



Early Eocene surface temperatures in an unprecedented high-resolution Earth system simulation

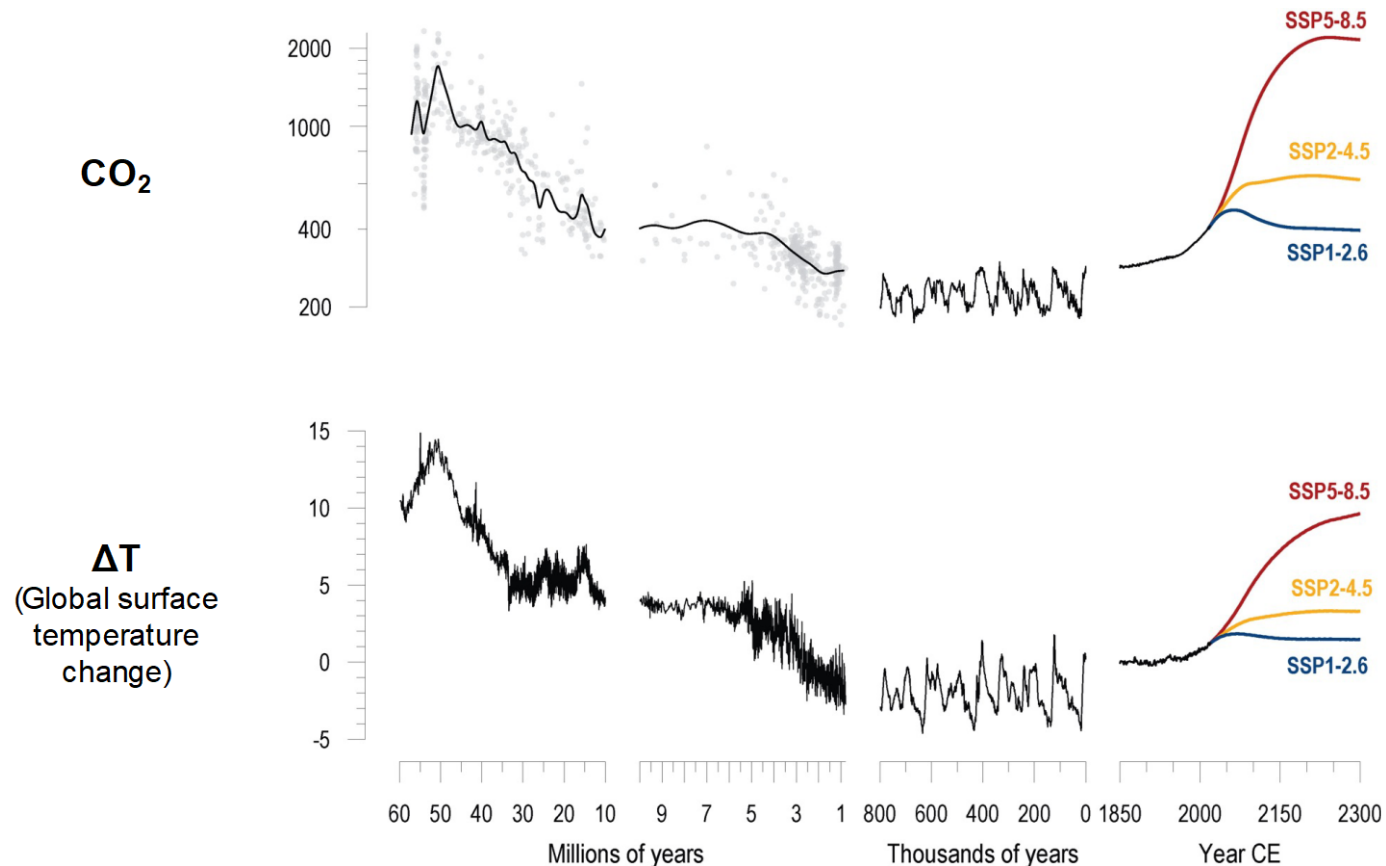
Jiang Zhu

Collaborators: B. Otto-Bliesner, E. Brady, J. Tierney, C. Poulsen, R. Feng, C. Tabor, A. Walters

February 26, 2024

Past climates inform our future (*Tierney et al., 2020, Science*)

- Directly calculate climate sensitivity (*Rohling et al., 2012, Nature*)
- Assess climate models (*Zhu, Poulsen, Otto-Bliesner, 2020, Nat. Clim. Change.*; *Lunt et al., 2020, CP*)
- Study hydroclimate & extreme events (*Cramwinckel et al., 2023, PP*; *Rush et al., 2021, Paleo³*)
- ...



