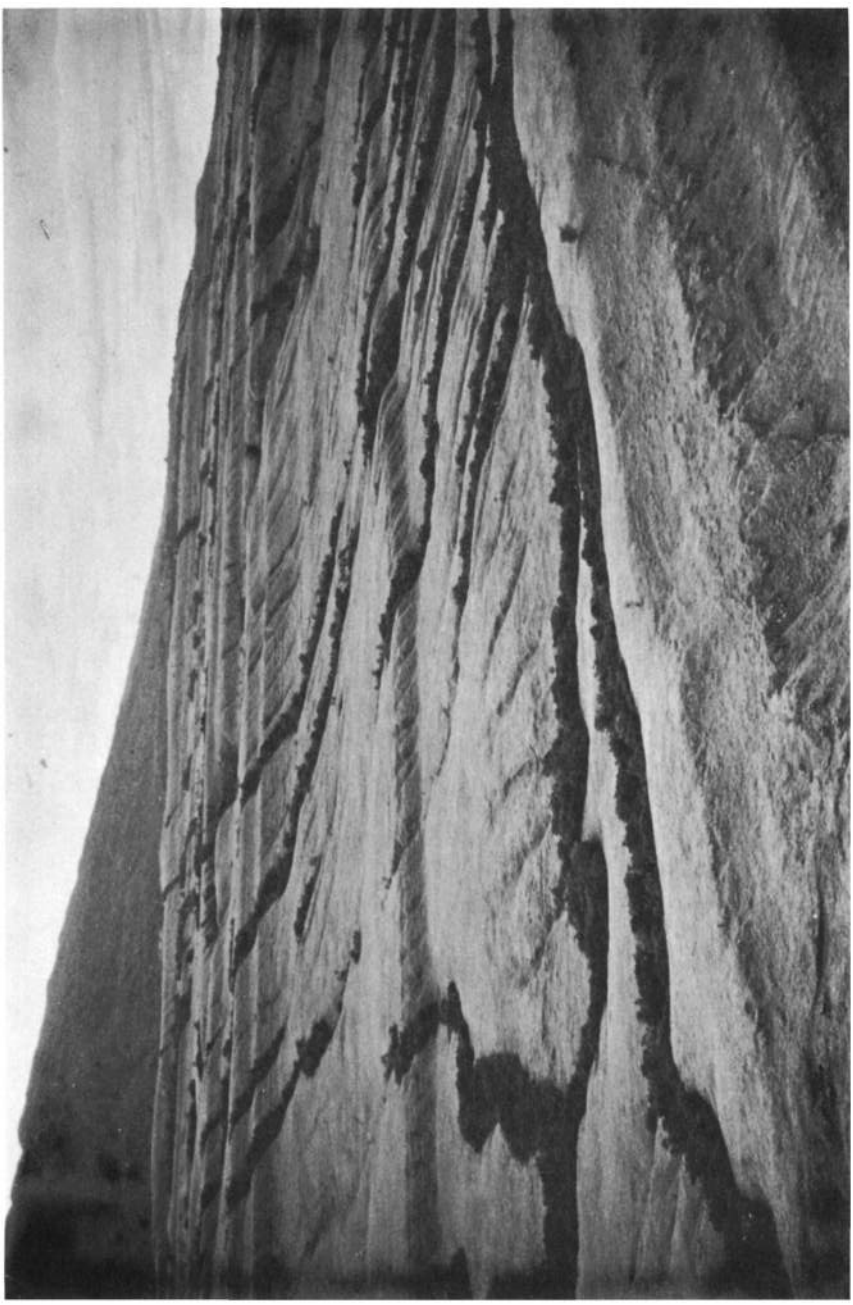
Climatic Change and Variability



Frontispiece. Coral and gravel terraces or 'steps' on the north coast of the Huon Peninsula, Papua, New Guinea. These indicate past changes in sea level due to the waxing and waning of ice sheets. Data from this area have been used to reconstruct the palaeoclimatic record (see Section 5.2 and p. 87). Photograph by D. L. Dunkerley.

