

solas news

issue 2 :: Autumn 2005 :: www.solas-int.org



▲ The site of the land-based SOLAS Observatory on São Vicente, Cape Verde Islands, to be established in 2006 jointly by the UK, Germany and Cape Verde. Marine time-series measurements are planned at an offshore site - 60 km to the north east. Photo: Phil Williamson

Welcome to the SOLAS Newsletter

This issue of the Newsletter concentrates on presentations from the 37th International Liège Colloquium on Ocean Dynamics: Gas Transfer at Water Surfaces, from May 2005. Thus, the science contributions are most relevant to SOLAS Focus 2: Exchange Processes at the Air-Sea Interface and the Role of Transport and Transformation in the Atmospheric and Oceanic Boundary Layers. The Implementation 2 Working Group (IMP 2) is responsible for planning and integration of SOLAS Focus 2, which aims "to develop a quantitative understanding of processes responsible for air-sea exchange of climate relevant compounds (CRCs), momentum and energy to permit accurate calculation and predictions of regional and global fluxes." The need for this cross-cutting research is illustrated in that most

coupled atmosphere-ocean climate models employ surface flux corrections and closures, indicating that the processes controlling air-sea fluxes are not properly parameterized. SOLAS Focus 2 research strives for a fundamental understanding of these processes, and its scientists will develop improved parameterizations for use in coupled climate models. The scientific presentations in this newsletter demonstrate our reasons to be optimistic that we will achieve these ambitions.

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plus...

- National reports from 13 SOLAS Countries
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GCP

The Global Carbon Program (GCP) is now fully engaged in two major activities: Vulnerabilities of the carbon cycle in the 21st Century, and Urban and Regional Carbon Management.

Vulnerabilities: Starting this year, there will be several working groups producing new assessments of the vulnerability of carbon pools in the ocean and on land due to warming and land use change. The selected pools in the ocean are: solubility, soft-tissue and carbonate pump pools, and methane hydrates; on land: permafrost, peatlands, vegetation/fires, soil carbon.

Carbon Management: A network of regional case studies has been established with the purpose to compare evolution of greenhouse gases emissions over the last 20 years and relate them to their proximal and ultimate drivers. The comparative analyses will allow designing future development pathways with lower GHGs signature.



The Inter-American Institute for Global Change Research (IAI) is a regional inter-governmental organization created by a treaty between 19 countries in the Americas. IAI is dedicated to promoting scientific excellence, international cooperation, and the full and open exchange of scientific information relevant to global change. In addition to funding cooperative research, the IAI funds and organizes training and education, such as the IAI Training Institute on Climate and Health in the Americas (November 7-18, 2005, Kingston, Jamaica). There are also IAI-NCAR Training Workshops and IAI/NCAR Postdoctoral Fellowships. The IAI sponsors, jointly with the Institute for Agriculture in the Tropics and the German Academic Exchange Service, DAAD, a 2005 Summer School on Integrated Resource Management in the Tropics (September 19-30, 2005, Göttingen, Germany) which brings together specialists from Forestry and Agriculture involved in sustainable management and land use with a regional focus in Latin America.



Alberto V. Borges from the Chemical Oceanography Unit of the Université de Liège (Belgium) works on carbon and carbonate cycling in coastal ecosystems with particular emphasis on air-sea exchange of CO₂ and on the coupling between inorganic carbon dynamics and biological processes.

Budgeting sinks and sources of CO₂ in the coastal ocean: Diversity of ecosystems counts

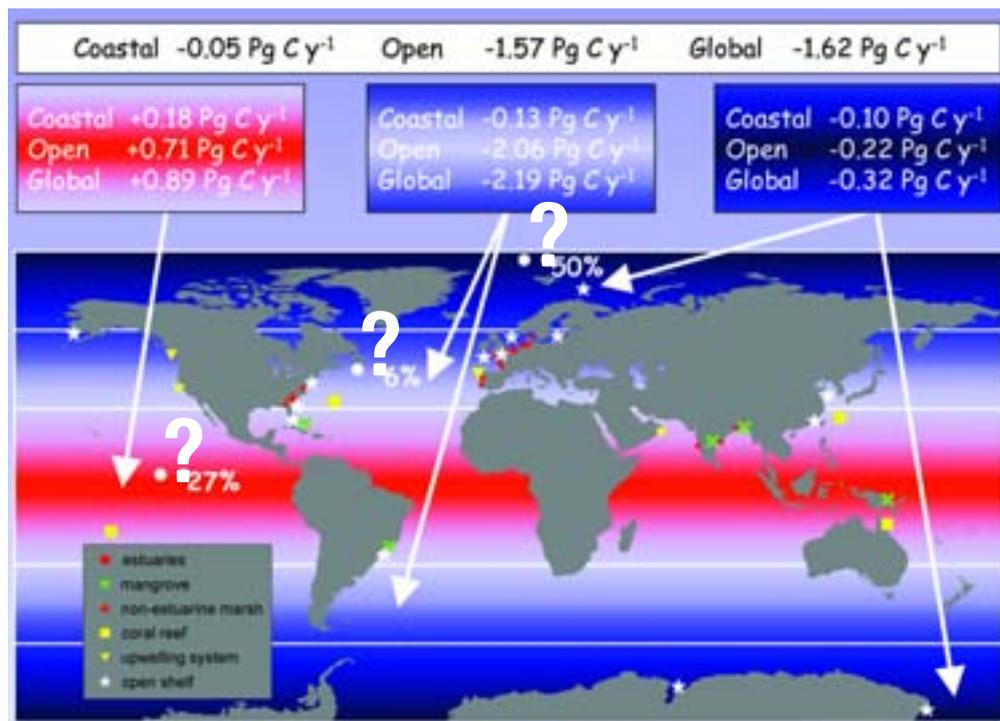
Alberto V. Borges, Bruno Delille, University of Liège, Chemical Oceanography Unit, Belgium, alberto.borges@ulg.ac.be

The coastal ocean has been to a large extent ignored in global carbon budgets, even if the related flows of carbon and nutrients are disproportionately high in comparison with its surface area. It receives massive inputs of organic matter and nutrients from land, exchanges large amounts of matter and energy with the open ocean across continental slopes and constitutes one of the most biogeochemically active areas of the biosphere. Hence, intense air-water CO₂ exchanges can be expected in the coastal ocean that could lead to a major re-evaluation of CO₂ flux budgets at regional or global scales. Also, 80% of the surface area of the coastal ocean is located in the Northern Hemisphere, with possible consequences for global atmospheric CO₂ inversion models and inter-hemisphere carbon transport estimates.

An exhaustive literature survey of air-water CO₂ fluxes was conducted and data in 44 coastal environments were gathered in 6

major ecosystems (marginal seas, upwelling systems, estuaries, mangrove and salt-marsh waters, and coral reefs). Marginal seas at high (Barents Sea, Bristol Bay, Prydz Bay, and Ross Sea) and temperate (Baltic Sea, North Sea, Gulf of Biscay, US Middle Atlantic Bight, and East China Sea) latitudes are net annual sinks of atmospheric CO₂ but at sub-tropical and tropical latitudes they are net annual sources of CO₂ to the atmosphere (US South Atlantic Bight, South China Sea, and Southwest Brazilian coast). Near-shore ecosystems (estuaries, saltmarsh waters, mangrove waters, coral reefs, and coastal upwelling systems) are net annual sources of CO₂. The most intense fluxes are located at the land-aquatic interface (estuaries, saltmarsh waters, and mangrove waters) due to inputs of terrestrial organic carbon that fuel the net heterotrophy of the aquatic compartment.

Air-water CO₂ fluxes in the coastal ocean were up-scaled by latitudinal bands of 30°,>



> taking into account its geographical and ecosystem diversity, and an overall integration of CO₂ fluxes was carried out using the most recent climatology for open oceanic waters¹. The coastal ocean would act as a net CO₂ sink at high and temperate latitudes and as a net CO₂ source at tropical latitudes. The inclusion of coastal air-water CO₂ fluxes would strongly increase the overall CO₂ sink at high and temperate latitudes, but would significantly increase the overall CO₂ source at subtropical and tropical latitudes.

Marginal seas act as a significant CO₂ sink (-1.62 mol C m⁻² yr⁻¹; -0.45 Pg C yr⁻¹) in agreement with previous estimates based on the extrapolation to worldwide continental shelves of data from the East China Sea² or the North Sea³. This agreement is due to the fact that although tropical and subtropical marginal seas are CO₂ sources they only represent 6% of the total surface area of the coastal ocean compared to 56% and 27% for, respectively, temperate and high latitude marginal seas. However, the global sink of CO₂ in marginal seas could be almost fully compensated by the emission of CO₂ (+11.09 mol C m⁻² yr⁻¹; +0.40 Pg C yr⁻¹) from the ensemble of near-shore coastal ecosystems, mostly related to the emission of CO₂ from estuaries (0.34 Pg C yr⁻¹). On the whole, the coastal ocean would act as a small CO₂ sink (-0.05 Pg C yr⁻¹) and would lead to a modest increase of the CO₂ sink from the global ocean (-1.57 versus -1.62 Pg C yr⁻¹, 3%).

The present up-scaling of air-water CO₂ fluxes shows the contrasted behavior of the proximal coastal ocean (ensemble of near-shore ecosystems) strongly influenced by terrestrial inputs and the distal coastal ocean (marginal seas) that exports carbon to the adjacent deep ocean as DIC and as organic carbon. This up-scaling also clearly illustrates the importance of the diversity of ecosystems and latitudinal variability in the overall role of the coastal ocean as a sink or a source of CO₂. This has significant consequences on our understanding of global cycles of carbon and CO₂.

Acknowledgements

Dedicated to Michel Frankignoulle and Roland Wollast, two dear friends and invaluable scientists.

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Further reading

Borges, A.V. (2005), Do we have enough pieces of the jigsaw to integrate CO₂ fluxes in the Coastal Ocean?, *Estuaries*, 28, 3-27.

Borges, A.V., B. Delille, and M. Frankignoulle (2005), Budgeting sinks and sources of CO₂ in the coastal ocean: Diversity of ecosystems counts, *Geophys. Res. Lett.*, submitted

Location of 44 coastal environments where annual integrated air-water CO₂ fluxes are available from literature and up-scaled fluxes in coastal, open and global oceans by latitudinal bands of 30°

Areas that require more research:

- a more complete description of the latitudinal and temporal variability of air-water CO₂ fluxes in marginal seas and near-shore ecosystems
- the uncertainty of surface area estimates of near-shore systems, in particular estuaries and the aquatic compartment associated to intertidal habitats (mangroves and marshes)
- the neglect of river plume data characterized by large fluxes and surface areas, although under-sampled and for which no global surface area estimate is available
- the lack of data in high-latitude estuaries and river plumes
- the assumption of a zero atmosphere-ice CO₂ flux at high latitudes that is inconsistent with recent data in the Arctic and in Antarctica
- the lack of data in certain coastal ecosystems such as highly productive seagrass and macrophyte dominated communities, systems mainly influenced by ground water inputs, and tidal and non-tidal lagoons.

national reports



Canada

Canadian SOLAS (C-SOLAS) is a major climate research project initiated in 2001. The SERIES (Subarctic Ecosystem Response to Iron Enhancement Study) campaign involved the introduction of iron to produce a phytoplankton bloom in the subarctic Pacific. Highlights of SERIES can be found in Boyd et al. (*Nature* 428, 449-553) and in the early 2006 *Deep-Sea Research II* Special Issue.

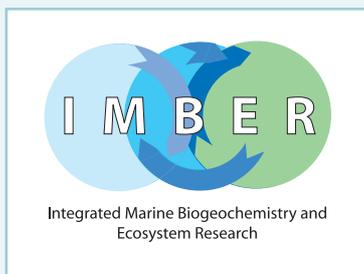
SABINA (Study of Air-Sea Biogeochemical Interactions in the Northwestern Atlantic) was a series of three cruises and aircraft overflights which followed natural phytoplankton blooms. SABINA's results include a better understanding of seasonal variations of climatically-active gas fluxes in the NW Atlantic and will be published in 2006.

A recent Letter of Intent for a Canadian Arctic SOLAS Network has been accepted for full proposal in early 2006 to conduct an east-west research study across Baffin Bay and Lancaster Sound during the International Polar Year 2007. For further information on C-SOLAS, go to www.csolas.dal.ca



China

The China National Committee for IGBP formally approved the establishment of the China IGBP-SOLAS Working Group in November of 2002 as the 'China Surface Ocean-Lower Atmosphere Study: Biogeochemical and Physical Process Coupling'. This program has been funded by the NSFC (National Natural Science Foundation of China) as a major project with a 4-year duration from 2004 to 2008. China SOLAS investigates air-sea biogeochemical interactions in the South China and Yellow Seas with two cruises in 2005 and one planned for 2006. In addition, a ground-based station, Qianliyan Island, which is located at 36°16N, 121°23E, will be set up for meteorological measurements and aerosol, trace gases and water sampling from autumn 2005. The China SOLAS project underscores the study of Asian dust and nitrogen deposition, their transport, flux into ocean and impact on the marine primary productivity. The China SOLAS Working Group is hosting and planning the next SOLAS Open Science Conference in Xiamen, 6-9 March 2007.



The IMBER International Project Office is now in operation. The Executive Officer, Dr. Sylvie Roy, has started in her new position in mid August, and an administrative assistant, Ms Elena Fily, began to work in the office in September. We are also in the process of hiring a Deputy Executive Officer. The IMBER Science Plan/Implementation Strategy has been published (IGBP Report 52) and is available electronically on our website (<http://www.imber.info>) or in hard copy by contacting the IPO.

A SOLAS/IMBER Carbon Group met in late September in Boulder, Colorado to take forward the writing of a joint SOLAS/IMBER Carbon Implementation plan (SOLAS Focus 3). In late October IMBER and GLOBEC will hold a joint IMBER/GLOBEC Executive meeting. This will involve detailed discussions regarding joint IMBER/GLOBEC activities and the relationship between IMBER and GLOBEC. Finally, a Special session entitled "The Mesopelagic and Bathypelagic Realms of the Ocean: Microbial Activity and DOM Cycling" will be convened under the IMBER umbrella at the 2006 Ocean Science Meeting, Honolulu, Hawaii.



