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The Oceans and Climate, Second Edition

The oceans are an integral and important part of the climate system. *The Oceans and Climate* introduces the multi-disciplinary controls on air–sea interaction – physical, chemical and biological – and shows how these interact. It demonstrates how the ocean contributes to, and is affected by, climate processes on timescales from seasonal to millennial and longer. Past, present and future relationships between the ocean and climate are discussed.

The new edition of this successful textbook has been completely updated throughout, with extensive new material on thermohaline processes in the ocean and their link to both abrupt climate change and longer term climate change.

This comprehensive textbook on the ocean–climate system will prove an ideal course and reference book for undergraduate and graduate students studying earth and environmental sciences, oceanography, meteorology and climatology. The book will also be useful for students and teachers of geography, physics, chemistry and biology.

Grant R. Bigg is Professor of Earth System Science at the Department of Geography, University of Sheffield. He was Editor of the Royal Meteorological Society's magazine *Weather* from 1998 to 2003, and has served on the Council of the Society. He has published over seventy peer-reviewed papers and contributed to popular science magazines such as *The Geographical Magazine*.

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Preface to the first edition

In 1827 Jean-Baptiste Fourier, otherwise known for his contributions to mathematics, speculated that human activities had the capacity to affect the Earth's climate. In 1990 the International Panel on Climate Change produced a report detailing our current understanding of these activities, and speculated on what impact they might have on climate. In 160 years of great human endeavour much has been learnt but definitive evidence for climatic change driven by mankind remains elusive.

The oceans play a significant role in this tardiness of the climate system's response to our species. They store immense amounts of energy for months, decades or even centuries, depending on the region, depth and the nature of the interaction between the atmosphere and ocean. This storage capacity acts as a giant flywheel to the climate system, moderating change but prolonging it once change commences. The ocean also stores vast amounts of carbon dioxide.

In 1897 Svante Arrhenius discovered that the amount of carbon dioxide in the atmosphere affected the global temperature through the greenhouse effect. In 1938 G. S. Callendar showed that atmospheric carbon dioxide was increasing due to human activities. However, it has only been since the late 1960s that a rough estimate of the magnitude of the potential climatic effect has been possible. Even today the likely impact of a doubling of atmospheric carbon dioxide on raising global temperature is not known to within 3°C; the global temperature at the height of the last Ice Age was only 4°C less than today.

A significant element in this uncertainty is the ocean. How is carbon dioxide and heat stored in the ocean? Are these mechanisms sensitive to climatic change? Could they interact with climatic change itself to accentuate, or lessen, such change? The exploration of these, among other, questions underlies this book.

The oceanic links to climate are complex and multi-faceted. The sciences of physics, chemistry and biology are interwoven in this tapestry. Therefore, after an introductory chapter on the climate system I devote chapters to the oceanic roles of each of these sciences, before examining some detailed ocean–atmosphere interactions affecting climate, and the role of the ocean in the past, and its potential role in the future climate.

My own introduction to this fascinating subject came through its physics, but I have aimed to make each science, and its links to the general problem of climate and air–sea interaction, understandable to readers coming from one of the other fields. English 'A' level standard physics, chemistry or mathematics would assist a reader but such a standard in only one of these subjects should not be a handicap. The book does not, therefore, contain many references – the

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climate literature is, in any case, vast and growing at an exponential rate – but does have a commented bibliography of the books and research papers that I have found most useful during its writing. This should provide the inquisitive reader with the tools to begin a more in-depth exploration of the subject. There is also a glossary of terms that are used repeatedly. The first use of each term is *italicized* in the main text.

The writing of such a book as this necessarily involves help from many sources. I would like to collectively thank the various publishers and authors who gave permission for diagrams to be used (individual identification is found in the appropriate figure legend). The Internet has been an invaluable tool for tracking down data sets, and even for producing diagrams; the climate data site at Lamont-Doherty Geological Observatory merits particular thanks. I would also like to thank Fred Vine and Peter Liss for encouraging me to persevere with the book during its darkest days, and my editor, Conrad Guettler, for his keeping the literary ship on course. Phil Judge drew many of the diagrams and Sheila Davies photographed them. Most of all, my wife, Jane, put up with three years of writing angst and made the extremely valuable contribution of an arts graduate's criticism of the clarity of the science!

It is appropriate to end this preface with the following extracts from Shelley's *Ode to the West Wind* that encapsulate the tumultuous interaction between air and sea that this book explores:

> O wild West Wind, thou breath of Autumn's being,
> Thou, from whose unseen presence the leaves dead
> Are driven, like ghosts from an enchanter fleeing.
> . . .
> Thou on whose streams, mid the steep sky's commotion,
> Loose clouds like earth's decaying leaves are shed,
> Shook from the tangled boughs of Heaven and Ocean,
> . . . . . Thou
> For whose path the Atlantic's level powers
> Cleave themselves into chasms, while far below
> The sea-blooms and the oozy weeds which wear
> The sapless foliage of the ocean, know
> Thy voice, and suddenly grow gray with fear,
> And tremble and despoil themselves: oh hear!

Preface to the second edition

In the six years since the first edition of this book was published the interaction between the ocean and climate has remained at the centre of climate investigation. New emphasis on abrupt climate change triggered by freshwater changes to the ocean's surface, and the interaction between the ocean's thermohaline circulation and climate on millennial timescales has arisen. Hence this edition, as well as updating the science generally, has added significant new sections in Chapters 2 and 5 to reflect this enhanced importance of thermohaline processes. Modelling is becoming increasingly important, and hence treatment of this tool has been moved forward to Chapter 1. Nevertheless, the basic science on which the first edition was built has been supplemented rather than overturned during

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these last active years. Thus readers will find the basic structure of the book similar to before, but brought up-to-date where necessary.

In the last edition I was unfortunate in the timing of publication relative to the IPCC series of reports, completing the writing of the book prior to the issue of the 1995 report. This time I benefit from the recent publication of the 2001 reports, enabling me to give timely revisions of the international community's views on climate change and the ocean's role in this. I therefore thank my editor, Matt Lloyd for prompting the second edition at the right time. Once again, I also have to thank Phil Judge for drawing many new diagrams or revising old ones, and Sheila Davies for supplying the photographic versions. The continuing rise of the web as a medium for science communication and education leads me to provide a web-page for the book with relevant links to many valuable sites concerned with the science, and provision of data, for climate study. I hope readers find this edition even more stimulating than the last!

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