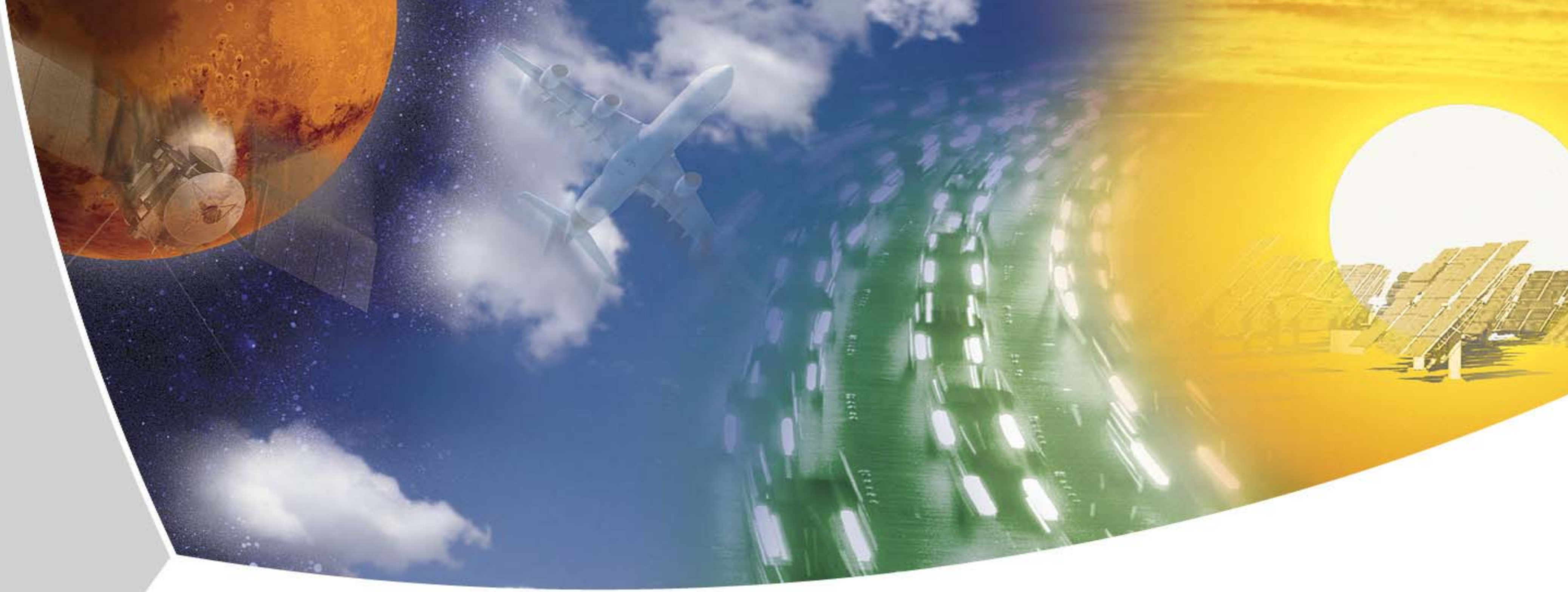

Impact of international shipping on aerosols and clouds – Simulations with ECHAM5/MADE

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Impact of international shipping on aerosols and clouds – Simulations with ECHAM5/MADE

