Welcome to the SOLAS Newsletter

This is the fourth issue of the SOLAS Newsletter, and most of the contributions are targeted toward SOLAS Focus 3 science: Air-sea flux of CO₂ and other long-lived radiatively-active gases. An Implementation Plan for this research area has been developed jointly with the Integrated Marine Biogeochemistry and Ecosystems Research (IMBER) project, and it sets out research priorities for the two projects over the next decade. This scientific intersection provides a unique opportunity for the two projects to synergistically collaborate toward common goals. In order to facilitate international coordination, the two projects have developed the Joint SOLAS/IMBER Carbon Group (SIC), and this group works closely with the International Ocean Carbon Coordination Project (IOCCP) to provide a framework for oceanic carbon research coordination.

The science implementation for SOLAS and IMBER revolves around three main areas: Carbon inventories and fluxes, sensitivity to global change, and the air-sea flux of N₂O and CH₄. Within the Joint SOLAS/IMBER Implementation Plan, these research foci are mapped to the relevant SOLAS Activities and IMBER Themes and Issues, and within each of these subsections, the specific objectives are identified and implementation requirements are described.

We encourage you to download a copy of the Joint Implementation Plan and join us as we make progress in this exciting area of air-sea interaction and oceanic research. (To download, see: http://www.uea.ac.uk/env/solas/SPIS/SPS1.html)

Truls Johannessen – co-Chair, SIC, Bjerknes Centre for Climate Research, Bergen, Norway
Arne Körtzinger – co-Chair, SIC, Institut für Meereskunde an der Universität Kiel, Germany
Sea ice production, a mean of enhancing air-sea CO2 transport

Leif G. Anderson, Department of Chemistry, Göteborg University, Sweden – contact: leifand@chem.gu.se

During a study of a fjord in southern Svalbard, Storfjorden, in late April 2002 we observed very high salinities in the bottom water, about 35.8 psu compared to that of the surface mixed layer 34.8 psu. The fjord bottom water had not been ventilated since last summer and the high salinity was a result of brine production during sea ice formation. The high salinity bottom waters had elevated concentrations of dissolved inorganic carbon (DIC) and pCO2 compared to the surface water (Fig 1), even if pCO2 throughout the water column was well below that of the atmosphere. This signal in DIC was not paralleled by that of nutrients and oxygen, so it is unlikely that biological activity is the cause of the high pCO2 levels. Instead, uptake from the atmosphere was suggested (Anderson et al., 2004) as a result of an efficient exchange through the surface film during the ice crystal formation and the rapid transport of the high salinity brine out of the surface layer as illustrated in Figure 2.

The difference in CO2 partial pressure between the surface water and the overlying atmosphere is about ~90 µatm (286 µatm relative to 376 ppm). This strong under saturation in the surface water results in a gradient that will drive a flux from the atmosphere into the sea, if the conditions are favorable, such as during sea ice production. A similar process functions for CFCs and oxygen, but in the present study with less effect, as their surface water concentrations were closer to being in equilibrium with atmospheric concentrations.

The total CO2 uptake, computed by integrating the excess DIC down to 150 m relative to the average DIC concentration in the top 50 m of the profile was about 9 g C m-2. If this entire signal was attributed to the winter season of 2001-2002, the CO2 uptake is about 25% of that estimated into the Barents Sea, where the latter flux is driven by both cooling and biological primary production.

This process has not previously been considered for the oceanic uptake of atmospheric CO2 in high latitudes during the winter season. Our suggested mechanism will be functioning and efficient in taking up atmospheric CO2 in regions of polynyas and leads if the surface water is under-saturated with respect to CO2 during this period (as is the case for most surface waters of the Arctic Ocean). In a world of changing climate, larger areas are likely to be ice free and open for sea ice production during the fall and early winter, thus making this process quantitatively more important.

References:

The decrease of the oceanic carbon sink in the North Atlantic Subpolar Gyre

Antoine Corbière - Laboratoire d’Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN/IPSL), Université Pierre et Marie Curie, Paris, France. Contact: corbiere@ccr.jussieu.fr

The evaluation of interannual variations of oceanic carbon sources and sinks represents an important step for better understanding the coupling between climate change and the global carbon cycle. It is well observed that the atmospheric CO$_2$ is increasing regularly at 1.34 ± 0.54 µatm/yr since 1960. The decadal change of pCO$_2$ in the ocean (pCO$_2^{oc}$) is much less known. In this context, long term regional observations are crucial to detect the trends of pCO$_2^{oc}$ and validate the modelling approaches.

Since 1993, regular sea surface water sampling for both hydrological and carbon parameters has been conducted in the North Atlantic between Iceland (64°N) and Newfoundland (47°N) (Figure 1). DIC (Dissolved Inorganic Carbon) and TA (Total Alkalinity) were measured in laboratories in the USA (1993-1997, LDEO) and France (since 2001, LOCEAN). In this study, we present new pCO$_2^{oc}$ calculations based on DIC and TA, and we focus the analysis on the open ocean region of the North Atlantic subpolar gyre (NASG). This region has been well identified as a strong net CO$_2$ sink, and the area exhibits large interannual and decadal variability driven by large-scale climatic events such as the North Atlantic Oscillation (NAO), through thermodynamics, wind speed, biological processes, freshening and ocean circulation changes.

For the period that was not sampled for the carbon parameters (1997-2000), we extrapolated the wintertime pCO$_2^{ac}$ with a simple robust relationship based on SST. The calculated pCO$_2^{ac}$ (1993-2003) showed a gradual increase during the observational period (Figure 2). As both DIC and TA were relatively stable over 1993-2003, the decadal variation of pCO$_2^{oc}$ is likely controlled by the rapid warming (+1.5°C over ten years) experienced in this region since the decrease of the NAO index in 1996. We have estimated an increasing rate of +2.8 µatm/yr for wintertime pCO$_2^{oc}$ (Corbière et al., 2006). If the change of wintertime pCO$_2^{oc}$ is assumed to be constant at multidecadal time scales, these results are in good agreement with estimates based on winter pCO$_2$ reconstruction for 1972-1989 (~ 3.0 µatm/yr, Omar and Olsen, 2006). We have also compared our summer observations (1993-2003) with those obtained in August-September 1981 during the TTONAS experiment. On average pCO$_2^{oc}$ was lower in 1981 than during the 1990s. The decadal trend of pCO$_2^{oc}$ for summer (August-September) was +1.8 µatm/yr. This is in good agreement with the value deduced from the synthesis of pCO$_2$ observations conducted between 1982-1998 (Lefèvre et al., 2004).

This synthesis suggests that the carbon sink has decreased since 1972 in the high latitude of the North Atlantic. The origin of this change requires further investigation to separate the effect of primary production, warming and advection of sea water from temperate latitudes. Preliminary results for the most recent cruises (2004-2006), suggest that the pCO$_2^{ac}$ increase is faster than in the atmosphere. This highlights the need for continuing long-term sea surface ocean observations of carbon properties (DIC, TA and pCO$_2$) and investigating, in more detail, the interannual and decadal variability in close collaboration with the modelling community.

Acknowledgements

The SURATLANT Project is supported by Institut National des Sciences de l’Univers (INSU), and Institut Paul Emile Victor (IPÉV). Special thanks are also due to the Service National d’Analyse des Paramètres Océanique du CO$_2$ (SNAPCO$_2$) at LOCEAN/IPSL for DIC and TA analysis. This work is also supported by the French program Flamenco CO$_2$, a component of SOLAS-France.

References


Since the early 19th century the atmospheric mixing ratio of nitrous oxide ($N_2O$) has been increasing, and it currently makes a significant contribution to the radiative forcing of the atmosphere (the greenhouse effect). The total global source of atmospheric $N_2O$ is approximately $23.6 - 28.3$ Tg $N_2O$ yr$^{-1}$, and the surface ocean alone is thought to contribute between 4.7 and 10.7 Tg $N_2O$ yr$^{-1}$. The uncertainty range for the surface ocean source is clearly rather wide, estimates ranging between 17 and 45 percent of the global total.

The Atlantic Meridional Transect programme (AMT), a NERC-funded consortium project, provided an ideal opportunity to collect valuable new data on the latitudinal surface water (0-300m) distribution and sea-to-air flux of $N_2O$ in a range of biogeochemical provinces ranging from oligotrophic gyres to highly productive upwelling regions.

Figure 1 shows a latitudinal cross section of percent $N_2O$ saturation (100% = atmospheric equilibrium) in the upper 300 m of the Atlantic Ocean during the AMT12 and AMT13 cruise tracks. The dominant feature of both was a seasonally persistent “plume” of high $N_2O$ saturation at tropical latitudes (25ºN - 25ºS); the maximum observed during AMT12 was around 400 %, at 302m (12º2’N, 32º3’W), and a similar maximum occurred during AMT 13; 390 % (33 nmol L$^{-1}$) at 304m (20º6’N, 18º2’W).

The $N_2O$ “plume” coincided with high $NO_3^-$ and low $O_2$ concentrations, and $\Delta N_2O$ (the $N_2O$ concentration in excess of atmospheric equilibrium) significantly correlated both with $NO_3^-$ and Apparent Oxygen Utilization (AOU), strong evidence for a nitrification $N_2O$ source. Estimated sea-to-air $N_2O$ emissions from the Tropical Atlantic were $0.17 - 0.26$ Tg $N_2O$ yr$^{-1}$ (AMT 12) and $0.19 - 0.32$ Tg $N_2O$ yr$^{-1}$(AMT13). The upper and lower boundaries of the flux ranges derive from using the wind speed-based transfer velocities of Liss and Merlivat (1986) and Wanninkhof (1992) respectively. Slightly higher $N_2O$ emissions from the eastern Tropical Atlantic are consistent with strong upwelling off the coast of Mauritania, where higher $N_2O$ saturations were found in the mixed layer (~ 5 – 25ºN).

This new data should aid improving our understanding of the processes involved in marine $N_2O$ cycling and its sea-to-air flux.

