



**Operation of the new observing components
including assessment of data delivered**

Deliverable Nr. 3.9





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To contact the authors:

Claire Gourcuff (Claire.Gourcuff@locean-ipslupmc.fr)



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EXECUTIVE SUMMARY / ABSTRACT

In the framework of PERSEUS project, new observing components have been implemented in the Southern European Seas (SES), namely gliders, Continuous Plankton Recorder and Vessel Monitoring Systems, leading to various newly available datasets and approaches useful for the understanding of the marine ecosystem and helping the implementation of environmental public policies.

Gliders endurance lines and specific platform experiments were implemented between 2012 and 2015 in several sub-basins of the Mediterranean Sea. Unfortunately, no glider could be deployed in the Black Sea. The PERSEUS coordination of the answers to the JERICO TNA for gliders, which was proposed in this project by our WP3, did not reveal any candidate for supporting a glider operation there yet. Real time data from PERSEUS gliders deployments are public, freely available and quality controlled. As a legacy of the FP7 GROOM (Gliders for Research, Ocean Observation and Management) project and the EGO COST Action (Everyone's Gliding Observatories, ES0904), Coriolis is now the Global Data Assembly Center (GDAC) for gliders in Europe (in line with other data management initiatives) and linked with other Data Assembly Centers (DAC). This GDAC is the single access point where the PERSEUS database can import quality controlled data, in a common format. Deployments that were not imported from the GDAC in the PERSEUS database (due to technical reasons) have been identified and this transfer will be completed before the PERSEUS General Assembly in December. Data are additionally displayed and available for download on various regional, national and European portals, for example: the EGO web page (Everyone's Gliding Observatories), SOCIB portal (Spanish deployments), EMODnet, etc. Data from other platforms (floats, cruise data, etc.), collected during the multiplatform experiments (Alborex and DeWEX) are also available through the PERSEUS portal, following the different data management specificities of the platforms and in line with international standards according.

Data from two monitoring systems also considered here, the Continuous Plankton Recorder (CPR) and the Vessel Monitoring System (VMS) are available in the PERSEUS database as far as is feasible/permitted for the platform/type of data (see below). As these systems develop and a better assessment of their usefulness to different type of users, greater opportunities to make the collected data and product visible and available can be sought.

Since October 2014, PERSEUS partners initiated the use of the Continuous Plankton Recorder (CPR) in the Eastern Mediterranean along a Cyprus-Israel-Cyprus transect and set up the full facility and expertise to analyze the samples locally. The data collected are organisms and one can derive zooplankton and phytoplankton



abundances and diversity, biological productivity, as well as temperature and salinity data. Due to the nature of the CPR samples and the time needed for the taxonomic analysis of samples, a considerable time lag is created between the acquisition of the samples and the extraction and exploitation of data. Seasonal CPR data products are made available upon request through The Cyprus Institute. Salinity and temperature data derived from the logger are being transferred to the PERSEUS and Coriolis databases and will be available at the end of the project (December, 2015).

Work has been also done on the compilation and analysis of Vessel Monitoring System (VMS) data for Mediterranean EU fishing fleets operating in Spanish, Italian and Greek waters. VMS primary data on the location of fishing vessels for the three study areas are confidential but accessible for research purposes upon request to the appropriate authorities. Fishing effort estimates by bathymetric strata have been made available for visualization and input into models. The estimated values of fishing effort (Days at sea, Days * Gross Tonnage (GT), Days * Kilowatt (KW) are accessible via the PERSEUS geoportal.

The new observing components and their integration, developed through PERSEUS have contributed to upgrade and expand the observing capacity in the SES, towards the fulfillment of several scientific and society needs, with emphasis on a better characterization of the present status and variability of the marine environment. This effort has also increased capabilities of the observing systems to support the implementation of MSFD by providing new data in key areas and knowledge about important processes at stake in line with several MSFD Descriptors.

The measurements collected during the PERSEUS project between January 2012 and June 2015 lead to significant scientific results, including better understanding of physical and biogeochemical processes, characterization of submesoscale processes and their importance for deep water formation/export and primary production processes, seasonal variability, and estimates of ocean transports variability in key regions.

Common procedures and methodological steps for analysis of Vessel Monitoring System data have been developed in order to estimate fishing effort by different partners in various implementations satisfying National and European requirements. This has led, for the first time, to the construction of a common VMS database.

The MedCPR survey has marked the beginning of a baseline database for the Levantine Bassin. The availability of a monitoring system able to deliver physical and



biological data, during and after events such as the expanding of the Suez Canal, temperature increases, intense hydrocarbon exploration, etc. will be an asset to scientists and stakeholders of the region, in particular for the implementation of the MSFD. Through this experience, the Cyl has gained valuable insights, which will facilitate the expansion of the survey in other keys areas in the SES and expand the marine research collaborations in the region. This will be of major importance for the implementation of the MSFD in European waters and for the Ecosystem Approach (EcAp) promoted by UNEP/MAP in the framework of its Integrated Monitoring and Assessment Program (IMAP).



SCOPE

Within Task 3.3, new observing components have been implemented in the Southern European Seas (SES), contributing in filling gaps identified in Task 3.1 in particular. The new components of the observing system, implemented in relation to national programs, include glider endurance lines, multi-platform experiments, a Continuous Plankton Recorder System and a Fishing Fleet Vessel Monitoring System. The data collected within this context will help to better meet the needs of the MSFD.

The aim of this deliverable is mainly to describe these new observing system components, each having a dedicated PERSEUS deliverable:

- D3.3: Implementation of the Continuous Plankton recorder (CPR) in the Mediterranean Sea
- D3.4: Common methodological procedures for analysis of VMS data
- D3.6: Operation and data analysis from glider experiments in the SES
- D3.8: Operation and data analysis from multi-platform synoptic intensive experiments

In this deliverable D3.9, we report on how these new observing components have operated, and assess the resulting available datasets collected during the PERSEUS project, particularly in relation with their potential use for a better implementation of the MSFD. We will refer to the deliverable D3.3, D3.4, D3.6 and D3.8 for further details about the operations, data analysis and scientific contributions.



1. Description of the new observing components

1.1. Gliders

Gliders are buoyancy-driven autonomous underwater vehicles that can sample most of the Essential Ocean Variables (EOV) along vertical saw-tooth trajectories between the surface and 1000m depth for months (Testor et al. 2010 for a review). We relate here the operations of 7 glider experiments (endurance lines and process studies) implemented between 2012 and 2015 in the Mediterranean Sea (Figure 1). For a complete review of scientific results obtained from the data collected through the glider deployments, please refer to D3.6. Unfortunately, no glider has been deployed in the Black Sea yet, due to a lack of human resource in the Black Sea PERSEUS partner institutes to initiate additional sampling programs during PERSEUS time frame. This is a sampling and capacity gap that should be addressed within future programs.

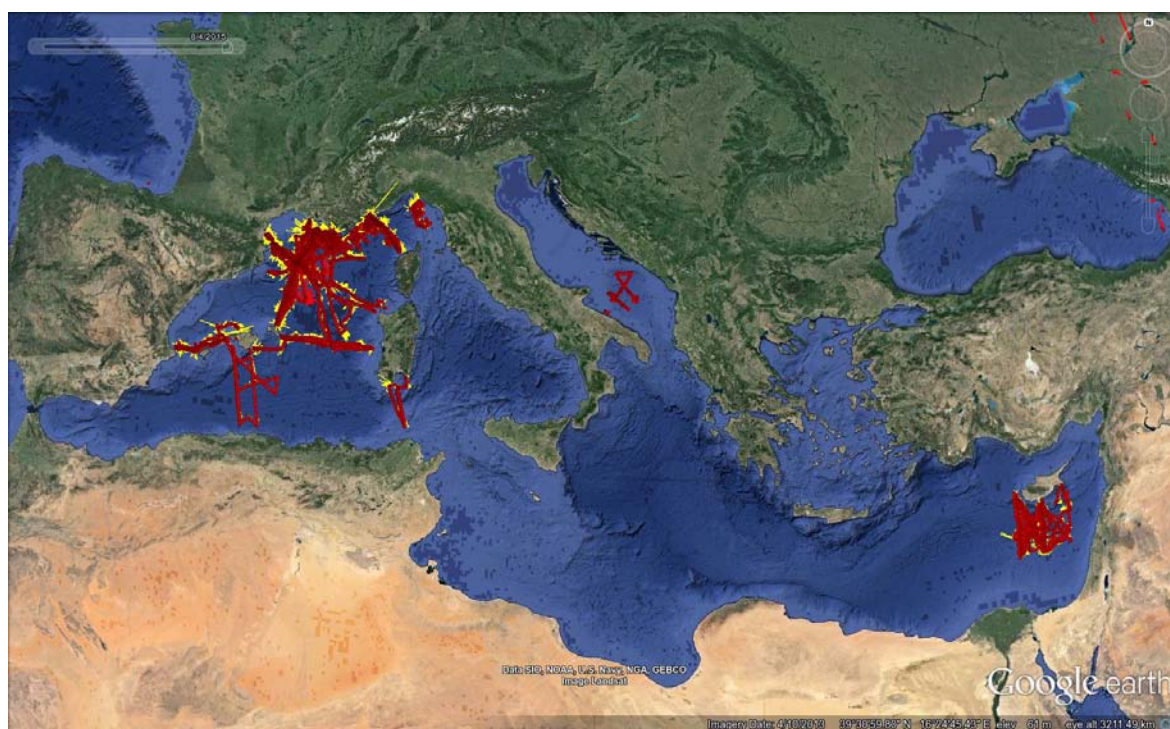


Figure 1. PERSEUS glider experiments in the Mediterranean Sea between January 2012 and June 2015. Surface position and trajectories (red dots and lines) and depth-average currents (yellow arrows).



1.1.1. MOOSE glider monitoring program (CNRS)

Since the beginning of PERSEUS (2012), 26 glider missions were carried out in the framework of the MOOSE (Mediterranean Ocean Observing System for the Environment) program, each between 1 and 3 months of duration. Glider missions were carried out along MooseT00 (Nice-Calvi, Ligurian Sea, 13 deployments) and MooseT02 (Marseille-Menorca, Gulf of Lion, 13 deployments) lines (Figure 2).

