SUGGESTIONS. — (1) Recall the previous experiments on convection (Chapter XII, 10). (2) Open a window on a cold day when no wind is blowing. Why does the cold air enter the room? (3) Keep a record of the wind direction for twenty days. How many days did the wind blow from each of the four quarters (north, east, south, and west)? For the same period keep a record of the direction that the higher clouds are moving. How many days do they move from each quarter? (4) On an outline map make a sketch of the winds of the globe similar to Fig. 408. Make a sketch to show the change in position of the belt of calms (Figs. 439, 440). (5) If the instruments are available, keep a record of the wind direction and force, humidity, temperature, clouds and rain, and barometric pressure (Appendix G). Tell when cyclonic storms and anticyclones are passing, and carefully record the relation between air pressure and the other phenomena. From your observations predict the weather for the following day. (6) Study weather maps (Appendix H). (7) With apparatus obtained from the physics laboratory make an electric spark. This is a lightning flash on a small scale, and the noise is thunder. A similar flash and noise may often be noticed as a trolley car passes. (8) If thunder storms occur, keep a record of all the phenomena and report upon them. (9) Read, say in *Harper's Weekly* for the autumn of 1900, an account of the destruction of Galveston. Be on the outlook next fall for newspaper reports of hurricanes or typhoons; also, next summer, for reports of tornadoes.

Reference Books. — HARRINGTON, *Rainfall and Snow of United States*, Bulletin C, U. S. Weather Bureau, Washington, D.C., 1894; FERREL, *Popular Treatise on the Wind*, Wiley & Sons, New York, 1889, $4.00; FINLEY, *Tornadoes*, Hine, New York, 1887, $1.00. (See also references at end of Chapter XII.)

CHAPTER XIV.

WEATHER AND CLIMATE.

181. Difference between Weather and Climate. — *Weather* refers to daily changes in temperature, wind, clouds, and rain. *Climate* is the average result of these weather changes. For example, certain parts of the tropical zone are said to have a rainy climate. This does not mean that it rains every day, but that, though the weather on some days is clear, on still more it is rainy. Thus the average condition, or the climate, is rainy.

The following are some of the more important kinds of climate: dry, hot desert climates; hot, rainy climates, as in the belt of calms; damp, equable ocean climates; extreme and variable climates, common in the interior of continents; and frigid climates. The greater part of the United States has a variable climate. These different climates, and the reasons for them, can best be understood by studying the conditions in various parts of the world.

Summary. — *Climate is the average of weather, which is the daily condition of temperature, wind, clouds, and rain. There are a number of very different climates on the earth.*

182. Zones of Heat. — (A) *The Five Zones.* — The most widespread cause for variations in climate is the distribution of sun's heat from equator to poles. This results from the differences in angle at which the sun's rays reach the earth in different latitudes (p. 239). From this has arisen the common division of the earth into five climatic zones, — two frigid, two temperate, and one torrid, or tropical (Fig. 430).

It is customary to draw the boundaries between these zones of heat along the parallels of latitude; but the actual boundaries are by no means so regular. Indeed, there are some portions of the torrid zone that have as low temperature as parts of the frigid zones; and some parts of the temperate zones have summer climates that are quite torrid. Several reasons for these irregularities are the following influences.

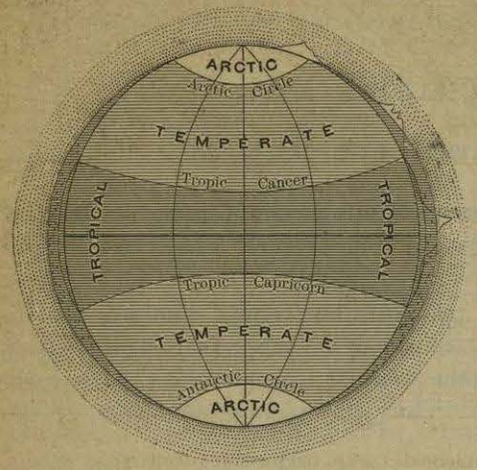


FIG. 430. — The five zones, showing, also, how on highlands a frigid climate may extend even into the tropical zone.

