

Toward a prognostic representation of stratospheric sulfate aerosol in CESM

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NCAR is funded by the National Science Foundation



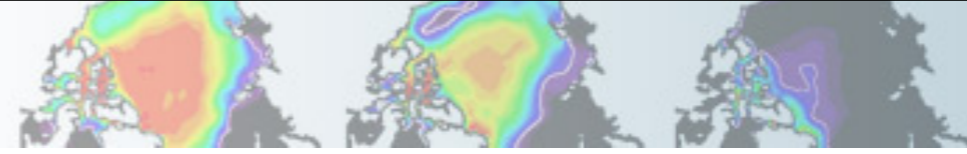
NCAR



WACCM

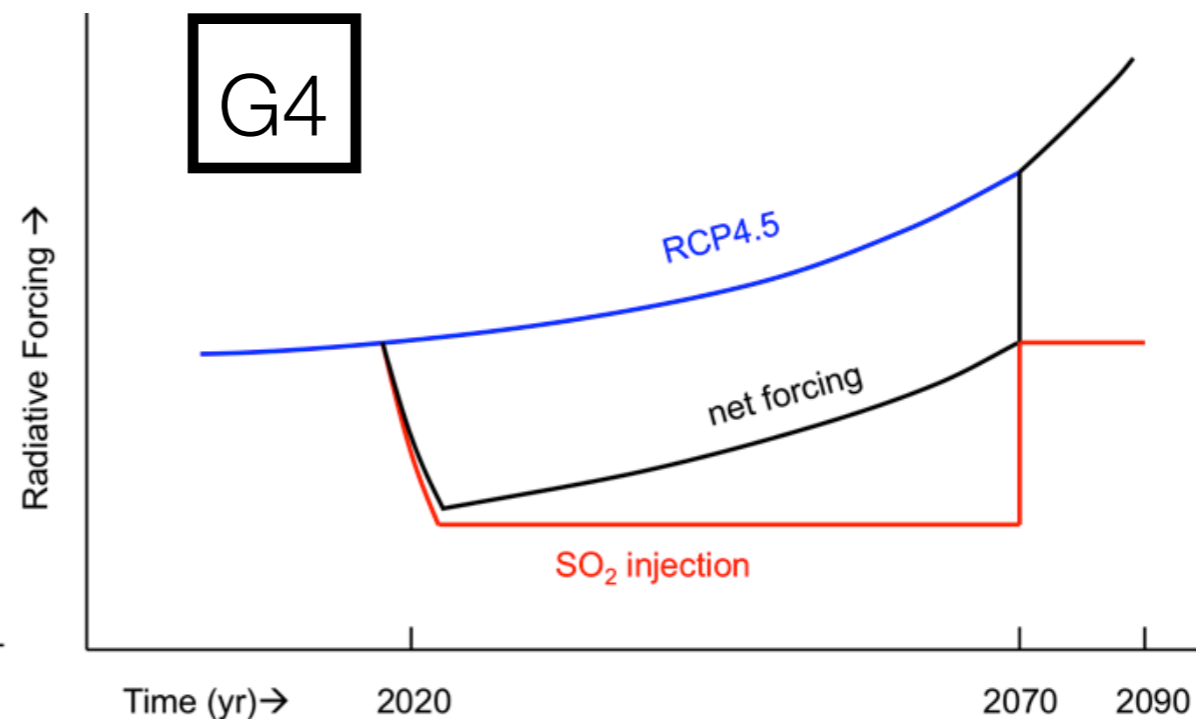
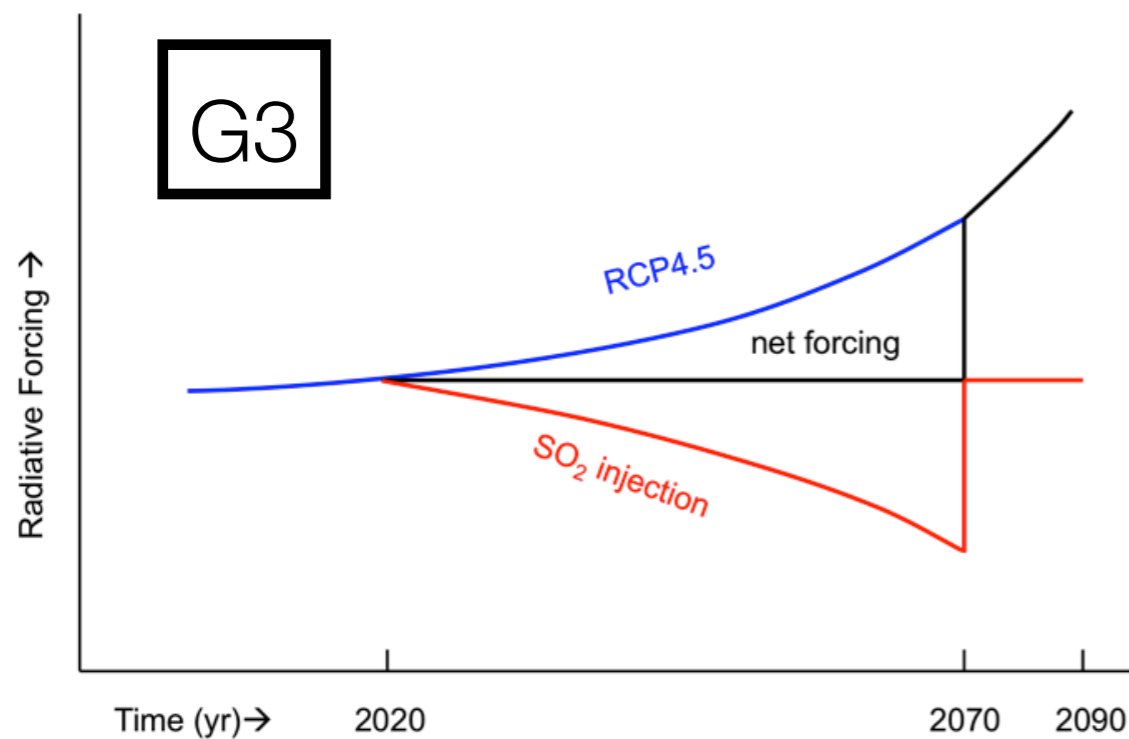
*Whole Atmosphere
Community Climate Model*



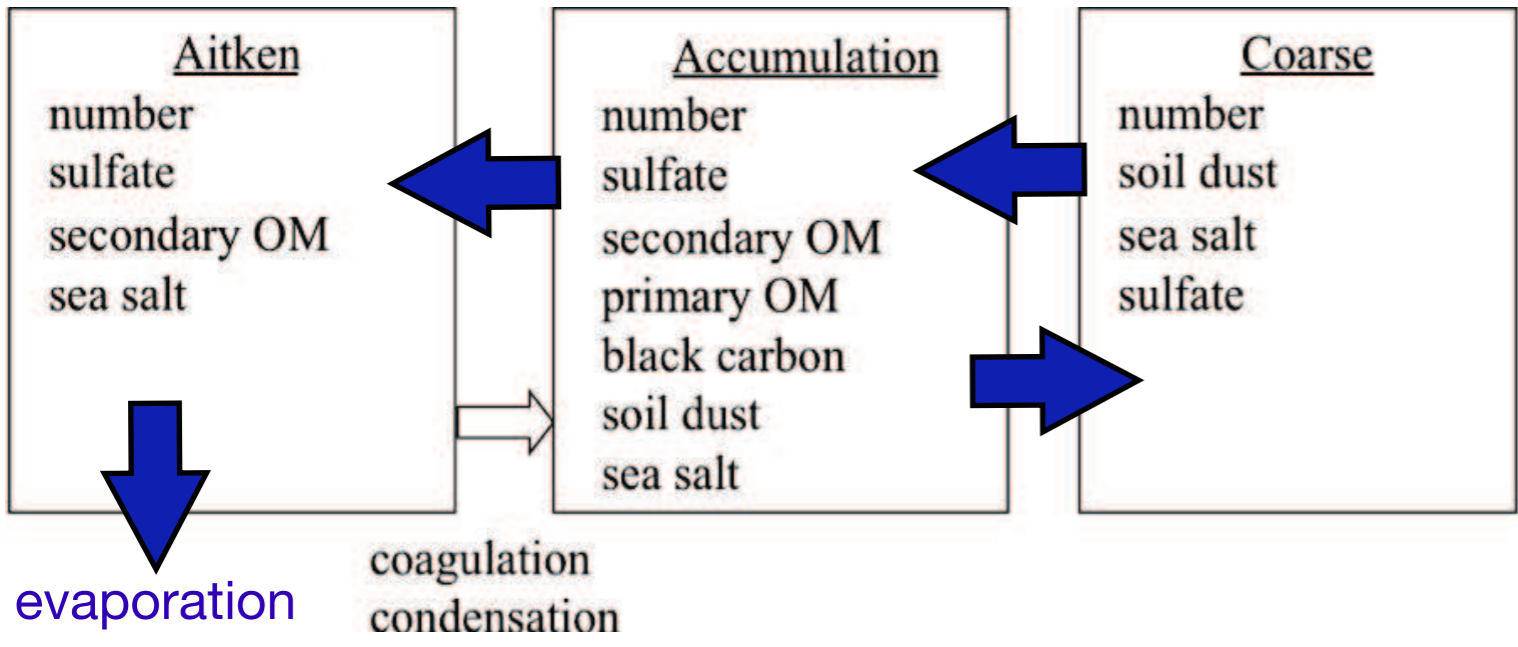


Motivation for emission-based volcanoes in CESM

- 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”



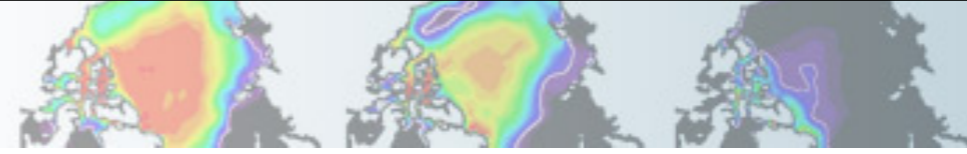
MAM3 for stratospheric aerosols



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:

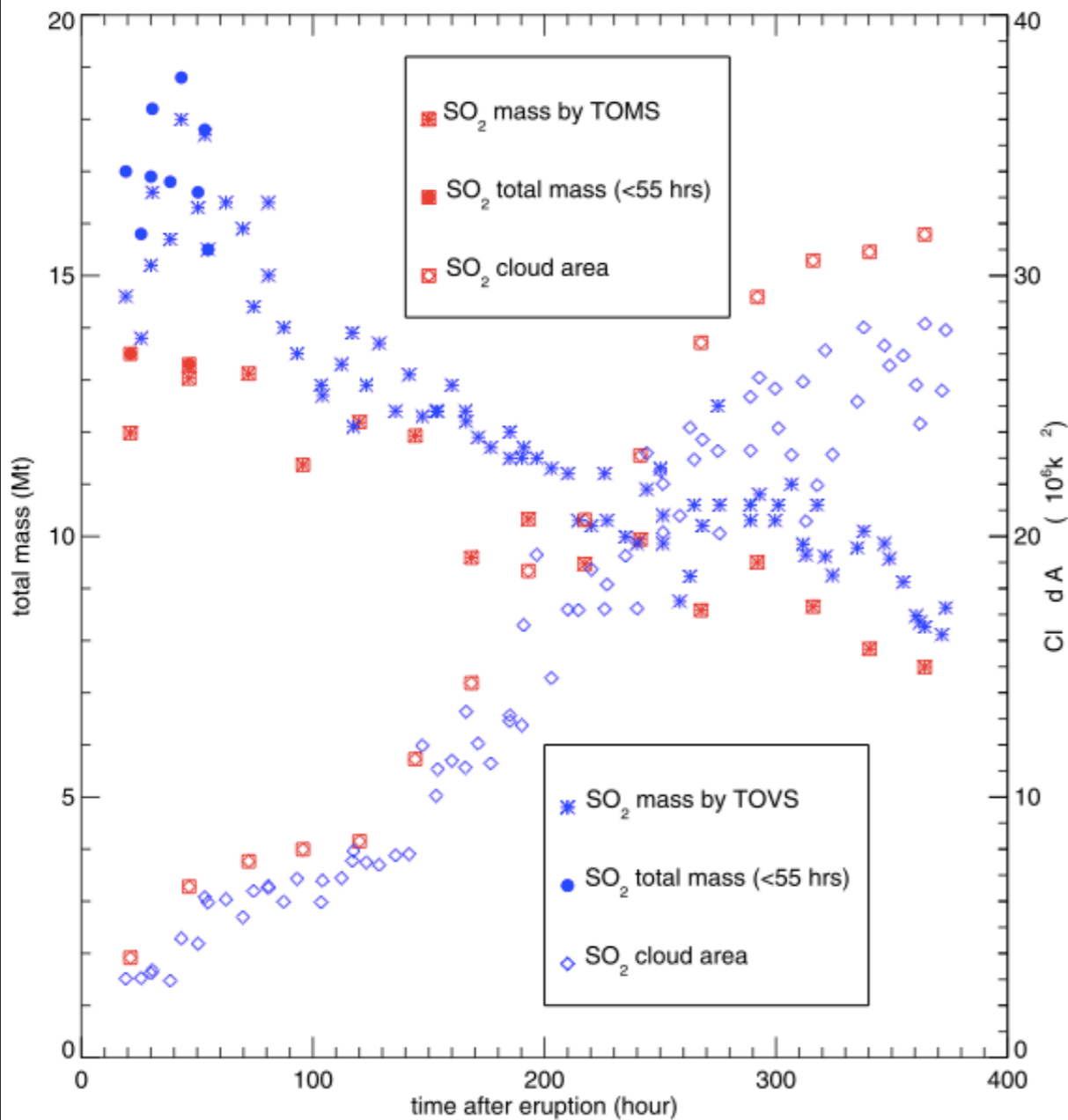
	a1 accum	a2 Aitken	a3 coarse
SO4	✓	✓	✓
POM	✓		
SOA	✓	✓	
BC	✓		
dust	✓		✓
salt	✓	✓	✓
number	✓	✓	✓

Mode	Aitken	Accumulation	Coarse
CAM5-MAM3 diameter (µm)	0.0087 - 0.052	0.0535 - 0.44	1.0 - 4.0
CAM5-MAM3 geom. std. dev.	1.6	1.8	1.8
WACCM5-MAM3 diameter (µm)	0.0087 - 0.052	0.0535 - 1.1	0.9 - 4.0
WACCM5-MAM3 geom. std. dev.	1.6	1.6	1.8, 1.4



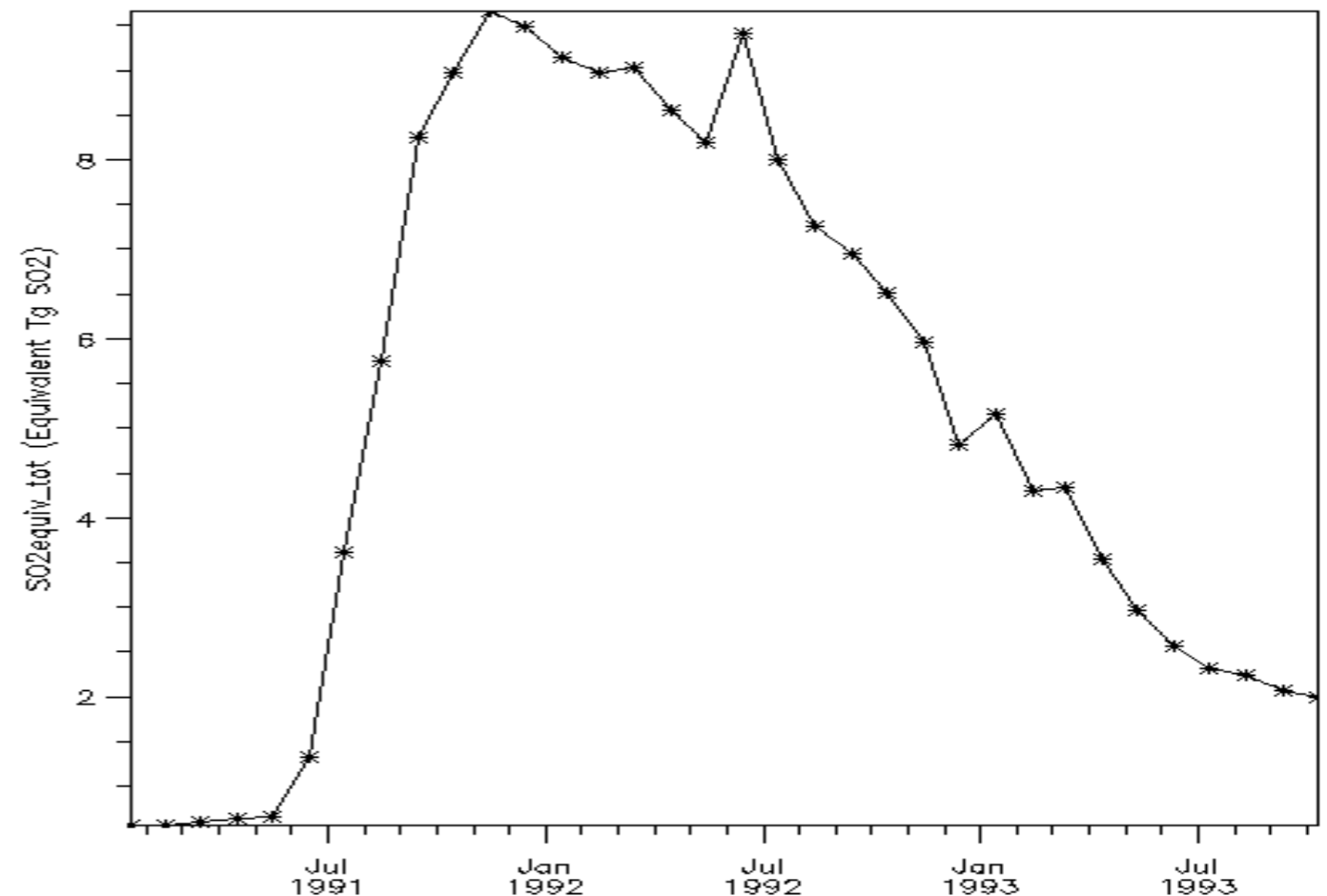
Pinatubo simulation: How much SO₂?

