Eos, Transactions, American Geophysical Union, Vol. 73, No. 49, December 8, 1992, Pages 529–530.

Global Forcing and Regional Interactions

The Climate System Modeling Program (CSMP) sponsored a "Global Forcing and Regional Interaction Workshop" from October 21 to 23, 1991, at Colorado State University's Pingree Park campus, to evaluate the relationship between global climate forcing and the response of the land surface on a regional scale.

The general aim of the workshop was to develop specific action plans and preliminary science research strategies for regional-global interactions. Each participant was invited to identify tractable, high pay-off science issues related to global forcing and regional interactions. The workshop, with twenty-six participants about evenly split between atmospheric scientists, hydrologists, and ecologists, was also designed to facilitate a network of collaborators to prepare multidisciplinary research proposals. Discussion also focused on regional climate over the last 200 years and included the influence of atmosphere-land surface processes on natural climate variability. Several major recommendations were made on topics discussed.

With respect to the response of regional climate to altered global climate forcing, improved understanding and simulation of local and regional processes are required for assessment of regional responses to global change. Specific recommendations include assessing the role of nonmethane biogenic hydrocarbon production in nocturnal cooling. B. Hayden (University of Virginia) presented evidence that at sunset, when relative humidities are below 60–70%, hydrocarbons with an atmospheric concentration of around 1–3 parts per billion radiatively act to reduce long-wave cooling to space so that minimum nighttime temperatures are substantially greater than dew point temperature, which normally limits the minimum temperature at night. Such land surface climate-lower tropospheric chemistry interactions are currently omitted in global models.

The influence of vertical grid resolution in General Circulation Model (GCM) calculations on the magnitude of estimates of minimum nighttime temperatures over land needs to be evaluated. With coarse vertical resolution, is the flux divergence of long-wave radiation properly represented so that accurate estimates of meteorological screen level temperatures can be obtained? This is a critical question in the ability of GCMs to simulate temperatures at the same height as obtained from land-based temperature measurements. One-dimensional boundary layer simulation experiments should be performed to address the importance of high vertical resolution near the surface.

The hydrologic and carbon cycle for relatively large, economically important weather sensitive regions, such as the U.S. Great Plains, should be investigated by conducting coupled meteorological-ecological-hydrological model simulations for key weather events and by comparing outputs to available observations. While coupling of these models is being developed as one-way linkages (for example, hydrology driven by climate dynamics), two-way interactive models need to be developed to fully evaluate the role of biospheric and hydrologic feedbacks in regional climate change.

The influence of air pollution on regional ecosystem dynamics and climate should be assessed further. For example, what is the long-term impact of atmospheric nitrogen input to the forests of the U.S. and southeast Canada coupled with dry and wet nitric acid deposition?

The utility of statistical techniques to estimate point predictions from GCMs alone and GCMs with nested mesoscale model grids needs to be determined.

The mesoscale models that have been or are being applied to downscale GCM input should be compared when driven by current large-scale climate prediction models (for instance, GCMs using current date-specific synoptic weather data) and compared for available past and planned field experiments including FIFE, ABRASO, BOREAS, HAPEX, OASIS, Battelle N.W., STORM-summer, and METROMEX. In such field-model intercomparisons, focus should be given to comparing parameterization and structure of land surface packages incorporated into mesoscale models and GCMs.

Members of the climate assessment community are encouraged to interface with policy studies and investigations that will impact environment and society. An understanding of the needs of such research efforts in terms of climate variables and types of statistics (for example, daily versus monthly outputs, extrema versus means) will enhance the utility of global and regional climate projections and help direct future model implementations. And, the influence of regional processes on global changes needs to be assessed.

Scaling-up of mesoscale meteorological and land surface/biophysical processes that exhibit high spatial heterogeneity at a range of scales is required to assess their influence on global climate. Detailed recommendations include that meteorological model responses to current and historic landscape characteristics should be assessed at the regional scale and averaged over GCM grids, the cumulative global impact of existing landscape changes from the natural state should be evaluated in terms of changes in GCM grid-area averaged values and subgrid scale variability, and the interaction of land cover and greenhouse gas-induced climate changes should be estimated.

Methodologies to compute spatial averages from point data and estimates of point values from spatial averages need to be developed. This includes procedures to aggregate and parameterize ecological and hydrologic processes when moving from site-specific processes to local area to mesoscale grid cell to GCM grid scale. Functional similarity indices derived from variables that dominate the modeled process also need to be developed.

The biological elements of the coupled atmosphere-ecosystem are not static, even in the short-term of this interaction. The transport of water from the soil to the atmosphere through plants, for example, is associated with the process of photosynthesis, where water loss represents a "cost" to plants of performing photosynthesis.

Ecophysiologists have taken a viewpoint, based on evolutionary theory, that the enzyme kinetic mechanism that regulates stomatal conductance may respond to light, CO_2, and water availability in a manner that optimizes the use of water and other resources with respect to carbon gain in the plant. This concept of optimization needs to be explored further in the development of parameterizations of vegetation-atmosphere interactions, as well as in the broader context of ecosystem-global climate feedbacks. As an example of this optimization principle, leaf shape, size, and biochemistry and the distribution of these quantities with height have apparently evolved so that available sunlight is used optimally for photosynthesis throughout the canopy. S. Running (University of Montana) suggested that the entire ecosystem is optimized through stomatal response optimization, which influences water use efficiency. The time integral of this quantity helps determine the length of the growing season and thus species composition in regions where growth is water-limited.