References


Grant Forster completed his Ph.D. in Marine Biogeochemistry at Newcastle University in 2006, based on data that he collected on legs 12 and 13 of the AMT programme. He is currently Research Laboratory Manager in the Ocean Research Group at Newcastle and his personal research interests include marine nitrogen and carbon cycling with an emphasis on biogas production and sea-air flux.
The role of local and regional environmental conditions in the carbon fluxes of a tropical coastal zone

Martinez-Arroyo, A.1, Castro, T.1, Wences, R.2, Rojas, A.3, Mendoza, M.2, Saavedra M.I.1, Mamani, R 1. Contact – marroyo@servidor.unam.mx

(1) Centro de Ciencias de la Atmosfera, UNAM (2) Unidad Academica de Desarrollo Regional, UAG (3) Unidad Academica de Ecologia Marina, UAG

An interdisciplinary approach will be adopted to characterize the land-air-sea carbon exchange behavior in a tropical region of the Mexican Pacific coast around 16°N-99°W (Figure 1). Three complementary aspects will be investigated in this project which was designed to focus on quantification of carbon fluxes, searching for the relative weight of human activities and natural events over these processes. Physical, biochemical and socioeconomic aspects which could influence the atmospheric carbon geographical distribution and interannual variability will be analyzed jointly, following a multiple scale strategy regarding both space and time.

The coastal zones have been recognized as spaces with intense interaction processes. They can act as zones of accumulation and transport of carbon towards the ocean. Nevertheless, the great heterogeneity of the environmental conditions and of the impact of human activities on the ecosystems makes uncertain if the continental margins must be considered sources or sinks of carbon gases and what are the forces driving them in one or another way.

Sources and sinks of carbon dioxide and methane will be evaluated in two coastal lagoon ecosystems and their adjacent marine environment during different weather conditions. Both sites are tropical coastal lagoons sharing many natural characteristics (i.e. climate regime, river inputs, mangrove forest presence, open communication with sea and similar sizes). One (Laguna de Tres Palos) is located in a highly urbanized area near of Acapulco, Guerrero, Mexico. The other (Laguna de Chautengo) is located about 200 km southward of Acapulco, and is surrounded by a rural environment with very different human activities and land uses.

The main goals for the first 18 months in each site are summarized as follows:

1) Atmospheric characterization, looking for spatial and temporal patterns of marine and land influences, through meteorological observation, physico-chemical analysis of atmospheric composition and transport, pCO2 gradients measurement as well as methane and dioxide carbon emissions and uptake from soils, water bodies and vegetation (mean land-air fluxes, sea-air fluxes).

2) Hydrological dynamics characterization, regarding mainly budget and transport (circulation and mix) of carbon species (total, particulate and dissolved organic and inorganic carbon) in the lagoon-sea system (land-sea fluxes).

3) Human dimension characterization by means of the analysis of socio-economic data regarding human population, land and natural resources uses, and by exploring patterns, temporal variability and potential changes (scenarios), as well as identification of human activities related with the atmospheric carbon.

The experimental part of this project includes testing the researchers’ capacity to reach an adequate integration of the multidisciplinary visions. In a next stage, model development will be necessary to achieve a quantitative understanding of the mechanisms through which the temporal and spatial structure of the carbon fluxes are produced as well as the potential sources for their variation.

Scientists and students of atmospheric, environmental and social sciences from two academic institutions, are developing this project in which the field phase will begin on October 2006. The Center of Atmospheric Sciences from the National Autonomous University of Mexico (UNAM) and the Academic Units of Regional Development and of Marine Ecology from the Autonomous University of Guerrero (UAG) invite the SOLAS community to contribute with the project, by direct participation or visiting as well as by means of suggestions about specific issues.

Figure 1: The two coastal lagoon ecosystems of Laguna Tres Palos and Laguna de Chautengo, where a study is being carried out to determine and compare the role of environmental condition on carbon flux, located along the Mexican Pacific Coast.
The Atlantic Meridional Transect programme is an open-ocean, in-situ, observing system that aims to improve understanding of the structure and functioning of marine ecosystems; the interactions between tropical, subtropical and biogeochemical processes; and the impact of global change on the Atlantic Ocean. Biological, chemical and physical data are collected in order to quantify the nature and causes of ecological and biogeochemical variability in planktonic ecosystems, and to assess the effects of this variability on the biological carbon pump and on air-sea exchange of radiatively-active gases. The programme began in 1995, utilising the passage of scientific research vessels between the UK and the Atlantic (50°N to 52°S), southwards in September and northwards in April each year. As well as collecting an internally consistent set of ‘core’ ecological and biogeochemical measurements, AMT also provides the contextual and educational infrastructure for UK and international scientists and students to participate in open-ocean cruises to enhance their science. AMT is, thus, both a ‘basin-scale observatory’ monitoring the health of Atlantic Ocean ecosystems and a ‘floating University’ training the next generation of oceanographers. Eighteen 40-day 13,500 km cruises have been completed so far, involving 180 scientists from 11 countries measuring up to 70 parameters each day to produce 140 peer-reviewed publications and contribute to 68 PhD theses.

The programme held a successful meeting at the Royal Society in London in July 2006 sponsored or endorsed by the IGBP National Committee and EUR-OCEANS. Poster and oral presentations from the meeting included talks by Patrick Holligan, Tim Jickells, Carlos Duarte, Nick Bates and Emilio Manano are available from the AMT website. The Scientific Committee for Ocean Research (SCOR) sponsored two young researchers from Chile and Argentina to attend this meeting and then participate in a workshop aimed at increasing awareness and use of the unique decadal AMT dataset.

Papers arising from results collected on recent AMT cruises are to be published in two special issues of Deep-Sea Research II in 2006 and 2007; and a proposal to continue AMT until 2012 has been submitted and is currently under review.

Hermann Bange is a chemical oceanographer at the IFM-GEOMAR in Kiel. His research interests include the marine nitrogen cycle with emphasis on nitrous oxide and the oceanic pathways of climate-relevant trace gases, such as methane. He participated in cruises in the tropical North Atlantic, the Arabian Sea, the Mediterranean Sea and the North and Baltic Seas.

Where the Sahara meets the Atlantic: First results from the SOLAS cruise P320/1 to the Mauritanian upwelling

Hermann W. Bange & P320/1 scientific party, Marine Biogeochemistry Res. Div., IFM-GEOMAR, Leibniz-Institut für Meereswissenschaften, Kiel, Germany. Contact: hbange@ifm-geomar.de

At the end of March 2005 ten scientists (Figure 1) from the Marine Biogeochemistry Research Division of the IFM-GEOMAR and a colleague from the “Institut Mauritanie des Recherches Océanographiques et de Pêches” (Nouadhibou, Mauritania) left Las Palmas (Canary Islands) for a cruise to the upwelling region off Mauritania. The cruise took place from 21 March to 7 April 2005 with the research vessel (R/V) Poseidon and was the second of a series of German SOLAS cruises in the tropical North Atlantic Ocean (see e.g. Wallace and Bange, 2004).

The contrasting biogeographic provinces off Mauritania, which are located in direct proximity to the Sahara, form an ideal natural laboratory to study the biogeochemical interactions between the surface ocean and the lower atmosphere. Due to the seasonally meandering Intertropical Convergence Zone (ITCZ) the Mauritanian coastal waters experience a pronounced seasonality of the wind-driven coastal upwelling. During the intensive upwelling season which peaks in February/March, the coastal region off Mauritania was expected to be a ‘hot spot’ of biogenic trace gas emissions and iron input into the ocean because it is site of very high biological productivity, upward mixing from subsurface layers; and enhanced atmospheric deposition of Fe-rich Sahara dust. Thus, the major objectives of leg 1 of the 320th cruise of R/V Poseidon (P320/1) were to investigate the biogeochemical cycling of climate-relevant trace gases and iron (Fe) and to study the physical setting off Mauritania during the peak of the upwelling season. The main working packages included measurements of:

- atmospheric and dissolved concentrations of carbon dioxide, nitrous oxide, methane and halocarbons (bromoform and others),
- Fe in the upper water column,
- aerosol composition (in cooperation with A. Baker, UEA, Norwich),
- chlorophyll and other marker pigments (with I. Peeken, IFM-GEOMAR),
- transparent exopolymer particles and polysaccharides (with U. Passow, AWI, Bremerhaven),
- dissolved nutrients and continuous underway oxygen concentrations,
- water column microstructure.

Besides an extensive underway measurement programme, 32 stations on a 0.5°x0.5° grid were occupied in the area between 21°-17°N and 20°-16.5°W. The cruise ended in Mindelo (Cape Verde Islands). The data set from P320/1
will be available as of May 2006, and data requests should be submitted to the author. As expected, intensive coastal upwelling was found as a narrow band along the Mauritanian coast. The upwelled waters could be easily identified by the drop in the sea surface temperatures from about 22°C to about 17°C. Both enhanced nutrient and chlorophyll a concentrations (up to 11 µg.L⁻¹) were associated with the upwelled waters causing strong gradients between the open ocean and the coastal zone. Highest phytoplankton biomass was associated with a dominance of diatoms in the phytoplankton community, while in “aged” upwelled waters prymnesiophytes and cyanobacteria tend to dominate the algae community.

Upwelled waters originate from a depth range of 50-300 m and are mainly fed by the northwards flowing upwelling undercurrent along the continental slope, providing South Atlantic Central Water (SACW) to the upwelling region. Dissolved CO₂, O₂ and N₂O in the surface layer are clearly associated with the upwelling (Figure 2) whereas surface CH₄ concentrations are only slightly enhanced (data not shown). CHBr₃ surface concentrations are not directly linked to the upwelled waters but are generally enhanced towards the boundary to the upwelling area (data not shown). The upwelling region off Mauritanian is a strong source of atmospheric CO₂ and N₂O (Figure 2). This is in line with previous observations from other coastal upwelling areas such as the Arabian Sea. CO₂ and N₂O concentrations were mirrored by the O₂ concentrations implying that both gases originated from remineralisation of organic material before the waters have upwelled. More surprising are the results of the bromoform (CHBr₃) measurements. In contrast to our earlier hypothesis, the upwelled waters are not a strong source of atmospheric CHBr₃. The maximum surface water concentrations are found in the oligotrophic waters of the open ocean. CHBr₃ showed different correlations with phytoplankton pigments in the cold and warm waters, suggesting various biological sources. The emissions of CHBr₃ from the upwelling are too low to maintain the observed atmospheric mixing ratios, which are supplemented by additional not yet identified coastal sources. Currently, the results from P320/1 are being analysed in detail and we are looking forward to the results of the forthcoming German SOLAS cruises to the tropical NE Atlantic Ocean. For example, during leg 3 of the RV Meteor cruise 68 in July/August 2006, the region off Mauritania will be revisited during the non-upwelling season.

