Modal Aerosol Formulation and Indirect Effects in NCAR CAM

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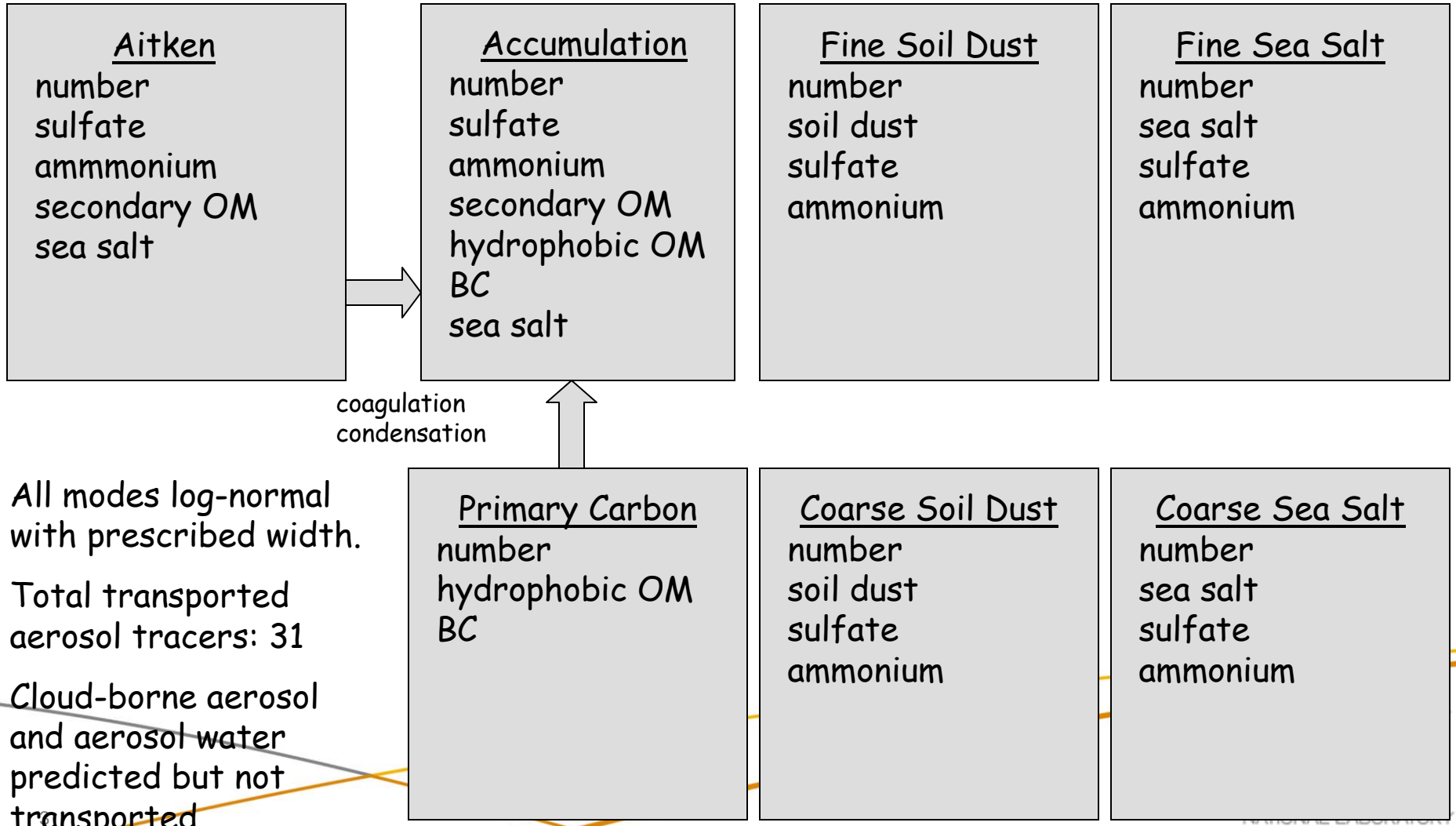
Bulk Aerosol Model (BAM)

- External mixtures of all important aerosol types: sulfate, sea salt, dust, hydrophobic and hydrophilic OC & BC
- Prescribed size distribution
  - ➢ number proportional to mass
- Coupled to 2-moment cloud microphysics
- Tuned to produce an acceptable climate

Benchmark 7-Mode Modal Aerosol Model (MAM)



All modes log-normal with prescribed width.

Total transported aerosol tracers: 31

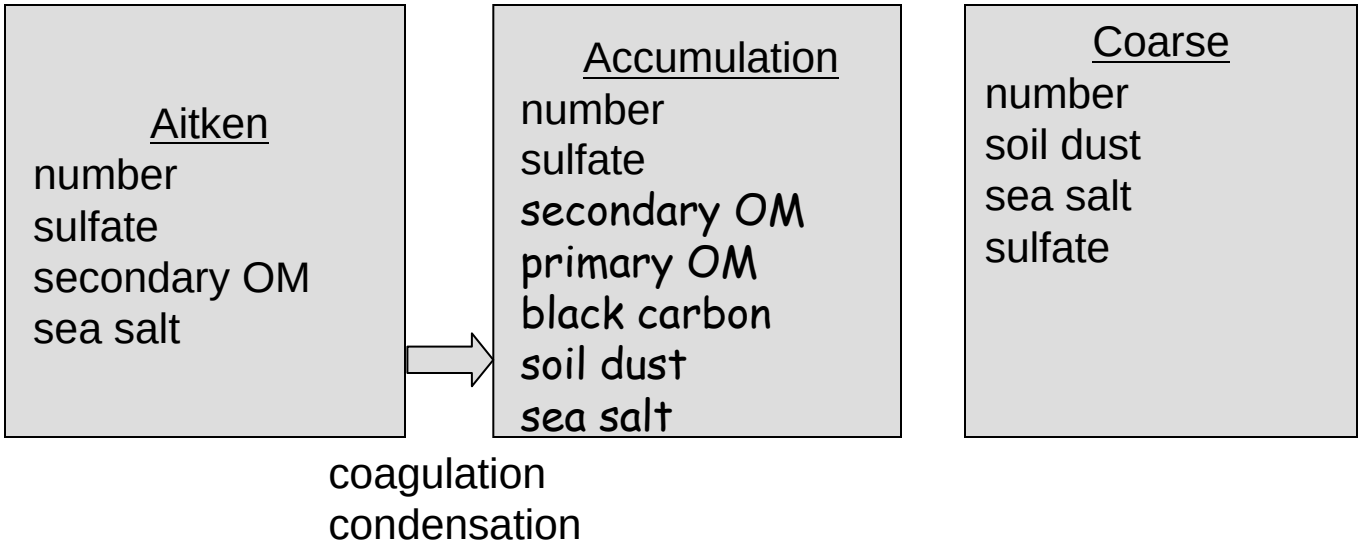
Cloud-borne aerosol and aerosol water predicted but not transported.

Simplified 3-mode version of MAM

Assume primary carbon is internally mixed with secondary aerosol.

Neglect aerosol water transport.

Assume ammonium neutralizes sulfate.



Total transported aerosol tracers: 15

CAM Simulations (CAM3.5.54)

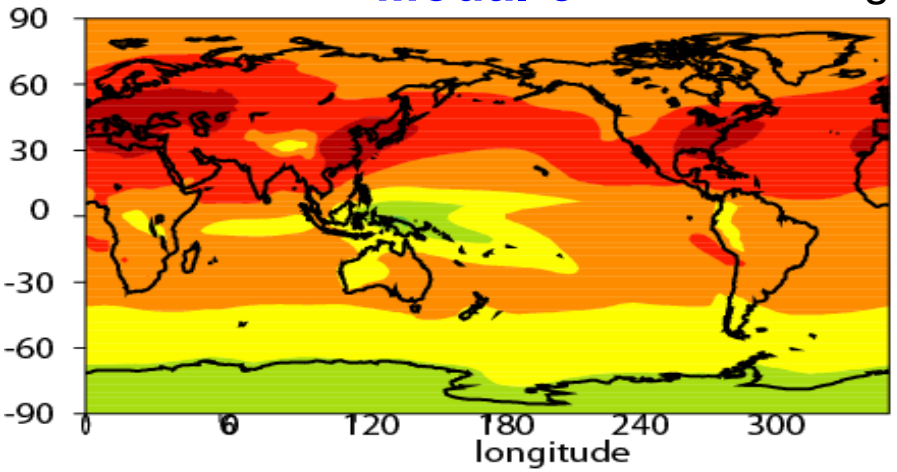
- Modal aerosol (1.9x2.5), 5 years
  - 3-mode present-day (PD) simulations
  - 3-mode pre-industrial (PI) simulations
  - 7-mode present-day (PD) simulations
  - 7-mode pre-industrial (PI) simulations

- Bulk aerosol (1.9x2.5), 5 years, PD and PI simulations

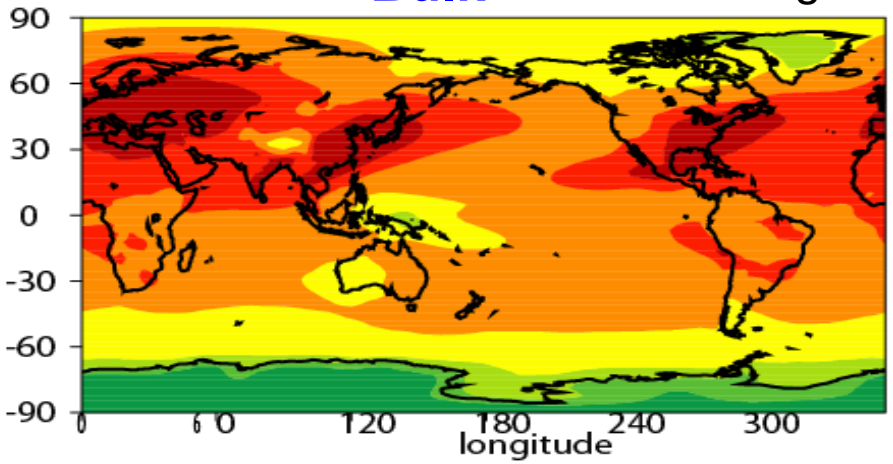
- **Coupled with 2-moment MG cloud microphysics**
- **Same NCAR emissions (OC, BC, DMS, SO2, SO4) for PD & PI**
- **Same emission schemes (dust and coarse sea salt)**
  - **ultrafine sea salt and SOA(g) emissions for Modal aerosol**
- **Same oxidant fields for PD and PI (Modal and Bulk)**

