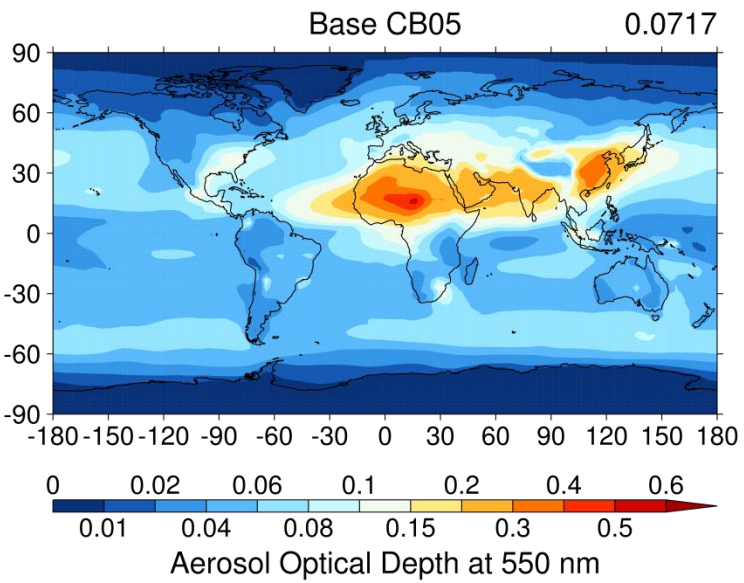
Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

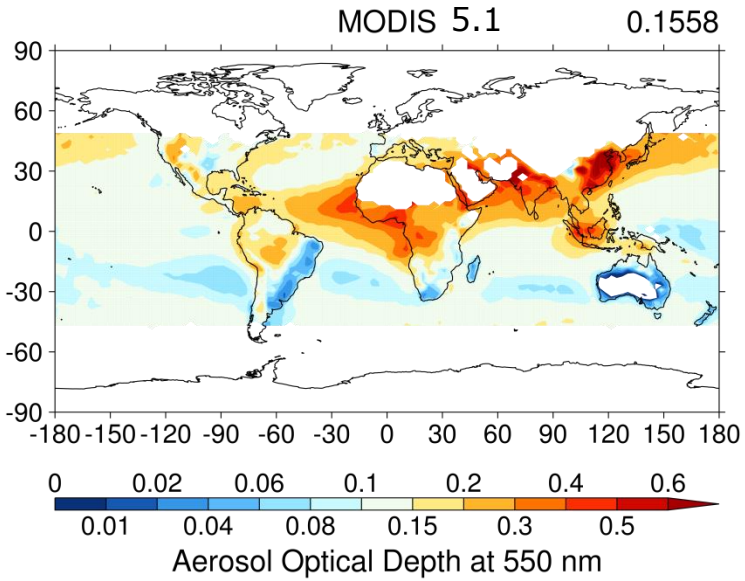
Aerosol Sensitivity Simulations in relation to Wet Scavenging, Emissions and Treatment of Nitrate

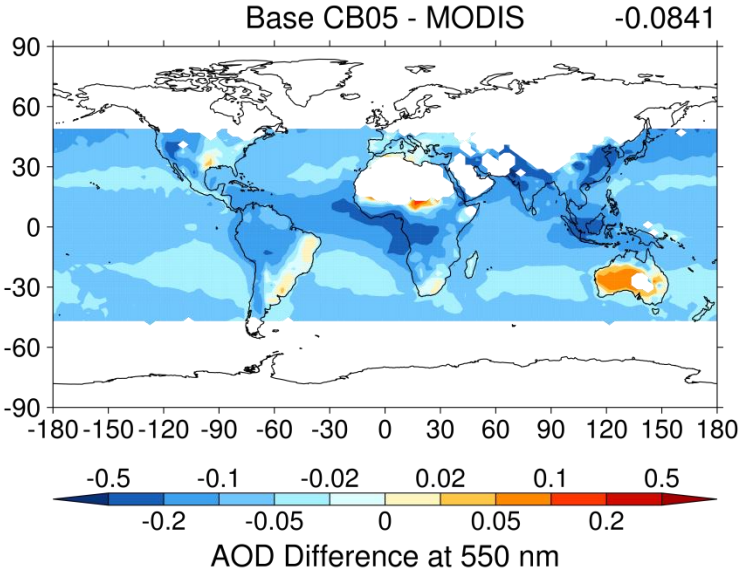
Twan van Noije (KNMI)

TM5 meeting, Utrecht, 19-20 January 2015

TM5/M7 AOD (2006)