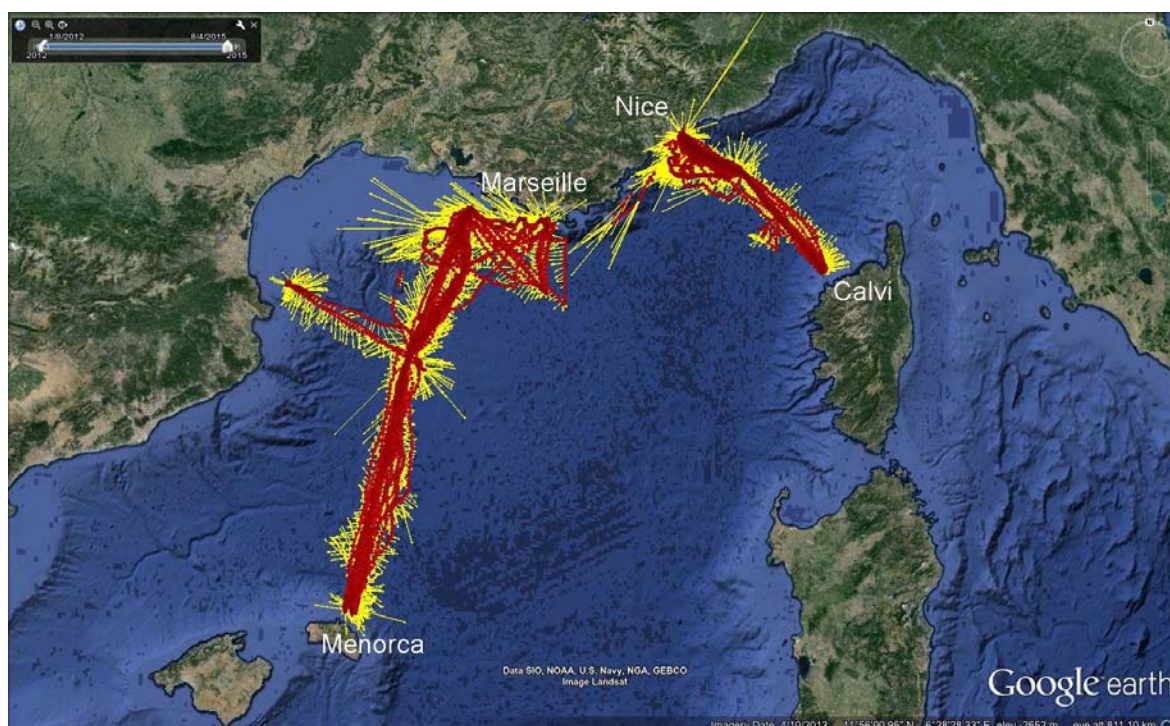


Figure 2. MooseT00 (east) and MooseT02 (west) glider endurance lines between January 2012 and June 2015. Surface position and trajectories (red dots and lines) and depth-average currents (yellow arrows).

Objectives

Both endurance lines ensure a multi-scale monitoring of the northwestern basin from East to West and from the French coast to Balearic Islands and Corsica, considering in particular winter mixing processes (even deep convection in the Gulf of Lion) and bloom events. One objective is to study the winter convection and its impact on the thermohaline circulation and primary production. Another objective is to monitor the variability of the Northern Current at the mesoscale level and its impact on coastal and open sea circulation. The gliders data and well as the other data collected by MOOSE are also made available to the agencies in charge of the implementation on the MSFD.



Platforms and Sampling

Temperature and salinity are always measured to 1000 m. Gliders are also equipped with dissolved oxygen, turbidity and Chl-a fluorescence sensors. Data are acquired at a rate of 4-8s and transmitted in real time at a rate of 24s to save communication costs. Occasional full depth calibration profiles at the beginning and end of the mission were carried out for dissolved oxygen and optical parameters during MOOSE CTD cruises. In most cases data are collected both on downcasts and upcasts.

Most of the MOOSE deployments were performed using Teledyne Webb Research Slocum G1 gliders, and a few were performed with iRobot Seaglidors.

Operations assessment

Most of the missions ended successfully with a coastal recovery but we had to deplore the loss of two gliders along MooseT02 at about the same place: sg509 on 28 July 2013 (deployment PerseusT02_03, last position at 16:43 GMT) and nearchos on 27 May 2015 (deployment MoosePerseusT02_09, last position at 14:14 GMT). The gliders disappeared in the vicinity of the continental slope. Since their last transmissions were not interrupted (by a possible collision with a ship), it is likely the losses result from bad altimeter functioning close to a steep and muddy bottom that could have trapped the instruments. Order of 16000 profiles of the water column were obtained during the 2012-2015 period which represents an order of magnitude more profiles than all the previous profiling floats and ship-based hydrography.

1.1.2. Ibiza Channel endurance line monitoring (SOCIB/CSIC)

The SOCIB/IMEDEA ‘canales’ glider endurance line missions were initiated in January 2011 and are the continuity of efforts started in 2007 (Ruiz et al 2012) now in the frame of the Large Scale Spanish Marine Infrastructure SOCIB (Tintoré et al, 2012). 27 missions were undertaken during the PERSEUS Project period, January 2012 – December 2015.

A typical ‘canales’ mission takes approximately twenty four days to complete; the glider is deployed close to Mallorca, samples the Mallorca Channel once, then samples the IC 4 to 6 times before returning to Mallorca via the same route (*Figure 3*).

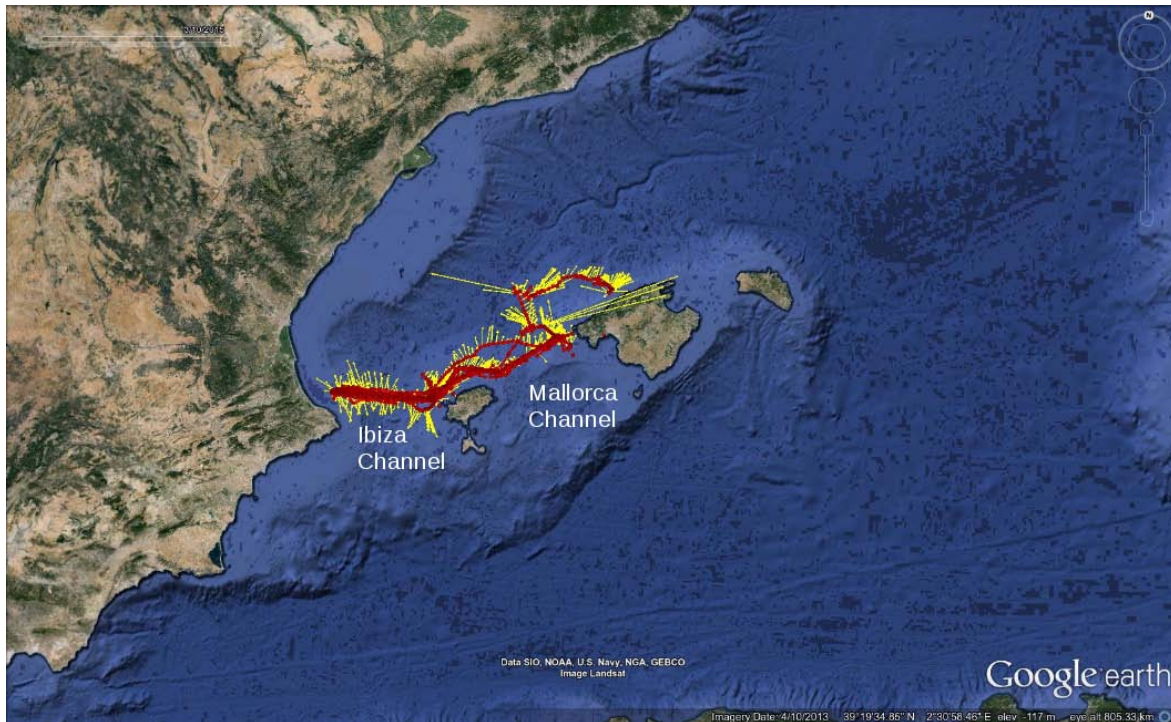


Figure 3. Canales endurance line (red dashed line) between January 2012 and June 2015. Surface position and trajectories (red dots and lines) and depth-average currents (yellow arrows).

Objectives

Although large cruise-to-cruise variability in transport through the Ibiza and Mallorca channels had previously and frequently been noted (e.g. García-Ladona et al 1996), characterization of this variability had not been possible with the limited number of historical ships cruises, mainly undertaken during the summer. In the face of the high spatial and temporal complexity in the IC, an important ‘choke’ point in the Mediterranean circulation (Heslop et al, 2012), gliders were seen as the means to extend our knowledge of the high frequency dynamics of the channel, through repeated transect monitoring across all seasons, and thus improve our understanding of the scales of variability from high frequency, to seasonal and then interannual.

Platforms and sampling

Three different glider platforms have been used during the 4.5 years of monitoring: Teledyne Webb Research Slocum G1 and G2 gliders and iRobot Seagliders. The



sampling strategy and data processing however are consistent across all platforms. The gliders carry a standard Seabird CTD (GPCTD-SBE), measuring temperature, conductivity and pressure), a Wetlabs Puck (FLNTU-SLK), measuring Fluorescence at 470/695nm (Chlorophyll-a) and Turbidity at 700nm, and an Aanderaa Oxygen Optode (OPTODE_5013 or 4330), measuring absolute oxygen content, relative air saturation and temperature. The CTD is set to sample at 0.5 Hz and to the full depth of the water column, the Wetlabs Puck and the Oxygen Optode at 8 s and to 200 m. Sampling is on downcast only, except for at least one transect for each deployment, where data are also collected on upcasts (for thermal lag correction application).

Operations assessment

Overall the glider monitoring of the Ibiza Channel endurance line has been highly successful, since 2011 the IC has been sampled approximately 124 times and the MC approximately 45 times, with of order 14000 profiles of the water column obtained between January 2012 and June 2015, which represents an order of magnitude more profiles than all the previous ship based hydrography.

1.1.3. Cyprus National Glider Monitoring Program (OC-UCY)

During 2012-2015, three long glider missions were carried out in the eastern Levantine Basin, each between 5 and 6 months of duration.

