CCSP Synthesis and Assessment Product 1.1

SAP-1.1

Prospectus for

Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences

U.S. Climate Change Science Program

Lead Agency
National Oceanic and Atmospheric Administration (NOAA)

Contributing Agencies
National Aeronautics and Space Administration (NASA)
Department of Energy (DOE)
National Science Foundation (NSF)

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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 1.1**

Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences

Chief Editor: Thomas R. Karl
Associate Editors: Christopher D. Miller, William L. Murray

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

Independently produced data sets that describe the four-dimensional temperature structure from the surface through the lower stratosphere provide different temperature trends. These differences are seen in varying degrees in comparisons of separate *in situ* (surface and weather balloon) data sets, in comparisons of separate space-based data sets, and in comparisons of individual data sets drawn from the different observational platforms and different trend analysis teams.

This U.S. Climate Change Science Program (CCSP) synthesis and assessment product will address the accuracy and consistency of these temperature records and outline steps necessary to reconcile differences between individual data sets. Understanding exactly how and why there are differences in temperature trends reported by several analysis teams using differing observation systems and analysis methods represents a necessary step in reducing the uncertainties that underlie current efforts focused on the detection and quantification of surface and tropospheric temperature trends. Consequently, this synthesis and assessment product promises to be of significant value to decisionmakers, and to the expert scientific and stakeholder communities. For example, we expect this assessment to be a major contributor to the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* (due to be published in 2007). In addition, we expect the information generated will be used by the Global Climate Observing System Atmospheric Observation Panel to help identify effective ways to reduce observational uncertainty.

Recent efforts to address the uncertainties regarding the temperature structure of the lower atmosphere (i.e., from the surface through the lower stratosphere) have included release of a report under the auspices of the National Research Council (NRC) entitled "Reconciling Observations of Global Temperature Change" (NRC, 2000) and the IPCC *Third Assessment Report* (IPCC, 2001, pp 101-123). Although these documents provided a great deal of useful information, the complexities of the issue coupled with shortcomings of the available observing systems prevented resolution of a number of fundamental questions, including:

1) Why do temperatures vary vertically (from the surface to the stratosphere) and what do we understand about why they might vary and change over time?
2) What kinds of atmospheric temperature variations can the current observing systems measure and what are their strengths and limitations, both spatially and temporally?

*Product 1.1 drafting has taken place concurrent with completion of the prospectus, as the *Guidelines for Producing CCSP Synthesis and Assessment Products* were finalized. This approach was taken in order to coordinate work on the product with other international efforts—in particular, as input for the IPCC *Fourth Assessment Report* development process.

3) What do observations indicate about the changes of temperature in the atmosphere and at the surface since the advent of measuring temperatures vertically?
4) What is our understanding of the contribution made by observational or methodological uncertainties to the previously reported vertical differences in temperature trends?
5) How well can the observed vertical temperature changes be reconciled with our understanding of the causes of these changes?
6) What measures can be taken to improve the understanding of observed changes?

These questions provide the basis for the six main chapters in the synthesis and assessment product. They highlight several of the fundamental uncertainties and differences between and within the individual components of the existing observational and modeling systems. The responses to the questions will be written in a style consistent with major international scientific assessments [e.g., IPCC assessments, and the Global Ozone Research and Monitoring Project (WMO, 1999)].

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

NOAA is the lead agency for this synthesis product. Relevant agency personnel are presented in the following table:

CCSP Agency	Agency Leads
DOC (NOAA)	Tom Karl/Chris Miller/Bill Murray Thomas.R.Karl@noaa.gov Christopher.D.Miller@noaa.gov William.L.Murray@noaa.gov
DOE	Rick Petty Rick.Petty@science.doe.gov
NASA	Eric Fetzer Eric.J.Fetzer@jpl.nasa.gov
NSF	Jay Fein jfein@nsf.gov

3. Lead Authors: Required Expertise and Biographical Information

A list of lead author nominees was identified based on past records of interest and accomplishment in framing the core issues related to changes, trends, and uncertainties in the lower atmospheric temperature records, advancing relevant scientific arguments, and contributing to increased understanding of the behavior of respective components of the end-to-end system that provides the required data sets. Past contributions to relevant scientific assessments, success in peer-reviewed proposal funding competitions, and publication records in refereed journals are among the measures used in the selection process. The lead authors selected on the basis of these criteria are listed below. Chapter assignments and biographical information are presented in Appendix A.

Lead Authors

John Christy (University of Alabama/Huntsville)
Chris Folland (Hadley Centre, U.K. Met Office)
Chris Forest (Massachusetts Institute of Technology)
Jim Hurrell (National Center for Atmospheric Research)
John Lanzante (NOAA/Geophysical Fluid Dynamics Lab)
Carl Mears (Remote Sensing Systems)
Jerry Meehl (National Center for Atmospheric Research)
David Parker (U.K. Met Office)
Joyce Penner (University of Michigan)
Thomas C. Peterson (NOAA/National Climatic Data Center)
Roger Pielke Sr. (Colorado State University)
V. Ramaswamy (NOAA/Geophysical Fluid Dynamics Lab)
Dick Reynolds (NOAA/National Climatic Data Center)
Ben Santer (Lawrence Livermore National Laboratory)
Dian Seidel (NOAA/Air Resources Laboratory)
Steve Sherwood (Yale University)
Roy Spencer (University of Alabama-Huntsville)
Peter Thorne (Hadley Centre, U.K. Met Office)
Kostya Vinnikov (University of Maryland)
Russell S. Vose (NOAA/National Climatic Data Center)
Frank Wentz (Remote Sensing Systems)
Tom M.L. Wigley (National Center for Atmospheric Research)

4. Stakeholder Interactions

The questions addressed by the report were framed by the lead agency with the benefit of consultation from members of the Climate Change Science Program Office, the NOAA Science Advisory Board Climate Monitoring Working Group[1], and participants at a workshop on Reconciling Vertical Temperature Trends that was held at NOAA's National Climatic Data Center on 27-29 October 2003, and attended by 55 scientific experts from academia, the U.S. government, the private sector, and several scientific experts from other countries. The workshop was designed to address a broad range of issues related to vertical temperatures trends, and it provided a scientific foundation for the development of this CCSP synthesis product. The workshop presentations and results of breakout groups are posted on <http://www.ncdc.noaa.gov/oa/rvtt.html>. The workshop assessed the current state of knowledge on this topic, identified near-term and long-term steps to address existing uncertainties, and provided a framework for a synthesis and assessment product structured around the six questions listed above.