Further cruises as part of the proposed German SOLAS contribution SOPRAN (Surface Ocean Processes in the Anthropocene) are in the planning stages.

Acknowledgements

We are indebted to many land-based colleagues for their excellent collaboration without whom P320/1 would not have been successful. We thank the authorities of Mauritania for permission to work in territorial waters and acknowledge the excellent support by the officers and crew of RV Poseidon. The cruise P320/1 has received SOLAS research endorsement and was financially supported by the IFM-GEOMAR and the Deutsche Forschungsgemeinschaft (DFG).

References


![Figure 2: Surface distributions of (A) temperature (SST) in °C, (B) O₂ in µmol L⁻¹, (C) CO₂ in µatm and (D) N₂O in nmol L⁻¹.](http://www.agu.org/journals/ss/SOLAS1/)
CH₄ and N₂O are important atmospheric trace gases, which play significant roles in global warming and atmospheric chemistry (IPCC, 2001), and the global oceans are net natural sources of atmospheric CH₄ and N₂O. Although coastal regions such as continental shelves, estuaries and bays only occupy a small part of the world ocean area; they appear to be responsible for a large part of the oceanic CH₄ and N₂O emissions (Bange et al., 1994; 1996). Therefore, studies on the biogeochemistry of dissolved CH₄ and N₂O in coastal waters will be helpful to estimate the contribution of oceanic emissions to the atmospheric CH₄ and N₂O on a global scale, and to predict the influence of oceanic emissions to the global climate.

Distributions and fluxes of CH₄ and N₂O were determined during two surveys on the Yangtze River estuary and its adjacent areas in April-May and November 2002. CH₄ and N₂O concentrations in both the surface and bottom waters of the study areas show apparently seasonal variations, which are higher and more variable in spring than in autumn. The most conspicuous feature seen in all of the horizontal distributions of CH₄ and N₂O is the decrease of concentration along the freshwater plume from the river mouth to the open sea. Dissolved CH₄ and N₂O in the surface waters of the mainstream and tributaries of Yangtze River were determined during a survey in April-May 2003 and the results range from 5 to 300 nmol/L and 102 to 482 nmol/L, respectively, for CH₄ and N₂O. Based on the mean concentrations in the mainstream and a mean discharge of Yangtze River, total CH₄ and N₂O input via the Yangtze River is estimated to be 1.24 and 1.34 (x 10⁶) mol/yr, which indicates that the Yangtze River is a very important source for CH₄ and N₂O in the estuary and its adjacent area.

CH₄ and N₂O are important atmospheric trace gases, which play significant roles in global warming and atmospheric chemistry (IPCC, 2001), and the global oceans are net natural sources of atmospheric CH₄ and N₂O. Although coastal regions such as continental shelves, estuaries and bays only occupy a small part of the world ocean area; they appear to be responsible for a large part of the oceanic CH₄ and N₂O emissions (Bange et al., 1994; 1996). Therefore, studies on the biogeochemistry of dissolved CH₄ and N₂O in coastal waters will be helpful to estimate the contribution of oceanic emissions to the atmospheric CH₄ and N₂O on a global scale, and to predict the influence of oceanic emissions to the global climate.

Distributions and fluxes of CH₄ and N₂O were determined during two surveys on the Yangtze River estuary and its adjacent areas in April-May and November 2002. CH₄ and N₂O concentrations in both the surface and bottom waters of the study areas show apparently seasonal variations, which are higher and more variable in spring than in autumn. The most conspicuous feature seen in all of the horizontal distributions of CH₄ and N₂O is the decrease of concentration along the freshwater plume from the river mouth to the open sea. Dissolved CH₄ and N₂O in the surface waters of the mainstream and tributaries of Yangtze River were determined during a survey in April-May 2003 and the results range from 5 to 300 nmol/L and 102 to 482 nmol/L, respectively, for CH₄ and N₂O. Based on the mean concentrations in the mainstream and a mean discharge of Yangtze River, total CH₄ and N₂O input via the Yangtze River is estimated to be 1.24 and 1.34 (x 10⁶) mol/yr, which indicates that the Yangtze River is a very important source for CH₄ and N₂O in the estuary and its adjacent area.

In situ incubation experiments of sediments show that methane release rates, from two sediments, are 2.42 and 1.91 mmol·m⁻²·d⁻¹, and the N₂O release rates are 2.02 and -1.88 mmol·m⁻²·d⁻¹, which indicates that sediments can act as both a source and a sink of N₂O in the water column, while it is a net source of CH₄ in the water column. In situ incubation experiments of the surface and bottom waters show that biological activity in the water column of the studied areas can act as both a source and a sink of CH₄, but it is a net source of N₂O. The estimated average CH₄ fluxes using long term wind speeds and LM86 relationship are 11.7±10.8 and 7.7±7.87 mmol·m⁻²·d⁻¹ (Fig 1), and the average N₂O fluxes are 8.78±4.95 and 4.82±5.42 mmol·m⁻²·d⁻¹ in spring and autumn, respectively (Fig 2). Hence the Yangtze River estuary and its adjacent areas are net sources of atmospheric CH₄ and N₂O in both spring and autumn, and its strength appears to be relatively higher compared to the open ocean and the shelf region.

References:
Detecting anthropogenic carbon inventory growth in a noisy ocean

Scott C. Doney and Naomi M. Levine, Woods Hole Oceanographic Institution, Woods Hole MA USA. Contact: sdoney@whoi.edu

The uptake of atmospheric carbon dioxide (CO₂) by the ocean can, to some extent, slow the growth of this potent greenhouse gas arising from fossil fuel burning and land-use change. In the late 1980s and early 1990s, the WOCE/GOFS CO₂ Survey provided the first, globally consistent view of the ocean inorganic carbon system. Key results included new data-based estimates of the distribution and global inventory of anthropogenic carbon in the ocean (e.g., Sabine et al., 2004). The anthropogenic signal is a small perturbation on top of a large, natural dissolved inorganic carbon (DIC) background. Currently, surface waters are elevated by 50-60 mmol/kg relative to preindustrial levels of approximately 2000 mmol/kg. The anthropogenic signal is mostly contained in the upper thermocline and drops off with depth to <5 mmol/kg in deep waters. Best estimates are that roughly a third of all anthropogenic carbon emissions since the beginning of the industrial revolution have ended up in the ocean.

The WOCE/GOFS era data also serves as an excellent baseline for observing the uptake of anthropogenic CO₂ over time (e.g., Peng et al., 1998). Field programs (such as CLIVAR/CO₂) are now underway to measure changes in the ocean carbon system by conducting repeat occupations of key basin-scale transects on 5-10 year intervals (http://ushydro.ucsd.edu/). The expected rate of increase in anthropogenic DIC is small, from 0.5 to 1.5 mmol/kg/yr in the thermocline. With such coarse temporal sampling, approaches are needed to remove the effects of mesoscale eddies and interannual variability that would otherwise obscure the long-term anthropogenic trend of interest (top Figure panel). We are using numerical results from a coupled climate-carbon model (NCAR CSM-1.4; Fung et al., 2005; Doney et al., 2006) to investigate the magnitude of natural variability in the ocean carbon cycle and the impact of this variability on the detection and attribution of decadal-scale ocean DIC changes.

Since modern-day DIC data include both pre-industrial and anthropogenic contributions, several different techniques have been developed to remove the preindustrial background and interannual variability in order to calculate anthropogenic carbon. Specifically, we apply two commonly used empirical methods, the ∆C* technique and a multiple linear regression (MLR) analysis (Wallace, 1995), to the model dataset to determine the extent to which these methods can be used to filter out natural variability from repeat ocean transect data. While the ∆C* technique performs well at low latitudes, it is unable to remove some of the natural variability in the ocean carbon cycle, particularly at high latitudes (middle and bottom Figure panels). In these regions, ∆C* overcompensates for changes in apparent oxygen utilization (AOU) leading to significant errors (up to ±10 mmol/kg for transects sampled a decade apart) in the estimate of anthropogenic CO₂. The MLR analysis does a better job at recovering the true simulated temporal change in anthropogenic CO₂; however, the MLR approach is unable to account for changes in DIC due to secular trends (e.g. ocean warming) because the basic assumption of a stationary ocean no longer holds true. In addition, both the ∆C* and MLR techniques can only be applied to the upper water column (0-200m) with some caution.

Data-based estimates of the ocean uptake of anthropogenic carbon are essential for the evaluation of the numerical models used for future climate projections. We argue that traditional hydrographic section data should be augmented with additional information from time-series, profiling floats (such as the Argo array), satellite remote sensing, and numerical hindcasts in order to best determine ocean carbon system changes.

References


Figure: The top panel shows the simulated rms (1σ) natural variability in dissolved inorganic carbon (DIC) along a north-south section in the Atlantic from the CSM-1 coupled carbon-climate model. The middle panel shows the change in DIC over a 10 year period in a simulation with anthropogenic CO₂ emissions, and the bottom panel illustrates the resulting error when the ∆C* technique is applied to estimate the change in anthropogenic carbon.
Nitrous oxide and methane in the upwelling area off Mauritania (NW Africa)

Sarah Gebhardt* and Hermann W. Bange - Forschungsbereich Marine Biogeochemie, IFM-GEOMAR, Leibniz-Institut für Meereswissenschaften, Kiel, Germany - Contact: gebhardt@mpch-mainz.mpg.de

* now at: Abteilung Chemie der Atmosphäre, Max-Planck-Institut für Chemie, Mainz, Germany.