Climatic Change and Variability

A Southern Perspective

Editors: A. B. Pittock L. A. Frakes
D. Jenssen J. A. Peterson J. W. Zillman
on behalf of the
Australian Branch, Royal Meteorological Society

Based on a conference at Monash University, Melbourne, Australia, 7–12 December 1975 which was co-sponsored by the Australian Academy of Science

CAMBRIDGE UNIVERSITY PRESS
CAMBRIDGE
LONDON·NEW YORK·MELBOURNE

Shaftesbury Road, Cambridge CB2 8EA, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

We share the University's mission to contribute to society through the pursuit of education, learning and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9780521172264

First published 1978
First paperback edition 2010

A catalogue record for this publication is available from the British Library

Library of Congress Cataloging-in-Publication data
Main entry under title:
Climatic change and variability.
Based on edited papers from the Australasian Conference
on Climate and Climatic Change.
Bibliography: p.
Includes indexes.
1. Climatic changes. 2. Climatic changes –
Southern Hemisphere. 1. Pittock, A. Barrie,
1938– 11. Royal Meteorological Society, London.
Australian Branch. III. Australasian Conference
on Climate and Climatic Change, Monash University,
1975.
QC981.8.C5C56 551.6′9 76-53521

ISBN 978-0-521-21562-6 Hardback
ISBN 978-0-521-17226-4 Paperback

Contents

Contents

Contributors

J. L. Anderson: Department of Economics, Latrobe University, Victoria 3083, Australia
G. W. Arnold: CSIRO Division of Land Resources Management, Western Australia 6014, Australia
R. G. Barry: Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado 80302, USA
R. J. Bray: PO Box 494, Nelson, New Zealand
R. A. Bryson: Institute for Environmental Studies, University of Wisconsin, Madison, Wisconsin 53706, USA
W. Budd: Antarctic Division, Melbourne 3004, Australia
J. Chappell: Department of Geography, Australian National University, ACT 2600, Australia
M. Charlesworth: Philosophy Department, Deakin University, Belmont, Victoria 3216, Australia
D. M. Churchill: Royal Botanic Gardens, Melbourne, South Yarra, Victoria 3141, Australia
M. J. Coughlan: Bureau of Meteorology, Melbourne, Victoria 3000, Australia
R. W. Fairbridge: Columbia University, New York 10027, USA
H. Flohn: Meteorological Institute, University of Bonn, Federal Republic of Germany
L. A. Frakes: Department of Earth Sciences, Monash University, Victoria 3168, Australia
J. R. Freney: CSIRO Division of Plant Industry, Canberra, ACT 2601, Australia
I. E. Galbally: CSIRO Division of Atmospheric Physics, Aspendale, Victoria 3195, Australia
K. A. Galbraith: CSIRO Division of Land Resources Management, Western Australia 6014, Australia
R. W. Galloway: Division of Land Use Research, CSIRO, Canberra, ACT 2601, Australia
W. J. Gibbs: Bureau of Meteorology, Melbourne, Victoria 3000, Australia
J. S. Godfrey: CSIRO Division of Fisheries and Oceanography, Cronulla, NSW 2230, Australia

J. S. A. Green: Atmospheric Physics, Imperial College, London SW7 2RH, UK
B. V. Hamon: CSIRO Division of Fisheries and Oceanography, Cronulla, NSW 2230, Australia
S. Hastenrath: Meteorology Department, University of Wisconsin, Madison, Wisconsin 53706, USA
B. G. Hunt: Australian Numerical Meteorology Research Centre, Melbourne, Victoria 3000, Australia
D. Jenssen: Meteorology Department, University of Melbourne, Parkville, Victoria 3052, Australia
B. McInnes: Meteorology Department, University of Melbourne, Parkville, Victoria 3052, Australia
J. V. Maher: Bureau of Meteorology, Melbourne, Victoria 3000, Australia
G. R. Manley: Department of Environmental Sciences, University of Lancaster, Lancaster, UK
H. A. Martin: Department of Botany, University of New South Wales, NSW 2033, Australia
W. J. Maunder: New Zealand Meteorological Service, Wellington, New Zealand
B. R. Morton: Department of Mathematics, Monash University, Victoria 3168, Australia
J. Oliver: Geography Department, James Cook University, Townsville, Queensland 4811, Australia
G. W. Paltridge: CSIRO Division of Atmospheric Physics, Aspendale, Victoria 3195, Australia
G. I. Pearman: CSIRO Division of Atmospheric Physics, Aspendale, Victoria 3195, Australia
J. A. Peterson: Department of Geography, Monash University, Victoria 3168, Australia
A. B. Pittock: CSIRO Division of Atmospheric Physics, Aspendale, Victoria 3195, Australia
R. A. S. Ratcliffe: British Meteorological Office, Bracknell RG12 2SZ, UK
N. J. Shackleton: Subdepartment of Quaternary Research, University of Cambridge, Cambridge CB2 1ER, UK
G. Singh: Research School of Pacific Studies, Australian National University, ACT 2600, Australia
G. B. Tucker: CSIRO Division of Atmospheric Physics, Aspendale, Victoria 3195, Australia
H. van Loon: National Center for Atmospheric Research,* Boulder, Colorado 80303, USA

* The National Center for Atmospheric Research is sponsored by the National Science Foundation.

