CMIP5 models' shortwave cloud radiative response and climate sensitivity linked to the climatological Hadley cell extent

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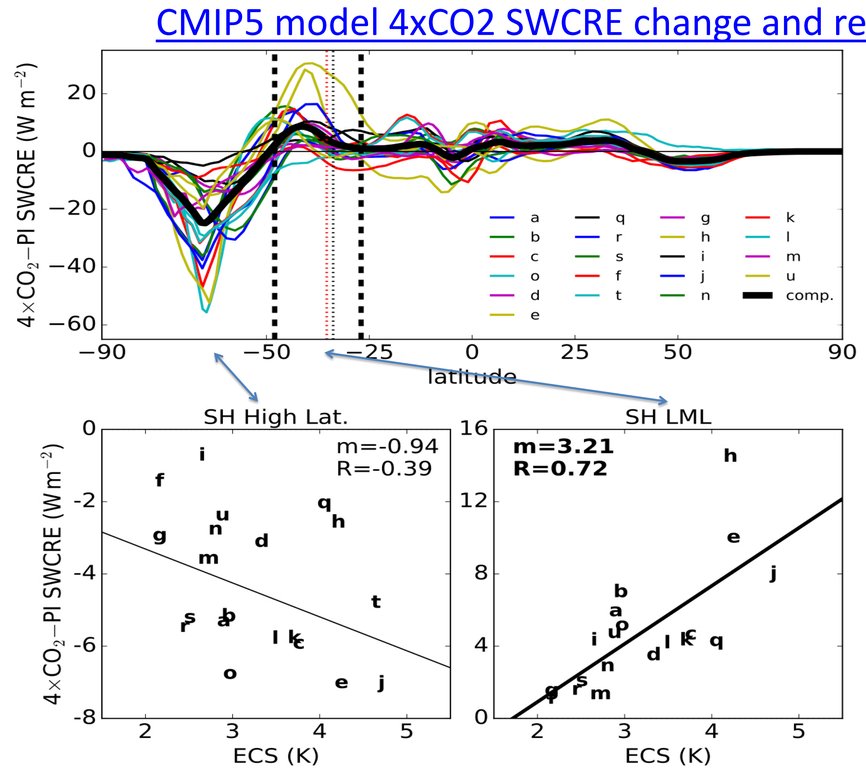
Geophysical Research Letters, 44, no. 11, 5739-5748