In early August PAGES held its 2nd Open Science Meeting in Beijing with a broad range of excellent presentations about the themes "Paleoclimate, Environmental Sustainability and Our Future" (<http://www.pages2005.org/>). Beyond the ongoing research the meeting and the preceding SSC meeting also generated constructive discussions and feedback from the PAGES community on the future requirements of paleoscience and the role of PAGES. A resulting draft of a new systematic structure for paleoscience activities endorsed by PAGES, highlights primary issues ranging from the reconstruction of climate forcings all the way to the understanding of interaction of paleoclimate with humans and the paleoenvironment. PAGES and related communities of IGBP and beyond are invited to join expertises and suggest respective science initiatives.



Emilie Brévière holds a French engineering diploma in chemistry and chemical engineering from the ENSCMu, and post-graduate in oceanographic sciences. Her Ph.D work encompassed the temporal variability of air-sea CO₂ fluxes in the Southern Ocean.

Large temporal air-sea CO₂ flux variations in the Southern Ocean south of Tasmania

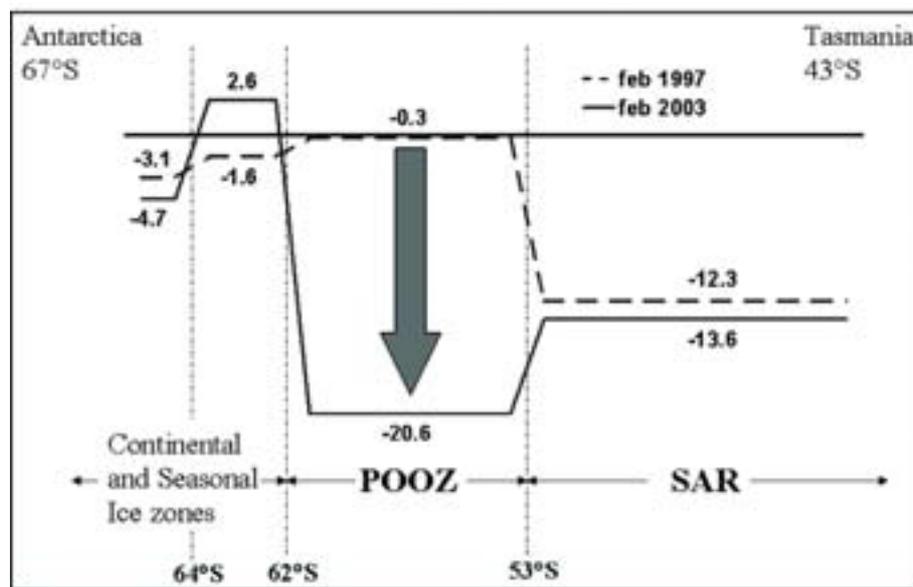
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To reach a more realistic global carbon budget estimate, it is essential to have a better understanding of the seasonal and interannual variations of the oceanic carbon cycle at global scale. Recent models indicate that the Southern Ocean would be very sensitive to climate change. Its study is crucial to predict reliable changes in the coming decades. Furthermore in this area, the lack of long-term monitoring *in situ* data leads to large carbon budget uncertainties. A few data are available in the Southern Ocean south of Tasmania, most of them in summer (Metzl, 2005). For the first time, this region was sampled 8 times in 2002/03, from the end of winter (October) to late summer (March), as part of the long term observational programs, MINERVE/OISO.

Surface seawater *in situ* data (SST, SSS, fCO₂, TCO₂, nutrients and Chlorophyll-a) were collected during OISO10 cruise onboard the R.V. *Marion-Dufresne* and 5 MINERVE cruises onboard the S.S. *Astrolabe*, in spring-summer 1996/97 and 2002/03 between Hobart (43°S, Tasmania, Australia) and Dumont D'Urville (67°S, Adelie Land, Antarctica). With these parameters we analysed the interannual

variations of the CO₂ system in the Southern Ocean south of Tasmania and compared the seasonality during spring and summer for two different years: 1996/97 and 2002/03.

From previous work, the Southern Ocean is known to be a jigsaw of CO₂ sinks and sources (e.g. Metzl et al., 1991) the intensity and location of which evolve with time. In our study, the Southern Ocean south of Tasmania, appears to be also a moving spatio-temporal mosaic of sinks and sources of CO₂. As an example, Fig.1 shows a diagram depicting calculated net air-sea CO₂ fluxes in February 1997 and 2003 south of Tasmania (Brévière et al., 2005a). The surface waters of the SubAntarctic Region (SAR) were an intense CO₂ sink in February 1997 and 2003 driven by a strong biological activity. During these summers the CO₂ flux exhibits a pattern already noticed south of Tasmania by Metzl et al. (1999) and Inoue and Ishii (2005). On the contrary, south of 62°S, there is not yet a clear conclusion concerning the sign of the CO₂ flux, which reminds that closer to Antarctica, the extend and evolution of the sea ice appear to influence the air-sea fluxes. >



▲ Fig. 1 Diagram depicting the air-sea CO₂ fluxes (mmol.m⁻².d⁻¹) observed in the 4 distinct zones during February 1997 (black dashed line) and February 2003 (black solid line). The arrow highlights the dramatic change in the POOZ. CO₂ fluxes were calculated based on measured ocean fCO₂, atmospheric fCO₂ and satellite derived wind speeds using the gas transfer coefficient proposed by Wanninkhof and McGillis, 1999.

> The largest interannual contrast in the CO₂ system observed on this transect between February 1997 and 2003 took place south of the Polar front: In the POOZ, the sink occurring in February 2003 was due to an increase of the phytoplankton biomass when all previous observations indicated this region was a small sink or near-equilibrium in summer (Inoue and Ishii, 2005) as it was in 1997.

Special atmospheric and oceanic conditions noticed in 2002/03, allowed us to revive the discussions about the limiting factors of primary production in High-Nutrient, Low-Chlorophyll (HNLC) zone. A multidisciplinary approach of the question was necessary to understand the different mechanisms involved in these variabilities. Several processes were explored and analysed (changes in solar radiation, ocean stratification, clouds cover, phytoplankton species and distribution, dust storms inputs). Finally, our study indicated that the unusual CO₂ sink laid out in February 2003 in the POOZ due to an increase of biomass, couldn't be a consequence of changes in SST, light/mixing regime and/or total stratospheric ozone but might be due to episodic iron deposition from Australia and related to the 2002/2003 ENSO event (Brévière *et al.*, 2005b).

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Hiromichi Tsumori was born in Japan in 1977. He received the B.Eng. degree in civil engineering in 2000, the M.S. degree in 2002, and Ph.D. degree in 2005 from Kyushu University, Fukuoka, Japan.

Relationship between free-surface turbulence and air-water gas transfer

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The free-surface divergence is closely connected with a surface-renewal motion at the air-water interface. Laboratory and theoretical studies of the air-water gas transfer have been made on the basis of the surface divergence (e.g., McKenna and McGillis, 2004). However, the relation between the surface divergence and characteristic lengthscale of turbulence has not been sufficiently revealed, though it is important to understand the scale of surface-renewal eddies when we formulate the gas transfer velocity. The purpose of this study is to investigate

experimentally the relation between free-surface turbulence and the air-water gas transfer in a grid-stirred tank, noticing the surface divergence and turbulent lengthscales.

Experiments are carried out using a grid-stirred tank. The horizontal velocity fields at the water surface are measured using a particle image velocimetry (PIV). Characteristic quantities such as the turbulent kinetic energy k_s , the dissipation rate ϵ_s , the Taylor microscale λ and the root-mean-square of the surface divergence β_{rms} are obtained from the PIV

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national reports



New Zealand

Ongoing SOLAS activities in New Zealand include the submission of manuscripts from NZ-SOLAS experiments, the planning of a further thematic voyage scheduled for March 2006, and preparations for hosting a SOLAS-sponsored workshop on iron enrichment in November 2005. The main findings of our two SOLAS experiments - FeCycle (a study of upper ocean iron biogeochemistry in a mesoscale SF₆ labelled unperturbed patch of HNLC waters) and SAGE (SubAntarctic Gas Exchange, a study of gas exchange during a mesoscale iron enrichment) have now been synthesised via workshops, and submitted for publication (FeCycle - a special section of 7 manuscripts in *Global Biogeochemical Cycles*; SAGE - various journals). The planned voyage in March 2006 will study the relative contributions of the atmosphere (N, Fe (N fixation) and ocean (microbial foodweb, upper ocean physics) in supplying nitrogen to the subtropical oligotrophic waters N of New Zealand. A pilot voyage took place successfully in March 2005. In November 2005 NIWA will host a SOLAS-sponsored workshop to synthesize the findings of the more than 10 mesoscale iron and nutrient enrichment experiments in HNLC and oligotrophic waters.



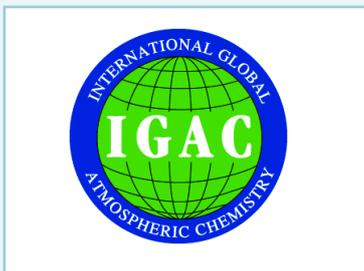
Netherlands

The SOLAS activities in the Netherlands are in the fields of air-sea aerosol exchange (in particular sea-spray aerosols; their source function obtained empirically in the field, via satellite, or from modelling), DMS, CO₂, and momentum fluxes. Several institutions are also involved in work on the carbon cycle with strong national participation in the EU Integrated Project CarboOcean. In addition, there are researchers in the nation working on nitrogen fixation and on the effects of bubbles for air-sea gas transfer and for aerosol production (field and laboratory work). A close link with IMBER is expected within the Netherlands as well. A re-vitalization and stronger organization for SOLAS activities and coordination within the nation was initiated earlier in the year, and it is expected that a strong Netherlands SOLAS network will soon develop.



With a membership of over twenty countries, the Asia-Pacific Network for Global Change Research (APN) today plays a significant role in supporting global change research in the region. It now has a successful ten-year record of promoting cooperation and enhancing scientific research capacity, particularly in developing countries. For the next five years, the APN will continue to build on these foundations, particularly through its Annual Regional Call for Proposals (ARCP) and its "CAPaBLE" capacity building programme.

This new journey starts with the new Framework document, aligned to the APN's new strategic plan, and devising ways of providing a stronger connection to the Asia-Pacific community. Expectantly through this outreach, as the needs and particular interests of the APN members are identified, the APN will be able to engage in further joint activities, leveraging new resources through partnerships, and subsequently have the ability to develop and expand the work it already supports.



The International Global Atmospheric Chemistry (IGAC) project has recently endorsed three new projects: AMMA-Atmospheric Chemistry (a component of the African Monsoon Multidisciplinary Analysis); DEBITS (Deposition of Biologically Important Trace Species); and POLARCAT (Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate Chemistry, Aerosols and Transport). You can learn about these and the other IGAC Tasks at <http://www.igac.noaa.gov/currproj.php>. We welcome proposals for new tasks from all members of the atmospheric chemistry community.

Results of all IGAC projects and other IGAC-relevant research will be shared at our next international open science conference, which will be held jointly with CACGP and WMO in Cape Town, South Africa 17-23 September, 2006:

<http://www.atmosphericinterfaces2006.co.za/>

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measurements. The gas transfer velocity k_L is obtained through aeration experiments of the oxygen. Also, the process of the gas transfer by surface-renewal eddies is visualized by using a laser-induced fluorescence (LIF) technique, for which the carbon dioxide is used as a tracer gas.

By the definition of the Taylor microscale, β_{rms} can be expressed as the ratio of the 1/2 power of the turbulent kinetic energy to the Taylor microscale at the air-water interface as follows:

$$\beta_{rms} \sim \overline{(\partial u' / \partial x)^2}^{1/2} \sim \overline{u'^2}^{1/2} / \lambda \sim k_x^{1/2} / \lambda$$

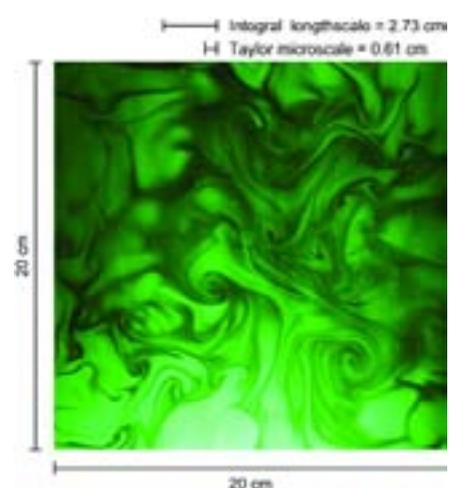
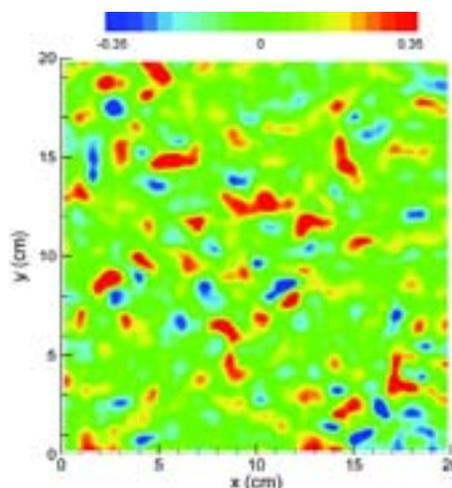
where u' is the turbulent velocity fluctuation at the air-water interface. The validity of this relation is confirmed by the PIV measurements. Thus, the surface divergence should be expressed in terms of the Taylor microscale. The present results show that k_L is proportional to the 1/2 power of β_{rms} . These facts imply that the Taylor microscale becomes a key parameter for the gas transfer velocity at the air-water interface. According to these relations, we can inevitably obtain $k_L Sc^{1/2} / k_s^{1/2} \propto Re_T^{-1/4}$, where Sc is the Schmidt number, Re_T a turbulent Reynolds number defined as $k_s^2 / (\epsilon_s \nu_w)$ and ν_w the kinematic viscosity of water. The dimensionless expression agrees with that of a small-eddy model assuming that the Kolmogorov lengthscale eddies control the gas transfer process. This means that the scale of turbulent eddies connected with the gas transfer cannot be determined from only the Reynolds number dependence.

