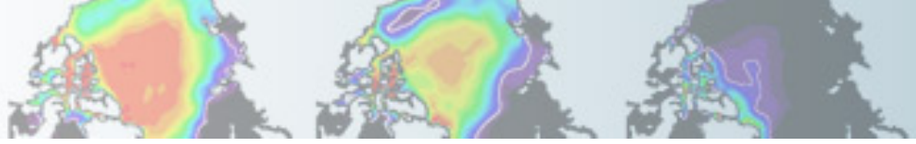

A new prognostic representation of stratospheric aerosols in CESM

Whole Atmosphere Working Group
CESM Workshop, Breckenridge
June 16, 2015

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Anja Schmidt, University of Leeds
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Richard Easter, PNNL
Steve Ghan, PNNL

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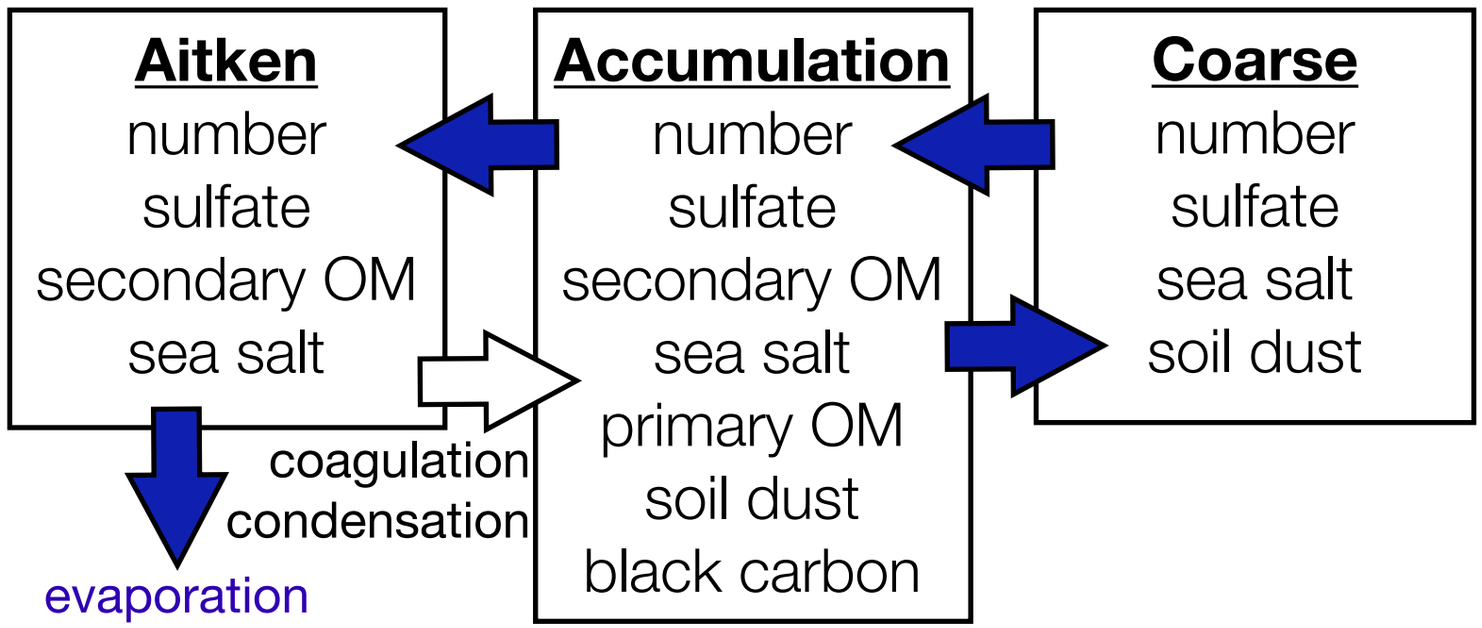
Extend modal aerosol model (MAM3) for stratospheric aerosols



Gas-phase species: H_2SO_4, SO_2, DMS, SOA (gas)

Added: OCS, S, SO, SO_3, HSO_3

Added sulfate evaporation above tropopause

Added growth between modes

Adjusted diameter ranges, mode widths

Mode	Nucleation	Aitken	Accumulation	Coarse
Standard 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
Modified 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
SOCOL-AER (Sheng et al, 2015)
AER2D (SPARC, 2006)
Chin et al. (2000)
Chin & Davis (1995)