In addition, Principals on the CCSP Interagency Committee provided input from a governmental perspective during the CCSP review, and other stakeholders provided input during the public comment period (see <http://www.climatescience.gov/Library/sap/sap1-1/sap1-1prospectus-comments.htm> for a collation of the comments submitted during public comment period).

5. Drafting, including Materials to be Used in Preparing the Product

The lead NOAA focal point is the Product 1.1 Chief Editor. The assistant NOAA focal points serve as Associate Editors. The core of a scientific author team presented in Appendix A has been drawn from the participants in the workshop described above. This core group has been supplemented with a number of individuals who have made major contributions to our present understanding of the issues related to vertical temperature change.

Under the leadership of a convening lead author for each of the six chapters, this group of lead authors and contributors is charged with the preparation of the scientific/technical analysis section of the synthesis report. They will draw upon published, peer-reviewed scientific literature in the drafting process.

The synthesis and assessment product will include an Executive Summary which will present key findings from Chapters 1-6. It will be written by a team consisting of a convening lead author assisted by the convening lead authors from each of the six chapters.

The synthesis product will identify disparate views that have significant scientific or technical support, and will provide confidence levels for key findings, as appropriate.

This synthesis and assessment product will pay special attention to addressing uncertainties and confidence levels in our statements regarding the temperature trends. We note that increased understanding of the complexities of the vertical temperature variability can lead to increased uncertainties regarding long-term behavior patterns. Just as independent data sets must be used for comparisons of results, the basic evaluation process must maintain appropriate degrees of separation; for example, data set developers should not be the only evaluators of data reliability in their products.

The communication of uncertainties will be quantitative in many instances but, from discussion during the Asheville workshop, it is clear that expert judgment will also be used because standard statistical methods alone do not reflect the full range of uncertainty. Our intent is to follow the protocol developed in the IPCC (2001) assessment and subsequent updates provided by IPCC.

[1] The NOAA Science Advisory Board Climate Monitoring Working Group, which has since been merged with the Climate and Global Change Working Group, was charged to provide, in the context of national and international activities, scientific advice and broad program direction to NOAA on the condition and capabilities of NOAA's observing systems/data management systems for the purpose of climate monitoring.

6. Review

NOAA, the lead agency for this product, plans to present the document to an NRC expert committee for scientific review. The NRC Proposal (NAS Proposal No. 04-DELS-385-01) to conduct the review states that the review will address the following issues:

1) Are the goals, objectives, and intended audience of the product clearly described in the document? Does the product address all questions outlined in the prospectus?
2) Are findings and recommendations adequately supported by evidence and analysis? If any recommendations are based on value judgments or the collective opinions of the authors, is this acknowledged and are adequate reasons given for reaching those judgments?
3) Are the data and analyses handled competently? Are the statistical methods applied appropriately? Are the uncertainties and confidence levels evaluated and communicated appropriately?
4) Are the document's presentation and organization effective? Are the questions outlined in the prospectus addressed and communicated in a manner that is appropriate for the intended audience?
5) Is the document scientifically objective and policy neutral? Is it consistent with the scientific literature, including recent NRC reports and other scientific assessments on the same topic?
6) Does the summary concisely and accurately describe the content, key findings, and recommendations? Is it consistent with other sections of the document?
7) What other significant improvements, if any, might be made in the document?

The period of performance for the review is expected to be approximately January to April 2005.

Following expert review, the lead authors will revise the draft product by incorporating comments and suggestions from the reviewers, as the lead authors deem appropriate. Following this revision, the draft product will be released for public comment. The public comment period will be 45 days, and will take place from 1 June to 15 July 2005.

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 the revisions are complete, the lead agency will submit the synthesis and assessment product to the CCSP Interagency Committee for approval. If the CCSP Interagency Committee determines that further revision is necessary, their comments will be sent to the lead agency for consideration and resolution by lead authors. If needed, the NRC will be asked to provide additional scientific analysis to bound scientific uncertainty associated with specific issues.

If the CCSP Interagency Committee review determines that no further revisions are needed and that the product has been prepared in conformance with the *Guidelines for Producing CCSP Synthesis and Assessment Products* (see <http://www.climatescience.gov/Library/sap/sap-guidelines.htm>) and the Data Quality Act (including ensuring objectivity, utility, and integrity as defined in 67 FR 8452), they will submit the product to the National Science and Technology Council (NSTC) for clearance. Clearance will require the concurrence of all members of the Committee on Environment and Natural Resources. Comments generated during the NSTC review will be addressed by the CCSP Interagency Committee in consultation with the lead and supporting agencies and the lead authors.

7. Related Activities: Coordination with Other National or International Assessment Processes

This CCSP synthesis and assessment product has been coordinated internationally with a U.K. Met Office workshop on understanding vertical profiles of temperature trends conducted in September 2004 in Exeter, England. The coordination included presentations in Exeter by the synthesis and assessment product lead authors to provide an interim look at progress on addressing each of the key

questions. There is also ongoing coordination with a newly constituted Global Climate Observing System (GCOS)/ Atmospheric Observations Panel for Climate (AOPC) Working Group on Reconciling Vertical Temperature Trends. The synthesis and assessment product is expected to provide input to the IPCC *Fourth Assessment Report*.

8. Communications

NOAA, the lead agency, will produce and release the completed product using a standard format for all CCSP synthesis and assessment products. The final product and the comments received during the expert review and the public comment period will be posted, without attribution (unless specific reviewers agree to attribution), on the CCSP web site.

