intercomparisons with previously successful LSSs to attempt model refinement in these further focused evaluations. Ideally, this procedure should be pursued for a range of different climates and ecotypes, including at least one from a mid-latitude grassland such as Cabauw, Caumont, or Red River; at least one from a frozen soil environment, such as Valdai or Thorne River; and at least one from tropical and arid regimes.

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PRUDENCE Employs New Methods to Assess European Climate Change

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Both decision-makers and the general public need detailed information on future climate to evaluate the risks associated with possible climate change due to anthropogenic emissions of greenhouse gases. Projections of future climate change already exist, but they are deficient, in terms of both the characterization of their uncertainties and their regional detail. To date, the assessment of potential impacts of climate change has generally relied on projections from simple climate models or coarse resolution coupled Atmosphere-Ocean General Circulation Models (AOGCMs). The former include, at best, only a limited physical representation of the climate system. The latter are unable to resolve processes occurring at scales of less than ~300 km. This resolution limitation precludes the simulation of realistic extreme events and the detailed spatial structure of variables like temperature and precipitation over regions characterized by heterogeneous surfaces. Typical examples of such regions are mountainous areas such as the Alps or Scandinavia or coastal zones, and areas surrounding inland seas, such as the Mediterranean and Baltic.

Over the past decade, increased attention has been devoted to the development of regional climate scenarios. In its recent Third Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) assessed the regional climate information provided by AOGCMs and techniques used to enhance regional climate detail [*Giorgi et al.*, 2001]. It was noted that these techniques have been substantially improved over the last 5 years and have become more widely applied. They fall into three categories: high and variable resolution atmosphere-only AGCMs, nested regional climate models (RCMs), and empirical/statistical and statistical/dynamical downscaling methods. They exhibit different strengths and weaknesses, and their use depends on the needs of specific applications.

A recent conference brought together a multidisciplinary group of approximately 60 participants from Europe and North America to initiate a new, large European climate change project—Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects (PRUDENCE). The three central scientific objectives of PRUDENCE are to address and reduce deficiencies in regional climate projections; to quantify confidence and uncertainties in the predictions of future climate and its impacts by using an array of climate and impact models along with expert judgment on their performance; and to interpret the model results in light of European policies for adapting to or mitigating climate change.

PRUDENCE is an interdisciplinary project that includes, among others, climate modelers, ecologists, economists, agronomists, hydrologists, and geographers. In addition, the external advisory board of the project includes a number of representatives from industry and other economic sectors that have a strong interest in the potential impacts of future climate change. This mixture of interests should provide a stimulating environment for policy-relevant and innovative research.

PRUDENCE is a 3-year effort that will run until 2004. It is coordinated by J. H. Christensen of the Danish Meteorological Institute (one of the authors of this report) and formally comprises 21 research groups from nine European countries. Encouragingly, several additional groups in Europe and elsewhere have already expressed their interest in contributing to the project. Therefore, it has been decided to operate an "open door policy," such that, to the extent possible, the project would share model data and analysis among a wider community, including groups outside Europe. This policy is also reflected in the list of participants at the conference.

Addressing Limitations of Earlier Studies of Extreme Weather Events

Climate change is expected to affect the frequency and magnitude of extreme weather events in response to higher temperatures, an intensified hydrological cycle, and more vigorous atmospheric circulations. Four major limitations in previous studies of extremes have been a lack of appropriate computational resolution, which limits or even precludes the analysis of extremes; an absence of long-term, high-resolution climate model integrations, which drastically reduces the statistical significance of any simulated changes in extremes; poor coordination across climate modeling groups, which limits the ability to compare

different studies; and a limited use of high-resolution model output by impact analysts, which severely restricts any evaluation of the utility of such output for impact assessment.

These four issues are all thoroughly addressed in PRUDENCE. First, PRUDENCE utilizes a suite of state-of-the-art, high-resolution global and regional climate models, ensuring that model simulations span a statistically meaningful time period of 30 years. Second, PRUDENCE coordinates its project goals to address critical aspects of uncertainty. Finally, PRUDENCE applies impact models and impact assessment methodologies to provide the link between climate information and its application to serve the needs of society.

Climate modelers working within PRUDENCE will conduct a series of high-resolution climate change simulations for the periods 1961–1990 and 2071–2100 over Europe. The variability and level of confidence in these simulations will be characterized in terms of uncertainties in model formulations, natural/internal climate variability, and alternative scenarios of future atmospheric composition. In particular, the project will provide a quantitative assessment of the risks arising from changes in regional weather and climate over different parts of Europe by estimating future changes in extreme events such as floods and windstorms and the likelihood and magnitude of such changes.

The project will evaluate the performance of high-resolution model information, not only through conventional climatological intercomparison, but also by inputting simulated climate data to a range of impact models and comparing the estimated impacts. The project will also examine the uncertainties in potential impacts induced by the range of climate scenarios developed by the climate modeling groups. This will provide useful information for climate modelers on the level of accuracy in climate scenarios required by impact analysts. It may also shed new light on the robustness of conclusions obtained from recent impact assessments in Europe and offer fresh insights into the scope for adaptation and mitigation responses to climate change. Furthermore, PRUDENCE places special emphasis on the wide dissemination of information and results, both via its Web site and through the preparation of a non-technical project summary aimed at policy-makers and other interested parties.

