POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

Review of ocean observing systems in the SES and recommendations on upgrades to serve PERSEUS needs

Deliverable Nr. 3.1

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To contact the authors:
Pierre-Marie Poulain (ppoulain@ogs.trieste.it)

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Authors & Institutes Acronyms	Pierre-Marie Poulain (OGS), Joaquin Tintoré (CSIC), Emma Heslop (CSIC), Giuseppe Manzella (ENEA), Katrin Schroeder (CNR), Dimitris Kassis (HCMR), Pierre Testor (CNRS), Maurizio Ribera (SZN), Vlado Dadic (IOF), Rosalia Santoleri (CNR). Participants: CNR, CONISMA, HCMR, IFREMER, MHI, IO-BAS, IOF, OC-UCY, GeoECoMar, OGS, CSIC, SAROST, SIO-RAS, SZN, ENEA		
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Contents

EXECUTIVE SUMMARY/ABSTRACT

This PERSEUS deliverable provides an overall summary of the existing observational capabilities in the Southern European Seas (SES), including Lagrangian observations with floats and drifters, measurements from ships of opportunity and from fixed moorings, classical oceanographic surveys, local and coastal observing networks, and observations collected by glider and satellites. It summarizes and integrates the information compiled in the six internal reports from the sub-tasks of Task 3.1.

This inventory of SES observing systems effective prior to the PERSEUS project is as complete as possible, although some omissions are inevitably possible.

The existing observing capacities in the SES are analyzed, gaps are identified and recommendations are given on how to fill them in order to serve the scientific and socio-economical needs of PERSEUS and the more general scientific and strategic society needs of the SES area over the longer term, beyond PERSEUS.

Scope

The overall objective of WP3 is to upgrade and expand the present observing capacity in the SES towards fulfillment of the scientific and society needs addressed by PERSEUS with an emphasis on the characterization of the present state, increasing forecasting capabilities and the provision of solid grounds for the implementation of MSFD.

To this end, the first objective of WP3 is the identification of needs (from local to sub-basin and basin scale), of existing observing capacities and of gaps to be filled. In particular, Task 3.1 includes a review of the existing observing capacities that enable monitoring at basin, sub-basin and local scale, thus focusing on four major observing platforms: Lagrangian profilers and surface drifters, research vessels, moorings and gliders. The capacities provided by satellite data and the new possibilities from recently developed algorithms in the coastal and open ocean are also assessed. Integration is essential so as to combine the different monitoring capabilities and to understand scale interactions, from which the major gaps can be identified and specific suggestions will be proposed for addressing them, both in PERSEUS and later, as part of the European Ocean Observing Strategy.

1. SUB-TASK 3.1.1: ARGO PROFILERS, SURFACE DRIFTERS AND OTHER EXPENDABLE SENSORS (SUB-BASIN AND BASIN)

The SES have been sampled by Lagrangian instruments more or less uniformly over the last decades, providing data on surface temperature and currents (drifters) and temperature and salinity profiles, subsurface currents (floats) in most areas of these seas. Recently, floats have been fitted with new sensors to measure biogeochemical properties (dissolved oxygen, chlorophyll concentration, etc.) and with interactive satellite telemetry (Iridium and Argos 3) allowing the collection of multi-parametric data with optimized/adaptive sampling.

In this section, the Lagrangian observations of the Mediterranean and Black seas are reviewed and needs and gaps are identified, in particular to complement the other in situ and satellite observations. New Lagrangian observations are proposed for the process experiments described in WP1 and to fill gaps important to PERSEUS and the MSFD. Emphasis is given to the Black Sea, given the lack of data in its deep areas. Calibration procedures are also proposed to inter-compare Argo observations with XBT and CTD data (3.1.2).

The SOOP/VOS and COOP strategy and experience in the SES (mainly XBT probes from ships of opportunity) is also reviewed in order to harmonize these observations with the PERSEUS observational concepts. An analysis of technological and methodological improvements is carried out in order to provide recommendations at national and regional levels. The SOOP/VOS monitoring strategy is then designed in order to provide information on thermal characteristics of the SES at basin and regional scales. This design also includes the different options for the monitoring and the ship companies/research ships that can be involved. New technologies for the sampling of surface water biochemical properties (e.g. F-LIDAR) are also evaluated. Existing quality assessment procedures are evaluated and implemented, in order to fulfill the PERSEUS objectives for data quality.

1.1 ARGO PROFILERS

1.1.1 Historical Argo float data in the SES (2000-2012)

Profiling Argo floats are mobile autonomous platforms that move freely, horizontally with the currents and vertically in the water column. Sub-surface currents can be estimated from their sub-surface displacements while drifting at the parking depth during the cycle period (1 to 10 days). Water mass properties (pressure, temperature, salinity, oxygen, chlorophyll and nitrate concentrations, and optical properties) are measured when the floats are profiling up to the surface.

Argo floats have been deployed in the SES since 2000. In 13 years, 179 floats have been deployed by several countries, including the United States, France, Italy, Spain, Germany, Bulgaria, Greece and the European Union (as part of the FP5 MFSTEP and FP7 Euro-Argo PP programs) (Fig. 1.1). In total, 16 floats have been deployed in the Black Sea and 161 floats in the Mediterranean Sea.

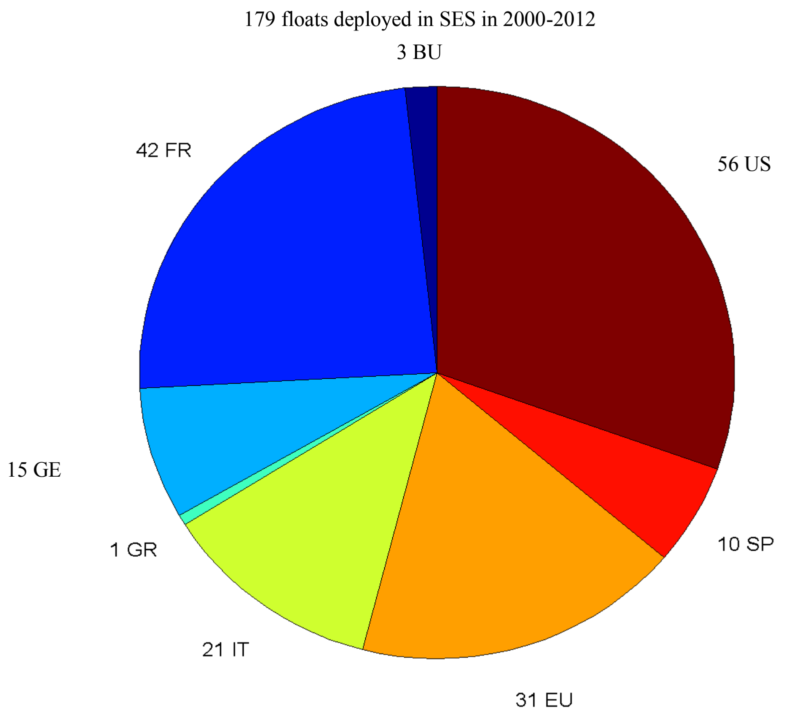

Figure 1.1. Distribution of the nationality (country) of the Argo floats operated in the SES in 2000-2012.

The majority of the floats were Apex designs manufactured by Teledyne Webb (http://www.webbresearch.com/). A large number of Provor and Arvor floats produced by NKE (www.nke.fr) in France were also used. Five Nemo instruments designed and produced in Germany (www.optimare.de) were operated. The distribution of float types operated in the SES is shown in Fig. 1.2.

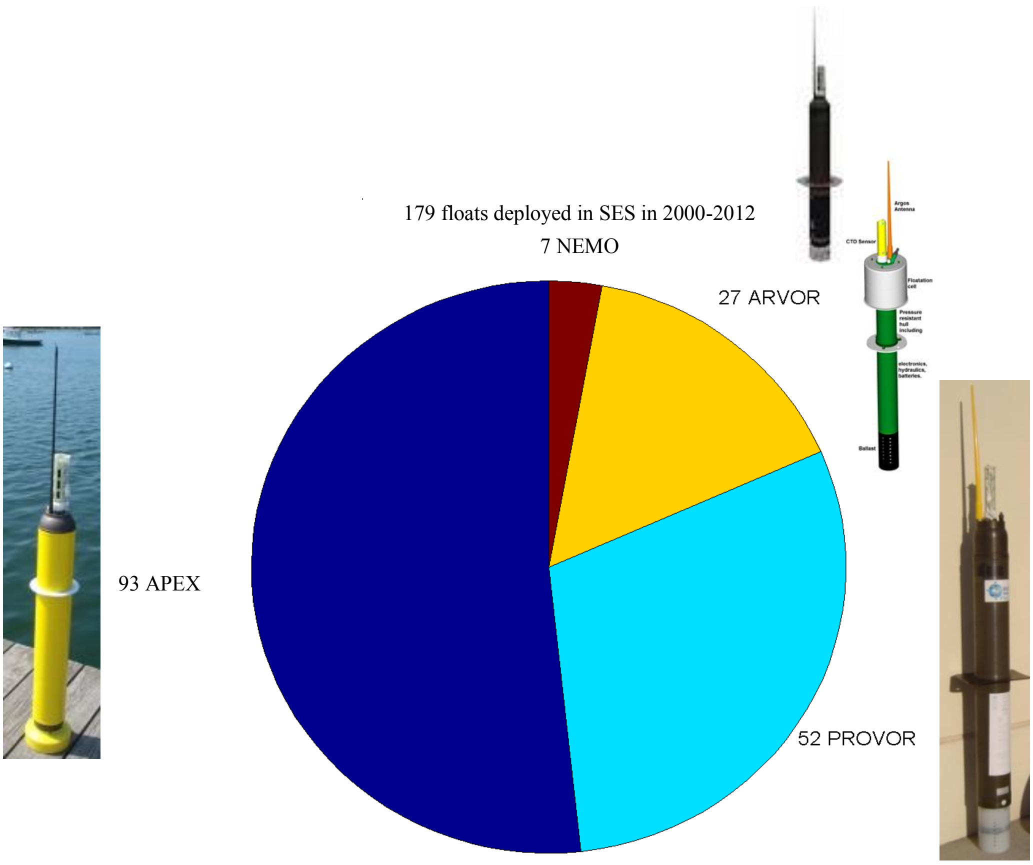

Figure 1.2. Distribution of the types of Argo floats operated in the SES in 2000-2012.

All floats were equipped with Sea-bird CTD, 8 with dissolved oxygen sensors, 5 with optical sensors (chlorophyll fluorescence, etc.) and 3 with nitrate sensors. In total 156 floats were located by, and transmitted data to the Argos system onboard near-polar orbiting satellites, including 4 units for which the new Argos-3 improved system (wider band for dat transmission, downlink) were tested (Fig. 1.3). Twenty-three floats were equipped with GPS receivers and Iridium modems. Their data were transmitted via the Iridium global telephone system based on geostationary satellites using SBD messages. The Iridium downlink was successfully used on some units to change their cycling characteristics, for instance, the cycling period of WMO 1900848 was changed from 5 to 3 days, and then back to 5 days, in the southern Adriatic.

The operating lives of the profiling floats operated in the SES range from 0 day (failure at deployment) to about 7 years. The histogram of life times for the 170 floats is shown in Fig. 1.4. In total, 8 floats failed at deployment and 18 floats failed in the first month

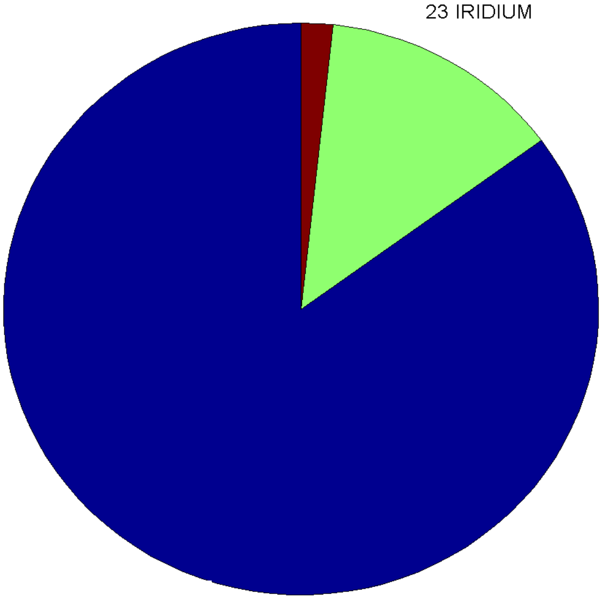

Figure 1.3. Distribution of the type of data telemetry for the Argo floats operated in the SES in 2000-2012.

The longest life of about 6 years and 8 months corresponds to two Provor floats (WMO 1900602 and 1900605) deployed in April 2006 as part the French EGYPT project in the southern Ionian (more than 240 cycles of 10 days). Their trajectories are depicted in Figs. 1.5a and 1.5b. Even though the floats are generally expendable, some floats were recovered near the coast (or after grounding) and were successfully redeployed (after refurbishing or not). This the case of two Apex floats of the MSTEP program which were used up to three times (corresponding to WMO numbers 6900226, 6900278 and 6900300 for one float and WMO 6900227, 6900279 and 6900453 numbers for the other) after recoveries near or at the Spanish shores.

The tracks and voltage time series of the 130 floats that stopped operating before December 2012 were analyzed to investigate their type of "death" or "end of operating life". The results are listed in Table 1.1. More than a quarter of the floats (28%, 36 units) ended their operating life due to stranding on the coast or pick-up by seafarers and about 16% of the floats (21 units) stopped functioning because of battery failure. For about half of the floats (60 units) the cause of "death" cannot be easily determined.

	Stranding/beaching	Battery Failure	Recovered	Pick-up	Failure at deploy	Unknown
Number of floats	29	21	5	7	8	60

Table 1.1 Types of "death" for the 130 floats operated in the SES.

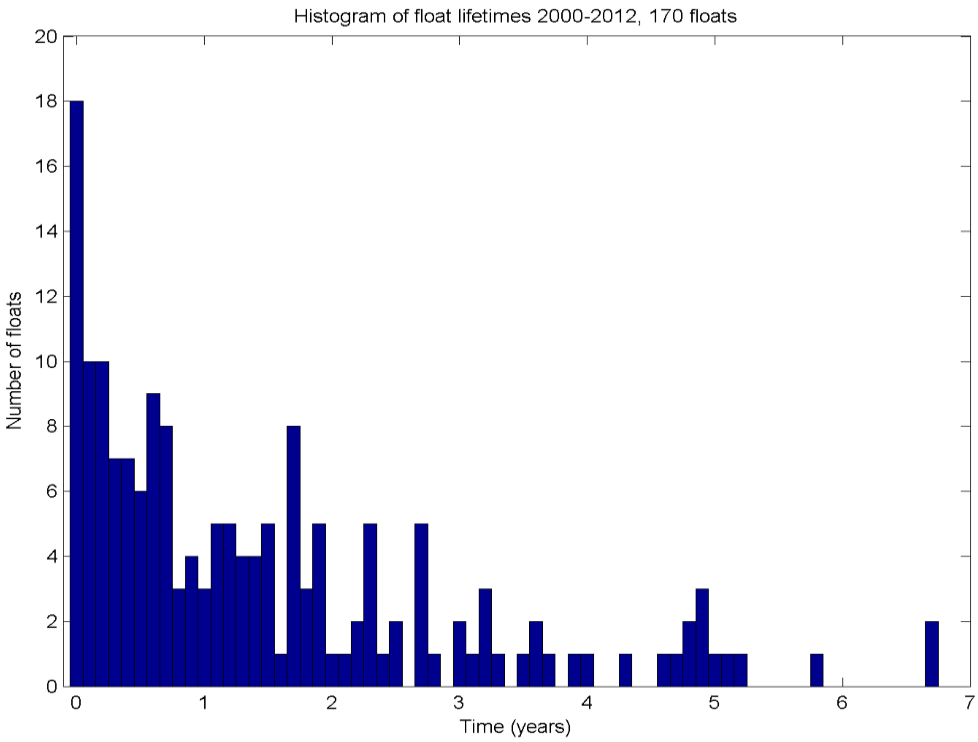

Figure 1.4. Histogram of life times for 170 Argo floats operated in the SES in 2000-2012.

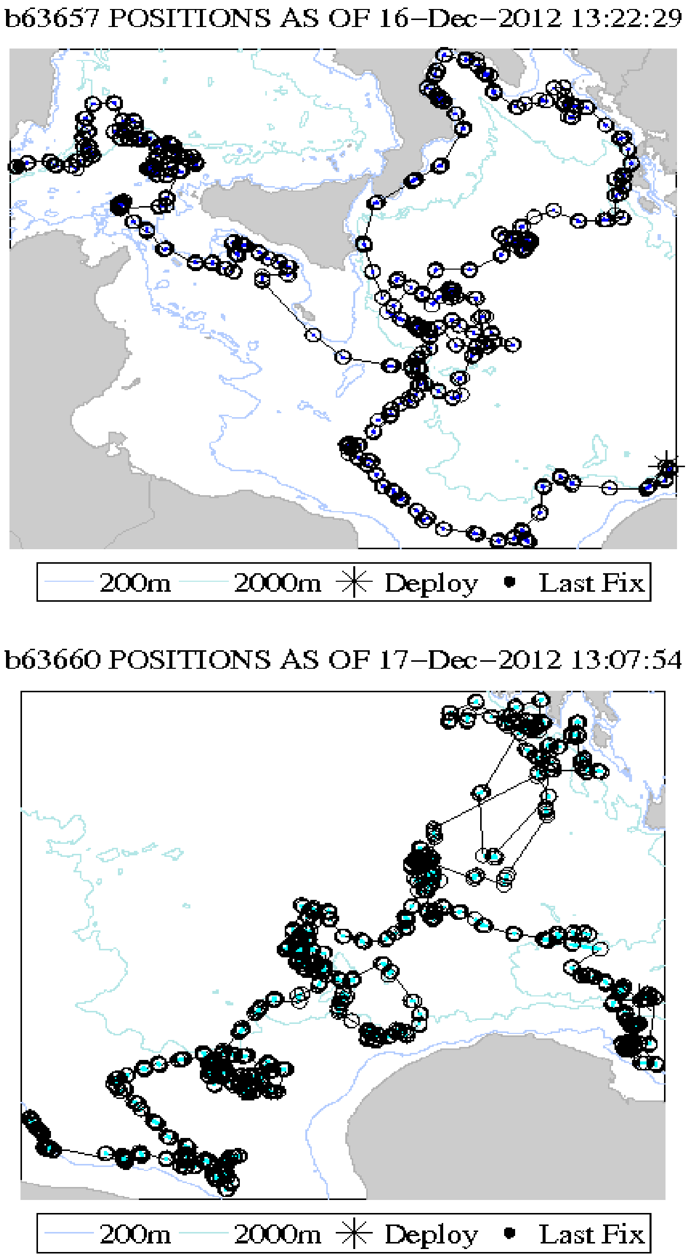

Figure 1.5. Trajectories and profile locations (circle symbols) for floats 63657 (WMO 1900602, top panel) and float 63660 (WMO 1900605, bottom panel) with longest life times in the SES.

The parameters used to program the sampling of the floats are listed separately for the Mediterranean and Black Seas in Tables 1.2 and 1.3. Starting in 2003 with the MFSTEP program, the majority of the floats in the Mediterranean Sea were programmed with a parking depth of 350 m, which corresponds to the typical depth of the Levantine Intermediate Water, and with cycles of 5 days. The maximum depth of the CTD profiles was set to 2000 m, every 10 cycles (for the

MFSTEP floats) and 2 cycles (for most floats in the Mediterranean after 2005), with intermediate profiles set to a maximum depth of 700 m. The diversity in parking and maximum profiling depths is due to the different scientific needs of all the projects in which they were deployed.

Cycle period (days)	Parking depth (m)	Maximum profiling depth (m)	Number
5	350	700 and 2000 (every 10 cycles)	31
5	350	700 and 2000 (every 2 cycles)	16
5	350	2000	19
10	350	700 and 2000 (every 10 cycles)	6
10	350	2000	5
5	600	600	12
Other parameters			72
TOTAL			161

Table 1.2 Cycling and sampling characteristics of the floats operated in the Mediterranean Sea.

Cycle period (days)	Parking depth (m)	Maximum profiling depth (m)	Number
5	200	700 and 1500 (every 2 cycles)	6
5	750	700 and 1500 (every 5 cycles)	3
7	1500	1500	4
Other parameters			5
TOTAL			18

Table 1.3 Cycling and sampling characteristics of the floats operated in the Black Sea.

We now summarize the amount of data collected by Argo floats in the SES since 2000 based on 174 floats. The temporal distribution of available data is shown in Figs. 1.6 and 1.7 in terms of number of operating floats and number of CTD profiles per month, respectively. Starting in 2005, the number of floats reached 30 units and the number of CTD profiles per months reached 140. This threshold was reached thanks to the FP5 MFSTEP project (Poulain et al., 2007). At the end of

2012, these numbers gradually increased to reach about 46 active floats providing more than 240 profiles per month.

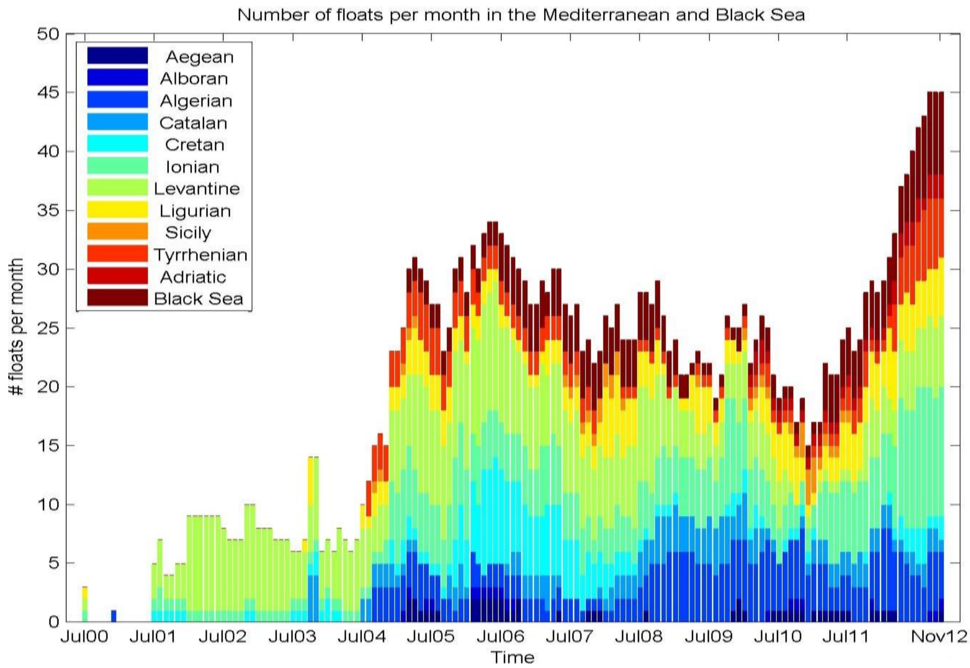

Figure 1.6. Temporal distribution of the number of Argo floats operated in the SES in 2000-2012, color-coded as a function of the sub-basins.

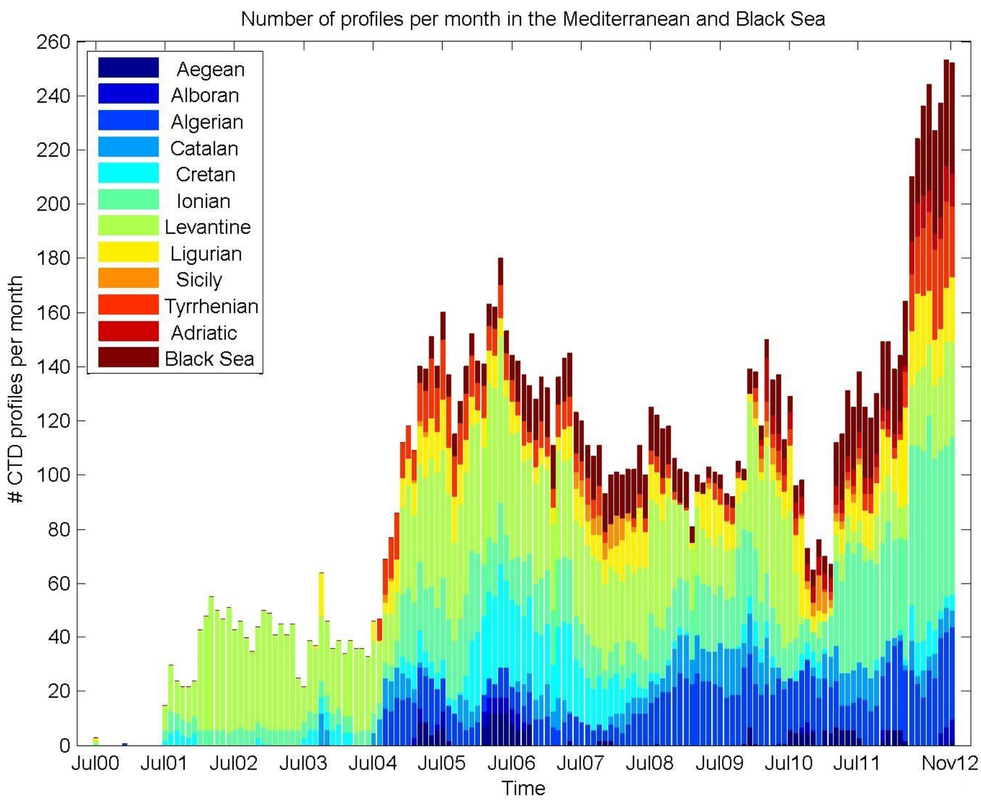

Figure 1.7. Temporal distribution of the number of Argo float profiles obtained in the SES in 2000-2012, color-coded as a function of the sub-basins.

In total, more than 14000 profiles of temperature and salinity have been obtained in less than 12 years in the SES. Their geographical distribution is shown in Fig. 1.8. The Levantine sub-basin is where the data are more abundant with more than 4000 CTD profiles. The number of CTD profiles were binned in areas of 1º x 1º to show better the geographical distribution of data (Fig. 1.9). More data are available in the Levantine, in the central Ionian and NW Mediterranean. Data are more scarce in the Algerian Current, the Tyrrhenian, the southern and eastern Ionian, the Adriatic, Aegean and northern Black Sea. The variability in the spatial distribution just described already points to some initial evidences of gaps in some sub-basins, a result that will be later discussed.

The Near-Real Time (NRT) and Delayed Mode Quality Control (DMQC) CTD data from the floats operated in the SES are archived at the Argo Global Data Assembly Center (Coriolis operational Oceanography Center located at Ifremer in Brest, France). They are freely available and can be downloaded in netcdf format via the web page: http://www.coriolis.eu.org/. Oxygen data are also available via Coriolis. In addition, information (tracks, tabulated statistics) about the historical Argo floats and about the floats currently operated in the SES can be obtained from the MedArgo Center located at OGS in Trieste, Italy (http://nettuno.ogs.trieste.it/sire/medargo/). MedArgo is the official Argo Regional Center for the SES. MedArgo coordinates the float deployments in the SES and is responsible for the DMQC of the SES float CTD data.

The data collected by the floats equipped with biochemical/optical sensors can be visualized and downloaded from the "Oceanographic Autonomous Observations" web site (http://www.oao.obs-vlfr.fr/), hosted by the Laboratoire d'Océanographie de Villefranche (France).

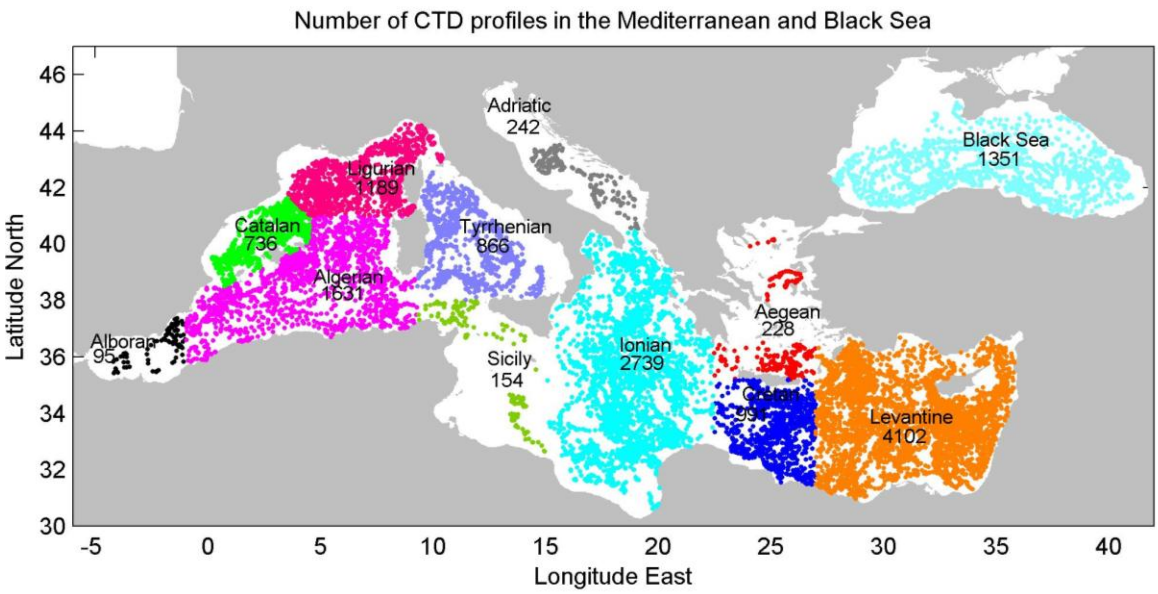

Figure 1.8. Spatial distribution of the Argo float profiles obtained in the SES in 2000-2012, color-coded as a function of the sub-basins.

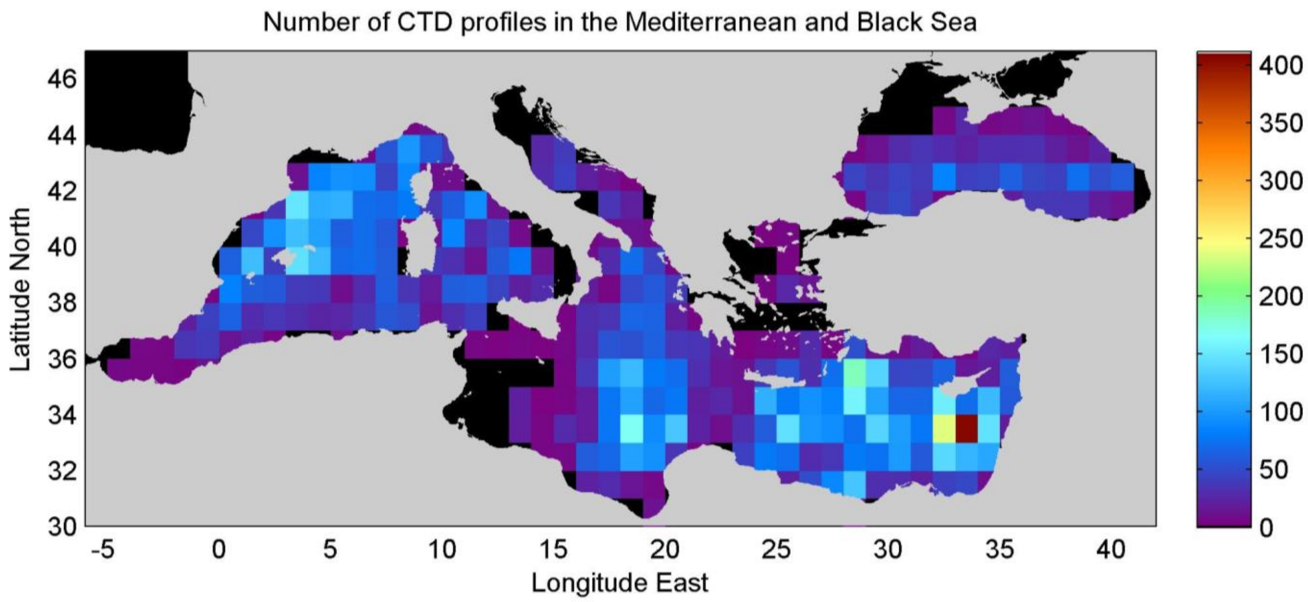

Figure 1.9. Spatial distribution of the number of Argo float profiles obtained in the SES in 2000-2012 in bins of 1º x 1º.

1.1.2 Argo floats in the SES at the end of 2012 and plans for 2013-2014

The number of Argo floats active in the SES in December 2012 was 49 in total, including 7 in the Black Sea and 42 in the Mediterranean Sea. Their locations are displayed in Fig. 1.10. Several French floats are equipped with biochemical/optical sensors in the northwestern Mediterranean: two Provors with dissolved oxygen sensors (as part of the Hymex project) and two Provors with optical sensors (active and passive; as part of the NAOS and REMOCEAN projects).

Figure 1.10. Argo floats active in the SES in December 2012. Green dots indicates the positions of floats declared in the Argo Information Centre (AIC). White dots correspond to floats not declared in the AIC.

Float deployments plans for 2013 are listed in Table 1.4. Despite the fact that a few long-lived floats will stop operating in 2013 (e.g. 4 French floats which have already made 200 cycles), the Argo float population in the SES will reach 80 units in 2013, including 5 floats with oxygen sensors and about 12 floats with biochemical/optical sensors (Provnut). About 70 floats will sample the Mediterranean and 10 floats the Black Sea. In this way the float population density in these marginal seas will be twice as much the standard adopted for the Argo in the World Ocean (1 float in 3º x 3º).

So we can say that, the Argo float population over the next years in the SES will be in general adequate to monitor the physical and biochemical/optical properties of seawater, thanks to national programs, EU projects such as Perseus and within the framework of Euro-Argo.

One of the goals of Argo is to maintain an adequate population of floats in the oceans/seas so as to be able to conduct climate/oceanographic research and to provide data to operational oceanography systems. Likewise the continuous monitoring of water properties with Argo floats in most areas of the SES is an important objective for basic and applied research on these seas, and in particular within Perseus.

Country	Quantity	Basin	Type	Comments
Italy	3	Black Sea	Arvor-I, CTD	Argo-Italy, Deployed by Bulgaria
14	2	Levantine	Arvor-I, CTD	Argo-Italy, Deployed by Cyprus
	1	Ionian	Arvor-I, CTD	Perseus ADREX campaign
	1	Adriatic	Arvor-I, CTD	Perseus ADREX campaign
	2	Ionian	Provnut	Perseus ADREX campaign
	3	Tyrrhenian	Arvor-I, CTD	Argo-Italy
	1	Ligurian	Arvor-I, CTD	Argo-Italy
	1	Western Med	Avor-A3, CTD	E-AIMS
France	10	Western Med	Provnut	NAOS
13	3	Western Med	Provor, DO	HYMEX
Spain	2	Western Med	Apex, CTD	SOCIB
Greece	1	Aegean	Arvor-I, CTD	Bought with Perseus funding
	2	Aegean	Arvor-I, CTD	Argo-Greece
Germany	2	Ionian	Apex, CTD	Argo-Germany
	2	Levantine	Apex, CTD	Argo-Germany
Romania	1	Black Sea	Nemo, CTD, optics, DO	Bought with Perseus funding
Ukraine	1	Black Sea	Arvor-I, CTD, DO	Bought with Perseus funding
Bulgaria	1	Black Sea	Apex, CTD	BulArgo
	1	Black Sea	Arvor-I, DO	Bought with Perseus funding
	2	Black Sea	Provbio, nut	E-AIMS
Turkey	4	Levantine		
	2	Black Sea		
Total	**48**			

Table 1.4. Plans for Argo float deployments in the SES in 2013-2014 (DO= dissolved oxygen).

The following gaps can be identified:

- In terms of coverage, we can see that the Aegean, Algerian Current, the southern and eastern Ionian and the southern Levantine Basin are less/scarcely sampled. There is a strong need to seek ships of opportunity and collaboration with North African countries in order to deploy and or recover floats in these areas.
- Regarding the multi-parametric observations, we note that floats with oxygen and biochemical/optical sensors are currently missing in the Black Sea. As a result, efforts should be made to equip more floats with oxygen sensors, and some of them with biochemical/optical sensors in the near future.

1.2 SURFACE DRIFTERS

1.2.1 Historical surface drifter data in the SES (1986-2012)

Drifter designs

The majority of the drifters deployed in the SES are of three types: Surface Velocity Program (SVP) drifters which are the standard design of the Global Drifter Program (Lumpkin and Pazos, 2007; Sybrandy and Niiler, 1991) with a sub-surface holey-sock drogue centered at a 15 m or 50 m nominal depth; Coastal Ocean Dynamics Experiment (CODE) drifters which were developed by Davis (1985) in the early 1980s to measure coastal currents in the first meter below the surface; Compact Meteorological and Oceanographic Drifters (CMOD) or XAN-1 drifters (Selsor, 1993) which were mainly operated by the U.S. Navy (Fig. 1.11). All these drifters measure near-surface currents and sea surface temperature (SST).

