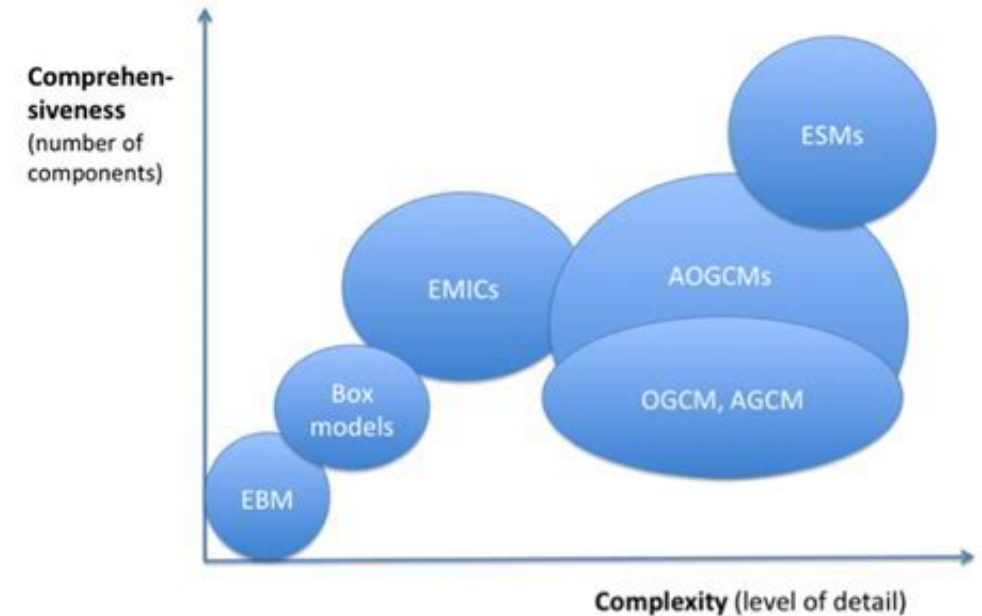


How do models inform paleoclimate, and how does paleoclimate inform (~~validate~~) models?

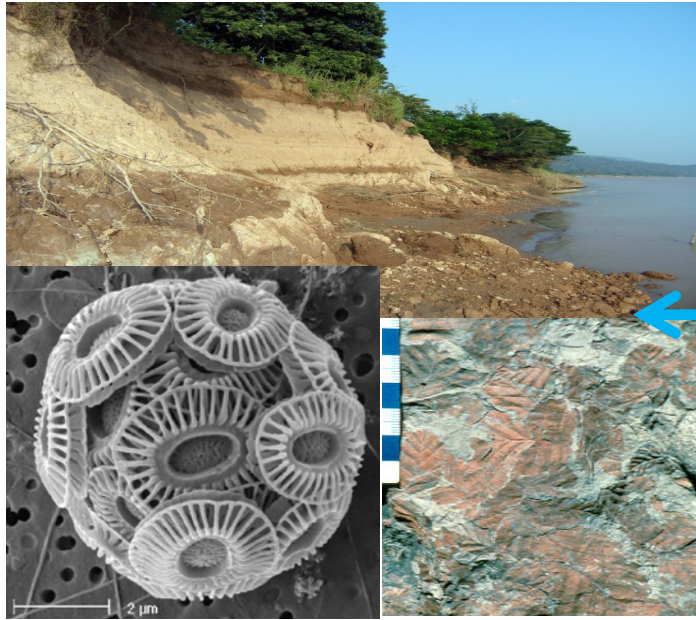
A perspective from Earth System Models (AOGCMs)

Bette Otto-Bliesner

With contributions by Esther Brady, Ran Feng, Clay Tabor, Jiang Zhu, and many more



How do models inform paleoclimate?