OCS: 170
283, 286

SO_2: 2.5
13, 12

H_2SO_4: 0.8
1.3, 1.6

Aerosol: 122
114, 109, 187

DMS: 0.005
0.01, 0.02

Stratosphere

Troposphere

OCS: 2800
2650, 2470

SO_2: 440
350, 430

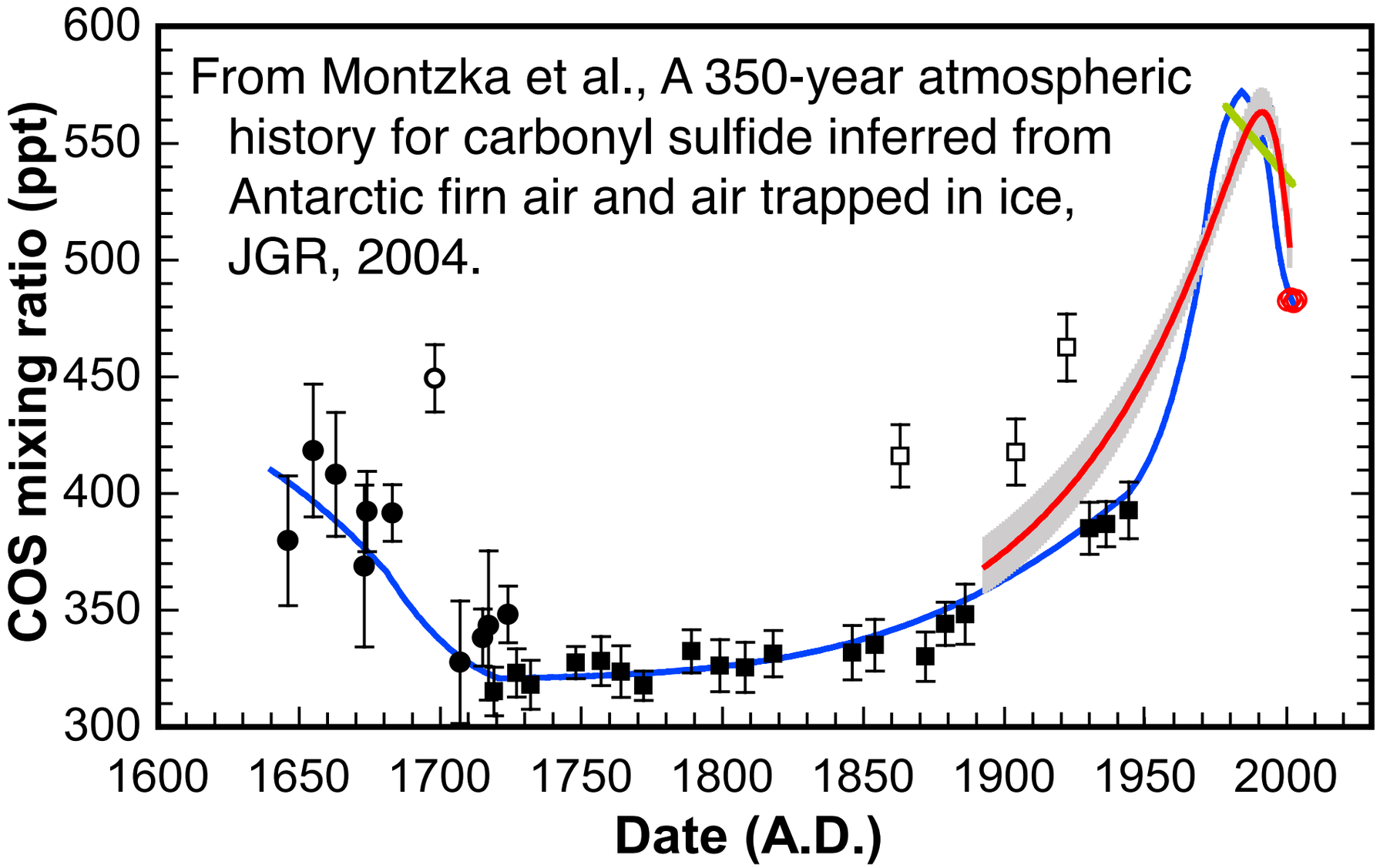
H_2SO_4: 2

Aerosol: 440
491, 630

DMS: 53
44, 73

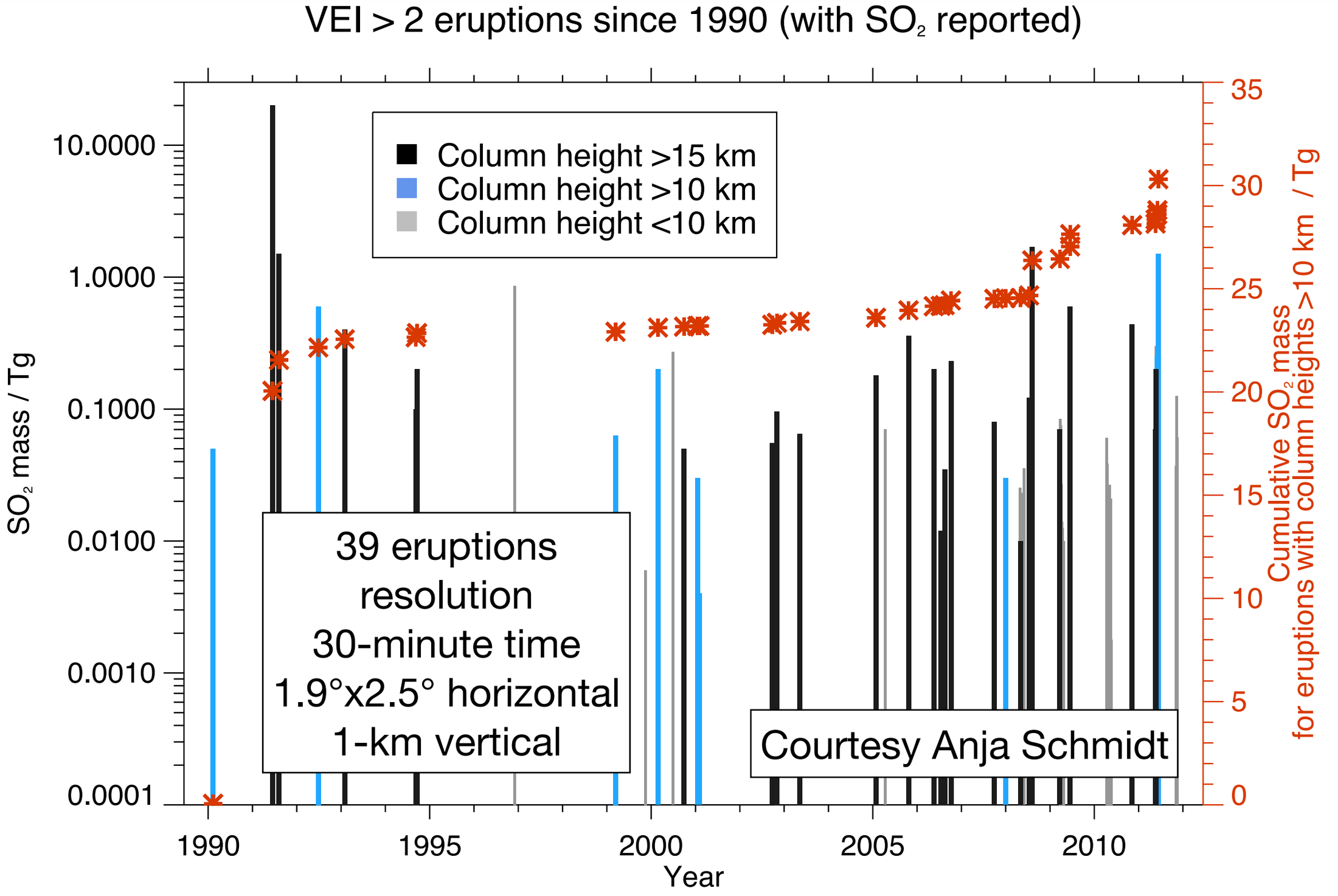
Surface

Time-varying lower boundary condition for OCS

