

Prognostic stratospheric sulfate aerosol for with MAM3 in CESM

Michael Mills, NCAR
Charles Bardeen, NCAR
Dan Marsh, NCAR
Ryan Neely, NCAR
Simone Tilmes, NCAR
Andrew Conley, NCAR

Richard Easter, PNNL
Steve Ghan, PNNL
Phil Rasch, PNNL



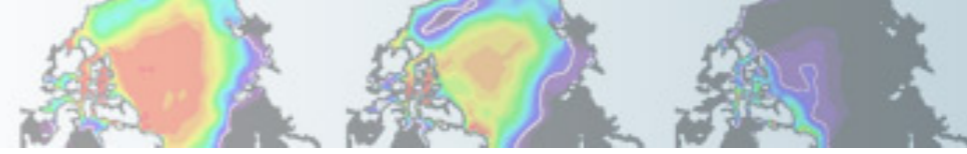
NCAR is funded by the National Science Foundation



WACCM

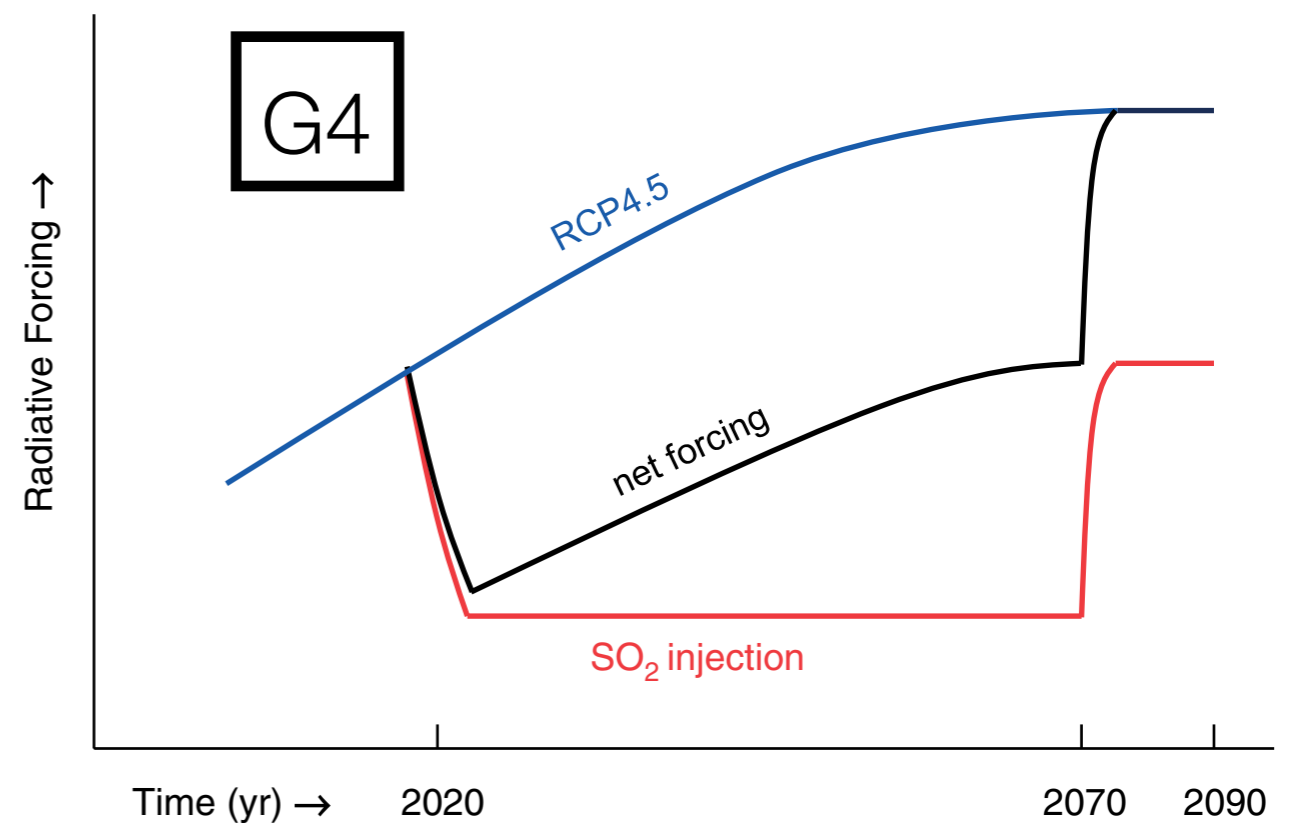
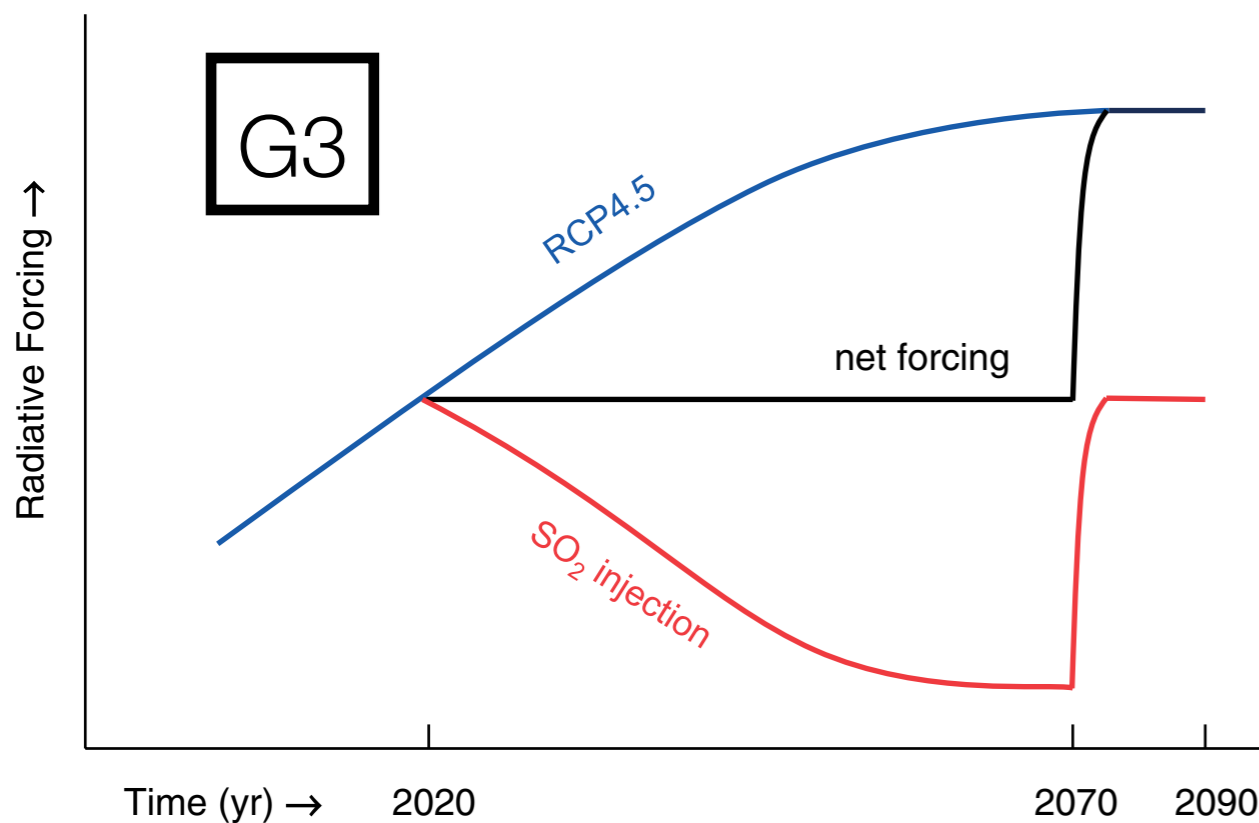
Whole Atmosphere
Community Climate Model





Emission-based stratospheric sulfate aerosols in CESM

- Model development is increasing self-consistency
- Volcanic aerosol remains one of the few prescribed climate forcings
- Enables study of historical and theoretical eruptions
- Geoengineering studies: “artificial volcanoes”





