Prospectus for Synthesis and Assessment Product 5.2

Best Practice Approaches for Characterizing, Communicating and Incorporating Scientific Uncertainty in Climate Decision Making

Sponsoring Agency: National Oceanic and Atmospheric Administration
Supporting Federal Partners: Department of Energy
Department of Transportation
Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation

1. OVERVIEW

1.1 Introduction

The U.S. Climate Change Science Program (CCSP) is an interagency endeavor designed to create an extensive body of scientific knowledge and associated decision support tools that can foster improved understanding and adaptation in the face of a dynamic climate system. In order to help bridge the gap between science and practical management challenges in sectors and regions that are sensitive to climate change and variability, the CCSP contributes to and participates in a range of regional and international assessment activities, including the Intergovernmental Panel on Climate Change (IPCC). In addition to participation in broader assessment activities, the CCSP is committed to developing a series of Synthesis and Assessment Products (SAPs) that summarize the current state of scientific understanding about key issues related to climate change, variability, ecosystems and human society[1]. Essentially, these products will communicate what is known, from a CCSP perspective, including degrees of uncertainty, about climate and its interactions with natural and socioeconomic systems in a context and format that may be useful for policymakers, resource managers, scientists and other stakeholders.

In order for CCSP research outputs/findings (including, but not limited to the SAPs) to be both scientifically accurate and useful to decision makers, scientific uncertainties must be acknowledged and clearly defined. Given the importance of providing clear information concerning uncertainties associated with the application of climate science and information in decision making, the CCSP is developing a Synthesis and Assessment Product (5.2) that explicitly focuses on best practices for characterizing, communicating and incorporating scientific uncertainty. This prospectus outlines the plans for the development of SAP 5.2.

1.2 Topic and Content

Uncertainty factors into large and small decisions made by individuals every day throughout society. The choice to bring an umbrella to work, take a new job, or to move to a new

[1] A complete list of CCSP SAPs can be found at www.climatescience.gov.

neighborhood all involve some degree of uncertainty, with various levels of risk and opportunity that must also be considered. In most cases, the uncertainties inherent in personal decisions are not treated as explicitly and systematically as they might be. Unlike personal decision-making, building an understanding of potential climate change impacts requires a synthesis of science, practical resource management strategies and an anticipation of the requirements for the long-term health and welfare of human society and the environment. This complex analysis creates a demand and opportunity for examining the way scientific uncertainty is articulated, communicated, and considered in decision making.

The *Strategic Plan for the U.S. Climate Change Science Program* defines uncertainty as:

> *An expression of the degree to which a value (e.g., the future state of the climate system) is unknown.*

Uncertainty concerning the nature and impacts of climate change and variability is the inevitable consequence of the necessary synthesis of various types of data of varying degrees of quality with models possessing varying degrees of skill in simulating natural processes and human behavior. Scientists work to minimize uncertainty in their projections by identifying its nature and source and, then by undertaking focused research to reduce the margin between what is known and what is not known. Various factors can complicate the accurate formulation and communication of uncertainty in climate change projections including the definition of concepts, terminology, and scale (Moss and Schneider, 2000).

The level of certainty in the projections of climate change and its effects has emerged as a central issue in the public discourse, reinforcing the need to evaluate current methods and to define best practices for assessing uncertainty. The scientific community – which includes researchers from academia, government, and the private sector, as well as scientific and operational agencies[2] - are looked to by policymakers, decision makers, and the media for "answers" (or insights) about trends, rates, impacts, and adaptation options related to climate change. Meeting these societal demands, and providing effective support for decisions in sectors and regions affected by climate change and variability, requires a better understanding and articulation of the nature and implications of uncertainty to enable more informed policy and management decisions. Essentially, researchers, technical experts and decision makers must develop a functional degree of shared understanding and language regarding uncertainty in order to facilitate a constructive dialogue between those who produce, and those who would utilize scientific information.

