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Joint SOLAS-IMBER Ocean Carbon Research

This issue of SOLAS news focuses on research associated with SOLAS Focus 3 - Air-Sea Flux of CO₂ and Other Long-Lived Radiatively Active Gases. Its objective is to characterise the air-sea flux of these gases and the boundary-layer mechanisms that drive them, in order to assess their sensitivity to variations in environmental forcing.

As the two SCOR/IGBP projects, SOLAS and IMBER (Integrated Marine Biogeochemistry and Ecosystem Research) have direct interest in, and responsibilities for, observations and research on several aspects of the global ocean carbon cycle, they established a joint SOLAS/IMBER Carbon Group (SIC Group) in collaboration with IOCCP (International Ocean Carbon Coordination Project). Recognising the need for scientific discussion and coordination of marine carbon research, a joint implementation plan was developed (available at www.solas-int.org). The SIC group is currently subdivided into three working groups. In this issue you will find an introduction to each of these groups’ goals alongside scientific articles from researchers involved.

After such a busy few months, this issue includes reports from a wide range of meetings and conferences including the SOLAS Mid-Term Strategy Initiative meeting on “Air-sea gas fluxes at Eastern Boundary Upwelling and Oxygen Minimum Zones (OMZs) systems”, GEOTRACES Mediterranean and Asia planning workshops, the COST Action 735 funded meeting on “Atmospheric versus land based controls of nutrient cycling and production in the surface ocean: from fieldwork to modelling”, IGBP/SCOR Fast Track Initiative on ‘Upper ocean nutrient limitation: Processes, patterns and potential for change’ and many more.

In this issue we also introduce 4 new members of the SOLAS Scientific Steering Committee (see In Focus) as well as a new SOLAS Project Integrator.

Photo: two research vessels of the Instituto del Mar del Perú, (in red the Humboldt and in white the Jose Olaya Balandra) seen in the Callao Bay, in front of the Institute. Photo taken by William Miller during the Air-sea gas fluxes at Eastern Boundary Upwelling and Oxygen Minimum Zones (OMZs) systems meeting. See page 29
Jean-Pierre Gattuso is a Senior CNRS Scientist who coordinates the European Project on Ocean Acidification (EPOCA) and chairs the SOLAS-IMBER Working Group on Ocean Acidification. His main research interest relates to the cycling of carbon and carbonate, with special emphasis on the effects of environmental changes. He is Founding President of the EGU Biogeosciences Division and Founding editor-in-chief of the journal Biogeosciences.

Nicolas Gruber's research focuses on biogeochemical cycles and their interaction with the climate system from global to regional scales. His goal is to better understand the physical, chemical and biological processes that control these cycles and to be able to make predictions for the future, especially with regard to the potential feedbacks between the global carbon cycle and a changing climate. His primary research tools are the interpretation and analysis of observational data coupled with the use of models ranging in complexity from simple box models to general circulation models.

Nicolas Metzl has been involved in CO2 cycle research since the WOCE-JGOFS era. He is the co-ordinator of a long-term observational project (OISO, Indian and Southern Oceans) for understanding the variability of ocean CO2 and air-sea CO2 fluxes. Nicolas has been chair of the SOLAS/IMBER Carbon group on Surface Ocean Systems since 2005.

The SOLAS-IMBER working groups on ocean carbon were established in October 2005 with the task to implement the joint SOLAS-IMBER Ocean Carbon research plan. Initially, three working groups (WG) were defined: WG1 and WG2 focusing on the carbon cycle in the surface ocean and ocean interior, respectively and WG3 tasked with developing plans and strategies for ocean manipulation experiments. The latter group was re-focused in September 2009 and became the working group on ocean acidification. The groups are jointly sponsored by IMBER and SOLAS, but also interact strongly with other international bodies, especially with the International Ocean Carbon Coordination Project (IOCCP).

Since their inception, the three groups have made substantial progress toward the accomplishment of their goals, but clearly much remains to be done.

**WG1 – Surface Ocean Systems**

The main goal of the surface ocean working group (WG1) is to enable the community to estimate the ocean-atmosphere CO2 flux globally and regionally with substantially higher accuracy than previously possible. The key current activity of WG1, to support this goal, is the collection and construction of an international sea surface pCO2 data-base, called SOCAT (Surface Ocean Carbon ATlas, see www.socat.info/, Figure 1). In the last two years, regional SOCAT meetings have been organised to progress on the data quality control (QC) and initial syntheses. The QC effort has progressed well and the first release of SOCAT will take place in 2011. The SOCAT product will help the international carbon community on various topics: it will improve regional and global air-sea CO2 flux estimates; it will permit us to evaluate pCO2 changes and trends; it will offer new constraints for atmospheric and oceanic inverse methods and it will provide crucial data to evaluate ocean and climate models.

**WG2 – Interior Ocean**

The main objective of the interior ocean working group (WG2) is to support the global community in its effort to determine the oceanic uptake, transport, and storage of anthropogenic CO2. An additional objective is the establishment of a novel observing system for ocean biogeochemistry on the basis of oxygen sensors mounted on Argo floats. The key current activity is the quality control and synthesis of interior carbon observations from the Repeat Hydrography Program. The goal is to establish a global estimate of the change in the oceanic storage of anthropogenic CO2 since the mid 1990s when the first global CO2 survey in the ocean was completed. This estimate will be of fundamental importance for the understanding of the global carbon cycle and the fate of the CO2 emitted into the atmosphere as a result of human activities, as it constrains the second of three key reservoirs, leaving only the terrestrial biosphere as an unknown. A major step toward the accomplishment of this goal is the organisation of a joint WG1 and WG2 international ocean CO2 meeting (about 3-4 days) in the fall of 2011 in order to prepare new analyses and community publications to be included in the upcoming Intergovernmental Panel on Climate Change (IPCC) report.

**WG3 – Ocean Acidification**

The main goal of the working group on ocean acidification (WG3) is to coordinate international research efforts in ocean acidification and undertake synthesis activities in ocean acidification at the international level. Several on-going synthesis activities, such as book projects and work by the IPCC are endorsed by the working group. One of the key current activities is the “SOLAS-IMBER ocean acidification coordinating program”, a package of activities which are critical to...
assess the effects of ocean acidification but are, for the most part, not funded at national or regional levels and must be carried out at the international level. Among them are the promotion of international experiments, the sharing of experimental platforms and the undertaking of intercomparison exercises. The working group has realised that it does not have the time nor the human and financial resources to launch any of the activities that it has identified. Hence, it is considering establishing an “Ocean Acidification International Coordination Office (OA-ICO)” (Figure 2). Ways to achieve its implementation will be investigated in the coming months.

Key joint goals and activities shared between the three working groups are the establishment and continuous support for ocean observing systems and in particular the integration of the different observing elements into a coherent set of observations. To this end, several white papers and plans were developed in the context of the OceanObs ’09 conference (e.g. Monteiro et al., 2010; Gruber et al., 2010a, Hood et al., 2010, and Feely et al., 2010) and integrated into overarching frameworks by Gruber et al. (2010b) and Iglesias-Rodriguez et al. (2010).

References:


Factors that may (or may not) affect calcification in foraminifera

Antje Funcke, Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, D-27570 Bremerhaven, Germany
Contact: Antje.Funcke@awi.de

Dissolved magnesium (Mg$^{2+}$) levels in seawater have varied in the geological past mainly due to tectonic processes. Today the Mg$^{2+}$ concentration is ca. 50 mM and high enough to contribute to the inhibition of inorganic calcium carbonate (CaCO$_3$) precipitation in the sea surface ocean, even though such waters are supersaturated with respect to aragonite and calcite, two biogenically produced CaCO$_3$ polymorphs. Foraminifera (amoeboid protists) are a prominent group of organisms producing calcite. Most foraminifera precipitate low-Mg calcite in spite of the high Mg$^{2+}$ concentrations in seawater. In order to do so, they have to exclude Mg$^{2+}$ from the calcification site, most likely at the expense of metabolic energy. At the calcification site, the fluid from which the calcite is precipitated has to be supersaturated with respect to low-Mg calcite. It could be expected that higher supersaturation in seawater would make this process more cost-efficient. However, seawater saturation of calcite is currently decreasing due to ocean acidification (OA), a process encompassing the dissolution of anthropogenic CO$_2$ in seawater and the subsequent decrease of pH (hence the name OA) and also the decrease in carbonate ion (CO$_3^{2-}$) concentrations. Two hypotheses derived from the above are as follows:

1) High Mg$^{2+}$ concentrations of seawater hamper calcification in foraminifera; and
2) OA will also hamper calcification.

To test the first hypothesis and to investigate the impact of Mg$^{2+}$ on calcification in foraminifera, juveniles of the low-Mg calcite precipitating foraminifera *Ammonia tepida* were cultured under experimental laboratory conditions. *A. tepida* is a cosmopolitan, benthic species, abundant in intertidal and shallow water sediments.

![Figure 1: Growth rates of *A. tepida* in the different magnesium treatments. Error bars represent standard deviations of the mean values.](image-url)
more energy than simply removing Mg\(^{2+}\) via seawater vacuoles would probably cost 100 mM, and lowest at Mg\(^{2+}\) then use them for calcification (Figure 2a). It was expected to find highest growth rates at Mg\(^{2+}\) concentrations of 10 mM and lowest growth rates at Mg\(^{2+}\) concentrations of 100 mM. Contrary to the expectations, results showed the highest growth rates of A. tepida at Mg\(^{2+}\) concentrations of modern seawater. Growth rates were only slightly lower at Mg\(^{2+}\) concentrations of 100 mM, and lowest at Mg\(^{2+}\) concentrations of 10 mM (Figure 1).

Results show that high Mg\(^{2+}\) concentrations do not severely influence calcification in A. tepida. This reflects most likely the adaptation of A. tepida to today's Mg\(^{2+}\) concentrations. Earlier studies (e.g., Chang et al. 2004; de Nooijer et al. 2009) suggested that foraminifera modify endocytosed seawater vacuoles and then use them for calcification (Figure 2a). A possible pumping of Mg\(^{2+}\) from the seawater vacuoles would probably cost more energy than simply removing Mg\(^{2+}\) via exocytosis and would have resulted in much lower growth rates. Since this was not the case, it can be concluded that A. tepida does not use modified seawater vacuoles as its calcification fluid. It is rather supposed that the cell extracts the necessary ions like Ca\(^{2+}\) and CO\(_3^{2-}\) from the vacuoles, while residual Mg\(^{2+}\) is exocytosed (Figure 2b).

The study showed that the high Mg\(^{2+}\) concentrations of modern seawater do not hamper calcification in the foraminifera A. tepida. The effects of OA on calcification in this species have been investigated by colleagues. Their initial results (Dissard et al. 2010) indicate much less sensitivity to carbonate changes than was previously found for the planktonic foraminifera Orbula universa (Bijma et al. 1999).

To draw reliable conclusions regarding the effect of OA on calcification, further research needs to be done on calcification mechanisms and observations of different studies need to be combined. Since often different species as well as different methods are applied, this goal is a challenging, yet interesting, task for the future.

References:


SOLAS Canada

The Canadian International Polar Year (IPY) Arctic SOLAS program is reaching its end (March 2011). Hence, most SOLAS researchers have been busy finalising the analysis of the samples collected in the High Canadian Arctic during the 2008 cruise. These field observations were complemented by SOLAS-related studies carried out as part of the IPY Circumpolar Flaw Lead (CFL) study in 2007-2008, with a year-round wintering 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 Journal of Geophysical Research (Oceans or Atmospheres) in the next few months. Two SOLAS-related 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.

At the Allen Bay ice camp outside of Resolute, we conducted an interdisciplinary study of carbon dioxide and DMS biogeochemistry and fluxes in sea ice. 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. Other SOLAS relevant work initiated in 2006 on the Scotian Shelf investigating the air-sea fluxes of CO\(_2\) and controlling mechanisms from short-term to multi-annual timescales are highlighted elsewhere in this SOLAS Newsletter.

Finally, a Quebec-Shandong workshop examining the impacts of ocean acidification on marine resources and biogeochemical cycles was held in Qingdao, China, 6-8 December 2010.

