The Visualization of Climate

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Preface

Recent concern about the environment has increased the need for a greater understanding of the climate in general. A wide variety of our activities and perceptions of the environment are influenced by the weather on a particular day and by the climate over a longer period of time. This material has been developed to facilitate further understanding of climate by providing supplemental information to the usual introductory textbooks in climatology and meteorology.

A very general review of the basic climatic elements and selected climatic classification systems and indices is contained in Chapter 1. In addition to the indices developed by Gaussen and Johansson, the classical schemes of classification developed by Koeppen and Thornthwaite are briefly reviewed as well as Terjung's more recent system based on human comfort. Chapter 1 is concluded with a discussion of techniques for evaluating the water balance based on recently developed methods of determining potential and actual evapotranspiration rates.

Chapter 2 deals with specific water-balance characteristics and the development of additional climatic indices. Water-balance climatology is shown to be a useful means of portraying the local climate, and water-balance diagrams are presented for 270 locations in North America. Since the use of mean data is incomplete without some indication of variability, a discussion of various ways of defining rainfall variability and the distribution of rainfall variability in the United States is included. Some features of the water balance were combined and an aridity index was developed for analyzing the aridity distribution in the United States. The annual distribution of aridity throughout the United States from 1948 through 1967 is discussed, and a comparison of aridity and rainfall variability is made. Chapter 2 is concluded with a climatic classification system based on temperature and aridity.

Remote sensing of the water-balance components is covered in Chapter 3. The use of satellite photographic sensors for cloud studies and urban climatic modifications is illustrated. Specific remote sensing experiments are described that utilize radio waves and microwave sensors for determining water balance and other climatic variables. Remote sensors from Skylab are used to show applications for assessing regional soil moisture, precipitation, and aridity characteristics across the United States.

The central theme that was selected for presentation of much of the material is the *visualization of climate*. While it is impossible to see the climate in nature unless air pollution or clouds are used as an indication, many indices, classification schemes, and illustration techniques have been aimed at presenting displays of climatic variables in such a way that a visual image is created that is very much related to the climate. It is in this sense that this book deals with the visualization of climate.

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1 Climatic Elements and Classification Systems

Introduction

The climate of particular locations may vary considerably over short distances. Because of the large number of variables that compose the climate, the number of slightly different local climates is almost endless. Thus if detailed information on the climate of a particular location is desired, local measurements must be utilized. Since these are not always available, other approaches may be necessary. Alternatives include considering measurements from an adjacent location or inspection of maps showing the general patterns of climate. In order to obtain general climatic regions, the numerous individual climates must be grouped together by some method. When individual climates are combined, it is impossible to keep from losing some detail, since the individuals are not exactly alike. Therefore it is not normally possible for a general climatic map to convey detailed information for a particular location. In addition, climatic maps are based on different atmospheric variables, depending on the type of information to be conveyed. Some of the various climatic elements and classification systems will be discussed in this chapter, while the following chapters will consider some of the climatic parameters for a large number of particular locations together with some generalized distributions. The last section is devoted to methods of remote sensing of various climatic components.

Climatology may be defined as the study of the long-term atmospheric environment at the earth-atmosphere interface. The lower atmosphere is influenced by general atmospheric characteristics as well as earth surface conditions. Thus our physical impression of the climate is determined in many cases by this integrated effect. Continuous measurements of various atmospheric variables are made separately at hundreds of different locations in the United States alone. Therefore the climatologist is confronted with the difficult task of assembling, analyzing, and displaying these individual data values in some form that describes and gives insight into causes of particular climates. In this book we are going to consider some of the past efforts in characterizing and portraying climate in addition to exploring some new ways of measuring and visualizing certain characteristics of the climate.

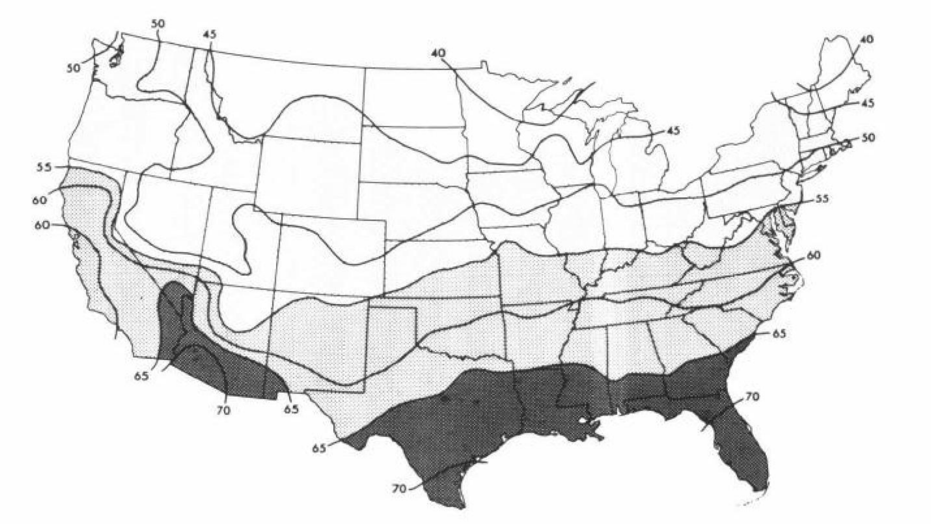

Figure 1-1. Mean Annual Temperature (°F)

Distribution of the Basic Climatic Elements

Various meteorological elements are measured continually at many locations. The long-term averages of these variables determine the various components of the climate. Therefore an understanding of the distribution of the separate components of the climate is useful before discussing composite classification systems.

