Revisiting the low-gradient problem with weather-resolving atmosphere-ocean coupled simulations

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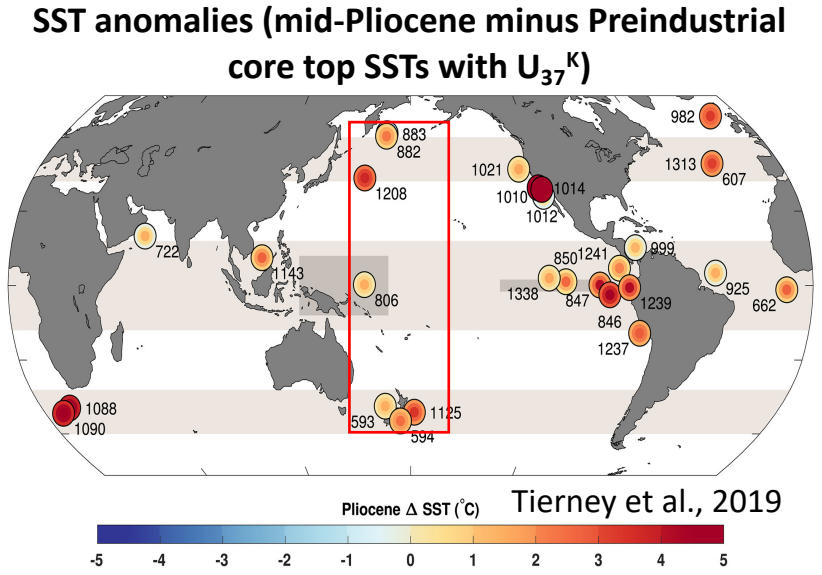
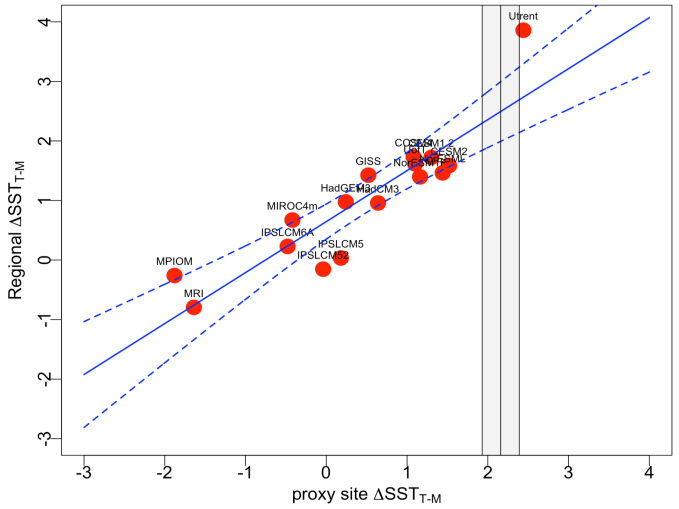
Warming in the mid-latitude Pacific

- Amplified warming in the Pacific mid-latitudes (e.g., Tierney et al., 2019)
- Remains difficult for the Pliocene Model Intercomparison Project 2 simulations to capture



