Study of aerosol direct and first indirect radiative effects with GEOS-Chem-APM

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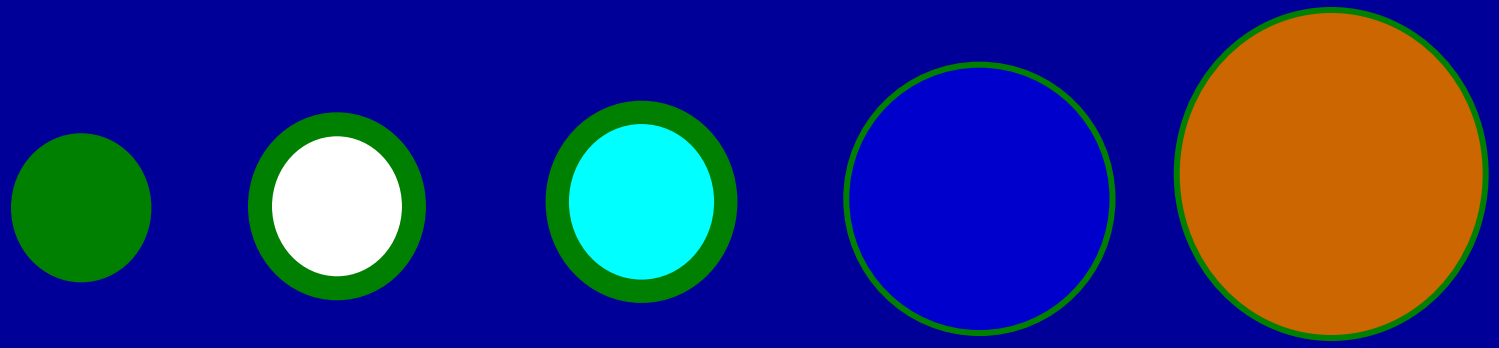
Aerosol DRF and IRF depend on

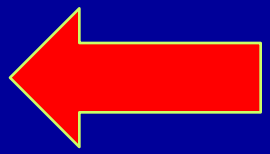


Concentrations,

Sizes,

Compositions,

Mixing States



Emission, Deposition,

Nucleation, Growth,

Coagulation,
Scavenging,

Aqueous Chemistry

which have large spatial and temporal variations.

Advanced Particle Microphysics (APM) model in GEOS-Chem

Turco et al., 1979; Jacobson et al., 1994; Yu and Turco, 1998; Yu and Luo, ACP, 2009

Secondary particles (SP) : **40** bins

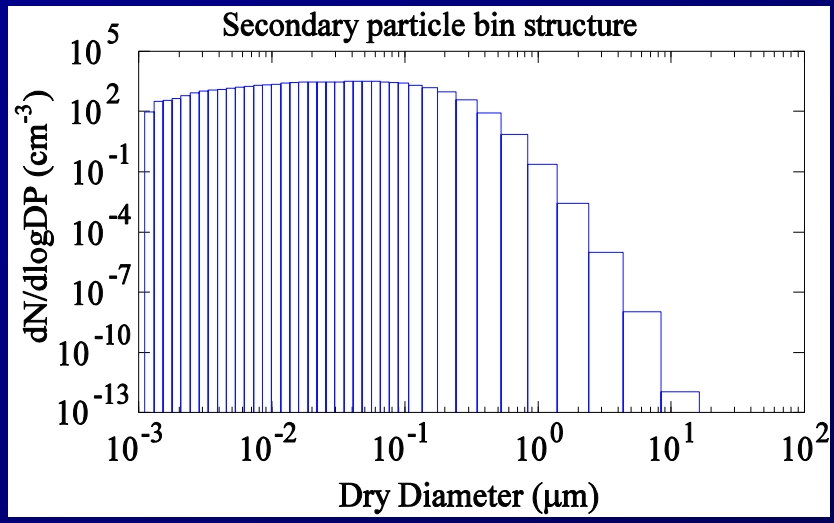
Sea salt particles: 20 bins

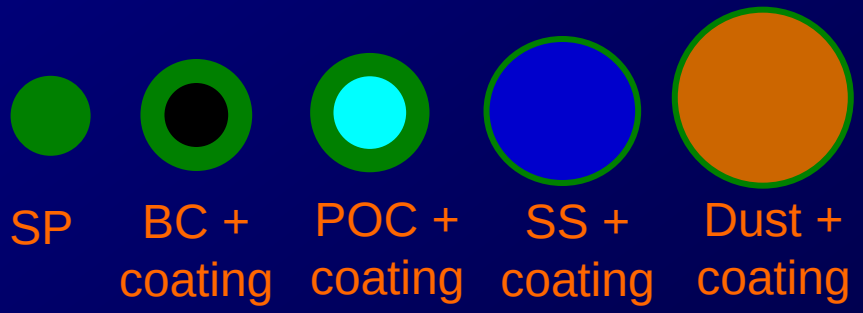
Dust: 15 bins

BC: two log-normal modes (one for fossil fuel, the other for biomass burning)

Primary OC: two log-normal modes

Coating of primary particles by SP species tracked.





GEOS-Chem-APM

Assimilated meteorology

Full chemistry (NOx, SOx, VOCs, etc.)

