

SOLAS France

compiled by: Rémi Losno

Notes: Many thanks to all the contributors

Reporting Period is January 2014 – December 2014

Information will be used for: reporting, fundraising, networking, strategic development & outreach

1. Scientific highlights

Cécile Guieu et al. The significance of the episodic nature of atmospheric deposition to Low Nutrient Low Chlorophyll regions

To examine the impact of aerosol deposition and its temporal variability in Low Nutrient Low Chlorophyll (LNLC) systems, we evaluated the potential impact of new atmospheric nutrient inputs (iron, nitrate and phosphate) in LNLC regions on primary production, N₂ fixation, surface Chl a concentrations, and export production by applying atmospheric deposition to a coupled 3D ocean ecosystem-biogeochemical model. We then compared the model results with a compilation of published experimental responses of natural LNLC seawater to aerosol addition, to further examine the impacts of episodicity of aerosol deposition. Field and laboratory bioassay experiments reveals that the overall impact is not a simple “fertilization effect of increasing phytoplankton biomass” as observed in HNLC regions (*Figure 1*). Although phytoplankton growth may be enhanced, increases in bacterial activity and respiration result in weakening of biological carbon sequestration. The application of models using climatological or time-averaged non-synoptic deposition rates produced responses that were generally much lower than observed in the bioassay experiments. Experimental data and model outputs show better agreement on short timescale when strong synoptic pulse, similar in magnitude to those observed in the field and introduced in bioassay experiments, is superimposed over the mean atmospheric deposition fields. These results suggest that atmospheric impacts in LNLC regions have been underestimated by models, at least at daily to weekly timescales, as they typically overlook large synoptic variations in atmospheric deposition and associated nutrient and particle inputs.

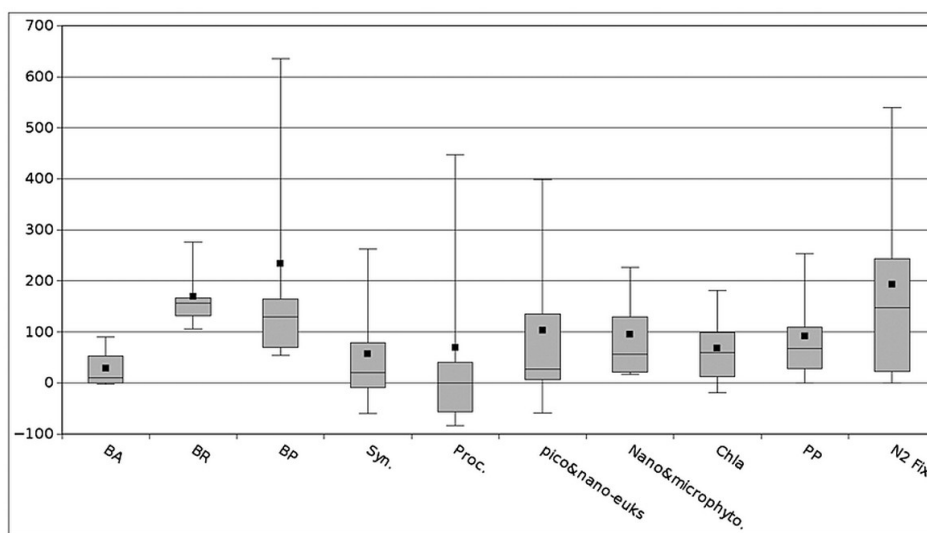


Figure 1. Whisker plots showing the responses of different biological variables to aerosol additions in LNLC waters: synthesized from available data from field and laboratory aerosol addition bioassay experiments and mesocosm experiments. The responses are % changes in the aerosol treatment relative to the control after 2-8 days, with zero indicating no difference between the aerosol treatment and the control, and a positive response indicating an increase in the parameter in the aerosol treatment relative to the control. Parameters: (BA) Bacteria Abundance, (BR) Bacteria Respiration, (BP) Bacteria Production, (Syn.) Synechococcus abundance, (Proc.) Prochlorococcus abundance, (pico & nano-euks) Nano- and Picoeukaryotes abundance, (nano & microphyto) nano- and micro-phytoplankton abundance, (Chl a) Chlorophyll-a, (PP) primary production, (N2Fix) nitrogen fixation.

Nathalie Lefèvre et al., Sea-air CO₂ fluxes in the western tropical Atlantic

The seasonal flux of CO₂ was assessed using quasi-synoptic cruises in the western tropical Atlantic (6°S-15°N, 52°W-24°W). The region is a sink of CO₂ for the atmosphere in March as it is dominated by the winter cooling of the northern hemisphere whereas it is a source of CO₂ in July. The main surface currents are characterized by different fCO₂. Overall the North Equatorial Counter Current (NECC) carries less saline waters with lower fCO₂ than the South Equatorial Current (SEC). This is explained by the advection of Amazon waters by the NECC and the presence of the Inter-Tropical Convergence Zone in boreal summer.

2. International interactions and collaborations (including contributions to international assessments such as the IPCC, links with observation communities, links with policy makers or socio-economics circles, etc.)

Meetings and workshops

Future of SOLAS Workshop, transition towards Future Earth (January 9-10th, 2014, Galway, Ireland (V. Garçon).

SFB754 Annual Retreat (February 17-18th, 2014, Kiel): invited speaker “ The Benguela/Namibia upwelling system “ and “EBUS as SOLAS natural playgrounds: What is next?” (V. Garçon)

“Low oxygen environments in marine, estuarine and fresh waters” (46th International Liège Colloquium, May 5-9th, 2014): Scientific Committee, participation

- “Mesoscale structures as barriers to mixing in the East Tropical Pacific Oxygen Minimum Zone”: J. Bettencourt (IFCS), C. Lopez (IFCS), E. Hernandez-Garcia (IFCS), I. Montes (GEOMAR/IGP), J. Sudre (LEGOS), B. Dewitte (LEGOS), A. Paulmier (IMARPE/LEGOS), and Véronique Garçon (LEGOS).
- “Inference of super-resolution ocean pCO₂ and air-sea CO₂ fluxes from non-linear and multiscale processing methods”: V. Garçon (LEGOS), J. Sudre (LEGOS), I. Hernandez-Carrasco (LEGOS), B. Dewitte (LEGOS), S. Illig (LEGOS), I. Dadou (LEGOS), A. Paulmier (LEGOS), I. Montes (GEOMAR/IGP), H. Yahia (INRIA/GEOSTAT), C. Garbe (U. Heidelberg), and A. Butz (KIT).
- “Seasonal and interannual variability of dissolved oxygen on the continental shelf of conception (36°S) over 2000-2008: physical versus biogeochemical factors.”: M. Pizarro-Koch (Udec), O. Pizazro (DG/UdeC), B. Dewitte (LEGOS), M.Ramos (CEAZA), A. Paulmier (LEGOS), and I. Montes (GEOMAR/IGP)
- EO for Ocean-Atmosphere Interactions Science. Responding to the new scientific challenges, SOLAS/ESA-ESRIN (Frascati, October 28-31th, 2014): Invited speaker “Ocean Upwelling and Oxygen Minimum Zone (OMZ): issues and perspectives from satellite observations” (A. Paulmier)
- Workshop “Mexican OMZ” (November 24-28th, 2014; CICESE, Mexico): Invited Speaker “OMZ mechanisms and hypotheses” (A. Paulmier)

Collaborative projects

July 2014: Grant awarded to LEGOS by the **EU ESASTAP plus program** to explore the potential R&D collaborations between University of Cape Town (UCT, South Africa), the Laboratoire d'Études en Géophysique et Océanographie Spatiale (LEGOS, Toulouse, France), and 2 German institutions, Leibniz Center for Tropical Marine Ecology (ZMT, Bremen, Germany) and the University of Hamburg (Germany) with the overarching goal of producing scenarios for strategic, long-term international partnerships for French, German and South African universities and research institutions and to create the conditions for implementation of these.