Summary. — *Owing to the angle at which the sun's rays reach different latitudes, the earth may be divided into five zones; but, for a number of reasons, the actual boundaries of the zones are irregular.*

(B) *Influence of Altitude.* — One important cause for irregularities in the boundaries of the heat zones is altitude. The climate of highlands is cooler than that of neighboring lowlands (p. 240). The isothermal charts[1] (Figs. 431–434) show numerous cases, as in the Rocky Mountains, where the isotherms are bent toward the equator in crossing highlands. The influence of altitude is also well shown along the Pacific

[1] An isotherm is a line connecting places having the *same average temperature.* An *isothermal chart* is one showing these isotherms for a given area (as the world, the United States, or a state) for a certain period of time. A chart for the year has isotherms passing through places whose average temperature for the year is the same ; a chart for January averages all the temperatures for that period, etc.

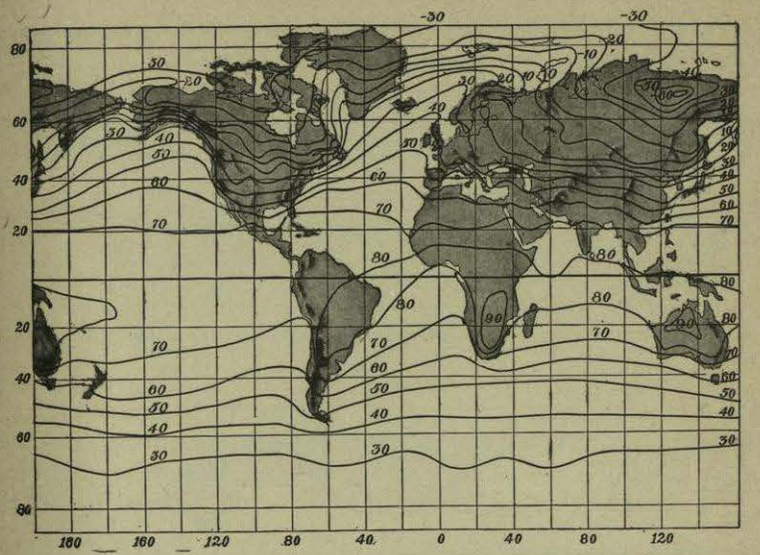


FIG. 431. — Isothermal chart of the world for January.

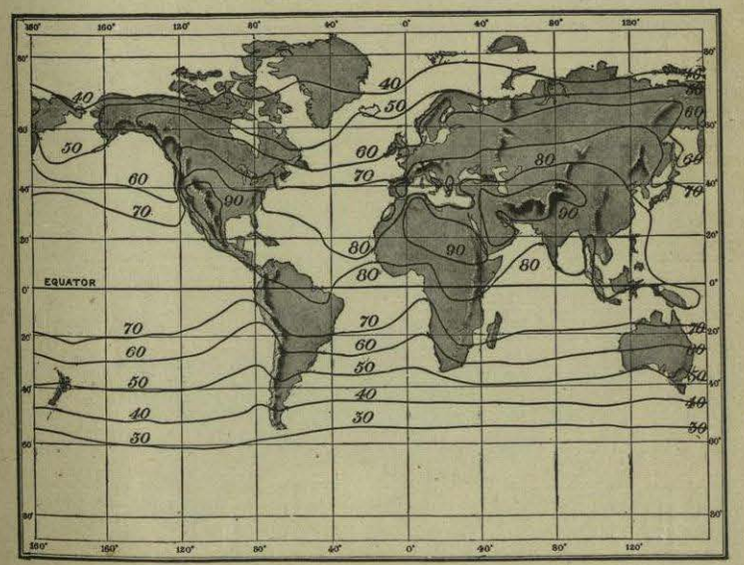


FIG. 432. — Isothermal chart of the world for July.

