Prospectus for Synthesis and Assessment Product 5.3

Decision-Support Experiments and Evaluations using Seasonal to Interannual Forecasts and Observational Data

Lead Agency: NOAA
Supporting Agencies: NASA, EPA, USGS, NSF

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1. Overview: Description of Topic, Audience, Intended Use, and Questions to be Addressed

1.1. Description of Topic

One of the most heralded and widely recognized success stories of earth system science has been the demonstration of the prediction of the El Niño/Southern Oscillation (ENSO) phenomenon. Through research and observational programs initiated in the 1980s, including (1) an ocean observing system (especially the ENSO observing system in the Pacific) for initializing and verifying models under development for ENSO prediction; (2) theoretical studies that elucidated the underlying oceanic and atmospheric processes accounting for the predictability of ENSO; (3) development of a variety of prediction models; and (4) empirical studies that better defined the global impacts of ENSO, routine predictions of climate variability on seasonal to interannual time scales have now become operational and consideration of these predictions has become more commonplace. These forecasts have demonstrated modest skill for strong ENSO events and some of its related regional climate impacts up to a few seasons in advance.

Because the ENSO cycle is central to short-term variability in the Earth's climate system, understanding its behavior is fundamental to an enhanced understanding of short-term climate fluctuations. Furthermore, developing a comprehensive knowledge-base of climate variability is critical to both identifying human perturbations and to predicting how anthropogenically introduced variables will affect the global radiative and chemical balances. On the applications side, forecast technology offers a possibility that society may be able to actively prepare for variations in temperatures or precipitation. For climate-sensitive sectors, this could mean that decisionmakers could incorporate the suite of high resolution information available for seasonal to interannual forecasts in their decisions.

After years of investing in the improvement of the technology, science agencies are investing in understanding decision contexts and existing coping strategies in order to contribute to more widespread and more effective applications of the forecasting technology in resource management. By coupling Earth system science and decision-support research, water resource managers have adjusted groundwater pumping schedules to include forecasts of increased precipitation because of ENSO events, farmers have changed their cropping plans in anticipation of changes in forecasted seasonal precipitation patterns, and negotiators working on transboundary fishing issues have included the impacts of climate forecasts in their talks.

Applications research has shown that practical use of climate forecast information is extremely challenging for reasons associated with the technology, the use and communication of probabilistic information, and the need for extensive education and training. Decisionmakers (including legislators, policy makers, service providers, business owners, and representatives from the general public and at-risk populations) must still contend with institutional barriers, questions about utility and accuracy of uncertain forecasts, and information delivered in unusable forms. Decisionmakers also need to incorporate emerging and existing technologies with new tools and methodologies to better use forecast information.

1.2. Audience

The Climate Change Science Program (CCSP) Synthesis and Assessment Product 5.3 will inform (1) decisionmakers about the experiences of others who have experimented with the use of seasonal and interannual forecasts and other observational data; (2) climatologists and social scientists on how to advance the delivery of decision-support resources that use the most recent forecast products, methodologies, and tools; and (3) science managers as they plan for future investments in research related to forecasts and their role in decision support. It will describe and evaluate current forecasts, assess how forecasts are being used in decision settings, and evaluate decisionmakers' level of confidence in these capabilities. The participants in the development of this product (primarily consisting of government officials, researchers, and users) will evaluate the forecasts as well as their delivery, to identify options for improving partnerships between the research and user communities.

1.3. Questions to be Addressed

CCSP Synthesis and Assessment Product 5.3 will concentrate on the water resource management sector. Focusing on a single sector will allow for detailed synthesis of lessons learned in decision-support experiments within that sector. Lessons learned from domestic as well as international studies will be incorporated. The Working Committee expects that the lessons learned from this Synthesis and Assessment Product will be relevant, transferable, and essential to other climate-sensitive resource management sectors.

The product will be developed in three sections:

- ***Section I: A Description and Evaluation of the Forecast/Data Products***
  This section describes and evaluates the seasonal to interannual forecasts and observational data currently available for use by decisionmakers. Among the questions the writers will address are: What are the seasonal to interannual forecast/data products currently available and how does a product evolve from a scientific prototype to an operational product? What steps are taken to ensure that this product is needed and will be used in decision support? What is the level of confidence of the product within the science community and within the decisionmaking community; who establishes these confidence levels and how are they determined?

- ***Section II: Decision-Support Experiments within the Water Resource Management Sector***
  This section describes the decisions related to water resources, including dam and reservoir management, irrigation and water allocation decisions, drought planning, fire management, drinking water and wastewater management and infrastructure planning, zoning, ecosystem protection, etc. The committee suggests that the authors address the following foci.
  - *Focus 1: The Range of Water-Related Decisions and Decision-Support Needs*
    What types of decisions are made related to water resources? What is the role that seasonal to interannual forecasts play and could play?
  - *Focus 2: Forecasts Needed by Resource Managers and How Information is Conveyed*
    How does climate variability influence water resource management? What seasonal to interannual (e.g., probabilistic) forecast information do decisionmakers need to manage water resources? How do forecasters convey information on climate variability and how is the relative skill and certainty of the information communicated to resource managers?
  - *Focus 3: Translating Climate Forecasts and Hydrology Information for Integrated Resource Management*
    What are the obstacles and challenges decisionmakers face in translating climate forecasts and hydrology information into integrated resource management? What are the barriers that exist in convincing decisionmakers to consider using risk-based hydrology information (including climate forecasts)?
  - *Focus 4: Decision Support Development*
    What is the role of probabilistic forecast information in the context of decision support in the water resources sector? What challenges do tool developers have in finding out the needs of decision makers? How much involvement do practitioners have in product development? What are the measurable indicators of progress in terms of access to information and its effective uses? How are data quality controlled?
- ***Section III: Analysis of Present and Past Decision-Support Experiments and a Look Towards the Future***
  Authors of this section will identify critical components, mechanisms, and pathways that have lead to successful utilization of climate information by water managers and discuss how these findings can be transferred to other sectors. They will also discuss options for (a) improving the use of existing forecasts/data products and (b) identify other user needs and challenges in order to prioritize research for improving forecasts and products.