NCAR

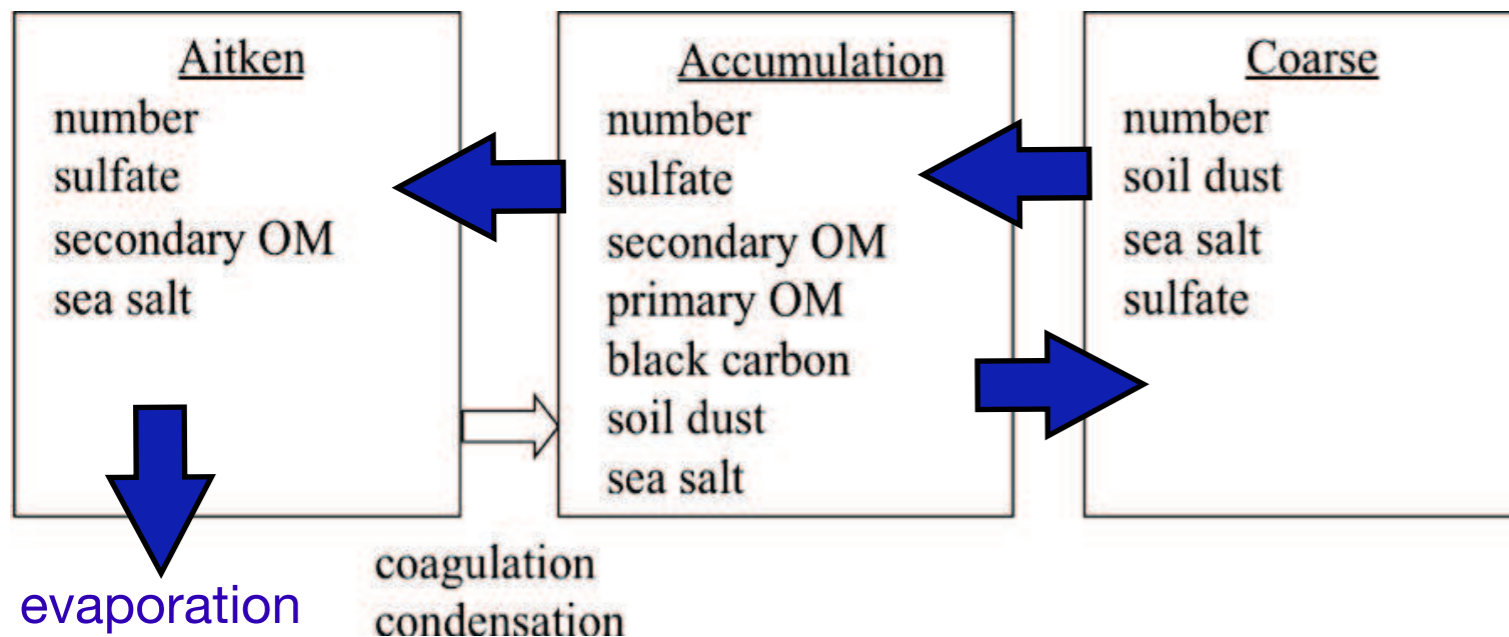


WACCM

Whole Atmosphere
Community Climate Model



Extend modal aerosol model (MAM3) for stratospheric aerosols

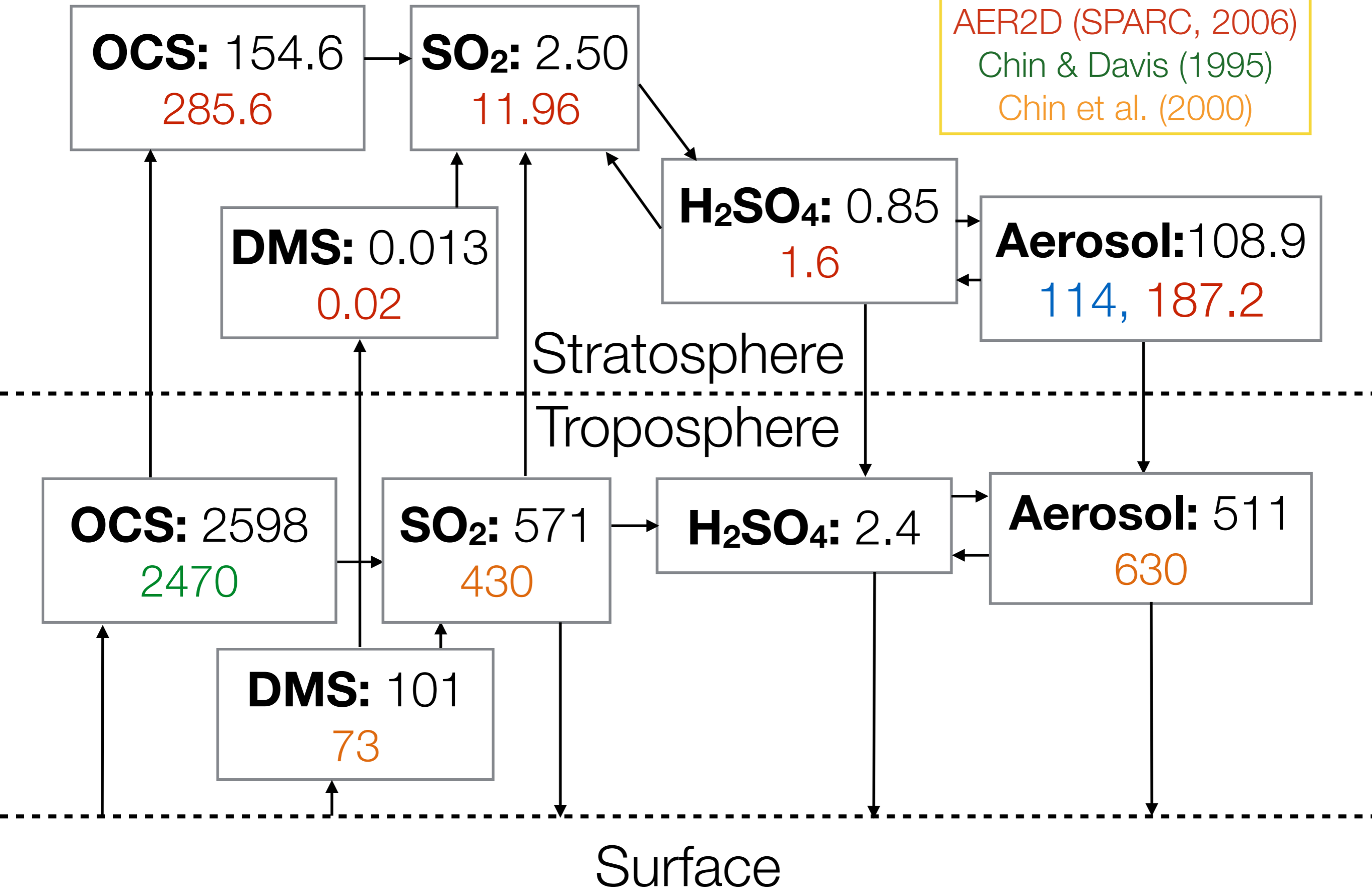


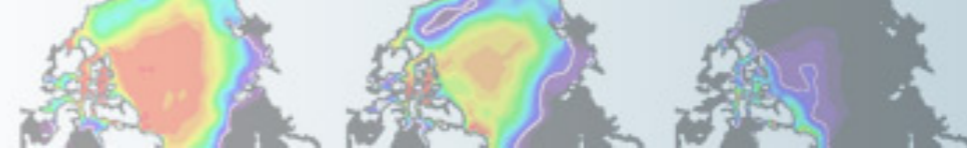
Gas-phase species: H₂SO₄, SO₂, DMS, SOA (gas)
 Added: OCS, S, SO, SO₃, HSO₃
 Added evaporation
 Added growth between modes
 Adjusted diameter ranges, mode widths

Mode	Nucleation	Aitken	Accumulation	Coarse
CAM5-MAM3 radius (µm) geom. std. dev	N/A	0.00435 - 0.026 1.6	0.02675 - 0.22 1.8	0.5 - 2.0 1.8
WACCM5-MAM3 radius (µm) geom. std. dev.	N/A	0.00435 - 0.026 1.6	0.02675 - 0.22 1.6	>0.22 1.2
ECHAM-M7 volcanic radius (µm) geom. std. dev.	<0.005 1.59	0.005 - 0.05 1.59	>0.05 1.2	N/A
ECHAM-M7 geoeng. radius (µm) geom. std. dev.	<0.005 1.59	0.005 - 0.05 1.59	0.05 - 0.2 1.59	>0.2 1.2

Non-volcanic sulfur burdens in Tg S

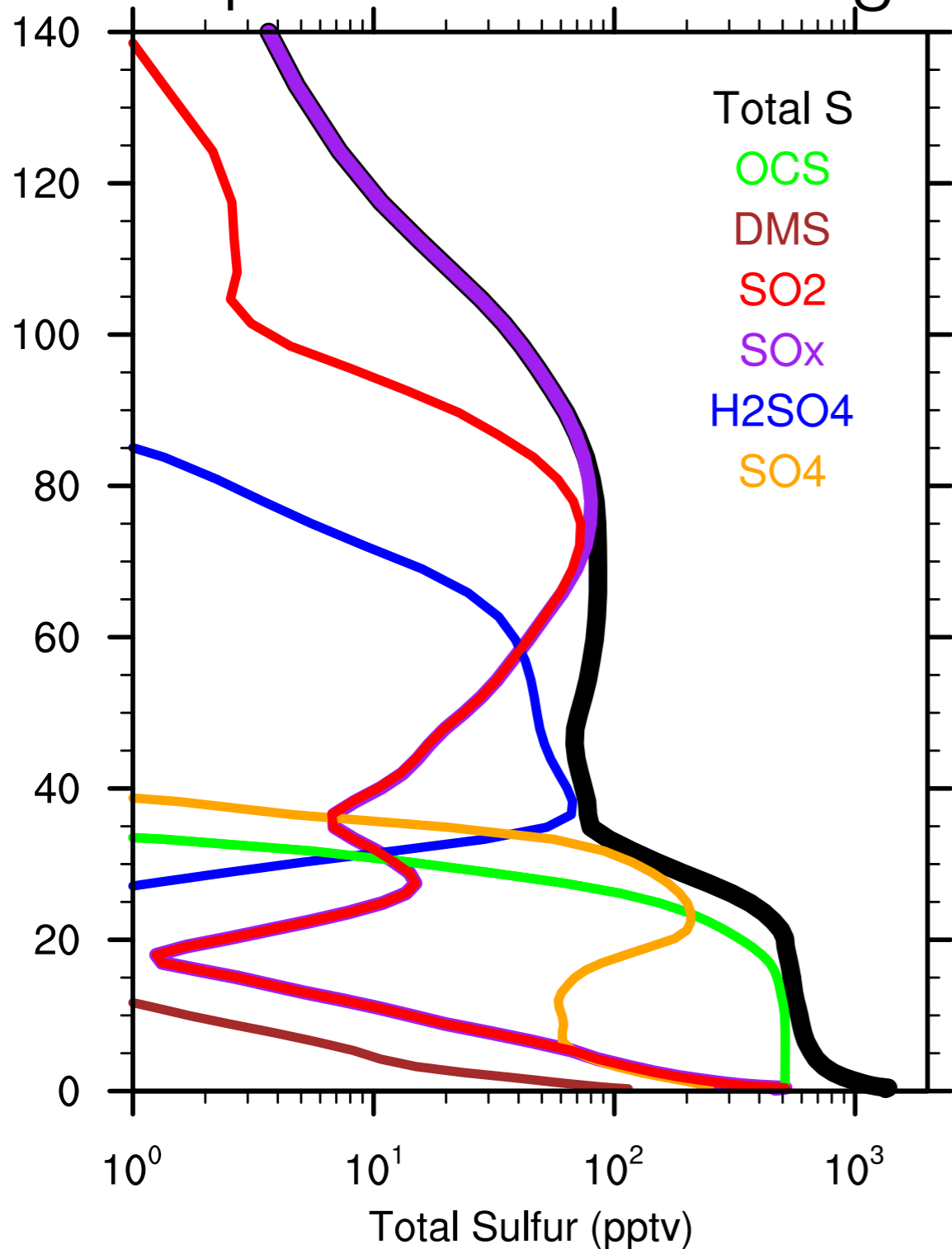
WACCM5-MAM3
SAGE-4λ
AER2D (SPARC, 2006)
Chin & Davis (1995)
Chin et al. (2000)





WACCM5-MAM3

Tropical annual average



Low SO₂ at 35 km: H₂SO₄ + hv cross sections too low? (Feierabend et al., CPL, 2006)

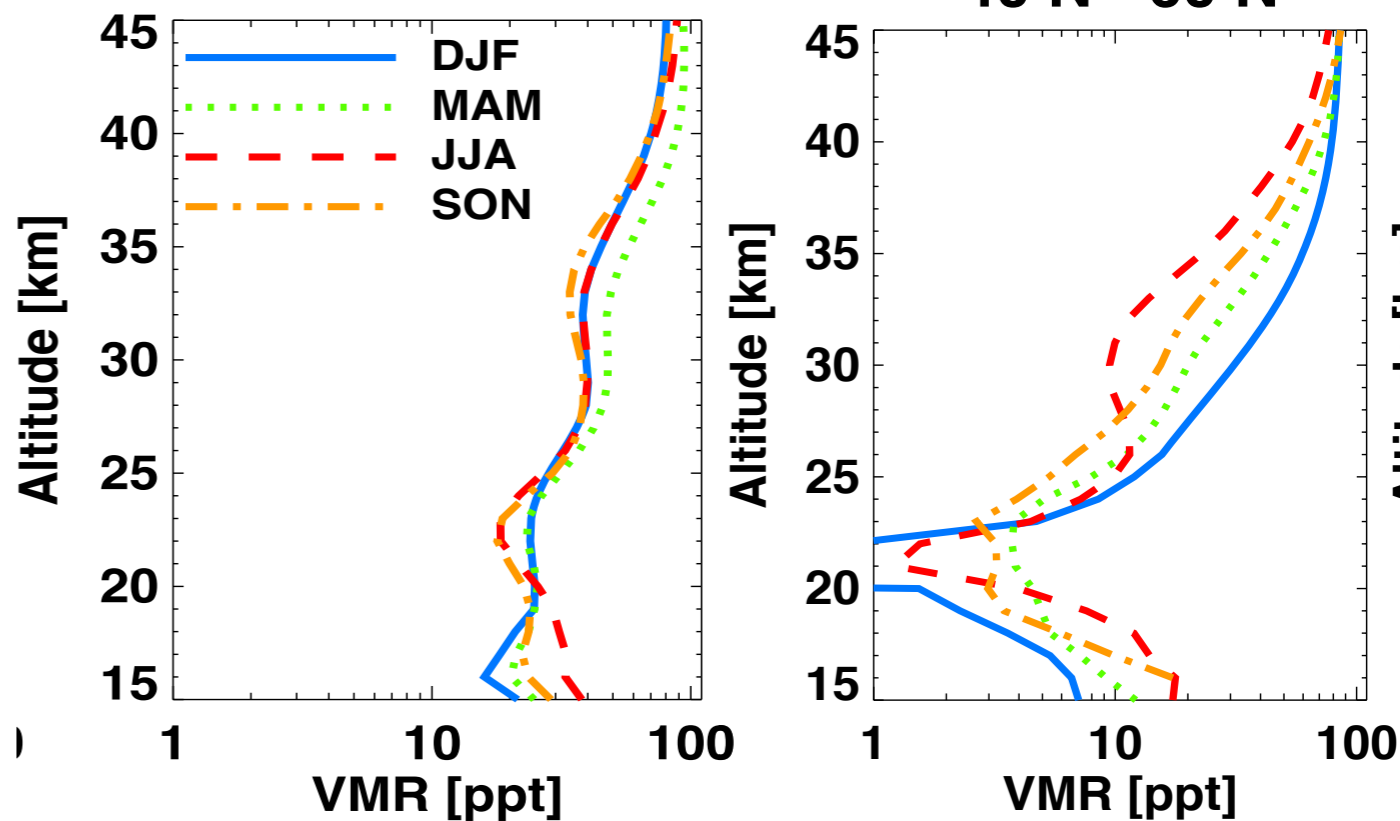
Low SO₂ at 20 km: ?