Nitrous oxide (N\textsubscript{2}O) and methane (CH\textsubscript{4}) are trace gases which play important roles in the chemistry of the Earth’s atmosphere. The ocean is a major source of N\textsubscript{2}O and a minor source of CH\textsubscript{4}. Coastal upwelling regions have been identified as ‘hot spots’ of oceanic emissions of both gases.

During the first leg of cruise no. 320 with RV Poseidon (P320/1) in the upwelling area off Mauritania (NW Africa) in March/April 2005, atmospheric and dissolved N\textsubscript{2}O and CH\textsubscript{4} were measured continuously in the surface layer. The cruise P320/1 was a pilot study for the upcoming German contribution to SOLAS named SOPRAN (Surface Ocean Processes in the Anthropocene).

The N\textsubscript{2}O surface distribution was closely associated with sea surface temperature (Figure 1). Depth profiles of N\textsubscript{2}O (not shown) support the view that N\textsubscript{2}O is accumulating in the subsurface oxygen minimum zone and then brought to the surface by upwelling processes. The cold, freshly upwelled waters along the coast showed significantly enhanced N\textsubscript{2}O concentrations. The N\textsubscript{2}O concentrations (saturation) ranged from about 7.8-nmol.L\textsuperscript{-1} (100-107%) in the open ocean up to 12.nmol.L\textsuperscript{-1} (150%) in the upwelling area. This implies that the narrow band of coastal upwelling off Mauritania was a strong source of atmospheric N\textsubscript{2}O. Since subsurface oxygen concentrations were well above the threshold for denitrification, we assume that nitrification is the major N\textsubscript{2}O formation process off Mauritania.

In contrast to N\textsubscript{2}O, CH\textsubscript{4} concentrations were only weakly affected by the upwelling (Figure 1). The N\textsubscript{2}O concentrations (saturations) ranged from about 2.0-nmol.L\textsuperscript{-1} (100%) in the open ocean up to 2.4-nmol.L\textsuperscript{-1} (107%) in the upwelling area. This is a rather unexpected finding, the reasons for which are not yet clear.

In order to resolve the seasonality of the trace gas emissions off Mauritania, further investigations are currently ongoing (RV Meteor cruise M68/3 in July/August 2006, Poseidon cruise P348 in February 2007). Based on these surveys of the trace gases their fluxes off Mauritania will be quantified. This work was partly funded by the DFG.
Andrew Lenton is an ocean biogeochemical modeler. He recently completed his PhD at CSIRO Marine and Atmospheric Research, Hobart, Australia, following degrees in physics and Antarctic Studies. Currently, he is a postdoctoral researcher based at LOCEAN in Paris in the framework of CARBOOCEAN. His research interests include global ocean biogeochemical modeling, development of sampling strategies and understanding the mechanisms that drive variability in the Southern Ocean.

How does the Southern Ocean Carbon Cycle respond to changes in the Southern Annular Mode (SAM)?

Andrew Lenton1,2,3,* Richard J. Matear2,3
1.Institute for Antarctic and Southern Ocean Studies (IASOS), University of Tasmania, Australia; 2. CSIRO Marine and Atmospheric Research (CMAR), Tasmania, Australia; 3. Antarctic Climate and Ecosystem Cooperative Research Centre (ACE CRC), University of Tasmania, Australia
* Now at: Laboratoire d’Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN/IPSL), Université Pierre et Marie Curie, Paris, France. Contact: Andrew.Lenton@lodyc.jussieu.fr

The Southern Ocean, with its energetic interactions between the atmosphere, ocean and sea ice, plays a critical role in ventilating the global oceans and regulating the climate system through the uptake and storage of heat, freshwater and atmospheric CO2. This uptake shows large variability at interannual and longer timescales, and this has important implications for the global carbon budget; therefore it is important to understand what drives this variability to be able to predict how it may respond to climate change.

We explore what role the Southern Annular Mode (SAM or AAO or HLM), the dominant mode of climate variability in the Southern Hemisphere, has in driving interannual Southern Ocean air-sea CO2 fluxes. The SAM induces changes in the strength of westerly winds that has been shown to induce significant changes in ocean circulation (Oke and England, 2004). These changes include: (1) changes in the strength of northward Ekman Flow and increased upwelling along the Antarctic Continent; (2) changes in the vertical tilt of the isopycnals; and (3) changes in the strength of the Antarctic Circumpolar Current (ACC) resulting in changes in mixed layer depth and oceanic heat transport. Present climate change projections suggest that the strength of the SAM will increase in future decades. We defined the SAM as the first EOF of the 850 hPa geopotential height anomaly following Marshall (2002).

The Southern Ocean remains one of the most poorly carbon sampled regions globally, particularly at the interannual and longer timescales. Therefore, to explore how the SAM affects the carbon cycle, we use a prognostic Biogeochemical Ocean Global General Circulation Model (BOGCM). The model we used was the CSIRO Mk 3 model, driven with NCEP-R1 atmospheric forcing and observed CO2 history following the protocol of NOCES (OCMIP3; http://www.ipsl.jussieu.fr/OCMIP/phase3/simulations/NOCES/WHOWTO-NOCES.html).

In this way we let the NCEP forcing fields generate our interannual variability. The air-sea CO2 flux and its components (wind speed, sea surface temperature, salinity, dissolved inorganic carbon (DIC) and alkalinity (ALK)) are regressed against the SAM in this study. This allows us to estimate and quantify the response of each to the SAM focusing on the period 1980-2000.

South of 40°S the response of the Southern Ocean to the SAM can be divided into two regions, north and south of the Subtropical Front (STF; ~45°S; Figure). In the positive phase of the SAM, the region south of the STF showed a net decrease in uptake of CO2, while north of the STF there was a net increase. While these regions did have some compensating effect, when integrated over the Southern Ocean, the region south of the STF was clearly dominant, inducing a change in CO2 uptake of 0.15 PgC per unit change in the SAM, significant relative to the annual mean uptake of 0.6 PgC/yr. Over the period 1980-2000 the SAM explains 32% of the variance in the total interannual variability in air-sea CO2 fluxes.

Our analysis demonstrates that while the SAM affects air-sea flux changes in both piston velocity and ΔpCO2, it was primarily (90%) changes in ΔpCO2 that drove the response of air-sea fluxes in the Southern Ocean. Our analysis further shows that changes in ΔpCO2 are in turn driven by changes in the concentration of DIC in Southern Ocean surface waters. South of the STF, during the positive phase of the SAM, ocean physics drove the increased supply of DIC and ALK to surface waters; the strongest response was associated with the Antarctic Divergence (~64°S). The increase in ΔpCO2 due to the supply of DIC was partially offset by an increase in ALK. North of the STF the increase in uptake was due to solubility changes due to sea surface cooling.

In the future, we expect that the effect of the SAM on air-sea CO2 fluxes, in particular the supply of DIC to the upper ocean, will be partially compensated for by the predicted ocean stratification due to global warming (Matear and Hirst, 1999). Our current research using a coupled ocean-atmosphere model is aimed at exploring and quantifying these interactions as well as detection of the SAM response in the observations collected in the Southern Ocean as part of the long-term international CO2 observational programs.

Acknowledgements

This research received support from the Australian Commonwealth Cooperative Research Program and the European Integrated Project CARBOOCEAN.

References


A Figure: The response of the Southern Air-sea CO2 fluxes to the Southern Annular Mode in its positive phase. Positive values (red) indicate an increase in uptake.
In Focus

Gerrit de Leeuw

Gerrit de Leeuw is a Senior Research Fellow at TNO, and visiting professor at the School of Earth and Environment at the University of Leeds (UK). He is soon commencing a full professorship at the University of Helsinki (UHEL)/Finish Meteorological Institute (FMI) in the field of “Climate change and air quality monitoring using satellite and in-situ observations”. With 25 years of experience with aerosol ground based measurements of physical, optical and chemical properties; lidar remote sensing; and air-sea interaction, he has published ca. 70 peer-reviewed articles in the fields of aerosols, remote sensing and ocean-atmosphere interaction. He has also participated in 18 EU projects. He chairs the Programme Committee for Remote Sensing of the Netherlands National Research Foundation NWO-ALW, is a member of the SOLAS International SSC, the WCRP Working Group on Surface Fluxes, the SOLAS IMP2 SC, of the EU FP6 NoE ACCENT AT2 (remote sensing) and Aerosols SSC’s, Associate Editor of JGR-Atmospheres.

Truls Johannessen

Truls Johannessen works as a scientist for a research group in chemical oceanography at the Geophysical Institute, University of Bergen where he received an MSc and PhD in Marine Geology. As part of the SOLAS SSC, Truls is also the co-Chair of the SOLAS/IMBER carbon group, the Chair of the SOLAS implementation group on carbon and a member of the IOCCP committee. These responsibilities follow a devout career within the SOLAS field, as a Chair for the Norwegian SOLAS initiative, and the position of the Chair of the National Committee for JGOFS, NGOFS. His current research revolves around the assessment of marine carbon sources and sinks; the effects of North Atlantic Climate Variability and carbon flux and feedback within the Barents Sea ecosystem; and the Ocean Abyssal Carbon Experiment.

Christiane Lancelot

Christiane Lancelot was born and raised in Brussels. She studied biochemistry at the ‘Université Libre de Bruxelles (ULB)’ where she then completed her PhD on North Sea Phytoplankton Ecology. She now holds the position of Professor and Director of the Laboratory ‘Ecologie des Systèmes Aquatiques’ at ULB. Her research activity addresses the study and modelling of the response of marine ecosystems to climate and anthropogenic changes throughout the understanding of the interactions between plankton organisms and marine biogeochemical cycles (C, N, P, Si, Fe). Her research questions the contribution of biological processes to air-ice-sea exchanges of CO₂ and DMS in the Southern Ocean as well as the response of coastal eutrophication and harmful algal blooms (e.g. Phaeocystis) to changing nutrient loads and climate in the North Sea. In this scope, she has been involved in several national and international projects and chaired and co-chaired international conferences such as the Gordon Research Conference on Polar Marine Science.

