Proposition de campagne à la mer
Flotte Océanographique Française

FLOTTE OCEANOGRAPHIQUE FRANCAISE

APPEL D'OFFRES 2014

Nom de la campagne : SOMBA-GE2014

Nom du responsable du projet / programme : Laurent Mortier

Nom du chef de mission principal : Laurent Mortier

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Dossier scientifique

WARNING: This request for ship time is made in the 'Observation' category, not as a 'Research' cruise as indicated in the CNFC web application which as not been updated yet to included this new item.

SOMBA-GE2014
Large Scale Marine Observations in the Algerian Bassin

1. International context: Mediterranean ocean observing systems

The present "ocean operational observing systems"* in the Mediterranean are a small number of regionally or nationally supported systems which are based on several measuring platforms, including in general RVs, to survey a given region (ADRICOSM in the Adriatic, CYCOFOS south of Cyprus, "Mediterranean Ocean Observing System on the Environment" [MOOSE] focused on the North Western Mediterranean, POSEIDON in the Greek waters, mainly the Aegean, and SOCIB around the Balearic Islands). The drivers of these systems span from societal ones to more scientific ones (e.g. POSEIDON monitoring mainly the marine weather for navigation safety and environmental hazard, or MOOSE which aims at monitoring the marine ecosystems in a region which is dominated by a bloom regime). All these systems deliver near real time and quality checked information which is distributed to the public, in particular through the Marine Core Service channels.

The coordination between these systems is weak, except from the platform point of view where several European MRIs (EuroSITES/FIXO3 for the deep moorings, EuroARGO for the profiling floats, GROOM for the gliders, JERICO for coastal observations, …) are active to guarantee in principle common methodologies at the European level, including for the above observing systems which all rely on these MRIs.

In addition to these systems, there are also some useful thematic systems or networks: some are based on one single platform (e.g. Research Vessel [RV] based hydrological survey of the RADMED project from IEO) and/or limited to a very restricted set of parameters (e.g. the HYDROCHANGES network of bottom moorings from CIESM). Some of these networks may have an international coordination but, in general in that case, no long term national nor European support.

2. Identified gaps in the Mediterranean ocean observing systems

All the systems and networks leave important areas uncovered, especially in the East and South of the basin. A detailed census of these gaps is being established in the frame of the FP7-PERSEUS project. PERSEUS also intend to provide a strategy for the integration of the observing systems and initiatives for long-term observations in the Mediterranean (and Black Sea) with international strategies such as GOOS and EuroGOOS. Other gaps in the parameters which are collected exist too, which might prevent at the moment for example, fulfillment of the needs related to the MSFD or the GMES. These gaps definitively prevents from having a global view of the Mediterranean Sea in both space and parameters. And as a consequence, there are big gaps in the data products that these systems and networks can deliver for the assessment and monitoring of the environmental conditions (e.g. needed for research oriented applications such as the MERMEX/MISTRALS program (see below), or for the indicators/descriptors of the MFSD, ...).

It also clear that the RV component of the observing systems is not as well defined as other components such as profiling floats, fixed point observatories or gliders, because of the lack of an agreed international coordination on the scientific objectives and obvious operational considerations.

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* Here the word 'operational' stands for systems who are organized to deliver data and products to a wide public on the long term, which implies institutional commitments.

But, even if RVs are no more the unique platform to collect in-situ hydrological information, RV based hydrological surveys are still needed for three important reasons:

- Some essential ocean parameters are only accessible through this platform;
- There is need for ground truth on the long term for modeling purposes as well as for the parameters collected by the other autonomous platforms, as their sensors can drift or because they collect only proxies;
- The deep water column and some regions (complex topography, strong currents, …) cannot be easily surveyed by the autonomous platforms (limited to the upper 2000m).

In synthesis, as stated in the "GO-SHIP Repeat Hydrography Manual" (http://www.go-ship.org/HydroMan.html), despite numerous technological advances over the last decades, ship-based hydrography remains the only method for obtaining high-quality, high spatial and vertical resolution measurements of a suite of physical, chemical, and biological parameters over the full water column. Ship-based hydrography is essential for documenting ocean changes throughout the water column, especially for the deep ocean below 2km.

