Aerosols and aerosol forcing in the CMIP5 versions of NorESM

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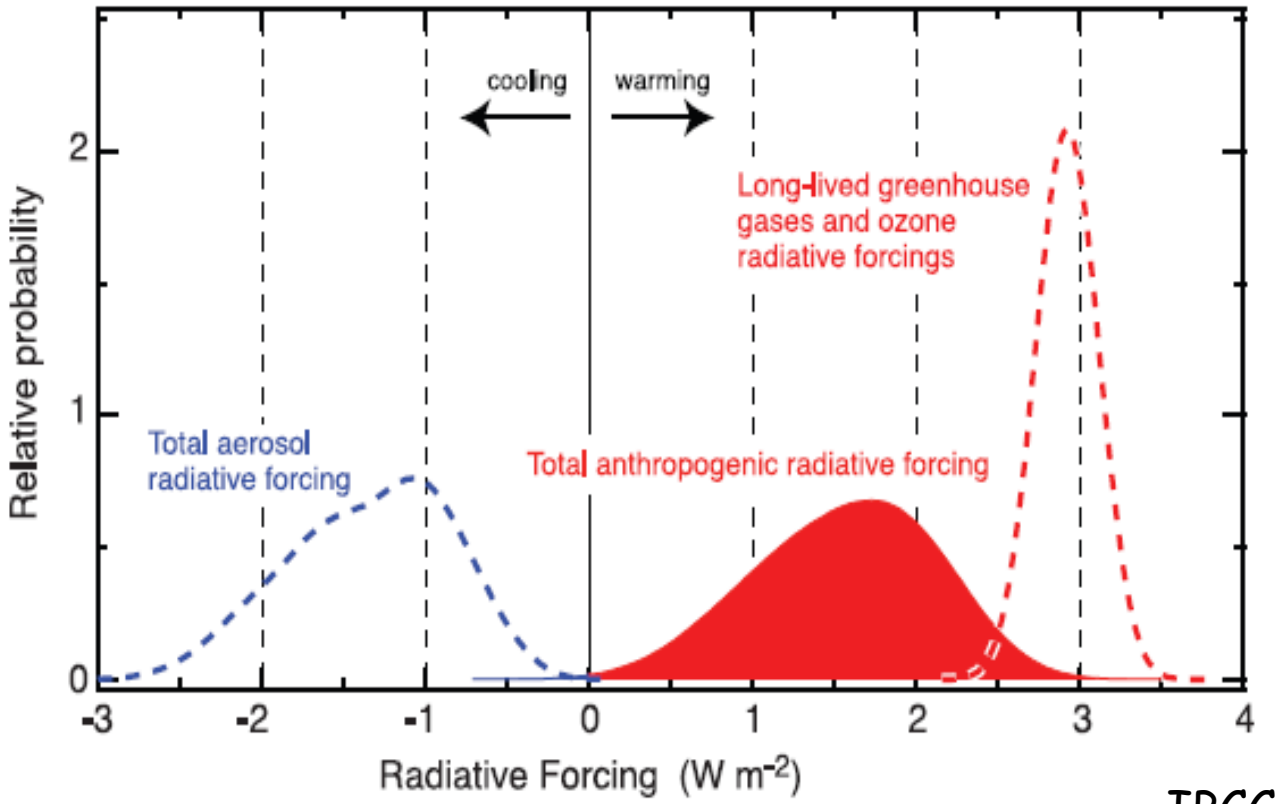
Corinna Hoose, Jon Egill Kristjánsson, Hamish Struthers, Annica Ekman,
Steve Ghan, Jan Griesfeller, Douglas Nilsson, and Michael Schulz

EarthClim all-staff meeting,
Olavsgaard, 30 August 2012


cooling
warming
Long-lived greenhouse gases and ozone radiative forcings
Total aerosol radiative forcing
Total anthropogenic radiative forcing
Relative probability
Radiative Forcing (W m-2)
0
1
2
-3
-2
-1
0
1
2
3
4

IPCC (2007)

Most of the results are from Kirkevåg et al. (2012):

Geosci. Model Dev. Discuss., 5, 1–87, 2012
www.geosci-model-dev-discuss.net/5/1/2012/
doi:10.5194/gmdd-5-1-2012

Geoscientific Model Development Discussions

Aerosol-climate interactions in the Norwegian Earth System Model – NorESM

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New features in CAM4-Oslo (NorESM) compared to CAM-Oslo:

Seland et al. (2008)
Hoose et al. (2009)
Struthers et al. (2009)

- **New and enhanced natural aerosol components** (vs. Seland et al., 2008):
  - Oceanic primary biogenic OM: emissions distributed as sea-salt and scaled to 8 Tg/yr globally
  - MSA produced from the oceanic DMS included, treated as POM
  - Natural SOA produced from land vegetation and treated as POM is almost doubled

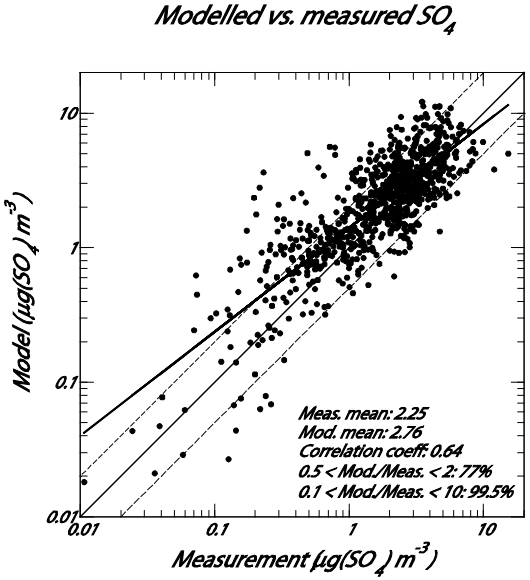
- **New processing of natural aerosols:**
  - Sea-salt emissions depend now on wind and temperature, *updated* Struthers et al. (2011)
  - In-cloud scavenging coefficient for dust is reduced from 1 to 0.25 [increased from 0.1 in Hoose et al., 2009]

