The Role of Deep Convection and Large-scale Circulation in Driving Model Spread in Low Cloud Feedback and Equilibrium Climate Sensitivity

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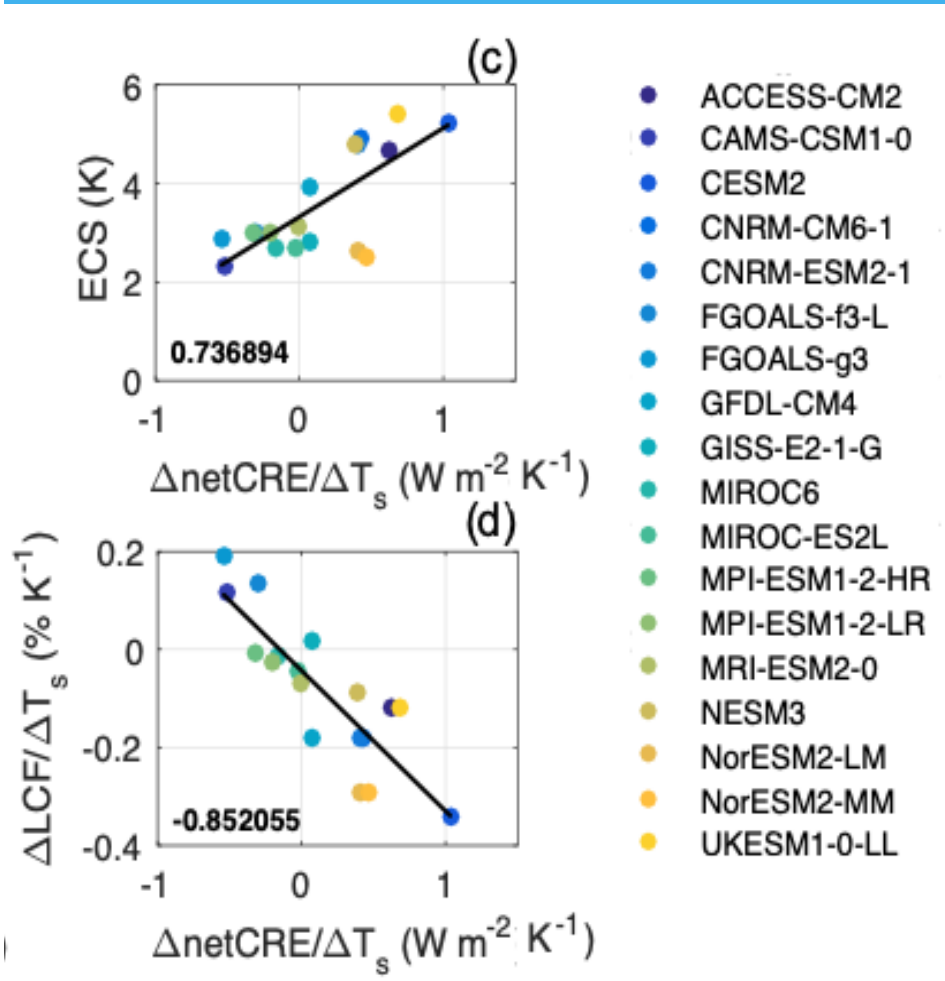
[6]Lawrence Livermore National Laboratory