MIPAS SO₂ Observations

Hopfner et al., ACP, 2013

0° - 20°N

40°N - 60°N



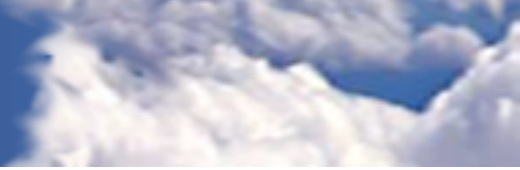


NCAR



WACCM

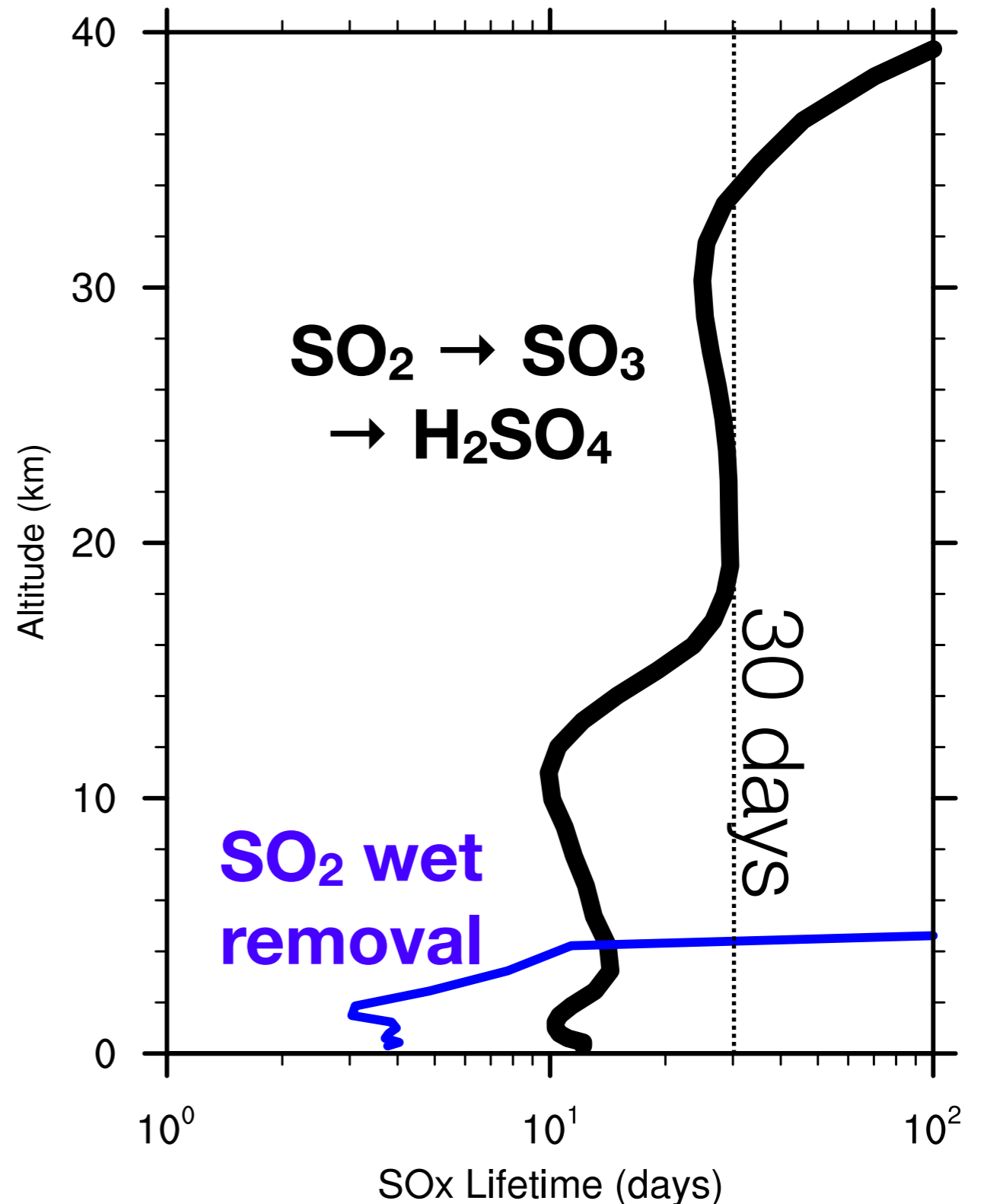
Whole Atmosphere
Community Climate Model

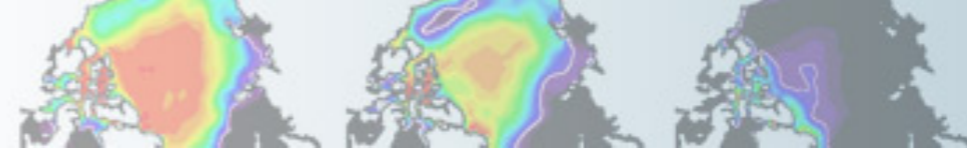


Lifetime of $\text{SO}_x = \{\text{S}, \text{SO}, \text{SO}_2, \text{HSO}_3, \text{SO}_3\}$

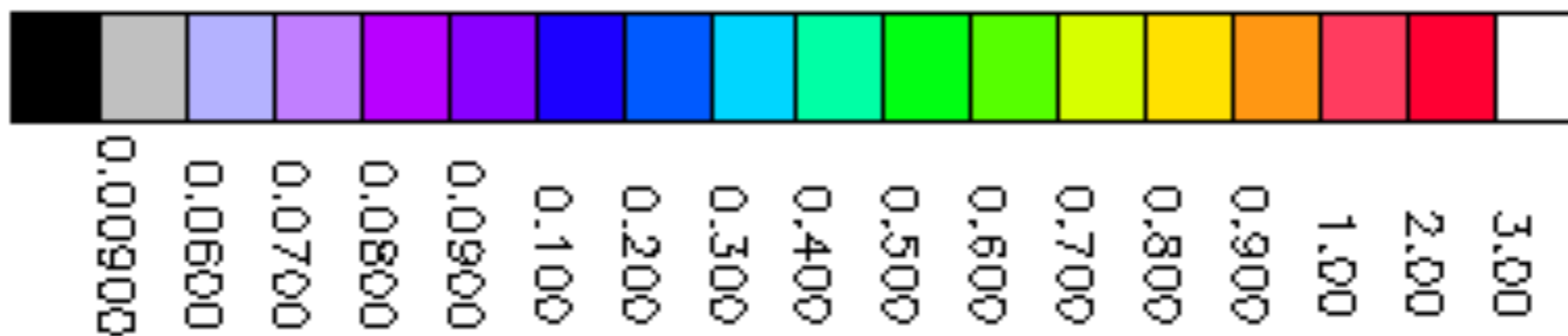
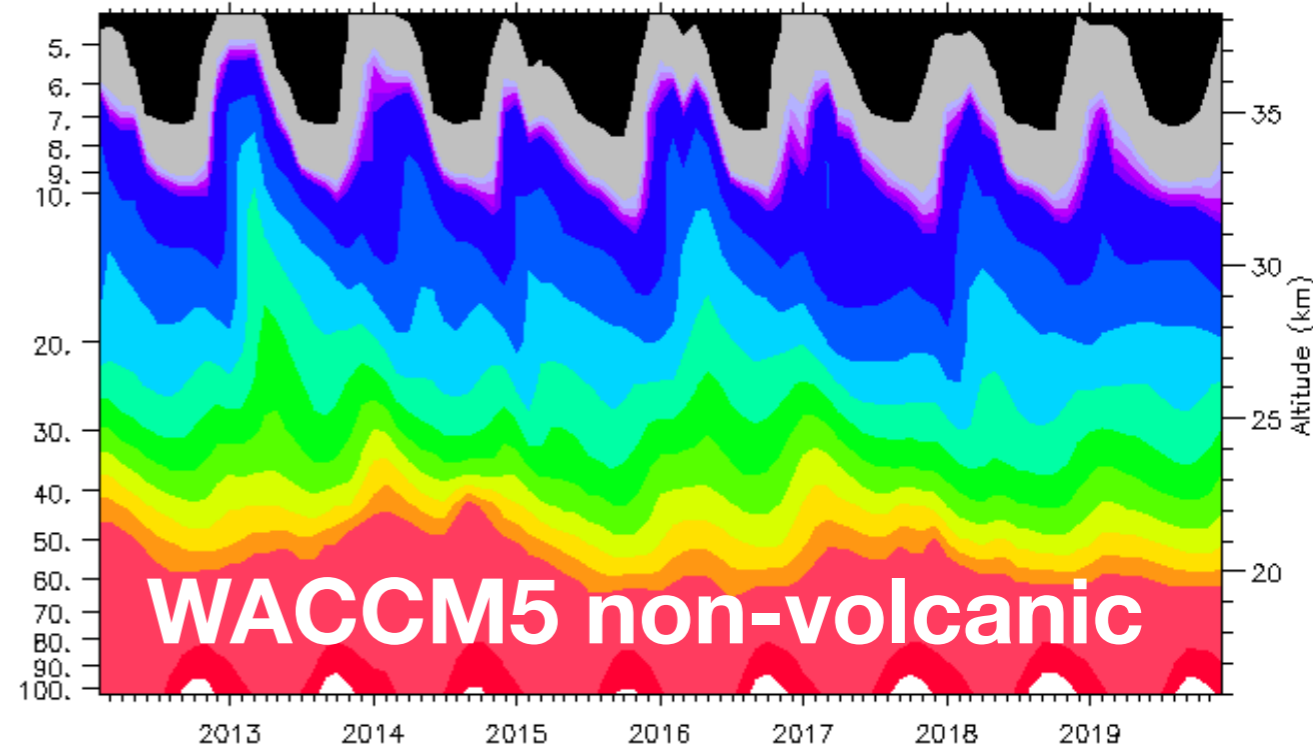
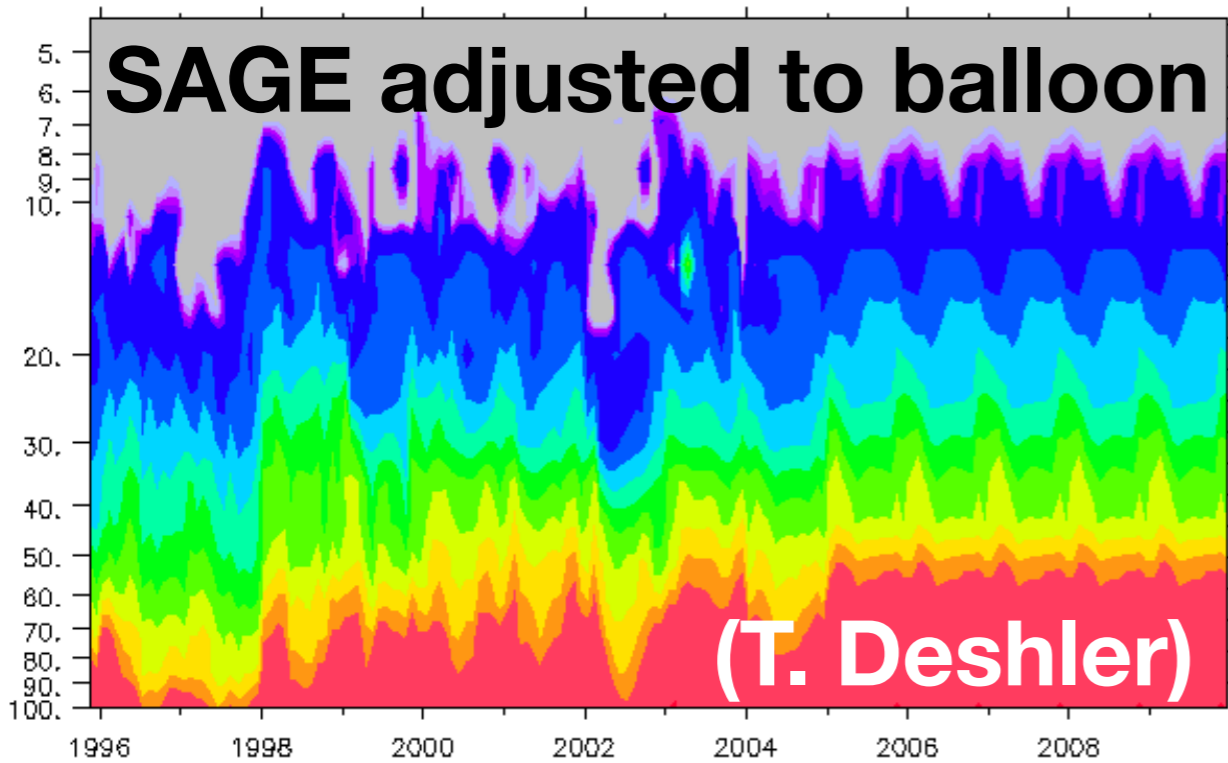
30-day oxidation
lifetime agrees with
post-Pinatubo
observations

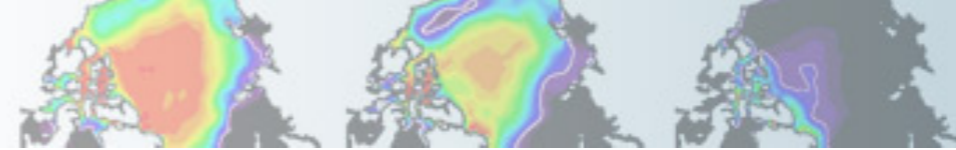
Neu wet
deposition scheme
gives 3- to 4-day
lifetime up to 4 km





Background aerosol surface area densities ($\mu\text{m}^2/\text{cm}^3$)



