Geophysical Research Abstracts
Vol. 13, EGU2011-12822-1, 2011
EGU General Assembly 2011

Parameterisation of ship plumes for regional and global models

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Emission of exhaust gases and particles from seagoing ships contribute significantly to the anthropogenic emissions thereby affecting the chemical composition of the atmosphere, local and regional air quality and climate. The emitted compounds are injected into the atmosphere in form of coherent plumes, often in relatively pristine parts of the MBL. Models studying effects of these emissions are, however, using inventories that are calculated from emission totals distributed over the model domain with the help of spatial proxies of ship traffic. These emissions are instantaneously spread onto large inventory grid boxes. It is widely recognized that nonlinearities in atmospheric processes make the global-scale distributions sensitive to mixing processes. The plume processes thus may significantly affect the large scale distribution of chemical species in the atmosphere and effects of these subgrid-scale processes need to be accounted for.
The chemical transformation of ship emissions in plumes were investigated with a plume version of MOCCA model developed for this purpose during the Quantify project. The nonlinear chemistry of ozone formation from oxides of nitrogen causes that NO_x emissions that are in a regional-scale or a global models distributed directly over large grid squares, form more ozone than if they were treated in a gradually dispersing plume. A method of plume parameterisation has been developed by Cariolle et al. (J. Geophys. Res. 114, doi:10.1029/2009JD011873, 2009) where the plume stage of emission is treated as a NO_x emission tracer. Parameterised first order reaction rates for ozone (Keff*[tracer]) and relative NO_x loss (β) in plume are given for aircraft plume and Keff for ozone is also suggested for ship plumes in this study. The rates of reactions affecting ozone, NO_x and OH were further investigated with a plume model here. A new removal rate for the NO_x tracer was added to this parameterisation to improve its performance. This new parameterisation with sink for NO_x tracer + OH behaves well in terms sensitivity of τ to tested conditions. At nighttime, the NO_x sink needs to be treated in a different way taking into account the heterogeneous reactions of NO_x.