Tierney et al., 2019

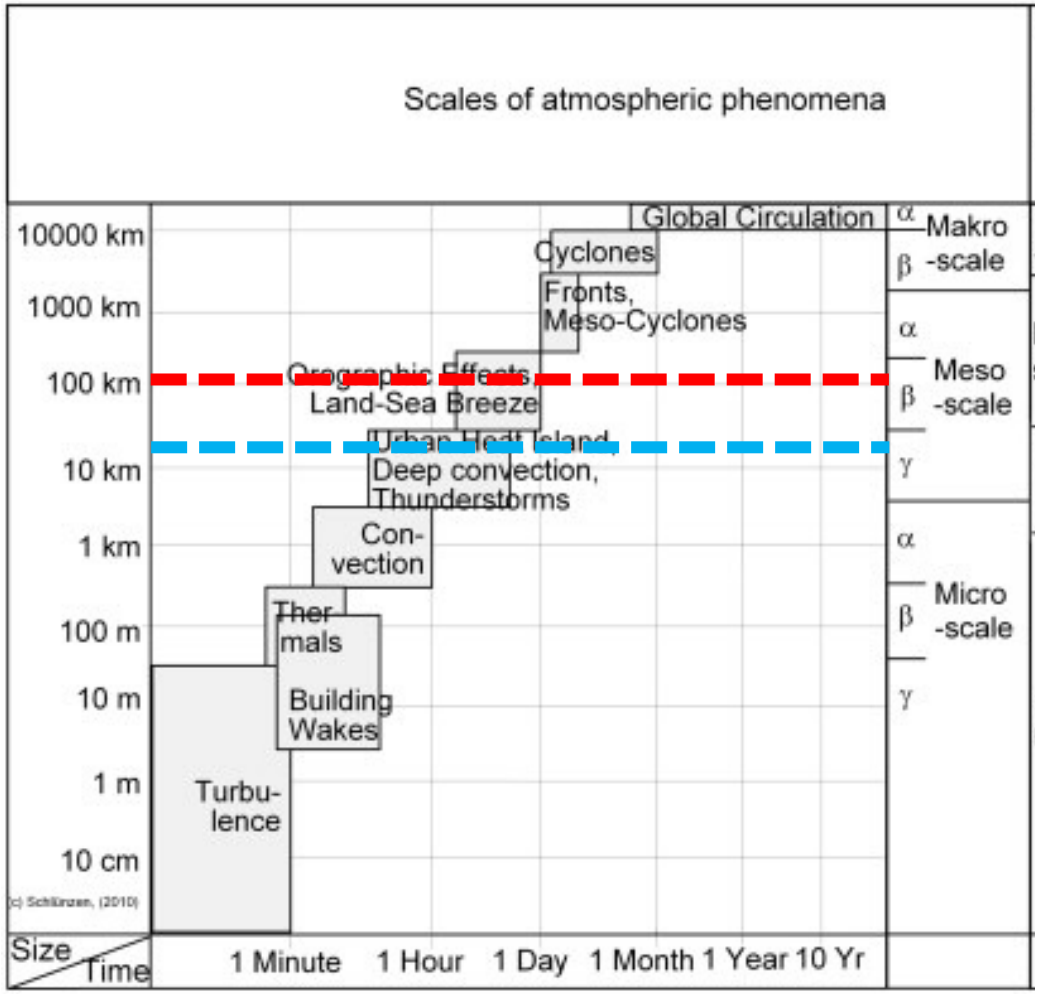
(40 – 60°N/S minus 10°N – 10°S, 145°E to 200°E)



Unpublished, in prep

Possible explanations, and added benefit from high resolution

- Perturbed ocean diffusivity (Fedorov et al., 2010, Sci.; Lohmann et al., 2022, P&P)
- Perturbed cloud albedo (Burls et al., 2014, P&P)
- Differences in moist processes and heat transport by the atmosphere?
  - high resolution may lead to different results?

