On-line Aerosols in the Oslo Version of CAM3: Some shortcomings

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"CAM-Oslo" extended from "CCM-Oslo"

- **Basis: NCAR CAM3 extended with**
  - **aerosol lifecycling, production-tagged composition**
  - **Particle interactions with radiation**
  - **Particle interaction with clouds**

From CCM-Oslo
(based on CCM3.2; used in AeroCom B):

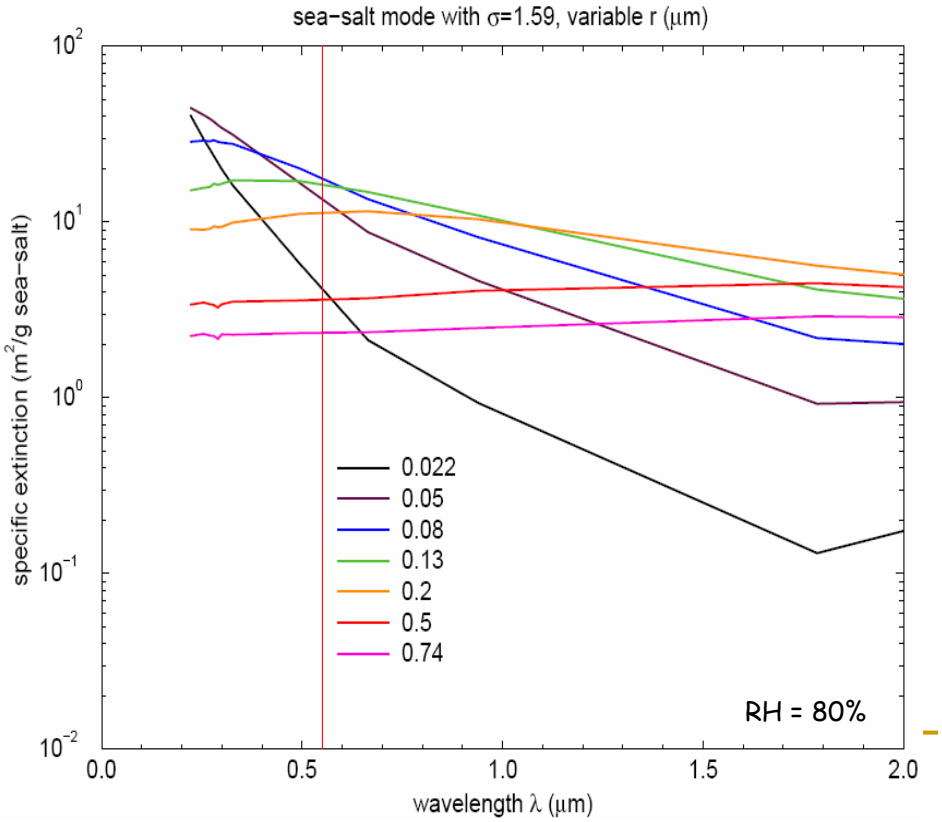
- **Sulphur and Black carbon**
  (Iversen and Seland, 2002; Kirkevåg and Iversen, 2002; Kristjansson, 2002; Kristjansson et al., 2005)
- **Particulate organic matter** (Kirkevåg et al. 2005)

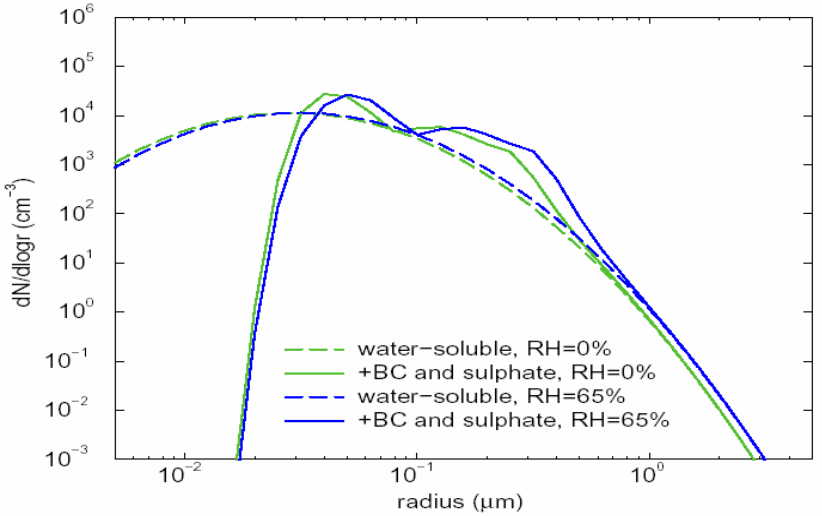
Major change to CCM-Oslo:

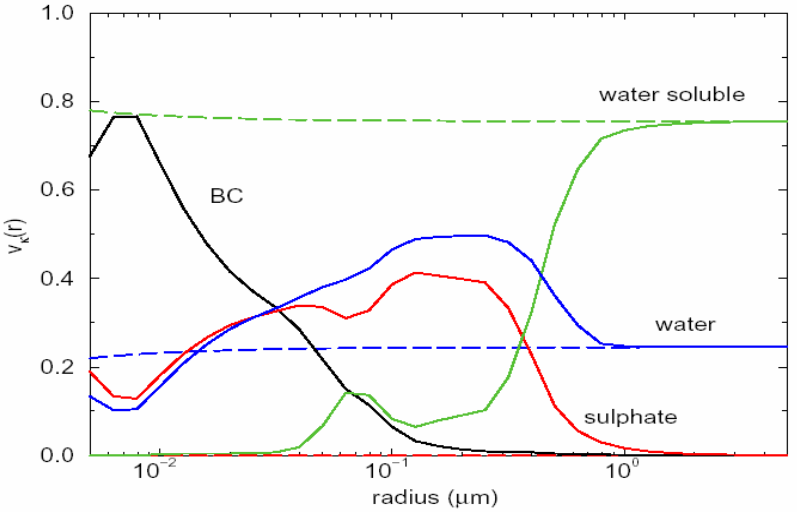
- **Lifecycling of sea-salt and mineral aerosols**
- **Aitken size category included separatly**
- **Numerous different combinations of internal mixing from condensation and coagulation**

