E-AIMS

EURO-ARGO IMPROVEMENTS FOR THE COPERNICUS MARINE SERVICE

SEVENTH FRAMEWORK PROGRAMME

PROJECT CONTEXT AND OBJECTIVES

In November 2007, the international Argo programme reached its initial target of 3,000 profiling floats. These floats measure temperature and salinity throughout the deep global oceans, down to 2,000 meters. Argo is the first-ever global, in-situ ocean-observing network in the history of oceanography, providing an essential complement to satellite systems.

Argo delivers critical data for assimilation in ocean analysis and forecasting systems. Float technology is evolving to include new sensors and new capabilities that are essential for climate change research and for the Copernicus Marine Environment Monitoring Service (CMEMS).

The Euro-Argo research infrastructure organizes and federates European contribution to Argo (www.euro-argo.eu). Euro-Argo is a legal entity (Euro-ERIC) which was officially set up in May 2014. It allows European countries to consolidate and improve their contribution to the International Argo Program.

The main challenges for Argo and Euro-Argo are:

- to maintain the global array and ensure its long term sustainability
- to prepare the next phase of Argo with an extension towards biogeochemistry, the polar oceans, the marginal seas and the deep ocean (below 2,000 meters).

In that context, the following activities have been carried out as part of the E-AIMS FP7 project:

- R&D on float technology
- Impact and design studies for CMEMS
- Impact of Argo observations for the validation of satellite observations
- R&D on the Euro-Argo data system and interfaces with CMEMS
- Real time processing, assessment and impact

A NEW EUROPEAN RESEARCH INFRASTRUCTURE CONTRIBUTING TO THE ARGO INTERNATIONAL PROGRAM

- **12 COUNTRIES**
- **25 ORGANISATIONS**
- **250 PEOPLE**

R&D ON FLOAT TECHNOLOGY

The objective was to test several new profiling floats which had been recently developed, and were available from float manufacturers. An end-to-end test for the following new floats was carried out: floats with oxygen and biogeochemical sensors, deep floats, floats with two way communication capabilities and Arctic floats. 1

ARVOR APEX NAVIS NEMO PROVBIO DEEP ARVOR

1 NEW ARGO FLOATS TESTED AT SEA AS PART OF E-AIMS.

Test of oxygen sensors

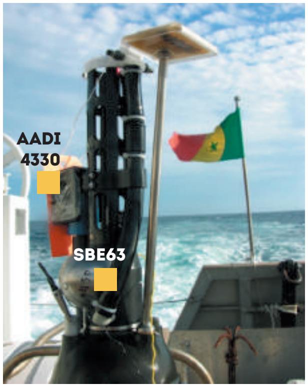
The purpose was to compare the performance of the Aanderaa optode (model 4330) and the Seabird optode (SBE63). The two sensors were mounted on three Navis floats (Seabird manufacturer) and two Arvor floats (NKE manufacturer). The Navis floats were deployed in the OMZ region (off the West African coast), whereas the Arvor floats were launched in the North Atlantic. All the sensors were calibrated with in-situ measurements at deployment.

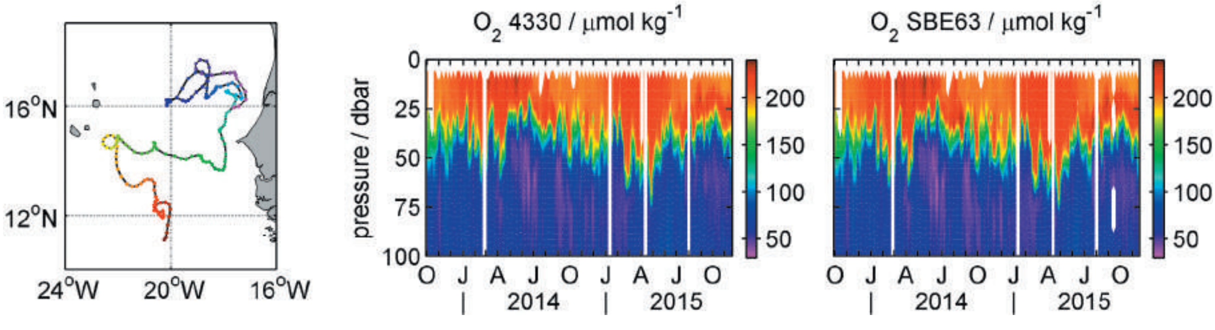
The two Navis floats and one Arvor float showed very good results after several months of working at sea. However, the SBE63 sensor of the first Arvor failed during the first descent at depth (the float was recovered in September 2015).

The SBE63 is integrated in the pump flow path of the CTD. It exhibits a better time-response than the 4330 and better renders the gradients in the profile. Overall, however, the effect is small.

Oxygen measurements were made in air with the Aanderaa optode 4330. This was used for calibration. Combined with pressure correction for oxygen optode calculations, it considerably improved the data accuracy and the stability of the data.

These experiments demonstrated that by making reference measurements at deployment, implementing in-air measurements and by taking into account a few minor improvements, both floats fitted with the Aanderaa 4330 optode can lead to a fully operational solution for Argo. This could also be the case in the future if in-air measurement and pre-aging of the foils can be performed with the SBE63 optode. 2



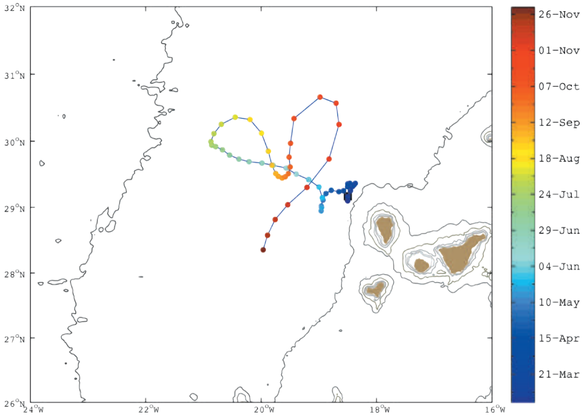


2 OXYGEN PROFILES MEASURED WITH THE AANDERAA AND THE SBE63 OPTODES FOR THE NAVIS FLOAT F0271.

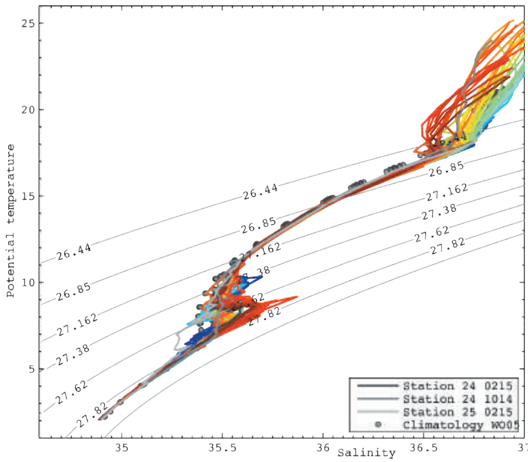
Deep floats

The objective was to test a float able to perform profiles down to 4,000 m depth. The new "Deep-Arvor" model from NKE was used, fitted with a SBE 41CP-CTD. One float was deployed close to the Canary Islands in early 2015 3. By early November, the float had done 51 profiles at 4,000 dbar 4 5. The regularity of the cycles along time, the stability of the float at parking depth and the quality of data transmission were very satisfying. The Deep Arvor was easy for the end-user to program and test for deployment and also to reprogram via the Iridium transmission system. Regarding the SBE41CP sensor, the temperature measurement was very good whereas the salinity showed a fresh water bias and a constant drift. The fresh bias was not pressure dependent and could be corrected for after calibration.