CARBOCHANGE (EU FP7) Two merchant ships are equipped with an autonomous CO₂ system and provide underway fCO₂ data along the track from France to French Guiana and France to Brazil. Two moorings of the PIRATA array (6°S, 10°W and 8°N, 38°W) are equipped with a CARIOCA sensor for hourly fCO₂ monitoring. The data are sent to international databases and are used by the Surface Ocean CO₂ Atlas (**SOCAT**) project (www.socat.info). Collaborations exist with Brazil to enhance the network of CO₂ observations in the western tropical Atlantic within the ongoing research program **INCT AmbTropic** (National Institute on Science & Technology in Tropical Marine Environments, www.inctambtropic.org/). One of the research theme is directly related to SOLAS, CLIVAR and PIRATA activities: **WG 3.2 - Biogeochemical Cycles, CO₂ Fluxes and Acidification of the Tropical Atlantic Ocean** led by Moacyr Araujo (UFPE, Brazil) & Nathalie Lefèvre (IRD, France).

BIOAMAZON, IRD-UFMA (Université Fédérale du Maranhão, Brazil) project, 2014-2016. Biological and biogeochemical properties off the coast of Maranhão and in the Amazon plume (Antônio Carlos Leal de Castro & Nathalie Lefèvre).

3. Activities/main accomplishments (research projects, cruises, special events, workshops, remote sensing used, model and data intercomparisons etc.)

Jaqueline Boutin and Liliane Merlivat: diurnal to seasonal variability of P_{CO2} and DIC in Southern Ocean from CARIOCA measurements. We analyzed the importance of physical and biological processes at different scales according to regions and seasons (Resplandy et al 2014) quantified the net Community production (NCP) from the CARIOCA measures and compared to satellite estimates (Merlivat et al 2014A). As part of KEOPS2 project, we have shown that the variability of the ASC estimates from CARIOCA action was strongly related to the variability of iron contents off the Kerguelen Plateau, reinforcing the hypothesis of fertilization of the area by iron (Merlivat et al. 2014b). We also finalized a study showing the influence of internal waves on hourly variability pCO₂ daily in the tropical Atlantic (Parard et al 2014). We pursued the acquisition of pCO₂ measurements wetting Compass (Western Mediterranean sea) with a miniaturized CARIOCA sensor developed as part of the ANR BIOCAREX (one and a half of acquired measurements). A detailed analysis of the measures will be conducted in 2015.

Lars-Eric Heimbürger et al.: Vertical export flux of metals in the Mediterranean Sea. In Mediterranean Sea, vertical export flux is driven by primary production and water convection. Metal (Al, V, Cr, Mn, Fe, Ni, Cu, Zn, Cd and Pb) and particulate organic carbon (OC) concentrations of the marine vertical export flux at the DYFAMED time-series station in the Northwestern Mediterranean Sea were examined, using data of a suite of natural and anthropogenic metals from sediment trap moorings deployed at 1000 m-depth between 2003 and 2007. A highly significant correlation was observed between most metal concentrations, whatever the nature and emission source of the metal. Temporal variability and metal concentrations of atmospheric and marine fluxes are distinct and suggest that dense water convection and primary production and not atmospheric deposition control the marine vertical export flux. This argument is strengthened by the fact that significant Saharan dust events did not result in concomitant marine vertical export fluxes nor did they generate significant changes in metal concentrations of trapped particles. The variability of metal and OC concentrations is relatively low (RSD = 21-43 %) compared to the variability of vertical export flux (RSD = 147 %). This implies that the temporal variability of TM and OC fluxes (calculated as the product of TM, or OC, and vertical export flux) is almost entirely governed by the variability of the vertical export flux. We notice that this is also the case for other Mediterranean sediment trap moorings, suggesting that this is a general feature. Lastly, we point out the vertical export fluxes are highest in the more productive Western MED Sea compared to the less productive, but more dust-impacted Eastern MED Sea, arguing again for dense water convection and primary production-controlled vertical export fluxes.

Aurelien Paulmier (aurelienLEGOS@gmail.com), **Boris Dewitte**, **Véronique Garçon**, and **Christophe Maes**: **AMOP** for "Research Activities dedicated to the Oxygen Minimum in the East Pacific".

AMOP international project is focused on the study of the formation of OMZ formation, in the largest OMZ and in the most productive upwelling system, the Peru system. Conversely to other projects dedicated to different OMZ impacts study, AMOP is specifically oriented on the oxygen pa-

parameter, with the objective to carry out the most complete O_2 budget as possible taking into account physical (advection/diffusion) and biological (e.g. O_2 consumption/production through bacteria and zooplankton) contributions. The project implies a transdisciplinarily approach: biogeochemistry, microbiology, physics, coupling with atmosphere, acoustics, ecology, disciplines all aiming towards the understanding of the O_2 fluxes. The approach is based on a monitoring mooring associated with a modeling effort in order to improve the *in situ* observations strategy and to assist data interpretation, but especially on a process-oriented cruise of 30 days involving the R/V L'Atalante from IFREMER that took place off Peru from the 25th of January to the 22nd of February 2014. The cruise included 8 fixed stations of ~54 hours duration and 28 other hydrological stations along a rectangular box parallel to the Peruvian coasts, with sampled cross-shore transects at 7°S, 12°S, and 14°S, providing a comprehensive unprecedented high-resolution data set. Original *in situ* observations have combined on board experimentations and use of new technologies, including a drifting line (with current-meters, sediment traps, oceanographic sensors and *in situ* O_2 dynamics auto-analyzers or IODAs), a free-rising CTD, 9 Argo-floats and the OCARINA trimaran for atmospheric near-surface measurements. In particular, biogeochemical experiments have been carried out in order to characterize with high refinement O_2 and organic matter distribution and fluxes in the OMZ associated with ecosystem communities from bacteria toward zooplankton and higher trophic level. Atmospheric forcing controlling the OMZ variability has been documented in detail through the use of an atmospheric mast and the releases of radiosondes (*Figure 2*).

