CCSP Synthesis and Assessment Product 1.3

SAP-1.3

Prospectus for

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

U.S. Climate Change Science Program

Lead Agency
National Oceanic and Atmospheric Administration

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Department of Energy
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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 1.3

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

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

This prospectus provides a 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 decisionmakers and policymakers 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 report will be in the form of a synthesis and assessment product 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 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 are now advancing to create reanalyses for the ocean, land surface, and the coupled climate system, and so emerging capabilities and initial findings will also be discussed for these areas.

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

- What is a climate reanalysis, and what role does reanalysis play within a comprehensive climate observing system?
- What can reanalysis tell us about climate forcing and the veracity of climate models?
- What is the capacity of current reanalyses to help us identify and understand major seasonal-to-decadal climate variations, including changes in the frequency and intensity of climate extremes such as droughts?
- To what extent is there agreement or disagreement between climate trends in surface temperature and precipitation derived from reanalyses and those derived from independent data?
- What steps would be most useful in reducing spurious trends and other major uncertainties in describing the past behavior of the climate system through reanalysis methods? Specifically, what contributions could be made through improvements in data recovery or quality control, modeling, or data assimilation techniques?

The primary value of this section of the report 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 from 1948 to the present, and will focus on climate variations and changes over the North American region. The emphasis of this section will be on advances in our understanding of the causes of major climate variations over this region and period 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 follow:

- What is climate attribution, and what are the scientific methods used for establishing attribution?

- What is the present understanding of the causes for North American climate trends in annual temperature and precipitation during the reanalysis record?
- What is the present understanding of causes for seasonal and regional differences in U.S. temperature and precipitation trends over the reanalysis record?
- What is the nature and cause of apparent rapid climate shifts, having material relevance to North America, over the reanalysis record?
- What is our present understanding of the causes for high-impact drought events over North America over the reanalysis record?

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 U.S. climate trends 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.

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 follow:

NOAA (Lead) Dr. Randall M. Dole
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DOE Dr. Rick Petty
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Phone: 301-903-5548

3. Lead Authors: Required Expertise and Biographical Information

Appendix A provides brief biographies for each of the proposed authors. As needed, 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, Earth System Research Laboratory) is the proposed lead author for Section 2.

3.2. Contributing Authors

Proposed contributing authors follow:

- Dr. Phil Arkin (University of Maryland)
- Dr. James Carton (University of Maryland)
- Dr. Gabriele Hegerl (Duke University)
- Dr. Eugenia Kalnay (University of Maryland)
- Dr. David Karoly (University of Oklahoma)
- Dr. Randal Koster (NASA, Global Modeling and Assimilation Office)
- Dr. Arun Kumar (NOAA, Climate Prediction Center)

- Dr. Roger Pulwarty (NOAA, Climate Program Office)
- Dr. David Rind (NASA, Goddard Institute for Space Sciences).

4. Stakeholder Interactions

Stakeholder interactions have been initiated and additional opportunities are proposed throughout the process. In April 2005, the National Research Council (NRC) Climate Research Committee (CRC) was briefed on planning efforts on the nature and scope of the synthesis and assessment product. Informal comments received from CRC members at the meeting provided useful input toward development of this product. 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 was convened in September 2005 on "The Development of Improved Observational Data Sets for Reanalysis: Lessons Learned and Future Directions". Additional sessions related to this report are planned for the AGU Fall 2006 meeting and the American Meteorological Society (AMS) Annual Meeting to be held in January 2007. Input provided by scientists, decisionmakers, and other interested parties during the public comment periods will also be used to inform 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 CCSP Synthesis and Assessment Products are classified as "highly influential" under the terms of the Office of Management and Budget's Final Information Quality Bulletin for Peer Review (issued 16 December 2004). The review process will be conducted in accordance with the OMB guidelines, which include making the peer review plan web accessible.

NOAA, the lead agency for this product, plans to present Synthesis and Assessment Product 1.3 to the NRC for scientific review. The reviewers, who will be selected by the NRC, will be charged to focus on the scientific and technical content of the draft report to ensure that the report adequately answers the questions posed in the approved prospectus, that the report is objective, unbiased, and does not contain policy recommendations, and that the report is written at a level appropriate for the intended audience that will include government and private sector managers and decisionmakers.

Upon receipt of the expert review comments, all comments will be considered and addressed. The lead agency will disseminate the peer review report, including the agency's response to the review, on the agency's web site. A second

draft of the product will be prepared and released for a 45-day public comment period. The lead authors will prepare a third draft of the product in response to the public comments, incorporating changes, as appropriate.

The third draft of the document will be submitted to the CCSP Principals for final review and subsequent submission to the National Science and Technology Council (NSTC) for approval for release.

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	December 2005
Public Comment	January 2006
Revised Draft	September 2006
Clearance	November 2006
Stakeholder Interactions	
Reanalysis Workshop	September 2005
AGU Session	December 2006
AMS Special Session	January 2007
Drafting	
Initial Draft	June 2007
Final Draft	February 2008
Review	
NRC Review	December 2007
Public Comment	February 2008
CCSP Review	March 2008
NSTC Clearance	May 2008
Communications	
Communications Plan	May 2008
Hardcopy Production	June 2008
Web Production	June 2008
Dissemination	July 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.

Gabriel Hegerl
Professor Hegerl is an Associate Professor in the Earth and Ocean Sciences Division at Duke University. Her primary areas of research are the detection and attribution of climate variations and change due to natural and anthropogenic changes in radiative forcing (such as greenhouse warming, climate effects of volcanic eruptions and changes in solar radiation). Dr. Hegerl is also

an expert in the application of statistical techniques for climate research. Dr. Hegerl serves as a coordinating lead author for the chapter on "Detection and Attribution" for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, as well as on committees for the National Research Council and US CLIVAR.

Martin P. Hoerling
Dr. Hoerling is a research meteorologist in the NOAA Earth System Research Laboratory 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.

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.

Randal Koster
Dr. Koster joined NASA/GSFC in 1987 upon receiving his Sc.D. from M.I.T. His early work focused on the analysis of global water isotope geochemistry. Most of his professional career, though, has focused on the development of improved treatments of land surface physics for atmospheric general circulation models and on the analysis of interactions between the land and atmosphere using these models. With the advent of the Global Modeling and Assimilation Office in 2003, Koster was given the responsibility of coordinating the many disparate land surface modeling activities at GSFC. He has authored or co-authored over 70 refereed papers, and he currently serves on panels or subpanels for WCRP, CLIVAR, and GEWEX. He has served for the last several years as a lecturer for the climate program at George Mason University.

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 for the NOAA Climate Program Office, and is leading a Climate Project Office in Boulder, CO to develop a "National Integrated Drought Information System". 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.

David H. Rind
Dr. David Rind is a staff scientist at the NASA Goddard Institute for Space Sciences in New York, NY. Dr. Rind's expertise is in the application of observations and theory together with advanced climate models to ascertain causes of past changes and implications for future changes. Dr. Rind's work encompasses time scales ranging from paleoclimate variations to present climate and projections of future changes. Recent studies by Dr. Rind and colleagues include a review of water vapor feedbacks in climate models, examination of the roles of tropospheric and stratospheric changes on large-scale modes of climate variability like the Artic Oscillation/North Atlantic Oscillation, relative influences of solar and anthropogenic forcing, and impacts of sea ice on climate.

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*.