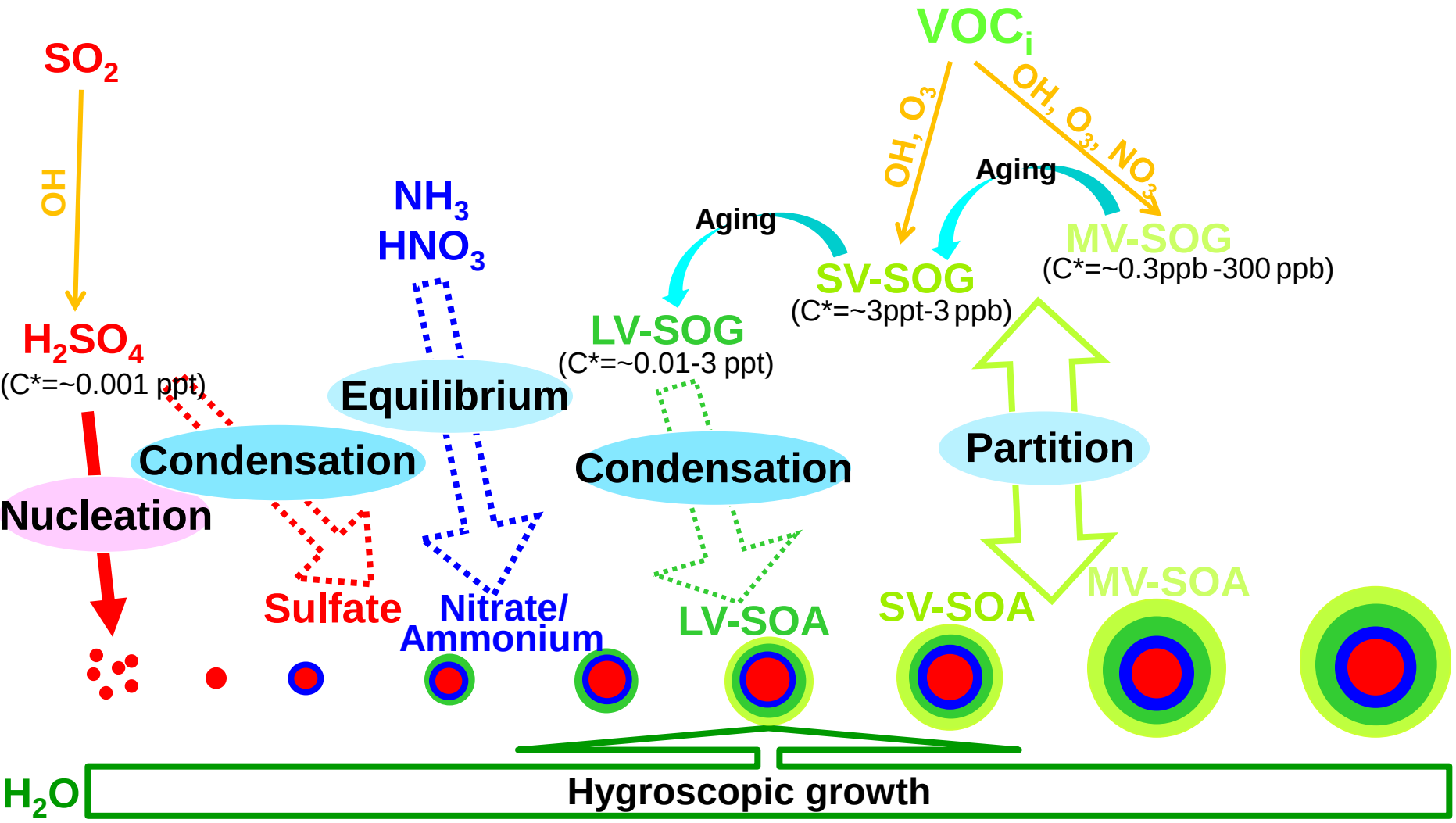
Full size-resolved microphysics

Computing cost (8-core workstation)

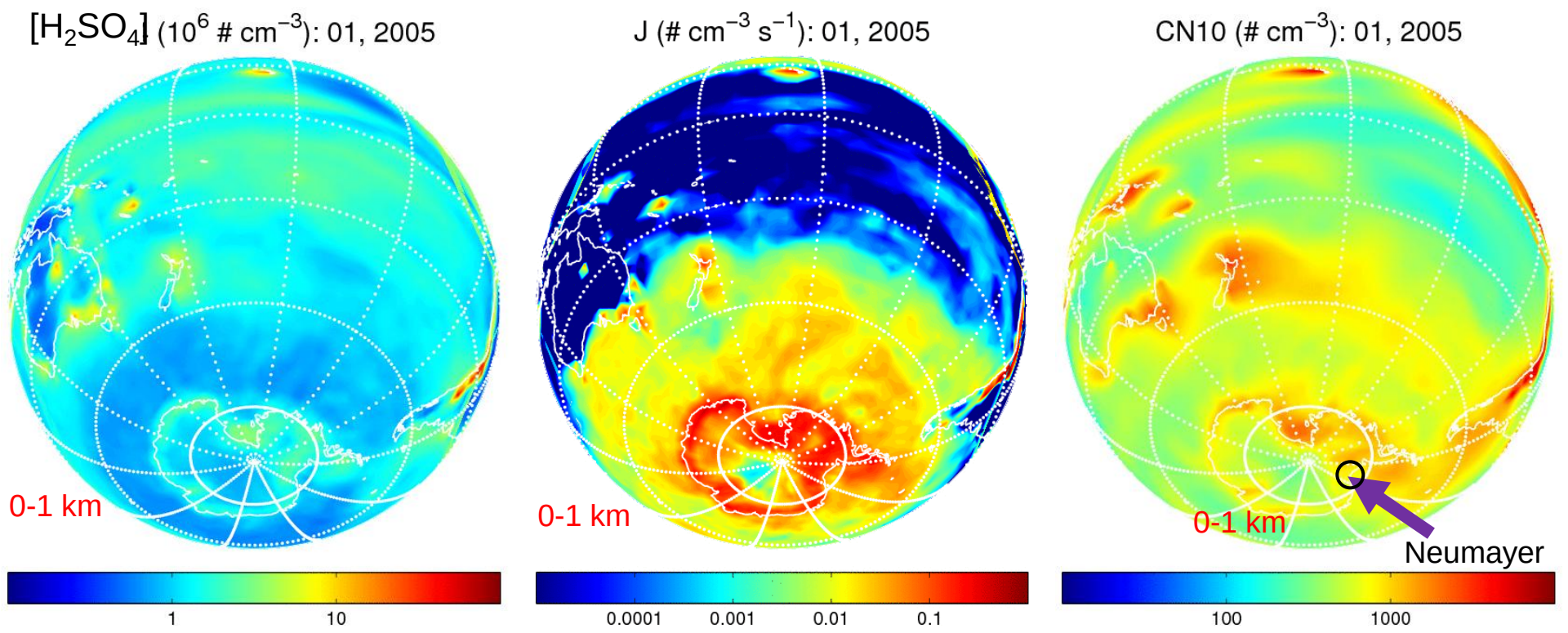
GEOS-Chem (4^ox5^o , 47 layers, **1 yr**)

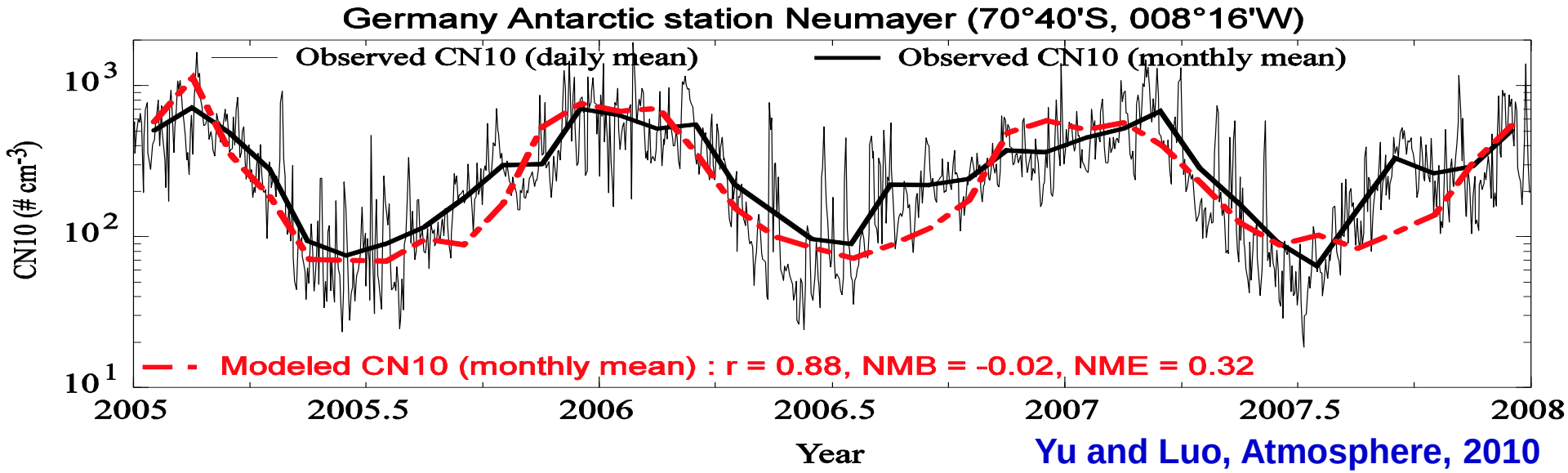
Original model	With APM
59 tracers	59+88= 147 tracers
~ 1 day	**~ 2** days

