WORKSHOP ON CLIMATE SYSTEM FEEDBACKS

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The Workshop on Climate System Feedbacks was organized by the GEWEX Radiation Panel and the JSC/CLIVAR Working Group on Coupled Models. The term "feedback" looms important in many WCRP (and Intergovernmental Panel on Climate Change [IPCC]) documents and is used to motivate many WCRP programs and projects. We all have some sense of what the feedback concept means in the climate system in that a perturbation of the climate system is either amplified or diminished by a feedback process. Linear control theory (from engineering) has been used since the late 1970s to assess radiation-climate feedbacks in terms of simple energy balance models using the top-of-atmosphere (TOA) radiative fluxes as the dependent variable and global mean surface temperature as the independent variable. This type of analysis has led to discussion of a whole host of feedbacks on surface temperature: water vapor feedback, ice/snow albedo feedback, and many different cloud feedbacks, including those associated with changes in total cloud cover, cloud top temperature (and/or infrared emissivity) or height, cloud optical thickness (or solar albedo), cloud droplet size, and boundary layer or cirrus cloud cover. Many other feedbacks that do not involve radiation directly have also been described, notably ones that alter water exchanges. **The continuation of attempts to isolate and describe more climate feedbacks and to quantify those already mentioned in this same way has become very confusing and misleading because application of this simple linear control theory to the complex, non-linear climate system composed of many coupled sub-systems is simply not appropriate.** In particular, in observations of the variations of the real climate, many feedback processes act simultaneously so that their intrinsic magnitude cannot be estimated. The most obvious demonstration of the flaw in such an analysis approach comes from studies that show that the magnitude of "feedback factors" determined from climate model experiments depends on the order in which they are evaluated — this expresses the fact that most feedbacks are coupled to others. In particular, most feedbacks are coupled to cloud feedbacks because the climate can only be altered by changing its energy and water cycles, which are really one cycle involving clouds. Considering the derivation of the mathmatical expressions commonly used to determine feedback factors shows that several very strong assumptions are required, none of which is true of the real climate or even of climate Global Circulation Models (GCM). **Moreover, even if the feedback concept is useful in summarizing the overall sensitivity of a climate model to changes of forcing, the way in which these quantities are evaluated in practice cannot be reproduced with observations: in other words, this way of describing a climate model's sensitivity can never be verified.**

Although the notion of climate feedback is useful for evaluating sensitivity of a climate model to forced changes and the roles of different physical processes in determining the model sensitivity when they are isolated in special experiments, we need a more appropriate, yet still practical way of analyzing climate model feedbacks that can be verified from a similar analysis of observations. To explore useful ways of addressing the feedback problem and to evaluate alternate analysis approaches, the GEWEX Radiation Panel and the Joint Steering Committee (JSC)/CLIVAR Working Group on Coupled Models (WGCM) sponsored a workshop in Atlanta, Georgia, USA on 18–20 November 2002 to discuss:

(1) Advanced analysis methods for complex, nonlinear dynamical systems; and
(2) Better applications of the concept of feedbacks for understanding, evaluating and improving climate models.

The desired outcome of the meeting was suggestions for new lines of research to develop better analysis approaches to be applied to both climate observations and climate model outputs and assessments of possible metrics for evaluating climate model feedbacks and sensitivities.

About 30 scientists attended the 3-day workshop. Papers and discussion sessions during the first two days of the meeting were arranged around consideration of two topics:

(1) Analysis of Multi-Variate, Non-Linear Dynamical Systems Like Climate, Their Behavior and Their Predictability,
(2) Advanced Methods of Model-Data Comparison and Parameterization Testing

The last day of the meeting was composed of two parallel break-out meetings and a final plenary session to formulate some suggestions and recommendations in response to three questions:

(1) How do we evaluate the usefulness of new analysis methods?
(2) How do we diagnose climate and climate model behavior more effectively?
(3) How do we better compare observations and models?

A number of interesting proposals for different ways to analyze non-linear dynamical systems, like climate and climate models, were presented; but very few of the talks actually concerned climate feedbacks directly. Some of these methods have been applied to climate models in informative ways but they could not be applied to observations of the real climate in practice. In particular, it was noted that the common modeling practice of evaluating climate model feedbacks by finite differences between the state variables of two "equilibrium runs" of the model could not be verified against observations. A number of other aspects of model sensitivity testing were also discussed and some specific suggestions for the design of such activities were made and incorporated into the WGCM plan for a "cloud feedback" experiment. Also, several aspects of model-data comparisons were discussed, leading to a specific decision to employ the "International Satellite Cloud Climatology Project (ISCCP) simulator" (http://gcss-dime.nasa.gov/simulator.html), which converts model cloud output into a form that allows for direct comparison of the space-time distributions of cloud top pressure and optical thicknesses as seen by satellites in the ISCCP data set, in the WGCM cloud feedback exercise.

Very interesting discussions occurred, covering a wide range of topics, and some useful suggestions for improved analysis were made; but the **basic questions of how to make progress on quantifying climate feedbacks and verifying models of them remained unanswered.** The participants believe that this fact indicates the depth of the feedback problem, that there is a general lack of understanding by the climate research community of the issues involved in the feedback problem, and that what the climate research community is mostly working on is not what really needs to be worked on. A tentative conclusion was that the whole feedback approach may not be viable, when applied to such a complicated system as the climate, but that a focus on a more general diagnosis of the dynamic relationships among variables in the system, using methods capable of handling non-linear, multi-variate relationships, would be useful. Another conclusion was that, whatever advanced analysis techniques were to be developed, they would have to determine quantities from models that can also be determined from observations.

Although not well defined, the next steps would seem to include the formulation of a small set of analysis tasks that all of the proposed analysis methods could be applied to, using the same data sets and the outputs from a hierarchy of climate models of varying complexity. The purpose would be to compare and evaluate the results obtained by the different analysis methods to learn what aspects of the dynamical system they are describing and to examine how the results depend on the complexity of the system being considered. Also, this comparison of different diagnostics when applied to different kinds of climate models could help determine what information about the model's feedback processes can be extracted in practice. The participants agreed to continue discussions towards more definite plans for such coordinated studies, possibly leading to another workshop in about 18 months.