

# 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

# 113/2466 INSTITUT

# FÜR METEOROLOGIE U. KLIMATOLOGIE

#### UNIVERSITÄT HANNOVER HERRENHÄUSER STR. 2 • 3000 HANNOVER 21

List of contributors	xii
Foreword C. H. B. Priestley, Australian Academy of Science	XV
Preface Editors, including extract from 'Said Hanrahan'	xix
1 An overview A. B. Pittock	1
1.1 Concepts and perspectives	1
1.2 The Southern Hemisphere aspect	3
1.3 Intentional climate modification	6
1.4 A problem for all humanity	7
2 The physical basis of climate	9
2.1 The climatic system Editorial	9
The energy source	9
Sun-earth geometry	10
Planetary energy balance	11
Effects of latitude	12
Components of the climatic system	13
Underlying physics	15
2.2 The general circulation of the atmosphere G. B. Tucker	16
The form of the circulation	17
Mean and eddy states	21
Zonally averaged budgets	23
The global energy cycle	24
The longitude-dependent circulation	27
Uniqueness of the general circulation	30
2.3 The role of the oceans B. V. Hamon & J. S. Godfrey	31
Structure	33
Circulation	34
Oceanic fronts	38
Pack ice	38
Ocean-atmosphere interaction	40
Ocean variability and climate	44
Importance of oceanography in climate research	52
3 The long-term climatic record	53
3.1 Cenozoic climates: Antarctica and the Southern Ocean	52
L. A. Frakes	53
The early Cenozoic	53

The middle Cenozoic	57
The Pliocene and Quaternary	61
Global correlations	65
3.2 Some results of the CLIMAP project N. J. Shack	kleton 69
Climates of 18,000 years ago	70
Southern Hemisphere climate changes	73
3.3 Climatic and topographic changes from glaciologic	al
data D. Jenssen	77
Elevation change effect	77
Separation of elevation from climatic changes in the	
δ-record	80
3.4 Quaternary climates of the Australian region	
D. Walker	82
The region today	82
Advantages and limitations	84
The biggest climatic fluctuations	87
The climate of the full glacial	88
Climatic change around the Pleistocene-Holocene	
transition	92
Climatic variation in the Holocene	94
Conclusions	95
3.5 Closed lakes and the palaeoclimatic record D. M.	•
Churchill, R. W. Galloway & G. Singh	97
Some properties of closed lakes	98
Former evaporation rates	100
Former discharge	100
Former lake area	101
The prehistoric record from Lake George	104
The twin crater-lakes, Gnotuk and Bullenmerri	106
Summary	107
3.6 Eustatic sea-level changes and environmental grad	ients
H. A. Martin & J. A. Peterson	108
Climatic gradients	110
Eustatic sea-level change: a complicating factor	112
Late-Pleistocene climatic gradient in Tasmania	113
Evidence from the Nullarbor	117
The vegetation	118
The pollen counts	120
Climatic interpretations	121
Ice-age environmental gradients: Northern Australia a	and
Bassiana	122
Summary	124
3.7 Abrupt events in climatic history H. Flohn	124

		Contents
	The Alleröd-Younger Dryas fluctuation	125
	Further examples during the Pleistocene	127
	Possible causes of abrupt climatic events	129
	Inquiry into the initiation of a glaciation	133
	Prevention of a new ice age?	134
4	Patterns of shorter-term change and variability	135
	4.1 Climatic variability and extremes W. J. Gibbs,	
	J. V. Maher & M. J. Coughlan	135
	Concept of climate	135
	Climatic variability	137
	Analysis of climatic variability	138
	Nature of the data	138
	Homogeneity of records	138
	Frequency distributions and indices of variability	140
	Examples of variability	142
	Time-series analysis	142
	Principal component analysis	144
	Climatic extremes	144
	Statistics of extremes	145
	Extreme climatic events	146
	Extreme low temperatures	148
	Extreme high temperatures	149
	Extremes of point rainfall	150
	4.2 Climatic fluctuations during the periods of historica	1
	and instrumental record R. G. Barry	150
	The data base	150
	Instrumental data	152
	Historical records	152
	Proxy data	153
	Interpretation of proxy data	153
	Dendroclimatology	153
	Glaciology	154
	Climatic characteristics of the last half-millennium	156
	Major fluctuations	156
	The instrumental period	158
	Statistical properties	161
	Circulation features	163
	Concluding remarks	166
	4.3 Patterns of variability in relation to the general	g you
	circulation A. B. Pittock	167
	Main controls	167
	Walker Circulation	170
	Standing wave pattern in the Northern Hemisphere	170