DOE PI Meeting, October 14, 2020, Virtual

Motivation

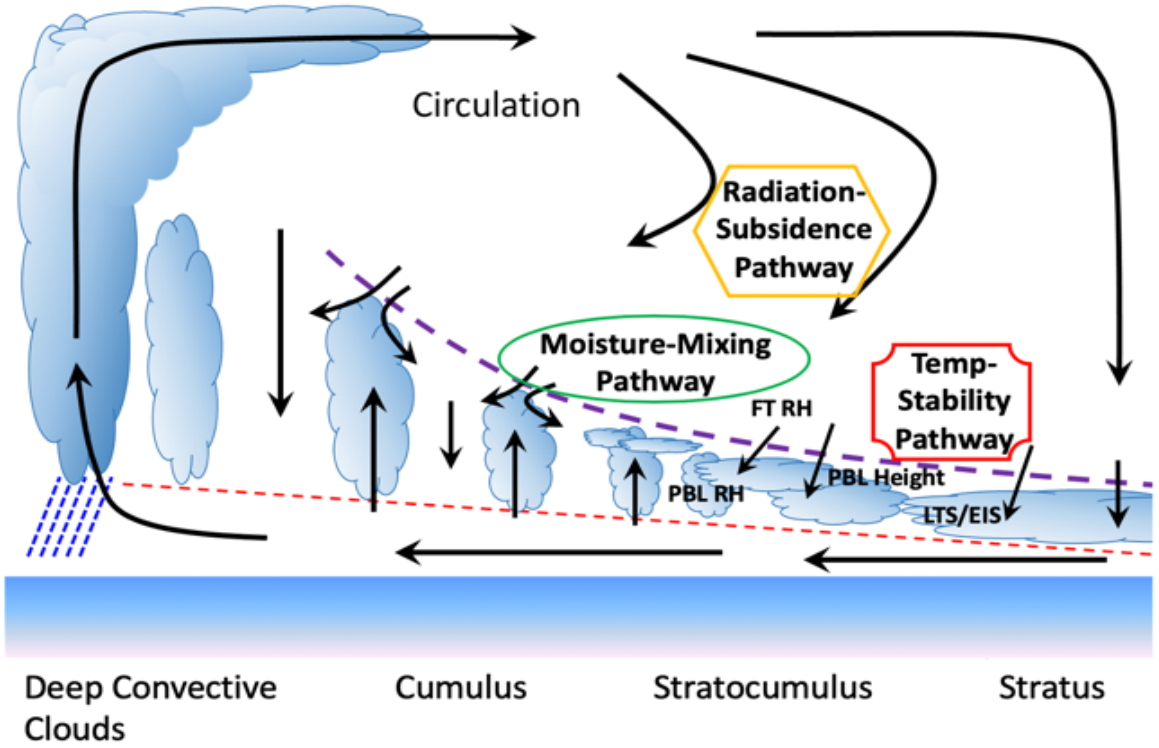


* Tropical low cloud feedback (30°S-30°N) contributes significantly to the inter-model spread in ECS for CMIP6.

Δ = 2086-2100 in "ssp8.5" – 2000-2014 in "historical"

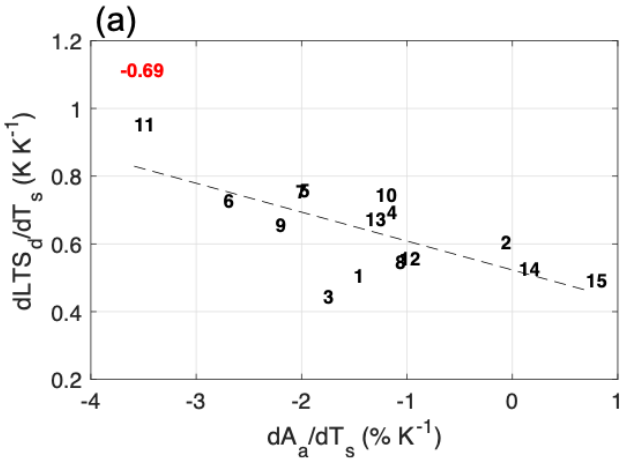
Hypothesis

- The differences in deep convective parameterizations between climate models drive a significant fraction of inter-model spread in low cloud feedback and ECS.

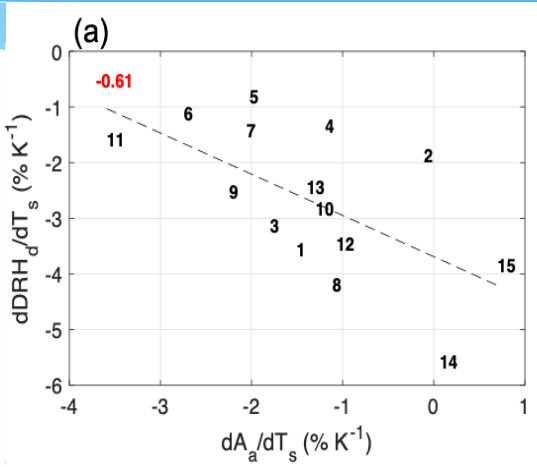


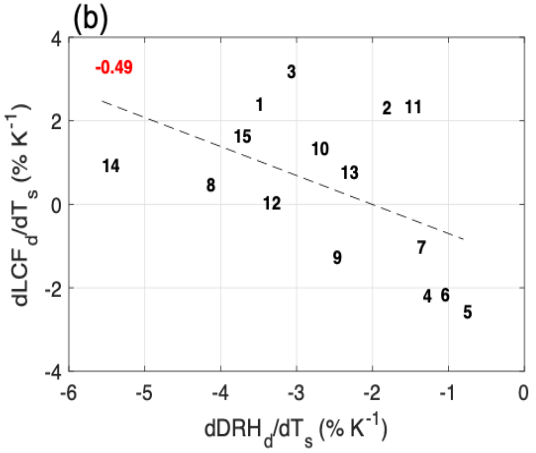
Inferences from CESM Perturbed Physical Experiments