The MedGO-SHIP initiative (http://www.ciesm.org/online/monographs/Supetar12.pdf) has recently reviewed the different strategies that could be consistent with the Mediterranean Basin [MedB] characteristics and has proposed to organize the surveys at the basin scale. Other initiatives already consider the gaps in the East and South of the basin. An initiative by academics from Algeria, France and Spain in the frame of the "Système d'Observation à la Mer du Bassin Algérien" [SOMBA] and of the MERMEX/MISTRALS program has started with the objective to extend and coordinate the observations in the Algerian Basin [AB] with the existing observing systems in the North of the Western Basin [WB]. The present application for ship time concerns this initiative.

3. National Context : MERMEX and MOOSE

The "Marine Ecosystems Response in the Mediterranean Experiment" [MERMEX] project is one of the seven projects of the "Mediterranean Integrated STudies at Regional And Local Scales" [MISTRALS] program. MISTRALS is a long term research coordinating program (decade) dedicated to the understanding of the response of the MedB environment to the global change. The main objective is a better understanding of the response of ecosystems to modifications of physico-chemical forcing at various scales, both in time and space, linked to changing environmental conditions (e.g. climate warming) and increasing human pressure. In fact, long term and some more recent observations already show change in the hydrology, in the biogeochemical systems and in ecosystems (MERMEX group, 2010 ; Schroeder et al. 2005 ; Béthoux 2002 ; Marty and Chiavérini, 2002 ; Malanotte-Rizzoli et al., 1999).

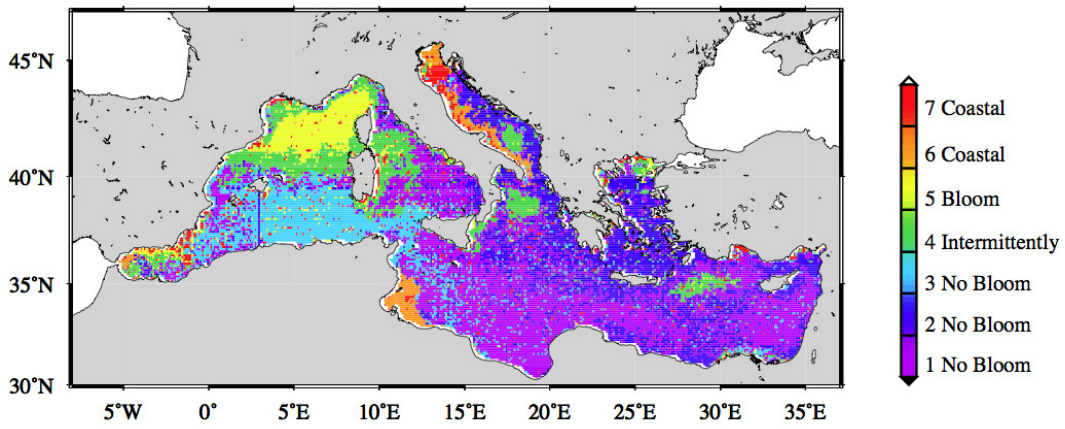

Figure 1. Spatial distribution of the clusters obtained from the k-means analysis of the ten years dataset of SeaWifs chlorophyll concentration maps.

MERMEX proposes a comprehensive, integrated approach considering the continuum between the coastal zone and the open sea and its interfaces, including ocean-continent, ocean-atmosphere and water-sediment to precisely describe and model the current state of the Mediterranean ecosystems and the complex interactions existing between the environmental and human factors (MERMEX group, 2010). The project relies on dedicated experiments targeted on specific scientific objectives such as the on going "Deep Water Experiment" started in Sept. 2012.

One of the guidelines to organize the spatial extension of these experiments is based on the different trophic regimes that Ocean Color allows to determine (D'Ortenzio & Ribera d'Alcalà, 2009). In the WB, figure 1 clearly shows two main regions: One in the North which is dominated by a "bloom" regime with temporal characteristics close the North Atlantic ones, and another in the AB with a "non blooming" (according to Longhurst classification) bimodal distribution with higher and quite constant values in fall-winter and lower and uniform values in late spring-summer (D'Ortenzio & Ribera d'Alcalà, 2009).

For the long term perspective, MERMEX relies on the "Système d'Observation et d'Expérimentation au long terme pour la Recherche en Environnement" [SOERE] MOOSE supported by the alliance of French ministers and agencies for the environment ALLENVI. In fact, MOOSE supports the general MERMEX objectives by providing the long term observation frame (> decade) to observe the long term evolution of the NW Mediterranean in order to be able detect and identify long-term environmental anomalies and to build efficient indicators of the environmental status in the NW MedB. Obviously the coordination with other observing systems in other Mediterranean sub-basins is crucial for that. Among others, the I-MOOSE initiative is building this coordination to be able to have a coherent basin scale approach.

