Examining state dependence of the cloud feedback using a perturbed parameter ensemble

Jiang Zhu (jiangzhu@ucar.edu), Bette L. Otto-Bliesner, Esther C. Brady, Andrew Gettelman, Trude Eidhammer
National Center for Atmospheric Research

1. Motivation

1. Past climates inform our future; understanding of the state and forcing dependent response is critical.
   - How does the cloud feedback depend on climate states? Are there non-linear tipping points?
   - How does the cloud feedback interact with temperature and its spatial pattern?

2. Past climates inform the equilibrium climate sensitivity (ECS) in models.
   - Community Earth System Model v2 (CESM2) fails to simulate the Last Glacial Maximum (LGM) & the early Eocene (EECO): its high ECS (~5°C) is unrealistic
   - An LGM-calibrated CESM2 still fails to simulate the Early Eocene
   - Which processes/parameters control the nonlinear cloud feedback ($\lambda_{as}$)?

2. Approach: perturbed parameter ensemble (PPE)

1. Community Atmosphere Model v6 (CAM6) in ~2°C
   - PaleoCalibr fixes: no cloud-ice-number-limiter (nimax); shorter microphysical Δ

2. 45 parameters in convection & cloud parameterizations (see below for a subset)

3. PPE setup
   - 250 ensemble simulations (5 years each) from Latin Hypercube sampling
   - Preindustrial SST (prei) and SST+4K (p04k) & SST+8K (p12k) & SST+16K (p24k) with uniform change

4. Future plans: SST+8K, +12K, +16K & patterned warming

3. Results: asymmetrical response to warming/cooling

Over the low-lat. subsidence regime, moist turbulence & deep convection have the strongest impact on the SW $\lambda_{as}$ nonlinearity

1. Temperature-dependent surface moisture flux change?

Over the high-lat. regime, cloud microphysics has the strongest impact on the SW $\lambda_{as}$ nonlinearity

1. Temperature-dependent adiabatic cloud water content change?

2. Temperature-dependent cloud ice content change?

4. Preliminary summary

- Within the model parameter space, the cloud feedback exhibits strong and robust state dependence, i.e., asymmetrical response to warming/cooling
- Mechanisms are cloud regime specific, and may include the dependence of stratocumulus fraction, low-tropospheric stability, moisture flux/content, cloud ice content on the background temperature.