The figures show a CO₂ concentration field in the horizontal plane very close to the air-water interface visualized by the LIF technique and a contour map of the free-surface divergence obtained from the PIV measurements, respectively. We should note that these are obtained under the same

condition but not at the same time. The values of the integral lengthscale, the Taylor microscale and the Kolmogorov lengthscale are 2.73 cm, 0.61 cm and 860 μm, respectively. The dark regions in the concentration field denote those of high CO₂ concentration. Surface-renewal patches whose CO₂ concentration is relatively low are visualized by the LIF technique. In the regions of the patches, the concentration boundary layer is broken and the gas can be efficiently absorbed at the air-water interface. High CO₂ concentration fluids are converged in the regions of the negative surface divergence, and transported into the bulk water region. The spatial pattern of the concentration field shows a fine structure and it seems to be similar to that of the surface divergence. In addition, both spatial patterns are characterized by the Taylor microscale rather than the integral lengthscale or the Kolmogorov lengthscale. Herlina and Jirka (2004) also investigated the gas transfer process across the air-water interface in a similar flow field using a LIF technique. They reported that surface-renewal eddies have an intermediate spatial scale between the integral lengthscale and the Kolmogorov lengthscale. We infer from these experimental results that the Taylor microscale is a crucial lengthscale for the air-water gas transfer.

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Frédéric Guérin is post-graduated in Environmental Sciences with a specialization in marine and coastal biogeochemistry. He is currently completing his PhD, working on the biogeochemical processes responsible for CH₄ and CO₂ emissions in tropical freshwaters (reservoirs and natural floodplains in French Guiana and Brazil). He has carried on field experiments on gas fluxes and has determined gas production rates and methane oxidation rates in the laboratory. He is now developing a 2D physical-biogeochemical model of the Petit Saut reservoir in French Guiana.

Gas transfer velocities measured by eddy correlation and floating chamber techniques at a tropical reservoir.

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We have measured simultaneously the methane (CH₄) and carbon dioxide (CO₂) surface concentrations and fluxes in the Petit-Saut reservoir (French Guiana) during two field experiments in wet (May 2003) and dry season (December 2003). CO₂ and CH₄ fluxes were measured with floating chambers (FC) at various sites on the artificial lake and with the eddy covariance (EC) technique for CO₂ during a 24h experiment. For each chamber measurement, wind speed was measured at 1m above the water surface and recalculated at 10m. During the 24h EC experiment the wind speed at 10m (U₁₀) and the rainfall rates were recorded by a meteorological station. For each flux measurement the gas transfer velocity was normalized to a Schmidt Number of 600.

The difference between the two chambers used to measure CH₄ fluxes (4±6 mmol.m⁻².d⁻¹) were within 7% for the two campaigns. Average CO₂ fluxes during the same 24h period were 91±73 mmol.m⁻².d⁻¹ and 135±90 mmol.m⁻².d⁻¹ for the EC and the FC techniques respectively. The difference between these two mean fluxes was within 30%. This discrepancy can be attributed in a large part to the differences

in measurements durations (FC: 5-10 min versus EC: 30 min) which resulted in different average wind speeds (FC: 0.18 to 7.8 m.s⁻¹; EC: 0.18 to 3.87 m.s⁻¹) and rainfall rates (FC: 5.25±6.9 mm.h⁻¹; EC: 3.4±2.6 mm.h⁻¹). Nevertheless, when comparing FC and EC k₆₀₀ for a given wind speed, both methods gave similar results (see Figure). Thus, the FC appears to be a reliable and inexpensive technique to determine the gas transfer velocity in various environments. To avoid the creation of artificial turbulence, chambers must however have walls extending few cm into the water and measurements must be performed while drifting.

On the Petit-Saut Lake and excluding all rainy events, we obtained an exponential relationship between k₆₀₀ and U₁₀ average over wind speed bins of 1 m.s⁻¹ ($k_{600} = 1.66e^{0.25U_{10}}$ r² = 0.92, p = 0.0030, n= 7). The intercept at zero wind speed is relatively high in comparison to previous studies, which could be due to important thermal effect. Average T_{air}-T_{water} = 2.15°C ranged from -2.2°C to 6.7°C. Thermal convection could enhance the k₆₀₀, particularly in tropical environments.

The residual k₆₀₀ (wind corrected k₆₀₀) was also positively related to rainfall rates reaching 26.5 cm.h⁻¹ for a rainfall rate of 36 mm.h⁻¹ consistent with the formulation of Ho et al. (1997). On the basis of a 24h at the beginning of the wet season (December 2003) it was shown that rainfall contribute to 25% of the CO₂ and CH₄ emissions. The effect of rainfall on gas fluxes cannot be neglected in tropical environment.

Further reading

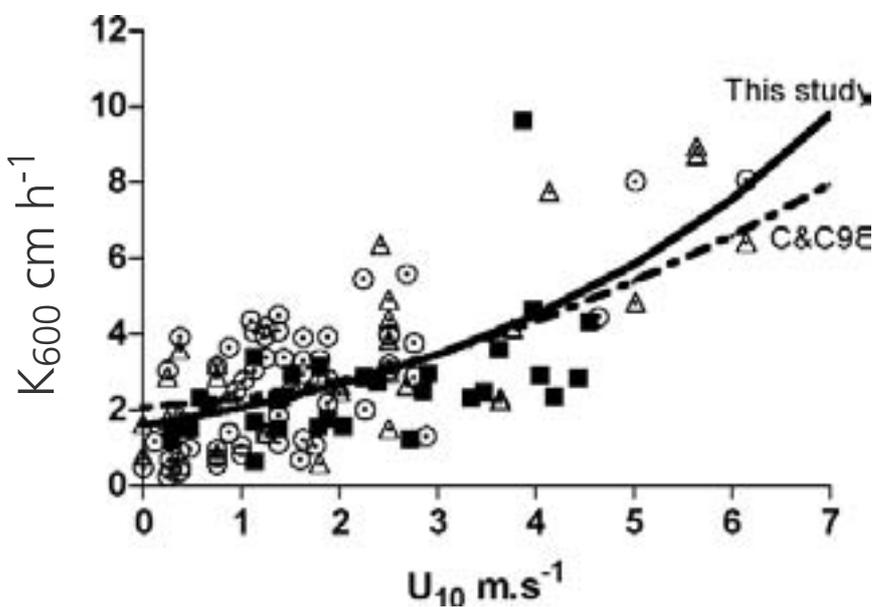
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Acknowledgments:

The authors thank the Hydreco Staff for laboratory and field assistance, J.-L. Fréchette for flux measurements during the December campaign. This study was funded by EDF and CNRS National Programs (PNCA and ECCO). We thank Alain Grégoire (EDF) for his continuous confidence and financial support. F.G. benefited from a PhD grant by EDF.



< Gas transfer velocities (k₆₀₀, cm.h⁻¹) plotted against wind speed (U₁₀) at the Petit-Saut Lake. K₆₀₀ were computed from CO₂ fluxes measured by eddy correlation (solid square) and CO₂ (open circle) and CH₄ (open triangle) fluxes measured by the floating chamber technique. The solid line represents the relationship between k₆₀₀ and U₁₀ obtained when k₆₀₀ were average over U₁₀ bins of 1m.s⁻¹ and the dash-dotted line is the relationship of Cole and Caraco (1998).



Rapid advances in ocean carbon research are being driven by targeted ocean biogeochemical process studies, on-going time-series programs, global ocean carbon surveys, and satellite observations. As part of the new Ocean Carbon and Climate Change (OCCC) program, a science workshop The Ocean Carbon System:

Recent Advances and Future Opportunities (http://www.who.edu/sites/OCCC_workshop) was held August 1st-4th, 2005 at the Woods Hole Oceanographic Institution. More than a hundred scientists participated in the four-day meeting, which was supported by the National Science Foundation. The objectives of the workshop were to: highlight recent scientific findings in ocean carbon science; foster improved communication among existing ocean carbon observing programs and process studies; and discuss applications of emerging observational technologies in marine biogeochemistry. Several scientific themes emerged including the importance of biogeochemical cycling on coastal margins, potentially large future geochemical and ecological impacts due to ocean acidification (lower pH) resulting from oceanic uptake of anthropogenic CO₂, and opportunities arising from new shipboard and in situ chemical sensors, ships of opportunity, and autonomous platforms such as moorings, gliders, and floats.



The Climate and Cryosphere (CliC) project conducted in 2005 its first science conference (Beijing, 11-15 April 2005). Ice sheet models intercompared with CliC's assistance are becoming an important component of the Earth System models capable to resolve ice age cycles. CliC is coordinating the preparation of a major Integrated Global Observing Strategy Partnership report on future cryospheric observations. Cold region hydrological observations and oceanographic observations under the sea-ice are being developed. Reprocessing of sea-ice satellite SAR data archives leads to new generation polar data sets. CliC coordinated WCRP's contribution to planning the International Polar Year 2007/2008, which resulted in submission of many high quality project proposals.



Alastair D. Jenkins graduated with a Ph.D. in physics from Aberdeen University, U.K., in 1978, and has worked for various Norwegian research institutions since 1982. His research interests include the effect of surface waves on processes in the lower atmosphere and upper ocean. He is currently a senior scientist at the Bjerknes Centre for Climate Research in Bergen, engaged in coupled atmosphere - ocean - sea-ice modelling.

Dynamically consistent computation of exchange processes at the air-sea interface

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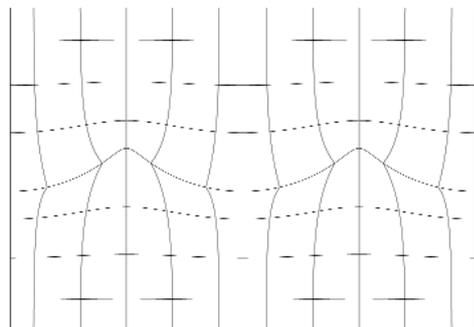
A dynamically consistent framework for modelling the exchange of gas species such as CO₂, O₂, etc., as well as of other quantities such as momentum or heat, must take account of surface waves and other movements of the air-water interface, either explicitly or implicitly. In order to calculate the effect of waves, it is necessary to employ a consistent formulation of the balance of energy, mass and momentum, within the airflow, wave field, and water column. In the vicinity of the sea surface, since physical and chemical variables such as temperature and concentration have large gradients normal to the air-water interface, it is also very advantageous to use a coordinate system which can represent such variations at scales much smaller than the wave height. We can, for example, use a surface-following coordinate system, such as the one shown in the upper part of the figure (Jenkins 1992), which may also be employed in interpreting gas concentration and flux measurements made from measurement platforms whose position is affected by wave motions.

A coupled model system may also take account of the effect of turbulence and

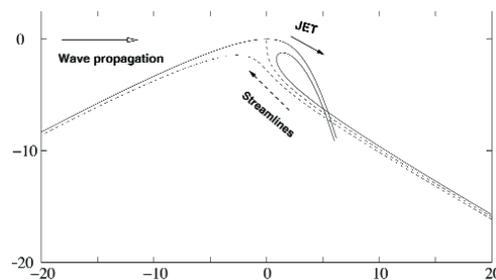
depth-varying currents on wave propagation and dissipation, the presence of surface films and sea ice (Jenkins and Jacobs 1997), and the generation of helical wind-direction-oriented Langmuir circulations. Wave breaking (see the lower part of the figure), which disrupts the surface laminar boundary layer, enhances air-sea gas transfer coefficients to a considerable extent. Surface-following coordinate systems have been fundamental to understanding the theory of steep and breaking waves and associated free-surface hydrodynamic phenomena.

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▲ Example of a coordinate system, above and below a wave surface. Here, coordinate-system displacements follow wave motions at the air-water interface, and decrease exponentially as we move away from the interface.



▲ Stationary-flow approximation for breaking-wave crest (Jenkins 1994). The jet emerging from the wave crest, on impact with the water surface in front of the wave, will generate a turbulent plume and lead to vigorous mixing, will inject bubbles deep into the water column, and generate spray droplets, enhancing atmospheric humidity and aerosol content. The streamlines are shown in the reference frame moving with the wave crest.



Elena Jurado is a PhD student in Marine Sciences in the Environmental Chemistry Department of CSIC-Barcelona, with a background in Environmental Engineering. She is beginning the last year of the 4-year program in research related to the modelling of the atmosphere-ocean transfer of persistent organic pollutants (POPs), organic carbon and soot. During the past few years, Elena has attended the SOLAS and ESA summerschools, an experience which she strongly recommends. Recently she worked in the European Research Institute in Ispra, which has allowed her to obtain a closer view of the policy side of research.

Atmospheric inputs of Persistent Organic Pollutants (POPs) and aerosol carbon to the global oceans

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Persistent Organic Pollutants (POPs) are transported long-distances from source regions to remote regions through atmospheric transport and deposition. Subsequently, deposition of POPs may be the major process by which they impact remote oceanic areas, raising environmental concerns because of their toxicity and accumulation in aquatic food webs. However, available measurements of POP atmospheric deposition fluxes to oceanic regions are very scarce, most of them referred to local ground-based measurements. On the other hand, those pollutants are not only a stressor for aquatic ecosystems but they can also be considered as tracers of persistent organic matter in the atmosphere.

We have developed a new methodology that combines satellite retrieved parameters (sea surface temperature, wind speed, rain, aerosol size distributions....) and measured atmospheric field concentrations of polychlorinated biphenyls (PCBs) and chlorinated dibenzo-p-dioxins and furans (PCDD/Fs) during north-south Atlantic Ocean transects. Atmospheric depositional fluxes of POPs, namely dry aerosol deposition, precipitation scavenging (wet deposition) and diffusive gaseous exchange between the atmospheric boundary layer and the surface ocean (air-water exchange) are estimated. Additional features not treated in traditional studies have also been addressed, such as size-dependent dry deposition velocities derived from remote sensing data, adsorption of contaminants onto raindrops and enhancement of diffusive air-water exchange due to the turbulence generated by rain droplets.

