## Contents

**List of Contributors**  ix  
**Preface**  xi  
**Abbreviations, Constants, and Nomenclature**  xiii  

### 1 The Climate of the Earth  1  
_E John Lockwood_  
1.1 Basic Climatology  1  
1.2 General Atmospheric Circulation  3  
1.3 Palaeoclimates  6  
1.4 Polar Climates  12  
1.5 Temperate Latitude Climates  16  
1.6 Tropical Climates  20  
Questions  28  
References  28  
Further Reading  30  

### 2 Chemical Evolution of the Atmosphere  31  
_E Richard Wayne_  
2.1 Creation of the Planets and Their Earliest Atmospheres  34  
2.2 Earth’s Atmosphere before Life Began  37  
2.3 Comparison of Venus, Earth, and Mars  38  
2.4 Life and Earth’s Atmosphere  41  
2.5 Carbon Dioxide in Earth’s Atmosphere  47  
2.6 The Rise of Oxygen Concentrations  50  
2.7 Protection of Life from Ultraviolet Radiation  60  
2.8 The Great Oxidation Event and Related Issues  64  
2.9 The Future  68  
Questions  68  
References  69  
Further Reading  74
3 Atmospheric Energy and the Structure of the Atmosphere 75
Hugh Coe
3.1 The Vertical Structure of Earth’s Atmosphere 75
3.2 Solar and Terrestrial Radiation 77
3.3 Solar Radiation, Ozone, and the Stratospheric Temperature Profile 82
3.4 Trapping of Longwave Radiation 85
3.5 A Simple Model of Radiation Transfer 85
3.6 Light Scattering 90
3.7 Conduction, Convection, and Sensible and Latent Heat 96
3.8 Energy Budget for Earth’s Atmosphere 103
3.9 Aerosols, Clouds, and Climate 106
3.10 Solar Radiation and the Biosphere 109
3.11 Summary 111
Questions 112
References 112
Further Reading 114

4 Biogeochemical Cycles 115
Dudley Shallcross and Anwar Khan
4.1 Sources 119
4.2 Sinks 119
4.3 Carbon 124
4.4 Nitrogen 132
4.5 Sulphur 134
4.6 Halogens 142
4.7 Hydrogen 152
4.8 Summary 153
Questions 153
References 154
Further Reading 157

5 Tropospheric Chemistry and Air Pollution 159
Paul Monks and Joshua Vande Hey
5.1 Sources of Trace Gases in the Atmosphere 159
5.2 Key Processes in Tropospheric Chemistry 164
5.3 Initiation of Photochemistry by Light 165
5.4 Tropospheric Oxidation Chemistry 166
5.5 Night-Time Oxidation Chemistry 178
5.6 Halogen Chemistry 182
5.7 Air Pollution and Urban Chemistry 187
# Contents

5.8 Summary 195  
Questions 197  
References 199  
Further Reading 202  

6 Cloud Formation and Chemistry 203  
*Peter Brimblecombe*  
6.1 Clouds 203  
6.2 Cloud Formation 204  
6.3 Particle Size and Water Content 207  
6.4 Dissolved Solids in Cloud Water and Rainfall 209  
6.5 Dissolution of Gases 211  
6.6 Reactions and Photochemistry 219  
6.7 Radical and Photochemical Reactions 224  
6.8 Summary 227  
References 228  
Further Reading 231  
Websites 231  

7 Particulate Matter in the Atmosphere 233  
*Paul I. Williams*  
7.1 Aerosol Properties 235  
7.2 Aerosol Sources 245  
7.3 The Role of Atmospheric Particles 254  
7.4 Aerosol Measurements 262  
7.5 Summary 265  
Acknowledgement 266  
Questions 266  
References 267  

8 Stratospheric Chemistry and Ozone Depletion 271  
*Martyn P. Chipperfield and A. Rob MacKenzie*  
8.1 Ozone Column Amounts 272  
8.2 Physical Structure of the Stratosphere 275  
8.3 Gas-Phase Chemistry of the Stratosphere 282  
8.4 Aerosols and Clouds in the Stratosphere 287  
8.5 Heterogeneous Chemistry of the Stratosphere 290  
8.6 Future Perturbations to the Stratosphere 291  
8.7 Summary 295  
Questions 295  
References 296
9 Boundary Layer Meteorology and Atmospheric Dispersion  299
   Janet Barlow and Natalie Theeuwes
9.1 The Atmospheric Boundary Layer  299
9.2 Flow over Vegetation  307
9.3 The Urban Boundary Layer  312
9.4 Dispersion of Pollutants  319
9.5 Summary  326
Questions  327
References  327
Further Reading  329

10 Urban Air Pollution  331
   Zongbo Shi
10.1 Introduction  331
10.2 Urban Air Pollution – A Brief History  331
10.3 Scale of Urban Air Pollution  333
10.4 Air Pollutants and Their Sources in the Urban Atmosphere  334
10.5 From Emissions to Airborne Concentrations  339
10.6 Urban-Scale Impacts  343
10.7 Means of Mitigation  349
10.8 Summary  361
Acknowledgement  363
Questions  363
References  364
Further Reading  365

11 Global Warming and Climate Change Science  367
   Atul Jain, Xiaoming Xu, and Nick Hewitt
11.1 Historical Evidence of the Impact of Human Activities on Climate  369
11.2 Future Outlook of Climate Change  379
11.3 The Integrated Science Assessment Modelling (ISAM)  386
11.4 Potential Impacts of Climate Change  393
11.5 Summary  395
Acknowledgement  396
Questions  396
References  396

Appendix: Suggested Web Resources  399
Index  401