Howard J. Critchfield

THIRD EDITION

# GENERAL CLIMATOLOGY

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# *GENERAL CLIMATOLOGY*

# Preface

Travelling through space at more than 100,000 kilometers per hour in a nearly circular orbit around the sun, we have a vital need to understand the functioning of our planetary air-conditioning system. This book deals with the processes that involve heat, moisture, and motion in the earth's atmosphere. Its objective is to introduce the fundamentals of general climatology in a manner that will serve those who have a concern for the global environment, whether their primary interests lie in the natural sciences, the social sciences, or the emerging environmental sciences. Its scope encompasses both the nature of climate and the significance of climate to mankind.

This third edition retains the basic outline of the first and second editions and strives as before to incorporate recent developments in the sciences that deal with the atmosphere. A new chapter at the end summarizes advances in the growing study of inadvertent and experimental modification of weather and climate. There are also new sections on the water budget, the heat budget of the human body, air pollution and health, and perception of climate. The division of the broad field of climatology into three parts allows flexibility of both the emphasis and the topical sequence in a college course to fit various instructional patterns. Part One introduces the atmospheric exchanges of heat, moisture, and mo-

mentum that result in our weather and climate. It includes brief discussions of observational techniques, which are necessary for our understanding of atmospheric processes and regional differences in climate. Part Two treats the classification of climatic types and their geographical distribution, employing the fundamental pattern of world climates as a model for explanatory description. Part Three relates atmospheric processes to the biotic environment and human activities, concluding with chapters on past climatic changes and human modification of climates. Its arrangement facilitates treatment of separate sections in conjunction with topics in Parts One and Two if desired.

Both the text and figures of this edition emphasize the use of international units of measurement. If a justification is needed, it can be found anywhere in the realm of science and in the transactions of an increasing proportion of the world's people. The selections of supplementary readings at the ends of chapters and the bibliography are intended to encourage further investigation. They should guide the curious to sources of current information on topics of special interest.

I am greatly indebted to my teachers, who laid the foundation that made this book possible, and to my students, who have inspired many of the decisions on content and organization. I am especially grateful for the constructive criticism by teachers who have used previous editions in their classes. Any errors, inconsistencies, or omissions remain my responsibility, however.

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*Bellingham, Washington*

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PART ONE

# *The Physical Elements of Weather and Climate*

*chapter one*

# Climate and the Atmosphere

Studies of the planet we call earth fall into four broad categories that embrace the solid *lithosphere,* the liquid *hydrosphere,* the gaseous *atmosphere,* and life forms of the *biosphere.* Although the study of weather and climate focuses on the envelope of gases, continuous interchanges among the "spheres" produce an integrated environment, and no component can be understood adequately without reference to the others.

The processes of exchange of energy and mass between the earth and the atmosphere over a long period of time result in conditions which we call *climate.* Climate is more than a statistical average; it is the aggregate of atmospheric conditions involving heat, moisture, and air movement. Extremes must always be considered in any climatic description in addition to means, trends, and probabilities. Climate is an important element of the physical environment of mankind, for, although man usually thinks of himself as a creature of the land, he actually lives at the bottom of a deep "ocean" of air that surrounds the earth. *Weather* is the day-to-day state of the atmosphere and pertains to short-term changes in conditions of heat, moisture, and air movement. Weather results fundamentally from processes that attempt to equalize differences in the distribution of net radiant energy received from the sun.

## THE SCOPE OF CLIMATOLOGY

*Climatology* is the science that seeks to describe and explain the nature of climate, why it differs from place to place, and how it is related to other elements of the natural environment and to human activities. The term originated from the Greek words *klima,* referring to the supposed slope of the earth and approximating our concept of latitude, and *logos,* a discourse or study. Climatology is closely allied with *meteorology* (literally a "discourse on things above"), which treats day-to-day atmospheric conditions and their causes. Often defined as the physics of the atmosphere, meteorology uses the methods of the physicist to interpret and explain atmospheric processes; it is equated increasingly with atmospheric science. *Aerology* and *aeronomy* ordinarily denote studies of the upper atmosphere.

Climatology extends the findings of meteorology in space and in time to encompass the entire earth and periods of time as long as observations or scientific inference will permit. Because climatology involves the collection and interpretation of observed data, whether for developing generalizations or for testing theories, it necessitates instrumental and statistical techniques. It is more than statistical meteorology, however. In its investigations of spatial relationships it makes abundant use of the tools of geography, including maps. Its close affinity with geography arises from its multiple-factor approach to explanation of phenomena and from its concern with climate as an element of our natural environment.

The study of climate in the following chapters comprises three fundamental subdivisions: physical, regional, and applied. The basic question to be answered in physical climatology is: What causes the variations in heat exchange, moisture exchange, and air movement from time to time and from place to place? That is, why do we have different climates? As a first step toward the solution, we seek, through observation, facts relating to these variations. Several observable elements aid in the description of atmospheric conditions: radiation, duration of sunshine, temperature, humidity, evaporation, cloudiness and fog, precipitation, visibility, barometric pressure, and winds. The occurrence of these elements in a particular combination is the result of a number of processes involving the transfers of heat, moisture, and momentum which occur within the atmosphere and between the atmosphere and the earth's surface. Processes of weather and climate are influenced, in turn, by differences in latitude, altitude, land and water surfaces, mountain barriers, local topography, and such gross atmospheric features as prevailing winds, air masses, and semipermanent pressure centers. Part One discusses the roles of these factors and processes.

Regional climatology has as its goal the orderly arrangement and explanatory description of world climates. It includes the identification of significant climatic characteristics and the classification of climatic types, thus providing a link between the physical bases of climate and the investigation of problems involving climatic processes. Because it deals with spatial distributions regional climatology implicates the concept of scale. In keeping with the broad approach of this book, Part Two treats the large-scale macroclimatic regions of the world, but in a more detailed analysis mesoclimates and microclimates also require differentiation and explanation. Indeed, many of the problems whose study calls upon the principles and methodology of climatology are highly localized. As a result it is common to regard microclimatology as a group of techniques in applied climatology rather than as a branch of regional climatology. Where local climates are closely related to the surface conditions the term *topoclimatology* is sometimes employed to designate studies in an intermediate or mesoscale.

The third major division, applied climatology, explores the relationship of climatology to other sciences and considers its potential for improving human welfare, finally confronting the complexities of climatic change and modification of climates. It is in this phase of *general* climatology that the interdependence of sciences and the unity of human knowledge become increasingly evident. Not only has there been growing cooperation among the traditional sciences in the investigation of climatic problems, but new combinations also have begun to evolve. Bioclimatology, agroclimatology, medical climatology, building climatology, and urban climatology are examples. The proliferation of specialized studies clearly illustrates the wide scope and variety of climate-related phenomena.

## NATURE OF THE ATMOSPHERE

The atmosphere is a deep blanket of gases and suspended liquids and solids that entirely envelops the earth. It is as much a part of the earth as the land and the oceans, but it differs from them in several respects. "Pure" air is colorless, odorless, tasteless, and cannot be felt except when in motion. It is mobile, elastic, compressible, expansible, and can transmit compression waves. It is transparent to many forms of radiation, yet it can absorb others. Although air is not nearly as dense as either land or water, it has weight and exerts pressure, but, because it is compressible, its density decreases rapidly with altitude. About half of the total mass of the atmosphere lies below 5,500 meters (18,000 feet), and nearly 99 percent lies within 30 kilometers (20 miles) of the earth's surface.