### Contents

**Preface** ................................................................. xi
**Acknowledgements** ............................................................. xiii

**CHAPTER 1  Climate** ............................................................. 1

1.1  The components of climate .................................................. 1

*Introduction and outline of the book* ........................................... 2
*The climate system* ............................................................... 4

1.2  Climate change assessment .................................................. 7

1.2.1  *The scientific perspective* ................................................. 8
1.2.2  *The human perspective* .................................................. 14

1.3  Climate forcings ............................................................... 17

1.3.1  *External causes of climatic change* .................................... 18
*Milankovitch variations* ....................................................... 18
*Solar activity* ................................................................. 21
*Other external factors* ....................................................... 21

1.3.2  *Internal factors: Human-induced changes* .................................. 21
*Greenhouse gases* ............................................................ 22
*Tropospheric aerosols and clouds* ............................................ 22
*Stratospheric ozone* .......................................................... 22
*Land-surface changes* ....................................................... 25

1.3.3  *Internal factors: Natural changes* ...................................... 28
*Volcanic eruptions* .......................................................... 28
*Ocean circulation changes* ................................................... 30

1.4  Climate feedbacks and sensitivity ......................................... 31

1.4.1  *The ice-albedo feedback mechanism* .................................... 33
1.4.2  *The water-vapour 'greenhouse'* ......................................... 33
1.4.3  *Cloud feedbacks* ....................................................... 33
1.4.4  *Combining feedback effects* ............................................. 34

1.5  Range of questions for climate modelling ................................ 39

*Recommended reading* ....................................................... 40
## CHAPTER 2  A History of and Introduction to Climate Models

2.1 Introducing climate modelling
- The need for simplification
- Resolution in time and space

2.2 Types of climate models
- 2.2.1 Energy balance climate models
- 2.2.2 One-dimensional radiative–convective climate models
- 2.2.3 Two-dimensional climate models
- 2.2.4 General circulation models
- 2.2.5 The interactive biosphere

2.3 History of climate modelling

2.4 Sensitivity of climate models
- Equilibrium climatic states
- Equilibrium conditions and transitivity of climate systems
- Stability of model results

2.5 Parameterization of climate processes
- Interactions in the climate system
- The need for observations

2.6 Simulation of the full, interacting climate system: One goal of modelling

Recommended reading

## CHAPTER 3  Energy Balance Models

3.1 Balancing the planetary radiation budget

3.2 The structure of energy balance models
- 3.2.1 Zero-dimensional EBMs
- 3.2.2 One-dimensional EBMs

3.3 Parameterizing the climate system for energy balance models
- Albedo
- Outgoing infrared radiation
- Heat transport

3.4 A Basic energy balance climate model
- Description of the EBM
- EBM model code
- Energy balance model exercises

3.5 Energy balance models and glacial cycles

3.6 Box models – another form of energy balance model
- 3.6.1 A simple box model of the ocean–atmosphere
- 3.6.2 A coupled atmosphere, land and ocean energy balance box model

3.7 Energy balance models: Deceptively simple models

Recommended reading