Glider missions were carried out in the framework of the CYCOFOS according to the “butterfly” or “bow tie” patterns established in YPOKINOUMODA (Cyprus Research Promotion Foundation Infrastructure Upgrade grant). These patterns cover an area of about 200km x 200km south of Cyprus, and in particular overlap many years of ship hydrography (from 1995). Because of the scales of variability (about 20 km) and the time to complete a butterfly (about 1 month), the pattern allows little chance for features to go unobserved. Because of historical observations, the western butterfly is preferred as the most likely location for the Cyprus Eddy. However, in some missions, the eastern butterfly was performed to provide more coverage and in fact “find” the Cyprus Eddy (which has been observed on every mission, but with varying size, strength, and position). This explains the somewhat irregular glider tracks (besides the fact that the glider is deflected by the eddy currents, and sometimes had to be re-routed to make headway) (Figure 4).

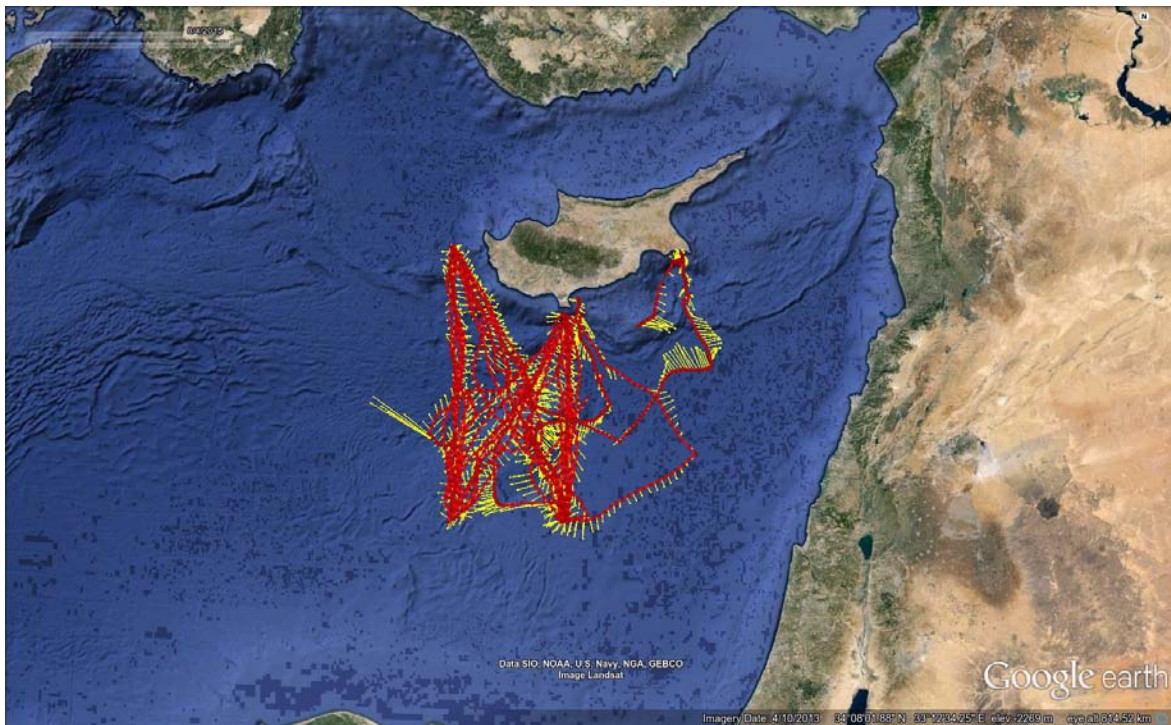


Figure 4. Eastern Levantine glider endurance lines between January 2012 and June 2015. Surface position and trajectories (red dots and lines) and depth-average currents (yellow arrows).

Objectives

The objectives of this experiment were to study: (1) the pathway of Atlantic Water and the associated Mid Mediterranean Jet, (2) the fluctuation of the Cyprus warm core eddy, its position, size and intensity, (3) the Levantine Intermediate Water formation and spread, (4) the Cyprus eddy generation, maintenance, and destruction.

Platforms and sampling

Two Seagliders have been used. Sampling strategy is as follows. Temperature and salinity are always measured to 1000 m (10 s). Dissolved oxygen is measured at 60 s from surface to 600 m. Optical parameters (backscatter at 470 nm and 700 nm, and chlorophyll-a fluorescence) are measured only in the upper 300 m at 60 s intervals. Occasional full depth calibration profiles at the beginning and end of the mission were carried out for dissolved oxygen and optical parameters.



Operations assessment

No particular problems were faced, and each mission ended successfully with a coastal recovery.

1.1.4. South Adriatic pit (OGS)

The endurance line performed during PERSEUS covers a Bari-Dubrovnik transect. A second transect along the longitudinal axis of the Adriatic Sea was performed as well as a butterfly path in the vicinity of the E2-M3A buoy site. As a whole, the Seaglider Amerigo, equipped with a CTD, an Optode and a Wetlabs optical sensor, was deployed three times during Perseus time frame. The first mission lasted one day in the coastal zone (March 2013), the second one week over the Adriatic pit (May 2013) and the last time the deployment operated for 3 weeks, along a butterfly pattern in the Adriatic pit, from February 15 to March 6, 2014 (Figure 5).

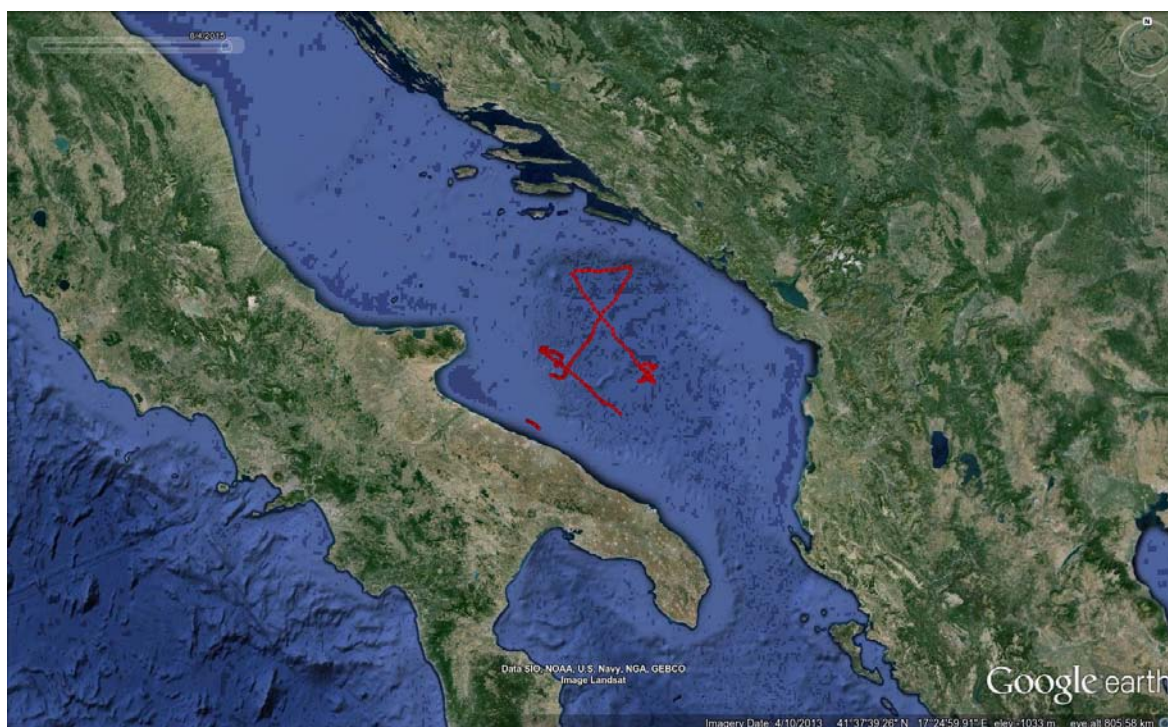


Figure 5. Deployments in the Adriatic Sea between January 2012 and June 2015. Surface position and trajectories (red dots and lines).

Objectives



The purpose of the experiment was to study the winter deep water convection in the South Adriatic pit area, with improved sampling, in particular using data collected during winter.

Platforms and sampling

The three deployments were done using an iRobot Seaglider, equipped with a SBE pumped CTD measuring temperature, conductivity and pressure, an Aanderaa Optode measuring oxygen and a Wetlabs sensor measuring optical backscatter and Chl-a fluorescence.

Operations assessment

The first deployment ended after one day, due to a leakage in the Wetlabs connector, and strong currents were faced during the second deployment, that forced the pilot to change the initial waypoints. Finally, the last deployment was operated as planned, following the 'butterfly' path (Figure 5).

1.1.5. JERICO TNA – Menorca-Sardinia – GABS - CSIC/SOCIB

A deep water sea glider (to 1000m depth) was used in two missions between Balearic Islands and Sardinia (Figure 6) conducted in March and October 2013.