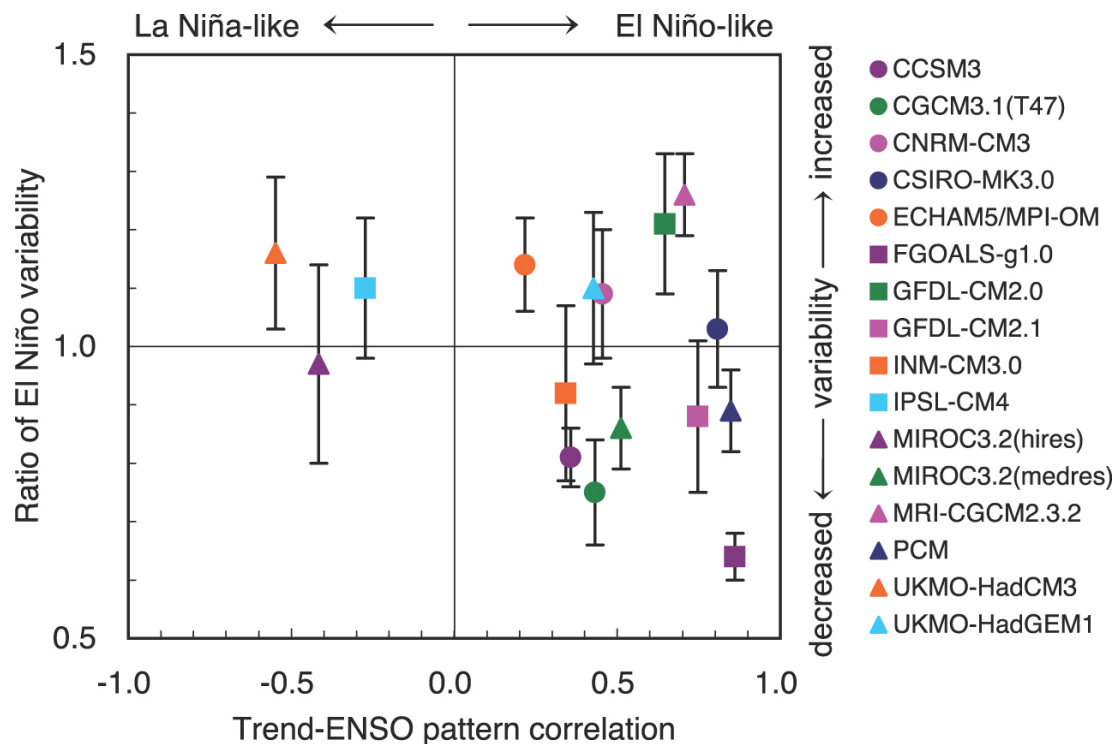
LGM ENSO
Low CO₂

Eocene ocean temperatures
High CO₂

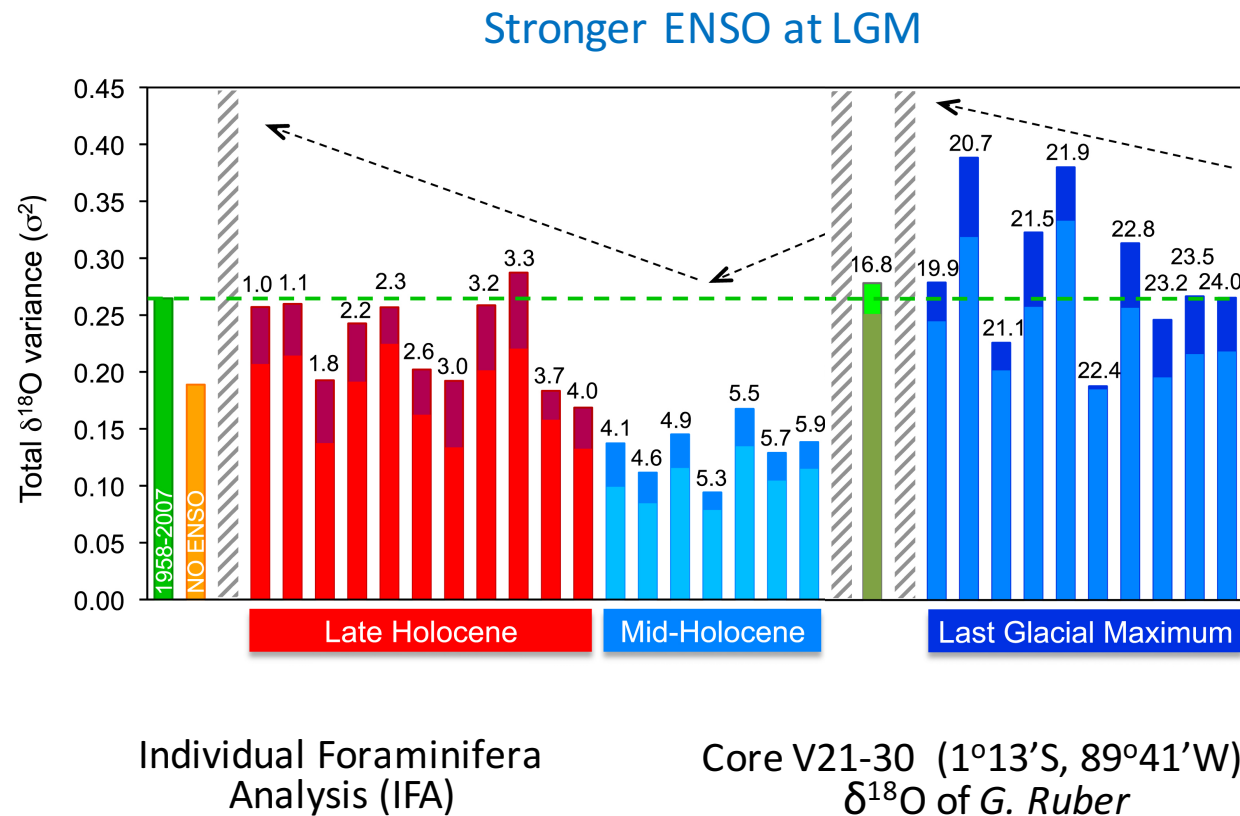
African hydroclimate
Deglaciation – increasing CO₂



Models informing paleoclimate: ENSO



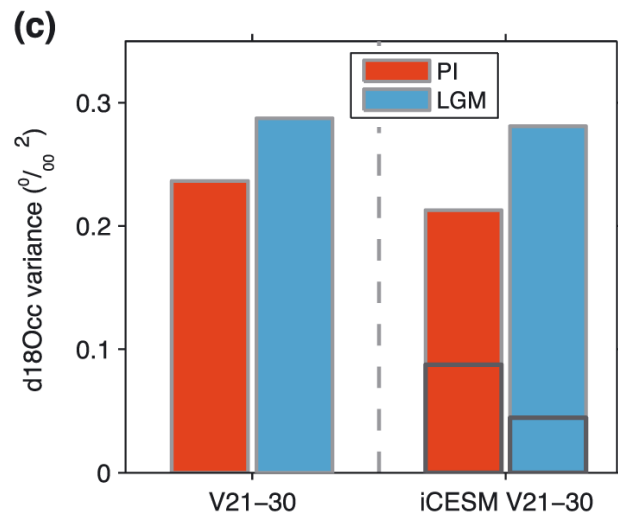
IPCC AR4 WG I, 2007



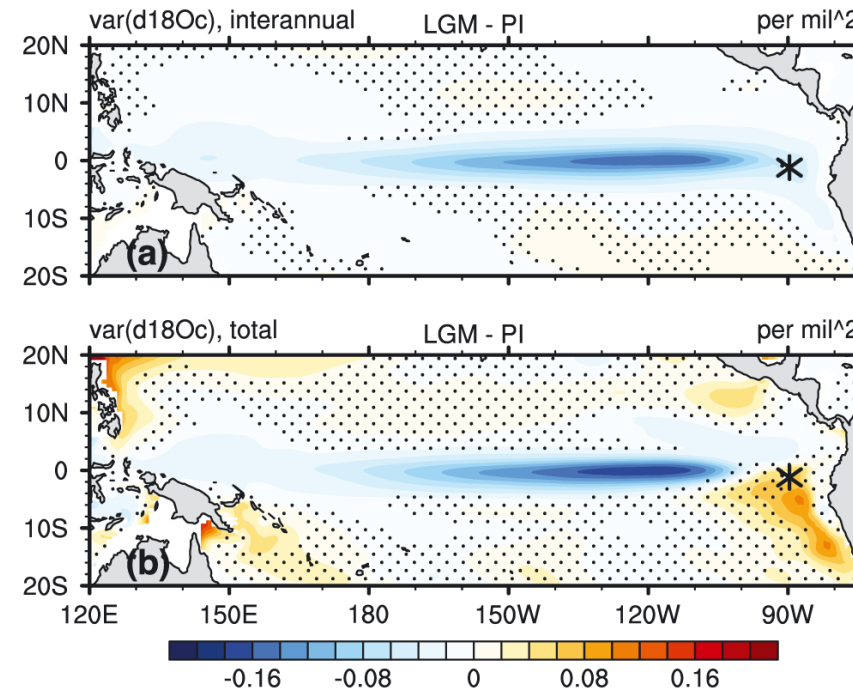
Koutavas and Joanides, *Paleoceanography*, 2012

Models informing paleoclimate: ENSO

Percentage variance of total variance explained by interannual variance depends on location



