

New prescribed and prognostic volcanic and stratospheric aerosol options in CESM

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WACCM

Whole Atmosphere
Community Climate Model

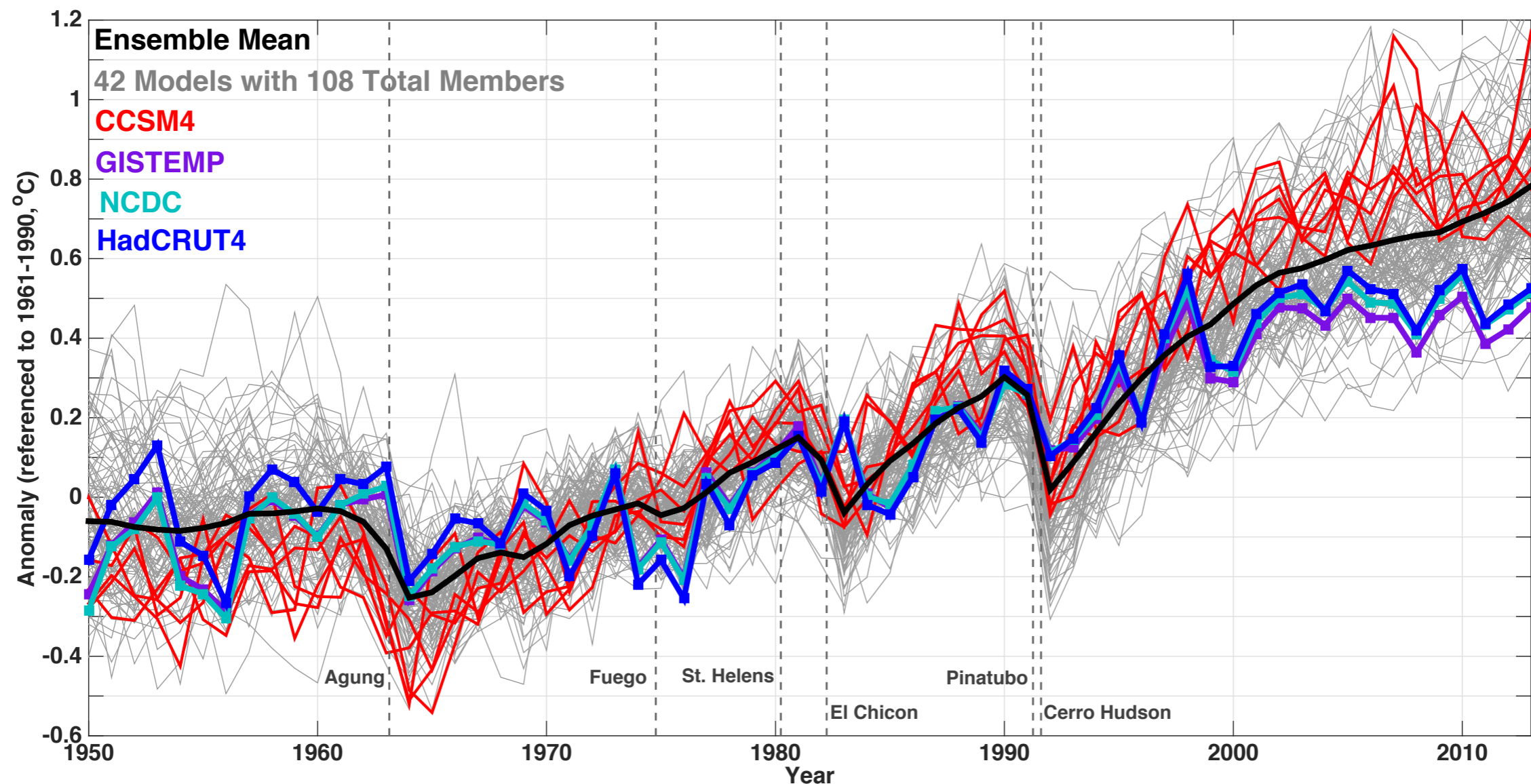


A Consistent Prescription of Stratospheric Aerosol for Both Radiation and Chemistry in the Community Earth System Model (CESM1)

R. R. Neely III^{1,2}, A. Conley², F. Vitt², and J. F. Lamarque²

Geosci. Model Dev. Discuss., 8, 10711–10734, 2015
www.geosci-model-dev-discuss.net/8/10711/2015/
doi:10.5194/gmdd-8-10711-2015

Motivation: poor global response of most models in CMIP5 to colossal volcanic perturbations to stratospheric aerosol



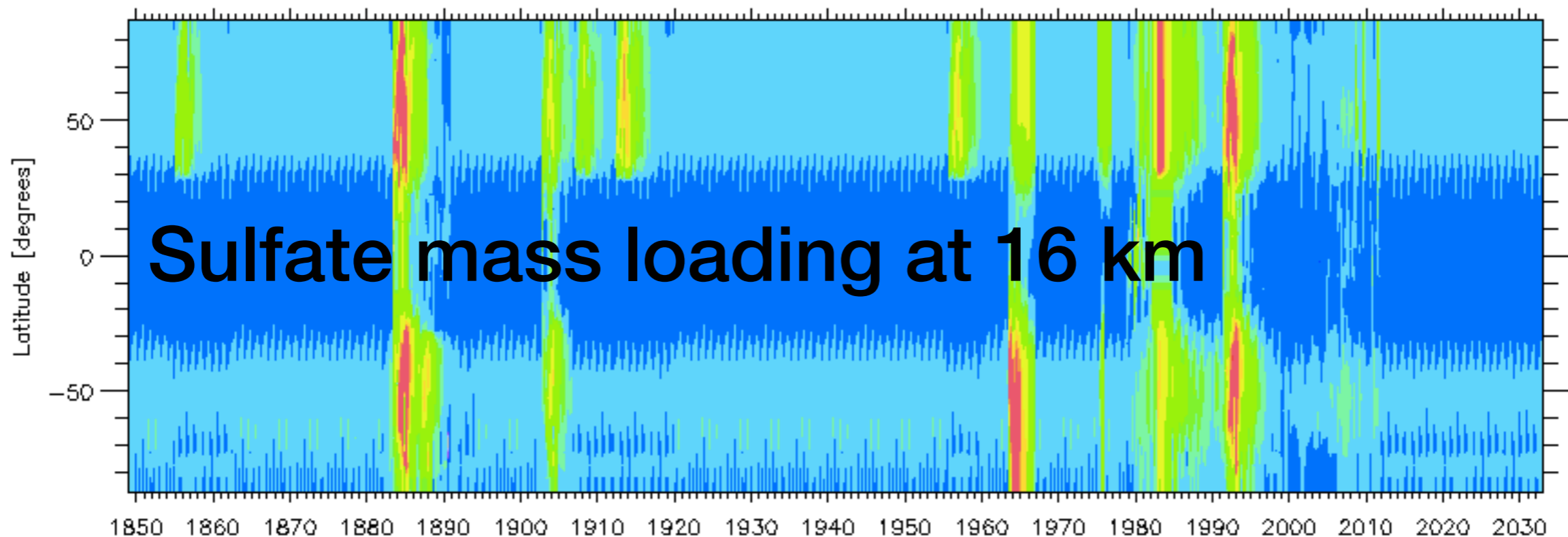
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New prognostic stratospheric aerosol scheme

- accounts for variation in *effective radius* in addition to mass loading
- improved historical volcanic database for 1850–2015 (reduced mass for large eruptions)
- non-volcanic background aerosol included during control simulations and volcanically quiescent periods, including 2016–2100

