W. B. No. 999

Issued January, 1930

UNITED STATES DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

MONTHLY WEATHER REVIEW

[Supplement No. 33]

CLIMATE OF MEXICO

BY

JOHN L. PAGE

Submitted for publication November 14, 1929

QC
983
.A21
no. 33
1930

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1930

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CLIMATE OF MEXICO

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PREFACE

The climatic conditions of Mexico are little known because of the meager amount of published material on this subject. The purpose of this SUPPLEMENT is to portray and interpret various phases of Mexican climate. No attempt, however, is made to cover in detail every phase of the climate of Mexico.

The data upon which this study is based are in the form of (1) instrumental observations made by the observers throughout the country, compiled at the Central Meteorological Observatory at Tacubaya, Mexico, and (2) published descriptions of some phases of the climate.

All available instrumental data of most elements for stations of more than three years, and some cases, where stations were widely separated, records of three years or less, were tabulated by months, reduced to averages, and used in this study. The number of stations and length of years of records differs with the climatic elements. For rainfall, days with rainfall, and maximum rainfall in 24 hours 220 stations, varying in length from 3 to 50 years, were used. For temperature and days with frost the number was 130 and the length from 3 to 50 years, though, in general, the records were shorter and more broken than for rainfall. The records for the other elements as relative humidity, hours of sunshine, days with thunderstorms, cloudiness, cloudy, partly cloudy, and clear days, pressure and wind direction were for only about 45 stations and length of years somewhat less than for temperature.

Only in case of the available records for pressure and wind direction was a uniform period of years used, that of 1921–1927, and in these elements no adjustment was made of the shorter to the longer stations.

The Bigelow tables for reducing pressure readings to sea level were used in this study. And because of the great probability of inaccuracy in reducing these pressure readings to sea level a few isobars were dashed where the results did not seem in accord with general conditions.

Only average conditions were mapped, because the records at many stations are short and recorded extremes would very likely be far from what the extremes would be for a long period of years. Some maps had to be generalized and lines drawn on the basis of information other than instrumental records.

The metric system has been used throughout this study because it is the system of the country and consequently the system in which the records were found.

In the preparation of this SUPPLEMENT acknowledgments are made to Charles F. Brooks, under whose direction it was written, for many helpful suggestions and criticisms both as to content and method of treatment as well as making it possible to secure the data from Mexico; to Señor José C. Gomez, chief of the Central Meteorological Observatory at Tacubaya, for making records readily accessible during a period of two months and for invaluable assistance in having a large part of the data compiled; to the observers in many parts of the country for letters describing various phases of the weather in their locality; and to Clark University for a fellowship through the academic year 1928–29.

INTRODUCTION

An adequate understanding of the climate of any country necessitates, first of all, a consideration of the major controls, for it is these that explain why the climate of one locality differs from that of another region, near by or remote. Thus the major factors that control the climate of Mexico as well as other regions are: (1) Latitude; (2) land and water, including ocean currents; (3) elevation and exposure; (4) prevailing winds, and (5) storms.

As the sun is obviously the control of all climate, and as the amount of solar heat received at a given locality depends upon the length of the day and the angle at which the sun's rays strike the earth, a consideration of the latitude of the region must be given first place in the study of the climatic controls, even though it may not be the dominant one.

Mexico, lying as it does between 14° and 32° 40′ N. latitude, should, as far as its latitude is concerned, be a country with a tropical and subtropical climate. Yet its low latitude has less effect upon its temperature than might be supposed since most of the country is at an elevation sufficiently high to counteract the effect of latitude. Extending over but 18° of latitude, there is but little difference in the length of the day between the most northern and most southern parts—the longest day in northern Mexico being only 1 hour and 15 minutes more than the longest day in southern Mexico—and but slight difference between the annual temperature of the two sections. Only in winter is the north-south temperature gradient pronounced. In general, south of the Tropic of Cancer the month of maximum temperature is before June, whereas to the north of it the maximum is not recorded until June, July, August, or even September.

The latitude of Mexico is also an important factor in the distribution of pressure and consequently the occurrence of storms and the amount and distribution of rainfall. The northern part of the country is far enough north to come under the influence of cyclonic storms in winter, and the southern part far enough south to be within the doldrum belt in summer. Nearly all parts of Mexico may be lashed in the fall of the year by tropical hurricanes. And only few sections are exempt from the fury of the norther in winter. The more northerly sections, Lower California, Sonora, and parts of Chihuahua and Coahuila, lie within the belt of subtropical calms and are normally dry, while the southern sections lying within the low-pressure belt in summer are excessively wet and humid.

The second major control of the climate of Mexico is the distribution and temperature of the water bodies which bathe its shores. These water bodies are Gulf of Mexico, Caribbean Sea, Gulf of Tehuantepec, Pacific

Ocean, Gulf of California, and, locally, lakes and marshes. To the difference in temperature of these bodies may be attributed some curious anomalies of climate. Thus the west coast of Mexico, excepting Lower California, has a higher temperature than the Gulf coast at the same latitude. Since the prevailing winds are on-shore at all places the difference must be explained chiefly on the basis of the surface temperatures of the water bodies which bathe these shores. The Satavento coast of Vera Cruz is much more refreshing than the scorching Valley of Tehuantepec on the south, for the former enjoys sea breezes from the relatively cool Gulf of Mexico, whereas the latter is scorched by descending winds from the mountains. And the Peninsula of Lower California, though bordered on three sides by water, remains arid, because the wind blowing on-shore from the cool California current rarely is forced to give up its moisture.

Only along the lowlands of the coast does the marine influence upon the climate make itself particularly felt, for the mountains rise so rapidly and precipitously. Thus at only a few coastal stations can the effect of the sea in reducing the annual temperature be studied. The retardation of the months of maximum and minimum temperature, so typical of a marine climate, is best exemplified along the west coast.

Though the surrounding water bodies have but little influence upon the temperature of Mexico, they have, however, by supplying an abundant quantity of water vapor a very profound influence upon the rainfall. The Gulf of Mexico, especially, serves Mexico well in this regard. For not only are the mountains drenched with rain as the moisture-laden winds are forced upward over their flanks, but sufficient moisture is left to make the central valleys within well watered and fertile.

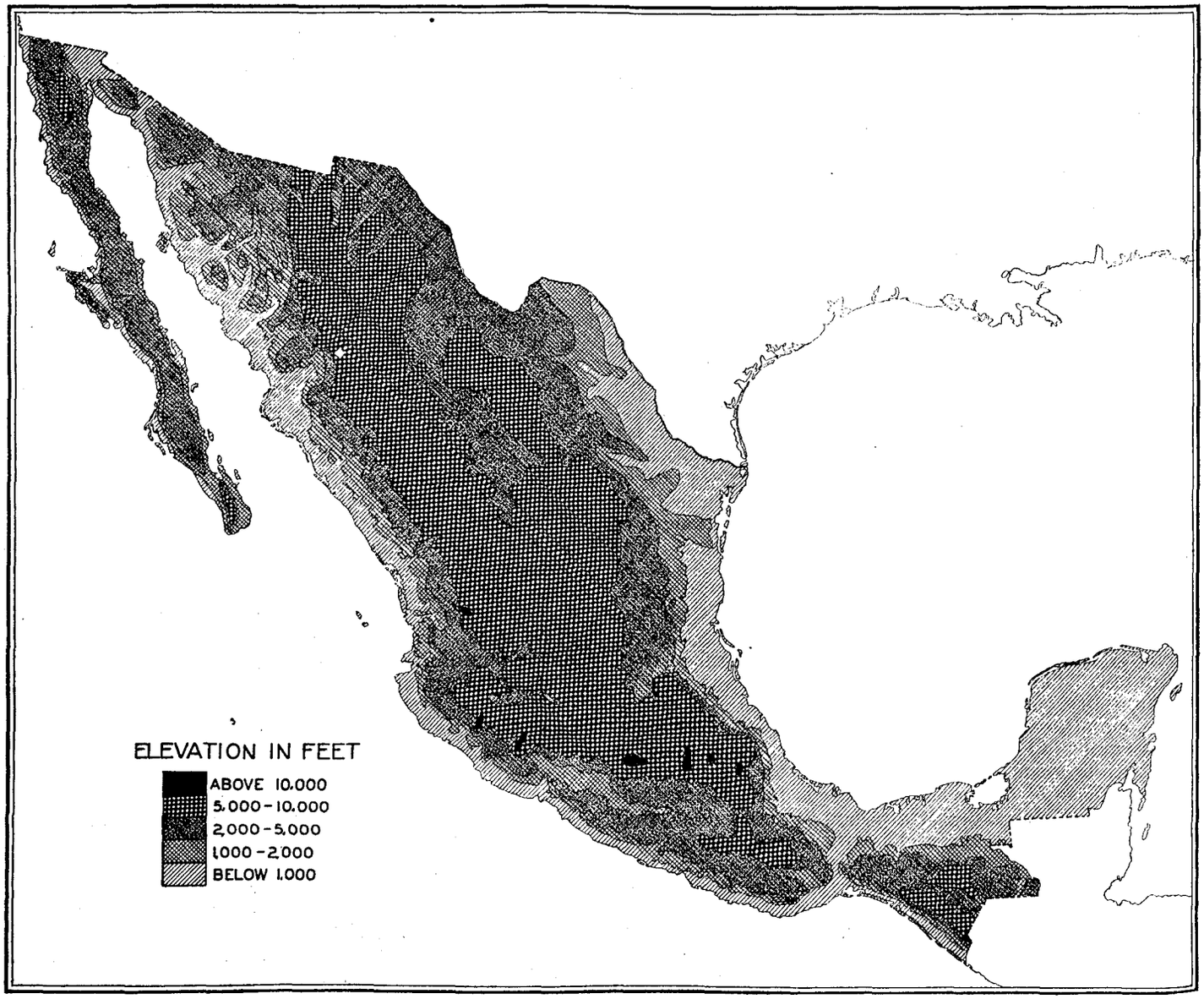

FIGURE 1.—Relief map of Mexico

Indeed, it is to its mountains and elevation that Mexico owes its salvation. For mountains and high plateaus transform much of Mexico from a tropical to a truly temperate country, and changes regions that might have been almost waterless to regions of copious rainfall. Observe Figure 1, a relief map of Mexico. Innumerable variations in relief cause numerous local variations in climate. Thus Mexico City has a mean temperature in all months about 10° C. lower than Vera Cruz, but 275 miles to the east; a north wind at Puerto, Mexico, in

winter is cool and humid, but in the Valley of Tehuantepec it is dry and scorching; the west coast may be basking in the warm sun, while the Gulf coast is experiencing the biting fury of a norther; and four times as much rain falls at Coatepec, Vera Cruz, as at Perote in the same State only 20 miles away. From tropical heat to arctic cold is merely a matter of a few hours' travel.

During some of the year all of Mexico is in the so-called belt of northeast trades, yet many parts of the country have prevailing northeast winds at no time during the year. Here again mountain barriers cut off or deflect the wind into directions as varied as the topography itself. Along the Gulf coast, however, the winds are northeast and east for much of the year, and exert a considerable influence on the climate of the coast as well as the eastern and northern slopes of the Sierra Madre Oriental. Along the west coast westerly winds exert a marine influence along the lowlands, and bring rain as they rise along the slopes of the western mountains.

Finally, under the influence of storms, extratropical or tropical, the normal effect of the other climatic controls may be obscured. Of little avail to the Gulf coast is its subtropical latitude when ravaged by a norther. A winter cyclone moving far south of its normal course may drench the arid regions of northern Mexico. Or a hurricane moving westward and northward from the Carribbean Sea may lash the southern part of the country with violent wind and rain.

FIGURE 2.—Average sea-level pressure, January

FIGURE 3.—Average sea-level pressure, April

PRESSURE WINDS AND STORMS

Pressure differences being the cause of all wind movement, whether it be gentle zephyr, cyclonic storm, tropical hurricane, or tornado, it is not unnatural that a study of this pressure element should precede that of winds and storms. The latitude of Mexico places it, in part, in the subtropical high-pressure belt but largely in the so-called northeast trade wind belt. As has already been pointed out the more northerly part of the country comes under the influence of the westerly winds and their associated cyclonic storms during the winter season, while the more southerly part is dominated by the tropical low-pressure belt in summer.

FIGURE 4.—Average sea-level pressure, July

FIGURE 5.—Average sea-level pressure, October

Sea-level pressure maps for Mexico (figs. 2–5) show a general decrease in pressure from northeast to southwest. The pressure gradient is strongest in January, when 5 to 7 millimeters difference is found between the Gulf and Pacific coasts. (Fig. 2.) This general January pressure distribution is to be expected when one considers the lower temperatures along the Gulf than along the Pacific, a fact attributable to the lower trade wind latitude of the

latter and the free exposure of the former to cold invasions from the United States and Canada. The higher pressure along the Gulf is further enhanced by the precipitous mountain wall of the Sierra Madre Oriental which acts as a barrier to the free movement of the northeast winds and causes a piling up of these winds along the coast. Just to the west of the Sierra Madre Oriental in January

FIGURE 6.—Prevailing winds for January

an area of relatively low pressure is found, while farther west is again a ridge of higher pressure.