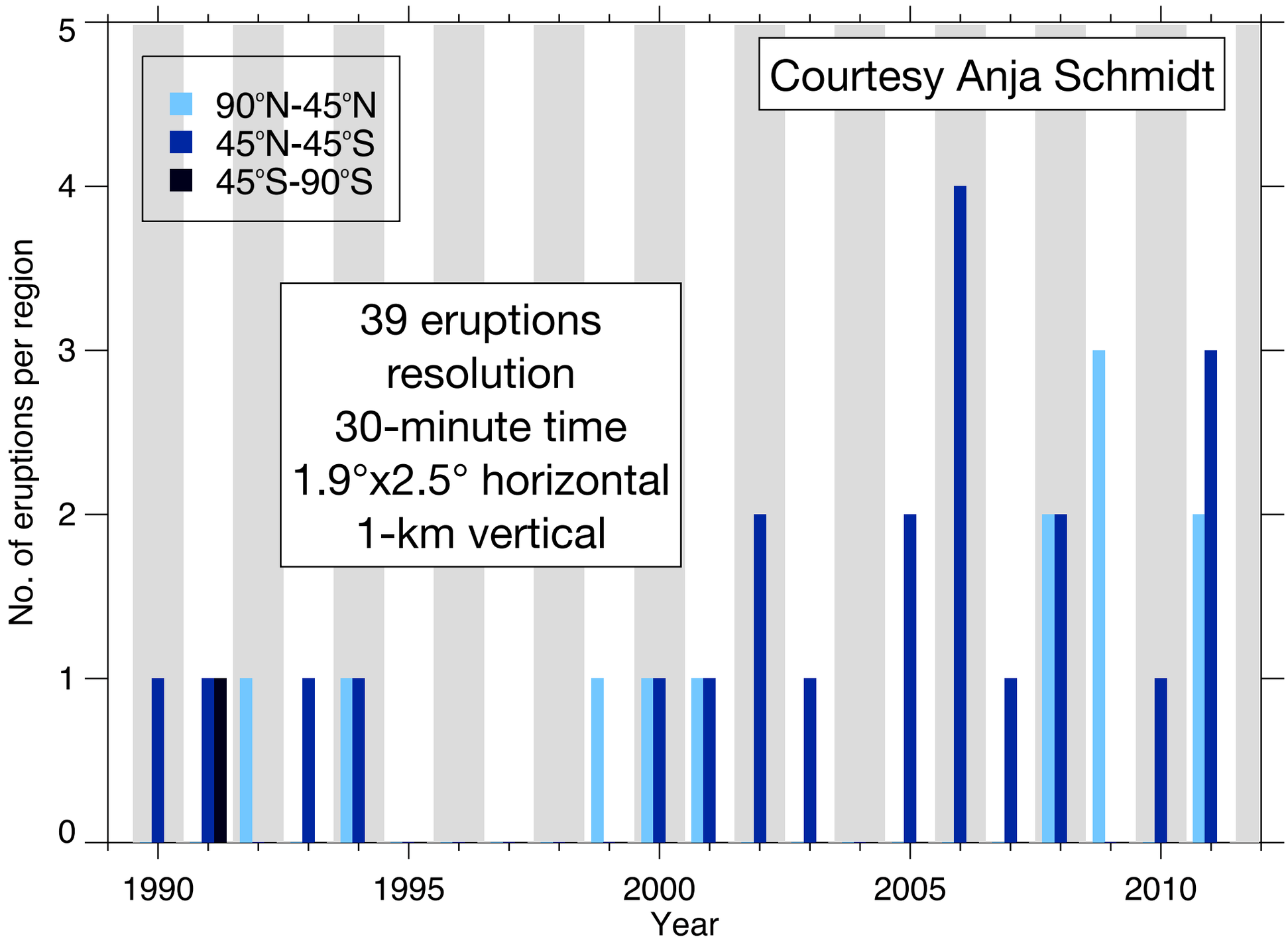


- New LBC file for runs with chemistry (WACCM, CAM-chem)
- External forcing files developed for SO_2 produced from OCS oxidation in CAM without chemistry: 1850, 20th Century

3D volcanic strat/trop SO_2 input file for 1990-2011



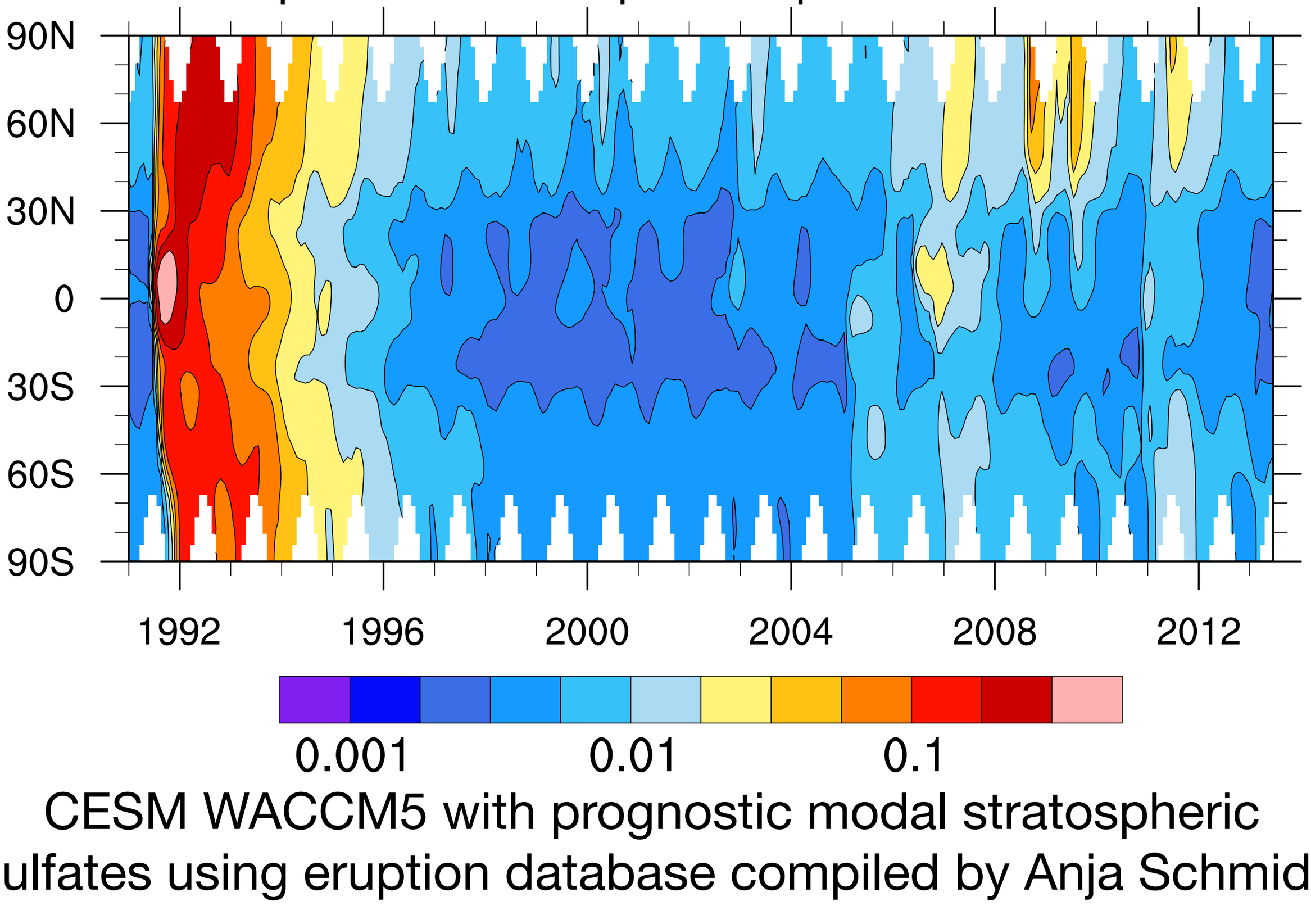
3D volcanic strat/trop SO_2 input file for 1990-2011