The distribution of four of the basic climatic elements is shown in Figures 1-1 through 1-4. These variables, temperature, specific humidity, precipitation, and wind were evaluated for 222 locations and represent thirty-year mean annual values. See Appendix B for specific data and locations.

1. The *temperature banding* is primarily east-west in response to greater available energy farther southward. It is apparent that nonradiation induced patterns exist along the West Coast and in the southwestern United States.

2. The *specific humidity*, representing the number of grams of water vapor per kilogram of moist air, reveals the Gulf of Mexico as a major source of moisture for the United States. This results from the frequent occurrence of southerly flow of air as well as the blocking influence of the Rocky Mountains for moisture from the Pacific.

3. The *mean annual precipitation* is influenced considerably by the moisture distribution. The major exception is the Pacific Northwest, which

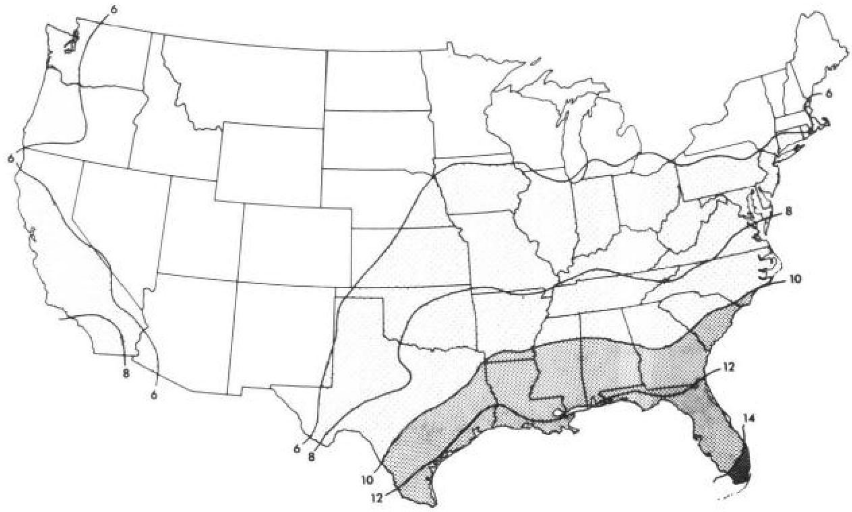

Figure 1-2. Mean Annual Specific Humidity (g/kg)

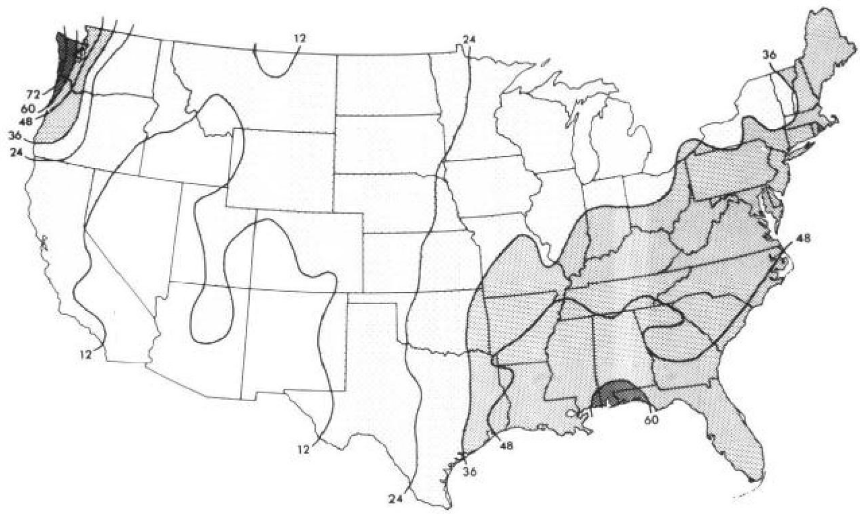

Figure 1-3. Mean Annual Precipitation (In.)

is influenced by the frequent on-shore winds north of the semipermanent high-pressure area in the Pacific as well as the frequent cyclonic storms with associated fronts.