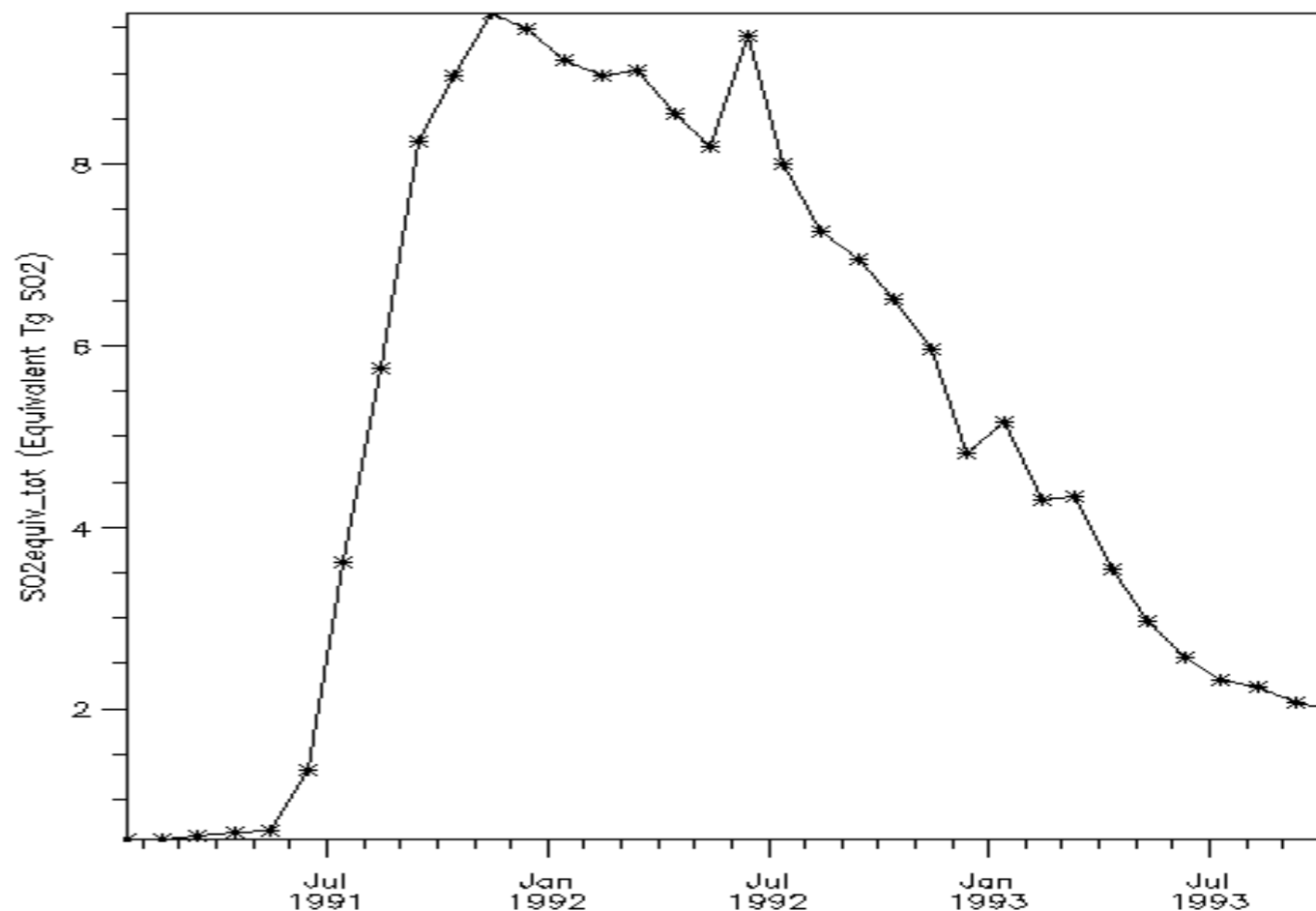
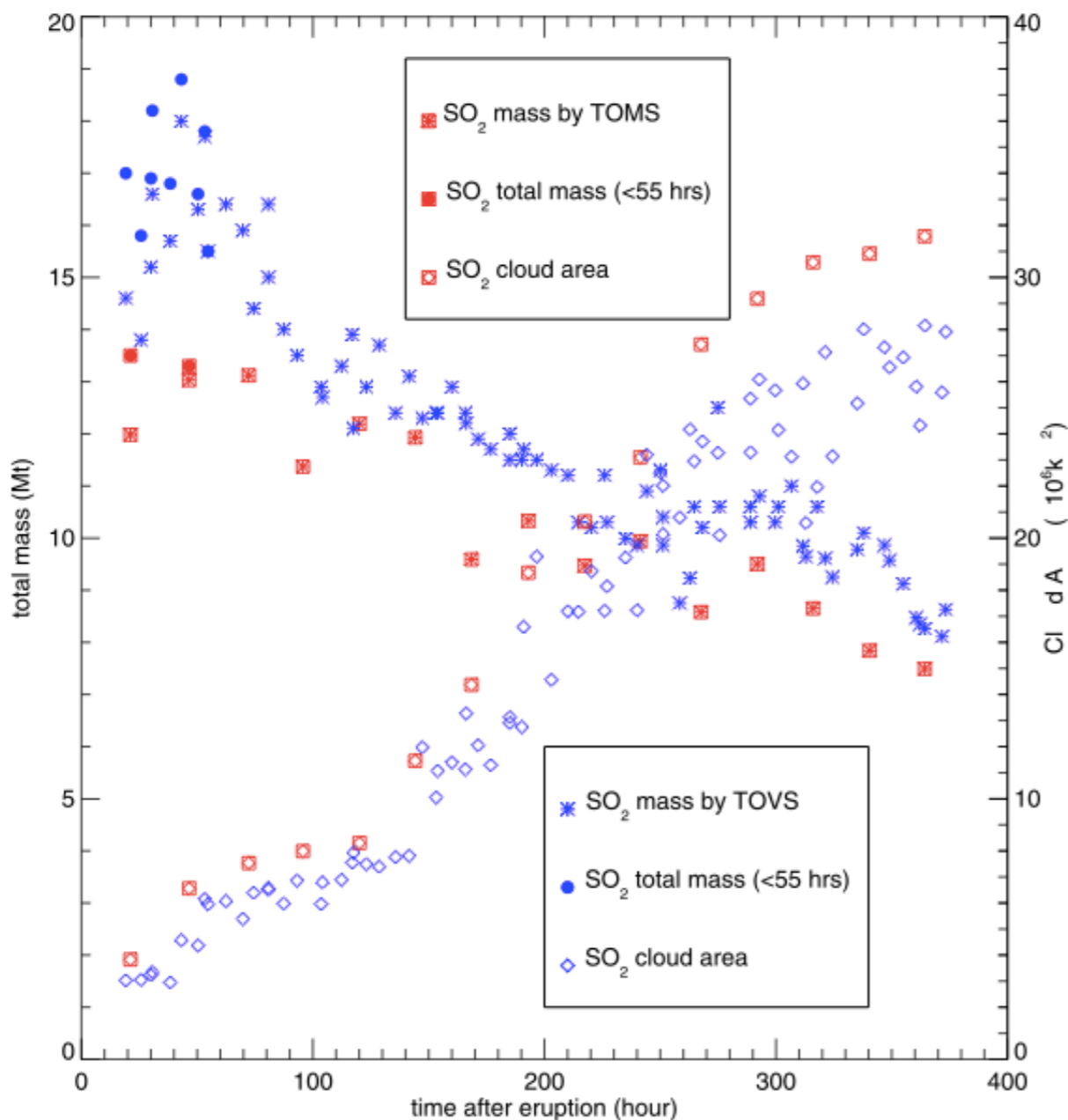


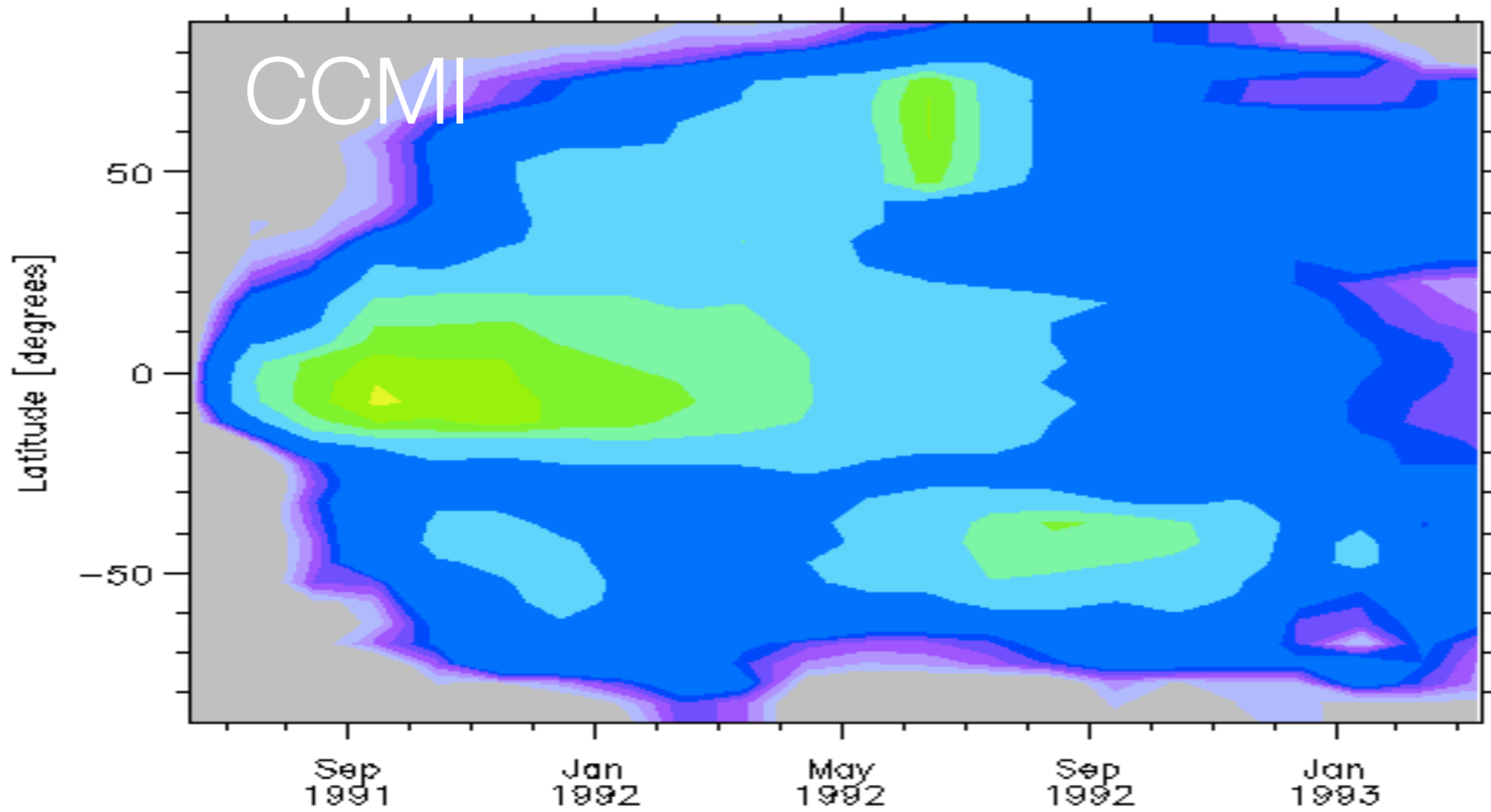
Pinatubo simulation: How much SO₂?

