Aerosol indirect effects in tropical shipping corridors: global modeling corroborates results from observations

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Motivation

Aerosol indirect effects (AIEs) are the largest source of uncertainty in estimates of anthropogenic climate forcing (Forster et al., 2007)

⇒ further basic research is needed

Why ships?

– Emissions from ships modify the composition of the often pristine marine boundary layer (MBL)

⇒ Straightforward attribution of AIEs (“ship tracks”) to the emissions

⇒ Future implications through an increase in ship traffic (IMO (2008))

Local vs. large-scale effects of shipping emissions

– large-scale AIEs from shipping emissions unconstrained from observations

– global modeling suggests AIEs from shipping of up to -0.6 W/m² (Lauer et al., 2007)

⇒ Combining observations and modeling yields opportunities for reducing uncertainties!

Methodology

Global model

– ECHAM-HAM (Roecker et al., 2003; Zhang et al., 2012)

Emissions (aerosols and precursor gases)

– EU-IP QUANTIFY for ships (Behrens, 2006)

– AeroCom otherwise (Dentener et al., 2006)

Setup

– T63 (1.8°×1.8°), 31 levels

– analysis period 2000 – 2004 (after spinup)

– prescribed SST

– nudged dynamics (ERA-Interim)

Experiments (among others)

ns Control simulation without shipping emissions

A AeroCom emission parameterisation

Bsc More soluble particles emitted, emissions scaled by 1.63

Bsc10 as B, but emissions scaled by 10

cf. Peters et al. (2012) for detail

Consistency check with observations

– systematic sampling for “clean” and “polluted” oceanic regions

⇒ Eulerian-type sampling as in Peters et al. (2011), who did not find statistically significant AIEs on large-scale cloud fields over tropical oceans (using satellite data)

Results

1st order signal, i.e. altered aerosol population?

– obvious differences in column-integrated radiative properties

⇒ mostly identical shape

⇒ “offset-like” perturbation

⇒ relative differences to “no-ship” show change at shipping lane

2nd order signal, i.e. altered cloud properties?

– only unrealistically high emissions show “real” effect

– across corridor gradients also mostly identical

⇒ impossible to detect signal for current emissions level using single simulations

Extracting a signal (Δgradient ?) from single simulations?

⇒ constant wind direction sampling Ø(days)

– Assertion: evident change in gradient downwind of shipping lane with increasing duration of across-corridor winds

1st order signal, i.e. altered aerosol population?

Subtle differences in across-corridor gradients, similar for both experiments up- as well as downwind of shipping lane, suggest higher importance of air-mass history than expected.

Effect of shipping emissions at the level of individual shipping lanes (in the tropics) fails to be detectable as “step-like function” even in strongly forced GCM experiments; modification of the large-scale environment is evident, though!

References

Forster et al., QUANTIFY deliverable D-1-1-2-2 (confidential), 2006; Bremer et al., Atmos. Chem. Phys., 12, 3131-3144, 2012; Peters et al. (2012) for detail

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