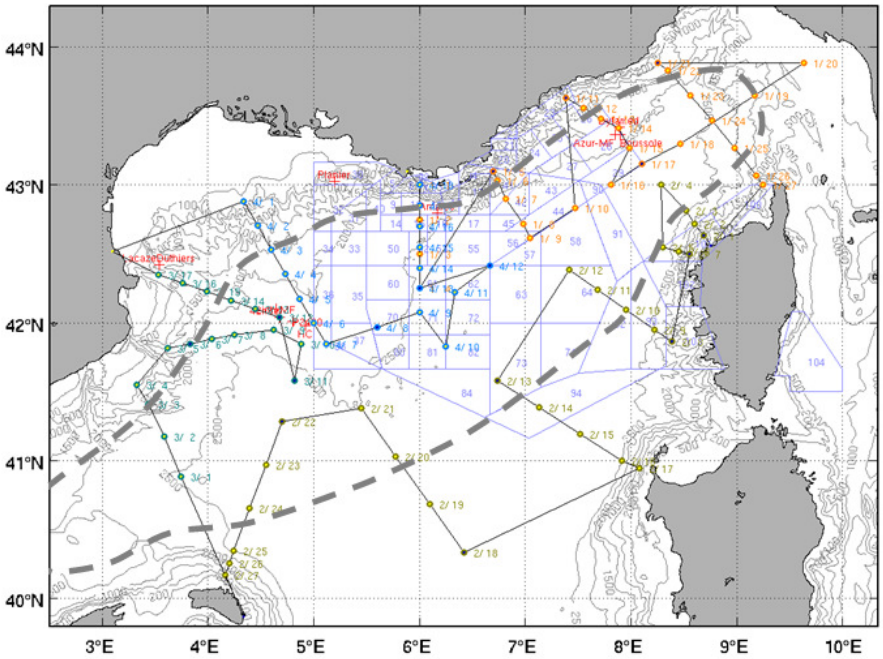

Figure 2. Map of the MOOSE-GE2011 cruise on the RV Tethys II. The cyclonic gyre is schematized by the dotted grey line.

In the frame of MOOSE, RV cruises over almost the whole NW Mediterranean have already been carried annually since 2010 (MOOSE-GE2010 to 2012 on the Tethys II and Le Suroît RVs), with a relatively high spatial resolution. The suffix GE stands for "Grande Echelle" meaning Large Extension. This survey is scheduled at least up to 2020. In this area, the annual basis is motivated by the rapid changes of deep water formation because of the internal dynamics of the basin and of climate variability and warming.

The spatial organization of the MOOSE-GE cruises relies on the existence of the cyclonic Northern gyre. The distribution of the hydrological stations is organized in sections from the coast toward the two moorings, LION and DYFAMED, in the center of the gyre or across the gyre (see fig. 2). The parameter space of MOOSE is based on the « Essential Oceanic Variables » (EOV): Continuous profiles of CTD, oxygen, fluorescence, turbidity and current (LADCP) and samples from the rosette for the nutrient are collected at each stations, while inorganic carbon and pigments are sub-sampled to approx. one half of the stations. In addition, thanks in particular to new optical devices, the parameters surveyed during the MOOSE-GE cruises is extending now to much more complex information (zooplankton indicators from video, particle counters, ...).

4. Algerian context : SOMBA

SOMBA is an observational system at sea in the Algerian Basin that will support "MERMEX Algerie" efforts in Algeria. SOMBA was thought to address the following main questions:

- Understanding biogeochemical cycles and budgets in the Algerian basin for the main bio-components (C, N, P); assessing anthropogenic carbon penetration and air-sea O2 and CO2 fluxes; investigating changes in the circulation and its effect on oxygen distribution in subsurface waters, as well as on productivity.
- Understanding the interactions between contaminants, biogeochemical cycles and food web, together with the terrestrial input variability, in order to define a panel of indicators (physical/biological/chemical) that will help policy makers to ensure a sustainable development along the Algerian coast. SOMBA also includes the understanding and monitoring of the coastline with application to its management.

