LME Solar Forcing Experiments: Results from Preliminary Analysis

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Solar Forcing (1)

- PMIP4 SSI (solar spectral irradiance), Vierra et al. 2011

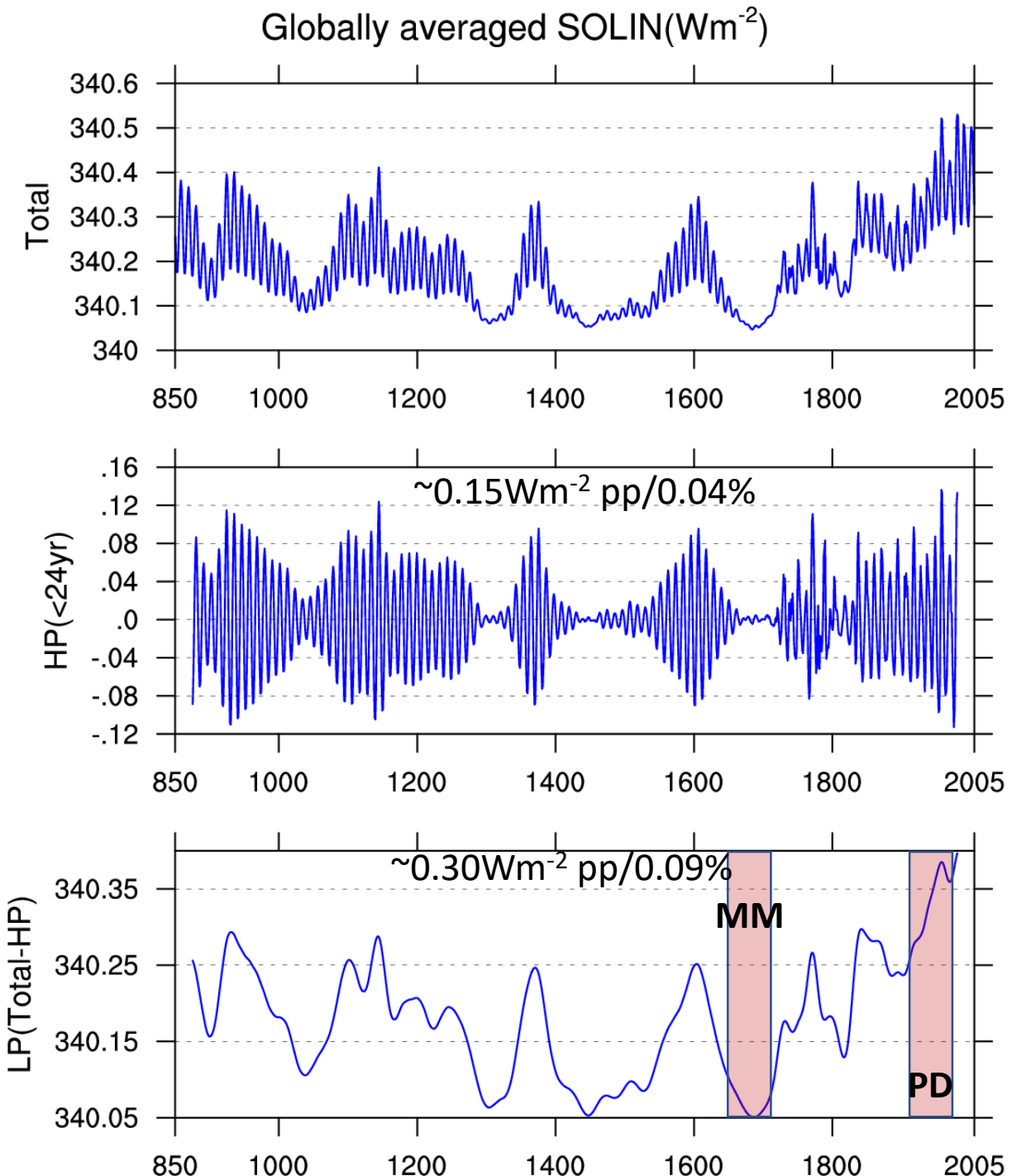
$$TSI = \int_{\lambda min}^{\lambda max} SSI \; \partial\lambda$$

$$SOLIN = TSI/4$$

- Two time scales: (1) 11-year solar cycle and (2) multi-decadal to century scale variations –
  - first look at 11-year solar variability (< 24 year)
  - interesting responses from LF forcing too