Temperature-Stability Pathway

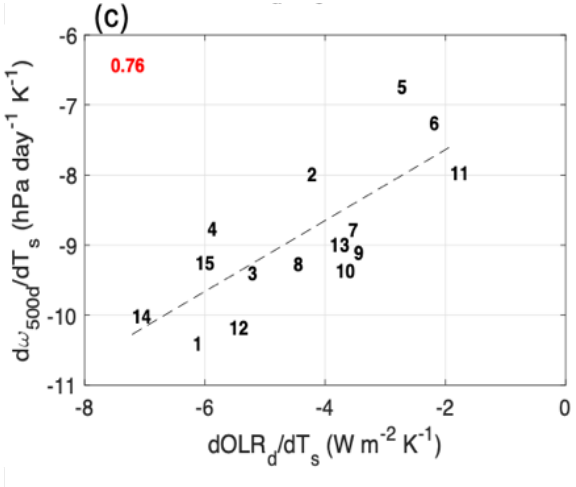


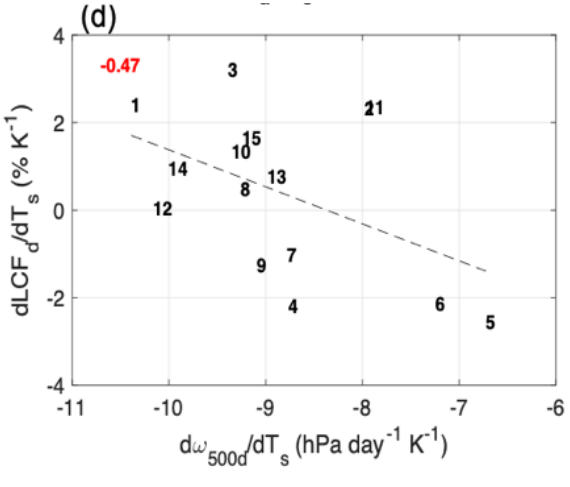
Moisture-Mixing Pathway





Radiation-Subsidence Pathway





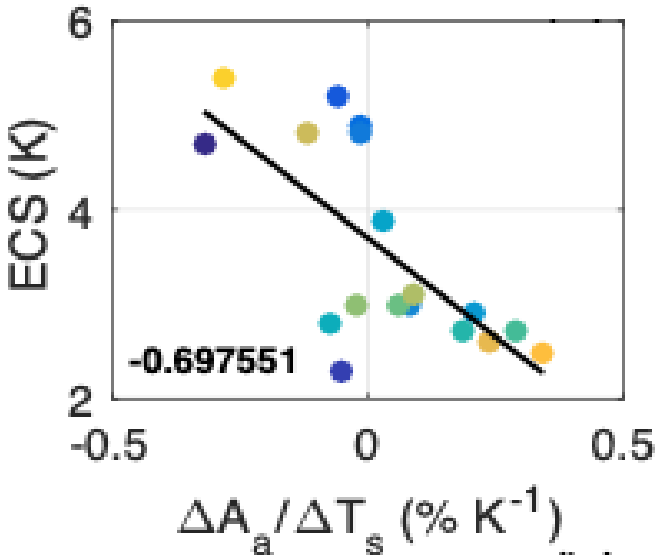
Objectives

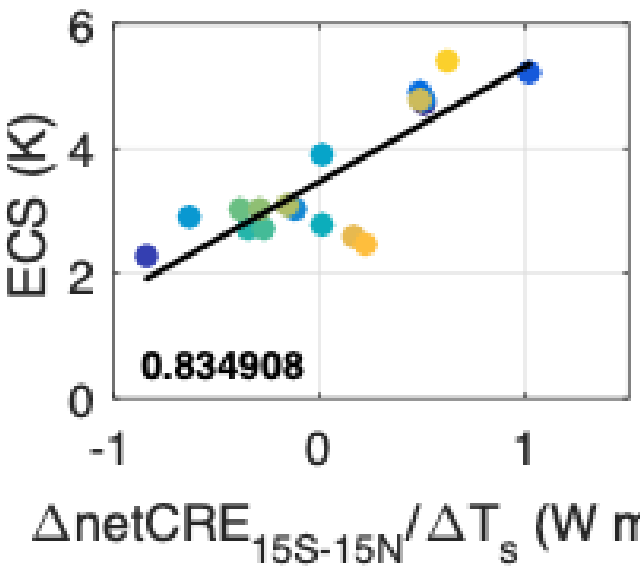
1. Characterize the physical pathways in CMIP6 model simulations linking convection, circulation and cloud feedback

2. Evaluate CMIP6 model performance in convection and clouds using observations and process-oriented model diagnostics

3. Conduct E3SM PPEs following the Cloud-Associated Parameterizations Testbed (CAPT) protocol and isolate model convective parameterization errors

