The Oceans and Rapid Climate Change: Past, Present, and Future

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THE OCEANS AND RAPID CLIMATE CHANGE: PAST, PRESENT, AND FUTURE Edited by Dan Seidov, Bernd J. Haupt, and Mark Maslin

PREFACE

Until a few decades ago, scientists generally believed that significant large-scale past global and regional climate changes occurred at a gradual pace within a time scale of many centuries or millennia. A secondary assumption followed: climate change was scarcely perceptible during a human lifetime. Recent paleoclimatic studies, however, have proven otherwise: that global climate can change extremely rapidly. In fact, there is good evidence that in the past at least regional mean annual temperatures changed by several degrees Celsius on a time scale of several centuries to several decades.

Humanity is now faced with the contentious problem of global warming and the potential for catastrophic climatic change. How will the global climate system react to the ever-increasing amounts of anthropogenic carbon dioxide now entering the atmosphere? Although paleoclimatology can provide neither a political nor an economic perspective here, it can enhance our understanding of the global climate system and how it has changed. This understanding of the past is essential for more reliable scenarios of possible future change.

Currently there is evidence that we are on a warming trend, which many scientists suggest is evidence of global warming. There are researchers, however, who argue that the same trend is a more natural adjustment of the global climate system recovering from the Little Ice Age, the last major climate deterioration that ended 100 years ago. Be that as it may, if we are in a period of enhanced global warming, what consequences might follow from the melting of Arctic or Antarctic ice? Or is it possible, in a period of general global warming, that the conveyor belt of deep water will be “switched off,” plunging Europe into a new Little Ice Age?

Although such questions are complex, there are basic features of the climate system that can help to narrow our search for answers and dramatically improve our understanding of how climate works. One key approach is to use paleoclimatology to assess the dynamics of the climate system on decadal to millennial time scales using both the geologic record and climate models. In particular, this approach brings into focus the world ocean as the most important element controlling climate system dynamics on large time scales.

By its thermal, freshwater and dynamic impacts, the ocean affects our environment in many ways. The effects of the ocean impact are evident in ocean-atmosphere interactions, sea-ice dynamics, and sea level changes. When measured in decadal to millennial time scales, however, the ocean proves most important for climate change via its enormous heat capacity and its capability to redistribute heat by ocean currents. Although such time intervals are too long for the atmosphere to be dynamically important, they are too short in comparison with the changes of Earth orbital parameters, ice sheet dynamics, or tectonic activity. In addition, we must consider the heart beat of global climate, the thermohaline ocean circulation, which seems to be surprisingly sensitive to relatively small changes of freshwater in the high latitudes. It has also been speculated that anthropogenic global warming may threaten the stability of this oceanic overturning and thus present a considerable challenge to human society.

New evidence from ice cores and deep-sea sediments also suggests that the climates of the two hemispheres may not be synchronized in their response to climate forcing. These findings, which question the role of the thermohaline circulation even further, point to other questions as well: can the thermohaline circulation be altered by surface impacts in the northern and southern hemispheres; what role, if any, does thermohaline play in the previously observed synchronicity; and how can the thermohaline alter those impacts?

Our research, as a result, is multifaceted if focused on charting feedbacks in the climate systems as facilitated by ocean circulation in conjunction with other climatic elements. For example, we know that the engine of long-term climate change, the deep-ocean circulation system, can change dramatically in response to freshwater impacts that are usually associated with the melting of some elements of the cryosphere, either as melting sea ice or ice sheet surges. These and related subjects are the major focus of the present volume.

By focusing on ocean dynamics and the ocean-atmosphere-cryosphere coupling during geologically rapid climate changes, the authors of this volume address the fundamental unresolved issues in paleoclimatology, including factors that may cause or influence strong long-term internal variability of the climate system. The volume provides discussion of proxy data, hypotheses, modeling and synthesizing papers that address key aspects of rapid climate change, ocean circulation variability, and sea-surface conditions during the Late Quaternary.

To structure the material within the volume, we have taken a linear approach. We begin by reviewing what we know about geologically abrupt climate changes of the Pleistocene, and then gradually move from data to ideas, hypotheses, modeling, and finally to perspectives that we may infer from data and modeling analyses.

The book combines discussions of paleoclimatic and paleoceanographic reconstructions with the modeling of past and future, colder and warmer climates, and gives a basis for synthesizing the results and gaining a new momentum in studying millennial-scale ocean and climate variability. In this capacity, the volume is targeted to scientists, researchers, graduate students, and others interested in paleoclimatology, paleoceanography, and the future of the climate system.

This volume delineates work in progress, and does not present ultimate solutions to the problems addressed; rather it proposes initial answers to the key questions summarized above. The first part, *Data and Climate Models: Windows to the Past*, presents data interpretation, hypotheses based on data analyses, and ideas that may shed new light on many aspects of past climates and their evolution. The second part, *Ocean and Climate Models: Bridges from Past to Future*, features climate system models that focus on the role of the world ocean in the past and possible future climate change, starting with simpler, ocean-only models that unroll into full, three-dimensional models of the entire climate system. Importantly, most papers emphasize the role of global ocean links, especially between the Northern and Southern Hemispheres.

The book can be considered a continuation of the AGU volume, *Mechanisms of Global Climate Change (Clark, P.U., S. R. Webb and L. D. Keigwin, Editors, AGU, Washington, DC, 1999)*, but in no way repeats that volume. In fact, the gallery of results presented here provides a unique vision of what new observations and modeling can offer for assessing the role of the different components of the climate long-term alteration, and especially the still poorly understood southern oceans connection.

The volume derives from presentations and discussions at two special sessions devoted to rapid climate changes on decadal to millennial time scale. The first took place at the AGU Fall Meeting, San Francisco (December 1999), the second at the Ocean Science Meeting, San Antonio (February 2000). Presenters responded enthusiastically when asked to contribute to the volume. To further enhance the project, several other researchers, who contributed to the discussions, were asked to join the project, and many agreed.

As editors, we are very grateful to all authors, who worked hard to meet the deadline and did everything they could to make this project a success. We appreciate the help, patience, and expertise of AGU staff, who worked diligently to publish the book. We are especially thankful to Allan Graubard, our acquisitions editor, whose support, encouragement, and advice was crucial for finalizing the entire project. We are grateful to the reviewers who devoted so much of their time and effort helping to improve the volume.

Dan Seidov
Earth System Science Center, Penn State University

Bernd J. Haupt
Earth System Science Center, Penn State University

Mark Maslin
Department of Geography, University College London