The lead authors will also be encouraged to publish their findings in the scientific literature.

9. Proposed Timeline

Preparation of this synthesis and assessment product has been underway during completion of this prospectus because of the time required to finalize the overall *Guidelines for Producing CCSP Synthesis and Assessment Products*. This approach was taken in order to coordinate work on the product with other international efforts, in particular, so the product could be completed in time to provide an input to the IPCC *Fourth Assessment Report*. Comments received on the draft prospectus were taken into account in the process, and all procedures used in preparing the report have been adjusted to be consistent with those mandated by the Guidelines.

The timeline is divided into two phases. The planned completion date for Phase 1, which will result in the submission of the first draft of the synthesis product for scientific review by the National Research Council, is January 2005. The planned completion date for Phase 2, which will culminate with approval of the synthesis product by the President's National Science and Technology Council, is October 2005. Specific milestones follow.

PHASE 1

- Lead authors nominated – July 04
- Synthesis product prospectus released for public comment – July 04
- First lead author meeting – August 04
- Second lead author meeting – October 04
- Third lead author meeting – December 04
- Synthesis product first draft submitted for NRC scientific review – January 05

PHASE 2

- NRC review completed – April 05
- Synthesis product second draft released for public comment – 1 June 2005
- Public comment period completed– 15 July 2005
- Synthesis product third draft and compilation of comments submitted to CCSP Principals – August 05
- Synthesis product accepted by CCSP and submitted to NSTC for final review and approval – September 05
- Synthesis product approved by NSTC – October 05

References

IPCC, 2001: Observed climate variability and change. In: *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, U.K.

NRC, 2000: *Reconciling Observations of Global Temperature Change*. National Research Council, Board on Atmospheric Sciences and Climate, Commission on Geosciences, Environment and Resources, National Academy Press, Washington D.C., 85 pp.

WMO, 1999: S*cientific Assessment of Ozone Depletion: 1998*. Global Ozone Research and Monitoring Project, Report #44. World Meteorological Organization, Geneva, Switzerland.

APPENDIX A – List of Synthesis Report Chapter Titles and Lead Authors

Chapter 1- Why do temperatures vary vertically (from the surface to the stratosphere) and what do we understand about why they might vary and change over time?

Convening Lead Author: V. Ramaswamy (NOAA/GFDL) – V. Ramaswamy is a Senior Scientist at the NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ. He is the Chair of the Stratospheric Temperature Trends Assessment (a project of the WCRP Stratospheric Processes and Their Role in Climate (SPARC) Project (1993-present). Dr. Ramaswamy has been a Lead Author on the WMO State-of-art Stratospheric Ozone Assessment (1992,1994,1998, 2002) and a Lead Author the United Nations-Intergovernmental Panel on Climate Change (1992,1994,1995, 2001). He has an extensive publication list and has received numerous awards including the Department of Commerce Gold Medal Award in 2002 for "world-renowned scientific contributions to the recently concluded state of the art assessment of the science of global change", and the World Meteorological Organization Norbert Gerbier MUMM Award – 2003 for the paper "Stratospheric Temperature Trends: Observations and Model Simulations" by V. Ramaswamy et al., published in Reviews of Geophysics, 39, 71-122, 2001. Other relevant publications include:

- Ramaswamy, V., M-L. Chanin, J. Angell, J. Barnett, D.Gaffen, M. Gelman, P. Keckhut, Y. Koshelkov, K. Labitzke, J-J. R. Lin, A. O'Neill, J. Nash, W. Randel, R. Rood, K. Shine, M. Shiotani, R. Swinbank, Stratospheric Temperature Trends: Observations and Model Simulations, Reviews of Geophysics, 39,1,71-122,2001.
- Ramaswamy V., and M.D. Schwarzkopf, Effects of Ozone and Well-Mixed Gases on Annual Mean Stratospheric Temperature Trends, Geophysical Research Letters, 10.1029/2002 GL015141,2002.

Lead Author: Jim Hurrell (NCAR) – Jim Hurrell is a senior scientist and deputy director of the Climate and Global Dynamics Division of the National Center for Atmospheric Research. His research has centered on empirical and modeling studies and diagnostic analyses to better understand climate, climate variability and climate change. He has authored or co-authored more than 60 peer-reviewed journal articles and book chapters, as well as dozens of other planning documents and workshop papers. His peer-reviewed publications include numerous articles on understanding and reconciling differences in surface versus tropospheric temperature trends, and in part for that work he received the Clarence Leroy Meisinger Award from the American Meteorological Society in 2001. Currently, Jim is extensively involved in the World Climate Research Programme on Climate Variability and Predictability (CLIVAR), and he serves as co-chair of Scientific Steering Committee of U.S. CLIVAR. Jim has also been involved in the assessment activities of the Intergovernmental Panel on Climate Change, and he has served on several National Research Council panels. Publications of particular relevance include the following:

- Hurrell, J. W., and K. E. Trenberth, 1996: Satellite versus surface estimates of air temperature since 1979. Journal of Climate, 9, 2222-2232.
- Hurrell, J. W., and K. E. Trenberth, 1998: Difficulties in obtaining reliable temperature trends: Reconciling the surface and satellite MSU records. Journal of Climate, 11, 945-967.

- Hurrell, J. W., S. J. Brown, K. E. Trenberth, and J. R. Christy, 2000: Comparison of tropospheric temperatures from radiosondes and satellites: 1979-1998. Bulletin of the American Meteorological Society, 81, 2165-2177.