2. Contact Information for Responsible Individuals at Lead and Supporting Agencies

NOAA is the lead agency for this synthesis product with NASA, EPA, USGS and NSF as the supporting agencies. Because NOAA is the lead agency, the product will be subject to NOAA guidelines implementing the Information Quality Act (IQA). Contact information for responsible individuals at lead and supporting agencies is in the following table.

Agency/Participants	E-Mail	Telephone Number
Lead: NOAA • Nancy Beller-Simms* • Claudia Nierenberg • Mike Brewer • Pedro Restrepo	 Nancy.Beller-Simms@noaa.gov Claudia.Nierenberg@noaa.gov Michael.J.Brewer@noaa.gov Pedro.Restrepo@noaa.gov	 301-427-2351 301-427-2349 301-713-1970 x123 301-713-0640 x210
NASA • Shahid Habib	 shahid.habib.1@gsfc.nasa.gov	 301-614-5392
EPA • Janet Gamble	 gamble.janet@epa.gov	 202-564-3387
USGS • Ron Berenknopf	 rbern@usgs.gov	 650-329-4951
NSF • L. Douglas James	 ldjames@nsf.gov	 703-292-8549

*Coordinating lead author

3. Lead Authors: Required Expertise and Biographical Information

This study requires an interdisciplinary team that is able to integrate scientific understanding about forecast and data products with a working knowledge of the needs of water resource managers in decisionmaking.

Listed below are the authors recommended by the Working Committee for this product. These nominees were identified based on a variety of considerations, including their past interests and involvements with decision-support experiments and their knowledge of the field as demonstrated by practice and/or involvement in research and/or publications in refereed journals. Because the topics covered in this synthesis and assessment product are so diverse, the list of recommended authors is long and includes representatives from a variety of Federal agencies, universities, and private institutions. Additional contributors will be enlisted as required; lead author, contributing author, and expert reviewer nominees should be provided to the principal lead agency contact, Dr. Nancy Beller-Simms.

Section I: A Description and Evaluation of the Forecast/Data Products
Nathan Mantua, University of Washington (lead)
Michael Dettinger, United States Geological Survey
Thomas Pagano, United States Department of Agriculture
Kelly Redmond, Western Regional Climate Center

Section II. Decision-Support Experiments within the Water Resource Management Sector
Denise Lach, Oregon State University (co-lead)
Upmanu Lall, Columbia University (co-lead)
Dan Basketfield, Seattle Public Utilities
Martyn Clark, NOAA CIRES
John Furlow, USEPA

Ari Georgakakos, Georgia Institute of Technology
Kosta Georgakakos, Hydrologic Research Center
Holly Hartmann, University of Arizona
Jin Huang, NOAA OGP
Katherine Jacobs, University of Arizona
Pedro Restrepo, NOAA NWS
Robert Webb, NOAA CDC
Brent Yarnal, Pennsylvania State University

Section III: Analysis of Present and Past Decision-Support Experiments and a Look Towards the Future
Helen Ingram, University of California, Irvine (lead)
Gregg Garfin, University of Arizona
Maria Carmen Lemos, University of Michigan
Robert Lempert, RAND Corporation
John Schaake, Consultant to NOAA NWS
W. James Shuttleworth, University of Arizona
With additional input and representation from lead authors of Sections 1 and 2, and the coordinating lead author

The authors will be constituted as a NOAA advisory committee under the Federal Advisory Committee Act (FACA), and will operate in a fashion consistent with the requirements of the Act. Contact Dr. Nancy Beller-Simms to obtain a copy of the CCSP Synthesis and Assessment Product 5.3 FACA charter. The advisory committee will be convened as soon as feasible after the CCSP Interagency Committee approves the final prospectus. Drafting begins immediately thereafter.

4 Stakeholder Interactions

Stakeholder involvement is key to the success of this product. It is important to keep in mind, however, that the number and interests of the stakeholders is vast and the committee acknowledges that all stakeholder interests and requirements cannot be addressed.

The committee will encourage authors of this product to solicit input from stakeholders through appropriate scientific symposia and industry association meetings, periodic surveys of the community (if deemed fitting), and creation of appropriate web sites. Given the backgrounds of the proposed authors and their direct involvement in the forecast, water resource, and decisionmaking community, we expect that they will consult with local and regional decisionmakers and stakeholders (e.g., city, county, and state water resource managers, reservoir operators, aquifer managers, etc.) while working on this product. In addition, each member agency of the CCSP Synthesis and Assessment Product 5.3 Working Committee will inform their constituent communities of the progress and opportunities for review or input to the final product.

Input from stakeholders is most essential in drafting the third section of this product concerned

with discussions of the future. The authors of this section, in consultation with the sponsoring agencies, will develop a plan for stakeholder involvement at their first meeting. At a minimum, we expect that the CCSP Synthesis and Assessment Product 5.3 Working Committee will help the writers to convene at least one workshop where the findings of the first two sections of the product will be presented and where stakeholders can provide comments to the Section III writing team.