By April (fig. 3) pressure throughout the country is lower. The pressure gradient is still, in general, from northeast to southwest, but much weakened. Moderately high pressure covers the middle and southern Gulf coast, Yucatan, the southern plateau, and northern Pacific coast,

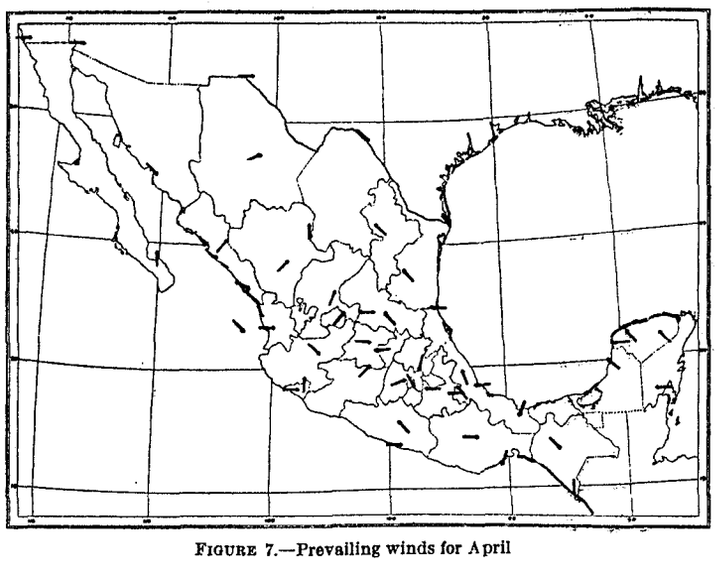

FIGURE 7.—Prevailing winds for April

while the northern plateau has become an area of relatively low pressure.

With the coming of summer and the rains (fig. 4, July) Yucatan and the southeastern portion of the Mexican plateau have become the areas of high pressure, while the Pacific coast and northwestern Mexico remain as areas of low pressure.

In October the southeastern part of the plateau continues as an area of high pressure, while the general pressure gradient is still from northeast to southwest. (Fig. 5.) Thus throughout the year the general sea-level pressure gradient over Mexico is from northeast to southwest with a slight alteration of the pattern from season to season.

Much of Mexico being a plateau of considerable elevation, pressure reduction to sea level changes the general plan of pressure from that at the actual elevation of the stations. This fact plus the effect of very diverse local

FIGURE 8.—Prevailing winds for July

topography often causes the prevailing wind direction to be different from that indicated by the sea-level pressure maps. Compare Figures 2–9. The direction of the surface winds is not determined by the sea-level pressure distribution but by general pressure distribution at the level of the various stations and by the local topography. Nothing in particular can be said about the general wind

FIGURE 9.—Prevailing winds for October

direction except that along the Pacific coast the winds for the most part are on-shore all year. The sea breeze, one of the saving graces of the Tropics, is perhaps largely responsible for these prevailing on-shore wind conditions. Exceptions to this may be found at stations around the Gulf of California where the direction varies from month to month, and the prevailing offshore wind around the Gulf of Tehuantepec. This offshore wind is a result of the general pressure gradient from northeast to southwest, the gradient being stronger in this region than elsewhere in Mexico, and to the generally low elevation of

the Isthmus of Tehuantepec which permits the northeast winds to cross without much difficulty.

On the Gulf coast the prevailing winds are more in accord with general pressure conditions than in any other part of the country. The subtropical Atlantic high-pressure area, an arm of which extends over the Gulf, produces northeast winds all along the Gulf coast.

In the plateau section of Mexico the wind direction is determined by local pressure distribution and relief. Consequently marked differences in direction prevail at different places not far distant. Compare Toluca and Tacubaya for January. (Fig. 6.) Tacubaya has a prevailing north-northwest and Toluca a south-southeast wind.

The general distribution of pressure over North America and adjacent oceans has a profound influence on the weather and climate of Mexico. Lopez, who has probably been the greatest contributor to Mexican climatology, writes that the weather of the Republic of Mexico is controlled by (1) the center of action of the Pacific of the north, (2) the equatorial depression, and (3) the center of action of the Atlantic of the north. His treatment of weather controls is so valuable that a part of his discussion, as translated by the writer, will be presented here.

> The intensity and position of the center of the Atlantic high pressure exercises a marked influence on the weather of the country. During the winter season if the pressure over the Atlantic is above normal the weather is hot and rainy in the Republic * * * In the summer these same conditions give rise to good weather and increase of temperature. On the other hand if the pressure over the center [Atlantic] is below normal in winter, cold, dry weather is the result; and a summer with these same pressure conditions is a cold one. * * *
>
> The relation between the center of low pressure in Alaska and the high over Hawaii demonstrates that an accentuated depression in Alaska translates itself into a high in Hawaii and shortly afterwards rainy weather in the Republic [Mexico]. On the contrary a high in Alaska coincides with a depression in Hawaii which presents itself afterwards on the west coast of the United States followed by heat and good weather in our country [Mexico]. * * *
>
> The long dry and hot periods of weather which are so damaging to agriculture are governed by a type of weather which frequently presents itself during the months of April and May. This is characterized by a center of low pressure of semistable character, of very moderate intensity, and whose center is situated little to the north of the frontier with the United States, embracing in its area all or almost all of the Republic. In this case the country is situated to the south or southwest of the center and therefore the winds are dry and hot, and blow from directions between south and west.
>
> In Mexico the frosts and cold waves are generally the result of anticyclones which descend from the territory of the United States at the back of a cyclone which has crossed the country. The premature frosts of the autumn, however, are caused by a moderate anticyclone which develops by radiation in the Mesata, persisting there many days with little movement (*48, p. 135–137*).

Perhaps one of the most interesting as well as most important phenomenon in Mexican weather is the strong, cold, and often humid wind which blows in winter, especially on the Gulf coastal region. This wind is referred to in Mexican literature as "el Norte." It has been the object of study and investigation by various people. Lopez likens it to the Mistral of France and the bora of the Dalmatian coast (*50, p. 91*). It often makes itself felt in its low temperatures and rainfall in Yucatan, Tabasco, and Vera Cruz. At times its effect is also felt in the Valley of Tehuantepec, not as a cold moist wind, but as a foehn with all the features that characterize the foehn of the Swiss Valleys of the Alps (*50, p. 92*).

W. C. Redfield early maintained that northers around Tampico and Vera Cruz were always accompanied by hurricanes or rather were the results of hurricanes (*2*). It is now generally known, however, that a norther is not necessarily the result of a hurricane but may prevail when there is a widespread barometric depression over the western part of the Gulf of Mexico or Caribbean Sea region, or when a well-developed cyclone moves across the northern part of Mexico with a pronounced anticyclone over the north central part of the United States.

Jose Guzmán recognizes the following conditions as necessary for northers on the Gulf coast: (1) Barometric depression on the coast of the Gulf of Mexico, (2) high temperature in this region, (3) southerly winds in the same, and (4) anticyclone in or very near the Rocky Mountains of considerable intensity with relation to the depression on the coasts (*50, p. 94*).

According to Batturoni the northers often reach Frontera before they reach Vera Cruz or even Tampico. He attributes this fact to the less resistence between the wind and water than between the wind and land. As an example he cites the occasion of the heavy norther of February 7–9, 1892, in which he says:

> He saw the cloud bank in the north and east on the 8th; the records showed that the norther had begun at Frontera on the morning of the 7th (200 miles east-southeast of Vera Cruz) and that it began at Tampico about 4 a. m. of February 9 (200 miles north-northwest of Vera Cruz) but did not begin at the latter place until 8.30 a. m. of the night 9th (*1*).

Batturoni distinguishes two classes of northers, each having its own characteristics: (1) Northers that come from the United States south to Vera Cruz, and (2) northers that begin and die away on the Gulf coast of Mexico (*1*).

As examples of the first class he cites the ones of February 7–9, 1892, while the following northers illustrate the second class: February 9, 1892, and September 23–25, 1892 (*1*).

Finally, Mexico is frequently beset in summer and fall by the tropical hurricane. The warm waters of the Caribbean Sea and the Pacific adjacent to the coast of Mexico are favorable to the formation and growth of these tropical storms. The chief of the forecast division of the Mexican Meteorological Service, Senor Pablo Vásquez Schiaffino, recognizes the following five classes of tropical hurricanes that effect the weather of Mexico.

> (1) Antillian hurricanes of normal course which either curve toward the northest in the latitude of Florida or in the eastern portion of the Gulf of Mexico.
>
> (2) Cyclones which originate in the Caribbean Sea or the the east * * * take a course generally toward the west crossing the Peninsula of Yucatan and the Gulf of Mexico only to recurve in the western portion of the same or enter the Mexican territory on the coast of [the State of] Tamaulipas.
>
> (3) Cyclones which originating in the Caribbean Sea or to the east, follow a normal course and after crossing the southern part of the Peninsula of Yucatan continue moving toward the west, passing the Gulf of Campeche and penetrating the Republic between 18° and 20° of north latitude, conserving sufficient energy to cross the Mexican Mesata and appear on the Pacific where they disappear to the northwest or recurve toward the north.
>
> (4) Cyclones which have their origin in the Caribbean Sea or to the east, and take a similar course as (3) except that, after they cross Central America and pass to the Pacific Ocean they pursue a northwest course, recurving between 18° and 22° north latitude to penetrate the Gulf of California or strike against the west slope of the country where they dissolve themselves. In this group may also be included the cyclones originating in the waters of the Pacific, to the south of the Gulf of Tehuantepec or in more westerly longitudes.
>
> (5) Cyclones of similar origin as the above which cross the Mexican Mesata from southwest to northeast appear in the Gulf of Mexico and move toward Florida (*61*).[2]

A map showing the course of these five classes appears as Figure 10.

[2]Translated by the writer.

Tropical cyclones in the Pacific waters of Mexico have been the subject of recent investigation by Willis Edwin Hurd. To quote him:

[An average of five cyclones annualy have been recorded during the last 19 years, with an extreme number of 13 for a single season. One has occurred in May.] There is an average occurrence for June of a trifle more than one in two years. In July and August there is a slight increase in numbers and activity, but September is preeminently the month of most frequent storminess of this character, about two-fifths of the entire number of cyclonic disturbances occurring then. In October they wane appreciably in frequency, though gaining slightly in intensity, and November adds only an occasional outburst—a violent one more often than otherwise—to close the activities of the season (*41, p. 43*).

Hurd classifies the cyclones of this region as follows: (1) The coastwise storms, (2) cyclones that run perpendicular to the coast, (3) cyclones of the Revillagigedo Islands, and (4) cyclones west of the one hundred and twenty-fifth meridian (*41, p. 45*).

TEMPERATURE

Although lying largely within the Tropical Zone, Mexico presents great diversity in its temperature. It is frequently thought of as a hot country because of its latitude. Mexico in reality is transformed from a tropical to a truly temperate country by its altitude.

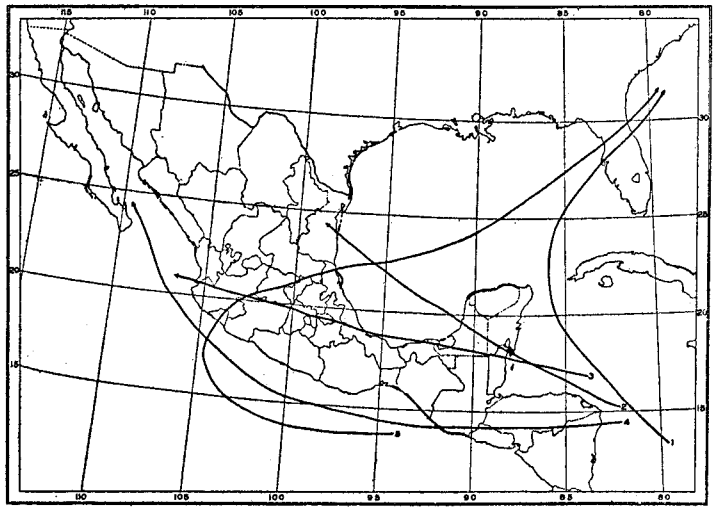

FIGURE 10.—Tracks of tropical cyclones

Mexico offers practically all types of climate from the permanently snow-capped volcanic peaks to the regions of tropical palms on the lowlands of the Pacific and Gulf coasts. It is only a matter of hours in going from one extreme to the other, for on clear days one can stand on a permanently snow-capped peak and view the tropical palms and wild bananas on the lowlands not far away. Most of Mexico falls within this Temperate Zone.

One need only glance at a temperature map to note the marked influence of altitude on temperature in Mexico. The average vertical temperature gradient between Vera Cruz and Mexico City is 1° C. per 200 meters and much of Mexico is above 2,000 meters, an altitude sufficient to cause a markedly lower temperature on the plateau than on the coastal lowlands. The effect of altitude is well seen in Figure 11, which shows the annual course of temperature for a Pacific coast station (Manzanillo, Colima, altitude 4 meters), a Gulf coast station (Vera Cruz, altitude 16 meters), and a plateau station (Mexico City, altitude 2,250 meters), all in approximately the same latitude.

In climatological literature Mexico is often referred to as having three thermal regions: Tierra caliente or hot land, tierra templada or temperate land, and tierra fria or cold land. Figure 12 shows the areas represented by each of these thermal regions. In delimiting these regions the same degree of temperature was used as that employed by Hernandez (*35, p. 1*). The tierra caliente is that part of Mexico which has an average annual temperature above 22.5° C. It is restricted to the lowland section of the country. This region has as its boundaries altitude lines rather than latitude lines, though latitude, exposure, and cool water of the Pacific along the west coast of Lower California assert themselves in the northern part of the country. The tierra templada is that part of Mexico where the temperature is between 15° and 22.5°, and is determined more by altitude than by latitude. This region embraces the major portion of the country, practically all of the plateau and most of Lower California. The tierra fria is restricted to the higher mountain sections of Mexico, where the annual temperature is below 15°, some areas of which do not appear on the map because of their very small size or the absence of data and the lack of a good relief map.