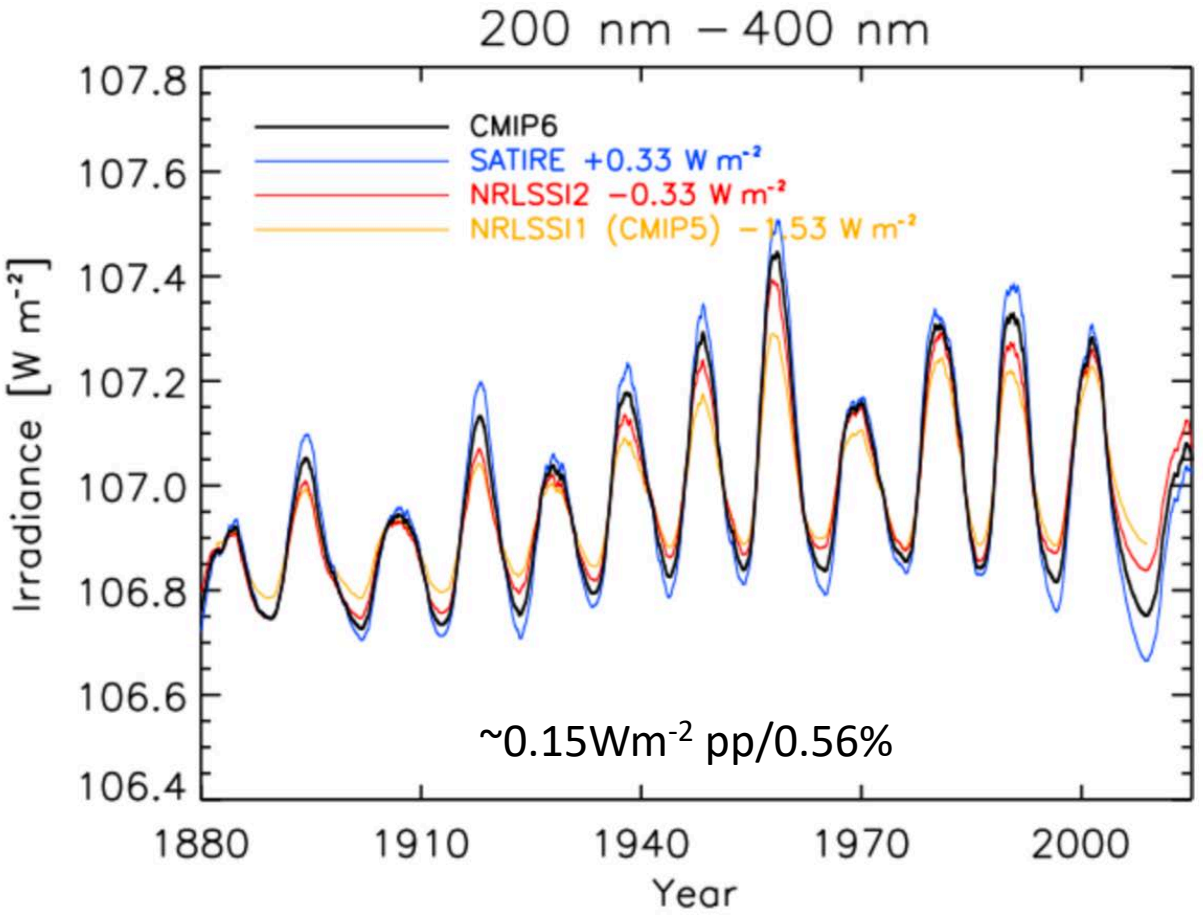
- Low top (standard CAM5) 30 layer up to ~3hPa/40 km: 4 solar only +2 sensitivity experiments, LF only PD – MM x 2.5.

- "bottom up" mechanism: increased SOLIN changes warm (cool) surface, increase (decrease) SST and LHFLX driving precipitation and circulation changes. Potential feedbacks via cloud cover and FSNS changes.