Budget analysis

	EC-Earth	ERA-Interim	Other studies
Sulfate			
Burden (Tg S)	0.522	0.498	0.67 ± 0.17^{d}
Lifetime (days)	4.93	4.73	5.0 ± 2.0^{d}
			4.1 ± 0.7^{e}
Dry deposition rate (day^{-1})	4.68×10^{-3}	4.57×10^{-3}	0.03 ± 0.02^{e}
Wet deposition rate (day^{-1})	0.198	0.207	0.22 ± 0.05^{e}
Optical depth	2.13×10^{-2}	2.08×10^{-2}	0.044^{f}
Black carbon			
Emissions (Tg $year^{-1}$)	7.77		
Burden (Tg)	0.145	0.149	0.16 ± 0.07^{d}
Lifetime (days)	6.81	6.99	7.4 ± 3.4^{d}
			7.1 ± 2.3^{e}
Dry deposition rate (day^{-1})	6.17×10^{-3}	5.65×10^{-3}	0.03 ± 0.02^{e}
Wet deposition rate (day^{-1})	0.141	0.137	0.12 ± 0.04^{e}
Optical depth	1.11×10^{-3}	1.15×10^{-3}	0.0085^{f}
Organic aerosols			
Emissions (Tg $year^{-1}$)	69.5^{b}		
Burden (Tg)	1.18	1.16	1.6 ± 0.8^{g}
Lifetime (days)	6.18	6.08	5.7 ± 1.6^{g}
Dry deposition rate (day^{-1})	5.23×10^{-3}	4.69×10^{-3}	0.029 ± 0.046^{g}
Wet deposition rate (day^{-1})	0.157	0.160	0.16 ± 0.04^{g}
Optical depth	9.28×10^{-3}	9.29×10^{-3}	0.024^{f}
Nitrate			
Burden (Tg N)	2.29×10^{-2}	1.27×10^{-2}	0.1 ± 0.0^{h}
Optical depth	6.82×10^{-4}	3.99×10^{-4}	0.007 ± 0.001^{h}

	EC-Earth	ERA-Interim	Other studies
Sea salt			
Emissions (Pg $year^{-1}$)	7.35 ± 0.11^{c}	6.83 ± 0.09^{c}	8.2 ± 8.2^{i}
			16.6 ± 33.0^{e}
Burden (Tg)	6.81	6.17	7.9 ± 5.5^{i}
			7.5 ± 4.1^{e}
Lifetime (days)	0.338	0.330	0.48 ± 0.28^{e}
Dry deposition rate (day^{-1})	2.42	2.40	4.3 ± 9.4^{e}
Wet deposition rate (day^{-1})	0.538	0.630	0.79 ± 0.61^{e}
Optical depth	2.66×10^{-2}	2.35×10^{-2}	0.055 ± 0.016^{j}
Mineral dust			
Emissions (Pg $year^{-1}$)	1.78		1.84 ± 0.90^{e}
Burden (Tg)	12.1	13.4	19.2 ± 7.7^{e}
Lifetime (days)	2.48	2.75	4.1 ± 1.8^{e}
Dry deposition rate (day^{-1})	0.311	0.287	0.23 ± 0.19^{e}
Wet deposition rate (day^{-1})	9.20×10^{-2}	7.60×10^{-2}	0.08 ± 0.03^{e}
Optical depth	1.55×10^{-2}	1.71×10^{-2}	0.043 ± 0.014^{j}

[a] Includes 0.12 Tg S $year^{-1}$ from volcanoes. [b] Includes 19.1 Tg $year^{-1}$ representing SOA (see Sect. 2.2.5). [c] Standard deviations calculated from the simulated interannual variability. [d] ACCMIP multi-model means and standard deviations for the year 2000 from Shindell et al. (2013). [e] AeroCom phase-I multi-model means and standard deviations from Textor et al. (2006). [f] MACC reanalysis (Benedetti et al., 2009) results for the year 2003 as provided on the AeroCom phase-II web interface (http://aerocom.met.no/cgi-bin/aerocom/surfobs_annualrs.pl; simulation labelled "ECMWF_FBOV"). [g] AeroCom phase-II multi-model means and standard deviations from Tsigaridis et al. (2014). [h] Results for 1998–2002 from a CMIP5 simulation with the Hadley Centre climate model HadGEM2-ES by Bellouin et al. (2011). [i] AeroCom phase-I multi-model means and standard deviations from Textor et al. (2007), based on a selection of seven models from Textor et al. (2006). [j] MACC reanalysis results with uncertainty estimates from Bellouin et al. (2013).