The climate research community has taken steps in recent years to explain the nature of uncertainty in their assessment efforts. The Intergovernmental Panel on Climate Change (IPCC), the largest international climate assessment effort, recognized the need for a more formal, decision analysis based treatment of uncertainty in Chapter 11 of its report on *Climate Change 1995: The Science of Climate Change* (McBean et al., 1995). In response to this need, recommendations for reporting uncertainty were developed for the authors of the IPCC Third Assessment Report (TAR) and the ongoing Fourth Assessment Report (AR4).

[2] In the context of this discussion, operational agencies are those who regularly provide science-based products, including short-term climate forecasts and diagnostic information, for consumption by the general public.

SAP 5.2 is intended to further develop this topic through the synthesis, assessment, and communication of what is known about the character of uncertainty (as it applies to climate), and to address some potential approaches to decision making under uncertainty. The report will address uncertainty dimensions that are inherent to the full spectrum of decision support activities, ranging from the conduct and communication of research to the actual consideration and use of scientific knowledge and information products in decision making.

1.3. Audience and Intended Use

SAP 5.2 is designed to address two distinct purposes and audiences. One purpose of the report is to synthesize and communicate the current state of understanding about the characteristics and implications of uncertainty related to climate change and variability to an audience of policymakers with an interest in developing a fundamental understanding of the issue. Such an understanding could contribute sound scientific underpinnings to an informed discourse about the nature and implications of climate change and variability. SAP 5.2 will contribute insight about the nature of uncertainty that is fundamental to a priority issue identified in the CCSP Strategic Plan: *an understanding of how the methods and capabilities for societal decision making under conditions of complexity and uncertainty about global environmental variability and change can be enhanced*. An increased awareness and understanding of the characteristics of scientific uncertainty as applied to climate is a critical step in this effort.

The second purpose is to provide recommendations for best practices for characterizing, analyzing and communicating uncertainty for scientists, science managers, and technical operational entities involved in conducting research and assessments, and producing climate information in the context of decision support, based on a thorough, state-of-the-art assessment of the current state of understanding. This latter audience includes, but is not limited to, the ongoing and future CCSP synthesis and assessment effort.

The potential stakeholders of the CCSP synthesis and assessment product effort are broad and diverse, consisting of resource managers and planners across various geographical and institutional scales, policymakers, and the national and international scientific and operational communities. Two segments of this broader stakeholder community are intended as the primary audience for SAP 5.2: a) decision makers and policy makers with a desire to better understand the nature of uncertainty as a foundation for interpreting scientific information regarding climate change and variability, and to apply this knowledge in considering adaptation needs and options; and b) the scientific and operational communities involved in producing and disseminating scientific information and products.

Given the intended audiences, it is anticipated that SAP 5.2 may be used as a) a relatively sophisticated summary and assessment of the state-of-the-art understanding of the characteristics of uncertainty and the illumination of some potential approaches to decision making under such uncertainty; b) decision analysis and social science-based guidelines for ongoing and future CCSP synthesis, assessment and decision support activities and for researchers participating in broader assessment activities, such as the IPCC.

1.4 Key Questions

SAP 5.2 will address the following questions in the context of climate change and variability:

- How is uncertainty estimated and measured?
- What are the sources and types of uncertainty that influence the way scientific information is communicated and understood by non-scientists?
- Why is an enhanced understanding of uncertainty important for communicating and utilizing climate information?
- What are some of the cognitive challenges in estimating uncertainty?
- How is uncertainty analyzed, and how can it be applied in analyses of adaptation options?
- What are some effective methods for communicating uncertainty?
- How can decision makers consider and incorporate uncertainty?
- What are considered to be the best practices for the incorporation and communication of uncertainty in scientific assessments?

