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	
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. Shacklet	on 69
Climates of 18,000 years ago	70
Southern Hemisphere climate changes	73
3.3 Climatic and topographic changes from glaciological	
data D. Jenssen	77
Elevation change effect	77
Separation of elevation from climatic changes in the	
ð-record	80
3.4 Ouaternary 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 gradien	ts
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 and	
Bassiana	122
Summary	124
3.7 Abrupt events in climatic history H. Flohn	124

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 historical	
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	
circulation A. B. Pittock	167
Main controls	167
Walker Circulation	170
Standing wave pattern in the Northern Hemisphere	170

Characteristic patterns of variation 171 Australian rainfall 171 Global pressure, temperature and rainfall 172 Impact on climatic theory 173 Impact on climatic theory 173 Interpretation of climatic variation 173 Application to longer time scales 174 Implications for climate modelling 173 Concluding remarks 174 Concluding remarks 176 Concluding remarks 176 Concluding remarks 176 Mapping the Southern Oscillation 188 Mapping the Southern Oscillation 188 Variations in the Oscillation 188 Variations in the Atlantic-Pacific circulation 188 Choservational basis 188 Large-scale rainfall variations 188 Atmospheric circulation of drought and flood regimes 18 Trends of winter temperature in the Southern Hemisphere 1 J. Williams & H. van Loon 19 Temperature and pressure trends over the Southern 19 Temperature and pressure trends over the Southern 19 Rainfall trends 19	Latitudinal shift of circulation features	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 173 Implications for climate modelling 173 Cocal anomalies and anthropogenic effects 176 Other applications 176 Concluding remarks 177 A.4 The Southern Oscillation 186 Mapping the Southern Oscillation 187 Machanism of the Oscillation 188 Mechanism of the Oscillation 188 Variations in the Atlantic-Pacific circulation 187 S. Hastenrath 188 Observational basis 188 Large-scale rainfall variations 188 Trends of winter temperature in the Southern Hemisphere 19 J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature trends 19 Rainfall trends 19 Rainfall trends 19 Rainfall periodicities 19<	Characteristic patterns of variation	171
Global pressure, temperature and rainfall 173 Impact on climatic theory 173 Interpretation of climatic variation 173 Application to longer time scales 174 Implications for climate modelling 173 *Local anomalies and anthropogenic effects 176 Other applications 178 Concluding remarks 178 Concluding remarks 178 Mapping the Southern Oscillation 188 Mapping the Southern Oscillation 188 Mapring the Southern Oscillation 188 Mechanism of the Oscillation 188 Variations in the Atlantic–Pacific circulation 188 Variations in the Atlantic–Pacific circulation 188 Large-scale rainfall variations 188 Large-scale rainfall variations 188 Large-scale rainfall variations 189 Temperature trends at two Antarctic stations 199 Data and data treatment 199 Data and data treatment 199 Temperature trends 199 Rainfall trends 199 Rainfall periodicities 199	Australian rainfall	171
Impact on climatic theory 17 Interpretation of climatic variation 17 Application to longer time scales 17 Implications for climate modelling 17 Cocal anomalies and anthropogenic effects 17 Other applications 17 Concluding remarks 17 4.4 The Southern Oscillation 18 Mapping the Southern Oscillation 18 Mapping the Southern Oscillation 18 Machanism of the Oscillation 18 Variations in the Atlantic-Pacific circulation 18 Variations in the Atlantic-Pacific circulation 18 Atmospheric circulation of drought and flood regimes 18 Atmospheric circulation of drought and flood regimes 18 Temperature trends at two Antarctic stations 19 Data and data treatment 19 Temperature trends 19 Rainfall rends 19 Rainfall periodicities 19 Rainfall peri	Global pressure, temperature and rainfall	173
Interpretation of climatic variation 173 Application to longer time scales 173 Implications for climate modelling 173 *Local anomalies and anthropogenic effects 174 Other applications 174 Concluding remarks 176 A.4 The Southern Oscillation 186 Mapping the Southern Oscillation 187 Lag relationships 186 Mechanism of the Oscillation 186 Variations in the Atlantic-Pacific circulation 187 Observational basis 188 Large-scale rainfall variations 188 Observational basis 188 Atmospheric circulation of drought and flood regimes 188 Trends of winter temperature in the Southern Hemisphere 19 J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Rainfall periodicities 19 Rainfall periodici	Impact on climatic theory	173
