

AS11-05-A007: Aerosol Indirect Effects from Shipping Emissions Over Tropical Oceans

Karsten Peters¹, Johannes Quaas², Philip Stier³, Hartmut Grassl⁴



¹ARC Centre of Excellence for Climate System Science, Monash University, School of Mathematical Sciences, Clayton, VIC, Australia (karsten.peters@monash.edu); ²Institute for Meteorology, University of Leipzig, Leipzig, Germany (johannes.quaas@uni-leipzig.de); ³University of Oxford, Department of Physics, Oxford, OX1 3PU, Great Britain (Philip.Stier@physics.ox.ac.uk); ⁴Max Planck Institute for Meteorology, Hamburg, Germany (hartmut.grassl@zmaw.de)

Motivation

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

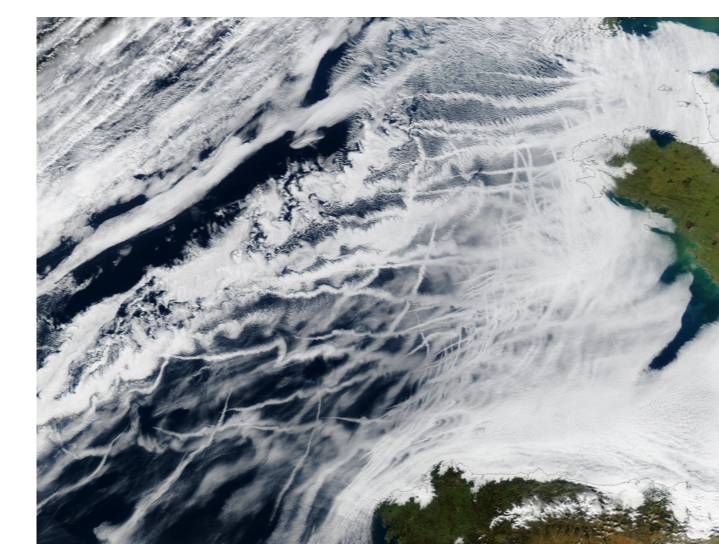
⇒ further basic research is needed

Why ships ?

