

# Toward a prognostic representation of stratospheric sulfate aerosol in CESM

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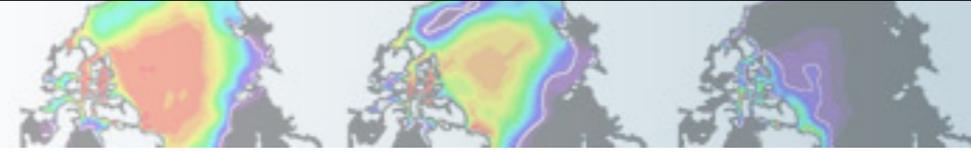
Michael Mills, NCAR  
Dan Marsh, NCAR  
Ryan Neely, NCAR

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



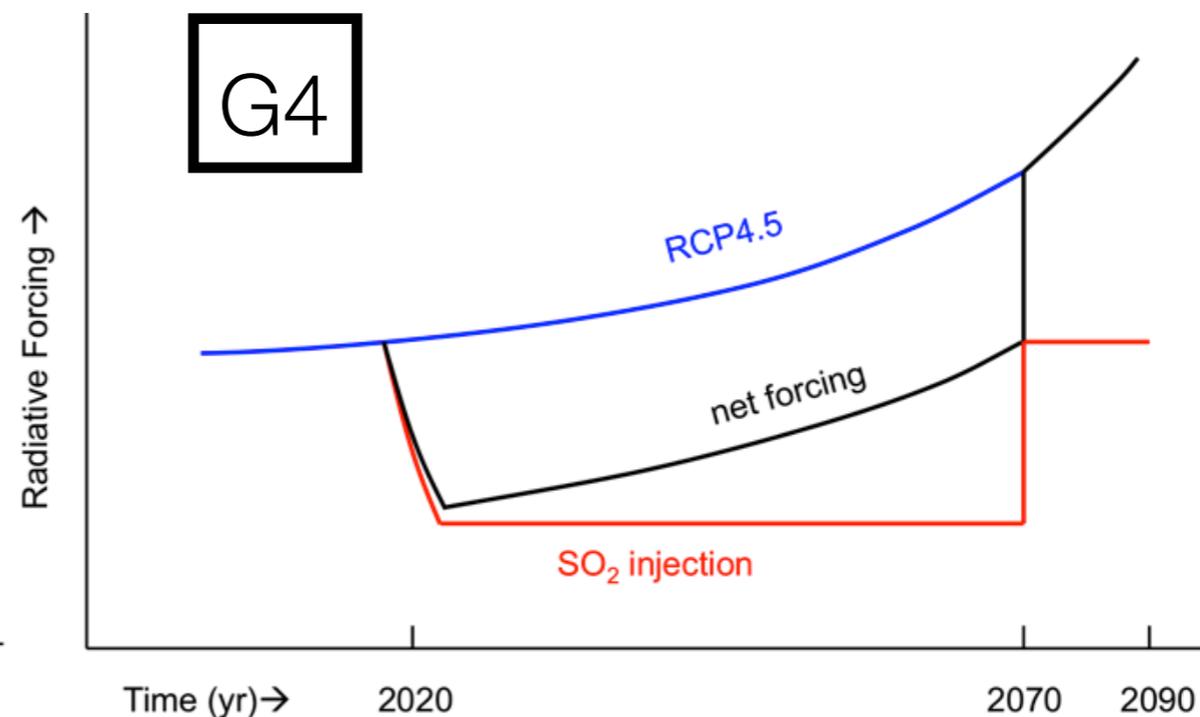
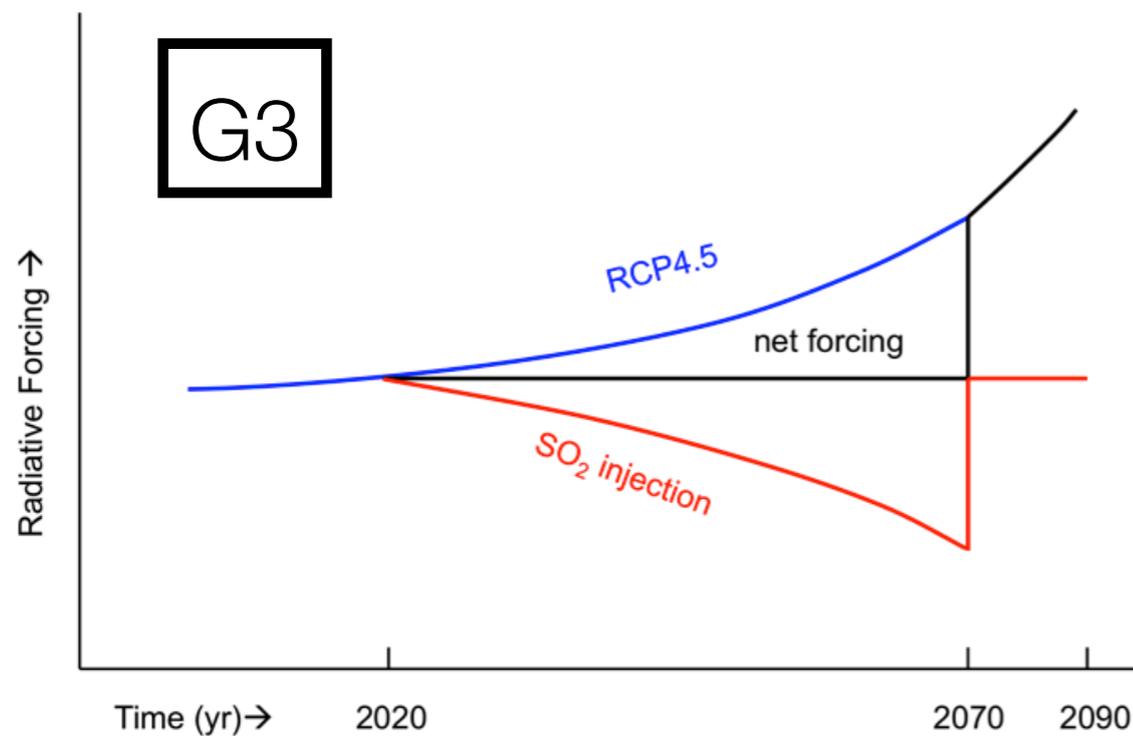
NCAR is funded by the National Science Foundation



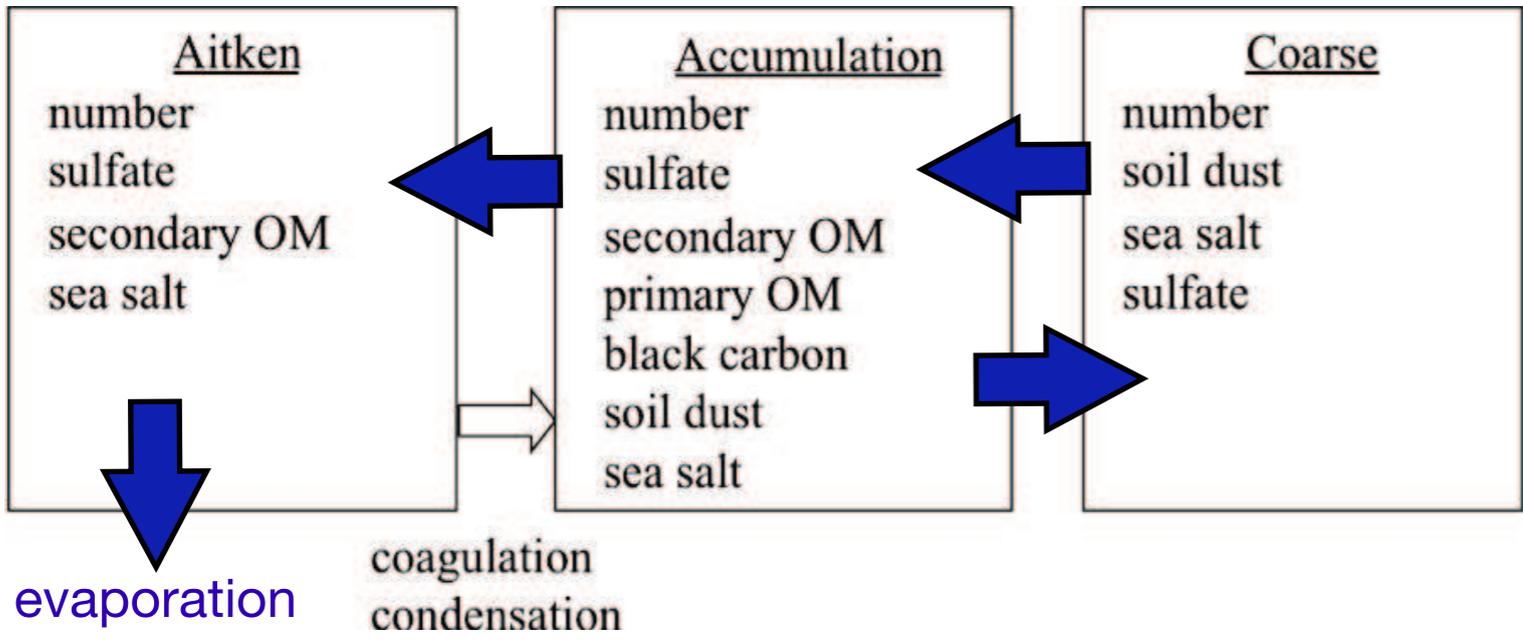


# Motivation for emission-based volcanoes in CESM

- 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”



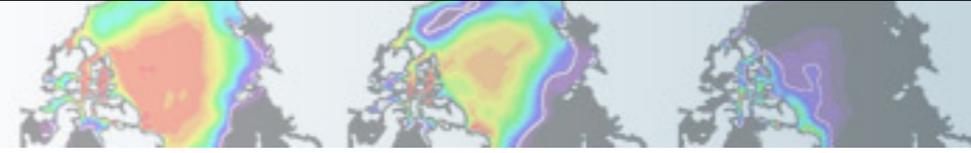
# MAM3 for stratospheric aerosols



Gas-phase species: H<sub>2</sub>SO<sub>4</sub>, SO<sub>2</sub>, DMS, SOA (gas)  
 Added: OCS, S, SO, SO<sub>3</sub>, HSO<sub>3</sub>  
 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

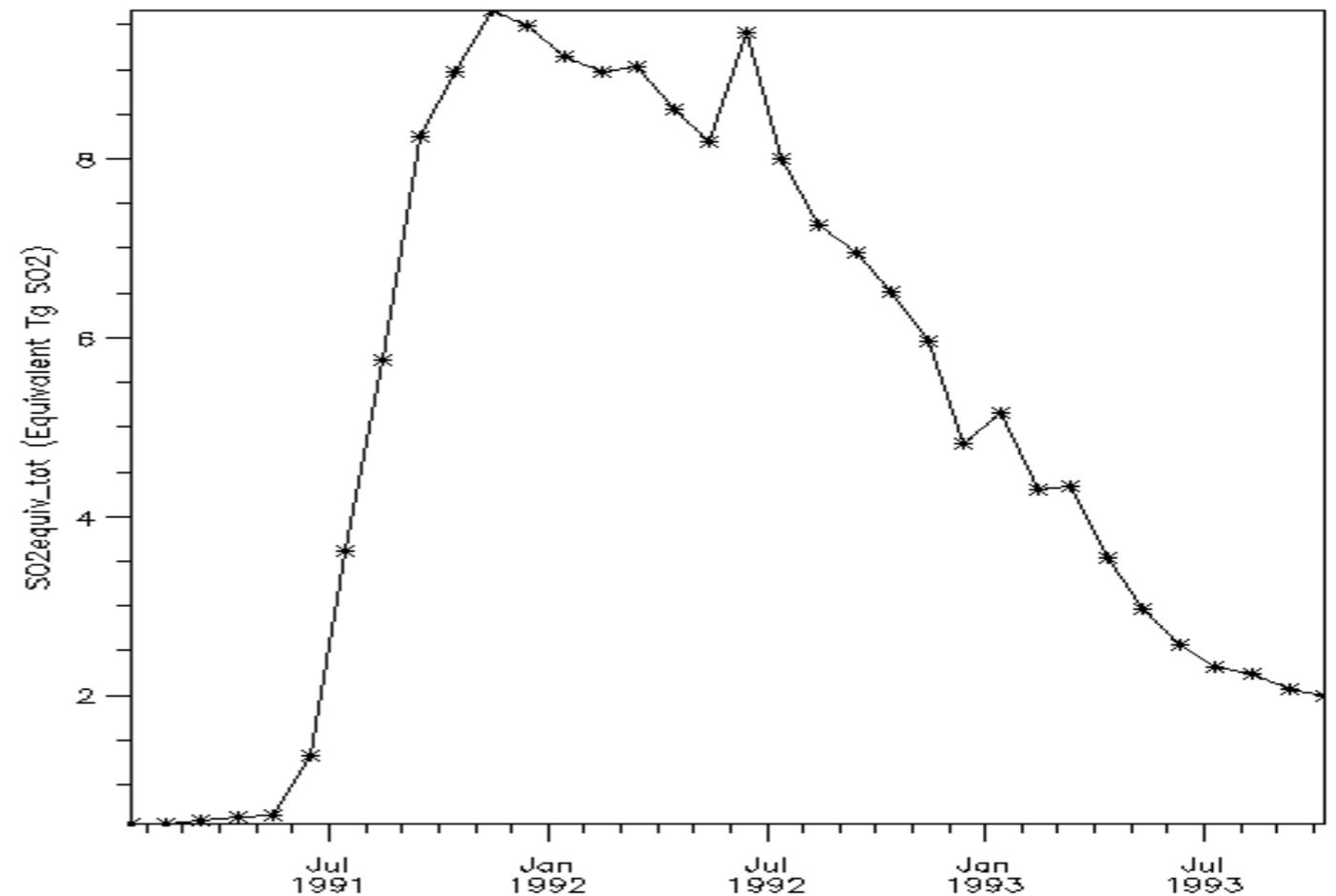
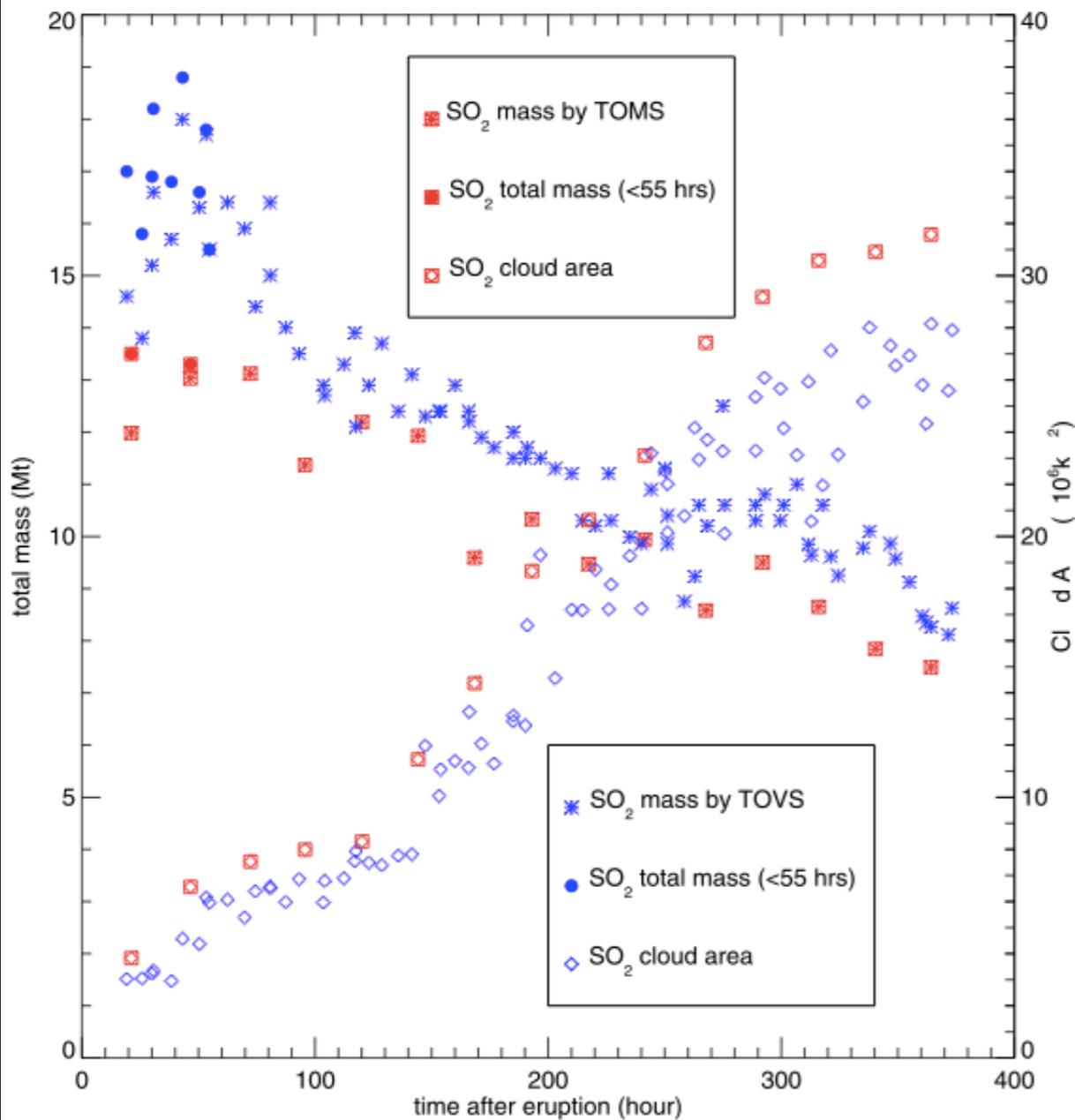


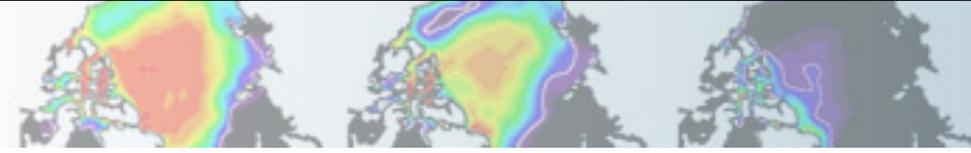
# Pinatubo simulation: How much SO<sub>2</sub>?