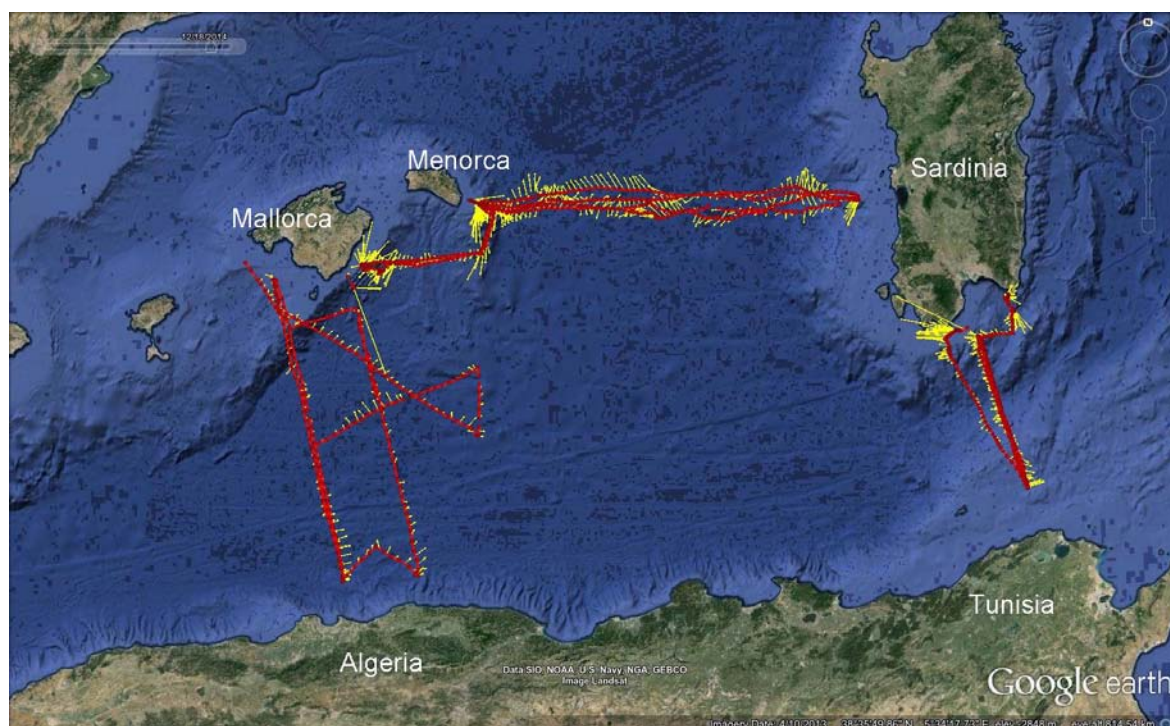


Figure 6. JERICO TNA glider lines: Menorca-Sardinia, Sardinia-Tunisia and Mallorca-Algeria between January 2012 and June 2015. Surface position and trajectories (red dots and lines) and depth-average currents (yellow arrows).

Objectives

The aim of this experiment was to study the physical and biological characteristics of surface and intermediate water masses in the area between 37.5° and 40°N of latitude in the western Mediterranean, considering also the seasonality of the system.

Platforms and Sampling

The glider used in the experiments was a Seaglider manufactured by iRobot. It acquired CTD data once every 5 s, down to a depth of 1000 m. Both ascending and descending profiles were used. The glider was also equipped with a Wetlabs ECO Triplet fluorometer capable of measuring fluorescence and furnishing derived Chlorophyll-a values. During the first week of the survey, the fluorometer was active in the first 300 m of the water column. From the second week onwards, its maximum sampling depth was reduced to 180 m to minimize energy consumption. Once the west-to-east section was completed, it was decided to use the fluorometer on every fourth dive only because the energy consumption continued to remain too high.



Technical specifications here above described are valid for both the glider missions in March and October 2013.

Operations assessment

Both deployments in 2013 (March and October) were successful after a first deployment in October 2012 which ended up prematurely due to a severe technical problem. The glider could be recovered and repaired. The two successful deployments provided around 1000 profiles of data in total.

1.1.6. JERICO TNA – Sardinia-Tunisia – CNRS/SAROST

With the support of JERICO TNA (EU-FP7), a deep water glider was deployed from the R/V Tethys in the Sardinia-Tunisia Channel, during the SOMBA campaign (Figure 6).

Objectives

The Sardinia-Tunisia Channel is a zonally oriented passage connecting the Algerian and the Tyrrhenian basins, with a sill depth of about 1900m.

In order to clarify some of the processes in place in the area, including the behavior of the Algerian current and associated eddies, our methodology is based on a combined approach using glider observations and sea surface features observed by satellite. By autonomously collecting high-quality observations in three dimensions, gliders allow high-resolution oceanographic monitoring and provide useful contributions for the understanding of mesoscale dynamics and multidisciplinary interactions.

Platform and sampling

During this experiment, a significant dataset has been collected through the Sardinia Channel. The innovation stands in the high spatial resolution, in the temporal repetition (6 days) and in the number of parameters sampled simultaneously by the deep (1000m depth) Slocum G1 glider, equipped with a CTD, an O₂ sensor, and a Wetlabs sensor measuring fluorescence (ChlA), and back scattering (470 and 880 nm). A total of 750 vertical profiles were collected in the area.



Operation assessment

The glider was programmed by the technicians of the French Facility (CETSM, Toulon) to follow a path close to SARAL satellite track #887, and has carried out 3 return trips during the period from the 16th of August 2014 to the 19th of September 2014 between Sardinia and Tunisia, sampling the water column on 1000 profiles.

1.1.7. JERICO TNA – Mallorca-Algeria – CSIC/SOCIB

The research project named ABACUS (Algerian BASin Circulation Unmanned Survey) was realized between September and December 2014 through access to JERICO TNA infrastructures at SOCIB/IMEDEA (Mallorca-Spain). Two Slocum deep glider missions of one month duration each were completed along the monitoring line between Mallorca and the Algerian Basin (Figure 6).

Objectives

The proposed research aims to combine traditional (ship collected) in situ data, glider observations and a large set of satellite observed variables to get insights into the Algerian Basin circulation, dominated by the presence of very energetic mesoscale structures, characterized by meandering of the Algerian Current and isolated cyclonic and anti-cyclonic mesoscale eddies.

Platforms and sampling

ABACUS project field activities were performed using a Slocum G2 glider for deep water (1000m maximum depth) with a horizontal speed of 0.18 ± 0.02 m/s.

Along a total of four transects, ocean physical and biological features were monitored from surface to 975m depth performing one deep CTD, O2 sensor and fluorometer cast every 4km. The glider was programmed to sample only on downcast.

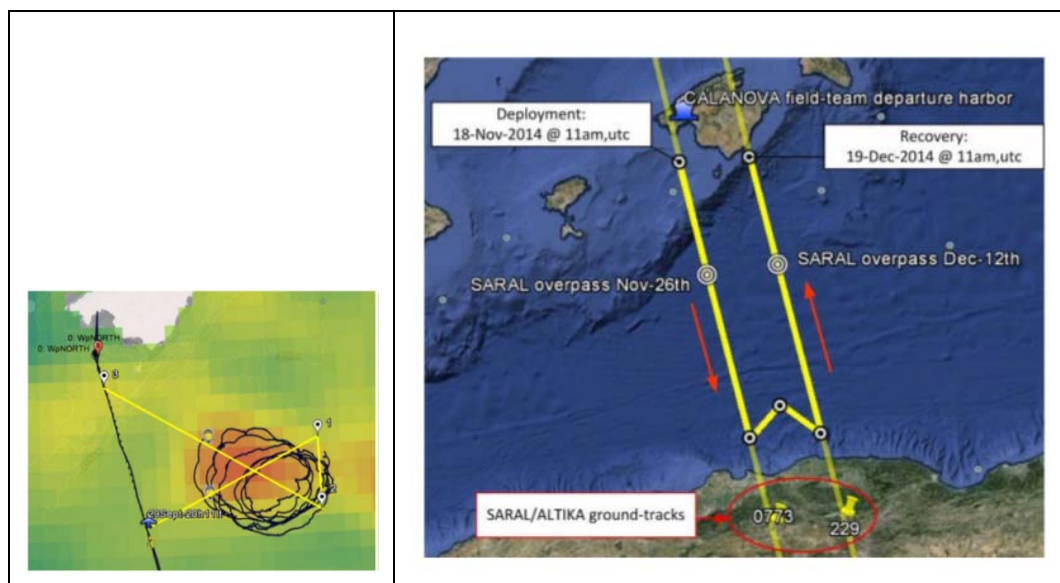


Figure 7. JERICO TNA - Mallorca-Algeria glider lines. Left: Sept-Oct 2014 deployment. Right: Nov-Dec deployment.

Operations assessment

The first mission started its first route along the SARAL satellite track for a successful 36 days cruise down to the Algerian Current edge and back to Mallorca on the 15th of September 2014 (Figure 7, left panel). Additionally, during the return leg, a butterfly route has been inserted trying to sample an eddy, at east-side of initially programmed route, evidenced by the AVISO altimetry and ratified by two SOCIB SVP drifters.

On the 18th of November, after some technical problems were solved, the second mission re-started, aiming at having the glider overflown by SARAL-ALTIKA satellite twice, on Nov 26th and Dec 12th, in two neighbor ground tracks (#773 and #229 respectively) (Figure 7, right panel). This experiment provided data on 850 profiles in total.

1.2. Continuous Plankton Recorder

Here we describe succinctly the establishment and implementation of the Continuous Plankton Recorder (CPR) Facility (CyCPR) and survey in the Mediterranean (MedCPR). For more information and details of operational and scientific aspects, the reader is referred to the document D3.3.



The CPR is a robust sampling device used to collect plankton from horizontal transects, while towed by ships of opportunity (SOOP) (Figure 8A) at a depth of 6-10m. As water enters an opening at the nozzle of the CPR it expands in the filtering compartment and plankton is collected on an exposed section of a long strip of mesh. The mesh advances continuously driven by the rotation of the CPR propeller's, thus sampling a new section of mesh every five nautical miles. This instrument has been widely used in many Oceans (e.g. Atlantic Ocean, Southern Ocean, Pacific Ocean and North Sea) over the past 80 years, but was never implemented in the eastern Mediterranean Sea.

Since October 2014, PERSEUS has initiated the use of the CPR in the Levantine Sea along the Cyprus-Israel-Cyprus transect (Figure 8B) from the newly established CyCPR Facility at The Cyprus Institute (Cyl). The Cyl has kindly been provided with the use of the chemical tanker PETROLINA OCEAN as SOOP and well-trained crew members, for the monthly deployment and towing of the CPR. After each deployment, the CPR device and all crucial equipment pass through strict inspection and maintenance procedures. Samples are analyzed in the aforementioned specially configured laboratory at the Cyl.