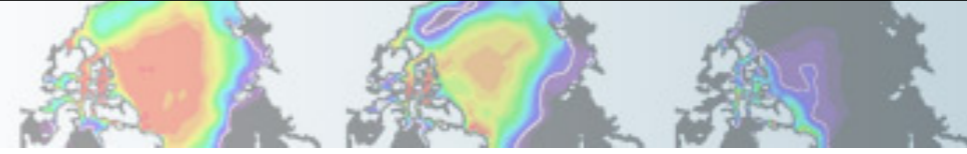
Guo et al., 2004: 15-19 Tg



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

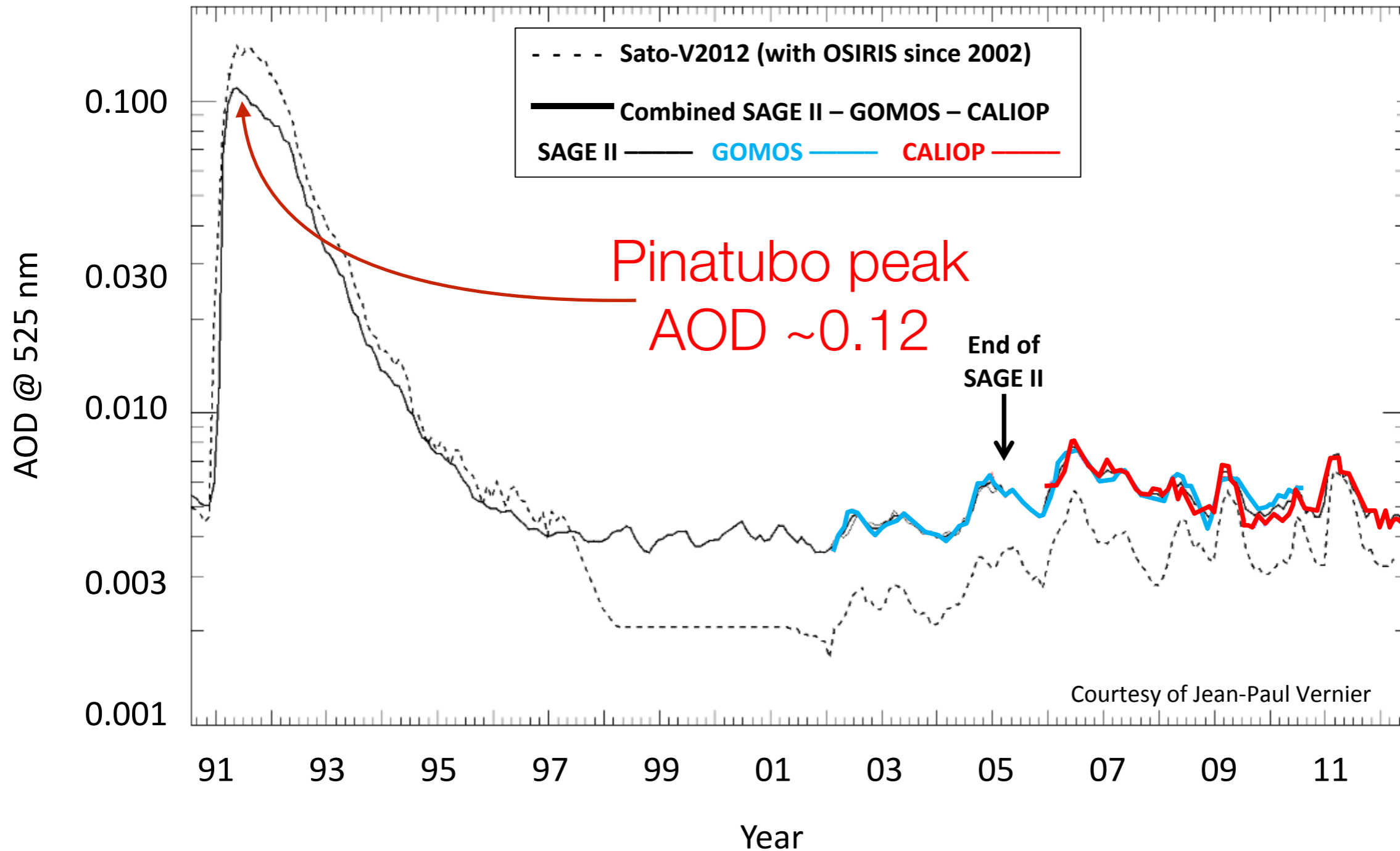




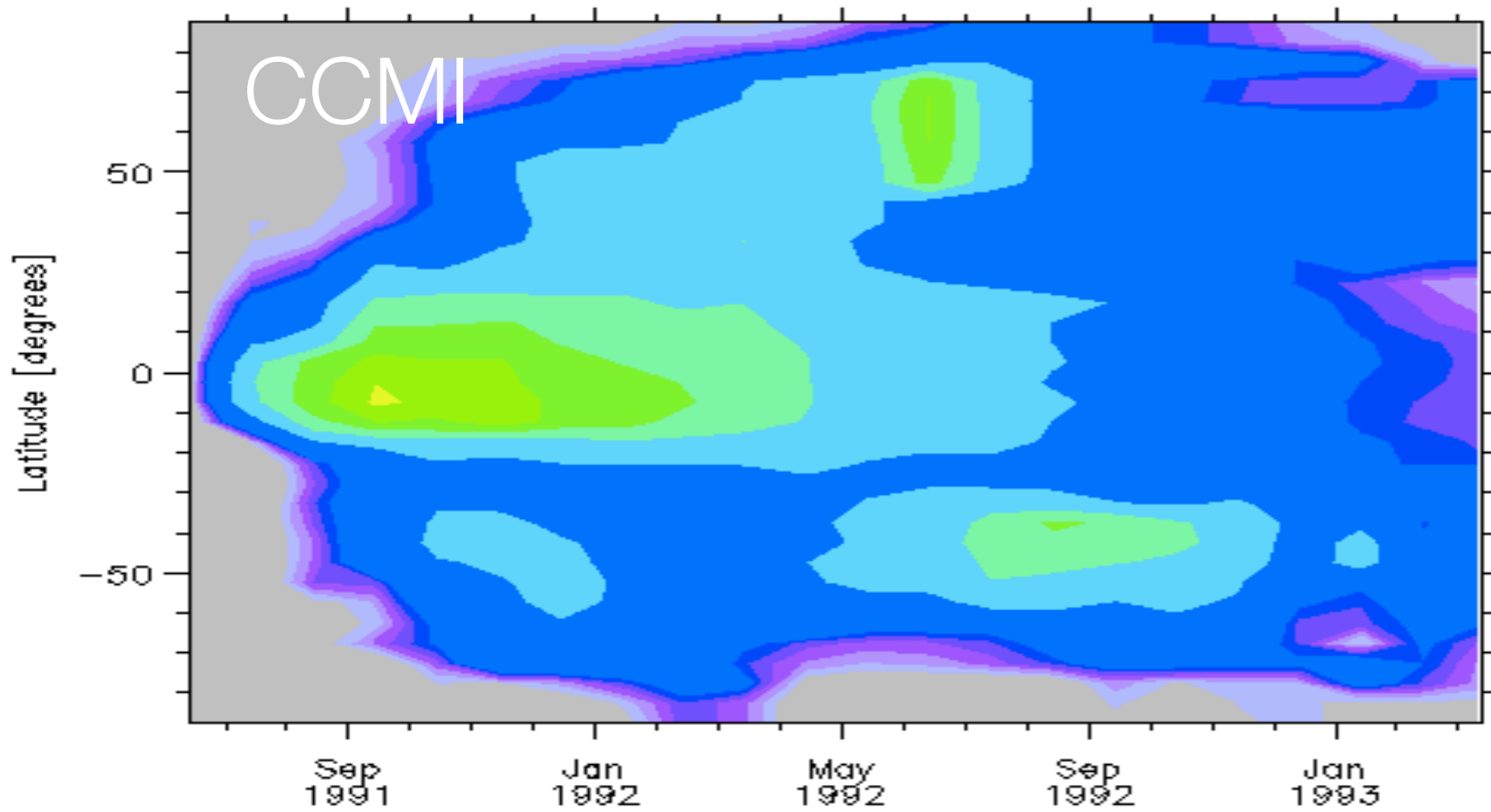
New long term record of stratospheric aerosol properties

(B.P. Luo, F. Arfeuille, J.P. Vernier, L.W. Thomason, T. Peter, CCMI Workshop, May 2013)

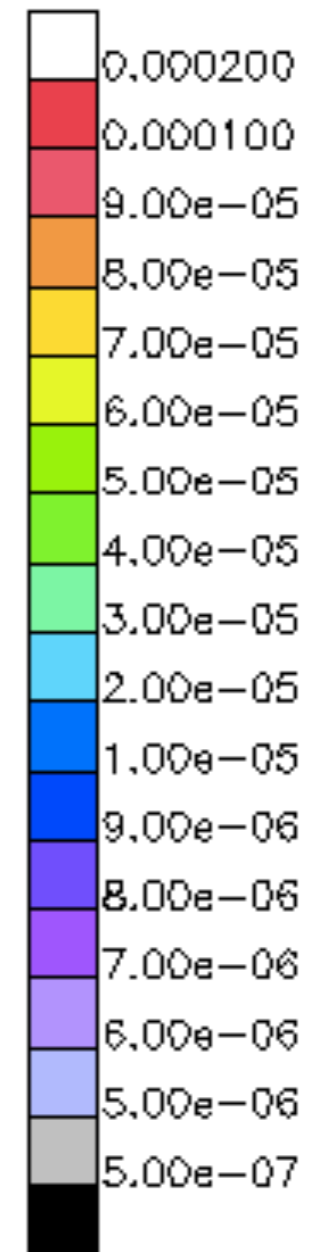
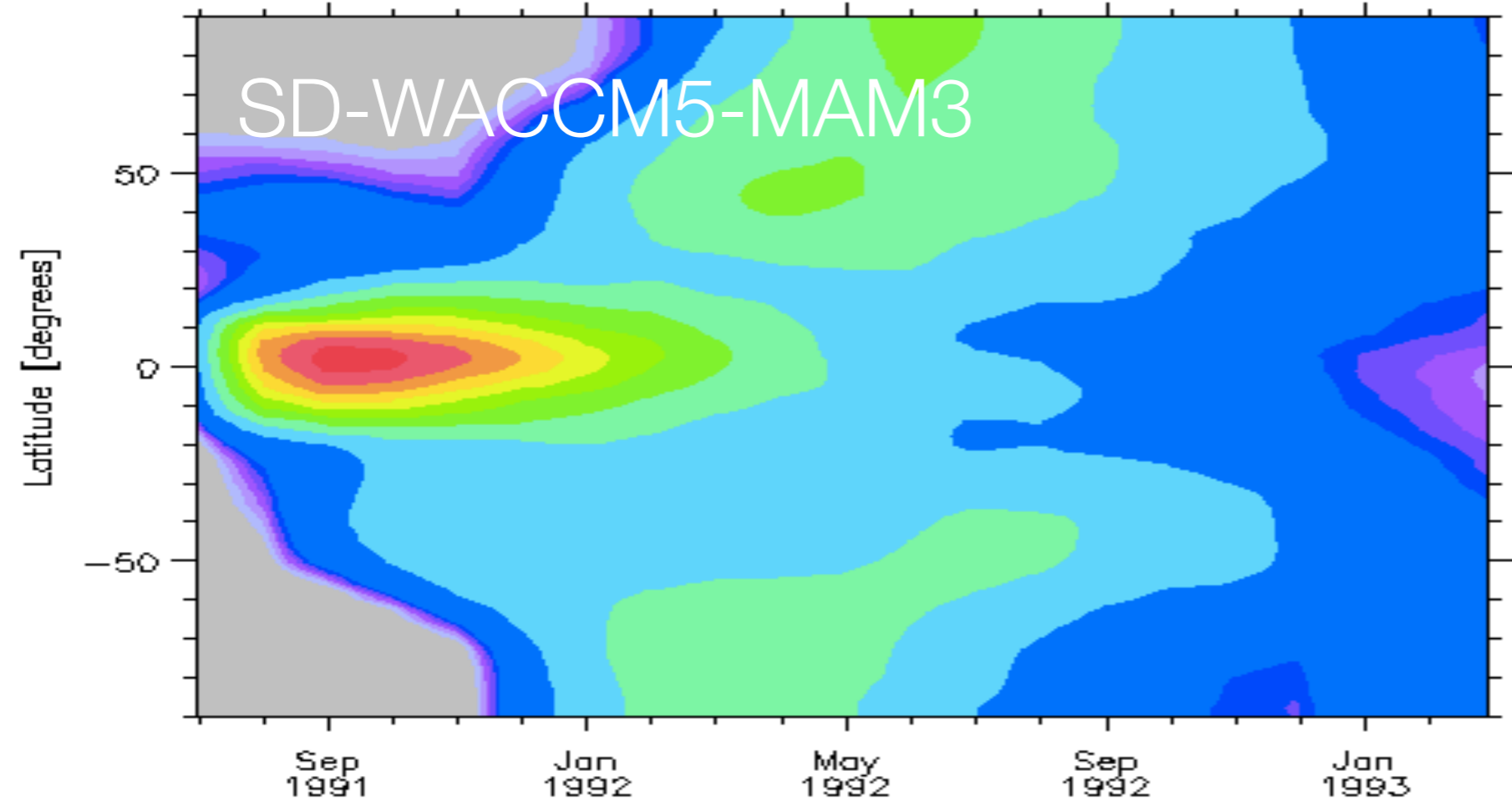
AOD 15-35 km 50°N-50°S



- Overlap of instruments allows to test SAGE II – CALIPSO transition
- Important differences to Sato GISS data

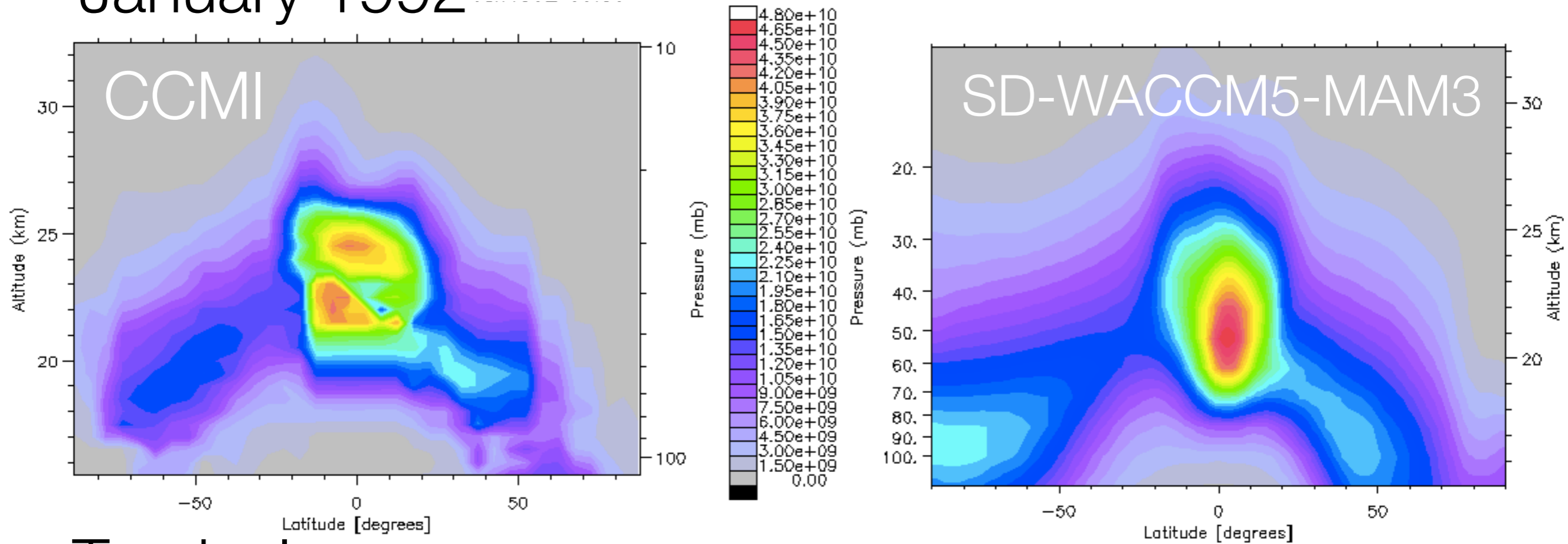


Stratospheric
sulfate
column
(kg/m²)

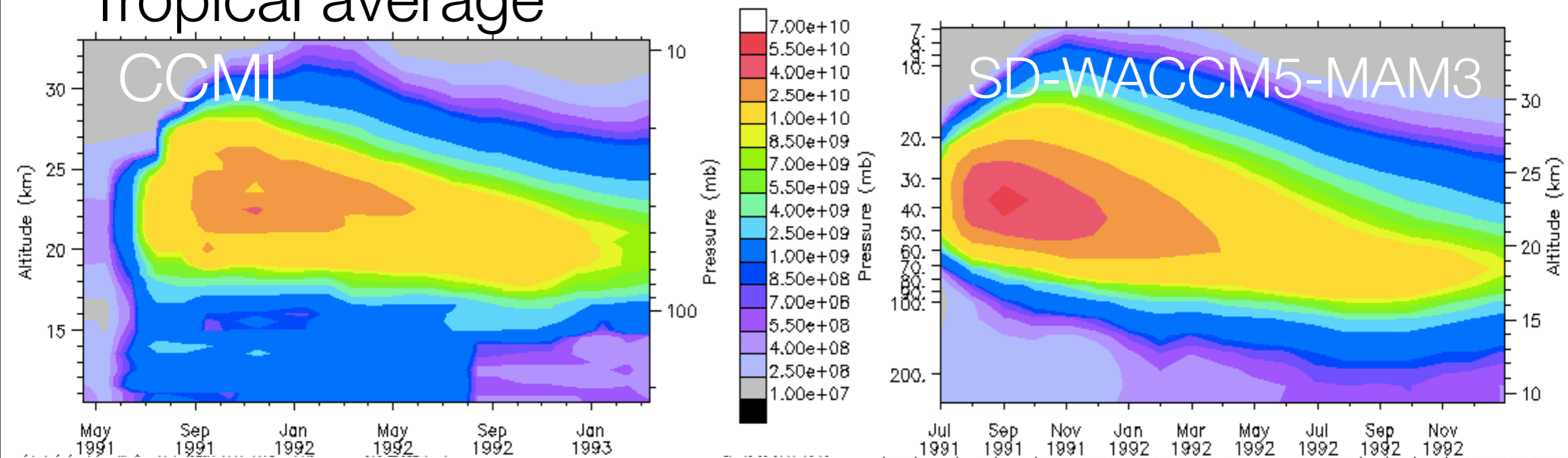


Sulfate concentration (molec/cm³)