*Modified after
IPCC AR6
Figure TS.1*

Early Eocene Climate Optimum (EECO, ~50 Ma) as a hothouse climate

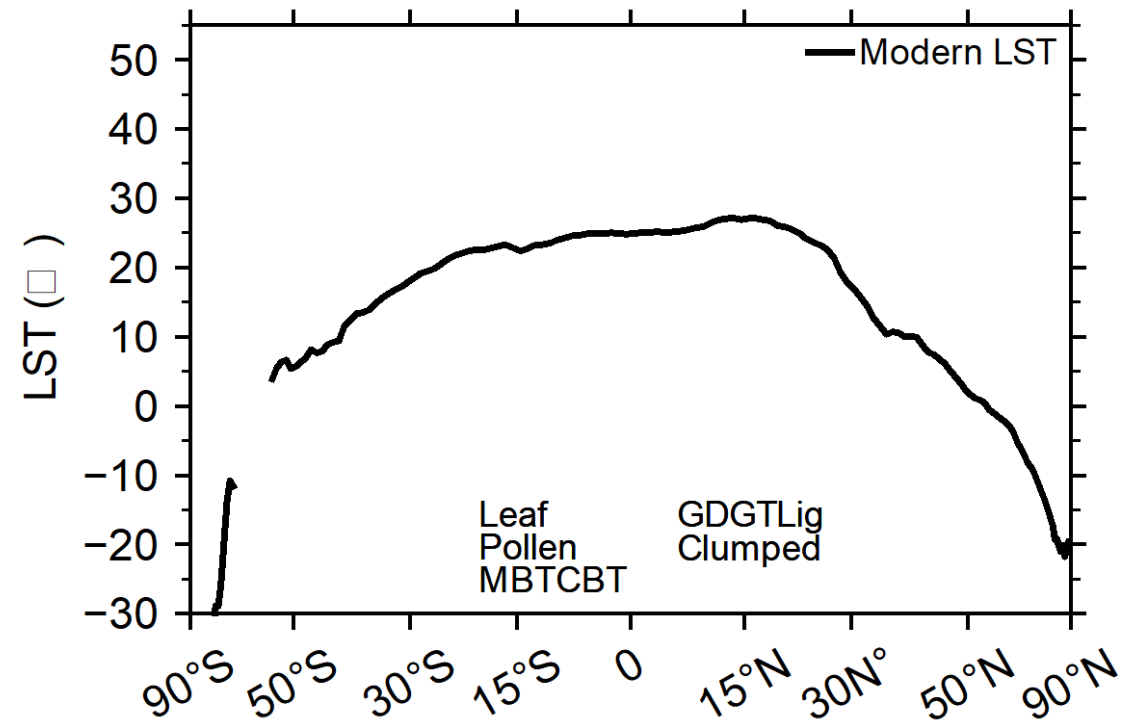
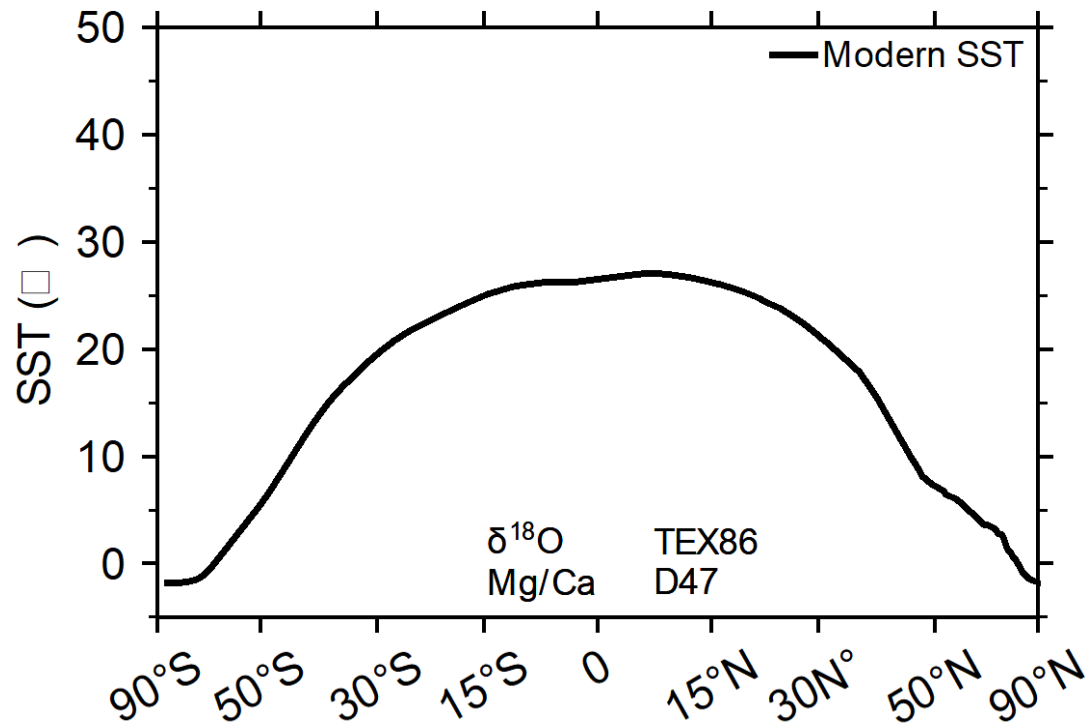
Fossil palm trees / crocodiles at polar regions (above-freezing winters)

- *Estes & Hutchison, 1980, Paleo3*
- *Shuijs et al., 2009, Nat. Geosci.*
- *Pross et al., 2012, Nature*
- ...



