PERSEUS

POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

Report on operation and data analysis from Multi-Platform Synoptic Intensive Experiment (ALBOREX)

Deliverable D3.8

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CONTENTS

1. EXECUTIVE SUMMARY / ABSTRACT

A major intensive multi-platform and multidisciplinary experiment was completed in May 2014 as a part of PERSEUS EU funded project, lead by CSIC and with strong involvement of SOCIB, OGS, CNR, WHOI and McGill U. The multi-platform ALBOREX experiment conducted during 8 days, included 25 drifters, 2 gliders, 3 Argo floats, one ship and 50 scientists. The week long experiment was designed to capture the intense but transient vertical motion associated with mesoscale and sub-mesoscale features such as ocean eddies, filaments and fronts, in order to fill gaps in our knowledge connecting physical process to ecosystem response, and so facilitate the sustainable management of our ocean resources and MFSD policy implementation.

The ALBOREX experiment fulfilled all its objectives of sampling the intense front where Atlantic and Mediterranean waters meet in the Eastern Alboran Sea. In situ systems, including R/V, gliders and drifters were coordinated with satellite data to provide a full characterization of the physical and biochemical scenario during the ALBOREX experiment: Surface salinity samples revealed the frontal location with gradients ranging from 36.6 (Atlantic Waters) to 38.2 (Mediterranean Waters), drifters followed a massive anticyclonic gyre for a few days. The glider data revealed submesocale structures associated with the frontal zone. 3 Argo floats were deployed and transmitting high frequency and interdisciplinary data. More than 500 samples (chl and nutrients) were collected at 66 CTD stations. Near real time data from ADCP showed coherent patterns with currents up to 1m/s (2 knots) in the southern part of the sampled domain.

This intensive multi-platform and multidisciplinary experiment is an example of the new integrated and quasi real time approach to Ocean Observation thanks to joint and collaborative efforts of scientists and technicians from diverse international institutions.

2. SCOPE

Within Subtask 3.3.4 of PERSEUS project it was proposed to design and conduct a multi-platform synoptic experiment (ALBOREX) in the eastern Alboran Sea, an area characterized by sharp gradients that lead to the appearance of intense mesoscale and submesoscale features with correspondingly raised levels of eddy kinetic energy, but relatively low sampled by previous studies. The final goal is to monitor and establish the vertical exchanges associated with mesoscale and submesoscale (e.g fronts, meanders, eddies and filaments) and their contribution to upper-ocean interior exchanges.

3. RELATED TASK PROJECT

Subtask 3.3.4: Multi-Platform Experiment
Lead: CSIC

Improving our knowledge on the relationship between the physical, chemical and biological processes in the upper ocean is essential for understanding and predicting how the ocean and the marine ecosystems respond to changes in the climate system. Advection and mixing associated with mesoscale and sub-mesoscale oceanic features such as fronts, meanders, eddies and filaments are of fundamental importance for the exchanges of heat, fresh water and biogeochemical tracers between the surface and the ocean interior. The challenges associated with mesoscale and sub-mesoscale variability (between 1-20 km), imply therefore high resolution observations (both in situ and satellite) and multi-sensor approaches.

Accordingly, a multi-platform synoptic experiment under Spanish funding, yet in close coordination with WP1 and WP4 (mostly), will be designed in an area characterized by intense density gradients and strong mesoscale activity to monitor and establish the vertical exchanges associated with mesoscale and sub-mesoscale structures and their contribution to upper-ocean interior exchanges. In situ systems, including R/V, gliders and drifters will be coordinated with satellite data to provide a full description of the physical and biogeochemical variability. Phytoplankton size is vital to understanding the functional role of phytoplankton in the trophic flows of the ecosystem. Phytoplankton size spectra are known to be particularly sensitive to dynamics fields under high mesoscale forcing such as those associated with the Atlantic Jet of the Alborán Sea (Rodríguez et al., Nature, 2001). At the same time, as indicated in Task 3.2.4, remote sensing of phytoplankton populations is evolving from the bulk estimation of chlorophyll content at the surface ocean to the exploration of spectral reflectance for diagnosing the size structure of primary producers. Therefore, these are critical test bed areas to validate the remote sensing algorithms of phytoplankton size structure (from WP4) and to implement new CAL/VAL measurements from space through an intensive combined field and space monitoring exercise. The
SMOOS potential will also be addressed.

4. INTRODUCTION

Mesoscale dynamics have significant impacts on large-scale circulation (Lozier, 1997) as well as on energy, heat flux transfers (Wunsch, 1999). Understanding the relationship between the physical and biological processes is crucial for predicting the marine ecosystems response to changes in the climate system (McGillicuddy et al 2007). Vertical motion associated with mesoscale and submesoscale features plays a major role in the exchanges of properties between the surface and the ocean interior (Klein and Lapeyre 2008).

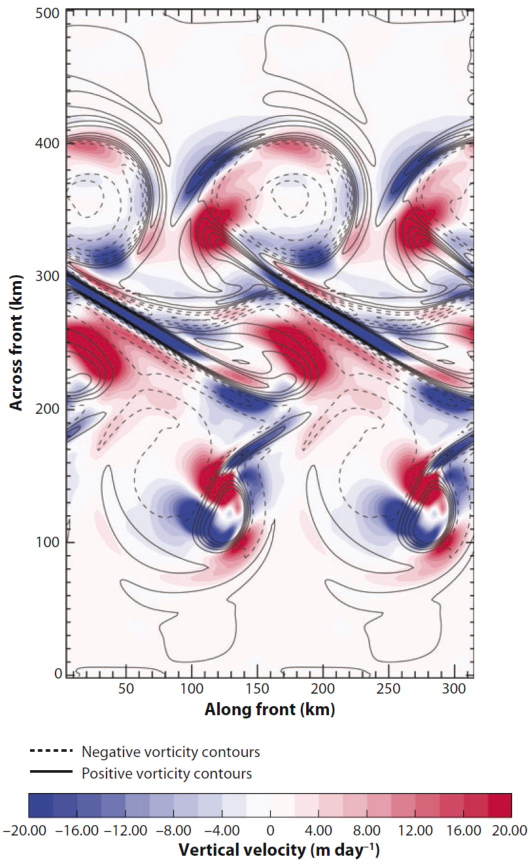

Figure 1.Vertical velocities at 90 m from primitive equation simulations, from Lévy et al., (2001).

Modelling studies of frontal regions (Lévy et al 2001; Mahadevan and Tandom 2006) suggest that vertical exchange is enhanced at density fronts (Figs. 1 and 2). Unfortunately, it is not yet possible to make direct measurements of vertical velocities of values less than 1000 m/day. Instead, it can be inferred from a 3D field of the density field by assuming a few simplifications in the QG formulation (Hoskins et al. 1978).

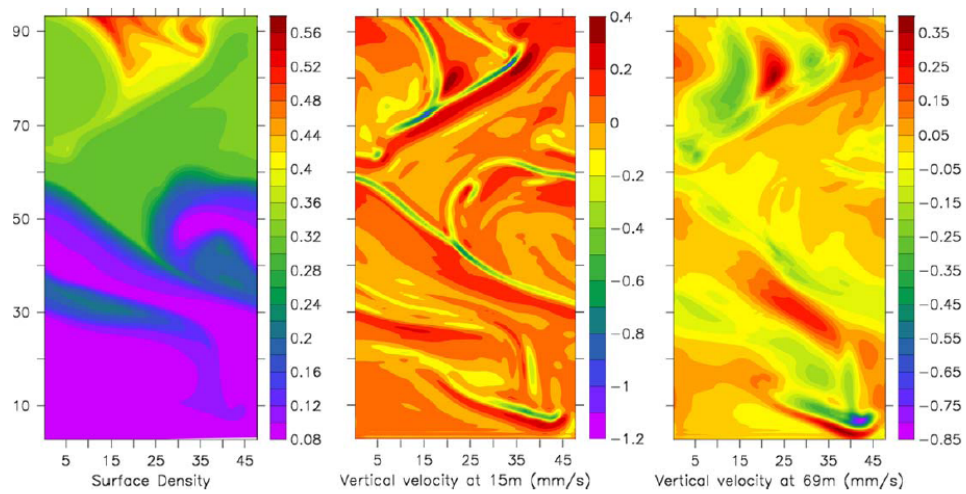

Figure 2. Surface density, vertical velocity at 15 m and 69 m depth from primitive equation simulations (Mahadevan and Tandon, 2006).

In the Western Mediterranean, the transition region between the Alboran Sea and the Algerian sub-basin to the east is characterized by strong fronts (1.5 sigma-t differences and mostly governed by salinity) and mesoscale anticyclonic eddies (Fig. 3).

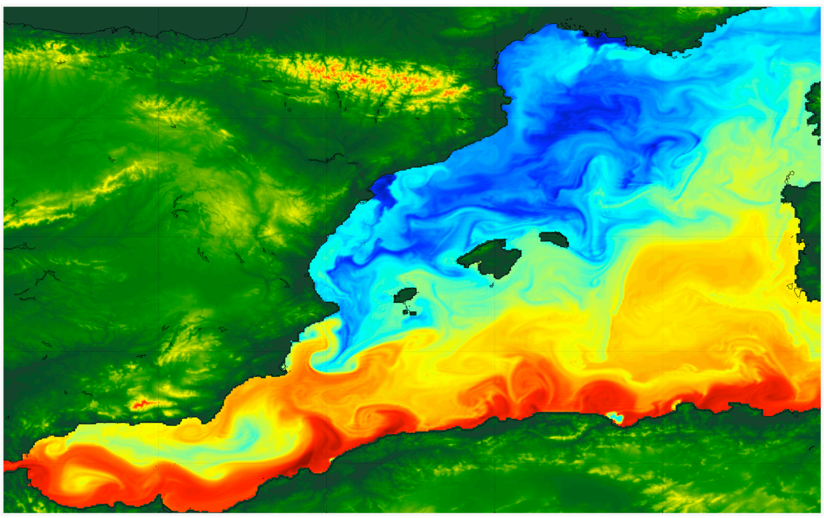

Figure 3. Sea Surface Temperature in the Western Mediterranean from ROMS model.

Transient fronts, such as the Almería-Orán front, separate Atlantic Water (AW) flowing into the Mediterranean Sea, and recirculating Mediterranean Water (MW) that intrudes southwestward along the Spanish coast. Quasi-geostrophic vertical motions estimated from a combination of altimetry and glider observations south of Cartagena by Ruiz et al. (2009) are of the order ±1 m/day (Figs. 4 and 5), although higher velocities (up to ±20-25 m/day) can be assumed for smaller submesoscale structures embedded within the front, Tintoré et al. (1991). The challenges associated with mesoscale and submesoscale variability (between 1-10 km), imply therefore high-resolution observations (both *in situ* and satellite) and multi-sensor approaches (Pascual et al. 2010; Pascual et al. 2013).

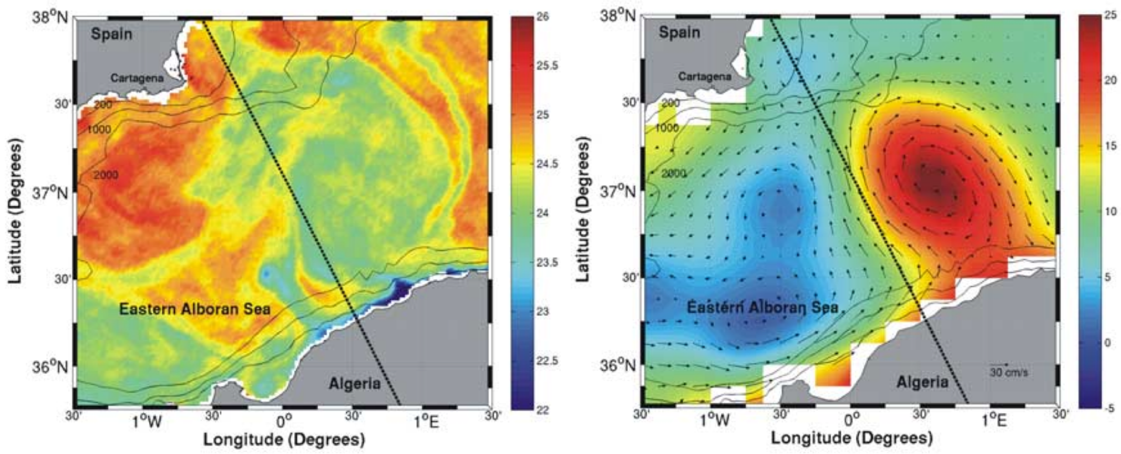

Figure 4. Night AVHRR SST images for 23 July 2008 in the Eastern Alboran Sea (left), the temperature scale is in °C. Interpolated altimeter maps of ADT for same date with surface geostrophic currents (right).

Within Subtask 3.3.4 of PERSEUS we propose to design and conduct a multi-platform synoptic experiment (ALBOREX) in the eastern Alboran Sea. The final goal is to monitor and establish the vertical exchanges associated with mesoscale and submesoscale (e.g fronts, meanders, eddies and filaments) and their contribution to upper-ocean interior exchanges (Mahadevan and Tandom 2006; Buongiorno Nardelli et al. 2012).

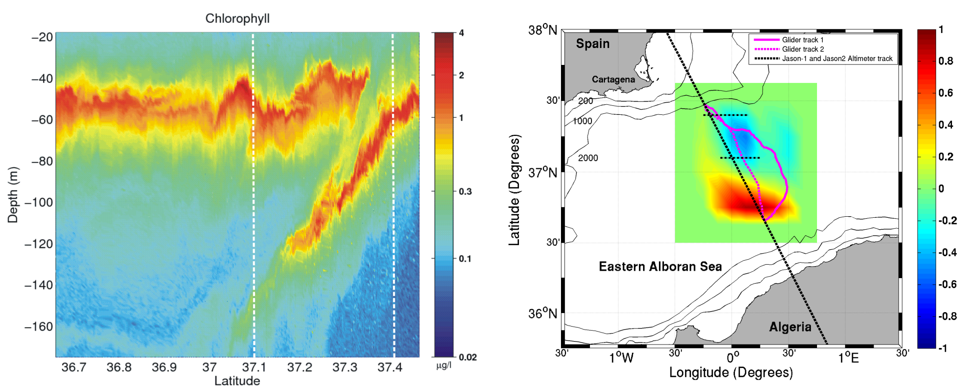

Figure 5. Vertical section of chlorophyll (ug/l) from glider (left) and quasi-geostrophic vertical velocity (right) at 75 m (m/day), from Ruiz et al., (2009). The dashed line corresponds to an OSTM/Jason-2 track.

5. FIELD EXPERIMENT

A synoptic multi-sensor experiment was designed to be conducted onboard SOCIB coastal vessel (Fig. 6) between 25 and 31 May 2014 in the eastern Alboran Sea (Western Mediterranean). *In situ* systems, including gliders, drifters and Argo floats were coordinated with satellite data and modeling simulations to provide a full description of the physical and biochemical variability. Two high-resolution grids were sampled with the ship (area covered 40 km x 40 km). At each station one CTD cast and water samples for Chl and nutrients analysis were collected. Additional ADCP data was registered in continuous mode. Two gliders sampled an intense front. Details of the sampling for each of the platforms are given below, in the observing multi-platform capabilities section.

Figure 6. Coastal Ocean Research Vessel SOCIB. See further details about this vessels at http://socib.es/?seccion=observingFacilities&facility=vessel

5.1. Participants

INSTITUTION	CONTRIBUTION
CSIC (ES) **Ananda Pascual; Benjamín Casas; Ana Massanet; Félix Magirier; Margarita Palmer; Joaquín Tintoré; Simón Ruiz; Alejandro Orfila; Antonio Tovar; Emma Heslop; Evan Mason; Miguel Martínez; Juan Carlos Alonso**	Lead partner Scientific and technical coordination Gliders Drifters Argo Biochemical samples Remote sensing Modelling (ROMS, delayed time)
SOCIB (ES) **Joaquín Tintoré; John Allen; Carlos Castilla; Pau Balaguer; Mélanie Juza; Marc Torner; Temel Oguz; Charles Troupin; Irene Lizarán; Kristian Sebastián; Baptiste Mourre;**	Ship Glider facility Modelling (ROMS operational, Biochemical) Data management
OGS (IT) **Pierre Poulain, Giulio Notarstefano**	Drifters, Argo Drifter deployment strategy and data analysis
CNR (IT) **Antonio Olita**	Glider deployment strategy and data analysis Ocean color images
WHOI (USA) **Amala Mahadevan**	Physical-Biochemical modelling
McGill U (CANADA) **Mariona Claret**	Physical-Biochemical modelling

Table 1. Participants involved in the Alborex experiment.

5.2. Oceanographic context from satellites

Sea Surface Temperature (SST), Ocean Colour (OC) and Sea Surface Height (SSH) from remote sensing provide a synoptic view of the meso and submesoscale activity at the study area, and helps to determine the position of interesting features (meanders, eddies and front) to be sampled. Satellite data were essential for the design of the mission.

5.2.1. Sea Surface Temperature

The SST images at 1 km spatial resolution showed below corresponds to Level-2 SST acquired by the Moderate-Resolution Imaging Spectroradiometer (MODIS) sensor on board Aqua and Terra satellites were obtained from Ocean Color Level 1&2 server (http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am). During the week before the experiment SST images were checked to track the evolution of the mesocale and submesocale structures in the study area. A clear frontal zone between warm and cold waters were identified between 0 and 1° W longitude. Moreover, the presence of an anticyclonic eddy with associated small structures (filament) was evident in the images (Fig. 7).

SST images contemporaneous with the field experiment (Fig. 8) confirmed the presence of a clear anticyclonic eddy and the presence of submesocale filaments. Those images, together with ocean colour and altimetry images helped to determine the final positions of the 2 CTD surveys conducted during the experiment.

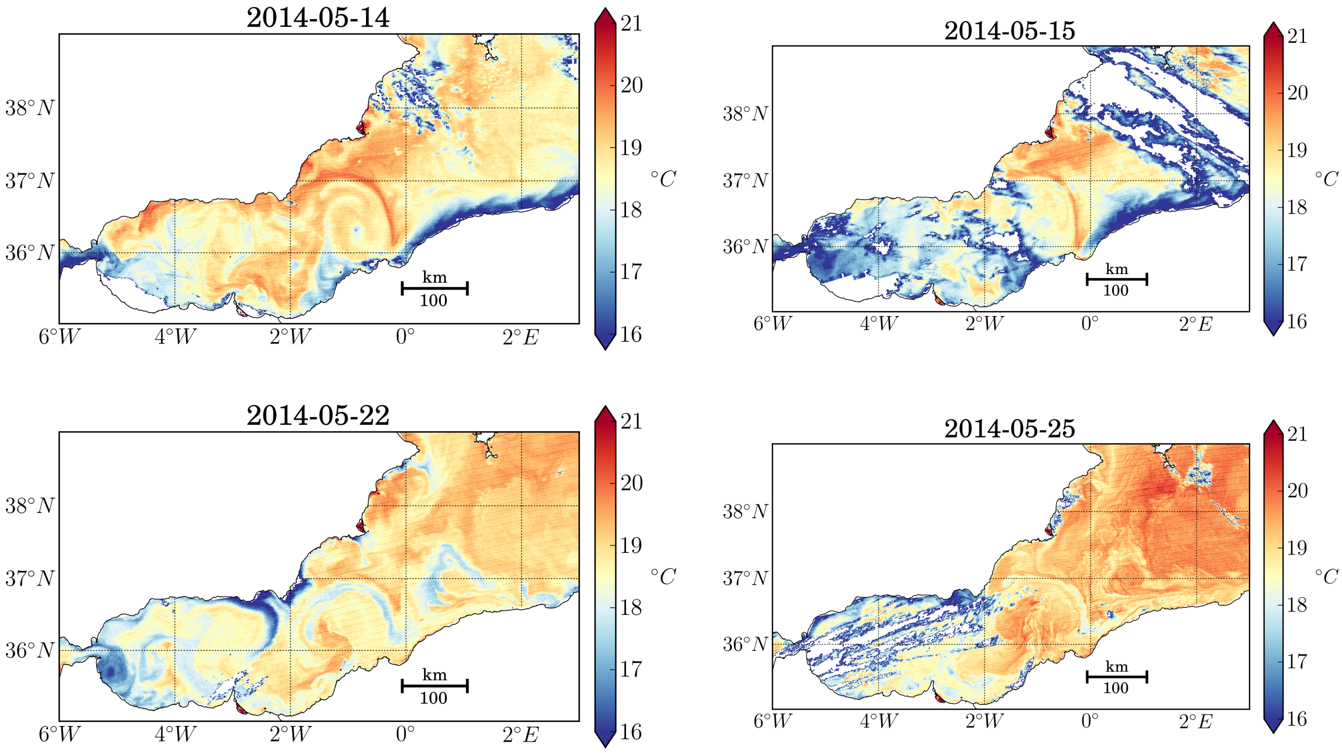

Figure 7. From top to bottom and left to right: SST images corresponding to days 14, 15, 22 and 25 May 2014.

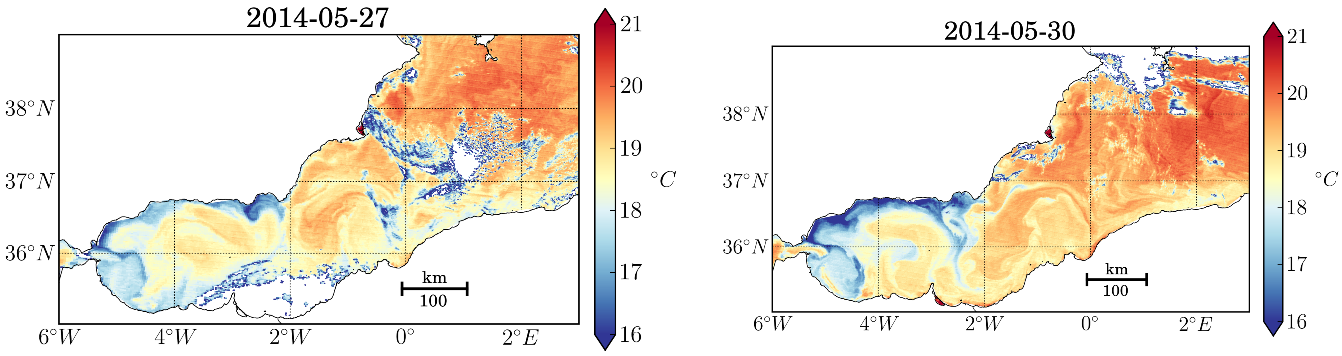

Figure 8. SST images contemporaneous with the field experiment: 27 (left) and 30 (right) May 2014.

5.2.2. Ocean colour

MODIS level-2 single swaths provide among others, ocean colour products (Chlorophyll-a concentration for example). The Ocean Colour data were processed and provided by Dr. A. Olita (CNR). Figure 9 shows an ocean colour image corresponding to 29 May 2014. This image reveals the frontal area in the northern margin of the anticyclone. At the same time a Chl filament detaching from the coast seems to feed the eddy (Olita, 2014).

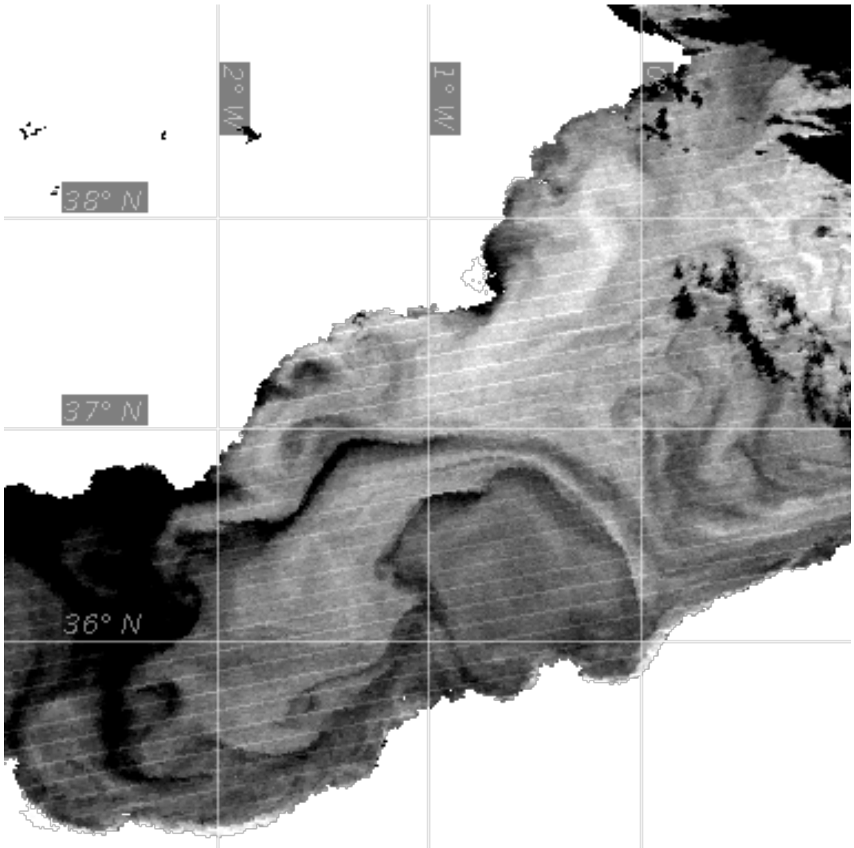

Figure 9. Chl-a image corresponding to May 29, 2014. (Courtesy: A. Olita, CNR).

5.2.3. Sea Surface Height

During the Alborex experiment, we benefited from the availability of up to 4 altimeter missions (OSTM/Jason-2, Cryosat, SARAL/AltiKa, HY-2). DUACS gridded altimeter products (Sea Level Anomaly, SLA) produced by CNES were used to estimate surface currents in the area of study. We use the SMDT-MED-2014 (Río et al., 2014) to obtain Absolute Dynamic Topography (ADT) and derive the corresponding Absolute Geostrophic Currents.

A few months before the field experiment, there are not evidences of anticyclonic structures around 0 degrees longitude in the altimetry maps (Fig. 10). Instead, the presence of the Algerian Current flowing eastwards along the African coast is so clear. From 10 April onwards, an instability of this current is observed around 1.5° W longitude. At the beginning of May 2015, this instability of the flow has evolved forming a clear anticyclonic structure, propagating eastwards, near the area of the field experiment.

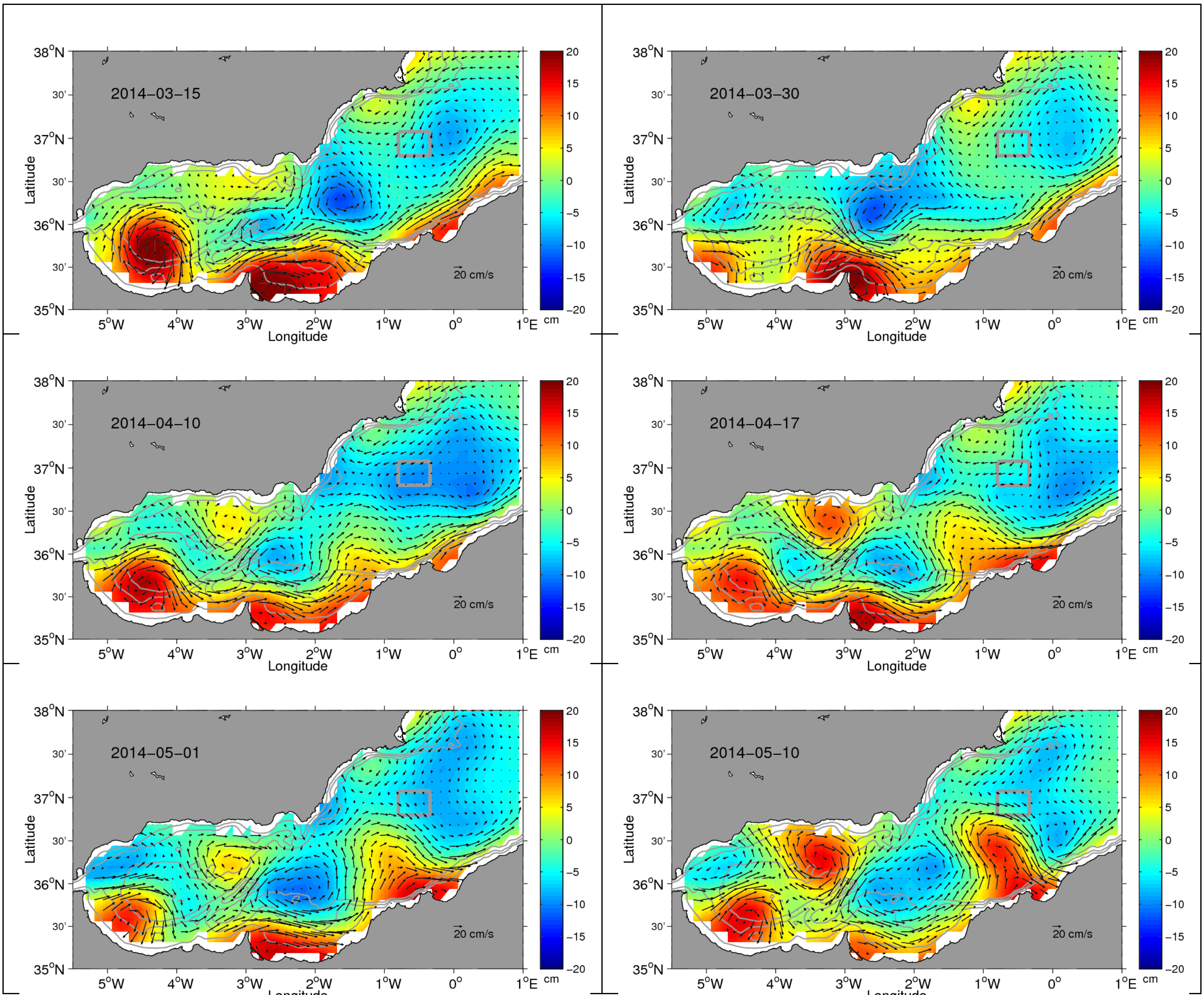

Figure 10. ADT (cm) with associated geostrophic currents (cm/s) in the study are corresponding to 15 and 30 March, 10, 17 April and 1, 10 May 2014. The grey box corresponds to the boundaries of the domain covered during ALBOREX experiment (CTD grid).

A few days before starting the field experiment, altimetry data also confirmed the presence of a well-defined anticyclonic eddy near the study area with maximum velocities larger than 50 cm/s (Fig. 11).

