS measured at various locations within the SMOS swath and an absolute bias correction taken from a 4 year mean of Argo climatology (ISAS), while both the second an third steps use optimal mapping methods, with monthly ISAS products as first guess. As done in Hernandez et al. (2014) and Kolodziejczyk et al. (2015b) independent thermosalinograph (TSG) data from ships of opportunity – not included in the ISAS analysis – are used to validate and assess the L2 SMOS SSS corrections.

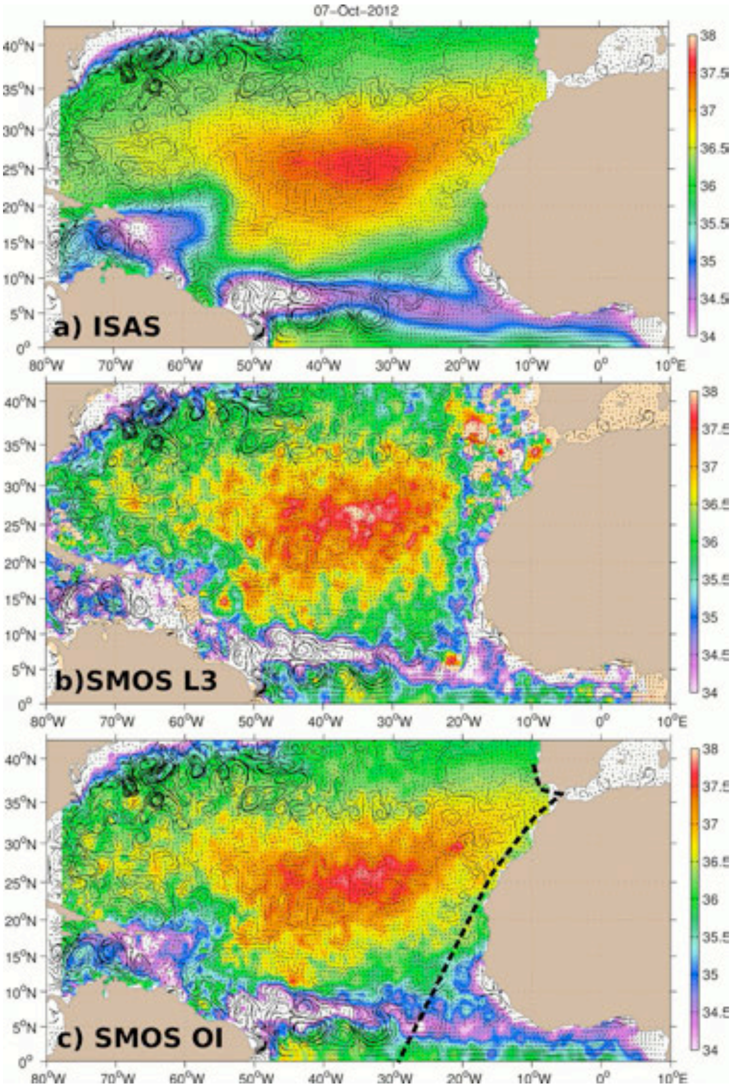

Figure 2: a) Monthly ISAS SSS interpolated on 7 October 2012. b) 10 days L3 SMOS SSS from CEC-LOCEAN over the period 1-10 October 2012. c) Weekly SMOS OI SSS over the period 4-10 October 2012 (in pss) and M.S. 'Santa-Cruz' route between 8-15 October 2012 (dashed black). Corresponding weekly AVISO surface currents are overlaid (in m.s-¹).

• Systematic bias corrections (coastal bias and some RFIs)

As shown between 1-11 October 2012 **(Fig. 2)**, large discrepancies are observed in the coastal regions between 10 days L3 CATDS CEC-LOCEAN gridded products (100x100km^2; **Fig. 2b**) and monthly ISAS climatology **(Fig. 2a)**. They can exhibit amplitudes larger than ±1.5 pss and produce large scale salinity artifacts up to several hundred kilometers (>800 km) from the coasts (Reul et al. 2014; Boutin et al., 2013) which are especially well defined along the Western African coast.

The coastal biases has been shown on brightness temperatures to come from a shadowing of the continent (Reul et al. 2012; Boutin et al., 2013; polarimetry validation report available on http://smosp.acri.fr/docs/vr.pdf; section 3.2.2). SSS is retrieved from about 100 brightness temperatures measured in various parts of the SMOS field of view at various incidence angles so that the contamination by the land on these Tbs depend on the orientation of the cost line and on the emissivity of land. Hence, in our method we estimate a contamination in SSS for each pixel as a function of the location within the swath. The 4 years of SMOS data and Argo climatology (mid-2010-mid-2014) have allowed characterizing systematic near coastal discrepancies. The bias correction is eventually applied at each individual L2 SMOS SSS retrieval.

• Large scale and seasonal orbit biases corrections

In the Subtropical North Atlantic, Hernandez et al., (2014) have applied a raw seasonal correction for the large scale biases. They estimate the biases for each month by comparing the monthly ISAS products and SMOS products averaged in their study area, i.e. they basically use in situ measurements to adjust the mean SMOS measurement over the Subtropical North Atlantic SSS maximum.

As a preliminary noise reduction, we first selected a low pass filtered (2 pixels half window running mean) along dwell lines the L2 SMOS SSS data over a 10 day period for both ascending and descending orbits. Then, ascending and descending orbit data are first mapped separately with an optimal interpolation scheme at large scale (500 km) with a Gaussian shaped correlation function. The seasonal and large scale biases are deduced from the comparison of ascending and descending large scale maps and monthly ISAS SSS product. Then, these estimated seasonal and large scale biases are removed from the L2 SMOS data set. This approach is analog to Reynolds (1988), who used available in situ data measurements to correct large scale retrieved SST from infrared radiometer satellite daytime and nighttime measurements which had been contaminated by the volcanic aerosols from Mont Pinatubo eruption during the 1991-92 years.

• Reduction of noise and optimal mapping

The last step is a noise reduction and mapping every 7 days using optimal interpolation with a Gaussian correlation function scaled to 75 km over a window of 10 days of L2 SMOS SSS data centered on the day of mapping, using the corresponding monthly ISAS SSS fields as first guess. Remaining biases between different dwell lines of different orbits have been corrected (for more details see Le Traon et al., 1998). At mesoscale, it is hypothesized that SSS features are also strongly constrained by mesoscale current advection. Therefore, an additional correlation scale is included in Gaussian correlation function involving a larger correlation along-stream-lines computed from AVISO Ssalto-DUACS altimetric products (Nardelli, 2012). This improved mapping method allows recovering spatial scales slightly smaller than 75 km and improves the geometry of the synoptic features **(Fig. 2c)**. Figure 2c shows preliminary results for the weekly SMOS OI field compared with the L3 SMOS CEC-LOCEAN products between 4-10 October 2012. As hoped for, the coastal and large scale biases appear to be absent. This is confirmed by direct comparison along independent TSG SSS transects which exhibit a much improved agreement especially along the coast and in the tropical region of Inter-Tropical Convergence Zone where strong SSS meridional gradients are present **(Fig. 3)**.

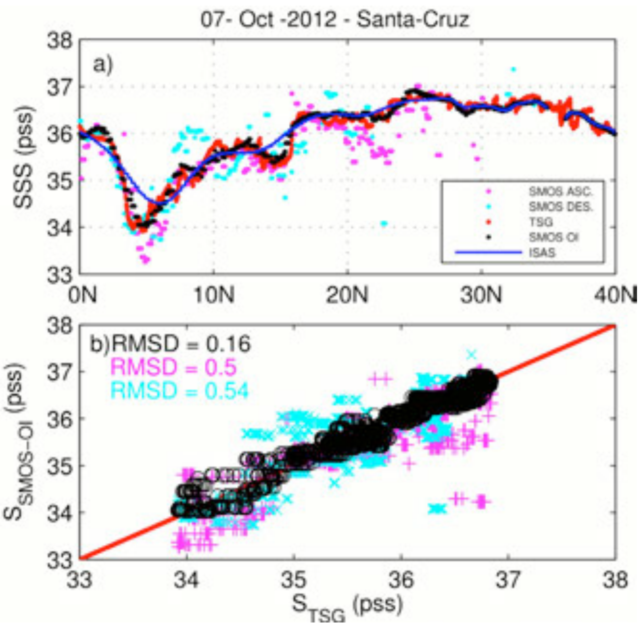

Figure 3: a) SSS colocated along M.S. 'Santa-Cruz' route (see Fig. 2c) from thermosalinograph (red), ascending (magenta) and descending (cyan) SMOS orbits corrected from coastal bias, SMOS OI SSS (black) and monthly ISAS climatology (blue). b) Comparison between TSG SSS and SMOS SSS. The color code is the same as in Fig. 3a.

Preliminary comparisons with independent TSG data – not included in ISAS product - provide an estimate of the improvement in biases, RMSD (Root Mean Square Difference) and correlation between 10 day L3 LOCEAN products and SMOS OI **(Fig. 2 and 4)**. This mapping procedure strongly reduces the biases (<0.2 pss; Fig. 4b) of weekly SSS fields. The RMSD from TSG measurements is on the average improved from 0.53 pss to 0.38 pss over the whole set of valid TSG transects (Fig. 4b). Note that, in regions of low SSS variance (far from the rivers run off), such as in the SSS maximum region, the RMSD is less than 0.2 pss (not shown). In the ITCZ area (0-15°N), the SSS gradients are also well reproduced with RMSE on the order of 0.2 pss **(Fig. 3 and 4b)**. This is better than previously expected from 10 days L3 SMOS SSS retrievals **(Fig. 4b)**. Along the TSG sections, the TSG-SMOS OI correlation is also improved **(Fig. 4d)**. This has been possible only because mesoscale features are resolved in SMOS SSS data (Reul et al., 2014; Hernandez et al., 2014; Kolodziejczyk et al., 2015b), but is strongly improved by bias corrections and noise filtering. It is however worth commenting that bias corrections and mapping methods perform better in region where raw L2 SMOS SSS data are less affected by noise and bias contaminations. Many artifacts and unexplained contaminations are left that deserve further work.

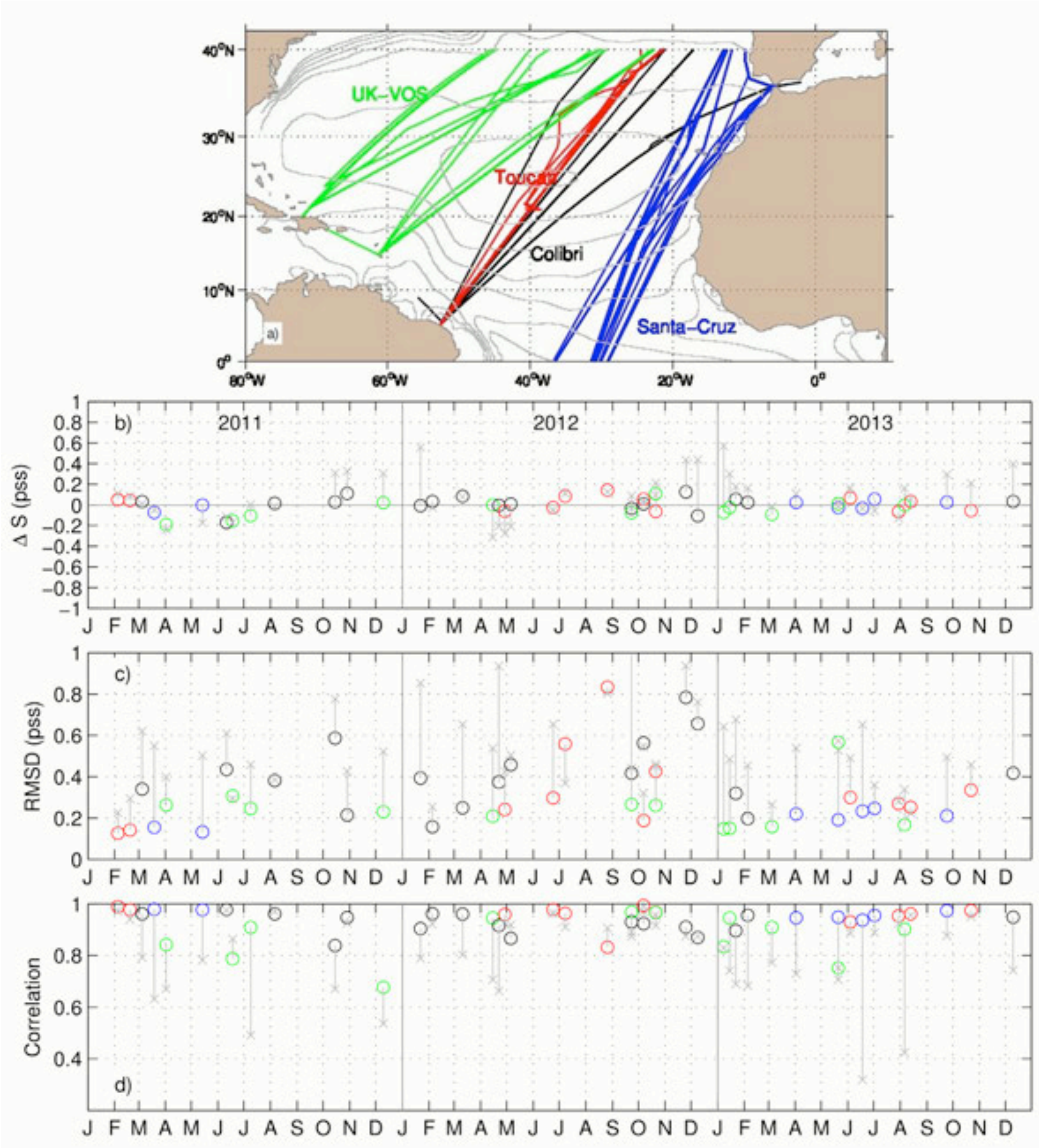

Figure 4: In situ and SMOS SSS comparison (0.25°-10 day) statistics along the available TSG transects between 2011-2013 (a): Bias (b); Root Mean Square Difference (c); and correlation (d) for 10 days L3 SMOS LOCEAN products (gray crosses) and SMOS OI (circle). Differences between SMOS L3 and SMOS OI is identified by a gray vertical segment. The color of the circle refers to the merchant ship (Black: M.S. Colibri; red: M.S. Toucan, blue: M.S. Santa-Cruz; green: UK VOS)

Conclusion

This preliminary work shows a very high complementarity between SMOS and Argo data. SMOS SSS measurements provide for the first time mesoscale resolution maps with an unprecedented coverage in regions poorly sampled by Argo array. Argo provides high quality data at large scales which greatly helps L2 SMOS SSS calibration. Ongoing work is to better quantify the accuracy of the new SSS products and improve the mapping methods. While the present work focuses on a bias correction method applied onto retrieved SSS, it is worth noticing that these biases originate from systematic biases on Tbs. In parallel to these efforts in correcting SSS biases, the reduction of biases at Tb level is under study by other SMOS teams.

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FRENCH PIRATA CRUISES S-ADCP DATA PROCESSING

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Abstract

In the framework of the PIRATA program, several types of observations are carried out in the Tropical Atlantic during yearly cruises, including Shipboard Acoustic Doppler Current Profilers (SADCP) data. The present note is a brief review of the SADCP data processing methodology applied for 8 PIRATA cruises by using CASCADE software. To illustrate the processing steps and demonstrate the CASCADE software capabilities, an example of SADCP data processing obtained from PIRATA-FR24 cruise has been shown. This data set is made available on the PIRATA website and will also be used in the framework of the EU PREFACE program (see http://preface.b.uib.no/).

Introduction

The PIRATA (Prediction and Research Moored Array in the Tropical Atlantic) observing network is a contribution to the GOOS (Global Ocean Observing System), GCOS (Global Climate Observing System), and the GEOSS (Global Earth Observing System of Systems), endorsed by the international program CLIVAR (CLImate VARiability and predictability). Launched in 1997 thanks to a multinational cooperation between France (IRD and Météo-France), Brazil (INPE) and USA (NOAA), PIRATA mostly maintains 18 meteo-oceanographic buoys (ATLAS system; see www.pmel.noaa.gov/tao/ for detail) by carrying out yearly cruises for their servicing (Bourlès et al., 2008). In France, PIRATA is recognized as a National Observatory ("Service National d'Observation"), and yearly cruises also allow, in addition to ATLAS buoys servicing, to carry out different opportunity operations (e.g. ARGO autonomous profilers deployments) and to get several types of observations along repeated track lines, including oceanic currents from Ship mounted Acoustic Doppler Current Profiler (SADCP; see http://www.brest.ird.fr/pirata/index_fr.php). After a brief reminder of ADCP principle and a description of main characteristics of SADCP instrument onboard different research vessels used for PIRATA cruises, we present the SADCP data processing that has been applied for 8 PIRATA cruises carried out from 2007 to 2014, by using the CASCADE (Chaîne Automatisée de Suivi des Courantomètres Acoustiques Doppler Embarqués) software (Le Bot et al., 2011). An example of SADCP data processing obtained from one PIRATA cruise is also shown.