Formation and growth of atmospheric particles



Yu, ACP, 2011

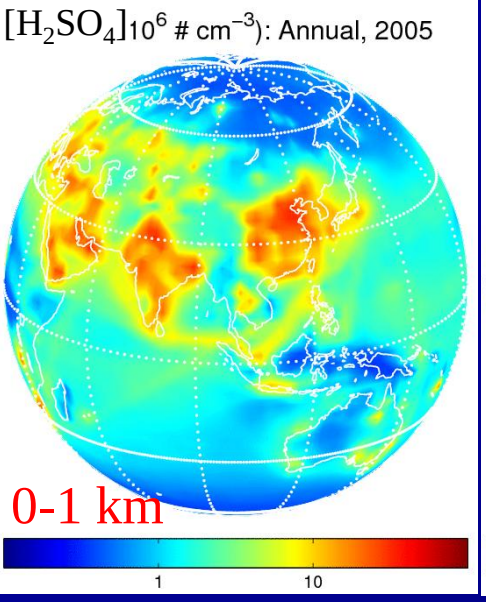


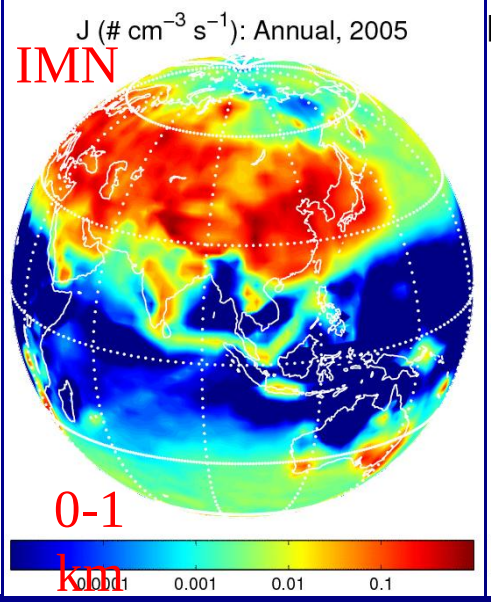


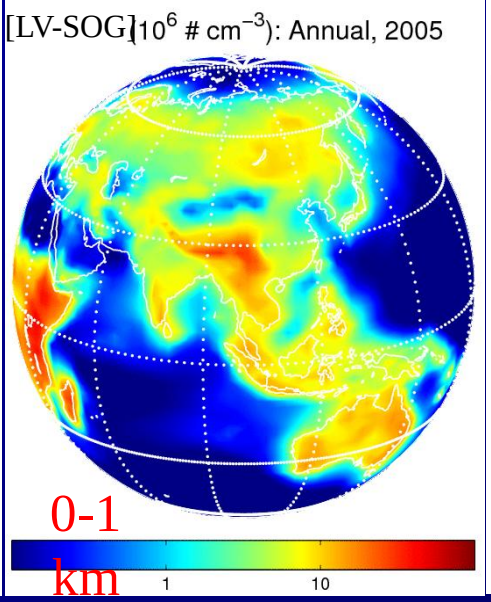
Yu and Luo, Atmosphere, 2010

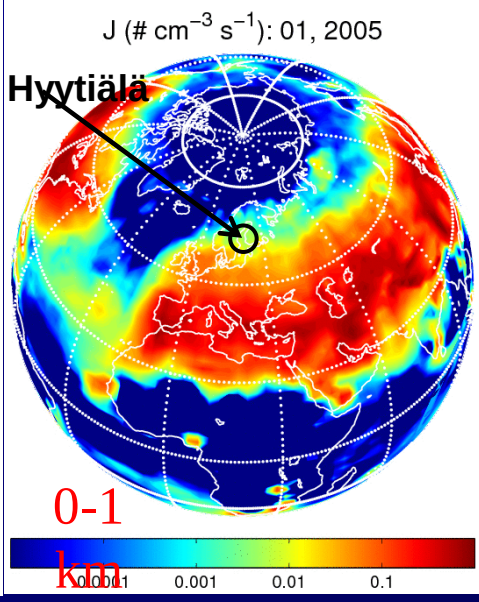
data references: König-Langlo et al. (1998), Weller and Lampert (2008)

Modeling results are for surface layer









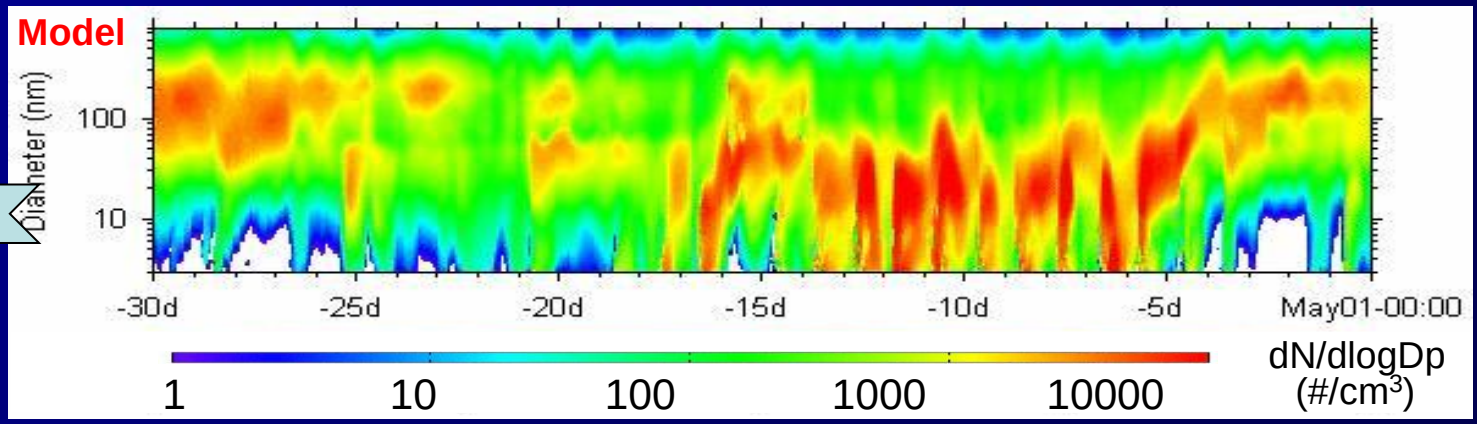
CN

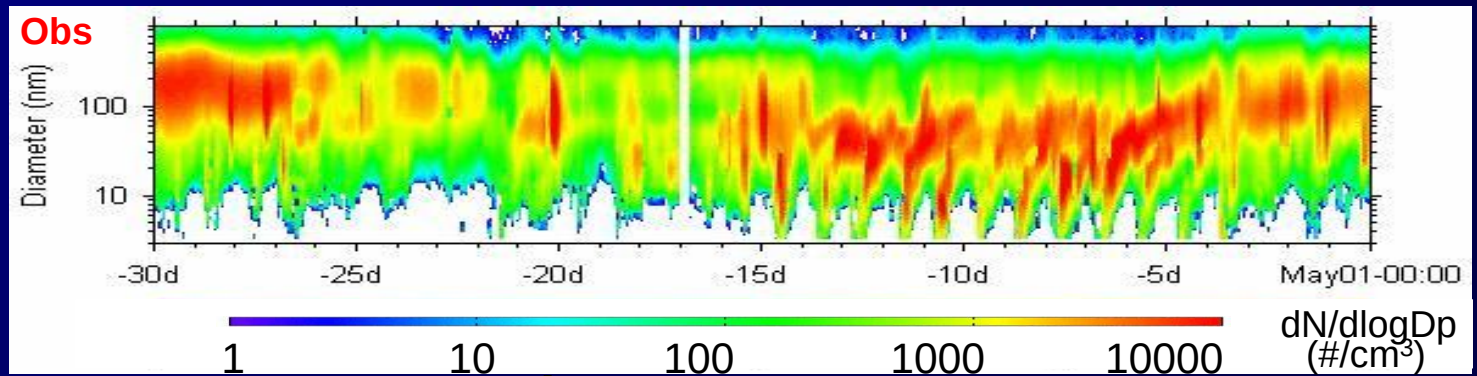
CCN/IN

Ext Coef.

AOD

Simulated and observed particle size distribution at Hyytiälä





Data acknowledgements: Prof Markku Kulmala, CREATE and EUSSAR data base.