Lead Author: Jerry Meehl (NCAR) – Gerald Meehl is a Senior Scientist at the National Center for Atmospheric Research. He is a member of the CLIVAR/WCRP Working Group on Coupled Models (WGCM) and is chairman of the Coupled Model Intercomparison Project, as well as chairman of the WGCM Climate Simulation Panel and co-chairman of the Community Climate System Model Climate Change Working Group. He has been prominent in the Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment activities. Dr. Meehl was a convening lead author of Chapter 9 in "Climate Change 2001: The Scientific Basis," produced as a contribution of Working Group 1 to the Third Assessment Report of the IPCC. He has written or co-authored several refereed articles on the topic of tropospheric and surface temperatures and has a long history of written publications in this area including:

- Meehl, G.A., W.M. Washington, C. Ammann, J.M. Arblaster, T.M.L. Wigley, and C. Tebaldi, 2004: Combinations of natural and anthropogenic forcings and 20th century climate. J. Climate, in press.
- Meehl, G.A., W.M. Washington, J.M. Arblaster, and A. Hu, 2004: Factors affecting climate sensitivity in global coupled models. J. Climate, 17, 1584--1596.

Chapter 2 – What kinds of atmospheric temperature variations can the current observing systems measure and what are their strengths and limitations, both spatially and temporally?

Convening Lead Author: John Christy (University of Alabama/Huntsville) –John R. Christy is Professor of Atmospheric Science at the University of Alabama in Huntsville, Alabama State Climatologist and Director of the UAH Earth System Science Center. He is/was a member of several National Research Council panels dealing with climate and space based observations and is currently on the NRC Committee on Environmental Satellite Data Utilization. He was selected as a Lead Author of the IPCC 2001 WG 1 (chapter on observations) and as a member of the panel which wrote the AGU Official Statement on Climate Change adopted in 2003. He has written several articles on surface, tropospheric and stratospheric temperatures, including basic construction methodology of conventional and spaced-based data sets, tests for their precision, and analysis of the climate products. His most recent paper "What may we conclude about tropospheric temperature trends?" will appear soon in Geophysical Research Letters. Other relevant publications include:

- Christy, J.R. and W.B. Norris, 2004: What may we conclude about tropospheric temperature trends? Geophys. Res. Lett., 31, No. 6, L0621.
- Christy, J.R. and R.W. Spencer, 2003: Reliability of satellite data sets. Science, 301, 1046-1047.
- Christy, J.R., R.W. Spencer, W.B. Norris, W.D. Braswell and D.E. Parker, 2003: Error estimates of Version 5.0 of MSU/AMSU bulk atmospheric temperatures. J. Atmos. Oceanic Tech. 20, 613-629.

Lead Author: Dian Seidel (NOAA Air Resources Laboratory) – Dian J. Seidel is a Research Meteorologist at NOAA's Air Resources Laboratory in Silver Spring, Maryland. She has contributed to IPCC Scientific Assessments, WMO/UNEP Scientific Assessments of the Ozone Layer, and scientific assessments by the WMO program on Stratospheric Processes and their Role in Climate. She is a former member of the NRC Climate Research Committee and contributed to several NRC reports, including "Reconciling Observations of Global Temperature Change" in 2000. She is a Fellow of the AMS and currently chairs its Committee on Climate Variability and Change. Her research on observed climate variations and change has focused on upper-air observations, particularly from radiosondes, and on data quality issues, and is reported in articles in peer-reviewed journals. Relevant publications include:

- Fu, Q., C.M Johanson, S.G. Warren, and D.J. Seidel, 2004: Contribution of stratospheric cooling to satellite-inferred tropospheric temperature trend, Nature, in press.
- Seidel, D.J., J.K. Angell, J. Christy, M. Free, S.A. Klein, J.R. Lanzante, C. Mears, D. Parker, M. Schabel, R. Spencer, A. Sterin, P. Thorne, and F. Wentz, 2004: Uncertainty in signals of large-scale climate variations in radiosonde and satellite upper-air temperature datasets. J. Climate, 17, 2225-2240.
- Seidel, D.J., and M. Free, 2003: Comparison of lower-tropospheric temperatures at low and high elevation radiosonde sites. Climatic Change, 59, 53-47.

Lead Author: Steve Sherwood (Yale University) – Steve Sherwood is an Assistant Professor at Yale University. He has published refereed articles on diverse topics relevant to the lower atmosphere temperature trend problem. These topics include moist instability and the physics of vertical (convective) and horizontal (baroclinic) heat transport within the tropical troposphere and tropopause region; the optimal estimation of small climate signals within imperfect datasets; and some performance characteristics of the VIZ and Vaisala radiosonde instruments. He was a contributing author to the 2000 SPARC report on upper troposphere/lower stratosphere water vapor. Relevant publications include:

- Sherwood, S. C., Climate signals from station arrays with missing data, and an application to winds. Journal of Geophysical Research, Vol. 105, No. D24, 2001, pp. 29,489-29,500.
- Sherwood, S.C. On moist stability. Monthly Weather Review, Vol. 128, No. 12, 2000, pp. 4139--4142.
- Sherwood, S.C. Convective precursors and predictability in the tropical Western Pacific. Monthly Weather Review, Vol. 127, No. 12, 1999, pp 2977-2991.

Chapter 3 – What do observations indicate about the changes of temperature in the atmosphere and at the surface since the advent of measuring temperatures vertically?

Convening Lead Author: John Lanzante (NOAA/GFDL) – John Lanzante is a research meteorologist at NOAA's Geophysical Fluid Dynamics Laboratory. He is a member of the working group charged by the Climate Change Science Program to produce a report defining science requirements for the next U.S. Reanalysis. In this regard, he has taken the lead in developing a plan for the temporal homogenization of data to be used as Reanalysis input. He recently led a project that produced a temporally homogenized radiosonde temperature dataset which is gaining wide use by climate-change scientists. In a spin-off project, these data are being used and updated to produce upper-air temperature climate monitoring products for NOAA. Some

of his past and current work also involves the use of radiosonde data in comparison with/evaluation of satellite data as well as output from climate models. He has been a lead or co-author on a number of refereed papers during the last 5-10 years relevant to the study of atmospheric trends. Relevant publications include:

- Lanzante, J., S. Klein, and D. Seidel, 2003: Temporal homogenization of monthly radiosonde temperature data. Part I: Methodology. Journal of Climate, 16(2), 224-240.
- Lanzante, J., S. Klein, and D. Seidel, 2003: Temporal homogenization of monthly radiosonde temperature data. Part II: Trends, Sensitivities, and MSU comparison. Journal of Climate, 16(2), 241-262.
- Gaffen, D., M. Sargent, R. Habermann, and J. Lanzante, 2000: Sensitivity of tropospheric and stratospheric temperature trends to radiosonde data quality. Journal of Climate, 13(10), 1776-1796.