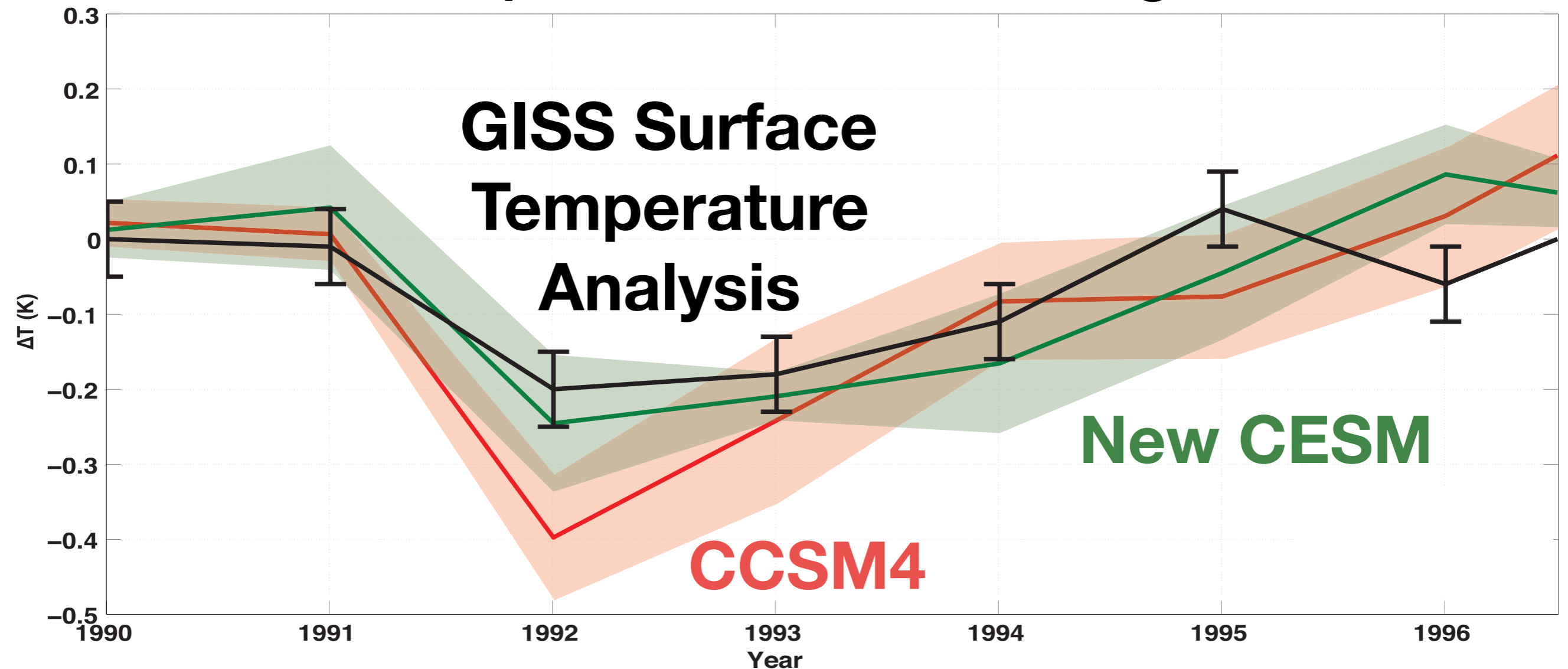


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Improved surface cooling



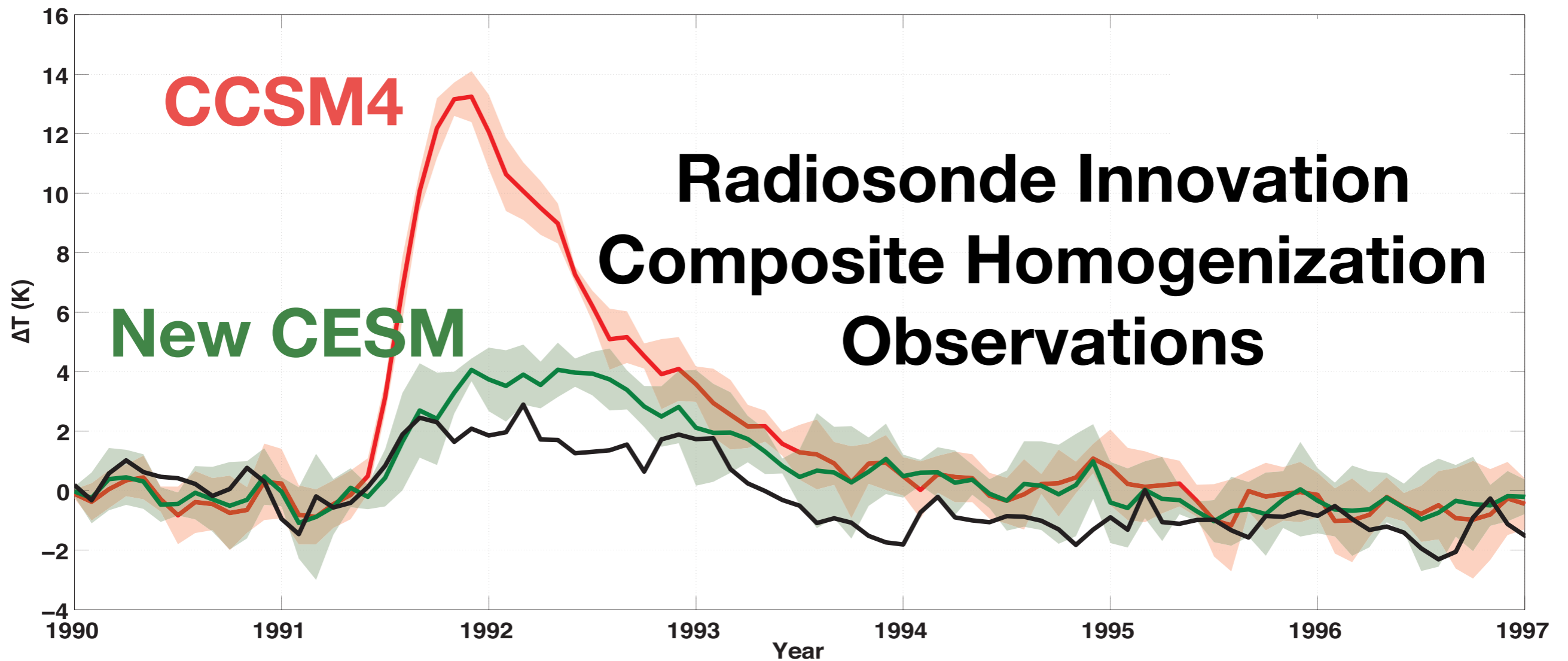
Global annual average surface temperature anomaly