The results show that there is an important spatial and seasonal variability in the fluxes. In addition, model validation shows good agreement with available coastal data measurements of dry and wet deposition fluxes. The total dry aerosol deposition of

PCBs and PCDD/Fs to the Atlantic Ocean is estimated to be 2200 kg yr⁻¹ and 500 kg yr⁻¹, respectively, while the wet deposition is 4100 kg ΣPCBs yr⁻¹ and 2500 kg PCDD/Fs yr⁻¹ and the net air-water exchange is 22000 kg ΣPCBs yr⁻¹ and 1300 kg PCDD/Fs yr⁻¹. Furthermore, a comparison of the relative importance of each depositional mechanism is assessed at the global scale and it is found that diffusive air-water exchange constitutes the main transfer mechanism of organic semivolatile compounds from the atmosphere to the ocean for compounds found mainly in the gas phase, such as PCBs, as can be seen in the Figure. This tendency reverses in some oceanic regions and for highly chlorinated PCDD/Fs.

Using the developed methodology and other optical satellite retrieved meteorological parameters, atmospheric inputs of aerosol organic and black carbon are also estimated. The estimated global fluxes are of 20 Tg OC yr⁻¹ by dry deposition, 77 Tg OC yr⁻¹ by wet particle deposition, but still diffusive fluxes of total OC remain to be quantified even though they may be important.

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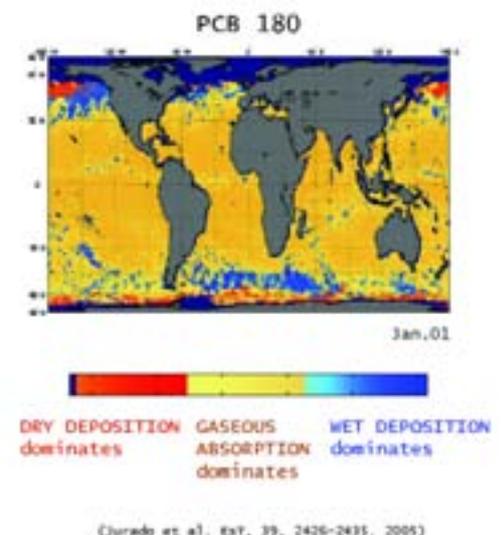
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Acknowledgements

The authors would like to thank MODIS, NOAA, ATSR and Goddard DAAC processing and distribution teams for remote sensing data. This work was supported by the Spanish Ministry of Science and Technology through project AMIGOS (REN2001-3462/CLI).

Compelling Questions to be Answered

- What are the interactions between atmospheric deposition of POPs and their water column biogeochemical cycling?
- How is the effect of climate change in global atmospheric inputs of POPs?
- Which is the role of the scavenging of POPs associated to marine aerosol?
- Spatial and temporal variability of the deposition of rain-dissolved organic carbon (DOC) and diffusive air-water exchange of gas-phase organic carbon?





The International Ocean Carbon Coordination Project (www.ioccp.org) is a communication and coordination service for the ocean carbon community that works with national, regional, and global ocean carbon research and observation programs to create a network of ocean carbon activities. The IOCCP held its first Scientific Steering Group meeting in early October to discuss on-going and planned activities, as well as new activities that will be developed as a result of the new Terms of Reference adopted by the IOCCP sponsors in June of this year. The SOLAS representative on the IOCCP SSG is Truls Johannessen. From November 14-17, the IOCCP is co-sponsoring a workshop on repeat hydrography in Kamakura, Japan, to review post-WOCE ship-based hydrography activities, information and data accessibility issues, and to identify priorities for ship-based hydrography to meet the needs of the ocean carbon community and the specific aims of CLIVAR.

WRCP / WGSF

The World Climate Research Programme's Working Group on Surface Fluxes (WRCP/WGSF) had its first official convening October 2004 in Halifax during the SOLAS Open Science Conference. A summary of the meeting was submitted to the WRCP/JSC meeting in Ecuador (2005). Some more recent activities include:

- Grand opening of the WGSF website at NOAA/ETL <http://www.etl.noaa.gov/et6/wgsf/>
- Plans for the inaugural WGSF newsletter to come out in October. The newsletter will be edited by Sergey Gulev and Nadia Kovaleva of the Shirshov Institute of Oceanography.
- The WG plans to produce two review papers on the state of parameterizations of air-water transfer of gases (McGillis) and particles (DeLeeuw).
- Work continues on a handbook for best practices in making routine air-sea flux measurements from ships. Frank Bradley spent three weeks in Boulder (July-August 2005) working with Chris Fairall on the handbook.



Dr. Vassilis Kitidis completed his Ph.D. in Marine Biogeochemistry at the University of Newcastle upon Tyne following a B.Sc. in Marine Biology. He is currently employed as a Research Associate at Newcastle University and his research interests include marine nitrogen, phosphorus and carbon cycling with emphasis on marine photochemistry.

Methane cycling in the Ria de Vigo

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Methane (CH₄) is the second most important biogenic greenhouse gas after carbon dioxide (CO₂) in terms of radiative forcing perturbation since the beginning of the 19th century. The coastal ocean is thought to contribute the majority of marine methane sources via microbial methanogenesis in anaerobic environments and significant contributions from thermogenic sources. The Ria de Vigo (NW Spain) is a shallow coastal inlet subject to seasonal upwelling during summer. Geophysical surveys have shown evidence of shallow gas accumulation (acoustic blanking) and gas escape (pockmarks and water column acoustic turbidity) from Holocene fill-sediments in the Ria de Vigo, with CH₄ as a major component of this gas (Garcia-Gil, 2003). However, little is known about the biogeochemical cycling of CH₄ in the water column of the Ria de Vigo. During two field campaigns in the Ria de Vigo in April 2003 (start of upwelling season) and September 2004 (end of upwelling season) we investigated the surface and water column as well as sediment porewater distribution of dissolved CH₄. In addition we investigated the stable isotopic composition of C in sediment porewater CH₄ (¹³CH₄) and carried out sediment-slurry incubations to determine microbial methanogenesis or methane oxidation. All surface water samples were supersaturated with respect to atmospheric equilibrium (<8500 %) indicating that the Ria de Vigo was a significant source of CH₄ to the

atmosphere. Sediment porewater dissolved CH₄ was 2-3 orders of magnitude higher than in the overlying water column and isotopically 'lighter' with respect to atmospheric ¹³CH₄ indicating a biogenic sedimentary source. Sediment-slurry incubations confirmed methanogenic activity in deeper- (0.6 m) and methane oxidation in surficial-sediments. We estimated that sedimentary sources of CH₄ contributed ~40 % of water column CH₄ in the middle part of the Ria de Vigo in April, with additional 10 % from in situ water column methanogenesis in the vicinity of the pycnocline. The remaining 50 % were derived from advection of freshwater and sedimentary inputs upstream. In September dissolved CH₄ in surface waters was up to 4-fold higher than in April throughout the Ria de Vigo (Figure 1), presumably due to stimulation of methanogenesis by 'fresh' organic matter after the summer water column productivity maximum.

Our data suggest that the Ria de Vigo was a strong source of CH₄ to the atmosphere. Significantly, the Ria de Vigo is thought of as an annual sink for atmospheric CO₂ due to the high productivity and CO₂ drawdown during the upwelling season (Borges and Frankignoulle, 2002). Our budget calculations suggest that up to 40 % of the C drawn down from the atmosphere as CO₂ is returned as CH₄ over an annual cycle in the Ria de Vigo.

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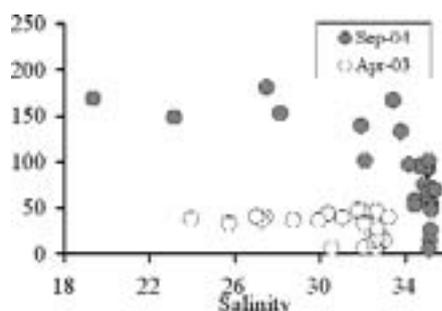


Figure 1: Dissolved CH₄ against salinity in surface waters of the Ria de Vigo



Ira Leifer earned his PhD from the Georgia Institute of Technology in 1995 on modeling bubbles. He then worked at the University College, Galway on bubble measurements. Currently he is at the University of California, Santa Barbara studying bubble processes associated with marine hydrocarbon seeps, fluid flow through subsurface fracture networks, petroleum on the sea surface and on bubble surfaces, bubble formation from breaking wave, and numerical modeling of these processes.

Bubbles, bubble plumes, and breaking wind-wave characteristics

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During the LUMINY experiment, measurements of bubble plumes, bubble-plume bubbles, background distributions, and breaking-wave characteristics were made for paddle-amplified, wind-stress breaking waves in a large, fresh water, wind-wave channel in Marseille, France. The approaches are described in (Leifer et al., 2003) and (Caulliez, 2002). Bubble plumes varied significantly with bubble size-distributions, physical extent, and dynamics. A classification scheme was developed that segregated based on size and the ability to optically obscure (dense) or not (diffuse) the background. For each class, the time and size-resolved bubble population distribution, $\phi(t,r)$ (# μm^{-1}), where r is the equivalent spherical bubble radius, and average plume extent were determined. ϕ is the total number of bubbles in the plume in each radius increment and is conserved during the injection phase, decreasing during the rise phase as bubbles surface. The plume formation rate, P , for each class was estimated at different fetches.

Wave characteristics and wave-breaking rate and intensity were strongly fetch dependent due to the rapid evolution of the mechanically-generated waves along the tank from the effects of wind, dissipation, and nonlinear wave-wave interactions. Trends in wave-breaking and P were similar, with P for dense plumes reaching a maximum at the fetch of maximum wave-breaking. The ratio of dense to diffuse plumes was even more sensitive to the occurrence of the most intense wave breaking, where dense plume P was greatest.

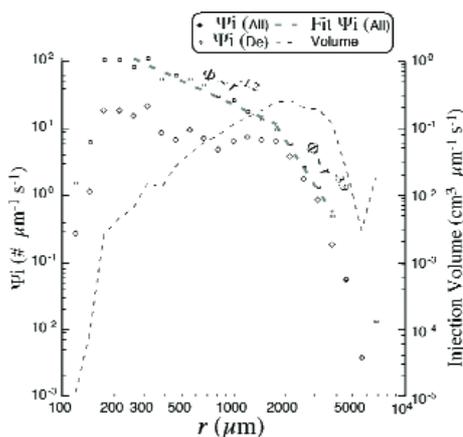
There was a highly significant difference between ϕ for dense and diffuse plumes. For the injection ϕ (ϕ_i), for diffuse plumes were weakly size dependent to $1000\mu\text{m}$, then decreasing steeply for larger bubbles. Δi for dense plumes were multimodal with a steeply decreasing small bubble population, a second, broad peak at $1700 - 2000 \mu\text{m}$ radius, and a steep decrease for larger bubbles. The relationship between diffuse and dense P and wave-breaking rate as well as differences in ϕ strongly suggest different formation mechanisms. Due to this large bubble peak, dense plumes contributed to the total plume volume much more than diffuse plumes. The void fractions of diffuse plumes were greater at the time of maximum plume penetration than dense plumes. Also, the injection and rise phases for all plumes were roughly equal in time.

Using P and ϕ_i for each plume class, the global bubble-plume, injection size-distribution, $\psi_i(r)$, was calculated (Fig. 1). ψ_i decreases as $\psi_i \sim r^{-1.2}$ for $r < 1700\mu\text{m}$ and $\psi_i \sim r^{-3.9}$ for larger r . The volume injection rate for the study area was $640 \text{ cm}^3 \text{ s}^{-1}$, divided approximately equally between bubbles smaller and larger than $1700\mu\text{m}$ radius. Using plume volumes at the time of maximum penetration for each class, a concentration distribution was calculated and showed plume concentrations were one to several orders of magnitude greater than the background population with the largest differences for the greatest bubbles.

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< Fig 1. B. Global, injection, bubble-population size-distribution, ψ_i , versus radius, r for all plumes, and only dense plumes, least-squares, linear-regression analysis fit, and corresponding volume size distribution. Data key on figure.



Norway

The University of Bergen and the Bjerknnes Centre of climate research conducted the SOLAS 2005 mesocosm experiment in May. Ulf Riebesell was the scientific leader and planned the design of the experiment. Aside from being a clear SOLAS activity, the results directly contribute to the European CarboOcean project and the people to the network of excellence EUR-OCEANS. In addition, a cruise in into the Barents Sea lead by Paul Wassman was recently conducted, studying the general biogeochemistry and biology inside, at, and close to the ice edge. In modeling, there has occurred an integration of a biogeochemistry module to the Bergen Climate model. An assessment of the pH effect on global carbonate production, dissolution and the effect on export production has been performed. At the moment there is no pure SOLAS programme, there are some projects contributing to SOLAS science. But Norway is directly involved in SOLAS science through our engagement in EU-projects.



Taiwan

There are several research projects that are closely related to SOLAS goals, although there is no research project in Taiwan dedicated to SOLAS nominally. Two notable projects of such nature are the Long-Term Observation and Research of the East China Sea (LORECS) and the South-East Asia Time-series Study (SEATS). LORECS is aimed at understanding the biogeochemical cycle in the East China Sea under natural conditions and detecting biogeochemical changes induced by human activities, such as damming. Responses of phytoplankton to Asian dust storms in spring are one of the research foci of LORECS. SEATS has been conducted since 1998 with seasonal cruises and moored instruments in the northern South China Sea. The purpose is for the investigation of the biogeochemical responses to physical forcing of different time scales, ranging from short-term events (e.g., typhoons, dust-fallouts) to seasonal changes (e.g., monsoons) and inter-annual oscillations (e.g., ENSO). In both projects, air-sea exchange of CO₂ is included in the study.

SOLAS Summer School 2005



poster session



lunch break



coffee break



practical workshop

"SOLAS is about the interaction between the ocean and the atmosphere. To me, they look both very big and their physical and chemical processes are not so easy to understand. The SOLAS summer school was able to give me the broad picture of this very fascinating interaction. Now I know what the big SOLAS scientific questions are and this is an unvaluable feeling that will strongly help my future research. Life, along the atmosphere and the ocean, is another important thing to me. The SOLAS summer school was also able to give me the opportunity to share two weeks of my life with students and lecturers from about two dozens different nationalities, with different cultures and different scientific backgrounds. These things broaden your mind and improve your research."