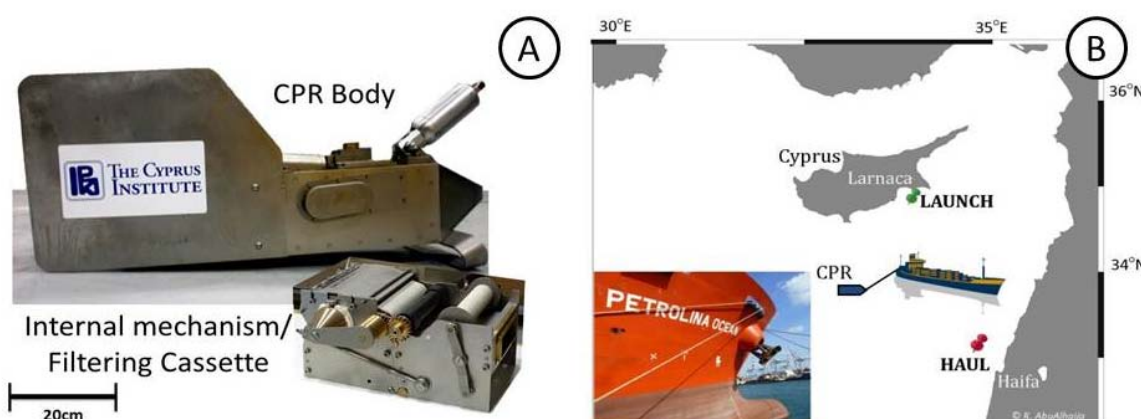


Figure 8. (A) The Continuous Plankton Recorder (above) and its filtering mechanism (below). (B) The first MedCPR route samples the Larnaca-Haifa-Larnaca transect in the Levantine Basin.

The CyCPR Facility is designed to host the preparation of the CPR device prior to sampling and accommodates sample analysis. The CPR filtering mesh itself is divided into samples and viewed directly under the microscope for part of the analysis (Figure 9). Specialized equipment and consumables were either modified to fit the specifications required for the survey or purchased directly through the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS), the leading laboratory for CPR surveys. Targeted training on CPR methodology and laboratory setup were also provided through SAHFOS.



The CPR data include zooplankton and phytoplankton abundances and diversity, biological productivity measurements, as well as temperature and salinity data that are collected by a data logger attached to the CPR during each tow. The Levantine Sea is known as ultra-oligotrophic and is highly influenced by non-indigenous species (NIS) from the Red Sea that are introduced to the Levantine Sea through the Suez Canal. Data obtained from the Cyprus-Israel-Cyprus transects will provide information on plankton populations from coastal and offshore waters, NIS dispersion, biological productivity, as well as sea surface temperatures and salinities on a high-resolution temporal and spatial scale.

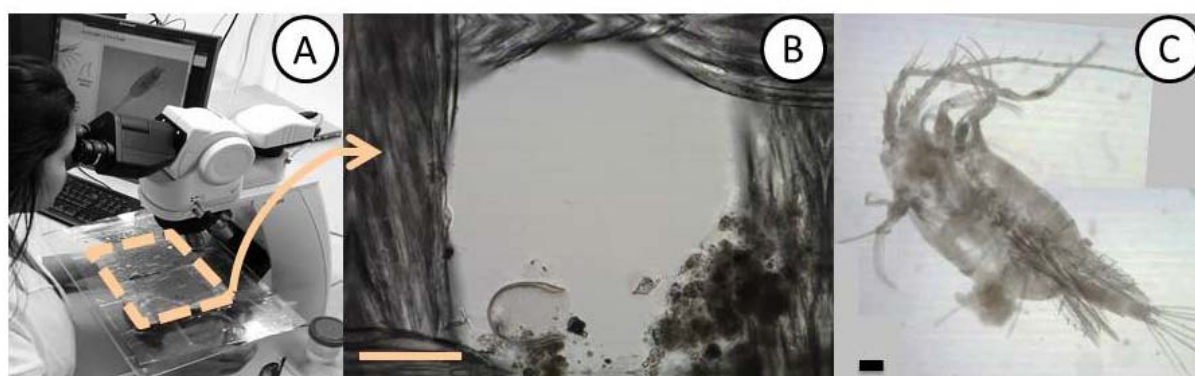


Figure 9. The analysis of CPR samples is adjusted to the viewing of specimens collected on a mesh (A); Protists (B) and mesozooplankton (C) alternate dominance along the CPR transect.

1.3. Vessel Monitoring Systems

This section summarizes the compilation of Vessel Monitoring System (VMS) data for Mediterranean EU fishing fleets operating in Spanish, Italian and Greek waters. A full description of the system is available in D3.4.

According to the Commission Regulation (EC) No2244/2003, fishing vessels with total length greater than 15 meters are obliged to be equipped with Vessel Monitoring System, which provides by each vessel the location, heading and speed to the fisheries authorities at a two-hour interval dataset. VMS data are characterized as “confidential” and are provided after relevant application document by the responsible authority. If a university or a research center requests these data, there is a commitment that the data will be used only for research purposes and never the activity of a specific vessel will be reported. This means that the identification number of the vessel is protected and



does not become visible anywhere. The starting period to collect VMS data differs between countries. For Spain and Italy the starting year was 2006 while in Greece was the year 2009. For the purposes of this subtask, Spain analyzed data covering the area of Balearic Islands for the year 2012. Italy and Greece analyzed data covering the whole country: 2012 for Italy and 2010-2011 for Greece.

Common methods were applied to estimate fishing effort from bottom trawlers and purse seines at an annual and monthly scale for each case study. In addition, the analysis of spatiotemporal patterns of fishing pressure on bathymetric zones was performed for the the western (Spain- Balearic islands) and eastern (Greece) Mediterranean Sea (Figure 10).

1.3.1. Greek data (Hellenic Center for Marine Research)

In Greece, all trawlers (295 vessels) are equipped with VMS, while 225 purse seiners and 84 coastal vessels have total length greater than 15 meters and therefore are equipped with VMS. The majority of coastal fishing vessels are not obliged to have VMS.

1.3.2. Italian data (CNR – ISMAR, Università degli Studi di Roma)

The Italian fleet consists of about 13,000 vessels, 3500 of which were commercial vessels (the rest were recreational vessels). Over 60% of these 3500 vessels is equipped with VMS. Moreover, the majority (over 60%) of the 2076 Italian vessels equipped with VMS are licensed to use more than a single gear type. VMS data generated from the Italian fishing fleet are currently processed by the methods proposed in Russo et al. (2011a;b).

1.3.3. Spanish data (Centre Oceanographic de les Balears)

The Spanish VMS dataset covers the area situated between the islands of Mallorca and Menorca during the period 2005-2010. The data was provided by the national Fisheries Monitoring Centre (Secretaría General del Mar). The dataset includes information on all fishing vessels longer than 15 m, which in our case only includes bottom trawlers since all small-scale units do not reach that length. The vessels



equipped with the VMS are committed to automatically transmit their positions at least every two hours.

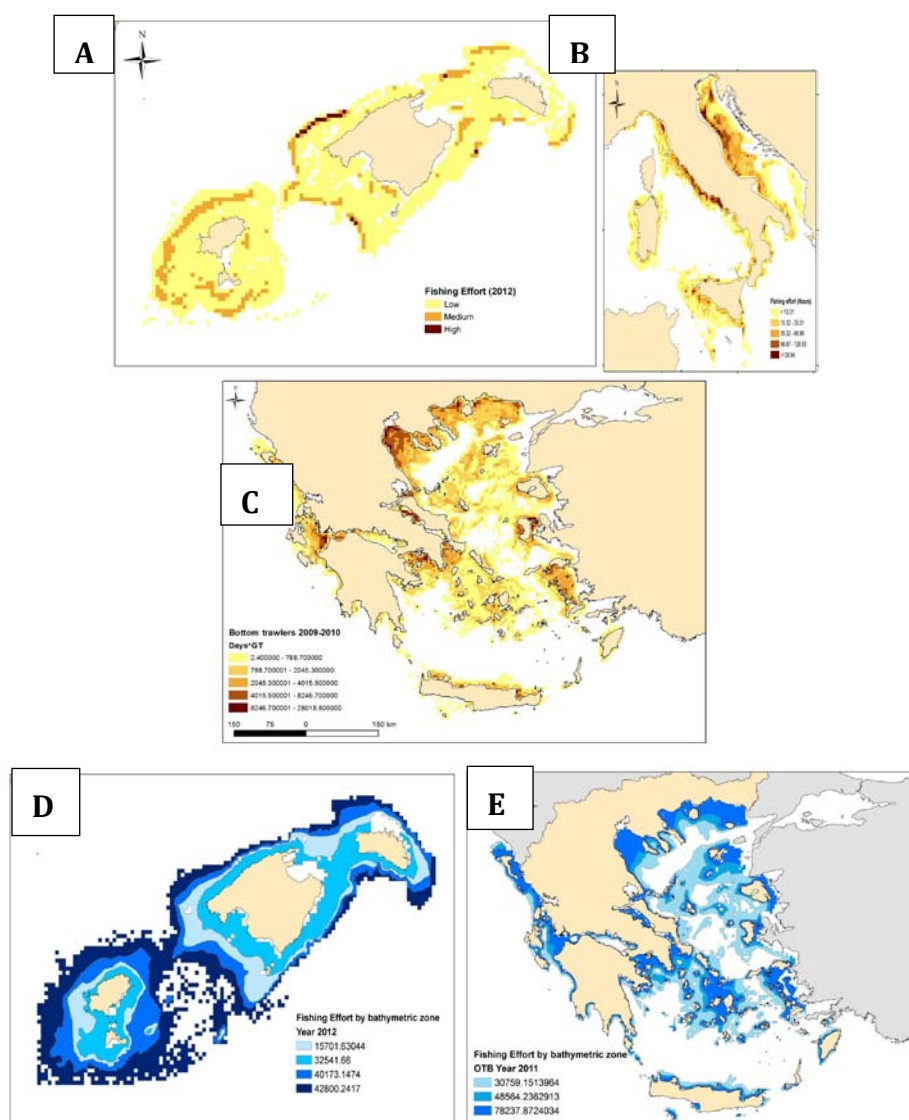


Figure 10. Fishing effort from bottom trawlers in A) Balearic Islands, B) Italy, C) Greece, and fishing effort by bathymetric zone in D) Balearic Islands and E) Greece.

Overall, this is the first time that common methodologies have been established in the SES in an observing system using VMS of direct relevance to MSFD implementation, Marine Spatial Planning, fishing fleet migration strategies, fishing grounds, etc. This is an important step forward for a scientific-based management of the SES. The data analysis methods and modeling with other biotic and abiotic parameters could also likely be used as a guide for implementing in other European areas. Monitoring the fishing efforts on a sustained basis following the methodologies established during the

PERSEUS project would be an asset for a better understanding of how the resources can evolve.