Identifying Work Priorities and Key Objectives

In their review of the current state of regional climate change and related impact modeling, speakers at the conference reinforced many of the findings expressed in the Third Assessment Report, emphasizing in particular that future research, as taken up by PRUDENCE, needs to prioritize work focusing on:

- Assessment of GCM regional attributes and climate change simulations;
- Systematic comparisons of the relative strengths and weaknesses of different techniques to derive regional climate information;
- Intercomparison of RCM simulations across a range of models and across different realizations of the same experiment with individual models;
- Assessment of the uncertainties attributable to RCM simulations driven by different AOGCM simulations;
- Intensified efforts to evaluate variability (daily to inter-annual) and extreme events both in GCMs and RCMs, and comparison between the two. A systematic evaluation of uncertainties in regional climate information derived from multiple sources;
- Enhanced methods of applying climate model simulations in the assessment of the potential impacts of anthropogenic climate change; and
- Improved representation of uncertainties in future impacts, whether attributable to uncertainties in climate scenarios, uncertainties in non-climate scenarios, or uncertainties in impact estimation.

A key objective of the first PRUDENCE meeting was to identify gaps in knowledge and potential bottlenecks that might hinder the progress of the project. Two of the important issues to emerge were the design of an effective suite of inter-comparison studies by both climate modelers and impact assessors, and agreement on and development of standard protocols for transferring and applying climate model information for impact assessment.

The conference, "Prediction of Regional scenarios and Uncertainties for Defining European Climate Change Risks and Effects—PRUDENCE," was held 3–5 December 2001 in Snekkersten, Denmark.

Additional information is available at http://www.dmi.dk/f+u/klima/prudence/index.html.

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Survey of "Emerging Contaminants" in U.S. Streams Indicates Need for Further Research

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The first nationwide reconnaissance of pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) in U.S. streams has found one or more targeted compounds in 80% of the streams sampled. The U.S. Geological Survey (USGS) study, released on 13 March, detected 82 of 95 specific compounds in the 139 streams sampled.

Herbert Buxton, coordinator of the USGS Toxic Substances Hydrology Program, which conducted the study, said, "This is the first hard environmental occurrence information on a large number of environmental compounds on which we did not have information before." Buxton said the findings may aid research on potential human and ecological effects from these compounds and on understanding in what concentrations the compounds occur individually and in combinations.

The Bush administration has proposed transferring the USGS Toxic Substances Hydrology Program to the National Science Foundation (NSF) in fiscal year 2003. USGS officials said the transfer would effectively end further work on the stream-sampling project.

Concentrations Generally Low

The report cautions against considering the findings representative of all U.S. streams. The design of the study focused on selected compounds—including veterinary and human antibiotics, prescription and non-prescription drugs, steroids and hormones, and other wastewater-related compounds—based upon their usage, toxicity, potential hormonal activity, and persistence in the environment. The study design also selected sampling sites in areas considered susceptible to contamination.

The study found generally low concentrations of compounds, and few exceeded drinking water guidelines, health advisories, or aquatic-life criteria. However, the study noted that "many of the 95 OWCs do not have such guidelines or criteria determined. In fact, much is yet to be known about the potential toxicological effects of many of the OWCs under investigation."

Thirty-three of the 95 contaminants could potentially disrupt normal endocrine functions, and about 45 are pharmaceutically active in some way, according to the report. In addition, even the low-level presence of antibiotics in the environment "could increase the rate at which pathogenic bacteria develop resistance to these compounds," the study says. The study also notes that the presence of detectable quantities of these contaminants "implies that many such compounds survive wastewater treatment and biodegradation."

"EPA Should be Concerned"

Robert Hirsch, USGS associate director for water, said the study sets the stage for further research on "emerging contaminants." Hirsch noted that he is neither more worried nor less worried about the contaminants than before the study was done. "I am better informed," he said. "I know that these [chemicals] must be getting into the water. What is worrisome is not having any idea about their levels. What we are doing now is beginning to discover what these levels are."

Michael Thurman, research hydrologist with the USGS division of water resources and a co-author of the study, said the general public should not be worried about the situation, because detected contaminant levels are low enough such that they do not pose a direct health threat. But he said local water treatment facilities and the U.S. Environmental Protection Agency (EPA) should be concerned. Edward Ohanion, acting director of the EPA Office of Water's health and ecological criteria division, said EPA currently is collaborating with other agencies to develop measures for pharmaceutical and personal care products as wastewater contaminants.

Robert Hale, associate professor of marine science at the Virginia Institute of Marine Science, said the USGS study "sheds additional light on our general lack of understanding of what organic chemicals are present in our environment."