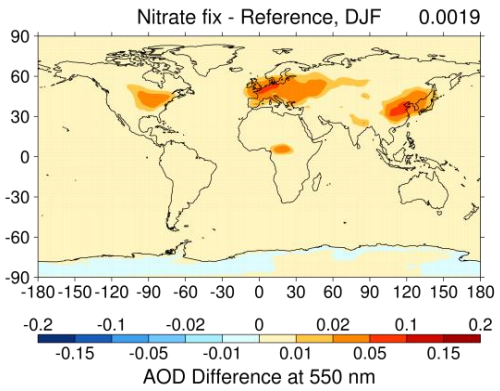
Simulation of tropospheric chemistry and aerosols with the climate model EC-Earth
Van Noije et al., GMD, 2014

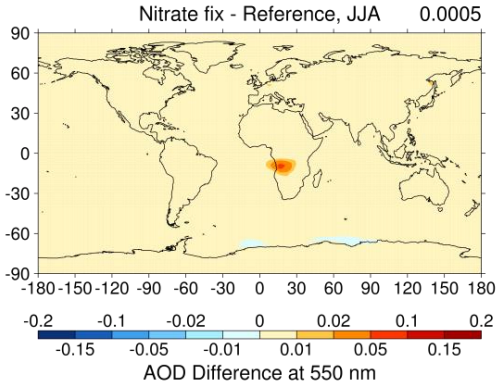
Sensitivity studies

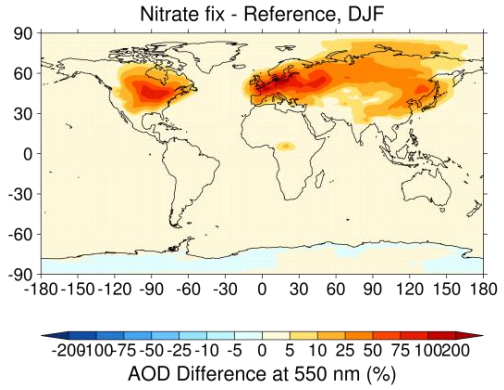
- Treatment of nitrate aerosol
- Volcanic sulfur emissions
- Online mineral dust emissions
- Wet scavenging:
  - Scavenging coefficients
  - Sub-grid mixing (large-scale clouds and precipitation)

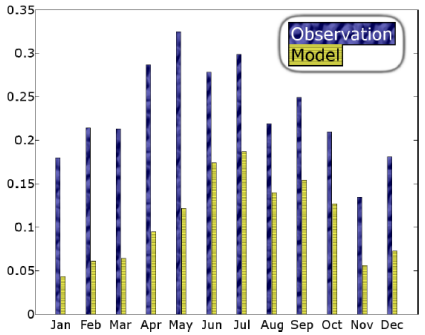
Treatment of nitrate aerosol

- Nitrate described as bulk aerosol (EQSAM)
- Assumption in (M7 based) Mie calculations: formed by condensation onto exisiting particles in soluble accumulation mode
- Previously, only included in refractive index of the mixture
- Particle growth due to nitrate mass and associated water uptake was missing!
- Agreement with Mie calculations by C. Lacagnina and O. Hasekamp (SRON)









Comparison old code with AERONET in Europe

(Aan de Brugh et al., 2011)

