LLNL-PRES-672120
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344.

RELATIONSHIP BETWEEN INTER-ANNUAL AND LONG-TERM GLOBAL CLOUD FEEDBACK

C. Zhou[1], A. E. Dessler[2], M. D. Zelinka[1], S. A. Klein[1]

[1]Lawrence Livermore National Laboratory, Livermore, CA

[2]Texas A&M University, College Station, TX

Email: zhou8@llnl.gov

Introduction

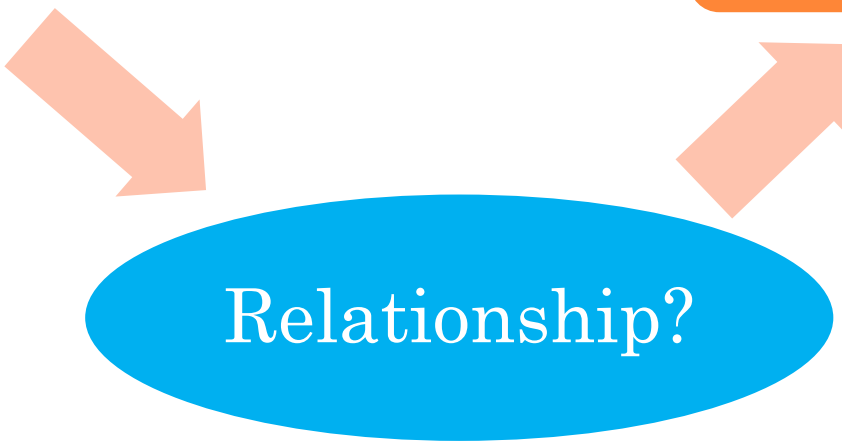
- It is impossible to reliably calculate global long-term cloud feedback under climate change from satellite observations. (too short duration, artifacts and spurious trends)
- Alternatively, we may calculate global inter-annual cloud feedback (or short-term feedback) in response to climate fluctuations using short-term satellite observations.

What we can observe

Inter-annual cloud feedback

What we want to know

Long-term cloud feedback

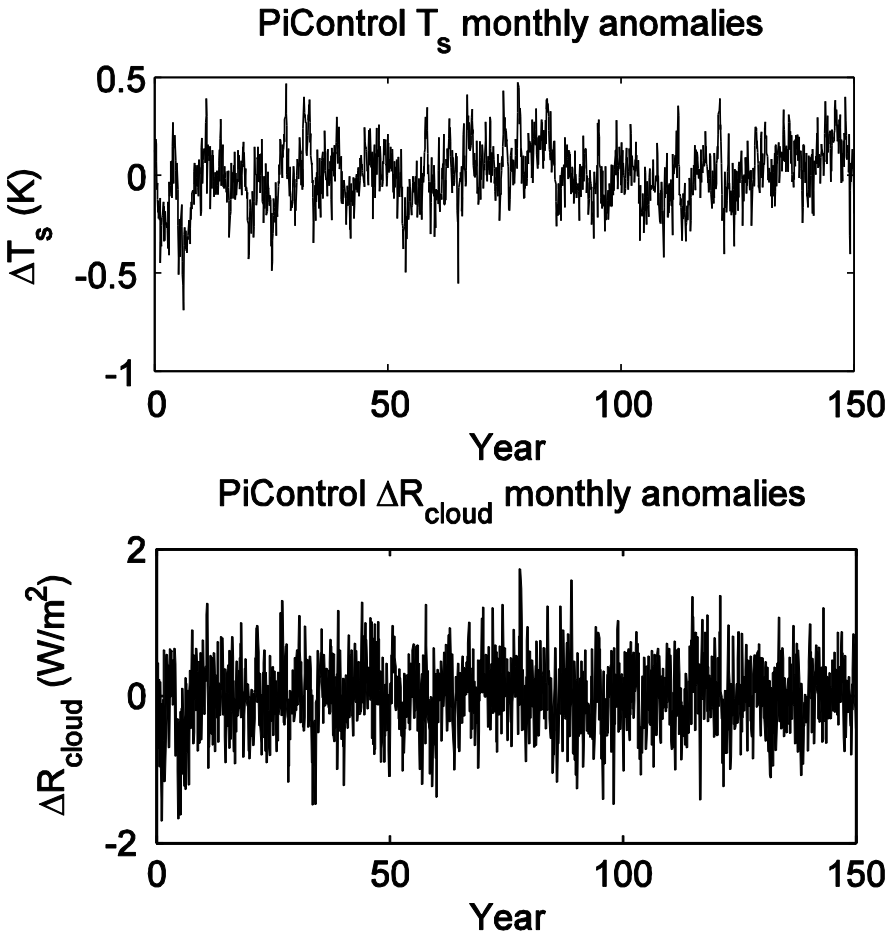


We analyze this relationship with CMIP5 simulations:

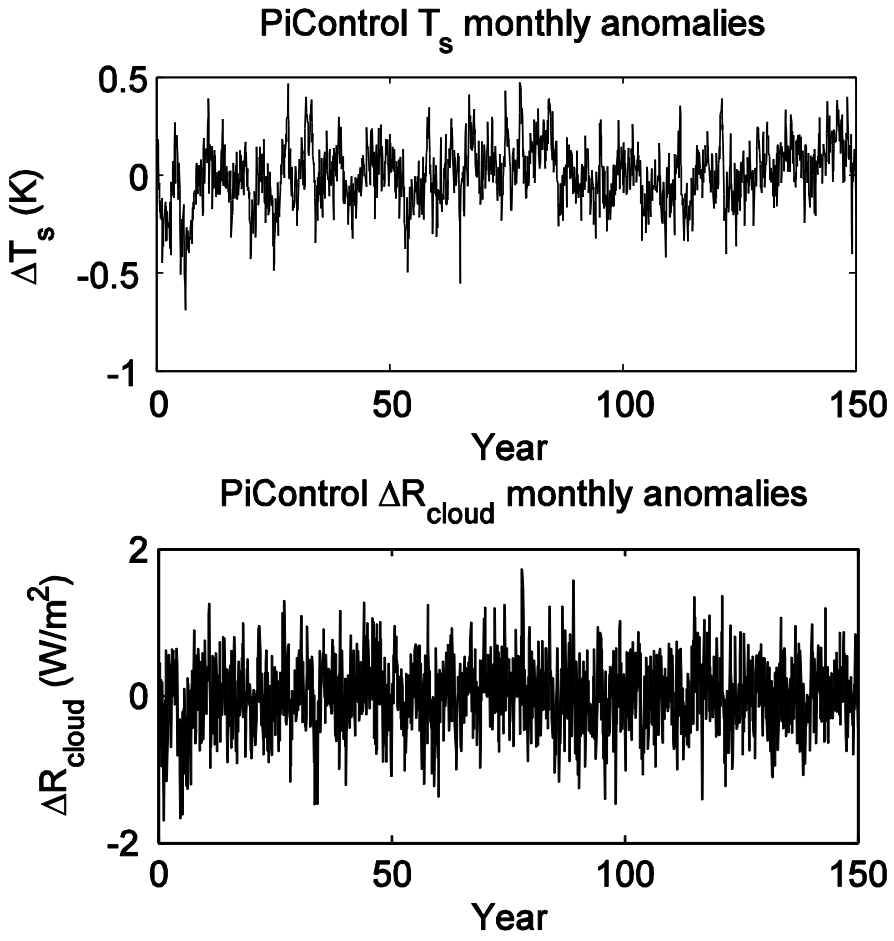
- Long-term cloud feedback is calculated from abrupt4xCO2 experiments, where the change of surface temperature is primarily driven by long-term global warming.
- Inter-annual cloud feedback is calculated from pre-industrial control (PiControl) simulations, where the change of surface temperature is induced by internal climate fluctuations.