Guo et al., 2004: 15-19 Tg

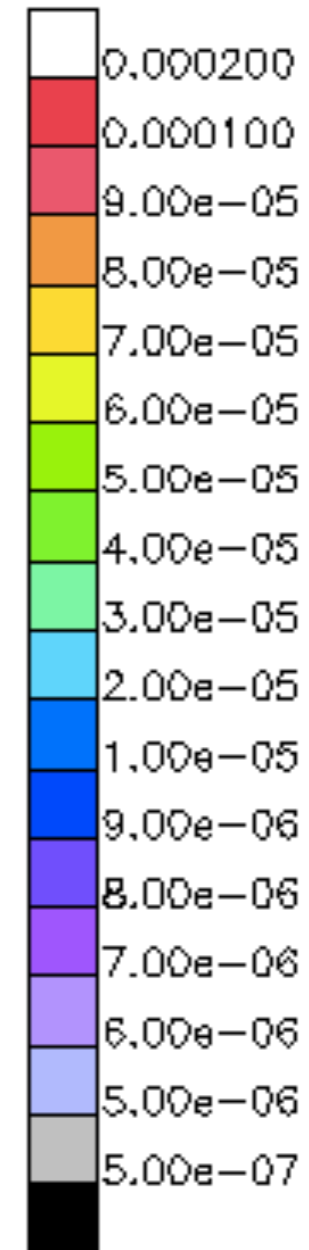
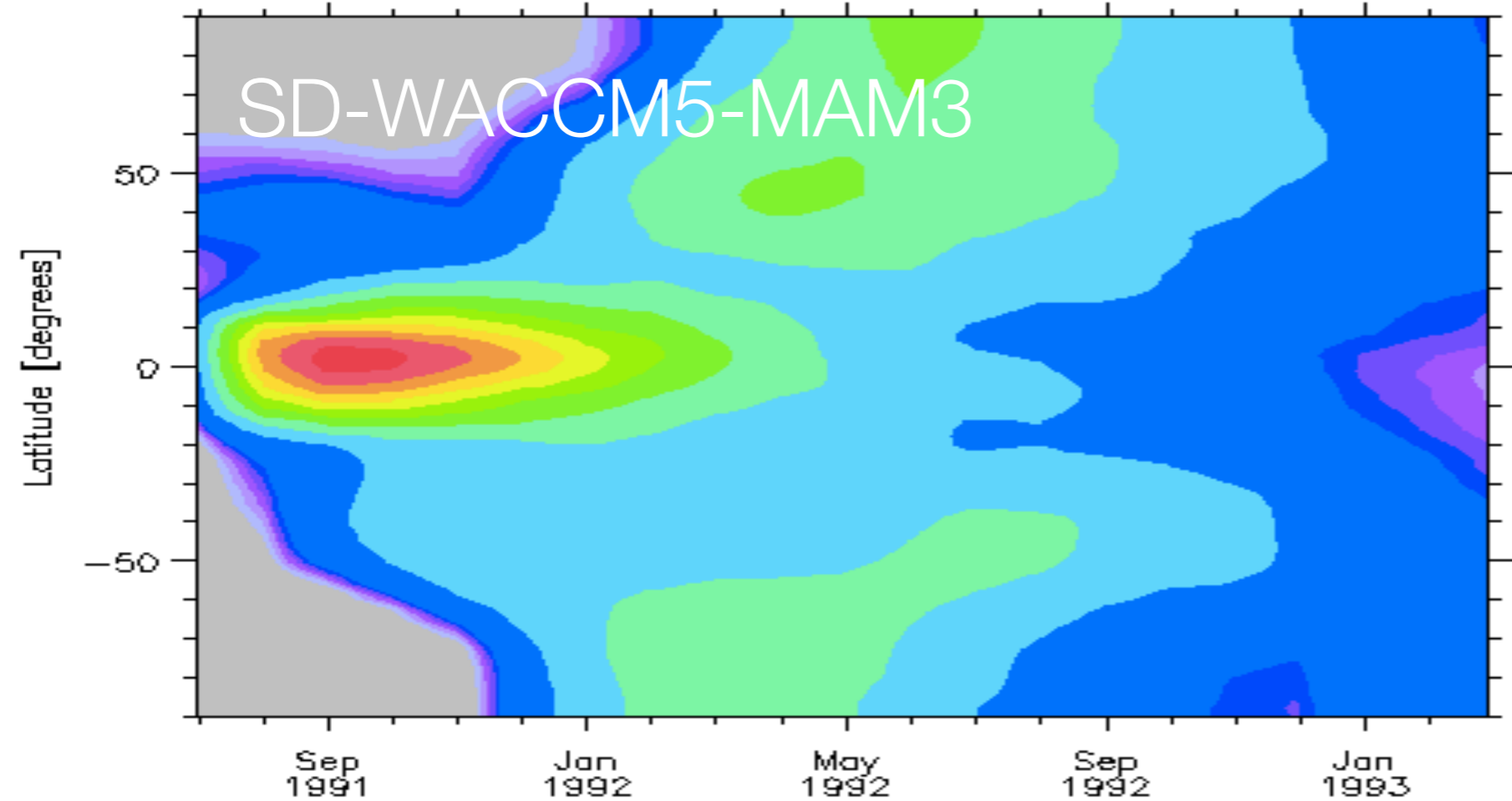
New data set for Chemistry-Climate Model Initiative based on SAGEII 1984-2005, extinction coefficients at 1020, 525, 452 and 386 nm.

CCMI input data file: 9.7 Tg



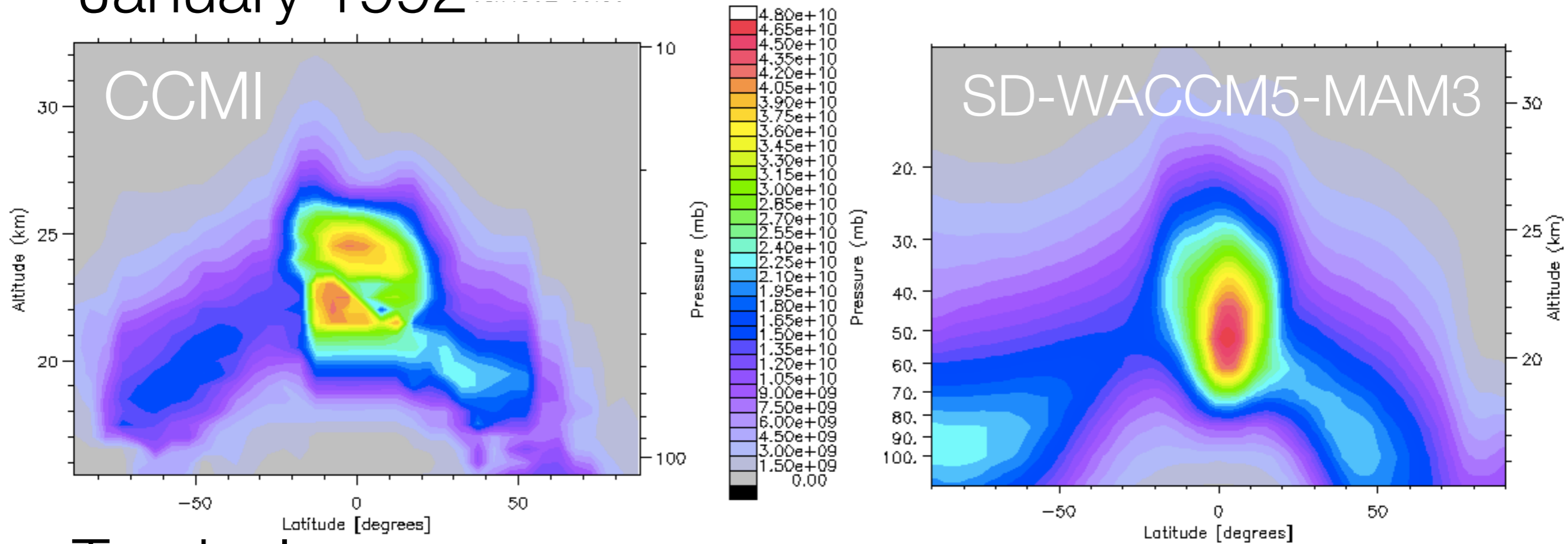


Stratospheric sulfate column (kg/m^2)

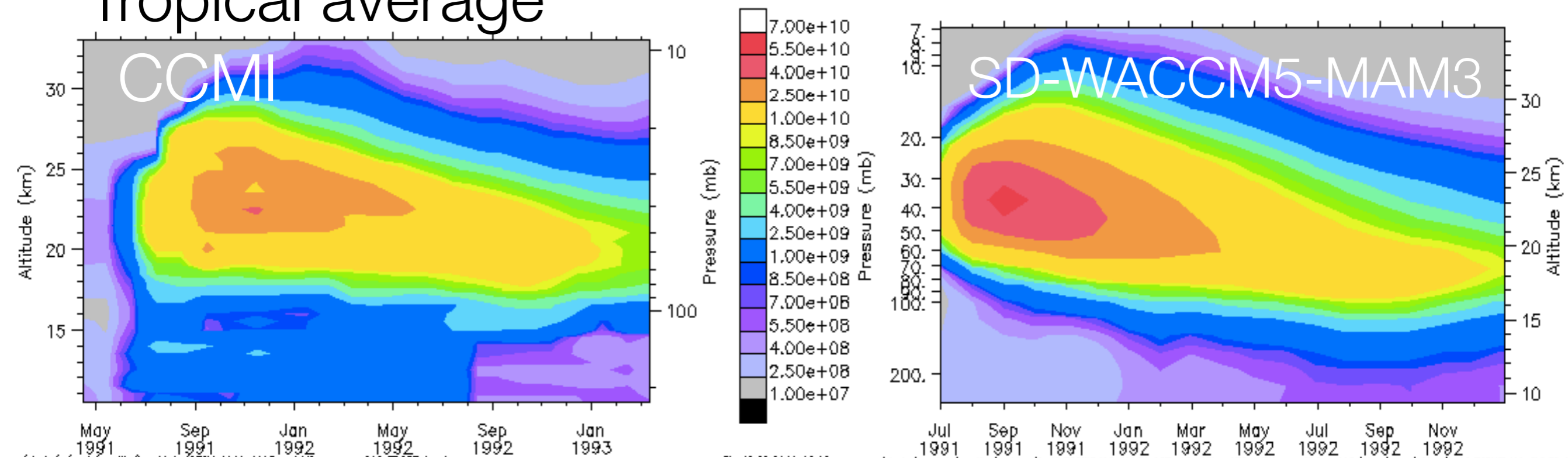


Sulfate concentration (molec/cm³)