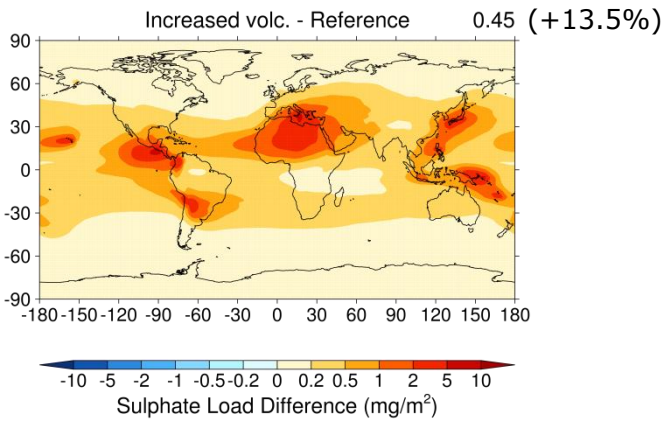
Volcanic sulfur emissions

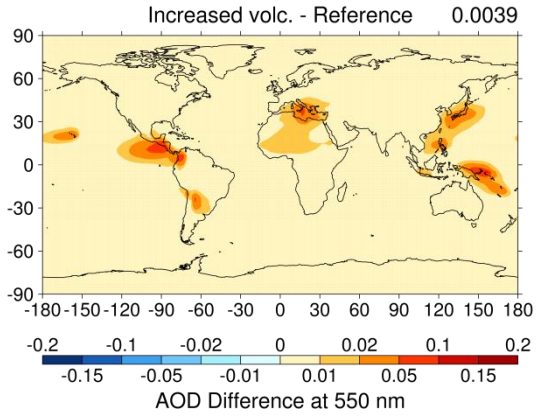
	EC-Earth	ERA-Interim	ACCMIP
DMS			
Emissions (Tg S year^{-1})	19.4 ± 0.2*	19.1 ± 0.3*	23 ± 5
SO_2			
Total emissions (Tg S year^{-1})		57.2	65 ± 2
Volcanic emissions (Tg S year^{-1})		4.67	$\sim 12 \pm 2$
Total reactive sulfur			
Emissions (Tg S year^{-1})	78.1	77.8	89 ± 6
Dry deposition (Tg S year^{-1})	27.0	27.2	37 ± 10
Wet deposition (Tg S year^{-1})	51.1	50.7	52 ± 8

Van Noije et al., 2014

Volcanic emissions (from MACC) scaled up to 15.6 Tg S/yr:

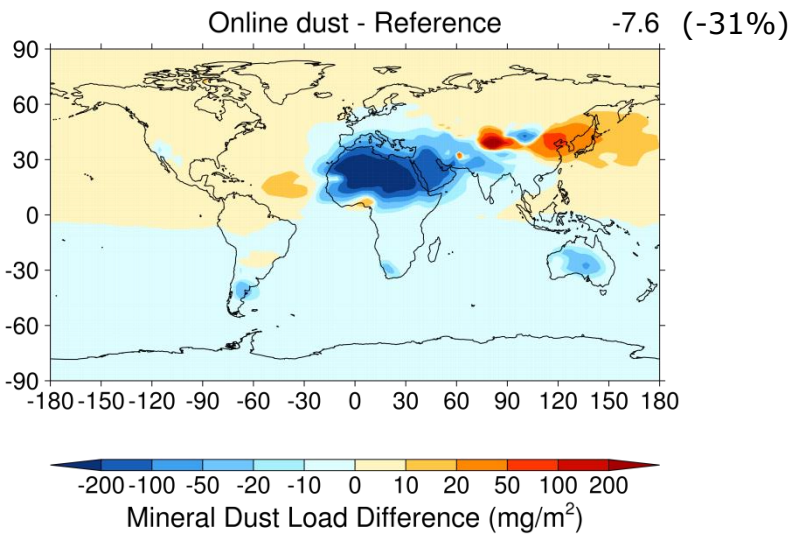
10 Tg S/yr SO_2 (Halmer et al., 2002); SO_2 fraction of 64% (Andres and Kasgnoc, 1998)

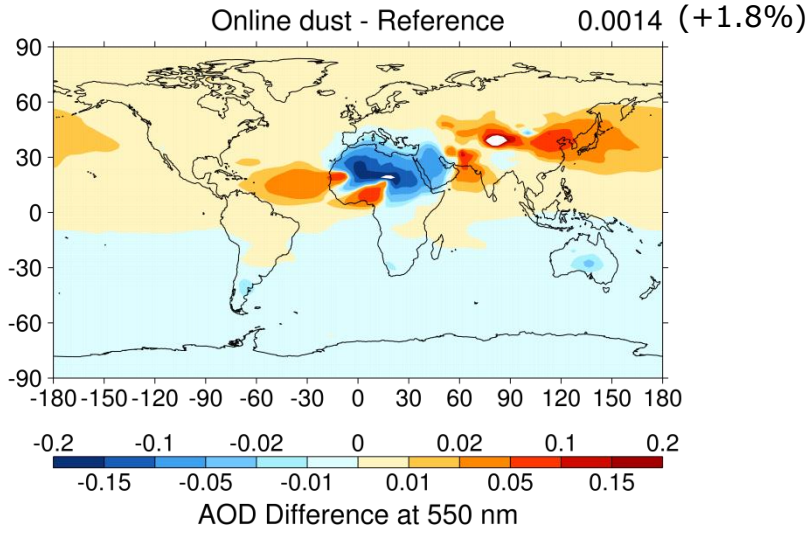




Online mineral dust emissions

Global emissions reduced from 1776 to 985 Tg/yr (-45%)





Scavenging coefficients (1)

- Coefficients for scavenging in convective systems and large-scale clouds (account for both nucleation and impaction by precipitation)
- Updated to values assumed in ECHAM

Mode	Stratiform Liquid Clouds		Stratiform Mixed Clouds	Stratiform Ice clouds	Convective Mixed Clouds	
Nucleation Soluble	0.06	0.0	0.06	0.06	0.20	1.0
Aitken Soluble	0.25	0.0	0.06	0.06	0.60	1.0
Accumulation Soluble	0.85	1.0	0.06	0.06	0.99	1.0
Coarse Soluble	0.99	1.0	0.75	0.06	0.99	1.0
Aitken Insoluble	0.20	0.0	0.06	0.06	0.20	1.0
Accumulation Insoluble	0.40	0.0	0.06	0.06	0.40	1.0
Coarse Insoluble	0.40	0.0	0.40	0.06	0.40	1.0