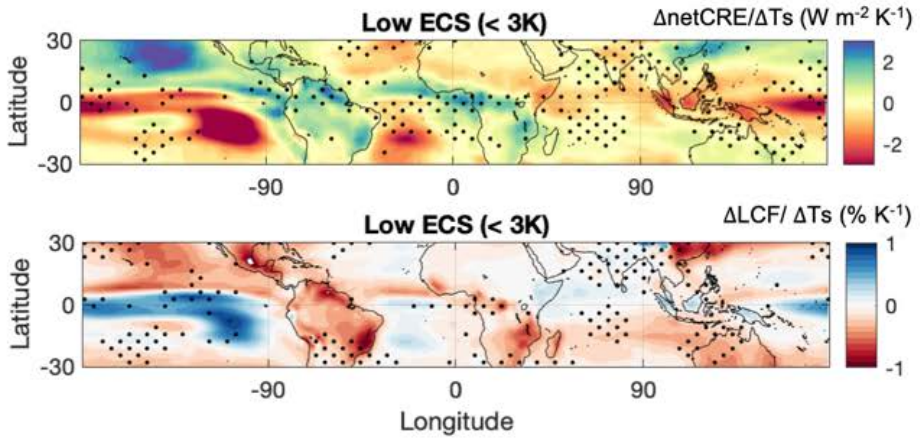
Task 1: Analyzing CMIP6 Models

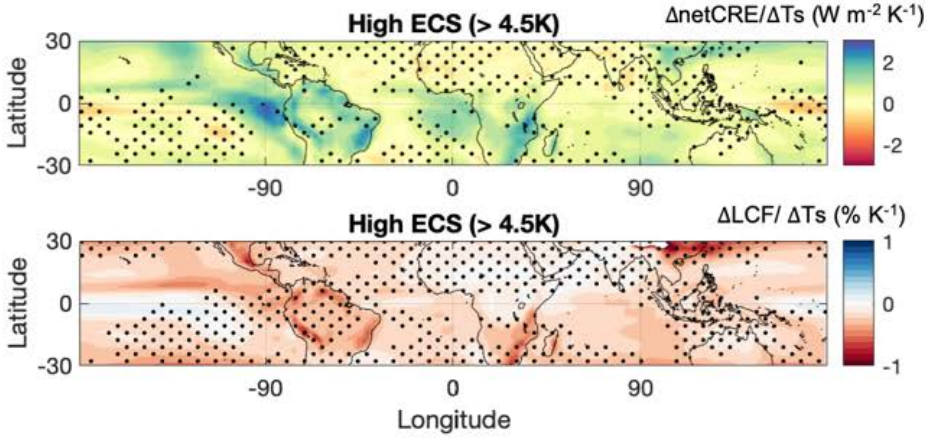




- ACCESS-CM2
- CAMS-CSM1-0
- CESM2
- CNRM-CM6-1
- CNRM-ESM2-1
- FGOALS-f3-L
- FGOALS-g3
- GFDL-CM4
- GISS-E2-1-G
- MIROC6
- MIROC-ES2L
- MPI-ESM1-2-HR
- MPI-ESM1-2-LR
- MRI-ESM2-0
- NESM3
- NorESM2-LM
- NorESM2-MM
- UKESM1-0-LL

Composites by ECS





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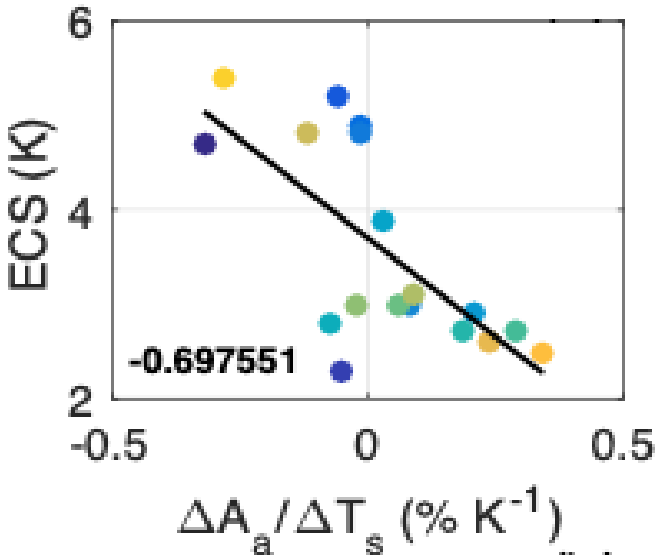