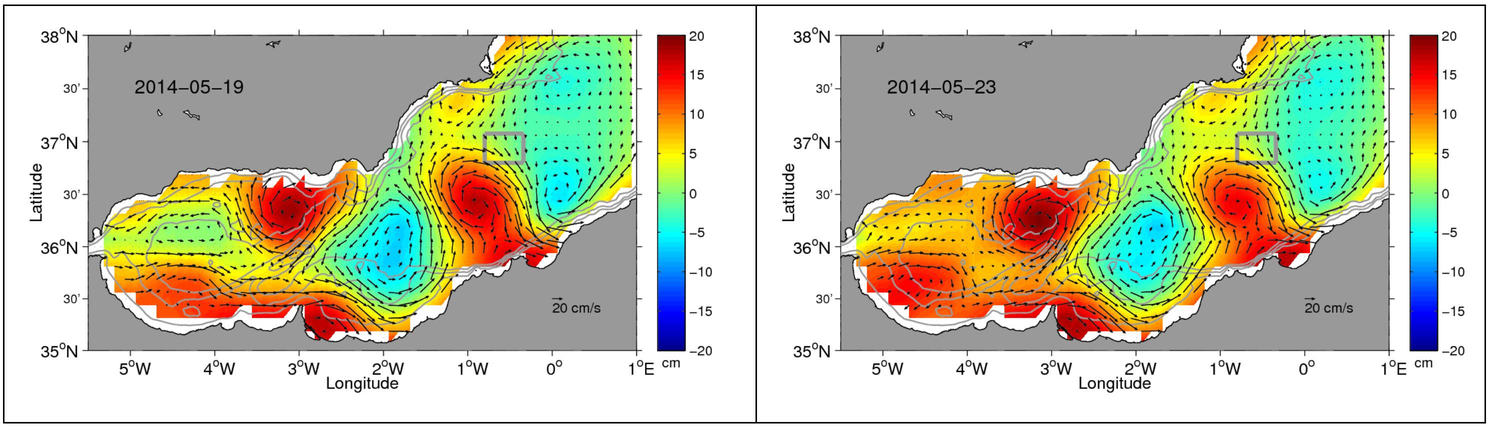

Figure 11. **ADT (cm) with associated geostrophic currents (cm/s) in the study area for 19 and 23 May 2014. Alborex experiment started on 25 May 2014.**

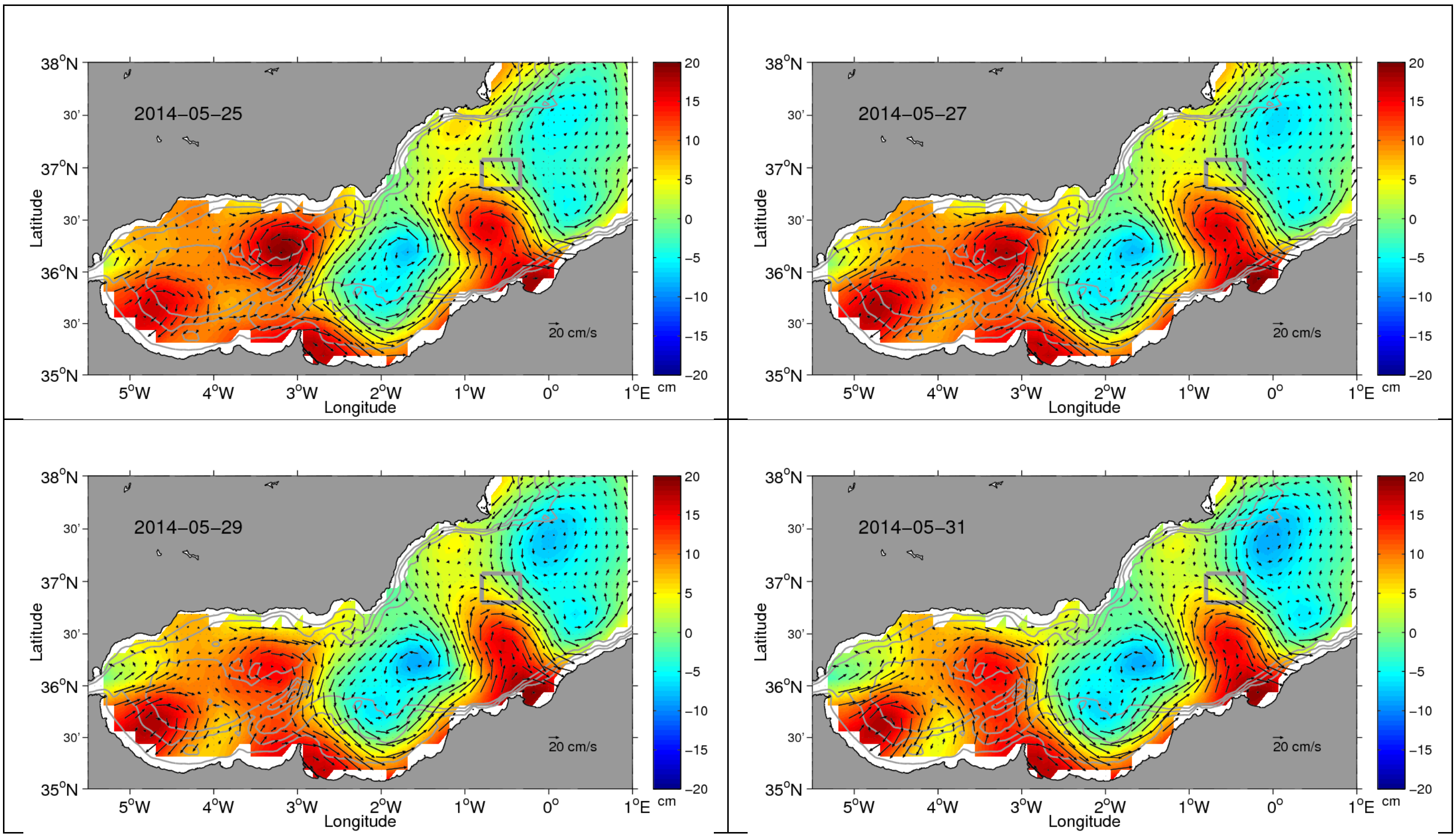

Figure 12. **From left to right and top to bottom; ADT (cm) with associated geostrophic currents (cm/s) for 25 and 27, 29 and 31May 2014.**

During the date of the field experiment (Fig. 12) the eddy appear to be centered around longitude 0.5° W and slightly advecting eastwards. Small structures such as filaments previously observed in SST and OC data, are not present in altimetry maps due to the limited resolution (filtering applied to the AVISO product).

5.3. Observing multi-platform capabilities

CTD, ADCP and water samples (chl, nutrients) were gathered from the R/V SOCIB (Fig 13). All physical and biochemical in situ data were quality controlled and delivered by SOCIB data center. As mentioned in the previous section, the exact location of the CTD stations was fixed based on the presence of mesoscale and submesoscale features present in SST data from remote sensing. Maximum depth reached at all the CTD casts was 600 m and water samples were collected at each station at the following depths: 5, 20, 40, 60, 90, 100, 120, 150 m. Salinity samples were collected at different depths in one out of two stations. An additional sample at 350 m was collected at certain stations for salinity calibration. First CTD survey 1 consisted of 34 CTDs distributed on 5 North/South legs, performed on 26-27 May 2014 (Fig. 14). During survey 2, 28 CTDs were done on 29-30 May 2014 in almost the same positions of CTDs done during survey 1 (Figs. 15). ADCP were continuously registered during the night (22:00 UTC – 6:00 UTC) at a speed of 10 knots and also during CTD surveys (at stations and between stations).

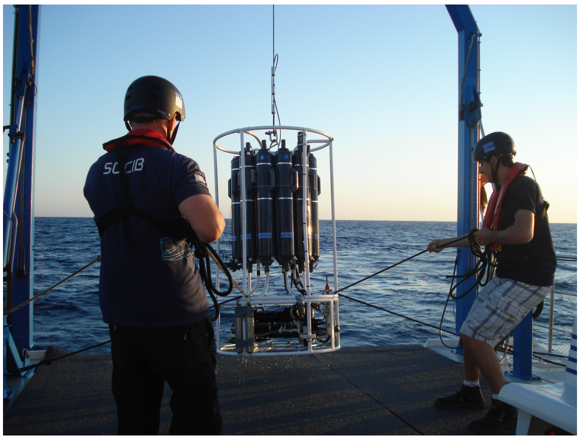

Figure 13. CTD operations and water samples analysis.

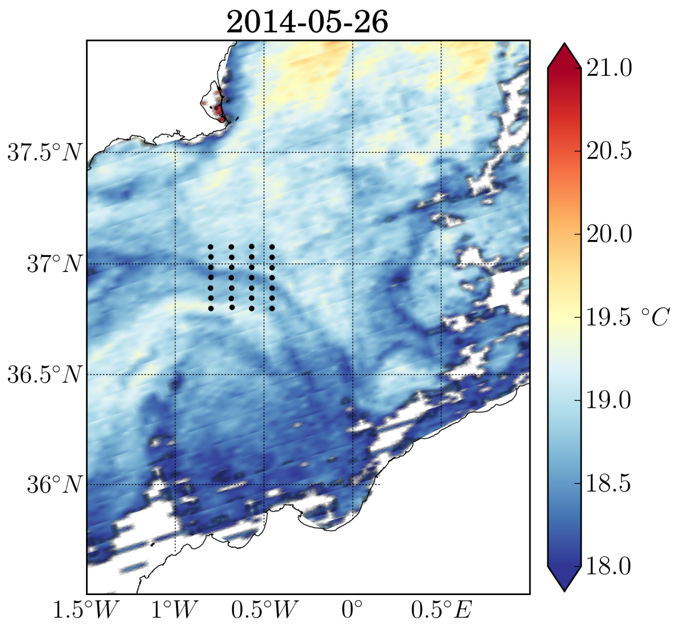

Figure 14. **SST for 26 May 2014 and CTD positions during survey 1 (26-27 May 2014).**

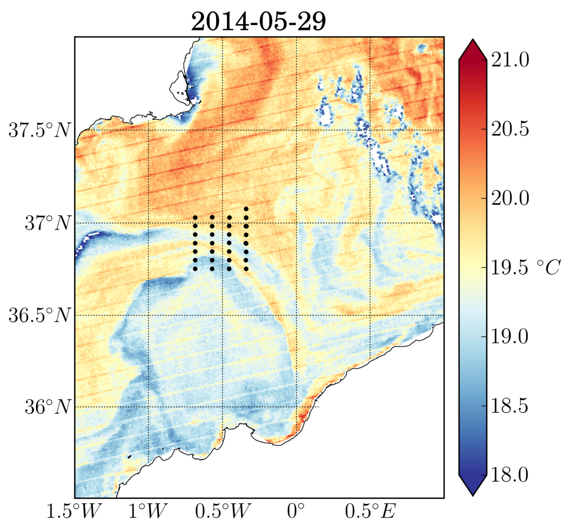

Figure 15. **Right: SST for 29 May 2014 and CTD positions during survey 2 (29-30 May 2014)**

Two gliders (1 deep Slocum, 1 shallow Slocum, Fig. 16) were deployed to sample an intense front. Glider profiles reach down to 200 m for the shallow unit (as part of a TNA Jerico proposal from A. Olita –CNR) and down to 500 m for the deep unit. Gliders collect high-resolution temperature, salinity, oxygen and fluorescence profiles. The sampling strategy was based on two parallel north-south transects of 50 km shifted 10 km. Each transect (one way) should be covered in approximately 2 days (depending on currents) and therefore it was expected that the gliders repeat the transects about 4 times during the entire ALBOREX cruise.

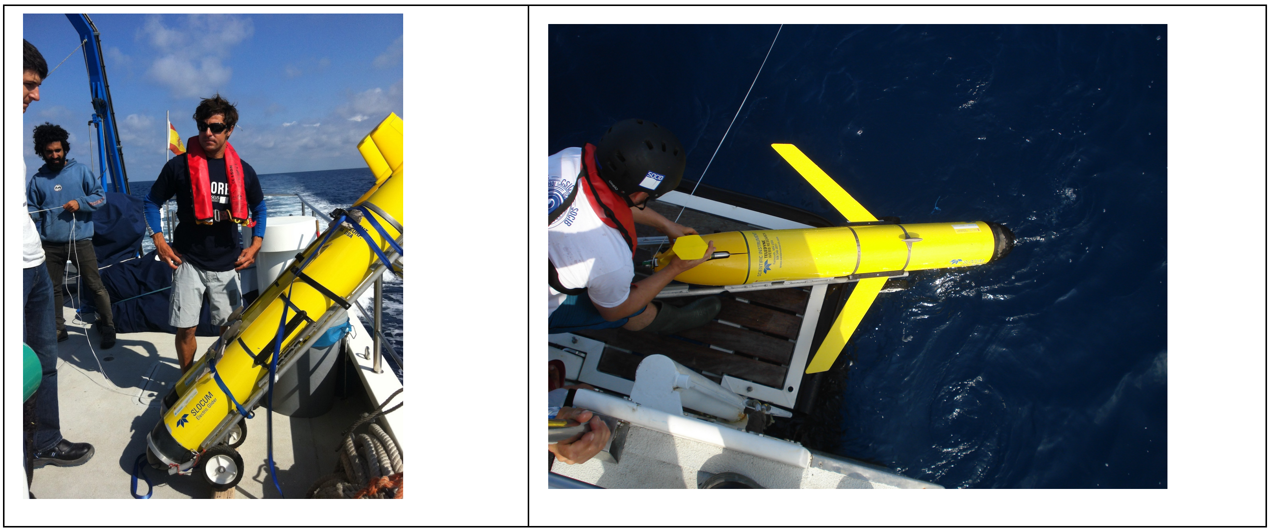

Figure 16. Gliders used during Alborex experiment and deployment operations.

However, due to the intense currents in the area gliders were advected eastwards and the sampling strategy was modified in real-time. Glider performed several transects crossing the frontal zone but not following always the same track (Fig. 17).

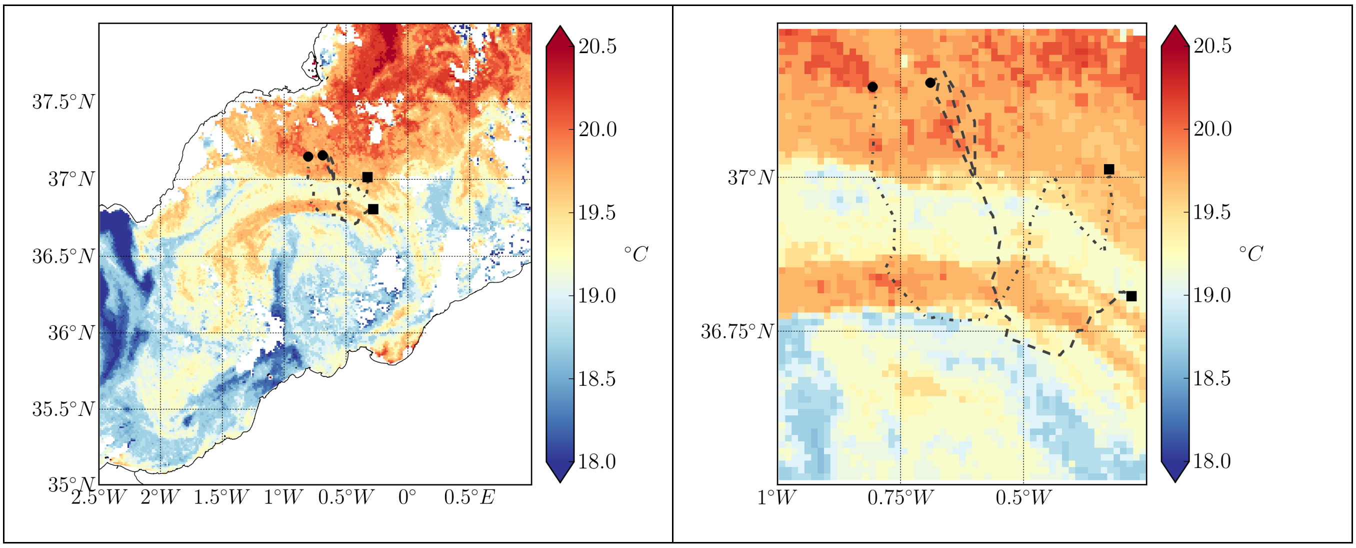

Figure 17. Left: Real trajectories (dashed lines) performed by coastal and deep gliders during the Alborex experiment. Dots correspond to initial glider deployment, located 10 km apart, squares indicate recovery glider positions. The background field corresponds to an SST image for 28 May 2014. Right: Idem, zoom view.

25 surface drifters (Fig. 18) were deployed within the domain. Surface currents derived from drifters can be used to study the temporal and spatial variability of fronts and filaments and ideally to detect convergence and divergence. In addition, drifter observations are useful to validate altimetry, glider, models and CTD derived geostrophic velocities. The deployment strategy addressed the goal to sample frontal areas and even try to detect any convergence/divergence. For that purpose, the drifters were deployed over a uniform initial array across the frontal areas and/or in convergence/divergence zones with drifter separation distance less than the major scale of variability (a few km, see Figure 19). The exact position of deployment was determined based on the position of frontal areas determined from satellite imagery. The drifters were followed and tracked at http://apps.socib.es/dapp/.

Drifter data were transmitted in real time to SOCIB data center and to OGS to contribute to the Med-SVP program.

Figure 18. Drifter preparation and deployment on board R/V SOCIB.

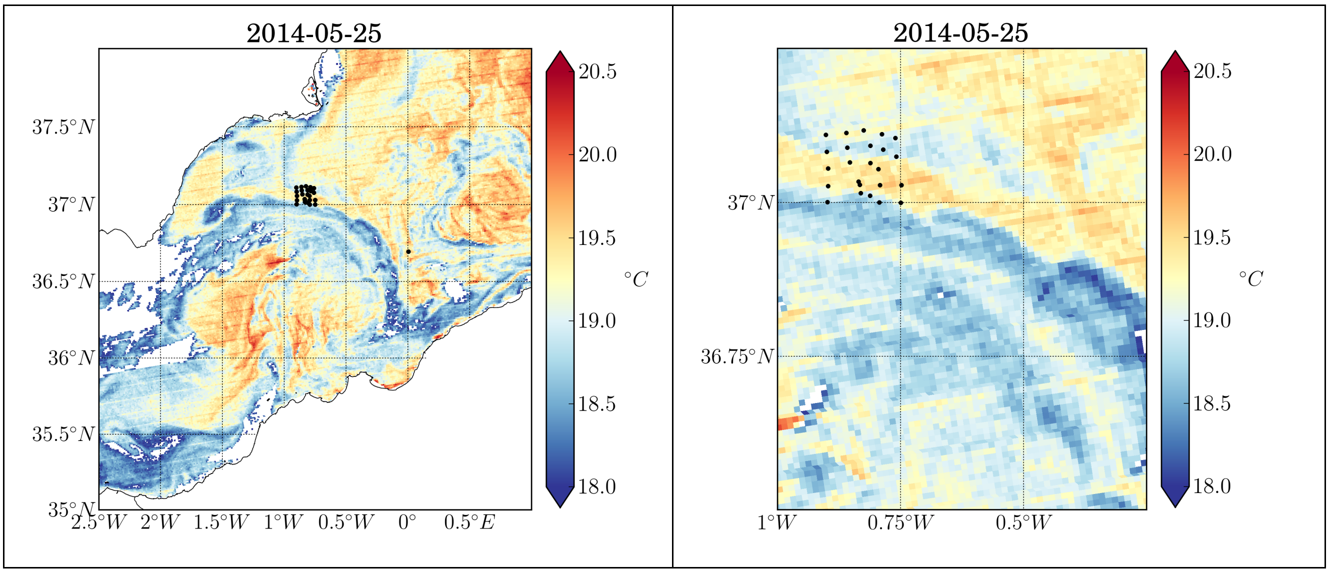

Figure 19. **Left: Drifter's deployment positions. Drifters were deployed 3 km apart around the frontal area. The background field corresponds to an SST image for 25 May 2014.**

3 Argo floats (Fig. 20) were deployed in a line along the frontal zone (with a separation of a few kms). The Arvor-C was programmed with 3-h cycles down to 400 m. The Arvor-A3 was initially configured to have daily cycles. At the end of the campaign, it was left at sea and its cycle was changed to 5 days (MedArgo standard) using the downlink of the Argos 3 telemetry.

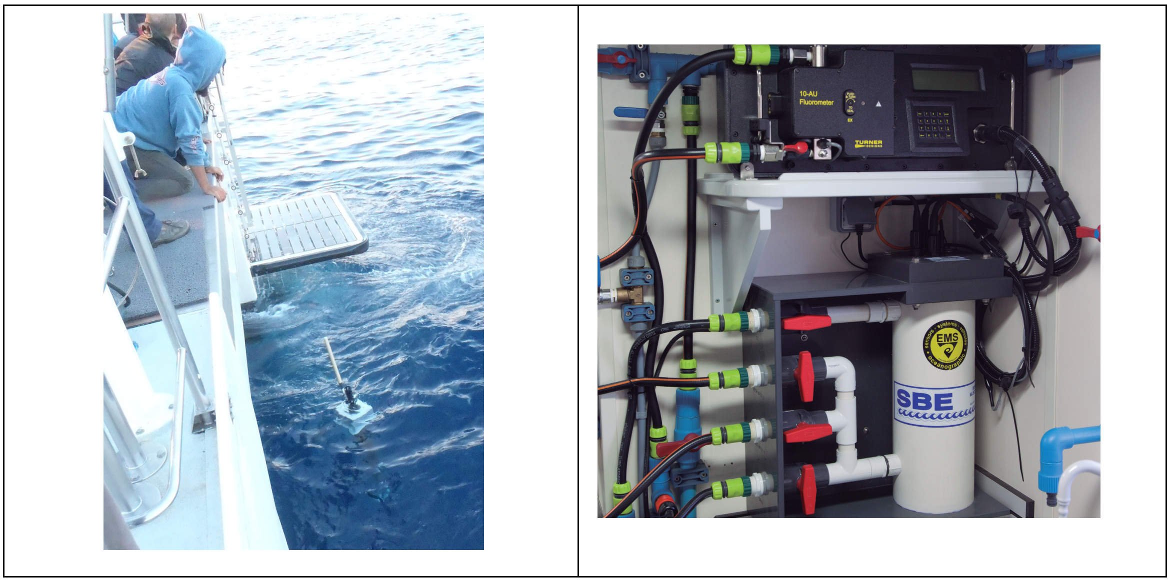

Figure 20. **Left: Deployment of Argo float. Right: Thermosalinograph installed on board R/V SOCIB.**

Both the Arvor-C and Arvor-A3 measured temperature and conductivity (salinity) in the water column. The Prov-bio float had initial daily cycles synchronized to profile near local noon time. It was left at sea after the campaign and its cycle was changed to 5 days using the Iridium downlink. In addition to temperature and salinity, the Prov-bio measure dissolved oxygen, chlorophyll-a, CDOM, backscattering at 700 nm, downweling irradiance at 380, 410, 490 nm and PAR.

Surface temperature and salinity was measured during all the cruise time using a thermosalinograph, which also helped to detect the location of the front.

OBSERVATIONS & NUMERICAL MODELLING CAPABILITIES

- CTDs (2 regular surveys on a regular grid of 10x5 km)
- ADCP (continuous during night)
- Gliders (2 IMEDEA)
- Drifters (25 SVP drifters: 1+7+6+6 IMEDEA [14 DBI + 6 Pacific Gyre], 5 OGS)
- Argo floats (3: 1 IMEDEA [Arvor-C], 2 OGS [1 Arvor-A3, 1 Prov-Bio])
- Nutrients
- Chlorophyll
- Remote sensing (sub-basin and local scale):
  - SST
  - Ocean Colour
  - Altimetry
- Modeling:
  - SOCIB WMOP (ROMS operational real-time specific simulation Alborán sub-basin, http://socib.es/?seccion=modelling)
  - SOCIB Biochemical modeling (POM + NPZD2)
  - Ocean Process Study numerical model (Mahadevan et al., 1996a,b).

Details about data processing of data collected by the different platforms are given in the annexes.

5.4. Modelling capabilities

High-resolution numerical models are able to represent the full evolution of oceanic structures in the three spatial dimensions, thus providing a complementary and very valuable source of information to describe and understand mesoscale and submesoscale processes. At the same time, the realistic generation and evolution of such processes stills remains very challenging due to the chaotic nature of the oceanic flow, making direct model-data comparisons often hazardous at the smallest scales.

Different models and setups will be used in the framework of this experiment.

First, high-resolution operational model forecasts will be used to support the preparation and execution of the sea trial.

Then, several retrospective simulations will be carried out over the sea-trial period using different modeling nesting techniques and data assimilation approaches, with the aim to simulate the small scale oceanic fields as realistically as possible so as support the analysis and interpretation of the collected dataset. These simulations will be inter-compared to better understand the strengths and limitations of the different approaches.

Finally, a Process Study Ocean Model will be run to help understanding and isolating the mechanisms of vertical transport at the front observed in the multiplatform experiment ALBOREX.

1) WMOP operational model

The WMOP model is run operationally at SOCIB since the end of 2010, producing a daily 72-hour forecast of the coastal and ocean currents and eddies, as well as surface and subsurface ocean properties. Validation procedures based on inter-comparison of model outputs against observations have been implemented to assess the capability of the model to reproduce the features observed from in-situ systems and remote sensing.

Model configuration

- ROMS (http://www.myroms.org, Shchepetkin and McWilliams, 2005)
- Covering the Western Mediterranean from the Strait of Gibraltar to Sardinia channel (from 6ºW to 9ºE and from 35ºN to 44.5ºN, Fig. 21).
- 32 sigma levels, bottom topography from 30" database (Smith and Sandwell, 1997)
- Spatial resolution ~1.8-2km
- Boundary conditions from MFS/MOON (Tonani et al., 2012) or Mercator-Océan.
- Forced by AEMET Hirlam atmospheric forcing , 3hours, 5-6km
- Rhône and Ebro river runoffs from a climatology based on the RivDis (UNESCO) database.
- In the absence of data assimilation, the model is re-initialized every week from the parent model (alternatively MFS or Mercator-Océan) after a 3-week spinup period
- Outputs already available at: http://socib.es/?seccion=modelling
- Daily images (SST, SSS, SSH, surface UV) over the experimental area are available at
- http://dataserver.imedea.uib-csic.es/~balop/Figures_WMOP_operational/
- wit names (here SST):

  last_ROMS_WMOP_MER_T_AlboranWestAlgerian_avg_00_24h.png

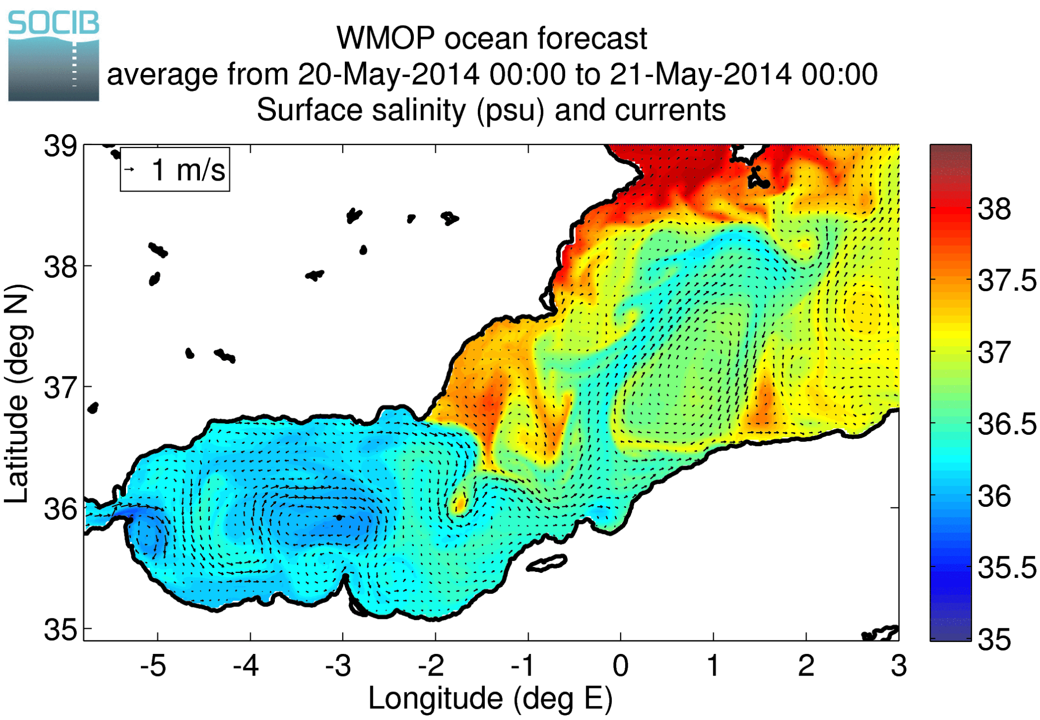

Figure 21. **WMOP simulation.**

2) WMOP retrospective simulation including data assimilation

The WMOP model will be retrospectively re-run over the experimental period using the analysis forcing fields. The collected data will be assimilated in the model to produce a reanalysis of the oceanographic scenario. Details of the data assimilation approach still need to be determined.

3) One-way nested downscaled retrospective simulation

A series of one-way nested ROMS solutions is to be focused on the sampled region. These simulations will enable increased spatial (horizontal and vertical) and, if needed, temporal resolutions across the features of interest. We use established nesting techniques that have been proven at submesoscale resolutions down to below 100 m (e.g., Uchiyama et al., 2014).

Envisaged model configuration:

- ROMS AGRIF (Shchepetkin and McWilliams, 2009)
- 1-3 nested grids in the Alboran Sea
- Spatial resolutions to < 1 km
- Boundary forcing: WMOP or suitable alternative
- Surface forcing: AEMET or WRF if available

4) Ocean Process Study numerical model.

Ocean Process Study (OPS) model has been implemented to study submesocale processes associated with intense frontal zones. OPS is a non-hydrostatic and free-surface numerical model that simulates the volume-preserving flow of a rotating and stratified fluid under the Boussinesq approximation (Mahadevan et al. 1996a,b).

6. FIRST RESULTS

6.1. Hydrographic fields

The Eastern Alboran Sea is characterized by strong gradients in salinity due to the confluence of recent Atlantic water (recent AW) entering from Gibraltar and the more saline resident Mediterranean Water, which is referred here as old Atlantic Water (old AW). During the Alborex experiment the thermosalinograph measured differences in salinity of about 1.5 in less than 5 km (Fig. 22). The northern part of the sampling area is characterized by salinity around 38.2 while below 37°N latitude, salinity is around 37.5 or fresher.

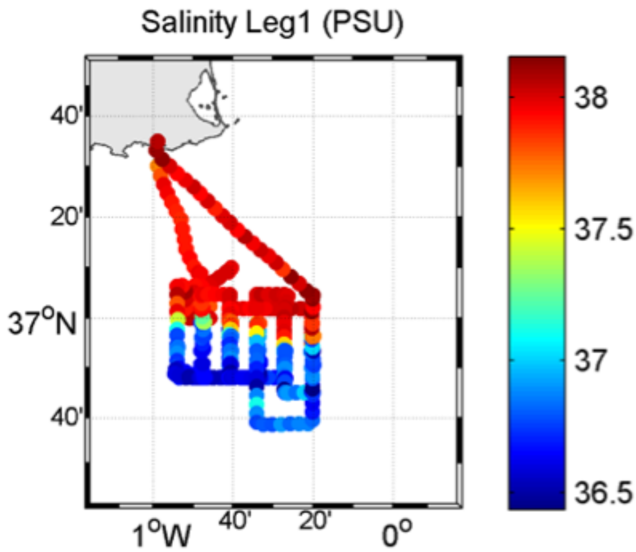

Figure 22. Surface salinity from thermosalinograph installed on board R/V SOCIB.

T-S diagram for survey 1 (Fig. 23) confirms the presence of both type of waters, not only at the surface but also at deeper levels (note that with the aim of reducing time, the casts were performed only down to 600 m and in consequence the presence of deep waters – Levantine Intermediate Water and Deep Mediterranean Water - is only partially detected). Both recent and old AW can also be identified with data from survey 2, but with a higher degree of mixing in the upper layer with respect to survey 1 (Fig. 23).

Hydrographic data have been interpolated at 1 km resolution using an optimal interpolation scheme with a correlation length scale of 12 km. Structures larger 20 km have been filtered out with a low-pass filter (Pedder et al. 1993). See further details about CTD data processing in the annex I.

