

Cloud Feedbacks in the Superparameterized Climate Model SP-CCSM4

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Summary

- SP-CCSM4 has moderate positive shortwave and longwave cloud feedbacks and an ECS of 2.8 K
- It shows weak rapid adjustments in all cloud types
- As the climate warms:
 1. Low cloud decreases over land as surface dries.
 2. Midlevel cloud decreases and polar cloud increases (like CMIP5 models).

Experiments

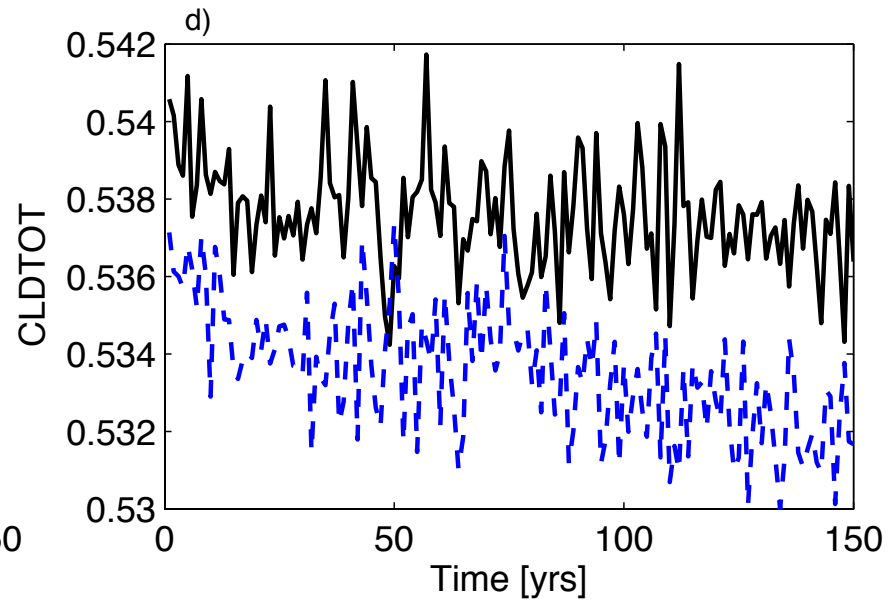
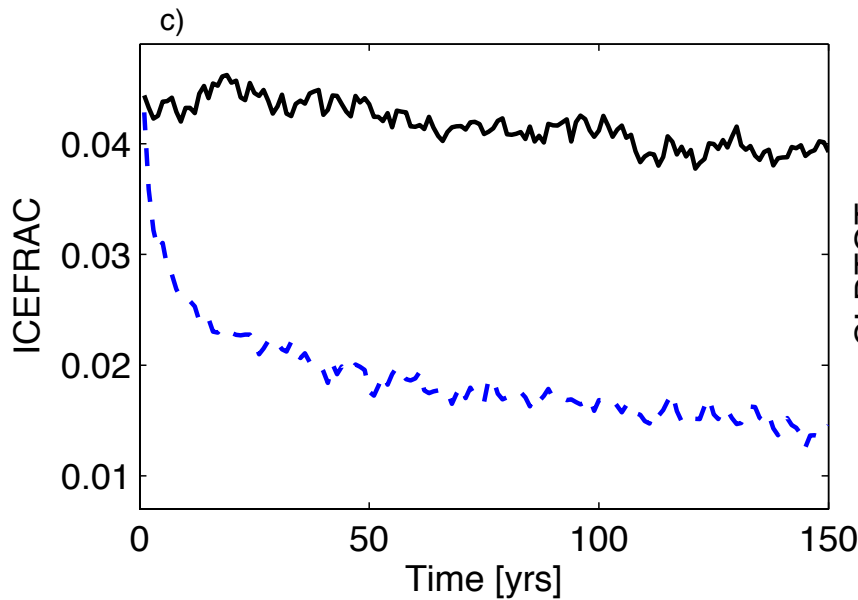
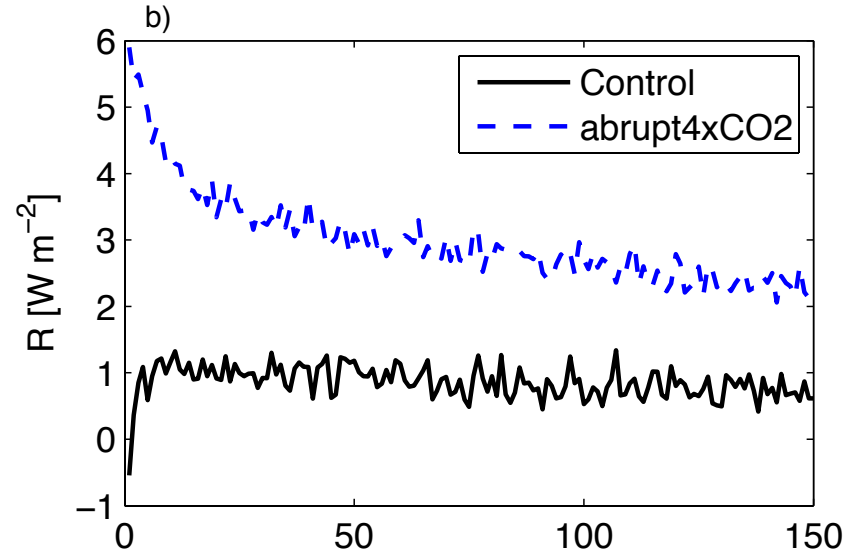
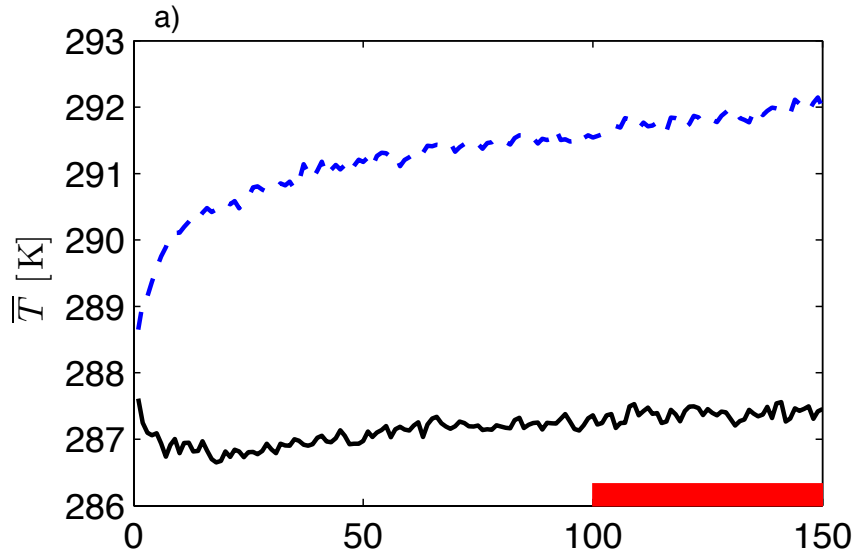
Coupled