SVP drifters can be equipped with additional sensors, such as thermistor chains to measure temperature at various depths down to 50 or 100 m, pressure gauges to monitor atmospheric pressure, optical sensors, sensors to measure wind speed and direction, and CTDs to measure sea surface salinity. CODE drifters can also be fitted with thermistor chains and also acoustical sensors (ADCP) to measure relative flow and shear. Some of these “special” drifters have been operated intermittently in the SES. In contrast SVP with barometers (called SVPB) and with thermistor chains (called SVPBT) have been operated successfully in the Black Sea and some areas of the Mediterranean Sea.

Surface drifters are mostly used to measure the surface or near-surface currents via their successive positions. Drifters move freely with the currents but are actually quasi-Lagrangian because they can slip with respect to the near-surface water due to the direct effect of the local wind and waves acting on elements protruding above the sea surface. This slip varies substantially amongst the different drifter designs. Direct measurements of 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 winds of 10 m s^{-1} (Niiler et al., 1995). Slip measurements (Poulain et al., 2002) with acoustic current meters showed that the CODE drifters follow the surface currents within 2 cm s^{-1} and that they move in a manner consistent with the near-surface Ekman dynamics with a velocity component to the right of the prevailing wind.

Figure 1.11. Photographs of SVP, SVPB, CODE and CMOD surface drifters.

Most drifters are localized by, and transmit data (sea surface temperature, voltage, drogue presence indicator, etc.) to, the Argos Data Collection and Location System (DCLS) onboard polar-orbiting satellites. The Doppler-based Argos tracking has an accuracy of 300–1000 m and positions are typically available 6–12 times per day, but the most frequent sampling period is about 100 minutes corresponding to the period of the orbiting satellites. Some units (mostly CODE drifters) are also equipped with GPS receivers to obtain more accurate (~10 m) and more frequent (hourly) positions. In recent years, some drifters have used Iridium and Globalstar (SPOT) satellite systems for data telemetry.

Drifter data processing and archiving

In addition to the processing and archiving operated by individual drifter owners, most of the SES drifter have also been processed and archived at the MedSVP laboratory of the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) in Trieste (Italy) using common standard techniques. At MedSVP, drifter position and SST data are first edited for outliers and spikes (Poulain et al., 2004; Gerin and Bussani, 2011). Edited positions are interpolated at regular intervals (e.g. 0.5 h) with a kriging optimal interpolation technique (Hansen and Poulain, 1996). Velocities are estimated by central finite differencing the interpolated positions. For some applications, positions and velocities are also low-pass filtered to remove high-frequency motions, and subsampled every 6 h. The data are finally archived in several databases (organized by sub-basins or projects) accessible through the MedSVP web site (http://nettuno.ogs.trieste.it/sire/medsvp/) . Drifter data are processed both in near-real time and in delayed-mode. They are also provided to the MyOcean Operational Oceanography network.

The data from SVP-type drifters (SVP, SVPB, SVPBT) are also processed and archived at the Global Drifter Programme drifter Data Assembly Center (GDP DAC; http://www.aoml.noaa.gov/phod/dac/). These drifter data are available in near-real time on the Global Telecommunication System (GTS). The worldwide operations of SVP-type drifters are coordinated by the Data Buoy Cooperation Panel (DBCP; http://www.jcommops.org/dbcp). French drifter data are available at Coriolis (http://www.coriolis.eu.org/Data-Services-Products/View-Download/Surface-drifters-data).

Historical drifter data in the SES available at MedSVP

In total, for the time period June 1986 – December 2012, more than 255 drifter-years worth of data were collected in most areas of the SES and were processed and archived at MedSVP (see Fig. 1.12). They correspond to 1458 individual tracks, including 624 (604) tracks of CODE (SVP) designs. The temporal distribution of the drifter data (Fig. 1.13) is very intermittent due to the relative short lifetime of the drifters. The drifter population in the SES reached its maximum in May 2003 with more than 70 active instruments. The longest drifter track (618 days) corresponds to a SVP drifter. The half-lives varies between 39 days (CMOD) and 102 days (SVP).

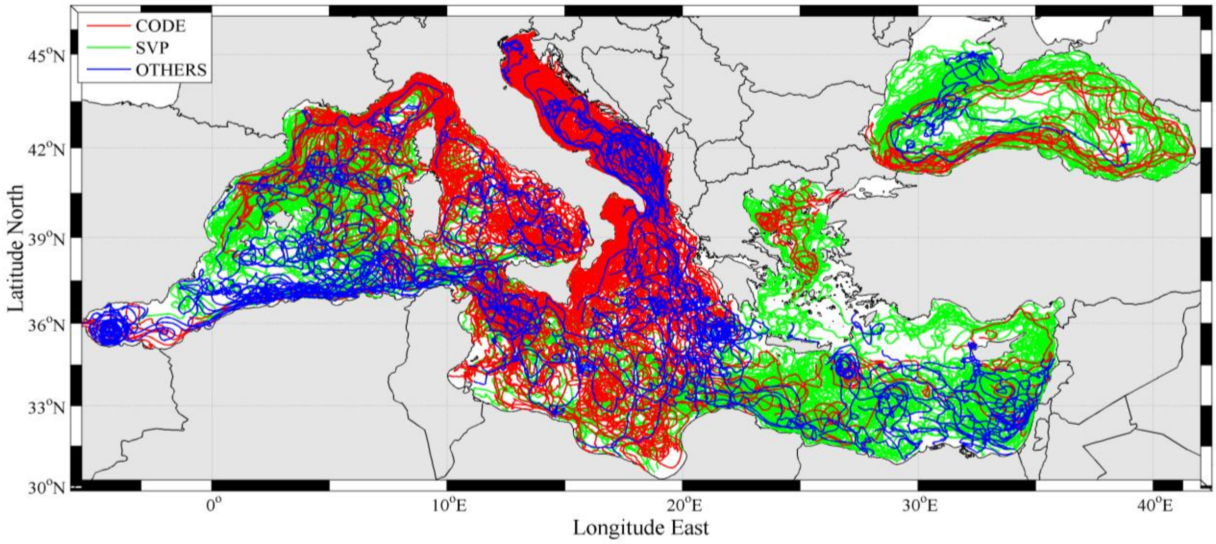

Figure 1.12. Composite diagram with all the tracks of surface drifters operated in the SES in 1986-2012, color-coded as a function of drifter types.

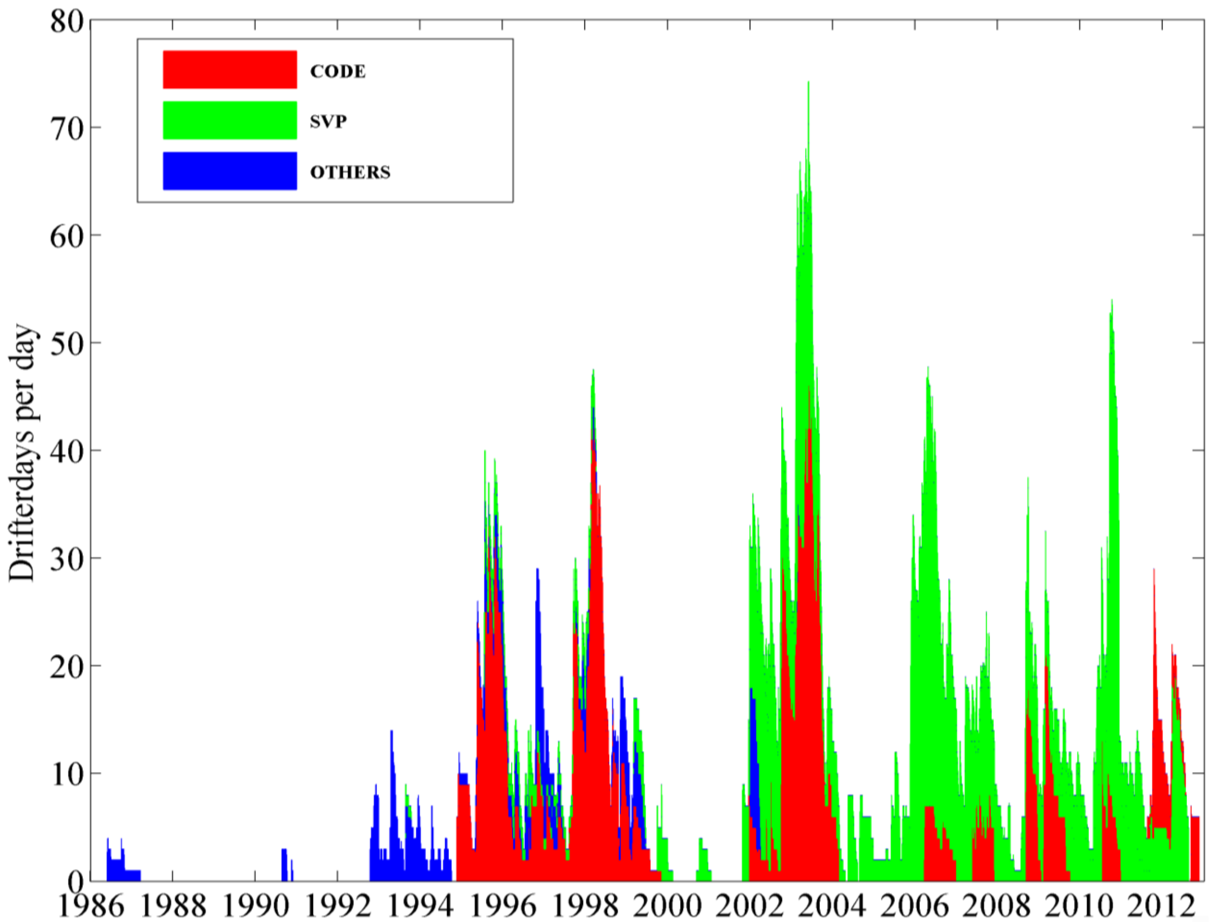

Figure 1.13. Temporal distribution of the number of surface drifters operated in the SES in 1986-2012, color-coded as a function of drifter types.

Other drifter experiments in the SES

In addition to the MedSVP drifters reviewed above, drifters have also been used to measure circulation features in local coastal areas such as off the Italian coast in the middle and southern Adriatic (Haza et al., 2007) and in the Gulf of La Spezia (Molcard et al., 2009; Haza et al., 2010). Extensive local drifter experiments have also recently been carried out in the Gulfs of Naples and Trieste in Italy, and in other Mediterranean areas (northern Aegean, off Toulon in France, and in the vicinity of the Balearic Islands in Spain), as part of an ongoing project funded by the European Commission (TOSCA, www.tosca-med.eu). The information on this specific drifter project is briefly presented here since it plays an important role in the present state of the art and the data are available to the community, hence contributing to reduce the gaps and needs in some areas. The TOSCA drifters have the following common goals:

- to measure the coastal circulation with high geographical resolution using an array of drifters which are deployed and recovered several times during the period of study. This is often done in conjunction with the operation of high frequency (HF) coastal radars (see Molcard et al., 2009). Drifter data enable the calibration and validation of radar measurements, and the combination of both types of data (in practice the radar data corrected by the drifters) represents the best description of the spatial structure and temporal evolution of the coastal circulation.
- to study dispersion by the surface currents. In particular, drifters released in clusters (e.g. closely separated pairs or triplets) enable the investigation of relative dispersion and the corresponding mixing and stirring properties of the surface flow field.
- to assess the water-following capabilities of several types of surface drifters (CODE, I-SPHERE, TOSCA) and to measure the relative shear of currents, near or below them, using acoustic current meters and profilers. All these studies are in progress and will be reported in the coming years.

In these local experiments, drifters are generally not expendable as they can be often recovered, used many times and stored for use in other experiments.

A few drifters equipped with wind sensors and with passive optical sensors have also been used in the Adriatic with limited success (Poulain et al., 2003). Drifters specifically designed to follow surface oil spills (which are moving with the currents and the winds) have also been used in the SES as part of the Italian PRIMI and EC TOSCA projects, amongst others. Drifters equipped with CTDs have been developed and used to provide calibration/validation data for the SMOS and AQUARIUS satellite sensors (J. Font, CSIC, Barcelona, Spain). The NATO Centre for Maritime Research and Experimentation (CMRE) also operates drifters in the Mediterranean Sea as part of rapid assessment exercises. These data are usually available via MedSVP.

1.2.2 Surface drifters in the SES at the end of 2012 and plans for 2013-2014

At the end of 2012, according to MedSVP, nine drifters were still active in the Mediterranean and none in the Black Sea. They include one Spanish drifter, one CMRE drifter and 7 Italian drifters in the western Basin and central Mediterranean (Fig. 1.14). Five of the Italian drifters are SVP designs recently deployed in the Malta Channel (see their trajectories in Fig. 1.15).

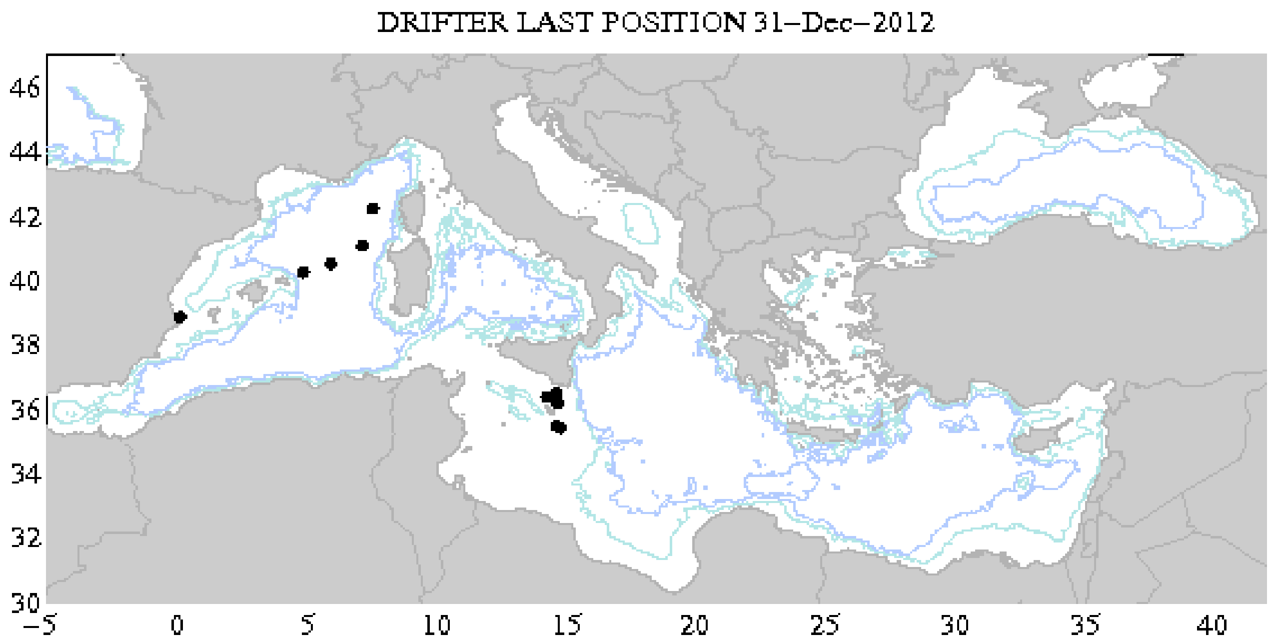

Figure 1.14. Positions (black dots)) of the surface drifters active in the SES on 31 December 2012 as displayed in near real-time on the MedSVP web site.

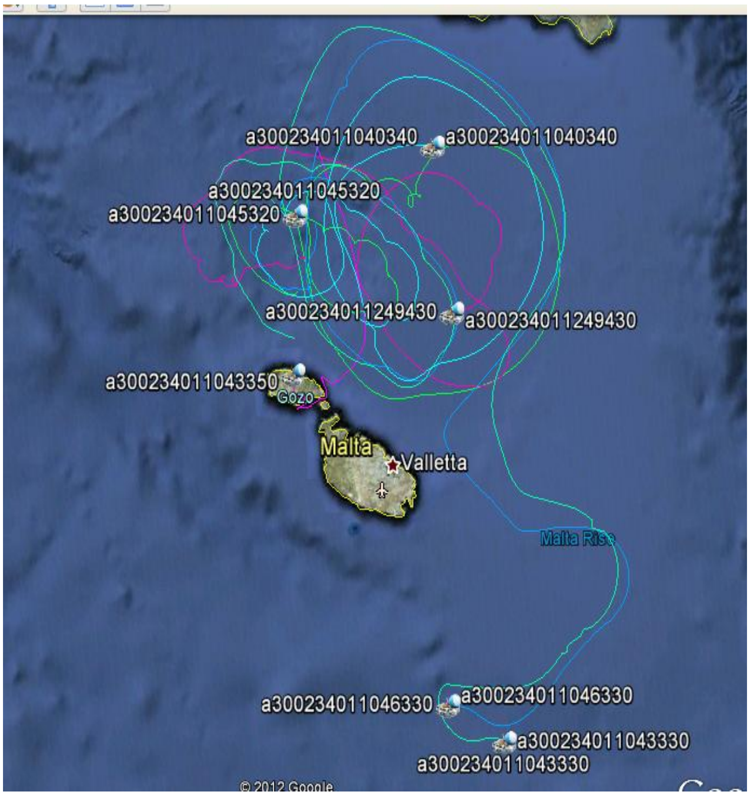

Figure 1.15. Trajectories and positions on 31 December 2012 (drifter symbols and numbers) of SVP drifters deployed on 14 December 2012 in the Malta Channel as displayed in near real-time on the MedSVP web site.

Drifter deployment plans are shown in Table 1.5. Italy should deploy more than 20 SVP in the Central Mediterranean. Spain and France should deploy SVP drifters in the Western Mediterranean. CMRE will probably deploy a few drifters during rapid assessment exercises. MeteoFrance will deploy SVPBT, SVPS (SVP with CTD), and MARISONDE drifters as part of the Hymex programme.

Country	Quantity	Basin	Type	Comments
Italy	12 12 15	Ionian Sicily Channel Adriatic	SVP SVP CODE	Perseus ADREX campaign Deployed by Malta EU COCONET campaign
France	11	Western Med	SVPBT, SVPS, MARISONDE	HYMEX
Spain	8	Western Med	SVP	SOCIB
NATO	?		CODE	CMRE
Total	**58**			

Table 1.5. Plans for surface drifter deployments in the SES in 2013-2014.

The following gaps can be identified:

- The Aegean, Levantine and Black Seas have been relatively under sampled with drifters and will stay like that in 2013, as there are no deployments planned.
- More coastal experiments using a large number of low-cost drifters (like TOSCA) should be conducted to measure dispersion of contaminants, especially in coastal waters.

1.3 OTHER EXPENDABLE SENSORS (SHIP OF OPPORTUNITY PROGRAMME)

1.3.1 Introduction

The Ship-of-Opportunity Programme (SOOP) makes use of volunteer merchant ships that routinely transit strategic shipping routes. Ships officers or dedicated technicians deploy Expendable Bathythermographs (XBTs) at predetermined sampling intervals to acquire temperature profiles in the open ocean. Worldwide marine meteorological and oceanographic communities are working in partnership under the umbrella of the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology, in order to respond to interdisciplinary requirements for met/ocean observations, data management and service products. Normally, selected data, which accurately represent the entire data profile, are transmitted by satellites to shore centers, for insertion and exchange on the GTS, and assimilation into operational ocean models. In the Mediterranean it has been decided to transmit full resolution data using commercial telecommunication systems, in this way no information is lost regarding the vertical stratification. The programme is managed by the SOOP Implementation Panel (SOOPIP), also a part of the JCOMM Ship Observations Team.

A SOOP was established in the Mediterranean in September 1999, on behalf of the EC funded project Mediterranean Forecasting System – Pilot Project (MFS-PP, Pinardi et al., 2003). Temperature-XBT profiles were collected along six transects crossing the western and the eastern basins from North to South and one transect crossing the whole sea from east to west. These transects were designed to specify, in each of the sub-basins (the Algero-Provencal, the Tyrrhenian, the south Adriatic, the Ionian and the Levantine), the variability of the main circulation features. The programme has always been strongly dependent on budget constraints. It has been sustained by the Mediterranean Forecasting System - Pilot Project (MFSPP), Mediterranean Forecasting System - Toward Environmental Prediction (MFSTEP), the ADRICOSM projects. Internal resources have also been used to maintain it, at least along some particular tracks. For these reasons the Mediterranean SOOP moved from an operational observing system finalized to provide data to forecasting systems, to a climate variability observing system. During the last two years the SOOP has included also another component called Volunteer Observing System (VOS) that is providing meteorological data over the Mediterranean Sea (Fig. 1.15). The Mediterranean VOS is part of the WMO observing system.

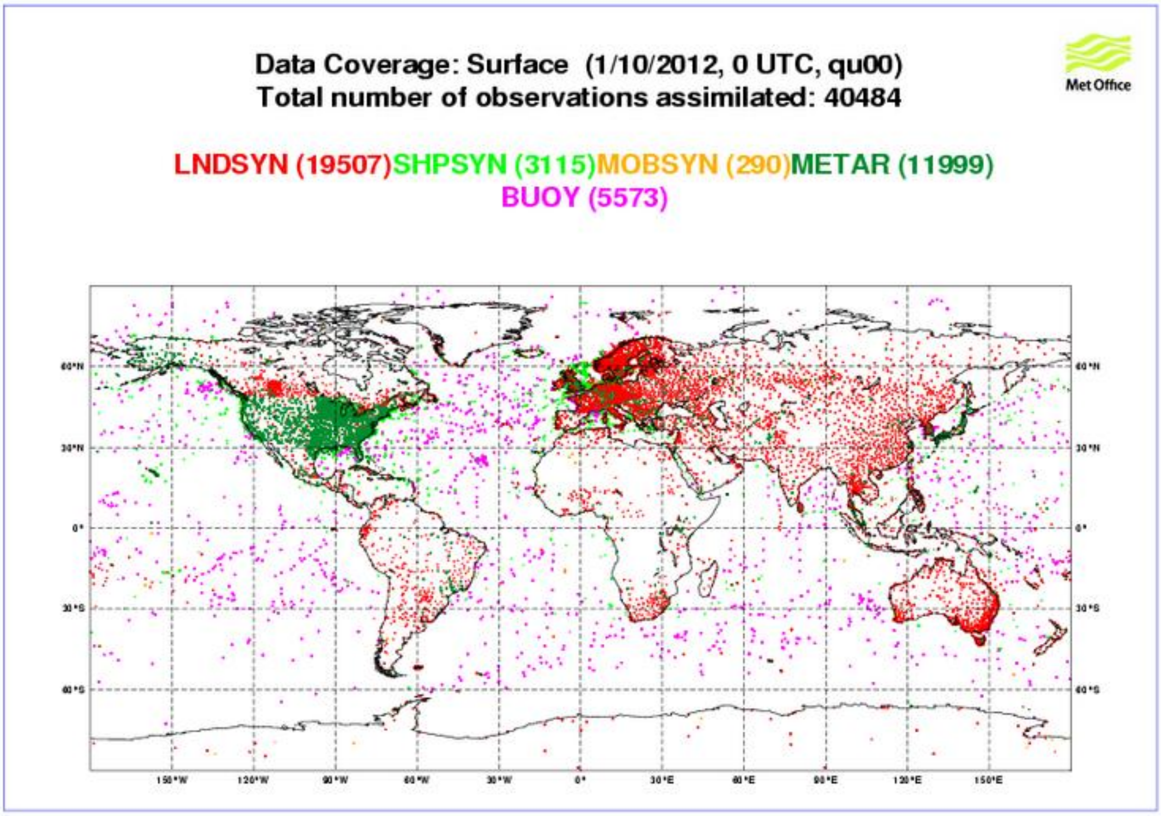

Figure 1.15. Surface meteorological observation over the Earth on Oct 1, 2012 H00. The Mediterranean is covered by few buoys (BUOY) and some ships (SHPSYN).

1.3.2 The Ship Of Opportunity Programme in the Mediterranean

The existing database of historical XBT data can be found in the WODC. It also contains recent temperature profiles collected as part of the Mediterranean SOOP. The first temperature profiles included in the WODB were collected with bathy-thermographs in 1966; however, there are also temperature profiles collected in previous years. One example is provided in Fig. 1.16 were bathy-thermographs data collected during the Second World War are shown.

A general view on BT/XBT data coverage during different years from 1968 to 2012 is provided in Fig. 1.17.

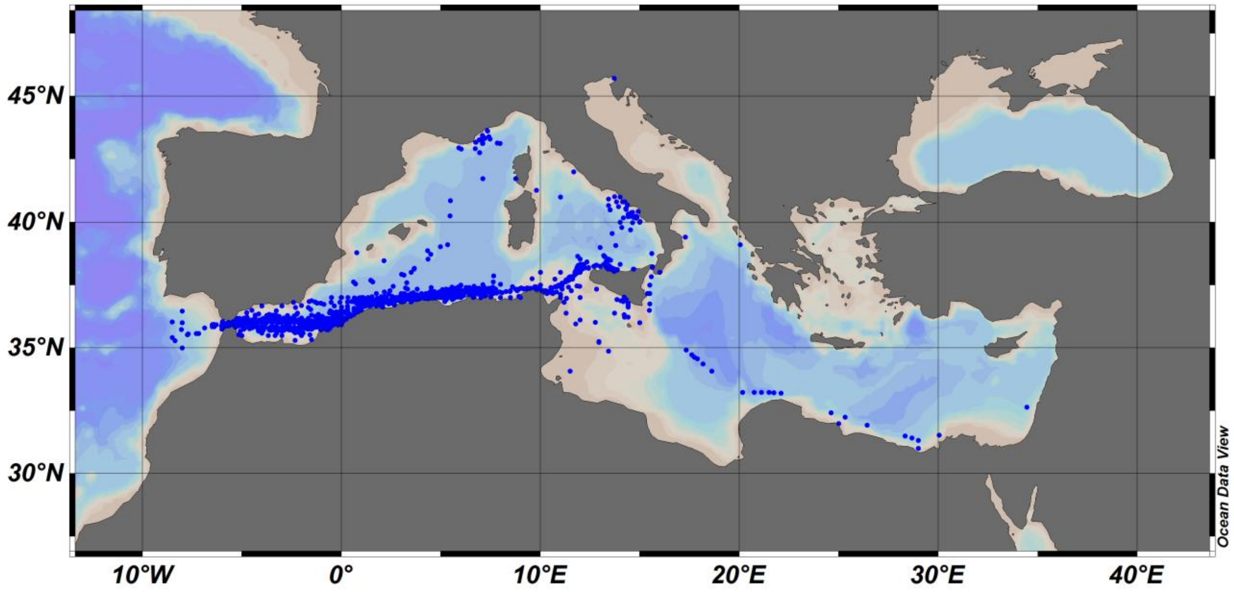

Figure 1.16.

A “ship of opportunity” program was launched as part of the Mediterranean Forecasting System Pilot Project (MFSPP). During the operational period (September 1999 to May 2000), six tracks covered the Mediterranean from the northern to southern boundaries approximately every 15 days, while a long east-west track, from Haifa to Gibraltar, was covered approximately every month. The MFS-SOOP design is shown in Fig. 1.18. MFSPP was the first program developed in the Mediterranean region that was able to set up a long term, widespread, working link between research institutions and merchant ship companies. The VOS MFSPP project was mission oriented. Merchant ships provided routine observations for forecast. Furthermore, the long term, widespread, and routine measures provided a cost-effective database for the study of changes in the upper layer of the Mediterranean Sea. The principal aim of VOS MFSPP is then the continuous and regular sampling the Mediterranean upper thermocline (0-400 m) thermal structure using XBT measurements.

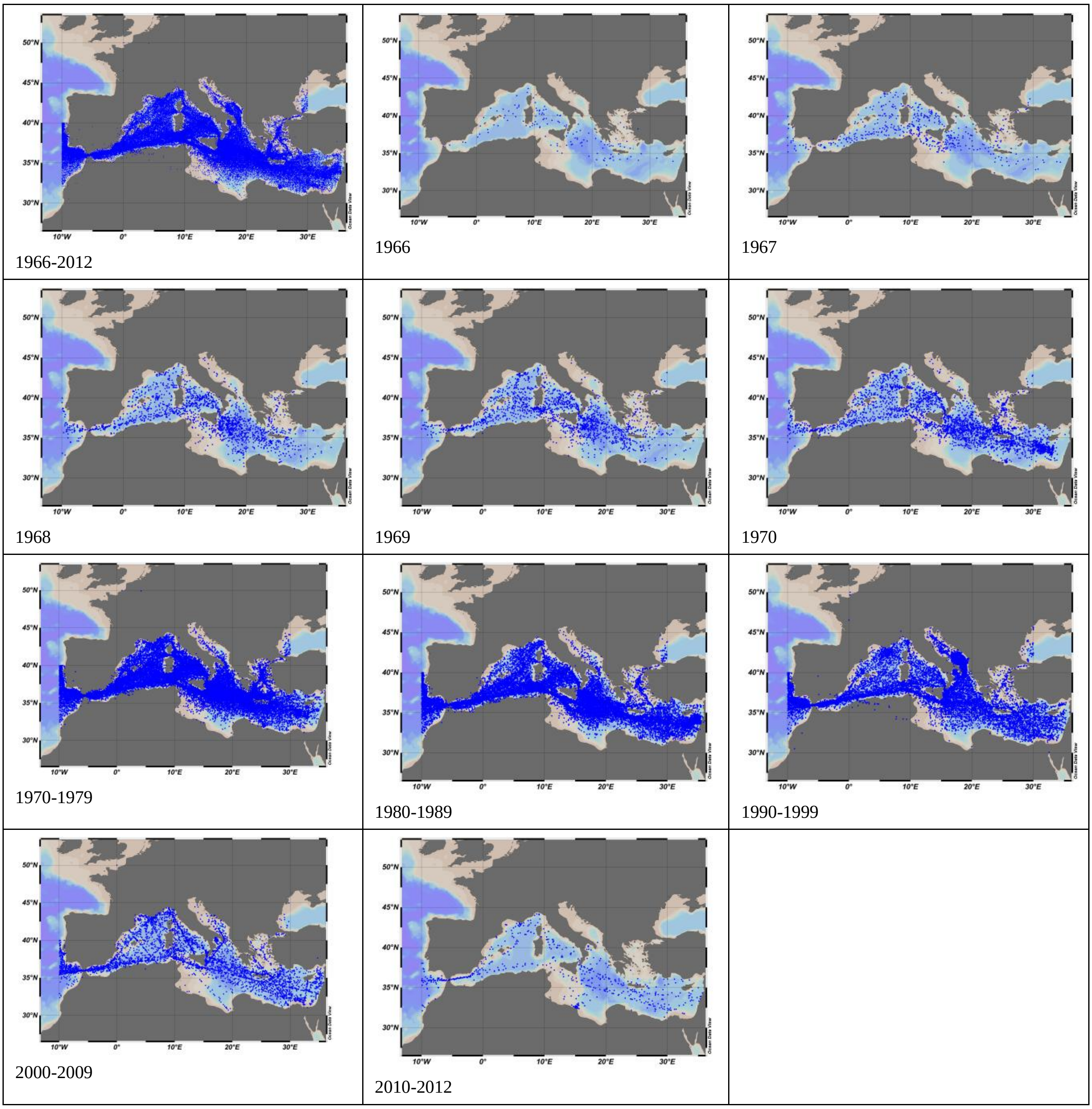
1966-2012
1966
1967
1968
1969
1970
1970-1979
1980-1989
1990-1999
2000-2009
2010-2012

Figure 1.17.

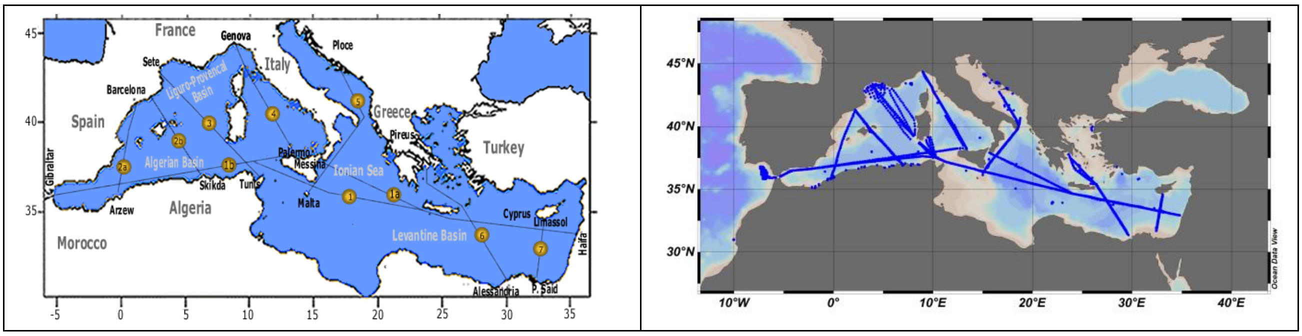

Figure 1.18. The SOOP design for the Mediterranean Forecasting System Pilot Project (left) and observations (right)

Some changes were made in the design for the Mediterranean Forecasting System - Toward Environmental Prediction (MFSSTEP, 2003-2004). They were done to avoid the logistic problems related to the long track # 1.

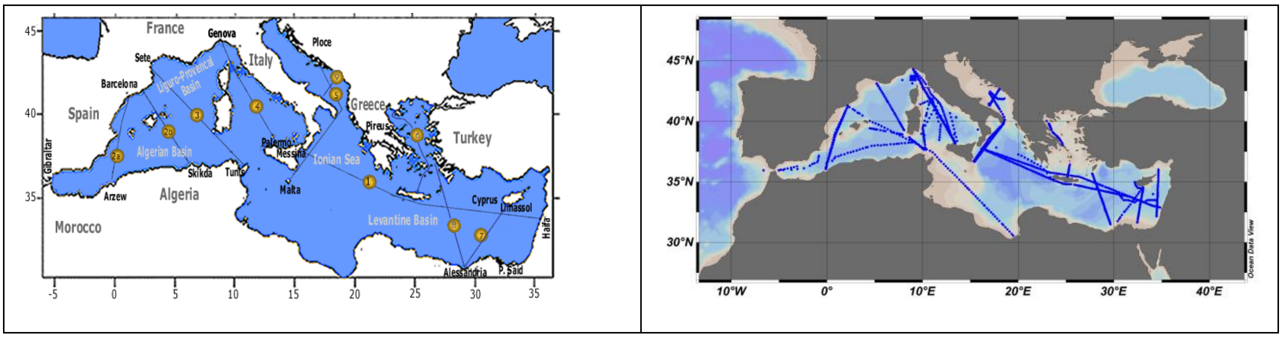

Figure 1.19. Design (left) and realization (right) of the Mediterranean SOOP during MFSTEP

Some changes occurred during the realization of the design. The most important of which was the possibility to make some measurements in the Gulf of Sirte, after decades of no data collection in this area. An additional change was due to the possibility to use research vessels in what was called 'Cruise Of Opportunity'.

The ADRICOSM projects (2005-2006 and 2007-2009) gave the possibility to monitor the southern Adriatic. At the same time, Cruises Of Opportunity allowed to collect data also in other areas of the Mediterranean.

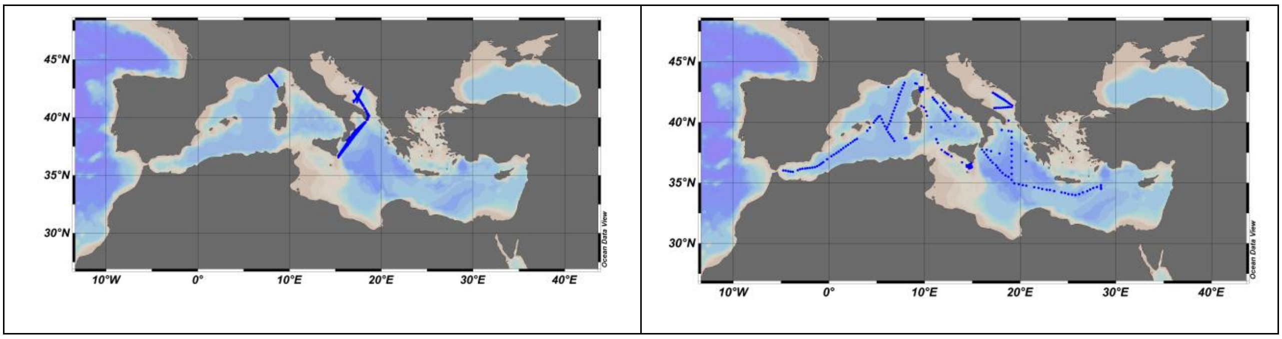

Figure 1.20. SOOP during 2002-2003 (left) and 2007 - 2009 (right)

From 2009 the Mediterranean SOOP has been providing data not in operational way. There is the intention to maintain three tracks, to be covered at a seasonal scale: Genova - Gibraltar, Genova - Palermo and Messina - Turkey.

