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Sixth Edition



Atmosphere, weather and climate

SIXTH EDITION

ROGER G. BARRY AND RICHARD J. CHORLEY



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Preface to the sixth edition

When the first edition of this book appeared in 1968, it was greeted as being 'remarkably up to date' (*Meteorological Magazine*). Since that time several new editions have extended and sharpened its description and analysis of atmospheric processes and global climates. Indeed, succeeding Prefaces provide a virtual commentary on recent advances in meteorology and climatology of relevance to students in these fields and to scholars in related disciplines.

In 1971 major additions were made regarding the energy budget of the earth, the spatial pattern of the heat budget components, atmospheric stability, orographic precipitation, oceanic circulation and associated climatic effects, vorticity, mesoscale systems in middle latitudes, rainfall variability and aspects of the climate of the sub-Arctic, the Mediterranean and eastern Asia.

The third edition of 1976 involved the substantial recasting of Chapters 2, 4 and 7 and the addition of a new Appendix on synoptic weather maps. New material was introduced on atmospheric composition and its variations with time, the radiation budget, adiabatic temperature changes, the effects of topographic barriers on winds, land and sea breezes, the southern hemisphere circulation and air masses, depression structure and the spatial distribution of precipitation, long-range forecasting, the climate of the Mediterranean, the intertropical confluence, tropical disturbances and subsynoptic systems, and urban climates.

In 1982 Chapters 7 and 8 were substantially

rewritten and the units were standardized throughout. Major additions and revisions involved the material on solar radiation, thunderstorm mechanisms, drought, mesoscale rainfall systems, tornado structure, disturbances within subtropical high-pressure belts, the energy balance of vegetated surfaces, urban climatology, atmospheric pollution and the nature and causes of climatic change. This fourth edition contained over 100 new or revised figures and many new plates, compared with the first edition.

The fifth edition of 1987 included new sections on modelling the atmospheric circulation, forecasting, the African monsoon and ENSO events, together with a new appendix on data sources. Additional material was provided on greenhouse gases and volcanic dust, sunspot activity, albedo, satellite measurements of the planetary energy budget, atmospheric stability, condensation nuclei and cloud processes, mechanisms of orographic precipitation, convergence and divergence, subtropical highpressure behaviour, hemispheric circulation patterns, southern hemisphere air masses, frontal structures, mesoscale convective systems, super-cell thunderstorms, European blocking conditions, regional winds of Iberia, rainstorms of the south-west USA, the Intertropical Convergence Zone, tropical weather systems, cloud clusters, the Asian monsoon circulation, climate of the Sahara, climatic change in the Sahel Zone and Europe, the climatic effect of global vegetation changes, and the use of mathematical models for climatic forecasting. Some seventy new or revised figures and plates were introduced.

Since the previous edition appeared, the recognition of the reality and possible effects of human activities on the environment has revolutionized attitudes to the study of the atmosphere and of world climate. This revolution has led us to make the most comprehensive of all our revisions of this book for the sixth edition, while retaining its welltried format. A substantially changed Chapter 1 now includes extended treatments of greenhouse gases and their recent increases; the greenhouse effect; aerosols; the formation, destruction and distribution of ozone; the carbon cycle; global cloud cover; the thermal role of the oceans; and the exosphere and magnetosphere. Chapter 2 improves coverage of orographic precipitation and has an added section on acid precipitation; and Chapter 3 contains new material on aerodynamic roughness and airflow over topographic obstructions, a new section on the Walker circulation, and material on modelling the atmosphere/earth/ ocean system. Chapter 4 treats medium-range and long-range forecasting more fully, and Chapter 5 has additional material on wind activity over Western Europe. Chapter 6 has been significantly revised with added coverage of hurricanes; Asian monsoon mechanisms; monsoon depressions; the timing, intensity and phases of the Asian summer monsoon; the Walker circulation; and the West African monsoon and associated circulations. Major features of Chapter 6 are new sections on the climates of Amazonia and southern Africa.