List of contributors

D. Walker: Research School of Pacific Studies, Australian National University, ACT 2600, Australia

P. J. Walsh: CSIRO Division of Building Research, Victoria 3190, Australia

J. Williams: International Institute for Applied Systems Analysis, 2361 Laxenburg, Austria

P. B. Wright: Department of Oceanography, University of Hawaii, Honolulu, Hawaii 96822, USA

J. W. Zillman: Bureau of Meteorology, Melbourne, Victoria 3000, Australia

Foreword*

It is a very remarkable thing that climatology faces such an important, possibly a dramatic future, when it is the oldest science we have. Though astronomy rivals this latter claim, it was climate that decided early man where and how to live and when to migrate. He came to study the heavens *because* he had learnt that the passage of the sun across them determined the day, and that variations in its trajectory determined the seasons. Since the big light composed the theme of the seasons, perhaps the little lights would be found to compose the variations. Probably this was man's first scientific speculation.

Over such a long period, from then till now, effort has waxed and waned. The most recent stagnant period was that following the development of meteorological instruments, when the thought reigned that one had merely to amass enough years of simple figures, and the averages would describe the climate.

However, about 100 years ago, a dynamic and synoptic climatology began to emerge, based on the tracks and centres of action of the synoptic systems. For the Southern Hemisphere, names like Russell, Kidson and Griffith Taylor provide the landmarks. There was a classification climatology too, of which the architect was Köppen. But it was only within the working span of old-timers like myself, that we have seen the beginnings of a physical climatology.

Compared with its sedate history, the present scene in climatology is one of bustle. We recognise that climate is a many-splendoured thing. And yet we have no accepted strict definition of what the word climate means. No wonder then that some people's concept of what can be called climatic change differs widely from others.

Unfortunate climatic episodes, sequences of years with drought or flood, are an inevitable consequence of the year-to-year variability, and need not by any means imply that the climate is changing. The upward trend in world population and communications, with increasing use of marginal land, means that a climatic episode today tends to cause much more suffering and attract wider notice than a similar episode of the past. While there are great uncertainties about climate changes being on the way,

* Adaptation of Opening Address at Australasian Conference on Climate and Climatic Change, Monash University, 7 December 1975

there is no uncertainty about one thing. The world population must learn to live more successfully with the year-to-year variability. One would like to see much more work, by economists, social scientists, agriculturalists, and subsequently educationists, on how man is best to live with this variability. If they could quantify what they have to say, this could do much to avoid and alleviate suffering.

These social and economic questions lead us into the future, where the other big questions, and I stress that they are two different questions, are the predictability of climatic change and the predictability of the year-to-year variation. It is very tempting for we meteorologists, who tend to get hauled over the coals if a weather forecast is proved wrong, as happens very occasionally, to take up climatic predictions. Then we will only be proved wrong after we are dead. But this is a real challenge to our sense of responsibility as a profession. There have been rather too many claims of recent years, made on too little evidence.

Those who have read Shakespeare's plays will know that he often starts a scene with what he calls 'alarums and excursions', and those who have seen these plays know that this means trumpets blowing, bells ringing and people rushing here, there and everywhere. Environmental science, of which climatology is an important part, has a weakness for writing some of its scenarios in the same way, and this is an image which the mass media love to project, because it is good theatre. But it is not good science, and others of us may breathe more freely about climatic change because we hope that we are now through the alarums and excursions, and settling in to Act 2, Scene 1.

There is a consensus that a vital key to the future lies in the numerical model, but here again we must be careful not to overstate the case in order to attract funds. Going round the world during 1975, I found few who felt hopeful of real breakthroughs in climate predictability in less than ten years. On the other hand, ten years' delay of investment now will mean ten years' postponement of ultimate understanding. This is the sort of story which we should be telling to the public. They pay the piper, and have the right to know what tune they are calling.

A second key to the future is also widely considered to lie in the Global Atmospheric Research Programme, the first real test of blending the numerical models with the fuller potential of the new satellite-oriented observing techniques. By supplementing and re-shaping the tools of the future, the ultimate benefits of GARP to the understanding of climate may be immense, particularly in the Southern Hemisphere where the present gaps are so much wider. It is hoped that the scientists of all countries, most of all our own, will succeed in persuading their governments to give the necessary support to this imaginative and vital programme.