Credit: USGS & Smithsonian

EECO surface temperatures & the equable climate problem

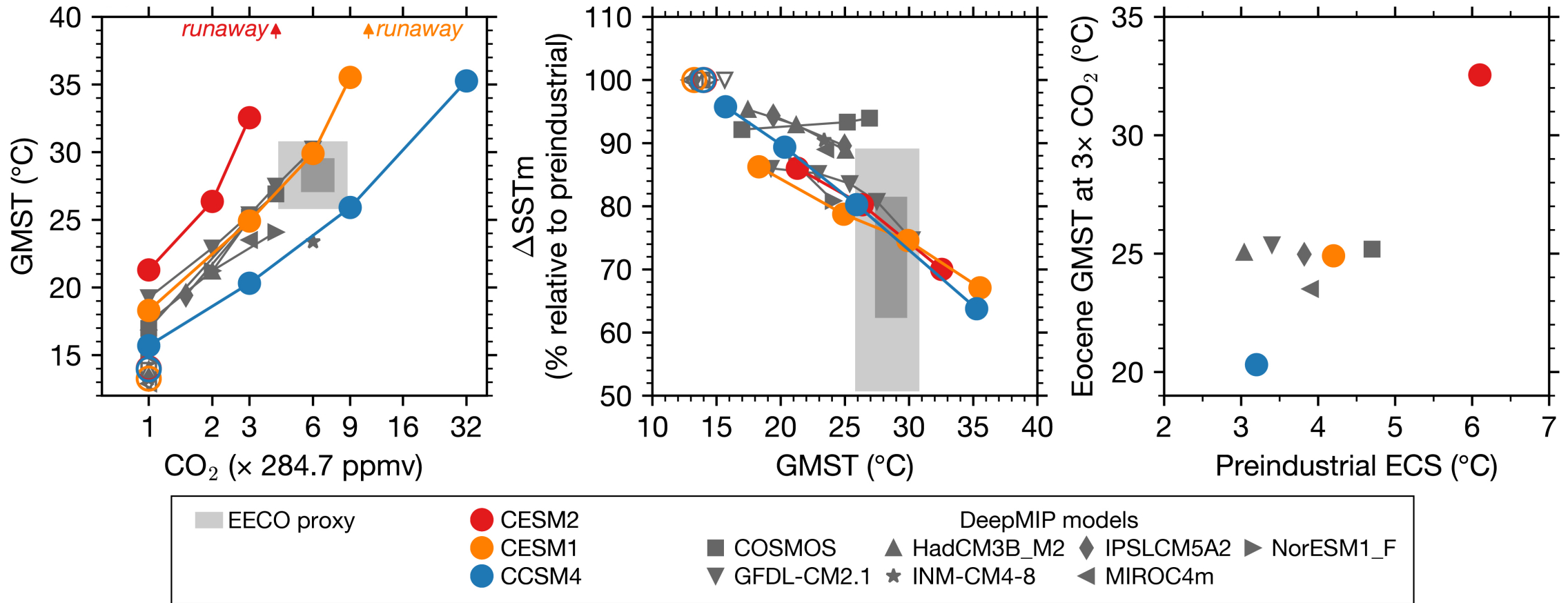


Two simplest metrics

- **GMST +14°C**
- **Equator-to-pole gradient -30%**

Zhu, Poulsen, Otto-Bliesner, 2024, Annu Rev Earth Planet Sci

CESM1 simulates large-scale features of the equable climate

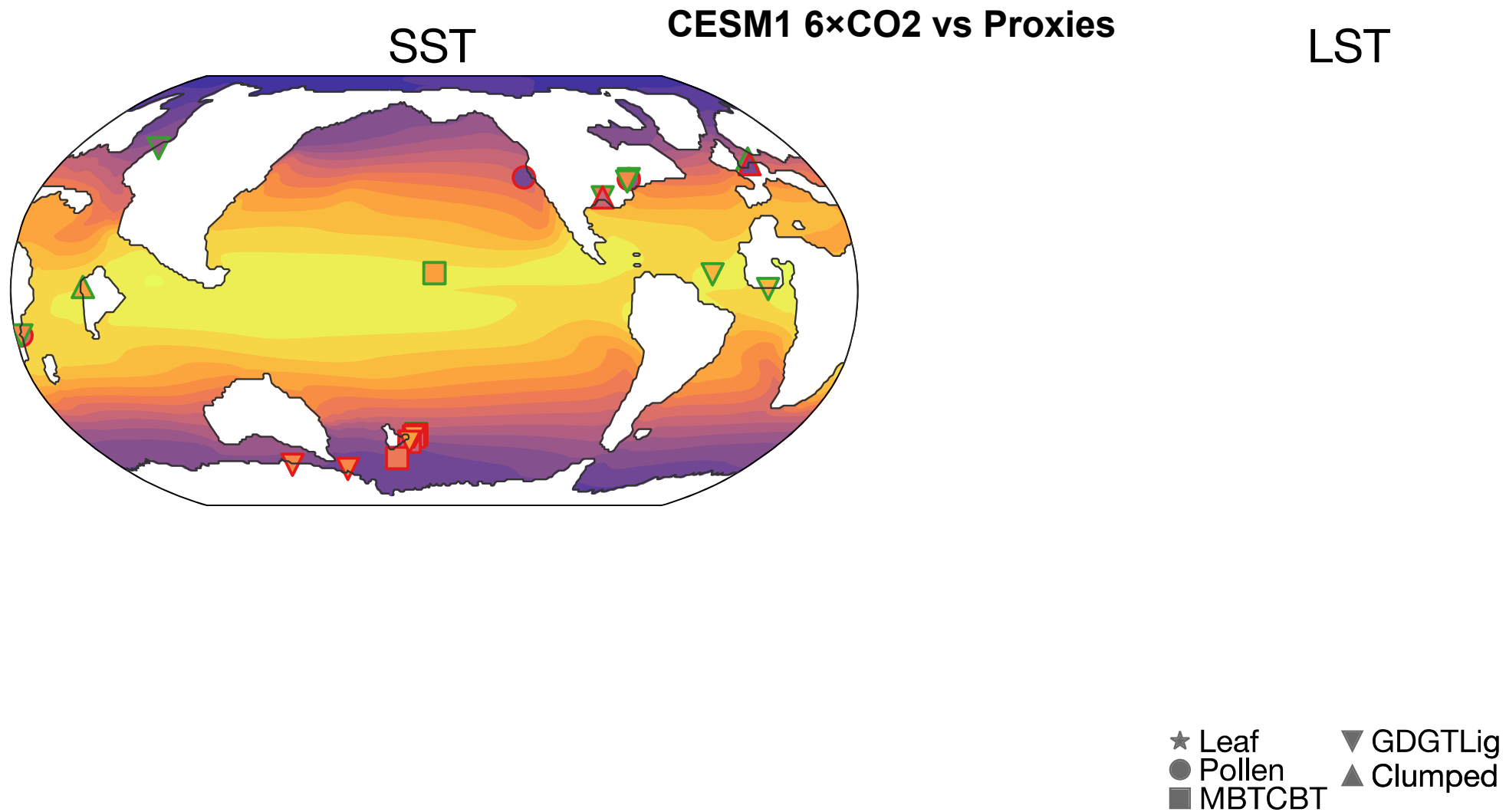


Zhu, Poulsen, Tierney, 2019, *Sci. Adv.*

Zhu, Poulsen, Otto-Bliesner, 2020, *Nat. Clim. Change.*