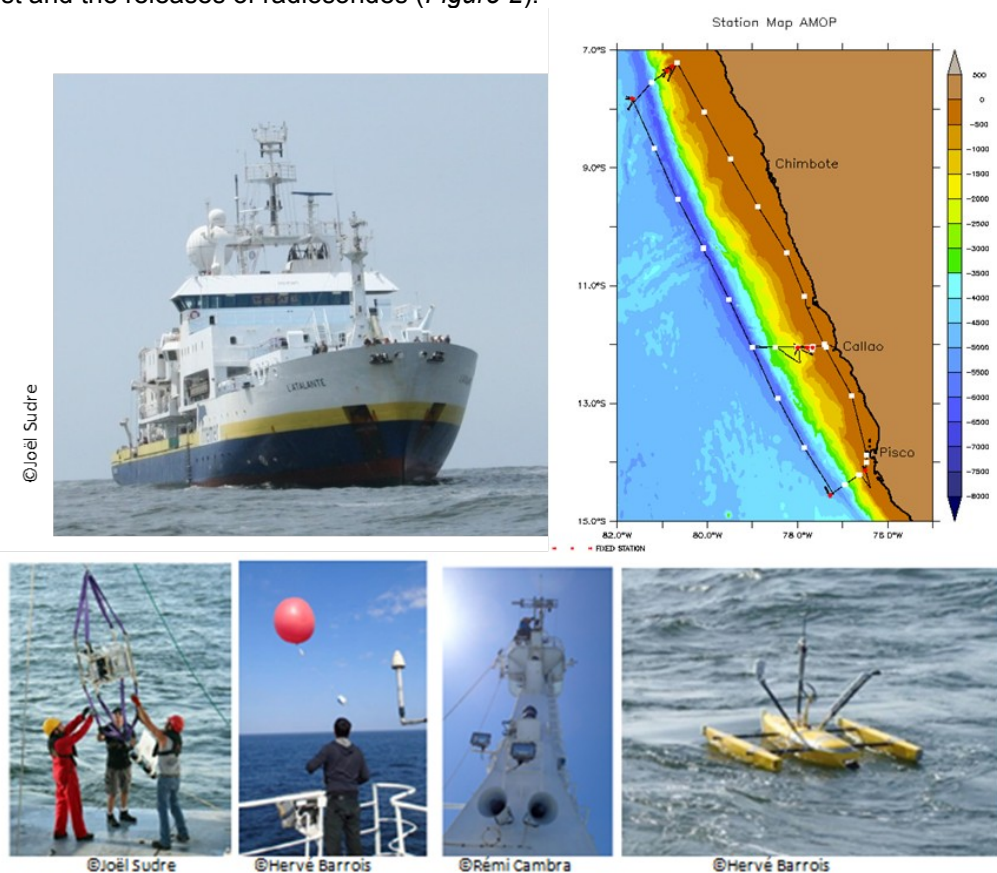


Figure 2: *Atalante* Research vessel (left) and cruise track in January-February 2014 (right) including the 8 fixed stations off Peru in red (up). *In situ* Oxygen Dynamics Auto-analyzer (IODA), radiosonde release, atmospheric mast, Ocarina tri-maran (down).

Catherine Schmechtig (schmechtig@obs-vlfr.fr), **LEFE-CYBER Database:** Hosted at the LOV in Villefranche sur Mer, The LEFE-CYBER database dedicated to biogeochemical data received this year data from the GEOVIDE Cruise in the NORTH ATLANTIC Ocean (PI: Geraldine Sarthou and Pascale Lherminier) (<http://www.geovide.obs-vlfr.fr/>) and is about to receive data from the OUTPACE cruise (<https://outpace.mio.univ-amu.fr/spip.php?rubrique20>) in the Pacific (PI: Thierry Moutin and Sophie Bonnet), Check the website of the database <http://www.obs-vlfr.fr/proof/>

Karine Sellegri (K.Sellegri@opgc.univ-bpclermont.fr), **Barbara d'Anna, Nicolas Marchand and Richard Sempere:** ANR "SAM", primary and secondary marine emissions. Marine emissions are among the largest source of both primary particles and do highly contribute secondary organic

aerosols (SOA) at a global scale. Whereas physical processes control the primary production of marine aerosols, biological activity is responsible for most of the organic fraction released from marine sources, potentially transformed into SOA when exposed to atmospheric oxidants. The Mediterranean atmosphere displays important concentrations of SOA, especially in summer, when atmospheric oxidants and photochemical activity are at their maximum. The origin of these elevated concentrations of SOA remain unclear.

Here we present the results from a mesocosms study in a remote location in Corsica and a chamber study (using fresh sea water from Western Mediterranean) as part of the Source of marine Aerosol particles in the Mediterranean atmosphere (SAM) project. The mesocosm study was conducted at the Oceanographic and Marine Station STARESO (Corsica) in May 2013. During these experiments 3 mesocosms were deployed, filled with 2260 L of bay water, and covered with a transparent Teflon dome. One of the mesocosms was used as a control (with no enrichment) and the other two were enriched with nitrate and phosphate respecting Redfield ratio (N:P = 16) in order to produce a bloom of biological activity. Physical and chemical properties of the enclosed water samples together with their surrounding atmosphere were monitored during 20 days by a multi-instrumental high-time resolution set-up. In parallel, numerous additional measurements were conducted including water temperature, incident light, pH, conductivity, chemical and biological analyses, fluorescence of chlorophyll, dissolved oxygen concentration. The chamber studies were performed in April 2014 in a Teflon chamber of 1.5m³ that accommodates a pyrex-container for the fresh sea-water samples. After injection of sea-water in the pyrex-container, the system is allowed to stabilize to 20-30 minutes, then it was exposed to 60-100ppbv of ozone and/or UV-A irradiation. Aerosol concentrations and their physical characteristics were followed by means of Scanning Mobility Particle Sizers; clusters concentration was monitored using a Particle Size Magnifier (PSM); the gas-phase composition of volatile organic compounds was determined by using Proton Transfer Reaction Time-of-Flight Mass Spectrometer and cartridges. Aerosol chemical composition was investigated using High Resolution Time-of-Flight Aerosol Mass Spectrometer, filters analysis and TEN-EDX microscopy. Results evidence a complex nature of the primary emitted aerosol which is not clearly associated to the biological bloom (ex. chlorophyll) (Schwier et al. ACPD 2014), VOCs emission was observed during high biological activity periods. New particles formation was observed both in the mesocosms and in the chamber studies and seems to be related to iodine species (in the absence of any macroalga population).