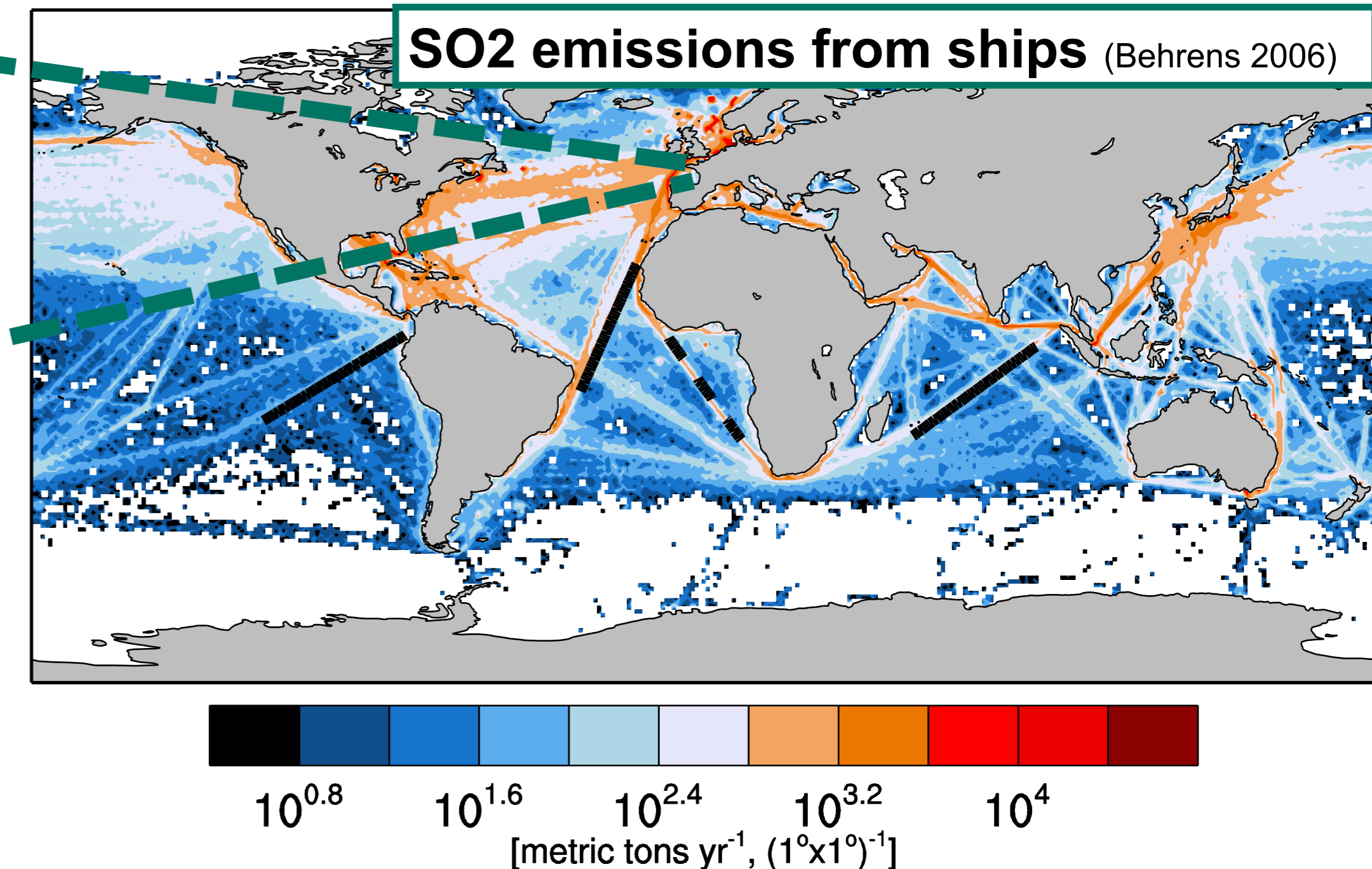
- Emissions from ships modify the composition of the often pristine marine boundary layer (MBL)
 - ⇒ Straight forward attribution of AIEs (“ship tracks”) to the emissions
 - ⇒ Future implications through an increase in ship traffic (IMO (2008))

Local vs. large-scale effects of shipping emissions

- large-scale AIEs from shipping emissions unconstrained from observations
- global modeling suggests AIEs from shipping of -0.6 to -0.1 Wm^{-2} (Lauer et al., 2007, Peters et al., 2012, 2013)
 - 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 ($1.8^\circ \times 1.8^\circ$), 31 levels
- analysis period 2000 – 2004 (after spinup)
- prescribed SST
- nudged dynamics (ERA-Interim)