On a first phase which is starting now, SOMBA intend to set up a pilot zone in the central part of the AB (coastal and marine waters), because this area shows the highest anthropogenic pressure as compared to other parts of the Algerian coast (demography, industry, waste waters …). The observational system in this area will be composed of:

- High frequency measurements: deployment of a sea level gauges coastal network, in the Algiers bay; a mooring in the center of the same bay for temperature and current survey.
- Weekly to seasonal measurements for the hydrological parameters (temperature, salinity), main contaminants (hydrocarbons, heavy metals), biogeochemical tracers (oxygen, pH, nutrients, total alkalinity, nutrients), specific benthic and pelagic organisms (pollution indicators) covering Algiers (polluted) and Bou Ismaïl (almost pristine) bays.
- An off-shore time series station (ALBA) for the monthly survey of the hydrological and biogeochemical parameters.
- An annual hydrological – geochemical cruise in the Algerian Basin (SOMBA-GE).

Contacts have been established with Spanish and French partners (IMEDEA and SOCIB partners in Spain, MOOSE partners in France) for the implementation of these components in order to share the effort when relevant (e.g. for the annual cruise) and above all to use similar analytical procedure and data management methods.

Here, it must be emphasized that several international initiatives are accompanying the national or local initiatives, like the SOMBA one, in the countries in the South and the East of the Mediterranean, MISTRALS provides support to "bottom-up" initiatives to build networks between Southern and European countries through the ENVIMED call for proposals. Other similar mechanisms are obviously active at the EU level (FP7-INCO, ENPI, …).

5. The SOMBA-GE cruises rationale

The annual SOMBA-GE cruises have been defined is the whole context.

The main objective of SOMBA-GE is to start the companion time series of MOOSE for the "Essential Oceanic Variables" in the Algerian Basin, with an extension and spatial scales coherent with the general circulation. This long term information will be essential for ALL the

scientific projects and models developed in the frame of MERMEX and other national or international programs.

*As for MOOSE, SOMBA being a **service**, detailed scientific exploitation plans are not done here since they rely on the scientific projects from the laboratories. However, it worth mentioning that the Mediterranean general circulation model developed in the frame of MISTRALS for HYMEX and MERMEX need is coupled with two trophic models (PISCES and ECO3M, both focused on primary production), which have a crucial need of these data in the AB.The 3D extension of the cluster analysis presented below will allow rely on these data as they already do with MOOSE ones.*

As a matter of fact, although the AB features (Algerian Current, anticyclonic eddies at surface, cyclonic gyres at depth, see below) are known to be essential for the spreading of the Mediterranean Atlantic Waters [MAW] in the whole MedB, and for the trophic regime of the AB as shown by the cluster analysis shown in figure 1, only a few oceanographic cruises have been conducted in this region over the past decades and none of them have considered the AB as an unique dynamical entity.

In addition, the D'Ortenzio's cluster analysis is restricted to the very upper of the photic layer which may be a strong limitation in the AB where very high values of chlorophyll concentration at the Deep Chl. Maximum [DCM] can be found in June (Raimbault et al, 1993). Very high value in autumn have also been reported from some observational programs conducted along the Algerian coast by ENSSMAL (Illoul H., unpublished material, master thesis). These values are also in clear relation with the intense isopycnal and diapycnal mixing associated to the mesoscale activity (Raimbault et al, 1993) associated to the instabilities of the Algerian Current (Millot, 1985). How the hydrological and dynamical features in the AB affect nutrient distribution ? How the latter favor or not the existence of DCM as shown in Raimbault et al.? And how this will be affected by the changes in time of the forcing, these are the main scientific questions that will be supported by the SOMBA-GE annual time series starting with the 2014 one.

Building consistent regimes taking into account the production at depth will rely on statistical methods that can only develop with the adequate distribution of data on the water column and on the horizontal in order the extrapolate Chlorophyll content get from sea color remote sensing. A multi-platform approach combining gliders, BioArgo profiling floats which are being deployed now in the frame of the NAOS project (http://en.naos-equipex.fr/News/Roadmap-for-the-deployment-decision-of-the-NAOS-Bio-Argo-Mediterranean-floats) and RVs based hydrology is what has been proposed in the context of MERMEX to solve this problem.

It is also known that the circulation and deep water formation in Mediterranean play an important role in the anthropogenic carbon sequestration and also that the Mediterranean acts as a source of anthropogenic carbon for the Atlantic Sea (Ait-Ameur et Goyet, 2007). The increase of CO2 in sea water leads to a pH decreases (Orr et al., 2005) and this decrease affects calcareous species and calcium carbonate water saturation (Kleypas et al., 2006). Few data are available concerning the carbonate system in the Algerian Basin (Bendas and Mebarki, 2010, Internal Report ENSSMAL) but modeling show that the Algerian basin acts as a sink for atmospheric CO2 (Louanchi et al., 2009) which is also the case anthropogenic CO2 (Touratier et al. 2012). Another aspect concerns oxygen cycling in the Southwestern Mediterranean area. Then, more insight in the spatial distribution of these processes and time evolution concentrations will also be supported by the SOMBA-GE cruises:

- How these anticyclonic eddies favor oxygen and carbon dioxide penetration and how the deep gyres transport affect their distribution in the whole AB ? Do we observe or not a de-oxygenation trend as in other world regions ?
- What is the inventory of anthropogenic carbon in this area ? How the latter have already affected surface water acidity ?