Zhu, Poulsen, Otto-Bliesner, 2024, *Annu Rev Earth Planet Sci*

Discrepancies in regional temperatures, e.g., the Southwest Pacific

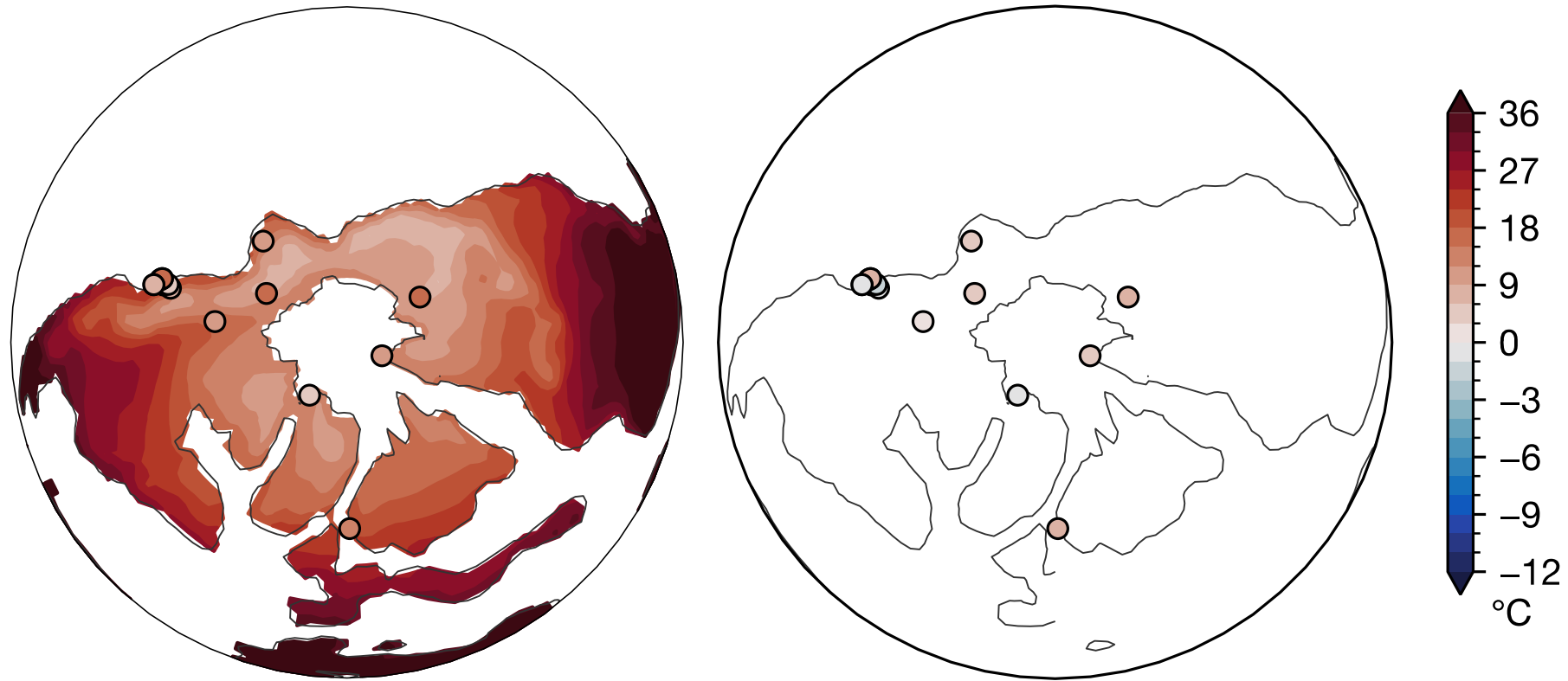


Discrepancies in winter temperatures, e.g., the New Siberian Islands

CESM1 6×CO₂ vs Proxies

Land Surface Temperature

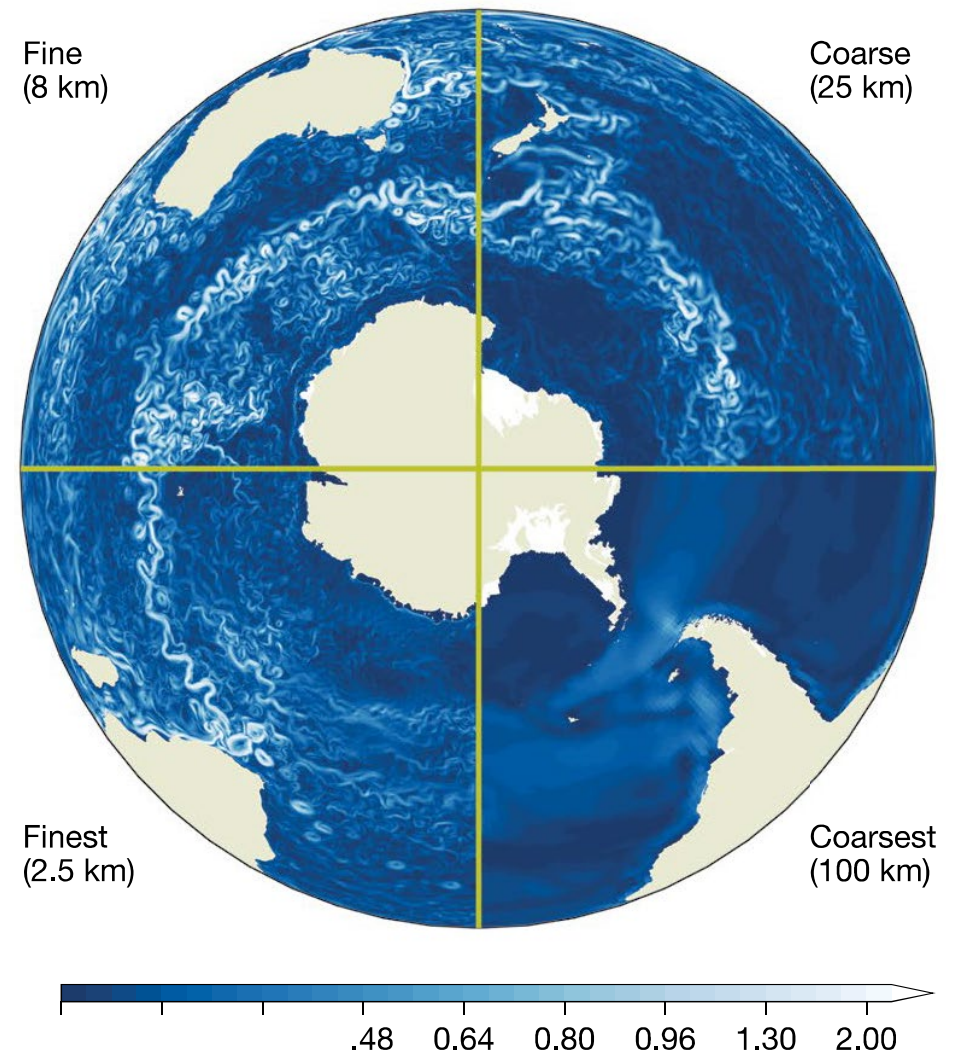
cold month mean



Proxy from West et al., 2020, CP

Can higher resolution (HR) further improve the simulation?

- ***Coupled iCESM1.3_HR***
