PREFACE

Report Motivation and Guidance for Using this Synthesis/Assessment Report

A primary objective of the U.S. Climate Change Science Program (CCSP) is to provide the best possible scientific information to support public discussion and government and private sector decision-making on key climate-related issues. To help meet this objective, the CCSP has identified an initial set of 21 synthesis and assessment products that address its highest priority research, observation, and decision-support needs. This Synthesis/Assessment Report, the first of the 21 Reports, focuses on understanding the causes of the reported differences between independently produced data sets of atmospheric temperature trends from the surface through the lower stratosphere.

Background

Measurements of global surface air temperature show substantial increases over the past several decades. In the early 1990s, data from NOAA's polar orbiting satellites were analyzed for multi-decadal trends. These initial analyses indicated that temperatures in the troposphere showed little or no increase, in contrast with surface air measurements from ships, land-based weather stations, and ocean buoys. This result led some to question the reality and/or the cause of the surface temperature increase, on the basis that human influences, thought to be important contributors to observed change, were expected to increase temperatures both at the surface and in

the troposphere with larger increases expected in the tropical troposphere. This surprising result led to an intensive effort by climate scientists to better understand the causes of the apparent differences in the rates of temperature increase between the surface and the troposphere.

Scientists analyzing the data knew that there were complex and unresolved issues related to inadequacies of observing systems that could lead to misinterpretation of the data. There were also uncertainties in our understanding of how the climate might respond to various forcings as is often assessed through the use of climate models. In an attempt to resolve these issues, in 2000 the National Research Council specifically addressed the general issue of troposphere and surface derived temperature trends. In its Report, the NRC concluded that "the warming trend in global-mean surface temperature observations during the past 20 years is undoubtedly real and is substantially greater than the average rate of warming during the twentieth century. The disparity between surface and upper air trends in no way invalidates the conclusion that surface temperature has been rising." The NRC further found that corrections in the Microwave Sounding Unit (MSU) processing algorithms brought the satellite data record into slightly closer alignment with surface temperature trends. They concluded that the substantial disparity that remains probably reflects a less rapid warming of the troposphere than the surface in recent decades due to both natural and human-induced causes.

In 2001, the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report devoted additional attention to new analyses of the satellite, weather balloon, and surface data to evaluate the difference in temperature trends between the surface and the troposphere. Similar to the NRC, the IPCC concluded that it was very likely that the surface temperature increases were larger and differed significantly from temperature increases higher in the troposphere. They concluded, "during the past two decades, the surface, most of the troposphere, and the stratosphere have responded differently to climate forcings because different physical processes have dominated in each of the regions during that time." (IPCC; Climate Change 2001 The Scientific Basis, Chapter 2, p. 122-123; Cambridge University Press).

Focus of this Synthesis/Assessment Report

The efforts of the NRC and IPCC to address uncertainties about the temperature structure of the lower atmosphere (i.e., from the surface through the lower stratosphere) have helped move us closer to a comprehensive understanding of observed trends of temperature. Although these documents provided a great deal of useful information, full resolution of the issue was hampered by the complexities coupled with shortcomings of the available observing systems. To more fully address remaining fundamental questions, a broader examination has been undertaken here to answer the following questions:

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?

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 this Synthesis/Assessment Report (the chapter numbers correspond to the question numbers above). 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 are written in a style consistent with major international scientific assessments (e.g., IPCC assessments, and the Global Ozone Research and Monitoring Project of the World Meteorological Organization). The Executive Summary, which presents the key findings from the main body of the Report, is intended to be useful for those involved with the policy-related global climate change issues. The Chapters supporting the Executive Summary are written at a more technical level suitable for non-climate specialists within the scientific community and well-informed lay audiences.

To help answer the questions posed, climate model simulations of temperature change based on time histories of the forcing factors thought to be important, have been compared with observed temperature changes. If the models replicate the observed temperature changes, this increases confidence in our understanding of the observed temperature record and reduces uncertainties about projected changes. If not, then this implies that the time histories of the important forcings are not adequately known, all of the important forcings are not included, the processes being simulated in the models have serious flaws, the observational record is incorrect, or some combination of these factors.

This U.S. Climate Change Science Program Assessment/Synthesis Report assesses the uncertainties associated with the data used to determine changes of temperature, and whether such changes are consistent with our understanding of climate processes. This requires a detailed comparison of observations and climate models used to simulate observed changes, including an appreciation of why temperatures might respond differently at the surface compared to higher levels in the atmosphere.

This CCSP Report addresses the accuracy and consistency of the temperature records and outlines 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 different observation systems and analysis methods is a necessary step in reducing the uncertainties that underlie current efforts focused on the detection and quantification of surface and tropospheric temperature

trends.