Géraldine Sarthou (geraldine.sarthou@univ-brest.fr) and **Rachel Shelley** (rachel.shelley@univ-brest.fr) **GEOVIDE** (An international GEOTRACES study along the OVIDE section in the North Atlantic and Labrador Sea):

Aerosol and rain samples were collected during the GEOVIDE campaign from Lisbon, Portugal -Greenland-St John's, Canada (May/June 2014) for the determination of trace and major elements. The aerosol samples were leached in the home laboratory in order to estimate the fractional solubility of aerosol trace metals. Aerosol loadings were typically low (preliminary results are available) and sampled from air masses with predominantly north – north westerly back trajectories (i.e. minimal interaction with major continental land masses). One of the goals of this project was to quantify the atmospheric flux of trace elements (with a focus on iron) to the surface ocean. However, one of the largest uncertainties in atmospheric flux calculations (dry deposition) is the choice of deposition velocity. An alternative technique is to determine the atmospheric flux of a radioisotope, such as Be-7, and use the ratio of trace element/ Be-7 in order, to better constrain the flux estimates. We are collaborating with Pere Masque's group at Universitat Autònoma de Barcelona in an effort to realise this goal. (Shelley, R. and Sarthou, G. 2015, *Elemental composition of atmospheric deposition during the GEOVIDE campaign (Lisbon, Portugal-St John's, Canada; GEOTRACES GA01)*, Aquatic Sciences Meeting, Granada, Spain. 22-26 Feb).

Géraldine Sarthou, Rachel Shelley and Patrice Brehmer (patrice.brehmer@ird.fr), **The AWA Project** (An ecosystem Approach to the management of fisheries and the marine environment in West African waters)

Aerosol samples were collected during three research cruises (UPSEN-2, ECOAO, AWA) to the Canary Current Eastern Boundary Upwelling System off the coast of West Africa in Feb/March 2013

and 2014. The focus of this project is to provide estimates for the parameterisation of the atmospheric flux of trace elements in coupled physical-biogeochemical models. As expected, due to the proximity to major global dust sources, aerosol loadings were high, and were of predominantly Saharan origin. Of interest was the observation that samples collected from air masses that tracked south across the heavily-populated coastal cities (e.g. Dakar, Senegal) were grey in colour compared to ones that did not (these samples were brown). In terms of the trace element concentrations this observation had little significant effect, indicating the dominance of Saharan dust on aerosol composition in the study region. The samples have been leached to investigate trace metal solubility, an approximation of bioavailability, to consider the impact of the presence of relatively higher anthropogenically-derived aerosols (e.g. derived from industrial processes and transportation). This work was funded via a LabexMER postdoctoral research fellowship, the French Research program of INSU-CNRS LEFE-CYBER, the French ANR (Agence Nationale de la Recherche, SIMI-6 program, ANR-13-BS06-0014-01), and the AWA project (*Shelley, R., Sarthou, G., Machu, E., Tymen, G., Messenger, C., Gorgues, T., Diadhio, H., and Brehmer, P., 2014, Towards quantifying the aerosol flux of trace and major elements: a case study of the West African Eastern Boundary Upwelling System, International conference "Ecosystem Approach to the Management of Fisheries and the Marine Environment in West African Waters" (AWA), 9-11 Dec., Dakar, Senegal*).

Frédéric Gazeau (f.gazeau@obs-vlfr.fr), **MedSea**: Mesocosms experiment

SOLAS endorsed. MedSeA (Mediterranean Sea Acidification in a changing climate, EU FP7, February 2011-July 2014). We performed two mesocosm experiments in the oligotrophic North-Western Mediterranean Sea during two seasons with contrasting environmental conditions: in summer 2012 in the Bay of Calvi (Corsica, France) and in winter 2013 in the Bay of Villefranche (France). This was done in order to assess the effects of ocean acidification on planktonic communities in oligotrophic areas. Both experiments gathered a multi-disciplinary team composed of 20-25 participants, originating from 7 different countries (France, Spain, Greece, Italy, UK, Belgium and USA). Large-scale in situ mesocosms (9 x 54 m³, 12 m deep) have been CO₂ enriched following a pCO₂ gradient approach with 3 controls and 6 mesocosms with increasing pCO₂ levels. The two multidisciplinary datasets (biology and chemistry) obtained during these experiments have been uploaded to Pangaea with a restricted access for the moment to the MedSeA consortium. They represent the first results ever obtained on the impact of ocean acidification by means of large pelagic mesocosms in the coastal waters of the Mediterranean Sea. A special issue that compiles scientific manuscripts analyzing data from these two experiments has been launched in December 2014 in the journal *Estuarine, Coastal and Shelf Science* (*Figure 4*).

J.-P. Gattuso (gattuso@obs-vlfr.fr) and **Frédéric Gazeau**, **eFOCE** (BNP-Paribas, 2011-2014, European Free-Ocean Carbon dioxide Enrichment experiments: development of benthic experimental systems to study the effects of ocean acidification of benthic communities in the field (Bay of Villefranche, Mediterranean Sea);

After 2 years of development, a 5-month experiment has been launched in June 2014. During 5 months, we have studied the effects of ocean acidification on a seagrass bed in the bay of Villefranche through the use of the eFOCE system: an experimental system that allows regulating pH in situ. This stand-alone system comprises a surface buoy (solar panels, wind turbine, batteries, high CO₂ water) and 2 plexiglass chambers (2 m³ each). pH has been perturbed in one of the chambers during 5 months at an offset of -0.25 pH unit as compared to the control chamber. We have collected a large amount of samples in the seagrass bed at the 2 pH levels (Posidonia leaves, roots, sediment, epiphytes etc...) that will be analyzed in 2015 (*Figure 4*).

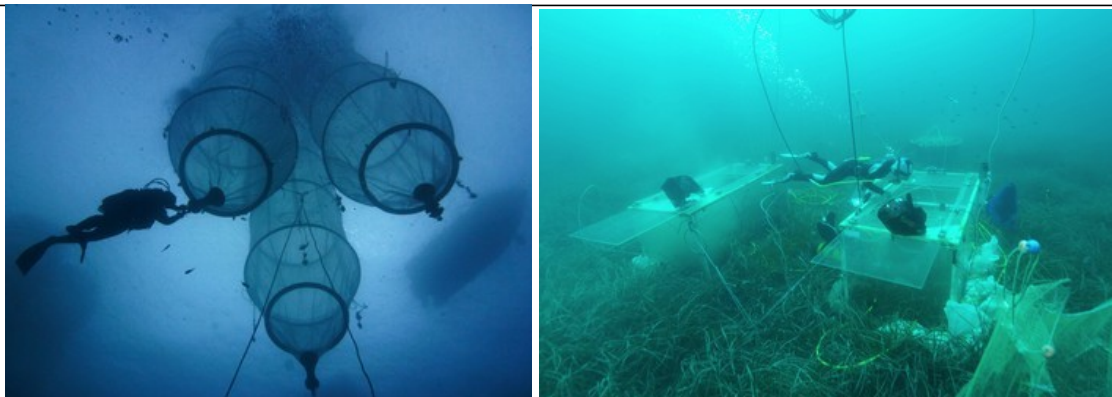


Figure 4: Left: MedSeA mesocosm experiment conducted in the Bay of Calvi in July 2012 (credit: OOV). Right: eFOCE chambers deployed in the Bay of Villefranche in summer 2014 (credit: OOV)

Cécile Guieu , Céline Ridame, Ejvira Pulido-Villena, Matthieu Bressac, Karine Desboeufs, and François Dulac, Impact of dust deposition on carbon budget: a tentative assessment from a mesocosm approach,

This work was done in the frame of the DUNE project, a SOLAS-endorsed project. A special Issue of the Biogeoscience journal comprises 13 papers and 2 other papers were published elsewhere.