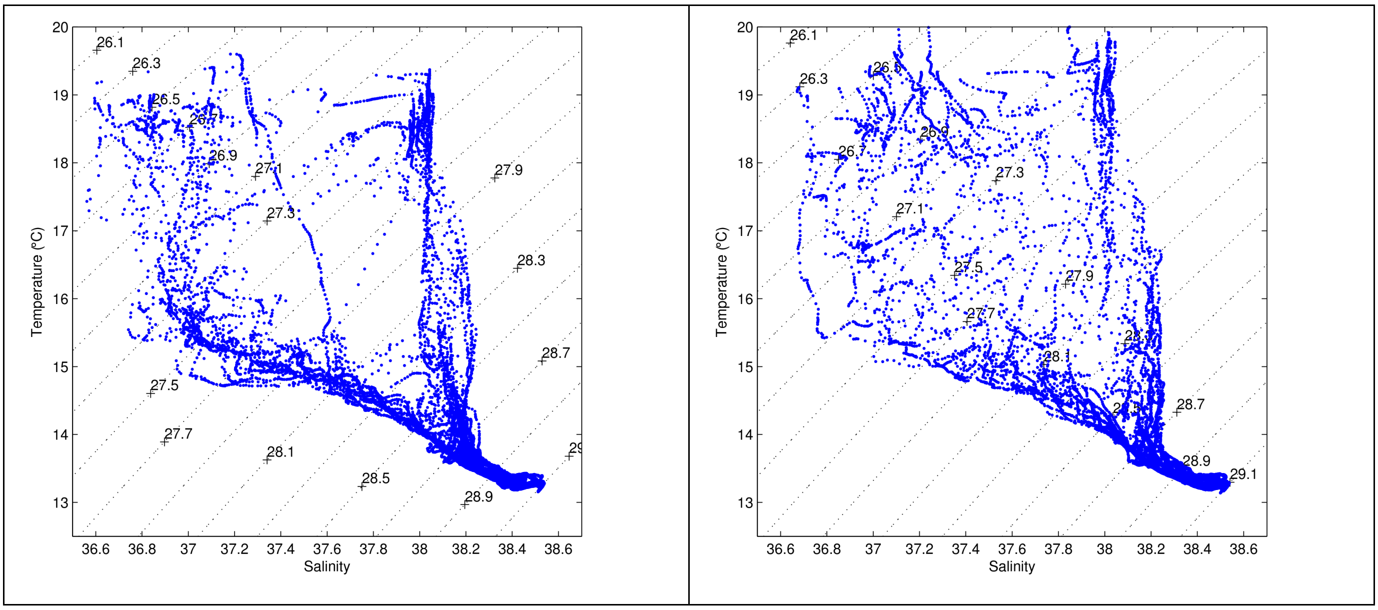

Figure 23. T-S diagrams from survey 1 (left) and survey 2 (right).

Potential temperature, salinity and density fields at 50 m depth from surveys 1 and 2 (Fig. 24) confirm the marked front. The comparison between hydrographic fields from survey 1 and survey 2 reveals the rapid evolution of the salinity front. It suffers a clear deformation during days 29 and 30 May, evolving with the anticyclonic structure and modifying significantly the salinity pattern observed during survey1 (Fig. 24). Vertical sections of salinity (Fig. 25) from survey 1 and 2 reveal that salinity front is present until 120 m depth.

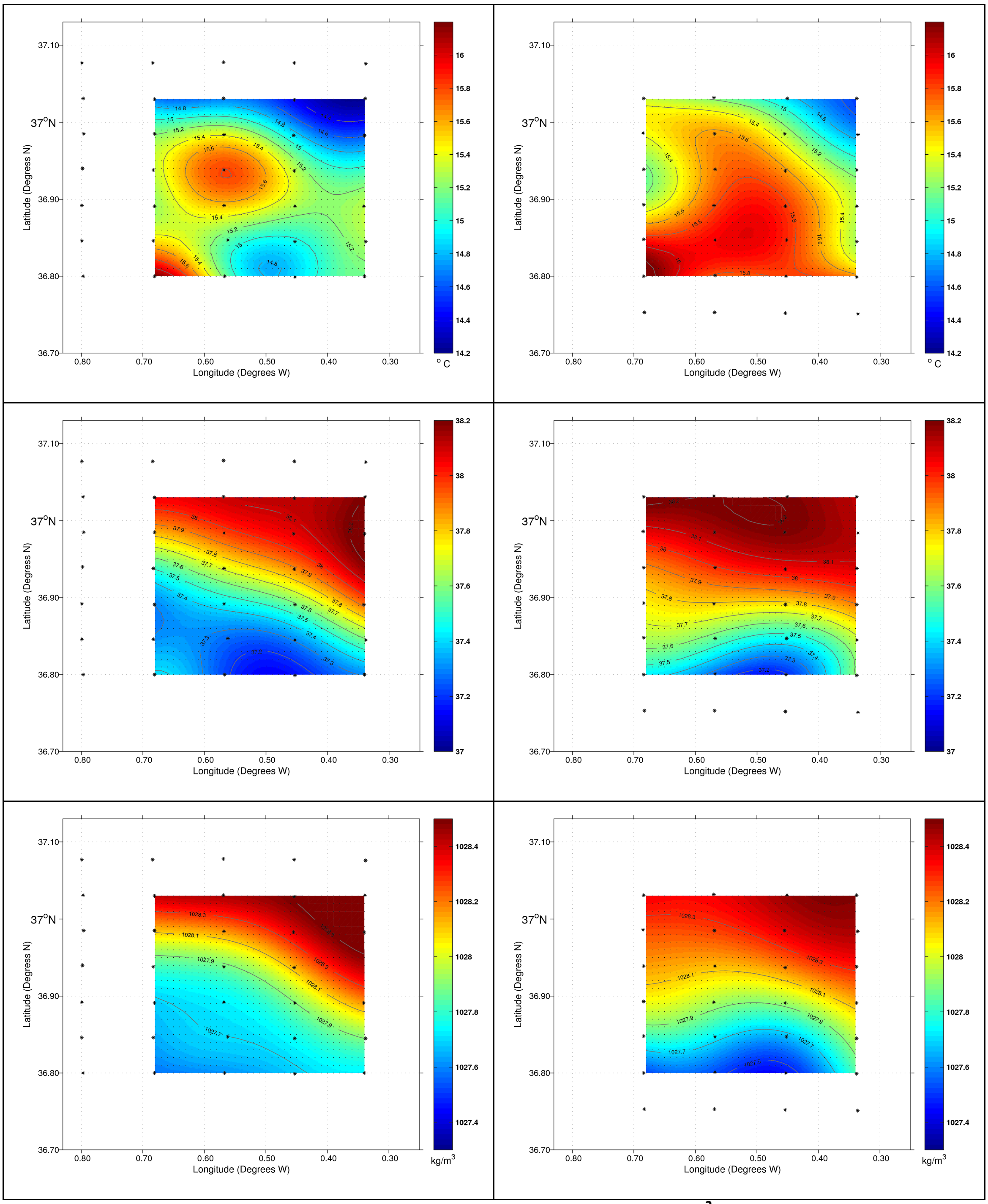

Figure 24. **Potential temperature (°C), salinity and density (kg/m^3) at 50 m depth from CTD survey 1 (left) and survey 2 (right)**

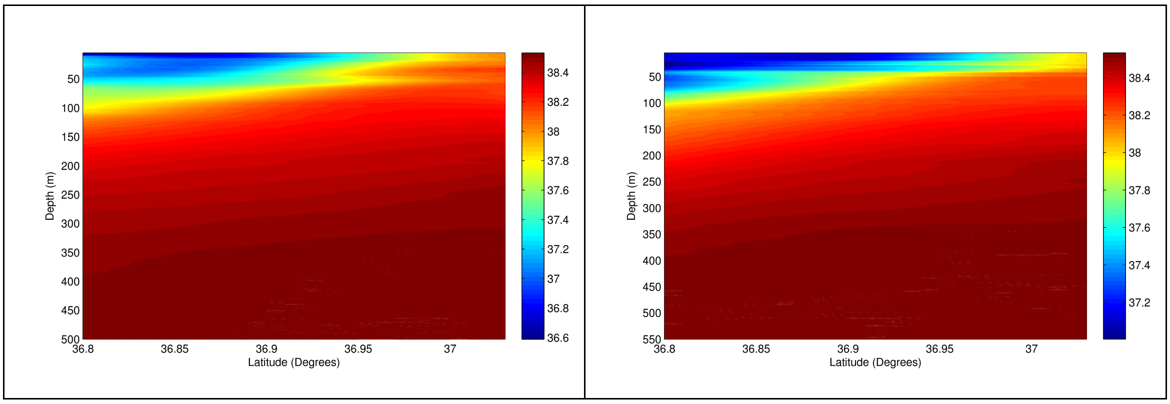

Figure 25. **Vertical section of salinity (Longitude 0.58° W) from CTD survey 1 (left) and survey 2 (right)**

6.2. Horizontal velocity fields

Surface drifters (SVP) deployed during the Alborex experiment allow to investigate several aspects of the surface dynamics such as the mesoscale circulation in the area or relative dispersion by surface waters. Figure 26 displays the trajectories of drifters deployed during the ALBOREX 2014 campaign with their initial (circles, on 25 May 2014) and final (asterisks, on 14 July 2014) positions. Drifters deployed more to the south were quickly captured by the Algerian Current (Fig. 26) and transported along the Algerian coast for ~500 km (Poulain et al., 2015).

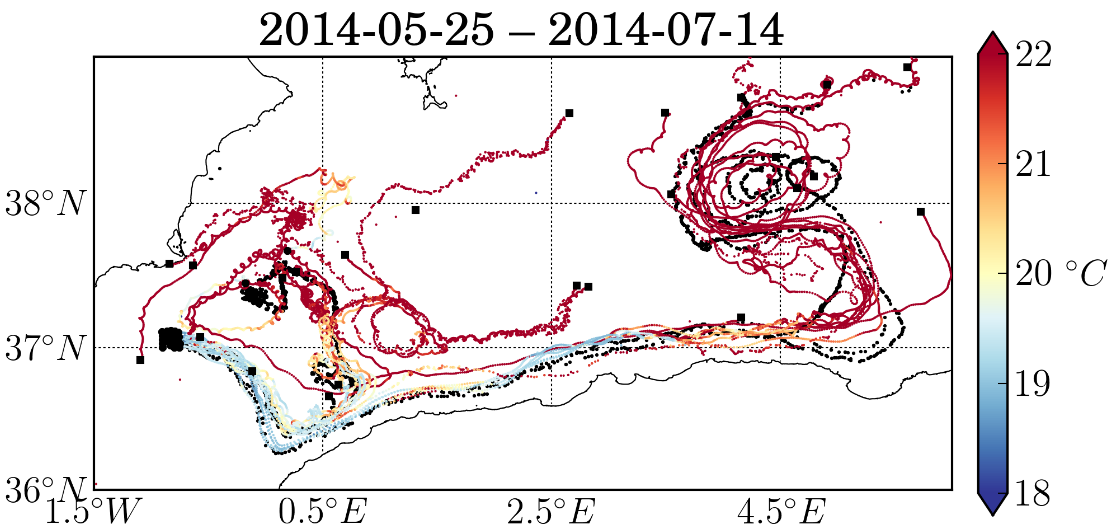

Figure 26. **SVP drifters tracks between 25 May 2014 and 14 July 2014. Colour indicates SST measured by drifters.**

At ~5°E they turned northward describing an anticyclonic eddy located between 37.5°-38.5°N and 4-5°E (Fig. 27). Drifters deployed more to the north were transported south-eastward for ~100 km, then were deflected northward and split in two directions (Fig. 28): some of them moved eastward and traced an anticyclonic eddy whereas the others moved north-eastward and described a cyclonic pathway (Poulain et al., 2014). See furthers details about the weekly displacement of the drifters during the period 25 May 2014 - 12 July 2014 in the annex V.

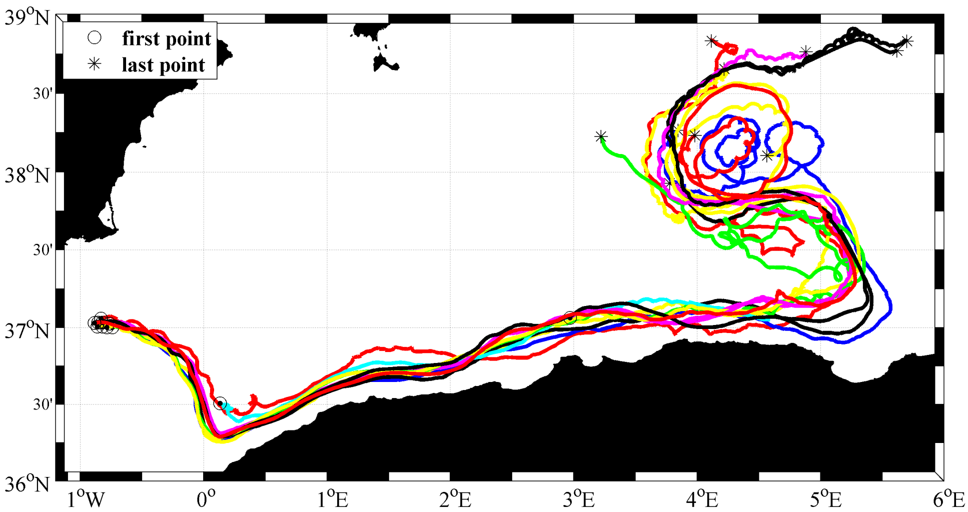

Figure 27. **Trajectories of the 11 SVP drifters captured by the Algerian Current.**

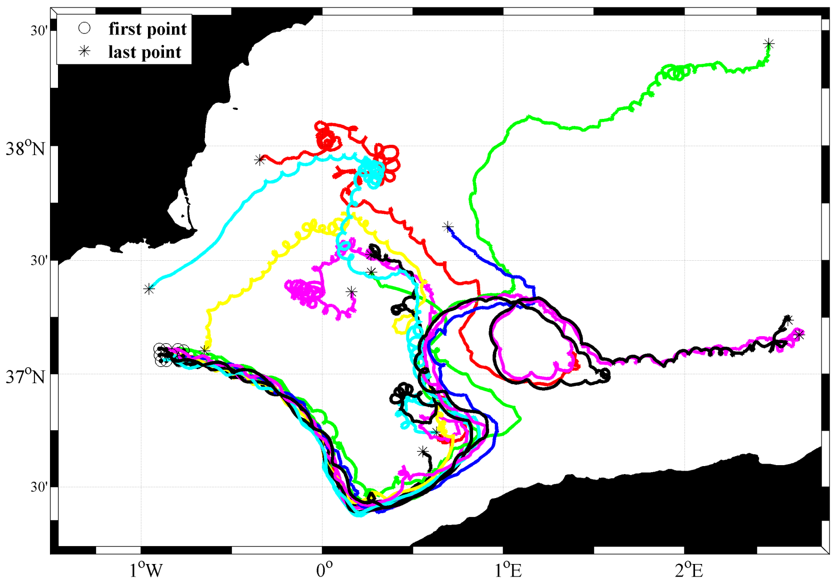

Figure 28. **Trajectories of the 13 SVP drifters deflected northward at ~0.8°E.**

Direct current measurements were obtained from a VM-ADCP 153kHz, having an accuracy of about 1 cm/s. The instrument was calibrated to correct the misalignment angle and scaling actor as described in Pollard and Read (1989). Original profiles were collected every 2 minutes, which produce approximately 1 profile very 0.5 km. In the vertical, data were also averaged over 8 m depth bins. Velocity from the first bin (16 m depth) reached values near 1 m/s (Fig. 29). At deep levels, the quality of ADCP data is usually low due to the weak intensity of the echo signal. The index 'percent-good' (Fig. 29) represents the percent of pings received with a noise-to-signal ratio below a threshold. During the Alborex experiment, the perfect good was high (> 90%) in the upper 200 m, which gives confidence about the quality of data. See more technical details in Annex II.

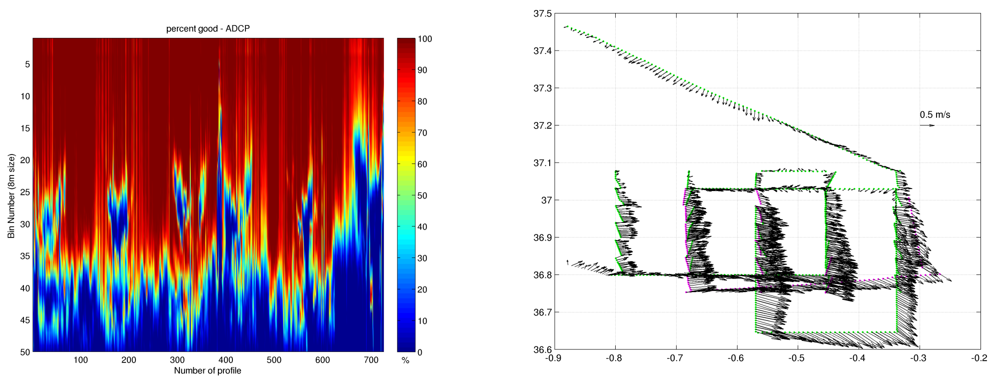

Figure 29. Percent-good index (left) for Alborex Experiment and velocity field from ADCP at 16 m depth (right).

Geostrophic velocity has been computed from CTD data, using a reference level of 550 m depth, which is assumed as the level of no motion. This hypothesis seems to be not very critical, previous authors have reported very small velocities (2-4 cm/s) at those depths (Allen et al., 2001). Figure 30 shows geostrophic velocities at 50 m depth from survey 1 and survey 2. The signal of an anticyclonic eddy is clearly identified and is coherent in terms of pattern with the velocities registered from VM-ADCP (Fig. 29). For the second survey the deformation of the front mentioned above is also visible and velocity field is stronger in the southeastern part of the domain.

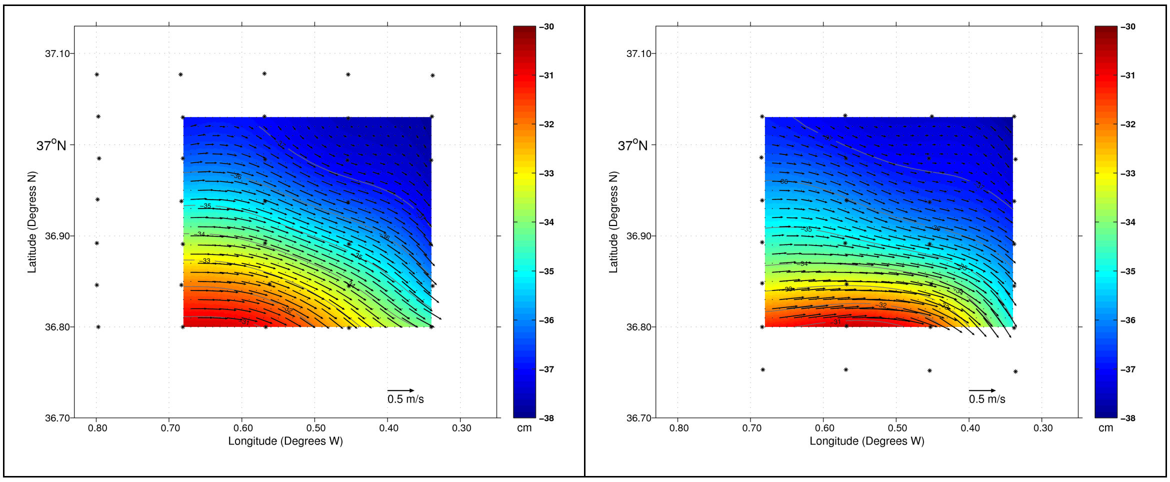

Figure 30. **Dynamic height (cm, background colour) and geostrophic velocity (cm/s, vectors) at 50 m depth from survey 1 (left) and survey 2 (right).**

It is worth to note that mean geostrophic flow at 50 m depth (~40 cm/s) is smaller than those from ADCP, which is about 50 cm/s (not shown). That is expected since ADCP measured actual velocity, including all velocity components (geostrophic, ageostrophic, etc). Moreover, in the southern part of the domain, geostrophic and actual velocity patterns show some difference in the path of the flow. This needs to be investigated carefully; the initial hypothesis is that actual flow includes a cyclostrophic acceleration, which also produces an additional deformation of the flow. This component has been evaluated in previous studies in the area to be of the order of 20% (Gomis et al., 2001).

Regarding the first modeling results, figure 31 shows the impact of glider data assimilation in a vertical section of salinity. The characterization of the frontal zone between the Atlantic and Mediterranean waters is clearly improved in the model after the assimilation process.

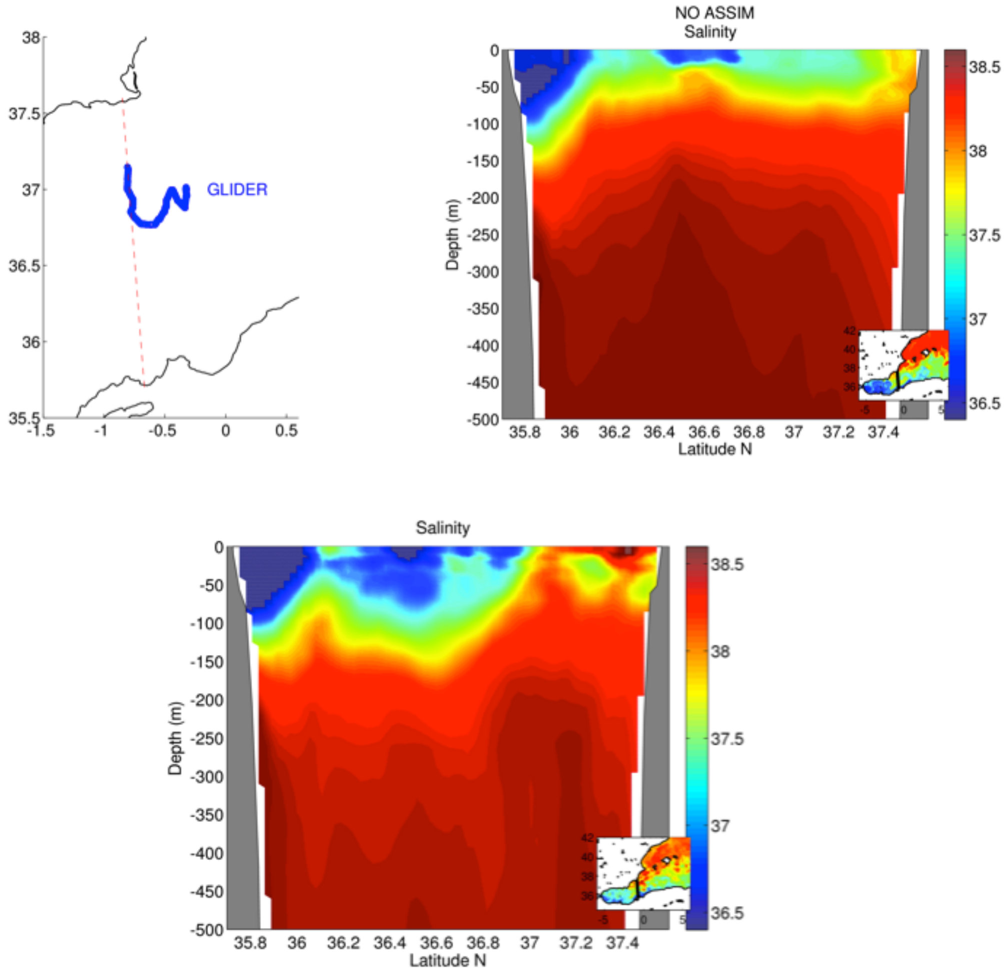

Figure 31. **Vertical section of salinity from WMOP model without glider data assimilation (top) and with glider data assimilated (bottom).**

6.3. Quasi-Geostrophic vertical velocities

The diagnostic QG Omega equation is used to quantify the vertical motion (Tintoré et al., 1991). Assuming boundary conditions for w and from a snapshot of the density field, the vertical velocity can be inferred. We set w=0 at the upper and lower boundaries and Neumann conditions at the lateral boundaries. Figure 32 shows the QG vertical velocity field estimated at 50 m depth for survey 1. The pattern is coherent having upwelling/downwelling upstream/downstream of the flow. The magnitude is about ±20 m/day. These vertical velocities are associated to structures larger that 20 km, the energy and potential contributions from smaller structures (which are present as it revealed by gliders) have been filtered out in the QG analysis using a low-pass filter.

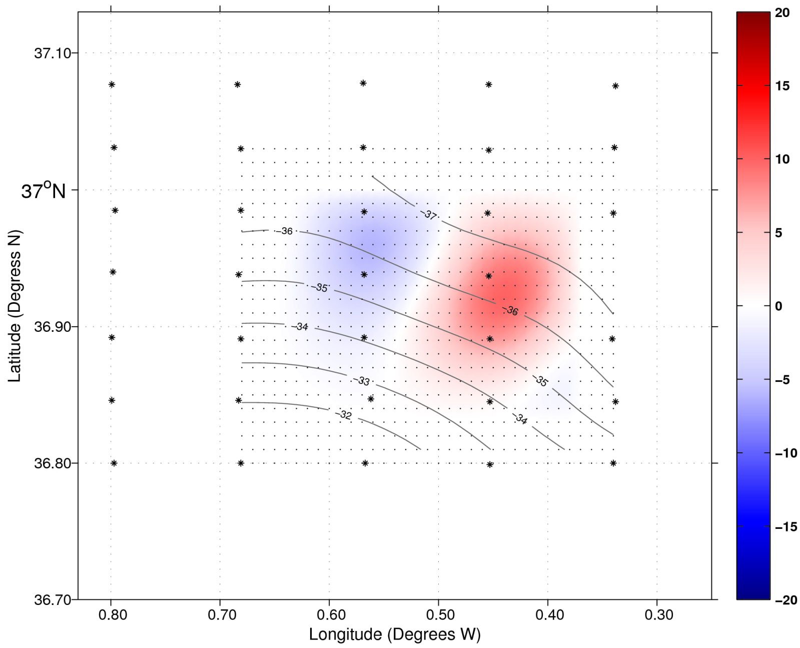

Figure 32. QG vertical velocity (m/day) at 50 m depth from density field of survey 1.

6.4. Submesoscale processes

Gliders were able to sample at high-resolution the frontal zone. The coastal glider (CG) was configured to collect hydrographic and biochemical data at about 0.5 km while resolution of data from the deep glider (DG) was of about 1 km along track. Figures 33 shows the temperature and fluorescence from DG. Small scales (less than 10 km width) filaments subducting are observed in different parts of the sampled area. These small structures are also observed by the CD in temperature, salinity and oxygen (Fig. 34).

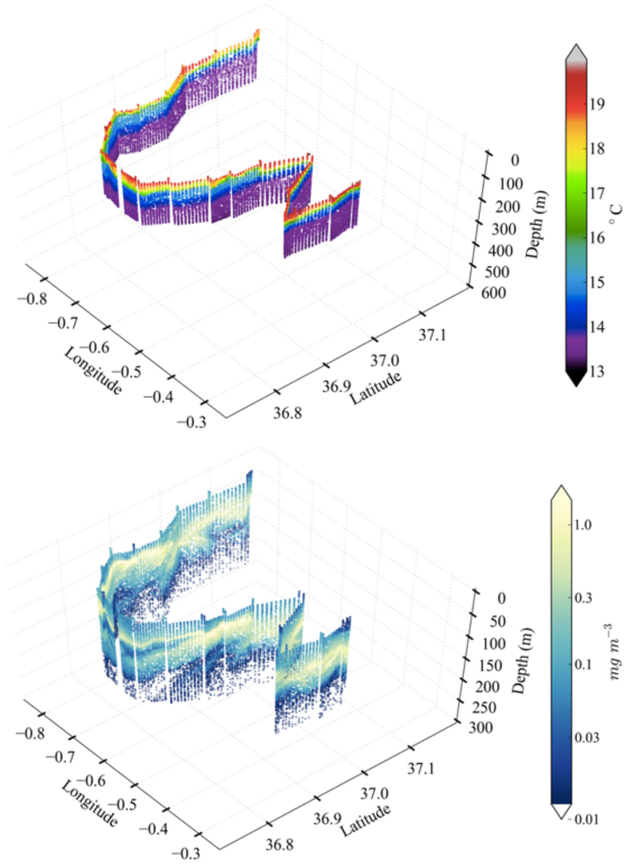

Figure 33. Temperature and chlorophyll concentration collected by deep glider.

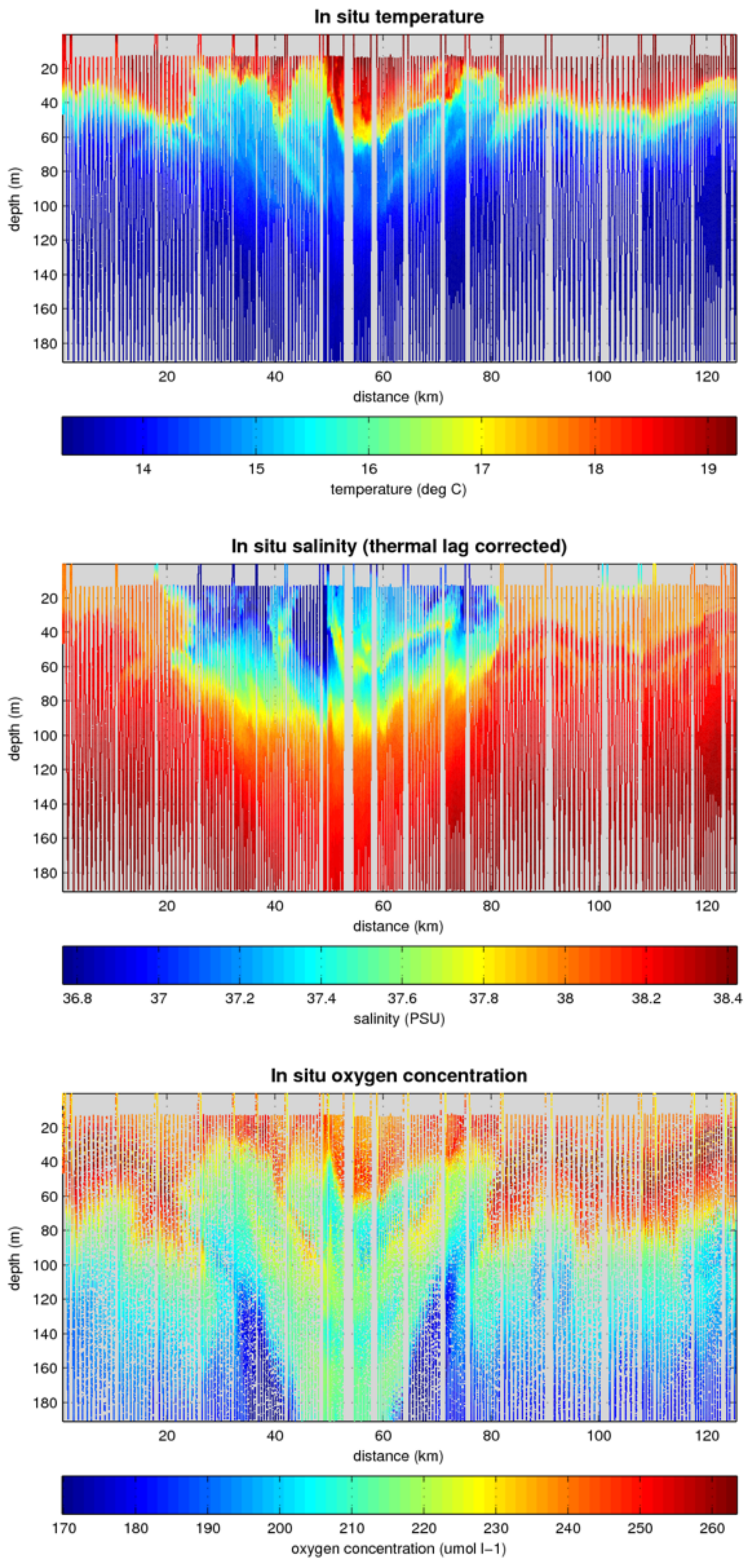

Figure 34. Temperature (°C), salinity and oxygen concentration (um/l) from coastal glider.