Sulfate Column Burden

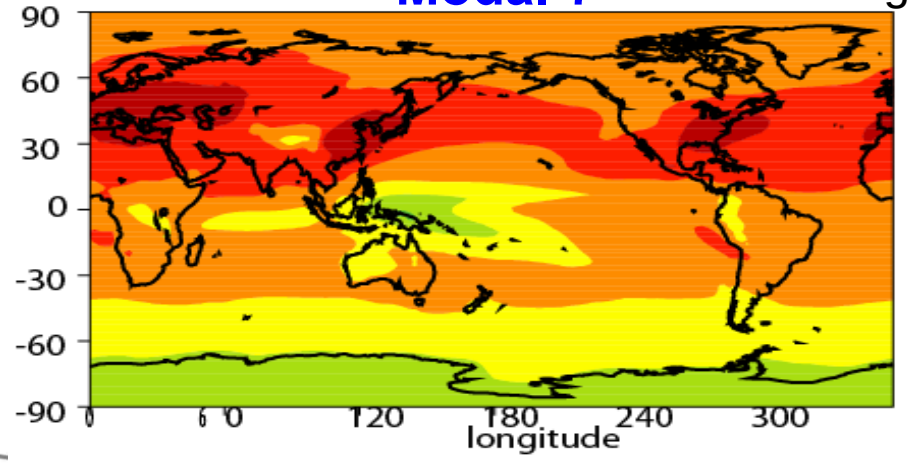
Modal-3 0.69 TgS



Bulk 0.77 TgS

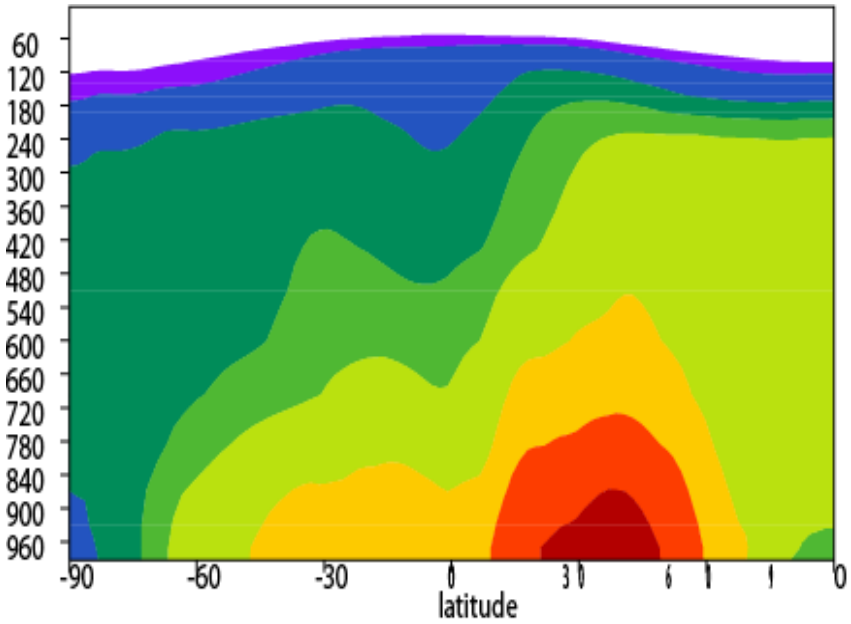


Modal-7 0.66 TgS

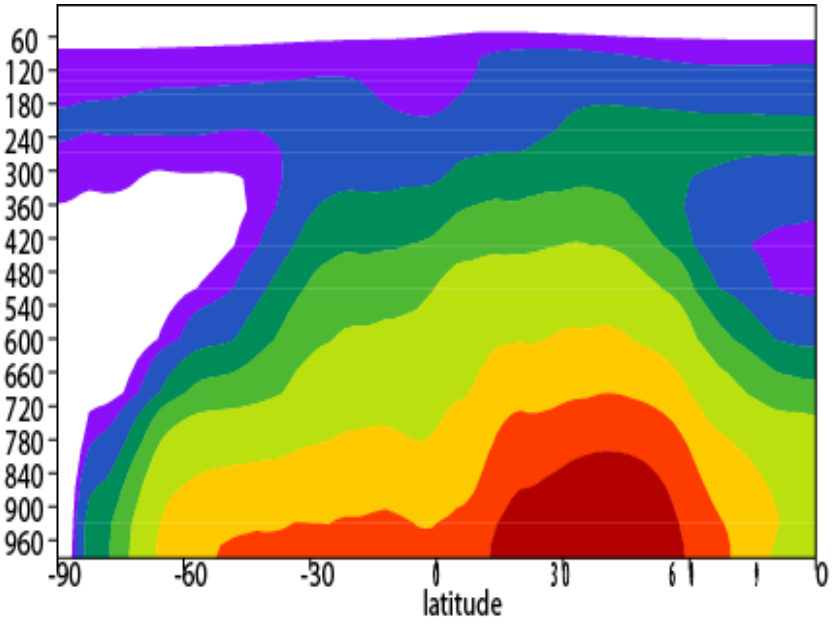


SO4 Zonal

Modal-3



Bulk



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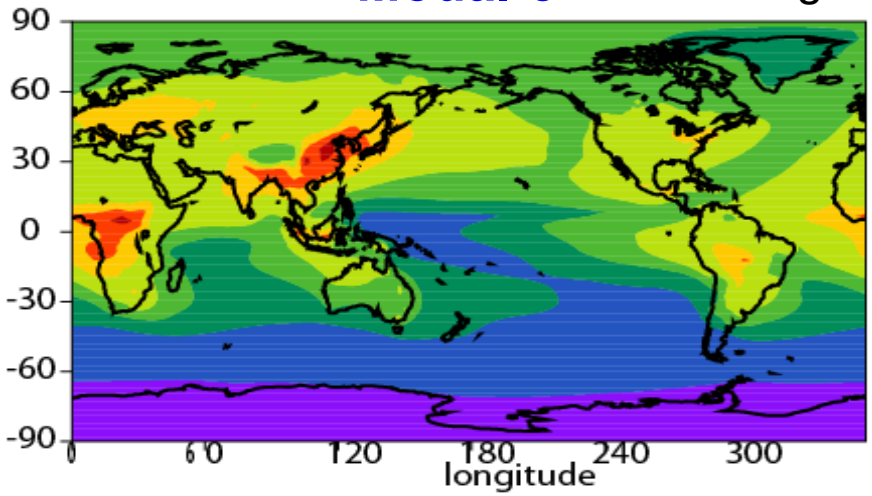
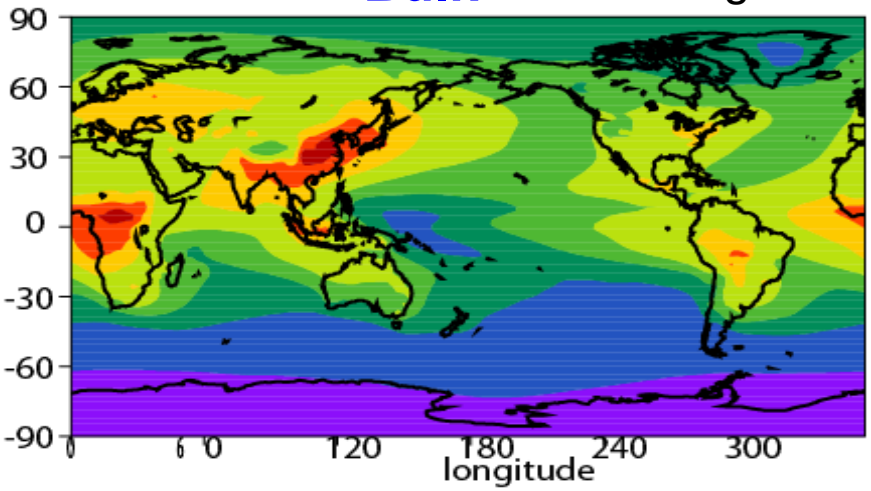
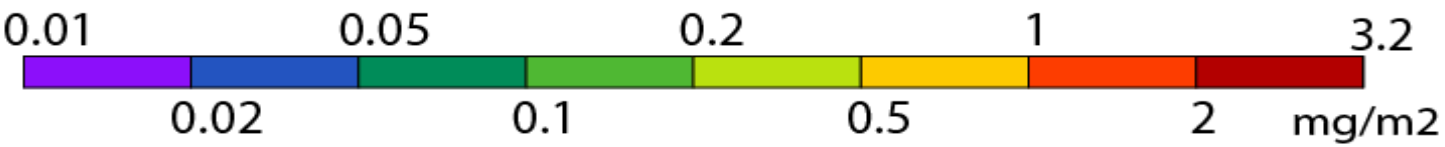
BC Column Burden

