Prospectus for Synthesis and Assessment Product 1.3

Re-Analysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change

Lead Agency: NOAA
Supporting Agencies: DOE, NASA

---

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

This prospectus provides an implementation plan for developing and producing CCSP Synthesis and Assessment Product 1.3, "*Re-Analysis of Historical Climate Data for Key Atmospheric Features: Implications for Attribution of Causes of Observed Change*." Re-analysis (henceforth, reanalysis) is the process of reconstructing a long-term climate record by integrating carefully quality-controlled data obtained from disparate observing systems together within a state-of-the-art model to create a comprehensive, high-quality, temporally continuous, and physically consistent *climate analysis* data set. Over the past several years, reanalysis data sets have become a cornerstone for research in advancing our understanding of *how* and *why* climate has varied over roughly the past half-century. Increasingly, reanalysis data sets and their derived products are also being used in a wide range of climate applications.

The proposed Report is intended to provide an expert assessment of the capability and limitations of state-of-the-art climate reanalyses, as defined above, to describe past and current climate conditions, and the consequent implications for scientifically interpreting the causes of climate variations and change. The information in the Report will provide a basis for decision- and policy-makers to understand the present level of confidence and uncertainties in describing how the climate system has varied in the recent historical past, and how this has enabled, and in some cases limited, our ability to identify the causes of such variations. The Report will conclude with a discussion of steps that could be taken to improve future analyses and reanalyses of the climate system, and how this information can be developed and applied more effectively to increase confidence and reduce uncertainties in interpreting the causes for past and ongoing climate variations and change.

This proposed CCSP product will be in the form of a Synthesis and Assessment Report that (a) summarizes the present status of national and international climate reanalysis efforts, and (b) discusses key research findings on the strengths and limitations of the current reanalysis products for describing and analyzing the causes of climate variations and trends that have occurred during the time period of the reanalysis records (roughly the past half-century). The proposed report will describe how reanalysis products have been used in documenting, integrating, and advancing our knowledge of climate system behavior, as well as in ascertaining significant remaining uncertainties in descriptions and physical understanding of the climate system. By identifying key limitations of the current generation of reanalyses, the report will be useful to policymakers in identifying and understanding the causes for remaining uncertainties, and for climate program managers in developing priorities for future observing, modeling, and analysis systems required to advance national and international efforts to describe and attribute causes of observed climate variations and change.

This report will focus on the *strengths and limitations of current reanalysis products* in addressing two primary issues of interest to policymakers and the public.

1.1. Descriptions of Past Climate Variations and Trends

As one of their central applications, reanalysis data sets have been employed extensively in research to identify and describe climate variations over times extending from approximately the mid-20th century to the present. This work has led to many important scientific advances. However, limitations of past and current observations, models, and data assimilation systems have also contributed to significant uncertainties in representing past climate system behavior or, in some cases, even to spurious climate "discontinuities" or shifts. This section of the report will focus on the strengths and limitations of current reanalysis systems for identifying and describing past climate variations. The "first-generation" of reanalyses focused only on the atmospheric component, and includes the NCEP/NCAR reanalysis, the NCEP/DOE reanalysis, the NASA/DAO and GMAO reanalyses, and the European Center for Medium Range Weather Forecasts (ECMWF) ERA-40 reanalysis. Because of the relatively greater maturity and more extensive use of these atmospheric reanalyses, they will constitute the primary focus of this report. However, efforts have been advancing very rapidly to create reanalyses for the ocean, land surface, and the coupled climate system, and so emerging capabilities and initial findings will also be discussed more briefly for these areas.

The primary questions to be addressed in this section of the report are:

- What is a climate reanalysis? What are its essential components?
- What role does reanalysis play within a comprehensive climate observing system?
- To what extent are the current reanalysis products useful for describing climate variations or changes that are significant to society, such as in temperatures, storm tracks, or the hydrological cycle?
- What is the capacity of current reanalyses to identify changes in the frequency and intensity of climate extremes, or represent seasonal-to-decadal climate variations, such as of El Niño-Southern Oscillation (ENSO) or other major modes of climate variability?
- Where are the areas of greatest disagreement among the reanalyses? For example, to what extent do the reanalysis data sets differ in the tropics, high latitudes, or the southern hemisphere oceans?
- What is the extent of agreement or disagreement between climate trends derived from reanalyses and those derived from independent data, for example, directly from surface temperature and precipitation observations?
- Is there evidence for spurious climate changes or trends in the reanalysis data sets? What are possible causes, and what steps can be taken to reduce this problem?
- What steps would be most useful in reducing major uncertainties in describing the past behavior of the climate system through reanalysis methods? For example, what

contributions could be made through improvements in data recovery or quality control, modeling, or data assimilation techniques?

