CESM Sensitivity to Aerosol Forcing in the PETM (55 Million Years Ago)

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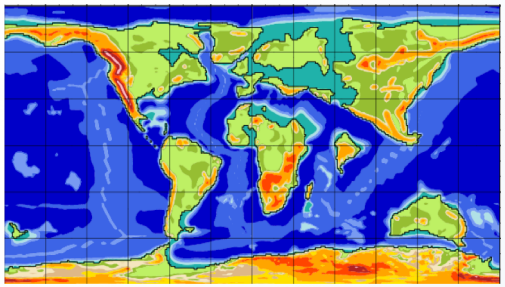
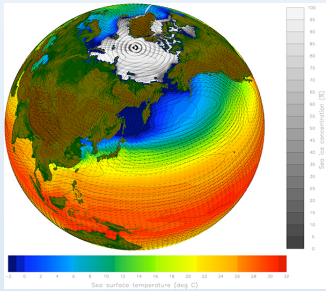


Outline



Our Science Question:

How do different aerosol forcings affect the climate of the Paleocene Eocene Thermal Maximum (PETM)?

- ❑ How do models supplement proxy data?
- ❑ How can we use models and data together to answer questions?

How do models supplement proxy data?

- Proxy data are measurements apply to specific latitude and longitude sites (fossils of flora and fauna, sediments, etc.)
- Models estimate climates a) globally b) regionally diverse areas (topography, biomes) assuming the model has the appropriate resolution
- Models test mechanisms, i.e. What dynamics drive the monsoon? What do different aerosol forcings affect the global climate? Regional climates?

How can we use proxy data and models together?

- Evaluate model simulations at specific paleo latitude and longitude locations
- Models can test theories by synthesizing proxy data
- Model sensitivity tests (to understand mechanisms) can be designed using proxy data and uncertainties around the proxy data

Model Details

Model:

DT-CESM (CAM5) 2deg Fully Coupled

(CESM1.2 release + code modifications for warm worlds)

Boundary Datasets:

DeepMIP protocol

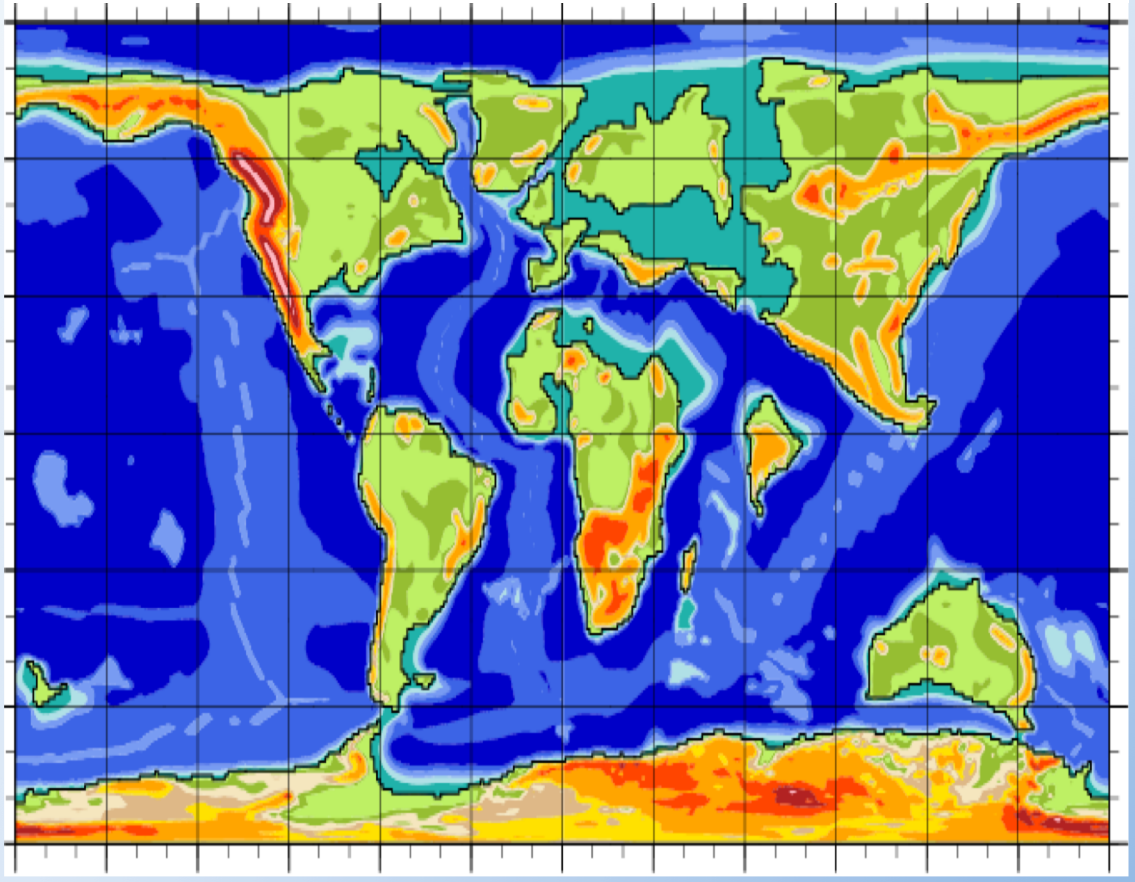
(The Deep-Time Model Intercomparsion Project,