Shipboard Acoustic Doppler Current Profilers (SADCP)

2.1 Principle

We recall here the principle of the ADCP measurements, in order to better understand the data processing steps detailed afterwards.
ADCP estimates horizontal and vertical velocity of flowing water with sound, using the principle of Doppler Effect. It does so by emitting « pings» of acoustic signal at a known and constant frequency into the water. The acoustic pulses ricochet off small particles suspended in the moving water (plankton, sediments, or other solid particles) and reflect back to the transducer with a slightly changed frequency. The ADCP uses the Doppler frequency shift of this backscattered signal measured by the transducer to measure the fluid velocity along the beam path. For measuring the three velocity components of the current, ADCP usually uses four beams inclined from the vertical plane at an angle θ (called 'beam angle') and pointing in different directions. In this configuration, ADCP estimates horizontal and vertical velocities and also an error used to qualify the data. The determination of the Doppler frequency is made by considering the ensemble of signal in time windows, which define cells or 'bins'. The accuracy of the measure, the vertical resolution and the acoustic noise, depends on the ADCP's type (Broadband or Narrowband) and on the frequency of the SADCP instrument (typically: 38, 75, 150, 300, 600 or 1200 kHz). Low frequency systems provide long range and low resolution measurements, while high frequency systems have shorter ranges with much higher resolution.

2.2 ADCP onboard PIRATA research vessels

Table 1 below presents the summary of the 8 cruises carried out from 2007 to 2014 in the framework of the PIRATA program, and the frequency of ship-mounted SADCP instrument used for each cruise. For the 4 first cruises onboard the R/V L'Antéa, an Ocean Surveyor 75 kHz system was used while it was a broad-band 150 kHz system for the 4 last cruises onboard the R/V Le Suroit. The 75 kHz ADCP are suited for a range about twice as deep as the 150 kHz (about 600 meters in broad-band mode). The standard deviation of velocity data obtained using broad-band ADCPs are significantly lower than that for narrow-band ADCPs, but the range is shallower. For all these PIRATA cruises, the vertical profiling resolution was nominally 8 m (= bin size) for the 150 and 75 kHz ADCPs. For additional background and references on the oceanographic application of shipboard ADCPs, see e.g. Firing and Hummon (2010).

Greenland	Month	Year	Latitudinal Range	Research Vessel	SADCP (KHz)
PIRATA-FR16	5 - 6	2007	0° - 15°N	L'Antéa	OS75
PIRATA-FR17	6 - 7	2007	10°S - 5°N	L'Antéa	OS75
PIRATA-FR18	9 - 10	2008	10°S - 15°N	L'Antéa	OS75
PIRATA-FR20	9 - 10	2010	10°S - 15°N	L'Antéa	OS75
PIRATA-FR21	5 - 6	2011	10°S - 15°N	Le Suroit	BB150
PIRATA-FR22	3 - 5	2012	10°S - 15°N	Le Suroit	BB150
PIRATA-FR23	5 - 6	2013	10°S - 15°N	Le Suroit	BB150
PIRATA-FR24	4 - 5	2014	10°S - 15°N	Le Suroit	BB150

Table1: Summary of the 2007-2014 PIRATA oceanographic cruises and frequency used by SADCP for each cruise

To estimate the absolute current velocity in earth coordinates, one needs to remove the ship movement using the best navigation data available (position, speed, tilt, heading). This information is provided by specific instruments that depend upon the ship. During the PIRATA cruises addressed here, the ship's position, pitch, roll and heading onboard the R/V Le Suroit are measured by an inertial navigation system based on fiber-optic gyroscope technology which integrated GPS information, whereas they are provided by an optical gyrocompass and motion sensor parted from a high precision GPS system onboard the R/V L'Antéa. The transformation from beam ADCP to earth coordinates is performed using the Vessel-Mounted Data Acquisition System (VmDAS). VmDAS is the constructor's software (RDI's software) used for RDI ADCP acquisition. It generates files containing averages mono-ping ADCP data and best navigation data available. The ADCP velocities recorded are relative to the ship, in earth coordinates and averaged in time: FILE.STA files for 'Short Term Average' with 2 minutes averages and FILE.LTA files for 'Long Term Average' with 10 minutes averages, for instance. These files are then processed and analyzed by the Matlab CASCADE software ("Chaîne Automatisée de Suivi des Courantomètres Acoustiques Doppler Embarqués"). The following section presents the CASCADE software and gives a brief review of the basic post-cruise processing steps realized after the cruise.

Processing and quality checks of SADCP data

The data processing software: CASCADE

CASCADE is a Matlab software developed by the Laboratory of Physical Oceanography (Le Bot et al., 2011) in order to process Vessel-mounted ADCP data collected along vessel transects. The programs have been specifically tested for Windows and Linux and can be downloaded from: http://wwz.ifremer.fr/lpo/Le-Laboratoire/Actualites/CASCADE-V6.2. It is used in different research organisms and has been implemented in operational mode by the data center SISMER ("Systèmes d'Informations Scientifiques pour la MER") at IFREMER. Regular updates of the software are made in order to take into account the users feedbacks and the suggestions of improvements.

The CASCADE inputs files are the binary FILE.STA/FILE.LTA files obtained from the acquisition software VmDAS. In our case, we used the version 6.2 of CASCADE to analyze and process the SADCP data collected during 8 PIRATA cruises carried out between 2007 and 2014 in the eastern tropical Atlantic **(see table 1)**. In the following section, we describe briefly the main processing steps of CASCADE software.

Overview of ADCP data cleaning stages in CASCADE

Complete cleaning of ADCP data requires several steps. CASCADE first converts the FILE.STA/FILE.LTA files generated by VmDAS software into a single NetCDF file containing all the information but also the absolute current velocities in earth coordinates calculated from the relative and ship velocities. From this NetCDF file, the user can add important external ancillary data (like estimations of bathymetry and barotropic tide for example), flag the velocity data according to adjustable parameters, estimate and apply rotations of the ADCP coordinate system to realign it with the ship system, and, finally, smooth the data in time and/or depth. At the end of the cleaning stage, the three components of the absolute current velocity (U, V, W) are flagged 1 (good), 2 (dubious) or 3 to 9 (bad). The cleaning and correction are an iterative process. Automatic and visual quality checks of the data help the user to choose the best cleaning parameters and the best ADCP correction (misalignment/amplitude) if needed. It is also possible to flag suspect data manually between two dates or two ensembles. When the current data are supposed to be the best, the user can create section and/or station files. These files contain the absolute current velocities re-averaged in space (for the section file) or time (for the station file). From these averaged section/station files, user can plot the absolute velocities as vectors or contouring plots.

Example of processed SADCP data obtained from PIRATA-FR24 cruise.

In this section, an example of PIRATA SADCP data processed with CASCADE software is presented, i.e. the data collected during the leg1 of the PIRATA-FR24 cruise from April 9 to May 22, 2014 aboard the R/V Le Suroit from Dakar (Senegal) to Abidjan (Ivory Coast) **(figure 1)**. The velocity and direction of the currents were measured along the route by a BB150 SADCP **(table 1)**, able to investigate the current field down to nearly 250 m. For this cruise, data were acquired with a blanking interval of 4m and vertical bin size of 8m and were preliminary processed onboard with the VmDAS software. Only the data processed after the cruise by CASCADE software (version 6.2) from VmDAS FILE.STA files (pings averaged in two minutes ensembles) are presented.

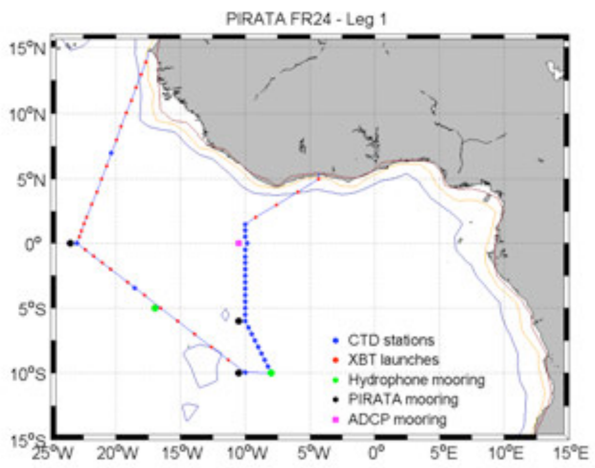

Figure 1: Track of the leg1 of PIRATA-FR24 cruise.

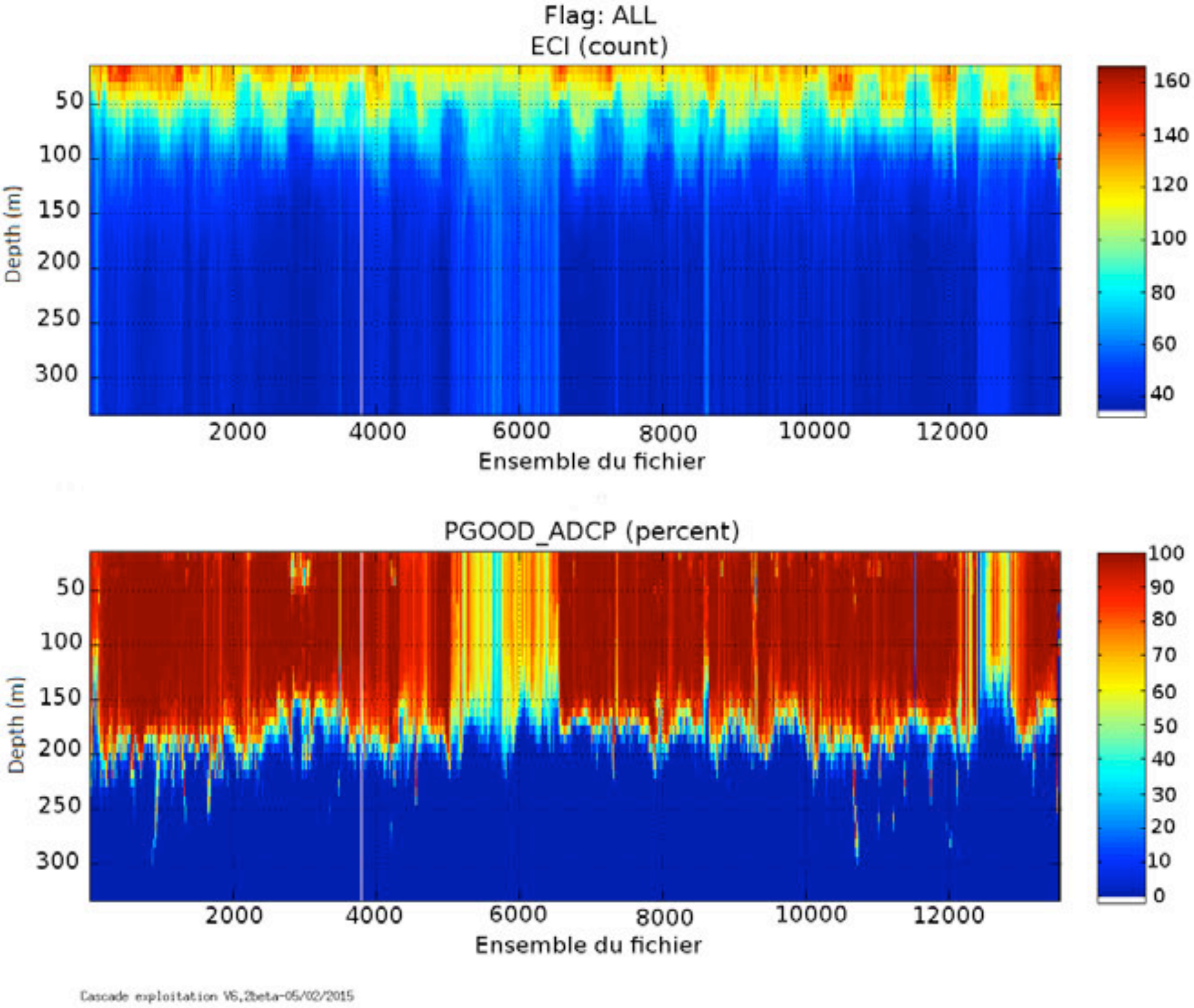

Figure 2: Mean Echo Intensity (upper plot) and percentage of good data (lower plot).

Some controls about the quality of the data can be made before the processing. The Percent Good variable plotted on figure 2 represents the percentage of pings using the four beams for each two-minute average ensemble. Data are considered as acceptable data when the percentage is > 10 %. The percentage of good data is highest for the bins near the surface and rapidly falls below 50 % at some depth. This feature is the basic profile usually observed and indicates that the ADCP data quality for this cruise is rather good. Nevertheless, a decrease of the percentage of good data happens locally for shallow cells (around the ensembles 6000 and 12500), associated to a low echo intensity, indicating that the signal-to-noise for these water cells is also low, maybe due to the presence of passive backscatters. The CASCADE cleaning data step gives the following result:

Flag	Meaning	Percent on the whole ensembles
1	Good data	55.86 %
2	Doubtful data	0.89 %
3	Bad data: median filter over 20 ensembles beyond 3 standard deviations.	0 %
4	Vertical shear > 0.2 s^{-1}	0 %
5	Vertical current speed > 100 cm/s PGOOD_ADCP < 10%	0 %
6	Horizontal current speed component > 4 m/s	0 %
7	Missing data	43.25 %
8	Data under the bottom (bottom ping)	0 %
9	Manual invalidation between 2 ensembles	0 %

Table 2: Flags attributed to the PIRATA-FR24 SADCP data (leg1 only) using CASCADE software.

The data are also corrected from barotropic tide (using the model TPX0 7.2 (Egbert and Erofeeva, 2002)) and horizontally and vertically smoothed. To detect misalignments or navigation errors, it is possible to plot comparison of absolute current velocities averaged on the reference layer, “en route” versus “in stations” (not shown). A misalignment can also be identified when a correlation of the amplitude and direction of the ship velocity with those of the absolute current velocity is noticed **(figure 3)**. For this part of the cruise neither misalignment nor navigation errors have been detected.

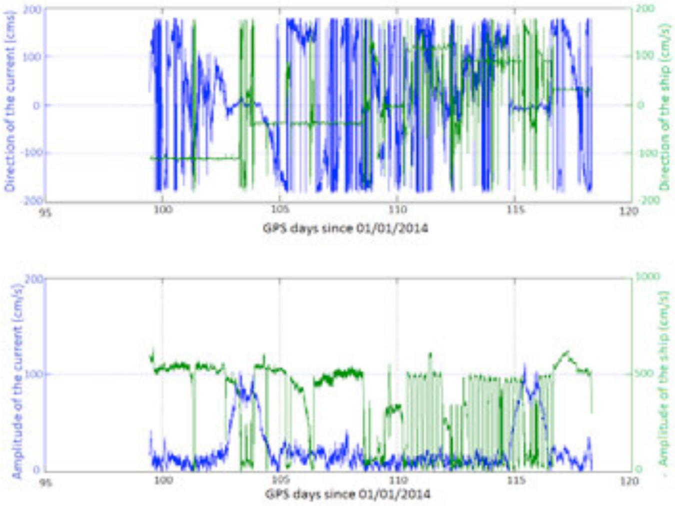

Figure 3: Upper panel: direction of ship (green line) and direction of the current estimated from ADCP (blue line) ; lower panel: amplitude of the ship (green line) and amplitude of the current estimated from ADCP (blue line).

For each strait or segment of interest, an average section of the velocity is calculated. For this cruise four 5km average-sections are defined from 2-minutes average files **(see figure 4)**. Figure 5 shows the vector plots of the 2 minutes horizontal velocities obtained from 18 m to 98 m depth (left) and from 98 m to 202 m depth (right) averaged every 5 km along the sections 1-4 of the ship track. Only the data affected to the flag 1 are used.

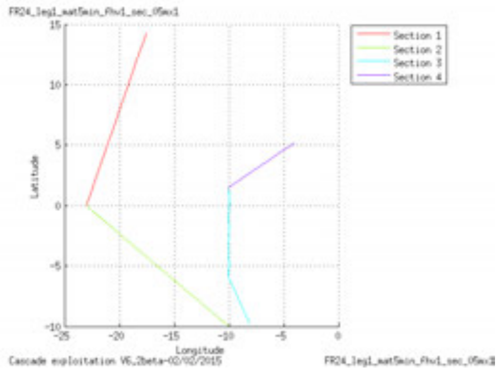

Figure 4: Sections along the leg1 of PIRATA-FR24 track.

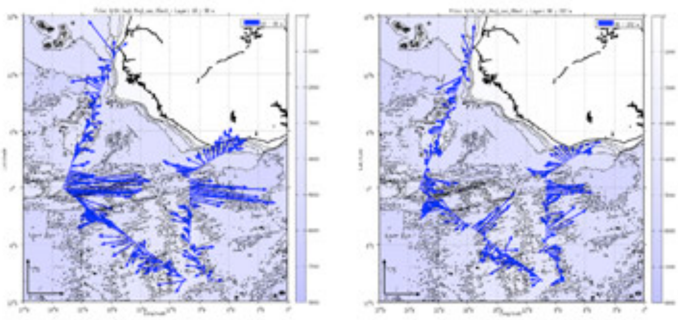

Figure 5: Vector plots of the 5km averaged horizontal current along the leg1 of PIRATA-FR24 cruise’s track averaged from 18 to 98 meters depth (left) and from 98 to 202 meters depth (right) superimposed on the bathymetry of the area. The arrows are displayed every 5 data points.