Latitudinal shift of circulation features	171
Characteristic patterns of variation	171
Australian rainfall	171
Global pressure, temperature and rainfall	173
Impact on climatic theory	173
Interpretation of climatic variation	173
Application to longer time scales	175
Implications for climate modelling	175
Local anomalies and anthropogenic effects	176
Other applications	178
Concluding remarks	178
4.4 The Southern Oscillation P. B. Wright	180
Mapping the Southern Oscillation	182
Lag relationships	182
Mechanism of the Oscillation	184
4.5 Regional mechanisms and variations	185
Variations in the Atlantic-Pacific circulation	
S. Hastenrath	185
Observational basis	185
Large-scale rainfall variations	187
Atmospheric circulation of drought and flood regimes	188
Trends of winter temperature in the Southern Hemisphere	
J. Williams & H. van Loon	191
Data and data treatment	191
Temperature trends at two Antarctic stations	191
Temperature and pressure trends over the Southern	
hemisphere	192
Changes in Australian rainfall and temperature	
M. J. Coughlan	194
Rainfall trends	194
Rainfall periodicities	196
Temperature trends	196
5 Models of climatic change	200
5.1 Global cycles and climate R. W. Fairbridge	200
Introduction: the scale of cycles	200
The dawn of history	203
First life and oxygen	204
Mountains, trees and coal	205
The Mesozoic	207
The Cenozoic	208
Conclusion	211
5.2 Theories of Upper Quaternary ice ages J. Chappell	211
Comparison of selected geological records	212

<b>Contents</b>
-----------------

Status of various ice-age theories	216
Alternately open and frozen Arctic	217
Periodic major surges of Antarctic ice	217
Alternations of state of ocean circulation	217
Volcanism and magnetic theories of glaciation	218
The Milankovitch hypothesis: orbital perturbations and	
glaciation	219
Glacial initiation, termination and North Atlantic	
temperatures	222
Concluding discussion	224
5.3 Modelling of ice masses: implications for climatic	
change	225
Some introductory considerations Editorial	225
Modelling surging glaciers and periodic surging of the	
Antarctic ice sheet W. Budd & B. McInnes	228
The model	228
Application to an East Antarctic ice sheet flowline	230
Assessment of other drainage basins in Antarctica	232
Assessment of other ice sheets	233
Ice-mass modelling and climate models Editorial	234
5.4 Mathematical modelling of climate	234
Basic considerations in climate modelling J. S. A. Green	234
The main components and mechanisms	235
Numerical techniques	238
Results	240
Climate models Editorial	245
Theoretical tools	246
Aims and means	247
Minimum entropy exchange, global dynamics and climate	
G. W. Paltridge	249
The basic model concept and development	249
Results	253
Conclusion	253
5.5 Volcanic events, climate, and climate modelling	256
Volcanic eruptions and climate during the past 500 years	
J. R. Bray	256
Grain yield	256
Temperature	257
Glaciation	260
Conclusions	262
A simulation of the possible consequence of a volcanic	
eruption on the general circulation of the atmosphere	
B. G. Hunt	263

	The model experiment	263
	Large-scale diffusion of the volcanic debris	265
	Large-scale atmospheric consequences	267
6	Modification of climate	269
	6.1 The biosphere, atmospheric composition and climate	
	I. E. Galbally & J. R. Freney	269
	Ozone	269
	Carbon dioxide	273
	Atmospheric aerosol	276
	Sea salt	277
	Mineral dust	278
	Gas-to-particle conversion	279
	Cloud condensation nuclei	280
	Conclusions	282
	6.2 Atmospheric carbon dioxide: recent advances in	
	monitoring and research G. I. Pearman	282
	Atmospheric monitoring of CO <sub>2</sub>	283
	The use of large-scale gradients to infer fluxes of CO <sub>2</sub>	286
	Prediction of future fossil fuel CO <sub>2</sub> production and	
	atmospheric concentration	289
	The temperature effect of increasing CO <sub>2</sub>	291
7	The effect of climatic change and variability on mankind	294
	7.1 Cultural and economic aspects	294
	The grand speculations Editorial	294
	More detailed analyses	296
	Case study one: climatic change and agriculture in Western	
	Australia G. W. Arnold & K. A. Galbraith	297
	Some general considerations	297
	Analysis of likely effects using simulation models	298
	Case study two: climatic variability and the thermal	
	performance of buildings P. J. Walsh	301
	Typical variability	301
	Energy requirements for heating and cooling	304
	Urban effects	306
	Natural long-term variability	307
	A grand synthesis? Editorial	308
	7.2 Climate and the historians J. L. Anderson	310
	Problems of data	310
	Problems of interpretation	312
	Methodology: science, history and economic history	314
	Conclusion	315
	7.3 The cultural, economic and climatic records	
	R. A. Bryson	316

	Contents
A global view of cultural change from the climatic	
perspective	316
Specific cases	320
Mycenae	320
Mill Creek	321
The Indus culture	322
Modern cases	324
Conclusion	326
7.4 Economic and political issues W. J. Maunder	327
Weather and climate as variable resources	327
The range and importance of weather and climatic	
variations	330
Commodities, weather information and politics	332
7.5 Mankind, climate and doomsday science	
M. Charlesworth	334
8 Progress and prospect	339
8.1 The problem of short-term climatic forecasting	
R. A. S. Ratcliffe	339
Short-term climatic forecasting in Britain	340
Relevance to the Southern Hemisphere	346
8.2 Possible future climatic trends: a panel discussion	350
8.3 Reflections on climatological research	360
A climatologist's view G. Manley	360
A geographer's view J. Oliver	363
An applied mathematician's view B. R. Morton	366
References	376
Author Index	427
Subject Index	434