Outline

1 Introduction

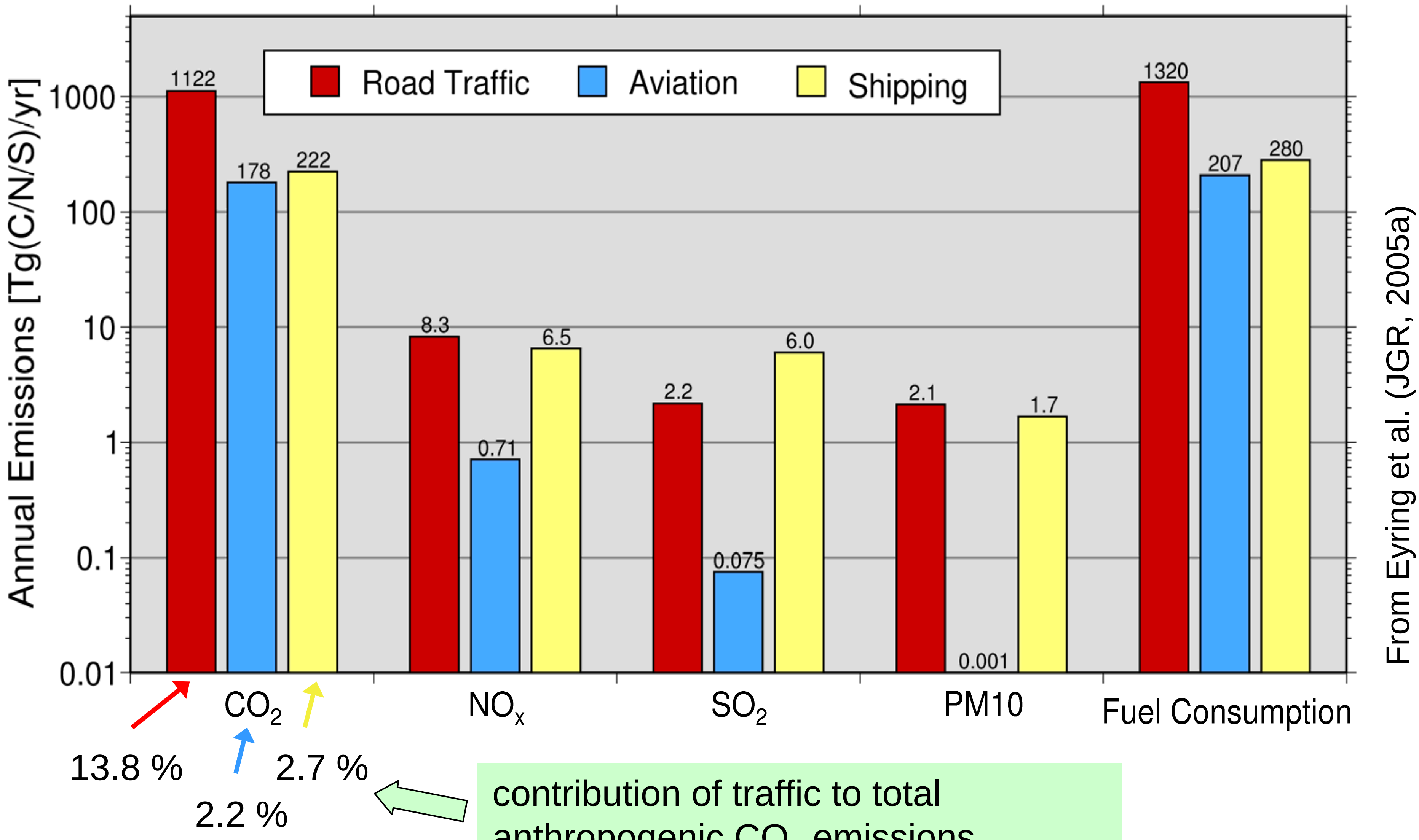
2 The model system ECHAM5/MADE

3 Impact of ship emissions on aerosols and clouds

4 Conclusions and Outlook

Introduction

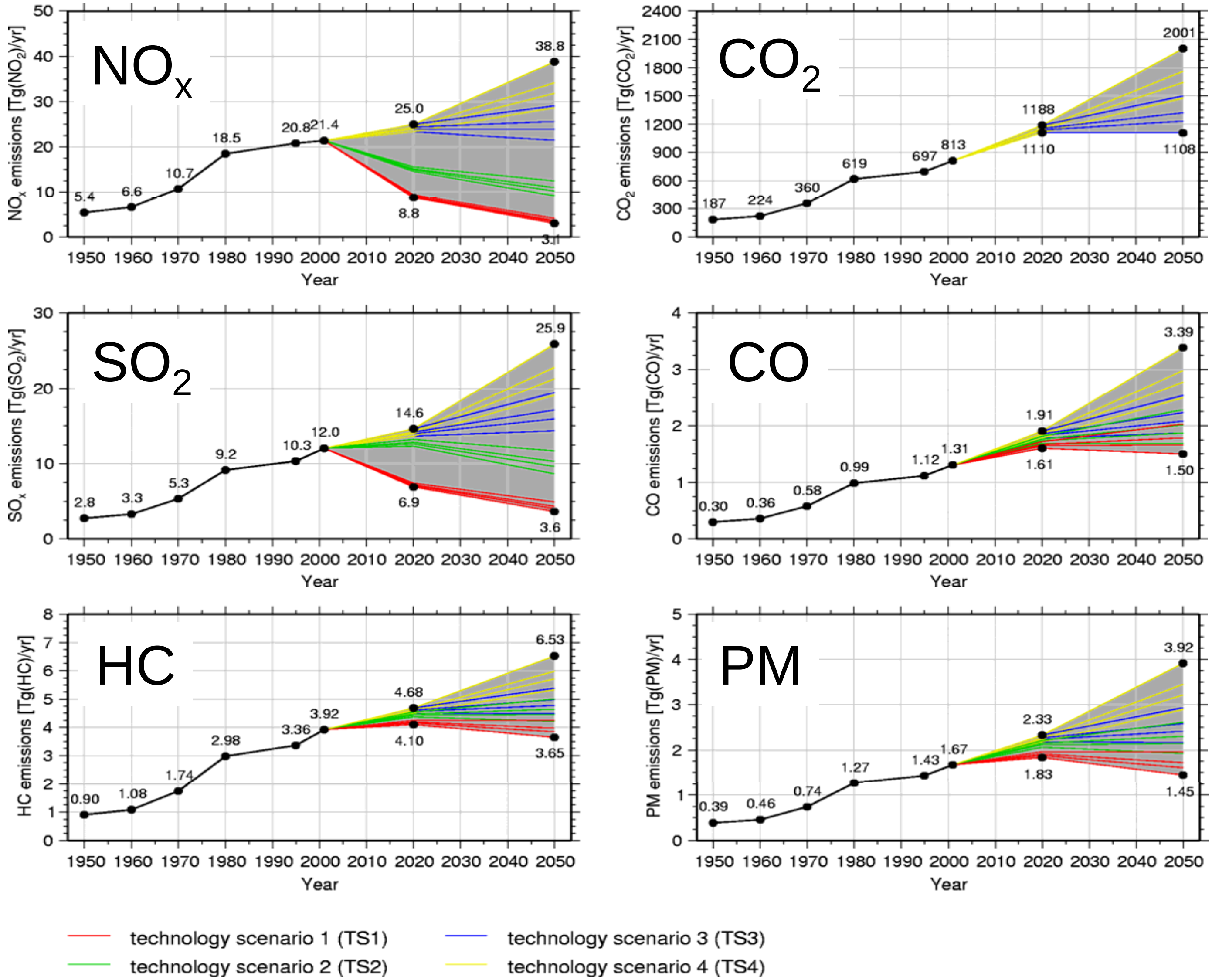
Transport-related annual emissions (2000)



contribution of traffic to total anthropogenic CO_2 emissions

Future ship emission scenarios until 2050

4 Demand Scenarios (GDP growth based on IPCC SRES Scenarios) & 4 Technology Scenarios



From Eyring et al. (JGR, 2005b)