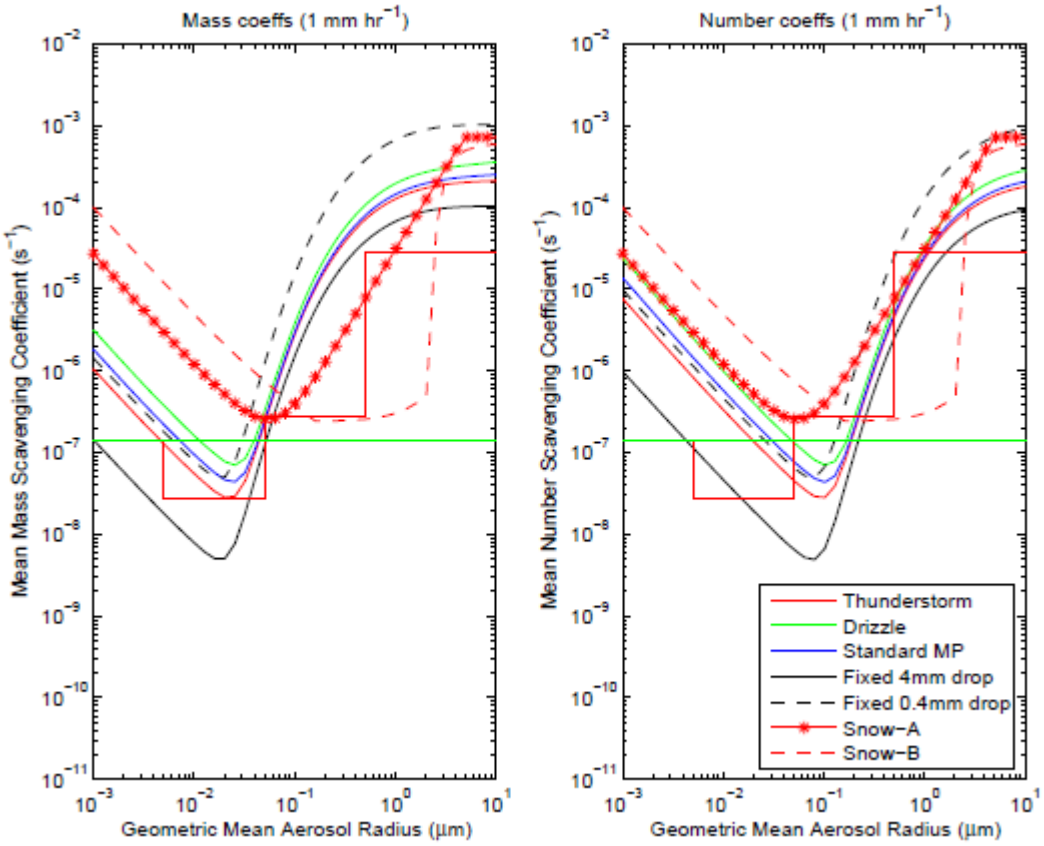
Base code

Stier et al., ACP, 2005

Bourgeois and Bey, JGR, 2011

Scavenging coefficients (2)

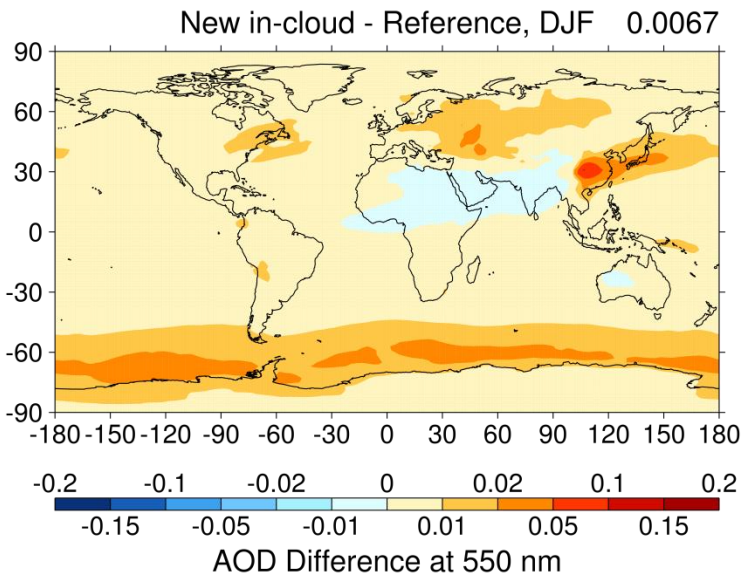
- Coefficients for below-cloud impaction scavenging by large-scale precipitation
- For mass and number concentrations per mode, based on Croft et al. (ACP, 2009)