DUNE project allows us the first attempt to evaluate the changes induced in the carbon pools of an oligotrophic system after a simulated Saharan dust deposition above a large body of water during a 7 days period and considering the vertical dimension. We show (*Figure 5*) (i) that the organic carbon sinks dominate the organic carbon fluxes demonstrating that the dust deposition induced a loss of organic carbon of the system in all the experiments, and (ii) that this loss is due to dissolved organic carbon consumption resulting in case of simulation of wet deposition in a significant drawdown of the DOC stock, that consequently will not be exported during the winter mixing. DUNE seeding experiments confirm that heterotrophic bacteria are key players in the response to dust deposition as it was previously shown by Pulido-Villena et al. (2008) and Marañón et al. (2010) using microcosm approaches and Bonilla-Findji et al. (2010), from *in situ* data. Interestingly, we show that even dominated by heterotrophy, the closed system impacted by wet deposition still maintain a POC export out of the base of the mesocosms in 7 days of ~ 0.5 g C.

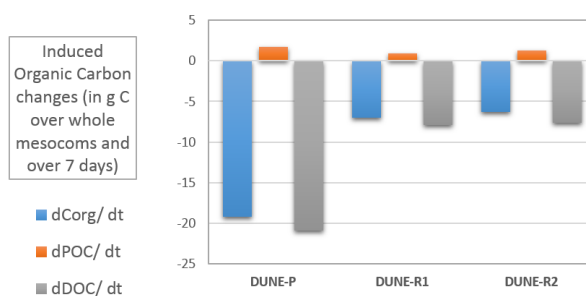


Figure 5. Estimated induced changes in the organic carbon pool inside the mesocosm where wet dust deposition was simulated (in g of C in the whole mesocosm during 7 days).

Karine Desboeufs (karine.desboeufs@lisa.u-pec.fr), **Marc Mallet** (Marc.Mallet@aero.obsmp.fr), **Elvira Pulido-Villena** (elvira.pulido@univ-amu.fr) **MERMeX** (Marine Ecosystems Response in the Mediterranean Experiment)

The main MERMeX activities relevant to SOLAS are the assessment of gas fluxes (CO_2) and acidification and the impacts on ecosystems and biogeochemical cycles, the study of aerosol fluxes at the air-sea interface [coupled with the component ChArMEX of MISTRALS (ChemistryAerosol Mediterranean Experiment)] considers both the formation of marine aerosol and the atmospheric deposition of nutrients and the influence of solar radiations on biogeochemical cycles includes the potential effect of aerosol and tropospheric ozone attenuation on marine ecosystems. A full report of the MERMeX-SOLAS activities can be found in the SOLAS endorsed projects reports. Among those, we briefly describe some of them here:

- **CALIBORON (Calibration of paleo-pH reconstruction technique based on boron isotopes in calcareous species (corals and bivalves) from the Mediterranean Sea: quantification of surface water acidification due to industrial era)**

This project started in 2011 with the main contribution of Cécile Gonzalez (LSCE's PhD student). The growth rate of corals or Mediterranean bivalves cultured at various temperature or pH conditions being low, the amount of carbonate materials available for isotopic analysis are about 5-10 mg. So the first objective of CALIBORON has been to revisit the LSCE's chemistry (today adapted for 200-400 mg of coral: ~20 µg of B) to extend further boron isotope studies for smaller samples. This work has been successfully completed and today we have the ability to properly analyze 5 mg of carbonates concentrated at 50 ppm (~ 250 ng of B). Boron isotopes were measured by using MC-ICPMS Neptune^{plus} at the LSCE with an accuracy of ± 0.3 ‰.

- **CARBORHONE (Carbon Cycle in the Rhône estuary and Gulf of Lions)**

The results from the 4 cruises performed in the Gulf of Lions and Rhone region, show that overall the Rhône plume has the potential to influence the seasonal dynamics of air-sea CO₂ fluxes at regional scale. The seasonal cruises were not designed to capture extreme events but to study the seasonality of air-sea CO₂ fluxes, we therefore did not capture extreme conditions. However, the strongest signals in pCO₂ have always been observed at the mouth of the Delta. During spring, fall and winter all regions acted as a sink of CO₂ with a clear gradient from highest to lowest fluxes, from the coast to the shelf. During summer, all regions acted as a source of CO₂ for the atmosphere.

- **MEDSEA-14C-MESO 14C incorporation techniques applied to a large mesocosm experiment in the bay of Villefranche during the bloom period**

Funding provided by MISTRALS in 2013 allowed performing primary production measurements based on 14C incorporation in the frame of a large pelagic mesocosm experiment. To assess the response of primary production and respiration of plankton communities to increasing pCO₂ levels in Low Nutrient Low Chlorophyll areas, two mesocosm experiments were conducted in the Bay of Calvi (Corsica, France) and in the Bay of Villefranche (France) in June-July 2012 and February-March 2013 under different trophic state, temperature and irradiance condition. Nine mesocosms of 50 m³ were deployed for 20 and 11 days respectively, and were subjected to seven pCO₂ levels (3 control and 6 elevated levels). The metabolism of the community was studied using several methods based on *in situ* incubations (oxygen light-dark, ¹⁸O and ¹⁴C uptake). Increasing pCO₂ had no significant effect on gross primary production, net community production, particulate and dissolved carbon production, as well as on community respiration. These two mesocosms experiments, the first performed under low nutrient and low chlorophyll, suggest that in large areas of the ocean, increasing pCO₂ levels may not lead to a significant change of plankton metabolic rates or the biological carbon pump. A special issue dedicated to the MEDSEA results (ECSS) was opened in December 2014.

- **PARTICULE (Impact of anthropogenic particles on coastal zones in PACA area).**

The main goals of this project are to quantify the atmospheric flux of anthropogenic particles and derived organic (mainly phthalates) and mineral compounds as well as their fate in the water column. The project was co-funded by PACA region, OT-Med Labex and Mermex for the acquisition of atmospheric and seawater sampling devices. Aerosol sampling is being conducted continuously at the Endoume station for analysing organic compounds including phthalates, organic acids and hydrocarbons. A one-year survey of the stoichiometric ratios and enzymatic activities in organic matter from atmospheric deposition has just started (MOOSE atmospheric station at Frioul Island, NW Mediterranean Sea). A marine survey will be soon conducted at the ANTARES MOOSE marine site (NW Mediterranean Sea) for determining bacterial and enzymatic activities and stoichiometric ratios of dissolved organic matter in surface profiles.

