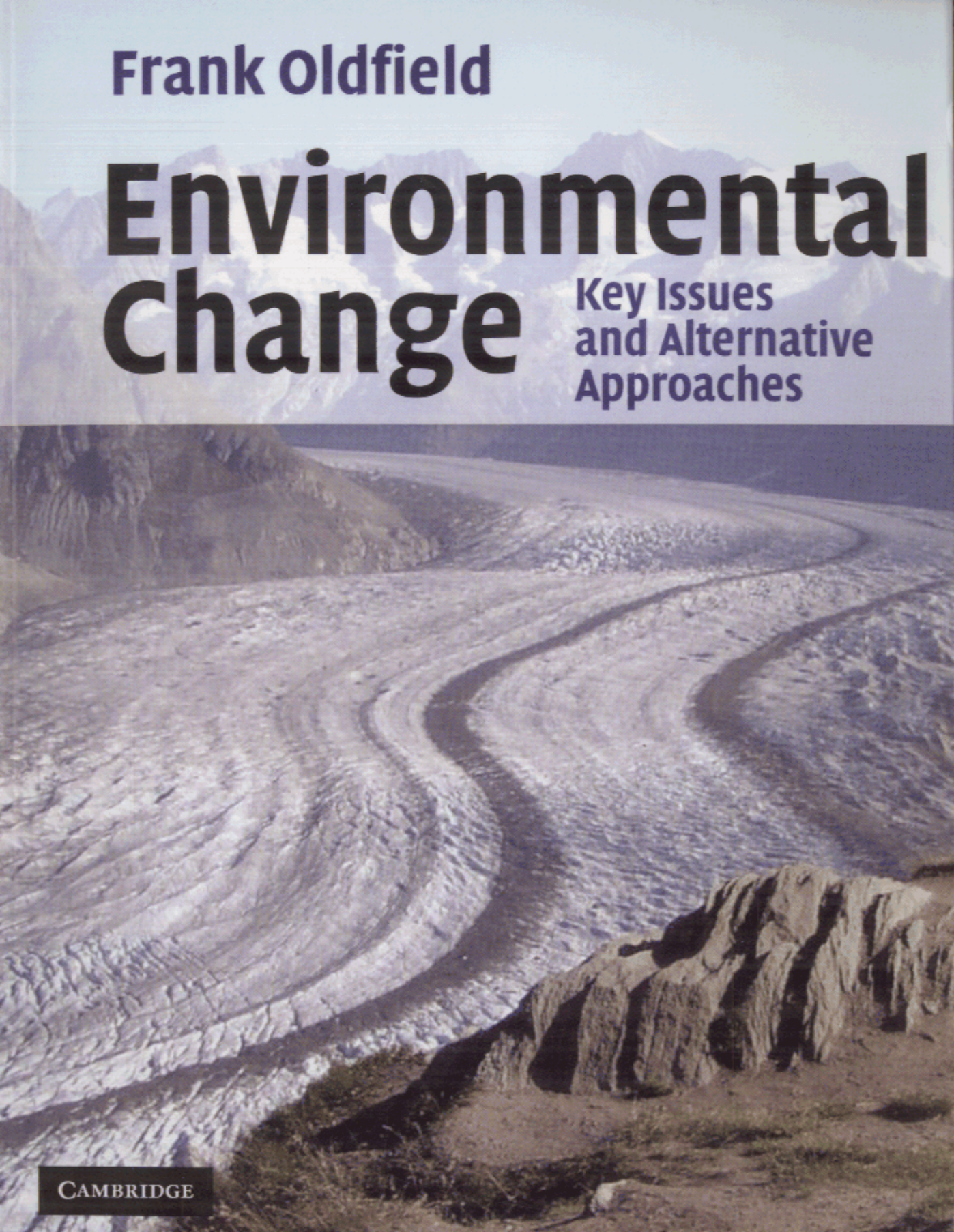


**Frank Oldfield**

# **Environmental Change**

**Key Issues  
and Alternative  
Approaches**

**CAMBRIDGE**

A photograph of a large glacier flowing through a valley, with rocky terrain in the foreground and mountains in the background. The glacier is a mix of white and grey, with dark lines indicating its flow paths. The foreground shows a rocky outcrop with some sparse vegetation. The background features a range of mountains under a clear sky.