3 DEPLOYMENT OF THE DEEP ARVOR BY IEO.



4 TRAJECTORY OF THE E-AIMS DEEP ARVOR FLOAT.



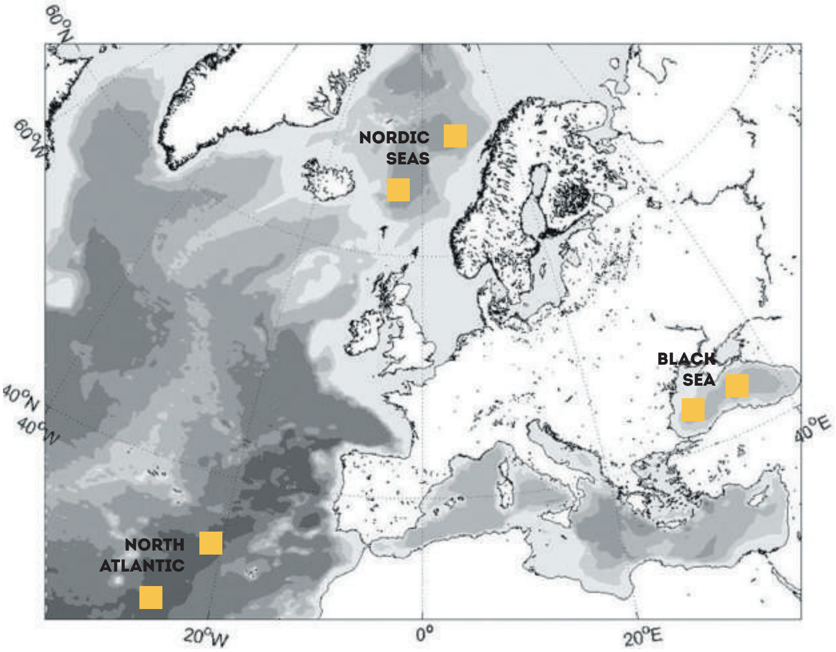
5 POTENTIAL TEMPERATURE / SALINITY DIAGRAM AFTER CALIBRATION.

To complement this analysis, results of another experiment that used three Deep-Arvor floats (NAOS French project) were used. NAOS Deep Arvor floats have had excellent behaviours. A particularly impressive result was obtained: one of the floats achieved 142 cycles between 3,500 to 4,000 m with oxygen measurements and with its CTD pump running continuously.

These results show that Deep Argo floats are now a very reliable and robust solution for operational implementation. Some issues remain on the quality of CTD measurements but these are not pressure dependant and can be corrected thanks to delayed mode quality control procedures.

Test of new biogeochemical floats

The biogeochemical float experiment was carried out by deploying six Argo floats with biogeochemical sensors (NKE Provor Bio-Argo floats) in three different regions with different physical, chemical and biological conditions 6: two floats in the Nordic Seas, two floats in the Atlantic Ocean, and two floats in the Black Sea. The floats were equipped with the Seabird 41CP for pressure, salinity, temperature, an Aanderaa optode 4330 for dissolved oxygen and a Satlantic optical pack named "Rem-A" for irradiance, Chl-A and backscattering (bbp) with two channels (532 and 700 nm). The two bbp-channels allow us to estimate the spectral dependency of bbp: an increase of the ratio bbp (532): bbp(700) is related to an increase in the concentration of small versus large particles.

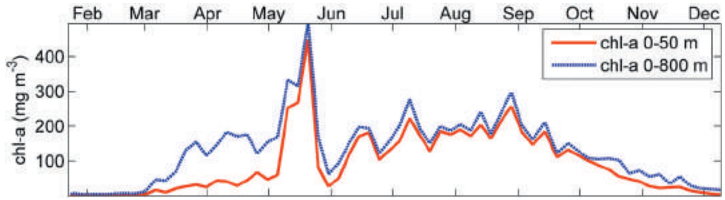


6 6 PROVOR BIO-ARGO FLOATS WERE DEPLOYED:

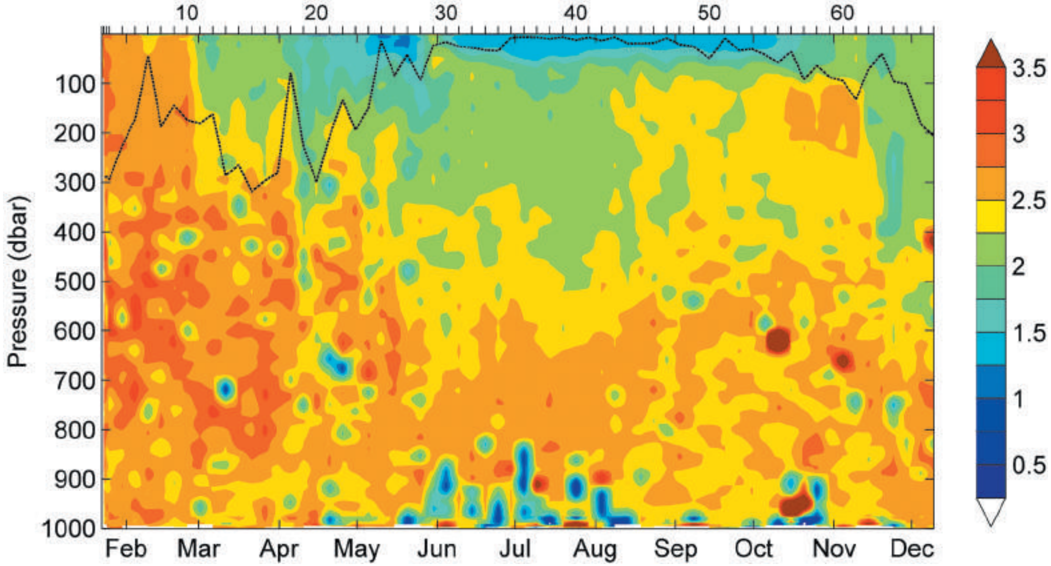
2 FLOATS IN THE NORDIC SEAS BY IMR IN NOVEMBER 2013 AND JANUARY 2014.