- 4x: abrupt4CO2 – control (150 years)
 Initialized from Jan. 2006 of 20C CCSM4 run
 Years 100-150 used for means

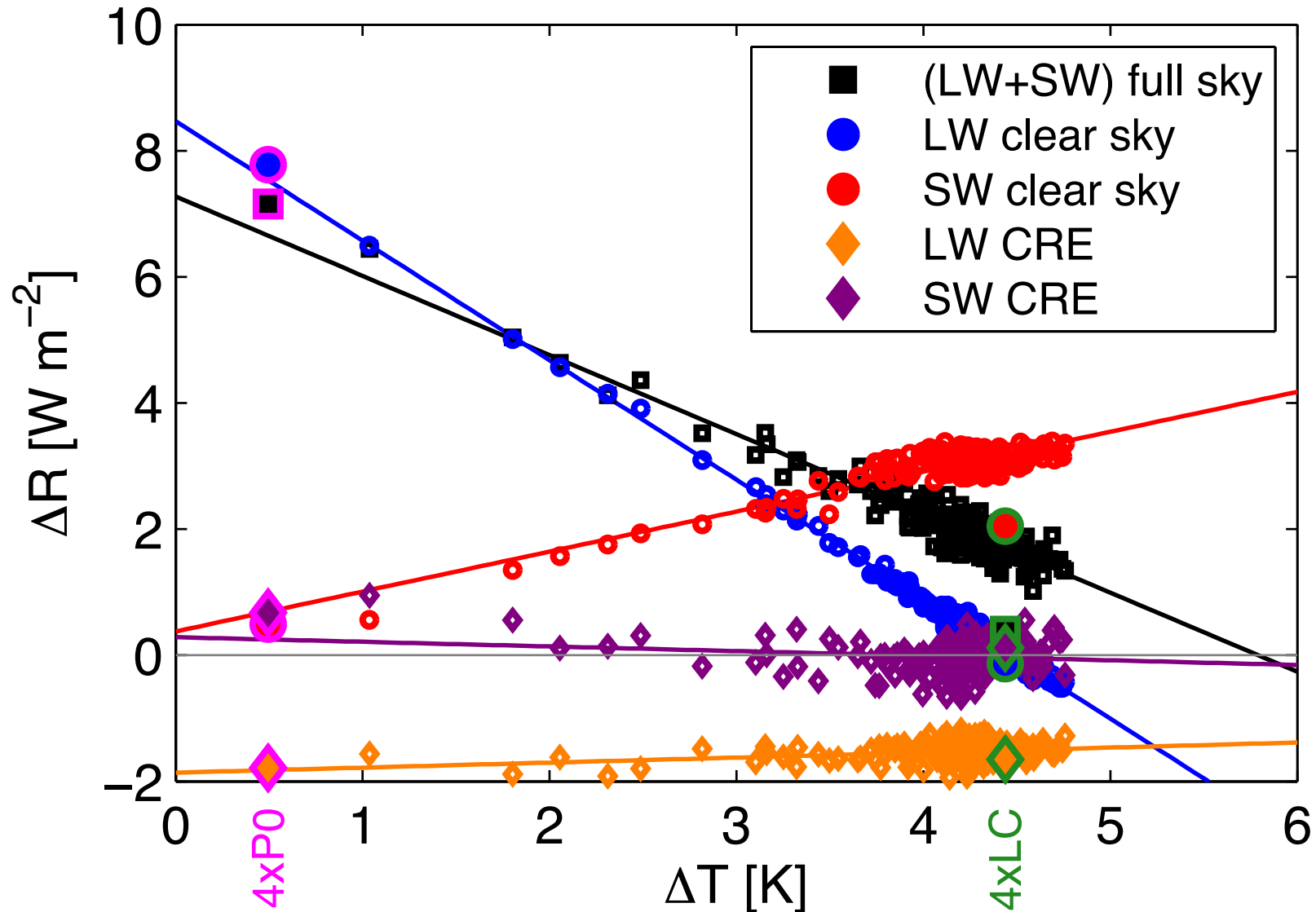
Specified SST

- 4xP0: amip4CO2 – amip (35 years)
- P4: amip4K – amip (35 years)
- 4xLC: $4xP0 + 0.87P4$ (same CO2 and T as 4x)
 ‘amip’ = 1949-2002 monthly-mean SST
 Years 2-35 used for means