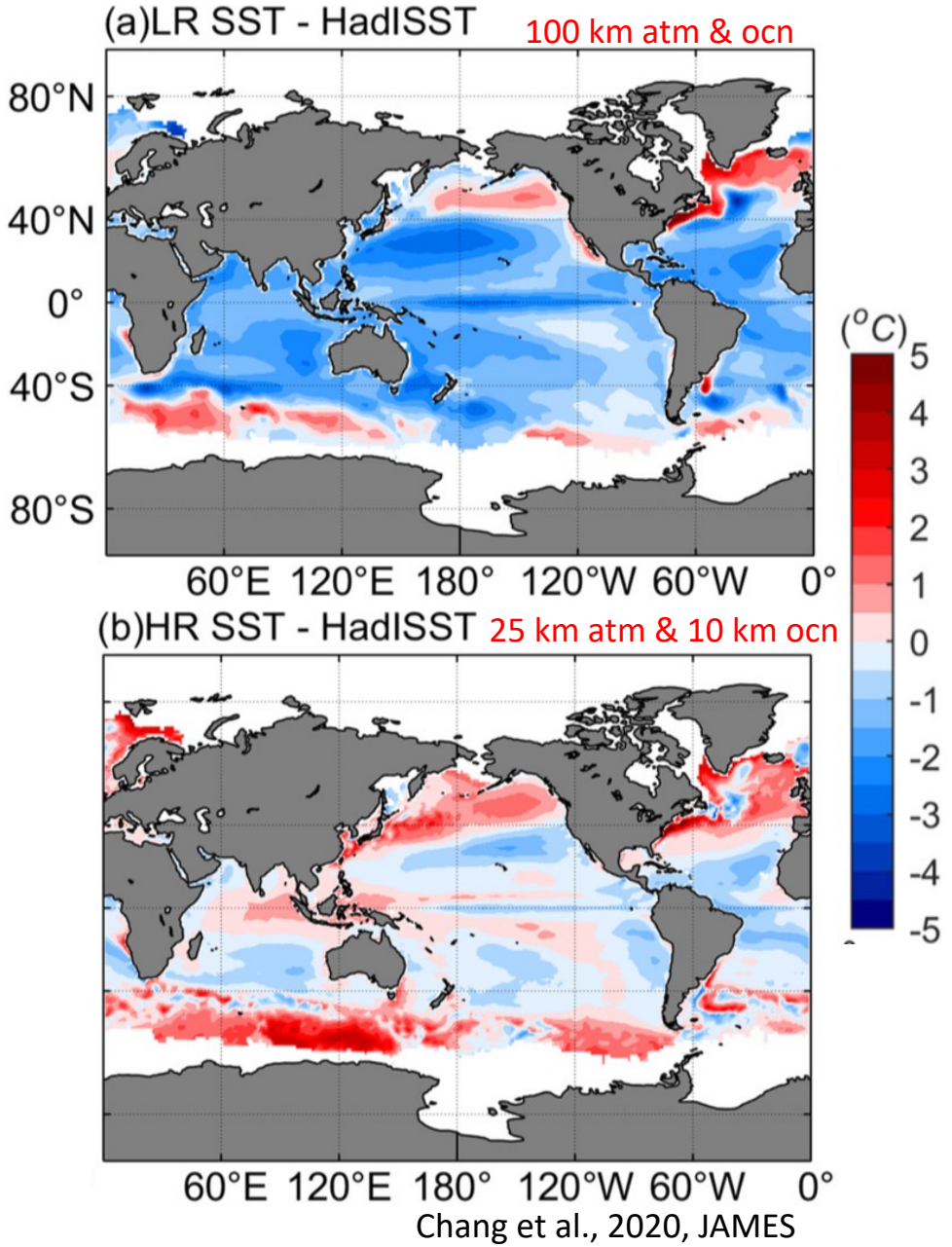


Schlunzen et al., 2011

Modeling framework

- Community Earth System Model version 1.3
  - Adapted for high resolution simulations (25 km atmosphere and land, 10 km ocean) (Chang et al., 2020)
  - Applied for historical and future climate projections (Meehl et al., 2013; Chang et al, 2020, JAMES)
- Experiments and resolutions
  - HR: ~25 km atmosphere, land and ~100 km ocean
  - LR: ~100 km atmosphere, land and ~100 km ocean
  - Two experiments: HR and LR Pliocene
    - Initialized with Feng et al., (2020, JAMES)

