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# SOLAS Australia

*compiled by Michael Grose*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

Australian research continues to highlight the importance of the Southern Ocean in the global system:

**1. Southern Ocean biogeochemistry** remains a strong focus of Australian research, particularly the fields of iron cycling and ocean acidification. New Australian work has led to new understanding of the effect of ocean acidification on the microbial loop and ocean biota such as foraminifera, coccolithophores and pteropods. Recently published work has examined the global impact of dust deposition off the Australian continent (Gabric et al. 2010, details below). New work has also examined iron cycling in the Southern Ocean and Antarctic sea ice zone more closely than ever before:

Lannuzel et al. (2010) uses recent data of dissolved iron in Antarctic sea ice to assess its spatial and temporal variability. While the study highlights that the concentration of dissolved iron in coastal sea ice was similar to the more offshore Antarctic seas, it found that seasonal processes seem to control the distribution of dissolved iron both in land-attached and free-drifting sea ice. The authors also monitor large inter-annual variations in total iron and organic matter in the East Antarctic sector between 2003 and 2007. Differences in the magnitude of primary productivity and upwelling mechanisms during the onset of sea ice formation were proposed as critical to this variability. The seasonal cycle of iron is summarised in the schematic included below (labelled Figure 6).

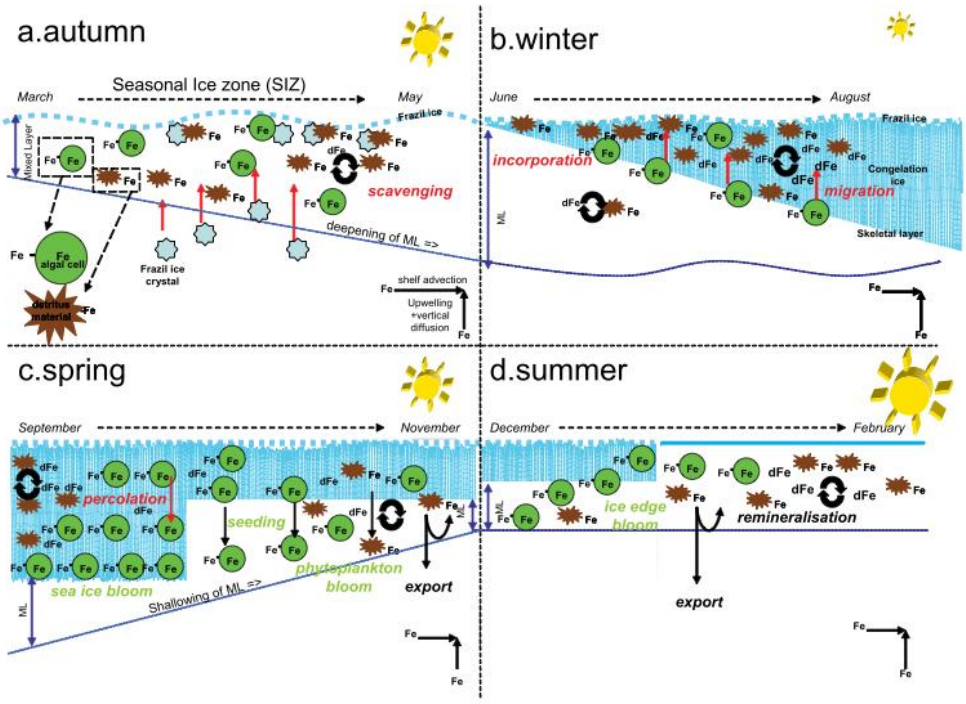



**Figure 6.** Schematic sequence of events proposed for the seasonal cycle of Fe (sources, pathways, and fate) in the seasonal ice zone. The brown symbol represents Fe adsorbed onto detritus, while the green symbol represents intra- and extracellular Fe associated with living organic matter. The blooms occurring in the seasonal ice zone are indicated in bright green letters (sea ice bloom, seeding, phytoplankton bloom, and ice edge bloom). The black arrows represent the main pathways for Fe sources and sinks in the seasonal ice zone (remineralization, export and "new" Fe sources), while the red arrows highlight the key processes controlling Fe accumulation within the ice cover (scavenging, incorporation, migration, and percolation). The lengths and thicknesses of the arrows are not representative of the magnitude of the fluxes.

**2. Cloud condensation nuclei (CCN)** in the clean marine boundary layer of the Southern Ocean have been the focus of ongoing work at the Cape Grim Baseline Air Pollution Station. Recently published work included a study of the enhancement of nanoparticles in postfrontal conditions, including the implications for CCN:

Nanoparticle concentrations were enhanced in 94% of all the 121 cold fronts passing over Cape Grim in a two-

year period. The enhancements typically began 9-11 hours after the front and peaked at 15 hours after the front. Most enhancements were during periods of drier conditions, indicating increased entrainment of free tropospheric air. These events are estimated to contribute between 1 and 8% of CCN, but may contribute up to ~30% of the Aitken population in the marine boundary layer.

Gras JL, Jimi SI, Siems ST and Krummel PB 2009 'Postfrontal nanoparticles at Cape Grim: observations.' *Environmental Chemistry* **6**: 508-514.

Further measurements at Cape Grim are underway and more are planned for the near future to gain further understanding of particles and CCN in the clean marine air. Other new work at Cape Grim includes measurements of persistent organic pollution and background atmospheric mercury.

## 2. Main accomplishments

As well as the work covered in the research highlights above and the publications listed below, there are other areas of ongoing work. These are numerous and so won't be listed comprehensively here. Instead, two research highlights are given:

The Australian Antarctic Division has been involved in numerous projects regarding the effect of ocean acidification and iron limitation on the Southern Ocean marine microbial loop and food web. This work has included a major series of 'minicosm' experiments in Antarctica examining the effect of increased $CO_2$ on photosynthesis and ecosystem dynamics in the microbial loop under controlled conditions. The major field campaign has now complete and the work will be published later in 2011.

In 2010 the Centre for Australian Weather and Climate Research CAWCR (a partnership between CSIRO and BOM) commissioned the Gunn Point Tropical Atmospheric Research Station in the Northern Territory of Australia, approximately 30km north east of Darwin. A major motivation for the Station is to characterize the atmosphere of the Australian tropics in terms of reactive gases (including volatile organic compounds, VOCs) and climatically active aerosol. The Station is situated approximately 1km from the coast and marine emissions impact the site for several months each year during the wet season. Measurements will give valuable information about sources and sinks of marine VOCs and aerosol in the Australian tropics.

## 3. Top 10 publications in 2010

Gabric AJ, Cropp RA, McTainsh GH, Johnston BM, Butler H, Tilbrook B and Keywood M, 2010, 'Australian dust storms in 2002-2003 and their impact on Southern Ocean biogeochemistry', *Global Biogeochemical Cycles,* 24**,** 17.

Gras JL, 2009, 'Postfrontal nanoparticles at Cape Grim: impact on cloud nuclei concentrations', *Environmental Chemistry,* 6**,** 515-523.

Gras JL, Jimi SI, Siems ST and Krummel PB, 2009, 'Postfrontal nanoparticles at Cape Grim: observations', *Environmental Chemistry,* 6, 508-514.

Jones, G, Fortescue, D, King, S, Williams, G & S Wright, 2010, 'Dimethylsulphide and dimethylsulphoniopropionate in the South-West Indian Ocean sector of East Antarctica from 30° to 80°E during BROKE-West', *Deep-Sea Research Part II: Topical Studies in Oceanography,* 57**,** 863-876.

Lannuzel D, Schoemann V, de Jong J, Pasquer B, van der Merwe P, Masson F, Tison JL and a Bowie, 2010, 'Distribution of dissolved iron in Antarctic sea ice: Spatial, seasonal, and inter-annual variability', *Journal of Geophysical Research-Biogeosciences,* 115, 13.

Law RM, Steele LP, Krummel PB and W Zahorowski, 2010, 'Synoptic variations in atmospheric CO2 at Cape Grim: a model intercomparison', *Tellus Series B-Chemical and Physical Meteorology,* 62, 810-820.

Leck C and EK Bigg, 2010, 'New Particle Formation of Marine Biological Origin', *Aerosol Science and Technology,* 44, 570-577.

Mayewski PA, Meredith MP, Summerhayes CP, Turner J, Worby A, Barrett PJ, Casassa G, Bertler NAN,

Bracegirdle T, Garabato ACN, Bromwich D, Campbell H, Hamilton GS, Lyons WB, Maasch KA, Aoki S, Xiao C and T van Ommen, 2009, 'STATE OF THE ANTARCTIC AND SOUTHERN OCEAN CLIMATE SYSTEM', *Reviews of Geophysics,* 47, 38.

Nicol S, Bowie A, Jarman S, Lannuzel D, Meiners KM and P van der Merwe, 2010, 'Southern Ocean iron fertilization by baleen whales and Antarctic krill', *Fish and Fisheries,* 11, 203-209.

Tagliabue A, Bopp L, Dutay J-C, Bowie AR, Chever F, Jean-Baptiste P, Bucciarelli E, Lannuzel D, Remenyi T, Sarthou G, Aumont O, Gehlen M and C Jeandel, 2010,' Hydrothermal contribution to oceanic dissolved iron inventory' *Nature Geoscience*, 3, 252 – 256, doi:10.1038/NGEO818

Sspecial edition of *Deep Sea Research II: topical studies in Oceanography* **57:** Various authors in 2010, over 10 papers describing the results from the Antarctic research cruise 'BROKE-West'

## 4. International interactions and collaborations

SOLAS Australia participants actively collaborate with more than 50 researchers from 15 international countries. By way of example, in May/June 2011, GEOTRACES and SOLAS activities will be carried out along a zonal section of the South Pacific from Brisbane to Tahiti. This expedition will form voyage GP13 of the GEOTRACES Science Plan, and include researchers from Africa, Europe, North America, Australia and New Zealand on a two-ship study of the marine biogeochemical cycles of trace elements and their isotopes in the Pacific Ocean.

## 5. Goals and plans for future activities

Of interest to the SOLAS community is the planned inclusion of specialised aerosol and atmospheric chemistry laboratory on the new research vessel commissioned by CSIRO. This facility will significantly increase the capacity for ocean-atmosphere measurements in the Australian marine science program.

In March 2011 a 4-week volatile organic compound (VOC) and aerosol measurement campaign is planned at Cape Grim Tasmania to explore the links between aerosol chemical composition and CCN.

CSIRO Marine and Atmospheric Research are planning to make measurements of CCN and VOCs including DMS and isoprene during the Surface Ocean Aerosol Production study at Chatham Rise in summer 2012. (Please contact Mike Harvey for more info on the SOAP cruise). m.harvey@niwa.co.nz

## 6. Other comments

I will be handing over responsibility for the role of Australian representative for SOLAS as of January 2010. The new representation comprises a primary contact, Sarah Lawson, and expert assistance from Andrew Bowie. Sarah is a research scientist at CSIRO atmospheric research focussing on ocean and atmosphere processes related to aerosol and particles. Andrew a researcher at the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) and the University of Tasmania in the area of Southern Ocean biogeochemistry. Andrew is also the Australian representative for the GEOTRACES international study of marine biogeochemical cycles of trace elements and their isotopes

Representative: Sarah Lawson, Sarah.Lawson@csiro.au
Southern Ocean specialist: Andy Bowie, Andrew.Bowie@acecrc.org.au

# SOLAS Belgium

*compiled by Christiane Lancelot*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### Air-sea $CO_2$ fluxes in the global coastal ocean

The exchange of $CO_2$ between the atmosphere and the global coastal ocean was evaluated based on a compilation of air-water $CO_2$ fluxes scaled using a spatially-explicit global typology of inner estuaries (excluding outer estuaries such as large river deltas) and continental shelves (Fig.1). The computed emission of $CO_2$ to the atmosphere from estuaries (+0.27±0.23 PgC yr-1) is ~26-55% lower than previous estimates while the sink of atmospheric $CO_2$ over continental shelf seas (-0.21±0.36 PgC yr-1) is at the low end of the range of previous estimates (-0.22 to -1.00 PgC yr-1). The air-sea CO2 flux per surface continental shelf seas (-0.7±1.2 molC m-2 yr-1) is the double of the value in the open ocean based on the most recent $CO_2$ climatology. The largest uncertainty of scaling approaches remains in the availability of $CO_2$ data to describe the spatial variability, and to capture relevant temporal scales of variability.

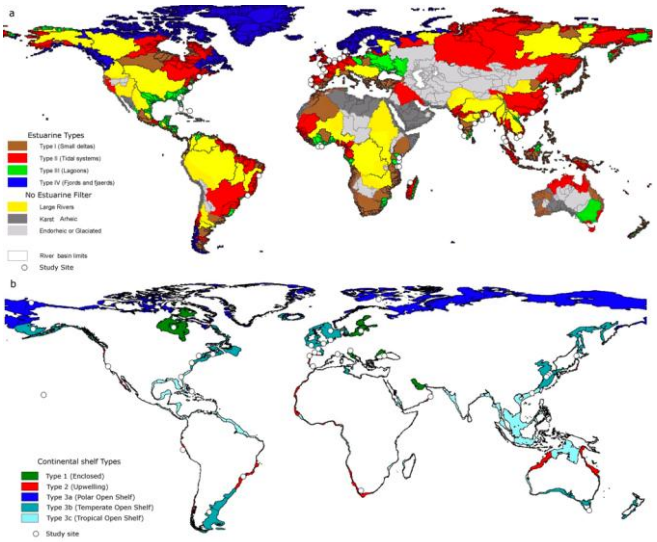



**Figure 1:** Typology of estuarine environments (a) and continental shelf seas (b) developed by Laruelle et al. (2010) to scale globally coastal CO2 fluxes.

### Air-ice-sea DMS fluxes

High resolution profiles of ice dimethylsulfide (DMS) and dimethylsulfoniopropionate (DMSP) concentrations were measured during a time series of decaying summer level first-year sea ice throughout December 2004 during the Ice Station Polarstern drift experiment (Western Weddell Sea, Antarctica). Very high DMSP and DMS concentrations were observed (up to 2627 nM and 1430 nM respectively) at the bottom of the ice sheet (Fig.2).
On this basis we estimated that decaying level first-year sea ice alone could significantly contribute to the regional sulfur budget of the Weddell Sea with an average loss rate of 5.7 µmol DMS(P) $m^{-2}$ $d^{-1}$ toward the atmosphere and the ocean.

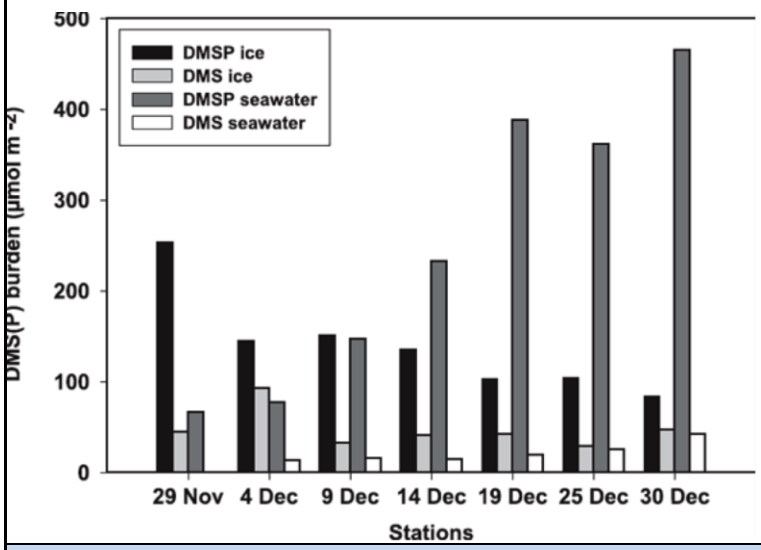



**Figure 2:** DMSP and DMS burden evolution in the ice and underlying 40 m water (Tison et al. in prep.)

## 2. Main accomplishments

- A.V. Borges organized a workshop in October 2010 in Liège on "Experimental, typological and modelling approaches to evaluate at global and regional scales horizontal and vertical fluxes from land to the open ocean through rivers, estuaries and the coastal ocean" (jointly sponsored by COST Action 735 and LOICZ), with 31 participants from EU, USA and Taiwan.
- A.V. Borges lead the Regional Coastal Group on the 2nd level quality check of SOCAT (Surface Ocean CO2 atlas) that was completed late October 2010. SOCAT will be publicly released early 2011.
- C. Lancelot attended the COST Action 735 meetng on 'Atmospheric versus land-based controls of nutrient cycling and production in the surface ocean: from fieldwork to modelling' held in Istanbul (Turkey) on 8-9 December 2010.
- Survey of air-ice-water $CO_2$ fluxes in Kapissilit (Greenland) in March 2010 (coordinator. S. Rysgaard)

## 3. Top 10 publications in 2010

Borges AV & N Gypens, 2010, 'Carbonate chemistry in the coastal zone responds more strongly to eutrophication than to ocean acidification', *Limnology and Oceanography*, 55, 346-353.

Hassler, CS, Schoemann V, Nichols CAM, Butler ECV and PW Boyd (2010), 'Saccharides enhance iron bioavailability to Southern Ocean phytoplankton', *Proceedings of the National Academy of Sciences USA*, doi: 10.1073/pnas.1010963108.

Lannuzel D, Schoemann V, de Jong J, Pasquer B, van der Merwe P, Masson F, Tison J-L and A Bowie, 2010, 'Distribution of dissolved iron in Antarctic sea ice: Spatial, seasonal, and interannual variability', *J. Geophys. Res.,* 115, G03022, doi:10.1029/2009JG001031.

Laruelle GG, Dürr HH, Slomp CP & AV Borges, 2010, 'Evaluation of sinks and sources of CO2 in the global coastal ocean using a spatially-explicit typology of estuaries and continental shelves', *Geophysical Research Letters,* 37, L15607, doi:10.1029/2010GL043691.

Le Clainche Y, Vezina A, Levasseur M, Cropp R, Gunson J, Vallina S, Vogt M, Lancelot C, Allen I, Archer S, Bopp L, Deal C, Elliott S, Jin M, Malin G, Schoemann V, Simo R, Six K and J Stefels, 2010, 'A first appraisal of prognostic ocean DMS models and prospects for their use in climate models', *Global Biogeochem. Cycles,* doi:10.1029/2009GB003721.

Suykens K., Delille B, Chou L, De Bodt C, Harlay J & AV Borges, 2010, 'Dissolved inorganic carbon dynamics and air-sea carbon dioxide fluxes during coccolithophore blooms in the Northwest European continental margin (northern Bay of Biscay)', *Global Biogeochemical Cycles*, 24, GB3022, doi:10.1029/2009GB003730.

Tison, J.-L., F. Brabant, I. Dumont, and J. Stefels (2010), High-resolution dimethyl sulfide and

dimethylsulfoniopropionate time series profiles in decaying summer first-year sea ice at Ice Station Polarstern, western Weddell Sea, Antarctica, J. Geophys. Res., 115, G04044, doi:10.1029/2010JG001427.

**5. Goals and plans for future activities**

- BELSPO funded research project BIGSOUTH (BIoGeochemical cycles in the SOUTHern Ocean: Role within the Earth System) will start in January 2011. The consortium of VUB, ULB, RMCA, UCL, ULg, NIOZ and LEGI will study the significance of sea-ice physical and biogeochemical processes

- FNRS funded research project by ULB and ULg on DMS cycling in the North Sea (present day status and past reconstructions) will start on January 2011.

- ULg will host the 43rd International Liege Colloquium on Ocean Dynamics “Tracers of physical and biogeochemical processes, past changes and ongoing anthropogenic impacts, 2 - 6 May 2011 (http://modb.oce.ulg.ac.be/colloquium/)

- C. Lancelot will attend the SCOR WG131 Modelling and Synthesis Workshop

# SOLAS BRAZIL

*compiled by AMAURI OLIVEIRA*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

**Project 1. FluTuA *Turbulent Fluxes over the Tropical Atlantic. Coordinator:Jacyra Soares. Air-Sea Interaction Laboratory. Institute of Astronomy, Geophysics and Atmospheric Sciences University of São Paulo, São Paulo, Brazil (jacyra@usp.br)***

The local ocean-atmosphere interaction has been investigated through the direct observation of air-sea variables, using a set of slow and fast micrometeorology sensors installed in a 10-meter tower in the Brazilian Archipelago. The major goals are to characterize observationally the interaction between the atmosphere and the ocean in micro, meso and macro scales in order to develop, calibrate and verify the parameterization formulae used to indirectly estimate flux from conventional meteorological variables. The Archipelago, located in the centre of the tropical Atlantic, is an outcrop of the mid-Atlantic Ridge; its largest island (Belmonte island) has an area of approximately 7500 $m^2$ with the highest point at 17 meters (Bacellar et al. 2009).

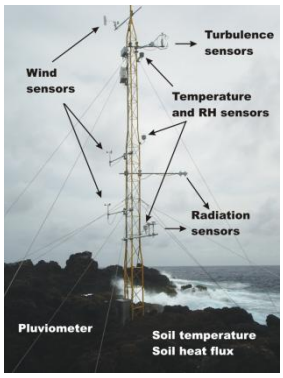




**Fig. 1:** The Archipelago and the instrumented tower.

Figures 2 and 3 illustrate the data gathered by the slow response sensors and Figs.4 and 5 by the fast response sensors.

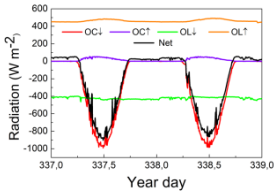



**Fig. 2:** Radiation balance. Year day 337 (02 December 2009) to 339 (04 December 2009). Sampling rate of 5 minutes.

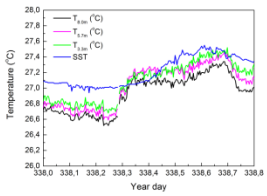



**Fig. 3:** Air and sea surface temperatures. Year day 343 (08 December 2009) to 344 (09 December 2009). Sampling rate of 5 minutes. The air temperatures were gathered at 3.3, 5.7 and 8 meters. The SST was measured at north side of the island.

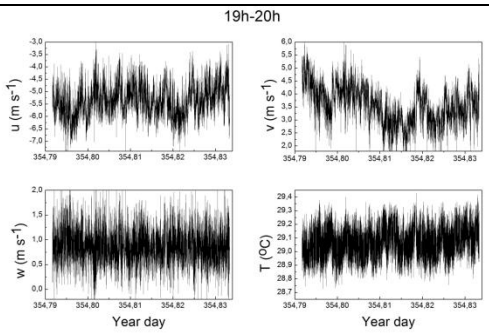



**Fig. 4:** Velocity components and air temperature data obtained during 1 hour period (19-20 h). Sampling rate of 20 Hz. Year day 354 (19 December 2009).

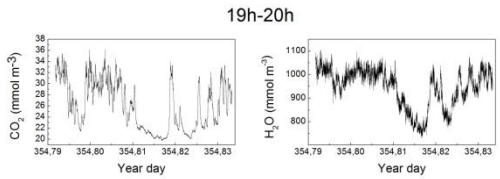



**Fig. 5:** $CO_2$ and $H_2O$ concentrations obtained during 1 hour period (19-20 h). Sampling rate of 20 Hz. Year day 354 (19 December 2009).

The observations carried out in the tower (Fig. 1) have been analyzed and results indicated that the surface energy balance at night (Fig. 2 -3) and the diurnal evolution of the intensity of turbulence (Fig. 4) and turbulent fluxes at the surface (Fig. 5) in the Archipelago area are dependent on the ocean state and trade winds intensity (Oliveira *et al*., 2009).

## References

Oliveira, A P, J Soares and J Servain, 2009: Preliminary results from the FLUTUA project: Micrometeorology in situ measurements at St Peter & St Paul archipelago (01°N-29°W). In: Tropical Atlantic Meeting & PIRATA - 14 SSC/PRB Meeting, 2009, Toulouse. PIRATA Annual Meeting Proceedings. Toulouse: Météo - France, pag. 21.

Bacellar, S, A P Oliveira, J Soares and J Servain, 2009: Assessing the diurnal evolution surface radiation balance over the Tropical Atlantic Ocean using in situ measurements carried out during the FluTuA Project. *Meteorological Application. http://dx.doi.org/10.1002/met.111.*

*Project 2.**Study of the Atmospheric Boundary Layer in the Region of Brasil-Malvinas Confluence.** Coordinator: **Marcelo Dourado. Centre for Ocean Studies. Federal University of Paraná, Pontal do Sul, PR, Brazil (dourado@ufpr.br).***

A subproject entitled “Coupled Modeling the Ocean and Atmospheric Boundary Layer in upwelling region” was the major activity developed during 2010. Turbulence in the oceanic (OBL) and atmospheric (ABL) boundary layer plays a vital role in the interaction between ocean and atmosphere, by controlling exchanges of heat, momentum and mass at the sea surface. These air-sea exchanges have great importance on determining the weather and the climate. The assessment of air-sea interactions is particularly relevant over the coupled oceanic regions. In the Cabo Frio region (23$^o$S, 42$^o$W), the upwelling has great influence on the primary productivity and in local climate. The coupling between the ABL and OBL has to be understood as a problem of fluid dynamics, where the main difference is the fluid’s density. Basic dynamic equations, in which the density is one of the variables, can be applied to both sides of the interface, and in some cases the similarity of the physical processes in the two media, can be notable. For instance, a vertical profile of normalized dissipation rate of the turbulent kinetic energy in the OBL and ABL are very similar when turbulence is kept by thermal convection.

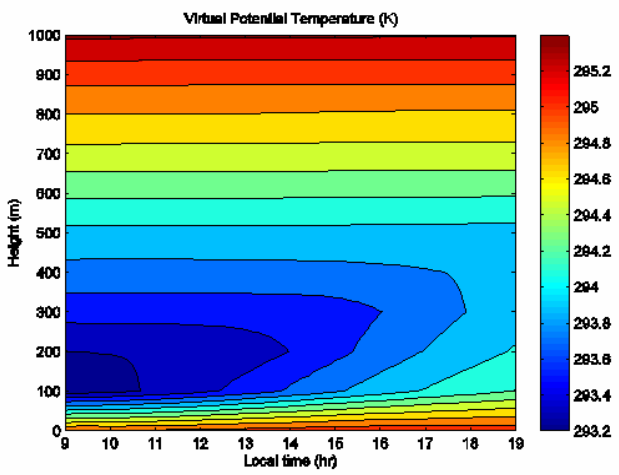



**Figure**-1.Time evolution of modeled virtual potential temperature during the passage of a cold front disrupting of the upwelling regime.

The model was tested against data from different oceanic regions and the results are satisfactory. A scientific paper is now being written.

## 2. Main accomplishments

A Coupled one-dimensional numerical model was developed to simulate the diurnal evolution of the vertical structure of the both oceanic and atmospheric boundary layers. This model is based in the 2.5 closure of Mellor and Yamada applied to the set of differential equations describing the behavior of temperature, salinity (water vapor), two horizontal components of current (wind speed) and for their respective variances and covariances in the ocean and atmosphere. In the ocean, the vertical grid resolution is equal to 1 m (100 meters). In the atmosphere, the grid resolution varies from 4 to 16 meters at the top (1000 meters).

## 3. Top 10 publications in 2010

Bacellar, S, A P Oliveira, J Soares and J Servain, 2009: Assessing the diurnal evolution surface radiation balance over the Tropical Atlantic Ocean using in situ measurements carried out during the FluTuA Project. *Meteorological Application. http://dx.doi.org/10.1002/met.111.*

Oliveira AP, Soares J and J Servain, 2009, 'Preliminary results from the FLUTUA project: Micrometeorology in situ measurements at St Peter & St Paul archipelago (01°N-29°W)'. In: Tropical Atlantic Meeting & PIRATA - 14 SSC/PRB Meeting, 2009, Toulouse. PIRATA Annual Meeting Proceedings. Toulouse: Météo - France, pag. 21.

Soares J, Oliveira AP, Skielka UT, Servain J, 2009, '*10 anos da ECASPSP".* In: O Arquipélago de São Pedro e São Paulo: 10 anos da Estação Científica ed.Brasília, DF : SECIRM, p. 37-44. https://www.mar.mil.br/secirm/publicacao/arquipe.pdf. *Book chapter*.

Skielka, UT, 2009, Estudo numérico da evolução da camada de mistura oceânica do Atlântico equatorial utilizando o modelo GOTM. Dissertação (Meteorologia) - Universidade de São Paulo. (http://www.iag.usp.br/meteo/labmicro/publicacoes/Teses&Dissertacoes/Skielka_2009-Estudo_numerico_da_evolucao_da_CMO_no_oceano_atlantico_equatorial_utilizando_o_modelo_GOTM.pdf). *Master Dissertation* (in Portuguese).

Skielka UT, Soares J, Oliveira, AP, 2010, 'Study of the equatorial Atlantic Ocean mixing layer using a one-dimensional turbulence model', *Brazilian Journal of Oceanography,* 58, 57 – 69. doi: 10.1590/S1679-87592010000700008.

## 4. International interactions and collaborations

FluTuA Project will be benefit for a lot of national (*i.e.* Brazilian ASPSP Project) and international (*i.e.* PIRATA, VATAPA, …) research programs.

## 5. Goals and plans for future activities

Main objective of the Solas Brazil is to incorporate new projects and promoting the development of the air-sea interaction in Brazil by involving new research groups.

# SOLAS CANADA

*compiled by Maurice Levasseur*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### 1. Publication of The first intercomparison of oceanic DMS models

**Le Clainche Y**, Vézina AF, Levasseur M, Cropp R, Gunson J, Vallina S, Vogt M, Lancelot C, Allen I, Archer S, Bopp L, Deal C, Elliott S, Jin M, Malin G, Schoemann V, Simó R, Six K, Stefels J (2010). A first appraisal of prognostic ocean DMS models and prospects for their use in climate models, *Global Biogeochem. Cycles*, doi:10.1029/2009GB003721

This community paper represents the first attempt to compare and evaluate the existing Oceanic DMS models (1D and 3D). This is the main deliverable of the SOLAS-funded CODiM international workhop held in Brussels in 2007. The exercise was highly informative and highlighted the similarities and divergences between the models. Most models failed to reproduce the summer DMS peak measured at low latitudes, which underlines the importance of identifying and parameterizing physiological functions (ex. light stress) stimulating DMS production.

2. Seguin, A.M., Norman, A.L., Eaton, S., Wadleigh, M.A., Sharma, S. (2010) Elevated biogenic sulfur dioxide concentrations over the North Atlantic. *Atmospheric Environment,* 44, 1139-1144.

Sulfur dioxide from dimethylsulfide oxidation, or biogenic $SO_2$, was found at very high concentrations over the North Atlantic in summer, reaching 82 nmol $m^{-3}$, the highest reported in the literature. Biogenic $SO_2$ was higher in polluted than in clean marine air suggesting anthropogenic pollutants influence its prevalence and potentially enhance CCN formation.

## 2. Main accomplishments

**1. Arctic SOLAS** - The Canadian International Polar Year (IPY) Arctic SOLAS program is reaching its end (March 2011). Hence, most SOLAS researchers have been busy finalizing the analysis of the samples collected in the High Canadian Arctic during the 2008 and 2009 cruises. These field observations were complemented by other SOLAS-related studies carried out as part of the IPY Circumpolar Flaw Lead (CFL) study in 2008-2008, during a year-round deployment of the Canadian icebreaker CCGS Amundsen. A subset of papers from these closely related cruises will be submitted to a special *IPY Circumpolar Flaw Lead and Arctic SOLAS* section in the Journal of

Geophysical Research (Oceans or Atmospheres) in the next few months.

2. **Biogeochemical Impacts of Asian Dust on the North Pacific Ecosystem and Climate -** Two cruises were also conducted in the North-East Pacific during the summer to investigate the impact of dust and ash depositions on plankton ecosystems and dimethylsulfide production as well as to explore how changes in pH could affect these responses. These cruises were conducted in partnership with several researchers from the Institute of Ocean Sciences (Dept. of Fisheries and Oceans) and under the umbrella of a joint Quebec-Shandong Provinces research initiative.

**3. Arctic research** - As part of the Arctic-ICE project, we conducted an interdisciplinary study of carbon dioxide and DMS biogeochemistry and fluxes in sea ice at the Allen Bay ice camp near Resolute. As part of the ArcticNet summer cruise on the Amundsen, we conducted a detailed study, including marine organic photochemistry, of air-sea $CO_2$ exchange in Hudson Bay, looking at how the fluxes vary across the salinity gradient from fresh to sea waters.

## 3. Top 10 publications in 2010


1. Le Clainche Y, Vézina AF, Levasseur M, Cropp R, Gunson J, Vallina S, Vogt M, Lancelot C, Allen I, Archer S, Bopp L, Deal C, Elliott S, Jin M, Malin G, Schoemann V, Simó R, Six K, Stefels J (2010). *A first appraisal of prognostic ocean DMS models and prospects for their use in climate models, Global Biogeochem. Cycles*, doi:10.1029/2009GB003721

2. Shadwick, E. H., Thomas, H., Comeau, A., Craig, S. E., Hunt, C. W., and Salisbury, J. E.: *Air-Sea $CO_2$ fluxes on the Scotian Shelf: seasonal to multi-annual variability*, Biogeosciences, 7, 3851-3867, doi:10.5194/bg-7-3851-2010, 2010.

3. Miller LA, Papakyriakou TN, Collins RE, Deming JW, Ehn JK, Macdonald RW, Mucci A, Owens O, Raudsepp M, Sutherland N. Carbon dynamics in Sea Ice: A Winter Flux Time Series. (in press JGR), doi: 10.1029/2009JC006058.
4. Royer S-J, Levasseur M, Lizotte M, Arychuk M, Scarratt MG, Wong CS, Lovejoy C, Robert M, Johnson K, Peña A, Michaud S, Kiene RP (2010). *Microbial dimethylsulfoniopropionate (DMSP) dynamics along a natural iron gradient in the northeast subarctic Pacific*. Limnol. Oceanogr. 55(4), 2010, 1614–1626
5. Papakyriakou T, Miller L. *Springtime $CO_2$ exchange over seasonal sea ice in the Canadian Arctic Archipelago.* (in press *Ann. Glaciol.*)
6. Wurl O, E. Wurl, L. Miller, K. Johnson, S. Vagle. 2011. *Formation and global distribution of sea-surface microlayers.* Biogeosci. **8**: 121-35.

7. Shadwick EH, H. Thomas, M. Chierici, B. Else, A. Fransson, C. Michel, L.A. Miller, A. Mucci, A. Niemi, T.N. Papakyriakou, and J.-É. Tremblay. 2011. *Seasonal variability of the inorganic carbon system in the Amundsen Gulf region of the southeastern Beaufort Sea*. *Limnol. Ocea*nogr. **56**(1): 303–22.

8. Mucci A, B. Lansard, L.A. Miller, and T.N. Papakyriakou, 2010. *J. Geophys. Res.* 115, C04003, doi: 10.1029/2009JC005330. $CO_2$ fluxes across the air-sea interface in the southeastern Beaufort Sea: Ice-free period.

9. Arctic SOLAS data management. Martine Lizotte (U Laval) is working on the incorporation of the metadata and data from the Canadian IPY Arctic SOLAS program into the Polar Data Catalogue.

## 4. International interactions and collaborations

1. A Quebec-Shandong workshop examining the impacts of ocean acidification on marine resources and biogeochemical cycles was held in Qingdao, China, in December 6-8, 2010. The workshop was funded by the Government of Québec, and has been conducted under the umbrella of SOLAS.


## 5. Goals and plans for future activities

**1. Arctic-ICE-Resolute 2011 project**- An ice camp will be conducted for the second year in May-July 2011 near Resolute in the High Canadian Arctic. The sampling will focus on the impact of ice on the light field and the response of the ice algae and phytoplankton. Production/fluxes of $CO_2$, DMS and $N_2O$ will be determined. Main investigators are CJ Mundy, M Gosselin, D Barber, T Papakyriakou, L Miller, and M Levasseur.

**2. Biogeochemical Impacts of Asian Dust on the North Pacific Ecosystem and Climate -** Onboard incubation experiment will be conducted on the combined effect of dust and pH on the plankton community and its capacity to produce DMS during the August 2011 Line P cruise in the Northeast subarctic Pacific. Main investigators are M Levasseur, L Miller, P Tortell, N Steiner, M Scarratt and JE Tremblay.

## 6. Other comments

Results from the Canadian IPY Arctic SOLAS program will be submitted to JGR-Ocean and JGR-Atmosphere to be part of the special section 'IPY Circumpolar Flaw Lead and Arctic SOLAS Experiments: Oceanography, Geophysics and Biogeochemistry of the Southern Beaufort, Amundsen Gulf, and NW Passage during a year of unprecedented sea ice minima'. The following papers are either submitted of in an advanced stage of writing:

Song G, Xie H, Aubry C, Zhang Y, Gosselin M, Mundy CJ, Philippe B, Papakyriakou TN. *Spatiotemporal variations of dissolved organic carbon and carbon monoxide in first-year sea ice in the western Canadian Arctic*. JGR-Ocean (submitted)

Luce M, Levasseur M, Scarratt MG, Michaud S, Kiene R, Lovejoy C, Gosselin M, Poulin M, Gratton Y. *Distribution and microbial metabolism of dimethylsulfoniopropionate and dimethylsulfide*

*during the 2007 Arctic ice minimum*. JGR-Ocean (submitted)

Motard-Côté J, Levasseur M, Scarratt MG, Michaud S, Lovejoy C, Rivkin R, Keats K, Gosselin M, Tremblay J-E, Kiene RP, Gratton Y. *Distribution and phylogenetic affiliation of dimethylsulfoniopropionate (DMSP)-degrading bacteria in Northern Baffin Bay*. JGR-Ocean (in prep)

Rempillo O, Seguin M, Norman A-L, Scarratt M, Michaud S, Levasseur M, Sjostedt S, Chang R, Abbatt J, Else B, Papakyriakou T, Sharma S. *DMS fluxes and the growth of the biogenic sulphur aerosol component: a study aboard an icebreaker in the Arctic in the fall of 2007 and 2008*. JGR-Atmosphere (in prep)

Randall K, Scarratt MG, Levasseur M, Xie H, Gosselin M, Michaud S. *Arctic sea ice: source or sink for nitrous oxide?* JGR-Ocean (in prep)

Chang R, Sjostedt SJ, Pierce JR, Papakyriakou TN, Scarratt MG, Michaud S, Levasseur M, Leaitch WR, Abbatt JPD. *Relating atmospheric and oceanic DMS levels to particle nucleation events during the Canadian Arctic summer*. JGR-Atmosphere (in prep).

Else BGT, Papakyriakou TN, Galley RJ, Drennan WM, Miller LA, Thomas H. *Eddy covariance measurements of wintertime $CO_2$ fluxes in an arctic polynya: Evidence for enhanced gas transfer during ice formation* (submitted JGR).

Annual Report for the year 2010:

# SOLAS China (Beijing)

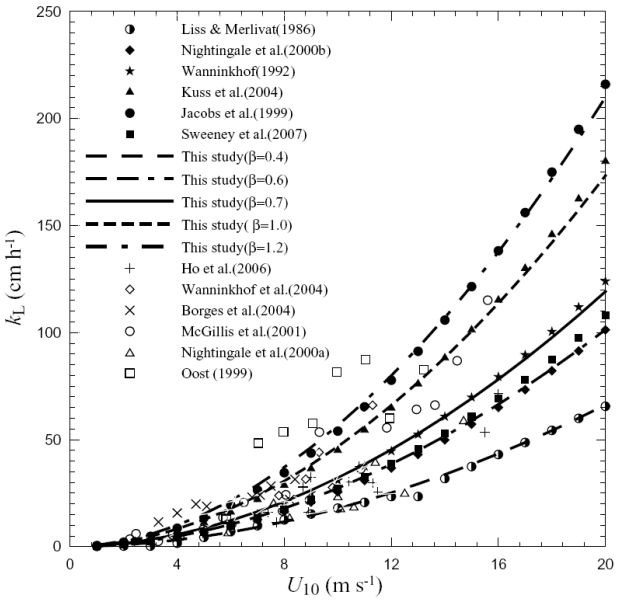
*compiled by Huiwang Gao and Minhan Dai*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### 1) A Practical Bi-parameter Formula of Gas Transfer Velocity Depending on Wave States

The parameter that describes the kinetics of the air-sea exchange of a poorly soluble gas is the gas transfer velocity which is often parameterized as a function of wind speed. Both theoretical and experimental studies suggest that wind waves and their breaking can significantly enhance the gas exchange at the air-sea interface. A relationship between gas transfer velocity and a turbulent Reynolds number related to wind waves and their breaking is proposed based on field observations and drag coefficient formulation. The proposed relationship can be further simplified as a function of the product of wind speed and significant wave height. It is shown that this biparameter formula agrees quantitatively with the wind speed based parameterizations under certain wave age conditions. The new gas transfer velocity attains its maximum under fully developed wave fields, in which it is roughly dependent on the square of wind speed. This study provides a practical approach to quantitatively determine the effect of waves on the estimation of air-sea gas fluxes with routine observational data.



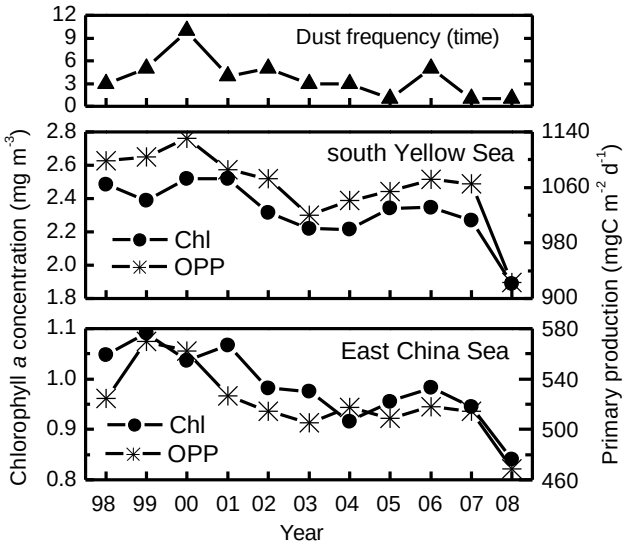

***Comparisons of gas transfer velocity at wave age of 0.4, 0.6, 0.7, 1.0 and 1.2 with other parameterizations in terms of wind speed. Some observational data are also plotted in the figure***

Zhao, D. L. and L. Xie, 2010. *Journal of Oceanography,* 66: 663-671

### 2) **Correlation of Asian dust with primary productivity in the coastal seas of China**

Satellite chlorophyll a (Chl a) concentrations and estimated primary production in the coastal seas of China were correlated with Asian dust events during 1998-2008. Severe and very severe dust events

correlated well and positively with Chl a concentrations and primary production in the south Yellow Sea and East China Sea. In the south Yellow Sea, Chl a concentration and primary production increased and eventually bloomed 1-21 days after the occurrence of the 16 out of 22 dust storms. In the south Yellow Sea, PAR and AI accounted for most of the variability of primary production for all storms, in addition, spring algae blooms were due to dust particles transported in the <3 km layer of the atmosphere which passed through the loess plateau and/or megacities, while the higher level (>5 km) dusts, originated mainly from the Taklimakan Desert, Mongolia and/or west of Inner Mongolia, had not impact.