Modal-3 0.11 TgC

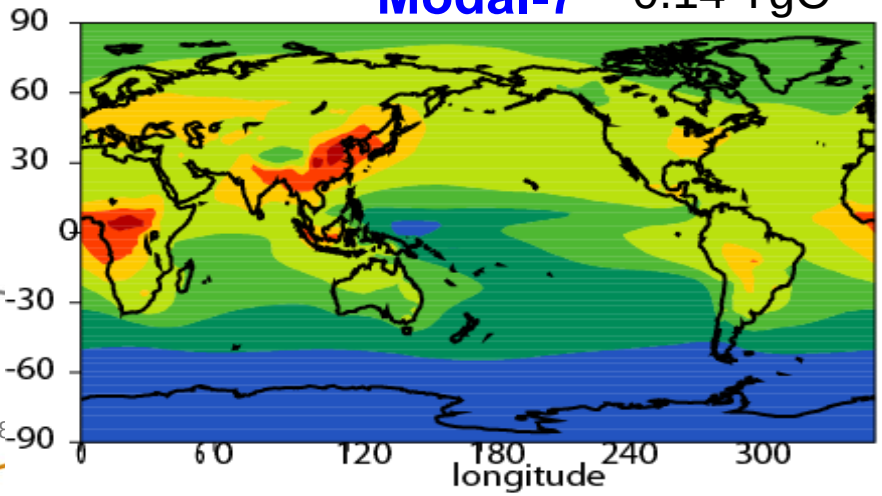


Bulk 0.13 TgC



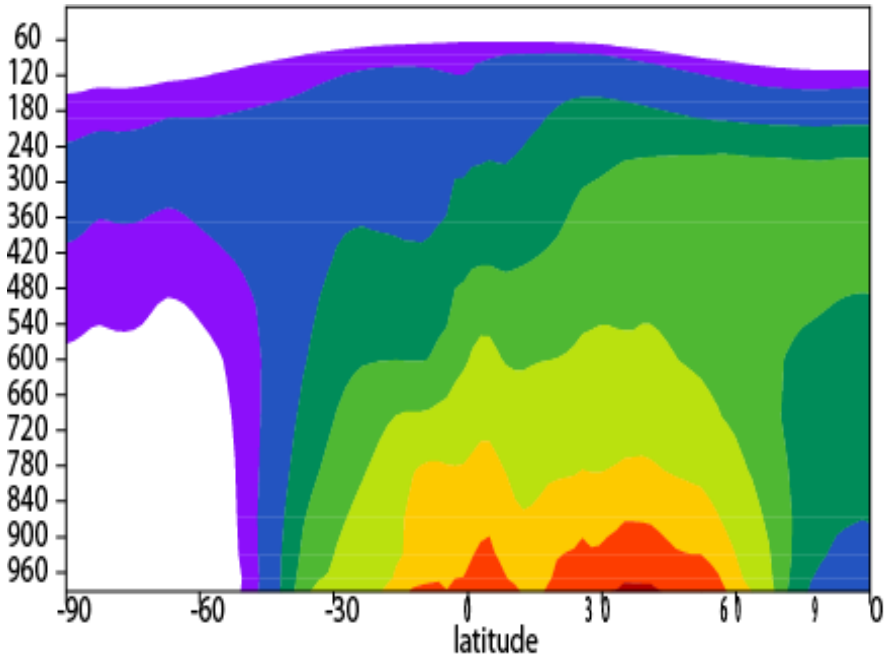


Modal-7 0.14 TgC

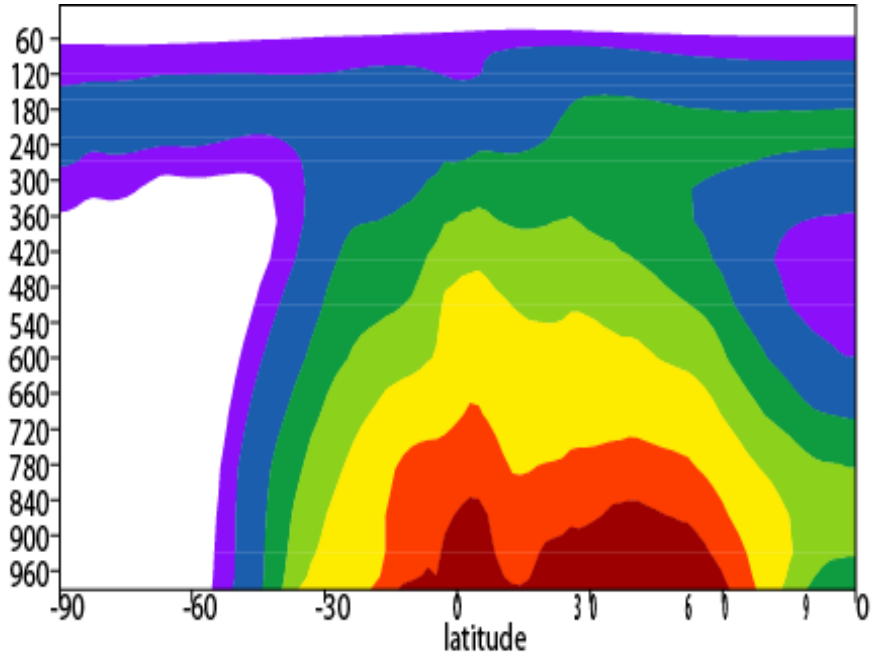


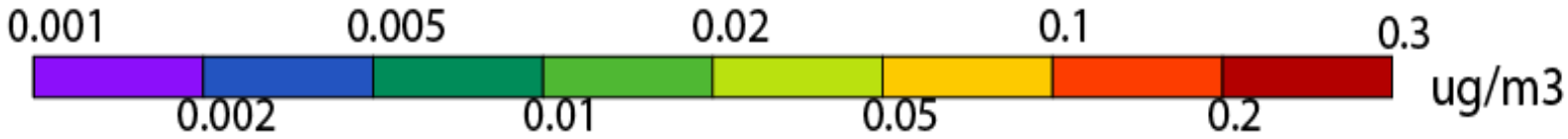
BC Zonal

Modal-3



Bulk





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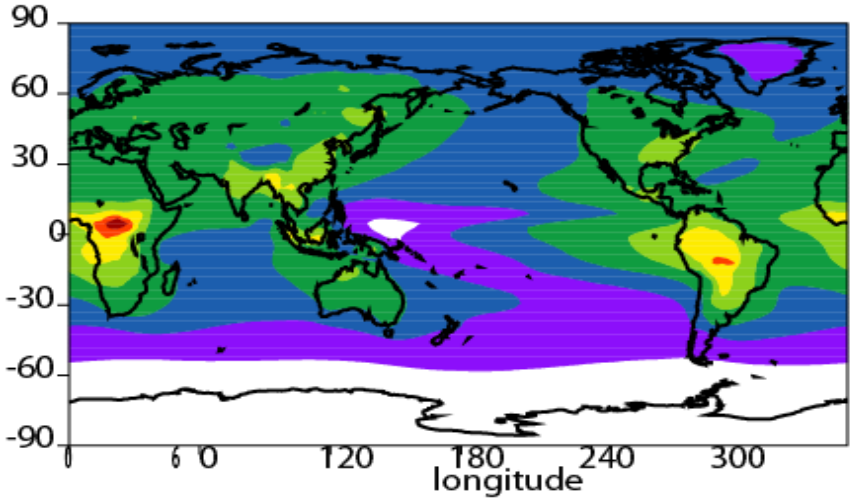
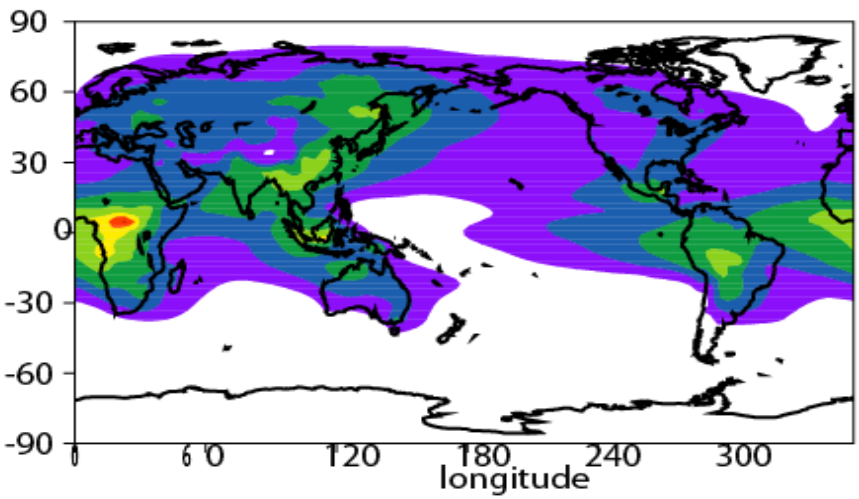
OC Column Burden