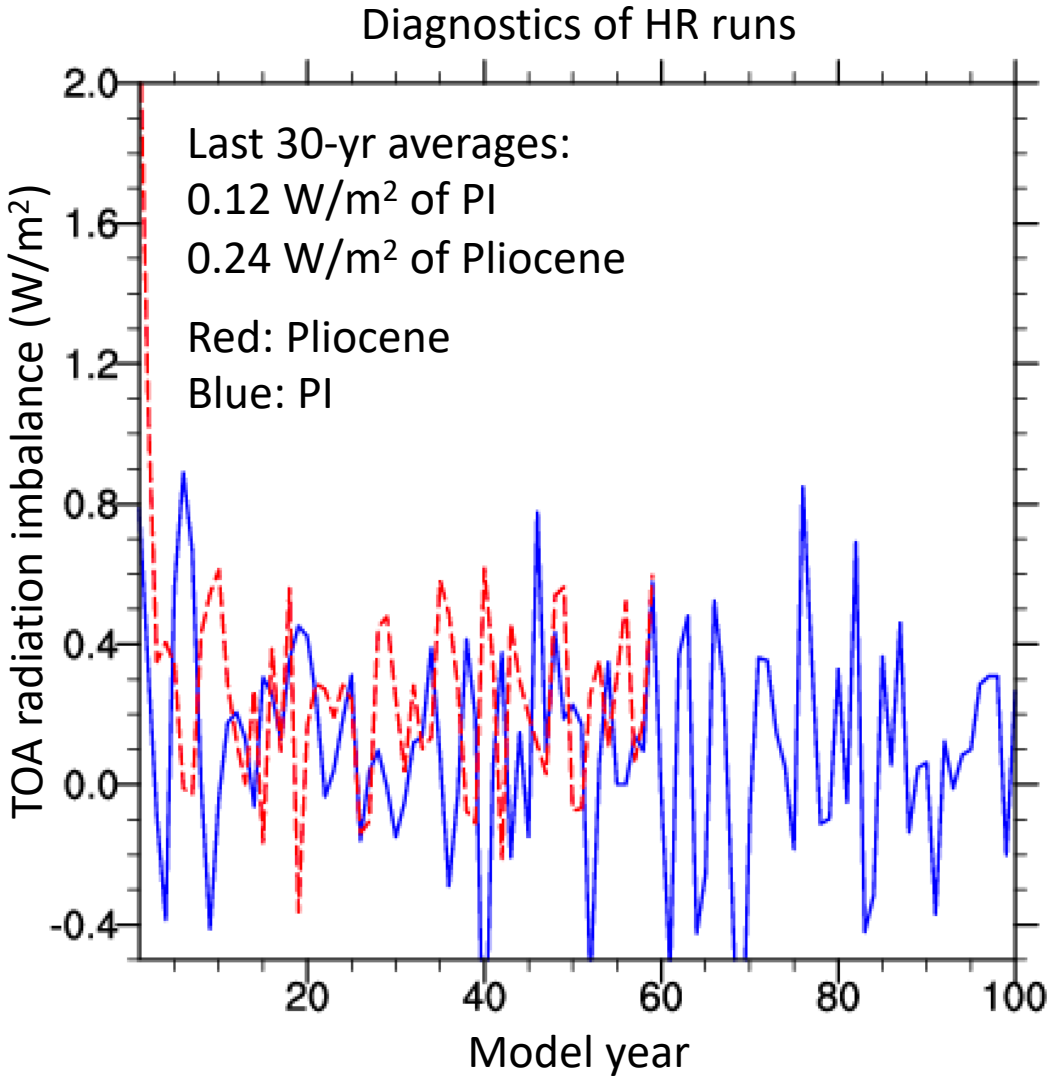
SST bias comparison between LR and HR



Chang et al., 2020, JAMES

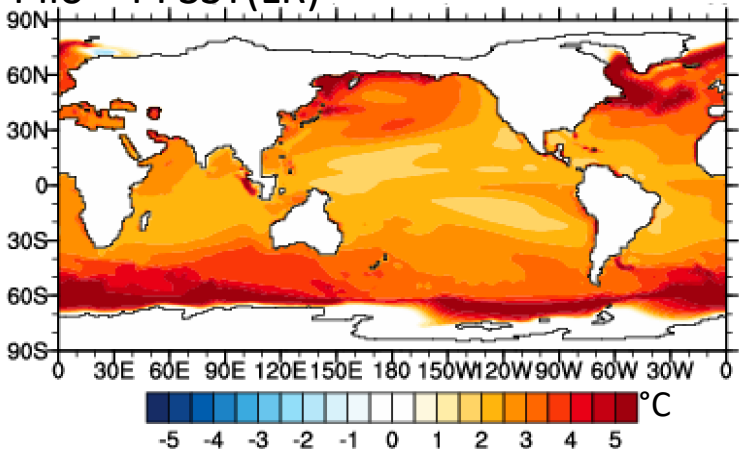
Comparison between HR and LR and equilibration

- Comparison of HR Pliocene minus PI, and LR Pliocene minus PI
- HR: 100 yrs of PI (Rosenbloom at NCAR) and 60 yrs of the mid-Pliocene