National Representative

Maurice Levasseur

(Maurice.Levasseur@bio.ulaval.ca)
SOLAS Taiwan - ROC

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 goals of LORECS are 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. In the past decade, LORECS scientists have conducted repeated expeditions, including 9 cruises this year, in the East China Sea and the adjacent western North Pacific. Recently they investigated the chemical compositions of Asian dusts collected over the same area. They found significant amounts of air pollutants from the fast developing industrial areas in 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 fertilise 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 north-eastern Taiwan in 2008, scientists observed sea surface temperature drop by an average of 3°C resulting from enhanced upwelling. By deploying floating traps, they found the sinking flux of particulate organic carbon increased by up to 70% above the normal level of 140-180 mg C m⁻² d⁻¹. Numerical models have been developed to investigate the coupling between physical and biogeochemical processes in the East China Sea. Numerical experiments have demonstrated solar radiation as the main control of the seasonal variation of primary production in the East China Sea, while the riverine nutrient loading further boosts the high productivity in summer.

National Representative
Gwo-Ching Gong
(gcgong@mail.ntou.edu.tw)

Claire Lo Monaco has been a Research Associate in marine biogeochemistry at LOCEAN-IPSL (Paris, France) since 2006. Her research is focused on observing and understanding the changes in the Southern Ocean carbon cycle in relation to global changes.

**Observed changes in dissolved inorganic carbon in mode waters: the interplay between anthropogenic CO₂ uptake and ocean variability**

Claire Lo Monaco¹, Nicolas Metzl¹ and Andrew Lenton²

¹Laboratoire d’Océanographie et du Climat: Expérimentation et Approches Numériques - LOCEAN/IPSL - Université Paris 6 - 4 place Jussieu - 75252 Paris cedex 5 - France.
²CSIRO Marine and Atmospheric Research - Castray Esplanade - Hobart, Tasmania 7000, Australia.

Contact: claire.lomonaco@locean-ipsl.upmc.fr

Understanding the current perturbations of the ocean carbon cycle is crucial to identify the potential feedback to climate change. The invasion of anthropogenic CO₂ in the ocean has been one of the major concerns. Different methods were developed to derive anthropogenic CO₂ concentrations from ocean observation, all assuming that the ocean operates at steady state (Vázquez-Rodriguez et al., 2009; Khatiwala et al., 2009). However, climate variability may also impact on the distribution of dissolved inorganic carbon in the ocean (e.g. Rodgers et al., 2009). Here we investigate these changes observed in the South Indian Ocean, a region where anthropogenic CO₂ is believed to accumulate rapidly, (e.g. Khatiwala et al., 2009).

Mode waters are key in this oceanic uptake by providing a direct pathway between the surface and interior ocean at mid-latitudes (Figure 1).

We compared measurements collected 15 years apart during the INDIGO and OISO cruises, which form part of the new quality controlled CARINA dataset (Lo Monaco et al., 2010). Dissolved inorganic carbon (DIC) measurements show a clear increase in mode waters by 5-10 µmol/kg over the 15-year period (Figure 2a). This signal, however, is lower than the 15 µmol/kg increase expected by assuming oceanic CO₂ uptake is close to the trend in atmospheric CO₂. The INDIGO and OISO data also allow the anthropogenic CO₂ (CANT) increase to be calculated over this time period using different calculation methods.

**Figure 1**: Distribution of anthropogenic carbon (Cant) at 500m estimated from observations collected in the 1990's during WOCE (1995-1996, black circles) and OISO cruises (1998-2001, grey triangles). Cant calculation is derived from Lo Monaco et al. (2005). Inverted triangles show the position of the historical data INDIGO1 (1985). Potential density (σθ) is also shown (grey lines).
In mode waters, all methods lead to the same conclusion: the increase in $C_{\text{ant}}$ was larger than the increase in DIC by about 5µmol/kg (Figure 2).

To try and understand what is driving the decoupling between the increase in $C_{\text{ant}}$ and DIC, and to understand its implication, we used the IPSL ocean biogeochemical model (OPA-PISCES). The model simulations show changes in $C_{\text{ant}}$ and DIC consistent with those observed in the Western Indian Ocean over the same period, which suggests that a decrease in natural (pre-industrial) DIC occurred at intermediate depths (500-1500 m). This decrease appears to be associated with a change in ocean dynamics (slow down and/or shift southwards of the subtropical gyre circulation) in response to a strengthening Southern Annular Mode. Interestingly, the changes that are observed and simulated in the Southern Indian Ocean do occur over much of the Southern Hemisphere, warranting further investigation. The recently published CARINA Southern Ocean data synthesis will further investigation. The recently published CARINA Southern Ocean data synthesis will be critical in furthering this work, thereby.


**Acknowledgements:**

The long-term observational project OISO is supported by three French institutes, INSU, IPEV and IPSL. Warmfull thanks to the captains and crews onboard the R.S.S. Marion-Dufresne, IPEV and TAAF operational chiefs, and many colleagues at IPEV and LOCEAN for their help during the cruises. This work was also supported by the European Integrated Project CARBOCEAN and the national program LEFE/Cyber (component of SOLAS-IMBER-France).

**References:**


Figure 2: Decadal changes in dissolved inorganic carbon (DIC) and anthropogenic carbon ($C_{\text{ant}}$) in mode waters of the South Indian Ocean (30-40°S, 70-80°E) as a function of potential density (σθ) between 1985 (triangles) and the period 1998-2001 (blue dots). In 1985 DIC concentrations were higher just north of the Subantarctic Front at 35-40°S (light green) than further north at 30°S (dark green).
SOLAS France

Driven by the French initiative MISTRALS (Mediterranean Integrated Studies at Regional And Local Scales) – an interdisciplinary program initiated in 2008 - two new projects are directly related to SOLAS science:
(i) ChArMEX (the Chemistry-Aerosol Mediterranean Experiment) 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) is focused on the response of ecosystems to modifications of physiological and chemical forcing at various scales, both in time and space, linked to changing environmental conditions and increasing human pressure.

The ANR DUNE, running since 2008, has demonstrated so far that large clean mesocosms are suitable to quantify and parameterise the impact of atmospheric chemical forcing in a low nutrient, low-chlorophyll (LNLc) ecosystem. Several specific papers have been published during this year. In addition to the successful running experiment a new field campaign took place this summer in the Scandola Preservation Area (Corsica).

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 until 2011 at Kerguelen. In addition, another station is running from 2010 until 2011 at Crozet Island to assess gradient information on a 1000 km scale.

The AMOP (Activité de recherche dédiée au Minimum d’Oxygène dans le Pacifique tropical sud est) will start end of 2010 in the southern Ocean (Kerguelen Island) (MISTRALS). 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 until 2011 at Kerguelen. In addition, another station is running from 2010 until 2011 at Crozet Island to assess gradient information on a 1000 km scale.

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(which of course has time and resource implications), our understanding of how these various genotypes are spatially and temporally distributed in the ocean is also limited – thus further constraining the ecological/biogeochemical messages that can be conveyed. That said, global efforts are now beginning to show that OA is likely to be an important selection factor in future oceans. Even if species populations simply ‘shuffle’ genotypes under higher CO2 so that taxonomic diversity remains unaffected (at the species level), any change will potentially carry biogeochemical implications associated with how much organic carbon is fixed (and in turn used for production of new cells versus cellular maintenance) and exported from surface oceans. Thus consideration of the interaction of CO2 alongside other climate change variables, e.g. temperature and light, and for other key microalgal groups, must remain a priority for future research.

References:

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Acknowledgements:
Data and concepts presented here represent efforts of many collaborators and technicians at the University of Essex. Our work is supported by NERC grants and the UK Ocean Acidification Research Programme.

IMBER is an IGCP-SCOR project that aims to understand the physical, biological and chemical aspects of the ocean’s role in global change and effects of global change on the ocean. 2010 has been an eventful year for IMBER. Eileen Hofmann took over as Chair of the SSC and when GLOBEC ended in March, the ongoing programmes – Climate Impacts on Top Oceanic Predators (CLIOTOP) and Ecosystem Studies of Sub-Arctic Seas (ESSAS) were incorporated into IMBER. In light of these events, two important documents were published 1. A supplement to the IMBER Science Plan containing the recommendations of the Task Team, established to assist with the merger of IMBER and GLOBEC, and 2. ‘The way forward for IMBER’ which outlines the plan for IMBER in the next few years, was published in the IMBER and GLOBEC newsletters.

IMBER’s biennial summer school was held in Brest, France in August in collaboration with IUEM and GIS Europôle Mer. Over 70 ‘ClimECO2’ participants considered A Multidisciplinary Approach to Oceans, Marine Ecosystems, and Society facing Climate Change.

IMBER IMBIZO II Integrating marine biogeochemistry and ecosystems in a changing ocean – Regional comparisons took place at the Hellenic Centre for Marine Research in Crete, Greece in October. Three concurrent but interacting workshops within the larger meeting structure considered:
1. The effect of varying element ratios on community structure at low trophic levels and food quality at mid and high trophic levels
2. Large-scale regional comparisons of marine biogeochemistry and ecosystem processes: Research approaches and results
3. Sensitivity of marine food webs and biogeochemical cycles to enhance stratification.

An IMBER Regional Project Office will open at the East China Normal University in Shanghai, China in early 2011. Its initial responsibility will be the coordination of IMBER continental margins activities.

Lisa Maddison,
IMBER Executive Officer, IMBER IPO
www.imber.info
Air-Sea CO2 Fluxes on the Scotian Shelf: a temperate continental shelf acting as a source for atmospheric CO2

Elizabeth Shadwick and Helmut Thomas, Department of Oceanography, Dalhousie University, 1355 Oxford Street, Halifax, Nova Scotia, B3H 4J1, Canada
Contact: Elizabeth.Shadwick@dal.ca

To better understand the role of the coastal ocean in the global ocean carbon budget, upscaling schemes have been proposed to extrapolate results from studies of individual systems globally. A recent synthesis (Chen and Borges, 2009) proposes the use of temperature and latitudinal characteristics to upscale regional findings. These patterns suggest that temperate and high-latitude coastal oceans act as sinks for atmospheric CO2. In light of recent work on the CO2 system in the Scotian Shelf, we propose the inclusion of a hydrographic system structure as an additional measure to complement attempts at upscaling coastal air-sea CO2 fluxes.

The Scotian Shelf is a temperate continental shelf region adjacent to the Gulf of Maine and upstream from the South and Middle Atlantic Bights. Both the South (Jiang et al., 2008) and the Middle Atlantic Bight (DeGrandpre et al., 2002) are net sinks for atmospheric CO2 in line with Chen and Borges (2009). Recent work employing high-frequency pCO2 observations, shipboard sampling, and remote sensing, indicates that the Scotian Shelf acts as a source of atmospheric CO2 (Shadwick et al., 2010a; 2010b).

In winter, surface waters are supersaturated with respect to atmospheric CO2 despite the near-zero water temperature (Figure 1). The productive season begins in April; a brief but pronounced undersaturation of surface waters is observed. Biological production continues through October. Surface waters warm by roughly 20°C in summer, increasing in pCO2 by more than 150 μatm over the season. In the absence of summer biological production, surface pCO2 would reach values on the order of 650 μatm (Shadwick et al., 2010b). In autumn, the surface waters cool, decreasing pCO2; over the same period, respiration of organic matter increases pCO2. In winter, surface CO2 losses to biological production and outgassing are balanced by the delivery of carbon-rich subsurface water via wind-driven and convective mixing and episodic upwelling events. The majority of the outgassing occurs during autumn and winter when the destratification of the water column maintains CO2 supersaturation. This is in contrast to the interpretation of Chen and Borges (2009) for temperate continental shelves, which tend to act as sinks for CO2 in the autumn and winter seasons.

The timing and extent of the spring bloom, and subsequent CO2 draw-down, vary from year to year. The overall direction and inter-annual variability of the annual CO2 fluxes are preconditioned by temperature and wind. This occurs largely through the control of the mixed-layer depth and consequently the availability of nutrients to fuel the spring bloom (Figure 1). It has been suggested that a trend of decreasing air-sea pCO2 gradient (ΔpCO2), or weakened outgassing, has occurred over the last decade (Shadwick et al., 2010). This negative trend in ΔpCO2 is explained by a cooling of surface waters over the same period and is potentially related to a negative or near-neutral North Atlantic Oscillation (Petrie, 2007). While the opposing effects of temperature and biology play an important role in controlling surface pCO2 on the Scotian Shelf, vertical mixing is also a dominant factor. The additional consideration of the hydrographic setting in this region complements the classification of Chen and Borges (2009), facilitating regional upscaling with the Scotian Shelf properly represented as a source of atmospheric CO2.