Solar Forcing (2)

- One High-top simulation (CESM-WACCM, 70 layers, 80km) – well resolved stratosphere & mesosphere + active chemistry
- Solar influence on climate through ”bottom up” and “top down mechanism”. Spectral dependence matters for the latter:
  - SSI changes ~200-400 nm are larger than TSI and increase (decrease) O_3 production and absorption
  - warming (cooling) associated with O3 changes affect circulation in the mesosphere and stratosphere
  - subsequent interaction with and propagation downward into the troposphere



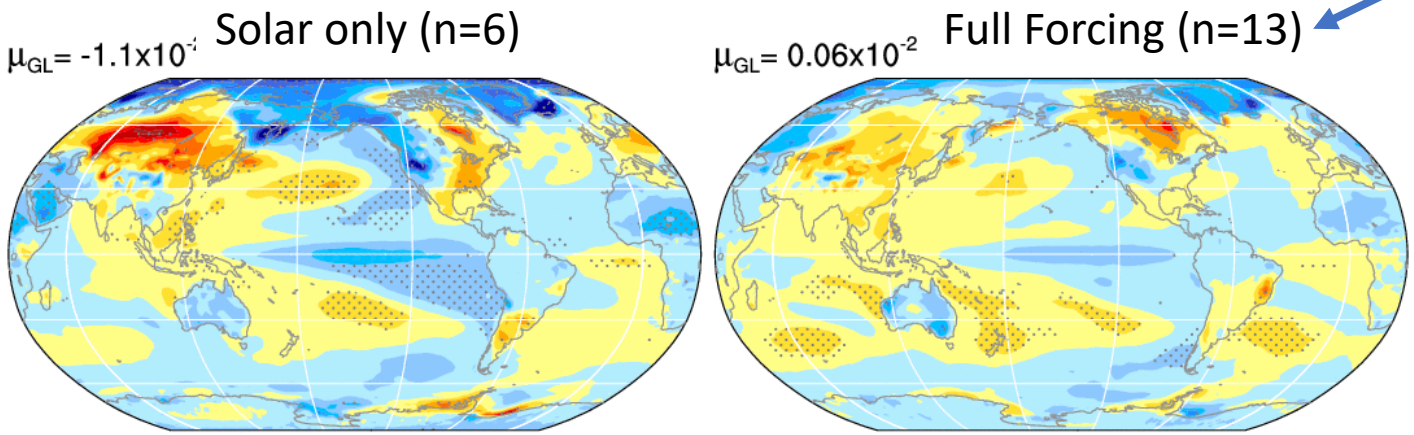
An example of CMIP 6 HF variations forcing, from Matthes et al., 2017

DJF TS Regression onto SOLIN x 0.15Wm^{-2} (°C)

solar
volcanic
LULC
orbital
aero/ozone
GHG (only using 850-1850)

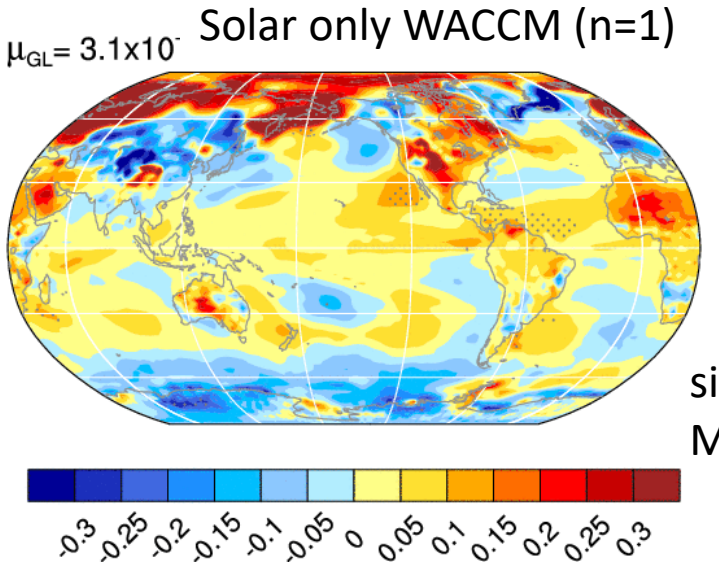
Low top

- Weak but significant PDO/IPO like pattern in the Pacific – large sample size. Meehl et al., 2007, find La Niña pattern, but ≥ 4x (or 8x) stronger.
- Full Forcing low top patterns qualitatively similar confirming robustness of the response



High top

- Moderate warming in the Arctic, cooling in the Antarctic, most areas not statistically significant – having only 1 simulation makes detection difficult
- Tropical and mid-latitude response pattern mostly out of phase with low–top, in contrast to Meehl et al., 2009.