The data collection in 2009, 2010 and 2011 is presented in Fig 1.21.

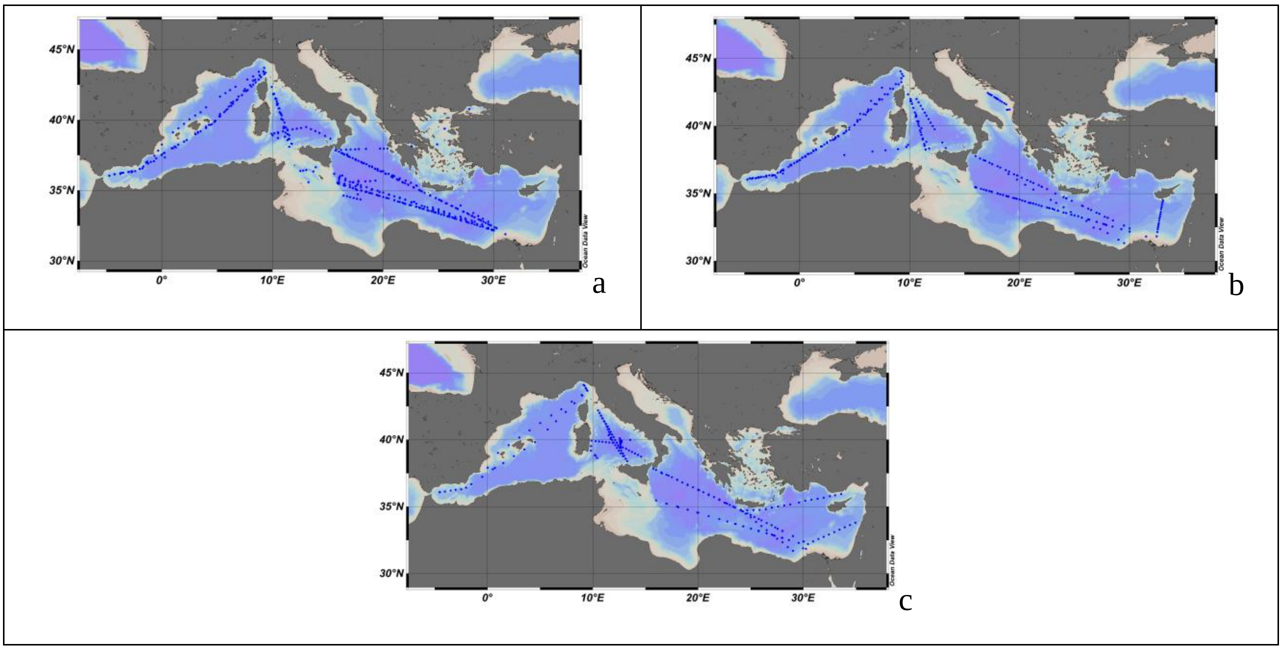

Figure 1.21. Tracks during 2009 (a), 2010 (b) and 2011 (c). The data were collected in collaboration with NOAA (USA) and BOM (Australia)

1.3.3 Quality assurance and quality control of SOOP data

Data quality management entails the establishment and deployment of roles, responsibilities, policies, and procedures concerning the acquisition, maintenance, dissemination, and availability of data. Good data can be obtained by following precise methodologies and protocols during all phases of data collection, from preparation of surveys and instruments to post-processing. These activities can be divided into two broad categories: a) Quality Assurance and b) Quality Control.

Details on SOOP quality assurance and control protocols are included in Appendix 1.

1.3.4 Expendable probes

Expendable Bathythermograph - Expendable Sound Velocimeter (XBT/XSV)

The following section is extracted from Sippican LM manuals.

A standard XBT/XSV system consists of an expendable probe, a data processing/recording system, and a launcher. An electrical connection between the probe and the processor/recorder is made when the canister containing the probe is placed within the launcher and the launcher breech door is closed. Following launch, wire dereels from the probe as it descends vertically through the water. Simultaneously, wire dereels from a spool within the probe canister, compensating for any movement of the ship and allowing the probe to freefall from the sea surface unaffected by ship motion or sea state.

The XBT/XSV system uses a sea water ground. As soon as an electrode within the nose of the expendable probe makes contact with the water, the circuit is complete and temperature or sound velocity data can be telemetered to the ship-board data processing equipment. Data are recorded and displayed in real time as the probe falls. The nose of each expendable probe is precision weighted and the unit spin-stabilized to assure a predictable rate of descent. From this rate of descent, probe depth is determined to an accuracy of +2%.

The XBT contains a precision thermistor located in the nose of the probe. Changes in water temperature are recorded by changes in the resistance of the thermistor as the XBT falls through the water. The XBT is capable of temperature accuracies of about 0.1°C.

The different probes produced by Sippican LM and used in the Mediterranean are listed in the Table 1.6.

	T4	**T6**	**T7**	**deep blue**
Max Depth (m)	460	460	760	760
Rated Ship Speed (kts)	30	15	15	20
Vertical resolution (cm)	65	65	65	65

Table 1.6 Some XBT characteristics

Expendable Conductivity/Temperature/Depth (XCTD) Profiling Systems have rarely been used in the Mediterranean due to the high cost of each probe (about 400 €). There are attempts to develop expendable probes with a fluorimeter but the development is still underway.

1.3.5 Gaps and needs

The primary goal of SOOP is to fulfill upper ocean data requirements, which have been established by GOOS and GCOS.

Table 1.7 shows the Essential Climate Variables defined in the framework of GCOS, that include also Ocean Variables. SOOP is providing only temperature profiles, as a consequence is giving information on thermal changes and variability at seasonal, inter-annual and decadal time scales.

XBT data are also used for assimilation in operational forecast models (marine weather), as was intensively done during MFSPP and MFSTEP.

The main requirements of the SOOP were defined in MFSPP. An ideal sampling design is based on four goals:

- provide repetitive measurements along transects from coast to coast,
- the transects must cross significant dynamical features of the circulation,
- the sampling distance should resolve, as well as possible, the mesoscale,
- the technologies for data collection must be robust and simple, to be used on ships of opportunity, eventually by ship personnel.

PIERRE, REVISE THE TABLE, OCEANIC Variables are not well aligned…

Atmospheric	Surface:1	Air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget
	Upper-air:2	Temperature, wind speed and direction, water vapour,
Oceanic	Surface:5	Sea-surface temperature, sea-surface salinity, sea level, sea state, sea ice, surface current, ocean colour, carbon dioxide partial pressure, ocean acidity, phytoplankton
Terrestrial		River discharge, water use, groundwater, lakes, snow cover, glaciers and ice caps, ice sheets, permafrost, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (FAPAR), leaf area index (LAI), above-ground biomass, soil carbon, fire disturbance, soil moisture

Table 1.7. Essential Climate Variable defined in GCOS

The experience of MFSPP indicated that there was a need for technology allowing full resolution data and metadata transmission in order to avoid wrong interpolations and misinterpretation of the ocean dynamics. Other requirements were defined in MFSTEP, in terms of services to be provided to the forecasting systems as well as to intermediate and end users:

- intermediate users need QC data for their particular goals, as they are producers of other services and the access to data should be based on mutual satisfaction;
- end users are interested in products (e.g. maps of data, changes with respect to climatology, etc.).

The satisfaction of end-users is of paramount importance to sustain the observing system.

Gaps and needs are related to the objectives of the monitoring systems. Here four applications are analyzed.

Climate application

XBT monitoring is providing useful information on long term variability. Advantages are related to the fact that XBT lines are normally done along pre-defined transects that are covered for a long time period (years). This is impossible in terms of costs with research ships or gliders, and is practically impossible with Lagrangian floats (Argo). In a situation of strong limitation in economical resources, it is necessary to select appropriate transects, however the international SOOP community is having problems in the maintenance of the monitoring system.

In the Mediterranean only ENEA is maintaining a SOOP along two transects: Genova-Palermo in the Tyrrhenian, Genova - Gibraltar in the western Mediterranean. The main gap is then the coverage of the eastern Mediterranean, that is done only occasionally by ENEA or by Mediterranean SOOP partners (e.g. OC-UCY). An ideal coverage for the entire Mediterranean was proposed at the end of MFSTEP: three North-South transects (e.g. Spain - Algeria, Genova - Palermo, Greece - Egypt). In this way it is possible to calculate the transfer of heat across the Mediterranean basins and assess its variability/change.

Assimilation in marine weather forecast models

The requirements presented above (repetitive transects, resolve meso-scale, etc.) are actually impossible for economical reasons, since XBT drops should be done at spatial intervals of 5 - 10 nautical miles and temporal interval of 5 - 10 days (more or less).

Support to environmental assessment

This requires the development of new expendable probes. An attempt was done in MFSTEP by developing a T-FLAP, i.e. a probe providing temperature and fluorimeter data. However, this development is not yet completed.

Basin to basin exchanges

Combined use of XBT and XCTD along North-South transects could provide important information on the exchanges of mass and heat. The main problem is related to the costs of XCTD (about 400€ each). The normal procedure adopted in this case is to drop a certain number of XBT in between two XCTD drops. The salinity is then calculated by interpolating data and, possibly, using algorithms for the calculation of synthetic salinities. From temperature and salinity it is possible to calculate the geostrophic velocities and then the mass and heat transport through basins.

A final remark is related to the materials that are constituting the XBT/XCTD probes, which needs to be more 'environmental friendly'.

In conclusion, the gaps are related to:

- only a few transects are maintained currently (only by ENEA); an enhanced effort at basin scale is needed;
- new materials; some materials of probes could be changed in order to allow major biodegradability at least of some components;
- lack of cheap multi-parametric expendable probes.

Needs are related to:

- the combination of SOOP (and VOS) with other programmes (e.g. ferrybox, Argo)
- the development of a new sampling strategy of a coordinated multi-platform programme.

In a world in which the economical resources are continuously reduced, it is important to have a major coordination and complementarities of programmes in order to reduce overlaps, duplicate and make a more optimal use of the few resources still existing.

1.3.6 Ferrybox

We close section 1 by mentioning the Ferrybox program (http://www.ferrybox.org) in which automated instrument packages are operated on ships of opportunities. These instruments range from the simple "Continuous Plankton Recorder (CPR)" with its single purpose of collecting plankton samples during regular ship cruises (included in PERSEUS, WP3 activities planned) up to the most recent sophisticated "FerryBoxes" with an ensemble of different sensors and biogeochemical analysers. According to the Ferrybox program, there is only one line in the Mediterranean, connecting Pireus to Heraclion in Greece, which has been recently active (Fig. 1.22).

Similar activities are carried out as part of the CIESM PartnerSHIPS programme (http://www.ciesm.org/marine/programs/partnerships.htm) whose aim is to develop a network of ships of opportunity (Fig. 1.23) for automated monitoring of the surface waters of the Mediterranean, using a complex of different physical, chemical sensors to measure the physical and biogeochemical parameters (temperature, salinity, oxygen and pCO2, chlorophyll, etc.).

Figure 1.22. Active Ferrybox lines in the Mediterranean Sea.

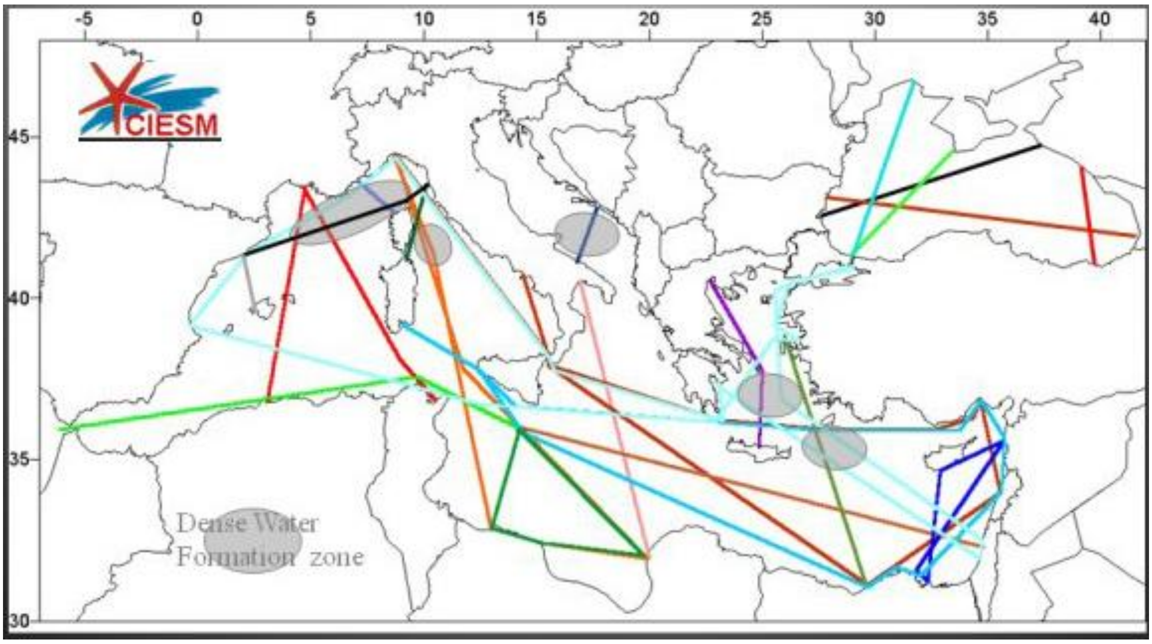

Figure 1.23. CIESM PartnerSHIPS potential network

Since May 2010, the CIESM PartnerSHIPS project operates between Genoa (Italy), Malta and Libyan harbours (Fig. 1.24)

Figure 1.24. CIESM PartnerSHIPS line operated in mid-December 2010.

2. SUB-TASK 3.1.2: Research Ships monitoring (local, sub-basin and maybe basin)

2.1 INTRODUCTION

The aim of sub-task 3.1.2 is to review the observational network based on research ship surveys over the last years in all sub-basins of the Mediterranean and Black Sea. Gaps are identified and recommendations are given to improve the network as a whole and to meet the PERSEUS objectives. Particular attention is given to all the physical (T, S, currents) and biogeochemical (oxygen, chlorophyll, nutrients, alkalinity, etc.) parameters measured, and to the procedures for data collection, processing (including QC) and archiving. The following sub-basins have been identified: Western (IEO, CNRS, CNR, CSIC), Central – Adriatic and Ionian (OGS), Aegean and Cretan Arc (HCMR), Levantine (OC-UCY), Black Sea (SIO-RAS, METU, MHI)

In the following we report the research ship monitoring programmes over the years 2009-2011, i.e. before the start of PERSEUS. Partners and other institutions were asked to complete a questionnaire concerning their RV surveys in 2009, 2010 and 2011. Some information were also derived from Cruises databases, such as the Partnership for Observation of the Global Oceans (POGO) Cruise inventory (http://www.pogo-oceancruises.org).

We received 11 questionnaires, from the following institutes:

1) Basin scale
- CNR (Italy)
- CNRS/IFREMER (France)
- IFM GEOMAR & ZMAW (Germany)

2) Sub-basin scale
- HCMR (Greece)
- GEOECOMAR (Romania)
- OC-UCY (Cyprus)
- SIO RAS (Russia)
- IOF (Croatia)

3) Local scale

- IMS-METU (Turkey)
- IEO-COB (Spain)
- IOLR (Israel)

A fleet of 34 research ships were used for the surveys. They are listed in the following:

1) RV MARIA S. MERIAN (Germany)
2) RV POSEIDON (Germany)
3) METEOR (Germany)
4) Gorgo (Cyprus)
5) FLYING ENTERPRISE (Cyprus)
6) EAS (Cyprus)
7) Megalohari (Cyprus)
8) Bilim 2 (Turkey)
9) Lamas (Turkey)
10) L'Europe (France)
11) Téthys II (France)
12) Antea (France)
13) Le Suroît (France)
14) Côtes De La Manche (France)
15) Pourquoi Pas ? (France)
16) L'Atalante (France)
17) Beautemps-Beaupré (France)
18) Haliotis (France)
19) Odón de Buen (Spain)
20) Sarmiento de Gamboa (Spain)
21) Cornide de Saavedra (Spain)
22) García del Cid (Spain)
23) F.P. Navarro (Spain)
24) Tio Gel II (Spain)
25) Marviva (Spain)
26) Imedea (Spain)
27) Miguel Oliver (Spain)

28) AEGAEO (Greece)
29) FILIA (Greece)
30) IOLKOS (Greece)
31) ARCHAGELOS (Greece)
32) Mare Nigrum (Romania)
33) URANIA (Italy)
34) BIOS DVA (Croatia)

The parameters that were routinely measured vary from institute to institute, and overall they comprise:

- CTD (Temperature, salinity, depth)
- Dissolved oxygen parameters in the water column
- Salinity (water samples at discrete depths)
- Dissolved oxygen (water samples at discrete depths)
- Horizontal velocity of the water column (ADCP and LADCP)
- Thermosalinograph
- Surface drifters
- Optical backscatter
- Fluorescence
- Dissolved inorganic nutrients
- Dissolved organic matter
- Particulate organic matter
- Chlorophyll
- Primary productivity
- pH
- Eh
- Hydrogen sulphide
- Bacteria/micro-organisms
- Phytoplankton (water samples at discrete depths)
- Zooplankton (samples from net tows at discrete layers)
- Phytobenthos
- Zoobenthos

- Sediment traps
- Petroleum hydrocarbons
- Organic biomarkers
- Multibeam sounding
- Heterotrophy

For each Institute we have produced a station map, with different colors for different years. In the following we report on the surveys at three different spatial scales: basin, sub-basin and local.

2.2 research ship surveys

2.2.1 Basin scale surveys

CNR (Italy) activities are mainly concentrated in the Tyrrhenian, the Adriatic, and the Sicily Channel with also some extensive surveys also covering the Western Mediterranean (Fig. 2.1) .

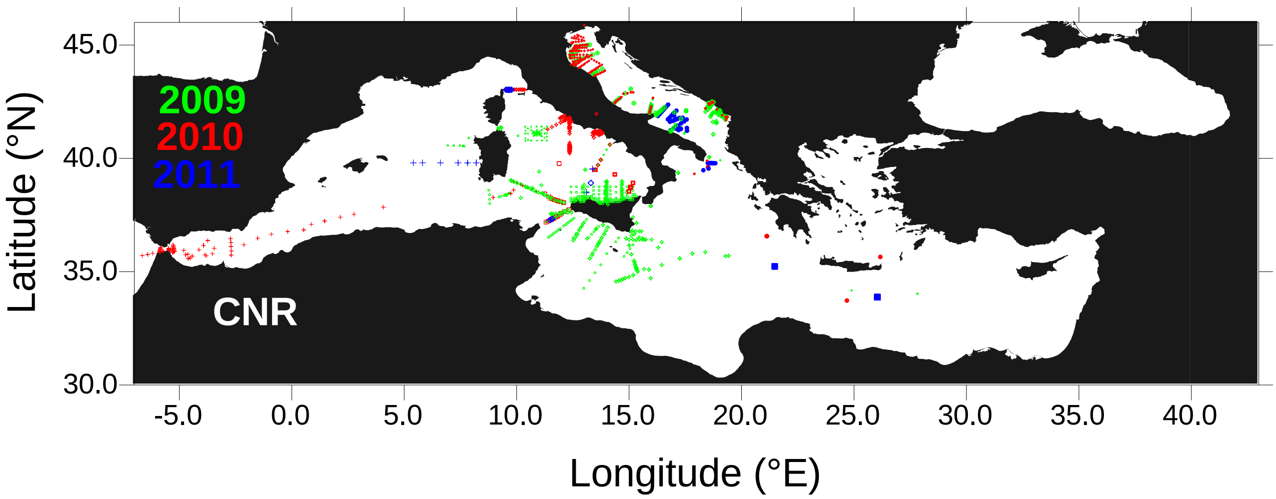

Figure 2.1. Station map 2009-2011 of CNR.

CRNS/IFREMER (France) activities are mainly concentrated in the Algero-Provencal basin. Some stations also in Levantine (Fig. 2.2).

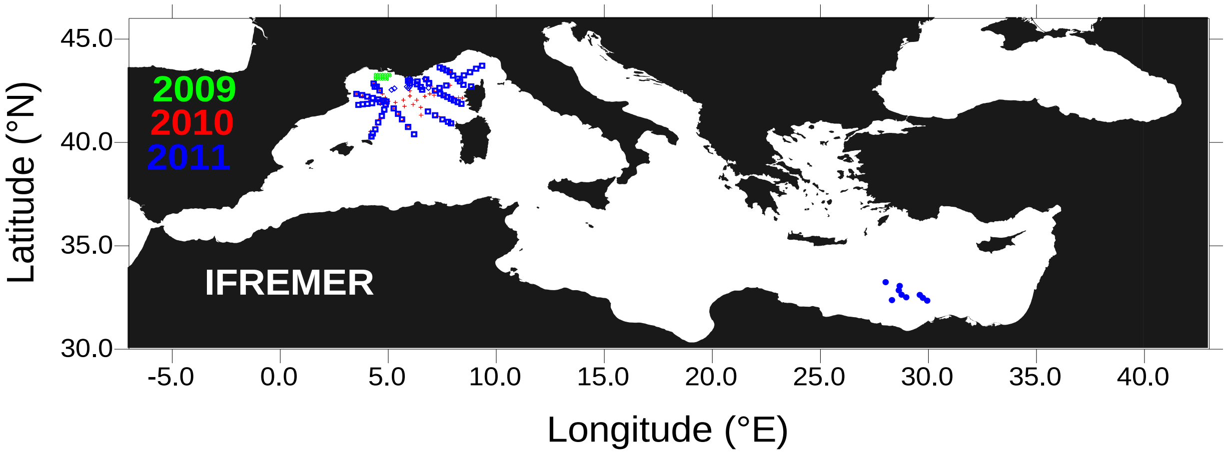

Figure 2.2. Station map 2009-2011 of CNRS/IFREMER.

IFM GEOMAR & ZMAW (Germany) activities are mainly concentrated in the Ionian and South Adriatic. Some extensive trans-Mediterranean surveys have also been carried out (Fig. 2.3).

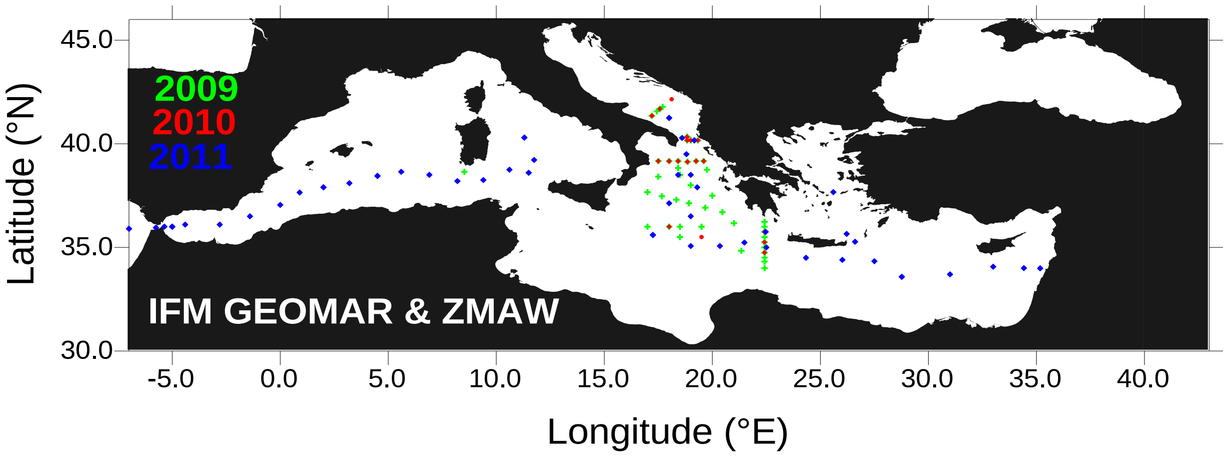

Figure 2.3. Station map 2009-2011 of IGM GEOMAR & ZMAW.

2.2.2 Sub-basin scale surveys

HCMR (Greece) activities are mainly concentrated in the Aegean and Cretan Sea (Fig. 2.4).

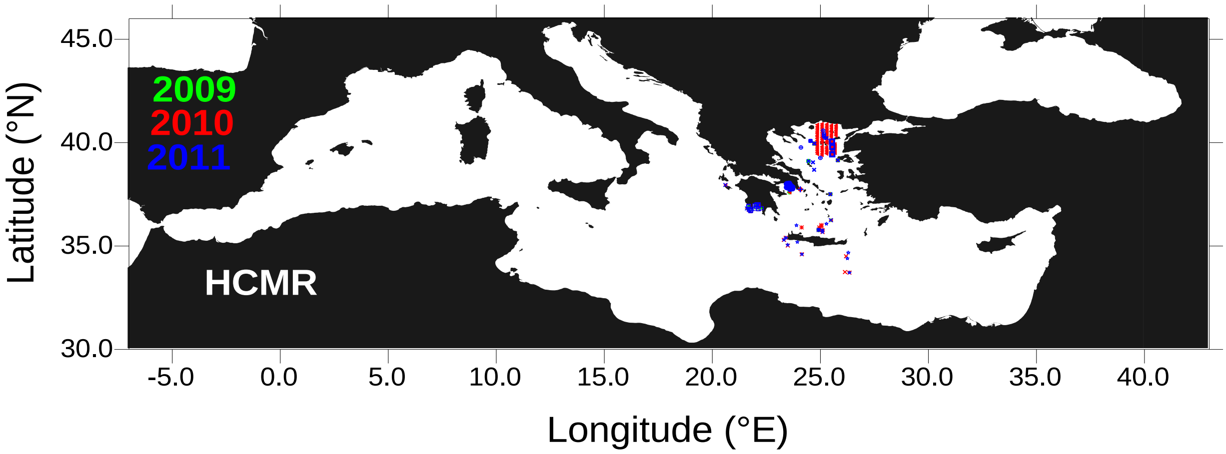

Figure 2.4. Station map 2009-2011 of HCMR.

GEOECOMAR (Romania) activities are mainly concentrated in the western Black Sea. Some extensive surveys also in the Eastern Black Sea (Fig. 2.5).

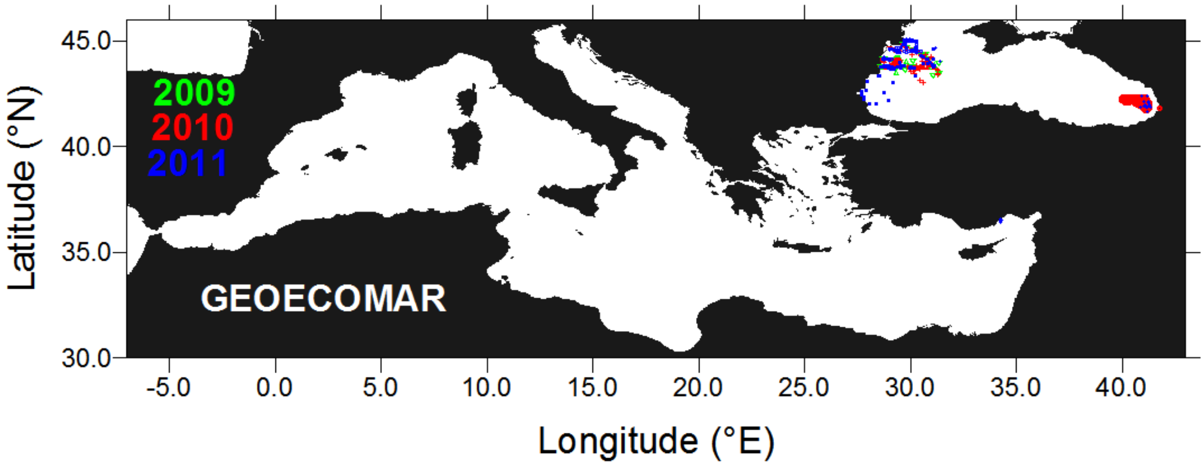

Figure 2.5. Station map 2009-2011 of GEOECOMAR.

OC-UCY (Cyprus) activities are mainly concentrated in the Levantine, south of Cyprus (Fig. 2.6).

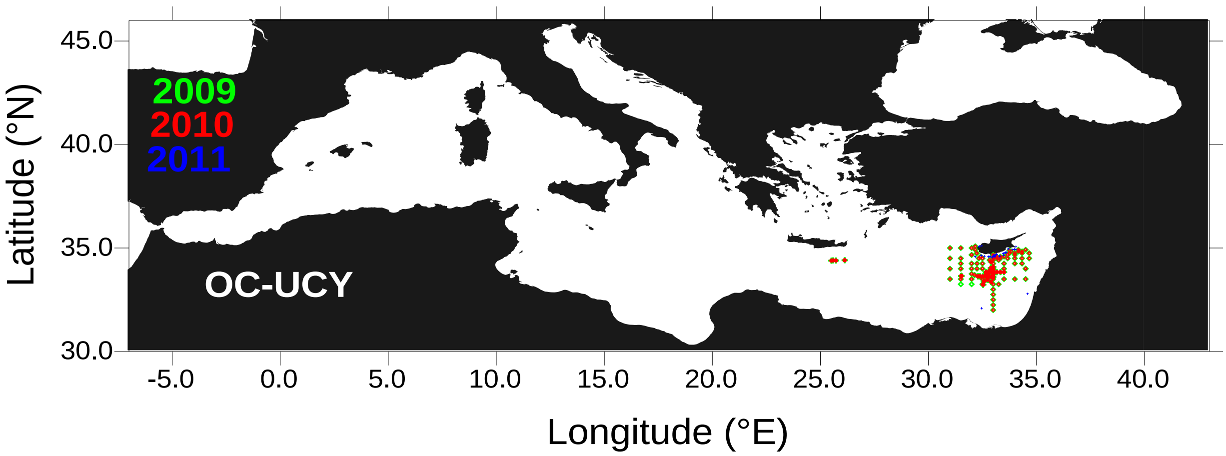

Figure 2.6. Station map 2009-2011 of OC-UCY.

SIORAS (Russia) activities included only one cruise in 2009 in the eastern Black Sea (Fig. 2.7).

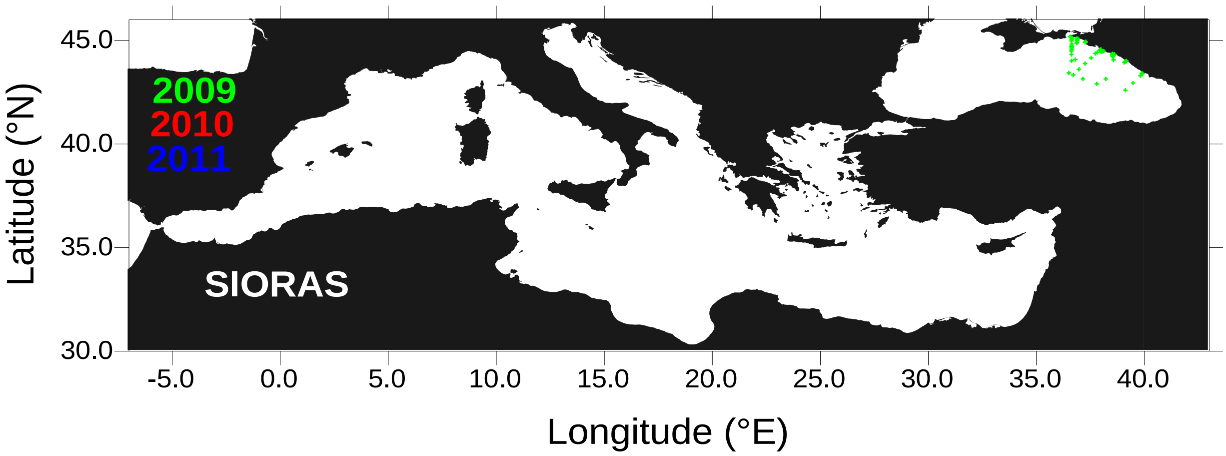

Figure 2.7. Station map 2009-2011 of SIORAS.

IOF (Croatia) activities concentrated in 2009 and 2010 in the Adriatic Sea (Fig. 2.8).

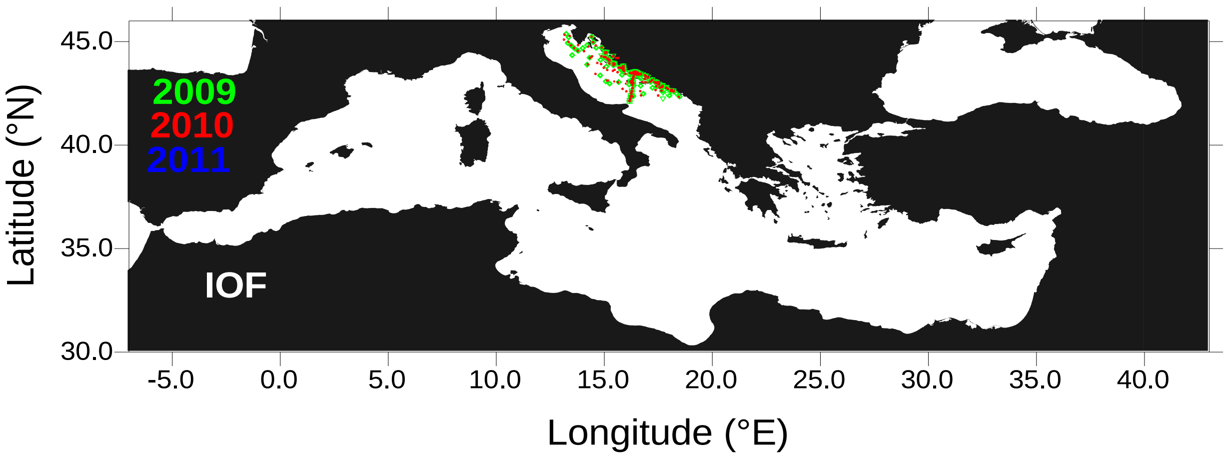

Figure 2.8. Station map 2009-2011 of IOF.

2.2.3 Local scale surveys

IMS-METU (Turkey) activities concentrated along the whole coast of Turkey in the Mediterranean as well as in the Black Sea (Fig. 2.9).

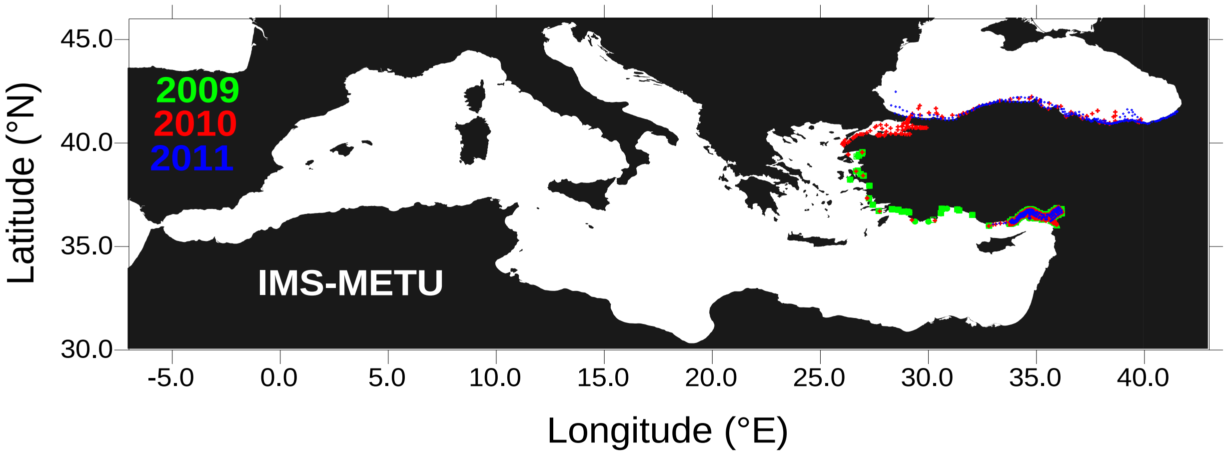

Figure 2.9. Station map 2009-2011 of IMS-METU.

IEO-COB (Spain) activities concentrated along the whole coast of Spain, including the Balearic Islands, and extended from the coast to the outside slope (Fig. 2.10).