Aerosol optical properties and radiative forcing

based on GEOS-Chem-APM (Yu et al., 2012a,b; Ma et al., 2012)

Optical properties

Core-shell model (Ackerman and Toon, 1981)

Radiative transfer

CCCMa 1D RT model (Li and Barker, 2002) – no McICA

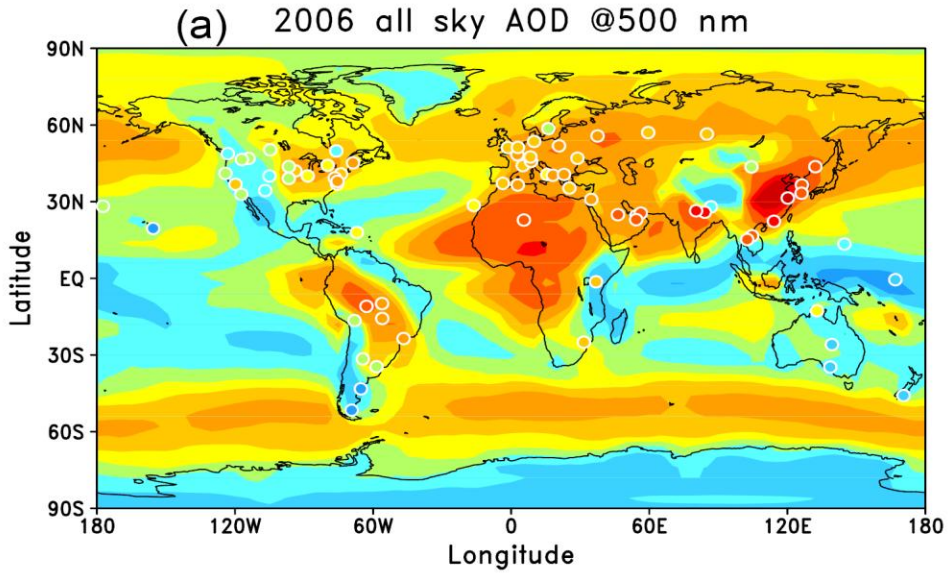
AER column RRTMG model (Clough et al., 2005)

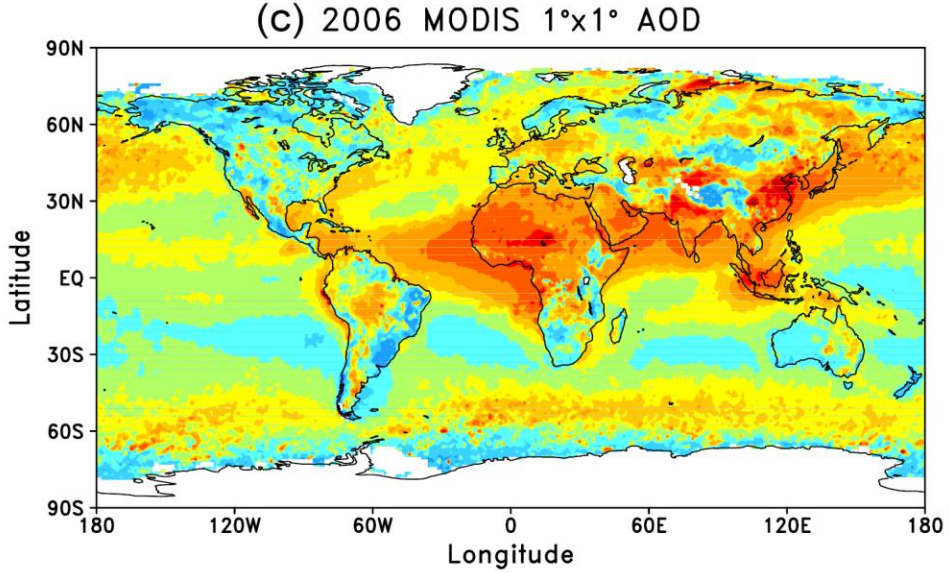
– with McICA, all DRF and IRF results shown below are based on RRTMG

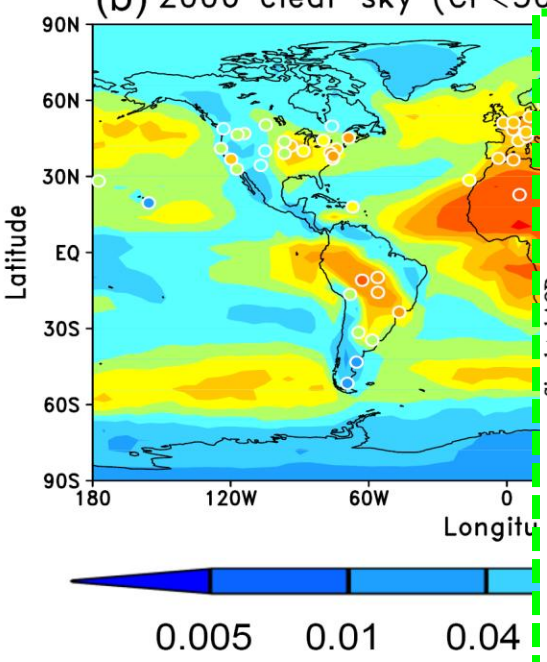
Aerosol-cloud interaction

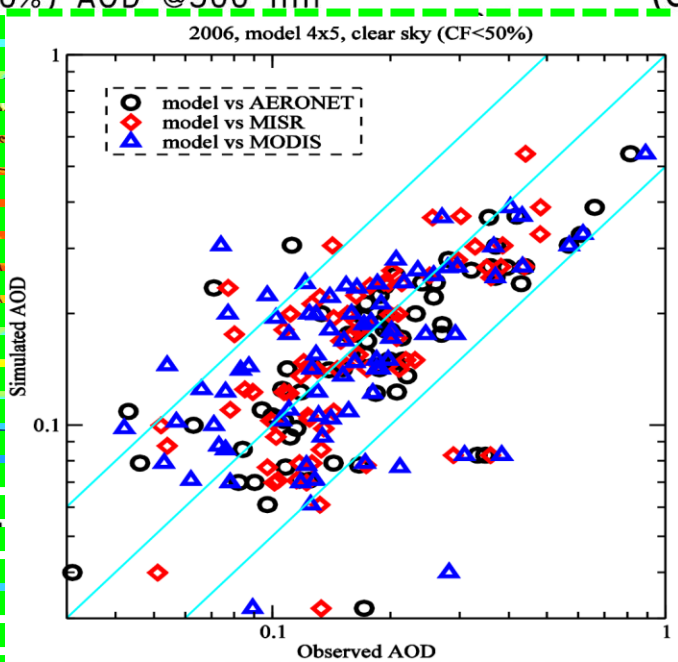
Cloud droplet formation (Jones et al., 1994; Abdul-Razzak and Ghan, 2002), Ice nucleation (Liu and Penner, 2005)