Application to longer time scales 17. Implications for climate modelling 17. Tocal anomalies and anthropogenic effects 17. Other applications 17. Concluding remarks 17. 4.4 The Southern Oscillation 18. Mapping the Southern Oscillation 18. Lag relationships 18. Mechanism of the Oscillation 18. Variations in the Atlantic–Pacific circulation 18. Variations in the Atlantic–Pacific circulation 18. Atmospheric circulation of drought and flood regimes 18. Trends of winter temperature in the Southern Hemisphere 19. J. Williams & H. van Loon 19. Data and data treatment 19. Temperature trends at two Antarctic stations 19. Temperature and pressure trends over the Southern 19. Rainfall periodicities 19. Temperature trends 19. Rainfall periodicities 19. Temperature trends 19. Rainfall periodicities 19. Temperature trends 19. Models of climatic change 20.	Interpretation of climatic variation	173
Implications for climate modelling 173 *Local anomalies and anthropogenic effects 176 Other applications 178 Concluding remarks 178 4.4 The Southern Oscillation 188 Mapping the Southern Oscillation 188 Lag relationships 188 Mechanism of the Oscillation 188 Variations in the Atlantic–Pacific circulation 184 Observational basis 188 Large-scale rainfall variations 188 Atmospheric circulation of drought and flood regimes 186 Trends of winter temperature in the Southern Hemisphere 19 J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature and pressure trends over the Southern 19 Rainfall trends 19 Rainfall periodicities 19 Temperature trends 19 Rainfall periodicities 19 Models of climatic change 20 5.1 Global cycles and climate R. W. Fairbridge 20 Introduction: the scale of cycles 20	Application to longer time scales	175
*Local anomalies and anthropogenic effects 174 Other applications 175 Concluding remarks 176 4.4 The Southern Oscillation 186 Mapping the Southern Oscillation 186 Lag relationships 187 Mechanism of the Oscillation 186 Variations in the Atlantic-Pacific circulation 187 Variations in the Atlantic-Pacific circulation 187 Variations in the Atlantic-Pacific circulation 188 Variations in the Atlantic-Pacific circulation 188 Atmospheric circulation of drought and flood regimes 187 Trends of winter temperature in the Southern Hemisphere 19 J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature and pressure trends over the Southern 19 Rainfall periodicities 19 Rainfall periodicities 19 Temperature trends 19 Rainfall periodicities 19 Temperature trends 19 Models of climatic change 20 5.1 Global cycles and climate R. W. Fairbr	Implications for climate modelling	175
Other applications178Concluding remarks1784.4 The Southern Oscillation P. B. Wright188Mapping the Southern Oscillation188Lag relationships186Mechanism of the Oscillation186Variations in the Atlantic-Pacific circulation187Variations in the Atlantic-Pacific circulation188Observational basis188Large-scale rainfall variations188Atmospheric circulation of drought and flood regimes188Trends of winter temperature in the Southern Hemisphere19J. Williams & H. van Loon19Data and data treatment19Temperature and pressure trends over the Southern19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change2005.1 Global cycles and climate R. W. Fairbridge200Introduction: the scale of cycles200The dawn of history200First life and oxygen200Mountains, trees and coal200The Mesozoic200Conclusion2105.2 Theories of Upper Quaternary ice ages J. Chappell210Comparison of selected geological records210	Local anomalies and anthropogenic effects	176
Concluding remarks1744.4 The Southern Oscillation P. B. Wright188Mapping the Southern Oscillation187Lag relationships188Mechanism of the Oscillation188Variations in the Atlantic-Pacific circulation188Observational basis188Large-scale rainfall variations188Observational basis188Large-scale rainfall variations187Atmospheric circulation of drought and flood regimes188Trends of winter temperature in the Southern Hemisphere19J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change2005.1 Global cycles and climate R. W. Fairbridge200Introduction: the scale of cycles200The dawn of history200First life and oxygen200Mountains, trees and coal200The Mesozoic200Conclusion2105.2 Theories of Upper Quaternary ice agesJ. ChappellComparison of selected geological records210	Other applications	178
4.4 The Southern Oscillation P. B. Wright 186 Mapping the Southern Oscillation 187 Lag relationships 187 Mechanism of the Oscillation 188 Variations in the Atlantic-Pacific circulation 188 Variations in the Atlantic-Pacific circulation 188 Observational basis 188 Large-scale rainfall variations 188 Atmospheric circulation of drought and flood regimes 188 Trends of winter temperature in the Southern Hemisphere 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature and pressure trends over the Southern 19 hemisphere 19 Changes in Australian rainfall and temperature 19 Rainfall trends 19 Rainfall periodicities 19 Temperature trends 19 Models of climatic change 20 5.1 Global cycles and climate R. W. Fairbridge 20 Introduction: the scale of cycles </td <td>Concluding remarks</td> <td>178</td>	Concluding remarks	178