References:
Metabolic gases heterogeneity within the upper meters of the ocean surface: observations and consequences

Maria Ll. Calleja1,2, Carlos M. Duarte1, Marta Álvarez3, Raquel Vaquer-Sunyer1, Susana Agustí1, and Gerhard J. Herndl4

1Department of Global Change Research. IMEDEA (CSIC-UIB), Mallorca, Spain. 2Department of Oceanography, University of California Santa Cruz (UCSC), USA. 3Spanish Institute of Oceanography (IEO), A Coruña, Spain. 4Department of Marine Biology, University of Vienna, Austria

Contact: marialluch.calleja@gmail.com

Our understanding of the global oceanic uptake of atmospheric CO2 is mainly derived from observed differences in CO2 partial pressure (pCO2) between the surface ocean and the atmosphere (Takahashi et al., 2002, 2009). As pCO2 spatial and temporal variability in surface water is much greater than that of atmospheric CO2, the direction and magnitude of the gradient-driven flux is mainly regulated by changes in oceanic pCO2.

Accordingly international efforts have been made to assemble a global surface water pCO2 data set, now exceeding 3 million estimates (Takahashi et al., 2009), capturing seasonal and geographical variability (http://ioc3.unesco.org/ioccp/UW.html). These estimates are largely derived from automated underway systems on board research vessels and ships of opportunity continuously recording the pCO2 in the lower atmosphere and subsurface waters. These systems commonly sample water from 3 to 7 meters below the surface, the depth of the intake on the vessel haul (Takahashi et al., 2002, 2009) and consider these measurements to be representative of that at the water surface by assuming homogeneous distribution of gases below the air-sea diffusive boundary layer.

Between 2003 and 2007, at seven different cruises encompassing a wide range of oceanic conditions (North East Subtropical Atlantic Ocean, Southern Ocean, Arctic Ocean and Mediterranean and Black Seas), we tested the assumed vertical homogeneity of pCO2 in the upper surface meters. A strong and prevalent pCO2 vertical variability was observed across the 83 stations measured. The range of variability across the top cm to 5 m profile was quite substantial for pCO2 (mean ± SE = 12.6 ± 1.4 µatm) and the maximum absolute vertical difference reached 63 µatm.

In an attempt to partition this variability between a thermodynamic and a biological component, the corresponding vertical changes in temperature and oxygen concentration within this layer were also determined. Oxygen concentration also showed considerable vertical variability within stations (mean ± SE = 6.69 ± 1.03 µmol O2 Kg⁻¹) with a maximum absolute difference of 67 µmol O2 Kg⁻¹. pCO2 and O2 concentration values differed systematically, but not consistently, between the top cm and 5 m depth, showing almost all possible profiles (see some examples in Figure 1). There was neither a significant relationship between the wind velocity and the range of gas variability, nor with the anomalies relative to temperature changes (P > 0.05), that accounted for less that 20% of the observed vertical pCO2 changes.

However, we observed a prevalence of negative relationships between the deviations of pCO2 and O2 concentration from the values expected from temperature variability, pointing out that biological processes likely play a significant role in supporting the observed pCO2 heterogeneity, and suggesting that metabolic effects on pCO2 changes within the top meters of the ocean could be faster than mixing time scales, confirming previous results (Calleja et al. 2005).

Neglecting the observed heterogeneity in metabolic gases and assuming pCO2 homogeneity within this layer can constitute a significant source of error in both the magnitude and the direction of air-sea CO2 flux estimates. Thus processes affecting top meters pCO2 variability should be investigated further to improve our understanding of air-sea CO2 exchange.

References:


Upcoming Activities
22-24 March 2011: OCB Ocean Acidification PI Meeting (Woods Hole, MA) - an invited workshop for lead investigators of funded ocean acidification-related research projects to promote dialogue and build relationships among scientists from all disciplines, agency affiliations, and regions.
23-25 May 2011: OCB Scoping Workshop - A Biogeochemical Flux program aligned with the Ocean Observatories Initiative (OOI) (Woods Hole, MA)
18-21 July 2011: 2011 OCB Summer Workshop (Woods Hole, MA)

Recent Activities
July 2010 (La Jolla, CA): The 2010 OCB Summer workshop included sessions on the Arctic, Low-Oxygen Regions, and Benthic-Pelagic Coupling – meeting report is available in the Nov 2 issue of Eos and meeting presentations and archived webcasts are available at www.whoi.edu/workshops/ocbworkshop2010/.
September 2010 (Honolulu, HI): OCB Scoping Workshop Sea change: Charting the course for ecological and biogeochemical ocean time-series research – view workshop website at www.whoi.edu/sites/OCB_Time_Series.
December 2010: Coastal Synthesis Workshop (San Francisco, CA) – a joint activity of OCB and the North American Carbon Program (NACP) to stimulate the synthesis of observational and modelling results on carbon cycle fluxes and processes along the North American continental margins.
For more information see www.whoi.edu/workshops/coastal_synthesis/.
Heather Benway, Executive Officer, OCB Project Office http://www.us-ocb.org/

Ocean Carbon and Biogeochemistry (OCB)

Sea Surface pCO2 Mapping in the Global Ocean - a Neural Network Approach
Maciej Telszewski1, Shin-ichiro Nakaoka1, Yukihiro Nojiri1, Chihiro Miyazaki1, Norihisa Usui2, Vinu Valsala1
1National Institute for Environmental Studies, Center for Global Environmental Research, Tsukuba, Japan
2Meteorological Research Institute, Tsukuba, Japan
Contact: maciej.telszewski@nies.go.jp

The global oceans absorb roughly a quarter of the excess CO2 emitted into the atmosphere by anthropogenic activities every year. This natural uptake (sink) shows large variability at interannual and longer timescales, restricting our ability to separate potential long-term trends which, once confirmed, could have complex and important implications for the global carbon budget. Several data-based and modelling studies have shown at least regional evidence for decreasing capacity of the global ocean’s surface layer to take up excess atmospheric CO2, due to the faster-than-atmospheric rise of sea-surface pCO2. The primary aim of this work is to identify the interannual-to-decadal trends of the pCO2 over the North Pacific (10-60°N, 120°E-90°W) for 2002-2008 and to suggest processes that might be responsible. A longer term aim is to establish a robust and reliable method for estimating the global marine pCO2 field at a nearly-online basis.

Our research utilises an artificial neural network as a method for the spatial and temporal interpolation of the available measurements of marine pCO2. The Self Organising Map (SOM) was shown to allow a near-real time monitoring of the marine pCO2 in the North Atlantic by combining in-situ measurements, satellite data and operational ocean models (Telszewski et al., 2009). The current SOM benefits from several technical improvements as well as major changes of the calculating system (Telszewski et al., 2010). However, the internal SOM structure remains the same.

We hypothesise that seawater pCO2 in the North Pacific may be parameterised as a function of basin-wide available parameters:

Figure 1: Mean seasonal distribution of sea surface pCO2 in the North Pacific for winter (top panel) and summer (bottom panel) estimated by the Self Organising Map.
The focus of Surface Ocean-Lower Atmosphere Processes is biogeochemical interactions between the surface ocean and the lower atmosphere. Lectures from the 2007 Summer School have been developed into a textbook ‘Surface Ocean - Lower Atmosphere Processes’ (SOLAP). The textbook is designed to provide graduate students, postdoctoral fellows and researchers from a wide range of academic backgrounds with a basis for understanding the nature of ocean-atmosphere interactions and the current research issues in this area. The book is published by AGU and edited by Corinne Le Quéré and Eric Saltzman.

To find out more about this textbook and the SOLAS summer school visit www.solas-int.org/summerschool/textbook.htm

To order your copy visit www.agu.org/pubs/books

Reference:
By what pathways does atmospheric anthropogenic CO₂ enter into the vast expanse of the global ocean? Over the last few decades, our understanding of air-sea CO₂ fluxes and changes in the ocean interior CO₂ inventory has improved greatly, but the mechanisms regulating these exchanges remain in many ways unknown.

In the North Pacific, one can find a number of important water masses, including Subtropical Mode Water (STMW) and Central Mode Water (CMW) (Figure 1). Their formation regions coincide with the regions of large contemporary CO₂ fluxes from the atmosphere to the ocean (Takahashi et al., 2009), and their distributions in the ocean interior coincide with regions of large inventories of anthropogenic carbon (Sabine et al., 2004). It will be beneficial to evaluate quantitatively changes in the interior carbon content of these mode waters with available observations in order to better understand their role in absorbing and subsequently transporting atmospheric CO₂ in the ocean interior.

We have been making measurements of dissolved inorganic carbon (DIC) in water columns repeatedly at a series of stations along 137°E since 1994. At 30°N for example, we have successfully identified the decadal trends in DIC concentration on the isopycnal surfaces corresponding to upper STMW (σθ~25.0) through lower CMW (σθ~26.4) (Figure 2).

Large temporal variability and a decadal trend have also been found for dissolved oxygen. It is likely that the observed changes in apparent oxygen utilisation (AOU) for these isopycnals reflect change in the region of formation and/or subsequent interior ventilation pathways, in addition to changes in ocean biology.

In order to correct for these changes reflected in AOU, we have calculated what we will refer to as preformed DIC concentrations by Mode waters: uptake windows of atmospheric CO₂ into the ocean interior

Masao Ishii is a research scientist at the Meteorological Research Institute, Tsukuba, Japan. His research interests focus on the marine carbon cycle and aim to understand the natural and anthropogenic changes in ocean CO₂ by observations.
subtracting AOU multiplied by stoichiometric CO₂/(O₂) ratio of respiration (117/170) from the measured DIC concentrations. This reveals the DIC concentration of a water mass parcel when it was last in contact with the atmosphere. The preformed DIC concentrations show significant trends toward increased concentrations of order +0.6±0.2 to +1.1±0.1 µmol kg⁻¹ year⁻¹ for CMW and STMW, respectively. These rates are compatible with the rate of atmospheric CO₂ increase over the last 15 years, and indicate that the large volume of waters in these density classes are absorbing and transporting anthropogenic carbon from the atmosphere into the ocean interior. A preliminary analysis of LDEO database (Takahashi et al., 2009) for the STMW formation region also shows that pCO₂ in surface water in winter at σθ~25.2 is also increasing at a similar rate to that in the overlying atmosphere (K. Rodgers, private communication).

An important fraction of anthropogenic CO₂ absorbed within STMW may be expected to return to the surface while circulating within the extra-tropics and contribute to the long-term increase in surface pCO₂ and the acidification (Midorikawa et al., 2010). Yet another fraction would be transmitted equatorward within the interior branch of the North Pacific Subtropical Cell. In conjunction with anthropogenic carbon being transported from the South Pacific, it would contribute to increasing carbon concentrations for surface water in the equatorial Pacific (Ishii et al., 2009). One would also expect a significant export of anthropogenic carbon to the Indian Ocean via the Indonesian Throughflow, given that the Indonesian Throughflow transport of thermocline water is expected to be well in excess of 10 Sv for the mean state.

**References:**


**New SOLAS National Network – Peru**

SOLAS is pleased to welcome Peru to its network of countries conducting research under the 3 SOLAS foci. Instituto del Mar del Perú (IMARPE) in Lima, Peru, was the venue for the recent SOLAS Mid Term Strategy meeting “Air-sea gas fluxes at Eastern Boundary Upwelling and Oxygen Minimum Zones (OMZs) systems” (see page 29 for the report) and was attended by many Peruvian researchers.

Michelle Graco, of IMARPE, takes on the role of National Representative.