Abstract

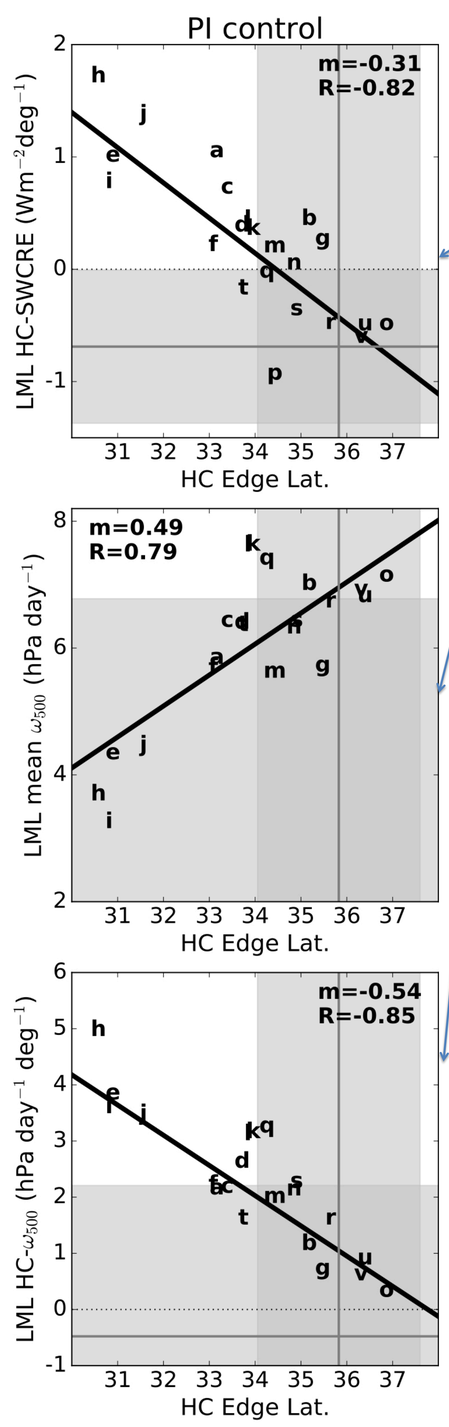
This study analyzes CMIP5 model output to examine the covariability of interannual Southern Hemisphere Hadley Cell (HC) edge latitude shifts and shortwave cloud radiative effect (SWCRE). With poleward HC expansion, many models substantially reduce the shortwave radiation reflected by clouds over the lower midlatitude (LML) region, although no such reduction is seen in observations. These biases in HC-SWCRE covariability are linked to biases in the climatological HC edge latitude. Notably, models with excessively equatorward climatological HC edge latitude have weaker climatological LML subsidence and exhibit larger increases in LML subsidence with poleward HC expansion. Because in models increases in subsidence are correlated with increases in SWCRE, models with a more equatorward climatological HC edge latitude also exhibit larger increases in LML SW warming with poleward HC expansion. This behavior, based on interannual variability, has important implications for the CO2-forced model response and equilibrium climate sensitivity. In 4→CO2-forced runs, models with excessively equatorward climatological HC edge latitudes produce stronger LML SW warming and exhibit higher ECS than models with more realistic climatological HC

CMIP5 model 4xCO2 SWCRE change and relation to ECS



- SWCRE warming in the SH Lower Midlatitude (LML, 28°-48°S) region strongly correlates with ECS, while SH High Latitude SWCRE cooling does not

Observational and model PI control run SWCRE response to 1-degree poleward HC shift

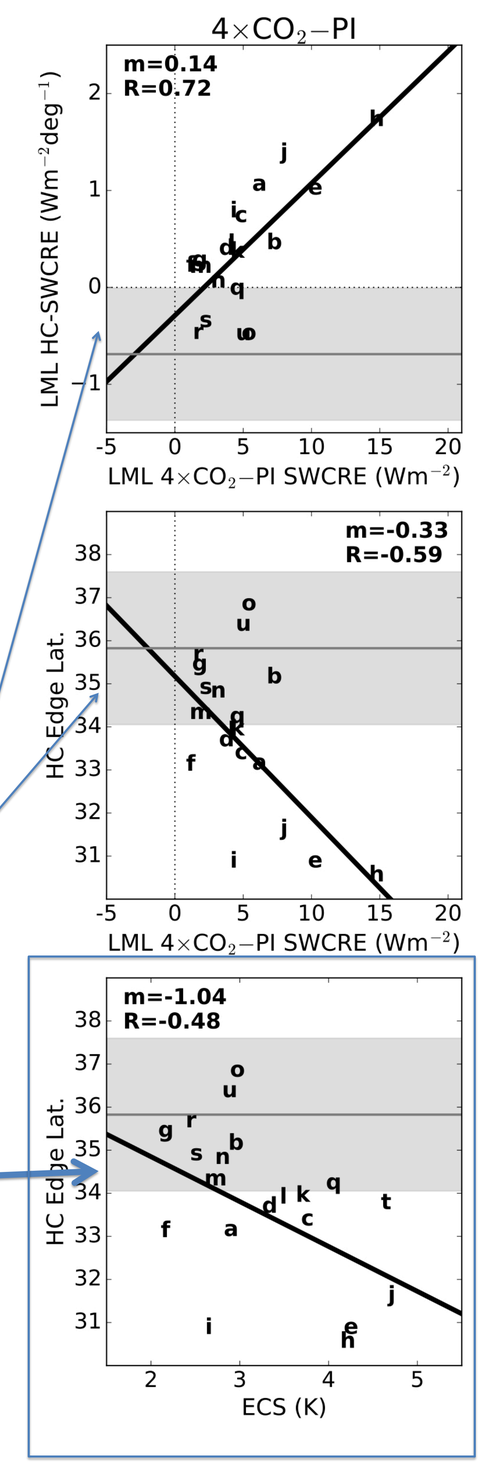


In Pre-Industrial control runs:

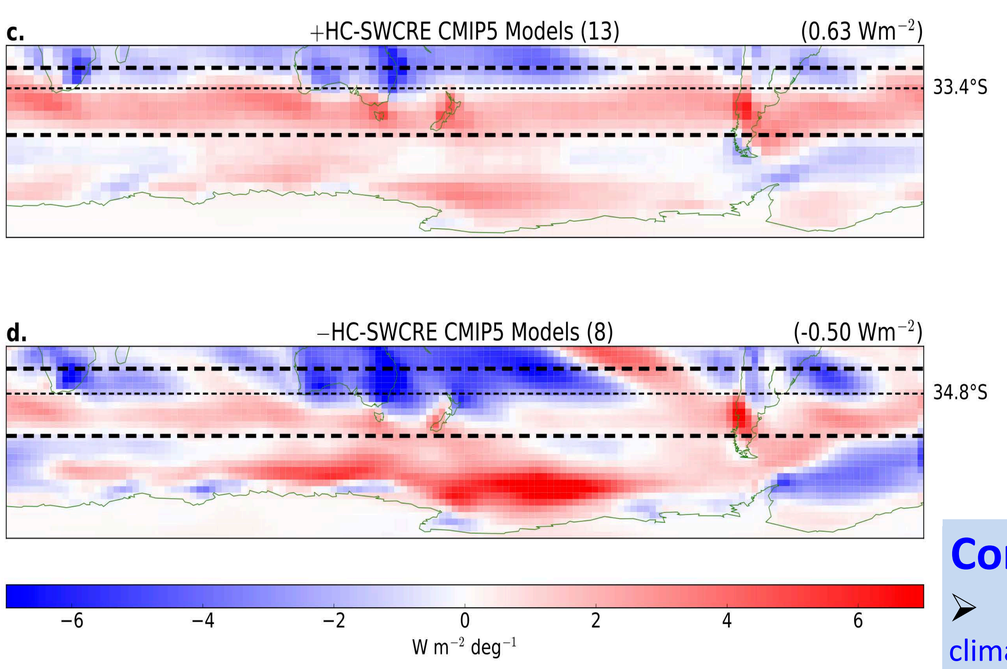
- Changes in LML SWCRE with poleward Hadley cell shift correlate strongly with HC edge climatological position
- This is because LML mean subsidence is weaker in models with more narrow HC, and their subsidence change is larger when the HC edge shifts poleward

In 4xCO2 runs:

- LML SWCRE warming is significantly predicted by control SWCRE change with poleward HC shift and, thus, by climatological HC edge position
- ***Therefore, ECS is significantly constrained by the climatological HC edge position, and models with more realistic HC edge positions tend to have lower ECS values***



- Unlike the observations, model control runs show a zone of SWCRE warming in the SH LML region when HC edge shifts poleward.



- Most models warm the SH LML region when the HC shifts poleward while some models produce moderate cooling
- Models that produce warming tend to have more narrow climatological HCs than models that produce cooling

Conclusions

➢ CMIP5 model climate sensitivity is related to the position of the SH Hadley Cell edge in the model control climate simulations

➢ In 4xCO2 simulations, models with excessively narrow Hadley Cells in their control climate tend to warm more strongly the SH lower midlatitude regions (28°-48°S) and thus produce higher climate sensitivities than models with more realistic Hadley Cell extents.