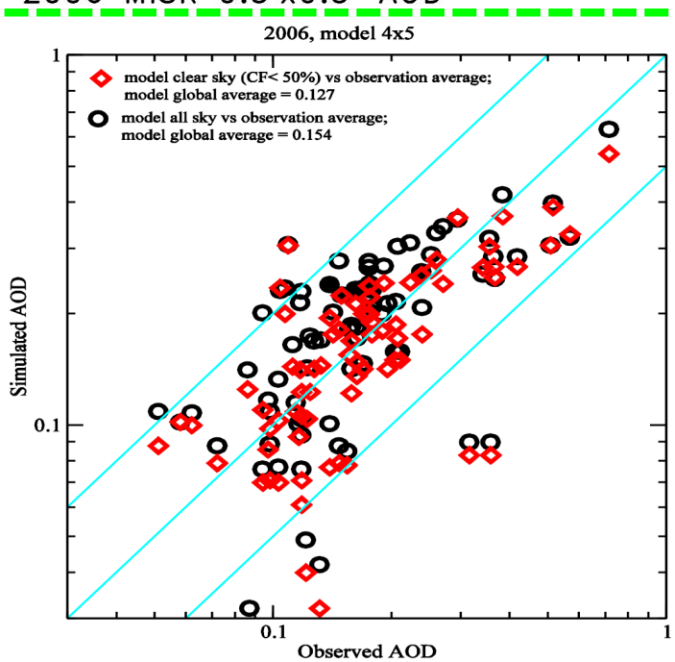
Comparison with AOD measurements

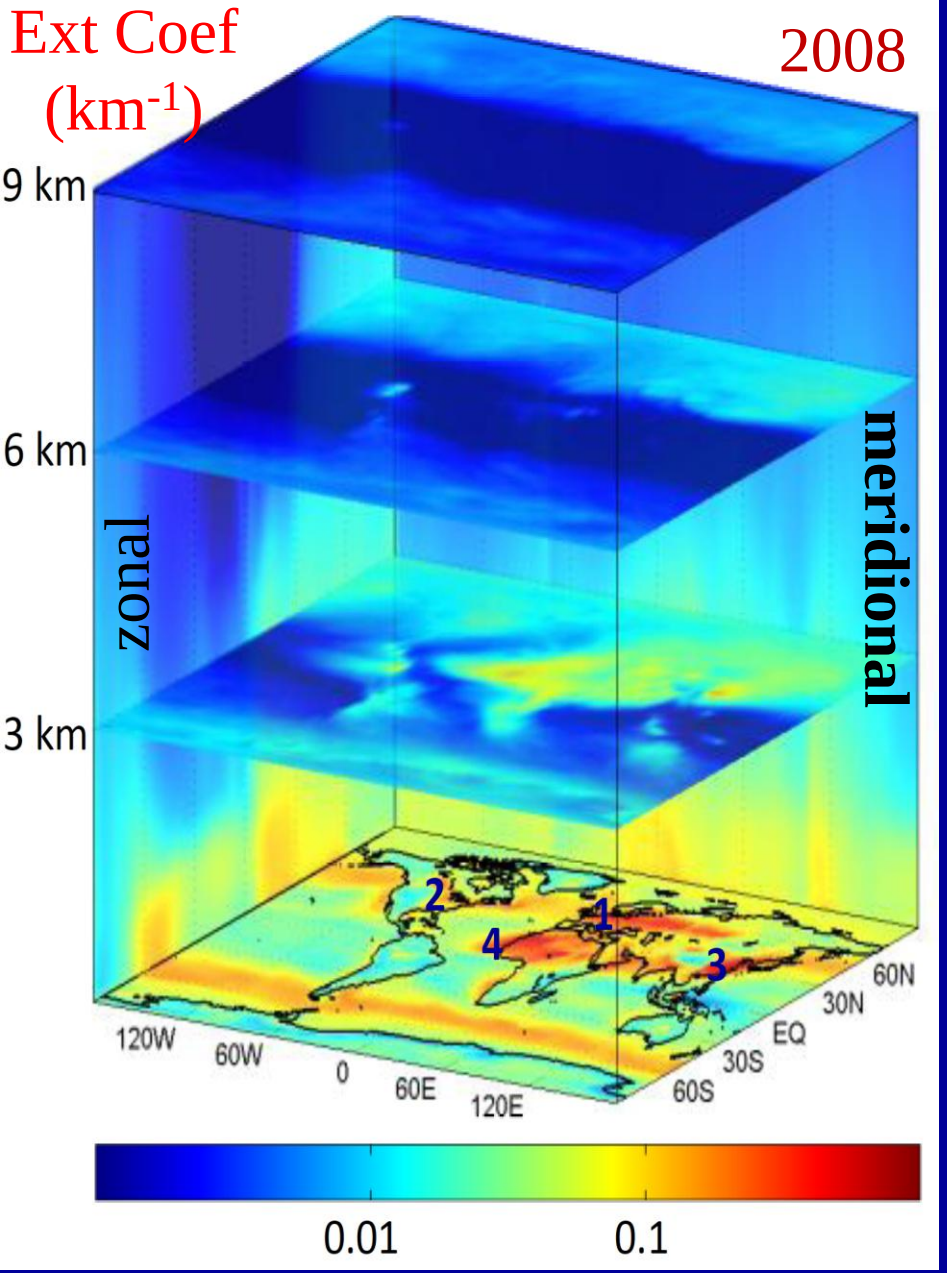


