

California's Natural Regions

THE CALIFORNIA GEOLOGICAL SURVEY (previously known as the California Division of Mines and Geology) has divided the state into 12 geomorphic provinces based on rock type and topography (figure 1.1). The words *topography* and *geomorphic* refer to the shape of the land: *topography* means “place picture,” and *geomorphic* means “earth form.” These geomorphic provinces represent natural units within which the boundaries of landforms are remarkably consistent with those of biological communities. That is, the shape of the earth influences climate, and climate influences the distribution of plants and animals. I have adapted geomorphic provinces, with some modifications, into “natural regions” which shall provide the framework of organization for this book (figure 1.2).

Reference to landforms is way to refer to geographic features. They can be illustrated by means of aerial photographs or they may be depicted in the form of a relief map that shows topography, highlighting mountains and valleys (figure 1.2). Outlines of the landforms on a relief map show how California can be divided

into “natural regions” which will be the subject of most of the chapters in this book. Other authors have divided the state into natural regions using different criteria. Some of these divide the state into fewer regions and others include more categories. Peter Berg and Raymond Dasmann in the 1970s divided the state into “bioregions,” which roughly correspond to the natural regions to which I refer (Table 1.1). M.D.F. Udvardy in 1975 described biogeographical provinces of the world, and Robert Bailey in 1976 introduced the idea of “ecoregions.” In 1983, he defined 19 ecoregions in California. The concept behind bioregions or ecoregions is that ecological boundaries need not correspond to political boundaries. Bioregions are supposed to be based on a series of criteria including humans living in harmony with the natural environment. W.J. Barry in 1991 described 24 ecological regions and Hartwell Welsh, who was associated with the US Forest Service, in 1994, divided the state into 16 bioregions, while other authors refer to 10 or 6. Adoption of the bioregion system, therefore, has been inconsistent. Some authors would

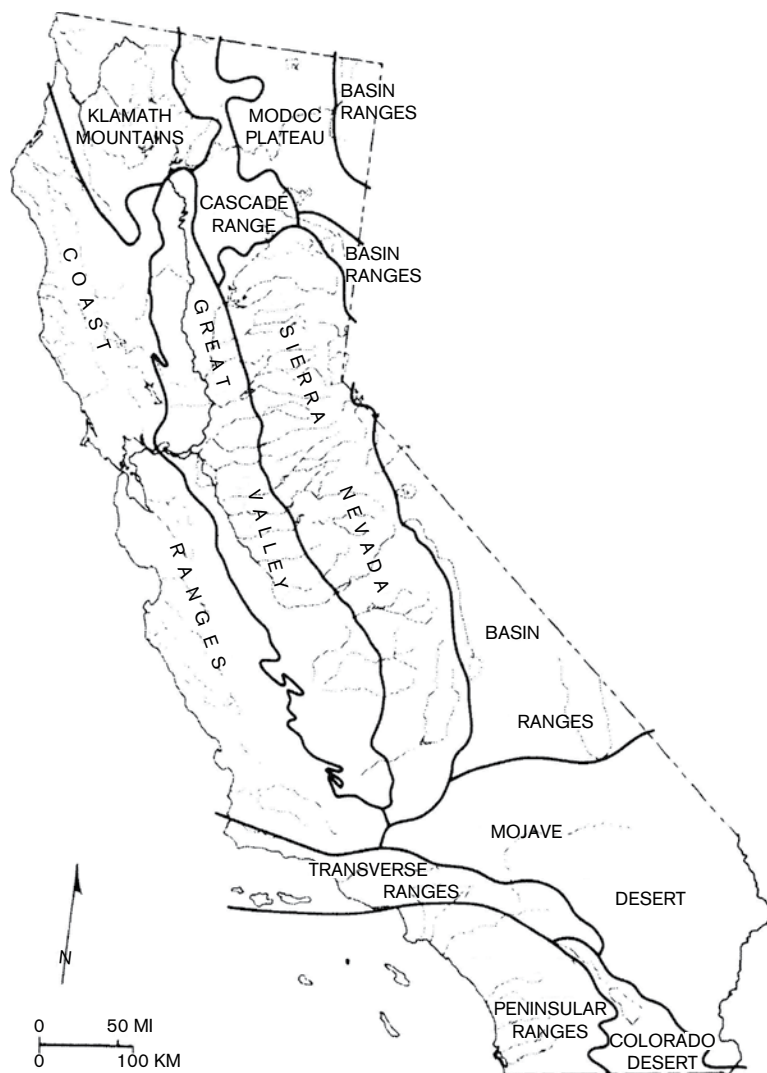


FIGURE 1.1 Geomorphic provinces (from Hill 1984).

divide the coastal mountains into three parts, north, central, and south, using the term South Coast to refer to the region I call Cismontane Southern California, which includes the Transverse and Peninsular Ranges. Other authors would split the Coast Ranges in the San Francisco area with a region called Bay/Delta. I recognize three desert regions, Great Basin, Mojave, and Colorado, from north to south. Others do not recognize the Great Basin Desert in California, instead referring to the areas as Eastern Sierra and/or Modoc in reference

to the Modoc Plateau in the northeastern corner of the state. Most authorities refer to the southernmost desert as the Colorado Desert, which is the California part of a larger desert unit, the Sonoran Desert, which also occurs in southern Arizona, Baja California, and the state of Sonora in northwestern Mexico. Some would not recognize the Colorado Desert at all, but instead refer simply to the Sonoran Desert in California. Bailey divided the Colorado Desert of California into Sonoran and Colorado subdivisions.



FIGURE 1.2 Landforms and natural regions of California (courtesy of California Insect Survey, Department of Entomology and Parasitology, University of California).