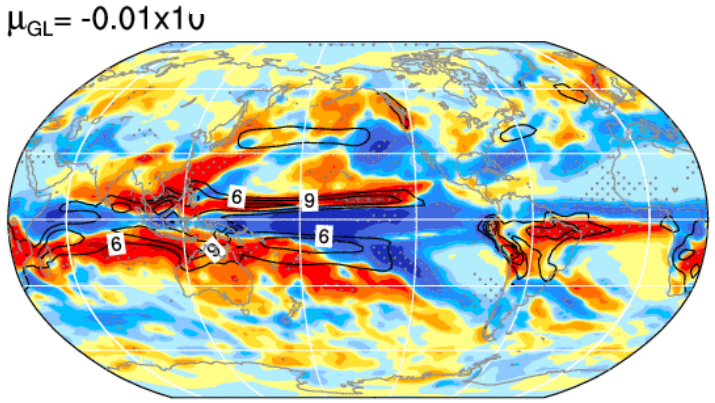
simulation by:
Mike Mills (ACOM)

DJF PRECT Regression onto SOLIN x 0.15Wm^{-2} (mm day^{-1})

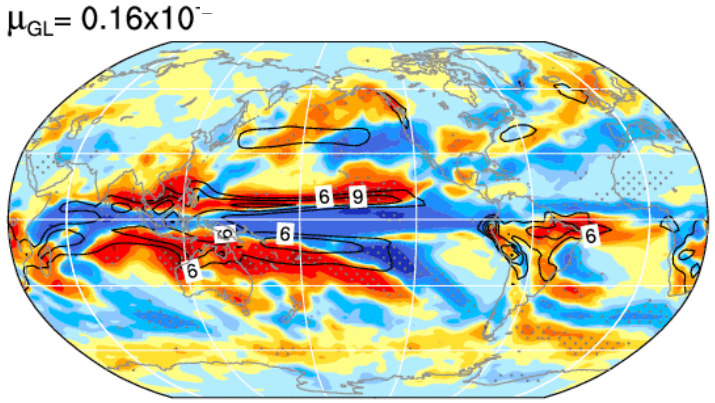
Low top

- Decreased precipitation on equator, increased off equator in the Pacific and Indian ocean.
- Decreased precipitation in the NH, increased in the SH in the Atlantic
- Full Forcing low top patterns qualitatively similar confirming robustness

Solar only (n=6)



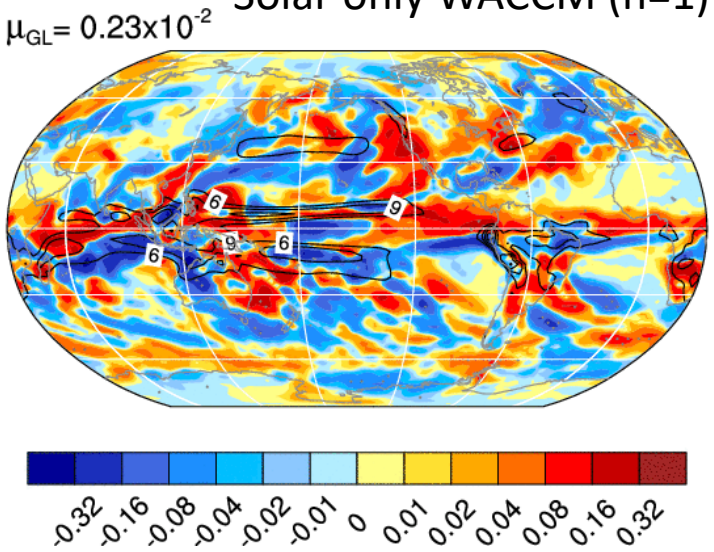
Full Forcing (n=13)



High top

- Tropical response pattern mostly out of phase with low–top, similar to temperature response

Solar only WACCM (n=1)