*The yearly variations of FDS, annual average Chl a concentration and OPP in the south Yellow Sea and East China Sea*

Sai-Chun Tan, Guang-Yu Shi, Jin-Hui Shi, Hui-Wang Gao, Xiaohong Yao, 2010. **Correlation of Asian dust with chlorophyll and primary productivity in the coastal seas of China during the period from 1998 to 2008. Submitted to *Journal of Geophysical Research*.**

## 2. Main accomplishments

### 2.1 Cruise

Under the SOLAS endorsed project CHOICE-C (Carbon cycling in China Seas - budget, controls and ocean acidification), a multiple PI project sponsored by China National Basic Research Program (973) with funding period of 2009-2013, two 40-day long and multidisciplinary CHOICE-C cruises have been conducted onboard R/V Dongfanghong II in 2010. They were conducted on Dec. 23, 2009-Feb. 5, 2010 and Oct. 25-Dec. 10, 2010, covering the CHOICE-C domains of both the northern South China Sea and East China Sea (Fig. 1).

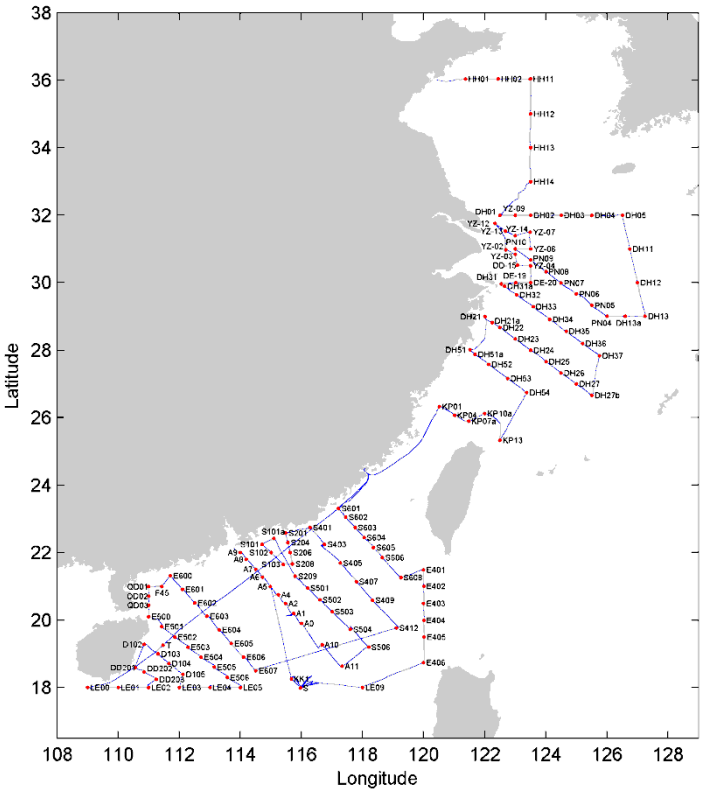



***Fig. 1. Map of the China Seas showing the sampling stations during the CHOCIE-C cruises in 2010***

## 2.2 Workshop

1) CHOICE-C workshop - project progress and cruises Summary Workshop, May 7-9, 2010, Qingdao, China
2) CHOICE-C workshop - mid-term summary, Aug. 8-10, 2010, Kunming, China
3) Ocean Science Session, Physical Processes and Biogeochemistry of Coastal Ocean and Tropical Estuaries, 7th Asia Oceania Geosciences Society (AOGS) Annual Meeting, Jul. 4-9, 2010, Hyderbad, India (co-chaired by Sarma Vedula V. S. S., Murty Vadlamani, Minhan Dai and Jianping Gan)
4) 5th Workshop on Asian Dust and Ocean EcoSystem (ADOES). After four workshops held in 2005, 2006, 2007 and 2009, joint 5th Workshop on Asian Dust and Ocean EcoSystem (ADOES) with Asian SOLAS/WESTPAC/METMOP/SALSA was organized. This workshop was held during 29 November-2 December 2010, in Nagasaki, Japan.
5) Quebec-Shandong joint workshop on the impacts of ocean acidification on marine ressources and biogeochemical cycles was held by the scientists from Canada and China from 6 to 8, December, 2010 in Qingdao, China.

## 3. Top 10 publications in 2010

*For journal articles please follow the proposed format:*
*Author list (surname and initials (one space but no full stops between initials), year of publication, article title, full title of publication (italics), volume, page numbers, DOI (DOI optional).*

1) Dong, H. P., D. Z. Wang, M.H. Dai and H. S. Hong, 2010. Characterization of particulate organic matters in the water column of the South China Sea using a shotgun proteomic approach. ***Limnology and***

***Oceanography,*** 55(4): 1565-1578.

2) Gao, K. S. and Y. Zheng, 2010. Combined effects of ocean acidification and solar UV radiation on photosynthesis, growth, pigmentation and calcification of the coralline alga Corallina sessilis (Rhodophyta). ***Global Change Biology,*** 16(8): 2388-2398.
3) Gan, J. P., Z. M. Lu, M. H. Dai, A. Y. Y. Cheung, H. Liu and P. Harrison, 2010. Biological response to intensified upwelling and to a river plume in the northeastern South China Sea: A modeling study. ***Journal of Geophysical Research,*** 115, C09001 DOI: 10.1029/2009JC005569.
4) Kao, S. J., M. H. Dai, K. Selvaraj, W. Zhai, P. Cai, S. N. Chen, J. Y. T. Yang, J. T. Liu, C. C. Liu and J. P. M. Syvitski, 2010. Cyclone-driven deep sea injection of freshwater and heat by hyperpycnal flow in the subtropics. ***Geophysical Research Letters,*** 37, L21702 DOI: 10.1029/2010GL044893.
5) Shang, S. L., Z. P. Lee and G. M. Wei, 2011. Characterization of MODIS-derived euphotic zone depth: Results for the China Sea. ***Remote Sensing of Environment,*** 115: 180-186.
6) Zhao, D.-L., and L. Xie, 2010. A practical bi-parameter formula of gas transfer velocity depending on wave states. ***Journal of Oceanography***, 66, 663-671.
7) Shi, J., H. Gao, J. Qi, J. Zhang, and X. Yao, 2010. Sources, compositions, and distributions of water-soluble organic nitrogen in aerosols over the China Sea, ***Journal of Geophysical Research***, 115, D17303, doi:10.1029/2009JD013238.
8) Zhang, G.-L., J. Zhang, S.-M. Liu, J.-L. Ren, and Y.-C. Zhao, 2010. Nitrous oxide in the Changjiang (Yangtze River) Estuary and its adjacent marine area: riverine input, sediment release and atmospheric fluxes, ***Biogeosciences***,7, 3505–3516.
9) Gui-Peng Yang, Wei-Lei Wang, Xiao-Lan Lu, Chun-Yan Ren, 2010. Distribution, flux and biological consumption of carbon monoxide in the Southern Yellow Sea and the East China Sea, ***Marine Chemistry***, 122(1-4): 74-82.
10) Xiao-Lan Lu, Gui-Peng Yang, Gui-Sheng Song, Liang Zhang, 2010. Distributions and fluxes of methyl chloride and methyl bromide in the East China Sea and the Southern Yellow Sea in autumn, ***Marine Chemistry,*** 118(1-2):75-84.

## 4. International interactions and collaborations

Proposal to IOC Sub-Commission for the Western Pacific (IOC/WESTPAC) for a working group of WESTPAC-ADOES was approved at the WESTPAC-VIII meeting held in Bali, Indonesia on may 10-13, 2010. Within its 4 year life span (2010-2014), WESTPAC-ADOES is to bring together scientists from both fields of marine and atmospheric sciences to further promote the study of Asian dust and its impact on ocean ecosystems in the Western Pacific. This WG is co-chaired by Profs. Huiwang Gao from Ocean University of China and Mitsuo Uematsu from the University of Tokyo.

## 5. Goals and plans for future activities

China-SOLAS has recently devoted considerable efforts in promoting the initiative on studies of “Asian Dust and Ocean EcoSystem” (ADOES). SOLAS has approved to form a TASK Team of ADEOS to examine physical and chemical variations of dust aerosol during its downwind transportation, transport path and layer of dust and its deposition flux to northern Pacific Oceans, and impacts of dust on biogeochemistry and ocean ecosystem.

# SOLAS China (Taipei)

*compiled by Gwo-Ching Gong and Kon-Kee Liu*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

Long-term Observations and Research of the East China Sea (LORECS) is the Taiwanese research project most relevant to SOLAS. Another integrated project, Carbon cycles in Taiwan and the South China Sea basin – from monitoring to modeling (CarboTaiwan), is also related to SOLAS. The major goal of LORECS is to understand how external forcing controls the biogeochemistry and ecosystem of the East China Sea. The types of external forcing investigated include Asian dust storms, typhoons and monsoons. LORECS scientists investigated the chemical compositions of Asian dusts collected over the same area and found significant amount of air pollutants from the fast developing industrial areas in the East Asia as an important source of aerosol materials. The bio-availability of many trace metals in the dust is enhanced by the presence of air pollutants due to the acids in the aerosols. In addition, the anthropogenic materials also contain nutrient elements, which may fertilize the oligotrophic ocean. Another aspect of the project focused on how typhoons influence the export production. Shortly after the passing of Typhoons Fengwong and Sinlaku off northeastern Taiwan in 2008, scientists observed sea surface temperature drop and the sinking flux of particulate organic carbon increased by up to 70%.

**Typhoons boosting biological pump in the oligotrophic southern East China Sea**

Dr. Chin-Chang Hung and his colleagues deployed floating traps in the southern East China Sea off northeastern Taiwan to measure fluxes of sinking particulate organic matter. After passage of typhoon Fengwong in 2008, the sea surface temperature dropped by 3$^{o}$C. The average POC flux measured 5 days after passage of the typhoon was 265 mg C m$^{-2}$ d$^{-1}$, 1.7-fold that during non-typhoon periods. A smaller but significant increase in POC flux (224-225 mg C m$^{-2}$ d$^{-1}$) was detected following typhoon Sinlaku. The consistent observations indicate that typhoon events can increase biogenic carbon flux. Model-estimated new/export productions are consistent withobservations following typhoon Fengwong. The same model suggests that during non-typhoon conditions approximately half of the export of organic carbon occurs via convective mixing of dissolved organic carbon.

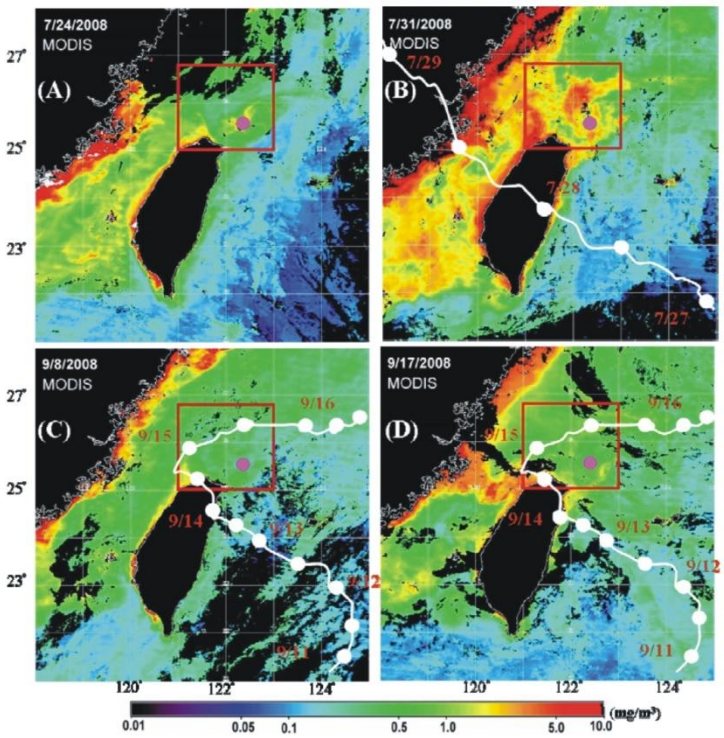



**Figure 1**: The surface Chl-a concentrations derived from MODIS data before and after typhoon Fengwong (panels A and B, from 24 July to 31 July 2008) and Sinlaku (panels C and D, from 8 September to 17 September 2008) respectively. The pink dot represents the sampling location; the white curves with dots represent the typhoon tracks.

**Air pollutants enhance iron solubility in Asian dust**

Dr. S.C. Hsu and his colleagues collected aerosol particles over the East China Sea and analyzed them for water-soluble Fe ($Fe_S$) and total Fe ($Fe_{-T}$). Compared with low Asian dust (LAD) samples, the high Asian dust (HAD) samples (total Al concentrations ≥1500 ng/m$^3$.) samples had lower percentage of $Fe_T$ soluble in deionized water (%$Fe_S$), which varied with transport pattern and air mass history. Although HAD occurs for only a few days each year, the supply of $Fe_S$ through dry deposition to the surface ocean may be more common than previously thought because LAD occurs frequently and their $Fe_S$ concentrations are not much different from those of the HAD. Soluble Fe correlated with non-sea-salt sulfate, water-soluble organic carbon, and nitrate, possibly due to an anthropogenic, relatively soluble, form of Fe or enhanced dissolution caused by reactions with anthropogenic acids.

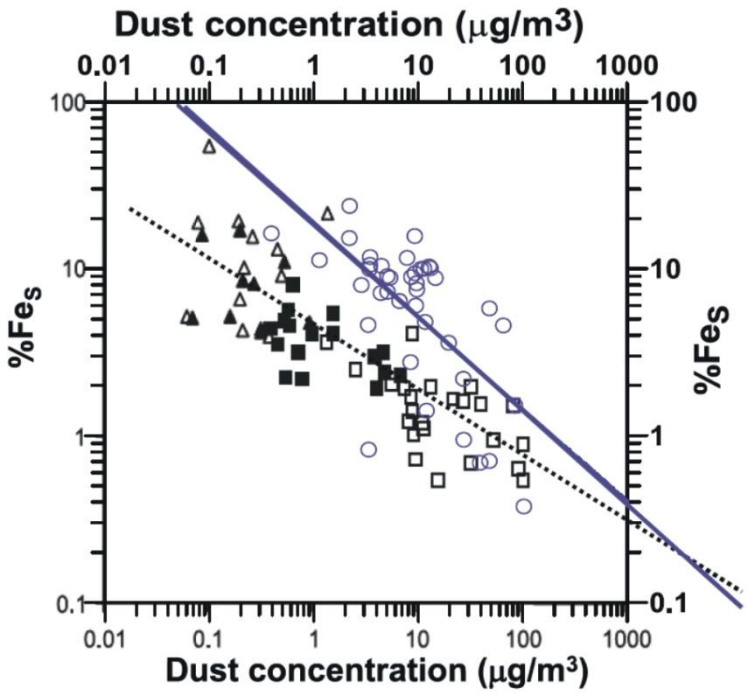



**Figure 2**: A log-log scatterplot of the percent soluble Fe (%$Fe_S$) versus dust concentration. Blue circles are from the LORECS study, and black symbols represent the data set of Baker and Jickells (2006). [Open symbols: Northern Hemisphere samples; Solid symbols: Southern Hemisphere samples; Squares: tropical/subtropical samples; Triangles: temperate samples.] Theinverse relationship suggests that the %$Fe_S$ may be increased by acid processing during transport.

## 2. Main accomplishments

Thirteen cruises on board R/V Ocean Researcher I and II and other vessels were conducted for the LORECS project in the year 2009. Special focus was given to investigate how typhoons may enhance the biological pump in the oligotrophic western North Pacific Ocean. A one-day workshop was organized by Director Gwo-Ching Gong in Keelung, Taiwan in March 2010 to present and discuss recent findings from the LORECS project.

## 3. Top 10 publications in 2010

Chen H-Y, Chen L-D, Chiang Z-Y, Hung C-C, Lin F-J, Chou W-C, Gong G-C and L-S Wen, 2010, 'Size fractionation and molecular composition of water-soluble inorganic and organic nitrogen in aerosols of a coastal environment', *Journal of Geophysical Research,* 115, D22307, doi:10.1029/2010JD014157.

Hsu S-C, Wong GTF., Gong G-C, Shiah F-K, Huang Y-T, Kao S-J, Fujung T, Lung S-CC., Lin F-J, Lin I-I, Hung C-C and C-M Tseng , 2010, 'Sources, solubility, and dry deposition of aerosol trace elements over the East China Sea', *Marine Chemistry* 120(1-4), 116-127.

Hsu S-C, Liu SC, Arimoto R, Shiah F-K, Gong G-C, Huang Y-T, Kao S-J, Chen J-P, Lin F-J, Lin C-Y, Huang J-C, Tsai F and S-CC Lung, 2010, 'Effects of acidic processing, transport history, and dust and sea salt loadings on the dissolution of iron from Asian dust', *Journal of Geophysical* Research, 115, D19313, doi:10.1029/2009JD013442.

Hung C-C, Gong G-C, Chou W-C, Chung C-C, Lee M-A, Chang Y, Chen H-Y, Huang S-J, Yang Y,

Yang W-R, Chung W-C, Li S-L and E Laws, 2010, 'POC/Th-234 ratios in particles collected in sediment traps in the northern South China Sea' *Estuarine Coastal and Shelf Science*, 88(3), 303-310.

Hung CC, Gong GC, Chou W-C, Chung C-C, Lee M-A, Chang Y, Chen H-Y, Huang S-J, Yang Y, Yang W-R, Chung W-C, Li S-L, and E Laws, 2010, 'The effect of typhoon on particulate organic carbon flux in the southern East China Sea', *Biogeosciences,* 7(10), 3007-3018.

Liu H-C, Gong G-C and J Chang , 2010, 'Lateral water exchange between shelf-margin upwelling and Kuroshio waters influences phosphorus stress in microphytoplankton', *Marine Ecology-Progress Series*, 409: 121-130.

Liu KK, Chao SY, Lee H-J, Gong G-C and Y-C Teng, 2010, 'Seasonal variation of primary productivity in the East China Sea: A numerical study based on coupled physical-biogeochemical model', *Deep-Sea Research Part II-Topical Studies in Oceanography,* 57(19-20): 1762-1782.

Tsai AY, Gong GC, Sanders R, Wang, C-J and K-P Chiang, 2010, 'The impact of the Changjiang River plume extension on the nanoflagellate community in the East China Sea', *Estuarine Coastal and Shelf Science* 89(1): 21-30.

## 4. International interactions and collaborations

In March 2010 Director Gwo-Ching Gong hosted the visit of Prof. Mark Ohman of Scripps Institution of Oceanography to discuss potential future collaboration in establishing a comparative study of the two major boundary current systems of the North Pacific Ocean, namely, the Kuroshio and the California Current system. Prof. Ohman is leading the CCE-LTER project, while Director Gong is planning a Kuroshio ecosystem study as a follow-up of the LORECS project. Since the two boundary currents form the two limbs of the gyre of the North pacific, the North Pacific Gyre Oscillation (NPGO) affects both limbs. The comparative study may allow us to investigate how NPGO control the variation of biogeochemical conditions across the North Pacific Ocean.

## 5. Goals and plans for future activities

The LORECS project will end in July 2012. A new project focused on the Kuroshio is under planning. The atmospheric forcing and the biogeochemical responses of the boundary current system will likely be the focus of the new study. Since the Kuroshio has a strong influence on the East China Sea, the long-term goals of the LORECS project will likely be incorporated in the new project.

# SOLAS Denmark

*compiled by Lise Lotte Sørensen and Mikael Sejr*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### New analysis methods for $CO_2$ air-sea flux

Different flux estimation techniques to evaluate air-sea exchange is developed and suggested for use on moving platforms. Techniques using power spectra and cospectra to estimate fluxes are suggested and applied to measurements of wind speed and sensible heat, latent heat and $CO_2$ fluxes (Sørensen and Larsen, 2010). The $CO_2$ fluxes can be calculated from the dissipation technique utilizing the inertial sub-range of the power spectra and from estimation of the cospectral amplitude. Even data having poor signal-to-noise ratio can be used for flux estimations using these methods. The methods are compared to eddy covariance fluxes, which is shown in figure 1.

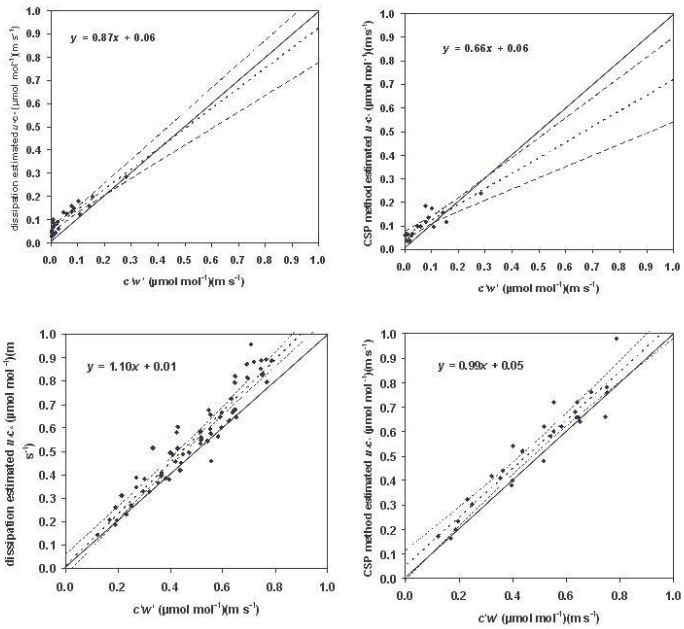



Fig 1. Comparison of $CO_2$ fluxes estimated by the spectral techniques and eddycorrelation. The flux data used for comparisons are sampled over a coastal area and a grass field.

## 2. Main accomplishments

Danish SOLAS members from Aarhus University, National Environmental Research Institute participated in a field experiment in Kapisilit to study air-ice-sea carbon exchange. The field experiment was coordinated and hosted by the Greenland Climate Research Centre. The experiment was partly supported by the project: "Air-sea-ice exchange of $CO_2$ in the Arctic coastal area", which is a project funded by the Nordic Council of Ministers.

## 3. Top 10 publications in 2010 (Reports, articles, models, datasets, products, website etc)

Sørensen LL and SE Larsen, 2010, 'Atmosphere-surface fluxes of $CO_2$ using spectral techniques', *Boundary Layer Meteorology*, 136 (1): 59-81 DOI:10.1007/s10546-010-9499-7.

Sempreviva AM, Schiano ME, Pensieri S, Bozzano R, Borghini M, Grasso F, Semedo A, Soerensen LL, Teixeira J, Transerici C and R Tomé, 2010, Observed development of the vertical structure of the marine boundary layer during the LASIE experiment in the Ligurian Sea, *Ann. Geophys.* 28, 17-25.

## 4. International interactions and collaborations

The Danish SOLAS group has strong collaboration with Greenland Climate Research Centre , Lund University and Uppsala University.

## 5. Goals and plans for future activities

A new national project ECOCLIM to estimate $CO_2$ exchange between the atmosphere and the biosphere is funded. The project will to a large extend focus on air-sea $CO_2$ exchange in coastal regions. The project will be coordinated from National Environmental Research Institute at Aarhus University and Greenland Climate Research Centre. Other partners are from Lund University and Uppsala University.

Furthermore a new Nordic Centre of Excellence named DEFROST is starting in 2011. A WP in DEFROST will focus on air-sea-ice exchange of $CO_2$. This WP will be coordinated by Lise Lotte Sørensen, Aarhus University and Søren Rysgaard, Greenland Climate Research Centre. Activities in DEFROST will be coupled to the activities in the projects: “Air-sea-ice exchange of $CO_2$ in the Arctic coastal area” and ECOCLIM”. A measurement station for air-sea exchange of $CO_2$ will be established in the Nuuk Basin, Greenland in 2011 and in Young Sound in NE Greenland in 2012.

# SOLAS France

*compiled by Rémi Losno, Véronique Garçon and Cécile Guieu*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

French scientific activities in the SOLAS topics were numerous, including achievement and continuation of endorsed projects.

- The FLATOCOA project on dust flux over the southern Ocean (Kerguelen Island) started in 2008. The atmospheric total deposition flux and the atmospheric dust concentration are now measured for more than 1 year at Kerguelen. In addition, another station is running from 2010 until 2011 at Crozet Island to assess gradient information on a 1000 km scale. Results will not be available before end of 2011. (http://www.institut-polaire.fr/ipev/programmes_de_recherche/en_cours/1188_flux_atmospherique_d_origine_continentale_sur_l_ocean_austral).
- The AMOP (Activité de recherche dédiée au Minimum d'Oxygène dans le Pacifique tropical sud est) started end of 2010 in collaboration with scientists from Peru, Germany, Ireland, Denmark, and Mexico.
- The IBAO project: Iron Biogeochemistry from the Atmosphere to the Ocean. Role of bioaerosols in the iron biogeochemical cycle started end 2008. It involves organic and biological complexation of iron.
- Participation to the MEECE program (http://www.meece.eu/) concerning models of CO2 and trace gas exchange at the air-sea interface.
- Atmospheric aerosol impact and $N_2$ fixation is an important topic within SOLAS-France (DUNE, BOUM).
- Continuous activity is running using CARIOCA buoys and commercial ship equipment to quantify $CO_2$ air-sea exchange, as part of the CARBOOCEAN and LATEX projects.

Analytical innovation is carried at Dunkerque (LPCA) to measure the evolution of the solid state chemical speciation of atmospheric iron during long-range transport events, using TEM. Results obtained on samples collected in West Africa show that a heterogeneous distribution of the iron oxidation state inside individual dust particles is frequently observed, with a dominance of $Fe^{3+}$. The tomographic reconstruction of typical dust particles clearly indicates the presence of iron oxide nodules inside the aluminosilicate matrix. As a result, iron present in such inclusions may be inaccessible to reduction processes initiated by soluble compounds and may not be bioavailable in the ocean.

## 2. Main accomplishments

A key moment of the DUNE project (http://www.obs-vlfr.fr/LOV/DUNE/) in 2010 was the new mesocosms experiment that took place in the Preservation area of Scandola (Corsica Island) in summer during which 7 large clean mesocosms have been deployed (3 ‘control', 3 ‘dust’ and 1 ‘dust’ for optical measurements). Two successive seeding were performed and a large panel of chemical and biological parameters were measured during 15 days. The experiment was successful and some results will be presented by PhD students at the upcoming ASLO meeting. DUNE is a SOLAS endorsed project and more recent information (on the 2010 experiment and on recent publications) can be found at: http://www.solas-int.org/science/researchendorsements/resendprojects/endorsedprojects.html

A view of the optical cluster (3 instruments) deployed during the 2010 seeding experiment to follow the concentration, the size and the composition (mineral vs organic) of the sinking particles (here: outside of the mesocosm while performing a 'control'). Particulate export after the seeding was shown to be a multistep process and, as a function of time, the exported material has a variable proportion of mineral and organic particles. The third export event that occurred 20-28 hours after the seeding was due to large aggregates composed by a mixing of organic and inorganic matter. This corresponded to the start of increase in chlorophyll induced by the dust addition: we can make the hypothesis that the organic matter is in part the one freshly produced via the fertilization. (from Bressac M., Guieu C., Doxaran D., Bourrin F., Obolensky G. and Grisoni J.M.: Optical measurements to observe the fate of Saharan dust in seawater: a simulated dust deposition during the DUNE project. Particles in Europe (PiE) 2010, Villefranche-sur-mer, 15-17 November 2010). (photo, David Luquet, OOV).

## 3. Top 10 publications in 2010


Deboudt K, Flament P, Choël M, Gloter A, Sobanska S and C Colliex, 2010, 'Mixing state of aerosols and direct observation of carbonaceous and marine coatings on African dust by individual particle analysis', *Journal of Geophysical Research - Atmospheres*, doi:10.1029/2010JD013921.

Guieu C, Dulac F, Desboeufs K, Wagener T, Pulido-Villena E, Grisoni J-M, Louis F, Ridame C, Blain S, Brunet C, Bon Nguyen E, Tran S, Labiadh M, and J-M Dominici, 2010, 'Large clean mesocosms and simulated dust deposition: a new methodology to investigate responses of marine oligotrophic ecosystems to atmospheric inputs', *Biogeosciences,* 7, 2765-2784

Guieu C, Loÿe-Pilot M-D, Benyaya L and A Dufour, 2010, 'Spatial and temporal variability of atmospheric fluxes of metals (Al, Fe, Cd, Zn and Pb) and phosphorus over the whole Mediterranean from a one-year monitoring experiment, biogeochemical implications', *Marine Chemistry*, 120, 164–178

Heimbürger LE, Migon C, Dufour A, Chiffoleau JF and D Cossa, 2010, 'Evolution of trace metal concentrations in the Northwestern Mediterranean atmospheric aerosol between 1986 and 2008', *Science of the Total Environment*, 408, 2629-2638.

Jouandet MP, Blain S, Metzl N and C Mongin, 'Interannual variability of the net community production and air-sea CO2 flux in a natural iron fertilization region of the Southern Ocean. (Kerguelen plateau)', *Antarctic Science*, (in press).

Laghdass M, Blain S, Besseling M, Catala P, Guieu C and I Obernosterer, 'Impact of Saharan dust on the microbial community during a large clean mesocosm experiment in the NW Mediterranean Sea', *Aquatic Microbial Ecology*, accepted.

Metzl N, Corbière A, Reverdin G, Lenton A, Takahashi T, Olsen A, Johannessen T, Pierrot D, Wanninkhof R, Ólafsdóttir SR, Olafsson J and M Ramonet, 2010, 'Recent acceleration of the sea surface fCO2 growth rate in the North Atlantic subpolar gyre (1993 2008) revealed by winter observations', *Global Biogeochem. Cycles,* 24, GB4004, doi:10.1029/2009GB003658.

Paris R, Desboeufs KV, Formenti P, Nava S and C Chou, 2010, 'Chemical characterisation of iron in dust and biomass burning aerosols during AMMA-SOP0/DABEX: implication for iron solubility', *Atmos. Chem. Phys.,* 10, 4273–4282.

Pulido-Villena E, Rerolle V and C Guieu, 2010, 'Transient fertilizing effect of dust in P-deficient LNLC surface ocean', *Geophysical Research letters*, 37, L01603, doi:10.1029/2009GL041415.

Paulmier A, Ruiz-Pino D and V. Garçon, 'CO2 maximum in the OMZ', *Biogeoscience,* accepted.

Racapé V, Lo Monaco C, Metzl N and C Pierre, 2010, 'Summer and winter distribution of $^{13}$CDIC in

surface waters of the South Indian Ocean (20°S-60°S)', *Tellus-B*, DOI: 10.1111/j.1600-0889.2010.00504.x.

Ternon E, Guieu C, Loÿe-Pilot M-D, Leblond N, Bosc E, Gasser B, Martin J and J-C Miquel, 2010, 'The impact of Saharan dust on the particulate export in the water column of the North Western Mediterranean Sea', *Biogeosciences*, 7, 809–826, 2010.

Wagener T, Guieu C, Leblond N, 2010, 'Effects of dust deposition on iron cycle in the surface Mediterranean Sea: results from a mesocosm seeding experiment', *Biogeosciences Discuss*., 7, 2799-2830.

## 4. International interactions and collaborations

Meetings organized (See full report on these 3 meetings in this SOLAS Newsletter issue) :

- The GEOTRACES Mediterranean Planning Workshop, 6-8 Oct. 2010, Nice, France
- The International SOLAS Workshop on the "OMZs systems", 8-10 November 2010, Lima, Peru : http://www.solas-int.org/aboutsolas/organisationaandstructure/midtermstrategy/omzmeeting.html.

The COST Sub-working group 2&3 meeting "Atmospheric versus land based controls of nutrient cycling and production in the surface ocean: from fieldwork to modeling", 8-9 December 2010, Istanbul, Turkey.

## 5. Goals and plans for future activities

Driven by the French initiative MISTRALS (Mediterranean Integrated STudies at Regional And Local Scales; http://mistrals.insu.cnrs.fr/spip/) – an interdisciplinary program initiated in 2008 - two new projects are directly related to SOLAS science: (i) ChArMEx (the Chemistry-Aerosol Mediterranean Experiment; http://charmex.lsce.ipsl.fr) aims at a scientific assessment of the present and future state of the atmospheric environment and of its impacts in the Mediterranean basin; and (ii) MerMeX (Marine Ecosystems Response in the Mediterranean Experiment; http://mermex.com.univ-mrs.fr/) is focused on the response of ecosystems to modifications of physicophysical and -chemical forcing at various scales, both in time and space, linked to changing environmental conditions and increasing human pressure.

A joint meeting with the French IGAC community is planned for June 2011 in Paris.

## 6. Other comments

All details of the SOLAS-France activities is presented on the SOLAS-FRANCE web pages: http://www.lisa.u-pec.fr/SOLAS.

# SOLAS GERMANY

*compiled by Hermann W. Bange (IFM-GEOMAR, Kiel)*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

**Air-sea gas transfer velocity for oxygen derived from float data**

Christoph Kihm and Arne Körtzinger (IFM-GEOMAR, Kiel)

We estimated the air-sea gas transfer velocity for oxygen using 3 consecutive years (September 2003 to August 2006) of high-quality oxygen measurements from profiling floats in the central Labrador Sea. Mixed layer oxygen concentrations exhibit strong seasonality characterized by biologically and thermally driven evasion during spring/ summer and invasion during fall/winter caused by cooling and ventilation of oxygen deficient subsurface waters. Mixed layer oxygen budgets entirely excluding the spring bloom period are employed to estimate the air-sea transfer velocity for oxygen. By using colocated wind speed data acquired by scatterometry from the QuikSCAT satellite, wind speed-dependent parameterizations for the air-sea gas transfer velocity k660 (CO2 at 20°C and salinity 35) are established and compared with prominent parameterizations from the literature. Quadratic, cubic, and quartic functions are fitted to the data for short-term and long-term wind speed averages separately (Fig. 1). In both cases, the quadratic functions yield the poorest fit to the observations. Overall, the stronger curvature of the cubic functions provides the best fit, while the quartic function also fits the data less well. Our results generally confirm the stronger wind speed dependencies among the suite of published parameterizations. Also, the better fits found for cubic function point at the strong importance of very high wind speed for air-sea gas exchange of O2. [1]

[1] Kihm, C., and A. Körtzinger (2010), Air-sea gas transfer velocity for oxygen derived from float data, J. Geophys. Res.,115, C12003, doi:10.1029/2009JC006077.

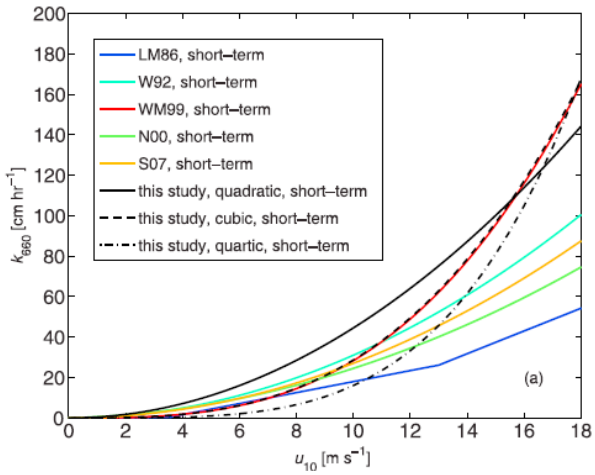



Fig. 1: Comparison of fits for short-term winds with prominent parameterizations from the literature Figure is taken from [1].

**Nitrous oxide emissions from the upwelling area off Mauritania (NW Africa)**
(Franziska Wittke, Annette Kock and Hermann W. Bange; IFM-GEOMAR, Kiel)

Nitrous oxide ($N_2O$) flux densities across the ocean/atmosphere interface from the Mauritanian upwelling (16°–18.5°W, 16°–21°N, Fig. 1) were computed with a simple upwelling model using $N_2O$ measurements from four cruises between 2006 and 2008 as well as wind data from the QuikSCAT satellite. The resulting $N_2O$ flux densities show a strong seasonality reflecting the wind-driven

seasonality of the upwelling: $N_2O$ flux densities are highest in the northern part (19.5°–21°N) and show a decreasing trend towards the south (Fig. 2). The summer periods with no upwelling (and thus associated with no or negligible $N_2O$ flux densities) are most pronounced in the southern part (16°–17°N). The mean seasonally and regionally weighted annual $N_2O$ emissions from the Mauritanian upwelling were estimated to 1.0 Gg N. This is low compared to other major upwelling areas (Arabian Sea, off Chile) indicating that $N_2O$ emissions from the Mauritanian upwelling are a minor source of atmospheric $N_2O$ [2].

[2] Wittke, F, et al., 2010, Nitrous oxide emissions from the upwelling off Mauritania (NW Africa), *Geophysical Research Letters*, 37, L12601, doi: 10.1029/2010GL042442.

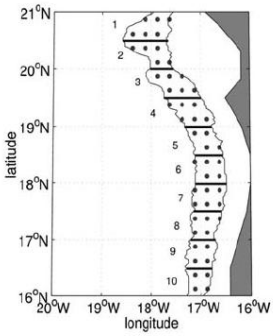



**Figure 1.** Schematic representation of the coastal region off Mauritania. The points represent the coordinates of available QuikSCAT data within the boxes #1–#10 (see text for details.)

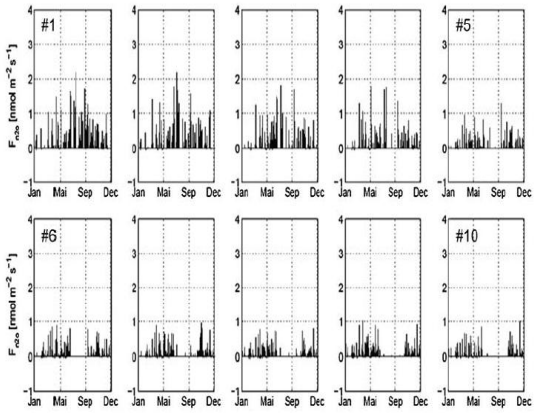



**Figure 2.** Time series of $N_2O$ flux densities for the boxes #1–#10 (see Figure 1). Periods without data originate from times when $u_{crit} < 4.6$ m s$^{-1}$ and indicate periods of no upwelling.

### Estimates of equatorial upwelling by a new method

(Monika Rhein, Univ. of Bremen )

In the upwelling regions of the tropical Atlantic, the thermocline is directly connected to the surface mixed layer and thus allows the exchange of biogeochemical properties between the ocean's interior and the atmosphere (e.g., exchange of $CO_2$, $N_2O$, nutrients). To quantify these exchanges, upwelling velocities w are needed. Unfortunately they are too small to be directly observed. As a German contribution to SOLAS, upwelling velocities were calculated using the observed helium isotope ($^3He/^4He$) disequilibria in the mixed layer. This recently proposed method was applied for the first time [2]. Of the calculated upwelling velocities, 48% were $<1.0\times10^{-5}$ m/s, 19% were between 1.0 and $2.0\times10^{-5}$ m/s, and 33% were $>2.0\times10^{-5}$ m/s. Highest upwelling velocities were found in late June 2006. Meridional upwelling distribution indicated an equatorial asymmetry with higher vertical velocities between the equator and 1° to 2° South compared to north of the equator. By combining upwelling velocities with sea surface temperature and productivity distributions, a mean monthly equatorial upwelling rate of 19 Sv was estimated for June 2006 and a biweekly mean of 24 Sv was estimated for September 2005 [3].

[3] Rhein, M, et al., 2010, Upwelling and associated heat flux in the equatorial Atlantic inferred from helium isotope disequilibrium, *Journal of Geophysical Research*, 115, C08021, doi:10.1029/2009JC005772.

## 2. Main accomplishments

*The **2nd phase of SOPRAN** was recently funded by the German BMBF with more than 8 million EUR. SOPRAN II started its work in February 2010 and will be finished by January 2013. SOPRAN II is organised according to "platforms" (incl. Cape Verde/Mauritania, Equatorial Atlantic Ocean, mesocosms, Heidelberg Aeolotron and FINO2 platform, and modelling). 37 PIs from 10 partner institutions (IFM-GEOMAR, IOW, AWI, U Bremen, U Hamburg, U Heidelberg, IfT Leipzig, GKSS, MPI Mainz and MPI Jena) work in 27 sub-projects. SOPRAN hompage: www.sopran.pangaea.de.

* **Poseidon cruise P399, legs 2 and 3: 'DRIVE'** (Diurnal and Regional Variability of halogen Emissions) campaign to the Mauritanian Upwelling and Eastern Subtropical North Atlantic, 31 May – 24 June 2010. The cruise funded by SOPRAN II. The chief scientist was Hermann W. Bange (IFM-GEOMAR, Kiel). An extensive atmospheric and oceanic measurement program (halocarbons, BrO, $N_2O$, $CO_2$, $CH_4$, $O_3$, Hg, aerosols) was conducted together with meterological (radiosonde launching) and standard hydrographic measurements (CTD, $O_2$, nutrients). Participating institutes were IFM-GEOMAR, Kiel, Univ. of Hamburg, Univ. of Heidelberg, Univ. of East Anglia, Norwich, MPI for Biogeochemistry, Jena, MPI for Chemistry Mainz, ICCM, Telde (Gran Canaria).

## 3. Top 10 publications in 2010


Bange, H W, et al., 2010, Dissolved methane during hypoxic events at the Boknis Eck Time Series Station (Eckernförde Bay, SW Baltic Sea), *Biogeosciences*, 7, 1279-1284.