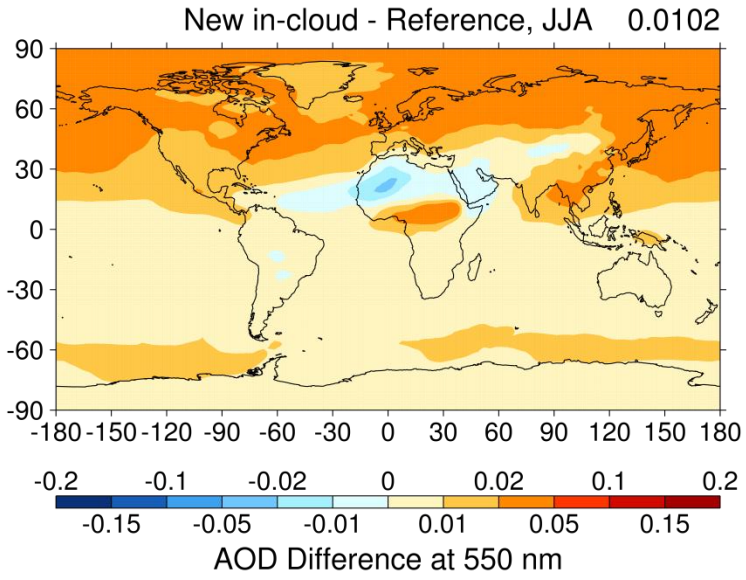


Scavenging coefficients (3)

Impact on annual/global mean AOD:

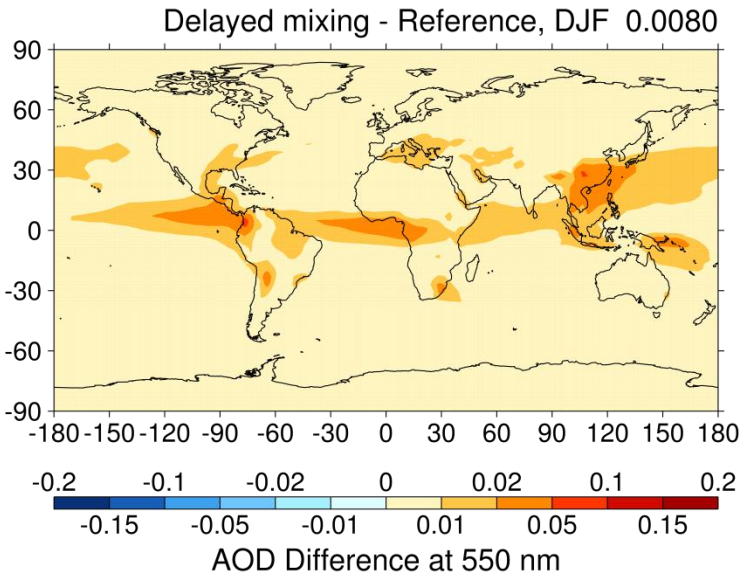
- Convective: +0.0014
- Large-scale in/below clouds: **+0.0082** / +0.0016

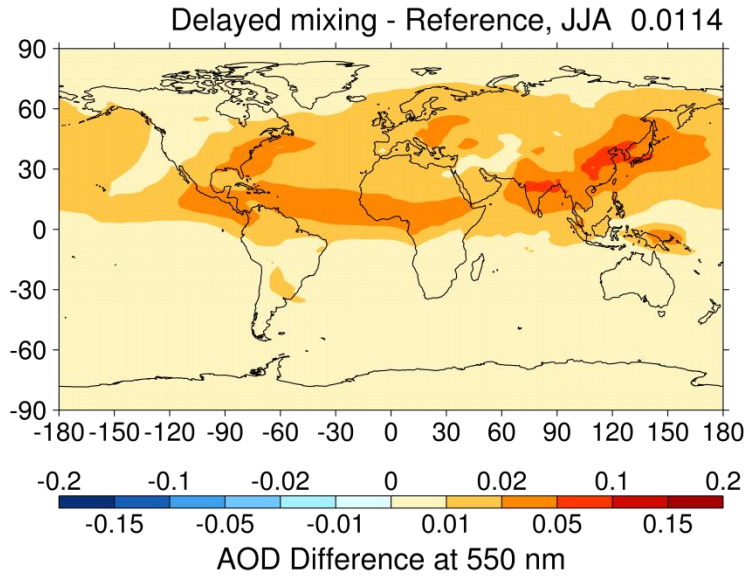




Sub-grid mixing (large-scale scavenging)