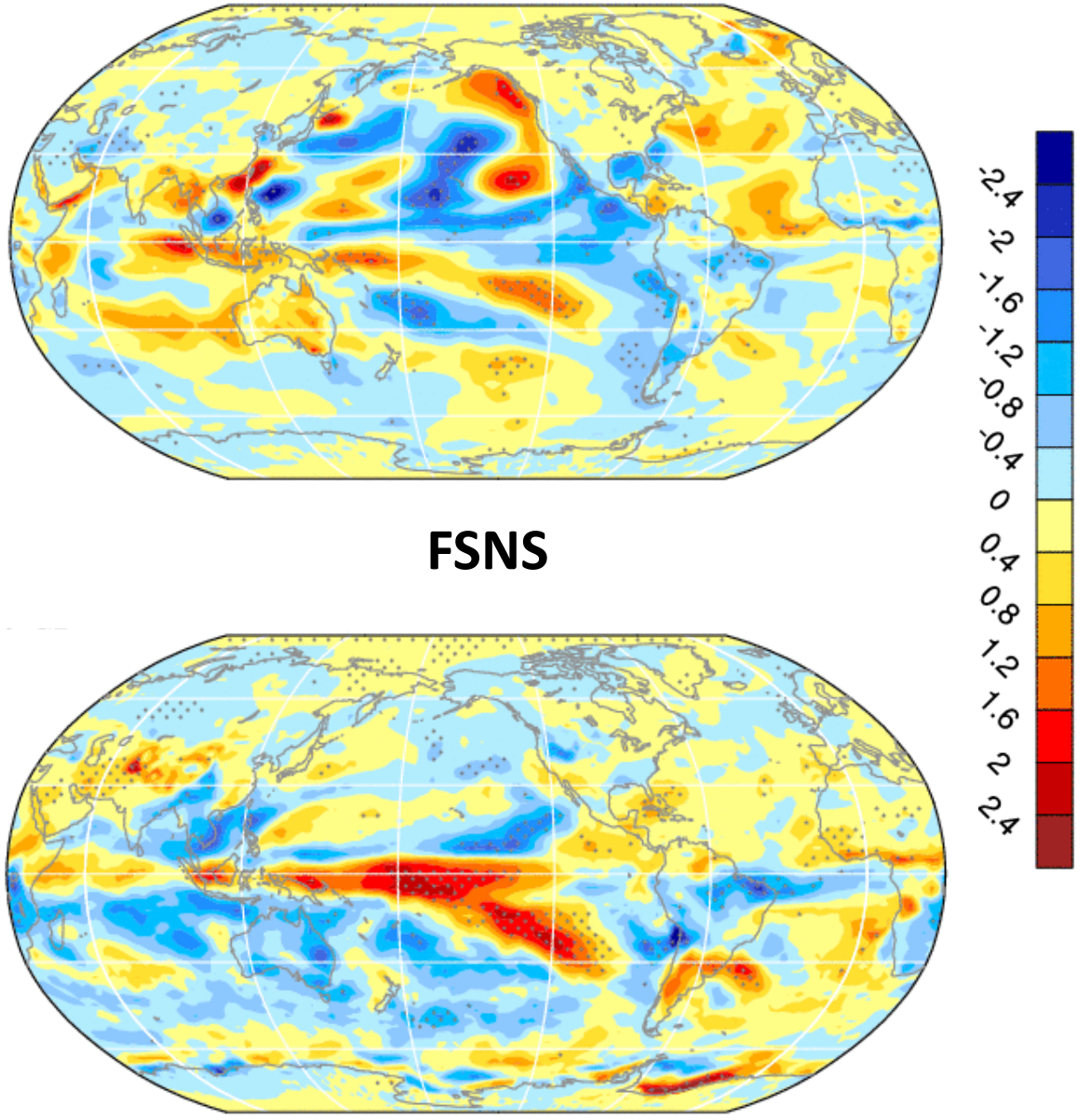


DJF LHFLX and FSNS Regression onto SOLIN x 0.15Wm^{-2} (Wm^{-2})

Solar only, low top

- Some positive LHFLX co-located with FSNS – one of the ingredients in mechanism proposed by Meehl et al. 2008
  - SPCZ and west equatorial Pacific
  - Does this drive precipitation and circulation responses that feedback onto clouds and FSNS?