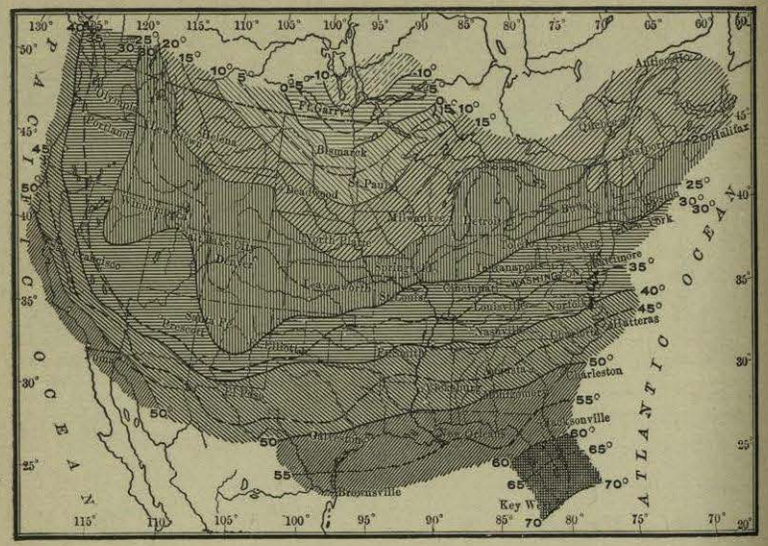


FIG. 433. — Isothermal chart of United States for January.

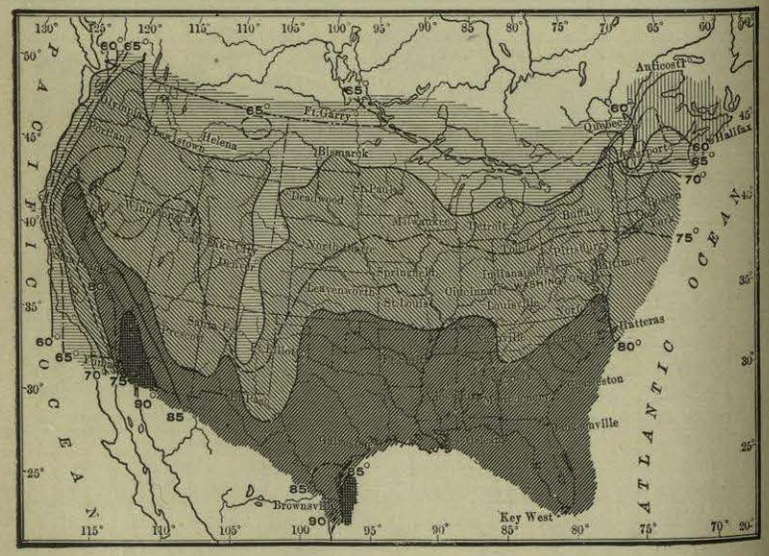


FIG. 434. — Isothermal chart of United States for July.

slope (Fig. 433), where winds from the equable ocean blow upon a rising coast, with mountains extending north and south. Along this coast the climate is warm and equable; but on the mountain slopes the temperature descends. Therefore the isotherms extend north and south instead of east and west, as is commonly the case.

Summary. — *Highlands are cooler than neighboring lowlands. Therefore highlands cause the isotherms, or lines connecting places having the same average temperature, to extend irregularly.*

(C) *Influence of Water.* — Distance from water (p. 238) is another cause for variation in temperature. Oceanic islands have cooler summers and warmer winters than the mainland in the same latitude; and seacoasts have more equable climates than interiors. This is clearly illustrated by comparing the isotherms in the interior and on coasts of continents.

Examine Figs. 433 and 434, for example, to see how much difference there is in January and July between Minnesota, the state of Washington, and Nova Scotia. Find other illustrations

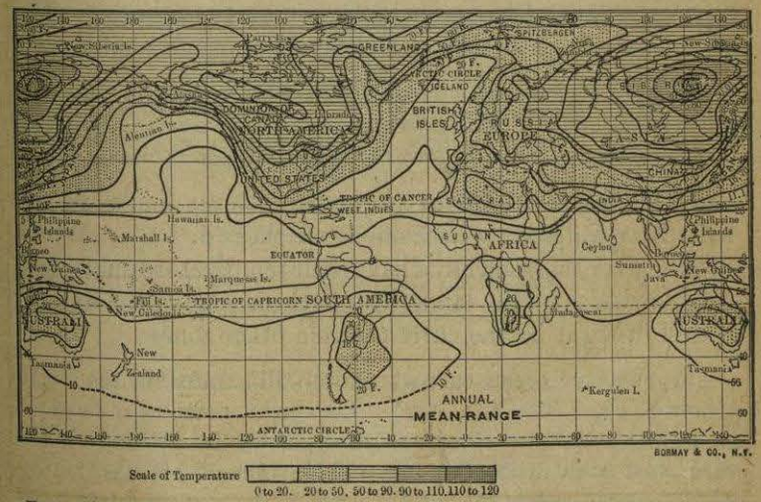


FIG. 435. — To show the annual mean (average) range in temperature for the world.