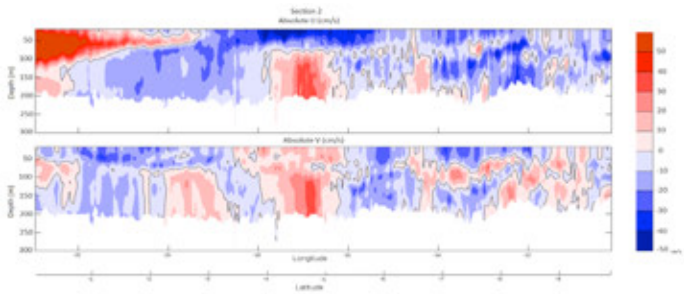

Figure 6: Vertical distribution of zonal and meridional current (in cm/s) function of longitude along section 2 from April 21 2014 to April 27 2014 during the leg1 of the PIRATA-FR24 cruise.

Several interesting features of the flow field can be observed in this presentation of the data: an eastward current is well visible on the 18-98 m average plot (figure 5, left) in the range 2°S – 2°N. It corresponds to the Equatorial Under-Current (EUC), a quasi-permanent feature of the zonal equatorial circulation in both the Atlantic and Pacific oceans (see e.g. Philander, 1973 ; Wyrtki and Kilonsky, 1984). The EUC is strongly attenuated bellow 100m depth (figure 5, right), as already shown in recent studies dedicated to the EUC and using some PIRATA ADCP measurements (e.g. Arhan et al., 2006; Kolodziejczyk et al., 2009, 2014). CASCADE software gives also the possibility to plot vertical distribution of velocities along each section, as illustrated by figure 6 that shows these distributions along the section 2. We can see that the EUC exhibits a core depth between 25 and 100m between 23°W and 22°W, with maximum core speeds in the range of 50-60 cm/s. Around 17°W below 100m depth is the subsurface SEUC (South Equatorial Under Current) (see e.g. Schott et al., 1998). Above it, we can observe the westward surface-intensified flow of the cSEC (central South Equatorial Current).

Data archiving and data access

The set of SADCP processed data from these 8 PIRATA oceanographic cruises are made available on the ftp website: ftp://ftp.ifremer.fr/ifremer/ird/pirata/pirata-data/ . For each cruise, different files are available:

- NetCDF data files - Raw data and processed data (date/time, latitude, longitude, depth, horizontal and vertical absolute current, navigation data...).
- UNIX tar files containing figures (section map, images and vector plots of the sections).
- Report which contains information about data collection, quality checks, processing procedures applied to data and problems encountered with the data.

The files are also archived and directly downloadable on the SISMER portal (under Data access http://www.ifremer.fr/sismer/index_UK.htm)

Conclusion

During each yearly oceanographic PIRATA cruise, current measurements are carried out in the Tropical Atlantic (from 0 to 700 m max). These current-meter measurements made using ADCP require relatively complex processing and checking, taking into account navigational parameters and ship's attitude. In this note, a brief review of processing methodology by using the CASCADE software applied to SADCP data obtained from the 8 2007-2014 PIRATA cruises has been made. Thus, CASCADE allows computing the ancillary data (such tide and bathymetry), flags, re-computing data for a given misalignment and/or amplitude, smoothing the data according to time or/and depth, defining sections or stations with a spatial or temporal sampling and providing graphical display of the data. The processing steps realized by CASCADE software have become increasingly automated, nevertheless they do not replace a scientific analysis and human judgment that is still required for the final product. To illustrate the processing steps and demonstrate the CASCADE software capabilities, an example of SADCP data processing obtained from PIRATA-FR24 cruise in April-May 2014 has been shown. Once processed, the SADCP data are available for the scientific community as soon as possible via internet. PIRATA data sets have already allowed numerous studies carried out by several French laboratories, focusing on the oceanic processes and data assimilation technique, especially in the frame of the operational MERCATOR global Ocean forecasting system.

Aknowledgements

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TPOS2020: TROPICAL PACIFIC OBSERVING SYSTEM FOR 2020

After the partial collapse of the TAO/TRITON array, building a renewed, integrated, internationally-coordinated and sustainable observing system in the Tropical Pacific, meeting both the needs of climate research and operational forecasting systems.

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Abstract

This paper presents the new international TPOS2020 project: why it has been established, what are its scientific objectives, its proposed organization, governance, and what the expected outcomes are. It is aiming at informing Coriolis, Mercator Océan, and the operational oceanography communities, all concerned, and involved in generating interest and contributions to the project. Building upon its scientific activities in the Pacific and the surrounding countries, the French community is willing to take an active role in this international project.

The TPOS 2020 Project is a focused, finite term project, which began in 2014 and will be completed in 2020. It will evaluate, and where necessary provide guidance, to change all elements that contribute to the Tropical Pacific Observing System (TPOS) based on a modern understanding of tropical Pacific science. Learning lessons from the great success-and finally partial collapse- of the TAO/TRITON array, the project objective is to build a renewed, integrated, internationally-coordinated and sustainable observing system in the Tropical Pacific, meeting both the needs of climate research and operational forecasting systems.

The scientific objectives are:

- To redesign and refine the TPOS to observe El Niño Southern Oscillation (ENSO) and advance scientific understanding of its causes,
- To determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services,
- To advance understanding of tropical Pacific physical and biogeochemical variability and predictability.

TPOS2020 is coordinated by a steering committee with task teams and working groups working on specific aspects of the observing system. Since much of the use and benefit of TPOS data will be achieved through model assimilation and syntheses, the operational modeling centers are considered key partners. The TPOS2020 project also opens partnerships with other global ocean observing communities: the meteorological community, and the coastal and regional ocean communities.

TPOS 2020 embraces the integration of complementary sampling technologies; it will consider the different observing system components as an integrated whole, targeting robustness and sustainability, along with a developed governance and coordination.

Historical background

Establishment of the Tropical Pacific observing system, 1985-1994

The tropical Pacific is home for the ENSO cycle, the dominant interannual climate signal on Earth. ENSO is an oscillation of the ocean-atmosphere coupled system between anomalous warm (El Niño) and anomalous cold (La Niña) conditions in the central-eastern equatorial Pacific. It impacts the weather anomalies, the frequency and intensity of tropical cyclones, the marine and terrestrial ecosystems and the fisheries. Through atmospheric teleconnections, its environmental and socio-economic impacts are felt worldwide, and the importance of its prediction is of prime importance to many countries around the world (Harrison et al., 2014).

The El Niño event of 1982-83, neither predicted nor detected, highlighted the need for real-time data, to help prediction, detection and understanding of the phenomenon. It was the impetus for the establishment of the international Tropical Ocean/Global Atmosphere (TOGA) program, and the original development of the Tropical Pacific observing system. One of the major achievements of TOGA (1985-1994) was the development of the Tropical Atmosphere/Ocean (TAO) array, the backbone of the observing system, consisting of 70 moorings in the equatorial band transmitting oceanic and atmospheric data in real time (McPhaden et al., 1998). This array, developed with support mainly from the United States, France, and Taiwan, took a decade to built **(Figure 1)**. In the 80s-90s, France (IRD) took an active part in the array design, deployment and maintenance. The french team in New Caledonia was at the forefront of designing and supporting the TPOS, and conducted cruises along the 165°E meridian (Delcroix and Eldin, 1995). In 2000, the TAO array officially became the TAO/TRITON array, with sites west of 165°E occupied by Triangle Trans-Ocean Buoy Network (TRITON) buoys maintained by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and moorings east of 165°E maintained by the US National Oceanic and Atmospheric Administration (NOAA), with a dedicated ship, the Ka'imimoana.

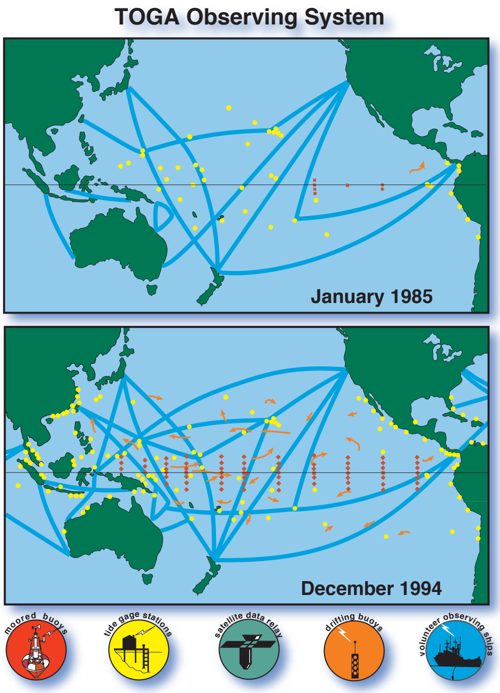


Figure 1: From McPhaden et al., (1998). The in situ Tropical Pacific Ocean Observing System developed under the auspices of the TOGA program. (top) The observing system in January 1985 at the start of TOGA; (bottom) the observing system in December 1994 at the end of TOGA. The four major elements of this observing system are (1) a volunteer observing ship expendable bathythermograph program (shown by schematic ship tracks); (2) an island and coastal tide gauge network (circles); (3) a drifting buoy program (shown schematically by curved arrows); and (4) a moored buoy program consisting of wind and thermistor chain moorings (shown by diamonds) and current meter moorings (shown by squares). By December 1994 most measurements made as part of this four-element observing system were being reported in real time.

Great success of the observing system 1994-2012

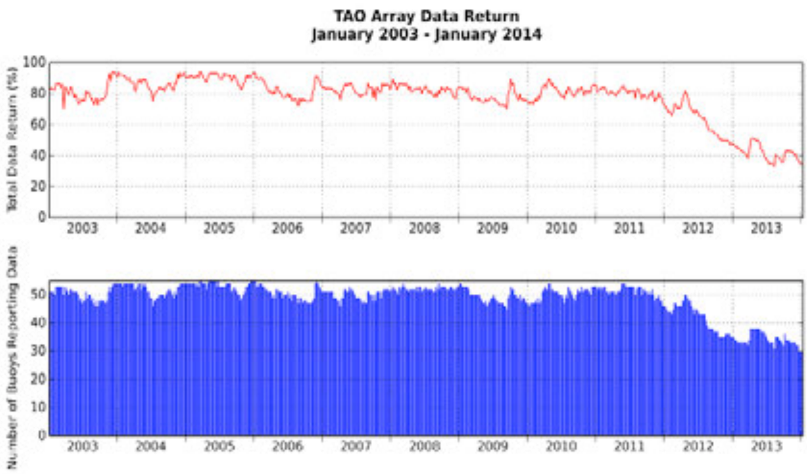
When it was first established, the primary rationale for the observational system was to improve description, understanding and prediction of seasonal to interannual variability in the tropical Pacific. In fact, the TAO/TRITON array's value, complemented by other sources of data, extended well beyond seasonal forecasting. Tremendous progress has been made on our understanding of the Tropical Pacific since the beginning of the TOGA program, even if many unknowns still remain. Oceanic and atmospheric data collected were used for a broad range of applications and process studies, and lead to the discovery and improved description of many processes important for the coupled system, but also for chemical and biogeochemical oceanography, studies of aerosols or meteorological phenomena, among others.

This observing system still continues to support routine forecasting systems and research. It also benefits to operational oceanography and ocean forecasting centers. In the past years, this community has been conducting various Observing System Experiments (OSE's) in order to measure the impact of its different components, TAO/TRITON being part of this assessment (Mercator Océan has carried out one specific OSE's, Rémy, pers. comm. 2015) (see also Lea et al., 2014, Fujii et al., 2015). Corresponding networks were developed in the tropical Atlantic (PIRATA) and Indian Oceans (RAMA) during and after TOGA, contributing to seasonal forecasts and to improved knowledge of climate variability in these regions.

Partial collapse of the TAO/TRITON array, 2012

20 years after the end of TOGA, sustaining a TPOS is proving challenging, in particular the TAO/TRITON array of moored buoys. In 2012, the retirement of the Ka'imimoana (not replaced, due to US budget cuts) led to a major reduction in data returns for the TAO part of the array. Since then, the TAO array has partially collapsed (Figure 2a) and data return dropped to around 40% in 2013, obscuring a large part of ENSO-related measurements. JAMSTEC has also begun to withdraw some of its TRITON moorings. These withdrawals interrupted times series of more than 30 years. Long time series are needed to understand decadal variability-which is large in the Pacific-, such as the Pacific Decadal Oscillation (PDO), climate change and how they interact with ENSO.

This partial collapse also highlighted the vulnerability of this observational array that underlies the capability for seasonal forecasting around the globe. An observational system relying too much on one nation, or one instrument, is at risk. An example in given in Figure 3, showing comparison between the objective analysis (without ocean model) and data assimilation results for two periods: in 2010, and in August 2013, when the distribution of data from the TAO array becomes very sporadic in the central and eastern equatorial pacific. It shows the larger dispersion among the objective analyses in 2013 compared to 2010 resulting from the lack of TAO/TRITON array data (Fujii et al., 2015).



The exact locations of TRITON buoys

Feb. 8, 2015

Location	Location (WGS84)		Date(yyyy/mm/dd)
	Lat.	Long.	
8N156E			operation stopped since 2014
5N156E			operation stopped
2N156E	02-02.33'N	156-01.22'E	30/12/2014
EQ156E	00-01.05'N	156-02.53'E	28/12/2014
2S156E	02-01.03'S	155-57.47'E	26/12/2014
5S156E			operation stopped
5N147E			operation stopped since 2014
2N147E	02-04.57'N	146-56.98'E	06/01/2015
EQ147E	00-03.58'N	147-00.65'E	08/01/2015
8N137E	07-39.10'N	136-41.96'E	17/01/2015
5N137E	04-51.90'N	137-16.22'E	13/01/2015
2N138E	02-04.05'N	138-03.88'E	12/01/2015
EQ138E			operation stopped since 2013
8N130E			operation stopped since 2013
2N130E			operation stopped since 2013

Figure 2: Left: TAO array data return (upper) and number of ATLAS buoys reporting data (bottom), between 2003 and January 2014. Source: Mike McPhaden, NOAA/PMEL, USA. Right: status of the TRITON array, in February 2015. Source: Ken Ando, JAMSTEC, Japan.

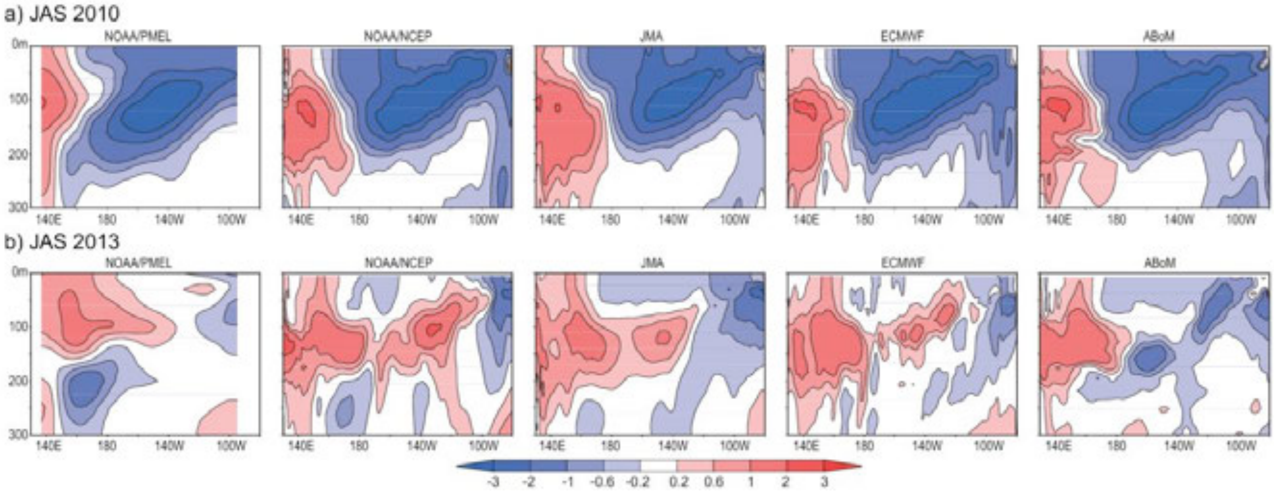


Figure 3: From Fujii et al., 2014 Temperature anomaly (unit: °C) distribution averaged in a) July-September 2010, and b) July- September, 2013 in the equatorial vertical section in the Pacific in the objective analysis from the TAO/TRITON data produced by NOAA/PMEL and the operational DA results of NOAA/NCEP, JMA, ECMWF, ABoM. The anomaly is calculated as the deviation from the WOA09 for the objective analysis, and those from the monthly climatology of each system in 1989-2007 for the DA results.