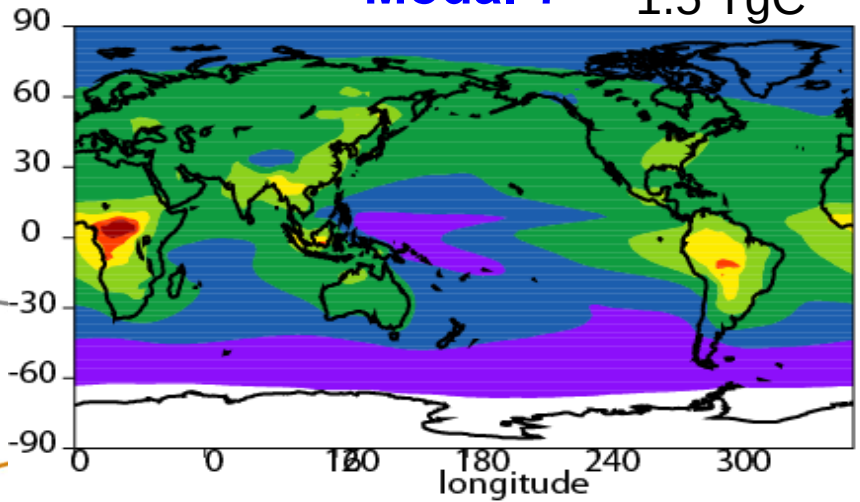
Modal-3 1.3 TgC



Bulk 0.62 TgC

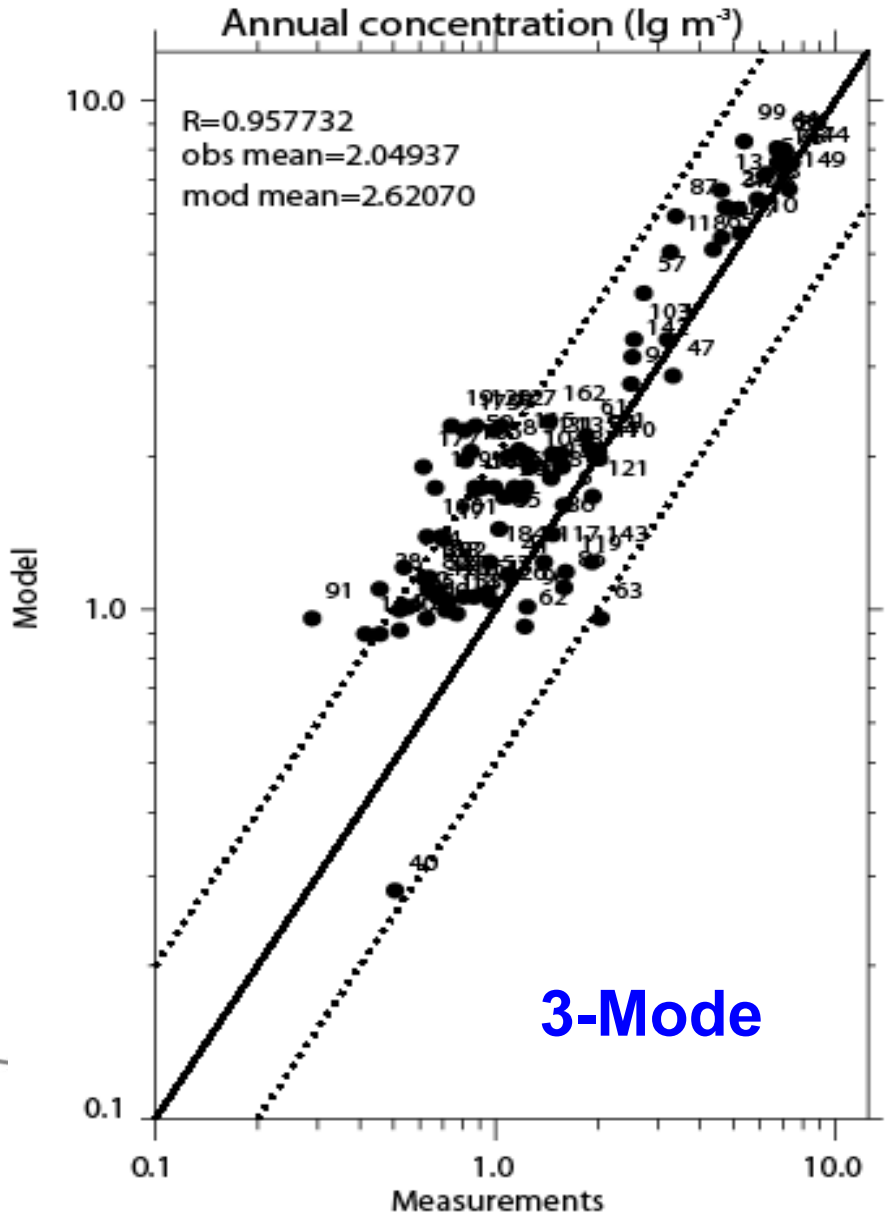


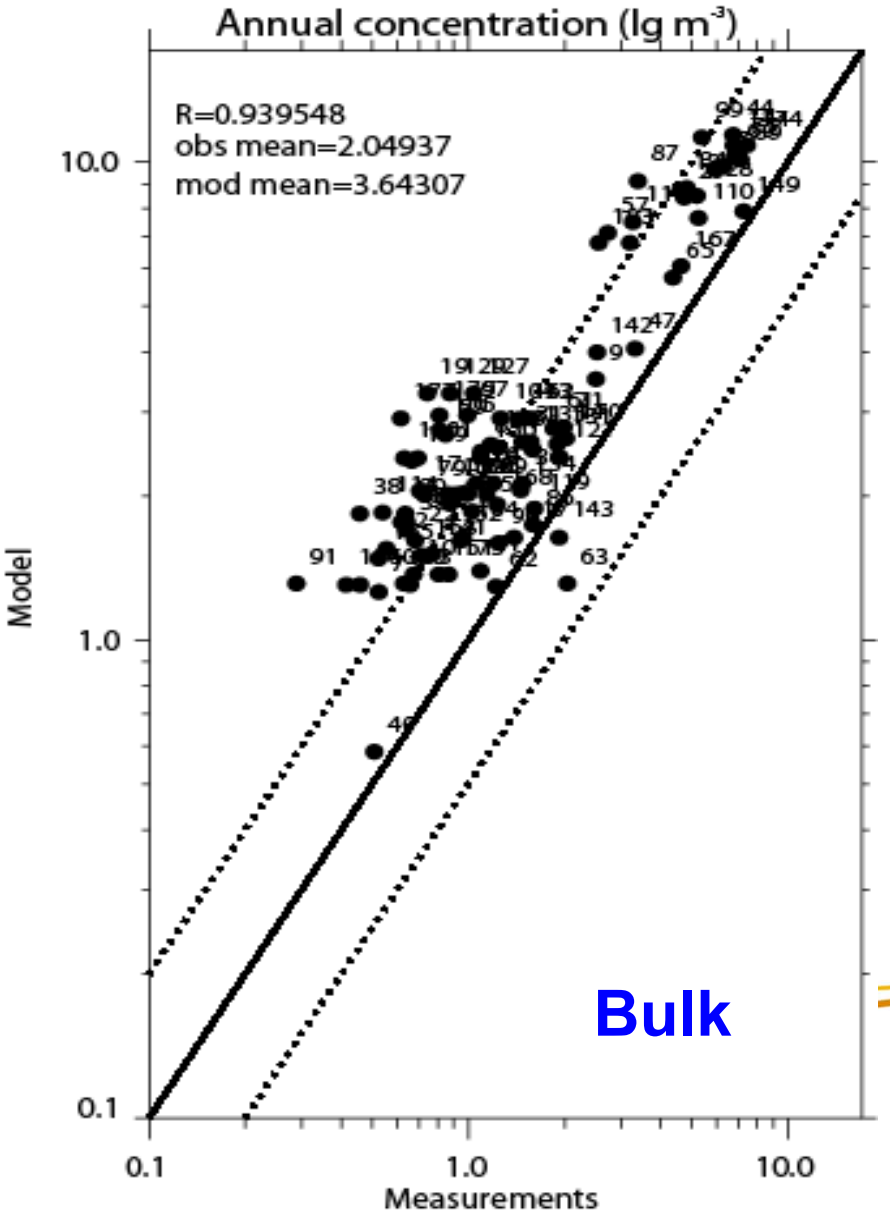
Modal-7 1.5 TgC



MAM includes SOA treatment

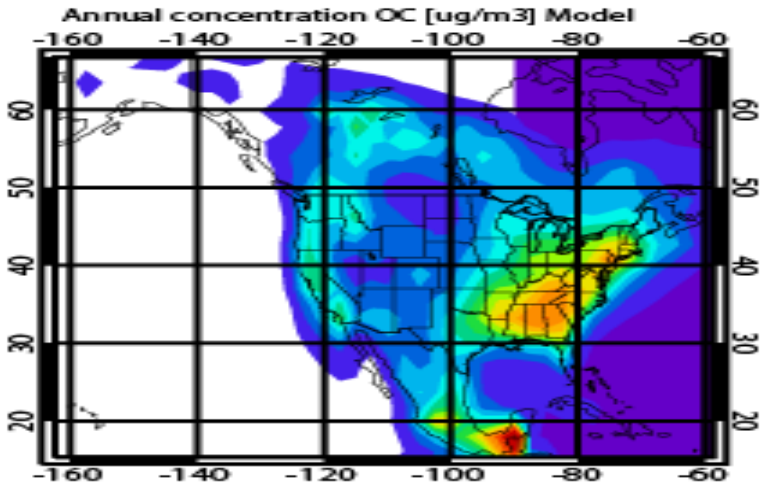