2 FLOATS DEPLOYED IN THE ATLANTIC OCEAN BY UKMO/PML IN OCTOBER 2013.

2 FLOATS DEPLOYED IN THE BLACK SEA BY IOBAS USOF IN DECEMBER 2013.



7 **VERTICAL SUM OF CHLOROPHYLL-A FLUORESCENCE IN THE UPPER 50 AND 800 M.**



8 **RATIO OF PARTICULATE BACKSCATTERING (BBP532:BBP700) AS A FUNCTION OF DEPTH AND TIME. THE SOLID BLACK LINE IS THE MIXED-LAYER DEPTH.**

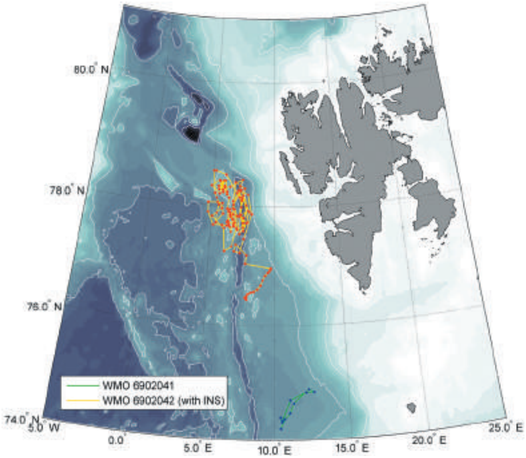
The measurements for the Norwegian Sea detected the vernal phytoplankton bloom as well as the relative abundance of small versus large particles (i.e., the ratio of bbp (532): bbp (700)). Small particles peaked in winter when phytoplankton were essentially absent from the water column (spectral bbp ratio is at its maximum in January-February). In March the relative abundance of large particles started to increase within the mixed layer as the bloom started (bbp ratio decreased). The abundance of large particles relative to small particle was largest in the productive layer during spring and summer when the bloom still existed, and increased also in the mesopelagic layer as the summer advanced. 7 8

New satellite communications on floats

Argo floats with Iridium and Argos-3 communication were tested. Both telemetry systems turned out to be capable of changing, as needed, the mission parameters of the floats. As a result, they can be used effectively on more Argo floats in order to improve the reliability or sustainability of Argo, especially for applications related to the CMEMS. In the North Atlantic both Webb Apex and SeaBird Navis floats, using Iridium Rudics, were tested. The Rudics downlink was successfully tested to change the float cycle time (10 days to 5 days) and profile resolution (to high resolution over the whole profile) and to programme the float to surface around mid-afternoon to maximize the probability of measuring near surface stratification. In the Mediterranean Sea, tests with two NKE Arvor floats have demonstrated that Argo profiles can be transmitted successfully on a single Argos-3 satellite pass during 3-8 minutes only. The Argos-3 downlink was tested to change the float cycle time (2 to 5 days). **9**

9 DEPLOYMENT OF THE E-AIMS FLOAT (ARVOR FLOAT / ARGOS-3) FROM R / V SOCIB ON 25 MAY 2014.

Test of new Artic floats



10 TRAJECTORIES OF THE TWO E-AIMS ARCTIC FLOATS DEPLOYED SOUTH AND WEST OF SPITSBERGEN IN JULY 2014.

Two Nemo Arctic floats were deployed by IOPAS. These floats were adapted to operate in ice covered areas by using an ice sensing algorithm and a hardware protection against shocks, and by postponing data transmission in case of ice detection. One of them was fitted with a new Inertial Navigation System (INS) that was developed for this experiment. Its purpose was to compute the trajectory of the float at depth. One of the two floats showed a good behaviour and delivered good T & S quality data. It was also remotely controlled by a two way Iridium communication. It was still working in early November 2015 (109 profiles) where it was situated not far from the Arctic Ocean drifting sea ice. The data transmitted from the INS system showed that it was not sufficiently sensitive to provide accurate position under ice and should be improved. **10**

MAIN ACHIEVEMENTS FROM E-AIMS R&D ON FLOAT TECHNOLOGY

- In-depth laboratory and at sea characterization of two oxygen sensors were carried out. It was shown that oxygen measurements could be considerably improved by adding in-air measurements when the float is at the surface. Thanks to these tests and improvements operational monitoring of oxygen with Argo floats can now be implemented.
- Tests of several deep floats showed that these floats are ready for operational implementation; they also highlighted the issue of the quality of sensor (CTD) measurements in the deep ocean.
- The successful test of several Bio-Argo floats demonstrated the maturity of the float technology, even though some work remains to be done on validation of the different sensors.
- Use of the two satellite communication systems (Iridium, Argos-3) demonstrated the feasibility and benefits of these improved telecommunication techniques (reduced transmission time, two way communication).
- The test of Arctic floats showed the feasibility but also the inherent technological limitations of navigating in ice covered regions.

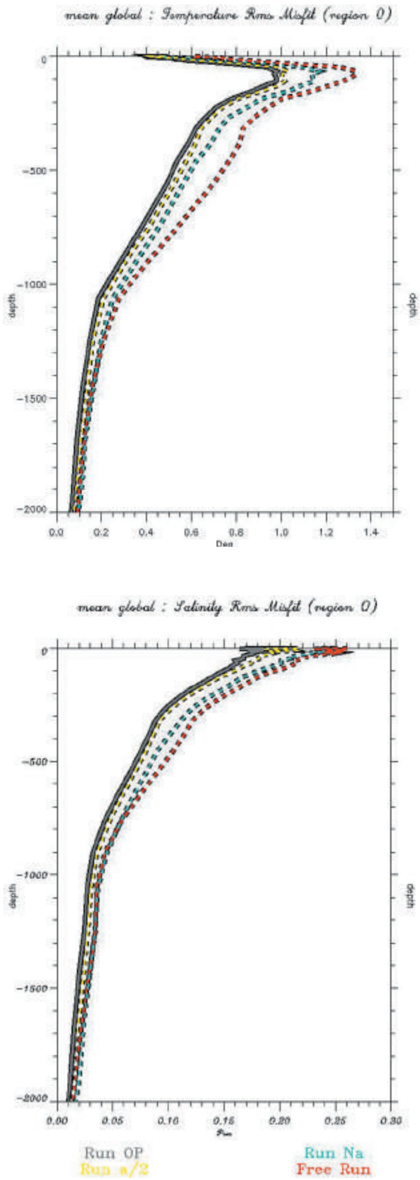
IMPACT AND DESIGN STUDIES FROM THE COPERNICUS MARINE SERVICE MODELING AND FORECASTING CENTERS

The main objective was to perform Observing System Evaluations (OSEs) (with real data) and Observing System Simulation Experiments (OSSEs) (simulate and assimilate observations to test new observing capacities) with the CMEMS assimilative systems to assess the potential of Argo and its extensions.

