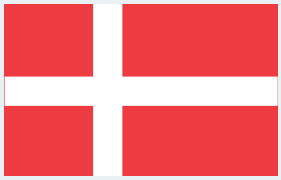

SOLAS Denmark

Denmark can proudly boast several exciting developments within their SOLAS nation and is able to announce a new project, 'ECOCLIM'. The project goal is to estimate CO_2 exchange between the atmosphere and the biosphere in Denmark and will to a large extent, focus on air-sea CO_2 exchange in coastal regions. Partners include Copenhagen University, DTU and Roskilde University and will be coordinated from the Department of Environmental Science at Aarhus University.

The aforementioned ECOCLIM project and the project 'Air-sea-ice exchange of CO_2 in the Arctic coastal area' funded by the Nordic Council of Ministers, will be some of the activities of the new Nordic Centre of Excellence named DEFROST http://www.ncoe-defrost.org/. DEFROST includes a working package focussing on air-sea-ice exchange of CO_2, coordinated by Lise Lotte Sørensen and Søren Rysgaard. Measurement stations for air-sea exchange of CO_2 will be established in the Nuuk fjord this year and at Young Sound in 2012. These stations will be managed from the Greenland Climate Research Centre where several Danish SOLAS members recently participated in a field experiment in Kapisigdlit (see front cover image) to study air-ice-sea carbon exchange. This experiment was part supported by the project, 'Air-sea-ice exchange of CO_2 in the Arctic coastal area', and the project 'Marine Carbon Cycle' coordinated by Ronnie Glud, University of Southern Denmark.

Further to this SOLAS Denmark's scientific highlight is the development of new analysis methods for CO_2 air-sea flux. Different flux estimation techniques to evaluate air-sea exchange have been developed and suggested for use on moving platforms. Techniques using power spectra and cospectra are applied to estimate fluxes of momentum, sensible heat, latent heat and CO_2 (Sørensen and Larsen, 2010, Boundary Layer Meteorology, 136 (1): 59-81). The CO_2 fluxes can be calculated from the dissipation technique utilising the inertial sub-range of the power spectra and from estimation of the cospectral amplitude.

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Geert Vinken is a PhD student at the Department of Applied Physics at Eindhoven University of Technology in The Netherlands. Currently, he is focusing on better understanding how global ship NOx emissions affect marine atmospheric composition, as part of the project 'Attributing the sources of tropospheric ozone from space'.

From ship smokestack to global air pollution: bridging the scales to better constrain ship NO_X emissions from space

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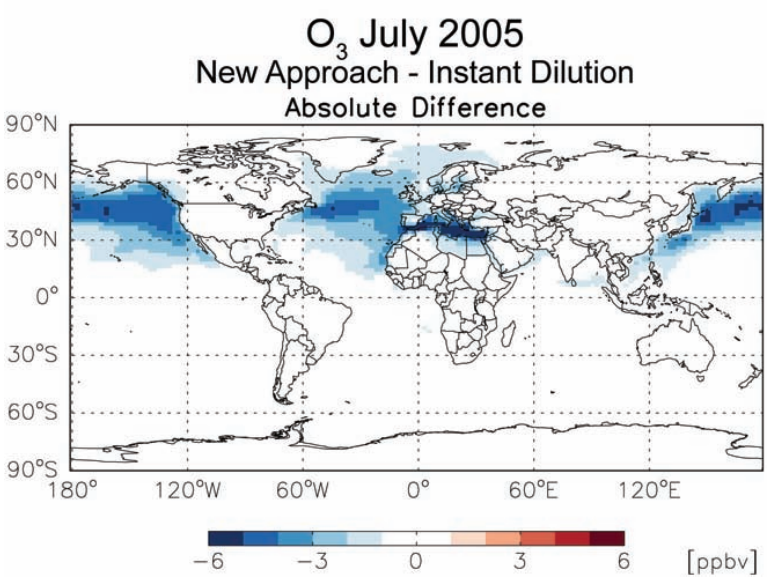
Seagoing ships combust massive amounts of marine heavy fuel, which leads to significant emissions of nitrogen oxides (NO_x = NO + NO_2), important precursors for ozone (O_3) and particulate matter in the lower marine atmosphere. Ship NO_x emissions are high, but also highly uncertain: recent estimates suggest that they represent between 15 to 30% of global NO_x emissions (e.g. Eyring et al., 2010). Because most of the ship emissions occur within 400 km of land (Corbett et al., 1999), it is important to understand how global shipping affects atmospheric composition and how it affects air quality in densely populated coastal regions. These enhanced NO_2 concentrations along shipping lanes from Europe, via the Middle East, to eastern Asia can be observed from space (Figure 1) illustrating the significance and global character of ship pollution.

The impact of ship emissions on atmospheric composition is usually assessed with so-called chemistry transport models in combination with emission inventories. These models instantly dilute emissions of highly localised sources such as ship smokestacks over the entire volume of a model grid cell (typically 200 km by 200 km). This is a reasonable approach for chemically inert species, or for situations with many individual sources present within a grid cell. However, for strongly localised emissions in clean background conditions, it fails. Previous work (Kasibhatla et al., 2000; Davis et al., 2001) has shown that using the instant dilution approach for ship emissions leads to strong overestimations of NO_x and O_3 concentrations over the oceans, because the non-linear chemistry occurring in the initial stages of plume dispersion is neglected.