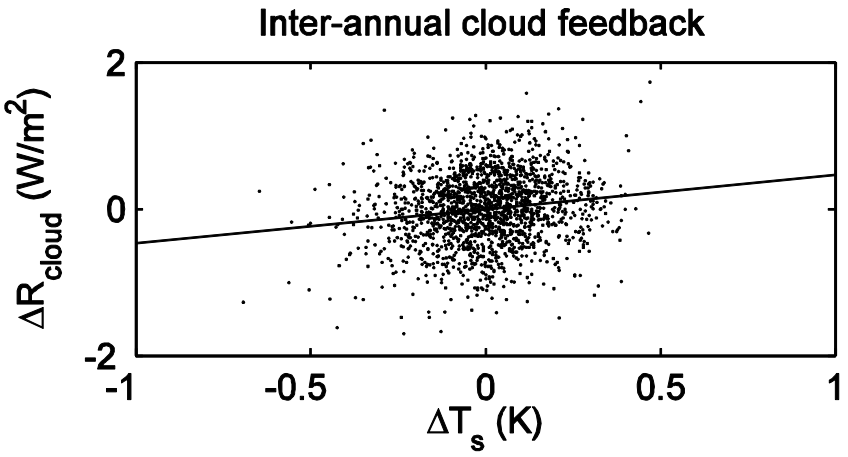
$$feedback = \frac{dR_{cloud}}{dT_s}$$

Calculation of Inter-annual cloud feedback



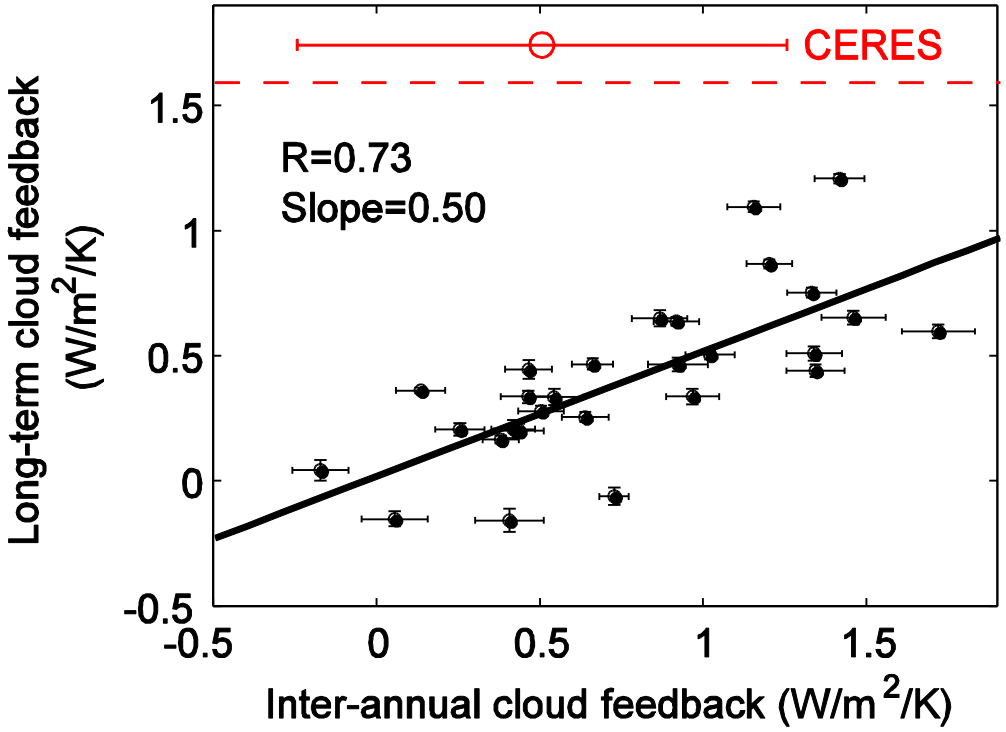
Calculation of Inter-annual cloud feedback





$$feedback = \frac{dR_{cloud}}{dT_s}$$

INTER-MODEL CORRELATION

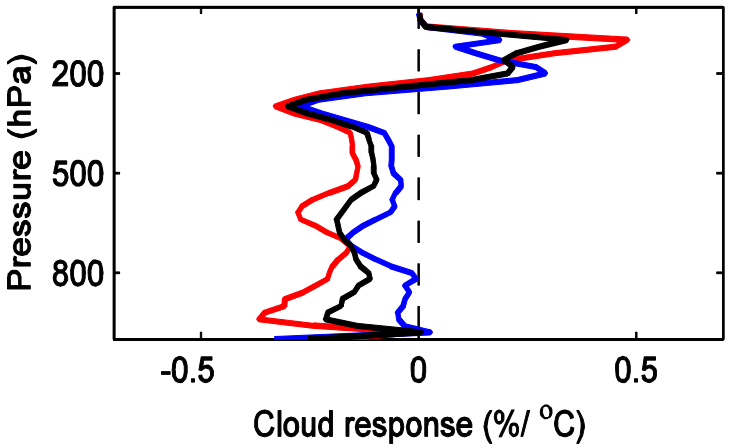


Climate models with large inter-annual cloud feedback also show large long-term cloud feedback.