For this first cruise, the same approach adopted by MOOSE a been chosen. Testor el al., 2005 have shown the existence of two deep cyclonic gyres in the Algerian Basin, which have been shown to partly control the circulation of the Mediterranean Atlantic Water in the surface layers. In particular, these gyres are responsible for the cyclonic circuit made by most of the Algerian eddies [AEs] at surface. Complex barolinic/barotropic interactions take place here. So, in addition to the instabilities of

the Algerian Current and to the AEs which are generated by these instabilities, this is **the main dynamical constraint which has been considered for the planning of SOMBA-GE2014**. The LADCP information (and the ADCP of the boat) will be therefore crucial for the exploitation of the results and will complement the few lagrangian and eulerian data acquired in this basin at depth at the end of the 90s (Testor el al., 2005).

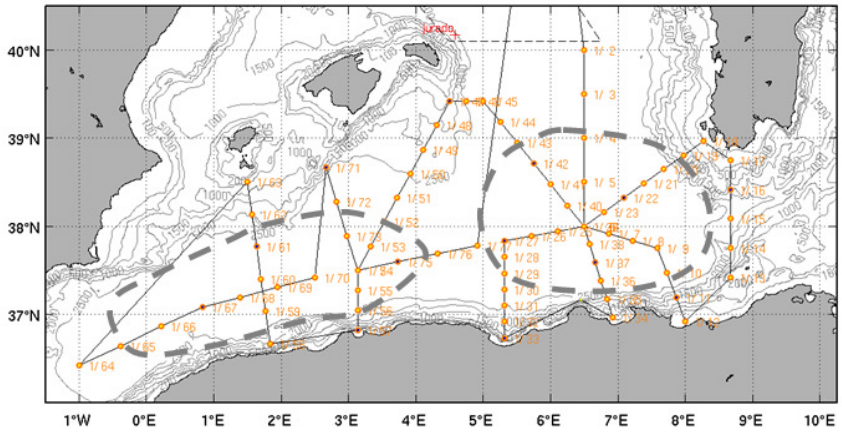

Figure 3. Schematic map of the proposed SOMBA-GE2014 cruise on the RV Tethys II. The two (deep) cyclonic gyres are schematized by the dotted grey line. The distribution of the stations on each section is drawn as regular but will be adapted with higher resolution on the shelf slope than in the abyssal plain.

Remote sensing information (Altimetry, SST, Sea color) and the data from the profiling floats, in particular from the two BioARGO profiling floats of the NAOS project (providing nitrate and fluorescence profiles) that will be launched in the AB in late 2013, will allow to put in the right temporal frame the CTD and rosette data that will be collected in the surface layers which depend on a "random" distribution of water properties due to the AEs. In addition, the monthly cruise to the ALBA point off the Algiers bay (point 1.55 figure 3) by the RV Benyahia will provide a reference time series complementing the ground truth at annual scale made by SOMBA-GE cruises.

6. The SOMBA-GE2014 cruise organization

6.1 Requested ship, duration and period

The temporal schedule considers the following rules in force in the "Flotte Océanographique Française" on the requested Tethis II which is a "façade" class vessel (~25m)

- Work of the crew from 7h am to 23 pm, for a 7 persons crew.
- A day of rest after 5 days continuously at sea.

Three days have also been added to cover ship loading and unloading, meteorological and other hazards (refueling in Algerian harbors, …). Based on the network of stations and transit time (see 6.2), **twenty three (23) days of ship time are requested.**

The requested period is end of summer. The main reasons for this choice are logistical but they do not go against the scientific objectives. Firstly, the MOOSE-GE2014 will take place in late spring in the NW basin with almost the same French scientific team. Secondly, the September period has low winds which strongly minimize the meteorological hazard for the requested vessel class.

The SOMBA-GE2014 cruise is the first of this time series. In the following years, the SOMBA-GE cruises may be conducted by ENSSMAL with its RV Benyahia.

