100 East Francis
Aspen, Colorado 81611
Phone: 303/925-7376
Fax: 303/925-7097
E-Mail: AGCI/EcoNet

Aspen Global Change Institute

1992 Summer Science Session II:
"The Coupled Climate System and Global Change"
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Dr. Gerald Meehl and Dr. David Schimel, Co-Chairs

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1992 Aspen Global Change Institute (AGCI) Summer Session II: The Coupled Climate System and Global Change

Current estimates of future global climate change rely on coupled models of the climate system. These models are both a measure of our level of understanding of coupled processes occurring in nature, and of our ability to simulate with computer models the possible changes in these processes due to increased CO_2 and trace gases. Central to coupled models is air-sea interaction, but processes involving the cryosphere, biosphere, atmospheric chemistry/radiation and land surface are also intimately involved. Monitoring and analyzing observations are critical for understanding and interpreting results from the coupled models. These model and observational studies are extensively used by the climate-impacts community, and are eventually interpreted and passed along to policymakers (e.g., the Intergovernmental Panel on Climatic Change (IPCC) process organized by the World Meteorological Organization).

A group of 27 researchers from disciplines involved with coupled modeling and observational analysis of the climate system, as well as representatives from the climate-impacts community who apply the results from global models, were invited to Aspen, Colorado, to present research results and outline outstanding issues of concern. The goal was for participants to gain a greater mutual understanding of the disciplinary issues relevant to coupled models, observations, and global change, and to identify connections and interfaces between disciplines and areas of study in the coupled climate system.

The following topics were addressed in the context of modeling, observational analyses, and/or impact studies: observed climate-change signals, El Niño-Southern Oscillation (ENSO), tropical cyclones, the Indian monsoon, role of ocean circulation (in particular, the global "conveyor belt" circulation), the cryosphere (snow, sea ice, glaciers), the biosphere (land-surface processes and terrestrial ecosystems), atmospheric chemistry and radiation (trace gases and ozone), low-frequency variability of the climate

system in observations and global coupled models, climate-impact applications, and policy formation from coupled model results.

Interdisciplinary interface issues related to the coupled climate system and global change that were identified as being shared in common by all the researchers involved in studying observations, models, and impacts included 1) spatial scales, 2) level of complexity of model components, 3) variability, and 4) science-policy interface. Various uncertainties were also identified involving understanding and model parameterization of clouds, convection, cryospheric and land-surface processes, land-ocean-atmosphere coupling, ocean circulation, data availability and management, parameterization of subgrid-scale processes, chemistry, radiation, and the terrestrial ecosystem. Several issues involving consequences for human societies were noted: 1) adaptation vs. mitigation of climate change, 2) public good vs. private interest, and 3) the role of technology.

After having identified these issues of shared concern, a number of "next steps" where progress is most likely to occur, or is most required, were identified. Higher resolution in coupled GCMs was noted to be possible with more powerful supercomputers. But comparable improvements in model physics must accompany such increases of horizontal and vertical resolution because higher resolution by itself does not guarantee better simulations. Imbedding mesoscale models (continental to regional scale) in global GCMs improves the prospects for better regional-scale resolution in climate-sensitivity studies, particularly in midlatitudes. However, these models contain the errors of the global GCMs used to drive them. So-called "time slice" integrations are starting to be performed to improve regional-scale simulations. With this technique a high-resolution global GCM is run for a short time (several years) at the end of a long integration of a coarse-resolution coupled GCM. The sea-surface temperature and sea-ice distributions from the climate-sensitivity experiment in the coarse-grid model (with the appropriate changes in CO_2 or trace gases from the end of the coarse-grid model run) are used to force (or initialize) the high-resolution GCM. Once again, model errors from the coarse-grid model are passed to the higher-resolution model just as in the imbedded mesocale

model. Innovative parameterizations of subgrid-scale processes may improve regional-scale simulations. But it was noted that some small-scale phenomena of interest to policymakers may never be resolved in the models, in validation data from stations, or in remote-sensing data.

The appropriate level of coupled model component complexity has only recently being recognized as being an important model strategy issue. With a number of earth system modeling projects currently underway internationally, there is the desire to take any number of component models (e.g., atmosphere, ocean, sea ice, land-surface processes, terrestrial ecosystems, atmospheric chemistry, etc.) and couple them all together. There is a growing awareness that present-day computer resources will limit the feasibility of such an exercise with the current level of complexity present in the stand-alone components. In some cases, strategic decisions about implementing more complex sub-models will need to be driven by the specific question posed. One approach is for the components to initially capture only very basic and/or the most important processes while more detailed component models are developed for future coupling. The issue of level of complexity was acknowledged to be a major element of managing not only earth system modeling efforts but the associated analysis and impact studies as well.

The observed and modeled climate system displays variability on all time and space scales. Such variability is emerging as a formidable factor in definitively attributing climate-change signals to forcing from anthropogenic sources, as well as in making climate impact studies more difficult. It was noted that we must understand the mechanisms and signals of various forcing of variability in observations and in model experiments, not just from increasing CO_2 and trace gases but from ENSO, solar activity, volcanos, the thermohaline "conveyor belt" circulation in the ocean, etc.

