SOLAS Denmark

Denmark can proudly boast several exciting developments within their SOLAS nation and is able to announce a new project, ‘ECOCCLIM’. The project goal is to estimate CO₂ exchange between the atmosphere and the biosphere in Denmark and will to a large extent, focus on air-sea CO₂ 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 ECOCCLIM project and the project ‘Air-sea-ice exchange of CO₂ 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 ‘Greenland Climate Research Centre’ coordinated by Ronnie Glud, University of Southern Denmark.

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

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’.

Seagoing ships combust massive amounts of marine heavy fuel, which leads to significant emissions of nitrogen oxides (NOₓ = NO + NO₂), important precursors for ozone (O₃) and particulate matter in the lower marine atmosphere. Ship NOₓ emissions are high, but also highly uncertain: recent estimates suggest that they represent between 15 to 30% of global NOₓ 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 NOₓ 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 NOₓ and O₃ concentrations over the oceans, because the non-linear chemistry occurring in the initial stages of plume dispersion is neglected.

Figure 1: Absolute difference plots between monthly mean global O₃ 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).

O₃ July 2005

New Approach - Instant Dilution Absolute Difference

-6 -3 0 3 6 [ppbv]
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 NOx in the first five hours after emission. Then, the reduced NOx emissions, plus the secondary pollutants ozone and HNO3, 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 NOx 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 NOx concentrations by up to a factor of five, whereas our new approach results in NOx concentrations that match best with observations. Instant dilution of ship emissions also tends to overestimate O3 concentrations; in a trade route above the North Atlantic, O3 is too high by 10-25% (3-5 ppbv).

Now that we accurately simulate NOx 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 NOx observations from space by instruments like the Ozone Monitoring Instrument (OMI, Figure 2). Combining our improved representation of ship NOx pollution in a global model with state-of-science satellite observations, will provide valuable top-down constraints on ship NOx 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

References

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Figure 2: OMI tropospheric NO2 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.