plasma, corresponding to a strongly anisotropic plasma. Virtually every disturbance of a plasma—a gradient in density, temperature, or magnetic field, a velocity or field shear, the flow of a current or heat flux—corresponds to a nonthermal plasma.

Clearly, plasma dynamics are substantially different from the dynamics of neutral gases. And yet these differences rest on the same fundamental principles that govern all of classical nonrelativistic physics: Newton's laws, Maxwell's equations, and the laws of thermodynamics. In particular, plasmas, like all other physical systems, are subject to the Second Law of Thermodynamics: entropy increases. In a neutral fluid or gas, a local disturbance that might contain some useful information that the second law requires to be dissipated is, in fact, rapidly smoothed by close encounter particle collisions. However, in many plasmas, neither close encounter collisions nor Landau damping can provide effective dissipation; there must be another mechanism that can quickly enforce the second law.

In many space plasmas, that mechanism is the growth of relatively short-wavelength plasma instabilities and the subsequent enhancement of wave-particle interactions. If a plasma is nonthermal, it is said to possess "free energy." If there is a sufficient amount of this quantity, the consequences of wave-particle interactions are turned around. Thus, instead of particles gaining energy from fields so that fluctuations are damped, the particles give up energy to the fields so that the electric and magnetic fluctuations grow in time, and an instability develops. A simple example here is a current associated with a relative drift between the electrons and protons. If this drift is relatively modest, the ion acoustic wave remains damped, albeit less strongly than at zero relative drift. But if the relative velocity difference between the two species becomes significantly greater than the ion thermal speed, the plasma becomes sufficiently anisotropic to permit the ion acoustic wave to grow in time. Because the mode is driven unstable by the relative motion of the electrons against the ions, we use the term "electron/ion acoustic instability" to describe this mode.

Different kinds of free energy lead to the growth of different kinds of plasma instabilities. For example, an anisotropy due to two groups of electrons with different average velocities streaming through each other can give rise to the electron/electron plasma instability. And, just as it increases the number of plasma waves, so does the presence of a background magnetic field substantially increase the number of possible instabilities [*Melrose*, 1986; *Gary*, 1993].

As the field fluctuations of the instability grow, they produce stronger wave-particle interactions that act to change the momentum and energy of the particles. Although fluctuation growth can be described by linear theory, nonlinear theory must be used to describe how the particles respond to the growing waves and how the fluctuations reach their maximum, or saturation, energy (as they must under the mandate of the First Law of Thermodynamics). The changes induced by wave-particle interactions are, of course, such as to reduce the free energy and return the plasma toward stable, more nearly thermal conditions. In the example of the electron/ion acoustic instability, the primary consequence of wave-particle interactions is to reduce the electron/ion relative drift back toward values corresponding to wave stability.

Instabilities play a role in many different space plasmas. The flow of thermal energy away from the Sun corresponds to a free energy in solar wind electrons; there is good evidence that this leads to heat flux instabilities that act to limit this thermal flow. The strong plasma perturbations associated with the planetary bow shocks and solar wind shocks cause the ions to become anisotropic; the resulting instabilities not only act to isotropize these particles but also to accelerate a few of them to high energies. The plasma and field gradients associated with certain configurations at the magnetopause and in the magnetotail give rise to instabilities that are thought to trigger magnetic reconnection processes at these locations.

As a final example, consider the anisotropic distributions of energetic particles trapped in the Earth's radiation belts that lead to plasma instabilities. The enhanced wave-particle interactions resulting from these growing fluctuations act to make these distributions more isotropic; however, this increases the number of energetic particles that can move downward along the geomagnetic field lines. As these particles reach the Earth's atmosphere, they collide with and excite neutral gas molecules, causing them to emit radiation that we recognize as auroral phenomena. In this way, plasma instabilities make important contributions to the aurora.

More generally, plasma instabilities are worthy of study because they offer the potential of relatively complete understanding through the use of existing spacecraft data. The small-scale, local nature of many plasma instabilities implies that present-day particle and field measurements from single spacecraft may be sufficient for theoreticians to develop comprehensive models for instability growth and the consequences of wave-particle interactions. The same cannot be said for studies of larger-scale space plasma phenomena, which will require future multiple-spacecraft missions to provide the data necessary for a full understanding of their properties.

Furthermore, the local nature of plasma instabilities implies broad applicability for successful theories of their development. For example, an understanding of whether and how instabilities contribute to reconnection in the terrestrial magnetosphere is very likely to improve our ability to explain the same process in the magnetospheres of Jupiter, Saturn, and other planets, including those not yet discovered. And the understanding we may gain from space plasma instabilities may have application to a variety of laboratory plasmas, including those used in fusion research.

