Constraining Cloud Feedbacks
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within the cantilever per cycle are smaller than the energy of each energy transfer, the energy from many cycles can build up enough to produce appreciable motion of the cantilever, limited ultimately by nonlinearities present in the system.

Being able to direct energy from the small to the large is an important ability if, for example, one wants to harvest chemical or other forms of energy toward powering functional nanostructures. The work of Lotze et al. is an intriguing demonstration of how this can work in a synthetic structure. Although the elegance and efficiency of biological systems in this regard may provide inspiration, the initial step taken by this experiment provides a strong direction for further research, toward controlling and directing large-scale motion from nanoscale or even single-molecule energy sources.

References

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Constraining Cloud Feedbacks

Despite decades of improvements in computer models of Earth’s climate, estimates of the climate sensitivity—the change in global average surface air temperature in response to a doubling of carbon dioxide concentration—remain uncertain (1). Much of the uncertainty results from radiative feedbacks that amplify or dampen climate changes. Particular attention has been given to the cloud feedback. Global warming is expected to change the cloud cover, but these changes and their effects on global temperature are very difficult to predict. On page 792 of this issue, Fasullo and Trenberth (2) present an observational test of the cloud feedback based on satellite measurements of relative humidity (RH) in cloud-free subtropical regions. The authors focus on environmental conditions that are easier to observe than the cloud properties themselves.

Clouds cool the climate by reflecting incoming sunlight back to space, but they also warm the climate by absorbing upwelling terrestrial radiation from the surface. Their net effect is to cool the planet, but changes in clouds in response to global warming may increase or reduce this cooling. Climate models do not agree on the spatial patterns of cloud changes or their net radiative effects, and the cloud feedback is responsible for most of the uncertainty in climate sensitivity in model studies (3–5). Observational data are needed to resolve these issues.

Global, reliable satellite data are available for only a few decades, too short a time to directly observe century-scale feedbacks.

Thus, determining the climate sensitivity from observations requires two nontrivial steps. First, the relation between short-term (seasonal, interannual, or decadal) and long-term feedbacks needs to be determined using models. Second, modeled short-term feedbacks must be compared to observations to test the models.

If similar processes control both short-term and long-term feedbacks—for example, cloud cover increases or decreases in a predictable manner in response to temperature increases—then these short-term observations can perhaps be used as proxies for longer-term changes. However, short-term and long-term cloud feedbacks do not appear to be correlated in models (6). Thus, the first step is not only difficult but may even be impossible, if short-term observations are not a guide to long-term changes.

Regarding the second step, one reason for the

Fig. 1. Linking relative humidity to cloud feedbacks. Water vapor (in cm) (A), cloud fraction (B), and reflected solar radiation (in W/m²) (C) for July 2012. Black regions in the water vapor plot indicate missing data, often due to high cloud coverage. Regions with high cloud fraction and reflected solar radiation generally coincide with high amounts of water vapor. Note in particular the subtropical regions with low reflected solar radiation. Fasullo and Trenberth use the correlations of these three fields to relate relative humidity changes to reflected solar radiation changes and, hence, cloud feedbacks.

0.0 0.2 0.4 0.6 0.8 1.0
0.0 1 2 3 4 5 6
0 213 425

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lack of success in evaluating cloud feedbacks is the difficulty of obtaining cloud properties from either satellite or surface-based observations. Assumptions of cloud droplet size or vertical distribution must go into these retrievals, and instrument error may be significant. Furthermore, due to the large temporal variability of clouds, observations at different times may result in different estimates of the cloud feedback (7).

Fasullo and Trenberth sidestep the difficulty in measuring cloud properties by using a quantity—the seasonal change in RH in the dry subtropics—that is easier to measure and that is strongly correlated with cloud cover. Analyzing previous model results, the authors find a strong correlation between the boreal (Northern Hemisphere) summer average of the simulated RH over the subtropical ocean (for the period 1980 to 1999) and the equilibrium climate sensitivity of climate models.

In boreal summer, the location of maximum solar heating moves north, resulting in air flow across the equator. Warm, moist air rises, loses water through rain, moves north or south, and descends in the high-pressure subtropical zones as relatively dry air (see the figure, panel A). The decreased RH makes condensation, and hence cloud formation, less likely (panel B). More sunlight is absorbed, leading to warming (panel C).

The subtropical RH does not represent merely a local process, but rather the whole subtropical atmospheric circulation. Thus, RH in these locations corresponds to cloud changes over a large region. Subtropical dry zones are expected to expand and intensify as a result of anthropogenic climate change (8). The strength of the annual RH cycle of the dry zones may therefore be a proxy for future changes, providing an observational constraint on models.

Fasullo and Trenberth find that only models with relatively high climate sensitivities (~4°C for a doubling of CO₂) replicate the observed seasonal RH changes. Models with large sensitivities have strong moist zones in the tropical lower troposphere and strong dry zones in the subtropical upper troposphere. An improvement of modeled subtropical dry zones may lead to better projections of future climate.

This work is but one piece of the climate sensitivity puzzle. Knowing that a modeled relative humidity is incorrect does not directly translate into the necessary model improvements, and models might not correctly simulate the dependence of cloud properties on relative humidity. Even if models capture the response of subtropical clouds to climate change, other feedbacks (including water vapor, temperature, snow and sea ice, and high-latitude cloud feedbacks) may not be related to subtropical RH or may have short-term feedbacks that differ from their long-term feedbacks. Nonetheless, the simple diagnostic reported by Fasullo and Trenberth is an encouraging step that links observations to climate sensitivity.

References