2. AGENCY CONTACT INFORMATION

The National Oceanic and Atmospheric Administration (NOAA) is the lead agency for SAP 5.2, supported by the Department of Energy (DOE), the Department of Transportation (DOT), the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF). Together, these agencies constitute the interagency working group (IWG) responsible for overseeing the production of SAP 5.2[3]. Contact information for the agency personnel involved in this product is listed below.

Agency	Key IWG Personnel and Contact Information
NOAA	Tom Karl (Thomas.R.Karl@noaa.gov) Margaret McCalla (Margaret.R.McCalla@noaa.gov) Lisa Vaughan (Lisa.Vaughan@noaa.gov), Lead Agency Coordinator
DOE	John Houghton (John.Houghton@science.doe.gov)
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EPA	Brooke Hemming (Hemming.Brooke@epamail.epa.gov) Mike Slimak (Slimak.Michael@epa.gov)
NASA	DeWayne Cecil (LCecil@hq.nasa.gov)
NSF	Robert O'Connor (RoConnor@nsf.gov)

[3] The respective roles of the Lead Agency and the IWG are outlined in the *Guidelines for CCSP Synthesis and Assessment Products*, available at www.climatescience.gov.

3. SAP 5.2 LEAD AND CONTRIBUTING AUTHORS

As articulated in the *Guidelines for Producing CCSP Synthesis and Assessment Products*, lead and contributing authors of SAPs are expected to be individuals with recognized technical expertise in a field relevant to the specific question(s) addressed by the SAPs, as evidenced by publication record and/or pertinent achievements and contributions to their field. Authors can be drawn from the international community of experts.

The authors of SAP 5.2 are well-respected scientific experts, who are solely responsible for the content of the report that will be submitted to the CCSP for review. He is responsible for selecting the contributing authors for the report. They are all considered to be experts in the characterization and treatment of uncertainty, and represent various perspectives from throughout the community; biographical information is included in this document as an appendix.

The CCSP research portfolio includes a suite of interdisciplinary centers dedicated to Decision Making Under Uncertainty (DMUU) in the context of climate change and variability. The DMUU centers are explicitly designed to conduct research and develop tools that can be utilized to increase understanding and adaptation options associated with the risks and uncertainties presented by climate change and variability. Five DMUU centers were established in 2004 through a highly competitive peer review process managed by the National Science Foundation (NSF). Given this substantial investment in decision support oriented studies of uncertainty, SAP 5.2 will capitalize on the work and expertise of the DMUU centers. The lead author identified for SAP 5.2 is associated with one of these centers, the DMUU Climate Decision Making Center. The National Science Foundation is supporting the lead and contributing authors for SAP 5.2 through a cooperative agreement with this DMUU Center.

Lead Author

Dr. Granger Morgan, Department of Engineering and Public Policy, Carnegie Mellon University, and leader of the DMUU Climate Decision Making Center

Contributing Authors

Dr. Hadi Dowlatabadi, Institute for Resources, Environment and Sustainability, University of British Columbia
Dr. Max Henrion, Lumina Decision Systems
Dr. David Keith, Department of Chemical and Petroleum Engineering and Department of Economics, University of Calgary
Dr. Robert Lempert, The RAND Corporation
Dr. Thomas Wilbanks, Environmental Science Division, Oak Ridge National Laboratory

4. STAKEHOLDER INTERACTIONS

CCSP synthesis and assessment products will be developed in consultation with a diverse group of stakeholders. The team of individuals identified as SAP 5.2 authors is composed of highly

active members of the scientific community who are engaged in the current discourse related to uncertainty in the context of climate change and variability. They interact frequently on this topic with their scientific colleagues at workshops, conferences and advisory panels as well as decision makers, seeking and receiving feedback on specific theories, approaches and conclusions. The team will continue to do so, and will seek specific opportunities to vet this material by participating in conferences, workshops and other forums that present an opportunity for obtaining feedback from members of the broader stakeholder community, including but not limited to, the lead authors of other CCSP SAPs. In addition, options for including the perspective of decision makers in the expert review phase of this process will be explored. Finally, the interagency working group charged with overseeing the development of SAP 5.2 will make a concerted effort to inform the broader scientific and decision making communities of the opportunity for input presented by the public review of this prospectus and the actual product (see below for information regarding the review process).