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North Pacific Marine Science Organization Section on Carbon and Climate (PICES CC-S)

The PICES Section on Carbon and Climate (CC-S) was created in the fall of 2005 to deal with changing climate and biogeochemical cycles in the Pacific and its marginal seas. In its first 5 year term, CC-S has sponsored topic sessions at PICES Annual Meetings (“Decadal changes in carbon biogeochemistry in the North Pacific,” “Anthropogenic perturbations of the carbon cycle and their impacts in the North Pacific”) and a special section of the Journal of Oceanography (vol. 65 #5, 2009) arising from one of these. CC-S oversaw the publication of the Guide to Best Practices for Ocean CO₂ Measurements (PICES Special Publication Number 3, 2007, also listed as IOCCP Report #8). The Guide is freely available in electronic form from CDIAC at http://cdiac.ornl.gov/oceans/Handbook_2007.html

CC-S is currently coordinating a data synthesis project PACIFICA. PACIFICA has collected biogeochemical data (DIC, TA, nutrients, oxygen, and salinity) from more than 200 cruises in the Pacific and implemented a set of algorithms for crossover analysis that permit the construction of a basin-wide, consistently calibrated data set. The PACIFICA algorithms were adapted from CARINA and implemented by Toru Suzuki (Japan). The data product is expected to be publicly available in 2011.

CC-S will be a key coordinating body for scientific analysis of the PACIFICA and SOCAT data sets for the North Pacific, and will continue to be a critical resource for other PICES bodies addressing issues relating to climate change, ocean acidification, and deoxygenation. We are interested in accepting new members, particularly in the area of ocean acidification and its ecosystem impacts. Scientists from PICES countries interested in becoming members should contact CC-S members from their home country.

Other international organisations or programs interested in appointing an ex officio member should contact CC-S co-chairs Jim Christian (jim.christian@ec.gc.ca) and Toshi Saino (tsaino@jamstec.go.jp), or PICES Executive Director Alex Bychkov (Bychkov@pices.int).

http://www.pices.int/members/sections/CC.aspx
Lisa L. Robbins is a Senior Scientist at the U.S. Geological Survey in St. Petersburg FL studying the flux of carbon in coastal and marine waters and the effects of ocean acidification on calcifying organisms. Prior to USGS, she was a Professor at the University of South Florida for 11 years.

Joanie Kleypas is a marine ecologist/geologist at the National Center for Atmospheric Research with a background ranging from fish ecology to coral reef modeling. Her work concentrates on the interactions between coral reef ecosystems and climate, particularly on the large-scale environmental controls on coral reef ecosystems.

CO2calc: A User-Friendly Seawater Carbon Calculator for Windows, Mac OS X, and iOS (iPhone)

Lisa L. Robbins and Joanie A. Kleypas

Scientists who conduct research on the chemical behaviour of inorganic carbon in seawater have had several “packages” for calculating CO2-system chemistry. Ernie Lewis and Doug Wallace first undertook the monumental effort of sorting through the original literature and equations to produce CO2SYS (Lewis and Wallace 1998), a Windows-based program that has been an invaluable and well-documented service to the research community. The equations and documentation of CO2SYS have since been adapted for use within Microsoft Excel (Pierrrot et al. 2006) and coded for use within programming languages such as MatLab (van Heuven et al. 2009), and R (SeaCarb; Lavigne and Gattuso 2010). Unfortunately, these programs are not particularly user-friendly, or they require a decent understanding of a computer language.

While walking with our iPhones at the OCB Short Course on Ocean Acidification in November 2009, we decided that developing an iPhone app for CO2SYS would be a novel tool for many researchers, and particularly for new students of the field. With the excellent programming of Mark Hansen and Stephan Meylan of the U.S. Geological Survey (USGS) in St. Petersburg, we have developed CO2calc, an easy-to-use CO2-system calculator that is designed for anyone with a PC, Mac, or iPhone (Robbins et al. 2010). Like the other calculators, it is largely based on CO2SYS, but includes several new developments in CO2-system calculations, including options to use the dissociation constants of Lueker et al. (2000) as well as the constants of Millero (2010), constants which are a better fit for estuarine waters. An entirely new feature is the option to calculate air-sea CO2 fluxes according to the gas-transfer velocity formulations of Wanninkhof (1992), Nightingale et al. (2000), or Ho et al. (2006).

CO2calc has an intuitively designed graphical user interface for choosing constants (Figure 1) and for data entry and results (Figure 2a,b). It also includes many additional features such as the ability to tag data with date, time, latitude/longitude (all of which can be automatically retrieved on iPhone 3, 3GS, 4, and Windows hosts that have NMEA-enabled GPS), sample name, and comments. It also allows batch file processing, as well as an option to save sample information, data input, and calculated results as a comma-separated value (CSV) file for use with Microsoft Excel, ArcGIS, or other applications; and finally, an option to export points with geographic coordinates. A Figure 1 : CO2calc display for selection of constants.
coordinates as a KMZ file for viewing and editing in Google Earth. CO2calc documentation is provided as a PDF file, which on the iPhone version is organised into separate tab-based folders. The CO2calc programs, for Mac and PC, and the link to the iPhone app, are available on US Geological Survey sites (http://pubs.usgs.gov/of/2010/1280/ or http://coastal.er.usgs.gov/flash/index.html ) and the CDIAC website (http://cdiac.ornl.gov/oceans/CO2SYS_calc_MAC_WIN.html ).

One important lesson that was learned in developing CO2calc is that the small format of the iPhone forced the design of the interface to be simple and intuitive, so much so that the format was adapted for the PC and Mac interfaces. We feel this new application is not only novel, but also very handy to both inexperienced and experienced researchers.

Disclaimer:

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References:


Young LOICZ Forum 2011-01-19

Held concurrently with the LOICZ Open Science Conference 2011 “Coastal Systems, Global Change and Sustainability” the Young LOICZ Forum is a combination of OSC sessions and specific, targeted activities for early-career scientists and young coastal managers.

The Young LOICZ Forum takes place 8-15 September 2011. Deadline for applications is 1 April, 2011.

Global Carbon Project (GCP)

The international carbon cycle research community is currently coordinating the largest, most comprehensive assessment it has ever undertaken: the Regional Carbon Cycle Assessment and Processes (RECCAP). The objective: to establish the mean carbon balance and change over the period 1990-2009 for all sub-continents and ocean basins.

Three key objectives justify the need for such a new assessment of regional carbon fluxes and their drivers: (1) To provide higher spatial resolution for the global carbon balance with the aim of improving quantification and understanding of drivers, processes and hot-spots regions; (2) To address a growing demand for a capacity to Measure, Report, and Verify (MRV) the evolution of regional fluxes and the outcomes of climate mitigation policies; and (3) To respond to the Group on Earth Observations (GEO) in establishing a global carbon observing system, as in the GEO Carbon Observation Strategy report (http://www.globalcarbonproject.org/mis c/JournalSummaryGEO.htm).

RECCAP’s fundamental tenet is to establish carbon budgets in each region by comparing and reconciling multiple bottom-up estimates, which include observations and model outputs, with the results of regional top-down atmospheric CO2 inversions. The effort is guided by a methodology that includes diverse data with their uncertainties, and a 2-tier system that ensures a common approach and a minimum set of analyses performed by all regions.

There are 14 regions in the RECCAP synthesis, including 10 terrestrial (Africa, Arctic tundra, Australia, Europe, Russia, East Asia, South Asia, Southeast Asia, Central and South America, North America) and 4 ocean regions (Atlantic +Arctic, Indian, Pacific, Southern Ocean). In addition, 8 global syntheses will support the integration of the regional carbon budgets into a global picture, and provide the link to the top-down constraints delivered by atmospheric observations and inversion models.

RECCAP is an assessment of the Global Carbon Project (GCP) with several sponsors including EU-COCOS, USA-Carbon Cycle Research Program, and Australia-CSIRO.

Pep Canadell, Executive Director, Global Carbon Project

www.globalcarbonproject.org/reccap

Nathalie Goodkin received her Ph.D. in Chemical Oceanography from the MIT/WHOI Joint Program before completing a Post Doctoral Fellowship at the Bermuda Institute of Ocean Sciences. She is currently an Assistant Professor in the Environmental Science Program at the University of Hong Kong.

Atmospheric CO2 Trends Hinder Detection of Oceanic CO2 Accumulation

Nathalie F. Goodkin¹, Naomi M. Levine², Scott C. Doney³, Rik Wanninkhof⁴

¹University of Hong Kong, Hong Kong SAR China, ²Harvard University, Organismic and Evolutionary Biology, Cambridge, MA, USA, ³Woods Hole Oceanographic Institution, Dept. of Marine Chemistry and Geochemistry, Woods Hole, MA USA, ⁴Atlantic Oceanographic and Meteorological Laboratory, NOAA, Miami, FL USA

Contact: goodkin@hku.hk

The ocean is a critical reservoir in the carbon cycle for mitigating the effects of rising atmospheric CO2. While the oceanic sink is estimated to currently be 25% of annual CO2 emissions (eg. Le Quéré et al. 2009), this is likely to decrease over the next 100 years as ocean temperatures increase and the ocean becomes saturated with CO2. In order to anticipate changes in oceanic uptake, we must improve our understanding of how much anthropogenic CO2 is currently being absorbed by the ocean.

Since the 1980s, internationally organised field campaigns such as the World Ocean Circulation Experiment (WOCE) monitored the ocean carbon sink through the collection of column hydrographic data. Many of these surveys are being repeated every 5-10 years through efforts such as the CLIVAR/CO2 repeat hydrography program.

Natural variability, however, makes it hard to discern increases in anthropogenic derived carbon. Therefore, empirical techniques such as the extended Multiple Linear Regression (eMLR) (eg. Friis et al 2005) are commonly used to isolate the anthropogenic carbon signal from natural variability.

In our study (Goodkin et al., submitted), we use the Community Climate System Model (CCSM) to better understand the impacts climate and atmospheric CO2 trends may have on estimates of the ocean carbon sink on decadal to centennial time scales in the Southern Ocean (south of 32°S). Specifically, examining the commonly used eMLR technique, we find that secular trends in both CO2 and temperature decrease the reliability of the eMLR technique.

Figure 1: DIC residuals (µmol/kg) across the Southern Ocean from the MLR for 1990 (blue) and 2030 (green) versus 1980 MLR residuals. Residuals are calculated for each decade by subtracting model DIC from MLR predicted DIC using model output of temperature, salinity, oxygen, phosphate, and alkalinity.
MLR techniques take advantage of relationships between dissolved inorganic carbon (DIC) and hydrographic properties to filter out natural variability. This technique, however, depends on a linear relationship between DIC and hydrographic properties and stable regression residuals through time (Figure 1). Non-uniform and non-linear increases in DIC due to variable anthropogenic carbon uptake and long-term trends in the physical and biological state of the ocean result in an increasingly non-linear relationship between DIC and hydrographic properties with time. Ultimately, as the time interval increases, the regression residuals no longer cancel and our predictive ability decreases. After a period of 40 years, the residuals are no longer significantly correlated and the error in predicted anthropogenic carbon has increased to greater than 20% (Figure 2).

These results are a conservative estimate due to low-climate sensitivity of the CCSM model and as the analysis was conducted using decadal means that average sub-decadal scale variability. Therefore, we believe that significant errors could occur on much shorter time scales and that repeat observations are needed on the order of decades to avoid the impact of secular change on the empirical estimates of anthropogenic CO₂.

As we approach the 30th anniversary of WOCE, the oceanographic community recognises the importance of extensive field measurements in order to closely monitor the role the ocean will play in absorbing CO₂. For instance, the GO-SHIP effort (www.go-ship.org) co-sponsored by SOLAS is an international effort towards a sustained global survey of the ocean interior.

References:


Southern Ocean Carbon – Climate Observatory: South Africa’s contribution to understanding the variability and long term trends of ocean – atmosphere CO₂ gas exchange

Pedro Monteiro CSIR, PO Box 320, Stellenbosch 7599, South Africa
Contact: pmonteir@csir.co.za

The Southern Ocean, through its seasonally biased under sampling, is not only one of the main sources of uncertainty in global estimates of ocean – atmosphere CO₂ exchanges but also, through changes in the upper and lower cells of the MOC and increased mixed layer buoyancy fluxes, a modulator of long term trends. This poses a challenge to the objective of reducing the uncertainties of global CO₂ fluxes to 10% and understanding its sensitivity to changing physics and biogeochemical drivers (Bonning et al., 2008; Lenton et al., 2006; 2009; Le Quéré et al., 2009; Doney et al., 2009; Monteiro et al., 2010).

