How does the changing general circulation affect observed cloud types?

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Circulation shifts alter clouds, radiation budget

Simulations by Orist et al. (2013) illustrate the chain of events resulting from ozone depletion over the southern hemisphere. They find that (1) ozone depletion shifts the midlatitude jet poleward, (2) middle and upper level clouds follow, and (3) the resulting cloud radiative forcing amounts to ~0.25 W/m².

Buttere et al. (2013), The ozone hole leads to changes in upper tropospheric clouds, influencing the precipitation of the midlatitude jet in the Southern Hemisphere, Q. J. R. Meteorol. Soc., 139, 3921-3934. doi:10.1002/qj.2370

Faust and Trenberth (2012) suggest the link between dynamics and clouds may aid in narrowing down the range of modeled climate sensitivities. Specifically, modeled climate sensitivities to warming may be more sensitive. They find that modeled large scale dynamics may explain both the relative humidity and sensitivity discrepancies between models.

Faust and Trenberth, 2012, A Link between Dynamics and Clouds: The Role of Subtropical Subsidence in Climate Sensitivity, Science, 335(6072), 970-974. doi:10.1126/science.1221893

Studies disagree on whether cloud shifts are due to a shifting midlatitude circulation

The IPCC 4th assessment report assessments subpolar clearing, along with a poleward and upward shift of cloudiness. In order for results to be comparable to observations, we plan to simulate HIRS measurements of the simulated earth using radiative transfer code.

Kay et al. (2013) model cloud shifts which are too strong to be accounted for by jet shifts alone, judging from interannual variability. The forced jet shift amounts to 1 deg, but the forced cloud response is +5% greater than the cloud anomalies associated with jet shifts. Forcetd cloud changes are attributed instead to warming and to stability changes.

Kay et al. (2013), How do cloud types affect inter-satellite biases?, AGU Fall Meeting, San Francisco (CA), 9-13 December, Talk A44B-19.

Studies disagree on whether cloud shifts are due to a shifting midlatitude circulation

We simulate changes in ISCCP cloud types from time-slice simulations

We perform 30-year constant-forcing simulations with the GFDL AM2.1 model, with either control or year-2100 greenhouse gas concentrations and surface temperatures. Currently, only 30 years have been performed with ISCCP output. Here we compare mean differences in cloudiness. Mean differences in circulation are not significant. We use a bootstrapping approach to gain some measure of uncertainty.


Low, medium, and high cloud tops are defined as in Klein and Jacob (1999), by cloud top heights below 3 km, between 3 km and 4 km, and above 4 km, respectively.

Figure 1. Top: Projected 4xCO2 changes in cloud fraction over the 21st century, by cloud type. Middle: DJF mean cloud fraction change for the 2100 experiment. Bottom: DJF mean cloud fraction change for the 4xCO2, SST2100 experiment.

Results highlight tropospheric adjustment, thermodynamic changes

The strong cloudiness shift from the radiatively forced experiment highlights the importance of a tropospheric cloud adjustment prior to surface temperature increases. Our simulations are not yet long enough to make a statement about the additivity of the radiative and temperature-forced cloud change. Even with such short simulations, however, the role of thermodynamics seems clear:

Toward the construction of a cloud-type specific radiance database

Although the global cloud feedback has been established, the contributions of specific cloud types may be more readily discerned. NOAA polar orbiting satellites, each with similar infrared sounders (HIRS) and imagers (AVHRR), have now been in orbit nearly continuously for the past four decades. We aim to combine infrared radiances from sounders and retrieved cloud-types from imagers, to form a cloud-type specific radiance record. We can then examine the observation record for any cloud-type specific radiance trends similar to those simulated in climate change experiments. Progress in the construction of this dataset was presented at the recent AGU Fall Meeting (Staten et al., 2013).


Suggestions for expansion, refinement, and verification

This preliminary work is hampered by the shortness of the current simulations. Extending these simulations is a first priority. Extending the simulations beyond the AM2-1 framework is also desirable. AM3, for example, is known to greatly improve the representation of cloud processes, and we consider AM3 a prime candidate for additional work.

In order for results to be comparable to observations, we plan to simulate HIRS measurements of the simulated earth using radiative transfer code.

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