1.4. Multi-platform synoptic intensive experiments

1.4.1. ALBOREX experiment (CSIC)

Within subtask 3.3.4 of PERSEUS, a major intensive multi-platform and multidisciplinary experiment was completed in May 2014 as a part of PERSEUS project, lead by CSIC and with strong involvement of SOCIB, OGS, CNRS, WHOI and McGill University. The multi-platform ALBOREX experiment was conducted during 8 days, included 25 drifters, 2 gliders, 3 Argo floats, one research vessel and involved 50 scientists (Figure 11). The Deliverable D3.8 is specifically dedicated to this experiment.

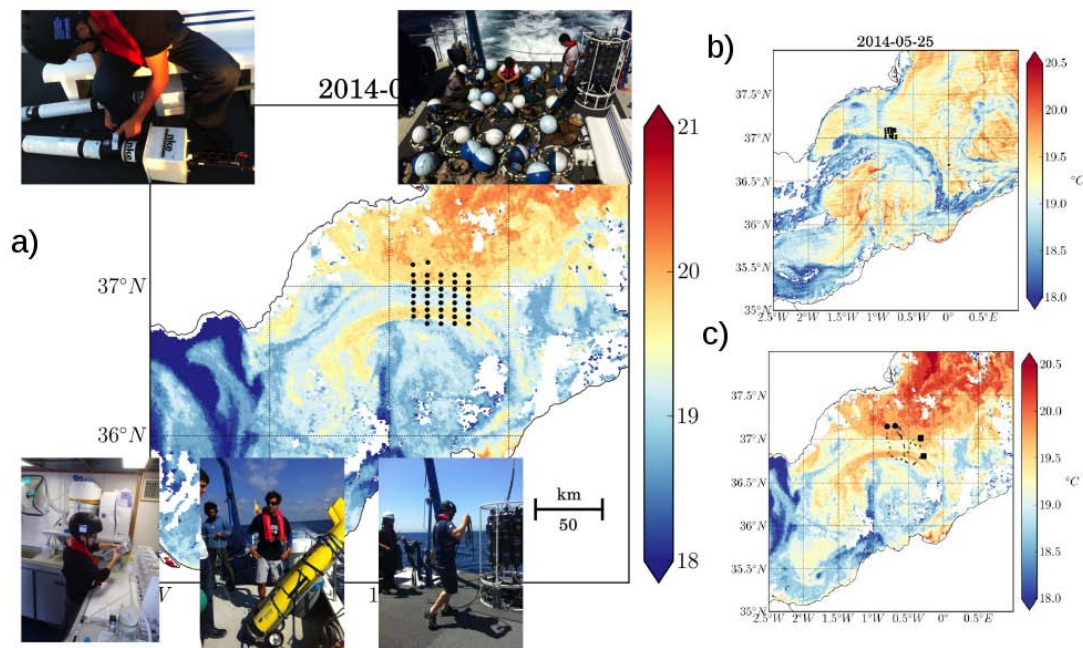


Figure 11. Eastern Alboran Sea - Multiplatform Alborex Experiment. CTD casts locations (a), drifters deployment locations (b) and glider trajectories (c) over different SST images.



Objectives

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.

Operations summary

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: 3 Argo floats were also deployed and transmitting high frequency and interdisciplinary data. More than 500 samples (Chl-a 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.

1.4.2. DeWEX experiment

Another example of such multi-platforms experiments is the DeWEX experiment (Impacts of Deep Water formation on Mediterranean pelagic ecosystems), implemented in the northwestern Mediterranean Sea (Gulf of Lion).

Objectives

The aim of the experiment was (1) to help understanding the biological response of high productivity in this region known to be the place of high mixing and deep water



formation, (2) to describe the seasonal variations of the biogeochemical parameters with respects to the evolution of the mixed layer (3) to study the mesoscale and sub-mesoscale activities in the region.

Operations summary

From July 2012 to October 2013, intensive observations have been carried out thanks to several national and European projects (GROOM, JERICO, PERSEUS, MOOSE, MERMeX, HyMeX, ASICSMED, Ducrocq et al 2013, Testor et al 2014, Estournel et al 2015a). Thirty deployments of gliders equipped with biogeochemical sensors have been carried out during this period (most of them already listed in section 1.1). Ten profiling floats equipped with biogeochemical sensors were deployed too, together with six cruises (Figure 12). These combined measurements not only cover for the first time the seasonal cycle at the basin scale, but also allowed us to perform high quality inter-calibration of T-S in-situ data.

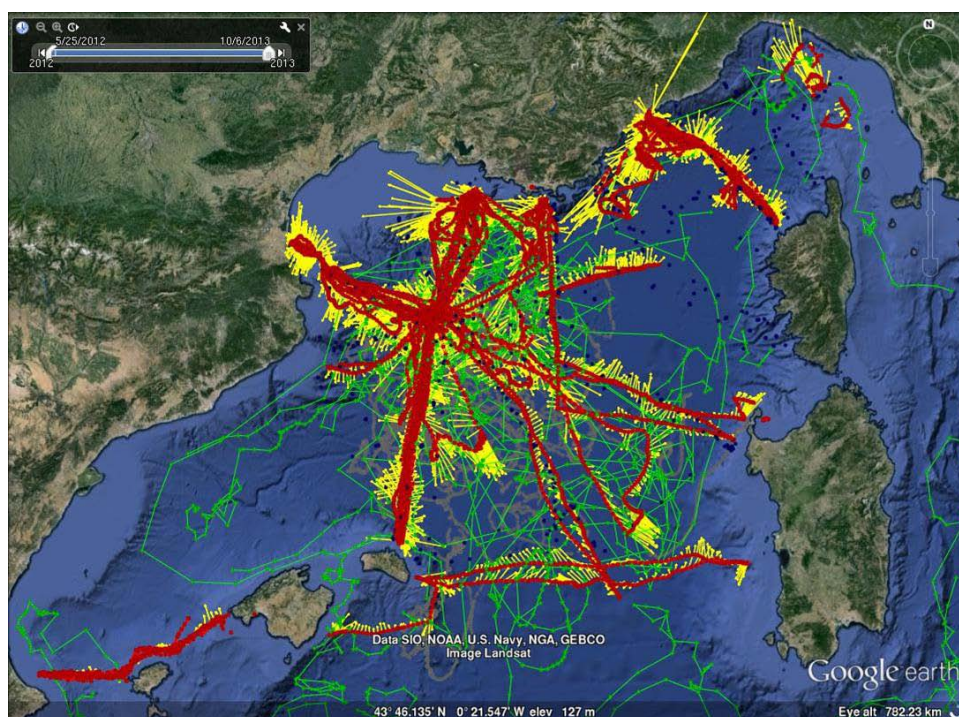


Figure 12. DeWEX experiment (July 2012 - September 2013). Gliders tracks in red, with averaged currents in yellow, float tracks in green, CTD casts in dark blue, and trajectories of surface drifters in grey. Including, in this timeframe and above, SOCIB 'canales' glider endurance line missions and SOCIB JERICO TNA Sardinia missions, indicating the benefit of coordinated actions.



2. Assessment of data delivered

Most of the data collected since the beginning of the PERSEUS project via the new observing system's components described above have been made public and freely available in Real Time, via the PERSEUS portal (http://isramar.ocean.org.il/perseus_data/Default.aspx). Some data collected by these new components, mainly those who have a real time data flow, are not yet available because of technical reasons related to the automatic link between the real time data service (DAC or GDAC) and the PERSEUS data management system. Other type of data are not available because they are not handled by the PERSEUS data management system or because they are protected data according to national or European regulations.

This section aims at providing a detailed assessment of the availability of data collected through the new observing system components implemented during PERSEUS.

2.1. Gliders data

Most of the glider data collected between January 2012 and June 2015 that have been co-funded by PERSEUS (i.e. data from 60 deployments in total), are available through the PERSEUS portal today (http://isramar.ocean.org.il/perseus_data/Default.aspx), and the whole dataset will be available by the end of November 2015.

Following the work carried out in the framework of the COST Action ES0904 EGO and FP7 GROOM project, it was agreed in PERSEUS WP3 that Coriolis data center would be the Global Data Assembly Center for gliders data collected by all the European glider partners. An architecture with several Data Assembly centers, hosting data in the agreed EGO exchange format has been set up, and data (and metadata) are now available in Real Time both via the Coriolis geographic profile selection interface (<http://www.coriolis.eu.org/Data-Products/Data-Delivery/Data-selection>) as profiles, and via the Coriolis EGO http server (<http://www.ifremer.fr/co/ego/ego>) in the agreed EGO NetCDF format with one file per deployment.

Every few months, a transfer is performed to make PERSEUS data sent to Coriolis in Real Time - among which gliders data - available through the PERSEUS portal, in Ocean Data View format.



All the PERSEUS glider data follow the data flow described above, except for a couple of deployments, for which technical problems were encountered (~15 % of the data) and raw data were not sent or not processed by Coriolis before the import in PERSEUS database. The problematic deployments have been identified (the three deployments of the South Adriatic pit experiment, five of the Moose deployments and one of the Ibiza Channel deployments) and the data are now being re-processed by Coriolis so that all processed data are available on Coriolis database before the last transfer to PERSEUS portal (before the end of the project).

The fact that all the variables measured by gliders deployed in the SES during PERSEUS could be visualized on various institution and community web sites definitely helped to assess the glider data flow from the glider operators to the various data bases by providing reference products. These sites include:

1. the EGO web page (<http://www.ego-network.org/dokuwiki/doku.php?id=public:glidersdeployments>),
2. the OGS glider home page (http://nettuno.ogs.trieste.it/sire/glider/home_sire_glider.php),
3. the CYCOFOS web page (<http://www.oceanography.ucy.ac.cy/cycofos/glider.html>),
4. the SOCIB glider portal (<http://www.socib.es/index.php?seccion=observingFacilities&facility=glider>)

Work has been done to also publish the glider data in Delayed Mode with specific Quality Control data procedures. The development of Quality Control process and data corrections have been time consuming, but the procedures are now ready and can be applied to all the datasets. It is planned to publish a PERSEUS Mediterranean Glider Data set and to get a doi during the following months.