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

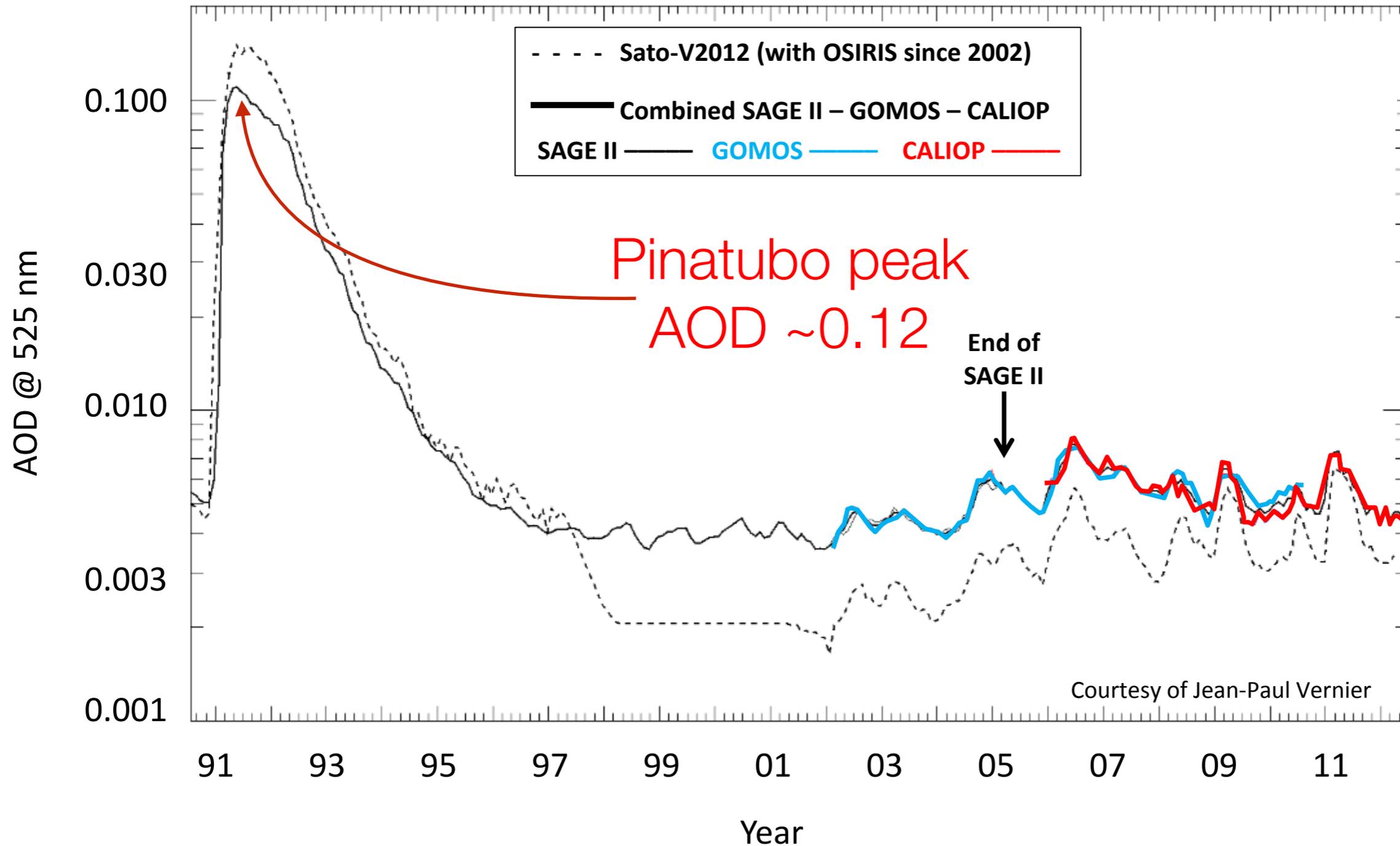




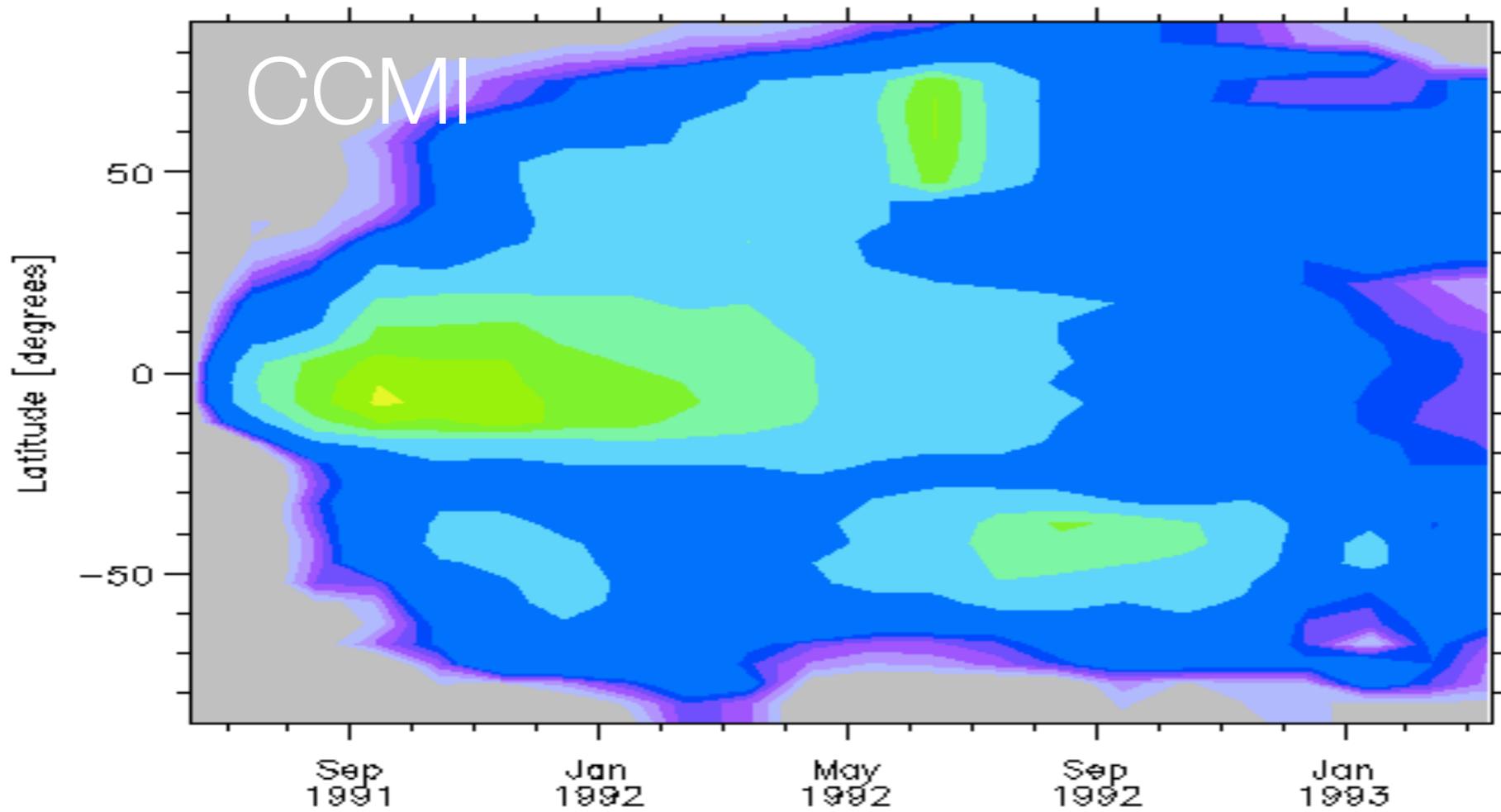
# New long term record of stratospheric aerosol properties

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

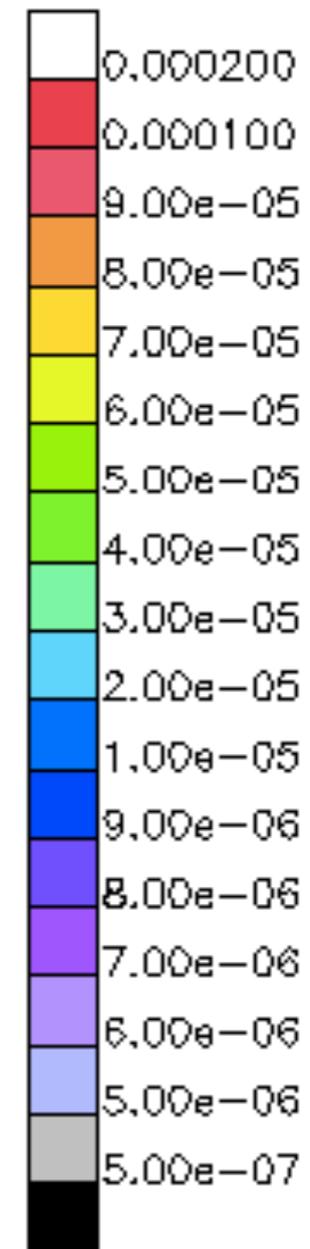
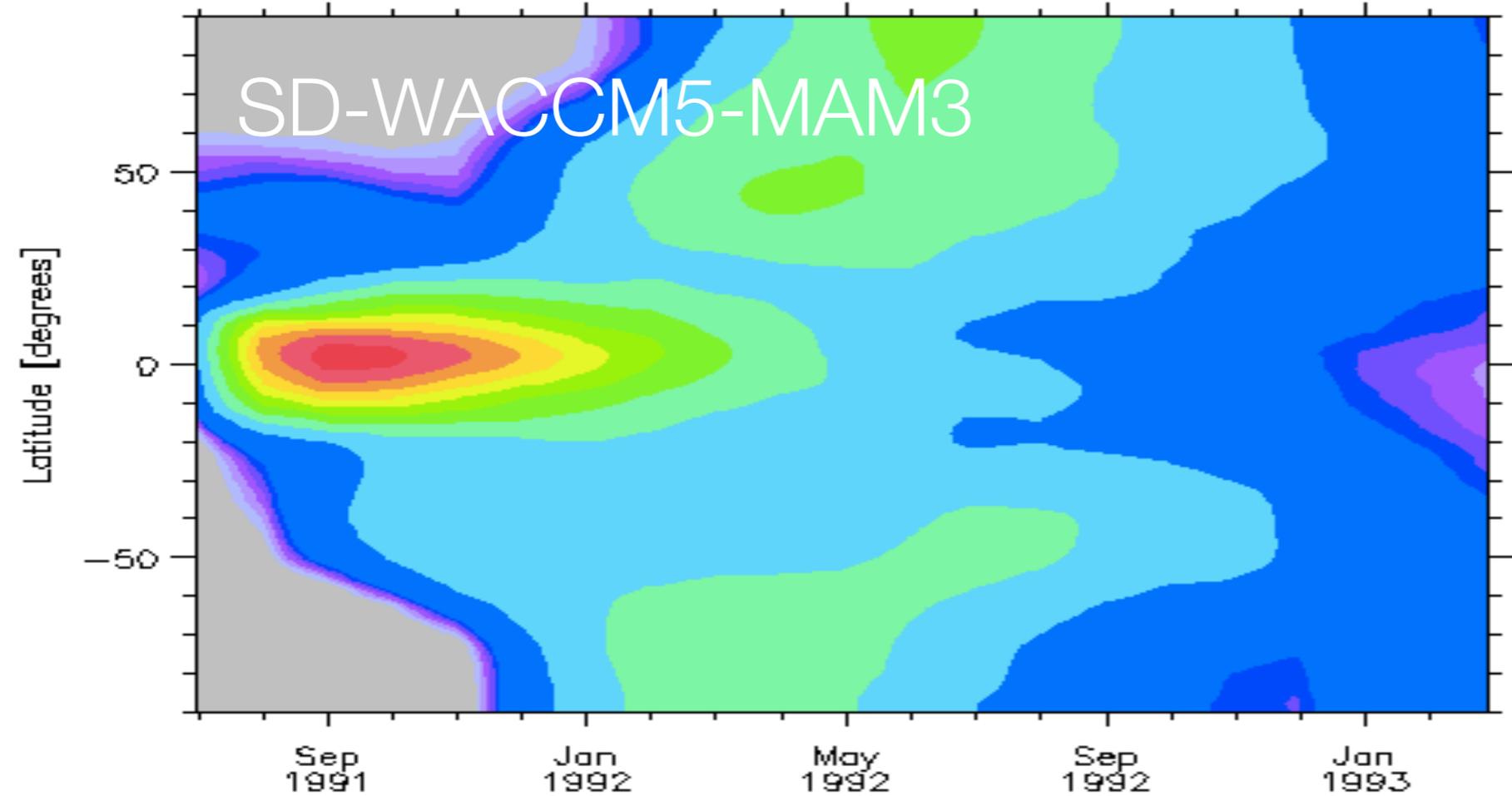
## AOD 15-35 km 50°N-50°S



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

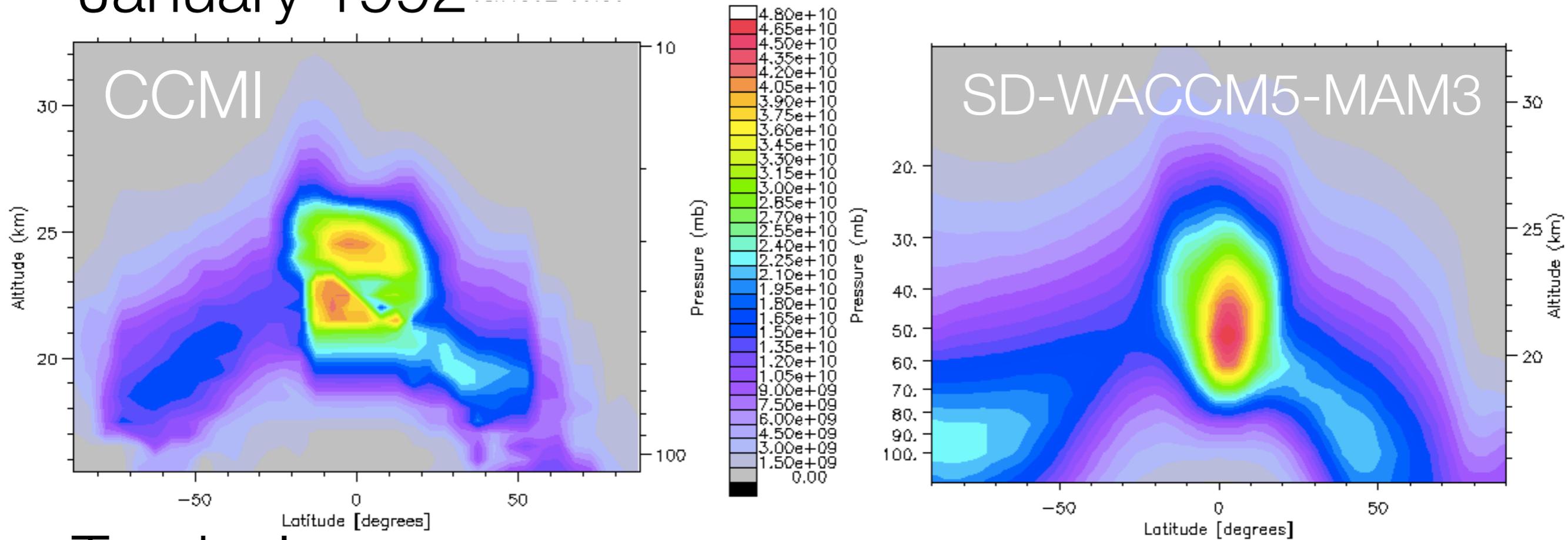


Stratospheric  
sulfate  
column  
( $\text{kg}/\text{m}^2$ )