Heller, M I, and Croot, P L, 2010, The kinetics of superoxide reactions with dissolved organic matter in tropical Atlantic surface waters near Cape Verde (TENATSO), *Journal of Geophysical Research*, 115, C12038, doi:10.1029/2009JC006021.

Hense, I, and Burchard H, 2010, Modelling cyanobacteria in shallow coastal seas *Ecological Modelling*, 221, 238-244.

Kihm, C, and Körtzinger, A, 2010, Air-sea gas transfer velocity for oxygen derived from float data, *Journal of Geophysical Research*, 115, C12003, doi: 10.1029/2009JC006077.

Martínez Avellaneda, N, et al., 2010, Response of th eastern subtropical Atlantic SST to Saharan dust: A modeling and observational study, *Journal of Geophysical Research*, 115, C08015, doi: 10.1029/2009JC005692.

Müller, K, et al., 2010, Particle characterization at the Cape Verde atmospheric observatory during the 2007 RHaMBLe intensive, *Atmospheric Chemistry and Physics*, 10, 2709-2721.

Ohde, T, and Siegel H, 2010, Biological response to coastal upwelling and dust deposition in the area off Northwest Africa, *Continental Shelf Research*, 30, 1108-1119.

Rhein, M, et al., 2010, Upwelling and associated heat flux in the equatorial Atlantic inferred from helium isotope disequilibrium, *Journal of Geophysical Research*, 115, C08021, doi:10.1029/2009JC005772.

Schafstall, J, et al., 2010, Tidal induced mixing and diapycnal nutrient fluxes in the Mauritanian upwelling region, *Journal of Geophysical Research*, 115, C10014, doi: 10.1029/2009JC005940.

Stolle, C, et al., 2010, Succession of the seasurface microlayer in the coastal Baltic Sea under natural and experimentally induced low-wind conditions, *Biogeocsciences*, 7, 2975-2988.

Wittke, F, et al., 2010, Nitrous oxide emissions from the upwelling off Mauritania (NW Africa), *Geophysical Research Letters*, 37, L12601, doi: 10.1029/2010GL042442.


## 4. International interactions and collaborations

Plenty

## 5. Goals and plans for future activities

* SOPRAN mesocosm $CO_2$ enrichment study in Bergen (Norway), May-July 2011, PI Ulf Riebesell (IFM-GEOMAR, Kiel)
* SOPRAN cruise with R/V Merian to the equatorial Atlantic Ocean, 22 June – 21 July 2011, PI Arne Körtzinger (IFM-GEOMAR, Kiel)
* SHIVA SONNE cruise with RV Sonne: Exchange of halocarbons between the ocean and the stratosphere, 14 – 30 Nov 2011,
South China and Zulu Seas, PI: Brigit Quack (IFM-GEOMAR, Kiel)
* SOPRAN mesocosm experiment in 2012 (location and scientific objectives to be decided) PI Ulf Riebesell (IFM-GEOMAR, Kiel)

# SOLAS India

*compiled by M. Dileep Kumar*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### a. Atmospheric deposition of N, P and Aerosol soluble Fe over Bay of Bengal

Spatio-temporal variability in the fractional solubility of aerosol iron [WS-Fe (%)] has been studied based on chemical composition of size-segregated aerosols ($PM_{10}$ and $PM_{2.5}$) collected from tropical Bay of Bengal (BoB) during January-2009. During the study, continental outflow from the two major source regions has been identified, viz: (1) outflow from the Indo-Gangetic Plain (IGP) sampled over north-BoB; and (2) south-east Asian (SEA) outflow over south-BoB. A significant linear relationship among fractional Fe solubility [WS-Fe (%)] and nss-$SO_4^{2-}$ over north-BoB (characterized by higher abundance of aerosol iron ($Fe_A$) and $SO_4^{2-}$) provides evidence for acid processing of mineral dust during atmospheric transport from IGP. In contrast, a temporal shift in the winds, representing the outflow from south-east Asia and aerosol composition over south-BoB, exhibit enhanced fractional solubility of aerosol Fe (range: 11.4 to 49.7 %) associated with the lower abundance of dust (<100 ng $m^{-3}$ of $Fe_A$) and nss-$SO_4^{2-}$ (<15 µ g $m^{-3}$). These observations suggest the dominance of combustion sources (biomass burning and fossil-fuel combustion) in dictating the aerosol iron solubility over south-Bay of Bengal (Kumar et al 2010). The water-soluble inorganic nitrogen ($N_{Inorg}$) dominates the total soluble nitrogen ($N_{Tot} = N_{Inorg} + N_{Org}$), accounts > 90% of $N_{Tot}$ and exists mainly in fine mode as $NH_4^+$ - N and makes up as much as 98 % of $N_{Inorg}$. On average inorganic N: P molar ratio in the dry-deposition (Av = 12 ± 8) is comparable to the Redfield ratio (N: P = 16: 1). Our results suggest that atmospheric deposition of $N_{Tot}$ is not a significant source of new nitrogen to the Bay during wintertime (Jan).

**Reference:**

Kumar, A, MMSarin, B Srinivas, (2010) 'Aerosol iron solubility in MABL of Bay of Bengal: Contribution from chemical processing vis-à-vis combustion sources', Marine Chemistry, 121, 167-175, 10.1016/j.marchem.2010.04.005.

### b. Application of stable oxygen isotopes for estimation of transfer velocity of trace gases

Rate of sea-to-air flux is directly controlled by transfer velocity (*k*). The *k* has been parameterized to obtain averages of weekly to several years using either artificial tracer, such as $SF_6$/$^3$He, bomb radiocarbon, numerical models or eddy covariance method but with several assumptions. Based on oxygen isotope balance air-sea transfer velocity can be estimated. Two processes control the variations in $^{17}$□ anomaly in the mixed layer, i.e., GPP and air-sea exchange of $O_2$. In the absence of GPP, the changes in $^{17}$□ anomaly are solely controlled by exchange of $O_2$ at the air-water interface. In order to quantify transfer velocity of oxygen, the night-time variations in $^{17}$□ anomaly were measured, when no GPP occurs, in the subarctic North Pacific and Sagami Bay (northwestern Pacific) during different periods.

The results clearly established that natural $^{17}$□ anomaly method can be effectively used to derive gas transfer velocities at air-water interfaces, which is free from operational constraints of artificial tracers. The major advantage of this method is that (1) it can be applied to any aquatic environments, such as lakes, coastal regions, and Open Ocean, and (2) it does not involve any artificial or radioactive tracers such as $SF_6$, $^3$He, and $^{14}$C. The present method is more robust and easy to estimate *k* at any region. The oxygen isotopes are being measured on routine basis under the ongoing or planned international projects such as SOLAS, IMBER, and GEOTRACES. That will hopefully facilitate an application of this method on a large scale in order to gain a comprehensive global picture of the transfer of greenhouse gases across air-water interface thereby reducing uncertainties in the oceanic sinks/sources of trace gases. Such a view is now more attainable.

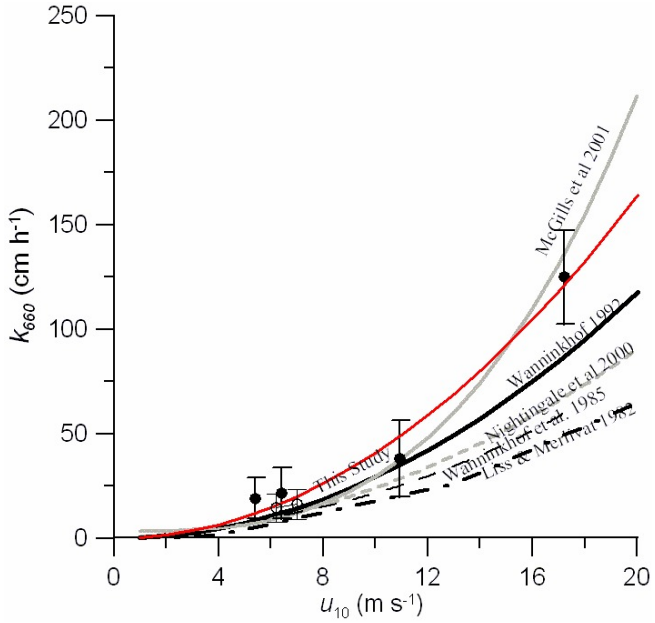



Figure 1: Relationship between transfer velocity, normalized to Schmidt number 660, and wind speeds, normalized to 10m height from the sea surface. Comparison with other estimates using different tracers is also shown where red line fit derived from data collected in the subarctic North Pacific.

References:

Sarma, V.V.S.S., O. Abe, M. Honda, and T. Saino. 2010. Estimating of gas transfer velocity using triple isotopes of dissolved oxygen, J. Oceanogr., **66**: 505-512.

## 2. Main accomplishments

The 5th International Symposium on Biological and Environmental Chemistry of DMS(P) and Related Compounds was held at National Institute of Oceanography, Goa, 9 - 22 October, 2010. Atmospheric and ocean scientists have been brought together for the first time in the series of DMS(P) Symposia. The symposium was structured into 42 oral presentations which included 11 invited talks and 14 poster presentations under the 5 topics (a - Regulation and Dynamics; b - Ecosystems and Regional Experiments; c - Sea-air fluxes, aerosols and Climate Change; d – Methodology; and e – Modeling) identified. The Symposium was attended by more than 60 delegates from 12 countries. The Symposium manuscripts are being processed for a special issue of the journal 'Biogeochemistry'.

## 3. Top 10 publications in 2010

Kumar A, Sarin MM and Bikkina Srinivas, 2010, 'Aerosol iron solubility in MABL of Bay of Bengal: Contribution from chemical processing vis-à-vis combustion sources', *Marine Chemistry*, 121, 167-175, doi: 10.1016/j.marchem.2010.04.005.

Sarma, VVSS, Abe O, Honda M, and T Saino, 2010, 'Estimating of gas transfer velocity using triple ixotopes of dissolved oxygen', *Journal of Oceanography*, 66: 505-512.

Uematsu M, Hattori H, Nakamura T, Narita Y, Jung J, Matsumoto K, Nakaguchi Y and MD Kumar, 2010, 'Atmospheric transport and deposition of anthropogenic substances from the Asia to the East China Sea', *Marine Chemistry*, 120: 108-115.

## 4. International interactions and collaborations

Oxygen isotopic work by Sarma and dust transport to China Sea work by Dileep Kumar were performed with Japanese collaborations.

## 5. Goals and plans for future activities

Influence of ocean biology on the regional cloud microphysics is planned.

# SOLAS Ireland

*compiled by Brian Ward*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

**Upper Ocean Turbulence in the Labrador Sea**

The Air-Sea Interaction Profiler (ASIP) was successfully deployed in the Labrador Sea in May on the CCGS Hudson. This project was a collaboration with Jonathan Lilly at Northwest Research Associates in Seattle, and the Bedford Institute of Oceanography in Halifax, and was funded by NUIG as well as the NSF.The objectives were to investigate the origin of the rapid freshwater capping after deep convection which takes the form of a thin freshwater layer regularly seen across the entire 600 km diameter basin. ASIP was deployed on 6 separate occasions and acquired over 200 profiles over the upper 100 m with sub-centimetre resolution measurements of shear, temperature, salinity, PAR, and velocity.

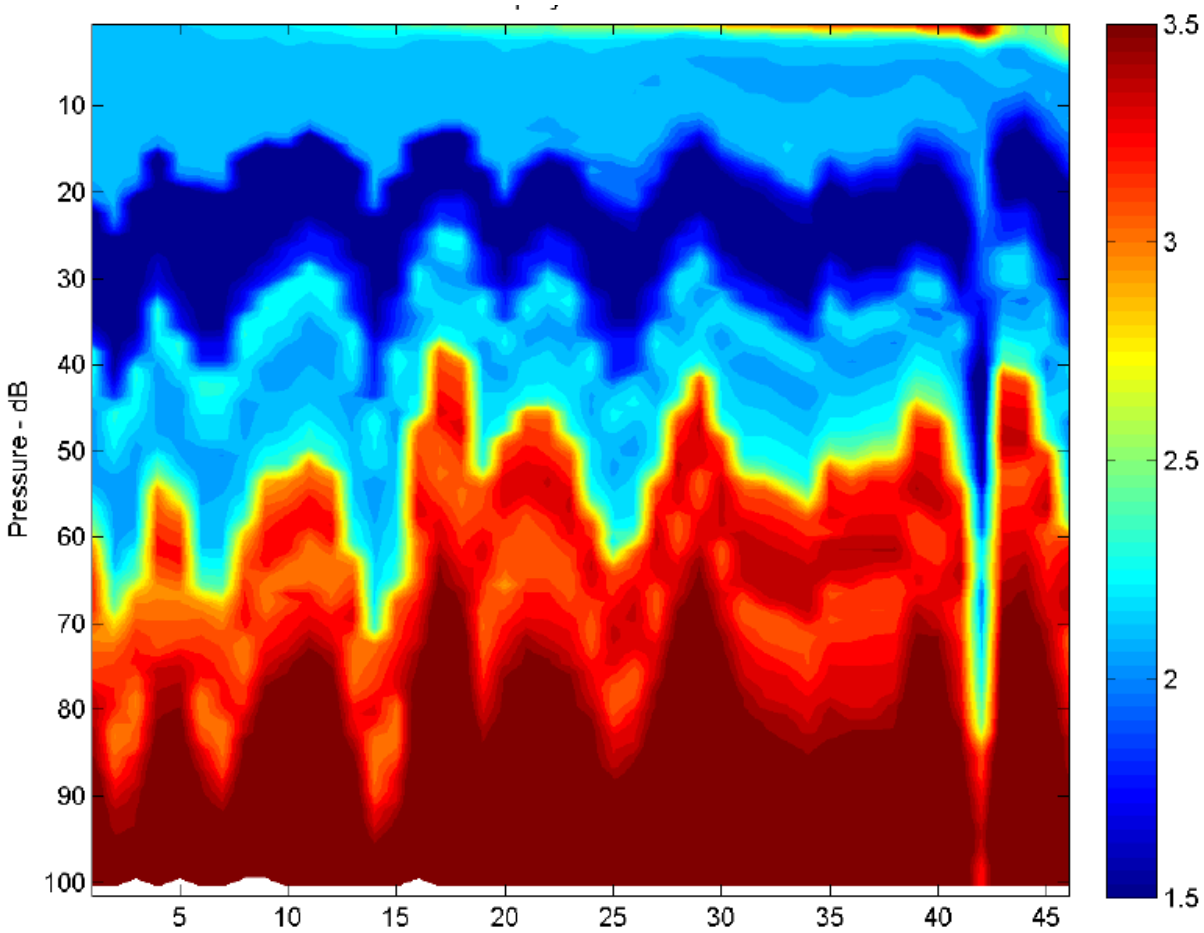



Fig 1: Time-depth plot of temperature from the Labrador Sea experiment in May 2010.

**Highlight: Molecular iodine emission rates and photosynthetic performance of different thallus parts of *Laminaria digitata* (Phaeophyceae) during emersion**

*Note: This work is the result of an interdisciplinary collaboration between atmospheric physicists of UCC (Dr Sophie Dixneuf, Dr Albert A. Ruth, Laser Spectroscopy Group, Physics Department) and marine botanists of NUIG (Udo Nitschke, Dr. Dagmar B. Stengel, Botany and Plant Science group,*

*School of Natural Sciences, Environmental Change Institute, Martin Ryan Institute).*

Iodine escapes the ocean in its elemental form, that is gaseous $I_2$, or in volatile iodo-carbons (e.g. $CH_3I$, $CH_2I_2$, $C_2H_5I$, $C_3H_7I$, $CH_2ClI$, $CH_2BrI$) (Carpenter, 2003). Once released into the atmosphere, these iodine-containing species undergo photolysis by solar radiation, resulting in atomic iodine to be formed. The latter reacts with ozone, forming IO radicals, whose self reaction leads to the formation of OIO; the latter, in turn, self-reacts to form $I_nO_m$ (with $n \geq 2$ and $m \geq 4$). At the end of a complex catalytic cycle involving the destruction of ozone, newly nucleated aerosol particles eventually emerge (McFiggans et al., 2004). Both the depletion of ozone and the formation of new particles affect the atmospheric radiation balance and therefore have an impact on the global climate.

In coastal areas, because $I_2$ concentrations typically exceed those of volatile iodo-carbons (for instance $CH_2I_2$) and because $I_2$ has a substantially shorter photolytic lifetime, it is likely that molecular iodine represents the dominant source for atomic iodine (McFiggans et al., 2004). During field campaigns at Mace Head and Carna (west coast of Ireland), significant concentration peaks of tropospheric $I_2$ coinciding with times of spring low tide suggested that the beds of kelps (exposed to air at very low tide only) were the origin of the observed $I_2$ (Saiz-Lopez and Plane, 2004; Bitter et al., 2005; Seitz et al., 2010; Huang et al., 2010). Thus, the emission of $I_2$ from kelp deserved a closer examination due to its key role in atmospheric chemistry processes (O'Dowd and Hoffmann 2005). Even though quantification techniques of biogenic iodine emissions are still being debated (Ball et al. 2010), only few $I_2$ emission rates have been published for brown macroalgae (Palmer et al. 2005; Ball et al. 2010). These data suggest that $I_2$ emission rates from macroalgae need to be considered in relation to several different parameters such as the corresponding species, biotic and abiotic environmental impacts and the physiological status of the algae (Laturnus et al. 2004).

In this work time-resolved flux measurements of $I_2$ emitted by the brown macroalgae *Laminaria digitata* were achieved using incoherent-broadband cavity-enhanced absorption spectroscopy (Fiedler et al., 2003), with the optical cavity perpendicular to the direction of the main $I_2$ carrying flow. The measurements on fresh algal samples took place at the Finavarra research station, Co. Clare, Ireland, in November 2009. More precisely, $I_2$ emission rates of three different (air-exposed) thallus parts of *L. digitata* were investigated in relation to the plant's dry weight and surface area, under low light and dark conditions. In order to address important aspects of the physiology of iodine in *Laminaria*, $I_2$ emission rates were measured (for the first time) in conjunction with the physiological stress experienced by the alga upon air-exposure, based on the plant's photosynthetic performance. The study revealed that the emission of $I_2$ is spatially inhomogeneous over the thallus; initial $I_2$ emission rates (measured within 30 min of exposure to air) were highest for stipes (median values: 2,999 and 5,222 pmol g-1 dw min-1 in low light and dark, respectively) and lower, by one order of magnitude, for meristematic regions and distal blades (see Figure 1 for an example). $I_2$ emission rates were not affected by the light regimes tested. Moreover, the results indicate the presence of an iodine pool which is easily volatilised and depleted due to air-exposure, even under apparently low stress conditions.

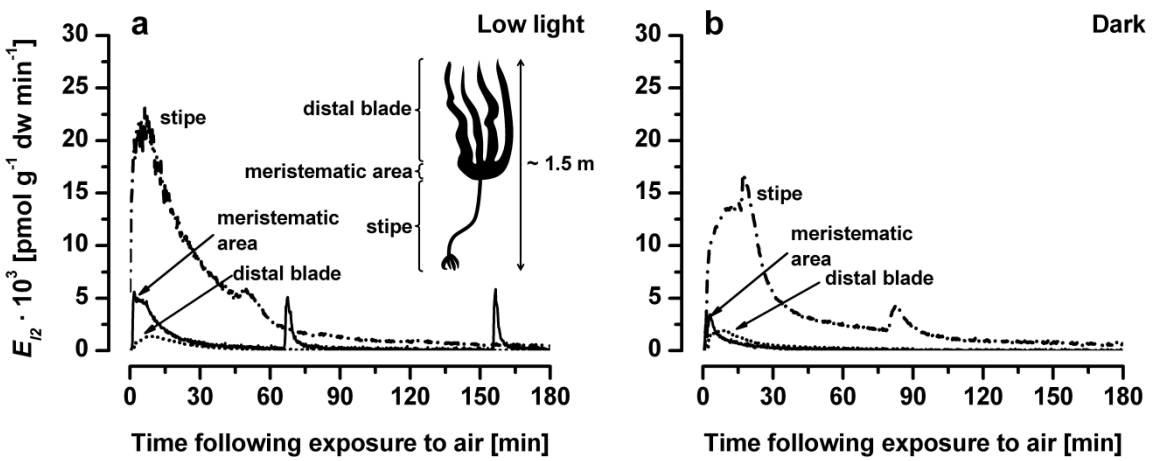


**Fig. 2.** The strongest $I_2$ emitting specimens of air-exposed *Laminaria digitata* as examples of an $I_2$ emission rate, $E_{I2}$ (pmol $g^{-1}$ dw $min^{-1}$) as a function of time, with respect to different parts of the thallus: 'stipe', 'meristematic area', and 'distal blade'.

## 2. Main accomplishments

- Labrador Sea cruise on CCGS Hudson May 2010
- Underway pCO2 measurements on R/V Celtic Explorer
- Eddy correlation flux measurements on R/V Celtic Explorer

## 3. Top 10 publications in 2010

Anttila T, Langmann B, Varghese S and C O'Dowd, 2010, 'Contribution of isoprene oxidation products to marine aerosol over the North-East Atlantic', *Adv. in Meteorol.,* Volume 2010, Article ID 482603, doi:10.1155/2010/482603.

Monahan C, Vuollekoski H, Kulmala M and C O'Dowd, 'Modelling the Contribution of Iodine Oxide to Marine New Particle Formation', *Adv. in Meteorol.,* in press.

McVeigh P, O'Dowd C and H Berresheim, 2010, 'Eddy correlation measurements of ozone fluxes over coastal waters west if Ireland', *Adv. in Meteorol.,* Volume 2010, Article ID 754941, doi:10.1155/2010/754941.

O'Dowd C, Scannell C, Mulcahy J and SG Jennings, 'Wind Speed Influences on Marine Aerosol Optical Depth', *Adv. in Meteorol.,* Article ID 830846, doi:10.1155/2010/830846.

Coleman L, Varghese S, Tripathi OP, Jennings SG and CD O'Dowd, 2010, 'Regional-scale Ozone Deposition to North-East Atlantic Waters', *Adv. in Meteorol*., Volume 2010, Article ID 243701, doi:10.1155/2010/243701.

Myriokefalitakis S, Vignati E, Tsigaridis K, Papadimas C, Sciare J, Mihalopoulos N, Facchini MC, Rinaldi M, Dentener FJ, Ceburnis D, Hatzianastassiou N, O'Dowd CD, van Weele M and M Kanakidou, 'Global modelling of the oceanic source of organic aerosols', *Adv. in Meteorol.*, Volume 2010, Article ID 939171, doi:10.1155/2010/939171.

Rinaldi M, Decesari S, Finessi E, Giulianelli L, Carbone C, Fuzzi S, O'Dowd CD, Ceburnis D and MC Facchini, 2010, 'Primary and secondary organic marine aerosol and oceanic biological activity: recent results and new perspectives for future studies', *Adv. in Meteorol.,* Volume 2010, Article ID 310682,, doi:10.1155/2010/310682.

O'Dowd CD, Monahan C and M Dall'Osto, 2010, 'On The Occurrence of Open Ocean Particle Production Events', *Geophys. Res. Letts.,* 37, L19805, doi:10.1029/2010GL044679.

Huang RJ, Seitz K, Neary T, O'Dowd CD, Platt U, and T Hoffmann, 2010, 'Observations of high concentrations of $I_2$ and IO in coastal air supporting iodine-oxide driven coastal new particle formation', *Geophys. Res. Letts.*, 37, L03803, doi:10.1029/2009GL041467.

Dall'Osto M, Ceburnis D, Martucci G, Bialek J, Dupuy R, Jennings SG, Berresheim H, Wenger JC, Healy RM, Facchini MC, Rinaldi M, Giulianelli L, Finessi E, Worsnop D, Ehn M, Mikkil¨a J, Kulmala M, Sodeau J and C D O'Dowd, 2010, 'Aerosol properties associated with air masses arriving into the North East Atlantic during the 2008 Mace Head EUCAARI intensive observing period: an overview', *Atmos. Chem. Phys.,* 10, 8413-8435, doi:10.5194/acp-10-8413-2010.

Nitschke U, Ruth AA, Dixneuf S and DB Stengel, 'Molecular iodine emission rates and photosynthetic performance of different thallus parts of Laminaria digitata (Phaeophyceae) during emersion', *Planta*,

doi: 10.1007/s00425-010-1334-3, 2010, in press.

## 4. International interactions and collaborations

MaCloud Inc. (Marine Aerosol Cloud Interactions) took place December 2010 and again in May 2011 at Mace Head and will focus on the impact of primary and secondary marine aerosol on cloud microphysics.

## 5. Goals and plans for future activities

- Gas Exchange cruise in collaboration with Eric Saltzman and Scott Miller in June/July 2011

# SOLAS Netherlands

*compiled by Jacqueline Stefels*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### 1. Atmospheric $CO_2$ and $O_2$ observations from the F3 North Sea platform, Lutjwad (the Netherlands) and Mace Head, Ireland.

*I.T. van der Laan-Luijkx and H.A.J. Meijer (Centre for Isotope Research, University of Groningen)*

The new atmospheric measurement station on the North Sea platform F3 (54º51'N, 4º44'E) has been established in 2006. From June 2006 flasks have been sampled every week and from August 2008 continuous measurements have been performed. The main focus of the measurement station are atmospheric $CO_2$ and $O_2$ measurements, the combination of both species yields information on the (global) marine $CO_2$ uptake. The results of both methods are presented in figure 1.

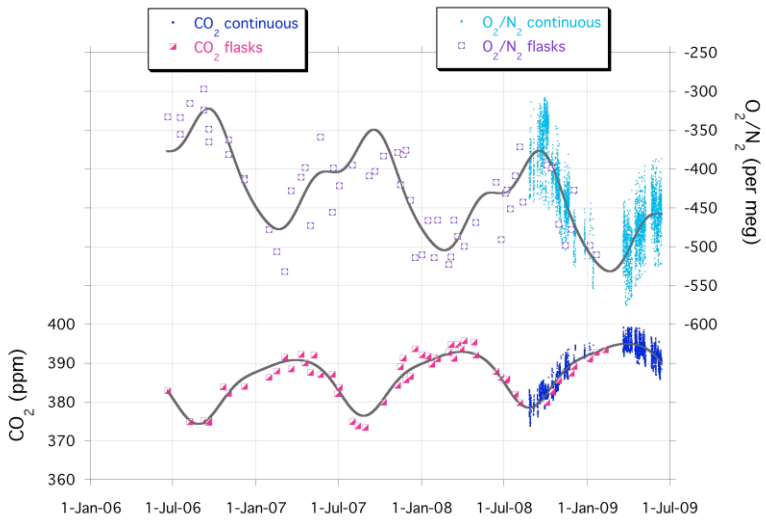



**Figure 1**: Observations at the F3 platform for the period June 2006 through June 2009. The continuous measurements of $\delta O_2/N_2$ (small light circles) and $CO_2$ (small dark squares) are shown together with the measurements of flask samples (open symbols). Both y-axes have been adjusted so that their ranges are nearly the same on a molar basis.

Furthermore, the $O_2$ and $CO_2$ observations from flask samples at two other European measurement sites have been analyzed: Lutjewad in the Netherlands and Mace Head in Ireland (Figure 2). The records for these two stations are much longer (almost 10 years), which enables estimates of long-term trends. The trends observed at Mace Head during the studied period were 1.90 ± 0.04 ppm/year for $CO_2$ and -18.5 ± 0.7 per meg/year for $O_2$. A basic estimate of the global average marine $CO_2$ uptake can be made using the long term trends in the atmospheric $CO_2$ and $O_2$ concentrations which are combined to form the trend in the atmospheric potential oxygen (APO). Using the APO time series from the flasks sampled between 1998 - 2009 at Mace Head (during restricted baseline conditions) and information on the net oceanic $O_2$ exchange, the global oceanic $CO_2$ uptake is estimated at 1.8 ± 0.8 PgC/year.

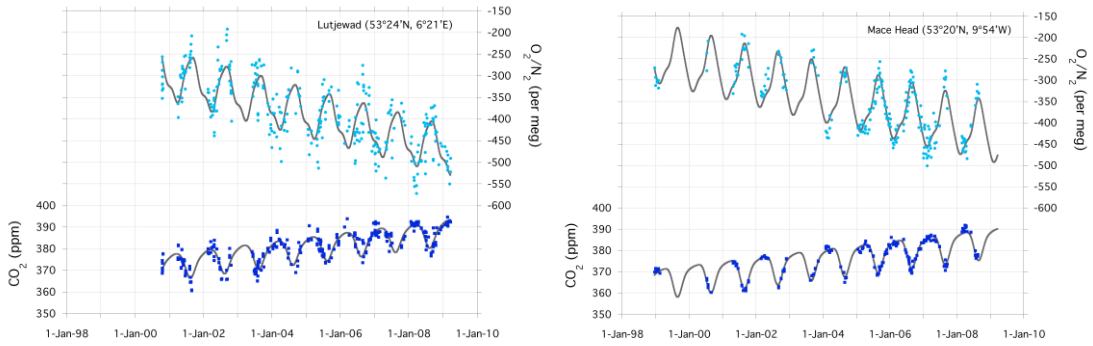



**Figure 2**: Observations of the atmospheric $O_2$ (lighter circles) and $CO_2$ (darker squares) concentrations at station Lutjewad (a) and Mace Head (b) during 2000-2009, based on flask measurements. The fits through the data points are a combination of a three harmonic function and a linear trend.

Future research will focus on the continuation and thereby extension of these data series. The longer time series will enhance the quality of the estimate of the marine $CO_2$ uptake by the Atlantic Ocean and the North Sea. Continuous $O_2$ measurements will also be started at Lutjewad, which –together with the continuous data from the F3 platform and marine measurements– will provide additional information on the North Sea $CO_2$ uptake variability.

**2. Inorganic carbon uptake by Southern Ocean phytoplankton in a changing world**

*Ika Neven, Jacqueline Stefels, Theo Elzenga, Hein de Baar (University of Groningen, Dept. of Plant Ecophysiology)*

Because phytoplankton is known to play an important role in the sequestration of anthropogenic carbon by means of a process called the biological pump, it is important to determine whether primary productivity is susceptible to changing atmospheric $CO_2$ levels. In the last decade it has been shown, that Antarctic primary productivity can be severely reduced by a co-limitation of dissolved iron (dFe) and light. However, due to the special chemistry of DIC in seawater, the concentration of $CO_2$ – which is the only suitable carbon species for photosynthetic fixation in the Calvin cycle – might pose another limiting factor. An increase of DIC in seawater due to anthropogenic activity, and hence an increased concentration of $CO_2$ might have a significant effect on future phytoplanktonic production.

Carbon acquisition of natural phytoplankton assemblages in the Atlantic sector of the Southern Ocean has been quantified during a field campaign with *R.V. Polarstern* (February until April 2008). Using the isotopic disequilibrium technique the contribution of different carbon species ($CO_2$ and bicarbonate ($HCO_3^-$)) to the overall DIC uptake and the extent to which the enzyme external carbonic anhydrase (eCA) plays a role in facilitating DIC uptake was estimated. Simultaneous uptake of $CO_2$ and $HCO_3^-$ was observed in all cases, but the proportions in which different DIC species contributed to carbon assimilation varied considerably between stations. The contribution of $CO_2$ to total DIC uptake was positively correlated to ambient concentration of $CO_2$ in seawater. Consequently, it can be anticipated that Southern Ocean microalgae will increase the proportion of direct $CO_2$ uptake under future high atmospheric $CO_2$ levels. $CO_2$ is a relatively small and uncharged molecule, which is able to enter the cell by simple diffusion, whereas the uptake of bicarbonate is always energy costly. Our results suggest that phytoplanktonic cells might benefit from higher atmospheric $CO_2$ levels in terms of reduced costs for DIC uptake. Although numerous factors that might influence phytoplanktonic production (e.g. mixed layer

depth, ice cover, sea surface temperature, nutrient concentrations) need to be considered, this indicates that photosynthetic sequestration of DIC in the Southern Ocean can become stimulated.

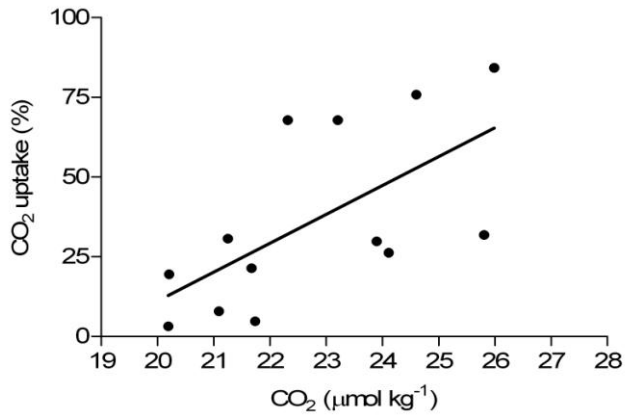



**Figure:** Influence of ambient $CO_2$ concentration (in µmol·kg$^{-1}$) on phytoplanktonic uptake of $CO_2$ (in %).

**3. The analysis of dimethylsulfide and dimethylsulphoniopropionate in sea ice**

*Jacqueline Stefels[1], Gauthier Carnat[2], John W.H. Dacey[3], Thomas Goossens[2], J. Theo M. Elzenga[1], Jean-Louis Tison[2] (1. University of Groningen, Netherlands; 2. Université Libre de Bruxelles, Belgium; 3. Woodshole Oceanographic Institution, USA)*

Sea ice is thought to be an important source of the climate-active gas dimethylsulfide (DMS), since extremely high concentrations of its precursor dimethylsulfoniopropionate (DMSP) have been found associated with high algal biomass. Accurate measurements of DMS and associated compounds in sea ice were until now not possible due to difficulties associated with the unavoidable melting process before analysis. We have developed two new methods to analyze DMS and DMSP in sea-ice cores accurately. The first, describes the dry-crushing method, which has its focus on the volatile compound DMS. A sub-sample of deeply frozen ice is crushed in a stainless steel vessel and the released gas phase is analyzed directly for DMS. The remaining ice is subsequently analyzed for its total DMSP content. The second method involves a melting procedure during which the conversion of compounds is monitored by adding differently deuterated isotopes of DMS and DMSP. Natural concentrations and stable isotopes of DMS and DMSP are simultaneously analyzed on a Proton-Transfer-Reaction Mass Spectrometer (PTR-MS). Loss and conversion rates of the artificial isotopes are used to reconstruct the original concentrations of DMS and DMSP in ice and give important information on potential dynamical processes in sea-ice communities.

With the dry-crushing method we were able to resolve accurate DMS and DMSP profiles even in ice cores stored deeply frozen for two years. When direct processing and analysis of the samples is possible, the isotope-addition method has the advantage that besides providing concentrations of all S-compounds, including dissolved and particulate fractions, it is suitable to determine process rates within the S-cycle.

The dry-crushing method was used to measure high- resolution profiles of ice DMS and DMSP concentrations during a time series of decaying summer- level first- year sea ice throughout December 2004 during the Ice Station Polarstern drift experiment (western Weddell Sea, Antarctica) (Figure 4).

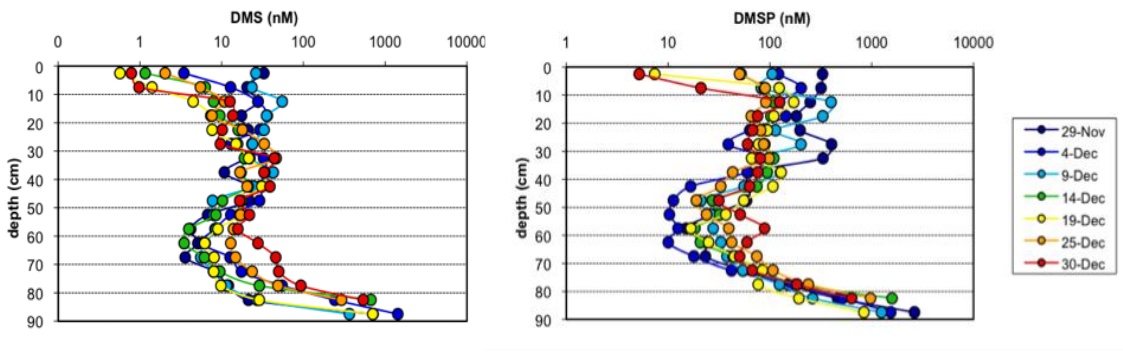



**Figure 4.** Time series of DMS and DMSP profiles in decaying first-year sea ice at the ISPOL site in the Weddell Sea, Antarctica, during November-December 2004 (after Tison et al. 2010).

Ice DMSP and DMS concentrations were always maximum at the bottom of the ice sheet (636–2627 and 292–1430 nM, respectively) where the highest chlorophyll a levels were also found (15–30 µg $L^{-1}$). Diatoms dominated the overall DMSP production because of their much larger biomass. Decreasing DMSP concentrations and increasing DMS- to- DMSP ratios in the bottom layers with time suggested active DMSP- to- DMS conversion in a slowly degrading environment. First- order flux estimates show that decaying summer- level first- year sea ice alone can significantly contribute to the regional sulfur budget of the Weddell Sea with an estimated average loss rate of 5.7 µmol DMS(P) $m^{-2}$ $d^{-1}$ toward the atmosphere and the ocean.

## 2. Main accomplishments

PhD defence of Ingrid van der Laan-Luijkx. Title of her thesis:
I.T. van der Laan-Luijkx (2010), Atmospheric oxygen and the global carbon cycle. Observations from the new F3 North Sea platform monitoring station and 6 additional locations in Europe and Siberia. PhD thesis University of Groningen.

Two new sea-ice projects have started:
"The sea-ice sulphur cycle in a global climate model" (J.Stefels, University of Groningen)
"Support of seasonal sea-ice ecosystems by essential trace nutrient elements iron and manganese" (V. Schoemann, Royal NIOZ)

## 3. Top 10 publications in 2010

Le Clainche Y, AF Vezina, M Levasseur, R Cropp, J Gunson, S Vallina, M Vogt, C Lancelot, I Allen, S Archer, L Bopp, C Deal, S Elliott, M Jin, G Malin, V Schoemann, R Simo, K Six, J Stefels (2010): A first appraisal of prognostic ocean DMS models and prospects for their use in climate models. Global Biogeochemical Cycles 24, GB3021, doi:10.1029/2009GB003721

Sirignano C, Neubert R E M, Rödenbeck C and Meijer H A J (2010): Atmospheric oxygen and carbon dioxide observations from two European coastal stations 2000-2005: continental influence, trend changes and APO climatology. Atmospheric Chemistry Physics, 10:1599-1615.

Tison J-L, Brabant F, Dumont I, Stefels J (2010): High resolution dimethylsulfide (DMS) and dimethylsulfoniopropionate (DMSP) time-series profiles in decaying summer first-year sea ice at Ice Station Polarstern (ISPOL, Western Weddell Sea, Antarctica). Journal of Geophysical

Research – Biogeosciences, 115, G04044, doi:10.1029/2010JG001427

Van der Laan-Luijkx I T, Neubert R E M, van der Laan S and Meijer H A J (2010): Continuous measurements of atmospheric oxygen and carbon dioxide on a North Sea gas platform, Atmospheric Measurement Techniques, 3: 113-125

Van der Laan-Luijkx I T, Karstens U, Steinbach J, Gerbig C, Sirignano C, Neubert R E M, et al. (2010): CO2, O2/N2 and APO: observations from the Lutjewad, Mace Head and F3 platform flask sampling network. Atmospheric Chemistry and Physics 10: 10691-10704.

Annual Report for the year 2010:

# SOLAS New Zealand

*compiled by Philip Boyd & Cliff Law*

## 1. Scientific highlights

### Can we better assess the likelihood of a dust-mediated phytoplankton bloom in open ocean waters?

A recent review in a Special Issue of Marine Chemistry (volume 120, 1-4 Aerosol Chemistry and Impacts on the Ocean) has focussed on better defining the relationship between aerosol iron supply and a biological response by reappraisal of published reports of a causal link between dust supply and bloom of phytoplankton. In most cases there has been misattribution of cause and effect. In order to minimise such attribution in the future, Boyd et al. have published a simple triage tool that can be used, with information selected and inputted by the user, to ascertain whether a causal link between aerosol iron and a phytoplankton bloom.

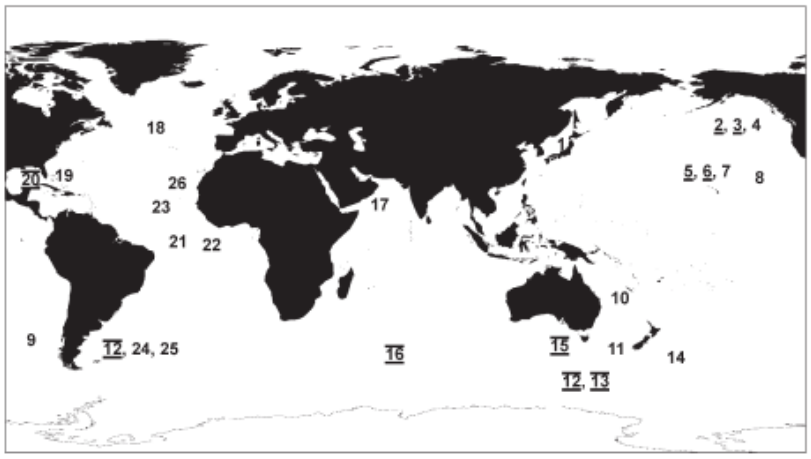



Fig. 3. Global distribution of studies that have either directly or indirectly examined the link between dust supply and a consequent biological response. Studies that are underlined denote a relationship between dust and the biota, those that are not underlined denote that no relationship was reported. The underlined studies that are also overlined indicate that they have in subsequent re-analysis to be found to have misattributed the causes of the biological response to dust supply

*Boyd, P.W., D.S. Mackie and K.A. Hunter (2009) Aerosol iron deposition to the surface ocean — Modes of iron supply and biological responses. Marine Chemistry, doi:10.1016/j.marchem.2009.01.008*

### Time Series study of CO2 in Sub-Antarctic Water

The Munida time series is now 12 years old. Carbon dioxide parameters are measured in the surface waters along a transect covering neritic, modified subtropical and sub-Antarctic surface waters every two months (Fig 1a), The seasonal cycle is now well documented, with surface $pCO_2$ primarily dictated by biological processes. The time series of $pCO_2$ of sub-Antarctic waters for the 1998-2009 is shown in Fig 1b The area is a sink for atmospheric CO2, although the long term trend indicates an increase in surface pCO2. The trend is complicated by substantial interannual variability, which is currently being interpreted with the aid of a simple box model.