Hale said some chemicals found in the study may be relatively benign because they are neither very toxic nor persistent in the environment. But he said the presence of other chemicals could give cause for concern. These include ethynyl estradiol, an artificial estrogen used in birth control pills that was present in 70% of the USGS water samples.

Hale also noted that there is a need to analyze for many more chemicals and, in some cases, to analyze for chemicals below the 1-part-per-billion level.

Opposition to Toxics Program Transfer

In response to the USGS study, Stephen Sundlof, director of the Center for Veterinary Medicine of the U.S. Food and Drug Administration (FDA), said that his agency will review the levels of pharmaceutical compounds it regulates and compare them with environmental assessments done on those drugs. "The presence of contaminants in rivers and creeks downstream of areas of intense urbanization and livestock activity, although at very low levels, may raise a potential public issue that requires additional study," he said.

Tamar Barlam, an infectious disease specialist with the Center for Science in the Public Interest, said the next step for research "is to see if there is a connection between contamination of our waterways and antibiotic-resistant infections in people." She said that "bacteria are more likely to become resistant to drugs the more they encounter [these] antibiotics."

Rebecca Goldburg, senior scientist with the environmental advocacy group, Environmental Defense, commented that, "While it may not be clear which compounds occur with enough frequency and combination to cause a public health hazard, clearly the notion that these compounds are here is disturbing."

Goldburg called for support of the USGS toxics program. She said the program "collects data that wouldn't otherwise be collected in the nation's waterways and groundwater. It is a central program to open the public's and policy-makers' eyes to potential chemicals ending up in water." On 13 March, more than 30 environment groups, including Environmental Defense, issued an open letter to the U.S. Senate opposing the transfer of the USGS toxics program.

Hirsch of USGS said that while it might be possible for NSF to entertain proposals from academia for work somewhat similar to the USGS toxics program, there are many questions about whether that agency could continue the work with the same breadth as the USGS. "The likelihood," he said, "is that if the budget proposals are to go through, that this work would end at the end of this fiscal year by the USGS."

For more information on the study, which was published in *Environmental Science & Technology* (vol. 36, no. 6, 10.1021/es011055j, 2002), visit the Web site: http://toxics.usgs.gov/regional/emc_surfacewater.html.

Randy Showstack, Staff Writer

BOOK REVIEWS

Seismic Ray Theory

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VLASTISLAV CERVENÝ
Cambridge University Press, New York; viii + 713 pp; ISBN 0-521-36671-2; 2001; $130.

Ray method, a forward modeling tool of seismic wave propagation, is a powerful and useful tool for interpretation, if not the unique one at our disposition: full-wave modeling often provides us synthetic seismograms as complex as real ones. Especially with the ambition and the necessity of three-dimensional wave seismic interpretation, efforts in the last twenty years have been performed to avoid failure configurations of the ray theory and to extend its domain application.

Seismology requires specific development of the ray method which cannot be found in optics, in oceanography or in atmospheric propagation, as for example, the description of effects coming from curved interfaces between two heterogeneous anisotropic media. Seismologists have developed their own approaches, and Vlastislav Cervený has played a key central role in the last forty years in Central Europe, creating a very active Czech group aside fruitful Russian and American poles in this specific domain of ray theory.

His book is a careful presentation of the seismic ray method and its recent revival and, with that respect, it is more than a review of the field, although extensive references might help the reader to gather original contributions. The pedagogic approach selected by the author is didactic and the reader starts from the beginning with the elastodynamic equations describing the medium until ray synthetic seismograms estimation going through anisotropy and attenuation subtilities. This will bring this book as a reference for people involved in seismic ray tracing problems but may prevent a novice reader to start his own initial understanding of ray theory through this book. Moreover, mathematical background required for understanding this theoretical approach is, at least, at the graduate level. Nevertheless, this book will stay for a long time as a golden mine for people interested in asymptotic approaches. Consequently, this book should be suggested for readers already familiar with ray theory and, even, I am sure that experts on the subject will find new ideas in this so complete book.

After a presentation of full wave solutions leading to the Green function basic formulation, the author describes how to obtain ray trajectories and travel times, key elements for ray theory. The author presents traditional approaches of solving ordinary differential systems through characteristics, the so-called ray tracing method, as well as rediscovered methods based on wavefront trackings or ray perturbations, well known in optics as Gauss optics. Needless to say that advanced presentations through Lagrangian or Hamiltonian formulations and curvilinear systems for both isotropic and anisotropic media will make this book as invaluable for the reader.

The central presentation of the so-called dynamic ray tracing or paraxial ray theory introduces the propagator matrix and the KMAH index estimation for caustic detection. Different applications of the paraxial information as the two-point ray tracing or the spreading estimation related to Jacobian computation are very exhaustive and provide precise formulae useful for algorithm construction.

The ray amplitude, which was so difficult to compute ten years ago, becomes simpler to estimate with the use of the paraxial ray tracing gathering information of what is happening around the ray itself. Gaussian beam summations or WKBJ or the recent Maslov-Chapman integrals are new, well-described features of