January 1992

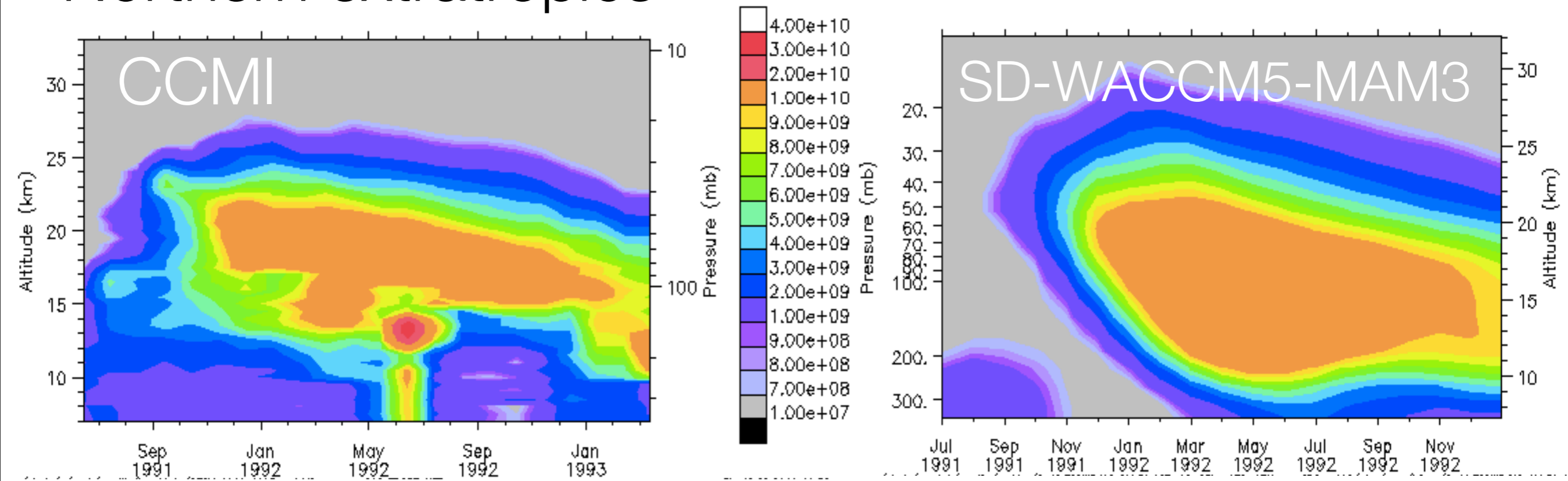


Tropical average

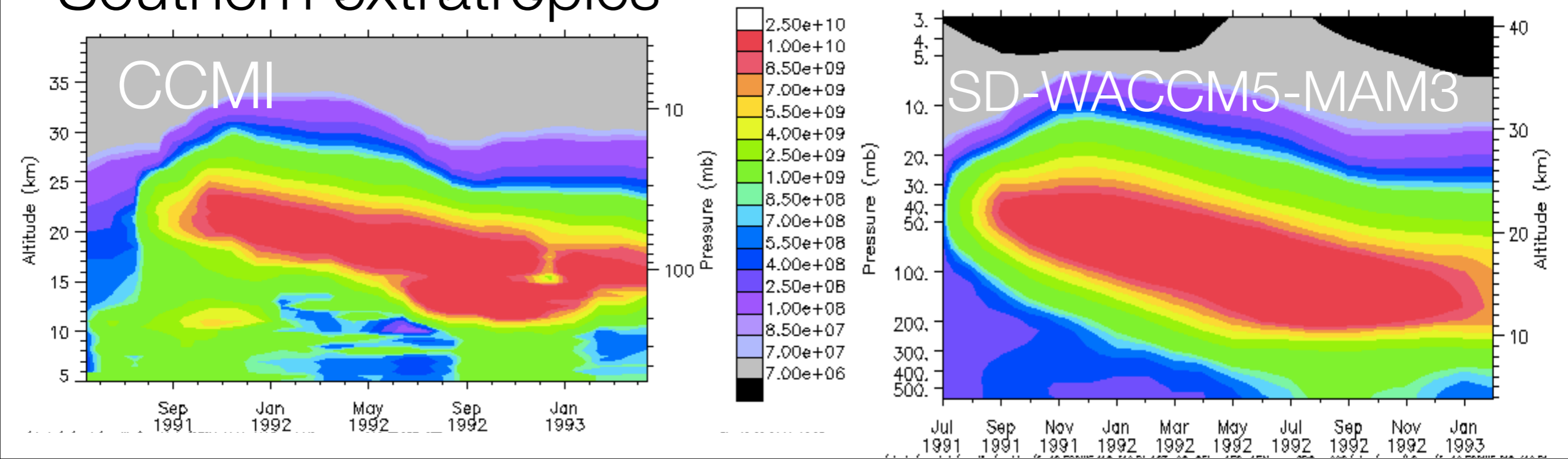


Sulfate concentration (molec/cm³)

Northern extratropics

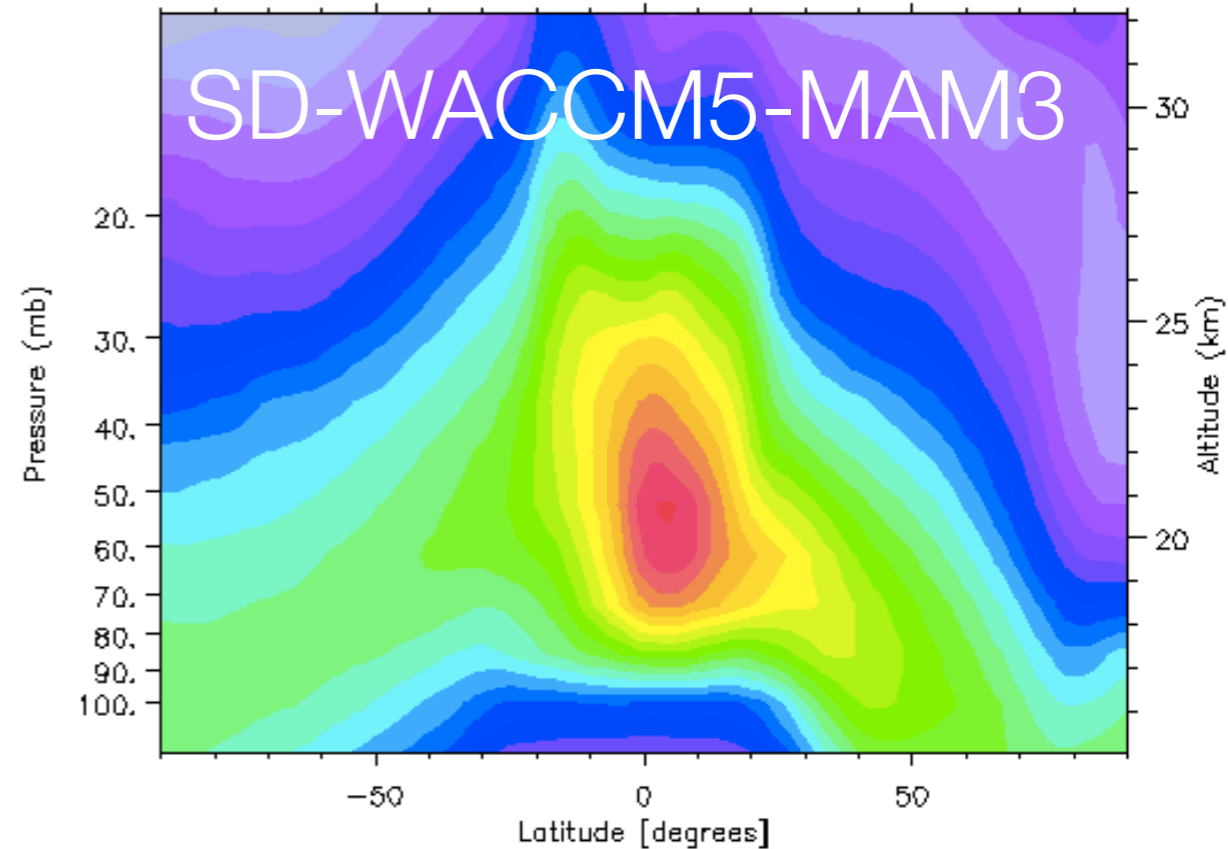
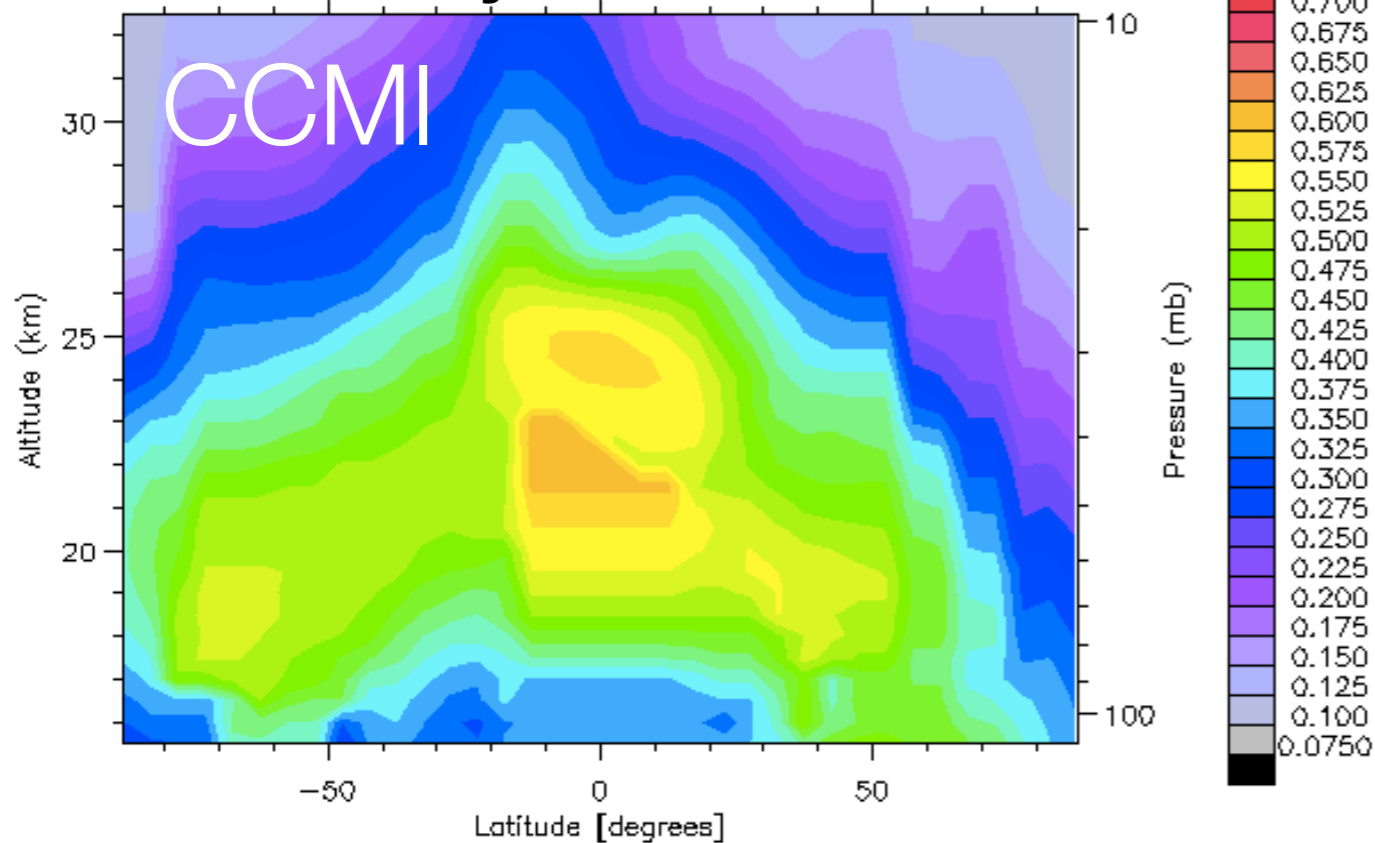


Southern extratropics

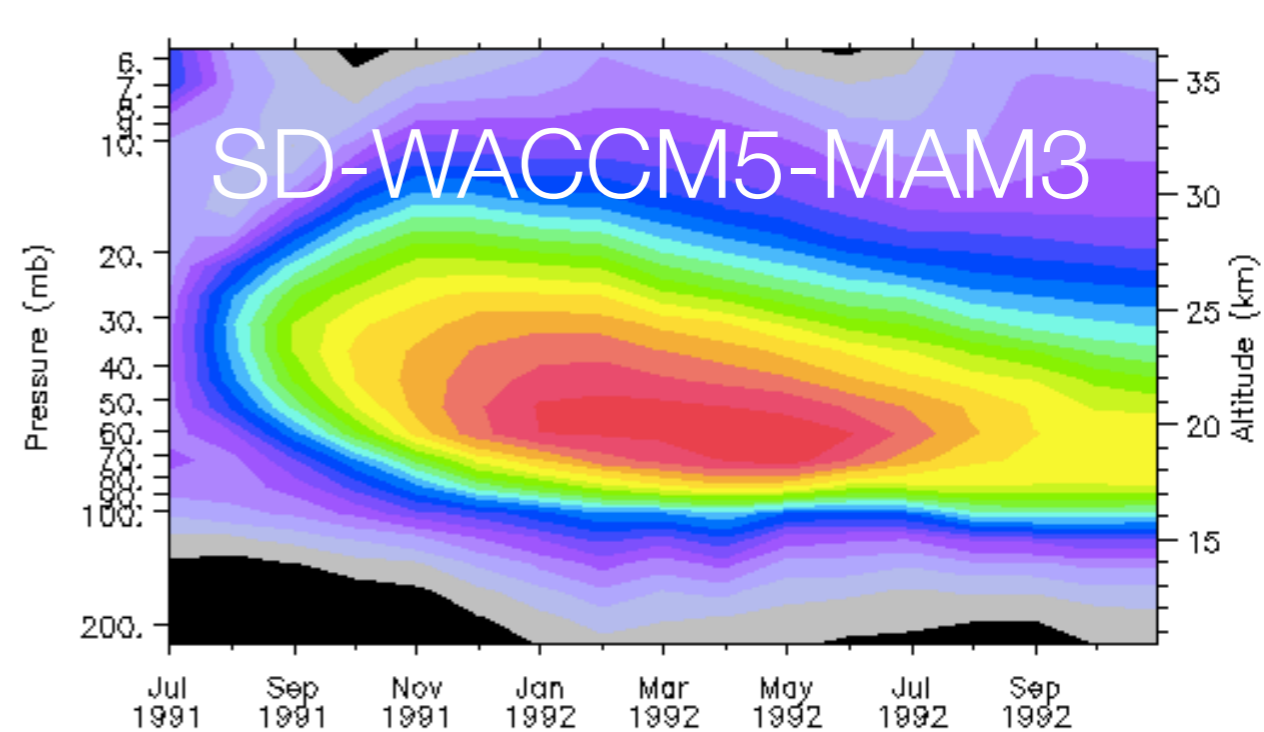
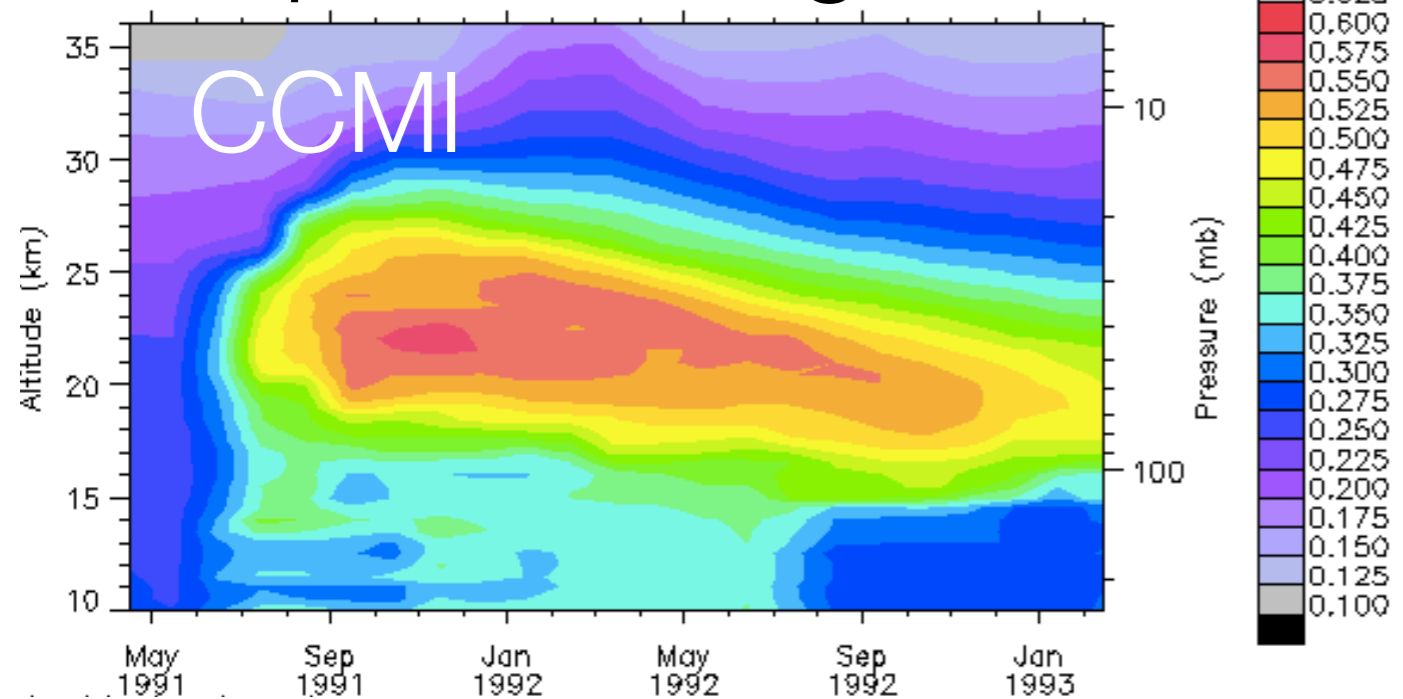