Mapping the Southern Oscillation182Lag relationships183Mechanism of the Oscillation1844.5 Regional mechanisms and variations184Variations in the Atlantic–Pacific circulation184S. Hastenrath185Observational basis185Large-scale rainfall variations186Atmospheric circulation of drought and flood regimes186Trends of winter temperature in the Southern Hemisphere186J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19hemisphere19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change2005.1 Global cycles and climate R. W. Fairbridge200Introduction: the scale of cycles200The dawn of history200First life and oxygen200Mountains, trees and coal200The Mesozoic200Conclusion2105.2 Theories of Upper Quaternary ice ages J. Chappell210Comparison of selected geological records210	4.4 The Southern Oscillation P. B. Wright	180
Lag relationships183Mechanism of the Oscillation1844.5 Regional mechanisms and variations183Variations in the Atlantic-Pacific circulation184S. Hastenrath185Observational basis185Large-scale rainfall variations186Atmospheric circulation of drought and flood regimes186Trends of winter temperature in the Southern Hemisphere186J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change2005.1 Global cycles and climate R. W. Fairbridge200Introduction: the scale of cycles200The dawn of history200First life and oxygen200Mountains, trees and coal200The Cenozoic200Conclusion2105.2 Theories of Upper Quaternary ice ages J. Chappell210Comparison of selected geological records210	Mapping the Southern Oscillation	182
Mechanism of the Oscillation18-4.5 Regional mechanisms and variations18:Variations in the Atlantic-Pacific circulation18:Variations in the Atlantic-Pacific circulation18:Observational basis18:Large-scale rainfall variations18:Atmospheric circulation of drought and flood regimes18:Trends of winter temperature in the Southern Hemisphere18:J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19Nemisphere19Changes in Australian rainfall and temperature19Rainfall periodicities19Rainfall periodicities19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate20S.1 Global cycles and climate20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice agesJ. ChappellComparison of selected geological records21	Lag relationships	182
4.5 Regional mechanisms and variations 18: Variations in the Atlantic-Pacific circulation 8: S. Hastenrath 18: Observational basis 18: Large-scale rainfall variations 18: Atmospheric circulation of drought and flood regimes 18: Trends of winter temperature in the Southern Hemisphere 18: J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature and pressure trends over the Southern 19 hemisphere 19 Changes in Australian rainfall and temperature 19 Rainfall trends 19 Rainfall periodicities 19 Temperature trends 19 Rainfall periodicities 19 Temperature trends 19 Models of climatic change 20 5.1 Global cycles and climate R. W. Fairbridge 20 Introduction: the scale of cycles 20 The dawn of history 20 First life and oxygen 20 Mountains, trees and coal 20	Mechanism of the Oscillation	184
Variations in the Atlantic-Pacific circulationS. Hastenrath18:Observational basis18:Large-scale rainfall variations18:Atmospheric circulation of drought and flood regimes18:Trends of winter temperature in the Southern Hemisphere19:J. Williams & H. van Loon19:Data and data treatment19:Temperature trends at two Antarctic stations19:Temperature and pressure trends over the Southern19:hemisphere19:Changes in Australian rainfall and temperature19:Rainfall trends19:Rainfall rends19:Rainfall periodicities19:Temperature trends19:Models of climatic change20:5.1 Global cycles and climate R. W. Fairbridge20:The dawn of history20:First life and oxygen20:Mountains, trees and coal20:The Mesozoic20:The Cenozoic20:Conclusion21:5.2 Theories of Upper Quaternary ice ages J. Chappell21:Comparison of selected geological records21:	4.5 Regional mechanisms and variations	185
S. Hastenrath 18: Observational basis 18: Large-scale rainfall variations 18: Atmospheric circulation of drought and flood regimes 18: Trends of winter temperature in the Southern Hemisphere 18: J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature and pressure trends over the Southern 19 hemisphere 19 Changes in Australian rainfall and temperature 19 Rainfall trends 19 Rainfall periodicities 19 Temperature trends 19 Rainfall periodicities 19 Rainfall periodicities 19 Temperature trends 19 Rainfall periodicities 19 Temperature trends 19 Models of climatic change 20 5.1 Global cycles and climate R. W. Fairbridge 20 Introduction: the scale of cycles 20 The dawn of history 20 First life and oxygen 20 Mountains, trees and coal 20	Variations in the Atlantic-Pacific circulation	
Observational basis18:Large-scale rainfall variations18:Atmospheric circulation of drought and flood regimes18:Atmospheric circulation of drought and flood regimes18:Trends of winter temperature in the Southern Hemisphere19J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19hemisphere19Changes in Australian rainfall and temperatureM. J. Coughlan19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	S. Hastenrath	185
Large-scale rainfall variations18' Atmospheric circulation of drought and flood regimesTrends of winter temperature in the Southern HemisphereJ. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southernhemisphere19Changes in Australian rainfall and temperatureM. J. Coughlan19Rainfall trends19Rainfall periodicities19Temperature trends19Rainfall periodicities19Rainfall change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Observational basis	185