Zhu, Liu, Brady, Otto-Bliesner, GRL, 2017



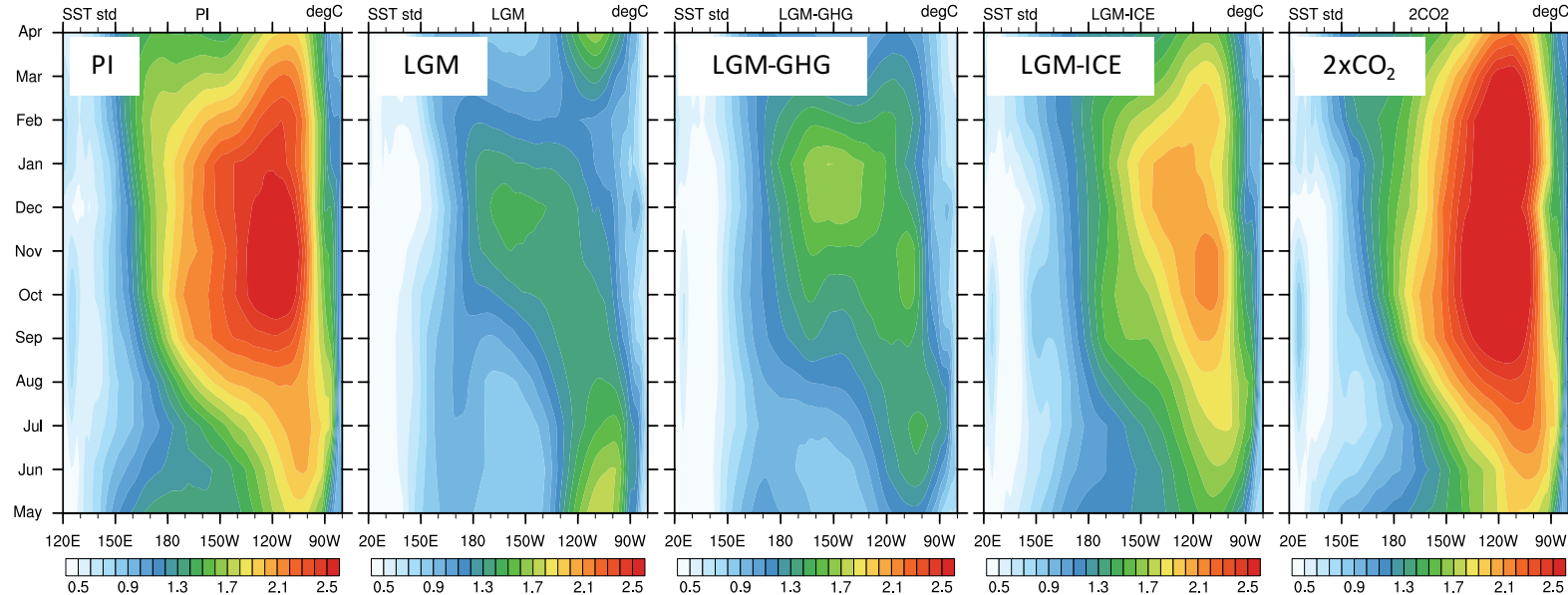
Weaker ENSO at LGM



Models informing paleoclimate: ENSO

Weaker LGM ENSO primarily caused by lowered concentration of GHGs;
secondly by large and extensive LGM ice sheets.

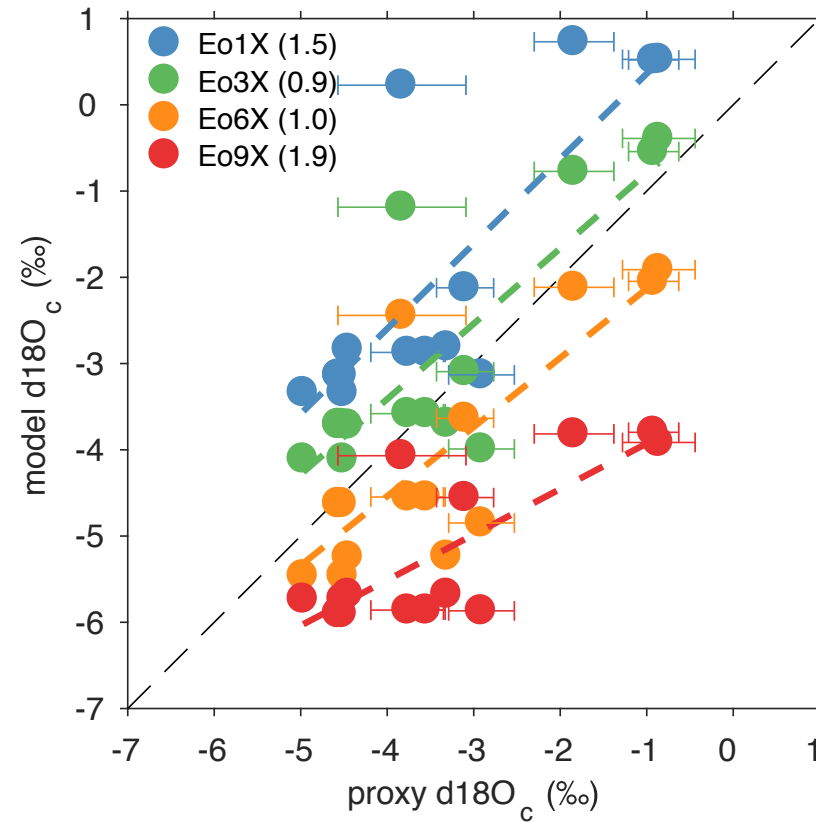
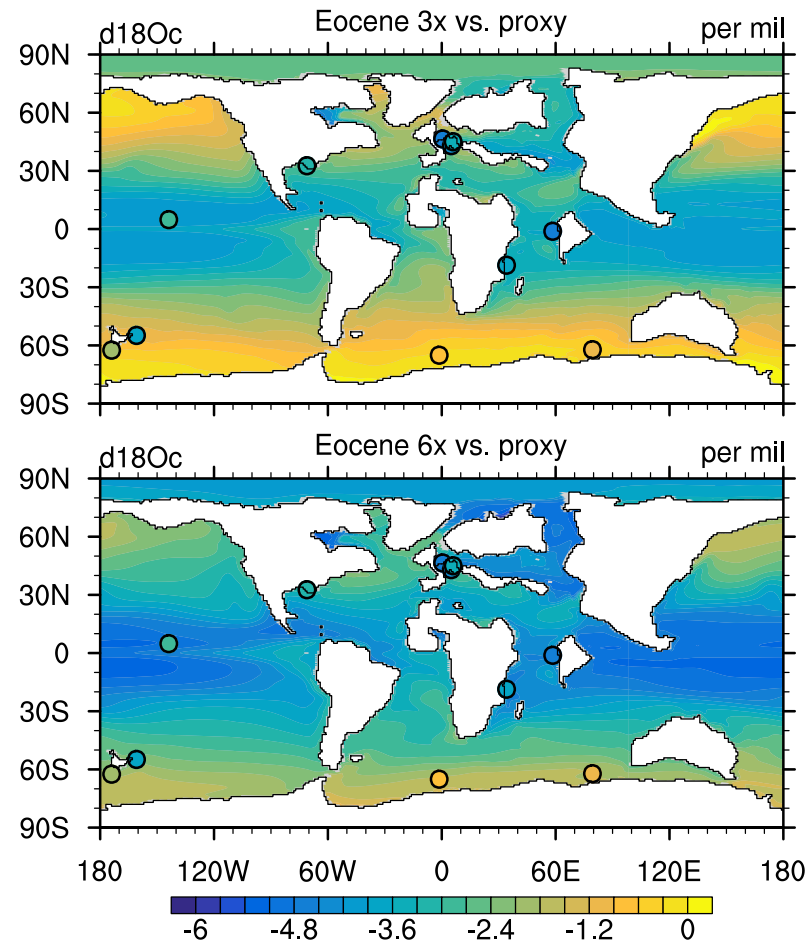
Future ENSO should be stronger