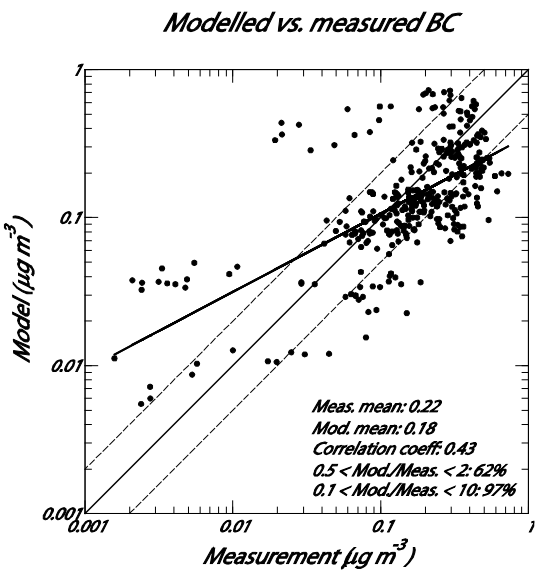
- **New treatment affecting both natural and anthropogenic aerosols** (vs. Seland et al., 2008):
  - OM/OC ratio for emissions of biomass burning POM: increased from 1.4 to 2.6
  - Updated tropospheric oxidant fields from Oslo-CTM2
  - Rate of replenishment of H_2O_2 in cloud droplets changed from a fixed value of 1 h to 1-12 h, ~ $(1.1\text{-cldmax})^2$
  - Gravitational particle settling speed is now calculated at all heights

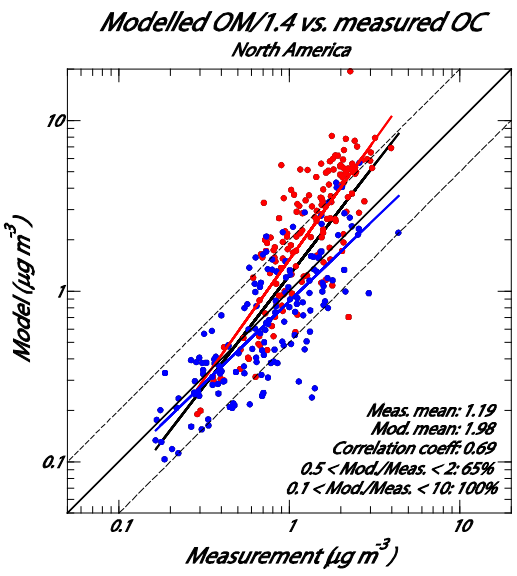
  - Pre-industrial emissions were AeroCom 1750, now: IPCC AR5 1850 for aerosols and precursors
  - Present-day emissions were AeroCom 2000, now: AeroCom 2006

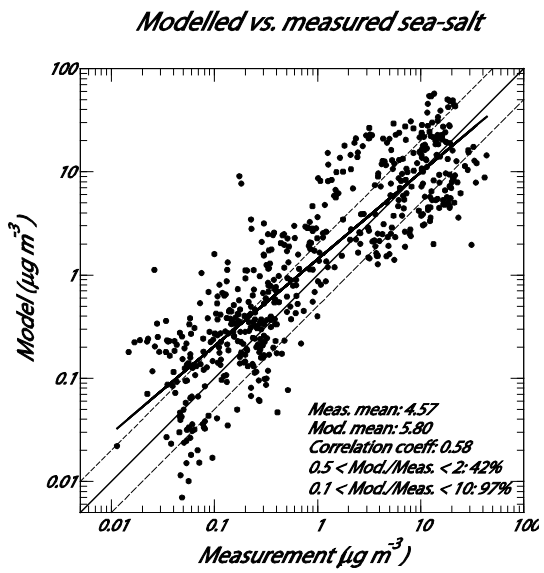
+ **New cloud droplet spectral dispersion formulation** (vs. Hoose et al., 2009)

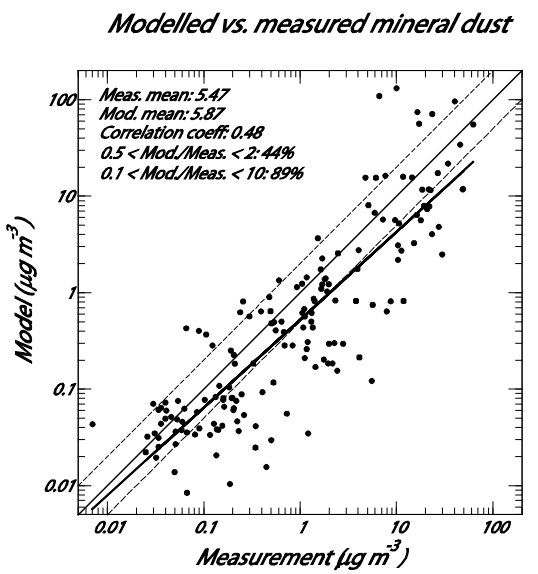
Monthly near-surface aerosol mass concentrations