- What are applications for which reanalyses are now of sufficient quality to be usefully employed, and where do present limitations warrant particular caution by users?
- How can reanalysis products be made more useful for applications?
- How can reanalyses be employed to assess or improve climate models, including those used for climate change predictions or projections?
- How might deficiencies of current reanalyses introduce errors that propagate into other related products and applications, such as climate forecasts?

The primary value of this section of the Report to decision-makers and policy-makers will be as a summary of the present level of scientific confidence and remaining uncertainties in identifying and describing how the climate system has varied over approximately the last half-century. The discussion of limitations of current reanalyses will provide valuable information for science program managers for developing priorities for data recovery and quality control efforts and future requirements for improving models, data assimilation methods, and observing systems to reduce uncertainties and improve our ability to describe past and ongoing climate variability and change. The assessment of the capabilities and limitations of current reanalysis products for different applications will also be of value to users of reanalysis products.

1.2. Attribution of the Causes of Climate Variations and Trends

The second section of the report will assess present uses and limitations of reanalysis products for attributing the causes of observed climate variations and trends. The assessment will be limited to the time period included in the present-generation reanalyses, which is effectively from 1948 to the present. The focus of this section will be on advances in our understanding of the causes of major climate variations that have occurred during this period and that were published subsequent to work included in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report published in 2001.

Questions to be considered in this section are:

- What is our present understanding of the causes for regional climate variations over the reanalysis record, including the role of the oceans or other natural or non-greenhouse gas anthropogenic effects, including land-use changes?
- What is the nature and cause of apparent rapid climate shifts in the atmospheric circulation during the 20th century (e.g. the mid-1970s)?
- What is our present understanding of the causes for other observed high-impact climate events, such as prolonged, severe droughts or variations in the frequency or magnitude of major climate variations, for example, of ENSO or other climate modes?
- What (if any) signatures of volcanic eruptions or other external forcing mechanisms appear in the reanalyses? What might this indicate about uncertainties in our present understanding and modeling the responses to these forcings?

The primary audience for this section is policymakers, who would have an improved basis for ascertaining the present state-of-knowledge, as well as uncertainties, in our scientific understanding of the causes of major climate variations over roughly the last half-century. The scientific community and public would also benefit from a report assessing our present understanding of the causes of past climate variations, especially for those events that have high societal, economic, or environmental impacts, such as large and prolonged droughts or ENSO events.

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

NOAA is the lead agency for this CCSP deliverable, with NASA and DOE 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:

NOAA (Lead) Dr. Randall M. Dole
NOAA Earth System Research Laboratory
Physical Sciences Division
325 Broadway
Boulder, CO 80305
Email: Randall.M.Dole@noaa.gov
Phone: 303-497-5812

NASA Dr. Tsengdar Lee
Email: Tsengdar.J.Lee@nasa.gov
Phone: 202-358-0860

DOE Dr. Rick Petty
Email: Rick.Petty@science.doe.gov
Phone: 301-903-5548

3. Lead Authors: Required Expertise and Biographical Information

Appendix A provides brief biographies for each of the proposed authors. It is anticipated that additional authors will be added to the team in order to ensure comprehensive and balanced subject matter expertise, in conformance with requirements for the Federal Advisory Committee Act (FACA). The author team will also depend extensively on solicitation of relevant information from experts in the Federal and academic research community during the preparation of this report.

3.1. Lead Authors

Dr. Siegfried Schubert (NASA, Global Modeling and Assimilation Office) is the proposed lead author for Section 1 of this report, and Dr. Martin P. Hoerling (NOAA, Climate Diagnostics Center) is the proposed lead author for Section 2.