Zhu, Liu, Brady, Otto-Bliesner, GRL, 2017



Models informing paleoclimate: Eocene CO₂

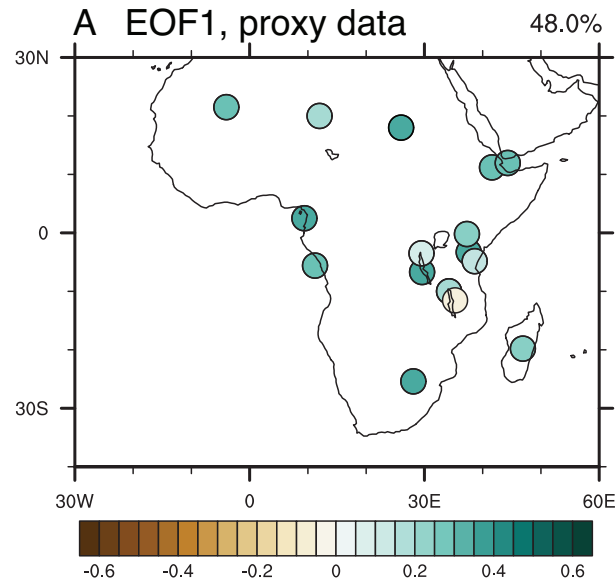


Zhu et al., in prep, 2019



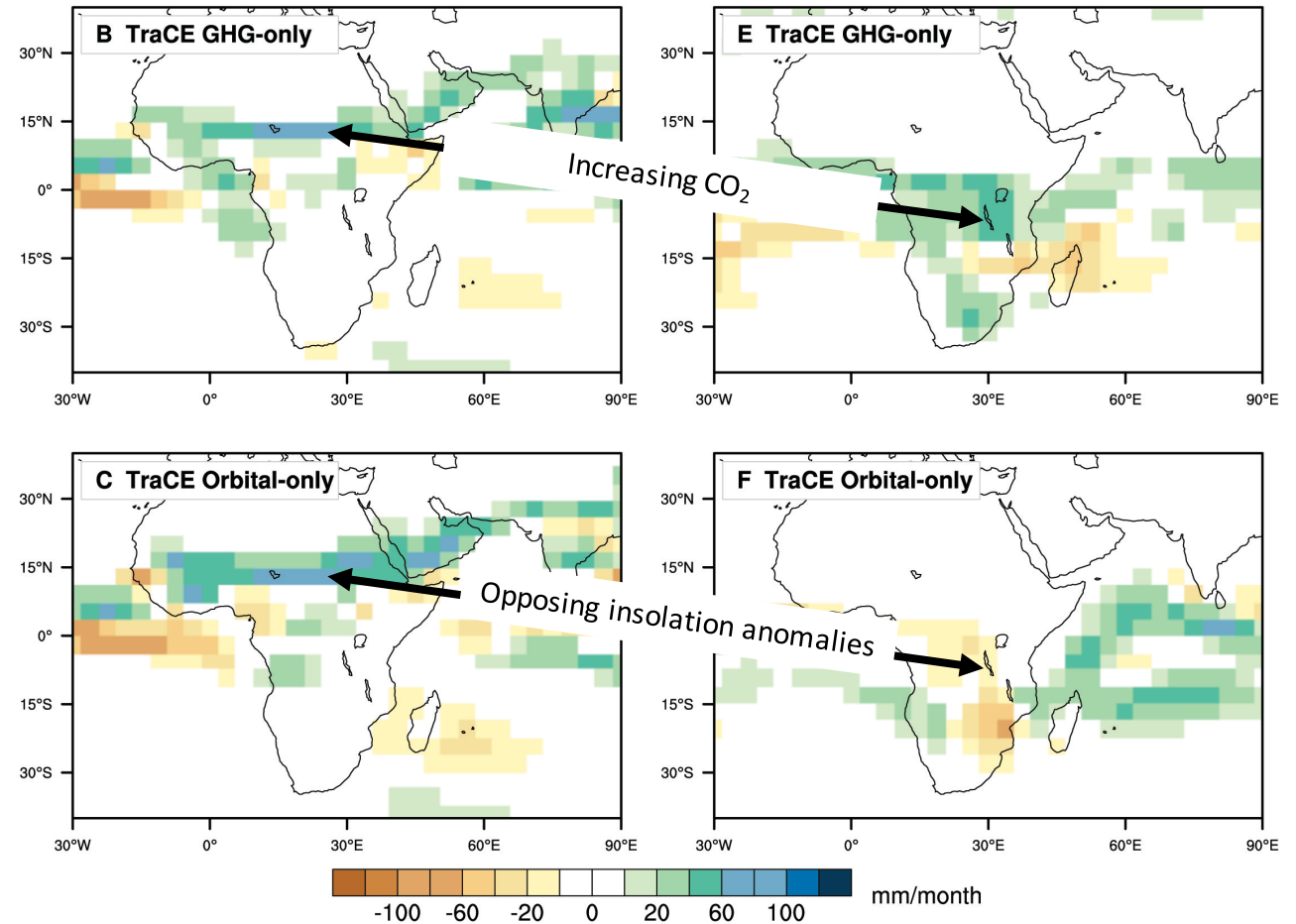
Models informing paleoclimate: Hydroclimate in Africa

Deglacial period – 20ka to 11ka
Increasing moisture availability

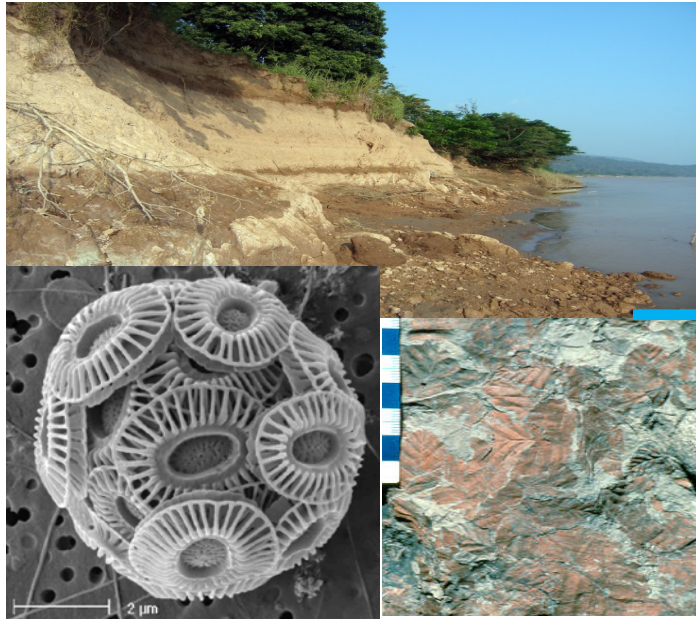


Otto-Bliesner et al., Science, 2014

NH Summer (JJA) Precipitation SH Summer (DJF)