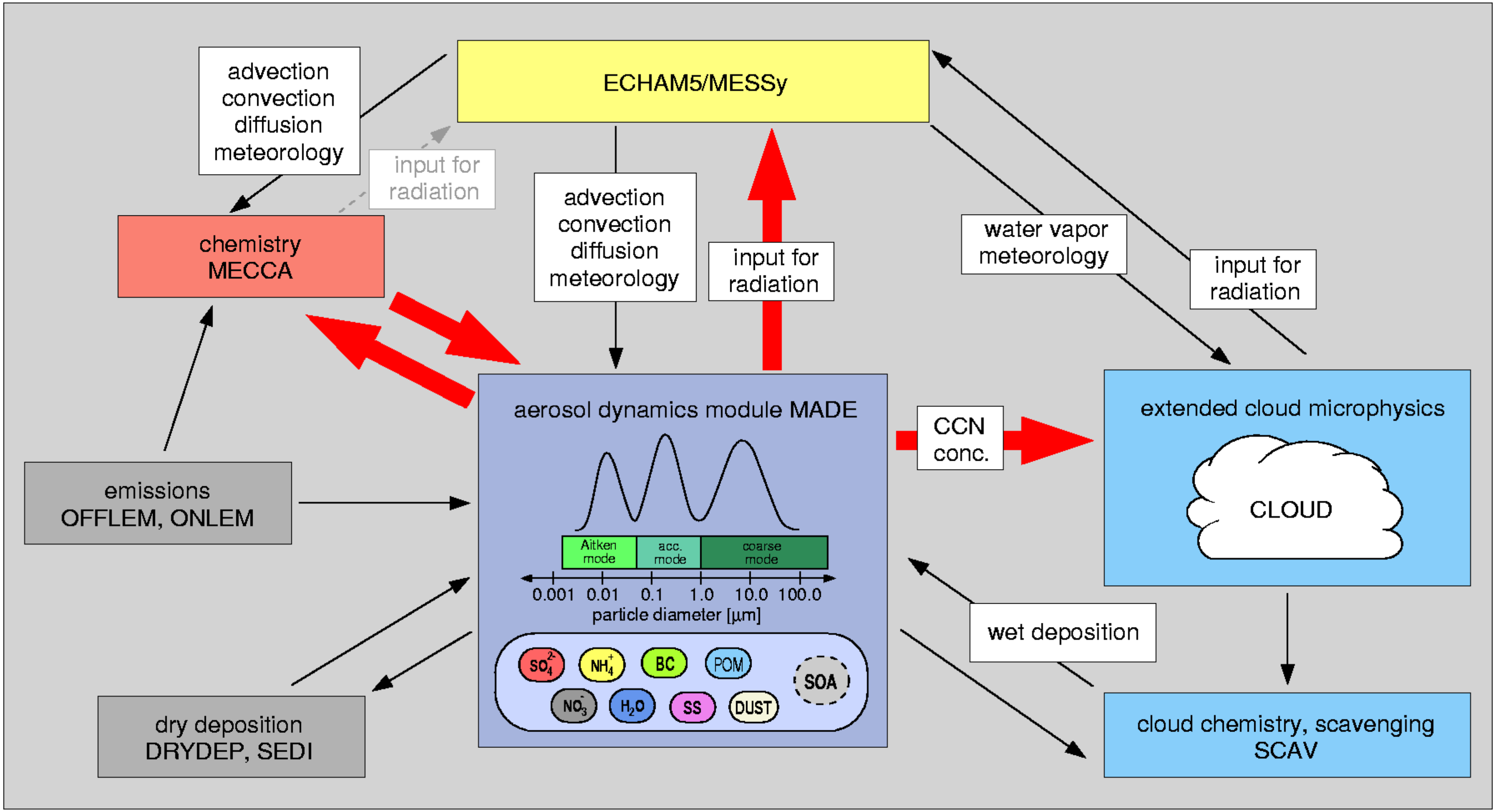
Introduction

Why investigate the impact of shipping on aerosols and clouds?

- Shipping contributes significantly to total budget of transport-related emissions
- Currently one of the least regulated sources of anthropogenic emissions
- Rapid growth of ship traffic expected in the future
- Currently large uncertainties about overall impact of emissions from shipping on atmospheric composition and climate, in particular on aerosols and clouds

The model system ECHAM5/MADE

The model system ECHAM5/MADE (MESSy version)

