Time Invariance of Low-cloud Albedo Feedback

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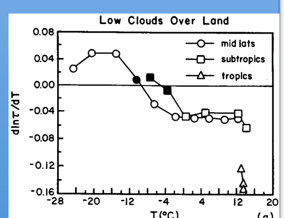
Background

Previous research using satellites and in situ observations has suggested that the optical depth of low clouds increases along with cloud temperature in the high latitudes (Somerville and Remer, 1984; Tselioudis et al., 1992), which leads to a negative feedback, while tropical clouds show decreased opacity with warmer temperatures. Can this behavior be replicated by climate models, and can they help us understand why clouds in different regions respond differently? We also examine if the feedback seen in short-term variability (days to years) provide information on century-scale feedbacks.

Data

Climate model output from the Cloud Feedback Model Intercomparison Project (CFMIP) control and $2xCO_2$ runs for 8 different climate models.

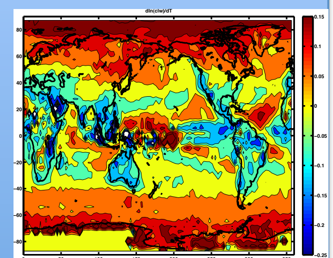


from Tselioudis et al. (1992)

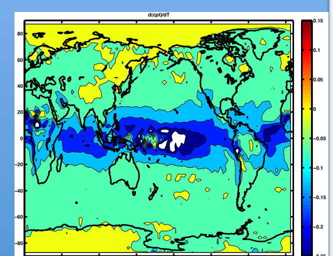
Source of Optical Thickness Variability

To understand why the optical thickness of the model clouds varies with cloud temperature, we represent optical thickness as:

$$\tau = \frac{3}{2}\frac{LWC * \Delta z}{r_e}$$

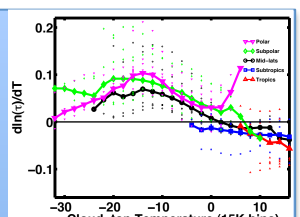


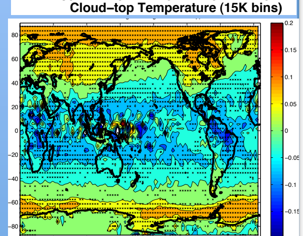
For the CCCMA model, there is a strong increase in liquid water content (top) for clouds in the midlatitude and polar regions. In the subtropical and tropical regions, we see the decrease in optical thickness comes from a decrease in cloud physical thickness (bottom).

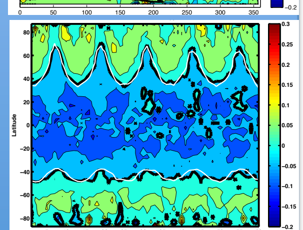


CMIP Model Analysis

The results for the control climate of six of the CMIP models replicate the behavior of saltellite-observed cloud properties. Models clearly demonstrate different responses of clouds at different temperatures, and in different regions. The plot below shows the feedback value averaged over latitude bands over the 5-year control integration. The location of the zero feedback value (solid black line) corresponds to average cloud temperature of 0°C (solid white line).

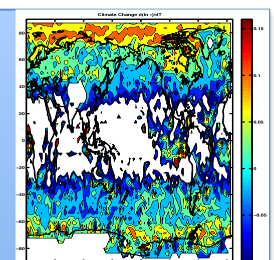


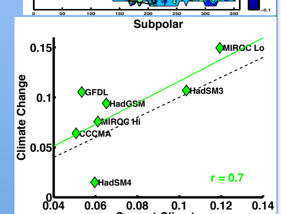


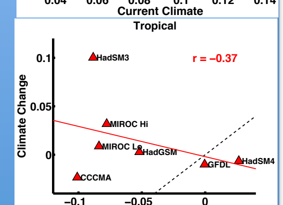


Timescale of Feedbacks

Finally, we diagnose if present-day observations can be applied to a long-term climate change scenario. Here is the climate change feedback value for CCCMA, calculated as the average difference in optical thickness, divided by the average cloud temperature change for each location. By averaging over different regions, we compare the control climate response of clouds to that predicted in a climate change scenario. The timescale of feedbacks are similar only in certain regions.







References

Somerville, R.C.J. and L.A. Remer, 1984. *J. Geophys. Res.*, 89, 9668-72.

Tselioudis, G., W.B. Rossow and D. Rind, 1992. *J. Clim.*, 5, 1484-95.

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