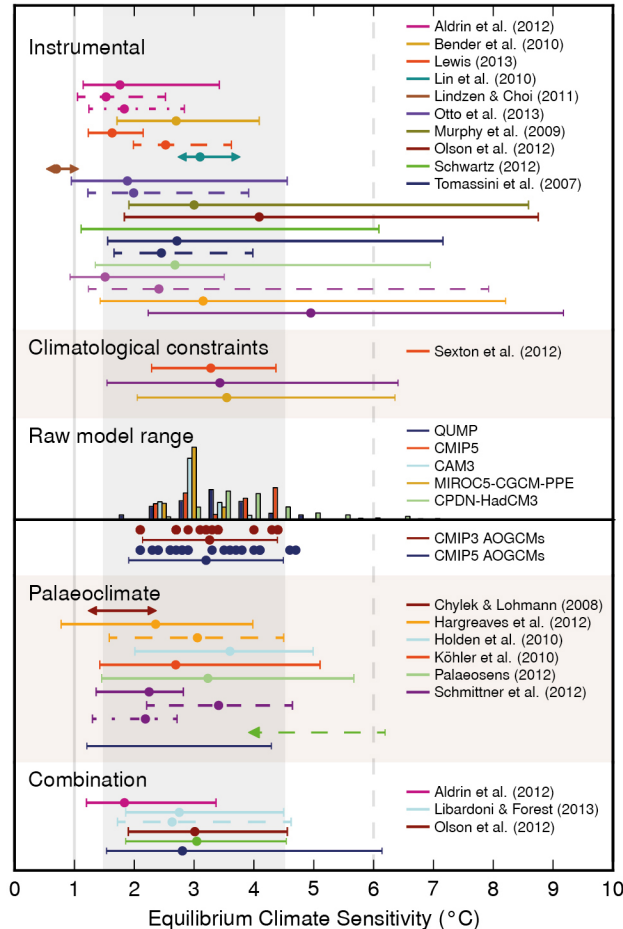
How does paleoclimate inform models?



Equilibrium Climate Sensitivity

Indices of Climate

Paleoclimate informing models: Climate Sensitivity



ECS (Equilibrium Climate Sensitivity): Equilibrium (steady state) change in the annual global mean near-surface air temperature for a doubling of atmospheric CO_2

Commonly estimated by running atmosphere models coupled to a slab ocean model

Relatively fast responses (i.e. next 150 years or so) of atmosphere and Earth's surface

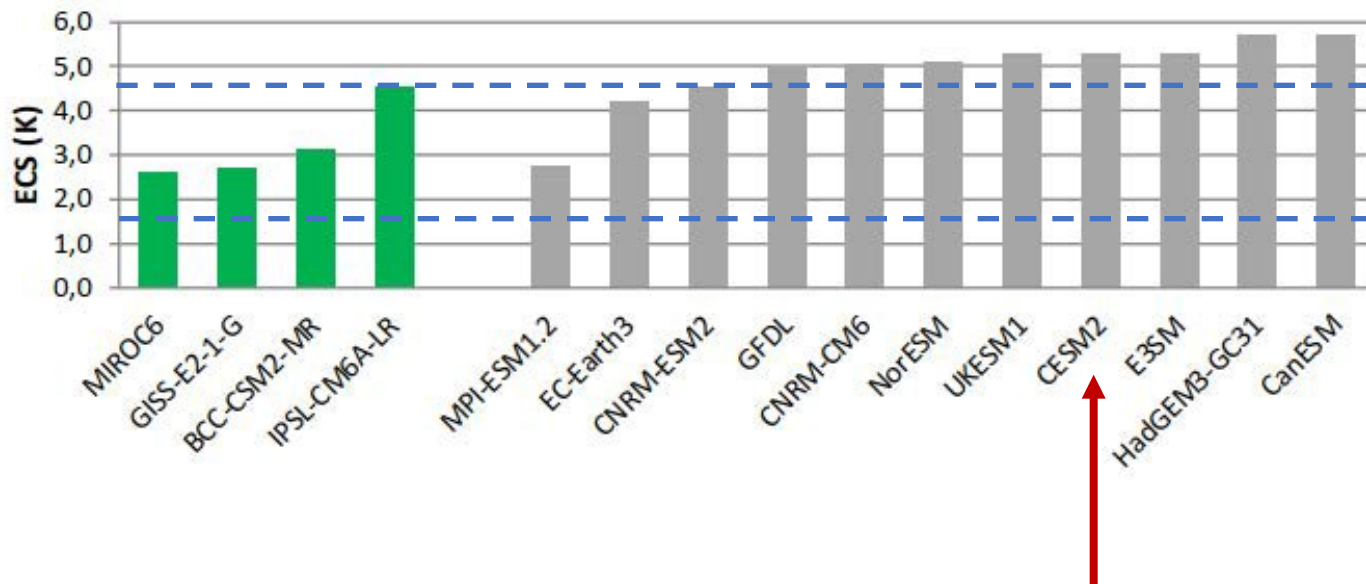
For paleomodeling, need to include additional radiative forcing by imposed boundary conditions (e.g. ice sheets in LGM simulations)

IPCC AR5 WG I, 2013



Paleoclimate informing models: ECS

CMIP6



Equilibrium Climate Sensitivity ($2 \times \text{CO}_2$)
Nominal 1° resolution with a Slab Ocean Model (SOM)

CCSM3: 2.9°C CMIP3 (AR4)