Whilst I have pleaded for balance in public utterances, I know that within

our own discipline there is plenty of room for controversy in this complex the vitally important subject, and a little extremism here can serve a very useful purpose. It remains for me to congratulate our Branch of the Royal Meteorological Society on its initiative in calling the original conference, which the Academy was delighted to co-sponsor and which led to this publication. The great mathematician, John von Neumann, described the general circulation of the atmosphere, that is to say the quantitative machinery of the climate, as the most difficult unsolved problem still to confront the scientific intellect of man, and his words strike a suitable note on which to introduce this book.

C. H. B. PRIESTLEY
Australian Academy of Science

Preface

The study of climatic change and variability involves a vast range of disciplines, interests and techniques. It is unfortunate, therefore, that it has suffered in the past from a lack of effective communication across disciplinary barriers. Thus, for example, the geological literature contains many examples of sound geology of palaeoclimatic interest which is nevertheless coupled with inadequate meteorological interpretation. Similarly, too much of the meteorological literature, including the new breed of numerical modelling, is lacking in perspective as to the reality of what has happened in the past (and *ipso facto* is possible). Rigorous interdisciplinary collaboration is lacking in most areas of study, although the CLIMAP programme (CLIMAP Project Members, 1976) is a notable exception.

We aim therefore, in this book as in the conference on which it is based, to bridge these barriers. We have sought to exclude jargon, and to avoid technical details better found in the specialised literature to which there is ample reference. In so doing, we hope to have produced a book intelligible to the educated layman and particularly to tertiary students and specialists in related fields. We hope it will open some windows, and even a few doors, to stimulating ideas and interactions across disciplinary and institutional barriers.

The book arises out of, but is not a straight proceedings of, a conference on the theme 'Climatic change and variability, with particular reference to the Australian or Southern Hemisphere region', which was held at Monash University in December 1975. The aim of the conference was 'to bring together people particularly from the Australasian region interested in questions of climate and climatic change so that they may familiarise themselves with the broad scope of the field, its relevance to their individual needs, interests and disciplines and interest others in the contribution they can make to the broader fields'.

The conference largely succeeded in its aim, with 94 papers and 224 participants including a number from overseas. We believe the original aim will be further achieved by the publication of this book based on edited versions of the invited review papers, supplemented by a small selection of heavily edited versions or amalgams of contributed papers. These latter contributions have been selected because they usefully illustrate or round

off themes developed in the invited papers, and describe either some major new development from a Southern Hemisphere worker or some unique insights to be found from a study of Southern Hemisphere climate.

The Southern Hemisphere theme is further expounded in Chapter 1. Suffice it to say here that the study of Southern Hemisphere climate is different from that of the Northern Hemisphere in several important aspects. Not only are there significant climatic differences due to different land–sea distributions, but the smaller land base and different historic/cultural development of the Southern Hemisphere populations have led to much greater ignorance and neglect of Southern Hemisphere climate. Much has been written about Northern Hemisphere climate, sometimes as if it were the global story, but relatively little is available which focuses on the south.

The atmosphere and oceans are of course not bounded at the equator, and it is both impossible and undesirable to exclude rigorously Northern Hemisphere contributions, data, or results from this volume. Nevertheless we have borne the Southern Hemisphere emphasis in mind while editing this book in the belief that it provides a useful and stimulating focus.

Differing views and inconsistencies exist in the climatological literature, and in the available contributions, on numerous questions, particularly on matters of definition and usage. The editors believe that these should be pointed out and discussed, but not editorially eliminated. To eliminate them would be to present one particular view rather than a balanced over-view of the state of the art. Such differing views will be found most obviously in Chapters 7 and 8, but also in Chapter 4 where the term 'climatic variability' is used by some authors to mean variability *of* climate, and by others to mean variability *within* climate, depending on the time scale used implicitly or explicitly to define 'climate'. This inconsistency within the book has led the editors to accept consciously the ambiguity implicit in its very title: *Climatic Change and Variability*. This may appear to be unduly confusing, but it accurately reflects a confusion which exists far beyond the confines of this book.

One other question that has concerned the editors is whether our theoretical understanding of climatology as a science justifies a logical development in this book from theory to example and practice. The more pessimistic view is that climatology is still essentially an observational science in which the data must be presented first, as a basis from which to examine critically the many competing and largely qualitative hypotheses about the nature and causes of climatic change.