Effective radius (μm)

January 1992

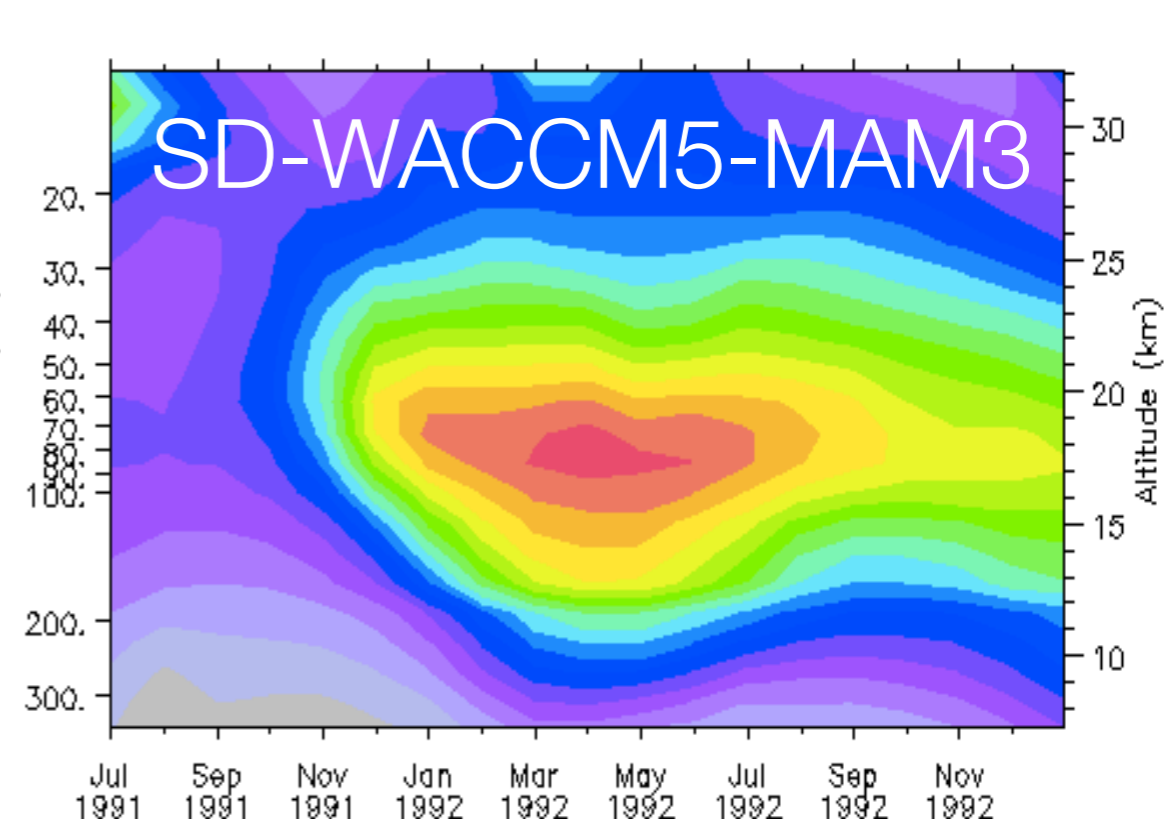
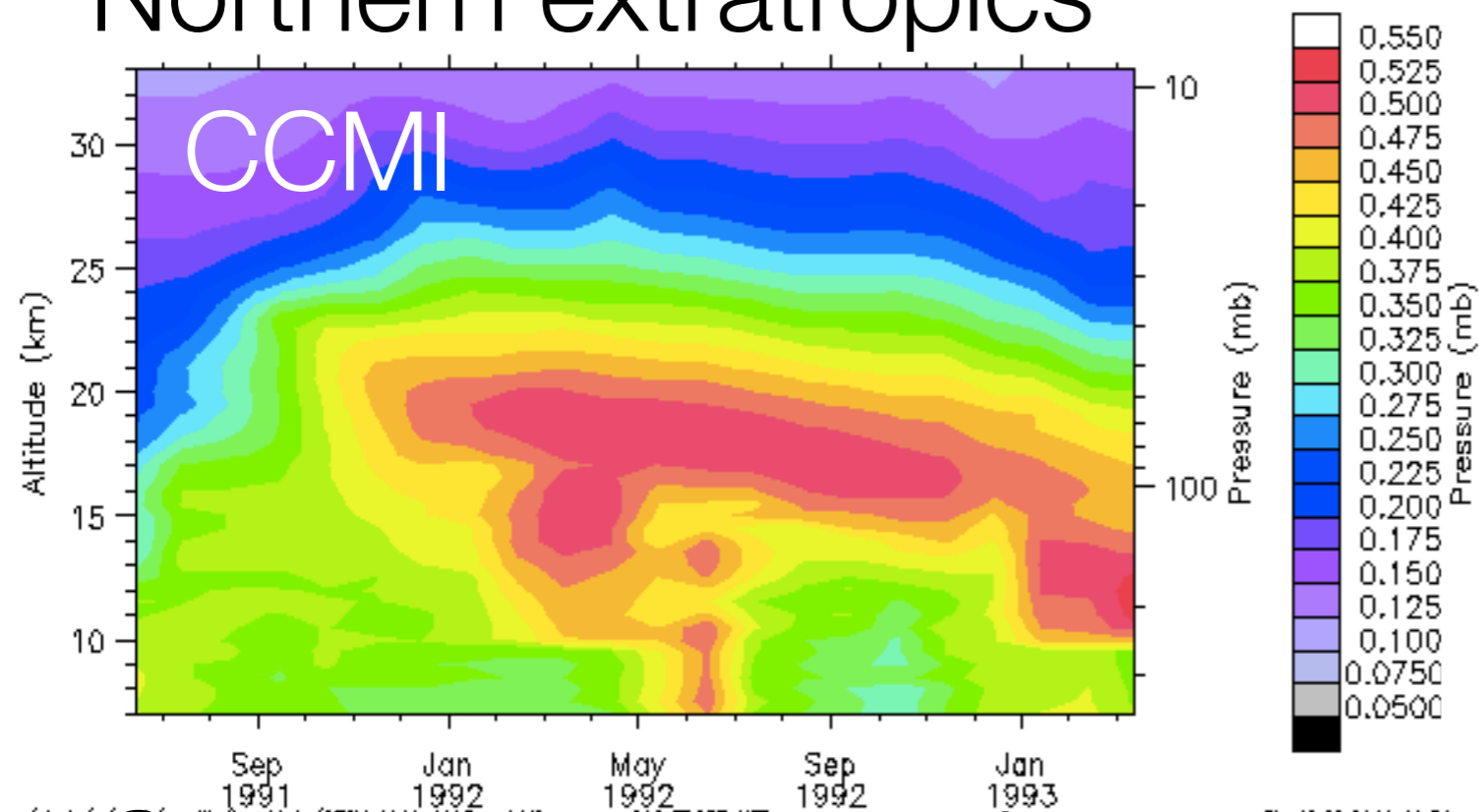


Tropical average

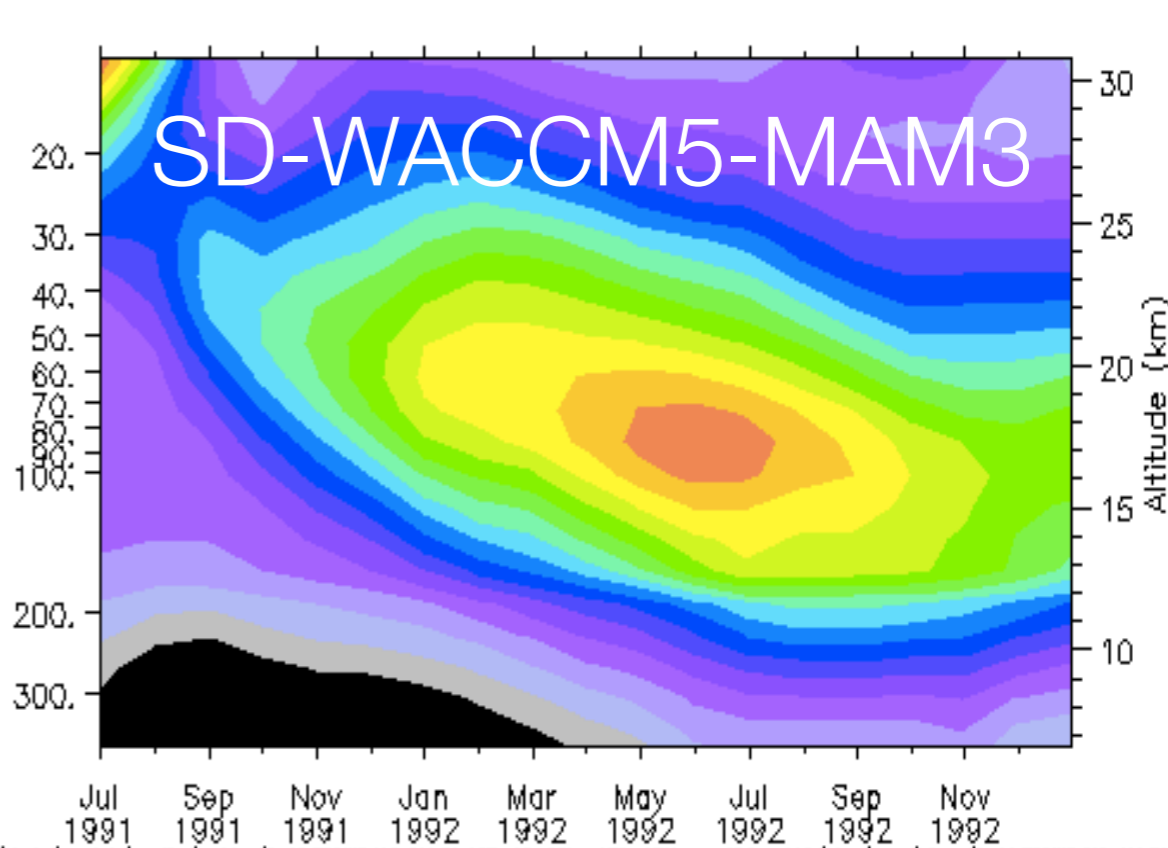
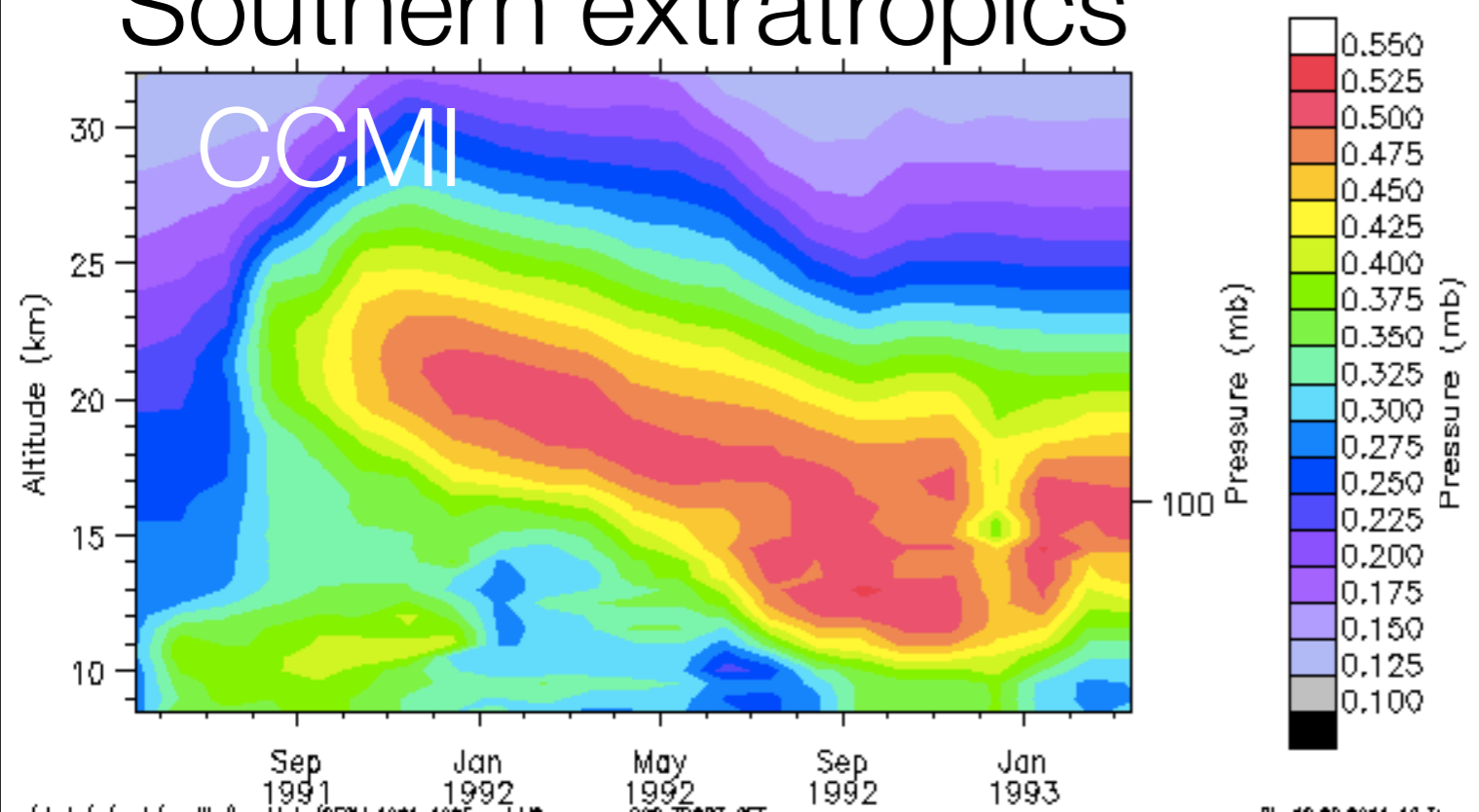


Effective radius (μm)