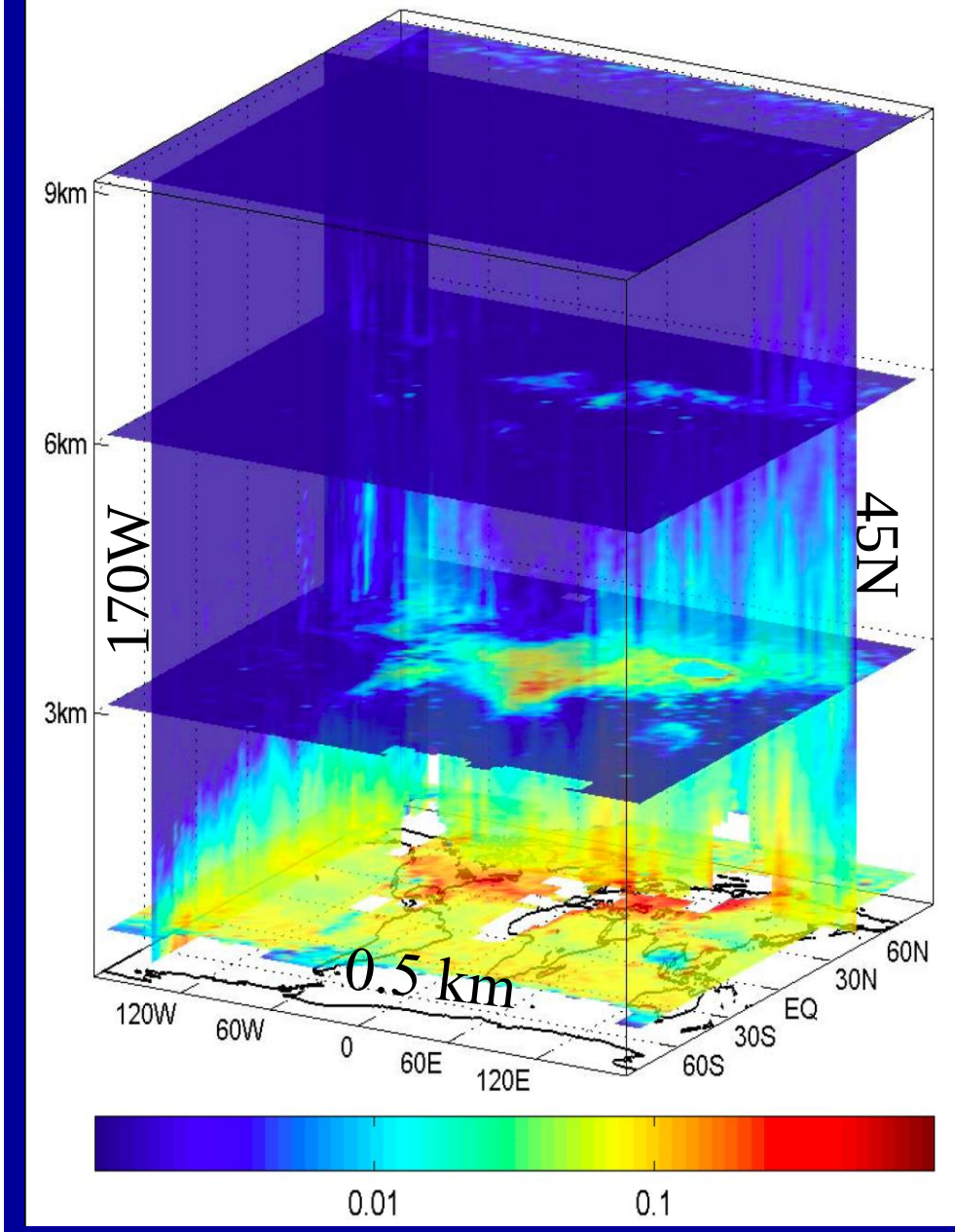






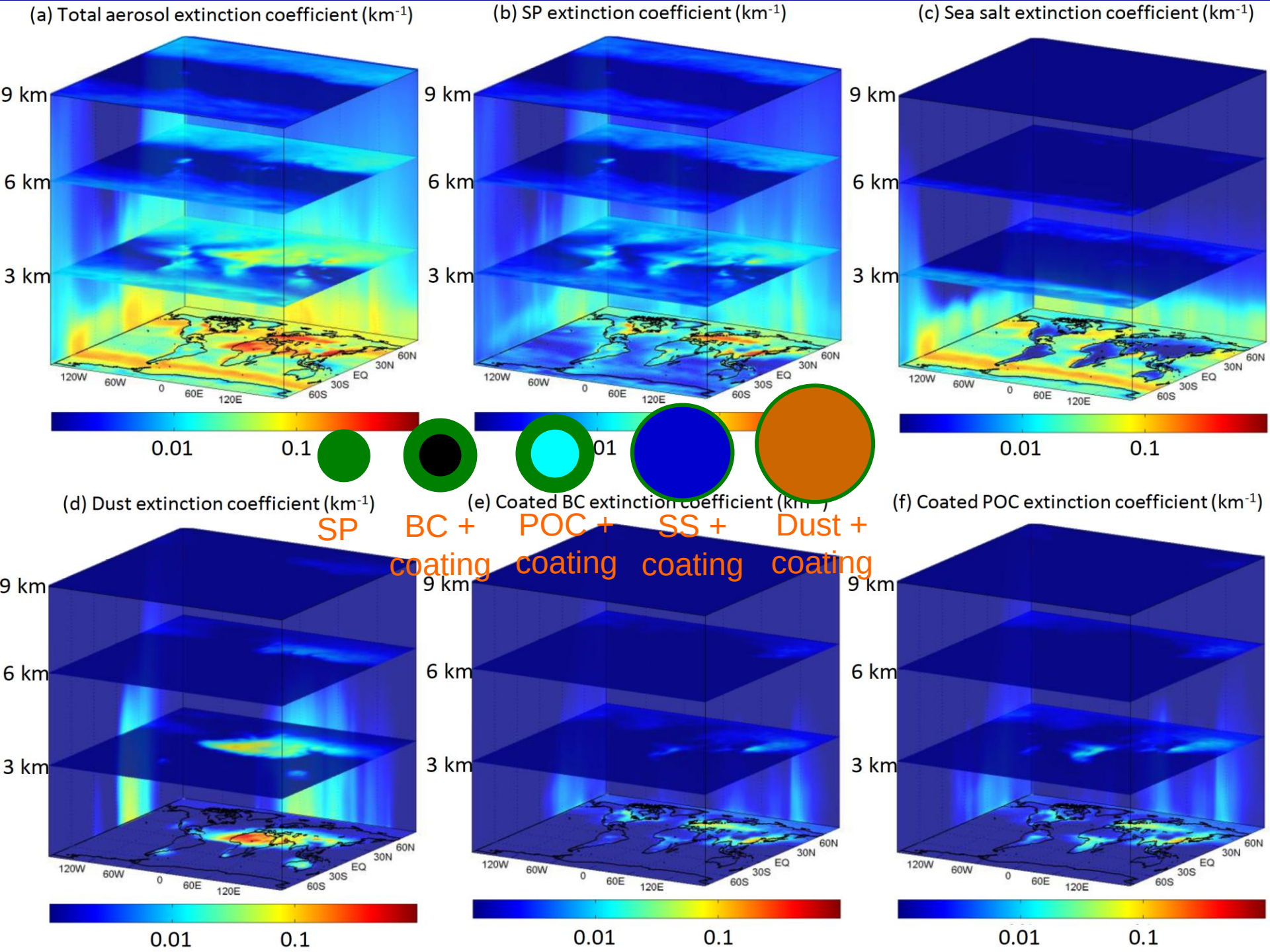


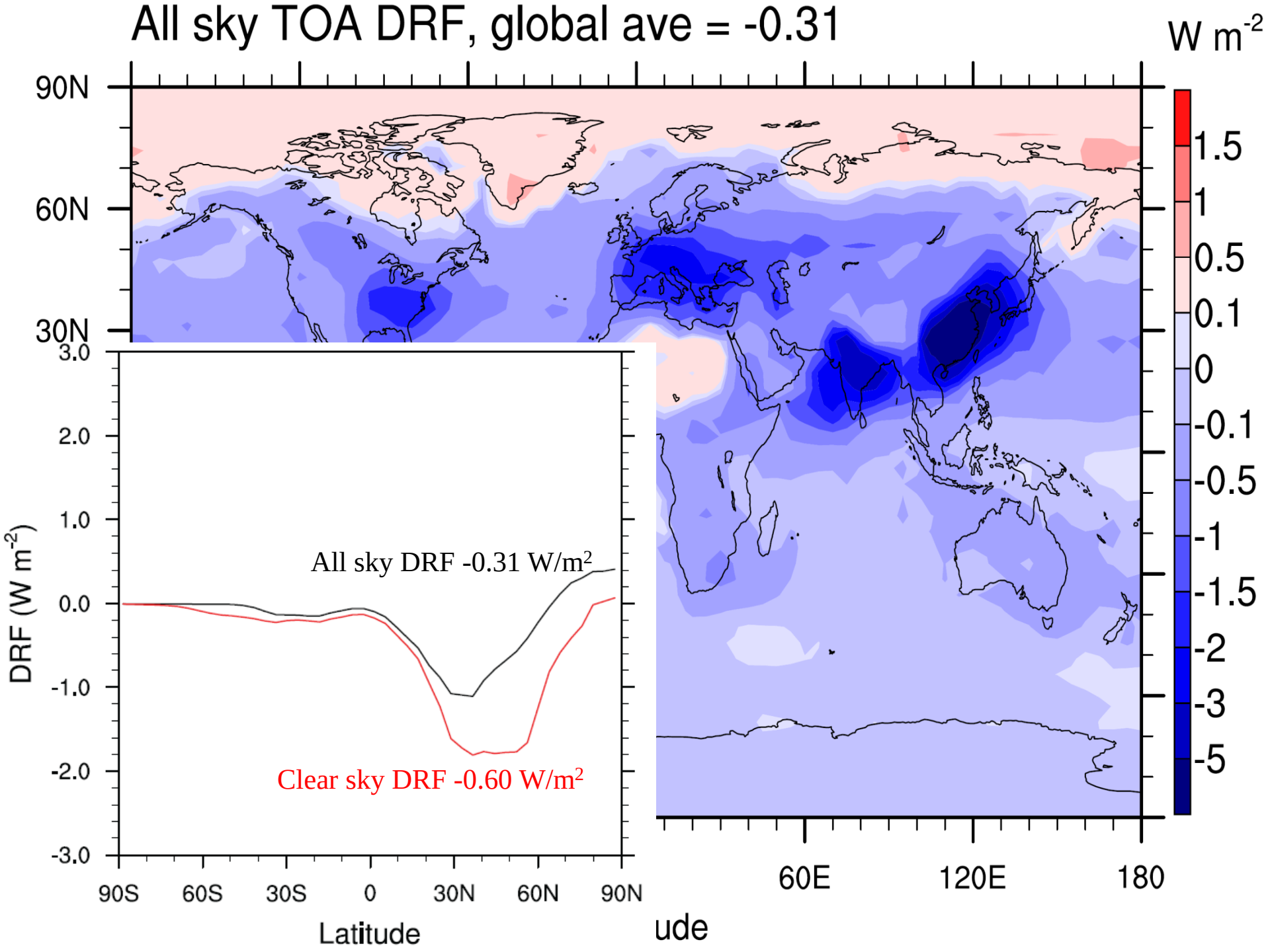