Individuals or organizations interested in providing input or wanting to be included on an e-mail mailing list that will provide periodic updates of the progress of this product should contact Dr. Nancy Beller-Simms at the e-mail address provided.

5. Drafting Process (including Materials to be Used in Preparing the Product)

The lead author of each section will organize meetings that may include in-person conferences, teleconferences, and e-mail exchanges to write the three sections of this product. The first two sections will be written and completed at the same time. The lead authors of these sections will need to periodically confer; but, in general, the committee expects that these can be independent writing efforts. The third section will be started once the first two sections are approaching completion and at least a preliminary draft of their sections has been completed. At least one representative of each of the first two sections as well as the coordinating lead author will be part of the writing team of the third section. It is the responsibility and prerogative of each lead author to incorporate material from the contributing authors into the draft product.

The leads of the three major sections along with the coordinating lead author will compile the final product, which will include an Executive Summary and findings from each of the three groups.

The authors of this product will consider efforts that have been completed or have a record of accomplishments as well as projects currently in progress. They will draw primarily upon published, peer-reviewed scientific literature. Because of the nature of the material discussed in this product as well as its newness, we plan to augment the peer-reviewed materials with materials representative of the experiments, some of which are in the review process or are derived from professional resource management practice. The authors and the committee will consult with the CCSP Office as situations occur where there is not sufficient or adequate peer-reviewed literature available to adequately address sections of this product.

The Working Committee members will be available as a resource to the writers and suggest that as a first step, the writers take into consideration studies/projects with which the Committee has been involved. Some examples of these include:

- Chapter 5, “Water Cycle” of the *Strategic Plan for the U.S. Climate Change Science Program* (<http://www.climatescience.gov/Library/stratplan2003/default.htm>)
- Regional assessments from the *U.S. National Assessment of the Potential Consequences of Climate Variability and Change* (<http://www.usgcrp.gov/usgcrp/nacc/background/regions.htm>)

- The Intergovernmental Panel on Climate Change (<http://www.ipcc.ch>)
- the National Integrated Drought Information System (<http://www.westgov.org/wga/initiatives/drought>)
- Regional Integrated Science and Assessment Centers (<http://www.ogp.noaa.gov/mpe/csi/risa/index.htm>)
- The International Research Institution for Climate Prediction (<http://iri.columbia.edu>)
- Agricultural Water Resources and Decision Support (<http://www.asd.ssc.nasa.gov/m2m/default.aspx?c=dss&tab=decision_support>)
- Water 2025 (<http://www.doi.gov/water2025>).

6. Review

There will be ample opportunity for both expert peer review and public comment. The timetable for these reviews may be found in Section 9 of this prospectus.

The lead agency plans to ask the National Academies Committee on the Human Dimensions of Global Change to provide a scientific review of this product.

The lead authors will revise the product and will prepare a written response to the National Academies Committee's comments explaining its agreement or disagreement with the views of the reviewers; the actions taken in response to the review; and the reasons why those actions respond to the reviewers' key concerns.

The revised product will then be released for public comments. Notice of the public comment period will be disseminated on the CCSP web page, in the Federal Register, and through other publications, web sites, and means as appropriate to the product, to encourage wide public participation in the review. The public comment period will be 45 days.

The lead authors will prepare a third draft of the product, incorporating relevant changes, as determined by the lead authors, submitted during the public comment period. The scientific judgment of the lead authors will determine responses to the comments.

Once NOAA, as IQA Lead Agency, determines that the report conforms to CCSP and IQA guidelines, it will submit a draft of the product and a compilation of the comments received to the CCSP Interagency Committee. If the CCSP Interagency Committee identifies areas for further revision, their comments will be sent to the committee comprised of the lead authors who in turn may need additional input from the authors and/or reviewers.

Once the CCSP Interagency Committee determines that no further revisions are needed and that the product conforms to the Guidelines for Producing the CCSP Synthesis and the Data Quality Act, they will submit the product to the National Science and Technology Council (NSTC) for clearance. Clearance will require the concurrence of all members of the Committee on Environment and Natural Resources

The CCSP Interagency Committee in consultation with the lead and supporting agencies and the lead authors will address comments generated during the NSTC review.

7. Related Activities

Preparation of the product will be coordinated with a number of related activities, including other national and international assessment processes such as IPCC assessments, the NSTC Subcommittee on Water Availability and Quality (SWAQ), and the Subcommittee on Natural Disaster Reduction (SNDR), NOAA and the Western Governors' Association's National Integrated Drought Information System, etc.
Given the multi-agency nature of the CCSP Synthesis and Assessment Product 5.3 Working Committee, many of the principals of these related activities have been or will be involved with the final product.

8. Communications

The lead agency will produce and release the completed product using the standard format for all CCSP synthesis and assessment products. The final product and the comments received during the expert review and the public comment period will be posted on the CCSP web site.

9. Proposed Timeline

The Working Committee expects completion of the product by December 2007; the completion date will depend upon the various review processes. Specific tasks and expected completion dates follow.

