

**Cloud physics and cloud-climate feedbacks:
Connecting this course to current research**

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November 14, 2006

Start from two sections of Curry & Webster:

Parameterization of Cloud Microphysical Processes (Section 8.6), pages 241 - 244. Understand the ideas behind the equations on page 242 and note the remarks on page 244.

Cloud-radiation Feedback (Section 13.4), especially the last 2 paragraphs of Section 13.4.1 on pages 368, 369, and the last paragraph of Section 13.4 on page 374.

What do we mean by "parameterization"?

Some physical processes are too poorly understood, and/or they occur on too small space and time scales, so we cannot adequately represent them in global numerical climate models.

For example, clouds and cloud-radiation interactions are important to climate and to modeling climate change.

We don't know how to include these processes correctly, but we cannot afford to omit them.

A working definition of "parameterization":

A parameterization is an algorithm or rule for obtaining the statistical effect, of an ensemble of small-scale processes (e. g., cloud processes), on the large-scale prognostic fields computed explicitly in a model (e. g., wind, pressure, temperature, humidity).

In general, the parameterization must be explicit, in the sense that the statistical effect can be computed as a function of the large-scale variables themselves.

Example: cloud fraction might be a function of humidity.

First, some background.

We define "climate sensitivity" as the equilibrium change in global average surface atmospheric temperature in response to doubling the present atmospheric concentration of carbon dioxide. (There are many alternative definitions).

Many (but not all) reputable models have sensitivities ranging from about 1.5 deg C to 4.5 deg C. This range is an old result. It has not changed in nearly 30 years. Why?

Cloud effects dominate climate sensitivity.

In a typical comparison of coupled models, some of which have the same atmosphere, and some of which have the same ocean, the clear result is that it is the atmospheric model which largely determines the sensitivity, and in particular, it is clouds.

This is another confirmation of something known for a long time. Changing the cloud-radiation scheme in one model replicates the sensitivity spread of many models.

The problem is we don't know which scheme is best.

Cloud algorithms require comprehensive approaches.

Cloud radiative processes are determined BOTH by cloud macrophysics (cloud size, altitude, thickness, etc.) AND by cloud microphysics (water content, phase, particle shapes and size distributions, etc.).

The old procedure of predicting clouds as a simple function of relative humidity, and then assigning radiative properties arbitrarily, is not good enough.

Zeroth-order cloud effects are still unclear.

Models don't agree on even the simplest aspects of cloud changes as climate warms. Some predict cloud amount increases; some predict it decreases.

If in-situ and satellite interpretations can show an observed long-scale secular trend in cloud amount in recent decades, our models must be able to simulate that.

To be believable, climate models must pass tests.

It's unacceptable that models with different sensitivities all manage to reproduce the global mean 20th-century temperature evolution by using dramatically different assumptions on forcing.

The temptation is to treat the 20th-century record of solar variability, volcanism, aerosols and greenhouse gas changes as parameters that can be tuned so the model produces the observed record of surface temperature as a function of time.

Climate sensitivity cannot be only 1 global number

The annual cycle may be masked in average results or thrown away in perpetual-month simulations. In some models, cloud feedback in the longwave (terrestrial) is about the same in all seasons, but the shortwave (solar) cloud feedback actually changes sign over the annual cycle, due to cloud amount changes.

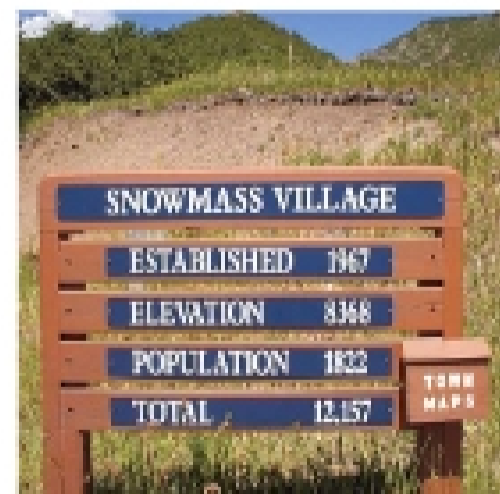
The concept of cloud feedback should also include spatial as well as temporal variability.