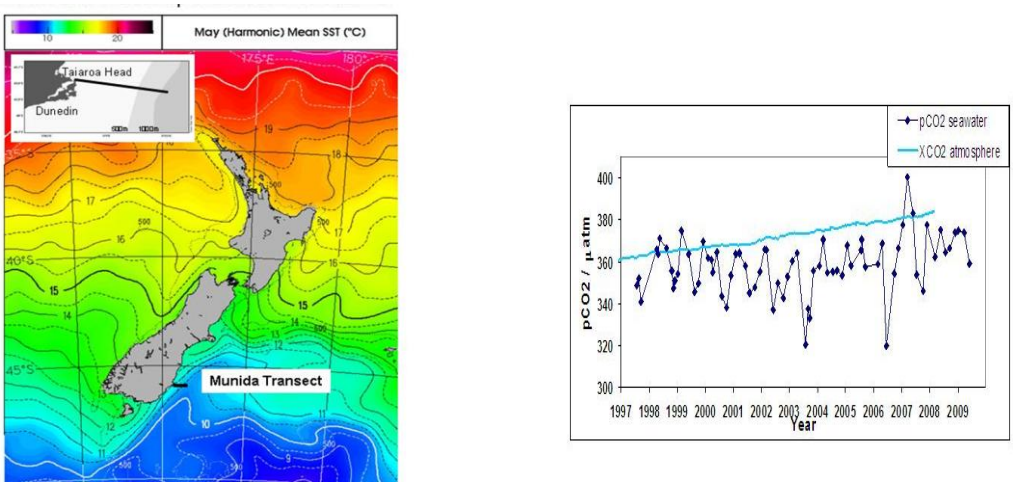



Fig 1 a) The location of the Munida Transect extending into Sub-Antarctic Waters overlain on Sea Surface temperature. b) Temporal variation of atmospheric XCO2 at the GAW at Baring Head site and surface water pCO2 at the sub-Antarctic station on the Munida transect.

*Currie, K.I., Reid, M.R., Hunter, K.A., 2009. Interannual variability of carbon dioxide drawdown by subantarctic surface water near New Zealand. Biogeochemistry 10.1007/s10533-009-9355-3.*

## 2. Main accomplishments

A three-year project examining the variability and controls of trace gas and $CO_2$ emissions in NZ coastal waters has just been completed. The study confirmed that coastal regions had the highest methane & $CO_2$ emissions per unit surface area in the NZ EEZ, with particularly high concentrations (and emissions) in regions that support shallow geothermal vents in the Bay of Plenty. Physical measurements in a strongly heterotrophic coastal region showed strong control of flux by stratification, together with a strong benthic source of methane (as opposed to riverine input) which was significantly modulated by tidal depth in shallower water

We continue to participate in the Maritime Aerosol Network (MAN) http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html with measuremnts across the western Pacific on VOS in collaboration with NIES, Japan as described by Smirnov et al (2009) http://dx.doi.org/10.1029/2008JD011257

## 3. Top 10 publications in 2010

Law, C S, Nodder, S.D., Mountjoy, J., Marriner, A., Orpin, A., Pilditch, C.A., Franz, P., Thompson, K. 2010. Geological, hydrodynamic and biogeochemical variability of a New Zealand deep-water methane cold seep during an integrated three year time-series study, Marine Geology 272:189-208, doi: 10.1016/j.margeo.2009.06.018.

Smith, M.J.; Ho, D.T.; Law, C.S.; McGregor, J.; Popinet, S.; Schlosser, P. Uncertainties in gas exchange parameterization during the SAGE dual-tracer experiment. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Accepted Manuscript. <http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.025>

Minnett, P.J.; Smith, M.; Ward, B. Measurements of the oceanic thermal skin effect. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Accepted Manuscript. <http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.024>

Peloquin, J.; Hall, J.; Safi, K.; Ellwood, M.; Law, C.; Thompson, K.; Kuparinen, J.; Harvey, M.; Pickmere, S. Control of the phytoplankton response during the SAGE experiment: A synthesis. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Accepted Manuscript.

<http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.019>

Peloquin, J.; Hall, J.; Safi, K.; Smith Jr, W.O.; Wright, S.; van den Enden, R. The response of phytoplankton to iron enrichment in Sub-Antarctic HNLCLSi waters: Results from the SAGE experiment. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Accepted Manuscript. <http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.021>

Harvey, M.J.; Law, C.S.; Smith, M.J.; Hall, J.A.; Abraham, E.R.; Stevens, C.L.; Hadfield, M.G.; Ho, D.T.; Ward, B.; Archer, S.D.; Cainey, J.M.; Currie, K.I.; Devries, D.; Ellwood, M.J.; Hill, P.; Jones, G.B.; Katz, D.; Kuparinen, J.; Macaskill, B.; Main, W.; Marriner, A.; McGregor, J.; McNeil, C.; Minnett, P.J.; Nodder, S.D.; Peloquin, J.; Pickmere, S.; Pinkerton, M.H.; Safi, K.A.; Thompson, R.; Walkington, M.; Wright, S.W.; Ziolkowski, L.A. The SOLAS air-sea gas exchange experiment (SAGE) 2004. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Accepted Manuscript. <http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.015>

Archer, S.D.; Safi, K.; Hall, A.; Cummings, D.G.; Harvey, M. Grazing suppression of dimethylsulphoniopropionate (DMSP) accumulation in iron-fertilised, sub-Antarctic waters. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Corrected Proof. <http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.022>

Currie, K.I.; Macaskill, B.; Reid, M.R.; Law, C.S. Processes governing the carbon chemistry during the SAGE experiment. Deep Sea Research Part II: Topical Studies in Oceanography In Press, Accepted Manuscript. <http://dx.doi.org/DOI: 10.1016/j.dsr2.2010.10.023>

## 4. International interactions and collaborations

Alex Baker (UEA, UK) – comparison of meridional dust deposition trends between the Atlantic (AMT) and Pacific (Japan to New Zealand)

Ship Inn project – collaboration with Australian colleagues (Griffith University, Brisbane) in the development of a graphic for predicting ocean biota response to dust deposition

PINTS voyage (Australia/New Zealand) – collaboration with Australian colleagues (UT Sydney; ANU, Melbourne; CSIRO) on voyage examining of the response of the Tasman Sea pelagic community to dust deposition in incubations

Contributing authors to the IOC Summary for Policymakers on Ocean Fertilisation

SOLAS/GEOTRACES aerosol database intiative

Maritime Aerosol Network (MAN) (see above)

## 5. Goals and plans for future activities

Planning and preparation for the Pre-SOAP (Southern Ocean Aerosol Processes) voyage which will examine the impact of coccolithophore blooms on the production of aerosol precursors in February 2011 (with collaborators from Australia and Finland). This preliminary voyage will test techniques & strategies for the SOAP voyage in 2012, which will have additional international participation from the US, UK & Ireland.

Planning and preparation for the NZ Geotraces voyage (32$^{o}$S, June 2011) which includes a SOLAS component looking at the trace metal and dust controls of nitrogen fixation

## 6. Other comments

# SOLAS NORWAY

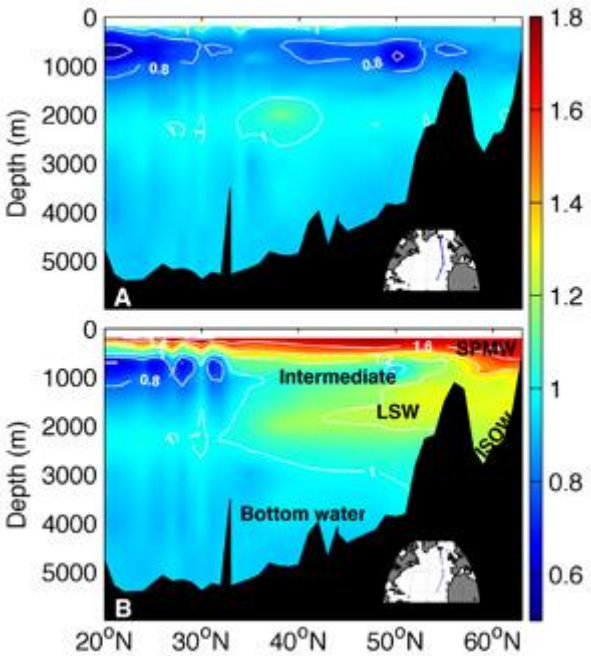
*compiled by Abdirahman M. Omar*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

**Large $\delta^{13}C$ Gradients in the Preindustrial North Atlantic Revealed**

In a recent article in the journal Science, Are Olsen and Ulysses Ninnemann from UniBjerknes Centre and University of Bergen reported that the modern isotopic ratio of carbon in the ocean, which is used when interpreting marine sediment cores, is strongly influenced by anthropogenic $CO_2$. The authors show that correcting for this effect (known as the Suess effect) enhances the interpretation of past ocean climate which is archived in the microfossils deposited in the sediment of the deep ocean through time.




Upper panel displays the distribution of δ13C, a measure of the $^{13}C$ vs. $^{12}C$ relationship in the modern - anthropocene-North Atlantic ocean, while the lower shows the Suess effect corrected - preindustrial-distribution. The Suess effect has erased the $\delta^{13}C$ signature of important, recently ventilated, water masses such as the Labrador Sea Water (LSW), the Subpolar Mode Water (SPMW) and the Iceland-Scotland Overflow Water (ISOW), while older intermediate and bottom waters have not been affected to the same extent.

For a popular description of the study see:

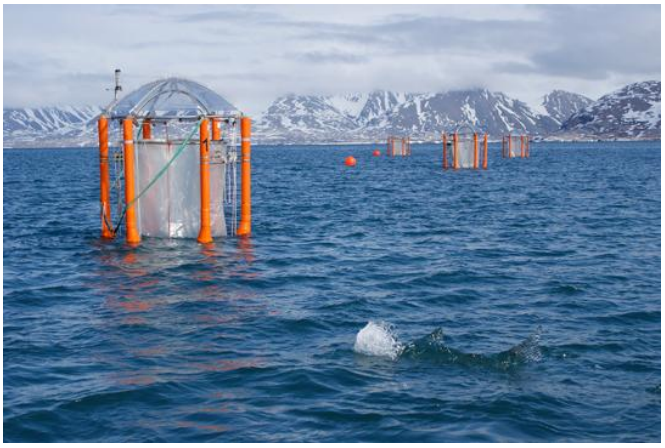
http://www.bjerknes.uib.no/pages.asp?kat=8&id=1909&lang=2

Reference: Olsen, A. og U. Ninnemann (2010), Large d13C Gradients in the Preindustrial North Atlantic Revealed, Science 29 oktober 2010. Vol. 330. no. 6004, pp. 658 - 659 .

## 2. Main accomplishments

**EPOCA's Arctic Experiment (http://www.epoca-project.eu/index.php/what-do-we-do/science/arctic-2010.html)**

Richard Bellerby, Tor de Lange, Gisle Nondal, and Anna Silyakova from the UniBjerknes Centre participated in an Arctic mesocosm experiment in Ny Ålesund (79°N) May-July 2010**,** arranged by the EU project EPOCA (Eropean project on Ocean Acidification). This was the northernmost, biggest and longest ocean acidification experiment ever conducted, being specifically designed to advance our understanding of the biological, ecological, biogeochemical, and societal implications of ocean acidification. The UniBjerknes Centre scientists were responsible for measuring $CO_2$ system variables in the water contained in the mesocosms bags (photo).



Mesocosms are plastic bags filled with seawater andsupported by hard frames, here seen floating in Kings Bay. (Photo by Anna Silyakova)

## 3. Top 10 publications in 2010

Assmann KM, Bentsen M, Segschneider J and C Heinze, 2010, 'An isopycnic ocean carbon cycle model', *Geoscientific Model Development*, 3, 143–167, www.geosci-model-dev.net/3/143/2010/

Bernard CY, Laruelle GG, Slomp CP and C Heinze, 2010, 'Impact of changes in river nutrient fluxes on the global marine silicon cycle: a model comparison', *Biogeosciences*, 7, 441–453.

Nondal G (2010), 'A study of the high and mid latitude biogeochemistry in the Atlantic Ocean: the influence of surface processes', PhD dissertation, University of Bergen.

Olsen A and U Ninnemann, (2010), 'Large d13C Gradients in the Preindustrial North Atlantic Revealed', *Science*, 330, 6004, 658 - 659 .

Omar A, Olsen A, Johannessen T, Hoppema M, Thomas H and AV Borges, 2010, 'Spatiotemporal variations of fCO2 in the North Sea', *Ocean Science* 2010 (6), 77-89.

Tjiputra, J. F., K. Assmann, and C. Heinze 2010, Anthropogenic carbon dynamics in the changing ocean, Ocean Sci., 6, 605-614, doi:10.5194/os-6-605-010.

Tjiputra, J.F., K. Assmann, M. Bentsen, I. Bethke, O.H. Otterå, C. Sturm, and C. Heinze, 2010, Bergen earth system model (BCM-C): Model description and regional climate-carbon cycle feedbacks assessment, *Geoscientific Model Development*, 3, 123–141, www.geosci-model-dev.net/3/123/2010/.

## 4. International interactions and collaborations

Are Olsen, Abdirahman M. Omar, Benjamin Pfeil, and Ingunn Skjelvan from UniBjerknes Centre and University of Bergen contributed to the second level quality control of the SOCAT (Surface Ocean $CO_2$ Atlas) database.

Are Olsen (UniBjerknes Centre) and Benjamin Pfeil (University of Bergen) successfully completed and updated the SOCAT (Surface Ocean $CO_2$ Atlas) database which will be released in 2011.

Benjamin Pfeil (University of Bergen) attended the SOCAT Pacific and Indian Ocean regional meeting held in Tokyo, Japan in February 2010 and the SOCAT Southern Ocean and Indoan Ocean regional workshop held in Hobart, Australia in June 2010.

Christoph Heinze is member of the SOLAS SSC since 1 January 2010. He participated in the SSC meeting 26-28 April 2010 at Lüneburg, Germany.

Peter Landschützer successfully completed his master thesis under supervision of Christoph Heinze in collaboration of the University of Bergen, the Bjerknes Centre for Climate Research, and

the University of Graz by December 2010. Title of the thesis: Air-Sea Gas Exchange under Climate Change.

**5. Goals and plans for future activities**

The University of Bergen and the Bjerknes Centre for Climate Research submitted a proposal "CarboChange" (Changes in carbon uptake and emissions by oceans in a changing climate) to the European Commission for a large-scale integrating collaborative project under the 7th framework programme. The proposal was favourably evaluated and will start on 1 March 2011. The consortium includes 28 partnres from Europe, Africa, and North America. It builds on the results of the previous EU FP6 Integrated Project CARBOOCEAN. Project director of CarboChange is C. Heinze. The InternationalProject Office will be located at the University of Bergen, Geophysical Institute and Bjerknes Centre for Climate Research.

The University of Bergen and UniBjerknes are also partners on the following projects all with starting dates between 2010 and early 2011: GreenSeas, EuroBasin, Monarch, and PolarBouy.

# SOLAS Southern Africa

*compiled by Carl Palmer, UCT.*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### Studying the effects of Volcanic Ash on Marine Life

In May this year (2010), marine scientists from Britain, amongst other European countries, and South Africa, were aboard the UK's Natural Environment Research Council (NERC) vessel *RRS Discovery* as iron-rich volcanic ash rained down onto the decks of the ship from Iceland's Eyjafjallajökull volcano, which first erupted beneath a glacier in April. The reason for being in such an inhospitable place was to study the effects of volcanic ash deposition on marine life in the surface of the ocean as part of an International climate change programme, Surface Ocean Lower Atmosphere Study (SOLAS).

*A dramatic scene of a storm in the ash cloud.* Image: Mike Lucas

In truth, the volcanic eruption was serendipitous; the cruise to this important sub-polar region of the North Atlantic ocean just south of Greenland and Iceland had been planned 2 years earlier to study the effects of artificial iron fertilisation on phytoplankton growth. Phytoplankton are microscopic single-celled plants that float in the surface of the ocean and "fix" carbon dioxide ($CO_2$) into their cells as organic carbon during the process of photosynthesis.

### Phytoplankton and the Global Carbon Cycle

Although microscopic, total phytoplankton productivity in all the world's oceans is almost exactly the same as that of all terrestrial plants on Earth. Both terrestrial plants and phytoplankton play a unique and important role in the global carbon cycle, with consequences for climate change and global warming.

When phytoplankton cells die and sink to the ocean floor perhaps 3-5km below the sea surface, they take this fixed carbon with them, helping to remove $CO_2$ from the atmosphere for periods of 100's to 1000's of years. This is an important process that scientists believe helps to reduce the concentration of $CO_2$ in the atmosphere, a "green-house gas" that causes the unwanted global warming that is of so much concern today. This sub-polar region in the North Atlantic is in fact the most important region of any of the world's oceans, in terms of removing atmospheric $CO_2$, due to phytoplankton growth and sinking of their cells.

**Why study Volcanic ash deposition?**

All plants need inorganic nutrients such as nitrate ($NO_3$) and phosphate ($PO_4$) to grow, as well as light to drive photosynthesis. Over the last 20 years, it has also been recognised that soluble (ferrous) iron (Fe) is also needed by plants in minute amounts to promote healthy growth. This is also true for phytoplankton. But the problem for them is that, while Fe is abundant in terrestrial environments, it is very scarce in many of the world's oceans. In fact, if you could dissolve a single small nail in a 3km deep water column beneath our ship *RRS Discovery,* this would give you the minute amount of iron found dissolved in this part of the ocean. This scarcity severely limits phytoplankton growth, and therefore the potential of these tiny plants to control atmospheric $CO_2$ concentrations.

Many mechanisms introduce iron into the oceans including desert dust storms and volcanic ash deposition, which is very rich in iron and other elements such as aluminium. Since surface waters of the sub-polar oceanic region south of Greenland and Iceland are deficient in iron, we hypothesised that the volcanic ash cloud would add vast amounts of iron to the ocean and that this in turn would stimulate phytoplankton growth. If so, this would also remove more $CO_2$ from the atmosphere.

**What did we find?**

The Icelandic volcanic ash cloud that so disrupted international flights in April and May 2010 covered a vast area of the North Atlantic as well as Europe, even extending as far south as North Africa. This ash cloud therefore clearly also had the potential to fertilise extensive areas of the ocean. But how did we test this? Firstly, we used special particle collectors on the ship to trap and collect ash that could later be analysed for nutrient and iron content. Other scientists measured dissolved iron concentrations in the surface ocean, while others measured phytoplankton growth rates in bottles to which iron was added, and compared to growth rates of phytoplankton that were starved of iron.

Beneath the ash cloud, dissolved iron concentrations in the surface ocean increased by 10,000 fold relative to nearby ocean regions that were unaffected by the ash cloud. The amount (biomass) of phytoplankton in the water increased 3-fold, and the efficiency with which they photosynthesised increased substantially also, which means better and faster growth rates because the phytoplankton now had all the nutrients they needed, especially iron. Other scientists on the ship measured the amount of $CO_2$ removed from the atmosphere due to photosynthesis, which also increased beneath the ash cloud in response to increased phytoplankton growth rates.

Increased phytoplankton biomass and growth rates also means there is more food for herbivorous (= plant eating) zooplankton, minute creatures about the size of a grain of rice that themselves are a vital part of the food chain, providing the link between phytoplankton and commercially important fish such as Cod, as well as fish eating animals such as many sea-birds, seals and some whales.

**What next?**

Our study is only part completed and we do not yet know the longer-term effects of volcanic ash on the marine environment, but we intend to find out. To this end, we are set to return to this oceanic region on *RRS Discovery* for a 5-week cruise from mid-July to mid-August 2011. Once there, we will make very similar measurements to those we made in April. You will be able to follow our progress by logging onto the internet at:- http://www.noc.soton.ac.uk

*Mike Lucas, UCT*

## 2. Main accomplishments

ACCESS LAUNCH

2010 saw the official launch of the Applied Centre for Climate and Earth System Science (ACCESS), which was held at the University of the Western Cape (UWC), Cape Town in August. ACCESS aims to be the focal point for all climate change related activities in South(ern) Africa. The programme has three foci; Research, Education and Operational Activities. ACCESS aims to promote an African perspective on climate change that regards global warming not merely as a

threat that calls for adaptation and mitigation but an opportunity for education and innovation. The launch was opened by the South African deputy minister for Science and Technology and attended by the vice chancellor of UWC along with a plethora of local climate scientists, biogeochemists, anthropologists and palaeontologists.

See www.access.ac.za .

HOW TO BUILD A HABITABLE PLANET STUDENT WORKSHOP

This year saw the 4th incarnation of the immensely successful ACCESS 'How to Build a Habitable Planet' winter school. The winter school takes undergraduate students from the sciences, along with a few humanities students, from all over Southern Africa and aims to act as an introduction to the environmental sciences by gradually explaining why planet Earth is habitable. Students start with a simple physical model of the Earth as a ball of rock at a given distance from the Sun, and calculate an effective temperature which leads to the observation that the planet would be an icy -20 C. This is clearly not habitable. Throughout the winter school, we gradually add layers of complexity to this simple model (atmosphere, ocean, life) until we arrive at discussing the more complicated political issues around climate science. The winter school has been a remarkable success, specifically with regards to helping attract more students to research (a big problem in RSA). As such, it is now funded by the Department of Science and Technology to be run 4 times a year for the next 4 years, and has been renamed a student workshop rather than winter school! To sum up the importance of the workshop, here are the words of one of the students that previously attended the workshop:

"The immensely successful Student Workshop seeks to dispel the myth [that science can only be enjoyed by an elite few] by captivating all students from all backgrounds and keeping them enchanted.

Speaking as one of the Marine Science students – an ichthyologist sharing a classroom with an oceanographer, a botanist, a meteorologist and a farmer – it successfully imparted us with the tools to engage our imaginations again. Elegance is so often embodied by the simplest of designs, and the integrated earth system science module patterns itself on this. Go outside and be awed by clouds, climb a mountain with a thermometer, puzzle over why lush forests exist shoulder-to-shoulder with scrub and fynbos. Remember how to question – and question. As pioneers at a remarkable time in our history as *Homo sapiens*, and custodians of a truly extraordinary planet. As learners who never stopped wondering why the sky is blue and how light can be both a particle and a wave.

The desire to share that magic has been irrepressible."
- Lauren Biermann, lauren.biermann@gmail.com

OPENING OF THE NANSEN TUTU CENTRE

The Marine Research Institute at the University of Cape Town, together with the Nansen Environmental and Remote Sensing Centre in Bergen, Norway, has played an instrumental role in establishing the Nansen-Tutu Centre in Cape Town. The centre offices are hosted by the Department of Oceanography at the University of Cape Town.

The vision of the centre is to serve Africa through advancing the knowledge of the marine environment and climate system in the spirit of the Nobel Peace Laureates Desmond Tutu and Fridtjov Nansen.

The overall goal is to improve the capacity to observe, understand and predict marine ecosystem variability, on time scales ranging from days to decades, in support of scientific and societal needs, which include fisheries, coastal management, maritime security, recreation and tourism.

The primary research focus of the Nansen-Tutu Centre will be to understand, model and predict conditions in the ocean as the meteorological services do for the weather. In that respect, developing ocean modelling capacity in South Africa is a major component of its activities.

The Nansen-Tutu Centre is a joint venture between Ma-Re UCT and other members, including the African Centre for Climate and Earth System Science, the Department of Environmental Affairs, the South African Environmental Observation Network, Norwegian partners: the Nansen Environmental and Remote Sensing Centre, the Institute for Marine Research, the Geophysical Institute at the University of Bergen, and the Geosciences Department at Princeton University in the United States.

ST HELENA BAY MONITORING LINE

Monthly short cruises along a new monitoring line have been undertaken along the west coast in the Benguela Current. A number of measurements have already been taken on these cruises including, CTD, $pCO_2$, $tCO_2$ and gas bottle samples for VHOC analysis at UCT. These cruises form part of the Fisheries Department effort to monitor changes in the Benguela Current and how these changes relate to important South African fish stocks. The cruises are intended to continue indefinitely to obtain more physical and biological and chemical data on the globally important Benguela current.

SANAE 49 CRUISE REPORT

*Participants:* Dr Sandy Thomalla (scientist in charge), Dr Robert Scholes, Dr Thato Mtshali, Dr Yuri Controneo, Amy Harington, Sarah-Anne Nicholson, Ceinwen Smith, Samantha Maxwell-Hafen, Fiona Preston-Whyte, Patrick Hayes-Foley

*Principal Investigators:* Dr Pedro Monteiro (CSIR), Dr Howard Waldron (UCT), Dr Mike Lucas (UCT), Dr Ray Barlow (MCM), Dr Michael Bender (Princeton)

The ocean has the most significant overall potential as a sink for anthropogenic $CO_2$. However, our understanding of the link between surface $CO_2$ flux and the underlying physical and biogeochemical drivers remains incomplete. Our ability to estimate the response of the oceanic carbon sink under an altered future climate depends on our ability to improve the constraints on computer models that predict regional and global fluxes. For this we need more accurate field data, hence the importance of increasing our number of observations both in space and time. Our participation on the SANAE relief voyages to the Southern ocean each year aims to increase the quantity of observational data in order to improve our understanding of the Southern Oceans role as a $CO_2$ sink in both the present and future climate.

This year's cruise SANAE 49 was a success on all accounts. The continuous underway measurements of air-sea $CO_2$ fluxes, net and gross primary production and phytoplankton community responses will enable us to better constrain the knowledge gaps that link the physical driver scales with those of the biogeochemical responses which makes the Southern Ocean one of the most important sinks of anthropogenic $CO_2$. These results complement the discrete underway and CTD measurements which provide more detailed information on the physical and chemical structure of the environment as well as the phytoplankton community structure and the biogeochemical controls of primary production and export. When considered together, these results represent important new data that allows South African oceanographic research the opportunity to begin to correctly quantify the Southern Ocean $CO_2$ sink which will enable realistic climate simulations to be made. Our ability to tackle pertinent questions such as these will bring South African science into the forefront of a globally significant topic and improve our standing in the international science community.

The results from this cruise will provide the necessary data for a number of scientific publications in internationally recognised journals and will also form the basis of one masters project and two honours projects, all of which will be published upon completion. A data workshop was held on the 16$^{th}$ of March 2010 where all the preliminary data from the cruise was presented along with discussions as to the progress of the cruise data so that publication topics and responsibilities can be solidified.

SOCO WORKSHOP: SCALE-SENSITIVE COUPLING OF CLIMATE AND CARBON CYCLING IN THE SUB-ANTARCTIC ZONE

*Pedro Monteiro, Philip Boyd, Tom Trull, Richard Bellerby and workshop participants as listed on-line*

There is increasing evidence in the Southern Ocean that meso- and seasonal scales play an important role in coupling of ocean carbon cycling and climate. The seasonal cycle is one of the strongest modes of variability in different components of the carbon cycle in the Southern Ocean and the mode which couples climate forcing to ecosystem responses such as productivity and ultimately biogeochemical signals including carbon export. However, not only are these scales of coupling poorly understood but there appear to be important regional differences in the way they couple climate to carbon. With this as an overarching theme, a workshop in Cape Town, South Africa brought together scientists working in the Southern Ocean, south of Australia, New Zealand and South Africa. The importance of the Sub-Antarctic Zone (SAZ) as a carbon sink made it an ideal system to focus the workshop.

Prior to the workshop, we proposed and circulated the following hypothesis to focus presentations and stimulate general discussion. Climate change forcing will be reflected in changes to the magnitude, phasing and persistence of the seasonal cycle in mixed layer physics, ocean biogeochemistry and the carbon cycle.

Workshop presentations focussed on the causes of important regional differences in the Southern Annular Mode, its implications for the seasonal cycle of mixed layer depth, seasonal variability in remotely sensed phytoplankton biomass, the interactions of iron and light in driving phytoplankton production, and reviews of the state of modelling of biological pump processes. Other talks emphasized the importance of mesoscale features within the SAZ such as eddies and filaments, and sub-seasonal timescales including those of anomalous meteorological events in modulating ocean-atmosphere-ecosystem interactions. Many talks presented at the workshop are available on-line (www.subantarctic.net).

## 3. Top 10 publications in 2010


Poulton AJ, Charalampopoulou A, Young JR, Tarran GA, Lucas MI and GD Quartly, 2010, 'Coccolithophore dynamics in non-bloom conditions during late summer in the central Iceland Basin (July-August 2007)', *Limnology and Oceanography*, 55, 1601-1613.

Mafimbo AJ and CJC Reason, 2010, 'Air-sea interaction over the upwelling region of the Somali coast', *J. of Geo. Res.*, 115, C01001, doi:10.1029/2009JC005439.

Palmer CJ, 2010, 'Contrasting the surface ocean distribution of bromoform and methyl iodide, implications for boundary layer physics, chemistry and climate'. In: IOP Conf. Series: 'Earth and Environmental', *Science*, 13, doi:10.1088/1755 1315/13/1/0120.

Durgadoo JV, Ansorge JI and JRE Lutjeharms, 2010, 'Review Oceanographic observations of eddies impacting the Prince Edward Islands, South Africa', *Antarctic Science*, 22(3), 211-219.

Pohl B, Fauchereau N, Reason CJC and M Rouault, 2010, 'Relationships between the Antarctic Oscillation, the Madden-Julian Oscillation, and ENSO, and consequences for rainfall analysis', *Journal of Climate*, 23, 238-254.

Veitch J, Penven P and F Shillington, 2010, 'Modeling equilibrium dynamics of the Benguela Current System', *Journal of Physical Oceanography*, 40(9), 1942-1964.

Wilson DI, Piketh SJ, Smirnov,A. Holben BN and B Kuyper, 2010, 'Aerosol optical properties over the South Atlantic and Southern Ocean during the 140$^{th}$ cruise of the M/V S.A. Agulhas', *Atmospheric Research*, 98, 285-296.

Zahn R, Lutjeharms J, Biastoch A, Hall I, Knorr G, Park W and CJC Reason, 2010, 'Investigating the global impacts of the Agulhas Current', *EOS,* 91(12) 109-110.

Brunke EG, Labuscagne C, Ebinghaus R, Kock HH and F Stemr, 2010, 'Gaseous elemental mercury depletion events at Cape Point during 2007-2008', *Atmospheric Chemistry and Physics,* 10, 1121-1131.

Thomalla SJ, Waldron HN, Lucas MI, Read JF, Ansorge IJ and E Pakhomov, 'Phytoplankton distribution and nitrogen dynamics in the Southwest Indian Subtropical gyre and Southern Ocean Waters', *Ocean Science,* accepted in 2010.

## 4. International interactions and collaborations

See Nansen Tutu Centre in section 2.

**South African student on R/V Knorr**

Brett Kuyper, a PhD student from UCT, was aboard the American *R/V Knorr* on a cruise run by Dr Lisa Beal looking at variability within the Agulhas current. During this time, a number of concurrent measurements were made. The primary aim of the cruise was to deploy a string of moorings along a satellite track that runs perpendicular to the Agulhas current. The moorings, all fitted with ADCPs, will remain in place until the end of 2011. Bathymetric surveys and CTD measurements were taken at the sites of mooring deployment. Samples were concurrently taken for onboard VHOC analysis while nutrient and phytoplankton samples were taken for post cruise analysis.

## 5. Goals and plans for future activities

**1. Methods for empirical estimates of oceanic pCO2 and ocean-atmosphere delta fCO2 in the Southern Ocean.**

This project stems from the need to reduce uncertainties in our extimation of O-A CO2 fluxes in the SO (SRP project) ? While in-situ measurement of CO2 concentrations in the Ocean and Atmosphere are difficult in the SO, we are making here the hypothesis that pCO2 and deltapCO2 are function(s) of a range of environmental parameters (physical and biological). The goal of this project is to derive empirically these functions in order to use the spatially and temporally available satellite data to estimate pCO2 and delta pCO2 for the whole SO.

These underlying functions (even their forms) are unknown a-priori and most probably non-linear (example with SST ?). Within the context of non-linear prediction and modelling in environment and ecology, non-linear regression, Artificial Neural Networks (ANN) and Genetic Programming (GP) have been proved useful and applied e.g. to the prediction of rainfall, HABs, and SOM (a flavor of ANN) has been even applied for pCO2 estimation in the North Atlantic. We propose here to explore the feasibility of using these methods for developing empirical estimates of pCO2 and delta pCO2 for the SO.

*Nicolas Faucherea, CSIR.*

Also:

- In 2011 Cape Town SOLAS scientists are planning to establish a biogeochemistry network around the cities 2 major universities and other research institutes.
- Eva Bucciarelli is visiting UCT from the University of Brest to take part in a range of projects around DMS field and culture measurements.
- Continuation of the St Helena Bay monitoring line.
- Development of plans for targeted climate-carbon-ecosystem process studies in the vicinity of SAZ hot-spots – with 2013-14 as a probable start of a two year circumpolar seasonal cycle study.
- Construction of new oceanographic vessels by South Africa to be ready June 2012.

# SOLAS SPAIN

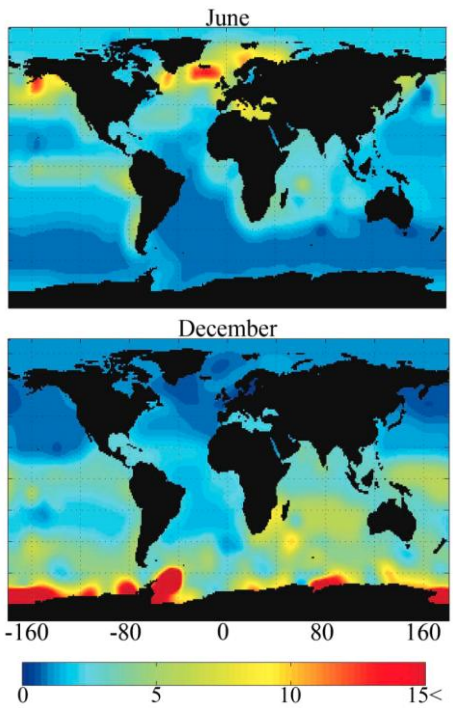
*compiled by Rafel Simó*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### Oceanic volatile sulphur emissions in better focus

New maps showing the monthly distribution of the concentration of dimethyl sulphide (DMS) in the global ocean will help scientists improve climate models' ability to simulate climate and predict its current perturbation by human pollution. The results – computed at the Institut de Ciencies del Mar (ICM-CSIC, Barcelona, Spain) as the core task of the international SOLAS DMS-GO initiative sponsored by the European projects COST Action 735 and EUROCEANS – are freely available at http://www.bodc.ac.uk/solas_integration/implementation_products/group1/#dms. The research, which appeared in the journal *Global Biogeochemical Cycles* [1], provides new insight into the geographic and seasonal variability in the concentration and atmospheric emission of this trace gas, the form in which oceans contribute the large majority of the natural sulphur burden in the troposphere. The new climatology, constructed on the bases of >47,000 surface seawater measurements, projects DMS concentrations typically in the range of 1 - 7 nM, with higher levels occurring in the high latitudes, and with a general trend towards increasing concentration in summer [Fig]. It also provides an estimate of ca. 28 Tg S $yr^{-1}$ for the annual oceanic DMS emission to the atmosphere. Owing to the potential role of sulphur in general, and DMS in particular, in cloud seeding and climate regulation, this new DMS climatology represents a valuable tool for atmospheric chemistry, climate, and Earth System models.




Contact person: Rafel Simó, ICM-CSIC; rsimo@icm.csic.es

*1. Lana A., T.G. Bell, R. Simó, S.M. Vallina, J. Ballabrera-Poy, A.J. Kettle, J. Dachs, L. Bopp, E.S. Saltzman, J. Stefels, J.E. Johnson, P.S. Liss (2010). An updated climatology of surface dimethlysulfide concentrations and emission fluxes in the global ocean. Global Biogeochemical Cycles doi:10.1029/2010GB003850.*

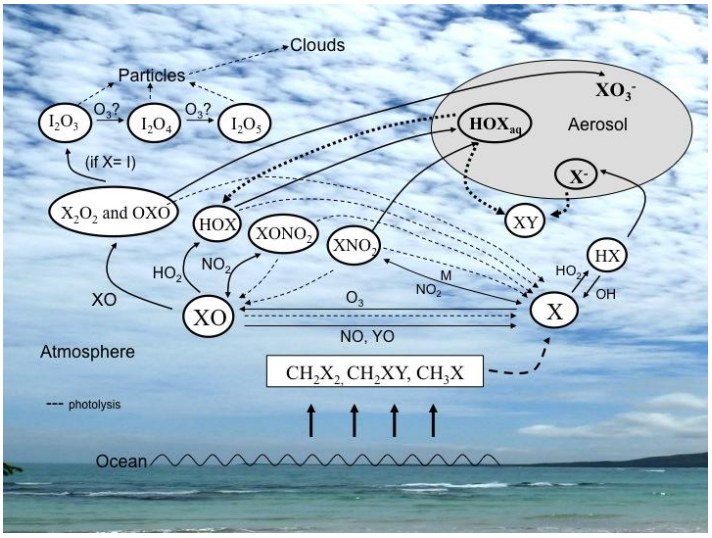
**Figure**: Surface seawater DMS concentrations (nmol $L^{-1}$) in the global ocean for the months of June (top) and December (bottom). The maps were obtained from sparse discrete measurements treated by interpolation and objective analysis techniques, with the use of the Longhurst's biogeographic provinces.

### Tropical halogens:
### The Climate and HAlogen Reactivity tropicaL EXperiment (CHARLEX)

Reactive halogen compounds potentially play important roles in the chemistry of the atmosphere

by: destroying ozone ($O_3$), changing hydrogen oxide (OH, $HO_2$) and nitrogen oxide (NO, $NO_2$) radical chemistry, oxidising species such as dimethyl sulphide (DMS) and mercury, and contributing to form ultrafine particles involved in cloud condensation [1-5]. However, their specific roles in the remote marine boundary layer are still far from clear. Observations in the tropical Pacific marine boundary layer reveal large levels of IO (as estimated from satellite [6]) and late summer drops in $O_3$ concentrations (to <5 ppb) that cannot be explained by surface deposition and photolysis losses.

The Laboratorio de Ciencias de la Atmósfera y el Clima (CIAC) – CSIC, in Toledo (Spain), is leading a year-long campaign based at Isabella, on the Galapagos Island archipelago, with continuous measurements of IO, BrO, OIO, $I_2$, $NO_x$, $O_3$ and meteorological data (in collaboration with the University of Leeds) and intensive periods with measurements of aerosol size and distribution (Instituto Nacional de Técnica Aeroespacial), halocarbons (University of East Anglia) and mercury compounds (University of Manitoba). The Charles Darwin Foundation (CDF) and the Galapagos National Park (GNP), both based in Ecuador, are directly involved in the logistical planning of the study and interested in the results for further developing programmes promoting sustainability and conservation of the Galapagos Islands.




CHARLEX is designed with an aim to, (a) validate the satellite observations of high IO in the region, (b) characterise the role of halogen species in the Pacific remote marine boundary layer, (c) explain the very low surface $O_3$ values observed in the past and (d) determine whether the levels of IO observed here can lead to particle formation and subsequent cloud condensation nuclei formation.

Contact person: Alfonso Saiz-López, CIAC-CSIC; a.saiz-lopez@ciac.jccm-csic.es

**Figure**: Simplified scheme of bromine and iodine chemistry in the marine boundary layer


1. *Alicke, B. et al. Iodine oxide in the marine boundary layer. Nature **397**, 572-573(1999).*
2. *Barrie, L.A. et al. Ozone destruction and photochemical-reactions at polar sunrise in the lower arctic atmosphere. Nature **334**, 138-141(1988).*
3. *Read, K.A. et al. Extensive halogen-mediated ozone destruction over the tropical Atlantic Ocean. Nature **453**, 1232-1235(2008).*
4. *Saiz-Lopez, A. et al. Boundary layer halogens in coastal Antarctica. Science **317**, 348-351(2007).*
5. *O'Dowd, C.D. et al. Marine aerosol formation from biogenic iodine emissions. Nature **417**, 632-636(2002).*
6. *Schönhardt, A. et al. Observations of iodine monoxide (IO) columns from satellite. Atmospheric Chemistry and Physics **8**, 637-653(2008).*

## 2. Main accomplishments

Seceral **projects** quicked off or speeded up during 2010:

MALASPINA 2010. On December 15, 2010, the Expedition Malaspina 2010 sailed off from Cadiz, Spain, to circumnavigate the global oceans. The research vessel BIO Hesperides steamed from Spain to Rio de Janeiro, from where it will head to Cape Town, Perth, Sydney, Honolulu and Cartagena de Indias, with arrival to Cartagena, Spain, planned for mid July 2011. The expedition, co-ordinated by Carlos Duarte (IMEDEA-CSIC, Mallorca), aims to: (1) provide a large-scale coherent inventory of physical, chemical, and biological measurements that may shed light on the footprints of global change on the open ocean ecosystems; (2) explore deep-sea microbial and genetic diversity across the world's oceans; (3) leave a collection of samples of organisms, DNA/RNA, and organic matter for the next generation of researchers; (4) build cooperative frameworks within the Spanish oceanographic community; (5) promote scientific vocations among Spanish youth, and train a new generation of young scientists with a global outlook to ocean ecosystems; (6) celebrate the 200th anniversaries of the birth of Charles Darwin (1809) and the death of Alessandro Malaspina (1810), who led the first Spanish scientific circumnavigation, and raise awareness on his expedition; and (7) inform society of all aspects above, with a dual emphasis on the impacts of global change on ocean ecosystems and the opportunities for exciting discoveries in the exploration of deep-sea biodiversity. The scientific activities include SOLAS-relevant measurements such as air-sea exchanges of $CO_2$, $O_2$, biogenic trace gases (DMS, isoprene, ammonium), organic pollutants, aerosols, and $N_2$ by nitrogen fixation.

The carbon system in bioreactors for the uptake of CO2 by marine microalgae: CO2 injection and budget (BIOCAPMAR). Funding agency: MICINN (Spain). 2009-2011. PI: J.M. Forja Pajares. University of Cadiz.