- **CHIPIE Evolution of the behavior of chemical elements with biogeochemical interest (N, P, Fe etc.) and carbon at the atmosphere-ocean interface under changing environmental conditions.**

The objective of this project is to study the impact of climate and environment change on the behavior of chemical elements and particulate carbon at the atmosphere-ocean interface. Three experiments were conducted in order to follow the evolution of the total concentrations and organic/inorganic speciation of nutrients (P, N, Fe) after the dust seeding in large tanks (300L)

inside a clean room. Preliminary results indicate no change in nitrate dynamic as a function of pH but strong effects were observed for DFe and a negative effect of acidification on aggregates formation was observed. This work confirm the importance to take into consideration the vertical dimension (sinking of particulate matter) when describing dissolved/particulate exchanges involved after atmospheric deposition. Those experiments and the methodological development of those 'clean minicosms' are determinant for a part of the work that is proposed in the frame of the PEACETIME campaign during which 6 of those mesocosms will be used to conduct seeding experiments modifying both pH and temperature to follow the impacts on biota in 3-4 ecoregions of the Mediterranean Sea. (1 paper submitted to *FRONTIERS*).

- **SUNMEX (Potential effect of aerosol and tropospheric ozone attenuation on marine ecosystems and seagrass rarefaction)**

The scattering and absorption of radiation by aerosols in the atmosphere attenuate the intensity of solar radiation available at sea surface and water column. In case of significant emissions such as those encountered in episodes of Saharan dust, the radiation attenuation can be the basis of a decrease in photosynthesis (Mallet et al., 2009). Although it has been little studied so far, it is likely that aerosol emissions from fires, combustion of fuels episodes of fossil attenuate UV and visible radiation reaching the Earth's surface and affect both phytoplankton growth and the intensity of photochemistry in the marine surface layer. In addition, natural and anthropogenic aerosol deposition may stimulate or inhibit primary and secondary productions. These processes are certainly exacerbated near urban megacities in the Mediterranean because of the intensity of radiation, the summer dust episodes and regular anthropogenic aerosols inputs. Solar radiations and Aerosol impacts on Mediterranean marine coastal waters are studied in MERMEX WP4 Sunmex action by monitoring aerosol optical depth (with a CIMEL photometer and UV/Visible radiations in the atmosphere and in the water column as well as, CDOM, marine particles and Chlorophyll a fluorescence in Marseille Bay by using a bio-optical mooring line deployed. All the parameters are measured continuously and the data are sent by GPRS and available on a web site (http://www.com.univ-mrs.fr/ssc/info/sunmed/?page_id=26).

- **PHOTOMED Metabolic and structural changes of the bacterial community in response to the phototransformations of dissolved and particulate organic matter in the Mediterranean Sea**

In the PHOTOMED project, we propose to study the effects of solar radiation on the alteration of contrasted DOM and POM originating from the Rhône River (i.e., terrestrial origin) and a phytoplanktonic culture (*Emiliana huxleyi*) (i.e., recent biological origin) and the consequences of these alterations on the metabolism and the diversity of the marine bacteria using this organic matter. Results from two experiments with DOM coming from the Rhone (sampled in March and June) and one with DOM coming from phytoplanktonic culture (*Chaetoceros* sp.) indicate that the photodegradation of DOM from the Rhone results in contrasting effects on both bacterial activity and diversity (DNA fingerprint by CE-SSCP) depending of the dates: when a stimulation and a change in diversity were observed in March, no effects on both parameters were measured in June. Concerning the photodegradation of phytoplanktonic DOM, we observed a decrease in bacterial activity and a modification in bacterial structure (454 pyrosequencing). Other experiments confirm the existence of an important oxidative stress in the bacteria attached to phytodetritus. It now remains to determine if this stress has a significant effect on the growth and diversity of attached bacteria. Concerning the autoxidative processes occurring in the POM in a salinity gradient, the results obtained showed a very intense autoxidative degradation of some lipidic components (unsaturated sterols and fatty-acids) of these particles in seawater and not in MilliQ water. This induction of autoxidative processes was attributed to radical cleavage of photochemically-produced hydroperoxides (formed on land during the senescence of higher plants) catalyzed by some metal ions released by the particles during the increase in salinity.

Elvira Pulido, DONUT (Dependence of dissolved organic matter cycling on atmospheric inputs of nutrients in the surface oligotrophic ocean):

Recent research has shown that dust may impact the functioning of the microbial loop, enhancing bacterial DOM mineralization, and so limiting the carbon export. On the other hand, the interaction between heterotrophic bacteria and DOM in surface ocean can increase the residence time of DOM (MCP 'Microbial Carbon Pump) promoting its export and sequestration in the deep ocean. The main goal of DONUT was to experimentally assess whether the bacterial response to dust deposition is

susceptible to have an effect on the residence time of the DOM pool by modifying its bioavailability. The bacterial degradation of DOM was followed on dust-amended and control treatments during long-term incubations. The remaining water was then filtered and re-use as new culture medium to a bacterial natural assemblage. Despite the poor replicability of the control treatment, bacterial abundance and production was lower in the treatment previously submitted to dust enrichment (see Figure 6), suggesting a decrease in DOM lability after a dust deposition event. These preliminary results suggest a new link between dust and carbon cycle through the modification of the residence time of the DOM pool. A new set of experiments will be launched during 2015 to confirm these results.

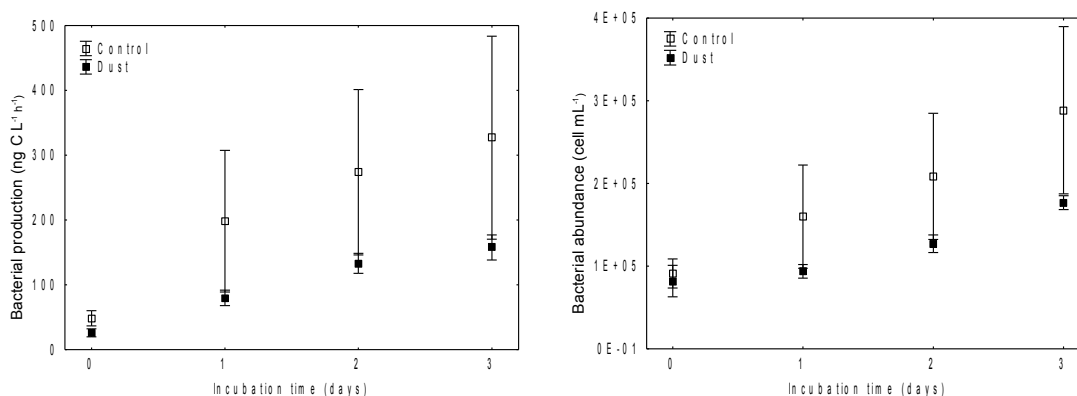


Figure 6

Benoit Laurent, (benoit.laurent@lisa.u-pec.fr) **DEMO-ChArMEx**, (Monitoring of dust deposition in the Western Mediterranean area):

In order to study the spatial and temporal variability of Saharan dust deposition in the Western Mediterranean area, CARAGA collectors were installed at 6 sites: Lampedusa - Italy; Mallorca - Spain; Ersa, Frioul, Casset and Montandon - France. Measurements of the mass of the total insoluble dust deposition are performed since mid-2010. Two additional partner stations were also equipped with a CARAGA collector: Granada - Spain, and Medenine - Tunisia. The statistical analysis of the first 3 years of measurements allows studying the frequency of Saharan dust deposition as well as the intensity of dry and wet deposition events. The representation of dry and wet deposition processes in 3-D models (CHIMERE, REG-CM and ALADIN - coll. LISA, LA, CNRM) is tested comparing the mass deposition simulated and measured for well-documented dust events. A specific work on how Saharan dust emitted from different source areas affects the Mediterranean marine biosphere is also in progress.