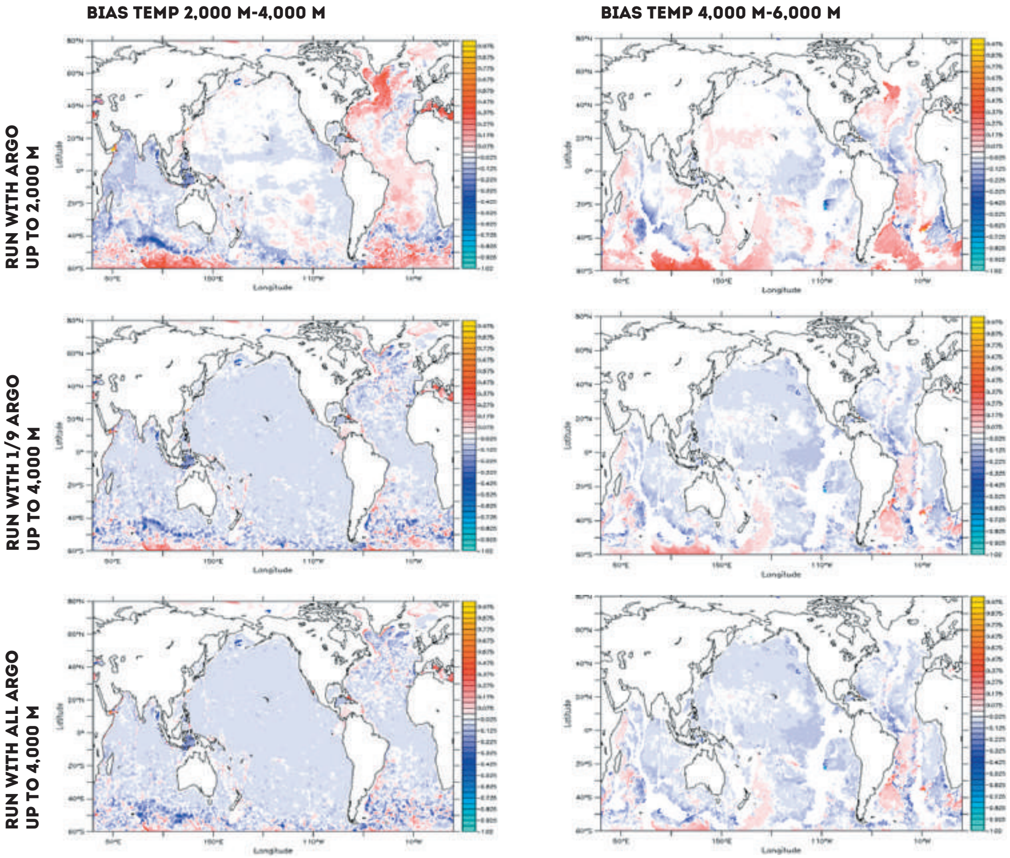
Impact of Argo on the Mercator Ocean global ocean analysis and forecasting system

A one year OSE with the Mercator Ocean global ¼° ocean analysis and forecasting system showed that the present Argo coverage allows a significant reduction of the model-observation misfit at all depths down to 2,000 meters compared to a simulation without Argo data assimilation **11**. Using only half of the floats significantly degraded the results.

The ocean deeper than 2,000 m is nearly unobserved. Measurements are required to validate and control model temperature and salinity fields below 2,000 m, which tend to drift away from climatological fields. The impact of deep measurements was estimated with simulated observations (OSSE); a coarse array (1/9 of the Argo coverage) with 4,000 m depth profiling capability significantly reduced deep model biases **12**.



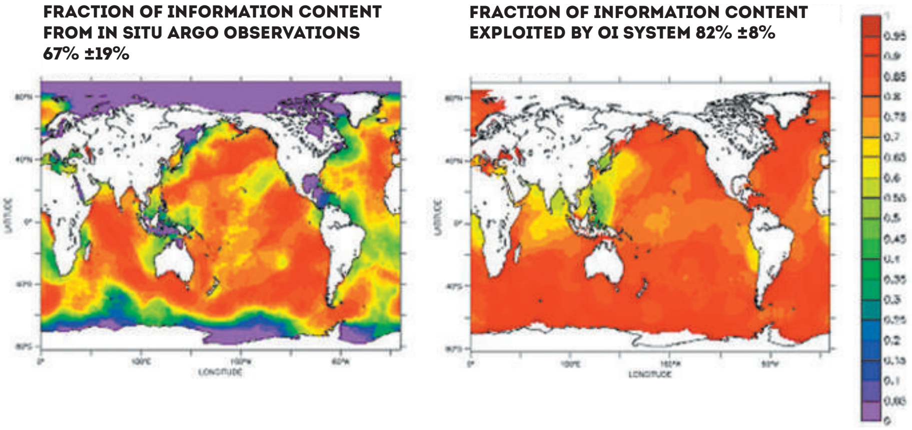
11 RMS OF TEMPERATURE AND SALINITY INNOVATIONS (MODEL FORECAST MINUS OBSERVATIONS) FROM 0-2,000 M FOR RUN-REF (GREY) (ALL DATA ASSIMILATED), RUN-ARGO2 (YELLOW) (HALF OF THE ARGO DATA ASSIMILATED), RUN-NOARGO (BLUE) AND FREE RUN (RED) OVER THE LAST SIX MONTHS OF THE EXPERIMENTS DONE WITH THE GLOBAL MERCATOR OCEAN ANALYSIS AND FORECASTING SYSTEM.



12 MEAN DEEP OCEAN TEMPERATURE ERRORS IN THE DIFFERENT DEEP ARGO OSSES CARRIED OUT WITH THE MERCATOR OCEAN GLOBAL OCEAN ANALYSIS AND FORECASTING SYSTEM FOR TWO DIFFERENT DEPTH RANGES: 2,000-4,000 M (LEFT) AND 4,000-6,000 M (RIGHT).

Impact of Argo on the CLS multivariate data analysis system

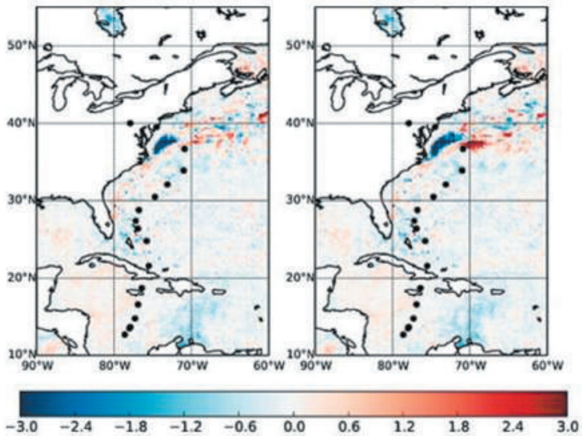
CLS has developed a multivariate data analysis system that merges satellite (altimetry and sea surface temperature) and in situ observations through linear regression and optimal interpolation (ARMOR3D). The ARMOR3D system was used to assess the impact of Argo observations to map temperature and salinity fields with satellite observations using Degree of Freedom of Signal (DFS) diagnostics. DFS provides a measure of the gain in information brought by the observations. When three datasets are considered: Argo, other in situ and satellite, results for the temperature field show that most of the information comes from the Argo observing system (67%) and that almost no redundancy is found in the Argo dataset. **13**