Peter Liss

Peter Liss received his BSc in chemistry and physics from Durham University and his PhD in marine chemistry from the University of Wales. After holding a NERC Fellowship at Southampton University, he was appointed to the faculty of School of Environmental Sciences at the University of East Anglia. His research has involved studies of biological and photochemical processes of oceanic gases and their transfer mechanisms and rates across the air-sea interface, as well as the roles that they play on atmospheric chemistry and global climate regulation. He is Guest Professor at the Ocean University of Qingdao, China; the recipient of the Challenger Society, the John Jeyes and the Plymouth Marine Sciences Medal; and was awarded the title of ‘Royal Society of Chemistry’s Environmental Chemistry Distinguished Lecturer’. He has served NERC for 5 years and was Chair of the Scientific Committee of the IGBP. In 2007, he will take up the Chair of the Royal Society’s Global Environmental Research Committee. He is currently Chair of the SOLAS SSC.

In each issue of SOLAS news, we give you the chance to meet some of the members of the SOLAS Scientific Steering Committee.
Wade McGillis

Wade McGillis is currently Doherty Scientist at the Lamont-Doherty Earth Observatory and Associate Professor of Earth and Environmental Engineering at Columbia University. Dedicated to interdisciplinary environmental science and engineering, his research focuses on understanding surface processes and the coupling between aqueous and atmospheric systems, in particular, the role of air-sea CO₂ exchange on local and global carbon cycles. He was previously an Associate Scientist in the Applied Ocean Physics and Engineering Department at Woods Hole Oceanographic Institution. He holds a BSc in mechanical engineering from Northeastern University, and an MSc and PhD in mechanical engineering from the University of California, Berkeley. He is currently Chair of the United States Surface Ocean-Lower Atmosphere Study; a member of the World Climate Research Program – Working Group on Fluxes; the Geochemistry Division at Lamont Doherty Earth Observatory, and Associate Editor of the Journal of Geophysical Research.

Guang-Yu Shi

Guang-Yu Shi, a professor of the Institute of Atmospheric Physics, Chinese Academy of Sciences. He was born in the Shandong province of China in October, 1942 and graduated from the Department of Physics, Shandong University, in 1968. Dr. Shi got his PhD degree in Atmospheric Physics from Tohoku University of Japan in February 1982. His research background and interests are of the physical and chemical processes of the Earth’s climate system, especially the atmospheric radiative transfer, radiative forcing of climate change and the climate-chemistry interaction. For the SOLAS Program, Dr. Shi has a special interest in the Asian Dust and Ocean EcoSystem (ADOES) after he engaged in the Sino-Japanese ADEC (Aeolian Dust Experiment on Climate Impact) Project during the past five years as the PI from Chinese side.

Shigenobu Takeda

Dr. Shigenobu Takeda is an associate professor of Aquatic Biology and Environmental Science Laboratory at The University of Tokyo in Japan. His research interests include biological and chemical interaction between trace metals such as iron and marine phytoplankton, biogeochemical cycle of silicon and processes regulating primary productivity in the ocean. He is taking an active part in North Pacific Marine Science Organization (PICES) as a Chair of the Advisory Panel on Iron Fertilization Experiment.

Osvaldo Ulloa

Osvaldo Ulloa received his BSc in Marine Biology from the University of Concepción, Chile, and his MSc in Marine Biology and PhD in Oceanography from Dalhousie University, Canada. His PhD work concentrated on primary production and bio-optics. Osvaldo did postdoctoral work on the carbon cycle at the Niels Bohr Institute in Copenhagen. He is the Director of the Laboratory for Oceanographic Processes and Climate and a Professor of Oceanography at the Universidad de Concepción. His research activities include phytoplankton ecology, bio-optics and remote sensing of ocean colour, microbial oceanography, interactions between biological and physical processes; and biogeochemical cycling and climate. He has served as a member of the International Ocean Colour Coordinating Group and of the Coastal Panel of the Global Ocean Observing System. He currently is a member of the SCOR Working Group on Natural and Human-Induced Hypoxia and Consequences for Coastal Areas.
GLOBEC-CLIO TOP symposium

A major symposium organised by the GLOBEC regional programme, Climate Impacts on Oceanic TOP predators (CLIO TOP) has recently been announced. The symposium will consist of sessions from the four CLIO TOP working groups plus cross-cutting sessions on climate change and top predators, meso-scale issues, global change implications for management and conservation strategies of top predators; and future scientific challenges. The symposium will be held 3-7 December 2007 in La Paz, Mexico.

Further details: www.globec.org

GLOBEC is also holding a workshop on the “impact of climate variability on marine ecosystems: a comparative approach”. The aim of the workshop is to enhance understanding of the response of marine ecosystems to environmental change and to improve our knowledge of the impact of climate variability on marine ecosystems. The workshop will follow the Dahlem conference format and will be devoted entirely to discussion, with background papers submitted prior to the workshop. These papers, plus summaries of the discussions, will be published in a special volume of the ‘Journal of Marine Systems’. If you would like to be kept informed of the outcome of the meeting please contact the GLOBEC IPO: globec@pml.ac.uk

On 4-5 September, a joint meeting of the WCRP Working Group on Surface Fluxes (WGSF, Chris Farall, Chair) and the SOLAS Focus 2 Implementation Group (IMP2, Wade McGillis, Chair) met at the University of Heidelberg in Germany. These closely affiliated groups got together to discuss coordination and collaboration, along with planning future directions for the projects prior to participation in the International Workshop on Transport at the Air-Sea Interface. In particular, WGSF participated in the October 2006 WCRP Working Group on Numerical Experimentation (WGNDE) Surface Flux Analysis Project (SURFA) in Boulder Colorado. WGSF will provide a plan to create a SURFA archive, including a list of in situ platforms; a list of numerical weather prediction products; a prospective site for the archive; and a list of interested researchers. WGSF has also most recently developed a Handbook of Climate Quality Measurements at Sea and are in the process of completing two review papers on air-sea gas and particle fluxes. Other WGSF/IMP2 discussions were conducted on current field campaigns, including a proposed Southern Ocean GasEx cruise, the UK-led DOGEE cruise, laboratory work, and advances in remote sensing of gas transfer.

The western continental shelf of India: A hotspot of anaerobic biogeochemical transformations including production of nitrous oxide

Hema Naik and S.W.A. Naqvi - National Institute of Oceanography, Goa. India. Contact: hema@nio.org

Dr. Hema Naik is a scientist at NIO. Her primary research interest is biogeochemical cycling of nitrogen in the oceanic oxygen minimum zones.

Oceanic oxygen-deficient zones (ODZs) are sites of N₂ production through heterotrophic denitrification and autotrophic anaerobic ammonium oxidation. Such production of N₂ makes up for N₂ fixation, thereby keeping atmospheric N₂ content constant over geological time scales. However, an imbalance between the two terms can bring about sizable changes in the combined nitrogen inventory and affect oceanic capacity to sequester atmospheric CO₂, thereby modulating climatic (glacial-interglacial) cycles (Altataet al., 2002; Codispoti, 2006). Moreover, ODZs are also important for the global N₂O budget with the oceanic efflux accounting for about one-third of all N₂O inputs to the atmosphere (Bange, 2006). N₂O emission does not occur uniformly over the oceanic surface, though. In fact, the surface seawater is nearly saturated with N₂O in most areas, and substantial supersaturations are only observed in upwelling zones especially those containing ODZs. This is because N₂O is formed both during nitrification and denitrification. Production via both pathways is very sensitive to oxygen distribution in the low range. N₂O yield during nitrification increases greatly at low oxygen levels. N₂O is both produced and consumed during denitrification (N₂O ----> NO ----> N₂) in most denitrifying environments, characterized by the accumulation of nitrite. N₂O concentrations are generally quite low (<10 nM), but its accumulation invariably occurs at the boundaries of the ODZs making them strong net sources of N₂O to the rest of the ocean and ultimately to the atmosphere (Codispoti & Christensen, 1985).

ODZs are located along the eastern boundaries of the oceans with the exception of the Indian Ocean where the ODZ is found in the northwestern – in the Arabian Sea and – it impinges upon a much larger area of the continental margin than do the ODZs of other oceans. The major portion of the Arabian Sea ODZ lies beyond the continental shelves in the northeastern and central regions. Vertical profiles of N₂O here contain two maxima sandwiching a minimum, and since the upper N₂O maximum is located barely a few tens of metres beneath the sea surface it sustains large efflux of N₂O to the atmosphere. In addition to the perennial open-ocean ODZ, reducing conditions also develop seasonally over the western continental shelf of India (Naqvi et al., 2000). Although the largest of its kind in the world (area ~200,000 km²), the coastal ODZ still occupies a two orders of magnitude smaller volume than its perennial open-ocean counterpart. During the summer monsoon, coastal circulation is conducive for upwelling off the Indian west coast, which brings low-oxygen water over the shelf. But this water is generally prevented from surface due to the presence of a thin (<10 m) warm, fresher layer formed as a result of intense rainfall. Respiration of organic matter coupled with strong near-surface stratification leads to suboxia/anoxia at very shallow depth (sometimes within 10 m) of the sea surface. Off Goa, where sustained observations have been made since 1997 at a time-series station (depth ~ 28 m) CATS (Candolim Time Series), near-bottom oxygen reaches suboxic levels in August, and complete denitrification is followed by sulphate reduction in September-October (Figure). With the reversal of surface currents, oxic conditions are re-established in November-December. While the oxygen deficiency over the Indian shelf has been known to occur for several decades, there is no indication of sulphate reduction in the historical data sets. Therefore, it would seem that the intensification of the oxygen-deficient conditions has occurred in recent years, possibly as a consequence of increased loading of nutrients from land (Naqvi et al., 2000).