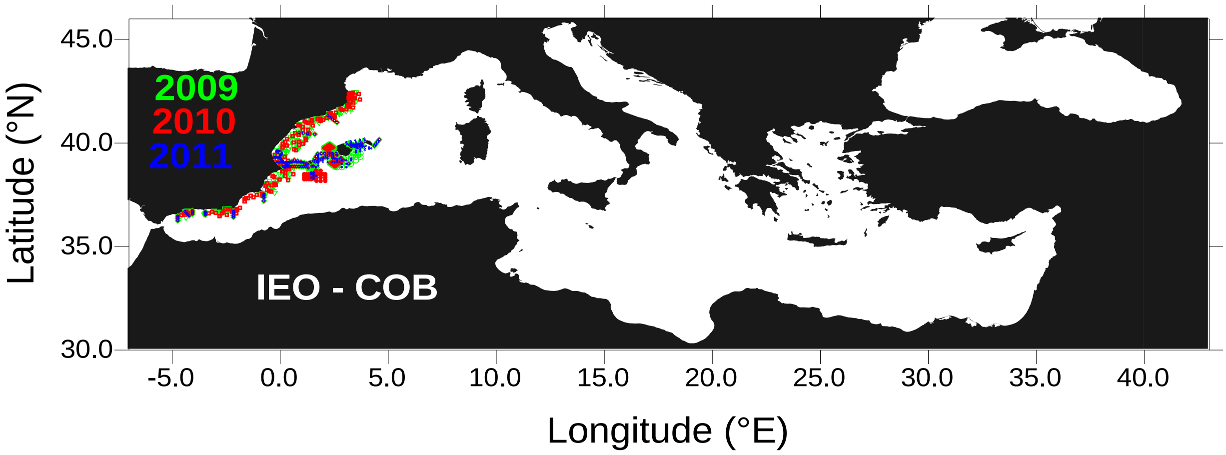

Figure 2.10. Station map 2009-2011 of IEO-COB.

IOLR (Israel) activities mainly concentrated along the HAIFA section, off the coast of Israel (Fig. 2.11).

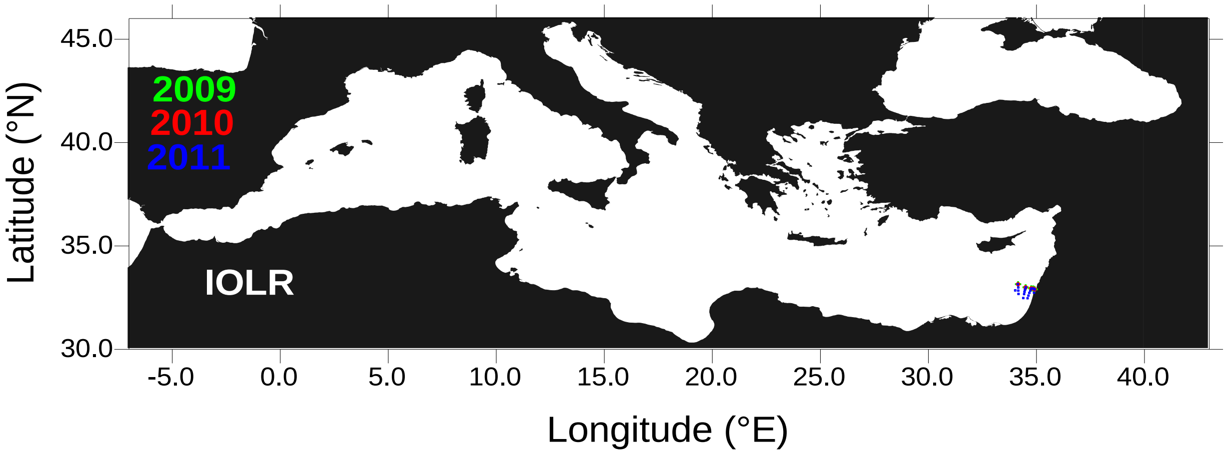

Figure 2.11. Station map 2009-2011 of IOLR.

2.2.4 Overall picture & gaps

The Mediterranean and Black Seas have been sampled quite extensively by different countries during the past years. In order to provide an overall picture that will allow us to identify gaps, in this section we combine the station maps of all institutes, by single years as well as for the whole period (see Figs 2.12 to 2.15). The single years are quite similar, denoting the tendency of performing repeated cruises of most of the institutes.

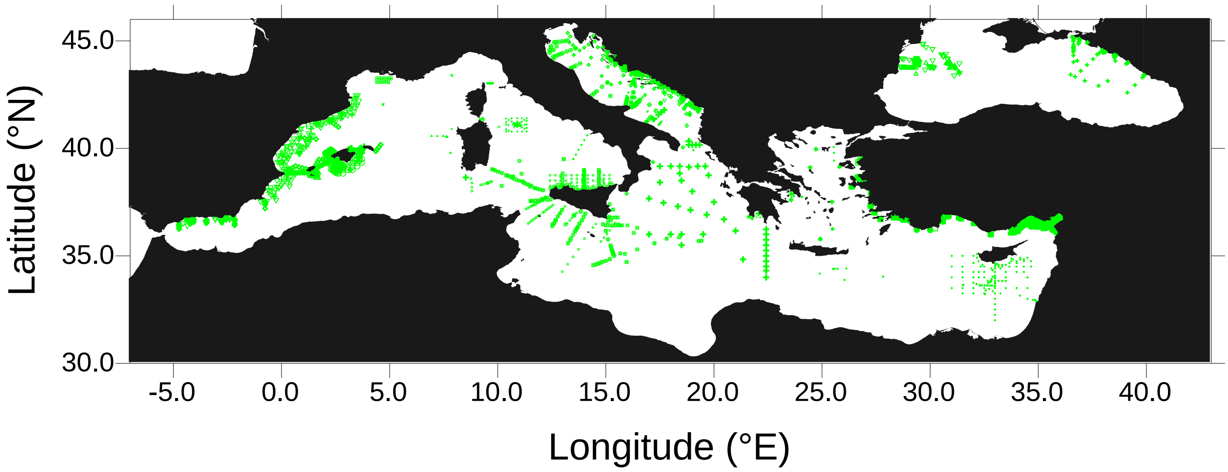

Figure 2.12. Station map 2009 of all Institutes.

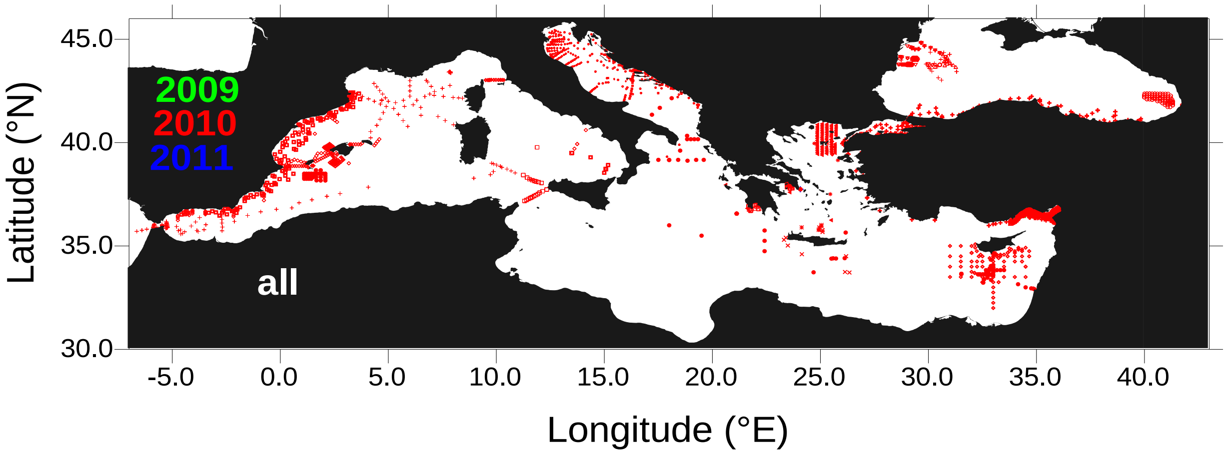

Figure 2.13. Station map 2010 of all Institutes.

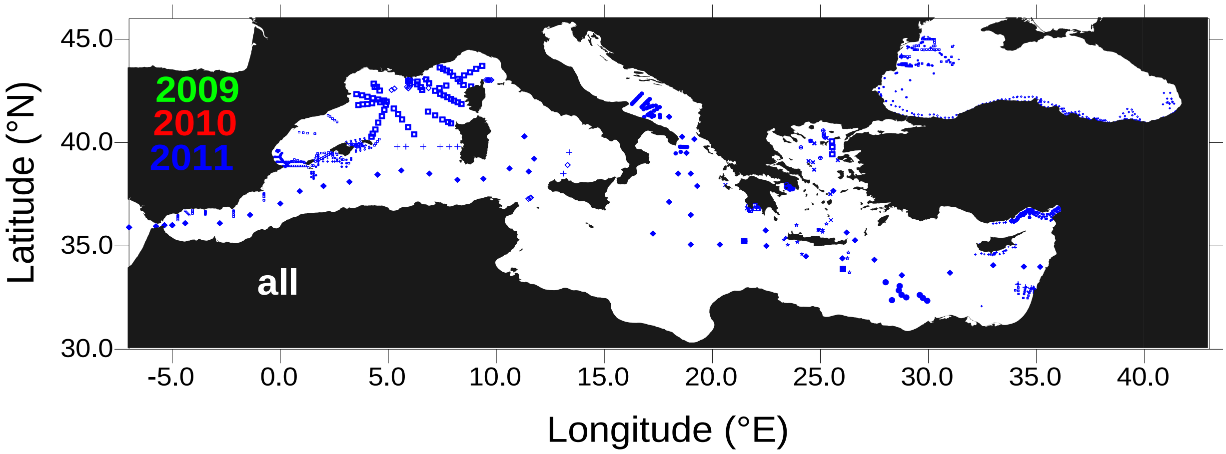

Figure 2.14. Station map 2011 of all Institutes.

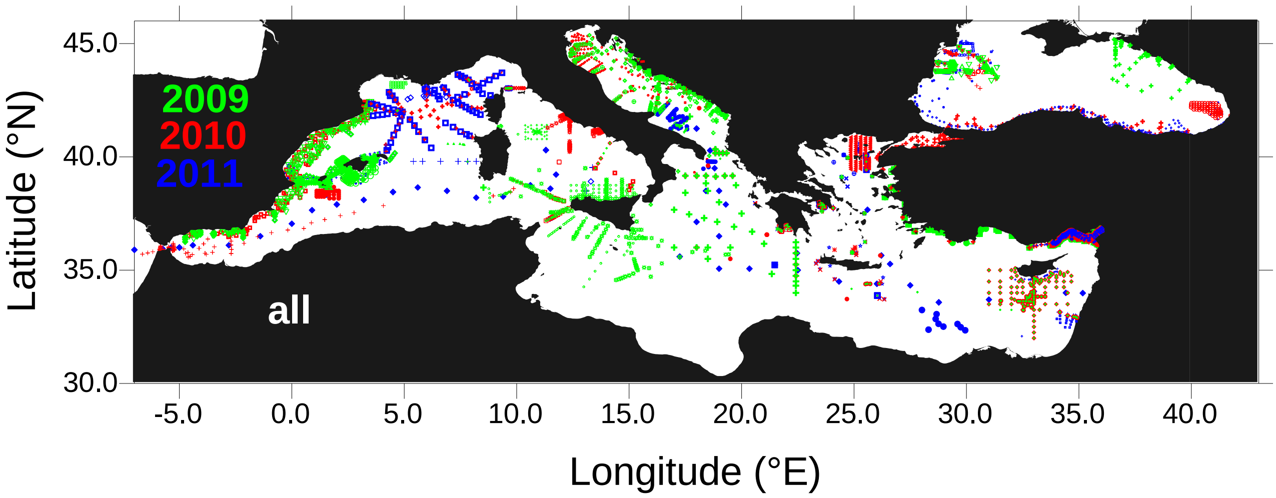

Figure 2.15. Station map 2009-2011 of all Institutes.

The above maps were carefully analyzed and gaps are identified and recommendations are given to improve the network as a whole and to meet the PERSEUS objectives. The following map (Fig. 2.16), showing all stations surveyed by the above mentioned institutes between 2009 and 2011 (i.e. before the start of PERSEUS), highlights the presence of “blank areas” (denoted by the circles), and the importance for SES community to increase the horizontal extension of their surveys in certain areas.

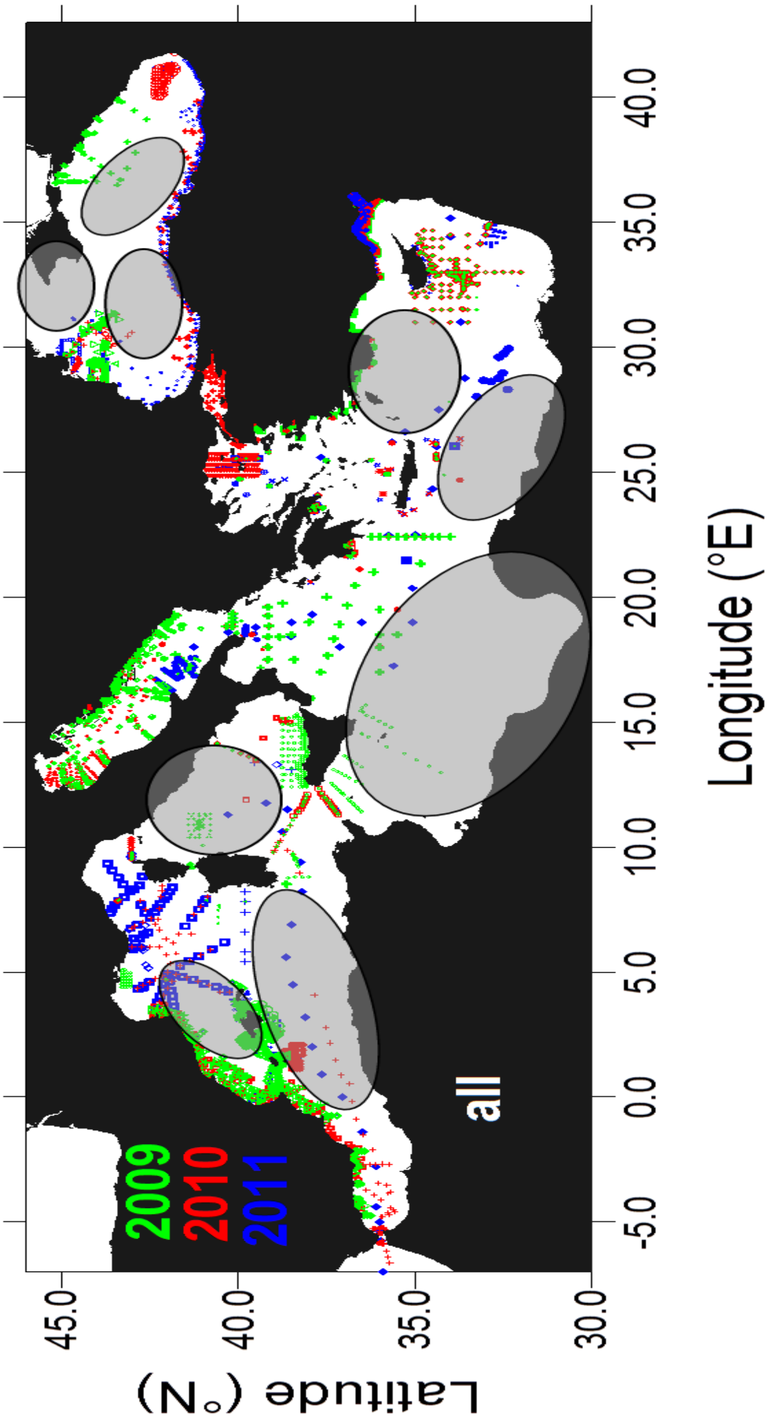

Figure 2.16. Station map 2009-2011 of all Institutes highlighting gaps in the coverage.

2.2.5 Procedures for data collection

A table included in Appendix 2 provides a synthesis of the procedures for data collection, processing (including QC) and archiving adopted by the institutes that have taken part in the survey. Many of the data are confidential, but are available upon request and scientific collaboration with the PIs is encouraged even in cases when the data are open. Most data are archived locally and/or only metadata are accessible via web. Data availability is certainly area topic where improvements should be seen in the forthcoming years.

3. SUBTASK 3.1.3 MOORINGS (DEEP AND COASTAL, “WATER COLUMN”-ORIENTED)

The Mediterranean mooring network consists of coastal and open sea Eulerian observatories that monitor a variety of atmospheric and water physical and biochemical parameters. This network of fixed point observatories is a component of the Mediterranean observing system that has been developed through major EU projects (MFSPP 1998-2001, MFSTEP 2001-2005) and national initiatives (ESEO, Adricosm, POSEIDON, CYCOFOS etc) under the coordination of MOON (www.moon-oceanforecasting.eu) and MedGOOS (www.medgoos.net). Other components of the Mediterranean observing systems are the Argo floats (MedARGO), the VOS program and the remote sensing component for delivery or customized products for assimilation into ocean forecasting systems (fig. 3.1). The target of this section is to review the existing mooring network focusing, primarily, on the multi-parametric open sea moorings (EuroSITES) but also the components of the national buoy networks that have a water column monitoring capability. The existing and planned configuration of the systems will be reviewed (sensors, depths, technology) with emphasis on their capacity to deliver data relevant to marine environmental monitoring and assessment (MSFD). Re-analysis of the existing time series from these stations will be used to identify temporal scales of variability from inter-annual to seasonal and synoptic time scales (including episodic events).

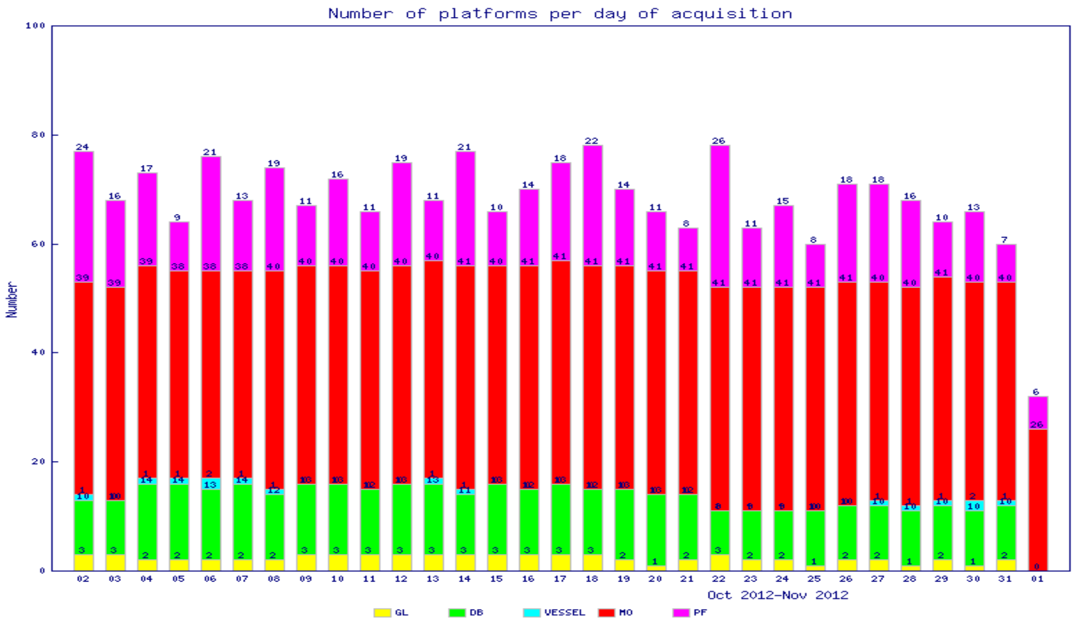

Figure 3.1. Daily files per platform hosted in Med portal (HCMR). Red are moorings.

http://www.poseidon.hcmr.gr/myocean/output/kpi2a/2012/11/kpi2a_bars_20121101.png

3.1 MOORING NETWORKS

3.1.1 EuroSITES observatories – M3A array

The EuroSITES project was funded within the EU FP7 to aid the convergence of the efforts of the 11 European-wide deep ocean observatories which formed its core. A major output of the project was envisaged as the synergies of the 13 partners working together to create a network providing sets of data in near-real-time, and in delayed-mode, which have been collected and processed in such a way as to be accessible to the wider scientific community, and comparable across time and site. The common data policy agreed by all the partners at the start of the project, and the evolution of a EuroSITES quality control manual which includes all the observatories practices, have formed the framework within which each data management group has delivered datasets which now carry the EuroSITES 'brand' as well as all the originators details.

The M3A array has been developed for the needs of the Mediterranean Forecasting System (MFS, an initiative of the Mediterranean Task Team of EuroGOOS) through a number of European research projects (1998-2005). The long-term goal of MFS is to develop an operational ocean monitoring and forecasting system for the Mediterranean Sea with forecasting capability up to the primary production. The system was then merged with other European efforts to develop a Global Ocean Monitoring and Forecasting capacity through the MERSEA (EU/FP6 funding) project while it now contribute to the EuroSITES project (EU/FP7 funding) that coordination the European contribution to OceanSITES.

From the 11 sites contributing to EuroSITES, six are located in the Mediterranean, of which three of them are included in the M3A array. Five of these observatories are reviewed in this section. In the Western Mediterranean there is the Dyfamed station located in the North-West of Ligurian Sea and operating since 1991, while in the Eastern Mediterranean there is the POSEIDON-Pylos station located in the South Ionian Sea and operating since 2007. The M3A array consists of the prototype system E1-M3A which operates in the south Aegean Sea (Eastern Mediterranean) since 2000 while two more systems operate since 2004: the E2-M3A in the south Adriatic Sea and the W2-M3A in the Ligurian Sea. Their locations are displayed in Fig. 3.2.

Figure 3.2. The EuroSITES network in the Mediterranean. Green dots correspond to associated with EuroSITES mooring sites (http://www.eurosites.info/sites.php).

3.1.2 National buoy networks

National buoy programs have also contributed for many years to the Mediterranean buoy network. These sites in most cases are coastal and monitor only the basic sea surface and meteorological parameters. For the scope of PERSEUS a number of such observatories with enhanced monitoring capacities which are operating mostly through national funding in the Mediterranean Sea were also examined. In the Western Mediterranean there are the Boya Bahia de Palma, Minorca and CC1000 in the Balearic Sea and MESURHO station in the Gulf of Lion. In the central Mediterranean there are the COR station near Corsica, CO1 and CO2 near Sicily and in Kastela Bay (Adriatic Sea). In the Eastern Med there are the Paralimni and Zygi in the Levantine and five stations in the Black Sea (Katsiveli, HYPOX, NE_BlackSea, Zmiinyi and EUXRoO1-3).

3.2 MOORED PLATFORM REVIEW

3.2.1 Review templates

A template form was disseminated to operators so as to gather useful information regarding station's configuration, characteristics, history, funding etc. (Table 3.1).

Observatory Name:										
WMO number:										
Position (degrees east/north):										
Bottom depth (m):										
PI:										
Latest News:										
If no more funding is found when will your observatory stop?										
Parameters/Variables	Depth	Sensor (or say if from water samples)	Frequency	Units of Measure	Start Year	Near real-Time (Yes/No)	Data Contact Name	Data Contact Email Address	National Funding	EU funding
ATMOSPHERIC										
OCEAN										
Additional samplers in test phase / short-term deployments (not yet part of the long-term time-series)										
Parameters/Variables	Depth	Sensor	Frequency	Units of Measure	Year	Near real-Time (Yes/No)	Data Contact Name	Data Contact Email Address	Funding (name and ti	EU funding

Table 3.1. Table form that has been dissiminated to PERSEUS partners.

The forms submitted by PIs detailed 21 stations, which is more than the 11 stations indicated in the DOW.

3.2.2 Review results

The following table shows the stations submitted in that query (Table 3.2). Most of the stations are coastal, whilst 7 of the platforms can be characterized as open sea moorings with regard to the distance from coast and deployment depth. Regarding the water parameters measured, most of the platforms are capable of recording temperature and salinity (T&S) at several depths, whilst the minority include additional biochemical or acoustic sensors. An important number of platforms only measure surface T&S (Fig. 3.3).

Station	Country/Organization	Offshore/Coastal	Water column	Biochemical	Acoustic
DYFAMED	France CNRS	Offshore	Yes	Yes	No
LION	France CNRS	Offshore	Yes	No	No
Boya Bahía de Palma	Spain IMEDEA	Coastal	No	Yes	No
COR	Italy CNR	Coastal	Yes	No	No
W1M3A	Italy CNR	Offshore	Yes	Yes	Yes
E2M3A	Italy OGS	Offshore	Yes	Yes	No
CO1	Italy CNR	Coastal	Yes	No	No
CO2	Italy CNR	Coastal	Yes	No	No
POSEIDON-PYLOS	Greece HCMR	Offshore	Yes	No	Yes
E1M3A	Greece HCMR	Offshore	Yes	Yes	No
CC1000	Spain IMEDEA	Coastal	No	No	No
MINORCA	Spain IMEDEA	Offshore	No	No	No
Kastela Bay	Croatia IOF	Coastal	No	No	No
MESURHO	France Ifremer	Coastal	Yes	Yes	No
Paralimni	Cyprus UCY	Coastal	No	No	No
Zygi	Cyprus UCY	Coastal	No	No	No
Katsiveli	Cyprus UCY	Coastal	No	No	No
HYPOX	Romania GeoEcoMar	Coastal	No	Yes	No
EUXRoO1-3	Romania GeoEcoMar	Coastal	Yes	Yes	No
NE_BlackSea	Russia SIORAS	Coastal	Yes	Yes	No
Zmiinyi	Ukraine ONU	Coastal	Yes	Yes	No

Table 3.2. Stations submitted for the needs of Perseus 3.1.3 subtask.

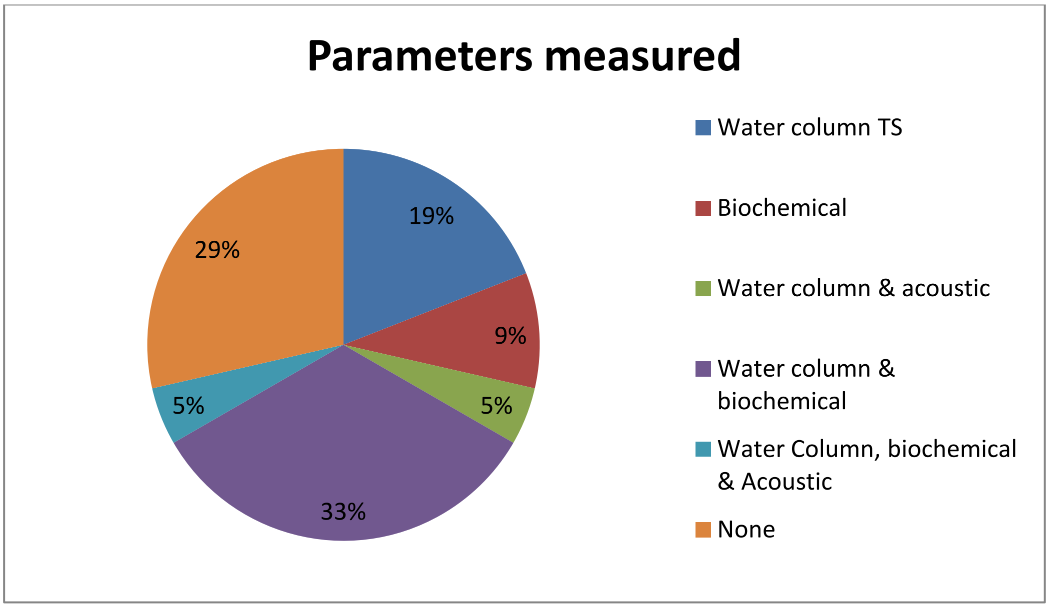

Figure 3.3. Parameters measured by reviewed stations.

In the templates received several attributes were missing some of which are important either for data management issues (e.g. the WMO numbers) or regarding funding for the station's maintenance and operation.

3.2.3 Examples and graphs

Two of the reviewed stations are presented here. The first is MESURHO platform located in the NW Mediterranean Sea, at the Rhone river mouth in the Gulf of Lions (Fig. 3.4). It is one of the best examples of coastal stations, as it is integrating a large variety of physical and biogeochemical sensors, with measurements at several depths. The station is used to assess the inputs from the river, as the Rhône is the main fresh water input to the Mediterranean Sea and brings nutrients, chemicals and solid materials to the open sea. The different measurements are used to compute liquid and solid fluxes and the inputs of chemicals (naturals and anthropic). A large amount of sediments are subject to deposit and resuspending during extreme events (floods, etc). The central node of the system is a BFI (Submerged Floatation Buoy) mooring used for navigation, hosting sensors down to 20m depth, and the surface buoy for real time telemetry and air-sea interaction measurements. An ADCP and a benthic station (for dissolved oxygen measurements in sediment) are connected to the system via cables. The mooring line configuration hosts two NKE SMATCH buoys at 2.5m depth and 19m depth for temperature, salinity, pressure, turbidity, dissolved oxygen and fluorescence. The mooring is using a cable that allows transmission of data from the sensor packages to the surface buoy. The surface buoy hosts a set of sensors for air-sea interaction studies (wind speed and direction, air pressure, air temperature, relative humidity, precipitation rate and light irradiance surface). At the seafloor, an ADCP is used to provide currents along the water column and wave heights and directions, together with the temperature at the bottom. Table 3.3 presents the platform's configuration.

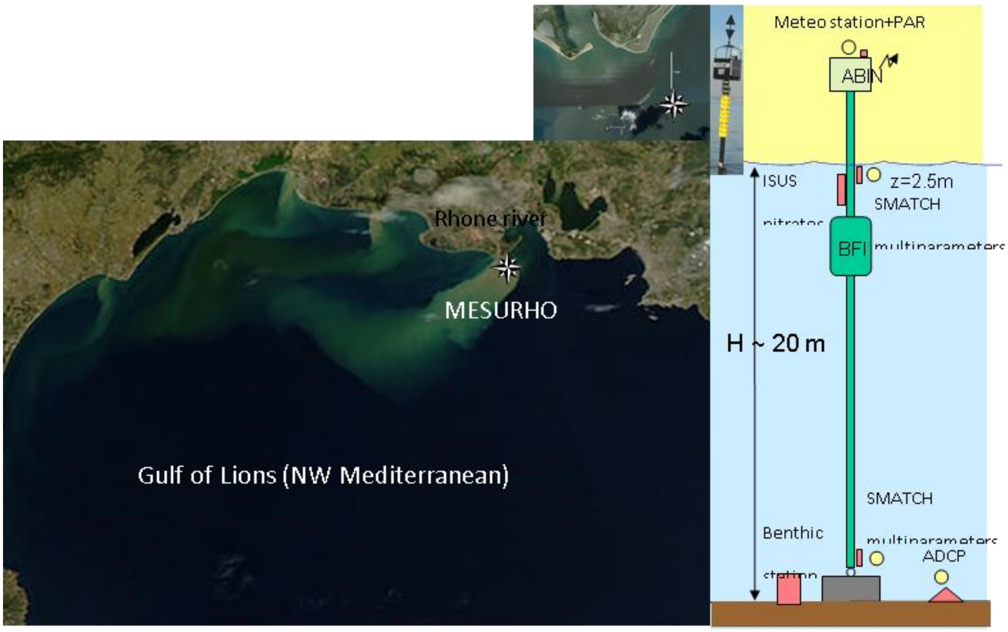

Figure 3.4. MESURHO station in the Gulf of Lions.

Parameter	Depths measured (m)	Sensor(s) used
Wind speed/dir.,	Surface	Vaissala
Air Pressure,	Surface	
Air temperature,	Surface	
Precipitation Rate	Surface	
Relative humidity	Surface	
Light Irradiance PAR	Surface	
Salinity	3m,19m	NKE SMATCH/VTW sensor
Turbidity	3m,19m	NKE SMATCH/Seapoint sensor
Dissolved Oxygen	3m,19m	NKE SMATCH/Anderaa sensor
Fluorescence	3m,19m	NKE SMATCH/turner design sensor
Pressure	3m,19m	NKE SMATCH

Seafloor platform

Benthic Dissolved Oxygen	20m	Aanderaa Optode
Currents	0.5-19m, 37 bins of 0.5m	RDI-600kHz
Pressure	20m	RDI-600kHz
Waves	20m	RDI-600kHz
Temperature	20m	RDI-600kHz

Table 3.3. MESURHO station configuration

Groups / P.I.s /labs /countries involved or responsible:

IFREMER, LER PAC, France

P.I. : Ivane Pairaud (ivane.pairaud@ifremer.fr)

Partners (French) : IRSN, LSCE, MIO, Cerege, CETMEF, Phares et balises

The second platform presented here is the POSEIDON-Pylos multi-parametric platform (Fig. 3.5). The site in the SE Ionian Sea incorporates the steep marginal slopes and basins of the western segment of the Hellenic Arc and Trench System. It is a typical subduction zone that is the geotectonically most active region in Europe implying a complicate submarine morphology with numerous, deep, pull apart sub-basins and a variety of geohazards like high seismicity, slope instabilities and basin wide tsunamis. The deep waters of the sub-basins of the Ionian are sensitive to climate changes since the deep sub-basins are the ultimate destination of dense water masses formed in the Adriatic and Aegean. Consequently the temperature, salinity and dissolved oxygen of bottom waters provides an archive of the interannual and long term variability of climatic forcing in the area. Furthermore, being the most oligotrophic European Sea the deep ecosystem is sensitive to climate changes. It is also well known that the Hellenic Trench is a major pathway and important feeding ground for cetaceans in the Eastern Mediterranean (SE Sicily-SW Peloponnese-S Crete-W Cyprus).

Figure 3.5. Location of POSEIDON Pylos station in the SE Ionian.

The central node of the system is the mooring line hosting sensors in its upper 1000m, and the surface buoy for real time telemetry and air-sea interaction measurements. An autonomous seabed platform is hosting a set of sensors for near bed measurements including high frequency pressure for Tsunami detection. The platform communicates with the surface buoy through acoustic modems. Both systems are deployed at 1670m depth (Fig. 3.6).

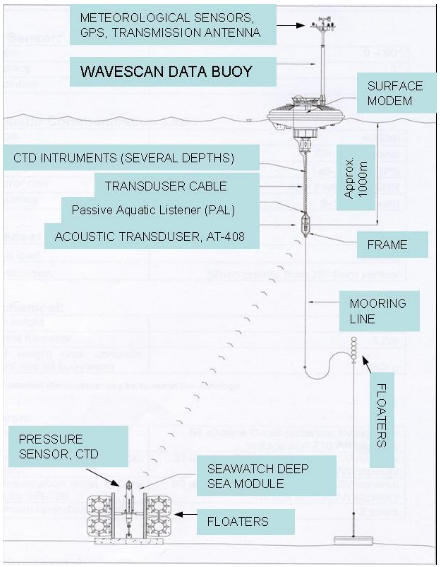

Figure 3.6. Architecture of POSEIDON Pylos station.

The following table describes the buoy's and seabed platform's configuration (Table 3.4)

Groups / P.I.s /labs /countries involved or responsible:

Hellenic Centre for Marine Research

Institute of Oceanography

P.I.: Kostas Nittis (knittis@hcmr.gr)

Parameter	Depths measured (m)	Sensor(s) used
Wind speed/dir.,	Surface	Young 04106
Air Pressure,	Surface	Vaisala PTB 220A
Air temperature,	Surface	Omega
Wave Height, direction, period	Surface	Fugro OCEANOR Wavesense
SST, SSS surface,	Surface (1m)	Seabird 37-IM SIP

Currents	Surface (1m)	Nortek Aquadopp 400 kHz
Temperature	20, 50, 75, 100, 250, 400, 600, 1000m	Seabird 37-IM C-T
Salinity	20, 50, 75, 100, 250, 400, 600, 1000m	Seabird 37-IM C-T
Pressure	250m	Seabird 37-IM C-T-P
Sound	500m	PAL

Seabed platform

Temperature	1670m	Seabird 16plus-C-T
Salinity	1670m	Seabird 16plus-C-T
Dissolved oxygen	1670m	Aanderaa Optode
Pressure	1670m	Paroscientific

Table 3.4. POSEIDON Pylos station configuration.

The following graph presents water temperature, multi-depth time series, as recorded by the station during the period 2008-2010 (Fig. 3.7).

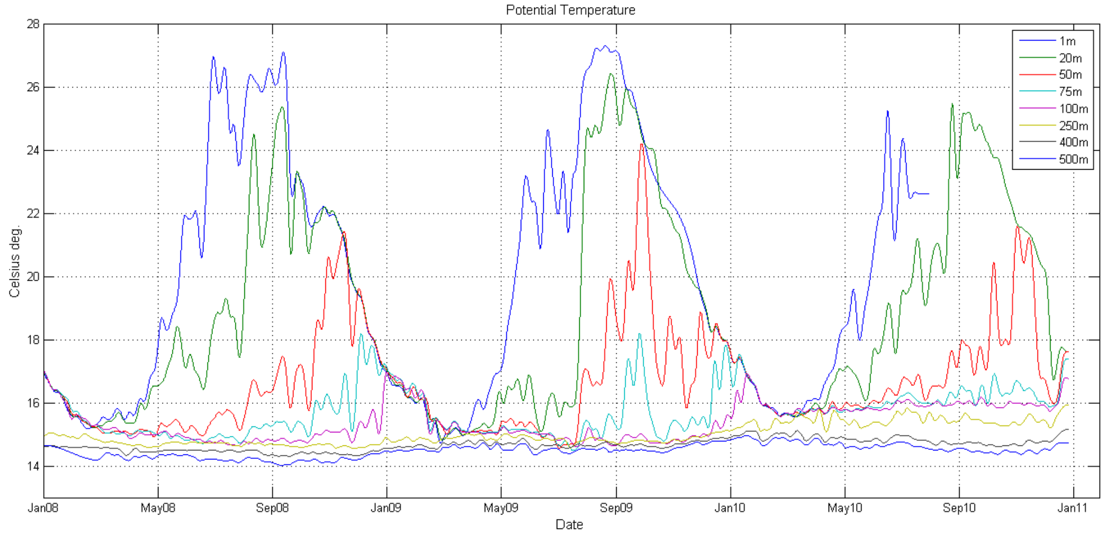

Figure 3.7. Potential temperature at multi-depths from POSEIDON Pylos station.