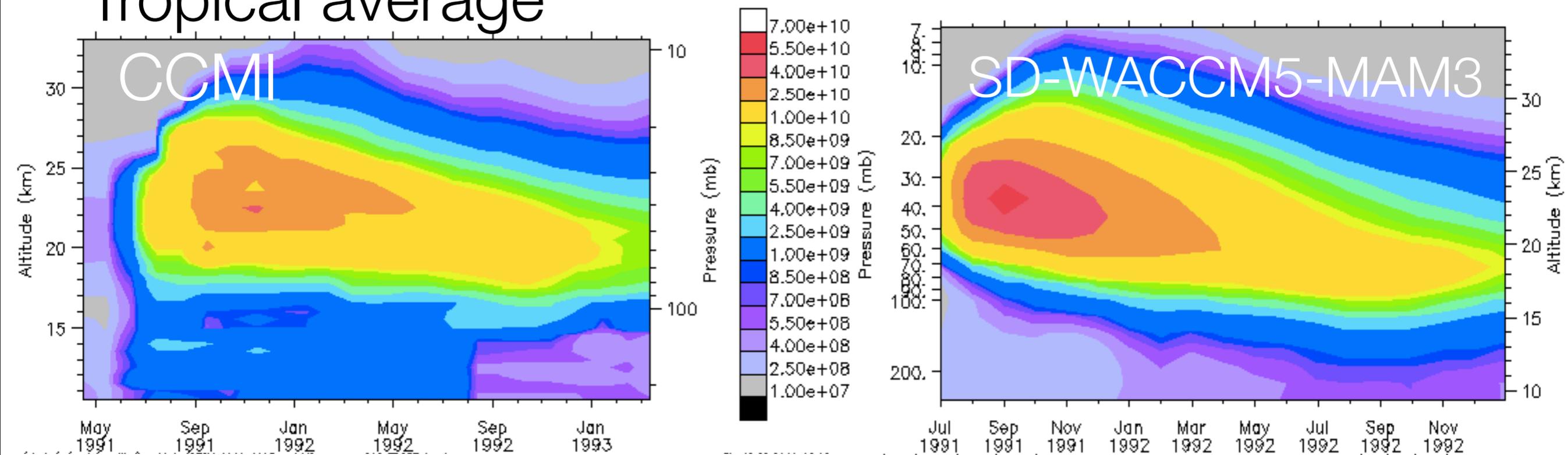


# Sulfate concentration (molec/cm<sup>3</sup>)

## January 1992

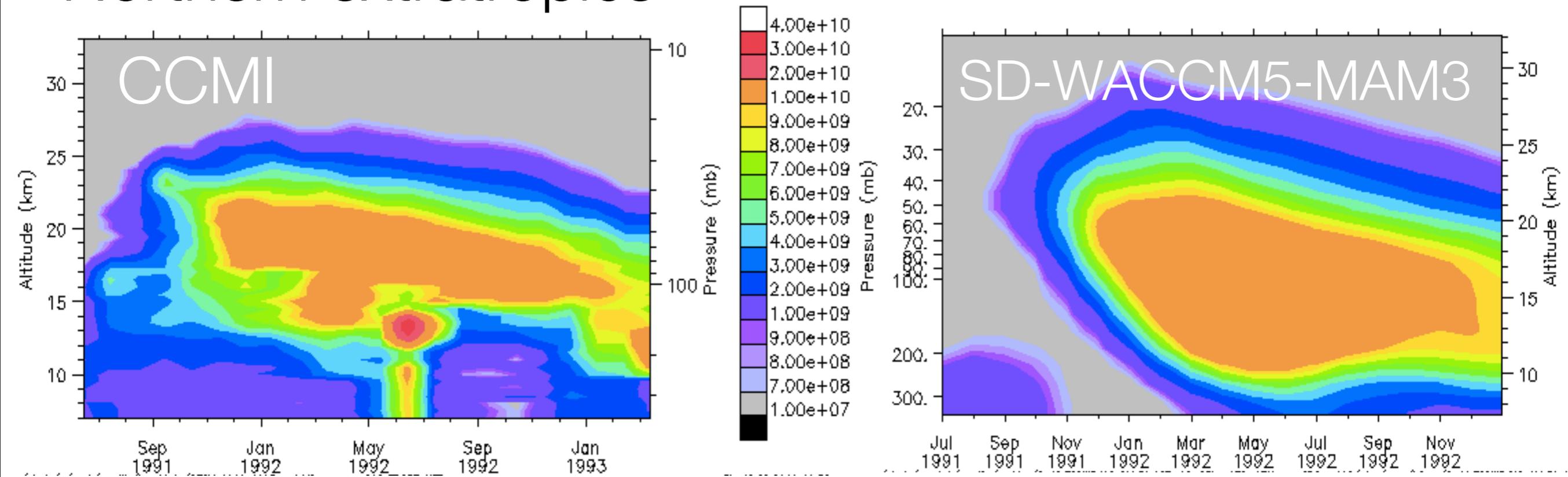


## Tropical average

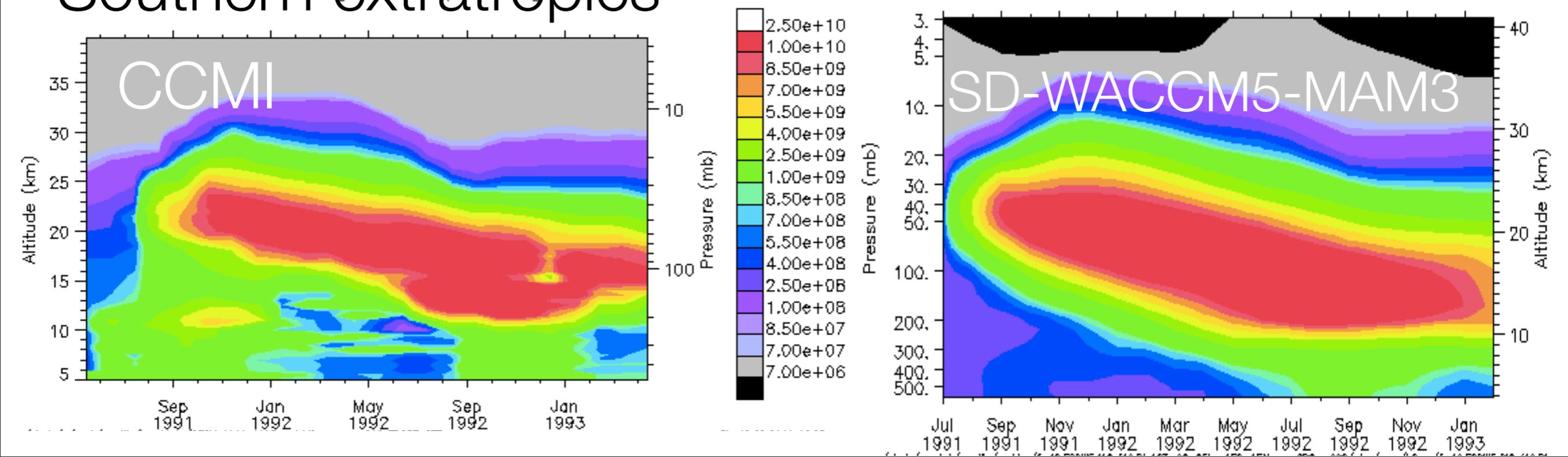


# Sulfate concentration (molec/cm<sup>3</sup>)

## Northern extratropics

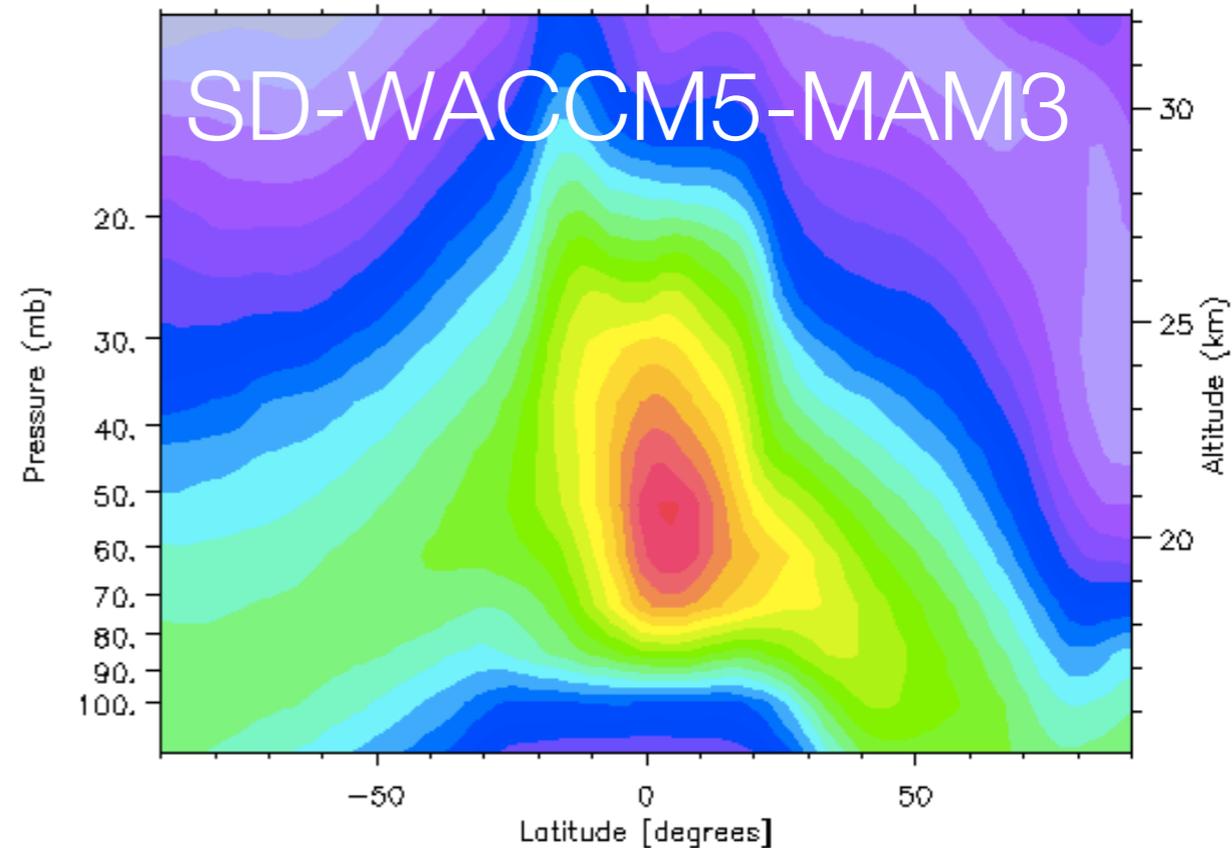
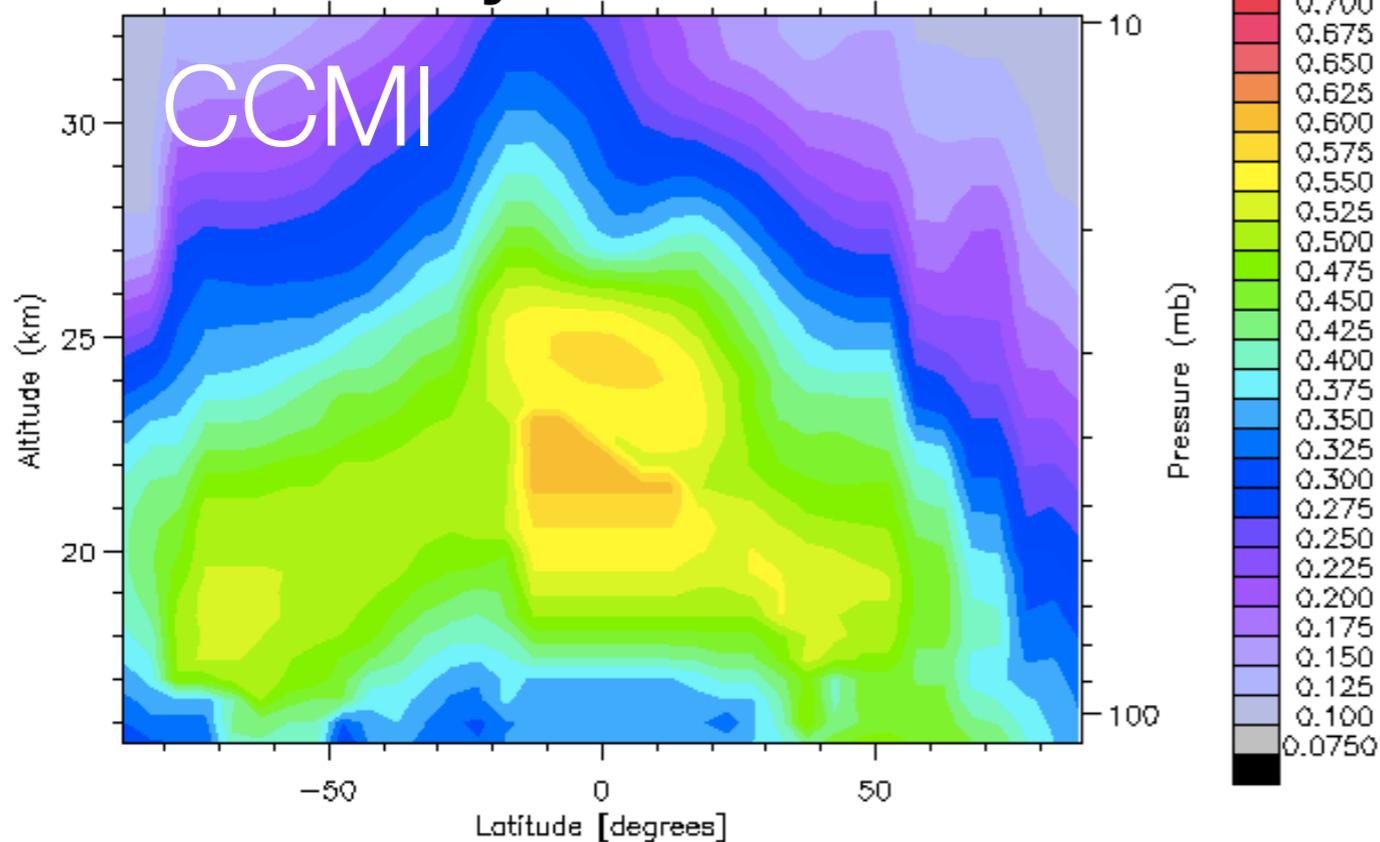


## Southern extratropics

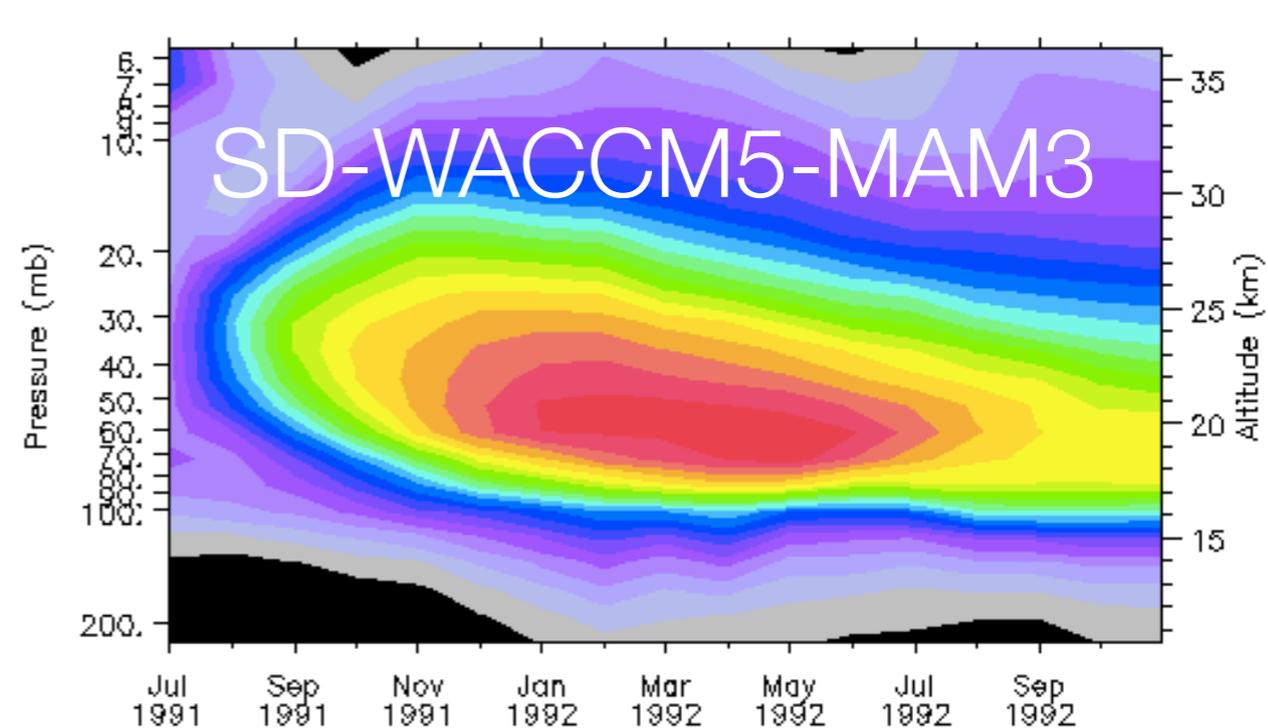
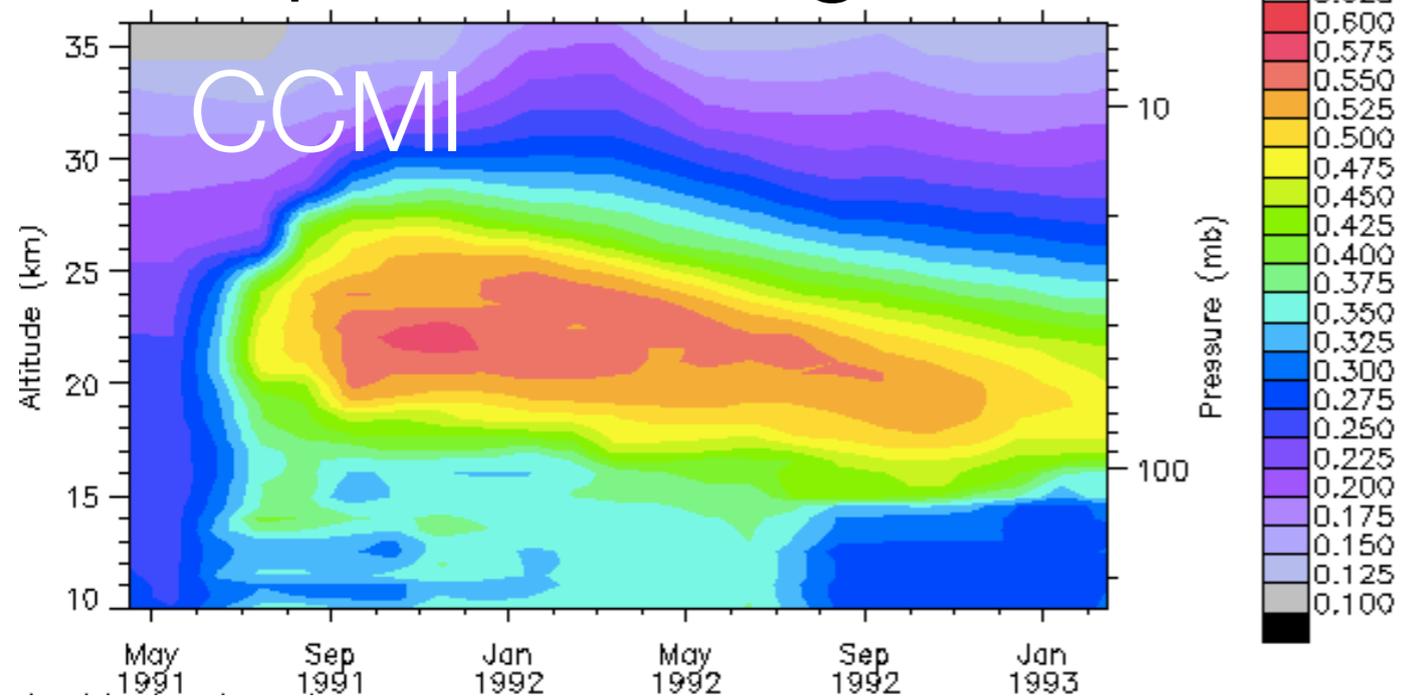