We have chosen a compromise in which the physical framework which we believe underlies climate is first described (Chapter 2), the climatic record is next presented and analysed (Chapters 3 and 4), and then various models of climatic change are discussed (Chapter 5). These are

followed by sections on the inadvertent modification of climate (Chapter 6), the economic and social impact of climatic change (Chapter 7), and a final review of progress and prospects.

Much controversy has been generated recently by various hypotheses and statements as to the likely onset of rapid climatic change (e.g. Alexander, 1974; Bryson, 1973*a*; Calder, 1974; International Federation of Institutes for Advanced Study, 1974; Lamb, 1974*a*). Given the present state of knowledge about the causes and mechanisms of climatic change and variability, many of these must be regarded as somewhat speculative, but they have tended to divide climatologists into those who might be termed climatic optimists on the one hand, and pessimists on the other. Issues of social responsibility and scientific objectivity are raised when positions are taken on such matters which are of obvious importance to humanity.

These questions are touched upon particularly in Chapters 7 and 8. Whatever the long-term trends and prospects, however, even a continuation of the normal year-to-year climatic variability described in the instrumental record of the last 100 years or so (see Chapter 4) will become increasingly critical to human survival as the world population increases, world food reserves are used up, more and more marginal land is brought into agricultural production, and water resources are more fully utilised.

Climatic variability is part of Australian folklore, and it is perhaps instructive as well as amusing to ponder one of the classics of popular Australian literature, the ballad 'Said Hanrahan', by P. J. Hartigan ('John O'Brien', 1879–1952), a Catholic priest who for many years was stationed at Narrandera in south-central New South Wales. Hanrahan is perhaps the archetypal pessimist.

Said Hanrahan*

'We'll all be rooned,' said Hanrahan,
In accents most forlorn,
Outside the church, ere Mass began,
One frosty Sunday morn.

'It's lookin' crook,' said Daniel Croke;
'Bedad, it's cruke, me lad,
For never since the banks went broke,
Has seasons been so bad.'

'If rain don't come this month,' said Dan,
And cleared his throat to speak –
'We'll all be rooned,' said Hanrahan,
'If rain don't come this week.'

* Verses from 'Said Hanrahan' from *Around the boree log*, reprinted by permission of Angus and Robertson Publishers. © John O'Brien 1921 and Fr F. A. Mecham 1952.

Preface

'We want a inch of rain, we do,'
O'Neil observed at last;
But Croke 'mantained' we wanted two
To put the danger past.

'If we don't get three inches, man,
Or four to break this drought,
We'll all be rooned,' said Hanrahan,
'Before the year is out.'

In God's good time down came the rain;
And all the afternoon
On iron roof and window-pane
It drummed a homely tune.

And every creek a banker ran,
And dams filled overtop;
'We'll all be rooned,' said Hanrahan,
'If this rain doesn't stop.'

And stop it did, in God's good time:
And spring came in to fold
A mantle o'er the hills sublime
Of green and pink and gold.

And, oh, the smiles on every face,
As happy lad and lass,
Through grass knee-deep on Casey's place
Went riding down to Mass.

While round the church in clothes genteel
Discoursed the men of mark,
And each man squatted on his heel,
And chewed his piece of bark.

'There'll be bush-fires for sure, me man,
There will, without a doubt;
We'll all be rooned,' said Hanrahan,
'Before the year is out.'

Increasing scientific knowledge should bring optimists and pessimists closer together and eventually enable climatologists to discharge their social responsibilities with somewhat fewer confusing 'alarums and excursions'.

The conference on which this book is based was organised by the Australian Branch of the Royal Meteorological Society, with the co-sponsorship of the Australian Academy of Science. Major financial contributions to the success of the conference came from:

Government of Victoria
Australian Government
Australian Academy of Science
Jennings Industries Ltd
CSR Co. Ltd
Broken Hill Proprietary Co. Ltd.
Commonwealth Foundation (London)
Rockefeller Foundation

with additional support from Monash University, Trans Australia Airlines and numerous individuals and their supporting institutions.

Thanks are due to all these, plus of course, individual contributors, and Cambridge University Press, for making this book possible.

In addition, special thanks are due to Dr U. Radok (University of Melbourne), Dr W. Budd (Antarctic Division), and Mr M. Coughlan (Bureau of Meteorology) for scientific help, and to Mrs M. Leicester, Mrs H. Macdonald, Mrs L. Masson, Mrs V. Murphy, and Mrs R. Hampson for typing and re-typing many mangled manuscripts.

Melbourne
July 1976

A. B. PITTOCK
L. A. FRAKES
D. JENSSEN
J. A. PETERSON
J. W. ZILLMAN