Chapter 7 contains updates on tropical forest climatology, urban pollution, urban canyon climatology and urban heat islands, together with a new section on tropical urban climates. Chapter 8 has been extensively rewritten and expanded to contain new material on climatic change during the past 100 years; possible causes of climatic change, including forcing and feedback mechanisms of the atmosphere/earth/ ocean system; Pleistocene climatic changes; and short-term changes with particular reference to anthropogenic causes of changes in atmospheric composition and global vegetation. The chapter ends with a preview of the changes in atmospheric composition, temperature and humidity, and of sea level projected to take place over the next 100 years, together with a cautionary postscript highlighting our present inadequate knowledge regarding the operations of the global climate system. SI units of energy flux density are now used exclusively throughout and this edition contains some ninety new or redrawn figures and tables, compared with its predecessor.

Wherever possible, the criticisms and suggestions of colleagues and reviewers have been taken into account in preparing this latest edition.

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Introduction

In this book we aim to provide a non-technical account of how the atmosphere works, thereby developing an understanding of weather phenomena and of global climates. The atmosphere, which is vital to terrestrial life, is a shallow envelope equivalent in thickness to less than 1 per cent of the earth's radius. Most weather systems form and decay within its lowest 10 km. It is thought that the earth's atmosphere evolved to its present form and composition at least 400 million years ago when extensive vegetation developed on land. Its presence provides an indispensable shield from harmful radiation from the sun and its gaseous contents sustain the plant and animal biosphere on which human life depends.

Over much of the globe, the state of the atmosphere is far from constant in response to varying weather processes. Weather extremes gales, blizzards, tornadoes, floods - drastically affect human activities and frequently result in loss of life, even when anticipated. Hence, by seeking to understand atmospheric phenomena, we can hope to forecast their vagaries and in some instances control or modify them in a beneficial way. This broad endeavour constitutes the field of the atmospheric sciences. Meteorology is specifically concerned with the physics of weather processes. Weather systems which produce the variety of instantaneous states of the atmosphere - differ in their size and life-span. Four scales are commonly recognized: mesoscale systems, such as thunderstorms, extend some 10 km horizontally with a lifetime

of a few hours; *synoptic-scale* systems, like midlatitude cyclones and tropical storms, have a diameter of a few thousand km and a lifetime of about 5 days; *planetary-scale* waves in the atmospheric circulation span 5000–10,000 km and usually persist for several weeks. In addition, small-scale wind eddies near the earth's surface and processes operating within vegetation canopies are the concern of *micro-meteorology*.

Climate introduces the longer time-scales operating in the atmosphere. It is sometimes loosely regarded as 'average weather', but it is more meaningful to define climate as the long-term state of the atmosphere encompassing the aggregate effect of weather phenomena – the extremes as well as the mean values. It is also usual to distinguish regional and global macroclimate, on the one hand, from local or topo-climates related to terrain features (valleys, hill slopes), on the other hand.

A recent view of climate, which has emerged over the past 10–15 years, envisages a *climate system* involving interactions between the atmosphere, oceans, land surface, snow and ice cover, and the biosphere (see Figures 3.43 and 8.14). Couplings between these components operating on short time-scales (hours to months), that may involve two-way interactions, are considered to represent processes *internal* to the system. Changes, usually over years to millennia, in the earth's surface, biosphere, atmospheric composition, and incoming solar radiation that may affect the whole climate

system without being affected by it, are considered to be *external* processes. This view of the climate system has resulted in a widening interest in climate processes and their effects by biologists, chemists, oceanographers, glaciologists, solar physicists and scientists in many other disciplines. This interest in climate processes has been the major theme of this book since its inception a quarter of a century ago; the concept of the world climate system was introduced in the edition of ten years ago and that of mathematical modelling in the fifth edition five years ago. In the sixth edition the concept of the world climate system is a central theme.

The structure of the book represents this viewpoint. We will look first at the composition and structure of the atmosphere and its role in the global exchange of energy, the moisture balance and wind systems. Then weather and climate in middle and low latitudes are discussed and, finally, small-scale climates and climatic change. The key to atmospheric processes is the radiant energy which the earth and its atmosphere receive from the sun. In order to study the receipt of this energy we need to begin by considering the nature of the atmosphere – its composition and basic properties.

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