7. PERSPECTIVES

The analysis of data collected by ALBOREX multi-platform experiment will provide new insight on the potential mechanism governing the upward/downward motion in frontal zone. As mentioned above, the QG theory can partially explain vertical exchanges at the mesoscale, however at smaller scales (submesocale), with Rossby number higher than 1, other mechanisms such as frontogenesis and mixed layer instability may play an important role and need to be investigated in detail. Moreover, the effect of winds on vertical motion (Ekman pumping contribution) also should be considered and quantified.

Further steps consist in isolating mechanisms using a Process Study Ocean Model that would aim to resolve vertical transport at the front. Preliminary results obtained from initializing the model with observational data show that lateral buoyancy gradients in the area are large enough to trigger submesoscale mixed layer instabilities (MLIs). Once MLIs develop, vertical velocities are enhanced. These are likely to support the subduction of tracers from the surface mixed layer to the pycnocline beneath.

In order to model frontal mechanisms that will help interpret ALBOREX observations the following steps need to be taken:

1. Expand the model domain in order to resolve both mesoscale and submesoscale dynamics. Since the observations cover a region of 40km in spatial extent, we will use the SOCIB Western Mediterranean ROMS configuration (WMOP) model output to initialize a larger domain for our model. This ROMS simulation assimilates ALBOREX observations. Our model will examine processes over a region that extends ~100 km in extent.
2. Restore buoyancy in order to maintain the front since MLIs act to restratify it at a time scale smaller than that of the mesoscale.

Acknowledgments

The Alborex experiment was conducted in the framework of PERSEUS EU-funded project (Grant agreement no: 287600) with substantial support from SOCIB. Glider operations were partially funded by JERICO FP7 projects. We would like to thank all the crew on board R/V SOCIB for their efficient collaboration during the Alborex experiment. SST images at 1 km spatial resolution corresponds to Level-2 SST acquired by the Moderate-Resolution Imaging Spectroradiometer (MODIS) sensor on board Aqua and Terra satellites were obtained from Ocean Color Level 1&2 server (http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am). Also SST data from the EUMETSAT Satellite Application Facility on Ocean & Sea Ice (SAF's homepage http://www.osi-saf.org) were used. The altimeter products were produced by Ssalto/Duacs and distributed by AVISO, with support from CNES (http://www.aviso.altimetry.fr/).

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Annexes

Annex I: CTD technical report

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This partial report includes information regarding the CTD data processing during the Alborex experiment.

Data acquisition

Overall, 2 surveys were conducted in the study area. During survey 1 a total of 5 N/S transect were performed in less of 2 days, collecting data at 34 CTD stations. In survey 2 4 N/S transects were repeated in the area with 28 CTD stations. At each station CTD data were recorded at 24 Hz on both down cast and up cast for all parameters. In addition water bottle samples were acquired at each station, with a spread of depths from surface, mid and deep waters, for future salinity calibration. The CTD rosette carried the following instruments:

- Sea-Bird SBE 911Plus CTD, with 2 conductivity and temperature sensors and 1 pressure sensor units
- SBE 43 oxygen sensor
- Seapoint [FTU] fluorescence and turbidity sensor

Data processing ships CTD

Processing Overview - Steps

The CTD data underwent a 4 stage processing process:

Step 1: The raw data was processed using the SeaBird Seasave software, the 24 Hz data was saved as an ascii file.

Step 2: The data output from Step 1 was processed using a set of standard processing routines from the SeaBird Seasave software. The data output were averaged into 0.5 db bins and saved as an ascii file.

Stage 3: The data output from Step 2 were read into MATLAB routines created to enable data visualisation and quality control, see below for details. As problems were identified, the data was re-viewed and action taken depending on the issue. Through this iteration a set of SOCIB standard parameters were selected for Step 1, based on generally accepted internationally standards, but adapted for the ALBOREX mission. In this case we followed the BODC recommendations for parameters and processing sequence. Any changes made to the raw data or to the standard processing parameters to solve the identified problems were noted, see Table 1.

When all transects had been quality controlled and corrected, the 6 transects (45 stations), were processed sequentially to produce a 'mission' data file.

Step 4: Data calibration from bottle samples. Not yet completed. This is to calibrate the salinity using the water samples collected at each station, and apply corrections as required.

Processing Details

Following each cast the data was saved to the ships data server, in the form:

D:\OCEANO\CTD\DATOS\SOCIB-ALBOREX\Station_S2-16.hex

D:\OCEANO\CTD\DATOS\SOCIB-ALBOREX\Station_S2-16.con

D:\OCEANO\CTD\DATOS\SOCIB-ALBOREX\Station_S2-16.btl

The raw data files were processed using the SeaBird Software, Seasave V 7.22, using a script created by Benjamin Casas, SOCIB ETD Team Leader and following BODC standard processing recommendations.

Step 1: Conversion with Seabird Software

This step (step01_cnv_files) converts the .hex files using the manufacturer supplied sensor calibrations and then splits the files into upcast and downcast, essentially outputting raw data files.

1. datcnv - A raw data conversion routine. Datcnv reads in the raw data file (*.hex) output by the SeaBird sensors and converts the raw binary data to engineering units using manufacturer supplied calibration constants.

2. split - to split up and down casts. Bad data were excluded.

Data output was 24 Hz, upcast and downcast, per station, as ascii files. Saved as u*.cnv, d*.cnv.

Step 2: Standard Seabird processing routines

The second step (step02_cnv_files) applies a series of Seabird processing routines, in order, to identify spikes, apply standard corrections and finally bin the data for output.

1. wildedit - A de-spiking routine, was run on pressure, the 2 temperature sensors and the two conductivity sensors; The data was scanned twice calculating the standard deviation (SD) of a set number of scans, setting values that are outside a set number of standard deviations of the mean to bad data values. The scan range was set to 100 measurements (equivalent to 4 s of data), with first pass of 2 x SD (2 sigma) as the threshold and a second pass 7 x SD (7 sigma). The second pass is lower than the BODC norm, however it performed slightly better for the ALBOREX datasetd. Bad data were excluded.

2. filter – This performs a low pass filter of the data. Following BODC standards filter is run on pressure to smooth out any instrument response time issues, with a time constant set to 0.15 s low pass filter A and to 0.5 s for low pass filter B.

3. alignctd - This program aligns conductivity, temperature and/or oxygen relative to pressure. The BODC shift the Oxygen sensor relative to the pressure data by 2 seconds compensating for lags in the sensor response time, in ALBOREX the oxygen sensor was set to advance by 3 s.

4. celltm - The effect of thermal 'inertia' on the conductivity cells was removed using the conductivity thermal mass correction routine, celltm. This routine uses the temperature variable to adjust the conductivity values. It should be noted that if spikes exist in the former they are amplified in the latter thus this routine should only be run after wildedit and other routines that flag or exclude 'bad' data values. The parameters used were: thermal anomaly amplitude, $\alpha = 0.03$, and thermal anomaly time constant, $1/\beta = 7$ for both sensors.

5. loopedit – This routine marks a scan with badflag if scan fails pressure reversal or minimum velocity test, or to eliminate surface soak data. As we included a pressure reversal edit in Step 3 the options for this should be re-evaluated. Minimum CTD velocity was set at 0.25 ms^{-1}, window size is 300 s, the surface soak depth is 10 m, with a minimum soak depth of 5 m and a maximum od 20 m.

6. derive - this calculates depth, salinity, density and sigma, based on EOS-80 equations (Practical Salinity) for plots etc. These derived variables are later recalculated from the corrected potential temperature and salinity in Step 3.

7. binavg – the 24 Hz data was averaged in 0.5 db bins. Note this binning routine is the last routine performed, after 'bad' data had been excluded by the previous routines.

The output files from this process are per station downcast and upcast file (e.g. upcast_s2-30.cnv, downcast_s2-30.cnv), containing header information and data. In addition standard figures were output by Benjamin Casas to compare the output from the sensors per station using in-house MATLAB routines.

Screen shots of the Seabird processing routines with parameters and options selected are provided as a reference in Digital Annex 1.

Step 3: Data quality control and visualisation

The following MATLAB script, ctdDataDevelopment_ALBOREX.m, was created to visualise the data. The ascii files from each transect were placed in transect folders and the program reads all the .cnv files in that folder to visualise the data per transect. The data can be interrogated through this script, with the processing of upcast or downcast profiles, the different sensors, per profile figures and standard figures per transect. The data can be output and saved as a MATLAB matrix, per transect or per mission.

Within the program the following selections can be made; select data from sensor 1 or 2, to identify a station to create figures for a specific profile. The stations (*.cnv files) are read from folders called T1, T2 and T3 etc. and they can be a mix of upcast and downcast. Note: normally only the down cast is processed, as this is less affected by heave of the vessel. However for this mission the ability to mix upcast and downcast profiles was provided, due to the need to use the upcast profiles for some stations (Note when using this option, place only one upcast or downcast in the folder per station, not both). The quality controlled and corrected data, were were saved as transects, e.g. T1_processed_ctd.mat.

The main MATLAB routine is ctdDataDevelopment_ALBOREX.m, and this calls the following subroutines:

- cnv2mat_2013.m to convert the data, taking information from the header and data lines/section, and placing this within a matrix structure (dataCTD) as follows:
- createWaterFigs_ALBOREX: creates transect overview figures (prefix a2), θ/S, temperature and conductivity profiles ('strings'), colour plots of temperature, salinity, fluorescence and turbidity.
- createWaterFigs_ALBOREX_profile: creates figures (prefix a2), to view detail of individual profiles, this has a option selection. This option can be switched on and off at the start of the script (options.checkProfile = true/false).
- correctDepthInversions_ALBOREX: this removes pressure inversion problems at the base of profiles by removing pressure inversion data points from the end of the profile
- correctProfiles_ALBOREX: this removes sections od data that have been deemed un correctable – the corrections are hard coded into this file. This option can be switched on and off at the start of the script – options.checkProfile = true/false.

When all transects the had been quality controlled and corrected, the transects were processed sequentially to produce a 'mission' data file, saved as ALBOREX092013_processed_ctd.mat, with the following format:

missionCTD.sciTime	= time (mean serial time since 01-Jan-0000)
missionCTD.latitude	= latitude (mean latitude in degrees for the profile)
missionCTD.longitude	= longitude (mean longitude in degrees for the profile)
missionCTD.profile	= station number e.g. s2-30
missionCTD.transect	= transect number e.g. 1
missionCTD.mission	= cruise name ALBOREX 09/2013;
missionCTD.temperature	= temperature (°C)
missionCTD.salinity	= salinity (PSU);
missionCTD.conductivity	= conductivity (mScm-1)
missionCTD.fluorescence	= fluorescence(¿?);
missionCTD.turbidity	= turbidity(¿?);
missionCTD.maxDepth	= maximum depth of profile (m);
missionCTD.minDepth	= minimum depth of profile (m)
missionCTD.pressure	= pressure from CTD unit (db)

Additional variables derived using the standard SEAWATER Libraries v3.2.

missionCTD.ptemp	= potential temperature (°C);
missionCTD.pdensity	= potential density (kgm-3);
missionCTD.sigma	= (potential) sigma (kgm-3);

Note: The last two subroutines 'correction' subroutines are specific to ALBOREX data, however can be easily altered to correct other datasets:

General options selected ALBOREX

downcast

sensor 2

Standard processing parameters for Step 2 (Seabird Seasave software)

datcnv	Manufacturers calibration
split	up and down cast

wildedit	2 sigma, 7 sigma, scan range 100
filter	0.15 s and 0.5 s
alignctd	oxygen advanced by 3 s
celltm	thermal anomaly amplitude 0.03, thermal anomaly time constant 7
loopedit	Min CTD velocity 0.25 ms-1, window size 300 s, surface soak depth 10 m, min soak depth 5 m, max 20 m
derive	calculates depth, salinity, density and sigma
binavg	0.5 db

Annex II: ADCP, Navigation, Ship's Attitude and Position technical report

Authors: John Allen, SOCIB, Palma de Mallorca, Spain and Benjamin Casas-Perez, IMEDEA-CSIC, Esporles, Spain

In this report, we look at the collection of vessel mounted acoustic Doppler current profiler (VM-ADCP) data from the 150 kHz RDI VM-ADCP fitted to B/O SOCIB during the PERSEUS Alborex cruise 24th May – 1st June 2014.

Ship's position and attitude data

Meaningful water velocities from the vessel-mounted acoustic Doppler current profiler (VM-ADCP) can only be obtained when the ADCP data are corrected for the ship's direction, speed and attitude; in effect removing the ship's motion from the ADCP's initial estimate of water column movement.

There are three principle sources of error when attempting to derive ocean currents from a VM-ADCP instrument. The first is the error in the attitude of the VM-ADCP relative to the attitude of the vessel, the second is the error in the knowledge of the ship's heading and the third is the error in the knowledge of the vessel's velocity through the water. Typically a vessel's velocity through the water is between one and two orders of magnitude greater than the currents we are trying to measure and therefore these sources of error can easily dominate the signal. The first of these errors is overcome through calibration, discussed in a later section. The second and third of these sources of error are corrected for on B/O SOCIB through the use of an Ashtech ADU800 3D GPS instrument, fitted in July 2013. The ADU800 uses a system of three antennas mounted on the bridge roof to provide geographical positions to better than around 10-20 cm accuracy, and heading, pitch and roll to better than 0.1°.

The ship's position and attitude was setup to be measured at 1Hz by the new ADU800 3D GPS Ashtech. This is the latest Trimble-AshTech system measuring the phase difference, at three antennas, between incoming satellite signals from which the ship's heading, pitch and roll are determined through ultra short baseline navigation principles. Launched in February 2013, unlike previous systems it only uses three antennas; assuming only a slowly varying or invariant altitude the ADU800 reduces both the uncertainty error in attitude calculation and affords one less antenna.

150 kHz Vessel Mounted Acoustic Doppler Current Profiler (VM-ADCP)

Summary

SOCIB is a well equipped research vessel (http://www.socib.es/?seccion=observing_Facilities&facility=vessel) with a 150 kHz, RDI Ocean Surveyor, VM-ADCP transducer located in the port hull just forward of the accommodation bulkhead in front of the fuel tanks at a depth of ~ 2 m. The RDI deck unit is mounted in the computer rack on the port "dry" side of the Laboratory. It is connected to PCLAB02 for VMDas control and WinADCP software. The VM-ADCP was operated and logged throughout most of the cruise. The deck unit had firmware upgrades to VMDas 23.17 and PCLAB02 ran RDI software VmDAS v1.46.

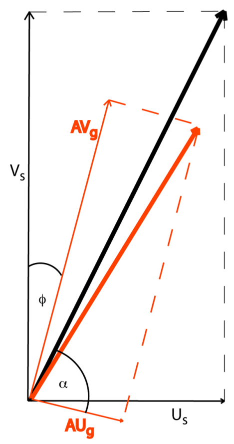
Calibration

To calibrate the installation of the VM-ADCP in the vessel hull, bottom track STA files are examined for mis-alignment calibration checks. The ancillary navigation and bottom tracking data are saved as text files through WinADCP, The text files are read into Excel and sections of the data are copied and pasted into a prepared Excel VM-ADCP calibration spreadsheet. The sections of data pasted into the spreadsheets are chosen on the basis of relatively constant ship velocity and bottom depth. The spreadsheet calculations follow the standard theory for VM-ADCP installation calibration from bottom track information, which is as follows (Joyce, 1989; Pollard and Read, 1989).

In the following diagram, let us consider AUg and AVg the velocity components of the bottom past the VM-ADCP as measured by the VM-ADCP, and Us and Vs the velocity components of the vessel from GPS navigation data. Now trigonometry tells us that

$$\frac{V_S}{U_S} = \tan(\alpha - \phi) = \frac{\sin(\alpha - \phi)}{\cos(\alpha - \phi)} = \frac{\sin\alpha\cos\phi - \cos\alpha\sin\phi}{\cos\alpha\cos\phi + \sin\alpha\sin\phi},$$

but, $\cos\alpha = \dfrac{U_g}{\sqrt{U_g^2 + V_g^2}}$ and, $\sin\alpha = \dfrac{V_g}{\sqrt{U_g^2 + V_g^2}}$;



therefore, $\dfrac{V_S}{U_S} = \dfrac{V_g \cos\phi - U_g \sin\phi}{U_g \cos\phi + V_g \sin\phi}$.

If we cross multiply, divide through by $\cos\phi$, and re-arrange, we can show that the mis-alignment angle ϕ is given by

$$\tan\phi = \frac{V_g U_S - U_g V_S}{V_g V_S + U_g U_S}$$

Now we observe also that

$$U_S = AU_g \cos\phi + AV_g \sin\phi,$$

and

$$V_S = AV_g \cos\phi - AU_g \sin\phi,$$

$$\therefore \quad \tan\phi = \frac{V_g\left(AU_g \cos\phi + AV_g \sin\phi\right) - U_g\left(AV_g \cos\phi - AU_g \sin\phi\right)}{V_g V_S + U_g U_S};$$

which, after expanding, simplifying, dividing through by $\sin\phi$ and inverting both sides, gives the amplification factor, A,

$$A = \frac{\left(V_g V_S + U_g U_S\right)}{\left(U_g^2 + V_g^2\right)\cos\phi}$$

Vessel mounted 150 kHz acoustic doppler current profiler data acquisition and processing

B/O SOCIB left the port of Cartagena at ~ 06:00 GMT on the 25/05/2013 and the 150 kHz RDI VM-ADCP was started shortly afterwards in bottom track mode ~ 06:15 GMT; files ALBOREXMay14001_000000.***. The initialisation file ALBOREX_May2014_BT8m.ini was used with the following configuration set.

Transducer depth = 2 m
Blank beyond Transmit = 8 m (As determined in the acceptance trials)
Number of bins = 50
Bin Thickness = 8 m
long range (narrowband) mode
Bottom tracking = on
Maximum bottom track distance = 400 m
Ping as fast as possible

EA Heading alignment set to -45.50.

STA files = 120 second ensembles
LTA files = 600 second ensembles
Velocity Scale factors set to 1.0000 (for calibration purposes)

The command file ALBOREX_May2014.txt was used to set the assumed salinity to 38.000 ppt.

At ~08:00 GMT, the files were cycled to put the VM-ADCP in water track mode using ALBOREX_May2014_WT8m.ini, with the following configuration:

Transducer depth = 2 m
Blank beyond Transmit = 8 m (As determined in the acceptance trials)
Number of bins = 50
Bin Thickness = 8 m
LoRes
long range (narrowband) mode
Bottom tracking = off
Ping as fast as possible

EA Heading alignment set to -45.50.

STA files = 120 second ensembles
LTA files = 600 second ensembles
Velocity Scale factors set to 1.0060 (determined from previous cruise calibrations)

The assumed salinity had to remain at the default 35.000 ppt, as we haven't worked out how to take a velocity scaling factor from the .ini file and a salinity from the .txt file simultaneously. In practice the salinity value used makes very little difference and due to the large temperature difference across the thermocline, using a lower salinity will tend to compensate for the use of surface temperature in the sound velocity compensation; files ALBOREXMay14002_000000.***.

The VM-ADCP files were cycled at ~20:45 GMT following a successful day deploying two gliders, 25 surface drifters and three Argo floats. The file cycling took place just west of the south-west corner of the Alborex CTD survey region to begin an overnight VM-ADCP box survey around the south-west corner of the CTD survey region. The instrument setup remained the same and the new files were ALBOREXMay14003_000000.***.

The bottom track data collected across the very short width of shelf off Cartagena, were examined for calibration values, derived f (misalignment angle) and A (scaling factor) were as follows:

ϕ (misalignment angle)	A (scaling factor)
0.4201 ± 0.7606	1.0066 ± 0.0038

The derived scaling factor was clearly very close to the applied factor of 1.0060, and thus this would be left alone. The derived mis-alignment angle suggested that we should reduce the rotational heading offset magnitude from -45.50 °, however the standard deviation was considerably bigger than the suggested correction and the subsequent sections viewed in WinADCP indicated a good calibration so no correction was applied.

Following the end of the overnight VM-ADCP survey, the VmDAS recording was cycled at 04:37 GMT 26/05/14 to begin files ALBOREXMay14004_000000.***. However due to an inter-operator miscommunication these were cycled again just before the beginning of the first CTD survey at 05:13 GMT, 26/05/14, with files ALBOREXMay14005_000000.***.

With the 1st CTD survey more than half completed, at ~22:25 GMT the VM-ADCP files were cycled to begin an overnight box survey over the eastern and south-eastern side of the CTD survey area: new filenames were ALBOREXMay14006_000000.***. This survey showed the strongest eastern currents associated with an anticyclonic Algerian current eddy were just south of the centre of the survey region; with core velocities of > 1 m s^{-1} (~ 2 knots). This current turned largely southwards, south of the eastern extremity of the CTD survey area (**Figure 1**).

At ~04:56 GMT on the 27/05/14, we re-started the 1st CTD survey where we had finished the night before and the VM-ADCP recording was cycled again. The new files were ALBOREXMay14007_000000.***. The sea-state was very calm, a gently undulating mirror, but according to all forecasts it was the 'calm before the storm', with bad weather and a day in Cartagena predicted for the next day.

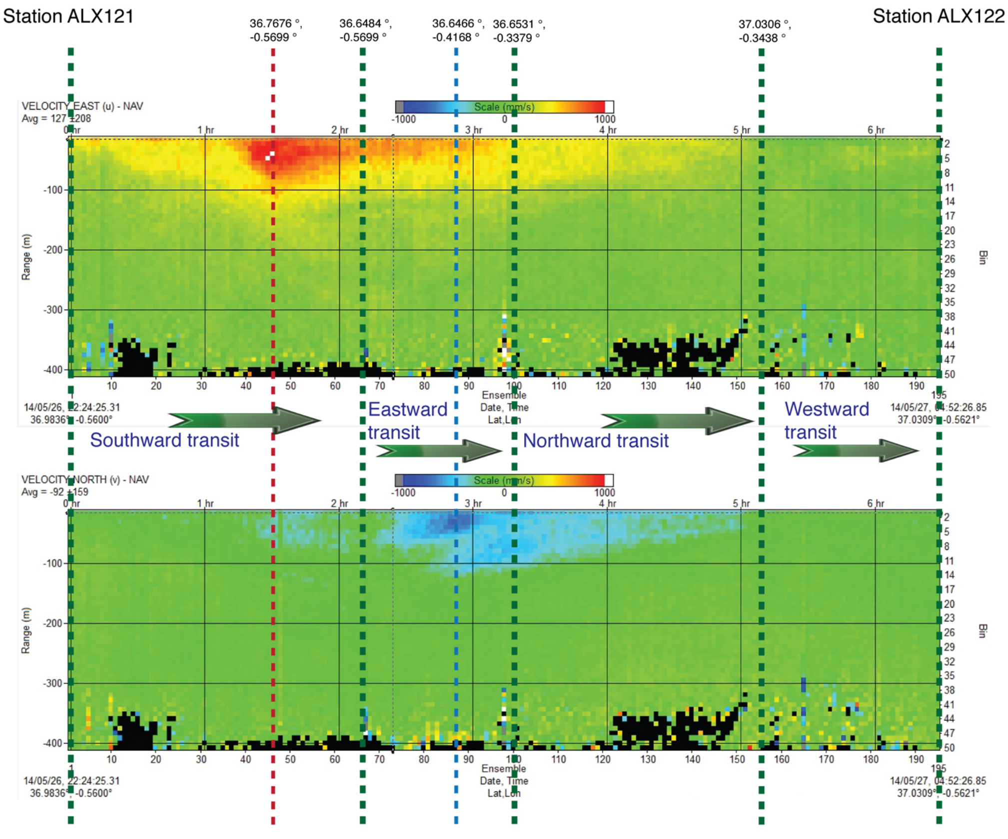


Figure 1: *East component (top) and north component (bottom) of the VM-ADCP velocity profiles contoured for the overnight box survey ALBOREXMay14006_000000.STA. Green dotted lines are the start, stop and turning*

points of the survey. The red and blue dotted lines give the points of core maximum east and south currents, showing the curvature of the current jet from eastwards to south-eastwards.

Following completion of the CTD survey at ~ 18:15 GMT, SOCIB set course for Cartagena to avoid the forecasted bad weather. The VM-ADCP files were cycled at ~21:10 GMT after crossing the westward shelf edge current and reached the narrow continental shelf off Cartagena. Files ALBOREXMay14008_000000.*** were recorded in bottom track mode using the initialisation file ALBOREX_May2014_BT8m.ini but this time this initialisation file had been edited for:

Velocity Scale factors set to 1.0060

VM-ADCP recording was stopped at ~ 21:50 GMT as we approached our berth in the port of Cartagena.

On Thursday 29th May, SOCIB departed Cartagena after bunkering at ~ 07:00 GMT. Again, the VM-ADCP was started in bottom track mode using the latest ALBOREX_May2014_BT8m.ini initialisation to record files ALBOREXMay14009_000000.*** out to the shelf edge. At ~ 08:00 GMT the VM-ADCP files were cycled into water track mode as the shelf edge fell away and we entered deep abyssal plain waters, using ALBOREX_May2014_WT8m.ini, the new files were ALBOREXMay14010_000000.***.

The bottom track data collected into and out of Cartagena, were examined for calibration values, derived ϕ (misalignment angle) and A (scaling factor) were as follows:

ϕ (misalignment angle)	A (scaling factor)
-0.1607 ± 0.1508	1.0023 ± 0.0020
-0.1416 ± 0.7463	1.0007 ± 0.0067

These suggested increasing the scaling factor to 1.007 or even 1.008, but with significant uncertainty. The derived mis-alignment angle suggested that we should slightly increase the rotational heading offset magnitude from -45.50 °, however again with considerable uncertainty; so no further correction was applied to either the scaling or the misalignment angle.

Following completion of the first 11 CTD stations of the 2nd CTD survey, the VM-ADCP recording was cycled at ~ 21:10 GMT to begin an overnight box survey of the south western region of the CTD survey area; the new files were ALBOREXMay14011_000000.***. The overnight survey finished at ~ 03:20 GMT on 30/05/14. During the overnight survey, the maximum depth of the eddy periphery current had been observed between planned stations ALX243/241 and around ALX241 in particular; there was no apparent southward component to this current.

At ~ 03:20 GMT, files ALBOREXMay14012_000000.*** were started whilst we remained hove-to on station ALX231 waiting for the morning watch to continue the 2nd CTD survey at ~06:00 GMT. The third line of the 2nd CTD survey began at 05:55 GMT in a northward direction. Upon completion of this line SOCIB transited back to the east of the survey region to pick up the two gliders deployed at the beginning of the cruise. The 4th and final, western, line of the 2nd CTD survey began ~ 17:55 GMT and finished at it's northern end ~ 22:27 GMT. At this point the VM-ADCP files were cycled to begin the long transit back to Palma, files ALBOREXMay14013_000000.***.

On the 31/05/14, at 07:52 GMT, the VM-ADCP recording was stopped and a number of tests were made to try to restart the ADCP speed log output feed through COM port 6 to the bridge. This took some time and a number files named ALBOREXMay14014_000000.*** were written and overwritten, the remaining files with this name are not to be used. Communication was eventually re-established but sadly, rather mysteriously, we still have no idea why this cruise and several recent cruises had not been able to provide the speed log and neither do we understand how we re-started it.

At 10:22 GMT the VM-ADCP was put back into bottom track mode using the initialisation file ALBOREX_May2014_BT8m.ini, again with:

Velocity Scale factors set to 1.0060

The new files were ALBOREXMay14015_000000.*** and these were recorded across the Ibiza and Mallorcan continental shelves and back towards Palma. The VM-ADCP was stopped and shut down as we passed Faro Figuera on the way into the Bay of Palma at 16:26 GMT.

Annex III. Gliders technical report

Author: Marc Toner, SOCIB, Palma de Mallorca, Spain.
Edited by Simón Ruiz, IMEDEA, Esporles, Spain

1. Infrastructure: Platform, Information-Technologies (IT), facilities and vehicles.

Gliders ICOAST00 (along with IDEEP00), part of the IMEDEA(CSIC-UIB) glider fleet, was deployed in the Alboran Sea (Spain, in front of Cartagena's coast) from May-25th to May-30th of 2014 in fulfillment of the glider participation in the ALBOREX-2014 experiment led by Dra. Ananda Pascual.

Glider deployment was, from a technical point-of-view, successful. The navigational performance of the autonomous vehicles met the pre-mission expectations while scientific sensors on-board the gliders gathered solid time series of values for the target variables such as temperature, conductivity and pressure, amongst others. During the deployment period, ICOAST00 or IDEEP00 did not require emergency piloting, nor in-situ, interventions. Recovery was efficiently executed from R/V SOCIB following a pre-established action plan.

ICOAST00	
Platform Type	*AUV (Glider)*
Manufacturer	*Teledyne Webb Research Corp.*
Model	*Slocum, 1st generation, shallow version (200m)*
Unit Ref.	*U050 ("ICOAST00")*
Battery Technology	*Alkaline C-cell*
Glider Software Version	*7.13 (navigation), 3.17 (science)*
On-board Sensors	*CTD* *Oxygen* *Fluorescence-Turbidity*

IDEEP00	
Platform Type	*AUV (Glider)*
Manufacturer	*Teledyne Webb Research Corp.*
Model	*Slocum, 1st generation, deep version (1000m)*
Unit Ref.	*U184 ("IDEEP00")*
Battery Technology	*Alkaline C-cell*
Glider Software Version	*7.13 (navigation), 3.17 (science)*
On-board Sensors	*CTD-A4468 sn 0195* *Oxygen-3830 sn 0841* *Fluorescence-Turbidity SLK sn 2128*

Chart 1. Main specifications for ICOAST00 (top) and IDEEP00 platforms (bottom).

Sampling data-set were successfully downloaded from the Glider and uploaded to SOCIB's data-centre FTP once the vehicles were returned to IMEDEA's glider-lab. Preliminary analysis and post-processing revealed coherency in the time series created during field work. NetCDF files were produced and are available at SOCIB's public repository waiting to be used for deeper scientific analysis.

IMEDEA Primary Gateway	*(RUDICS[1]) 00881600005178*
IMEDEA Bakcup Gateway	*(DIAL-UP[2]) 0034971611753*
SOCIB Primary Control Station	*Dockserver-136 (at IMEDEA's building)*
SOCIB Backup Control Station	*Dockserver-243 (at IMEDEA's building)*
IMEDEA GSM Modem	*Accessed by Dockservers. Sends SMSs to Pilots*
SOCIB Data-Center	*(see Annex V.2)*
Piloting Equipment	*Personal laptops and smartphones used by Pilots for 24/7 monitoring and surveillance*
Backup Positioning System	*(ARGOS[3])Subscription to online access for message download*
[1, 2]: Service Provider Info. at https://www.iridium.com/ProductList.aspx?productCategoryID=9	
[3]: Service Provider Info at http://www.argos-system.org/	

Chart 2. IT Infrastructure key-elements

The following chart contains a list of the facilities and vehicles used during the different stages of the Glider mission.

Preparation	
Facilities	*GliderLAB (IMEDEA)* *WetLABs-Ballasting&Pressure-(IMEDEA)*
Vehicles	*SOCIB's MobileLAB-Van (road transport)* *R/V-SOCIB (loading & final pre-departure check)*
Execution	
Facilities	*GCR-Glider Control Room-(IMEDEA)* *Data-Centre (SOCIB)*
Vehicles	*R/V-SOCIB (launching/recovery platform)*
Conclusion	
Facilities	*GliderLAB (IMEDEA)* *GCR-Glider Control Room-(IMEDEA)* *Data-Centre (SOCIB)*
Vehicles	*SOCIB's MobileLAB-Van (road transport)*

Chart 3. Facilities and Vehicles involved

2. Description of activities

2.1 Preparation

The glider ALBOREX-2014 experiment started with an introductory meeting that took place at IMEDEA (http://www.imedea.uib-csic.es), Mallorca, on the 14th of April of 2014. After that, multiple meetings were held to discuss all the aspects related to the ICOAST00 and IDEEP00 deployments. Those aspects were compiled in a Pre-mission Report.