https://www.deepmip.org/)

Aerosol emissions datasets:

Aerosol emission created from CLM4/MEGAN (**M**odel of **E**missions of **G**ases and **A**erosols from **N**ature, Guenther et al. GMD, 2012) based on vegetation type.

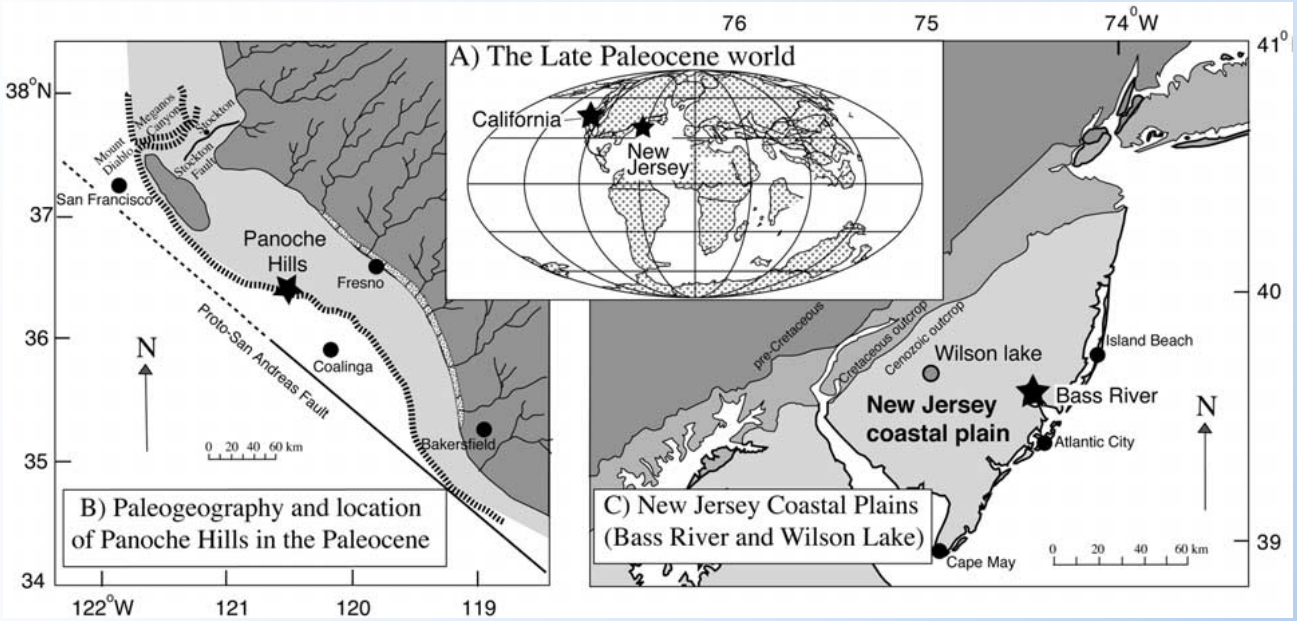
PETM (Paleocene Eocene Thermal Maximum, 55 Mya



Based on Markwick et al.