3.3 CONCLUSIONS

3.3.1 Issues of concern – Identifying gaps

The Mediterranean buoy network has been a significant component of Mediterranean monitoring and forecasting, and has undergone several upgrades during the last decade. Compared to other operational platforms, moorings are presenting divergences between them, hence there are some points operators should focus on in order to cover today's needs. Some of these issues of concern and gaps are the following:

- Need for homogenization of data management policy, which includes common data quality procedures, metadata description, common vocabularies etc.
- WMO numbers are missing and so is provision of information to central databases (ex. EDIOS)
- In many cases lack of sufficient funding for maintenance and upgrades
- Geographical coverage is poor (see Fig. 3.8) especially for open sea moorings. Important sub basins are understudied in terms of a fixed point continuous monitoring (Levantine, Central-South basin etc.)
- New sensor technology (optical, acoustic, etc.) has not been integrated yet in the majority of platforms
- Lack of monitoring additional parameters. A few biogeochemical timeseries are available today while water-column and seabed data are sparse

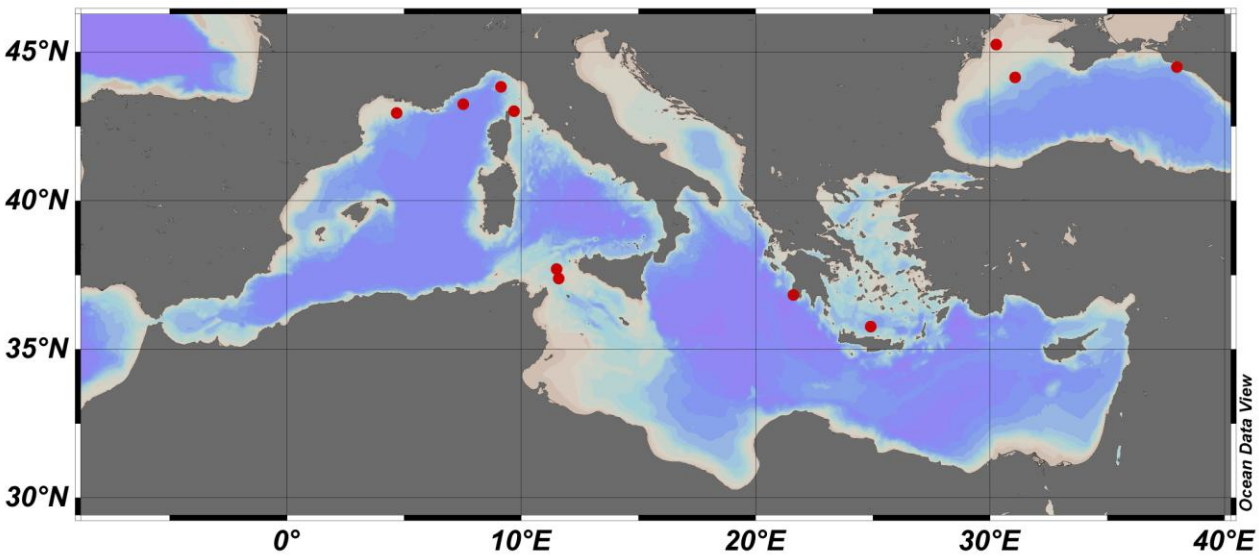

Figure 3.8. Locations of water-column oriented moorings operational in the SES at the beginning of the PERSEUS project.

In the framework of PERSEUS these issues will be further specified and clarified with discussions between other WPs, partners and operators in order to meet the needs of MFS and MFSD.

3.3.2 Recommendations

There must be an effort during the upcoming period towards an effective cooperation between agencies and PIs in order to establish a more homogenous management of moored platforms. Each operator must be encouraged to submit all necessary information in pan European directories and databases, keep track of changes and update regularly. Each station should have a unique WMO number. Data management recommendations must be circulated to operators and validation-calibration procedures must be established in a more comprehensive way. Encouragement and support new buoy deployments emphasising in offshore locations of important transitional areas where timeseries will boost research studies and operational work. Emphasis must also be given in integrating biochemical sensors as timeseries moorings are at present the only method/technology to provide a complete long term suite of biogeochemical variables, such as chlorophyll, oxygen, CO2, oxygen, nutrients. These data are essential for validation and assessment purposes. Operators must keep track of new sensor technologies and propose new fields of research and monitoring such as environmental studies, geology, benthos etc.

4. SUBTASK 3.1.4 GLIDERS (LOCAL, SUB-BASIN)

In this section we review the glider activity in the Mediterranean Sea since the very first deployments in 2004. About 130 gliders missions have been gathered for this study. We provide a yearly description of the glider activity and indexes of these glider missions according to 3 sub-regions: Western, Central and Eastern basins. The monitoring programs, in which framework gliders are nowadays regularly deployed, are then described. Finally, we review the existing glider activity and identify the gaps in the observational network in term of spatio-temporal coverage and parameters.

4.1 Glider activity summary

Glider operations in the Mediterranean Sea have started in the framework of European projects of operational oceanography. In the framework of the MFSTEP project, two gliders (ifm01 and ifm02/Deepy) were deployed in the Ionian basin by IFM-GEOMAR, IAMC, and LPO teams. First, a repeat section between Italy and Libya was carried out during the period September 2004 - February 2005. Further deployments (from September 2005 until now) of gliders by DT-INSU, IFM-GEOMAR, IMEDEA, LOCEAN, LOV, LPO, NOCS, OC-UCY, OGS and SOCIB teams have been carried out in the Mediterranean Sea in the framework of the MERSEA, DOCONUG, LIVINGSTONE, and other national initiatives. Noteworthy are several glider fleet experiments (with up to 9 gliders working together) that focus on specific oceanic processes (deep convection, mesoscale features) or try to achieve adaptive sampling, that were carried out for periods of up to few months thanks to international collaboration. Nowadays, gliders are still being deployed in the Western and Eastern parts of the Mediterranean on a more or less regular basis, mainly in the framework of national projects (MOOSE, SOCIB, and YPOKINOUMODA) and European (FP7-JERICO and FP7-PERSEUS) projects.

Both single glider and fleet experiments have been carried out. Single glider deployments have been carried out for demonstration purposes, or in conjunction with other observations in the framework of scientific experiments, or in the framework of regular transects (repeat-sections/endurance lines). Fig. 4.1 shows the overall spatial coverage of these deployments over the period 2004-2012. This consists of more than 60 000 profiles (max 1000 m depth) that can be considered as vertical, considering the dive/ascent slopes (17-26 degrees to the surface) of the gliders that are much steeper than the slopes of the measured oceanic variables. The equivalent horizontal resolution between the profiles depends on the depths of the dives but typically ranges from ~500 m for 200 m dives to 2-4 km for 1000 m dives.

Figure 4.1 : Map of all glider deployments from September 2004 to December 2012.

All gliders collect temperature and salinity 'vertical' profiles as well as the average horizontal current over the dives (by comparing GPS fixes at surface and the dead reckoned position at depth). Most of the gliders have been equipped with miniaturized biogeochemical sensors. The most frequent of which are sensors collecting fluorescence chlorophyll concentration (CHL-A) and oxygen concentration, and sensors measuring the water turbidity through optical backscatter at various wavelengths. There are also some deployments with irradiance sensors, beam attenuation sensors and more recently nitrate and noise sensors. The lack of a standardized science bay for biogeochemical applications has lead to a rather heterogeneous fleet of Mediterranean gliders in terms of configuration. However, most of the gliders are equipped with oxygen and fluorescence CHL-A sensors so the map of glider measurements including these parameters is identical to the distribution shown in Fig. 4.1. For the other parameters there would be more drastic modification. For instance, only two deployments of gliders equipped with nitrate sensors have been carried out so far in the Ligurian Sea.

See Appendix 3 for a list of glider missions in the Western, Central and Eastern Mediterranean Sea.

4.2 Spatio-temporal coverage

Gliders have been intensively deployed in the Mediterranean Sea compared to other areas studied by European glider teams. Since the pioneering deployments in the Ionian Sea, one can only observe a growing activity in the western and eastern parts of the Mediterranean Sea and some areas are now covered in such a way that climatologies have to be updated. Glider operations in the Mediterranean Sea started with Slocum gliders in the framework of European projects of operational oceanography. Indeed, in the framework of the MFSTEP project, two gliders have been deployed in the Ionian basin by IFM-GEOMAR, IAMC, and LPO teams. A repeat section between Italy and Libya was carried out during the period September 2004 - February 2005 with a 200 m glider as well as a virtual mooring south of Calabria in February 2005 with the first 1000 m Slocum prototype (Fig. 4.2).

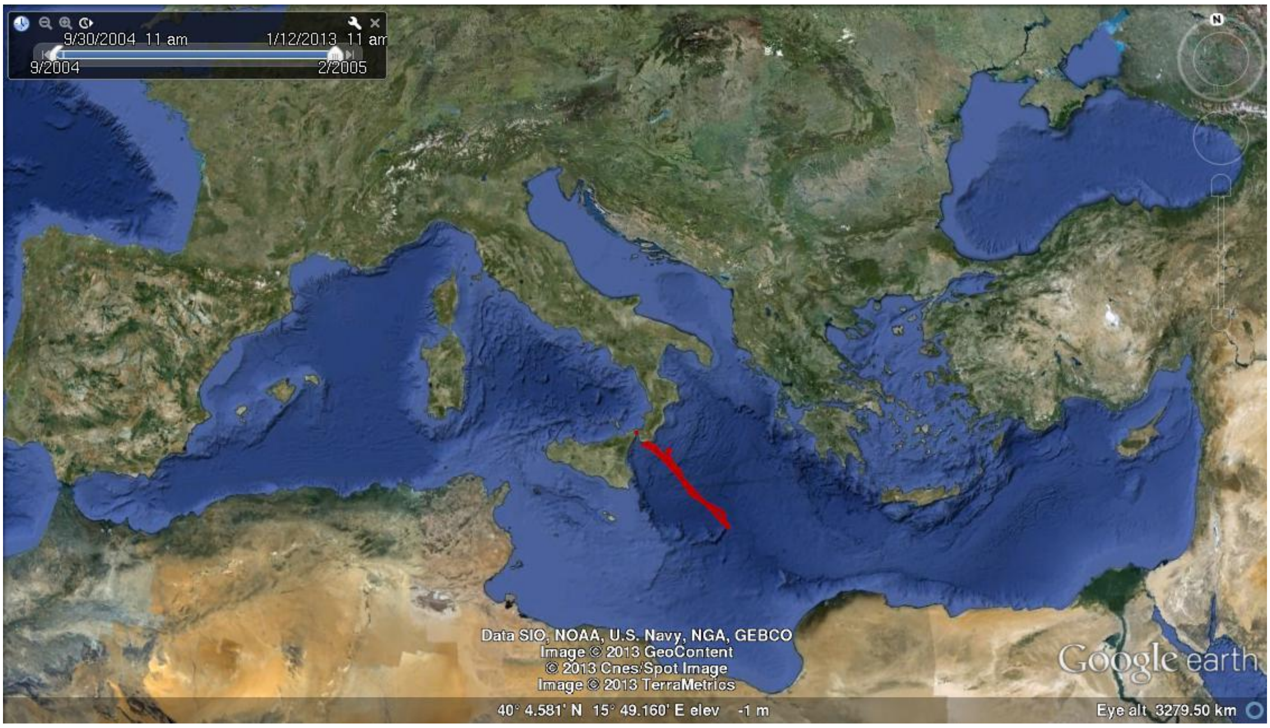

Figure 4.2 : Map of all glider deployments from 1st September 2004 to 1st September 2005.

After these first successful deployments, glider operations were carried out in the Western Mediterranean Sea in 2005 in the framework of the MERSEA project. Several deployments were carried out offshore of Mallorca (Fig. 4.3) in order to further test the prototype deep Slocum and prepare the upcoming experiments planned to start in winter 2007.

Figure 4.3 : Map of all glider deployments from 1st September 2005 to 1st September 2006.

A major fleet experiment was carried out in winter 2007 with 7 gliders sampling the northwestern Mediterranean Sea (including the Balearic straits) at the same time, for a period of 3-4 months (Fig. 4.4). The deployments involved the following gliders: ifm02_deepy, ammonite, bellamite, coprolite, pytheas, icoast00, tournesol and spray016. This experiment was possible thanks to the coordination of various projects:

- the MERSEA project aiming to "feed" numerical models with appropriate (physical and biogeochemical) data for operational oceanography, in particular in combination with mooring data such as the M3A moorings array.
- the DOCONUG project (in black) focusing on the deep convection events occuring in the Gulf of Lions responsible for the ventilation of the deep waters of the whole western Mediterranean Sea
- the PABO project (in orange) aiming to supplement the long terms biological, chemical, and physical observations carried out at the same station DYFAMED since 1995 with gliders equipped with bio-optical sensors
- the LIVINGSTONE project (in purple) designed to study the exchanges across the continental slope between the shelf and the open-ocean from both physical and biogeochemical points of view.

These glider operations in the Mediterranean were coordinated in order to demonstrate the capability of a network of gliders for oceanographic observations. The gliders were deployed in order to gain, for the first time, an observing network in this region that is capable of sampling an area at various temporal and spatial scales from the smallest (~500 m horiz./minutes) to the largest (~300 km/weeks).

Figure 4.4 : Map of all glider deployments from 1st September 2006 to 1st September 2007.

As stated in Testor et al. (2007), only Mother Nature itself was able to spoil the observations of deep convection by producing one of the warmest winters on record. The very mild air temperature conditions of that winter triggered convection down to only 400m depth, which is not a proper deep convection event. Considering the sampling carried out by these gliders it was very unlikely that deep convection reached greater depths than that. Partly due to this problem, the EGO2007 experiment was repeated a year later in 2008 (Figure 4.5) with 9 gliders sampling the deep water formation area during the winter. In parallel to a detailed data analysis showing the potential of gliders to collect biogeochemical data (Nieviadomska et al. 2008). Later, in 2008, a first deployment in the Alborán Sea was carried out in the framework of the EU project SESAME which demonstrated the capability of gliders to operate in areas characterized with very high currents (Ruiz et al., 2009a). A synergy with operational products was carried out (L'heveder et al., 2009). The glider trajectories were actually forecasted using the MERCATOR model outputs during the experiment. This allowed a better steering and coordination of the whole fleet while the bottom line was that the operational products were getting better locally around the glider measurements assimilated by the forecasting systems. In addition, Loveday et al. (2012) showed that gliders can be used to assess the performance of regional forecast models. Ruiz et al. (2009a) combined this glider data with satellite altimetry in order to obtain estimates of oceanic vertical velocities. Among other results, Merckelbach et al. (2010) showed that the gliders could be used to measure vertical velocities during deep convection events as high as ~10cm/s. This allowed several studies of the mesoscale variabitility and abrupt winter mixing characterized by gliders by Ruiz et al. (2009b, 2012) and Bouffard et al. (2010) in the northwestern Mediterranean Sea. In parallel, glider activity started in the Eastern Mediterranean Sea in the framework of the YPOKINOUMODA project (see section 4.3).

Figure 4.5 : Map of all glider deployments from 1st September 2007 to 1st September 2008.

Starting in 2009, gliders have been deployed along endurance lines to monitor the oceanographic variability of the western basin (Figure 4.6) across a few key sections in the framework of MOOSE and SOCIB (Ruiz et al. 2011 - see Section 3) which induced further studies such as Bouffard et al. (2012) and Heslop et al. (2012). In addition, a deployment was carried out by OGS in the Tyrrhenian Sea to study the circulation around a seamount (Mauri et al., 2010) and an adaptive sampling experiment (Alvarez and Mourre, 2012; Mourre et al., 2012) carried out by the NATO/NURC in the Ligurian Sea.

Figure 4.6 : Map of all glider deployments from 1st September 2008 to 1st September 2009.

In December 2009, six gliders were deployed to characterize the Warm Core Cyprus Eddy in the framework of the EYE experiment (Hayes et al., 2010; see Fig. 4.7). The Eye of the Levantine glider experiment (EYE) was carried out from the end November 2009 to April 2010 south of Cyprus. Thanks to the 4th EGO meeting and Glider School, that was held in Cyprus in November 2009, additional gliders were deployed in addition to the YPOKINOUMODA gliders. A total of six gliders (Atalanta, Bonpland, Eudoxus, Hannon, Pytheas, Trieste-1) were deployed off Limassol toward the Erathostenes Seamount in order to sample the so-called Shikmona Gyre (EYE/Glider) and the Warm Core Cyprus Eddy which is somehow a persistent flow pattern south of Cyprus, an eddy attached to the Eratosthene seamount. This project took advantage of the synergies between ship-borne measurements from the ship TARA and data collected by these 6 steerable autonomous platforms, to understand the dynamics of this remarkable oceanic feature in terms of flow, hydrology and phytoplankton concentration. The interest was twofold. The eastern Mediterranean Sea, and in particular the Levantine basin, is an oligotrophic (i.e. with very low presence of phytoplankton) ocean and its dynamics could be then considered representative of oceanic regions having similar behaviors (like the south Pacific Gyre). South of Cyprus, over the last 2 decades, a permanent cyclonic structure has been recurrently observed during cruises and more continuously (but only at the surface) with satellite. An accurate 3-dimensional survey of this structure was still lacking. This structure is supposed to create a physical barrier, which disconnects the “inside gyre” ecosystem dynamics to the “outside gyre” dynamics, therefore in a few kilometers two contrasting ecosystems may be present. Automated control and adaptive techniques (Lekien et al., 2010) were tested during this experiment in order to better sample this circulation pattern. In summer 2010, the LIDEX experiment in the vicinity of the Corsica Channel was carried out by OGS and LOCEAN with a glider sampling around Lagrangian surface drifters.

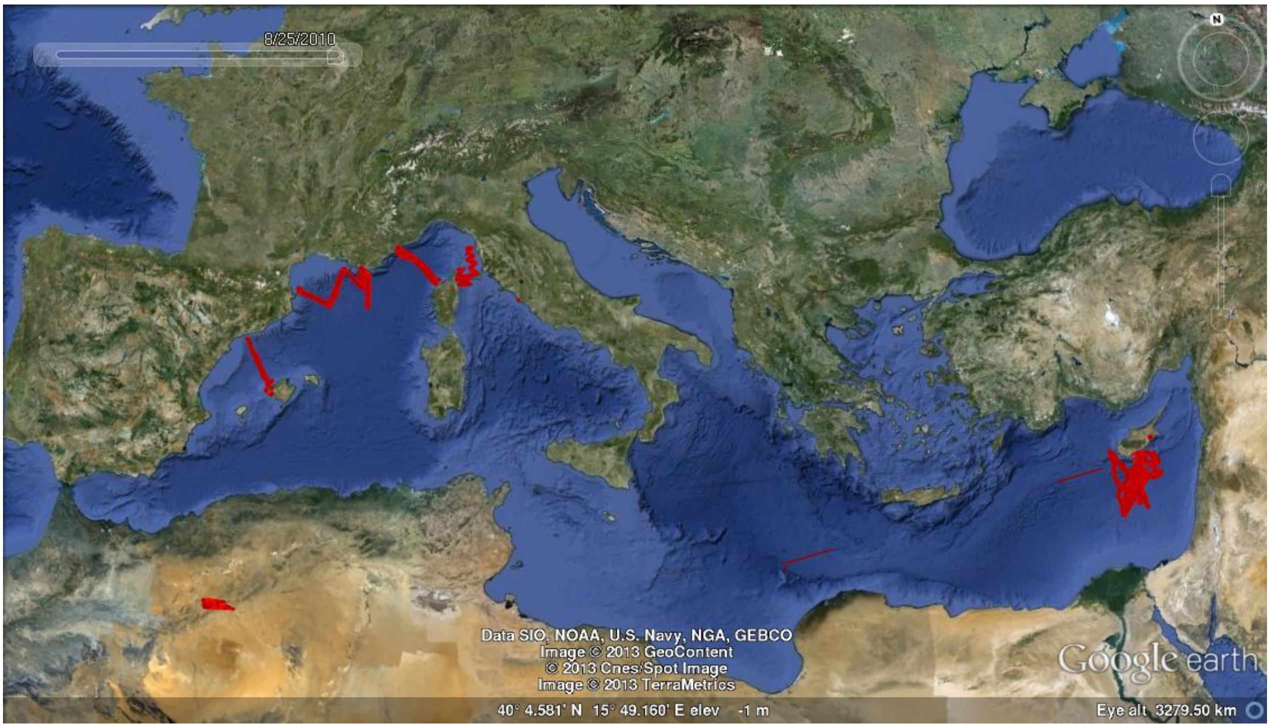

Figure 4.7 : Map of all glider deployments from 1st September 2009 to 1st September 2010.

In 2010-2011 (Fig. 4.8), the glider deployments in the Mediterranean Sea were carried out mostly in the framework of the MOOSE, SOCIB and YPOKINOUMODA projects, consolidating the long-term monitoring approach adopted by these projects. Two deployments were carried out in the Gulf of Lion in winter on the shelf and offshore in order to study the deep water formation both from cascading processes and open-ocean deep convection (Cascade project).

In 2011-2012 (Fig. 4.9), the glider deployments in the Mediterranean Sea were continued in the framework of MOOSE, SOCIB and YPOKINOUMODA projects, in the long-term monitoring approach adopted by these projects. Noteworthy, an experiment was carried out south-east of Toulon in the framework of the EU project TOSCA in order to monitor the currents and their role in the dispersion of oil spills and the first deployment of a glider equipped with a nitrate sensor was conducted in the framework of the PRONUTS project (D'Ortenzio et al., 2012).

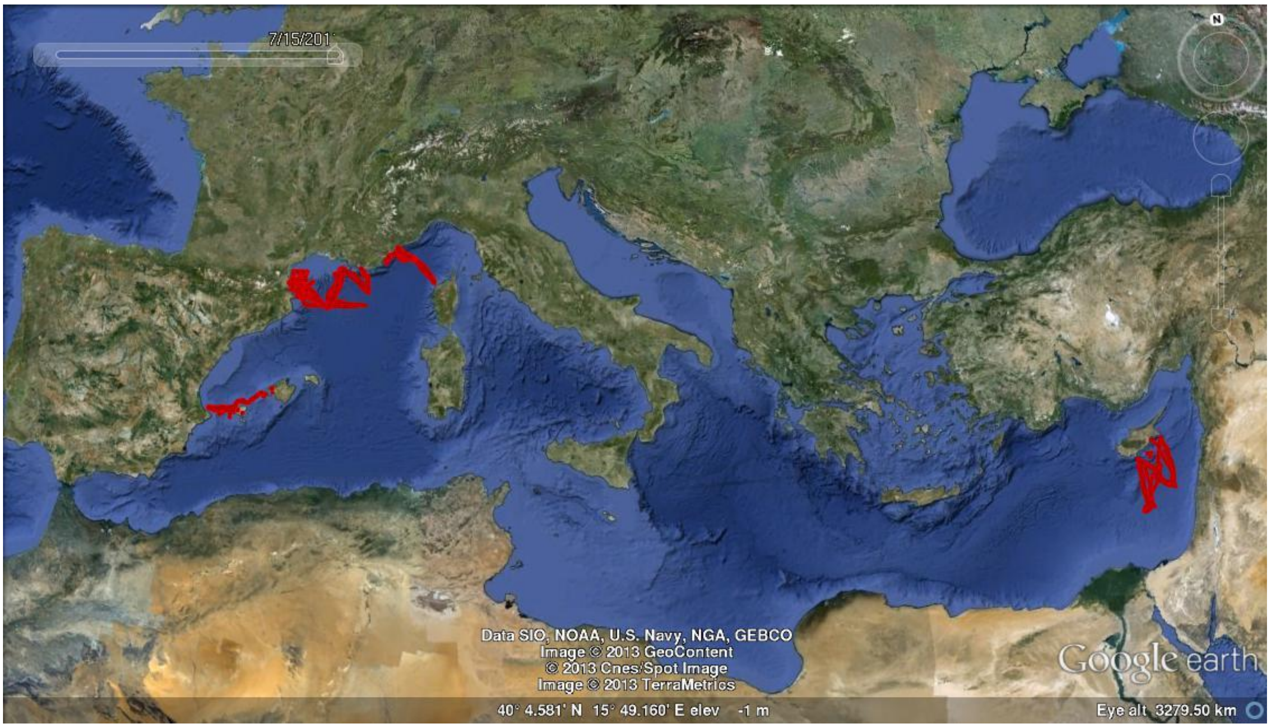

Figure 4.8 : Map of all glider deployments from 1st September 2010 to 1st September 2011.

Figure 4.9 : Map of all glider deployments from 1st September 2011 to 1st September 2012.

In 2012-2013, a major experiment was carried out within the framework of MyMeX/MerMeX/MOOSE/NOMR12 in the northwestern Mediterranean Sea (Fig. 4.10). Up to 6 gliders were operated together and covered the whole sub-basin. The objective was to carry out the coordinated control of a fleet of gliders and to measure the oceanic conditions that could be responsible for heavy rain events in this area in autumn. Within this framework, noise sensors were first deployed in order to characterize the wind intensity and precipitations rates. Noise measurements could also be used to monitor the mammal activity or be used in seismology and this was just a first step towards the full integration of acoustic sensors on gliders.

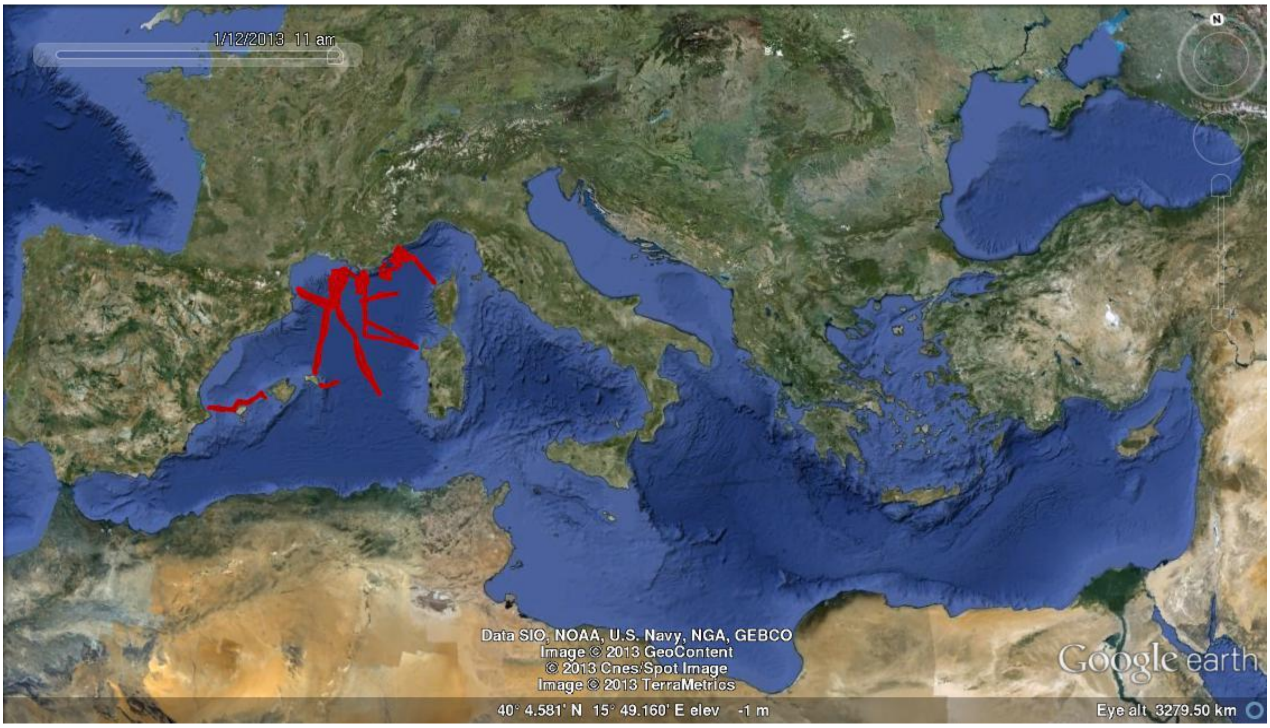

Figure 4.10 : Map of all glider deployments from 1st September 2012 to 1st January 2013.

4.3. EU contribution and glider national monitoring programs

The glider activity started within the framework of European project of operational oceanography and this certainly helped gliders to be adopted by several marine research institutions as part of their portfolio of observing platforms. The Mediterranean Sea also benefited from its relatively secure character, favoring glider deployments that were carried out by institutions starting with this technology in the framework of research projects that were designed both to test the technology and to gather scientific information, like the DOCONUG project.

Nowadays the glider activity is structured around 3 monitoring programs in which repeat-sections are carried out. Rotations with gliders can ensure an almost continuous presence at sea and a spatio-temporal coverage that was never previously achieved. Typically a glider travels around 300 km horizontally in 10 days and this allows quite high repetition rates for these repeated-sections. These projects reflect the early deployments of the gliders in the fact that they are strongly oriented to operational oceanography and long-term monitoring perspectives. This perpetuates and harmonizes an observing system in the northwestern Mediterranean, which is operational and covers the coastal and offshore dynamics, to improve and deliver operational applications (prediction oceanographic and meteorological), used widely with civil society.

4.3.1. Mediterranean Ocean Observing System on the Environment (MOOSE)

The aim of the MOOSE project is to observe the long-term evolution of the Western Mediterranean Sea in the context of global changes (climate and anthropogenic). The MOOSE observing network tries to fulfill the needs required by scientific objectives and is adapted to the observation on the long term (more 10 years) in relation to the projects HyMeX, MerMeX and CharMeX. MOOSE is also committed to meet operational needs. Indeed, in the GOOS strategy, products from operational oceanography are critical for defining and estimating indicators of global change and its impacts on marine ecosystems used for societal applications.

The MOOSE system puts into place adequate systems (transmission data in real time) with an interest in the operational programs such as MERCATOR/PREVIMER, SNOCO and wider international level in the context of the MOON and MyOcean programs. This observation network is based on fixed stations (mooring lines, instrumented surface buoys, surface radars, semaphores), mobile platforms (gliders, profiling floats) and measures by research and opportunity vessels. This multi-site-platform network is covering the Northwestern Mediterranean coastal and offshore areas (in conjunction with SOMLIT and NNMH), considers the continuum between the very coastal area and the offshore region including both the continent-ocean and ocean-atmosphere interfaces (with Météo-France and IFREMER).

MOOSE is a multidisciplinary monitoring network which focuses on the impact of climate change and anthropogenic effects on the dynamics and the marine ecosystem of the northwestern Mediterranean Sea. The goal is ultimately to provide the major trends and anomalies over the long term for particular processes (physical, biological and biogeochemical) which are responsible for the evolution of the Gulf of Lions area and the Ligurian Sea. The purpose of MOOSE is also to study particular structures and processes which have been little studied so far and whose role is anticipated to be important in the coupled physical / biogeochemical variability (variability of the community structures on time scales ranging from seasonal to ten, seasonal intensity of mesoscale structures and their influence on the biogeochemical properties of systems, the variability of the processes affecting the coastal-offshore continuum, etc.) at various space and time scales. The MOOSE observational network is organized in workpackages to meet the requirements needed by 5 scientific issues: the mesoscale variability of the northern Gyre (WP1), the contributions of rivers (WP2), the major biogeochemical cycles and acidification (WP3), the biodiversity and biological resources (WP4) and the air-sea exchange (radiative flux and atmospheric inputs, WP5). The set of parameters provided by the MOOSE network consists of the basic variables necessary to provide time series. This includes data delivered in near real-time (6h) data and delayed (up to 6 months) mode data. Some data are measured continuously by in-situ sensors from fixed and mobile platforms and others are from discrete measurements (from water samples). In the context of oceanographic observations, producing indicators of change is essential in order to deliver products that are understood by society and used by policy makers dealing with issues such as energy, marine pollution and control of fisheries quota. The quality of these indicators depends heavily on the quality of the models but also the data streams being transmitted in near real-time and/or delayed mode. This data should be acquired at high frequency (at least daily), be obtained by automatic means, and calibrated, validated and stored in dedicated databases. This data can be used directly for applications (e.g. maritime safety, environmental monitoring). Most should also feed models that provide synoptic estimations and forecasting elements: they are then used for the validation in real time or delayed time and data assimilation.

In this context, two large “coast-offshore” glider repeat-sections (or "endurance lines") are operated to observe long-term key areas such as the shelf edge, the continental slopes, the deep ocean as well as water formation areas. The sections link Nice and Calvi (MooseT00), and Marseille and Banyuls through the center of the convection area (around 42N, 5E) or the Balearics Islands. Due to their autonomy (lithium battery), two gliders will permanently sample the water column (0-1000m) along these sections and measure basic physical (T, S and P) and biogeochemical variables (CHL-A, CDOM, backscatter and O2). The goal here is mainly to observe the variability of the Northern Current at the mesoscale and the effects on the physical-biogeochemical coupling in relation with WP1 but also provide continuously a large scale oceanographic context for the other WPs. A better characterization of the physical and biogeochemical properties is necessary to observe the impact on the coastal circulation, the thermohaline circulation and the biogeochemical cycles. The glider repeat-sections were also designed to create a link between coastal and offshore fixed stations and provide us with a better characterization of the spatial variability around these fixed points.

4.3.2. Coastal Ocean Observing and Forecasting System in the Balearic Islands (SOCIB)

New monitoring technologies are being progressively implemented in coastal ocean observatories. These new observing systems are delivering new insight into coastal ocean variability, that triggers new theoretical and technological developments, increasing our understanding of open ocean, coastal and nearshore processes and contributing to a more science based and sustainable management of the oceans and coastal areas.

The Coastal Ocean Observing and Forecasting System located in the Balearic Islands (SOCIB) is one of such systems, a new facility of facilities open to international access. SOCIB responds to a change of paradigm in the observation of our oceans and coasts, an observation that has evolved from being centered on a unique platform, the oceanographic ships with data availability being delayed in time, to an observation now based on multi-platform and integrated systems (using buoys, satellites, ships, autonomous underwater vehicles, HF radar, Argo profilers, etc.), also assuring quasi real time quality controlled data availability for both researchers and society. This change of paradigm is very significant and allows being able to respond to the three key drivers identified by SOCIB back in 2009: (1) science priorities, (2) technology development, (3) response capacity to society needs.

SOCIB is a multi-platform distributed and integrated system that provides streams of oceanographic data and modelling services to support operational oceanography in a European and international framework, therefore also contributing to the needs of marine and coastal research in a global change context (Tintoré et al., 2013). In line with EuroGOOS, operational oceanography is here understood in a wide sense, including both the systematic long-term measurements of the seas and their interpretation and dissemination, and also the sustained supply of multidisciplinary data to cover the needs of a wide range of scientific research and societal priorities. This allows a quantitative increase in our understanding of key questions on oceans and climate change, coastal ocean processes, ecosystem variability, sea level rise, etc. and also drives us towards a more science based coastal and ocean management. It is important to note that in its present format and financial status, SOCIB is not formally carrying out direct research activities (except in specific areas directly related to SOCIB objectives) but provides support for them. The research activities are being carried out by IMEDEA, COB/IEO and UIB, among other organizations, in close coordination to SOCIB.

SOCIB has a major glider component (that continues now on a routine basis the IMEDEA activities that started back in 2005) and accordingly glider repeated sections are carried out in this framework. The first line established on a continuous basis is a section crossing the Balearic Channels in order to monitor the flow between the islands and in particular the flow of Atlantic water coming from the South which is thought to have a strong link with the circulation of the whole western basin. The Balearic channels are located at a key hot spot of biodiversity and represent a key choke control point to monitor the Atlantic/Mediterranean waters interactions and exchanges and its impact on the ecosystem response in the Western Mediterranean (Heslop et al., 2012). Further details on the glider facility and other SOCIB activities can be found at www.socib.es .