Rémi Losno, (losno@ipgp.fr) and **Zihan Qu** (zihan.qu@lisa.u-pec.fr) **Dust From Patagonia**, (To measure chemical composition of dust exported to the Southern Ocean from Patagonia). The Austral region ranging from about 40° and 65° south is one of the major CO₂ sink. Atmospheric dust feeds open ocean surface waters with trace metals and enhance phytoplankton primary productivity and CO₂ removal. Patagonia is suspected to be the major dust source for the oceanic region ranging between 40°S and 60°S. The aim of this project is to document as far as possible the chemical properties and the amount of dust exported from Argentinian Patagonia to the Southern Ocean. 3 years of aerosol measurements and surface soil sampling for chemical analyses were achieved in 2014. A strong seasonality is observed for iron content in aerosol at Rio Gallegos (East coast, South Patagonia) which let suspect a seasonality of dust export to the Ocean (*Figure 7*). This program will end in 2015.

Atmospheric Na and Fe content at Rio Gallegos

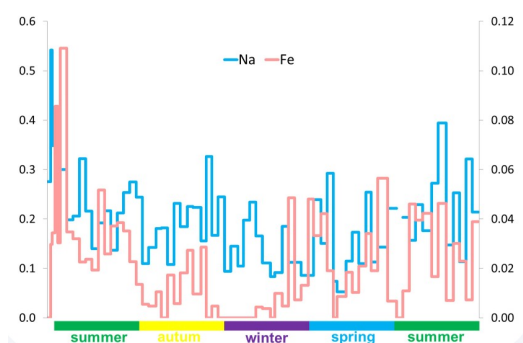


Figure 7, from Qu Z, Losno R, Monna F, Vaillant M, Quisefit JP, Journet E, Quesne A, Heimbürger A, Salvador J, Bulnes D, Ristori P & Quel E Spatial and Temporal Variations of Dust Elemental Composition in Patagonia, Goldschmidt Conference, Sacramento, June 8th-13th, 2014.

Nathalie Lefevre:

- **ICOS France** The Integrated Carbon Observation System includes the French CO₂ observatories for long term monitoring. The general assembly took place in July 2014 in Paris.

- **PIRATA (Prediction and Research moored Array in the Tropical Atlantic)**

- **PIRATA BR 2014**

R/V: NOc. Antares (H40), Brazilian Navy

Period: 10 July – 2 Sept. 2014

Replacement of the CARIOCA sensor at the ATLAS buoy 8°N, 38°W and seawater samples taken for inorganic carbon and alkalinity measurements.

- **PIRATA FR-2014**

N.O. Suroit

Period: 9 April-22 May 2014

Replacement of the CARIOCA sensor at the ATLAS buoy 6°S, 10°W and seawater samples taken for inorganic carbon and alkalinity measurements.

- **Camadas Finas V (Amazon river plume)**

R/V: NHo. Cruzeiro do Sul (H38), Brazilian Navy

Period: 17 Sept. – 01 Oct. 2014. Underway fCO₂ measurements were realized by Felipe Gaspar (Ph-D student of Manuel Flores and Nathalie Lefèvre) using the French CO₂ system.

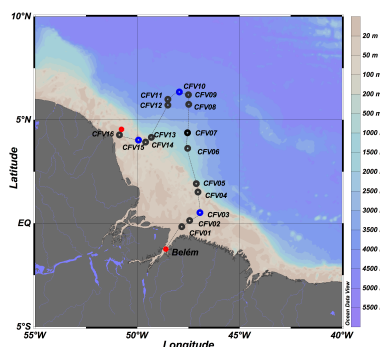


Fig. 3. Track of the Camadas Finas V cruise.

- **Participation to the 1st international ICOS conference** 23-25 Sep. 2014, Brussels, Belgium. Conference website: <http://www.icos-infrastructure.eu/scienceconference>.

Participation to the TAV-PIRATA19-OceanSITES-Brazil-EU Dialogues meeting Tropical Atlantic Variability Meeting – Prediction and Research moored Array in the Tropical Atlantic 19 Meeting – OceanSITES Meeting - Brazil-European Union Dialogues in Marine Research Meeting, 3-7 Nov. 2014, Porto de Galinhas-PE, Brazil. Session on Physical-Biogeochemical. Conference website: www.tav-pirata19.com. and contributions (3) www.tav-pirata19.com/documents/BookOfAbstracts.pdf

