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 marine boundary layer (MBL).
- 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 W m⁻² (Lauer, et al., 2007, Peters et al., 2012, 2013).

Combining observations and modeling yields opportunities for reducing uncertainties!

Methodology

Global model
- ECHAM-HAM (Roelckner 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.
- Prescribed SST.
- Nudged dynamics (ERA-Interim).

Experiments
- CTRL: Control simulation without shipping emissions.
- AeroCom emission parameterisation.
- Bsc: More soluble particles emitted, emissions scaled by 1.63.
- Bsc10: As Bsc, but emissions scaled by 10.
- Bsc_mAt: As Bsc, but mid-Atlantic Ocean emissions only.

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).

What to expect OR “How clean is the clean environment”?
- Across-corridor emission gradients in experiment Bsc.
- Shading emissions of SO₂ clearly dominate over natural sources, removing processes very fast (not shown).
- Advection from coastal emissions evident at higher levels; cause for “offset-like” across-profile effects.
- Efficient aqueous oxidation to form sulfate aerosol limited to stratuscumulus regime off North-African coast.

Motivation

Conclusions

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
- 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.

References