*As for the MOOSE-GE2012, if the RV Le Suroît is available, this vessel could be used as well. Is that case, the cruise will last only **nineteen (19) days** with the same network.*

6.2 Spatial distribution and extension

The plan of the SOMBA-GE2014 cruise is presented in figure 3 where the two gyres are sketched with the dotted thick grey lines. The distribution of the stations on each section is drawn as regular but will be adapted with higher resolution on the shelf slope than in the abyssal plain. Two other constraints coherent with the "gyres" dynamical constraint, have been considered to built this plan:

- To provide one or two CTD profiles in the main Algerian bays (Alger, Bejia, Skikda, Annaba) which is a useful information for the SOMBA system in these important coastal sites.
- To provide profiles that could be useful for the MEDOCC project and cruises performed by ISMAR/CNR in Italy. MEDOCC cruises consider in particular a long West-East section in the middle of the BA which is useful to map the spreading of the Mediterranean Deep Water formed in the MOOSE area.

With the temporal constraint which have been considered, **76 stations can be performed**. If the crew were composed of 8 persons (in that case, work is possible the whole day), additional stations could be performed.

6.3 Equipement requested to the "Parc National d'Instrumentation de l'INSU"

A CTD equipped with two T/S sensors, oxygen, fluorescence, turbidity sensors, an altimeter and a bottom detector and the deckunit are requested for this cruise from the national facility.

6.4 Analysis of the data

Temperature and salinity, LADCP currents. Validation of these data are under the responsibility of LOCEAN and LOV. Data from the thermosalinometer and ADCP from the boat are processed directly by DTINSU/CNRS.

Biogeochemical data

Nutrient samples (NO3, NO2, SiOH4, PO4) will be performed by ENSSMAL and MIO.

HPLC pigments analysis is under the responsibility of LOV.

Dissolved inorganic carbon analysis (total alkalinity and total carbon) will be performed by ENSSMAL or SNAPO.

ENSSMAL will ensure on board the analysis of dissolved oxygen (Winkler protocol) and pH.

ENSSMAL and MIO will take advantage of this cruise to proceed to an inter-calibration exercise for nutrient and oxygen measurements based on SOMLIT recommendations (http://somlit.epoc.u-bordeaux1.fr).

Archiving of data

CTD data are transmitted in real time to the national center of real time oceanographic data (Coriolis) which performs the quality control, reformatting, archiving and broadcast on the GTS of the transmitted data. The CTD and biogeochemical data processed in delayed mode are also transmitted to Coriolis for access through its portal and for archiving to the NODC (SISMER). They will be also accessible through the MISTRALS portal (http://mistrals.sedoo.fr/). This data flow is exactly the one in use by MOOSE.

6.5 Scientific team

The scientific crew is composed of senior and young scientists of all the laboratories involved in MOOSE and SOMBA observatories and from IMEDEA. Most of them have a strong experience in research and monitoring cruises in all their components: organization and logistics, legal and maritime regulations aspects, work at sea, management of data including real time distribution to data center, … In particular, L. Mortier, X. Durrieu de Madron, and P. Testor have all been chief scientists of the large scale cruises conducted in the frame of MOOSE (MOOSE-GE2010, 11 and 12) and MERMEX (DoWEX2012, DeWEX2013-1 and DeWEX2013-2) on the RVs Tethis II or Le Suroît.

The final organization of the scientific crews will depend of the number of calls that could be done in Algerian harbors.

Durrieu de Madron Xavier	CEFREM	Researcher	Physical oceanography
Houpert Loic	CEFREM	PhD	Physical oceanography
Ait Ameur Nadira	ENSSMAL	Researcher	Biogeochemistry
Aït-Ouferoukh Lydia	ENSSMAL	PhD	Biogeochemistry
Boudjellal Benyahia	ENSSMAL	Engineer	Biogeochemistry
Eddalia Nabila	ENSSMAL	Engineer	Biogeochemistry
Zerrouki Mohamed	ENSSMAL	PhD	Biogeochemistry
Louanchi Ferial	ENSSMAL	Researcher	Biogeochemistry
Ruiz Simon	IMEDEA	Researcher	Physical oceanography
Dause Denis	LOCEAN	Engineer	Physical oceanography
Legoff Hervé	LOCEAN	Engineer	Physical oceanography
Mortier Laurent	LOCEAN	Researcher	Physical oceanography
Testor Pierre	LOCEAN	Researcher	Physical oceanography
Conan Pascal	LOMIC	Researcher	Biogeochemistry
Coppola Laurent	LOV	Researcher	Biogeochemistry
d'Ortenzio Fabrizio	LOV	Researcher	Physical oceanography
Taillandier Vincent	LOV	Engineer	Biogeochemistry
Lefevre Dominique	MIO	Researcher	Biogeochemistry
Raimbault Patrick	MIO	Researcher	Biogeochemistry

6.5 Funding

The cost of the analysis will be mostly supported by ENSSMAL. Travels and small logistics (transport from Brest, transport of samples when needed) will be supported by MOOSE. A specific request for funding will be done to the MERMEX-France or MERMEX-Algérie programs to fund the "ticket modérateur" for the ship.