Manuel Dall'Osto, University of Birmigham, UK



in the lab



working late



lecture

SOLAS Summer School 2005

The SOLAS Summer School was held in Cargèse, a beautiful Greek-influenced town on the French Mediterranean island of Corsica. Organised and run by the SOLAS IPO, Corinne Le Quéré (UEA) and Véronique Garçon (Toulouse) the school welcomed 74 students from nearly 30 countries with a wide range of scientific expertise and experience. The Summer School offers them the opportunity to broaden and deepen their knowledge of SOLAS science and to meet other PhD students and young post-docs from around the world studying SOLAS-related topics.

The lectures offer fascinating insights into various aspects of SOLAS science, including an introduction to SOLAS (Peter Liss); physical, chemical and biological oceanography (Ric Williams, Catherine Jeandel and Osvaldo Ulloa); greenhouse gases and climate change (Laurent Bopp); Gas Exchange Processes (Wade McGillis, Rik Wanninkhof) and biogeochemical modelling and data assimilation (Richard Matear). One scientific highlight was Nobel Laureate Paul Crutzen's thought-provoking lecture on the "Atmospheric Chemistry of the Anthropocene", in which he discussed the "Great Acceleration" of human-kind since the second world war, and the profound effect that this massive population, economic and technological growth has had on the earth-system, in particular the chemistry of the atmosphere and climate.

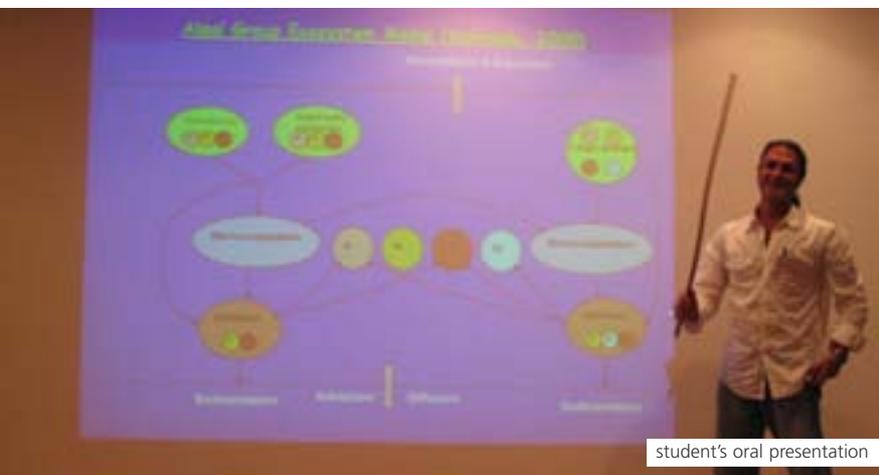
As well as lectures in the various fields spanned by SOLAS, the summer school offers the students some hands-on experience with a set of practical workshops based around oceanography, atmospheric science, modelling and gas exchange processes, run by lecturers attending the school. Workshops on written and oral communication provided students with advice on presenting science and constructive criticism on their spoken and written presentation. During the rest day, the students and lecturers go off on excursions, or relax on the beach in the sun; recuperating for the second week of lectures. The second series of lectures were given on atmospheric chemistry (Uli Platt), the iron cycle (Phil Boyd), coastal biogeochemistry (Leticia Cotrim da Cunha), paleo research (Markus Kienast), atmospheric dust (Ina Tegen), the DMS cycle (Ulrike Lohmann), marine particle formation (Eric Saltzman), Remote sensing (Frédéric Melin) and long-term observations (Nick Bates). Possibly most exciting were the presentations by the students themselves, describing the research of a new generation of SOLAS scientists.

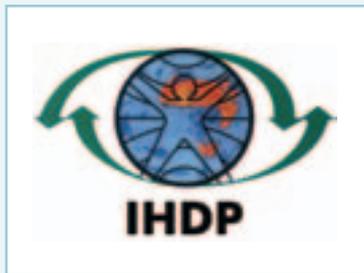
Martin Johnson,
SOLAS International Project Officer



"What the SOLAS Summer School 2005 brought to my career? Loads! Through the interaction with lecturers and students during and after lectures my work was put in a context and my focus was drawn towards the global dimensions of climate change and human induced perturbations to the system. And who would not enjoy discussing science with fellow students doing very similar research at the institute beach during the lunch breaks? I also had the chance to participate in workshops such as a research cruise and a follow-up laboratory analysis that taught me where the data comes from which I use for my modeling. Motivation and connections, guess these are the words describing best what I took home apart from the nice tan. Not to forget the personal experience – all the nights at the beach observing noctilucent phytoplankton, the social and natural science discussions during coffee breaks, a glass of good wine during the open-air postsessions and all the interesting and enthusiastic participants from all over the world..."

Meike Vogt, University of East Anglia, UK





In 2003, the International Human Dimensions Programme (IHDP) initiated a mid-term synthesis process to analyze IHDP achievements and create a basis for further scientific and strategic developments of human dimensions research. The resulting series of activities were highlighted at the October 2005 Open Meeting of the Human Dimensions Research Community in Bonn, Germany. The IHDP and its co-organisers welcomed 800 participants, 700 paper presentations, poster presentations, plenary speeches and round-table discussions (<http://openmeeting.homelinux.org/>). The IGBP/IHDP core project on Land-Use and Land Cover Change (LUCC) will conclude with a synthesis conference at the Open Meeting.

The IHDP welcomes new initiatives and project developments, namely the LOICZ II project (Land-Ocean Interaction in the Coastal Zone), which became fully operational in March 2004 under co-sponsorship of IGBP and IHDP, as well as the IGBP/IHDP Global Land Project and the project on Urbanization and Global Environmental Change, which were launched in March 2005. Further information can be obtained from: <http://www.ihdp.org>.



Following the success of the IGBP/SCOR Iron Fast Track Initiative (FTI), led by SOLAS, the International Geosphere-Biosphere Programme (IGBP) has initiated a number of other FTIs to address integrative questions in Earth System Science: Ocean Acidification Over Time (co-sponsored by SCOR and led by PAGES), Research Challenges in Undertaking System Level Science, and The State of the Planet in 2050. IGBP is holding a special session at the AGU Fall Meeting: B22 Global Change and the Earth System: Switch and Choke Points in Biogeochemical Cycling. We welcome SOLAS involvement in these activities. IGBP are in the process of completing the Science Plan and Implementation Strategy for the second Phase of IGBP. The document should be published in early 2006. For more details see www.igbp.net



Dr. Alexander P. Makshtas is a leading scientist of the Arctic and Antarctic Research Institute, Russia. His main scientific interests are the development of measurement techniques, the experimental study of turbulence, radiation energy, and CO₂ exchange between sea ice and atmosphere in the Polar Regions, as well as development of the climatic thermodynamic and dynamic-thermodynamic numerical models of sea ice cover in the Arctic Basin for investigations of long-term sea ice variability. He has taken part in field experiments on drifting stations (North Pole 22, 1974; North Pole 23, 1977-1978; Weddell-1, 1992; SHEBA, 1998; Barrow, 2001-2002), and during 15 ship expeditions to the Greenland, Barents, East-Siberian and Kara Seas.

The uncounted role of the Arctic sea ice in atmospheric CO₂ balance.

Makshtas A. (AARI, Russia), I. Semiletov (IARC-UAF, USA) and E. Andreas (CRREL, USA)

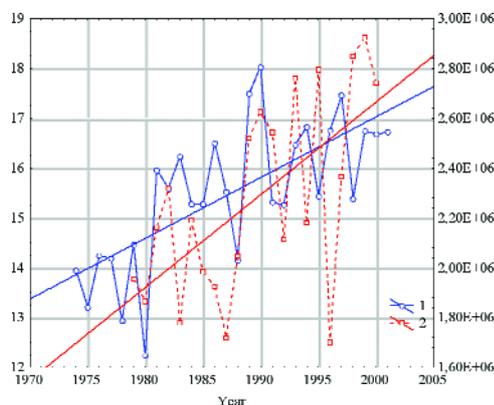
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The mean annual concentration of atmospheric carbon dioxide, its seasonal amplitude as well as its positive trends in the last decades have absolute maximum in the Arctic. Keeling et al. (1996) explain this large seasonal variation as increasing assimilation of CO₂ by land plants in response to the increase in air surface temperature and in the duration of the vegetation period. A related and unstudied issue, though, is the spatial – temporal variability of perennial or seasonal sea ice cover in the Arctic Ocean. But, as mentioned by Tison et al. (2002), currently, continuous sea-ice cover is considered to impede gaseous exchanges with the atmosphere so efficiently that no global coupled models include CO₂ exchange over sea ice. These seem to be serious omissions in light of the pioneering measurement of Gosink et al. (1976) in the 1960-70s; they showed high permeability of sea ice for CO₂ for temperatures above –15°C.

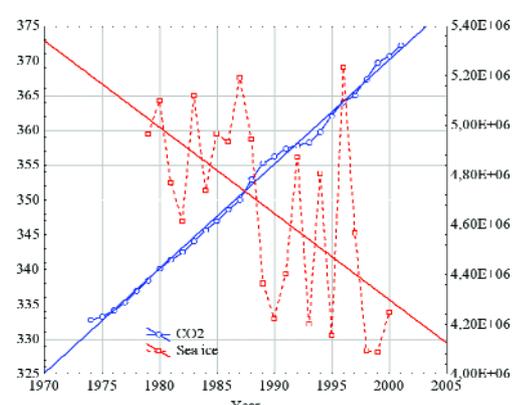
Small-Scale Gas Exchange Processes

We obtained data about small-scale CO₂ exchange processes in the presence of sea ice in June 2002 (Semiletov et al, 2004). Using eddy-correlation techniques, we measured the carbon dioxide flux on fast ice near Point

Barrow, Alaska. Additionally, to evaluate the CO₂ concentration and to obtain rough estimates of CO₂ fluxes through different parts of the sea ice cover (melt ponds, dry snow, bare ice), we used a chamber technique. Despite the scatter in our results, we infer that the turbulent flux of carbon dioxide during onshore winds tends to become more negative with time, indicating increasing surface gas absorption from air masses coming from the Arctic Ocean. These results agree well with our pCO₂ measurements in brines and in the water under the ice. These latter show significant undersaturation, down to 130-150 ppm. Our chamber data also show a drastic decrease of the equilibrium CO₂ concentration in the head-space above the growing melt ponds, especially when the daily mean temperature rose above 0°C and melt pond depth increased dramatically to 20 cm. These results agree well with the increase of incoming solar radiation absorbed in the melt ponds and beneath the sea ice. We suggest that increased PAR caused enhanced photosynthesis in the water in the melt ponds and in sea ice brines, and consequently, pCO₂ decreased in and beneath the sea ice. However, the role of biological and physical factors in the CO₂ flux in and from the sea ice needs additional studies. >



▲ Fig. 1. a. Interannual variability in the amplitude of the seasonal cycle of atmospheric CO₂ at Barrow (1) and in sea ice area in the Arctic Ocean (2).



▲ Fig. 1. b. Comparisons between atmospheric CO₂ concentration at Barrow and ice area in the Arctic Ocean in September.

The Importance of Sea Ice Cover in Large-Scale CO₂ Exchange

To show the possible importance of a changing sea ice cover in the regional CO₂ budget we compare the temporal variations of seasonal CO₂ amplitudes and sea ice area for 1974–2001 in the adjusted to Alaska part of the Arctic Ocean (http://polynya.gsfc.nasa.gov/seaice_datasets.html). The similar behavior of both CO₂ and sea ice seasonal amplitudes (Fig. 1a) and the inverse behavior of the annual mean of CO₂ concentration and sea ice area (Fig. 1b) in the Arctic Ocean are evident. We offer the following possible explanation for these observations. In summer, biological uptake of atmospheric CO₂ in the ice-free parts of the Arctic Ocean dominates due to intensive algae production in the stably stratified near-surface ocean. In contrast, in the fall, upwelling to the surface of bottom water enriched in CO₂ due to the decomposition of organic material changes the direction from invasion to evasion of CO₂ from the ocean. Under this scenario, the increase in the seasonal amplitude of CO₂ over the Arctic can be related to the summer decrease of sea ice extent in the Arctic Ocean and to the lengthening of the ice-free period in the marginal seas. Both trends enhance the summer uptake of atmospheric CO₂ by the ocean. Likewise, the general shrinking of sea ice extent allows enhanced evasion of CO₂ from sub-ice waters enriched by CO₂ into the atmosphere in

autumn before and during freeze-up due to convective mixing (Pipko et al., 2002) and possible additional evasion due to gas transfer through leads and the relatively “warm” ice cover. To support or reject this hypothesis the measurements of pCO₂ will be organized this summer in four international ship expeditions and Russian drifting station “North Pole”.

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▲ Igor Semiletov and Alexander Makshtas take measurements of pCO₂ on fast ice near Barrow

national reports



US

The US-SOLAS research program was initiated in 2001, and the US Scientific Advisory Committee has completed its science plan. Many SOLAS activities are supported by US funding agencies, including NSF, NOAA, NASA, and DOD. These activities are often in partnership with other nations including Canada and New Zealand. US-SOLAS and US-OCCC program have common scientific interests for carbon and will work on complementary organization, missions, and data management.

The US projects and activities include: 1) trace gas time series, North Atlantic African Dust-Aerosol Experiment (NAFDAE), global ocean trace gas surveys, and climate modelling; 2) gas exchange process studies, sea spray in situ and modelling studies, coupled ocean-atmosphere boundary layer studies for reactive gases, the Cape Verde air-sea interaction time series station in collaboration with UK-SOLAS and D-SOLAS; 3) coastal air-water carbon and methane fluxes, Southern Ocean CO₂, global surface carbon and methane surveys, and perturbation experiments; 4) Autonomous and Lagrangian Platforms (ALPS), satellite and model assimilations, summer school, and data management.



Australia

A group of Australian SOLAS scientists have proposed an experiment at Cape Grim, NW Tasmania, called ‘Precursors to Particle Campaign (P2P) 2006’. The aim of this campaign is to identify and quantify the gaseous precursors involved in new particle formation in Southern Hemisphere air at Cape Grim. The proposed dates of the experiment are January and February of 2006. In other national news, an effort is underway to establish a combined SOLAS/LOICZ national office in Australia.