The influence of mesoscale convective systems, low-level jets, maritime cyclones (for example, polar lows, and explosive ocean cyclogenesis), tropical cyclones, etc., on GCM simulations needs to be assessed. These features cannot be modeled properly in current GCMs due to inadequate spatial resolution. Modeling studies should address whether moisture, heat, and momentum fluxes from these mesoscale systems, when summed globally, are of sufficient magnitude to influence GCM results and conclusions.

The sensitivity of regional ecosystem dynamics and vegetation composition to climate changes needs to be determined because of their feedbacks to climate. Such assessments should be based on process-level models and include evaluations of net primary production and soil carbon storage. Changes in biomass production in the short term and vegetation composition in the long term influence the biophysical nature of the land surface. Changes in production and decomposition rates influence plant and soil emissions of radiatively active gases.

Requirements of ecological, hydrological, and other regional-scale models from climate models and their contributions to regional climate models need to be determined. Priorities for data set development include a high-resolution characterization of land-surface conditions that are essential for adequate assessment of mesoscale-global interactions. Data averaged globally at scales of at least 1-km horizontal spatial separation are needed. These data include information for meteorological models, for instance, terrain elevation, albedo, leaf area index, cloud cover (also over the oceans), physical characteristics of soils (for instance, not traditional taxonomic soil maps), and soil water (including temporal profile).

Additional information, counting temporal profiles, needed for ecologic, hydrologic, and other regional-scale models include vegetation community composition, biomass (separated into leafy material, live woody material, and dead material), watershed structures, and fraction of photosynthetically active radiation.

This information should be used to quantitatively assess the spatial and temporal variability of landscapes—perhaps in terms of statistical distribution functions, to develop parameterizations for GCMs, and to develop relationships between remotely sensed parameters and ecological variables, for example, net primary productivity. Mesoscale resolution data above the surface are also important in terms of regional response, including mesoscale spatial and temporal structure of water vapor and cloud distributions, for example, from GOES and NOAA satellites. Surface temperature and surface soil wetness distributions should also be obtained at the finest resolution feasible using these Earth-orbiting platforms. The integration of these meteorological data with surface characteristic data—for example, Normalized Difference Vegetation Index, soil proportion—at the same spatial scale should be a high priority.

Modelers should perform sensitivity tests to assess the spatial resolution, temporal frequency, and accuracy needed to simulate adequately key regional-global interactions and to assess the sensitivity of model outputs to specified parameters that can be determined primarily from remote sensing. These tests should be performed for a variety of biome types including tropical, temperate, and boreal forests. Model-derived surface values for temperature, for example, need to be compared with satellite-derived irradiances over the same areas.

Observations of surface net radiation and other thermodynamic energy fluxes should be obtained over a long time period for selected locations around the globe. Comparison of observed mean monthly values with simulated values from the range of available GCMs at the equivalent location would be a valuable test of these models, as demonstrated by J. Garratt (Australia Commonwealth Scientific Industrial Research Organization for Manaus in the Amazon). To accommodate these tests, GCM modelers should be encouraged to archive flux data and other model outputs, such as the water budget, and make them readily available at little or no cost to external users.

It was recommended that an electromagnetic spectral characterization of the land surface would permit more accurate evaluations across large heterogeneous regions of several of the parameters, including albedo, leaf area index, etc.

The extraction of remotely sensed data from prior years and its normalization with current imagery through programs such as EOS DIS Pathfinder is a valuable effort. Such progress will permit effective estimation of landscape changes for about the past 20 years.

On-going activities related to global forcing and regional interaction were discussed, including the recent establishment of the Terrestrial Ecosystem Regional Research and Analysis Laboratory in Fort Collins, Colo., by the Forest Service and Agricultural Research Service of the U.S. Department of Agriculture and the U.S. Geological Survey. The laboratory is to provide mechanisms to link landscape and regional models from different disciplines to apply these linked models to practical problems associated with land management, including evaluating impacts of regional climate change.

The establishment of a European climate change research program, the Climate of the 21st Century Program, involving groups from French, Danish, British, and Italian meteorological services and from NCAR, was discussed. This project is designed to apply limited area models for different GCM outputs to climate studies for model intercomparisons and determination of model uncertainties.

Action subcommittees were established at the end of the workshop to facilitate a continuation of the interactions initiated or encouraged. These subcommittees will cover long-wave radiation/lower boundary layer interactions, ecophysiological optimization, GCM grid point flux estimates, data needs, regional climate history, and uncertainty.

The workshop recommended key areas of research needed to clarify interactions between global and regional processes. Studies of critical surface-climate processes, improved techniques to scale such processes between meso- and GCM scales, and expanded global data sets for model parameterization and validation were recommended. Such efforts will accelerate progress toward improved simulations of global and regional climates and reliable predictions of climate change. While the focus of the workshop was on land-atmosphere interactions, parallel work is also required in the areas of mesoscale ocean-atmosphere and sea ice-atmosphere interactions.

This meeting was one of a series of CSMP workshops established to address critical research issues in modeling of the Earth's climate system, with particular emphasis on component interactions. Additional information is available from the CSMP Project Office, UCAR, Box 3000, Boulder, CO 80307–3000; tel. 303-497-1611; e-mail schimel@niwot. scd.ucar.edu (Internet), d.schimel (Omnet). CSMP is sponsored by the National Science Foundation, NASA, the Department of Energy, the U.S. Department of Agriculture, the U.S. Geological Survey, and the Environmental Protection Agency. This report was prepared by Dallas McDonald and Bryan Critchfield and was supported under NSF grant no. ATM-8915265.—*R. A. Pielke, D. Schimel, and T. G. F. Kittel, Colorado State University, Fort Collins; and F. Bretherton, University of Wisconsin, Madison*