LHFLX



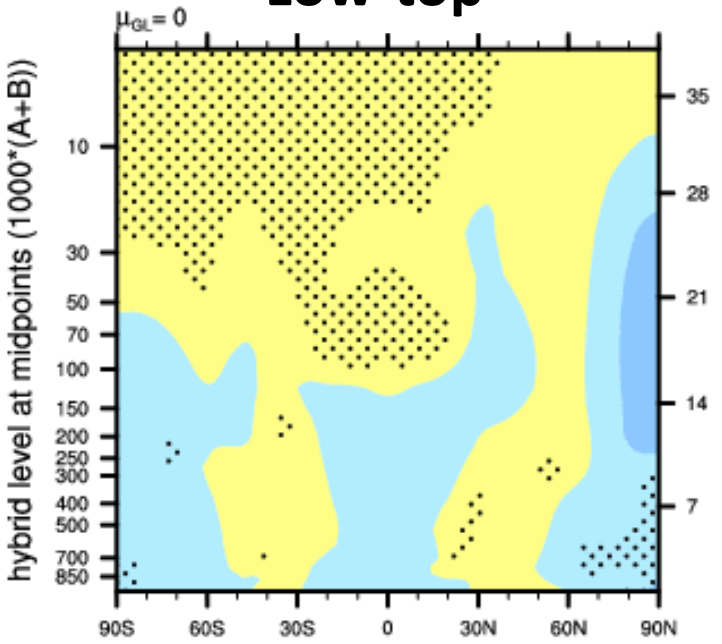
FSNS

DJF TS Regression onto SOLIN x 0.15Wm^{-2} (^{o}C)

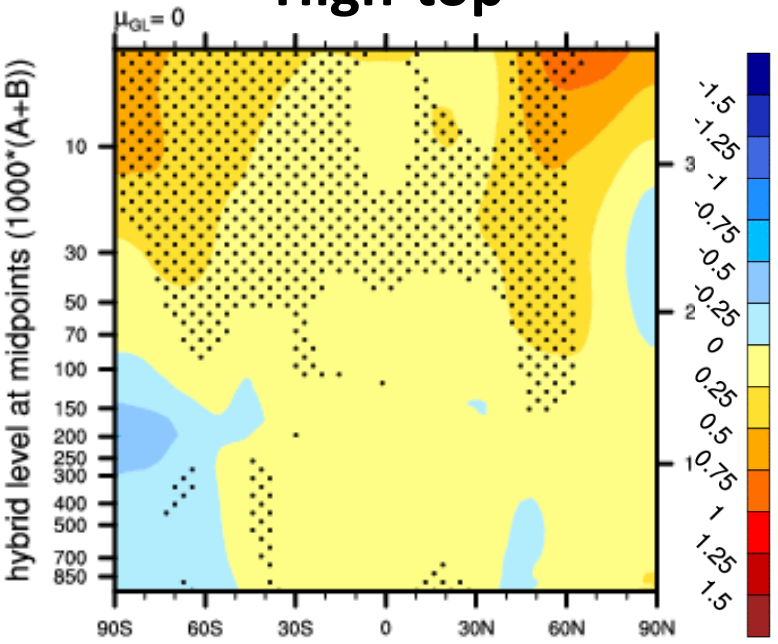
Low vs. high top

- At common levels, more stratospheric warming near poles in high top
- Response intensifies at higher levels in WACCM, local maxima winter pole at 50km and tropics 60-80km