on the world charts (Figs. 431, 432). Study the chart of temperature range (Fig. 435) to see where there are great and small ranges. Contrast the range over the Atlantic with that over Asia and America; and the range over the Southern Ocean with that over the lands of the northern hemisphere.

Summary. — *Oceans and coasts have a far more equable climate than the interiors of continents.*

(D) *Influence of Winds.* — The influence of winds in causing irregularity in the isotherms is best illustrated, on a large scale, where winds blow from water upon land, as in northwestern United States and Europe (Figs. 431–434). In these places the prevailing west winds, influenced by the water over which they pass, moderate the cold of winter and the heat of summer. It is for this reason that in western Europe agriculture thrives, and large cities are found in latitudes that, in eastern North America, are frigid and almost uninhabited. London is in the same latitude as southern Labrador, and St. Petersburg as northern Labrador. For the same reason, the January temperature at San Francisco is the same as that at Charleston, S.C. (5° farther south), while the July isotherm is that of Halifax (6° farther north).

Summary. — *Prevailing winds influence the temperature, the most pronounced influence being where winds from the ocean prevail, thus carrying the equable temperatures of the water upon the land.*

(E) *Influence of Ocean Currents.* — Ocean currents and drifts bear water from one zone to another (p. 193). Winds blowing over these currents have their temperature influenced, and, blowing upon the lands, bear to them some of the warmth or cold brought by the currents from other zones.

This effect of ocean currents is well illustrated in the North Atlantic (Figs. 320, 431, 432). The great northward bend of the isotherms off the European coast shows the influence of the warm west wind drift (Fig. 338). This influence is least noticeable in summer when the sun has warmed the surface water. Off

northeastern North America, the cold Labrador current bends the isotherms toward the equator. Therefore, the isotherms are crowded together on the American coast and spread apart, fan-shaped, on the European coast. In other words, there are much greater differences in temperature in a short distance in eastern America than in western Europe. Notice also the influence of ocean currents on the isotherms along the west coasts of the United States, South America, and Africa.

Summary. — *Ocean currents warm or cool the air over them; moving as winds this air transfers the influence of the currents to the land. This is well illustrated in the North Atlantic.*

(F) *Influence of Topography.* — Hills and valleys have an effect of a local nature on climate. Mountains produce far more widespread effects. By shutting off winds, mountain barriers influence the climate of places behind them. Thus, while the Pacific slope of United States has an equable climate, the country farther east, being cut off from ocean winds by the mountains, has hotter summers and colder winters than the coast lands.

The subtropical climate of Italy, southern Spain, and France is partly due to the influence of topography. The waters of the Mediterranean are warm; the Alps and other mountains shut out the cold north winds; and they interfere with south winds which might bear away warmth from the Mediterranean. Therefore, in this region, oranges and palms grow (Fig. 443) in the latitude of Boston, New York, and other places in the United States which are visited by killing frosts for several months of the year.

Summary. — *Hills and valleys have a local influence on climate, and mountains far greater effects, especially in shutting out winds.*

CLIMATIC BELTS OF THE TORRID ZONE.

183. Belt of Calms (Fig. 408). — The vertical position of the sun in the equatorial belt of calms (p. 259) causes the climate to be hot (p. 240). This belt is also a very rainy

one (Figs. 436–440, 444), because the rising air soon reaches an elevation where its vapor condenses (p. 268).

The weather of the belt of calms is monotonously uniform. On the ocean, or on oceanic islands, the air grows warmer each day after the sun rises; and from the clouds which form, and which often develop into violent thunder storms, heavy rain falls. During the night the humid air is still warm, for there is not enough radiation to cool it. Both day and night there is an absence of steady winds, and sailing vessels are often becalmed for days. These conditions are repeated with marked regularity. The daytime temperatures are higher on the land, and winds are often caused by differences in temperature, for example, along the coast where sea breezes blow (p. 256).