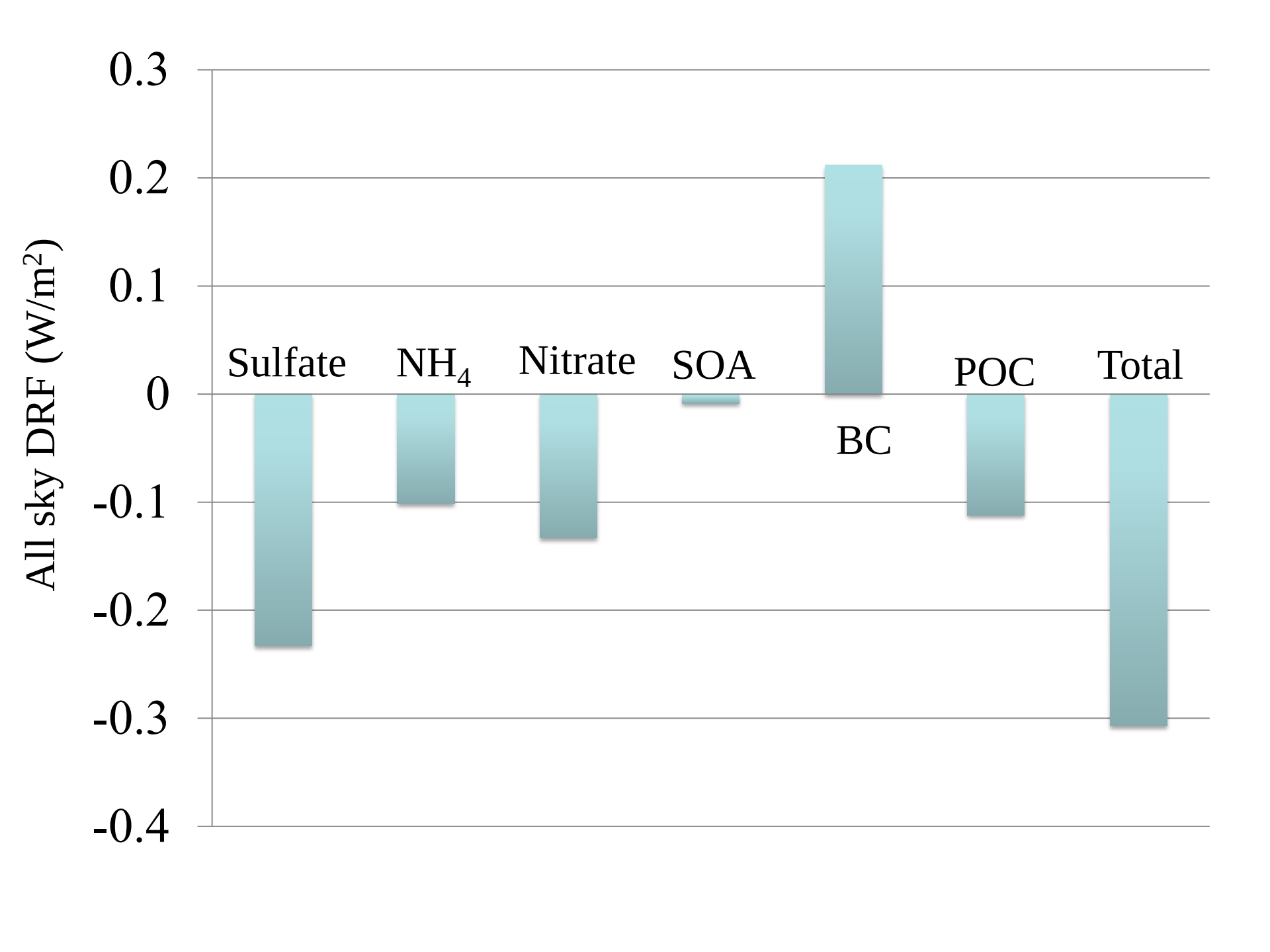


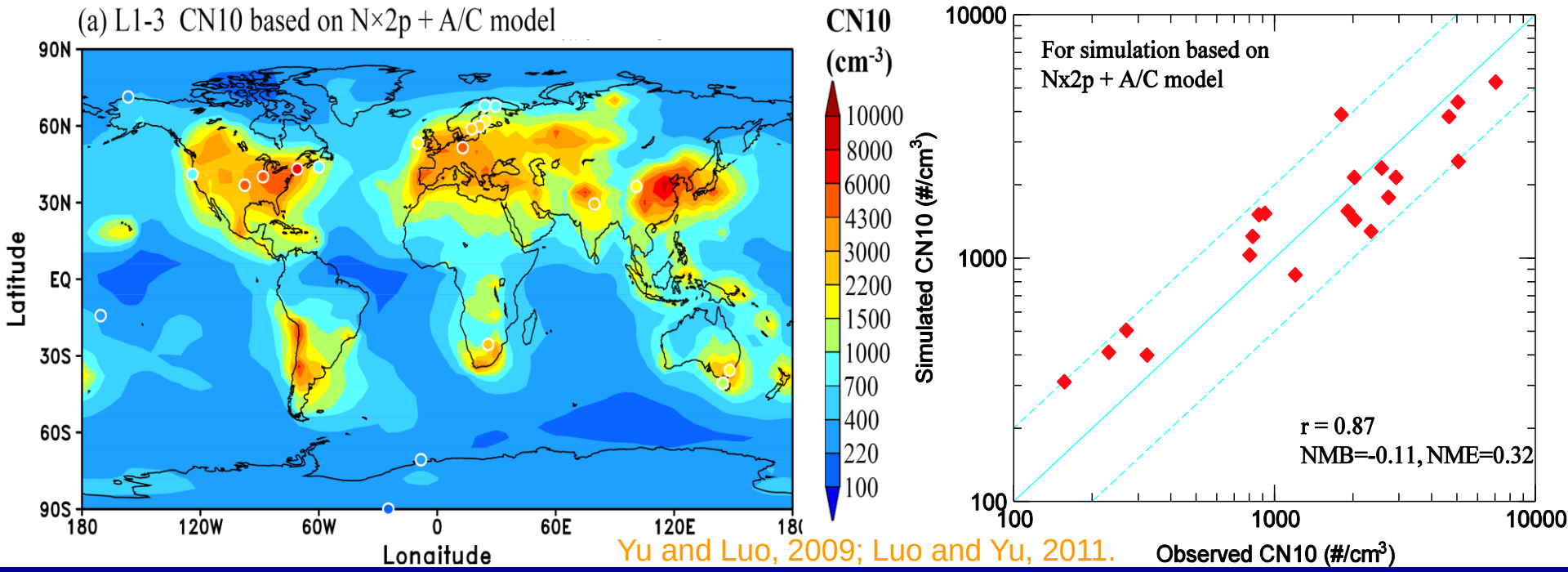
Model: All sky, annual average
Vertical sigma coordinate