- ***10× finer horizontal resolution***
 - ~10-km ocean & sea ice
 - ~25-km atmosphere & land
- Eocene with 3×CO₂
- Initialized from LR & ran for 60 yrs
- Cost/yr: 300 times more expensive



*Hewitt et al., 2022,
Nat. Clim. Change.*

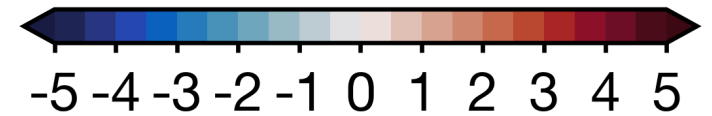
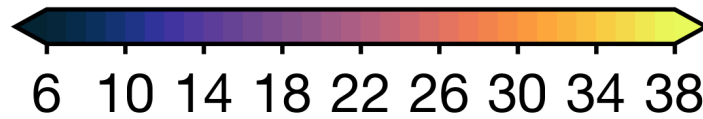
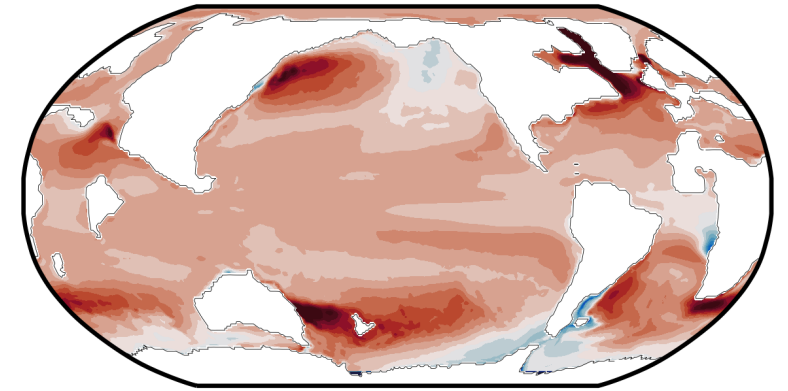
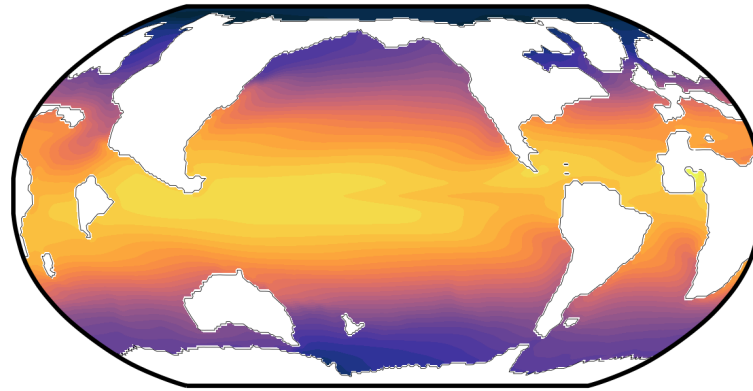
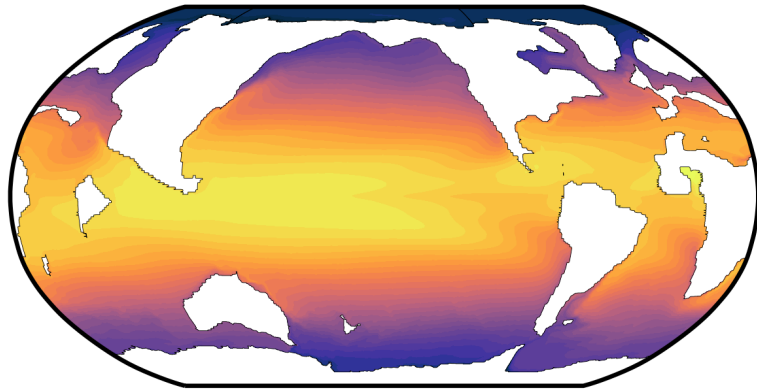
High-resolution simulation is more equable