Proxy Examples

Region	Latitude Range (degrees)	Longitude Range (degrees)	Reference
Bighorn Basin	53-55N	89-90W	[illegible] 2013
New Jersey	41-43N	49-51W	John et al, 2008
Maryland	40-42N	52-54W	Self-Trail et al., 2017
China	30-32N	110-112E	Chen et al., 2016
Spanish Pyrenees	34.5-36.5N	0-2E	Pujalte et al, 2015



Example of proxy data points translated to geography of the time, i.e. "Paleogeography"

Figure 1. Location and paleogeography. (a) Location during the Paleocene-Eocene of the two margins discussed in this article. (b) Paleogeography of the Lodo formation (California) during the late Paleocene to early early Eocene. (c) New Jersey margin sites.

PETM Climate Simulations (4)

Forcing Type	PETM Control Simulation	Low SOAG Simulation	High SOAG Simulation	DMS Sensitivity Simulation
CO_2 (ppmv)	1590	1590	1590	1590
CH_4 (ppmv)	16	16	16	16
[+]SOAG	4X MEGAN	2X MEGAN	8X MEGAN	4X MEGAN
[++]DMS	[+++]Paleotize PI *0.1	Paleotize PI *0.1	Paleotize PI *0.1	Paleotize PI

Additional SOAG-only Sensitivity Experiments (3)

Control except Paleotized SOAG	Control except 0.5 X SOAG MEGAN	Control except 2 X MEGAN

[+]SOAG = secondary organic aerosols, biogenic (Isoprene and Terpene)
[++] DMS = Dimethylsulfide (naturally occurring in the ocean produced by phytoplankton)
[+++]Paleotize = compute zonal averages from Pre-Industrial and distribute by latitude band for new geography

How can we use proxy data and models together?

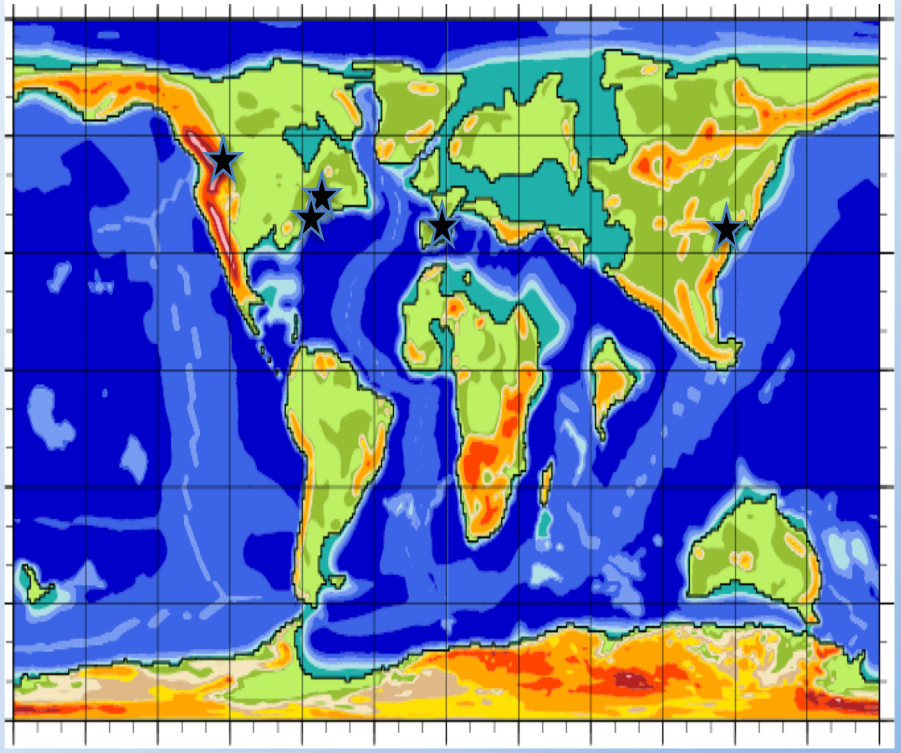
- ❑ Develop forcing (SOAG, DMS) by running experiments and comparing model data to proxy data
- ❑ Which gives the best guestimate of these values for model world?