The most unexpected aspect of N₂O distribution is the unprecedented accumulation of N₂O observed during the late summer – early autumn in the inner- and mid-shelf regions north of 12°N. The highest concentration (765 nM) observed is about four times the highest values reported from the eastern tropical South Pacific. The N₂O build-up coincides with the accumulation of nitrite and depletion of nitrate, the telltale signs of denitrification. This is in sharp contrast to the above-mentioned trend in the open ocean ODZ. These observations strongly point to transient production of N₂O from nitrate through a reductive pathway.

Even when a net consumption of N₂O occurs in near-bottom waters, surface concentrations (5-436 nM, mean 37.3 nM) during the upwelling period are almost always far in excess of the corresponding saturation values. Employing available models of air-sea gas
exchange, the average \( \text{N}_2\text{O} \) flux to the atmosphere has been computed to range from 39 to 264 \( \mu \text{ mole m}^{-2} \text{d}^{-1} \). An extrapolation of this flux, over a period of six months, yields a total \( \text{N}_2\text{O} \) efflux of 0.05-0.38 Tg \( \text{N}_2\text{O} \) from the study region (Naqvi et al. 2006). This is roughly of the same magnitude as the most recent estimate of \( \text{N}_2\text{O} \) efflux (0.39 Tg \( \text{N}_2\text{O} \) y\(^{-1} \)) from the entire Arabian Sea (Bange et al., 2001). If some of the high efflux is due to above-mentioned intensification of the coastal ODZ, it would imply that human activities may lead to an enhancement of \( \text{N}_2\text{O} \) emission from the ocean.

**References**


**Figure:**

Monthly-/fortnightly-averaged records showing annual cycle of (a) temperature, (b) salinity, (c) \( \text{O}_2 \), (d-g) inorganic nitrogen species, and (h) hydrogen sulphide at the Cardolim Time Series (CATS) site (15°31'N, 73°39'E) based on observations from 1997 to 2004 (from Naqvi et al., 2006).

In China, the research groups that focus on the global change issues were greatly increased since the end of last century. The information demands of the international global change research and co-operation were raised. In 1999, a professional institute for global change information service, named the Chinese Information Center for Global Environmental Change Studies (CICGEC), was established in Lanzhou City, northwestern China. CICGEC is sponsored by the Chinese National Committee for Resources and Environment of CAS, also named Lanzhou Library of National Scientific Library, and Chinese National Committees for IGBP, IHDP and WCRP. Some other important related organizations, for example, are the Chinese National Committee for DIVERSITAS, the Institute of Geographic Sciences and the Natural Resources Research of CAS, who have given CICGEC some special supports.

The focus of CICGECS is to:
- Serve the researchers on global change studies with data, documents and information;
- Enhance information exchange and academic intercommunications between Chinese and international organizations and researchers;
- Maintain and build databases and information systems related to global change studies;
- Vacate time for information analysis and soft science research on global change.
- CICGECs has been one of the important information service institutes in China. It is playing indispensability roles in the fields of global change studies.

Website: www.globalchange.ac.cn
E-mail: gcinfo@lzb.ac.cn
Director: Prof. Zhang Zhiqiang (zhangzq@lzb.ac.cn)
Executive Secretary: Dr. Qu Jiasheng (quj@lzb.ac.cn)

**partner projects**

GREENCYCLES is a Marie Curie Research Training Network (RTN), funded by the European Commission’s Sixth Framework Programme. Like all RTNs, GREENCYCLES has both scientific and training aims. Its overall scientific aim is to reduce uncertainties associated with biogenic feedbacks on climate and ecosystems. Its training aim is to support the development of young scientists interested in a research career in global biogeochemical cycles. To this end, 17 researchers are being hired across the 11 labs in the network. GREENCYCLES researchers are working on marine-related projects at LSCE (Gif-sur-Yvette, France), UEA (Norwich, UK), and MPI-BGC (Jena, Germany).

Maciej Telszewski, originally from Poland (it is necessary for RTN researchers to move country to undertake their research), is a GREENCYCLES researcher based at UEA. Maciej is developing novel techniques to reconstruct atmosphere-ocean surface \( \text{CO}_2 \) fluxes from satellite measurements, in order to better constrain ocean carbon general circulation models. Meike Vogt, also at UEA but originally from Germany, is working on the development of DMSP and DMS parameterisations for the Dynamic Green Ocean Model (DGOM).

UEA is hosting British researcher, Nicholas Stephens, and MPI-BGC is hosting Italian researcher, Valentina Sicardi. Nick is also working on the DGOM, but concentrating on the implementation of a nitrogen cycle, including the role of nitrogen fixers. In contrast, Valentina, originally from Italy, will be using an atmospheric tracer transport model in various modes to quantify oceanic carbon processes and detect changes in the general ocean circulation.

GREENCYCLES sponsors the integration of these projects across interested European labs, and especially with the development of earth system models. GREENCYCLES also sponsors the organisation of relevant workshops and meetings, and the attendance of GREENCYCLES researchers and senior scientists at training events such as the SOLAS summer school.

For more information on these and other GREENCYCLES projects please go to www.greencycles.org

**SOLAS Special Report: Chinese Information Center for Global Environmental Change Studies**
Andreas Albertino Hutahaean graduated from the University of Bremen in 2002 and works as a researcher at the Research Center for Maritime and Non Living Resources, Agency for Marine and Fisheries Research (BRKP) in Jakarta, Indonesia. At the moment his research focuses on the dynamics of nutrients and water cycles in the Indonesian Trough Flow System particularly in the Lombok Strait, Indonesia. This research also linked to the interactions among land, sea surface and atmosphere in the location.

The dynamic of nutrients and water cycles in Lombok Strait, Indonesia

Andreas A. Hutahaean 1, Selvi Makarim 1, Agus Supagat 1, 2, Sugirta Wirasantosa 1

1Research Center for Maritime and Non Living Resources, Agency for Marine and Fisheries Research (BRKP), Jakarta, Indonesia; 2Dept. of Oceanography, Bandung Institute of Technology, Indonesia. Contact: andreas@dkp.go.id

The Indonesian Through Flow is the leakage of western tropical Pacific water into the southeastern tropical Indian Ocean through the Indonesia seas. This movement of water is an important pathway for transfer of climate signals and their anomalies around the world’s ocean. While the heat and fresh water carried by this flow are known to effect the basin budget of both the Pacific and Indian Oceans, the magnitude and vertical distribution of the Indonesian Through Flow are not well known. The thousands of islands and numerous passages that connect a series of large, deep basins within the Indonesian seas provide for the flow (Figure 1). The tendency for ocean boundary currents to pass through the westward-most available passage and the sill depths of the various passages, largely define this pathway. The Indonesian Through Flow exits into the Indian Ocean through the major passages along the lesser Sunda Island chain one of which is the Lombok strait (Gordon and Fine, 1996).

The Lombok Strait separates the Indonesian islands of Bali and is one of the most important zones through which water is exchanged between the Pacific Ocean and the Indian Ocean and plays an important role in the global ocean circulation. Transport through the strait exhibits large seasonal variations due to changes in the atmospheric pressure gradient between the Pacific and the Indian Ocean which is a function of the monsoon. As a result, the seasonal currents through the strait are bidirectional. The main topography features inside the Lombok Strait are an island (Nusa Penida) and a sill between this island and the smaller Lombok islands in the southern mouth of the strait. The current pattern consists of the superposition of the main flow and the tidal flow. In the upper 100 meters the current velocity reaches 1.5 m/s at the center of the strait and 3.0 m/s in the sill region (Gordon, et al., 2003; Spritall, et al., 2004)

This research emphasizes mechanisms and feedbacks that control the dynamic nutrient and water cycles in the Lombok Strait as one of the exit gates of Indonesian Through Flows in the frame work of global climate change phenomena by measuring variables such as chemical parameters (nutrient, BOD, COD, etc), biological parameters (chlorophyll-a) and physical parameters (current velocity, salinity, temperatures, wind speed and direction, etc) regularly. One set of observations is shown on Figure 2, on the comparison of Phosphate, Silicate, Nitrite and Nitrate between St-3 and St-6.

References


< Figure 1: Maps of some sampling locations in the Lombok strait.
China SOLAS Special Session held at the Western Pacific Geophysics Meeting, Beijing, China, July 24-27, 2006

The China SOLAS special session on Asian Dust and the Ocean Ecosystems (ADOES) had a wide range of relative topics that covered many aspects of ADOES. The progress of the China SOLAS project since established in 2002 was summarized, especially in recent years (Gao). The first phase of China SOLAS was supported by the National Natural Science Foundation of China (NSFC) with a budget of 8 Million RMB for 2004-2008. The project has finished a cruise in the Yellow Sea and the South China Sea in 2005 and conducted another in the Yellow Sea in 2006. They also plan to make a suggestion to initiate an international task team: ADOES, which will mainly involve researchers in China, Japan, and Korea, as well as researchers from SOLAS countries beyond Asia. They are planning a few meetings to promote the second phase of China SOLAS project. Many of the talks were related to measurements and analyses of Asian dust. Remote sensing of dust storms are investigated using satellite thermal infrared measurements (Zhang). Heterogeneous chemical reactions of SO$_2$ and NO$_2$ at the surface of mineral dust particles and on the Reactive halogen compounds (RHCs) are presented (Zhu and Ge), as well as, the new observations of atmospheric nitrogen deposition and aerosol over the Yellow Sea and the South China Sea (Qi and Guo). Their compositions were also analyzed. Important biogeochemical variables were measured over the northern South China Sea, the southern Yellow Sea and the coastal waters of East China Sea (Yin and Zhai). The correlations between Asian dust events and biological productivity in the western North Pacific Ocean were addressed and a model was used to understand the impacts of iron supply on phytoplankton community structure in the North Pacific Ocean (Yuan and Jin).

The dependence of depth of oceanic mixed layer on bulk aerodynamic algorithm, breaking waves, and Langmuir circulation were studied using a model (Zhao). The distribution of Mercury in Mangrove Ecosystem of Zhangjiang Estuary was investigated (Ding).