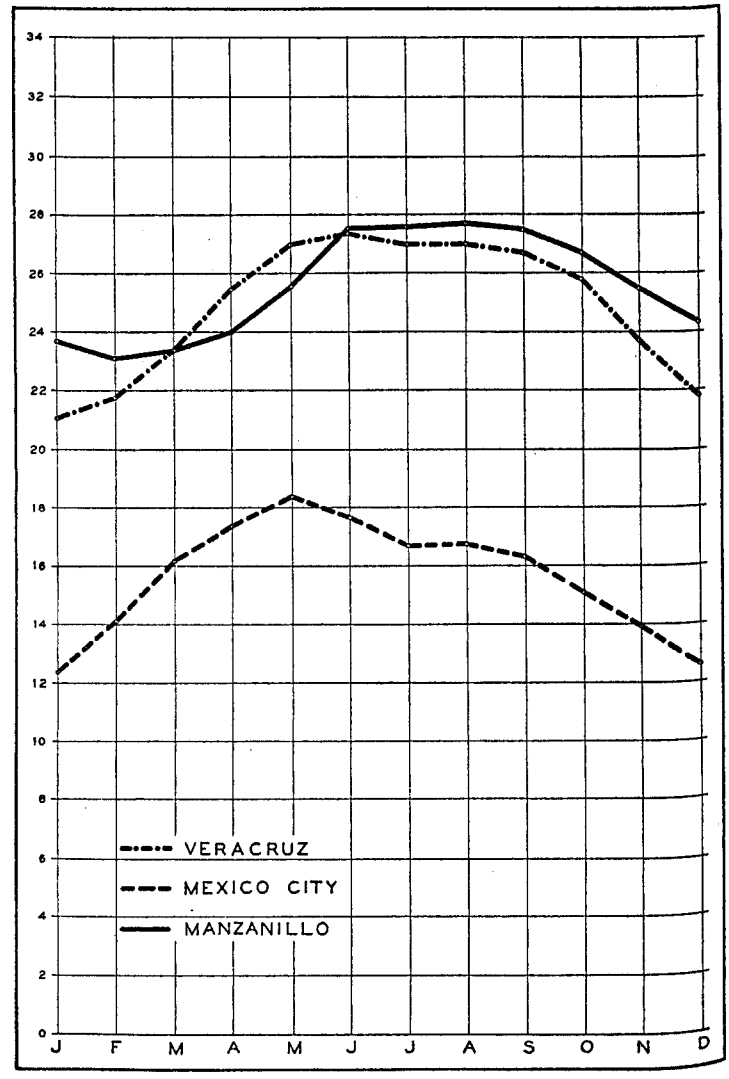

FIGURE 11.—Mean monthly temperatures for Vera Cruz, altitude 16 meters; Mexico City, altitude 2,250 meters, and Manzanillo, altitude 4 meters

For equal latitude the Pacific coast of Mexico, neglecting Lower California, is warmer than the Gulf coast.

The curves for the coastal stations of Manzanillo and Vera Cruz show that during all months except March, April, and May the Pacific coast station is warmer than the Gulf coast station. (Fig. 11.) This is true especially in winter when the northers bring low temperatures to all of the Gulf coastal region, a phenomenon which rarely occurs on the west coast and never so severe in the latter as in the former. To this may be added the further influence of the warmer Pacific than the Gulf waters, with prevailing on-shore winds in both cases. The water of the Pacific along the steamship route from 15° to 22° N. latitude has a mean temperature at a depth of 7 meters of 29° C. for January, March, June, August, and November, 1927 [3] and the average temperature of the surface water of the Gulf of Mexico for the same months for 1920–1927 is 26°.[4]

A few generalizations may be made regarding annual temperature of Mexico. There is a slight temperature decrease from south to north. The weak temperature gradient along the coast is accounted for by the low latitude of the country and the almost uniform temperature of the waters which bathe these coasts. An exception to this is the transition from warm to cool water along the west coast of lower California. In the interior of the country the decrease northward along the plateau is lessened by the decrease in elevation toward the north. The greater aridity in the northern part also permits more insolation, less evaporation, and consequently higher temperatures in summer, while a considerable amount of cloudiness in winter attending extratropical cyclones prevents the temperature from getting so low as it would otherwise do. The absolute maxima as well as the absolute minima temperatures for Mexico as a whole occur in the northern part of the country.

Pronounced temperature gradients are found in going from either the Gulf or the Pacific coast to the plateau. A trip by train from Vera Cruz to Mexico City in summer surely brings about a realization of this fact. Vera Cruz has a mean July temperature of 27° C., while at Mexico City the mean temperature for the same month is only 16.7°. A comparison of temperature and relief maps reveals a close conformity of the two.

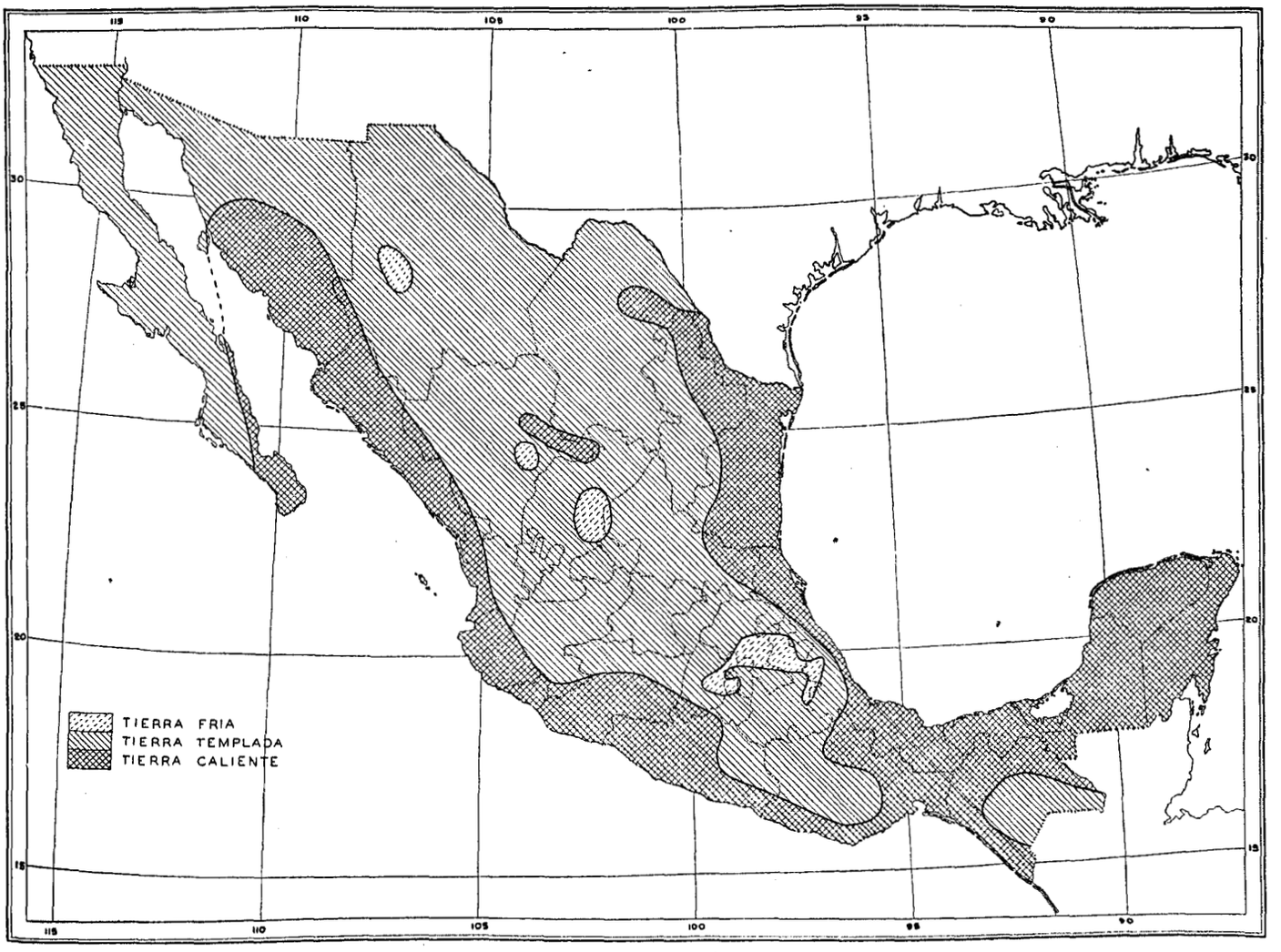

FIGURE 12.—Thermal regions

In January one isotherm cuts the Pacific coast more than 5° farther to the north than it does the Gulf. (Fig. 13.) In this month the States of Chihuahua and bordering sections of Sonora and Coahuila are the coldest parts of the country, the highest volcanic peaks excepted, with a mean temperature of less than 10° C., while the hottest part of the country is along the Pacific and Gulf of Tehuantepec coasts with a mean temperature of more than 25°. The cold area in the north is due to its more

[3] Temperatures recorded by Clark University's sea-water thermograph on the steam ship *Finland* plying between New York and San Francisco, 1927.

[4] Average of surface temperatures reported by ships at Greenwich mean noon, courtesy of F. G. Tingley, of U. S. Weather Bureau.

northerly location and consequently freer exposure to the cold invasions from the United States, as well as to its elevation, a considerable portion of which is more than 5,000 feet. The warm areas in the south are due to their more southern location and low elevation, much of one area being located in the valley of the Rio Balsas where little or no rain falls and bright sunshine prevails during this month.

A comparison of the relief and January temperature maps reveals a more dominant altitude than latitude

FIGURE 13.—Mean temperature (centigrade) January

control. In July the altitude control is even more pronounced. (Fig. 14.) Disregarding Lower California, only one isotherm cuts the coast in Mexico and that is the 30° C. isotherm in the desert region bordering the Gulf of California, the temperature of which is only slightly above 30°. Practically all of coastal and lowland Mexico has a July temperature about equal to that of

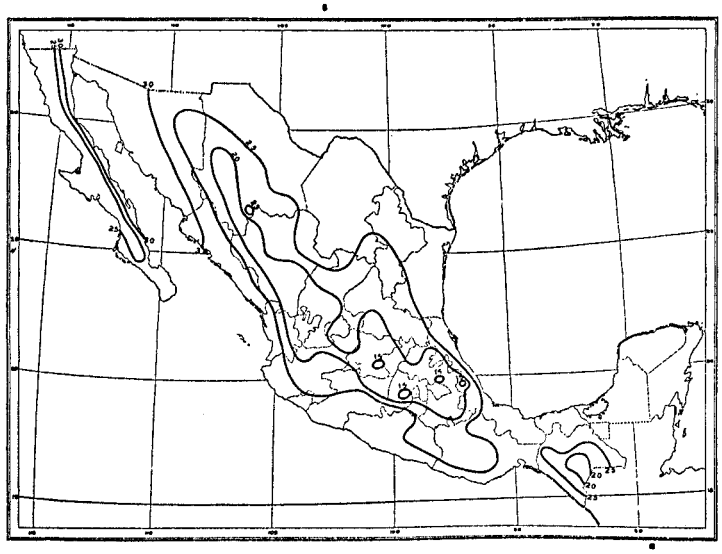

FIGURE 14.—Mean temperature (centigrade) July

Omaha, Nebr. (24.8°) and a considerable portion of the plateau lower than Portland, Me. (20.3°). The recorded extremes of average July temperature are 12.5°, at Las Vegas, Vera Cruz, and 31.1°, at Navajoa, Sonora.

An average July temperature chart does not give a true picture of summer temperature conditions in Mexico since July is not the hottest month in all parts of the country. A map has been constructed showing the average temperature for the hottest month, which varies from April to September. (Fig. 15.) The general trend of most of the isotherms is similar to that of July. There are, however, a few significant differences. The area having a temperature of less than 20° C. is much smaller than in July, and the areas with a temperature below 15° are fewer in number.

Because of the higher latitude and arid conditions the average annual ranges of temperature are more marked in the northern than in any other part of Mexico, some of the stations having ranges of almost 20° C., while the extreme ranges are more than 40°—that is the range between the average extreme maxima and the average extreme minima. In the south the temperature ranges are small. The most southern station of the country, Tapachula, in Chiapas, has only 0.5° difference between the January and July temperatures and at Tonala, in the same State, the July and January temperatures are the same. July, however, is not the month of maximum temperature at either place. The annual range is only 2° at Tapachula and 2.5° at Tonala. Throughout southern lowland Mexico the annual range is small. The difference between the average extreme

FIGURE 15.—Mean temperature (centigrade) of warmest month

maximum and the average extreme minimum at Tapachula is only 18.8°, while at Villa Ahumada in the State of Chihuahua is 49.2°. The temperature curves for all parts of Mexico except the desert region show the effect of the rainy season. They all have a rather pronounced increase in temperature from January to the starting of the rainy season, then a flattening out of the curve during the rainy season. Some stations even show a decrease in temperature while the season of rain persists, with a slight increase in temperature afterwards, and then a decrease to the winter months.

It has been shown that there is a considerable difference in the degree as well as the range of temperature in the different parts of Mexico. There is likewise a difference in the month in which the maximum temperature occurs, April, May, June, July, August, and September all being represented as the month of maximum temperature at one or more stations in Mexico.

The region which is hottest in April is small and embraces the most southerly part of the country, as is to be expected. The vertical ray of the sun reaches the southern part of this region about April 29, and in May cloudiness and rainfall increase, lasting throughout the months which would ordinarily be hottest,

preventing a further rise in temperature. The April temperature is, however, only slightly higher than that of May.

As the vertical ray of the sun moves northward with the advance of the season the month of maximum temperature becomes later. Most of the country south of the Tropic of Cancer is warmer in May than in any other month. This May maximum is attributable to the almost vertical ray of the sun and the fact that the rainy season has not yet started. The warmest month on the coast in some places in these latitudes is delayed. June is the hottest month in the north-central part of Mexico. The days are longer during this month than in any other and it is, in general, the month preceding that of maximum rainfall.

A July maximum of temperature is recorded in Sonora, northwestern Chihuahua and Sinaloa. In this area the cloudiness and rainfall are not sufficient to advance nor retard the month of maximum temperature from that of a normal continental type of climate. There is also a small area in the north and east of the Peninsula of Yucatan which records its maximum temperature in July. This delayed maximum is in accord with most coastal regions. The temperature of the Caribbean Sea is 0.2° C. higher in July than in June and 0.2° higher in August than in July, and the temperature of the Gulf of Mexico as a whole is 0.8° higher in July than in June and 0.3° higher in August than in July.[5]

In the remaining part of Mexico, largely coastal sections, the maximum temperature is delayed until August or even September. In much of the region of the lower Rio Grande Valley the maximum temperature occurs in August, because July has the greater percentage of cloudiness, slightly more rainfall, and a greater number of days with rainfall.