Phase	Task	Completion
1	Working Committee submits draft prospectus to CCSPO for approval	June 2005
2	After CCSP Interagency Committee approval & necessary revisions are made, synthesis product prospectus released for public comment	December 2005
3	Approved prospectus posted on CCSP web site	February 2006
4	Authors for sections 1 and 2 of product meet and write draft product	February 2006-April 2006
5	Authors for section 3 meet, hold workshop(s) and write draft product	April –October 2006
6	Lead authors complete first draft	January 2007
7	National Academies Committee on the Human Dimensions of Global Change review draft	March 2007
8	Lead authors revise draft product based on review draft; product made available for public comment (45 days)	April-June 2007
9	Draft product revised based on public comments	July 2007
10	CCSP Principals review product	August 2007
11	Synthesis product accepted by CCSP Principals and submitted to NSTC for final review and approval	September 2007
12	Lead agency produces final product accounting to CCSP specifications	October-December 2007

Appendix A – Biographies of the Potential Authors

Daniel L. Basketfield

Daniel L. Basketfield has been a practicing professional engineer since 1988 and is registered in the states of Washington (civil), Oregon (agricultural), Alaska (civil) and Hawaii (civil). Mr. Basketfield is currently responsible for real-time management of the City of Seattle's Chester Morse Lake, the Cedar River, South Fork Tolt Reservoir, and South Fork Tolt River operations during normal and flood conditions. He also performs hydrologic and hydraulic analyses of the City of Seattle's water supply storage and open-channel conveyance systems, formulates tactical forecasts of system precipitation, inflows and conveyance system response, and conducts supply reliability analyses. Among his other responsibilities are instream flow resource management support and operations, development and application of numerous water supply and conveyance hydrologic and hydraulic computer models, and project manager for various internal multidisciplinary project teams and water resource studies. Mr. Basketfield has served as SPU's representative to The National Academy of Sciences on matters relating to seasonal to inter-annual climatic "Decision Support Systems," as an advisor for programs within NOAA's Office of Global Programs.

Martyn P. Clark

Martyn P. Clark is a Research Associate in the Cooperative Institute for Research in Environmental Science at the University of Colorado. He is currently Principal Investigator on two major grants focusing on the development of experimental streamflow forecasting technologies; this research is funded by the National Oceanic and Atmospheric Administration. Dr. Clark's research interests include applied hydroclimatology, land surface and hydrologic modeling, statistical methods, remote sensing, and climate change. His recent research experience includes development and implementation of innovative streamflow forecasting methods in snow-fed river systems. Clark received a BS and MS in Geography from the University of Canterbury in Christchurch, New Zealand, and a PhD in Geography from the University of Colorado in 1998.

Michael D. Dettinger

Michael D. Dettinger is a research hydrologist for the U.S. Geological Survey, Branch of Western Regional Research, and a research associate of the Climate Research Division at Scripps Institution of Oceanography, La Jolla. He has monitored, evaluated, and researched the water resources of the West for over 20 years, with foci in the areas of regional surface water and groundwater systems, water availability, watershed modeling, streamflow prediction, and climatic influences on water resources. Among other activities, he received a Vice President's National Performance Review Award for leadership in Mojave Desert Ecosystems planning efforts in 1996*;* has been the program chair and fundraiser for the annual Pacific Climate (PACLIM) Workshops, 1998-present; is a founding member of the multi-institution CIRMONT Western Mountain Climate Sciences Consortium; serves on the external Science Steering Group for CCSP's Global Water Cycle programs; and is a member of California's CALFED Water Management Standing Science Board. Dettinger received a BA from the University of California, San Diego, in Physics, an MS from Massachusetts Institute of Technology in Civil Engineering of Water Resources, and another MS in Atmospheric Sciences from the University

of California, Los Angeles. His doctoral work in Atmospheric Science (climate dynamics) was completed at the University of California, Los Angeles, in 1997.

John Furlow

John Furlow is project manager with the U.S. Environmental Protection Agency Global Change Research Program (EPA/GCRP) with expertise in assessing the potential effects of climate change on water quality. He leads the water quality focus area at the EPA/GCRP. His past research includes investigations of the potential effects of climate change on drinking water and wastewater treatment practices. Studies include analyses of the vulnerability of coastal drinking water supplies to sea level rise and the vulnerability of Florida groundwater supplies to sea level rise. Other projects examine the potential effects of climate change on the robustness of wastewater and combined sewer system infrastructure. John managed the Great Lakes Regional Assessment as part of the U.S. National Assessment, and he manages ongoing projects in the Great Lakes looking at the effects of climate change on the agriculture and tourism industries. John serves as co-chair of the Climate Change Science Program Interagency Work Group on the Global Water Cycle. He studied environmental policy and environmental and development economics at the Fletcher School of Law and Diplomacy.

Gregg Garfin

Gregg Garfin is program manager for the NOAA-funded Climate Assessment for the Southwest (CLIMAS), a multidisciplinary integrated assessment project designed to identify and evaluate climate impacts on human and natural systems in the Southwest, and to identify climate services useful in assisting decisionmakers to cope with climate-related risks. As manager of CLIMAS, he works to bridge the science-society interface and to facilitate knowledge exchange across that interface. He is also an adjunct faculty member in the Department of Geography and Regional Development at the University of Arizona. His expertise includes climate variability, paleoclimatology, and the impacts of climate on society. His current research and outreach activities focus on drought, fire climatology, and the effective communication of climate concepts, history and forecasts to decisionmakers. He is a co-author of the 2004 Arizona Drought Preparedness Plan. He serves as co-chair of Arizona's state drought monitoring committee. He served as a member of the Western Governors' Association integrated team for the development of a National Integrated Drought Information System. His PhD in Geosciences is from the University of Arizona (1998), MS in Geography is from the University of Massachusetts (1992) and BS in Geography from the University of Massachusetts (1989).