Finally, although global modeling of space plasmas does not presently make much use of plasma instability information, that situation is likely to change as increased computing capability permits modelers of large-scale space plasma problems to address finer spatial scales and more detailed physical properties.

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Global Forcing and Regional Interactions

PAGES 529–530

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*

WHOI Receives $500,000 Grant

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The Woods Hole Oceanographic Institution (WHOI) has received a $500,000 grant from the Palisades Geophysical Institute, Inc., to establish the J. Lamar Worzel Assistant Scientist Fund. WHOI must raise an additional $500,000 to match the challenge grant. The $1 million will be used as endowment to support bright, young scientists pursuing careers in geophysical oceanography at WHOI.

The Palisades Geophysical Institute, Inc., is a nonprofit organization established in 1970 to conduct research and promote higher education in geophysics. Worzel, for whom the grant is named, has been its president since 1974. He was a young research associate at WHOI from 1940 to 1946, and later helped establish Columbia University's Lamont-Doherty Geological Observatory, the University of Texas at Austin's Geophysical Laboratory in Galveston, and the Palisades Geophysical Institute.

WHOI is the largest private, nonprofit marine research organization in the United States. The institution conducts about 350 research projects in applied ocean physics and engineering, biology, marine chemistry and geochemistry, geology and geophysics, and physical oceanography. Research is also conducted at WHOI's Coastal Research Center, Center for Marine Exploration, and Marine Policy Center.

WHOI also operates the global ranging vessels *Knorr*, *Atlantis II*, and *Oceanus*, as well as the deep-diving manned submersible *Alvin* and a variety of remotely operated vehicles and smaller boats.

G E O P H Y S I C I S T S

In Memoriam

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Michael J. Keen, 56, died in January 1991. He joined AGU (Tectonophysics) in 1990.

Milton Hudis, 69, died on August 22. He had been a member of AGU (Hydrology) since 1965.

George E. Siple died on March 10, 1990, at age 76. He joined AGU (Hydrology) in 1946.

George A. Kirkpatrick died recently at age 82. He joined AGU (Hydrology) in 1943.

Michael J. Hvorslev died recently at age 96. He had been a member of AGU (Hydrology) since 1948.

Y Bonillas died recently at age 83. He joined AGU (Seismology) in 1953.

Emanuel Baskir, 62, died on April 24. He had been a member of AGU (Seismology) since 1959.

Arno T. Lenz died on August 8 at age 85. He had been a member of AGU (Hydrology) since 1934.

Thomas B. Nolan died on August 2 at age 91. He had been a member of AGU (Tectonophysics) since 1934. Nolan was an AGU Fellow.

Myron B. Fiering died recently at age 58. He joined AGU (Hydrology) in 1980.

J. Brackett Hersey died on November 4 at age 79. He joined AGU (Ocean Sciences) in 1935.

Fred Jacka, 67, died on October 16. He had been a member of AGU (Aeronomy) since 1965.

Kenneth E. Burg died on February 23, 1991, at age 88. He joined AGU (Seismology) in 1944 and was a Life Emeritus Member.

Anthony J. Erlank died recently at age 55. He had been a member of AGU (Volcanology, Geochemistry, and Petrology) since 1989.

Lev Zonenshein, 62, died on November 4. He had been a member of AGU (Tectonophysics) since 1991.

William R. Greenwood died recently at age 54. He had been a member of AGU (Tectonophysics) since 1990.

Honors

John Watson, a senior research scientist at the Desert Research Institute, is the recipient of the first Alessandro Dandini Medal of Science. Watson pioneered the development of computer modeling techniques that estimate the contributions to pollution coming from specific sources of air pollution such as motor vehicle exhaust, industrial emissions, dust, and wood-burning stoves.

Michael P. Ryan, a research geologist in the Office of Earthquakes, Volcanos, and Engineering of the U.S. Geological Survey, has been awarded a fellowship from the Japan Society for the Promotion of Science Fellowship. The fellowship supports the study of the physics of magma generation and transport in island arcs, with application to Sakurajima Volcano.

The Renewable Natural Resources Foundation's first Sustained Achievement Award was given to internationally recognized geographer **Gilbert F. White** for his many contributions to science. His public service achievements date back to the 1930s, and he is also recognized for his work as a scholar and an educator. The RNRF said that he "personifies the ideal of a natural resources scientist committed to stewardship of our planet."