The months of minimum temperature in Mexico are December, January, or February, though for most part January is the coldest. A general exception to this is the west coast where the month of minimum is February.

Because of this difference in degree and course of temperature through the year the division of Mexico into eight temperature types or provinces seems called for, each differing essentially from the others in degree, annual march of temperature, or both.

The delimitation of these provinces with a composite graph of average temperature for each is shown in Figure 16. The provinces were selected after careful examination of graphs for about 100 stations in Mexico and bordering United States.[6] Figures 17–24 are composite graphs of the average monthly means, average monthly extremes,[7] average hours of sunshine per day per month, average number of days frost, and mean and minimum relative humidity for each of these provinces, except that the minimum relative humidity is not given for provinces A, B, and D. These composite graphs are not intended to show the exact conditions of any one station within the province. They present the general conditions throughout the region they represent, which after all is the more important. Hours of sunshine are treated along with temperatures because temperature is very much dependent upon the amount of sunshine the region receives, likewise relative humidity is added, for it fluctuates chiefly with the rise and fall of temperature. Where possible, the stations used in constructing the temperature graphs were also used in producing the other graphs. The humidity and sunshine diagrams, however, had to be based on fewer stations than temperature. Some of the local differences and of the peculiarities of individual places will come out in the discussion of each province which follows.

The Lower California province (fig. 16) is the most unsatisfactorily marked-off province in Mexico because of insufficient data, there being no stations in the interior and none on the west coast south of Ensenada. The graphs for this province, therefore, had to be based on a few stations with short records in the northwestern part of the peninsula.

The temperature curves are most peculiar. (Fig. 17.) The annual range of the monthly maximum is 5.5° C., while that of the monthly minimum is 11.2°, and the mean annual range is 8.4°. This region is cool along the west coast, thanks to the cool water of the Pacific.

The curves of the mean and minimum temperatures have a very similar course through the year, the mean

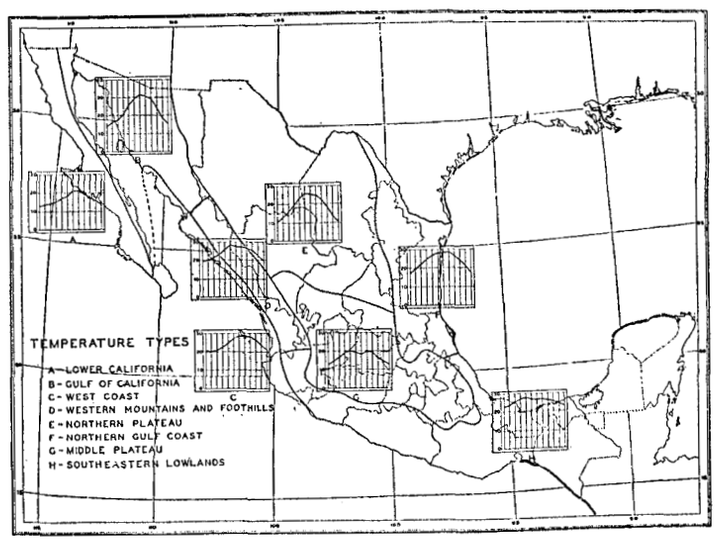

FIGURE 16.—Temperature provinces, centigrade

temperature being about 10° C. above the minimum. August is the warmest month, although only 0.1° warmer than July. There is a marked increase in the temperature from June to July and a marked decrease from August to September.

The highest monthly maximum temperatures come in October, though others nearly as high occur in November. Temperatures are prevented from reaching their highest degree during the summer months by the sea breeze.

Frosts are not frequent in Lower California, though they occur from November to March. December and January, are, however, the only months which average as many as one per month.

Humidity is high throughout the year according to the one available station near by, that of San Diego, Calif. The humidity evidently decreases considerably toward the south and away from the coast, where the temperature should be higher, rainfall less, and percentage of cloudiness very low.

The Gulf of California province (fig. 16, B) is the desert of Mexico, a region of abundant sunshine throughout the year. Some portions receive more than 90 per cent of the possible amount for some months. Very hot days in summer are the rule. There is a sign on one of the restaurants in Yuma, Ariz., a part of this same

[5] Average of surface temperatures reported by ships at Greenwich mean noon, courtesy of F. G. Tingley, of U. S. Weather Bureau.

[6] The average temperature, the average of the extreme maximum, and the average of the extreme minimum by months, were drawn on graph paper for the individual stations. They were then grouped according to their similarities as to degree and course of temperature through the year. They fell into eight distinct regions.

[7] Each value is the average of the individual extreme maximum or minimum temperature occurring each month year after year through the period of record.

region extending into the United States, which reads, "Free board every day the sun does not shine." (*64, p. 501.*)

Because of the latitude, aridity, and relatively free exposure to invasions of cold from the Great Basin of the United States, this province has a considerable annual range of temperature. (Fig. 18.) The summer days are hot and dry, temperatures of almost 43° C. being recorded in May, June, July, August, and September. All three temperature curves show their marked continental character.

The highest average as well as the highest extreme maximum temperature occur in July, while the extreme minimum reach their highest degree in August. The lowest temperatures in each case occur in January. Frosts are common in December and January, and occasionally in November, February, and March. They have occurred in April.

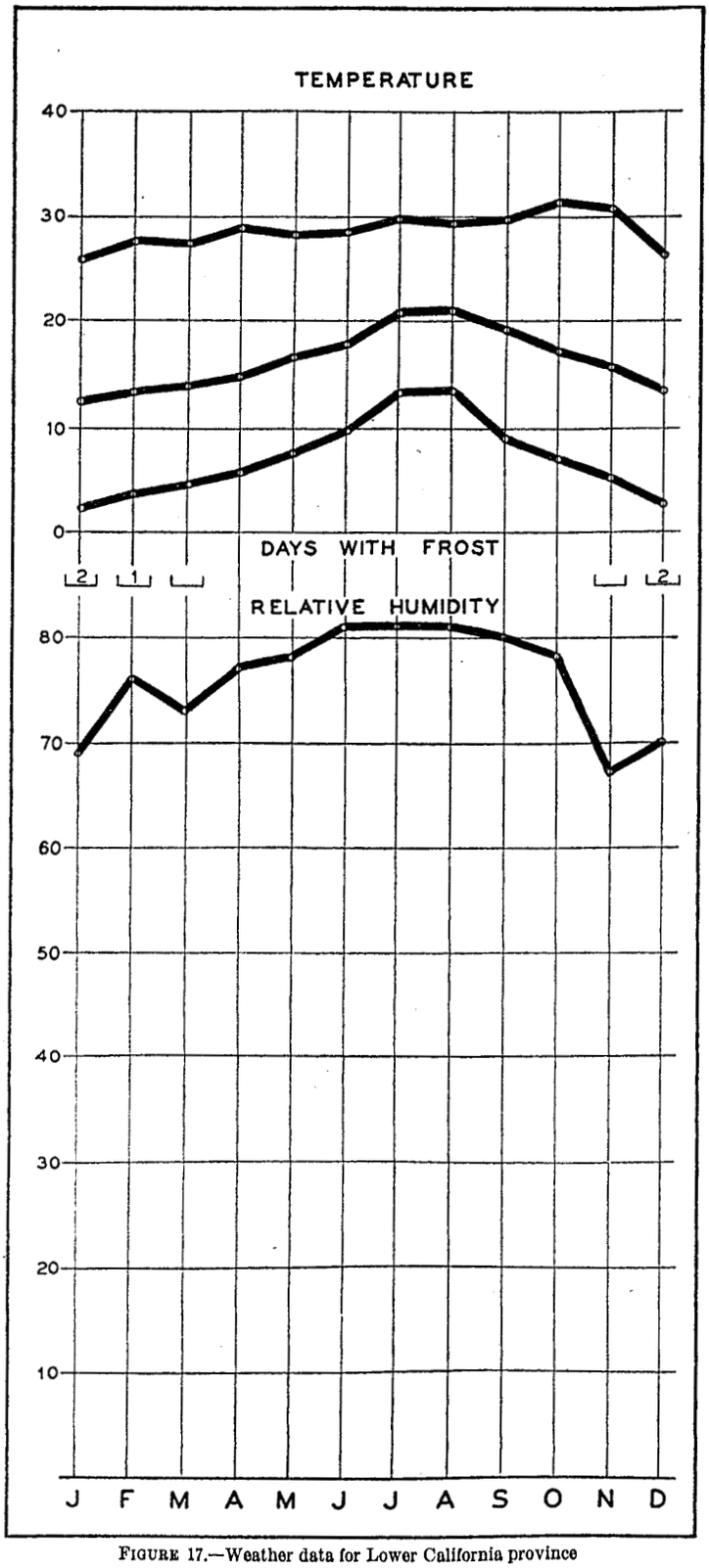

FIGURE 17.—Weather data for Lower California province

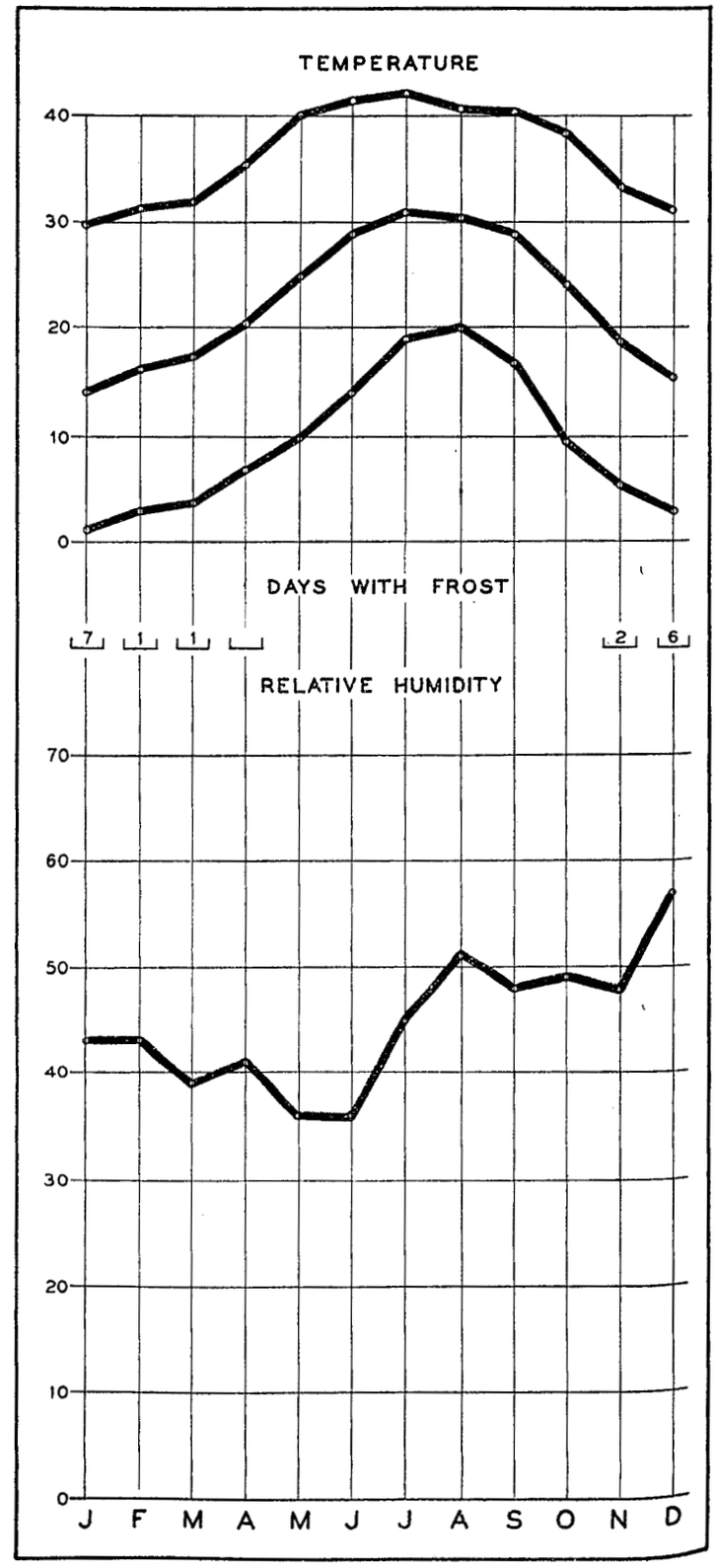

FIGURE 18.—Weather data for Gulf of California province

No Mexican station in this province records relative humidity, but the Yuma, Ariz., station may give a fair idea of the low humidities of the desert. The two months in which the maximum occur are those of most rainfall, though there is very little rainfall at any time.

The west coast province (fig. 16, C) is a strip along the Pacific coast, embracing the lowlands from Manzanillo, in Colima, to Guaymas, in Sonora. It is the one typically marine section of Mexico, with an August maximum and a February minimum of temperature, and an annual range of temperature small for its latitude and exposure, although greater than that of the lowlands farther to the south and east. (Fig. 19.) There is very little difference in the July, August, and September temperatures in either the average or the average of the extremes.

The average absolute maximum temperatures are a little higher in July than in August, a fact due probably to the more direct rays of the sun during the former month, as well as to the fact that August is a cloudier and rainier month in most of the region. The maximum temperatures are high in all months. The lowest extreme minimum temperature (the absolute minimum) occurs in February but is only 11.3° C., or equal to the mean January temperature of Los Angeles. The three temperature curves are closest together in September, the month in which cloudiness and relative humidity are at their maximum and sunshine at its minimum. The minimum temperatures have a greater and the maximum temperatures a smaller annual range that the mean temperature in this province.

As in the lowlands to the south and east, the month with the maximum hours of sunshine per day, June, precedes that of heavy rainfall. But June has only slightly more than April or May. The sunshine increases after the rainy season.