5. DRAFTING PROCESS, INCLUDING MATERIALS TO BE USED IN PREPARING THE PRODUCT

Support for SAP 5.2 is provided by an NSF award to the lead author, Dr. Granger Morgan of the Carnegie Mellon Climate Decision Making Center. The SAP 5.2 interagency working group (members identified in section 2 above) will determine through the creation of this prospectus (including the consideration of comments received during the public review period) the overall scope, focus, and balance of the product. The IWG will not participate in the drafting of the actual report; public review and expert review comments will be handled by the lead author and his team. The lead author is responsible for the initial draft as a basis for further development by the team of contributing authors. The content and focus of this report will be discussed by the lead author with members of the scientific and decision making communities throughout the drafting process; this feedback will be incorporated in the progressive drafts, along with input provided through the formal public and expert review phases described below. Authors will draw upon peer-reviewed scientific literature in the drafting process.

6. REVIEW

As the lead agency, NOAA will develop and oversee a review process that satisfies the SAP guidance issued by the CCSP, and is consistent with the Information Quality Act and the Office of Management and Budget's (OMB's) Final Information Quality Bulletin for Peer Review (December 2004). The *Guidelines for Producing CCSP Synthesis and Assessment Products* essentially requires three levels of review for each SAP: a) technical expert review; b) a 45 day public review; and c) a CCSP and National Science and Technology Council (NSTC) review prior to release of the final document. The review process outlined below is consistent with the requirements identified above.

As the lead agency for this project, NOAA will submit a draft of SAP 5.2 to the National Academies' National Research Council (NRC) for expert scientific review. The following questions are likely to be addressed in the review:

1) Are the goals, objectives and intended audience of the product clearly described in the document? Does the product address all questions outlined in the prospectus?
2) Are any findings and/or recommendations adequately supported by evidence and analysis? In cases where recommendations might be based on expert value judgments or the collective opinions of the authors, is this acknowledged and supported by sound reasoning?
3) Are the data and analyses handled in a competent manner? Are statistical methods applied appropriately?
4) Are the document's presentation, level of technicality, and organization effective? Are the questions outlined in the prospectus addressed and communicated in a manner that is appropriate and accessible for the intended audience?
5) Is the document scientific objective and policy neutral? Is it consistent with the scientific literature? Are the conclusions and general approaches for addressing uncertainty consistent with those embraced by other treatments of the topic (e.g., IPCC, NRC activities)? If not, are the differences supported by explicit and sound reasoning?
6) Is there a summary that effectively, concisely and accurately describes the key findings and recommendations? Is it consistent with other sections of the document?
7) What other significant improvements, if any, might be made in the document?

The findings of the NRC review will be posted on the CCSP web site following completion. The lead author, assisted by his team, will consider and incorporate the findings of the NRC review as they deem appropriate.

NOAA will post the revised draft for a public review period of 45 days. Comments will be considered by the lead author and the contributing team of authors, and incorporated based on their scientific judgment. The author's comments to the NRC review will be posted on the CCSP website.

NOAA will submit the revised draft to the CCSP Interagency Committee for approval. If the CCSP Interagency Committee concludes that further revision is necessary, their comments will be provided to the lead author, who will then consider and address these comments according to their scientific judgment. If the CCSP approves the draft product, they will submit it to the NSTC for review. Clearance will require the concurrence of all members of the Committee on Environment and Natural Resources. The sequence and potential timing of the review process is outlined in Section 9 of this prospectus.