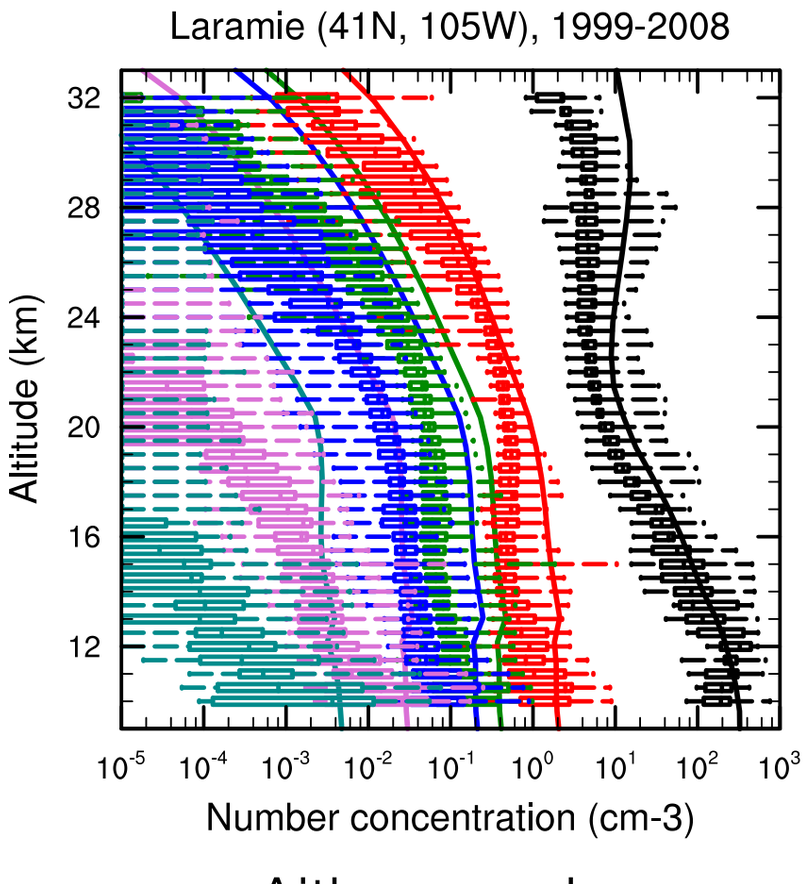
Community Earth System Model

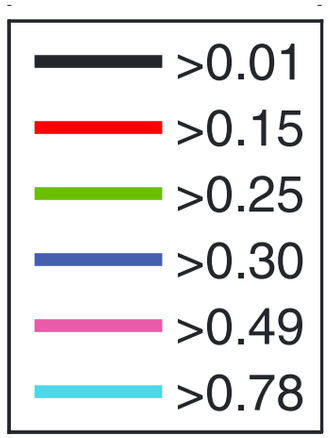
CESM

Stratospheric aerosol optical depth 550 nm



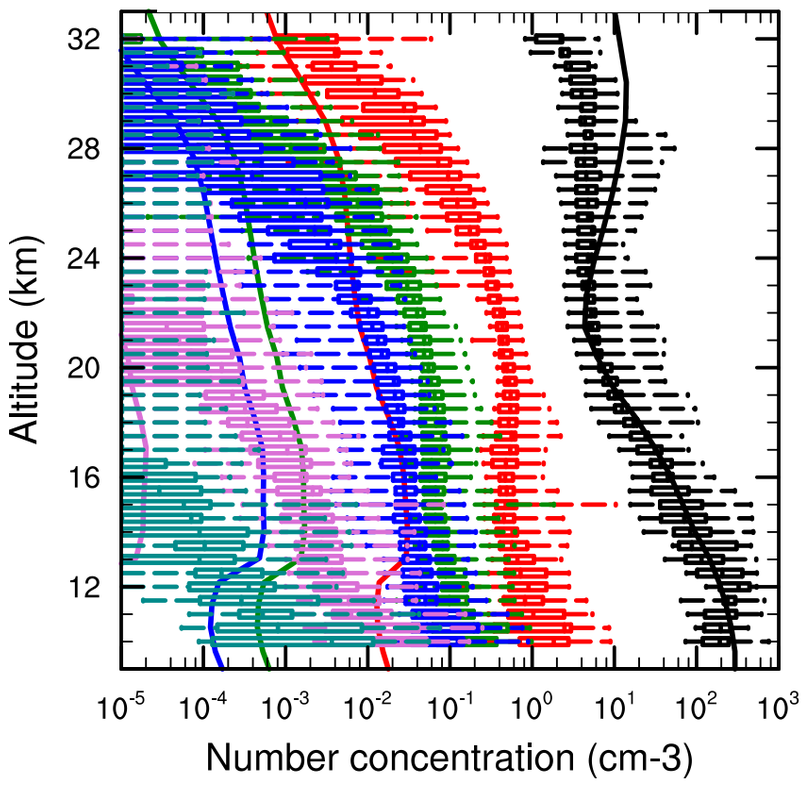
CESM WACCM5 with prognostic modal stratospheric sulfates using eruption database compiled by Anja Schmidt

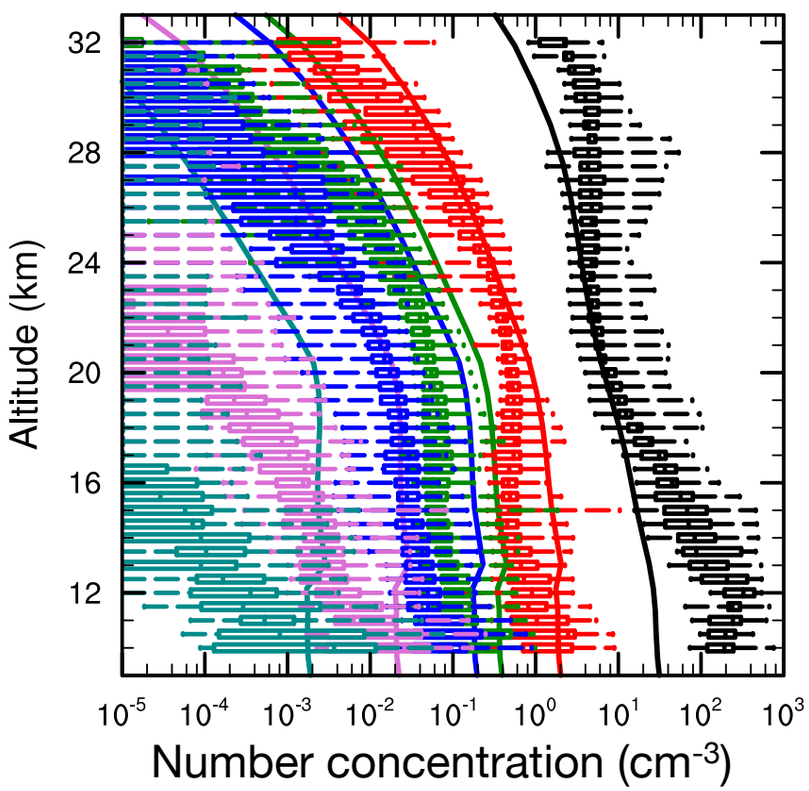


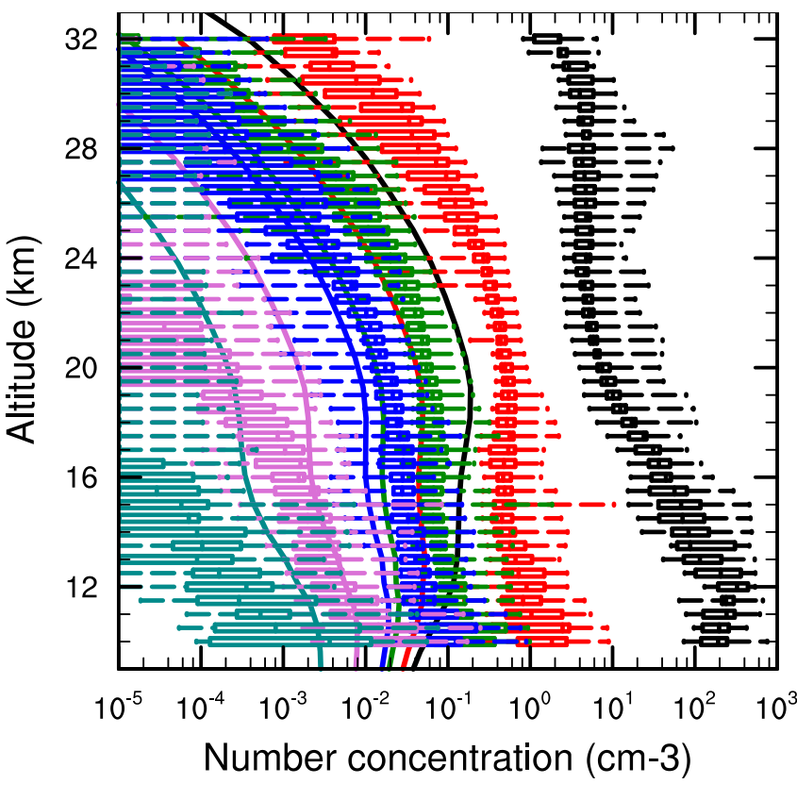


Cumulative number densities (for radii larger than stated radius in μm) calculated by CESM(WACCM5) compared to in situ stratospheric aerosol measurements over the period 1999–2008 at Laramie.

