Parameterized aerosol optics and cloud droplet properties in CCM-Oslo.

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4'th AeroCom workshop in Oslo, June 15-17'th, 2005.

Outline

- CCM-Oslo (in Aerocom B & Pre)
  - parameterizations of aerosol optics and cloud droplet properties
  - OD comparison with satellite and AERONET retrievals
  - simulated cloud droplet properties and indirect forcing
- CCM-Oslo vs. CAM-Oslo (preliminary results)
  - prescribed -> prognostic mineral & seasalt aerosols
  - effect of assumed modal radii on mass extinction coefficients (MEC)
  - direct forcing estimates
- Some conclusions

CCM-Oslo: NCAR CCM3.2 (T42, L18) extended with:

- Prognostic cloud water: Rasch P. J., and Kristjánsson, J. E., 1998. *J. Climate*, **11**, 1587.
- Aerosol life-cycle: Iversen, T., and Seland, Ø., 2002. *J. Geophys. Res.*, **107** (D24), 4751.

  + Revised convective transport and deposition (Seland & Iversen, 2005, paper in prep.)

- Direct effect, aerosol size distributions and optical properties: Kirkevåg, A., and Iversen, T., 2002. *J. Geophys. Res.*, **107** (D20), 4433.
- Indirect effect: Kristjánsson, J. E., 2002. *J. Geophys. Res.*, **107** (D15), 4246.

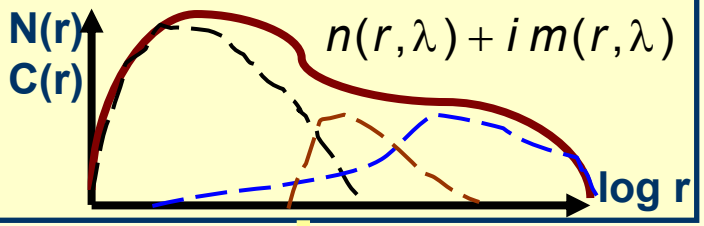
+ Revised schemes for aerosol optical parameters and cloud condensation nuclei in CCM-Oslo: Kirkevåg, A., Iversen, T., Seland, Ø., and Kristjánsson, J. E., 2005. *Institute technical report, No. 128.* (http://folk.uio.no/kirkevag/instrep128_Kirkevag-etal.pdf)

PRINCIPLE:

Background aerosol
+ SO_4, BC, OC, Rh

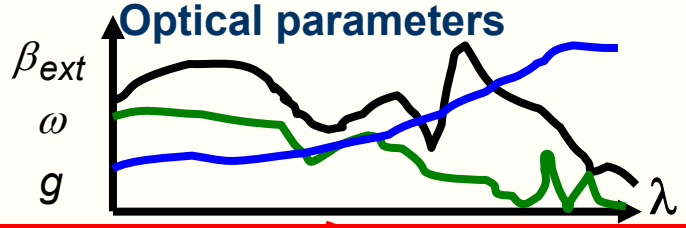
Cond., coag. & cloud processing
Continuity eq. → N(r) and C(r)

Size distribution and composition



Mie theory

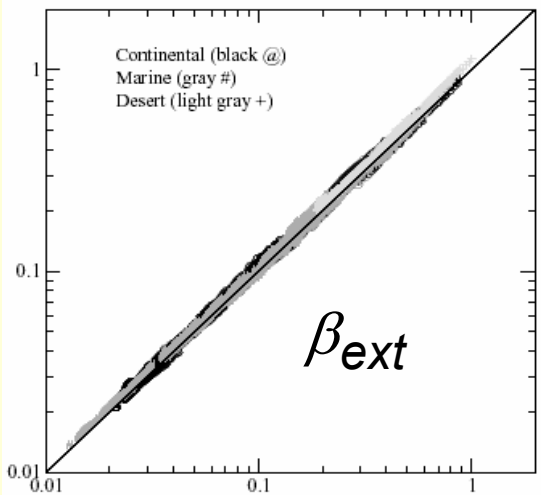
Optical parameters

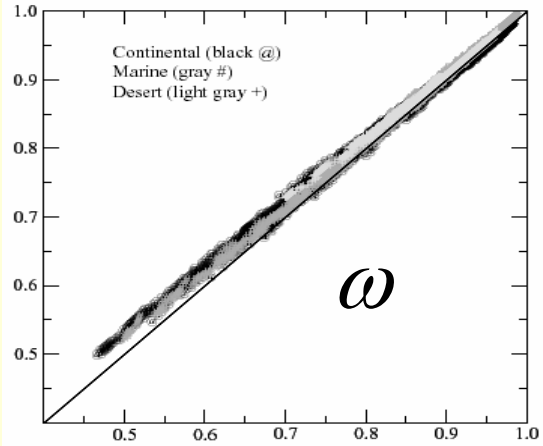


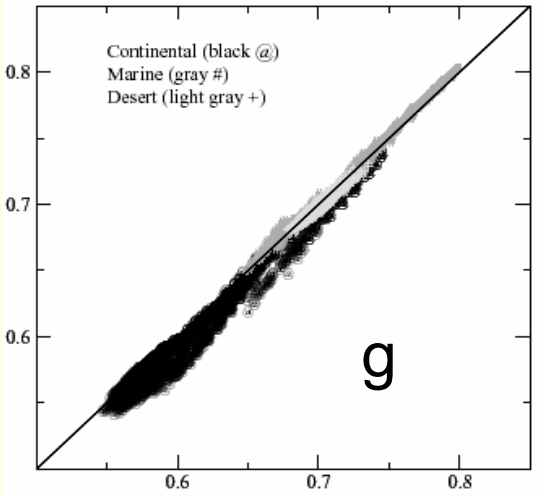
Tabulations

Radiative
Forcing, W/m²

Scheme for
parameterized
Optical
parameters





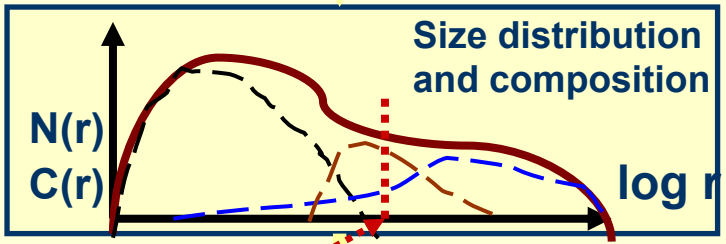


PRINCIPLE:

Scheme for parameterized Cloud parameters

Background aerosol + SO_4, BC, OC, S

Cond., coag. & cloud processing
Continuity eq. → N(r) and C(r)



Tabulations

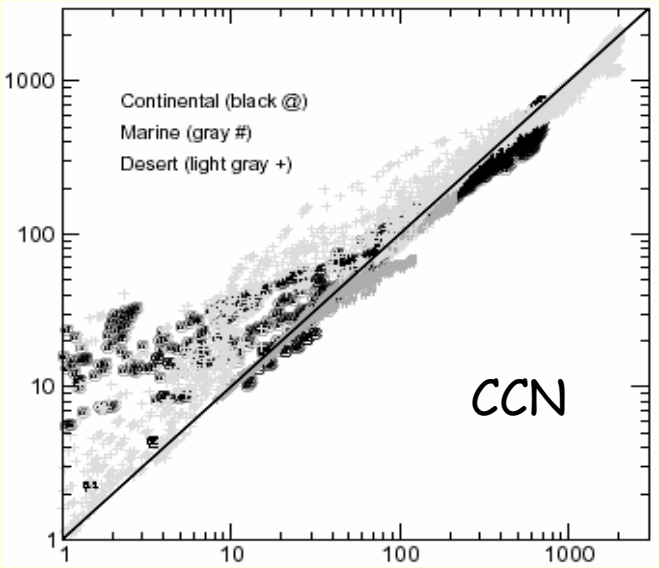
r_s

Köhler theory

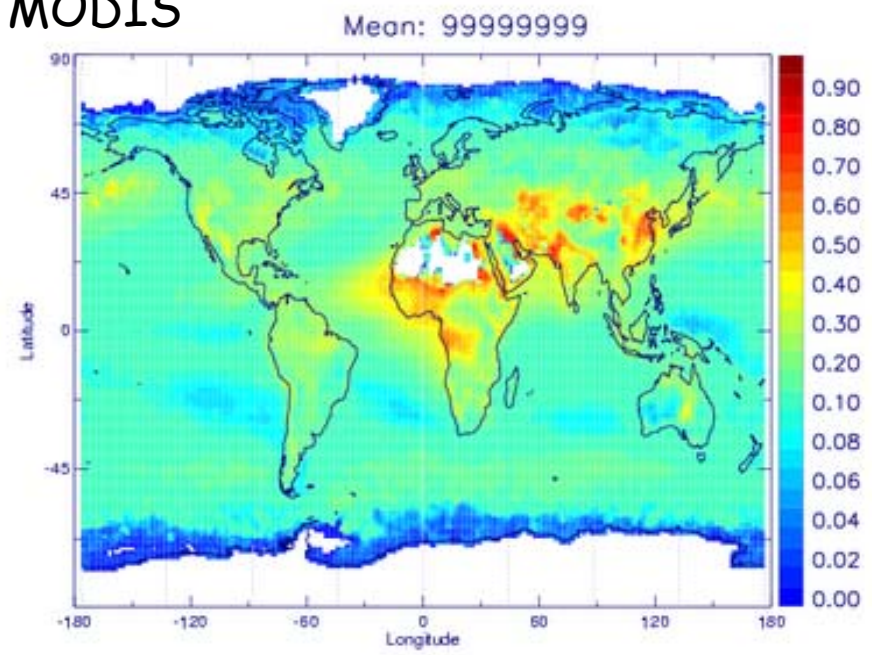
$$CCN(S) = \sum_k \int_{r_S}^{\infty} \frac{dN_k}{d\log r} d\log r$$

Clouds and Precip.

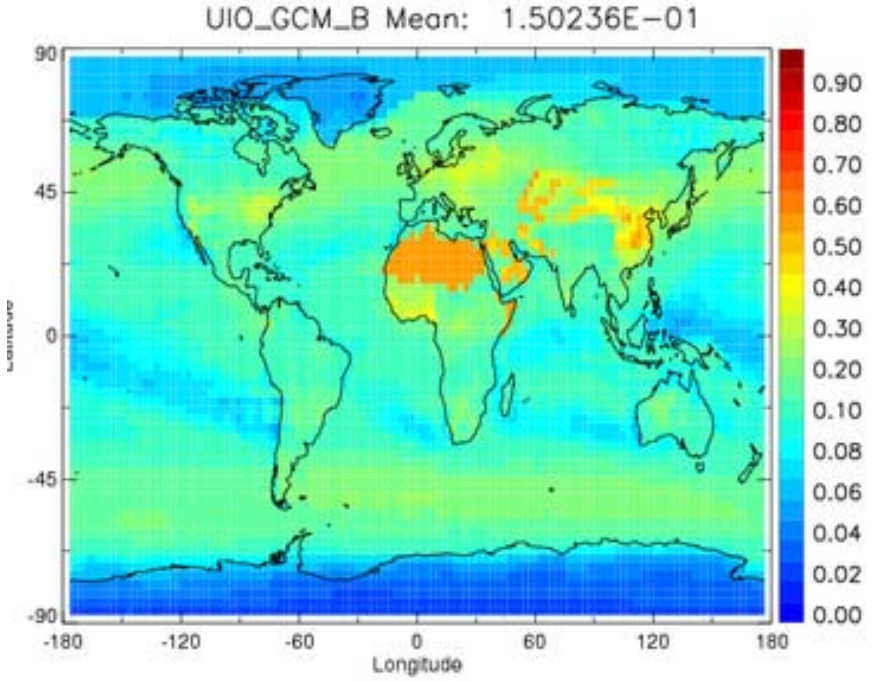
Radiative Forcing, W/m^2



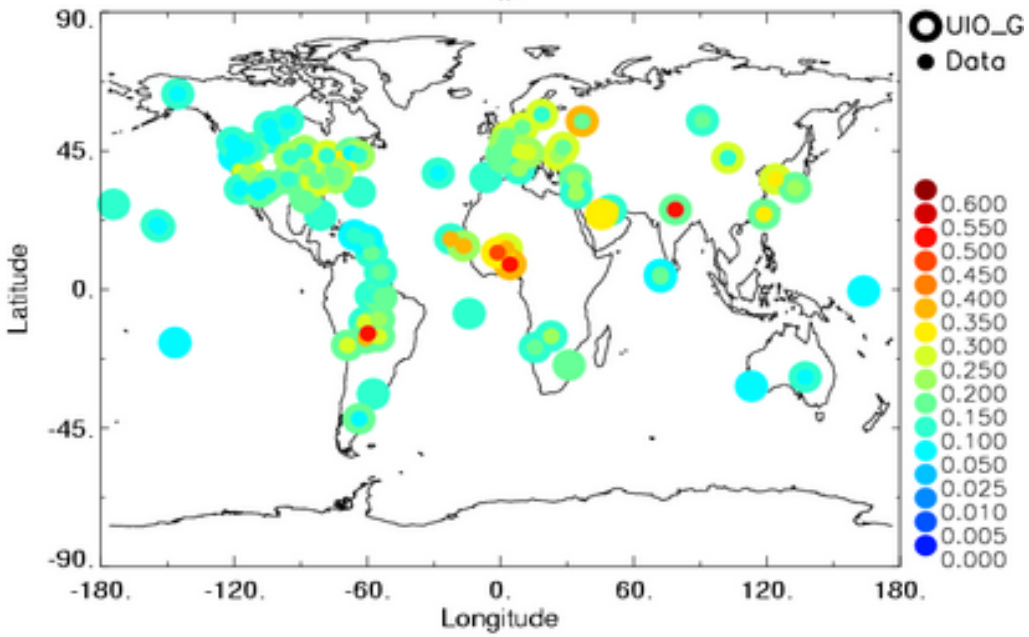
MODIS

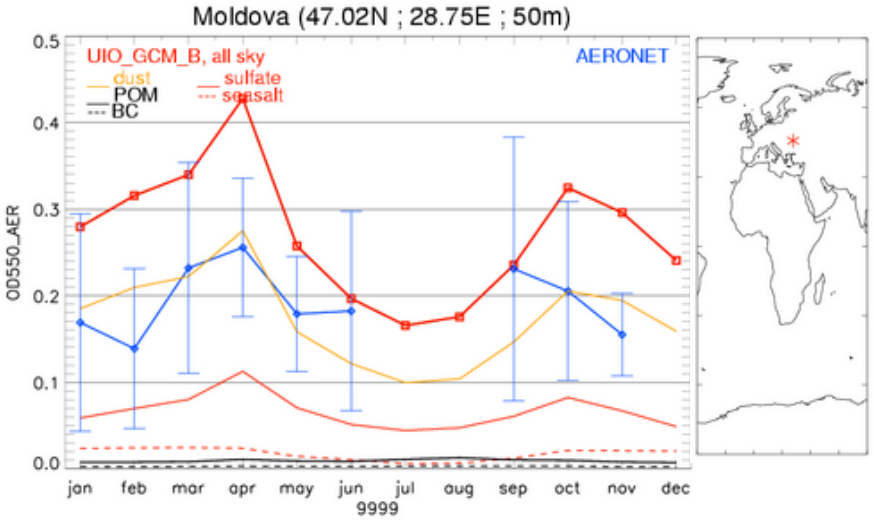


CCM-Oslo in AEROCOM B:

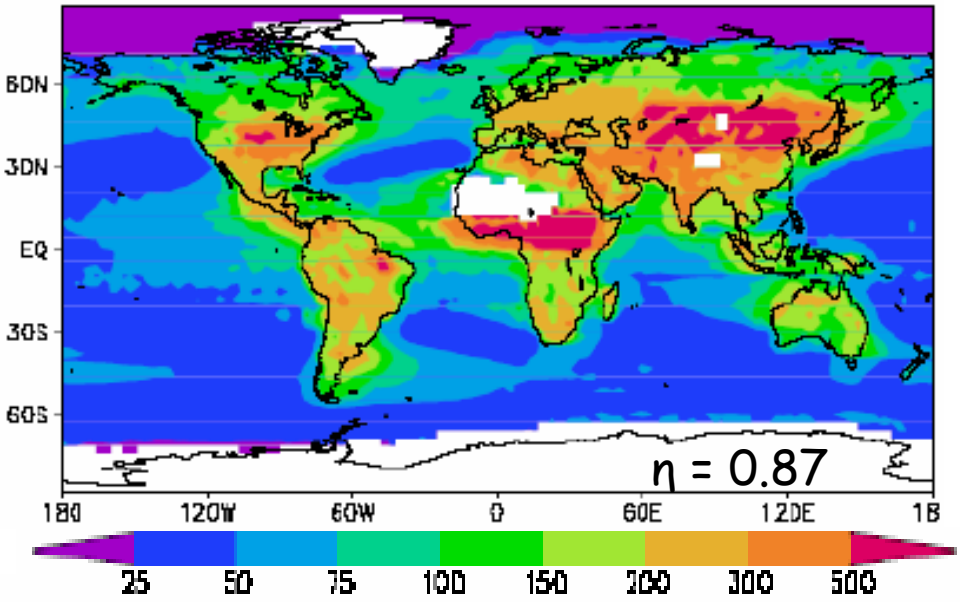


AERONET

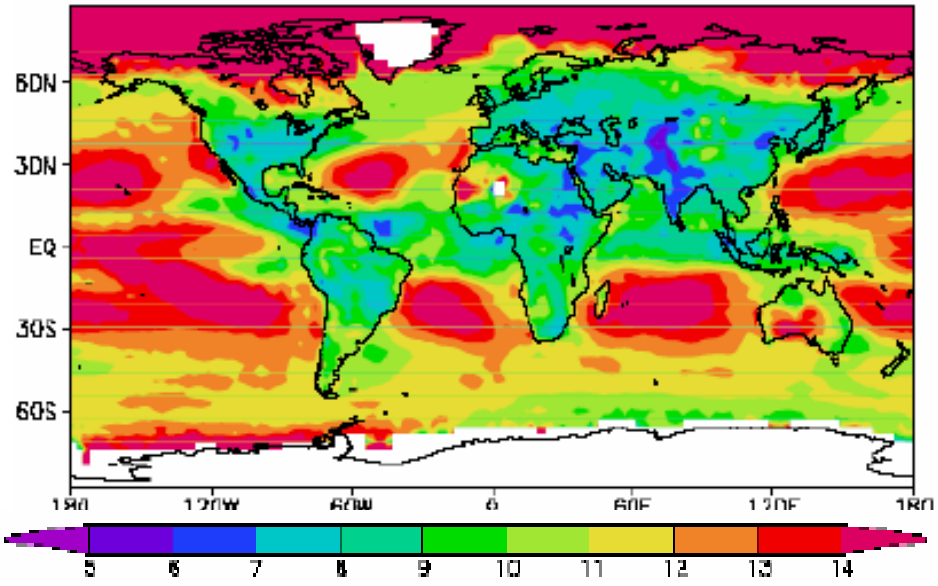




CDNC (cm^{-3})

