Dryland Climatology

Dryland Climatology provides a comprehensive review of dryland climates and their relationship to the physical environment, vegetation, hydrology, and inhabitants. Chapters are divided into four major sections on background meteorology and climatology; the nature of dryland climates in relation to precipitation and hydrology; the climatology and climate dynamics of the major dryland regions on each continent; and life and change in the world's drylands. It includes chapters on key environmental and ecological topics such as vegetation, geomorphology, dust, drought, desertification, microhabitats, and adaptation to dryland environments.

This interdisciplinary volume draws on the author's experience over several decades to provide an extensive review of the primary literature (covering nearly 2000 references) and a guide to the conventional and satellite data sets that form key research tools for dryland climatology. Illustrated with over 300 author photographs that demonstrate physical processes and the evolution of dryland landscapes, this book presents a unique view of dryland climates for a broad spectrum of researchers, environmental professionals, and advanced students in climatology, meteorology, geography, environment science, earth system science, ecology, hydrology, and geomorphology.

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Frontmatter
More Information

This book is dedicated to my son Ronnie, who has given much joy, support, and patience during the production of this book, and to Mary Seely, the former Director of the Namib Desert Ecological Research Unit (currently, Gobabeb Research and Training Centre). Dr. Seely's hospitality at Gobabeb and the fascinating research carried out at DERU were instrumental in creating this author's fascination with the dryland environment.

Contents

Preface

Climate was long defined as the mean weather conditions in a given location. A corollary to this definition is that climate is an inherent and invariant aspect of environment. More and more, climate is being recognized instead as an environmental variable, and an overwhelming body of evidence points to accelerated rates of climate change during the past century. At the same time, unmistakable environmental changes have occurred in dryland regions in response to human behavior. Some of the human factors include the sedentarization of nomads, the continual increase in urbanization, population increase, land-use changes, and technological means of exploiting the environment. The result is worldwide changes in the land surface, soils, and vegetation. One of the future challenges is to understand the interplay between these various aspects of the environment and managing the environmental resources in ways that provide for human well-being while conserving and protecting the resources.

There are pressing reasons for focusing on the drylands. First, because the essential resource – water – is discontinuously available in time and space, environmental processes are quite fragile. The semi-arid regions, in particular, are expected to be among those most sensitive to future climate change and increasing intensity of land use (IPCC 1996). Thus, the ability to predict changes in dryland landscapes is one of the top priorities for global change research (Breshears and Barnes 1999). Further, perhaps more than anywhere else, the environment of drylands is a consequence of closely tuned feedbacks among biological, geomorphological, hydrological, and human systems. Changes in any of these systems can readily upset the feedback loops, creating serious disturbances in the environment (Graetz 1991). Finally, an increasing body of evidence suggests that this sensitivity is such that, when critical thresholds of certain variables are surpassed, abrupt and irreversible changes in the ecosystem can occur (e.g., Rietkerk *et al.* 2004; Scheffer *et al.* 2001). Perhaps more importantly, misinformation concerning this sensitivity abounds, mainly as a result of an incomplete understanding of the role played by climate in the dryland environment. The issue of desertification, discussed in detail in this book, is a case in point.

Despite the relative paucity of vegetation in drylands, compared with humid areas, these regions may be more crucial in the context of understanding global change. The reason is that, unlike wetter, radiation-limited environments, vegetation in the drylands responds abruptly and intensely to changes in water availability; in turn, vegetation dramatically alters the distribution of water. Thus, one might argue that the feedbacks that couple vegetation and climate are much stronger and more apparent in the drylands.

Consistent with these interactions, this book takes the view that climate can be understood only in the context of the whole earth system. This system can be represented by five geophysical realms termed the lithosophere (i.e., solid earth), the atmosphere, the biosphere, the hydrosphere (liquid water), and the cryosphere (solid water) (Fig. 0.1). There are constant exchanges of energy, momentum, particulates, moisture, and solutes between these spheres. The atmosphere, and hence climate, is controlled by fluxes from below (the exchange of these various materials) and above (solar radiation).

The fluxes at the lower boundary are particularly important because the atmosphere is relatively transparent to solar radiation. Hence, solar heating of the atmosphere is indirect: the solar beam is absorbed at the surface and transformed to long-wave radiation, which is effectively absorbed by the greenhouse gases in the atmosphere. Moisture and greenhouse gases, such as carbon dioxide, also originate at the surface and vegetation plays a critical role in the exchange processes. This is clearly illustrated by the annual cycle of carbon dioxide (Fig. 0.2), which shows the phenology of vegetation growth and the contrast between the water and land hemispheres. Hence, climate drives vegetation, but vegetation also drives climate.