  - The model reaches equilibrium quickly
  - Focus on the atmospheric responses
- LR: 500 yrs of PI (Jiang Zhu at NCAR) and 150 yrs of the mid-Pliocene

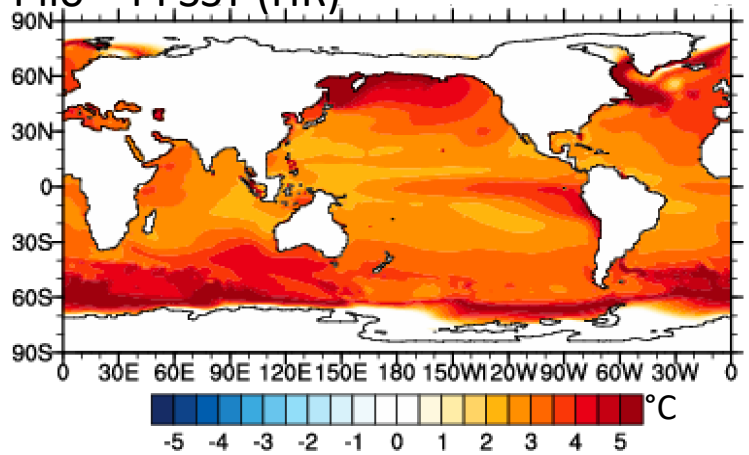


Does mid-Pliocene HR show more poleward amplified SST warming in the Pacific?

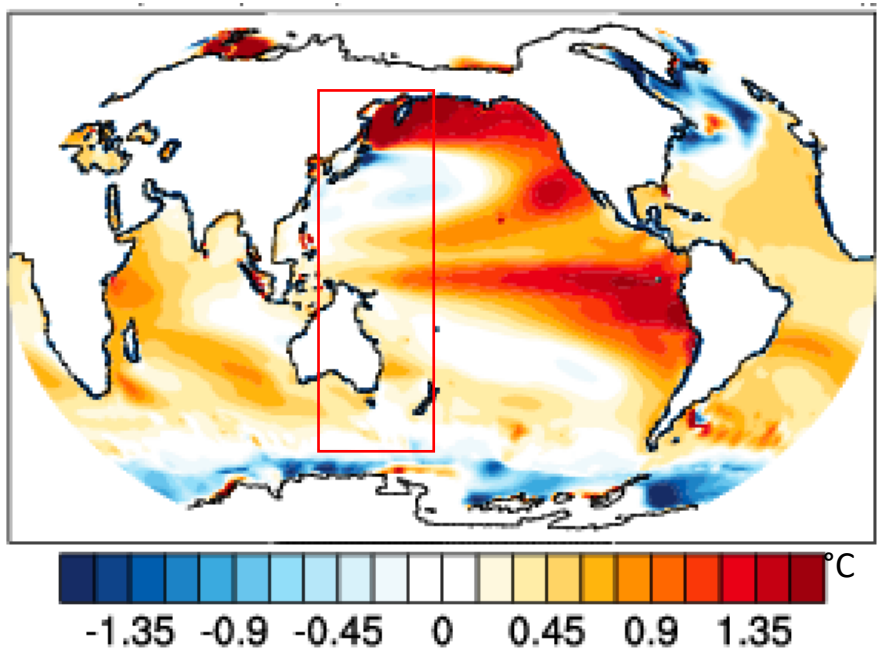
Plio – PI SST(LR)