CLASSIFICATIONS OF BIOTIC COMMUNITIES

Dividing the state into regions based on climate and geography leads to classifying its biotic communities. It has been recognized for many years that different vegetation is associated with different types of climate. Various classifications of vegetation, based on climatic data, have pervaded scientific and lay literature. Table 1.2 compares three such systems that apply to California's flora.

One of the earliest attempts was the life zone system of C. Hart Merriam. This system, published in 1892, was based primarily on tem-

perature. The zones were named for geographic areas that had temperature regimes similar to that which Merriam observed in Arizona as he traveled from the floor of the Grand Canyon to the summit of nearby San Francisco Peaks. Merriam worked for the US government, and his system became entrenched in government communications. It is still used by many naturalists who are employed by various federal and state agencies. The correlation between elevation and latitude has merit, but the fact that the system is based primarily on temperature and infers precipitation makes it truly applicable only to the southwestern United States.

TABLE 1.1
A Comparison of Natural Regions with Bioregions

Biome	California Community	Life Zone
Grassland	Valley Grassland	Lower Sonoran
Desert	Cactus Scrub	
	Sagebrush Scrub	
	Creosote Bush Scrub	
	Shadscale Scrub	
	Alkali Sink	
	Blackbrush Scrub	
Scrub	Joshua Tree Woodland	Upper Sonoran
	Coastal Sage Scrub	
	Lower Chaparral	
	Upper Chaparral	
	Desert Chaparral	
	Oak Woodland	
Coniferous Forest	Pinyon-Juniper Woodland	Transition
	Mixed Coniferous Forest	
	Montane Forest	
	Subalpine Forest	
Temperate Rain Forest	Coast Redwood Forest	–
	Mixed Evergreen Forest	
Tundra	Alpine	Arctic-Alpine
Temperate Deciduous Forest	Riparian	–

Two ecologists, Clements and Shelford, popularized the biome concept. Biomes are large ecosystems in which variations in temperature and precipitation have created a characteristic assemblage of plants and animals. On a broad scale, this system is appropriate, and its vocabulary is in widespread use.

In 1947, L. R. Holdridge proposed a scheme for classifying world plant formations based on evapotranspiration ratios. It is an eloquent system that applies raw climatic data more precisely than the biome system. The Holdridge scheme, however, lacks simplicity and has not gained widespread use.

California has been named one of the world's top 25 biodiverse regions of the world. In California, the range of climate is so extreme and the vegetation so diverse that broad classification schemes such as world plant formations or biomes have proved inadequate. Instead, the system of plant communities, published by Phillip Munz and David Keck in 1959, became a system of choice used by many ecologists in California. This system is based on one or more dominant plant species that occupy each area. It is broad enough that there are not too many categories to remember, and it is precise enough that its categories encompass meaning-

TABLE 1.2
A Comparison of Three Systems of Community Classification

Biome	California Community	Life Zone
Grassland	Valley Grassland	Lower Sonoran
Desert	Cactus Scrub	
	Sagebrush Scrub	Upper Sonoran
	Creosote Bush Scrub	
	Shadscale Scrub	
	Alkali Sink	
	Blackbrush Scrub	
Scrub	Joshua Tree Woodland	Upper Sonoran
	Coastal Sage Scrub	
	Lower Chaparral	
	Upper Chaparral	
	Desert Chaparral	
	Oak Woodland	Transition
Coniferous Forest	Pinyon-Juniper Woodland	
	Mixed Coniferous Forest	
	Montane Forest	
	Subalpine Forest	Hudsonian
Temperate Rain Forest	Coast Redwood Forest	—
	Mixed Evergreen Forest	
Tundra	Alpine	Arctic-Alpine
Temperate Deciduous Forest	Riparian	—

NOTE: The California communities listed here are modified from those described in 1959 by Munz and Keck in *A California Flora*.

ful units. Originally, the system included only 29 plant communities. Throughout this book, the Munz and Keck system of plant communities, with some modification to include about 35 categories, will provide a basic frame of reference.

Robert Bailey in 1983 developed a system of “ecoregions” that is used today by the US Forest Service. He divided California into 19 ecoregions. Using categories that are similar to ecoregions, the *Jepson Manual of the Vascular Plants of California* divides the state into 50 “geographic subdivisions.” These categories are arranged

hierarchically into Provinces, Regions, and Subregions. The categories are defined on the basis of geography, climate, and vegetation. The manual uses these 50 subdivisions to describe the distribution of California plants. These categories are a bit too refined for use in this book, but they will not be ignored entirely.

According to the *Jepson Manual*, there are three floristic provinces: California, Great Basin, and Desert. The California Floristic Province is the primary group of plants in the state, and is distinctly Californian. It includes the most diverse group of plants in the state.

The province essentially refers to everything west of the deserts, and it encompasses that part of California which is profoundly influenced by our Mediterranean climate, characterized by winter precipitation and dry summers.

A chain of mountain ranges extending the length of California forms a significant block to winter storms off the Pacific Ocean. From north to south, these ranges are the Cascade Mountains, Sierra Nevada, Transverse Ranges, and Peninsular Ranges. Deserts lie to the east of these ranges. The Great Basin Province is the western edge of the largest desert in North America, which extends eastward across Utah and Nevada all the way to the Rocky Mountains. This is a cold desert in which winter precipitation often arrives as snow. In general, the dominant vegetation is composed of cold-tolerant shrubs such as various forms of sagebrush (*Artemisia* sp.). The Desert Province is subdivided into the Mojave and Sonoran (Colorado) Deserts. These are warm deserts characterized predominantly by drought-tolerant shrubs such as Creosote Bush (*Larrea tridentata*). The Mojave gets primarily winter precipitation with snow at higher elevations. California's Colorado Desert has two rainy seasons with approximately half its precipitation arriving as summer thunderstorms.