7. RELATED ACTIVITIES

Several key activities with an explicit or implicit focus on the characterization and communication of uncertainty in the context of climate change and variability are currently underway. The SAP 5.2 effort is aware of, and in some cases, connected to these efforts through the participation of the lead and contributing authors. Relevant activities include the following:

- IPCC Fourth Assessment Report (AR4)[4], and associated activities, including the IPCC Workshop on Describing Scientific Uncertainties in Climate Change to Support Analysis of Risk and Options (Co. Kildare, Ireland; May 2004), and the development of *Guidance Notes for Lead Authors of the IPCC Fourth Assessment Report on Addressing Uncertainties*.

- NRC Board on Atmospheric Sciences and Climate (BASC) Study on Estimating and Communicating Uncertainty in Weather and Climate Forecasts.

- NRC BASC Analysis of Global Change Assessments.

- Ongoing and future CCSP synthesis and assessment activities.

8. COMMUNICATIONS

Throughout the process, the agency representatives are available to answer questions regarding the development and production of SAP 5.2.

As the lead agency, NOAA will manage the production and release of the completed product, utilizing a standard format established by the CCSP. The final report will be available in a PDF version, as well as in a hardcopy. The electronic information, and information about obtaining a hardcopy of the document, will be available on the CCSP web site (www.climatescience.gov).

9. TIMELINE

A timeline for SAP 5.2 is currently under development.

[4] IPCC AR4 is scheduled for completion in 2007.

APPENDIX A: Author Biographical Information

Lead Author

Dr. M. Granger Morgan

Dr. Morgan is Professor and Head of the Department of Engineering and Public Policy at Carnegie Mellon University where he is also University and Lord Chair Professor in Engineering. In addition he is a Professor in the Department of Electrical and Computer Engineering and in The H. John Heinz III School of Public Policy and Management. His research addresses problems in science, technology and public policy, much of it involving the development and demonstration of methods to characterize and treat uncertainty in quantitative policy analysis. At Carnegie Mellon, Morgan directs the NSF Climate Decision Making Center and co-directs, together with Lester Lave, the Carnegie Mellon Electricity Industry Center. Morgan serves as Chair of the EPA Science Advisory Board, Chair of the EPRI Advisory Council, and Chair of the Scientific and Technical Council for the International Risk Governance Council (based in Geneva, Switzerland). He is a Fellow of the AAAS, the IEEE, and the Society for Risk Analysis. He holds a BA from Harvard College (1963) where he concentrated in Physics, an MS in Astronomy and Space Science from Cornell (1965) and a Ph.D. from the Department of Applied Physics and Information Sciences at the University of California at San Diego (1969).

Contributing Authors

Dr. Hadi Dowlatabadi

Dr. Dowlatabadi is Canada Research Chair & Prof in Applied Mathamatics and Global Change, University of British Columbia. He is Associate Director of the Institute for Resources Environment and Sustainability and the Bridge Scholarship Program. He is a University Fellow at Resources for the Future and an Adjunct Faculty at Carnegie Mellon University. He is co-founder and Editor of the Integrated Assessment Journal and serves on the boards of four other periodical. He is co-founder of Offsetters and Cooldrivepass, and a Director of Canadian Bioenergy Corporation. His research has focused on the interface between humans and the environment and systems approaches to decision-making under uncertainty. He studies problems in technology choice, acid rain, air quality, infectious and vector-borne diseases, energy policy, equity, ethics and climate change. He received his BSc in physics from Edinburgh University (1980) and his PhD in Physics from Cambridge University (1984).