SO_4 compared with IMPROVE data



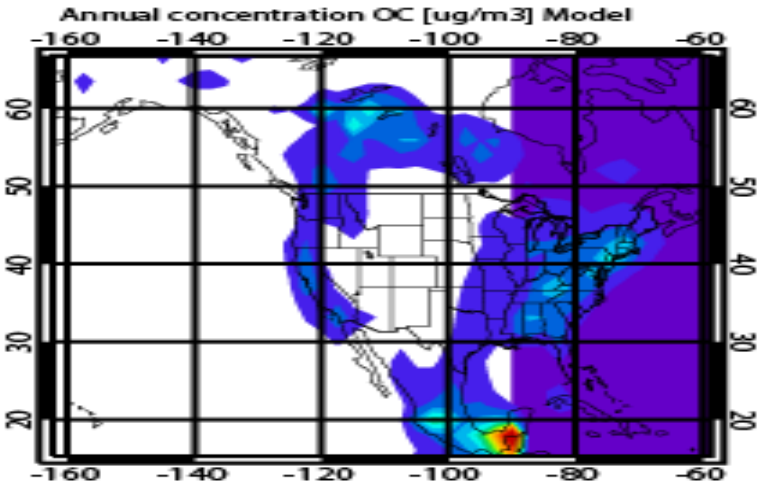


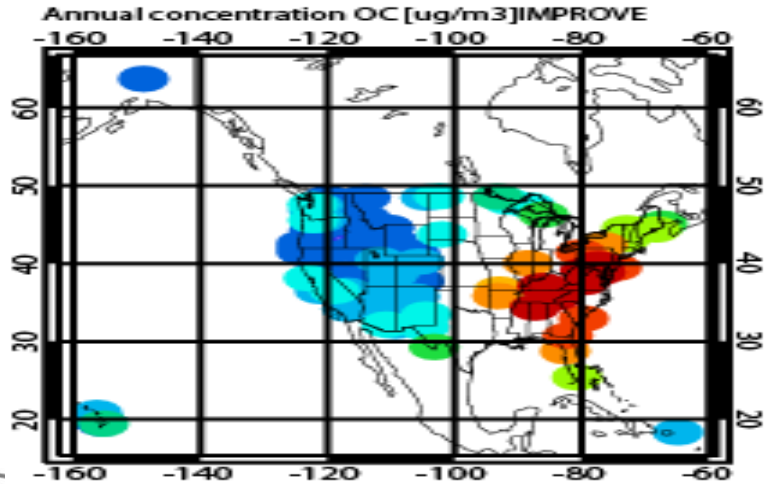
OC compared with IMPROVE data

3-Mode



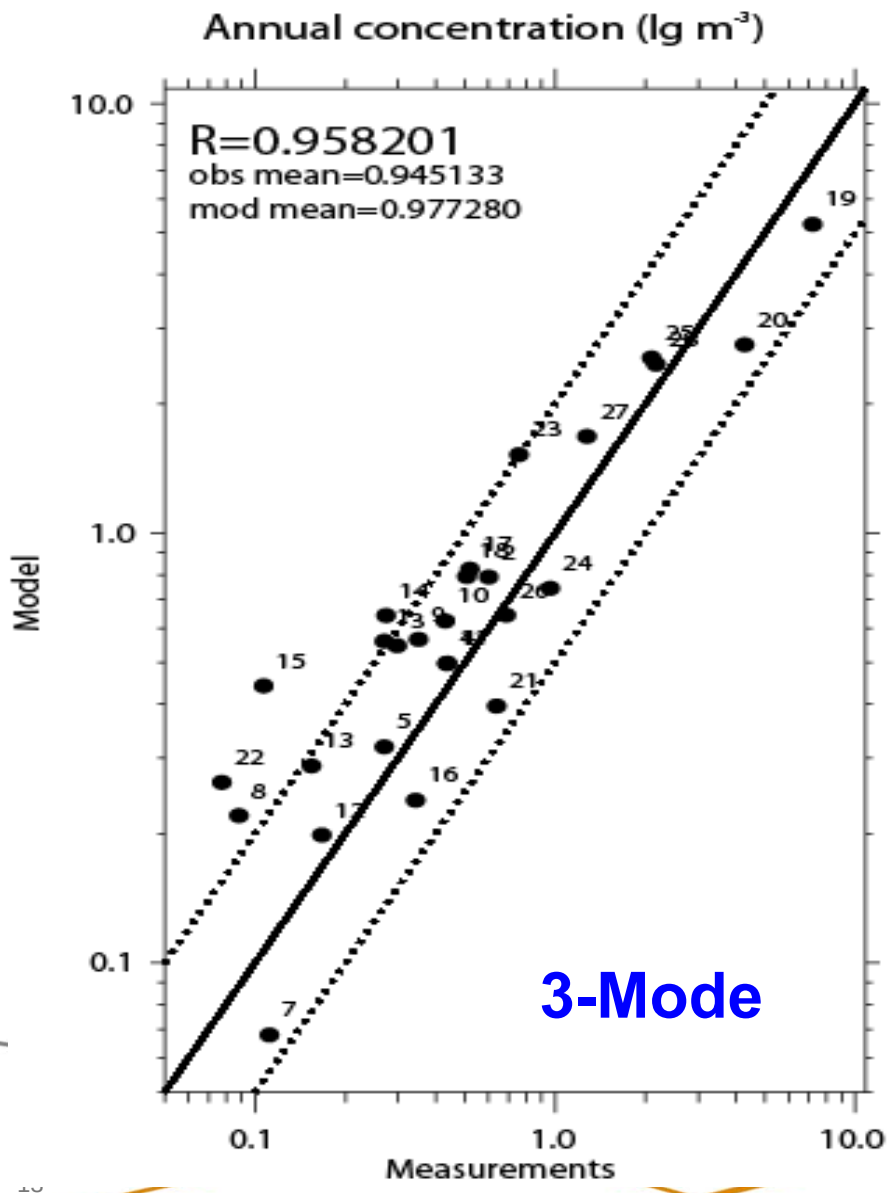
Bulk

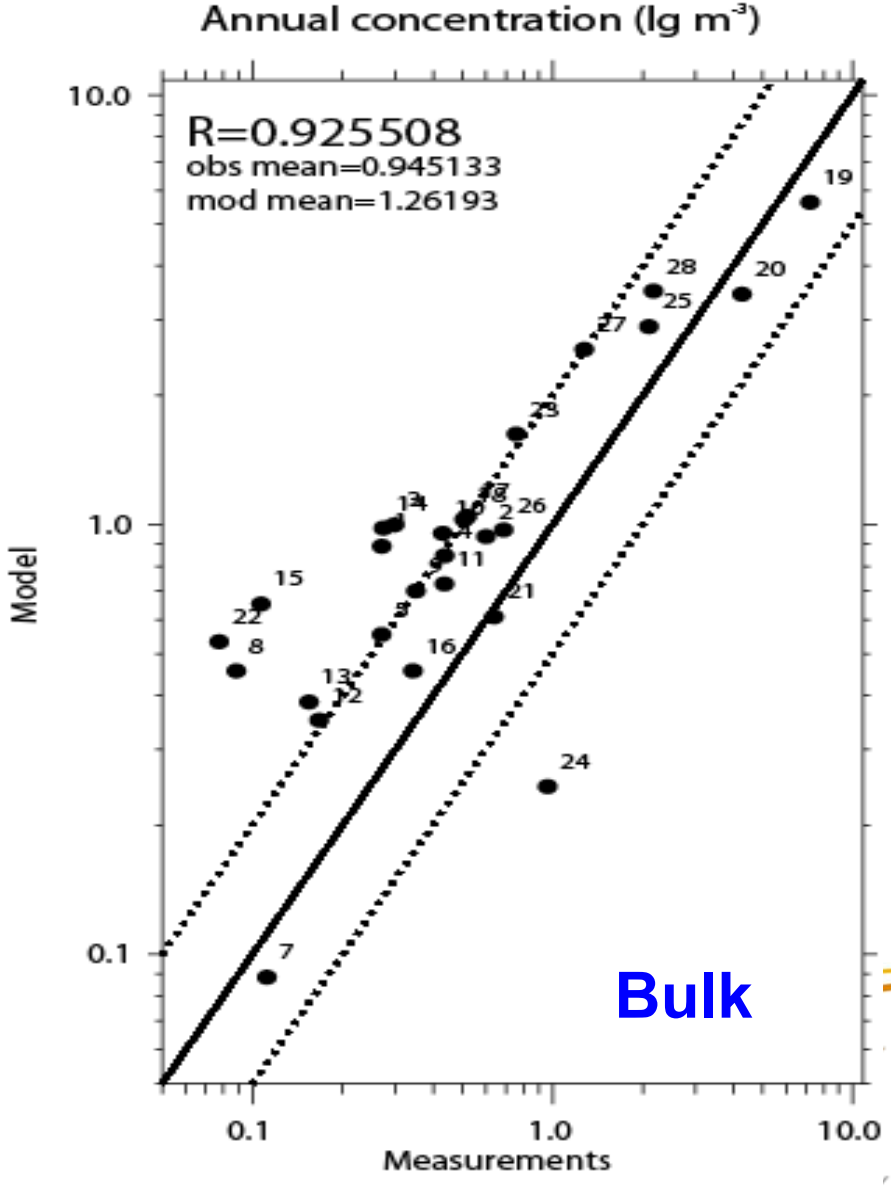