7. Cited and team References

Cited references

Béthoux J-P., Morin P. et Ruiz-Pino D., (2002). Temporal trends in nutrial ratios : chemical evidence of marine ecosystem changes driven by human activities. Deep sea Research II, 49: 2007-2016

D'Ortenzio, F., Ribera d'Alcala, M., 2009: On the trophic regime of the Mediterranean Sea: a satellite analysis, Biogeosciences, 6, 139–148

Louanchi F., Boudjardji M. and Nacef L., (2009). Decadal change in surface carbon dioxide and related variables in the Mediterranean Sea as inferred from a coupled data diagnostic model approach, ICES Journal of Marine Science, 66: 1538-1546

Malanotte-Rizzoli P., Manca B.B., Ribera d'Alcala M., Theocharis et al., (1999). The Eastern Mediterranean in the 80s and in the 90s: The big transition in the intermediate and deep circulation. Dynamics of Atmosphere and Oceans, 29: 365-395

Marty J-C., Chaiverini J., (2002). Seasonal and interannual variations in phytoplankton production at DYFAMED time-series station, northwestern Mediterranean Sea. Deep Sea research II, 49: 2017-2010

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, et al., (2005). Anthropogenic ocean acidification over the twenty first century and its impact on calcifying organisms. Nature, 437: 681-686

Raimbault P., Bernard Coste, Mostefa Boulhadid, Benyahia Boudjellal, 1993: Origin of high phytoplankton concentration in deep chlorophyll maximum (DCM) in a frontal region of the Southwestern Mediterranean Sea (algerian current), Deep Sea Research Part I: Oceanographic Research Papers, Volume 40, Issue 4, April 1993, Pages 791-804, ISSN 0967-0637. doi:10.1016/0967-0637(93)90072-B.

Testor P., Send U., Gascard J.-C., Millot C., Taupier-Letage I., and K. Béranger, 2005: The mean circulation of the southwestern Mediterranean Sea - the Algerian Gyres, J. Geophys. Res., 110, C11017. doi:10.1029/2004JC002861, 20056

Touratier, F., V. Guglielmi, C. Goyet, L. Prieur, M. Pujo-Pay, P. Conan, and C. Falco: Distributions of the carbonate system properties, anthropogenic CO2, and acidification during the 2008 BOUM cruise (Mediterranean Sea). Biogeoscience Discuss., 9, 2709–2753, 2012. doi:10.5194/bgd-9-2709-2012

Team reference

Aït-Ouferoukh L. & F. Louanchi, 2010. Variabilité décennale de l'oxygène dissous dans le bassin Algérien. Congrès International « Biodiversité et Ecosystèmes Littoraux – 02 », Oran, 28-30 Novembre 2010

Aït-Ameur N., C. Goyet, Distribution and transport of natural and anthropogenic CO2 in the Gulf of Cádiz, Deep Sea Research Part II: Topical Studies in Oceanography, Volume 53, Issues 11–13, June 2006, Pages 1329-1343, ISSN 0967-0645, 10.1016/j.dsr2.2006.04.0

Babali N. & F. Louanchi, 2010. Variations décennales du carbone anthropique dans le bassin algérien. Congrès International « Biodiversité et Ecosystèmes Littoraux – 02 », Oran, 28-30 Novembre 2010

Béranger K., L. Mortier, G-P Gasparini, L. Gervasio, M. Astraldi and M. Crépon. The dynamics of the Sicily Strait: A comprehensive study from observations and models. In Deep Sea Research II, Vol. 51:411-440, 2004

Béthoux J.P., X. Durrieu de Madron, F. Nyffeler, D. Taillez (2002). Deep water in the western Mediterranean: peculiar 1999 and 2000 characteristics, shelf formation hypothesis, variability since 1970 and geochemical inferences. Journal of Marine Systems, 33-34, 117-131

Conan P, Turley CM, Stutt E, Pujo-Pay M, Van Wambeke F (1999) Relationship between Phytoplankton Efficiency and the Proportion of Bacterial Production to Primary Production in the Mediterranean Sea. Aquatic Microbial Ecology, 17:131□144