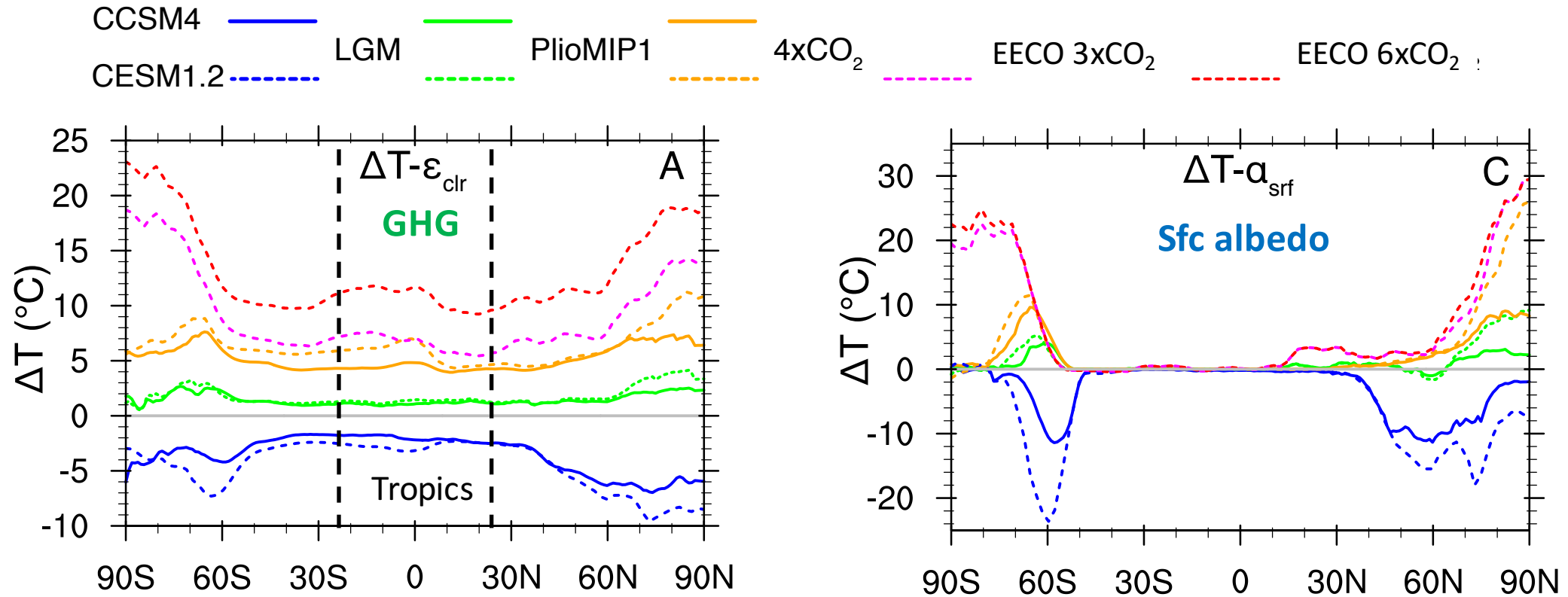
CCSM4 (CAM4): 3.2°C CMIP5 (AR5)

CESM1 (CAM5): 4.1°C

CESM2.0: 5.3°C CMIP6 (AR6)