3.2. Contributing Authors

The following individuals are proposed as contributing authors:

- Dr. Phil Arkin (University of Maryland)
- Dr. James Carton (University of Maryland)
- Dr. Paul Dirmeyer (Center for Ocean-Land-Atmosphere Studies)
- Dr. Eugenia Kalnay (University of Maryland)
- Dr. David Karoly (University of Oklahoma)
- Dr. Masao Kanamitsu (Scripps Institute of Oceanography)
- Dr. Arun Kumar (NOAA, Climate Prediction Center)
- Dr. Roger Pulwarty (University of Colorado)

4. Stakeholder Interactions

Stakeholder interactions have already been initiated and additional opportunities are proposed throughout the process. At the American Geophysical Union (AGU) Spring 2005 meeting, two special sessions directly related to this CCSP Synthesis and Assessment Product were held to brief the scientific community and discuss relevant recent research. The two sessions were "The Strengths and Limitations of First-Generation Reanalyses for Understanding Climate Variability and Trends" and "Attribution of Climate Variability During The Last 100 Years." Talks presented during these sessions have provided useful background about the current state of knowledge. Following the Spring AGU meeting, a more specialized workshop that will include lead and contributing authors as well as other scientific experts will be convened by June 30, 2006. The NOAA Climate Program Office (NCPO) has agreed to provide funding to support this Workshop. Additional sessions related to this report will be proposed for the 2006 spring AGU meeting. Input provided by scientists, decision-makers, and other interested parties during the public comment periods will also be used to inform the product development. In addition, the lead authors will solicit input from other experts, the applications community, and other stakeholders throughout the preparation of the synthesis report.

5. Drafting

The lead authors will draft answers to the key questions in their respective sections. They will also prepare an introductory section to describe the topic, the audience, and the intended use of this product. The coordinating lead author for each section may assign primary responsibility for drafting the text associated with a question to a specific contributing author. The lead authors will be responsible for incorporating materials from contributing authors in the draft product.

After the product is drafted, the lead authors (or coordinating lead author and the authors responsible for each of the questions) will write a non-technical summary. Lead and contributing authors will base their writing on published, peer-reviewed scientific literature. Where appropriate, the product and its non-technical summary will identify disparate views.

6. Review

The public is invited to nominate Expert Reviewers to participate in the peer review of the draft of CCSP Synthesis and Assessment Product 1.3. Nominations should be sent to Dr. Randall M. Dole, NOAA and IQA Lead Agency representative, at the address given in Section 2 of this prospectus. The reviewer nomination deadline is June 30, 2006. Nominations must include an up-to-date curriculum vitae and listing of publications. As IQA Lead Agency, NOAA will ensure that selected reviewers are technically qualified, as demonstrated by scientific experience, published work, and stature within and across the scientific community. NOAA will ensure that the slate of reviewers reflects a balance of scientific and technical perspectives. NOAA will also be responsible for screening the nominees for real or perceived conflict of interest and independence from NOAA and other agencies contributing to this report. Peer reviewers who are Federal employees will be subject to Federal requirements governing conflict of interest [see 18 U.S.C. 208, 5 C.F.R. Part 2635 (2004)]. Reviewers who are not Federal employees will be screened pursuant to the National Academy of Sciences policy for committee selection with respect to conflict of interest.

The Expert Review will include at least seven technical experts who will submit comments similar to those solicited as part of a journal peer review. In addition, at least three independent reviews will be obtained from non-climate scientists, selected by NOAA, to comment on how understandable and useful the draft product is to non-specialists.

NOAA will provide a charge statement for reviewers, which will be distributed with the draft product and posted at NOAA's Information Quality Act (IQA) site, and linked and/or replicated on the CCSP web site <http://www.climatescience.gov>. The charge statement will be posted on the above sites by June 1, 2006. The names and affiliations of the reviewers that are selected, as well as their unattributed comments, will be posted on these sites. Reviewers will be asked to use the following questions in formulating their comments:

1. Is the charge clearly described in the report? Are all aspects of the charge fully addressed? Do the authors go beyond their charge or their expertise?
2. Are the conclusions and recommendations adequately supported by evidence, analysis, and argument? Are uncertainties or incompleteness in the evidence explicitly recognized? If any recommendations are based on value judgments or the collective opinions of the authors, is this acknowledged and are scientifically defensible reasons given for reaching those judgments?

3. Are the data and analyses handled competently? Are statistical methods applied appropriately?
4. Are the report's exposition and organization effective? Is the title appropriate?
5. Is the report fair? Is its tone impartial and devoid of special pleading?
6. Does the executive summary concisely and accurately describe the key findings and recommendations? Is it consistent with other sections of the report?
7. Are signed papers or appendices, if any, relevant to the charge? If the report relies on signed papers to support consensus findings or recommendations, do the papers meet criterion 3 above?
8. What other significant improvements, if any, might be made in the report?