CALIOP: night time all sky, annual,
Vertical asl coordinate

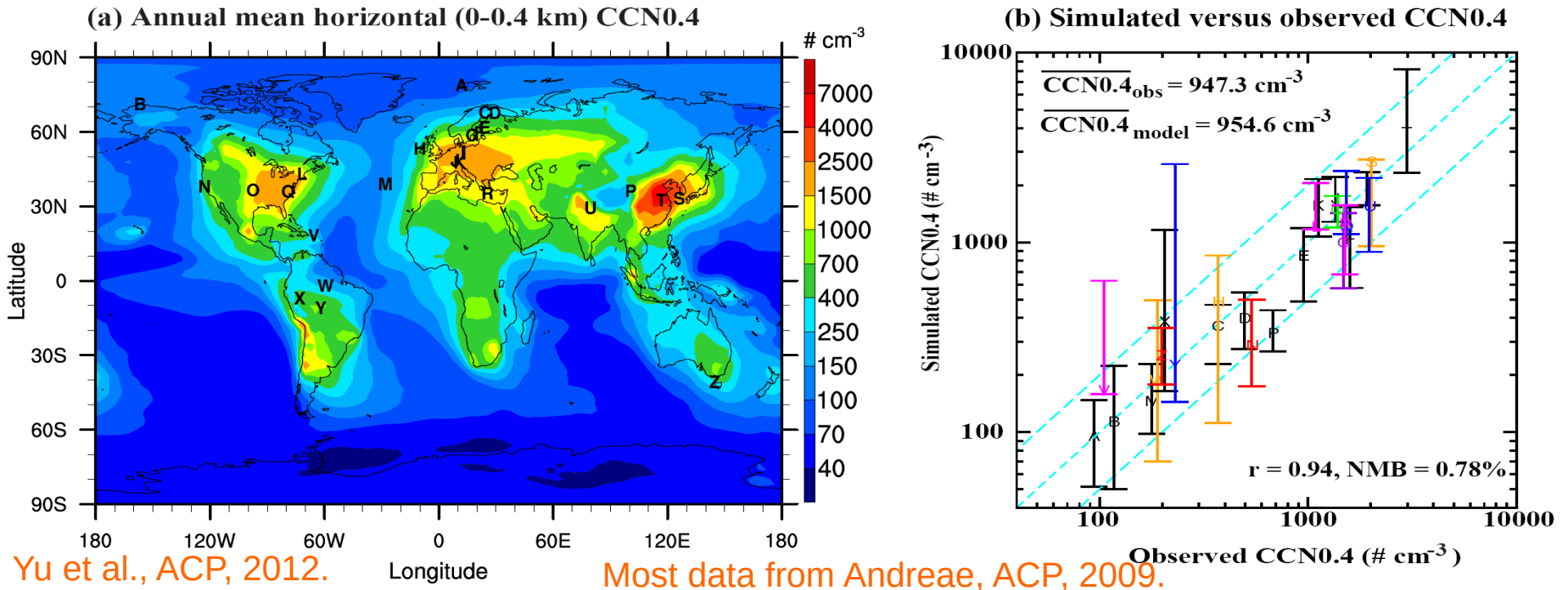

(a) Total aerosol extinction coefficient (km-1)
(b) SP extinction coefficient (km-1)
(c) Sea salt extinction coefficient (km-1)
9 km
6 km
3 km
120W
60W
0
60E
120E
60S
30S
EQ
30N
60N
0.01
0.1
(d) Dust extinction coefficient (km-1)
(e) Coated BC extinction coefficient (km-1)
(f) Coated POC extinction coefficient (km-1)
SP
BC + coating
POC + coating
SS + coating
Dust + coating


All sky TOA DRF, global ave = -0.31
W m-2
90N
60N
30N
1.5
1
0.5
0.1
0
-0.1
-0.5
-1
-1.5
-2
-3
-5
60E
120E
180
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
DRF (W m-2)
All sky DRF -0.31 W/m2
Clear sky DRF -0.60 W/m2
90S
60S
30S
0
30N
60N
90N
Latitude
ude


0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
All sky DRF (W/m2)
Sulfate
NH4
Nitrate
SOA
BC
POC
Total

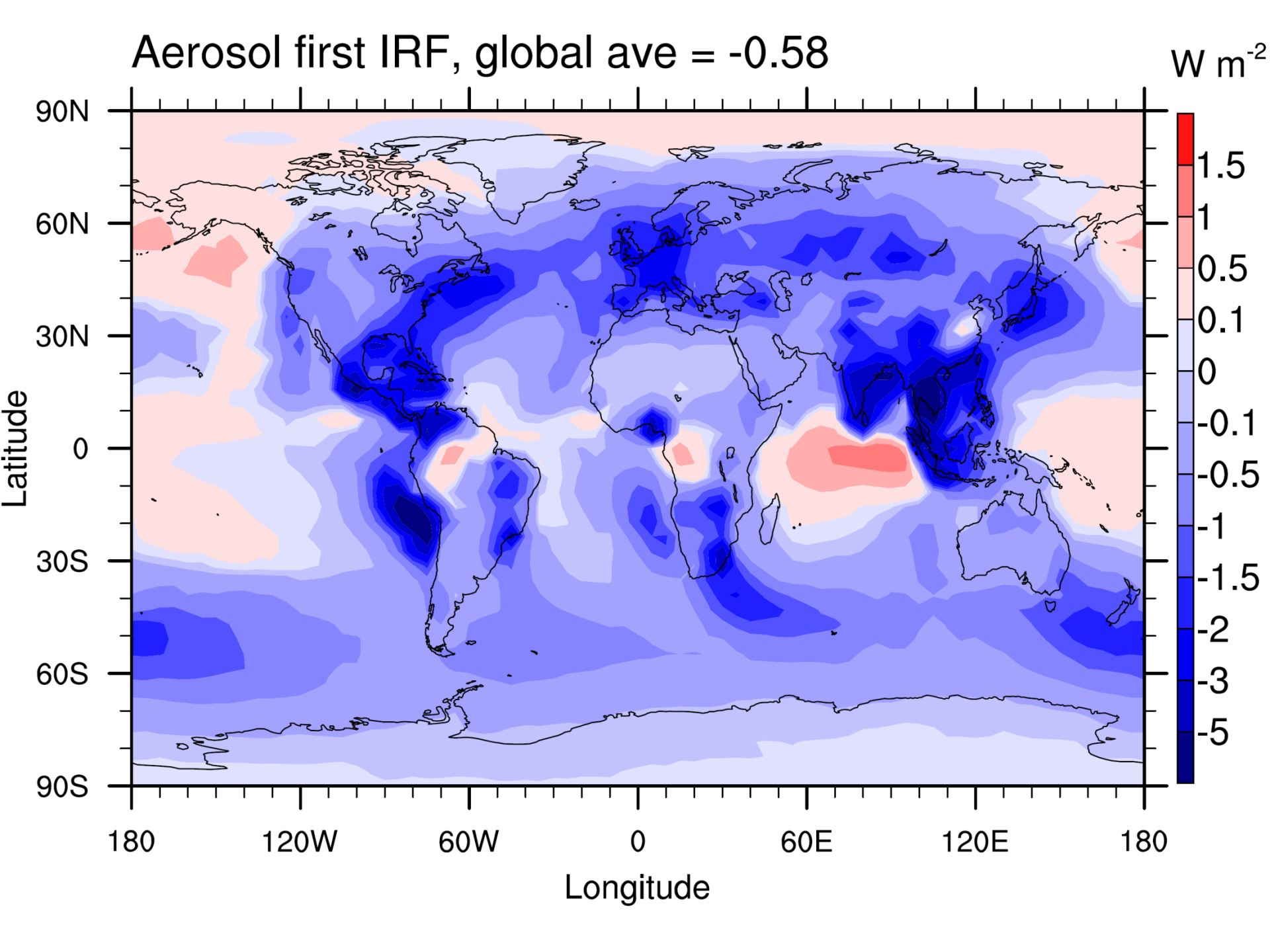


Yu and Luo, 2009; Luo and Yu, 2011.



Yu et al., ACP, 2012.

Most data from Andreae, ACP, 2009.


Aerosol first IRF, global ave = -0.58
W m-2
1.5
1
0.5
0.1
0
-0.1
-0.5
-1
-1.5
-2
-3
-5
90N
60N
30N
0
30S
60S
90S
Latitude
180
120W
60W
0
60E
120E
180
Longitude

Summary

Based on GEOS-Chem-APM:

Aerosol all sky DRF:

-0. 31 W/m^2

Aerosol first IRF (preliminary):

-0.58 W/m^2

My thoughts on possible additional inter-comparisons:

- Pre-industry aerosol properties
- Model uncertainties (Sensitivities of DRF and IRF to a selected list of schemes/parameterizations)
- Model derived dCDN/dAOD, dCDN/dAI for PD and PI