Atmospheric CO2. Drivers of past levels and Consequences of present emissions (ACDC). Funding agency: MICINN (Spain). 2010-2012. PI. Eva Calvo. ICM-CSIC, Barcelona.

Study of the biogeochemical behaviour of Fe in a high CO2-content environment (EFECO2). Funding agency: MICINN (Spain). 2009-2010. PI: J.M. Santana Casiano. University of Las Palmas de Gran Canaria.

The CO2 system in hydrographic section CLIVAR A59.30N (A1E). Funding agency: MICINN (Spain). 2010. PIs: J.M. Santana Casiano and M. González-Dávila. University of Las Palmas de Gran Canaria.

Primary and secondary marine aerosols: formation processes and biogeochemical fluxes (PRISMA). Funding agency: MICINN (Spain). 2010-2012. PI: J. Dachs. IDAEA-CSIC, Barcelona.

## 3. Top 10 publications in 2010

*For journal articles please follow the proposed format:*
*Author list (surname and initials (one space but no full stops between initials), year of publication, article title, full title of publication (italics), volume, page numbers, DOI (DOI optional).*

Pelejero C, Calvo E, Hoegh-Guldberg O (2010). Paleo-perspectives on ocean acidification. *Trends in Ecology & Evolution* 25: 332-344.

Ferrón S, Ortega T, Forja JM (2010). Nitrous oxide distribution in the north-eastern shelf of the Gulf of Cádiz (SW Iberian Peninsula). *Marine Chemistry* 119: 22-32.

Ferrón S, Ortega T, Forja JM (2010). Temporal and spatial variability of methane in the north-eastern shelf of the Gulf of Cádiz (SW Iberian Peninsula). *Journal of Sea Research* 64: 213-223.

Mahajan A S, Plane J M C, Oetjen H, Mendes L, Saunders R W, Saiz-Lopez A, Jones C E,

Carpenter L J, McFiggans G (2010) Measurement and modelling of tropospheric reactive halogen species over the tropical Atlantic Ocean. *Atmos. Chem. Phys.* 10: 4611-4624.

Castro-Jiménez, Eisenreich S J, Ghiani M, Mariani G, Skejo H, Umlauf G, Wollgast J, Zaldivar J M, Berrojalbiz N, Reuter H I, Dachs J (2010). Atmospheric occurrence and deposition of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) in the open Mediterranean Sea. *Environmental Science & Technology* 44: 5456-5463.

Nizzeto L, Lohmann R, Gioia R, Dachs J, Jones K C (2010). Atlantic ocean surface waters buffer declining atmospheric concentrations of persistent organic pollutants. *Environmental Science & Technology* 44: 6978-6984.

Ruiz-Halpern S, Sejr M K, Duarte C M, Krause-Jensen D, Dalsgaard T, Dachs J, Rysgaard S (2010). Air-water exchange and vertical profiles of organic carbon in a subarctic fjord. *Limnology and Oceanography* 55: 1733-1740.

Marañón E, Fernández A, Mouriño-Carballido B, Martínez-García S, Teira E, Cermeño P, Chouciño P, Huete-Ortega M, Fernández E, Calvo-Díaz A, Morán X A G., Bode A, Moreno-Ostos E, Varela M M, Patey M D, Achterberg E P (2010). Degree of oligotrophy controls the response of microbial plankton to Saharan dust. *Limnology and Oceanography* 55: 2339-2352.

González-Dávila M, Santana-Casiano J M, Rueda M J, Llinás O (2010). The water column distribution of carbonate system variables at the ESTOC site from 1995 to 2004. *Biogeosciences* 7: 3067-3081.

Galí M, Simó R (2010). Occurrence and cycling of dimethylated sulfur compounds in the Arctic during summer receding of the ice edge. *Marine Chemistry* 122: 105-117.

## 4. International interactions and collaborations

Collaboration with the Shirshov Institute of Oceanology (SIO), Russian Academy of Science, in the project “Interannual monitoring of thermohaline and current structure along 59.5º N for evaluation of climate change in the North Atlantic”, along thehydrographic section CLIVAR A5930N (A1E). J.M. Santana Casiano and M. González-Dávila (University of Las Palmas de Gran Canaria) are responsible for CO2 measurements.

Integration and enhancement of key existing European deep-ocean observatories (EuroSITES). VII Framework Programme of the EU, ENV.2007.4.1.3.2. PI at ULPGC: M. González Dávila.

Climate and Halogen Reactivity Tropical Experiment (CHARLEX) (2010-2011) at the Isabela Island (Galapagos Islands). CHARLEX is an international field campaign focused on ocean-atmosphere exchange of reactive iodine species and its atmospheric impact in the tropical marine troposphere. The experiment is led by A. Saiz-López, CIAC-CSIC, Toledo.

## 5. Goals and plans for future activities

Forthcoming projects:

Changes in carbon uptake and emissions by oceans in a changing climate. CARBOCHANGE. Funding agency: FP7-ENV-2010 (EU). 2011-2015. J.M. Santana Casiano and M. González-Dávila, University of Las Palmas de Gran Canaria.

Study of the biogeochemical behaviour of Fe in acidified marine environments (ECOFEMA). Funding agency: MICINN (Spain). 2011-2013. PI: J.M. Santana Casiano. University of Las Palmas de Gran Canaria.

# SOLAS Turkey

*compiled by Mustafa Koçak and Barış Salihoğlu*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

**Abrupt transition of the northwestern Black Sea shelf ecosystem from a eutrophic to an alternative pristine state**

A long-term data were applied to explore ecological changes from high to low production along the northwestern Black Sea in the early 1990. The results reveal that the northwestern shelf was a low production system before 1970s, a highly productive eutrophic system during the 1980s, and a relatively low production intermediate system after the early 1990s [Fig]. The low production system was N-limited and diatom-based phytoplankton production. Aforementioned system is characterized by high piscivore and zooplankton biomass and low biomass of small pelagics and phytoplankton biomass possibly due to trophic cascade. After 1970s phosphate and nitrate concentrations increased considerably and this enhancement supported an order of magnitude higher phytoplankton biomass, which in turn stimulated greater total capture production, including small pelagics. Another transition occurred in the early 1990s due to several concurrent events, including the proliferation of *Mnemiopsis* due to favorable climatic conditions and the collapse of many marine living resources, such as planktivorous fish, due to overfishing. During this period nutrient limitation shifted from nitrogen to phosphorus which the severely reduced plankton production. Contrast to the diatom and dinoflagellate dominated eutrophic pristine state, this period was characterized by low biomass with a mixotrophic composition. Moreover, conditions during the first half of the 2000s was found to be similar to that observed for 1990s. Therefore authors claimed that the occurrence of the ecological regime change by following shift from the highly productive and eutrophic coastal ecosystem to a less productive but degraded state during the early 1990s. It has been asserted that this system differs remarkably from the pristine state and does not truly indicate a recovery.

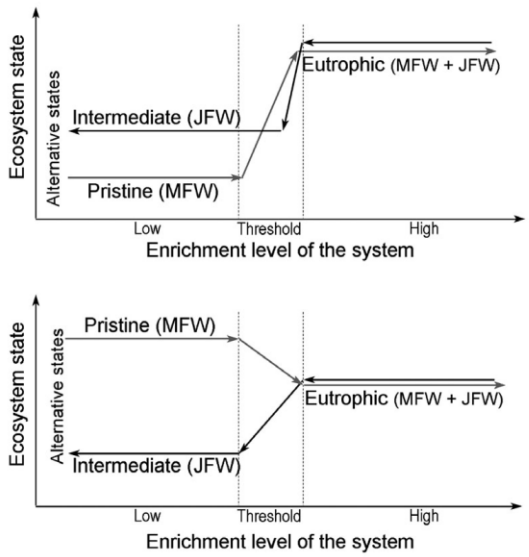



**Figure 1**: Schematic presentation of the 3 distinct ecosystem states for different properties of the ecosystem with respect to changing nutrient enrichment of the system. MFW and JFW denote the muscular and jelly food webs, respectively. The upper panel applies to *Noctiluca* and *Aurelia*, and the lower panel to trophic zooplankton and total fish catch.

Oguz T, Velikova V, (2010) Abrupt transition of the northwestern Black Sea shelf ecosystem from a eutrophic to an alternative pristine state. Marine Ecology-Progress Series, 405, 231-242.

**Atmospheric nutrient inputs to the northern Levantine Basin from long-term observation: sources and comparison with riverine inputs.**

Despite a great number of data on atmospheric nutrient fluxes in Eastern Mediterranean, there is no available data on riverine fluxes of nutrients except that estimated by Ludwig et al. (2009) while possible impact of both atmospheric and riverine inputs onto the Northeastern Levantine waters have not been evaluated yet. The current study is carried out by applying a long term aerosol, rainwater and riverine data collection in the Northern Levantine Basin (NLB) of the Eastern Mediterranean to address aforementioned gaps. The cluster analysis of the daily air mass back trajectories showed that phosphate and silicate concentrations in the aerosol and rain samples were found to be higher when air flow originated from the North Africa and the Middle East. During these events northern Levantine Basin was heavily influenced by large dust plumes from the Sahara and the Middle East deserts [Fig]. Deficiency of the alkaline material was the main reason of the acidic rains whereas; alkaline rain events were associated with mineral dust particles from arid and semi-arid regions. Flux calculations revealed that atmospheric nitrate flux was dominated by dry deposition (~80 %) whilst silicate and ammonium fluxes were mainly due to wet deposition (~60 %). Both wet and dry depositions were found to be comparable for phosphate. The comparison of the inputs from atmosphere and rivers asserted the importance of the atmospheric fluxes. For instance, dissolved inorganic nitrogen and phosphate inputs to NLB were dominated by atmospheric pathway (~90 % and (~60 %). However, the Si pool in the NLB was almost exclusively originated from riverine runoff (~ 90 %). Considering molar N/P ratios from the atmosphere (236) and riverine (22) sources it is clear that the NLB of the Eastern Mediterranean Sea receives excessive amounts of DIN; more than the amounts required by autotrophic organisms and this unbalanced P and N inputs may provoke even more phosphorus deficiency. Surprisingly, observed molar Si/N ratio suggested that Si limitation relative to N might cause a switch from diatom dominated communities to non-siliceous populations particularly at coastal areas where in NLB.

Koçak M, Kubilay N, Tugrul T, Mihalopoulos N, (2010) Atmospheric nutrient inputs to the northern Levantine basin from a long-term observation: sources and comparison with riverine inputs. Biogeosciences, 7, 4037-4050.

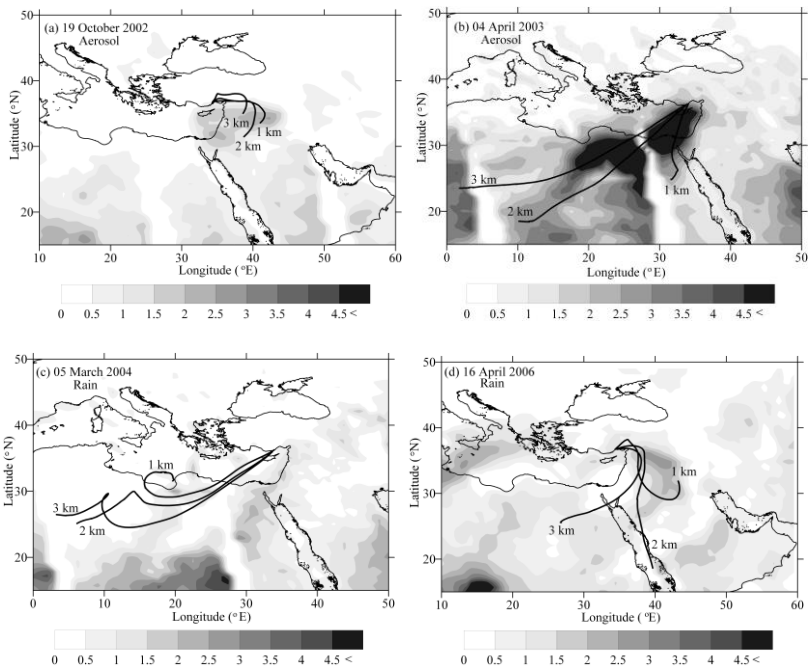



Figure 2. Three day back trajectories for 1, 2 and 3 km altitude along with Aerosol Index on the 19 October 2002 (TOMS, a), 04 April 2003 (TOMS, b), 05 March 2004 (TOMS, c) and 16 April 2006 (OMI, d).

## 2. Main accomplishments

The EU-funded COST Action 735 (http://www.cost-735.org/) has recently funded a 2 day workshop on «Atmospheric versus land based controls of nutrient cycling and production in the surface ocean: from fieldwork to modeling » as part of the SOLAS Mid-term Strategy Initiative. The meeting was organized by Cécile Guieu (France) and Baris Salihoglu, Mustafa Kocak (Turkey) and took place in Istanbul on 8-9 Dec. 2010.

The objectives of the meeting were to better assess the links between atmospheric deposition, ocean productivity, nutrient cycling and carbon export and to debate on the integration of atmospheric forcing into biogeochemical models. A large panel of 33 scientists from 13 countries with internationally recognized expertise in modeling, field work and/or experimental approaches critically examined and discussed the following topics:

1. Atmospheric deposition, ocean productivity and nutrient cycling: what have we learn from field and experimental approach and how can we go further?
2. Atmospheric versus land based inputs: how to consider expected changes?
3. Integration of atmospheric forcing into biogeochemical models: state of the art and current limits.
4. Hierarchisation of key processes to be considered, parameterization that can be handled by models, type of models, time and space scale: what should be done to better represent present and future carbon budget/cycle? submitted to high atmospheric inputs, a second paper on that topic is in discussion.

This meeting had a major importance that it helped promote SOLAS related activities in Turkey. Several Turkish researchers had the opportunity to meet and form links to scientists that are leading experts in SOLAS science.

## 3. Top 10 publications in 2010

Doğan TR, Saydam AC, Yeşilnacar MI, Gencer M, 2010, 'In-cloud alteration of desert-dust matrix and its possible impact on health: a test in southeastern Anatolia, Turkey', *European Journal of Mineralogy*, 22, 659-664.

Ibrayev RA, Özsoy E, Schrum C and HI Sur, 2010, 'Seasonal variability of the Caspian Sea three-dimensional circulation, sea level and air-sea interaction', *Ocean Science*, 6, 1, 311-339.

Im U, Markakis K, Unal A, Kindap T, Poupkou A, Incecik S, Yenigun O, Melas D, Theodosi C and N Mihalopoulos, 2010, 'Study of a winter PM episode in Istanbul using the high resolution WRF/CMAQ

modeling system', *Atmospheric Environment*, 44, 26, 3085-3094.

Koçak M, Kubilay N, Tugrul T and N Mihalopoulos, 2010, 'Atmospheric nutrient inputs to the northern Levantine basin from a long-term observation: sources and comparison with riverine inputs', *Biogeosciences*, 7, 4037-4050.

Koçak M, Theodosi C, Zarmpas P, Im U, Bougiatioti A, Yenigun O and N Mihalopoulos, 'Particulate matter (PM10) in Istanbul: Origin, source areas and potential impact on surrounding regions', *Atmospheric Environment*, doi:10.1016/j.atmosenv.2010.10.007, in press.

Oguz T and V Velikova, 2010, 'Abrupt transition of the northwestern Black Sea shelf ecosystem from a eutrophic to an alternative pristine state', *Marine Ecology-Progress Series*, 405, 231-242.

Saba VS, Friedrichs MAM, Carr ME, et al., 2010, '*Challenges of modeling depth-integrated marine primary productivity over multiple decades: A case study at BATS and HOT', Global Biogeochemical Cycles*, 24, GB3020, 21 PP, doi:10.1029/2009GB003655.

Turkes M and H Tatli, 2010, 'Use of the standardized precipitation index (SPI) and a modified SPI for shaping the drought probabilities over Turkey', *International Journal of Climatology*, 29, 15, 2270-2282.

## 4. International interactions and collaborations

IMS- METU collaborates with Prof Nikos Mihalopoulos and Prof Maria Kanakidou (Environmental Chemical Processes Laboratory, Department of Chemistry, University of Crete, POBox 2208, 71003 Voutes, Heraklion, Greece) within the citizen.

IMS-METU collaborates with Dr Malcolm Nimmo ( Plymouth Enviromental Research Center, School of Environmental Sciences, Uiversity of Plymouth, UK), Dr Barak Herut (Israel Oceanographic & Limnological Research, National Institute of Oceanography, P.O.Box 8030, Haifa 31080, ISRAEL ) within the framework of a NATO linkage project.

IMS-METU and CNRS (Veronique garcon), IfM GEOMAR (Andreas Oschlies), Istanbul Technical University (e.g., Mehmet Karaca, Tayfun Kindap, Alper Ünal, Namık Cagatay) and Sinop University (Sedat Karayücel) collaborates on various SOLAS related projects.

## 5. Goals and plans for future activities

The group that met during the COST 735 İstanbul workshop was motivated to form a consortium that could propose innovative research in the frame of a large project. Considering that there is a strong need for further research on the topic, several options were proposed by the experts. A consortium to focus on European Seas with special focus on the Mediterranean and the Black Seas can be formed or a comparative study with non-European Seas can be proposed. The group decided to form an e-mail group to continue the discussion.

IMS-METU group is planning to lead a national project on atmospheric versus land based controls of nutrient cycling and production in the surface Mediterranean and the Black Sea. Also a proposal to form the CENTER FOR MARINE ECOSYSTEMS AND CLIMATE RESEARCH (CMECLIM) planned to be proposed to the Turkish State Funding Agency where better monitoring of ocean atmosphere interactions in national seas is foreseen.

# SOLAS UK

***compiled by Phil Williamson*** *p.williamson@uea.ac.uk*

*Reporting Period is January 2010 – December 2010*

## 1. Scientific highlights

### Air-sea $CO_2$ exchanges at high wind speeds

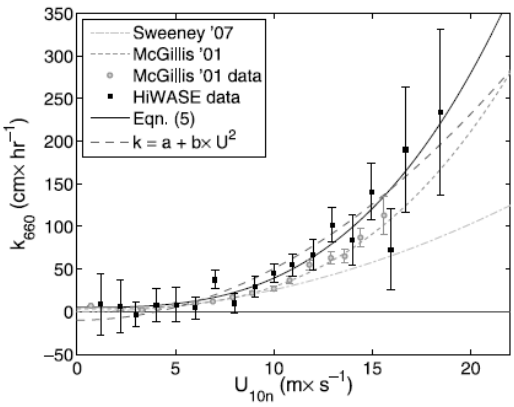
The rate at which $CO_2$ moves across the air-sea interface is critical for modelling the carbon cycle and its sensitivity to climate change. The transfer velocity coefficient (k) increases with wind speed, and various empirical relationships have been derived to describe this relationship. These different relationships agree reasonably well at low wind speeds, for which it is relatively easy to collect data; however, they differ greatly at high wind speeds – the conditions that determine most 'real world' $CO_2$ fluxes, yet are the most difficult to investigate. The HiWASE study, supported by the UK SOLAS programme in collaboration with the Norwegian Meteorological Office, has now provided (1,2) the largest set of directly-measured air-sea $CO_2$ flux data for the open ocean. Measurements were made on the weathership *Polarfront* over a 3 year period, using the eddy covariance technique and the Autoflux autonomous system. The collection of data at wind speeds up to 19 m per sec (70 km per hr) has provided a major advance in quantifying the wind speed dependence of k, whilst indicating that additional factors, such as sea state and bubbles, are also important. A new study, WAGES (Waves, Aerosol and Gas Exchange Study)(3) will use the Autoflux system on *RRS James Clark Ross* to extend the geographic coverage of the high-wind dataset.

*1. Prytherch J, Yelland MJ, Pascal RW, Moat BI, Skjelvan I, & Srokosz M. 2010. Open ocean gas transfer velocity derived from long-term direct measurements of the $CO_2$ flux. Geophysical Research Letters, 37, L23607. doi: 10.1029/2010GL045597*

*2. www.noc.soton.ac.uk/ooc/CRUISES/HiWASE*

*3. http://homepages.see.leeds.ac.uk/~lecimb/WAGES/*

**Figure:** Left, the Norwegian ocean weather ship *Polarfront* (no longer in service); below, the new relationship between $CO_2$ transfer velocity ($k_{660}$) and wind speeds, with 12 data points for the 18.5 m $s^{-1}$ grouping.




### Cape Verde studies show importance of reactive trace gases

Global models of atmospheric chemistry are now reasonably skilful, but don't get everything right. Considerable uncertainties still surround the marine emissions of many reactive trace gases

(halogens, oxidised nitrogen, carbonyls and isoprene) that together affect the lifetimes of ozone, methane and short-lived radicals, and also play a role in aerosol production. These knowledge gaps are greatest in tropical regions, where high quality measurements of such atmospheric components – that may only occur at part-per-trillion levels – are sparse. The Observatório Atmosferico de Cabo Verde: Humberto Duarte Fonseca (1) (a joint initiative by the UK, Cape Verde and Germany, with EU co-support) has helped fill those gaps. Results published in 2010 include an analysis of OH and $HO_2$ concentrations, and their control by the marine-emitted halogens IO and BrO (2). Halogen-mediated effects help explain the observed daily cycle of $O_3$ destruction at the Cape Verde site; they also reduce by 9% the estimated lifetime of methane. Ship and aircraft-based measurements (3, 4) complemented the ground-based studies; they provided data on vertical distributions and wider spatial variability – with the latter indicating that the Cape Verde observatory was representative of the tropical North Atlantic. However, ship-based measurements of a range of volatile organic iodine compounds showed that only 10-25% of the observed IO levels could be accounted for, indicating that significant iodine sources have yet to be identified (4, 5).

*1. http://ncasweb.leeds.ac.uk/capeverde/*

*2. Whalley LK, Furneaux KL, Goddard A, Lee JD, Mahajan A, Oetjen H, Read KA, Kaaden N, Carpenter LJ, Lewis AC, Plane JMC, Satlzman ES, Wiedensohler A, & Heard DE. 2010. The chemistry of OH and $HO_2$ radicals in the boundary layer over the tropical Atlantic Ocean. Atmospheric Chemistry & Physics, 10, 1555-1576.*

*3. Lee JD, McFiggans G and 44 others. 2010. Reactive Halogens in the Marine Boundary Layer (RHaMBLe): the tropical North Atlantic experiments. Atmospheric Chemistry & Physics, 10, 1031-1055.*

*4. Jones CE, Hornsby KE, Sommariva R, Dunk RM, von Glasow R, McFiggans G & Carpenter LJ. 2010 Quantifying the contribution of marine organic gases to atmospheric iodine. Geophysical Research Letters, 37, L18804. doi: 10.1029/2010GL043990.*

*5. Mahajan AS, Plane JMC, Oetjen H, Mendes L, Saunders RW, Saiz-Lopez A, Jones CE, Carpenter LJ & McFiggans GB. 2010. Measurement and modelling of tropospheric reactive halogen species over the tropical Atlantic Ocean. Atmospheric Chemistry & Physics, 10, 4611-4624*

**Figure.** The Observatório Atmosferico de Cabo Verde: Humberto Duarte Fonseca. In 2010, a new, wooden 30m tower was constructed, replacing the 4-year old metal tower that had become badly corroded. Improvements were also made to the container-based sampling air-sampling systems. (Image: Luis Mendes)

**Weak role of DMS feedback in future climate change?**

The potential role of dimethyl sulphide (DMS) in climate processes has been much debated since the CLAW hypothesis was first published by Charlson, Lovelock, Andreae and Warren in 1987. Recent analyses co-supported by the UK SOLAS programme and the UK Meteorological Office indicate that the global abundance of cloud condensation nuclei (CCN) – and hence cloud formation – is relatively insensitive to changes in marine DMS emissions (1). The study used an aerosol microphysics model to explore the CCN-DMS relationship using multiple present-day and future sea-surface DMS climatologies. For future, globally-warmed scenarios, a 10% change in

DMS flux was found to cause a ~1% change in global mean CCN at the sea surface. For the southern hemisphere, the effect of a 10% change was 2%. Such potential changes in CCN abundances are of comparable magnitude to current interannual differences due to variability in windspeed. Other feedback factors affecting aerosol formation, such as sea-spray and associated transfer of organic material, would seem of much greater importance (2).

*1. Woodhouse MT, Carslaw KS, Mann GW, Vallina SM, Vogt M, Halloran PR & Boucher O. 2010. Low sensitivity of cloud condensation nuclei to changes in the sea-air flux of dimethyl-sulphide. Atmospheric Chemistry & Physics 10, 7545-7559.*

*2. Carslaw KS, Boucher O, Spracklen DV, Mann GW, Rae JGL, Woodward S & Kulmala M. 2010. A review of natural aerosol interactions and feedbacks within the Earth System. Atmospheric Chemistry & Physics 10, 1701-1737.*

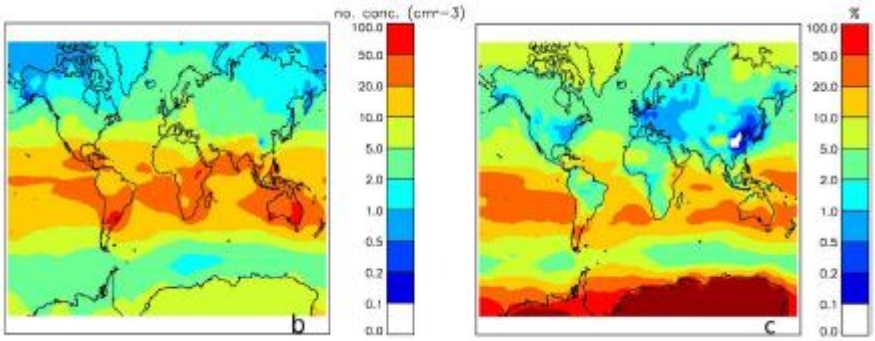



**Figure:** Left, model-based estimate of the absolute contribution of DMS to CCN; right, the fractional contribution of DMS to CCN. From Woodhouse et al, 2010.

**Alcohol in the ocean: first measurements of ethanol and propanol, and of turnover time for methanol**

Methanol and other oxygenated volatile organic compounds (OVOCs) significantly affect the oxidising capacity of the atmosphere, yet – because of the difficulty in measuring them – very little is known about their exchanges with the ocean. These technical problems have now been mostly overcome, with UK SOLAS researchers reporting that the North Atlantic may be an important source of ethanol and propanol, particularly in upwelling regions (1), whilst possibly providing a net sink for methanol (2). Experiments using $^{14}$C-labelled methanol showed its turnover time in the upper ocean to be 7-33 days, being metabolised by marine bacteria (and possibly some mixotrophic eukaryotes) not only as a significant energy source, but also use as a carbon source for incorporation into cellular biomass. Measurements for these studies have been made in coastal waters off Plymouth, on two UK SOLAS cruises and as part of the Atlantic Meridional Transect study, supported through the Oceans 2025 programme. The microbial uptake rates for acetone and acetaldehyde have also been measured for the first time.

*1. Beale R, Liss PS & Nightingale PD. 2010. First oceanic measurements of ethanol and propanol Geophysical Research Letters 37, L24607; doi:10.1029/2010GL045534*

*2. Dixon J, Beale R & Nightingale PD. 2010. Microbial methanol uptake in northeast Atlantic waters. ISME Journal, 1, 13. doi: 10.1038/ismej.2010.169*

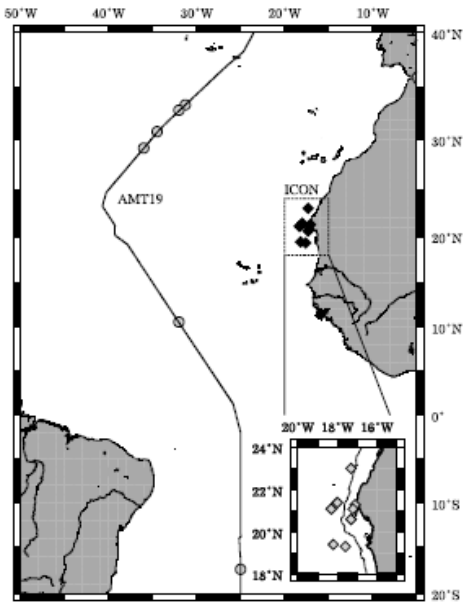



**Figure:** Sites for the measurement of ethanol and 1- and 2-propanol in the North and South Atlantic. Additional sites (not shown) were used for studies of methanol turnover.

## 2. Main accomplishments

The UK SOLAS programme has now formally ended as coordinated group of NERC-funded projects. To highlight the programme's achievements – and communicate them to a wider audience – an **open finale event was held on 23 March 2010** at the Meteorological Office, Exeter, attended by around 70 researchers and research users. Topics covered included the sources, processing and impacts of marine aerosols; the use of such data in global climate models; the insights into air-sea interactions provided by the Cape Verde observatory, the *Polarfront* time series and UK SOLAS research cruises; the significance of dust-derived nutrient inputs; the dynamics of marine biogenic gases, and molecular analyses of the sea surface microlayer.

UK research addressing SOLAS goals is, however, continuing, through many different activities at universities and marine Centres, funded by a range of mechanisms. Of particular note is the Marine Biogeochemical Cycles theme of the Oceans 2025 programme; the Waves, Aerosol and Gas Exchange Study (WAGES), involving the National Oceanography Centre, the University of Leeds, and the British Antarctic Survey; and the £12m UK Ocean Acidification (UKOA) research programme, co-funded by NERC and two government departments (Defra and DECC). *Also see Section 5 below.*

## 3. Top 10 publications in 2010

The list below identifies ~50 refereed papers published in 2010 arising from the UK SOLAS research programme. Those in bold are considered to be the 'top ten' (limited to those with UK-based lead authors), although that assessment is necessarily highly subjective. Note that this list is almost certainly incomplete; full information will be available in late March, when PIs have submitted their own annual reports to NERC. [* indicates publications already mentioned in Section 1 above].

Airs RL & Archer SD. 2010. Analysis of glycine betaine and choline in seawater particulates by liquid chromatography/electrospray ionization/mass spectrometry. *Limnology and Oceanography- Methods,* 8, 499-506

Archer SD, Ragni M, Webster R, Airs RL & Geider RJ. 2010. Dimethyl sulfoniopropionate and dimethyl sulfide production in response to photoinhibition in *Emiliania huxleyi. Limnology and Oceanography* 55, 1579-1589

Baker AR & Croot PL. 2010. Atmospheric and marine controls on aerosol iron solubility in seawater. *Marine Chemistry* 120, 4-13

**Baker AR, Lesworth T, Adams C, Jickells TD & Ganzeveld L. 2010. Estimation of atmospheric nutrient inputs to the Atlantic Ocean from 50°N to 50°S based on large-scale field sampling: Fixed nitrogen and dry deposition of phosphorus. *Global Biogeochemical Cycles*, 24, doi:10.1029/2009GB003634**

*Beale R, Liss PS & Nightingale PD. 2010. First oceanic measurements of ethanol and propanol *Geophysical Research Letters* 37, L24607; doi:10.1029/2010GL045534

Bell TG, Poulton AJ & Malin G. 2010. Strong linkages between dimethylsulphoniopropionate (DMSP) and phytoplankton community physiology in a large subtropical and tropical Atlantic Ocean data set. *Global Biogeochemical Cycles*, 24, GB3009

Breckels MN, Boakes DE, Codling EA, Malin G, Archer SD & Steinke M. Modelling the concentration of exuded dimethylsulphoniopropionate (DMSP) in the boundary layer surrounding phytoplankton cells. *Journal of Plankton Research* 32, 253-257.

Breider TJ, Chipperfield MP, Richards NAD, Carslaw KS, Mann GW & Spracklen DV. 2010. Impact of BrO on dimethylsulfide in the remote marine boundary layer. *Geophysical Research Letters*, 37, L02807; doi:10.1029/2009GL040868

Breitbarth E, Turner DR, Hunter KA, Jickells T, Baker AR, Sarthou G, Schoemann V, Hassler C, Duggen S, Croot PL, Achterberg EP, Ingri J, Hassellöv M, Gledhill M, Ardelan MV, Lohan M & Hoffmann LJ. 2010. Iron biogeochemistry across marine systems at changing times – conclusions from the workshop held in Gothenburg, Sweden (14-16 May 2008). *Biogeosciences*, 7, 1075-1097

Butler JH, Bell TG, Hall BD, Quack B, Carpenter LJ & Williams J. 2010. Technical Note: Ensuring consistent, global measurements of short-lived halocarbon gases in the ocean and atmosphere. *Atmospheric Chemistry and Physics*, 10**,** 327-330.

***Carslaw KS, Boucher O, Spracklen DV, Mann GW, Rae JGL, Woodward S & Kulmala M. 2010. A review of natural aerosol interactions and feedbacks within the Earth System. *Atmospheric Chemistry & Physics* 10, 1701-1737.**

Chance RJ, Shaw M,Telgmann L, Baxter M & Carpenter LJ. 2010. A comparison of spectrophotometric and denuder based approaches for the determination of gaseous molecular iodine. *Atmospheric Measurement Techniques,* 3, 177-185

Cunliffe M & Murrell JC. 2010. Eukarya 18S rRNA gene diversity in the sea surface microlayer: implications for the structure of the neustonic microbial loop. *ISME Journal*, 4, 455-458

Dall'Osto M, Harrison RM, Highwood, EJ, O'Dowd C, Querol X & Achterberg EP. 2010. The variation of the mixing state of Saharan dust particles with atmospheric transport. *Atmospheric Environment*, t44,3135-3146

***Dixon J, Beale R & Nightingale PD. 2010. Microbial methanol uptake in northeast Atlantic waters. *ISME Journal - Multidisciplinary Journal of Microbial Ecology*, 1, 13; doi: 10.1038/ismej.2010.169**

Dumousseaud C, Achterberg EP, Tyrrell T, Charalampopoulou A, Schuster U, Hartman M & Hydes DJ. 2010. Contrasting effects of temperature and winter mixing on the seasonal and inter-annual variability of the carbonate system in the Northeast Atlantic Ocean *Biogeosciences* 7, 1481-1492

Fuentes E, Coe H, Green D, de Leeuw G & McFiggans G. 2010. On the impacts of phytoplankton-derived organic matter on the properties of the primary marine aerosol - Part 1: Source fluxes. *Atmospheric Chemistry & Physics* 10, 9295-9317

Furneaux K L, Whalley LK, Heard DE, Atkinson HM, Bloss WJ, Flynn MJ, Gallagher MW, Ingham T, Kramer L, Lee JD, Leigh R, McFiggans GB, Mahajan AS, Monks PS, Oetjen H, Plane JMC & Whitehead JD. 2010. Measurements of iodine monoxide at a semi polluted coastal location. *Atmospheric Chemistry & Physics* 10, 3645-3663

Gilfedder BS, Chance R, Dettmann U, Lai SC & Baker AR. 2010. Determination of total and non-water soluble iodine in atmospheric aerosols by thermal extraction and spectrometric

detection (TESI), *Analytical and Bioanalytical Chemistry*, 398, 519-526.

Good N, Topping DO, Allan JD, Flynn M, Fuentes E, Irwin M, Williams PI, Coe H & McFiggans G. 2010. Consistency between parameterisations of aerosol hygroscopicity and CCN activity during the RHaMBLe discovery cruise. *Atmospheric Chemistry & Physics,*10, 3189-3203

Griessbaum F, Moat BI, Narita Y, Yelland MJ, Klemm O & Uematsu M. 2010. Uncertainties in wind speed dependent $CO_2$ transfer velocities due to airflow distortion at anemometer sites on ships. *Atmospheric Chemistry & Physics*, 10, 5123-5133; doi:10.5194/acp-10-5123-2010

Halloran PR, Bell TG & Totterdell IJ. 2010. Can we trust empirical marine DMS parameterisations within projections of future climate? *Biogeosciences,* 7, 1645-1656

Hill P, Zubkov MV, & Purdie DA. 2010. A.differential responses of prochlorococcus and SAR11-dominated bacterioplankton groups to atmospheric dust inputs in the tropical northeast Atlantic Ocean. *FEMS Microbiology Letters* 30, 682-89.

**Hopkins FE, Turner SM, Nightingale PD, Steinke M, Bakker D, Liss PS. 2010. Ocean acidification and marine trace gas emissions. *Proceedings of the National Academy of Sciences of the USA,* 107, 760-765**.

Huebert B, Blomquist B, Yang MX, Archer S, Nightingale P, Yelland MJ, Pascal RW, & Moat BI. 2010. Linearity of DMS transfer coefficient with both friction velocity and wind speed in the moderate wind speed range. *Geophysical Research Letters* 37, L01605

***Jones CE, Hornsby KE, Sommariva R, Dunk RM, von Glasow R, McFiggans G & Carpenter LJ. 2010 Quantifying the contribution of marine organic gases to atmospheric iodine. *Geophysical Research Letters,* 37, L18804. doi: 10.1029/2010GL043990.**

Korhonen H, Carslaw KS & Romakkaniemi S. 2010. Enhancement of marine cloud albedo via controlled sea spray injections: a global model study of the influence of emission rates, microphysics and transport. *Atmospheric Chemistry & Physics* 10, 4133-4143. doi:10.5194/acp-10-4133-2010

Korhonen H, Carslaw KS, Forster PM, Mikkonen S, Gordon ND & Kokkola H. 2010. Aerosol climate feedback due to decadal increases in Southern Hemisphere wind speeds. *Geophysical Research Letters*, 37, L02805, doi:10.1029/2009GL041320

Le Clainche Y, Vezina A, Levasseur M, Cropp RA, Gunson JR, Vogt M, Lancelot C, Allen KJI, Archer SD, Bopp L, Deal C, Elliott S, Jin M, Malin G, Schoemann V, Simo R, Six KD & Stefels J. 2010. A first appraisal of prognostic ocean DMS models and prospects for their use in climate models. *Global Biogeochemical Cycles*, 24, GB3021

***Lee JD, McFiggans G and 44 others. 2010. Reactive Halogens in the Marine Boundary Layer (RHaMBLe): the tropical North Atlantic experiments. *Atmospheric Chemistry & Physics*, 10, 1031-1055.**

Leigh RJ, Ball SM, Whitehead J, Leblanc C, Shillings AJL, Mahajan AS, Oetjen H, Dorsey JR, Gallagher M, Jones RL, Plane JMC, Potin P & McFiggans G. 2010. Measurements and modelling of molecular iodine emissions, transport and photodestruction in the coastal region around Roscoff. *Atmospheric Chemistry & Physics* 10,11823-11838

Lesworth T, Baker AR & Jickells T. 2010. Aerosol organic nitrogen over the remote Atlantic Ocean, *Atmospheric Environment*, 44, 1887-1893.

*Mahajan AS, Plane JMC, Oetjen H, Mendes L, Saunders RW, Saiz-Lopez A, Jones CE, Carpenter LJ & McFiggans GB. 2010. Measurement and modelling of tropospheric reactive halogen species over the tropical Atlantic Ocean. *Atmospheric Chemistry & Physics*, 10, 4611-4624

Mann GW, Carslaw KS, Spracklen DV, Ridley DA, Manktelow PT, Chipperfield MP, Pickering SJ & Johnson CE. 2010. Description and evaluation of GLOMAP-mode: a modal global aerosol microphysics model for the UKCA composition-climate model. *Geoscience Model Development*, 3, 651-734. doi:10.5194/gmdd-3-651-2010

Maranon E, Martınez-Garcıa S, Teira S, Cermeno P, Choucino P, Huete-Ortega M, Fernandez E,

Calvo-Dı´az A, Moran XAG, Bode A, Moreno-Ostos E, Varela MM, Patey MD & Achterberg EP. 2010. Degree of oligotrophy controls the response of microbial plankton to Saharan dust.*Limnology & Oceanography* 552339-2352

McConnell CL, Formenti P, Highwood EJ & Harrison MJ. 2010. Using aircraft measurements to determine the refractive index of Saharan dust during the DODO Experiments. *Atmospheric Chemistry & Physics* 10, 3081-3098

**McFiggans G, Bale CSE, and 33 others. 2010. Iodine-mediated coastal particle formation: an overview of the Reactive Halogens in the Marine Boundary Layer (RHaMBLe) Roscoff coastal study. *Atmospheric Chemistry & Physics* 10, 2975-2999**

Merikanto J, Spracklen DV, Pringle KJ & Carslaw KS. 2010. Effects of boundary layer particle formation on cloud droplet number and changes in cloud albedo from 1850 to 2000 , *Atmospheric Chemistry & Physics* 10,.695-705.

Metzger A, Verheggen B, Dommen J, Duplissy J, Prevot AS, Weingartner E, Riipinen I, Kulmala M, Spracklen DV, Carslaw,KS & Baltensperger U. 2010. Evidence for the role of organics in aerosol particle formation under atmospheric conditions. *Proceedings National Academy of Sciences of the USA*, 107**,** 6646-6651. doi:10.1073/pnas.0911330107

Patey MD, Achterberg EP, Rijkenberg MJA, Statham PJ & Mowlem M. 2010. Interferences in the analysis of nanomolar concentrations of nitrate and phosphate in oceanic waters. *Analytica Chimica Acta* 67, 3109-3116

Prytherch J, Yelland MJ, Pascal RW, Moat BI, Skjelvan I & Neill CC. 2010. Direct measurements of the $CO_2$ flux over the ocean: development of a novel method. *Geophysical Research Letters*, 37, L03607.

***Prytherch J, Yelland MJ, Pascal RW, Moat BI, Skjelvan I, & Srokosz MA. 2010. Open ocean gas transfer velocity derived from long-term direct measurements of the $CO_2$ flux. *Geophysical Research Letters*, 37, L23607. doi: 10.1029/2010GL045597**

Ragni M, Airs RL, Hennige SJ, Suggett DJ, Warner ME & Geider RJ. 2010. PSII photoinhibition and photorepair in Symbiodinium (Pyrrhophyta) differs between thermally tolerant and sensitive phylotypes. *Marine Ecology-Progress Series* 406, 57-70.

Rickli J, Frank M, Baker AR, Aciego S, de Souza G, Georg RB & Halliday AN. 2010. Hafnium and neodymium isotope distribution in surface waters of the eastern Atlantic Ocean: Implications for sources and inputs of trace metals to the ocean, *Geochimica et Cosmochimica Acta*, 74, 540-557.