South Africa is using its comparative geographical advantage to contribute innovatively to the global effort to address the Southern Ocean CO₂ challenge and in doing so also build a platform to support the development of advanced numerical and analytical skills. The South African programme, Southern Ocean Carbon – Climate Observatory (SOCCO) has two broad themes: i) the long term observation component, which is presently ship-based taking advantage of the three logistics voyages of the polar supply ship SA Agulhas into the Southern Ocean in the spring, summer and autumn and ii) a process oriented research focus which aims to improve our understanding of the drivers of the spatial and temporal variability of carbon fluxes and air – sea CO₂ fluxes.

The long term observational programme of underway pCO₂ already contributes to the global pCO₂ data set coordinated through IOCCP – CDIAC - SOCAT as well as building a data base of ancillary biogeochemical variables (O₂/Ar, Chla, ¹⁵N - Production, IOP and AOP bio-optics) and physics (underway CTD) for the South East Atlantic sector of the Atlantic Ocean (Figure 1). Our contribution here extends to improving the understanding of the links between pCO₂ variability and changes in the mixed layer physics through simultaneous very high resolution CTD (10 – 20nm) profiles using an underway CTD (Figure 2). We have completed two years of underway pCO₂ observations and the ancillary observations are increasing from year to year. From spring 2011 we also aim to begin glider missions that will close the mixed layer sampling gap between ships and Argo floats. Our process oriented research plans focus on using high resolution capabilities in both observations and modelling to understand the role of sub-mesoscale and sub-seasonal forcing of the mixed layer and its implications for CO₂ exchange and carbon export into the deep ocean. This aims to better understand the sensitivity of the carbon cycle to long term trends in large scale climate forcing.

The gaps in data and knowledge in the Southern Ocean can only be addressed through improved collaboration and coordination. SOCCO initially in collaboration with our Southern Hemisphere colleagues in Australia and New Zealand and participation of colleagues from Norway, US and France have initiated a seasonal cycle – mesoscale focus to understanding the sensitivity of the Southern Ocean carbon fluxes to changes in large scale climate forcing. We are inviting a wider global discussion to develop the ideas around a two year circumpolar experiment in 2013 – 2015, probably focused on the 40 – 50°S zone, to understand the roles of sub-seasonal and sub-mesoscale forcing on deep ocean carbon export and ocean – atmosphere CO₂ fluxes. This period will coincide with the commissioning of new polar research ships by both South Africa and Australia. The web site www.subantarctic.net will serve as a discussion forum for this purpose.
References:


Acknowledgements:
SOCCO is funded by the CSIR, DST and NRF in South Africa and further recognises the important contribution by the Norwegian RC grant (SOBER project: Prof Richard Bellerby) and a Prof. Michael Bender at Princeton University.

Figure 2: A meridional transect of mixed layer density between Cape Town and Antarctica obtained from high resolution underway CTD profiles in the summer of 2009/2010

SOLAS Summer School 2011

The 5th SOLAS Summer School will take place in Cargèse, Corsica, France from 29 August - 10 September 2011. Over 200 PhD students and early stage researchers applied this year and the standard of applications, as ever, was very high. The summer school represents an invaluable opportunity for participants from around the world to learn more about current understanding and recent advances in a wide range of SOLAS relevant research from world leading SOLAS scientists.

The success of the school depends, in large part, on the dedication of the schools organising committee, lecturers, international project office and the generosity of sponsors worldwide. SOLAS would particularly like to thank the following for their commitment to the SOLAS Summer School 2011.

SOLAS Summer School Organising Committee
Emilie Brévière (Germany), Minhai Dai (China), Véronique Garçon (France), Jeff Hare (USA), Cliff Law (New Zealand), Corinne Le Quéré (UK), Maurice Levasseur (Canada), Peter Liss (UK), Trish Quinn (USA), Eric Saltzman (USA), Mitsuo Uematsu (Japan), Doug Wallace (Germany).

SOLAS Summer School 2011 sponsors as of January 2011

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Warm thanks, of course, also goes to the summer school director, lecturers and demonstrators, a list of whom can be found at http://www.solas-int.org/summerschool/lecturers.html
The Southern Ocean is suggested to be one of the earliest ecosystems to be affected by ocean acidification because of higher solubilities of CO$_2$ and CaCO$_3$ in cold waters as well as the upwelling of deep seawater containing high CO$_2$ (Feely et al., 2004). Nevertheless, most research efforts have mainly been directed to understanding how tropical and temporal calcifying organisms (corals, some phytoplankton, shellfish etc) will be affected by ocean acidification (Doney et al., 2009).

Antarctic krill (hereafter krill) play a key role in the Southern Ocean ecosystem being both the primary prey for most of the Antarctic mega fauna and important grazer of the primary production. However, despite their critical importance almost nothing is known about their CO$_2$ sensitivities.

The Australian Antarctic Division (AAD) operates the only research aquarium where a large number of krill have been reared and successfully reproduced in captivity for research purposes. The AAD has been conducting various international collaborative experiments using our facility on krill life history, physiology, behaviour etc (Kawaguchi et al., 2010a). The AAD aquarium has recently further developed a capacity to conduct studies on effects of ocean acidification on krill (Figure 1) (Kawaguchi et al., 2010b).

Unlike most shallow-water planktonic calcifiers, krill eggs sink to the depth of 700-1000 m during their development (Quetin and Ross 1984) where seawater pCO$_2$ is generally higher than surface waters. Therefore, this habitat environment needs to be taken into account when designing experiments to assess the impacts of increased CO$_2$ on such species (Kawaguchi et al. 2010b).

We recently revealed that there are significant negative effects on hatch rates at 2000 µatm pCO$_2$ but not at 1000 µatm. At 2000 µatm pCO$_2$, development was disrupted by gastrulation in 90% of embryos and no embryos survived to hatch (Figure 2). Krill may have evolved a certain level of resistance to increased pCO$_2$, probably through their natural exposure from surface (380 µatm) to deep-sea pCO$_2$ levels, as a result of evolutionary adaptation, but they might be highly vulnerable to higher pCO$_2$ levels (Kawaguchi et al. 2010b). The model projection suggests that the seawater pCO$_2$
is unlikely to reach 2000 µatm within this century even at depths, but may exceed 1000 µatm under the IPCC IS92a scenario (Figure 3) (Kawaguchi et al. 2010b).

It is still difficult to estimate the CO2 sensitivities of krill in their natural habitat at various depths and thereby to what degree krill will be affected by the Southern Ocean climate change in the coming decades.

To answer this question we are planning to run a series of experiments to establish a finer CO2-and-effect relationship in the pCO2 range between 1000 and 2000 µatm during the coming reproductive season. Our ultimate goal is to undertake a comprehensive risk assessment of rising CO2 level on the lifecycle of Antarctic krill for the next 100 years.

References:
An update of global interior ocean carbon observations
Toste Tanhua, Leibniz Institute of Marine Sciences, Marine Biogeochemistry, Dueöstrombrooker Weg 20, D-24105 Kiel, Germany
Contact: ttanhua@ifm-geomar.de

Observations of inorganic dissolved carbon (DIC) in the interior ocean, and particularly the decadal change in DIC concentrations, provides an integrated view of the ocean uptake of atmospheric carbon dioxide (CO₂). Dedicated efforts to conduct measurements along the same ship-tracks where the carbon parameters have been measured previously are commonly referred to as "repeat hydrography", and its advantage is that, in principle, the observed change in DIC concentration can be regarded as the anthropogenic CO₂ signal. There are some obvious caveats to this approach such as variability of circulation, internal waves, changes in biological activity etc., but some techniques has been developed that can deal with some of these issues.

Repeat hydrography with carbon measurements
Repeat hydrography is being conducted by scientists of several nations, for instance by the US repeat hydrography program (http://ushydro.ucsd.edu/home.htm) but also by several other nations such as UK, Germany, Spain, Japan, France, the Netherlands etc. A large fraction of the repeat hydrography has been carried out as part of the Climate Variability and Predictability (CLIVAR, http://www.clivar.org/) program. However, the lack of an international agreed program focused on repeat hydrography has led to a decrease in trans-basin sections carried out, as well as a lack of coordination and uniform data sharing policies. In order to fix this and to better optimise the resources towards monitoring the change in biogeochemical parameters of the interior global ocean, the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP, http://www.go-ship.org/) was initialised in 2007. A white paper outlining a coordinated program for repeat hydrography was presented during the OceanObs’09 meeting in 2009, where the need for repeat hydrography was widely recognised. The GO-SHIP strategy is based on a network of 45 open-ocean hydrographic reference sections (Figure 1) that should be repeated on regular intervals. On several of these sections there are possibilities for inclusion of instrumentation for SOLAS relevant underway measurements. Some obvious candidates are aerosol samplers and underway measurements of sea-surface pCO₂, pH, oxygen etc. Some of these measurements are already included on the GO-SHIP cruises; on others there might still be a possibility to put your instruments on a ship. A good place to start looking for a ship that covers your favourite part of the ocean is the GO-SHIP webpage.

A revised hydrographic manual
One important product of the GO-SHIP effort is the release of a revised hydrographic manual (GO-SHIP, 2010, available at www.go-ship.org/HydroMan.html) that aims to...
at ensuring that measurements made by different groups are comparable, compatible, and of the highest quality possible. In the 15 years since the original publication of the WOCE Hydrographic Programme manual, many methods and techniques have changed and new sensors have been developed. The GO-SHIP manual provides detailed instructions for the high quality collection and analysis techniques of numerous ocean parameters, both physical and biogeochemical. The GO-SHIP group encourages you to consult these manuals to ensure that your data will have the highest possible quality.

**New interior ocean carbon data products**

Data of interior ocean carbon is regularly being submitted to the data centres, particularly to the Carbon Dioxide Information and Analysis Centre (CDIAC, http://cdiac.ornl.gov/oceans/). It is obviously very important that data is made available to the data centres in order to obtain an as complete picture as possible of the changes in the global carbon inventory. Recent news on the interior carbon data collections includes the completion of the CARINA (Carbon in the Atlantic Ocean) data collection. CARINA consists of quality controlled carbon relevant data from 188 cruises in the Arctic, Atlantic and Southern Oceans, and can be found at CDIAC (http://cdiac.ornl.gov/oceans/CARINA/). The CARINA data collection is described in detail in a special issue of Earth System Science Data (e.g. Key et al., 2010; http://www.earth-syst-sci-data-discuss.net/special_issue2.html). Another new and very exciting data collection focuses on the Pacific Ocean and will soon be finalised; the Pacific Ocean Interior Carbon (PACIFICA) data collection. PACIFICA currently contains data from about 260 cruises and can also be found at CDIAC (http://cdiac.ornl.gov/oceans/PACIFICA/).

**References:**


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**In Focus**

The SOLAS Scientific Steering Committee would like to extend a warm welcome to new members Diego Gaiero (Argentina), Christoph Garbe (Germany), Brian Ward (Ireland) and Lisa Miller (Canada), all of whom are introduced below, and extend our thanks to departing member Guang-Yu Shi (People’s Republic of China).

**Diego Gaiero**

Diego Gaiero graduated in 1989 in Geology from Cordoba University and obtained his Doctorate in Geological Sciences in 1995 at the same institution. He next went to the Centre de Geochimie de la Surface, Strasbourg (from 1998 to 2000) for a post-doctoral position studying the transport of particulate and dissolved matter from Patagonian to the South Western Atlantic Ocean. Granted by national (Antorchas, FONCYT) and international (AI, Weizmann Institute) science foundations his work focuses on low temperature geochemistry and on improving the understanding of mechanisms of dust transport and deposition in Southern South America. Since 2001 has been a researcher at CONICET (Argentina’s NSF) and since 2008 a Professor at the School of Geological Sciences in Cordoba University.

**Christoph Garbe**

Following his studies of physics at the Universities of Hamburg and Heidelberg, Christoph Garbe received his PhD and habilitation degree from the University of Heidelberg in 2001 and 2007 respectively. He has been guest investigator at the Scripps Institution of Oceanography, San Diego, CA / USA in 1999 and at the Woods Hole Oceanographic Institution, Woods Hole, MA / USA between 2002 and 2004. Currently, Christoph Garbe heads his independent research group at the University of Heidelberg, where he conducts interdisciplinary research focusing on environmental transport processes and image sequence analysis. He is currently involved in applying techniques from thermographic imaging of small-scale processes to global observations of trace gases in the polar regions as well as to the transport of Saharan dust, both from satellite remote sensing.