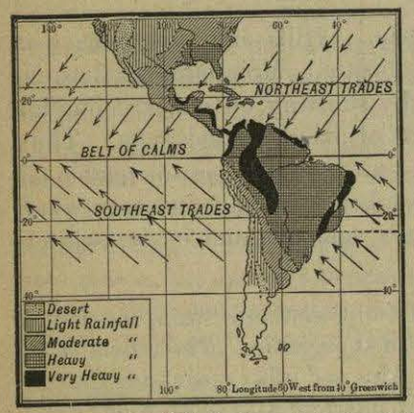


FIG. 436. — Rainfall of calm and trade-wind belts of America.

The rainfall is so heavy that dense forests thrive on the land, and the air within these is reeking with moisture. So warm and damp is the climate that it is difficult to work; the clearing away of vegetation for planting is such a task that it is rarely undertaken; and, in fact, there is little need for doing so, since, with little labor, the forest plants yield abundant food. For these reasons the tropical forest is inhabited by races depending directly upon nature for food, who, having little ambition for improving their condition, have made little progress toward civilization.

Summary. — *The belt of calms has a hot, humid climate with a general absence of winds. The heat and humidity cause a rank growth of tropical forest, but discourage progress among mankind.*

184. Rainy Trade-wind Belts. — To the north and south of the belt of calms the trade winds (p. 259) blow toward warmer regions. Vapor is therefore constantly rising into them, because, the warmer the air, the more vapor possible (p. 244). So much fresh water is thus removed that the sea is made more salt (p. 181) where the trade winds blow. These winds bear such quantities of vapor that, when they blow over rising land, where the air rises and cools, vapor is condensed. East-facing coasts, against which the trade winds blow, are, therefore, very rainy (Figs. 436–440, 444).

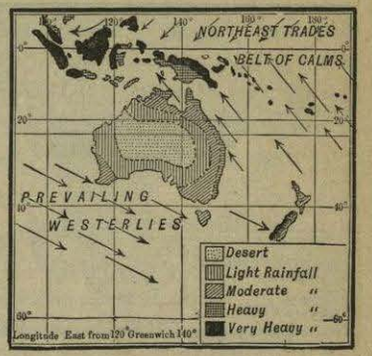


FIG. 437. — Rainfall of calm, trade-wind, and westerly belts of Australasia.

The east coast of South America, both north and south of the equator (Fig. 436), the East and West Indies, northeastern Australia (Fig. 437), and southeastern Africa (Fig. 438) have heavy rains, because the trade winds blow upon them from the sea. These places have a tropical forest, resembling that of the belt of calms. Mountainous oceanic islands in the trade-wind belt, like the Hawaiian Islands, have heavy rains on the eastern or windward side while the opposite side has a dry climate.

Summary. — *East-facing coasts in the trade-wind belts have a rainy climate, because, as the damp air cools in rising over the land, some of the vapor, evaporated from the ocean, is precipitated.*

185. Desert Trade-wind Belts. — In the trade-wind belts arid conditions are far more common than rainy; in fact, the trade winds furnish the most important cause for deserts. They take up vapor in passing over the land for the same reason as on the ocean; but there is so little moisture to be obtained on land that they become very dry winds, into which

vapor rises wherever possible. This leaves so little water for plants that the land is made desert; but even in the driest desert air there is some vapor, and rain occasionally falls. In the Mohave desert of Arizona the rainfall is less than two inches a year.

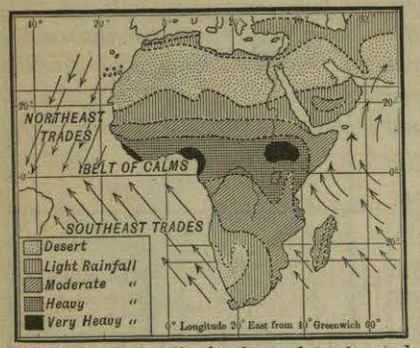


FIG. 438. — Rainfall of calm and trade-wind belts of Africa.