Because of the prevailing on-shore winds in all months of the year, the mean relative humidity is high, with little variation from month to month. A minimum is recorded in April and a maximum in September.

Frosts may occur in the province, but no stations reported them during the period 1921–1927.

The western mountains and foothills province (fig. 16, D) embraces a portion of the Sierra Madre Occidental and their western foothills. It differs from the west coast province in that it has a greater average annual range of temperature, and has a June instead of an August maximum and a January instead of a February minimum. (Fig. 20.) It is less continental than the Gulf of California province to the northwest.

There is a rather pronounced decrease in mean temperature from June to July with the onset of the rainy season, though the temperatures remain quite high through October.

The sunniest season is March to June. October is also sunny, while December is the least. Frosts rarely occur in this region except in the higher parts, where they have been reported in the months from November to March, but less than one per month, on the average. There are only few stations in the higher parts of the region and most of the discussion necessarily had to be based on records from station in the foothills.

There is considerable range in relative humidity. Low humidity occurs in spring and early summer, with the increase in temperature and high humidity in late summer and fall, when the temperature reaches and passes its highest degree.

The northern plateau province (fig. 16, E) is like the Gulf of California province in some respects, but differs enough to warrant a separate classification. It has continental temperature curves like those of the Gulf of

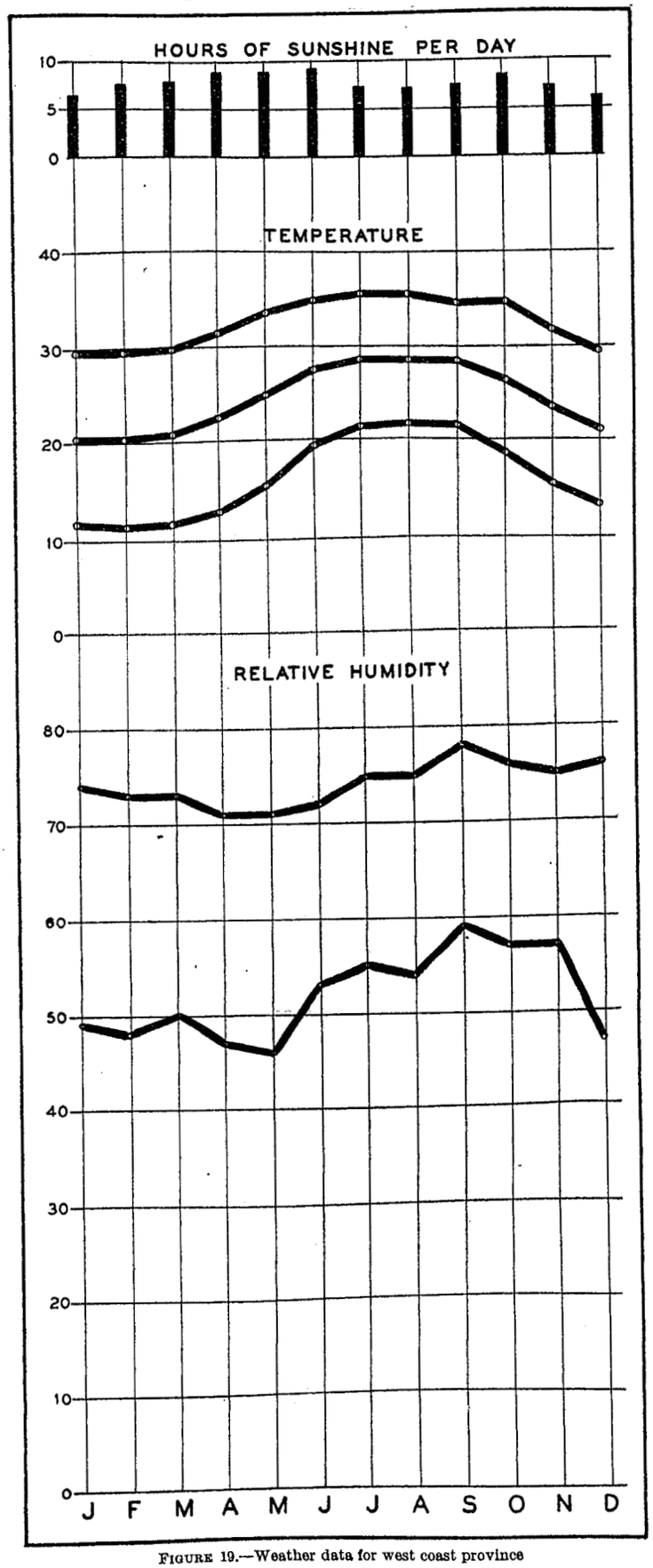

FIGURE 19.—Weather data for west coast province

California, but its temperature is several degrees lower in both summer and winter, and, because of the greater

amount of rainfall and cloudiness in the northern plateau the temperature curves are flattened out more during the rainy season. (Fig. 21.) Another difference is that

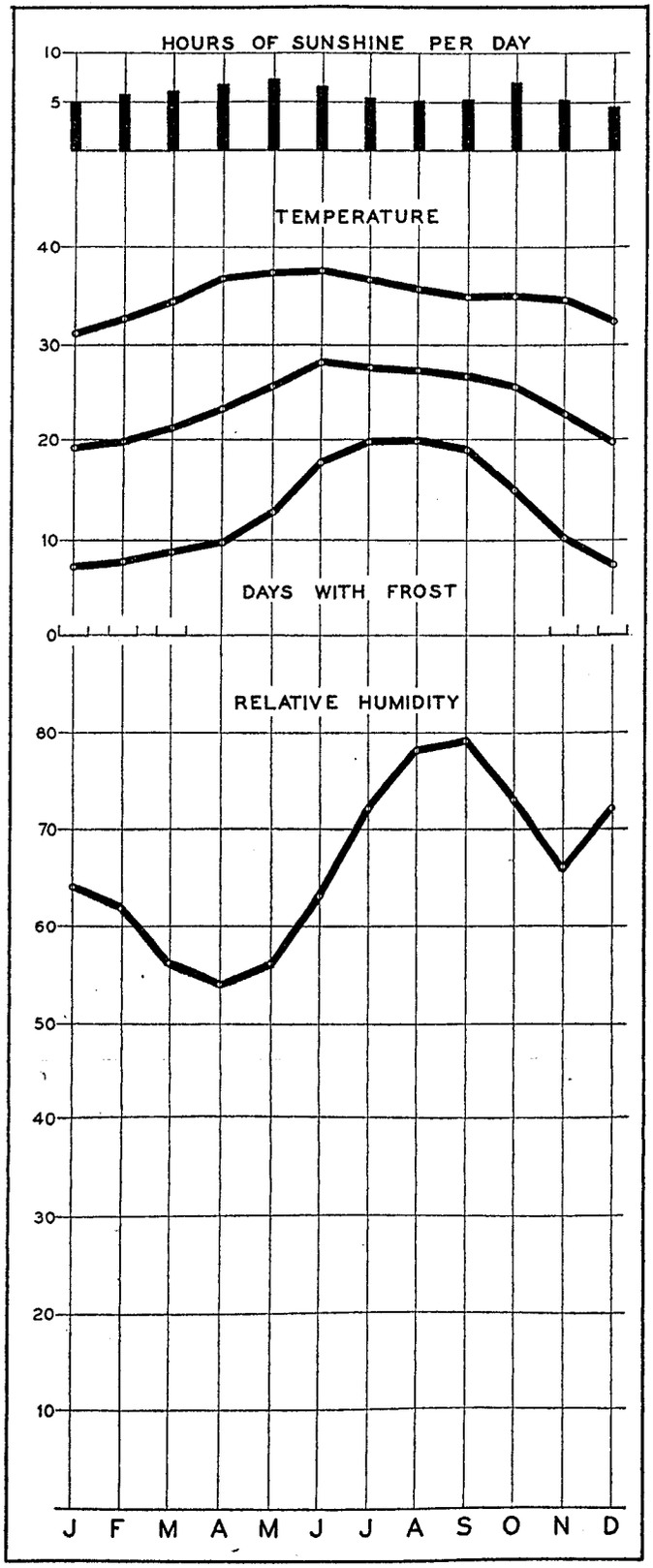

FIGURE 20.—Weather data for western mountains and foothill province

the average as well as the maximum temperatures reach their highest degree in June instead of July.

This is the coldest province in Mexico during the winter months. It has a considerable elevation besides being freely exposed to the invasion of cold winds from

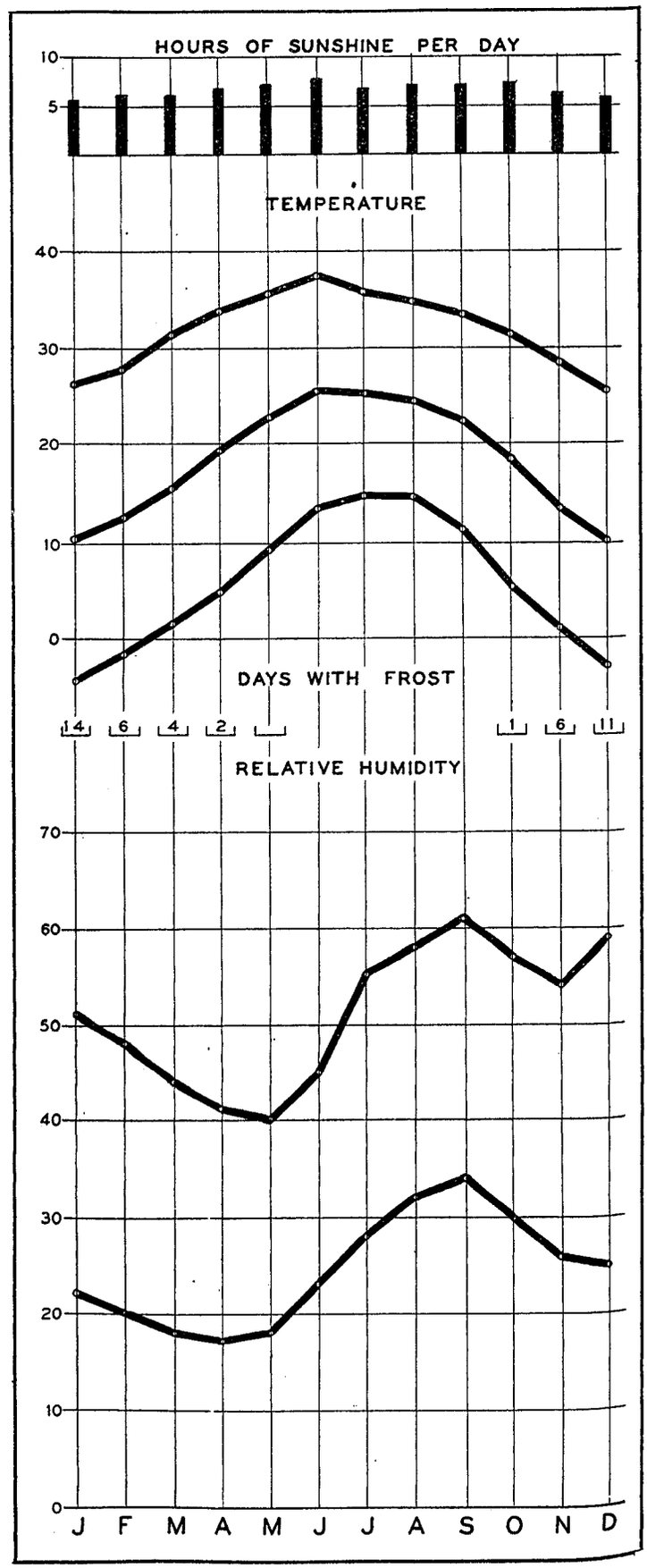

FIGURE 21.—Weather data for northern plateau province

the United States when a well-developed winter cyclone

swings far south in its course across North America. The average of the monthly minimum temperatures in December, January, and February is below 0° C., while in November and March it is only slightly above. A temperature of −20° has been reported at Ciudad Guerrero, in Chihuahua, and frosts occur in 8 of the 12 months.

Although much of the region has an altitude of 5,000 feet, temperatures of 40° C. are not uncommon in summer. However, relative humidity is low, the average minimum at Chihuahua City from November to June not being above 18 per cent and the mean for May is only 33 per cent. Thus a temperature of 40° is not so unbearable as the same degree would be at Vera Cruz where the humidity is high much of the time. The average annual range of relative humidity in this province is 20 per cent, September being the most humid and May the least.

The middle plateau province (fig. 16, G) embraces a portion of the middle and southern plateau sections of Mexico. This province, the most temperate section of the country, includes most of the large cities and supports most of the population. It might be characterized as a region which is tropical in its range of temperature but temperate in its degree. (Fig. 22.) The winter months are cool, clear, and bracing, with a considerable amount of sunshine, whereas the summers are cloudy, although not hot, except in the sunshine, for like other regions of high altitude it is a region of hot sun and cool shade. The higher the altitude the truer this designation.

The highest temperatures occur in May with a secondary maximum in August almost as pronounced. There is no marked annual range of temperature, but the temperature curves show the profound influence of the rainy season. With the onset of that season in June there is a decrease in the average temperature of about 2° C. from May to June with an increase to a secondary maximum in August. Neither the average of the extreme monthly maximum nor the average of the extreme monthly minimum temperature curves are like that of the average mean temperature. The absolute highest temperature is reached in May after which a decrease of more than 3° takes place in July, with no increase in August. The ground is wet after the rainy season and humidity is higher as well as the percentage of cloudiness being great, a combination of which prevents the absolute maximum temperature from being as high after as before the rains.

The month of highest minimum temperature is June, with July and August only slightly lower. The absolute minimum temperatures in December, January, and February often gets below 0° C., but on the average the absolute minimum temperature for January, the coldest month, is 1.2°.

Frosts occur in some parts of the region in 9 of the 12 months, but only 6 average as many as one per month.

The relative humidity comes to a minimum in March and a maximum in September. In spring the ground is dry, temperature is increasing and humidity consequently decreases. In September the ground is wet, temperature is decreasing and humidity is high.