Uncertainties and the next steps required to address them were identified for a number of different elements of the coupled climate system. Empirical and observational studies were noted as being likely to make large contributions to improving our

understanding of clouds and cloud processes (e.g., cloud optical depth feedback). Uncertainties were noted concerning convective schemes and their role in climate sensitivity in the GCMs. Since more detailed convective schemes in models at higher resolution do not always produce a better simulation, model physics must be improved and results from observational programs must be incorporated in the revised model formulations. Expanded monitoring of the cryosphere including, for example, sea-ice thickness and snow water equivalent, must occur to improve our ability to understand ocean salinity and land hydrology changes, respectively, and corresponding model processes.

Appropriate scaling of subgrid-scale processes should provide better representation of land-surface processes in coupled models. Both horizontal and vertical resolution improvements applied at the interface (e.g., better boundary layers) should also reduce land-atmosphere-ocean coupling uncertainties. Additionally, observational and modeling studies (e.g., TOGA COARE, FIFE, BOREAS) should advance our understanding of land-atmosphere and air-sea coupling. Interannual variability of observed coupled process regimes (e.g.. ENSO, the monsoons, and tropical cyclones) can be used as climate-sensitivity analogues to provide a context to interpret model sensitivity experiments. With the recent advent of global high resolution (1/2 to 1/3°) ocean models, a greater understanding of the mechanisms involved with the global thermohaline circulation or "conveyor belt" and its role in coupled climate variability should be possible.

Requisite global data sets (and time series) for initialization and validation of model simulations of various aspects of the coupled climate system should become more readily available. Data rehabilitation and reanalysis and more observational studies provide the hope of furthering our understanding of processes in the observed climate system. As better data sets become available, especially through the planned Earth Observing System (EOS) satellites in the late 1990's, and the use of global models increases, better parameterizations of subgrid-scale processes will take into account, for example, grid square inhomogenieties.

Chemical processes are now starting to be incorporated into atmospheric GCMs. This will be a considerable improvement over the present one-dimensional or two-dimensional atmospheric chemistry models and will provide insights into the role of atmospheric dynamics and transport. A better understanding of tropospheric and stratospheric ozone processes must be attained, and observed and modeled processes at the tropopause must be better understood. All the relevant trace gases (and their possible future changes), in addition to the more traditional CO_2 changes, are now beginning to be included in the GCMs used for climate-sensitivity studies. Observational programs such as ARM should improve our understanding of pertinent radiative processes. A recent recognition of the radiative importance of increases of tropospheric ozone will encourage interaction between the radiation and chemistry communities. Similar scrutiny of the radiative and chemical role of aerosols should also provide more insight into the various feedbacks that contribute to global change.

Terrestrial ecosystem models have now reached the stage of being ready for coupling to earth system models of atmosphere, ocean, etc. Data for initialization and validation of the models are still very limiting, including data on land-use changes and pollution in the formulations. Hopefully, remote-sensing data sets from the EOS program mentioned earlier will help address these needs.

The consequences of global change and the role played by observational and modeling studies were discussed in the climate-impacts context. Global coupled climate models that perform best on large scales are not necessarily optimal for studies of societal adaptation to global change, since such studies require detailed regional climate forecasts that are not presently feasible in coupled climate models. Rather, global and large-scale geographic results from present-day models provide compelling arguments for the formulation of mitigation strategies to prevent large-scale changes. In this regard, scenarios, case studies, and analogues based on model results have been shown to be useful for impact assessment (e.g., water-use decisions).

At least as important as climate change are global change pressures brought about from increasing population and development. A number of debates at the Earth Summit in Rio in July 1992 revolved around critical decisions regarding the public good vs. private interest. Policymakers routinely have to make these decisions in regards to other issues, and global change is now commanding attention from various sectors including a groundswell of concern from private citizens. One outcome may require judgments to override private interest to adapt to or mitigate global change in the interest of the public good. Additionally, technological solutions may play an important role in dealing with some problems related to population pressures and adaptation or mitigation to global change in the coupled climate system.

The IPCC exercise is an example of scientific concensus input to international policy, but there is also the need for information dissemination to national, state and local policymakers based on adaptations of model-based scenarios (with appropriate caveats) for policymaking. Education on all levels (from the international political realm to primary school) is an integral component of the science-policy interface. This activity encourages greater understanding of the scientific issues essential for informed policymaking in this and future generations. As part of this effort, AGCI is actively developing prototype educational programs. One of these, funded by NASA, involves elementary school children in the use of remote-sensing products to document environmental changes in their neighborhoods. The importance of hands-on student activities for the exploration of various aspects of the integrated earth system is emphasized.

For further information on the Aspen Global Change Institute and its activities, contact John Katzenberger, AGCI, 100 East Francis, Aspen, Colorado 81611; tel. 303-925-7376.

—Gerald A. Meehl and David Schimel, National Center for Atmospheric Research, Boulder, Colorado.