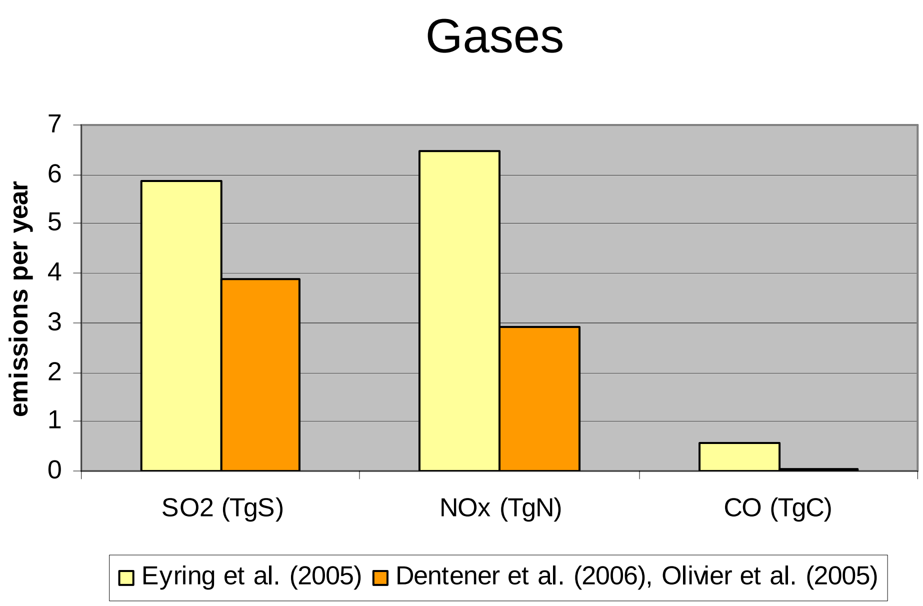


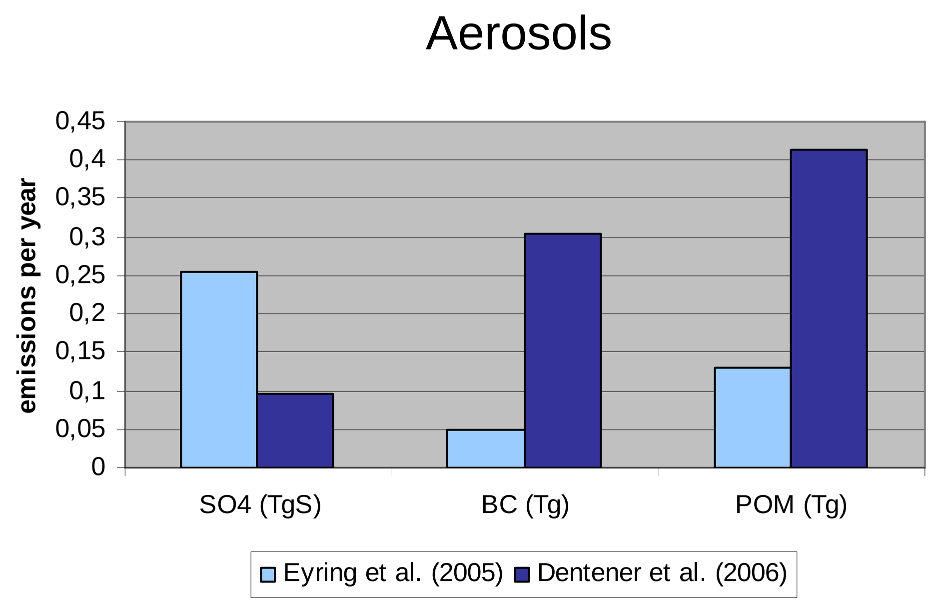
Model setup

- ECHAM5/MADE (MESSy v1.1): horizontal resolution T42, 19 vertical layers
- model dynamics nudged to ECMWF reanalysis (1998-2004)
- chemistry (MECCA): tropospheric background chemistry (NO_x, HO_x, CH_4, CO, O_3) + sulfur (DMS, SO_2)
- emissions (year 2000):
  - trace gases except SO_2 and DMS: EDGARv3.2-FT2000 (Olivier et al., 2005)
  - DMS and sea salt: on-line calculation
  - SO_2 and aerosols except sea salt: AeroCom 2000 (Dentener et al., 2006)
- 3 model experiments:
  - ship emissions from Eyring et al. (2005)
  - ship emissions from Dentener et al. (2006)
  - no ships

Emissions from international shipping

– Year 2000 –





Masking of Dentener et al. (2006) BC and POM ship emissions: 1°x1° land-/seamask

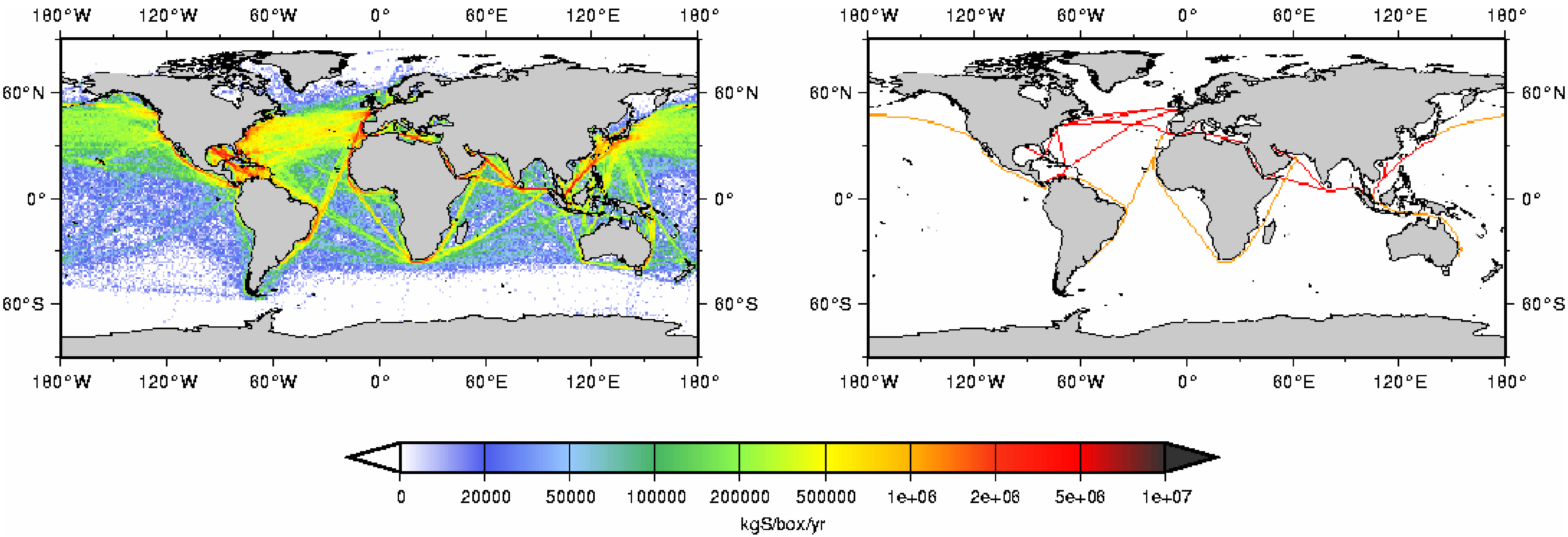
⇒ aliasing at coast lines (BC, POM)