13 DFS METRICS FOR THE TEMPERATURE FIELD AT 100 M OF THE 04/06/2008 ANALYSIS (65°S-65°N MEANS +/- 1 STD ARE ALSO INDICATED) (UNITS: X100%)

Impact on the UK Met Office global ocean/atmosphere coupled system

Coupling atmosphere and ocean models is mandatory on seasonal to decadal prediction time-scales, but the importance at shorter time-scales has not been extensively assessed. The development of short-range coupled prediction systems at the UK Met Office, which assimilate data into both ocean and atmosphere components of the coupled model, provided the first opportunity to assess the potential for Argo to improve weather forecasts. Using an Observing System Experiment, the effect of assimilating Argo profiles on coupled analyses and short-range forecasts was analysed. The atmosphere observation-minus-analysis statistics showed negligible systematic global impacts, although this was not unexpected due to the assimilation of all available atmosphere and SST observations in both experiments. However, case study forecasts of Hurricane Sandy highlighted that the assimilation of Argo profiles has an impact on the analysed position of the Gulf Stream with consequent impacts on atmospheric forecasts after the hurricane passes over the Gulf Stream. **14**



14 THE MEAN SST OBSERVATION-BACKGROUND DIFFERENCES (K) BINNED TO 0.25º FOR THE CONTROL (LEFT) AND NO-ARGO EXPERIMENT (RIGHT) OVER THE PERIOD 22-30 OCTOBER 2012. THE BEST-TRACK POSITIONS OF HURRICANE SANDY ARE SHOWN EVERY 12 HOURS.

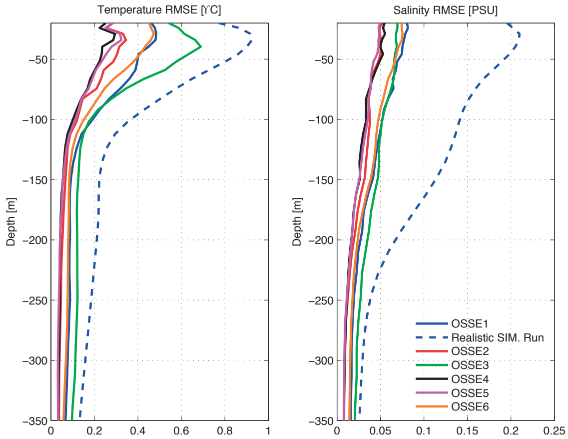
Impact on the KNMI decadal forecasting system

Decadal predictions were performed by KNMI using the EC-Earth model with full-field initialization. The aim was to investigate the impact of the geographic distribution of observations on the skill of decadal climate forecasts by artificially changing the initial conditions. As these observation-based fields are not compatible with the model climatology, the model starts, however, to drift away from the initial condition towards its own climatology. After subtraction of the drift, no useful signal is left. In the ocean the drift signal is much larger than the model's internal variability, and the drift is discernible over several years. In contrast, the drift in the atmosphere is small and of short duration. It is obviously not caused by the large drift in the ocean. These results cast doubts on the feasibility of decadal predictions, as the assumed mechanism (the large oceanic heat content that systematically influences the atmosphere) is not working, at least in the EC-Earth model.

Impact on the INGV Mediterranean Sea ocean analysis and forecasting system

Argo was shown to have strong impact on analyses and forecasts of the INGV Mediterranean analysis and forecasting system.

Different possible modifications to the real Argo network were tested through a series of OSSEs, changing for each experiment the parking depth (PD) (deeper or shallower than 350 m), the surfacing time (3 and 5 days) and vertical sampling. Results show a positive impact when reducing the surfacing time to three days or simulating 700 m parking depth. Perfect vertical sampling reduces the RMSE all along the water column. Full profile transmission could be considered also as a major improvement for the Mediterranean Sea. 15



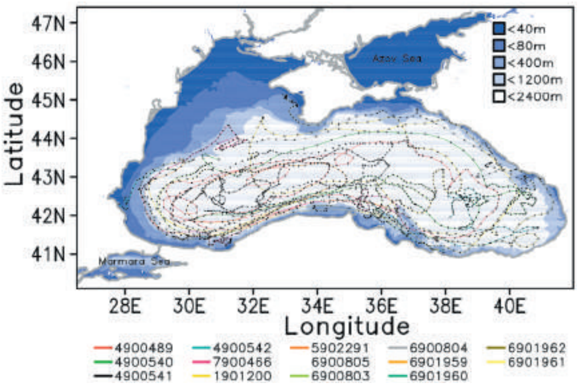
15 RMSE OF THE ARGO MISFIT DURING THE 2012 FOR ALL THE MEDITERRANEAN SEA. BLUE LINE OSSE1 (5 DAYS DRIFT, PD 350M), RED LINE OSSE2 (5 DAYS DRIFT, PD 700M), GREEN LINE OSSE3 (5 DAYS DRIFT, PD 150M), BLACK LINE OSSE4 (3 DAYS DRIFT, PD 350 M) MAGENTA LINE OSSE5 (3 DAYS DRIFT, PD 700M) AND ORANGE LINE OSSE6 (5 DAYS DRIFT, PD 350 M, PERFECT VERTICAL SAMPLING).

Impact on the Black Sea USOF ocean analysis and forecasting system

An observing system in the Black Sea combining remote sensing data such as sea level anomalies from altimetry, sea surface temperature from satellite radiometers and data from Argo floats has been analyzed by the USOF with the aim of quantifying the contribution of different information sources when reconstructing the ocean state. Of particular importance for the Black Sea, where the circulation is largely dependent on horizontal and vertical salinity gradients, is that there is no alternative to Argo data, which can be used operationally.

Experiments with different deployment strategies demonstrated that increasing the amount of Argo floats performs better than increasing the frequency of surfacing. Without Argo data the estimates in the upper mixed layer suffer from large errors. However profiling float measurements are especially important for depths below the seasonal thermocline because the transition from thermo-to-haline-dominated stratification shows only short spatial covariance length-scales.

One major conclusion from this research is that the present abundance 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. 16



16 TRAJECTORIES OF THE ARGO FLOATS USED IN THE ANALYSIS IN THE BLACK SEA.

MAIN ACHIEVEMENTS FROM E-AIMS IMPACT AND DESIGN STUDIES

There is a high dependency of Copernicus Marine Environment Monitoring System (CMEMS) with respect to Argo. Argo floats are mandatory to complement satellite observations to constrain CMEMS global and regional ocean analysis and forecasting systems. Based on E-AIMS results, the following recommendations can be given:

- The Argo observing system should continue to equally sample the entire world ocean.
- The existing global spatial and temporal coverage of Argo network should be maintained and possibly improved in regions of high mesoscale variability (e.g. western boundary currents).
- Higher space/time sampling and higher vertical resolution is required for the Mediterranean and Black Seas.
- Deeper measurements are needed to control model temperature and salinity fields. If 1/3 of Argo floats profiled down to 4,000 m on one cycle out of every three, the deep model biases would be significantly reduced.