Dr. Max Henrion

Dr. Max Henrion has 25 years of experience as a researcher, educator, software designer, consultant, and entrepreneur, specializing in the creation and effective use of decision technologies. He is the Founder and CEO of Lumina Decision Systems, which publishes decision software and provides consulting in decision analysis to corporate and government clients. He was the lead designer of Lumina's flagship product line, *Analytica* -- the software about which *PC Week* said *"Everything that's wrong with the common spreadsheet is fixed in Analytica"*. He was Vice President for Decision Technology at Ask Jeeves, Inc, where he led the division that created the Jeeves Advisor, offering online consumer advice. He has led consulting teams offering decision and risk analysis in environment and energy, telecommunications,

aerospace, healthcare, and consumer choice. He was the founding President of the Association for Uncertainty and Artificial Intelligence. He has (co)authored three books, including *Uncertainty: A Guide to dealing with Uncertainty in Policy and Risk Analysis* (Cambridge University Press, 1990), and over 60 peer-reviewed articles. He was Consulting Professor at Stanford University in Medical Informatics. He is now Adjunct Professor, and previously Associate Professor, at Carnegie Mellon University, where he taught in the Departments of Engineering and Public Policy, and Social and Decision Science. He has an MA in Natural Sciences from Cambridge University, Master of Design from the Royal College of Art, London, and a PhD from the School of Urban and Public Affairs at Carnegie Mellon University.

Dr. David Keith

Dr. David Keith is Canada Research Chair in Energy and the Environment; Professor Department of Chemical and Petroleum Engineering and Department of Economics, University of Calgary, and Adjunct Professor Department of Engineering and Public Policy Carnegie Mellon. Professor Keith works near the interface between climate science, energy technology and public policy. Roughly half of his technical and policy work addresses the capture and storage of CO_2, including work managing the risks of geologic storage and services as chair of a crosscutting group for the IPCC special report on CO_2 storage. Keith serves as a member of several advisory boards and panels including Canada's 'blue ribbon' *Panel on Sustainable Energy Technology*, and the InterAcademy Council study on *Transitions to a Sustainable Energy Systems*, and as member of US National Academy committees. Keith's broader climate and energy related research addresses the economics and climatic impacts of large-scale wind power, the use of hydrogen as a transportation fuel, and the technology and implications of geoengineering. Keith's has addressed technical audiences with articles in *Science* and *Nature*. He as consulted for national governments, industry and environmental groups and has reached the public through US and Canadian radio and television. Keith is trained as a physicist. As a graduate student at MIT, he built the first interferometer for atoms work which was the "hottest topic" in physics according to ISI's citation index. As an atmospheric scientist he worked at NCAR and Harvard, where he served as lead scientist for a new Fourier-transform spectrometer with high radiometric accuracy that flies on the NASA ER-2 high-altitude aircraft. Keith returned to Canada in 2004 taking a position at the University of Calgary where he leads a research group on energy and environmental systems.

Dr. Robert Lempert

Dr. 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 internationally-known scholar 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 has led studies on climate change policy, the environment, energy, national security strategies, and on science and technology investment strategies for clients that include the White House Office of Science and Technology Policy, the U.S. Department of Energy, the National Science Foundation, and several multinational firms. He holds a bachelor of arts and science degree in physics and political science from Stanford University and a doctorate in applied physics from Harvard University. A Professor of Policy Analysis in the RAND Graduate School, Dr. Lempert

is an author of the recent book *Shaping the Next One Hundred Years: New Methods for Quantitative, Longer-Term Policy Analysis*.

Dr. Thomas J. Wilbanks

Dr. Thomas Wilbanks is a Corporate Research Fellow at the Oak Ridge National Laboratory and leads the Laboratory's Global Change and Developing Country Programs. He conducts research on such issues as sustainable development, energy and environmental technology and policy, responses to global climate change, and the role of geographical scale in all of these regards. Wilbanks is a member of the Board on Earth Sciences and Resources of the U.S. National Research Council (NRC) and Chair of NRC's Committee on Human Dimensions of Global Change. He is Coordinating Lead Author for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Working Group II, Chapter 7: Industry, Settlement, and Society. He is a past President of the Association of American Geographers and a Fellow of the AAAS. He holds a BA from Trinity University (1960) and MA and PhD degrees in geography from Syracuse University (1967, 1969).

APPENDIX B: References

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