Lead Author: Frank Wentz (Remote Sensing Systems (RSS)) – Frank Wentz is the Director of Remote Sensing Systems, a research company specializing in climate monitoring via satellites. Over the last 25 years, he has been one of NASA's leading principal investigators in the field of microwave remote sensing. Under his direction, Remote Sensing Systems is providing the climate community with research-quality climate datasets, including tropospheric temperature, sea-surface temperature and wind, and atmospheric moisture (water vapor, cloud water and rain). He has served on the National Research Council's Earth Studies Board and on the NRC Panel on Reconciling Temperature Observations. He has a long list of publications on remote sensing and its application to climate monitoring, including recent papers on tropospheric temperature and sea surface temperature including:

- Wentz, F.J. and M. Schabel, Effects of satellite orbital decay on MSU lower tropospheric temperature trends, Nature 394, 661-664, 1998.
- Wentz, F.J., and M. Schabel, Precise climate monitoring using complementary satellite data sets, Nature, 403 (6768), 414-416, 2000.
- Mears, C. A., M. C. Schabel and F. J. Wentz, A reanalysis of the MSU channel 2 tropospheric temperature record, Journal of Climate 16(22), 3650-3664, 2003.

Lead Author: Kostya Vinnikov (University of Maryland) – Dr. Konstantin Vinnikov is a Senior Research Scientist in the Department of Meteorology, University of Maryland. He emigrated from Russia in 1991 and is a US citizen. Dr. Vinnikov was the lead and contributing author of several Intergovernmental Panel on Climate Change (IPCC) reports. Dr. Vinnikov is an expert in empirical analysis of observed data on contemporary climate change. He was the first to detect a century-scale (0.5K/100 yr) global warming trend in surface air temperature data (Budyko and Vinnikov, 1976). This was at the time when other climatologists believed in the "observed" global cooling and in the approaching of a new "Little Ice Age." Now, almost three decades later, and after having been confirmed by many other research groups, the surface global warming trend is an accepted fact. Most recently, he developed new statistical techniques to analyze diurnal and seasonal cycles and trends in climatic records with arbitrary observation times (Vinnikov et al., 2004) and in multi-satellite overlapping observations. He applied these techniques to tropospheric temperature observations and found that the satellite-observed tropospheric air temperature trend agrees well with surface observations (Vinnikov and Grody, 2003). Relevant publications include:

- Budyko, M. I., and K. Y. Vinnikov, 1976: Global warming. *Soviet Meteorol. Hydrol., No.* **7**, 12- 20.
- Vinnikov Konstantin Y., and Norman C. Grody, 2003: Global warming trend of mean tropospheric temperature observed by satellites. *Science*, **302**, 269-272. - Vinnikov Konstantin Y., Alan Robock, Norman C. Grody, and Alan Basist, 2004: Analysis of diurnal and seasonal cycles and trends in climatic records with arbitrary observation times. *Geophysical Research Lett.,* **31**, L06205, doi:10.1029/2003GL019196.

Lead Author: Thomas C. Peterson (NOAA/NCDC) - Tom Peterson, a research meteorologist at NOAA's National Climatic Data Center, is currently a lead author on the IPCC's Fourth Assessment Report, a member of the GCOS Atmospheric Observation Panel for Climate, and chair of the WMO Commission for Climatology (CCl) OPAG (Open Programme Area Group) on the Monitoring and Analysis of Climate Variability and Change. He has served as a member of the National Research Council's Panel on Reconciling Temperature Observations, chair of the joint WMO CCl/CLIVAR Working Group on Climate Change Detection, contributing author to the IPCC Third Assessment Report and CCl's rapporteur on Statistical Methods for Climatology with emphasis on analyses of extreme events. The primary foci of his research and publications are on the creation of global climate datasets (both in situ and blended satellite/in situ datasets), assuring the fidelity of these data (e.g., quality control, homogeneity testing, and urban heat island contamination), and climate change analyses using these data. Relevant articles include:

- Peterson, Thomas C., 2003: Assessment of Urban Versus Rural In Situ Surface Temperatures in the Contiguous U.S.: No Difference Found. *Journal of Climate*, **18**, 2941-2959.
- Peterson, T. C., D. R. Easterling, T. R. Karl, P. Ya. Groisman, N. Nicholls, N. Plummer, S. Torok, I. Auer, R. Boehm, D. Gullett, L. Vincent, R. Heino, H. Tuomenvirta, O. Mestre, T. Szentimre, J. Salinger, E. Førland, I. Hanssen-Bauer, H. Alexandersson, P. Jones, D. Parker, 1998: Homogeneity adjustments of in situ atmospheric climate data: A review. *International Journal of Climatology*, **18**, 1493-1517.
- Peterson, Thomas C. and Russell S. Vose, 1997: An overview of the Global Historical Climatology Network temperature data base. *Bulletin of the American Meteorological Society*, **78**, 2837-2849.

Chapter 4 – What is our understanding of the contribution made by observational or methodological uncertainties to previously reported vertical differences in temperature trends?