Once the majority of the technical/sampling requirements were consistent, the preparation of the gliderS began and was structured following the stages introduced as follows. Dates of each stage's execution are compiled in Chart 4.

Stage	Execution Date
Pre-Mission Report	*14-15 of April 2014*
Hardware & Functional Check	*10-17 of April 2014*
Ballasting	*30 of April 2014*
Final Sealing	*06 of May 2014*
Configuration File-Set	*13 of May 2014*
Transportation	*23 of May 2014*
Notification	*19 of May 2014*
Real-time Monitoring	*23 of May 2014*
On-board Check	*23 of May 2014*

Chart 4. Execution Time-table of Preparation stages

Pre-mission Report

This document, which can be requested to SOCIB's glider team (glidertech@socib.es), introduced the prime aspects and configuration of gliders in accordance to the requirements of ALBOREX-2014. Main sections covered were the following:

- Mission parameters (dates, duration, distance-to-cover, expected-consumption, waypoint-list, ...).
- Target water physical properties (expected values for Max.Temp[degC], Min.Salinity and derived Min.Density[gr/L]), vital for the ballasting stage.
- Risk assessment (predicted currents[m/s] in the survey area and collision against static and mobile objects/vehicles/natural-bodies)

- Instrumental settings (to reflect both navigational and scientific strategies)
- Timetable & HHRR Planning
- Emergency recovery protocol
- IT & Data management

Hardware & Functional Check

During this stage, the glider was physically and electrically configured with all the parts and sensors to be used during the deployment. At this point, the main objective was to verify the individual performance of each part and interoperability within the glider as a whole. Three main checklists are fulfilled during this stage:

1. Hardware & Mechanisms (in-lab)
2. Communications - local(RF) & global(Iridium) - (outdoor)
3. Battery Capacity (in-lab)

Resulting main configuration parameters are listed in the following chart:

Communications	
Iridium Primary Number	*00881600005178*
Iridium Alternative Number	*0034971611753*
Iridium SIM Card ICC	*00881621411722*
Argos ID / Contract	*62605 / 3196*
FreeWave Master Num.	*915-4418*
Battery	
Type	*Alkaline (non-rechargeable)*
Cells	*260 Duracell® LR14 1,5Vdc*
Overall Nominal Capacity	*153 Ah*
Available Capacity	*128 Ah (brand new pack, considering safety margin)*
Mission's Estimated Consumption	*46 Ah*
SOCIB's Reference	*(Roll) 20110802_AL_RO_D* *(Pitch) 20101022_AL_PE_A* *(Dome) 20091001_AL_DO_A&B*

Chart 5. Glider configuration for Communications and Battery systems

Ballasting

The gliders were tested in a salt-water tank and their weights adjusted and re-distributed as necessary in order to adapt their variable buoyancy capabilities to the hydrographic properties of the water to be navigated in the survey area.

Lowest density [gr/L] is considered as the worst case as the final goal is to assure the glider capability to break into the surface. To calculate that, the following conditions (see ballasting results as well) were used:

Conditions	
Max. Target Temp	*20 degC*
Min. Target Salinity	*37,5 psu*
Derived Min. Target Density	*1026,67 g/L*
Results	
Estimated Glider Displacement	*52 Liters*
Configured Glider Weight	*52,5 Kg*
Neutral Pitch/Roll/H-Distance	*-2,9 º / -0,9 º / 5,6 mm*

Chart 6. Ballasting conditions and results during ICOAST00 preparation

Final Sealing

The gliders, with all their mechanisms, wiring and sealing elements, were disassembled and checked system by system in order to certify the vehicles were ready to be deployed. Main steps during this check were:

- Mechanism and moving-parts verification (specially buoyancy piston)
- Batteries fixing and connection
- Science bay inventory (sensor serial numbering) and wiring dressing
- Interior of forward dome and hull debris clearance
- Electronics and wiring visual check (specially navigation mother board and communication modules)
- Power-on connector cleaning and lubrication
- Piston and air bladders visually inspected
- Tail-boom and emergency weight-drop verification
- Installation of all complementary parts (wing-rails, wings, pick-point, cowling,...)

Configuration File-set

All necessary files were created (or updated) accordingly to the mission definition parameters. Files in this set were:

- Mission File: crtx000.mi
- Mission-Auxiliary Files: surfac10.ma, surfac20.ma, surfac30.ma, surfac4(1/2/3/4).ma, surfac50.ma, goto_l10.ma, yo10.ma, sample1(1/2/3/4).ma
- Conf. Files: sbdlist.dat, tbdlist.dat

The resulting configuration derived from all this files is resumed in the following chart.

Aborting Conditions	
Max. Mission Duration	*777600 secs (9 days)*
Max. Diving Depth	*195 m*
Min. Battery Voltage	*11 V*
Max. Vacuum	*12 inHg*
Max. working depth	*200 m*
Surfacing Events	
Aborting condition satisfied	*Ends mission*
No heading commanded	*Ends mission*
No diving/climbing commanded	*Waits for user command or repeats last segment*
No comms during 12 hours	*Waits for user command or repeats last segment*
(Main Event) Segment Completed after 10 dives	*Waits for user command or repeats last segment*
Waypoint reached (less than 1000m from exact Lat/Lon)	*Waits for user command or repeats last segment*
Diving Strategy	
Target depth	*190 m*
Buoyancy Pump position	*-200 cc*
Max. distance to bottom	*20 m (Starting pinging at 2m. of depth)*
Pitch control	*Automatic servo control to maintain -26 deg*
Climbing Strategy	
Inflection depth	*20 m*
Buoyancy Pump position	*200 cc*
Pitch control	*Automatic servo control to maintain +26 deg*
Initial Waypoint List	
Start (and deployment)	*N36º 52.800' ; W00º 20.400'*
End	*N37º 04.200' ; W00º 20.400'*
Note: Waypoint list was adapted during the execution of the mission. Changes are documented in section III of this document	
Sensor Sampling	

CTD	*Sampling Freq.=0,5 Hz* *Sampling during both Diving and Climbing* *Sampling between -5 and 2000 meters*
OXYGEN	*(idem than CTD)*
FLNTU	*(idem than CTD)*
Note: This configuration stood for the maximum performance each sensor can provide. Therefore, the sampling frequency meant "1 sample every 2 seconds...or as fastest as possible". *Note1: Depth range was overset by 'max working depth', which was 190m*	
Real-time Data	
Engineering	*Commanded battery position (climbing and diving)* *Measured battery voltage (filtered and instantaneous while climbing and diving).* *Depth* *X,Y components of estimated currents (at surface)* *Measured GPS lat/lon (at surface)* *Measured pitch (diving and climbing)* *Time-stamp (always)* *Bottom distance (only when detected)* *Science-bay time-stamp (always)* *Dead-reckoning state (always)*
Scientific	*Science-bay time-stamp (always)* *CTD-water_pressure (all samples every 5th diving maneuver)* *CTD-water_conductivity (idem)* *CTD-water_temperature (idem)* *FLNTU-chlor (1/4 samples every 5th diving maneuver)* *FLNTU-turb (idem)*

Chart 7. Engineering, Sampling and Real-Time strategies configured for ALBOREX-2014

Transportation

During this stage all steps and verifications were taken in order to guarantee that all material was put all together, loaded on the transporting vehicle and well fastened and secured to minimize damages during displacement to launching platform (R/V SOCIB). This covers the following main tasks:

- Review contents of hand-tools and communication-devices boxes
- Verification of the glider itself and all complementary elements (wingrails, pick-point, ON-connector,...)
- (extraordinarily for this mission): digital multimeter and vacuum pump

Notification

Local and national maritime authorities were notified prior to the glider deployments. The notification document included:

- Introduction to Mission Plan
- Preliminary Mission Period (specially launching date)
- Preliminary Waypoint List
- Contact info. of the glider responsible

Notifications were delivered to:

- Spanish Maritime Safety Agency (http://www.salvamentomaritimo.es/spanish-maritime-safety-agency/) - Headquarters and Palma's Office -
- Spanish Ministry of Defense, Office of Warning to Sailors (avisosihm@fn.mde.es)

nearReal-Time Monitoring

Internal notifications about the imminent glider deployments were sent to SOCIB's data-centre (http://www.socib.eu/?seccion=dataCenter ; data.centre@socib.es). At the same time, a mission profile was signed-in at SOCIB's database to configure the near-real-time 24/7 monitoring service for SOCIB platforms (only gliders were configured during this stage). This system is the platform from which the main on-line tracker feeds to provide on-time valuable information to both SOCIB/ALBOREX staff and general public. Plus, there are others: (1) an auxiliary, and stand-alone, tracker for backup and (2) a mobile applications for open access. (See next chart).

SOCIB Glider Mission Trackers		
DAPP (Main)	*http://apps.socib.es/dapp/*	
GAPP (Backup)	*http://apps.socib.es/gapp/*	
Mobile APPS	*"SOCIB" available at:* Available on the App Store	*"ICTS SOCIB" available at:* Google play

Chart 8. On-line tracking tools for near-real-time glider mission monitoring

Additionally, but not less importantly, to engineering aspects, SOCIB's monitoring service offers scientific in-situ & near-real-time observations by processing, plotting and publishing science sampling sub-file sets sent by gliders from survey area, using the satellite link, during surface periods (see below "Surface Behavior" chart).

On-Board-Loading Final Checkout

ICOAST00 and IDEEP00 underwent a final checkout procedure, the last one physically feasible by SOCIB glider technicians, prior to the departure of the deployment platforms for ALBOREX-2014, R/V SOCIB. This was executed after placing the gliders, and related equipment, on-board.

The aim of this last check was a comprehensive certification of the gliders readiness for deployment. Of course, problems might have occurred during the cruise but those were left for detection during pre-launch and pre-mission-execution tests at the launching location. Main aspects of this protocol covered:

- mechanisms (specially buoyancy pump, steering fin and pitch adjustment)
- science-bay (sensors reporting coherent values)
- communications (locally -RF- and, specially, globally - Satellite -)
- configuration file-set verification

At this point, ICOAST00 and IDEEP00 were left all-ready for deployment. Proper securing and fastening was in charge of R/V-SOCIB's crew, as well as its custody until the day of the deployment. Gliders mounted Alkaline batteries, and had not any kind of hazardous substance on-board; therefore, no special safety measures had to be considered.

No issues were reported regarding the safety of ICOAST00, nor related personnel, during the cruise to deployment area.

Execution

The Execution is understood here as, first, the launching operation (with corresponding preliminary tests and verifications with the glider already in the water); secondly, the period of time during which the glider remains deployed

(SOCIB glider pilots compiled all relevant events in a registry called Mission Blog) and, lastly, the recovery operation.

During the entire survey works, the human team was geographically disperse (Fig. 1). The piloting staff was in close contact with scientific leaders of the experiment and, at the same time, these two were also receiving in-situ feedback (and support) from SOCIB's ETD facility members onboard R/V-SOCIB.

Voice channels in between Mallorca's shore-control and R/V-SOCIB were neither fluent nor robust while the vessel was operating in the survey area. Satellite communications were an option to overcome that but, due to its inherent limited quality of service, the majority of discussions occurred when R/V-SOCIB returned to its home port.

Time Period

ICOAST00 glider performed the survey during the time period defined in the next chart:

Start	*[Sunday] 2014/Feb/25*
End	*[Friday] 2014/Feb/30*

Start	*[Sunday] 2014/Feb/25*
End	*[Friday] 2014/Feb/30*

Chart 9. Deployment's period of time for ICOAST00 (top) and IDEEP00 (bottom).

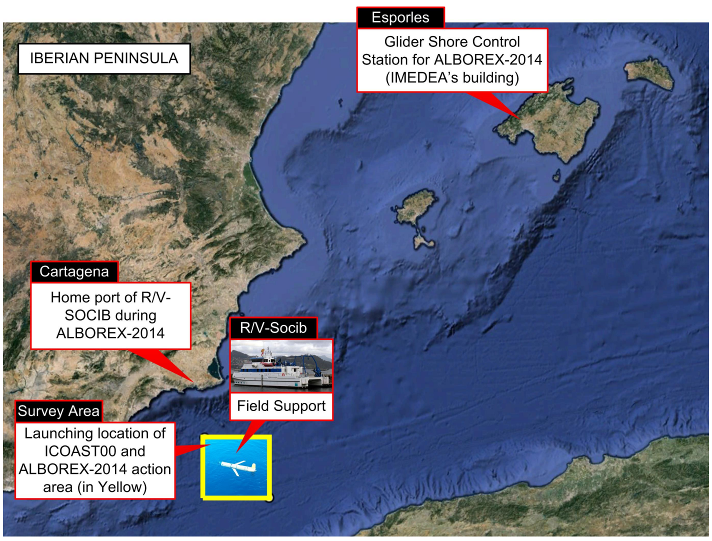


Figure 1. Mission execution scenario with remote piloting and on-site technical support

Deployment

The deployment was performed in accordance to the following main events:

- Gliders were turned on still on-board R/V-SOCIB so it established the first call to Shore-Control and went through a pre-launch verification driven by the remote Pilot.

- Once the on-board field technicians got the 'clear-to-launch' confirmation from shore, ICOAST00 and IDEEP00 were put in the water tethered to a buoy acting as safety measure against an eventual deficient flotation of the glider.

- Shore Pilot performed the first 'wet' verification and, after reviewing transmitted telemetry and receiving on-site feedback about the flotation of the glider, provided permission to field technicians to release the glider from the buoy.

Launching details	
Date	*[Sunday] 2014/Feb/25*
Glider turn-on	*08:40am(utc)*
Glider in-water	*09:25am(utc)*
Location	*N37°08.935' W00°48.663'*
Mother-Platform	*R/V-SOCIB*

Launching details	
Date	*[Sunday] 2014/Feb/25*
Glider turn-on	*10:16am(utc)*
Glider in-water	*11:08am(utc)*
Location	*N37°09.141' W00°41.630'*
Mother-Platform	*R/V-SOCIB*

Chart 10. Launching details for ICOAST00 (top) and IDEEP00 (bottom)

Finally, being officially deployed, ICOAST00 and IDEEP00 were left alone, and drifting, under the Pilot's control waiting to undergo the first pre-mission test dives.

The Cruise

Described Track

The gliders surveyed the area of action performing the tracks shown in Figure 2. In this document, a Track is considered as a combination of chained transects that are, at the same time, imaginary straight lines defined in between origin and destination waypoints.

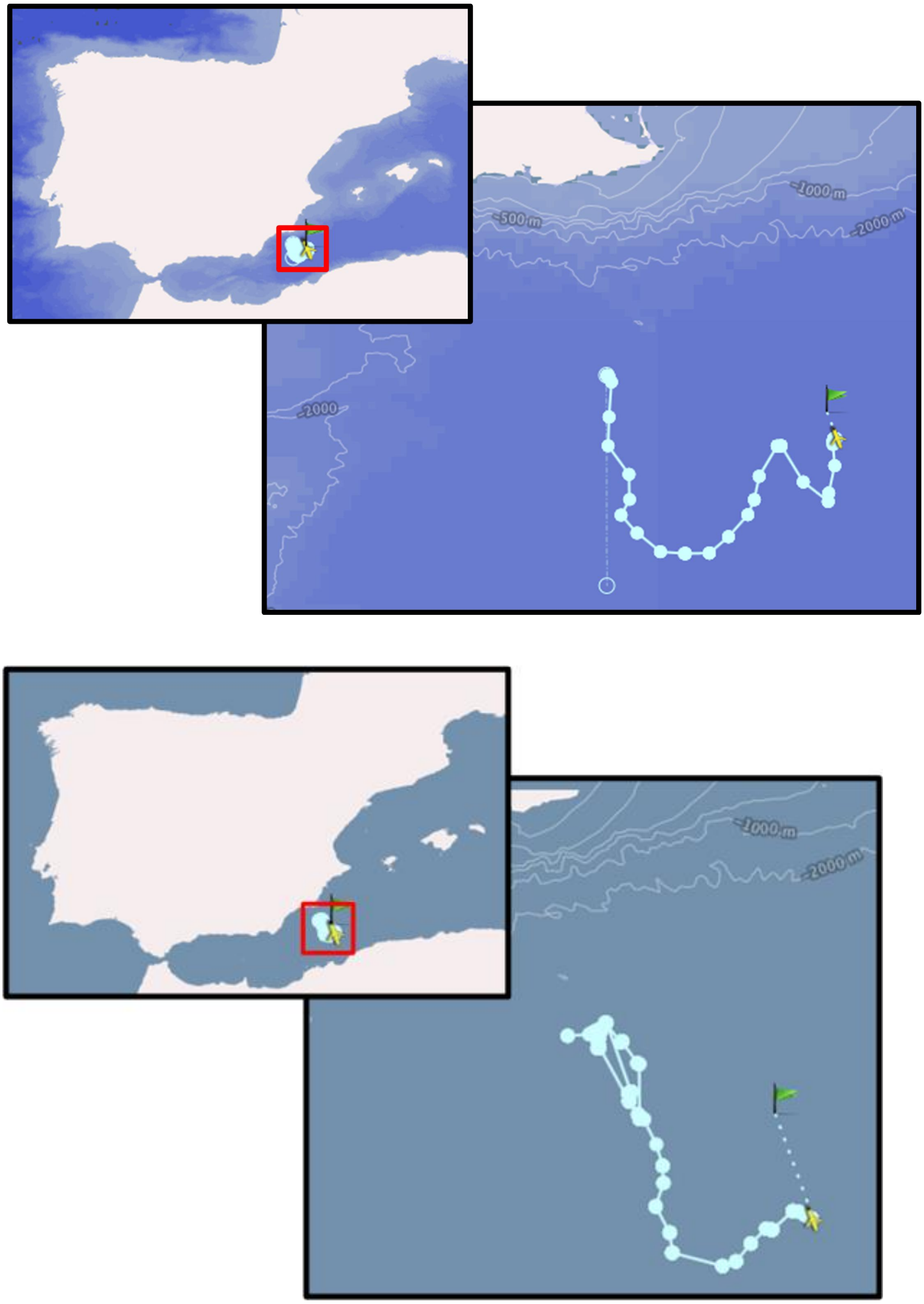


Figure 2. Final mission tracks and surface points for icoast00 (top) and ideep00 (bottom).

Surface Behavior

ICOAST00 and IDEEP00 emerged to the surface multiple times each day it remained deployed. Although the execution of this maneuver was, in practical terms, very similar; there was a varied set of triggering-causes and on-surface-actions as shown in next chart.

	Cause	Main Actions while at the surface	Occurrence
#1	*Auto-abort due to failure*	*Establishing a call to Shore-Control and wait for commands*	*Did not occur*
#2	*Lack of Target Waypoint*	*(idem than #1)*	*Did not occur*
#3	*Completed an even number of dives as commanded*	*Acquiring GPS fix; Establishing a call to Shore-Control and wait for commands.* *(<u>if requested, transmitting a sub-sample of engineering and scientific data</u>)* *(call could be managed with automatic script running in Shore-Control station)*	*Daily (an average of 4 times/day)*
#4	*Waypoint Hit*	*(idem than #3)* *Also choosing the next target waypoint in list*	*Once during the whole mission*
#5	*No stable* comms. for 12hrs.*	*(idem than #3)* **(comms. become stable after 1 min. of continuos link)*	*Once during the whole mission*

Chart 11. Types of mission surfaces (causes and taken-actions)

Underwater Behavior

The glider navigated following a saw-chain pattern (alternation of diagonal ascend and descend as shown in Figure 3) during the time elapsed in between surfaces.

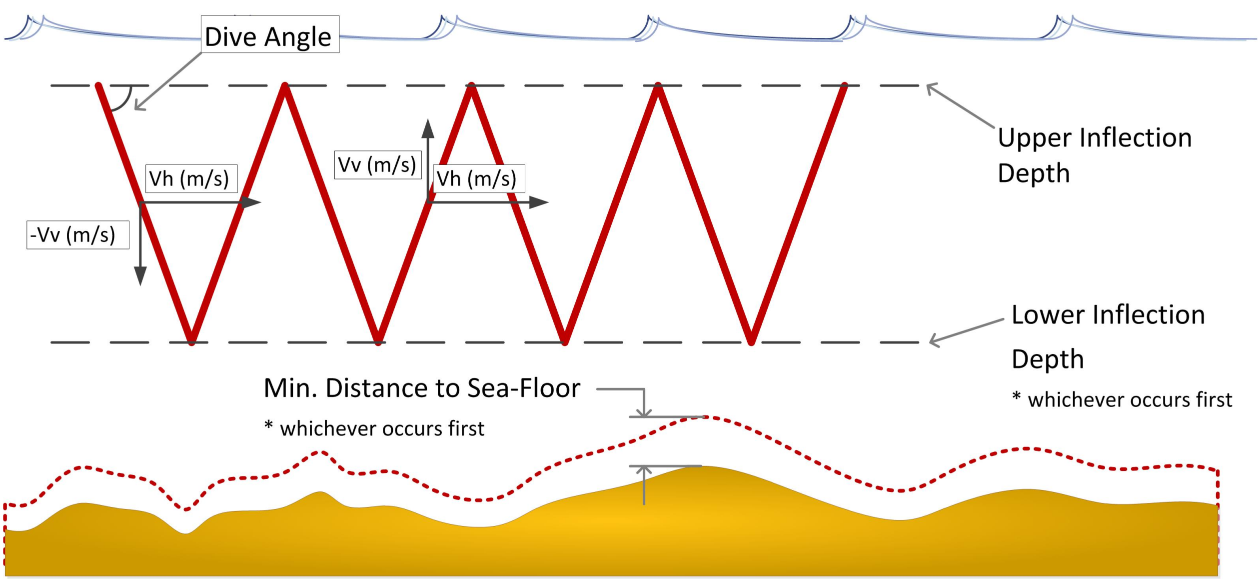


Figure 3. Typical saw-chain pattern followed by Glider during underwater navigation

Next chart summarizes the navigation strategies configured during the execution of the survey.

A: Navigation Strategy Identifier
B: Consecutive Dives in between surfaces
C: Upper Inflection Depth (m)
D: Lower Inflection Depth (m)
E: Minimum Distance to Bottom (m)
F: Gliding Angel (deg)
G: Buoyancy Drive for Propulsion (cc)

A	B	C	D	E	F	G	Description
#1	*02*	*15*	*45*	*20*	*±26*	*±200*	*First pre-mission test: navigation capabilities*
#2	*01*	*15*	*190*	*20*	*±26*	*±200*	*Second pre-mission test: resistance to max. operative depth*
#3	*10*	*15*	*190*	*20*	*±26*	*-190* *+200*	*Main gliding strategy. 'B' param. value was set seeking a 6hr. gapp in between surfaces*
#4	*02*	*15*	*190*	*20*	*±26*	*-190* *+200*	*Gliding strategy used while waiting for recovery. It pursued a balance between surfacing often and staying safe while recovery platform approached the glider's vicinity*
#5	*-*	*0*	*-*	*-*	*+26*	*±233*	*Only-Climbing strategy. Used during the ascending maneuvers that brought the glider to the surface for whichever cause was configured. (See chart in "Surface Behavior" section). These maneuvers started after the last consecutive dive was completed*

Chart 12. ***Summary of strategies implemented during sub-surface navigation***

As far as the scientific sampling is concerned, no special actions nor modifications were adopted with respect to the configuration applied during this deployment's preparation.

Mission Blog

Date	Event Description
25/May/2014	
08:43(utc)	*First Iridium call to shore control before launching*
09:20(utc)	*Start of pre-mission test dives*
10:10(utc)	*End of pre-mission test dives. Beginning of scientific mission*
17:47(utc)	*Iridium call after first scientific segment (10 dives down to 200m)*
26/May/2014	
00:00(utc)	*Iridium call managed by automatic piloting script*
06:05(utc)	*Iridium call managed by automatic piloting script*
12:08(utc)	*Iridium call to backup line. Incomplete call to Primary line*
18:04(utc)	*Iridium call managed by automatic piloting script*
27/May/2014	
00:01(utc)	*Iridium call to backup line. Incomplete call to Primary line*
06:05(utc)	*Iridium call managed by automatic piloting script*
	Several Pitch-motor oddities occurred during last segment
12:00(utc)	*Missed call*

18:23(utc)	Iridium call to backup line. Incomplete call to Primary line
18:29(utc)	No-Comms-for-a-While call as minimum call duration not satisfied during previous call
28/May/2014	
00:50(utc)	Iridium call managed by Piloting team
	New route configured (target waypoint change)
01:06(utc)	Iridium call managed by Piloting team
	New route configured (target waypoint change)
	Multiple Buoyancy-Pump oddities accumulated during surface drift
07:24(utc)	Iridium call managed by automatic piloting script
13:53(utc)	Iridium call managed by automatic piloting script
20:15(utc)	Iridium call managed by automatic piloting script
29/May/2014	
02:25(utc)	Iridium call managed by automatic piloting script
	Not traceable Coulomb-Counter oddity
08:43(utc)	Iridium call managed by Piloting team
	New route configured (target waypoint change)
15:20(utc)	Iridium call managed by automatic piloting script
19:18(utc)	Iridium call managed by automatic piloting script
	Glider reported Hit-a-Wpt
22:05(utc)	Iridium call managed by automatic piloting script
30/May/2014	
04:33(utc)	Iridium call managed by automatic piloting script
	2 Pitch-motor oddities
11:18(utc)	Iridium call managed by Piloting team
	Diving strategy modified to perform 2 dives (instead of 10) in between surfaces
	New route configured (target waypoint change)
	UTC end-time configure at 13am,utc
12:55(utc)	Iridium call managed by Piloting team
	Diving strategy modified to perform 1 dive in between surfaces
	UTC end-time deactivated
13:48(utc)	Iridium call managed by automatic piloting script
	Surface time extended while waiting for R/V-SOCIB interception
	Glider left drifting
13:58(utc)	Iridium call managed by Piloting team
	Mission kill. Glider taken out of mission mode.
	(R/V-SOCIB in the vicinity and standing-by to attempt recovery)
	Glider in recovery-mode
	Glider recovered on-board auxiliary RIB
14:34(utc)	Glider safe on-board R/V-SOCIB
	Glider turned OFF remotely

Chart 13. Mission Log created during Piloting & Monitoring for ICOAST00

Date	Event Description

25/May/2014	
10:19(utc)	*First Iridium call to shore control before launching*
11:21(utc)	*Start of pre-mission test dives*
14:02(utc)	*Navigation test (double-dive at 50m)*
14:45(utc)	*Depth test (four dives at 250m). Intermediate depth to avoid diving directly to 500m*
19:24(utc)	*Attempt to complete Depth Tests by configuring a single-dive at 500m* *An error raised by the Sensor's Payload prevented the mission continuation.* *An intense period of emergency piloting undertaken to deal with this situation*
21:10(utc)	*Sensor's Payload (SCIENCE_SUPER) disabled*
21:41(utc)	*Mission resumed with a double-dive at 50m commanded*
22:14(utc)	*Main diving strategy (Chart 15) configured*
26/May/2014	
08:50(utc)	*Sensor's Payload (SCIENCE_SUPER) put back into service*
10:55(utc)	*Science files checked and sampling data verified* *Main diving strategy (Chart 15) configured*
16:03(utc)	*Near-Real-Time file sending ordered by automated script*
21:33(utc)	*Near-Real-Time file sending ordered by automated script*
27/May/2014	
02:59(utc)	*Near-Real-Time file sending ordered by automated script*
07:31(utc)	*Near-Real-Time file sending ordered by automated script* *GPS position was excessively old. GPS seemed to not be able to get a fix*
08:29(utc)	*Manual mission stop* *Test mission STATUS run to test GPS*
08:34(utc)	*GPS gets a fresh fix* *Mission run again*
13:52(utc)	*Near-Real-Time file sending ordered by automated script*
14:20(utc)	*Glider got apparently stuck at currents* *New route programmed to fight against those currents*
20:04(utc)	*Near-Real-Time file sending ordered by automated script*
28/May/2014	
01:16(utc)	*Near-Real-Time file sending ordered by automated script*
06:44(utc)	*Near-Real-Time file sending ordered by automated script*
12:01(utc)	*Near-Real-Time file sending ordered by automated script* *CTD's pressure sensor usage for flying activated* *GPS failed to get a fix on time, between surface and Iridium call*
16:13(utc)	*Iridium call dropped prematurely*
19:40(utc)	*Iridium call dropped prematurely*
29/May/2014	
00:52(utc)	*Near-Real-Time file sending ordered by automated script*
06:10(utc)	*Near-Real-Time file sending ordered by automated script*
11:50(utc)	*Near-Real-Time file sending ordered by automated script* *New route programmed*
16:27(utc)	*Near-Real-Time file sending ordered by automated script*
18:31(utc)	*Near-Real-Time file sending ordered by automated script*
23:44(utc)	*Near-Real-Time file sending ordered by automated script*
30/May/2014	
05:01(utc)	*Near-Real-Time file sending ordered by automated script*

10:20(utc)	*End by UTC-time configured (next day at 14-UTC)*
10:49(utc)	*Glider surfaced reporting an ABORT (caused by Behavior-Error)* *New mission defined with a max. duration of 4 hours* *New route programmed (targeting to the final waypoint for recovery)* *Mission run*
13:04(utc)	*Gliding strategy for recovery programmed (Chart 15, #4)*
14:03(utc)	*Glider appears in GliderDOS after ending the mission due to UTC trigger*
14:11(utc)	*Mission run (gliding strategy #1, Chart 15, programmed)*
15:12(utc)	*Manual mission interruption* *U_MAX_TIME_IN_GLIDERDOS extended to allow a long enough surface drift*
15:36(utc)	*R/V SOCIB intercepted the vehicle*
15:40(utc)	*R/V-SOCIB's Auxiliary RIB recovered the glider*
15:50(utc)	*Glider hoisted on-board R/V-SOCIB. Field-team sent confirmation to Shore-Pilot*
15:54(utc)	*Shore-Pilot commanded the glider to enter in storage mode and provides permission to Field-team to proceed with the Glider shut-down*
16:00(utc)	*Glider turned OFF*

Chart 13 (continued) Mission Log created during Piloting & Monitoring for IDEEP00

Glider Command & Surveillance

The activity and performance of the gliders was constantly monitored from the beginning to the end of this mission's execution by SOCIB's Glider Piloting Team (glidertech@socib.es) taking advantage of the SOCIB's tracking systems (see "nearReal-Time Monitoring" section).

24/7 monitoring was sustained by

- (during glider surfaces) periodical analysis of telemetry and scientific sub-filesets sent in-situ by the glider.
- (during underwater periods) tactical discussions to validate navigational and sampling strategies held by SOCIB and ALBOREX members and
- (in case of emergency) a 24/7 remote-surveillance shift based on robust GSM/3G and Internet connectivity to SOCIB's shore control stations.

In this particular mission, local radio link (900 Mhz) was not used for piloting purposes although in-situ technicians on-board R/V-SOCIB used a radio receiver as a backup method to aid in the precise interception of the glider during the recovery operation.

Sources of Environmental Information

Within the context of glider survey, multiple sources of environmental information were permanently consulted to construct an up-to-date knowledge of the mission execution in the area of survey. It is not in the scope of this report to provide information about other sources that might have been consulted by the rest of participants in ALBOREX-2014 in relation to other aspects, operations and platforms.