TPOS Workshop in January 2014, La Jolla, USA

In January 2014, NOAA and JAMSTEC, in collaboration with the Ocean Observations Panel for Climate (OOPC), convened a review of the TPOS, through a Workshop and associated White Papers (see "information and contacts" section). The workshop was attended by 65 invitees from 13 countries and 35 institutes. This led to immediate actions to address the deterioration in the observing system. A key outcome was the recommendation to establish a TPOS 2020 Project, to achieve a significant change between now and 2020 in all elements that contribute to the Tropical Pacific Observing System. A Steering Committee (SC) was formed, consisting of 15 members from seven nations throughout the Pacific. France is represented because of its interests and its active research on the Tropical Pacific and the upwelling system of Peru and Chile, and the IRD center in New Caledonia. The SC first met in October 2014; it reaffirmed the goals set forth for the TPOS2020 project and began the planning required for a successful implementation of the Project. The rest of this paper will detail these recommendations and plans.

TPOS2020 project: why do we need a renewed observing system?

A more modern consideration of requirements, meeting both the research and operational forecasting needs

Our understanding of Tropical Pacific variability and predictability has advanced to a point where a fresh articulation of observational requirements and system design is needed.

The ocean-atmosphere system appears to be coupled on many time and space scales that matter for ENSO (Kessler at al., 2014). The key role of stochastic forcing on the development and irregularity of El Niño events was highlighted; the decadal and longer-term variability was recognized to modify the background state and modulate ENSO amplitude and frequency. High temporal resolution time series from the TAO/TRITON moorings have also underlined the importance of the tropical instability waves, of the diurnal cycle, and of the near surface stratification for a good understanding of the coupled system. The observing system also helped to reveal surprises such as the great diversity of ENSO, and the occurrence of so-called "Modoki El Niño". The recognition that ENSO is modulated at long timescales calls for sustaining an observing system in order to better address climate change issue.

The spatial extension of the TPOS should also be reconsidered, since experimental projects pointed out the demand to expand the observing system to the western Pacific (for example, the western boundary currents, key elements for the recharge/discharge of the equatorial band, may be important to monitor routinely) and to the eastern Pacific, the sites of key processes for the growth of strong El Niño event (Takahashi et al., 2014)

In addition, there has also been an evolution in the complexity of analysis, modelling and predictions systems. Besides seasonal forecasting, operational centers now develop sub-seasonal and decadal forecasts (Balmaseda et al., 2014), and ocean forecasts. TPOS 2020 will consider these new requirements and serve the needs of these forecasting systems.

An integrated observing system

TAO/TRITON was conceived and implemented more than 2 decades ago. In the last two decades, new in situ and satellite observational technologies have emerged, and became important components of the observing system. In particular, the international Argo array of profiling floats now provides broad-scale global observations of temperature and salinity down to 2000 m, and allows resolving many processes, including intraseasonal equatorial waves (Roemmich et al., 2014). Satellite observations of sea surface temperature, sea surface height and winds and sea surface salinity measurements from recent satellite missions have all emerged since TOGA (Lindstrom et al., 2014). Surface drifters, semi-autonomous platforms, tide gauges, repeated hydrographic cruises, sea surface salinity measurements onboard research and commercial ships and XBT deployments are also important components of this system **(Figure 4)**.

A strong general message of the La Jolla Workshop was that the observing system would benefit from being considered more as an integrated whole, including the aforementioned, modeling and data integration, as well as modern in situ technologies. It was also acknowledged that some redundancy in the system is essential to mitigate risks and improve quality control through redundancy.

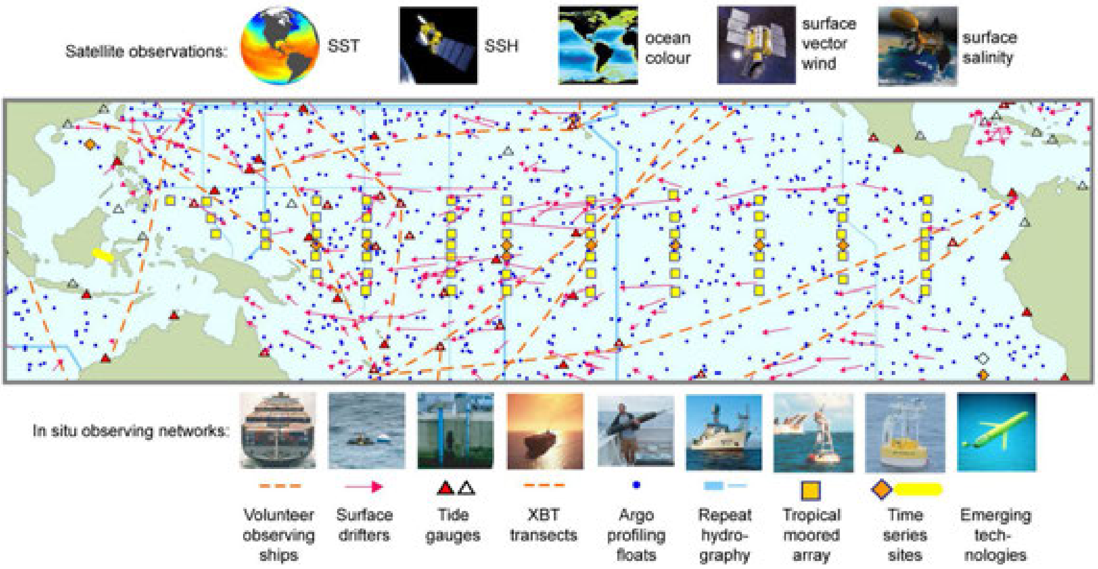


Figure 4: Tropical Pacific Observing System: current observations

Organization and expected outcomes

A Steering Committee is responsible for oversight and coordination, and Task Teams (TT) were appointed to organize the activities agreed on and report to the steering committee. These are:

- **the "Backbone TT"**, to evaluate and improve the backbone of the observing network
- **the "Planetary Boundary Layers" TT**, to elaborate the scientific need and feasibility of observing the planetary boundary layers, including air-sea fluxes, near surface processes and diurnal variability
- **the "Modelling and Data assimilation" TT**, to consider approaches to advancing modelling, data assimilation and synthesis so that observations can achieve their fullest impact.
- **the "BioGeoChemistry" TT**, to develop rationales, requirements and strategy for biogeochemical observations

The "Eastern Pacific" and "Western Boundary" working groups, to evaluate approaches to observation of the eastern and western boundary regions, are also in construction, and may evolve as Task teams too. In addition, a working group on Time series and the climate record will consider the possible criteria for assessing the relative values of fixed-point time series to the Tropical Pacific Climate record: the idea is to identify "key" sites, and progress toward a new TPOS in a way that minimizes the scientific loss of interrupting part of the Tropical Pacific ocean data record.

Objectives of the Task teams

Backbone Task Team

The "backbone" terminology emphasizes that there should be a core of the observing system that anchors and underlies all other pieces of the system; some of which may be implemented for a limited time in a specific region. Basically, it will be a mix of moorings, Argo floats, and satellites. In and near the equatorial waveguide, higher temporal and spatial resolution of temperature, salinity, carbon system variables and currents are needed than in many extra-equatorial areas. Similar considerations probably apply to the near-surface layer.
The backbone will be designed to maintain consistent and well-understood sampling rates and scales that allow for the detection of climate variability and climate trends.
The major objective of this Task Team is to recommend a feasible plan for achieving a new configuration of the observing system. Sampling for the backbone observing system aims at:

- Observing and quantifying the state of the ocean, on time scales from weekly to interannual/decadal;
- Providing data in support of, and to validate and improve, forecasting systems
- Supporting calibration and validation of satellite measurements
- Advancing understanding of the climate system in the tropical Pacific, including through the provision of observing system infrastructure for process studies
- Maintaining and, as appropriate, extending the tropical Pacific climate record.

Modelling and Data Assimilation Task Team

Although modelling of the tropical Pacific and seasonal forecasting using coupled atmosphere ocean models have improved since the end of the TOGA experiment, much remains to be done, as models continue to be plagued by large errors (Balmaseda et al., 2014; Fujii et al., 2015). The La Jolla Workshop identified inadequacies in models and in data assimilation as the major limiting factors for effective use of TPOS observations in seasonal-to-interannual predictions and the accuracy of related products, including both the analysis of the ocean state and the predictive skill of coupled model forecasts. Inadequacies could be model errors associated with either the atmospheric or oceanic component of the coupled models, or could be related to data assimilation methodologies. Consequently, a focused activity on the coordination of multi-model evaluations is presently carried on: Fujii et al (2015) offers a summary of existing OSEs studies measuring the impact of TAO/TRITON in data assimilation systems, for ocean short term forecast, seasonal, decadal prediction, but also for validation of operational systems. Despite the fact that OSE's results depend on the type of data assimilation, most studies indicate that temperature and salinity analyses are impacted by moored observations, in complement of Argo profiles. These ongoing results give indication that the loss of TAO/TRITON would degrade the forecasting skills of these operational centres. In response of TPOS2020, this operational oceanography and data assimilation community under the framework of CLIVAR/GSOP and GODAE OceanView, is also starting a real time intercomparison of ocean reanalyses and operational analyses on monthly basis (Xue, Fujii, Balmaseda, pers. comm., 2015), where eight operational forecasting systems (NCEP, ECMWF, JMA, GFDL, NASA, Bureau of Met., UK-Met, and Mercator Océan) provide temperature and heat content fields for multi-model and ensemble prediction and estimation, focusing also on assessing the impact of the different type of observations in the Tropical Pacific.

Considering these studies, the objectives of this task team are:

- To develop strategies for coordinated modelling and assimilation activities for designing and planning the future TPOS observing systems,
- To identify pathways that will contribute to improved understanding of systematic errors and subsequent model improvements, especially through promotion of joint activities with other bodies that have mandates to improve models.
- To contribute modelling and data assimilation insights into the identification of observational requirements.
- To provide guidance on the assessment of the impact of modelling and assimilation, including through systematic continuous evaluation (metrics and process-oriented diagnostics), OSEs, and OSSEs, of the TPOS and its design, especially using the multi-model approach.
- As appropriate, recommend strategies for model initialization that will promote the efficient use of TPOS information.
- To provide recommendations on improving coordination among centers currently engaged in ocean analysis and prediction towards assessment of TPOS and its influence on predictions.

Planetary Boundary Layers Task Team (Coupling, Interaction, Processes)

Improved monitoring, understanding, parameterization and modelling of ocean surface (air-sea interaction) and near-surface processes have been identified as a priority for TPOS 2020 (Cronin et al., 2014). Many essential ocean and climate variables are now derived from a combination of satellite and in situ data. Supporting the observational needs of these synthesis activities is essential (e.g., GHRSST for SST). Thus satellite calibration/algorithm development and validation requirements along with product synthesis pathways need to be imbedded in the new TPOS 2020 design.
In addition, the importance of the diurnal cycle in modulating SST and air-sea exchange is now apparent. The parameterization of fluxes (and boundary layer processes) under different regimes (stable/unstable boundary layer, sea wave state dependency, etc.) also needs dedicated observations.
The task team will have, among others, the charge to:

- Formulate a practical observing strategy and technical sampling requirement to ensure comprehensive air-sea fluxes can be estimated at hourly or better resolution across a set of key ocean and climate regimes in the tropical Pacific, covering the full suite of state variables to estimate heat, moisture, and momentum exchanges, including through use of bulk formula.
- Develop recommendations about measurements that should resolve the diurnal cycle in the oceanic and atmospheric boundary layers.
- Consider whether a subset of regimes where direct eddy-correlation approaches might be used is feasible and of value.
- Liaise with the existing and developing ocean satellite and modelling community on efficiently meeting their present and future requirements for ocean surface data.

Biogeochemistry (BGC) Task Team

During the La Jolla Workshop, the need of integration of biogeochemical observations in TPOS to improve understanding of the tropical Pacific in the global carbon budgets and ocean productivity was highlighted (Mathis et al., 2014). This task team will begin with carbon biogeochemistry as its core scientific concern; it will consider primary productivity but not higher trophic levels (zooplankton to fish). The main objectives of the task team will be:

- To develop strategies and design plans for the biogeochemical contributions to the Tropical Pacific Observing System
- Determine the requirements, including time and space scales that should be resolved
- Provide a prioritized list of variables that will be measured as part of the BGC observing network.
- Provide guidance on implementation, including needed/potential new technologies and required process studies.

Approaches to observations in the western and eastern boundaries

In addition to the "backbone" observing system, the western and eastern boundary regions and the Indonesian Throughflow were identified as key regions that require specific observational system designs.
In the Western Pacific, several large regional projects already exist or are planned (e.g. the Southwest Pacific Ocean Circulation and Climate Experiment (SPICE), Indonesian Throughflow programs and the North Pacific Ocean Circulation and Climate Experiment (NPOCE) under the auspices of CLIVAR). The results of these experiments and others should be used to assess which observations need to evolve into sustained systems, and a group was formed to do the 'due diligence' at the moment.
The far Eastern Pacific has been recognized as a key region for ENSO since this is where the thermocline feedback is the most effective allowing for the development of strong events with large societal and ecological impacts in surroundings countries. Non-linear processes important for ENSO are

also at work there, which are still insufficiently documented. Additionally, meridional processes originating in the southeast Pacific associated with surface winds and heat ocean- atmosphere exchange, potentially connected to the coastal upwelling system, could penetrate into the equatorial eastern Pacific and affect ENSO (Takahashi et al., 2014). A task team will develop a regional research project to address these issues, and provide guidance for sustained observational networks that would be needed in the region.

Why should French community be part of it?

• Measurements of TAO/TRITON buoys, together with the more recent arrays of PIRATA buoys in the tropical Atlantic Ocean and RAMA in the Indian Ocean, are the keystone of observability in the tropics. They serve as reference for the majority of other datasets, satellite or in situ. Observations of moorings transmitted in real time are also used on a daily basis by the operational centers, by Mercator Océan and ECMWF.
French researchers are, and have always been, strongly involved in observations in the tropics. Since 1970, more than 100 french cruises have been organized in the South Tropical Pacific, and in the 80s and 90s, the French research community was among the prime drivers for TOGA and featured prominently in the big success stories. IRD in collaboration with Meteo-France, CNRS and IFREMER, provides financial, technical and logistic support for PIRATA. In addition, France has the leadership for observations of sea surface salinity onboard commercial vessels (ORE-SSS), and regularly contributes to deployment of Argo floats and drifters in the region.
• Monitoring the Pacific Ocean requires an international effort from all nations whose oceanographic fleets steam across the Pacific, as the main constraint is ship access to remote areas. The French presence in the TPOS-2020 coordination committees will open the possibility of (a minima) occasional contributions, e.g., Argo releases during cruises or transits; maintenance of met stations on buoys, instrument rescues etc.
• To assist the design of the future observing system, TPOS will require enhanced coordination across various centers engaged in ocean analysis and prediction. Impact or sensitivity studies in numerical simulations may be needed to evaluate the importance of the different observational networks. Mercator Océan has already been pursuing a series of “Observing System Experiment” studies, as part of GODAE OceanView and there has been an interest within the national community to expand this effort to adress issues relevant to TPOS2020 (cf. GMMC letter of intention on “Impact of observations in the tropical Oceans” (PIs: A. Ganachaud, F. Hernandez)) and contribute to this emerging international program.

Governance

TPOS 2020 will be managed and implemented within the context of existing and planned activities of the Global Ocean Observing System (GOOS); and in particular the activities of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) which coordinates the implementation of many of the existing in situ networks.
Other critical partners include the Climate Variability and Predictability Project (CLIVAR) and its Global Synthesis and Observation Panel (GSOP) and GODAE OceanView. CLIVAR supports a number of research activities and projects relevant to TPOS2020, particularly with respect to modeling and process studies. GSOP aims at providing reliable estimation of the present and past ocean state, through ocean reanalysis synthesis in particular, for which past and future moored array high quality time series allow a consistent reconstruction of ocean parameters. The work of GODAE OceanView is relevant to the planned ocean prediction and observing system studies of the TPOS2020 project.
Four primary elements are included in the governance of the Project:

- A TPOS 2020 Steering Committee responsible for oversight and coordination. Chairs are Neville Smith (retired, Australia) and William Kessler (NOAA, PMEL, USA)
- A Resources Forum drawn from sponsors and responsible for coordinating resources.
- An Executive populated from the leadership of the above and responsible for reporting.
- A Project Office focused on coordination activities supported and resourced by the sponsors.

It is through these partnerships and governance structure that TPOS2020 will be able to fulfill its objectives.

Contacts and information

More information about the project, its partners, organization and outcomes can be found on the TPOS2020 official website: http://tpos2020.org/
The Terms of References for the Steering Committee and the different task teams are given.
This paper largely used material and sentences posted on this site, including the “prospectus” document.

The La Jolla 2014 Workshop Report, the white papers can also be downloaded on:
(http://tpos2020.org/tpos-2020-released-documents/ OR http://www.iode.org/index.php?option=com_oe&task=viewEventRecord&eventID=1383) and the oral presentations on (http://tpos2020.org/presentations/).

Sophie Cravatte (IRD/LEGOS, New Caledonia) is member of the Steering Committee and co-chair of the backbone task team.
Alexandre Ganachaud (IRD/LEGOS, Toulouse) is member of the backbone task team. He is also chair of the CLIVAR Pacific Panel.
Boris Dewitte (IRD/LEGOS) will be member of the Eastern Pacific Task team.
Fabrice Hernandez (IRD/LEGOS/Mercator Océan, Ramonville St Agne) is member of the Steering Scientific Group of PIRATA, co-chair of the Intercomparison and Validation Task Team of GODAE OceanView, and coordinating focused tropical ocean studies at Mercator Océan.