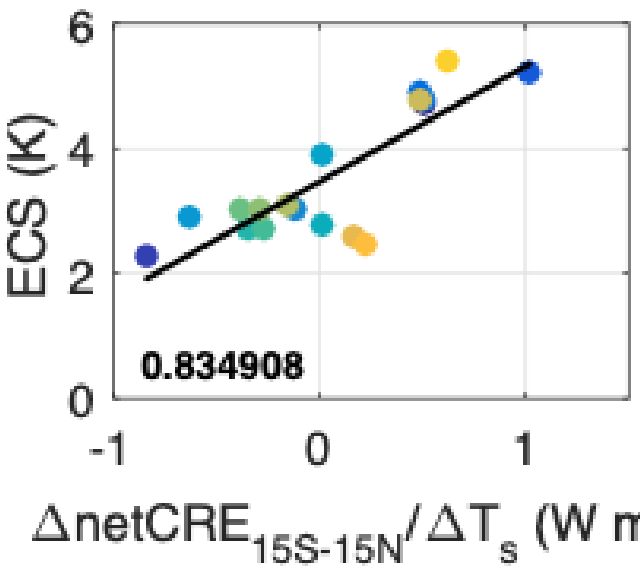

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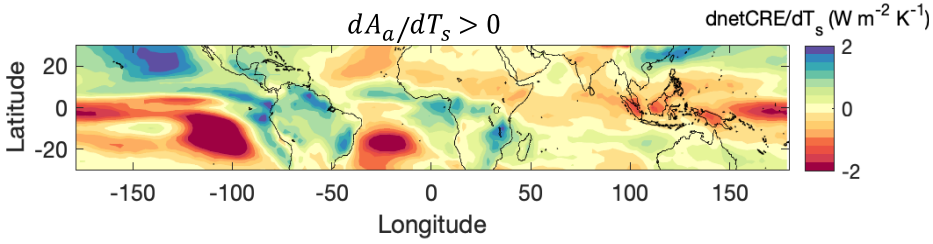
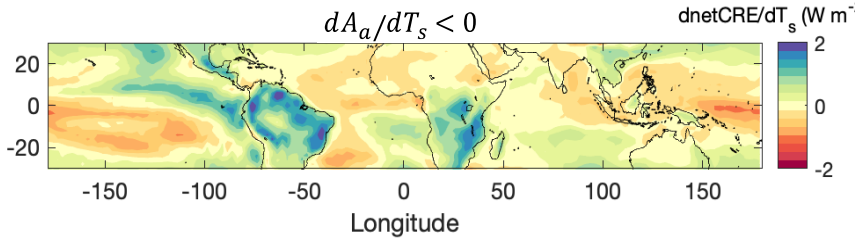
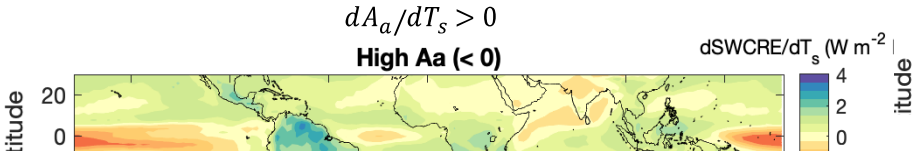
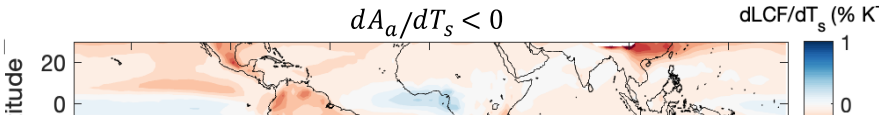
Composites by Tropical Ascent Area Change



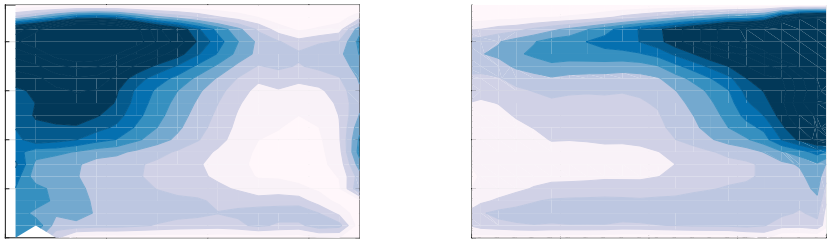






Task 2: Evaluating CMIP6 Models Against Observations

High ECS



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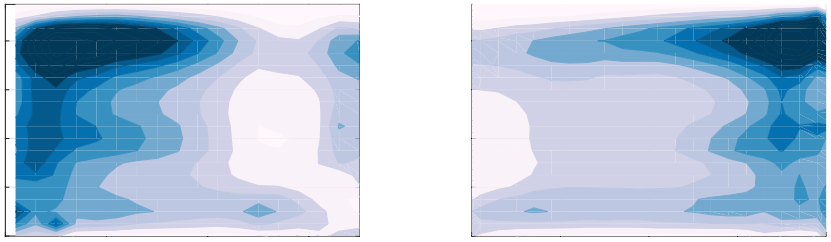
Low ECS