Plio – PI SST (HR)



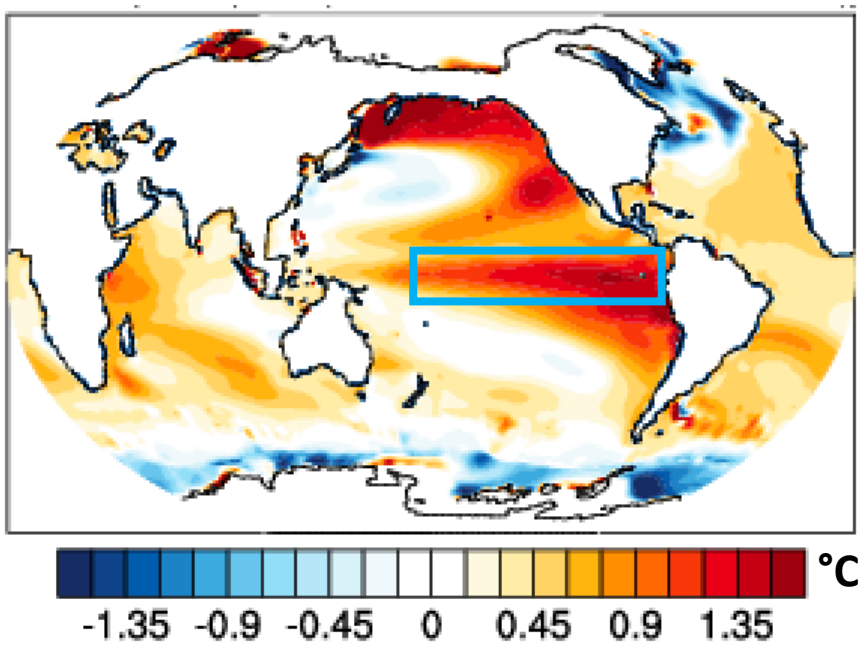
Difference in SST warming pattern between HR and LR



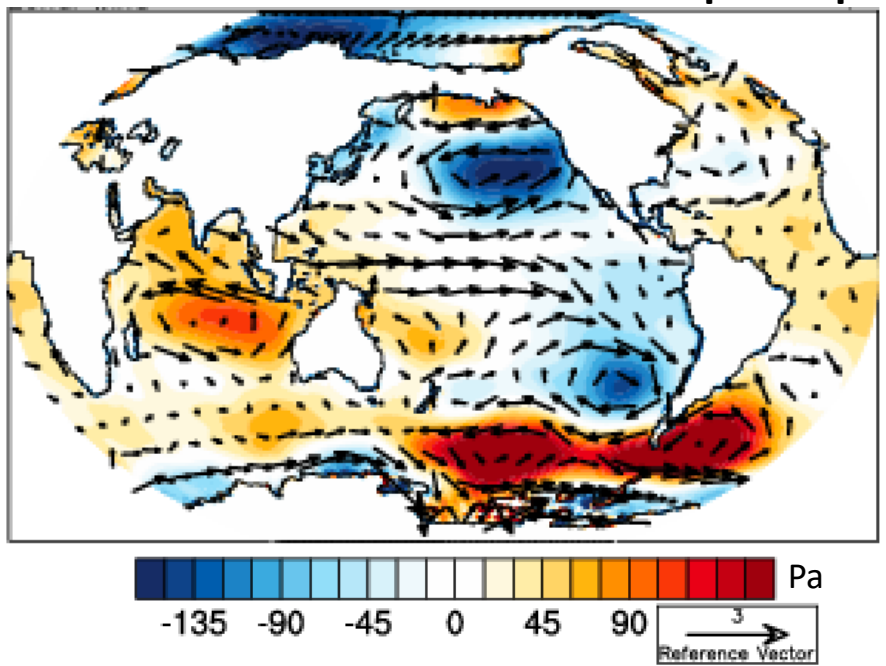
Possible role of atmospheric heat transport