The northern Gulf coast province (fig. 16, F) has an annual range in its extreme maximum temperature of 7.4° C., in its average mean of 11.3°, and in its absolute minimum of 15°. (Fig. 23.) August, being less cloudy and rainy than June or July, is the warmest month. The highest maximum temperatures are recorded in June. This and the Lower California province are the only two in Mexico which record the highest minimum and highest mean temperature in the same month. In the other provinces the highest minimum are delayed one or more months.

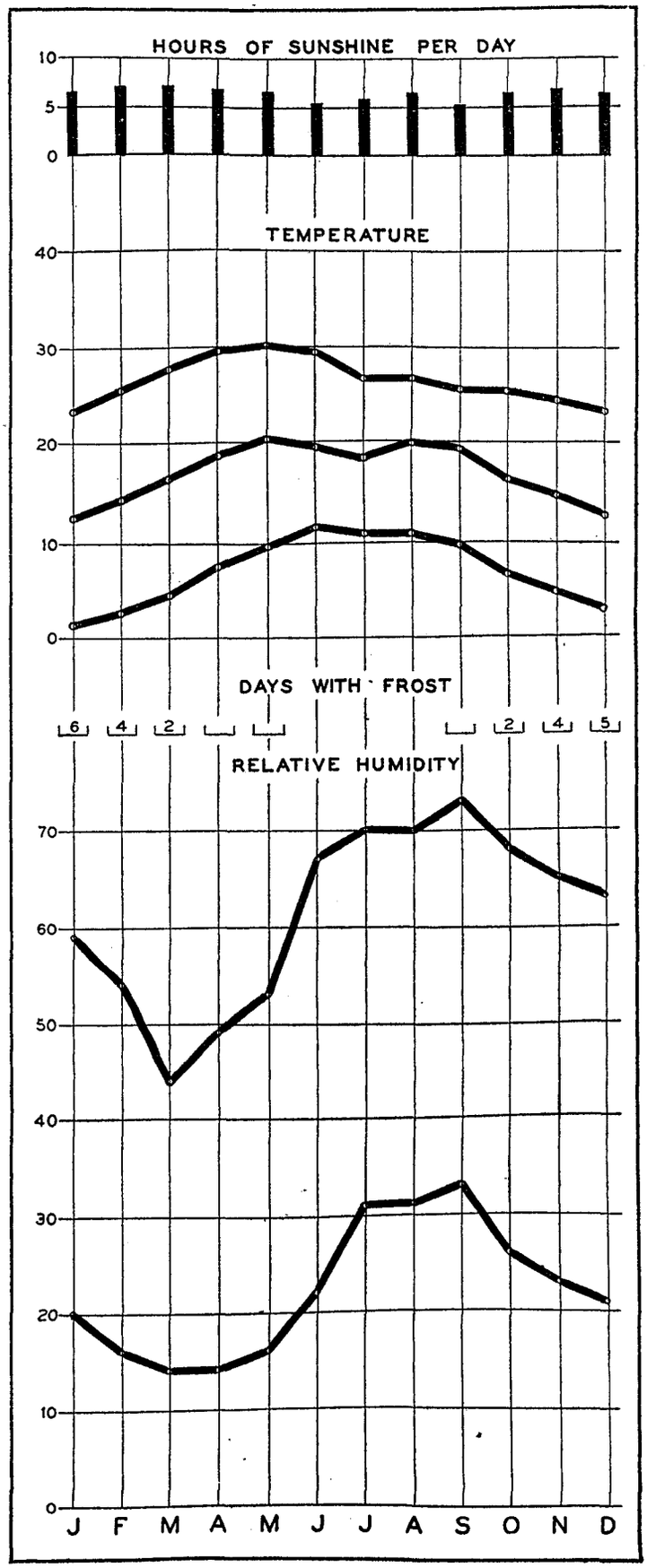

FIGURE 22.—Weather data for middle plateau province

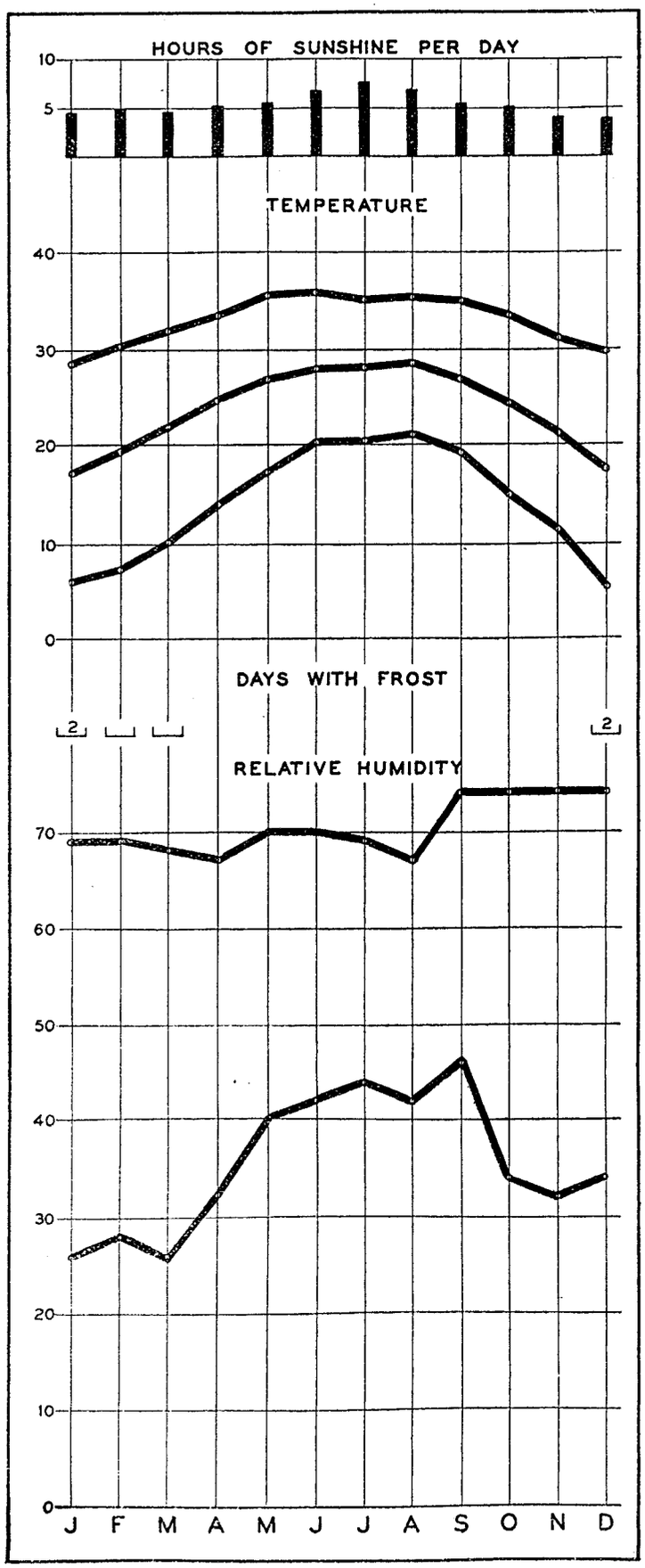

FIGURE 23.—Weather data for Northern Gulf province

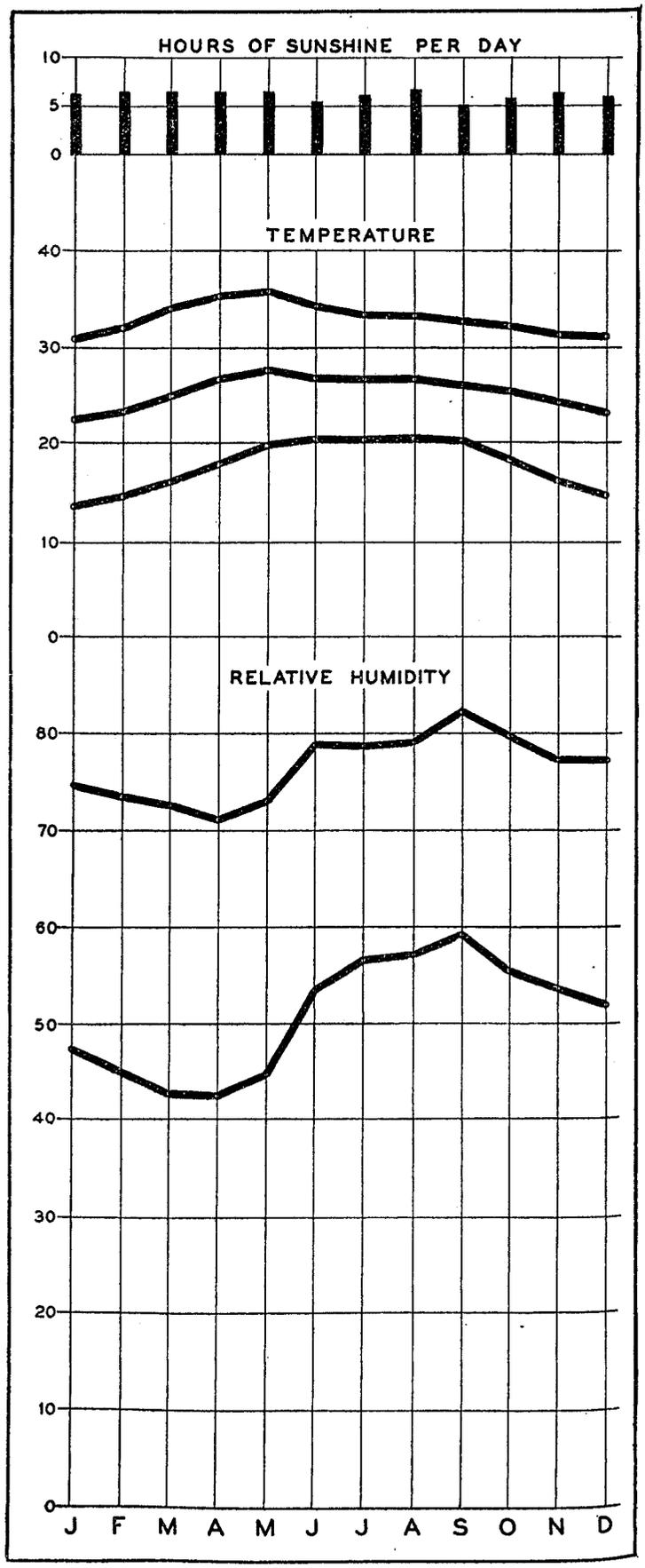

FIGURE 24.—Weather data for southeastern lowlands province

In the province the graph showing the average hours of sunshine per day per month is for the one station of Monterrey, which represents the drier and consequently sunnier section of the province, data for the other stations not being available. A minimum of 3.8 hours is recorded in December with a maximum of 7.8 hours in July. This shows the effect of the generally cloudy conditions in winter accompanying the cyclonic storms which take a more southerly course in winter than at other periods of the year.

Frosts occur in the province during the months of December, January, February, and March, although they are not numerous. The frost data were for Monterrey only.

The mean relative humidity is high throughout the year, the average annual range being only 7 per cent. It is kept high in winter by the lower temperature of the semicontinental climate, and in summer by the indraft of moisture from the Gulf of Mexico. The minimum relative humidity curve is for the stations of Tampico and Monterrey, no others being available.

The southern lowlands province, the largest (fig. 16, H) embraces the lowlands and foothills of southern and eastern Mexico, including the Yucatan Peninsula. It is a region of relatively high temperature with low annual range. (Fig. 24.) With the exception of a few stations May is warmest and at these stations May is nearly as warm.

Because of its low latitude the difference between the length of its longest and shortest day is not great, being only two hours in the most southerly part. January is the coldest month with a mean temperature of 22° C., and average extremes of 13.5° and 30.9°. The mean and maximum temperatures reach their highest degree in May, with 27.5° and 35.7°, respectively. The May maximum is a result of the vertical ray of the sun and a small amount of cloudiness preceding the rainy season.

The average absolute minimum temperatures trend upward until June, when the temperature of the province does not, on the average, fall below 20.5° C. June, July, August, and September record minimum temperatures within 1° to 0.2° of each other, on the average. The uniform minimum temperatures during these months is the result of much cloudiness, high humidity, and wet ground.