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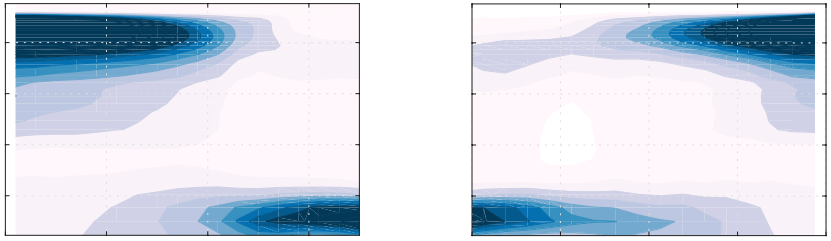
Observed



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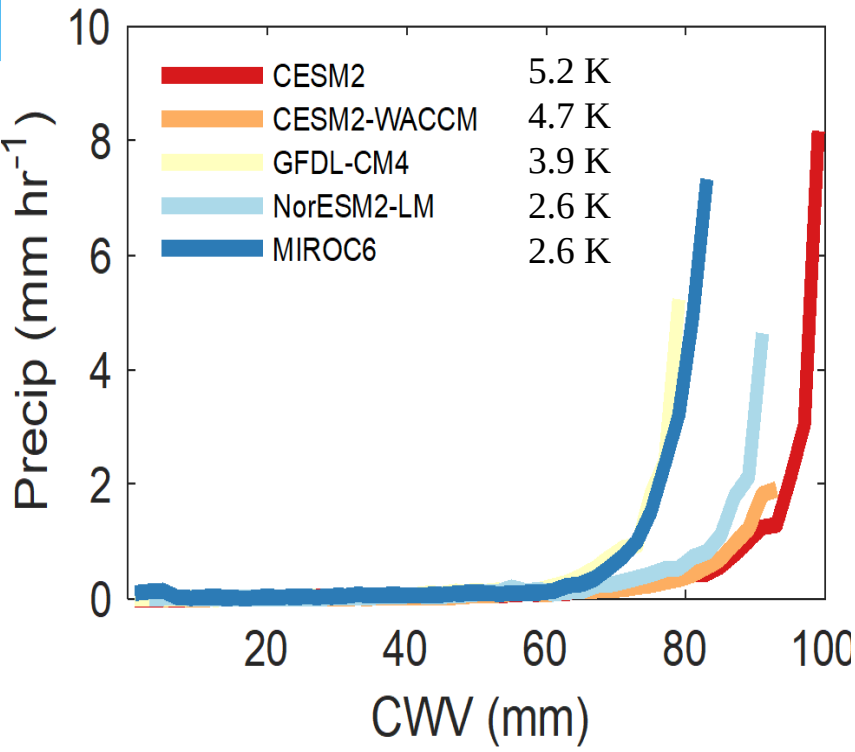
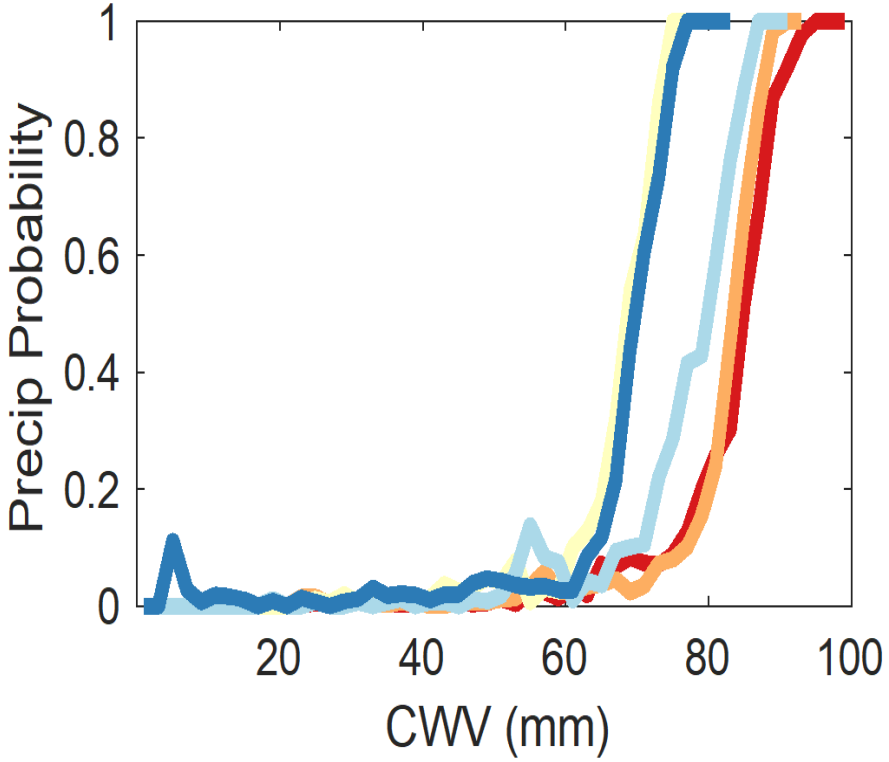
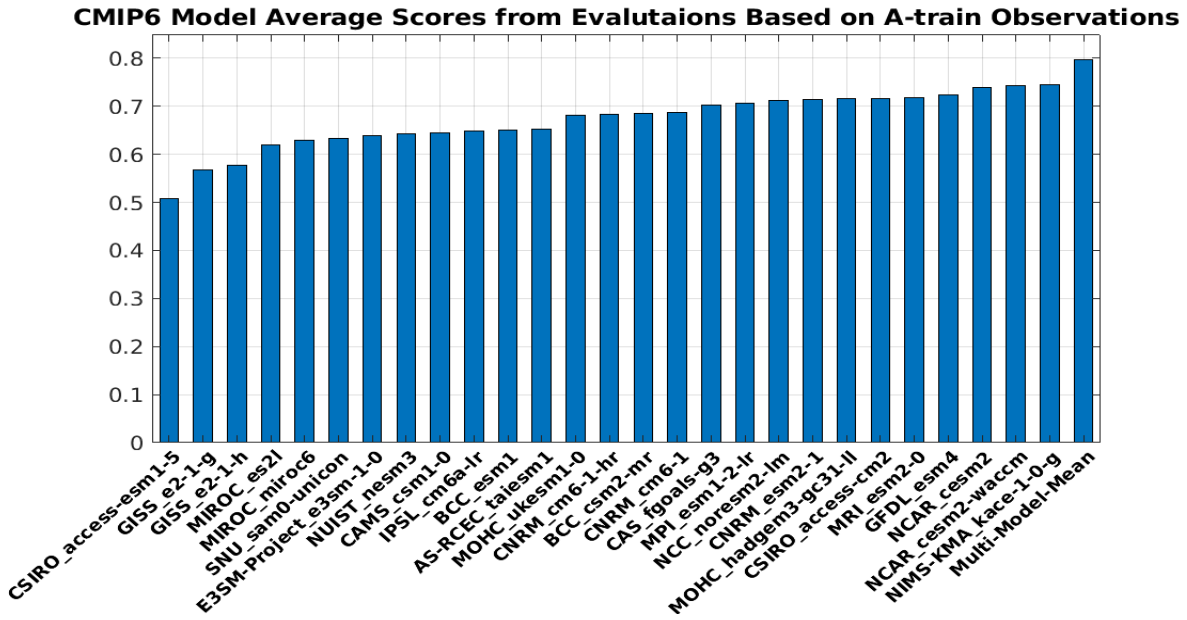