4. The *mean annual wind* shows considerable variation for different locations. The wind velocity is related to the pressure gradient, which is

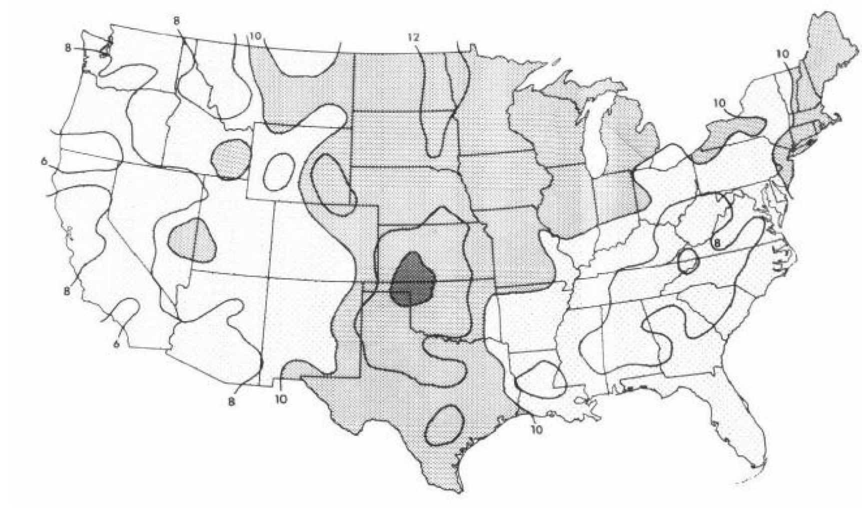

Figure 1-4. Mean Annual Wind Velocity (Mi/Hr)

influenced by radiation and storm systems. In addition, topography plays a role in wind velocities. Therefore this variable has the most complex distribution of any of the four basic climatic elements. The central United States is the only area where the mean annual wind velocity is greater than 14 miles per hour. An even larger part of this region has wind velocities greater than 12 miles per hour. The only other place besides the central or north central United States where wind velocities of this magnitude are measured is on Mt. Washington in New Hampshire, where the elevation is the influencing factor. Regions with wind velocities less than 8 miles per hour include much of the West Coast and the Appalachian Mountains region.

Although mean annual values are quite useful, they cannot fully describe any one variable. For example, the diurnal variation of temperature, Figure 1-5, is quite important and does not follow the same patterns as mean annual temperature. Diurnal temperature variations are more related to moisture content of the air because of greater radiational losses at night and additional heating during the day. Much of the western mountainous region has a diurnal temperature range in excess of 30°F, while most of the more humid eastern half has a diurnal range between 25 and 30°F. Average diurnal temperature ranges less than 25°F occur only in coastal areas and around the Great Lakes.

The basic climatic elements in combination determine the climate of a locality. The combination of some of the basic climatic elements also

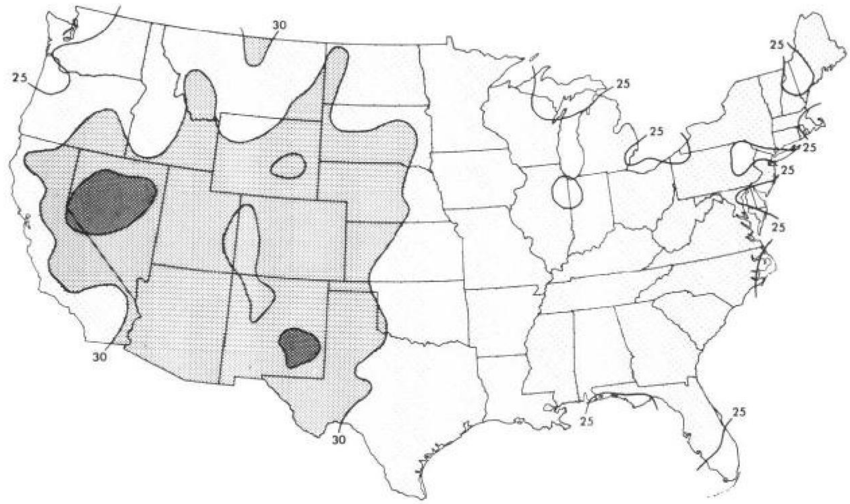

Figure 1-5. Mean Annual Diurnal Temperature Range (°F)

specifies additional climatic elements which may be as important as the basic elements. An example of such a combination is the height at which clouds form in the atmosphere, or lifting condensation level. This level is determined by the surface temperature and humidity, since unsaturated air cools at a constant rate if lifted until saturation occurs. The lifting condensation level (*LCL*) in feet is defined by the equation

$$LCL = 220\ (T - Td) \tag{1.1}$$

where *T* is the temperature in degrees Fahrenheit and *Td* is the dew-point temperature, which is measured directly or determined from the specific humidity.

The lifting condensation level for various regions of the United States is shown in Figure 1-6 (as determined from the temperature and specific humidity for the 222 stations used for the distribution of the basic climatic elements considered previously). Large variations of the lifting condensation level occur with mean annual values ranging from 7000 feet in the southwestern United States to less than 2000 feet in the Gulf Coast area, Great Lakes region, and Pacific Northwest.

Another important climatic element that is determined by a combination of variables is the rate of evaporation. Even though evaporation results from a combination of several elements, it is important in itself and will be considered in more detail in following sections.