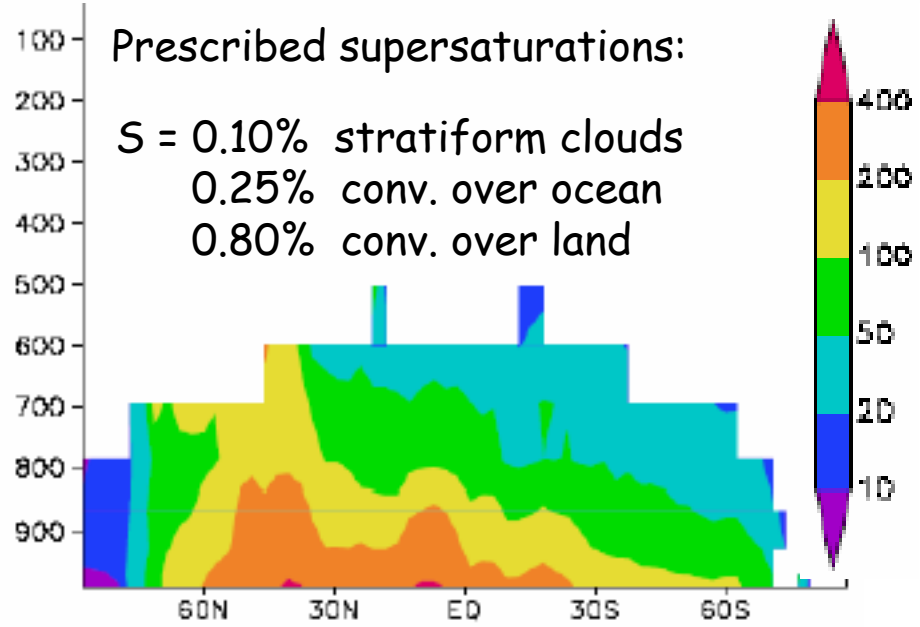


Effective droplet radii, r_{eff} (μm), as seen from satellite

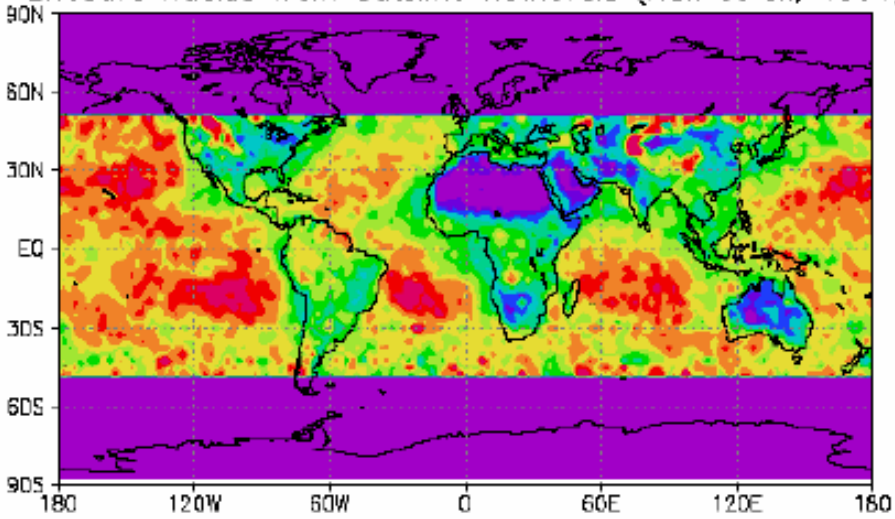


Prescribed supersaturations:

S = 0.10% stratiform clouds
0.25% conv. over ocean
0.80% conv. over land

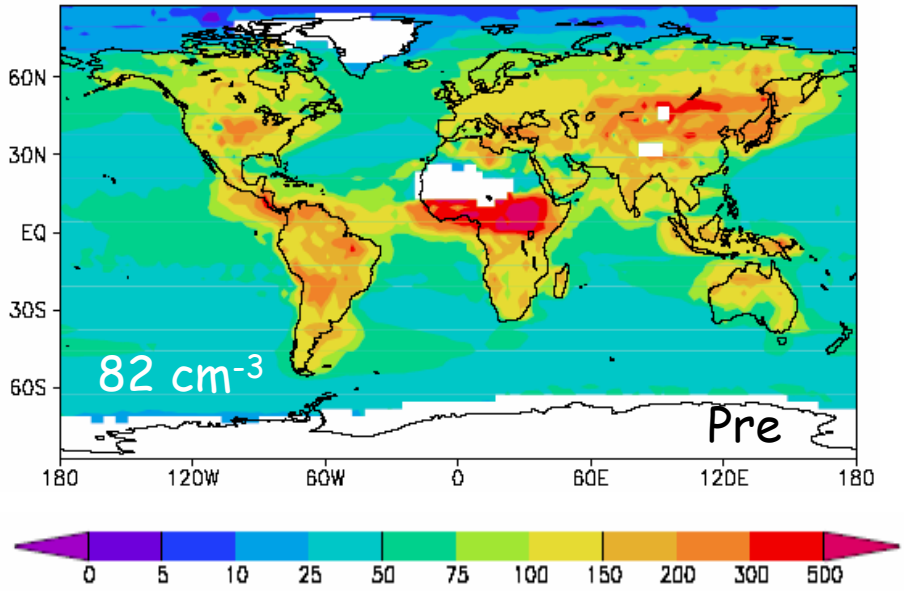


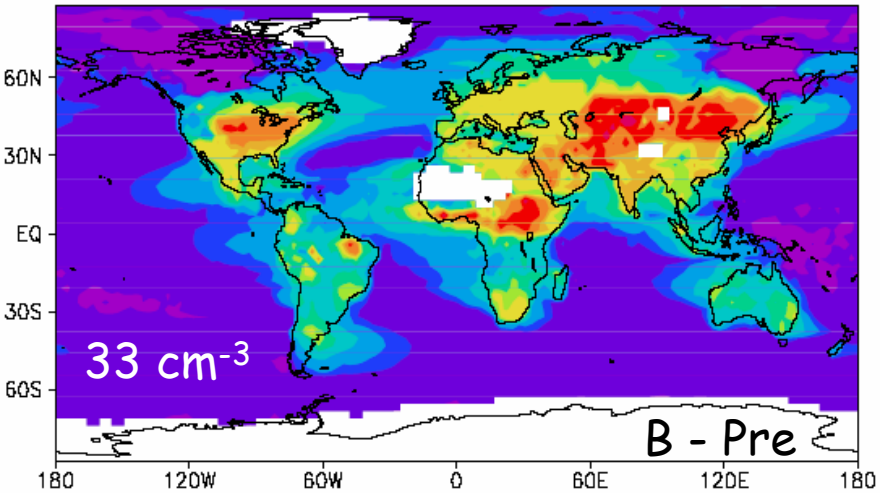
Effective Radius from Satellite Retrievals (Han et al., 1994)



CDNC (cm^{-3})

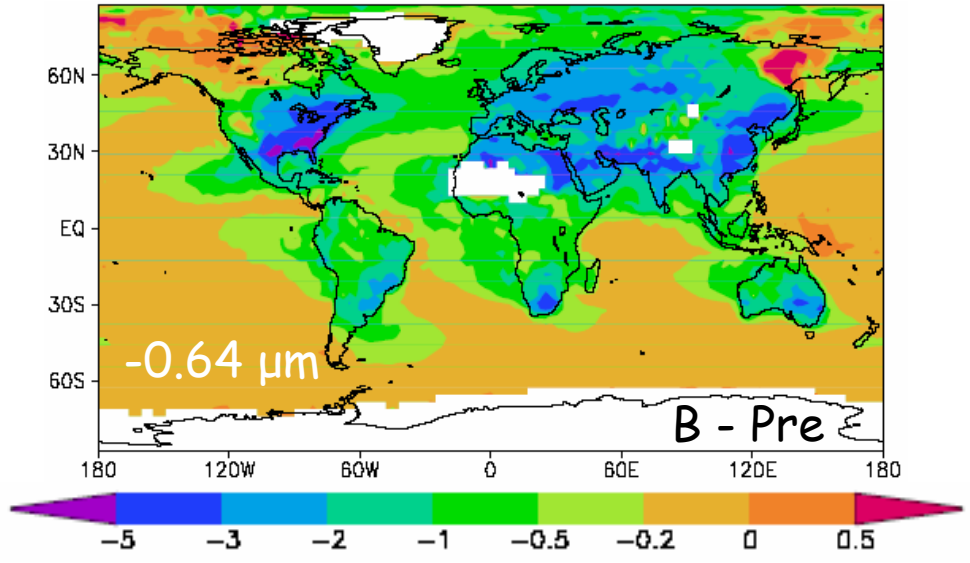
$\eta = 0.87$



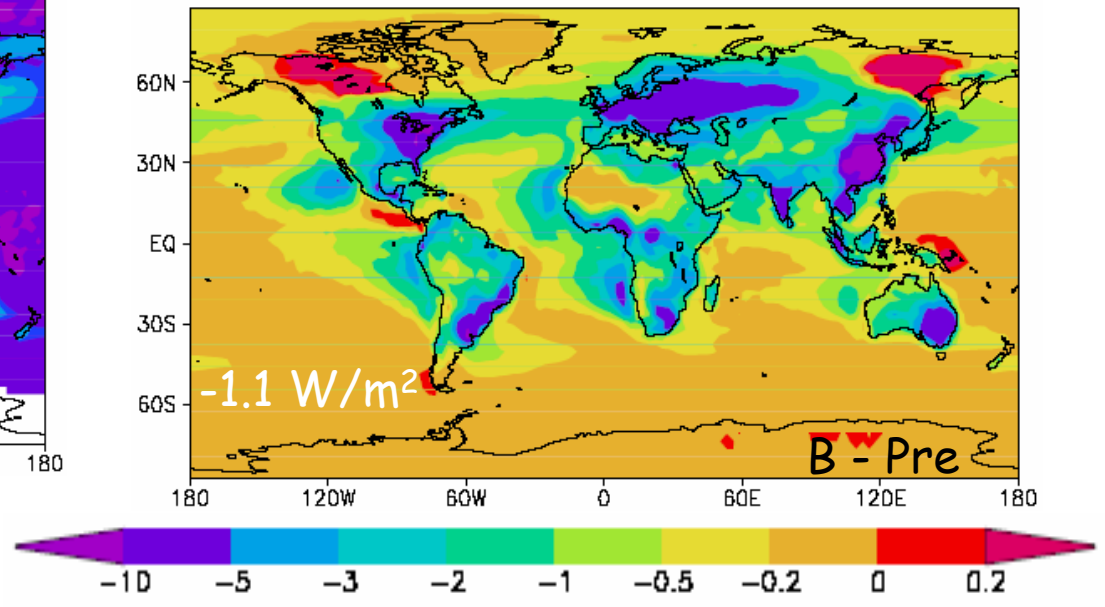


Effective droplet radii, r_{eff} (μm)

$\eta = 0.87$



SWCF (W/m^2) due to SO4, OC & BC



Model development after AerocomB:

CCM-Oslo (T42, L18) → CAM-Oslo (T42, L26)

AEROCOM B emissions of SO_4, BC and OC

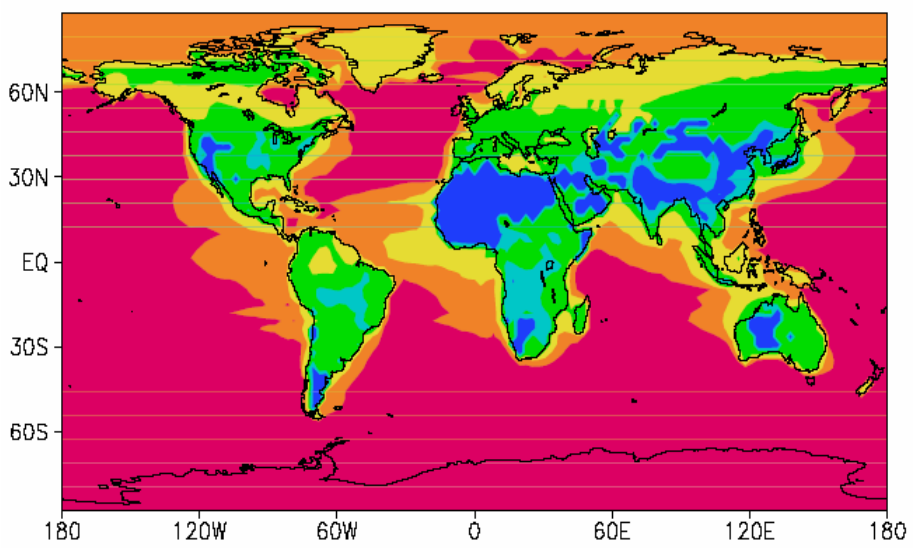
↓

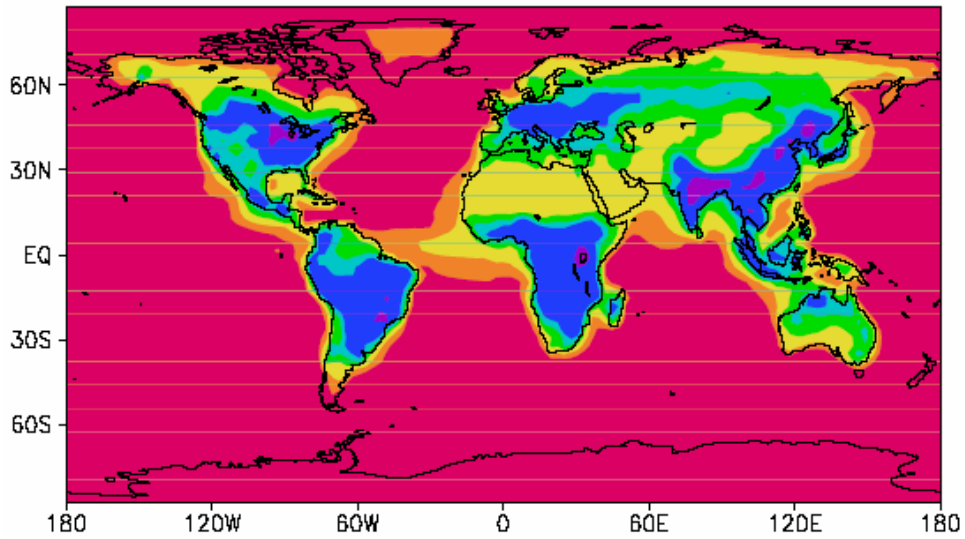
AeroCom B and Pre version

AEROCOM B emissions of SO_4, BC and OC,
+ sea-salt and minerals,
all prognostic

CCM-Oslo vs. CAM-Oslo

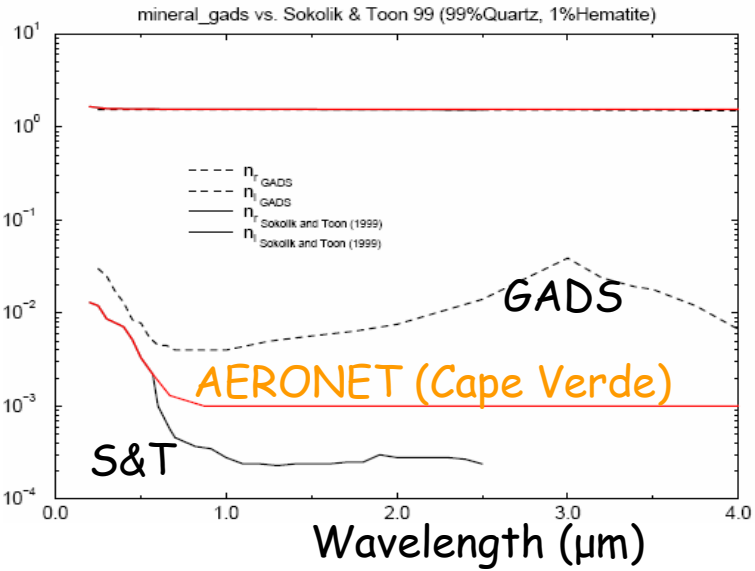
Near surface Single scattering albedo, $\omega_{0.55\mu m}$