4.3.3. YPOKINOUMODA

This research project aims to observe the eastern Levantine Basin of the Mediterranean Sea at a level of detail and accuracy never before achieved. To reach this target, it is necessary to utilize the most modern oceanographic platform available, the underwater vehicle known as a glider. With these relatively small and very efficient instruments, it is possible to collect many months of high resolution data from the upper 1000 m of the sea and cover thousands of kilometers on a single set of batteries. In this project, measurements will include temperature, salinity, currents, dissolved oxygen, chlorophyll and turbidity. The Oceanography Center of the University of Cyprus has won a grant from the Cyprus Research Promotion Foundation to purchase and operate two autonomous underwater gliders over a period of 4 years (2008-2011). The vehicles have been built at the Seaglider Fabrication Center of the University of Washington (late-2007). The measurements complement the existing observing programs and numerical modeling of the Levantine Basin carried out by the Center. Targets include the (1) accurate description and improved understanding of the general circulation and thermohaline structure of the Levantine Basin by continuously repeated transects, (2) the detailed understanding of the mesoscale variability in the Levantine Basin and its relation with the biogeochemical variability of the region using detailed analysis and supplemental, coordinated glider transects, (3) the strengthening of the skill in forecasting the ocean state by assimilation of glider data into existing European and regional ocean forecasting systems (including that of the Cyprus Oceanography Centre) and (4) the near real time availability of glider data via the Cyprus Oceanography Centre's web site using Iridium satellite telemetry system.

The knowledge on the physical and biogeochemical oceanographic processes and conditions in the Eastern Mediterranean is greatly enhanced. Indeed, the understanding of processes in any regional sea will be improved. The skill of forecasting systems to predict ocean conditions is raised as the availability and coverage of measurements, and as a result, end-users of such systems benefit: oil spill models, tracer dispersion models, search and rescue operations, fishing enterprises, ecosystem managers. A relatively small cost to sustain the gliders will continue to strengthen our observing and forecasting capabilities after the project.

4.4. Gap analysis and conclusions

This analysis could be carried out thanks to the coordination of the glider activities carried out in the framework of the COST Action ES0904 EGO (European Gliding Observatories) which considerably helped to prepare the work carried out on gliders here in PERSEUS. Another worth-mentioning project that also helped a lot to structure the glider community is the on-going European project FP7 GROOM (Gliders for Research, Ocean Observation and Management) which is a design study on a European Research Infrastructure for gliders. This project is committed to show how improvements on the glider system could be possible in terms of formats, procedures, protocols and data QC/flow for operational needs in the framework of a European research infrastructure. It develops these important aspects at the European and international levels (Testor et al. 2012). They are thus beyond the scope of PERSEUS and are not considered in this report.

The intense glider activity carried out in the Mediterranean Sea allowed the gliders teams to promote the gliders at the OceanObs'09 conference (Testor et al. 2010, Roemmich et . 2010, Claustre et al., 2010), as the new platforms able to fill the gaps left by the other components of the GOOS, being able to be steered in areas that are not covered by the present global observing system and to sample a continuum of space and time scales. As shown in the review of Testor et al. (2010) flying gliders actually enables the resolution of a wide range of spatial and temporal scales, one is generally amazed by the oceanic features they (and various sensors on-board) reveal. Glider data help us to better understand and characterize the oceanic variability and this concerns many physical and biogeochemical processes at large scale, mesoscale, and even submesoscale (from *~1000 km horiz. and ~1 month* to *~1 km horiz. and ~1 hour*). In addition, as shown in Dobricic et al. (2010) in particular, the assimilation of glider data in a numerical model of the Mediterranean Sea can significantly reduce the uncertainties of our ocean state estimates (physical and possibly biogeochemical) and there is now a general agreement that gliders can enable a new era in oceanography if deployed regularly in order to characterize the oceanic variability.

After the few and early pioneer deployments in 2004-2006, the glider activity grew continuously. While the facilities to operate long-term repeat sections were being set up, tests with glider fleet experiments were carried out. The coordination of a fleet of gliders is an appealing way to operate them, since they can provide a cost-effective way to get a 3D-Time view below the surface. The glider teams have also explored the synergies with other observing platforms (moorings, ships, satellites, drifters) and they are now considered in the framework of the monitoring programs. Important processes have been identified with gliders but they need to be monitored and this has started in the framework of the 3 monitoring programs MOOSE/ SOCIB and YPOKINOUMODA in the Western and Eastern parts of the Mediterranean respectively, with a network of repeat sections at the sub-basin scale (and ~10 days repetition rate) covering the Mediterranean and Black

Seas. As already mentioned by Mortier and Testor (2008), the present glider observing network should be expanded to fully cover the whole Mediterranean Sea, if one wants to observe accurately shifts in the circulation (EMT, WMT) and ecosystem response (as far as basic biogeochemical variables like fluorescence CHL-A/CDOM, turbidity, nitrate and oxygen concentration can characterize them -see Durrieu de Madron et al., 2011). The key here is that a high resolution sampling over long periods of time is necessary.

PERSEUS should help to consolidate this approach and should also help to start activities in parts of the Mediterranean and Black Seas that are not well covered by the glider operations. Areas that have not been covered more than once are the Alborán Sea, the Algerian basin, the Tyrrhenian Sea, the Adriatic Sea, the Ionian Sea, the Aegean Sea and the Black Sea. In the other sub-basins of the Mediterranean Sea that were covered by gliders, the coverage is hardly sufficient at the sub-basin scale to characterize the seasonal cycle and its interannual variability which are essential components of the variability to be measured if one wants to understand the physical and biogeochemical processes governing these regions.

In order to reach the PERSEUS objectives of a GES of the Mediterranean and Black Seas, the PERSEUS partners would have to try to perform a better spatio-temporal coverage with gliders (as well as a better characterization of the water column with additional biogeochemical sensors on board) with the PERSEUS resources. This means new sensors would have to be acquired in such a way that gliders measure not only temperature, salinity and the average current, but also oxygen concentration, fluorescence CHL-A/CDOM, turbidity and possibly nitrates or noise, in a harmonized and systematic way.

It is clear that starting additional long-term repeat-sections, which is what would be necessary to characterize the physical and biogeochemical variability of the Mediterranean Sea, would not be possible in the framework of the PERSEUS project given the available resources. Though, demonstration experiments should be favored since they help, as demonstrated by the present repeat sections that have been set up in Cyprus, France, and Spain, to establish national frameworks ensuring such repeat-sections to be maintained. An involvement of the southern and Black Sea countries would also be necessary, if one would like to cover the region of interest for PERSEUS as a whole.

In terms of new sub-basins to be covered, only deployments in areas that are contiguous to the existing observing systems deploying gliders should be planned on the short term due to obvious logistical constraints and funding issues. So, this could only concern the Adriatic Sea, the Algerian sub-basin and the Levantine were OGS, IMEDEA/SOCIB and the University of Cyprus could achieve deployments, respectively. An improvement would also possible between MOOSE and SOCIB by maintaining observations between the deep convection area and Menorca. There, a combined effort could help to improve the coverage at the scale of the northwestern sub-basin both in time and space.

The PERSEUS consortium should take advantage of the FP7 JERICO European project which is developing an approach towards a joint European research infrastructure network for coastal observatories. Around European coastal seas, the number of marine observing systems is quickly increasing under the pressure of both monitoring requirements and oceanographic research. The main challenge for the research community is now to increase the coherence and the sustainability of these dispersed infrastructures by addressing their future within a shared pan-European framework and this is the main objective of JERICO. It proposes a Pan European approach for a European coastal marine observatory network, integrating infrastructure and technologies such as moorings, drifters, Ferrybox and gliders. In addition to the networking activities and joint research planned in this project, yearly calls for proposals are organized in order to give access to research infrastructures to teams that do not have access to such tools. Several glider teams are concerned by this Trans National Access (TNA) and we strongly encourage the PERSEUS consortium to apply. This could provide the resources to organize experiments in areas that were never covered by gliders.

5. SUBTASK 3.1.5 LOCAL/COASTAL OBSERVING SYSTEMS

Despite the optimistic view shared by all the partners at the start of project, the number of sites where relevant information for the scope of PERSEUS and, in general, for the implementation of MSFD has been made available is much smaller than predicted. This does not mean that observations are lacking at all but rather that:

1. Observations are carried out episodically and, therefore, no regular records are available;
2. Observations are part of focused research efforts and their results are not available at present for sharing with a wider community;
3. The possible synergy between a EU supported effort such as PERSEUS and the local observation effort is not perceived as useful with the consequence that the people in charge of the observations do not react at all.

Since this lack of reaction is not only related to data but also to metadata sharing, this raises a major strategic issue in future EU and national environmental observational programs and policies. This recurrent problem is grounded in the ambiguity still holding between data and knowledge. When the scientific community is asked and supported for generating data and producing new knowledge, it should also be informed that data must be made available for everybody while there should be recognition for the intellectual contribution for new knowledge. In fact, the large majority of our community is very far from sharing and practicing this view. And integrated projects like PERSEUS have no tool to convince people to share even their metadata. The bottom line is that this report includes, very likely, much less that could be available in terms of coastal observing systems.

Considering all the above, this section reports where observations in the SES coastal environments are carried on (or have been carried on). Because of what said above the list is likely far from being exhaustive. However for some sites two aspects are specifically analyzed:

1. if the observations can contribute to fill existing gaps;
2. to what extent the information is accessible and how.

The former implies that systems are not listed according to their geographical location but rather to the information they provide. In turn, this implies that they may recur more than once in the list of selected sites.

The local and coastal observing systems considered along the perimeter of the SES, the straits and channels include coastal systems monitored by:

- meteo-marine buoys
- waverider buoys
- HF coastal radars
- multi-parametric moorings
- periodic sampling at a fixed station

A template was circulated in the community to collect information on:

- Geographical location and observed parameters
- Procedures for the data collection
- Procedures for processing and archiving

The feedback was not particularly effective, which leaves the possibility that the compiled inventory is still missing sites that are not part of observational networks.

Regarding SES sites included in established observational networks we report below a very synthetic description of different networks and links to them.

European Union

The most comprehensive network of real-time observations is that linked to the calibration/validation of MyOcean products. All data are accessible in real time at the website http://gnoo.bo.ingv.it/myocean/calval/. They include 40 sites for water temperature, 22 sites for water salinity, 24 sites for sea level, and 19 sites for currents.

Italy

Along the Italian coast there is an array of 33 tidal gauges managed by ISPRA, whose data can be accessed via the web site: http://www.mareografico.it/ .

Ten wavemeters along the Italian coast are also managed by Ispra with their location and characteristics available at the site: http://64.246.9.130:9990/index.htm .

Ten years of coastal monitoring data along the Italian coast area can be accessed at the website: http://www.sidimar.tutelamare.it/dati_ambientali.jsp

France

France has significantly improved during the last years an observational network along its Mediterranean coast. It consists of different projects managed by different organizations. The description of the different components is accessible at the following websites:

http://www.coriolis.eu.org/Observing-the-ocean/Observing-system-networks/MOOSE for MOOSE (Mediterranean Ocean Observing System on Environment)

http://somlit.epoc.u-bordeaux1.fr/fr/ for SOMLIT (Service d'Observation en Milieu LITtoral) with three stations in the Mediterranean (Banyuls-sur-Mer, Marseille et Villefranche-sur-Mer). Profiles of temperature, salinity and pressure, cholorophyll fluorescence are collected continuously, whereas waters samples are collected weekly or bi-weekly at several depths for measuring biogeochemical properties.

http://www.sonel.org/-Maregraphes-.html for a global system of sea level gauges, including the SES.

http://candhis.cetmef.developpement-durable.gouv.fr/ (Centre d'Archivage National de Données de Houle In Situ) for the monitoring of waves along the French coasts, including the Mediterranean.

Spain

Puertos del Estado is maintaining coastal and open sea buoys and moorings, coastal stations, coastal HF radars, etc., see details at the following web site:

http://www.puertos.es/oceanografia_y_meteorologia/redes_de_medida/index.html

The Coastal Ocean Observing and Forecasting System located in the Balearic Islands (SOCIB) is responsible for coastal observations in the Balearic Islands (www.socib.es).

As mentioned above, only a small number of institutes answered the questionnaire. The information collected is organized in a synopsis table (see Appendix 4).

For those sites and considering that PERSEUS had selected the following main pressures on coastal marine ecosystems:

1. Changes in freshwater and sediment riverine fluxes
2. Nutrients and organic enrichment
3. Contamination by hazardous substances
4. Physical damage and loss of habitats
5. Biological disturbance: Introduction of non-indigenous species
6. Biological disturbance: Extraction of species, including non-target catches
7. Marine litter
8. Underwater noise,

We inquired if any of the sites could provide information to better characterize the pressures and impacts listed above. The numbers reported below refer to single sites as in the synopsis table.

Changes in freshwater and sediment riverine fluxes: sites 3, 5, 6, 9, 10, 12, 19, 20

- Impact and vulnerability of benthic biocenoses to the reduced sediment transport: no useful information).
- Impact and resilience of benthic biocenoses to exceptional floods (no useful information).

Nutrients and organic enrichment: sites 5, 6, 9, 10 11, 19, 20

- Possible impact in the alteration of nutrient ratios (high N, lower P and possibly Si): useful information).
- Mechanisms of impact of increase in nutrients on the structure of food web in restricted areas: useful information only for sites 6, 9, 10, 11.
- Impact of possible increase in organic load on the functioning of planktonic food web: useful information only for site 6.
- Change in plankton community structure and functioning in the food web because of a reduced flux of nutrients (de-eutrophication): useful information only for sites 6, 9, 10, 11.

Contamination by hazardous substances: no site

- Contribution of river flood, big cities and ports to contaminant loads on coastal systems in the whole sub region.
- Contaminant emissions from ships and atmospheric inputs.
- Background levels at the sub region to better identify anthropogenic forcing, especially for trace metals.
- Regular monitoring of pollutants, including emerging pollutants, in sediments and biota, with emphasis in non-EU countries where there are less available data.
- Regular control of pollutant levels in fishing products.
- Biogeochemical processes at sediment-water interface.
- Bioaccumulation and bio magnification of pollutants through the food web.
- Risk assessments to predict hazards for biota and human health.

Physical damage and loss of habitats: no site

- Monitoring of intertidal benthic populations to confirm at land scale the loss of engineering species (Fucales: Cystoseira spp. and Sargassum spp).
- The status of the seagrasses Cymodocea nodosa and Zostera noltii.
- Integration of punctual studies about habitat modeling.

- Characterization of the modification of solid river discharges to the sea by promoting better monitoring campaigns. This will also serve to calibrate/validate predictive models linking water and solid discharges to assess the impact of this pressure under different conditions.
- The preserved habitats and those already lost.
- Studies on sensitive and opportunistic species to assess the positive and negative response to the different pressures and impacts

Biological disturbance: Introduction of non-indigenous species: sites 6, 9, 10, 11, 19, 20

- In some cases, it is difficult to determine when a given organism is a NIS and when it was introduced due to existing information gaps in some native taxonomic groups (which have not been fully catalogued or have been very recently): unclear whether possible but sites 6, 9, 10, 11 may contribute.
- Information in biology and ecology of NIS as well as in the induced ecological and economic impacts on native ecosystems: unclear whether possible but sites 6, 9, 10, 11 may contribute.
- Along the Spanish Mediterranean coast, most of the existing samplings are located in littoral ecosystems and focused on few groups such as macroalgae. Need to extend to other areas: no sites.

Biological disturbance: Extraction of species, including non-target catches: no sites

- Data on large pelagic fish breeding and spawning grounds and on areas in which juveniles are concentrated in order to understand the state of stocks.
- Structure of pelagic food webs and interactions among different levels.
- Contribution of overfishing on increasing jellyfish blooms.
- Quantification and control of illegal, unreported and unregulated fishing.
- Quantification of the impact of by-catch on sea turtles and cetaceans, with emphasis on non-EU countries.

Marine litter: no site

- Implementation of a standardized monitoring network at adequate time and spatial scales covering the different targets: litter in beaches, in the water column, in the seabed and micro particles.
- Determination of the origin of marine litter and its vectors of dispersion: risk assessment of transporting hazardous substances and/or invasive species.
- Identification of measures of waste reduction and their potential impacts on habitats and biodiversity.
- Assessment of the direct and indirect impacts of marine litter (including microparticles) on marine organisms that live in the water column and in the seafloor.
- Identification of suitable sentinel organisms and specific biomarkers to assess the toxicological effects of contaminants derived from marine debris plastics (PCBs, PAHs, brominated flame retardants, bisphenol, etc.).

Underwater noise: no site

- Development of a register of sources of low and medium frequency impulsive noises along the year and covering all areas of interest. Research should be emphasized in critical areas where noise might affect essential behaviour of marine mammals
- Scientific knowledge on the impact of impulsive noises on marine species, particularly on mammals but also on other organisms, such as fish, birds, and marine invertebrates.
- Study of the relationships between noise and animal stranding by analyzing the interactions between observed deaths and authorized “noisy” activities.
- Information about background noise.

6. SUBTASK 3.1.6 SATELLITE REMOTE SENSING

6.1 Introduction

In the last twenty years observations of the ocean by sensors on Earth orbiting satellites have become an essential element of 21st century oceanography. In fact, it is now widely recognized that to monitor the ocean with the necessary sampling frequency in both space and time, it is essential to supplement conventional in situ analysis methods with data derived using remote sensing technology, primarily from Earth observing satellites. In this context, physical properties of the ocean such as surface temperature and slope, wave height and surface winds are currently measured globally at high resolution providing information on the physical state of the ocean and reliable inputs to ocean circulation models. Similarly, ocean colour measurements of phytoplankton pigment concentration are now used to monitor the marine ecosystem as well as to validate marine bio-geochemical models.

The satellite observing capacity at global scale is ensured by the international and national space agencies (e.g. ESA, EumetSAT, NASA, NASDA, CNES, etc). These agencies have in their mission to ensure continuity of satellite earth observations and to provide access to remote sensing data acquired by the satellite orbiting around the earth. The space agency ground segments give access to the satellite data at different level of processing, from raw data acquired by the satellite sensors (e.g. L0) to derived oceanic variables (e.g. L2, geophysical products in the sensor coordinate or L3, data resembled onto standard geographical coordinates). The space data available from the ground segments are often used as input to national and regional processing systems to produce regional oceanic datasets and added value oceanic products. In particular, Mediterranean satellite observing has developed in the last 15 years as part of the MOON Scientific Strategic Plan with the following aims: 1) to provide Near Real Time (NRT) regional satellite data products to be assimilated in the MOON modelling forecasting systems, 2) to improve the quality of the oceanic observations in the SES. This observing system, using regional specialised processing chains, delivers a large variety of satellite observations covering the entire SES. This system is now one of the components of the European GMES Marine Core service developed by MyOcean.

In this report, we limit our review to processed satellite data providing information on the ocean state variables (e.g. L3 or L4 products) since this type of data can be easily used by the broad oceanographic community, that are not expert in satellite data retrieval. In particular, this section covers the remotely sensed measurements of sea surface temperature (SST), altimeter data (sea surface height, SSH), ocean colour (OC) measurements (chlorophyll, water transparency, remote sensing reflectance) and sea surface salinity (SSS) and aims to:

1. review the existing satellite observing capacities in the SES before PERSEUS
2. identify gaps
3. recommend possible ways of filling the gaps

6.2 Sea surface temperature data

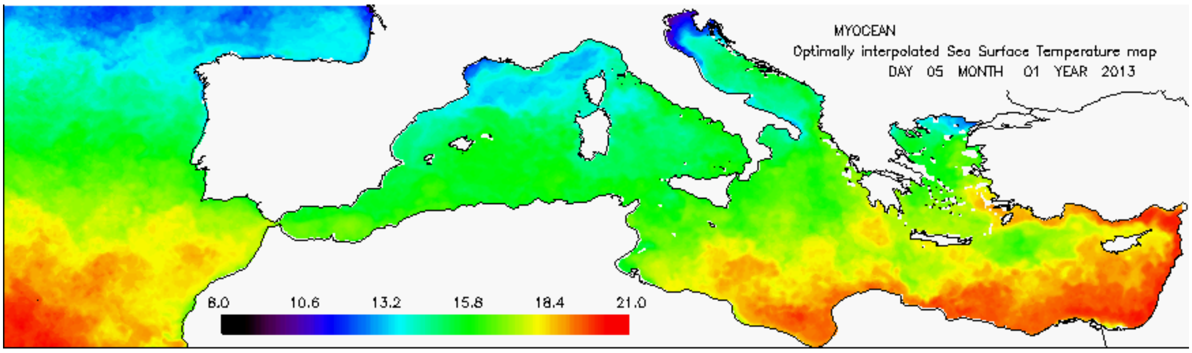

Figure 6.1. Example of HR SST L4 covering the Mediterranean Sea.

The SST observing systems covering the SES were initiated primarily through three international projects: Medspiration (European contribution to the Global Ocean Data Assimilation Experiment (GODAE) Gridded High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP), funded by the European Space Agency), MFSTEP (Mediterranean Forecasting System: Toward an Environmental Prediction, EU-FP5 Project) and MERSEA (Marine EnviRonment and Security for the European Area, EU integrated project), and have continued in the framework of the two European MyOcean projects, and within the GHRSST (Group for High Resolution SST, replacing the GHRSST-PP since 2009). MyOcean-1 covered the 2009-2012 period, and the SST observing system is now operated under the MyOcean-2 umbrella (2012-2014).

GHRSST is an international scientific and technical network specifically set up to address the need for high resolution SST estimates and reliable operational SST products. The GHRSST recommendations have been reflected in the design of the MyOcean sub-system devoted to the development and production of satellite SST data (SST-TAC, Thematic Assembly Centre during MyOcean-1 and OSI-TAC, Ocean and Sea Ice Thematic Assembly Centre during MyOcean-2).

Multi-sensor SST Level 3 data (more precisely L3S data, see the proceedings of the GHRSST Science Team for a definition of satellite product level) and Level 4 (L4) products covering the Southern European Seas (Mediterranean and Black Sea), are produced and disseminated within the SST-TAC/OSI-TAC. The L3S and L4 data correspond to daily (night-time) gridded, super-collated (multi-sensor) and optimally interpolated satellite SST estimates at High spatial Resolution (HR) and Ultra-High spatial Resolution (UHR), i.e. at 1/16° and 1/100°, respectively (see Table 6.1). These products are based on all infrared data available (AATSR, METOP, AVHRR, MODIS, SEVIRI) and specific sensor bias corrections and interpolation procedures are applied (Buongiorno Nardelli et al. 2013). Multi-year Mediterranean and Black Sea SST datasets at 1/16° spatial resolution based on AVHRR data were also re-processed during the European SESAME IP project. The validation of the re-processed SST datasets is described in Marullo et al. (2007) and Buongiorno Nardelli et al. (2009). SST products covering the SES are available from Space agencies ground segments (ESA, NASA) at lower processing levels, and L2P data (including the SST measurements from all sensors on the original swath and some ancillary information, and written in a common netcdf format) are also available directly from GHRSST.

We identified two major gaps in the present SST products: the first one is due to the loss of the AATSR sensor since April 2012. AATSR provided the most accurate SST estimates and was used as the primary sensor in the bias adjustment procedures. The impact of its loss on L3S and L4 product accuracy needs further investigations, but the same level will probably be regained only after the launch of ESA's Sentinel 3 satellite. Secondly, the products are released on daily basis and representative only of night-time SST. The availability of repeated measurements at regular time intervals from SEVIRI is not fully exploited and SES regional products resolving the daily cycle were developed only as scientific prototypes.

		Products	Spatial Resolution	Temporal Resolution
SST	L3	MyOcean HR L3S Mediterranean Sea	1/16°	Daily
		MyOcean UHR L3S Mediterranean Sea	1/100°	Daily
		MyOcean HR L3S Black Sea	1/16°	Daily
		MyOcean UHR L3S Black Sea	1/100°	Daily
	L4	MyOcean HR L3S Mediterranean Sea	1/16°	Daily
		MyOcean UHR L3S Mediterranean Sea	1/100°	Daily
		MyOcean HR L3S Black Sea	1/16°	Daily
		MyOcean UHR L3S Black Sea	1/100°	Daily
		HR RAN Mediterranean Sea	1/16°	Daily
		HR RAN Black Sea	1/16°	Daily

Table 6.1.

6.3 Ocean Color

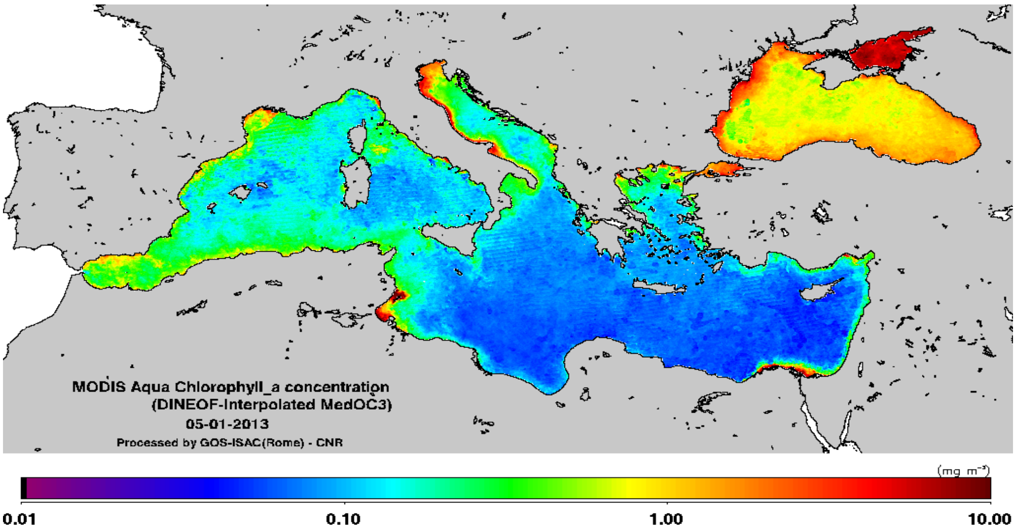

Figure 6.2. Example of chlorophyll concentration L4 covering the SES.

A specific SES Ocean Colour Observing System (OCOS) has been set up in the framework of the MyOcean Ocean Colour Thematic Assembly Centre (OCTAC), building on the experience of previous European initiatives such as the MERSEA project and MOON. The OCTAC was designed to bridge the gap between space agencies providing OC data and scientific users, public and private institutions and organizations that require OC-derived information. The OCOS was built by CNR to meet the growing demand for near real-time OC products for applications in OO and climate studies. The system was designed to produce: 1) fast delivery of images for environmental monitoring and operational support to oceanographic cruises; 2) accurate OC products for data assimilation into ecosystem models; 3) a consistent reanalysis product for climate change studies

The most important OC data products are the water-leaving radiance and chlorophyll concentration (CHL-A) whose accuracy targets have been established as 5% and 35%, respectively (Mueller and Austin, 1995). Fulfilling this accuracy requirement is challenged by uncertainties affecting the calibration of the space sensors, the atmospheric correction process and the bio-optical characteristics of the SES. The OC datasets produced using global algorithms, such as those available from space agency ground segments, are affected by very large errors when applied to the SES. Volpe et al. (2007) and Santoleri et al. (2008) quantified the uncertainties of some regional and global ocean colour CHL case-1 algorithms for the MED area and identified and developed optimal algorithms for the production of high quality ocean colour datasets. Further development included the generation of merged case-1/case-2 CHL products, based on the merging algorithm proposed by D'Alimonte et al. (2003) and on the regional algorithm for case-2 waters proposed by Berthon and Zibordi (2004) for the Adriatic Sea.

The satellite data input to the SES OCOS are the Level 1 (raw data formatted, L1A) or Level 0 (raw spacecraft data, L0) SeaWiFS, L1A (or L0) MODIS-Aqua and Level 2 (derived geophysical parameters, L2) MERIS passes covering the MED and BLS domain. SeaWiFS and MODIS processing chains are designed to process data from L1A (or L0) to Level 3 (single geophysical parameters, L3) and Level 4 (multi-day and/or multi-sensor products, L4), whereas MERIS processing chain only deals with L2 to L3 and L4 data (Figure 6.2). L0 are processed to L1A, in case L1A are not directly available from upstream data sources. The list of available products is presented in Table 6.2.

In addition to the OCTAC products the OCOS provides fast delivery images useful for operational support to oceanographic cruises and some sub-regional datasets for the Adriatic Sea . Both services are accessible from the CNR -ISAC -GOS web page : http://gosweb.artov.isac.cnr.it/ .

		Products	**Spatial Resolution**	**Temporal Resolution**
MODIS	**L3**	CHL (MedOC3 algorithm)	1.1 km	Daily
		CHL (MedOC3 algorithm)	7 km	Daily
		Kd490	7 km	Daily
		Kd490	1.1 km	Daily
		Rrs (412,443,488,531,547,667,869 nm)	1.1 km	Daily
		senz	1.1 km	Daily
		par	1.1 km	Daily
		CHL_1-2	1.1 km	Daily
		l2_flags	1.1 km	Daily
	L4	CHL (MedOC3 algorithm)	7 km	Five days

		CHL (MedOC3 algorithm)	7 km	Weekly
		CHL (MedOC3 algorithm)	7 km	Monthly
		Kd490	7 km	Five days
		Kd490	7 km	Weekly
SeaWiFS	**L3**	CHL (MedOC4 algorithm)	1.1 km	Daily
		Kd490	1.1 km	Daily
		Rrs (412,443,490,510,555,670,865 nm)	1.1 km	Daily
		senz	1.1 km	Daily
		par	1.1 km	Daily
		CHL_1-2	1.1 km	Daily
		L2_flags	1.1 km	Daily
	L4	CHL (MedOC3 algorithm)	7 km	Five days
		Kd490	7 km	Five days
MERIS	**L3**	CHL (MedOC4me algorithm)	1.1 km	Daily
		Rrs (412,443,490,510,560,665,865 nm)	1.1 km	Daily
		L2_flags	1.1 km	Daily

Table 6.2.

One of the biggest issue within the Ocean Colour scientific community is concerned with the loss of the MERIS sensor, since April 2012. The only available OC sensor currently operational is MODIS. In addition, although merged case-1/case-2 CHL products are now produced routinely, the case-2 algorithm clearly requires sub-regional calibrations. Another non-trivial issue is associated with the fact that currently there are no operational regional-CHL algorithms for the Black Sea.

6.4 Altimeter Data

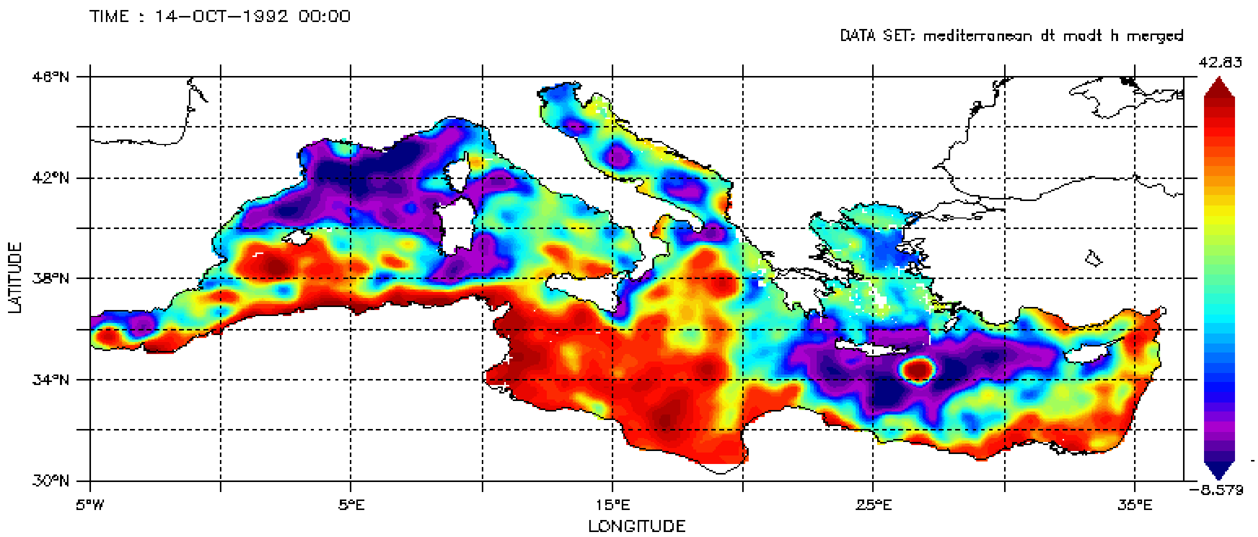

Figure 6.3. Example of Absolute Dynamic Topography L4 covering the Mediterranean Sea.

Specific products covering the SES have been developed by CLS/AVISO within the framework of different European projects (e.g. DUACS, MERSEA, ECOOP, MyOcean), and are directly distributed by AVISO and by MyOcean Sea Level Thematic Assembly Centre (SL-TAC).

DUACS was later re-defined as the Data Unification Altimeter Combination System and is now, part of the CNES multi-mission ground segment (SSALTO). It processes data collected by all altimetry missions (Cryosat-2, Jason-2, Jason-1, T/P, ENVISAT, GFO, ERS1/2, GEOSAT). All the measurements are homogenized with respect to a reference sensor (currently Jason-2), and used to generate several different L3 and L4 data. To produce Sea Level Anomaly (SLA) data in near-real time, the Ssalto/Duacs system exploits the most recent datasets available based on the enhanced OGDR+IGDR production. The multi-mission cross-calibration process removes residual orbit and long wavelength errors. Specific regional algorithms have been defined for both L3 and L4 processing on the SES. The list of available products is provided in Table 6.3.

		Products	Spatial Resolution	Temporal Resolution
Altimetry	L3	Mono-altimeter NRT SLA Mediterranean Sea-along track	14km (along track)	
		Mono-altimeter NRT SLA Black Sea-along track	14km(along track)	
		Mono-altimeter DT SLA Mediterranean Sea-along track	14km (along track)	
		Mono-altimeter DT SLA Black Sea-along track	14km(along track)	
		Mono-altimeter NRT ADT Mediterranean Sea-along track	14km/7km (along track)	
		Mono-altimeter DT ADT Mediterranean Sea-along track	14km/7km(along track)	
	L4	Gridded multi-mission NRT SLA Mediterranean Sea	1/8°	Daily
		Gridded multi-mission NRT SLA Black Sea-along track	1/8°	Daily
		Gridded multi-mission DT SLA Mediterranean Sea-along track	1/8°	Daily
		Gridded multi-mission DT SLA Black Sea-along track	1/8°	Daily
		Gridded multi-mission NRT ADT Mediterranean Sea-along track	1/8°	Daily
		Gridded multi-mission DT ADT Mediterranean Sea-along track	1/8°	Daily

Table 6.3.

The ability of satellite altimetry to resolve mesoscale processes is strongly related to the number of sensors flying simultaneously (Pascual et al., 2006). The loss of ENVISAT in April 2012 clearly reduced the number of available measurements. A second issue is related to the absence for the Black Sea of an equivalent of the Mean Dynamic Topography estimated for the Mediterranean Sea (Rio et al., 2007). Finally, the results of several research projects (see the list below) on the high resolution processing of coastal altimetry data are still too limited in terms of missions studied and/or operational accessibility of data, to provide operational tools, including this kind of data could have a significant impact on coverage for the SES, given their mostly coastal nature.

Coastal altimetry projects:

-COASTALT (2008-2011): ESA-funded, prototype ENVISAT Coastal Altimeter processor, http://www.coastalt.eu

–PISTACH (2007-2011): funded by CNES for Jason-2 http://www.aviso.oceanobs.com/index.php?id=1527

– ESURGE (2011-2013): ESA initiative for Earth Observation support to storm surge monitoring and forecasting http://www.storm-surge.info

6.5 Sea Surface SALINITY

Surface salinity (SSS) estimates are available from the ESA Soil Moisture and Ocean Salinity (SMOS) mission and the NASA Aquarius instrument mission, however due to instrumental/sampling limitations, these missions are not suitable for the Mediterranean and Black Seas. SMOS provides salinity estimates reaching an accuracy of 0.1 PSU only when averaged over 10-30 days and 200 km x 200 km areas, while Aquarius Aquarius level 3 data have a spatial resolution of 1 degree. Daily SSS only gets to 0.2 PSU accuracy at 150-kilometer resolution. They are available as daily, 7 day, monthly, seasonal (3 months) and annual averages.

6.6 Concluding remarks

The Mediterranean Sea satellite observing system is now an essential component of the SES observing system and is providing 1) fast delivery of products and images for environmental monitoring and operational support for oceanographic cruises; 2) accurate products for data assimilation in ecosystem models; 3) consistent reanalysis products for climate change studies.

Nevertheless, the availability of SES NRT remote sensing measurements is strongly dependent on the availability of earth observation satellite measurements. At least 3 satellite missions measuring the same parameter are required in orbit at the same time, in order to correctly observe the mesoscale signal of SES. After the loss of the ENVISAT mission, which occurred in April 2012, the risk of having insufficient input data sources is very high. This is especially true for the OC and SSH observing systems, as both use data from old satellite missions. In particular, the entire OC system now relies on a single sensor (MODIS Aqua) which is already far beyond its expected life cycle, with the real possibility that the operational acquisition of satellite data will cease, as was recently the case for MERIS, on-board ENVISAT. Similarly, the SSH observing system is based today on Jason-2, Jason-1 and Cryosat-2 missions. The probability of losing the Jason-1 altimeter is very high given that the mission has gone twice beyond its extended lifespan (10 years in orbit). The risk is lower for SST products, since they are based on several input sources which mean that the loss of one sensor, like ENVISAT, may degrade the product, but not stop it.