Size, optical properties and Cloud Condensation Nuclei from precalculated tables

Mass/specific extinction coeff.
MEC = AOD/[ss-Column] (m^2/g)







Both pure atmospheric simulations and climate equilibrium calculations coupled to slab ocean

Atmosphere off-line:

run for 5 years –

the last 3 are used for analysis

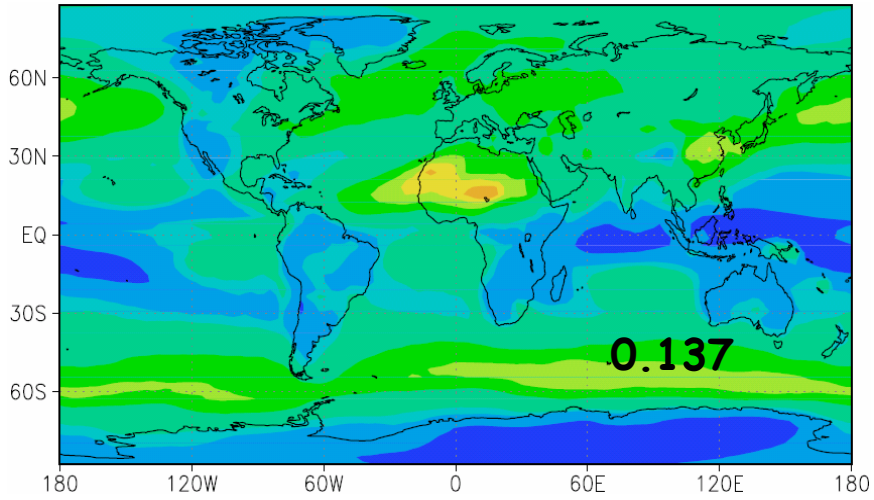
Equilibrium:

Up to 50 years simulations with first 10 years regarded as spin-up

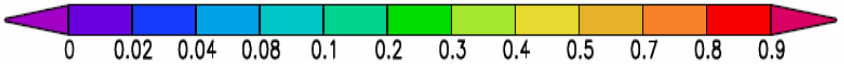
Model Evaluation Summary

- As most aerocom-models or better when compared to
  - most standard observations at ground level,
  - a few aircraft campaigns (all in Pacific Ocean)
  - Modis and MISR Satellite and aeronet retrievals of AOD and Angstrom parameter
  - Lidar vertical profiles
- Some important concerns:
  - Underestimations in tropical biomass burning regions
  - Wintertime Arctic haze underestimated
  - Very few particles in some remote regions (Pacific) (– error?)
  - Slightly positive direct aerosol forcing;
    - practically unsensitive to many uncertain assumptions
  - Indirect effects almost cancel 1.63xCO2-warming