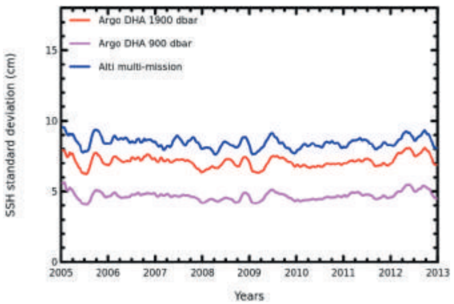
IMPACT OF ARGO OBSERVATIONS FOR THE VALIDATION OF SATELLITE OBSERVATIONS

A comprehensive analysis of the impact of Argo observations for the validation of satellite observations (sea level, ocean colour, sea surface temperature, and sea surface salinity) was carried out.

Altimetry

The comparison of altimetry with Argo data allows the detection of drift, jumps or anomalies in the altimeter measurements and the assessment of the impact of new altimeter standards in the Sea Level computation. Within the E-AIMS project, a better characterization of the sensitivity of altimetry validation to Argo data and their processing was carried out.

The detection of the altimeter drift and the quality assessment of new altimeter standards or products are highly sensitive to the choice of the reference level used to compute dynamic height from Argo **17**. For most situations of altimeter quality assessment, Argo profiles should be extended to deeper levels.

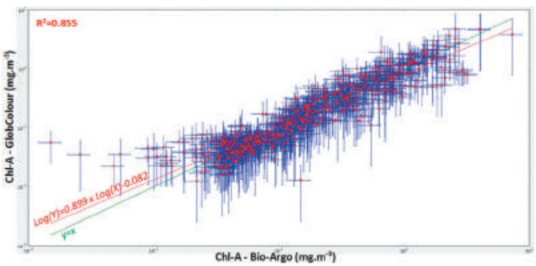


17 **STANDARD DEVIATION OF THE ALTIMETER SLA (BLUE) AND THE IN-SITU DYNAMIC HEIGHTS FROM ARGO PROFILES WITH A 900 DBAR REFERENCE (MAGENTA) AND 1,900 DBAR REFERENCE (RED) IN THE ANTARCTIC CIRCUMPOLAR CURRENT.**

Ocean Colour

Space agencies usually calibrate and validate their ocean colour measurements using very few static but perfectly calibrated buoys. With the arrival of Bio-Argo floats, this philosophy might change. Such a wide network of profiling measurements is unique and the quality of these measurements is very promising.

As part of E-AIMS, ACRI-ST has compared Chl-a satellite measurements with Chl-a from Bio-Argo (integrated over the upper layer); results **18** show a good correlation. The large number of matchups available promotes Bio-Argo as a highly competitive network for calibration and validation of remote sensing. Moreover, Bio-Argo floats are likely to become the keystone to connect the 2D perspective offered by remote sensing to 3D biogeochemical models. This is of prominent importance for a better monitoring of our oceans.



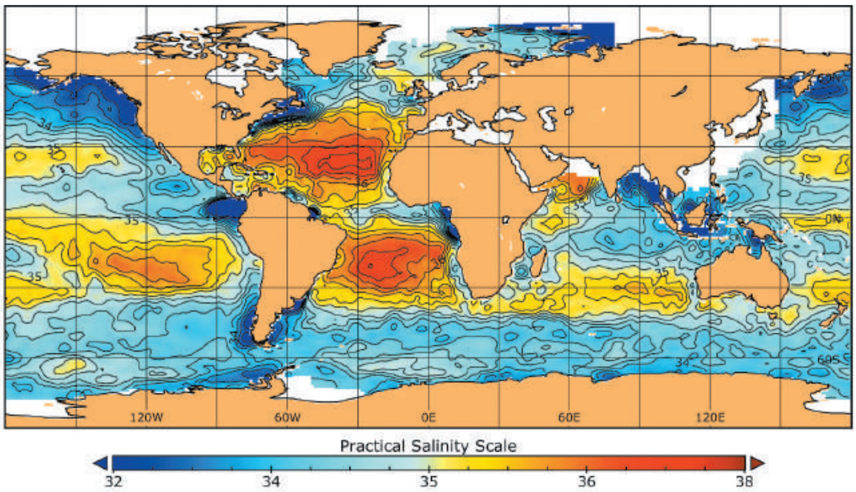
18 **COMPARISON OF BIO-ARGO AND SATELLITE CHL-A OBSERVATIONS (875 MATCHUPS).**

Sea Surface Temperature

An assessment of sampling requirements for the use of Argo to validate SST in daily in situ/satellite analyses has been carried out. It shows that the distribution of Argo floats should be maintained in order to allow their use for regional validation of SST analyses to continue on a monthly basis. An increase in the number of near-surface Argo observations would be required to validate SST analyses on weekly or daily frequencies. Routine monthly validation of OSTIA SST products (part of the CMEMS portfolio) using Argo has also now been set up.

Sea Surface Salinity

Validation of remotely sensed SSS strongly relies on Argo data because it is the only component of the ocean observing system providing near-global, all-weather, reliable estimates of the in situ salinity. The differences between three SSS products generated at SMOS-Barcelona Expert Centre and near-the-surface (no deeper than 10 m) Argo salinity measurements have been studied here. These differences reflect the inherent limitations of the remote sensing technology but also other geophysical sources of errors. Robust estimates of the rms differences between SMOS and Argo have been found to be 0.29 and 0.23 depending if matchups lie in the 60S-60N or 30S-30N latitude bands respectively. A slight negative bias (SMOS fresher) has been systematically found. 19



19 SEA SURFACE SALINITY - 1X1 OPTIMAL INTERPOLATION MAP - 17/26 FEBRUARY, 2012 - BEC PRODUCT

MAIN ACHIEVEMENTS FROM E-AIMS SATELLITE VALIDATION ACTIVITIES

E-AIMS demonstrated the fundamental role of Argo observations for the validation of sea level, sea surface temperature, ocean colour and sea surface salinity from space. This is a major asset for the validation of the Copernicus satellites (e.g. Sentinel-3A and 3B). The following recommendations can also be given:

- Speed up of the scientific calibration process of Argo data so that more high quality observations are available for satellite validation activities.
- Increase the vertical extent of Argo profiles to deeper depths (> 2,000 m).
- Increase the number of measurements in the upper four meters of the ocean.
- Increase sampling in regions of high variability.
- Optimise the matchup strategy for Bio-Argo floats (e.g. program floats to maximize the number of matchups with ocean colour satellites).

INTERNATIONAL OSE/OSSE WORKSHOP ORGANIZED JOINTLY BY GODAE OCEANVIEW, GSOP/CLIVAR AND E-AIMS

The workshop was held in Toulouse in December 2014. It was an excellent opportunity to present and discuss the final results of E-AIMS design and impact studies with the wider scientific community.