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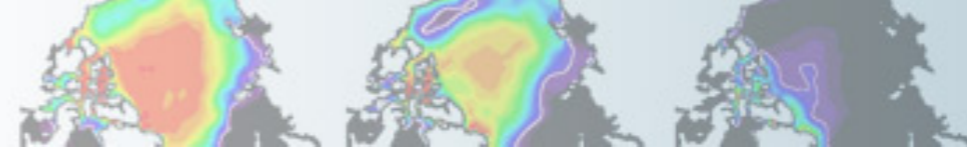
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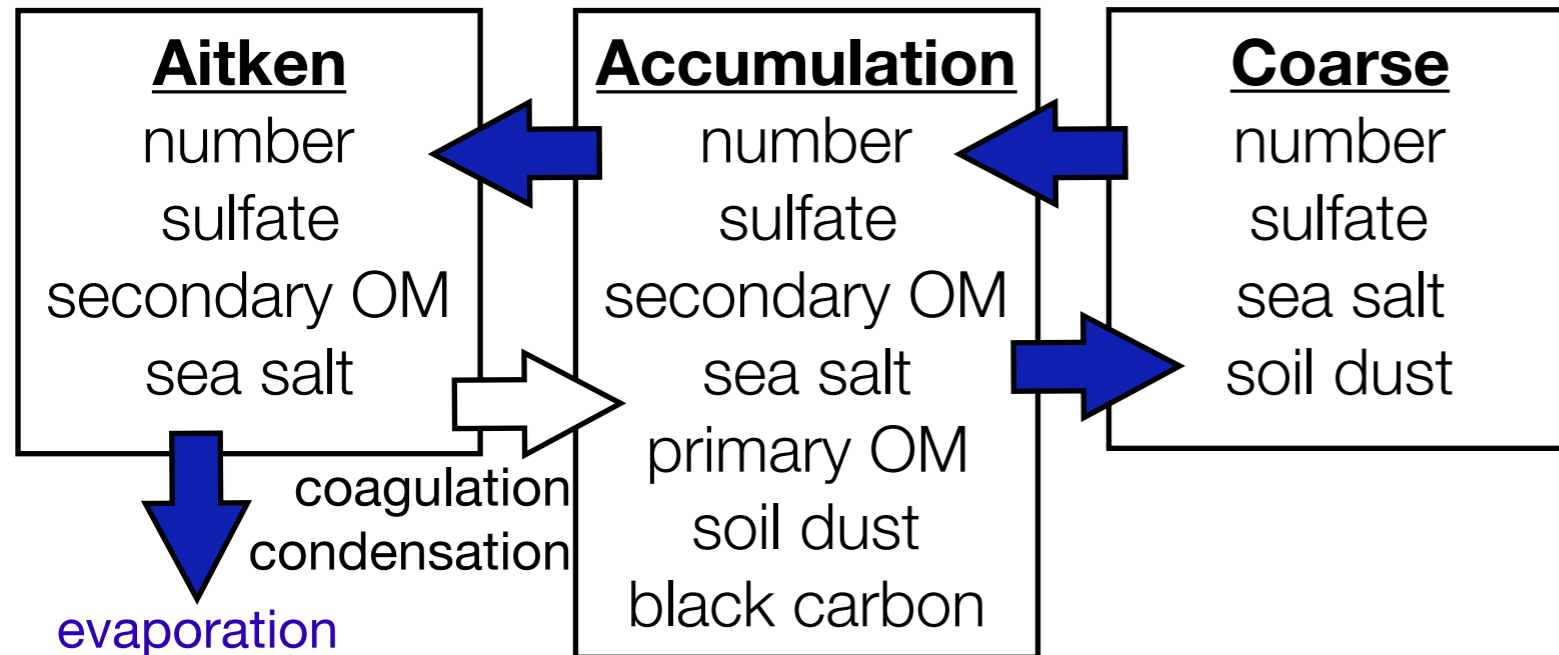
Improved stratospheric heating



Tropical monthly mean temperature anomaly at 50 hPa



Prognostic stratospheric aerosol option: Extend modal aerosol model (MAM3) for stratospheric aerosols



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

Added sulfate evaporation above
tropopause

Added growth between modes

Adjusted diameter ranges, mode
widths

Mode	Aitken	Accumulation	Coarse
Standard MAM3 radius (μm)	0.00435 - 0.026	0.02675 - 0.22	0.5 -
geom. std. dev	1.6	1.8	2.0
Modified MAM3 radius (μm)	0.00435 - 0.026	0.02675 - 0.22	>0.22
geom. std. dev.	1.6	1.6	1.2

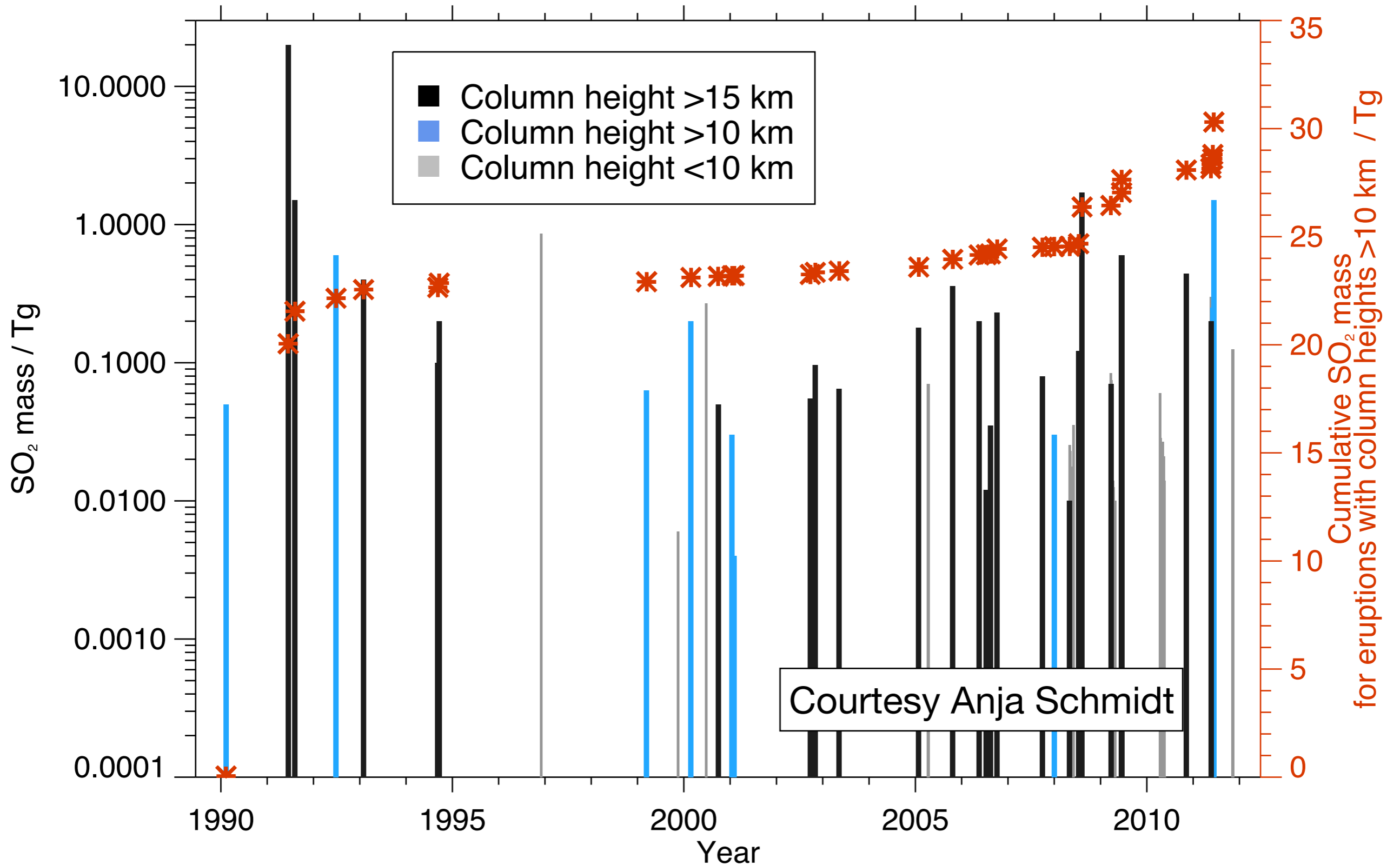
With chemistry: added OCS, S, SO, SO_3

Without chemistry:

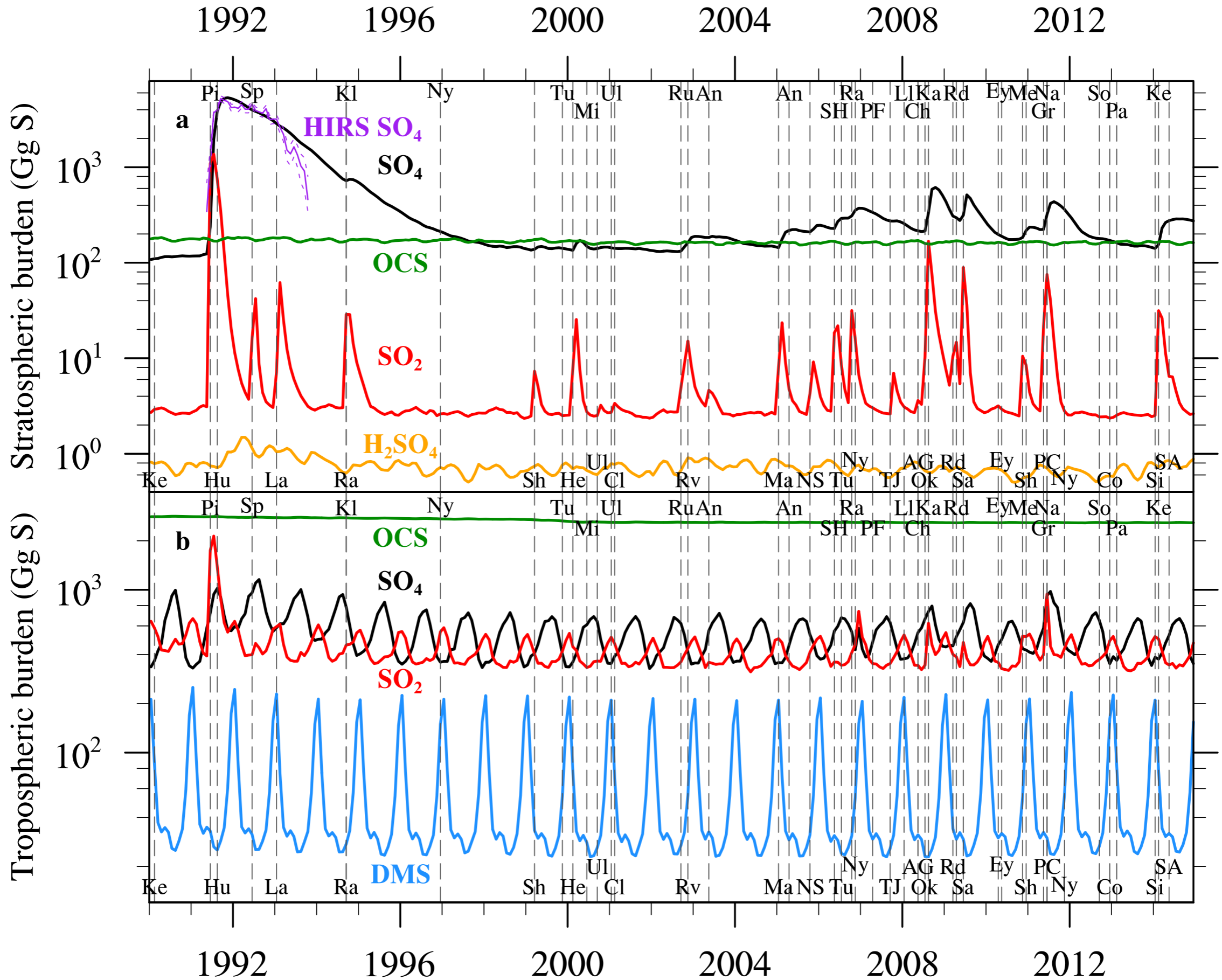
- added SO_2 external forcing from OCS oxidation
- added H_2O external forcing from CH_4 oxidation

VolcanEESM 3D volcanic strat/trop SO₂ input file for 1850-2015 (Schmidt, Neely)

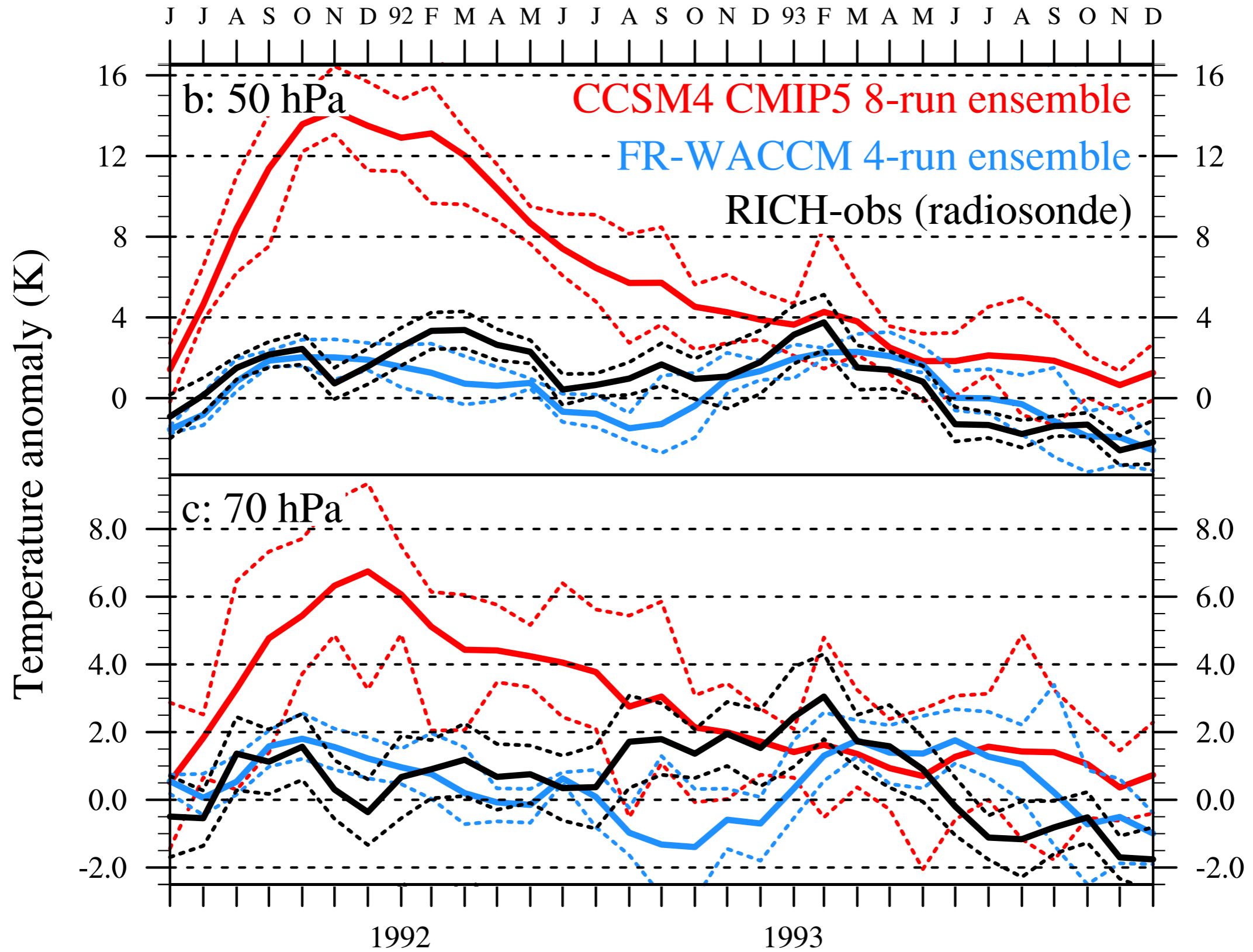
VEI > 2 eruptions since 1990 (with SO₂ reported)