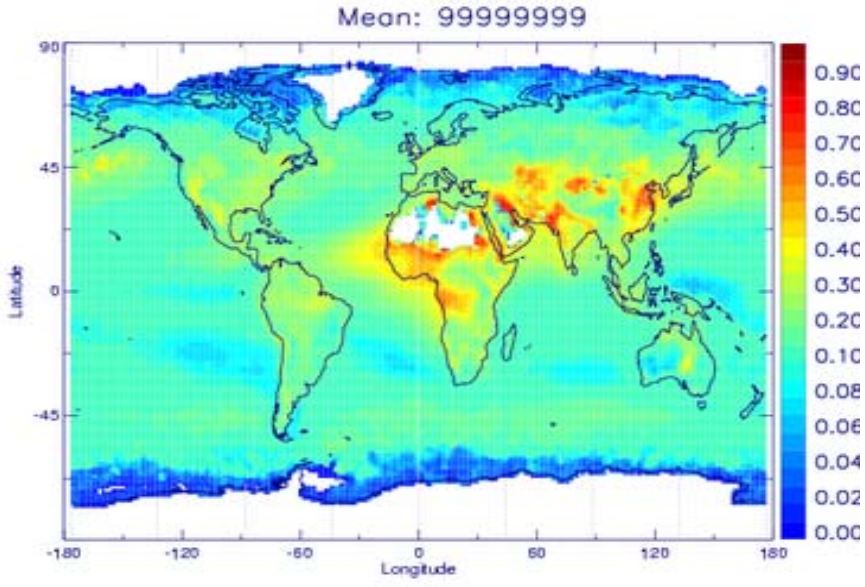
Total Aerosol Optical Depth, τ_{550}



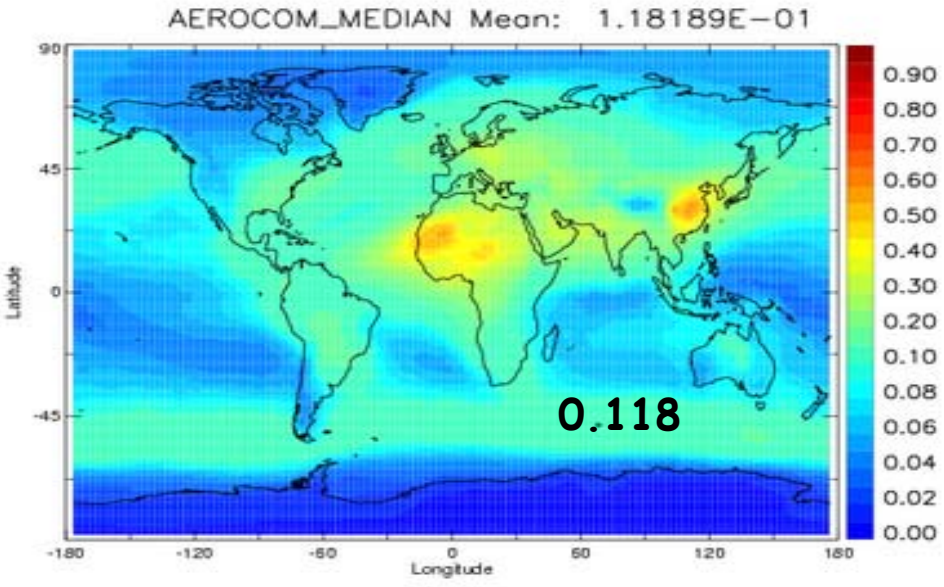
CAM-Oslo



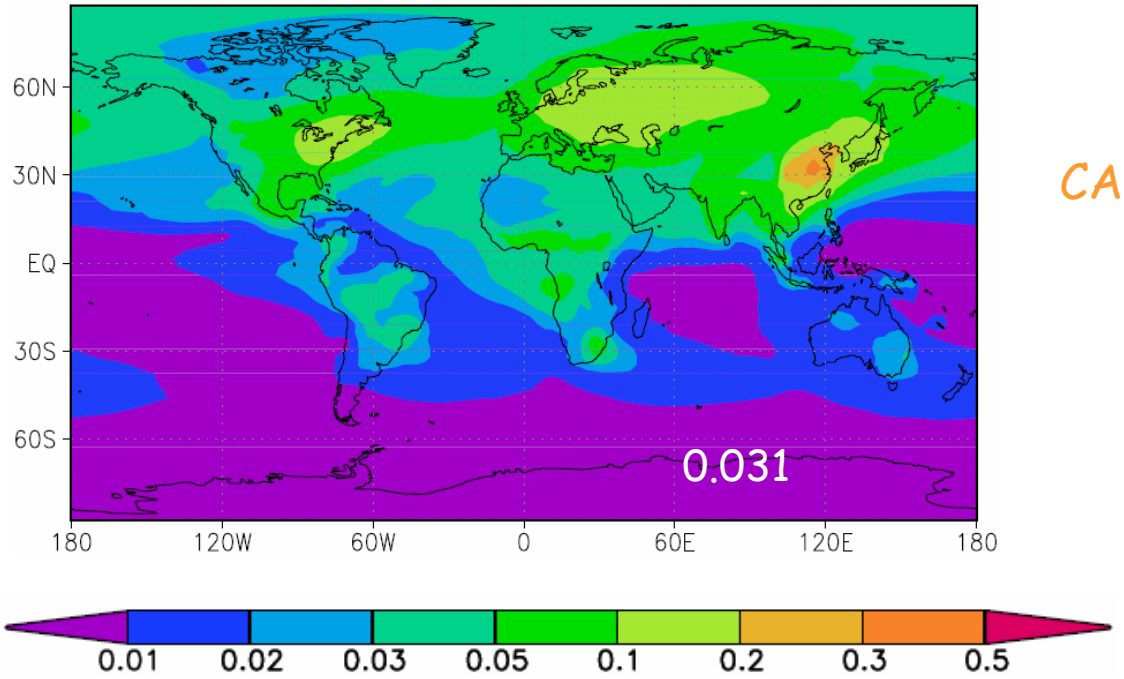
MODIS



AeroCom, Median



AOD (τ_{550}), anthrop. SO4, OC and BC
Increment from Pre-industrial to aerocomB (2000)
(B – Pre)



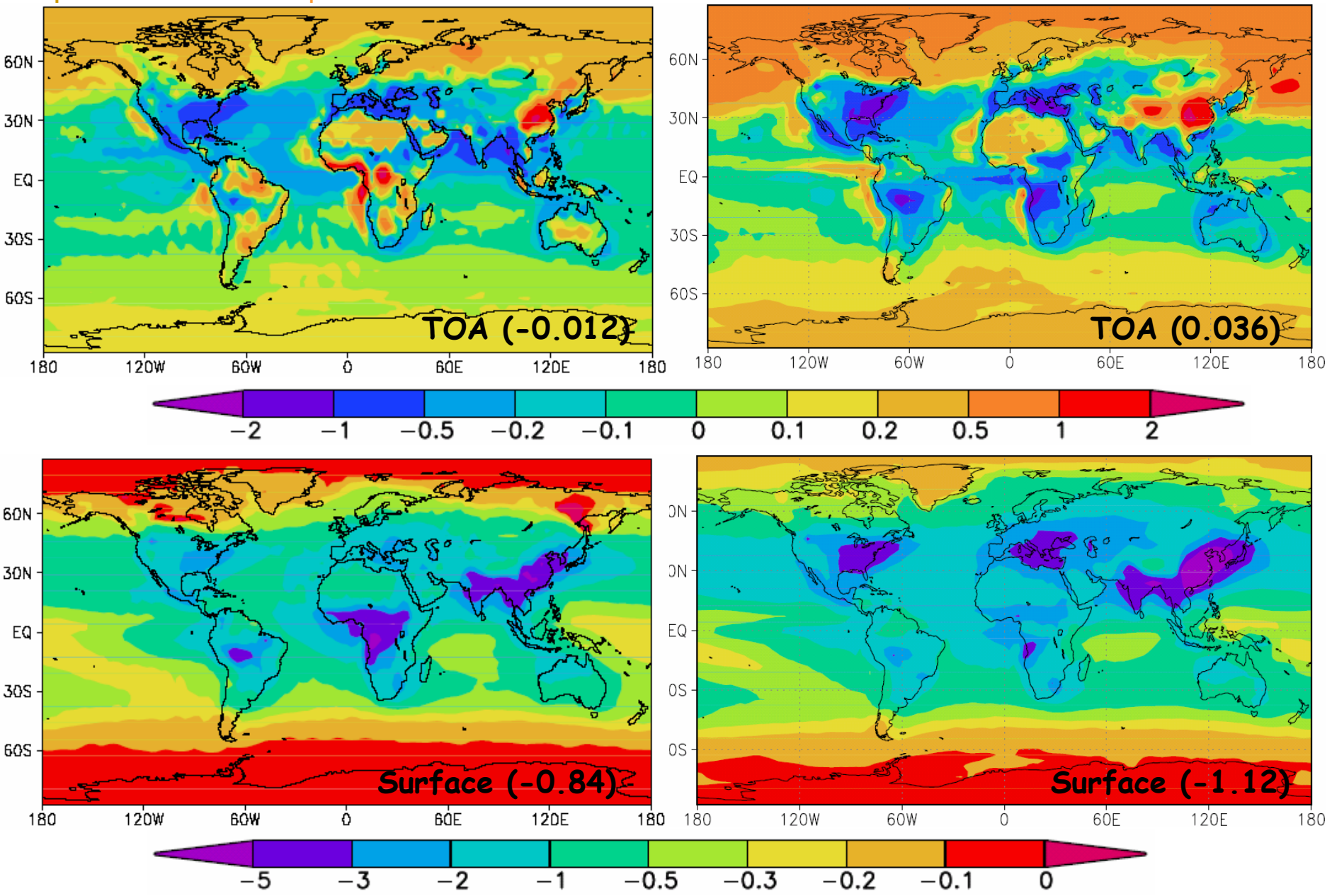
CAM-Oslo

DRF (Wm^{-2}) due to anthrop. SO4, OC and BC (aerocomB – Pre)