Warmer mid/high latitudes

HR 3x, annual

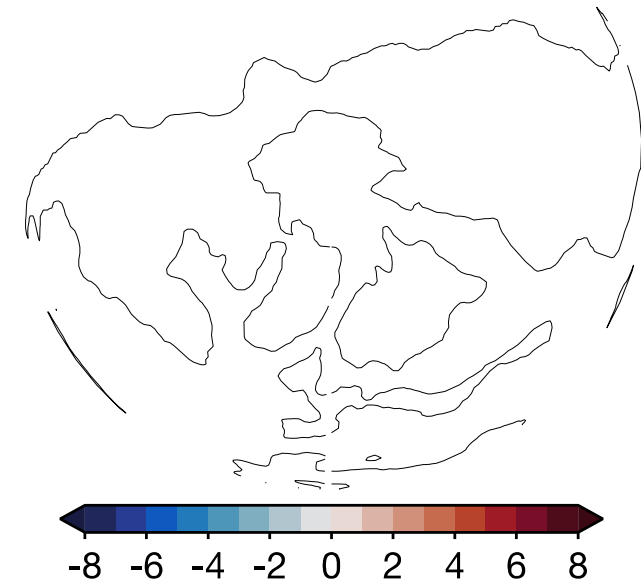
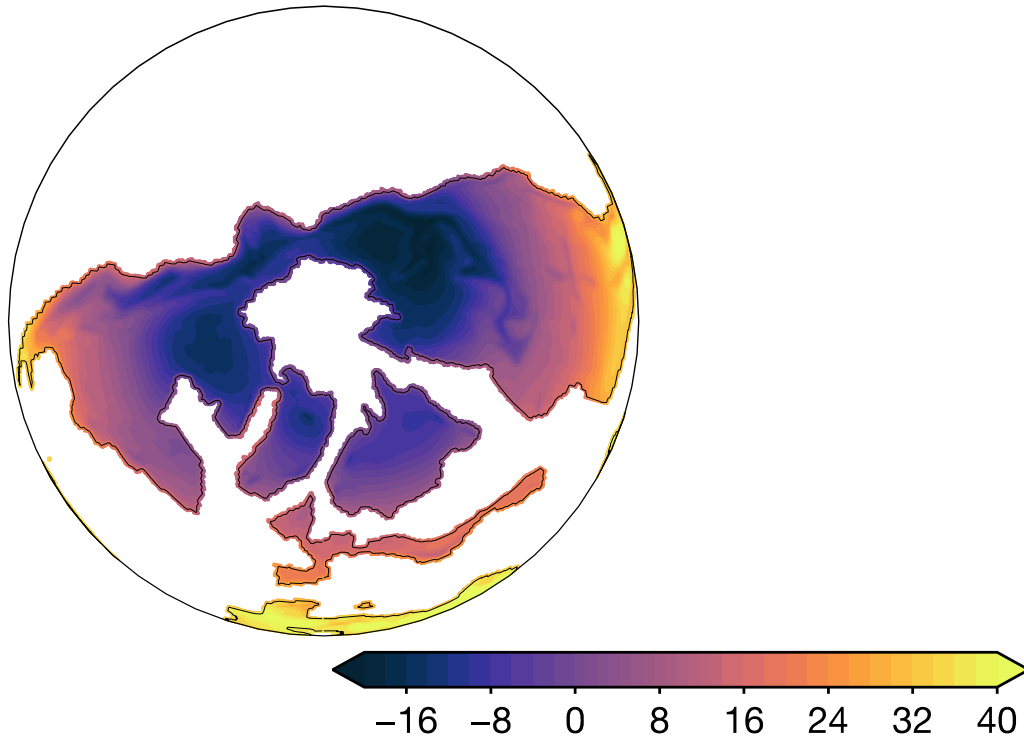
LR 3x, annual

HR - LR 3x, annual



High-resolution simulation is more equable

Warmer winters



Role of resolving ocean eddies (vs parameterizing)