In readiness for the International Polar Year (IPY), SOLAS is co-ordinating plans to optimise high latitude SOLAS research. Although bi-polar in ambition, the SOLAS IPY activities will initially be co-ordinated individually. For example, much of the Arctic science is co-ordinated through the OASIS program.

The SOLAS IPY will gather together the jigsaw pieces of planned SOLAS activities to form a coherent picture from which we can integrate actions to provide a holistic and synoptic understanding of high latitude ocean-atmosphere interactions. Through collaboration with other international research programmes, co-ordinated cross-disciplinary research will enable SOLAS scientists to complement, and profit from, science performed under these programmes.

An agreement has been made with the SASSI and CASO projects to liaise during project development to facilitate the identification of mutually beneficial research. To facilitate the overview of SOLAS IPY goals it is requested that SOLAS researchers and national SOLAS committees identify co-ordinated research plans specifying: planned SOLAS IPY research; geographical area of interest; and research platforms.

For more information about SOLAS IPY activities, please contact the SOLAS IPY Coordinator. Richard.Bellerby@bjerknes.uib.no

GEOTRACES

Chinese oceanographers organized a GEOTRACES workshop during late August 2005 at Xiamen University. Approximately 50 scientists attended the planning workshop, which was held at the Key Laboratory for Marine Environmental Research. Representatives from Korea (South), Taiwan, Hong Kong and Taiwan also attended to explore regional collaboration.

The GEOTRACES draft Science Plan was reviewed by SCOR during the summer 2005.



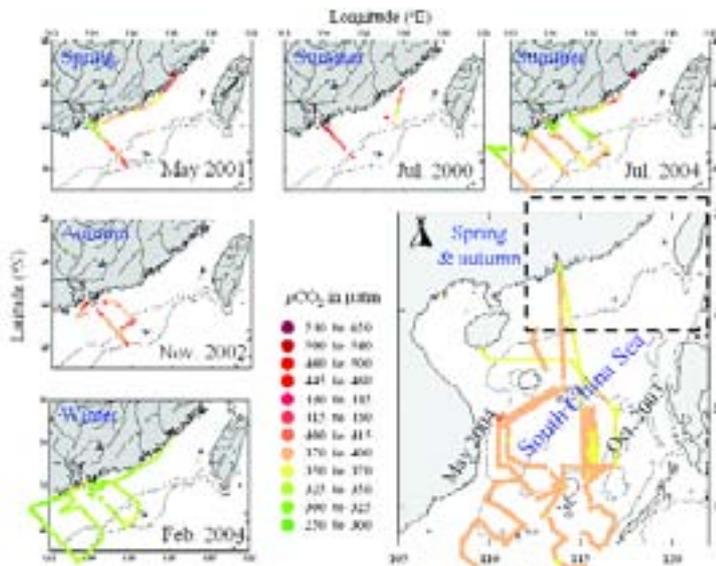
Dr. Minhan Dai holds a PhD from the University of Paris, Jussieu, and was a postdoctoral fellow at the Woods Hole Oceanographic Institution from 1995-1998. He is currently a professor of marine biogeochemistry at Xiamen University in China and works on ocean carbon cycling with special attention on estuarine and coastal systems.

The partial pressure of carbon dioxide and air-sea fluxes in the northern South China Sea: Seasonal variation and its possible controls

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< Fig. 1. Seasonal variation of pCO₂ in the South China Sea

Ocean margins play an important role in the global oceanic carbon cycling. Despite of many efforts devoted into the field through major international programs such as JGOFS, the air-sea fluxes associated with ocean margins remain largely uncertain (Fasham et al., 2001). In order to examine the potential difference between different latitudinal regions, air-sea CO₂ flux studies associated with the tropic and subtropical shelf waters are particularly required to better constrain the source/sink terms of margins at a global scale (Cai & Dai, 2004).

The South China Sea (SCS) is the world largest tropic and subtropical marginal sea. Since 2000, we have conducted 7 cruises in the region, which include 5 shelf surveys and 2 basin surveys. The five shelf surveys covered four seasons. Nearshore pCO₂ showed a very dynamic pattern due to the influence of river plumes and upwelling. For the outer shelf and slope regions, pCO₂ ranged between 320 and 450 matm and varied within a narrower range. During most surveys other than Oct 2003 and Feb 2004, the offshore surface pCO₂ values were higher than atmospheric pCO₂. A compilation of all of the pCO₂-based

CO₂ sea-air flux estimations in the South China Sea, including an earlier survey along the eastern boundary of the SCS during the summertime by Rehder & Suess (2001) suggest that on an annual base, the outer shelf of the northern South China Sea overall acts as a moderate or weak source of atmospheric CO₂ with uncertainty associated with the potential annual variability. Most field pCO₂ data of ours also show that distributions and seasonal variation of the SCS surface pCO₂ were mainly influenced by the variation of SST (Zhai et al., 2005). This study thus reveals that low latitude ocean margins may indeed behave differently from mid-latitude eutrophic shelves.

Taken together the available data in marginal seas in different physical and biogeochemical regimes, there appears to occur contrasting source or sink scenarios in different latitudinal regions, i.e. CO₂ uptake in high-mid latitude shelves and release at low latitudes. This is generally consistent with latitudinal differences in the supply and decomposition of terrestrial organic carbon.



Chris Zappa grew up north of Boston, Massachusetts. He attended Columbia University as an undergraduate and earned a Bachelors of Science in Mechanical Engineering. In 1992, he moved to Seattle to attend the University of Washington and began his graduate career at the Applied Physics Laboratory. Upon receiving his Ph.D. in 1999, Chris accepted a Postdoctoral Scholar Award at the Woods Hole Oceanographic Institution. Chris has been a Doherty Associate Research Scientist at the Lamont-Doherty Earth Observatory of Columbia University since October, 2003 and is a specialist in ocean-atmosphere interaction. His interests include wave dynamics and wave breaking, the effect of near-surface turbulence on heat, gas, and momentum transport, airborne infrared remote sensing, upper-ocean processes, coastal and estuary dynamics.

Scaling Gas Transfer with Turbulent Dissipation for a Range of Environmental Processes

Christopher J. Zappa¹, Wade R. McGillis^{1,2}, Peter A. Raymond³, James B. Edson⁴, Eric J. Hints⁵, Hendrik J. Zemmelen⁶, John W. H. Dacey⁷, and David T. Ho¹
¹Lamont-Doherty Earth Observatory, Columbia University, USA; ² Department of Earth and Environmental Engineering, Columbia University, USA; ³ School of Forestry and Environmental Studies, Yale University, USA; ⁴ Department of Marine Sciences, University of Connecticut, Avery Point, USA; ⁵ Marine Chemistry and Geochemistry Department, Woods Hole Oceanographic Institution, USA; ⁶ School of Environmental Sciences, University of East Anglia, UK; ⁷ Biology Department, Woods Hole Oceanographic Institution, USA

For sparingly soluble gases in the absence of bubbles, theory predicts that the gas transfer velocity, k , is controlled by turbulence in the surface aqueous boundary layer, which dictates the rate at which gases can be brought into contact with the surface to exchange with the atmosphere. Since gas transfer has been shown to scale with wind-generated turbulence in many field and laboratory wind-wave experiments, wind-based relationships to model k are typically used for gas exchange estimates from the open oceans to estuaries and rivers despite the acknowledged role of physical processes not related to wind (e.g., tidal currents, rain, stratification, surfactants, and water depth).

In an effort to explicitly relate turbulence near the surface aqueous boundary layer to gas exchange, models have been developed for k based on the turbulent kinetic energy dissipation rate, ϵ . A fundamental relationship shows k scales with $(\epsilon\nu)^{1/4} Sc^{-n}$, where the Schmidt number, Sc , is defined as the ratio of the kinematic viscosity of water, ν , to mass diffusivity. The Schmidt number exponent n is believed to vary between $_$ and $_$ depending on the surface boundary conditions. This expression for k based on ϵ is consistent with mass diffusion across a layer of the thickness of the Batchelor [1959] scale [Melville, 1996], and has been derived by Lamont and Scott [1970] using surface-renewal theory [Danckwerts, 1951] and also has been derived by Kitaigorodskii [1984] in the context of modeling the influence of patches of enhanced turbulence by breaking

We measured the turbulent dissipation rate using acoustic techniques and the gas transfer velocity using micrometeorological and active controlled flux techniques in the coastal ocean, a macro-tidal river estuary with wind and tidal forcing, a large tidal freshwater river, a model ocean, and wind-wave tanks. The results clearly show that gas transfer under

wind, waves, currents, rain, and surfactants indeed scales with the hypothesized model based on the turbulent dissipation rate over a wide range of environmental systems with different types of environmental forcing and processes. The bubble-mediated effect on k is not completely accounted for in this model and may lead to a case at high winds when the gas exchange is enhanced relative to the model based on turbulence alone.

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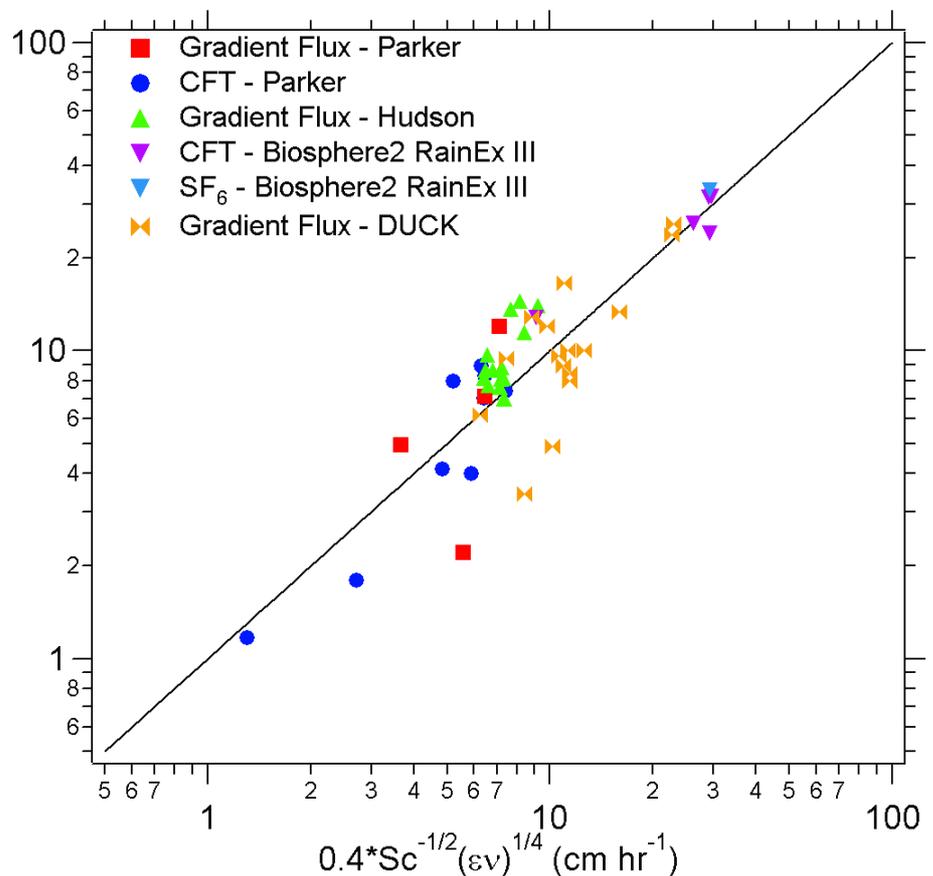
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Following from the Land-Ocean Interactions in the Coastal Zone (LOICZ) Inaugural Open Science Meeting in June 2005, a number of workshops have been held to shape the direction of future LOICZ research. The workshops focus on interactions between humans, ecosystems and material fluxes as drivers of coastal change. A LOICZ-Basins workshop was held in October 2005 in Sri Lanka, hosted by the LOICZ South Asia Node, explored changes in land-based material flows and their impact on the coastal zone system, with linkages to recent developments in the Integrated Coastal Area and River Basin Management (ICARM) to help inform practitioners about the usefulness of linked coastal and river basin management. This will be followed by a workshop to explore options for Science-Policy Interactions in coastal zone management in South Asia. Future activities include a coastal zone governance workshop to explore communication needs of policy makers from the science community and a UNEP-GEF workshop to explore how scientific results can be made accessible and relevant for policy makers. For more information see: www.loicz.org.



The Commission on Atmospheric Chemistry and Global Pollution (CACGP), one of two Commissions within the IAMAS (International Assembly on Meteorology and Atmospheric Sciences), is a sponsoring organization of SOLAS. Next year CACGP holds its Quadrennial Symposium with IGAC and WMO co-sponsorship, in Cape Town, South Africa, 17-23 September 2006. The theme is Chemistry at the Interfaces - of land, sea, climate - and touching on regional-global scales. For the Abstract Schedule and details, see <http://chemistryinterfaces2006.co.za>.



Lisa Miller is a research scientist with Fisheries and Oceans Canada in British Columbia, specializing in climate geochemistry. She also studies the carbon system in liquid seawater, as well as in the frozen kind.

More questions than answers about sea-ice carbon biogeochemistry and atmospheric CO₂ fluxes

Lisa Miller¹, Tim Papakyriakou², Owen Owens², Nes Sutherland¹, Jens Ehn², and C.J. Mundy²
¹Centre for Ocean Climate Chemistry, Institute of Ocean Sciences, Canada
²Department of Environment and Geography, University of Manitoba, Canada

Our understanding of how sea ice can influence the carbon cycle has been further confused by concomitant time series of sea ice carbon geochemistry and vertical CO₂ fluxes in the overlying atmospheric boundary layer during the winter of 2004 in the southern Beaufort Sea.