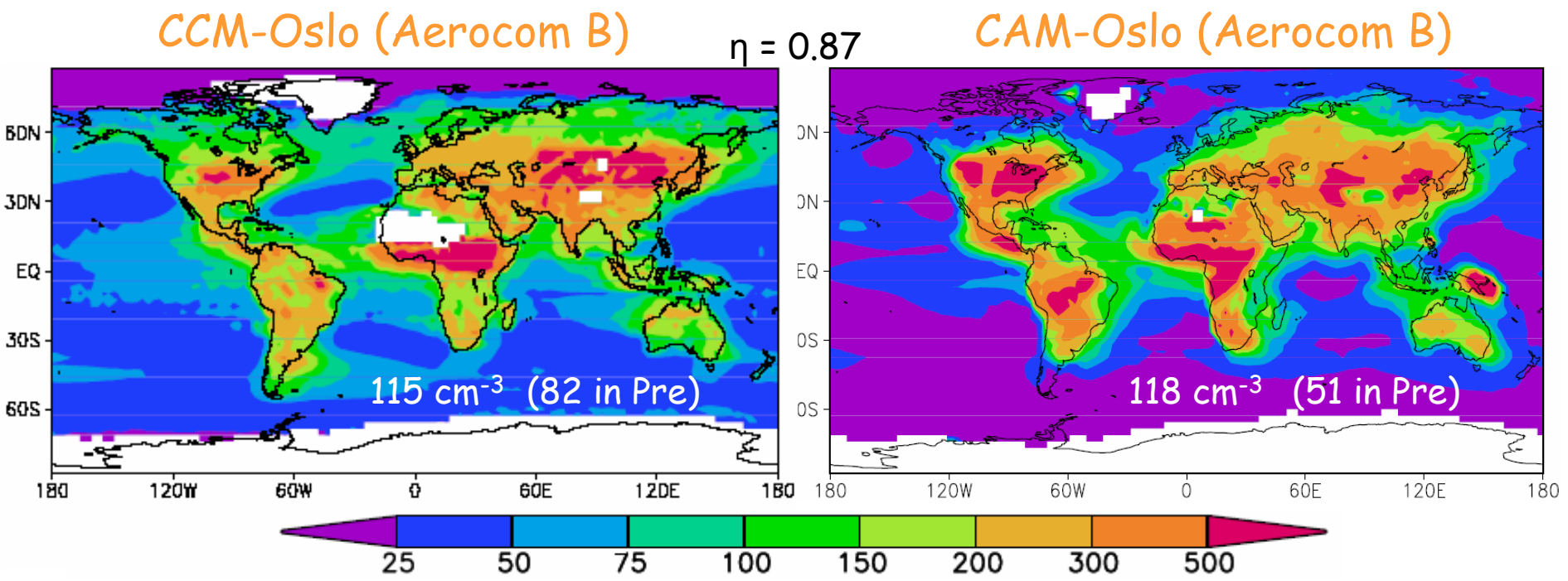
CCM-Oslo

Sea-salt and dust prescribed

CAM-Oslo



Cloud droplet number concentrations, **CDNC** (cm^{-3})



below ca. 870 hPa	CAM3, prescribed	CAM-Oslo, Diagnostic	Observations (Seinfeld and Pandis, 1997; Ghan et al., 1997)
Marine	~ 150 ~ 75 (sea-ice)	~ 5 - 200	~ 20 - 200
Continental	~ 200 - 400	~ 20 - 1000	~ 100 - 1000