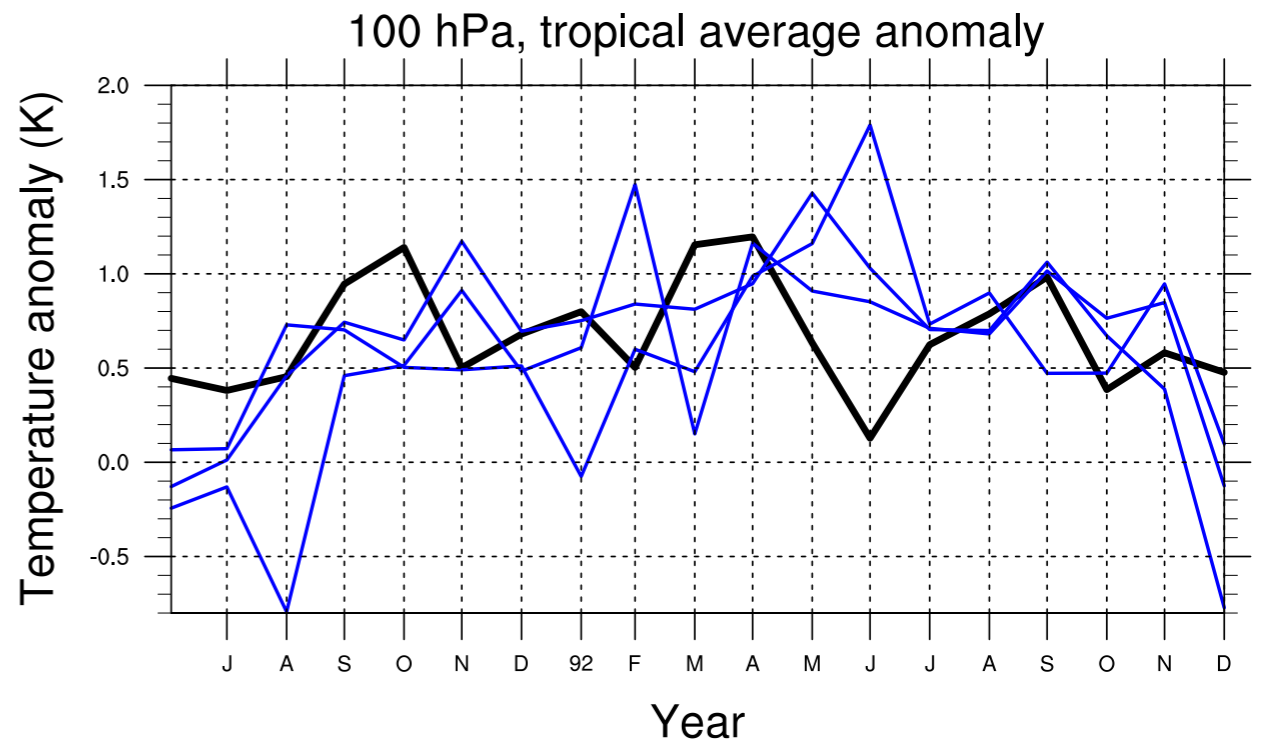
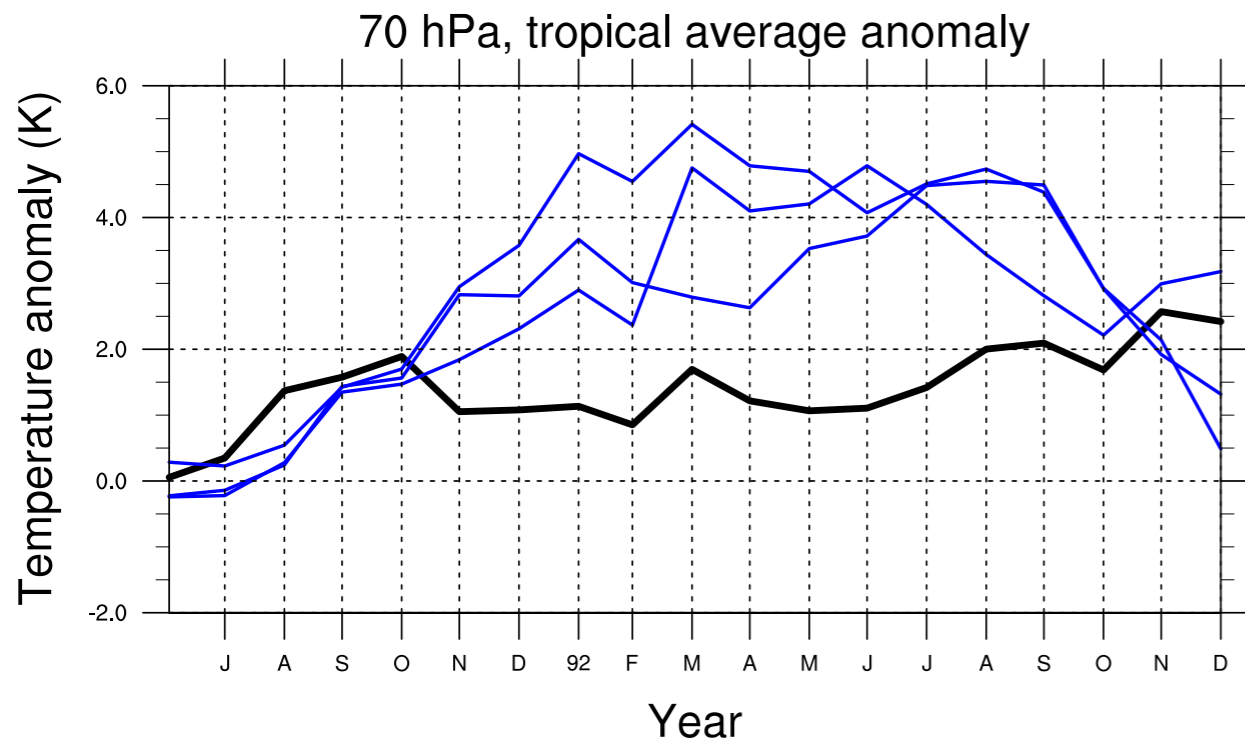
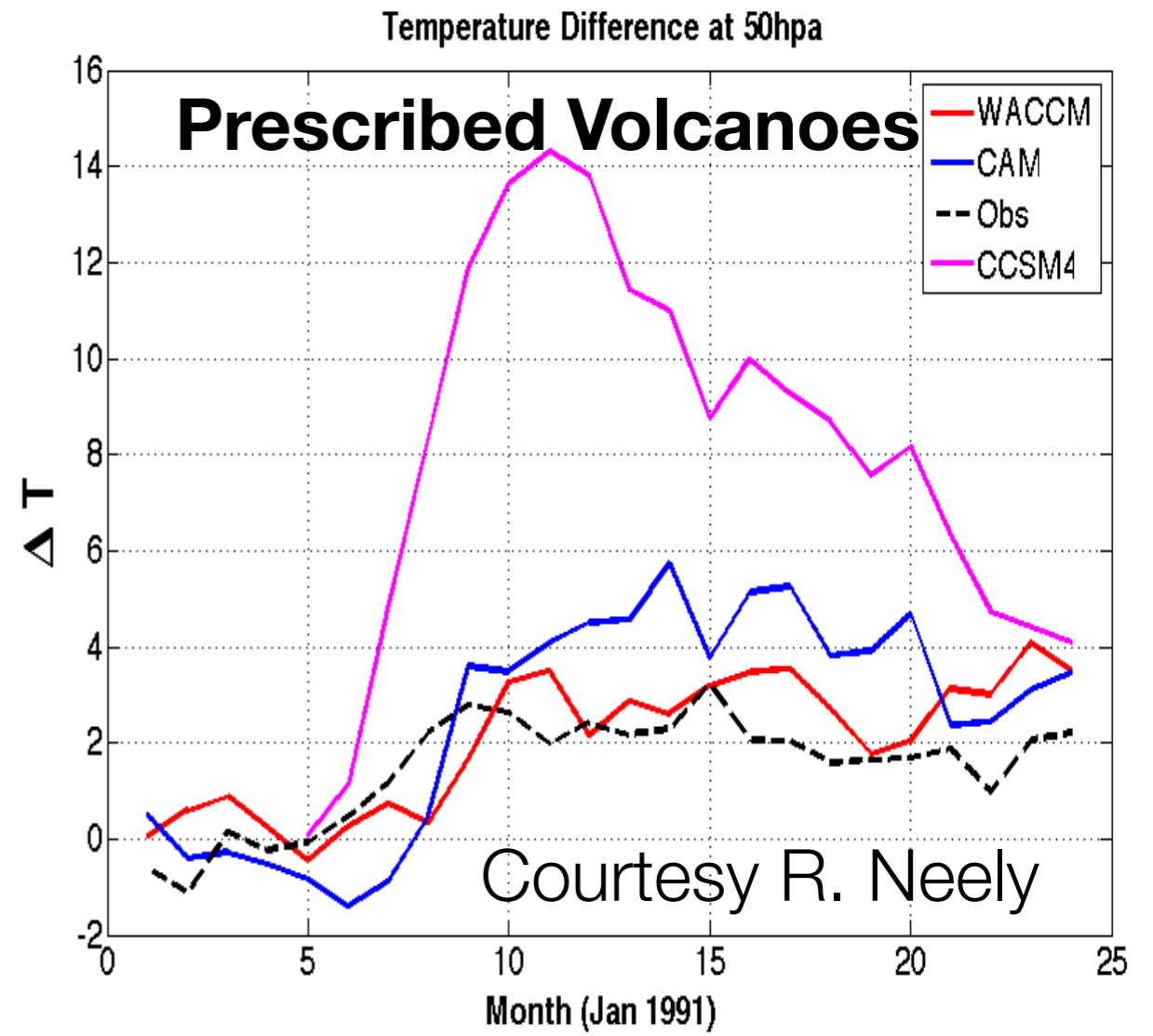
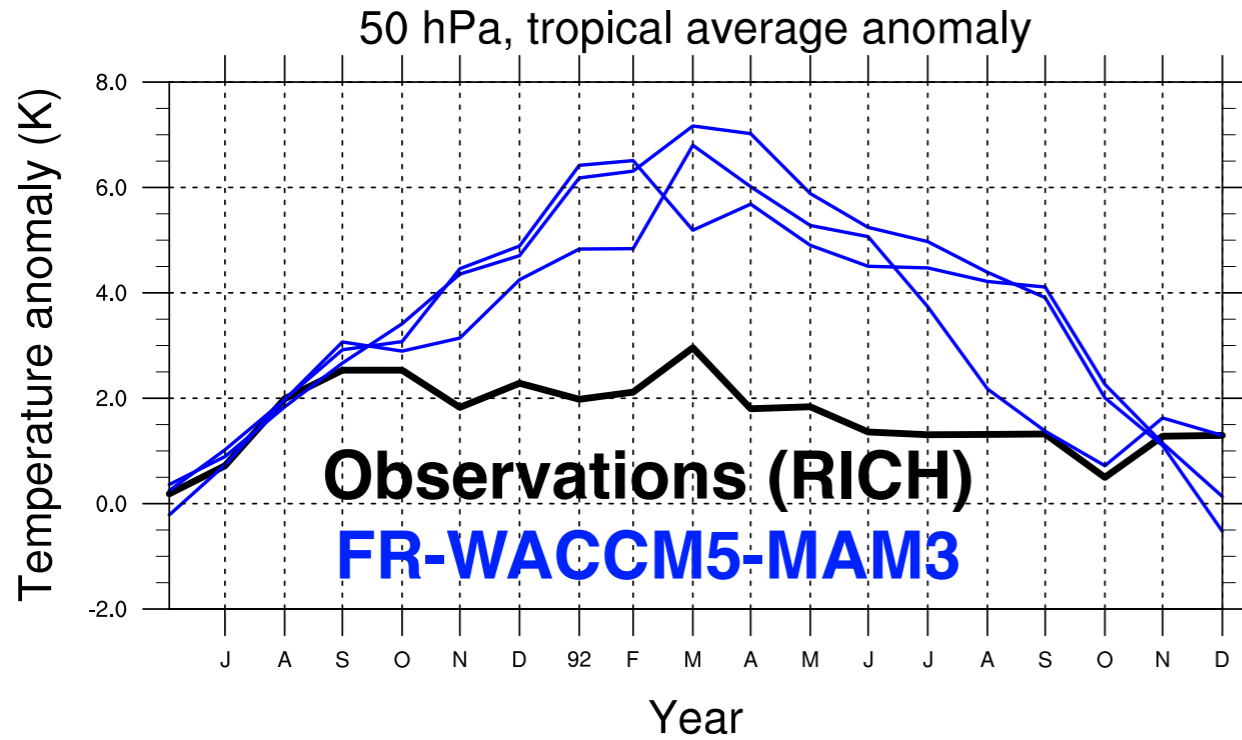
Northern extratropics

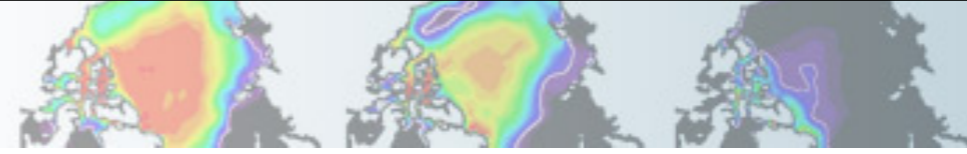


Southern extratropics

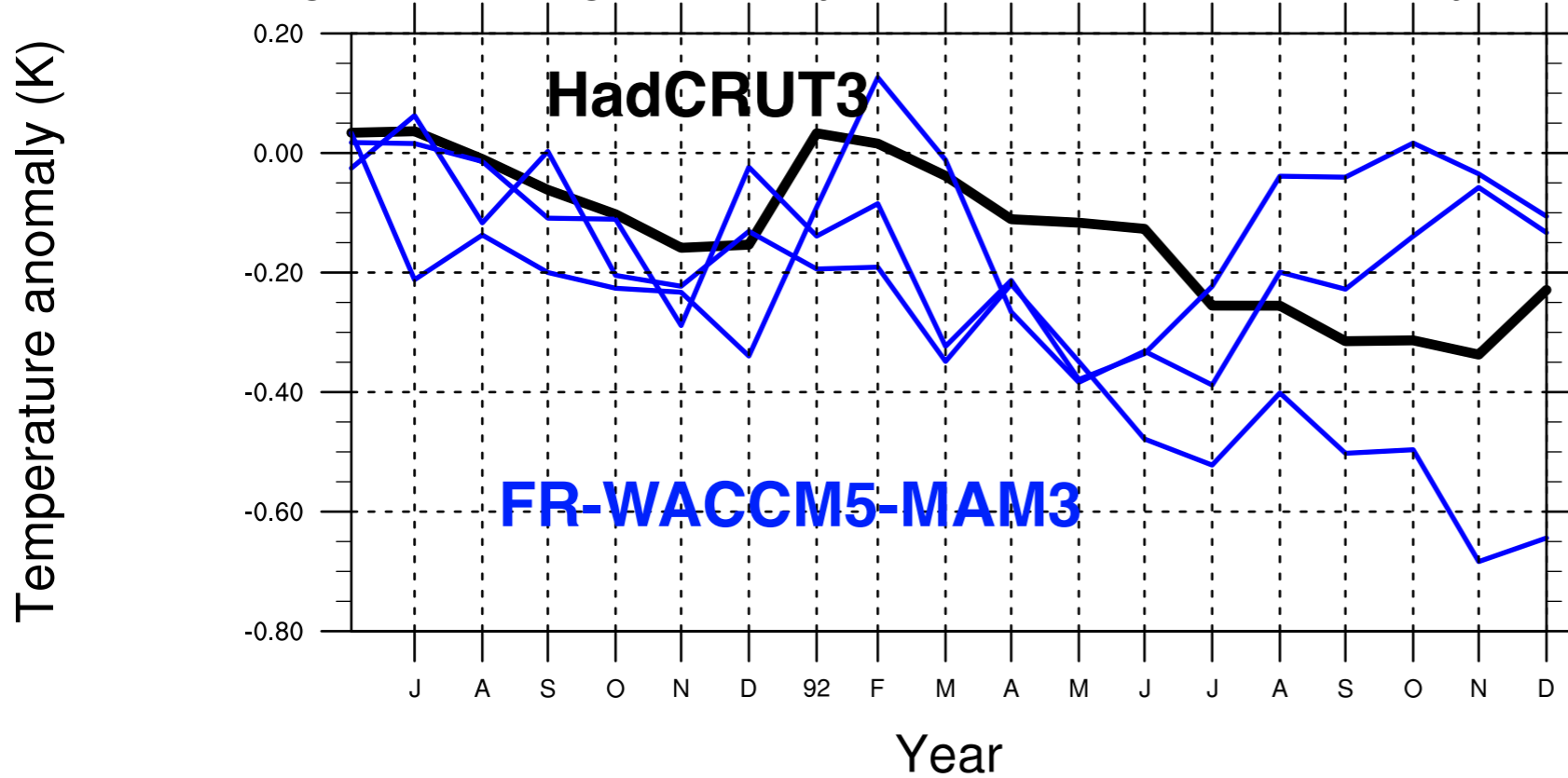


Stratospheric temperature anomalies



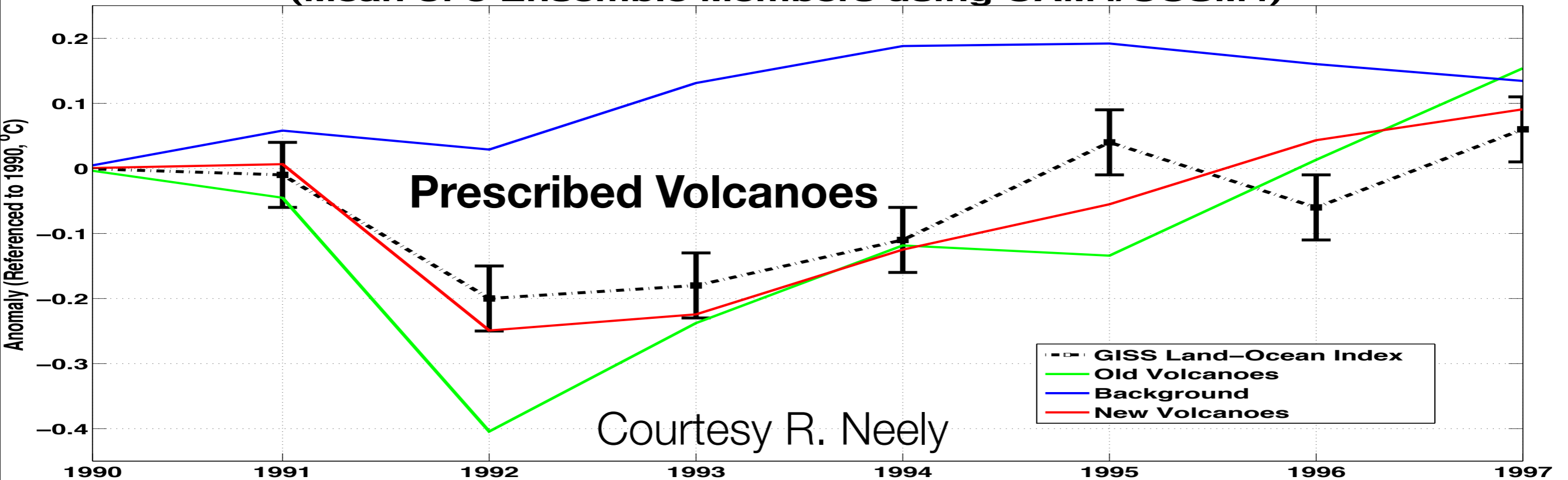


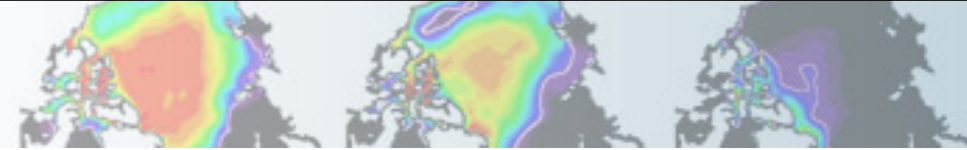
Surface, global average anomaly relative to June 1990 - May 1991 average