SO_2 emissions from international shipping

– Year 2000 –

Eyring et al. (2005), 5.9 Tg(S)/yr

Dentener et al. (2006), 3.9 Tg(S)/yr



Impact of ship emissions on aerosols

Total sulfate mass ($\mu g/m^3$) from international shipping

– climatological (1999-2004) annual averages –

surface level

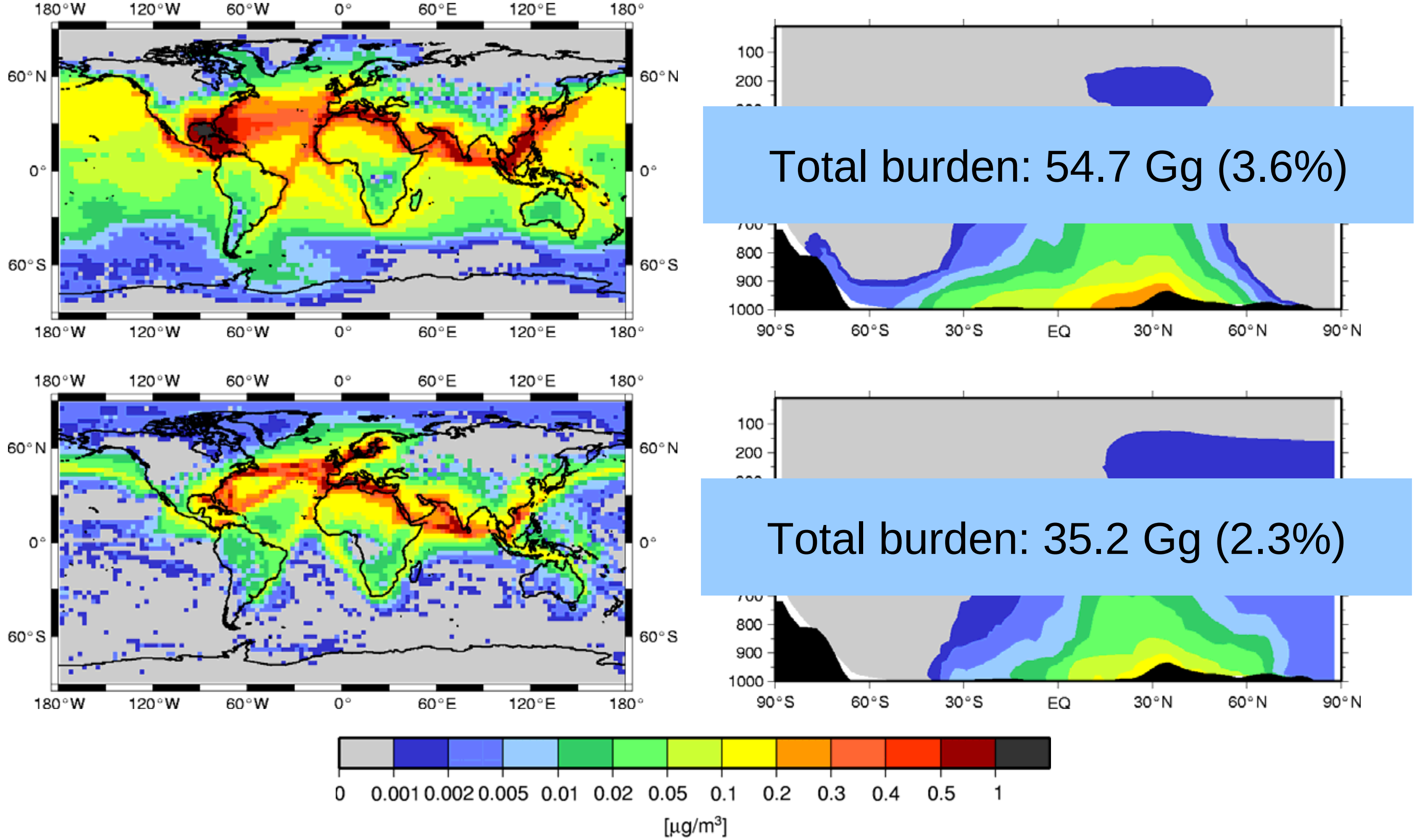
zonal average

Eyring et al. (2005) ships

Total burden: 54.7 Gg (3.6%)