Aris Georgakakos

Aris Georgakakos is a Professor at the School of Civil and Environmental Engineering at Georgia Tech. He is also the School's Associate Chair for Research, Head of the Environmental Fluid Mechanics and Water Resources Program, and Director of the Georgia Water Resources Institute. Dr. Georgakakos' research and technology transfer efforts aim to develop and implement decision support systems integrating data from conventional and remote environmental sensors (such as radar, satellite, and ground gages) with models for climate and hydrologic forecasting, agricultural planning; river, reservoir, and aquifer simulation and management; and hydro-thermal power system planning and scheduling. Dr. Georgakakos' decision support systems are used for river basin planning and management in several world regions including the Southeastern US, California, East Africa, Brazil, Argentina, Jordan, and

Greece. Dr. Georgakakos' research has been sponsored by U.S. and foreign organizations including the U.S. Geological Survey, U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, National Science Foundation, Environmental Protection Agency, Food and Agriculture Organization of the United Nations, World Bank, and several domestic and foreign electrical utilities.

Konstantine P. Georgakakos

Konstantine P. Georgakakos is the Managing Director of the Hydrologic Research Center in San Diego, California. He is also an Adjunct Professor with the Scripps Institution of Oceanography of the University of California, San Diego, and an Adjunct Professor with the Department of Civil and Environmental Engineering of the University of Iowa. Previously, he was an Associate Professor at the University of Iowa and with the Iowa Institute of Hydraulic Research, as well as a Research Hydrologist with the National Weather Service. He holds a Masters of Science and Doctor of Science degrees from the Massachusetts Institute of Technology. Honors and awards include the Presidential Young Investigator Award from the National Science Foundation and the NRC-NOAA Associateship Award from the U.S. National Research Council. He served as the associate editor of the ASCE Journal of Engineering Hydrology, the Elsevier Journal of Hydrology and the Elsevier Advances in Water Resources. He served as the U.S. Expert in Hydrologic Modeling for the World Meteorological Organization Commission for Hydrology, Working Group on Applications (1997-2000). He served on several National Research Council Committees. His current research interests are the modeling of uncertainty in short and long term hydrologic predictions, and the coupling of real time forecasts with decision models for water resources management.

Holly C. Hartmann

Holly C. Hartmann is a physical scientist in the Department of Hydrology and Water Resources at the University of Arizona, with experience in hydrologic modeling, water resources management, and water policy. Her participation in projects aimed at improving the societal relevance of hydroclimatic research has led to assessments of the performance of water and climate forecasts, assessments of communication of probabilistic forecasts, and development of Internet-based decision support tools. Her research interests include regional-scale hydroclimatic modeling; hydroclimatic forecasting and evaluation; communication among research, operations, and stakeholder communities; and evaluation of integrated research. Dr. Hartmann has actively fostered connections among hydroclimatic researchers, operational forecasters, and decisionmakers through committee and advisory appointments for the American Geophysical Union, American Meteorological Society (AMS), and National Weather Service. Her work has been funded by the National Oceanic and Atmospheric Administration, the National Science Foundation, the National Aeronautics and Space Administration, and the AMS. She received her PhD in Hydrology and Water Resources from the University of Arizona (2001), MS in Water Resources Management from the University of Michigan (1983), and BS in Natural Resource Planning from Southern Illinois University (1980).

Jin Huang

Jin Huang is a program manager of Climate Prediction Program for the Americas (CPPA), National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. Her expertise is in the area of land surface modeling, climate prediction and water resource

application. She worked as a senior research scientist at the NOAA Climate Prediction Center (CPC) from 1991 to 2000. Her past research includes development of climate forecast methodologies, understanding of land surface effects on climate predictability, land surface model development and paleoclimate studies. She developed and implemented several operational climate forecast tools for NOAA CPC. She is a member of the International GEWEX (Global Energy and Water Cycle) Hydrometeorology Panel and a member of US Climate Change Science Program Interagency Global Water Cycle Working Group. She received her PhD in Atmospheric Science from the University of Illinois, Champaign-Urbana (1991); MS in Atmospheric Science, from the University of Illinois, Champaign-Urbana (1985); and BS in Meteorology from Nanjing Institute of Meteorology (1982).

Helen Ingram

Helen Ingram holds joint appointments at the University of California, Irvine with the Departments of Urban and Regional Planning and Criminology, Law and Society in the School of Social Ecology, and the Department of Political Science in the School of Social Science. She is also Professor Emeritus at the University of Arizona and a Distinguished Research Associate at the University of Arizona's Southwest Center. She is the author of 13 books, over 45 articles and over 50 book chapters. Dr. Ingram holds a PhD in Public Law and Government from Columbia University. Her research interests include: (1) transboundary national resources, particularly on the US/Mexican border, (2) water resources and equity, (3) public policy design and implementation, (4) the impact of policy upon democracy, public participation and social movement formation, and (5) science and society. She is best known in the field of water research for her contribution to the understanding of water policy-making and its effects both internationally and domestically. Some of the awards she has received include the W. R. Boggess Award, American Water Resources Association, for the most outstanding article published in the *Water Resources Bulletin*, 1972, the Iko Iben Award in recognition of promotion, understanding and communication between disciplines involving water resources, American Water Resources Association, 1987, and the Abel Wolman Distinguished Lecture, sponsored by the Water Science and Technology Board of the National Research Council "Transnational Water Resources Management: Learning from the U.S.-Mexico Example," Washington, D.C., November 8, 1993. In 1995 she was the U.S. recipient of "Frontera" International Excellence Award, Fundación Margarita Miranda de Mascareñas, Ciudad Juárez, Mexico and in 1998, she received the "Friends of UCOWR" Certificate of Appreciation for vision and leadership in the advancement of water resources education and research, presented by the Board of Directors of Universities Council on Water Resources.