January 1992

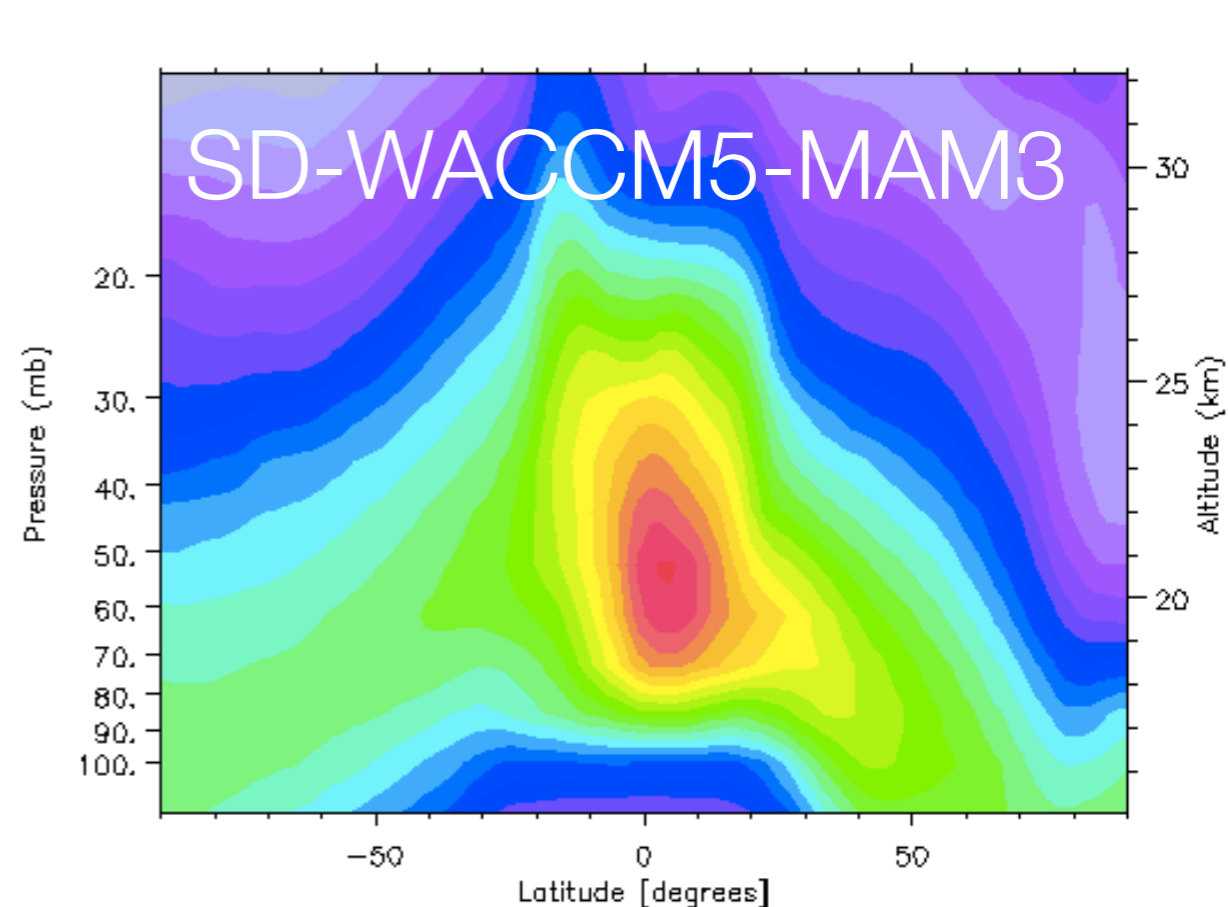
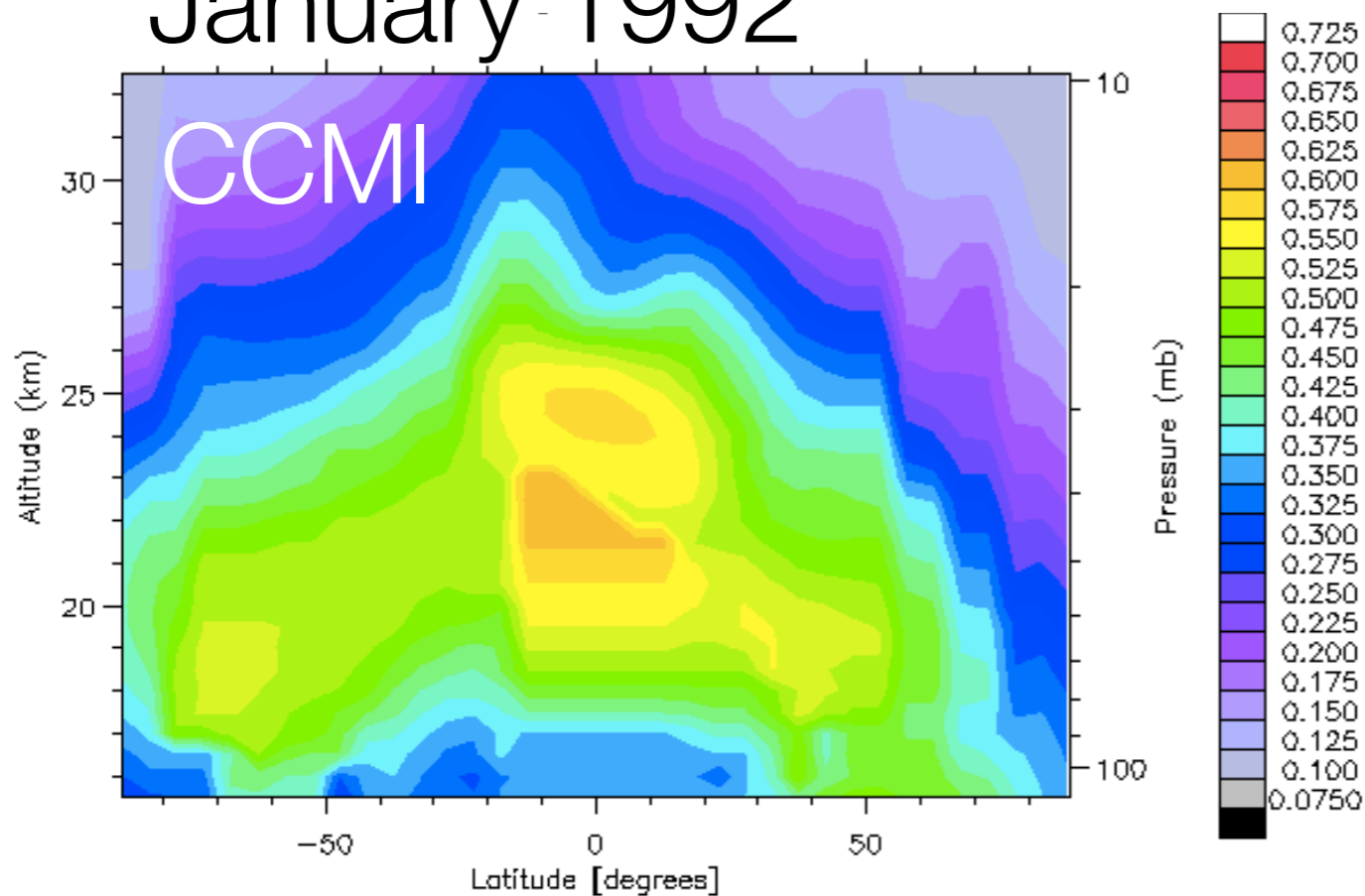


Tropical average

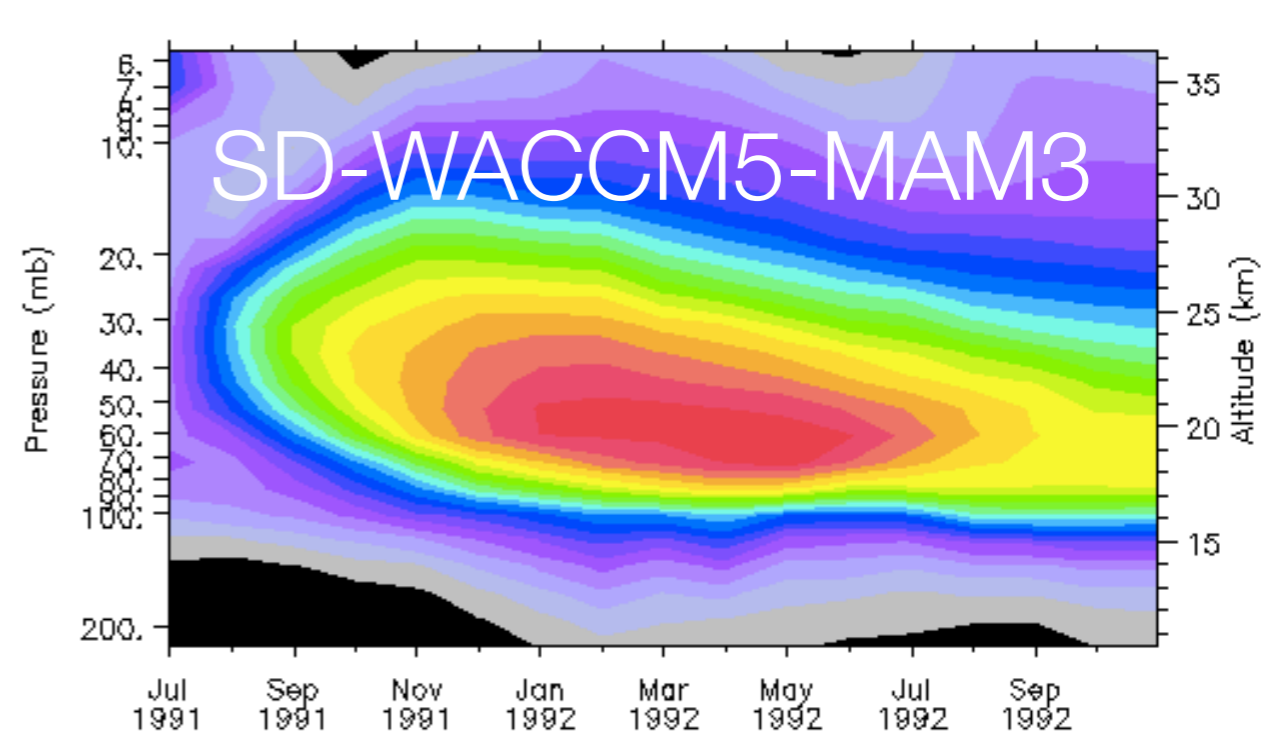
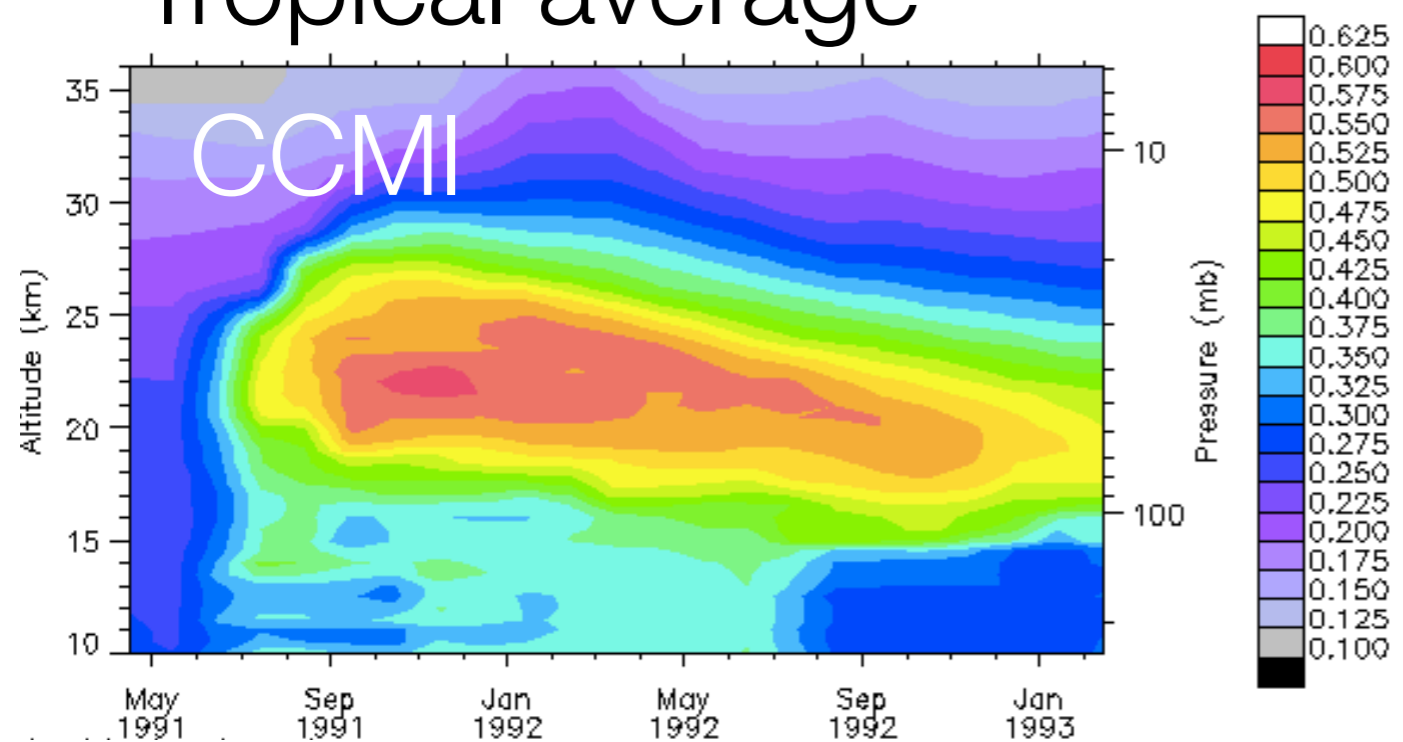


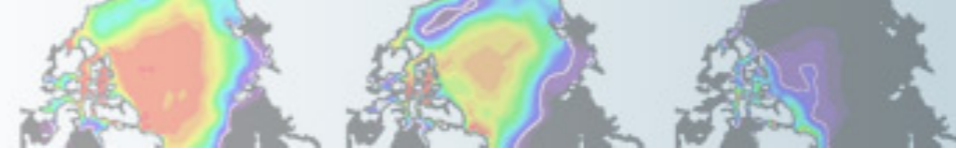
Effective radius (μm)