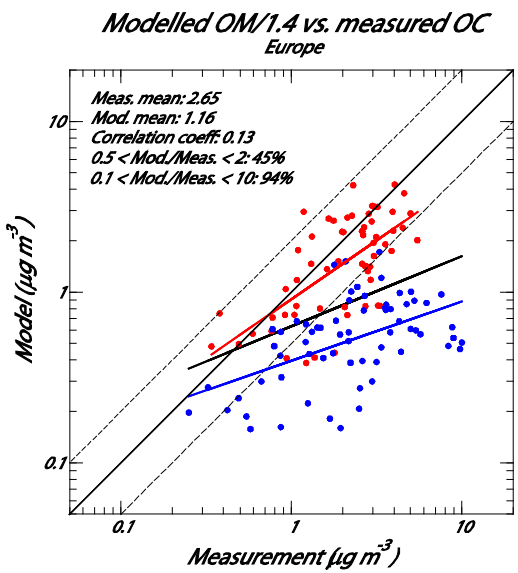






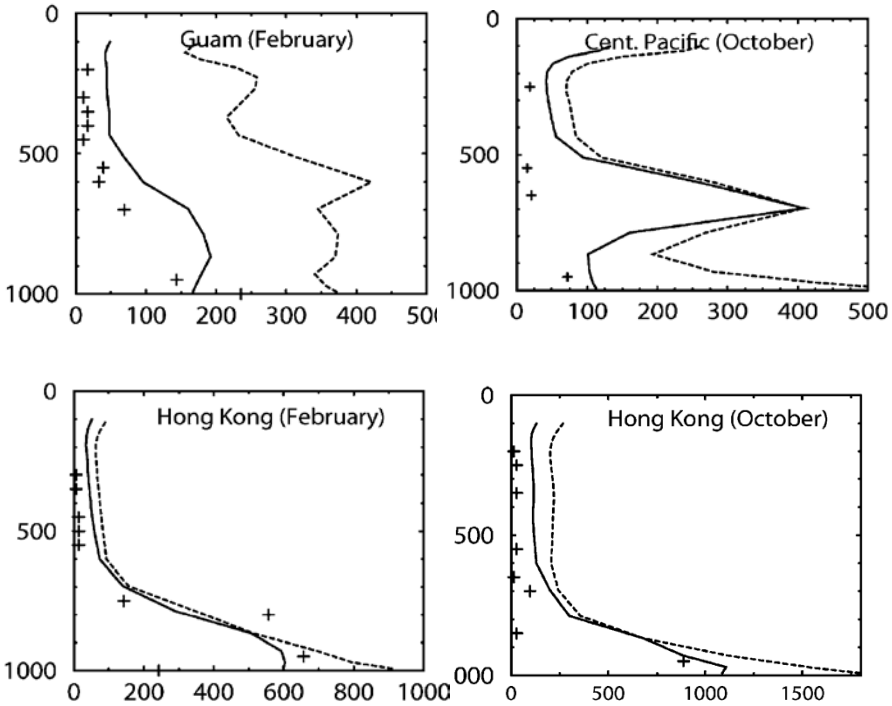




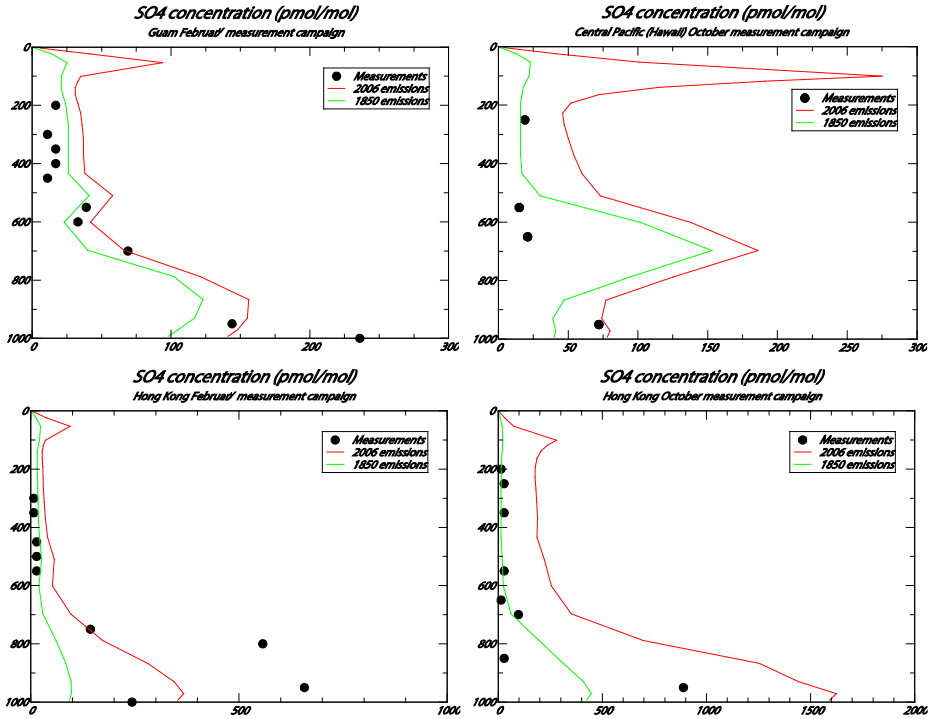


Vertical profiles of SO_4 mixing ratio

CAM-Oslo (Seland et al., 2008)