Shi ZB, Krom M, Bonneville S, Baker A, Jickells T, Carslaw K, Mann G & Benning LG. 2010. Influence of soil weathering on the potential iron solubility in soil dust subjected to atmospheric processing. *Geochemica et Cosmochimica Acta,* 74, A950-A950.

Spracklen DV, Carslaw KS and 32 others. 2010. Explaining global surface aerosol number concentrations in terms of primary emissions and particle formation. *Atmospheric Chemistry & Physics* 10, 4775-4793. doi:10.5194/acp-10-4775-2010

Ussher SJ, Achterberg EP, Sarthou,G, Laan P, de Baar HJW & Worsfold PJ. 2010. Distribution of size fractionation dissolved iron in the Canary Basin. *Marine Environmental Research* 70,46-55

***Whalley LK, Furneaux KL, Goddard A, Lee JD, Mahajan A, Oetjen H, Read KA, Kaaden N, Carpenter LJ, Lewis AC, Plane JMC, Satlzman ES, Wiedensohler A, & Heard DE. 2010. The chemistry of OH and $HO_2$ radicals in the boundary layer over the tropical Atlantic Ocean. *Atmospheric Chemistry & Physics*, 10, 1555-1576.**

Witt MLI, Mather TA, Baker AR, de Hoog C-J & Pyle DM. 2010. Atmospheric trace metals over the south-west Indian Ocean: Total gaseous mercury, aerosol trace metal concentrations and lead isotope ratios, *Marine Chemistry*, 121, 2-16.

***Woodhouse MT, Carslaw KS, Mann GW, Vallina SM, Vogt M, Halloran PR & Boucher O. 2010. Low sensitivity of cloud condensation nuclei to changes in the sea-air flux of**

**dimethyl-sulphide. *Atmospheric Chemistry & Physics* 10, 7545-7559. doi:10.5194/acp-10-7545-2010**

## 4. International interactions and collaborations

UK SOLAS researchers have developed many productive international collaborations, particularly with regard to fieldwork (e.g. at Cape Verde). Those linkages are apparent in the high proportion of international co-authors for the papers given in Section 3 above. Also of note:

- UK leadership of COST Action 735 and associated NERC-funded SOLAS data integration project
- UK involvement in the IOC-SOLAS/IGBP publication: "Ocean Fertilization: Scientific Summary for Policy Makers" (Wallace DWR, Law CS, Boyd PW, Collos Y, Croot P, Denman D, Lam PJ, Riebesell U, Takeda S & Williamson P; dated 2010 and published in January 2011).
- UK continued support in 2010, via NERC, for the SOLAS Nodal Project Office, hosted at the University of East Anglia, with responsibilities including the SOLAS website, the newsletter and COST Action administration.

## 5. Goals and plans for future activities

As stated under 2 above, SOLAS-related activities will continue in the UK, but without formal SOLAS grouping.

Nevertheless, the UK Ocean Acidification research programme (www.oceanacidification.org.uk) provides a mechanism for many marine-based linkages to continue. UKOA was formally announced in May 2010, and most component projects have now started. Studies include Atlantic-wide observations and synthesis to establish variability and trends of upper ocean pH; cruise-based studies of $CO_2$-influenced biogeochemistry around the UK (in 2011), in the Arctic Ocean (2012) and in the Southern Ocean (2013); modelling of $CO_2$ - carbon cycle - climate interactions at the regional and global scale; and analyses of palaeo- changes in ocean carbon chemistry. UKOA has close links with other European ocean acidification research (via the EU EPOCA and German BIOACID programmes) and is actively engaged in the SOLAS-IMBER Working Group on Ocean Acidification.

NERC has agreed to continue its co-support of the SOLAS Summer School in 2011.

A NERC Arctic programme is under development. It is not yet known whether this will include SOLAS-relevant science.

# BIOACID progress report 2010

## Accomplishments

### Research projects

Work in progress in 44 of 46 subprojects (1 to start in 2011, one PI accepted position abroad)

### Special events

**"Joint BIOACID** (www.bioacid.de) **, EPOCA** (www.epoca-project.eu) **and UKOARP** (www.oceanacidification.org.uk) **meeting"**

Atlantic Hotel, Bremerhaven, 27-30 September 2010, 230 participants

### Workshops

**"Best practices in ocean acidification research"**

at IFM-GEOMAR, Kiel, March 8-12, 2010

BIOACID jointly with EPOCA, CalMarO (www.calmaro.eu) and US-OCB (www.us-ocb.org) (Coordinator: U. Riebesell)

Lecturers: J. Barry, R. Bellerby, C. Brownlee, C. Clemmesen, J.-P. Gattuso, J. Havenhand, D. Hutchins, M. Lenz, A. Körtzinger, F. Melzner, A.-M. Nisumaa, J. Orr, B. Pfeil, R. Schlitzer, K. Schulz, M. Wahl

**"Physiological approaches to body fluid physicochemistry & acid-base regulation"**

at AWI Bremerhaven, March 15-19, 2010 (F. Sartoris, AWI)

**"Microsensor applications"**

at MPI Bremen, April 26 – May 9, 2010 (D. de Beer, MPI)

### Outreach

**New website**

(www.bioacid.de) with market place at Research Gate (www.researchgate.net)

**Project flyer**

downloadable from BIOACID website

### Capacity building

**"Guide to Best Practices for Ocean Acidification Research and Data Reporting"**
BIOACID scientists contributed substantially

## Publications


Fietzke J., Heinemann,A. Taubner, I., Böhm, F., Erez, J., Eisenhauer,A. (2010) Boron isotope ratio determination in carbonates via LA-MC-ICP-MS using soda-lime glass standards as reference material. *J. Anal. Atom. Spectrom*., 25, 1953-1957, doi:10.1039/C0JA00036A

Frommel, A., Stiebens, V., Clemmesen, C., Havenhand, J. (2010) Effect of ocean acidification on marine fish sperm (Baltic cod: *Gadus morhua*). *Biogeosciences* 7,1-5.

Hu, M.Y., Sucré, E., Charmantier-Daures, M.C., Charmantier,G., Lucassen, M., Himmerkus ,N., Melzner, F. (2010) Localization of ion-regulatory epithelia in embryos and hatchlings of two cephalopods. *Cell Tissue Res.* 339:571–583 DOI 10.1007/s00441-009-0921-8

Krug, S. A., Schulz, K. G., and Riebesell, U.( 2010) Effects of CO2-induced changes in seawater carbonate chemistry speciation on Coccolithus braarudii: a conceptual model of coccolithophorid sensitivities*, Biogeosciences Discuss*., 7, 8763-8778, doi:10.5194/bgd-7-8763-2010. On 13.01.2011 16:24

Lannig, G., Eilers, S., Pörtner, H.O., Sokolova, I.M., Bock, C.(2010).Impact of Ocean Acidification on Energy Metabolism of Oyster, *Crassostrea gigas*—Changes in Metabolic Pathways and Thermal Response. *Marine Drugs*, 8(8), 2318-2339., doi:10.3390/md8082318

Oschlies, A., Koeve, W., Rickels, W., Rehdanz, K. (2010) Side effects and accounting aspects of hypothetical large-scale Southern Ocean iron fertilization *Biogeosciences* (BG), 7 (12). pp. 4017-4035. ISSN 1726-4170

Müller, M. N., Schulz, K. G., U. (2010) Effects of long-term high CO2 exposure on two species of coccolithophores, *Biogeosciences*, 7, 1109-1116, doi: 10.5194/bg-7-1109-2010

Thomsen J., Gutowska, M.A., Saphörster, J., Heinemann, A., Trübenbach, K., Fietzke, J., Hiebenthal, C., Eisenhauer, A. , Körtzinger, A., Wahl, M., Melzner, F. (2010) Calcifying invertebrates succeed in a naturally $CO_2$-rich coastal habitat but are threatened by high levels of future acidification, *Biogeosciences*, 7, 3879-3891, doi: 10.5194/bg-7-3879-2010

Thomsen, J.; Gutowska, M., Saphörster, J., Heinemann, A., Trübenbach, K., Fietzke, J., Hiebenthal, C., Eisenhauer, A., Körtzinger, A., Wahl, M., Melzner, F. (2010) Calcifying invertebrates succeed in a naturally $CO_2$ enriched coastal habitat but are threatened by high levels of future acidification. *Biogeoscience* 7, 3879-3891

Thomsen, J.; Melzner, F. (2010) Moderate seawater acidification does not elicit long-term metabolic depression in the blue mussel *Mytilus edulis*. *Marine Biology* 157;2667-2676

## International collaboration

- BIOACID endorsed by SOLAS and IMBER
- BIOACID represented in SOLAS-IMBER OA working group
- BIOACID joined OA Reference User Group (RUG)

## Future activities

**Outreach**

- Ocean acidification video(s) for YouTube
- School project(s)

# Progress report of CHOICE-C in 2009-2010, an SOLAS endorsed project

# (http://973oceancarbon.xmu.edu.cn)

## I. Introduction

CHOICE-C (Carbon cycling in China Seas - budget, controls and ocean acidification) is a multiple PI project sponsored by China National Basic Research Program (973) with funding period of 2009-2013, and also a SOLAS endorsed project. Leading PI of this project is Minhan Dai from Xiamen University. CHOICE-C focuses on the carbon budget, controls, ecological response and future changes in coastal ocean systems. The focal area includes, but not limited to the continental shelves in both the South and East China Seas. Through an integrated study of the carbon cycling between field observation, remote sensing as well as numerical modelling in China seas with a contrast/ comparison strategy, CHOICE-C aims to determine the source and sink terms of atmospheric $CO_2$ and their associated controlling processes. What follows concentrates on the ecological response of the uptake of anthropogenic $CO_2$, primarily on the ocean acidification during the past 1-2 hundred years.

## II. Main research activities in 2009-2010

**1. Cruises：**

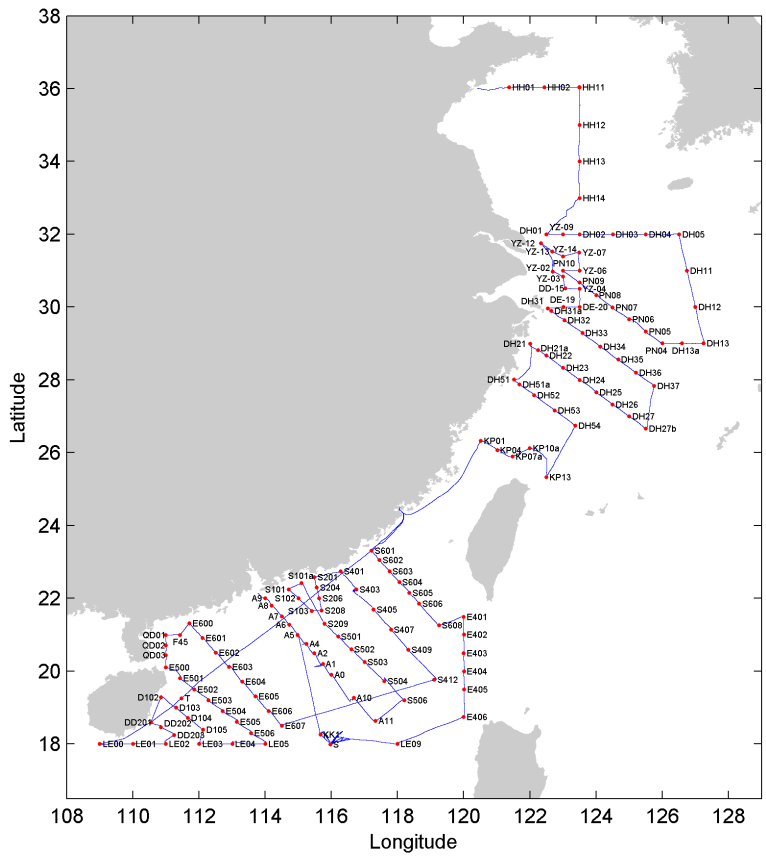



*Fig. 1. Map of the China Seas showing the sampling stations during the CHOCIE-C cruises in 2009-2010.*

Three 40-day long and multidisciplinary CHOICE-C cruises have been conducted onboard R/V Dongfanghong II since the launch of the project in Dec 2008. They were conducted on Jul. 18-Sept. 1, 2009, Dec. 23, 2009-Feb. 5, 2010, and Oct. 25-Dec. 10, 2010, covering the CHOICE-C domains of both the northern South China Sea and East China Sea (Fig. 1).

***Fig. 2. CHOICE-C cruise in summer 2010 to the East China Sea (Photo by Zuohua Zhao and Nan Zheng)***

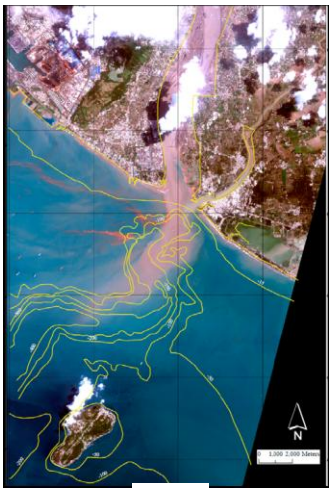
**2. Workshops and special sessions organized in 2010：**

1) CHOICE-C workshop - project progress and cruises Summary Workshop, May 7-9, 2010, Qingdao, China
2) CHOICE-C workshop - mid-term summary, Aug. 8-10, 2010, Kunming, China
3) Ocean Science Session, Physical Processes and Biogeochemistry of Coastal Ocean and Tropical Estuaries, 7$^{th}$ Asia Oceania Geosciences Society (AOGS) Annual Meeting, Jul. 4-9, 2010, Hyderbad, India (co-chaired by Sarma Vedula V. S. S., Murty Vadlamani, Minhan Dai and Jianping Gan)
4) Ocean Science Session, Trace Elements and Isotopes in Oceans, 7$^{th}$ Asia Oceania Geosciences Society (AOGS) Annual Meeting, Jul. 4-9, 2010, Hyderbad, India (cochiared by Sunil Kumar Singh and Deli Wang)

## III. Research highlights

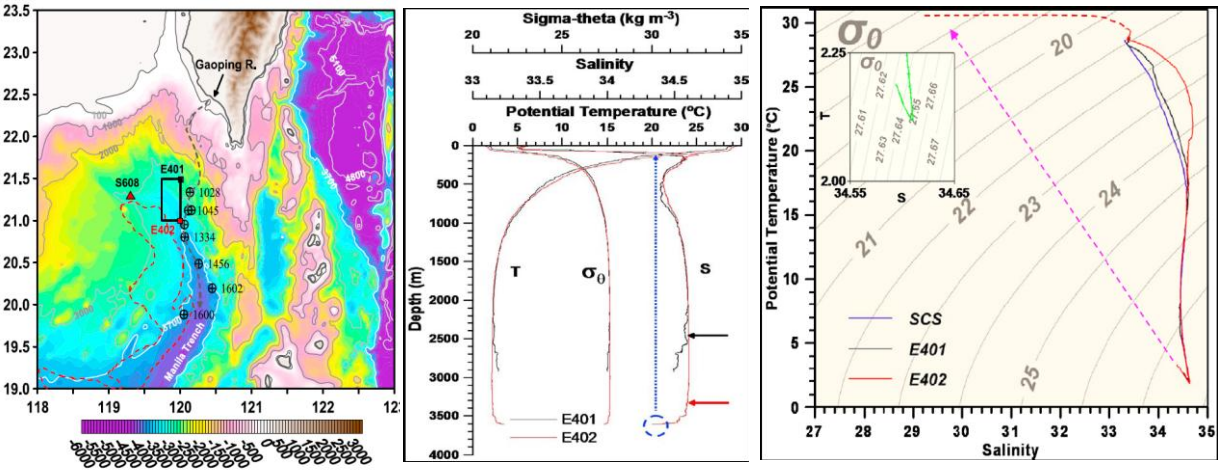
### 1. Cyclone-driven deep sea injection of freshwater and heat by hyperpycnal flow in the subtropics

Kao, S. J., Dai, M. H., Selvaraj, K., Zhai, W. D., Cai, P. H., Chen, S. N., Yang, J. Y. T., Liu, J. T., Liu, C. C. and Syvitski, J. P. M., *Geophysical Research Letters*, 2010. 37: L21702, doi:10.1029/2010GL044893.



(a)

The western tropical Pacific gives birth to 23 tropical cyclones annually, bringing torrential rainfall to mountainous islands across Oceania resulting in a global sediment production hotspot, in which many rivers have great hyperpycnal potential. By using a temperature (T) and salinity (S) profiler, we observed anomalously warm, low salinity turbid water at 3000-3700 m depths in seas similar to 180 km off southwestern Taiwan immediately after Typhoon Morakot in 2009. This 250m-thick bottom-hugging water occupies similar to 2400 km$^2$, and contains 0.15% freshwater, suggesting a remarkably high fraction (6-10%) of event rainfall from southwestern Taiwan. These characteristics indicate the turbid water originated from shallow coastal waters via hyperpycnal flow. Apparently, sediment produced from the land during tropical cyclones open an "express gate" to convey heat and freshwater vertically to the deep ocean basin subsequently warming the deep water from the bottom up.




(b) (c) (d)

***Fig.3. (a) Satellite image acquired on 13 August by FORMOSAT II with bathymetric contours superimposed. (b) Map showing southern Taiwan, the Gaoping River, the Gaoping Canyon (black dotted arrow), Manila Trench and three CTD stations of this study: E401 (black square), E402 (red square) and S608 (red triangle). A rectangular area is assumed for freshwater volume estimates (see text for details). Undersea cables had broken in sequence as marked by time on 12 August. (c) Depth profiles of salinity (S), temperature (T) and density ($\sigma_\vartheta$) at stations E401 (black) and E402 (red). Black and red arrows define the upper boundaries of turbidity water mass used for average salinity estimation. (d) The T-S diagram from this study combined with the statistical mean T-S profile of the South China Sea (SCS, purple). Note that the observed T-S profiles merge with the SCS curve when $\sigma_\vartheta$ is greater than 25.0; however, in the deep sea they are inverted. Inset diagram is an enlarged view of inverted portion of the T-S profile (T = 2.00-2.25°C and S = 34.55-34.65 at ~2900 m water depth) collected at station S608 located around 100 km away from the main axis of Gaoping Canyon.***

### 2. Diurnal variations of surface seawater $pCO_2$ in contrasting coastal environments

Dai, M. H., Lu, Z. M., Zhai, W. D., Chen, B. S., Cao, Z. M., Zhou, K. B., Cai, W. J. and Chen, C. T. A., Limnology and Oceanography, 2009. 54: 735-745.

We examined diurnal variations of surface seawater $pCO_2$ (partial pressure of $CO_2$) in a suite of coastal marine environmental systems in the vicinity of the South China Sea (SCS) from inshore and nearshore settings in Xiamen Bay, Shenhu Bay, and the southwestern Taiwan Strait, to offshore sites in the basin and on the slope of the northern South China Sea as well as in a coral reef system at Xisha Islands in the middle of the SCS. There were significant diurnal changes of surface $pCO_2$, ranging from 1.0 Pa to 1.6 Pa (10-16 $\mu$atm) in the offshore and oligotrophic sites, ~4.1 Pa in the Taiwan Strait, 5.1-15.2 Pa in Xiamen Bay and Shenhu Bay, to as high as 60.8 Pa in the coral reef system at Xisha Islands. Processes that modulate these $pCO_2$ diurnal variations were temperature, tide or current, and biological controls. Temperature was a major driver of the $pCO_2$ diurnal variability in the oligotrophic regions, while tidal effects were important in the nearshore. In the coral reef system, biological metabolism dominated variability. Diurnal variability could have a potentially important implication on the estimate of air-sea $CO_2$ fluxes, which may result in an uncertainty of ±0.48-0.77 mmol C $m^{-2}$ $d^{-1}$ for the offshore sites in the SCS. Such uncertainties were larger in nearshore settings.

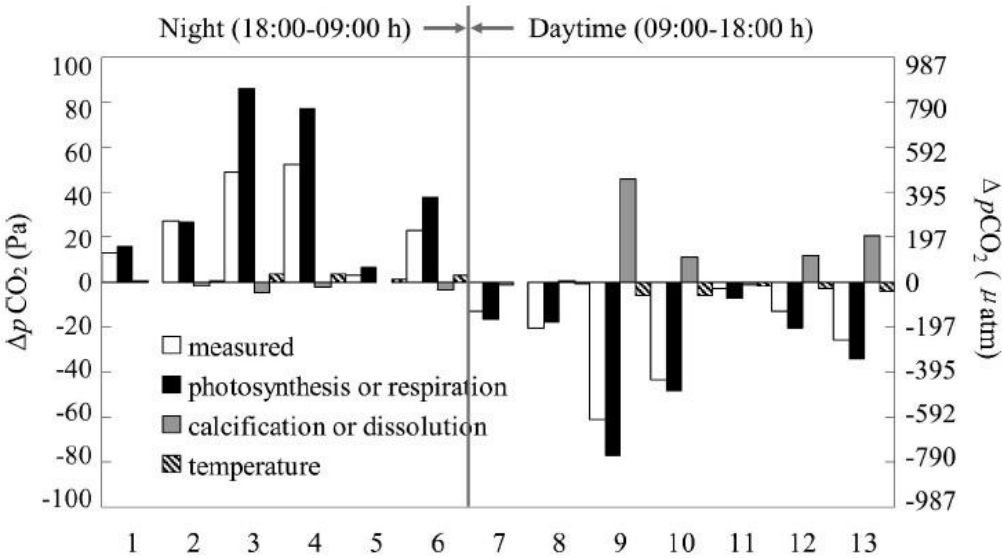



***Fig. 4. Contributions to ⊿$pCO_2$, the change in $pCO_2$ between a starting point and an end point in a monotonic decreasing or increasing segment by different controlling factors at the coral reef station at the Xisha Islands. The No. 1–13 represent 13 monotonic increasing and decreasing $pCO_2$ segments. The white bar represents measured $pCO_2$ changes in one segment, the black bar represents $pCO_2$ changes caused by photosynthesis or respiration, the grey bar represents $pCO_2$ changes due to TA variation, and the striped bar represents the temperature effects. The figure indicates that calcification and respiration have positive effects, and dissolution and photosynthesis have negative effects on $pCO_2$.***

## 3. Satellite-derived surface water $pCO_2$ and air-sea $CO_2$ fluxes in the northern South China Sea in summer

Zhu, Y., Shang, S. L., Zhai, W. D. and Dai, M. H., *Progress in Natural Science*, 2009. 19: 775-779.

An empirical approach is presented for the estimation of the partial pressure of carbon dioxide ($pCO_2$) and air-sea $CO_2$ fluxes in the northern South China Sea in summer using satellite-derived sea surface temperatures (SSTs), chlorophyll-a (Chl a) concentrations, and wind

fields. Two algorithms were tested. The first used an SST-dependent equation, and the other involved the introduction of Chl a. Regression equations were developed for summer based on in *situ* data obtained in July, 2004. Using the monthly average SST and Chl a fields derived from the advanced very high resolution radiometer (AVHRR) and the SeaWiFS (sea-viewing wide field of view sensor), respectively, the monthly $pCO_2$ fields were computed. The derived $pCO_2$ was compared with the shipboard $pCO_2$ observations conducted in July, 2000. This resulted in a root-mean-square error of 4.6 µatm, suggesting that the satellite-derived $pCO_2$ was in general agreement with the in *situ* observations. The air-sea $CO_2$ flux was further computed with the aid of the monthly mean QuikSCAT wind speed. We contend that more shipboard data are necessary for refining the empirical algorithms and reducing the uncertainty in the results.

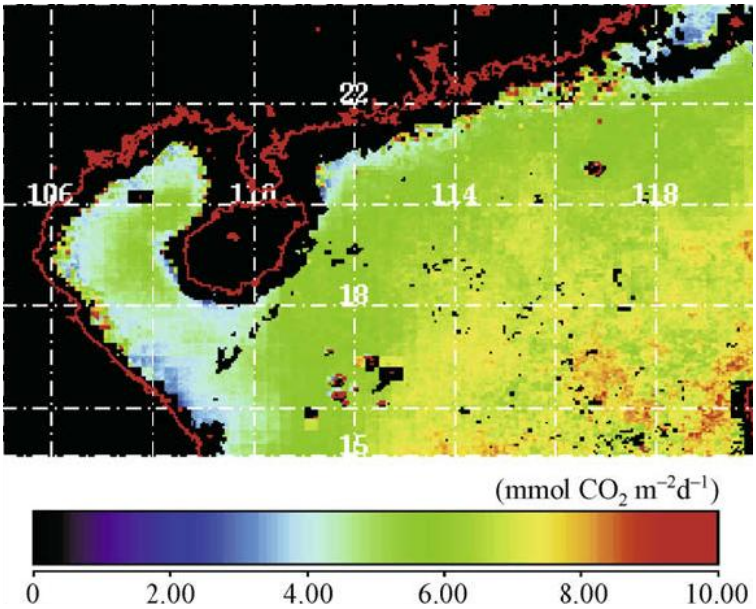



***Fig. 5. Distribution of satellite-derived air-sea $CO_2$ flux in the northern South China Sea in summer (2000–2005 mean).***

## 4. Excess total organic carbon in the intermediate water of the South China Sea and its export to the North Pacific

Dai, M. H., Meng, F. F., Tang, T. T., Kao, S. J., Lin, J. R., Chen, J. H., Huang, J. C., Tian, J. W., Gan, J. P. and Yang, S., *Geochemistry Geophysics Geosystems*, 2009. 10, Q12002, doi:10.1029/2009GC002752.

Depth profiles of total organic carbon (TOC) were measured in spring (2005) and winter (2006) in the South China Sea (SCS), the largest marginal sea adjacent to the North Western Pacific (NWP). Compared to TOC profiles in the NWP, excess TOC (3.2 ± 1.1 $\mu$mol kg$^{-1}$) was revealed in the intermediate layer of the SCS at $\sigma_\theta$ ~27.2–27.6 (~1000–1500 m). Below the depth of 2000 m, TOC concentrations were identical between the SCS and the NWP. Based on a one-dimensional steady state diffusion advection model constrained by potential temperature, we estimated a net TOC production rate of 0.12 ± 0.04 $\mu$mol kg$^{-1}$ yr$^{-1}$ to maintain this excess. A positive relationship between TOC and apparent oxygen utilization in the SCS deep water lent support to such a model-derived TOC production. This excess TOC in the out-flowing intermediate water may carry 3.1 ± 2.1 Tg C yr$^{-1}$ of organic carbon out from the SCS and potentially into the deep open ocean. In light of the short residence time of the SCS deep water,

the exported TOC was likely from the recently fixed organic carbon within the SCS. The export of such organic carbon, thereby less likely to return to the atmosphere may therefore contribute significantly to the carbon sequestration in the SCS.

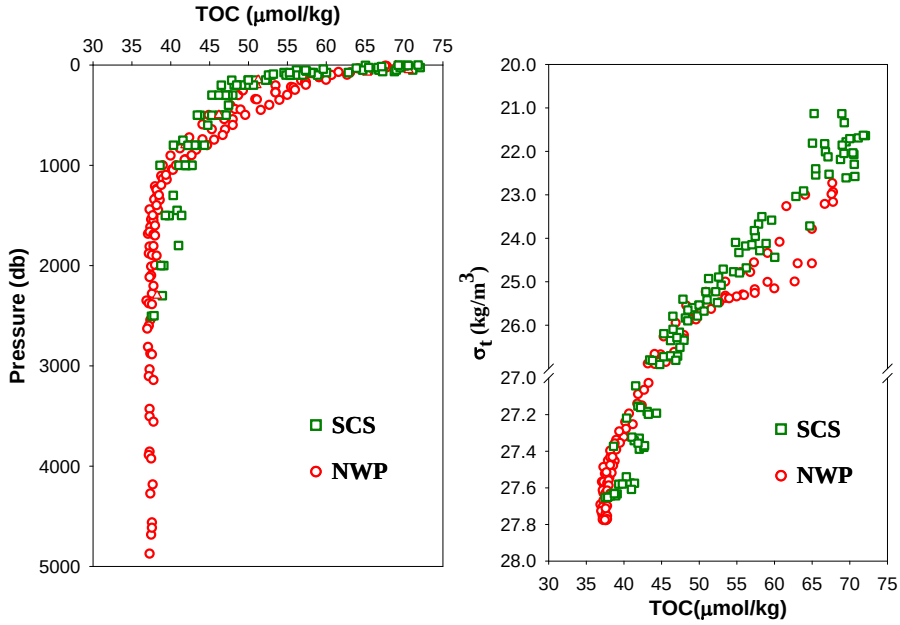



***Fig. 6. (a) Depth profiles of TOC for stations in the NWP and in the SCS. (b) Potential density (sq) versus TOC for all corresponding samples in Figure 3a. (c) Scatterplots of TOC versus sq in the SCS. (d) TOC versus AOU in the deep SCS water, where samples below 1000 m (dark gray dots) were selected and samples below 2200 m of the NWP (open triangles) are shown for reference. The Pacific data are from http://cdiac.esd.ornl.gov/oceans/RepeatSections/clivar_p02.html.***

## 5. On the seasonal variation of air - sea $CO_2$ fluxes in the outer Changjiang (Yangtze River) Estuary, East China Sea

Zhai, W. D. and Dai, M. H., *Marine Chemistry*, 2009. 117: 2-10.

Based upon seven field surveys conducted during April 2005 – April 2008, we examined the surface partial pressure of $CO_2$ ($pCO_2$) and dissolved oxygen (DO) in the outer Changjiang (Yangtze River) Estuary, on the inner shelf of the East China Sea (ECS). This area represents a most dynamic zone of the ECS where high $pCO_2$ riverine water meets with highly productive shelf waters, covering a 2°×3° area, ~10% of the surface area of the entire ECS. Surface $pCO_2$ ranged 320 - 380 μatm (average ~345 μatm) in winter, 180 - 450 μatm (average ~330 μatm) in spring, 150 - 620 μatm (average ~310 μatm) in summer and 120 – 540 μatm (average ~375 μatm) in autumn. The seasonal variation pattern of surface DO generally mirrored that of $pCO_2$ ranging 95% - 105% in winter, 96% - 142% (average 110%) in spring, 73% - 192% (average 118%) in summer and 81% - 178% (average 102%) in autumn. The dynamics of $pCO_2$ drawdown and DO enhancement in the warm seasons (from April to October) appeared to be controlled by primary productivity and air-sea exchange, while mixing dominated the aqueous $pCO_2$ in the cold seasons (from November to March of the following year). This study showed that the outer Changjiang Estuary served as a moderate or significant sink of atmospheric $CO_2$ in winter, spring and summer, while it turned to a net source in autumn. The integrated sea-air $CO_2$ flux in the outer Changjiang Estuary was estimated as −1.9±1.3 mol $m^{-2}$ $year^{-1}$, which is double the recent sea-air $CO_2$ flux estimation for the northern ECS.

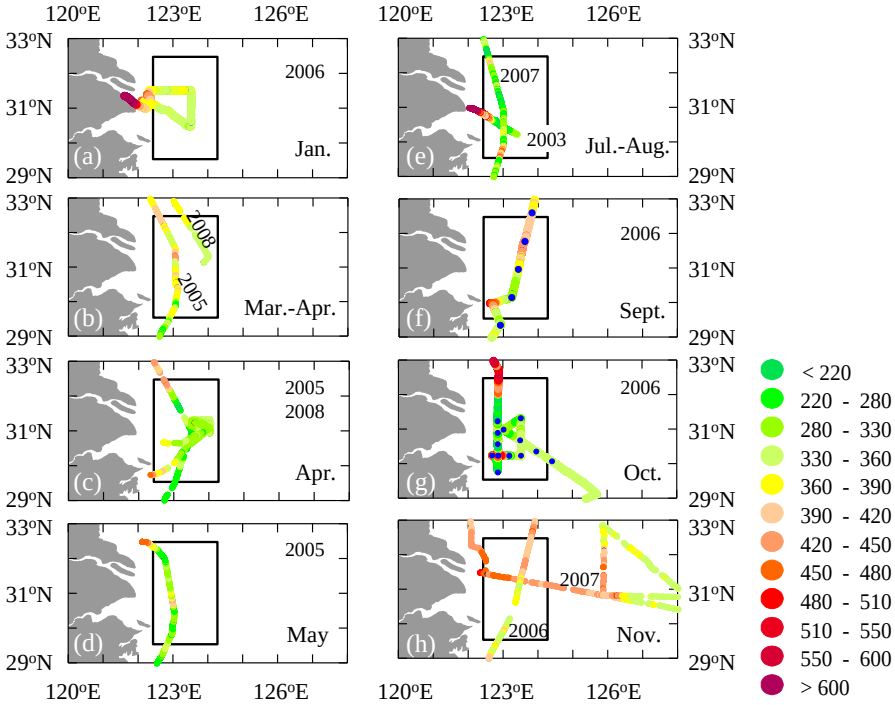



***Fig. 7. Seasonal aqueous $pCO_2$ distribution (in µatm) during the underway pumping surveys.***

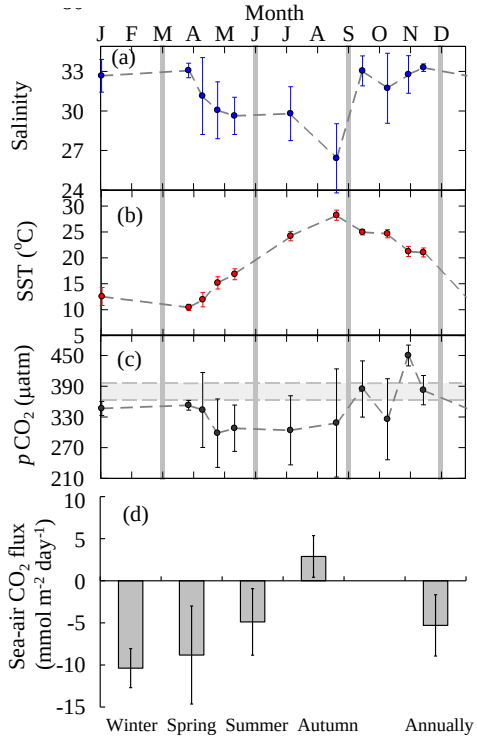



***Fig. 8. Seasonal cycles of salinity, SST, $pCO_2$ and DO saturation in the outer Changjiang Estuary. Two horizontal dash lines in panel (c) show the atmospheric $CO_2$ level.***

## 6. Coupling of surface $pCO_2$ and dissolved oxygen in the northern South China Sea: impacts of contrasting coastal processes

Zhai, W. D., Dai, M. H. and Cai, W. J., *Biogeosciences*, 2009. 6: 2589-2598.

We examined the relationship between $CO_2$ partial pressure ($pCO_2$) and dissolved oxygen (DO) based on a cruise conducted in July 2004 to the northern South China Sea (111$^o$ - 118$^o$E 18$^o$ - 23$^o$N), spanning from estuarine plume, coastal upwelling and deep basin areas. Distinct relationships between $pCO_2$ and DO saturation were identified in different regimes. In coastal upwelling areas and the Pearl River estuary, biological drawdown of $pCO_2$ and production of $O_2$ were simultaneously observed. The two properties were coupled with each other primarily via photosynthesis and respiration. The stoichiometric relationship of the two properties however, was quite different in these two environments due to different levels of chemical buffering capacity (Revelle factor). In the offshore areas, apart from the estuary and upwelling, the $pCO_2$ - DO relationship was controlled by the integrated effect of previous community metabolic processes and subsequent air-water exchange. Given the fact that air-sea re-equilibration of $O_2$ is much faster than that of $CO_2$, the observed $pCO_2$ - DO relationship deviated from that of the theoretical prediction based on the Redfield relationship in the offshore areas. Although this study is subject to the limited temporal and spatial coverage of sampling, we have demonstrated a simple procedure to evaluate the community metabolic status based on a combination of high-resolution surface $pCO_2$ and DO measurements, which may have applicability in many coastal systems with a large gradient of changes in their physical and biogeochemical conditions.

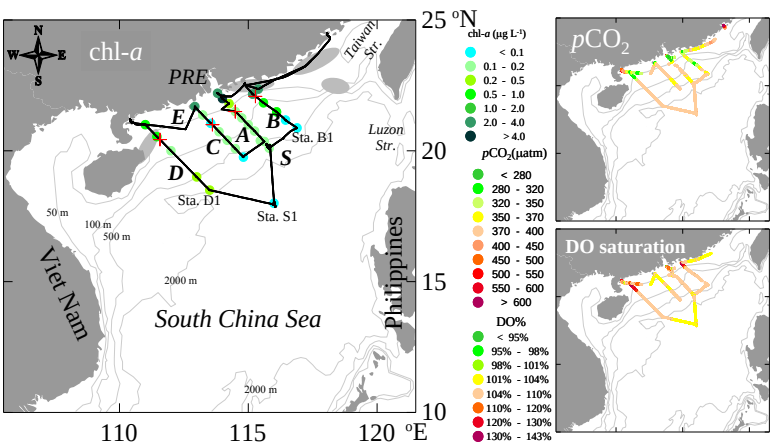



***Fig. 9. Geographic distributions of surface chlorophyll-a (chl-a), $pCO_2$ and DO saturation along surveying tracks (A, B, C, D, E and S) under study in July 2004. "+" symbols designate locations where we used to divide the shelf into nearshore and offshore areas in this study.***

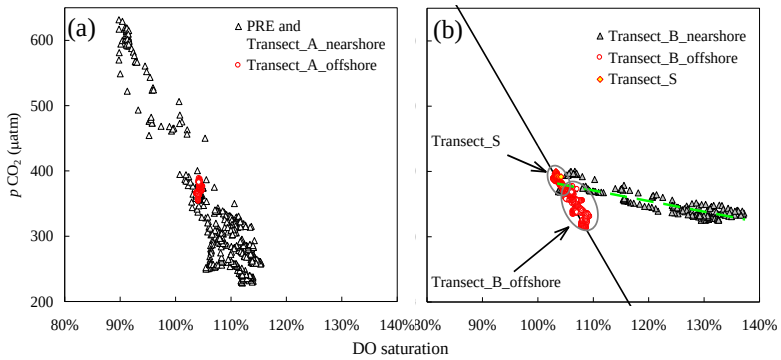



***Fig. 10. Relationship between surface $pCO_2$ and DO saturation along different transects. The two regression lines, fitted by minimizing the sum of the squares of the y-offsets, are: in the nearshore area in Transect B– y= −164 x + 552 ($R^2$ = 0.79, dashed lines) and the offshore area in Transect B– y= −1465 x + 1904 ($R^2$=0.88, solid lines).***

## 7. $CO_2$ flux and seasonal variability in a large subtropical estuarine system, the Pearl River Estuary, China

Guo, X. H., Dai, M. H., Zhai, W. D., Cai, W. J. and Chen, B. S., *Journal of Geophysical Research-Biogeosciences*, 2009. 114, G03013, doi:10.1029/2008jg000905.

This paper presents the spatial distribution and seasonal changes of the carbonate system and $CO_2$ fluxes in a complex river-estuary system located in a subtropical region, the Pearl River Estuary, based on five surveys covering primarily a wet and dry seasonal cycle on two major subestuaries of the Pearl River, namely Lingdingyang and Huangmaohai. Significant spatial and seasonal variations of surface water partial pressure of $CO_2$ ($pCO_2$) were observable in these two subestuaries. While both Lingdingyang and Huangmaohai had higher $pCO_2$ in their upper estuaries, which quickly decreased downstream as seen in many estuarine settings elsewhere, significant differences occurred between the two subestuaries in terms of $pCO_2$ level, with much higher $pCO_2$ in the upper Lingdingyang than the upper Huangmaohai. In terms of seasonality, substantially higher $pCO_2$ was observed in warm and wet seasons in both upper estuaries (2100-8350 $\mu$atm in the Lingdingyang and 1040-3590 $\mu$atm in the Huangmaohai) than in cold and dry seasons (1100-7460 $\mu$atm and 560-970 $\mu$atm in the Lingdingyang and the Huangmaohai, respectively). As a consequence, $CO_2$ emission from the Pearl River Estuary system in summer was similar to 6 times of that in winter. At the same time, we observed a clear drawdown of $pCO_2$ in the lower estuary in both summer and winter, reaching a level of water $pCO_2$ which was below the atmospheric level. This seasonal and spatial contrast can also be seen in the distribution of dissolved inorganic carbon (DIC) and total alkalinity. On the basis of a seasonal and zonal distribution of $pCO_2$, the annual $CO_2$ emission from the Pearl River Estuary was estimated to be ~ 3 x $10^{10}$ mol C, which is equivalent to ~ 6% of the total DIC export flux to the South China Sea from the Pearl River system.

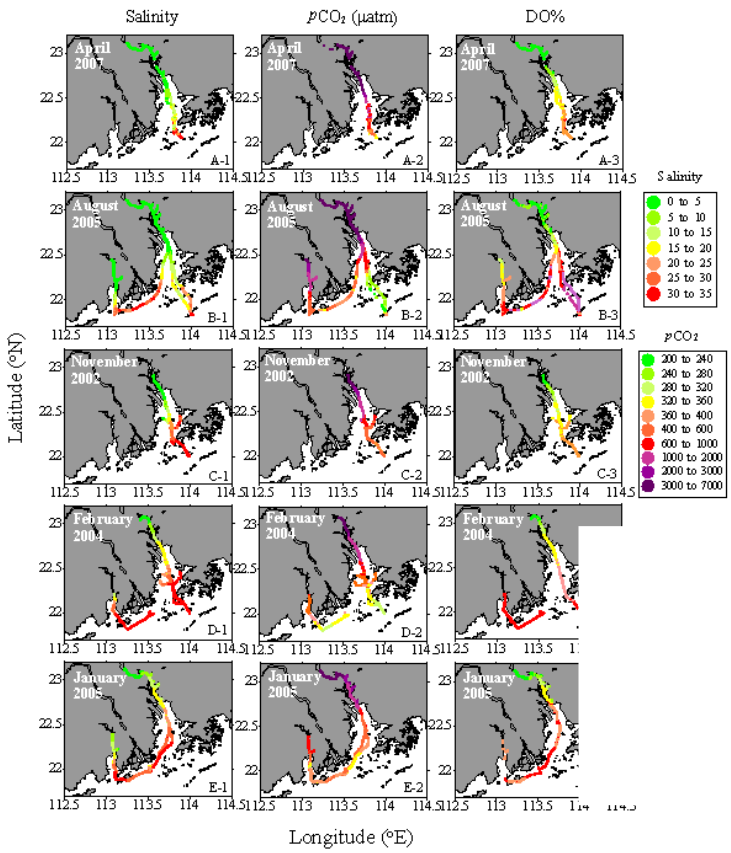



***Fig. 11. Spatial distribution of salinity, $pCO_2$ and DO saturation (%) in the Pearl River Estuary in Apr. 2007 (A1-3), Aug. 2005 (B1-3), Nov. 2002 (C1-3), Feb. 2004 (D1-3) and Jan. 2005 (E1-3). The $pCO_2$ and DO data in the upstream Humen of the Lingdingyang sub-estuary in Feb. 2004 were cited from Dai et al. [2006]***

## 8. Characterization of particulate organic matters in the water column of the South China Sea using a shotgun proteomic approach

Dong, H. P., Wang, D. Z., Dai, M. H. and Hong, H. S., *Limnology and Oceanography*, 2010. 55: 1565-1578.