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CALIBRATION OF CTD OXYGEN DATA COLLECTED IN THE CORAL SEA DURING THE 2012 BIFURCATION CRUISE

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Abstract
An updated procedure for a CTD-oxygen calibration along with new data processing was applied to recent hydrographic cruise data in the Coral Sea during the Cruise "BIFURCATION" in September 2012. After a brief introduction with the scientific context (section 1), we describe the contents and acquisition models of hydrological and chemical data that are used for the calibration (section 2), the post-cruise calibration method (section 3) and the calibration results (section 4).

Context
By its location within southwest Pacific Ocean, the Coral Sea is a key zone of connection between the South Pacific subtropical anticyclonic gyre and the equatorial regions. Because of its numerous reefs, islands and coral archipelagos, the Coral Sea is a place of formation of numerous, fine and intense oceanic jets, as the broad South Equatorial Current enters from its east.

Conducted in the context of the international program SPICE (Southwest PacIfic Ocean Circulation and Climate Experiment, Ganachaud et al. 2014), the BIFURCATION cruise had the main objective to complete the vision of the regional oceanic circulation in the Coral Sea, by documenting the fate of its main currents, the North Caledonian Jet as it flows over the Queensland Plateau off the Australian coast (Maes et al. cruise report, in preparation).

The cruise was led by the Institut de Recherche pour le Développement (IRD) aboard the oceanographic ship Alis between September 1st and September 15 2012, from Nouméa to Nouméa and produced forty hydrological profiles (**figure 1** ; stations 2-5 and 37-40 have been sampled at the same position).

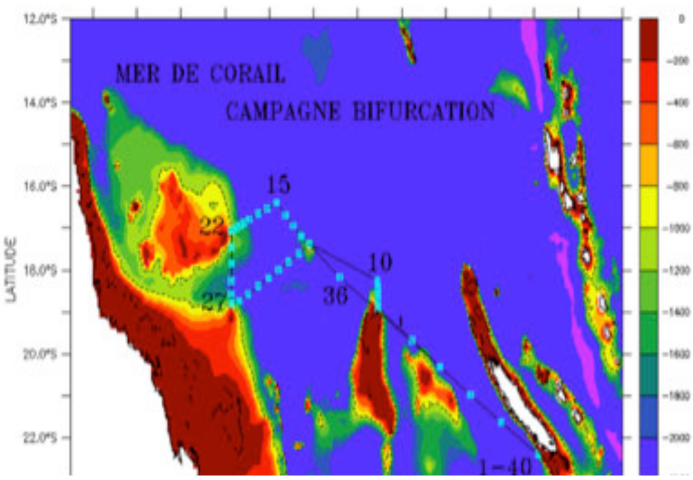

Figure 1: Route and Positions of 40 hydrological stations operated during the 2012 BIFURCATION Cruise

Post-cruise calibration procedure
At each station, two vertical CTD profiles are available. The first *downcast CTD profile* is obtained during the descent phase of the CTD rosette, from the surface to 2000 meters depth, with direct Seabird measurements of Pressure (dbar), Temperature (ITS-90, °C), Salinity (psu) and Dissolved-Oxygen concentration (O2). The second *upcast CTD profile* is obtained during the ascent phase of the CTD rosette, with again P/T/S/O2 Seabird direct measurements and in addition, water samples collected using a set of bottles mounted on the rosette. Those water samples provide chemical oxygen measurements through the Winkler procedure.

Hydrological Data
During the cruise, the CTD/O2 system which equipped the rosette was a real-time data acquisition system using a SBE911plusCTD type (http://www.seabird.com/sbe911plus-ctd) with two redundant measurement circuits for Conductivity/Temperature sensors, and a SBE-43 dissolved-oxygen sensor. The CTD/O2 system thus includes:

• one sensor for Pressure (P): range [0-6800] - resolution 0,068 - accuracy 1 dbar
• two sensors for Temperature (T1 and T2): range [-5-35] - resolution 0,0002 - accuracy 0,002 °C
• two sensors for Conductivity (C1 and C2): range [0-7] - resolution [4,1-5] - accuracy 0,0003 S/m
• two sensors for dissolved-oxygen concentration (DO1 and DO2): range [0-15] – resolution 0,01 - accuracy 0,01 ml/l

Each sensor has a serial number and was calibrated before the cruise, according to table 1. Post-calibration was made long after the cruise and was not used here.

Parameter	Calibration Date	Serial Number s/n
Pressure	05/11/2008	75674
Temperature T1	27/03/2012	2552
Temperature T2	27/03/2012	2551
Conductivity C1	14/03/2012	2343
Conductivity C2	14/03/2012	2340
Dissolved-Oxygen Concentration DO1	27/03/2012	0068
Dissolved-Oxygen Concentration DO2	14/03/2012	1337

Table 1: Serial numbers and calibration dates for primary and auxiliary circuits of SBE911plusCTD sensor used during the 2012-BIFURCATION cruise

The SBE43 dissolved-oxygen sensor allows the determination of the concentration of oxygen in the environment by counting the number of oxygen molecules per second (flux) that diffuse through a polarographic membrane. Knowledge of the flux of oxygen and the geometry of the diffusion path allows the determination of the concentration of oxygen. The permeability of the membrane to oxygen is a function of temperature and ambient pressure. The electronic interface provides voltages that proportional to membrane current (oxygen current) and membrane temperature (oxygen temperature).

Chemical Data

For twenty-one out of forty stations, water samples were collected during the ascent of the CTD rosette from 2000 meters to the surface, using eleven bottles mounted on the rosette (table 2). Chemical oxygen data (in umol/l) is obtained using the Winkler procedure (Langdon, 2010). For each bottle, the CTD pressure, temperature, salinity and oxygen are recorded. This gives the potential density needed for the post-cruise calibration procedure.

Station	7	8	9	12	13	14	16	17	18	19	21	23	25	26	28	29	31	32	33	34	40
Bottle ID																					
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
5	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9	X	X		X	X		X			X	X	X		X		X	X	X	X	X	X
10	X	X			X		X			X	X	X		X		X		X		X	
11		X			X		X			X		X		X							

Table 2: Characteristics of chemical oxygen measurements with corresponding station and bottle identities.
X: measurement ok - Yellow: Oxygen dubious value – N1: Broken nylon- Light-green: leaking - Dark-green: no salinity

Data processing

In order to simplify the different treatments, maximize compatibility, reduce error possibilities, and ensure all necessary parameters are available and documented, the Seabird-formatted data from the CTD unit deck is converted to Netcdf Ocean Sites format using a Perl script that we have developed. From there, variables names are unique, correspond to an international format. The system also allows to conserved three versions of each parameter: raw, calibrated (as sensors return from calibration) and adjusted, along with quality control flags.

Calibration Procedure

Two issues arise when using SBE43 oxygen sensors. First, electrochemical sensors generally exhibit a sensor response time of several seconds, which describes how long it takes a sensor to equilibrate with its surroundings as oxygen diffuses across its membrane. SEABIRD suggests modelling this as the following function of pressure (P) and temperature (T):

$$\tau=\tau 20\times e^{[d1\times p+d2\times(t-20)]}$$

τ20 is the response time at 20°C and atmospheric pressure. τ20, d1 and d2 are coefficients given by Seabird after the laboratory calibration of the sensor.

Second, electrochemical oxygen sensors that experience the high pressures of full depth sampling (P>1000 dbar) exhibit a noticeable hysteresis, with oxygen sensors voltages during descent sometimes considerably higher than voltages at the same pressures during ascent.

The procedure of post-cruise CTD-O2 calibration based on chemical (Winkler) measurements follows Uchida et al (2010), from WOCE/GOSHIP (http://cchdo.ucsd.edu/manuals.html). Each step of the post-cruise calibration is graphically represented figure 2. The key step is an adjustement of the initial calibration coefficients provided by Seabird from either pre-cruise or post-cruise sensor calibration by minimizing the differences between SBE43 and Winkler data. We developed our own set of Matlab routines, based on an initial code developed by the PMEL (Pacific Marine Environmental Laboratory).

The process thus takes place in four successive stages:

Step 1: Merging chemical Winkler data with CTD

Simple in principle, this step may be long as we merge data of different nature – chemical data from a hand-filled excel sheet by the chemist with CTD data from automated procedure.This important step includes formatting and typo corrections.

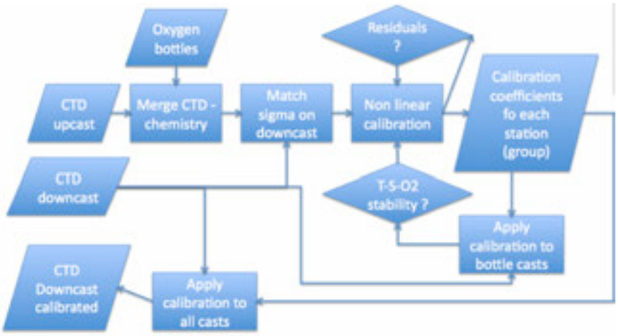

Figure 2:
Calibration process for SBE-43 dissolved oxygen sensor for the BIFURCATION-2012 cruise

Step 2: Density adjustment

The CTD group at PMEL suggest to do the minimization only on the downcast profile to avoid hysteresis issues, and to correct for vertical motion of isopycnals due to internal waves between downcast and upcast by adjusting each up-cast bottle pressure so that its potential density matches the downcast potential density (Uchida et al, 2010). Down-cast O2-CTD values are adjusted to (up-cast) Winkler data using an hybrid equation from models of Owens-Millard (1985) and Murphy et al. (2008) to calculate and calibrate the SBE-43 sensor oxygen. The equation used for oxygen sensor calibration thus follows:

$$O_2 = (1+a \times istat) \times S_{oc} \times (V+V_{off}+\tau_{20}{*}\ e^{(d1\times p+d2\times t)} \times dVdt) \times Os \times e^{[tcor\times t]} \times e^{[pcor\times p/_{[273,15+t]}]}$$

- istat: station number
- A: linear dependency upon station number
- O_2: the calculated CTD oxygen
- O_s: the oxygen saturation, calculated from Garcia and Gordon (1992) formula.
- V: the oxygen voltage, and dVdt its temporal derivative
- p the pressure, and t the temperature
- d_1, d2, S_{oc} , V_{off}, τ20, tcor and pcor: initial values of pre-cruise sensor calibrations performed at SEABIRD (table 3), then adjusted by minimisation to bottles data during the calibration process.

	Calibration date	soc	voffset	E	T20	Tcor	D1	D2
s/n 68	27/03/2012	0.5198	-0.5092	3.6000e-002	1.42	-0.0019	1.92634e-004	-4.64803e-002
s/n 1337	14/03/2012	0.4291	-0.7091	3.6000e-002	1.37	-0.0019	1.92634e-004	-4.64803e-002

Table 3: Pre-calibration coefficients for the primary (s/n 68) and auxiliary (s/n 1337) circuits of SBE43 dissolved-oxygen sensor at their calibration dates – source: SEABIRD Electronics, Washington

Step 3: Iterative optimization of oxygen equation coefficients

Differences between data bottles and adjusted CTD data are minimized by groups of stations, using a non-linear non-forced optimization algorithm. After that, the residuals (ctd-bottles) are calculated, and those exceeding 2.8 standard deviation are tagged as outliers, removed (Millard, 1993) and the minimisation is iterated, until the entire removal of residuals exceeding 2.8 standard deviation.Several options are possible for this optimization. To remove an initial linear trend in the residuals due to the evolution of the sensor itself, we introduced a linear dependency of the station number. On some cruises, it is necessary to divide this optimization for subgroups of stations.

Step 4: Filtering of final data by vertical interpolation if necessary

The coefficients of the non-linear equation of calibration obtained at the end of step 3 are applied to the entire *downcast* CTD profile. A visual comparison with the corresponding *upcast* CTD profile and others surroundings profiles allows obvious error detection. Downcast oxygen profiles are finally cleaned up and quality flags are attributed for each data. Potential spikes visible in the descent profile, obviously linked to an electronic problem, are removed and the profile is vertically interpolated. Data which may have been interpolated on more than 2 dbar are flagged with Qc=6 ; Qc =2 is attributed for well-calibrated oxygen data (WHP flags).

At the end of the calibration procedure, calibrated and flagged CTD-O2 data are stored in a Matlab file before being converted to the OceanSites netCDF format (and flags). Graphic representations give, station by station the vertical variations of temperature, salinity and oxygen versus pressure.

Results

Chemical data

11 bottles samples at each station provide regular samples along the water column between 2000 meters and the surface (table 2). Duplicates bottles gives an estimate of the analytical error, which is 0.96 umol/kg (DOE) within GO-SHIP standards. Two technical problems occurred: the bottle 5 at station 8 with a broken nylon and oxygen dubious value; and the bottles 12 and 13 at station 23 were leaking as they arrived on deck.

Density adjustment

The pressure differences between the downcast-CTD and upcast-bottles sigma-matched pressures can reach 30m, with no particular dependency on depth or station number (figure 3, right panels). The associated shifts in oxygen are of order 5 umol/kg and are smaller than those at constant pressure (compare blue and red circles on **figure 3**, right panels).

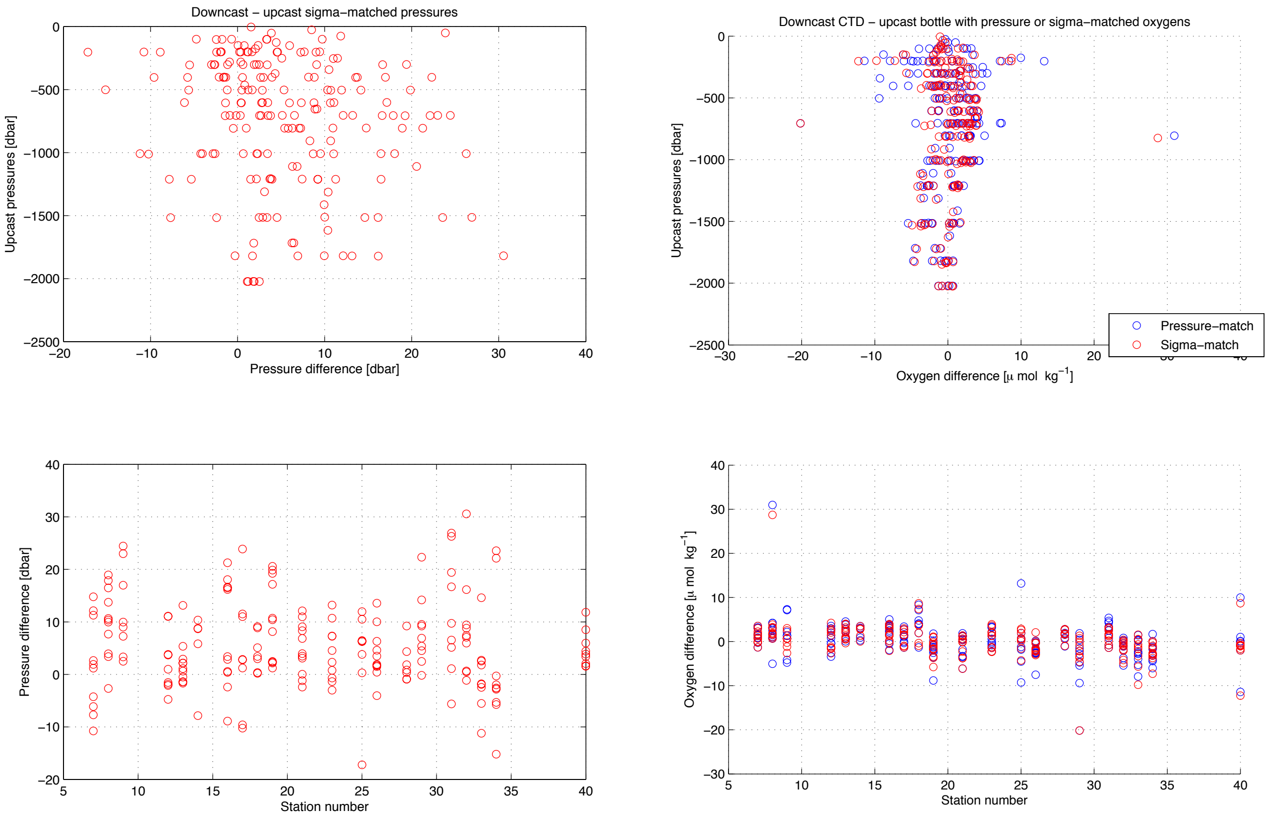

Figure 3: (left): Pressure differences (dbar) between downcast CTD-upcastBottle sigma-matched pressures, function of depth (top) and function of station number (bottom). (Right): Associated oxygen corrections (in umol/kg)

Minimizing the differences

To obtain the best fit, a linear dependency upon station number had to be introduced because a first trial indicated a trend in the residuals during the cruise. Figure 4 shows the residuals Oxygen (CTD-Winkler) after calibration: the total rms is close to 1.7 umol/kg. For this cruise, a global set of calibration coefficient was adapted without need for calibration by station subsets. Figure 5 shows a typical profile, with Winkler oxygen superimposed. The iterative procedure pointed to 6 outliers in the chemical data, which were flagged as such, out of a total of 195 samples.