CAM4-Oslo

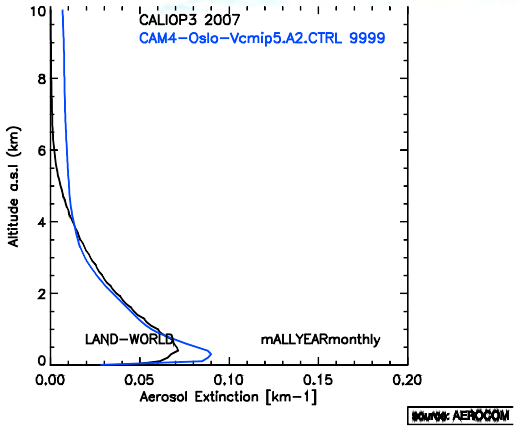


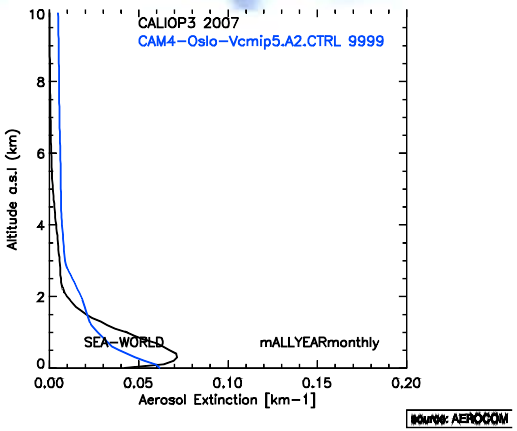
——— **PD simulation**

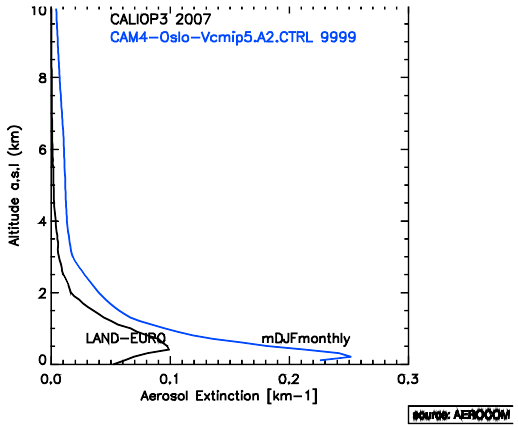
- - - - test simulation

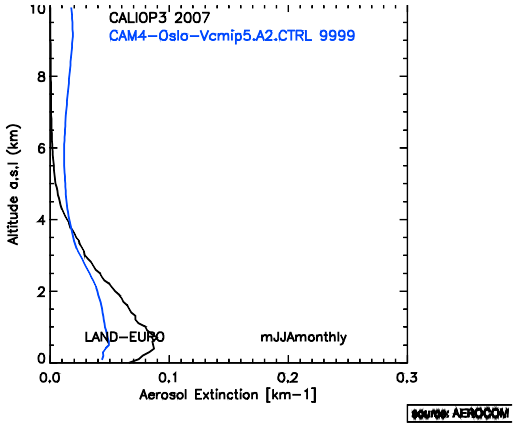
——— **PD simulation**

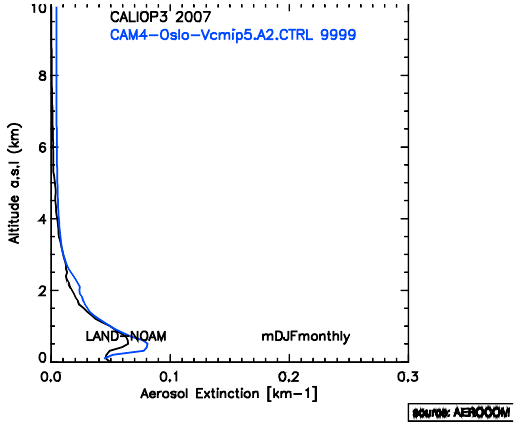
——— PI simulation

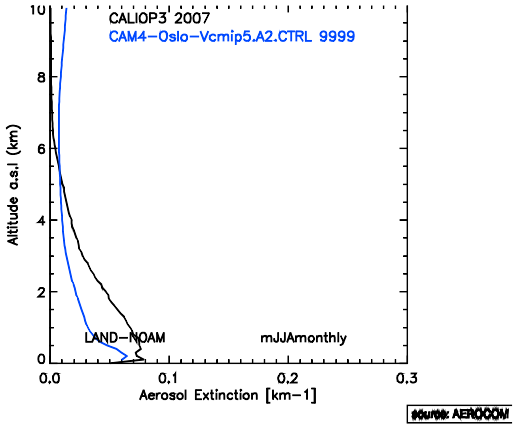








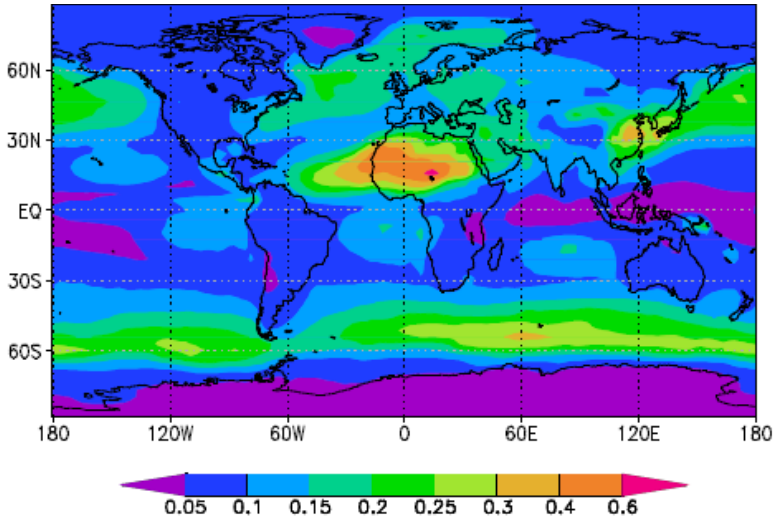




Vertical distribution of aerosol extinction vs. CALIOP lidar

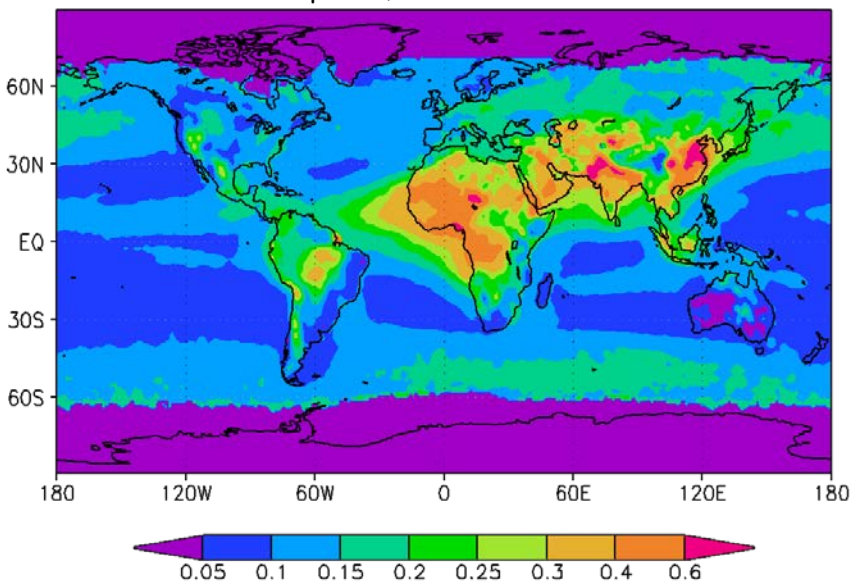
Clear-sky aerosol optical depth

CAM-Oslo (Seland et al., 2008)