Dentener et al. (2006) ships

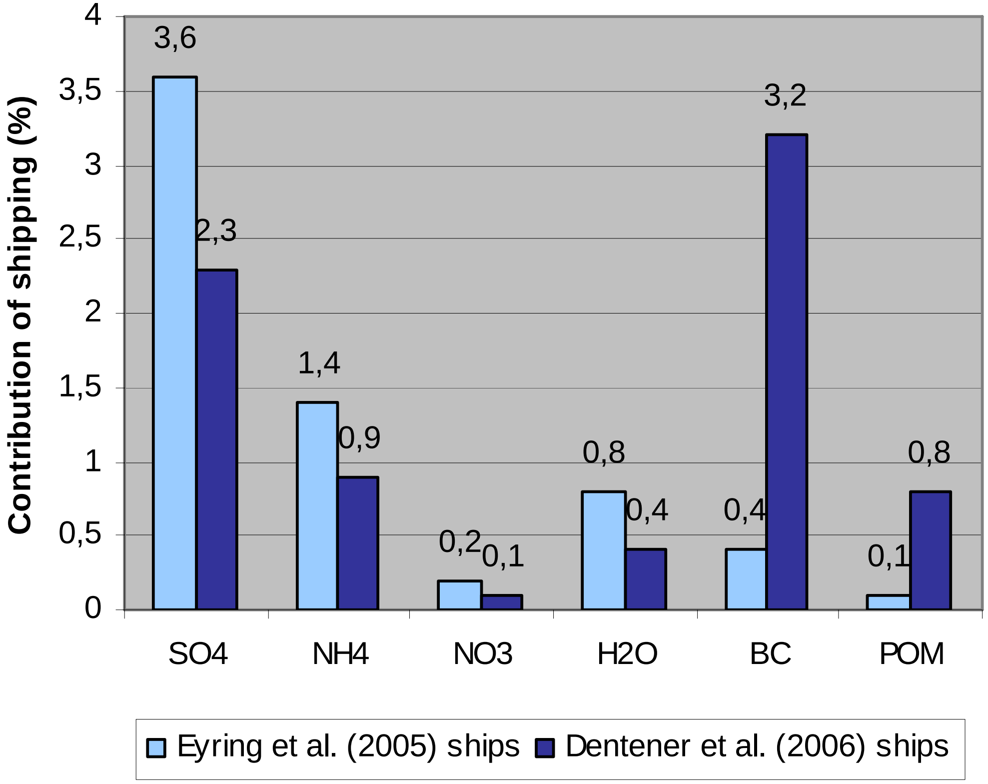
Total burden: 35.2 Gg (2.3%)



Contribution of shipping to total atmospheric burdens

– climatological (1999-2004) annual averages –

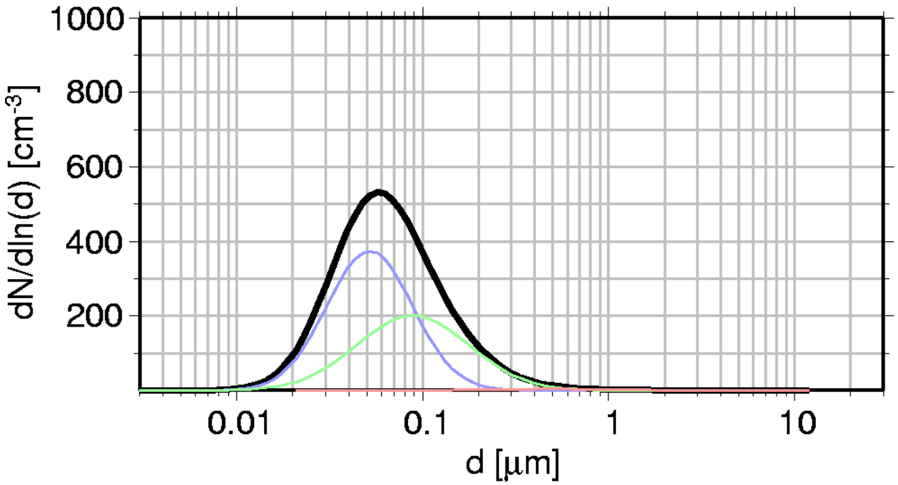
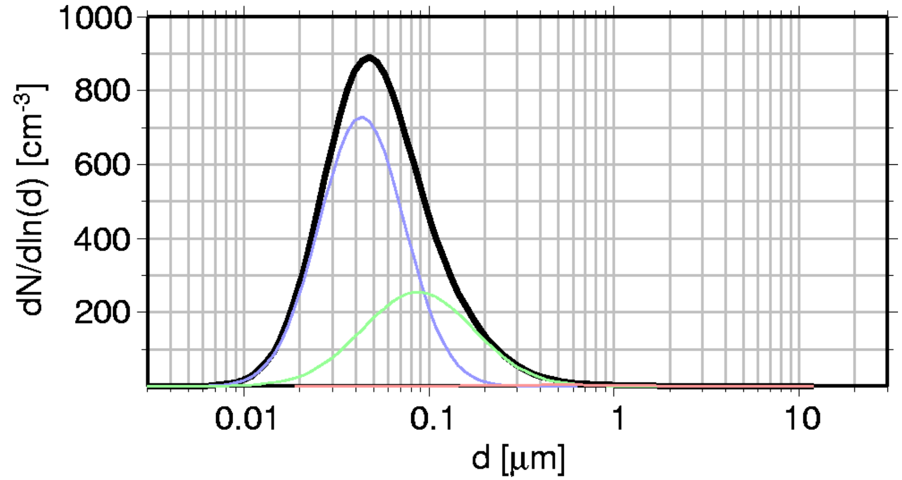
Total atmospheric burdens (Tg)		
compound	ship emissions from Eyring et al. (2005)	ship emissions from Dentener et al. (2006)
SO_4	1.531	1.511
NH_4	0.366	0.365
NO_3	0.146	0.146
H_2O	17.881	17.784
BC	0.119	0.122
POM	1.040	1.047
sea salt	3.588	3.582
mineral dust	9.042	9.045



Impact of shipping: number size distribution

– climatological (1999-2004) annual averages –

surface layer, Atlantic Ocean (85°W...5°W, 15°N...60°N)

no ships	with ships (Eyring et al., 2005)
	