Vertical profiles of particles >10 nm and >150 nm match observations well. MAM retains higher number densities of larger particles in the accumulation and coarse mode than are observed.







SAGE v7
Stratospheric OD
1020 nm

60N
30N
0
30S
60S

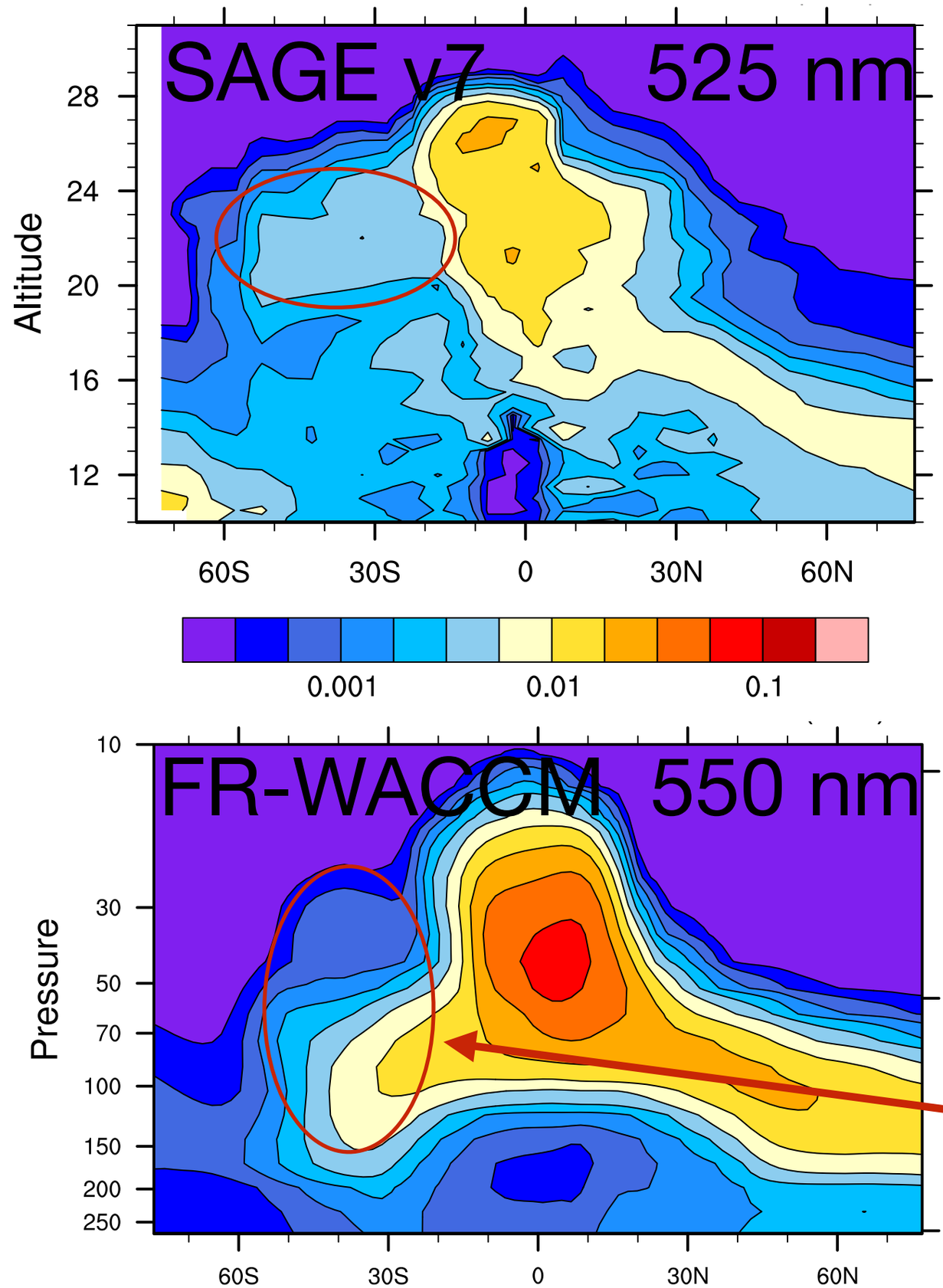