# Effective radius ( $\mu\text{m}$ )

## January 1992

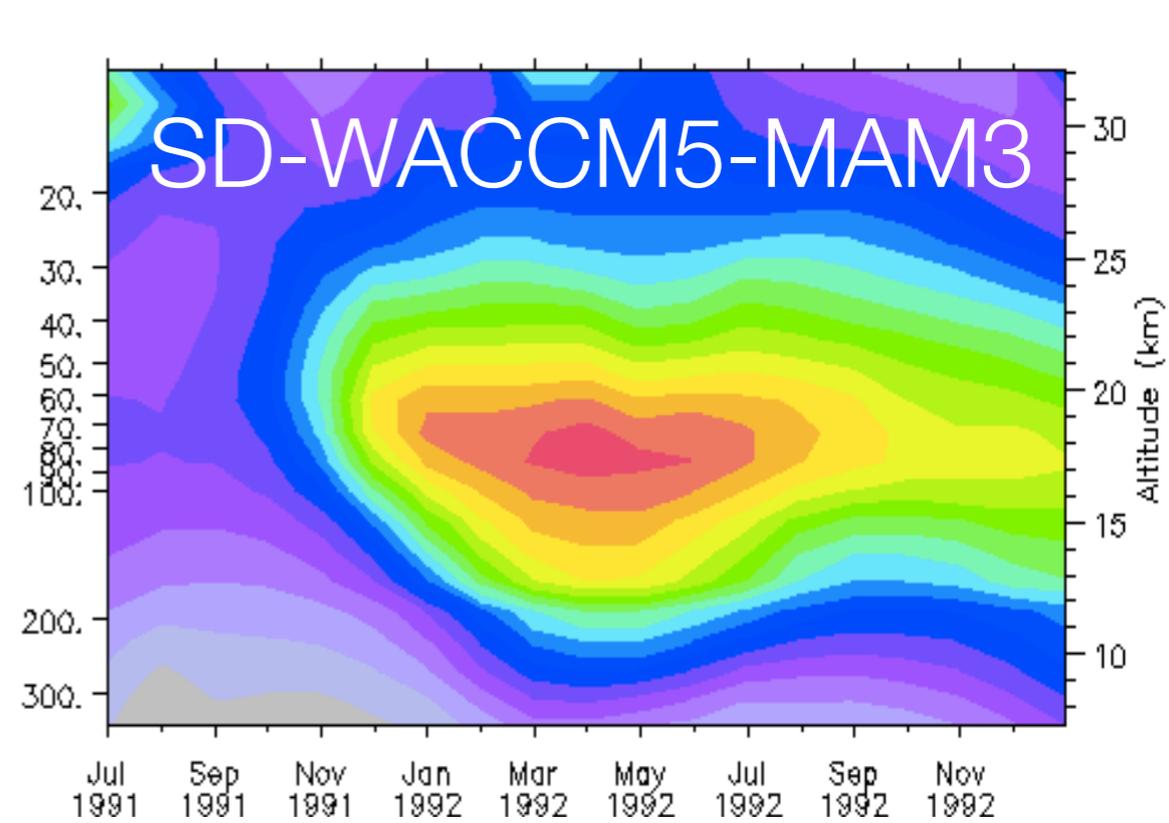
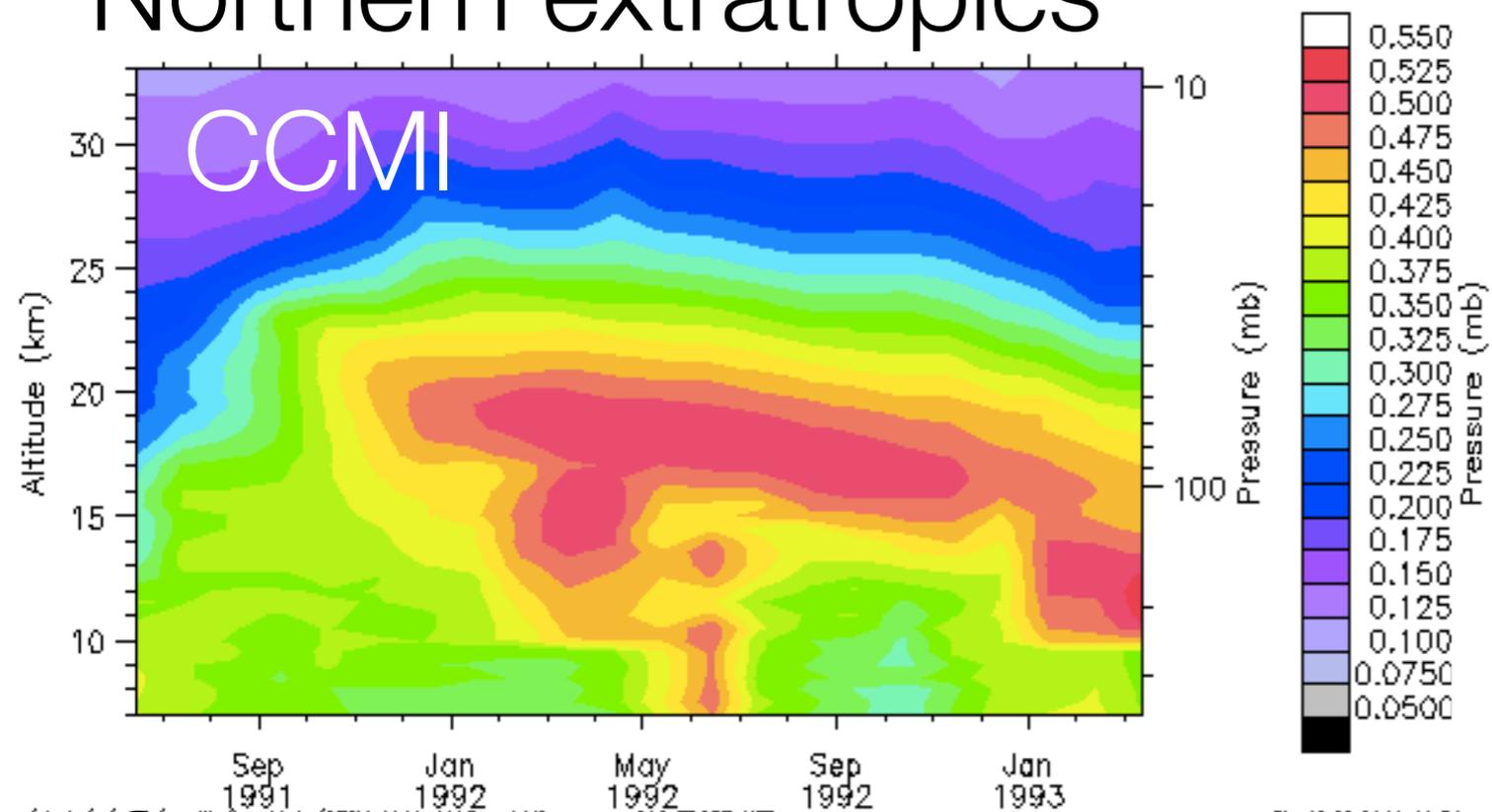


## Tropical average

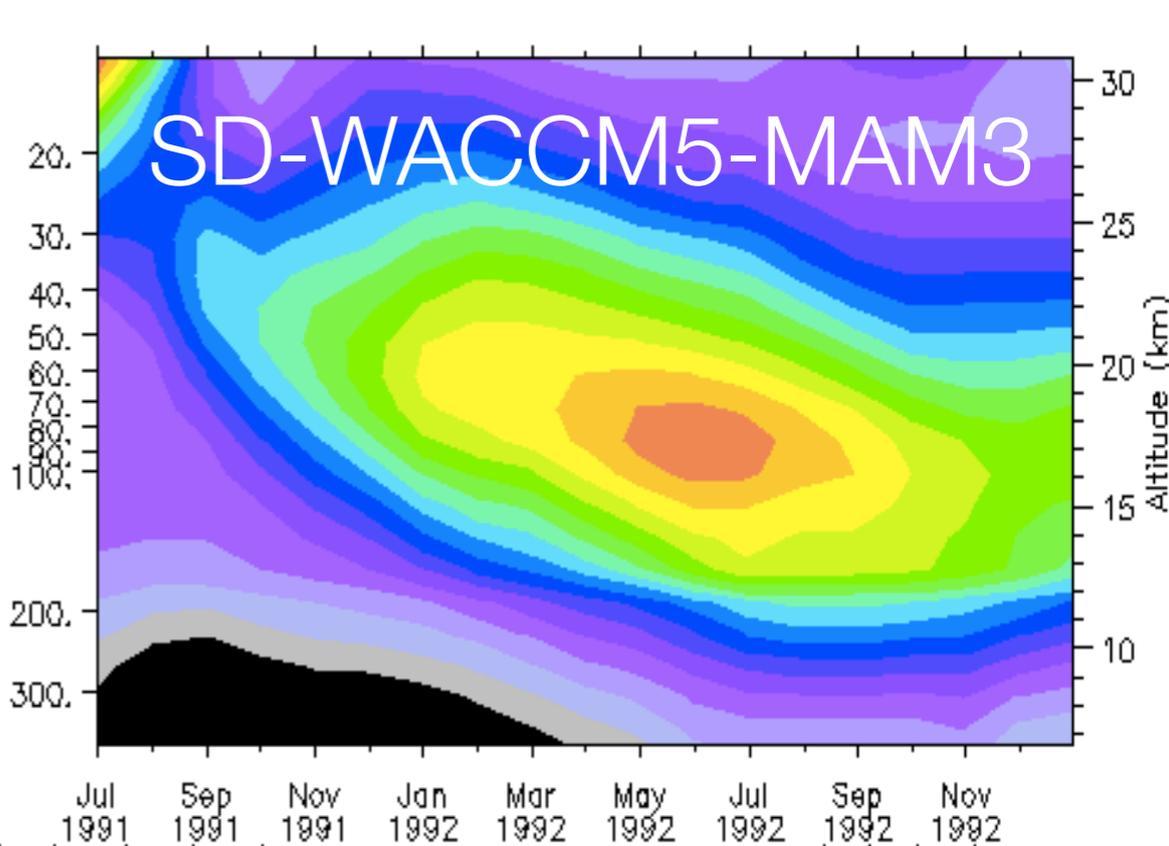
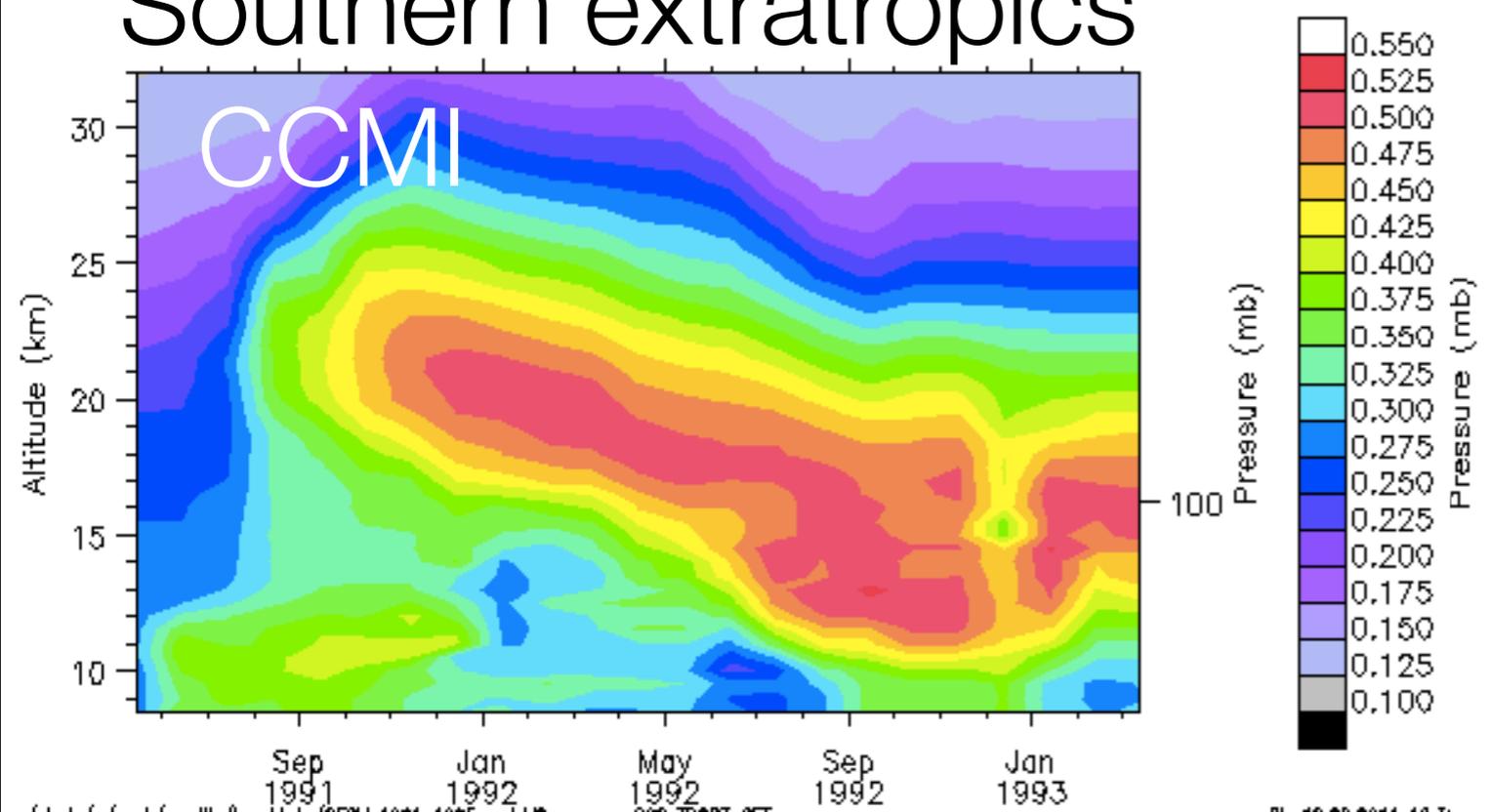