People who classify things could be splitters or lumpers. Lumpers are folks who tend to categorize things on the basis of similarities. Splitters like to see differences between things, and tend to assign a name to each of the categories. Phillip Munz and David Keck were lumpers. In recent years, splitters have developed various systems of plant community classification which may be referred to as "vegetation types." In association with the University of California's Natural Reserve System and the California Department of Fish and Game, Daniel Cheatham and J.R. Haller in 1975 developed a list of "habitat types" that included about 145 communities. In 1986, Robert Holland working on the California Natural Diversity Database for the California Department of Fish and Game developed a list of 260 "terrestrial natural communities." In 1995, the California Native Plant

Society published *A Manual of California Vegetation* by John Sawyer and Todd Keeler-Wolf. This manual was designed as an "evolving system" that would recognize rare or unrecognized vegetation types as well as refining categories into more specific plant associations and series. Originally, the manual included about 250 vegetation types. In the second edition in 2009, in collaboration with Julie Evans, the number of units called alliances was upped to nearly 500. Many hours of scientific surveys, mapping, and analysis went into preparation of these publications, and they are meant to be the basic reference for descriptions of California vegetation. Unfortunately, identification of many of these alliances in the field requires a certain amount of botanical knowledge, and alliances often are composed of a single species, which makes using the alliance system unwieldy for a book of this type. For example, the common forest community known as Mixed Coniferous Forest (formerly Yellow Pine Forest) is composed of about six common species of trees, each of which may grow in clumps. In the *Manual of California Vegetation*, this community is split into 10 alliances, basically associated with clumping of individual species. Therefore, without ignoring the needs of botanists, but describing vegetation that is understandable to a lay person, in this edition of the book, I will continue to use a system of recognizable plant communities (with some reference to alliances) that has been used by ecologists and nature writers for many years. To enhance understanding of California's diverse vegetation, a color-coded map of generalized vegetation cover is depicted in plate 1.

CLIMATE AND WEATHER

California's Mediterranean climate primarily is responsible for its great diversity of biotic communities, although other factors such as soil type and slope exposure are also involved. Unique among climates of the world, in a Mediterranean climate, precipitation occurs primarily during winter months, the coldest time of year and the time with short daylight hours. Since photosyn-

thesis in green plants provides the nutrient basis for food chains and ecosystems, it should be obvious that winter is generally not the optimum time to promote plant growth. Thus, most ecosystems associated with a Mediterranean climate must be considered relatively food-poor, and that dictates specialized adaptations among the plants and animals that inhabit the area.

The study of climate and weather is known as meteorology. *Climate* refers to the overall combination of temperature, precipitation, winds, and so forth that any region may experience. *Weather* refers to daily variations in these phenomena. Changes in temperature and precipitation are functions of many variables. As the earth rotates, light strikes its surface at different angles in different latitudes, and because the earth is tilted on its axis by 24° these angles change with the seasons. During summer in the northern hemisphere, the North Pole is tilted toward the sun so the sun's rays hit the surface more directly, and the photoperiod (day length) is longer. These differences cause uneven heating, which is expressed as wind. Winds carry water vapor, the amount of which is influenced by differing rates of evaporation and precipitation, depending on the temperature. Furthermore, wind circulation patterns are influenced by the earth's rotation on its axis and differences in local topography. All this translates into major generalizations about what causes climate and weather for a specific geographic region.

Major Movement of Air Masses

Near the equator, sunlight hits the earth directly. On the first day of spring in the northern hemisphere, or the first day of autumn in the southern hemisphere, the sun is directly over the equator, at which time daylight and darkness are 12 hr long all over the world. Wherever the sun shines straight down, there will be a greater degree of warming than anywhere else. Air will rise at that point. Meteorologists indicate that for every 1°F (1.7°C) increase in temperature the atmosphere can hold 4% more moisture. Air on the surface of

the earth will move as winds toward the point of rising air from the north and south. As the air rises, it becomes less dense and thus cooler. This is called adiabatic cooling. The precise amount of cooling varies with the amount of water vapor in the air, but on the average it is about $3\text{--}5^\circ\text{F}/1000\text{ ft}$ ($1^\circ\text{C}/100\text{ m}$). A drop in temperature of 20°F (11°C) will decrease the amount of water held by the air by one-half. When the air is cooled, water vapor condenses and falls in the form of rain. As a result, it rains nearly every day, usually in the afternoon, in a belt around the earth at the equator. As summer progresses in the northern hemisphere, the photoperiod gradually increases until the sun is shining directly on the Tropic of Cancer, 24° north of the equator. On the same day the sun is shining on the Tropic of Capricorn in the southern hemisphere, it shines down at its greatest angle. On this day, June 22, it is the summer solstice in the northern hemisphere and the winter solstice in the southern hemisphere: the longest day of the year in the north and the shortest day of the year in the south. The climate in this region between the tropics is therefore said to be tropical.

Where air descends to the earth, the process reverses. Descending air becomes compressed and heats at about the same rate as it cools when rising. This process causes the air to absorb water vapor. Descending air therefore tends to be dry and causes liquid water to evaporate from the environment. This dry air descends in two belts around the earth, approximately 30° north and south of the equator, just outside the tropics (figure 1.3). A quick glance at a world map will show that deserts lie along this belt, and along the southwestern coasts of each continent lie regions with a Mediterranean climate. When it is summer in the northern hemisphere, this belt of dry, descending air is pushed farther north. It therefore seldom rains in southern California in the summer. Los Angeles lies at about 35° north latitude. Meanwhile, the belt of precipitation has also moved farther north of the equator, creating regions of summer rainfall in the vicinity of the Tropic of Cancer.