While our eddy correlation measurements have confirmed that there can be significant and even large CO₂ fluxes over sea ice (routinely up to 50 mmol m⁻²d⁻¹, with even larger fluxes over short periods), pCO₂ values measured within the ice were consistently much higher than in the atmosphere, implying a CO₂ gradient contrary to the prevailing downward fluxes. Short, dramatic upward CO₂ fluxes were associated with periods when the temperatures in the atmosphere

and the ice were increasing, suggesting that as brine channels reopened, the high CO₂ within the ice was able to effectively outgas into the atmosphere. Occasional sudden decreases in pCO₂ within the ice may also reflect such catastrophic out-gassing events.

However, resolving the mechanism of the dominant downward fluxes will require development of more non-destructive methods for monitoring carbon biogeochemistry within the ice on time scales comparable to the eddy correlation measurements. Ideally, we need in situ microprobes that can measure pCO₂, CaCO₃, and TOC, as well as direct indicators of respiratory and photosynthetic activity, such as O₂, at the low temperatures (down to -40°C) and high salinities - over 200 (PSU) - observed in sea ice.



▲ University of Manitoba Master's student Owen Owens sampling CO₂ from sea ice in the southern Beaufort Sea during January 2004. The ship in the background, NGCC Amundsen, was frozen into the fast ice of Franklin bay from December 2003 to June 2004 as part of the Canadian Arctic Shelf Exchange Study (CASES), <http://www.cases.quebec-ocean.ulaval.ca/welcome.asp>.



Bernd Schneider studied chemistry at the University of Kiel with a Diploma in Physical Chemistry. He wrote his dissertation (1979) on trace metal enrichment at the air/sea interface at IfM-Kiel. He has conducted research on atmospheric trace metal deposition at the IfM-Kiel, GKSS Research Center, and with Bob Duce's group at URI. He was involved in JGOFS with studies on the oceanic CO₂ system. Since 1993, he has been a leading scientist at the Baltic Sea Research Institute (IOW) in Warnemuende, working mainly on the Baltic Sea CO₂ system, on its use for the identification and quantification of biogeochemical processes and on the dynamics of gas exchange.

Continuous pCO₂ and pO₂ measurements on a cargo ship in the Baltic Sea: A tool to study gas exchange and biogeochemical processes.

Bernd Schneider - Baltic Sea Research Institute Warnemuende (IOW), Germany

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In cooperation with the Finnish algaline project the CO₂ group of the IOW deployed a fully automated pCO₂ measurement system on cargo ship FINNPARTNER. The ship commutes regularly at two days intervals between Luebeck and Helsinki and thus passes the entire Baltic Proper. The pCO₂ measurements are based on a bubble-type equilibrator and CO₂ IR detection. The measurements started in June 2003 and since then more than 250 high quality pCO₂ transects have been obtained. The purpose of the investigations was originally confined to the determination of the net biomass production in particular during the midsummer N₂ fixation period. The seasonality of the pCO₂ in 2005 in the area between the Gotland Sea and the Gulf of Finland is shown in Fig. 1. The existence of two minima is typical for the Baltic Sea and indicates the spring bloom and the production fuelled by N₂ fixation, respectively.

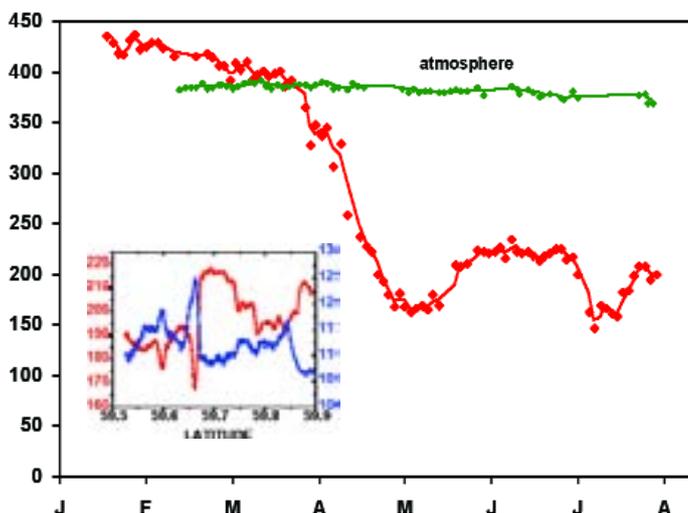
The net biomass production was estimated for different sub-regions on the basis of a CO₂ balance taking into account the CT depletion and the air/sea exchange. Since the abundance of calcifying plankton is neglectable in the Baltic Proper, the seasonal CT changes were calculated using the T, S records and the mean alkalinity. For the determination of the CO₂ gas exchange we used the various currently available

parameterizations of the transfer velocity. For the period after the spring bloom the production estimates were substantially higher than expected from the availability of phosphorus. Even after accounting for substantially enhanced C/P ratios (300 – 400) observed for the POC in the Baltic Proper, the net biomass production conflicted with the P budget. An analysis of the uncertainties involved in the CT calculations indicated that we possibly overestimated the CO₂ gas exchange which for some periods contributed significantly to the CT balance. We suspect that the formation of organic surface films considerably impeded the gas exchange. This hypothesis is supported by observations which showed an extreme accumulation of *Nodularia* at the surface of large areas of the Baltic Proper in midsummer.

In order to improve the determination of the gas exchange, we have recently added a module for the determination of the surface water pO₂ to the measurement system on FINNPARTNER. The measurements are based on a specially designed equilibrator and O₂ detection by an optode. The pO₂ data will be used to establish budgets for both CO₂ and O₂. Two independent mass balance equations will be obtained allowing the calculation of the two major unknown quantities: the net biomass production and the transfer velocity

(k_{660}). The combined CO₂/O₂ measurements started in July this year and first promising results (Fig. 1, inset) show the opposing effect of biological production on the CO₂ and O₂ concentrations.

< Fig. 1: Seasonality of the pCO₂ and the spatial distribution of the the pCO₂ and the oxygen saturation (inset) in the northern Baltic Proper.



Japan

During 1-2 June 2005, the first Asian SOLAS Meeting was hosted by SOLAS-Japan in Tokyo following the SOLAS SSC Meeting. Activities of SOLAS from China (Beijing and Taiwan), India, Japan, and Korea were reported and on-going studies in Japan were also introduced to over 40 participants. We exchanged knowledge and discussed future cooperative plans including cruises in the western North Pacific related to the SOLAS foci. The next Asian SOLAS Meeting will be hosted by China SOLAS in 2006.

The SEEDS II Workshop (Second Iron Enrichment Experiment in the Western Subarctic Pacific) was held at the Ocean Research Institute, University of Tokyo, from 17-18 October, 2005 (for more information, see <http://solas.jp/>). SEEDS II was an international collaborative experiment, conducted in the same western subarctic Pacific region as the initial SEEDS experiment, utilizing two research vessels, the R/V Hakuho Maru (Japan) and the R/V Kilo Moana (USA). This experiment was designed to characterize the evolution of a fertilized patch over a longer time scale (1 month) and with a greater range of parameters than was measured during SEEDS.



Brazil

The Brazilian Committee was organized in 2003, and it was initially created as a web site where Brazilian scientists could access information and network. So far, four projects involving the University of São Paulo (USP), National Institute of Research (INPE) and the Federal University of Pelotas (UFPEl) have been posted to the site. From the Brazilian scientific point of view, SOLAS is an umbrella to motivate the formation of local research groups in universities and research institutions in Brazil focusing on air-sea interaction. Scientific projects are under development by Brazilian researchers that are willing to collaborate with international SOLAS activities. All of the projects investigate processes responsible for air-sea exchange of mass, momentum and energy over the Atlantic Ocean.



WCRP is celebrating its 25th anniversary in 2005. Four WCRP core projects, "Climate Variability and Predictability (CLIVAR), Global Energy and Water Cycle Experiment" (GEWEX), Stratospheric Processes and Their Role in Climate" (SPARC), and "Climate and Cryosphere" (Clic) actively pursue their goals. Clic and GEWEX held major international science conferences in 2005. A series of atlases summarising the results of the WCRP World Ocean Circulation Experiment is being published. The WCRP focuses its projects at Coordinated Observation and Prediction of the Earth System (COPEs). The new WCRP Modelling Panel and Observation and Assimilation Panel will meet in 2005 to discuss coordination of modelling and observations to achieve COPEs goals. Other WCRP plans include reanalyses of the climate system, comprehensive reprocessing of satellite data, studies of mean sea level rise, predictability, monsoons, climate and chemistry, etc.



The Integrated Land Ecosystem - Atmosphere Processes Study (iLEAPS) is arranging three consecutive events in Boulder, Colorado: the First iLEAPS Science Conference, a Post-Conference Specialist Workshop, and the Scientific Steering Committee Meeting. By early October, the IPO received 270 abstracts for the conference. Continuous flux measurements are performed at hundreds of sites in the Americas, Africa, Europe, Asia, and Australia. The Specialist Workshop "Flux Measurements in Difficult Conditions" tackles the problems encountered in determining the exchange of energy, momentum, particles, as well as long-lived and reactive trace gases, between land ecosystems and the atmosphere. For example, sound methods for measurements are needed for nighttime when turbulence is weak and in sloping and heterogeneous terrain subject to advective flows. The contribution and origin of large eddies and magnitude of intermittency are other sources of uncertainty that the workshop will address. The workshop aims to identify and recommend key research areas for the next years. In addition to the three events mentioned above, iLEAPS will arrange various splinter meetings (for example, FLUXNET).



Hanna Silvennoinen is currently working on her PhD thesis, entitled "Nitrogen and greenhouse gas cycling in rivers and estuaries of the Bothnian Bay (The Baltic Sea)" within the Research Group of Biogeochemistry at the Department of Environmental Sciences, University of Kuopio, Finland.

Effluxes of N₂O and N₂ and nitrogen cycling in river and estuary sediments of the Bothnian Bay (Northern Baltic Sea)

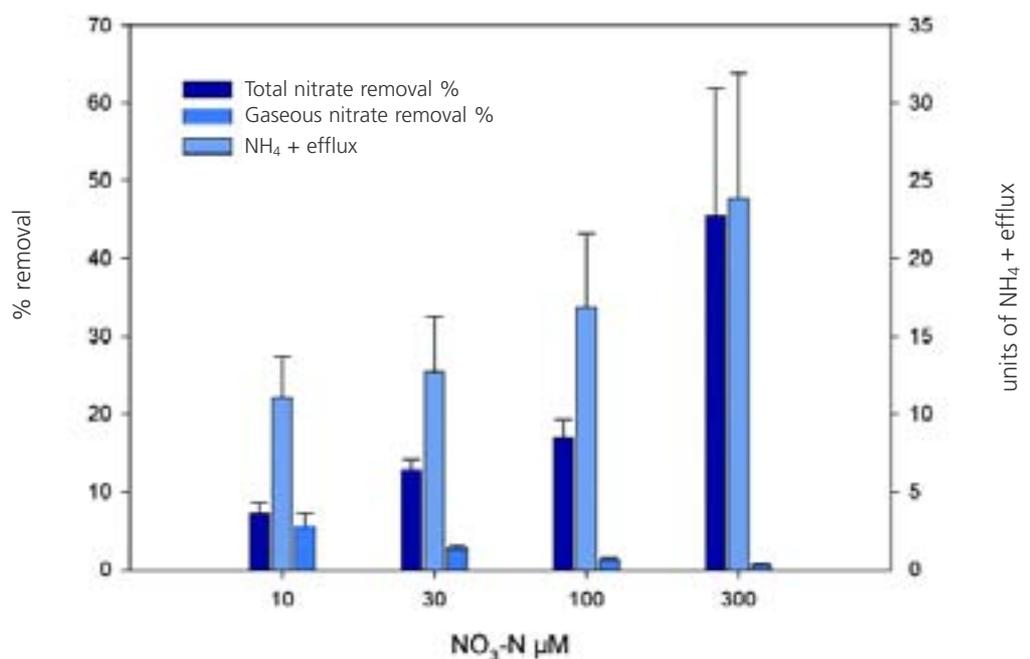
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Anthropogenic activity, e.g. agriculture, forestry, scattered dwelling and peat mining, has increased the nitrogen loading to the rivers and estuaries thus increasing the eutrophication of the Baltic Sea. Microbial activity in sediments of rivers and estuaries can remove dissolved inorganic nitrogen as gases from water to the atmosphere. Denitrification, an anaerobic, heterotrophic microbial process, reduces dissolved nitrate to gaseous compounds, nitrous oxide (N₂O) or molecular nitrogen (N₂). From these gases N₂ is abundant and harmless in the atmosphere whereas N₂O is an affective greenhouse gas. Denitrification is estimated to diminish the nitrogen loading to the estuaries in the Southern Baltic Sea up to 20-50 % (Seitzinger, 1988). Emissions of N₂O from estuaries and coastal areas are suggested to contribute up to 25 % to the global

anthropogenic N₂O, thus being one of the largest anthropogenic N₂O source (Seitzinger & Kroeze, 1998).

Baltic Sea suffers seriously from high nutrient load. This causes e.g. regular harmful blooms of cyanobacteria in summer time. The knowledge on fate of nutrients in Baltic Sea has importance for the attempts to control the eutrophication of this brackish water environment. The nitrate removal by denitrification, and N₂O emissions from the rivers and estuaries of the northern Baltic Sea have not been studied before. Here we present the nitrate removal capacity of various river sediments of the Bothnian Bay and how it is affected by nitrate availability in river water. Processes responsible for the nitrate removal were studied as well as the ratio of N₂ to N₂O produced in nitrification and



denitrification. The results have been obtained in the research project "Nitrogen and greenhouse gas cycling in rivers and estuaries of the Bothnian Bay (Baltic Sea)" (2003-2005) which belongs to the Baltic Sea Research Programme (BIREME) of the Academy of Finland. The project is a joint effort with the Centre for Environmental Research (UFZ Leipzig-Halle GmbH, Germany), Department of Soil Sciences.

Intact sediment samples were collected from the estuaries of the River Temmesjoki, the River Siikajoki, the River Pyhäjoki and the River Kalajoki and the nitrate removal was studied under nitrate concentration of 30 μM . The effect of different nitrate concentrations (10, 30, 100 and 300 μM) was studied with the sediments from the estuary of the River Temmesjoki. Concentrations of 10 and 30 μM are commonly found in river waters, whereas 100 and 300 μM are high but possible in waters flowing from the catchments to the rivers. The sediments were incubated at 15°C in a laboratory microcosm under a continuous, oxic water flow for four weeks.