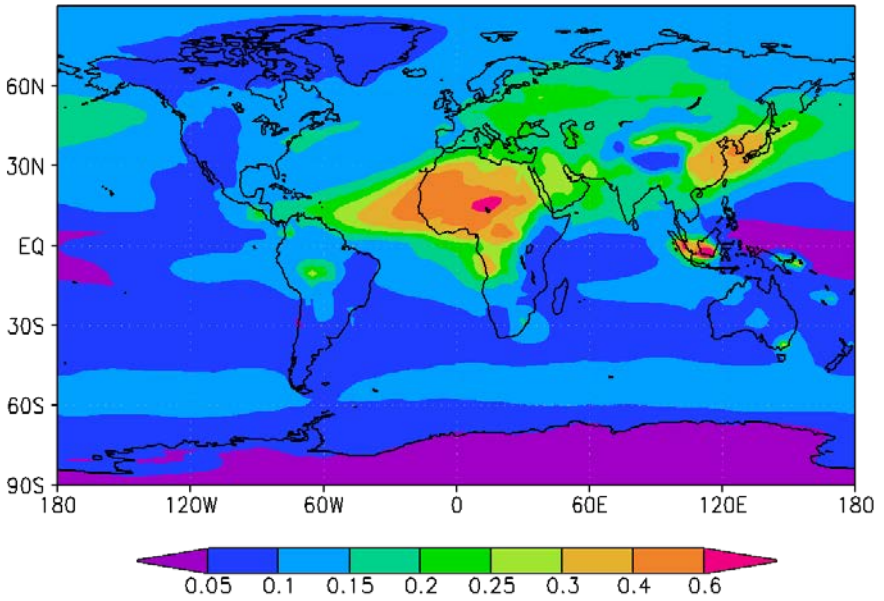


Remote sensed data

AOD composite, MODIS-MISR-AERONET

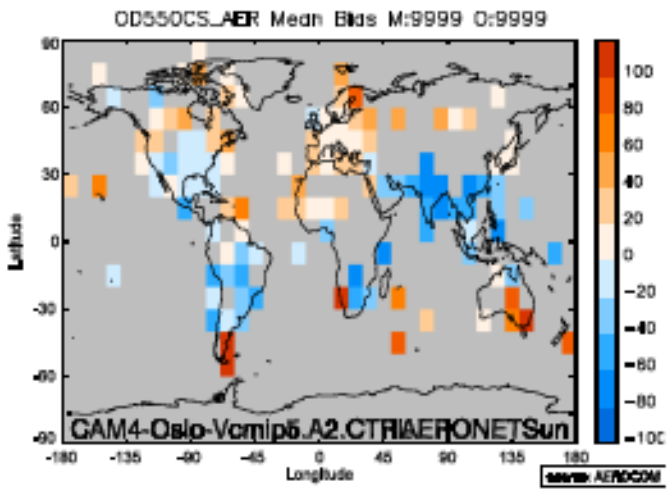


CAM4-Oslo

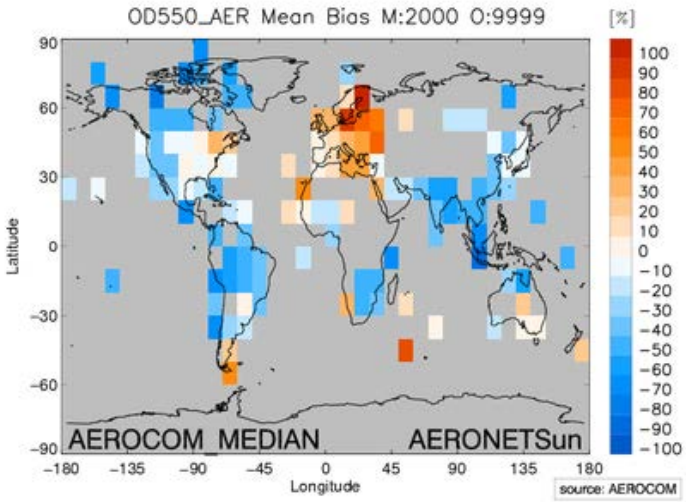


Clear-sky AOD bias (in %) compared to AERONET

CAM4-Oslo



AerCom Phase I median model

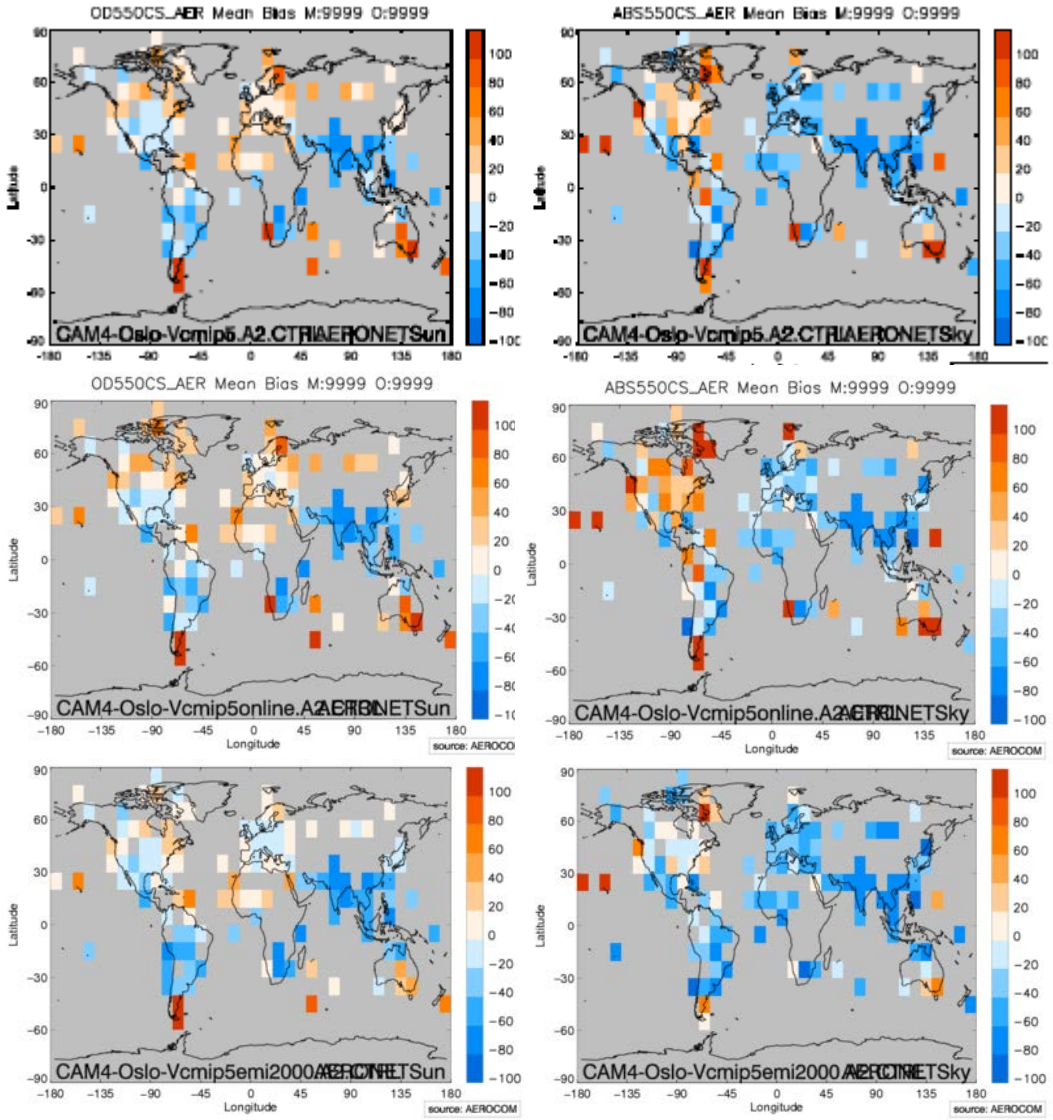


http://aerocom.met.no/

Bias (in %) compared to AERONET

clear-sky AOD

clear-sky ABS (absorption AOD)



offline, Aerocom 2006 emissions

online, AeroCom 2006 emissions

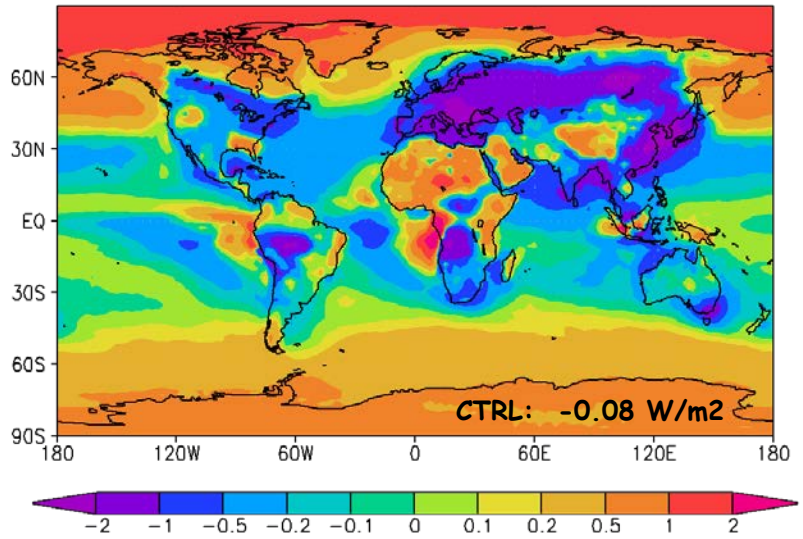
offline, **IPCC 2000** emissions (CMIP5)