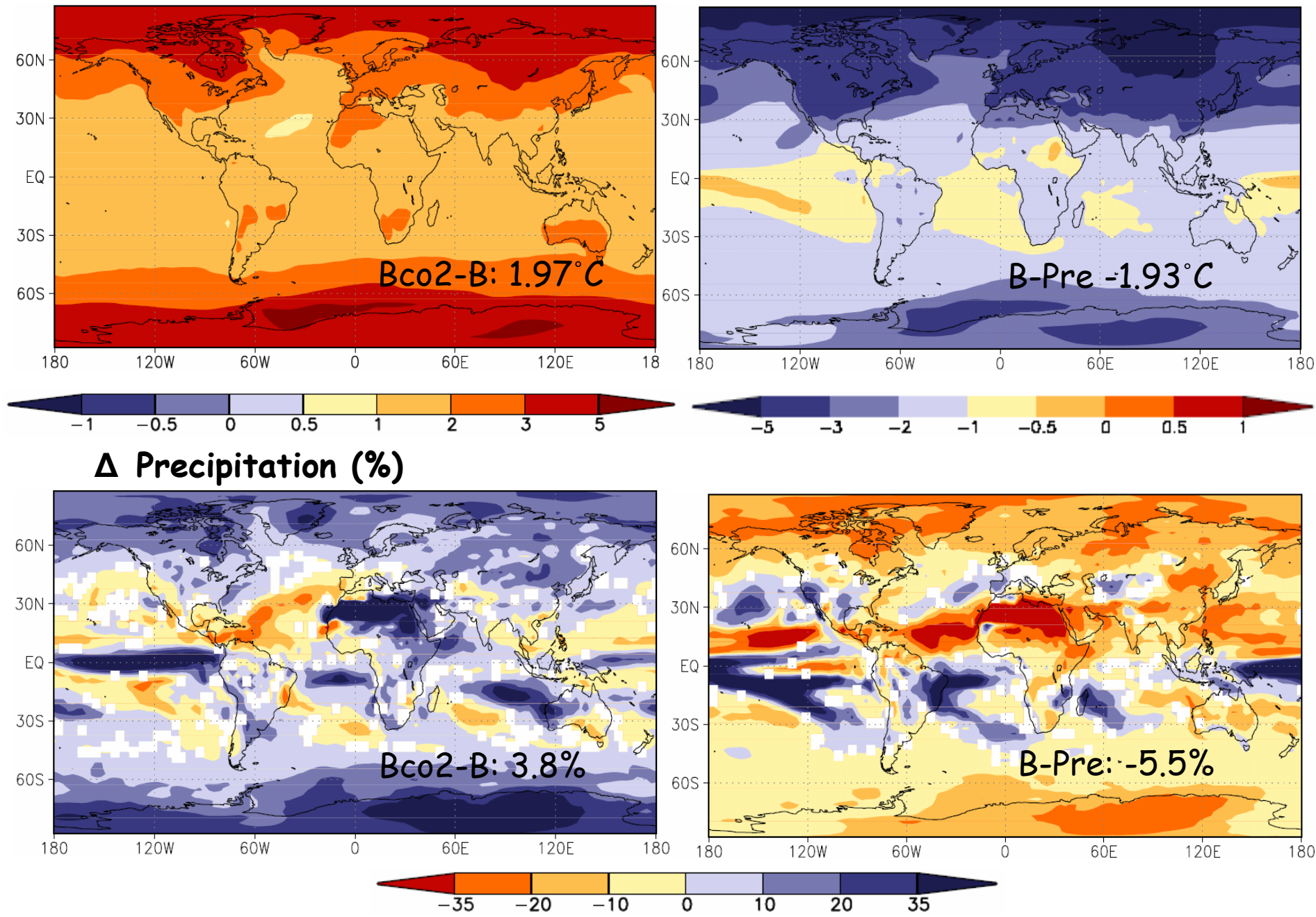
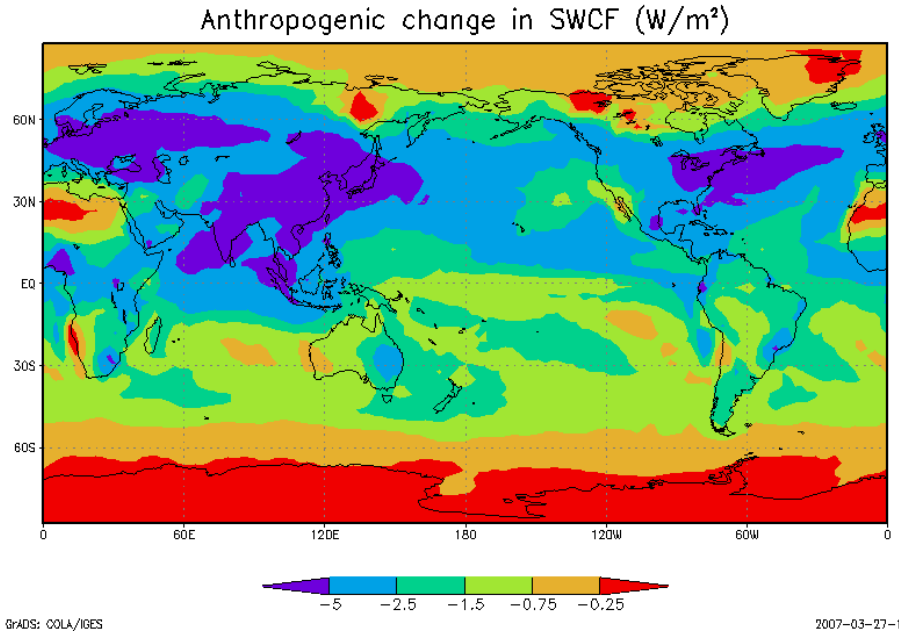

Δ T_{2m} (˚C)
1.63 x CO_2
vs.
anthropogenic aerosols
Bco2-B: 1.97˚C
B-Pre -1.93˚C
Δ Precipitation (%)
Bco2-B: 3.8%
B-Pre: -5.5%
60N
30N
EQ
30S
60S
180
120W
60W
0
60E
120E
−1
−0.5
0
0.5
1
2
3
5
−5
−3
−2
−1
−0.5
0
0.5
1
−35
−20
−10
0
10
20
35

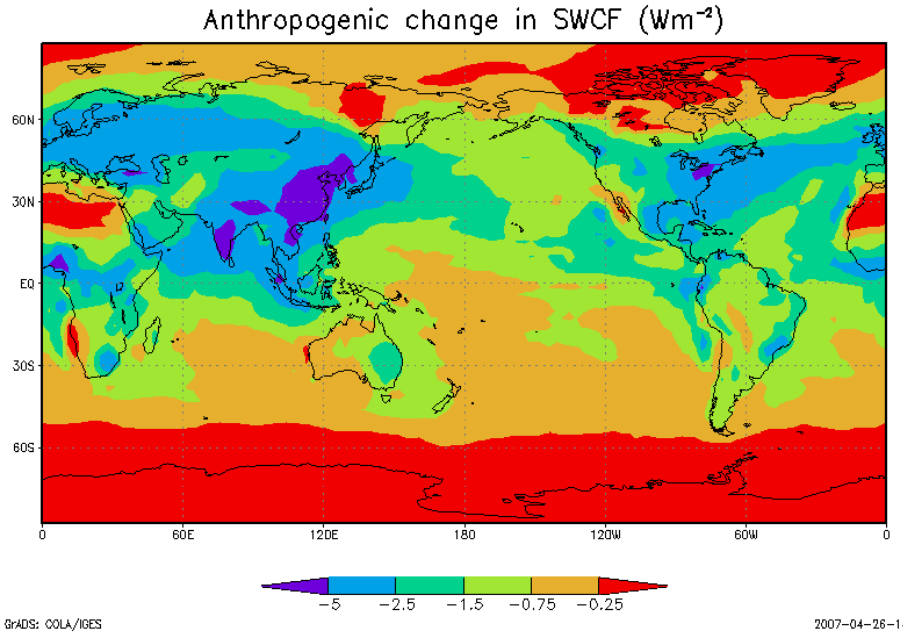
Table 5: Experiments with CAM-Oslo run as an atmospheric GCM, testing the sensitivity to background droplet number concentrations (CDNC). Changes in liquid water path (LWP), effective cloud droplet radii as seen from satellite ($R_{effl\text{-}S}$: as in Kristjánsson, 2002), as well as the combined first and second indirect forcing by anthropogenic aerosols (since pre-industrial time) are global annual means.