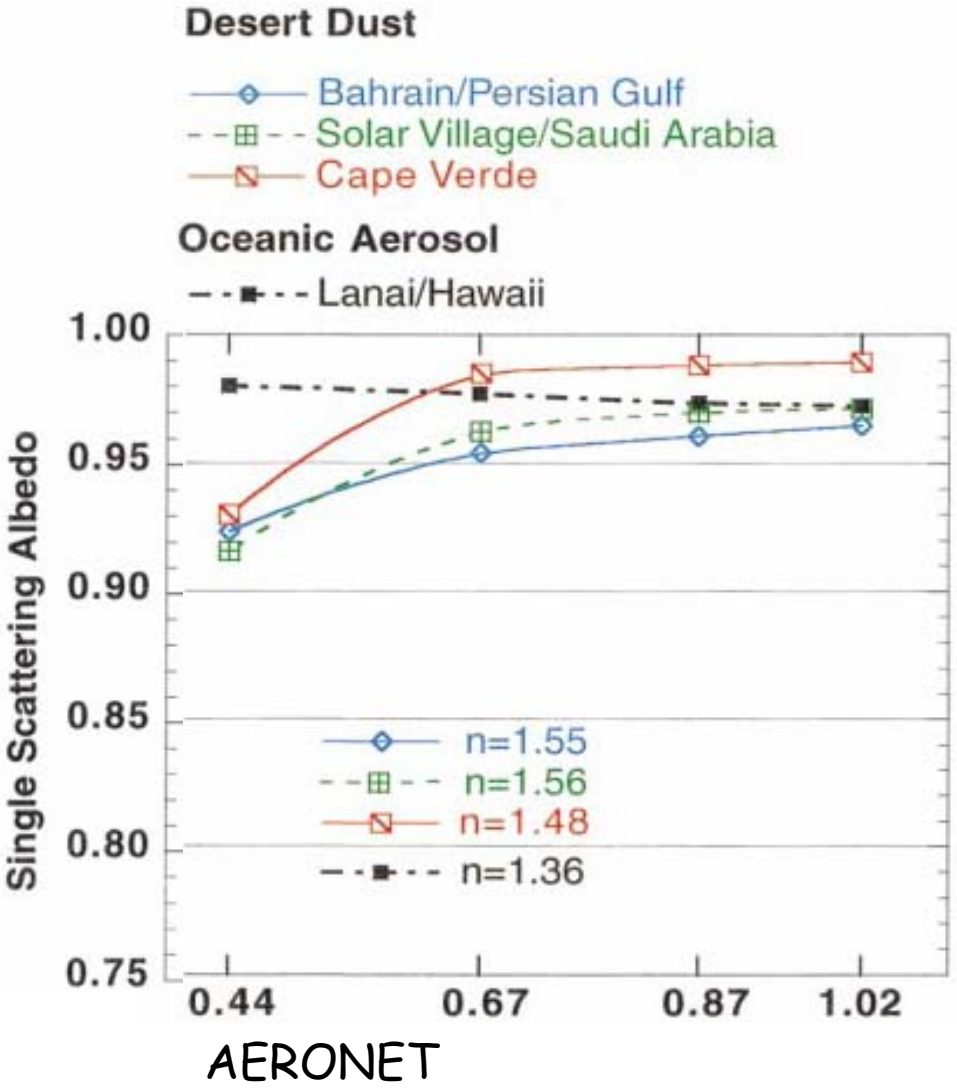
(prescribed background)

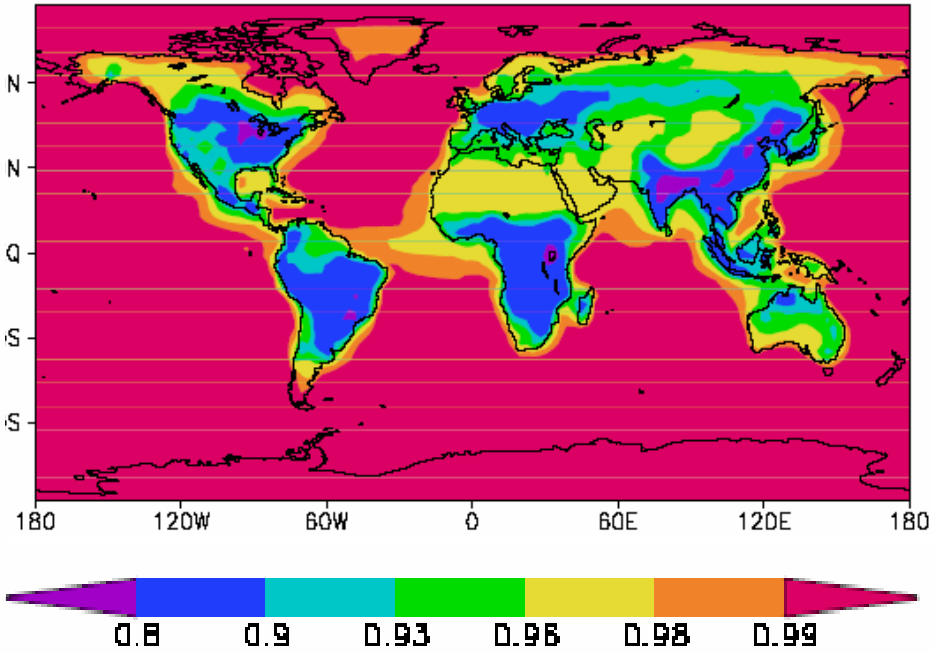
complex refractive index **Mineral**



CAM-Oslo

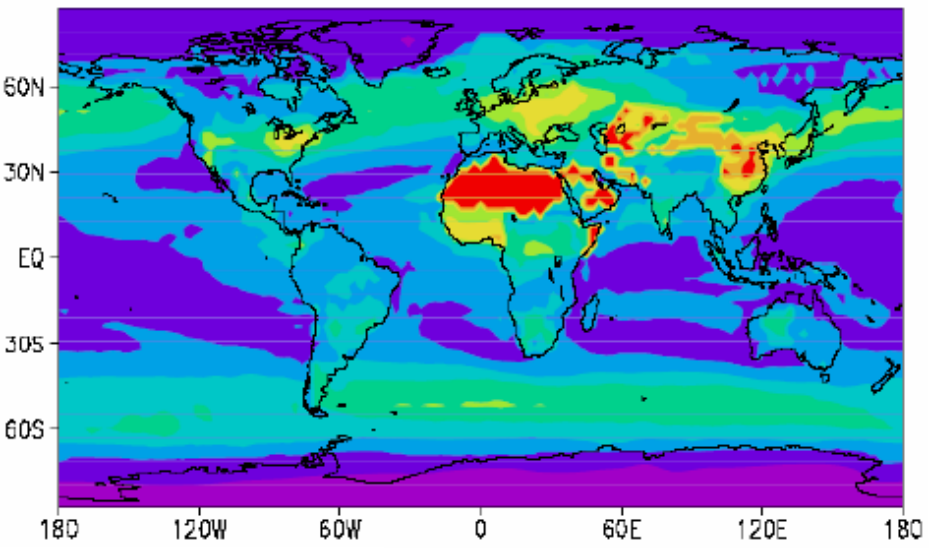
Near surface Single scattering albedo, $\omega_{0.55\mu m}$

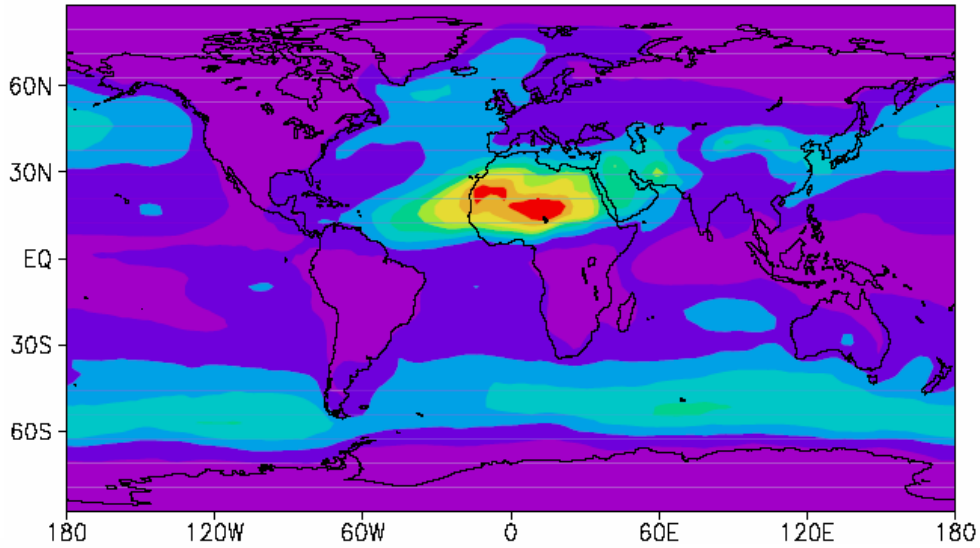




CCM-Oslo vs. CAM-Oslo

Optical depth OD550 (0.15) (0.09)



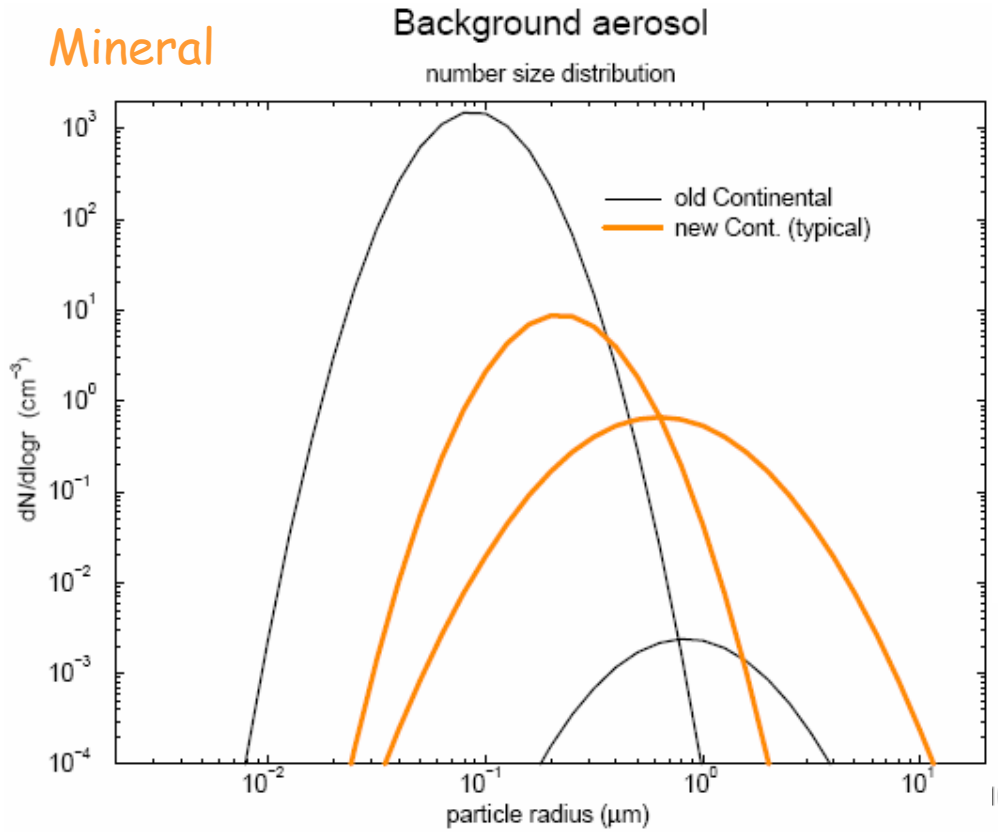


(prescribed mineral & seasalt)

(prognostic mineral & seasalt)

(preliminary result: no adjustments/tuning of parameterizations chemes to new background aerosol)

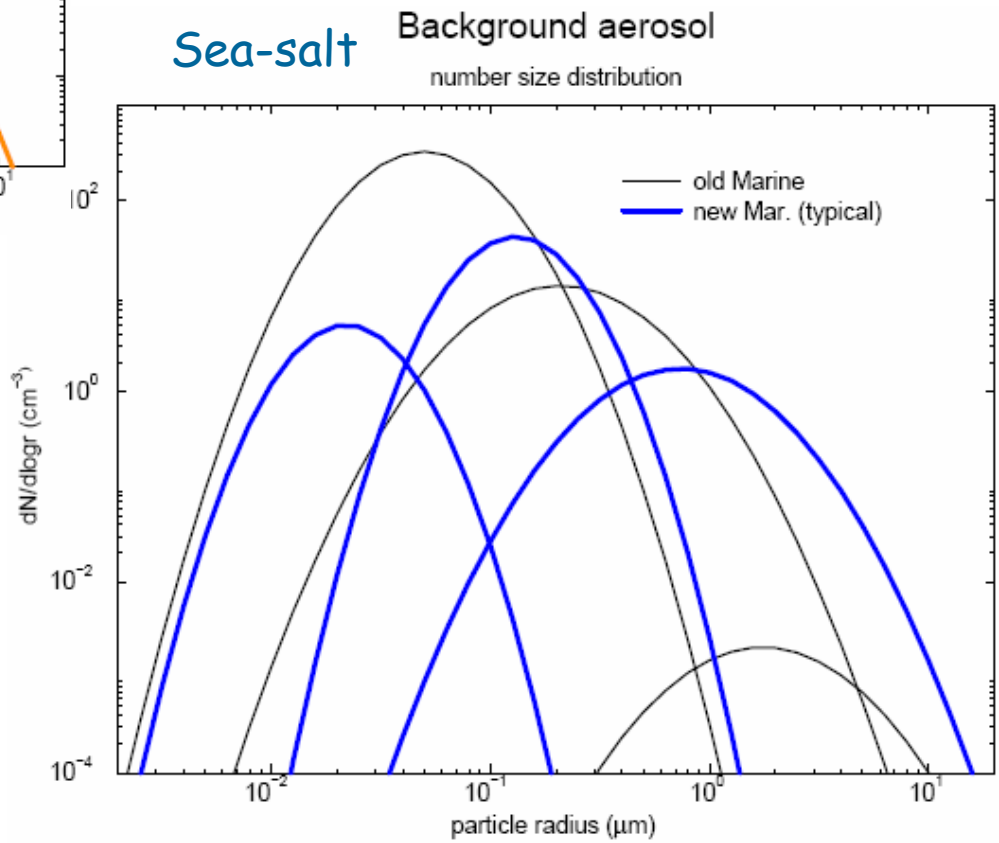
Mineral



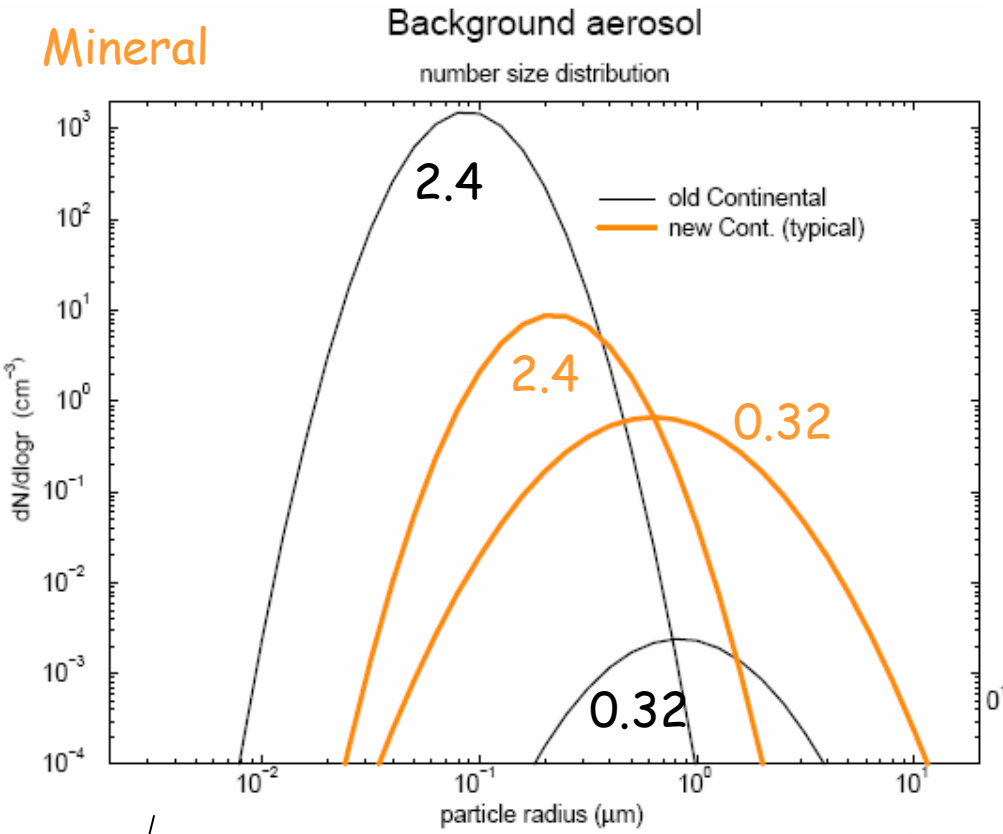
CCM-Oslo (prescribed)
vs.
CAM-Oslo (AeroCom B emis.)