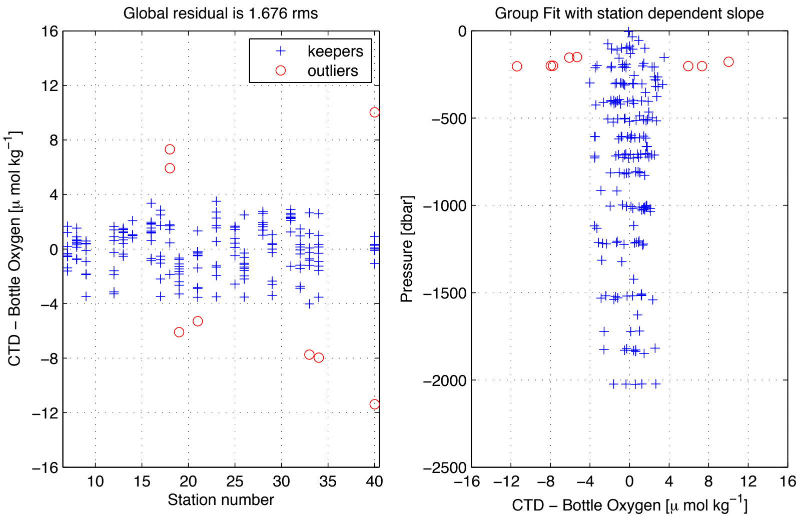

Figure 4: Oxygen residuals obtained at the end of the calibration procedure as a function of station number (left) or depth (right). Red circles indicate samples that were identified and flagged as outliers through the procedure (those are not used in the calibration).
Figure 5: (Left): Calibrated temperature/salinity with bottle salinities superimposed and (Right): Calibrated CTD Oxygen with Winkler Oxygen superimposed after density match, for station 8. The sampling bottle number is indicated.
For this station, bottle 5 as flagged in both oxygen and salinity.

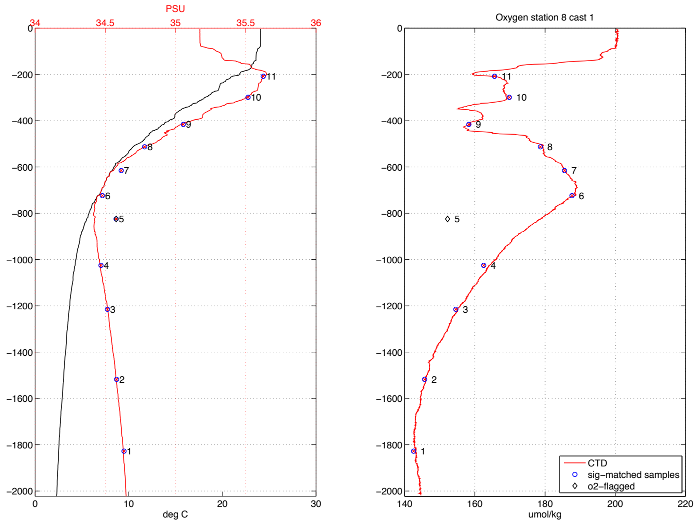

Figure 5: (Left): Calibrated temperature/salinity with bottle salinities superimposed and (Right): Calibrated CTD Oxygen with Winkler Oxygen superimposed after density match, for station 8. The sampling bottle number is indicated.
For this station, bottle 5 as flagged in both oxygen and salinity.

Conclusion

CTD-O2 calibration from hydrographic data remains a technically difficult and time-consuming procedure. Our system allows an optimization of the procedure, making best use of the international formats. We evaluate the engineer time needed for calibration to about 1 month/100 profiles with an adequate technical and scientific expertise on oxygen data. The codes and documentation are available on request to the research community.

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SURFACE CURRENT FIELD IMPROVEMENTS – REGIONAL ALTIMETRY FOR SPURS

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Abstract

Aiming at better understanding the processes controlling surface salinity in the North Atlantic subtropical region, intense sampling from in-situ data was realized in this region during the SPURS experiment in 2012-2013. Complementing this dataset, dedicated satellite-derived estimates of the current and surface salinity were used to compute surface currents. A particular effort was done on computing a new regional Mean Dynamic Topography (MDT) combined with higher resolution maps of Sea Level Anomalies (SLA). On both products, currents intensifies and smaller scale variability is improved: the new MDT better reproduces the Azores Current and regional maps of SLA increases signal variance and Eddy Kinetic Energy by 20% and 50% respectively, in particular in the 50-150km wavelength range. Total surface currents derived from these datasets improves the consistency with drifter data from the SPURS experiment, although not being able to reproduce the finest scales of variability (below 50km). Finally, good agreement are obtained between estimates of the Meridional Transport by the Eddy component from both data sets and show evidences of a divergence of the meridional eddy salt flux that occurs in spring near 22-23°N and 25-26°N.

Introduction

A dedicated experiment, SPURS, has been organized in 2012-2013 in order to improve our understanding of the processes controlling surface salinity in the region of maximum surface salinity of the North Atlantic subtropical region. The maximum salinity is related to the excess evaporation in the subtropical North Atlantic, compensated partially by Ekman convergence of fresher water (Qu et al., 2011). It has been suggested since the outset that horizontal transports associated with eddies would contribute significantly to the salinity budget in this region (Gordon and Giulivi, 2014). Thus, emphasis was dedicated to collect enough in situ data to provide direct estimates of the salinity budget over one year in part of the subtropical gyre. However, to better cover spatially the subtropical gyre and to provide a longer time series, it is important to use satellite-derived estimates of the current and of surface salinity to resolve meso-scale transports.

Altimetry is indeed very useful to provide data on mesoscale structures at the ocean surface with a good sampling. To have access to the absolute signal, a Mean Dynamic Topography must be added to altimetric Sea Level Anomalies. Roughly every 4 years, global Mean Dynamic Topography and SLA are reprocessed. Besides, other dedicated updates in specific regions can be done using new data, new standards, and a new processing.

In this paper we present the recent global products and specific improvements done in the framework of the SPURS project, and the impact of these products on the analysis of the SPURS experiment results. Section 2 presents the recent CNES-CLS13 MDT and the regional SPURS MDT. Then section 3 presents the regional SLA product referenced over the 1993-2012 period. Finally, section 4 presents results of the SPURS experiment.

MDT computation

What is MDT?

Mean dynamic topography is the average over a selected period of the height of the sea surface referenced to the geoid. The geoid is a gravity equipotential surface that would correspond with the ocean surface if ocean was at rest (i.e. with no currents under only the gravity field). Then, when the ocean is also influenced by wind, differential heating and precipitation and other sources of energy, the ocean surface moves from the geoid. Thus, the departure from the geoid provides information on the ocean dynamics.

Therefore, the MDT can be deduced from the difference between Mean Sea Surface and geoid height (both quantities have to be referenced to the same ellipsoid, for more details see Hughes and Bingham, 2008). However, a Mean Sea Surface (MSS) computed from altimetric data has a resolution of a few kilometers wheras recent geoid models from gravimetric mission such as GOCE (called satellite only geoid model) have a resolution of 100 km (Bingham et al, 2014 ; Brockmann et al., 2014). As a consequence, in addition to commission error originating from both surfaces, part of the raw difference between MSS and geoid height results from residual geodetic signal resolved by MSS but not by the geoid model (i.e. omission error).Two possibilities finally remains. First, altimetry can be used to increase the resolution of geoid model and to compute what it is called “combined geoid model” as done, among others, in Egm2008 (Pavlis et al., 2012) and Eigen6C4 (Förste et al., 2014). Such geoid models can then be subtracted from MSS to compute high resolution MDT as done by Andersen et al., (2009, 2014). Another method is to filter small scales not resolved by satellite only geoid model, compute a medium scale MDT and then add oceanic small scales based on in-situ data. The latter method is used by Rio and Hernandez 2004, Rio et al., 2011, 2014.

Global product MDT CNES-CLS13

The computation of the CNES-CLS13 MDT is fully described in Rio et al. (2014) and it is briefly recalled here. First a first guess is computed as the difference between the CNES-CLS11 MSS (Schaeffer et al., 2012) and the fourth release of the GOCE geoid model EGM-DIR4 (Bruinsma et al., 2013). The difference is then optimally filtered taking into account omission and commission errors through objective analysis.

In addition, oceanic in-situ data is processed to have the same physical content as MDT and associated mean geostrophic currents: ageotrophic signal is directly removed from in-situ data and temporal variability estimated from altimetry (Sea Level Anomalies and associated currents) is removed also to have an estimate of the mean component. The in situ data sets consist of temperature and salinity profiles from the Coriolis Ocean database ReAnalysis (CORA3.4) covering the years 1993 to 2012 (Cabanes et al., 2013), from the delayed-time drifting buoy data of the Surface Velocity Program (SVP) distributed by SD-DAC from January 1993 to September 2012 - for which the drogue loss date has been recently reevaluated (Lumpkin et al., 2012) -, and from Argo float surface velocities of the YoMaHa’07 (Yoshinari Maximenko Hacker) data set (Lebedev et al., 2007) covering the 2000–2013 period. Moreover, the Ekman current component has been estimated based on the 3-hourly wind stress data from the ERA-Interim reanalysis (Simmons et al., 2007).

For the purpose of the computation of the CNES-CLS13 MDT an important improvement has been done: drifting buoys having lost their drogue were taken into account by correcting them from wind slippage as well as Ekman drift estimated at surface (Rio et al., 2014).

Finally oceanic in-situ data are merged with the first guess through multivariate objective analysis to end up with the MDT CNES-CLS13 **(Figure 1)** and associated mean currents. **Figure 2** shows the difference with the previous version CNES-CLS09 (Rio et al., 2011). The main improvements are found in the western boundary and circumpolar currents and close to the coasts (close to Indonesia, the Bahamas, the Aleutian islands and along the Chilean Coast). The better resolution near the coast is due to an improvement of filter processing in the computation of the first guess and to the higher resolution of GOCE geoid model compared with the GRACE geoid model used in CNES-CLS09. Improvement in the main currents is due to GOCE and a better processing of in-situ data.

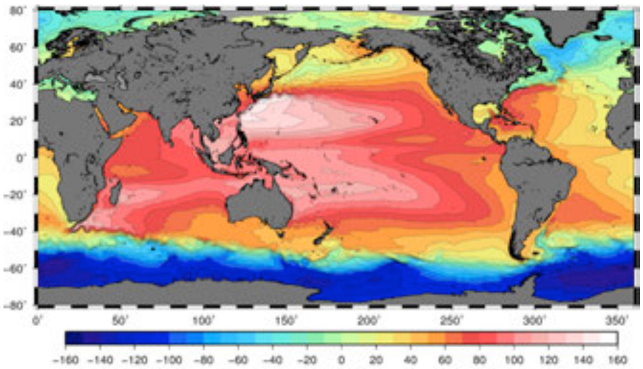


Figure 1: MDT CNES-CLS13 (cm)

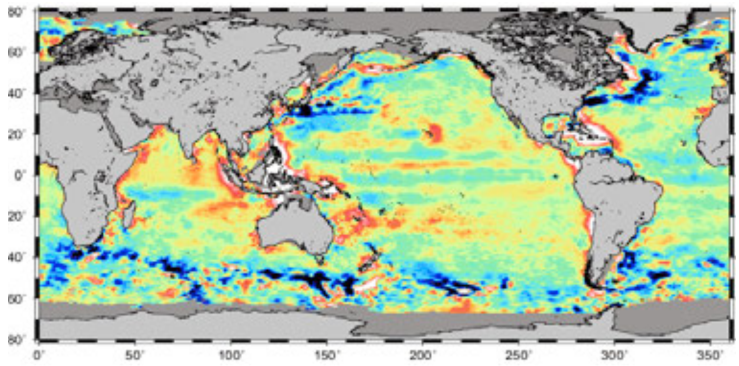
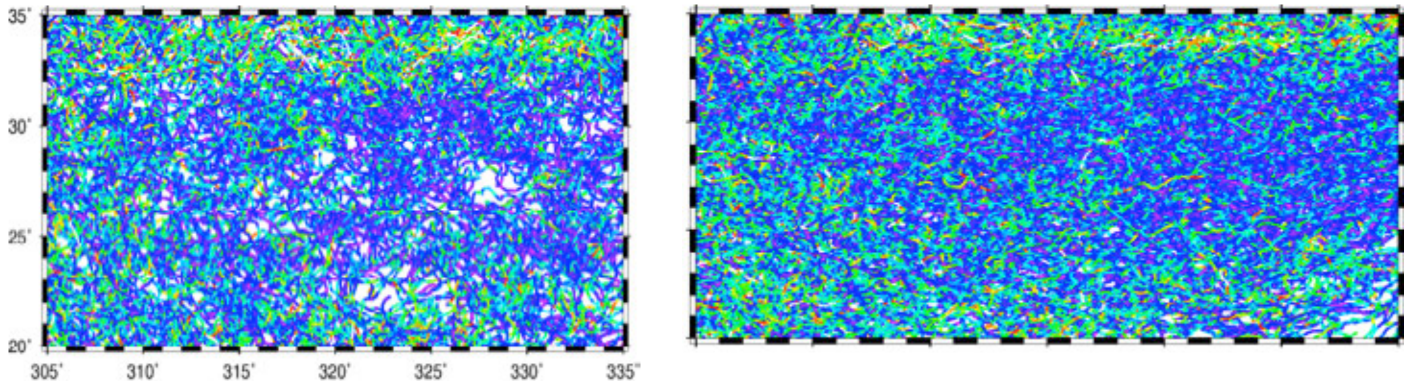


Figure 2: Difference between the CNES-CLS13 and CNES-CLS09 MDTs (cm)

Regional product (SPURS MDT)

For the computation of the SPURS MDT we updated the method used for CNES-CLS13 MDT. First, a more recent geoid model is used: a preliminary version of EGM-DIR5.This is the latest release of the GOCE geoid model computed using the direct approach (Bruinsma et al., 2014) and based on all the available data from the GOCE mission, including the last months when the satellite was flying at lower altitude. This geoid model is less noisy than previous releases at high resolution (i.e. about 100 km; Bruinsma et al., 2014). Second, to be consistent with new SLA products, all the in-situ data was reprocessed to have an estimated mean referenced over 1993-2012 instead of 1993-1999 (see section 3, **Figure 3 and Figure 4**). Note that the CNES-CLS13 MDT was computed over 1993-1999 but was later re-referenced over 1993-2012. Also we include in-situ data collected from the SPURS campaign (Argo floats and surface drifters, see section 4). Finally, the parameters of the multivariate objective analysis, as correlation scales, were adapted for the SPURS region and the SPURS MDT was computed over a higher resolution grid (1/8° instead of a ¼°).

Figure 5 shows the difference between the SPURS and the CNES-CLS13 MDTs. It shows that MDT gradient associated with the Azores current increased, and we also see more small scales structures.



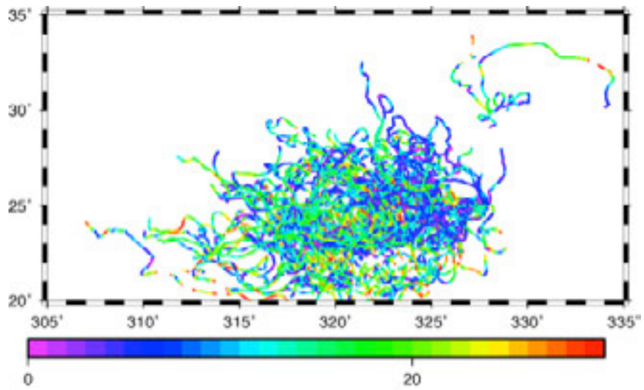


Figure 3: Intensity of the velocity of the drifters used to compute SPURS MDT (cm/s) from (top-left) drogued SVP drifters from SD-DAC, (top-right) undrogued SVP drifters from SD-DA and (bottom) SPURS drifters

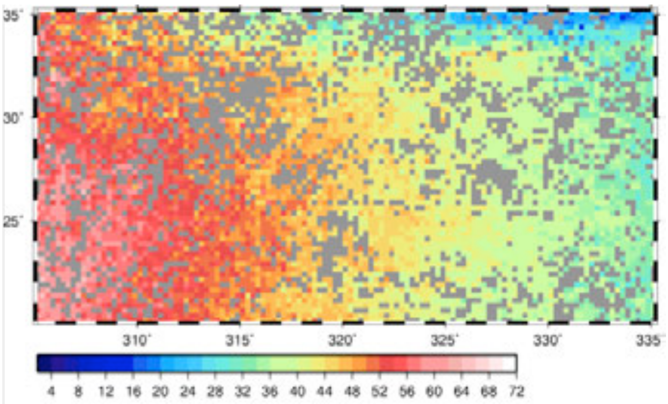


Figure 4: Synthetic MDT from processed T/S profiles (cm)

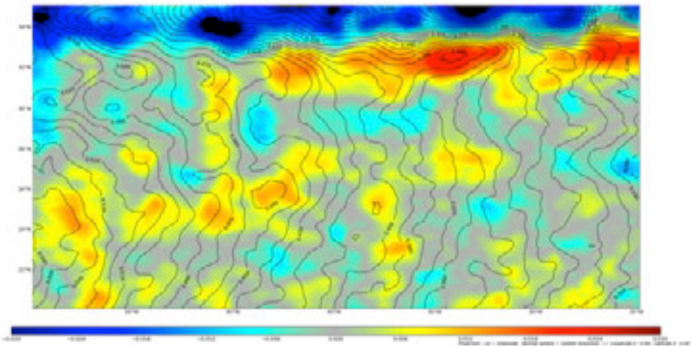


Figure 5: Difference between the SPURS and CNES-CLS13 MDTs (m). The contours show the SPURS MDT.