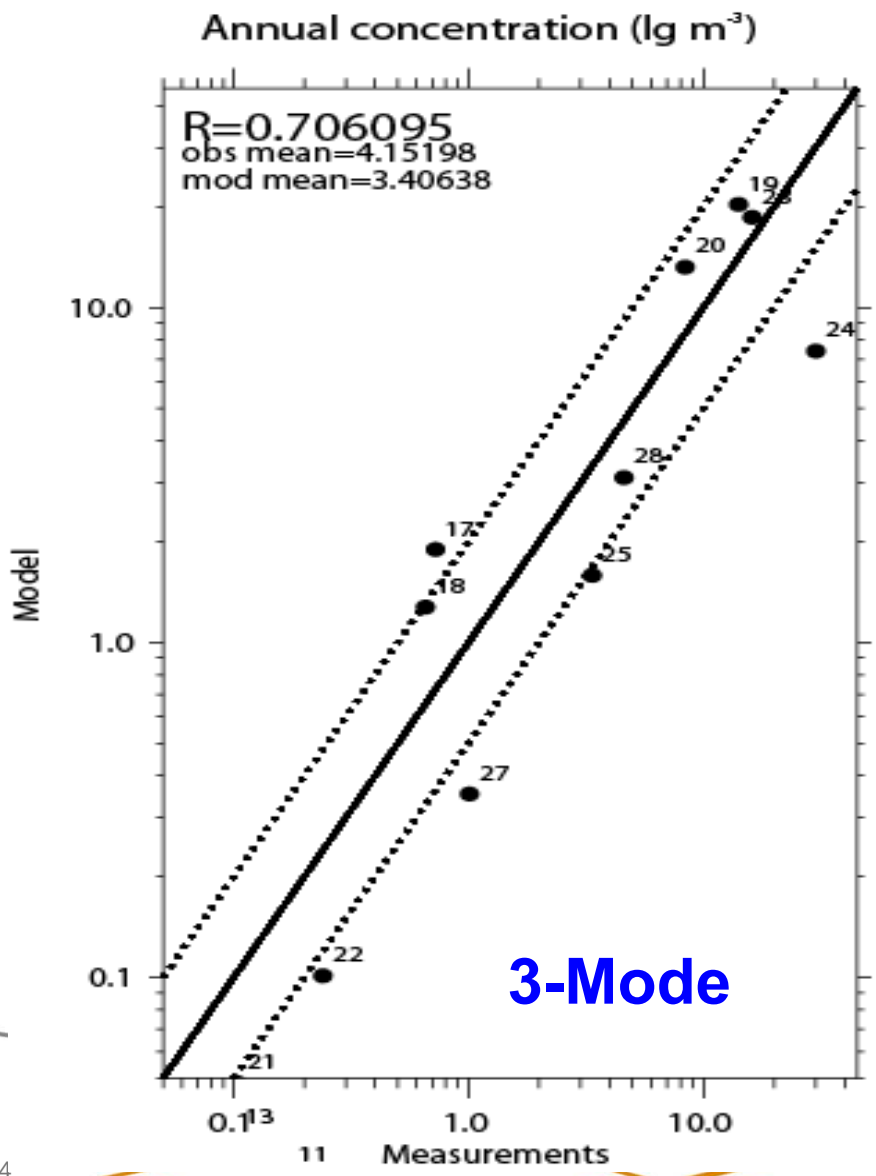
Obs

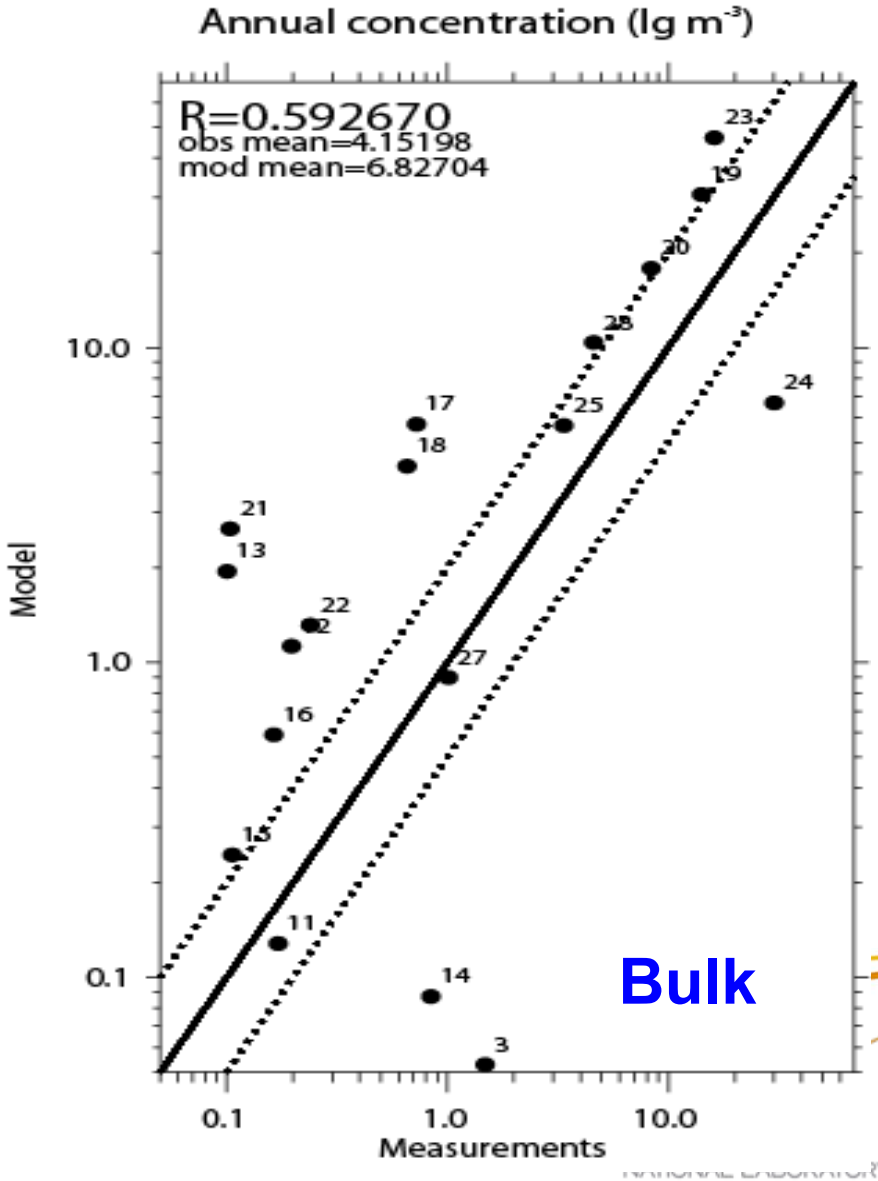
SO_4 compared with RSMAS data



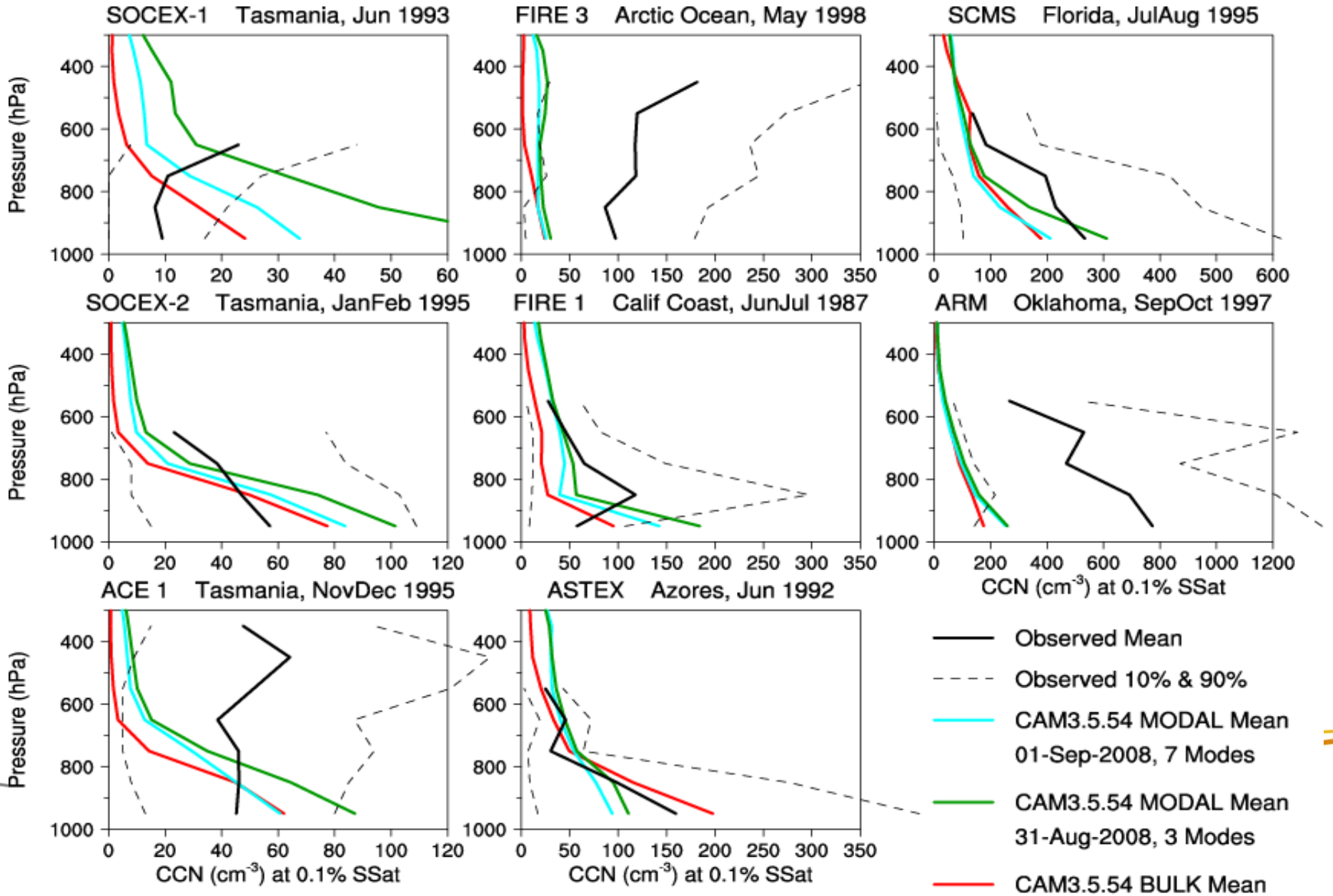


Dust compared with RSMAS data



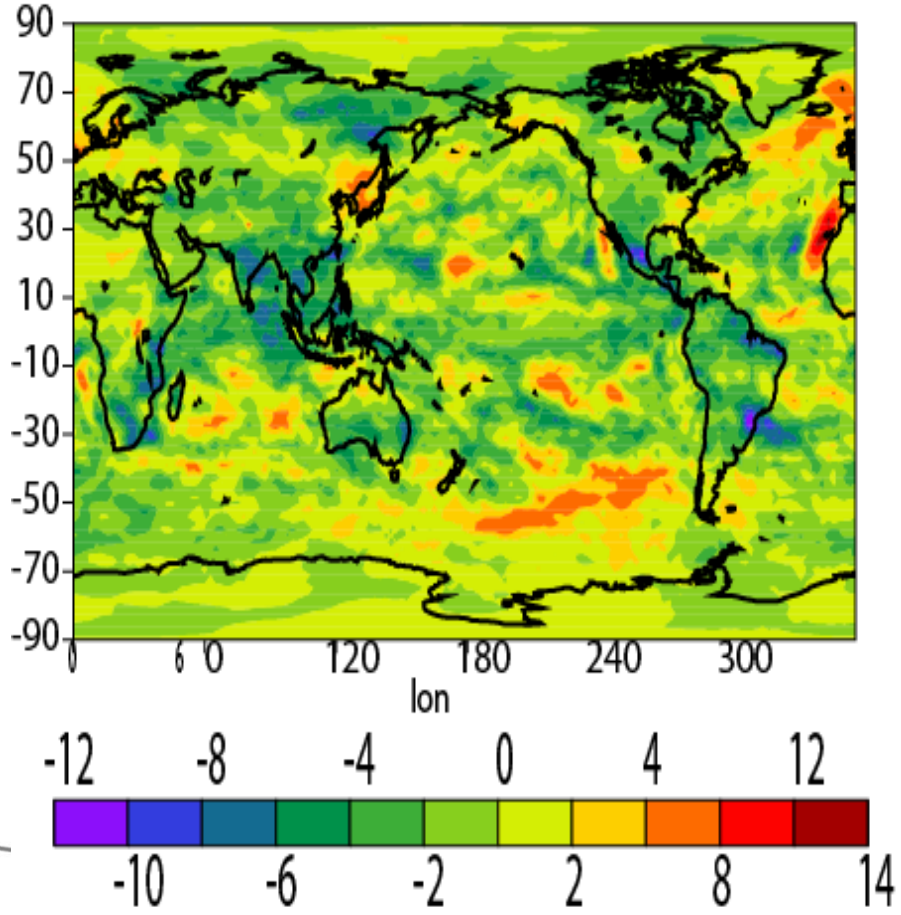


CCN (S=0.1%)