Aitkenmode

coarse mode

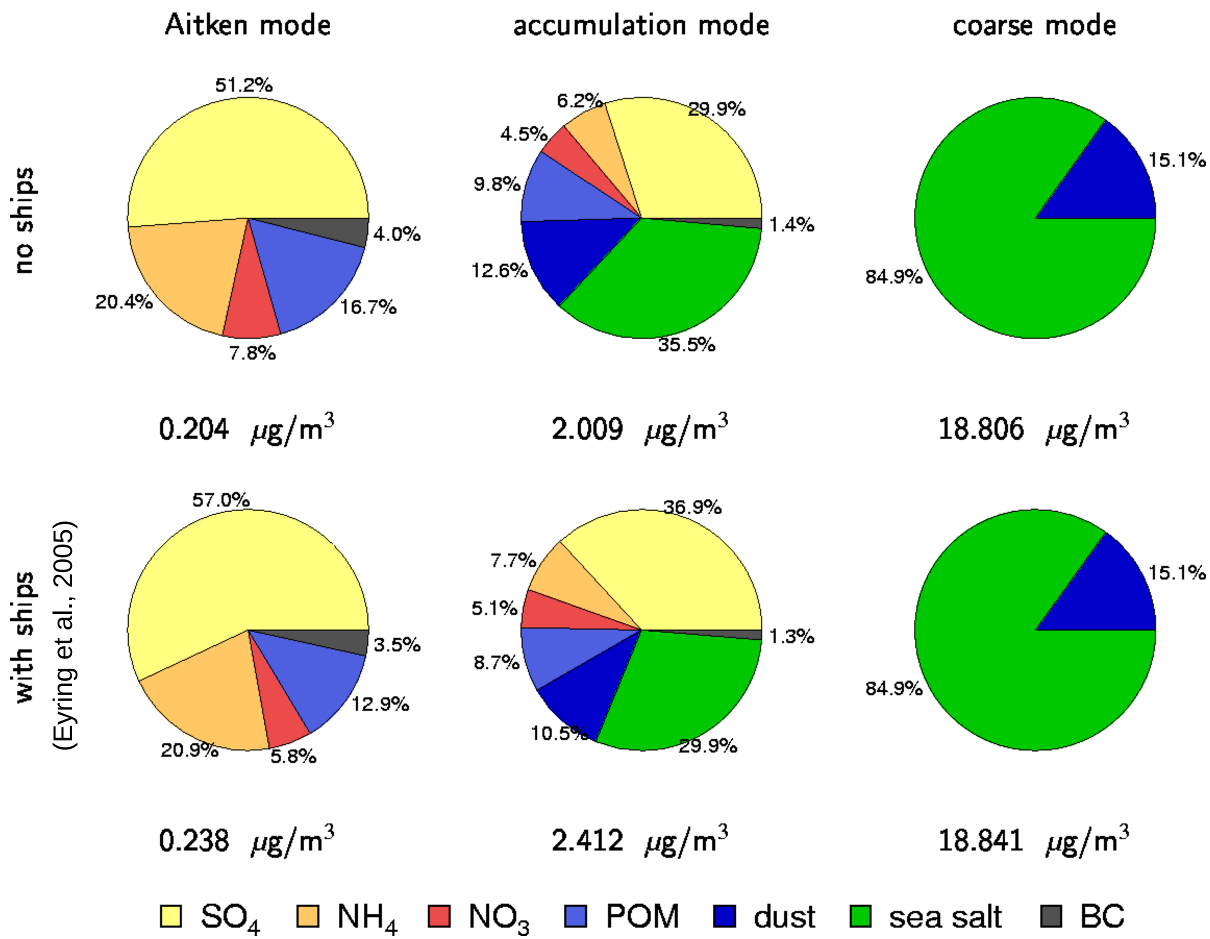
accumulation mode

total

Impact of shipping: particle composition

– climatological (1999-2004) annual averages –

surface layer, Atlantic Ocean (85°W...5°W, 15°N...60°N)



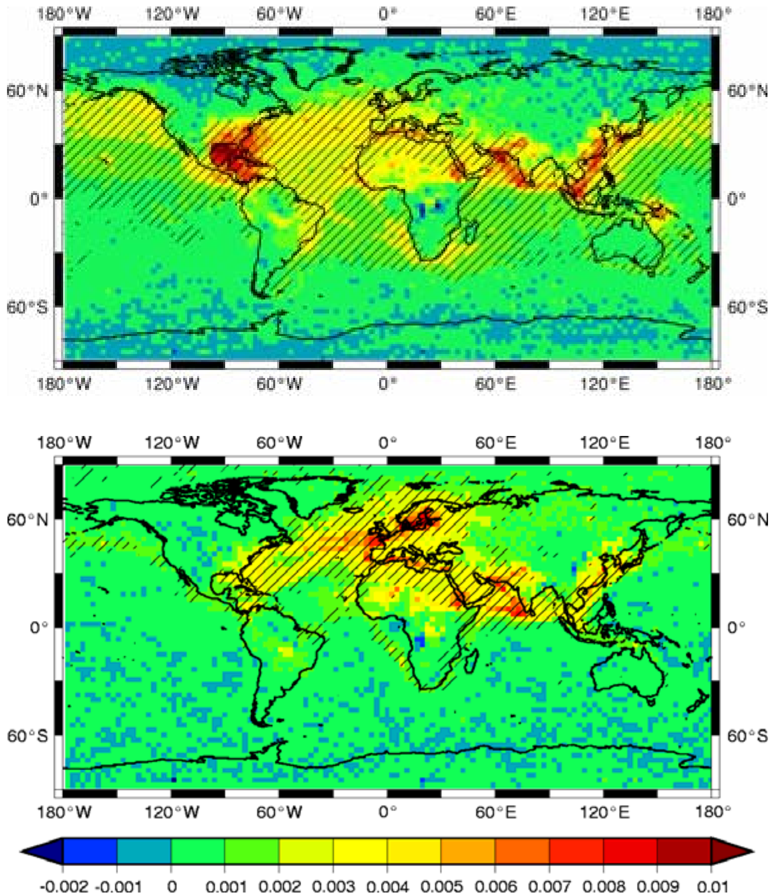
Impact of shipping: aerosol optical depth