Regional altimetry Level 4+ products computation

In addition to the MDT circulation, the temporal variability is provided by the Sea Level Anomaly (SLA) combined with MDT. The SLA products and derived fields of geostrophic current anomalies are computed by the DUACS system. It includes different steps as described by Dibarboure et al (2011). They consist in acquisition, homogenization, input data quality control, multi-missions cross-calibration, along-track SLA generation, multi-missions mapping, final quality control and dissemination of the products. The system can thus produce SLA and derived fields at global and regional scales. The processing steps are the same for both. Differences between global and regional products arise from the different parameterizations for each considered step of the processing.

The SPURS SLA products were generated over the mid-2012-2013 period, including measurements from Jason-2, AltiKa, Cryosat-2 and Jason-1 on its geodetic orbit. The altimetry standards, defining the orbit and altimeter measurement solution as well as applied instrumental, environmental and geophysical corrections, meet the most recent standards recommended by agencies and expert groups. They consist in GDR-D or equivalent standards, also used in the global ocean products as described in SeaLevel TAC Product Users Manual (2014).

Invalid measurements were rejected using different detection criteria that allow the detection of possible anomalies of the measurements or degraded quality from any applied corrections.

As altimeter measurements from the different missions are not homogeneous (geographically correlated biases are observed between measurements of different altimeters), a crucial step of the processing consists in reducing these very long-wavelength differences. The latter are dominated by the errors of the chosen orbit solution. To reduce these errors, cross-calibration is performed both on measurements from a reference mission and between measurements from the reference and secondary missions. This is achieved by minimizing the differences between measurements at crossover points on a global basis. Here, having the most precise orbit solution, Jason-2 is taken as the reference mission. Finally, residual long wavelength errors are reduced using an empirical correction based on Optimal Interpolation. This process reduces geographically correlated errors between neighboring tracks from different sensors. It also contributes in reducing the residual high frequency signal that is not fully corrected with the different corrections applied (mainly Dynamic Atmospheric Correction and Ocean tides).

The along-track SLA field is obtained by subtracting to the SSH a Mean Sea Surface (here the MSS_CNES_CLS_11 solution, Schaeffer et al, 2012), and when possible, a more precise estimation of this MSS along repetitive tracks (also called Mean Profiles - MPs). In all the cases considered, the MSS and MPs solutions refer to the 20-year [1993, 2012] period. In the perspective of the mapping process, along-track SLAs obtained are then low-pass filtered. This filtering aims to reduce the measurement noise that affects the data, but also part of the small mesoscale structures which cannot be correctly mapped due to the insufficient sampling across altimeter tracks. The filtering parameters were specifically tuned for the SPURS region in order to properly remove wavelength shorter than 50 to 60 km (depending on the mission considered). In the case of the global products, the wavelength filtered in the same area rather range around 100 to 150 km.

The mapping process consists in an Optimal Interpolation (OI) of the along-track measurements from all the available altimeters onto a regular grid. The regional SPURS products are computed at a 1/8x1/8° (Cartesian) spatial and daily resolution. The correlation scales considered, defining the spatial and temporal characteristics of the signal to be reconstructed, are geographically correlated. In the region, they range from 100 to 240 km and 10-45 days. The different errors observed on along-track measurements are also considered during the mapping process. They take into account both residual long-wavelength errors (as discussed below) and uncorrelated errors. The error budget was specifically estimated over the SPURS region in order to take into account the residual noise measurement after along-track filtering, the omission error corresponding to signal that cannot be mapped, the use of a less precise MSS for geodetic missions, and other specific errors observed on the different altimeters (e.g. altimeter without radiometer, usually used for wet-troposhere correction, will be considered as an additional error since a less precise solution is used in that case).

Finally, the gridded SLA product obtained can be used to derive the anomalies of the geostrophic current. For this purpose, the 9-point stencil width methodology (Arbic et al, 2012) is used, allowing us to correct the anisotropy inherent to the Cartesian projection. Additionally, a cyclo-geostrophy correction (Penven et al., 2014) is applied in order to account for the effects of centrifugal force on the geostrophic balance. This correction however has limited impact in the main part of the domain where Rossby number is quite low (usually < 0.1).

The SPURS regional is considered as a very low energetic area. The large/medium-mesoscale structures, usually quite well observed with altimeter products are only present on the northernmost part of the region. Elsewhere, the observability of small-mesoscale and sub-mesoscale structures remains limited even with a 4-altimeter constellation. Nevertheless, the regional processing of altimetry data leads to an improved representation of the surface signal compared to the existing global product, with additional signal. From a statistical point of view, this is underlined by the spectral content of the gridded SLA products being closer to the along-track measurement, with regards to the global product. This gain in energy is especially visible for wavelengths ranging 50-150km (cf. **Figure 6**), with an overall variance gain of 1cm² at these scales. This additional content is distributed over the entire region and locally represents up to 20% (50%) of the signal variance (EKE) in the lowest variable part of the region, i.e. less than 3 cm² (100 cm²/s²). Comparison between drifter measurements from the SPURS experiment and altimeter regional surface current underlines a better consistency than when considering altimeter global products (see section 4).

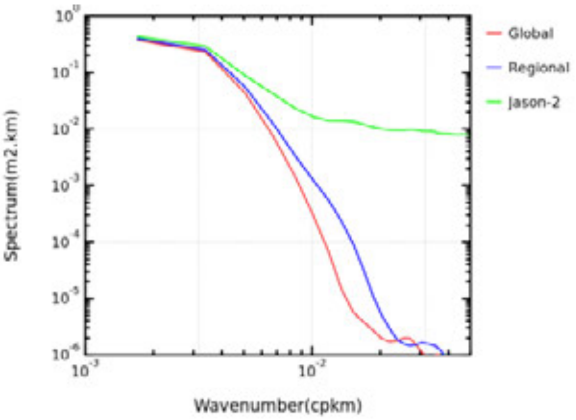


Figure 6: Average Power Spectral Density (m².km-1) for the global gridded MSLA product (red), the regional gridded MSLA product (blue) and Jason-2 unfiltered SLA signal (green) computed between March and December 2013. Gridded products have been interpolated along Jason-2 tracks for the comparison.

Results of the SPURS project

During SPURS, more than one hundred SVP drifters were deployed in the core of the subtropical gyre, a majority of them equipped to measure near-surface salinity as well as temperature and 15-m depth currents (Centurioni et al., 2015). The velocities of these drifters increase considerably the data base of in situ data to estimate an Ekman component by modeling the component of the current that is related directly to the wind. The buoy drifts contribute also significantly to the regional mean currents by combination with altimetric and geodetic data (see part 2.3). Furthermore, the drifter data can be used to directly estimate advection of salinity. Here, we will comment on meridional transport by the eddy component MET that we estimate for three-month long seasons. For that, we group the drifter data between 50°W and 30°W in 0.5° latitude bands. An ensemble average <V> and <S> is then estimated in each latitude band, and MET is estimated as METLD=< (V-<V>)(S-<S>)>, together with its uncertainty (LD stand for Lagrangian estimate from Drifters). These estimates might be biased due to the drifter sampling. This bias effect can be a posteriori tested by comparing the Eulerian estimates of MET (METE averaged on a regular grid and over the same time period) with METLA, which is estimated as for the drifters but with V and S originating from the gridded products interpolated at the drifter positions (LA stand for Lagrangien estimate from Altimetry). To be sure that estimates based on gridded data are reliable, it is important first to compare METLD with METLA. Here, we will comment on the use of the regional altimetric-derived current product to estimate METLA. Further details on the salinity products based on SMOS salinity retrievals (Font et al., 2010; Boutin et al., 2012) that we will use to estimate METLA are provided in a joint paper of this issue (Kolodziejczyk et al., 2015, this issue).

The first question we ask ourselves is how well the regional product succeeds in reproducing the currents. This is done by comparison with the buoy drifts. We first estimated the Ekman component of the buoy drifts, and found that it closely fits to the Rio (2012) model that is used in the current product. In the study, we chose to remove the estimate of the Ekman drift from the buoy drifts and to low-pass filter (at 30 hours) to remove inertial current before comparison with the regional current product. The situation portrayed for early April 2013 (Figure 7) corresponds to days with particularly large buoy drifts reaching up to 0.50 m/s and intense eddy structures that were not very well captured in the global maps. In the regional product, the largest currents are more intense than they were in the global product, albeit still weaker than the largest buoy drifts. Furthermore, the northwestern edge of a cyclonic eddy is intensified as expected from the drifters. Eddy positions or jet-like structures can still be slightly misplaced, but by less than 50 km.

Seasonal statistics of the comparisons to the drifter filtered velocities clearly indicate that a large part of the variability portrayed in the buoy drifts is reproduced by the current product. The residuals are usually smaller than the daily drifter velocities (for the zonal velocity component, rms difference of 0.08 m/s compared with 0.10 m/s in zonal velocity) and are of the same magnitude as the mapped velocities. Compared with the global product, the regional product presents 20% more variance (for colocations to the drifters), and the variance of the differences to the daily drifter velocities is reduced by 8%, which originates from the spring season, which is altogether the season with the most energetic eddies. Thus, not only does the product have mesoscale currents with an energy level closer to the observed one, but it is also often less noisy. We don't have the in situ data to characterize further the error spectra in the mapped current fields. Not surprisingly, however, some of the smallest circulation features are not reproduced, for example, a small cyclonic feature of 50km radius observed during the STRASSE cruise summer survey (Reverdin et al, 2015). Also, some structures are still a little weak, as illustrated on **Figure 7**.

The next step is in the comparison of METLA with METLD. We present one season which has particularly large eddy transport, as well as the annual average (Figure 8). Two estimates are presented, one with the ensemble mean estimated with drifter velocities, and the other with the regional product velocities at the drifter locations, both using the drifter salinities. The two estimates are very similar with similar meridional structures (and with little contribution of Ekman transport which is not included for the regional product velocities). Results for each season show the same level of agreement with no differences exceeding the error estimates.

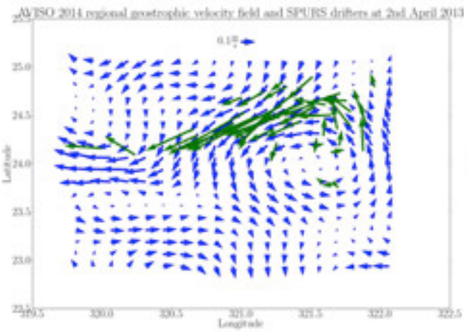


Figure 7:
meso-scale mapped regional currents on April 2 2013, as well as filtered drifter velocities at mid-day of April 1, 2 and 3 (green arrows).

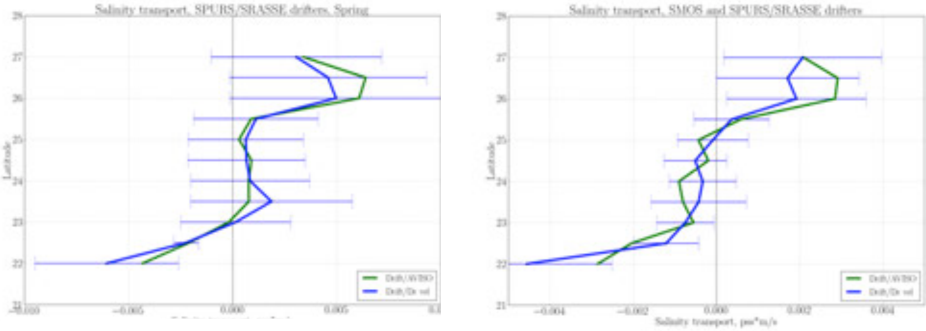


Figure 8:
Meridional profiles of <v'S'> in spring 2013 (May to June) (top) and for the whole year (September 2012 to August 2013) (bottom). Both curves use drifter salinity, either with the drifter velocities or with the regional velocity product collocated at the drifter profiles to estimate the ensemble mean meridional eddy transport at each latitude. Error estimates are provided on the blue curves.

This figure indicates in the spring (and for the annual average) a meridional eddy salt flux divergence, in particular near 22-23°N and near 25-26°N, which would contribute to freshen the region of maximum surface salinity found in between. The drifter data suggest a seasonal dependency in that effect. As results are not very sensitive to the use of regional product velocities instead of the drifter velocities (and also on SMOS-derived salinity, not shown), the mapped currents will be further used to investigate this meridional distribution and its seasonal dependency on the Eulerian grid MET^E.

Conclusion

This study shows how gridded surface current fields (from SLA and MDT) can be regionally improved. Also, it underlines the complementarity of satellite and in-situ data. In-situ data can be used either to validate satellite data or to be merged and improved satellite estimate.

In section 4, the regional gridded surface current field have been validated and used for the computation of the meridional transport by the eddy at the drifter locations. The next step will be to compute and analyzed the transport on the Eulerian grid MET^E.

Acknowledgments

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THE GROOM PROJECT AND THE GLIDER EUROPEAN RESEARCH INFRASTRUCTURE

By L.Mortier [1,2], P. Testor [2], V.Turpin[2]

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The GROOM project: context, objectives and results

The marine environment is overall a complex and turbulent system, characterized by strong interactions between physical, chemical, and biological processes. The study of these processes is difficult because there is a need to measure physical, chemical, and biological parameters simultaneously and the ocean is characterized by a high variability with significant variations over a wide range of spatial and temporal scales (<1km to 1000's km horizontally; <1day to years, decades and more).
At present, our predictive skill for ocean state and climate is mainly limited by our capacity to carry out a sufficient number (well distributed in time and space) of in-situ profiles to be able to characterize the ocean variability from the surface to the bottom, to estimate with accuracy the distribution of heat, salt and other properties in order to predict the ocean evolution based on such an analysis.

A new answer to this problem has come from the technology of autonomous underwater gliders. **That small, intelligent, and cheap ocean observing platforms can fill the gaps left by other observing systems.** These new platforms have been designed to allow continuous and remotely commanded (via two-way satellite link) ocean measurements from the surface down to typically 1km depth at high horizontal and temporal resolution. They can be considered as a "steerable" version of the profiling floats that are deployed in the framework of Argo.

Glider activity in Europe has started in 2004 in the framework of the EU FP5 MFSTEP project and continued with the EU FP6 MERSEA project. Thanks to the creation of the European Gliding Observatories (EGO) group in 2006 and the support from the ES0904 COST Action started in 2010, the European glider activity has been developed through a scientific and technological animation that attracted the glider communities from Australia, Canada and the USA. In parallel, many national projects across Europe have focused on process-oriented studies with one or more gliders and also sustained observations in particular in the coastal-open ocean transition region. As a result, small fleets of gliders have been formed in oceanographic institutions, whilst the technical and scientific skills to operate them and to use the large data fluxes collected by these platforms have started to grow in a distributed way.

But gliders use a two-way communication system, are reprogrammable which allows for a wide range of missions, from the simplest ones to the more complex glider fleet missions, and need periodic refurbishment. These aspects raise a large number of scientific and technological issues which have soon been considered to be addressed in the European Research Infrastructure framework, for the benefit of both fundamental marine research and operational oceanography.
GROOM has addressed these issues as a design study funded by FP-7 Infra 2011-2.1.1. It involved 19 partners and 9 countries across Europe (figure 1). The GROOM strategy was that significant progress would be achieved with a single entity for gliders and land facilities. Based on a number of distributed gliderports, this would allow a better scientific and technological coordination of the European resources, an harmonization of the procedures related to glider deployments, piloting and recoveries, a better definition of rules for access to the gliders, and a data management compliant with the international standards.

The work in GROOM has been organized in four scientific work packages (WPs):

- Integration in the Global Ocean Observing System (GOOS), addressing the sustainability of glider observation in the GOOS by a Glider (dedicated) European Research Infrastructure (GERI),
- Scientific Innovation, to demonstrate that a GERI can efficiently address "frontier sciences" problems,
- Targeted Experiments, to test the feasibility of glider observations for the GOOS and frontier research,
- Observatory Infrastructure, to design the organization of the GERI itself.

Figure 1: Distribution of the GROOM design study partner's

After 3 and a half years of work by the 19 partners, GROOM has successfully demonstrated that

- a distributed architecture of "gliderports" around the European seas and overseas working in close coordination, is the required and cost-effective way to operate fleets of gliders in combination with the existing observing systems,
- this infrastructure is suitable to deploy, maintain and operate an array of several fleets of gliders continuously for operational monitoring and research,
- this infrastructure can provide a world-class service to the research and environment monitoring communities.