Figure from Eyring, CMIP6 Barcelona Workshop

Paleoclimate informing models: Energy Balance Analysis



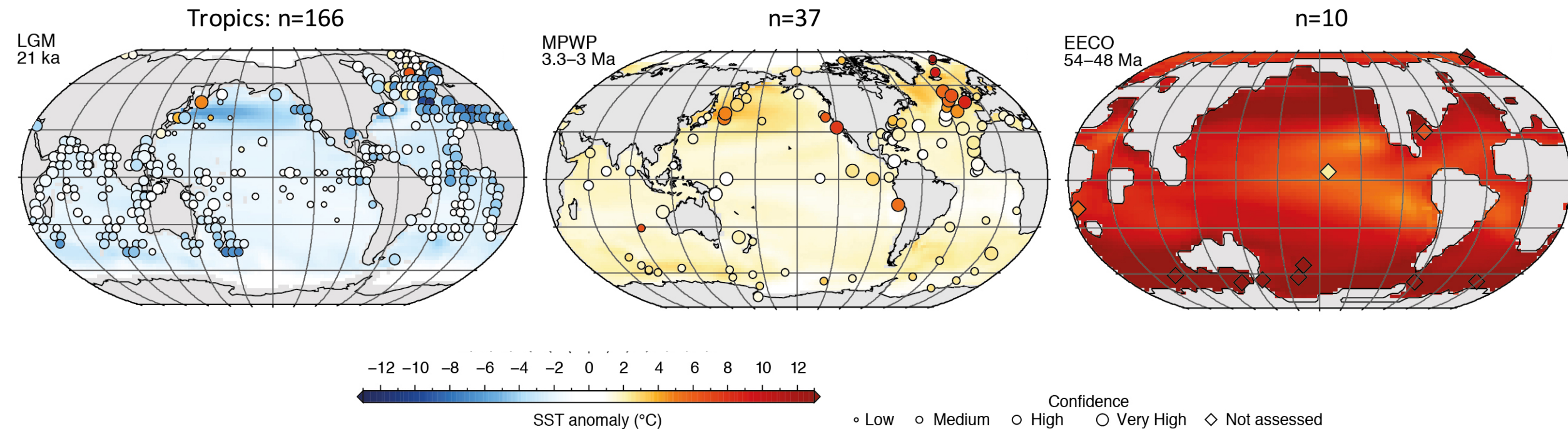
Tropics dominated by changes in GHGs

High latitudes dominated by changes in cryosphere

Figure from courtesy of Ran Feng



Paleoclimate informing models: SSTs



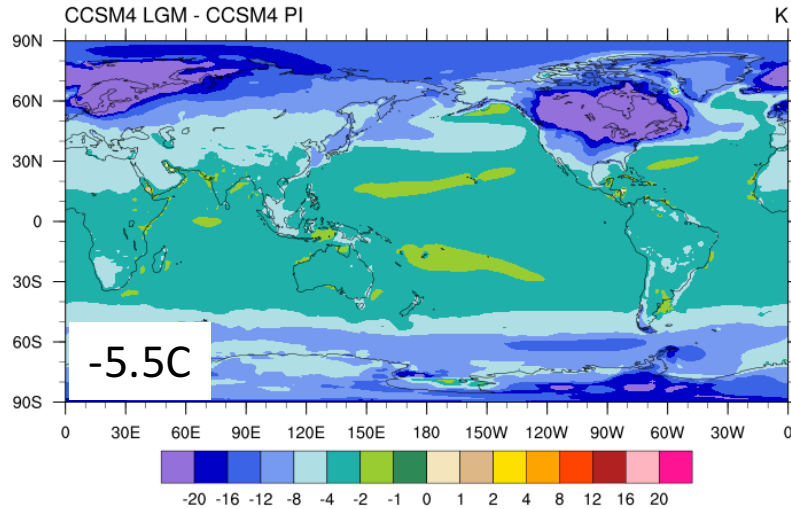
IPCC AR5 WG I, 2013



Paleoclimate informing models: Example from LGM

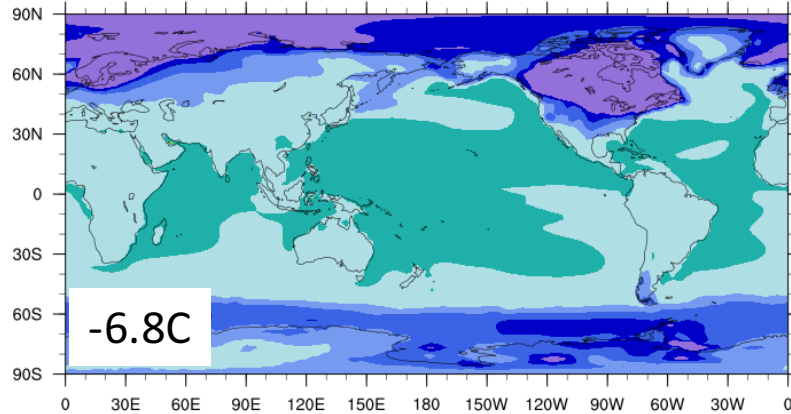
CCSM4

Change in surface temperature



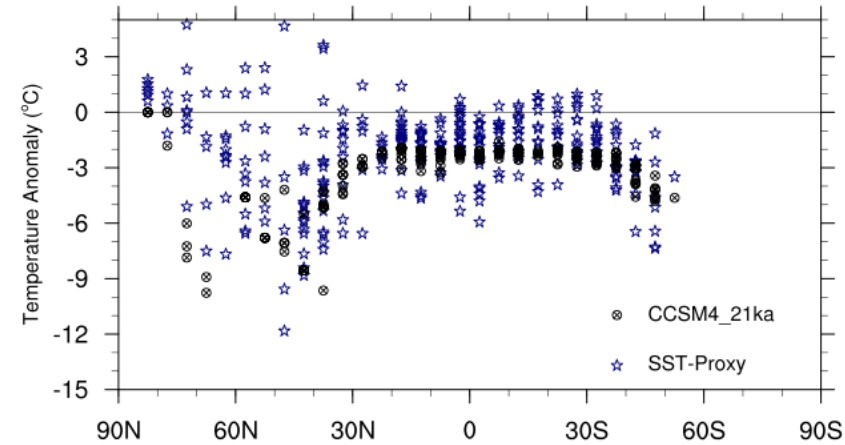
CESM1.2

LGM-C5nCN - CESM1-C5noCN PI



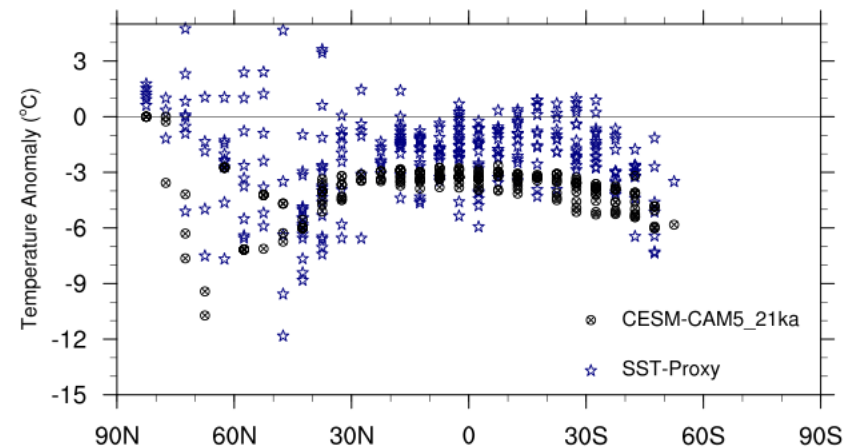
Change in SST

CCSM4_21ka v. SST-based Reconstruction



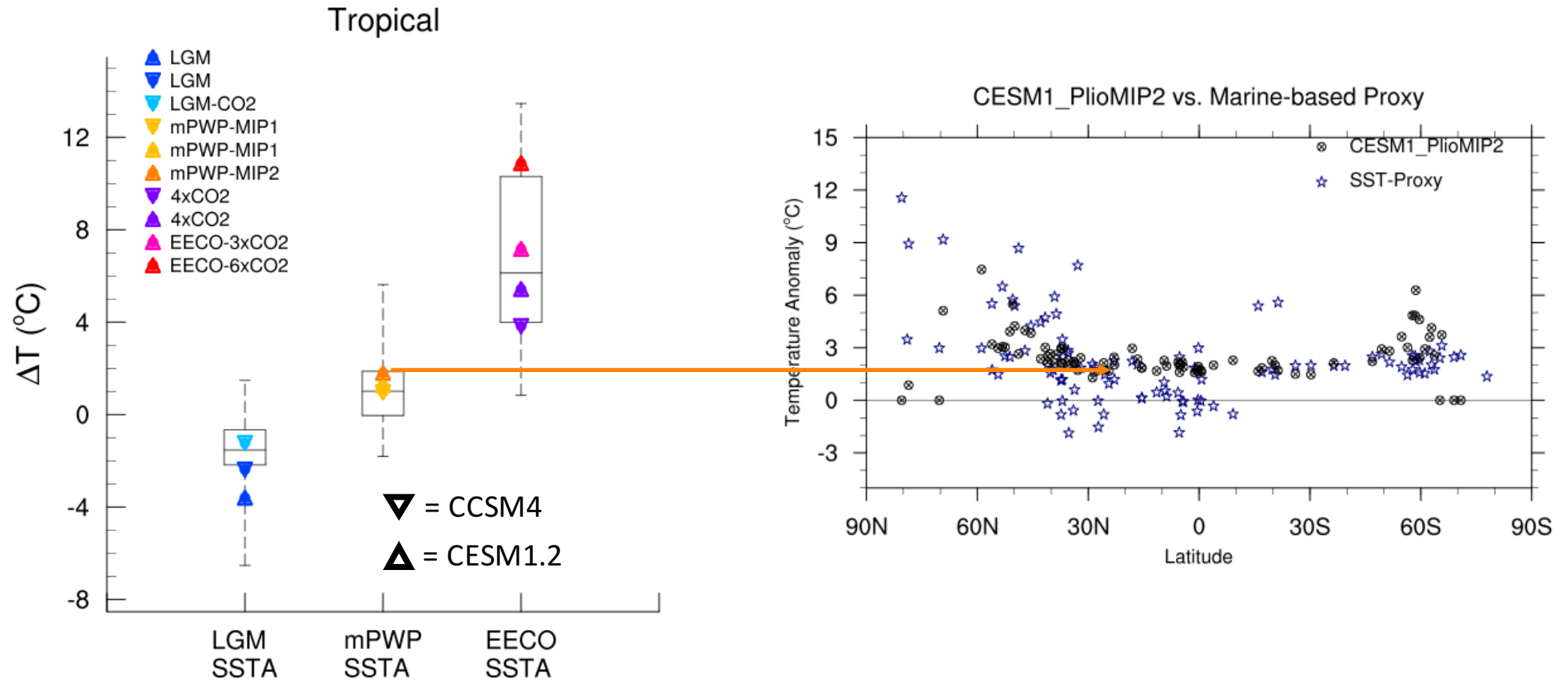
Simulated
Tropical ΔT_S
-2.4C

CESM-CAM5_21ka v. SST-based Reconstruction



-3.6C

Paleoclimate informing models: Data vs Model



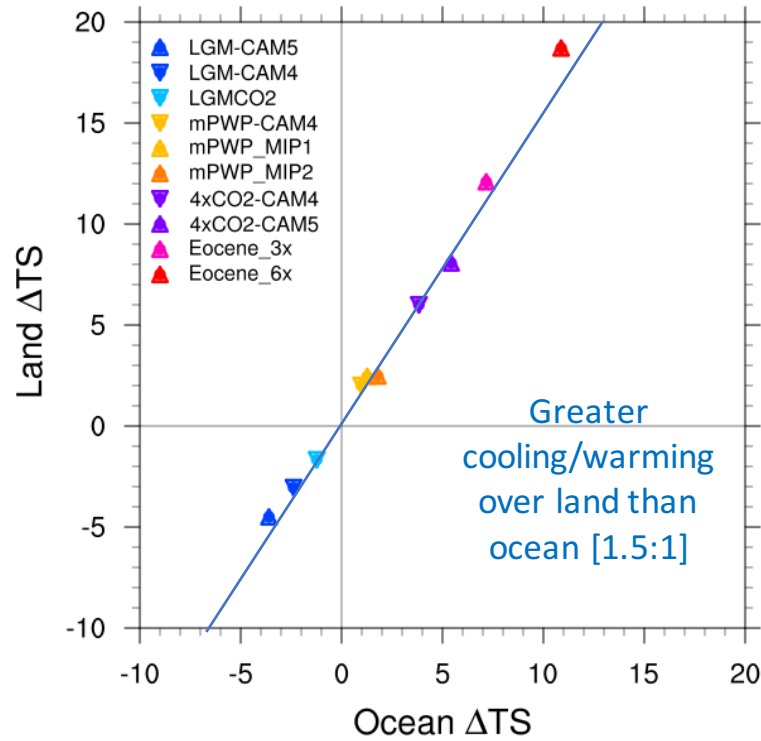
Paleoclimate informing models: Other indices

