MICROCLIMATE AND LOCAL CLIMATE

A microclimate is a canopy-scale atmospheric zone where the climate differs from the surrounding area. The term may refer to areas as small as a few square meters or as large as several square kilometers. Microclimates exist in the atmospheric boundary layer and the upper soil. Local climates are related to landscape elements (hill slopes, valley bottoms and ridge tops). They occur near water bodies, which may affect local temperatures and precipitation, in heavily urban areas, as a result of rapidly changing topography, or in the shadow of a mountain. Although general, larger-scale climate patterns are clearly important, local micrometeorological factors may have impacts on many elements, including local weather, ecological systems, soil climate, and agriculture. The topic of small-scale climate is therefore one that is of interest not only to climatologists but also to geographers, biologists, crop scientists, environmental scientists, hydrologists, and urban planners.

This book provides an up-to-date, comprehensive treatment of the variables and processes of microclimate and local climate, including radiation balance and energy balance. It describes and explains the climate within the lower atmosphere and upper soil, the region critical to life on Earth. Topics that are covered include not only the physical processes that affect microclimate, but also biological processes that affect vegetation and animals, including people. A geographic tour of the microclimates of the major ecosystems around the world is included. All major biomes and surface types are examined, including urban areas, and the effects of climate change on microclimate are described. This book is invaluable for advanced students and researchers in climatology in departments of environmental science, geography, meteorology, agricultural science and forestry.

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Preface

This book aims to provide a concise overview of microclimates and local climates – climatic conditions on scales of centimeters to meters and 10 m to 1 km, respectively. There has been no recent treatment of this topic. It has been a decade or more since these topics have been addressed in a textbook, and there have been numerous advances in methodology and understanding over that interval. New instrumentation and increased resolution of satellite and airborne remote sensing have greatly expanded the possibilities for observations and have been accompanied by improved models and data assimilation techniques.

The text is aimed at upper level undergraduates and beginning graduate students in environmental sciences, physical geography, climatology, and biological sciences. The topic of small-scale climate is one that is of interest not only to climatologists but also to biologists, crop scientists, and specialists in landscape design. There are texts that approach the subject from an agricultural perspective using a theoretical framework, and there are texts that either are outdated or have regional coverage. Our book fulfills the need for an up-to-date text that bridges both theory and practice, and encompasses a global geographic perspective. Its scope covers the physical principles that determine micro- and topoclimate.

The text begins with definitions of microclimate and local climate (or topoclimate), a brief history of the two areas, and a case study. Chapter 2 describes each of the microclimatic elements in turn (temperature, moisture, and wind) including carbon dioxide, photosynthesis and respiration, the nitrogen cycle, and pollutants. Chapter 3 summarizes methods of observation and instrumentation. Chapter 4 treats solar, infrared, and net radiation. Chapter 5 describes the energy balance components – soil heat flux, momentum and mass exchange, sensible and latent heat fluxes, and advective effects. Chapter 6 addresses the monitoring and modeling of radiation and energy balance via remote sensing and land surface models. Chapter 7 deals with the microclimates of different vegetated environments – arctic and alpine tundra, grassland, farmland, wetlands, and coniferous, deciduous, and tropical forests. Chapter 8 similarly treats the microclimates of physical systems – lakes, rivers, snow cover, mountains, and cities.

Chapter 9 examines human and animal bioclimatology. Part II opens with a discussion of urban climates in Chapter 10. Chapter 11 then analyzes topoclimatic effects on microclimates. Part III examines environmental change; Chapter 12 looks at the effects of climate change on microclimates. The book is completed by Problems, References, the glossary, Symbols, SI Units and Conversions, and the Index.

The scope of the book is ambitious in addressing the full range of natural and built environments. While the underlying physical principles remain the same, their application to diverse environments necessitates differences in approach.

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American Geophysical Union:

Eos 96(2015), p. 13, Fig. 2b.
Journal of Geophysical Research 114(2009): p. 4, Fig. 2.
Reviews of Geophysics 37(1999), p. 193, plate 4.
*Water Resources Research,*20(1984), p. 70, fig. 3; 50 (2014), p. 8436, fig. 13.

American Meteorological Society:

Bulletin of the American Meteorological Society 93(2012), p. 812, fig. 1 and p. 815, fig. 3; 96 (2015), p. 706, fig. 3.
*Journal of Applie*d Meteorology 13(1974), p. 860, fig. 6; 28(1980), p. 608, fig. 2; 33(1993), 38, p. 928, fig. 2; p. 410, fig. 5; 41(2002), p. 793, fig. 2.
Journal of Applied Meteorology and Climatology 17(1978), p. 1164, fig. 2; 46(2007), p. 2048, fig. 7; 54(2015), p. 150, fig. 8.
Journal of Climate 8 (1995), p. 1270, fig. 5; p. 1277, fig. 10; p. 2718, fig. 1; 16(2004), p. 139, fig. 3; 27(2014), p. 5114, fig. 2.
Journal of the Atmospheric Sciences 37(1980), p. 2739, fig. 4.
Journal of Hydrometeorology 4 (2003), p. 687, fig. 10; 9 (2008), p. 168, fig. 3.

Cambridge University Press:

The Global Cryosphere: Past, Present and Future, R. G. Barry and T. Y. Gan, 2011, p. 194, fig. 6.3.
Essentials of the Earth's Climate System, R. G. Barry and E. Hall-McKim, 2014, p. 87, fig 4.5.

Copernicus:

Geoscience and Model Development. 4(2011), p. 680, fig. 1.

Elsevier:

Agricultural and Forest Meteorology 144(2007), p. 19, fig. 1.
P. D. Blanken, 2015. *Canopy Processes*. In G. R. North, J. Pyle, and F. Zhang (eds.). *Encyclopedia of Atmospheric Sciences,* 2nd ed., Vol. 3: p. 246, fig. 2; p. 248, fig. 4; p. 250, fig. 6.
Vegetation and Atmosphere, J. L. Monteith(ed.), 1975, A. S. Thom, p. 80, fig. 1.
Journal of Great Lakes Research 37 (2011), p. 710, fig. 2.
National Research Council of Canada.
Institute for Research in Construction, Ottawa. *Canadian Building Digest* 1976 No. 180, fig. 2.

Royal Meteorological Society:

Quarterly Journal of the Royal Meteorological Society, 97 (1971), p. 549, fig. 1; 103 (1977), p. 400, fig. 1.

Springer:

Biogeochemistry 122(2015), fig. 2.
International Journal of Biometeorology 58(2014), p. 1991, fig. 5

Taylor and Francis:

R. G. Barry and R. J. Chorley 1987, *Atmosphere, Weather and Climate,* 5th ed., Routledge, p. 22, fig. 1.16.
R. G. Barry and R. J. Chorley 2010 *Atmosphere, Weather and Climate*, 9th ed., p. 422, fig. 12.27.
M. Kirkham, 2011. *Elevated Carbon Dioxide Impacts on Soil and Plant Water Relations*, p. 256, fig. 12.8 (CRC Press).

World Meteorological Organization:

1998, WMO/TD 1872 (Report No. 67), p. 3, fig. 1.2.1.