**Brian Ward**

Brian Ward completed his PhD in oceanography at the National University of Ireland, Galway (NUIG) in 1999. He then spent two years at the Geophysical Institute in Bergen Norway as a Marie Curie Fellow where he received funding from the Norwegian Research Council to develop the SkinDeEP profiler. He subsequently moved to the NOAA/AOML lab in Miami to participate in the GasEx2001 field study for about one year.

In 2006 Brian became an Assistant Professor at Old Dominion University in Norfolk VA. In 2008 he returned to NUIG as a lecturer and is currently working on upper ocean turbulence using the ASIP. Other projects include instrumentation development for air-sea greenhouse gas fluxes and a DIC system for the Argo float programme, both funded by Science Foundation Ireland. He is also a partner in the FP7 Carbochange project.

**Lisa Miller**

Lisa Miller is a climate geochemist at the Institute of Ocean Sciences, the Fisheries and Oceans Canada lab in British Columbia. After degrees in Chemistry from Humboldt State University and the University of California, Santa Cruz, in the U.S., her path to Canada passed through the University of Bergen and the Institute of Marine Research in Norway. Her research has covered a wide range of topics from trace metal technique development, to carbon drawdown by deepwater formation, to radionuclides as tracers of particulate export, to carbon cycling in polynyas, to carbonate system geochemistry in sea ice. Despite her apparent 5-year attention span, these disparate interests have been unified by an effort to ultimately understand how the oceans control atmospheric CO₂ concentrations.
SOLAS Special Reports

12th Symposium of the International Commission on Atmospheric Chemistry and Global Pollution (iCACGP) and 11th Science Conference of the International Global Atmosphere Chemistry (IGAC) Project

11-16 July 2010, Halifax, Canada

Frank Dentener
(frank.dentener@jrc.ec.europa.eu)

The iCACGP/IGAC conference took place under the title “Challenging the future” and was organised around five themes: 1. Climate chemistry interactions, 2. Observing atmospheric composition, 3. Chemistry at the interfaces, 4. Trace gas and aerosol source strengths and 5. Pollutant transformation and loss.

There were 65 oral and over 400 poster contributions from ca 370 participants (and many young scientists). All presentations are available at http://www.icacgp-igac-2010.ca. Recurring themes were:

- organic aerosols: formation processes, measurements (techniques) and modelling.
- tropospheric halogen chemistry: showing its apparent ubiquity and impact
- satellite observations: increasing importance for atmospheric chemistry understanding and synergetic use in models.
- source apportionment aerosol-gas techniques, using isotopes and other markers
- modelling and measurements of HOx radicals, pointing to a lack of sufficient understanding of hydroxyl chemistry and the potential role of recycling reaction pathways.

The underlying basic laboratory work in physical chemistry and kinetics has been weakly represented and deserves strengthening. Cross disciplinary talks linking to other components of earth system (land, ocean, stratosphere) were not sufficiently represented. Given the educational role of such conferences, this issue should be addressed in future in close collaboration with SOLAS, ILEAPS, and SPARC.

Integration of atmospheric chemistry knowledge with other fields is an arduous but valuable exercise. Ongoing interactions concern i) air pollution and health, ii) the role of pollutants as short-lived climate forcers, iii) atmospheric chemistry and biosphere / cryosphere. The processes involved are not sufficiently understood to accurately assess future impacts on atmospheric composition and climate.

The two key-note speakers John Seinfeld, and Douglas Dockery summarised well these challenges in the fields of climate modelling and understanding of pollution and health effects. The IGAC project and the iCACGP will actively keep identifying new directions for international atmospheric chemistry research: reaching out to other research fields departing from a strong disciplinary understanding.

New members of the International Commission on Atmospheric Chemistry and Global Pollution (www.icacgp.org) and officers have been elected. The new officers are John Burrows (president), Frank Dentener (secretary), and Laura Gallardo (vice-president).

The next IGAC Conference on “Atmospheric Chemistry in the Anthropocene” will be held in Beijing, in September 2012. The joint iCACGP-IGAC Symposium is planned for 2014, time and location to be decided.

Workshop on “Sea Change: Charting the course for ecological and biogeochemical ocean time-series research”

21-23 September 2010, Honolulu, Hawaii

Yrene M. Astor (yastor@edimar.org)
Fundación La Salle. EDIMAR, Isla de Margarita, Venezuela and Carlos Ferreira Santos (carlos.d.santos@indp.gov.cv)
Deputy Coordinator TENATSO – Cape Verde (Tropical Eastern North Atlantic Time-Series Observatory – www.tenatso.com)

This workshop was funded by Ocean Carbon and Biogeochemistry (OCB) and was hosted by the University of Hawaii (UH). The principal investigators of the three main National Science Foundation (NSF)- funded biogeochemical time-series (CARIACO, Frank Muller-Karger, BATS, Michael Lomas and HOT, Matthew Church) composed the steering committee, together with other key participants (Ken Johnson, MBARI, Susan Bahnahan, Ocean Leadership, and Laura Lorenzoni, CARIACO). Invited participants that had worked at other time-series around the

world were also present, including TENATSO (Cape Verde, Carlos Ferreira-Santos), CALCOFI (Tony Koslow) and several European times series observatories (ESTOC, CIS, ANTARES, PAP, Station M, DYFAMED, PYLOS etc.), represented by the EuroSITES project (Richard Lampitt). In total, 65 participants attended the workshop representing five different countries.

The main objective of the workshop was to gather members of the OCB community to help define future research at the aforementioned NSF-supported time-series sites. The workshop provided a synthesis of ongoing research at the US OCB time-series sites, summarised the knowledge gained on temporal variability and controls on key ecosystem processes and biogeochemical cycles though time-series research, highlighted capabilities at each of the time-series sites, and sought to promote community input in identifying priority directions and new opportunities for future research at the existing time-series sites. The participants were members of the international science community who were one way or another, involved with time-series work.

Four plenary talks and six informative talks provided the basis for discussion. The participants were asked to divide into working groups, to discuss issues pertinent to: 1. Critical science directions for the ongoing OCB time-series: scope, feedbacks and directions. 2. Coordination and implementation of novel sensing technologies at ocean time-series. 3. Defining future ocean time-series science activities.

Results from the working groups were summarised and further discussed by the participants. These will be used to compile a white paper that will contain recommendations for future development on time-series observations world wide.

coa-sponsored by SOLAS
5th International Symposium on Biological and Environmental Chemistry of DMS(P) and Related Compounds
19-22 October 2010, Goa, India

Martine Lizotte
(Martine.Lizotte@qo.ulaval.ca)
Université Laval (Québec-Océan), Québec City, Canada

Since its first event in 1995 in the United States, the International Symposium on Biological and Environmental Chemistry of Dimethylsulfide (DMS), Dimethylsulfoniopropionate (DMSP), and Related Compounds has been held roughly every four years throughout various countries (Netherlands, Canada, and United Kingdom). In 2010, India provided the venue for the 5th Symposium. Hosted by Drs. M. Dileep Kumar and Damodar M. Shenoy and their colleagues, the meeting reunited 60 delegates from 12 countries around the world.

Abstracts of the presentations listed in the scientific program were a vivid reminder of the critical role that DMS plays in the global biogeochemical sulphur cycle and of its influence on the Earth’s climate. Five sessions, chaired by members of the international scientific advisory board (Drs. G. Malin, J. Stefels, M. Levassueur, R. Simó, and S. Belviso), covered a vast array of topics including regulation and dynamics, ecosystems and regional experiments, sea-air fluxes, aerosols and climate change, methodology and modelling. Both oral and poster presentations alike aroused interest, sparked discussions and fuelled many exchanges often pursued in the outdoor reception and dining area overlooking Dias Beach, a beautiful small bay at the foot of NIO.

A few highlights of the meeting included the recognition of polar ice and coral reefs as sources of DMS for the atmosphere, the exploration of alternative explanations to the DMS “summer paradox”, progress made in identifying novel genes that participate in the catabolism of DMSP, reports of field studies from the Arctic Ocean to the Indian Ocean as well as laboratory and mesocosm studies investigating the possible effects of environmental stressors, such as ocean acidification, temperature rise and others, on the production of DMS.

A final discussion session, led by Dr. T. Bell, allowed participants to brainstorm on pressing issues related to the future of the DMS database. The symposium ended on a cheerful note with the prizes for best oral and poster presentations awarded to Mr. G. Humphries, Ms. M. Fernandes, Mr. D. R. Valavala and Ms. E. Ozge. Finally, the congenial “Symposium Oscars”, a tradition started in Norwich in 2006 and upheld in Goa, highlighted various exploits and jovial feats of a few participating scientists.

A SOLAS co-sponsored session at the PICES 2010 annual meeting
22-31 October 2010, Portland, Oregon, U.S.A.

Huiwang Gao (hwgao@ouc.edu.cn)
Ocean University of China, Qingdao, China

The PICES 2010 annual meeting (“North Pacific Ecosystems Today and Challenges in Understanding and Forecasting Change”) hosted more than 400 scientists from 16 countries and included 15 oral and 1 poster sessions, and 6 side workshops.

Session 2 entitled “Understanding the role of iron in regulating biogeochemical cycles and ecosystem structures in the North Pacific Ocean” was co-sponsored by SOLAS and was convened by Angelica Peña (Canada), Toshi Saino (Japan) and Mark Wells (U.S.A.).

The objective of this session was to discuss the physical, biological and chemical processes controlling iron distribution and transformation, linkages between iron and ecosystem responses, and the progress in field observations and modelling studies that connect iron cycling with ecosystem structures and carbon fluxes in the North Pacific Ocean.

The session consisted of 11 oral presentations in which two invited talks were given by Prof. J. T. Cullen - Iron speciation and bioavailability: Insight gained from analytical chemistry and microbial physiology and Prof. Huiwang Gao - Response of marine ecosystem to Asian dust fertilisation from coastal sea to open ocean.

Prof. Cullen presented an overview of recent progress by chemists and microbial physiologists, sometimes working side by side, studying how the chemical form of Fe impacts its bioavailability. Insights provided by metal-metal interactions during microbial uptake between Fe and Cd and Fe and Cu in the north Pacific were also summarized. Prof. Gao presented a study on the response of coastal ecosystem to dust events based on observations and incubation experiments. The possible relationship between Asian dust and primary productivity/blooms in the coastal seas of China were examined during 1998-2008.

The other talks addressed a few scientific questions related to iron cycle in the North Pacific Ocean. 1) Fe to the iron cycle (II) Oxidation Rates by Organic Complexing Ligands, 2) mechanisms controlling dissolved iron distribution, 3) advection of deep-sea and coastal water into the HNLC region, 4) impact of Asian dust on plankton and DMS production, 5) oceanic iron supply mechanisms supporting the spring diatom bloom, 6) the role of zooplankton in buffering geographical heterogeneity of primary productivity, 7) the impacts of mesoscale eddies on iron cycle and biogeochemical processes, 8) reviews of the influence of ocean fertilization on marine biodiversity.

Emilie Brévière from the SOLAS International Project Office also gave an overview on the SOLAS project and its Mid-Term Strategy.
A workshop associated with the IGBP Fast Track Initiative (FTI) on “Upper Ocean Nutrient Limitation: Processes, Patterns and Potential for change”

3-5 November 2010, Southampton, UK

Mark Moore
c.moore@noc.soton.ac.uk
National Oceanography Centre, Southampton, UK

Over the past 2 decades a number of significant advances have furthered our understanding of the processes responsible for patterns of microbial nutrient limitation in the upper ocean and subsequent consequences for marine biogeochemistry. Moreover, given past changes and the potential for significant perturbation of limiting nutrient inputs to the ocean over the remainder of the century, it was felt to be an opportune moment for the community to attempt a clarification of the current state of knowledge.

The workshop was attended by 19 participants from 10 countries and four continents. A wide range of different disciplines were represented from microbiologists to paleo-oceanographers, reflecting the theme of the FTI cross-cutting IGBP projects including SOLAS, IMBER, AIMES and PAGES. Given the topics to be covered, a number of pre-workshop reports were prepared, with material on these presented during the first day of the workshop.

Subsequent discussions were focused towards synthesising this material alongside additional novel insights coming from the group. The participants continued to focus on four broad themes: 1) the concepts and definitions of nutrient limitation, 2) patterns of limitation in the modern ocean, including the development of a new database of prior published results, 3) expected changes in the future and finally 4) the potential implications of such changes.