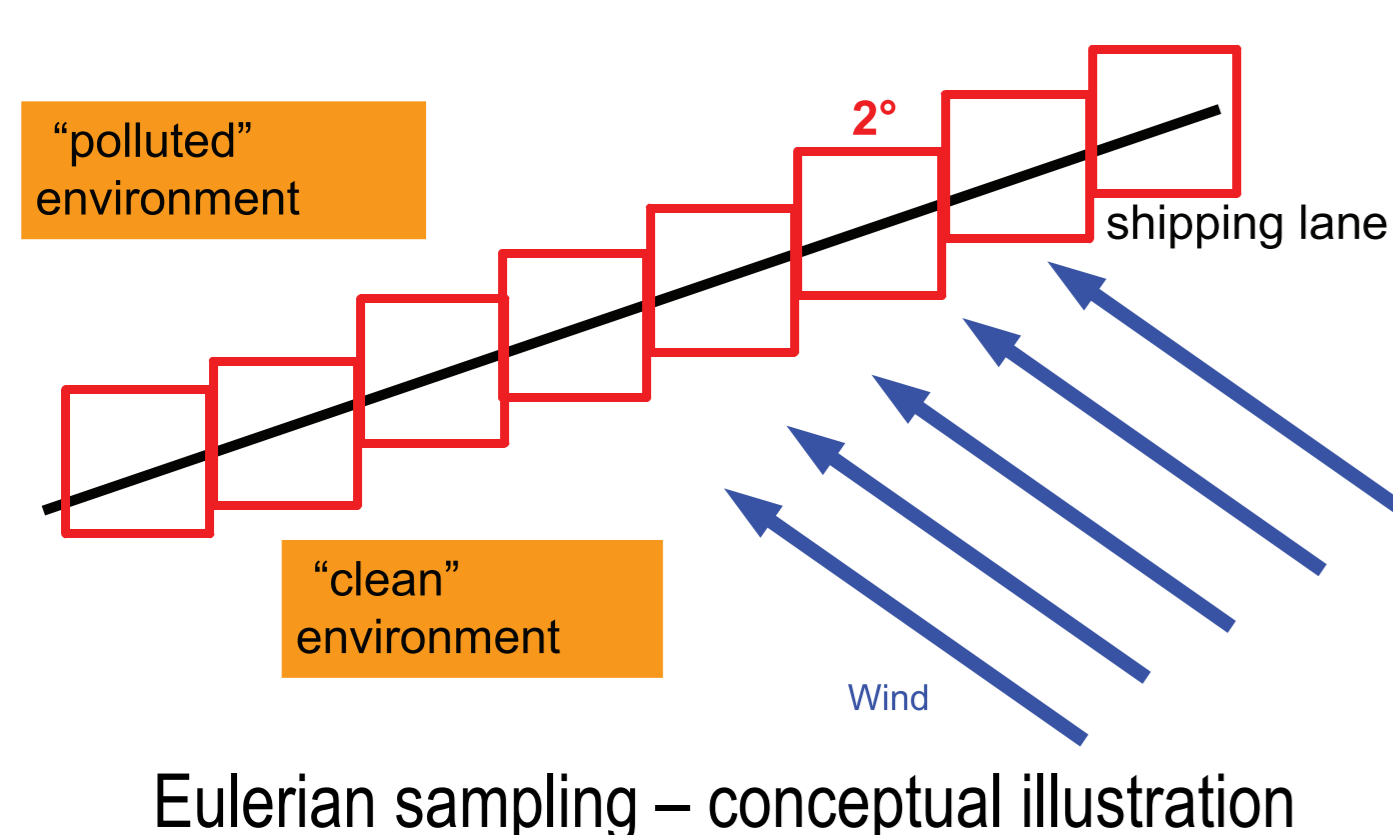
Experiments

- CTRL** 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
- Bsc_mAt** As **Bsc**, but mid-Atlantic Ocean emissions only