CDNC treatment	Change in LWP ($g\ m^{-2}$)	Change in $R_{effl\text{-}S}$ (μm)	$1^{st} + 2^{nd}$ Indirect Forcing ($W\ m^{-2}$)
Standard CDNC	9.25	-1.41	-2.34
Standard CDNC + 15 cm^{-3}	5.09	-0.99	-1.36

STD CDNC



STD CDNC + 15 cm^{-3}



What's missing?

- Improved cloud droplet budgets
  - Storelvmo et al (2006), based on droplet scheme of Ghan and Abdul-Raszak et al, reduced indirect effect from -1.1 to -0.1 W m^{-2}
- Ice-cloud effects
- Nitrate aerosols
- Primary aerosols:
  - Non-desert, dust-producing areas underestimated
  - No primary biological particles

Thank You

Aerosol optical depth and direct radiative forcing:

Exp.	AOD (B)	AOD (B) SO4	AOD (B) POM	AOD (B) BC	AOD (B) Sea-salt	AOD (B) Dust	DRF (B-Pre) (W/m^2) Surface	TOA,
E1	0.138	0.0238	0.0217	0.0018	0.0704	0.0203	-1.13	0.036
E2	0.136	0.0205	0.0222	0.0018	0.0706	0.0206	-1.15	0.080
E3	0.107	0.0244	0.0224	0.0019	0.0375	0.0205	-1.15	0.027
E4	0.140	0.0248	0.0212	0.0018	0.0716	0.0203	-1.12	0.027

E1: Base run

E2: 75nm SO4 primary acc. mode → H2SO4 gas

E3: standard Aerocom sea-salt

E4: 0.1% ss_coarse re-allocated to ss_aitken

Acknowledgement and references

- Acknowledgement
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- References

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  - Iversen and Seland(2002) JGR 107 D24 4751;
  - Mårtensson et al (2003) JGR 108 D9 2397
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  - Stier et al (2005) ACP 5, 1125-1156
  - Textor et al. (2005) ACP 5 8331-8420;

Lognormal externally mixed modes (Primary "Background")
Basis for Condensation and Coagulation

modes	modal median radius (μm)
SO_4(n), BC(n)	0.0118
OC(Ait)	0.04
BC(ac)	0.1 ("fluffy" fractal)
BC(Ait)	0.04
OCBC(Ait)	0.04
SO4(ac)	0.075
MINERAL	0.22, 0.63
SEA-SALT	0.022, 0.13, 0.76

For internal mixtures involving Sulfate, OC and BC:

- ✓ SO_4 from condensation
- ✓ SO_4 from cloud processing
- ✓ BC from coagulation
- ✓ OC from coagulation