We characterized particulate organic matter (POM) collected from both the surface (41 m and 200 m) and mesopelagic layers (500 m and 1000 m) in the western South China Sea. By using a shotgun proteomic approach, a total of 3035 proteins matching one or more peptides were detected from four POM samples, 505 of which were identified as high-confidence proteins matching two or more peptides. Cyanobacteria was the largest contributor throughout the water column, while crustaceans and dinophytes were the two major groups contributing to the particulate proteins in the POM collected from 200 m. Subcellular locations and biological processes of particulate proteins varied significantly between the 41-m and 200-m layers: photosynthesis-associated proteins were highly abundant in the 41-m layer while tubulins and actins accumulated in the midwaters, especially at the 200-m layer. Porins, adenosine triphosphate synthases, nutrient transporters, molecular chaperones, and ectoenzymes were frequently detected in the POM samples and presented different distribution patterns within the water column, revealing complex biological processes at the different water layers and/or during the sinking of POM. The sources of surface and midwater particulate proteins are different, and the cellular metabolism, generation of energy, and transport processes in POM are attenuated rapidly down ocean water column. Zooplankton fecal pellet packages and membrane

encapsulation might play important roles in protecting particulate proteins from degradation.

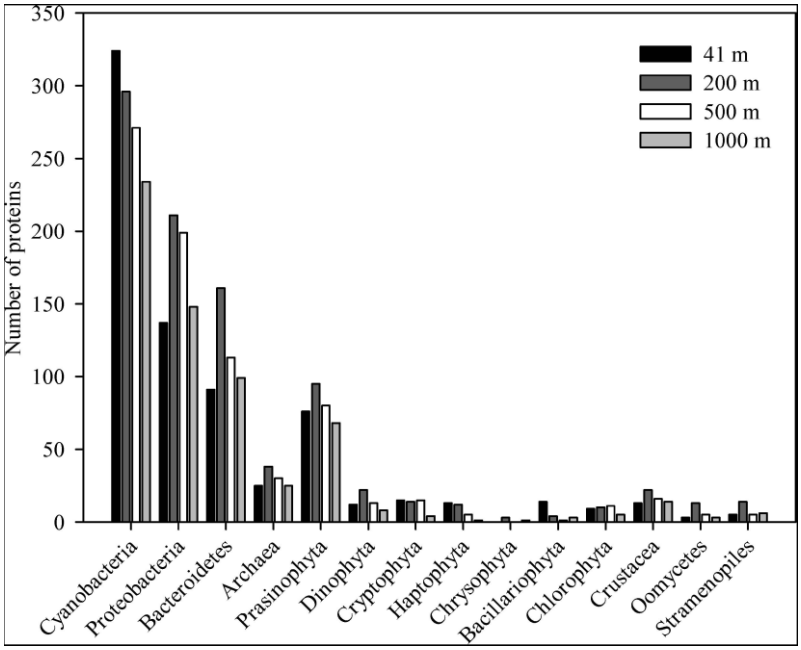



***Fig.12. Distribution of phylogenetic groups contributing to all identified proteins in the POM from the four water layers in the western South China Sea.***

## 9. Combined effects of ocean acidification and solar UV radiation on photosynthesis, growth, pigmentation and calcification of the coralline alga *Corallina sessilis* (Rhodophyta)

Gao, K. S. and Zheng, Y. Q., *Global Change Biology*, 2010. 16: 2388-2398.

Previous studies have shown that increasing atmospheric $CO_2$ concentrations affect calcification in some planktonic and macroalgal calcifiers due to the changed carbonate chemistry of seawater. However, little is known regarding how calcifying algae respond to solar UV radiation (UVR, UVA+UVB, 280-400 nm). UVR may act synergistically, antagonistically or independently with ocean acidification (high $CO_2$/low pH of seawater) to affect their calcification processes. We cultured the articulated coralline alga *Corallina sessilis* Yendo at 380 ppmv (low) and 1000 ppmv (high) $CO_2$ levels while exposing the alga to solar radiation treatments with or without UVR. The presence of UVR inhibited the growth, photosynthetic $O_2$ evolution and calcification rates by13%, 6% and 3% in the low and by 47%, 20% and 8% in the high $CO_2$ concentrations, respectively, reflecting a synergistic effect of $CO_2$ enrichment with UVR. UVR induced significant decline of pH in the $CO_2$-enriched cultures. The contents of key photosynthetic pigments, chlorophyll*a* and phycobiliproteins decreased, while UV-absorptivity increased under the high $pCO_2$/low pH condition. Nevertheless, UV-induced inhibition of photosynthesis increased when the ratio of particulate inorganic carbon/particulate organic carbon decreased under the influence of $CO_2$-acidified seawater, suggesting that the calcified layer played a UV-protective role. Both UVA and UVB negatively impacted photosynthesis and calcification, but the inhibition caused by UVB was about 2.5-2.6 times that caused by UVA. The results imply that coralline algae suffer from more damage caused by UVB as they calcify less and less with progressing ocean acidification.

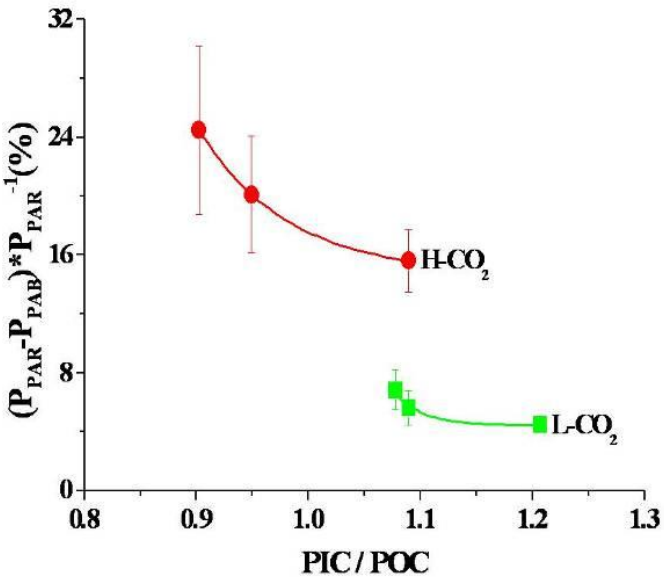



***Fig.13. UVR (UVA+UVB)-induced inhibition (%) of photosynthetic oxygen evolution as a function of the PIC/POC ratios in the thalli of Corallina sessilis grown under the low and high CO2 levels for 1, 15 and 30 days. The relationship was significant under both high ($R^2$=0.99) and low ($R^2$=0.87) CO2 levels (P<0.05). Data are the means ±SD (n=9), representing nine individuals in three measurements. PIC, particulate inorganic carbon; POC, particulate organic carbon.***

## 10. $CO_2$-induced seawater acidification affects physiological performance of the marine diatom *Phaeodactylum tricornutum*

Wu, Y. P., Gao, K. S. and Riebesell, U., Biogeosciences, 2010. 7: 2915-2923.

$CO_2$/pH perturbation experiments were carried out under two different $pCO_2$ levels (39.3 and 101.3 Pa) to evaluate effects of $CO_2$-induced ocean acidification on the marine diatom *Phaeodactylum tricornutum*. After acclimation (>20 generations) to ambient and elevated $CO_2$ conditions (with corresponding pH values of 8.15 and 7.80, respectively), growth and photosynthetic carbon fixation rates of high $CO_2$ grown cells were enhanced by 5% and 12%, respectively, and dark respiration stimulated by 34% compared to cells grown at ambient $CO_2$. The half saturation constant (K-m) for carbon fixation (dissolved inorganic carbon, DIC) increased by 20% under the low pH and high $CO_2$ condition, reflecting a decreased affinity for $HCO_3^-$ or/and $CO_2$ and down-regulated carbon concentrating mechanism (CCM). In the high $CO_2$ grown cells, the electron transport rate from photosystem II (PSII) was photoinhibited to a greater extent at high levels of photosynthetically active radiation, while non-photochemical quenching was reduced compared to low $CO_2$ grown cells. This was probably due to the down-regulation of CCM, which serves as a sink for excessive energy. The balance between these positive and negative effects on diatom productivity will be a key factor in determining the net effect of rising atmospheric $CO_2$ on ocean primary production.

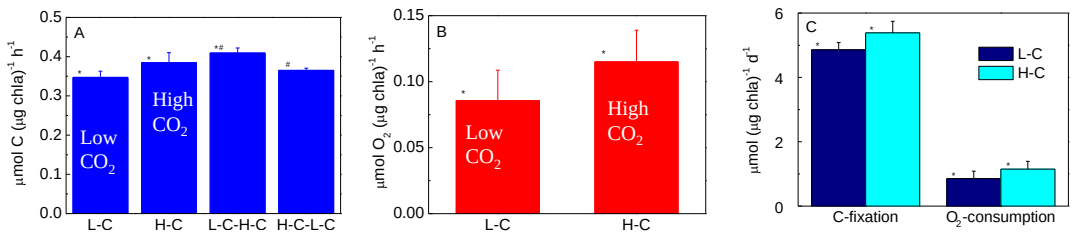


***Fig.14. Physiological response of the diatom Phaeodactylum tricornutum to increased $pCO_2$ (1000 ppmv) and acidity (pH 7.8). (A) Photosynthetic carbon fixation, (B) dark respiration, and (C) integrated daily photosynthetic carbon fixation and dark respiration of low (L-C) and high $CO_2$ grown cells (H-C), low $CO_2$ grown cells measured in high $CO_2$ (L-C-H-C) and high $CO_2$ grown cells measured in low $CO_2$ (H-C-L-C); vertical bars represent SD, n=9-12 for carbon fixation and 3-5 for oxygen consumption. An asterisk and a number sign "*" represent significant difference among treatments (p<0.05).***

## 11. Intensified upwelling over a widened shelf in the northeastern South China Sea

Gan, J. P., A. Cheung, X. Guo and L. Li, 2009. *Journal of Geophysical Research-Oceans*, 114, DOI: 10.1029/2007JC004660.

Observational and three-dimensional modeling studies reveal that the intensified upwelling in the northeastern South China Sea (NSCS) is formed as a result of intensified upslope advection of dense deep waters that cross the middle shelf toward the inner shelf over a distinctly eastward widened shelf. The strongest advection occurs over the converging isobaths near the head of the widened shelf. As these dense deep waters advance shoreward, they are advected downstream by the quickly developed upwelling current over the inner shelf and eventually outcropped at the lee of a coastal cape. Dynamically, the shoreward cross-isobath transport over the widened shelf is geostrophically enhanced by a quasi-barotropic negative (westward) along-isobath pressure gradient force as a result of the net rate of the momentum influx and by an intensified bottom frictional transport owing to the flow confluence near the head of the widened shelf. A negative pressure gradient also exists at the lee of the coastal cape over the inner shelf and locally amplifies shoreward motion. Induced by the respective widened shelf and the coastal promontory, the along-isobath variations of cross-isobath transport in the water column over the middle and inner shelves interactively characterize intensified upwelling in the NSCS.

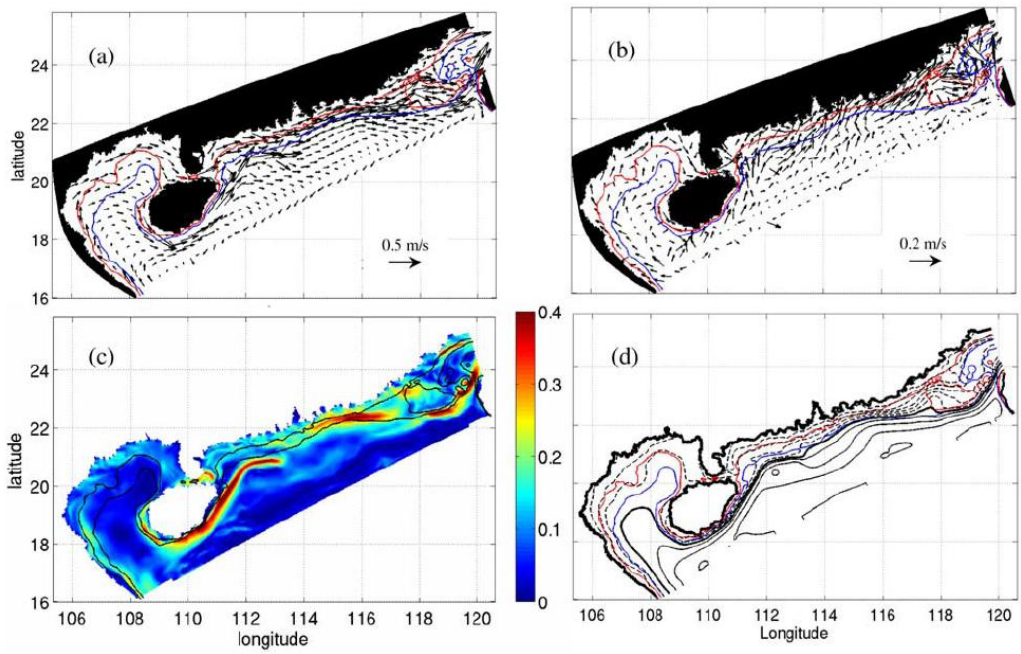



***Fig. 15. Daily mean (a) surface, (b) bottom velocity vectors (m $s^{-1}$), (c) depth-integrated velocity***

***magnitude (m s$^{-1}$), and (d) surface elevation (m) on day 30. The contour interval for elevation is 0.02 m with the heavy contour line for 0 m. Dashed and solid contour lines refer to the negative and positive elevations, respectively. The 30 and 50 m isobaths are shown as red and blue contour lines, respectively.***

## 12. Relationships between phytoplankton growth and cell size in surface oceans: Interactive effects of temperature, nutrients, and grazing

Chen, B. Z., R. D. Tadonléké, J. K. Llopiz, F. Ballantyne Iv, K. Nakayama, M. S. Souza, C. Savage, G. W. Holtgrieve, C. Buchwald and R. Vaquer-Sunyer, 2010. *Limnology and Oceanography,* 55(3): 965-972.

We compile two data sets from $^{14}$C uptake and dilution experiments conducted in surface waters of the global ocean to investigate the relationship between phytoplankton mass-specific growth rate and cell size. After temperature correction, both data sets suggest that this relationship might be described by a unimodal quadratic curve with the modal size (the size corresponding to the maximal growth rate) being 2.8 and 5.4 mm in the $^{14}$C and dilution data sets, respectively. Nutrient enrichment does not change the qualitative nature of the relationships, and we conclude that inherently low maximal growth rates of picophytoplankton, not ambient nutrient effects, play the major role in determining the positive relationships over the size range where phytoplankton size is below the modal size. Temperature-corrected phytoplankton grazing mortality rate is positively correlated with phytoplankton average size, but the proportion of daily primary production consumed by microzooplankton is negatively correlated with cell size, suggesting a reduced grazing effect as size increases. The unimodal relationship between phytoplankton growth rate and cell size is consistent with theoretical considerations and might reflect an adaptive response of phytoplankton to varying extents of nutrient limitation and grazing effect in marine systems.

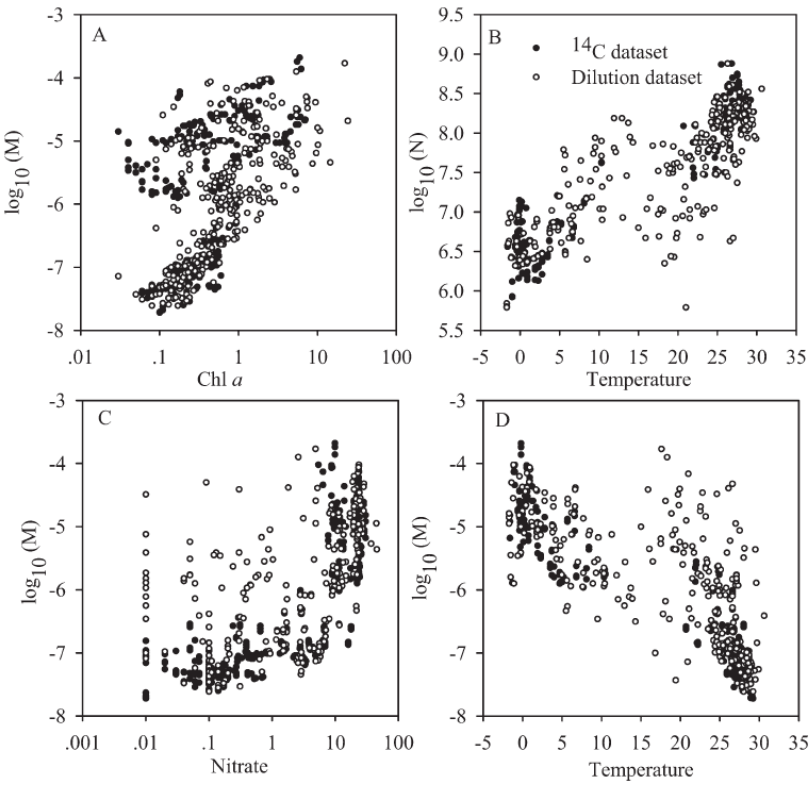


***Fig. 16. (A) Scatter plot of log-transformed average cell size ($log_{10}$ (M)) vs. Chl a concentration in both $^{14}C$ uptake and dilution data sets. (B) Scatter plot of log-transformed phytoplankton numerical abundance ($log_{10}$ (N)) vs. temperature. (C) $Log_{10}$ (M) vs. nitrate concentrations. (D) $Log_{10}$ (M) vs. temperature. Units are M: μg C $cell^{-1}$; Chl a: μg $L^{-1}$; N: cells $L^{-1}$; temperature: ℃; nitrate: μmol $L^{-1}$.***

**13. Biological response to intensified upwelling and to a river plume in the northeastern South China Sea: A modeling study.**

Gan, J. P., Z. M. Lu, M. H. Dai, A. Y. Y. Cheung, H. Liu and P. Harrison, 2010. *Journal of Geophysical Research*, 115, C09001 DOI: 10.1029/2009JC005569

A coupled three‐dimensional physical model and a nitrogen‐based dissolved inorganic nitrogen, phytoplankton, zooplankton, and detritus (NPZD) ecosystem model was used to study the ecosystem responses to the wind‐driven summer upwelling and to the Pearl River plume over a distinctly widened shelf in the northeastern South China Sea (NSCS). Forced with an idealized, but representative, upwelling‐favorable wind and the river discharge for the purpose of process‐oriented study, we identified two high chlorophyll centers that are typically observed over the NSCS shelf and stimulated by nutrient enrichment from intensified upwelling over the widened shelf and from the river plume. The nutrient enrichment has strong along‐shore variability involving the variable cross‐isobath nutrient transport between the middle and the inner widened shelf during the upwelling and an eastward expansion of the nutrient‐rich plume. About 20% of the upwelled nutrientrich deep water from the outer shelf reaches the inner shelf where algal blooms occur. Nutrient enrichment in the plume stretches over a broad extent of the shelf and produces significant biomass on the NSCS shelf. The plume is physically governed by intensified surface Ekman dynamics that leads to a strong offshore nutrient transport and eventually offsets the shoreward transport caused by the upwelling in the NSCS. Biological forcing and circulation dynamics of the surface Ekman layer jointly form the spatial dislocation and temporal variation of NO3, phytoplankton, and zooplankton biomasses in the upwelled and plume waters. The simulated results qualitatively resemble field and satellite measurements and demonstrate the physically modulated biological responses to the intensified upwelling and plume‐influenced NSCS shelf.

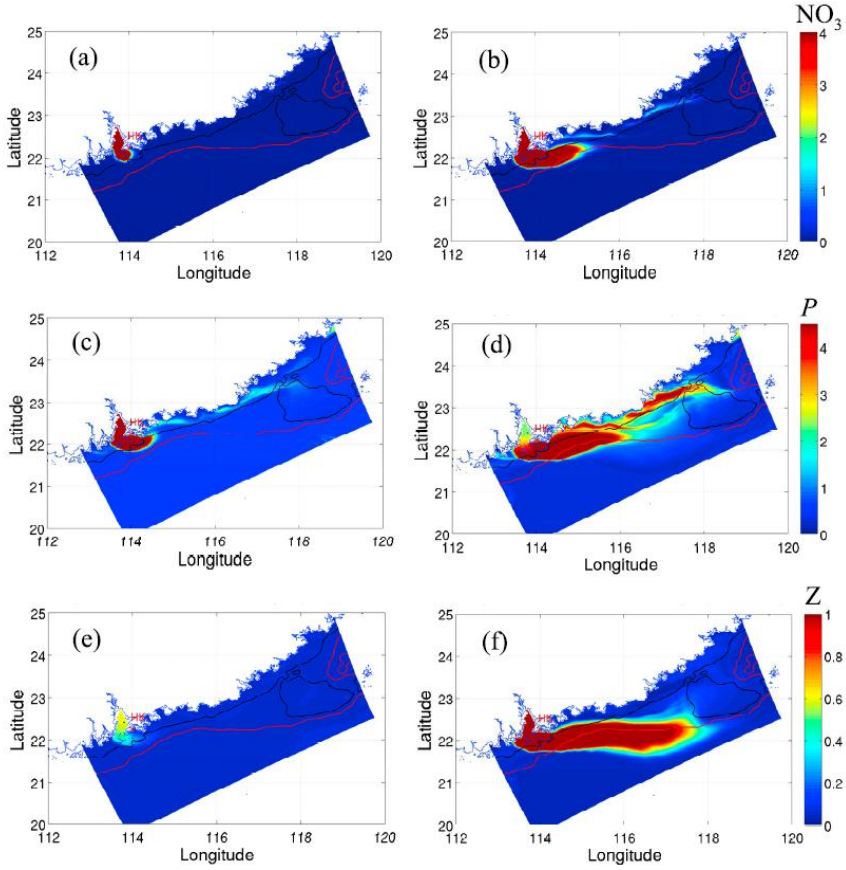



***Fig. 17. Surface (a and b) NO3 (mmol m−3), (c and d) chlorophyll (mg m−3), and (e and f) zooplankton (mmol m−3) on days 10 (left) and 30 (right)***

## 14. Characterization of MODIS-derived euphotic zone depth: Results for the China Sea

Shang, S. L., Z. P. Lee and G. M. Wei, 2011.. *Remote Sensing of Environment,* 115: 180-186

Euphotic zone depth (Zeu) products from ocean color measurements are now produced from MODIS ocean color measurements, one of which is based on inherent optical properties (IOP-approach) and the other is based on chlorophyll-a concentration (Chl-approach). For the first time, the quality of these satellite Zeu products is assessed with extensive field-measured Zeu (in the China Sea), where 78% of the measurements were made on the continental shelf (≤ 200 m). For the data with matching location and time window, we have found that the overall average difference ( ε ) between satellite and in situ Zeu is 21.8% (n=218, Zeu ranges from 4 to 93 m) with a root mean square error in log scale (RMSE) of 0.118 by the IOP-approach, while it is 49.9% (RMSE=0.205) by the Chl-approach. These results suggest that 1) MODIS Zeu products for waters in the China Sea are robust, even in shelf waters; and 2) Zeu produced with IOPs are more reliable than those produced with empirically derived Chl. Spatial and seasonal variations of Zeu in the China Sea are briefly described with Zeu products generated by the IOP-approach. These results will facilitate further research on carbon cycling and environmental changes on both local and global scales.

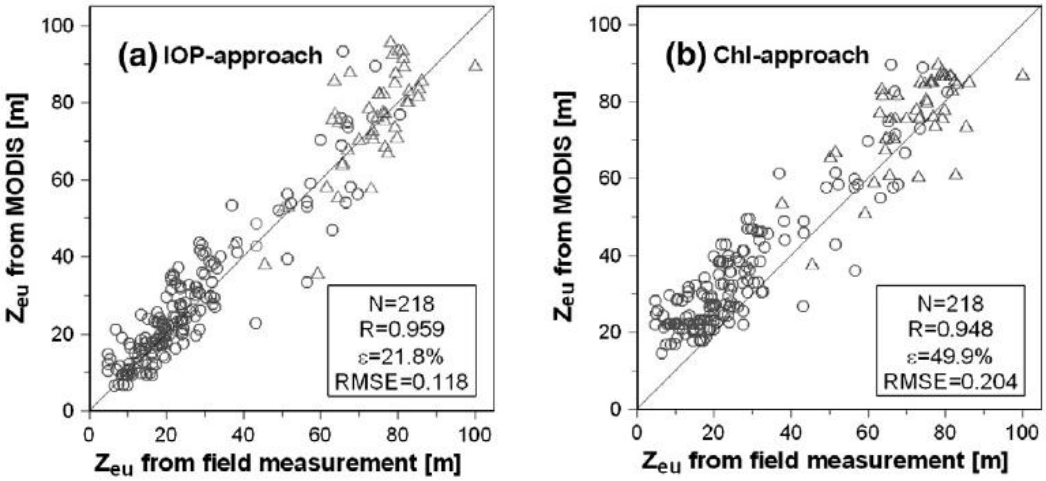



*Fig. 18. Comparison between satellite $Z_{eu}$ (by the IOP-approach (a) and Chl-approach (b)) and the $Z_{eu}$ derived from in situ measurements. Circles are samples on the shelf (depth ≤200 m) and triangles are those in the basin (depth N200 m); the same applied to the subsequent two figures*

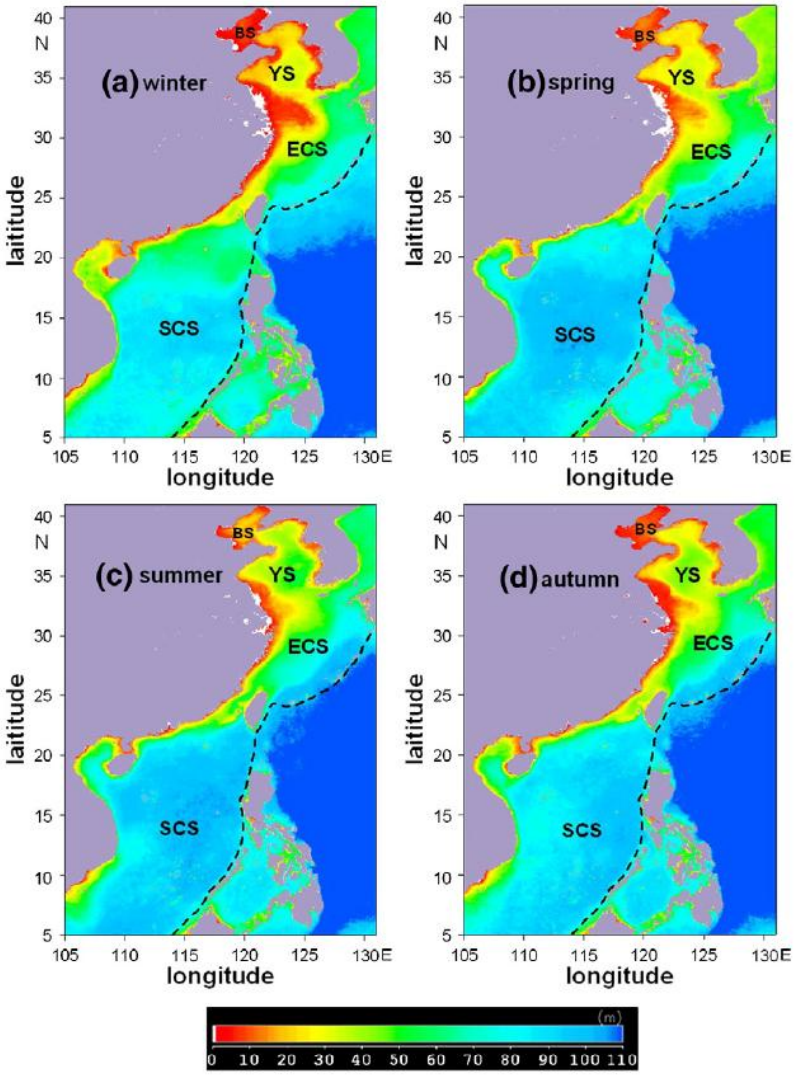



*Fig. 19. Climatological seasonal mean $Z_{eu}$ in the China Sea (IOP-approach, 2002-2009)*

**15. A Practical Bi-parameter Formula of Gas Transfer Velocity Depending on Wave States**

Zhao, D. L. and L. Xie, 2010. *Journal of Oceanography,* 66: 663-671

The parameter that describes the kinetics of the air-sea exchange of a poorly soluble gas is the gas transfer velocity which is often parameterized as a function of wind speed. Both theoretical and experimental studies suggest that wind waves and their breaking can significantly enhance the gas exchange at the air-sea interface. A relationship between gas transfer velocity and a turbulent Reynolds number related to wind waves and their breaking is proposed based on field observations and drag coefficient formulation. The proposed relationship can be further simplified as a function of the product of wind speed and significant wave height. It is shown that this biparameter formula agrees quantitatively with the wind speed based parameterizations under certain wave age conditions. The new gas transfer velocity attains its maximum under fully developed wave fields, in which it is roughly dependent on the square of wind speed. This study provides a practical approach to quantitatively determine the effect of waves on the estimation of air-sea gas fluxes with routine observational data.

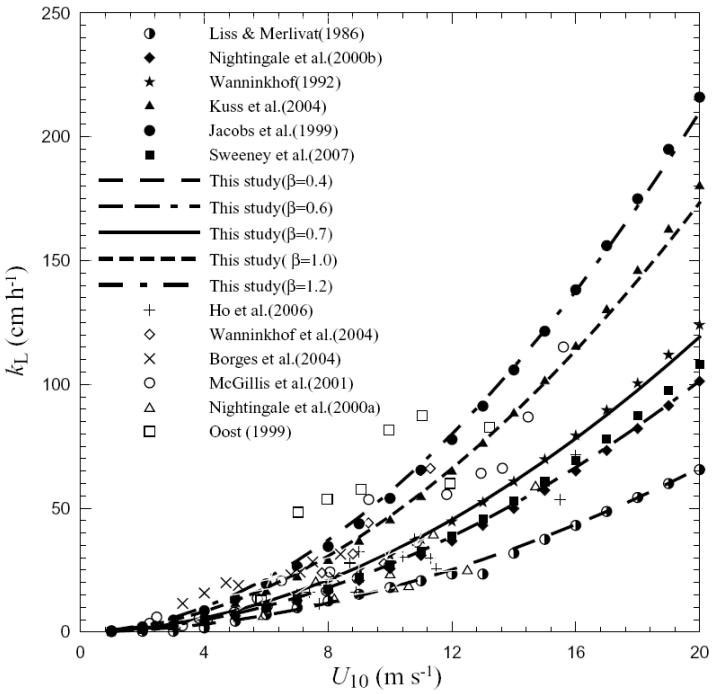



***Fig. 20. Comparisons of gas transfer velocity at wave age of 0.4, 0.6, 0.7, 1.0 and 1.2 with other parameterizations in terms of wind speed. Some observational data are also plotted in the figure***

## IV. Selected Publications：

**In 2009**

1. Bai, Y., X. He, D. Pan, Q. Zhu and F. Gong, 2009. The black water around the Yangtze River Estuary in spring of 2003. ***Acta Oceanologica Sinica,*** 28(4): 23-31.
2. Dai, M. H., Z. M. Lu, W. Zhai, B. Chen, Z. Cao, K. Zhou, W. J. Cai and C. T. A. Chen, 2009. Diurnal variations of surface seawater $pCO_2$ in contrasting coastal environments. ***Limnology and Oceanography,*** 54(3): 735-745.

3. Dai, M. H., F. F. Meng, T. T. Tang, S. J. Kao, J. R. Lin, J. Huang, J. W. Tian, J. P. Gan and S. Yang, 2009. Excess total organic carbon in the intermediate water of the South China Sea and its export to the North Pacific. ***Geochemistry Geophysics Geosystems*****,** 10, Q12002 DOI: 10.1029/2009GC002752.
4. Gan, J. P., A. Cheung, X. Guo and L. Li, 2009. Intensified upwelling over a widened shelf in the northeastern South China Sea. ***Journal of Geophysical Research-Oceans*****,** 114, DOI: 10.1029/2007JC004660.
5. Gan, J. P., L. Li, D. Wang and X. Guo, 2009. Interaction of a river plume with coastal upwelling in the northeastern South China Sea. ***Continental Shelf Research,*** 29(4): 728-740.
6. Gao, K. S., Z. Ruan, V. E. Villafane, J. P. Gattuso and E. W. Helbling, 2009. Ocean acidification exacerbates the effect of UV radiation on the calcifying phytoplankter Emiliania huxleyi. ***Limnology and Oceanography,*** 54(6): 1855-1862.
7. Guo, X. H., M. H. Dai, W. D. Zhai, W. J. Cai and B. S. Chen, 2009. $CO_2$ flux and seasonal variability in a large subtropical estuarine system, the Pearl River Estuary, China. ***Journal of Geophysical Research-Biogeosciences*****,** 114, G03013 DOI: 10.1029/2008JG000905.
8. He, X., Y. Bai, D. Pan, Q. Zhu and F. Gong, 2009. Cloud Top Height Retrieval Using Polarizing Remote Sensing Data of POLDER. ***Atmospheric and Oceanic Science Letters,*** 2(2): 73-78.
9. Qiu, Y., L. Li and W. Yu, 2009. Behavior of the Wyrtki Jet observed with surface drifting buoys and satellite altimeter. ***Geophysical Research Letters*****,** 36, L18607 DOI: 10.1029/2009GL039120.
10. Swapna, P., J. Gan, A. Lau and J. Fung, 2009. On the warm/cold regime shift in the South China Sea: Observation and modeling study. ***Deep Sea Research I,*** 56(7): 1039-1056.
11. Wu, H. and K. Gao, 2009. Ultraviolet radiation stimulated activity of extracellular carbonic anhydrase in the marine diatom Skeletonema costatum. ***Functional Plant Biology,*** 36(2): 137-143.
12. Xu, Z. and K. Gao, 2009. Impacts of UV radiation on growth and photosynthetic carbon acquisition in *Gracilaria lemaneiformis* (Rhodophyta) under phosphorus-limited and replete conditions. ***Functional Plant Biology,*** 36(12): 1057-1064.
13. Zhai, W. D., M. H. Dai and W. J. Cai, 2009. Coupling of surface $pCO_2$ and dissolved oxygen in the northern South China Sea: impacts of contrasting coastal processes. ***Biogeosciences,*** 6: 2589-2598.
14. Zhu, Y., S. L. Shang, W. D. Zhai and M. H. Dai, 2009. Satellite-derived surface water $pCO_2$ and air-sea $CO_2$ fluxes in the northern South China Sea in summer. ***Progress in Natural Science,*** 19(6): 775-779.
15. Zou, D. and K. Gao, 2009. Effects of elevated $CO_2$ on the red seaweed Gracilaria lemaneiformis (Gigartinales, Rhodophyta) grown at different irradiance levels. ***Phycologia,*** 48(6): 510-517.

**In 2010**

1. Bai, Y., X. Q. He, D. L. Pan, Q. K. Zhu, H. Lei, B. Y. Tao and Z. Z. Hao, 2010. The extremely high concentration of suspended particulate matter in Changjiang Estuary detected by MERIS data. . ***Proc. SPIE*** 7858 78581D.
2. Chen, B. Z., R. D. Tadonléké, J. K. Llopiz, F. Ballantyne Iv, K. Nakayama, M. S. Souza, C. Savage, G. W. Holtgrieve, C. Buchwald and R. Vaquer-Sunyer, 2010. Relationships between phytoplankton growth and cell size in surface oceans: Interactive effects of temperature, nutrients, and grazing. ***Limnology and Oceanography,*** 55(3): 965-972.
3. Dong, H. P., D. Z. Wang, M. Dai and H. S. Hong, 2010. Characterization of particulate organic

matters in the water column of the South China Sea using a shotgun proteomic approach. ***Limnology and Oceanography,*** 55(4): 1565-1578.

4. Gao, K. S. and Y. Zheng, 2010. Combined effects of ocean acidification and solar UV radiation on photosynthesis, growth, pigmentation and calcification of the coralline alga Corallina sessilis (Rhodophyta). ***Global Change Biology,*** 16(8): 2388-2398.
5. Gao, K. S. and Y. Q. Zheng, 2010. Combined effects of ocean acidification and solar UV radiation on photosynthesis, growth, pigmentation and calcification of the coralline alga Corallina sessilis (Rhodophyta). ***Global Change Biology,*** 16(8): 2388-2398.
6. Gan, J. P., Z. M. Lu, M. H. Dai, A. Y. Y. Cheung, H. Liu and P. Harrison, 2010. Biological response to intensified upwelling and to a river plume in the northeastern South China Sea: A modeling study. ***Journal of Geophysical Research*****,** 115, C09001 DOI: 10.1029/2009JC005569.
7. Guan, W. and K. Gao, 2010. Impacts of UV radiation on photosynthesis and growth of the coccolithophore Emiliania huxleyi (Haptophyceae). ***Environmental and Experimental Botany,*** 67(3): 502-508.
8. Guan, W. C. and K. S. Gao, 2010. Enhanced calcification ameliorates the negative effects of UV radiation on photosynthesis in the calcifying phytoplankter Emiliania huxleyi. ***Chinese Science Bulletin,*** 55(7): 588-593.
9. He, X., Y. Bai, Q. Zhu and F. Gong, 2010. A vector radiative transfer model of coupled ocean-atmosphere system using matrix-operator method for rough sea-surface. ***Journal of Quantitative Spectroscopy and Radiative Transfer,*** 111(10): 1426-1448.
10. He, X. Q., D. L. Pan, Q. K. Zhu, Z. Z. Hao and F. Gong, 2010. On-orbit assessment of the polarization response of COCTS onboard HY-1B satellite. ***Proc. SPIE*** 7862: 78620W.
11. Hu, J. Y., H. Kawamura, C. Y. Li, H. S. Hong and Y. W. Jiang, 2010. Review on current and seawater volume transport through the Taiwan Strait. ***Journal of Oceanography,*** 66(5): 591-610.
12. Huang, B. Q., J. Hu, H. Xu, Z. Cao and D. Wang, 2010. Phytoplankton community at warm eddies in the northern South China Sea in winter 2003/2004. ***Deep Sea Research II,*** 57(19-20): 1792-1798.
13. Kao, S. J., M. H. Dai, K. Selvaraj, W. Zhai, P. Cai, S. N. Chen, J. Y. T. Yang, J. T. Liu, C. C. Liu and J. P. M. Syvitski, 2010. Cyclone-driven deep sea injection of freshwater and heat by hyperpycnal flow in the subtropics. ***Geophysical Research Letters*****,** 37, L21702 DOI: 10.1029/2010GL044893.
14. Lu, Z. M., J. P. Gan, M. H. Dai and A. Y. Y. Cheung, 2010. The influence of coastal upwelling and a river plume on the subsurface chlorophyll maximum over the shelf of the northeastern South China Sea. ***Journal of Marine Systems*****,** 82, 35-46
15. Ma, Z., W. Li and K. Gao, 2010. Horizontal migration of Acartia pacifica Steuer (copepoda) in response to UV-radiation. ***Journal of Photochemistry and Photobiology B: Biology,*** 101: 233-237.
16. Ma, Z. L. and K. S. Gao, 2010. Spiral breakage and photoinhibition of Arthrospira platensis (Cyanophyta) caused by accumulation of reactive oxygen species under solar radiation. ***Environmental and Experimental Botany,*** 68(2): 208-213.
17. Pi, Q. L. and J. Y. Hu, 2010. Analysis of sea surface temperature fronts in the Taiwan Strait and its adjacent area using an advanced edge detection method. ***Science China (Earth Sciences),*** 53(7): 1008-1016.
18. Shang, S. L., Q. Dong, Z. P. Lee, Y. Li, Y. S. Xie and M. J. Behrenfeld, 2010. MODIS observed phytoplankton dynamics in the Taiwan Strait: an absorption-based analysis. ***Biogeosciences Discussion,*** 7: 7795-7819.

19. Shang, S. L., Z. P. Lee and G. M. Wei, 2011. Characterization of MODIS-derived euphotic zone depth: Results for the China Sea. ***Remote Sensing of Environment,*** 115: 180-186.
20. Thillai, R. K., M. Rajkumar, J. Sun, P. V. Ashok and P. Perumal, 2010. Bloom forming species of phytoplankton in two coastal waters, Southeast coast of India. ***Journal of Ocean University of China,*** 9(3): 265-272.
21. Wu, Y., K. Gao and U. Riebesell, 2010. $CO_2$-induced seawater acidification affects physiological performance of the marine diatom Phaeodactylum tricornutum. ***Biogeosciences,*** 7(9): 2915-2923.
22. Wu, Y. P. and K. S. Gao, 2010. Combined effects of solar UV radiation and $CO_2$-induced seawater acidification on photosynthetic carbon fixation of phytoplankton assemblages in the South China Sea. ***Chinese Science Bulletin,*** 55(32): 3680-3686.
23. Wu, Y. P., K. S. Gao, G. Li and E. W. Helbling, 2010. Seasonal Impacts of Solar UV Radiation on Photosynthesis of Phytoplankton Assemblages in the Coastal Waters of the South China Sea. ***Photochemistry and Photobiology,*** 86(3): 586-592.
24. Xu, J. and K. Gao, 2010. Use of UV‐A Energy for Photosynthesis in the Red Macroalga Gracilaria lemaneiformis. ***Photochemistry and photobiology,*** 86(3): 580-585.
25. Xu, J. and K. Gao, 2010. UV-A enhanced growth and UV-B induced positive effects in the recovery of photochemical yield in Gracilaria lemaneiformis (Rhodophyta). ***Journal of Photochemistry and Photobiology B: Biology,*** 100: 117-122.
26. Zhao, D. L. and L. Xie, 2010. A Practical Bi-parameter Formula of Gas Transfer Velocity Depending on Wave States. ***Journal of Oceanography,*** 66: 663-671.
27. Zou, D. and K. Gao, 2010. Acquisition of inorganic carbon by Endarachne binghamiae (Scytosiphonales, Phaeophyceae). ***European Journal of Phycology,*** 45(1): 117-126.
28. Zou, D. H. and K. S. Gao, 2010. Photosynthetic acclimation to different light levels in the brown marine macroalga, Hizikia fusiformis (Sargassaceae, Phaeophyta). ***Journal of Applied Phycology,*** 22(4): 395-404.