http://aerocom.met.no/

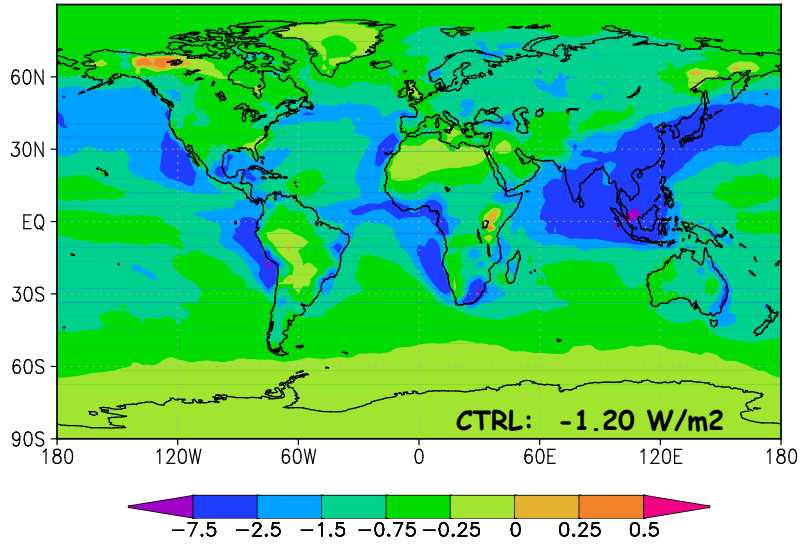
Sensitivity tests of mainly old versions of parameterizations in CAM4-Oslo coupled to *data* ocean & sea-ice models:

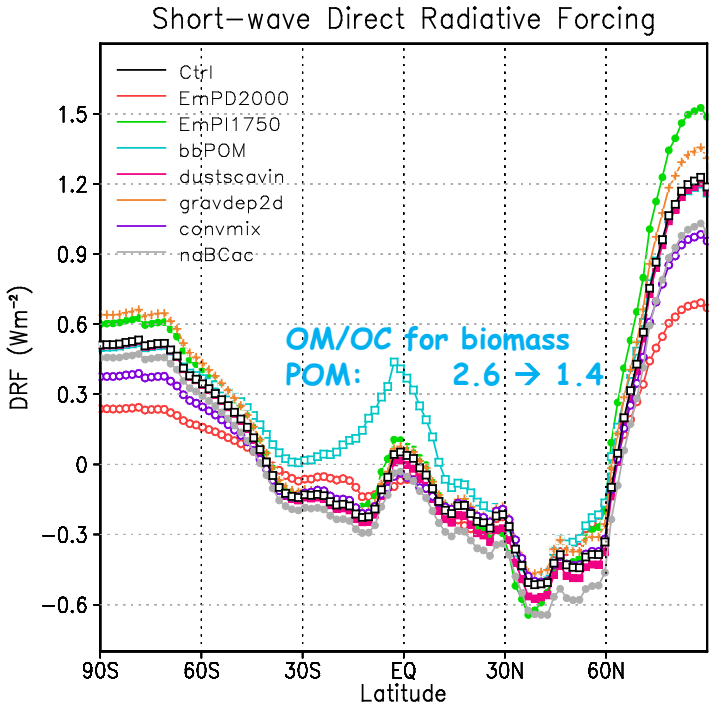
Identification	Short description
Ctrl	Standard Reference. All processes updated. Emissions years: PD = 2006; PRE = 1850.
natOM	As *Ctrl*, but with natural OM as in Se08.
natOMocn	As *Ctrl*, but no biogenic OM from oceans and MSA, as in Se08.
bbPOM	As *Ctrl*, but OM/OC = 1.4, as in Se08.
Struthers11	As *Ctrl*, but tuning of sea-salt emissions as in Struthers et al. (2011).
dustscavin	As *Ctrl*, but in-cloud scavenging efficiency for dust = 1, as in Se08.
cldtunorig	As *Ctrl*, but tuning of cloud microphysics as in NCAR CAM4 (Neale et al., 2010).
gravdep2d	As *Ctrl*, but gravitational settling only in the lowest model layer, as in Se08.
convmix	As *Ctrl*, but convective mixing of aerosols and precursors as in Se08.
noBCac	As *Ctrl*, but no primary emissions of BC(ac), i.e. all BC is emitted as BC(n).
replH2O2	As *Ctrl*, but replenishment time of H_2O_2 = 1 h, as in Se08.
no coating	As *Ctrl*, but without coating of dust and BC in CCN-activation.
prescrβ	As *Ctrl*, but effective cloud droplet radii parameterized as in Se08, Hoose et al. (2009), and Neale et al. (2010).
EmPD2000	As *Ctrl* (all processes updated). Emissions years: PD = 2000; PI = 1850.
EmPI1750	As *Ctrl* (all processes updated). Emissions years: PD = 2006; PI = 1750.
Online	As *Ctrl*, but with online interactions between aerosol forcing and atmospheric dynamics.