Katharine L. Jacobs

Katharine L. Jacobs is on the faculty of the University of Arizona's Soil, Water and Environmental Science Department. She is affiliated with the Water Resources Research Center, the Institute for the Study of the Planet Earth, and SAHRA, the National Science Foundation Center for Sustainability of Arid Region Hydrology and Riparian Areas. She was the director of the Tucson Active Management Area (AMA) of the Arizona Department of Water Resources from 1988 through 2001, and worked on statewide rural water resources issues and drought planning from 2002-2003. In 2001-2002 she worked at the National Oceanic and Atmospheric Administration on the use of scientific information in policy and decisionmaking. Ms. Jacobs earned her M.L.A. in environmental planning from the University of California, Berkeley. Her

expertise is in groundwater management and developing practical, appropriate solutions to difficult public policy issues. In her 22 years as a water manager, she was involved in all aspects of implementation of the Arizona 1980 Groundwater Management Act. She served on the Synthesis Team for the U.S. National Assessment of the Consequences of Climate Variability and Change and three National Research Council panels, Valuing Groundwater (1994), Endangered Species on the Platte River (2003) and Review of the NOAA/NASA GEWEX Americas Prediction Program (GAPP).

Denise Lach

Denise Lach is the Co-Director of the Center for Water and Environmental Sustainability, Associate Director of the Institute for Natural Resources, and an Associate Professor in the Department of Sociology at Oregon State University. In research supported by the National Oceanic and Atmospheric Administration (NOAA), Dr. Lach and colleagues developed three cases examining how climate products could be and were being used by water organizations in the Pacific Northwest, the Los Angeles Basin, and the Chesapeake Bay. She also has a U.S. Environmental Protection Agency grant to provide technical outreach services to communities in the American west facing air, ground, and water contamination. Currently funded research includes a national survey regarding the role of science and scientists in natural resource decisionmaking (NSF) and regulatory acceptability of bioremediation in cleaning up radionuclides and heavy metals (US DOE). Her expertise and experience is in organizational and institutional use of information, the role of science and scientists in environmental decisionmaking, and elicitation of public input in decisionmaking. Dr. Lach utilizes multiple research methods including mail and telephone surveys, case studies, in-depth interviewing, and participant observation. She received her PhD and MS in Sociology from the University of Oregon (1992) and her BA in English from the University of Minnesota (1976).

Upmanu Lall

Upmanu Lall is the Alan & Carol Silberstein Professor of Engineering and the Chair of the Department of Earth and Environmental Engineering at Columbia University. His areas of current research include the development of hydroclimatic forecasts and their application to the water and energy sectors. Specific areas of interest include a) improvement of seasonal or climate change forecasts through the combination of multiple models; b) empirical forecasts of water/energy demand and supply using climate precursors; c) quantitative analysis of flood and drought risk non-stationarity (structured long term change) related to climate and changing infrastructure and hydrology; d) the design of instruments (e.g., water allocation systems, reservoir operation rules, insurance contracts) to manage and mitigate the impacts of climate variability using forecast information, and e) participatory resource management and planning through existing institutions using innovations in group decisionmaking using climate forecasts. His past research has also included advances in statistical methods for risk management and space-time data analysis, systems optimization, reservoir management and planning, nonlinear dynamics and surface and ground water hydrology. He has had several research projects and consulting assignments in the areas listed above and has also served on a number of national committees whose objective related to climate change and variability. He received his PhD and MS in Civil & Environmental Engineering from the University of Texas (1981), and B Tech, Civil Engineering, Indian Institute of Technology, Kanpur).

Robert Lempert

Robert Lempert is a senior scientist at RAND and an expert in science and technology policy, with a special focus in climate change, energy, and the environment. An expert in the field of decisionmaking under conditions of deep uncertainty, Dr. Lempert is a Fellow of the American Physical Society, a member of the National Academy of Science's Climate Research Committee, and a member of the Council on Foreign Relations. Dr. Lempert is leading an NSF-funded study on the use of scientific and other information for climate change decisionmaking under conditions of uncertainty, with a focus on abrupt climate change and on water resource management. He has led studies on climate change policy; long-term policy analysis, and science and technology investment strategies for clients such as the White House Office of Science and Technology Policy, the U.S. Department of Energy, National Science Foundation, and a variety of multinational firms. A Professor of Policy Analysis in the RAND Graduate School, Dr. Lempert teaches a course in complex adaptive systems and policy analysis. He is an author of the recent book "Shaping the Next One Hundred Years: New Methods for Quantitative, Longer-Term Policy Analysis." He received his PhD in Applied Physics from Harvard (1985) and BAS in Physics and Political Science from Stanford (1980).