# Effective radius ( $\mu\text{m}$ )

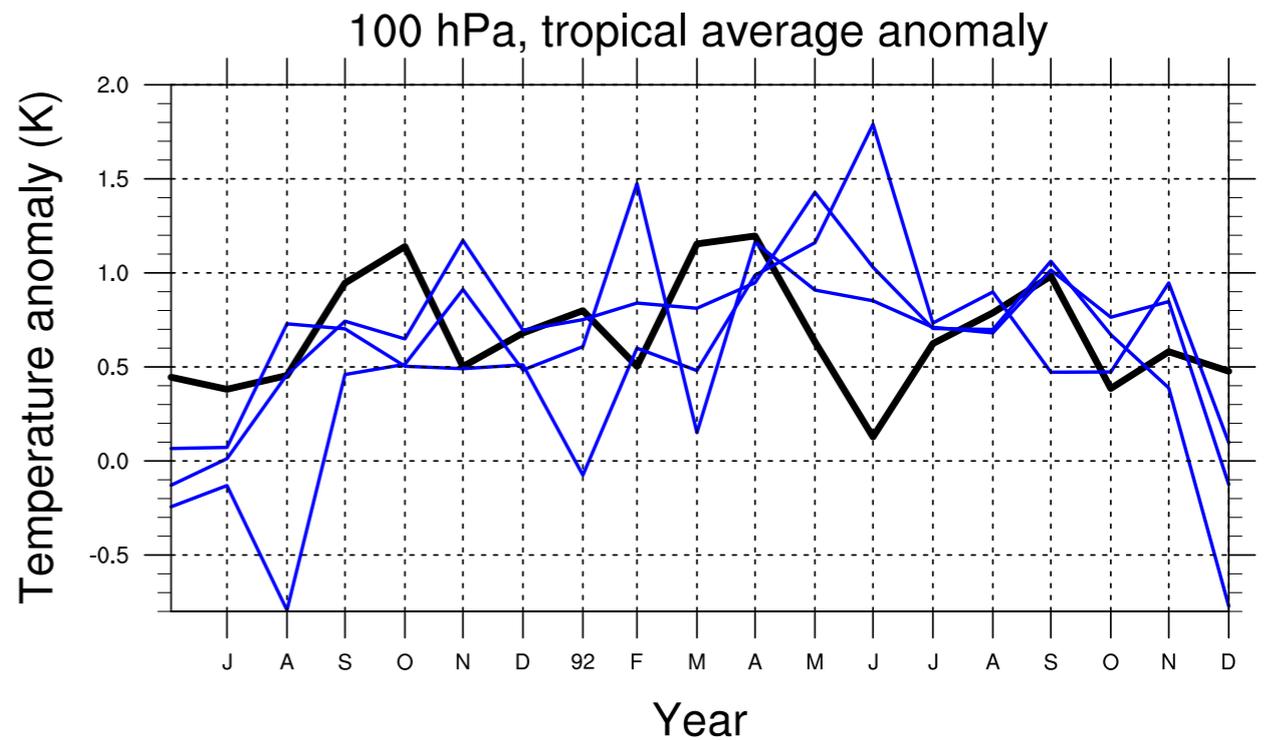
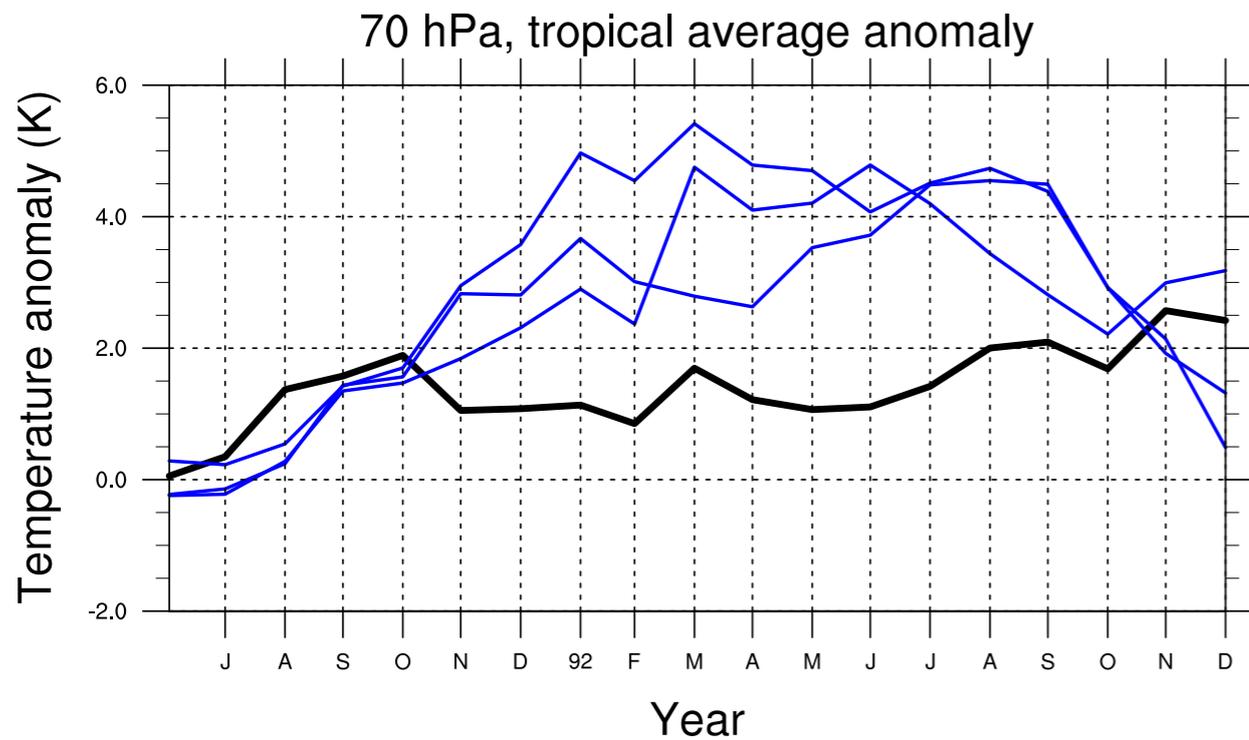
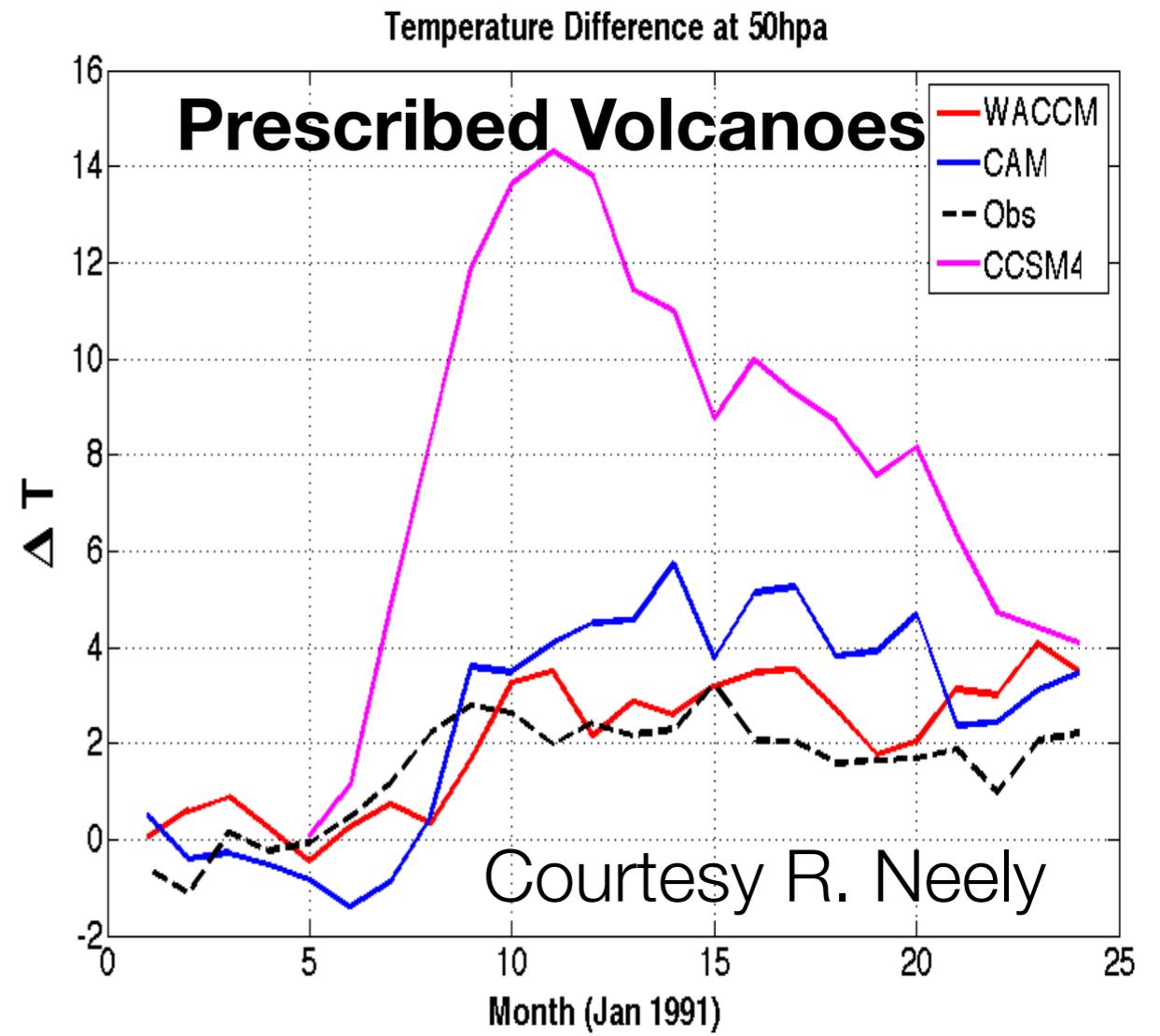
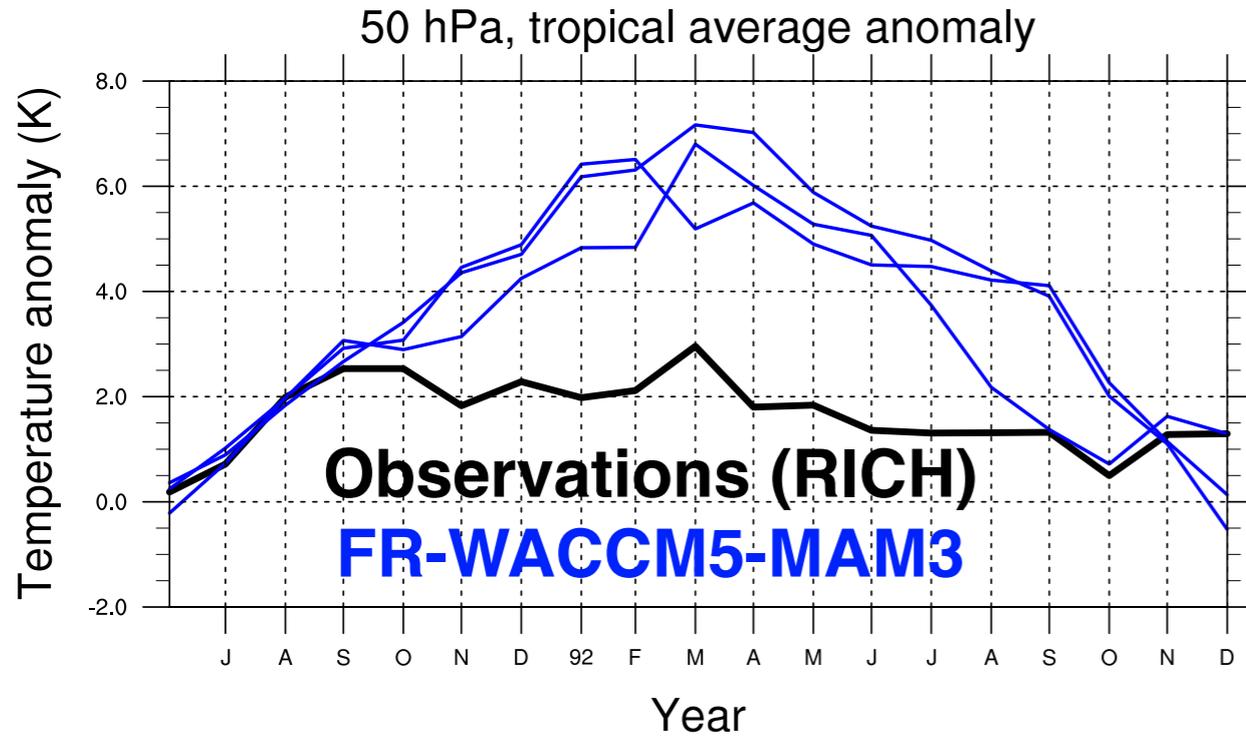
## Northern extratropics

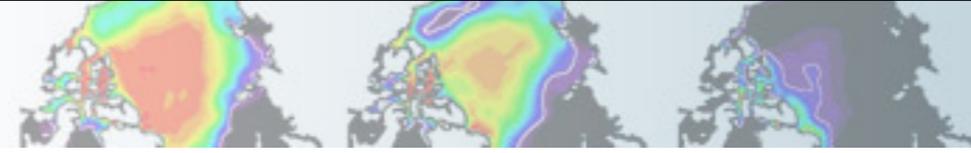


## Southern extratropics

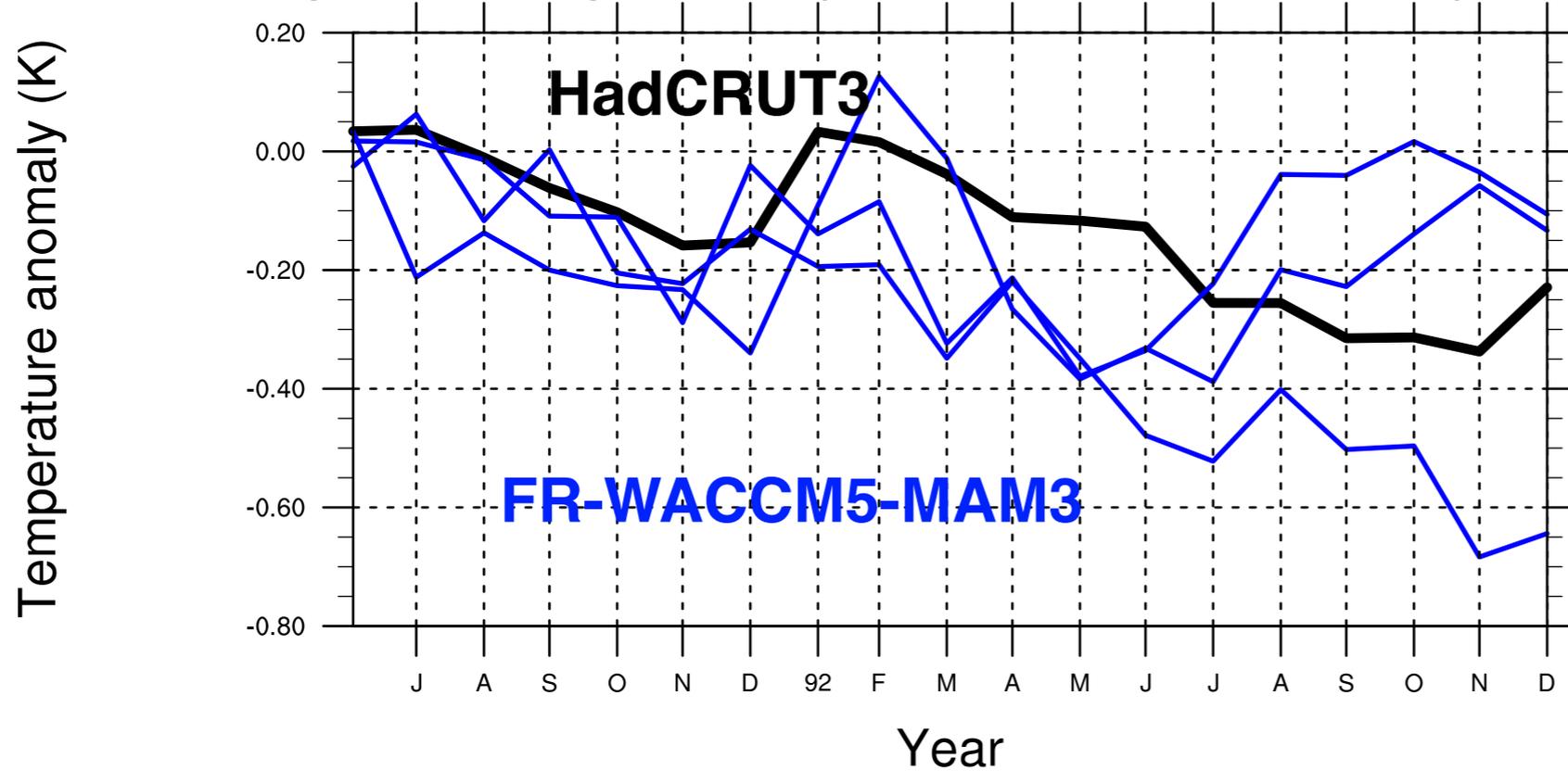


# Stratospheric temperature anomalies



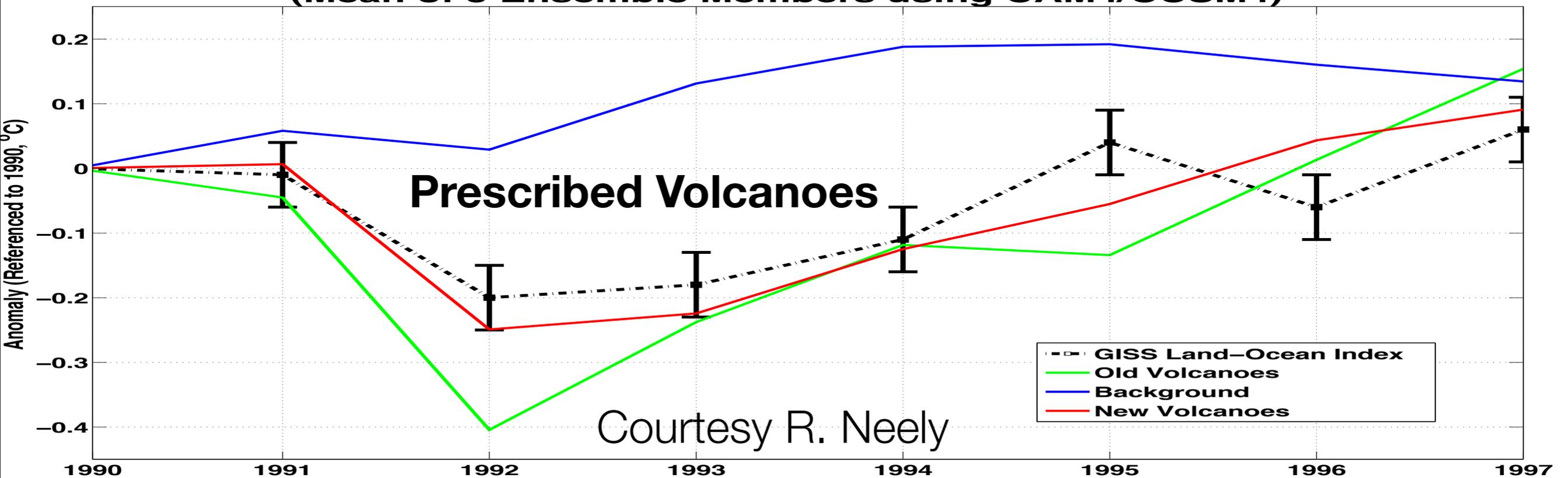


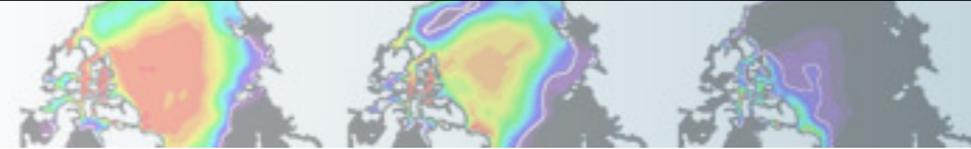
Surface, global average anomaly relative to June 1990 - May 1991 average



