Transient Climate Simulations With the Max Planck Institute Earth System Model

AEROCOM Meeting

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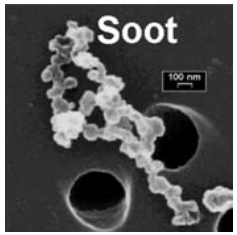
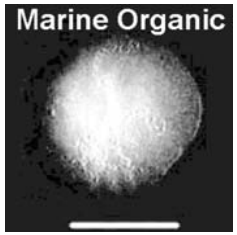
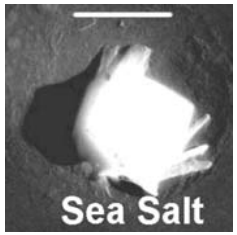
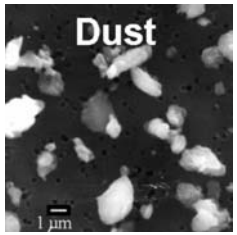
and the BMBF climate research program DEKLIM

HAM - Aerosol Representation

Considered Compounds:

Sulfate	Black Carbon	Organic Carbon	Sea Salt	Mineral Dust
				

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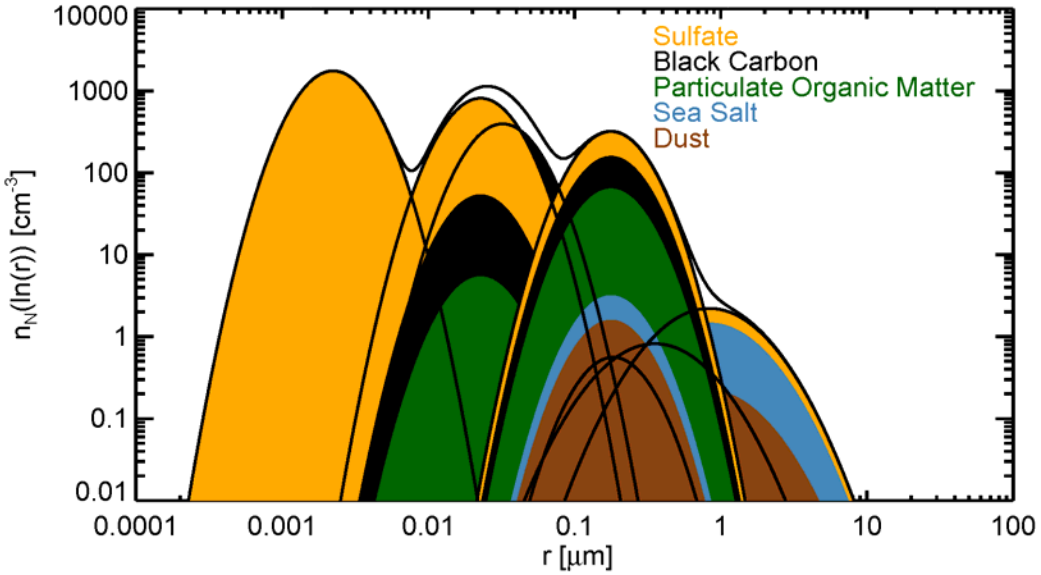
Resolve aerosol size-distribution by 7 log-normal modes

Three modes are composed of solely one aerosol component

Four modes are internal mixtures of several components



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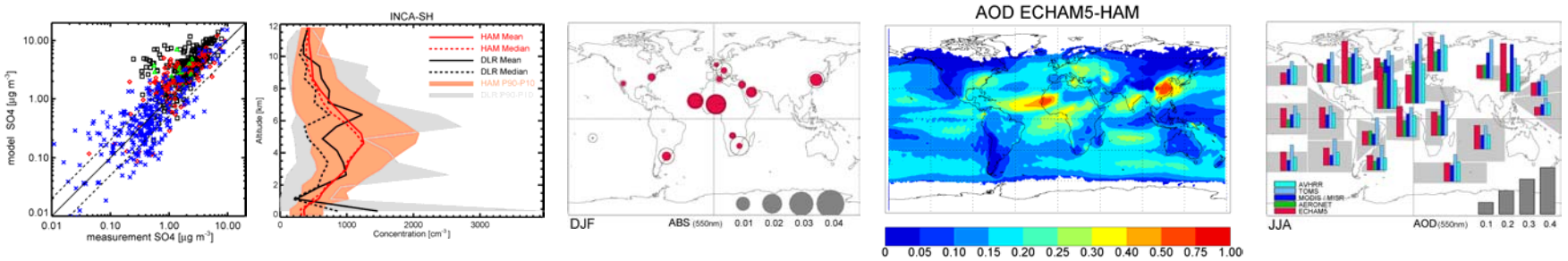
Three modes are composed of solely one aerosol component

Four modes are internal mixtures of several components

Mode size, mixing state, and composition predicted by microphysical and thermodynamical processes

Detailed description and evaluation in Stier et al., ACP, (2005)



HAM - Processes

Sulfur Chemistry ⇔ MOZART Chemistry
(Feichter et al., 1996) (Horowitz et al., 2003)

Size-Dependent Dry- and Wet-Deposition
(Ganzeveld et al., 1998; Slinn and Slinn, 1982; Stier et al., 2004)

Online emissions of Dust, Sea Salt, and DMS
(Tegen et al., 2002; Schulz et al., 2002; Kettle and Andreae, 2000)

Aerosol Microphysics M7
(Vignati, Wilson, and Stier, *2004*)

- Nucleation of sulfate particles
- Condensation of sulfate on existing particles
- Coagulation
- Inter-modal transfer
- Thermodynamical equilibrium with water vapour

Radiation Module
(Boucher and Stier)

Cloud Microphysics - Aerosol Activation
(Lohmann et al., 1999; Lohmann, 2002; Zhang et al., *in press*;
Lin and Leaitch, 1997; A.-Razzak and Ghan, 2000)

Transient Climate Simulations

Simulations with the MPI Earth System Model:

- **Atmosphere**: ECHAM5

  Atmospheric Aerosol: HAM

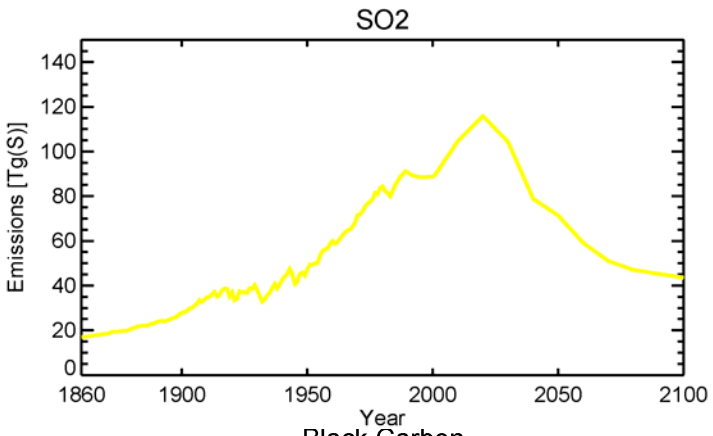
  - Explicit aerosol / cloud coupling

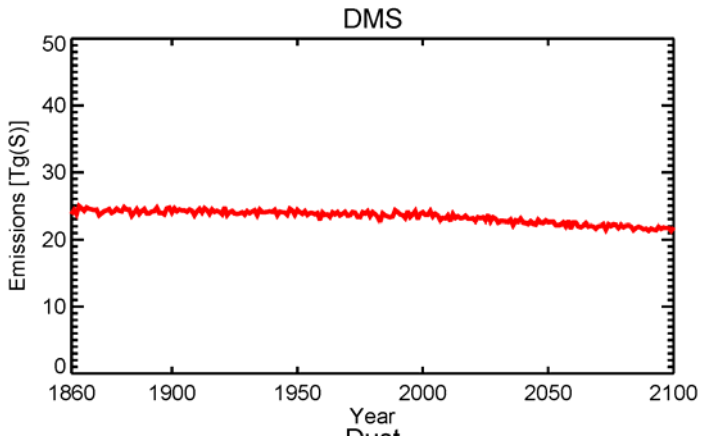
- **Ocean**: MPI-OM

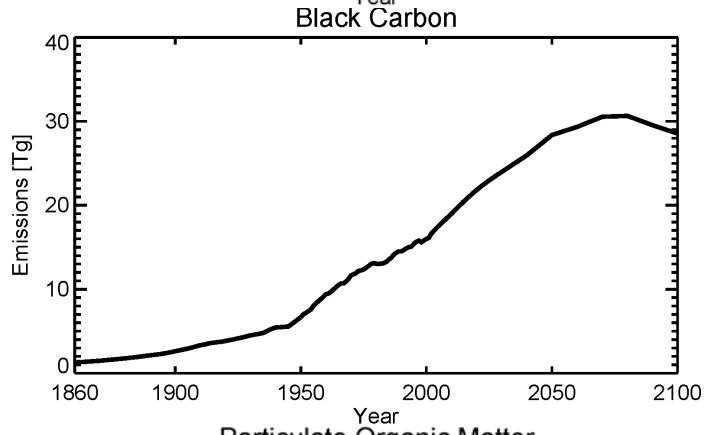
  Ocean Biogeochemistry: HAMOCC5

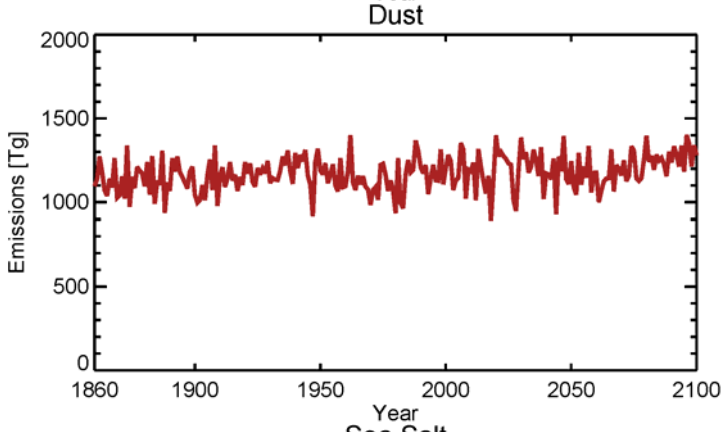
- **Coupling of biogeochemical cycles:** dust deposition + DMS emission
- **Anthropogenic forcings**: GHG and Ozone according to SRES A1B
- **Natural forcings**: solar variability and volcanic stratospheric aerosol
- **Aerosol emissions**: NIES emission inventory for SRES A1B