Overall the range and level of expertise facilitated a dynamic environment for stimulating and productive cross disciplinary discussions, which will hopefully be reflected in the quality of the outputs. The group are currently working towards the first of these, the submission of a major review to a high profile journal within the first half of 2011.

Further details on the FTI and the workshop are available at http://ocean.stanford.edu/IGBP_FTI/. All attendees are thanked for their participation alongside IGBP, the US Ocean Biogeochemistry Programme, EU-COST 735 and SCOR for the funding which made the meeting possible.

Joint 5th workshop on Asian Dust and Ocean Ecosystem (ADOES) with Asian SOLAS / WESTPAC1 / METMOP2 / SALSA3

29 November – 2 December 2010, Nakasaki, Japan

William Miller (bmlller@uga.edu)
Department of Marine Sciences, University of Georgia, USA

Professors Mitsuo Uematsu (Japan), Gang Yi Shi (China), and SoonChang Yoon (Korea) began the workshop by first welcoming the 33 participants from Japan, China, Korea, and the United States, and then outlining the workshop objectives for the group.

The workshop goals were to improve the scientific understanding of the processes controlling the origin, transport, physicochemical nature and effect of Asian dust on ocean biogeochemistry. Additionally, the meeting was intended to enhance regional cooperation among the ADOES group and with other similar SOLAS initiatives around the world.

The first goal was accomplished with the presentation of 21 science talks over two days. These were delivered by both senior researchers and students and presented a comprehensive coverage of essential problems facing ADOES and other studies of ocean-dust interactions.

Enhancing collaboration and coordination of work within ADOES and with other dust studies was discussed in an afternoon session on the second day to end the formal workshop. This included a brief overview by Professor William Miller about the SOLAS Mid-Term Strategy and the role of ADOES as a leader and model for excellent regional scientific collaborations in promoting these plans.

Professor Huiwang Gao presented a concise overview of initiatives that ADOES could pursue in the coming year including the ability for samples to be collected for distribution on upcoming Chinese cruises. Further discussion identified, as a minimum, the following action items:

1) Invite someone from the Australian Dust group to the ADOES/WESTPAC workshop to be held is Busan, S. Korea, 28-31 March, 2011 (20 December abstract deadline).

2) Determine the feasibility and possible availability of a “Dust Standard” to be used by the ADOES group and international dust community. The National Institute of Environmental Studies (Tsukuba, Japan) is now trying to sample the dust in Mongolia.

3) Continue the intercomparison of analytical results currently underway on seawater and aerosol filter samples collected during the R/V Hakuho Maru cruise (KH-10-1) between the Japanese and Chinese groups.

It is clear from the successful 5th ADOES workshop activities in Nagasaki that the ADOES group is making good progress in addressing the important scientific questions related to the interactions between Asian dust and ocean ecosystems.

1) IOC/WESTPAC (IOC Sub-Commission for the Western Pacific), 2) METMOP (Marine Ecosystem Transit from Marginal seas to Open Pacific), 3) SALSA (Development of Seamless Chemical Assimilation System and its Application for Atmospheric Environmental Materials)
Air-sea gas fluxes at Eastern Boundary Upwelling and Oxygen Minimum Zones (OMZs) systems. A SOLAS Mid-Term Strategy initiative.

8-10 November 2010, Lima, Perú

coop-sponsored by SOLAS

Michelle Graco (mgraco@imarpe.pe)
Instituto del Mar del Perú (IMARPE), Peru and Aurélien Paulmier
(aurelien.paulmier@legos.obs-mip.fr)
IRD/LEGOS, LMI DISCOH, Peru

This meeting had its genesis in May 2008 (4th IGBP Congress, Cape Town) during the SOLAS Scientific Steering Committee meeting where the future of SOLAS research activities were discussed. A “white paper” was proposed concerning the “Activity of the Minimum of Oxygen (OMZ) in the Pacific” (A. Paulmier and V. Garçon, 2008). In November 2009, during the SOLAS Open Science Conference in Barcelona, Air-sea interactions in Eastern Boundary Upwelling Ecosystems (EBUEs) and OMZs were considered important topics and now form one of the SOLAS Mid-Term Strategy Initiatives (SOLAS Newsletter Issue 11). The idea of holding a workshop in Lima (Peru) at IMARPE was proposed in March 2010. Since then, IMARPE has been involved in the meeting coordination, together with the SOLAS International Project Office. The meeting held on 8-10 November 2010 was attended by more than 70 scientists from Brazil, Chile, China, France, Germany, Ireland, Mexico, Peru, UK, USA, and Switzerland (See Photo below).

During the first day and part of the second morning of the meeting, the talks provided an overview associated with the different foci of SOLAS: exchange processes across the air-sea interface and processes in the oceanic boundary layer (Focus 2); long-lived radioactively active gases (Focus 3); and biogeochemical interactions between ocean and atmosphere (Focus 1).

All the presentations covered state of the art new results and national programs and perspectives in the broad thematic spectrum associated with EBUEs and OMZs, including present and past studies in the area, particularly in the eastern boundary of the Pacific Ocean.

After the talk sessions, the participants split into three working groups (WG):

WG1: Air-sea exchange of Climate-relevant, Reactive and Active trace Gases (CRAGS);

WG2: OMZs-EBUEs “engine” of the present and past biogeochemical activity at the oxycline and the core (organic matter (OM) production, export and degradation; micro- and macro-community structures; isotopic fractionation), producing and/or consuming CRAGs;

WG3: Physical control of large-scale and regional circulation and variability for the OMZs-EBUEs.

During the working group sessions, each group identified key questions and discussed the strategy and common international plans. The main scientific questions were:

1) What is the role of the OMZ on the present and past biogeochemical activity at the oxycline and core (OM) production, export and degradation; micro- and macro-community structures; isotopic fractionation), producing and/or consuming CRAGs;

2) What is the relative contribution of physics (e.g. circulation, winds, eddies, waves) and biogeochemistry (sensitivity to: O2, OM nature and stoichiometry, pH; Fe and other metals) on OMZ control?

3) What is the role of the OMZ on the highly O2-sensitive nitrogen cycle (loss and gain through N2 fixation, nitrification, anammox, denitrification and nitrogen assimilation) coupled with the phosphorus and carbon cycles?

4) What are the future scenarios in the context of the interannual trends and global change considering all the involved feedbacks on climate?

We will focus on process oriented studies and on coordination and optimisation of all research cruises to be held from 2011 until 2013 in the Eastern Boundary Pacific Ocean, particularly off Perú. These cruises will be based on fixed-stations, section series and inshore/off shore cruises, carried out by IMARPE on a seasonal basis and by other countries which will include intensive autonomous monitoring (moorings, gliders, floats). The subsequent strategy will be a joint initiative of a multinational (e.g. Chile, China, France, Germany, Mexico, Peru, UK, USA…), multi-disciplinary and multi-program Mega Experiment at sea along with science flights for 2014-2015. In continuous interaction with planned observations, three working groups for modelling will be formed in order to optimise field strategy (e.g. choice of the fixed stations and of glider/floats deployment) and to test simple hypotheses (1: process models (e.g. role of remineralisation depth in 1D setting); 2: regional coupled models (physics, biogeochemistry); 3: high resolution atmospheric modelling).

Finally, during this workshop, SOLAS-Peru was born and now forms part of the international SOLAS network. Michelle Graco (IMARPE, Peru) will be the National Representative.

More details about the SOLAS OMZs-EBUEs Mid-Term Strategy Initiative can be found at: http://www.solas-int.org/aboutsolas/organisationandstructure/midtermstrategy/omzmeeting.html
2010 GEOTRACES Asia Planning workshop

4-6 October 2010, Taipei, Taiwan

Tung-Yuan Ho
(tyho@gate.sinica.edu.tw)
Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan and Robert F. Anderson
(boba@ldeo.columbia.edu)
Lamont-Doherty Earth Observatory, Columbia University, New York, USA

East and South Asia, the most populous regions on Earth, face the Western Pacific Ocean, the Indian Ocean and their marginal seas. Diverse anthropogenic and natural forcings coexist and interact in the biogeochemical cycling of trace elements and isotopes (TEIs) in these waters. However, their key regulating processes still remain largely to be explored. The major objectives of the 2010 GEOTRACES Asia Planning workshop were first to identify the key processes that regulate the biogeochemical cycles of TEIs in the waters and then to generate a future action plan for TEIs research. The participants included 25 Asian scientists from China, India, Japan, Korea, and Taiwan, 10 American and European scientists, and about 30 local graduate students. Detailed workshop information is available at: http://proj3.sinica.edu.tw/~geotrace/index.htm.

Following plenary talks presented in the first two days, three breakout groups were formed for further topical discussion, including water column, sinking particles, and submarine groundwater discharge (SGD) groups. The suggestions proposed by the groups were further discussed in the final plenary session. Some of the major conclusions achieved are highlighted here.

First, capacity building is essential for most Asian countries prior to initiating a complete GEOTRACES program. Currently, only Japan and Taiwan own clean sampling facilities and only Japan is capable of doing shipboard analysis for contamination prone trace metals. It is thus important to select crossover stations at deep-water sites to maintain an intercalibration effort for the key TEIs as Asian countries develop their capacity for TEIs analysis. The SGD group recommended selecting SGD sampling sites in the waters along Chinese coasts where the population is huge to evaluate the relative importance of SGD for nutrient and trace metal inputs in comparison to riverine and aeolian sources. The sinking particle group emphasised that the East Asia oceanic waters are regions with exceptionally high external particle inputs from both atmospheric and riverine sources and also with high gradients of external inputs over the broad continental shelves. Evaluating the fate of aerosol deposition is a high priority for TEIs study in the regions. Some of the research topics proposed during the workshop match closely with the core study of SOLAS and provide opportunities for future collaboration.

Overall, the workshop was successful and productive, largely due to the open-handed suggestions and insights provided by the American and European scientists. At the end, a future cruise plan was proposed by the Asian representatives (Figure 1).
Since the inception of the international GEOTRACES Programme, a strong interest has developed in carrying out GEOTRACES-related activities on trace elements and their isotopes (TEI) in the Mediterranean Sea, due to the proximity and importance of the ocean-land-atmosphere domains, as well as the variety and intensity of exchanges between these domains. A funding opportunity from COST Action ES0801 culminated in a GEOTRACES Mediterranean Planning workshop. More than 50 participants from 15 countries met and discussed various aspects of implementing GEOTRACES in the Mediterranean.

On day 1, keynote speeches demonstrated the large variety of themes that could be handled under the umbrella of GEOTRACES in the Mediterranean Sea. Among other things, the SOLAS-GEOTRACES cooperation in the Mediterranean was enhanced. Advocacy speeches focused on key parameters, tracers, processes and sites of interest for Mediterranean GEOTRACES.

Several parallel break-out sessions took place on day 2 with the goal of defining key questions and addressing how a GEOTRACES section in the Mediterranean Sea (and Black Sea) could bring new insights regarding TEI fluxes and processes at ocean interfaces, particle cycles, Western and Eastern Mediterranean process study/studies TEI as proxies for past change and TEI and models. The ideal Mediterranean GEOTRACES section(s) were discussed: (1) one central (W-E) section by the R/V Pelagia (Netherlands) will likely occur in 2013 and (2) other sections dedicated to focused process studies in key area such as the Gulf of Lions, Adriatic Sea, Black Sea, off the Egypt/Israel coasts etc will have to be organised concomitantly with the central section, with other research vessels. Complementary to the work during GEOTRACES sections, processes studies at key sites (such as time series coupling atmospheric deposition and sediment traps) were also discussed and will be considered in the implementation. Deliberations from the GEOTRACES Mediterranean Planning workshop will be recorded in a workshop report which is currently being drafted.

Web site of the workshop: www.cybaes.org/gtmed/GMPW/index.html
Cécile Guieu (guieu@obs-vlfr.fr)  
Laboratoire d'Océanographie de Villefranche sur Mer (CNRS), France

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. 33 scientists from 13 countries with internationally recognised 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 learnt from field and experimental approaches and how can we go further?

2. Atmospheric vs 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, parameterisation 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?

