



CLIMATE CHANGE

A Multidisciplinary Approach

WILLIAM JAMES BURROUGHS

Climate Change

**A MULTIDISCIPLINARY
APPROACH**

WILLIAM JAMES BURROUGHS

339/4123 INSTITUT
FÜR METEOROLOGIE U. KLIMATOLOGIE
UNIVERSITÄT HANNOVER
HERRENHÄUSER STR. 2 - 30419 HANNOVER

DK: 551.583
551.586

J III 94



**CAMBRIDGE
UNIVERSITY PRESS**

CONTENTS

<i>Preface</i>	<i>page</i>	ix
<i>Acknowledgements</i>		xiii
<i>List of Boxes</i>		xv
1 INTRODUCTION		1
1.1 Weather and Climate		2
1.2 What Is Climate Variability and Climate Change?		2
1.3 Connections, Timescales and Uncertainties		3
2 RADIATION AND THE EARTH'S ENERGY BALANCE		10
2.1 Solar and Terrestrial Radiation		11
2.1.1 Radiation Laws		11
2.1.2 Solar Radiation		15
2.1.3 Terrestrial Radiation		15
2.1.4 The Energy Balance of the Earth		20
2.2 Solar Variability		27
2.3 Summary		30
3 THE ELEMENTS OF THE CLIMATE		32
3.1 The Atmosphere and Oceans in Motion		32
3.2 Atmospheric Circulation Patterns		36
3.3 Radiation Balance		45
3.4 The Hydrological Cycle		49
3.5 The Biosphere		50
3.6 Sustained Abnormal Weather Patterns		51
3.7 Atmosphere–Ocean Interactions		56
3.8 The Great Ocean Conveyor		67
3.9 Summary		71
4 EVIDENCE OF CLIMATE CHANGE		73
4.1 Peering into the Abyss of Time		74

4.2	Atmospheric Composition	85
4.3	Sea Level Fluctuations	87
4.4	The Ice Ages	90
4.5	The End of the Last Ice Age	95
4.6	The Holocene Climatic Optimum	98
4.7	Changes in Recorded History	100
4.8	The Medieval Climatic Optimum	104
4.9	The 'Little Ice Age'	104
4.10	The Twentieth Century Warming	110
4.11	Concluding Observations	113
5	CONSEQUENCES OF CLIMATE CHANGE	116
5.1	Geological Consequences	117
5.2	Flora and Fauna	118
5.3	Mass Extinctions	122
5.4	Glaciers, Ice Caps, Ice Sheets and Sea Levels	123
5.5	The Historical Impact of Climatic Variations	126
5.6	Agriculture	128
5.7	Spread of Diseases	132
5.8	The Economic Impact of Extreme Weather Events	134
5.9	Summary	137
6	THE MEASUREMENT OF CLIMATIC CHANGE	139
6.1	Instrumental Observations	140
6.2	Satellite Measurements	146
6.3	Historical Records	151
6.4	Proxy Measurements	153
6.4.1	Tree Rings	154
6.4.2	Ice Cores	157
6.4.3	Ocean Sediments	161
6.4.4	Pollen Records	163
6.4.5	Boreholes	166
6.4.6	Other Proxy Measurements	167
6.5	Dating	168
6.6	Isotope Age Dating	169
6.7	Summary	173
7	STATISTICS, SIGNIFICANCE AND CYCLES	175
7.1	Time Series, Sampling and Harmonic Analysis	176
7.2	Noise	180
7.3	Measures of Variability and Significance	182
7.4	Smoothing	193
7.5	Multidimensional Analysis	197
7.6	Summary	199

8	THE CAUSES OF CLIMATIC CHANGE	201
	8.1 Autovariance and Non-linearity	202
	8.2 Atmosphere–Ocean Interactions	204
	8.3 Ocean Currents	207
	8.4 Volcanoes	208
	8.5 Sunspots and Solar Activity	211
	8.6 Tidal Forces	217
	8.7 Orbital Variations	221
	8.8 Changes in Atmospheric Composition	225
	8.9 Human Activities	227
	8.10 Catastrophes and the ‘Nuclear Winter’	230
	8.11 Summary	235
9	MODELLING THE CLIMATE	239
	9.1 Global Circulation Models	240
	9.2 Simulation of Climatic Variability	247
	9.3 The Challenges Facing Modellers	252
	9.3.1 Clouds	253
	9.3.2 Land-Surface Processes	254
	9.3.3 Winds, Waves and Currents	255
	9.3.4 Other Greenhouse Gases	256
	9.3.5 Exploitation of Numerical Weather Prediction	256
	9.4 Summary	257
10	PREDICTING CLIMATE CHANGE	259
	10.1 Natural Variability	259
	10.2 Predicting Global Warming	261
	10.3 The Predicted Consequences of Global Warming	263
	10.4 When Will We Be Certain About Global Warming?	267
	10.5 Can We Do Anything About Climate Change?	271
	10.6 The Gaia Hypothesis	273
	<i>Bibliography</i>	277
	<i>Glossary</i>	283
	<i>Index</i>	293