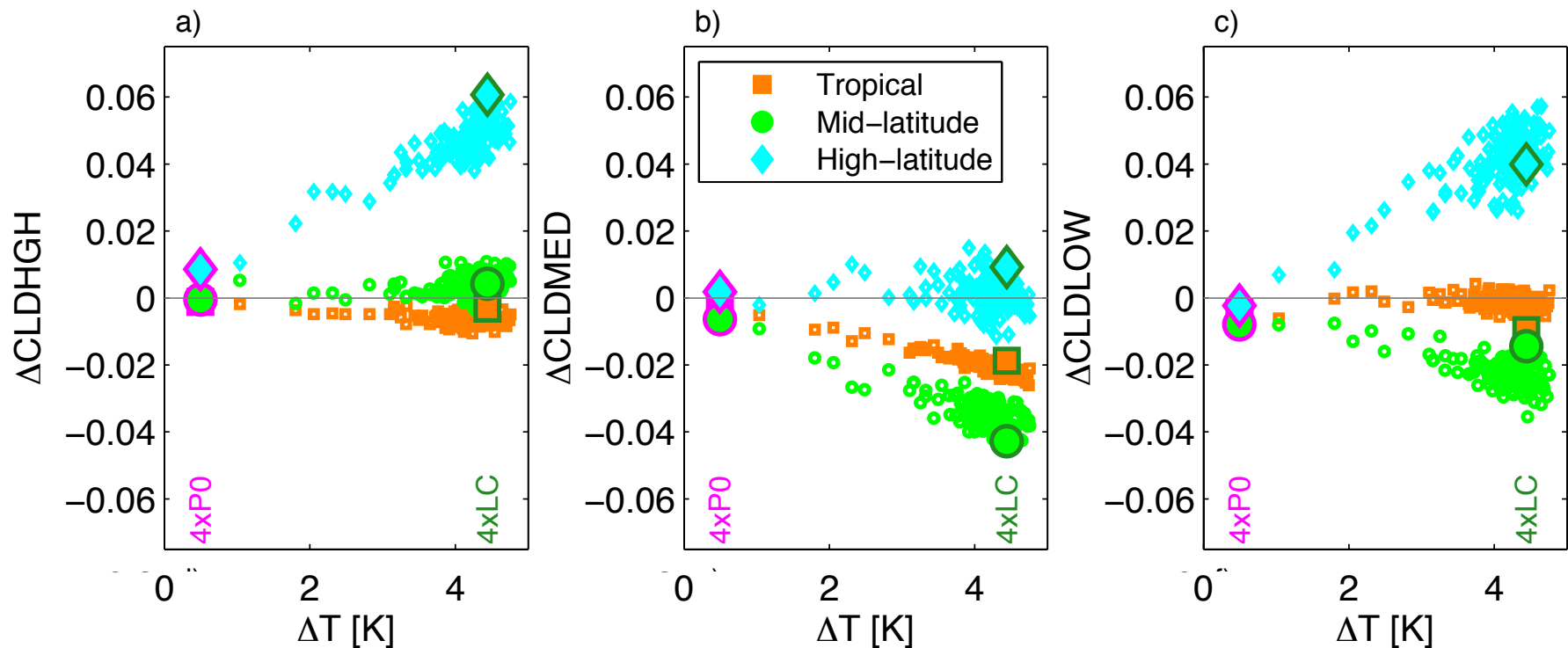
SP-CCSM4 4x response to abrupt 4xCO₂



4x Gregory Plot: Radiation components



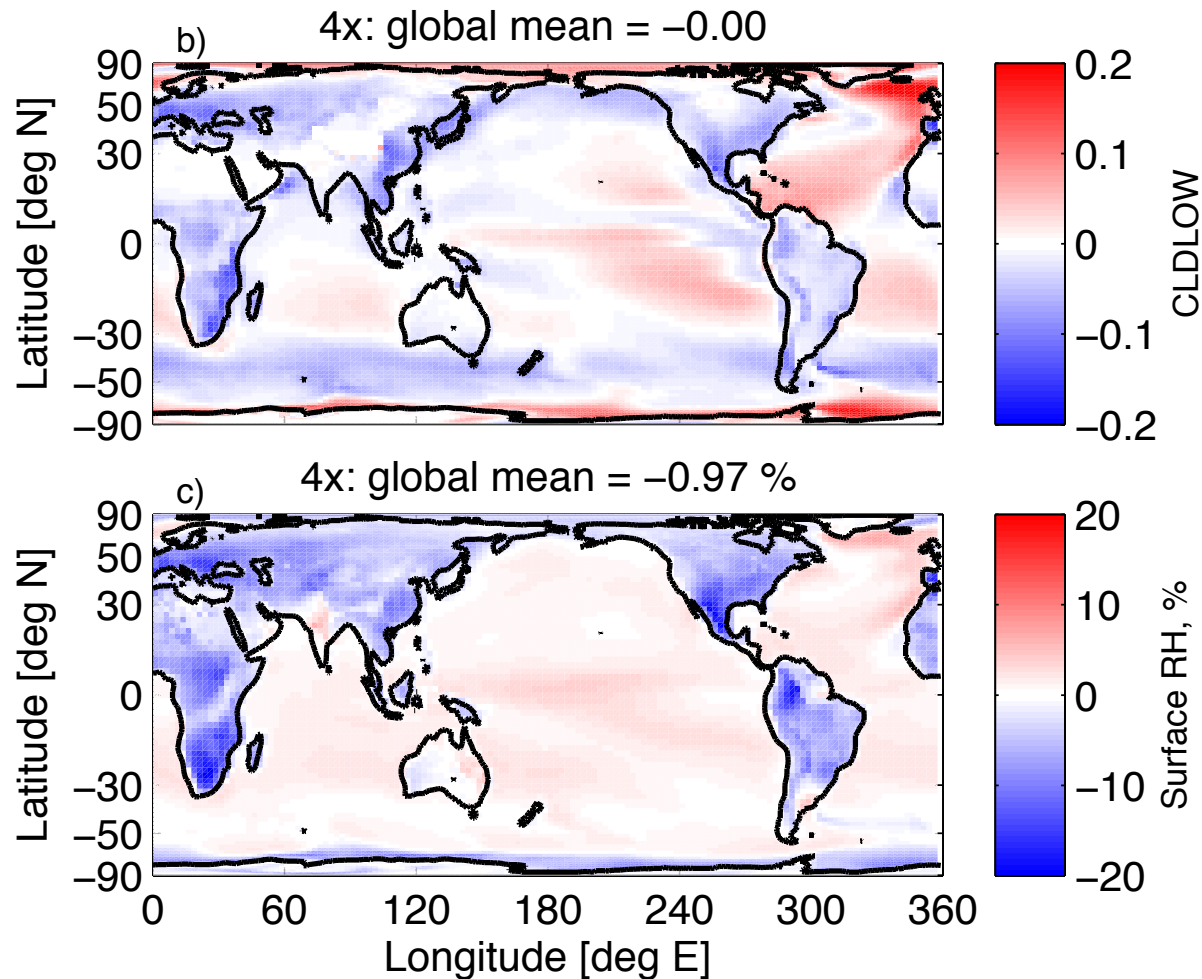
4x Gregory plot: clouds and precipitation



- Negligible rapid adjustment of cloud properties
- Large increase in high-latitude low and high cloud as ΔT increases
- Decrease in mid-level cloud except at high latitudes