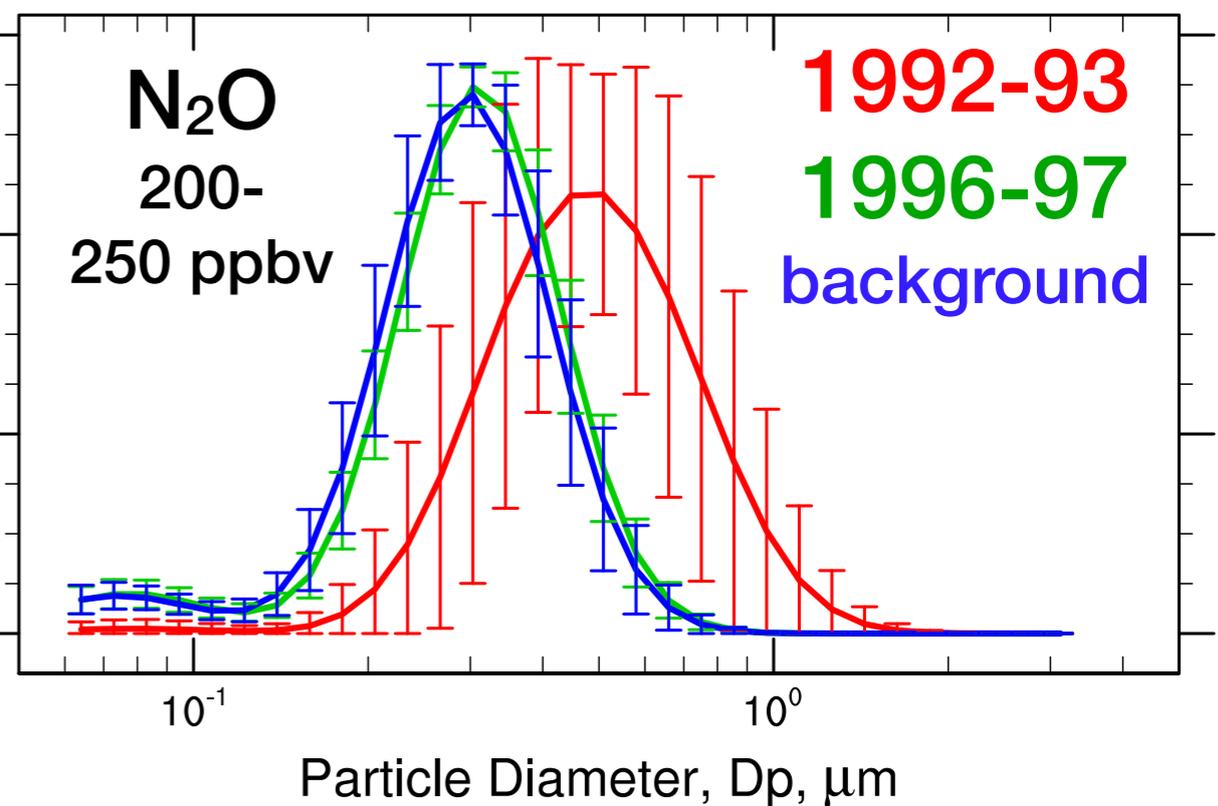
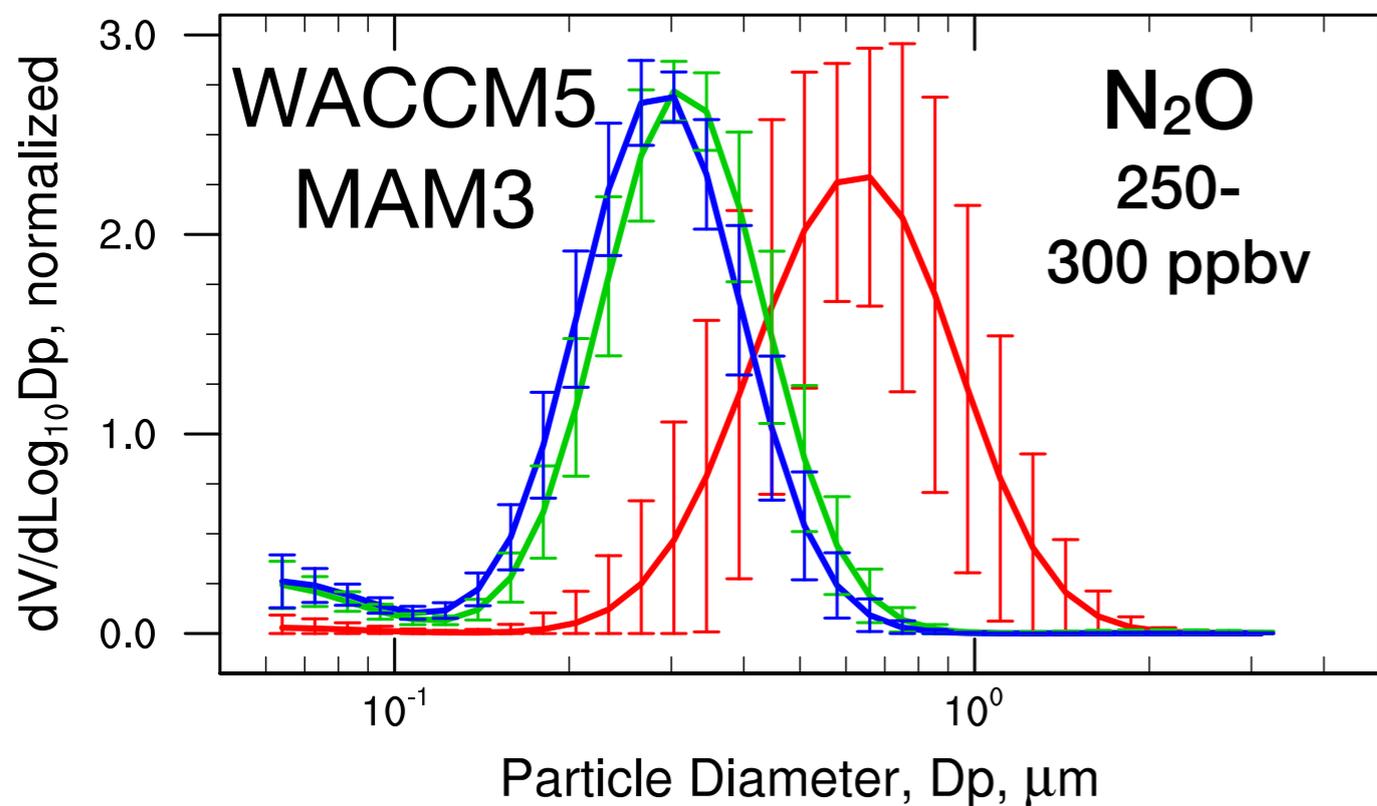
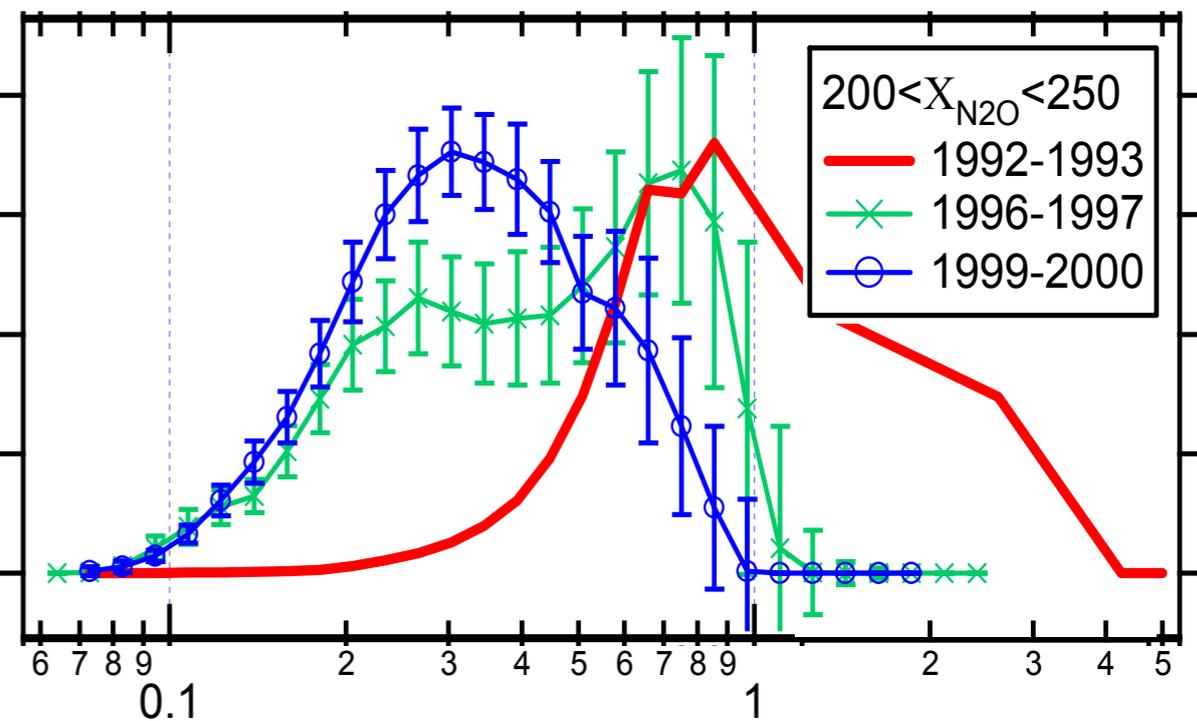
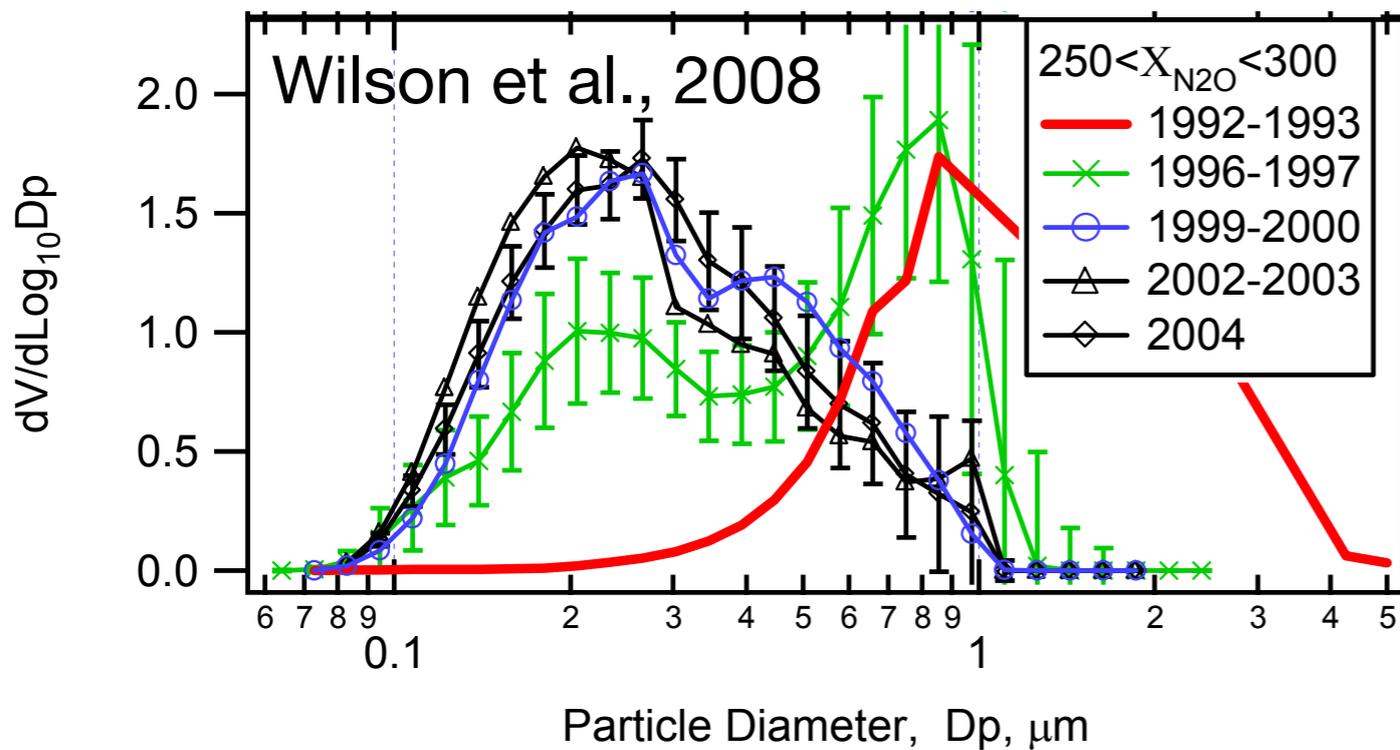
Surface temperature anomalies

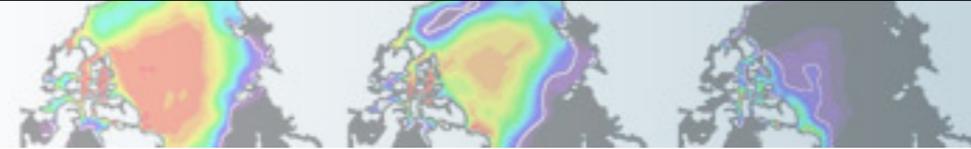
Global Annual Mean Surface Temperature (Mean of 5 Ensemble Members using CAM4/CCSM4)





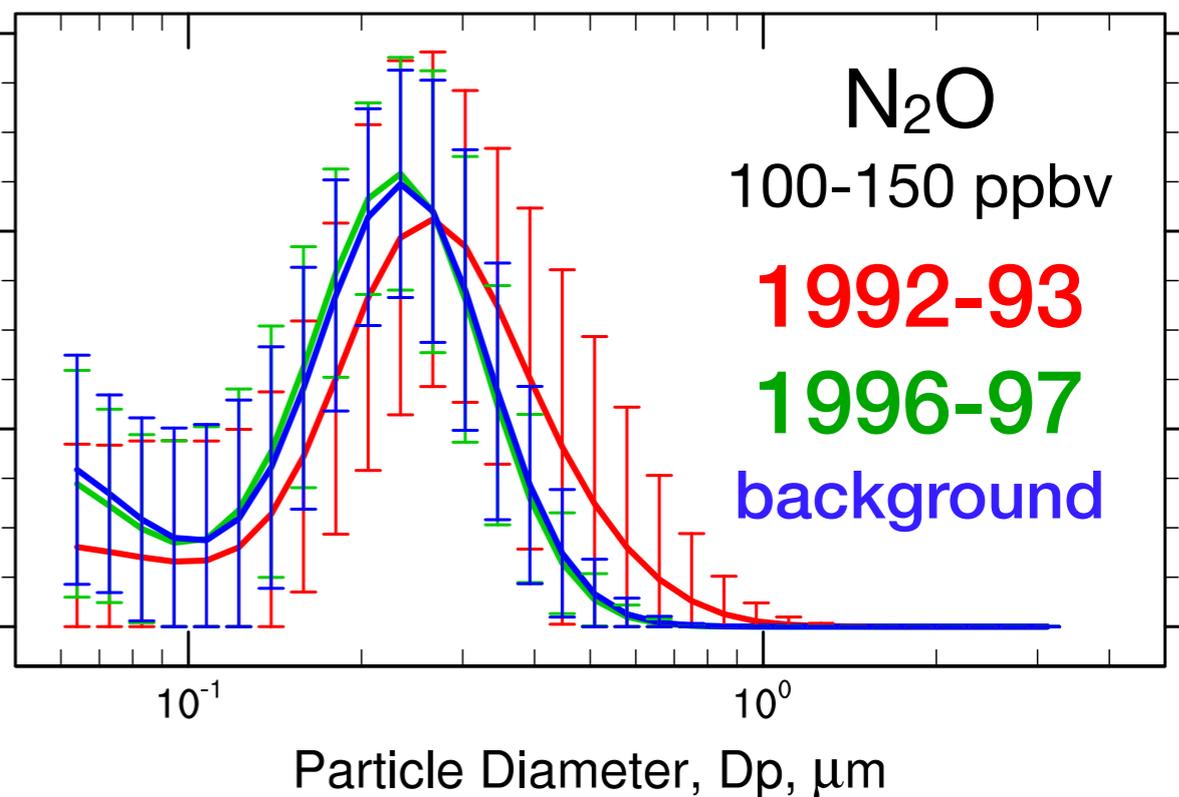
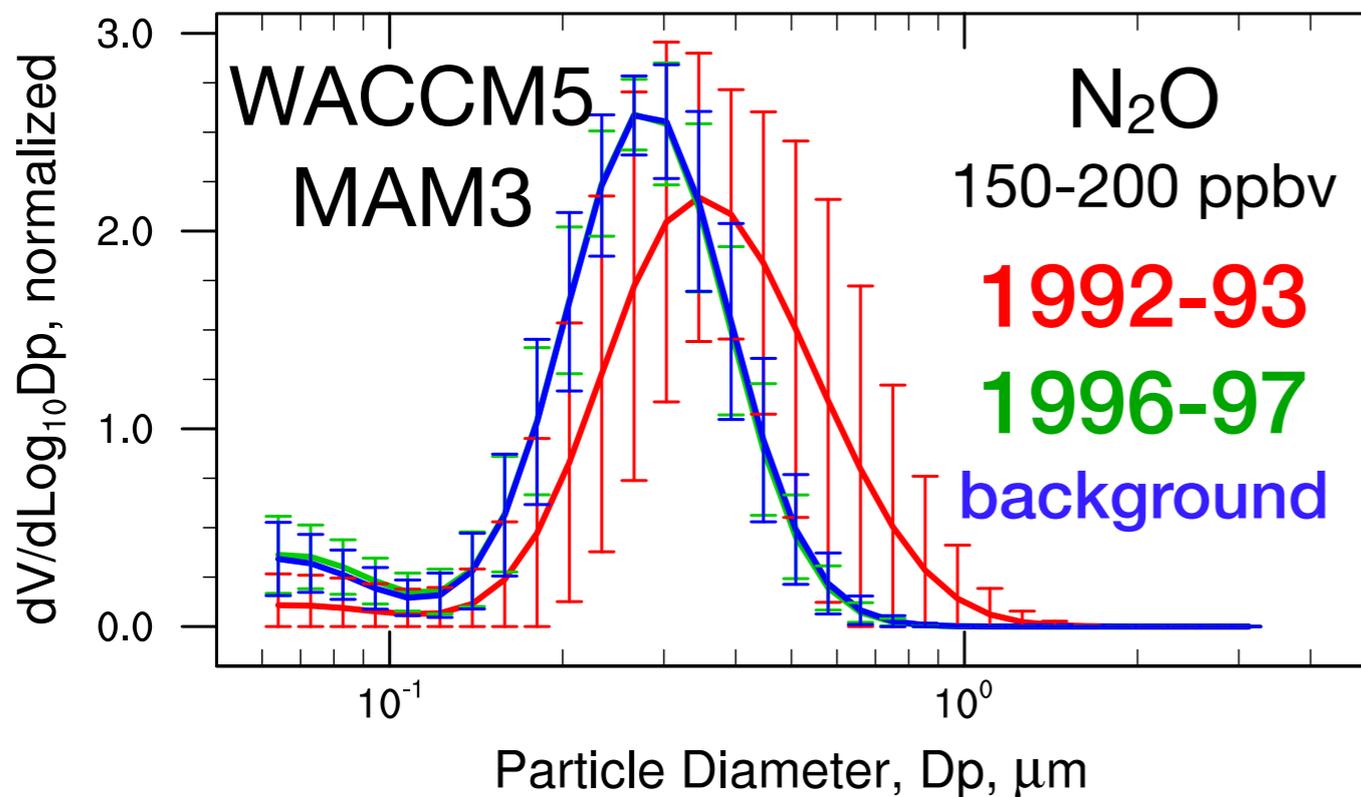
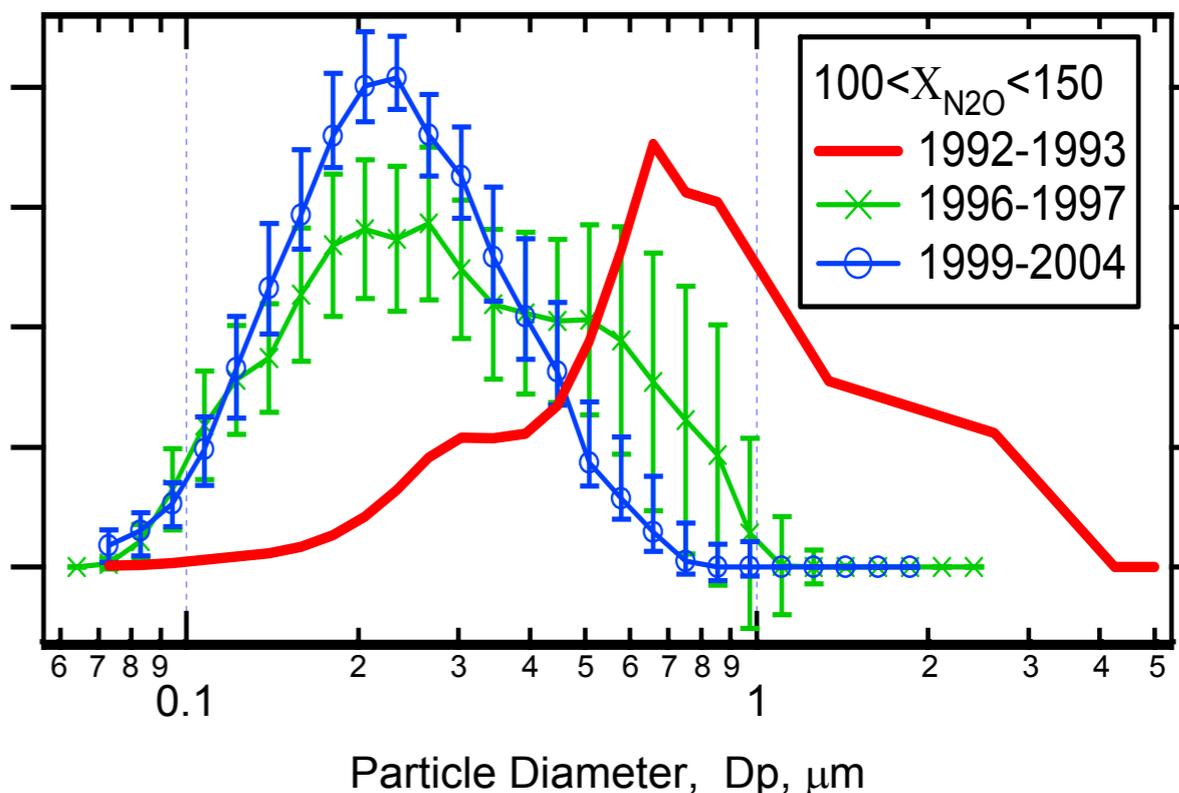
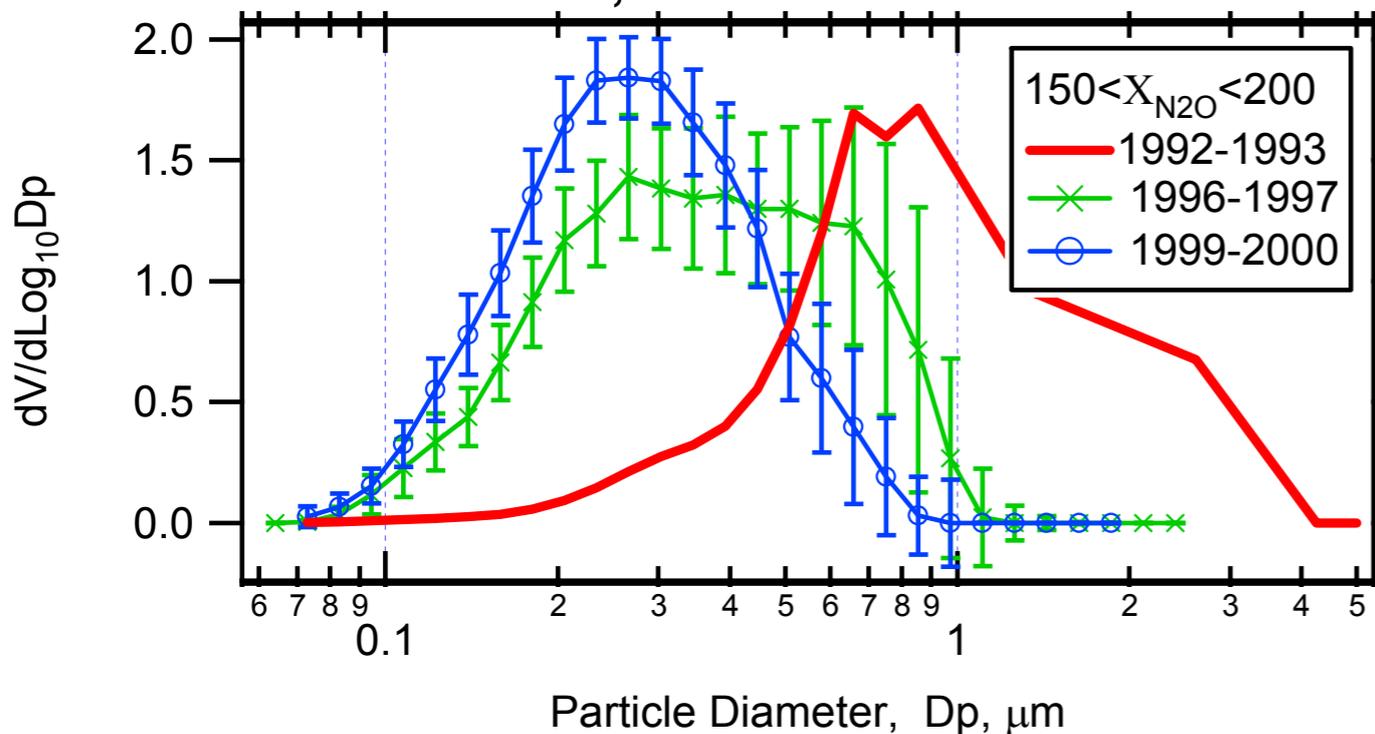
# Volume size distributions compared to observations