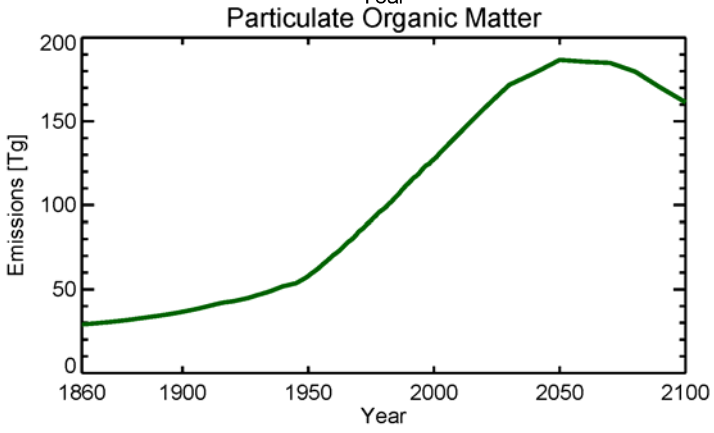
Emission Scenario

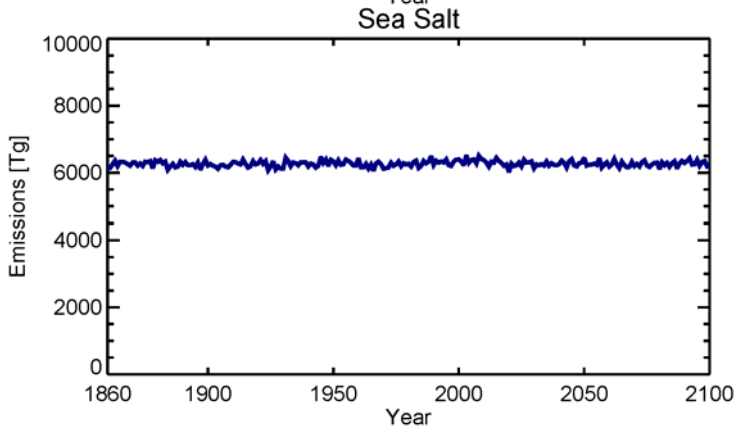






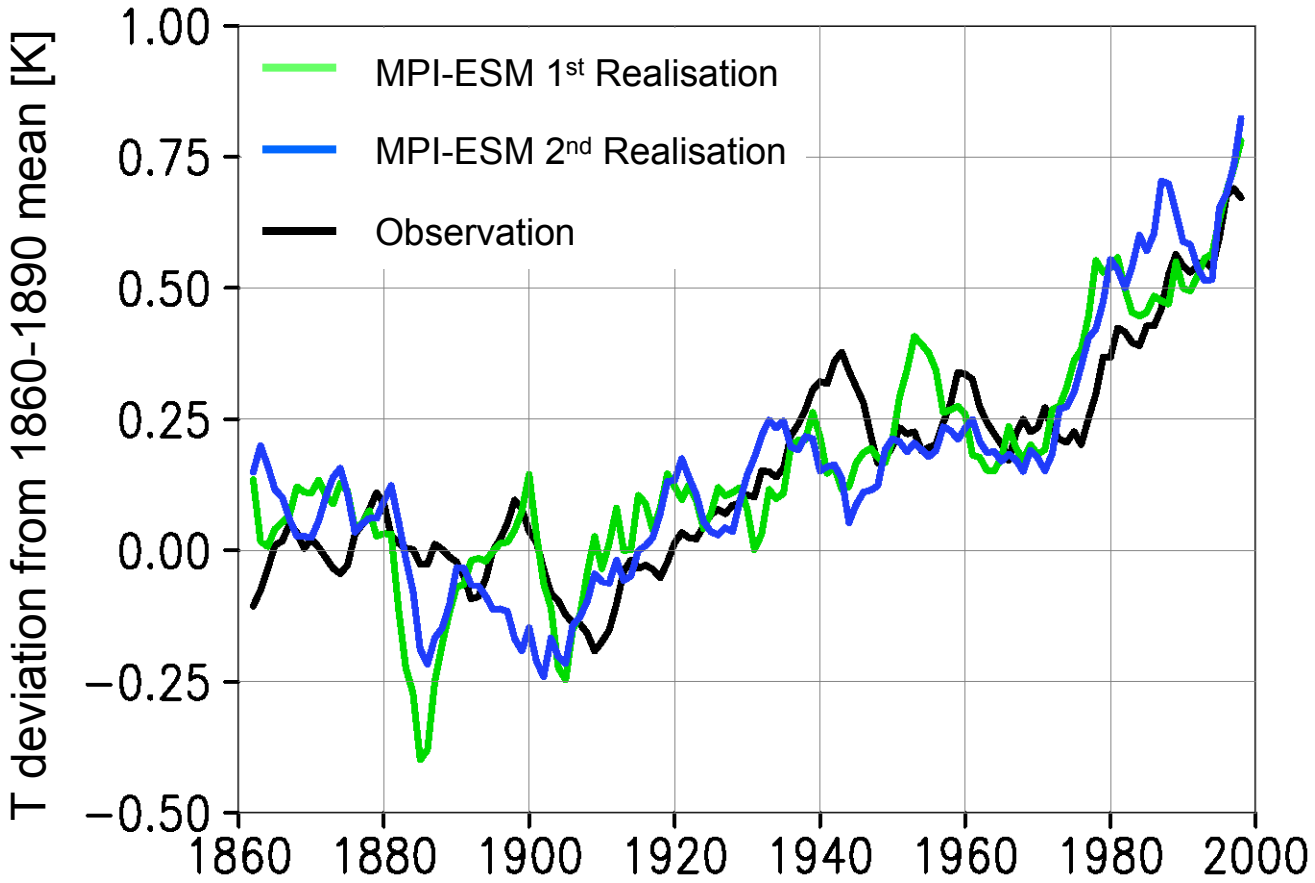






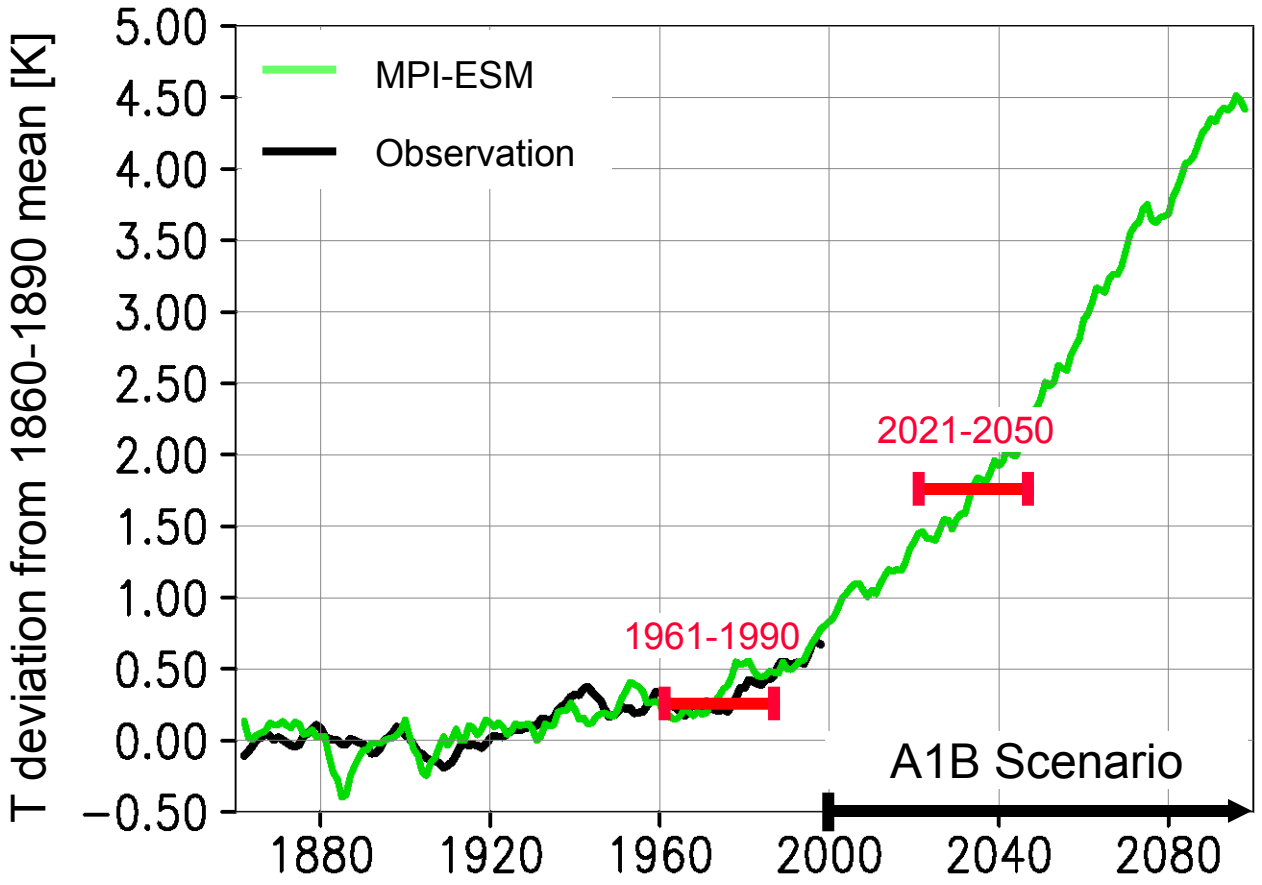
Global Mean Surface Temperature

Evolution of the global annual mean surface air temperature:



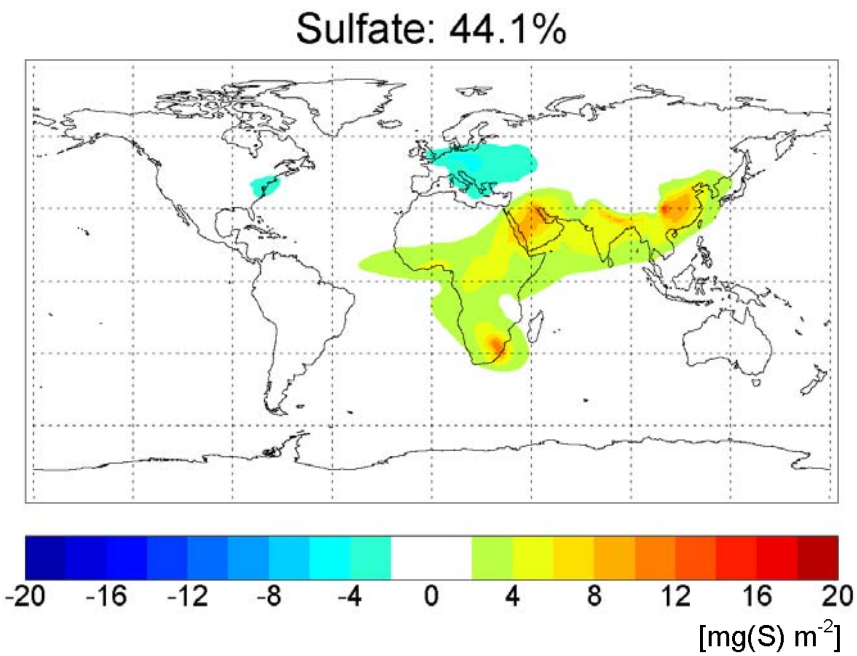
Global Mean Surface Temperature

Future evolution of the global annual mean surface air temperature:

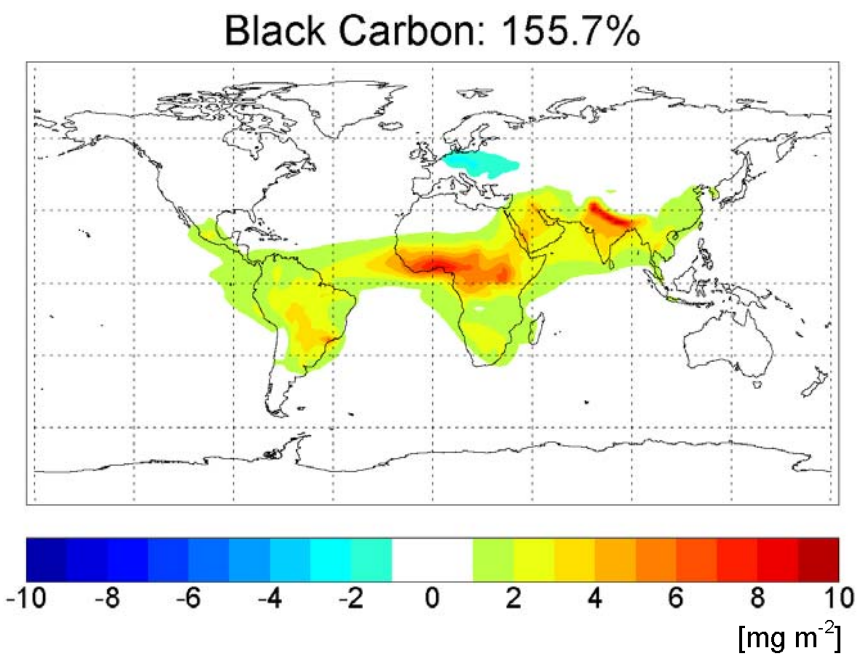


Aerosol Properties

Change of aerosol load from 1961-1990 to 2021-2050:



Sulfate Aerosol Load



Black Carbon Aerosol Load

Aerosol Properties

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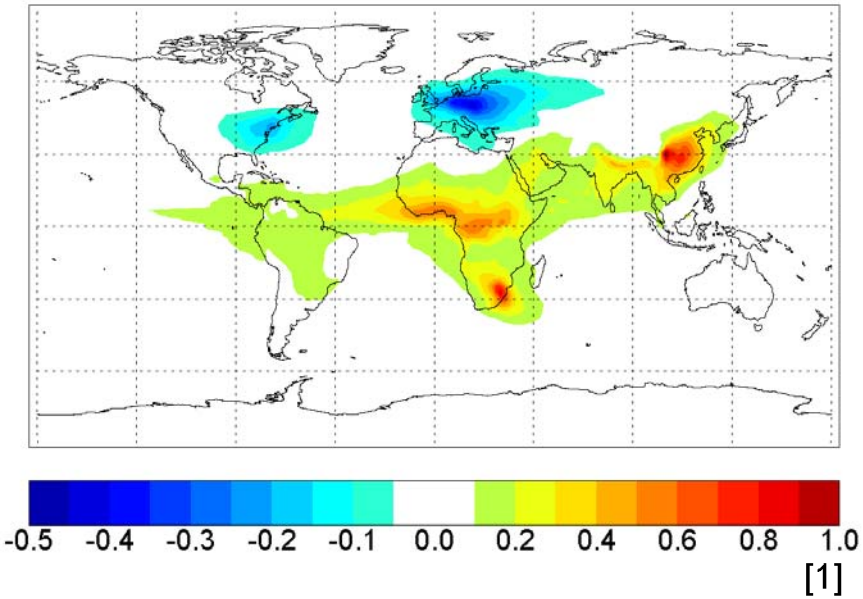
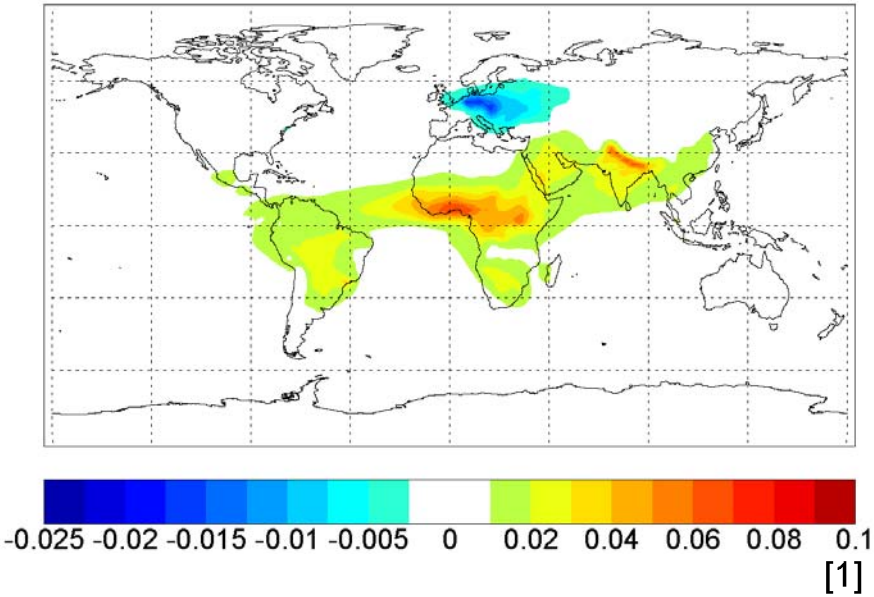