- Response of wind and sea level pressure pattern consistent with the “Gill mode” (Gill, 1980)
- Anomalous wind divergence from the eastern tropical Pacific
  - Enhanced poleward heat transport from the region

Difference in SST warming pattern between HR and LR

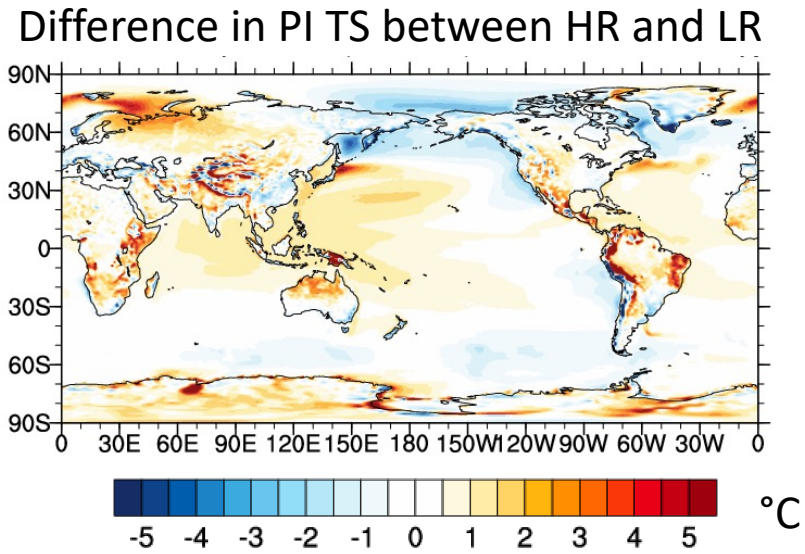


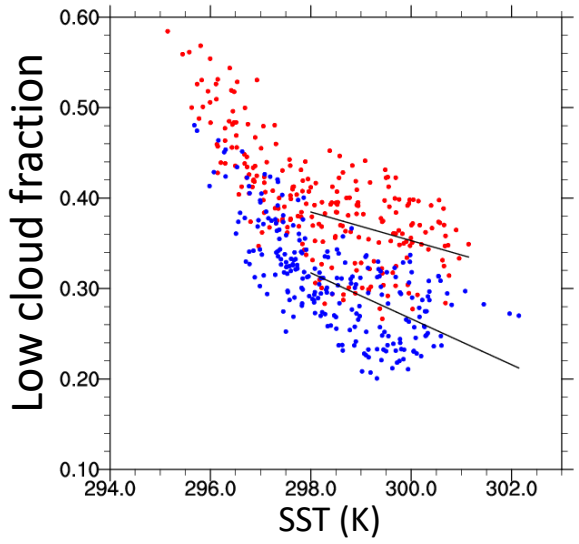
Difference in SLP and 850 hPa wind response pattern