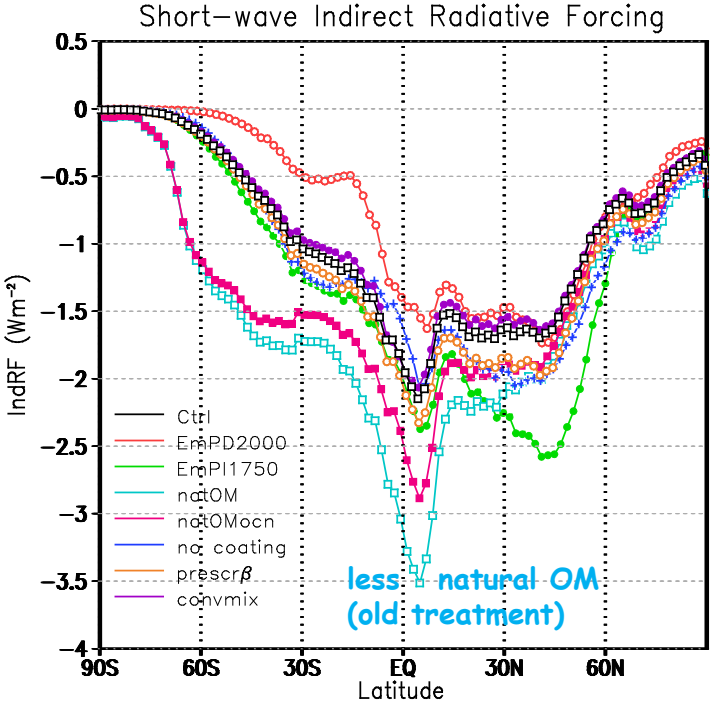
DRF at TOA



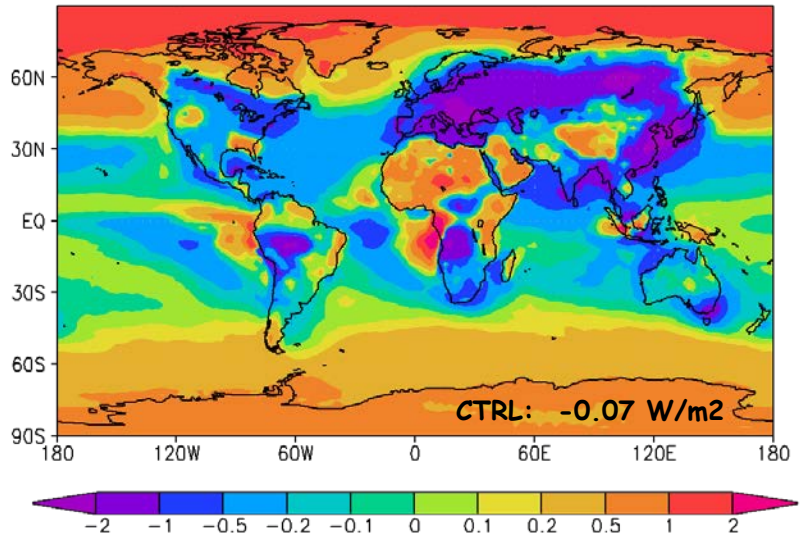
InDRF at TOA



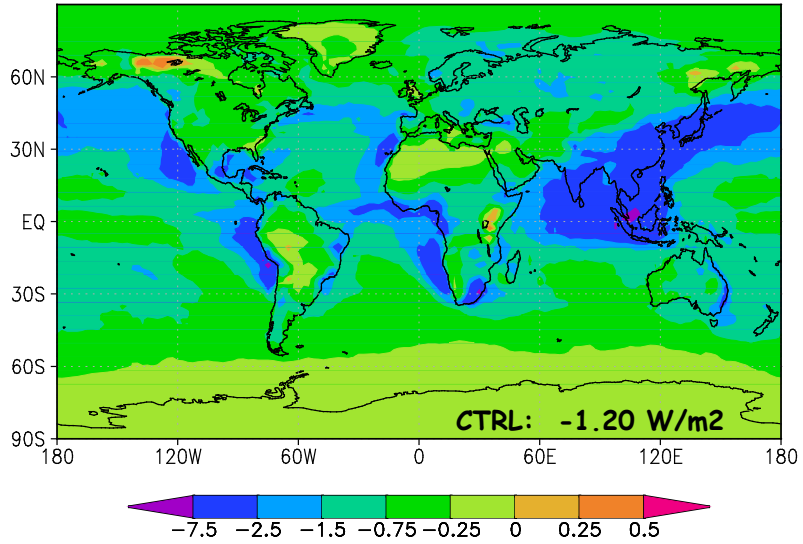


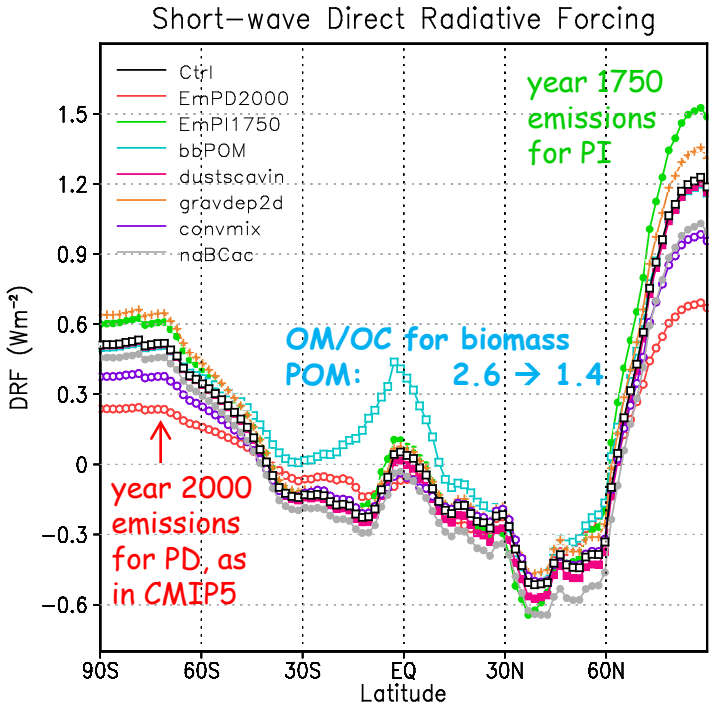


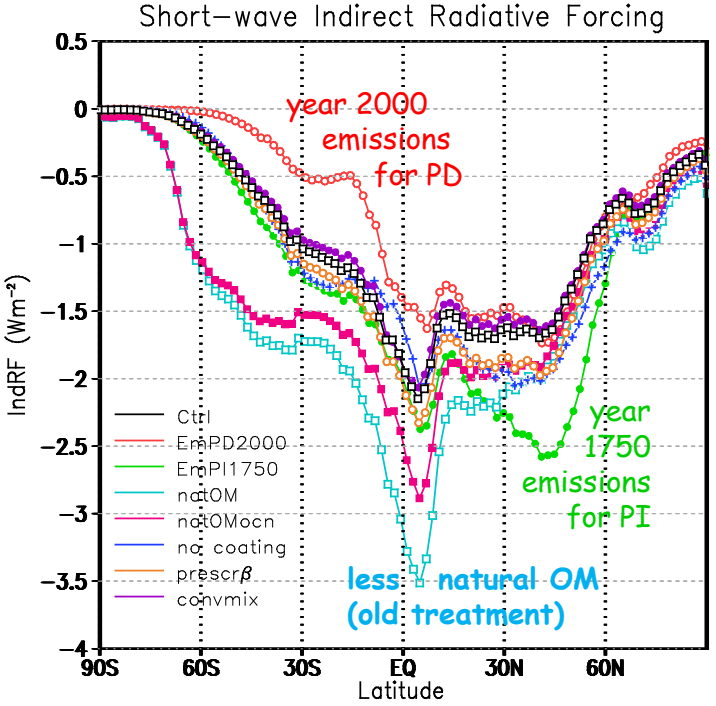
DRF at TOA



InDRF at TOA

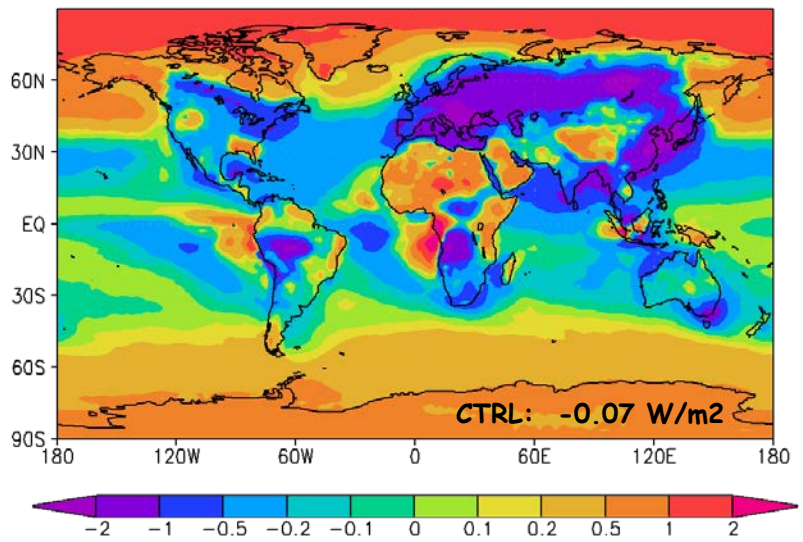


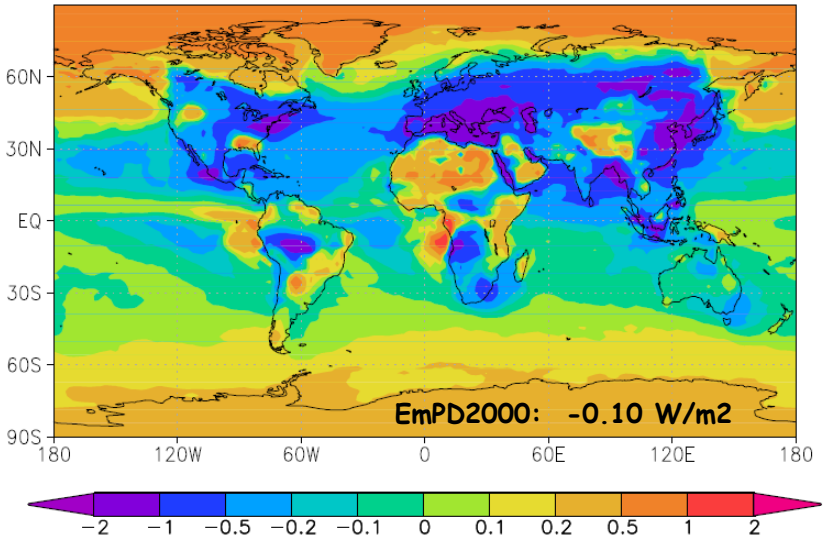




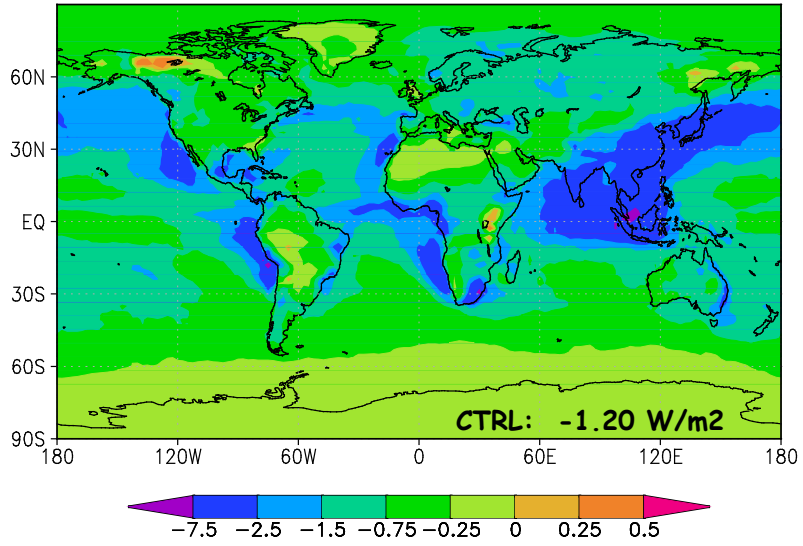
AeroCom ←→ CMIP5 (& AeroCom)

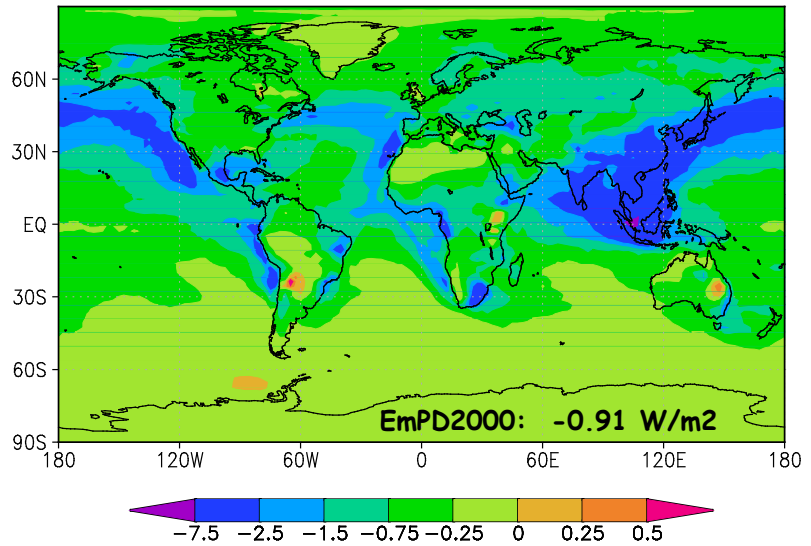
Emission years: 2006 - 1850 DRF at TOA 2000 - 1850





InDRF at TOA





Summary (1)

Near surface aerosol mass concentrations:

BC	under-estimated	(ca. as in Seland et al., 2008)
SO_4	over-estimated	(ca. as in Seland et al., 2008)
Dust	slightly over-estimated	(much improved from Seland et al., 2008)
Sea-salt	over-estimated	(improved from Struthers et al., 2011)
POM	over-estimated in N-America	(worse than in Seland et al., 2008)
	still underestimated in Europe	(improved from Seland et al., 2008)

Vertical aerosol profiles (extinction):

probably overestimated aloft, underestimated in marine BL and in cont. BL in summer

Column integrated optics:

AOD	still mostly under-estimated (improved from Seland et al., 2008)
	especially in south and south-east Asia,
	but overestimated at high latitudes
ABS	mainly under-estimated (although among the highest/best in AeroCom)

Summary (2)

Sensitivity results for global direct and indirect SW radiative forcing at TOA:

DRF is most sensitive to assumed *OM/OC* ratio for biomass burning POM (changes sign)
Basic emission years also important:
-0.10 Wm^{-2} for year 2000 – 1850 (**CMIP5**)
-0.07 Wm^{-2} for year 2006 – 1850 and 2000 – 1750
-0.04 Wm^{-2} for year 2006 – 1750

IndRF is most affected (-60%) by new/enhanced natural *OM* levels, and assumed basic emission years:
-0.91 Wm^{-2} for year 2000 – 1850 (**CMIP5**)
-1.2 Wm^{-2} for year 2006 – 1850 and 2000 – 1750
-1.5 Wm^{-2} for year 2006 – 1750