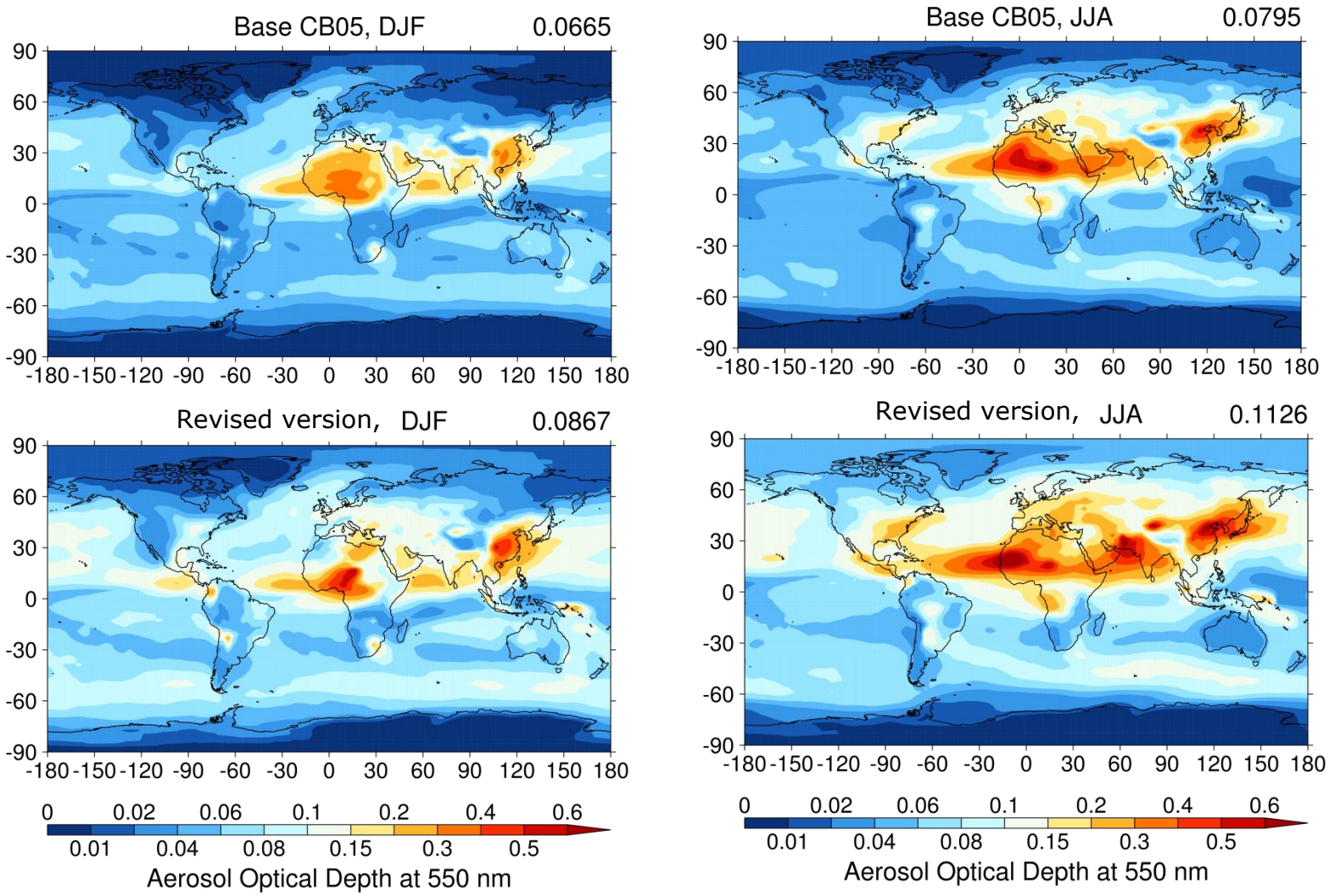
- Sub-grid mixing between air in/below precipitating clouds and free air is suppressed using a mixing time scale (thereafter 100% mixing)
- Increased from 3 to 6 h: **+0.01** in annual mean AOD