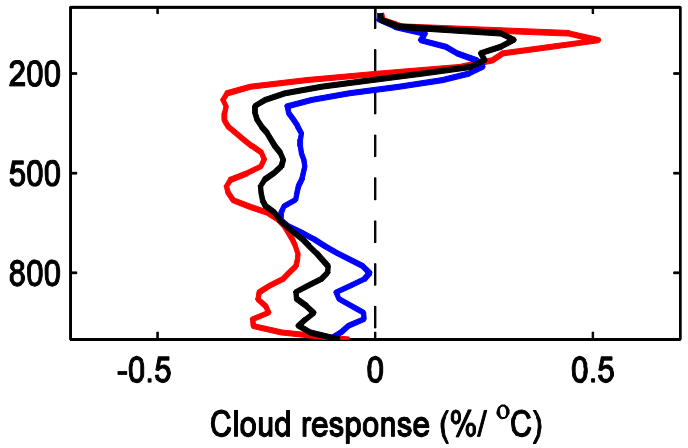
Why is there a correlation?

VERTICAL PROFILES OF CLOUD RESPONSES TO SURFACE WARMING

Inter-annual response

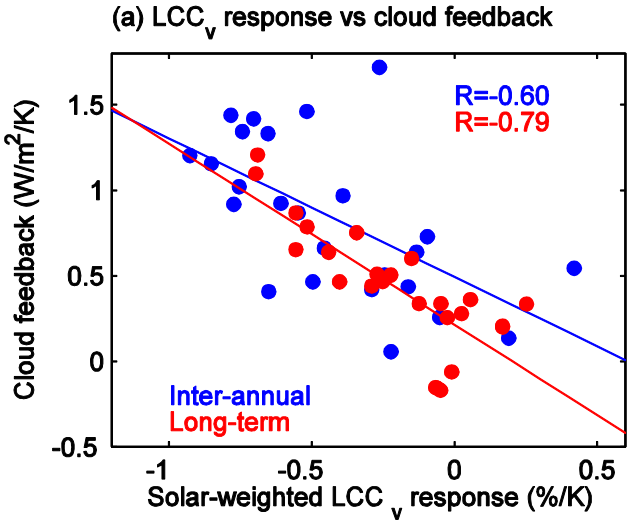


Long-term response



1. The vertical profiles look similar on the two timescales.
2. Large long-term cloud feedback models (red) have larger reductions in low/middle cloud fraction than the small long-term cloud feedback models (blue), on both timescales.

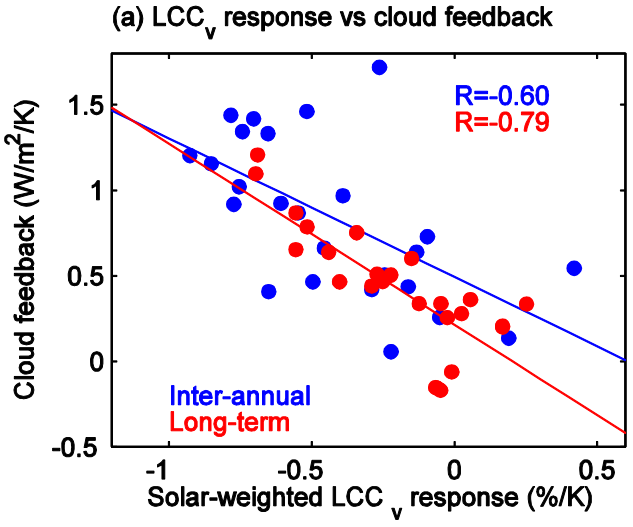
Low cloud cover (LCC) feedback



Low cloud cover is most responsible to the inter-model spread of cloud feedback.

