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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

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

28

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

45

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

56

57 **Focus of this Synthesis/Assessment Report**

58

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

- 67 1) Why do temperatures vary vertically (from the surface to the stratosphere)
68 and what do we understand about why they might vary and change over
69 time?
70

- 71 2) What kinds of atmospheric temperature variations can the current
72 observing systems measure and what are their strengths and limitations,
73 both spatially and temporally?
74
- 75 3) What do observations indicate about the changes of temperature in the
76 atmosphere and at the surface since the advent of measuring temperatures
77 vertically?
78
- 79 4) What is our understanding of the contribution made by observational or
80 methodological uncertainties to the previously reported vertical differences
81 in temperature trends?
82
- 83 5) How well can the observed vertical temperature changes be reconciled with
84 our understanding of the causes of these changes?
85
- 86 6) What measures can be taken to improve the understanding of observed
87 changes?
88

89 These questions provide the basis for the six main chapters in this
90 Synthesis/Assessment Report (the chapter numbers correspond to the question
91 numbers above). They highlight several of the fundamental uncertainties and
92 differences between and within the individual components of the existing
93 observational and modeling systems. The responses to the questions are written in a
94 style consistent with major international scientific assessments (e.g., IPCC
95 assessments, and the Global Ozone Research and Monitoring Project of the World
96 Meteorological Organization). The Executive Summary, which presents the key
97 findings from the main body of the Report, is intended to be useful for those involved
98 with the policy-related global climate change issues. The Chapters supporting the
99 Executive Summary are written at a more technical level suitable for non-climate
100 specialists within the scientific community and well-informed lay audiences.

101

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

111

112 This U.S. Climate Change Science Program Assessment/Synthesis Report assesses
113 the uncertainties associated with the data used to determine changes of temperature,
114 and whether such changes are consistent with our understanding of climate processes.

115 This requires a detailed comparison of observations and climate models used to
116 simulate observed changes, including an appreciation of why temperatures might
117 respond differently at the surface compared to higher levels in the atmosphere.

118

119 This CCSP Report addresses the accuracy and consistency of the temperature records
120 and outlines steps necessary to reconcile differences between individual data sets.

121 Understanding exactly how and why there are differences in temperature trends
122 reported by several analysis teams using different observation systems and analysis
123 methods is a necessary step in reducing the uncertainties that underlie current efforts
124 focused on the detection and quantification of surface and tropospheric temperature

125 trends.

126

127 **New observations and analysis since the IPCC and NRC Reports**

128

129 Since the IPCC and NRC assessments, there have been intensive efforts to create new
130 satellite and weather balloon data sets using a range of approaches. Having multiple
131 satellite data sets provides the opportunity for much greater understanding of
132 observed changes and their uncertainty than was possible in the previous assessments.
133 In addition, for the first time a suite of models simulating observed climate since
134 1979 (when satellite data began) has provided us a unique opportunity to inter-
135 compare observed trends from various data sets with model simulations using various
136 scenarios of historical climate forcings. Taken together, these advances lead to a
137 much greater understanding of the issues.

138

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

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

152

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

168

169 **How to use this Synthesis/Assessment Report**

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

184
185 Some terms used in the Report may be unfamiliar to those without training in
186 meteorology; a glossary and list of acronyms is thus included at the end of the Report.
187 Two sets of terms are useful to define at the outset since they are particularly
188 fundamental to this Report. This includes a set of terms related to various levels of
189 agreement or disagreement on key issues and findings among the expert Lead
190 Authors as well as terminology describing their considered judgment about the
191 likelihood of critical key results.

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

198

199 Preface figure 1

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

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

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205 Preface figure 2

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Terms for Layers of the Atmosphere Used in this Report

Preface table 1

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227 **Note: Abbreviated terms** --- Subscript ‘S’, refers to the Surface. Subscripts ‘2’ and ‘4’
228 refer to MSU data from channels 2 and 4. Subscript ‘2LT’ refers to a modification of
229 channel 2 data to focus more directly on the Lower Troposphere and reduce the influence
230 of stratospheric temperatures on channel 2 data. Subscripts ‘850–300’ and ‘100–50’ are
231 specific atmospheric layers sampled by radiosondes. Subscript ‘*_G’ refers to a
232 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

233 global averages, and ‘*_T’ refers to applicable tropical averages. For the model-
234 observation comparisons, the observation-based definitions as listed in the Table
235 were employed.
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238

239 **The Authoring Team**

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

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