Data from new sensors would mitigate such a risk. This implies: 1) speeding up access to new non-European satellite missions, such as the VIIRS missions which are still in the commissioning phase, and 2) the maintenance of the scheduling of the Sentinel-3 launch. These actions are essential to ensure the availability of SES remote sensing data in the coming years.

Compared to other operational platforms, the main issue of the satellite remote sensing is to quantify and to improve the quality of the products especially near the coast. This requires:

- the improvement of the retrieval algorithms in the SES shelf regions, via calibrating the algorithms with in situ measurements
- the acquisition of, and access to, in situ measurements required to calibrate the satellite data
- the monitoring of the quality of the products by comparing them with operational in situ observations
- the development of specific products for the coastal areas of the SES.

Finally it is important to underline that the present SES remote sensing products are limited to core variables (e.g. SST, SSH, CHL, etc), the development of remote sensing datasets more suitable to evaluating the ecosystem attributes relevant for the MSFD Descriptors (e.g. productivity, biological diversity, turbidity, etc) are required. This will part of the activity planned in PERSEUS WP4.

7. CONCLUSIONS

The above review of existing observing capacities in the SES reveals the following gaps, almost valid for all kinds of observations. Recommendations are given to fill them in order to address both the PERSEUS project specific objectives and the more general scientific and strategic society needs of the SES area over the longer term, beyond PERSEUS. This review and recommendations are partially related, and can be complementary, to existing reviews such as the recent review of Mediterranean unresolved issues published by IOC (Malanotte-Rizzoli and Pan-Med Group, 2012), the list of research and development challenges of MONGOOS (Giovanni Coppini, Personal Communication) and the reports of the EC Jerico project on the existing observation network, and recommendations on how to fill gaps, in the Mediterranean and Black Sea Regional Ocean Observing Systems (ROOS). However, our work is more detailed and specific to all the observations available in the SES and is, in this way, the first quantitative assessment of the SES observational capabilities. Specific gaps have been identified. A table is included at the end of this section with a synthetic summary of our findings and recommendations.

7.1 Geographical coverage

Although the spatial coverage and the horizontal resolution have increased over the last couple of years, mainly thanks to the operation of autonomous mobile platforms (drifters, floats and gliders) and to satellite-based observations, some areas of the SES are still under-sampled if we want to resolve the main scale of variability (mesoscale). In particular, the southern areas of the Mediterranean Sea and the entire Black Sea require denser observations.

This gap can be filled partially by involving scientists from North African countries in new observational programs in their coastal waters and using with them state-of-the-art instruments. This can only be done if European support (both in term of expertise and economical support) is attributed to train local scientists and to conduct capacity building activities in general. Likewise for the Black Sea, there is the need of more integrated observational programs amongst Black Sea countries and also involving other European partners.

A minimum population of Lagrangian instruments should be maintained throughout the SES (e.g., 50-60 floats and 30-40 drifters for the Mediterranean and 10-15 floats and 5-10 drifters in the Black Sea- for the basin-wide monitoring of the physical properties (temperature, salinity and currents). In areas of strong currents, such as the Algerian and Northern Currents, where Lagrangian instruments move rapidly, and as a consequence the density of their data is rather low, observations including repeated releases of low-cost drifters and floats, in concert with a few moorings and key glider transects, should be favoured. In addition, networks of drifters should be operated in coastal areas to measure shelf - deep sea exchanges and dispersion of contaminants. Fixed moorings should be maintained or implemented at key locations or choke points such as in channels and representative areas (e.g. Strait of Gibraltar; Channel of Sardinia, Corsica, Sicily and Otranto; Cretan Passage and open sea areas like in the Liguro-Provencal basin, Ligurian Sea, Adriatic Sea, Aegean Sea, Black Sea and Levantine basins). Essentially a total of about 15 moorings would be needed, including a few in fast currents. Obviously these pointwise multi-parametric observations should be complemented by mobile instruments (floats and gliders) operating in their vicinity. SOP and Ferrybox observations should be collected routinely along a limited number of existing and available transects. Gliders have already shown their capabilities and further use of gliders actions should be planned (a) along key transects at new choke control points/endurance lines, (b) in process oriented studies (e.g., water masses formation, mesoscale interactions, shelf/slope exchanges) and (c) including new technological platforms with new state-of-the-art sensors to potentially obtain cost effective multidisciplinary data in under-sampled areas. The number of oceanographic cruises should be maintained and should be more focused on the southern Mediterranean and Black Sea. It is important that the annual oceanographic cruises calendar is open, available and well know to facilitate cross-national and in country coordination between organisations, in order to maximise the use of ships and optimize the integration with other platforms. The constellation of operational satellites that provide crucial data on SES surface layer should be maintained and improved. Both at the European and international levels, efforts are underway, and should be sustained, to guarantee the continuity of global monitoring of sea level, sea surface temperature and chlorophyll concentration. But this is perhaps beyond the PERSEUS scope. In particular, efforts should be made to improve the horizontal resolution and accuracy of satellite-based sea surface salinity estimates in the SES.

7.2 biogeochemical observations

In-situ measurements of biogeochemical water properties, both by chemical (bottles on ships) and optical (on moorings, floats and gliders) methods are still generally scarce in the SES, in particular floats with oxygen and biochemical/optical sensors are currently missing in the Black Sea. More floats should be equipped with biogeochemical sensors and be used in concert with oceanographic cruises that are needed for calibration purposes. As part of Euro-Argo, efforts are underway to equip about a quarter of the Mediterranean Argo fleet with biogeochemical sensors. The biogeochemical measurements on moored stations should be maintained and increased.

7.3 Other MSFD observations

The Marine Strategy Framework Directive requires observations of pressures on the biodiversity in the European Seas. The physical and biogechemical measurements discussed above are definitely providing inputs to the MSFD in the SES. In addition, new pressures like acoustic noise and litter should be considered. So far, these measurements have been extremely scarce and not organized in the SES. In situ and remote sensing observational techniques must be developed, parameters describing acoustic noise and litter should be defined and observation standards and protocols should be developed. Then, monitoring should be implemented at the basin and local/coastal levels in the SES in a coordinated European way.

7.4 Technical developments and good practices for data collection

Technologies for the measurement of physical and biogeochemical properties of seawater are in continuous development, involving also nano-technologies. The precision, accuracy and robustness of some measurements are still below expected standards and should be improved. Methods for data collection must be robust, simple and user-friendly. Common standards should be defined for good practices for the setting of autonomous instruments and for the operation of instruments installed on ships-of-opportunity and operated by non-scientific personnel (see details in Appendix 1). Coordination at the SES level is a extremely essential element in order to collect observations as independent and complementary as possible and in order to avoid duplicates and to enable access to all data. It exists already as part of EC projects such as EUROARGO, EUROSITES, MyOCEAN, JERICO, GROOM and should be enhanced further as part of PERSEUS.

7.5 Calibration

Gaps exist in terms of the representativeness of some observations obtained by indirect methods such as those using optical methods and satellite-based remote sensing techniques. Special care should be focused on that and standard methods should be developed to guarantee the good quality of the measured parameters. This includes pre- and post-use laboratory calibrations, and also inter-comparison with collocated and co-temporal measurements obtained with direct chemical methods. For satellites, some algorithms for the retrieval of ocean parameters should be improved, and/or tailored for specific areas, using comparison with in-situ data.

7.6 Data management and dissemination

Good data management (of in situ observations but also of model outputs), both in real-time and delayed mode after fine quality control, is crucial to allow the scientific community to use the data correctly in a timely and useful manner in order to develop products and calculate indicators important for the scientific and socio-economical needs of PERSEUS. Hence the current data management (following MyOCEAN standards for real time and SEADATANET ones for delayed mode, for instance) should be expanded and improved to all types of marine observations in the SES. In particular, efforts are required for the non-physical parameters. This should be done at the levels of metadata, real-time and delayed-mode quality controlled data. For satellite remote sensing it is important to improve the quality of the algorithms and products especially near the coast using in situ measurements for calibration purposes. The development of products (from data and models) more suitable to evaluating the ecosystem attributes relevant for the MSFD descriptors (e.g. productivity, biological diversity, turbidity, etc) is definitely required.

7.7 Complementary use of the different kinds of observations to study multi-scale processes relevant to PERSEUS

In a world in which the economical resources are continuously reduced, it is important to have a major coordination and complementarities of programmes in order to reduce overlaps, duplication and to make a more optimal use of the limited resources available. The development of a new sampling strategy of a coordinated multi-platform programme in the SES is deemed essential. Better organization and homogenization of data collection and management are need, which includes common data quality procedures, metadata description, common vocabularies, etc.

At the sub-basin or coastal levels, the full spectrum of platforms (in situ and remote sensing) should be used in a coordinated and complementary way, taking advantage of the individual instruments and platforms and adopting an optimum sampling strategy to address specific issues addressed by PERSEUS and using the limited resources available.

	COVERAGE West Med	Central Med	East Med	Black Sea	SCALES Temporal/ spatial	BIOGEO CHEMICAL	DATA	OTHER	PERSEUS	ACTIONS Recommended
Argo Floats	Gaps in Algerian Current and African Coast	Gaps in South/Eastern Ionian	Gaps in Aegean and Levantine Basin			Gap in Black Sea			PERSEUS has funded Argo floats for Black and Med seas	
Drifters			Gaps in Aegean and Levantine Basin	Gap				European coordination		Experiments to study coastal dispersion of contaminants
SOOP			Gap			New economic probes required – under development		European coordination. Environmental friendly materials for XBT/CXBT	New Ferrybox in East Med	Ideal 3 N/S transects across Med
Ships surveys	Gaps in North Balearic Basin, South Balearics to Sardinia to African Coast	Gaps west of Sardinia, below Sicily to African coast	Gaps from Crete to African Coast, NE Crete to Turkey	Gaps in most Black Sea			Data availability		WP3 Ships survey data (2012 on) will be available in DM via PERSEUS web	

Moorings		South central	Levantine		Water column and seabed data	Optical, acoustic and biogeochemical not monitored most moorings	Homogenization of data policy. Provision to central databases		WP3 Data policy (handbook), will aid data standardisation. RT and DM data (2012 on) will be available via PERSEUS web	Add new moorings in important transitional areas. Effort to promote homogeneous data management between agencies. Submission of data to European directories. Integration of new biogeochemical moorings and sensors. Educate operators on new sensor technology
Gliders	Transects needed across important circulation points in Alboran Sea and Algerian Basin. Plus additional sub-basin coverage.	Transects needed across important circulation points in Tyrrhenian, Adriatic and Ionian Seas. Plus additional sub-basin coverage.	Transects needed across important circulation points in Aegean Sea. Plus additional sub-basin coverage.	Transects needed across important circulation points in Black Sea. Plus additional sub-basin coverage.				Provide transnational access to glider platforms.	PERSEUS WP3	Establish national frameworks of repeat sections to cover gaps. New operational centres/ capability for areas not covered (Aegean/Black Sea). Integrate gliders with other platforms as part of marine observing strategy.
Local/ coastal moorings					Observations are episodic.	Freshwater and riverine fluxes no benthic response info. Increase in organic load (one site), no contamination by hazardous substances, no physical damage and loss of habitat (perhaps this best with AUV's/surveys rather	Data not made available	Benefit of integrating/coordinating effort across Europe is not seen		

						than moorings). Biological disturbance: NIS unclear, extraction no sites. Marine litter no sites, underwater noise, no sites.				
Satellite Remote sensing	OC and SSH at risk	OC and SSH at risk	OC and SSH at risk	OC and SSH at risk				Improve the quality of products near the coast, requires access to operational in-situ measurements. Development of new MSFD Descriptor ecosystem products	PERSEUS WPX will work on algorithm for near the coast products	Fast-track access to non-European satellite data, maintenance of Sentinal-3 launch

8. REFERENCES

8.1 References cited in the text

Alvarez, A., B. Mourre, 2012. Optimum Sampling Designs for a Glider–Mooring Observing Network. J. Atmos. Oceanic Technol., 29, 601–612.

Berthon, J.-F. and Zibordi, G., 2004. Bio-optical relationships for the northern Adriatic Sea, Int. J. Remote Sens., 25, 1527–1532,

Bouffard, J., Pascual, A., Ruiz, S., Faugère, Y and Tintoré, J., 2010. Coastal and mesoscale dynamics characterization using altimetry and gliders: a case study in the Balearic Sea. Journal of Geophyscal Research, vol. 115, C10029, doi:10.1029/2009JC006087.

Bouffard, J., Renault, L., Ruiz, S., Pascual, P., Dufau, C., and Tintore, J., 2012. Sub-surface small scale eddy dynamics from multi-sensor observations and modelling, Progress in oceanography (accepted).

Buongiorno Nardelli B., S. Colella, R. Santoleri, M. Guarracino, A. Kholod, 2009.. A re-analysis of Black Sea Surface Temperature, J. Mar. Sys.., doi:10.1016/j.jmarsys.2009.07.001.

Buongiorno Nardelli B., C.Tronconi, A. Pisano, R.Santoleri, 2013. High and Ultra-High resolution processing of satellite Sea Surface Temperature data over Southern European Seas in the framework of MyOcean project, Rem. Sens. Env., 129, 1-16, doi:10.1016/j.rse.2012.10.012.

Claustre H., Antoine D., Boehme L., Boss E., D'Ortenzio F., Fanton D'Andon O., Gruber N., Hood M., Johnson K., Lampitt R., LeTraon P.-Y., Lequéré C., Perry M.-J., Testor P., Handegard N. O., Lewis M., Yoder J., 2010. Expanding and enhancing the system for observing biogeochemical and ecosystem variables in the open ocean: new observations and capabilities in the decade ahead. ,.in

Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E.& Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.89

D'Alimonte, D., Melin, F., Zibordi, G., and Berthon, J. F.: Use of the Novelty Detection Technique to Identify the Range of Applicability of Empirical Ocean Color Algorithms, IEEE Trans. Geosci. Remote Sensing, 41, 2833–2843, 2003.

Davis, R. E. 1985. Drifter observation of coastal currents during CODE. The method and descriptive view. Journal of Geophysical Research - Oceans, 90:4741–4755.

Dobricic S., Pinardi N., Testor P. and U. Send, 2010: Impact of data assimilation of glider observations in the Ionian Sea (Eastern Mediterranean), Dynamics of Atmospheres and Oceans, 50, 78-92, doi:10.1016/j.dynatmoce.2010.01.001.

D'Ortenzio, F., Le Reste, S., Lavigne, H., Besson, F., Claustre H., Coppola, L., Dufour, A., Dutreil, V., Laes, A., Leymarie E., Malardé, D., Mangin, A., Migon, C., Morin, P., Poteau A., Prieur, L., Raimbault, P., Testor, P., 2012. Autonomously profiling the nitrate concentrations in the ocean: the PRONUTS project. Coriolis-Mercator Newsletter, April 2012.

Durrieu de Madron X, Guieu C, Sempéré R, Conan P, Cossa D, D'Ortenzio F, Estournel C, Gazeau F, Rabouille C, Stemmann L, Bonnet S, Diaz F, Koubbi P, Radakovitch O, Babin M, Baklouti M, Bancon-Montigny C, Belviso S, Bensoussan N, Bonsang B, Bouloubassi I, Brunet C, Cadiou JF, Carlotti F, Chami M, Charmasson S, Charrière B, Dachs J, Doxaran D, Dutay JC, Elbaz-Poulichet F, Eléaume M, Eyrolles F, Fernandez C, Fowler S, Francour P, Gaertner JC, Galzin R, Gasparini S, Ghiglione JF, Gonzalez JL, Goyet C, Guidi L, Guizien K, Heimbürger LE, Jacquet SHM, Jeffrey WH, Joux F, Le Hir P, Leblanc K, Lefèvre D, Lejeusne C, Lemé R, Loÿe-Pilot MD, Mallet M, Méjanelle L, Mélin F, Mellon C, Mérigot B, Merle PL, Migon C, Miller WL, Mortier L, Mostajir B, Mousseau L, Moutin T, Para J, Pérez T, Petrenko A, Poggiale JC, Prieur L, Pujo-Pay M, Pulido V, Raimbault P, Rees AP, Ridame C, Rontani JF, Ruiz Pino D, Sicre MA, Taillandier V, Tamburini C, Tanaka T, Taupier-Letage I, Tedetti M, Testor P, Thébault H, Thouvenin B, Touratier F, Tronczynski J, Ulses C, Van Wambeke F, Vantrepotte V, Vaz S, Verney R, 2011. Marine ecosystems' responses to climatic and anthropogenic forcings in the Mediterranean. Progress In Oceanography 91:97-166

European Commission. 2013. Towards European Integrated Ocean Observation. Expert Group on Marine Research Infrastructures. Final Report. 96 pp. ISBN978-92-79-27319-3. doi: 10.2777/29343.

Hayes D., Testor P., Zodiatis G., Konnaris G., Hannides A., Mortier L., Beguery L., D'Ortenzio F., Mauri E., Lekien F., Gerin R., Poulain P.-M. and Lazar A., 2010. Glider transect in the Levantine Sea: a study of the ward core Cyprus eddy. Rapp. Comm. Int. Mer Medit., 39.

Heslop, S. Ruiz, J. Allen, J-L. Lopez-Jurado, L. Renault and J. Tintoré, 2012. Autonomous ocean gliders: monitoring variability at 'choke' points in our ocean system, Geophysical Research Letters 39(20), DOI: 10.1029/2012GL053717.

Gerin R., and A. Bussani A. 2011. Nuova procedura di editing automatico dei dati drifter impiegata su oceano per MyOcean e prodotti web in near-real time e delay mode. Technical Report OGS 2011/55 OGA 20 SIRE, OGS, Trieste, Italy, 13 pp.

Hansen, D. V. and P.-M. Poulain. 1996. Processing of WOCE/TOGA drifter data. Journal of Atmospheric and Oceanic Technology, 13:900–909.

Haza A. C., A. Griffa, P. Martin, A. Molcard, T.M. Ozgokmen, A.C. Poje, R. Barbanti, J.W. Book, P.-M. Poulain, M. Rixen, and P. Zanasca. 2007. Model-based directed drifter launches in the Adriatic Sea: Results from the DART experiment. Geophysical Research Letters, 34:L10605, doi:10.1029/2007GL029634.

Haza, A., T. Ozgokmen, A. Griffa, A. Molcard, Poulain P.-M. and G. Peggion. 2010. Transport properties in small-scale coastal flows: relative dispersion from VHF radar measurements in the Gulf of La Spezia. Ocean Dynamics, 60:861-882.

Lekien F., Mortier L., and P. Testor, 2008. Glider Coordinated Control and Lagrangian Coherent Structures, 2nd IFAC Workshop Navigation, Guidance and Control of Underwater Vehicles, Volume#2, Part#1, 10.3182/20080403-IE4914.00023

L'Hévéder B., Lellouche J.-M., Lherminier P., Mortier L., Terre T., Testor P., and G. Vinay, 2009. Operational Forecast of Glider trajectories during EGO 2008 operations in the Mediterranean Sea using Mercator Ocean Forecast, Mercator Ocean Quaterly Newsletter, January 2009.

Loveday B. R., Swart S., and Storkey D. 2012. Capturing convection in the Northwest Mediterranean Sea: Using underwater gliders to assess the performance of regional forecast models. Int. J. Soc. Underw. Tech., 30:3, 1-15, doi:10.3723/ut.30.071.

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.

Malanotte-Rizzoli P. and the Pan-Med Group. 2012. Physical forcing and physical/biochemical variability of the Mediterranean Sea: A review of unresolved issues and directions of future research. Report of the Workshop “Variability of the Eastern and Western Mediterranean circulation and thermohaline properties: similarities and differences” Rome, 7-9 November, 2011, 48 pp.

Marullo S., B. Buongiorno Nardelli, M. Guarracino, and R. Santoleri, 2007: Observing The Mediterranean Sea from Space: 21 years of Pathfinder-AVHRR Sea Surface Temperatures (1985 to 2005). Re-analysis and validation, Ocean Sci. , 3, 299-310.

Mauri E., Bolzon G., Bubbi A., Brunetti F., Gerin R., Medeot N., Nair R., Salon S. and Poulain P.-M. 2010. High resolution glider measurements around the Vercelli seamount (Tyrrhenian Sea) in May 2009. Rapp. Comm. Int. Mer Medit., 39.

Merckelbach, L.M., D.A. Smeed and G. Griffiths, 2010. Vertical water velocities from underwater gliders. J. Atmos & Oceanic Tech. 3(27), 547-563. DOI:10.1175/2009JTECHO710.1

Molcard, A., P.M. Poulain, P. Forget, A. Griffa, Y. Barbin, J. Gaggelli, J.C. De Maistre, and M. Rixen. 2009. Comparison between VHF radar observations and data from drifter clusters in the Gulf of La Spezia (Mediterranean Sea). Journal of Marine Systems, 78: S79-S89.

Mourre B., J. Chiggiato, F. Lenartz, and M. Rixen, 2012. Uncertainty forecast from 3-D super-ensemble multi-model combination: validation and calibration. Ocean Dynamics, 62(2), 283-294. doi: 10.1007/s10236-011-0504-6.

Mortier L. and P. Testor, 2008. In situ remote sensing with autonomous platforms: a new paradigm for observing the ocean interior, Towards an integrated system of Mediterranean marine observatories, CIESM workshop monographs, La Spezia, 16-19 January 2008.

Mueller, J. L., and Austin, R. W.: Ocean Optics Protocols for SeaWiFS Validation, Revision 1., NASA Tech. Memo. 104566, Vol. 25, Hooker, S. B., Firestone, E. R., and Acker, J. G. Eds, NASA Goddard Space Flight Center, Greenbelt, Maryland, 67 pp, 1995.

Niiler, P.P., A. Sybrandy, K. Bi, P.-M. Poulain, and D. Bitterman. 1995. Measurements of the water-following capability of holey-sock and TRISTAR drifters. Deep-Sea Research, 42:1951–1964.

Niewiadomska, K., H. Claustre, L. Prieur, and F. d'Ortenzio, 2008. Submesoscale physical-biogeochemical coupling across the Ligurian Current (northwestern Mediterranean) using a bio-optcal glider, Limnology and Oceanography, 53, 2210-2225.

Pascual A., Faugere Y., Larnicol G., Le Traon P.-Y. (2006). Improved description of the ocean mesoscale variability by combining four satellite altimeters. Geophysical Research Letters, 33(2), doi:10.1029/2005GL024633.

Poulain, P-.M., L. Ursella, and F. Brunetti. 2002. Direct measurements of water-following characteristics of CODE surface drifters. Extended Abstracts, 2002 LAPCOD Meeting, Key Largo, FL, Office of Naval Research. [Available online at http://www.rsmas.miami.edu/LAPCOD/2002-KeyLargo/abstracts/absC302.html.]

Poulain, P.-M., L. Ursella, E. Mauri, and D. Deponte, 2003. DOLCEVITA-1 Cruise 31 January – 24 February 2003. Report of drifter-related activities, Rel. 08/2003/OGA/03, OGS, Trieste, Italy 32 pp.

Poulain, P.-M., R. Barbanti, R. Cecco, C. Fayos, Mauri E., L. Ursella and P. Zanasca, 2004. Mediterranean Surface Drifter Database: 2 June 1986 to 11 November 1999. Rel. 78/2004/OGA/31, OGS, Trieste, Italy.

(CDROM and http://poseidon.ogs.trieste.it/drifter/database_med)

Poulain, P.-M., R. Barbanti, J. Font, A. Cruzado, C. Millot, I. Gertman, A. Griffa, A. Molcard, V. Rupolo, S. Le Bras, and L. Petit de la Villeon, 2007. MedArgo: a drifting profiler program in the Mediterranean Sea. Ocean Sci., 3, 379-395.

Rio M.H., Poulain P-M, Pascal A., Mauri E., Larnicol G., Santoleri R., 2007. A mean dynamic topography of the Mediterranean Sea computer from altimeter data, in situ measurements and a general circulation model. Journal of Marine Systems 65: 484-508.

Roemmich D., Boehme L., Claustre H., Freeland H., Fukasawa M., Goni G., Gould J., Gruber N., Hood M., Kent E., Lumpkin R., Smith S., Testor P., 2010. Integrating the ocean observing system: mobile platforms, ,.in Proceedings of OceanObs’09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E.& Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.89

Ruiz, S., A. Pascual, B. Garau, I. Pujol, and J. Tintoré, 2009a. Vertical motion in the upper-ocean from glider and altimetry data. Geophysical Research Letters, L14607, doi:10.1029/2009GL03856.

Ruiz, S., A. Pascual, B. Garau, Y. Faugere, A. Alvarez, J. Tintoré, 2009b. Mesoscale dynamics of the Balearic front integrating glider, ship and satellite data, Journal of Marine Systems, 78, S3-S16, doi: 10.1016/j.jmarsys.2009.01.007

Ruiz S., B. Garau, M. Martínez-Ledesma, B. Casas, A. Pascual, G. Vizoso J. Bouffard, E. Heslop, A. Alvarez, P. Testor, J. Tintoré, 2011. New technologies for marine research: 5 years of glider activities at IMEDEA-TMOOS Scientia Marina EOF-15.

Ruiz, S., L. Renault, B. Garau, and J. Tintoré, 2012. Underwater glider observations and modeling of an abrupt mixing event in the upper ocean, Geophys. Res. Lett., 39, L01603, doi:10.1029/2011GL050078.

Santoleri, R., G. Volpe, S. Marullo, and B. Buongiorno Nardelli, 2008. Open Waters Optical Remote Sensing of the Mediterranean Sea, in Remote Sensing of the European Seas, edited by V. Barale and M. Gade, pp. 103-116, Springer.

Selsor, H. D. 1993. Data from the sea: Navy drift buoy program. Sea Technology, 34(12):53-58.

Sybrandy, A. L. and P. P. Niiler, 1991. WOCE/TOGA Lagrangian drifter construction manual. SIO REF 91/6, WOCE Rep. 63, Scripps Institution of Oceanography, San Diego, CA, 58 pp.

Testor P., L. Mortier, U. Send, R. Davis, D. Smeed, L. Merckelbach,, A. Alvarez, J. Tintore, P. Lherminier, T. Terre, G. Krahmann, J. Karstensen, H. Claustre, J.-J. Naudin, V. Rigaud, T. Carval, L. Petit de la Villeon, C. Jones, J. Sherman, 2007. European Gliding Observatories (EGO), Coriolis Newsletter, October 2007.

Testor, P., Meyers, G., Pattiaratchi, C., Bachmayer, R., Hayes, D., Pouliquen, S., Petit de la Villeon, L., Carval, T., Ganachaud, A., Gourdeau, L., Mortier, L., Claustre, H., Taillandier, V., Lherminier, P., Terre, T., Visbeck, M., Krahman, G., Karstensen, J., Alvarez, A., Rixen, M., Poulain, P.M., Osterhus, S., Tintore, J., Ruiz, S., Garau, B., Smeed, D., Griffiths, G., Merckelbach, L., Sherwin, T., Schmid, C., Barth, J.A., Schofield, O., Glenn, S., Kohut, J., Perry, M.J., Eriksen, C., Send, U., Davis, R., Rudnick, D., Sherman, J., Jones, C., Webb, D., Lee, C., Owens, B., Fratantoni, D., 2010. Gliders as a component of future observing systems,.in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E.& Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.89

Testor P., L. Mortier1, J. Karstensen, E. Mauri, K. Heywood, D. Hayes, P. Alenius, A. Alvarez, C. Barrera, L/ Beguery, K. Bernardet, L. Bertino, A. Beszczynska-Möller, T. Carval, F. Counillon, E. Dumont, G Griffiths, P. M. Haugan, J. Kaiser, D. Kasis, G. Krahmann, O. Llinas, L. Merckelbach, B. Mourre, K. Nittis, R. Onken. F. D'Ortenzio, S. Pouliquen, A. Proelss, R. Riethmüller, S. Ruiz, T. Sherwin, D. Smeed, L. Stemmann, K. Tikka, J. Tintoré, 2012. EGO: Towards a global glider infrastructure for the benefit of marine research and operational oceanography, Coriolis-Mercator Newsletter, April 2012.

Tintoré, J., Vizoso, G., Casas, B., Heslop E., Pascual, A., Orfila, A., Ruiz, S., Martínez-Ledesma, M, Torner, M., Cusí, S., Diedrich, A., Balaguer, P., Gómez-Pujol, L., Álvarez-Ellacuría, Gómara S., Sebastian K., Lora, S., Beltrán, J.P., Renault L., Juzà, M., Álvarez, D., March, D., Garau, B., Castilla, Cañellas, T., C., Roque, D., Lizarán I., Pitarch S., Carrasco M.A., Lana, A., Mason E., Escudier R., Conti, D., Sayol, J.M., Barceló, B., Alemany, F., Reglero, P., Massuti, E., Velez-Belchí, P., Ruiz, J., Gómez, M., Álvarez, A., Ansorena L., Manríquez, M., 2013. SOCIB: the Balearic Islands Observing and Forecasting System responding to science, technology and society needs. Mar. Tech. Soc. J., Vol. 47, N. 1. 17 pp.

Volpe, G., R. Santoleri, V. Vellucci, M. Ribera d'Alcalà, S. Marullo and F. D'Ortenzio, 2007. The colour of the Mediterranean Sea: Global versus regional bio-optical algorithms evaluation and implication for satellite chlorophyll estimates; Remote Sensing of Environment, doi:10.1016/j.rse.2006.10.017

Volpe, G., S. Colella, V. Forneris, C. Tronconi, and R. Santoleri, 2012. The Mediterranean Ocean Colour Observing System – system development and product validation, Ocean Sci., 8, 869-883.

8.2. References not cited in the text, corresponding to section 1.3

Babin, B., J. Bosch, B. Burnett, M. Bushnell, J. Fredericks, S. Kavanaugh and M. Tamburri, 2009: QARTOD V Final Report, http://nautilus.baruch.sc.edu/twiki/pub/Main/WebHome/QARTODVReport_Final2.pdf

Flierl, G. and A.R. Robinson, 1977. XBT measurements of thermal gradients in the MODE Eddy. Journal of Physical Oceanography, 7(2), 300-302.

Boyer,T.P., J. I. Antonov , O. K. Baranova, H. E. Garcia, D. R. Johnson, R. A. Locarnini, A. V. Mishonov, T. D. O'Brien, D. Seidov, I. V. Smolyar and M. M. Zweng, 2009. World Ocean Database 2009. S. Levitus, Ed., NOAA Atlas NESDIS 66, U.S. Gov. Printing Office, Wash., D.C., 216 pp., DVDs.

Hanawa, K. and T. Yasuda, 1992. New detection method for XBT depth error and relationship between the depth error and coefficients in the depth-time equation. Journal Oceanograojy, 48, 221-230.

Locarnini, R. A., A. V. Mishonov, J. I. Antonov, T. P. Boyer, H. E. Garcia, O. K. Baranova, M. M. Zweng, and D. R. Johnson, 2010. World Ocean Atlas 2009, Volume 1: Temperature. S. Levitus, Ed. NOAA Atlas NESDIS 68, U.S. Government Printing Office, Washington, D.C., 184 pp.

Maillard, C., M. Fichaut and MEDAR/MEDATLAS GROUP, 2001. Medar-Medatlas protocol. R.INT.TMSI/IDM/SISMER/SIS00-084

Manzella, G.M.R., M. Gambetta, 2013. Implementation of Real Time Quality Control Procedures by Means Of Probabilistic Estimate of Sea Temperature and its Temporal Evolution, http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-11-00218.1

Manzella, G.M.R., F. Reseghetti, G. Coppini, M. Borghini, A. Crusado, C. Galli, I. Gertman, D. Hayes, C. Millot, E. Ozsoy, C. Tziavos, Z. Velasquez and G. Zodiatis, 2007. The improvements of the Ships Of Opportunity Program in MFSTEP. Ocean Science, 3, 245–258, www.ocean-sci.net/3/245/2007/.

Manzella, G.M.R., E. Scoccimarro, N. Pinardi, M. Tonani, 2003. Improved near real-time data management procedures for the Mediterranean ocean Forecasting System – Volunteer Observing Ship program. Annales Geophysicae, 21, 49-62.

MEDAR Group, 2002. Mediterranean and Black Sea Database of Temperature, Salinity and Biochemical Parameters and Climatological Atlas, IFREMER, Plouzane, France. (Available at http://www.ifremer.fr/sismer/program/medar/)

Pinardi N. and G. Coppini, 2010. Operational oceanography in the Mediterranean Sea: the second stage of development. Ocean Sciences, 6, 263–267, www.ocean-sci.net/6/263/2010/

Reseghetti F., M. Borghini and G.M.R. Manzella, 2007. Factors affecting the quality of XBT data – results of analyses on profiles from the Western Mediterranean Sea. Ocean Sciences, 3, 57 - 75, www.ocean-sci.net/3/59/2007/

8.3. References not cited in the text, corresponding to section 3

Nittis, K., Tziavos, C., Thanos, I., Drakopoulos, P., Cardin, V., Gacic, M., Petihakis, G. and Basana, R., 2003. The Mediterranean Moored Multi-sensor Array (M3A): System Development and Initial Results. Annales Geophysique, 21:75-87.

Nittis, K., Tziavos, C., Bozzano, R., Cardin, V., Thanos, I., Petihakis, G., Schiano, M.E. and Zanon, F., 2007. The M3A multi-sensor buoy network of the Mediterranean Sea. Ocean Science, 3:229-243.

Kassis D., D.Ballas, Nittis K., P. Pagonis, D.Georgopoulos, 2009. An integrated ocean observing system in the Ionian Sea. 3rd Conference on Underwater Acoustic Measurements: Technologies and Results, Nafplion, 21-26 June 2009, Book of Abstracts, p.144

Kassis D., Nittis K., Perivoliotis L., Chondronasios A., Petihakis G. & P. Pagonis, 2011: Hydrodynamic properties of the south Ionian Sea based on the POSEIDON Pylos observatory. In proccedings of the 6^{th} International Conference on EuroGOOS, Sopot – Poland, 04-06 October 2011.

Pouliquen, S., T. Carval, T. Loubrieu, K. von Schuckmann, H. Wehde, L. SjurRingheim, T.Hammarklint, A. Harman, K. Soetje, T. Gies, M. de Alfonso, L. Perivoliotis, D. Kassis and V. Marinova, 2012: Real Time In Situ data management system for EuroGOOS: A ROOSes-MyOcean joint effort. In proccedings of EGU General Assembly, Vienna, Austria 22 – 27 April 2012

9. APPENDICES

9.1. Appendix 1: Protocols of quality assurance and quality control of SOP data (3.1.1)

9.1.1. Quality assurance protocols

Quality Assurance procedures include training of personnel, testing of instruments, calibration/inter-comparison, and control of data and instruments during acquisition. For real time data the QARTOD (Quality Assurance of Real Time Oceanographic Data) project defined seven management guidelines to assure the quality of data:

1. Every real-time observation distributed to the ocean community must be accompanied by a quality descriptor.
2. All observations should be subject to some level of automated real-time quality test.
3. Quality flags and quality test descriptions must be sufficiently described in the accompanying metadata.
4. Observers should independently verify or calibrate a sensor before deployment.
5. Observers should describe their methodology/calibration in the real-time metadata.
6. Observers should quantify the level of calibration accuracy and associated expected error bounds.
7. Manual checks on the automated procedures, the real-time data collected and the status of the observing system must be provided by the observer on a time-scale appropriate to ensure the integrity of the observing system.

The initial problem in the VOS programme was to assure an equal quality of data among the different participants. Quality assurance protocols were implemented and have been recently revised in the framework of the EuroFLEETS projects, enlarging them to all ship measurements.

Quality assurance is based on the following elements:

1) knowledge of the instrument and sensors, accuracy;
2) calibration and eventually inter-comparison of sensors;
3) Quality of the sampling strategy;

4) Quality assurance of field work;

5) Quality assurance of collected data;

At the beginning of each data collection there is the need to have the most general descriptions of the instruments working principle and the expected results. This would allow making the right choice in case of problems encountered during cruises. As matter of fact, this requires the presence on board of trained and qualified personnel. The presence of trained/qualified personnel, the knowledge of instruments and the environment to be investigated and results expected allow making critical decisions in case of any material malfunction, deviation or deficiency relative to:

- description of procedures
- changes in the ship track with respect to the monitoring program
- malfunctions of the instrumentation
- failures in the data acquisition
- any kind of problem that can arise during the monitoring.

A complete scheme of the steps that have been analysed in EuroFEETS is shown in Fig. 8.1.