("typical" distributions)

Sea-salt

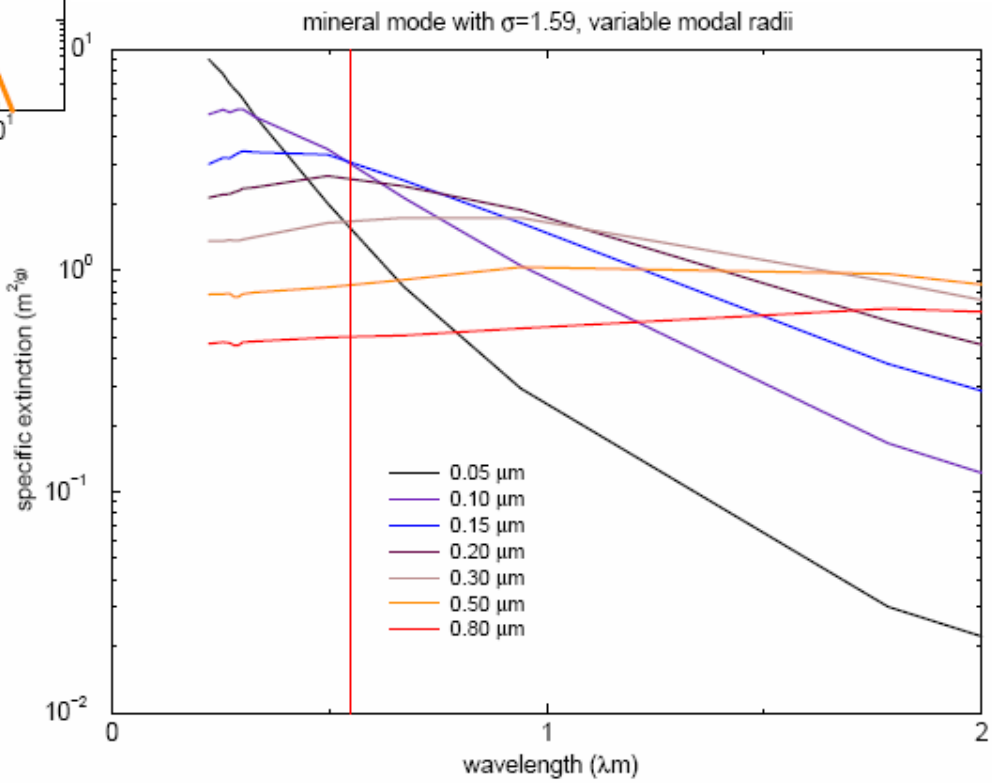


Mineral



Mass/specific extinction coeff. (m^2/g) at 0.55μm

MEC550 = OD550/(dry mass column)



Global average (at ambient RH):

CCM-Oslo: 1.10 m^2/g

CAM-Oslo: 0.70 m^2/g

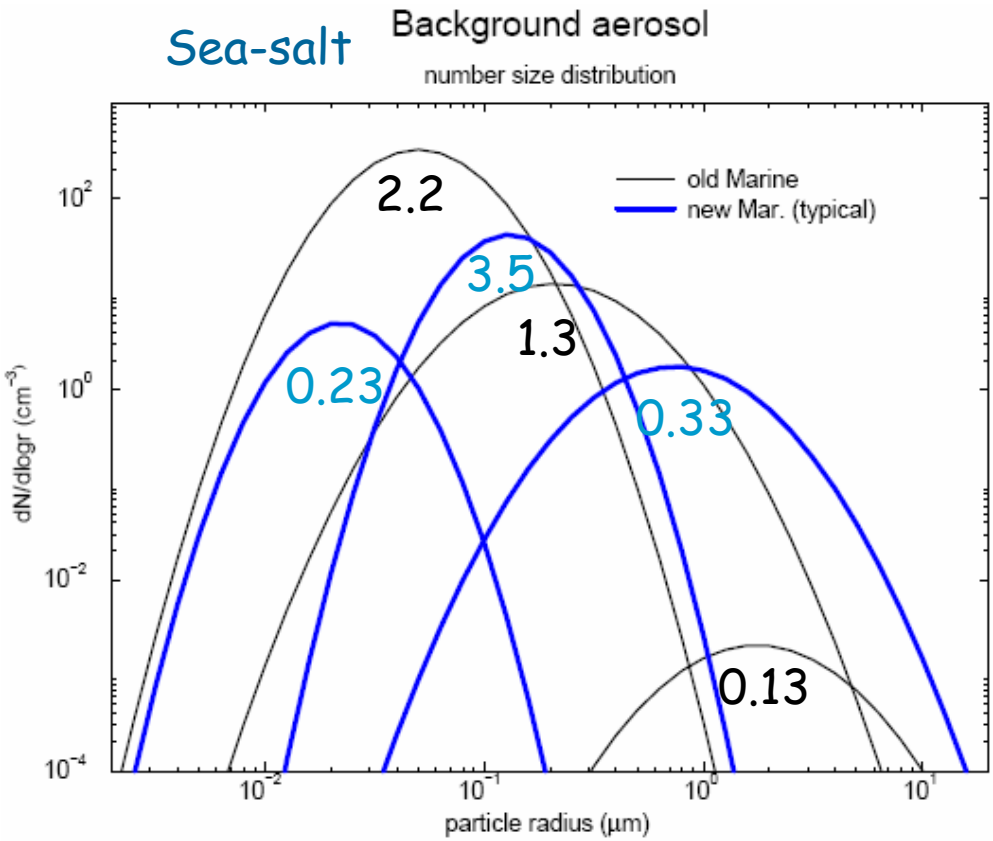
Column intergrated mass:

47 mg/m^2 in CCM-Oslo

34 mg/m^2 in CAM-Oslo → smaller OD

Mass/specific extinction coeff. (m^2/g) at 0.55µm

MEC550 = OD550/(dry mass column)

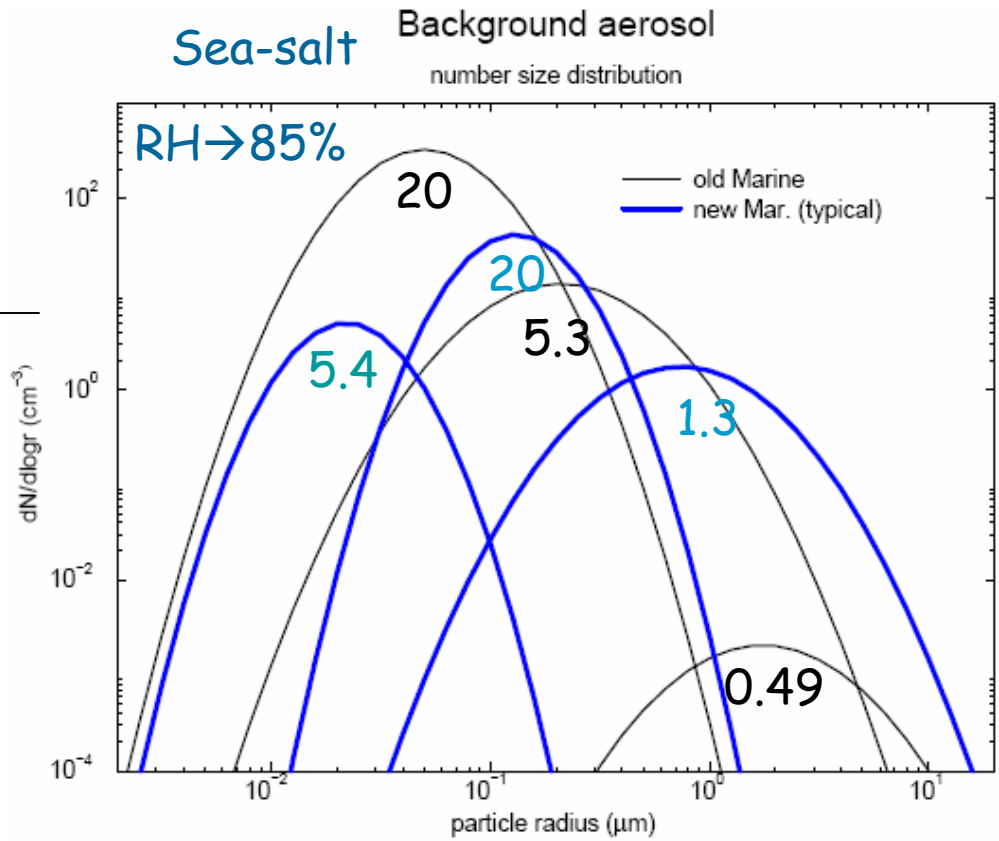


Mass/specific extinction coeff. (m^2/g) at 0.55µm

MEC550 = OD550/(dry mass column)

Global average (at ambient RH):

CCM-Oslo: 7.5 m^2/g
CAM-Oslo: 1.9 m^2/g



Column intergrated mass:
9 mg/m^2 in CCM-Oslo
26 mg/m^2 in CAM-Oslo → smaller OD

MEC550 (m^2/g)

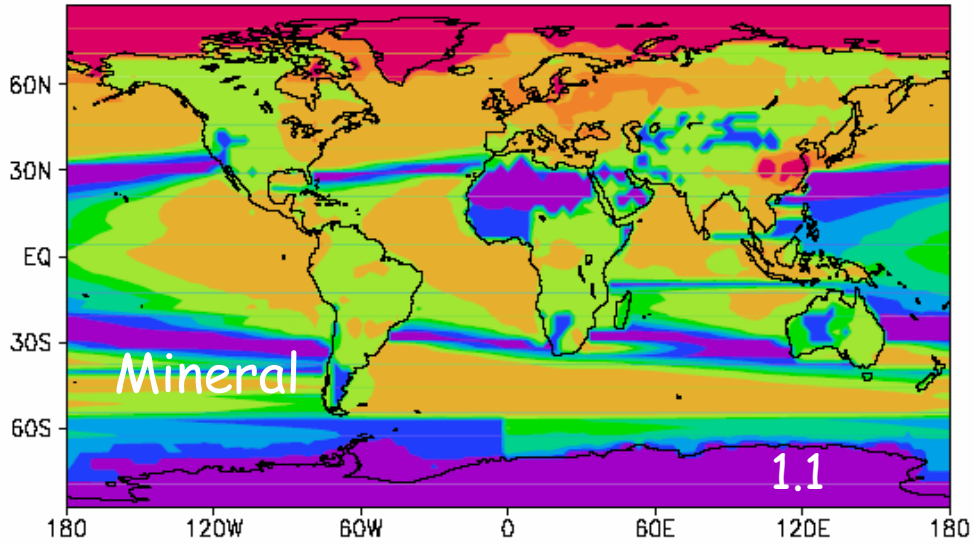
Component	CCM-Oslo, Aerocom B → CAM-Oslo	Median of AeroCom A*
Mineral	1.1 → 0.70	0.91
Sea-salt	7.5 → 1.9	2.4

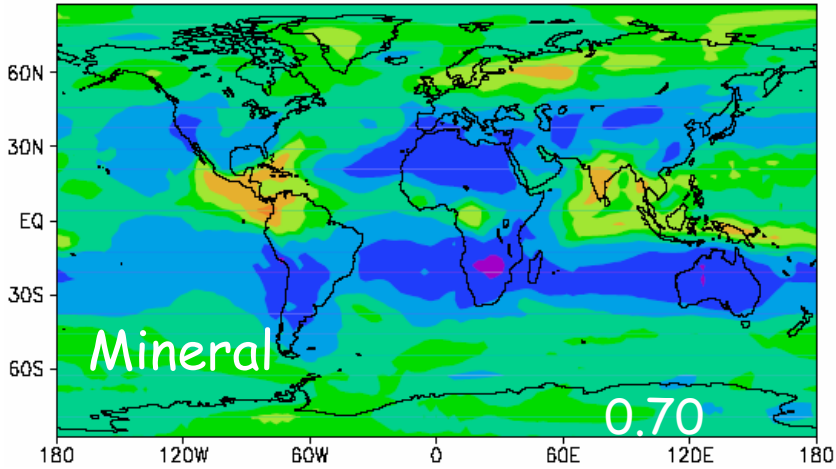
* Kinne et al. (2005)

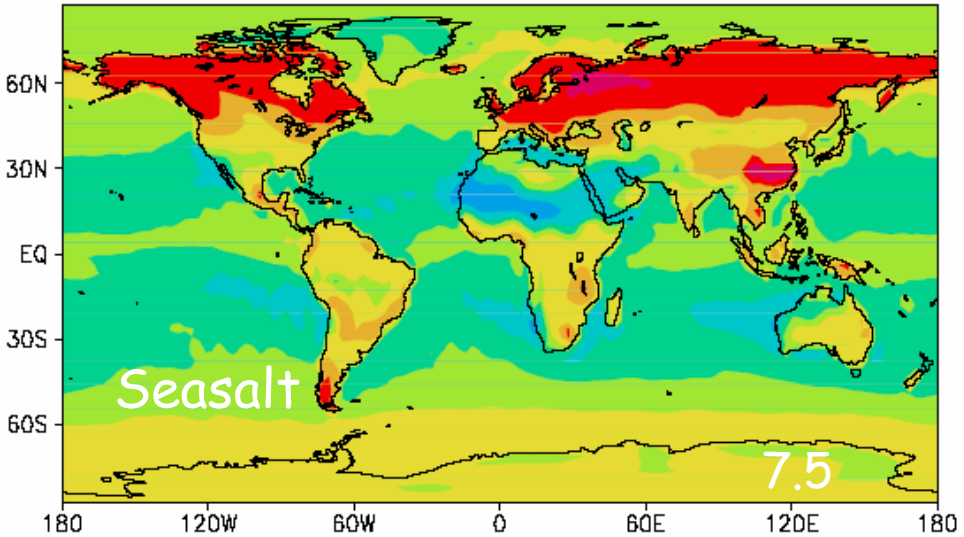
CCM-Oslo

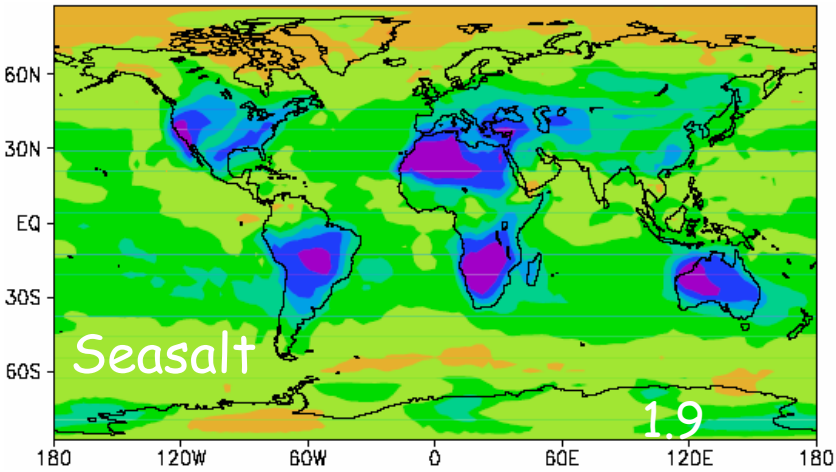
MEC550 (m^2/g)

CAM-Oslo

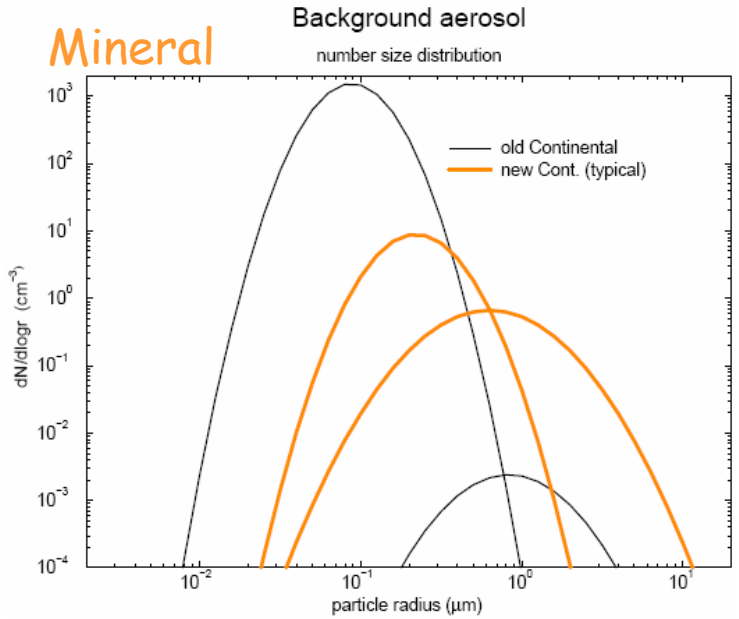




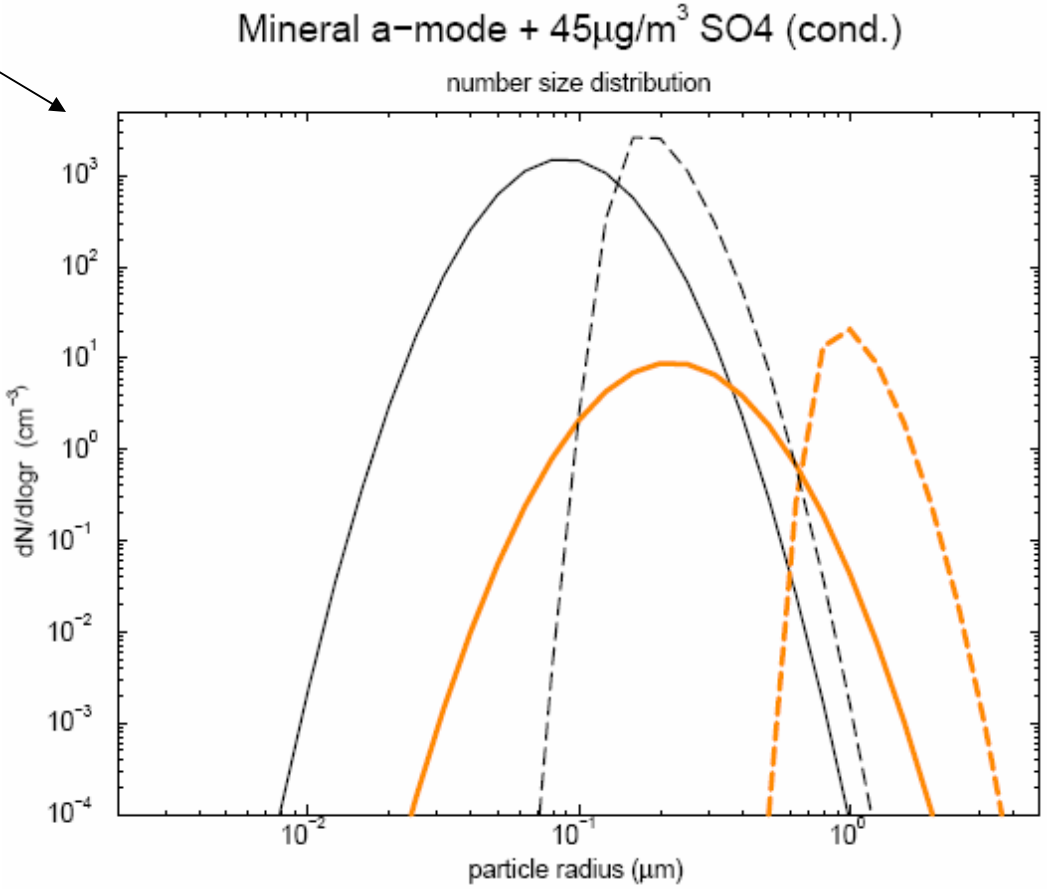


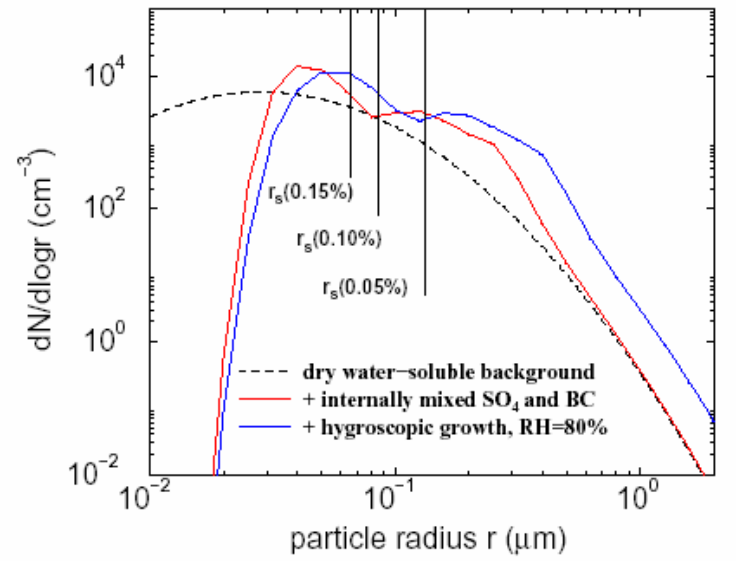


Mineral

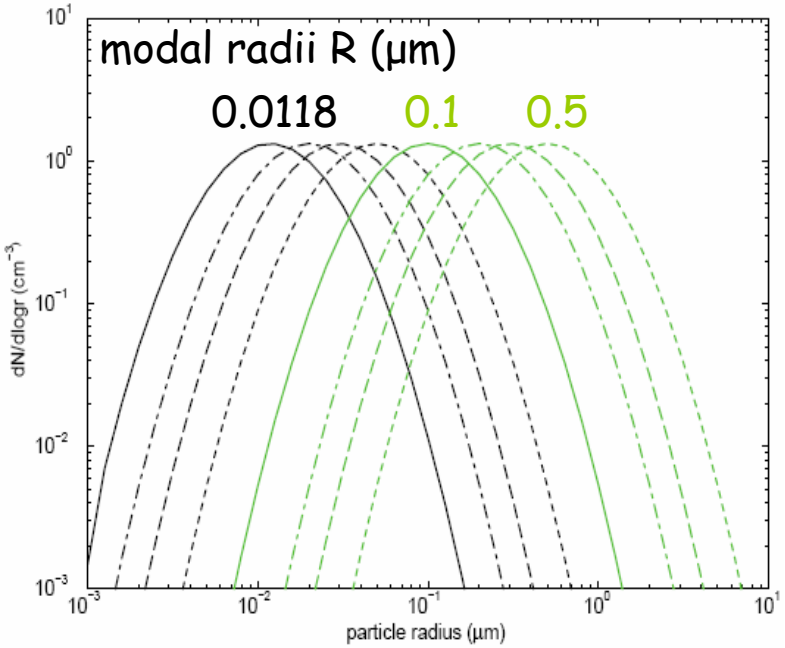


CCM-Oslo (prescribed)
vs.
CAM-Oslo (AeroCom B emis.)