cf. Peters et al. (2013, subm.) for details

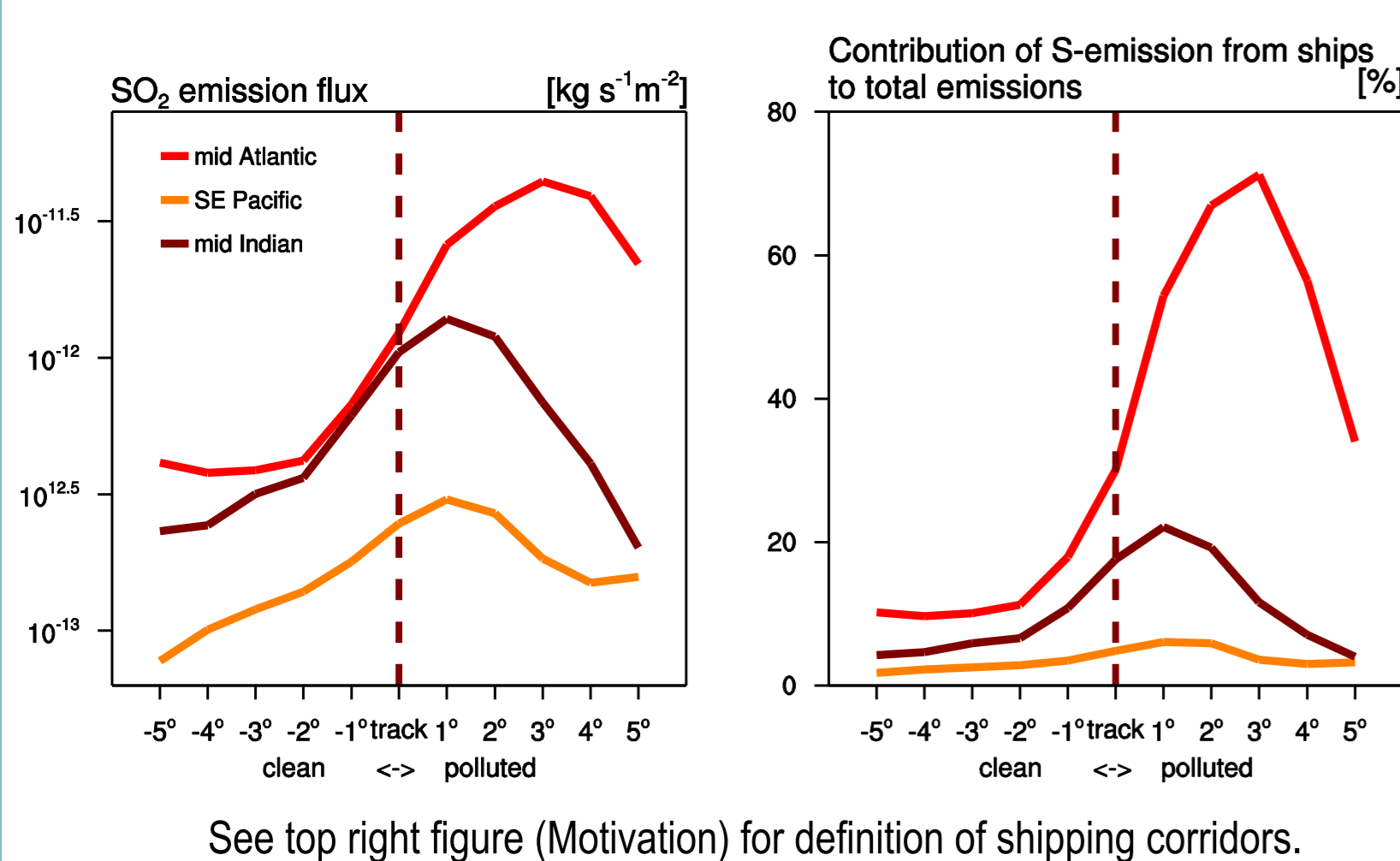
Consistency check with observations

- 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)



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” ?