Frosts are rare. They do, however, occur in the higher elevations, at times, in December, January, and February

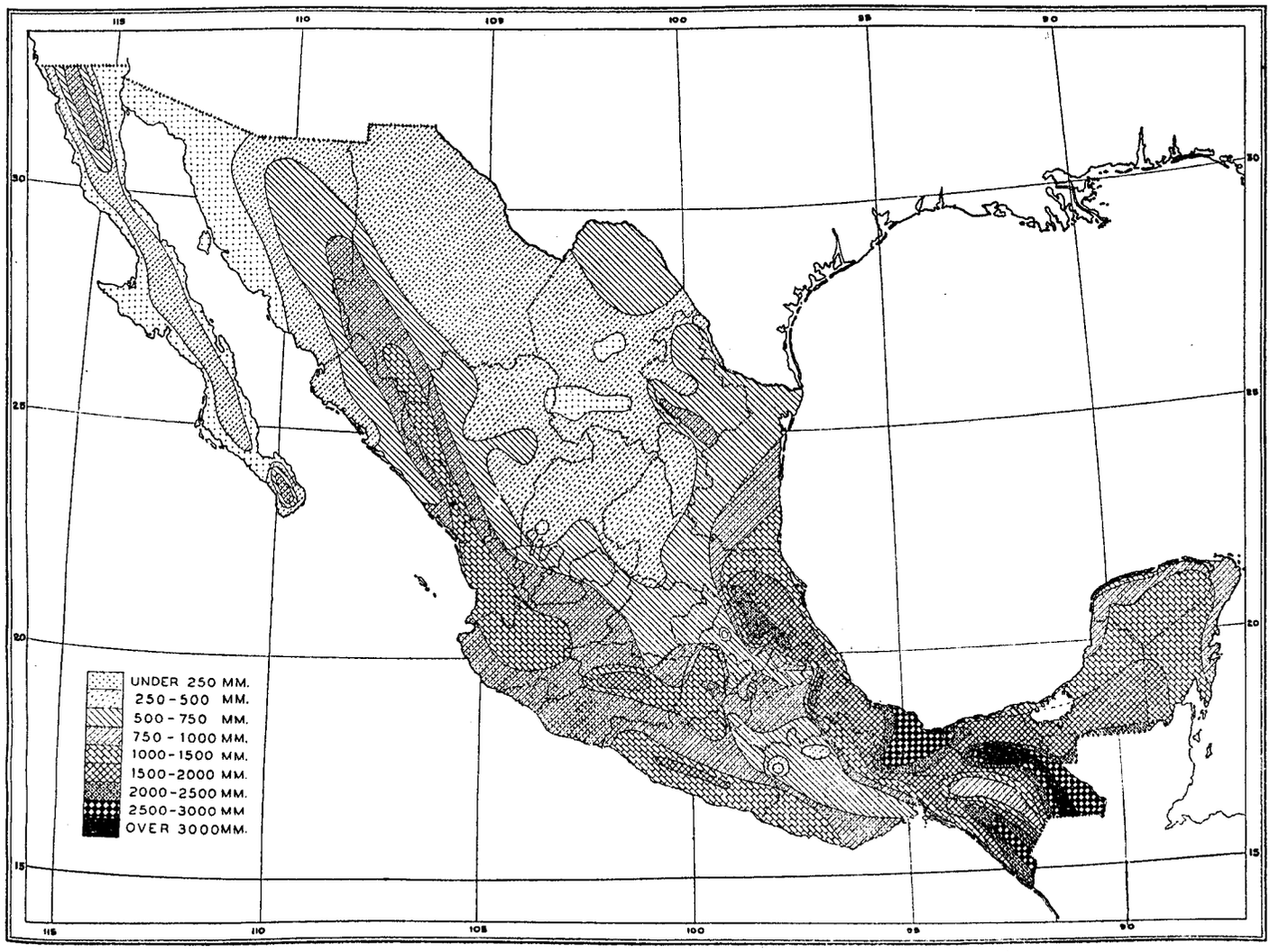

FIGURE 25.—Mean annual rainfall, millimeters

RAINFALL

The construction of a rainfall map for a country of such marked relief and locally contrasted exposure as Mexico presents numerous difficulties. The mountainous parts of Mexico are almost without stations, such as there are being located in valleys which vegetation shows to have considerably less rainfall than the neighboring heights. An added problem encountered is the lack of any relief map adequate as a guide in drawing the isohyets in areas

of few stations. Also many records are of short duration and include gaps extending over periods of months or years. Thus, local sparcity of stations, inadequate relief maps, and shortness of records, render the construction of an accurate rainfall map of Mexico difficult.

Nevertheless, an annual rainfall map based on data from 220 Mexican and near-by United States and Central American stations has been constructed. (Fig. 25.) No attempt was made to adjust the records to a uniform period of years, because of the extremely local character of the rainfall in much of Mexico and the broken nature of the records. Where stations were few or absent the probable effects of relief and exposure determined the course of the isohyets.

Mexico, with an area of only 750,000 square miles and with no part more than 400 miles from the sea, has great diversity in its annual amount of rainfall. It ranges from almost extreme desert conditions in the region bordering the Gulf of California, where the pressure is relatively high and the region hemmed in by mountains, to very heavy rainfall in the middle and southern Gulf slopes, which are freely exposed to the moisture-bearing trades from the warm Gulf of Mexico. The generally heavy rainfall of the Gulf slope is made locally excessive by the presence of mountains which rise precipitously from the flat and at places, narrow coastal plain.

Great local diversities occur. Windward sides of mountains may receive three or four times as much rainfall as the leeward. The greatest recorded differences are those between Teapa, in Tabasco, and Cintalapa, in Chiapas, with 4,638 and 769 millimeters, respectively, and between Santa Monica Xtilitia, in San Luis Potosi, and Ixmilquilpan, in Hidalgo, with 2,325 and 105 millimeters, respectively. Marked differences are also recorded between stations on the same side of a mountain range but at different elevations and exposures, the most notable being that between Teapa and Macuspana, in Tabasco, with 4,638 and 1,931 millimeters, respectively.

There are many areas of heavier and of lighter rainfall than in surrounding regions, as shown on the map.

Even where relief is not a factor, the maximum rainfall occurs not along the immediate coast but some miles inland. Frontera, with half as much rainfall as Comalcalco, and Progreso, with half as much as Merida, well illustrate this rule.

The northern basin plateau is the largest area of low rainfall as well as the driest area of high altitude in all Mexico. The aridity is attributable to its location within the subtropical high-pressure belt and its basin character. The Sierra Madre occidental is too high and unbroken to permit much vapor to enter from the west. And the Sierra Madre Oriental is sufficiently elevated and unbroken to be a considerable barrier to rain-bringing winds from the east.

Throughout Mexico the rainfall variation from year to year is considerable. In the drier regions some years have three to seven times as much rain as others. Muzquiz, in the State of Coahuilla, reports one of the greatest fluctuations with 150 and 1,070 millimeters, while Puebla reports one of the smallest, that of 570 and 1,270 millimeters. Figure 26 shows the yearly totals from year to year for a number of stations in the different parts of the country. All graphs are drawn to the same scale for a more ready comparison and all show a greater number of years below than above the normal. When the years are above normal they are often considerably above.

Whether there has been a general desiccation of the climate in any part of Mexico is still a matter of conjecture. Professor Lopez maintains that the drying up of Lake Texcoco has caused a desiccation of the climate of the Valley of Mexico. He states:

> The lakes which formerly existed in the Valley of Mexico were the cause of the exuberant vegetation and primeval climate which formerly dominated here as we were told in the chronicles of Humboldt, but with the drying up of these lakes local climates have been altered, clouds and rains have decreased, and the coldness of winter has been accentuated (*48, p. 115*).

The records taken at Mexico City show that there have been periods of wetter as well as periods of drier years in the Valley of Mexico, but they do not show a general decrease in the amount of rainfall during the past 50 years. The change in vegetation, which to-day is said to be less luxuriant than that described by Von Humboldt, may be due to causes other than decreased rainfall.

The records of Mexico are not of sufficient length for rainfall cycles, if present, to be recognized.

Mexico is a country of pronounced seasonal rainfall. Summer and fall are the seasons of maximum rainfall in all Mexico except the northwestern part where the Mediterranean rainfall regimé is found. In most parts of the country May to October are the rainy months. A map showing the percentage of the total rainfall occurring in these six months appears as Figure 27. Between 90 and 97 per cent of all rainfall in the southwestern part of Mexico occurs during this period, while in the northwestern part the percentage drops to less than 15, with a close crowding of the lines in the region around the Gulf of California.

The region bordering the Gulf of Mexico has a smaller percentage of its rainfall during this period than does the Pacific in the same latitude. This may be accounted for by the lower latitude of the Pacific, the greater number of tropical hurricanes on the Pacific than on the Gulf coast at this season, and the considerable amount of winter rainfall brought to the Gulf coast by the northers, and the more pronounced on-shore winds in the Gulf coastal region as contrasted with the Pacific coast. On the Pacific coast the prevailing on-shore winds seem to be more restricted to the coastal stations.

Although May to October is, in general, the rainy season in Mexico, March, April, May, and November are the only months not appearing as the month of maximum in some part of the country, and May is the month of maximum for a border station in the United States.

A feature common to most of western Mexico is the considerably heavier rainfall in December than in November or January. There is almost invariably a decrease from the rainy months to November then an increase to December and a decrease to January with very little rainfall again until the opening of the rainy season.

On the basis of amount and monthly course of rainfall Mexico falls naturally into 13 rainfall types or provinces, each differing essentially from the others. (Fig. 28.) The rainfall types here adopted are based upon the examination of a large number of plotted monthly rainfall amounts on an enlarged map of Mexico for stations in all parts of the country and the bordering sections of the United States. Each rainfall type is represented by a composite graph of from three to nine stations within the area. (Figs. 29–41.) The rainfall amounts are adjusted to months of equal length. Associated with these graphs are composite graphs (for the same stations where possible) of related phenomena, including average maximum rainfall in 24 hours, days with thunderstorms, days with any rainfall, cloudy, partly cloudy, and clear days, and percentage of cloudi-

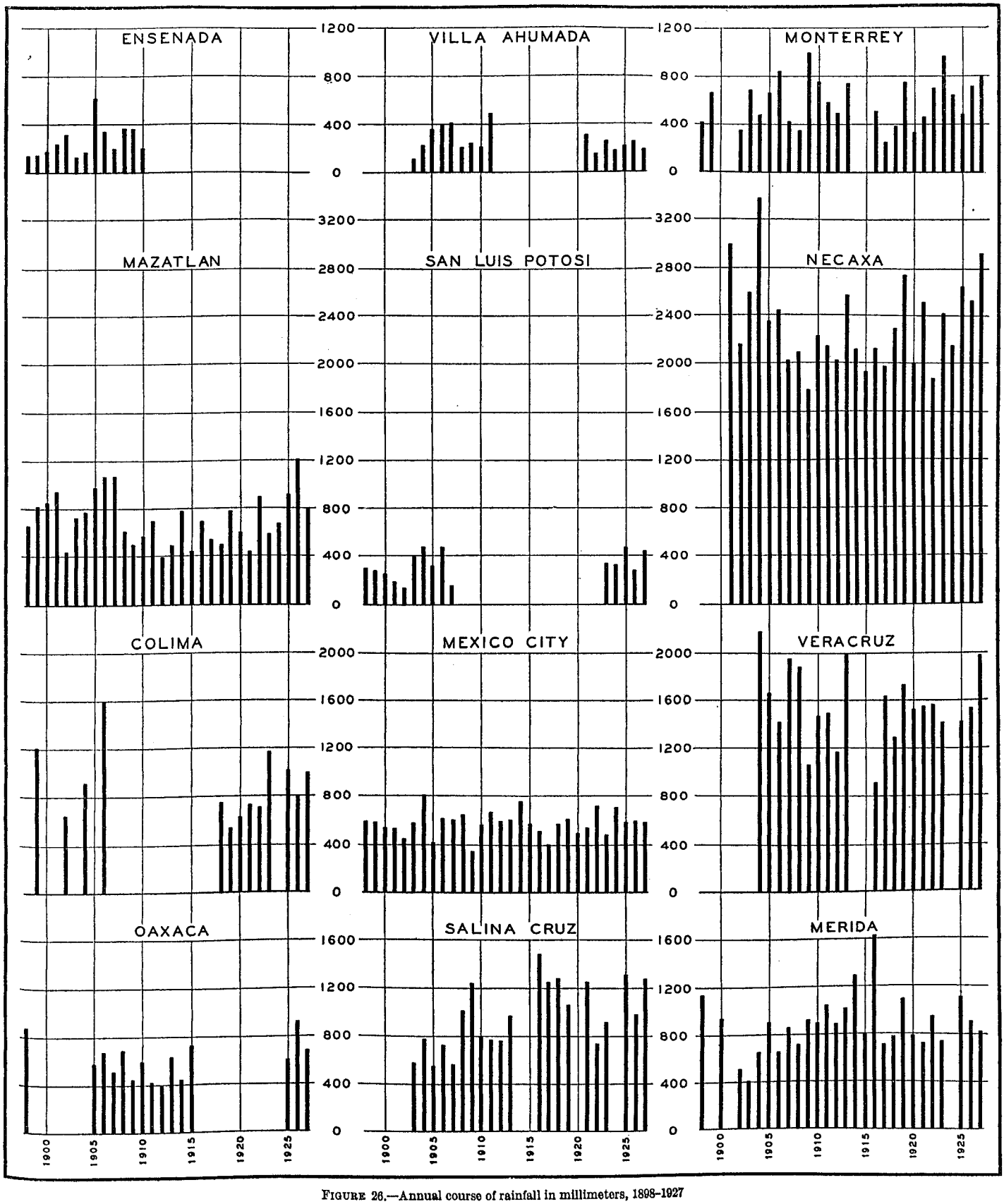

FIGURE 26.—Annual course of rainfall in millimeters, 1898–1927

ness. The graphs for all provinces are drawn on the same scale for more ready comparison.

A composite graph does not necessarily represent the exact conditions of any one station within the province. It does, however, give a better picture of the average conditions within a given region than would a number of graphs for individual stations within the same area. It has the additional advantage of smoothing out some of the minor irregularities of individual stations.

To prevent too much repetition in the discussion of rainfall provinces, they will be treated collectively and separately under the following heads: (1) Pacific coast, (2) Plateau, and (3) Gulf coast.

As has already been stated, Mexico is a country of pronounced seasonal rainfall. This fact is well shown on the composite graphs for the rainfall provinces of the Pacific coast section. (Figs. 29–34.) The rainy season is not made up of the same months throughout the Pacific coast region, nor is it the same length throughout.

In all of the Pacific coast provinces, except the Mediterranean and the desert, summer is the rainy season, and it is a marked rainy season. In the Mediterranean rainfall province, just the opposite is the case—winter is the marked rainy season, while in the desert province no month has much rainfall.

In the most southerly of the Pacific coast provinces six months each has more than 75 millimeters of rainfall. Proceeding northwestward along the coast the number decreases to 5, 4, 3, 0, 0, respectively.

Much of the rainfall comes in the form of heavy thunderstorms, but there is a marked difference in the number of thunderstorms in the different parts. Another feature common to much of the Pacific coast is heavier rainfall in December than in November or January.

The months of maximum rainfall in this general region are June, July, August, September, and December. Throughout, the rainy months are months of few clear days, while the dry season is one of much bright sunshine, except in the desert province where sunny conditions prevail at all times, there being, on the average, only 18 cloudy days per year in this province as shown by the station of Yuma, Ariz. A brief discussion of each province along the Pacific coast region follows.