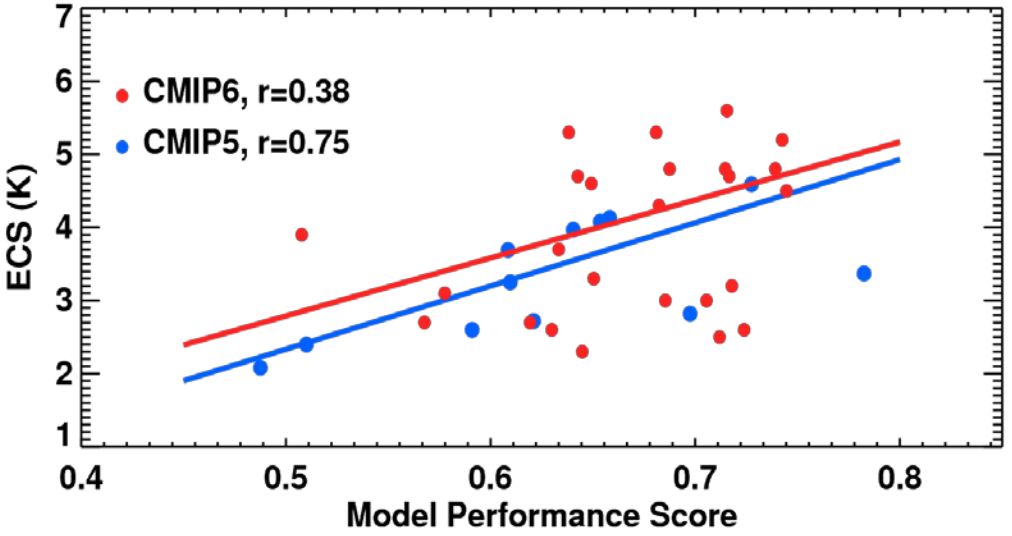


Does convective onset relate to cloud feedback?

