

1 **Preface. Report Motivation and Guidance for Using this** 2 **Synthesis and Assessment Report**

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7 A primary objective of the U.S. Climate Change Science Program (CCSP) is to provide
8 the best possible, up-to-date, scientific information to support public discussion and
9 government and private sector decision-making on key climate-related issues. To help
10 meet this objective, the CCSP has identified a set of 21 synthesis and assessment
11 products (SAP) to address its highest priority research, observation, and decision-support
12 needs. This SAP (3.4) focuses on abrupt climate change events where key aspects of the
13 climate system change faster than the responsible forcings would suggest and/or faster
14 than society can respond to those changes.

15 This report addresses Goal 3 of the CCSP Strategic Plan: Reduce uncertainty in
16 projections of how the Earth's climate and related systems may change in the future. The
17 report: 1) summarizes the current knowledge of key climate parameters that could change
18 abruptly in the near future, potentially within years to decades, and 2) provides scientific
19 information on these topics for decision support. As such, the SAP is aimed at both the
20 decision-making audience and the expert scientific and stakeholder community.

21 **Background**

22 Past records of climate and environmental change derived from archives such as tree
23 rings, ice cores, corals and sediments indicate that global and regional climate has
24 experienced repeated abrupt changes, many occurring over a time span of decades or less.
25 Abrupt climate changes might have a natural cause (such as volcanic aerosol forcing), an
26 anthropogenic cause (such as increasing carbon dioxide in the atmosphere), or might be
27 unforced (related to internal climate variability). Regardless of the cause, abrupt climate
28 change presents potential risks for society that are poorly understood. An improved

1 ability to understand and model future abrupt climate change is essential to provide
2 decision-makers with the information they need to plan for these potentially significant
3 changes.

4 The National Research Council (NRC) report “Abrupt Climate Change” (*Alley et al.,*
5 *2002*) provides an excellent treatise on this topic. Additionally, the Intergovernmental
6 Panel on Climate Change Fourth Assessment Report (IPCC AR4) (*IPCC, 2007*)
7 addresses many of the same topics associated with abrupt climate change. This SAP picks
8 up where the NRC report and the IPCC AR4 leave off, updating the state and strength of
9 existing knowledge, both from the paleoclimate and historical records, as well as from
10 model predictions for future change.

11 **Focus of This Synthesis and Assessment Product**

12 The content of this report follows a prospectus that was developed by the SAP Product
13 Advisory Group, made up of the co-authors of this preface. The prospectus is available
14 from the CCSP website (<http://www.climate-science.gov>).

15 SAP 3.4 considers four types of change documented in the paleoclimate record that stand
16 out as being so rapid and large in their impact that they pose clear risks to society in
17 terms of our ability to adapt. They are supported by sufficient evidence in current
18 research indicating that abrupt changes could occur in the future. These four topics, each
19 addressed as a chapter in this report, are:

- 20 1. Rapid Changes in Glaciers and Ice Sheets;
- 21 2. Hydrologic Variability and Change;
- 22 3. Potential for Abrupt Change in the Atlantic Meridional Overturning Circulation
23 (MOC); and
- 24 4. Potential for Abrupt Changes in Atmospheric Methane.

25 The following questions are considered in this report:

- 26 • Rapid Changes in Glaciers and Ice Sheets

- 1 ◦ What is the paleoclimate evidence regarding rates of rapid ice sheet
2 melting?
- 3 ◦ What are the recent rates and trends in ice sheet mass balance?
- 4 ◦ What will be the impact on sea level if the recently observed rapid
5 rates of melting continue?
- 6 ◦ What is needed to model the mechanical processes that accelerate ice
7 loss?
- 8 • Hydrologic Variability and Change
- 9 ◦ What is our present understanding of the causes of major drought and
10 hydrologic change, including the role of the oceans or other natural or
11 non-greenhouse gas anthropogenic effects as well as land-use
12 changes?
- 13 (Note that this question is posed to facilitate an assessment of what is
14 known about natural causes for hydrological change as opposed to
15 anthropogenic causes, such as increased greenhouse gases. The authors
16 of the Abrupt Hydrological Change chapter also address anthropogenic
17 influences, including greenhouse gases, as a potential source of
18 hydrological change, in the past, present and future.)
- 19 ◦ What is our present understanding of the duration, extent and causes of
20 megadroughts of the past 2,000 years?
- 21 ◦ What states of oceanic/atmospheric conditions and the strength of
22 land-atmosphere coupling are likely to have been responsible for
23 sustained megadroughts?
- 24 ◦ How might such a state affect the climate in regions not affected by
25 drought? (For example, enhanced floods or hurricanes in other
26 regions.)
- 27 ◦ What will be the change in the state of natural variability of the ocean
28 and atmosphere that will signal the abrupt transition to a megadrought?