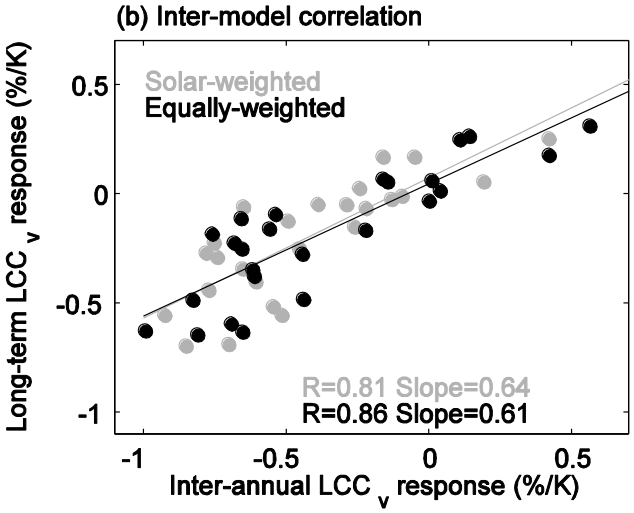
LCC_v = max(cl 680-1000hpa)

Low cloud cover (LCC) feedback

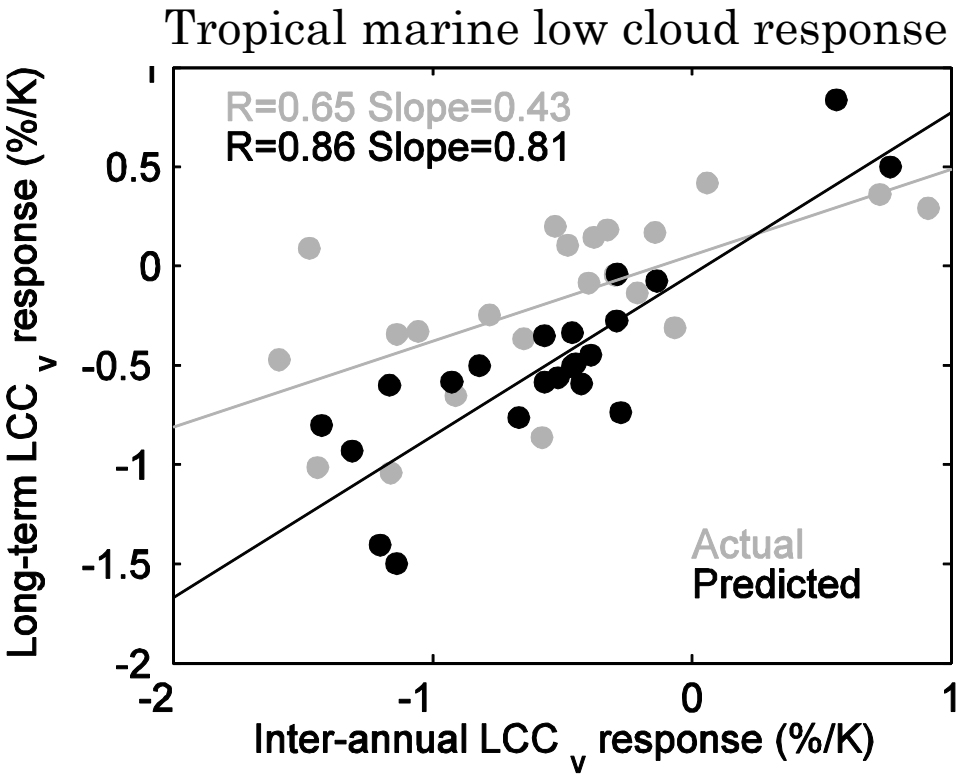


Low cloud cover is most responsible to the inter-model spread of cloud feedback.

LCC_v = max(cl 680-1000hpa)



Inter-annual and long-term low cloud cover is well correlated across models.



- This relationship can be partially explained by the regional simple model of Qu et al. (2014):

$$\Delta LCC = \frac{\partial LCC}{\partial SST}\Delta SST + \frac{\partial LCC}{\partial EIS}\Delta EIS,$$

Where EIS is estimated inversion strength.

The tropical marine LCC response predicted by this equation (black points) is well correlated on the two timescales. The predicted correlation is even higher than the actual value (grey points).

Qualitative explanation

- Both inter-annual and long-term cloud feedback are change of cloud radiative effect in response to global surface warming.
- In the tropics, the thermo-dynamical changes are similar in response to inter-annual and long-term global surface warming (increasing SST, EIS, static stability, tropopause height, etc.), and cloud feedback is primarily determined by these thermo-dynamical changes. (Bony et al. 2005)
- Surface warming pattern is different on the two timescales, so cloud feedbacks on the two timescales also have differences.