Convening Lead Author: Carl Mears (Remote Sensing Systems) - Carl Mears is a Senior Scientist at Remote Sensing Systems. Over the past 5 years, Dr. Mears has led a comprehensive independent analysis of the atmospheric sounding data from MSU channels 2,3, and 4, the results of which was recently published in the Journal of Climate. This work was inspired by the significance of the MSU data set in climate change research, and the possibility of systematic errors in it. Dr. Mears has also made numerous contributions to the calibration and validation of geophysical retrievals from several other earth sensing satellites, including SSM/I, TMI, and QuikScat. In addition to this climate-related remote sensing work, Dr. Mears also has extensive past experience in microwave hardware design and lab-based calibration activities. Relevant publications include:

- Mears, C. A., M. Schabel, F. J. Wentz, B. D. Santer and B. Govindasamy (2002). "Correcting the MSU middle tropospheric temperature for diurnal drifts." Proceedings of the International Geophysics and Remote Sensing Symposium III: 1839-1841.
- Mears, C. A., M. C. Schabel and F. J. Wentz (2003). "A reanalysis of the MSU channel 2 tropospheric temperature record." Journal of Climate 16(22): 3650-3664.

Lead Author: Chris Forest (MIT) – Dr. Chris E. Forest is a Research Scientist at the Massachusetts Institute of Technology in the Joint Program on the Science and Policy of Global Change. He is a member of the American Meteorological Society and the American Geophysical Union and focuses his research on merging issues of climate change detection and uncertainties in future climate prediction. He has written several refereed articles on the topic of using tropospheric and surface temperature diagnostics to estimate uncertainty in future climate change and has a long history of publications in this area. His most relevant articles on this issue are:

- Forest, C.E., M.R. Allen, A.P. Sokolov, and P. H. Stone, Constraining Climate Model Properties Using Optimal Fingerprint Detection Methods., Clim. Dynamics, 18, p.277-295, 2001.
- Forest, C.E., P.H. Stone, A.P. Sokolov, M.R. Allen, and M.D. Webster, Quantifying Uncertainties in Climate System Properties with the Use of Recent Climate Observations, Science, 295, p.113-117, 2002.
- Webster, M., C. Forest, J. Reilly, M. Babiker, M. Mayer, R. Prinn, M. Sarofim, A Sokolov, P. Stone, and C. Wang, Uncertainty Analysis of Climate Change and Policy Response, Climatic Change, 61(3): p.295-320, 2003.

Lead Author: Roy Spencer (U. Alabama-Huntsville) - Roy W. Spencer is a Principal Research Scientist at The University of Alabama in Huntsville where he directs a research program on the use of satellite passive microwave measurements to monitor weather and climate variables. He is co-developer of the original method for monitoring global deep-layer temperatures from satellite microwave radiometers, and is the U.S. Science Team Leader for Advanced Microwave Scanning Radiometer - EOS flying on NASA's Aqua spacecraft. He has authored numerous papers on the global monitoring of temperature, precipitation, and water vapor including:

- Christy, J.R., R.W. Spencer, W.B. Norris, W.D. Braswell and D.E. Parker, 2003: Error estimates of Version 5.0 of MSU/AMSU bulk atmospheric temperatures. J. Atmos. Oceanic Tech. 20, 613-629.
- Christy, J.R., R.W. Spencer and W.D. Braswell, 2000: MSU tropospheric temperatures: Dataset construction and radiosonde comparisons. J. Atmos. Oceanic Tech. 17, 1153-1170.

Lead Author: Dick Reynolds (NOAA/NCDC) – Dr. Richard W. Reynolds is a Research Oceanographer at the National Climatic Data Center (NCDC), which is part of the US National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite Data and Information Service. In 1980 Dr. Reynolds began his career at NOAA as the lead scientist responsible for the development, implementation and operational production of sea surface temperature (SST) analyses and associated products and has continued working in this area for the past 18 years. He has been active in improving the accuracy of the SST analyses by optimizing the advantages of in situ and satellite data. He has recently led the development of an improved historical sea surface temperature analysis which has been produced from 1880 to present. He has also been involved in the evaluation of the sea surface temperature observing

system. In this project, the situ sea surface temperature network was evaluated to determine the minimum number of in situ observations needed to correct any potential satellite bias. This procedure is now operationally produced and is resulting in optimization of US buoy deployment strategies. Dr. Reynolds is also the principal investigator in the US efforts to improve the collection and archiving of surface marine data for the International Comprehensive Ocean-Atmosphere Data Set (I-COADS).

- Reynolds, R. W, C. Gentemann and F. Wentz, 2004: Impact of TRMM SSTs on a climate-scale SST analysis. J. Climate, 17 (in press).
- Smith, T.M., and R.W. Reynolds, 2004: Improved Extended Reconstruction of SST (1854-1997). J. Climate, 17, (in press)
- Smith, T.M., and R.W. Reynolds, 2004: A global merged land and sea surface temperature reconstruction based on historical observations (1880-1997). NOAA internal review. to be submitted to the Journal of Climate.

Lead Author: Russell S. Vose (NOAA/NCDC) – Dr. Russell S. Vose is the chief of the Climate Analysis Branch at NOAA's National Climatic Data Center. Over the past 15 years his research has primarily focused on the construction of "baseline" datasets for use in international climate assessments. The best example of this work is the Global Historical Climatology Network database, which is used operationally by NOAA to monitor long-term global temperature trends. Dr. Vose is also currently involved in the creation of gridded temperature fields for global land areas and in the optimum design of station networks for monitoring climatic change (e.g., the U.S. Climate Reference Network). Relevant publications include:

- Vose, R.S. and M.J. Menne. 2004. A method to determine station density requirements for climate observing networks. *Journal of Climate* **17**: 2961-2971.
- Vose, R.S., T.R. Karl, D.R. Easterling, C.N. Williams, Jr., and M.J. Menne. 2004. Impact of land-use change on climate. *Nature* **427**:213-214.
- Vose, R.S., C.N. Williams, T.C. Peterson, T.R. Karl, and D.R. Easterling. 2003. An evaluation of the time of observation bias adjustment in the U.S. Historical Climatology Network. *Geophysical Research Letters* **30**:10.1029/2003GL018111.

Chapter 5 – How well can the observed vertical temperature changes be reconciled with our understanding of the causes of these changes?