Chairs: X. Jin, H. Gao and T. Zhu

SOLAS Special Report: China SOLAS Special Session

Figure 2: Comparison of Phosphate, Silicate, Nitrite and Nitrate between St-3 and St-6 in Lombok Strait.
The oceans absorb one third of the anthropogenic carbon emitted to the atmosphere each year. Scientists are using surface underway observations of pCO₂ to determine the pattern, controls, and interannual variability of air-sea CO₂ exchange. A workshop that will bring together the international community to discuss and interpret surface pCO₂ data, and to find synergies with other carbon-related observations (repeat hydrographic sections, time series, and remote sensing), will be held in mid-April 2007 at UNESCO headquarters in Paris. State-of-the-art modeling and data assimilation techniques will be presented, along with strategies to determine the shape of a future observing network.

A meeting on the vulnerability of the ocean uptake to climate change will be held in conjunction with the surface carbon workshop. This meeting will focus on predictions of the behaviour of the ocean sink of carbon into the future and will examine how climate change could impact ocean temperature, circulation and structure and how these changes may affect marine ecosystems and the ocean's ability to absorb CO₂ from the atmosphere.

Visit the IOCCP website: www.ioccp.org

Monsoon Asia Integrated Regional Study is a new international research program of the Earth System Science Partnership and was established by START to address key questions about the coupled human and environment system in the monsoon Asia region. MAIRS, guided by a Scientific Steering Group (SSG), is supported by an International Project Office (IPO), and is looking to partner with other projects for research and other activities.

MAIRS began by organizing workshops, by selection of members for the SSG, and by opening the IPO in Beijing in 2005, and this office is supported by the Chinese Academy of Science.

In January, a meeting of 10 experts was held on the Initial Science Plan (ISP) of MAIRS. The main outcome was the identification of four crucial zones in Asia: Coastal, Mountain, Semi-Arid and Urban Zones. In April, a workshop with 20 scientists from across Asia provided further substance, and the ISP has been completed.

Frits Penning de Vries, Executive Director IPO, Beijing
(frits.pdv@mairs-essp.org)
http://www.mairs-essp.org

Marc Strous teaches Microbial Ecology and supervises anammox research at the Radboud University Nijmegen. Originally a chemical engineer, he completed his PhD in Microbiology in 2000 at the Delft University of Technology. During his PhD, he identified the first anammox bacterium. He has been a part of anammox research since.

Anaerobic ammonium oxidation (anammox) is the Nitrogen’s cycle new kid on the block. For a long time the Nitrogen cycle was considered to be complete, and defined by two paradigms. First, “ammonium is inert in the absence of oxygen”. Second, “Denitrification is the only sink for fixed nitrogen in the oceans”. With the discovery of anammox both are no longer true, because anammox combines nitrate and ammonium into dinitrogen gas in the complete absence of oxygen. The responsible bacteria conserve the energy from the above reaction to fix carbon dioxide and grow. Or do they really grow? These bacteria divide only once every two weeks at maximum speed, far slower that all other known N-cycle bacteria. Surprisingly, several recent studies have shown that these unhurried creatures may actually constitute a major sink for fixed nitrogen in the oceans (Thamdrup and Dalsgaard, 2002; Kuypers et al, 2003; Kuypers et al, 2005).

In the 1980’s, 1990’s, oceanographers were still generally unaware of “anammox”. The oceanic N-losses were still by definition caused by denitrification and were measured by a method known as acetylene inhibition which does not detect N-losses caused by anammox. In the meantime, a group of wastewater engineers at Delft University of Technology silently invested two decades to build a laboratory bioreactor based on anammox – for the cheap removal of ammonia from wastewater. Ultimately they were successful and the key was the engineering of a system that allowed for the very slow growth of the anammox bacteria.

Once the anammox bacteria grew, it also became possible to develop the tools to detect the presence and activity of these bacteria in Nature. So far this has been done for anoxic basins, sediments and upwelling regions. It turned out anammox bacteria were active everywhere and even contributed between 50 and 100% to N-losses in many cases. Currently, many research groups have joined the effort to assess the contribution of anammox to marine N-losses on a global scale. Interestingly, the consequences of the rewiring of the nitrogen cycle for the marine carbon cycle are still completely unexplored. See also: www.anammox.com

References
Particulate organic carbon export from the North and South Atlantic gyres: the $^{234}$Th/$^{238}$U disequilibrium approach

Sandy Thomalla¹, Robert Turnewitsch², Mike Lucas², Alex Poulton²

¹Department of Oceanography, University of Cape Town, South Africa; ²National Oceanography Centre, Southampton, UK. Contact:

Sandy Thomalla is a PhD student at the University of Cape Town, South Africa. In 2003 she received a British Commonwealth split-site bursary which allowed her to base her PhD studies at the National Oceanography Centre, Southampton where her work has been affiliated with the George Deacon Division and the Atlantic Meridional Transect programme. She is currently completing her dissertation on the export of carbon in the North and South Atlantic Ocean.

The central subtropical gyres of the open oceans have long been regarded as homogenous and static “marine deserts” with low rates of primary production (Karl et al., 1996). However, more recent studies have shown a large degree of variability in phytoplankton productivity which coupled with the immense size of the subtropical gyres (>40% of the Earth’s surface) makes the overall carbon export of these areas significant (up to 50% of global carbon export) (Teira et al., 2005). Quantifying and better constraining the role of the North and South Atlantic in the global carbon budget is addressed as part of the Atlantic Meridional Transect (AMT) programme (http://www.amt-uk.org). During AMT 14, we used the radioactive disequilibrium between naturally occurring particle-reactive $^{234}$Th ($t_{1/2} = 24.1$ d) and its conservative (soluble) parent $^{238}$U ($t_{1/2} = 4.47 \times 10^9$ yr) to quantify particulate organic carbon (POC) export from the surface waters of the Atlantic Ocean between ~50ºS and ~50ºN during April/May 2004. The estimated downward flux of $^{234}$Th is combined with measured ratios of POC/$^{234}$Th on large settling particles to quantify POC export (Buesseler et al., 1992).

Based on latitudinal distributions of selected hydrographic and biological parameters the transect was divided into six regions: “temperate” (35º-50ºN and 35º-50ºS), ”oligotrophic” (20º-35ºN and 5º-35ºS), “equatorial” (5ºS-5ºN) and “upwelling” (5º-20ºN). The lowest POC export fluxes were found in the oligotrophic gyres and ranged from 0 in the northern to 6 mmol C m⁻² d⁻¹ in the southern oligotrophic indicating a tightly coupled food web. Enhanced POC export was associated with the equatorial (25 mmol C m⁻² d⁻¹) and upwelling region north of the equator (15 mmol C m⁻² d⁻¹). POC export in the temperate regions ranged from 7 mmol C m⁻² d⁻¹ to a maximum of 41 mmol C m⁻² d⁻¹. High fluxes at the poleward edges of the gyres probably result from episodic nutrient loading processes associated with submesoscale features. Results from this study suggest that although carbon export in the oligotrophic centres of the gyres may be low, carbon sequestration in the temperate fringes of the gyres as well as in the equatorial and upwelling regions can be substantial, and that spatio-temporal variability in these areas of the world’s oceans needs to be considered more fully in the context of global oceanic carbon export.

References


Figure 1: A composite SeaWiFS image of surface chlorophyll for the Atlantic showing the AMT 14 cruise track. Locations of thorium CTDs are marked in bold and labelled.

Figure 2: Primary production estimates integrated to the 1% light level and POC fluxes along the AMT 14 transect. CTD identifiers and biogeographical domains are indicated at the top of each diagram. (I) temperate; (II) oligotrophic; (III) equatorial and (IV) upwelling.
To reduce costs and environmental impact, The SOLAS Newsletter will convert to online format for most subscribers. To subscribe to the hardcopy, please email e.breviere@uea.ac.uk and include your full address.
Impacts of winter storms on air-sea gas exchange
Weiqing Zhang\textsuperscript{1,2}, Will Perrie\textsuperscript{1,2}, and Svein Vagle\textsuperscript{3,4}
\textsuperscript{1}Dept. Engineering Math, Dalhousie Univ., Halifax, Canada; \textsuperscript{2}Fisheries & Oceans Canada, Bedford Institute of Oceanography, Dartmouth, Canada; \textsuperscript{3}Institute of Ocean Sciences, Sidney, British Columbia, Canada; \textsuperscript{4}Dept. Earth and Ocean Sciences, Univ. Victoria, Victoria, Canada. - Contact: zhangw@mar.dfo-mpo.gc.ca

Gas exchange across the air-sea interface can be viewed as turbulent transfer across two fluid boundary layers, controlled by complex physical and biochemical factors. As this process is often driven by wind, the gas transfer velocities are typically parameterized in terms of wind speed. However, uncertainties in parameterizations among various transfer velocities are large, particularly at high winds. Of particular importance to gas exchange, especially for poorly soluble gases such as oxygen (O\textsubscript{2}) and nitrogen (N\textsubscript{2}), is the contribution of bubbles due to breaking waves. Factors such as the super saturation related to small bubbles and the transfer velocity caused by these processes are not well known (SOLAS Science Plan, 2004).

The bubble-mediated gas transfer velocity ($k_b$) can be approximated by whitecap coverage and wind speed (Asher et al., 1996), because breaking waves generate bubble plumes and whitecaps. Farmer et al. (1993) estimated that the transfer velocity in storms is approximately three times greater than that suggested neglecting wave breaking and bubbles. Perrie et al. (2004) showed that related gas transfer velocities have a similar variation during North Atlantic hurricanes. Given the difficulty in making high wind measurements (> 20 ms\textsuperscript{-1}), gas exchange estimates are largely extrapolated from less challenging conditions. Moreover, $k_b$ depends on the solubility as well as on molecular diffusivity, and thus it differs from direct transfer near the surface (Asher et al., 1996).