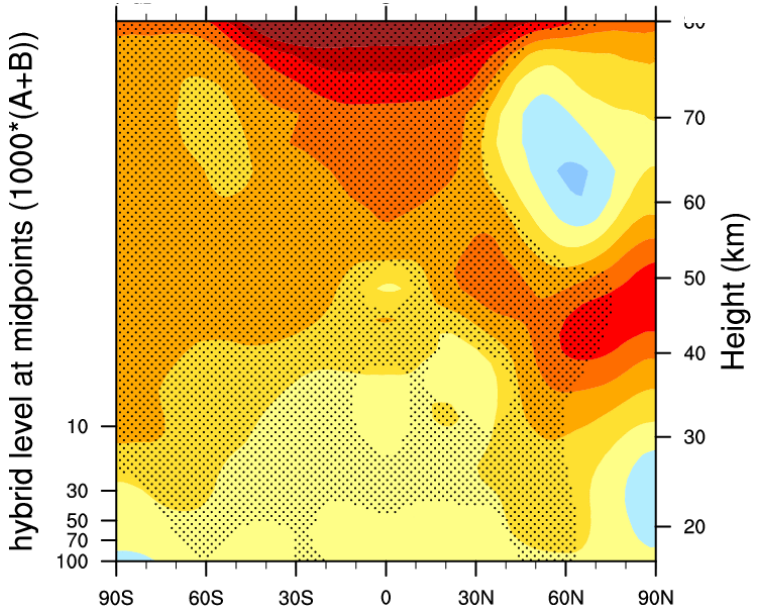
Low-top



High-top



All levels

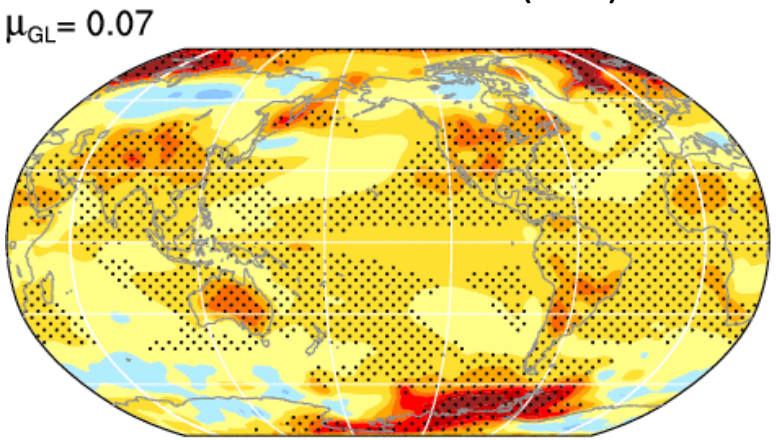


ANN TS Regression onto ***LF*** SOLIN x 0.30Wm^{-2} (°C)

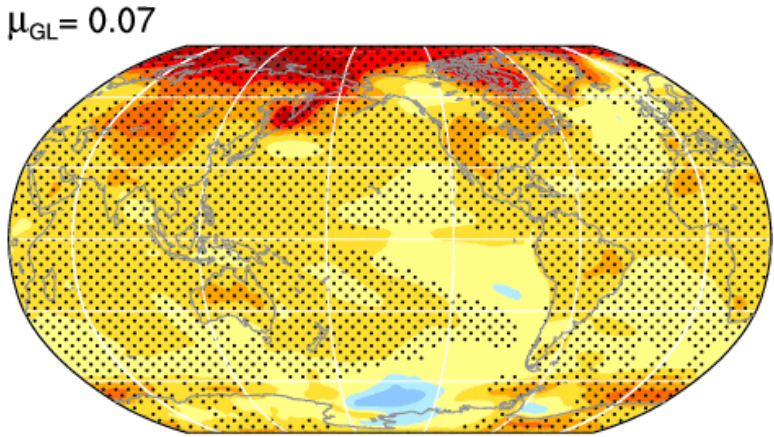
Low top

- Warming virtually everywhere, with polar amplification
- Stronger Arctic response with enhanced solar
- Patterns not at all similar to HF response

Standard Solar (n=4)



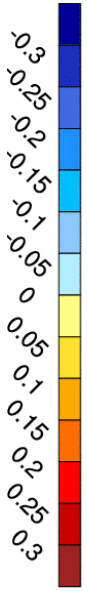
Enhanced Solar (n=2)



High top

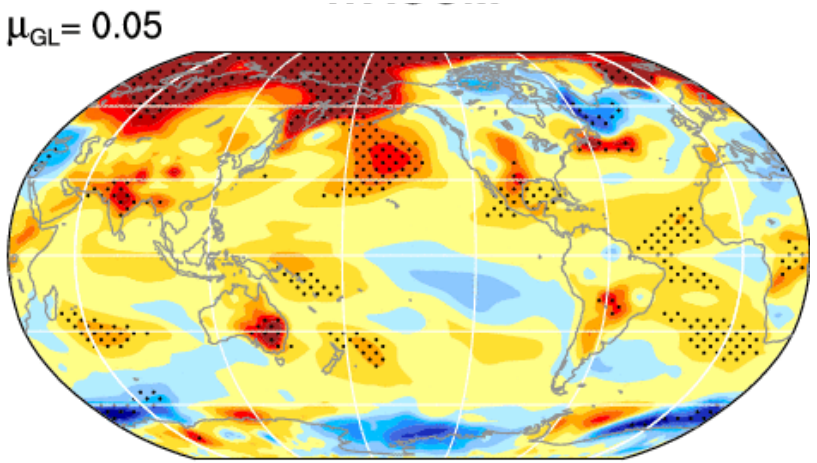
- More spatially complex

- Warming in the Arctic, cooling in Antarctic, + other features similar to HF response



full response = additional x 2.5

Standard Solar WACCM (n=1)