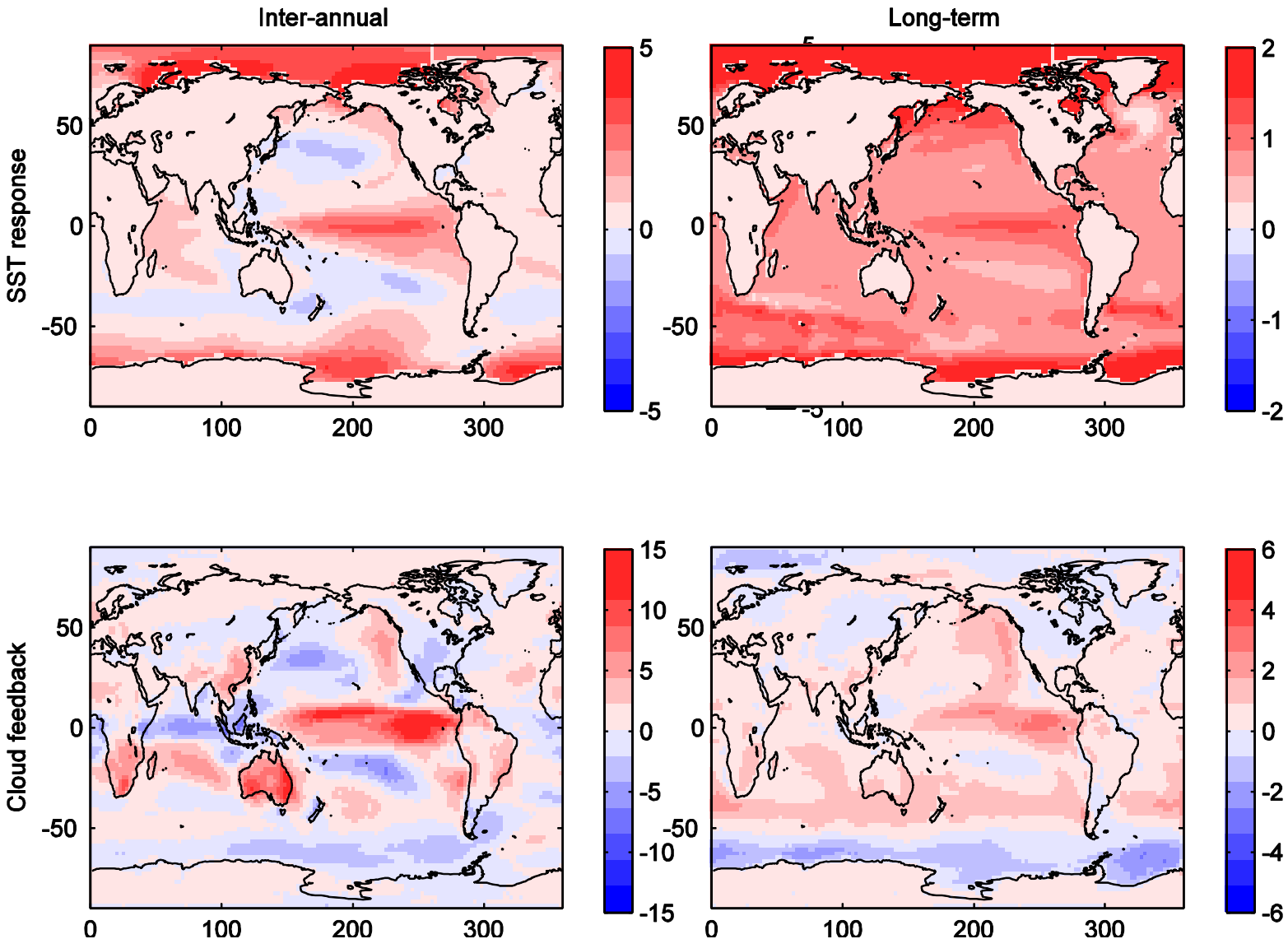
Conclusions

- 1. Inter-annual cloud feedback in response to climate variability and long-term cloud feedback in response to climate change are well correlated across models.
- 2. Cloud response to global surface warming have similar vertical profiles on these two timescales.
- 3. Low cloud cover, which is most responsible to inter-model spread of cloud feedback, is well correlated across models on the two time scales. This relationship can be partially explained by existing theories.
- 4. The magnitude of inter-annual cloud feedback is generally consistent in models and observations.