New observations and analysis since the IPCC and NRC Reports

Since the IPCC and NRC assessments, there have been intensive efforts to create new satellite and weather balloon data sets using a range of approaches. Having multiple satellite data sets provides the opportunity for much greater understanding of observed changes and their uncertainty than was possible in the previous assessments. In addition, for the first time a suite of models simulating observed climate since 1979 (when satellite data began) has provided us a unique opportunity to inter-compare observed trends from various data sets with model simulations using various scenarios of historical climate forcings. Taken together, these advances lead to a much greater understanding of the issues.

The science of upper air temperature issues is a rapidly evolving field. During the preparation of this Report, new findings were published and have been included in the current draft, causing numerous changes from draft to draft. The authors certainly expect that new data and discoveries that follow the release of this Report, will further improve our understanding. Some open questions originally discussed in the first drafts of this Report were actually resolved during the deliberations. For example, a recent article cleverly demonstrated a subtle problem in the method used in one of the data sets to correct for satellite orbital drift. Since it was possible for the error to be rectified fairly quickly, a new satellite-derived version of lower

tropospheric temperatures was available for this Report. At the same time, another research team produced their first version of satellite-derived lower troposphere temperature, and yet another team updated their tropospheric temperature time series as the final drafts were written. All these results are included in this Report.

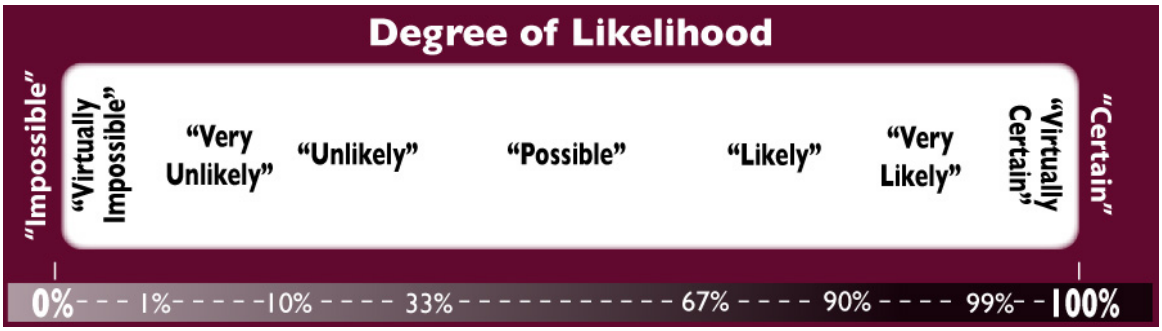
Factors that guided the authors in the selection of the climate records considered extensively in this Report were (a) publication heritage, (b) public availability, (c) use by the community at-large, (d) updated on a monthly basis, and (e) period of record beginning in 1979 or earlier. The three surface analyses that were used have many publications covering their construction methods. These data sets are readily available, and are widely used. Two of the three satellite data sets used, while relatively recent, are based on a heritage of published versions which have incorporated new adjustments as discoveries have been made. Each of these data sets allows ready access to the public and has been used in several research publications. A third, more recently developed, data set has been updated during the preparation of this Report. Two data sets used were based on weather balloon data. One of these data sets publicly appeared in 2005, but the authors had made the preliminary versions and methodology available to scientists as early as 2002 and have built upon the extensive experience acquired from previous versions of these data sets. Another data set has a heritage dating back several decades and was recently updated.

How to use this Synthesis/Assessment Report

This Report promises to be of significant value to decision-makers, and to the expert scientific and stakeholder communities. Readers of this Report will find that new observations, data sets, analyses, and climate model simulations enabled the Author Team to resolve many of the perplexities noted by the NRC and the IPCC in their earlier Reports. The Synthesis/Assessment Report already has had an important impact on the content of the draft to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), due to be published in 2007. In addition, we expect the information generated here will be used both nationally and internationally e.g., by the Global Climate Observing System Atmospheric Observation Panel to help identify effective ways to reduce observational uncertainty. The findings regarding observations and model-observation comparisons of lower stratospheric temperature trends will be useful for the 2006 WMO/UNEP Ozone Assessment.

Some terms used in the Report may be unfamiliar to those without training in meteorology; a glossary and list of acronyms is thus included at the end of the Report. Two sets of terms are useful to define at the outset since they are particularly fundamental to this Report. This includes a set of terms related to various levels of agreement or disagreement on key issues and findings among the expert Lead Authors as well as terminology describing their considered judgment about the likelihood of critical key results.