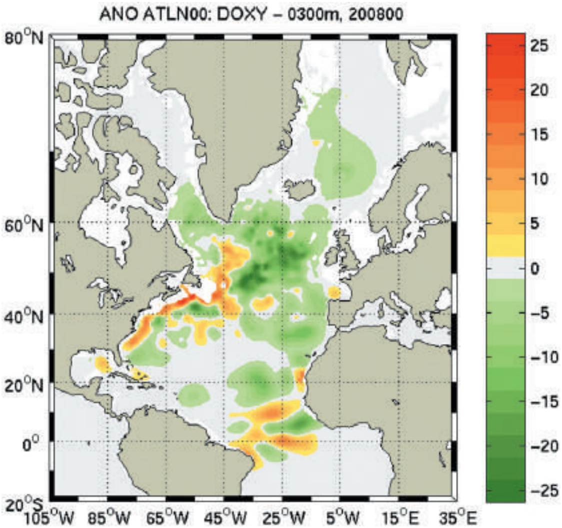
PRESENTATIONS AND WORKSHOP REPORT AT
www.godae-oceanview.org

20 ATTENDEES OF THE GODAE OCEANVIEW, CLIVAR GSOP AND E-AIMS WORKSHOP.

R&D ON EURO-ARGO DATA SYSTEM AND REAL TIME PROCESSING OF NEW ARGO FLOATS

Define, prototype and test data processing techniques for oxygen variable

The real-time and delayed-mode procedures to quality-control oxygen data measured by Argo floats was defined and implemented. Existing methods for delayed mode QC are based on adjustments from climatology, from reference calibrated in situ data and from measurements acquired in the air. The first method is useful when in situ or "in air" measurements are not available. Using reference in situ data provides much better results, especially in areas where the climatology is not well defined or subject to large inter-annual variability, but cannot be used to correct sensor drift. It is now highly recommended to acquire "in air" measurements because it allows correcting sensor drift and bias. The optimal interpolation tool ISAS initially developed for temperature and salinity data was adapted to oxygen data. This tool is useful for a careful secondary quality control procedure and for interpolating data on isobaric levels. 21



21 DISSOLVED OXYGEN CONCENTRATION ANOMALY AT 300 M DEPTH COMPARED TO THE WOA09. ALL ARGO OXYGEN DATA AVAILABLE AT CORIOLIS GDAC WERE INTERPOLATED WITH ISAS TOOL.

Define and test data processing techniques for other biogeochemical variables

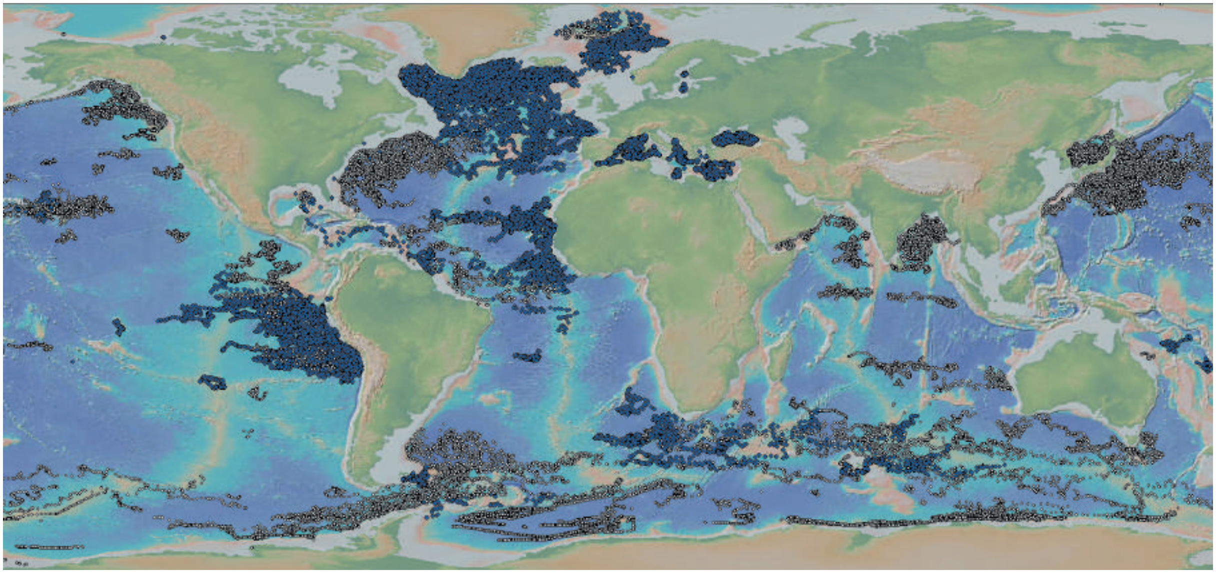
The real time QC applies basic tests about data format, consistency of measurements, concentration at high depth and some other physical components. These tests are applied as soon as the data are received by the processing centre. The delayed mode QC consists in a more comprehensive analysis of profiles that should be performed few times a year. Correlation between profiles performed at a short time range, analysis of noise along the profile or comparison to remote sensing measurements (ocean colour) are, for example, performed.

Develop the Euro-Argo DACs for the new Argo floats

The two Euro-Argo DACs (Ifremer/Coriolis and BODC) upgraded their processing chains to process bio-Argo floats, deep floats and high resolution surface profiles coming from multiple float providers. For Bio-Argo data management, Ifremer/Coriolis and BODC took a leading role in the definition of Bio-Argo data format at the Argo Data Management Meeting (ADMT) in Liverpool (2013) to reach an international agreement.

Real time data processing of new Argo floats

Data from the new E-AIMS floats were processed in real time using the updated processing chains set up as described above. Both BODC and Ifremer/Coriolis processing chains were turned to operation and the data delivered to the Argo DACs. The real time QC procedures for oxygen and chlorophyll were also turned into operation and applied not only to the E-AIMS floats but to all European floats measuring those parameters. 22



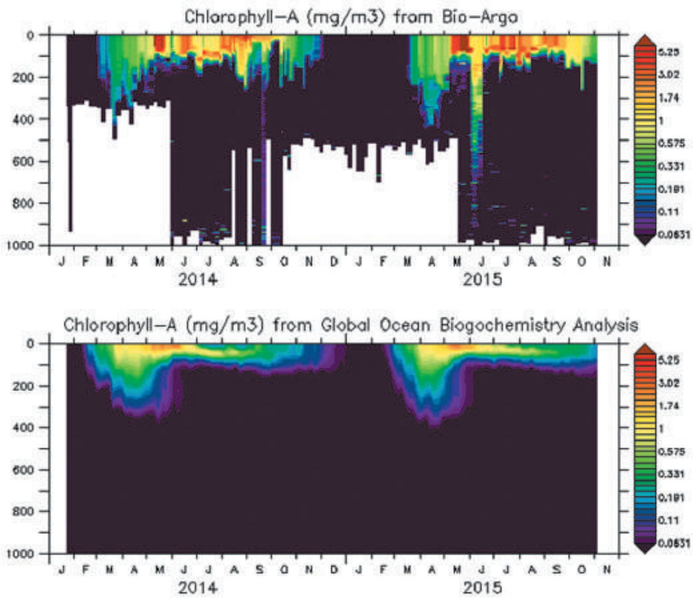
22 MAP OF THE 294 BIO-ARGO FLOATS DEPLOYED BY E-AIMS AND OTHER EUROPEAN PROJECTS (BLUE DOTS). THE OTHER BIO-ARGO FLOATS (USA, AUSTRALIA, JAPAN, CANADA, INDIA) ARE SHOWN AS GREY DOTS. BIO-ARGO FLOATS MEASURE PARAMETERS SUCH AS OXYGEN, CHLOROPHYLL, NITRATE, PH, BACK-SCATTERING, RADIANCE, IRRADIANCE AND PAR.