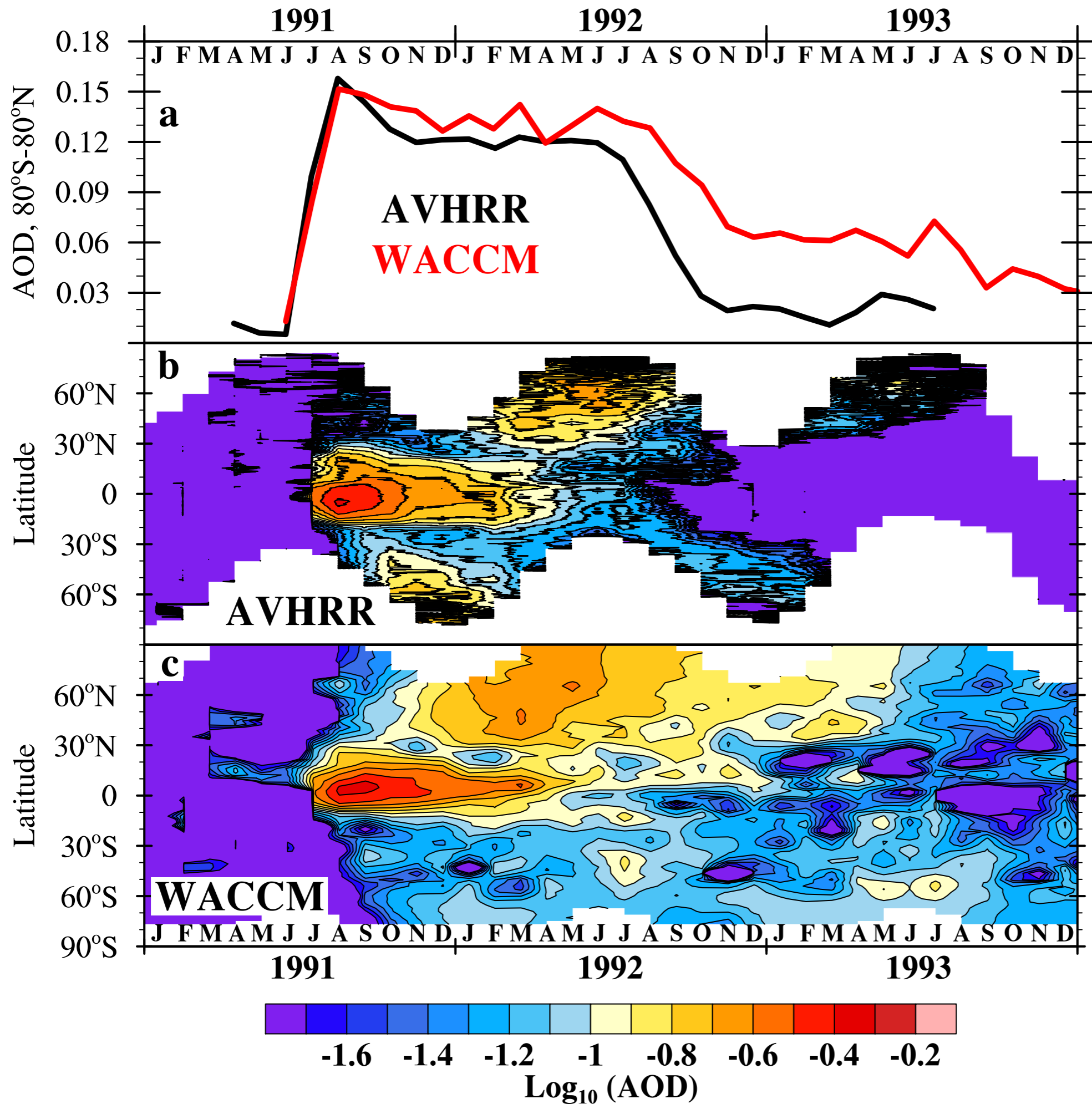
SD-WACCM simulations from "Global volcanic aerosol properties derived from emissions, 1990-2014, using CESM1(WACCM)," Mills et al., submitted to JGR.



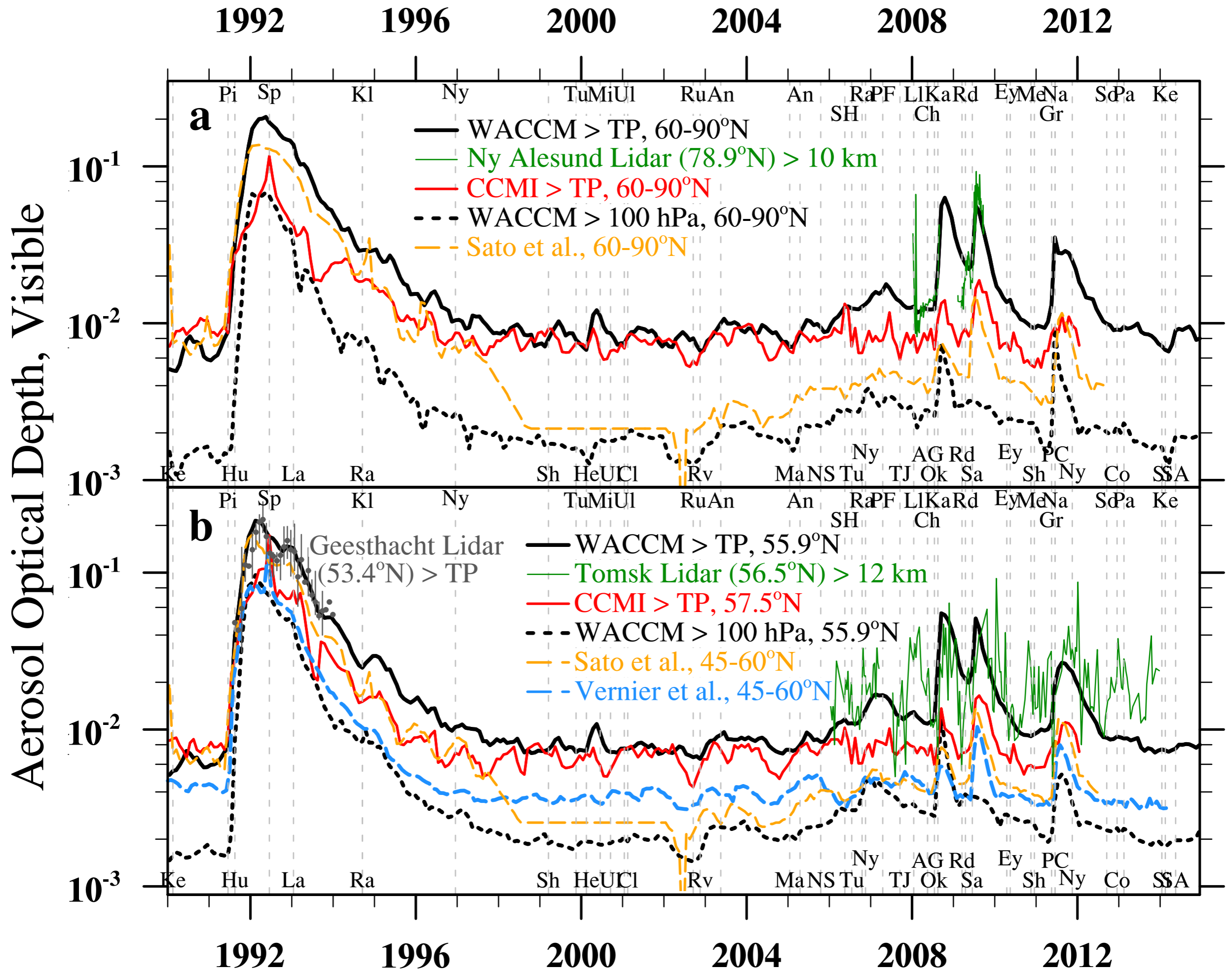
Prognostic aerosols: *Improved stratospheric heating*