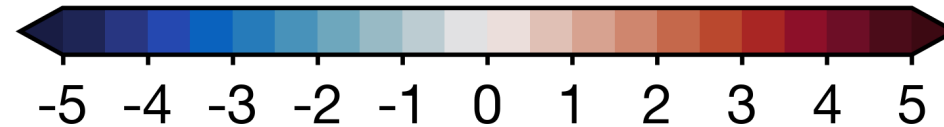
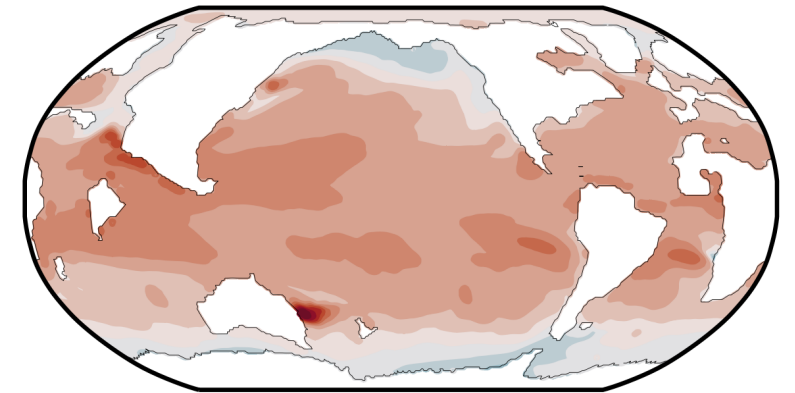
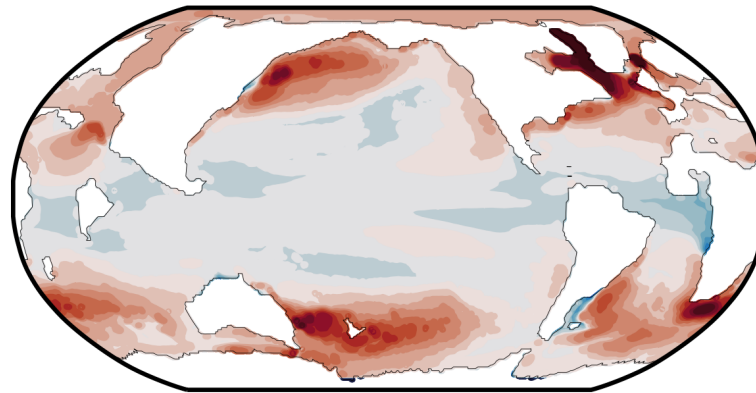
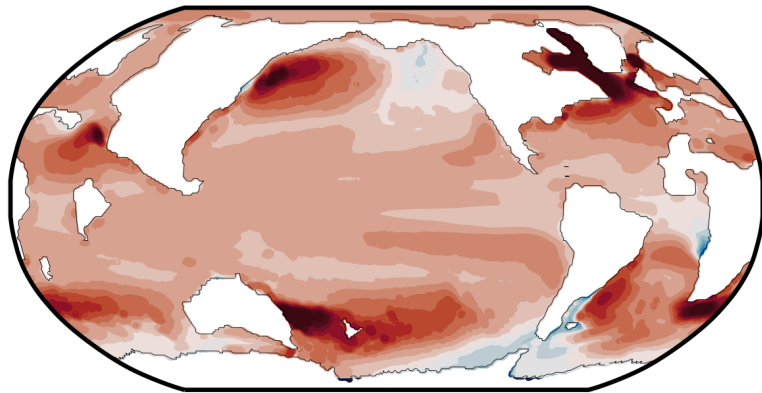
Role of HR-Ocean

Role of HR-Atmos.