January 1992

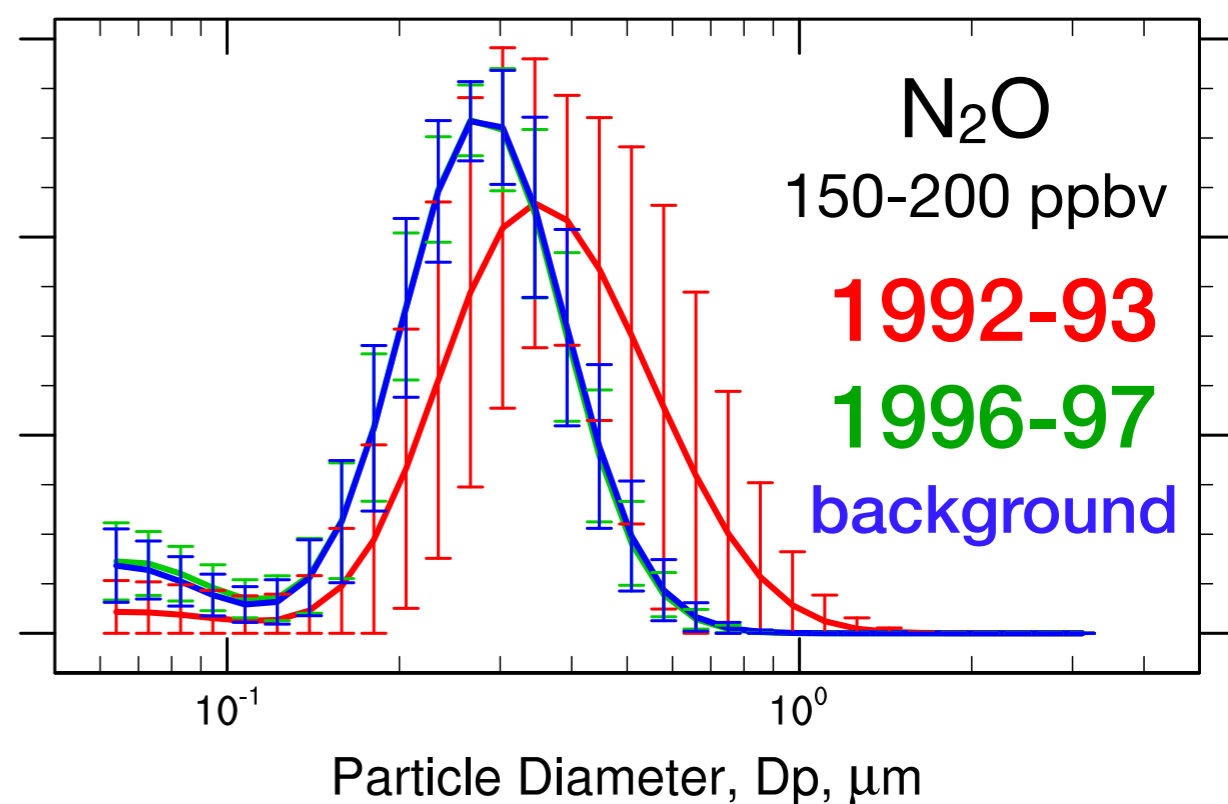
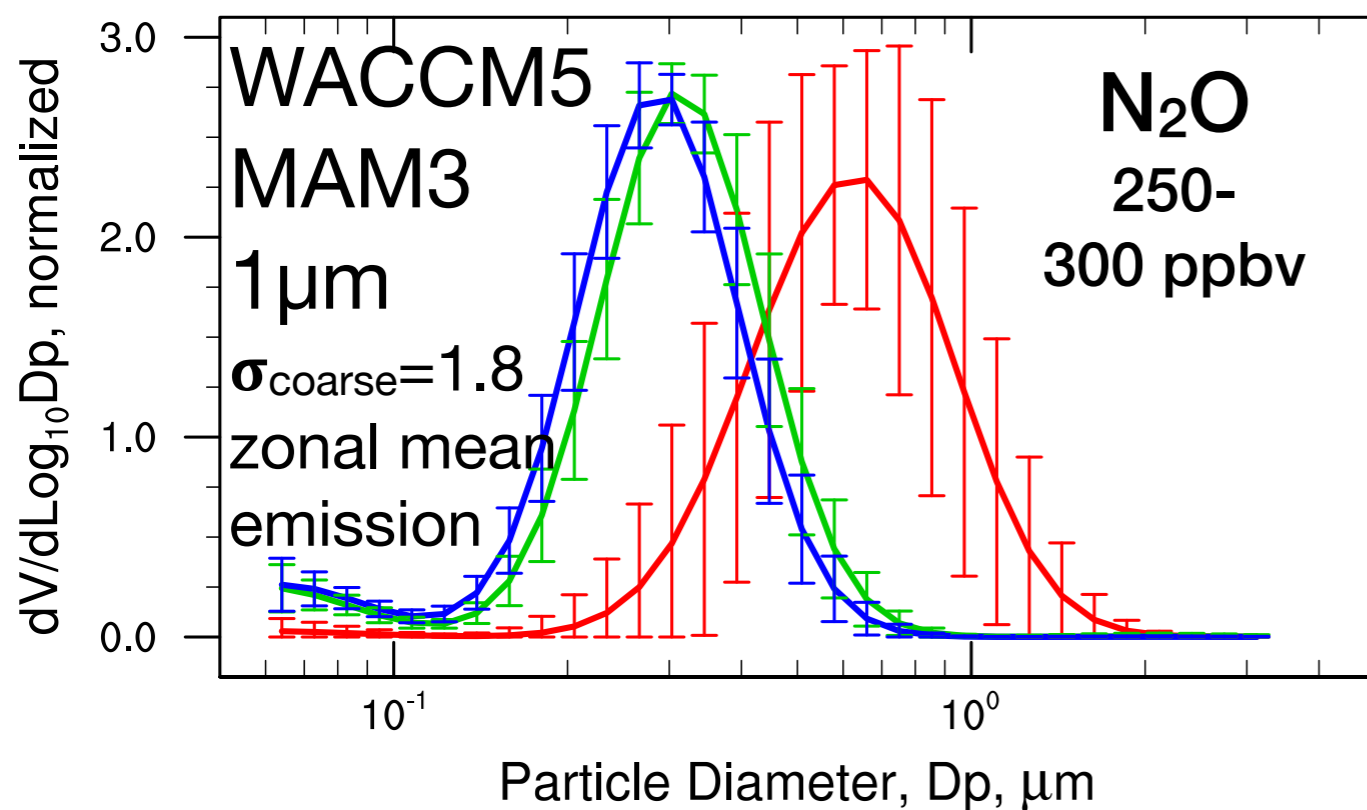
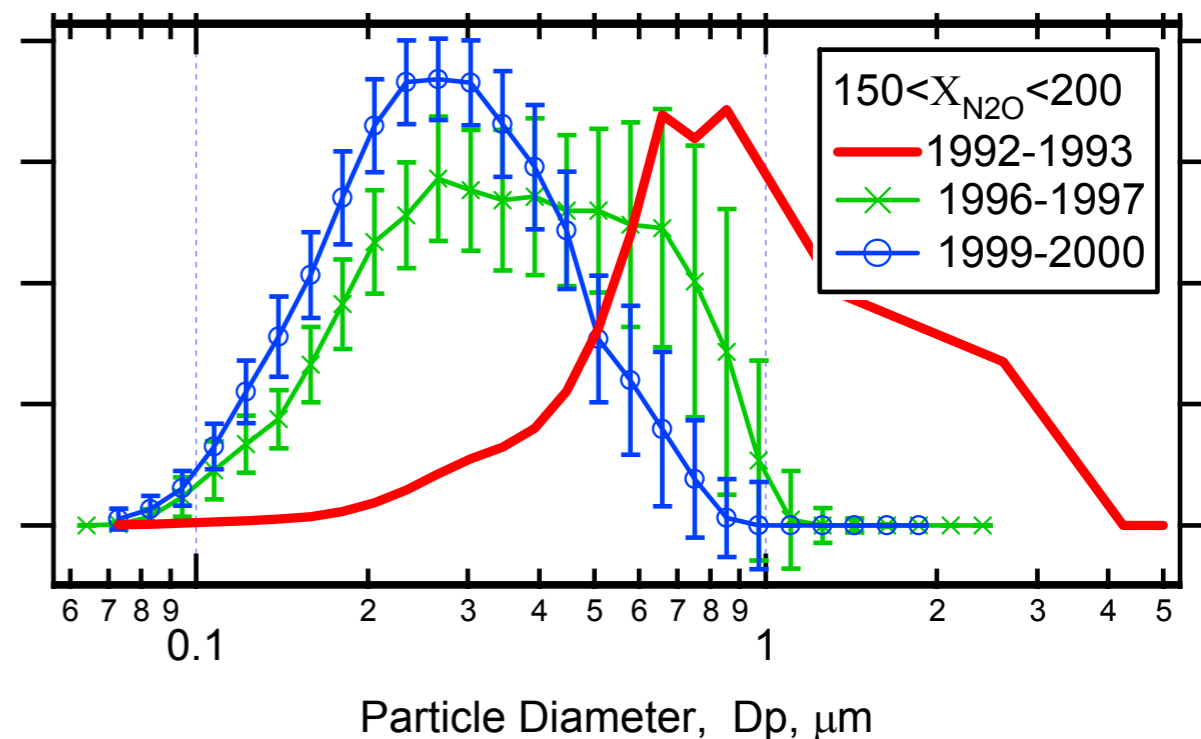
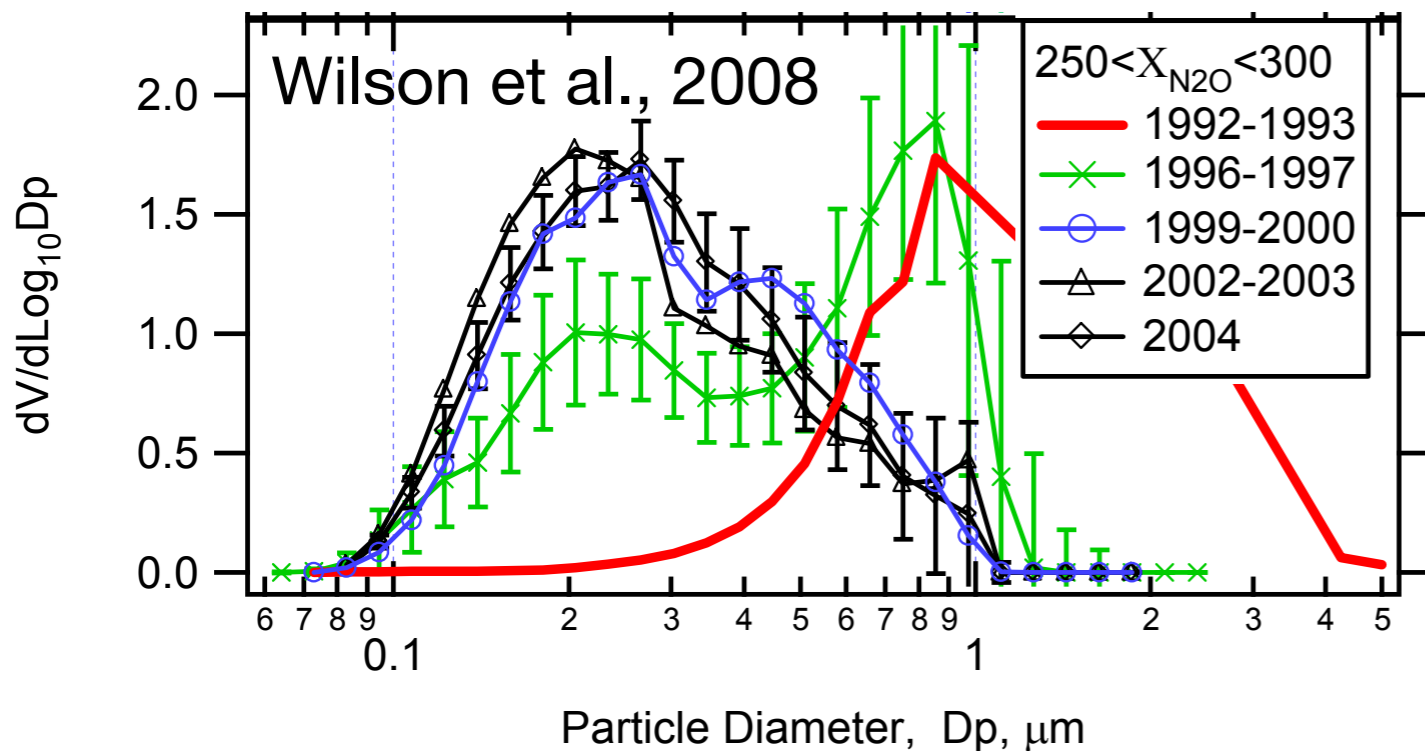