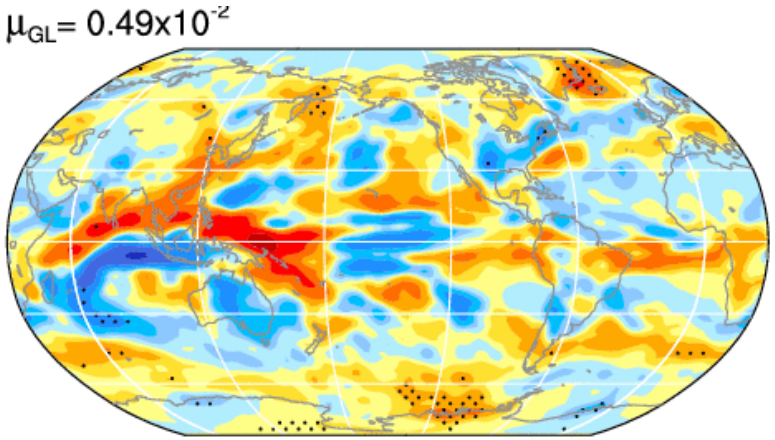


ANN PRECT Regression onto ***LF*** SOLIN x 0.30Wm^{-2} (mm day^{-1})

Low top

- A very weak but significant response in the storm tracks and high latitudes, more coherent and significant in the enhanced solar simulations

Standard Solar (n=4)



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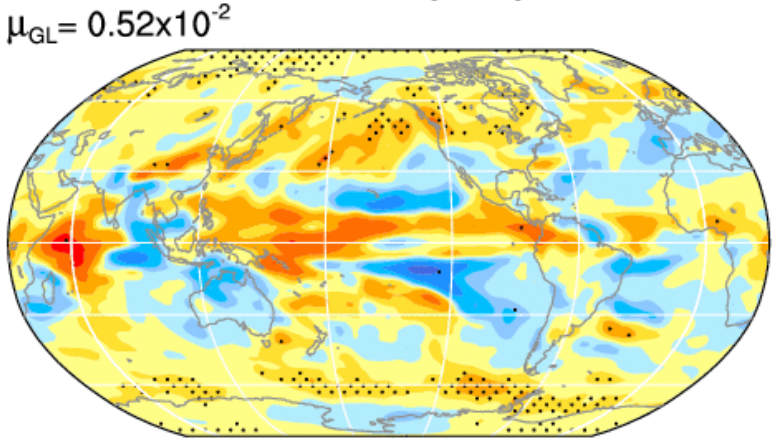
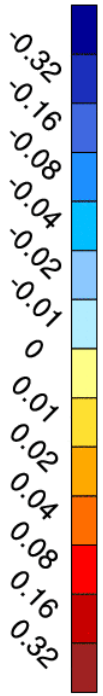


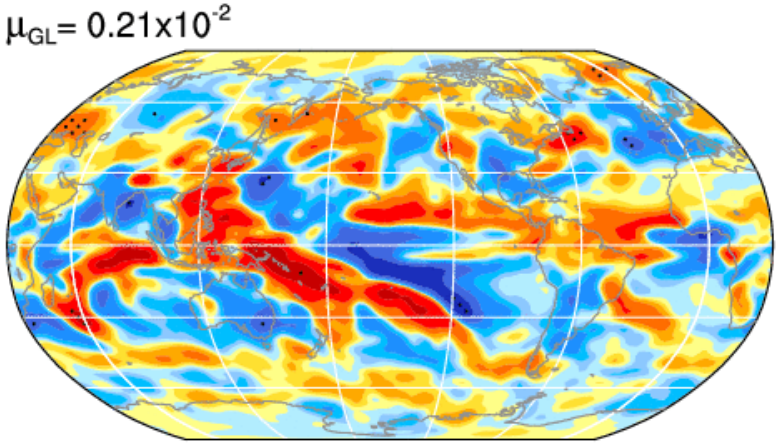
full response = additional x 2.5



High top

- Not much that is coherent and significant in this single simulation

Standard Solar WACCM (n=1)



Summary

- There are weak (few 10ths ^{o}C in TS & few 100ths mm day^{-1} in PRECT) but statistically significant climate responses to solar variations over the last millennium in CESM LME solar only and full forcing experiments. Without an ensemble of long simulations, detecting this signal would be difficult.

- The response patterns depend on the time scale of the forcing and whether the atmosphere component has a well resolved stratosphere and mesosphere with active chemistry. We have only 1 of these simulations.

- Forcing on ~11 year time scale is associated with a PDO/IPO pattern in the low top simulations, in broad agreement with some earlier results, but the amplitude is 4-8 times weaker in the LME.

- Solar variations on longer time scales are associated with global warming and bi-polar amplification in the low top simulations. In the high top simulation, the response pattern is more complex with Arctic warming & Antarctic cooling.