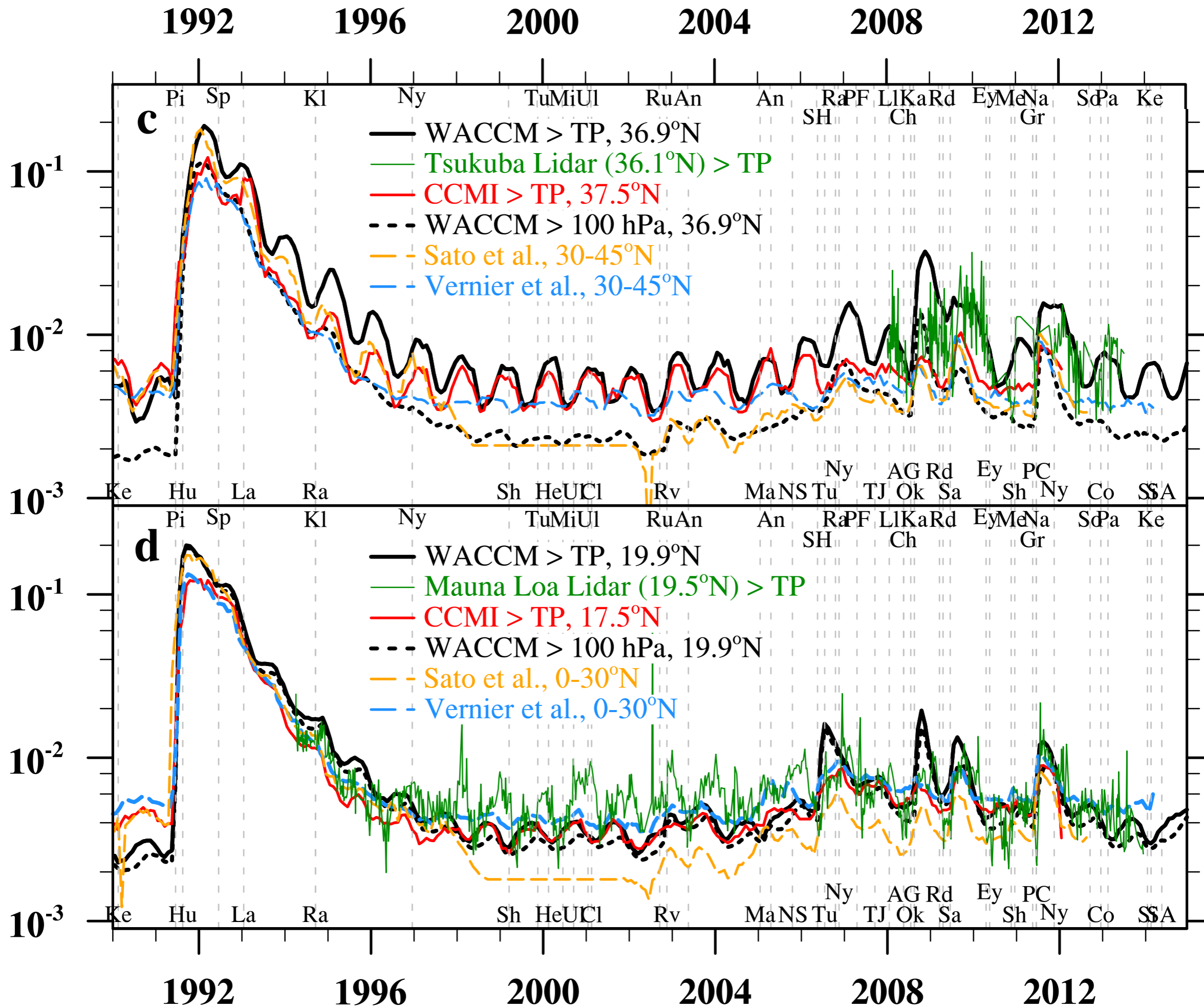
**Tropical temperature anomalies
from Mills et al., submitted to JGR.**