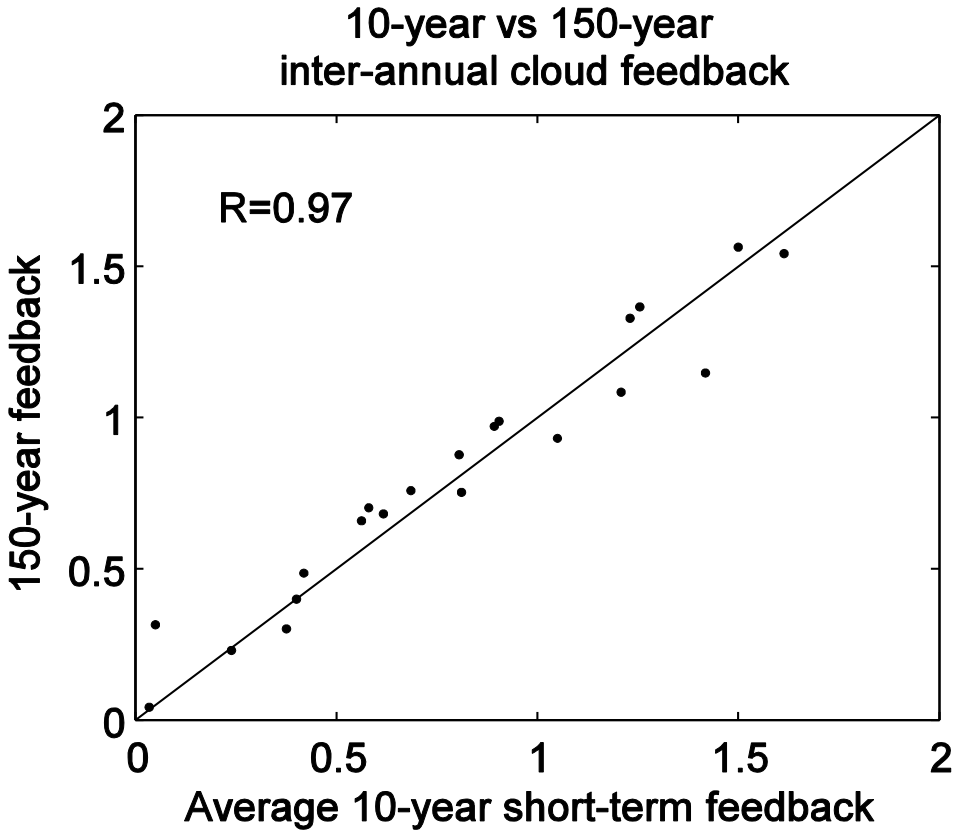
Email: zhou8@llnl.gov

Thanks

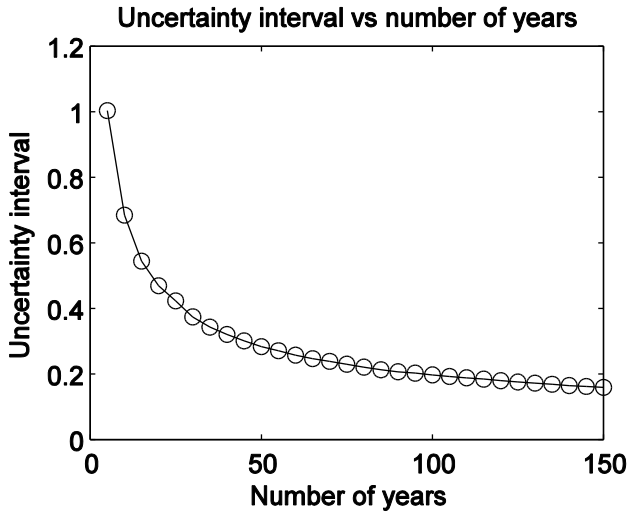
Supplementary figures



Supplementary figures



Supplementary figures



SUPPLEMENTARY FIGURES