- 1 • Potential for Abrupt Change in the Atlantic Meridional Overturning Circulation
- 2 ◦ What are the factors that control the overturning circulation?
- 3 ◦ How well do the current ocean general circulation models (and
- 4 coupled atmosphere-ocean models) simulate the overturning
- 5 circulation?
- 6 ◦ What is the present state of the MOC?
- 7 ◦ What is the evidence for change in the overturning circulation in the
- 8 past?
- 9 ◦ What are the global and regional impacts of a change in the
- 10 overturning circulation?
- 11 ◦ What factors that influence the overturning circulation are likely to
- 12 change in the future, and what is the probability that the overturning
- 13 circulation will change?
- 14 ◦ What are the observational and modeling requirements required to
- 15 understand the overturning circulation and evaluate future change?
- 16 • Potential for Abrupt Changes in Atmospheric Methane
- 17 ◦ What is the volume of methane in terrestrial and marine sources and
- 18 how much of it is likely to be released in various climate change
- 19 scenarios?
- 20 ◦ What is the impact on the climate system of the release of varying
- 21 quantities of methane over varying intervals of time?
- 22 ◦ What is the evidence in the past for abrupt climate change caused by
- 23 massive methane release?
- 24 ◦ How much methane is likely to be released by thawing of the topmost
- 25 layer (3 m) of permafrost? Is thawing at greater depths likely to occur?

- 1 ◦ What conditions (in terms of sea level rise and warming of bottom
2 waters) would allow methane release from hydrates in sea floor
3 sediments?
- 4 ◦ What are the observational and modeling requirements necessary to
5 understand methane storage and its release under various future
6 scenarios of abrupt climate change?

7 Each section of this report is structured to answer these questions in the manner that best
8 suits the topic. Questions are addressed either specifically as individual sections or
9 subsections of a chapter, or through a broader, more systematic discussion of the topic.
10 Additional subject matter is presented in a chapter, beyond what is asked for in the
11 prospectus, where the authors feel that this information is necessary to effectively treat
12 the topic.

13 It is important to note that the CCSP Synthesis and Assessment Products are scientific
14 documents that are intended to be of use not only to scientists but to the American public,
15 and to decisionmakers within the United States. As such, the geographic focus of the
16 Abrupt Climate Change SAP is United States, and by extension, North American climate.
17 Other regional examples of abrupt climate change are discussed when the authors feel
18 that the information serves as an important analog to past, present or future North
19 American climate.

20 **Suggestions for Reading, Using, and Navigating This Report**

21 This report is composed of four main chapters that correspond to the major climate
22 themes indicated above. There is also an introductory chapter that provides an extensive
23 overview of the information from the other four chapters, as well as additional
24 background information. The Executive Summary further distills the information, with a
25 focus on the key findings and recommendations from each chapter.

26 The four theme chapters have a recurring organizational format. Each chapter begins with
27 key scientific findings which are then followed by recommendations for future research
28 aimed at deepening our understanding of the critical scientific issues raised in the chapter.
29 The scientific theories, models, data, and uncertainties that are part of the author's

1 scientific syntheses and assessments are referenced through citations to peer-reviewed
2 literature throughout the chapter. Finally, side boxes are used to discuss topics the author
3 team felt deserved additional attention or served as useful case studies.

4 A reader interested in an overview of the state-of-the-science for the topic of abrupt
5 climate change might, therefore, start by reading the Executive Summary and
6 Introduction chapter (Chapter 1) of this report, then delve deeper into the thematic
7 chapters for more detailed explanations and information.

8 To integrate a wide variety of information and provide estimates of uncertainty associated
9 with results, this report utilizes the terms from the IPCC AR4 (*IPCC, 2007*). Terms of
10 uncertainty range from “extremely unlikely” (< 1% likelihood) to “virtually certain” (>
11 99% likelihood). See Box 1.1 in the Introduction chapter (Chapter 1) of this report for a
12 complete explanation of the uncertainty terms.

13 **The Synthesis and Assessment Product Team**

14 The primary authors of this report were constituted as a Federal Advisory Committee
15 (FAC) that was charged with advising the USGS and the CCSP on the scientific and
16 technical content related to the topic of abrupt climate change as described in the SAP 3.4
17 prospectus. (See Public Law 92-463 for more information on the Federal Advisory
18 Committee Act, and the GSA website <http://fido.gov/facadatabase/> for specific
19 information related to the SAP 3.4 Federal Advisory Committee.) The FAC for SAP 3.4
20 enlisted input from numerous contributing authors. These authors provided substantial,
21 relevant content to the report, but did not participate in the Federal Advisory Committee
22 deliberations upon which this SAP was developed.

23 **References**

24 Alley, R.B., et al., 2002: Abrupt climate change: Inevitable surprises. National Academy
25 Press, Washington, DC.
26 IPCC, 2007: Climate change 2007. The physical science basis. Contribution of Working
27 Group I to the Fourth Assessment Report of the Intergovernmental Panel on
28 Climate Change. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B.

- 1 Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press,
- 2 Cambridge, United Kingdom, 996 pp.