Following the Expert Review, the lead authors will revise the draft product by incorporating comments and suggestions from the reviewers, as the lead authors deem appropriate. NOAA will prepare a written response to the peer reviewers' comments explaining its agreement or disagreement with the views of the peer reviewers; the actions taken in response to the peer review; and the reasons why those actions respond to the peer reviewers' key concerns. Next, the draft product will be released for public comment following the CCSP guidelines. The Public Comment Period will be 45 days. The lead authors will prepare a third draft of the product, taking into consideration the comments 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 determines that further revision is necessary, their comments will be sent to NOAA and supporting agencies for consideration and resolution by the lead authors. If needed, NOAA may ask the National Research Council (NRC) to provide additional scientific analysis to bound scientific uncertainty associated with specific issues. Once the CCSP Interagency Committee has determined that the report has been prepared in conformance with the CCSP guidelines, the IQA, and FACA, it will submit the report to the National Science and Technology Council (NSTC) for final review and approval. The CCSP Interagency Committee in consultation with the lead and supporting agencies and the lead authors will address issues raised during the NSTC review.

7. Communications

Once NSTC clearance has been obtained, NOAA will coordinate publication and release of the Synthesis and Assessment Product. The published report will follow the standard format for all CCSP Synthesis and Assessment Products.

8. Proposed Timeline

Step	Expected Completion Date
Prospectus	
Drafting	June 2005
CCSP Review	November 2005
Public Comment	January 2006
Revised Draft	February 2006
Clearance	March 2006
Stakeholder Interactions	
AGU Session	May 2006
Reanalysis Workshop	June 2006
Drafting	
Initial Draft	December 2006
Final Draft	June 2007
Review	
Expert Review	January 2007
Public Comment	March 2007
CCSP Review	July 2007
NSTC Clearance	October 2007
Communications	
Communications Plan	June 2007
Hardcopy Production	November 2007
Web Production	November 2007
Dissemination	February 2008

Acronyms

AGU	American Geophysical Union
CCSP	Climate Change Science Program
DAO	Data Assimilation Office (NASA)
DOE	Department of Energy
ECPC	Experimental Climate Prediction Center
ENSO	El Niño–Southern Oscillation
ERA-40	40-year European Reanalysis
GMAO	Global Modeling and Assimilation Office (NASA)
NASA	National Aeronautics and Space Administration
NAO	North Atlantic Oscillation
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NCO	NOAA Climate Office
NOAA	National Oceanic and Atmospheric Administration
NSTC	National Science and Technology Council

Appendix A. Biographical Summaries for Proposed Authors

Phillip Arkin

Dr. Arkin is Deputy Director and Senior Research Scientist at the Earth System Science Interdisciplinary Center (ESSIC) of the University of Maryland. He helps to administer ESSIC and conducts research into the observation and analysis of precipitation and other aspects of the hydrological cycle of the global climate system. Until January 2002, he served as Program Manager for Climate Dynamics and Experimental Prediction in the Office of Global Programs at NOAA, where he managed the Applied Research Centers that provide the research and development that enable NOAA to provide better climate forecasts. From 1998-2000, he served as the Deputy Director of the International Research Institute for Climate Prediction (IRI) at Columbia University. He has spent the last 25 years working at NOAA as a research scientist and administrator in various parts of the climate community, including the Climate Prediction Center, the Office of Global Programs and the National Centers for Environmental Prediction. He invented the GOES Precipitation Index, a method for estimating rainfall from geostationary satellite observations, and led the Global Precipitation Climatology Project from 1985-1994. His B.S. in mathematics and M.S. and Ph.D. in meteorology are from the University of Maryland. Dr. Arkin has published more than 50 refereed papers in scientific journals, 22 atlases and chapters in books, and has had more than 100 non-refereed publications. He has served as a member of many national and international scientific panels, and has presented invited papers at more than 100 workshops and scientific meetings.

James Carton

Professor Carton is director of the graduate program and Associate Chair of the Department of Atmospheric and Oceanic Science at University of Maryland. His research includes the ocean's role in tropical climate variability on seasonal to decadal timescales. He received an undergraduate degree in Electrical Engineering from Princeton, an MS in Oceanography from University of Washington, and MA and PhD degrees from Princeton's program in Atmospheric and Oceanic Sciences, graduating in 1983. He was a postdoctoral fellow at Harvard until 1985 when he joined the faculty at University of Maryland. Professor Carton's research has had two major foci in the past decade. The first is to understand the sources of climate variability in the tropical Atlantic sector. The countries of the tropical Atlantic are subject to floods and droughts with substantial interannual and decadal variability. Evidence suggests that part, perhaps much of the memory in this system reflects the ocean's ability to store and redistribute heat. Work on this subject is summarized in a book last year, "Earth's Climate: the Ocean-Atmosphere Interactions", co-edited by Professor Carton. The second focus is his SODA effort to develop reanalyses of ocean circulation to complement the atmospheric reanalyses. Professor Carton has an active teaching program that has produced 9 PhDs and 22 Masters Degrees. Professor Carton is also active in international science, currently serving on the steering committees of the Community Climate System Science effort, the JASON altimeter and US CLIVAR.