SOCIB (http://www.socib.eu/?seccion=facilities)	
"facilities" ↓ *"observing facilities"*	*"Coastal Research Vessel", "Lagrangian Platforms", "Satellite"*
"facilities" *"modelling and forecasting facility"*	*Western Mediterranean "Sea Surface Temperature", "Sea Level Height", "Geostrophic Currents"*
Puertos del Estado (http://www.puertos.es/en-us/Pages/default.aspx	
"Forecast Data"	*"Waves Med.", "Currents", "Temperature", "Salinity"*
"Historical Data"	*"Waves", "Currents", "Temperature", "Salinity"*
AEMET (http://www.aemet.es)	
"Weather" ↓ *"Forecast"* ↓ *"Marine"*	*"Wind Forecast"*

Chart 14. Sources of environmental information supporting glider command

Recovery

The recovery was performed in accordance to the following main events:

- in-shore Pilot configured ICOAST00 and IDEEP00 to break into the surface more often than normal as a result of the coordination discussion with on-board technicians and scientific leaders.

- having received an estimated list of forthcoming surfacing times/locations, R/V-SOCIB cruised to the closest of these interception points. Once there, Pilot was notified and field-team stood-by.

- glider called in and Pilot commanded it to quit the mission and to wait drifting at the surface for the field team to establish visual contact. Latest GPS fix was transmitted from shore-control to the field team (glider would perform periodical calls to shore-control while drifting to allow GPS refresh).

- once the glider was within the reach of the technicians on-board R/V-SOCIB (using vessel's auxiliary RIB), Pilot was asked for permission to proceed with the extraction. Having received clearance-to-recover, RIB crew lifted the glider on-board and then returned to mothership.

- having confirmed to Pilot that glider was safe and securely fastened on-board, and waited for next glider call to shore-control, Pilot prepared the glider for shut-down and granted permission to on-board technicians to proceed with the physical disconnection

Recovery details	
Date	*[Friday] 2014/Feb/30*
Glider extraction	*14:20(utc)*
Glider in-water	*14:40(utc)*
Location	*N37°08.935' W00°48.663'*
Mother-Platform	*R/V-SOCIB's auxiliary RIB*

Recovery details	
Date	*[Friday] 2014/Feb/30*
Glider extraction	*15:40(utc)*
Glider shut-down	*16:00(utc)*
Location	*N36°48.113' W00°16.084'*
Mother-Platform	*R/V-SOCIB's auxiliary RIB*

Chart 15. Recovery details for ICOAST00 (top) and IDEEP00 (bottom).

Closing

Once vehicles were recovered, shut down and securely fastened on-board it was not operated again until it arrived at the SOCIB's glider laboratory located in the IMEDEA building (Esporles, Mallorca).

Similarly to what happened during the preparation stages introduced early in this report, an exhaustive checklist was followed to assure the following main actions were executed in the appropriate order. These were:

- Mechanical review (visual and functional)

- Data backup (full copy of glider's memory disks saving not only gathered sampling data-sets but configuration and status/engineering files as well)

- Sample data-set upload to SOCIB’s FTP (initial step of post-mission processing chain)
- Comprehensive preparation of glider for storage (leaving it ready for use) and shelf storage

Data post-processing and dissemination

SOCIB's data-center took the lead upon raw data-sets upload to SOCIB's FTP by Glider Facility technical staff. Direct contact to data-centre (data-centre@socib.es) is encouraged for details and further information.

Additionally, ALBOREX's P.I. (Dra. Ananda Pascual) should be contacted if precise and up-to-date information regarding the progress of the scientific review is sought.

Annex IV. Chlorophyll-a and nutrients

Authors: Antonio Tovar-Sánchez, Ana Massanet, IMEDEA, Esporles, Spain

Methods

Samples for chlorophyll (Chl a) and nutrients (NO2-, NO3-, PO43-) analysis were collected during the ALBOREX cruise at 66 stations and eight depths (5, 20, 40, 60, 90, 100, 120, 150 m depth, using 10 L Niskin bottles mounted on a Siber, SBE32, rosette sampler. At each station and depth one liter of water was filtered through a Whatman GF/F glass fiber filter for total Chl-a estimation. Nutrient samples were immediately frozen.

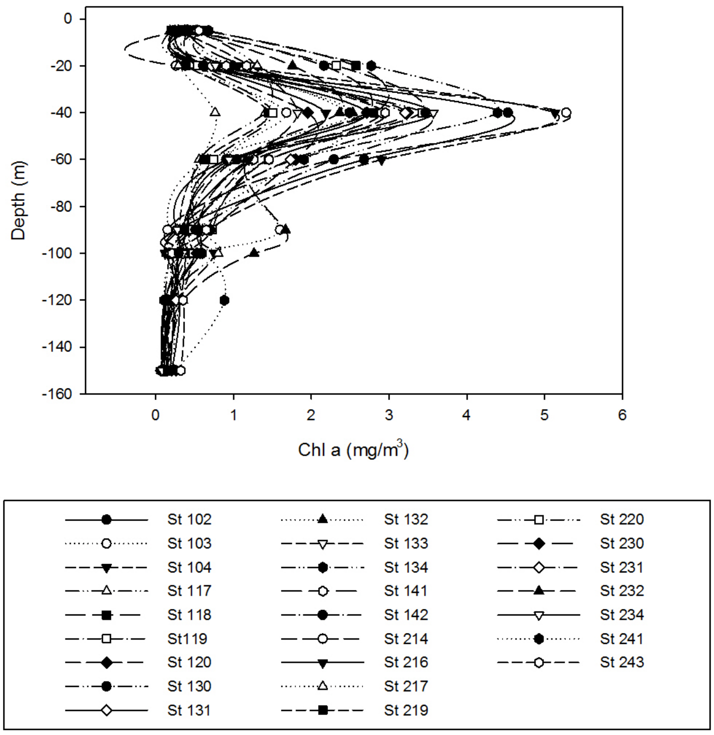
Chlorophyll concentrations were determined fluorometrically (Holm-Hansen et al. 1965) using a Trilogy Turner Design fluorometer after pigment extraction with 90% acetone for 24 hours in the dark at 4oC. Concentrations of dissolved NO2-, NO3- and PO43- were determined with an autoanalyzer (Alliance Futura) using colorimetric techniques (Grasshoff and Almgreen, 1976). The accuracy of the analysis was established using Coastal Seawater Reference Material for Nutrients (MOOS-1, NRC-CNRC), resulting in 110, 95, and 100% for NO2-, NO3- and PO43-, respectively.

Results

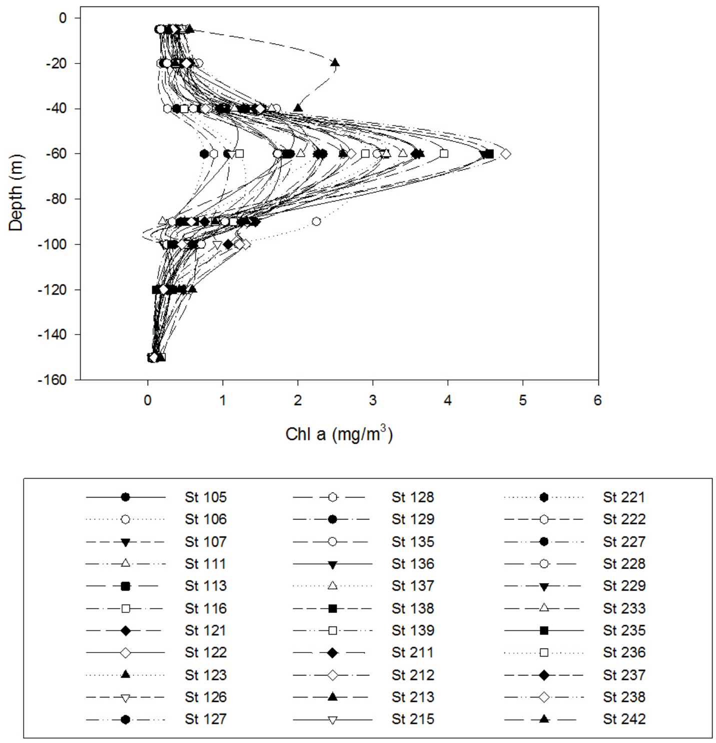
Table 1 shows the concentrations of inorganic nutrients and Chl-a for each station and depth. Range (maximum and minimum) and average concentrations of Chl-a per stations are showed in Table 2.

Chlorophyll values ranged from 0.05 at 150 m to 5.3 mg/m3 in the Depth Chlorophyll maximum (DCM), with an overall mean of 0.84 ± 0.93 mg/ m3, in the upper 150 m of the water column (Tables 1-2). These values are of the same order than previous concentrations measured in the Mediterranean (e.g. Agawin et al 2011). Chl-a concentrations higher than 5 mg/m3 were found at 40 m depth in stations 104 and 214. DCM was found mainly at 40 m (in 25 stations) and 60 m (in 35 stations), (Figure 1).

Nitrites (NO2-) concentration ranged from levels below detection limit (<0.001 μm) to 0.6 μM, with an overall mean of 0.09 ± 0.1 μM in the upper 150 m of the water column (Table 1). Most stations showed maximum concentrations at 60 and 90 m depth, however other stations showed two or even three peaks of higher concentrations (Figure 2). Nitrates (NO3-) concentration ranged from 0.11 to 23.5 μM, with an overall mean of 3.7 ± 3.3 μM, in the upper 150 m of the water column (Table 1). Nitrates profiles showed the maximum values at the deeper stations (i.e. 150 m), (Figure 3). Phosphate (PO43-) concentrations ranged from 0.14 to 1.82 μM with an overall mean of 0.86 ± 0.28 μM, in the upper 150 m of the water column (Table 1).



a)



b)

Figure 1. Vertical distribution of Chl-a: a) DCM at 40 m, b) DCM at 60 m.

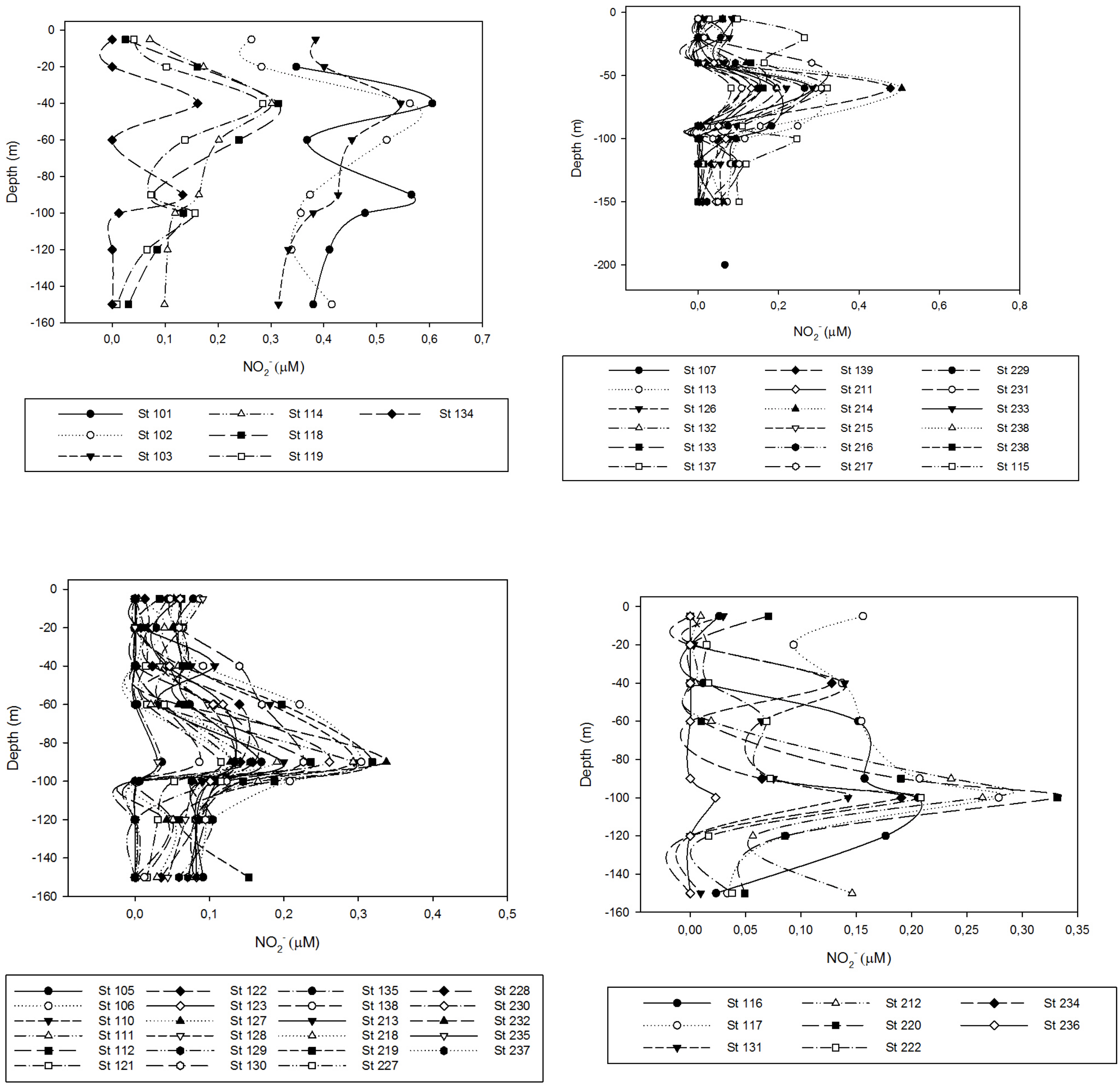


Figure 2. Vertical distribution of NO2- in the different stations.

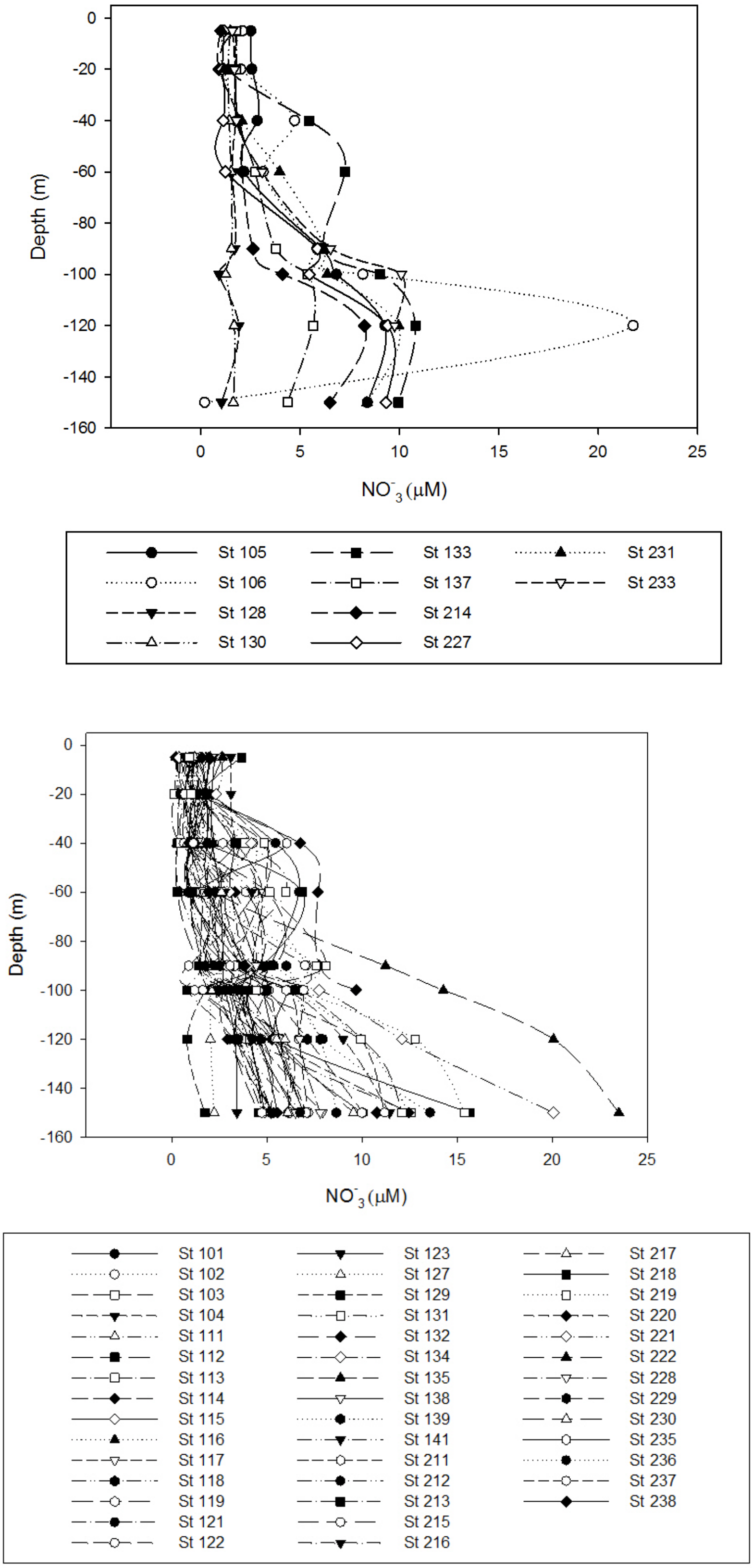


Figure 3. Vertical distribution of NO3- in the different stations.

References:

Agawin N.S.R., Tovar-Sánchez A., Stal L.J., Alvarez M., Agustí S., and Duarte C.M. Low water column nitrogen fixation in the Mediterranean Sea (Basin-wide experimental evidence). Aquatic Microbial Ecology 64, 135-147. doi:10.3354/ame01511. 2011

Grasshoff, K.; Almgreen, T. Methods of seawater analysis; Verlag Chemie: 1976

Holm-Hansen, O., Lorenzen, C.J., Holmes, R.W., and Strickland, J.D.H. Fluorometric determination of chlorophyll. J. Cons. perm. int. Explor. Mer, 30(1), 3-15. 1965.

Table 1

Nutrients and Chl-a concentrations for each station.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
101	20	0.348	1.994	n.a.	2.05
101	40	0.605	5.46	n.a.	1.597
101	60	0.368	6.688	n.a.	0.574
101	90	0.566	5.158	n.a.	0.682
101	100	0.478	4.806	n.a.	0.766
101	120	0.411	5.402	n.a.	0.441
101	150	0.38	6.929	n.a.	0.151
102	5	0.263	0.729	n.a.	0.447
102	20	0.282	0.693	n.a.	0.773
102	40	0.563	4.266	n.a.	4.528
102	60	0.519	4.392	n.a.	2.678
102	90	0.374	7.081	n.a.	0.275
102	100	0.357	6.505	n.a.	0.23
102	120	0.339	9.945	n.a.	0.237
102	150	0.415	12.471	n.a.	0.186
103	5	0.385	0.924	n.a.	0.554
103	20	0.401	1.014	n.a.	0.381
103	40	0.545	4.869	n.a.	1.679
103	60	0.453	5.14	n.a.	0.906
103	90	0.427	8.093	n.a.	1.598
103	100	0.38	4.441	n.a.	0.418
103	120	0.333	9.935	n.a.	0.113
103	150	0.314	12.108	n.a.	0.08
104	5	0.398	3.098	n.a.	0.372
104	20	0.091	3.112	n.a.	1.06
104	40	0.13	3.423	n.a.	5.131
104	60	0.245	4.763	n.a.	2.905
104	90	0.223	4.241	n.a.	0.688
104	100	0.307	6.067	n.a.	0.751
104	120	0.087	9.011	n.a.	0.268
104	150	0.084	11.461	n.a.	0.099
105	5	0.078	2.532	n.a.	0.416
105	20	0.055	2.58	n.a.	0.506
105	40	0.063	2.847	n.a.	0.96
105	60	0.074	2.186	n.a.	1.764
105	90	0.17	6.091	n.a.	1.308
105	100	0.106	6.829	n.a.	0.497
105	120	0.081	9.268	n.a.	0.195
105	150	0.091	8.388	n.a.	0.08
106	5	0.087	2.1	n.a.	0.534
106	20	0.065	2.025	n.a.	0.68
106	40	0.091	4.73	n.a.	1.713
106	60	0.221	3.153	n.a.	3.056

Table 1 cont.

Station	Depth (m)	NO_2^- (µM)	NO_3^- (µM)	PO_4^{3-} (µM)	Chl-a (mg/m^3)
106	90	0.304	5.851	n.a.	2.247
106	100	0.208	8.158	n.a.	1.204
106	120	0.1	21.761	n.a.	0.333
106	150	0.096	0.107	n.a.	0.112
107	5	0.09	0.386	0.603	0.454
107	20	0.057	0.4	0.646	0.567
107	40	0.051	0.425	0.69	1.044
107	60	0.194	0.825	0.457	3.613
107	90	0.183	2.138	0.683	0.381
107	100	0.094	2.561	0.785	0.211
107	120	0.08	2.765	0.584	0.307
107	200	0.067	5.336	0.737	0.047
110	5	0.059	0.324	0.68	0.436
110	20	0.058	0.33	0.646	0.758
110	40	0.075	0.4	0.655	1.776
110	60	0.181	1.338	0.648	2.558
110	90	0.294	1.929	0.653	3.015
110	100	0.145	2.651	0.657	1.209
110	120	0.081	3.851	0.756	0.354
110	200	0.071	5.725	0.827	0.049
111	5	0.061	0.196	0.559	0.458
111	20	0.062	0.297	0.655	0.62
111	40	0.058	0.267	0.552	1.155
111	60	0.028	0.419	0.603	3.398
111	90	0.293	2.066	0.505	1.398
111	100	0.165	3.068	0.591	1.3
111	120	0.081	3.861	0.657	0.491
111	150	0.078	4.815	0.708	0.088
112	5	0.062	0.433	0.623	0.308
112	20	0.062	0.35	0.577	0.406
112	40	0.07	0.285	0.528	0.654
112	60	0.067	0.283	0.605	1.206
112	90	0.236	1.608	0.578	1.698
112	100	0.145	3.792	0.906	1.141
112	120	0.086	3.259	0.674	0.411
112	150	n.a.	n.a.	0.783	0.117
113	5	<0.001	0.345	0.687	0.304
113	20	0.064	0.116	0.585	0.535
113	40	0.07	0.411	0.689	1.041
113	60	0.306	2.612	0.817	3.16
113	90	0.248	1.412	0.795	1.41
113	100	0.116	2.874	0.724	0.694
113	120	0.083	3.447	0.751	0.329
113	150	0.072	4.743	0.717	0.086
114	5	0.071	0.22	0.61	0.652

Table 1 cont.

Station	Depth (m)	NO_2^- (µM)	NO_3^- (µM)	PO_4^{3-} (µM)	Chl-a (mg/m^3)
114	20	0.172	0.556	0.689	2.832
114	40	0.301	1.364	0.302	2.36
114	60	0.201	3.318	0.884	1.246
114	90	0.164	4.414	0.792	0.575
114	100	0.119	2.823	0.609	0.251
114	120	0.104	2.925	0.776	0.23
114	150	0.099	5.353	0.783	0.115
115	5	0.097	0.379	0.683	0.584
115	20	0.264	1.338	0.685	2.138
115	40	0.164	3.225	0.754	1.652
115	60	0.322	3.067	0.756	1.286
115	90	0.11	4.361	0.598	0.304
115	100	0.245	3.192	0.73	0.249
115	120	0.119	4.051	0.635	0.205
115	150	0.101	4.874	0.507	0.265
116	5	0.026	1.02	0.759	0.452
116	20	<0.001	1.077	0.816	0.403
116	40	0.012	1.037	0.799	1.396
116	60	0.152	1.782	0.714	3.942
116	90	0.158	3.869	0.729	0.628
116	100	0.206	3.712	0.807	0.623
116	120	0.177	3.62	0.496	0.493
116	150	0.023	5.081	0.619	0.186
117	5	0.156	0.877	0.716	0.517
117	20	0.093	2.143	0.576	1.303
117	40	0.137	4.887	0.729	1.408
117	60	0.155	4.792	0.665	0.558
117	90	0.207	3.244	0.621	0.601
117	100	0.279	3.385	0.663	0.801
117	120	0.086	4.456	0.744	0.158
117	150	0.034	7.918	0.875	0.239
118	5	0.025	1.064	0.684	0.625
118	20	0.161	1.678	0.799	2.569
118	40	0.314	3.551	0.761	2.81
118	60	0.239	2.292	0.578	1.009
118	90	0.074	2.485	0.354	0.353
118	100	0.134	2.509	0.415	0.398
118	120	0.085	5.776	0.79	0.172
118	150	0.031	6.131	0.78	0.136
119	5	0.041	0.975	0.517	0.429
119	20	0.102	1.028	0.6	2.322
119	40	0.285	2.676	0.453	3.422
119	60	0.137	4.334	0.729	1.444
119	90	0.073	0.876	0.394	0.725

119	100	0.156	1.185	0.271	0.4

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
119	120	0.066	3.892	0.813	0.322
119	150	0.009	4.719	0.759	0.089
120	5	0.004	0.962	0.642	0.413
120	20	n.a.	n.a.	0.57	0.609
120	40	n.a.	n.a.	1.223	1.954
120	60	0.025	1.139	0.705	1.795
120	90	n.a.	n.a.	0.58	0.706
120	120	n.a.	n.a.	0.434	0.129
120	150	0.023	3.771	0.409	0.114
121	5	<0.001	0.889	0.542	0.321
121	20	0.012	0.979	0.568	0.379
121	40	0.015	0.866	0.578	0.974
121	60	0.016	1.035	0.682	2.268
121	90	0.115	2.801	0.752	1.43
121	100	0.053	3.704	0.688	1.068
121	120	0.031	3.503	0.54	0.476
121	150	0.016	6.657	0.705	0.086
122	5	0.013	1.142	0.727	0.399
122	20	0.018	1.817	0.712	0.531
122	40	0.023	1.092	0.68	1.307
122	60	0.14	2.486	0.572	2.707
122	90	0.142	3.852	0.631	1.326
122	100	0.111	6.101	0.591	1.305
122	120	0.086	6.686	0.754	0.57
122	150	0.035	7.177	0.563	0.077
123	5	0.061	2.237	0.792	0.374
123	20	0.024	2.11	0.721	0.497
123	40	0.042	2.122	0.723	1.277
123	60	0.118	2.531	0.748	2.263
123	90	0.133	2.69	0.748	0.495
123	100	0.101	2.792	0.788	0.442
123	120	0.083	3.319	0.894	0.42
123	150	0.083	3.419	0.737	0.085
126	5	0.084	1.902	0.6	0.398
126	20	0.078	1.752	0.587	0.426
126	40	0.066	4.851	0.64	0.808
126	60	0.219	1.804	0.54	3.141
126	90	0.096	2.626	0.522	1.176
126	100	0.079	2.553	0.702	0.928
126	120	0.056	2.697	0.769	0.2
126	150	0.059	2.69	0.801	0.093
127	5	0.052	1.784	0.448	0.36
127	20	0.051	1.665	0.573	0.344

127	40	0.074	1.618	0.54	0.698
127	60	0.073	1.817	0.674	2.334

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
127	90	0.128	2.039	0.654	1.155
127	100	0.079	2.034	0.591	0.516
127	120	0.094	2.026	0.781	0.186
127	150	0.083	2.222	0.672	0.057
128	5	0.091	1.772	0.644	0.351
128	20	0.064	1.729	0.547	0.439
128	40	0.034	1.759	0.57	0.746
128	60	0.098	1.584	0.582	2.602
128	90	0.135	1.701	0.621	1.214
128	100	0.089	0.927	0.298	0.498
128	120	0.067	1.916	0.684	0.196
128	150	0.044	1.05	0.367	0.091
129	5	0.044	1.378	0.436	0.21
129	20	0.029	1.66	0.619	0.238
129	40	0.046	1.008	0.337	0.383
129	60	0.037	1.568	0.57	1.066
129	90	0.155	1.47	0.524	0.836
129	100	0.076	1.727	0.734	0.653
129	120	0.105	0.795	0.393	0.244
129	150	0.059	1.727	0.732	0.061
130	5	0.047	1.488	0.543	0.218
130	20	0.059	1.379	0.457	0.611
130	40	0.14	1.439	0.503	3.467
130	60	0.17	1.525	0.49	2.289
130	90	0.226	1.543	0.637	0.51
130	100	0.123	1.258	0.584	0.297
130	120	0.094	1.681	0.695	0.118
130	150	0.071	1.642	0.799	0.157
131	5	0.03	1.198	0.945	0.249
131	20	0.003	1.482	1.297	0.629
131	40	0.139	3.841	1.038	2.714
131	60	0.064	5.995	1.061	0.957
131	90	0.075	1.984	0.908	0.407
131	100	0.143	2.194	1.138	0.287
131	120	<0.001	4.089	0.876	0.219
131	150	0.009	12.585	1.189	0.067
132	5	<0.001	1.554	0.908	0.288
132	20	<0.001	1.446	0.939	0.635
132	40	0.05	6.742	1.129	2.531
132	60	0.196	7.685	1.072	0.669
132	90	0.056	7.755	0.925	0.163
132	100	0.005	9.688	1.197	0.138

132	150	<0.001	10.792	1.112	0.105
133	5	<0.001	1.683	0.811	0.284
133	20	<0.001	1.347	0.814	1.214

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
133	40	0.132	5.443	1.638	1.822
133	60	0.161	7.244	1.232	1.234
133	90	0.052	6.176	1.297	0.446
133	100	<0.001	9.02	0.956	0.226
133	120	0.014	10.808	1.229	0.189
133	150	<0.001	9.941	0.913	0.064
134	5	<0.001	1.931	1.166	0.679
134	20	<0.001	1.784	0.535	2.771
134	40	0.161	4.163	0.998	4.396
134	60	<0.001	2.27	0.765	1.781
134	90	0.133	2.88	0.585	0.414
134	100	0.013	4.569	0.694	0.17
134	120	<0.001	5.649	1.806	0.107
134	150	<0.001	6.23	0.806	0.071
135	5	<0.001	2.027	0.742	0.35
135	20	<0.001	1.797	0.569	0.416
135	40	<0.001	2.176	0.703	0.809
135	60	0.003	1.902	0.666	1.723
135	90	0.036	3.518	0.712	0.84
135	100	0.006	3.264	0.896	0.536
135	120	<0.001	5.311	1.196	0.303
135	150	<0.001	6.905	1.081	0.091
136	5	0.03	2.497	0.571	0.318
136	20	<0.001	1.932	0.758	0.4
136	40	<0.001	1.811	1.15	0.987
136	60	<0.001	1.838	0.938	4.476
136	90	<0.001	4.459	0.758	1.115
136	100	<0.001	5.027	0.661	0.564
136	120	<0.001	6.189	0.871	0.206
136	150	0.016	7.565	1.267	0.061
137	5	0.027	1.798	0.523	0.441
137	20	<0.001	1.784	0.91	0.573
137	40	<0.001	1.878	0.647	1.507
137	60	0.082	2.743	0.853	3.178
137	90	0.024	3.787	0.569	0.92
137	100	0.002	5.377	0.742	0.688
137	120	0.009	5.653	0.878	0.209
137	150	<0.001	4.365	0.594	0.082
138	5	<0.001	2.081	1.035	0.336
138	20	<0.001	1.797	1.111	0.386
138	40	<0.001	1.757	0.422	1.297

138	60	0.034	0.83	1.138	4.552
138	90	0.086	3.714	1.07	0.622
138	100	<0.001	4.007	0.647	0.317
138	120	0.05	4.463	0.505	0.118

Table 1 cont.