1992
1994
1996
1998
2000

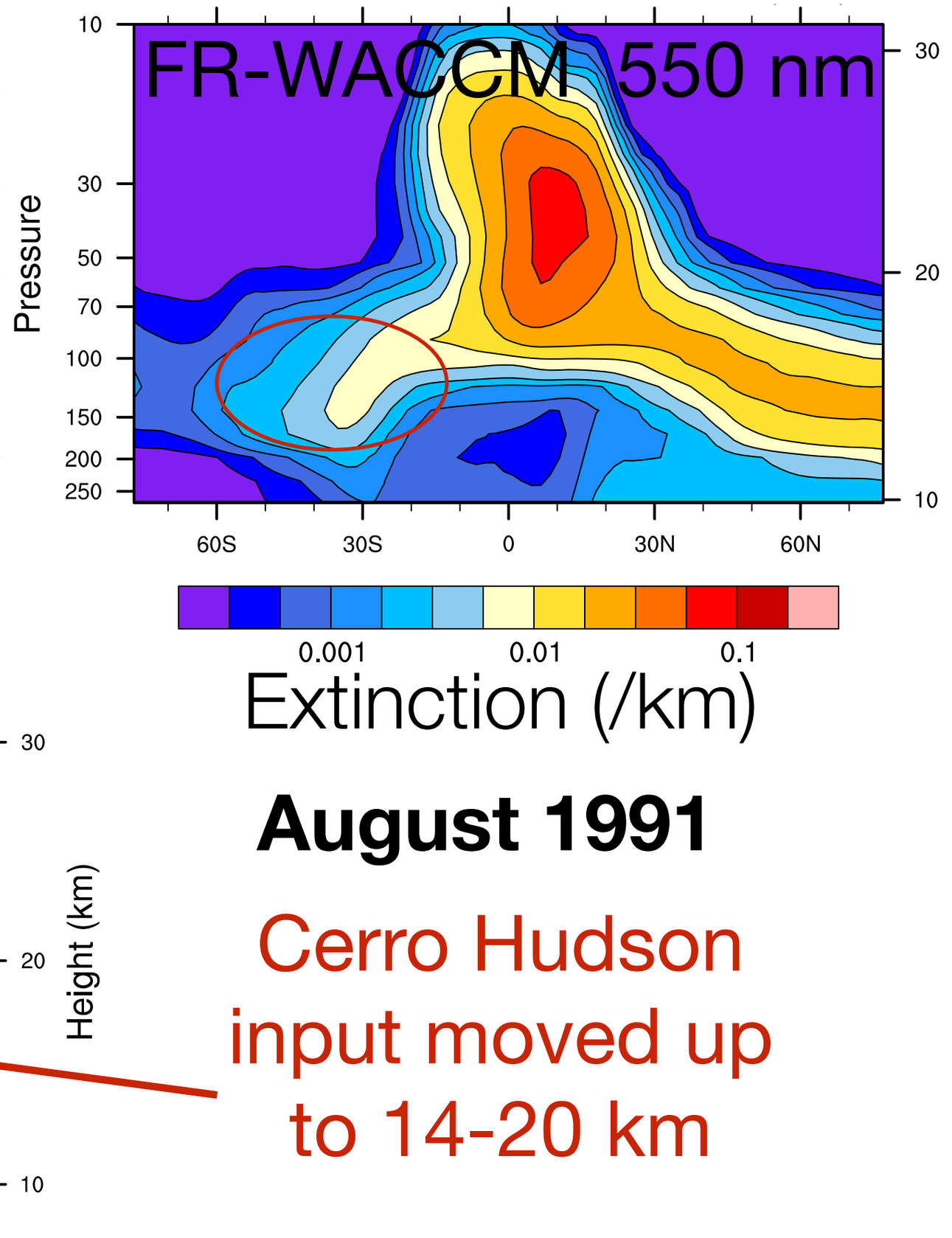
WACCM5
Stratospheric OD
1020 nm

90N
60N
30N
0
30S
60S
90S

1992
1994
1996
1998
2000

0.1
0.01
0.001

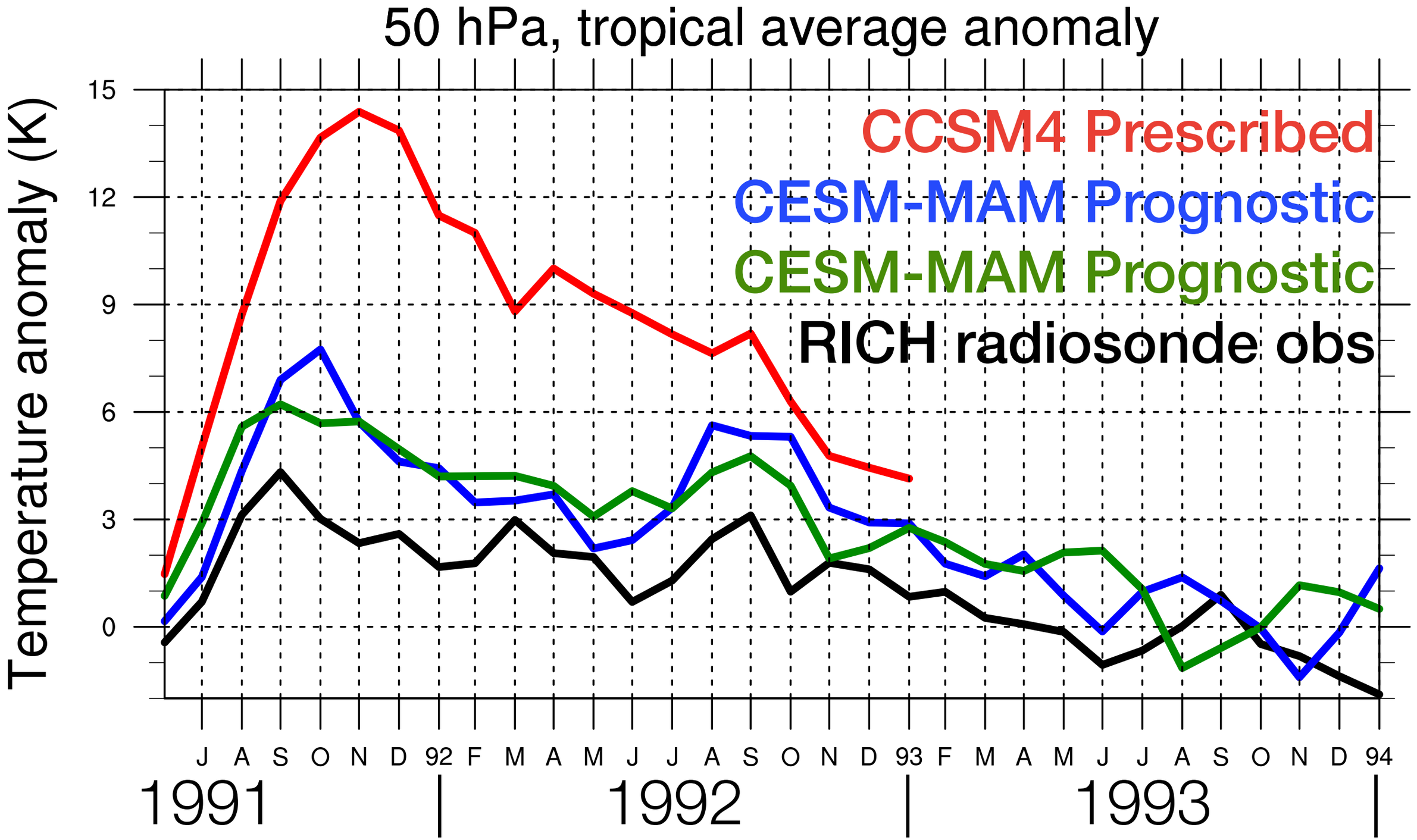




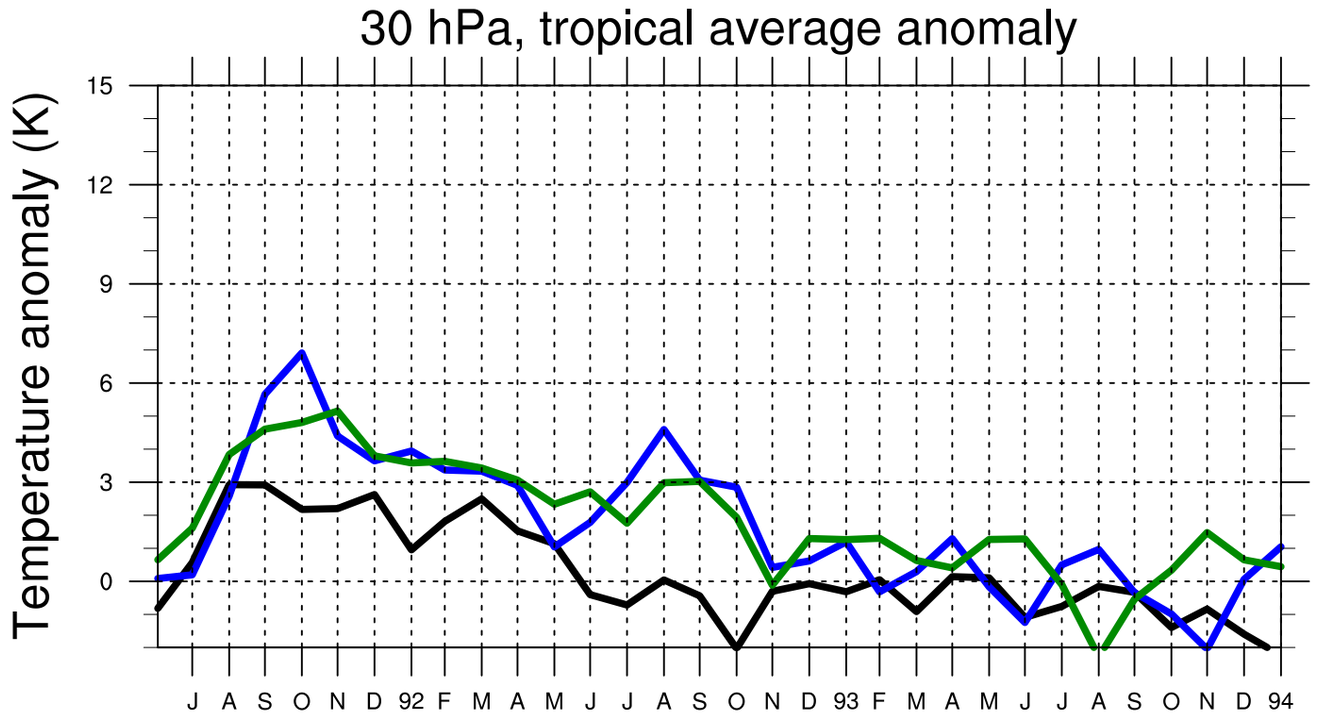
Extinction (/km)