Paul A. Dirmeyer

Dr. Dirmeyer received his Ph.D. from the University of Maryland in 1992. Dr. Dirmeyer conducts research on the role of the land surface in the climate system. This includes the development and application of land-surface models, studies of the impact of land surface variability on the predictability of climate, interactions between the terrestrial and atmospheric branches of the hydrologic cycle, and the impacts of land use change on regional and global climate. He has published more than 50 peer-reviewed papers and book chapters. He is chair of the GEWEX Global Land-Atmosphere System Study (GLASS) and the GEWEX Global Soil Wetness Project (GSWP), a member of the interagency Global Water Cycle Panel (GWCP) Science Steering Group, the International Geosphere-Biosphere Programme (IGBP) Integrated Land Ecosystem-Atmosphere Process Study (ILEAPS) Scientific Steering Committee, and the American Meteorological Society (AMS) Committee on Hydrology.

Martin P. Hoerling

Dr. Hoerling is a research meteorologist in NOAA's Climate Diagnostics Center located in Boulder, Colorado. His research interests include climate variability on seasonal to centennial time scales, focusing on air-sea interactions such as related to El Nino/Southern Oscillation, and the role of oceans in decadal climate variation and climate change. He received his Bachelors, Masters, and Ph.D. degrees from the University of Wisconsin-Madison, graduating in 1987. He is principal investigator on several research projects to understand the causes and origins for seasonal to centennial global climate variations, including North Atlantic climate change since 1950 (CLIVAR-ATL), and the factors controlling low frequency North Pacific-North American climate variations (CLIVAR-Pacific). He is also active in research on seasonal climate predictability and predictions, working in collaboration with operational prediction centers at the National Centers for Climate Prediction, Lamont-Doherty's International Research Institute, and the NASA Seasonal-to-Interannual Prediction Project (NSIPP). Dr. Hoerling has led a NOAA-funded program to explore and develop regional climate services. He has served as project manager for the climate component of NOAA's Regional Integrated Science Assessment on Water, Climate and Society in the Interior Western United States that is studying the region's sensitivity and responses to climate variations, and the need for climate information by regional decision makers. Dr. Hoerling has served as Editor for the American Meteorological Society’s *Journal of Climate*.

Eugenia Kalnay

Professor Kalnay became a Distinguished University Professor at the University of Maryland in 2002 after chairing the Department of Meteorology for 3 years. Previously she was the Lowry Professor at the University of Oklahoma (1999-2000), Director of the Environmental Modeling Center (EMC) of the NOAA National Centers for Environmental Prediction (1987-1996), and a member and later Head of the 911 Branch at NASA/Goddard that later became the GMAO (1979-1986). While she was director of EMC many improvements of the numerical models and methods of data assimilation were developed and implemented, including the widely used NCEP-NCAR Reanalysis. She has written about 100 peer reviewed papers, and published a book, *Atmospheric Modeling, Data Assimilation and Predictability* (2003), which is on its third printing. She has received several gold medals from NASA and NOAA, the Charney Award from the AMS, and was elected member of the National Academy of Engineering in 1995.

Masao Kanamitsu

Dr. Kanamitsu received his Ph.D. in meteorology from Florida State University in 1973. He is currently a Senior Scientist at the Experimental Climate Prediction Center at the Scripps Institute of Oceanography. Dr. Kanamitsu has been the Chief of the Weather and Climate Modeling Branch at the National Centers for Environmental Prediction (NCEP), and a Senior Scientist at the Climate Prediction Center. He played a major role in the implementation and execution of the first and second reanalysis projects at NCEP and was a member of the ERA-40 advisory committee. He has been a visiting scientist at the Japan Meteorological Agency, European Center for Medium Range Weather Forecasts, and Australian Numerical Meteorology Research Centre. He has served as an Editor for *Journal of the Meteorological Society of Japan*, and for *Monthly Weather Review*. Dr. Kanamitsu has published more than 50 papers in peer-reviewed journals. His research interests include climate modeling, seasonal predictions, reanalysis, and land-surface processes.