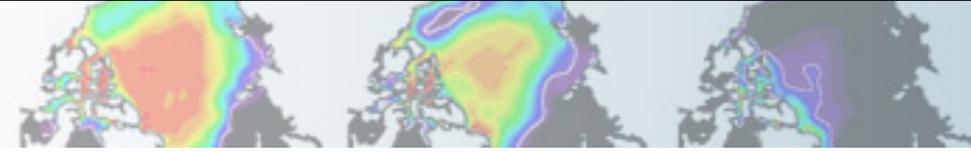




# Volume size distributions compared to observations

Wilson et al., 2008



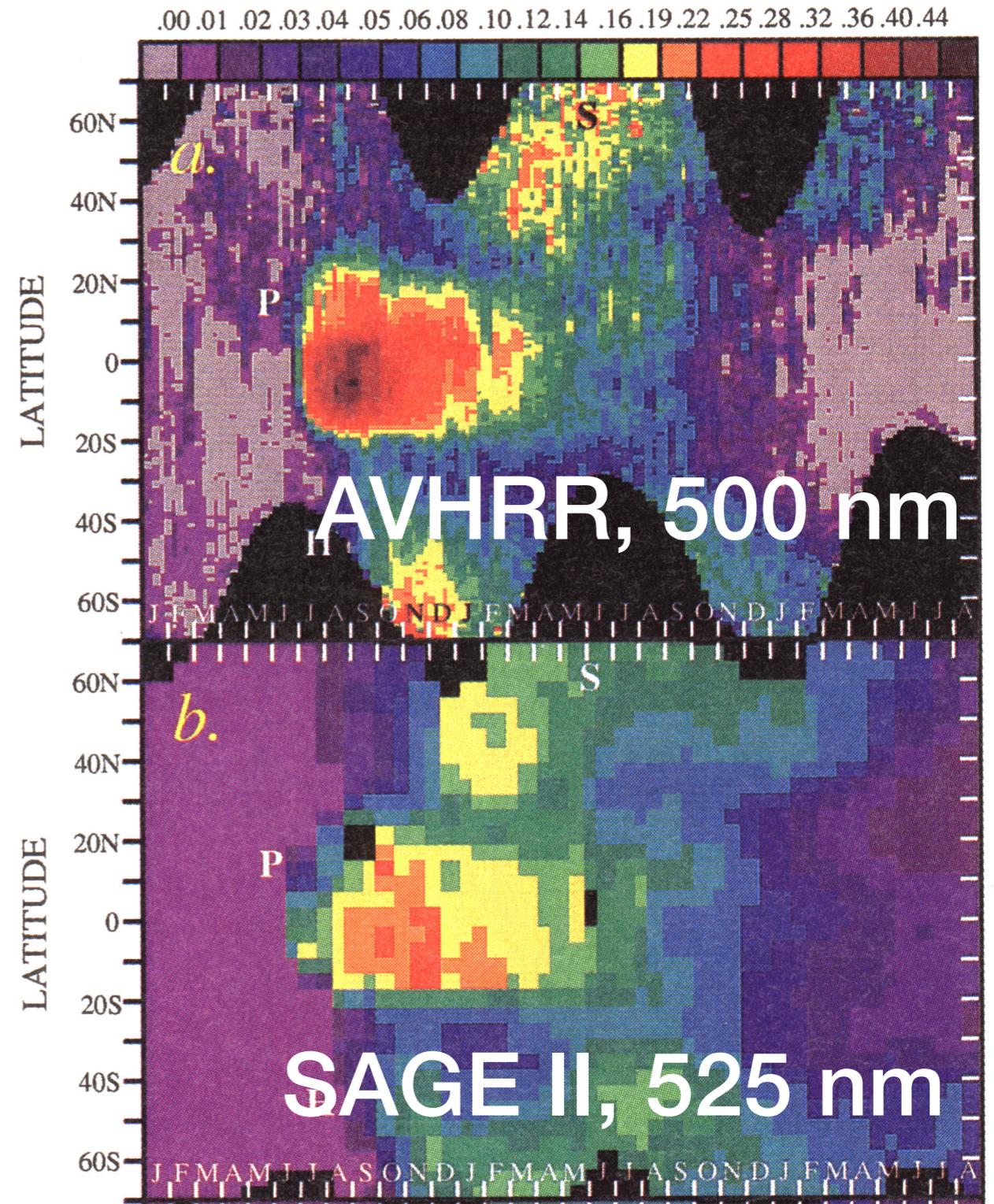
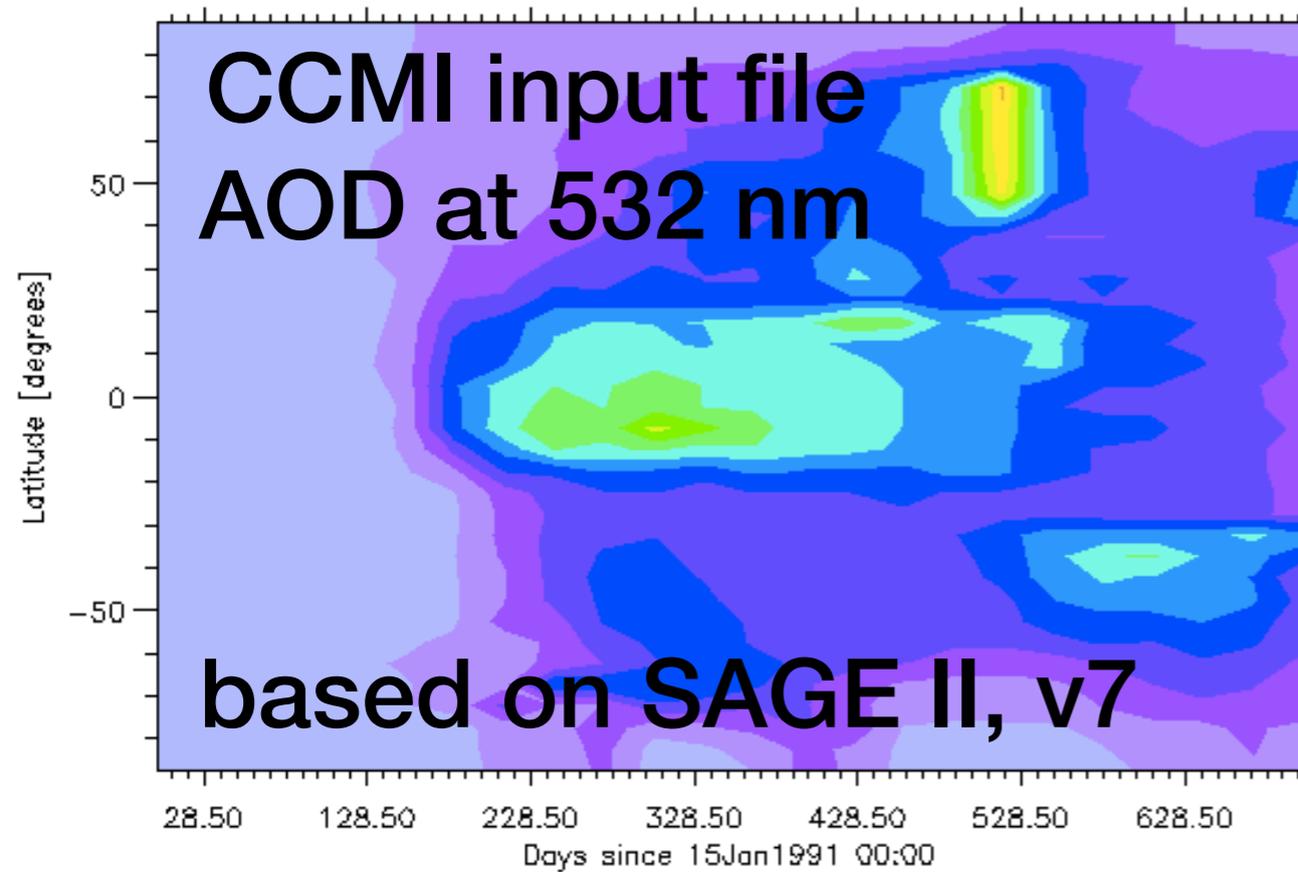
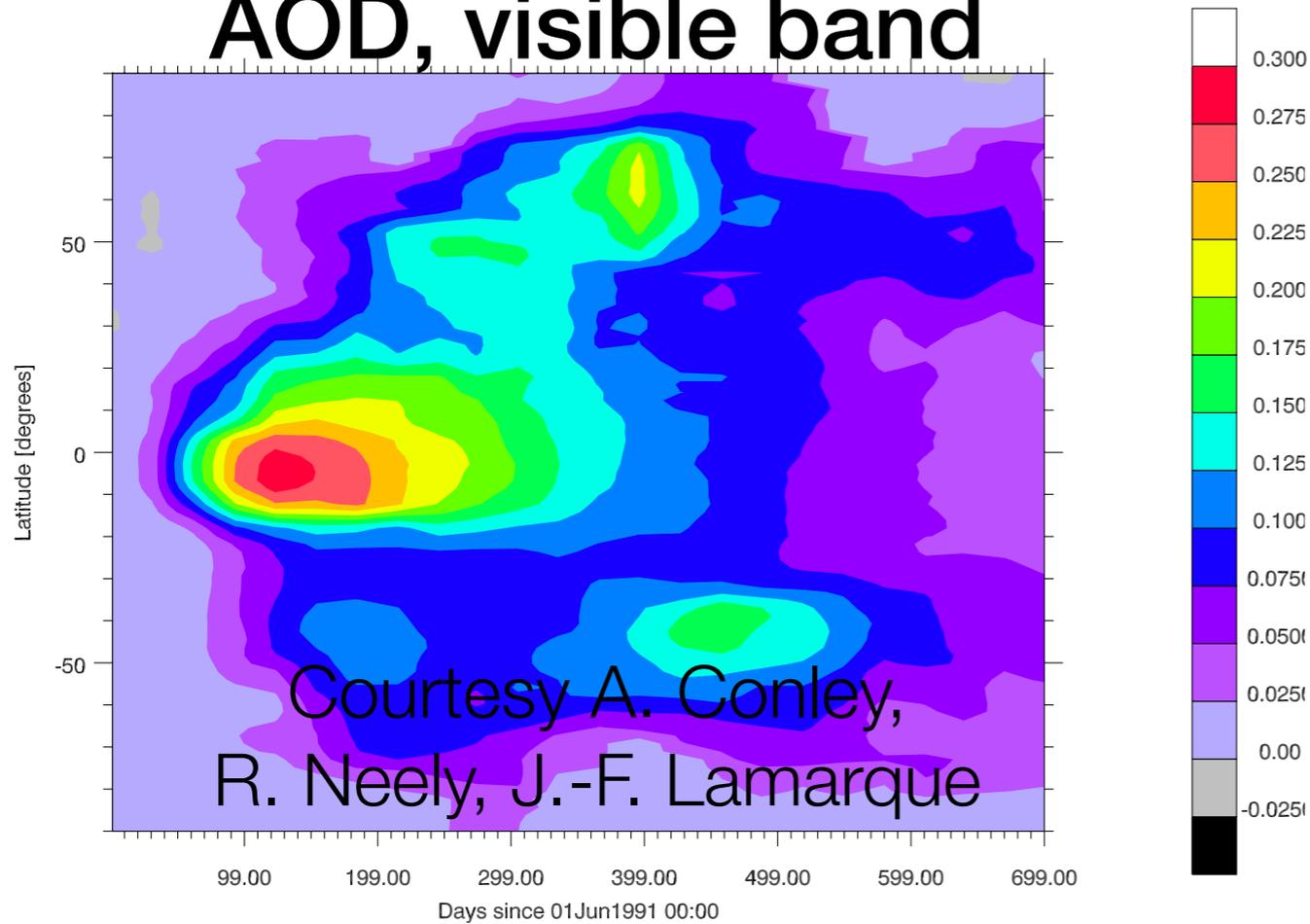


# Outstanding issues

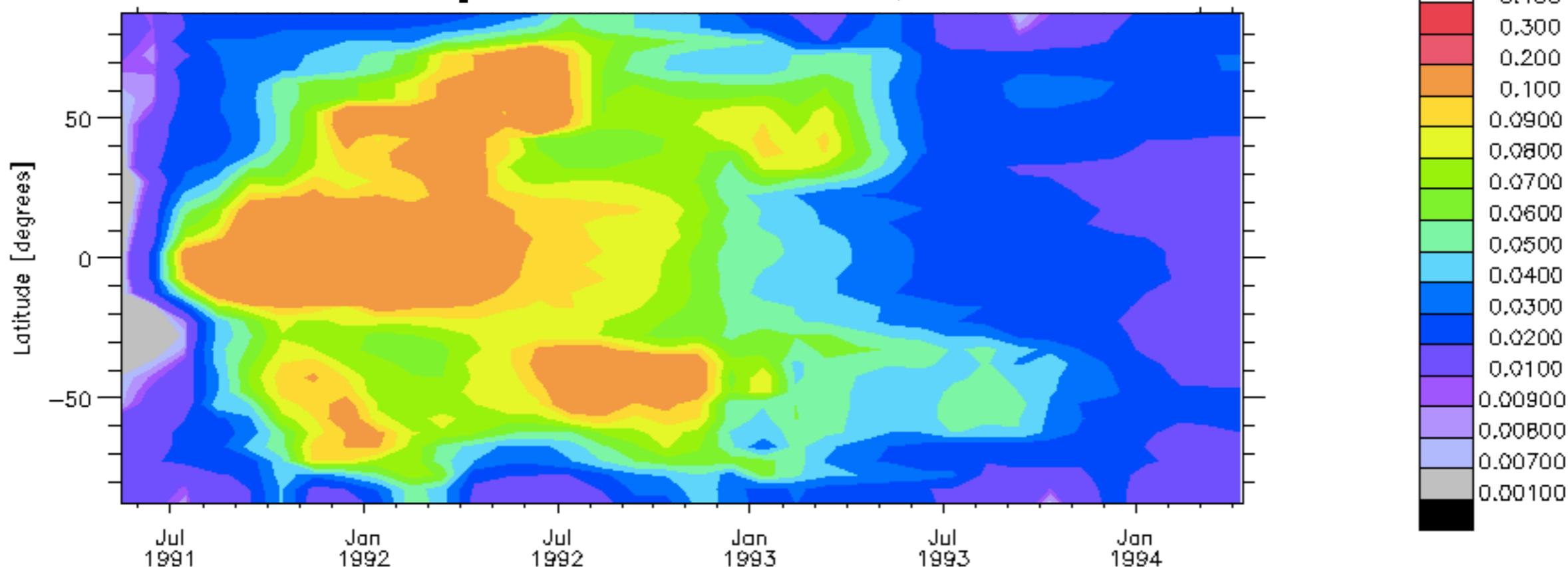
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- Investigate slow of growth to coarse mode
- Investigate alternate emission scenarios (zonal mean vs. plume)
- Adjustment of mode widths
- Treatment of sulfate in MAM3 as ammonium sulfate
  - The MAM3 “sulfate” species is ammonium bisulfate, causing ~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  $\text{NH}_4+$ .
- Need for additional modes, i.e. nucleation mode?