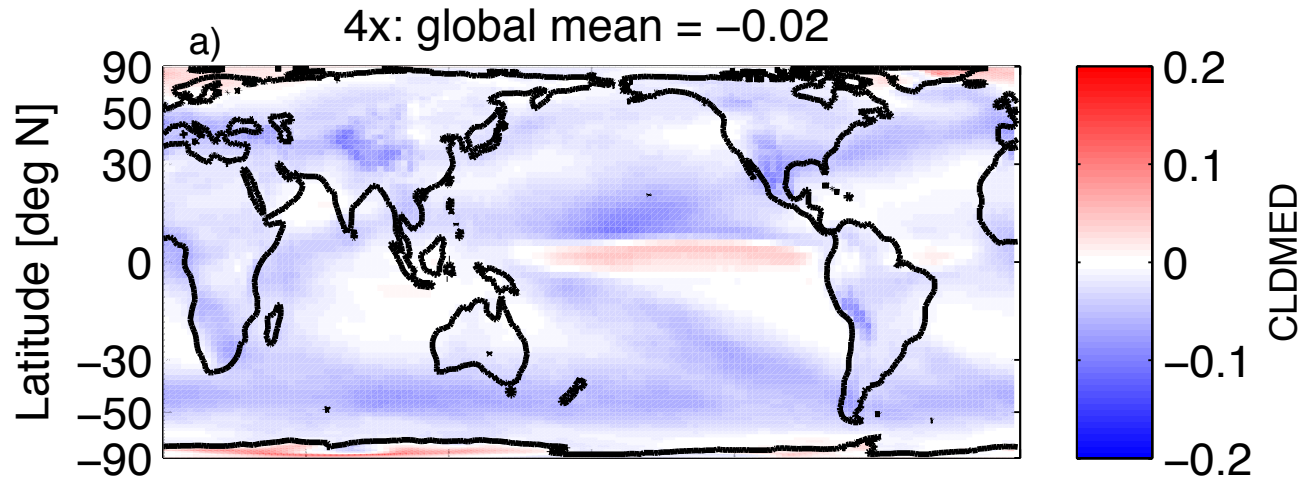
(Tropical: 30N-30S, Mid-lat: 30-60 N/S, High-lat: 60-90 N/S)

Low cloud decreases with ΔT over land

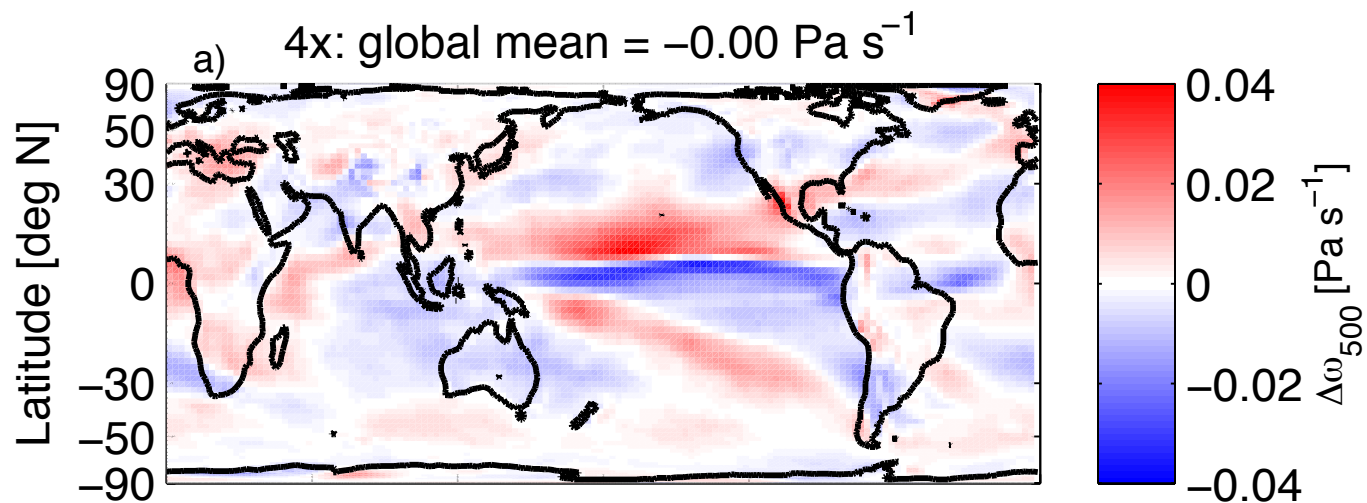


- Highly correlated with relative humidity decrease
- Due to decreased surface moisture availability