Precipitation (mm)	Big Horn Basin
Proxy Data	1150* (range 800-1400)
PETM 4xSOAG	875
PETM 2xSOAG	942
PETM 8xSOAG	772
PETM DMS	783

Sfc Air Temp (°C)	Big Horn Basin		
Temperature Type	MAT	WMM	CMM
Proxy Data	20	34	5
PETM 4xSOAG	22	41	8
PETM 2xSOAG	25	46	10
PETM 8xSOAG	**19**	**35**	**4**
PETM DMS	16	34	1

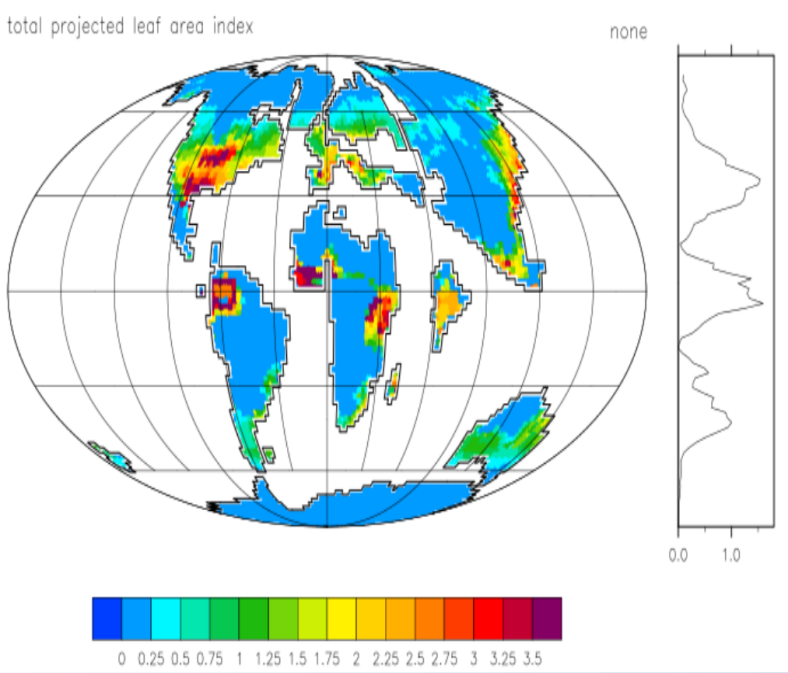
Note: shaded box is best global fit, **Bold** text is best local fit

PETM (Paleocene Eocene Thermal Maximum, 55 Mya



How can we use proxy data and models together?

- Looking at non-traditional variables across different model components may give you an indication of potential model pathologies.
- Example: CAM5 tends to run hot over the land, so by looking at TLAI (Leaf Area Index to see if vegetation/leaves are dying can give you an indication how model is doing!



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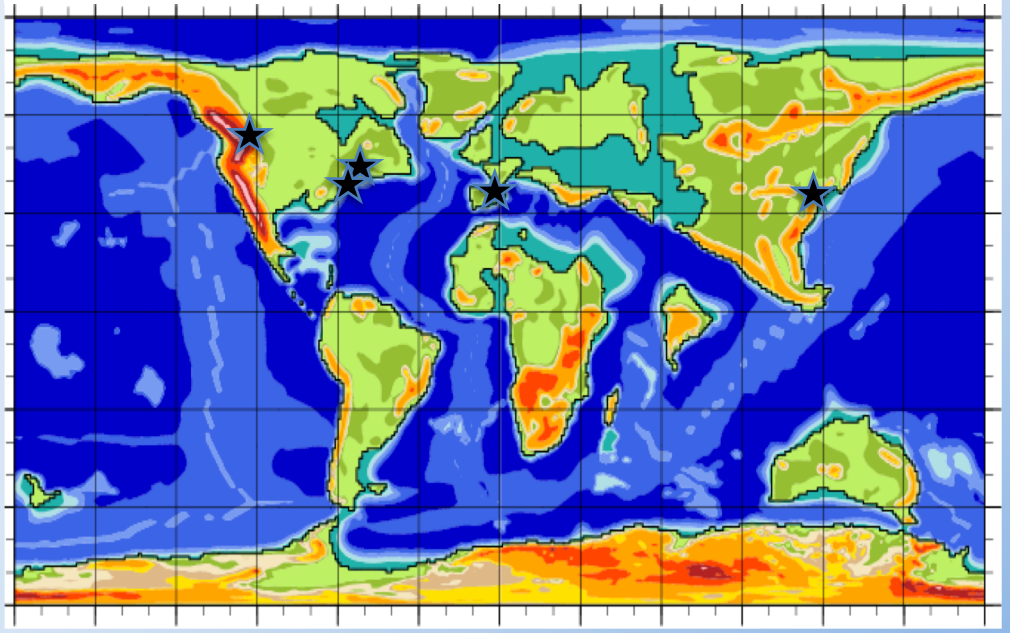