August 1991

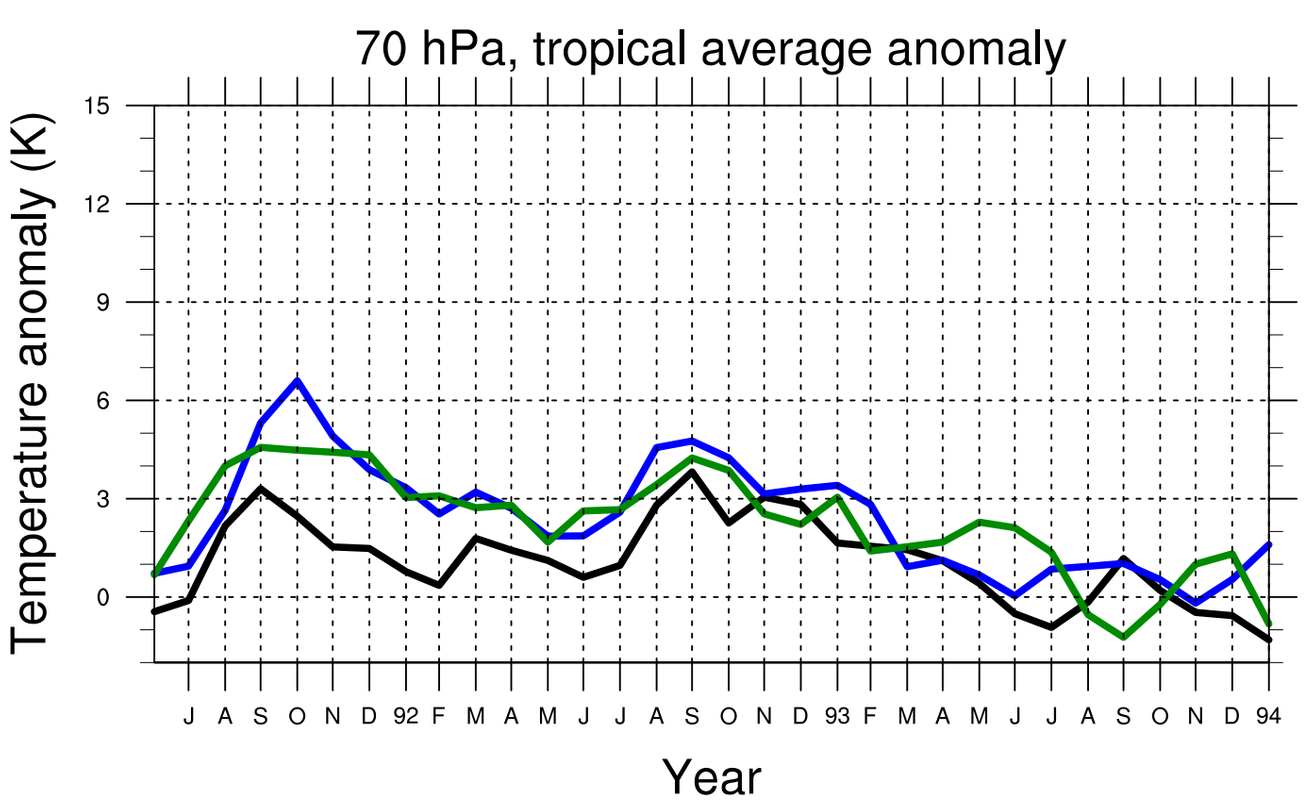
Cerro Hudson input moved up to 14-20 km

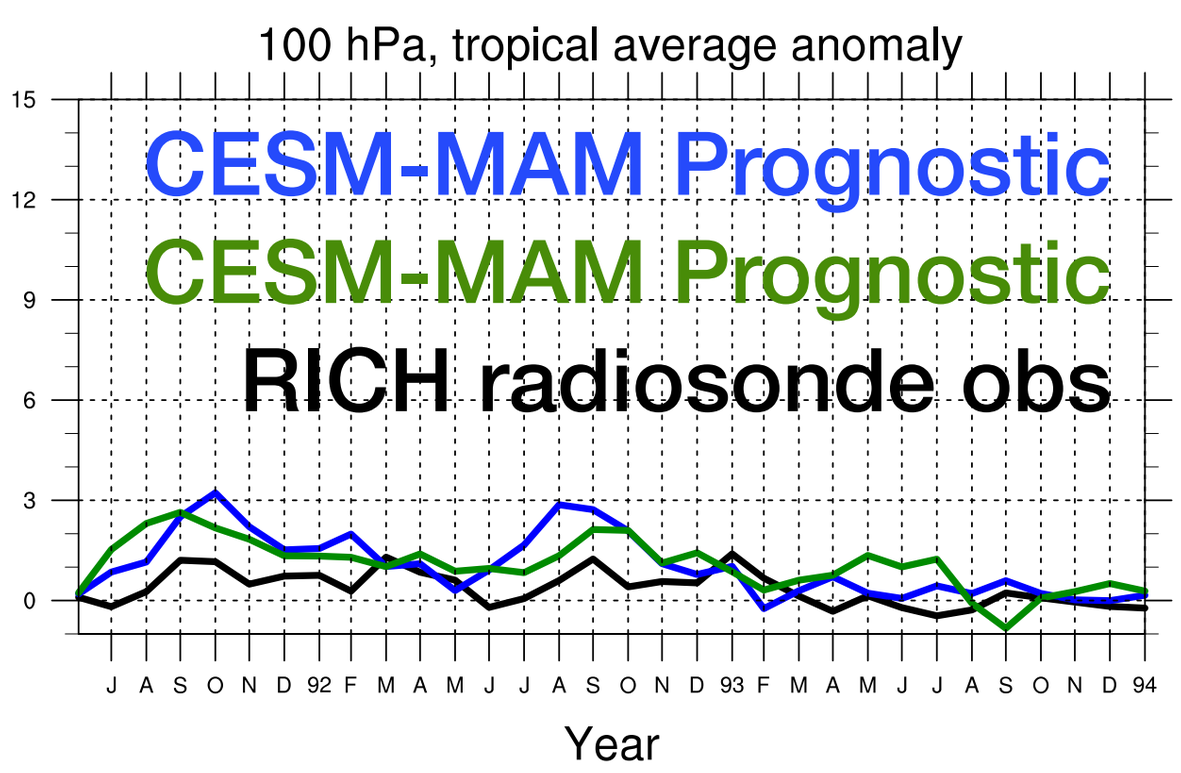


Pinatubo heating in the stratosphere greatly improved over CCSM4 prognostic volcanics.