2.2. Continuous Plankton Recorder

The MedCPR samplings were initiated in fall of 2014. Ever since, monthly tows (Table 1) collect plankton and physical data along a transect between the south coast of Cyprus (Larnaca, and occasionally Vasiliko) and Israel (Haifa). Each tow results in 24-30 samples, each representing a section of five nautical miles (5 nm) of the journey.



Table 1. CPR sampling tows in the Levantine Sea, route Cyprus-Israel-Cyprus

No	Tow Code	Date (dd/mm/yy)	Transect (From-To)
1	1MCHL	21/10/14	Larnaca-Haifa
2	2MCHL	05/11/14	Larnaca-Haifa
3	3MCHL	04/12/14	Larnaca-Haifa
4	4MCHL	22/01/15	Haifa-Larnaca
5	5MCHL	21/2/15	Vasiliko-Haifa
6	6MCHL	05/04/15	Vasiliko-Haifa
7	7MCHL	06/05/15	Larnaca-Haifa
8	8MCHL	24-25/06/2015	Vasiliko-Haifa
9	9MCHL	17-18/07/2015	Vasiliko-Haifa
10	10MCHL	19/07/2015	Haifa- Larnaca

For illustrative purposes, we mention here the results for the tow that took place in November 5, 2014. The transect was completed in about ten hours, therefore due to the time (diurnal) difference among observations it is perilous to extract any definite trends from the physical data. Nevertheless, the temperature profile of the November tow, which is in agreement with satellite measurements, shows warming of waters in both coasts, and a drop in offshore surface water (Figure 13A). The PCI information shows no little correlation with the temperature with a higher productivity near the coast of Haifa (Figure 13B). Protist (Figure 9B) and mesozooplankton (Figure 9C) dominance alternates while autotrophic species are the least abundant group in all samples. Both PCI and plankton abundances are higher closer to the coast of Haifa than near the Cyprus coast. Tintinids, tiny encased animals (Figure 9), ciliates and other protists are the most abundant group in samples near the Cypriot coast providing 64-45% of the total number of individuals.

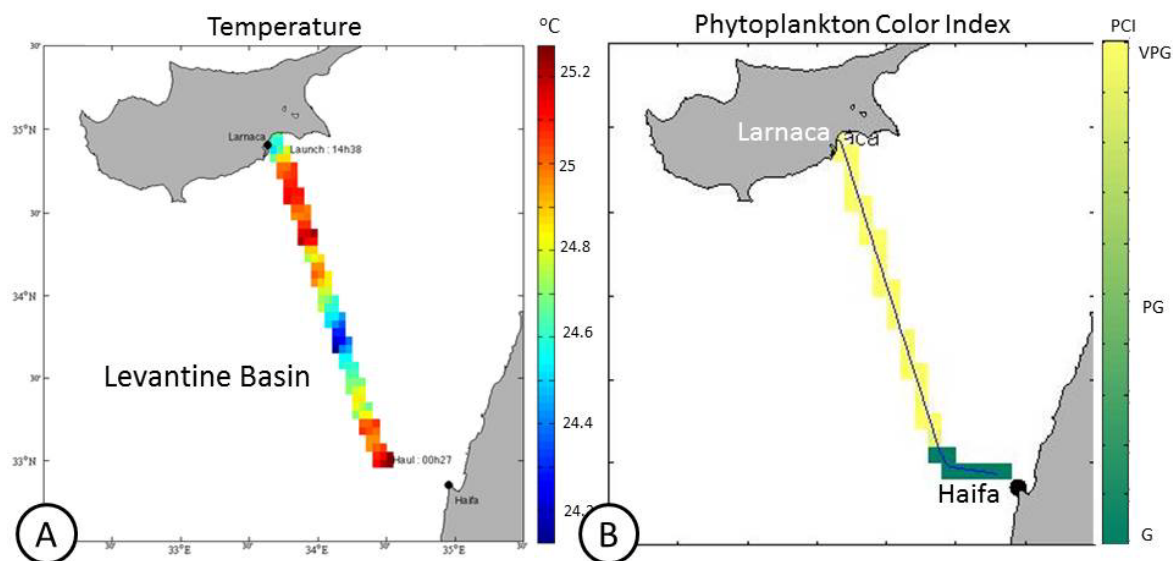


Figure 13. Temperature (A) and Phytoplankton color index (B) for the November 2014 transect (VPG: very pale green; PG: Pale green; G: Green)

Due to the nature of the CPR samples and the time needed for the taxonomic analysis of samples, a considerable time lag is created between the acquisition of the samples and the extraction of data. Seasonal CPR data products are available upon request through the Cyprus Institute.

A second set of data is produced through an oceanographic data logger (temperature, salinity and depth data). The data are being processed, and time and position referenced salinity and temperature data derived from the logger are being made available through the PERSEUS database.

2.3. Vessel Monitoring System

Through the VMS implementation process, several different data sets were used and created for the analysis and the validation of the proposed methods. These data can be classified as follows and the location and availability of the data noted where appropriate:

1. VMS primary data on the location of fishing vessels for the three study areas. These data are confidential and are accessible upon request from the appropriate authorities;



2. Fishing effort estimates and by bathymetric strata have been produced for visualization and for input in the models. The estimated values of fishing effort (Days at sea, Days * Gross Tonnage (GT), Days * Kilowatt (KW)) were calculated in a predefined spatial cell. This type of data can be accessible via the PERSEUS geoportal (<http://artemis2.ath.hcmr.gr/>);
3. The location of fishing ports in the study areas;
4. The National and European legislation for fisheries;
5. Environmental satellite images (Chlorophyll-a, Sea Surface Temperature etc.);
6. Fishing fleet register (<http://ec.europa.eu/fisheries/fleet/index.cfm>);

2.4. Multiplatform experiments

The data collected during the multi-platform experiments have followed the different management procedures and standards according to the platform type that have been developed so far thanks in particular to PERSEUS and previous EU projects. The data management of profiling floats, surface drifters, CTD from R/V, are now organized at the international level with recommended standards and protocols that have been followed by the PERSEUS partners.

All of the CTD, gliders and Argo float data collected during ALBOREX are available through PERSEUS portal (**¡Error! No se encuentra el origen de la referencia.**). The drifter data that are missing today, as well as a few Argo and glider profiles have been identified and should be added onto the PERSEUS portal in next transfer from Coriolis.

Regarding DeWEX experiment, most of the data are available through the PERSEUS portal, as displayed on Figure 14. Some data are missing but this will be fixed for the next transfer from Coriolis to the PERSEUS database.

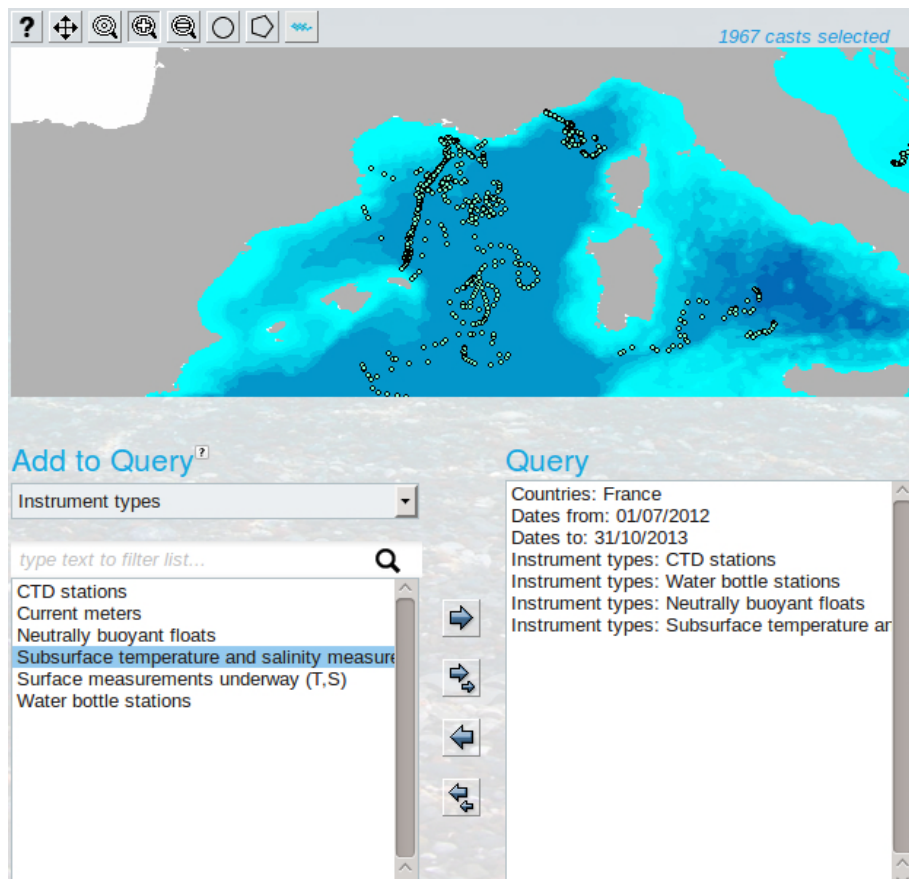


Figure 14. DeWEX glider, Argo and CTD data (Jul 2012 - Sep. 2013) on PERSEUS portal on the 13/11/2015.



3. Contributions of the new observing components to policy and science needs

The Mediterranean and the Black Seas system can be considered as a semi-enclosed sea covering approximately 2.5 million of km². It is connected to the Atlantic Ocean via the Strait of Gibraltar. Since 1869, it is connected to the Red Sea by the Suez Canal. It is divided into well-defined basins and sub-basins. High mountains surround the basins and channel the synoptic weather conditions into intense events like northerly dry and intense winds (Mistral, Tramontana, Bora, Etesian Winds) and air-sea interactions lead to extreme events such as Medicanes, heavy precipitations and floods or deep water formation and ventilation of the deep layers of the Mediterranean Sea. Major rivers flowing into it such as the Po, Rhone, Nile and Ebro, generate rapid horizontal and vertical transfers from the land to the open sea. The Mediterranean Sea is strongly influenced by weather and climate conditions and subjected to wide variations on all time scales. It has been demonstrated that the Mediterranean Sea and Black Seas system gives rise to amplified signals in response to climate change and is considered as one of the “hot spots” for the climate change.