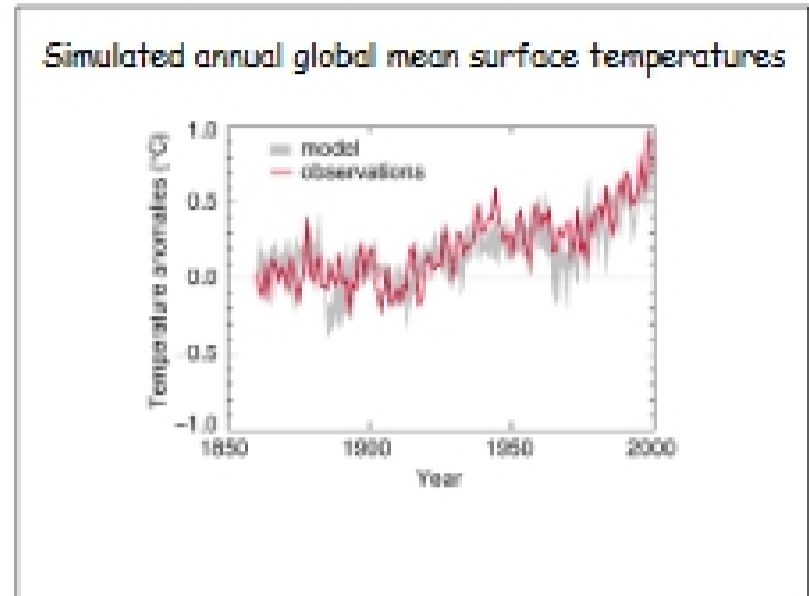
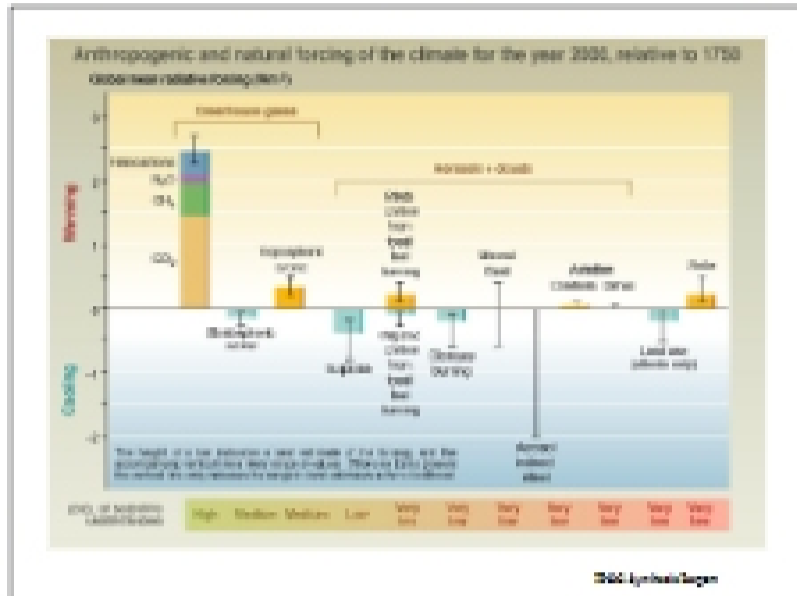
It may be a distraction to concentrate on global effects.

We already know that aerosol effects are highly local. Perhaps cloud effects are largely local too.

Even if cloud-radiation effects are not large globally, and we don't know yet if this is true, they may be very important locally.

All this uncertainty about how clouds should be modeled has motivated intense research, and one theme of this research is to observe real clouds.





There are two elements in this research (which is joint work by Sam Jacobellis and Richard Somerville):

1. We build parameterizations incorporating detailed and comprehensive cloud microphysics. For example, radiative properties of clouds depend on cloud water content, phase (liquid or ice or both), particle size distribution, ice crystal habit (shape), all of which can be treated explicitly as functions of known variables.
2. We test these parameterizations against field observations by using a special theoretical tool, the single-column model.