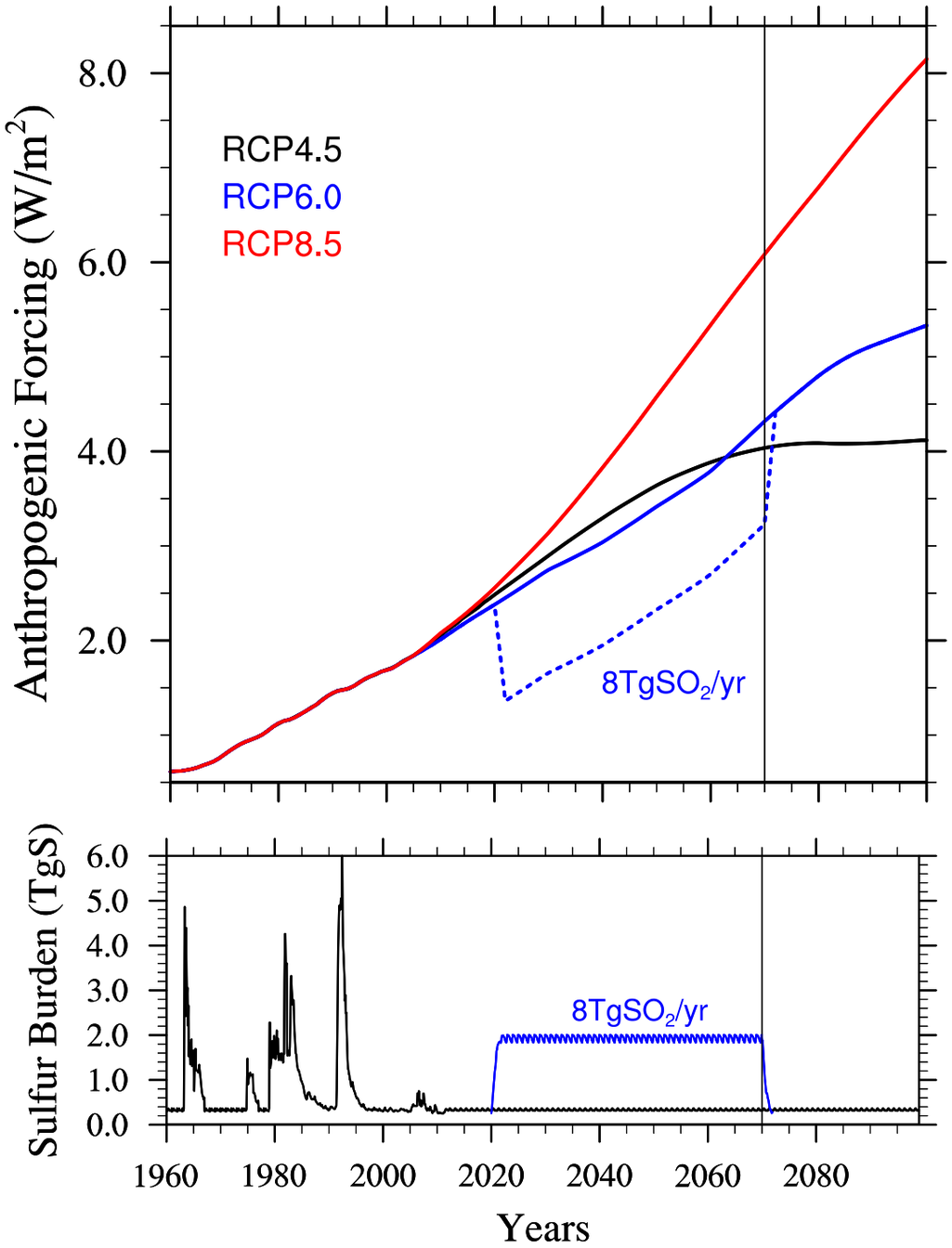


Volcanic temperature perturbation is reasonable from the tropopause up to 30 hPa.

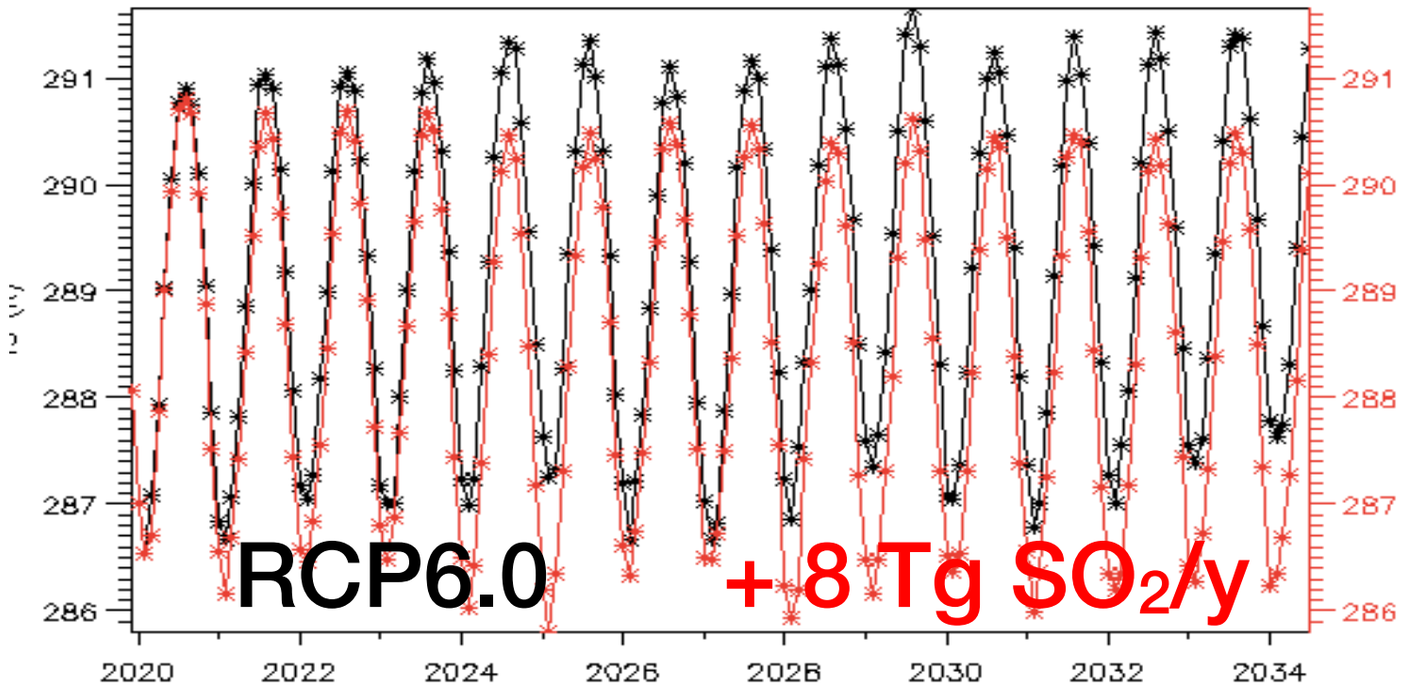




Geoengineering experiment in progress



From Tilmes et al. (GMD, 2015)



- RCP6.0 + 8 Tg SO_2/year, after Tilmes et al. (GMD, 2015)
- Global average stratospheric visible AOD increases over first 2 years, then steady at 0.14-0.15
- Global warming of ~1.2°C offset in the first 15 years

Summary: prognostic stratospheric sulfates with MAM

- Prognostic modal volcanic aerosol is not available for use in CESM.
- A volcanic input file has been developed for 1990-2011, with plans to extend it back to 1850.
- Number densities of small particles compare well to balloon observations from Laramie. This is important because small particles dominate the surface area densities relevant to heterogeneous chemistry in the stratosphere.
- Completed 1990-2012 runs with and without volcanoes. Testing sensitivity to input altitude, latitude, and mass with comparison to SAGE v7 data set of extinction and optical depth.
- Stratospheric heating after Pinatubo is greatly improved over prescribed volcanic sulfate in CCSM4.
- Running geoengineering experiment styled after Tilmes et al. (GMD, 2015): RCP6.0 with 8 Tg SO_2/year for years 2020-2070, compared to RCP6.0 control