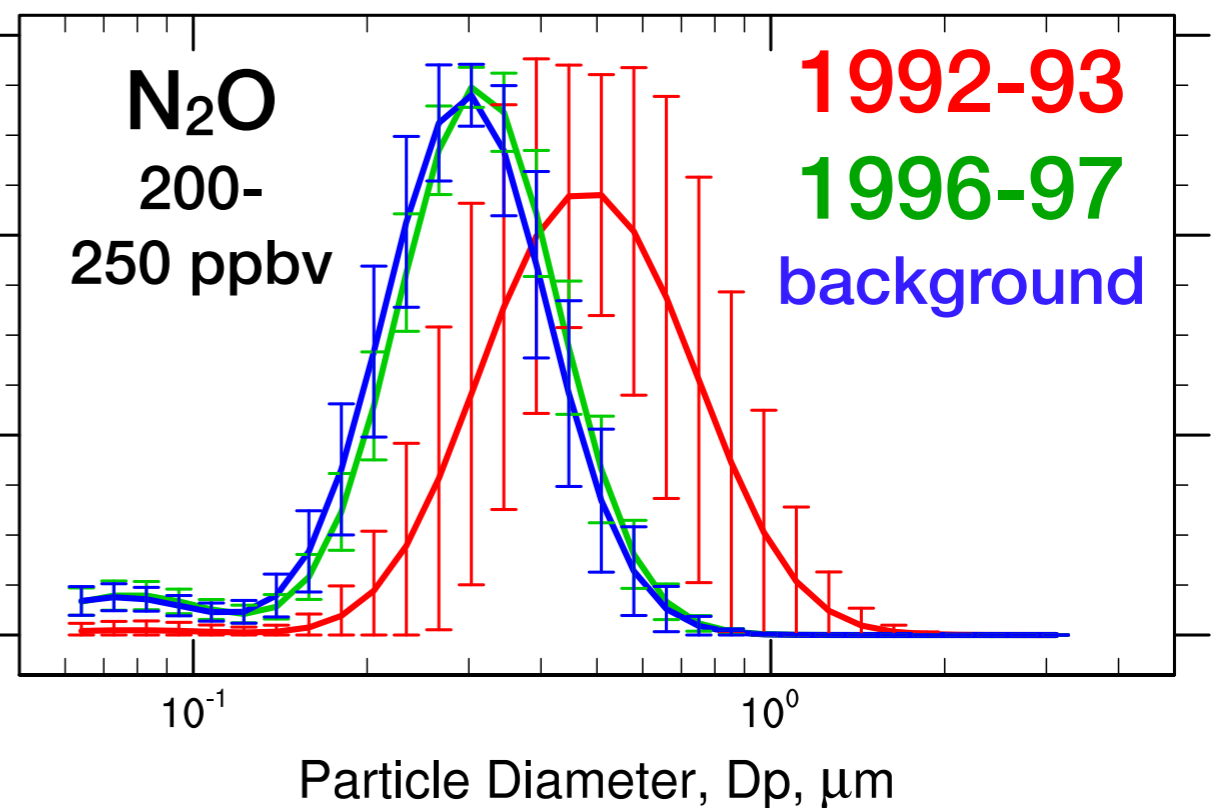
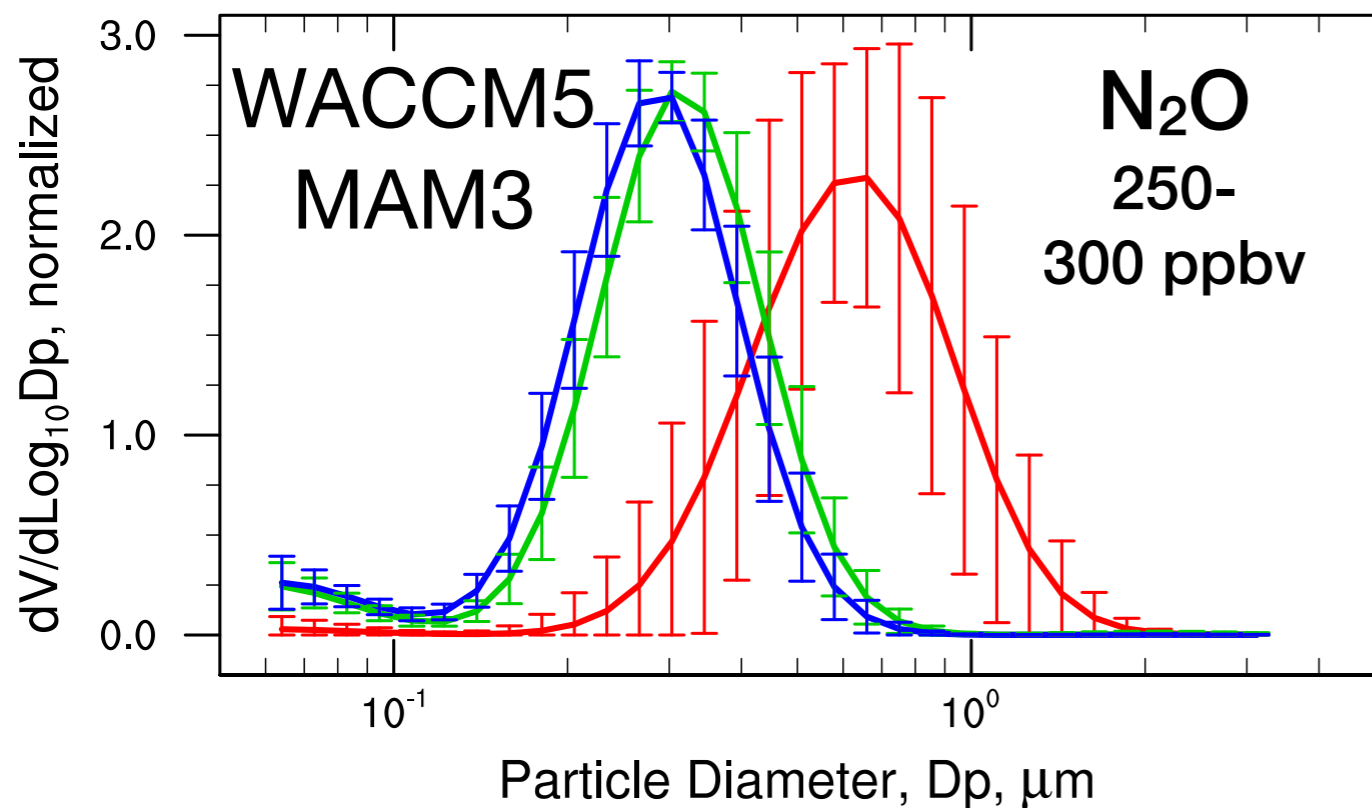
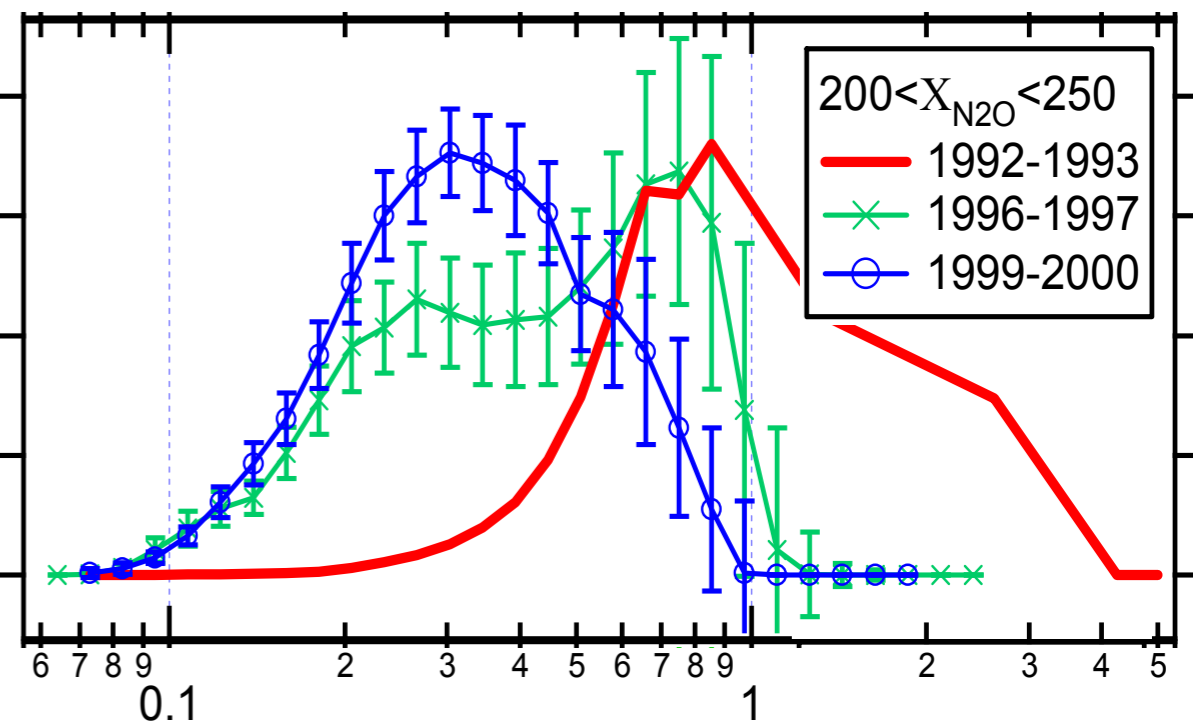
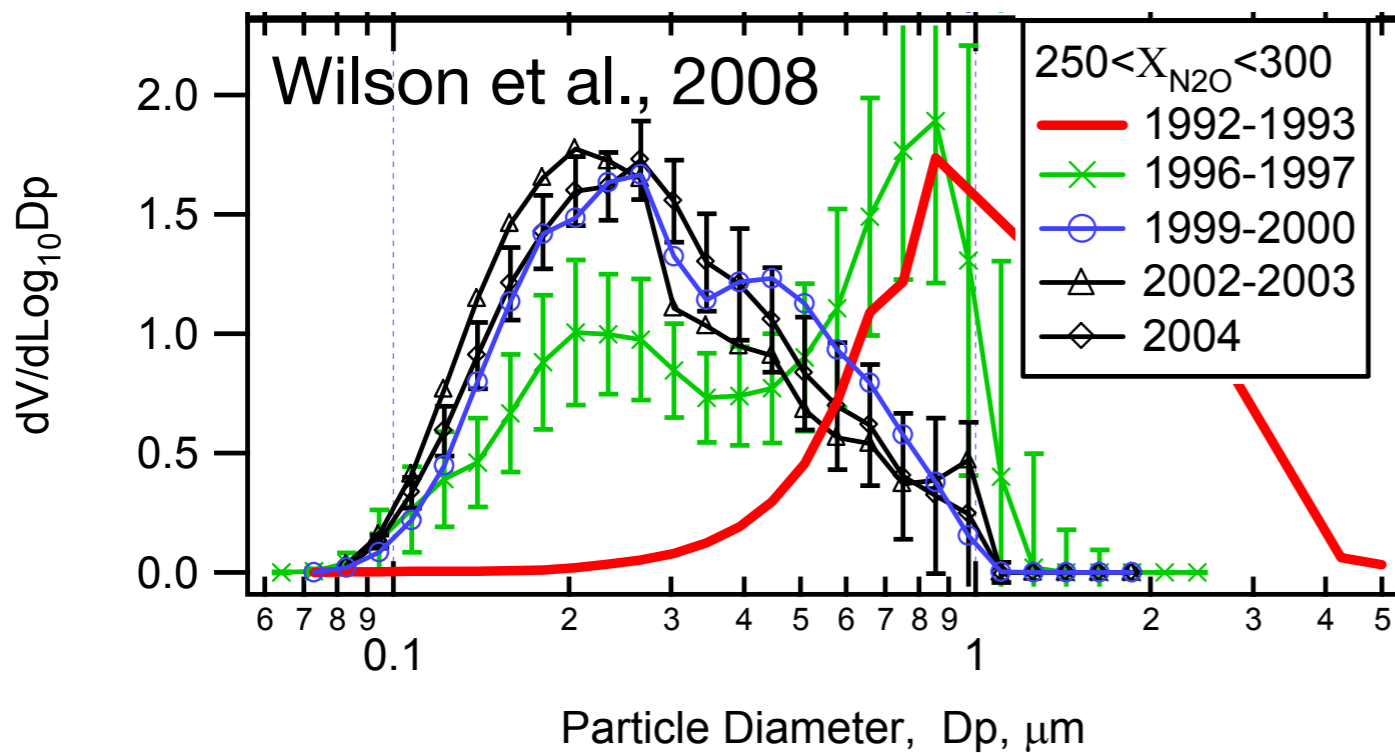
Surface temperature anomalies

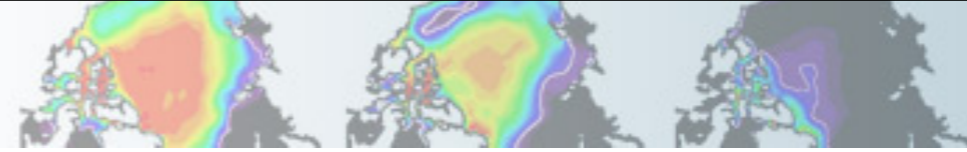
Global Annual Mean Surface Temperature (Mean of 5 Ensemble Members using CAM4/CCSM4)





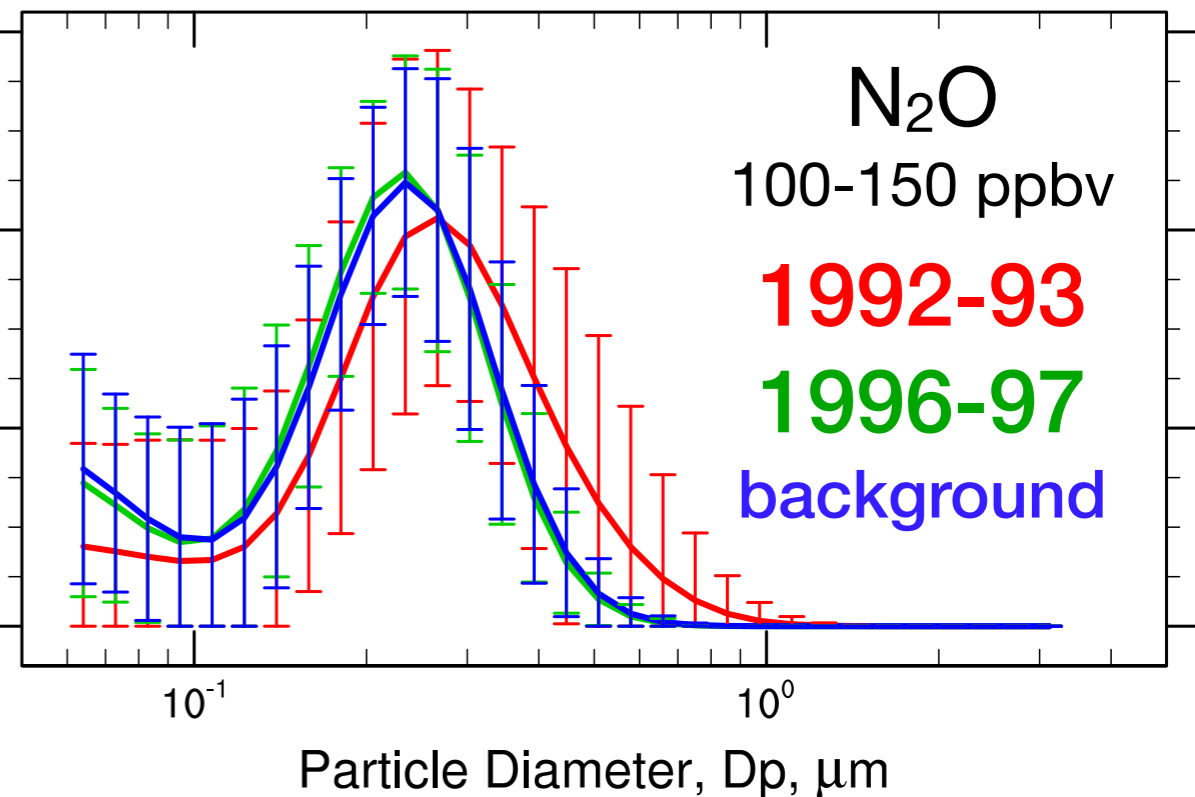
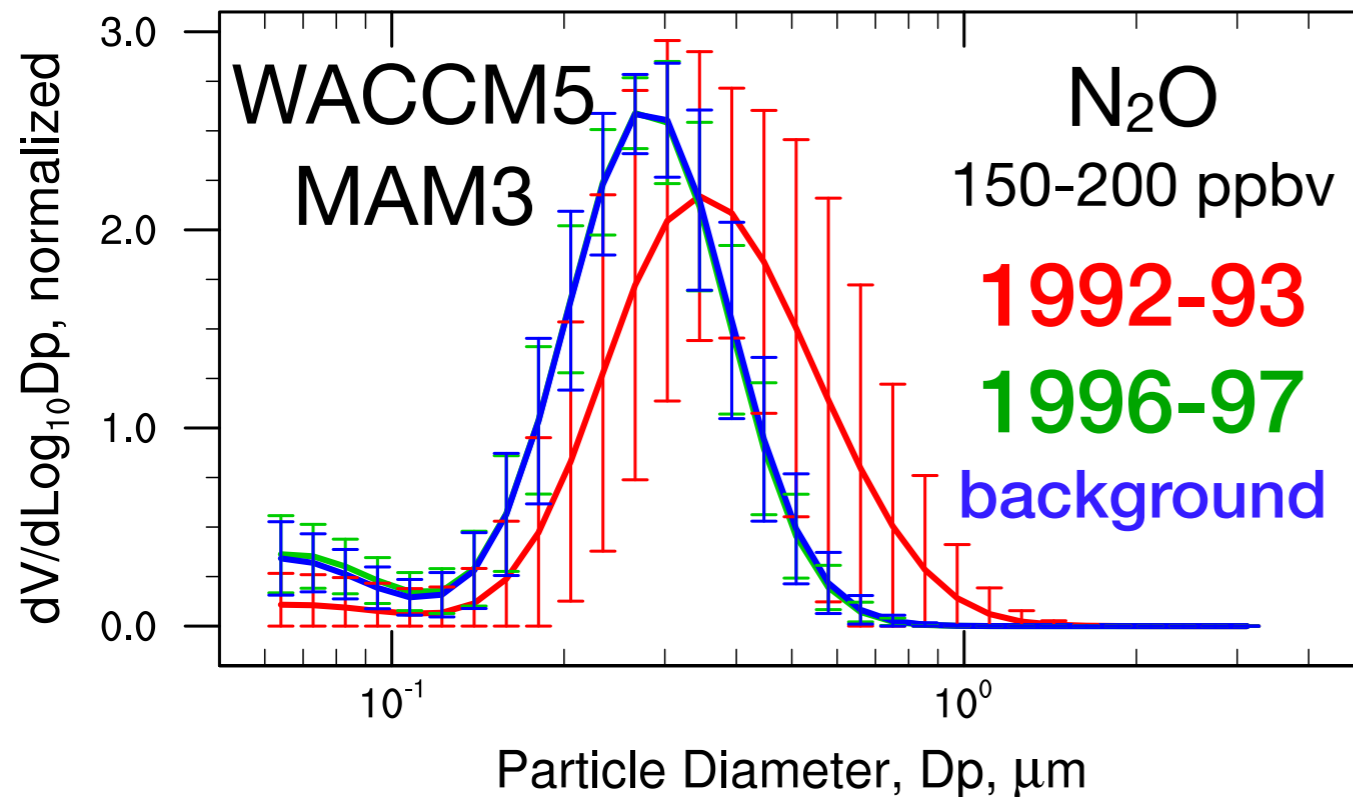
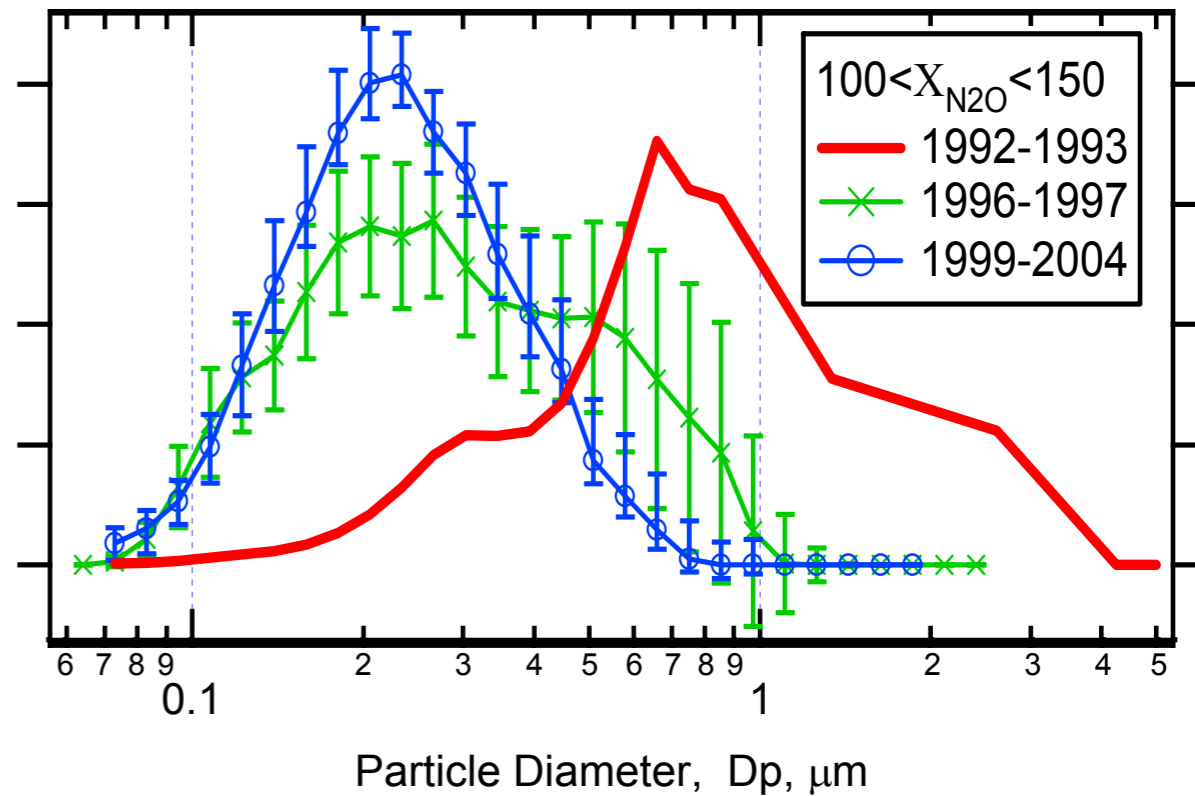
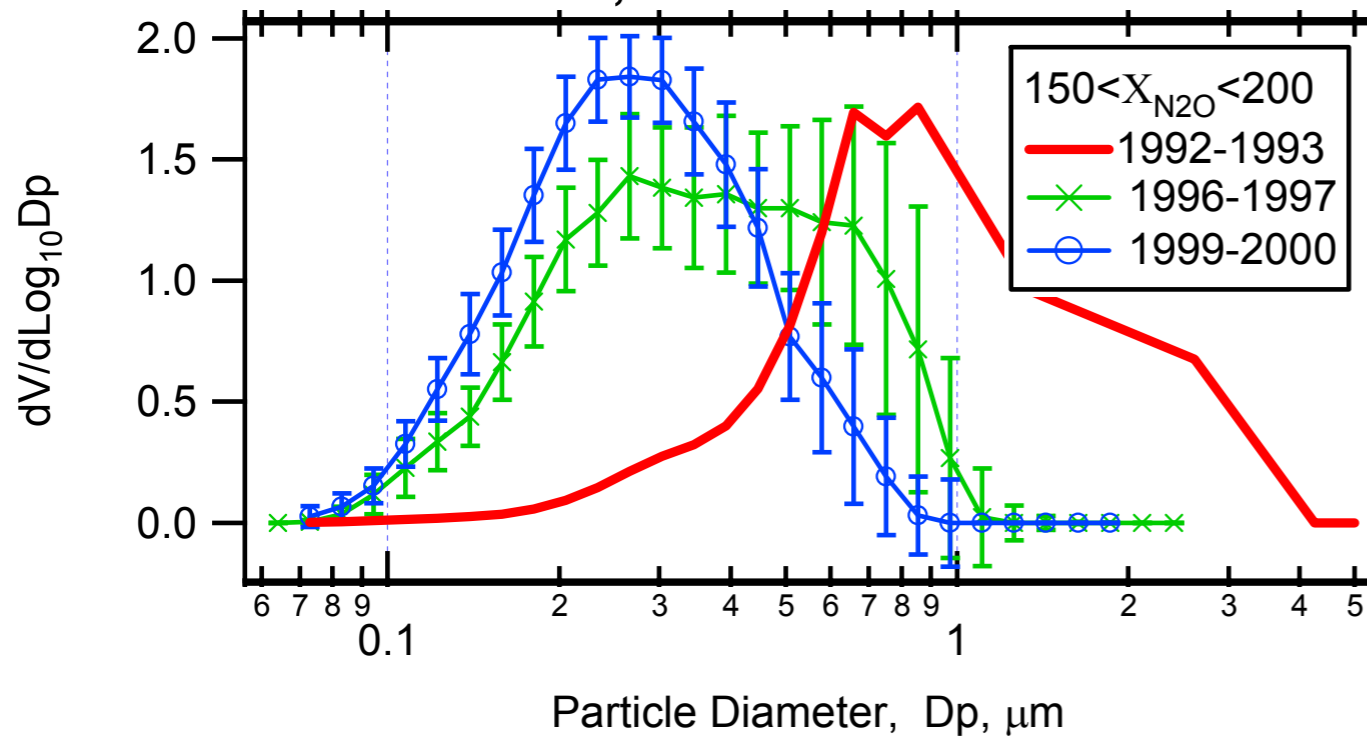
Volume size distributions compared to observations