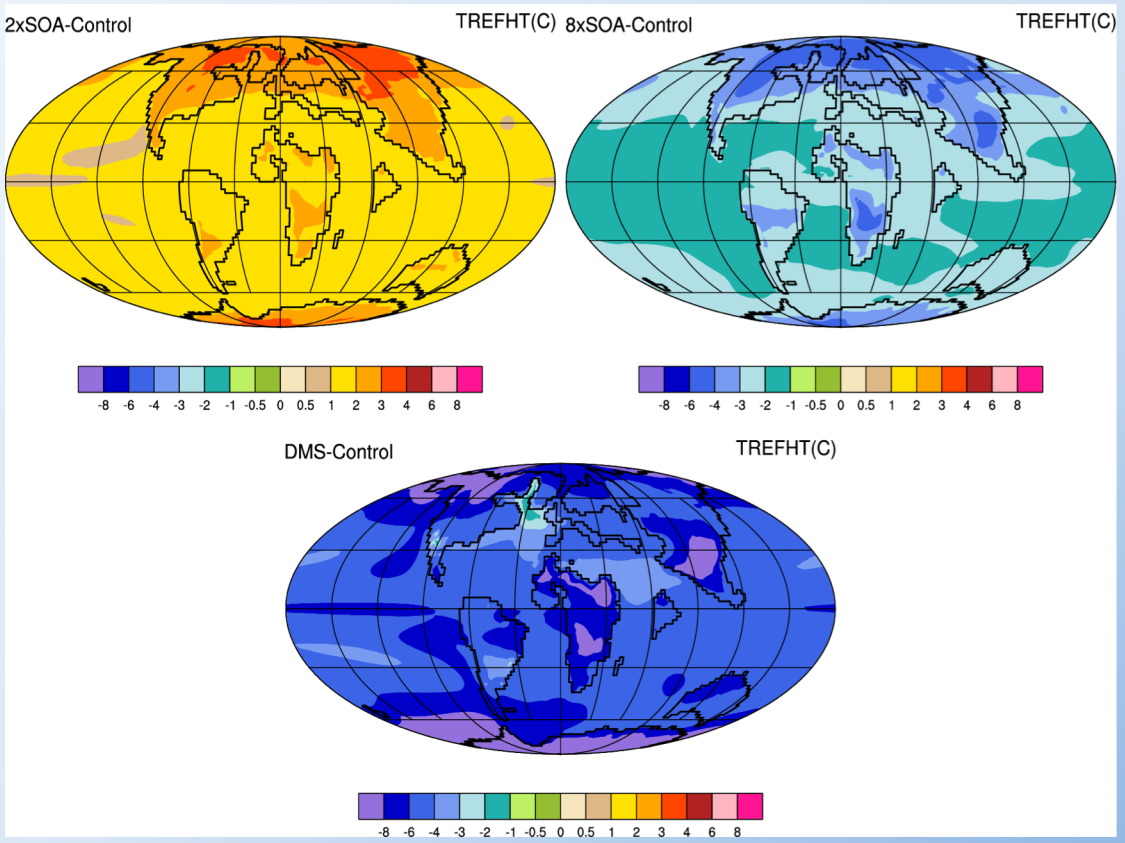
How do models supplement proxy data?

Varying responses to aerosols across the entire globe

Surface Air Temperature

- ❑ More SOAG cools the climate
- ❑ More DMS cools the climate
- ❑ Temperature response due to SOAG is more pronounced at high latitudes
- ❑ Temperature response due to DMS is most pronounced in the N. Atlantic.