David Karoly

Professor Karoly is Williams Chair Professor of Meteorology at the University of Oklahoma. He joined the University of Oklahoma in January 2003 from Monash University, Melbourne, Australia, where he was Professor of Meteorology and Head of the School of Mathematical Sciences. He was Director of the Cooperative Research Centre for Southern Hemisphere Meteorology at Monash University from 1995-2000. He is active in research into the dynamics of the large-scale circulation of the atmosphere and its variability on time scales from days to decades. Specific research interests include climate change, stratospheric ozone depletion and interannual climate variations due to the El Nino-Southern Oscillation. He is a member of a number of international and national committees, including the World Meteorological Organization Expert Team on Climate Change Detection, Monitoring and Indices, the Council of the American Meteorological Society (AMS), and the UCAR University Relations Committee. He was Coordinating Lead Author of the chapter "Detection of Climate Change and Attribution of Causes" in the third scientific assessment of climate change prepared by the Intergovernmental Panel on Climate Change. He is a Lead Author for the chapter "Assessment of Observed Changes and Responses in Natural and Managed Systems" in the IPCC Fourth Assessment report to be published in 2007. In 1993, Professor Karoly received the Meisinger Award from the AMS, with citation "for contributions to the understanding of the role of Rossby wave propagation in atmospheric teleconnections and to greenhouse climate change research." In 1999, he was elected a Fellow of the AMS for outstanding contributions to the atmospheric sciences over a substantial period of years. He is currently a member of the NRC's Climate Research Committee.

Arun Kumar

Dr. Arun Kumar received his PhD in Meteorology from Florida State University in 1990. Since October 2002, he has been the Deputy Director of Climate Prediction Center, National Centers for Environmental Prediction. Dr Kumar's research interests include analysis of climate variability and predictability, attribution of the causes for climate variability, analysis of climate models, and seasonal climate predictions. His research collaborators include scientists from the Climate Diagnostics Center, International Research Institute, Geophysical Fluid Dynamics Laboratory, and University of Washington, among others. He has published more than 50 research papers in peer-reviewed journals. He currently holds the position of Secretary for the Atmospheric Physics & Climate section of the American Geophysical Union. He has been a member of the science advisory boards of several research groups and has participated in several review panels.

Roger S. Pulwarty

Dr. Roger S. Pulwarty is a research scientist at the University of Colorado Cooperative Institute for Research in Environmental Sciences (CIRES). Dr. Pulwarty received his Ph.D. in 1994 from the University of Colorado. His research expertise is on the design of effective services to address weather and climate-related risks. Dr. Pulwarty's publications have focused on (1) hydroclimatic variability and change, 2) assessing social vulnerability and capacity to respond to climatic variations and weather extremes, and (3) the use of research-based information in natural resources policy and decision-making in the Western U.S., Latin America, and the Caribbean. From 1998 to 2002, Dr. Pulwarty led the development of the NOAA/Office of Global Programs/Regional Integrated Sciences and Assessments (RISA) Program. In addition to federal agencies and the National Research Council, Dr. Pulwarty has acted in advisory capacities to the Organization of American States (Sustainable Development Unit), the World Bank, the governments of Venezuela, Fiji, CARICOM (the Caribbean Economic Community) countries, and the Western Governors Association. Dr. Pulwarty chairs the American Meteorological Society's Board on Societal Impacts, is Deputy Director of the Western Water Assessment Project, and directs the vulnerability assessment component of the World Bank/GEF funded multi-country project on Mainstreaming Adaptation to Climate in the Caribbean. He is a lead author on chapters in the IPCC Fourth Assessment Report Working Group 2 and in the Millennium Ecosystem Assessment. Dr. Pulwarty is also a member of the U.S. Inter-Agency Water Sciences Committee and the North American Regional Reanalysis Advisory Group.

Siegfried D. Schubert

Dr. Siegfried D. Schubert received his Ph. D. in Meteorology from the University of Wisconsin-Madison in 1983. His research interests include climate variability and predictability, droughts, hydrological cycle, extreme events, and reanalysis. Dr. Schubert has authored or co-authored 60 papers in peer reviewed journals. He is currently the head of the Sub-Seasonal-to-Decadal group at the Global Modeling and Assimilation Office at NASA/Goddard Space Flight Center. He organized and directed NASA’s first reanalysis projects. He has served on the science working group of the North American Monsoon Experiment, and has been a member of international APEC Climate Network (APCN) working group. He has served as an Editor for the *Journal of Climate*.