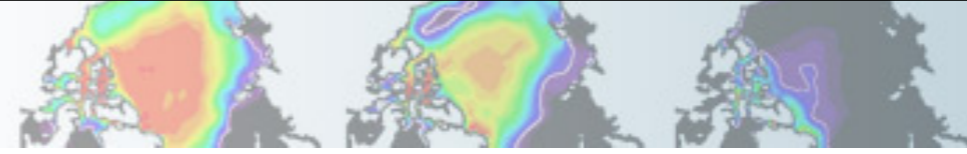




Volume size distributions compared to observations

Wilson et al., 2008

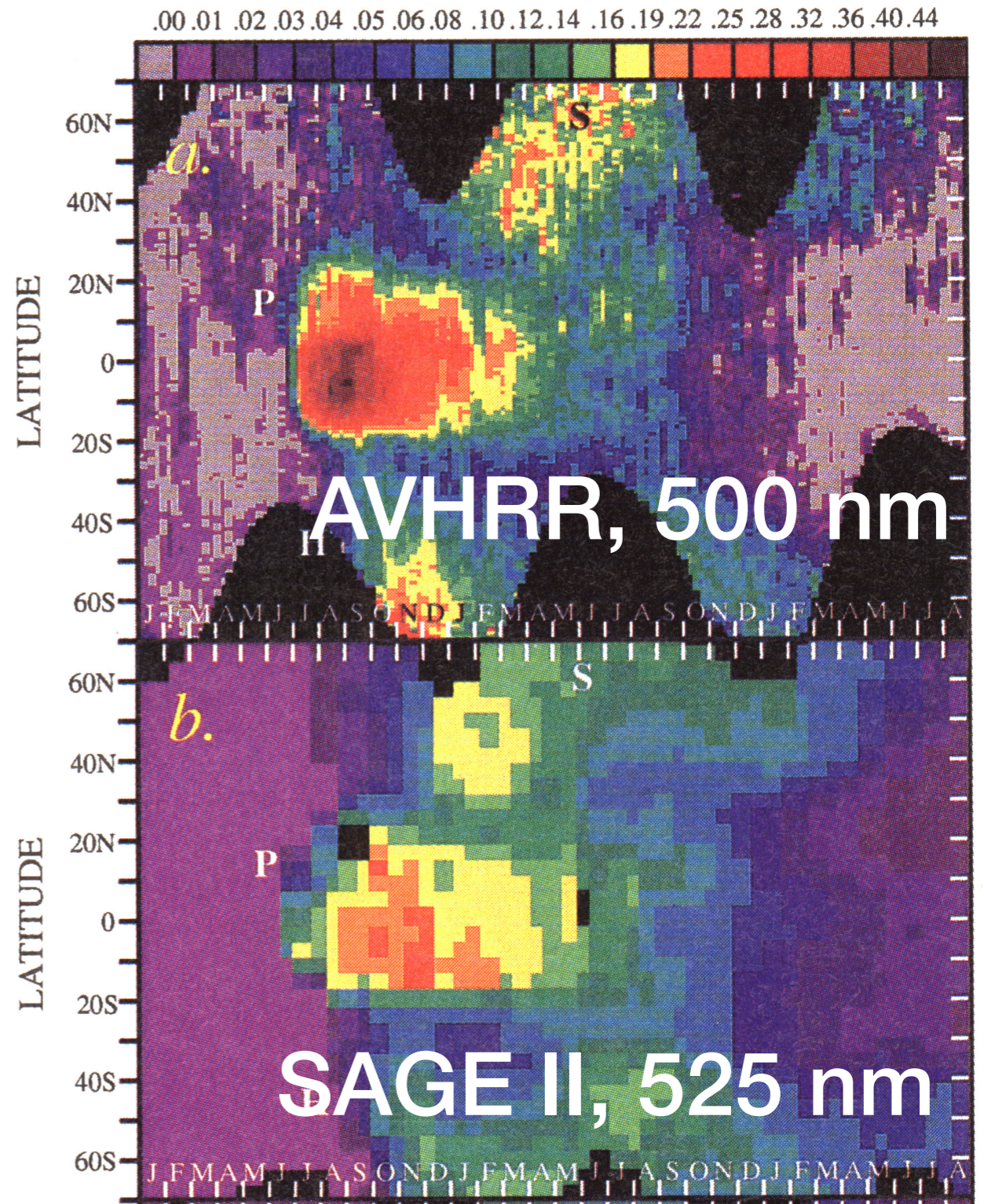
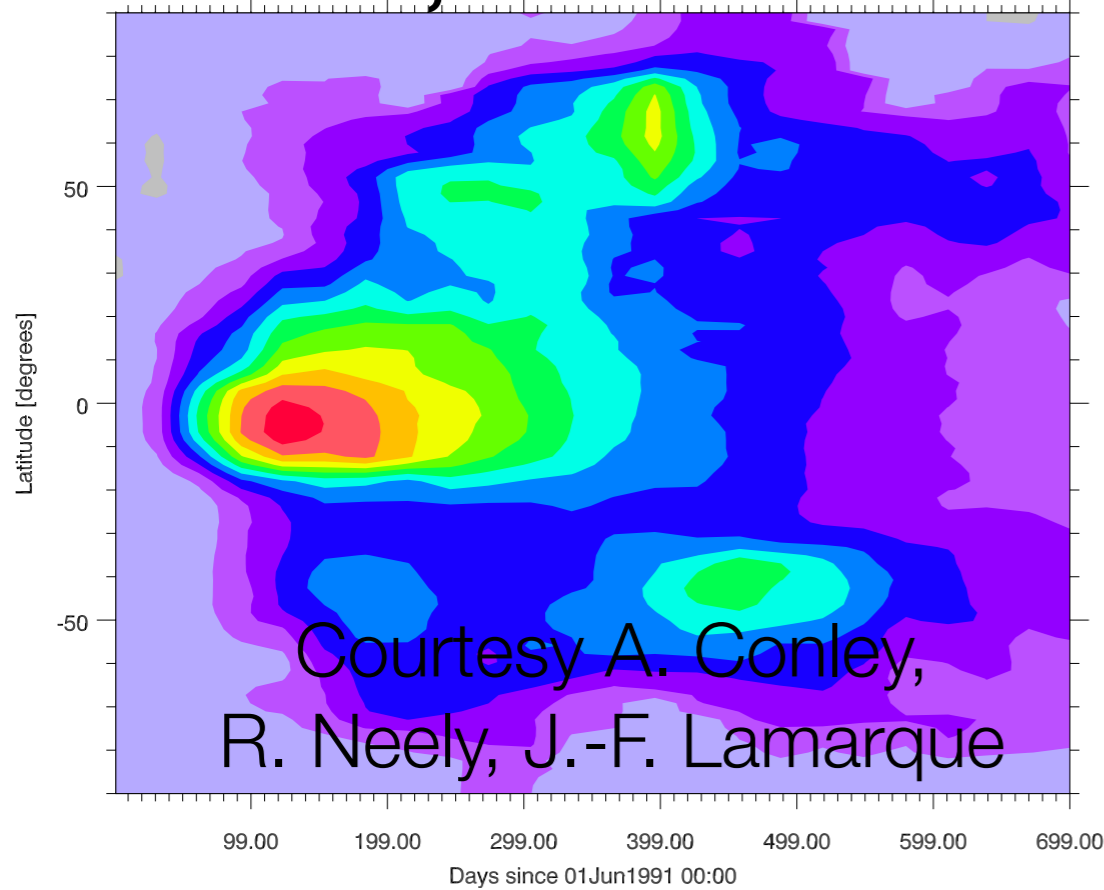




Outstanding issues

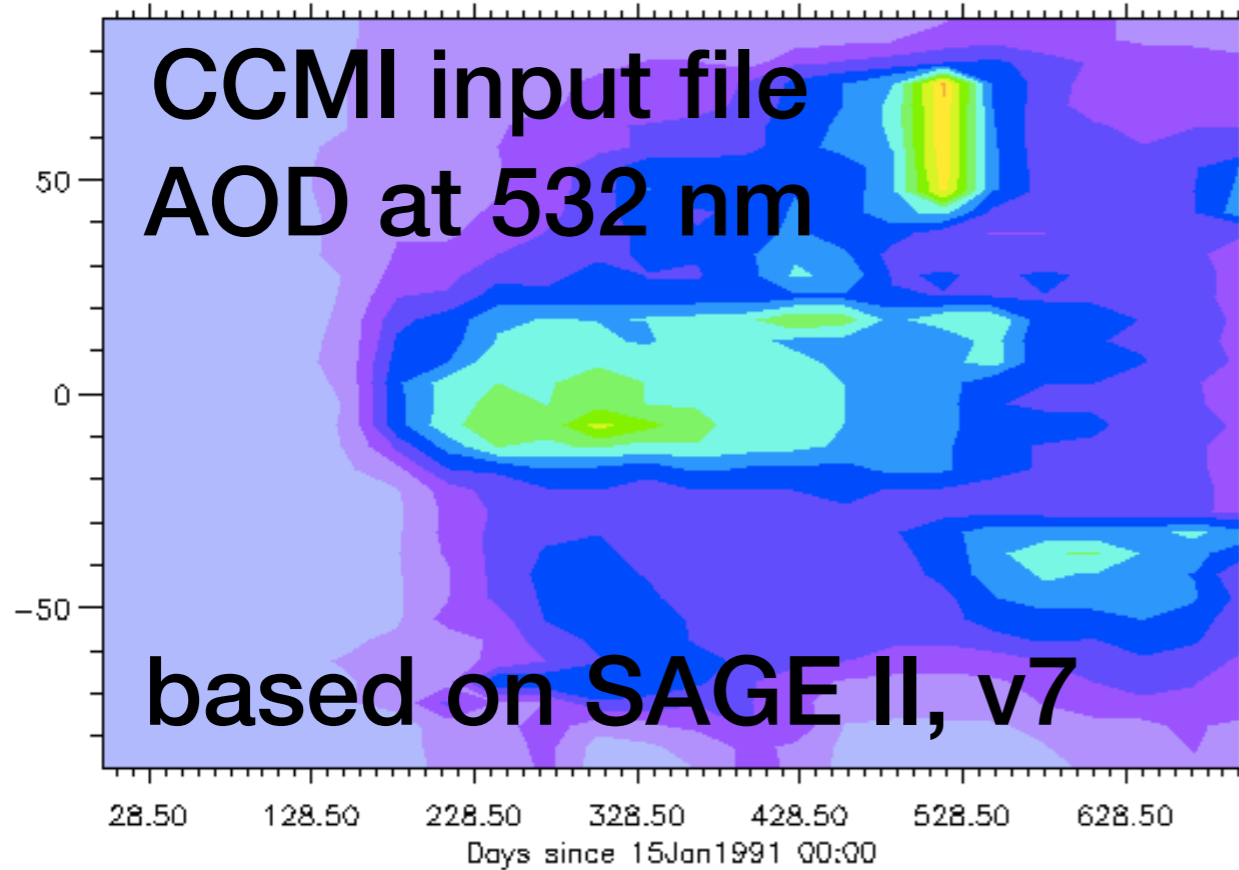
- Investigate slow of growth to coarse mode
- Investigate alternate emission scenarios (zonal mean vs. plume)
- Adjustment of mode widths
- Treatment of sulfate in MAM3 as ammonium sulfate
 - The MAM3 “sulfate” species is ammonium bisulfate, causing ~17% overestimate of stratospheric aerosol mass production from $\text{H}_2\text{SO}_4(\text{g})$ condensation. The code is getting the number of sulfate molecules correct, but when it goes from molecules to mass (and volume) it is 17% high.
 - This does not affect the sulfate weight percent composition, or equilibrium vapor pressures.
 - MAM7 has explicit treatment of $\text{SO}_4=$ and NH_4+ .
- Need for additional modes, i.e. nucleation mode?