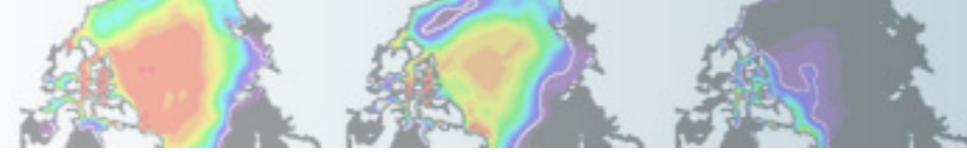
Tropical average



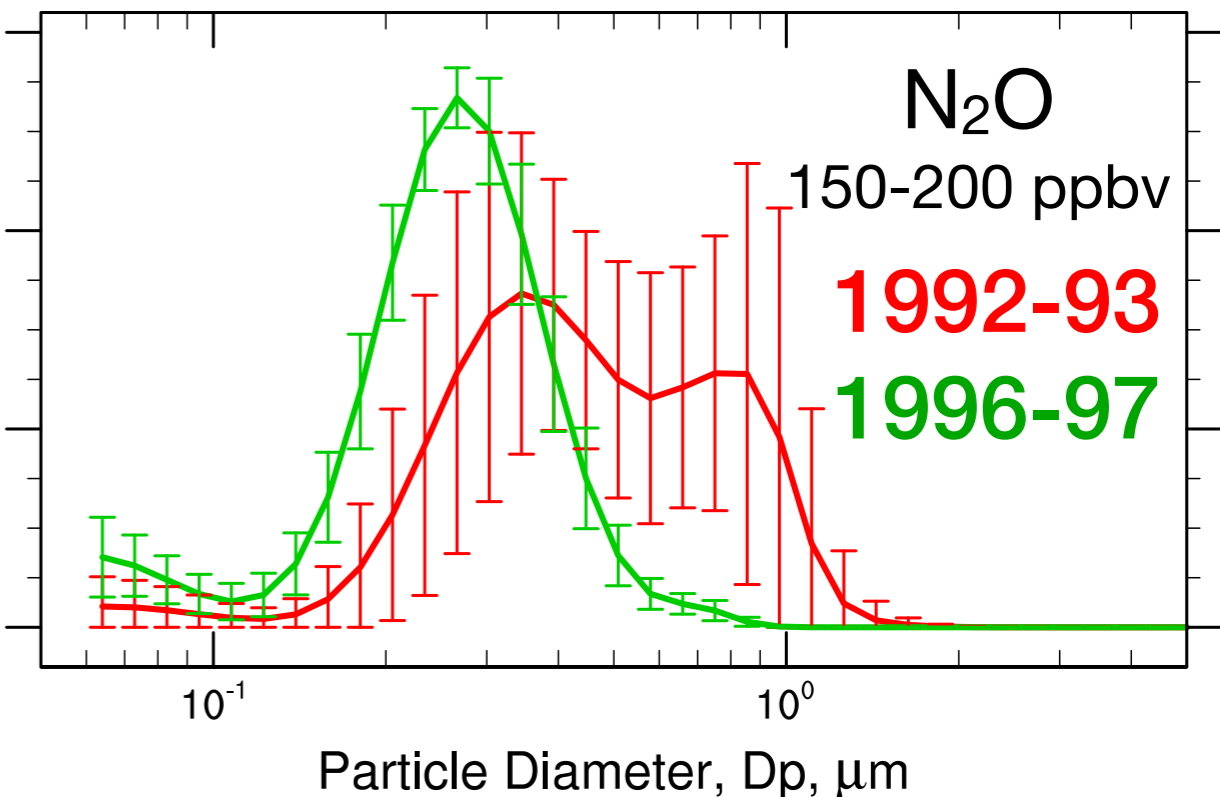
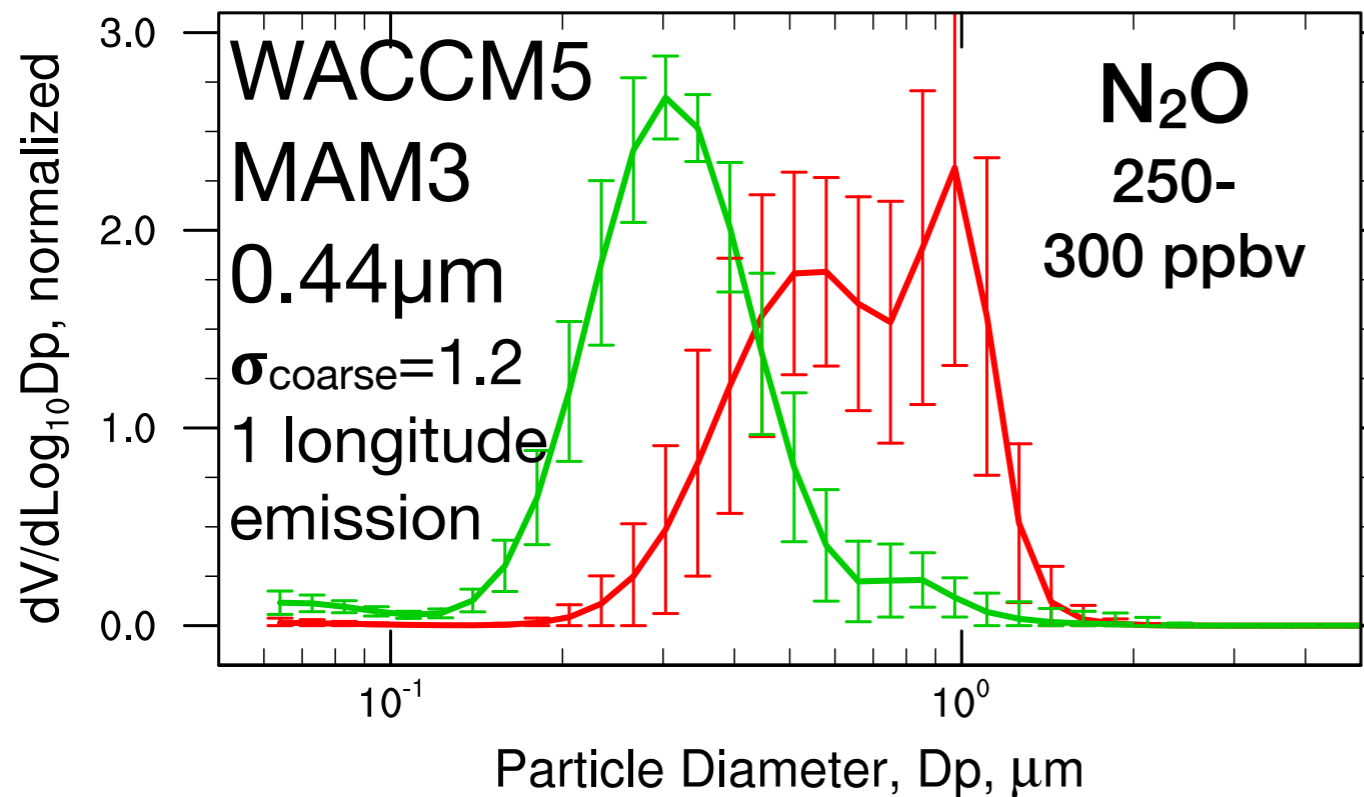
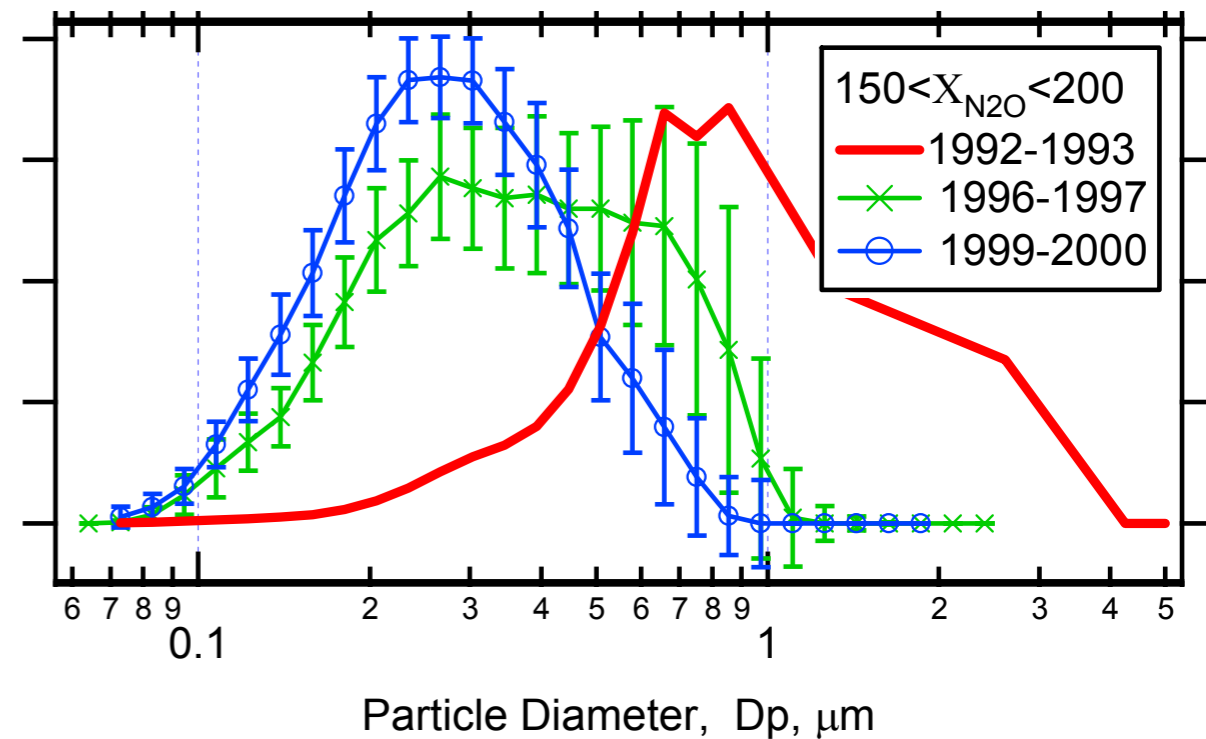
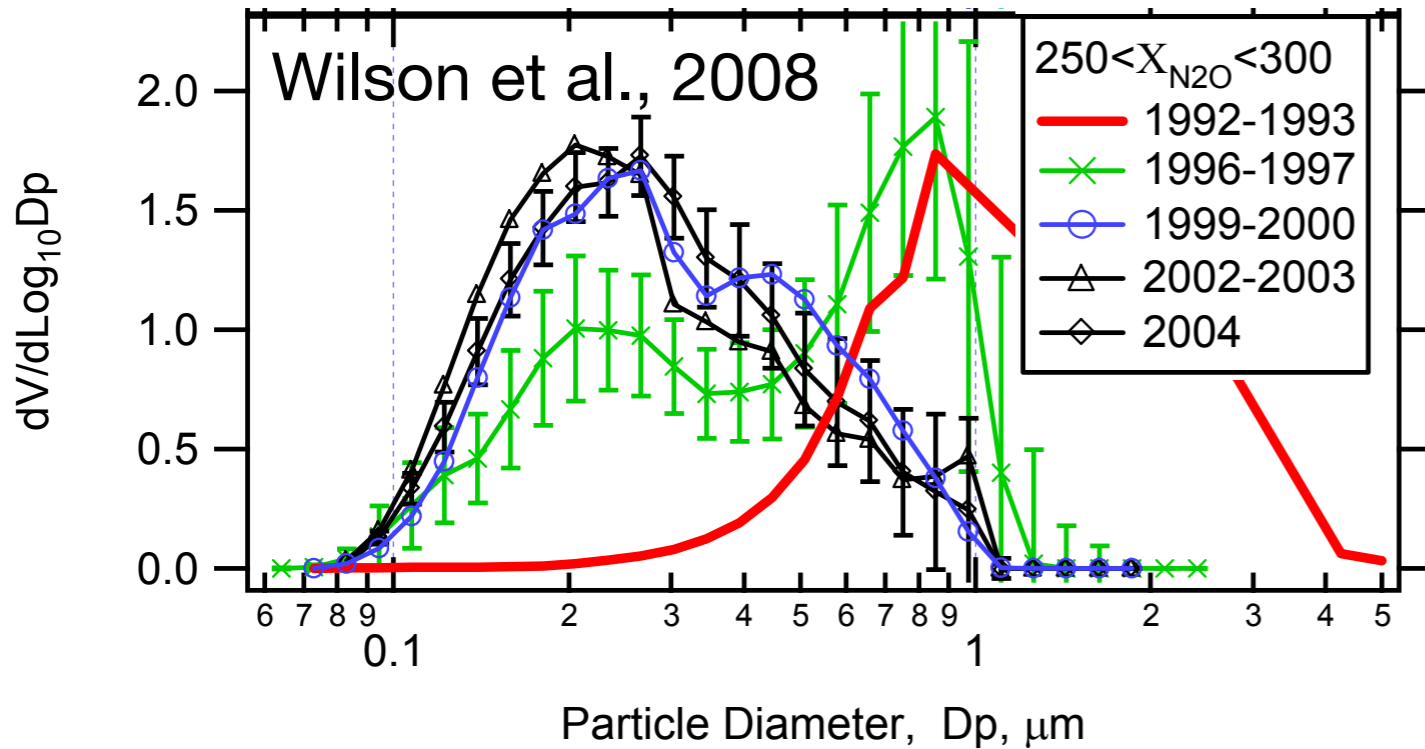


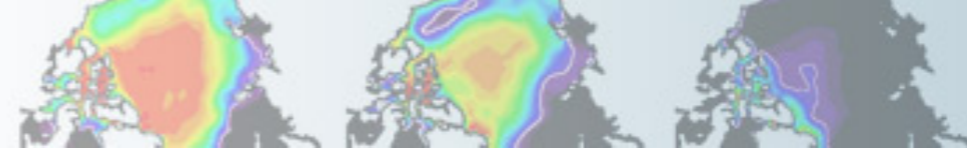
Volume size distributions compared to observations





Volume size distributions compared to observations





Outstanding issues

- Investigate low SO₂ in the tropics at 20 km and 35 km
- Investigate slow of growth to coarse mode
- Investigate alternate emission scenarios (zonal mean vs. plume)
- Adjustment of mode widths?
- Validation of Pinatubo temperature perturbations (stratosphere and surface) requires accounting for QBO effects (Stenchikov et al., JGR, 2004)
- Potential further development: Need for additional modes, i.e. nucleation mode?
- Begin GeoMIP G4 experiment