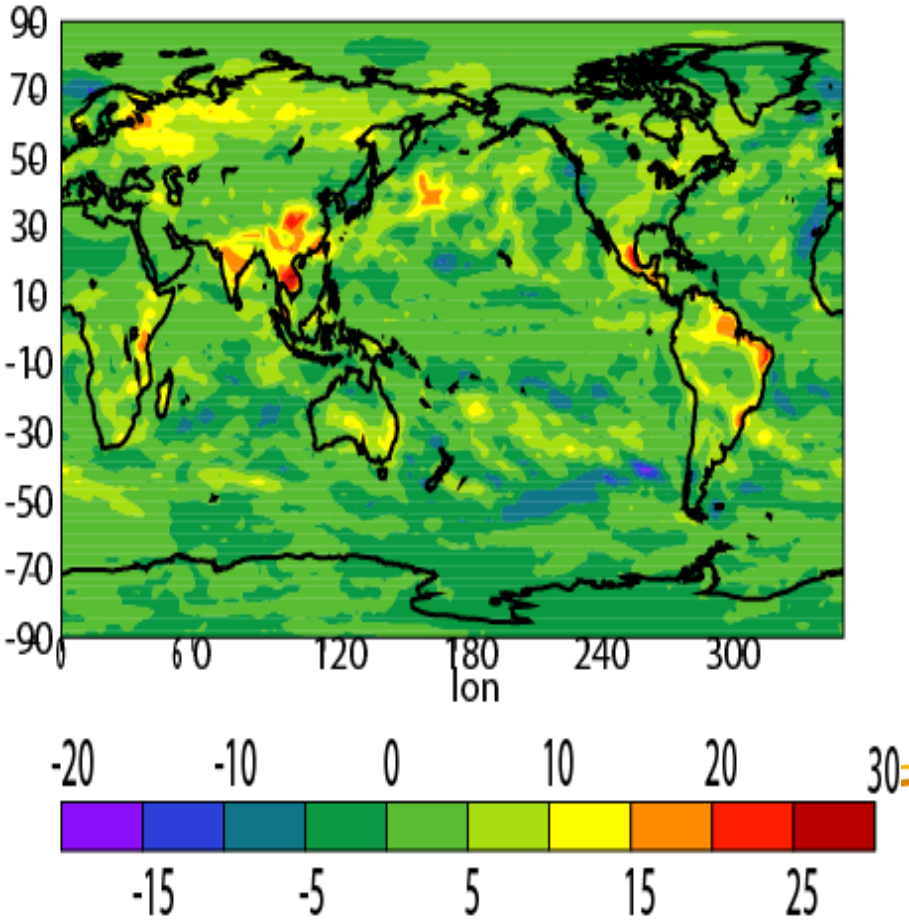

SOCEX-1 Tasmania, Jun 1993
FIRE 3 Arctic Ocean, May 1998
SCMS Florida, JulAug 1995
SOCEX-2 Tasmania, JanFeb 1995
FIRE 1 Calif Coast, JunJul 1987
ARM Oklahoma, SepOct 1997
ACE 1 Tasmania, NovDec 1995
ASTEX Azores, Jun 1992
Pressure (hPa)
CCN (cm-3) at 0.1% SSat
Observed Mean
Observed 10% & 90%
CAM3.5.54 MODAL Mean
01-Sep-2008, 7 Modes
CAM3.5.54 MODAL Mean
31-Aug-2008, 3 Modes
CAM3.5.54 BULK Mean
01-Sep-2008

Aerosol Indirect Effect

Present – Past Shortwave Cloud Forcing (W/m2)



Present – Past Liquid Water Path (g/m2)



Aerosol Indirect Effects

Modal-7

ΔTOA (Wm^{-2}) = -1.2
Δdirect (Wm^{-2}) = -0.3
Δindirect (Wm^{-2}) = -0.9

Modal-3

ΔTOA (Wm^{-2}) = -1.4
Δdirect (Wm^{-2}) = -0.4
Δindirect (Wm^{-2}) = -1.0

BAM

ΔTOA (Wm^{-2}) = -2.7
Δdirect (Wm^{-2}) = -0.7
Δindirect (Wm^{-2}) = -2.0

??

1. Natural aerosol (SOA, fine SS)
2. Aerosol treatments
3. Aerosol mass -> number

Summary

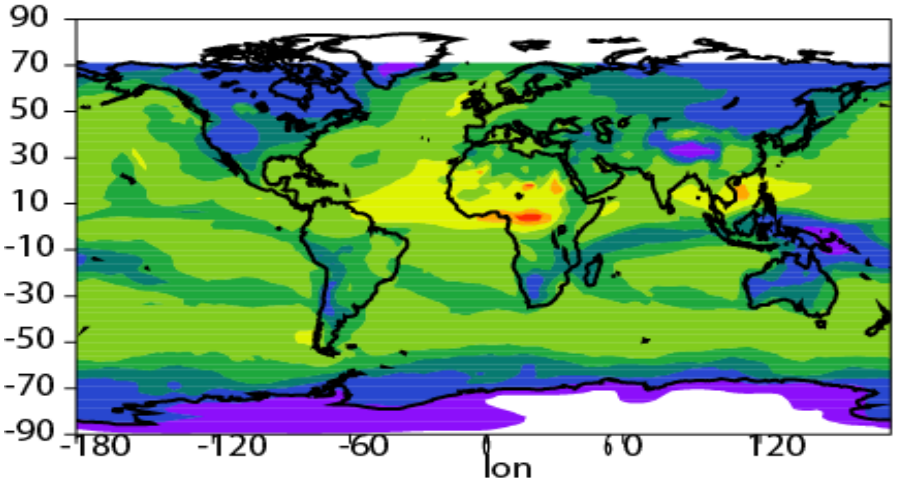
- Simplified 3-mode version captures the essentials of the aerosol microphysics and reduce the computer needs significantly (150% to 40% higher than BAM);

- Significantly higher indirect effects in the BAM than the modal aerosol;
  - Aerosol treatment (predicted aerosol in cloud phase in MAM)
  - SOA, ultra-fine sea salt emission
  - Aerosol mass to size for indirect effects

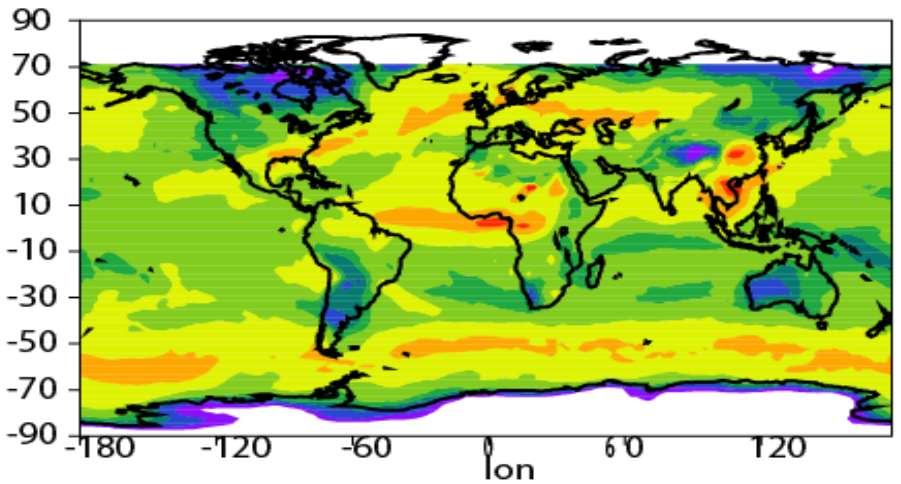
    important to predict aerosol size distribution!!