Day one was devoted to topical sessions focusing on each of the issues above. Synthesis presentations were given by session chairs, based on material collected from attendants before the meeting, allowing maximum time for constructive discussions. On day 2, reports from each of the 4 sessions allowed us to highlight the main issues concerning existing and missing knowledge of our present understanding on the impacts of atmospheric deposition on marine biogeochemical cycles and ecosystems. Discussions on how improved technologies, tools and new approaches could help in resolving some of the questions raised were very fruitful.

There were several outputs from the meeting. A review paper will aim to synthesise our knowledge in the global ocean, with a focus on the Low Nutrient Low Chlorophyll ocean where the atmospheric deposition is mainly occurring at present time. Considering that several experts from the Mediterranean and Black Sea were particularly interested in the atmospheric versus land based inputs in these regions subjected to high atmospheric inputs, a second paper on this topic is in discussion.

Finally, the whole group 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 multidisciplinary research on this topic, several options were proposed by the experts. A consortium to focus on European Seas with special focus on the Mediterranean and the Black Sea could be formed or a comparative study with non-European Seas could be proposed. The group decided to form an e-mail group to continue the discussion.

COST Action 735 (http://www.cost-735.org/) funded this 2 day workshop organised by Cécile Guieu (France) and Barış Salihoğlu (Turkey). The meeting greatly complimented the SOLAS Mid-Term Strategy initiative “Atmospheric control of nutrient cycling and production in the surface ocean.”

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//32 surface ocean - lower atmosphere study
New Project Integrator joins SOLAS

The last few months have seen a lot of changes for SOLAS data integration. We bid a fond farewell to Tom Bell, in December, wishing him the best of luck in his new role at the University of California, Irvine and thanking him for his enthusiasm and dedication to SOLAS over the past 3 years.

Although Tom will continue to be involved in the project the mantle of SOLAS Project Integrator has passed to Shital Rohekar who we welcomed in November. Shital is based at the University of East Anglia, UK, and has already been busy getting to know members of the SOLAS community.

Before joining SOLAS, Shital completed her Ph.D at the University of Cambridge, UK. Her research focussed on quantifying sulphur emissions from anthropogenic sources (e.g. research stations, ships, vehicles etc.) in Antarctica and developing emission inventories for the same. She has also worked on assessing the role of meteorology in transport and deposition of sulphur species within the Antarctic troposphere.

As a Project Integrator, Shital will work towards achieving SOLAS’s key objectives of assembling datasets, largely in terms of quantitative estimates of air-sea fluxes of gases and particles.

Initially, Shital will work with the aerosol community and focus on assembling the available aerosol/rain data. Some aerosol/rain data has already been submitted to define British Oceanographic Data Centre (BODC), Shital’s intention is to compile all the available data into a single database and link to this database through the SOLAS Integration website (http://www.bodc.ac.uk/solas_integration/). This could be of great importance to people who wish to compare their individual datasets or use it as input fields in their models.

If you wish to contribute aerosol/rain data or any other chemical species data towards SOLAS Implementation working groups I, II and III (http://www.bodc.ac.uk/solas_integration/implementation_products/) Shital would be very happy to hear from you. All contributors will be fully acknowledged for their contribution to global flux products.

Contact : S.Rohekar@uea.ac.uk

SOLAS Metadata Portal – A resource available to the community

Ever wondered what data has been collected by other members of the SOLAS community?

Ever known that data exists from a region but can’t remember who collected it and when?

Then try the SOLAS Metadata portal! http://tinyurl.com/46xnf9

The SOLAS Metadata Portal is an ongoing effort, initiated through SOLAS Integration (with the help of the SOLAS IPO), to identify what SOLAS data exists and where it is archived.

Metadata is, simply speaking, information about data. In the context of the SOLAS Portal, Metadata refers to information (or links to other sources of information) about a dataset (often collected throughout a research cruise or aircraft campaign). Much of the recent worldwide SOLAS Metadata has been assembled and archived into an inventory run by NASA (the Global Change Master Directory, GCMD).

This resource is freely-available to the entire community and enables the user to identify relevant datasets that include information about the actual data's location, when it was collected and the name of the data-provider. A wide range of compound and particle types are covered, making this useful to a wide range of SOLAS research, enabling increased collaboration and adding value to past and present scientific endeavour.

In its current state, the SOLAS Metadata Portal is an invaluable resource, in particular for communities that wish to generate a compilation of all relevant historical measurements at a global scale. However, if you have information that could be included, it’s a very quick job to contribute. Please contact Shital Rohekar (s.rohekar@uea.ac.uk) or use the template form which can be found at http://tinyurl.com/328zjr5.

www.solas-int.org
The 7th Management Committee (MC) meeting took place following the Working Group (WG) meeting “Atmospheric versus land based controls of nutrient cycling and production in the surface ocean: from fieldwork to modelling” (see report page 32) which many MC members also attended. The committee reviewed the progress of the Action over the last 6 months which included 4 WG meetings and 2 Short Term Scientific Missions (STSMs) currently in progress.

As the Action is drawing to a close the committee considered the achievements of the Action so far, including the outcomes and progress of WG meetings, the number of early stage researchers engaged through STSMs and attendance at WG meetings and the publications resulting from the Action. The committee discussed ideas for both a final action event and a publication to pull together the achievements of the Action so far.

The meeting was attended by the Actions Science Officer, Stefan Stueckrad, who updated the MC on newly established COST Actions and news from the Earth System Science and Environmental Management domain.

The committee approved the budget until the end of the Action including funding 2 further STSM’s and committing funds for publications resulting for the Action activities. The final MC meeting will take place in late 2011 (dates to be announced). For more information on COST Action 735 activities please visit www.cost-735.org

Forthcoming WG meetings and STSM’s are listed below.

Meetings

Sub-WG 2&3 meeting
‘What is the sea surface microlayer? Towards a unified physical, chemical and biological definition of the air-ocean interface’
Proposer: Michael Cunliffe
Date: 25-26 January 2011
Location: Plymouth, UK

Sub-WG 1&3 meeting
‘Sea-ice biogeochemistry and interactions with the atmosphere’
Proposer: Jacqueline Stefels
Date: 12-14 April 2011
Location: Amsterdam, Netherlands

STSMs

Jakub Kowalczyk
Instytut Oceanologii PAN (IOPAS), Sopot, Poland
Topic: Implementation of novel methods of particle flux measurements
Host: Lise-Lotte Sorensen, Aarhus Universitet, Roskilde, Denmark

Frances Hopkins
Plymouth Marine Laboratory, UK
Topic: Work on novel techniques for measuring DMS and organo-halogens
Host: Jacqueline Stefels, University of Groningen, The Netherlands

Ru-Jin Huang
National University of Ireland Galway, Ireland
Topic: Reaction Cycling of Particulate Iodine in the Marine Boundary Layer-A Chamber Study
Host: Thorsten Hoffman, University of Mainz, Germany

Petri Vaattovaara
University of Eastern Finland, Finland
Topic: The role of organics in SOAP (Southern Ocean Aerosol Processes)
Host: Michael Harvey, National Institute of Water & Atmospheric Research, New Zealand

Call for integrative sessions now open
If you have an idea for a session contact the SOLAS IPO at solas@uea.ac.uk. We will be happy to work with you to develop your proposal.
The organisation of this meeting was undertaken as part of the activities of WG I (Short-lived trace gas production and biological feedbacks) in Cost Action 735 and WG 2 (Intercalibration) and 3 (Data Management) in Cost Action 801. To represent a wide range of different disciplines and approaches to this topic, researchers actively working on plant element speciation, including a number of early career scientists, attended the meeting.

The aim of the meeting was to discuss the current state of the field with respect to measurements of trace metal speciation, identify the current groups working in this field and the current and potential users of this data. The main goal of the meeting was to bring workers in this field together and to develop a common criterion for data analysis and quality control for use in submitting data to a common database. For this purpose we also invited experts in oceanographic data management to help facilitate this interchange of information.

The meeting agenda was constructed around 3 invited talks that outlined the current state of the field and towards the construction of a database.

A main outcome of the workshop was the establishment of a Wiki for the exchange of information on trace metal speciation, theory and techniques. This Wiki is already functioning (https://portal.ifm-geomar.de/web/tmsis/wiki) and is being constantly updated. The wiki will form the initial repository for historical speciation data currently not available in online databases and include some more functions (e.g. templates, bibliographies). People interested in participating in the wiki should contact Peter Croot at pecr@pml.ac.uk.

A proposal for a research school for trace metal speciation will be explored to complement existing plans within GEOTRACES for shipboard intercalibrations for trace metal speciation.

An article summarising the results of this meeting will be submitted to EOS shortly (http://www.agu.org/pubs/eos-news/)

For further information on COST Action 801 visit http://costaction.earth.ox.ac.uk/

The aim of this workshop was to bring together a community of scientists working with different approaches ranging from field measurements to modelling, on fluxes from land to the ocean including vertical exchanges with the atmosphere. The major outcome expected from this workshop was to create synergies among this community to better constrain and evaluate transformation of matter and energy along the land-river-estuary-ocean continuum. Topics covered by the workshop were:

- Estimates of fluxes of major biogeochemical elements from land through rivers and estuaries to the ocean based on typological approaches to derive regional and global estimates.
- Modelling with different degrees of complexity and scaling of transformations of major biogeochemical elements during riverine and estuarine transit and in the coastal zone.
- Scaling of vertical fluxes (atmospheric exchange) of GHGs and other climatically active gases in riverine, estuarine and coastal oceanic environments.

At the end of the meeting stimulating discussions arose about the feasibility of:

- Coupling the RIVERSTRAHLER model with a simplified forcing field with the GLOBAL NEWS to provide more robust estimates of fluxes from rivers, at European and possibly global scales.
- Using the estuarine typology of U Utrecht to scale estuarine N2O and CH4 fluxes using MEMENTO and other data-bases.
- Using COSCAT continental shelf typology of University of Utrecht to scale DMS emissions from continental shelves.

It was noted that a mangrove GIS data-base has recently been developed and could be used to upgrade the University of Utrecht estuarine typology, to include inter-tidal areas.

Some participants expressed willingness to contribute CH4 and N2O data-sets to MEMENTO and to contribute carbon data-sets to GloRiCh in particular in the tropics. This will be highly valuable to calibrate/adjust the GLOBAL NEWS DIC model outputs and will also contribute to ongoing synthesis efforts on riverine fluxes in the RECCAP initiative.

All participants agreed that further interaction between WG3 with WG2 is needed to decide on best gas transfer velocity parameterisation, wind speed products and gridded gas transfer velocity to compute the CH4 and N2O fluxes based on the data compiled in MEMENTO.

We would like to thank Land-Ocean Interactions in the Coastal Zone (LOICZ) http://www.loicz.org/ for co-funding this meeting.
Ocean fertilization: from science to policy

Iron addition experiments in the 1990s helped develop the scientific rational for SOLAS, stimulating the programme’s major interest in the natural atmospheric controls of ocean productivity. Those studies also stimulated wider public and policy interest in whether ocean fertilization might help solve the climate change problem, as a relatively natural form of geoengineering. A policy-directed assessment of the viability of such an approach has now been published (Wallace et al., 2010; online via http://unesdoc.unesco.org/images/0019/001906/190674E.pdf), as a joint initiative between SOLAS and UNESCO’s Intergovernmental Oceanographic Commission.

Anyone looking for an endorsement of early claims that a tanker full of iron could start the next ice age will be disappointed by this review. Best estimates of enhanced global carbon storage achievable by deliberate ocean fertilization over the next hundred years are now 25-75 Gt, an order of magnitude lower than estimates from the early 1990s – and two orders of magnitude less than cumulative carbon emissions under unconstrained scenarios.

Whilst the possibility remains that ocean fertilization might be adopted as one of many ways of achieving climate stabilisation, this option is not risk-free. And the cost of showing that it is working (and not causing unintended consequences) could be high. There are also critical questions regarding the international acceptability and governance of any geoengineering approach that might involve adverse environmental consequences, as shown by recent discussions by the Convention on Biological Diversity.

The International Geosphere Biosphere Programme is now engaged in these issues, through a workshop on ecosystem impacts of geoengineering, with SOLAS involvement. (San Diego, 31 January – 2 February 2011).

Reference
To request a print copy please email solas@uea.ac.uk

If you would like to receive a hard copy of the SOLAS newsletter, please email solas@uea.ac.uk

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