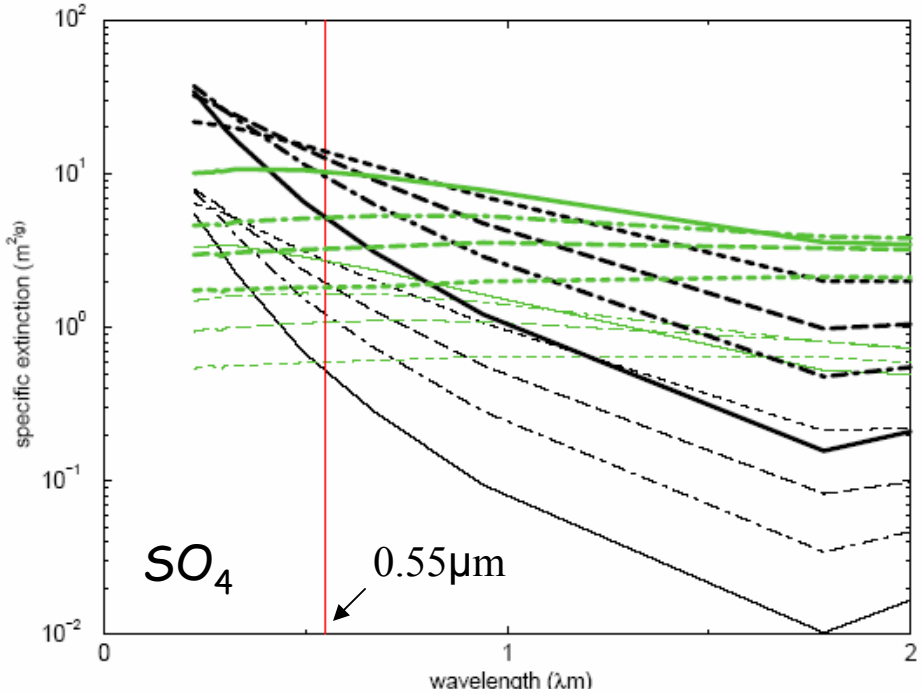


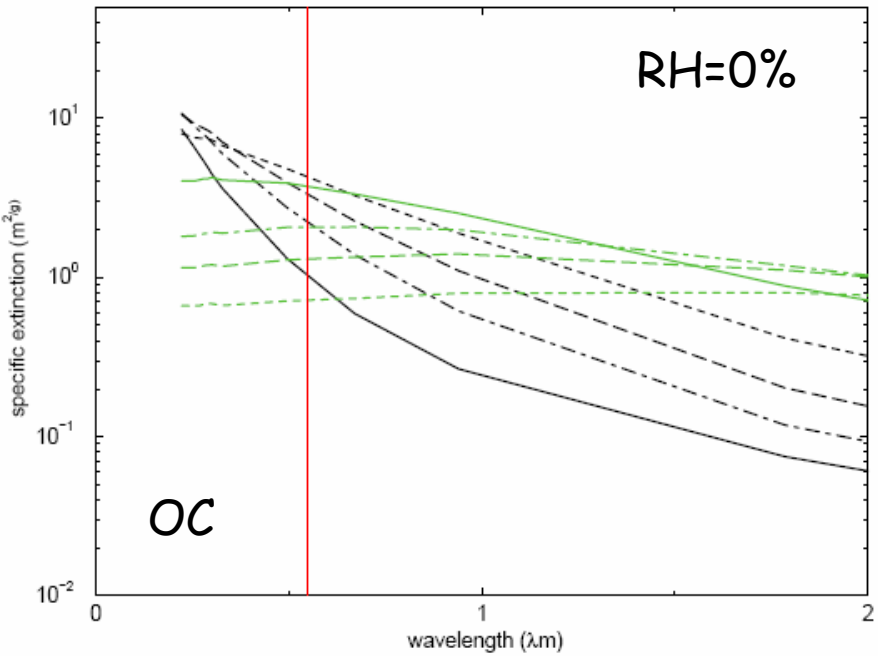


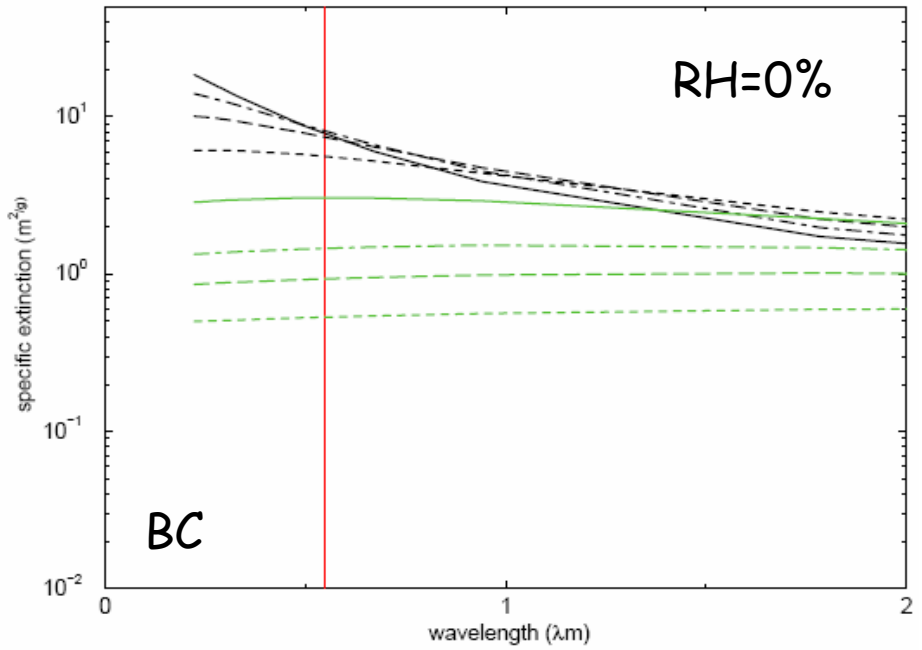
Number size distributions



MEC(λ) at RH=0% → 80%



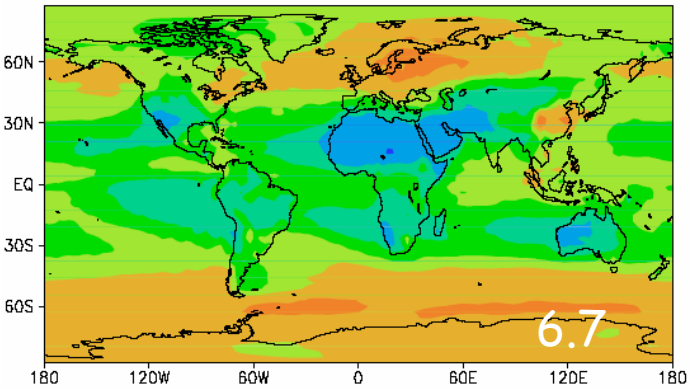




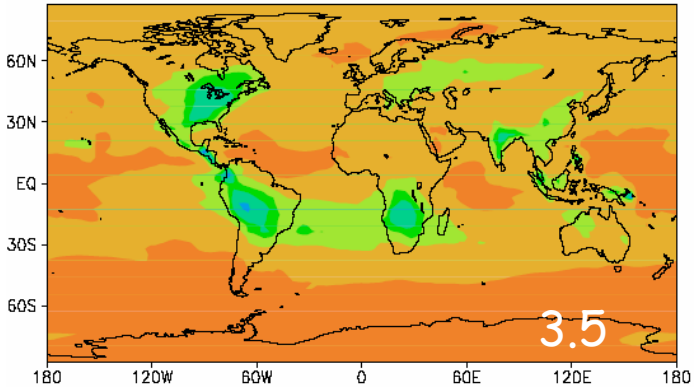
MEC550 (m^2/g)

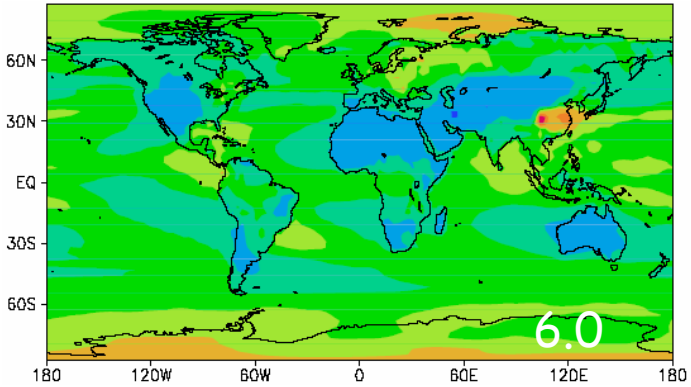
CCM-Oslo (in AeroCom B)

CAM-Oslo

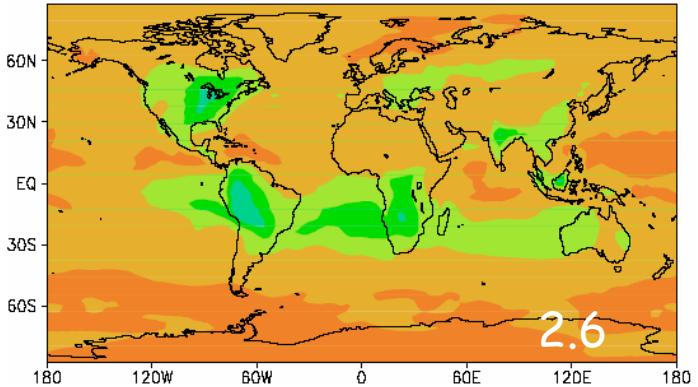


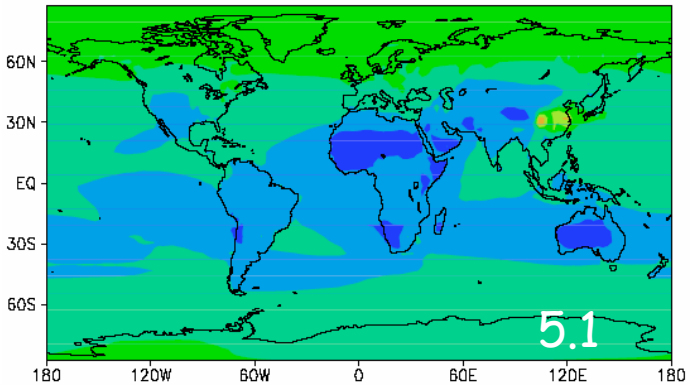
SO4



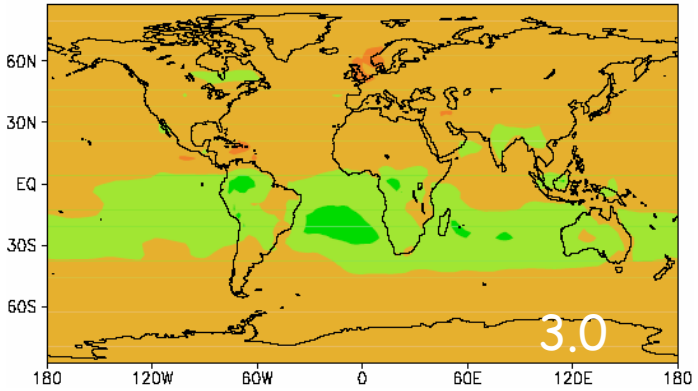


OC





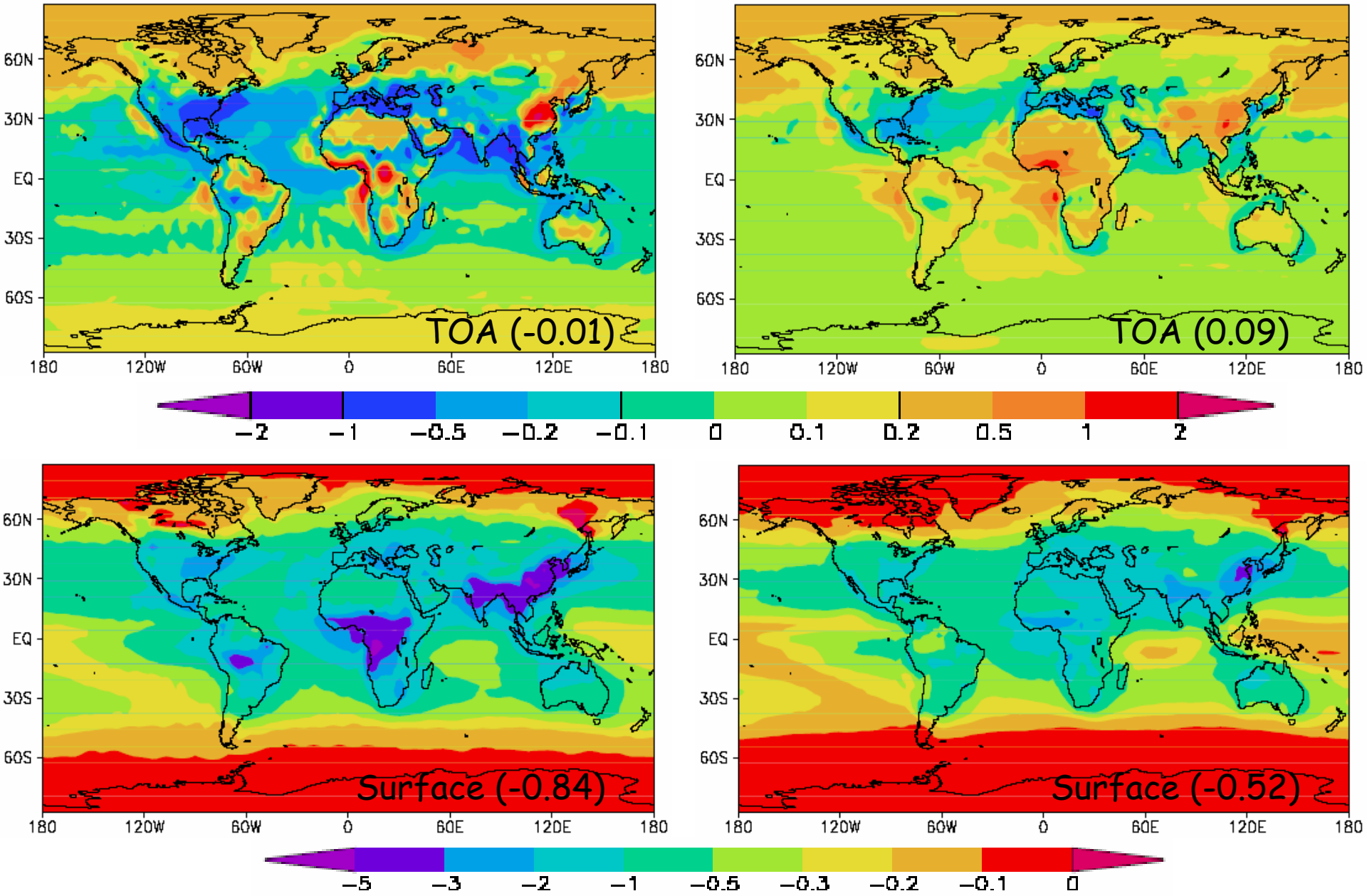
BC



CCM-Oslo (in AeroCom B)

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

CAM-Oslo



Some conclusions

- Prognostic SO_4, BC & OC + prescribed background aerosols in CCM-Oslo yield reasonably good agreement with yearly MODIS and AERONET ODs, but
  - too small mineral OD downstream of e.g. Sahara
  - too thick mineral OD over Europe and other "remote" areas

- Radiative forcing by SO_4, BC & OC (aerocom B-Pre):
  - DRF(TOA) = -0.01 W/m^2, DRF(S) = -0.84 W/m^2
  - INDRF(TOA) = - 1.1 W/m^2

	Aerocom Pre	Aerocom B
CDNC(η=0.87)	82 cm^{-3}	115 cm^{-3}
R_{eff}(η=0.87)	9.79 µm	9.15 µm

Some more conclusions

- High sea-salt and dust MEC550 values in CCM-Oslo, a result of prescribed background with weight on fine part:
  - CAM-Oslo: prognostic seasalt and mineral with Aerocom's modal parameters (weight on larger sizes)
    → MEC550 near meadian of Aerocom A

- Unexpected side-effect of fully prognostic aerosol in CAM-Oslo
  - Despite more realistic distribution of sea-salt and minerals, we get unrealistic small SO_4, OC and BC MEC550, due to a shift towards larger sizes for internal mixing
    → too small ODs!

