Modelling aerosol indirect effects from shipping emissions with ECHAM-HAM

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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)

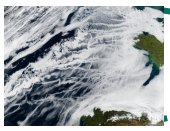
⇒ **further basic research is needed**

Why ships ?

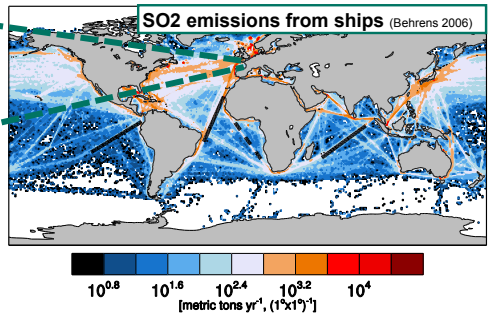
- Emissions from ships modify the composition of the often pristine marine boundary layer (MBL)
  - ⇒ Straight forward attribution of AIEs ("ship tracks") to the emissions
  - ⇒ Future implications through an increase in ship traffic (IMO (2008)

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 Wm^{-2} (Lauer et al., 2007)
  - ➢ **Combining observations and modeling yields opportunities for reducing uncertainties !**



AIEs from shipping emissions **on local scales**



Methodology

Global model

- ECHAM-HAM (Roeckner 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

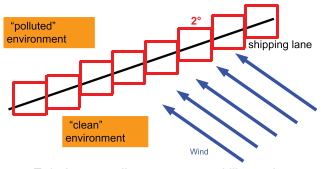
A	**AeroCom** emission parameterisation, unscaled shipping emissions
B	**more particles** assigned to soluble modes at point of emission
Asc	as **A**, but emissions scaled by 1.63
Bsc	as **B**, but emissions scaled by 1.63

cf. Peters et al. (2012) for more detail

as well as a control simulation without shipping emissions

Consistency check with observations

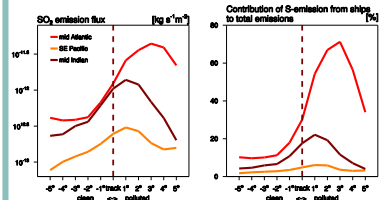
- systematic sampling for "clean" and "polluted" oceanic regions
  - ➢ **Eulerian-type sampling as in Peters et al. (2011)**, who **did not** find statistically significant AIEs on large-scale cloud fields over tropical oceans (using satellite data)



Eulerian sampling – conceptual illustration

Sampling of cloud- and aerosol properties along straight lines parallel to main shipping lane. Time-averages computed over red boxes, *i.e.* one model grid-box.

What to expect OR "How clean is the clean environment" ?



See top right figure (Motivation) for definition of shipping corridors.

Across-corridor emission gradients in experiment **Bsc**.

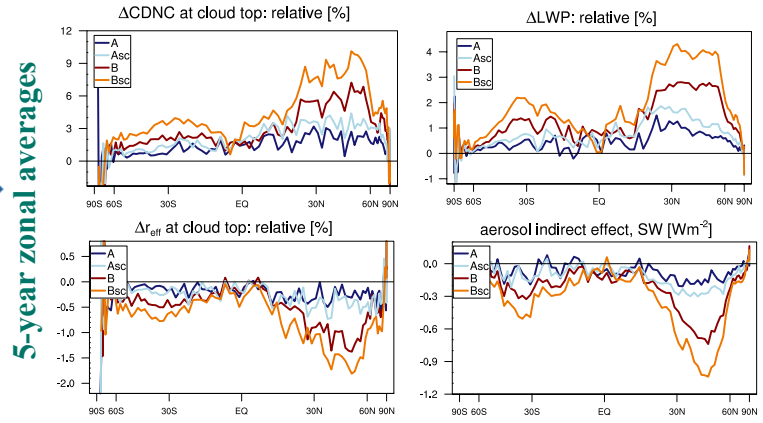
Left: annual mean ship-emission fluxes

Right: Share of sulphur (S) emissions from ships in the **total** emissions

Conclusions

- AIEs from shipping emissions **are lower than previously estimated**, and
- substantially depend on the **assumed particle size distribution** at the point of emission
- **Consistent with observations** (Peters et al. (2011)), large-scale AIEs are not clearly discernible over tropical oceans
- An **even higher** forcing can thus **not be ruled out !**

Results

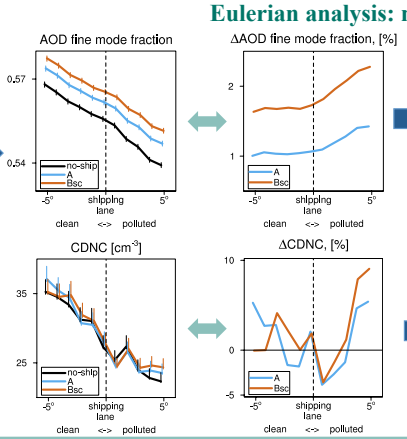


Experiment	AIE [Wm^{-2}]
A	-0.07 ± 0.02
B	-0.23 ± 0.01
Asc	-0.11 ± 0.02
Bsc	**-0.32 ± 0.01**

Peters et al., Atmos. Chem. Phys., 2012

- assumed **particle size distribution** matters far more than the total amount of emissions
- areas of **significant cloud changes** are mainly found over northern mid-latitudes (not shown)
  - ➢ **tropical oceans dominated by noise**
- highest estimate about **half of the previous upper estimate** from model simulations

Eulerian analysis: mid-Atlantic region



AOD signals related to aerosol perturbations **leading to strong global AIEs** are only discernible when **directly comparing** to the control simulation

Cloud changes ?

From the simulations alone (left), it is not possible to identify the simulation yielding the by far highest globally averaged AIEs (**Bsc**) !

Relative changes are obvious, though.

Peters, Quaas, Stier, Grassl: in preparation, 2012

References

Behrens, QUANTIFY deliverable D-1-1-2-2 (confidential), 2006; **Dentener et al.**, Atmos. Chem. Phys., 6, 4321-4344, 2006; **Forster et al.** Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007; **IMO**, MEPC.176(58) Amendments to the Annex of the Protocol of 1997 to amend the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (Revised MARPOL Annex VI), 2008.; 2391, 2010; **Peters et al.**, J. Geophys. Res., 116, D24205, 2011; **Peters et al.**, Atmos. Chem. Phys., 12, 5985–6007, 2012; **Roeckner et al.**, Max-Planck-Inst. für Meteorol., Hamburg, Germany, Tech. Rep., 349, 2003; Zhang et al., Atmos. Chem. Phys. Discuss., 12, 7545 – 7615, 201222

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