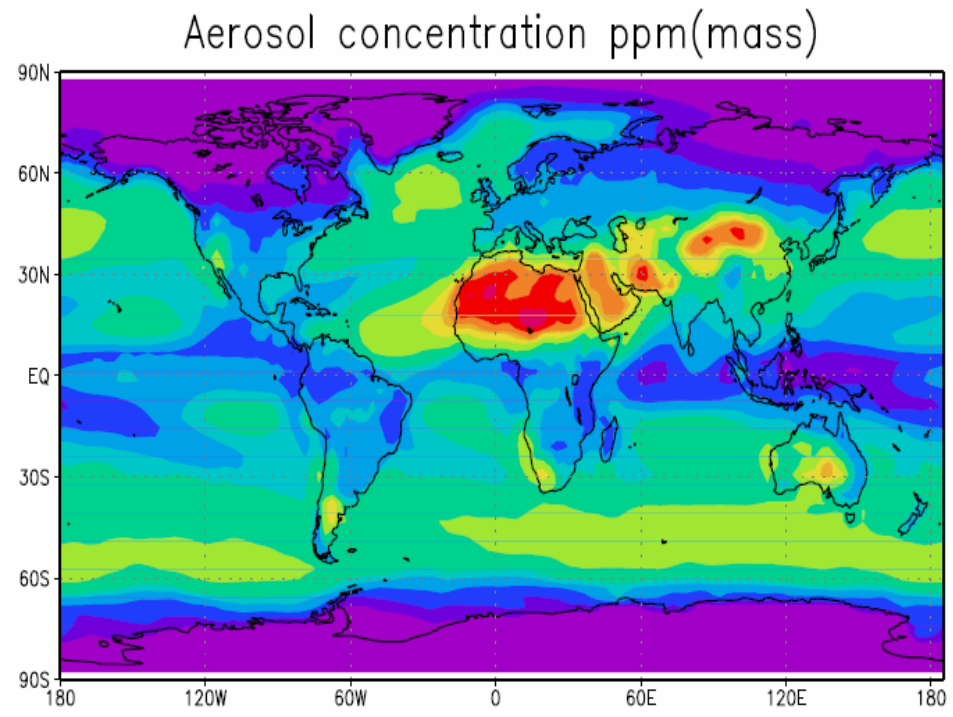
onto mode →

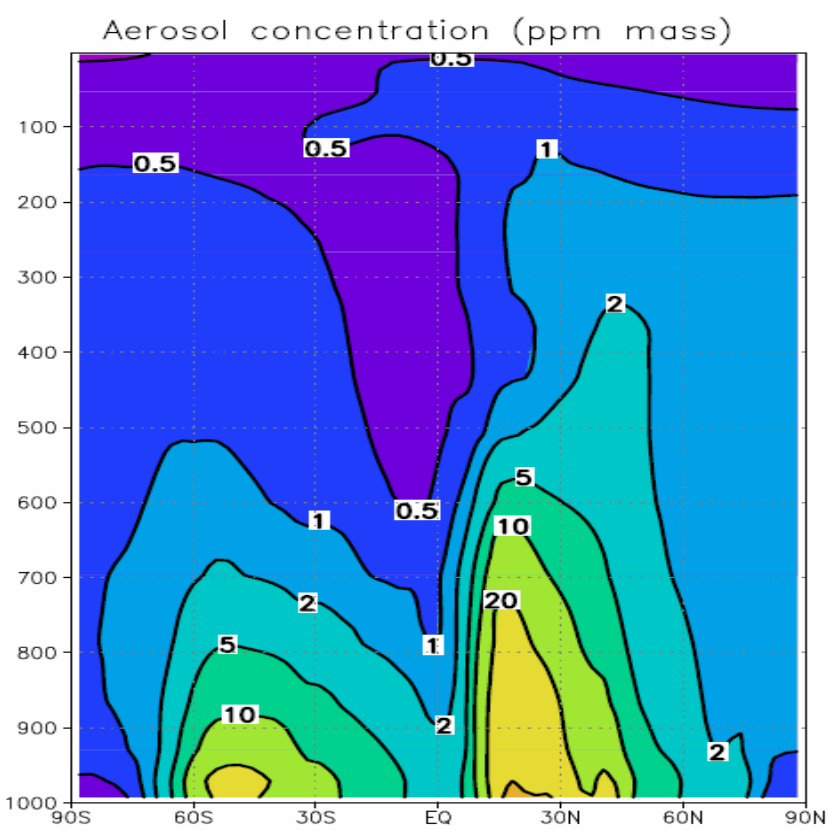
all pre-existing particles (ex. BC(ac))
min. & ss. & Ait & a modes
min. & ss. modes
min. & ss. modes

These processes, the optical properties, and the Kohler growth
Are tabulated in CAM3, based on process specific aerosol concentrations

Total mass concentrations / ppm(mass)