- Work in progress (in CAM-Oslo):
  - Revision of aerosol scheme w.r.t. internal vs. internal mixing of modes (→ more external) and sizes, to get more realistic mass loads, MECs and ODs for SO_4, OC and BC.

Extra slides

Revised background aerosol modes, mass densities and dry modal parameters

mode number k, and name	modal radius, r_k (μm)	modal width, $\log(\sigma_k)$	mass density, ρ_k (g/cm^3)	references
1. WASO*	0.0212	0.35	1.8	GADS
2old. INSO* 2new. MINSEA	0.471 0.0931	0.40 0.1975	2.0 2.5	GADS (MINF+SEASF)
3. MINF	0.088	0.1824	2.6	D02, GADS
4. MINC	0.83	0.2649	2.6	D02, GADS
5. MINT	0.64	0.2610	2.6	D02, GADS
6. SUSO	0.0695	0.3075	1.7	GADS
7. SEASF	0.05	0.2476	2.2	S03, HF90
8. WASOC*	0.0212	0.35	1.5	GADS, Gh01, AERONET
9. SEASA	0.209	0.3075	2.2	GADS
10. SEASC	1.75	0.3075	2.2	GADS

GADS refers to Köpke et al. (1997), D02 to Dubovik et al. (2002), Gh01 to Ghan et al. (2001a), HF90 to Hoppel and Frick (1990), S03 to Smirnov et al. (2003), and AERONET to http://aeronet.gsfc.nasa.gov/.

Aerosol background modes and number concentrations

aerosol type	modes included	surface number concentrations, N_k (cm^{-3})	vertical variation p_t/p_0, q_{lower}, q_{upper}	references
Continental	3. MINF 4. MINC 5. MINT	700 or 350 0.2 or 0.1 0 or 0.4	0.8, 5.0, 2.0	GADS, D02, SP98
Marine	5. MINT 7. SEASF 9. SEASA 10. SEASC	0.05 200 $0.4 \cdot \exp(0.18 \cdot U_0 + 1.4)$ $0.4 \cdot \exp(0.23 \cdot U_0 - 7.8)$	0.8, 8.0, 2.0	GADS, D02, HF90,Gh01, Go97, M03, SP98, S03
Desert	3. MINF 4. MINC	$2000 \cdot fdes^{\dagger}$ $12 \cdot fdes^{\dagger}$	0.5, 4.0, 1.0	GADS, D02, Gi01, Ch02
Arctic	3. MINF 9. SEASA	20 0.2-1.0*	0.8, 0.0, 1.0	GADS, AERONET
Antarctic (at the south pole only)§	5. MINT 7. SEASF 9. SEASA	0.00025 2.5 0.1	0.3, 0.0, 1.0	GADS, Sh82, AERONET, Seland & Iversen (Pers. Comm.)
Stratospheric	6. SUSO	10	$q = 1$ for $p/p_0 \leq 0.2$	GADS

GADS refers to Köpke et al. (1997), D02 to Dubovik et al. (2002), HF90 to Hoppel and Frick (1990), Gh01 to Ghan et al. (2001b), Go97 to Gong et al. (1997), M03 to Myhre et al. (2003), SP98 to Seinfeld and Pandis (1998), S03 to Smirnov et al. (2003), Gi01 to Ginoux et al. (2001), Ch02 to Chin et al. (2002), Sh82 to Shaw (1982), and AERONET to its project home page at http://aeronet.gsfc.nasa.gov/.

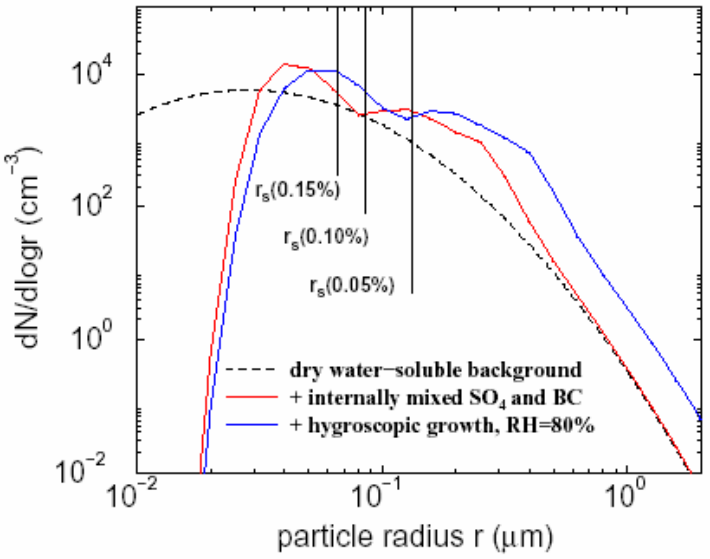
Externally mixed modes of Sulfate, BC and OC

mode number k, and name	modal radius, r_k (μm)	modal width, $\log(\sigma_k)$	mass density, ρ_k (g/cm^3)	references
11. H_2SO_4(n)	0.0118	0.301	1.8	
12. BC(n)	0.0118	0.301	2.0	
13. BC(a)	0.1	0.204	$\rho_{BC}\,(r_n/r)^{0.5}$	
14. OC(n)	0.0118→0.04	0.301→0.2553	1.5	GADS, Gh01

CAM-Oslo

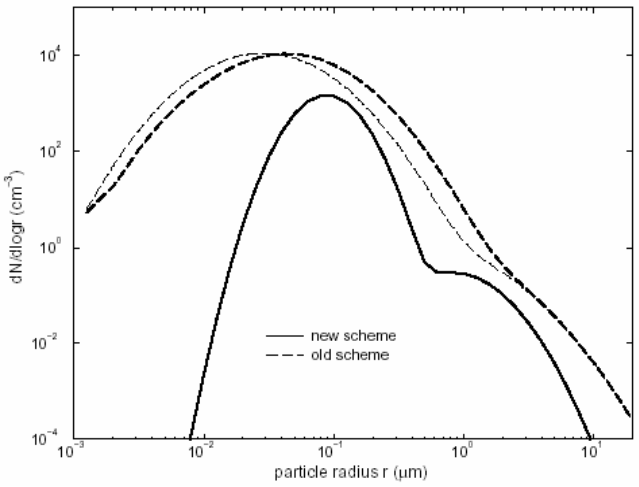
Internally mixed modes of Sulfate, BC and OC

- ✓ SO_4 from condensation of H_2SO_4
- ✓ SO_4 from cloud prosessing: $(NH_4)_2SO_4$
- ✓ BC from coagulation of BC(n)
- ✓ OC from coagulation of OC(n)

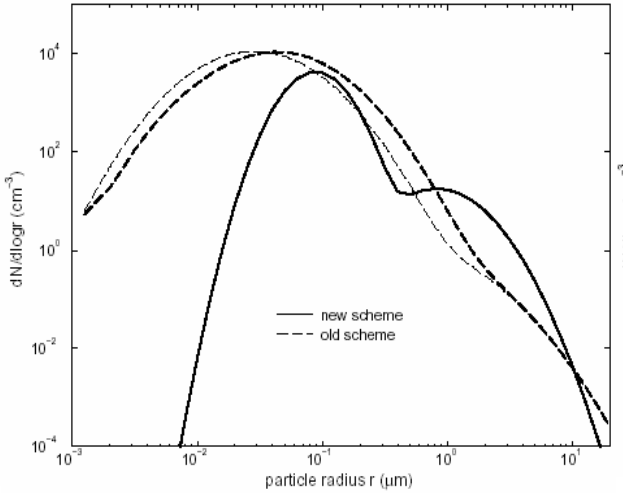


Number size distributions for clean background aerosols, dN/dlogr

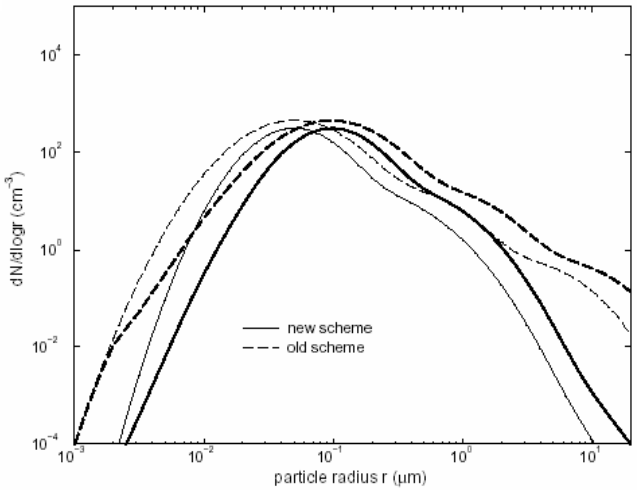
Continental



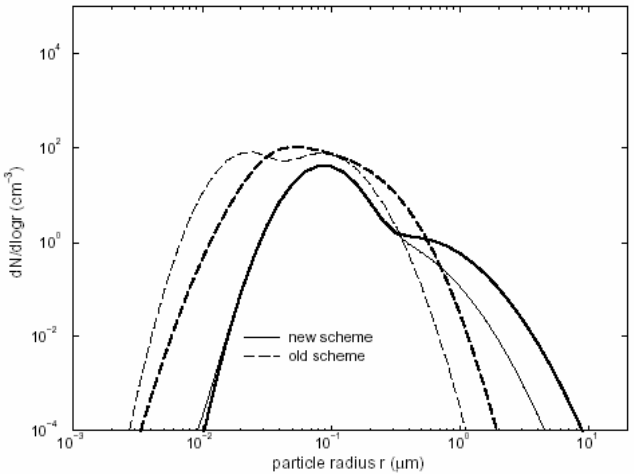
Desert



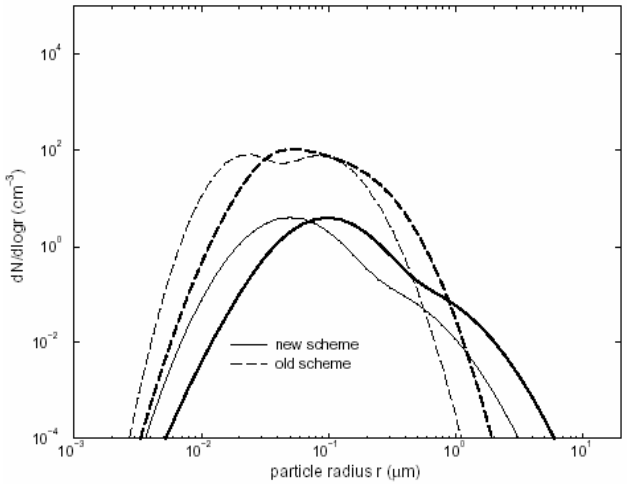
Marine



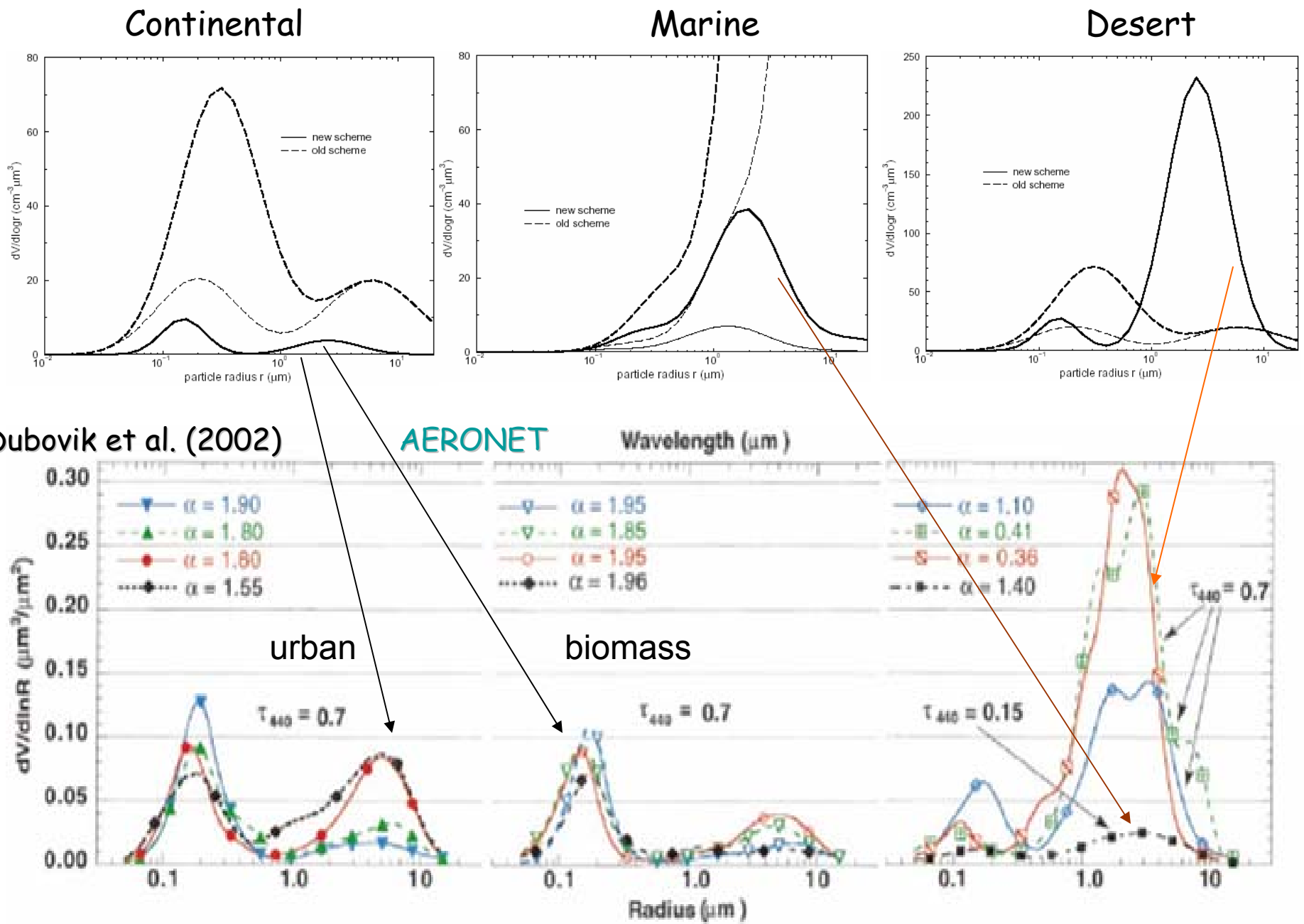
Arctic

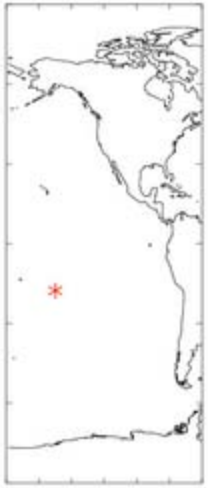


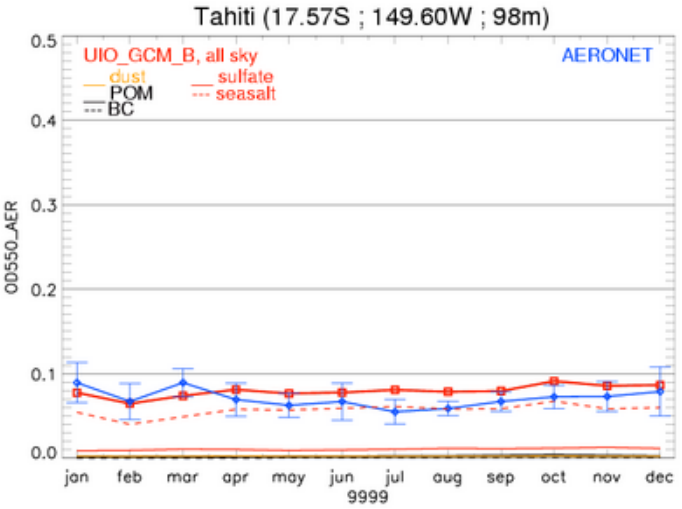
Antarctic

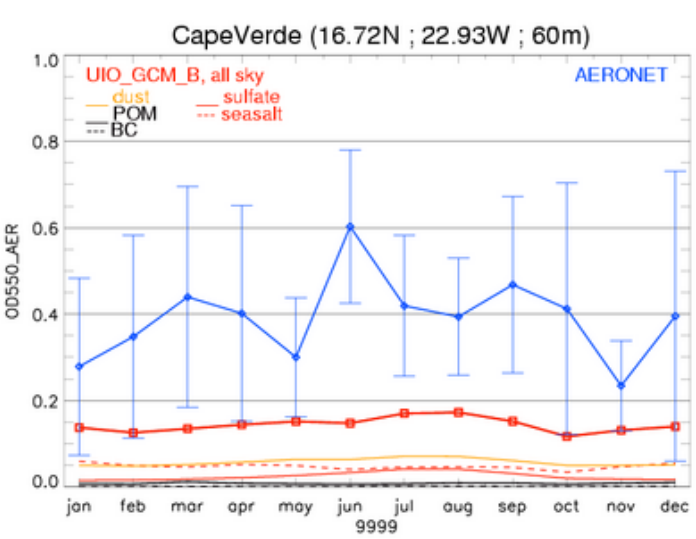


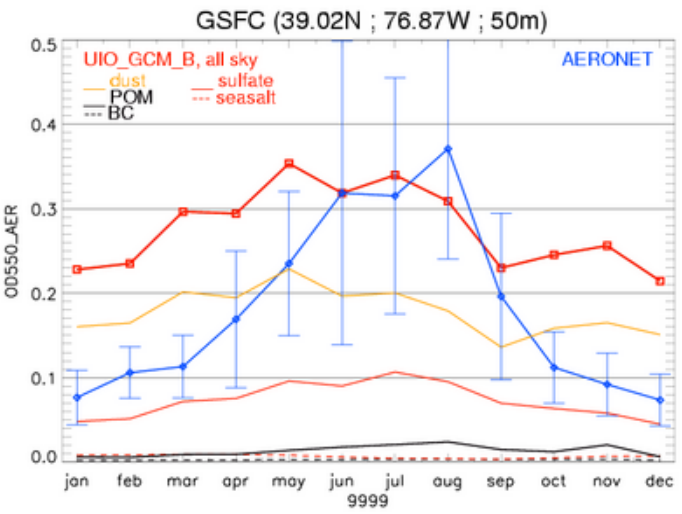
Volume size distributions for clean background aerosols, dV/dlogr