Station	Depth (m)	NO_2^- (µM)	NO_3^- (µM)	PO_4^{3-} (µM)	Chl-a (mg/m^3)
138	150	0.013	6.504	0.928	0.056
139	5	<0.001	0.986	0.939	0.354
139	20	<0.001	0.422	1.018	0.433
139	40	0.019	0.92	1.057	1.479
139	60	0.478	2.306	1.113	2.9
139	90	0.006	6.017	1.152	0.902
139	100	0.05	6.372	0.964	0.7
139	120	0.033	7.805	0.701	0.204
139	150	0.011	8.651	0.894	0.075
141	5	0.618	0.688	0.614	0.381
141	20	<0.001	1.286	0.522	1.167
141	40	0.314	2	0.575	2.902
141	60	0.147	2.772	0.632	1.26
141	90	0.096	2.556	0.64	0.538
141	100	0.136	2.407	0.588	0.572
141	120	<0.001	3.452	0.669	0.177
141	150	<0.001	5.208	0.623	0.207
142	5	<0.001	1.182	0.57	0.489
142	20	<0.001	1.423	0.689	2.163
142	40	0.121	2.498	0.577	2.712
142	60	0.073	2.652	0.822	1.043
142	90	<0.001	3.364	0.844	0.432
142	100	n.a.	n.a.	1.062	0.457
142	120	n.a.	n.a.	1.076	0.21
142	150	n.a.	n.a.	1.059	0.099
211	5	<0.001	1.024	0.993	0.33
211	20	0.003	0.686	0.934	0.456
211	40	0.039	0.903	1.122	1.429
211	60	0.132	0.969	1.038	3.565
211	90	0.05	3.325	1.1	0.756
211	100	0.069	5.076	0.975	0.59
211	120	<0.001	5.655	0.955	0.202
211	150	0.044	7.081	0.986	0.064
212	5	0.009	1.251	0.968	0.295
212	20	<0.001	0.973	0.9	0.526
212	40	0.005	0.924	0.937	0.768
212	60	0.019	0.9	0.971	1.748
212	90	0.236	2.234	1.188	1.191
212	100	0.264	3.56	0.946	1.223
212	120	0.057	4.241	0.943	0.258

212	150	0.146	6.749	0.145	0.09
213	5	<0.001	0.821	0.179	0.557
213	20	0.008	1.208	0.145	2.493
213	40	0.107	3.314	1.196	2.001
213	60	0.031	1.058	1.032	2.6

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
213	90	0.2	1.549	1.042	1.319
213	100	0.091	0.787	0.591	0.67
213	120	0.083	3.258	1.064	0.594
213	150	0.071	5.267	1.125	0.123
214	5	0.011	1.018	0.89	0.309
214	20	0.022	0.928	0.998	0.26
214	40	0.119	1.949	0.914	5.277
214	60	0.506	2.084	1.211	2.291
214	90	0.178	2.628	1.083	0.154
214	100	0.096	4.109	1.071	0.469
214	120	0.033	8.24	1.002	0.151
214	150	0.063	6.509	1.098	0.079
215	5	<0.001	1.076	0.983	0.25
215	20	<0.001	0.856	0.912	0.269
215	40	0.013	0.642	0.892	0.983
215	60	0.11	3.89	0.924	1.119
215	90	0.02	4.512	1.061	0.3
215	100	0.042	1.637	0.341	0.228
215	120	0.041	4.729	1.098	0.295
215	150	0.003	5.202	1.24	0.121
216	5	<0.001	1.043	1.047	0.255
216	20	<0.001	0.669	0.995	0.653
216	40	0.093	1.206	1.047	2.186
216	60	0.148	4.201	1.083	1.197
216	90	<0.001	4.759	1.147	0.293
216	100	<0.001	5.007	1.13	0.12
216	120	0.093	4.188	1.071	0.301
216	150	0.022	5.244	1.076	0.208
217	5	0.061	1.154	1.038	0.185
217	20	0.015	1.284	0.895	0.29
217	40	0.282	0.802	0.838	0.762
217	60	0.292	4.988	1.301	0.598
217	90	0.154	5.36	1.259	0.344
217	100	0.036	2.132	0.812	0.168
217	120	0.102	5.945	1.483	0.235
217	150	0.049	6.091	1.177	0.223
218	5	0.005	3.668	1.267	0.384
218	20	0.039	1.475	0.897	0.362
218	40	<0.001	1.813	1.038	0.549

218	60	0.021	6.876	1.327	0.528
218	90	0.19	4.716	1.139	0.702
218	100	<0.001	4.009	0.934	0.601
218	120	0.051	5.426	1.192	0.189
218	150	0.03	15.653	1.361	0.23
219	5	0.033	0.705	0.536	0.202

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
219	20	<0.001	1.178	1.158	0.388
219	40	0.064	1.59	1.038	1.451
219	60	0.197	1.541	0.835	0.623
219	90	0.319	7.579	1.267	0.308
219	100	0.187	6.878	1.658	0.303
219	120	0.059	12.791	1.4	0.183
219	150	0.153	15.399	1.015	0.16
220	5	0.071	1.948	0.966	0.23
220	20	<0.001	1.636	1.051	0.54
220	40	<0.001	0.907	0.812	1.504
220	60	0.01	1.981	1.346	0.744
220	90	0.19	1.763	0.791	0.417
220	100	0.332	3.07	1.115	0.478
220	120	0.085	5.279	0.887	0.326
220	150	0.049	12.465	1.19	0.123
221	5	0.113	2.634	1.224	0.167
221	20	0.016	2.32	1.209	0.247
221	40	0.005	1.201	1.032	0.39
221	60	0.013	3.034	1.368	0.754
221	90	0.057	3.98	0.844	0.439
221	100	0.095	7.737	1.12	0.355
221	120	0.003	12.1	1.312	0.178
221	150	0.034	20.078	1.462	0.128
222	5	<0.001	2.664	1.126	0.175
222	20	0.015	1.817	1.056	0.169
222	40	0.016	1.152	0.959	0.261
222	60	0.069	2.193	1.197	0.884
222	90	0.072	11.236	1.244	0.327
222	100	0.209	14.277	1.372	0.257
222	120	0.016	20.068	1.44	0.182
222	150	0.038	23.504	1.571	0.108
227	5	<0.001	1.178	0.952	0.145
227	20	<0.001	1.091	0.852	0.208
227	40	<0.001	1.13	0.673	0.493
227	60	0.039	1.239	0.776	1.9
227	90	0.135	5.878	0.814	1.134
227	100	0.115	5.463	0.792	0.552
227	120	<0.001	9.409	0.874	0.301

227	150	<0.001	9.317	0.926	0.117
228	5	<0.001	1.283	0.857	0.175
228	20	<0.001	1.357	0.642	0.26
228	40	0.002	1.163	0.606	0.607
228	60	0.107	1.48	0.711	1.731
228	90	0.158	4.429	0.644	1.029
228	100	<0.001	6.835	0.807	0.716

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
228	120	<0.001	6.722	0.761	0.24
228	150	<0.001	7.8	0.852	0.091
229	5	<0.001	1.139	0.776	0.291
229	20	<0.001	1.113	0.642	0.368
229	40	<0.001	1.143	0.759	1.232
229	60	0.265	0.844	0.606	2.274
229	90	0.075	3.756	0.862	1.16
229	100	0.002	5.003	0.974	0.331
229	120	<0.001	7.135	0.831	0.114
229	150	<0.001	10.048	0.819	0.076
230	5	<0.001	1.2	0.776	0.376
230	20	<0.001	1.126	0.663	0.634
230	40	0.046	1.663	0.811	3.239
230	60	0.105	2.6	0.964	0.915
230	90	0.261	1.482	0.745	0.555
230	100	<0.001	3.683	0.821	0.527
230	120	<0.001	5.504	0.85	0.194
230	150	0.002	9.542	0.878	0.08
231	5	<0.001	1.078	0.733	0.538
231	20	<0.001	1.174	0.845	0.717
231	40	<0.001	2.061	0.642	3.204
231	60	0.108	3.97	0.852	1.736
231	90	<0.001	6.243	0.983	0.274
231	100	<0.001	6.365	0.833	0.188
231	120	<0.001	9.948	0.952	0.265
231	150	<0.001	8.37	0.778	0.143
232	5	<0.001	1.152	0.718	0.401
232	20	<0.001	1.065	0.783	1.758
232	40	<0.001	0.809	0.475	2.362
232	60	0.059	4.194	1.038	1.16
232	90	0.337	3.067	0.783	1.668
232	100	<0.001	5.6	0.979	1.263
232	120	0.043	4.549	0.9	0.35
232	150	<0.001	4.909	0.723	0.071
233	5	0.015	1.589	1.359	0.289
233	20	0.057	1.697	1.319	0.58
233	40	<0.001	1.792	1.365	1.648

233	60	0.284	3.093	1.288	2.037
233	90	<0.001	6.528	1.626	0.197
233	120	0.006	10.089	1.488	0.188
233	150	<0.001	9.755	1.015	0.083
234	5	<0.001	1.528	1.276	0.298
234	20	<0.001	1.642	0.945	0.766
234	40	0.128	4.438	1.472	3.57
234	60	<0.001	6.509	1.423	0.942

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
234	90	0.065	6.086	1.359	0.278
234	100	0.191	4.96	1.298	0.35
234	120	<0.001	7.547	1.512	0.114
234	150	<0.001	10.057	1.816	0.081
235	5	<0.001	1.472	1.077	0.276
235	20	<0.001	1.434	1.163	0.438
235	40	<0.001	6.038	0.997	1.523
235	60	<0.001	1.302	1.193	1.853
235	90	0.031	3.064	1.156	0.525
235	100	0.004	6.015	1.224	0.315
235	120	<0.001	5.453	1.356	0.12
235	150	<0.001	9.981	1.497	0.096
236	5	<0.001	1.208	1.199	0.291
236	20	<0.001	1.34	1.077	0.379
236	40	<0.001	1.208	1.405	0.484
236	60	<0.001	1.151	1.11	1.222
236	90	<0.001	5.358	1.518	1.139
236	100	0.023	6.732	1.098	0.504
236	120	<0.001	7.943	1.252	0.253
236	150	<0.001	13.585	1.494	0.072
237	5	<0.001	1.208	1.291	0.374
237	20	0.008	0.672	0.804	0.563
237	40	<0.001	1.132	1.224	0.958
237	60	<0.001	1.226	1.282	2.327
237	90	0.134	6.998	1.387	1.247
237	100	0.006	6.938	1.344	0.591
237	120	<0.001	9.943	1.411	0.262
237	150	<0.001	11.189	1.359	0.078
238	5	0.061	1.58	0.583	0.331
238	20	<0.001	1.792	0.526	0.513
238	40	<0.001	1.844	0.583	1.496
238	60	0.157	1.975	0.605	4.771
238	90	<0.001	3.816	0.634	0.581
238	100	<0.001	3.665	0.577	0.458
238	120	<0.001	4.636	0.882	0.208
238	150	<0.001	5.551	0.735	0.09

241	5	n.a.	n.a.	0.821	0.339
241	20	n.a.	n.a.	0.786	0.992
241	40	n.a.	n.a.	0.921	2.49
241	60	n.a.	n.a.	0.935	1.905
241	90	n.a.	n.a.	0.956	0.373
241	100	n.a.	n.a.	1.023	0.598
241	120	n.a.	n.a.	0.894	0.881
241	150	n.a.	n.a.	0.83	0.262
242	5	<0.001	1.106	0.601	0.277

Table 1 cont.

Station	Depth (m)	NO_2^- (μM)	NO_3^- (μM)	PO_4^{3-} (μM)	Chl-a (mg/m^3)
242	20	<0.001	1.179	0.478	0.366
242	40	<0.001	0.592	0.257	1.272
242	60	<0.001	1.408	0.533	3.628
242	90	0.215	1.996	0.643	0.895
242	100	0.025	2.679	0.656	0.588
242	120	<0.001	2.662	0.603	0.119
242	150	<0.001	5.348	0.748	0.168
243	5	n.a.	n.a.	1.05	0.556
243	20	n.a.	n.a.	0.842	0.905
243	40	n.a.	n.a.	0.812	2.951
243	60	n.a.	n.a.	0.95	1.455
243	90	n.a.	n.a.	0.979	0.65
243	100	n.a.	n.a.	1.026	0.212
243	120	n.a.	n.a.	0.883	0.351
243	150	n.a.	n.a.	0.994	0.322
244	5	n.a.	n.a.	0.991	n.a.
244	20	n.a.	n.a.	0.836	n.a.
244	40	n.a.	n.a.	1.021	n.a.
244	60	n.a.	n.a.	0.912	n.a.
244	90	n.a.	n.a.	0.93	n.a.
244	100	n.a.	n.a.	0.563	n.a.
244	120	n.a.	n.a.	0.842	n.a.
244	150	n.a.	n.a.	0.827	n.a.

* The stations 107 and 110 were sampled at 200 m instead of 150 m.

Table 2.
Minimum, maximum and average concentration of chlorophyll at each station and depth of the DCM.

Station	Chl (mg/m^3) minimun	maximun	average	DCM depth (m)
1	0.12	4.65	1.48	60
2	0.07	4.13	1.36	60
101	0.15	2.05	0.68	20
102	0.19	4.53	1.59	40
103	0.08	1.68	0.63	40
104	0.1	5.13	1.74	40
105	0.08	1.76	0.58	60
106	0.11	3.06	1.03	60
107	0.05	3.61	1.16	60
110	0.05	3.01	1.09	90
111	0.09	3.4	1.03	60
112	0.12	1.7	0.55	90
113	0.09	3.16	0.99	60
114	0.12	2.83	1.03	20
115	0.21	2.14	0.75	20
116	0.19	3.94	1.23	60
117	0.16	1.41	0.45	40
118	0.14	2.81	1.08	40
119	0.09	3.42	1.18	40
120	0.11	1.95	0.76	40
121	0.09	2.27	0.72	60
122	0.08	2.71	0.83	60
123	0.08	2.26	0.71	60
126	0.09	3.14	0.98	60
127	0.06	2.33	0.74	60
128	0.09	2.6	0.82	60
129	0.06	1.07	0.35	60
130	0.12	3.47	1.24	60
131	0.07	2.71	0.86	40
132	0.1	2.53	0.86	40
133	0.06	1.82	0.65	40
134	0.07	4.4	1.57	40
135	0.09	1.72	0.51	60
136	0.06	4.48	1.45	60
137	0.08	3.18	1	60
138	0.06	4.55	1.5	60
139	0.08	2.9	0.93	60
141	0.18	2.9	0.9	40
142	0.1	2.71	0.97	40

Table 2 cont.

Station	Chl (mg/m^3) minimun	maximun	average	DCM depth (m)
211	0.06	3.56	1.15	60
212	0.09	1.75	0.58	60
213	0.12	2.6	0.96	60
214	0.08	5.28	1.83	40
215	0.12	1.12	0.38	60
216	0.12	2.19	0.71	40
217	0.17	0.76	0.22	40
218	0.19	0.7	0.18	90
219	0.16	1.45	0.43	40
220	0.12	1.5	0.43	40
221	0.13	0.75	0.2	60
222	0.11	0.88	0.25	60
227	0.12	1.9	0.62	60
228	0.09	1.73	0.56	60
229	0.08	2.27	0.77	60
230	0.08	3.24	1.01	40
231	0.14	3.2	1.07	40
232	0.07	2.36	0.8	40
233	0.08	2.04	0.79	60
234	0.08	3.57	1.16	40
235	0.1	1.85	0.67	60
236	0.07	1.22	0.42	60
237	0.08	2.33	0.72	60
238	0.09	4.77	1.56	60
241	0.26	2.49	0.81	40
242	0.12	3.63	1.16	60
243	0.21	2.95	0.91	40

Annex V. Drifters and Argo technical report

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1. Lagrangian Instruments

1.1 SVP drifters

Surface Velocity Program (SVP) drifters are the standard design of the Global Drifter Program (Lumpkin and Pazos, 2007). The SVP drifters used in ALBOREX 2014 are the mini–World Ocean Circulation Experiment (WOCE) SVP drifters. They consist of a surface buoy that is tethered to a holey-sock drogue, centered at a nominal depth of 15 m, that holds the drifter almost motionless with respect to the horizontal layer studied [for details on the SVP design, see Sybrandy and Niiler (1991)]. They have a drag area ratio of the drogue to the tether and surface buoy in excess of 40. A tension sensor, located below the surface buoy where the drogue tether is attached, indicates the presence or absence of the drogue. Measurements of the water-following capabilities of the SVP have shown that when the drogue is attached, they follow the water to within 1 cm s^{-1} in 10 m/s winds (Niiler et al., 1995). The drifters are equipped with a thermistor on the lower part of the top spherical buoy to measure SST.

Some drifters were localized by GPS and transmitted data (SST, voltage, drogue presence indicator, etc.) to the Iridium satellite system at hourly intervals. Others were positioned by, and transmitted data to, the Argos Data Collection and Location System (DCLS) onboard polar-orbiting satellites at non-uniform intervals of 2-3 h. Drifters were procured by different participants and from different manufacturers. See Table 1 for details. Figure 1 shows the weekly displacement of the drifters during the period 25 May 2014 - 12 July 2014. Please, see further results on drifters extracted from this partial report, in the 'Horizontal velocity field' section of this deliverable.

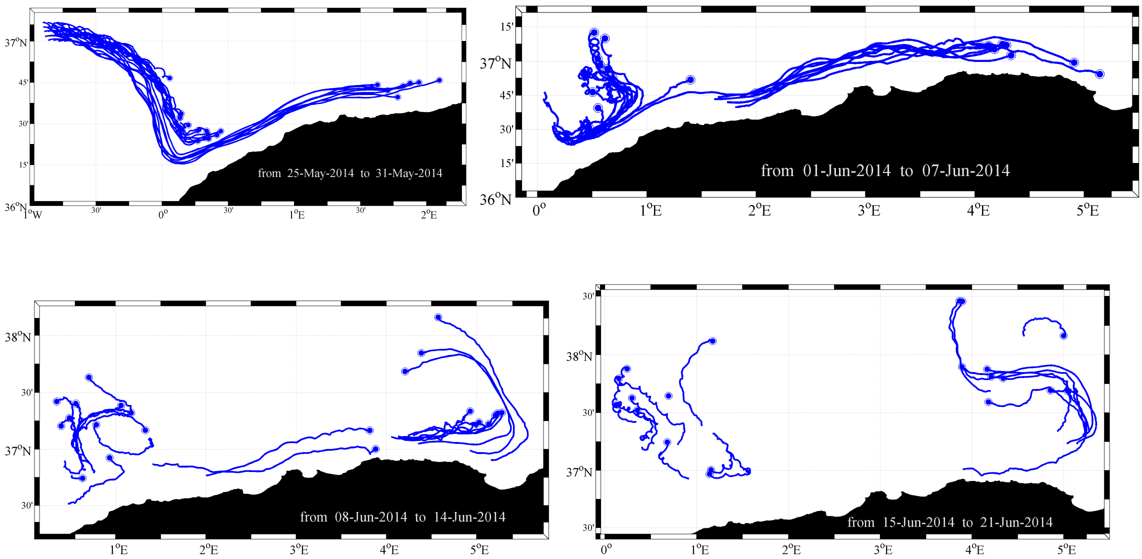


Figure 1. Weekly displacement of the SVP drifters during the period 25 May 20014 - 12 July 2014.

Quantity	Manufacturer	Owner	Country	Telemetry
5	Pacific Gyre	OGS	Italy	Argos
4	Pacific Gyre	SOCIB	Spain	Iridium
6	Pacific Gyre	IMEDEA	Spain	Iridium
4	Data Buoy Inst.	SOCIB	Spain	Iridium
6	Data Buoy Inst.	IMEDEA	Spain	Iridium
TOTAL = 25				

Table 1. Details on the SVP drifter used during ALBOREX 2014.

1.2 Argo floats

Three types of battery-powered Argo profilers were operated in ALBOREX 2014, all manufactured by NKE in Hennebont, France:

- Arvor-C: This is a sub-surface profiling float designed to operate in coastal environment and perform oceanographic measurements as a pseudo-eulerian station. Its design has been optimized to reduce its drift thanks to a seabed standby and anti-drift claws, an optimized profiling speed (~25 cm/s) and a short data transmission duration. It can perform more than 300 profiles, and transmits its data in real time via the Iridium satellite system with Sea-Bird CTD sensors (model 41 pumped MicroCAT with accuracies of 0.002ºC, 0.005 and 2.4 dbars for T, S and pressure, respectively).
- Arvor-A3: This float is equipped with a Sea-Bird CTD, and is localized, and transmit data to, the Argos-3 bi-directional satellite system. The deployment and test of this float with the new Argos-3 telemetry is part of the EC FP7 E-AIMS project.
- Provor-bio: This float is a Provor CTS 4 with Iridium global telephone network (RUDICS) for data telemetry and a GPS receiver for position. It measures at 1 m vertical resolution not only temperature and salinity (Sea-Bird CTD) but also irradiance at three wavelengths (412 nm, 490 nm, 555 nm), fluorescence of Colored Dissolved Organic Matter, fluorescence of Chlorophyll-a, backscattering coefficient (530 nm) and attenuation coefficient (660 nm).

The floats were programmed to cycle at intervals varying between 3 h and 5 days, and to drift at a parking depth of 350 or 1000 m, and collect oceanographic data in the water column between 400-2000 m and the surface (see Table 2 for details). Using the iridium downlink, the cycle length and parking depth of the provor-bio were changed after 7 June 2014 from 1 to 5 days, and from 1000 m to 350 m, respectively. Likewise, the Arvor-A3 was reset on 17 June 2014 using the iridium downlink.

Type	Owner	Project	Telemetry	Cycle	Parking	Max depth
Arvor-C	SOCIB		Iridium	3 h		400 m
Arvor-A3	OGS	E-AIMS	Argos-3	2 days	350 m	2000 m
Provor-bio	OGS	Argo-Italy	Iridium	1-5 days	1000/350 m	1000 m

Table 2. Details on the Argo floats used during ALBOREX 2014.

2. Deployments

The 25 SVP drifters were all deployed on 25 May 2014 in a tight square patterns (typical distance between drifters of ~3 km) located across a strong frontal area identified in SST satellite images. Information about the deployments can be found in Table 3.

ID Argos	Deploy date	Lat	Lon	Last Date	Lat	Lon	Status*
a116396	25 May 2014 16:07	37.08	-0.8	08 July 2014 04:18	37.96	-0.01	A
a116397	25 May 2014 16:16	37.11	0.8	08 July 2014 03:53	38.37	2.44	A
a116398	25 May 2014 16:26	37.07	0.83	08 July 2014 04:19	37.15	2.53	A
a116399	25 May 2014 16:36	37.08	0.83	28 May 2014 17:43	36.87	-0.15	D
a116401	25 May 2014 16:46	37.06	0.83	08 July 2014 04:17	38.75	4.31	A
a127159	25 May 2014 17:05	37	0.83	08 July 2014 04:18	37.94	3.8	A
a127160	25 May 2014 17:22	37	0.88	08 July 2014 03:53	38.59	4.2	A

a127161	25 May 2014 17:32	37.03	0.87	03 July 2014 19:05	38.84	5.31	D
a127162	25 May 2014 17:41	37.05	0.87	01 June 2014 20:31	36.66	0.56	D
a127163	25 May 2014 17:50	37.08	0.87	08 June 2014 04:29	36.74	0.64	D
a127164	25 May 2014 18:00	37.11	0.87	08 July 2014 03:52	37.26	0.14	A
a131972	25 May 2014 14:44	37.1	0.77	17 June 2014 03:28	37.15	0.63	D
a131973	25 May 2014 14:57	37.08	0.77	14 June 2014 03:57	37.63	0.65	D
a131974	25 May 2014 15:09	37.05	0.77	17 June 2014 04:42	37.05	4.65	D
a131975	25 May 2014 15:18	37.03	0.76	17 June 2014 04:29	37.73	5.11	D
a134924	25 May 2014 15:28	37	0.77	08 July 2014 04:00	37.81	3.84	A
a134926	25 May 2014 15:39	37	0.8	08 July 2014 04:00	38.3	4.7	A
a134927	25 May 2014 15:48	37.03	0.8	08 July 2014 04:00	38.73	4.77	A
a134929	25 May 2014 15:58	37.05	0.8	08 July 2014 03:01	37.15	-0.62	A
a134931	25 May 2014 16:55	37.03	0.83	08 July 2014 04:01	38.8	5.56	A
a136010	25 May 2014 18:13	37.11	0.9	08 July 2014 02:00	37.15	2.47	A
a136011	25 May 2014 18:27	37.08	0.91	25 June 2014 10:01	37.53	0.27	D
a136013	25 May 2014 18:32	37.05	0.9	08 July 2014 04:01	37.71	-0.48	A

a136014	25 May 2014 18:43	37.03	0.9	08 July 2014 03:01	37.97	4.01	A

Table 3. Information on the drifter deployments during ALBOREX 2014 and the drifter status on 8 July 2014. * A = Alive and D = Dead on 8 July 2014.

The Argo floats were also deployed in the thermal front in the vicinity of the drifters. See Table 4 for deployment information. Information about the deployments can be found in Table 4.

Type	Argos/Iridium	Deploy date	Lat	Lon	Last Date	Lat	Lon	Status
Arvor-C	300234061375680	25-May-2014 19:24	36.94	-0.9	15-Jul-2014 06:45	38.73	4.17	A*
Arvor-A3	109222	25-May-2014 18:59	37.01	-0.9	17-Jun-2014 13:16	36.31	0.54	A**
Provor-bio	300125010112590	25-May-2014 19:54	36.9	-0.9	12-Jul-2014 11:39	36.35	0.18	A

*Table 4. Information on the float deployments during ALBOREX 2014 and the float status on 15 July 2014. * The Arvor-C executed its last profile on 14 June 2014 and thereafter drifted at the surface.** The Arvor-A3 was reset on 17 June 2014 in order to optimize its surfacing time.*

<u>Arvor-C:</u>

The trajectory of the Arvor-C is shown in Figure 1. It drifted initially in the southeastward direction towards the African continent. Then it joined the Algerian Current and move rapidly along the coast in the northeastward direction as far as 4ºE.

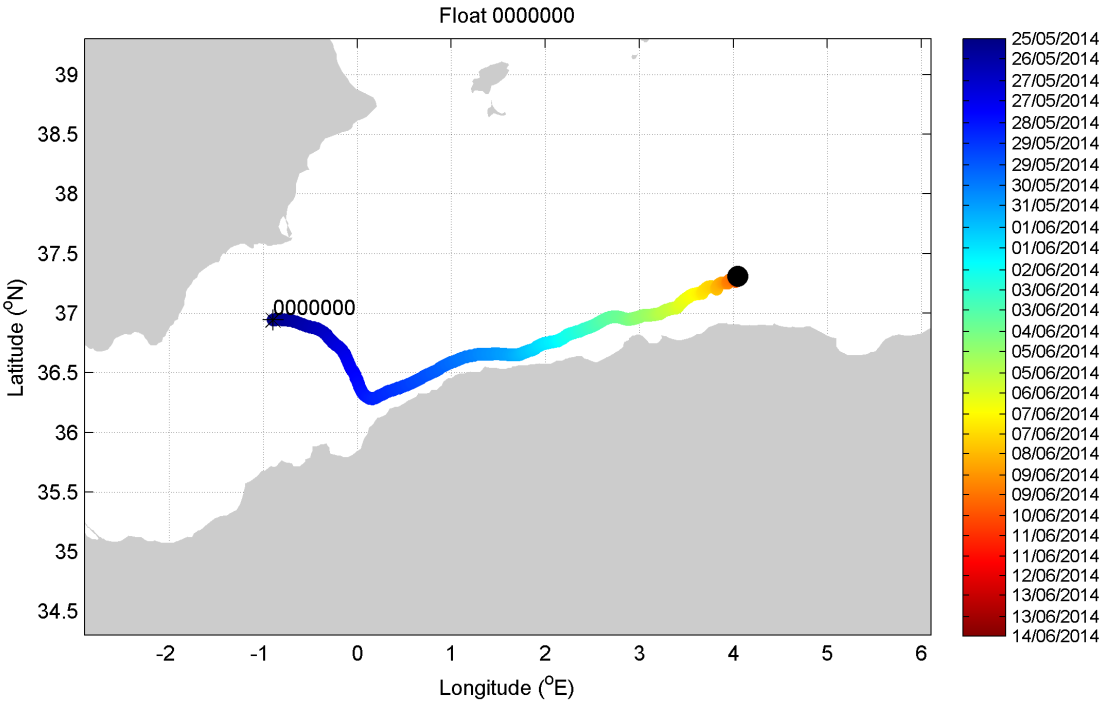


Figure 1.Trajectory of the Arvor-C (WMO 0000000) between deployment on 25/05/2014 (star symbol) and position on 14/06/2014 (black dot).

The Arvor-C executed more than 200 profiles between 400 m and the surface, at ~1.5 h intervals. The corresponding potential temperature and salinity profiles are plotted in Figure 2 (color-coded with date). The potential temperature and salinity data are also contoured versus depth and time in Figure 3.

The formation of the seasonal thermocline in late spring and the signature of the surface low-salinity water of Atlantic origin are evident. A secondary sub-surface (50-100 m) salinity minimum is also seen. It is mostly important during the first part of the drift (up to cycle 300).