Because of these conditions both north and south of the equator, there is a broad belt of arid and desert country extending almost completely across the continents, though on east-facing coasts interrupted by rainy belts. These desert belts include parts of Australia (Fig. 437), South Africa (Fig. 438), southern South America (Fig. 436), and southwestern United States (Fig. 442); but the largest desert tract is in the great land area of northern Africa and Asia. Commencing in western Africa, there is a series of deserts extending far toward the east coast of Asia (Fig. 444). The great Sahara is a part of this belt.

In many places the deserts of the trade-wind belts merge into the arid regions of the horse latitudes (p. 261). Here also the air is warming, and evaporation, therefore, proceeds rapidly.

Life in the deserts presents a far different picture from that in the tropical forest. Only a few species of plants are adapted to life amid the unfavorable conditions, and even these are scattered (p. 342). Therefore, the desert is a barren, open country; and neither animals (p. 357) nor men (p. 386) find it a favorable place for a home. Deserts are among the most sparsely settled parts of the world.

The weather is nearly always dry, the sky usually cloudless, and the winds often strong, blowing sand about (p. 87). Even in the temperate zone the days are warm, and in summer hot. For example, in the desert of southern Arizona, though far north

of the tropic of Cancer, the thermometer sometimes rises to 120° in the shade. The highest air temperature recorded (127°) was in the Algerian desert. But radiation is rapid in the dry desert air, and at night the ground and air cool so quickly that a blanket may be necessary before morning.

Summary. — *Where air is growing warmer, as in the trade-wind and horse-latitude belts, the climate is dry and the land arid or desert. Most of the deserts are in these belts. Deserts are unfavorable to life, — plant, animal, and human. The desert climate is dry, often windy, and hot days are followed by cool nights.*

186. Savanna Belts. — Between the rainy belt of calms and the trade-wind deserts there is, in each hemisphere, a region, called the *savanna* belt, that has alternate dry and wet seasons. This peculiar climate is caused by the migration of the belt of calms (p. 259). In the hot season the belt of calms migrates to the savannas and there is heavy rain (Figs. 439, 440); but in the opposite season the savannas are under the influence of the drying trade winds.

As a result of these changes, the hot season (the time of our summer in the northern hemisphere, and of our winter in the southern) has copious rainfall, and vegetation freshens and grows vigorously; but in the opposite season the ground is parched, and vegetation withers. The season of drought is too severe for many forms of vegetation, such as trees. Therefore, the savannas are covered with those plants, such as grass (Fig. 491), which are able to survive a period of drought (p. 342).

The *downes* of Australia, the *park lands* of Africa, the *llanos* of Venezuela and Colombia, and the *campos* of Brazil are examples of savannas. Their grass supports large numbers of plant-eating animals, upon which flesh-eating mammals prey.

Savannas are probably destined to become the most productive and best-settled lands in the tropical zone. The open country favors agriculture, and the drought makes necessary some provision for that season. Being thus forced to industry and thrift, the negroes of the savannas have become farmers and cattle raisers, and are the most advanced blacks of Africa.

Summary. — *The migration of the belt of calms brings abundant rain to the margin of the desert trade-wind belt during the hot season, giving rise to alternate seasons of drought and rain. This makes such regions, called savannas, great pasture lands, well adapted to life.*

187. The Indian Climate. — As a result of the influence of the monsoons (p. 256), parts of India have a peculiar climate with three well-defined seasons, — the hot season, the rains, and the cool winter. During the hot season, which lasts from April to June, hot, dry winds from the land cause the temperature to rise above 100° in the shade. In June the air becomes calm and the heat almost suffocating, and every one longs for the summer monsoon. When this begins, clouds appear, rain falls, and for a month or two rains are of almost daily occurrence, causing vegetation to grow profusely.

A short period of calm follows the summer monsoon, and again the heat is intense; but cool air from the interior soon begins to flow down toward the sea, and by October the winter monsoon is established. The air is then clear and cool, and by January, in many parts of India, fires are necessary. In February and March a sort of spring visits the land. Vegetation then bursts forth, only to be withered by the scorching drought of the hot season, which postpones the real growing season until the summer rains.

