CCSP Synthesis and Assessment Product 5.2

SAP-5.2

Prospectus for

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

U.S. Climate Change Science Program

Lead Agency
National Oceanic and
Atmospheric Administration

Contributing Agencies
Department of Energy
Department of Transportation
Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation

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Agency Leads

Lisa Vaughan
National Oceanic and Atmospheric Administration
Tom Karl
National Oceanic and Atmospheric Administration
Margaret McCalla
National Oceanic and Atmospheric Administration
John Houghton
Department of Energy
Richard Corley
Department of Transportation
Mike Savonis
Department of Transportation
Brooke Hemming
Environmental Protection Agency
Mike Slimak
Environmental Protection Agency
DeWayne Cecil
National Aeronautics and Space Administration
Robert O'Connor
National Science Foundation

For More Information

U.S. Climate Change Science Program
1717 Pennsylvania Avenue, NW, Suite 250
Washington, DC 20006 USA
+1.202.223.6262 (voice)
+1.202.223.3065 (fax)
http://www.climatescience.gov/

This prospectus has been prepared according to the *Guidelines for Producing Climate Change Science Program (CCSP) Synthesis and Assessment Products*. The prospectus was reviewed and approved by the CCSP Interagency Committee. The document describes the focus of this synthesis and assessment product, and the process that will be used to prepare it. The document does not express any regulatory policies of the United States or any of its agencies, or make any findings of fact that could serve as predicates for regulatory action.

Prospectus for Synthesis and Assessment Product 5.2

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

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 decisionmakers, 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 decisionmaking, 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 choices to bring an umbrella to work, take a new job, or to move to a new 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 decisionmaking, 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 decisionmaking.

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

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 scientists from academia, government, and the private sector, as well as research and operational entities[2]—are looked to by policymakers, decisionmakers, 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 decisionmakers 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.

[2] In the context of this discussion, operational entities are those which regularly provide science-based products for utilization by other technical entities and the general public.

The climate research community has recognized the need to improve the treatment of uncertainty in assessment efforts. The 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 *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 ongoing Fourth Assessment Report (AR4).

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 decisionmaking 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 decisionmaking.

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, decisionmakers, and members of the media and general public 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 variability and change. 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 decisionmaking 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, future CCSP assessment efforts.

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: (i) policymakers, decisionmakers, and members of the media and general public with a desire to better understand the complex 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 (ii) 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 (i) 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 decisionmaking under such uncertainty, and (ii) decision analysis and social science-based guidelines for future CCSP 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 science:

- 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 (e.g., the role of human judgment) and the relevance of these challenges to addressing climate?
- 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 decisionmakers 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 follows.

[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>.

Agency	Key IWG Personnel and Contact Information
NOAA	Tom Karl Thomas.R.Karl@noaa.gov Margaret McCalla Margaret.R.McCalla@noaa.gov Lisa Vaughan, Lead Agency Coordinator Lisa.Vaughan@noaa.gov
DOE	John Houghton John.Houghton@science.doe.gov
DOT	Richard Corley Richard.Corley@dot.gov Mike Savonis Michael.Savonis@fhwa.dot.gov
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. 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. The lead author 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 Appendix A.

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 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. NSF is supporting the lead and contributing authors for SAP 5.2, listed below, 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 decisionmakers, 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, decisionmakers will be invited to participate in one of the review meetings of the National Research Council (NRC) and will have the opportunity to interact directly with the authors in this context. Finally, the IWG charged with overseeing the development of SAP 5.2 will make a concerted effort to inform the broader scientific and decisionmaking communities of the opportunity for input presented by the public review of this prospectus and the actual product.

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 IWG 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 decisionmaking 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: (i) technical expert review; (ii) a 45-day public review; and (iii) 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 these requirements.

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

1) Are the goals, objectives, terminology, 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 appropriate and accessible for the intended audience?

5) Is the document scientifically objective and policy neutral? Is it consistent with the scientific literature? How do the conclusions and general approaches for addressing uncertainty compare with those embraced by other treatments of the topic (e.g., IPCC, NRC activities)? If not, are 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?

Findings of the NRC review will be available following completion. The lead author, assisted by his team, will consider and incorporate the findings of the NRC review as deemed appropriate.

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

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 the team's 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. Activities include:

- 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, will be available on the CCSP web site (<www.climatescience.gov>).

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

9. Timeline

2006

June	Public review of SAP 5.2 draft prospectus (30 days)
September	Establishment of NRC Committee for the review of SAP 5.2, and draft report #1 submitted to NRC for expert review
October	Final SAP 5.2 prospectus posted on CCSP web site
November/ December	NRC review of draft #1, including stakeholder session

2007

January	NRC review of draft report #1 delivered to CCSP
February	Author team considers NRC review and develops draft #2
March	Public review of draft report #2 begins (45-day period)
April	Author team considers public review and develops draft #3
April	Draft report #3 submitted to CCSP Interagency Committee and NSTC for review and approval
May	Final product posted on CCSP web site

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

CCSP, 2004: *Guidelines for Producing CCSP Synthesis and Assessment Products*. Available at http://www.climatescience.gov/Library/sap/sap-guidelines.htm.

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