Annually Average Differences from PETM Control (4X SOAG)



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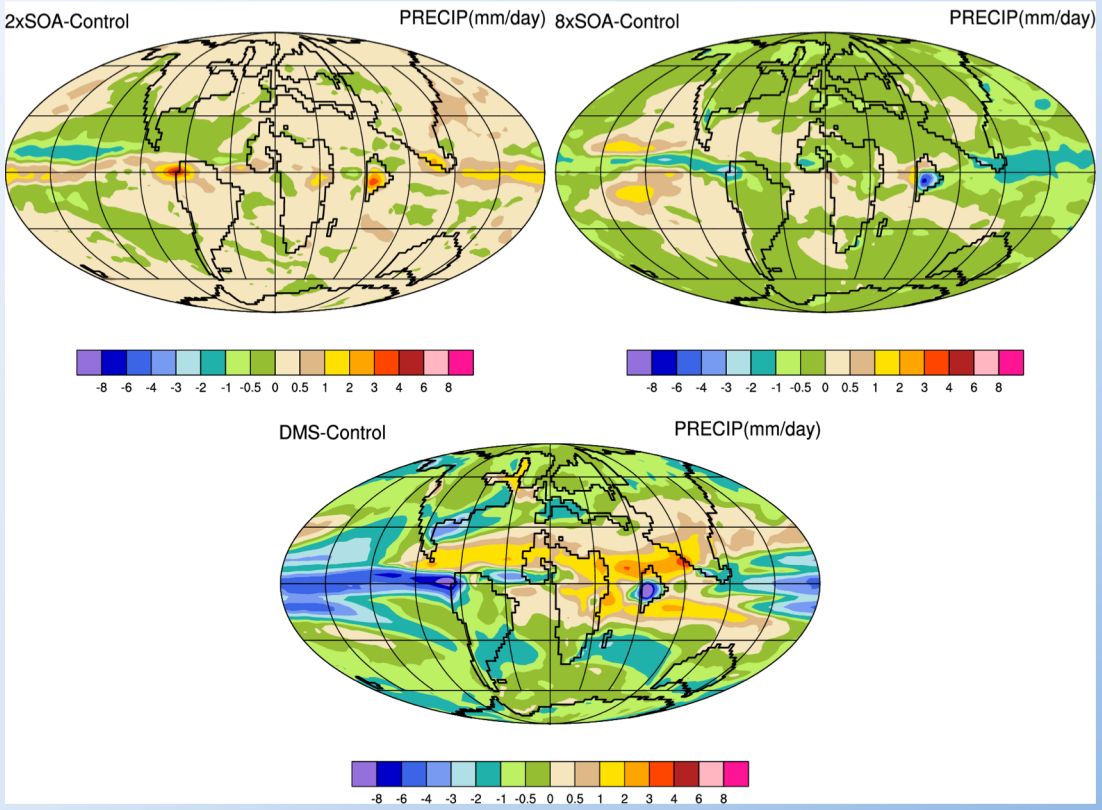