So heavy is the rainfall on the mountain slopes that, in places, the soil is completely washed away. The heaviest rainfall in the world is at the base of the Himalayas (Fig. 441). In a year there are about 500 inches of rain; that is, if it should all stand where it fell, it would form a layer of 40 feet. Of this amount about two thirds falls in the five summer months. On a single day there have been 40 inches of rain, or more than falls in most parts of the United States in a year.

Summary. — *The Indian climate consists of a hot season (April to June); a rainy season, during the summer monsoon (June to August); and a cool season, during the winter monsoon. In parts of India the rainfall during the summer monsoon is very heavy, the rainiest part of the world being in northern India.*

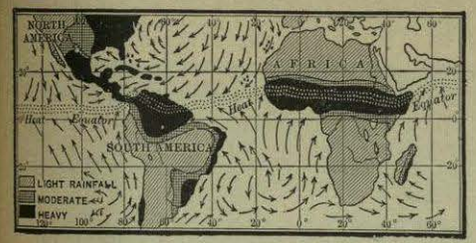
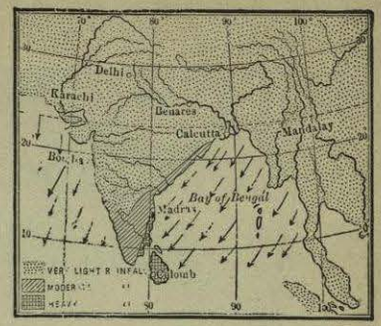


FIG. 439. — Sketch map of winds and rainfall in summer. Zone of greatest heat marked by dots, an imaginary line in the center of this area being the *heat equator*.

FIG. 440. — Sketch map of winds and rainfall in winter. Compare with Fig. 439 to see nature and effect of migration of wind belts.



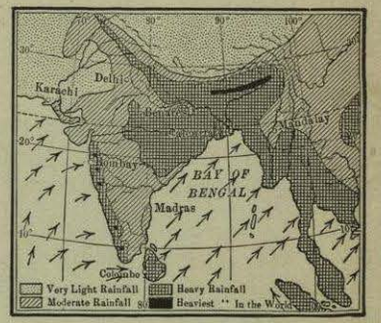


FIG. 441. — Summer and winter rainfall of India, the difference resulting from the monsoons.

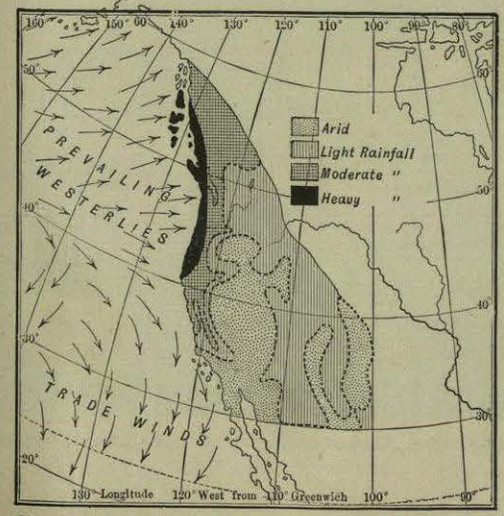


FIG. 442. — Rainfall of northwestern North America.

FIG. 443. — Subtropical flora of southern France, at Nice, in the same latitude as Portland, Maine.

CLIMATES OF THE TEMPERATE ZONES.

188. Variation (in Temperate Zones) from North to South. — (A) *Temperature.* — The temperature varies greatly from near the tropics toward the poles; but, excepting near the tropics, there is everywhere a decided difference between summer and winter. Near the polar circles the summers are so cool, and the winters so cold, that the climate is often called subarctic. No trees grow there (p. 340); little or no agriculture is possible; and there are scarcely any human inhabitants, excepting along the seacoast, or in mining camps, like the Klondike.

These treeless tundras merge into a forest belt, and vegetation becomes more and more luxuriant until, near the tropics, the climate is so warm that it is called subtropical. In this warm belt cotton, sugar, oranges, and even bananas, pineapples, and cocoanuts are grown.