The intact sediment samples were placed into the continuous water flow microcosm (Liikanen, et al. 2002). Artificial water was pumped over the sediments with a peristaltic pump at the rate of 50 mL h⁻¹. The artificial water was manipulated for the nutrient and gas concentrations in water. For studying the N₂ effluxes of the sediments with ¹⁵N tracer (see later), the normal N₂ atmosphere of the water was replaced with argon. In all of the experiments the concentrations of Ca²⁺ and Mg²⁺ in water were adjusted to correspond mean concentrations in river water. The removal of nitrate and the gases evolved in denitrification were calculated from the difference in the concentrations between the in- and outflowing waters.

Because of the high background N₂ concentration (78% in the atmosphere), the determination of N₂ formed in denitrification is impossible without special techniques. The ¹⁵N labelled nitrate (60 at%) was used here. The ¹⁵N₂ formed in denitrification from the labelled substance can be detected with mass spectrometry (Hauck et al. 1958, Russow et al. 1996). The addition of labelled nitrate enabled us to study also other microbial processes in nitrogen cycling, dissimilatory nitrate removal to ammonium (DNRA), immobilisation (method modified from Hopkins, 1991), nitrification and mineralization.

The sediments removed 8-60% of the added nitrate. With the concentrations commonly found in the Finnish river ecosystems (10-30 μM), the removal varied between 8-20% denitrification being the main process removing nitrate. The removal did not contribute significantly to the local N₂O budgets, because the main product of denitrification was N₂ (98-100%) of the gaseous products). With higher nitrate concentrations (100-300 μM), up to 60% of the nitrate was removed, but instead of denitrification, DNRA and immobilisation mainly contributed to the removal. Denitrification is the only process removing nitrate permanently from the ecosystem, thus diminishing the anthropogenic nitrogen loading to the Baltic Sea. However, DNRA produces ammonium, which is easily available to the algae and can also be oxidized back to nitrate. Therefore, if nitrogen loading and nitrate concentrations increase, nitrate will be transformed to other inorganic and organic compounds and remain in the ecosystem.

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- Seitzinger, S.P.I 1988. Denitrification in freshwater and coastal marine ecosystems: Ecological and geochemical significance. *Limnology and Oceanography*. 33: 702-724.
- Seitsinger, S.P. and Kroeze, C. 1998. Global distribution of nitrous oxide production and N inputs in freshwater and coastal marine ecosystems. *Global Biogeochemical Cycles*. 12: 93-113. Figure 1. Total and gaseous nitrogen removal proportions and ammonium efflux as a function of increasing nitrate concentration.



Germany

German SOLAS (D-SOLAS) concentrates on the air-sea exchange of trace gases, in particular marine emission of halogenated species, marine halogen chemistry, particle formation, response of environments to elevated carbon dioxide, and the role of dust.

Two major proposals have been submitted: 'Surface Ocean Processes in the Anthropocene' (SOPRAN) and 'Marine Multi-Phase Halogen Chemistry and its Coupling to Nitrogen and Sulfur Cycles' (MAPHiNS).

SOPRAN, due to begin in mid-to-late 2006, covers four themes: the oceanic response to atmospheric dust (Eastern Tropical North Atlantic), effect of anthropocene CO₂ levels on marine ecosystems and sea-to-air gas fluxes (Baltic), production / emission of radiatively and chemically active gases (Cape Verde and NW African upwelling region), and inter-phase transfer at the sea surface (Baltic).

The activities planned within MAPHiNS are: lab studies of liquid - phase reactions in marine aerosol particles with emphasis on halogen reactions and coupling to gas-phase chemistry, field studies of gaseous halogen species, DMS and nitrogen species in marine environments, field studies of the evolution of particle formation, satellite observations of halogen release events, coastal NO_x, and aerosol distributions, and development of parameterizations and comparison with field data.



Ireland

Ireland held its first SOLAS meeting in April of this year to enable the SOLAS-Ireland network. Groups participating in atmospheric physics, chemistry, meteorology, marine botony, and ocean dynamics gathered to outline their SOLAS-related research activities. In particular, Ireland is coordinating an EU-funded project MAP (Marine Aerosol Production from Primary and Secondary Sources), comprising 16 EU research groups active in SOLAS-related research. Further enabling of SOLAS research in Ireland was outlined and is under development.



UK

The first eleven SOLAS projects supported by the Natural Environment Research Council are underway, with the geographic focus of the eastern North Atlantic, from tropical waters off Africa to the Norwegian Sea.

There are five general research activities: 1) ocean processes affecting the atmosphere, including biological interactions affecting DMS production and the role of upwelling in trace gas emissions; 2) atmospheric processes affecting the ocean, including dust and nutrient inputs; 3) factors determining exchange rates at the sea surface, including the biology of the microlayer and physico-chemical events at high winds; 4) global modelling, with emphasis on aerosols and atmospheric chemistry; 5) establishment of an observatory on the Cape Verde islands in collaboration with German SOLAS and local institutions.

The first fieldwork will be a study of dust deposition off North West Africa, in early 2006, using the R/V Poseidon and the BAE-146 research aircraft, in collaboration with the UK Meteorological Office and AMMA (African Monsoon Multidisciplinary Analysis). Other cruises are planned for Apr/May and Nov/Dec of 2006, using the RRS Discovery to investigate air-sea exchanges in the Mauritanian upwelling region and in the high latitude NE Atlantic Ocean.

A funding competition is underway for the dynamics of halogen compounds in the marine boundary layer. For more information, see www.nerc.ac.uk/funding/thematics/solas/awards

SOLAS International Project Office

The SOLAS International Project Office is hosted by the School of Environmental Sciences at the University of East Anglia, Norwich, UK. It is funded by the UK Natural Environment Research Council.

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Lise Lotte Sørensen is a senior scientist at Risø National Laboratory. She has studied air-sea exchange of reactive gases (mainly nitrogen containing gases) since 1990 and for the past 7 years also air-sea exchange of CO₂. She is mainly an experimentalist and works on application of different flux measurement techniques (Spectral methods and REA techniques).

Air-Sea fluxes of water vapour and CO₂ in the North Atlantic

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Measurements of fluxes of water vapour, CO₂ and $\Delta p\text{CO}_2$ are obtained from a coastal site in Sweden, a platform in the North Sea and ships in the North Atlantic and Greenland Sea (see fig.1).

The fluxes were measured by use of three instruments: a Licor, an Ophir and an infrared sensor developed by KNMI, all combined with sonic anemometers for wind measurements. $\Delta p\text{CO}_2$ measurements and several flux estimation techniques were used; the co-variance-or eddy correlation technique, compared with the inertial dissipation method, the co-spectral method and the relaxed eddy accumulation technique.

It is difficult to obtain good data sets of surface fluxes using the traditional and direct covariance technique in the marine atmosphere since this method is very sensitive to the motion on a ship and flow distortion caused by the large structure of a ship or a marine platform. The measurements are additionally challenging due to the very small fluxes occurring over the marine surface. The inertial-dissipation method is a good alternative to the covariance technique because it relies on measurements at high frequencies, less distorted by the motion and the superstructure of the ship. Its application is based on relatively fast responding instruments. The method is best documented for momentum, but has also recently been tested for temperature, humidity and CO₂

[Fairall, et al, 1990, Edson et al, 1991, Larsen et al, 2001]. The co-spectral method similarly may make it possible to avoid signal frequencies contaminated by platform motion. It is somewhat more empirical than is the inertial dissipation method; on the other hand, it can be used with instruments with relatively low data rates. The relaxed eddy accumulation method makes it possible to estimate fluxes without fast responding instruments. The data analysis shows that water vapour and CO₂ fluxes obtained, using different micrometeorological methods, compare well with each other, when proper attention is paid to the necessary corrections.

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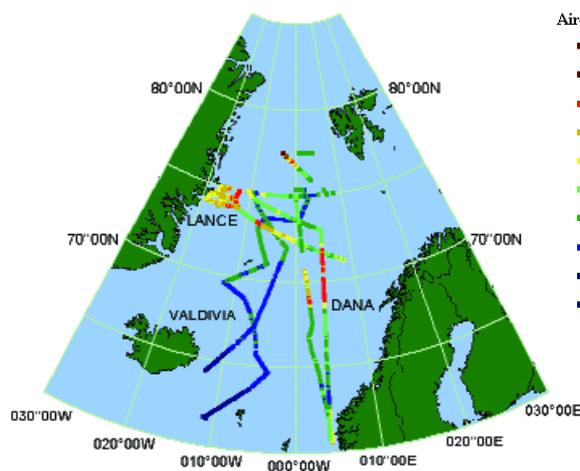


Figure 1 Air-Sea mixing ratio measured during three different cruises in the northern north Atlantic. Valdivia took place April 1999, Dana took place June 1999 and Lance took place in October 2003

And finally...

SOLAS Open Science Conference 2007



SOLAS is pleased to announce the next SOLAS Open Science Conference to be held in Xiamen, China, 6-9 March 2007. The International Organising Committee is chaired by Professor Guang Yu Shi (Chinese Institute of Atmospheric Physics, Beijing), and the Local Organising Committee is chaired by Dr Minhan Dai (Xiamen University). There will be plenary talks, discussion and poster sessions in the style of the successful SOLAS Open Science meeting in Halifax in 2004. The official announcement and call for abstracts will be made in Spring of 2006. We look forward to your contributions.

Thanks for reading the SOLAS Newsletter!

In the spirit of the international character of SOLAS, the contributions to this Newsletter have come from fourteen nations. Furthermore, the 2005 SOLAS Summer School was represented by students from twenty-nine countries. With the publication of this Newsletter, we take pride in communicating to you a slice of groundbreaking SOLAS science and a peek at the development of the next generation of SOLAS scientists. The International Project Office is now fully staffed, the Implementation Plans for the three SOLAS Foci have been posted on the website (<http://www.uea.ac.uk/env/solas>), and we look forward to imminent SOLAS scientific progress. In the meantime, we invite you to work with us to continue to strengthen the SOLAS International Network and to continue the progress of SOLAS science.

Jeff Hare – SOLAS IPO Executive Officer

Emilie Brévière – SOLAS IPO Project Officer

Martin Johnson – SOLAS IPO Project Officer

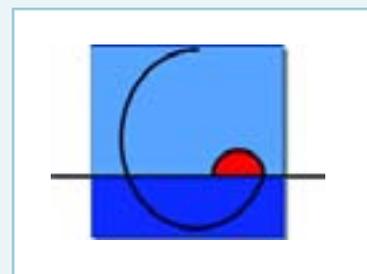
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partner projects



CarboOcean is funded for five years by the European Commission to assess marine carbon sources and sinks with focus on the Atlantic and Southern Oceans of -200 to +200 years from now. The project is scheduled in four project phases, which are Description, Understanding, Nowcast and Prediction, and Synopsis and Sustainment.

The Description phase includes the establishment of the CarboOcean reference description. One of the first experiments carried out was the first CarboOcean mesocosm experiment at the Marine Biological Station, 20 km south of Bergen, Norway. In order to study the reactions of marine plankton and biogeochemical feedback mechanisms under increased CO₂ concentrations, the first pelagic ecosystem CO₂ enrichment study was successfully run with two and three times present day CO₂ levels. To read more about the mesocosm experiment and CarboOcean please visit <http://www.carboocean.org/>.

The CarboOcean consortium will report on its latest findings and news at its first annual meeting in Amsterdam from 22-24 November.

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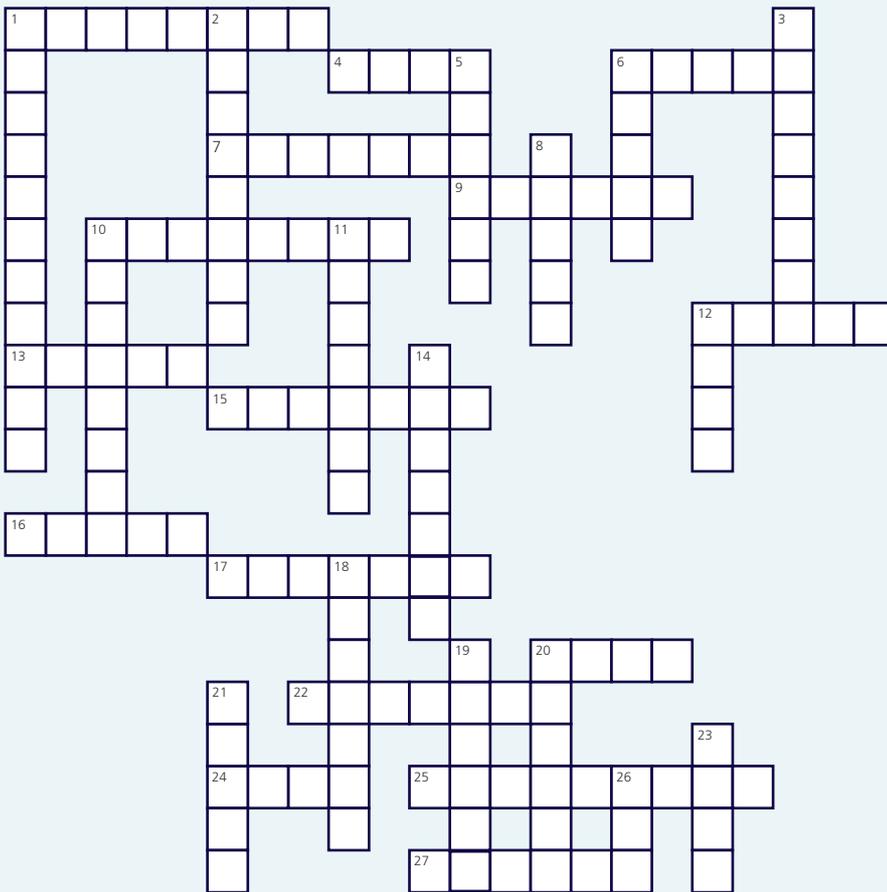
They Might be SOLAS Giants

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Printed by: Gallpen Colour Print,
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Design by: Woolf Designs,
www.woolfdesigns.co.uk
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Circulation: 1500

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