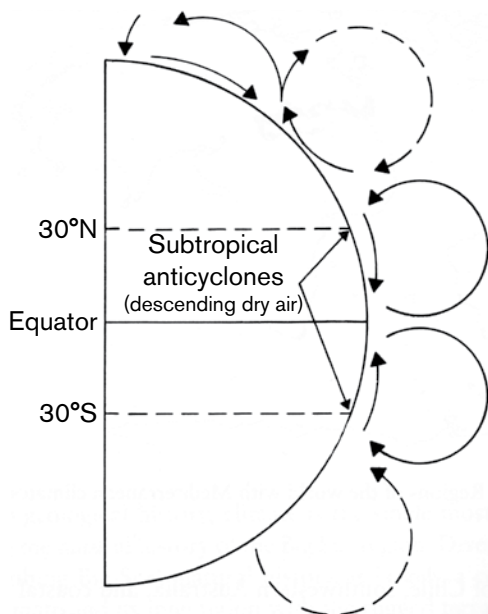


FIGURE 1.3 Simplified model of major movement of air masses (after Barry, R. G., and R. J. Charles. 1982. *Atmosphere, Weather, and Climate*. London: Methuen. Illustration from Hensson and Usner 1993, p.34).

A climate marked by periods of summer precipitation is called a monsoonal climate. That includes southern Florida in the United States.

It is not really accurate to use the terms *warm* and *cool* with respect to air masses. What actually causes air to rise or descend is a change in density. Warm air is less dense, so it will rise. Cool air is comparatively dense, so it will sink. As it sinks and becomes warmed by compression, it gets even denser. Even though it has become warmed, it will continue to descend. It is best, therefore, to compare air masses in terms of density. Dense air pushes downward with greater pressure; thus, it is said to represent a region of high pressure. Conversely, rising air represents a low-pressure region. Meteorologists explain changes in weather as changes in pressure, which are measured by a barometer. They translate predicted changes of pressure into a weather forecast. A reduction in air pressure might imply that a storm, or a mass of rising air, is approaching. Satellite photos show low-pressure areas covered by clouds and high-pressure areas are clear.

The Influence of Ocean Currents

The influence of the ocean on California's climate is profound. California's coastline is about 1100 mi (1760 km) long. This great range of latitude causes the climate to vary considerably along the coast from north to south. From Crescent City to San Diego, the range of average annual precipitation is from about 80 in (200 cm) to 10 in (25 cm). On the other hand, the proximity of the ocean means that air temperatures are not extreme. At the coast, freezing is rare, and the temperature rarely exceeds 100°F (38°C). At San Francisco, September temperature averages 62°F (17°C), and January temperature averages 51°F (11°C).

Ocean water along the California coast is generally cold. Off the northern California coast, winter water temperature is usually around 50°F (10°C). In its journey southward, it warms about 7–8°F (3–4°C). During summer, it is only 8–10°F (5–6°C) warmer. Cold ocean water causes frequent fog, and relative humidity remains high most of the time. Plants water themselves with fog drip, and evaporation rates are low. Along the coast, plant communities range from moist Mixed Evergreen Forest in the north to dry Coastal Sage Scrub in the south.

Ocean water swirls clockwise in the northern hemisphere and counterclockwise in the southern hemisphere (figure 1.4). This swirling, a product of the earth's rotation, is known as the Coriolis effect. The earth rotates in an easterly direction. That is why the sun appears to move westward, rising in the east and setting in the west. The effect of this eastward motion is that the water at the equator appears to flow westward. As the water moves westward relative to the earth's surface, it begins to turn toward the right in the northern hemisphere and toward the left in the southern hemisphere. This phenomenon occurs because the earth's motion is fastest at the equator, where the circumference of the earth is greatest. To make one complete rotation, the land at the equator has to travel farther than at any other place on earth. Because the surface of the earth moves

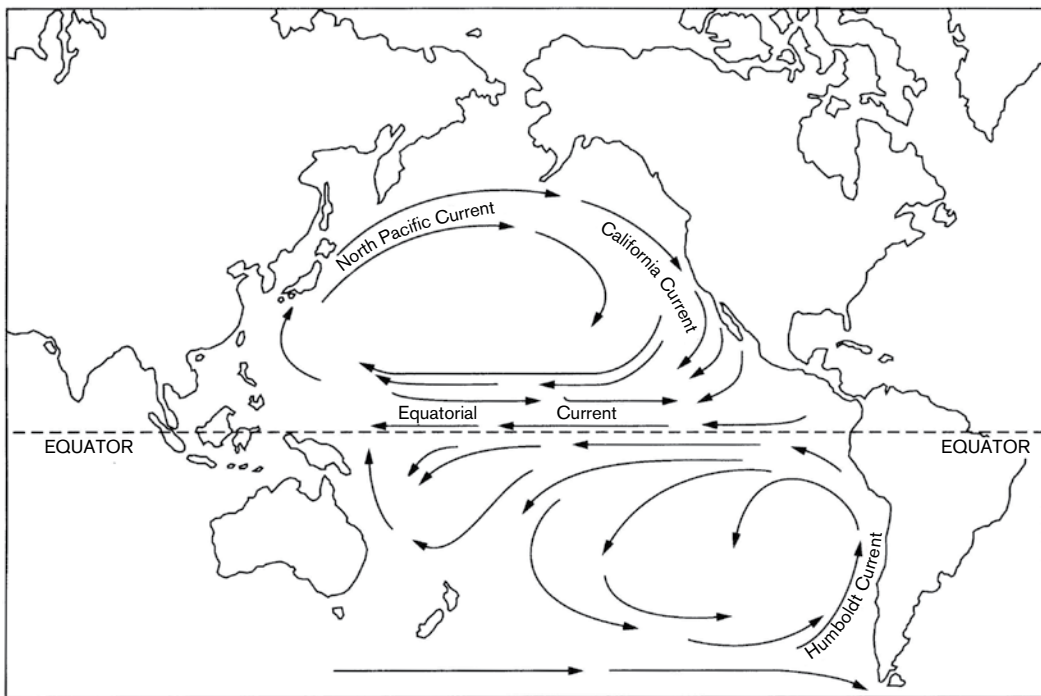


FIGURE 1.4 Pacific Ocean currents (from Caughman, M., and J. S. Ginsberg. 1987. *California Coastal Resource Guide*. Berkeley: University of California Press).

more slowly north or south of the equator, the increased drag makes flowing water turn to the right, clockwise, in the northern hemisphere and to the left, counterclockwise, in the southern hemisphere.