Λ Figure 1 : Absolute difference plots between monthly mean global O_3 concentrations simulated with GEOS-Chem for July 2005 for the instant diluting model and the new plume-in-grid model simulations, for the lowest model layer (0-0.12 km).

In a recently submitted paper (Vinken et al., submitted), we now present a new approach to better account for ship emissions and the subsequent non-linear chemistry in global models. We use a plume-in-grid method that is based on a Gaussian plume model in combination with a detailed chemical scheme, to explicitly simulate the chemical evolution during dispersion of the plume. The Gaussian plume model simulates the chemical transformations of NO_x in the first five hours after emission. Then, the reduced NO_x emissions, plus the secondary pollutants ozone and HNO_3, produced along the way, are released into the parent (grid) model.

By running the plume model for a wide range of relevant environmental parameters, and storing the reduced NO_x emissions in a look-up table, we have generated a computationally efficient tool to account for the non-linear effect of ship emissions in a global model. We applied our method on the global GEOS-Chem model, but other chemistry transport models could also easily use our look-up table to start accounting for non-linear chemistry in ship plumes.

The results we obtain with our plume-in-grid approach highlight that the commonly used instant dilution approach overestimates observed NO_x concentrations by up to a factor of five, whereas our new approach results in NO_x concentrations that match best with observations. Instant dilution of ship emissions also tends to overestimate O_3 concentrations; in a trade route above the North Atlantic, O_3 is too high by 10-25% (3-5 ppbv).

Now that we accurately simulate NO_x concentrations in a global CTM, we are in a better position to address the uncertainty in bottom-up ship emission inventories. We intend to do so by using global, long-term NO_2 observations from space by instruments like the Ozone Monitoring Instrument (OMI, Figure 2). Combining our improved representation of ship NO_x pollution in a global model with state-of-science satellite observations, will provide valuable top-down constraints on ship NO_x emissions.

Geert Vinken recently won a poster award for the work presented at 'Ship Plumes: Impacts on atmospheric chemistry, climate and nutrient supply to the oceans' held at EGU General Assembly 2011. His poster can be viewed at http://www.solas-int.org/news/newsletter/files/Poster_EGU.pdf

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Acknowledgements

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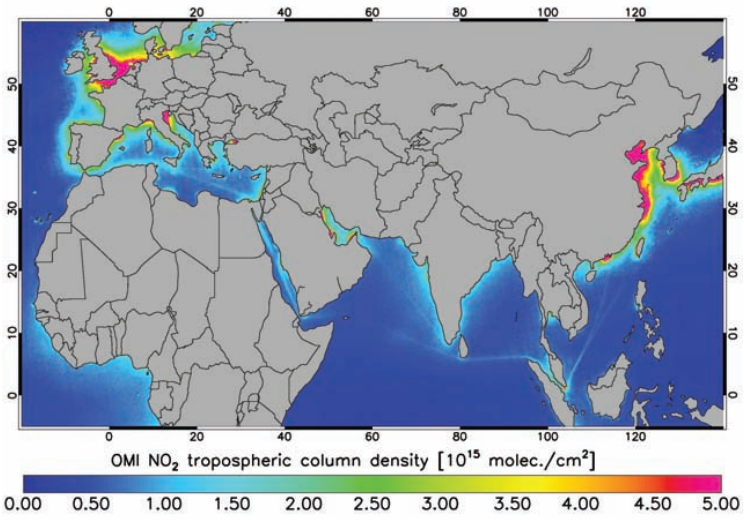

Λ Figure 2 : OMI tropospheric NO_2 columns averaged over 2005-2007 on 0.1° by 0.1° grid cells, clearly showing 8 ship tracks from western Europe to eastern Asia. Land masses have been greyed-out.

SOLAS India

After hosting the successful '5th International Symposium on Biological and Environmental Chemistry of DMS(P) and Related Compounds' in Goa last October (Full report can be found in SOLASnews Issue12). India's SOLAS scientists have kept up the pace by highlighting the exciting application of stable oxygen isotopes for estimation of transfer velocity of trace gases.

The rate of sea-to-air flux is directly controlled by transfer velocity (k). The k has been parameterized to obtain averages but using several assumptions. Air-sea transfer velocity can be estimated by measuring the two processes controlling the variations in the ^{17}O anomaly in the mixed layer i.e. gross primary production (GPP) and air-sea exchange of O_2. In the absence of GPP, the changes in ^{17}O anomaly are solely controlled by exchange of O_2 at the air-water interface. In order to quantify transfer velocity of oxygen, the night-time variations in ^{17}O were measured (when no GPP occurs) in the subarctic North Pacific and Sagami Bay during different periods.

The results clearly established that the natural ^{17}O anomaly method can effectively be used to derive gas transfer velocities at air-water interfaces. The major advantage of this method is that (1) it can be applied to any aquatic environments, such as lakes, coastal regions and the open ocean, and (2) it does not involve any artificial or radioactive tracers such as SF_6, ^3He, and ^{14}C. The present method is more robust and allows an easy estimation of k at any region. The oxygen isotopes are being measured on a routine basis under ongoing or planned international projects including SOLAS, IMBER and GEOTRACES. These measurements will contribute to gaining a comprehensive global picture of the transfer of greenhouse gases across air-water interface thereby reducing uncertainties in the oceanic sinks/sources of trace gases. This study has made such an overview more attainable.

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