4. Human dimensions (outreach, capacity building, public engagement etc.)

5. Top 10 publications in 2014 (Reports, **ACCEPTED** articles, models, datasets, products, website etc.)

- Aghnatiou C., Remi Losno, F. Dulac (2014), A fine fraction of soil used as an aerosol analogue during the DUNE experiment: sequential solubility in water with step-by-step decreasing pH, *Biogeosciences*, 11, 4627-4633.
- Araujo M, Noriega C & Lefèvre N, 2014, Nutrients and carbon fluxes in the estuaries of major rivers flowing into the tropical Atlantic, *Frontiers in Marine Science*, 1:10, doi: 10.3389/fmars.2014.00010.
- Franco-Novela, A.C., J. M. Hernández-Ayón, E. Beier, V. Garçon, H. Maske, A. Paulmier, J. Färber-Lorda, R. Castro-Valdez, R. Sosa-Avalos, 2014, Air-sea CO₂ fluxes above the stratified oxygen minimum zone in the coastal region off Mexico, *Journal of Geophysical Research - Oceans*, 119 (5), 2923-2937
- Guieu C., O. Aumont, A. Paytan, L. Bopp, C. S. Law, N. Mahowald, E. P. Achterberg, E. Marañón, B. Salihoglu, A. Crise, T. Wagener, B. Herut, K. Desboeufs, M. Kanakidou, N. Olgun, F. Peters, E. Pulido-Villena, A. Tovar-Sanchez, C. Völker, The significance of the episodic nature of atmospheric deposition to Low Nutrient Low Chlorophyll regions, *Global Biogeochem. Cycles*, 28, 1179–1198, doi:10.1002/2014GB004852.
- Guieu C., C. Ridame, E. Pulido-Villena, M. Bressac, K. Desboeufs, and F. Dulac, Impact of dust deposition on carbon budget: a tentative assessment from a mesocosm approach, *Biogeosciences*, 11, 5621–5635, 2014
- Heimburger Lars-Eric , Christophe Migon, Remi Losno, Juan-Carlos Miquel, Benoit Thibodeau, Marion Stabholz, Aurelie Dufour and Nathalie Leblond, (2014), Vertical export flux of metals in the Mediterranean Sea, *Deep Sea Research Oceanographic Research Papers* 87, 14-23.
- Lefèvre N., D. F. Urbano, F. Gallois, and D. Diverrès, 2014, Impact of physical processes on the seasonal distribution of CO₂ in the western tropical Atlantic, *Journal of Geophysical Research*, 119, doi: 10.1002/2013JC009248.
- Maugendre L., J.P. Gattuso, J. Louis, A. de Kluijver, S. Marro, K. Soetaert, F. Gazeau (2014) Effect of ocean warming and acidification on a plankton community in the NW Mediterranean Sea. *ICES Journal of marine Science*, 10.1093/icesjms/fsu161.
- Merlivat, L., J. Boutin, and D. Antoine (2014a), Roles of biological and physical processes in driving seasonal air--sea CO₂ flux in the Southern Ocean: New insights from CARIOCA pCO₂, *Journal of Marine Systems*, in press, doi:<http://dx.doi.org/10.1016/j.jmarsys.2014.04.015>.
- Montes, I., B. Dewitte, E. Gutknecht, A. Paulmier, I. Dadou, A. Oschlies, V. Garçon, 2014, High-resolution modeling of the Eastern Tropical Pacific Oxygen Minimum Zone: Sensitivity to the tropical oceanic circulation, *Journal of Geophysical Research: Oceans*, 1-17. <10.1002/2014JC009858>
- Noriega C, Araujo M, Lefèvre N, Flores Montes M, Gaspar F & Veeda D, 2014, Spatial and temporal variability of CO₂ fluxes in tropical estuarine systems near areas of high population density in Brazil, *Regional Environmental Change*, doi: 10.1007/s10113-014-0671-3.
- Parard, G., J. Boutin, Y. Cuypers, P. Bouruet-Aubertot, and G. Caniaux (2014), On the physical and biogeochemical processes driving the high-frequency variability of CO₂ fugacity at 6°S, 10°W: Potential role of the internal waves, *Journal of Geophysical Research: Oceans*, doi:10.1002/2014JC009965.
- Resplandy, L., J. Boutin, and L. Merlivat (2014), Observed small spatial scale and seasonal variability of the CO₂ system in the Southern Ocean, *Biogeosciences*, 11(1), 75-90,

6. Goals, priorities and plans for future activities/events

We will organize in June 2015 a SOLAS-France workshop and we hope in September a large participation of the French SOLAS community to the SOLAS OSC in Kiel.

January 2015: Submission of a Marie Skłodowska-Curie Innovative Training Network (ETN) entitled "VOYAGE: Variability of OXYGen in marine Ecosystems and climate change" with common topics on the variability of oxygen in marine ecosystems, in the context of climate change (Chile, Europe, South Africa, Turkey, USA). Contact: V. Garçon.

August 2015: Goldschmidt conference (August 16-21th, Prague): session "What are the Unifying Principles Common to all Three Oxygen Minimum Zones (OMZs)?" (A. Paulmier: co-convener with J. Moffet: aurelienLEGOS@gmail.com).

AtlantOS: Optimizing and enhancing the integrated Atlantic Ocean observing system. This H2020 project has been accepted. One objective is to equip the PIRATA mooring at 6°S, 8°E with a CARIOCA sensor for surface CO₂ monitoring. This mooring is located close to the Congo outflow.

PEACeTIME (ProcEss studies at the Air-sEa Interface after dust deposition in MEditerranean sea). (C. Guieu and K. Desboeufs) PEACETIME proposes to study the fundamental processes and their interactions at this key interface in the Mediterranean Sea, and how these processes impact, and will impact, the functioning of the pelagic ecosystem and the feedback to the atmosphere, today and in the future. This 4-year project, centered both on a cruise in the central MS (planned in May 2016 when the high dust deposition occurs) and on strong modeling developments (from 0-D to 3-D), involves 14 research institutes in France and 9 abroad for a total of 80 scientists. Such pluridisciplinary project focusing on the chemical, physical (with a strong focus on optics) and biological characterization of the Atmosphere-Ocean interface is the first of its kind for the French 'Ocean-Atmosphere' research community. The Mediterranean Sea is an area designed as a hot spot for biodiversity but also a hot spot for climate change and anthropogenic pressure: PEACeTIME constitutes an integrated approach at different time and space scales to the study of this environment at the air-sea interface: this will also be the first project of this kind to be conducted in the Mediterranean Sea. PEACeTIME has received support from the two international projects SOLAS and IMBER and was also endorsed by GEOTRACES as a process-study. A pre-proposal was submitted to ANR Blanc in October 2014. This coordinated multidisciplinary effort comprises 14 research institutes in France and 9 abroad for a total of 80 scientists. The PEACETIME proposal has been evaluated by the French fleet commission and the PEACETIME cruise has been ranked in priority number 1 for a scheduling in 2016 or 2017

LandSO (Land Supply of Limiting Nutrients in the Southern Ocean), R. Losno, F. Monna, L. Meynadier, J. Gaillardet, E. Viollier, D. Cardinal, C. Provost, D. Ruiz-Pino, Y. Balkanski, E. Quel and P. Ristori. We propose to quantify the impact of trace metals and silicon release by continents on the Southern Ocean and to determine how it is recorded in sediment. This ocean is of paramount importance in the global carbon cycle because it is the largest potential sink of anthropogenic CO₂ and its active biological pump exports large amounts of carbon to the deep ocean and sediments. Large uncertainties still remain on the evolution of this carbon sink and especially: i) on its forcing by atmospheric deposition of dust transported from the arid continental areas contribution to ocean micronutrient inputs and ii) on the transportation process downward the water column. In the present anthropogenic conditions related to greenhouse gas increase and global warming, feedback from the Southern Ocean biological pump produced by land nutrient supply are highly probable and must be investigated. One of the major goals of this project is to determine how the atmospheric deposition signal can be transferred into the surface sediment of the ocean. This project is today at a proposal state and not yet funded, it will be proposed to SOLAS endorsement.

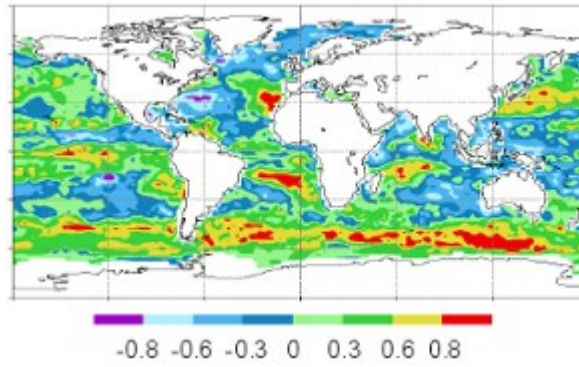


Figure 6: Correlation between atmospheric iron deposition and chlorophyll, from [Falkowski, P. G et al. (2003)]. The Southern Ocean shows the largest area of strong correlation and therefore of possible strongest influence of atmospheric deposition intensity.

7. Other comments