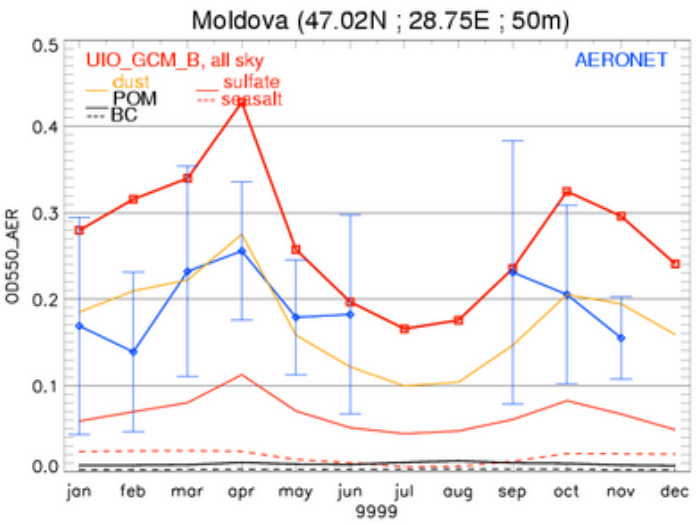


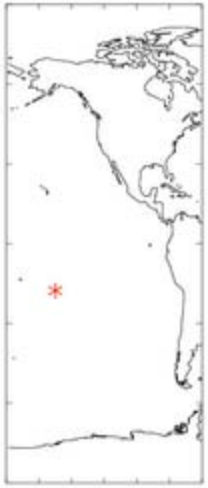


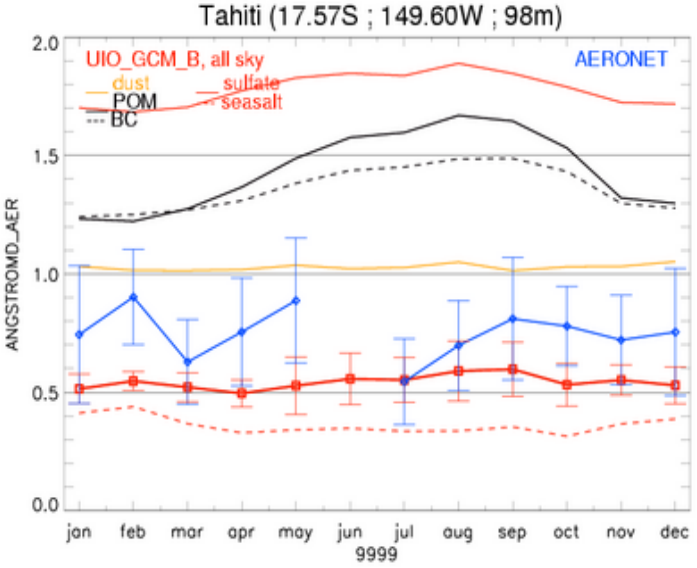

Tahiti (17.57S ; 149.60W ; 98m)
UIO_GCM_B, all sky
AERONET
dust
sulfate
POM
seasalt
BC
OD550_AER
0.0
0.1
0.2
0.3
0.4
0.5
jan feb mar apr may jun jul aug sep oct nov dec
9999

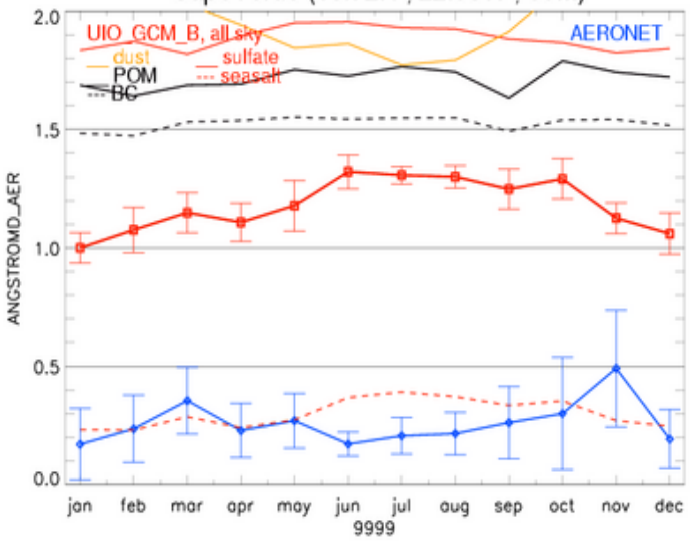

CapeVerde (16.72N ; 22.93W ; 60m)
UIO_GCM_B, all sky
AERONET
dust
sulfate
POM
seasalt
BC
OD550_AER
0.0
0.2
0.4
0.6
0.8
1.0
jan feb mar apr may jun jul aug sep oct nov dec
9999

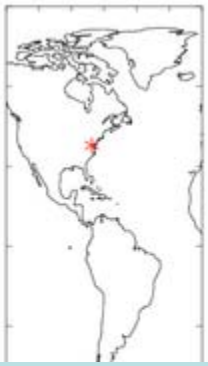

GSFC (39.02N ; 76.87W ; 50m)
UIO_GCM_B, all sky
AERONET
dust
sulfate
POM
seasalt
BC
OD550_AER
0.0
0.1
0.2
0.3
0.4
0.5
jan feb mar apr may jun jul aug sep oct nov dec
9999

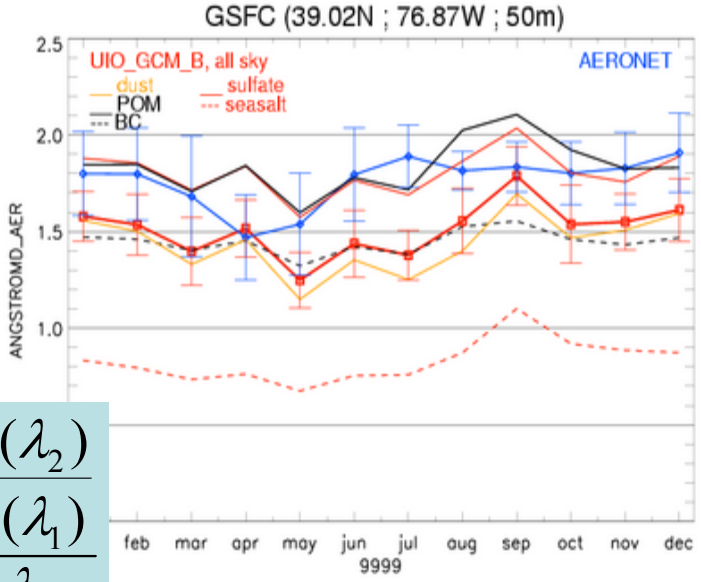

Moldova (47.02N ; 28.75E ; 50m)
UIO_GCM_B, all sky
AERONET
dust
sulfate
POM
seasalt
BC
OD550_AER
0.0
0.1
0.2
0.3
0.4
0.5
jan feb mar apr may jun jul aug sep oct nov dec
9999

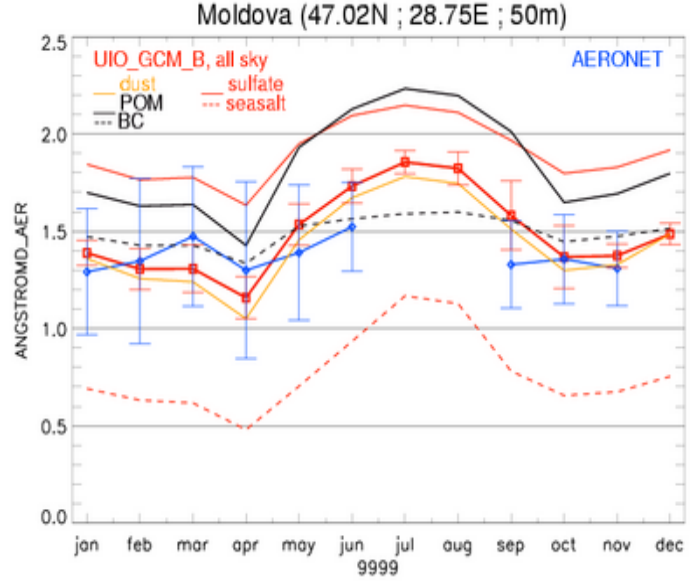






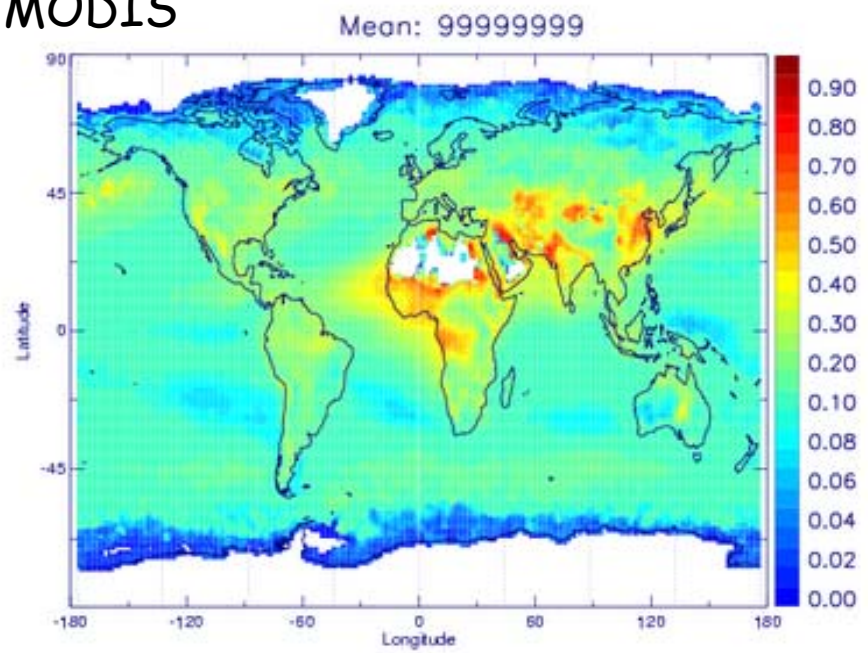




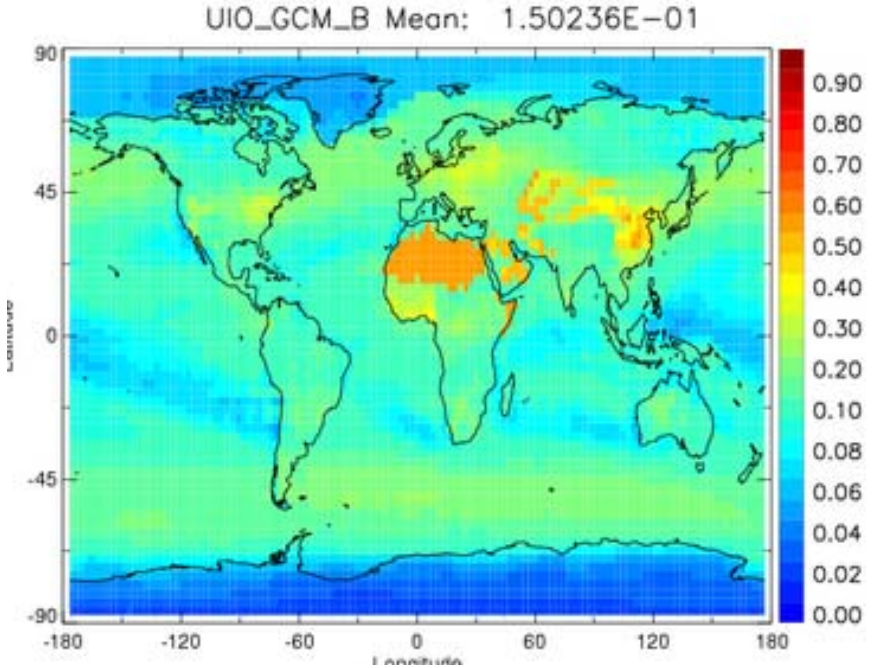


$$\alpha = -\frac{\ln \frac{\tau(\lambda_2)}{\tau(\lambda_1)}}{\ln \frac{\lambda_2}{\lambda_1}}$$

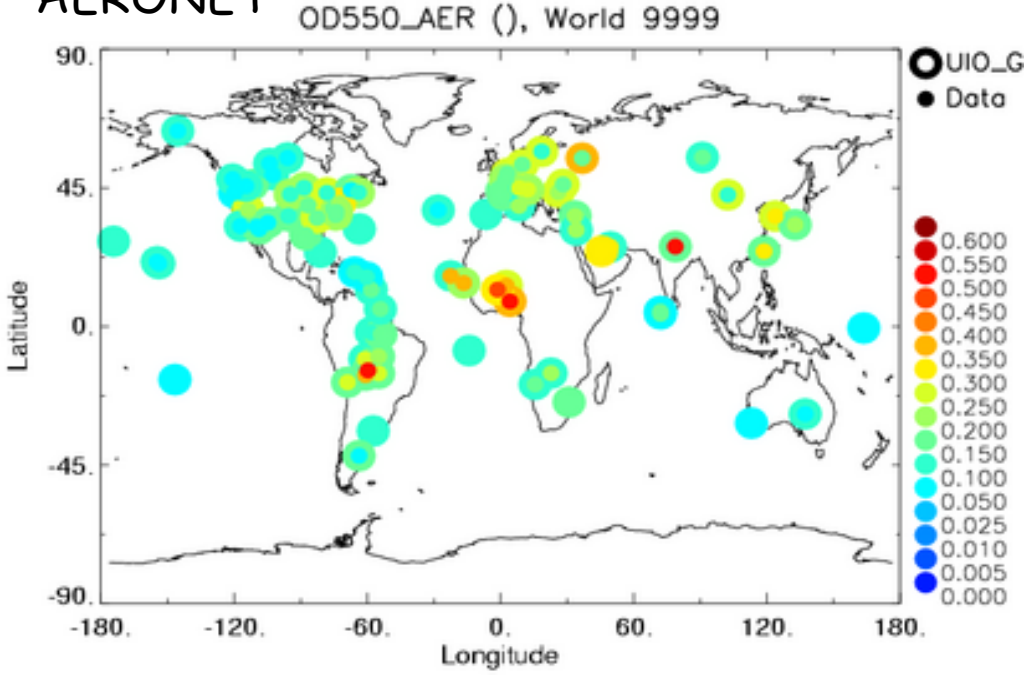
MODIS

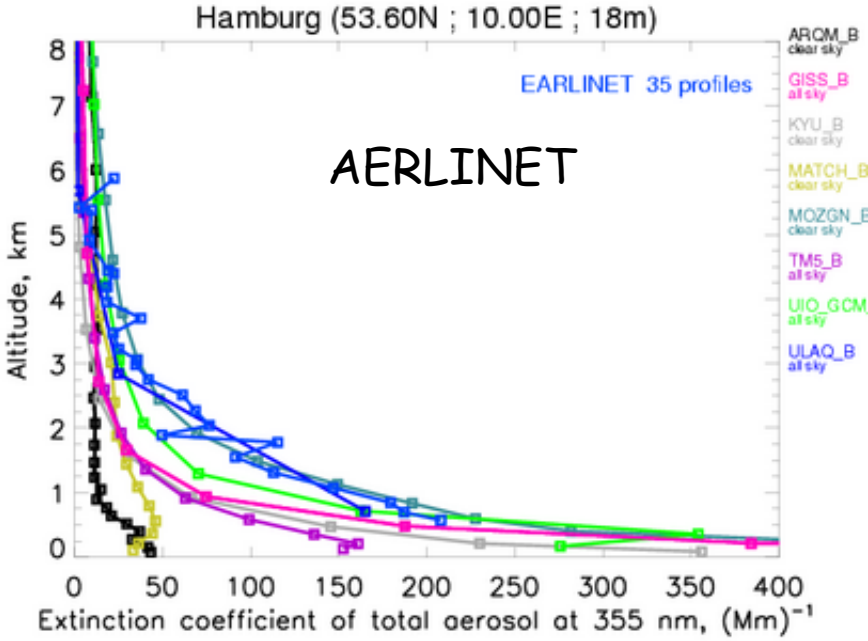


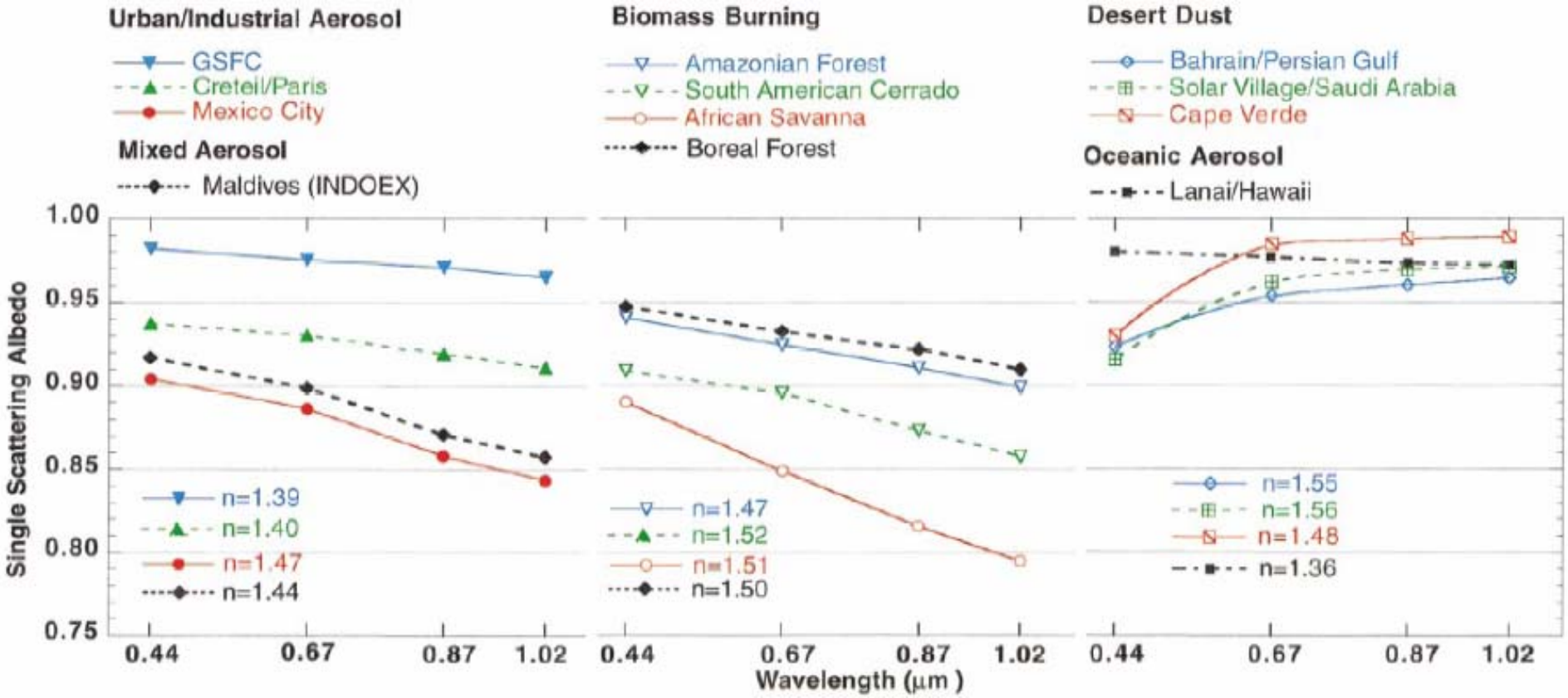
CCM-Oslo in AEROCOM B:



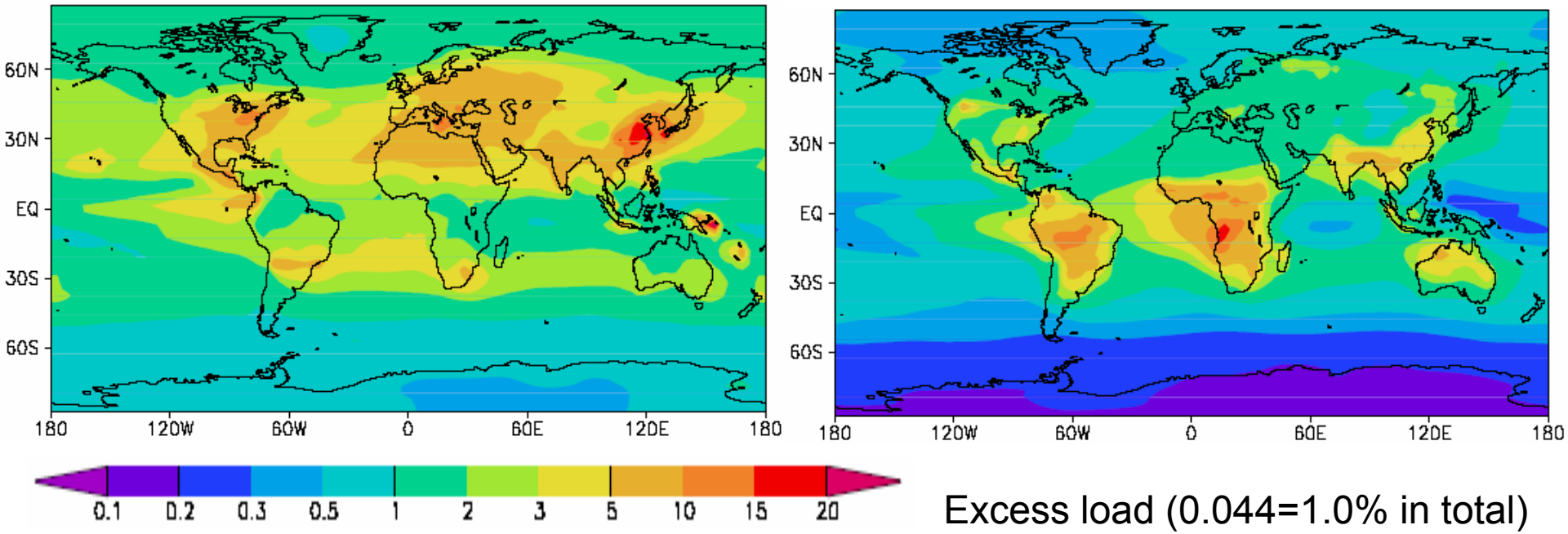
AERONET



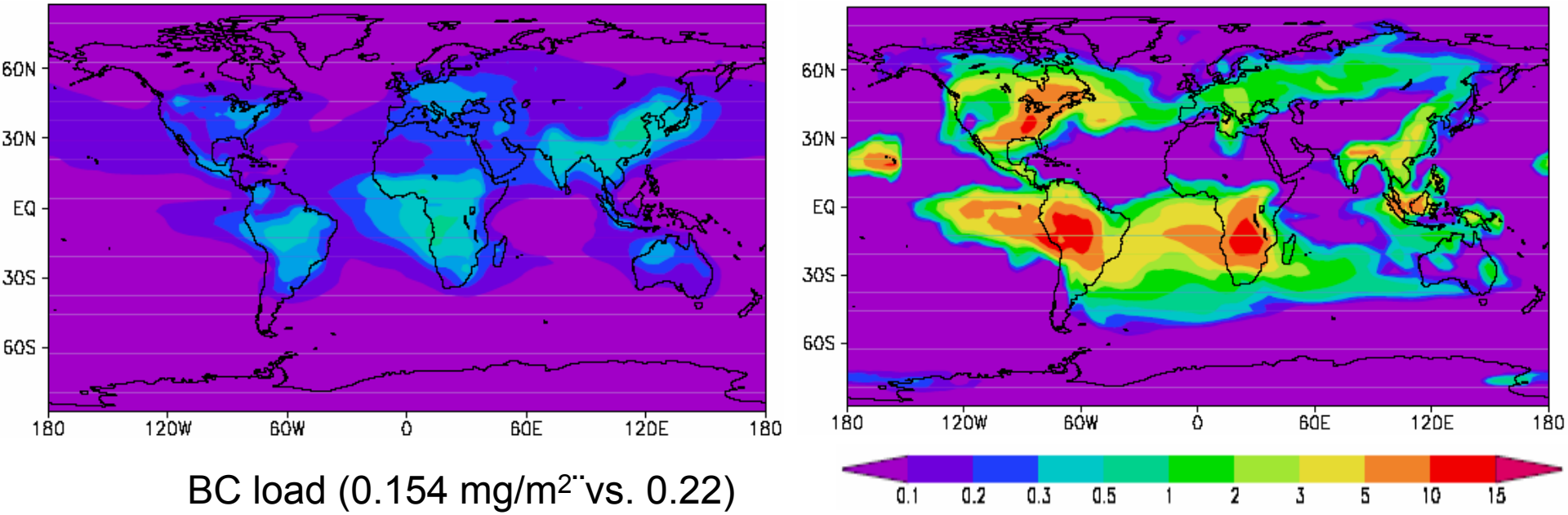



Urban/Industrial Aerosol
GSFC
Creteil/Paris
Mexico City
Mixed Aerosol
Maldives (INDOEX)
Biomass Burning
Amazonian Forest
South American Cerrado
African Savanna
Boreal Forest
Desert Dust
Bahrain/Persian Gulf
Solar Village/Saudi Arabia
Cape Verde
Oceanic Aerosol
Lanai/Hawaii
Single Scattering Albedo
1.00
0.95
0.90
0.85
0.80
0.75
n=1.39
n=1.40
n=1.47
n=1.44
n=1.47
n=1.52
n=1.51
n=1.50
n=1.55
n=1.56
n=1.48
n=1.36
0.44
0.67
0.87
1.02
Wavelength (μm)

Sulfate load (2.61 mg/m^2 vs. 2.9) CAM-Oslo OC load (1.52 mg/m^2 vs. 1.7)



Excess load (0.044=1.0% in total)

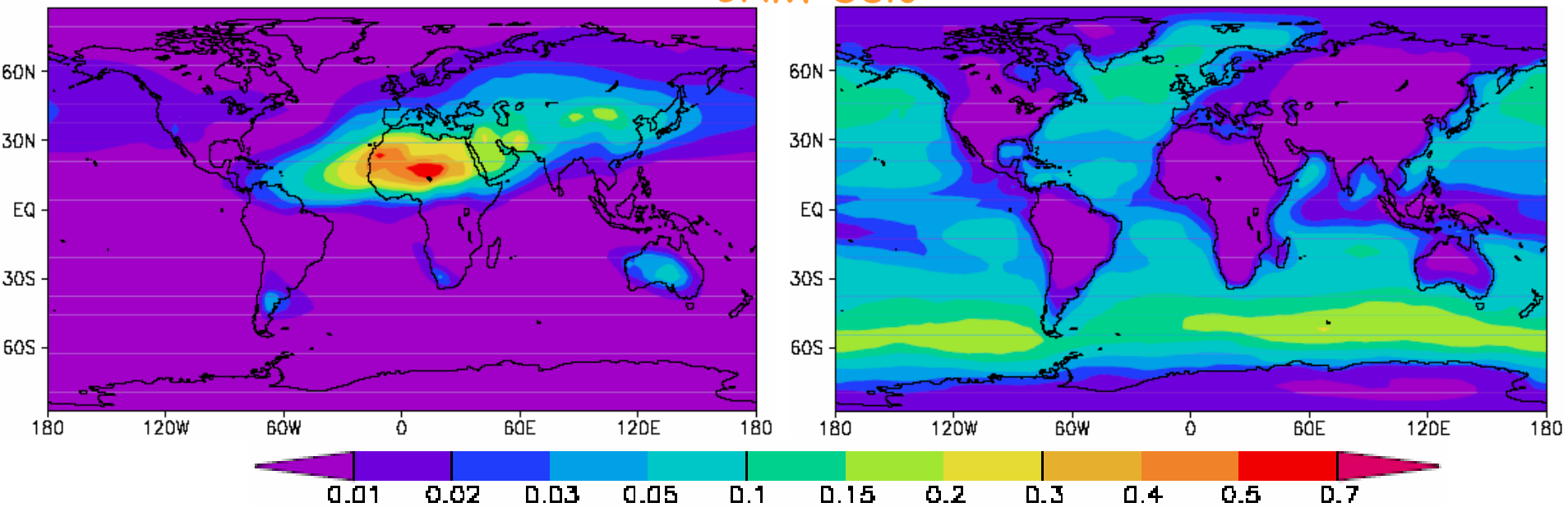


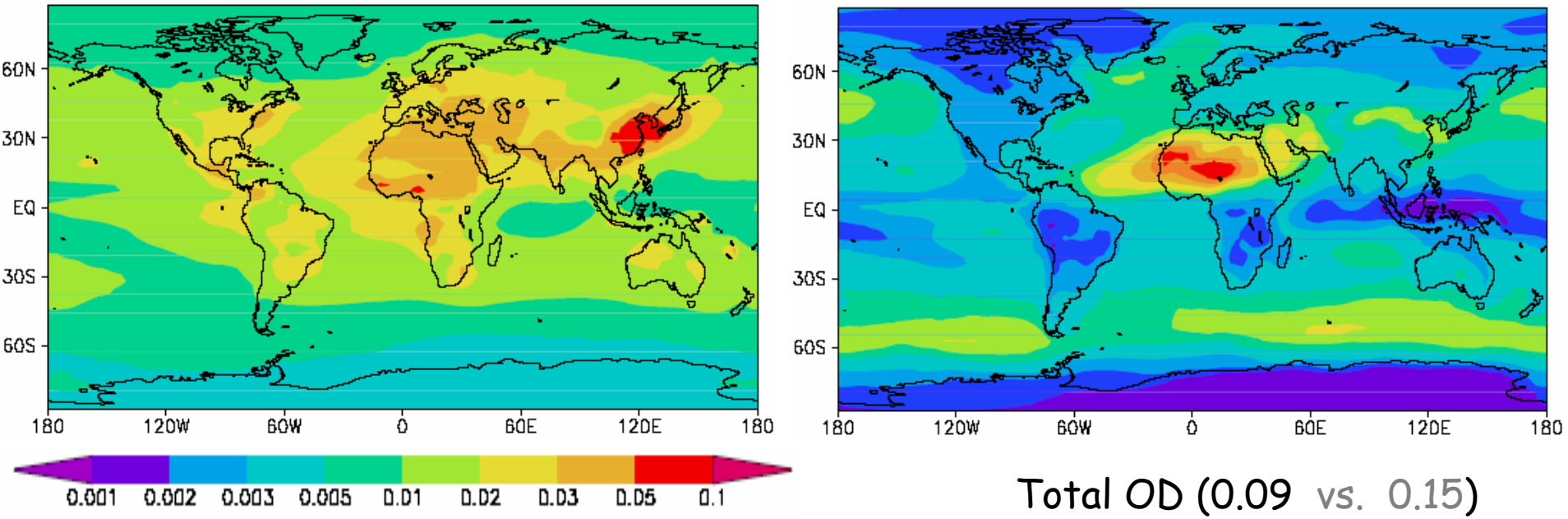
BC load (0.154 mg/m^2 vs. 0.22)

Mineral OD550 (0.025 vs. 0.051)

CAM-Oslo

Sea-salt OD550 (0.049 vs. 0.066)





SO_4, *BC & OC* OD550 (0.016 vs. 0.029)

Total OD (0.09 vs. 0.15)

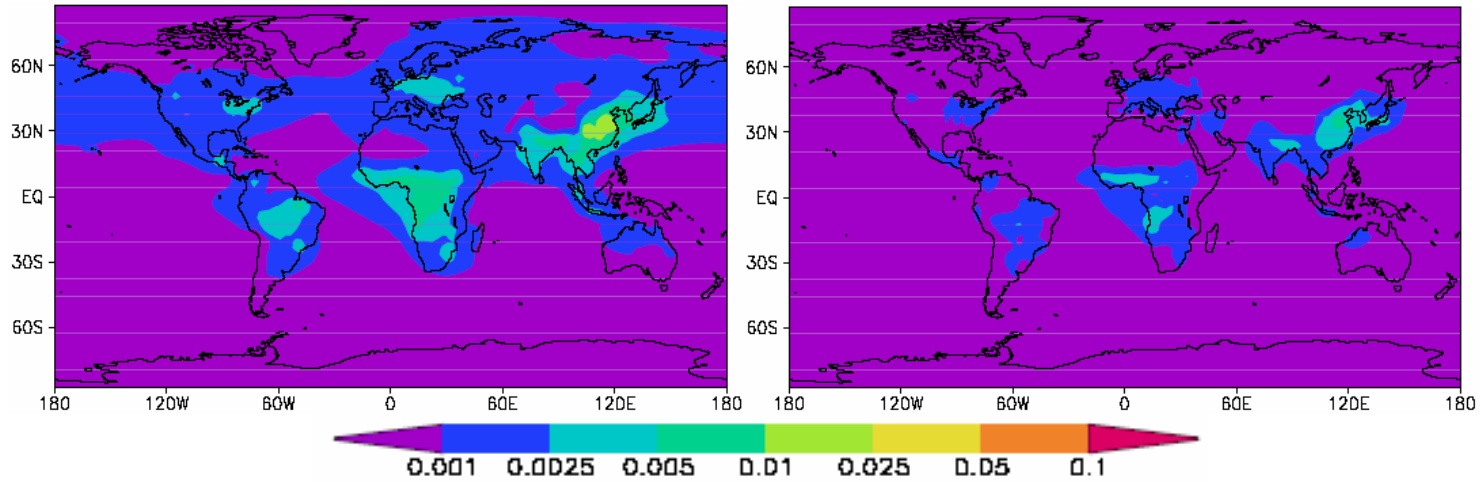
CCM-Oslo

CAM-Oslo

τ_{BC}

(0.001)

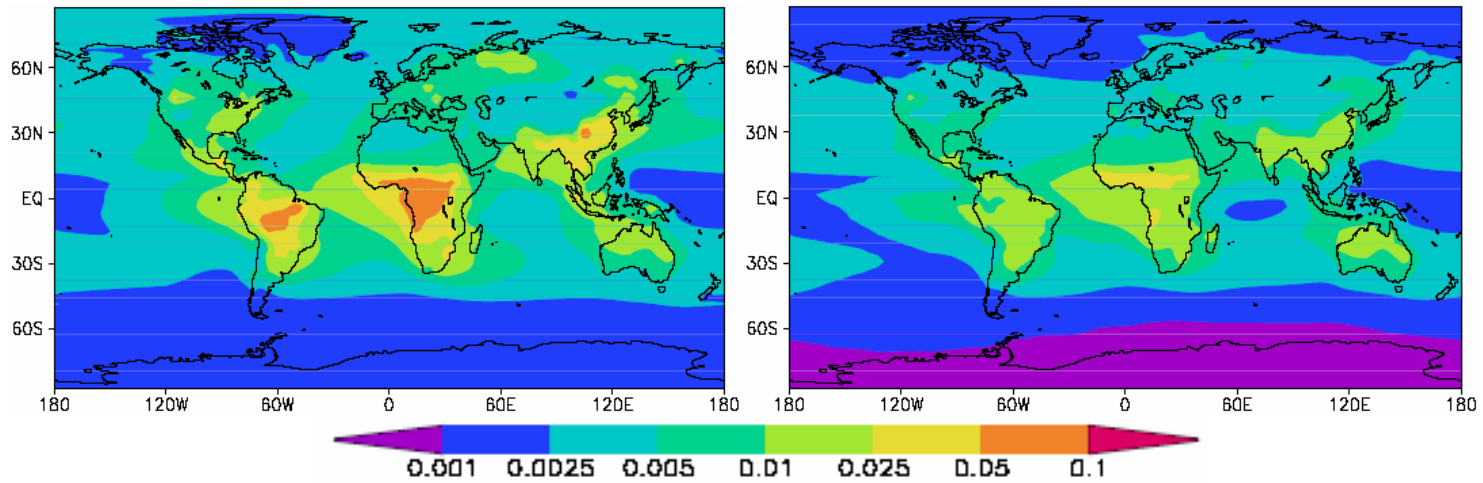
(0.0005)



τ_{OC}

(0.008)

(0.005)



τ_{SO4}

(0.020)

(0.010)