As the water moves westward at the equator, it picks up heat in the region of direct sunlight. Currents of water that come from the equator are comparatively warm, and they flow northward along the eastern edge of a continent in the northern hemisphere. As this water flows through the arctic region, it cools considerably. When the water flows southward again, toward the equator, it flows along the western edge of a continent. A cold current of this type flows southward along the coast of California.

In the southern hemisphere, ocean water swirls in an opposite direction. Warm currents from the equator flow southward on the eastern edge of a continent. Cold currents from the Antarctic flow northward along the western edge of continents. One bit of consistency to emerge from all this is that water off the east coast of

any continent is comparatively warm regardless of the hemisphere and water off the west coast of any continent is comparatively cold.

A climate dominated by the influence of the ocean is known as a maritime climate. On a daily basis, water temperature fluctuates very little. Therefore, air temperature fluctuations on the nearby land are also moderated. When the water offshore is comparatively cold, as it is on the west coast of the United States, fog forms over the water and adjacent land nearly every day, a condition that is accentuated as you go farther north. In southern California, rain is typically confined to the ocean and a short distance inland. For rain to occur farther inland, the land itself must be significantly cooler than the air. When the offshore current is comparatively warm, as it is on the east coast, it rains frequently on the land, and fog seldom forms.

Air masses tend to follow the ocean currents because they are also under the influence of the Coriolis force. The circles of flow, however, are interrupted by the descending air at latitudes

about 30° north and south. Where air is descending, very little wind flows transversely across the surface of the earth. Years ago, seamen in wooden sailing ships would have to row when they got becalmed in this part of the ocean, so they would throw over some of the cargo to lighten the load. So many horses from the old world were floating “belly up” that this part of the ocean became known as the Horse Latitudes. A comparable area of little wind, known as the Doldrums, occurs at the equator. Here, the air is rising. In the northern hemisphere, air flowing toward the earth at the 30th parallel turns to the right, forming a clockwise flow. The effect is that air south of the 30th parallel tends to flow southwestward, forming what is known as the Trade Winds, so named because sailing ships could use these winds to carry goods across the Atlantic to the new world. North of the 30th parallel, winds tend to flow from west to east. These winds are known as the Prevailing Westerlies.

Storms develop as low-pressure areas over the ocean, and are highly dependent on the water temperature. Warm air in a low-pressure cell rises, carrying with it evaporated water. Wind on the surface of the earth therefore blows toward a low-pressure cell from all directions. In the northern hemisphere, air moving across the surface to replace the rising air of a low-pressure cell must turn to the right, which gives the mass a counterclockwise spin. This spinning mass is similar to a spinning top. It moves randomly unless other forces give it a direction. Prevailing winds provide this force. Storms generated in the tropics tend to be blown westward by the Trade Winds, and storms generated over the northern part of the ocean tend to be blown eastward by the Prevailing Westerlies. In North America, major winter storm tracks come from the north Pacific and flow southeastward (figure 1.5A). They spin counterclockwise as they travel down the coast, so they continue to pull moisture off the ocean and dump it on the land. As one moves from north to south, the land warms faster than the water because air changes temperature more

rapidly. During summer, when the air and land in southern California is considerably drier and warmer than the water, the storm fizzles because water vapor won’t condense (figure 1.5B). During winter, storm after storm potentially makes its way down the coast before moving eastward across continental North America (figure 1.5A). This is basic reason that the northern half of the state gets two-thirds of California’s precipitation. Fewer storms cause precipitation in southern California and they rarely continue as far south as the center of Baja California. A high-pressure cell is like a dome of dense air over the southern part of the state and that deflects the storms northward and eastward. Baja California still has cold water offshore, but the land seldom experiences measurable precipitation. Because condensation in moist air occurs over cold water, the coast of Baja California is frequently foggy. Plants water themselves with fog drip but cannot depend on rainfall to provide adequate water. In Baja California, therefore, the desert occurs on the coastline.

At high elevation, there are two jet streams, a polar jet stream and a subtropical jet stream, which move eastward around 100 mph (160 kph). These jet streams tend to push storms eastward, carrying weather systems across the continental United States. The polar jet stream usually has more influence on California weather, but these masses of flowing air meander back and forth similarly to flowing water in a river. When the polar jet stream meanders southward, it pushes Pacific storms toward southern California and precipitation increases. During summer, this is an important force that brings precipitation to the forests of the Pacific Northwest and the northern Sierra Nevada. The subtropical jet stream also can meander northward and bring tropical (monsoonal) storms to southern California, a condition that is accentuated when the eastern Pacific Ocean is exceptionally warm. This is known as an El Niño condition, a Spanish word that is derived from a change in weather that also influences the coast of South America.