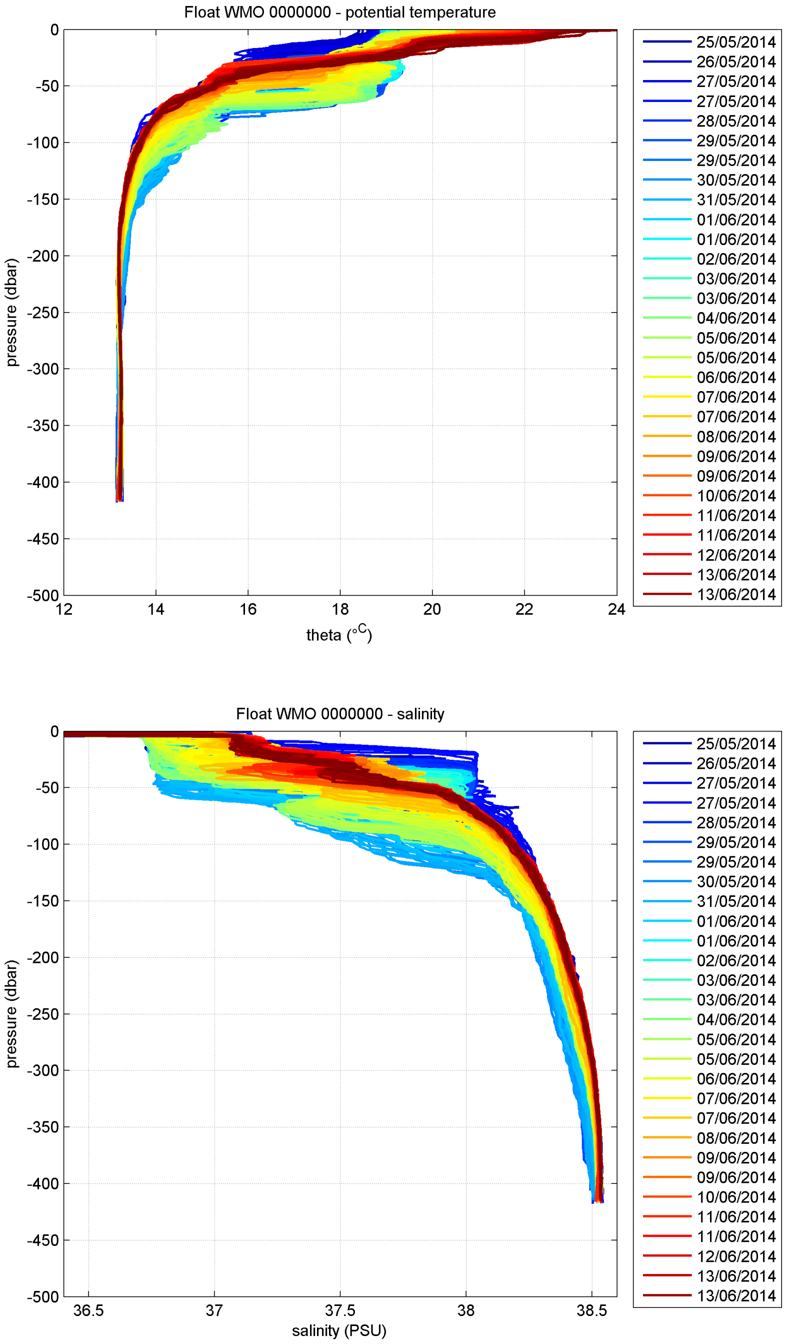
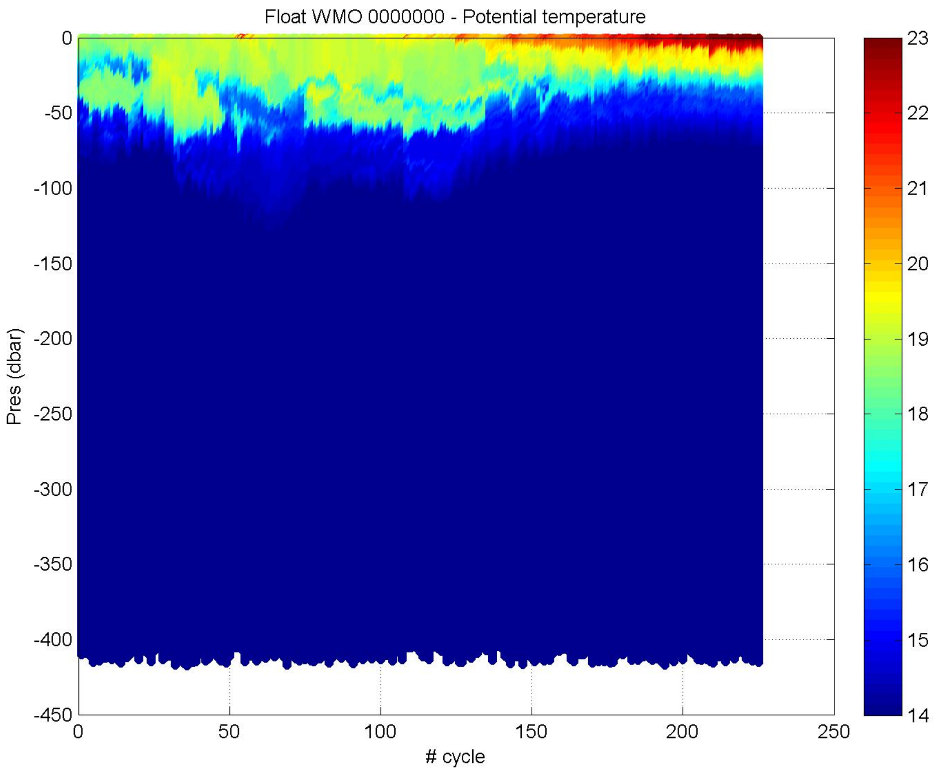


Figure 2. Potential temperature (top) and salinity (bottom) profiles measured by the Arvor-C every 1.5 h along its trajectory.



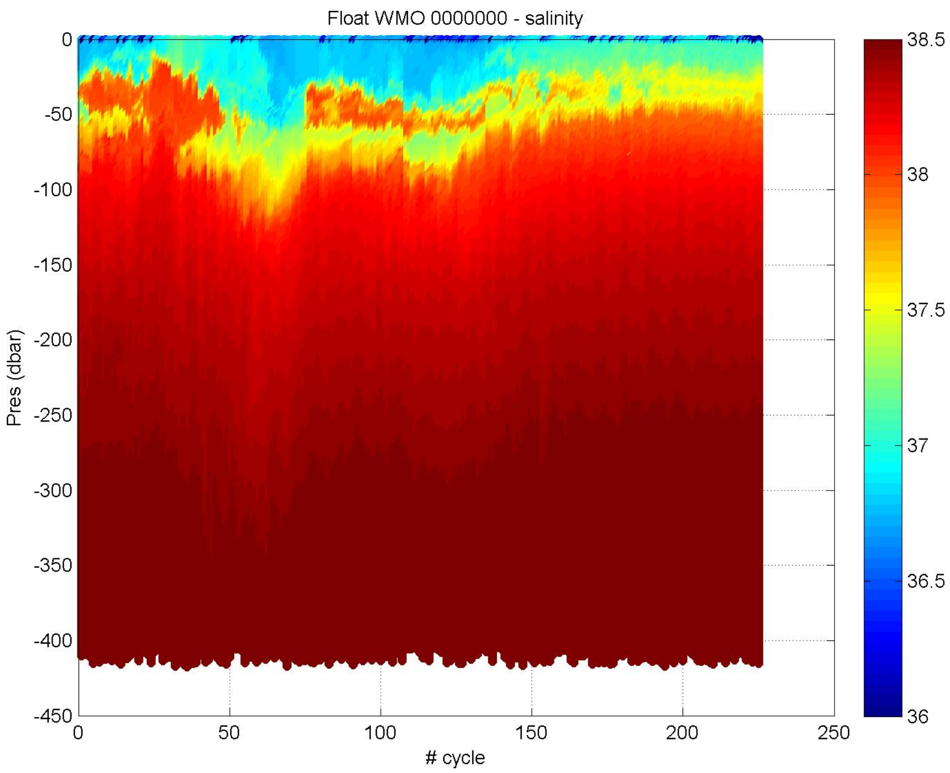


Figure 3. Contour plots of potential temperature (top) and salinity (bottom) data measured by the Arvor-C along its trajectory.

Arvor-A3:

The trajectory of the Arvor-A3 is shown in Figure 4, along with the positions of the CTD profiles executed by the float. It drifted to the southeast and arrived in the vicinity of the Algerian coast by mid-July 2014.

The potential temperature and salinity profiles provided by the Arvor-A3 are plotted in Figure 5. The thermal stratification and the low-salinity Atlantic water signature are evident.

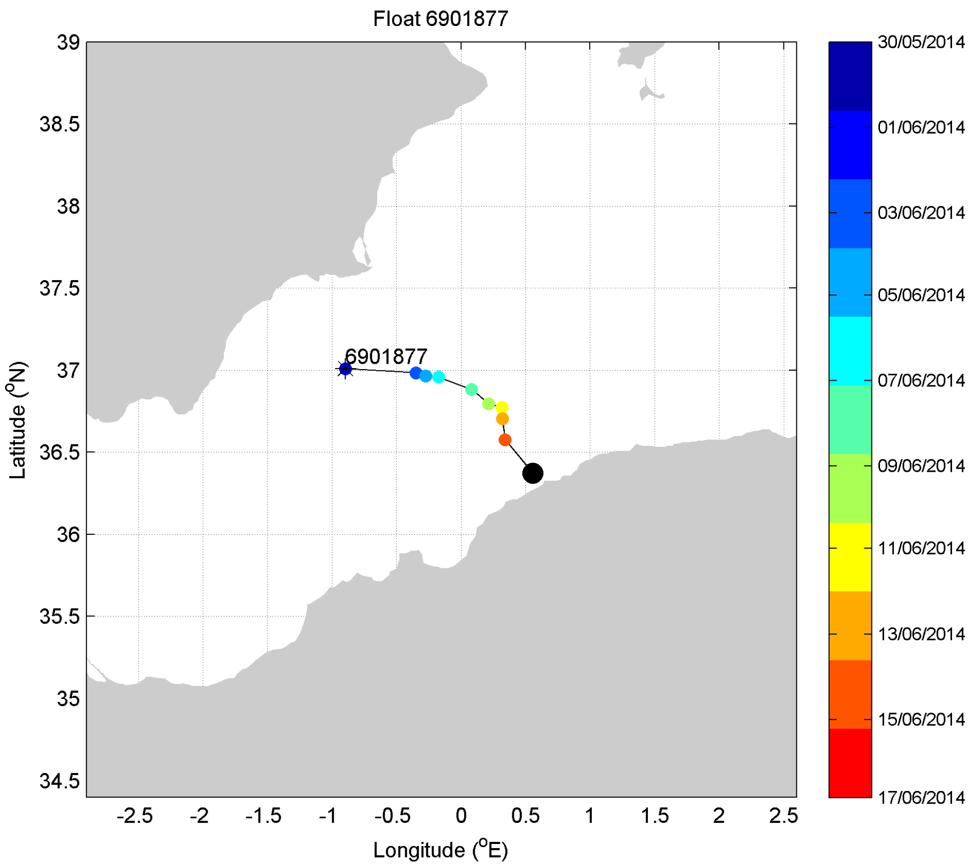
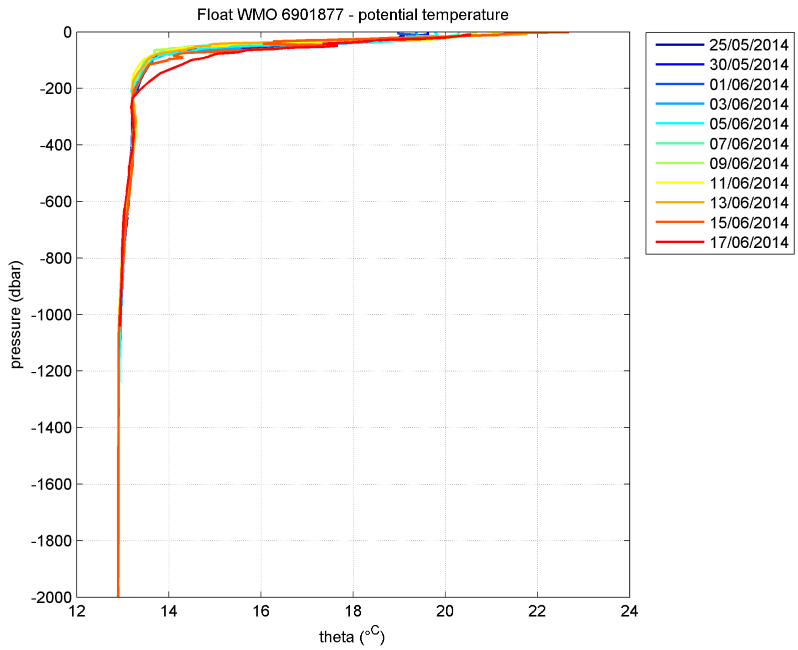


Figure 4. Trajectory of the Arvor-A3 (WMO 6901877) between deployment on 25/05/2014 (star symbol) and position on 17/06/2014 (black dot).



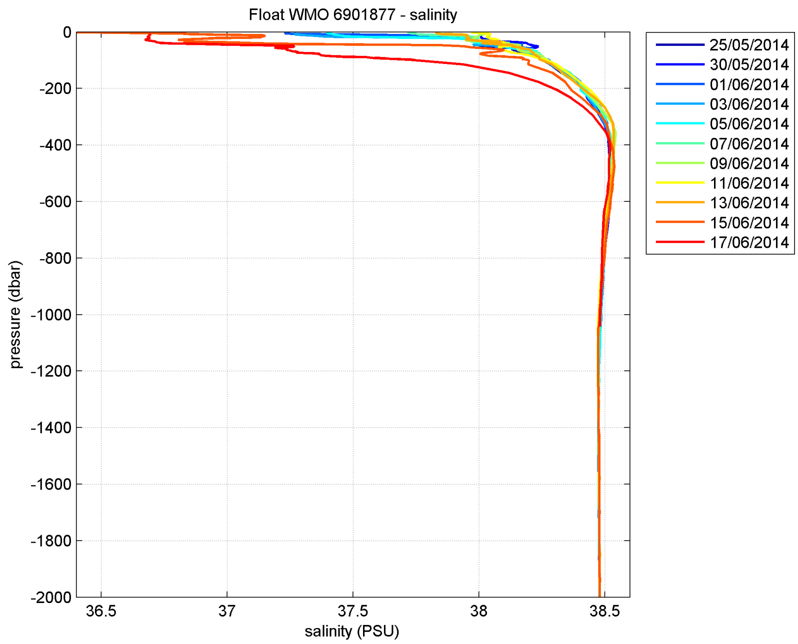


Figure 5.Profiles of potential temperature and salinity measured by the Arvor-A3, color-coded with date.

Provor-bio:

The Provor-bio trajectory and its profile locations (daily from deployment to 7 July 2014 and every 5 days thereafter) are shown in Figure 6. Daily profiles were collected until 7 June 2014 before the float cycle length was changed from 1 day to 5 days.

As an example, the profiles of physical, biogeochemical and optical parameters are displayed in Figure 7 for 7 July 2014. The sub-surface maximum in chlorophyll-a concentration is noteworthy.

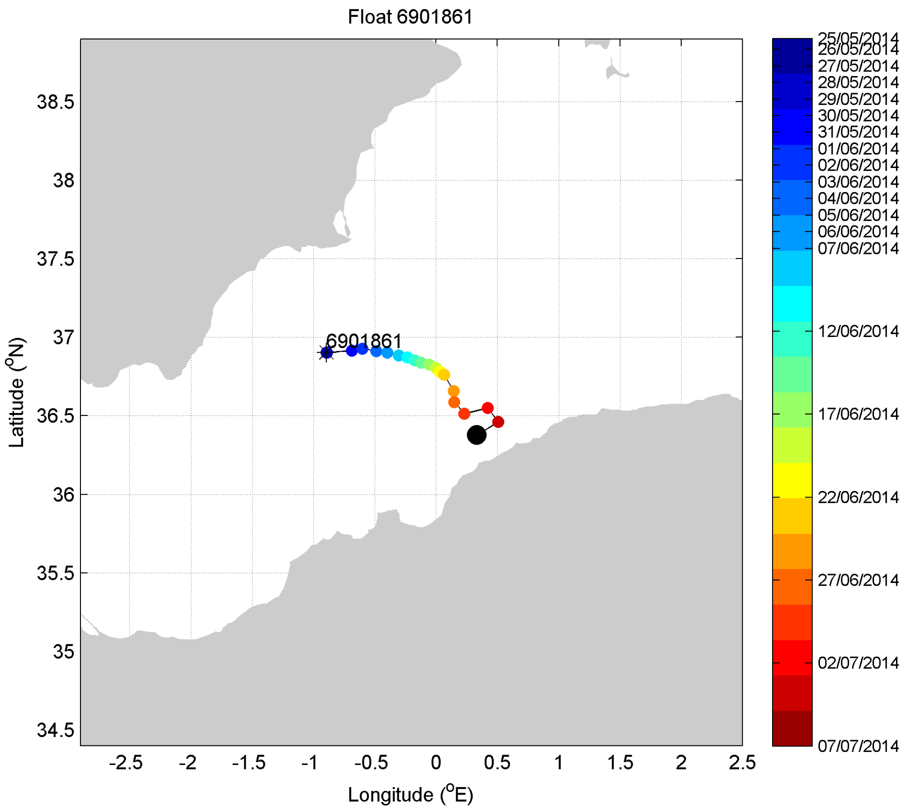


Figure 6. Trajectory of the Provor-bio (WMO 6901861) between deployment on 25/05/2014 (star symbol) and position on 7/07/2014 (black dot).

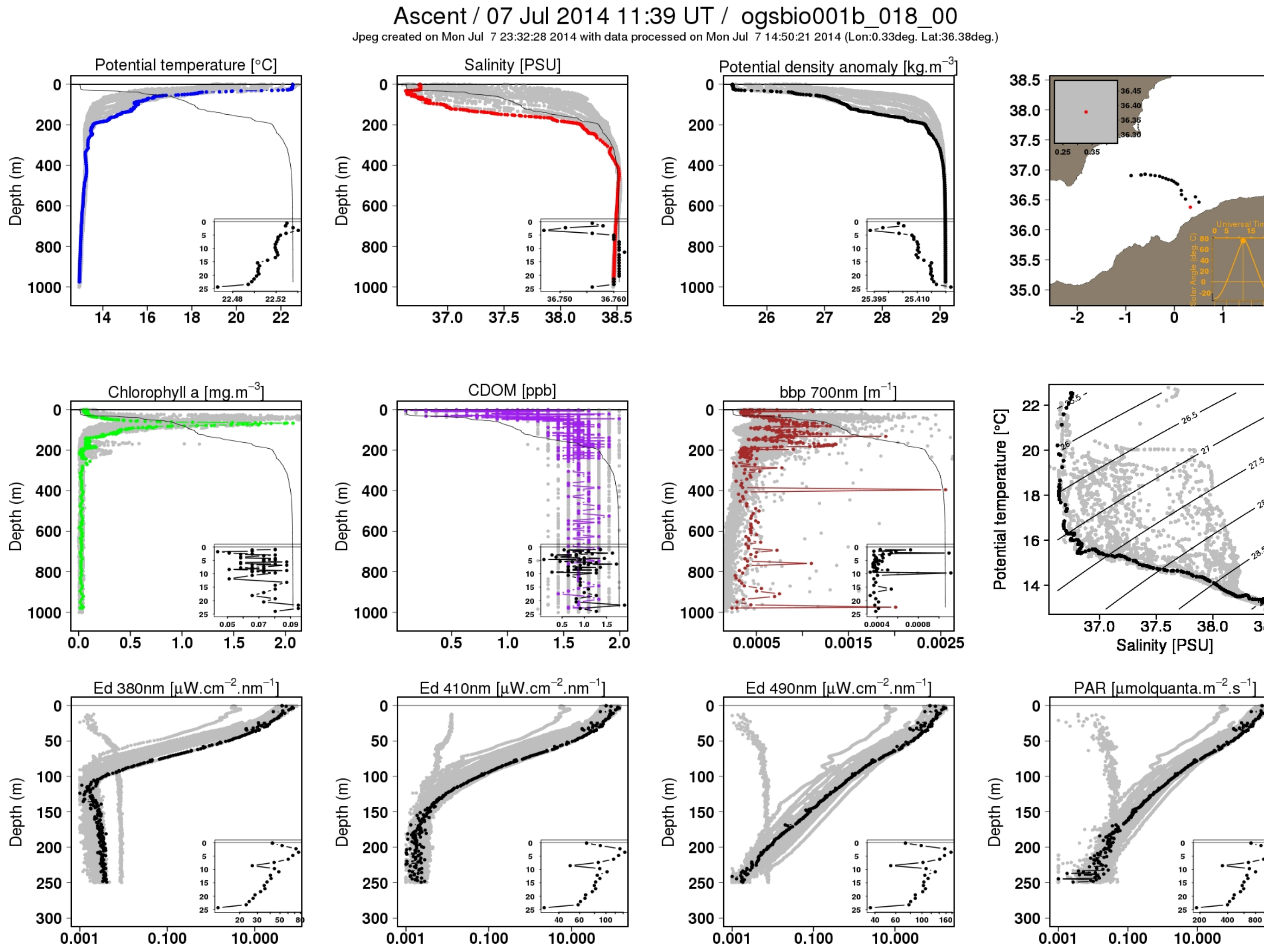


Figure 7. Profiles of physical, biogeochemical and optical parameters measured by the Provor-Bio (WMO 6901861) on 7 July 2014.

References

Lumpkin, R. and M. Pazos, 2007: Measuring surface currents with SVP drifters: The instrument, its data and some results. Lagrangian Analysis and Prediction of Coastal and Ocean Dynamics, A. Griffa et al., Eds., Cambridge University Press, 39–67.

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Annex VI. Presentations at scientific meetings

List of presentations during the Alborex Meeting (12-13 March, 2015).

- Presentation of PERSEUS project (Joaquín Tintoré)
- Overview of ALBOREX experiment: scientific objectives, design and achievements (Ananda Pascual)
- Enhancement of vertical fluxes at a front (Amala Mahadevan)
- Physical and biochemical interactions at the mesoscale (John Allen)
- Results of the ALBOREX CTD, glider and ADCP data (Simón Ruiz)
- Preliminary analysis of the ALBOREX drifter and float data (Pierre Poulain)
- Preliminary analysis of the ALBOREX chlorophyll and nutrient samples (Antonio Tovar)
- Deep Chlorophyll Maximum distribution in the Alboran sea and its relationship with mesoscale and frontal features through syn chronous multiple glider observations
(Antonio Olita)
- Preliminary results of the model implementation for the ALBOREX experiment (Mariona Claret)
- Diagnosing Alboran Sea biological production in relation to upper layer circulation features (Temel Oguz)
- Modeling the impact of tidal flows on the biological productivity of the Alboran Sea (José C. Sanchez)

Other meetings

- Ruiz, S.; A. Pascual, J.Allen, A. Olita, A. Tovar, T. Oguz, A. Mahadevan, P.Poulain, J. Tintoré. ALBOREX: an intensive multi-platform and multidisciplinary experiment in the Alboran Sea. EGU General Assembly, April 2015, Vienna.
Type of participation: Poster

- Olita, A.; A.Ribotti, S. Ruiz, A. Pascual. Deep Chlorophyll Maximum distribution in the Alboran sea and its relationship with mesoscale and frontal features through syncronous glider observations. EGU General Assembly, April 2015, Vienna.
Type of participation: Poster

- Pascual, A.; B. Casas, J.T. Allen, M. Torner, A. Olita, S. Ruiz, C. Troupin, E. Mason, M. Palmer, F. Margirier, C. Castilla, P. Balaguer, I. Lizarán, G.

Notarstefano, A. Massanet, K. Sebastián, J.P. Beltrán, M. Juza, A. Tovar, P. Vélez, T. Orguz, A. Mahadevan, P. Poulain, J. Tintoré. ALBOREX: a major intensive multi-platform and multidisciplinary experiment in the Alboran Sea. PERSEUS 2nd Scientific Workshop, December 2014, Marrakech (Morocco)
Type of participation: Speaker

Guest Master Students

Project title: The ALBOREX multi-platform experiment
University issuing the qualification: ENSTA
Student: Felix Margirier
Supervisors: Dr. A. Pascual and Dr. S. Ruiz
Date: 08/2014

Annex VII. Onboard diary

After the thorough preparation of the campaign, the SOCIB vessel was set to leave to the Eastern Alboran region on Sunday May 25th at 6:00 (UTC). Two teams were made, working on 4 hours shifts.

Sunday, 25 May

(GMT time)

06:00 Leaving Cartagena, direction the Eastern Alboran Sea.

07:00 Emergency procedure simulation.

08:00 Team meeting, distribution of tasks and shifts.

08:30 Arrival at the launch point of deployment of the first glider. Communication and overtime/ overdepth tests.

09:49 Glider OK and mission launched. CTD station with chlorophyll and nutrients samples ALX001 in the same point as the glider launch. ADCP velocities are low. Salinity around 38.2.

11:08 Arrival at the launch point of deployment of the second glider. Communication and overtime/overdepth tests.

13:00 Glider OK and mission launched. CTD station with chlorophyll and nutrients samples ALX002 in the same point as the glider launch. ADCP velocities are 15 cm.s-1 E. Salinity around 38.2.

14:35 First drifter launch after removing the magnets and testing their operation. ADCP velocities are 25/30 cm.s-1 E in the first 30m.

18:52 Last drifter launched.

18:55 Argo A3 launched after removal of the sensors' protections and testing.

ADCP velocities are 50/60 cm/s E in the first 100 m. Salinity of 36.6. Front found !

19:41 Second Argo (ARVOR-C) launched.

19:54 Third Argo (Pro-Bio) launched.

19:55 ADCP night transects, covering the projected CTD grid at constant velocity of 8 knots. The front seems thin and very deep.

20:00-24:00: ADCP transects constant ship’s velocity of 8 knots.

Night ADCP transects were completed showing currents up to 90 cm/s and salinity gradients between 36.6 and 38.2.

Monday, May 26

Station ALX101 began at ~ 6:00 GMT (CTD stations with biogeochemical samples).

The grid is re-evaluated and shifted south as the northern stations are not as interesting.

Tuesday, May 27

ADCP results show great results: velocities of 1m/s in the zonal direction in the north and to the south in the south-east portion. Drifter is seen during the CTD transects, suggesting they have traveled 30/35km in 40 hours, a 25cm/s velocity to the E-SE.

The CTD is inclined to the East in some stations, revealing the front. Salinities of 36.8 to 38 between two CTD stations. Promising results. The boat heads back to Cartagena after completing the first leg as bad weather is forecast.

Wednesday, May 28

Day off due to the weather conditions.

Thursday, May 29

On Thursday 29th May, SOCIB departed Cartagena after bunkering at **~ 07:00 GMT**. The sea state out of the harbour was light, but with a remnant swell of 1.5-2 m

At **~ 12:10 GMT**, SOCIB arrived at the south-eastern corner of the revised CTD survey area. CTD ALX2-42 was deployed at 12:15 at 36 ° 45.095' N, 0 ° 20.262' W. It appeared from the VM-ADCP that the station was in the peripheral eddy current with a southward (eastward) component flow of ~25-30 cm s-1 (75-80 cm s-1), i.e. ~ 80-85 cm s-1 in a ESE direction. The CTD was recovered at 12:42.

We began to head towards station ALX2-41 in a westward direction, but the swell was making the transit very slow and awkward, so we turned north towards ALX2-33. Station ALX2-33 began at **~ 13:25 GMT**, at 36 ° 47.963' N, 0 ° 21.221' W. From the VM-ADCP this appeared to be at the northern edge of the eddy current, with much reduced flows of ~ 50 cm s-1 maximum in an ESE direction. The CTD was safely recovered at 13:57 GMT.

Station ALX2-34 began at **~ 14:18 GMT**, at ~ 35 ° 51' N, 0 ° 20' W. The ESE current had increased again slightly here with a 60-70 cm s-1 (~ 35 cm s-1) eastward (southward) component. The CTD was safely recovered at 14:47 GMT.

Station ALX2-35 began at **~ 15:05 GMT**, at ~ 36 ° 53' N, 0 ° 20' W. The ESE current had weakened again similar to that at ALX2-33. The CTD was safely recovered at ~15:30 GMT.

Station ALX2-36 began at **~ 15:48 GMT**, at ~ 36 ° 56' N, 0 ° 20' W; and was safely recovered at ~ 16:15 GMT.

Station ALX2-37 began at **~ 16:33 GMT**, at ~ 36 ° 59' N, 0 ° 20' W; and was safely recovered at ~ 17:00 GMT.

The northern most station of this eastern leg, ALX2-38 began at **17:18 GMT**, at ~ 37° 01.8'N, 0 ° 20'W. According to the VM-ADCP any remnant signal of the eddy peripheral current had faded away just prior to reaching the station. The CTD was safely recovered at ~ 17:40 GMT, and SOCIB headed west to ALX2-27.

Station ALX2-27 began at **~ 18:20 GMT**, at ~ 37 ° 01.8' N, 0 ° 27' W; and was safely recovered at 18:48 GMT. SOCIB headed south to continue the survey lines in a north south direction.

Station ALX2-28 began at **~ 19:10 GMT**, at ~ 36 ° 59' N, 0 ° 27' W. The VM-ADCP showed the possible beginning of an eastward flow. The CTD was safely recovered at 19:36 GMT.

Station ALX2-29 began at **~ 19:55 GMT**, at ~ 36 ° 56' N, 0 ° 27' W. The VM-ADCP showed that we had re-entered the eastward peripheral eddy flow, but with only a very small southward component. The CTD was safely recovered at ~ 20:25 GMT.

Station ALX2-30 began at **~ 20:45 GMT**, at ~ 36 ° 53' N, 0 ° 27' W; and was safely recovered at ~ 21:08 GMT. This was the last station of the day, and we then began an overnight VM_ADCP box survey of the southwest region of the CTD survey area at ~ 21:10 GMT.

Friday, May 30

SOCIB was back at station ALX2-31 by **~ 03:20 GMT** on the morning of the 30/05/14. Just approaching station at ~ 03:10 GMT, distinct round blobs of bioluminescence were clearly seen in the vessel's wake. These discs of light were all much the same size, maybe 10-20 cm in diameter, and were probably jellyfish of some sort.

The first station of the day, ALX2-31, began at ~ 05:55 GMT, at ~ 36 ° 50' N, 0 ° 27' W; and was safely recovered at ~ 06:20 GMT. SOCIB proceeded to steam south towards ALX2-32.

Station ALX2-32 began at **~ 06:45 GMT**, at ~ 36 ° 48’ N, 0 ° 27’ W; and was safely recovered at ~ 07:05 GMT.

At the southern end of the line, station ALX2-41 began at 07:52 GMT, at ~ 36 ° 45’ N, 0 ° 27’ W; and was safely recovered at 07:52 GMT. SOCIB then steamed westwards to the bottom of the third line of the survey, station ALX2-43.

Station ALX2-43 began at **08:27 GMT**, at ~ 36 ° 45’ N, 0 ° 34’ W; and was safely recovered at ~ 08:50 GMT. SOCIB then proceeded northwards up the third line of the survey.

Station ALX2-17 began at **09:09 GMT**, at ~ 36 ° 48’ N, 0 ° 34’ W; and was safely recovered at ~ 09:33 GMT. This station appeared to be in the core of the eddy periphery current according to the VM-ADCP velocities.

Station ALX2-18 began at **09:53 GMT**, at ~ 36 ° 51’ N, 0 ° 34’ W; and was safely recovered at ~ 10:15 GMT. During this station, we were appraised of the times and the expected positions for glider surfacing, one at 15:00 CET at the north-eastern corner of the survey region and the other at 16:00 CET, just east of station ALX2-34 considerably further south and probably in the eddy periphery current.

Station ALX2-19 began at **~ 10:35 GMT**, at ~ 36 ° 53.5’ N, 0 ° 34’ W; and was safely recovered at ~ 10:55 GMT.

Station ALX2-20 began at **~ 11:20 GMT**, at ~ 36 ° 56.5’ N, 0 ° 34’ W; and was safely recovered at ~ 11:40 GMT.

Station ALX2-21 began at **~ 12:00 GMT**, at ~ 36 ° 59’ N, 0 ° 34’ W; and was safely recovered at ~ 12:21 GMT.

The final station on this line, station ALX2-22, began at **~ 12:41 GMT**, at ~ 37 ° 02' N, 0 ° 34' W; and was safely recovered at ~ 13:05 GMT. Following recovery, SOCIB set off approximately due west for the first of the two glider recoveries, this one around 11 nm away.

The shallow glider icoast00 was spotted at **~ 14:05 GMT**, the RIB was launched and all were safely recovered and on board by ~ 14:30 GMT. SOCIB then set course south to recover the deep glider.

Glider, ideep00, was spotted at **~15:20 GMT**. The RIB was launched approximately ten minutes later and personnel, glider and RIB had been safely recovered by ~15:30 GMT. SOCIB began the ~ 20 nm westward steam to the southern end of the 4th and final western leg of the CTD survey (station ALX2-44) at ~ 16:00 GMT.

Station ALX2-44 began at **~ 17:55 GMT**, at ~ 36 ° 45' N, 0 ° 41' W; and was safely recovered at ~ 18:15 GMT.

Station ALX2-16 began at **~ 18:37 GMT**, at ~ 36 ° 48' N, 0 ° 41' W; and was safely recovered at ~ 18:58 GMT.

Station ALX2-15 began at **~ 19:19 GMT**, at ~ 36 ° 51' N, 0 ° 41' W; and was safely recovered at ~ 19:40 GMT.

Station ALX2-14 began at **~ 20.00 GMT**, at ~ 36 ° 53.5' N, 0 ° 41' W; and was safely recovered at ~ 20:20 GMT.

Station ALX2-13 began at **~ 20:40 GMT**, at ~ 36 ° 56' N, 0 ° 41' W; and was safely recovered at ~ 21:00 GMT.

Station ALX2-12 began at **~ 21:24 GMT**, at ~ 36 ° 59' N, 0 ° 41' W; and was safely recovered at ~ 21:44 GMT.

The final station of the 2nd CTD survey, ALX2-11, began at **~ 22:03 GMT**, at ~ 37 ° 02' N, 0 ° 41' W; and was safely recovered at ~ 22.27 GMT. B/O SOCIB set course for Palma.

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