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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• National reports from 13 SOLAS Countries
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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, Pryzd 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 subtropical 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°.
Marginal seas act as a significant CO\(_2\) 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 Sea\(^2\) or the North Sea\(^3\). This agreement is due to the fact that although tropical and subtropical marginal seas are CO\(_2\) 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 CO\(_2\) in marginal seas could be almost fully compensated by the emission of CO\(_2\) (+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 CO\(_2\) from estuaries (0.34 Pg C yr\(^{-1}\)). On the whole, the coastal ocean would act as a small CO\(_2\) sink (-0.05 Pg C yr\(^{-1}\)) and would lead to a modest increase of the CO\(_2\) sink from the global ocean (-1.57 versus -1.62 Pg C yr\(^{-1}\), 3%).

The present up-scaling of air-water CO\(_2\) 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 CO\(_2\). This has significant consequences on our understanding of global cycles of carbon and CO\(_2\).

### Further reading

Borges, A.V. (2005), Do we have enough pieces of the jigsaw to integrate CO\(_2\) fluxes in the Coastal Ocean ?, Estuaries, 28, 3-27.


Location of 44 coastal environments where annual integrated air-water CO\(_2\) 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 CO\(_2\) 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 CO\(_2\) flux at high latitudes that is inconsistent with recent data in the Artic 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.

### Acknowledgements

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

### References


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, Adélie 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 bloom 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 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).

References


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 length scales.

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 $k$, the dissipation rate $\epsilon$, the Taylor microscale $\lambda$, and the root-mean-square of the surface divergence $\beta_{rms}$ are obtained from the PIV measurements. A multidisciplinary approach of the question was necessary to understand the different mechanisms involved in these variabilities.

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

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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.

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 iron ocean 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 submitted 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.
>continued from previous page

measurements. The gas transfer velocity $k_s$ 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, $\beta_{\text{micro}}$ can be expressed as the ratio of the 1/2 power of a turbulent kinetic energy to the Taylor microscale at the air-water interface as follows:

$$\beta_{\text{micro}} \sim \left( \frac{\langle u' \partial x \rangle}{\tau} \right)^{1/2} \sim u' w^{1/2} / \lambda \sim \lambda^{1/2} k_s / \lambda$$

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 $k_s$ is proportional to the 1/2 power of $\beta_{\text{micro}}$. 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 $k_s \sim \beta_{\text{micro}}^{1/2} \sim \epsilon^{1/4}$, where $\epsilon$ is the Schmidt number, $R_{\text{t}}$ a turbulent Reynolds number defined as $k_s^2 / \left( \varepsilon \nu \right)$ and $\nu$, 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 only from the Reynolds number dependence.

The figures show a CO$_2$ 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 $\mu$m, respectively. The dark regions in the concentration field denote those of high CO$_2$ concentration. Surface-renewal patches whose CO$_2$ 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 CO$_2$ 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 Kolomogorov lengthscale. We infer from these experimental results that the Taylor microscale is a crucial lengthscale for the air-water gas transfer.

References


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](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/](http://www.atmosphericinterfaces2006.co.za/)
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) was 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 (k600 = 1.66e0.25U10 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 Tair-Twater = 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


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 1 m.s-1 and the dash-dotted line is the relationship of Cole and Caraco (1999).
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.

Further reading
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, mainly 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 ∑PCBs yr⁻¹ and 2500 kg PCDD/Fs yr⁻¹ and the net air–water exchange is 22000 kg ∑PCBs 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.

Further reading


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?
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, and thus we investigated the surface and water column as sediment porewater distribution of dissolved CH4. In addition we investigated the stable isotopic composition of C in sediment porewater CH4 (δ13CH4) and carried out sediment-slurry incubations to determine microbial methanogenesis or methane oxidation. All surface water samples were supersaturated with respect to atmospheric equilibrium (c<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.