# Contents

<i>Preface</i>	<i>page</i>	xi
<i>Acknowledgements</i>		xiii
<i>List of Permissions</i>		xiv
<b>1 Defining and exploring the key questions</b>		<b>1</b>
1.1 Global changes present and past		1
1.2 Earth-system science		2
1.3 The key issues: a preliminary analysis		9
1.4 Scientific methodologies		13
1.5 Linking methodologies		16
1.6 The thematic sequence		17
<b>2 An introduction to models and modelling</b>		<b>19</b>
2.1 The role and rationale for modelling		19
2.2 Some essential generic concepts in climate and Earth-system modelling		20
2.3 Climate and Earth-system models of varying complexity		28
2.4 Subsystem models, with special reference to the oceans		30
<b>3 The palaeo-record: approaches, timeframes and chronology</b>		<b>34</b>
3.1 Introduction		34
3.2 Alternative approaches to the palaeo-record		35
3.3 The Vostok timeframe		36
3.4 Chronology -- subdivisions, tuning and dating		37
3.5 Temporal resolution		49
<b>4 The Palaeo-record: archives, proxies and calibration</b>		<b>50</b>
4.1 Instrumental and documentary archives of past environmental change		50
4.2 Environmental archives and proxies		54
4.3 Sources of evidence for patterns of external climate forcing		64
4.4 Reconstructing past changes in the world's oceans		67
4.5 Reconstructing past impacts resulting from climate change and human activities		71
4.6 The multi-proxy approach		73

## Contents

<b>5 Glacial and interglacial worlds</b>	<b>74</b>
5.1 Key aspects of past variability	74
5.2 Forcings, feedbacks and phasing	78
5.3 Marine isotope stage 5e and the last (Eemian)interglacial	86
5.4 Rapid climate oscillations during the last glacial period	88
5.5 The last glacial maximum (LGM)	94
<b>6 The transition from the last glacial maximum to the Holocene</b>	<b>97</b>
6.1 The temperature record at each pole	97
6.2 Spatial patterns of temperature change	99
6.3 Changes in continental hydrology	102
6.4 Dynamics, forcing and feedbacks	103
6.5 Transitions and feedbacks – deglaciation in the context of longer-term changes	110
6.6 Glacial–Interglacial changes and the modern world	117
<b>7 The Holocene</b>	<b>118</b>
7.1 The transition to the Holocene	118
7.2 Patterns of overall climate change during the Holocene	119
7.3 The early Holocene: delays, interruptions and biosphere feedbacks	122
7.4 Major hydrological changes – a green then a brown Sahara	125
7.5 Modes of variability	128
7.6 El Niño southern oscillation (ENSO)	129
7.7 The North Atlantic (NAO) and other oscillations	134
7.8 Examples of changing extremes	137
7.9 The Medieval Warm Period and the Little Ice Age	139
7.10 Signs of earlier synchronous changes from the mid Holocene onwards	142
7.11 External forcing	143
7.12 Feedbacks	146
7.13 Concluding comments	150
<b>8 The Anthropocene – a changing atmosphere</b>	<b>152</b>
8.1 The idea of the Anthropocene	152
8.2 Increasing concentrations of greenhouse gases	153
8.3 Atmospheric aerosols	162
8.4 Chlorofluorocarbons and Ozone	165
8.5 Other atmospheric contaminants	167
8.6 Summary and conclusions	168
<b>9 The Anthropocene – changing land</b>	<b>169</b>
9.1 Changed global nutrient cycles	169
9.2 Deforestation	171
9.3 Land degradation and desertification	173
9.4 The long-term palaeo-perspective	174

<b>10 The Anthropocene: changing aquatic environments and ecosystems</b>	<b>179</b>
10.1 Introduction	179
10.2 Changes in lake-water chemistry	179
10.3 Other hydrological changes – rivers and groundwater	183
10.4 Coastal and marine impacts	186
<b>11 Changing biodiversity</b>	<b>190</b>
11.1 Extinctions	190
11.2 Species diversity	192
11.3 Consequences for ecosystem function	193
<b>12 Detection and attribution</b>	<b>197</b>
12.1 Introduction	197
12.2 Detection and attribution – context and distinctions	197
12.3 Detection – a warming world	199
12.4 Rising sea-level	205
12.5 Ecosystem responses	212
12.6 Attribution	217
12.7 Concluding comments	227
<b>13 Future global mean temperatures and sea-level</b>	<b>229</b>
13.1 Future changes in global mean temperature	229
13.2 Future global mean sea-level	240
13.3 The longer term – are there ‘surprises’ round the corner?	242
13.4 Concluding comments and questions arising	245
<b>14 From the global to the specific</b>	<b>247</b>
14.1 Introduction	247
14.2 Future precipitation, evaporation and runoff	248
14.3 Modelling monsoons and ENSO	252
14.4 Circum-Arctic climates	254
14.5 High-resolution simulations	255
14.6 Floods in the future	258
14.7 Future droughts	259
<b>15 Impacts and vulnerability</b>	<b>262</b>
15.1 Introduction	262
15.2 Sectoral impacts and impacts on ecosystems	263
15.3 Impacts, risk and vulnerability assessment	275
<b>16 Sceptics, responses and partial answers</b>	<b>279</b>
16.1 Introduction	279
16.2 Some sceptical science-based arguments	280
16.3 Some non-scientific assertions	285
16.4 Key questions and some tentative responses	286

## Contents

16.5 A personal perspective on mitigation and adaptation	289
16.6 A final key issue	291
<i>References</i>	296
<i>Index</i>	346