Convening Lead Author: Ben Santer (Lawrence Livermore National Laboratory) – Ben Santer is a Physicist at Lawrence Livermore National Laboratory, where he works in the Program for Climate Model Diagnosis and Intercomparison. He was a member of the National Research Council panel on "Reconciling Observations of Temperature Change", and was the Convening Lead Author of Chapter 8 ("Detection of Climate Change, and Attribution of Causes") of the 1995 Second Assessment Report of the Intergovernmental Panel on Climate Change. He currently serves as a member of the Scientific Steering Committee for the NCAR Community Climate System Model, the Climate Modeling Advisory Panel of the Goddard Institute for Space Studies, and the Science Review Group of the Hadley Centre for Climate Prediction and Research. He has written a number of peer-reviewed articles that deal with comparisons of modeled and observed atmospheric temperature trends including:

- Santer, B.D., T.M.L. Wigley, J.S. Boyle, D.J. Gaffen, J.J. Hnilo, D. Nychka, D.E. Parker, and K.E. Taylor, 2000: Statistical significance of trend differences in layer-average temperature time series. *J. Geophys. Res.*, **105**, 7337-7356.
- Santer, B.D., T.M.L. Wigley, D.J. Gaffen, L. Bengtsson, C. Doutriaux, J.S. Boyle, M. Esch, J.J. Hnilo, P.D. Jones, G.A. Meehl, E. Roeckner, K.E. Taylor and M.F. Wehner, 2000: Interpreting differential temperature trends at the surface and in the lower troposphere. *Science*, **287**, 1227-1232.
- Santer, B.D., T.M.L. Wigley, G.A. Meehl, M.F. Wehner, C. Mears, M. Schabel, F.J. Wentz, C. Ammann, J. Arblaster, T. Bettge, W.M. Washington, K.E. Taylor, J.S. Boyle, W. Brüggemann, and C. Doutriaux, 2003: Influence of satellite data uncertainties on the detection of externally-forced climate change. *Science*, **300**, 1280-1284.

Lead Author: Joyce Penner (U. Michigan) – Joyce Penner is a Professor at the University of Michigan. She is a member of the National Research Council Committee on Metrics for Global Change Research and has been prominent in the Intergovernmental Panel on Climate Change (IPCC) Scientific Assessment activities. Prof. Penner was a convening lead author of "Climate Change 2001: The Scientific Basis," produced as a contribution of Working Group 1 to the Third Assessment Report of the IPCC. She has written several refereed articles on the topic of aerosols and their climate effects and has also worked on publications (with B. Santer, lead) in the area of comparing temperature trends with data.

- Santer, B.D., K.E. Taylor, T.M.L. Wigley, T.C. Johns, P.D. Jones, D.J. Karoly, J.F.B.Mitchell, A.H. Oort, J.E. Penner, V. Ramaswamy, M.D. Schwarzkopf, R.J. Stouffer, and S. Tett, 1996: A search for human influence on the thermal structure of the atmosphere, Nature, 382, 39-46.
- Penner, J.E., T.M.L. Wigley, P. Jaumann, B.D. Santer, and K.E. Taylor, 1997: Anthropogenic aerosols and climate change: A method for calibrating forcing, in Assessing Climate Change: Results from the Model Evaluation Consortium for Climate Assessment, ed. by W. Howe and A. Henderson-Sellers, Gordon & Breach Science Publishers, Sydney, Australia, pp. 91-111.
- Penner, J.E., S.Y. Zhang, and C.C. Chuang, 2003: Soot and smoke aerosol may not warm climate, J. Geophys. Res., 108, D21, Art. No. 4657, doi: 10.1029/2003JD003409.

Lead Author: Peter Thorne (U.K. Met Office/Hadley Centre) – Peter Thorne is a research scientist within the Hadley Centre at the Met Office. In 2001 he completed his PhD "Advancing climate change detection and attribution studies in the free atmosphere", available on-line from the Climatic Research Unit at the University of East Anglia. Results from these analyses have since been published in GRL and Clim. Dyn. Since 2001 Peter has been working in the climate variability group at the Hadley Centre. Work there has focused on generation of a new globally gridded (although incomplete) radiosonde dataset using neighbour comparisons, and understanding the physical causes of reported vertical temperature structure changes. A number of papers describing this work are in preparation. Relevant publications include:

- Thorne, P. W., Jones, P. D., Osborn, T. J., Davies, T. D., Tett, S. F. B., Parker, D. E., Stott, P. A., Jones, G. S., and Allen, M. R., 2002 Assessing the robustness of zonal mean climate change detection studies. GRL. doi:10.1029/2002GL015717.
- Thorne, P. W., Jones, P. D., Tett, S. F. B., Allen, M. R., Parker, D. E., Stott, P. A., Jones, G. S., Osborn, T. J., and Davies, T. D., 2003 Probable causes of late 20th Century tropospheric temperature trends. Climate Dynamics 21 573-591.

Chapter 6 – What measures can be taken to improve our understanding of observed changes?

Convening Lead Author: Roger Pielke Sr. (Colorado State University) - Roger A. Pielke Sr. is a Professor in the Department of Atmospheric Science at Colorado State University. He is a member of the National Research Council's Committee on Radiative Forcing Effects on Climate, and is the immediate Past-President of the American Association of State Climatologists. In 2004 he was elected as a Fellow in the American Geophysical Union. He has published articles on global and regional tropospheric and surface temperature variability and trends, including several papers on the role of land use change and vegetation dynamics in influencing these variations. He is a co-author of a book published by Cambridge University Press with William R. Cotton on Human Impacts on Weather and Climate, with a second edition to be completed this year.

