

Contents

Foreword	VII
Preface	XI
PART I. INTRODUCTION TO THE SUN-CLIMATE CONNECTIONS.....	1
1.1 The Earth's atmosphere: an introduction	3
1.2 The impact of solar variability on climate	13
1.3 The Sun-Earth connection, on scales from minutes to millennia	19
1.4 The role of the Sun in climate change: a brief history	27
1.5 The role of the Sun in climate change: a societal viewpoint.....	35
1.6 The debate about solar activity and climate change	41
References of Part I	49
PART II. SOLAR AND SPACE FORCING	53
2.1 Basics of solar and heliospheric modulation	55
2.2 Solar radiative forcing	67
2.3 Variability of solar and galactic cosmic rays	77
2.4 Variability and effects by solar wind	85
2.5 Variations of solar activity	91
2.6 Understanding solar activity	97
INFOBOX 2.1 Orbital forcing of glacial - interglacial cycles	103
INFOBOX 2.2 Grand minima and maxima of solar activity.....	111
INFOBOX 2.3 A practical guide to solar forcing data	113
References of Part II.....	121

PART III. DETECTING SOLAR INFLUENCE ON CLIMATE	127
3.1 Observations on paleoclimatic time scales	129
3.2 Ground-based observations	139
3.3 Satellite observations	155
3.4 Reanalysis data	165
3.5 Uncertainties and unknowns in atmospheric observations: How do they affect the solar signal identification?	171
3.6 Numerical models of atmosphere and ocean	179
3.7 From climate to Earth system models	187
3.8 Uncertainties in the modeling of the solar influence on climate	195
3.9 Detection and attribution: How is the solar signal identified and distinguished from the response to other forcings?	203
INFOBOX 3.1 Why are models needed in the first place, and can they be trusted?	211
INFOBOX 3.2 Model Equations and how they are solved	213
References of Part III	221
PART IV. IMPACTS ON THE EARTH SYSTEM	227
4.1 Direct impact of solar irradiance variability	229
4.2 'Top-down' versus 'bottom-up' mechanisms for solar-climate coupling	237
4.3 Interactions of different sources of variability	247
4.4 Impact of solar variability on the magnetosphere	255
4.5 Atmospheric ionisation by solar energetic particle precipitation	261
4.6 Impact of energetic particle precipitation on atmospheric chemistry and climate	267
4.7 The impact of cosmic rays on clouds	273
4.8 Impact of solar variability on the global electric circuit	281
INFOBOX 4.1 Modeled impact of total solar irradiance (TSI) forcing	289
INFOBOX 4.2 Lightning, cosmic rays and energetic particles	293

INFOBOX 4.3 The influence of solar variability on extreme weather	297
References of Part IV	301
PART V. CONCLUSION	309
Conclusions	311
References of Part V	320
Glossary	321
The authors	341