– climatological (1999-2004) annual averages –

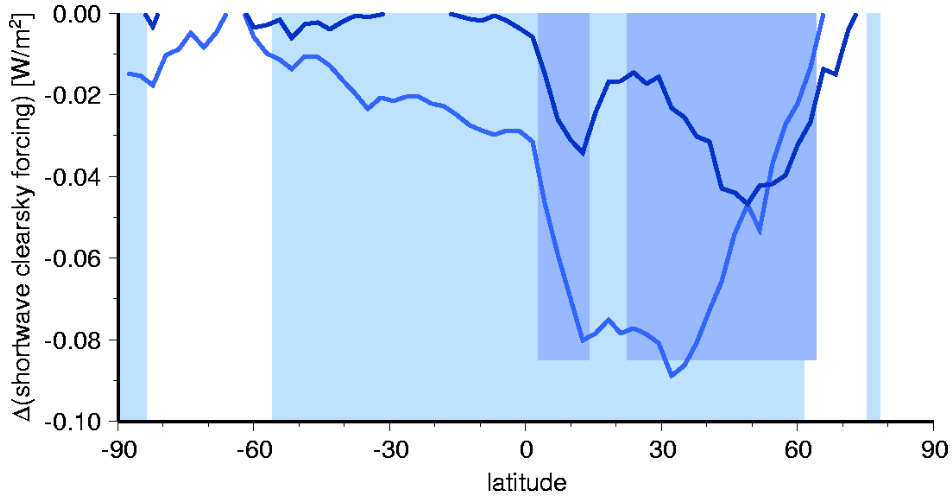
Δ aerosol optical depth (0.55 μm)

Eyring et al. (2005) ship emission

Dentener et al. (2006) ship emission



Δ clearsky TOA radiative flux (solar)



Changes in net clearsky fluxes

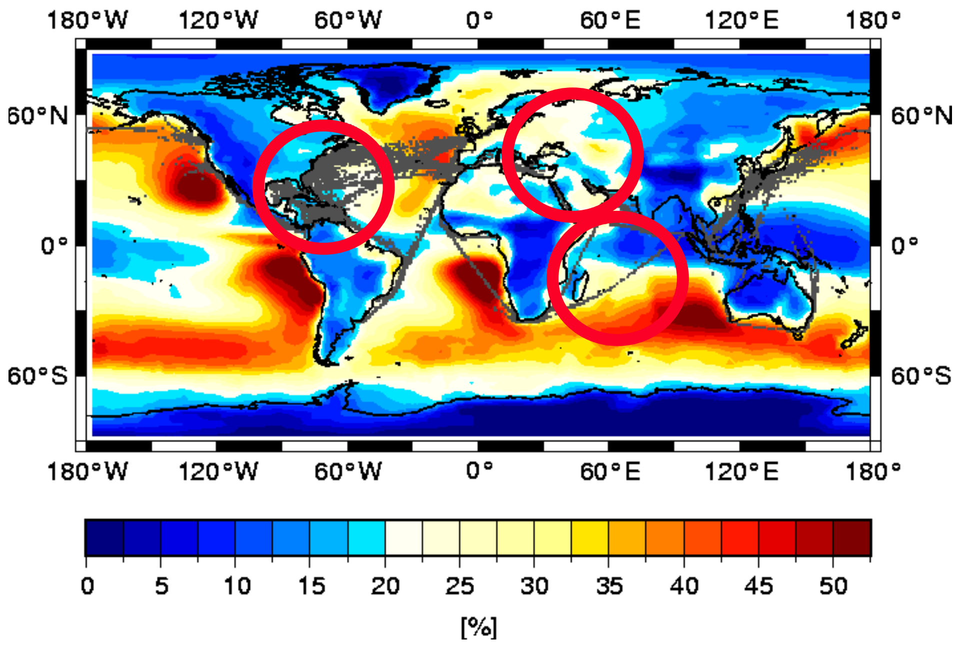
Eyring et al. (2005): -0.036 W/m²

Dentener et al. (2006): -0.013 W/m²

Impact of ship emissions on clouds

Impact of ship emissions on clouds

– climatological annual mean (1983-2004) of low cloud amount (ISCCP) –



ISCCP D2 MONTHLY MEANS AND CLIMATOLOGY:

http://isccp.giss.nasa.gov/products/browsed2.html

- Regions of interest: Areas with frequent low maritime clouds and major shipping routes

  ⇒ West Coast of North America and South Africa, Northeastern Atlantic

- Impact limited to warm clouds in the lower troposphere (< 1.5 km)

  ⇒ no modification of ice clouds

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Conclusions

1 shipping contributes significantly to global aerosol burdens, e.g. SO_4: 3.6% (2.3%)

2 increase in aerosol optical depth above the oceans up to 10%

⇒ change in net clearsky TOA radiative fluxes: -0.036 W/m^2 (-0.019 W/m^2)

3 about 75% of changes in radiative fluxes (TOA) are related to changes in sulfur budget

4 impact on clouds limited to

⇒ low warm clouds (< 1.5 km)

⇒ no impact on ice clouds

⇒ West Coast of North America and South Africa, Northeastern Atlantic

- strong dependence of results on emission data sets

⇒ geographical distribution important

⇒ implies high uncertainties

Impact of international shipping on aerosols and clouds – Simulations with ECHAM5/MADE

Outlook

Investigation of the effect of ship emissions on:

1 cloud microphysics

- ⇒ CDNC
- ⇒ LWC
- ⇒ effective cloud droplet radii

2 cloud properties

- ⇒ precipitation formation
- ⇒ cloud cover

3 radiation

- ⇒ cloud optical thickness
- ⇒ TOA cloud forcing