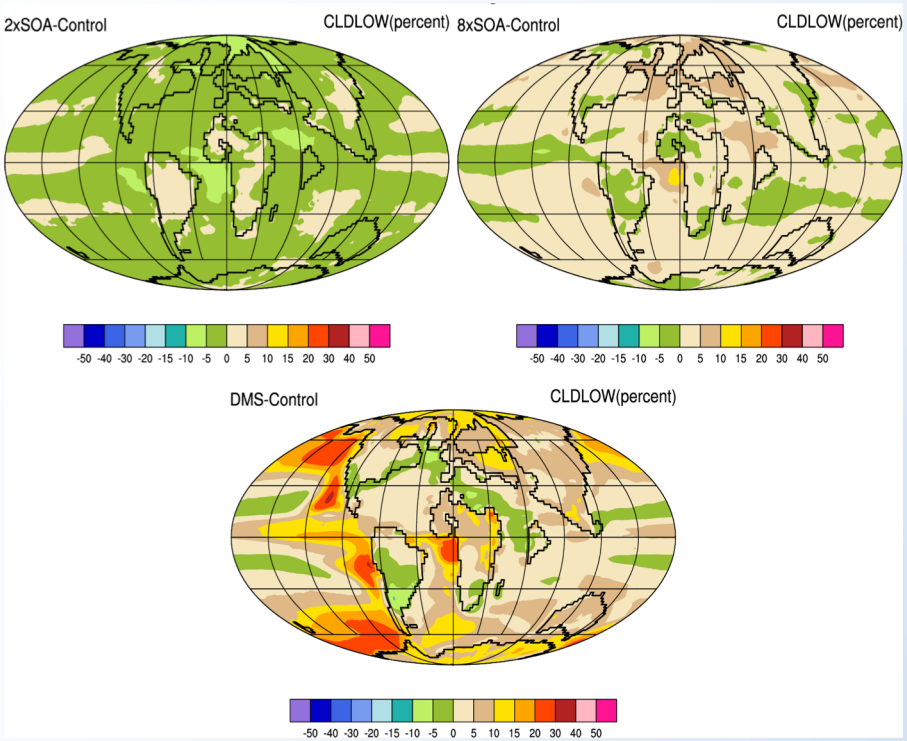
Precipitation

- Precipitation response to SOAG is most pronounced in tropical bands where intense convection occurs.

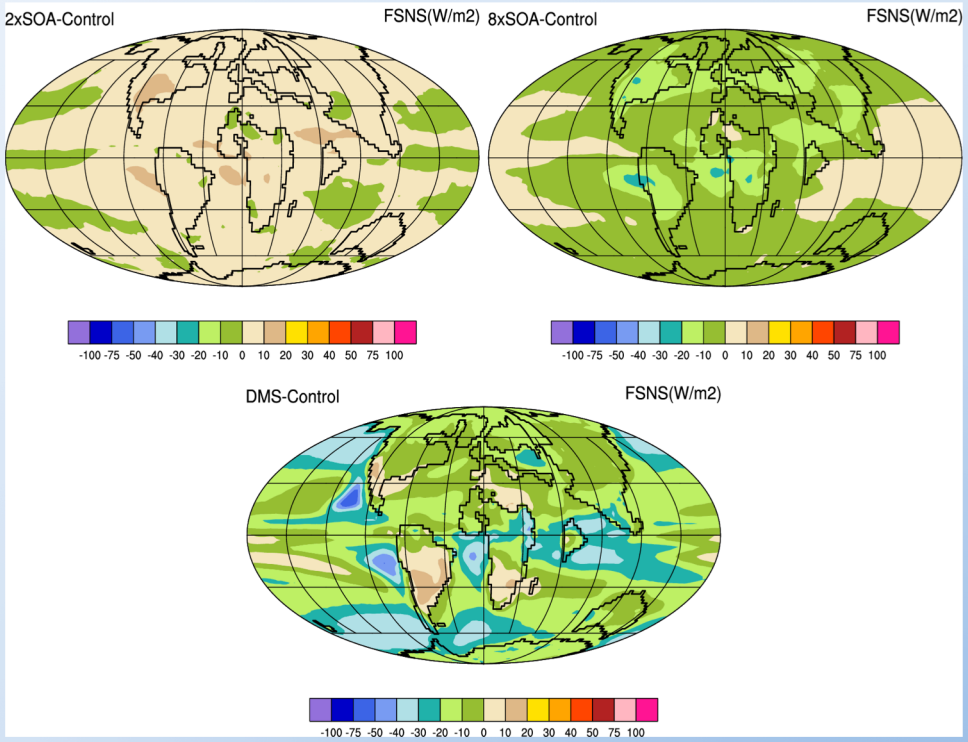
- Precipitation response to increasing DMS is diverse across different sections of the globe, however the largest impacts are again in the deep tropics, and over oceans where DMS is sourced.

How do models supplement proxy data?