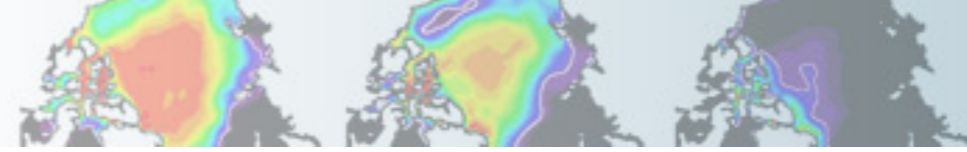


**Total AOD
over ocean
minus
background
from Mills et
al., submitted
to JGR.**



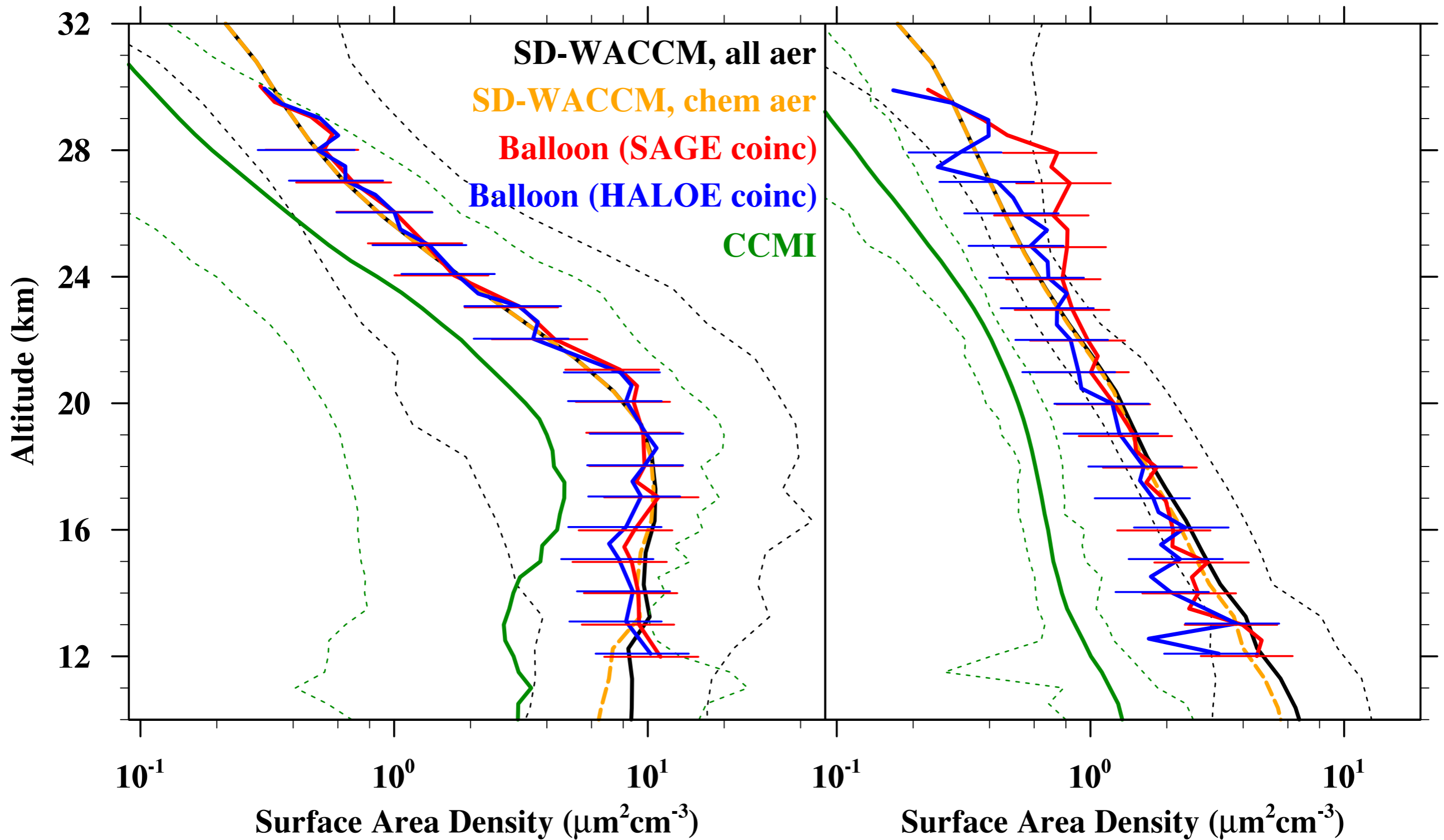
Aerosol Optical Depth, Visible





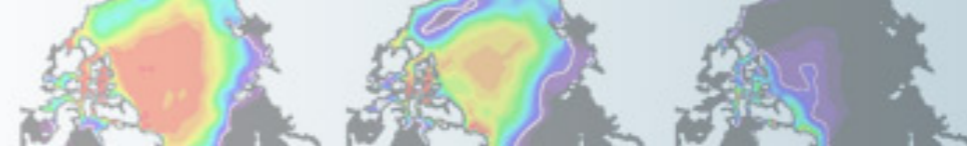
July 1991-December 1996

1997-2005



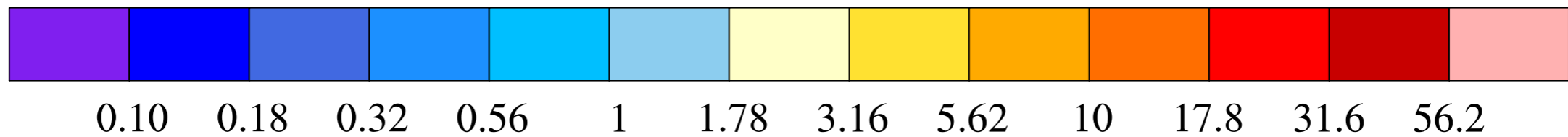
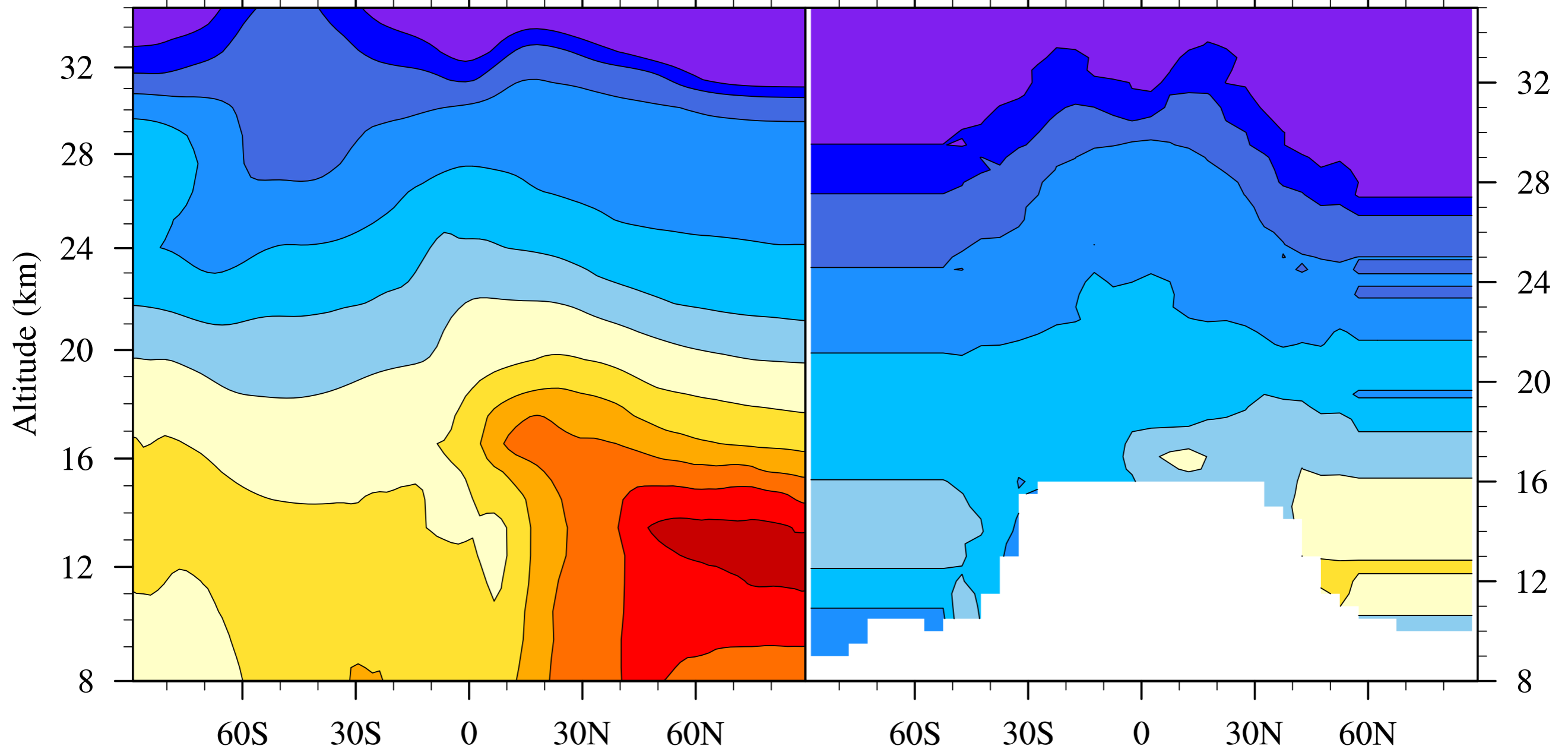
Calculated SAD matches obs. **CCMI SAD misses >60%.**

from Mills et al., submitted to JGR.