Midlevel cloud reductions

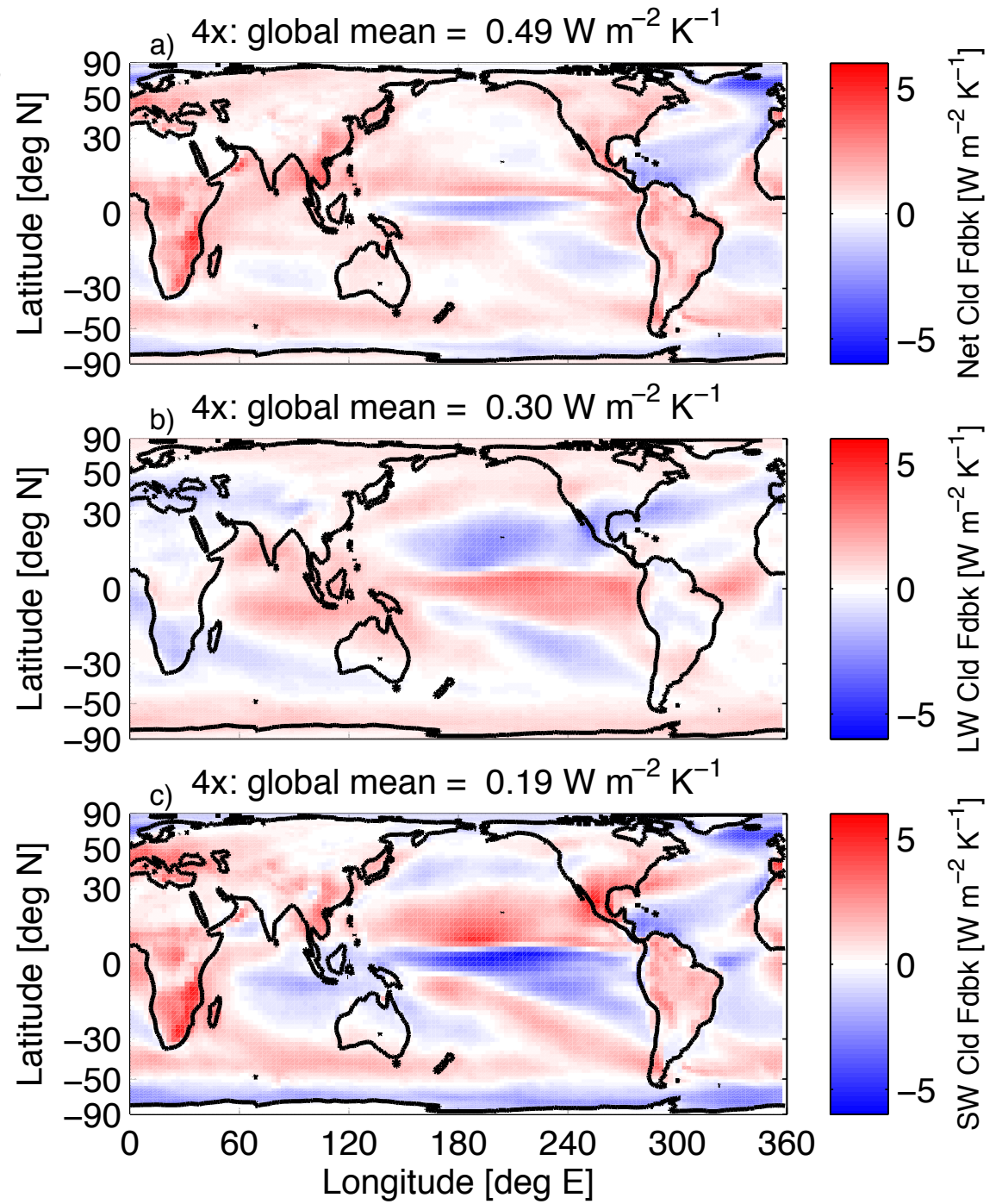


- occur nearly everywhere (above)!
- are modulated by vertical velocity changes (below)