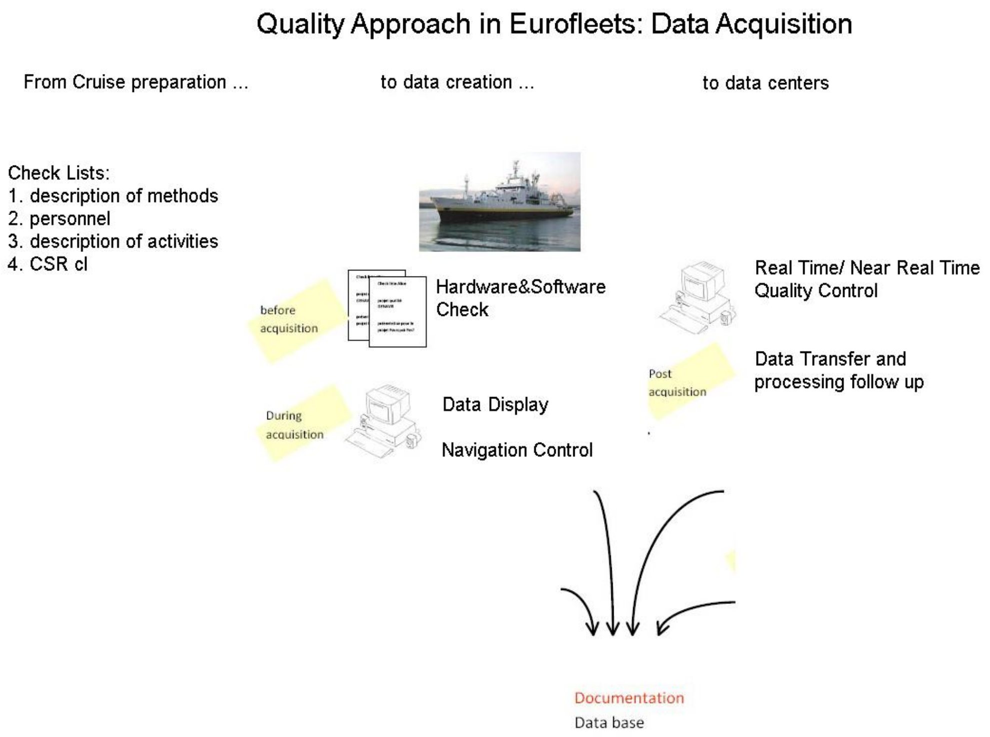

Figure 8.1. The best practices for data acquisition examined in EuroFLEETS.

Here the general concepts for quality assurance are presented.

Check List

These check lists are intended as reminder for the action to be done. Behind any check list there are the best practices that are defined in reports and protocols that must be well known by the technicians and scientists dedicated to data collection. Also the formal education of the personnel in data collection is the best assurance of data quality. The check list is a useful reminder that all necessary actions have been done before, during and after the cruise. It can be composed by many components that are herewith presented.

Description of Methods Check List

This part is related to the a priori knowledge on methods and instruments to be used during the measurement program, the results that can be expected and working instructions to personnel. It is required that the personnel is knowing the instruments, their working principles, what are the limitations in the use of such instruments and what is presumed to be the data to be collected. This means that manuals and protocols specifying how to use the instruments are available to personnel and have been assimilated in the working practices. The availability of historical data can greatly improve the quality of the work. The check includes:

- Principle of method described,
- What will be investigated,
- Representativeness of method stated,
- Drawing up working instructions
- Equipment list drawn up,
- Supplementary observations and measurements specified

Personnel Check List

This makes sure that the personnel is able to do the required work, and if the organisation of the work on board is well defined and clear to everybody. It includes

- Education of field personnel specified
- Personnel plan drawn up
- Field of responsibility for task defined

Description of Activities Check List

This is related to the planning of the cruises. Areas of investigation and ownership of data is included in this list:

- Station points clearly identified
- Description of measuring site prepared
- Other field activity described

Sensors Check List

It is also recommended to have a check list containing:

- a list of sensors selected for the cruise
- information on validation test performed before the use
- information on behaviour during the use
- state audit sensors and navigation

Software Check List

Tests have to be done also to the software used for data acquisition. In some cases, the complete data acquisition system composed by sensors, sensors' connections, cable to computer and computer could have a response that is varying on the base of sensor and computer models, as well as the hardware included in the computer for the acquisition of data. A check of the response is particular important when data are collected with different systems.

Cruise Summary Report Check List

This check list is important for the production of the CSR at the end of each cruise. Also in this case the responsibilities have to be well defined.

- Institute responsible for the cruise stated
- Person responsible for the cruise stated
- Record the personnel
- Note special aspects during the measurements
- Note deficiencies
- Ownership status clearly identified

Data acquisition hardware/software

This part is containing the necessary checks to be done on the instrumentation in order to assure:

- consistency checks on the sensors before the cruise
- monitoring control of the electronic
- state audit of sensors

This is done by means of tests on sensors and connection between sensors and a control on board of the sensors and connection functioning during their use.

Data display

This is part of the quality control process. Visualization of sensors' data will help the personnel providing alert and identifying malfunctions. This includes:

- visualization of all data (raw and engineering from sensors)

- visualization of wrong data
- identification of malfunctions
- reporting of sensors conditions

Navigation control

Navigation refers to the determination, at a given time, of the vehicle's location and velocity. It is an important component of metadata in Cruise Summary Report as well as in data file header. It is also important information to be accessed in real time. This will allow intervening in cases it is decided to change mission to cruise or the sampling strategy. Many instruments are used contemporary for the acquisition of position. Checks include:

- visualization of ship track during the navigation, as obtained by each instrument
- identification of bad instrument
- identification of malfunctions
- reporting of instrument conditions

These are checks to be done on the ship. For this reason there is a further check that must be introduced in the laboratory on shore, that is

- remote accessibility of navigation data and reporting of instrument conditions

PERSONNEL

The expertise and qualification of the personnel is of paramount importance for the quality of the results supplied. A quality assurance system must therefore include guidelines and procedures which will, at all times, aim to ensure the best possible and most relevant expertise relative to requirements.

Education

The formal education will mainly be adequate to the collection of XBT data and decisions to be taken in case of failures of the acquisition/transmission system. To ensure the quality, it is important that every field worker has adequate training relative to the methods, instruments and equipment used in the fieldwork. The field worker should also have the relevant information on the environment they are exploring, such as the temperature profiles expected during the ship trip.

Mobilization

A personnel plan must be prepared. It must contain an overview of how the field work is to be organised and what each person will do is essential for the organization of the fieldwork.

Field of responsibility

There will two level of responsibility:

1) the responsible scientist of each institution participating to MFSPP VOS (here after the 'institutional chief scientist') will:

a. ensure the contact network and lines of communication to and between the personnel

b. ensure that the personnel and material resources satisfy the MFSPP VOS demands

c. suggest the strategy of the data acquisition on the base of the ship track and timing,

d. discuss the deviations with respect to the planned measurements.

2) the technician on board will be responsible of the data acquisition and will continuously check the data acquisition/transmission system. Some decisions could be necessary during the trip. The technicians should use their experience/good-will. The field worker must decide any deviation with respect to the plans

WORKING PROCEDURES

Sippican cable

The cable length between the launcher and the computer is recommended to be almost 50 m, because the operator has to move freely, while looking for the right launching position. The launching can be performed successfully from a height on the sea surface ranging from 5 to 10 meters. This possibility is compatible with practically every type of vessel (container ship, cargo ship, gas tanker, ferry, etc…)

Launching operation: control of the launcher

The launching operation has to be performed on the side of the ship, as to avoid dangerous turbulence effects, and recommends manual launching, because the operator can control the impact angle of the probe into the sea surface as best as he can: this angle must be absolutely perpendicular. In case the probe should fall partially or totally on its side, the time needed to reach the regime fall rate would be increased and the

depth evaluated by the computer would be incorrect: the depth is not measured, but calculated by the Sippican Software, which uses an experimental speed rate, and the computation of the depth starts just at the moment the probe head gets in touch with the sea.

Wind influence

The launching side in the ship must be decided by taking the wind in consideration, because the wind could push the wire against the ship hull and break it. Launching operations: canister insertion and XBT drop After having put the canister into the launcher, the operator removes the pin, puts the arm out of the side of the ship as far as he can and points the launcher perpendicularly to the sea surface; at the right moment with regard to the wind and the ship rolling, he removes the plastic cap of the canister and drops the probe. In some cases the canister was tied to the end of a rod, in order to keep off the vessel side even more substantially. After the launch, the canister can be kept inside the launcher as to keep the electric contacts inside the launcher in good state.

Working instructions

The entire acquisition-transmission system, once properly installed, will be of a sufficient easy use. The following instructions will help to carry out the field work.

- Check the data acquisition-transmission system in the harbor every time before the beginning of the ship track.
- Record in the Cruise Summary Report the approximate ship speed.
- Prepare the launcher before reaching the measurement place. The canister must be inserted inside the launcher and the electric connections must be checked.
- The launches must be done at a predefined distance. This distance has to be calculated on the base of the ship speed.
- After the launch, the technician must check the regularity of the data acquisition by looking at the PC and record the GMT time in the Cruise Summary Report.
- Assure the saving of the original data file into diskettes, time by time.

In case of failures

Soon after the launch, the personnel must check if the temperature profile has been properly recorded by the system.

- Data out of range. In case a significant part of the profile is out of the admitted ranges, it is recommended to drop another XBT only if the time delay from the previous drop is less than 15 minutes for ships travelling at a speed less than 15 knt, or less than 10 minutes for faster ships.
- Wire break. The acquisition fault can be due to the wire break and the PC will display a profile with a depth less than the 400-460 m foreseen for the T4 probe. In this case it is recommended to drop another XBT only if the time delay from the previous drop is less than 15 minutes for ships travelling at a speed less than 15 knt, or less than 10 minutes for faster ships.

Supplementary observations and measurements

The frequency of data collection will not allow in general to make supplementary measurements. If additional information will be required to interpret and understand the results of measurements, this will be decided case by case, in order to assure the main task of this project, which is the XBT data collection for data assimilation. Some observations could help (wherever possible) on data analysis, such as: weather conditions, waves, atmospheric pressure and temperature. They can be recorder in the Cruise Summary Report.

SAFETY INSTRUCTIONS

One must constantly keep in mind that the risk of falling into the sea is always incumbent the operator: the floor can be wet and slippery, the operator can be tired after long shifts and has to lean out of the ship, the launching procedure could be performed during the night. The operator will be supplied with safety equipment, as life jacket, fastening harness and cable with spring catch to be locked to the ship before launching, lights for night operation, because the sea surface should be well lighted as to choose the right launching moment. It is recommended that safety directions should be written and agreed upon with the captain, who is responsible of enforcing them. An alarm clock should be also provided to be ready to launching even at night time. Additionally the operator will not be able to have meals with the other personnel and special provisions have to be taken with the cooking staff. In the case the launching hours should exceed a maximum, two or more people shall be hired. In any case only one of them will be the responsible of all the launching programme.

At any case it is clear that the launching frequency enforces the deployment of fully dedicated persons to XBT's launching and that the idea of employing the ship staff is not viable.

9.1.2. Quality control protocols

Some XBT probes are selected from various batches and calibrated in the CMRE (NATO marine research centre). During some ad hoc cruises, XBT and CTD data are compared. The quality control of the data includes the 'end of profile check' (when the XBT hits the sea floor), an automatic QC and a final visual check. The QC steps are the following ones:

- end of profile check
- position control*
- gross range check*
- elimination of spikes*
- interpolation at 1 metre interval*
- gaussian smoothing*
- general malfunction control*
- comparison with climatology*
- visual check, confirming the validity of profiles and providing an overall consistency.

The stars indicate the steps of the quality control performed automatically.

This procedure has recently been improved, even if it is not yet operationally used. The climatology has been substituted with best estimates. These 'best' estimates of monthly temperature profiles are calculated by using a maximum likelihood method. It has been found that more than one 'best estimate' temperatures can be defined in particular areas and depths, as a consequence of climate variability. Additional near-real time control procedures have been included in order to provide information on long-term variability associated with data. This information is included in metafiles to be used for re-analysis and studies on long-term variability/changes.

The quality control procedure now consists of ten steps:

1) date, position control (using the ETOPO1 bathymetry, for both near real-time and historical data, although the operator is requested to also check with a good hydrographic map), and control of vessel speed;
2) elimination of spikes;
3) interpolation at 1m intervals (if necessary using software provided with instruments);
4) Gaussian smoothing (for XBT);
5) general malfunction control;
6) regional range check;
7) comparison with best estimates and overall profile quality control;
8) comparison with historical data to assess the temporal variability;
9) property/property scatter (when two parameters are measured) to assess the consistency of controlled data with other historical values;
10) visual check, confirming the final validity of profiles.

9.2. Appendix 2: Results obtained with questionnaire for ship surveys (3.1.2)

	DATA PROCESSING	ARCHIVAL	QUALITY CONTROL	OWNERSHIP/AVAILABILITY
CNR	CTD data are pre-processed on board, and in the lab after post-calibration of the sensors Velocity data (if any) are processed after the cruise Chemical data are analyzed on board (oxygen), and onshore (nutrients)	Data are archived locally, metadata are available here http://www.mediterranean-marinedata.eu/	Data are quality checked before archiving Data are only partially quality checked before archiving, however data are being reprocessed at present, for final archive.	Most are confidential data, available upon request and scientific collaboration
CNRS & IFREMER	CTD data are pre-processed on board, and in the lab after post-calibration of the sensors Chemical data are analyzed onshore (oxygen, carbon, nutrients, pigments)	Data are archived locally and/or at http://www.coriolis.eu.org/, metadata are available at http://www.ifremer.fr/sismer/	Data are quality checked before archiving according to the procedures used by the Coriolis centre which are based on internationally agreed methods	Most are open data, but scientific collaboration with the PIs is encouraged
IFM GEOMAR & ZMAW	Delayed	in ODV and MEDATLAS format	Data are quality checked during data processing before archiving	Most data are publicly available, while other upon request and via scientific collaboration
HCMR	CTD data are pre-processed on board, and in the lab after post-calibration of the sensors Velocity data (if	Data and metadata are archived locally except for "POSEIDON-E1-M3A monitoring" program where	Data are quality checked before archiving For Messiniakos, Lavrio projects : QC charts analyzing	Most are confidential data, available upon request and scientific collaboration

	any) are processed after the cruise Chemical data are analyzed on board or onshore depending on the cruise duration. All data are provided in delayed mode.	metadata are archived on SEADATANET and data on HNODC	certified reference materials (VKI); participation to the QUASIMEME inter-laboratory exercise; ISO Certification according to the ELOT EN ISO / IEC 17025 procedure.	
GEOECOMAR	CTD data are processed on board and in the lab Water chemistry analyses done on-board	Data from geophysical lines (central-beam bathymetry, gravity and magnetics) are stored in dedicated databases. All the other data are locally archived	All data are quality checked before archiving Quality control of chemical analyses ensured by use of SRMs and/or samples with known concentrations (internal standards)	Data with third party beneficiaries are confidential. All the other data are available for scientific collaboration after agreement of the involved parts.
OC-UCY	Delayed	in ODV and MEDATLAS format	Data are quality checked during data processing before archiving	Most data are publicly available, while other upon request and via scientific collaboration
SIO RAS	CTD data are pre-processed on board, and in the lab after post-calibration of the sensors Velocity data (if any) are processed after the cruise Chemical data are analyzed on board (oxygen) Biological data are analyzed on	Data are archived locally	Data are quality checked before archiving	Most are confidential data, available upon request and scientific collaboration

	board and onshore			
IOF	CTD data are pre-processed on board, and in the lab after post-calibration of the sensors pH and oxygen data are analysed on board. Other chemical and all biological data are analysed in delayed mode onshore.	Data are archived locally, metadata are available here http://www.izor.hr/roscop	Data are quality checked before archiving	Most data are confidential, available upon request and scientific collaboration
IMS-METU	CTD data are pre-processed on board, and in the lab after post-calibration of the sensors. Chemical data: oxygen, hydrogen sulphide, pH and in most cases nutrients are analysed on board. Most of data on fish abundance, biomass and morphology are obtained and stored on board. Raw acoustic data are stored on board and processed in lab.	Data are archived locally, metadata are available here: http://www.ims.metu.edu.tr/IMS_Inventory/	Physical (including acoustic) and chemical data: all necessary QA procedures are applied. Data are quality controlled internally. Chemical laboratory takes part in inter-calibration exercises regularly. Data on fish abundance, biomass and morphology are QC-ed by expert(s) periodically, wrong data are excluded.	Data belong to organization/project. Public access to data is usually restricted, while access to data for scientific purposes is regulated by data policy and rules established by financing project.
IEO-COB	The data were processed on board and were later corrected in the laboratory from the calibration of the	Data were archived locally	Data were quality checked before archiving	Most of these data are confidential, available upon request and scientific collaborations

	sensors.			
IOLR	CTD data are pre-processed on board Chemical data are analyzed on board (oxygen), and onshore (nutrients)	Data are archived locally, metadata are available here http://isramar.ocean.org.il/perseus_data/Default.aspx	Data are quality checked before archiving	Most are confidential data, available upon request and scientific collaboration

9.3. Appendix 3: Glider deployments in the Mediterranean Sea

9.3.1. Glider deployments index for the Western Mediterranean Sea

Tintin	MooseT00_23	OOV-LOV	2013-01-08	2012-11-16
Tintin	test	OOV-LOV	2013-01-04	2013-01-04
Hannon	MistralsT02_01	LOCEAN	2012-12-03	2012-12-19
Sdeep00	Canales_Dec12	SOCIB	2012-11-27	2012-12-13
Bonpland	MooseT00_22	LOCEAN	2012-11-14	2012-12-20
Ideep02	CanalIbiza_11_12	IMEDEA	2012-11-01	2012-11-21
Ideep02	Canales_10_2012	IMEDEA	2012-10-24	2012-11-07
Sdeep02	JERICO_TNA_OCT2012	SOCIB	2012-10-23	2012-10-30
Campe	MistralsT02_00	DT INSU	2012-09-17	2012-11-16
Greta	nomr12groom	NURC	2012-09-16	2012-09-22
Sophie	nomr12groom	NURC	2012-09-16	2012-09-28
Jade	nomr12groom	NURC	2012-09-16	2012-09-22
Ideep00	Canales_09_2012	IMEDEA	2012-09-12	2012-09-17
Tintin	MooseT00_21	OOV-LOV	2012-09-10	2012-09-11
Zoe	nomr12groom	NURC	2012-09-06	2012-09-22
Noa	nomr12groom	NURC	2012-09-06	2012-09-28
Laura	nomr12groom	NURC	2012-09-06	2012-09-22
Natalie	nomr12groom	NURC	2012-09-06	2012-09-22
Eudoxus	PerseusT02_00	ENSTA	2012-09-05	2012-12-19
Elettra	nomr12groom	NURC	2012-09-05	2012-09-11
Hannon	MistralsT01_00	LOCEAN	2012-09-04	2012-10-23
Bonpland	MooseT00_20	LOCEAN	2012-08-23	2012-09-04
Ideep00	test	IMEDEA	2012-08-21	2012-09-11
Tintin	MooseT00_19	OOV-LOV	2012-06-13	2012-07-25
Sg508	MooseT02_09	DT INSU	2012-05-16	2012-07-24
Tintin	MooseT00_18	OOV-LOV	2012-04-18	2012-05-22
Sg509	MooseT02_07	DT INSU	2012-04-02	2012-04-02
Hannon	MooseT02_08	LOCEAN	2012-03-20	2012-03-23
Campe	Imedia	DT INSU	2012-03-05	2012-04-25
Tintin	MooseT00_17	OOV-LOV	2012-01-25	2012-02-11
Sg508	test	DT INSU	2012-01-11	2012-01-17
Bonpland	MooseT00_16	LOCEAN	2012-01-09	2012-01-25

Crate	Recette	DT INSU	2011-12-02	2011-12-19
Tintin	MooseT00_15	OOV-LOV	2011-11-30	2011-12-30
Hannon	Tosca	LOCEAN	2011-11-29	2011-12-19
Nearchos	testautopilot	ENSTA	2011-11-15	2011-12-02
Milou	MooseT00_14	OOV-LOV	2011-10-21	2011-12-06
Tintin	MooseT00_13	OOV-LOV	2011-09-20	2011-10-21
Icoast00	Canales_09_2011	IMEDEA	2011-09-20	2011-09-24
Milou	MooseT00_12	OOV-LOV	2011-08-11	2011-09-03
Eudoxus	MooseT02_06	ENSTA	2011-08-09	2011-09-26
Milou	MooseT00_11	OOV-LOV	2011-07-11	2011-07-16
Ideep00	Canales_06_2011	IMEDEA	2011-06-02	2011-06-19
Milou	MooseT00_10	OOV-LOV	2011-06-01	2011-06-22
Himilcon	MooseT02_05	LOCEAN	2011-05-30	2011-06-08
Ideep00	Canales_05_2011	IMEDEA	2011-05-03	2011-05-21
Sg508	MooseT02_04	DT INSU	2011-04-27	2011-05-30
Milou	MooseT00_09	OOV-LOV	2011-04-26	2011-05-12
Tintin	Suna	OOV-LOV	2011-04-21	2011-04-28
Ideep00	Canales_03_2011	IMEDEA	2011-03-18	2011-04-11
Nearchos	MooseT02_03	ENSTA	2011-03-09	2011-04-06
Tenuse	Cascade	DT INSU	2011-03-03	2011-04-28
Eudoxus	Cascade	ENSTA	2011-03-03	2011-04-06
Ideep00	Canales_02_2011	IMEDEA	2011-02-10	2011-03-04
Milou	MooseT00_08	OOV-LOV	2011-01-31	2011-03-14
Ideep00	Canales_01_2011	IMEDEA	2011-01-12	2011-02-04
Milou	MooseT00_07	OOV-LOV	2010-11-17	2010-12-27
Sg509	MooseT02_02	DT INSU	2010-11-12	2011-02-07
Wallis	latex	DT INSU	2010-08-25	2010-08-27
Sg508	MooseT02_01	DT INSU	2010-08-23	2010-09-29
Tenuse	latex	DT INSU	2010-08-23	2010-09-29
Pytheas	latex	ENSTA	2010-08-23	2010-09-30
Milou	MooseT00_06	OOV-LOV	2010-07-20	2010-09-06
Tintin	MooseT00_05	OOV-LOV	2010-07-09	2010-07-25
Tenuse	lidex10	DT INSU -OGS	2010-06-30	2010-07-25
Icoast00	JASON-1_Jun10	IMEDEA	2010-06-10	2010-06-16
Milou	MooseT00_04	OOV-LOV	2010-05-28	2010-07-08
Campe	MooseT02_00	DT INSU	2010-05-14	2010-07-13
Icoast00	JASON-1_Apr10	IMEDEA	2010-04-07	2010-04-20

Icoast00	JASON-1_Dec09	IMEDEA	2009-12-09	2009-12-20
Nearchos	MooseT01_05	ENSTA	2009-11-18	2009-12-20
Milou	MooseT00_03	OOV-LOV	2009-11-17	2009-12-17
Trieste_1	Tyrrh_01	OGS	2009-11-05	2009-11-08
Tintin	MooseT00_02	OOV-LOV	2009-11-02	2009-12-02
Milou	MooseT00_01	OOV-LOV	2009-10-12	2009-10-24
Icoast00	JASON-1_Oct09	IMEDEA	2009-10-01	2009-10-05
Milou	Boussole21	OOV-LOV	2009-09-09	2009-09-21
Himilcon	MooseT01_04	LOCEAN	2009-09-02	2009-09-04
Milou	Boussole20	OOV-LOV	2009-08-06	2009-08-10
Tintin	Boussole19	OOV-LOV	2009-07-16	2009-07-19
Tintin	Boussole18	OOV-LOV	2009-07-12	2009-07-15
Eudoxus	MooseT01_03	ENSTA	2009-07-05	2009-08-16
Tintin	Boussole17	OOV-LOV	2009-05-14	2009-05-20
Ideep02	SINOCOP_2009	IMEDEA	2009-05-12	2009-05-18
Icoast00	SINOCOP_2009	IMEDEA	2009-05-12	2009-05-18
Nearchos	MooseT01_02	ENSTA	2009-03-12	2009-05-03
Wallis	MooseT01	DT INSU	2009-01-25	2009-02-27
Icoast00	JASMIN_August2008	IMEDEA	2008-08-12	2008-08-27
Icoast00	ENVISAT-April2008	IMEDEA	2008-04-07	2008-04-23
Ammonite	ego2008	NOCS	2008-02-26	2008-03-27
Coprolite	ego2008	NOCS	2008-02-26	2008-03-27
Bellamite	ego2008	NOCS	2008-02-26	2008-03-27
Icoast00	ego2008	IMEDEA	2008-02-25	2008-03-26
Icoast00	CANALES_02_2008	IMEDEA	2008-02-18	2008-03-04
Ifm04	ego2008	IFM-GEOMAR	2008-02-14	2008-03-15
Potame	ego2008	LPO	2008-01-29	2008-04-07
Pytheas	ego2008	ENSTA	2008-01-28	2008-06-00
Himilcon	ego2008	LOCEAN	2008-01-16	2008-02-15
Hannon	ego2008	LOCEAN	2008-01-16	2008-02-15
Icoast00	ENVISAT-October2007	IMEDEA	2007-10-22	2007-10-23
Icoast00	ENVISAT-September2007	IMEDEA	2007-09-14	2007-09-17
Icoast00	Cabrera	IMEDEA	2007-07-18	2007-07-20
Icoast00	ENVISAT-July2007	IMEDEA	2007-07-06	2007-07-13
Potame	ego2007	LPO	2007-04-17	2007-06-07
Pytheas	ego2007	ENSTA	2007-03-01	2007-04-01

Ifm02_deepy	ego2007	IFM-GEOMAR	2007-01-31	2007-02-28
Icoast00	ego2007	IMEDEA	2007-01-14	2007-09-01
Ammonite	ego2007	NOCS	2007-01-01	2007-05-01
Bellamite	ego2007	NOCS	2007-01-01	2007-05-01
Spray016	ego2007	IFM-GEOMAR	2007-01-01	2007-06-01
Coprolite	ego2007	NOCS	2007-01-01	2009-05-01
Pytheas	Livingstone	ENSTA	2006-11-17	2006-11-29
Icoast00	MERSEA	IMEDEA	2006-09-19	2006-10-31
Ifm02_deepy	MERSEA-Balearic04	IFM-GEOMAR	2006-07-11	2006-07-24
Pytheas	BioProPhy	ENSTA	2006-05-01	2006-05-02
Ifm02_deepy	MERSEA-Balearic03	IFM-GEOMAR	2006-03-31	2006-07-10
Ifm02_deepy	MERSEA-Balearic02	IFM-GEOMAR	2006-03-27	2006-03-29
Ifm02_deepy	MERSEA-Balearic01	IFM-GEOMAR	2005-09-20	2005-10-06

9.3.2 Glider deployments index for the Central Mediterranean Sea

Ifm02_deepy	MFSTEP-Ionian	IFM-GEOMAR	2005-02-02	2005-02-22
Ifm01	MFSTEP-Ionian	IFM-GEOMAR	2004-09-01	2005-03-01

9.3.3. Glider deployments index for the Eastern Mediterranean Sea

Pheidippides	EasternLevantine 07	OC-UCY	2011-12-15	0000-00-00
Pheidippides	EasternLevantine 06	OC-UCY	2011-05-23	2011-06-16
Atalanta	EasternLevantine 05	OC-UCY	2010-10-28	2011-02-15
Pheidippides	EasternLevantine 04	OC-UCY	2010-08-01	2010-08-09
Atalanta	Cyprus09	OC-UCY	2009-11-23	2010-04-23
Trieste_1	Cyprus09	OGS	2009-11-12	2010-03-17
Hannon	Cyprus09	LOCEAN	2009-11-12	2009-12-18
Bonpland	Cyprus09	LOCEAN	2009-11-12	2010-01-09

Pytheas	Cyprus09	ENSTA	2009-11-12	2009-12-05
Eudoxus	Cyprus09	ENSTA	2009-11-12	2010-01-09
Atalanta	EasternLevantine 02	OC-UCY	2009-06-15	2009-08-13
Pheidippides	EasternLevantine 01	OC-UCY	2009-03-10	2009-04-10

9.4. Appendix 4: Synopsis Table with Coastal/Local Observations (3.1)

Site no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Geographical location	Sicily Straits (western sills)	Corsica channel	Israeli Shelf (Hadera, Ashkelon)	Southern Georgian Coast (Batumi, Kobuleti, Poti)	North-Eastern Black Sea (Galendzhik)	Gulf of Naples	Gulf of Naples	Gulf of Naples	Croation Coast (Kastela to Palagrouza)	Croatian Coast (Pag to Dubrovnik)	Central Adriatic Sea	Maiorca	Offshore Venice Lagoon	North-Eastern Adriatic sea	Nearshore Gulf of Trieste (Nearshore, Miramare)	Gulf of Trieste	Gulf of Trieste	Isonzo e Tagliamento (Rivers Gulf of Trieste)	Gulf of Trieste	Piran
Platform type	Mooring	Mooring	Ofshore structure	Meteo stations	Vertical profiles and hydrographic sampling	Hydrographic sampling	Sea gages	CODAR	Hydrographic sampling	Hydrographic sampling	Hydrographic sampling	Land/on shore structure	CODAR	CODAR	moored surface buoy	system of 3 moored surface buoy	moored surface buoy	river station	Long Term Ecological Record - C1 - Gulf of Trieste	Long Term monitoring site
Time coverage	decadal	decadal	pluriannual	pluriannual	pluriannual	decadal	pluriannual	pluriannual	decadal	decadal	decadal	pluriannual	2 years	2.5 years	Decadal	Pluriannual	Pluriannual	Pluriannual	Decadal	Decadal
Organization	ISMAR-CNR (Italy)	ISMAR-CNR (Italy)	IOLR (Israel)	TSU (Georgia)	SIO (RAS)	SZN (Italy)	CoNISMa (Italy)	CoNISMa (Italy)	IOF (Croatia)	IOF (Croatia)	IOF (Croatia)	SOCIB (Spain)	IOF-OGS	IOF-OGS	IOF-OGS	IOF-OGS	IOF-OGS	IOF-OGS	IOF-OGS	MIB
Access													Academic	Academic	Academic	By Negotiation	By Negotiation	By Negotiation	By negotiation	By negotiation
Parameters	Temperature of the water column	Temperature of the water column	Temperature of the water column	Sea level	Acoustic backscatter in the water column	Microzooplankton generic abundance in water bodies	Sea level	Horizontal velocity of the water column (currents)	Temperature of the water column	Temperature of the water column	Temperature of the water column	Sea level expressed as pressure	Horizontal velocity of the water column (currents)	Horizontal velocity of the water column (currents)	Air temperature	Other wave statistics	Air temperature	Horizontal velocity of the water column (currents)	Biodiversity indices	Air temperature
	Salinity of the water column	Salinity of the water column	Salinity of the water column	Air pressure	Salinity of the water column	Particulate total and organic nitrogen concentrations in the water column	Sea level		Salinity of the water column	Salinity of the water column	Salinity of the water column	Raw temperature and/or salinity instrument output			Air pressure	Spectral wave data parameters	Air pressure	Vertical velocity of the water column (currents)	Bacteria generic abundance in water bodies	Temperature of the water column
	Horizontal velocity of the water column (currents)	Horizontal velocity of the water column (currents)	Raw oxygen sensor output	Air temperature	Temperature of the water column	Nitrate concentration			Density of the water column	Density of the water column	Density of the water column	Air pressure			Alkalinity, acidity and pH of the water column	Wave direction	Alkalinity, acidity and pH of the water column		Carotenoid pigment concentrations in the water column	Salinity of the water column
	Dissolved oxygen	Dissolved oxygen	Raw fluorometer output	Precipitation and evaporation	Date and time	Nitrite concentration			Secchi disk depth	Secchi disk depth	Secchi disk depth	Sea level			Atmospheric humidity	Wave height and period statistics	Atmospheric humidity		Carbon concentrations in suspended particulate material	Dissolved oxygen

			Raw suspended particulate material optical sensor output	Wind speed and direction	Horizontal velocity of the water column (currents)	Raw oxygen sensor output			Dissolved oxygen	Dissolved oxygen	Dissolved oxygen				Concentration of suspended particulate material in the water column	Wave height estimates	Dissolved oxygen parameters in the water column		Particulate total and organic carbon concentrations in the water column	Dissolved oxygen
			Wind speed and direction	Temperature of the water column	Moored instrument depth	Phytoplankton taxonomic abundance in water bodies			pH	pH	pH	Air pressure			Dissolved oxygen parameters in the water column		Electrical conductivity of the water column		Chlorophyll pigment concentrations in the water column	Chlorophyll pigment concentrations in the water column
			Air pressure			Phaeopigment concentrations in the water column			Particulate total and organic nitrogen concentrations in the water column	Particulate total and organic nitrogen concentrations in the water column	Particulate total and organic nitrogen concentrations in the water column	Raw temperature and/or salinity instrument output			Electrical conductivity of the water column		Horizontal velocity of the water column (currents)		Dissolved organic carbon concentration in the water column	Nitrate concentration
			Sea level expressed as pressure		Chlorophyll pigment concentrations in the water column	Phytoplankton generic abundance in water bodies			Nitrate concentration	Nitrate concentration	Nitrate concentration	Electrical conductivity of the water column			Partial pressure (pCO2) and fugacity (fCO2) of carbon dioxide in the water column		Salinity of the water column		Wind speed and direction	Nitrite concentration
			Wave height and period statistics		Zooplankton dry weight biomass per unit volume of the water column	Light absorption in the water column			Nitrite concentration	Nitrite concentration	Nitrite concentration	Sea level expressed as pressure			Salinity of the water column		Sea level expressed as pressure		Raw fluorometer output	Raw oxygen sensor output
			Horizontal velocity of the water column (currents)		Nitrate concentration	Primary production in the water column			Silicate concentration	Silicate concentration	Silicate concentration	Raw temperature and/or salinity instrument output			Sea level expressed as pressure		Temperature of the water column		Concentration of dissolved organic matter in the water column	Phytoplankton taxonomic abundance in water bodies

					Nitrite concentration	Salinity of the water column			Zooplankton taxonomy-related abundance per unit volume of the water column	Zooplankton taxonomy-related abundance per unit volume of the water column	Zooplankton taxonomy-related abundance per unit volume of the water column	Electrical conductivity of the water column			Solar Radiation		Vertical velocity of the water column (currents)		Raw light meter output	Phytoplankton generic abundance in water bodies
					Ammonium concentration	Temperature variation in the water column			Phytoplankton taxonomic volume in water bodies	Phytoplankton taxonomic volume in water bodies	Phytoplankton taxonomic volume in water bodies	Sea level expressed as pressure			Temperature of the water column		Wind speed and direction		Microzooplankton taxonomic abundance in water bodies	Plankton abundance per unit volume of the water column
					Phosphate concentration	Plankton abundance per unit volume of the water column			Zooplankton dry weight biomass per unit volume of the water column	Zooplankton dry weight biomass per unit volume of the water column	Zooplankton dry weight biomass per unit volume of the water column	Horizontal velocity of the water column (currents)			Variable fluorescence parameters				Zooplankton dry weight biomass per unit volume of the water column	Silicate concentration
					Dissolved oxygen	Secchi disk depth			Phytoplankton taxonomic abundance in water bodies	Phytoplankton taxonomic abundance in water bodies	Phytoplankton taxonomic abundance in water bodies				Visible waveband radiance and irradiance measurements in the water column				Microzooplankton generic abundance in water bodies	Phytoplankton taxonomic volume in water bodies
					Silicate concentration	Density of the water column			Primary production in the water column	Primary production in the water column	Primary production in the water column				Wind speed and direction				Particulate total and organic nitrogen concentrations in the water column	Zooplankton taxonomy-related abundance per unit volume of the water column
						Silicate concentration			Plankton abundance per unit volume of the water column	Plankton abundance per unit volume of the water column	Plankton abundance per unit volume of the water column								Nitrate concentration parameters in the water column	Microzooplankton taxonomic abundance in water bodies

						Raw temperature and/or salinity instrument output			Microzooplankton taxonomic abundance in water bodies	Microzooplankton taxonomic abundance in water bodies	Microzooplankton taxonomic abundance in water bodies								Nitrite concentration parameters in the water column	
						Temperature of the water column													Raw oxygen sensor output	
						Raw suspended particulate material optical sensor output													Phytoplankton taxonomic abundance in water bodies	
						Phytoplankton taxonomic volume in water bodies													Phaeopigment concentrations in the water column	
						Zooplankton taxonomy-related abundance per unit volume of the water column													Phytoplankton generic abundance in water bodies	
																			Light absorption in the water column	
																			Primary production in the water column	
																			Salinity of the water column	
																			Temperature variation in the water column	

																			Plankton abundance per unit volume of the water column	
																			Secchi disk depth	
																			Density of the water column	
																			Silicate concentration parameters in the water column	
																			Raw temperature and/or salinity instrument output	
																			Temperature of the water column	
																			Raw suspended particulate material optical sensor output	
																			Phytoplankton taxonomic volume in water bodies	

																			Zooplankton taxonomy-related abundance per unit volume of the water column	

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