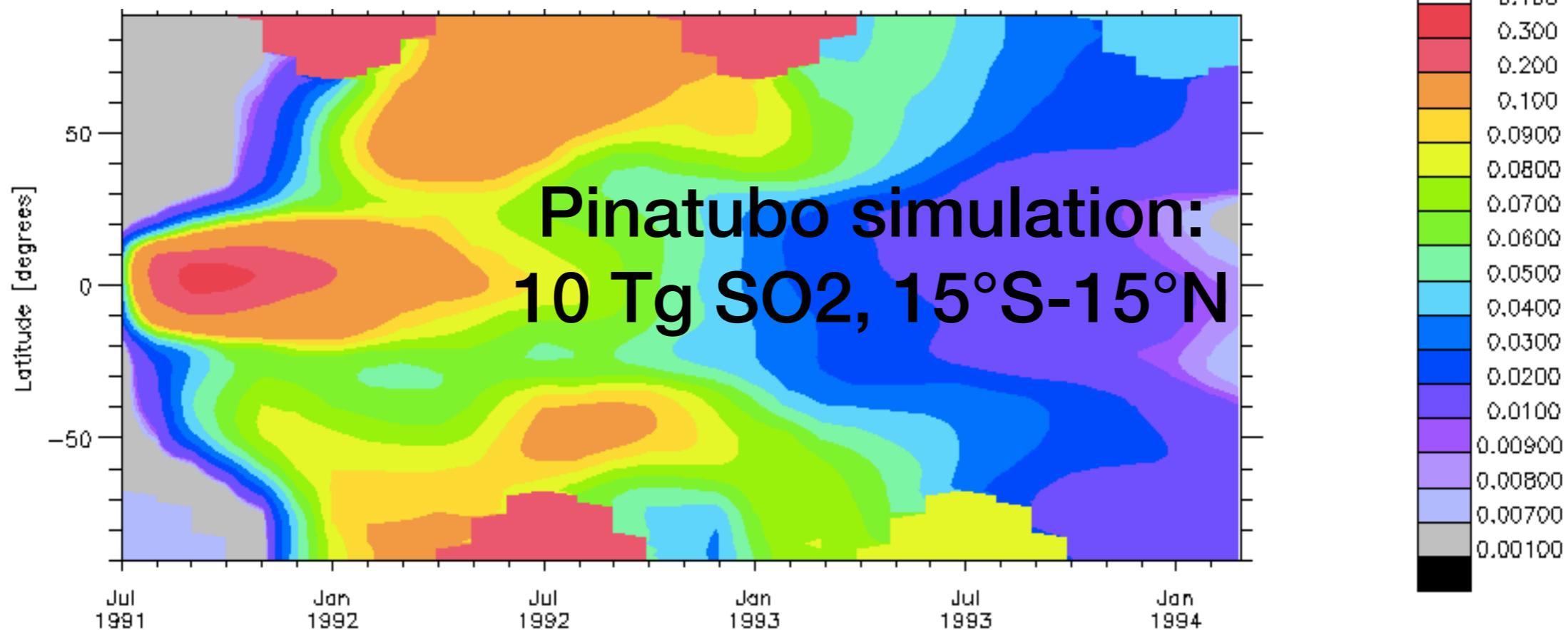
# CCMI CESM output AOD, visible band

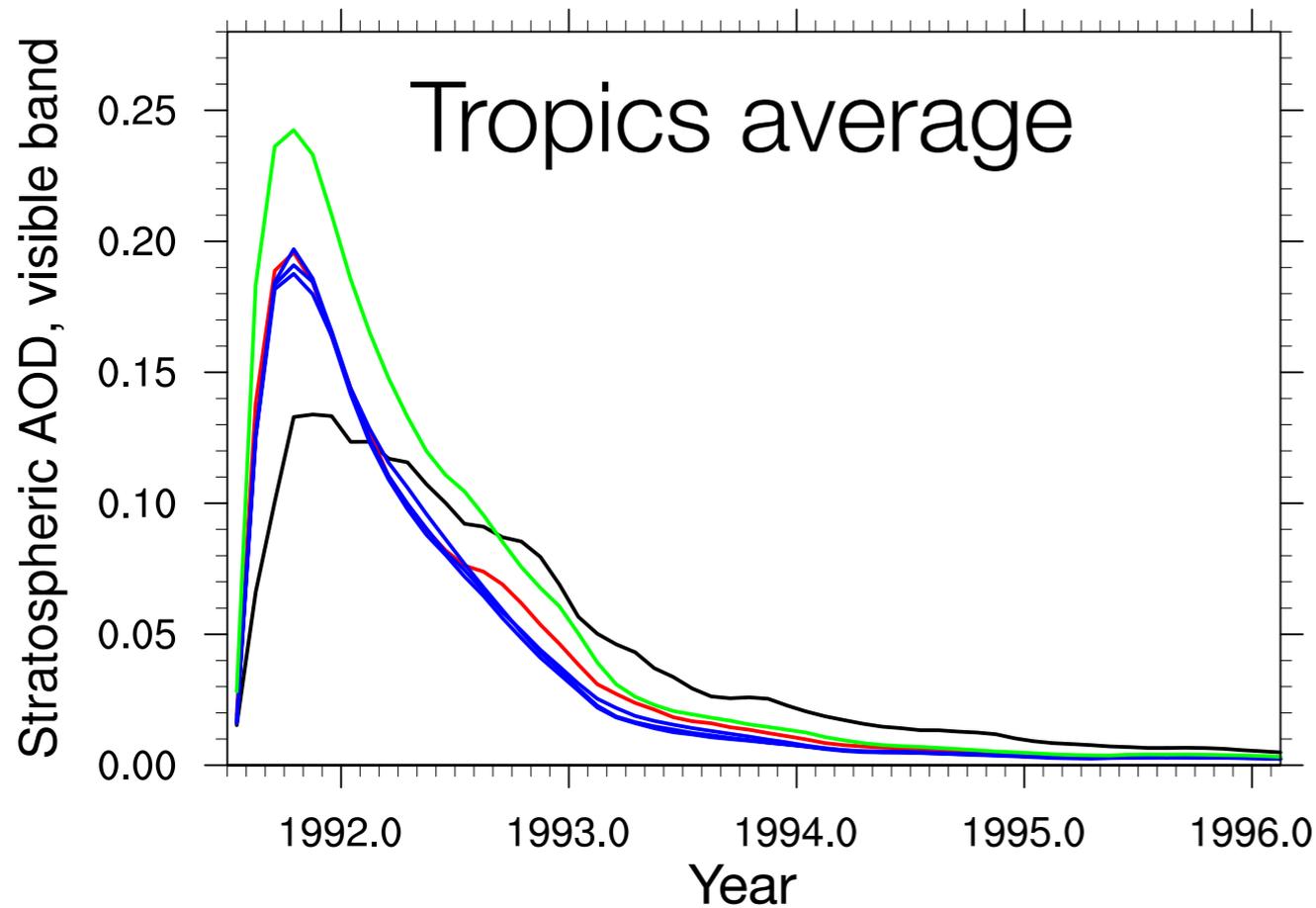
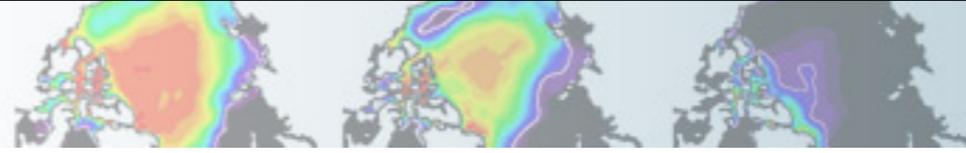


# CCMI Input File AOD, 532 nm



# SD-WACCM5-MAM3 AOD, visible





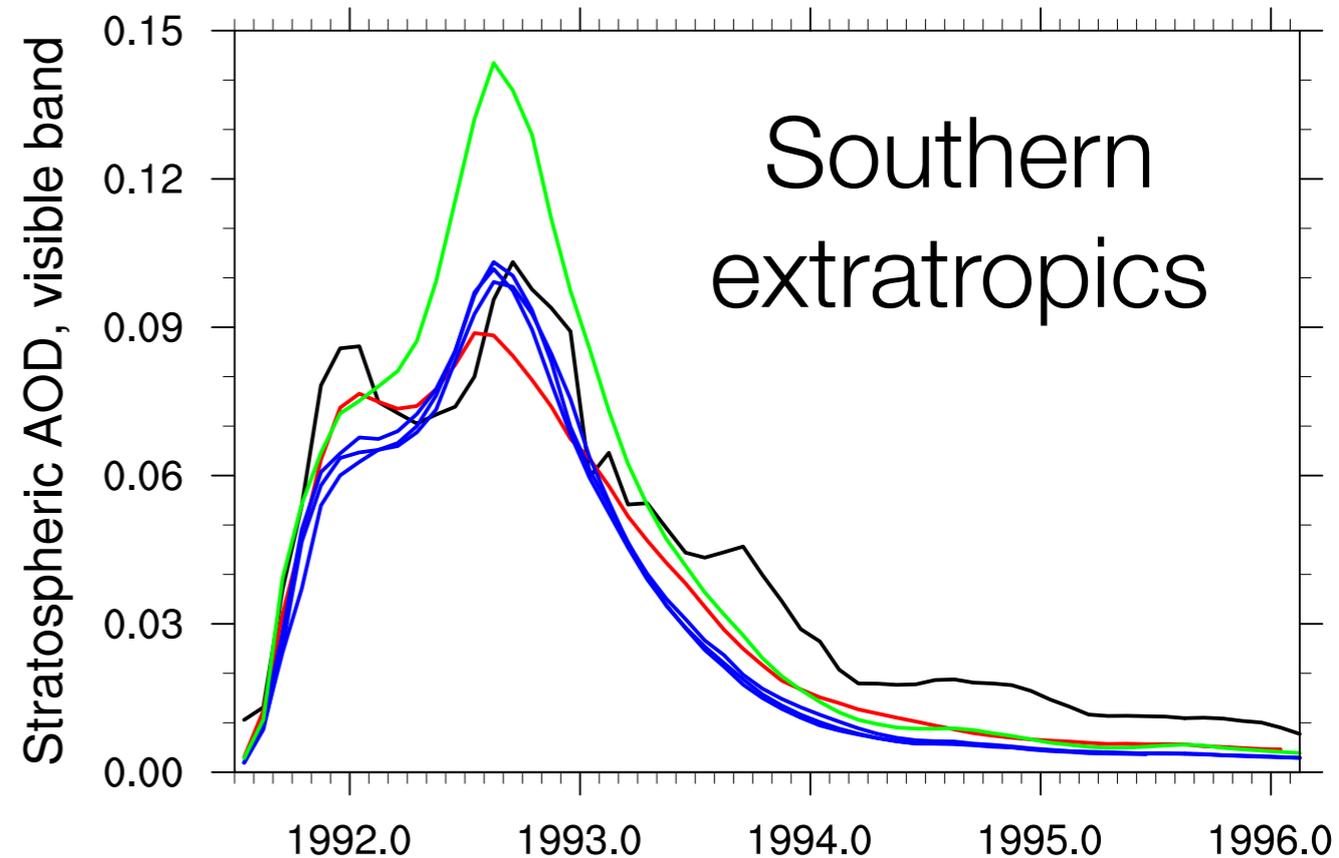
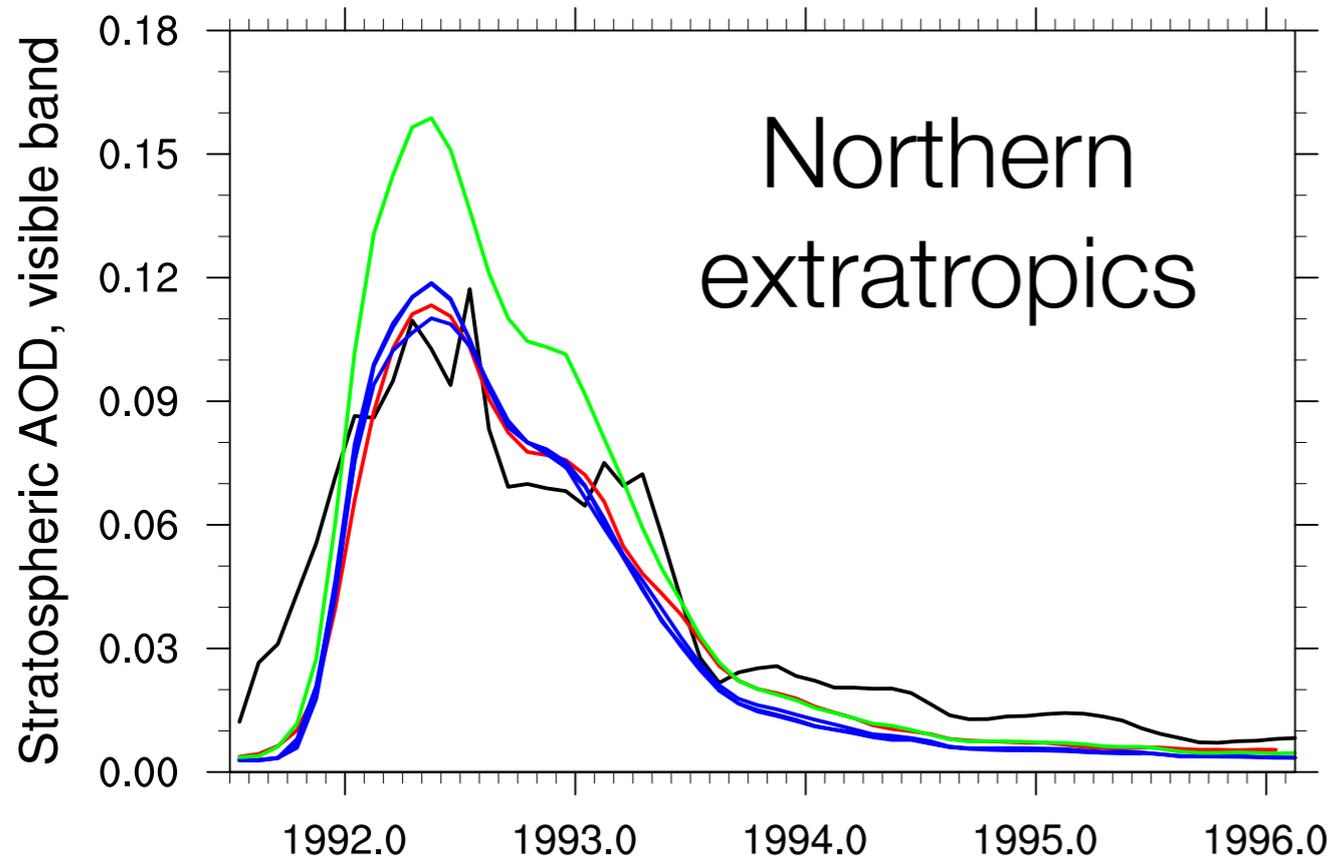
# Pinatubo simulation: 10 Tg SO<sub>2</sub>, 15°S-15°N

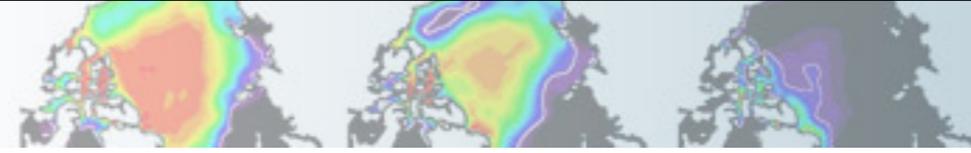
CCMI input file

**SD-WACCM5-MAM3**

**FR-WACCM5-MAM3**

**FR, wet radius**





# Volume size distributions compared to observations