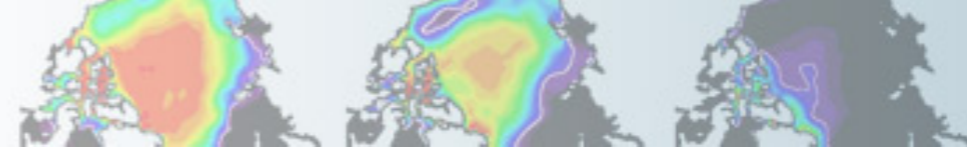


SD-WACCM SAD ($\mu\text{m}^2\text{cm}^{-3}$), July 2009

CCMI SAD ($\mu\text{m}^2\text{cm}^{-3}$), July 2009

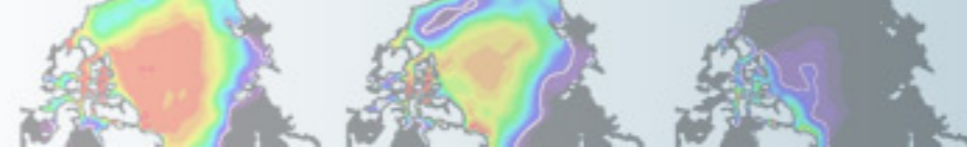


Post-Sarychev eruption: calculated SAD = 10x CCMI
 from Mills et al., submitted to JGR.



New prescribed and prognostic volcanic and stratospheric aerosol options in CESM

- Prescribed stratospheric aerosol based on effective radius, improved mass loading.
- Prognostic modal volcanic aerosol is now available for use in CESM.
- VolcanEESM SO₂ emissions available for 1850-2015.
- Completed 1990-2014 runs with and without volcanoes. Comparison to lidar shows excellent agreement, reveals limitations of satellite data in the lower stratosphere.
- Surface area densities from prognostic aerosols in excellent agreement with Laramie OPC data. In contrast, CCMI-recommended SAD misses 60% of observed SAD in both volcanic and quiescent periods.
- New prescribed and prognostic options greatly improve stratospheric heating after Pinatubo compared to CCSM4.
- CAM may be run with prognostic stratospheric aerosol, or prescribed based on WACCM prognostic run.



Extra slides



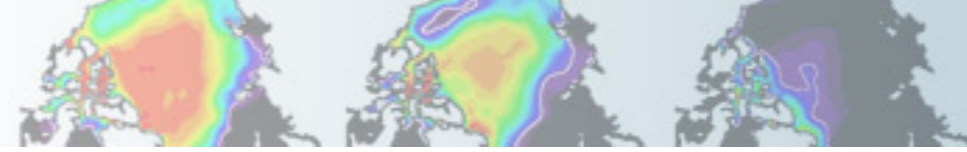
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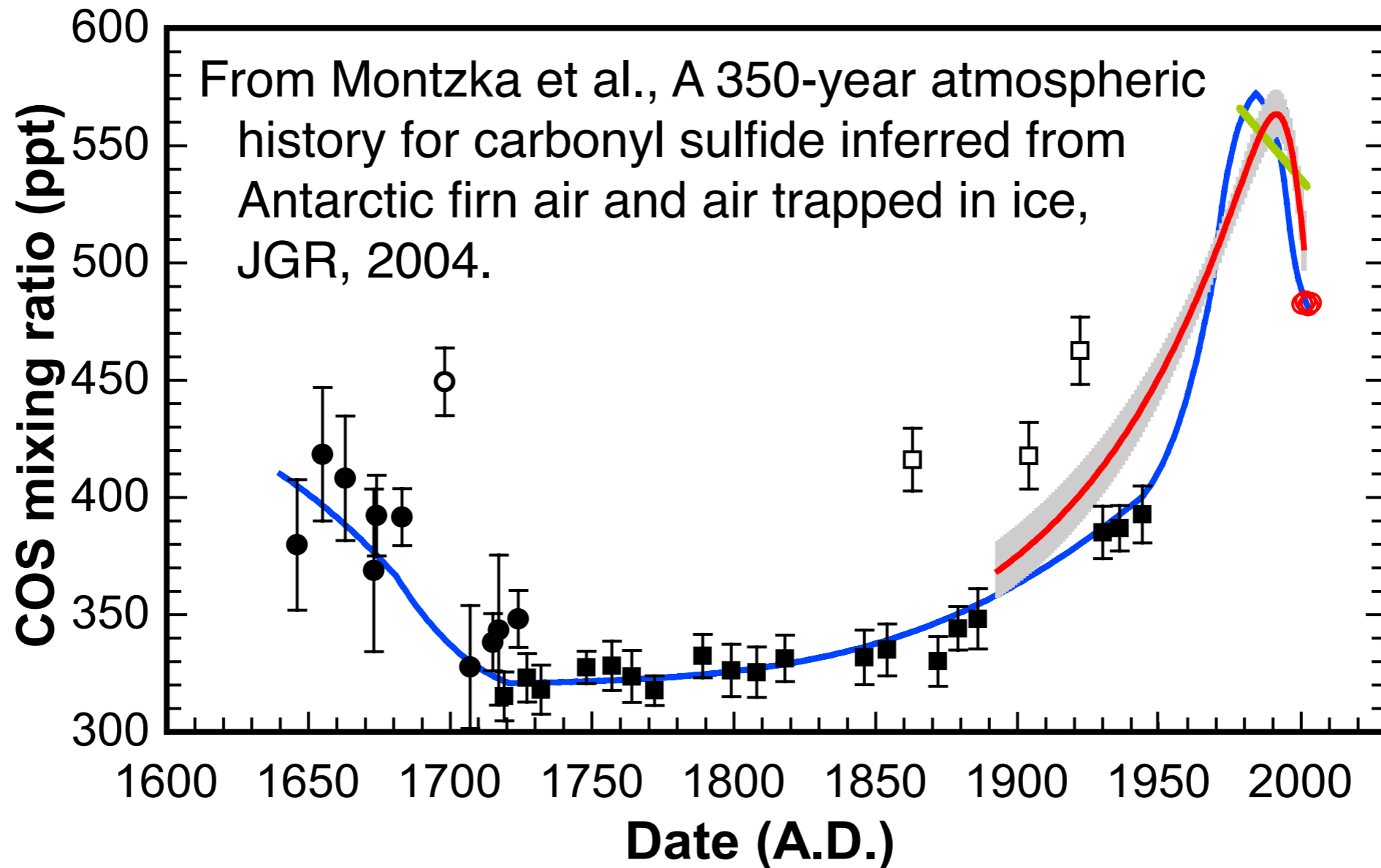
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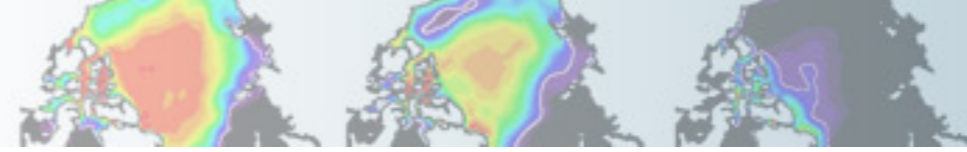




Time-varying lower boundary condition for OCS



- New LBC file for runs with chemistry (WACCM, CAM-chem)
- External forcing files developed for SO₂ produced from OCS oxidation in CAM without chemistry: 1850, 20th Century



3D volcanic strat/trop SO₂ input file for 1990-2011

No. of VEI > 2 eruptions with eruption column heights >10 km