CCMI CESM output AOD, visible band

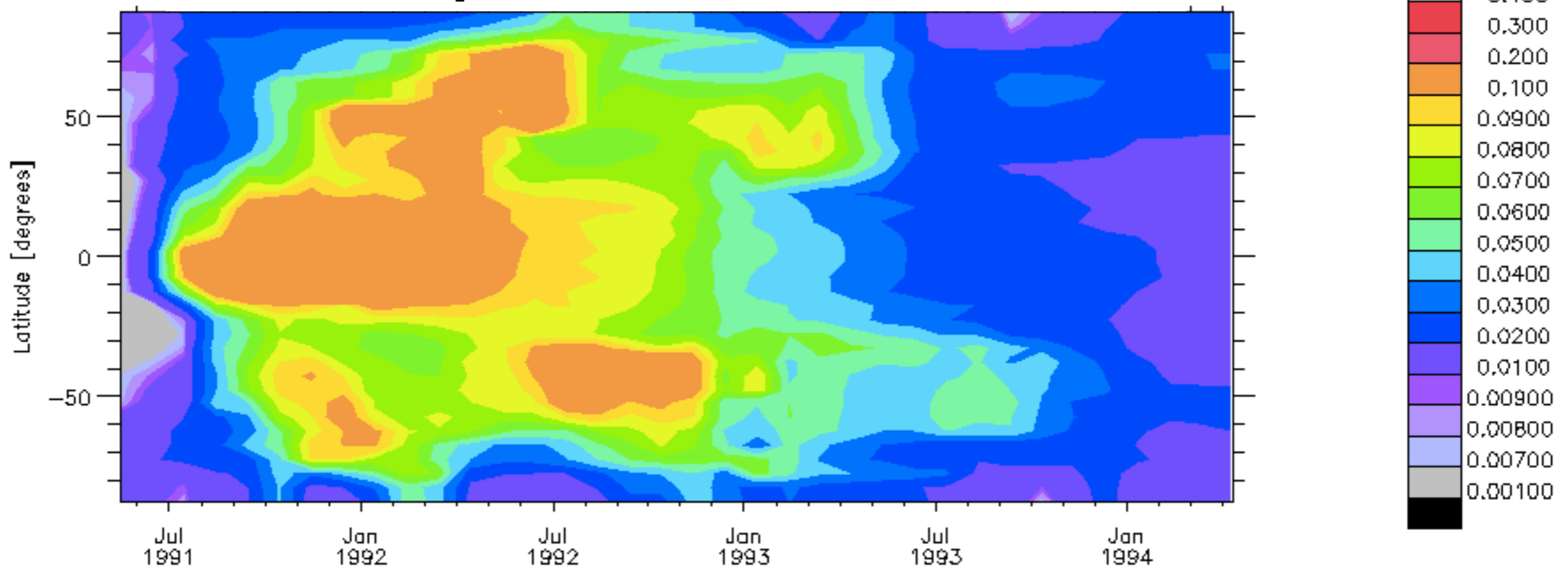


From Russell et al., 1996

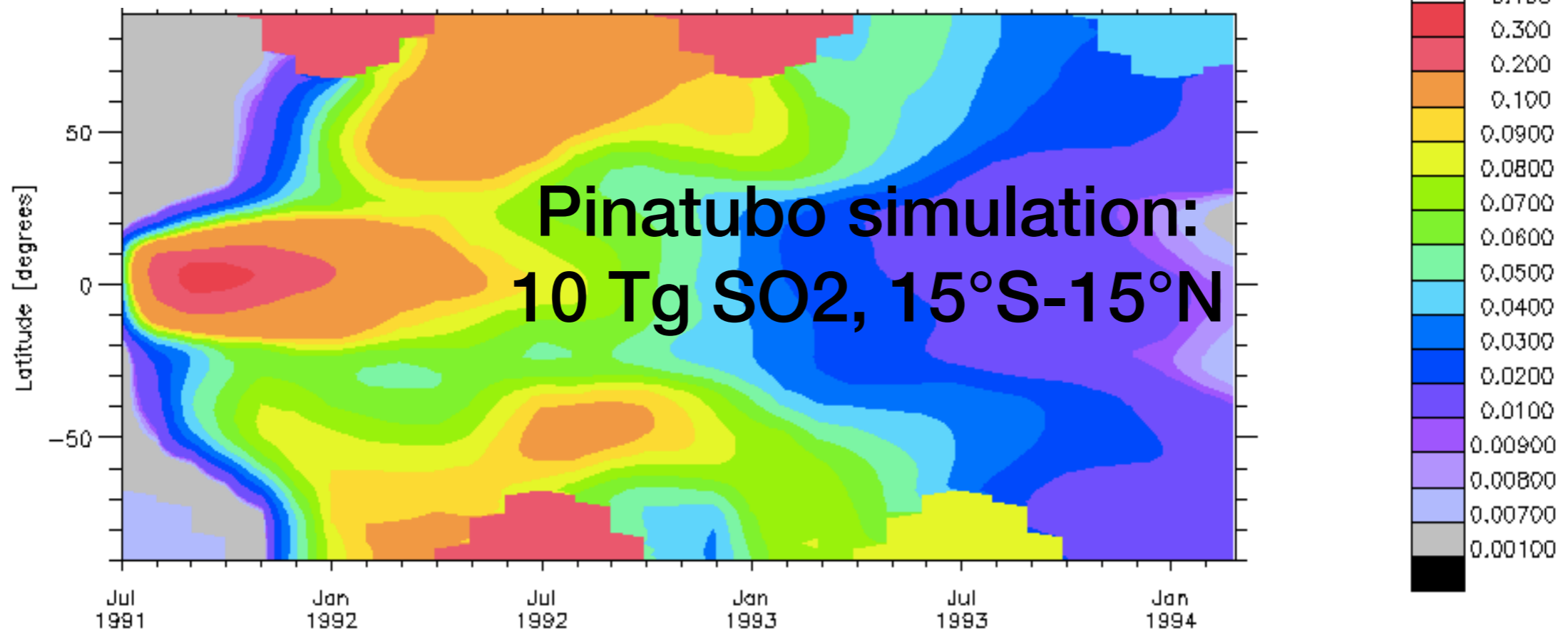
CCMI input file AOD at 532 nm

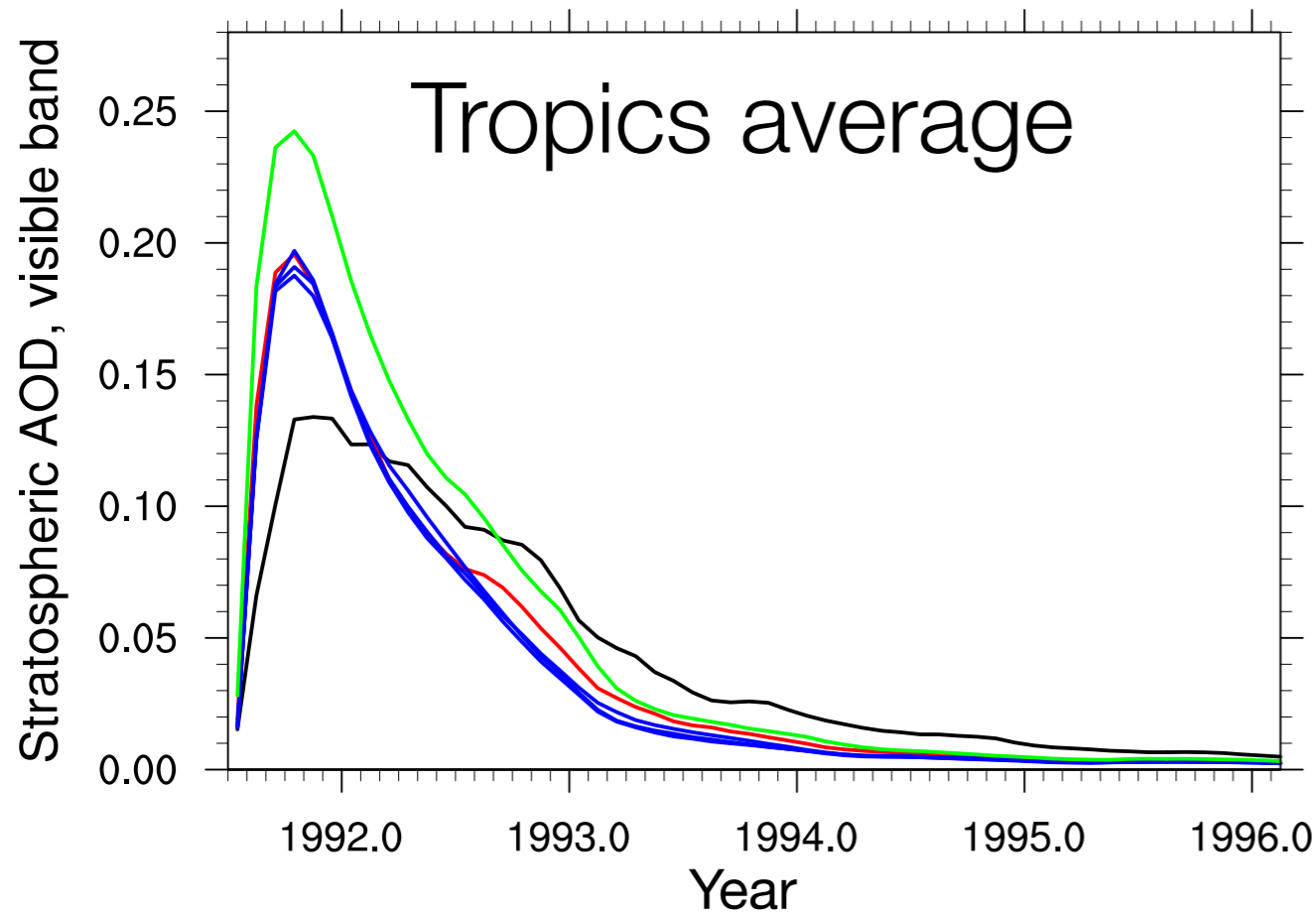
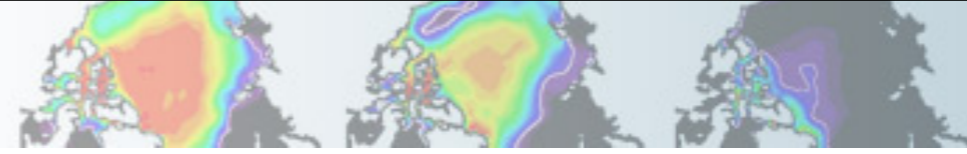


CCMI Input File AOD, 532 nm



SD-WACCM5-MAM3 AOD, visible





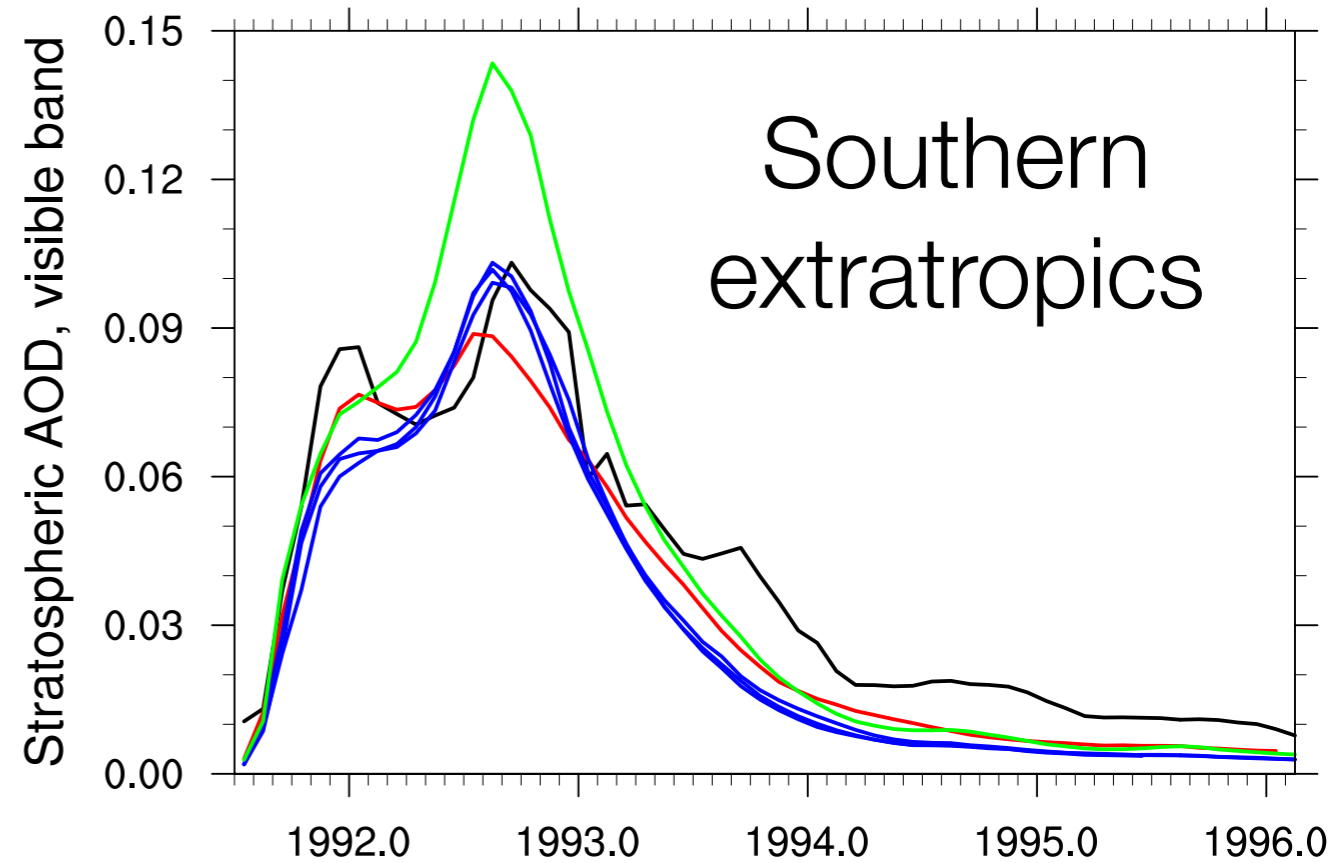
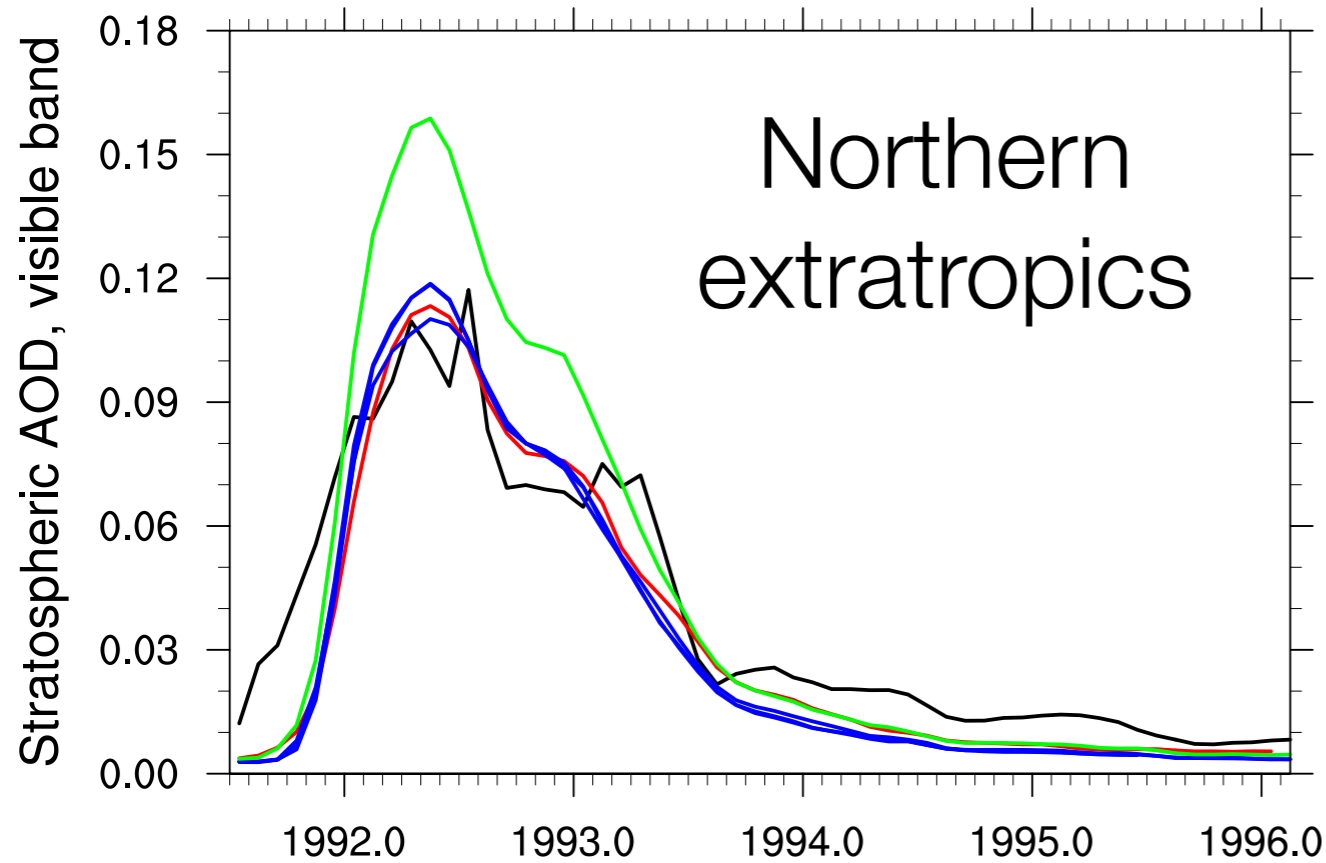
Pinatubo simulation: 10 Tg SO₂, 15°S-15°N

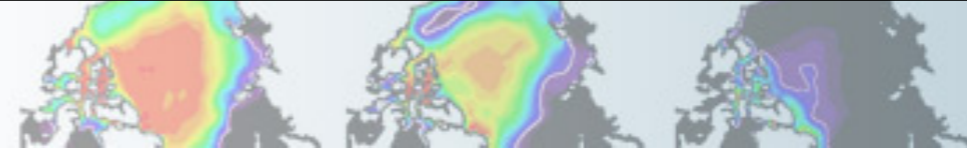
CCMI input file

SD-WACCM5-MAM3

FR-WACCM5-MAM3

FR, wet radius





Volume size distributions compared to observations