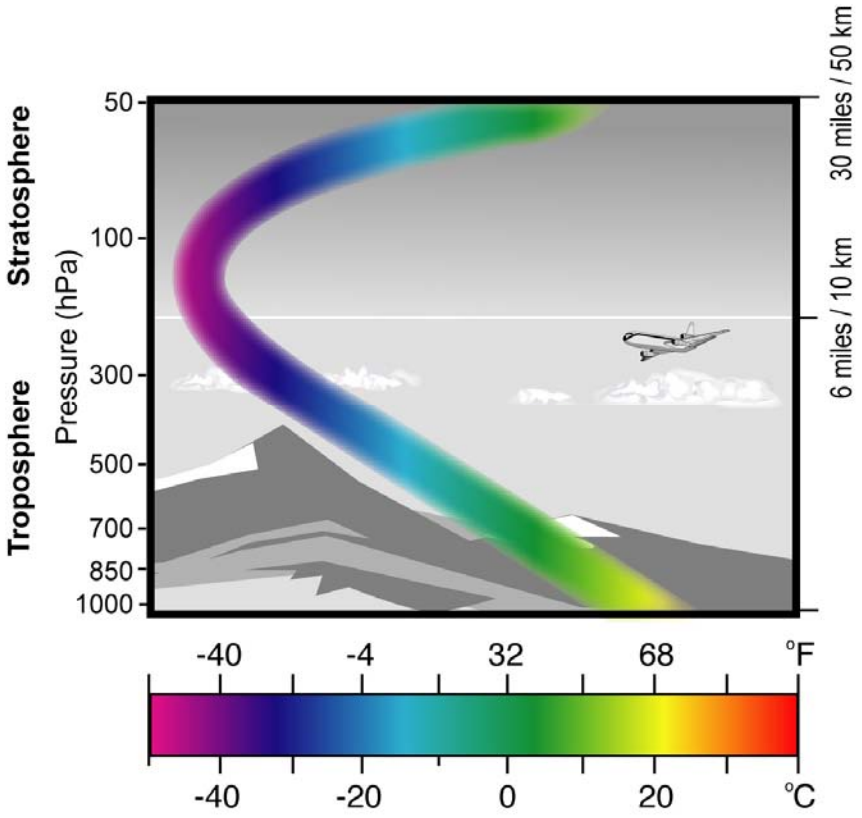
To integrate a wide variety of information, this Report also uses a lexicon of terms to express the team's considered judgment about the likelihood of results. Confidence in results is highest at each end of the spectrum. Unless otherwise noted, all statements are certain.



Preface figure 1

This illustration shows the layers of the atmosphere of primary interest to this Synthesis/Assessment Report. The multi-colored line on this diagram indicates the variations in temperature with altitude. The chart beneath the diagram defines the

terminology used in this Report for the layers of the atmosphere.



Preface figure 2

Terms for Layers of the Atmosphere Used in this Report

Preface table 1

Common Term	**Abbrev. Term for the temperature of that layer**	**Main region of Influence**	**Approximate altitude. (For satellite products: altitude range of bulk (90%) of layer measured.)**	**Lower and upper pressure level boundaries**
Surface	T_S	Air: Just above surface Water: Shallow depth	Surface Air: Land: 1.5 –2.0 m above surface; Ocean: ship deck-height (5 – 25 m) above surface. Surface Water: 1 – 10 m depth in ocean (SSTs)	Surface (or ~1000 hPa at sea level)
Lower Troposphere	T_{2LT}	Low to Mid-Troposphere	Surface – 8 km	Surface to 350 hPa
Troposphere (radiosonde)	$T_{(850-300)}$	Troposphere	1.5 – 9 km	850 – 300 hPa
Troposphere (satellite)	T^*_G	Troposphere	Surface – 13 km	Surface – 150 hPa
Tropical Troposphere (satellite)	T^*_T	Troposphere (tropics only)	Surface – 16 km	Surface – 100 hPa
Mid Troposphere to Lower Stratosphere	T_2	Mid and upper Troposphere to Low Stratosphere[1]	Surface – 18 km	Surface – 75 hPa
Lower Stratosphere (satellite)	T_4	Low Stratosphere	14 – 29 km	150 – 15 hPa
Lower Stratosphere (radiosonde)	$T_{(100-50)}$	Low Stratosphere	17 – 21 km	100 – 50 hPa

Note: Abbreviated terms --- Subscript 'S', refers to the Surface. Subscripts '2' and '4' refer to MSU data from channels 2 and 4. Subscript '2LT' refers to a modification of channel 2 data to focus more directly on the Lower Troposphere and reduce the influence of stratospheric temperatures on channel 2 data. Subscripts '850–300' and '100–50' are specific atmospheric layers sampled by radiosondes. Subscript '$*_G$' refers to a combination of channel 2 and channel 4 data derived by Fu and co-workers, applicable to

[1] Only about 10% of this layer extends into the lower stratosphere

global averages, and '$*_T$' refers to applicable tropical averages. For the model-observation comparisons, the observation-based definitions as listed in the Table were employed.

The Authoring Team

A full list of this Reports' authoring team (in addition to a list of lead authors provided at the beginning of each Chapter) is provided in an Appendix at the end of this Report. The focus of this Report follows the Prospectus developed by the Climate Change Science Program and posted on its website at http://www.climatescience.gov.