Biologically speaking, the Mediterranean and Black Seas system is also recognized as a “hot spot”, it is one of the “hot spots” of marine biodiversity. It shelters a great number of species, a high percentage of which are endemic. The low trophic levels of the Mediterranean Sea have been recognized to be organized in bioregions at the scale of sub-basins but it was also stressed that the variability is very high at small spatial scale and high frequency.

Ocean research over the past 20 years has given us great insight into global ocean circulation patterns and marine ecosystem functioning and has provided valuable knowledge. However, as we have tried to downscale towards regional and local needs, it has become increasingly clear that the ocean varies across a wide range of spatial and temporal scales with strong interactions, and that specific observing components needed to be developed for a better understanding of the role of the small scales and scales interactions on the physical and biological processes and how regional and local needs, such as those related to the MSFD, could then be met

Recently, the implementation by the member states of the MSFD has also revealed a lot of gaps and inadequacies of the existing observing systems at local, regional and national scales, as well as the lack of transnational integration of these systems.



Providing knowledge and starting to improve the observing systems for solving such issues is one of the core objectives of PERSEUS, in particular in WP3. Here, the new observing components are expected to play a central role. The importance of such new components has already been acknowledged in other European seas, but task 3.3 was aiming to actually establish these new components in the SES, as well as new approaches to deploy these components, and to provide a first assessment of their relevance in the SES for the implementation of the MSFD.

More precisely, the work carried out in the WP3 about new observing components followed four axes:

- demonstrate the capacity of a glider network to assess the physical and biogeochemical variability at various spatial and temporal scales to fill identified gaps (in D3.1)
- demonstrate the capacity of the CPR to provide information about biodiversity
- develop a common approach for monitoring the fishing efforts through VMS
- Explore the synergies between different in situ observing platforms (gliders, profiling floats, cruises, moorings) and satellites to better understand oceanic processes, filling gaps of knowledge in frontal dynamics and associated multidisciplinary instabilities at meso and submesoscale.

A better assessment of how the new observing components considered in the PERSEUS project can improve our knowledge and the processes toward a Good Environmental Status (GES) is now available. Criteria and indicators associated to the descriptors, listed in Table 1, provide a good framework to assess how the parameters collected by an observing platform, how the scales that can be assessed by the observing systems can fulfill the descriptor implementation

Table 2. Descriptors of the Marine Strategy Framework Directive for achieving Good Environmental Status.

Descriptors Nr.	
1	Biodiversity is maintained
2	Non Indigenous species do not adversely alter the ecosystem
3	The population of commercial fish species is healthy
4	Elements of food webs ensure long-term abundance and reproduction
5	Eutrophication is minimised
6	The sea floor integrity ensures functioning of the ecosystem



7	Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
8	Concentrations of contaminants give no effects
9	Contaminants in seafood are below safe levels
10	Marine litter does not cause harm
11	Introduction of energy (including underwater noise) does not adversely affect the ecosystem

3.1. Continuous Plankton Recorder

Plankton, passively drifting plants (phytoplankton) and animals (zooplankton), are particularly good indicators of environmental change (Hays et al 2005). The CPR collects plankton from coastal and offshore surface waters continuously, maximizing the spatial coverage while minimizing costs. In addition, the system is designed to be towed voluntarily by ships of opportunity (SOOPs) that follow a given route in high frequency, giving the opportunity to collect plankton in the required temporal resolution spanning from weekly to seasonal samplings.

Plankton includes many groups (photosynthetic organisms, larval stages of commercially important species, etc.), providing a wide range of information. Data obtained from the Cyprus-Israel-Cyprus transects will provide information on plankton populations from coastal and offshore waters. In a MFSD framework, it will enable estimates on plankton abundance, species composition (Descriptor 1, 4, 5, see Table 2) and Non Indigenous Species dispersion (Descriptor 2). The availability of high frequency data along repeated lines will also enable estimates of the variability of species abundance and composition. In addition, a quantitative method called Phytoplankton Colour Index (PCI) is used to assess biological productivity, based on the colour of each sample. The analysis of data collected will also help predicting future fish stock (Descriptor 4). The comparison of CPR data with physical data will provide insights of the impacts of the hydrographical conditions evolution on ecosystems (Descriptor 7).

One can also predict that the data collected by the future CPR surveys will contribute to the study of other aspects of the ecosystems evolution, through further analysis and association with other types of data (Descriptors 8-10). In particular, it must be noticed here that the CPR data could directly contribute to descriptor 10 by providing more insight in microplastic distribution over large areas.



The MedCPR in subtask 3.3.2 has established for the first time in the SES a capacity to have CPR data available for MSFD application. The present limited implementation of CPR surveys does not allow to assess the actual full relevance of the CPR at the SES scale, but on-going work in the EEZ of Cyprus, will provided a quantitative assessment of their interest in ultra oligotrophic areas such as the Levantine basin.

3.2. Vessel Monitoring System

The analysis of PERSEUS VMS data enabled the study of spatio-temporal distribution of fishing pressure on bathymetric zones (Maina et al. 2013). The results certainly help to fulfil MSFD needs providing information for the Descriptors 4 and 6 (Table 2).

By correlating total fishing effort with annual fisheries production, two indicators were computed by sub-area and by year: the ratio between days at sea and total days at sea in the study area, and the ratio between fisheries production and total fisheries production in the study area (Kavadas, et al, 2013) which are useful information for the Descriptor 4. The analysis also enabled to identify migration spatial patterns of open sea fishery and to identify fishing grounds for the target species of a gear (e.g. bottom trawl).

The VMS data and logbook data from trawlers and purse seiners can also be used to multi criteria decision analysis to estimate fishing pressure index, and help estimating the seabed integrity (Descriptor 6). Further work is required before full fishing impact on seabed integrity can be mapped in the areas investigated in subtask 3.3.3, and the relevance of the use of the VMS information to other areas in the SES.

3.3. Gliders and others in-situ platforms

Thanks to PERSEUS, the geographic coverage of Mediterranean in-situ observations has been notably improved, with in particular new glider endurance line transects supported by PERSEUS glider partners in particular in the framework of the JERICO TNA, enabling the observing system to be extended southward towards the north coast of Africa, an identified gap in Mediterranean ocean observations.

The glider deployments and multi-platform experiments (ALBOREX and DeWEX) have provided new 3D high resolution data, including observations of the classic physical parameters (Temperature and Salinity), but also biogeochemical data. Indeed, in



addition to the bio-Argo floats deployed during the multi-platform experiments, most of the gliders deployed in the framework of PERSEUS were equipped with oxygen, turbidity and Chlorophyll-A fluorescence sensors. These multi-platform experiments were embedded in a network of sustained glider repeat-sections complementing the other sustained in situ observations of the water column (profiling floats, repeat R/V surveys, moorings,...) and satellites. The temporal coverage of the in situ observations, has been notably extended during the PERSEUS project, thanks to the capacity of gliders to collect high-frequency profile data and to operate under any weather conditions. This thus enabled to collect data all year round along keys sections in particular, including during winter.

These valuable datasets put now into perspective how the hydrographic conditions can alter the marine ecosystem (Descriptor 7). This allowed us first to characterize the variability of deep water formation (Durrieu de Madron et al. 2013, 2015 Houpert et al. 2014, 2015, Estournel et al. 2015a) which affects the subsequent bloom in the Gulf of Lion. The collected data also allowed us to identify and characterize submesoscale processes (Bosse et al, 2015a, 2015b, Damien et al. 2015) important for the deep water formation and biogeochemical processes. The preponderant role of Submesoscale Coherent Vortices of about 5km radius and a lifetime order of a year has been highlighted, while submesoscale frontal processes are now better documented, in the Alboran Sea and along the Northern Current triggering vertical motions important for the development of phytoplankton and possibly higher trophic levels. In addition, transport estimates on a monthly/seasonal basis through the glider repeat sections carried out in the framework of PERSEUS provide a unique assessment (Heslop et al. 2012, 2015; Bouffard et al. 2016) on how the physical and biogeochemical properties of the Mediterranean Sea can evolve, revealing in particular seasonal 'modes'.

The spatio-temporal coverage has increased by an order of magnitude thanks to the gliders. They were used in combination with other in-situ observing systems (R/Vs cruise, moorings, profiling floats,...) and numerous results were obtained directly from the data while others come from synergies with numerical modelling on a wide range of scales, from the large scale to the submesoscale processes (Damien et al. 2015, Estournel et al. 2015b, Waldman et al. 2015). The data collected in the framework of PERSEUS was also a great benefit for operational oceanography. By providing high resolution data all year along, gliders helped to fill gaps in the spatio-temporal coverage of the whole Mediterranean and Black Sea Observing system and increase the realism of the analyses and the skill of the forecasts (Dobricic et al 2010).

It is now clear that the multi-platform approach, in particular with the intensive use of gliders, can help providing the appropriate density of data for most of the essential



ocean variables in the SES in order to adequately cover the relevant time and space scales in order to access most of the physical and biogeochemical processes that shape the marine environment and the evolution of marine ecosystems. In particular, gliders and multi-platform approach definitively help providing and improving realistic products (analyses and forecasts of the ocean circulation), which puts operational oceanography products in the forefront for many aspects linked to most MSFD descriptors.

4. Conclusion

Through the implementation of new glider lines, multiplatform experiments (mainly linked to MSFD Descriptor 7), and new innovative and promising monitoring techniques such as a Vessel Monitoring System (linked to Descriptors 4 and 6) and the Continuous Plankton Recorder surveys (linked to Descriptors 1, 2, 4, 5, 8, 9 and 10), a major step forward towards the implementation of the MSFD in the SES has been made. Numerous new scientific results were obtained by the PERSEUS partners and through the provision of data that were collected through the PERSEUS portal, the partners have reinforced their cooperation in terms of observing system operations, data processing, and data quality control. The collaborations between partners helped consolidate a sustained Mediterranean Sea monitoring system and make it evolve towards a better meeting of the MSFD needs.

Most of the new components of the Mediterranean and Black Seas observing system described in this document will be continued and can be considered as a baseline for a future sustained observing system for the SES. It has already and will continue to help to get a better understanding of the SES variability on different time scales and variables. It will constitute a baseline for scientists, policy-makers and the public to reach a shared understanding and use in a near future a decision-making system based on sound scientific knowledge, with particular reference to the MSFD and other relevant policies and initiatives.



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