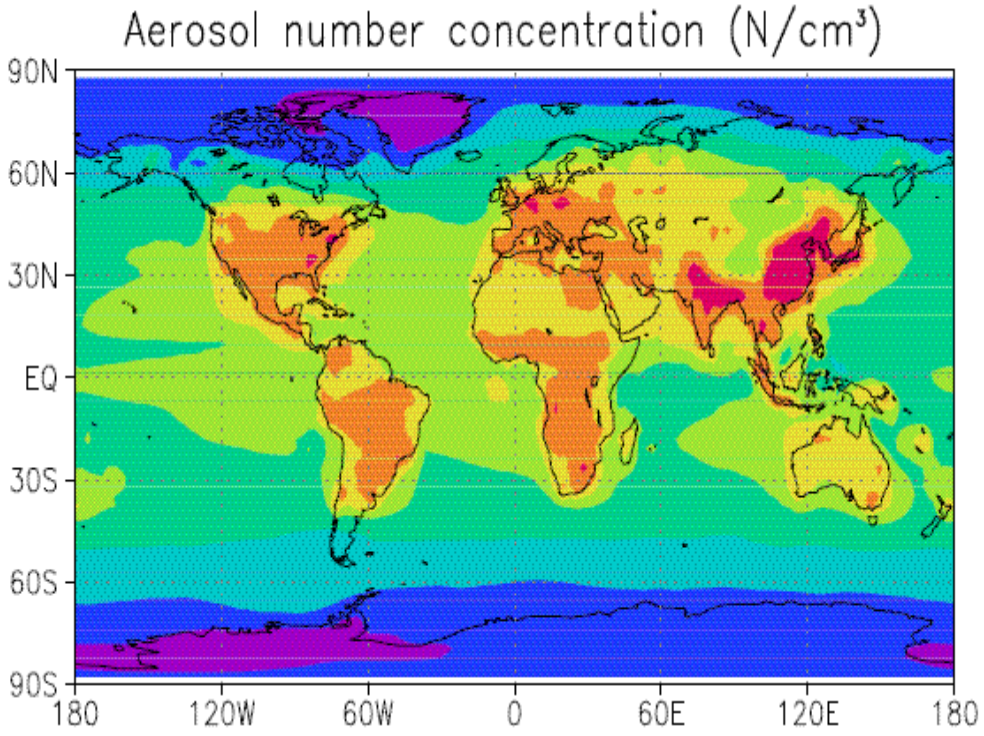
Lowest model surface

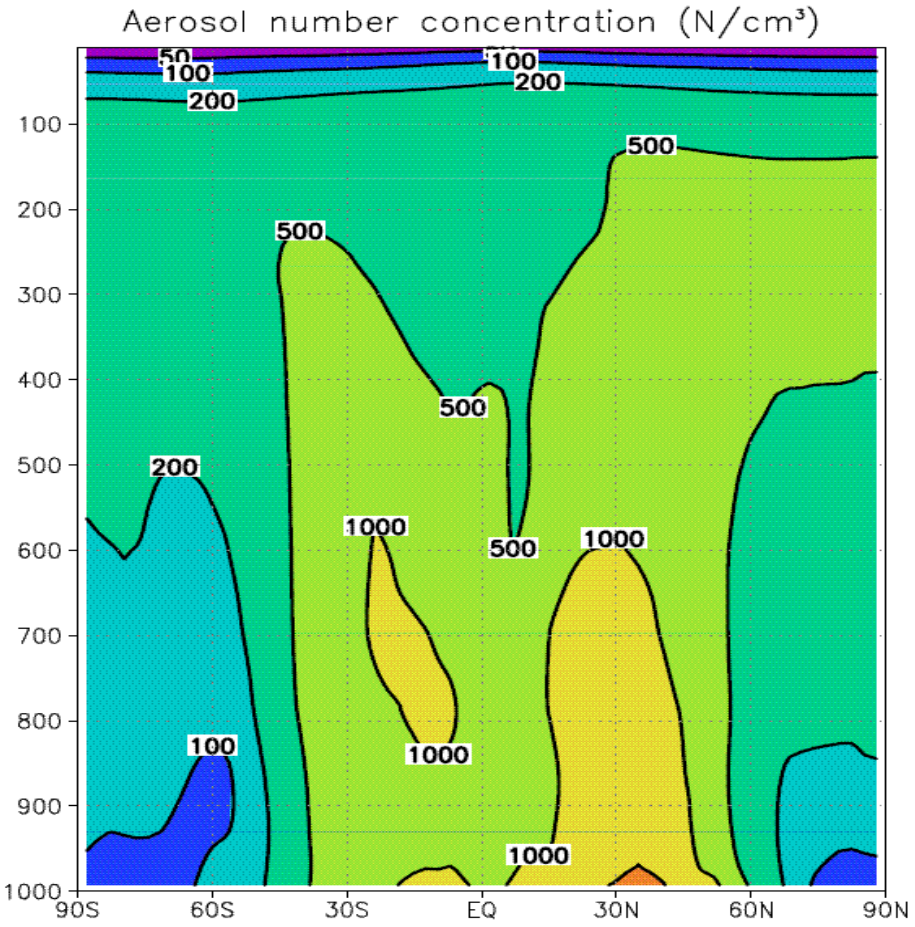


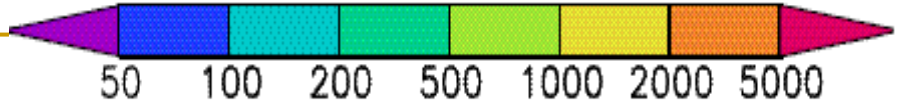


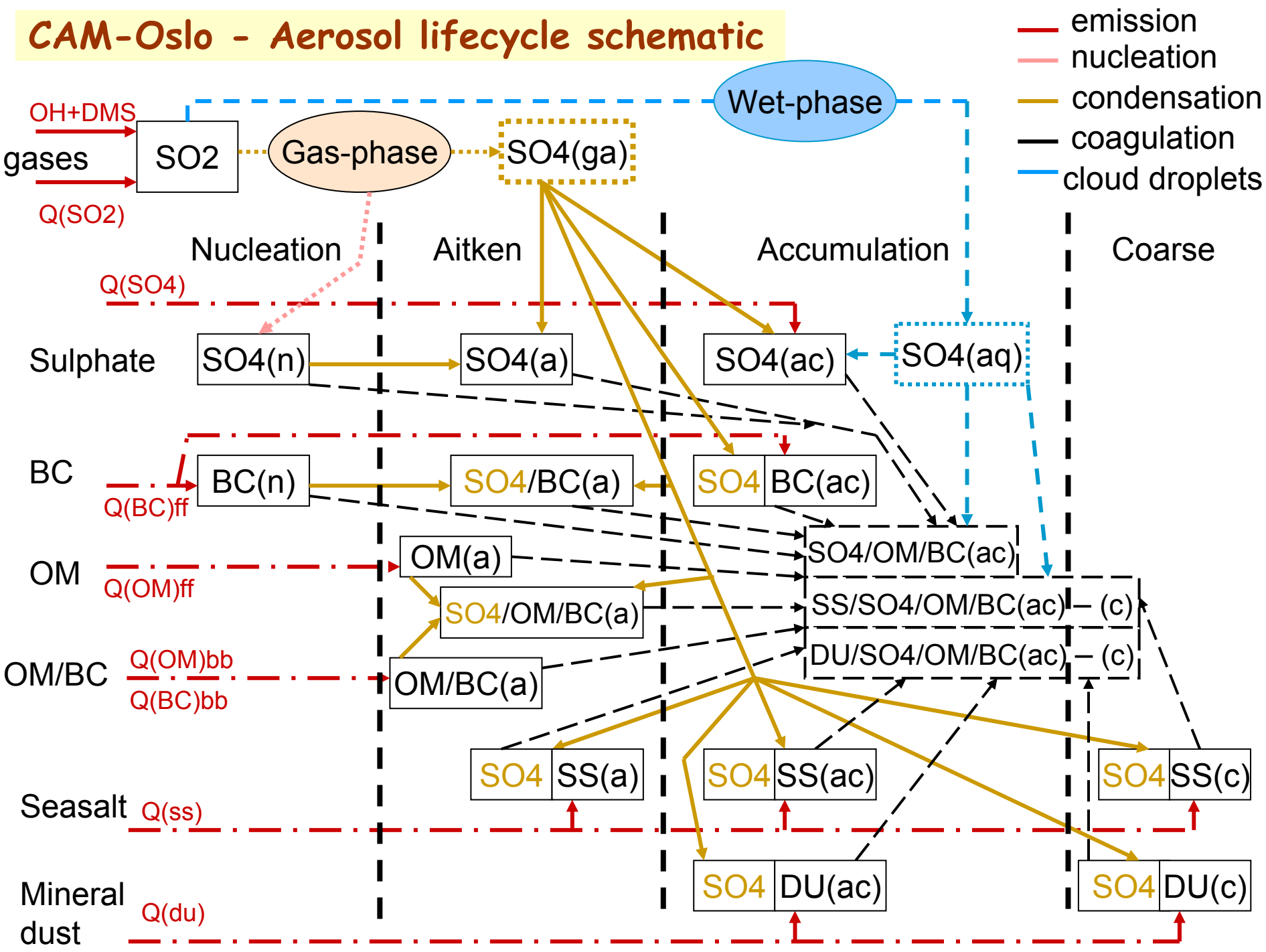
Total number concentrations / cm^{-3}

Lowest model surface








CAM-Oslo - Aerosol lifecycle schematic
emission
nucleation
condensation
coagulation
cloud droplets
Wet-phase
OH+DMS
gases
SO2
Q(SO2)
Gas-phase
SO4(ga)
Nucleation
Aitken
Accumulation
Coarse
Q(SO4)
Sulphate
SO4(n)
SO4(a)
SO4(ac)
SO4(aq)
BC
Q(BC)ff
BC(n)
SO4/BC(a)
SO4 BC(ac)
SO4/OM/BC(ac)
OM
Q(OM)ff
OM(a)
SO4/OM/BC(a)
SS/SO4/OM/BC(ac) – (c)
DU/SO4/OM/BC(ac) – (c)
OM/BC
Q(OM)bb
Q(BC)bb
OM/BC(a)
SO4 SS(a)
SO4 SS(ac)
SO4 SS(c)
Seasalt
Q(ss)
SO4 DU(ac)
SO4 DU(c)
Mineral dust
Q(du)