HR - LR 3x, annual

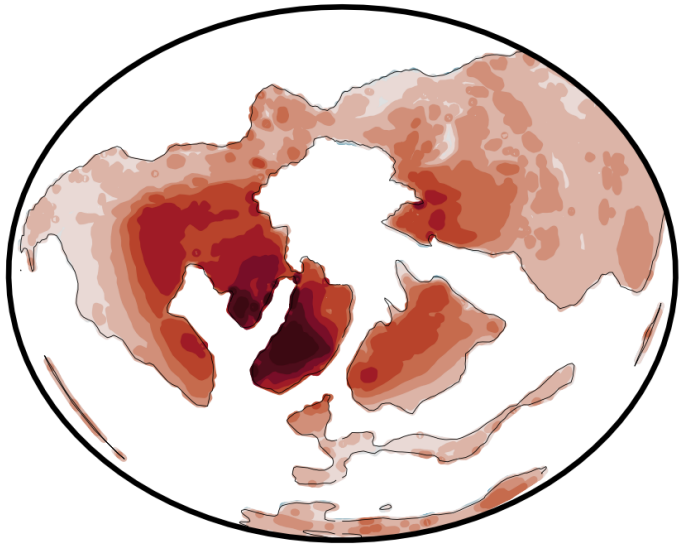
HR - MixR 3x, annual

MixR - LR 3x, annual



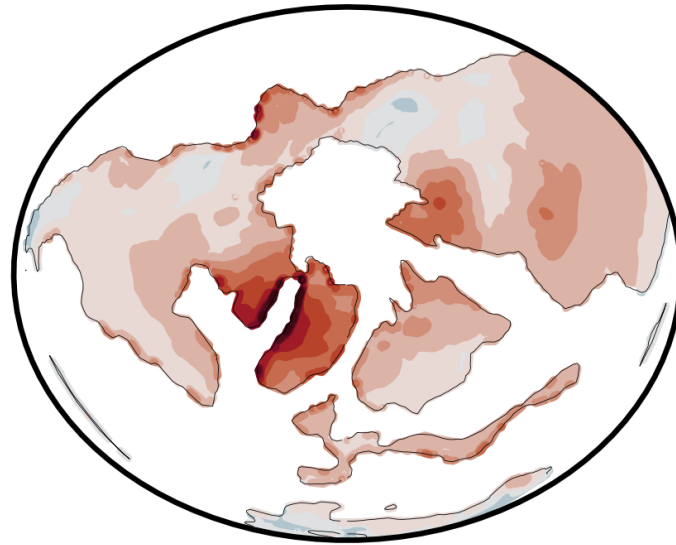
Role of HR ocean & atmosphere

HR - LR 3x, cold month



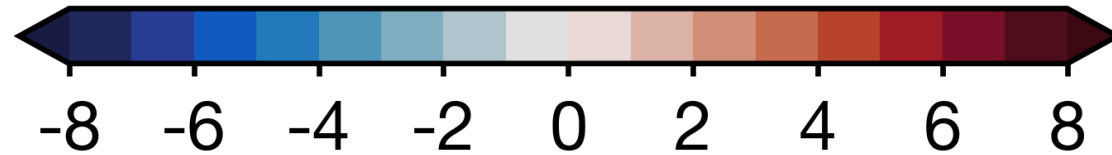
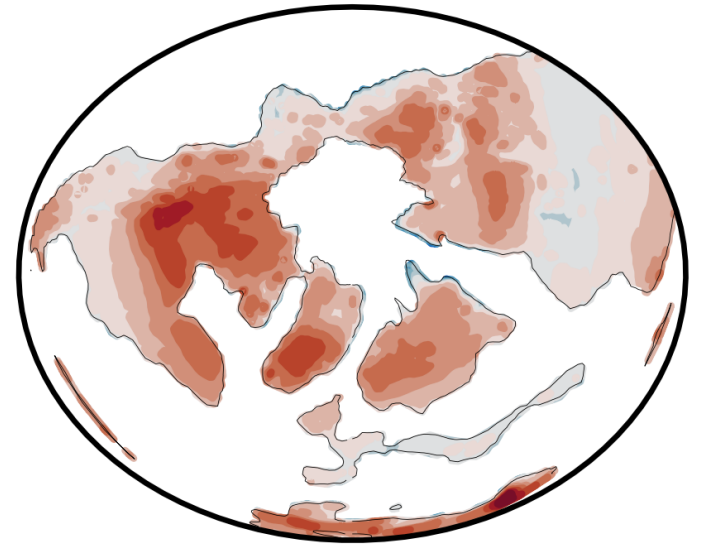
Role of HR-Ocean

HR - MixR 3x, cold month



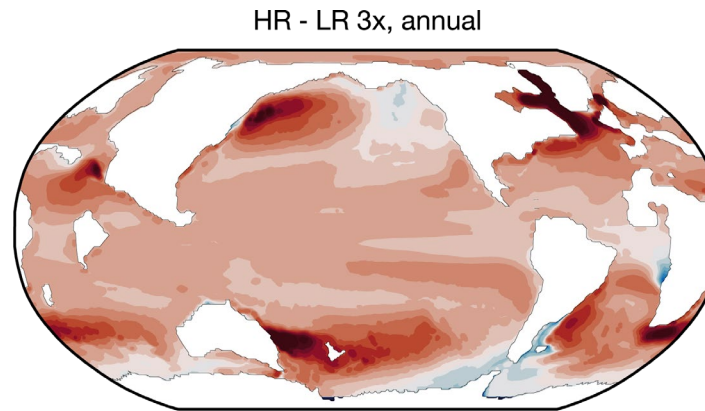
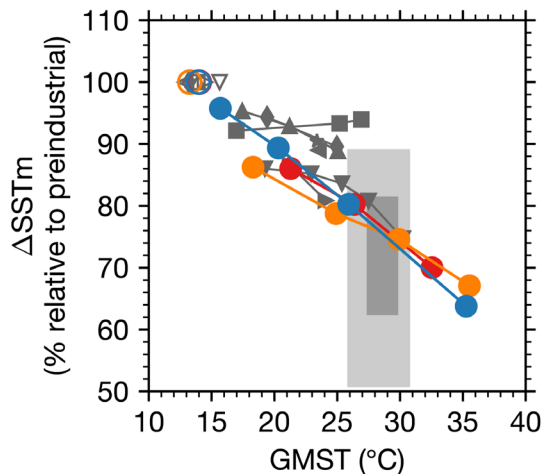
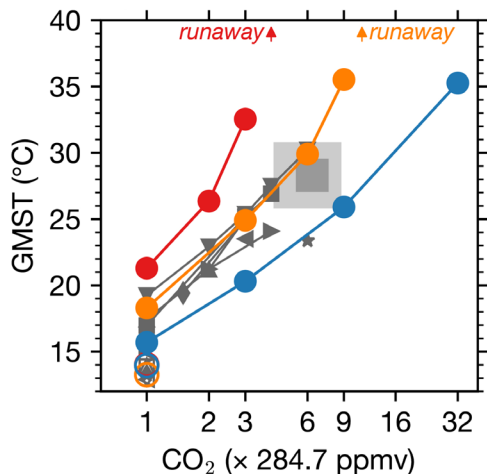
Role of HR-Atmos.

MixR - LR 3x, cold month



Summary: high resolution provides a better solution to the equable climate problem

- Low-res. CESM1 simulates the large-scale features: GMST & meridional gradient
 - Discrepancies remain at regional & seasonal scales
- High-res. CESM1 improves by simulating warmer mid-/high-lat. & winters
 - Likely due to resolving ocean eddies (vs parameterizing)
 - Atmosphere convection/clouds may also play a role
- *Better regional/seasonal proxies are needed: multiple methods & precise location*



Thank you!
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