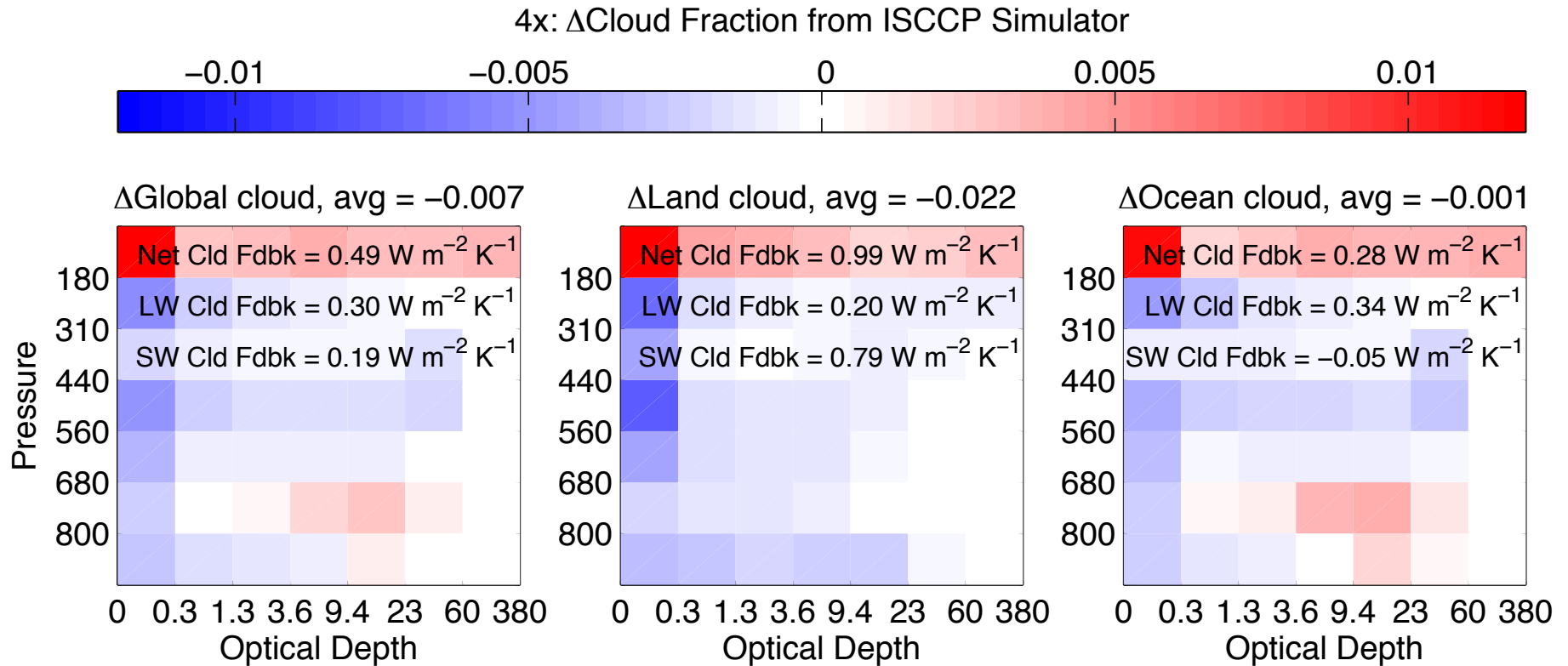


Cloud feedbacks

- ISCCP simulator method (Zelinka et al. 2012)
- Positive altitude-driven global LW feedback
- Positive global SW feedback due to less low cloud over land
- Local feedbacks affected by circulation changes
- Global net cloud feedback comparable to many CMIP5 models.