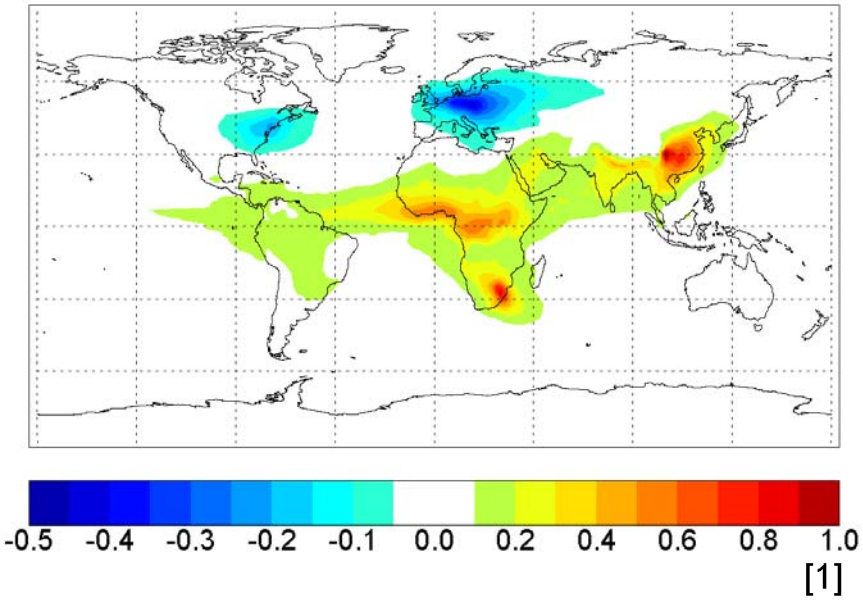
Aerosol Optical Depth



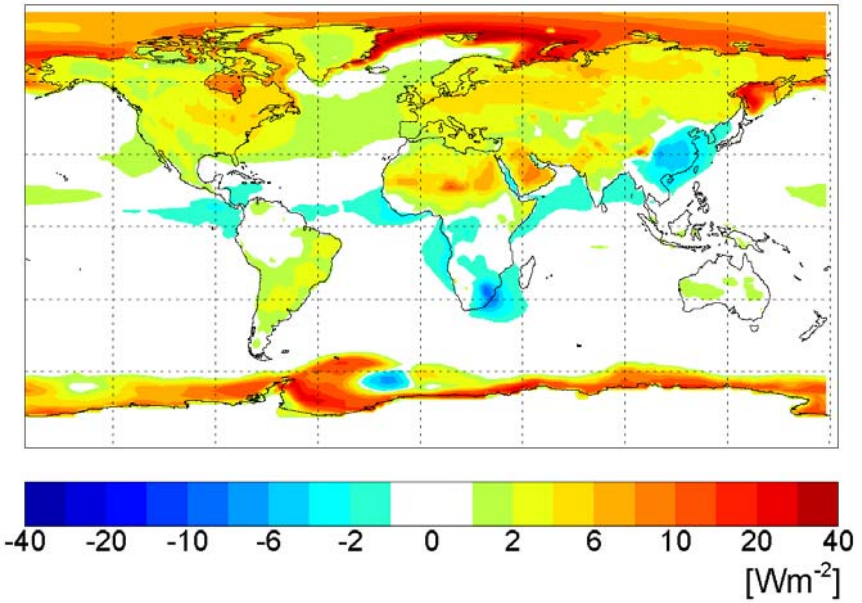
Absorption Aerosol Optical Depth

Radiative Perturbations

Change of aerosol and radiative properties from 1961-1990 to 2021-2050:



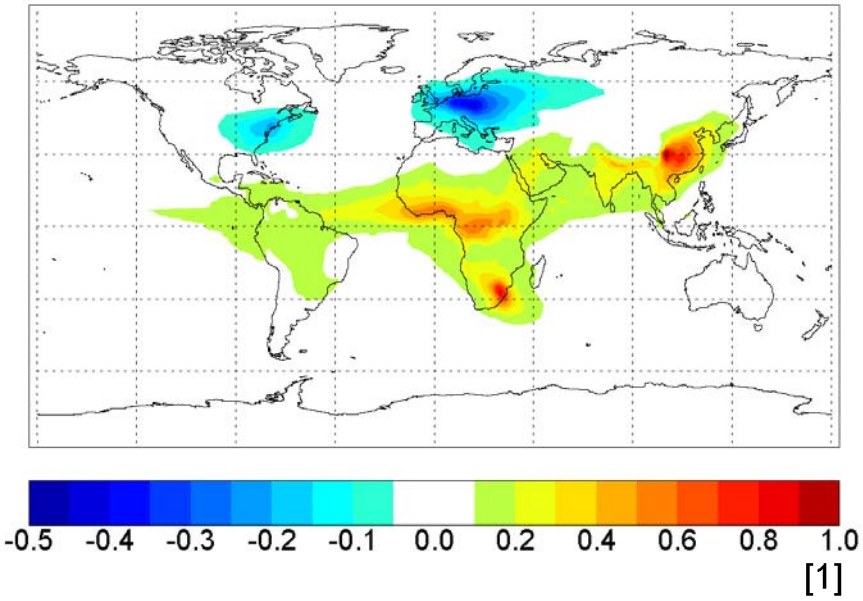
Aerosol Optical Depth



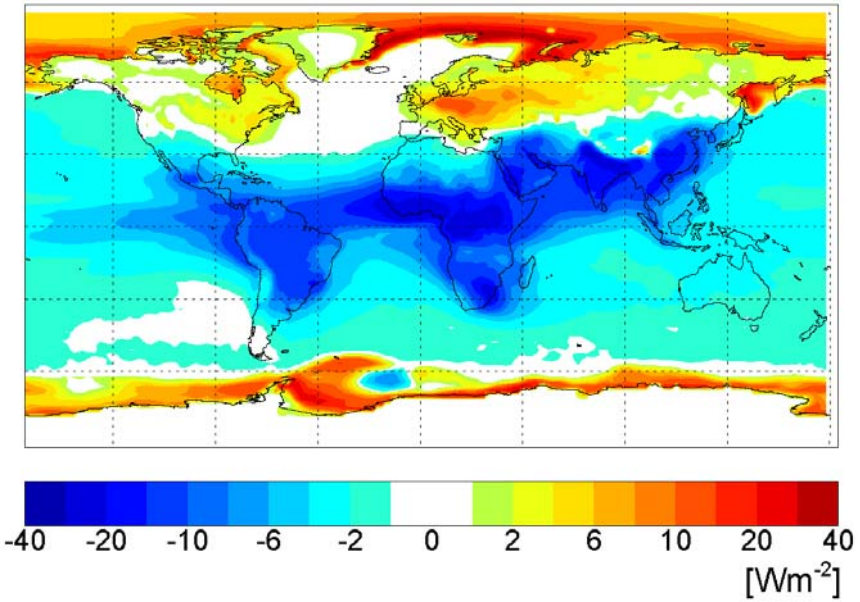
Top of the Atmosphere Short Wave Flux

Radiative Perturbations

Change of aerosol and radiative properties from 1961-1990 to 2021-2050:



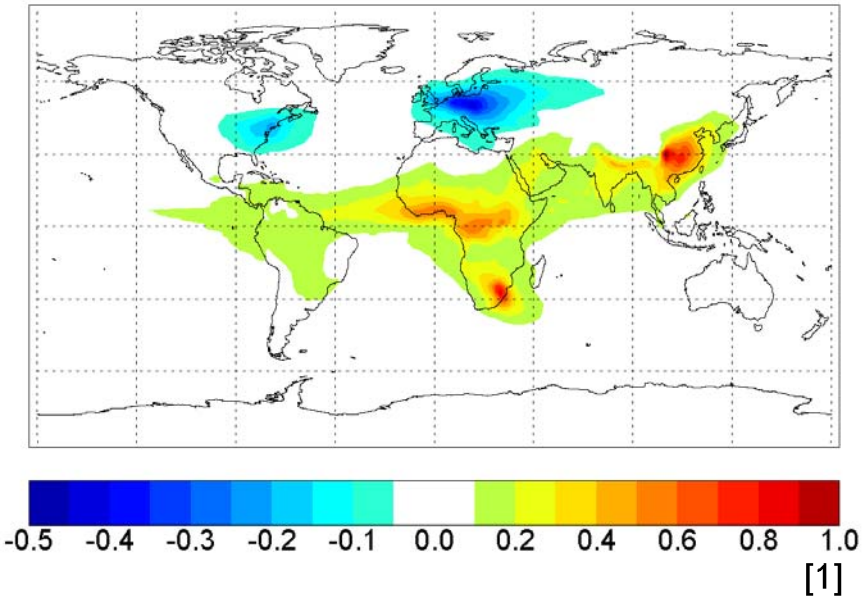
Aerosol Optical Depth



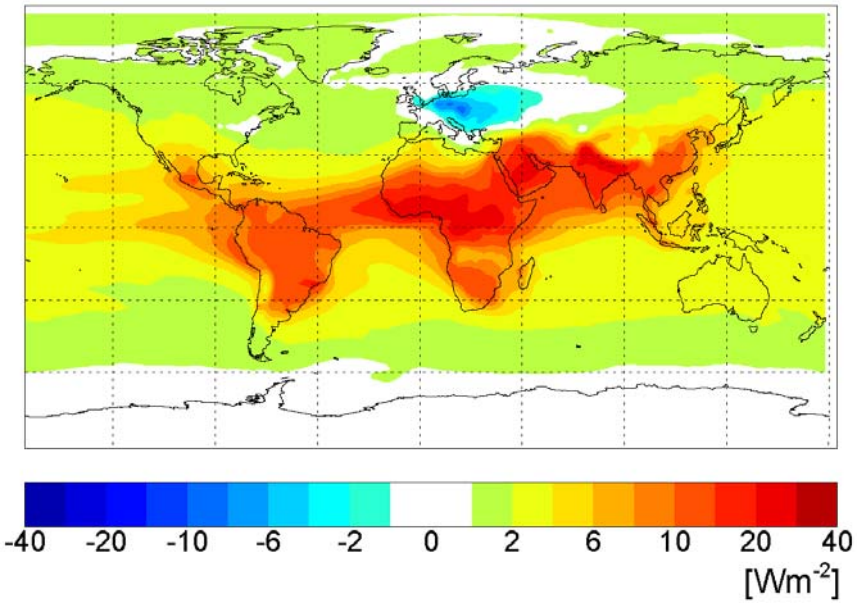
Surface Short Wave Flux

Radiative Perturbations

Change of aerosol and radiative properties from 1961-1990 to 2021-2050:



Aerosol Optical Depth



Short Wave Atmospheric Absorption

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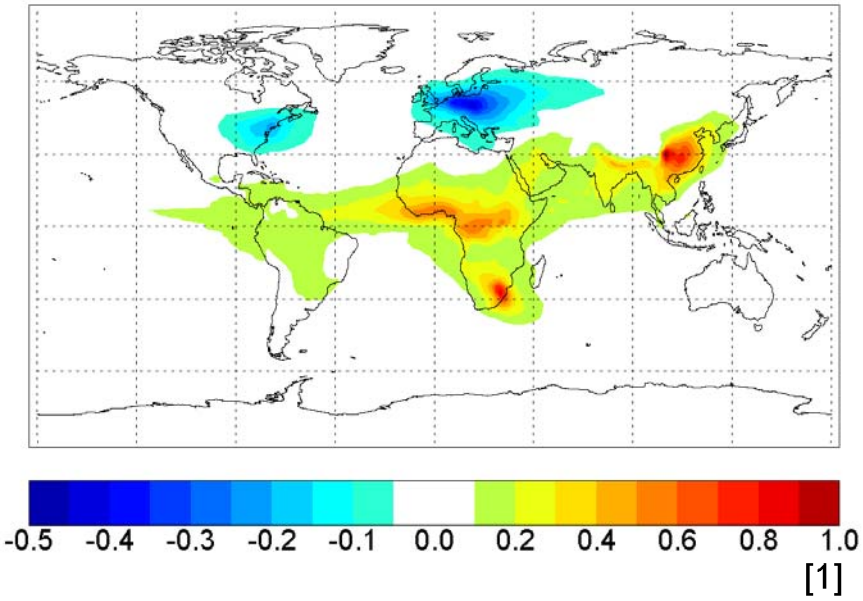

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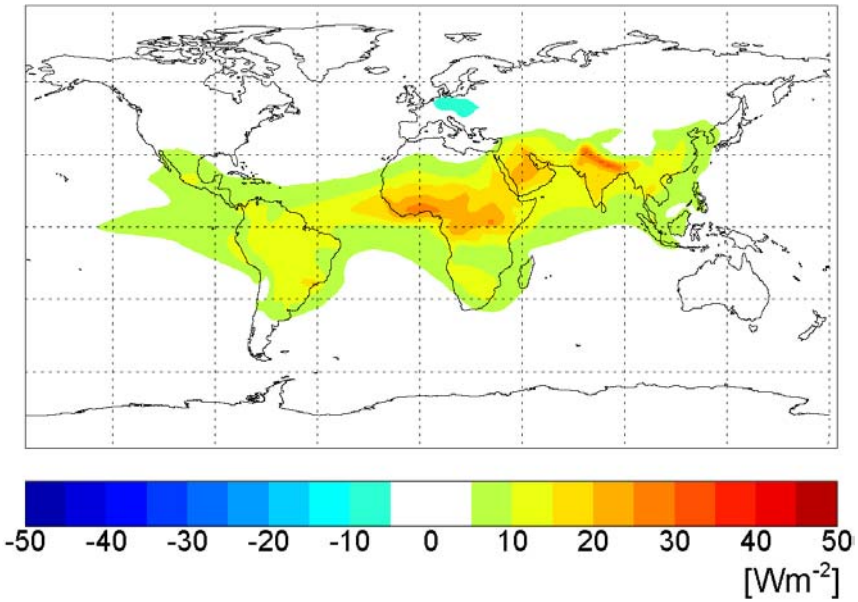
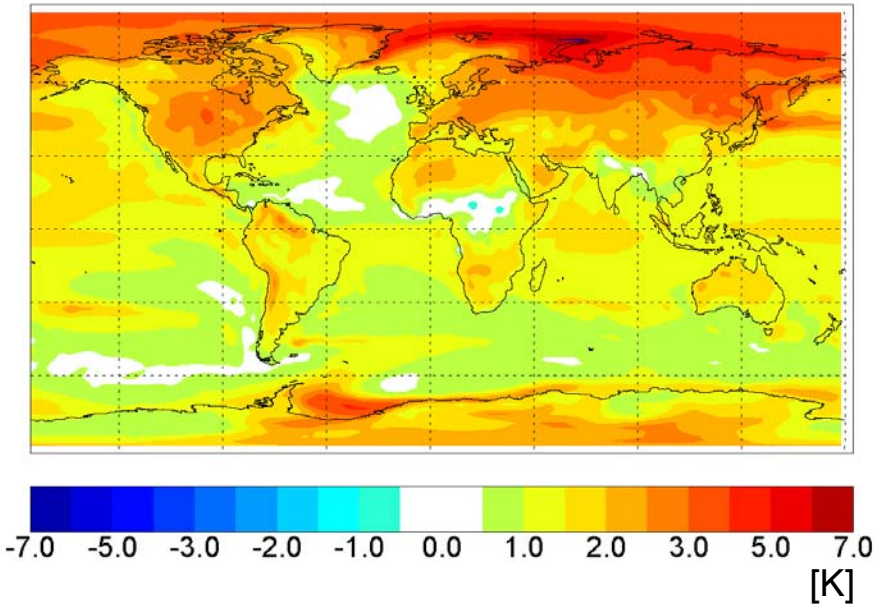


Short Wave Atmospheric Absorption

Climate Effects

Change of climatological properties from 1961-1990 to 2021-2050:



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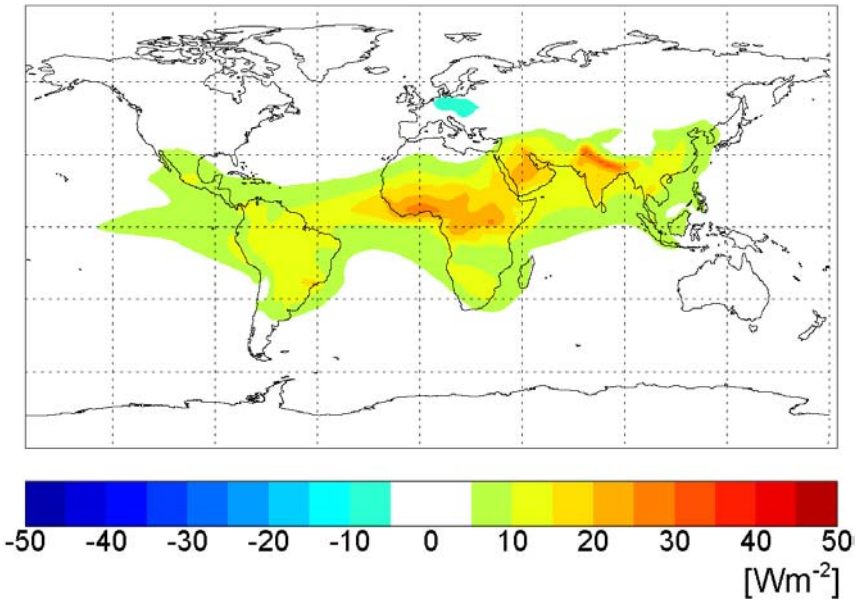

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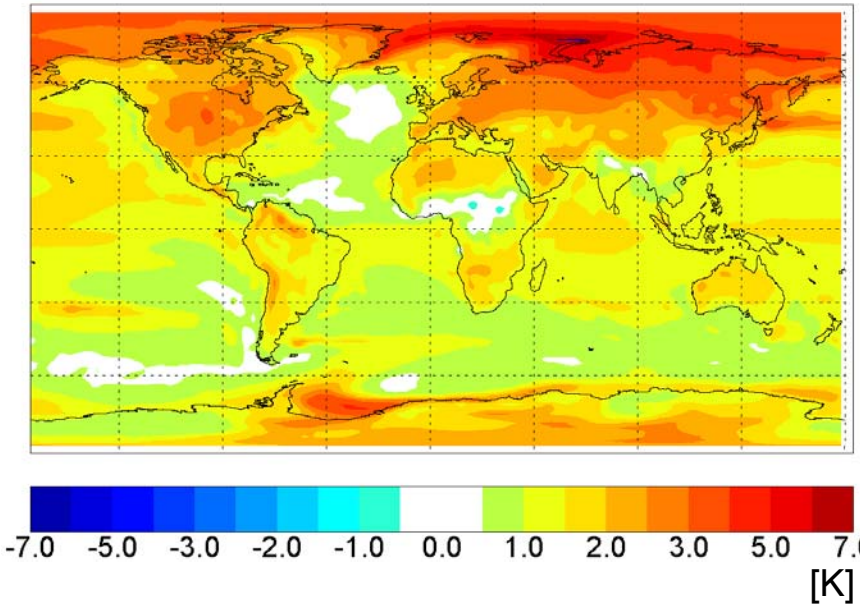

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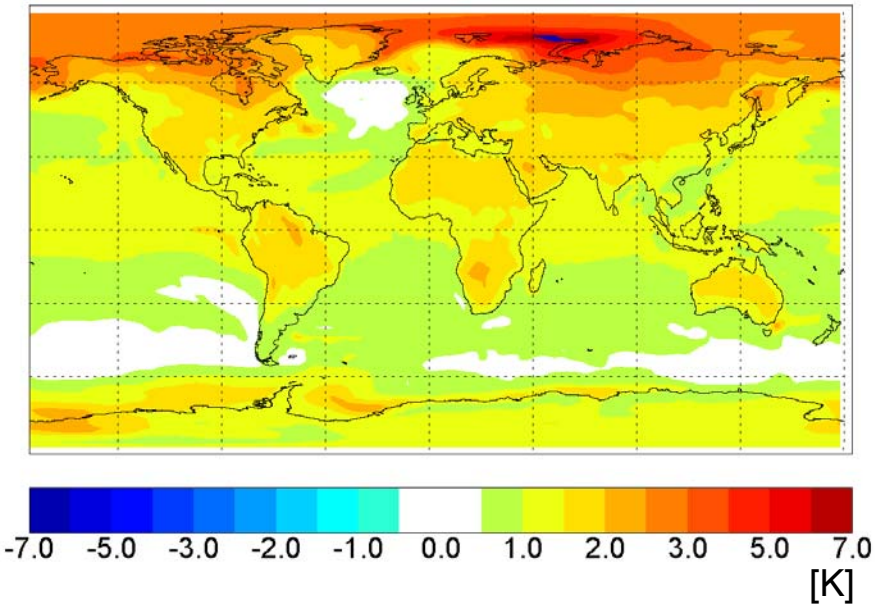
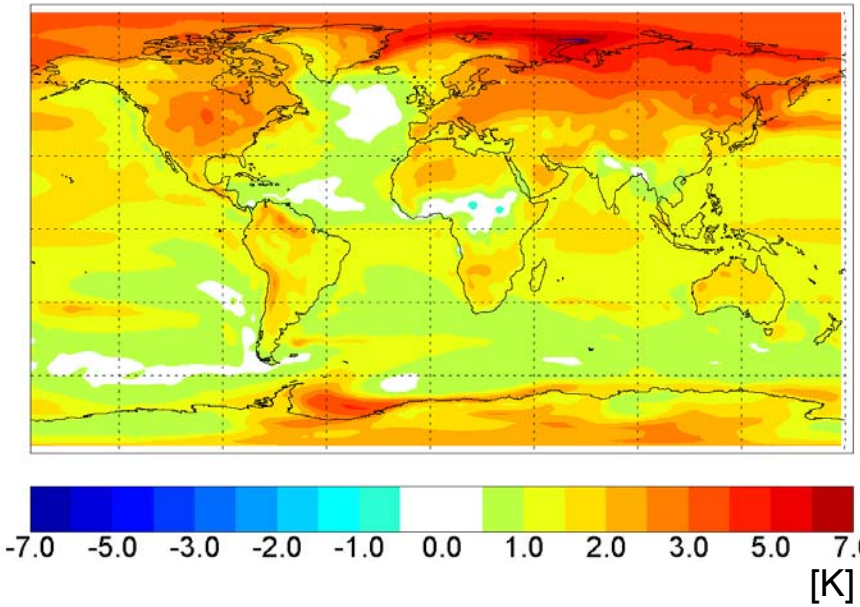


ECHAM5 + MPI-OM:

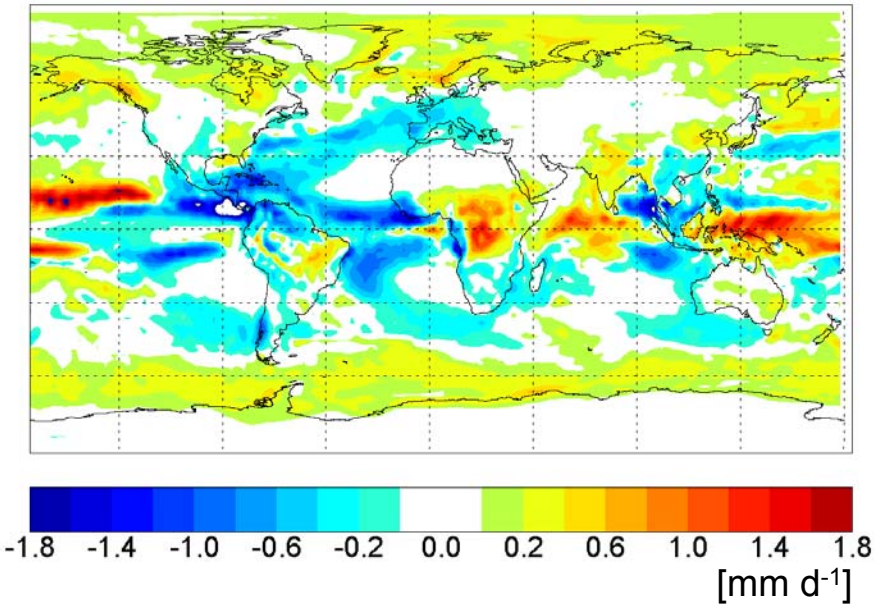
- only sulfate aerosol prescribed
- no carbonaceous aerosols
- no natural forcings

Hydrological cycle

Change of hydrological properties from 1961-1990 to 2021-2050:



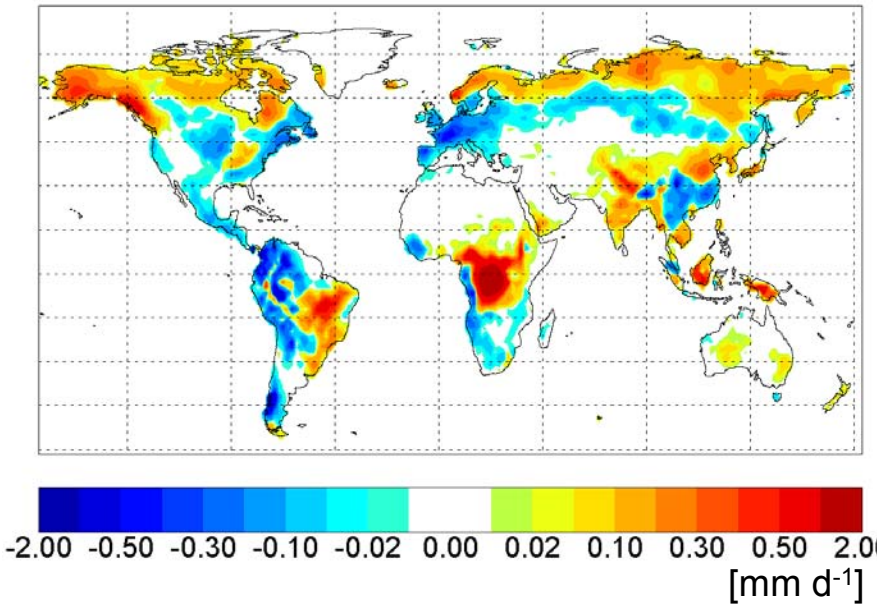
Surface Temperature



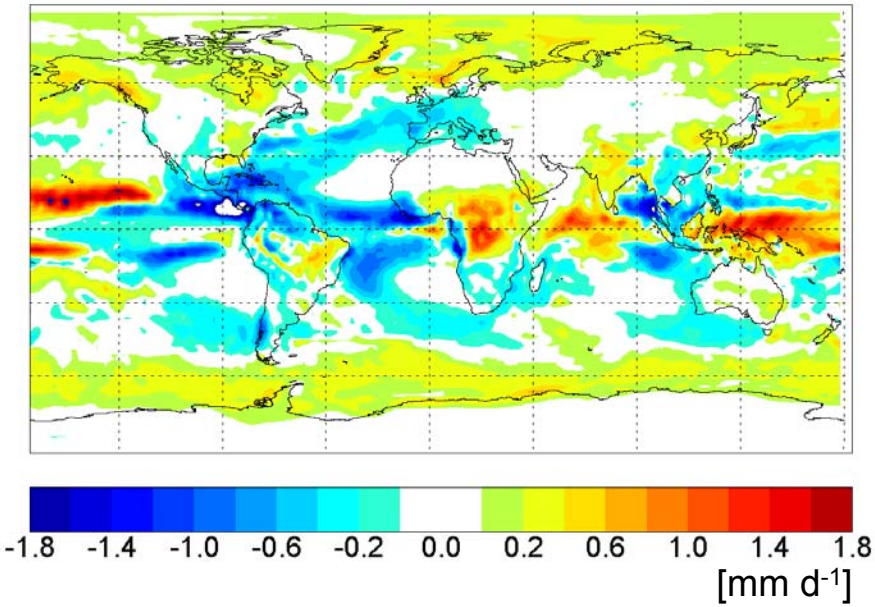
Precipitation

Hydrological cycle

Change of hydrological properties from 1961-1990 to 2021-2050:



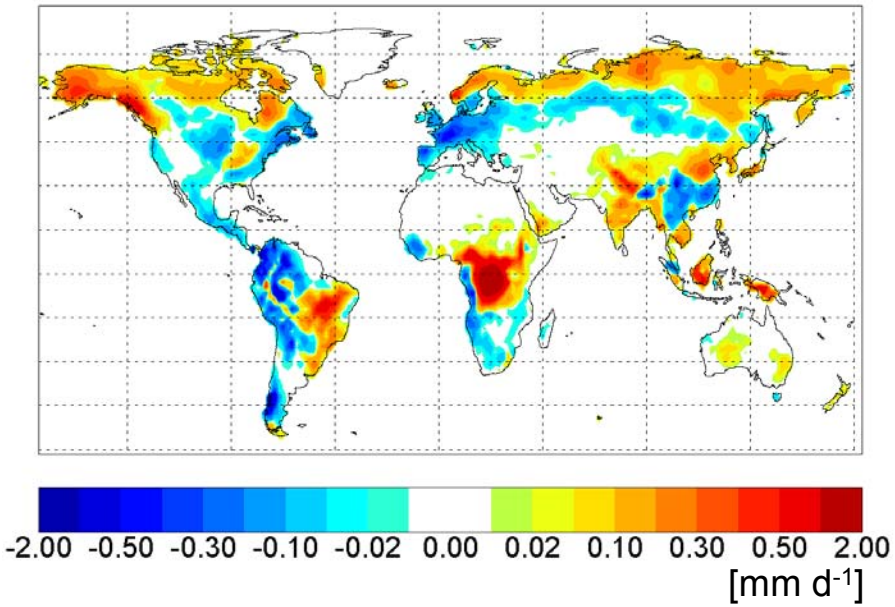
Surface Run-Off



Precipitation

Hydrological cycle

Mechanisms for the impact of carbonaceous aerosol on regional climate:



Surface Run-Off

- Increase in absorption
  ⇒ Thermally direct circulation
- Reduction of surface radiation
  Enhanced moisture convergence
  ⇒ Persistently higher soil moisture
  ⇒ Positive feedback

(Röckner et al., submitted)

Conclusions

Introduction of the microphysical aerosol module HAM

- Prognostic treatment of aerosol composition, size-distribution, and mixing state

Transient climate simulations with the MPI-ESM:

- Regionally significant climate impact of aerosols
- Significant increase in low-latitude absorbing aerosols (NIES SRES A1B emission scenario)
- Regional decrease of surface radiation and surface temperature
- Enhanced moisture convergence, precipitation and run-off

Caveats:

- Significant uncertainties even for present day emission inventories
- These add to the uncertainty in future emission scenarios

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Aerosol Lifetime