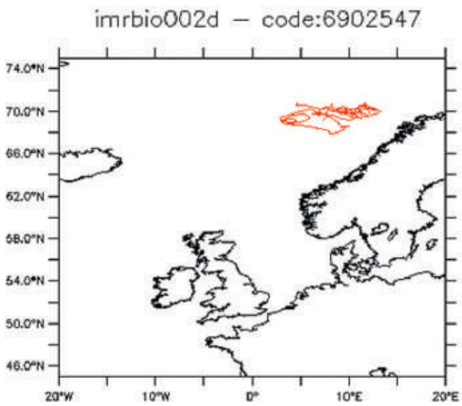
Impact and use for CMEMS and for satellite Cal/Val

The objective was to demonstrate that Euro-Argo data centers can process in real time the new E-AIMS floats and distribute them to the CMEMS monitoring and forecasting centers for validation and/or assimilation. The activity started in the last year of the project when E-AIMS floats were deployed and were shown to produce qualified data. Data were distributed by the Coriolis data center which is the in-situ thematic assembly center of the CMEMS.

Comparisons between model and Argo observations showed a good agreement and when assimilated allow the analysis to be closer to observations. Both physical and biogeochemical variables were considered **23**. The efficiency of the overall system from testing new instruments, launching floats and transmitting real time qualified data to the CMEMS was thus fully demonstrated. New Argo float data can be readily used by CMEMS for assimilation and/or validation.

New Argo floats deployed within the E-AIMS project were also used in quasi near real time for satellite Calibration/Validation of each satellite variables: altimetry, SST, SSS and Ocean Colour. Despite the limited number of floats available, their potential of use was fully demonstrated.





23 **COMPARISON OF CHLOROPHYLL-A OBSERVATIONS FROM IMR E-AIMS BIO-ARGO FLOAT WITH THE MERCATOR OCEAN/CMEMS GLOBAL BIOGEOCHEMICAL MODEL.**

GENERAL CONCLUSION AND MAIN RECOMMENDATIONS

E-AIMS organized an end-to-end evaluation of several new Argo floats. European Argo data centers were, in parallel, adapted so that they can handle them. Observing System Evaluations and Simulation Experiments were conducted to provide robust recommendations for the next phase of Argo and quantify the impact on the Copernicus Marine Environment Monitoring System (CMEMS). A real time demonstration of the utility of these new floats for the CMEMS was successfully carried out.

E-AIMS thus demonstrated that procurement, deployment and processing of these new floats for Copernicus can be organized at European level. The maturity/feasibility of new float technology (oxygen, Bio-argo, deep Argo and Arctic) from instrument/sensors to data processing and use uptake by CMEMS was demonstrated. The impact of the CMEMS was clearly shown.

The main recommendations from E-AIMS project are to maintain at least the present density of global Argo (with possibly an improved coverage in specific regions such as western boundary currents), reinforce Euro-Argo efforts in the Mediterranean Sea, Black Sea and Nordic/Arctic Seas and start as soon as possible implementing Deep Argo and Bio-Argo. There is also a need to strengthen the Argo and Euro-Argo data system. Argo proposed extensions will have a high impact for the CMEMS. They are also essential for the Copernicus Climate Service.

Thanks to the comprehensive and very successful R&D activities carried out as part of E-AIMS, the Euro-Argo ERIC is now in an excellent position to agree on and start implementing the new phase of Argo that will be highly beneficial to the CMEMS.

Main E-AIMS scientific publications

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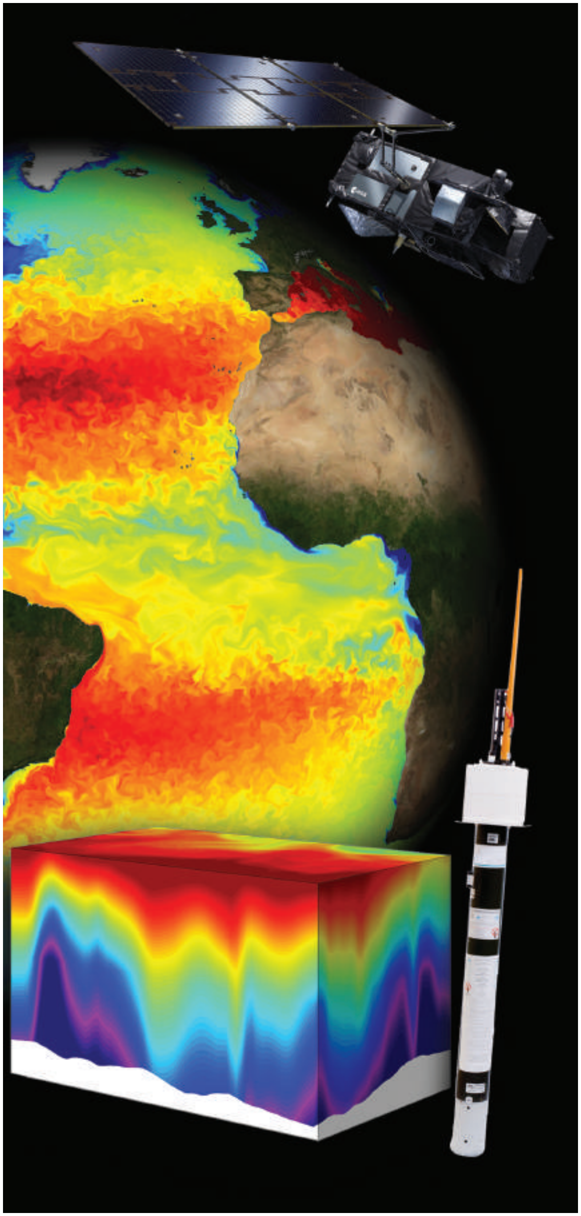
- Hoareau N., M. Portabella, J. Vogelzang, J. Ballabrera-Poy, and A. Turiel (Under review). Part I: In-situ comparison and wavenumber spectral analysis (On the geophysical consistency of Sea Surface Salinity products). Journal of Geophysical Research.
- Ninove, F., P.Y. Le Traon, E. Remy, S. Guinehut (2015). Spatial scales of temperature and salinity variability estimated from Argo observations. Ocean Science. DOI:10.5194/osd-12-1793-2015.



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