▽ = CCSM4

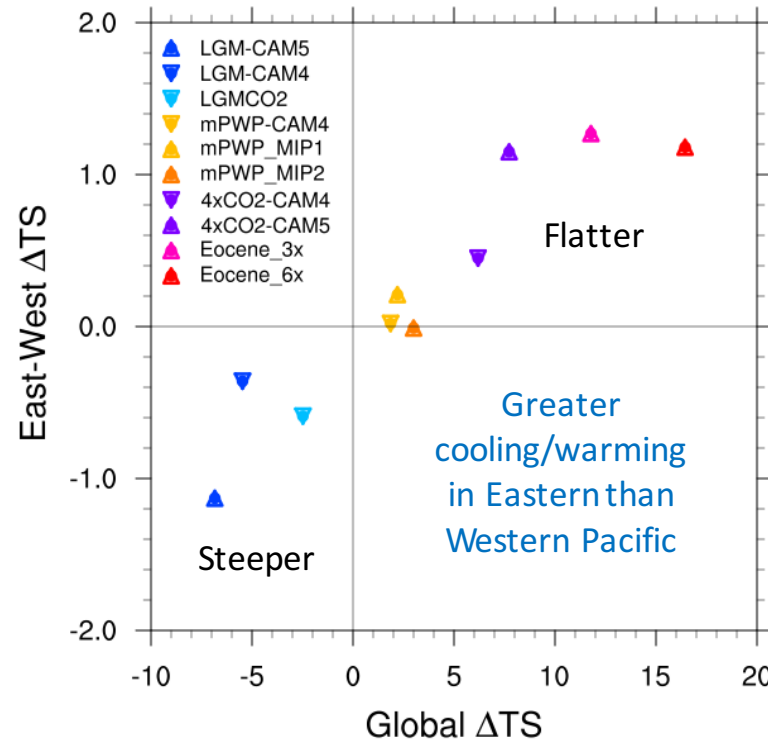
▲ = CESM1.2

Still needed: Data!

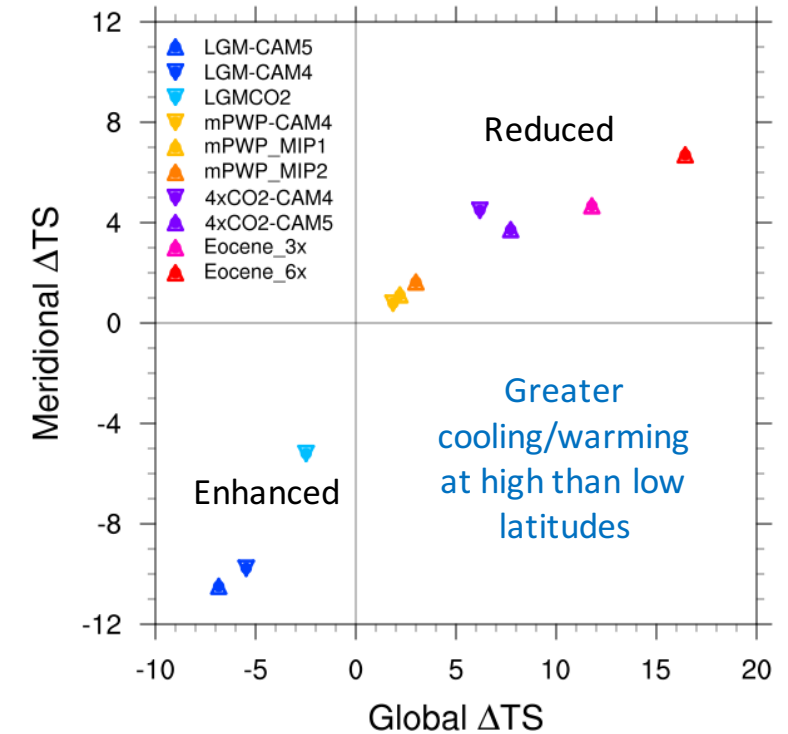
Tropics (23S-23N)



Pacific Equatorial E-W ΔTS Slope



NH Meridional ΔTS



How should models inform paleoclimate?

How should paleoclimate inform models?

Together



How should models inform paleoclimate?

How should paleoclimate inform models?

1. Useful information for future climate change can also be provided from times in the geologic past when CO₂ and other GHGs were lower than today, and from times with transient increases in CO₂.
2. Simulation of water isotopes and other geotracers in models, and understanding the climatic and non-climatic factors influencing their signals in geologic archives, will enhance model-data comparisons.
3. Should look across multiple time periods, for multiple climate indices (not just ECS), and with multiple models and proxies in answering these questions.