Atmospheric circulation of drought and flood regimes18Trends of winter temperature in the Southern Hemisphere19J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19hemisphere19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Rainfall periodicities19Rainfall change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Large-scale rainfall variations	187
Trends of winter temperature in the Southern Hemisphere19J. Williams & H. van Loon19Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19hemisphere19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Atmospheric circulation of drought and flood regimes	188
J. Williams & H. van Loon 19 Data and data treatment 19 Temperature trends at two Antarctic stations 19 Temperature and pressure trends over the Southern 19 hemisphere 19 Changes in Australian rainfall and temperature 19 Rainfall trends 19 Rainfall periodicities 19 Temperature trends 19 Rainfall periodicities 19 Temperature trends 19 Models of climatic change 20 5.1 Global cycles and climate R. W. Fairbridge 20 Introduction: the scale of cycles 20 The dawn of history 20 First life and oxygen 20 Mountains, trees and coal 20 The Cenozoic 20 Conclusion 21 S.2 Theories of Upper Quaternary ice ages J. Chappell 21 Comparison of selected geological records 21	Trends of winter temperature in the Southern Hemisphere	
Data and data treatment19Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19hemisphere19Changes in Australian rainfall and temperature19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Cenozoic205.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	J. Williams & H. van Loon	191
Temperature trends at two Antarctic stations19Temperature and pressure trends over the Southern19hemisphere19Changes in Australian rainfall and temperature19M. J. Coughlan19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Data and data treatment	191
Temperature and pressure trends over the Southern hemisphere19Changes in Australian rainfall and temperature19M. J. Coughlan19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Temperature trends at two Antarctic stations	191
hemisphere19Changes in Australian rainfall and temperatureM. J. CoughlanRainfall trendsIf Rainfall periodicitiesTemperature trendsModels of climatic changeSolution: the scale of cyclesIntroduction: the scale of cyclesThe dawn of historyFirst life and oxygenMountains, trees and coalThe CenozoicConclusionS.2 Theories of Upper Quaternary ice agesJ. ChappellComparison of selected geological records	Temperature and pressure trends over the Southern	
Changes in Australian rainfall and temperatureM. J. Coughlan19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20S.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	hemisphere	192
M. J. Coughlan19Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Changes in Australian rainfall and temperature	
Rainfall trends19Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20S.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	M. J. Coughlan	194
Rainfall periodicities19Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Rainfall trends	194
Temperature trends19Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Rainfall periodicities	196
Models of climatic change205.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Temperature trends	196
5.1 Global cycles and climate R. W. Fairbridge20Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Models of climatic change	200
Introduction: the scale of cycles20The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice agesJ. ChappellComparison of selected geological records21	5.1 Global cycles and climate R. W. Fairbridge	200
The dawn of history20First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Introduction: the scale of cycles	200
First life and oxygen20Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	The dawn of history	203
Mountains, trees and coal20The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	First life and oxygen	204
The Mesozoic20The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	Mountains, trees and coal	205
The Cenozoic20Conclusion215.2 Theories of Upper Quaternary ice ages J. Chappell21Comparison of selected geological records21	The Mesozoic	207
Conclusion215.2 Theories of Upper Quaternary ice agesJ. Chappell21Comparison of selected geological records21	The Cenozoic	208
5.2 Theories of Upper Quaternary ice ages J. Chappell 21 Comparison of selected geological records 21	Conclusion	211
Comparison of selected geological records 21	5.2 Theories of Upper Quaternary ice ages J. Chappell	211
	Comparison of selected geological records	212

5

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 ₂	283
	The use of large-scale gradients to infer fluxes of CO ₂	286
	Prediction of future fossil fuel CO ₂ production and	
	atmospheric concentration	289
	The temperature effect of increasing CO ₂	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	
	K. A. Bryson	316

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	
Subject Index	434