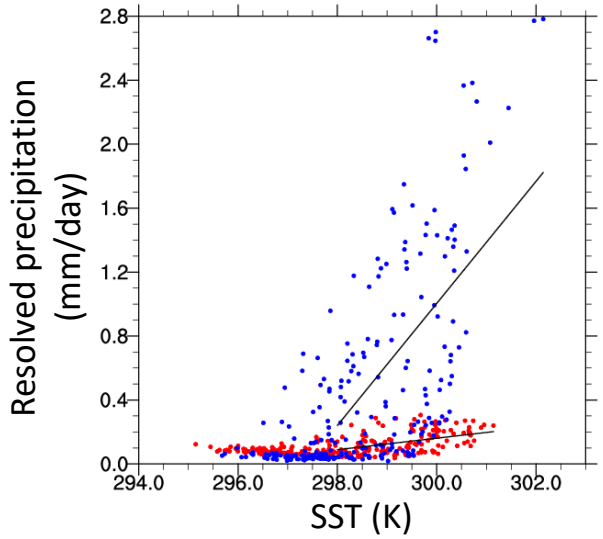


Possible role of moist convection in the EEP

- Base PI state EEP SST is similar between HR and LR
- More pronounced low cloud reduction at high SSTs
- Greater increase in the resolved heavy precipitation with high SSTs







Red: LR
Blue: HR

Preliminary findings:

- HR simulates more poleward amplified SST warming along the western Pacific
  - Enhanced EEP SST warming and potential heat transport by extratropical Rossby waves
  - Better resolved moist convection may lead to greater low cloud reduction at high SSTs?

Thank you!

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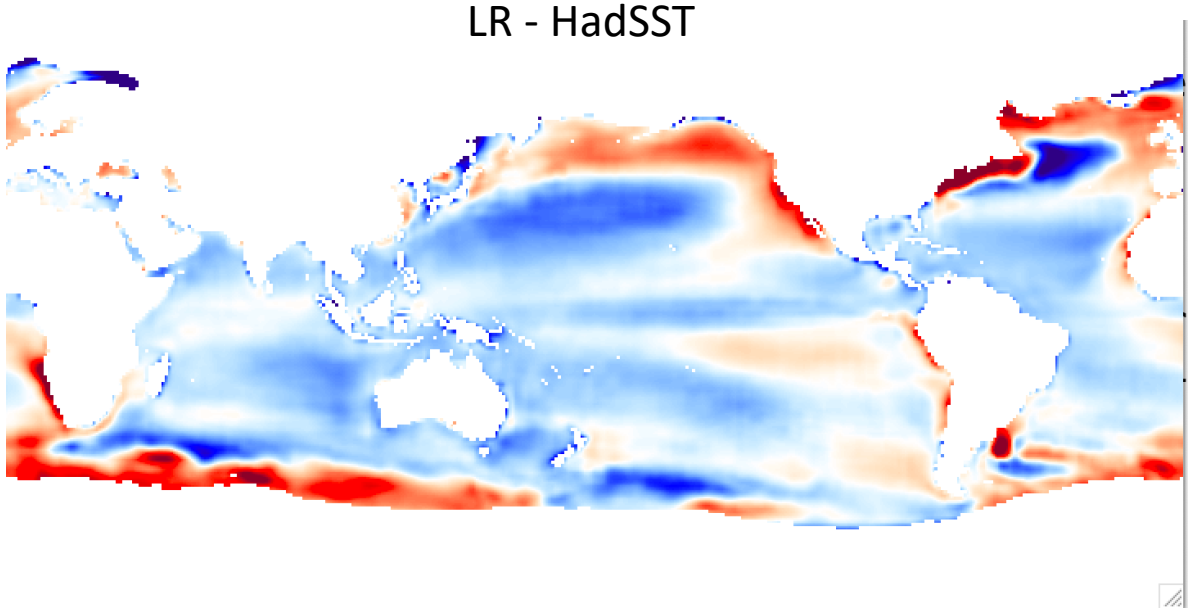
Upcoming HR simulations (10 km ocean) for LGM, Pliocene, and Eocene (Contact: ottobli@ucar.edu)

Comparison of PI SSTs with obs

LR - HadSST



HR - HadSST