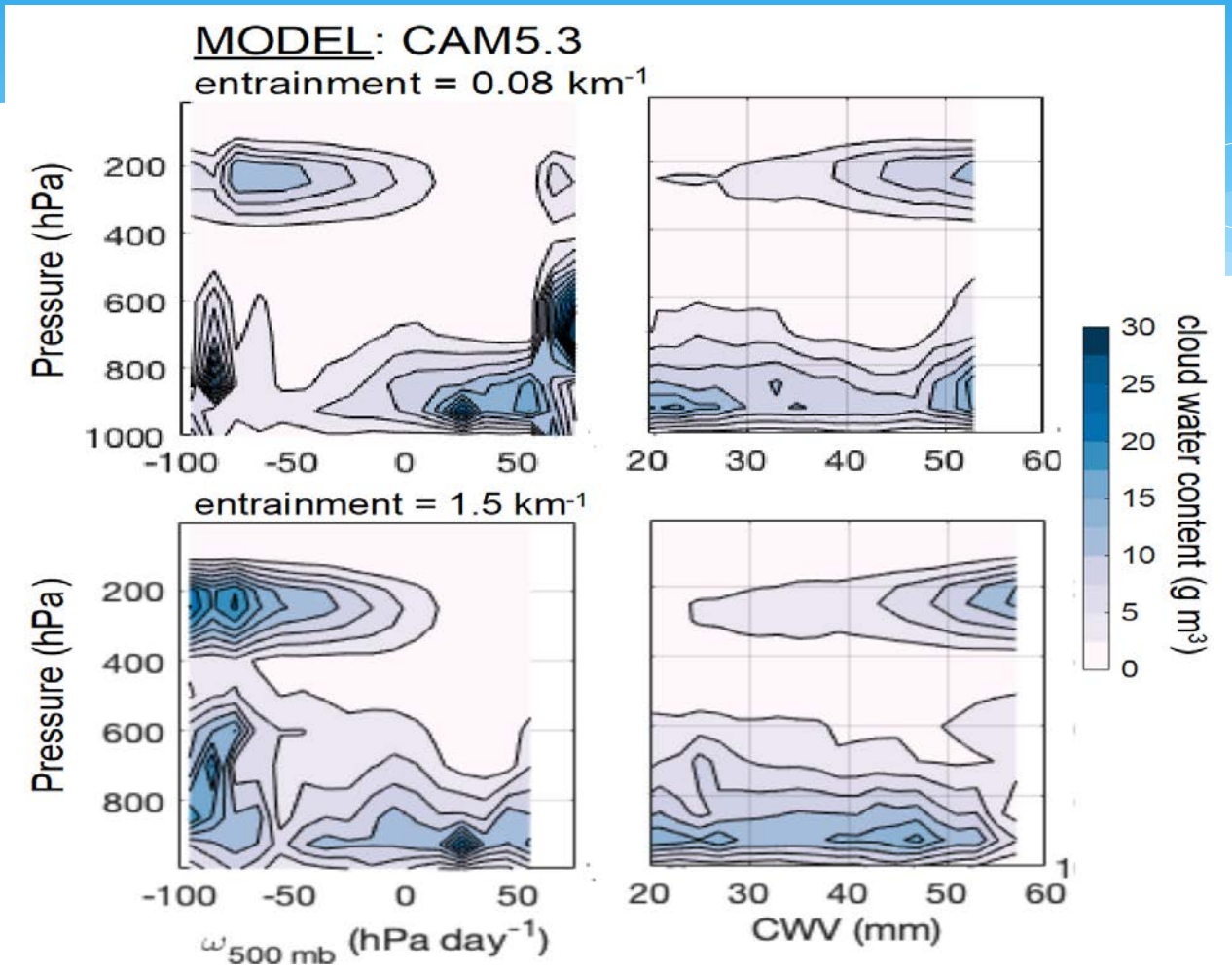
Task 2: Evaluating CMIP6 Models Against Observations



Jiang et al. (2020, to be submitted)



Task 3: Conducting E3SM PPEs



- Stronger entrainment rate leads to less erroneous mid-level clouds over the subsidence regime.

Summary

- The PPEs with modified deep convective parameters show that changes in deep convection and large-scale circulation can modulate low cloud response to surface warming through the temperature-stability pathway, moisture-mixing pathway and radiation-subsidence pathway.

- The CMIP6 models' ECS is correlated with the tropical ascent area change and the cloud radiative feedback within the deep tropics (15°S-15°N). High ECS models show stronger tropical ascent tightening and greater positive cloud feedback.

- Model performance scores in representing climatological mean tropical cloud and moisture structures are correlated with the models' ECS. High ECS models have higher performance scores.