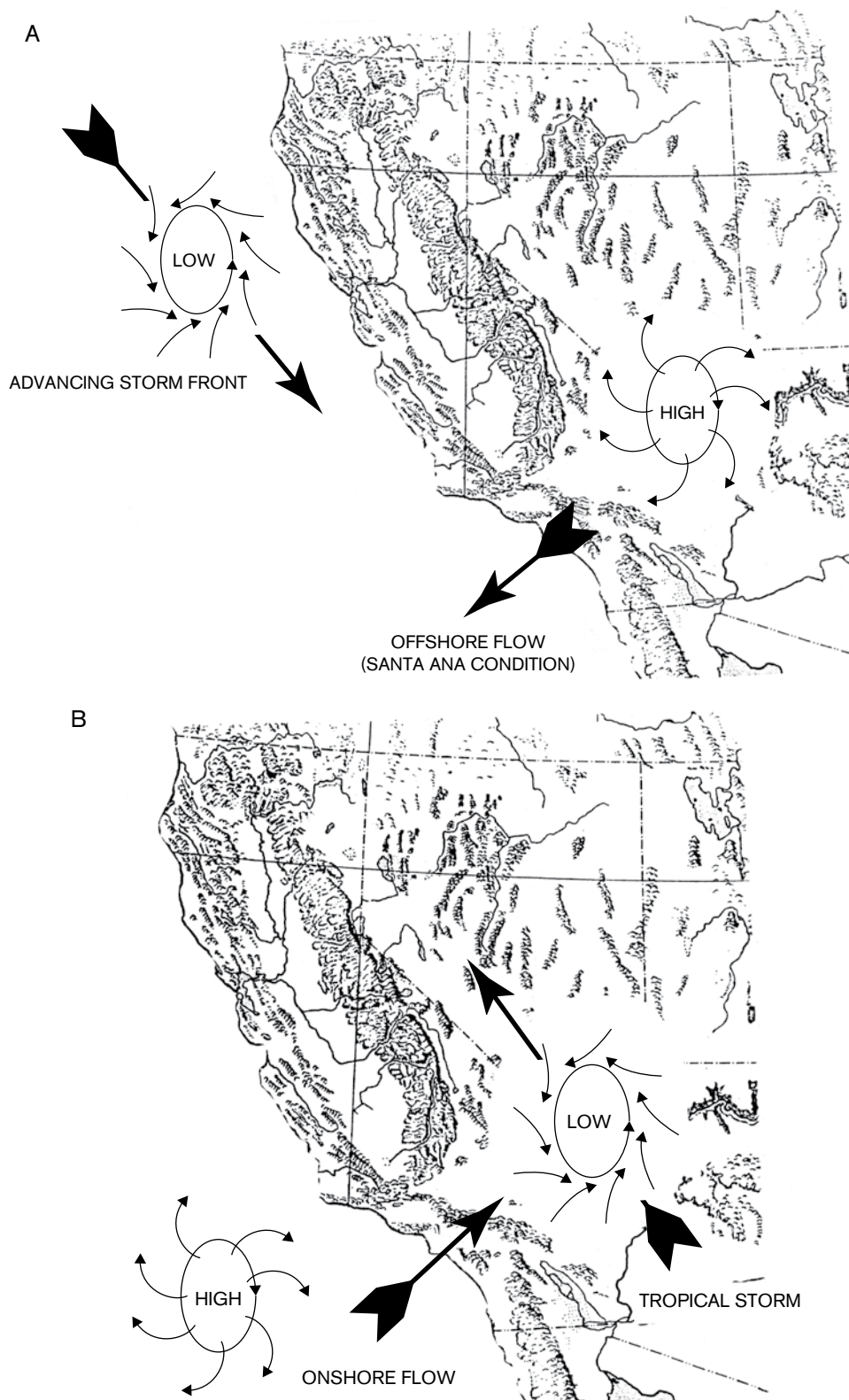
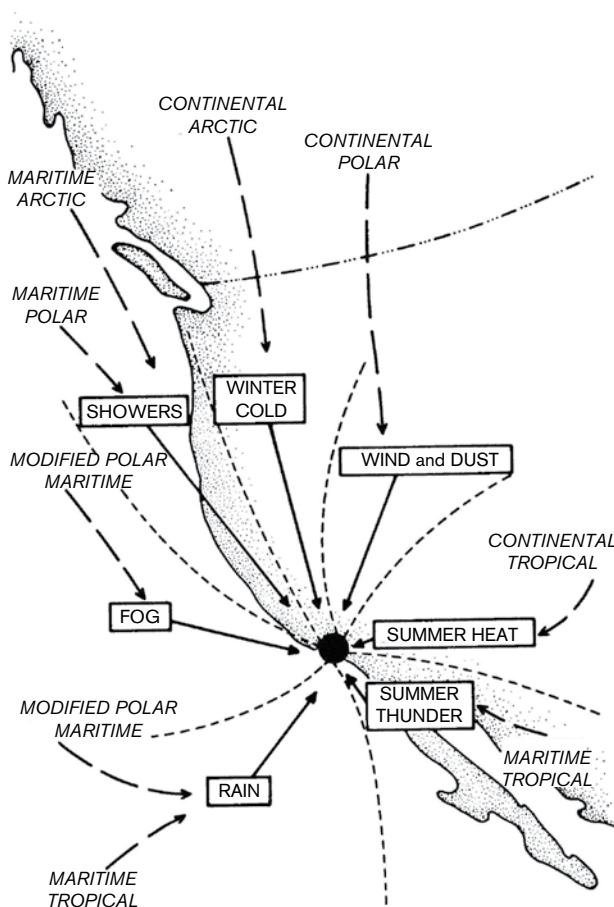


FIGURE 1.5 Seasonal weather patterns showing locations of winter and summer high- and low-pressure zones.
 (A) Winter weather pattern.
 (B) Summer weather pattern.

FIGURE 1.6 Different weather conditions. Arrows indicate the direction and source of different weather conditions and seasons for the southern part of California (from Bailey 1966).



Heavy rain would arrive around Christmas time along the coast of Peru and Chile where climate is desertlike. The name is in reference to the birth of the Christ child at that time of year. El Niño conditions brought heavy rains, essentially double of normal amounts to parts of California in 1978, 1983, 1993, 1998, 2016 and 2017.