Aerosol Optical Depth (AOD) - January

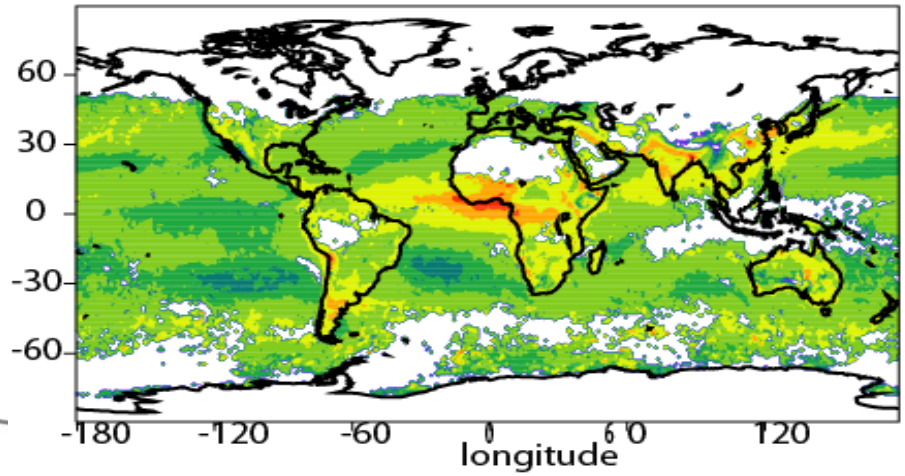
Modal AOD=0.11



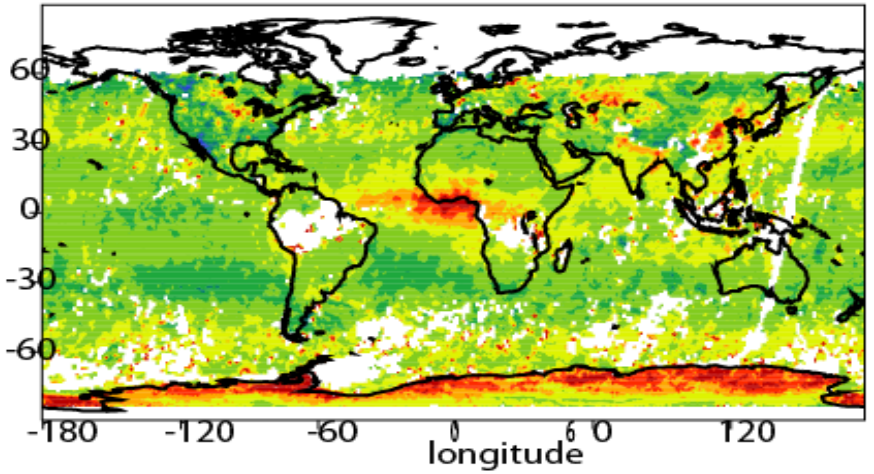
Bulk AOD=0.19

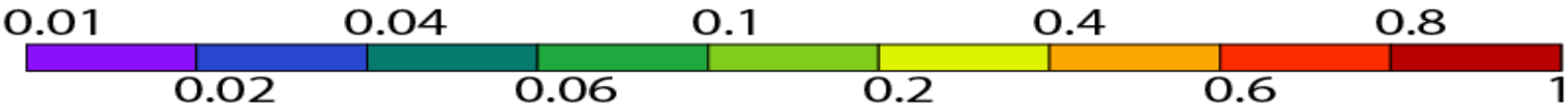


MODIS



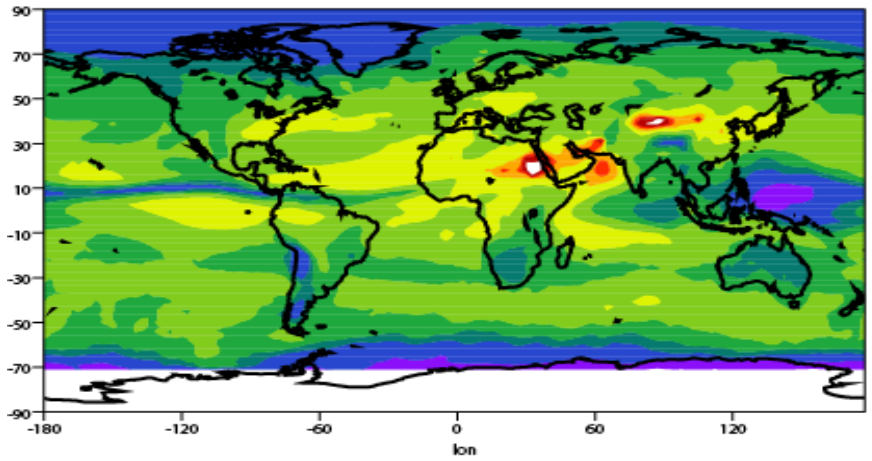
MISR



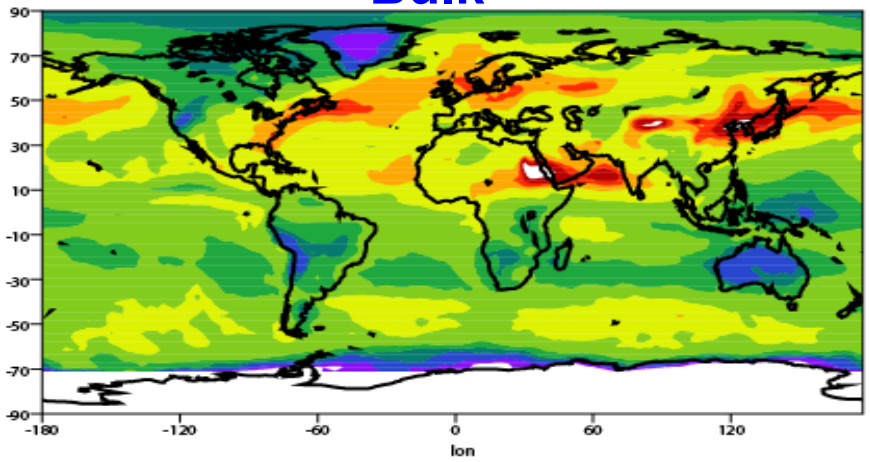


Aerosol Optical Depth (AOD) - July

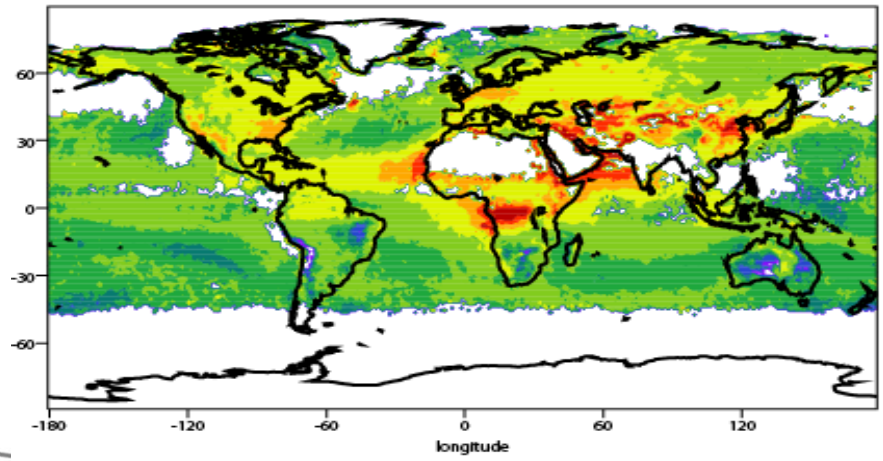
Modal AOD=0.13



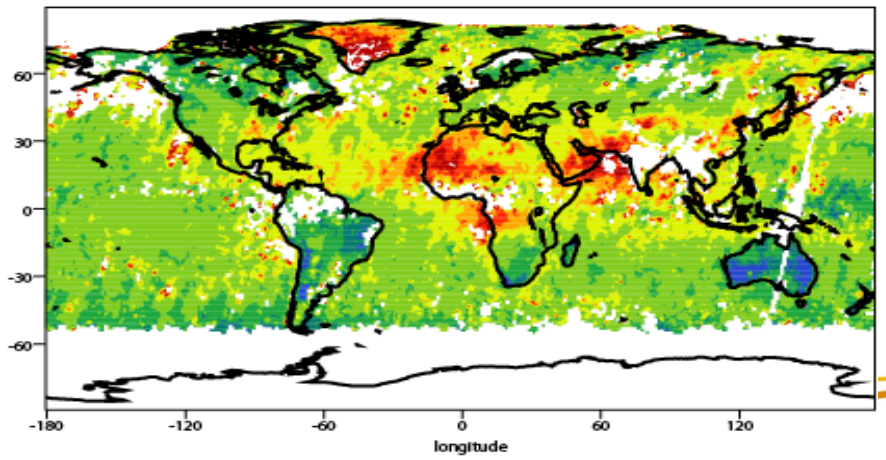
Bulk AOD=0.20



MODIS

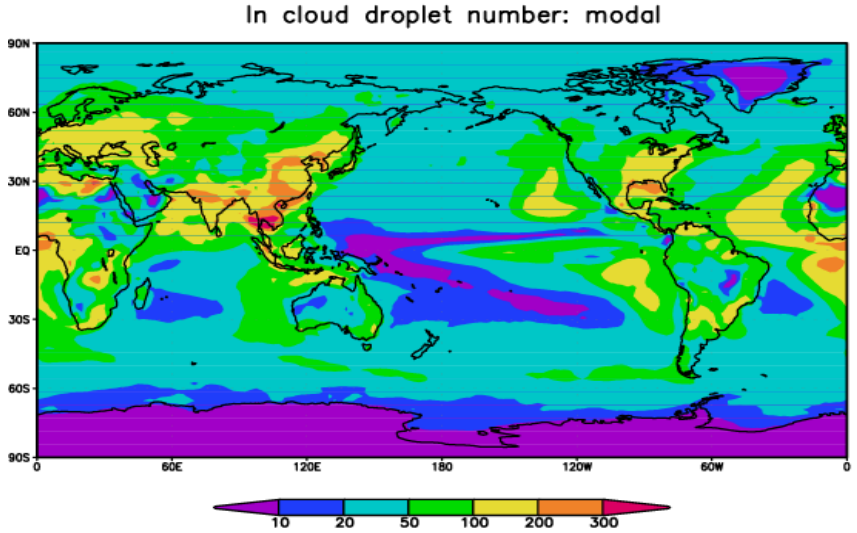


MISR

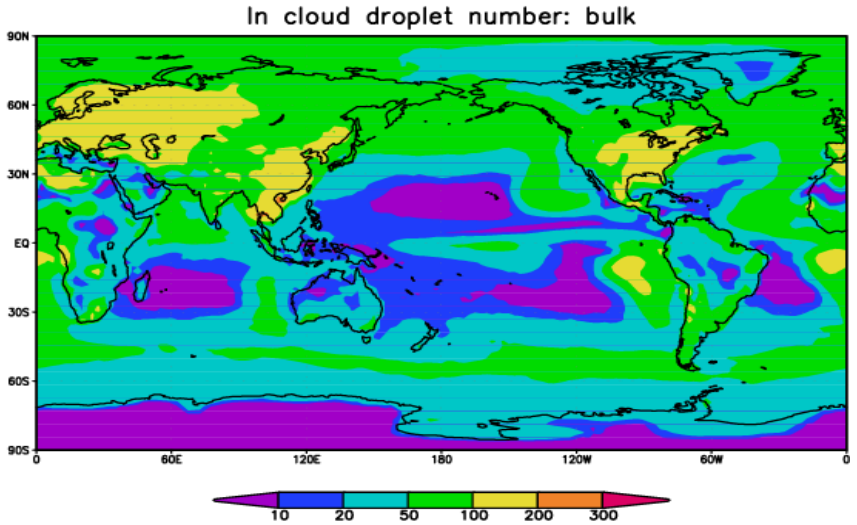


Cloud Droplet Number at 903 hPa

Modal-3



Bulk



Modal-7