References


Figure 1: Dissolved CH4 against salinity in surface waters of the Ria de Vigo
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, wave-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 the size and the ability to optically obscure (dense) or not (diffuse) the background. For each class, the time and size-resolved bubble population distribution, φ(r, ψ), 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 ψ(r), for diffuse plumes were weakly size dependent to 1000μm, then decreasing steeply for larger bubbles. ΔP for dense plumes were multimodal with a steeply decreasing small bubble population, a second, broad peak at 1700 - 2000 μm 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, for each plume class, the global bubble-plume, injection size-distribution, Ψ(r), was calculated (Fig. 1). ψ decreases as ψi ∼ r⁻1.2 for r < 1700μm and ψi ∼ r⁻3.9 for larger r. The volume injection rate for the study area was 640 cm³ s⁻¹, divided approximately equally between bubbles smaller and larger than 1700μm 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.

References


Fig 1 B. Global, injection, bubble-population size-distribution, Ψ, 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 Bjerknes 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 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
The SOLAS Summer School was held in Cargése, 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; recouperating 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 noiticulent phytoplankton, the social and natural science discussions during coffee breaks, a glass of good wine during the open-air poster sessions and all the interesting and enthusiastic participants from all over the world..."

Meike Vogt, University of East Anglia, UK
The uncounted role of the Arctic sea ice in atmospheric CO\textsubscript{2} balance.

Makhtas A. (AAAR, Russia), I. Semiletov (ARC-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 CO\textsubscript{2} 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 CO\textsubscript{2} 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 CO\textsubscript{2} for temperatures above –15°C.

Small-Scale Gas Exchange Processes

We obtained data about small-scale CO\textsubscript{2} 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 CO\textsubscript{2} concentration and to obtain rough estimates of CO\textsubscript{2} 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 pCO\textsubscript{2} 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 CO\textsubscript{2} 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, pCO\textsubscript{2} decreased in and beneath the sea ice. However, the role of biological and physical factors in the CO\textsubscript{2} flux in and from the sea ice needs additional studies. >
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”.

References


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 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

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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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.
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, \( \varepsilon \). A fundamental relationship shows \( k \) scales with \( (\varepsilon \nu)^{1/4}Sc^{-n} \), where the Schmidt number, \( Sc \), is defined as the ratio of the kinematic viscosity of water, \( \nu \), to mass diffusivity. The Schmidt number exponent \( n \) is believed to vary between 0 and 1 depending on the surface boundary conditions. This expression for \( k \) based on \( \varepsilon \) 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 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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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.
Continuous pCO₂ and pO₂ measurements on a cargo ship in the Baltic Sea: A tool to study gas exchange and biogeochemical processes.

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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_{t660}). 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.

Bernd Schneider studied chemistry at the University of Kiel with a Diploma in Physical Chemistry. His wrote his dissertation (1979) on trace metal enrichment at the airsea 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 Warnemünde, 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.
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 (Seitziger & 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.
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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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’ (SPORAN) and ‘Marine Multi-Phase Halogen Chemistry and its Coupling to Nitrogen and Sulfur Cycles’ (MAPHiNS). SPORAN, 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 NOₓ 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.
Air-Sea fluxes of water vapour and CO₂ in the North Atlantic

Lise Lotte Sørensen, Søren E. Larsen, Søren W. Lund and Jan Nielsen: Risø National Laboratory, DK-4000 Roskilde, Denmark, Corresponding author e-mail: Lotte.geern@risoe.dk

Measurements of fluxes of water vapour, CO₂ and ΔpCO₂ 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. ΔpCO₂ 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.

References


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.carbocean.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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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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They Might be SOLAS Giants

ACROSS
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4  Kiwi Ironman (4)
6  From Sensei to Guru (6)
7  Coined Term ‘Anthropocene’ (7)
9  Ran (From) CSOLAS (6)
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21  Chilly Guy (5)
23  Charney’s Prize Student (4)
26  Middle Kingdom SOLAS He (3)

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