Taking into account the existing frameworks for ocean observation and vision statements to organize the European and global capability for ocean observations, the work done by GROOM have brought significant results in particular for:

- the integration of gliders into the existing global and regional/coastal ocean observing systems,
- the Law of the Sea and maritime traffic issues that the glider platforms raise,
- the "frontier research" that gliders and new sensors capabilities can address,
- the exploitation of the open access to glider data as an educational "window" on the oceans and their role in climate and marine resources,
- the use and adaptation of existing data management framework to gather and make available consistent and quality controlled datasets,
- the assessment of the existing legal frameworks and existing RI entities for joint funding and management of the proposed GERI,
- the integration of the proposed GERI in an international network of similar capacities, with the aim of an European leadership.

Role, objectives and functioning of the glider european research infrastructure

The GROOM partners have achieved a comprehensive GERI definition based on the main scientific and technical results of the project. The GERI shall ensure a European capacity to deploy and maintain many gliders at sea 1) for long term sustained observations and 2) to service dedicated scientific process studies or environmental surveys, for public and private organizations. Considering these high level objectives, our studies led to the following common vision. The GERI shall:

- Coordinate, facilitate and optimize the access and use of the available regional and national glider infrastructures and facilities in Europe to guarantee the optimal benefit to the ocean observation community;
- Provide high level services for research (oceanography: ecosystem and climate), operational oceanography (Copernicus Marine Core Service, GOOS) and broader communities involved in marine environmental management;
- Fully endorse the multi-platform observation paradigm through optimal gliders deployments in combination with conventional platforms and existing systems, and in particular those developed by marine ERIC (Euro-Argo, EMSO, EMBRC);
- Initiate and maintain international cooperation with other initiatives on ocean observations. It shall promote and organize this international cooperation in the framework of the Copernicus, GOOS, and GEOSS and contribute to the European Ocean Observing System (EOOS) that is starting to be set up;
- Promote the glider technology to wider communities, its utilization and new technological developments, mostly in cooperation with SMEs in the frame of the marine technology parks where most existing infrastructures are established;
- Participate to the blue growth by creating new knowledge, technologies and services, focusing on social impacts and engaging with local and regional stakeholders.

The GERI will help to coordinate and federate the European glider community and its functionalities will be to:

- Define best practices, protocols and standards for the glider activity (operations in lab and at sea, sensors and data management) and support their evolution
- Develop and share tools for mission planning, piloting, data analysis as well as for the preparation, maintenance, deployment and recovery of the gliders
- Provide access to the gliders and facilities, ensure appropriate outreach to all relevant stakeholders, and support the evolution of its services in line with the scientific and societal needs

These functionalities will be geographically distributed over a central facility and different "gliderports" which actually service the gliders.

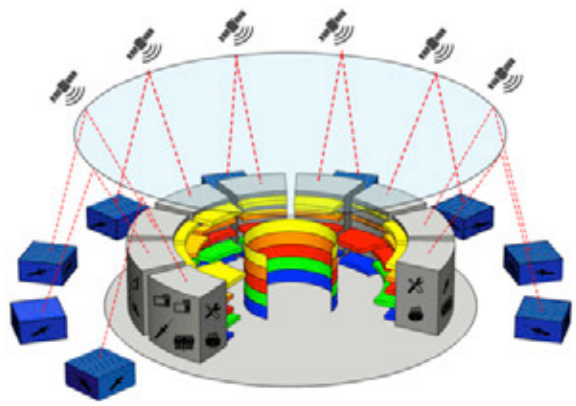

Figure 2: An artistic view of the future GERI organization

Figure 2 describe a network of facilities operating gliders in different areas of the world while coordinated by the central facility of the GERI in the centre, which would be the entry point to GERI users. Facilities are distributed geographically and are different in terms of 1) personnel (scientists/engineers/technicians) and equipment (buildings; pools of gliders, possibly of different types; workshops; computers and communication facilities; access to sea via small/medium/large ships) and 2) developments of the five aspects of the glider activity (mission planning and piloting, operations and maintenance, data management, hardware calibration and maintenance, public relations), as suggested by the different sizes of the inner coloured boxes (yellow, orange, red, green, blue). This figure illustrates the interoperability between the distributed gliderport and the modularity organization concepts that emerged from the GROOM design study. Each specific task associated with each aspect of the gliders activity (different colours) needed for a user of the GERI will be operated by the different facilities composing the GERI, under the supervision of expert groups, providing world-class services, tailored to the needs of the users.

The GROOM design study has demonstrated that this approach based on number of products and services distributed in different locations for a better coverage, and coordinated at the European level by the GERI, is an efficient organization for the glider activities. This presents a lot of advantages in terms of logistics, robustness and costs optimization. Each service shall be managed by one (or more) expert team(s) and could be combined with other services by defining standard interfaces.

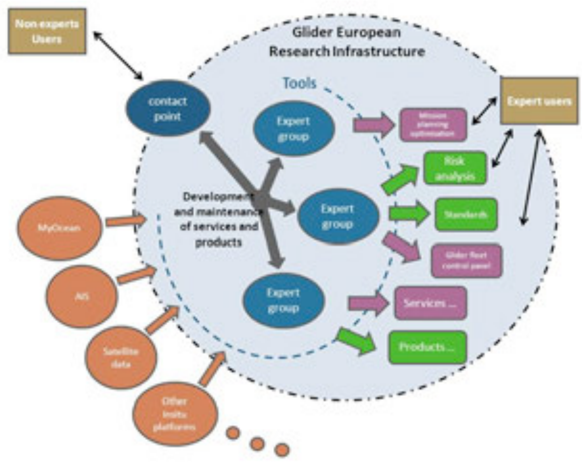

Figure 3: Conceptual design of the modular organization of the software dimension of the GERI.

Figure 3 illustrates that modularity organization concept and the access to the RI.

Many modules (services and products) have already been designed and are or will be soon operational. This concerns the access to specific calibration facilities, mission planning tools, piloting services (fleet coordination, adaptive sampling), data management and analysis. Outreach and communication activities should also be shared and a system to borrow/lend gliders between the partners could be set up to reach a better usage rate. The GERI shall have to develop a compensation system in order to encourage partners to support the modularity functioning.

Public access, international connections, synergies with other Marine Research Infrastructures will be managed by the GERI contact point. The contact point facilitates the interactions with the external users and stakeholders, guides them when needed to the right expert groups, products or services offered by the GERI. The central facility will play this coordination role and will ensure fleet monitoring and endurance lines supervision and can also participate to gliders procurement. It will also ensure that the expertise on all aspects of the glider activity is sustained and further developed.

To ensure high quality access, the GERI shall be promoted in major European entities for marine research and sustained observations, including universities, institutes for fundamental and applied research, marine management agencies, marine clusters and the private sector.
To guarantee its functionalities, the GERI shall have to be a European legal entity, have an office set up governance like in an ERIC. Moreover, this legal status is the unique way to facilitate a number of activities. For instance, part of the European gliders could be purchased through such a central facility and distributed among the "glider ports" to benefit from scale economy or because the legal aspects concerning glider deployments in EEZ waters as well as maritime traffic issues could be better handled.
The membership of the GERI will be open to all entities comprised in the ERIC status, in particular public entities or private entities with a public-service mission. Such entities should be beneficial to the GERI if they are committed for the development and sharing of tools and services that are useful for the gliders activities. It must be emphasized that robots like gliders will evolve a lot in the future and the GERI shall be able to accommodate to these evolutions.
Moreover, GERI must be able to adapt to the evolution of the marine technology landscape in Europe, where major marine clusters which focus on marine robotics are emerging. This could be developed in particular in the framework of European structural funding which is a serious option for helping to fund the hardware or buildings of the GERI in different locations of the main European seaboards and basins and this has to be explored in the next years.

The glider european research infrastructure in the future landscape of marine research infrastructures

European Marine Research Infrastructures will face a deep reorganization in the next decade. The organization into platform-oriented RIs needs to be clarified at a European level. In addition, how platform-oriented RIs will participate in "observatory-oriented" RIs is a major issue. Several stakeholders are investigating such matters but the organization of the Marine Research Infrastructures is still a "hot topic" in Europe.

As demonstrated during GROOM, building a research infrastructure dedicated to gliders is essential in order for this technology to become the main tool to make the link between the open ocean and the coastal area and to complement the GOOS, as well as a tool for discovery and fundamental research. On the other hand, the strength of the gliders comes from their complementarities with the other platforms.

The complementarities between Argo floats and gliders are obvious. Argo floats are dedicated to open ocean and climate research while gliders focus on the transition from open ocean to the coastal shelves. Long term observations carried out by gliders will definitely complement the present Global Ocean Observing System. Synergies between Argo floats and gliders are numerous (cross validation with Argo profiles, filling the gaps left by the Argo array, increase the sampled variables, go deeper). There are also trends toward Bio-Argo floats and more intelligence on board Argo floats with remote control of the sampling behavior. All this, delineates large commonalities between the present EuroArgo ERIC and the future GERI.

Synergies with EMSO (and its water column component developed by the on-going FP7-FIXO3) are also very interesting for ocean science and Observing Systems. First, gliders can replace and supplement moorings when deployed in a virtual mooring mode. Then, moorings face the issue that they provide only time series and ignore the spatial dimension. Considering the oceanic variability, this leads to a difficult interpretation of the measurements and gliders have shown an exceptional capability for solving this problem by criss-crossing around a mooring. Presently, work package 11 of FIXO3 ("Optimization of ocean observing capability") is using "Virtual Observing Network" to work out this question.

The GROOM design study has also highlighted interesting complementarities of gliders with EMBRC for biological observations. Gliders are already and will become more and more interesting tools for biologists. The high modularity of the scientific payload of a glider allows the installation of a great variety of "biological" sensors that can be used to simultaneously sample the physical and biological environments and contextualize their specific measurements.

Regarding Observing Systems, the GERI is already identified as a key component of the observing system in the open ocean and the coastal area and the transition zone in-between (GOOS). In relation with IOOS in the USA, the Canadian glider facilities, and other partners around this ocean, AtlantOS will implement a sustained glider component of the Integrated Atlantic Observing System. Some of the Mediterranean sub-basins have already a sustained glider observing component, and The Mediterranean Sea is often referred as the “paradigmatic” sea for glider observations. It is more than likely that an integrated approach will soon be supported by EC in the Mediterranean, and the GERI will have here the opportunity to show its scientific usefulness and give evidence to its organizational maturity. Last but not least, EuroGOOS and the Marine Board have started the EOOS agenda and the coming years will offer a fantastic opportunity to capitalize on a pioneering glider period of ten years concluded by GROOM.

To progress toward a glider technology better suited for industry needs and to capitalize on the glider effort done in Europe since 2004, several GROOM partners complemented by European SMEs have successfully proposed the BRIDGES project (Bringing together Research and Industry for the Development of Glider Environmental Services) to H2020 in the Blue Growth focus area. BRIDGES will provide deep and ultra-deep gliders and new sensors for frontier science, improved monitoring, and responsible exploitation of the marine environment while assuring its long-term preservation. In addition to the services already offered by state of the art gliders, BRIDGES intends to propose fit-to-purpose glider services to the oil and gas and the deep sea mining industries. BRIDGES is the clear demonstration that the know-how developed by GROOM has produced the appropriate innovation ecosystem with research institutes and industries, which is one of the main roles of European RIs.

Implementation plan for the future glider european research infrastructure

During the relatively short story of gliders in Europe, the European calendar of MRIs has always been ahead of what the glider community could achieve. The glider community was ready for a Design Study only at the end of the FP7 program and thus, the project results were not mature enough to impact the first programming phase in H2020. Now, GROOM has made very substantial progress, but the European glider community is not yet considered as mature enough to join the 2016 ESFRI roadmap.
Despite this, EuroGOOS has first acknowledged the need to help GROOM continuing his work toward a GERI, and a EuroGOOS Glider Task Team has been established to facilitate new progress. Key GROOM partners representing their own glider RI are involved in four H2020 projects: JERICO-Next and ENVRI+ as INFRA project, AtlantOS, and BRIDGES in the Blue Growth focus area. These four projects will also allow the glider community to pursue its organization during the next years. The involvement of glider teams in these EU projects and in several other national glider projects are indeed an adequate context to reinforce some outputs of GROOM, and to further develop its modular organization, making the community mature enough to participate to the 4th update of the ESFRI roadmap project selection in 2017.

The present Memorandum of Understanding signed during the GROOM project by all partners is considered by all as a sufficiently binding agreement to keep the glider community as a whole and being represented by these key GROOM partners. GROOM core partners have to continue to operationally structure the community in order to better show its maturity and to implement the roadmap toward the GERI represented in **figure 4**.

The next two years (2015-2016) will be dedicated to the creation of the main technical conditions for running operationally the Research Infrastructure (data flow, monitoring of the fleet …). In addition, work at the national level for funding commitments to make sustained the existing RI which are not yet sustained, will be continued (e.g. Italy, France, Norway) and may start in other countries (see below).

The second phase of the process (2017-2018) will depend on GROOM partners’ capacity to obtain the agreement of their Research Ministries about the necessity for a GERI. As a main option for this, applying to the 4th ESFRI roadmap update (new RI or major update of an existing one) will require dedicated efforts. In that case, the 2018-2019 H2020 programming phase for the infrastructure preparatory phase will thus be a major step for the GERI implementation. It is also likely that the glider community will be able to answer H2020 calls to consolidate its international dimension as well as a service-oriented dimension in relation with the Copernicus Marine Environment Service.

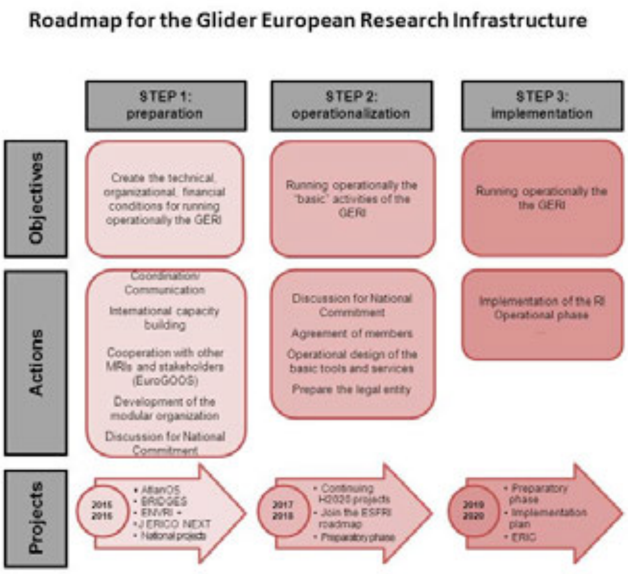

Figure 4: Roadmap for the implementation on the GERI

Conclusion

During the last three years, the GROOM community has studied the feasibility and advantages of a European Research Infrastructure for gliders. This design study has proposed operational contours for a future distributed GERI. A modular organisation where the services and products to be offered by the infrastructure are managed by one (or more) expert team(s) and operated by one (or more) of the distributed facilities, has been proposed.
The creation of a central facility for the coordination of the GERI is also a strong recommendation of the design study. The main roles of the central facility are to ensure networking and communication into and outside the community, to develop international connections for Ocean Observations and to coordinate the community in its day to day activity, and in particular the data flow. Then, depending on the level of integration that will be achieved, the central facility will play additional roles like monitoring the European glider fleet, participating to the data flow to the GDACs and delivering ultimate products to the users, maintaining the work flow between facilities including the compensation between facilities, purchasing new gliders for the partners, contributing to the sustained endurance lines in the framework of the Observing Systems (GOOS, EOOS and its ROOSs), and developing in-depth synergies with other RI (EuroArgo, EMSO) and ocean observing organization (JERICO-next).

The GERI will also foster the collaborations between the “gliderports” and the SMEs. This “Blue Growth” aspect for the creation of European glider sector is a strong argument for the GERI. This has been well demonstrated by the successful H2020 BRIDGES project which is a direct output of the role of the GROOM coordinator and the Stakeholder Open Forum activities during GROOM. A GERI that could include a strong partnership with the private sector, which could include SMEs as GERI partners, is considered as the best solution to answer the needs of a broader audience, and to help emerge new markets.

The financial model to build the infrastructure will be based on national commitments, monetary contributions from the partners through projects and service access funding procedures. In the end, like for any European RI, no European money will be necessary for running the infrastructure. However, the first steps of the implementation of a GERI will have to be supported by European projects. Institutions and existing RIs will continue to purchase and operate gliders on their own but today the development of the capacities of the consortium needs some dedicated funding at the European level, and possibly at the regional level.

List of acronyms

BRIDGES: Bringing together Research and Industry for the Development of Glider Environmental Services

EC: European Commission

EEZ: Exclusive Economic Zone

EGO: European Glider Observatories (or Everyone’s Gliding Observatories)

EMBRC: European Marine Biological Resources Centre

EMSO: European Multidisciplinary Seafloor and water column Observatory

EOOS: European Ocean Observing System

ERIC: European Research Infrastructure Consortium

ESFRI: European Strategy Forum on Research Infrastructure

GDAC: Global Data Assembly Center

GEOSS: Global Earth Observation System of Systems

GERI: Glider European Research Infrastructure

GOOS: Global Ocean Observing System

IOOS: Integrated Ocean Observing System (USA)

GROOM: Glider for Research, Ocean Observations and Management

MRI: Marine Research Infrastructure

ROOS: Regional Ocean Observing System

RI: Research Infrastructure

SME: Small and Medium Enterprise

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