Low Clouds



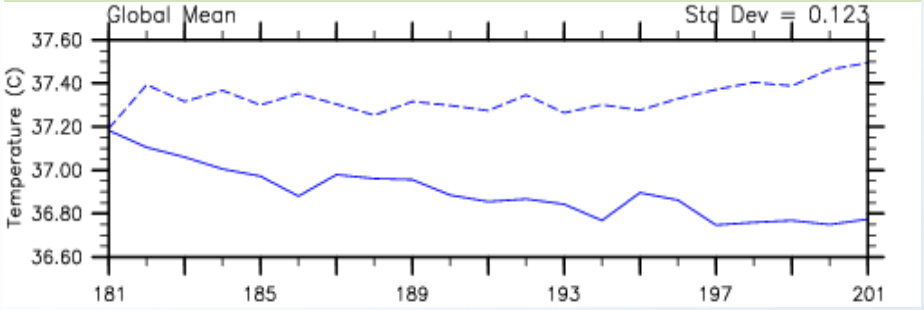
Net Solar at Surface

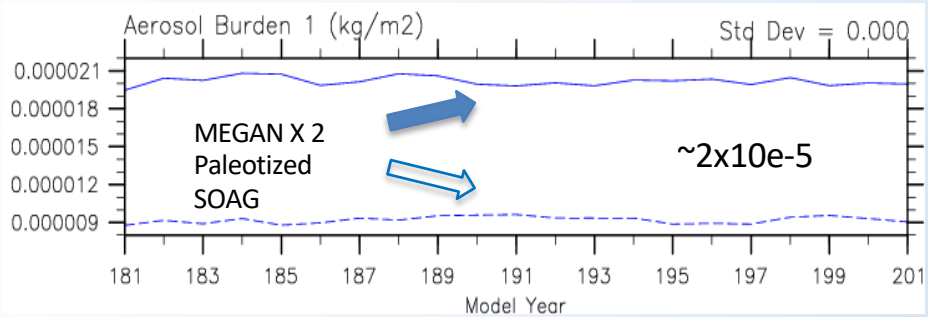


Low clouds and solar radiation at the surface have opposite responses, where there are more clouds due to aerosols, there is less solar reaching the surface.

Understanding How Model Forcing Works: Amount of Aerosols Matter!

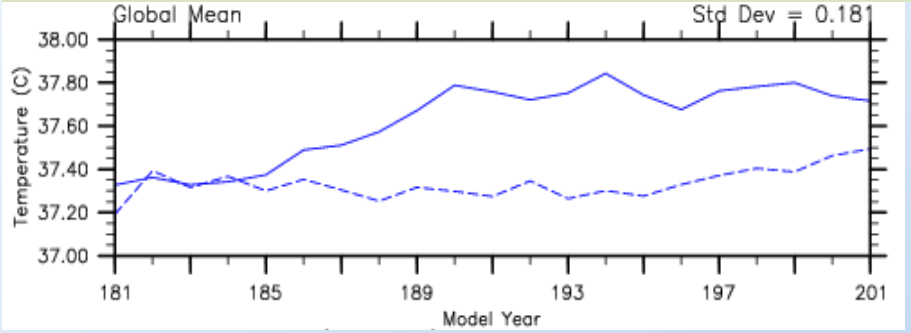
MEGAN X 2 = Cooling compared "Paleotized" aerosols

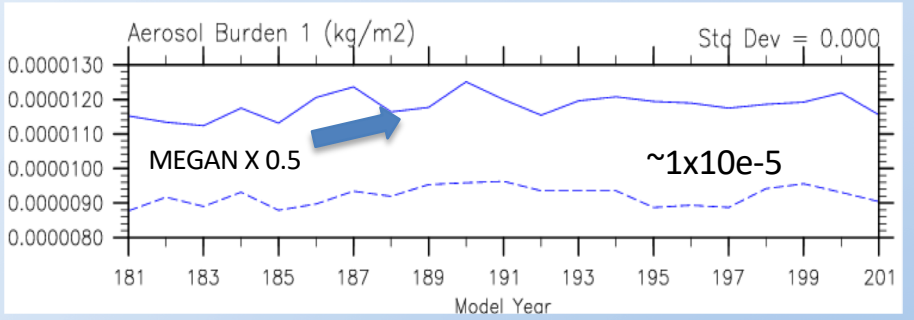




Accumulation (Mode 1) primary aerosol source in MEGANX2

MEGAN X 0.5 = Warming compared to "Paleotized" aerosols





Accumulation in MEGAN X0.5 is half of what it is in X2

Aerosols in CAM5 are divided into three modes:

- ❑ Aitken (small). – Mode 2
- ❑ Accumulation (medium) – Mode 1
- ❑ Coarse (large) -- Mode 3

- ❑ With increased CCN, the transition from Aitken to Accumulation will change the radiative impact.
- ❑ This transition threshold will be different for different periods depending on aerosol type and amount.

Take away points…

- Models and proxies can be used together to create a more comprehensive picture of Earth's climate for paleoclimatic time periods.

- Models and proxies can be used together to diagnose pathologies in the model.

- Aerosol size distributions and amount matter. Simulation design and aerosol forcing should be considered thoughtfully especially for simulations of the deep past.