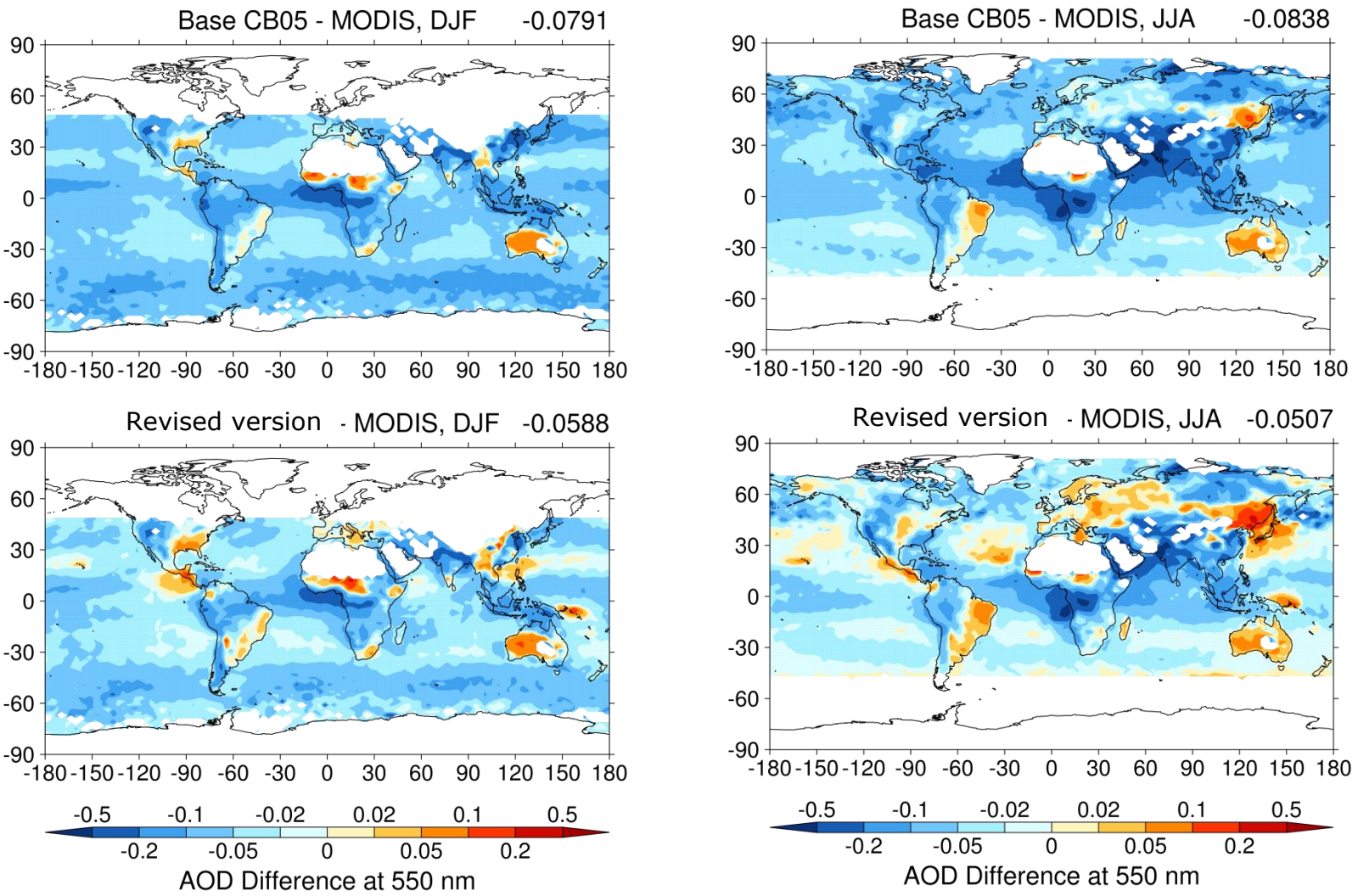


Combined effect

Annual/global mean AOD increased from 0.072 tot 0.099 (+38%)



Comparison with MODIS



Note: stratospheric AOD (~0.01-0.02) not included in model

Comparison with MACC reanalysis

Component	Base version	Revised version	MACC
Sulphate	0.0227	0.0379	0.044
Black Carbon	0.0012	0.0017	0.0085
Organic Aerosol	0.0088	0.0128	0.024
Nitrate	0.0004	0.0006	0.007 ± 0.001
Sea salt	0.0227	0.0287	0.055 ± 0.016
Mineral Dust	0.0159	0.0175	0.043 ± 0.014

Recommendations

- Review amounts and size distributions of natural emissions (mineral dust, sea salt, DMS)
- Include look-up tables for large-scale below-cloud scavening
- Test calculating below-cloud precipitating fraction as in ECHAM (Croft et al., 2009)
- Test further reduction of sub-grid mixing (e.g. 24-h time scale)
- Analyse resolution dependence (compare against 1^{o} x 1^{o} simulation)
- Review assumed particle densities
- Increase emissions of black carbon (Bond et al., 2013)
- …
- More detailed evaluation, e.g. using AERONET measurements