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

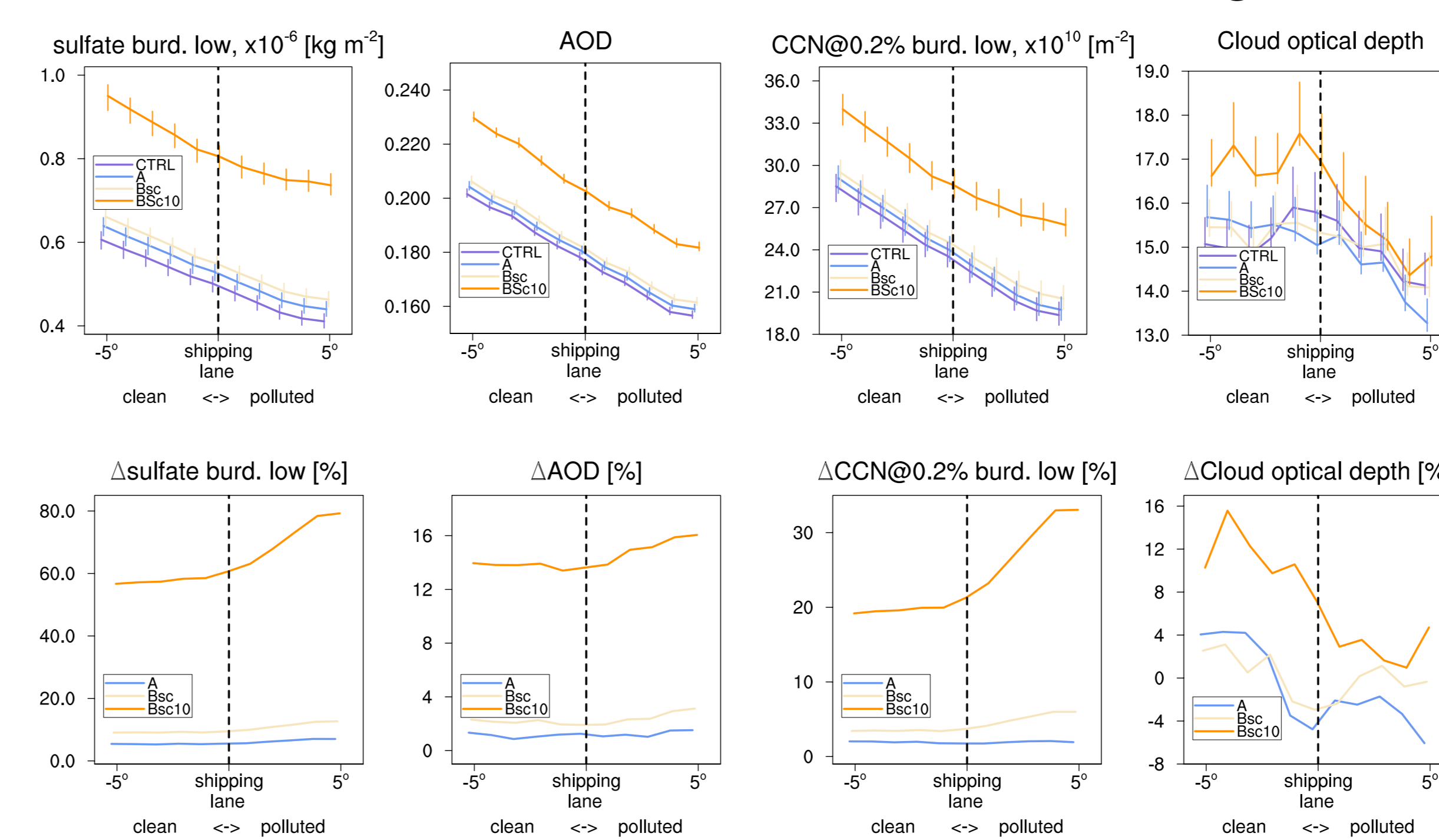
Left: annual mean ship-emission fluxes
Right: Share of sulphur (S) emissions from ships in the total emissions

Conclusions

- Shipping emissions clearly modify the environment of main shipping corridors
- Manifested as “offset” compared to control case
- Consistent with observations (Peters et al. (2011)), large-scale effect of shipping emissions not clearly discernible
- Advection as well as fast removal of emissions **AND** high low-cloud variability blur out possible signal