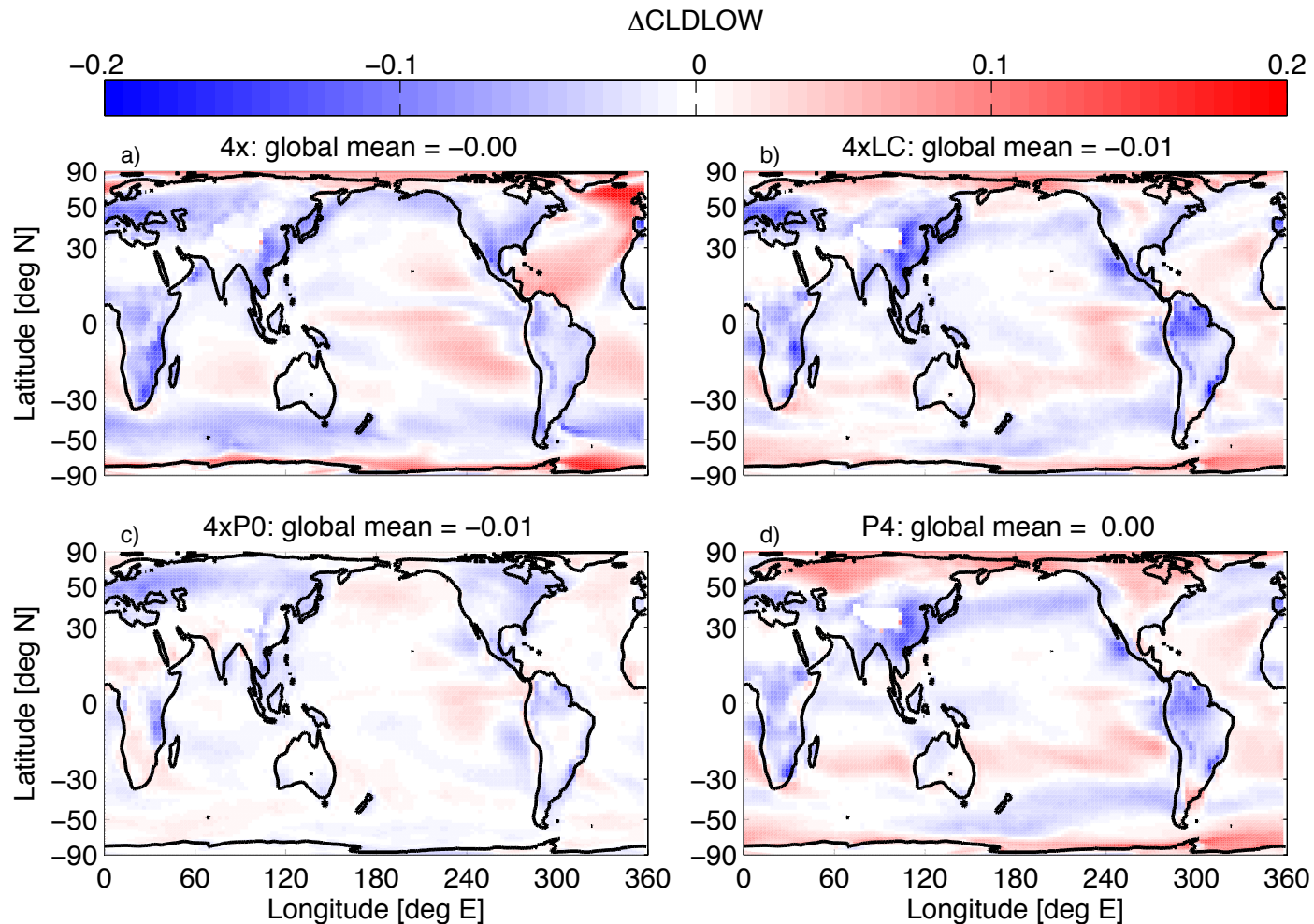


Zelinkagrams for 4x climate change



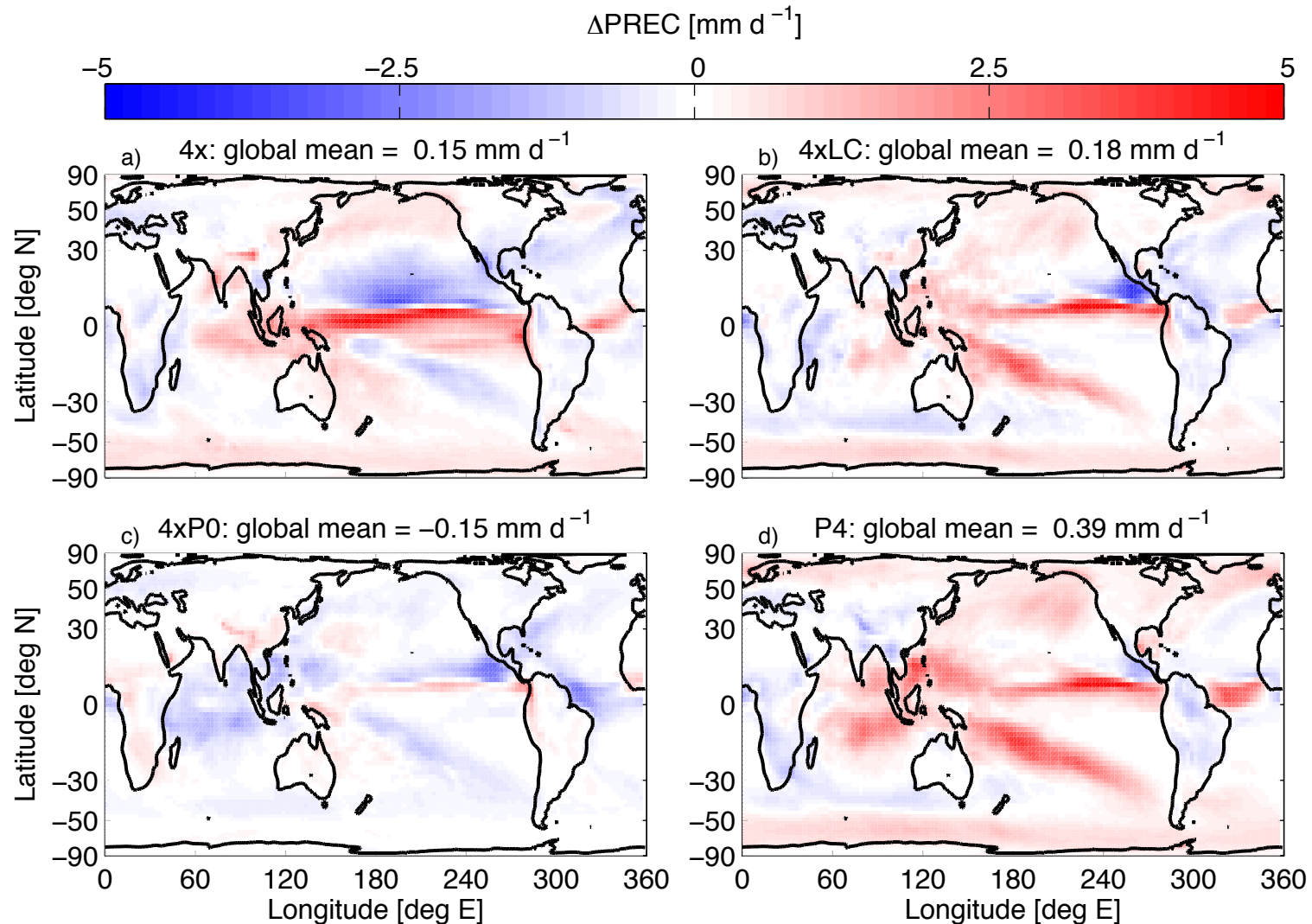
- Highest cloud tops rise
- Most other cloud categories reduce
- Optically-thick low clouds increase over ocean but not land

4x vs. specified-SST response: Low cloud



- 4x regional patterns of low cloud changes fairly well matched by 4xLC linear combination of specified-SST experiments.
- Rapid adjustment (4xP0): less low cloud over many land areas.

4x vs. specified-SST response: Precipitation



- Rapid adjustment smaller than most CMIP5 models

References

Bretherton, Blossey, and Stan (2014), Cloud feedbacks on greenhouse warming in the superparameterized climate model SP-CCSM4, *JAMES*, submitted.

Stan and Xu (2014), Climate simulations and projections with the super-parameterized CCSM4. *Env. Model. Soft.*, accepted.

Acknowledgements

This work was supported by the NSF CMMAP STC, with computing resources from NERSC (DOE) and XSEDE (NSF).