The objective of this study is to investigate air-sea gas exchange during winter storms and possible mediation by bubbles, using field measurements from the C-SOLAS mooring at Ocean Station Papa in the Northeast Pacific (50°N, 145°W). We analyze a 6-day storm in January 2004 with winds in excess of 15 ms\textsuperscript{-1} over a 2-day period, and show that increasing gas transfer rates are coincident with increasing winds and deepening depth of bubble penetration. This process depends closely on the peak of the storm, wind speed and the composite sea state.

Our results are shown in Figure 1, suggesting that the bubble enhancement to the gas transfer velocity for O\textsubscript{2} and N\textsubscript{2} is up to ~20\%, in comparison to the formulation by Wanninkhof and McGillis (1999), and that the latter formulation plus the bubble formulation of Woolf (1997) can qualitatively approach values achieved by the Zhao et al. (2003) formulation. The simulated storms also can exhibit asymmetry in the sense that a sudden increase in gas fluxes and concentrations may occur with the onset of a storm, and follow by gradual recoveries to pre-storm conditions. Thus, wave breaking clearly influences the gas transfer velocity during the passage of the storm, and uncertainties in the sea state and bubble processes suggest the need for further study.

\textbf{References}

\begin{figure}
\begin{center}
\includegraphics[width=\textwidth]{figure1.png}
\end{center}
\caption{(a) Simulated wind speed (ms\textsuperscript{-1}), SWH (m), and whitecap fraction (W, \%), during storm event with the same y-axis scale; (b) calculated gas transfer velocities for O\textsubscript{2}, using $k_T$ from Wanninkhof and McGillis (1999), $k_b$ from Woolf (1997), and $k_T$ from Zhao et al. (2003).}
\end{figure}
The scientific challenges for IMBER-Intergretated Marine Biochemistry and Ecosystem Research

The goal of IMBER is to investigate the sensitivity of marine biogeochemical cycles and ecosystems to global change, on time scales ranging from years to decades, due to the society’s need to understand and respond to the impacts of climate change. The IMBER Science Plan and Implementation Strategy is structured around four major research themes. Theme 1 focuses on identifying and characterizing interactions between key marine biogeochemical cycles and ecosystem processes including the transformation of organic matter in food webs, transfers of matter across ocean interfaces, and material flow in end-to-end food webs. Central to meet the IMBER goal is Theme 2 which will develop a predictive understanding of how marine biogeochemical cycles and ecosystems respond to complex forcings, such as large-scale climatic variations and changing physical dynamics, carbon cycle chemistry, changes in nutrient fluxes, and the impacts of marine harvesting. IMBER seeks an improved understanding of the impacts of climate-induced changes such as circulation, ventilation and stratification, and of seasonal to inter-decadal variability on food web-biogeochemical interactions. IMBER seeks a better understanding of the expected CO₂-driven changes in carbonate chemistry and their effects on marine organisms and metabolism and ultimately on biogeochemical cycles, ecosystems and their interactions. In addition to this direct effect of changing carbonate chemistry, IMBER also focuses on the indirect changes via pH on the availability and speciation of macro- and micronutrients and toxic trace metals on ocean ecosystem structure and function. Another forcing is the predicted two-fold increase in nitrogen and phosphorous inputs from land to the ocean by the middle of this century (Figure 1). How changes in the abundance, distribution and stoichiometry of nutrient elements affect food web structure and function, and how will increases in hypoxia and anoxia affect food webs and cycles of key macro- and micronutrients, are central questions to IMBER. The third theme focuses on the present and future capacity of the ocean to control the climate system via atmospheric composition and ocean heat storage. Key scientific issues for this theme include (i) the varying capacity of the ocean to store anthropogenic CO₂; (ii) ecosystem feedbacks on ocean physics and climate; and (iii) impact of changes in low-oxygen zones on the nitrogen cycle, especially transformations involving N₂O. Finally, Theme 4 integrates natural and social sciences, drawing on information from the previous three themes to investigate key interactions with the human system and the options for mitigating or adapting to the impacts of global change on marine biogeochemical cycles and ecosystems.

Website: http://www.imber.info/ e-mail: imber@univ-brest.fr

A glimpse of the future ocean: mesocosm perturbation experiments

The absorption of fossil-fuel CO₂ into the world’s oceans, over the past two centuries, has led to an increase in gaseous CO₂ concentration and a decrease in pH and carbonate ion concentration, which has, in turn, served to lower the saturation state of seawater with respect to biogenic calcite and aragonite (Sabine et al., 2004; Feely et al., 2004). Although these changes in carbonate chemistry of the upper ocean may seem small; in reality, they have ample potential to cause changes in marine ecosystems. Changes in the ocean influence not only the most sensitive ecosystem components (e.g. acidification impacts on calcifying organisms), but also those components which interact with them; as predators, prey, competitors, epibionts, etc. The transfer of effects through the ecosystem may be dampened or amplified, depending on the prevalence of negative or positive feedback loops. Accordingly, system responses to changing environmental conditions can be gradual or catastrophic (“regime shifts”), including the potential for a complete reorientation of biogeochemical cycles. The identification of sensitive components, dampening and amplifying mechanisms, and

A Figure 1: Predicted riverine fluxes of dissolved inorganic nitrogen for various regions in 1990 and 2050 for the “business-as-usual” scenario. From Seitzinger et al. (2002).
feedback loops is urgently needed to develop scenarios for future ecosystem functioning and biogeochemical cycles. For an integrated understanding of the sensitivity of marine systems to global change, there is a particular need for manipulative experiments on the community to ecosystem level. This can be achieved both in large enclosures and open ocean in situ experiments. While mesoscale in situ experiments are often not practical or feasible for perturbations other than iron release. Mesocosm perturbation studies, however, offer a reasonable alternative, allowing the manipulation of complex ecosystems in a semi-natural setting under a range of oceanographic settings.

Recently a series of multinational mesocosm experiments were conducted to examine the effects of future forcing on marine pelagic ecosystems (e.g. Engel et al. 2005, Delille et al. 2005, Kim et al. 2006). In the true spirit of SOLAS, these experiments covered a wide range of disciplines from marine chemistry, marine biology, molecular & cell biology to biogeochemistry, atmospheric chemistry, and earth system modelling. Results from these experiments highlighted the sensitivity of key components of the pelagic ecosystem to ocean acidification and revealed associated biogeochemical feedback processes. Studies on the effects of projected future forcings on marine ecosystems will increasingly rely on manipulative experiments at the community level and may lead to a renaissance in mesocosm experimentation. To ensure comparability of the results from these experiments it will be important to develop guidelines and quality standards for mesocosm experiments. This should include questions concerning extrapolation to the natural system; addressing relevant scientific issues; optimal mesocosm size for the plankton community considered; closed versus open systems; and replication and controls. To promote comparative studies on results from multiple mesocosm experiment it will also be extremely helpful to collect and archive the data centrally and make them available to the scientific community.

Despite their broad applicability, mesocosm experiments have some significant limitations. Wall effects, unnatural mixing regimes and turbulence levels, and the exclusion of higher trophic levels create an environment which differs from ambient conditions. Moreover, presently available mesocosm facilities are either land-based or located near-shore. Mesocosm studies are therefore restricted to the generally more robust coastal ecosystems. To allow testing of ecosystems and processes most sensitive to ocean change requires the development of mobile mesocosm facilities which can be used in a variety of oceanographic settings, including open ocean locations. The technology for such a facility is presently under development as part of the German SOLAS Programme SOPRAN (Surface Ocean Processes in the Anthropocene). Another limiting factor is the relatively short duration of mesocosm studies, which due to wall effects and deviation of the enclosed communities from the natural system, are restricted to time scales of weeks to months. Like most experimental studies mesocosm experiments therefore run short in assessing long-term, chronic effects of environmental perturbations. With increasing evidence now suggesting microevolutionary adaptation to be a potentially important dampening mechanism in response to global change, this should be a top priority of future research in global change biology. One possible strategy for gaining a realistic assessment of this chronic effect is to artificially bath a patch of ocean or coral reef with high CO2 levels (Donny, 2006). Oceanographers are just beginning to explore the feasibility of such manipulative experiments.

In spite of some limitations, in situ mesocosm perturbation studies provide an effective tool to unravel the effects of projected future forcing on natural aquatic ecosystems and will provide the link between in vitro experiments and field observations. As human-induced global change continues to alter marine environmental conditions, manipulative experiments at the community to whole ecosystem level will become increasingly relevant.

Kitack Lee (ktl@postech.ac.kr)
Ulf Riebesell (uriebesell@ifm-geomar.de)
SOLAS Open Science Conference
6-9 March 2007 - Xiamen, China

Invited plenary speakers:
Laurent Bopp, France
Jill Cainey, Australia
Minhan Dai, China (Beijing)
Laura Farias, Chile
Véronique Garçon, France

Barry Huebert, USA
Kitack Lee, Korea
Maurice Levasseur, Canada
Craig McNeil, USA
Lisa Miller, Canada

Colin Murrell, UK
Phil Nightingale, UK
Tom Pedersen, Canada
Joyce Penner, USA
Eric Saltzman, USA
Lise Lotte Sørensen, Denmark

Shigenobu Takeda, Japan
Wuting Tsai, China (Taipei)
Doug Wallace, Germany
Roland Von Glasow, Germany
Andy Watson, UK
Tong Zhu, China (Beijing)

IMPORTANT NEWS!
To reduce costs and environmental impact, The SOLAS Newsletter will convert to online format for most subscribers. To subscribe to the hardcopy, please email e.breviere@uea.ac.uk and include your full address.

Production - SOLAS News is printed on Greencoat paper. Greencoat contains 80% recycled fibre and the remaining 20% virgin pulp is TCF (Totally Chlorine Free). In recognition, the range has been awarded both the NAPM and Eugropa recycled marks, two of the most prestigious and recognisable recycled certificates available.

Printed by: Gallpen Colour Print, +44 (0) 1603 624893
Design by: Woolf Designs, www.woolfdesigns.co.uk +44 (0) 1603 631711
Circulation: 1500

SOLAS sponsors
IPO Sponsors

Please recycle