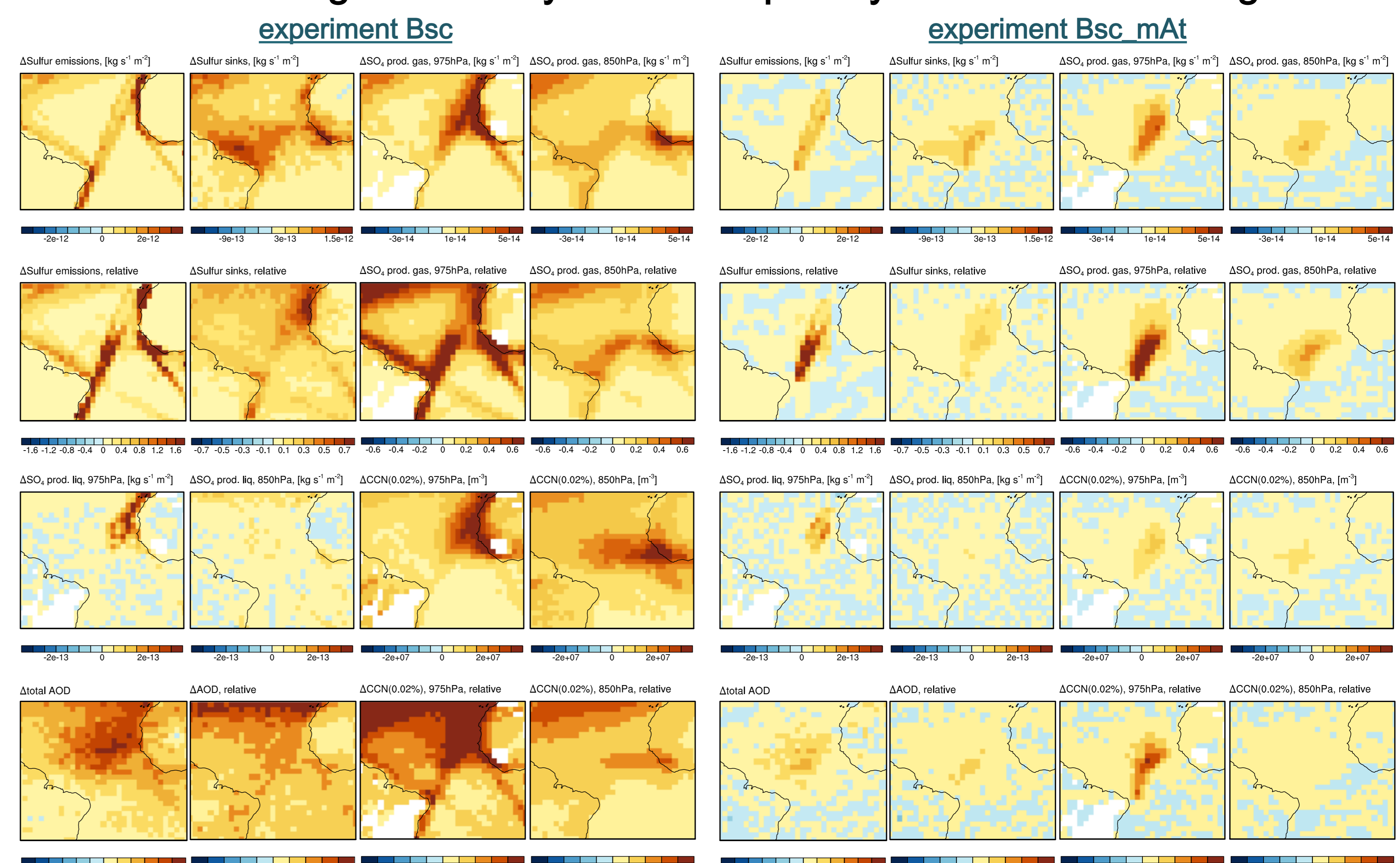
Results

mid Atlantic Ocean: AIE-relevant model diagnostics



- obvious differences in column-integrated radiative properties
- mostly identical shape
 - “offset-like” perturbation
- relative differences to “no-ship” show change at shipping lane
- unrealistically high emissions also yield no clear signal in cloud properties
 - impossible to detect signal for current emissions level using single simulations

Process-level insights from 5-year mean spatially resolved model diagnostics



- shipping emissions of SO_2 clearly dominate over natural sources, removal processes very fast (not shown)
- advection from coastal emissions evident at higher levels; cause for “offset-like” across-corridor profiles
- efficient aqueous oxidation to form sulfate aerosol limited to stratocumulus regime off north-African coast
- isolated emissions highlight **locality of CCN concentration changes** both horizontally and vertically
- changes in column-integrated radiative properties, i.e. AOD, negligible and most probably undetectable from satellite remote sensing

Peters et al. (2013), submitted

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; Peters et al., submitted to Tellus B, 2013; 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