Maria Carmen Lemos

Maria Carmen Lemos is an Assistant Professor of Natural Resources and Environment at the University of Michigan. She is also a Senior Policy Analyst with the Udall Center for Studies of Public Policy where she develops research initiatives in the U.S-Mexico border. Her research focuses on the human dimensions of global climate change, especially the co-production of science and policy, the role of technocrats as decisionmakers, the use of seasonal climate forecasting in drought planning and water management, the role of stakeholder-driven science in producing usable knowledge, and the broader social and political impacts of the use of technoscientific knowledge in policy making. She was the Principle Investigator (PI) for a NOAA Office of Global Programs funded interdisciplinary project on the socioeconomic and political implications of the use of seasonal climate forecasting on drought-relief and agricultural policymaking in Northeast Brazil. She is currently the PI on two other grant proposals—funded by NSF and NOAA—to understand institutional opportunities and constraints for the use of techno-scientific information, especially seasonal climate forecasting, in water management in Brazil and Chile. Professor Lemos holds a PhD and a MS. in Political Science from the Massachusetts Institute of Technology.

Nathan Mantua

Nathan Mantua is an affiliate Assistant Professor of Atmospheric Sciences and Marine Affairs at the University of Washington, and a full time research scientist with the University of Washington's Climate Impacts Group. This project is sponsored by NOAA's Office of Global Programs, as part of the Regional Integrated Sciences and Assessments (RISA) program. There are two main themes to his research, one aimed at better understanding large-scale climate dynamics, and the other focused on the regional impacts of climate on the water cycle, forests and marine ecosystems in the Pacific Northwest, and how climate information is or isn't being used in resource management decisions. He received a B S from the University of California at Davis in 1988, and a PhD from the University of Washington's Department of Atmospheric Science in 1994. He spent one year as a postdoctoral Fellow at Scripps Institute of Oceanography working on a pilot project for the International Research Institute for Climate Prediction. In April

2000 he received a Presidential Early Career Award for Scientists and Engineers for his climate impacts research and public outreach activities.

Thomas C. Pagano

Thomas C. Pagano has been an operational water supply forecaster with the Natural Resources Conservation Service of the US Department of Agriculture since joining the agency in 2002. He is responsible the production of seasonal outlooks for water management on the Colorado and Arkansas-Canadian Rivers, the Rio Grande, as well as the Yukon and other rivers in Alaska. His expertise lies in the fields of hydroclimatology, seasonal forecasting and climate change, as well as forecast evaluation, communication of uncertainty and the visual display of quantitative information. He was a select participant in the first American Meteorological Society (AMS) Policy Colloquium and the recipient of the American Geophysical Union Horton PhD Research Award in 2001. He was also selected to be an independent auditor for Aquila Energy Corporation's seasonal climate forecast competition. Following on an undergraduate degree in physics from New York University in 1996, Dr Pagano received a MS (1999) and PhD (2005) from the University of Arizona department of hydrology under Dr. Soroosh Sorooshian. His masters research involved a survey of the actual use of climate forecasts for water management in Arizona during the 1997-98 El Nino, and his doctorate addressed the role of climate variability in operational water supply forecasting.

Kelly T. Redmond

Kelly T. Redmond received a BS degree in Physics from the Massachusetts Institute of Technology (1974), and MS (1977) and PhD (1982) degrees in Meteorology from the University of Wisconsin in Madison. He worked in the Atmospheric Sciences Department at Oregon State University from 1982-1989, the last six years as State Climatologist for Oregon, and served as President of the American Association of State Climatologists in 1989-90. Since 1989 he has been the Regional Climatologist at the Western Regional Climate Center (WRCC) located at the Desert Research Institute in Reno, and Deputy Director since 1992. His research and professional interests span every facet of climate and climate behavior, its physical causes and behavior, how climate interacts with other human and natural processes, and how such information is acquired, used, communicated, and perceived. He has played an active role nationally in development of the climate services sector. Dr. Redmond is currently participating in efforts to form links between the NOAA Regional Climate Center Program, NSF CUAHSI hydrologic observatories and information systems, the NSF National Ecological Observatory Network, the GEOSS Integrated Surface Observing System, National Weather Service Coop Modernization, the NOAA Climate Reference Network, the Consortium for Integrated Climate Research in Mountain Regions (CIRMOUNT) and its Mountain Climate Network, the National Integrated Drought Information System (NIDIS), numerous California observing networks, and coastal and upper air climate data sets. He has had substantial interactions with the NOAA Regional Integrated Sciences and Assessment Program. This unique activity performs rigorous examination of the decision environment and context in which climate data and information are understood, interpreted, and incorporated (or not).

Pedro J. Restrepo

Pedro J. Restrepo is the Senior Scientist at the Hydrology Laboratory of the Office of Hydrologic Development, National Weather Service. He is responsible for setting the directions of research

in hydrology for the National Weather Service, and serves as the NWS' representative to a number of Federal Interagency Committees. His areas of expertise involve hydrologic modeling, parameter optimization, data assimilation, water resources, hydropower optimization, optimal reservoir operation, flood forecasting and control, water supply management. Prior to joining the National Weather Service, he was a private consultant on hydrology and water resources in many countries in the Americas, Europe and Asia. (PhD Hydrology and Water Resources, MIT, 1982; Sc.M. Hydrology and Water Resources, MIT, 1979; BS Civil Engineering, National University of Colombia, 1974).