In the summer, it seldom rains in southern California (figure 1.6). The sun has moved northward so that it shines straight down on the Tropic of Cancer. That is where the belt of rising air generates tropical storms. Because the rising air is farther north at this time, so is the descending air, and that keeps southern California dry in the summer. Even in the absence of an El Niño, during late August or September occasional tropical storms move into southern California from the south. These

storms are usually carried westward from the east Pacific toward Hawaii, but some of them move into the belt of descending air where there is no surface wind to give them a westward push. These storms can spin erratically (like a top) and may move over the land, dumping a considerable amount of water in a short time. These sporadic storms, known in Baja California as *chubascos*, are able to move northward. Such thunderstorms over the Colorado Desert and Peninsular Ranges may cause intense local flooding. Some 5–10 in (12–25 cm) of rain may fall in a few hours, representing a large portion of the annual share of precipitation. Some of these tropical storms also come all the way from the Gulf of Mexico.

The moist forests of the Pacific Northwest contain a variety of relict species that depend on the relatively predictable supply of summer

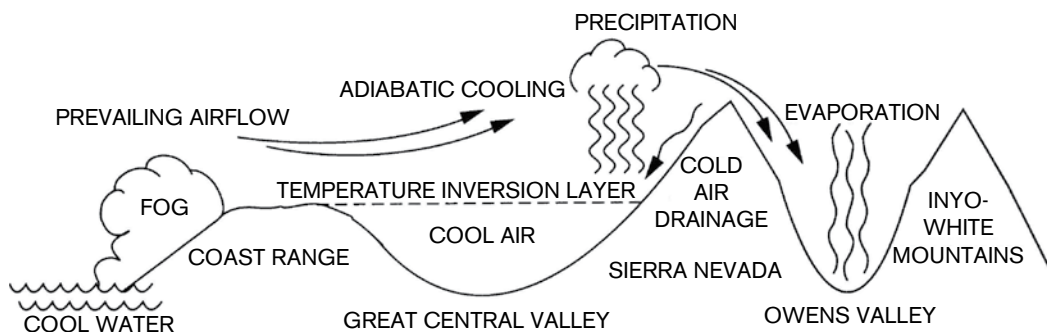


FIGURE 1.7 The influence of local topography on climate and weather, as indicated by an exaggerated cross section of California at about the latitude of Fresno.

rain from the tail end of Alaskan storms. Summer rain in southern California, however, may not occur every year. Nevertheless, certain plant species, such as different populations of relict cypress (*Cupressaceae*), to some degree owe their existence to summer rain.

The center of the North American continent tends to be dry because it is a long way from the ocean, the main source of water. Pacific storms, during summer, are deflected over the Midwest by the southern belt of high pressure. In winter, strong storm systems carry precipitation all the way to the interior, where the moisture may be added to the storms traveling eastward from the Pacific. If the difference in pressures between the two storm fronts is extreme, at the contact point between the warm southern storms and the cold Pacific storms, there may be a belt of tornados. Furthermore, during summer, thunderstorms from the southern storm belt carry northward across the Gulf of Mexico all the way to the plains states. They may carry as far as California's Colorado Desert. In late August, these storms often reach as far as Arizona, where locally heavy precipitation is common. The Arizona portion of the Sonoran Desert experiences considerable summer precipitation. This rain falls during the hottest time of the year, however, so that evaporation rates are very high and the water does not sink very far into the ground. The area around Tucson is a desert, whereas the area around Los Angeles is not. Both areas receive

approximately the same amount of precipitation each year.

The Influence of Local Topography

Rain-Shadow Effect

Mountain ranges have a profound influence on climate. Figure 1.7 is an exaggerated cross section through the state of California at about the latitude of Fresno. It shows how the Sierra Nevada intercepts precipitation on its western slope. This phenomenon is known as the rain-shadow effect. As moisture-laden air flows inland from the ocean, it passes eastward, rising over the Sierra Nevada. Air is chilled adiabatically as it reaches higher elevations, like rising air at the equator. This chilling causes precipitation on the side of the mountain toward the coast. As the air descends from the mountain into Owens Valley, on the eastern side of the Sierra, it becomes heated by compression and causes evaporation. Thus, the Great Basin Desert occurs in the rain shadow of the Sierra Nevada.

On the western side of the Sierra Nevada, the influence of elevation is similar to that of changes in latitude. As air moves up the western slope of the Sierra, its temperature decreases adiabatically by about $3\text{--}5^{\circ}\text{F}/1000\text{ ft}$ ($1^{\circ}\text{C}/100\text{ m}$), which is roughly equivalent to moving about 300 mi (480 km) northward. Precipitation increases accordingly, and the form of precipitation switches to snow. Moving northward,

biotic zones occur at lower elevation. In northern California, coniferous forests occur at sea level. Climate above 11,000 ft (370 m) is roughly equivalent to that of the Arctic. A mountain is thus a microcosm of many types of climate.

Temperature Inversion Layers

Valleys also affect climate. Dense air flows downhill like water, a phenomenon known as cold-air drainage. Also like water, cold air collects in low spots that have limited or no drainage, such as the Great Central Valley of California. Cold air flows from the mountains at night and collects in the valley, filling it to the brim. In this case, the brim is the top of the Coast Ranges. Sometimes this cold air is so dense that winds are unable to disturb it. These circumstances produce dense fog that may remain in the valley for many days. In the Great Central Valley, this is known as a tule fog. Episodes of tule fog are famous for causing massive traffic jams and huge chain-reaction collisions. What is unique about these puddles of cold air is that normal temperature relationships seem to be inverted. It is supposed to become gradually cooler as one goes higher in an air mass, but when cold-air masses are trapped in a valley, it becomes suddenly warmer at the top. This paradoxical phenomenon is known as a temperature inversion layer.