D'Ortenzio F., Ludicone D., de Boyer Montegut C., Testor P., Antoine D., Marullo S., Santoleri R., and G. Madec, 2005: Seasonal variability of the mixed layer depth in the Mediterranean Sea as derived from in situ profiles, Geophysical Research Letters, 32, 12, L12605

Lavigne H.,d'Ortenzio F., Claustre H., Poteau A., 2011: Towards a merged satellite and in situ fluorescence ocean chlorophyll product, Biogeosciences Discussion, 8, 11899-11939

Louanchi, F., and R. G. Najjar (2000), A global monthly climatology of phosphate, nitrate, and silicate in the upper ocean: Spring-summer export production and shallow remineralization, Global Biogeochem. Cycles, 14(3), 957–977, doi:10.1029/1999GB00121

MERMEX group (2011) Marine ecosystems' responses to climatic and anthropogenic forcings in the Mediterranean. Progress in Oceanography, 91, 97-166

Najjar, R. G. , Jin, X. , Louanchi, F. , Aumont, O. , Caldeira, K. , Doney, S. C. , Dutay, J. C. , Follows, M. , Gruber, N. , Joos, F. , Lindsay, K. , Maier-Reimer, E. , Matear, R. J. , Matsumoto, K. , Monfray, P. , Mouchet, A. , Orr, J. C. , Plattner, G. K. , Sarmiento, J. , Schlitzer, R. , Weirig, M. F. , Yamanaka, Y. and Yool, A. (2007): Impact of circulation on export production, dissolved organic matter and dissolved oxygen in the ocean: Results from OCMIP-2 , global biogeochemical cycles., 21 (3)

Pascual, Ananda, Damià Gomis, Robert L. Haney, Simón Ruiz, 2004: A quasigeostrophic analysis of a meander in the palamós canyon: vertical velocity, geopotential tendency, and a relocation technique. J. Phys. Oceanogr., 34, 2274–22

Pujo-Pay M., Conan P., Oriol L., Cornet-Barthaux V., Falco C., Ghiglione J.-F., Goyet C., Moutin T., Prieur L., 2011. Integrated survey of elemental stoichiometry (C, N, P) from the western to eastern Mediterranean Sea. Biogeosciences, 8, 883–899.

Ruiz, S., A. Pascual, B. Garau, I. Pujol, and J. Tintoré (2009), Vertical motion in the upper ocean from glider and altimetry data, Geophys. Res. Lett., 36, L14607, doi:10.1029/2009GL038569

Testor P., Béranger K., and L. Mortier, 2005: Modeling the deep eddy field in the southwestern Mediterranean: the life cycle of Sardinian Eddies, Geophys. Res. Let., 32, No. 13, L13602, doi:10.1029/2004GL022283.

Tusseau-Vuillemin, M.-H., L. Mortier, and C. Herbaut, 1998: Modeling nitrate fluxes in an open coastal environment (Gulf of Lions): Transport versus biogeochemical processes, J. Geophys. Res., 103(C4), 7693–7708, doi:10.1029/97JC03709

Van-wambeke F., Ghiglione J-F., Nedoma J., Mével G., Raimbault P., 2009. Bottom-up effects on bacterioplankton growth and composition during summer-autumn transition in the open NW Mediterranean Sea. Biogeosciences, 6: 705-720

Béthoux J-P., Morin P. et Ruiz-Pino D., (2002). Temporal trends in nutrial ratios : chemical evidence of marine ecosystem changes driven by human activities. Deep sea Research II, 49: 2007-2016.

Louanchi F., Boudjardji M. and Nacef L., (2009). Decadal change in surface carbon dioxide and related variables in the Mediterranean Sea as inferred from a coupled data diagnostic model approach, ICES Journal of Marine Science, 66: 1538-1546.

Malanotte-Rizzoli P., Manca B.B., Ribera d'Alcala M., Theocharis et al., (1999). The Eastern Mediterranean in the 80s and in the 90s: The big transition in the intermediate and deep circulation. Dynamics of Atmosphere and Oceans, 29: 365-395.

Marty J-C., Chaiverini J., (2002). Seasonal and interannual variations in phytoplankton production at DYFAMED time-series station, northwestern Mediterranean Sea. Deep Sea research II, 49: 2017-2010.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, et al., (2005). Anthropogenic ocean acidification over the twenty first century and its impact on calcifying organisms. Nature, 437: 681-686.