John C. Schaake

John C. Schaake is a Senior Consultant with the Office of Hydrology Development at the NOAA National Weather Service (NWS). His research interests include: hydrologic modeling and parameter estimation; areal precipitation estimation and error analysis; land surface aspects of coupled atmospheric/hydrologic models; and application of precipitation forecasts and climate information in hydrologic prediction. Prior to becoming a senior consultant to NOAA/NWS, he served as Senior Scientist to the Office of Hydrology (1987-2000), He has initiated, chaired and been a member of numerous professional hydrologic-related committees, some of his present committees include: American Geophysical Union (AGU) Hydrology Section, Surface Water Committee, GAPP Science Advisory Group, and the Chair, IAHS Predictions for Ungaged Basins (PUB) Strategic Advisory Group (2003-2005), Co-Chair Hydrologic Ensemble Prediction Experiment (HEPEX), Co-chair, Model Parameter Estimation Experiment (MOPEX). He has also served in a number of advisory positions such as with the University of Arizona SAHRA Project External Review Panel. Among the awards he has received are: named special session at the 2001 AGU Fall Meeting: An Integrated Approach to Hydrologic Research and Applications: A Session in Honor of Dr. John Schaake; an American Meteorological Society Fellow (1997), and a Federal Interagency Superior Service Award, U.S Departments of Interior, Agriculture and Energy, 1986. He has a BSE in Civil Engineering from Johns Hopkins University (1958) and a PhD from Johns Hopkins University in Environmental Engineering (1965). He was a Postdoctoral Fellow at Harvard University (1966).

W. James Shuttleworth

W. James Shuttleworth is Professor of Hydrology and Hydrometeorology at the University of Arizona. He joined its Department of Hydrology and Water
Resources in 1993, having previously been Head of the Hydrological Processes Division at the Institute of Hydrology, United Kingdom. His major research interests are in physical processes in hydrology, with emphasis on evaporation and hydrometeorology, as applied to environment change at local, regional and global scales, including effects on global climate due to Amazonian deforestation and African desertification. Present research includes: the representation of heterogeneous land surfaces in Global Climate Models, the application of remote sensing methods within hydrology, and the micrometeorology of natural semi-arid vegetation and riparian systems in the desert Southwest. He serves on committees for the International Council of Scientific Unions, the International Hydrology Programme, the International Geosphere-Biosphere Project, the World Climate Research Programme and the International Pacific Research Center. A Fellow of the American Geophysical Union, the American Meteorological Society and Royal Meteorological Society, he holds a PhD in High Energy Nuclear Physics and a D.Sc. from Manchester University in the United Kingdom. He is a member of the U.S.

National Committee for the International Union of Geodesy and Geophysics; previous NRC service includes the Committee on Global Change Research, the Delegation to the Workshop on Hydrology and Water Resources, and the Global-Ocean-Atmosphere-Land System Panel.

Robert Webb

Robert Webb is a physical scientist and acting deputy director at the NOAA OAR Climate Diagnostics Center in Boulder, Colorado. He received his AB (1981) in Earth Sciences from the Dartmouth College, and his MS (1985) and his PhD (1990) in Geological Sciences from Brown University. While working at the NASA Goddard Institute for Space Studies and at the NOAA National Geophysical Data Center Paleoclimatology program, his research focused on the reconstruction of past climate from lake sediments and other paleoenvironmental proxies, and using global climate models to investigate the mechanisms of the past climate variability and change. Webb's current paleoclimate work involves developing new techniques to reconstruct streamflow and drought from tree rings in the intermountain west for use in water resource management. His research also focuses on improving the use and usability of climate products and services to provide information and decision support tools for proactive planning, impact mitigation, cost reductions and improved decisionmaking.

Andy Wood

Andy Wood recently became a research faculty member in the Land Surface Hydrology Research Group at the University of Washington (UW) Department of Civil and Environmental Engineering. Previously, he served for two years as a visiting scholar at the US Army Corps of Engineers Institute for Water Resources, where his work centered on wetland restoration, hydrologic forecasting and water resources decisionmaking. Andy has authored and co-authored a number of publications on the effects of climate change on hydrology and water resources, and worked extensively on improvements in seasonal hydrologic forecasting and nowcasting. At the UW, he is a primary developer of the UW West-wide Seasonal Hydrologic Forecast System, which for several years has produced semi-operational hydrologic and streamflow forecasts. He recently launched the UW Experimental Surface Water Monitor, a real-time simulation of national surface water conditions. He is a current participant in the Climate Prediction Center's US Drought Outlook, and is a regular presenter at forecast-related workshops and meetings, particularly in the Pacific Northwest. He has also participated in a variety of field campaigns directed at ground verification of remote sensing algorithms for soil moisture, snow, and most recently boundary layer atmospheric dynamics. Andy completed both his Masters degree (1995, focusing on climate change effects on water resources systems) and doctorate (2004, focusing on hydrologic forecasting) at the University of Washington, after receiving a BA in English from Amherst College (1988).

Brent Yarnal

Brent Yarnal is Professor of Geography and Director of the Center for Integrated Regional Assessment at the Pennsylvania State University. He is currently Principal Investigator on two major grants focusing on developing infrastructure to support long-term monitoring and assessment of global change in local places. The National Science Foundation and the Office of Global Programs at the National Oceanic and Atmospheric Administration support this research. He has also been a Principal Investigator, Co-Principal Investigator, and Investigator on several other major projects addressing the causes and consequences of global change in regions and

locales. His research interests span the physical and social sciences and include climate variation and change, land-use/land-cover change, natural hazards, water resources, and the use of environmental information in decisionmaking. His degrees include an AB in History (major) and Anthropology (minor) from the University of California at Davis, an MS in Geography (paleoclimatology emphasis) from the University of Calgary, and a PhD in Geography (climatology and glaciology emphases) from Simon Fraser University.