(Low) Cloud Effects Phenomenological Theme

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Background

Changes in the radiative forcing associated with cloud effects "remain the largest source of uncertainty" in model-based estimates of the climate sensitivity[1]. The sensitivity of climate projections to the representation of clouds was identified at the outset of attempts to systematically investigate and quantify climate change (Arakawa, 1975; Charney et al., 1979). The FANGIO[2] studies Cess et al. (1989) were perhaps the first to systematically document the degree to which systematic differences among GCMs could be attributed to clouds, and helped establish the cloud radiative forcing as the metric for evaluating cloud effects on GCMs. And while the past 30 years have seen little progress in our ability to constrain representations of clouds at the level of climate prediction; we have made progress in more definitively establishing the role of clouds in the climate system, articulating ways in which they may respond to perturbations; and most recently, attributing uncertainty to specific cloud regimes (Bony et al., 2004; Bony and Dufresne, 2006; Wyant et al., 2006).

Early studies of cloud effects on climate models emphasized stratocumulus. Recent work suggests that the representation of shallow cumulus in the trade-wind regions may be equally (or more) important (Medeiros et al., 2007). Both stratocumulus and shallow cumulus are weakly forced and are characterized by clouds of modest vertical extent, two reasons why many believe them to be more amenable than most regimes to perturbations of the atmospheric aerosol Twomey (1974); Albrecht (1989); Pincus and Baker (1994). Recent years have seen increasing attention directed toward these issues, and while the possibility remains that shallow cloud regimes may exhibit marked sensitivity to the aerosol (the IPCC cites a an aerosol-cloud effect of anywhere from -0.3 to -1.8 Wm^{-2}) such effects are among the most uncertain to enter the mainstream conversation of climate change.

Because of their importance, cloud effects (more specifically low-cloud effects) on climate have been extensively studied. In addition to our own efforts, a number of international initiatives and observing systems raise new possibilities for advancement. Indeed, many of the participants in CMMAP (and we anticipate members of this focus group) were participants in the low-clouds and climate CPT (Climate Process Team, Bretherton et al., 2004a). This CPT established and deepened interactions between a number of groups and both the NCAR and GFDL modeling centers, and helped us better understand the ways in which the two models (AM2 and CAM3) were sensitive to their representation of clouds. Two initiatives to emerge from this effort, which we should try to take advantage of, include a single column modeling exercise examining the equilibria of low clouds, and an aqua-planet intercomparision study. In addition to the CPT other important activities include the emergence of the Cloud Feedback Intercomparision Project, led by Sandrine Bony, Mark Webb and Jean-Louis Dufresne; a forthcoming study group by the Frankfurt Institute

[1] IPCC Fourth Assessment Report Summary for Policy Makers, 2 February 2007

[2] Feedback analysis in GCMs for intercomparision and observations

for Advanced Studies; and the development of new modeling capacity based on the use of climate models in a forecast mode. Important new data sets characterizing stratocumulus and trade-wind cloud regimes (Bretherton et al., 2004b; Stevens et al., 2003; Rauber et al., 2007) have a bearing on these issues and are being integrated (with an emphasis on cloud microphysical processes) by the boundary layer working group of GCSS. Finally, a very significant development that has direct bearing on our activities is the launch of CloudSat in the late spring of 2006. Data from this instrument will shed new light on cloud processes, especially in advance of precipitation.

In summary, the role of low clouds in climate change remains a very important question that we can hope to answer through the course of the lifetime of our Center. Wouldn't that be a fitting legacy?

Goal

The goal of our effort will be to develop at least a "medium" level of scientific understanding[3] of how low-clouds behave in the climate system. I would characterize our current level of scientific understanding as low, or very low.

Strategy

Our strategy will incorporate the following elements:

1. Targeted use of a full range of models and observations, especially CloudSat and the prototype MMF.
2. Active engagement in international efforts directed toward understanding cloud feedbacks, especially the GCSS boundary layer working group.
3. The use of our developing understanding to improve existing models, with a focus on those expected to contribute to future efforts by the IPCC.
4. The identification and clear articulation of specific questions that can be answered in a one to three year time frame and around which our activities can be organized.
5. The prioritization of CMMAP funding for team members who contribute to the tactics, strategies and goals of the focus group.
6. The identification of activities which both span the group (thereby allowing minor participation) as well as those that are concentrated within sub-groups (thereby allowing individuals or smaller collections of people the freedom to pursue some issues on their own).

Tactics

Improved CRM and MMF: We wish to define a configuration of the MMF capable of exploring cloud effects from shallow convection. To do so we first ask: What is the minimal CRM configuration that can can provide a compelling representation of GCSS boundary layer working group test cases? We will call this configuration the SAMsc (SAM Shallow Convection). The SAMsc will then be incorporated into the

[3]Here we use "medium" in the sense of the IPCC. For reference the IPCC uses this phrase to characterizes our current understanding of tropospheric ozone as a component of the radiative forcing

MMF, perhaps alongside the default configuration, to explore cloud feedbacks. Doing this may require delocalization of SAM from the CAM vertical grid. Another component of this effort is to expand the microphysical capabilities of SAM to allow for a more sophisticated microphysical representation. This we will do by defining a microphysical interface for SAM and by identifying (and exploring) microphysical modules that may be coupled to it.

AquaPlanet Studies: CESS type experiments with MMF will be used to assess the extent to which the MMF low cloud response is well captured in the aqua-planet configuration. Statistics from such studies will be used to both derive off-line forcings for both higher resolution LES studies, SAMsc and single model evaluations, and determine the extent to which the climate system already samples a sufficient diversity of states to constrain the cloud response.

Equilibrium Cloud Structure: The equilibrium stratocumulus and trade-cumulus structure will be explored using LES (at the highest possible resolutions), SAMsc, and single column models. Two types of simulations will be configured: one based on seasonal climatology; the other based on forcing data sets which include realistic transient variability. Here we are asking: What is the contribution of the transient response to the low-cloud climatology?

What we need to accomplish at this meeting

- Identify our members
- Revise and approve this document.
- Review activities since we last met.
- Define an organizational structure.
- Distribute tasks.
- Identify broader issues that should be addressed by the center as a whole.

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