- Chase, T.N., R.A. Pielke Sr., B. Herman, and X. Zeng, 2004: Likelihood of rapidly increasing surface temperatures unaccompanied by strong warming in the free troposphere. Climate Res., 25, 185-190.
- Marshall, C.H. Jr., R.A. Pielke Sr., L.T. Steyaert, and D.A. Willard, 2004: The impact of anthropogenic land cover change on warm season sensible weather and sea-breeze convection over the Florida peninsula. Mon. Wea. Rev., 132, 28-52
- Davey, C.A., and R.A. Pielke Sr., 2004: Microclimate exposures of surface-based weather stations - implications for the assessment of long-term temperature trends. Bull. Amer. Meteor. Soc., submitted.

Lead Author: David Parker (U.K. Met Office) – David Parker manages a small group involved in research into observed climate variability at the Met Office's Hadley Centre. A particular focus is tropospheric temperature and humidity as observed by radiosondes and from satellites and comparisons with surface temperature and humidity. In 1999-2000 Mr Parker was a member of the National Research Council's Panel on Reconciling Temperature Observations, and is the author of one of the leading radiosonde temperature data sets. David has written many papers in the peer-reviewed literature on climate variability and climate observations. He has also contributed to the recent WMO Global Climate System Review and to the 2nd GCOS Report on the Adequacy of the Global Climate Observing System for the UN Framework Convention on Climate Change. Mr Parker was a Lead Author of the Supplementary and Second Assessments of the Intergovernmental Panel on Climate Change and a contributing author to the First and Third Assessments. Relevant publications include:

- Parker, D.E., Gordon, M., Cullum, D.P.N., Sexton, D.M.H., Folland, C.K. and Rayner, N., 1997: A new gridded radiosonde temperature data base and recent temperature trends. Geoph. Res. Letters, 24, 1499-1502.
- Parker, D.E., 2000: Temperatures high and low. Science, 287, 1216-1217.
- Rayner, N.A., Parker, D.E., Horton, E.B., Folland, C.K., Alexander, L.V, Rowell, D.P., Kent, E.C. and Kaplan, A., 2003: Global analyses of sea surface temperature, sea ice and night marine air temperature since the late nineteenth century. J. Geophys. Research (Atmospheres), 10.1029/2002JD002670.

Lead Author: Dick Reynolds (NOAA/NCDC) – Dr. Reynolds is also serving as a Lead Author on Chapter 4; his biographical information is listed under that Chapter.

Executive Summary

Convening Lead Author: Tom M.L. Wigley (NCAR) - Tom Wigley, a senior scientist at the National Center for Atmospheric Research, is one of the world's experts on climate change. He is a U.S. citizen, born and educated in Australia where he trained as a meteorologist with the Commonwealth Bureau of Meteorology. His Ph.D. is in Theoretical Physics. He has published widely in the field of climatology and related sciences. He is the author of more than 200 refereed journal articles and book chapters and is one of the most highly cited scientists in the field. He is a Fellow of the American Meteorological Society (AMS) and of the American Association for the Advancement of Science (AAAS). His main current interests include projections of future climate and sea-level change, carbon-cycle modeling, and the interpretation of past climate changes (including the detection of anthropogenic influences). He has contributed as an author to all Intergovernmental Panel on Climate Change assessments, and developed the MAGICC coupled gas-cycle/climate model that has been used to produce the primary temperature and sea level projections given in these assessments. He also authored 'The Science of Climate Change: Global and U.S. Perspectives' published by the Pew Center on Global Climate Change (<http://www.pewclimate.org/>). Wigley is the former Director of the Climatic Research Unit, University of East Anglia, Norwich, U.K. Relevant publications include:

- Wigley, T.M.L. and Raper, S.C.B., 2001: Interpretation of high projections for global-mean warming. Science 293, 451-454.
- Wigley, T.M.L., Smith, S.J. and Prather, M.J., 2002: Radiative forcing due to reactive gas emissions. Journal of Climate 15, 2690-2696.
- Wigley, T.M.L. and Raper, S.C.B., 2002: Reasons for larger warming projections in the IPCC Third Assessment Report. Journal of Climate.

Coordinating Lead Author – Comprehensive Document Review: Chris Folland, (Hadley Centre, U.K. Met Office) - Prof. Christopher Kenneth Folland, BSc CPhys CSCI FInstP, is Head of the Climate Variability Research Group at the Hadley Centre for Climate Prediction and Research, UK Met Office, and an Honorary Professor at the School of Environmental Sciences, University of East Anglia. Early in his career, Dr. Folland worked in oceanography. surface instrument development, and hydrometeorology. Since 1980, he has specialised in the scientific leadership of research into climate change and variability. This has included observed and modelled climate studies, as well as climate data set development and long range forecasting. He was a Lead or Coordinating Lead Author of the four Scientific Assessments of the Intergovernmental Panel on Climate Change between 1990 and 2001. He is a Fellow of the American Meteorological Society and a Meteorological Fellow of the Link Foundation of New Zealand. Dr. Folland's awards include the World Meteorological Organisation International Norbert Gerbier-MUMM Medal and Prize in 1996 for leading the UK Met Office research into tropical seasonal rainfall forecasting. He is co-chair of the WMO/CLIVAR Climate of the Twentieth Century modelling project and a member of the WMO/CLIVAR/CCl Expert Team on Climate Change Detection, Monitoring and Indices. Relevant publications include:

- Folland, C.K., N. Rayner, P. Frich, T. Basnett, D. Parker & E.B. Horton, 2000: Uncertainties in climate data sets - a challenge for WMO. WMO Bull.,49, 59-68.
- Folland, C.K., Rayner, N.A., Brown, S.J. Smith, T.M. Shen, S.S. Parker, D.E., Macadam, I., Jones, P.D., Jones, R.N., Nicholls, N. and Sexton, D.M.H., 2001: Global temperature change and its uncertainties since 1861. Geophys. Res. Lett., 106, 2621-2624.
- Rayner, N.A., Parker, D.E., Horton, E.B., Folland, C.K., Alexander, L.V., Rowell, D.P., Kent, E.C., and A. Kaplan, 2003: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. J. Geophys. Res., 108(D14), 4407, doi: 10.1209/2002JD002670, 2003. (29pp + 8 supplementary color pages).