**V. Selected Conference Presentations:**

1. Delu Pan, “Why Ocean color in China?”, 14th IOCCG Committee meeting and International ocean color workshop, Apr. 20-24, 2009, Hangzhou, China. (invited talk)
2. Jun Sun, “Phytoplankton provinces in China Seas”, 3th China-Japan-Korea GLOBEC/IMBER Symposium, May 18-20, 2009, Jeju, South Korea. (invited talk)
3. KunShan Gao, “Ecological and physiological impacts of ocean acidification on marine calcifying algae”, 9th International Phycological Congress (IPC), Aug. 2-8, 2009, Tokyo, Japan. (invited talk)
4. Jianping Gan, "Intensifications of Upwelling and Nutrient Enrichment Induced by the Widened Shelf and River Plume in the Northeastern South China Sea”, International Workshop on Modeling the Ocean. Feb. 23-26, 2009, Taipei. (invited talk)
5. Minhan Dai, Changes in coastal ocean carbon cycling – current understanding and challenges, PICES 2010 Annual Meeting, North Pacific Ecosystems Today, and Challenges in Understanding and Forecasting Change, Science Board Symposium, Oct. 22-31, 2010, Portland, USA. (Invited talk)

6. Minhan Dai, Carbon Biogeochemistry of the South China Sea–current understanding and potential changes in the context of global change, The International Conference on Marine Environment and Biodiversity Conservation in the South China Sea, Jul. 16-17, 2010, Kaohsiung, China. (Plenary talk)
7. Minhan Dai, Carbon biogeochemistry under the influence of both a river plume and coastal upwelling in the Northern South China Sea, 2010 IPACES Annual Meeting, Jul. 1-2, 2010, Hangzhou, China. (Plenary talk)
8. Jianping Gan, Coastal upwelling, river plume and bio-geochemical responses in the eastern Guangdong, 2010 joint Canadian Meteorology and Ocean Society (CMOS) and Canadian Geophysical Society (CGS) Congress, May 31-June 4, 2010, Ottawa, Canada. (Invited talk)
9. Jun Sun, Phytoplankton provinces in China Seas- focus on the Yellow Sea and East China Sea spring bloom, 3rd China-Japan-Korea GLOBEC/IMBER Symposium, May 18-20, 2010, Jeju, South Korea. (Invited talk)
10. Dazhi Wang, Proteomics research of harmful algal bloom species, 9th International Marine Biotechnology Conference, Oct. 8-12, 2010, Qingdao, China. (Invited talk)
11. Jianyu Hu, Comparison between OFES results and in situ observations near the Luzon Strait, the 3rd OFES International Workshop, Nov. 4-5, 2010, Yokohama, Japan.
12. Jianyu Hu, Review on water volume transport and Kuroshio's intrusion through the Luzon Strait, International Workshop on NPOCE Implementation, Jan.17-18, 2010, Xiamen, China.
13. Shaoling Shang, Comparison between two primary productivity models in the Southern Ocean-preliminary results, SPIE Defense, Security and Sensing 2010, Apr. 5-9, 2010, Orlando, USA.
14. Shaoling Shang, Phytoplankton dynamics in the Taiwan Strait : MODIS observation, 2nd International Conference on Global Change and the Environment in Asia and Pacific (GCEAP), Inland Waters and Coastal Environment, Oct. 28-29, 2010, Hong Kong.
15. Shaoling Shang, Application of satellite ocean color data in biogeochemistry researches in the China Sea, I: Workshop for Ocean Colour Data Collection, Distribution and Utilization for East Asian Coastal Waters; II: the Korean-Japan Ocean Colour Workshops, Dec.18-20, 2010, Hokkaido, Japan.
16. Dazhi Wang, Proteomics analysis of intestinal protein profiles in mice acutely exposed to okadaic acid, 6th International Conference on Marine Pollution and Ecotoxicology, May 30-Jun. 3, 2010, Hong Kong.
17. Dazhi Wang, Comparative proteomics reveals different protein expression pattern and modifications in toxic and non-toxic alexandrium tamarence strains, 14th International Conference on Harmful Algae Invitation, Nov.1-6, 2010, Grace.

# Update concerning the DUNE project : January 2011.

A key moment of the DUNE project in 2010 was the new mesocosms experiment that took place in the Preservation area of Scandola (Corsica Island) in summer during which 7 large clean mesocosms have been deployed (6 were devoted to biogeochemistry: 3 'control', 3 'dust' and 1 additional 'dust' was devoted to optical measurements). 16 scientists from marine and atmosphere field covering a large spectrum of expertise (chemistry, biology, physics) were involved. The scientific objectives were the same as during the 2008 field experiment: to investigate the impact of Saharan dust inputs onto biogeochemical cycles of an oligotrophic environment but additional parameters were investigated and 2 successive seeding were performed. The two seeding corresponded to a 10 $g.m^{-2}$ deposition, identical to the one performed in 2008. A large panel of chemical and biological parameters were measured during 15 days to follow (1) the impact on chemical cycles of C, P, N, Si, Fe, Mn, Co, Al, (2) the response in term of abundance and diversity of viruses, bacteria, phytoplankton and zooplankton, (3) the impact of light, and (4) the impact on material and carbon export. For this last topic, a coupling of chemical and optical measurements were performed (a mesocosm was devoted to the optical measurements, figure 1). The experiment was successful as all the planned work was achieved thanks to excellent cohesion and efficiency of the team (both the local team from the preservation area of Scandola and the scientist) and … good meteorological conditions. Some results of this recent experiment will be presented by PhD students at the upcoming ASLO meeting.

Bressac Matthieu, Guieu Cécile, Doxaran David, Bourrin François, Wagener Thibaut and Obolensky Gregor, Fate and effects of Saharan dust in seawater: a simulated dust deposition during the DUNE (a Dust experiment in a low nutrient low chlorophyll ecosystem) project. Oral presentation, Session #:S52

Wuttig Kathrin, Anna Dammshäuser, Matthieu Bressac, Thibaut Wagener, Peter Streu, Cecile Guieu, Peter L. Croot, Temporal Changes in the Biogeochemistry of Mn, Fe and Al after an Artificial Dust Deposition to Large Mesocosms (DUNE Project), Oral presentation, Session #:S49

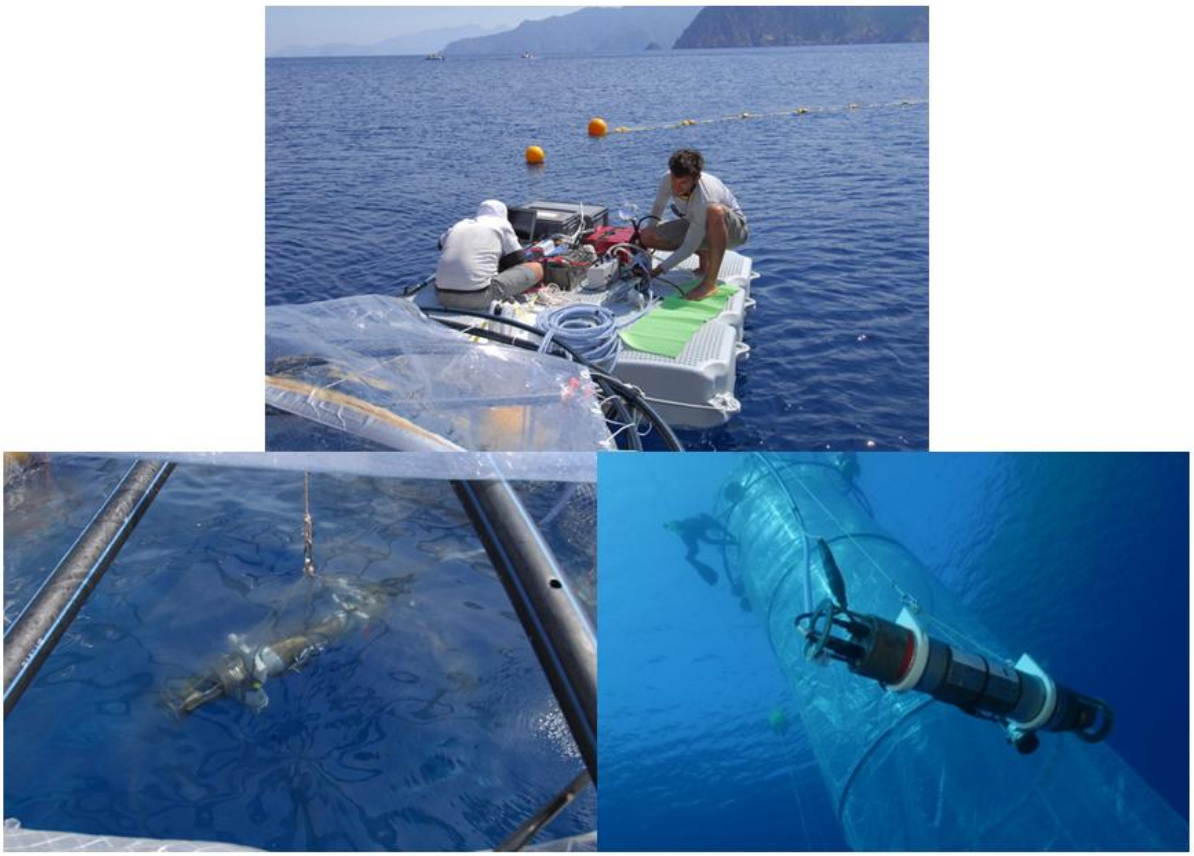


Figure 1. A view of the 2010 experiment: the mesocosms devoted to optical measurements to follow the concentration and the size of the sinking particles and to estimate the composition of the particulate assemblage (mineral vs organic). (top) The plate-form for data acquisition, (bottom, left) the optical cluster (3 instruments) in sub-surface during the seeding: the color beige is due to the Saharan particles that are sprayed at the surface, (bottom, right) a view of the optical cluster outside of the mesocosm while performing a 'control' without Saharan particles. Results show that particulate export after the seeding is a multistep process and that, as a function of time, the exported material has a variable proportion of mineral and organic particles. Among other results, the experimental setup allowed to show that the third export event occurred 20-28 hours after the seeding and was due to large aggregates composed by a mixing of organic and inorganic matter. This corresponded to the start of increase in chlorophyll induced by the dust addition: we can make the hypothesis that the organic matter is in part the one freshly produced via the fertilization. Preliminary results of this experiment were presented in 2010: Bressac M., Guieu C., Doxaran D., Bourrin F., Obolensky G. and Grisoni J.M.: Optical measurements to observe the fate of Saharan dust in seawater: a simulated dust deposition during the DUNE project. Particles in Europe (PiE) 2010, Villefranche-sur-mer, 15-17 November 2010.

2010 was also very fruitful as several manuscripts have been written following the 2008 field experiments. Several of those papers are now published.


Guieu C., F. Dulac, K. Desboeufs, T. Wagener, E. Pulido-Villena, J.-M. Grisoni, F. Louis, C. Ridame, S. Blain, C. Brunet, E. Bon Nguyen, S. Tran, M. Labiadh, and J.-M. Dominici, 2010, Large clean mesocosms and simulated dust deposition: a new methodology to investigate responses of marine oligotrophic ecosystems to atmospheric inputs, Biogeosciences, 7, 2765-2784, 2010

Wagener, T., Guieu C., Leblond N., Effects of dust deposition on iron cycle in the surface Mediterranean Sea: results from a mesocosm seeding experiment., Biogeosciences, 7, 3769-3781, 2010.

Laghdass M., S. Blain S., M. Besseling M., P. Catala P., C. Guieu C., I. Obernosterer I., Impact of Saharan dust on the microbial community during a large clean mesocosm experiment in the NW Mediterranean Sea, accepted, Aquatic Microbial Ecology, 2010

Pulido-Villena E., Rerolle V., Guieu C., 2010, Transient fertilizing effect of dust in P-deficient LNLC surface ocean, Geophysical Research letters, vol. 37, L01603, doi:10.1029/2009GL041415

Ye Y., Wagener T., Volker C., Guieu C., Dieter A. Wolf-Gladrow D.A., 2010, Dust deposition: iron source or sink? A case study, Biogeosciences Discuss., 7, 9219-9272, 2010

At least 3 manuscripts are still in progress and will be submitted soon.

Desboeufs, K., Guieu C., Dulac F. and Leblond, N.: Chemical and mass budget in sediment traps after dust fertilisation in large mesocosm: Assessment of new dust tracer to estimate lithogenic fluxes, in preparation, 2010.

Ridame, C., Biegala, I., Dekaemacker, J., Bonnet, S., L'Helguen, S., and Guieu, C.,: Impact of a Saharan dust event on N2 fixation and diazotrophs abundance in the NW Mediterranean Sea: results from a large clean mesocosm experiment, in preparation, 2010.

Guieu, C., Ridame, C., Pulido-Villena, E., Blain, S., Wagener, T., Dulac, F., Desboeufs, K., Pondaven, P., Leblond, N., Stemman, L., Obernesterer, I., and Dominici, J. M.: Dust inputs and marine carbon cycle: new insights from mesocosms study, in preparation, 2010.

In addition, 2 oral presentations at the ASLO 2011 meeting will be performed:

Dulac François, Desboeufs Karine, Bon Nguyen Elizabeth, Tran Sophie, Losno Rémi, Chevaillier Servanne, Guieu Cécile, Leblond Nathalie, Labiadh Mohamed, A method to produce large amounts of mineral dust for controlled in situ experiments on the marine biogeochemical impact of atmospheric deposition. Session #:S49

Guieu Cécile, Ridame Céline, Pulido-Villena Elvira, Blain Stéphane, Wagener Thibaut, Dulac Francois, Desboeufs Karine, Pondaven Philippe, Leblond Nathalie, Stemman Lars, Obernesterer Ingrid, Dominici Jean-Marie, Dust inputs and marine carbon cycle: new insights from mesocosms study. Session #:S49

The DUNE project was funded by the French Agence Nationale pour la Recherche (ANR). The project will officially end in 2011 and a final workshop will take place in Villefranche in March 2011. The mesocosms developed in the frame of DUNE are proposed in the frame of different project. The first will be the EU funded project MedSea and a pilot phase will consist in deploying 2 mesocosms in the Villefranche Bay in Septembre 2011.

**EPOCA progress update (2010)**

The European Project on Ocean Acidification (EPOCA) is the first international research effort on ocean acidification. Launched in May 2008 for four years, it comprises 31 European institutions from 10 countries and more than 100 scientists. EPOCA is partly funded by the European Commission (6.5 M€ for a total budget of 16 M€).

**Overall objectives**

The overall goal of EPOCA is to fill the numerous gaps in our understanding of the effects and implications of ocean acidification. More specifically, the project aims to:

- improve the understanding of the past and present spatio-temporal changes of ocean acidification due to increasing $CO_2$ uptake.
- determine the impacts of ocean acidification on marine biota, their physiology, ecosystems, the potential for acclimation and adaptation, the impacts on elemental cycling and production of climate-relevant gases.
- improve our understanding of future changes in ocean chemistry and biogeochemical feedbacks in terms of hotspots, uncertainties, and thresholds. EPOCA also seeks to improve the description of the carbon cycle in coupled ocean-climate models. The key element cycles investigated are carbon, nitrogen, sulfur and iron.
- synthesise information on tipping points.

**Scientific highlights**

EPOCA has generated a large number of critical data. From the launch of the project, 114 papers were published or are in press. In 2010, 65 papers were published (see Annex 1). Among the SOLAS-relevant main findings are:

- Data from the team of Luc Beaufort suggest heavier coccoliths at lower $pCO_2$ in the geological record, even if the pattern is sometimes out of sync.
- The team of Jon Olafson has shown a pH decline in the Iceland Sea between 1985 to 2008 1,5 times larger than that observed in the temperate Atlantic.
- Results from Marco Steinacher and colleagues show that 10% of the surface Arctic Ocean may be corrosive to aragonite within 10 years from now.
- Work by Claudine Hauri and colleagues suggest that some coastal upwelling systems are as vulnerable as polar regions.
- Comeau et al. have shown the first results on shelled pteropods, a 30% decrease in calcification rate at seawater characteristics anticipated for 2100. Maier et al. showed a 50% decrease in calcification rate in cold-water corals subjected to similar carbonate chemistry.

EPOCA carried out its second large-scale $CO_2$ perturbation experiment in Ny-Ålesund, Svalbard, from the end of May to mid-July 2010. For the first time, offshore mesocosms were used in the Arctic Ocean to study the impacts of ocean acidification on biological and chemical processes taking place in the water column. The mesocosms, developed by scientists at IFM-GEOMAR in Kiel, consist of 8 m high and 2 tons heavy floating frames containing 17 m long flexible bags. Each bags enclose a water column of approximately 40 cubic meters. The water enclosed in each one of the 9 mesocosms deployed was acidified by addition of high-$CO_2$ water, in order to achieve a range of $CO_2$ concentrations from present values (~385 µatm) to values expected for the middle of the next century (1000 – 1250 µatm). The mesocosms were sampled daily during a 5-week period. See the EPOCA 2010 Arctic blog for detailed information on the experiment: http://epocaarctic2010.wordpress.com/.

Experiments performed include:

- Viral and bacterial abundance, diversity and lipid composition.
- Biodiversity and abundance of protists using genetics and morphological aspects.
- Bacterial respiration and enzyme activity.
- Abundance, diversity, primary production and TEP production of phytoplankton.
- Community composition/diversity.
- Phytoplankton growth rate and zooplankton grazing rates.
- Production of climate-relevant gases (DMS, DMSP, DMSO, halocarbons).
- Oxygen cycling.

Preliminary results suggest alterations in community composition (bacteria and archaea) and in respiration rates (mesopelagic prokaryotes) at elevated $pCO_2$. The results are still being analyzed and preliminary conclusions will be presented at a special session of the 2011 EGU meeting in Vienna.

EPOCA scientists have, together with international colleagues, put together the community reviewed "Guide to best practices in ocean acidification research and data reporting". The final version was launched in May 2010 and is available online and in print (http://www.epoca-project.eu/index.php/Home/Guide-to-OA-Research/).

**Training**

35 students and post-docs selected from over 90 applicants participated in a one-week training workshop held at IFM-GEOMAR in Kiel, 8-12 March 2010. The workshop was a joint effort by EPOCA, the German project BIOACID, the FP7 Marie Curie Initial Training Network CalMarO and the US Ocean Carbon and Biogeochemistry program (OCB) and covered best practices in ocean acidification research. The program included 18 lectures and 16 hands-on practicals and was based on the "Guide to best practices in ocean acidification research and data reporting".

**Outreach**

During 2010, EPOCA continued to actively disseminate key research on ocean acidification, in particular via the Reference User Group (RUG). The RUG developed in 2010 to also support the German project BIOACID and the UK ocean acidification research programme (UKOARP). A follow-up document to the guide to policymakers produced by the RUG in 2009 was launched in November 2010 in Monaco with the endorsement of HSH Prince Albert II. The document is available in 5 languages on the EPOCA web site: http://epoca-project.eu/index.php/what-do-we-do/outreach/rug/oa-questions-answered.html).

Dissemination also took place via regular updates of the project web site (www.epoca-project.eu) and the blog, co-sponsored by SOLAS (http://oceanacidification.wordpress.com/). Other key outreach activities include:

- EPOCA Svalbard experiment blog http://epocaarctic2010.wordpress.com/
- In February 2010, EPOCA produced together with OCB and UKOARP "Frequently asked questions on ocean acidification": http://www.epoca-project.eu/index.php/what-is-ocean-acidification/faq.html.
- New 8 page educational document on the Arctic 2010 experiment and hands-on experiments for school teachers. Translation of a virtual laboratory on ocean acidification in French in cooperation with the Inquiry-to-Insight (I2I) project. See http://epoca-project.eu/index.php/what-do-we-do/education/classroom.html.
- EPOCA was present at COP16 in Cancun with a stand on ocean acidification organised with UKOARP, Plymouth Marine Laboratory and Oceana.
- Several EPOCA scientists contributed to the 52 minute long documentary, "Tipping Point", by Laurence Jourdan. The movie covers some of the EPOCA work such as the Svalbard 2010 campaign.

**International collaboration and activities**

EPOCA has developed strong interactions with national (BIOACID, UKOARP and US projects in the framework of the FOARAM act), as well as international (upcoming EU FP7 project MedSea). A joint EPOCA/BIOACID/UKOARP meeting was organised in September 2010 in Bremerhaven, Germany (see

http://epoca-project.eu/index.php/what-do-we-do/meetings/epoca-2010-meeting.html).

The EPOCA Executive Board members sit in the SOLAS-IMBER subgroup on ocean acidification, which had its second meeting in Washington DC, 29-30 November 2010.

Several EPOCA scientists are involved in the preparation of the Fifth Assessment Report of the IPCC.

**Data management**

EPOCA data management continued efficiently in 2010 and the EPOCA data ase now includes 30 archived data sets. In addition, a data compilation on ocean acidification initiated via the EU EUR-OCEANS project and taken over by EPOCA currently include 110 data sets from 130 papers. More information on the data compilation can be found in the article by Nisumaa et al. 2010:

Nisumaa A.-M., Pesant S., Bellerby R. G. J., Delille B., Middelburg J., Orr J. C., Riebesell U., Tyrrell T., Wolf-Gladrow D. & Gattuso J.-P., 2010. EPOCA/EUR-OCEANS data compilation on the biological and biogeochemical responses to ocean acidification. *Earth System Science Data* 2(2): 167-175.

**Upcoming activities**

Much of the results from the two major EPOCA experiments, the Svalbard 2009 and 2010 campaigns, will be presented at a special session at the upcoming EGU meeting in Vienna, 3-8 April 2011.

EPOCA's annual meeting 2011 will take place in Brussels from 9-13 May 2011. A three-day long science meeting will be followed by a meeting of the Ocean Acidification Reference User Group on 12 May and a public day with representation from the European Commission and the European Parliament on the 13th.

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## Annex 1 - List of publications 2010


Anderson L. G., Björk G., Hjalmarsson S., Jones E. P., Jutterström S., Rudels B., Swift J. H., Tanhua T. & Wåhlstöm I., 2010. Arctic Ocean shelf – basin interaction: an active continental shelf CO2 pump and its impact on the degree of calcium carbonate solubility. *Deep Sea Research I* 57:869-879.

Barry J. P., Hall-Spencer J. M. & Tyrrell T., 2010. *In situ* perturbation experiments: natural venting sites, spatial/temporal gradients in ocean pH, manipulative *in situ* p(CO2) perturbations. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 123-136. Luxembourg: Publications Office of the European Union.

Barry J. P., Tyrrell T., Hansson L., Plattner G.-K. & Gattuso J.-P., 2010. Atmospheric CO2 targets for ocean acidification perturbation experiments. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 53-66. Luxembourg: Publications Office of the European Union.

Bernie D., Lowe J., Tyrrell T. & Legge O., 2010. Influence of mitigation policy on ocean acidification. *Geophysical Research Letters* 37, L15704. doi:10.1029/2010GL043181.

Blackford J. C., 2010. Predicting the impacts of ocean acidification: challenges from an ecosystem perspective. *Journal of Marine Systems* 81:12-18.

Boudreau B. P., Middelburg J. J. & Meysman F. J. R., 2010. Carbonate compensation dynamics. *Geophysical Research Letters* 37:L03603.

Comeau S., Gorsky G., Alliouane S. & Gattuso J.-P., 2010. Larvae of the pteropod *Cavolinia inflexa* exposed to aragonite undersaturation are viable but shell-less. *Marine Biology* 157:2341–2345.

Comeau S., Jeffree R., Teyssié J.-L. & Gattuso J.-P., 2010. Response of the Arctic pteropod *Limacina helicina* to projected future environmental conditions. *PLoS ONE* 5, e11362. doi:10.1371/journal.pone.0011362.

De Bodt C., Van Oostende N., Harlay J., Sabbe K. & Chou L., 2010. Individual and interacting effects of pCO2 and temperature on *Emiliania huxleyi* calcification: study of the calcite production, the coccolith morphology and the coccosphere size. *Biogeosciences* 7:1401-1412.

de Kluijver A., Soetaert K., Schulz K. G., Riebesell U., Bellerby R. G. J. & Middelburg J. J., 2010. Phytoplankton-bacteria coupling under elevated CO2 levels: a stable isotope labelling study. *Biogeosciences* 7:3783-3797.

Deigweiher K., Hirse T., Bock C., Lucassen M. & Pörtner H.-O., 2010. Hypercapnia induced shifts in gill energy budgets of Antarctic notothenioids. *Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology* 180:347-359.

Dias B. B., Hart M. B., Smart C. W. & Hall-Spencer J. M., 2010. Modern seawater acidification: the response of foraminifera to high-CO2 conditions in the Mediterranean Sea. *Journal of the Geological Society* 167:843-846.

Dumousseaud C., Achterberg E. P., Tyrrell T., Charalampopoulou A., Schuster U., Hartman M. & Hydes D. J., 2010. Contrasting effects of temperature and winter mixing on the seasonal and inter-annual variability of the carbonate system in the Northeast Atlantic Ocean. *Biogeosciences* 7:1481-1492.

Dupont S., Dorey N. & Thorndyke M., 2010. What meta-analysis can tell us about vulnerability of marine biodiversity to ocean acidification? *Estuarine, Coastal and Shelf Science* 89:182-185.

Dupont S., Lundve B. & Thorndyke M., 2010. Near future ocean acidification increases growth rate of the lecithotrophic larvae and juveniles of the sea star *Crossaster papposus*. *Journal of Experimental Zoology Part B: Molecular and Developmental Evolution* 314B:382-389.

Dupont S., Ortega-Martínez O. & Thorndyke M., 2010. Impact of near-future ocean acidification on echinoderms. *Ecotoxicology* 19:449-462.

Engel A., Barcelos e Ramos J., Geider R., Hutchins D. A., Lee C., Rost B., Röttgers R. & Thingstad F., 2010. Production and export of organic matter. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 181-200. Luxembourg: Publications Office of the European Union.

Findlay H. S., Kendall M. A. & Widdicombe S., 2010. Relative influences of ocean acidification and temperature on intertidal barnacle post-larvae at the northern edge of their geographic distribution. *Estuarine, Coastal and Shelf Science* 86:675-682.

Fiorini S., Gattuso J.-P., van Rijswijk P. & Middelburg J. J., 2010. Coccolithophores lipid and carbon isotope composition and their variability related to changes in seawater carbonate chemistry. *Journal of Experimental Marine Biology and Ecology* 394:74-85.

Frölicher T. L. & Joos F., 2010. Reversible and irreversible impacts of greenhouse gas emissions in multi-century

projections with the NCAR global coupled carbon cycle-climate model. *Climate Dynamics* 35:1439-1459.

Frommel A. Y., Stiebens V., Clemmesen C. & Havenhand J., 2010. Effect of ocean acidification on marine fish sperm (Baltic cod: *Gadus morhua*). *Biogeosciences* 7:3915-3919.

Ganssen G., Peeters F., Metcalfe B., Anand P., Jung S., Kroon D. & Brummer G.-J., 2010. Quantifying sea surface temperature ranges of the Arabian Sea for the past 20 000 years. *Climate of the Past Discussions* 6:2795-2814.

Gattuso J.-P., Gao K., Lee K., Rost B. & Schulz K. G., 2010. Approaches and tools to manipulate the carbonate chemistry. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 41-52. Luxembourg: Publications Office of the European Union.

Gazeau F., Gattuso J.-P., Dawber C., Pronker A. E., Peene F., Peene J., Heip C. H. R. & Middelburg J. J., 2010. Effect of ocean acidification on the early life stages of the blue mussel *Mytilus edulis*. *Biogeosciences* 7:2051-2060.

Gutowska M. A., Melzner F., Langenbuch M., Bock C., Claireaux G. & Pörtner H.-O., 2010. Acid–base regulatory ability of the cephalopod (*Sepia officinalis*) in response to environmental hypercapnia. *Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology* 180:323-335.

Gutowska M. A., Melzner F., Pörtner H.-O. & Meier S., 2010. Cuttlebone calcification increases during exposure to elevated seawater pCO2 in the cephalopod *Sepia officinalis*. *Marine Biology*

Havenhand J., Dupont S. & Quinn G. P., 2010. Designing ocean acidification experiments to maximise inference. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 67-80. Luxembourg: Publications Office of the European Union.

Hofmann A. F., Middelburg J. J., Soetaert K., Wolf-Gladrow D. A. & FJR M., 2010. Proton cycling, buffering, and reaction stoichiometry in natural waters. *Marine Chemistry* 121:246-255.

Jones B. M., Edwards R. J., Skipp P. J., O'Connor C. D. & Iglesias-Rodriguez M. D., 2010. Shotgun proteomic analysis of *Emiliania huxleyi*, a marine phytoplankton species of major biogeochemical importance. *Marine Biotechnology (NY)*

Jutterström S. & Anderson L. G., 2010. Uptake of CO2 by the Arctic Ocean in a changing climate. *Marine Chemistry* 122:96-104.

Kranz S. A., Wolf-Gladrow D., Nehrke G., Langer G. & Rost B., 2010. Calcium carbonate precipitation induced by the growth of the marine cyanobacteria *Trichodesmium*. *Limnology and Oceanography* 55:2563-2569.

Krug S., Schulz K. & Riebesell U., 2010. Effects of CO2-induced changes in seawater carbonate chemistry speciation on *Coccolithus braarudii*: a conceptual model of coccolithophorid sensitivities. *Biogeosciences Discussions* 7:8763-8778.

Langdon C., Gattuso J.-P. & Andersson A., 2010. Measurements of calcification and dissolution of benthic organisms and communities. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 213-232. Luxembourg: Publications Office of the European Union.

Langer G., De Nooijer L. J. & Oetjen K., 2010. On the role of the cytoskeleton in coccolith morphogenesis: the effect of cytoskeleton inhibitors. *Journal of Phycology* 46:1252–1256.

Lannig G., Eilers S., Pörtner H.-O., Sokolova I. M. & Bock C., 2010. Impact of ocean acidification on energy metabolism of oyster, *Crassostrea gigas* - changes in metabolic pathways and thermal response. *Marine Drugs* 8:2318-2339.

LaRoche J., Rost B. & Engel A., 2010. Bioassays, batch culture and chemostat experimentation. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 81-94. Luxembourg: Publications Office of the European Union.

Liu J., Weinbauer M. G., Maier C., Dai M. & Gattuso J.-P., 2010. Effect of ocean acidification on microbial diversity, and on microbe-driven biogeochemistry and ecosystem functioning. *Aquatic Microbial Ecology* 61:291-305.

Lombard F., da Rocha R. E., Bijma J. & Gattuso J.-P., 2010. Effect of carbonate ion concentration and irradiance on calcification in planktonic foraminifera. *Biogeosciences* 7:247-255.

Marchant H. K., Calosi P. & Spicer J. I., 2010. Short-term exposure to hypercapnia does not compromise feeding, acid–base balance or respiration of *Patella vulgata* but surprisingly is accompanied by radula damage. *Journal of the Marine Biological Association of the United Kingdom* 90:1379-1384.

McQuatters-Gollop A., Burkill P. H., Beaugrand G., Johns D. J., Gattuso J.-P. & Edwards M., 2010. Atlas of calcifying plankton: results from the continuous plankton recorder survey. 20. Plymouth, UK: EPOCA and Sir

Alister Hardy Foundation for Ocean Science.

Müller M. N., Schulz K. G. & Riebesell U., 2010. Effects of long-term high CO2 exposure on two species of coccolithophores. *Biogeosciences* 7:1109-1116.

Nisumaa A.-M., Pesant S., Bellerby R. G. J., Delille B., Middelburg J., Orr J. C., Riebesell U., Tyrrell T., Wolf-Gladrow D. & Gattuso J.-P., 2010. EPOCA/EUR-OCEANS data compilation on the biological and biogeochemical responses to ocean acidification. *Earth System Science Data* 2:167-175.

Oschlies A., Blackford J., Doney S. C. & Gehlen M., 2010. Modelling considerations. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 233-242. Luxembourg: Publications Office of the European Union.

Pesant S., Hook L. A., Lowry R., Moncoiffé G., Nisumaa A.-M. & Pfeil B., 2010. Safeguarding and sharing ocean acidification data. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 243-258. Luxembourg: Publications Office of the European Union.

Piontek J., Lunau M., Händel N., Borchard C., Wurst M. & Engel A., 2010. Acidification increases microbial polysaccharide degradation in the ocean. *Biogeosciences* 7:1615-1624.

Pörtner H.-O., 2010. Oxygen- and capacity-limitation of thermal tolerance: a matrix for integrating climate-related stressor effects in marine ecosystems. *Journal of Experimental Biology* 213:881-893.

Pörtner H.-O., Bickmeyer U., Bleich M., Bock C., Brownlee C., Melzner F., Michaelidis B., Sartoris F.-J. & Storch D., 2010. Studies of acid-base status and regulation. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 137-166. Luxembourg: Publications Office of the European Union.

Pörtner H.-O., Dupont S., Melzner F., Storch D. & Thorndyke M., 2010. Studies of metabolic rate and other characters across life stages. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 167-180. Luxembourg: Publications Office of the European Union.

Pörtner H.-O. & Peck M. A., 2010. Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. *Journal of Fish Biology* 77:1745-1779.

Pörtner H. O., Schulte P. M., Wood C. M. & Schiemer F., 2010. Niche dimensions in fishes: an integrative view. *Physiological and Biochemical Zoology* 83:808-826.

Provoost P., van Heuven S., Soetaert K., Laane R. W. P. M. & Middelburg J. J., 2010. Seasonal and long-term changes in pH in the Dutch coastal zone. *Biogeosciences* 7:3869-3878.

Raitzsch M., Dueñas-Bohórquez A., Reichart G.-J., de Nooijer L. J. & Bickert T., 2010. Incorporation of Mg and Sr in calcite of cultured benthic foraminifera: impact of calcium concentration and associated calcite saturation state. *Biogeosciences* 7:869-881.

Ridgwell A. & Schmidt D. N., 2010. Past constraints on the vulnerability of marine calcifiers to massive carbon dioxide release. *Nature Geoscience* 3:196 - 200.

Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P., 2010. Guide to best practices for ocean acidification research and data reporting, 260 p. Luxembourg: Publications Office of the European Union.

Riebesell U., Lee K. & Nejstgaard J. C., 2010. Pelagic mesocosms. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 95-112. Luxembourg: Publications Office of the European Union.

Rodolfo-Metalpa R., Lombardi C., Cocito S., Hall-Spencer J. M. & Gambi M. C., 2010. Effects of ocean acidification and high temperatures on the bryozoan *Myriapora truncata* at natural CO2 vents. *Marine Ecology* 1-9.

Rodolfo-Metalpa R., Martin S., Ferrier-Pagès C. & Gattuso J.-P., 2010. Response of the temperate coral *Cladocora caespitosa* to mid- and long-term exposure to pCO2 and temperature levels projected for the year 2100 AD. *Biogeosciences* 7:289-300.

Small D., Calosi P., White D., Spicer J. I. & Widdicombe S., 2010. Impact of medium-term exposure to CO2 enriched seawater on the physiological functions of the velvet swimming crab *Necora puber*. *Aquatic Biology* 10:11-21.

Smith S. V. & Gattuso J.-P., 2010. Balancing the oceanic calcium carbonate cycle: consequences of variable water column Ψ. *Aquatic Geochemistry*

Steinacher M., Joos F., Frölicher T. L., Bopp L., Cadule P., Cocco V., Doney S. C., Gehlen M., Lindsay K., Moore J. K., Schneider B. & Segschneider J., 2010. Projected 21st century decrease in marine productivity: a multi-model

analysis. *Biogeosciences* 7:979-1005.

Thomsen J., Gutowska M. A., Saphörster J., Heinemann A., Trübenbach K., Fietzke J., Hiebenthal C., Eisenhauer A., Körtzinger A., Wahl M. & Melzner F., 2010. Calcifying invertebrates succeed in a naturally CO2 enriched coastal habitat but are threatened by high levels of future acidification. *Biogeosciences* 7:3879-3891.

Tittensor D. P., Baco A. R., Hall-Spencer J. M., Orr J. C. & Rogers A. D., 2010. Seamounts as refugia from ocean acidification for cold-water stony corals. *Marine Ecology* 31:212-225.

Turley C., Eby M., Ridgwell A. J., Schmidt D. N., Findlay H. S., Brownlee C., Riebesell U., Fabry V. J., Feely R. A. & Gattuso J.-P., 2010. The societal challenge of ocean acidification. *Marine Pollution Bulletin* 60:787-792.

Walther K., Anger K. & Pörtner H.-O., 2010. Effects of ocean acidification and warming on the larval development of the spider crab *Hyas araneus* from different latitudes (54° vs. 79°N). *Marine Ecology Progress Series* 417:159-170.

Widdicombe S., Dupont S. & Thorndyke M., 2010. Laboratory experiments and benthic mesocosm studies. In: Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), *Guide to best practices for ocean acidification research and data reporting*, pp. 113-122. Luxembourg: Publications Office of the European Union.

FLATOCOA - January 2011 Update

December 2010 is the end of the sampling period and the beginning of intense laboratory work including measurements and modelling. About 180 samples were collected at Kerguelen (2 years) and Crozet (1 year) islands. At the date where we are writing this, half of the samples are still travelling back to the lab. Because of the shipping and delivery difficulties on these areas, only the first year of Kerguelen sample have been analysed but some major conclusions can be done on the measured flux of metals and metalloid, as partially indicated in the March 2010 update:

- Measured flux of continental dust is in good agreement with previously modelled by global deposition models: **490 ± 60 µg.m$^{-2}$.d$^{-1}$ of dust** as a yearly average over Kerguelen.
- Measured aerosol concentration at ground level is definitively not representative of the air column and cannot be used to foreseen deposition flux: scavenging ratios would be as high as unrealistic 20000 (kg/kg).
- Duplicate sampling at the same location is necessary to validate sampling and measurements, because this work will give the first measurements ever done.

Enough data and interpretation is now established to be submitted for publication during year 2011 and will be part of the PhD thesis of Alexie Heimburger who joins the program.

*Flux and concentration measurement methods*

Deposition samples are collected in 1 L PP bottles (Nalgene™) acidified with UPA Romil™ nitric acid (1%) and a 12 cm diameter PTFE funnel. Water in bottles appears very clean without any visible particles. Analyses were made on unfiltered samples by HR-ICP-MS (Thermo Element II) and ICP-AES (Spectro ARCOS) with an ultrasonic nebulization (CETAC). Aerosol is collected by pumping 200 to 500 cubic meters of air through Zefluor 47mm diameter and 0.5µm porosity filters at a 1 m$^3$/h rate. Analyse was done by XRF (Pananalytical 2400).

Measured elements by XRF in aerosols are Al, Si but also Na, Mg, S, K and Ca.

Flux is measured for the elements given in figure 1:

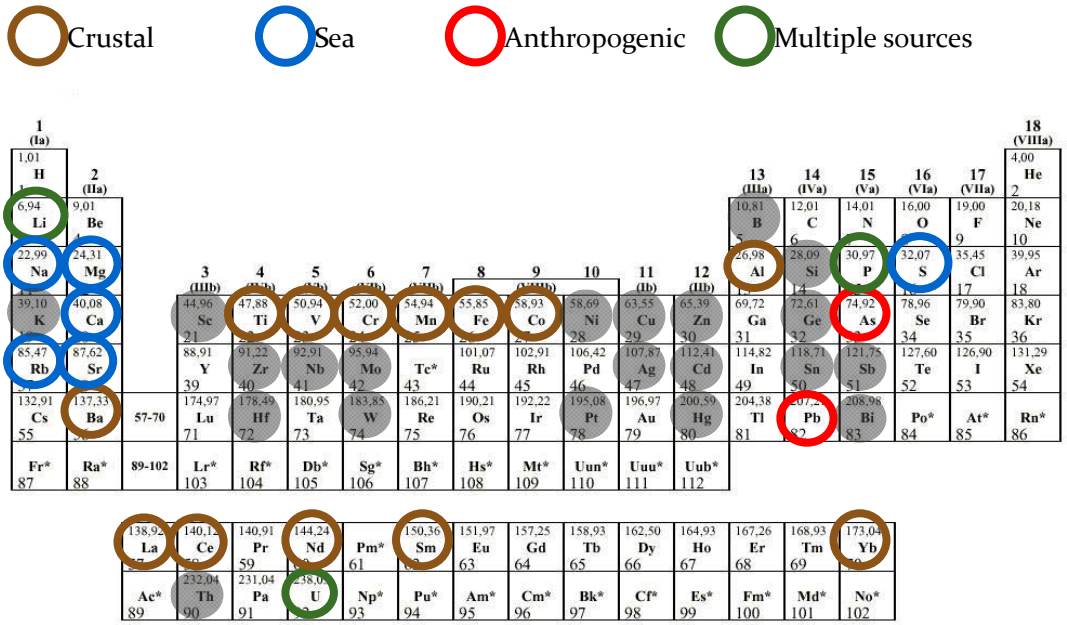


***Figure 1:*** Elements where flux is measured. Greyed disks are well measured elements but under detection limits.

*An example of technical achievements on the field*

Carrying out clean sampling on the field needs clean places to perform manipulation and sample preparations. We have deployed during the field campaign a mobile clean room made with laminar flow benches and plastic films. The volume inside the plastic tent is inflated by the air blown by the benches. Environment is ISO-1 in the benches and ISO-5 at the desk level in the room.

***Photo 1:*** a view of the mobile clean room at Kerguelen (BioMar building).