Summary. — *The climate of the temperate zones changes from cold, or subarctic, near the polar circles to hot, or subtropical, near the tropics; and with these changes there are variations in vegetation from treeless tundra to subtropical forest.*

(B) *Rainfall.* — The rainfall also varies from north to south. Most temperate regions have a moderate rainfall, decreasing toward the frigid zone and also toward the tropics. The rainfall decreases toward the frigid zone, because there can be less vapor in cold than in warm air (p. 245). It decreases toward the tropical zone because the horse latitudes are naturally arid regions (p. 282).

The arid horse-latitude belts, in which are included southern California, southern Texas, Spain, Italy, Greece, and the steppes of Russia, grade in one direction into the deserts of the trade-wind belts, and, in the other, into the damp climate of the mid-temperate zone. They may be called the belts of *steppes*. Some parts of the horse-latitude belts, like Florida, have abundant rain-

fall, because exceptional conditions cause winds to blow from the ocean. Some parts, on the other hand, are true desert.

Steppes are dry in summer; but some sections are reached by the west winds when they migrate southward in winter, bringing snow and rain. Therefore irrigation is necessary for agriculture, as in Italy, which has dry summers and rainy winters. Where best developed, steppes are too dry for trees; but grass grows in spring, curing to a natural hay during the warm, dry summer, thus serving as a food for cattle.

Summary. — *The rainfall decreases toward the north because the air is cool; in most places it also decreases toward the south, and, in the horse-latitude belts, there are regions of arid steppes.*

(C) *Effect of Mountains.* — While in southern Europe (p. 279) subtropical plants grow in the latitude of the New England and Middle Atlantic States, in our country such plants do not thrive, even in northern Florida. There are no lofty mountains to prevent cold north winds from sweeping down to the Gulf. Therefore cold waves reach as far as New Orleans and northern Florida, causing frosts so destructive that it has been necessary to give up orange culture in northern Florida. In one respect these cold winds are an advantage, for they are invigorating, and the people of the South do not suffer, as some warm temperate peoples do, from the enervating effects of too much warmth.

Summary. — *The absence of east-west mountain chains makes it possible for cold waves to reach even to the Gulf.*

189. Variation (in Temperate Zones) from West to East. — Owing to the fact that the prevailing winds of the temperate zones are from the west, there are decided differences in climate from west to east.

(A) *West Coasts.* — The warm, damp winds that blow from the ocean upon west-facing coasts cause a humid, equable climate. This is well illustrated on the northwest coast of the United States and Europe (pp. 278 and 279). While in eastern United States droughts often cause the grass to become parched, the dampness of the air in the British

Isles keeps it green. Hence the name Emerald Isle for Ireland.

The heaviest rainfall in the United States is on the northwest coast (Figs. 442, 445), where damp air from the ocean rises up the mountain slopes. There the rainfall amounts to 100 inches a year; and in winter, when the land is cool, and the westerlies most steady, there is rain, drizzle, or fog almost daily. For the same reason there is heavy rainfall on the southwestern coast of Chile (Fig. 444). But in the horse-latitude and trade-wind belts, as in southern California and northern Chile, the climate, even on the seashore, is arid.

Summary. — *On west coasts of the temperate zone, where reached by the prevailing west winds, the climate is damp and equable. The heaviest rainfall in the United States is on the northwest coast.*

(B) *Effect of North-south Mountains.* — Along the west coast of Europe there is especially heavy rainfall on the mountain slopes, as in Wales, Scotland, and Norway. But, since these mountains are not very high or continuous, the winds are able to carry vapor far inland, even into Asia. Because of this fact Europe, north of the horse-latitude belt, is well watered and the seat of extensive agriculture.

In western North America, on the other hand, as the air rises over the high, continuous mountains, so much of its vapor is condensed that it descends on their eastward slopes as dry air. Accordingly, from the Sierra Nevada-Cascade ranges eastward to the 100th meridian — the part of North America which corresponds in position to Germany, Austria, and eastern Russia — most of the country is arid; and even farther east, in the Mississippi valley, there are frequent and destructive droughts.

Summary. — *Western United States differs from Europe in the greater influence of its higher, more continuous mountains, which cause the winds that cross them to reach the other side dry, forming arid regions as far east as the 100th meridian.*