This interaction and sensitivity suggests a new definition of climate: "climate encompasses the mean weather conditions, their variability, causes, and interrelationships with the global earth system." This definition is at the heart of the

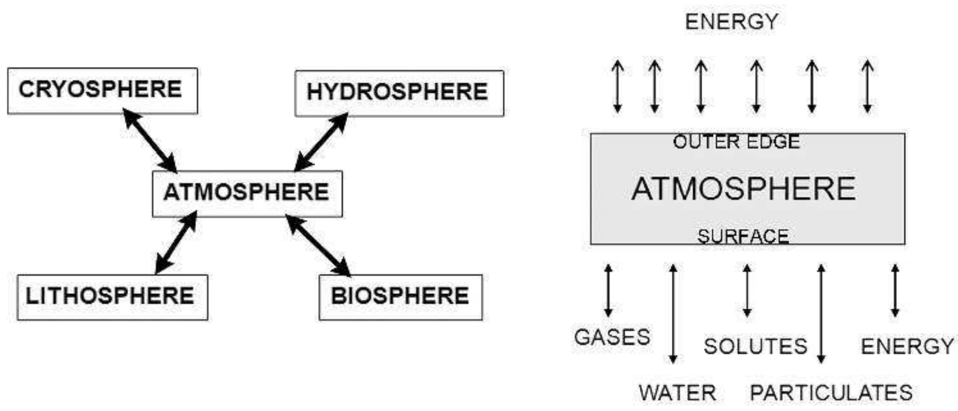

Fig. 0.1 Diagrams illustrating the relationship of climate to the whole earth system and the relevant exchanges between system components.

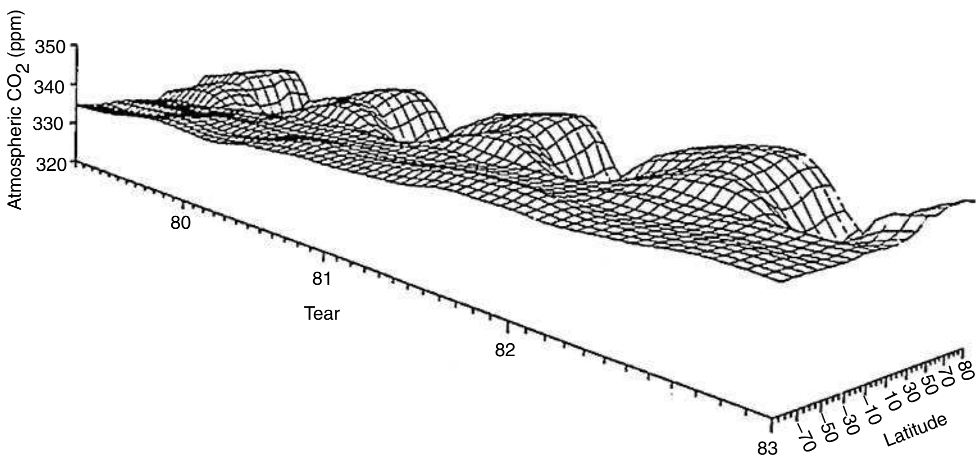

Fig. 0.2 Atmospheric carbon dioxide concentration (ppm) as a function of latitude and month.

interdisciplinary framework of this book. It also fits well into emerging interdisciplinary areas such as hydroclimatology and ecohydrology (Rodriguez-Iturbe *et al.* 1994; Rodriguez-Iturbe 2000; Breshears 2005; Newman *et al.* 2006).

Some pressing issues involve the interplay between climate and other geophysical spheres: atmospheric dust and its influence on climate, dwindling water resources, desertification and land degradation, and biomass burning. In writing this book the author hopes to provide a repository of information that can help researchers meet the challenges posed by these issues and aims to provide simple explanations that can facilitate the exchange of information among the relevant disciplines. Such interdisciplinary understanding is at the heart of designing experiments, creating models, and understanding and interpreting climatic variability and change.

For this reason, *Dryland Climatology* provides not only basic climate information on the earth's drylands, but also puts them into the context of the geophysical system "earth." This requires consideration not only of climate, but of the biogeophysical characteristics of the environment and how they interact with climate. The book therefore includes detailed, up-to-date treatments of new research areas not only in climate dynamics, but also in hydrology, ecology, and geomorphology. Some of the book's recurrent themes are the complexity of the dynamics governing dryland climate; the spatial heterogeneity of characteristics and processes; the episodic nature of the water cycle; and the inextricable interactions of the vegetation, soils and water cycle.

Dryland Climatology was first conceived nearly 30 years ago. At the time, the author was a traditional climatologist who found herself assigned to teach a course entitled the Climatology and Geomorphology of Arid Lands. She had the good fortune not only to learn about the deserts from her then colleagues Larry Lewis and Len Berry, but also to meet and learn from pioneering researchers of an earlier generation, including Jean Dubief, Heinz Lettau, Heinrich Schiffers, Théodore Monod, Pierre Rognon, Mohammed Kassas, Nicole Petit-Maire, Raymond Bonnefille, Francoise Gasse, Dick Grove, Hermann Flohn, David Sharon, Hubert Lamb, Ken Hare, Horst Mensching, and many others. She gratefully acknowledges the inspiration she has gained from these scientists and hopes that, through these associations, she can provide a nearly century-long look at our evolving knowledge of the global drylands. The most noteworthy trends are the proliferation of information on deserts during the last one or two decades and the change in the tools we possess to study them. Hopefully, *Dryland Climatology* will serve as a guide to these new resources.

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