The same kind of temperature inversion occurs in the Los Angeles Basin, where air is trapped by the Transverse and Peninsular Ranges (figure 1.7). Cool marine air, which flows inland from the ocean and joins cool air flowing off the mountains, is held in the basin by the onshore flow of marine air.

A serious consequence of an inversion layer is that exhaust gases or other pollutants rise until they reach a layer of equal density. The difference in density is so great at the inversion layer that pollutants are unable to rise above it. Below the inversion layer, sunlight effects a chemical change on these materials, causing photochemical smog, a mixture of haze and oxidized chemical vapors. Smog is not restricted to the Los Angeles Basin or the Central Valley, but it is especially bad there because of the amount

of industry and vehicular traffic, which produce the vapors. On nearly any summer day, from a position in the mountains above the inversion layer of the Great Central Valley or the Los Angeles Basin, one can see the flat top of a yellowish brown mass of air trapped in the valley below.

In the Los Angeles Basin, the only relief from the inversion layer occurs when the prevailing airflow is offshore rather than onshore. The flow of air is commonly onshore, however, because inland air heats up more quickly than air over the ocean. This creates a low-pressure cell, and air flows toward a low. The inland air rises and draws the marine air onshore, where it becomes trapped by the mountains. Occasionally, though, when air becomes cooler or denser in the Great Basin and the Mojave, a high-pressure cell is formed. Air flows away from a high, so a flow toward the coast can occur (figure 1.5A). To escape from the desert, air must travel through Cajon Pass, one of the few gaps in the surrounding mountains. Situated between the San Gabriel and San Bernardino Mountains, Cajon Pass allows air to flow from the high desert at approximately 3500 ft (1200 m) elevation downhill toward the coast, where the Los Angeles Basin lies just above sea level. This flow occurs at irregular intervals, during autumn and winter when the air in the desert is cooler than it is in the basin. At the extreme, a strong wind from the desert blows through Cajon Pass and becomes heated by compression as it descends to the Los Angeles Basin. This is known as a Santa Ana wind because air follows the course of the Santa Ana River as it pushes pollutants out to sea.

Unlike the Los Angeles Basin, the Great Central Valley has little chance to be cleared out by a wind. It is too thoroughly surrounded by mountains. The only gap is where San Francisco Bay has formed an opening in the Coast Ranges. Air usually flows onshore through that gap, and when it flows toward the coast, it tends to flow over the dense air of the Great Central Valley.

Seasons in California

People acquainted with traditional eastern seasons find seasons in California to be confusing.

The pattern of the eastern United States has been popularized for years by romantic poets, novelists, and songwriters. Winter snow is followed by a spring awakening. Green summer forests are followed by autumn color. This pattern, associated with eastern deciduous forests, is caused by a climate in which some form of precipitation can be expected at any time of year. Water is seldom scarce, and the vegetation responds to marked seasonal change in temperature. A person from the east who yearns to see that sort of change in California must visit a community where vegetation borders a permanent stream. This is called a Riparian (riverside) community. Canyons all over the mountains of California experience seasonal change similar to that of the eastern United States. Water is always present, and temperature fluctuates markedly. Autumn color in aspen groves on the eastern side of the Sierra Nevada provides a scene of great beauty that may be reached by driving Highway 395 northward from Owens Valley (plate 8B). In southern California, autumn color is provided by sycamores and cottonwoods in canyons bordering the Los Angeles Basin.

The claim that southern California has no seasons is simply untrue. In southern California, the most significant variable component of the climate is precipitation rather than temperature. In lowlands, the “awakening” season is winter, when hillsides and valleys turn green as vegetation responds to winter precipitation. If precipitation has been heavy enough, spring wildflowers may cover many acres, even in the desert. Summer is the season of warm, sunny days. It is the time to visit the beach or go hiking in the mountains. Autumn brings the Santa Ana winds, and trees along streams take on red and yellow colors. Clear skies and warm days extend into October. In winter, rainstorms alternate with clear, warm days associated with mild Santa Ana conditions. Football games, viewed by fans in summer clothing, are played in stadiums surrounded by snow-capped peaks—all on national television! Spring may seem to be the least spectacular of southern

California’s seasons because of many foggy days along the coast. A short trip inland or to the mountains, however, may reveal carpets of wildflowers, a reward for any Californian willing to drive 1 hr from the coast (plate 14B). Critics of southern California’s climate emphasize the worst: spring fog followed by summer smog, autumn fires followed by winter floods. Nevertheless, seasons are distinct. If you are willing to travel, you can find examples of any sort of climate somewhere in the state.

Northern California may experience precipitation any time of year, although it is heaviest in winter. Along the coast, fog is frequent as a result of persistently cold water offshore. The influence of a maritime climate is felt over the entire coastline, but it seems to be stronger in northern California because of the persistent fog. Coast Redwoods (plate 11A), which require a great deal of moisture, do not do well beyond the influence of maritime climate. Heavy winter precipitation is followed by persistent summer fog, which condenses on the foliage and continues to wet the soil by dripping.

A chain of mountains formed by the Cascades, Sierra Nevada, Transverse Ranges, and Peninsular Ranges forms a rain shadow, east of which lies a vast desert area. In California, the Great Basin Desert (plate 15A) covers the Modoc Plateau and extends southward to Owens Valley. The Great Basin is a region of winter precipitation, mostly snow. South of the Great Basin, the Mojave Desert (plates 4A and 15B) gets snow at higher elevations. Still farther south, the Colorado Desert (plates 4B and 16A) rarely gets snow, but it does get about half of its precipitation as summer rain in the form of thunderstorms that move northward from the tropics.

California has a surplus of water in the north and in the mountains. Toward the south, evaporation and transpiration rates exceed precipitation, creating a net deficit of water. Two-thirds of the water is in the north, but two-thirds of the people live in the south. California’s massive water transport systems are an attempt to solve this discrepancy.