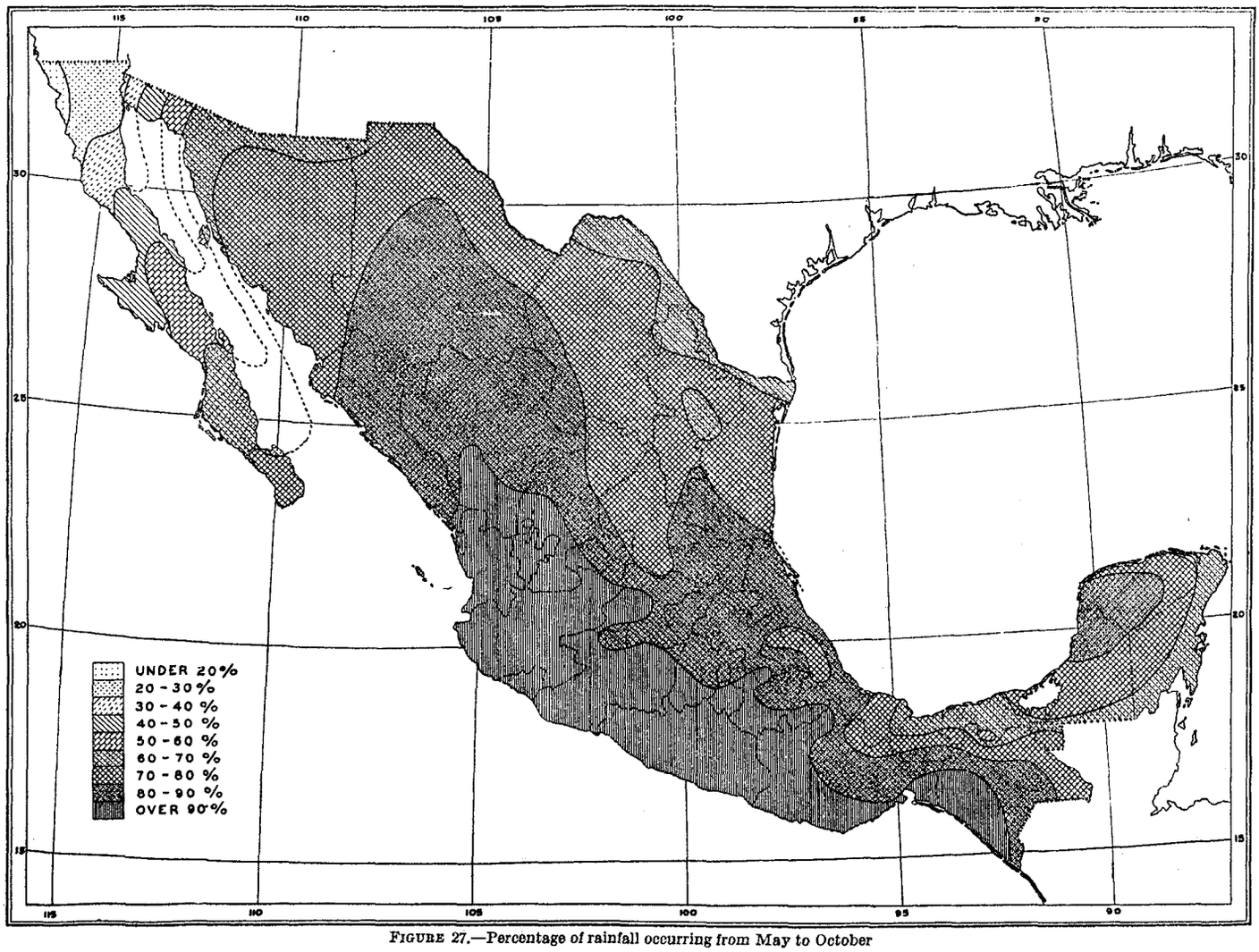

FIGURE 27.—Percentage of rainfall occurring from May to October

The Gulf of Tehuantepec province (fig. 28 L) includes a relatively small portion of the country but there is great diversity in its total amount of rainfall. Tapachula, which has free exposure to the moist winds from the Gulf of Tehuantepec, with 2,214 millimeters, and Tehuantepec City, located in the protected valley of the same name, with 437 millimeters, are the recorded extremes.

It is a province with five wet months, June to October, and five dry months, December to April, with May and November as transition months. (Fig. 29.) Almost no rain falls in the region from December to April, less than 6 per cent of the total in these five months. June, with 274 millimeters, is the wettest month. This is the time of the year when the low-pressure belt has shifted north attended by a great amount of convectional rainfall.

July and August have considerably less rainfall than June although they each have 170 millimeters. With the occurrence of tropical hurricanes and the general decrease in pressure in this region in the fall rainfall again increases and September records 230 millimeters, with October nearly as wet as July and August.

During the four rainiest months, June to September, there are less than two clear days per month, while December and January each has on the average more than 18.

Thunderstorms are more numerous in this province than in any other part of the country. June, July, and August average 10 each, while January alone is free of this phenomenon. During the rainy season the days with thunderstorms are almost as numerous as the days with any rainfall.

To the northwest of this province the course of rainfall changes and gives rise to another rainfall type, here named the southern west coast rainfall province. (Fig. 28, I.) The rainfall curve is very much like that of the Gulf of Tehuantepec except that the maximum rainfall comes in September instead on June and the secondary maximum in June instead of September. (Fig. 30.) The total rainfall in this province is about 1,000 millimeters, and ranges from 1,400 millimeters at Acapulco to 700 millimeters at Isla Maria Madre. It is most all concentrated in the five months, June to October. Heavy downpours occur, September having as its average maximum rainfall in 24 hours 96 millimeters. Thunderstorms are less frequent in this province than in the gulf of Tehuantepec region, but cloudiness is greater during the rainy season. September, the cloudiest month, has 16 cloudy days, and 16 days with some rainfall, on the average. This province gets a fuller effect of the tropical hurricanes in September than does that to the southeast. The first four months of the year each has less than one day with rainfall, making that a season of sunny weather.

The middle west coast province (fig. 28, F.) extends inland over a considerable portion of the western plateau in these latitudes. This province may be characterized as one having four wet and eight dry months. (Fig. 31.) There is a more abrupt change from the dry to the wet and from the wet to the dry season than in any other province in Mexico. May has 7 millimeters, June 152 millimeters, September 223 millimeters, and October 63 millimeters of rainfall. In the period June to September 85 per cent of the total rainfall is recorded. Seventy-eight per cent of the days with rainfall also occur in these four months. During the four rainy months there are only 12 clear days, on the average, and June has half of them. The months January to May are almost rainless, March and April each having only 2 millimeters. As is shown by the graphs, thunderstorms are frequent during the rainy season. November is much drier than either October or December.

The average maximum rainfall in 24 hours is considerable, though not so large a proportion of the total as in some of the other provinces.

Proceeding northwestward along the coast to the northern west coast rainfall province (fig. 28, C.) the length and intensity of the rainy season becomes somewhat less. For 8 of the 12 months there is only about one-third of the sky covered with clouds. May, the least cloudy month, has only 2.8 sky cover and only 4 cloudy days. In all months except July, August, and September there are many clear sunny days. In this province less than 6 per cent of the total rainfall is recorded in the first five months of the year. The rainy season starts in June, with increase in percentage of cloudiness, number of cloudy days, days with rainfall, and days with thunderstorms. (Fig. 32.) The height of the rainy season is reached in August, one month later than in the region to the south, when 136.2 millimeters, or almost 30 per cent of the total rain falls. There are only 6 clear days during this month. July, August, and September are the three rainy months, with 71 per cent of the total, while to the south there were four rainy months. These three months stand out prominently on all the graphs. A large part of the rainfall of this province comes in one shower each month, on the average, as shown by the graph of maximum rainfall in 24 hours.

Thunderstorms are frequent during the rainy season, July, August, and September each having about five, they being about half as great in number as the days with rainfall. In this province December has twice as much rainfall as November and January combined.

The region bordering the northern part of the Gulf of California (fig. 28, B) including much of the Peninsula of Lower California, is a desert region and is here called the desert rainfall province. It differs from all other parts of Mexico in having such a small amount of rainfall. (Fig. 33.) No month has more than 12 millimeters for the

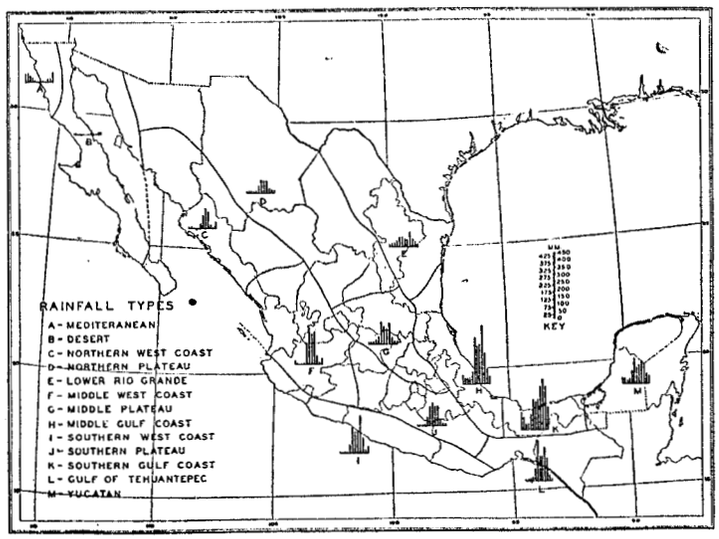

FIGURE 28.—Rainfall provinces

region as a whole, though there appear to be areas which, because of relief and exposure, have a considerably heavier rainfall, but there are no records to verify this. This region may be characterized as one with little or no rainfall in all months. The average of the region is only 70 millimeters, a good portion of which comes in heavy thunderstorms, more or less of the cloudburst type, common in deserts.

No Mexican station in this province records cloudy, partly cloudy, and clear days, but the Yuma, Ariz., station may give a fair idea of the few number of cloudy days in this desert region. At Yuma there are only 18 cloudy days per year, on the average.

The latitude of the region, placing it in the interrupted subtropical high-pressure belt for a part of the year; mountains of Lower California from 2,000 to 10,000 feet elevation; the cool current along the west coast of Lower California; and its interior location are the principal factors combining to make this a desert province.

In the northern part of Lower California (fig. 28, A) the Mediterranean rainfall régime is found. As the name connotes to a climatologist, this is a region of winter rains and summer droughts. (Fig. 34.) The cause of the rainfall distribution is generally known to be the migra-

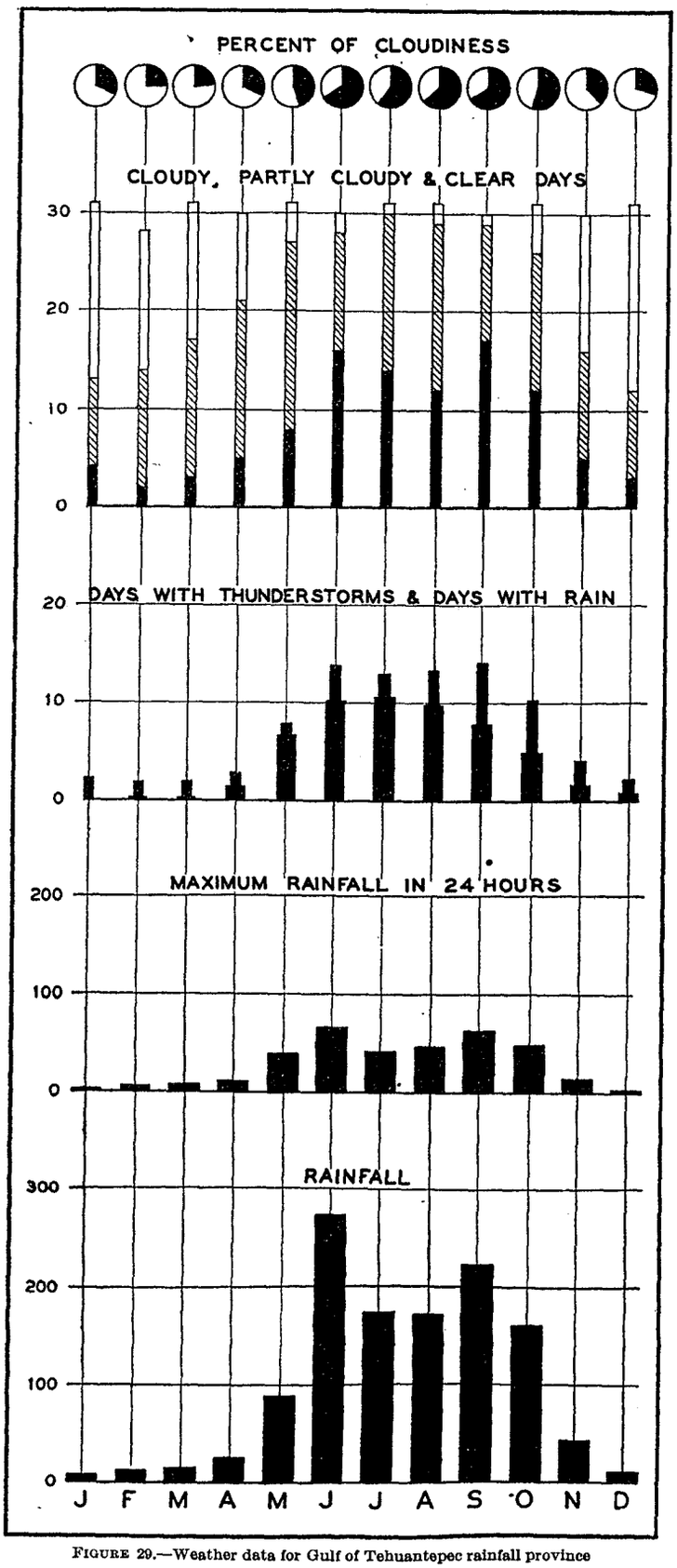

FIGURE 29.—Weather data for Gulf of Tehuantepec rainfall province

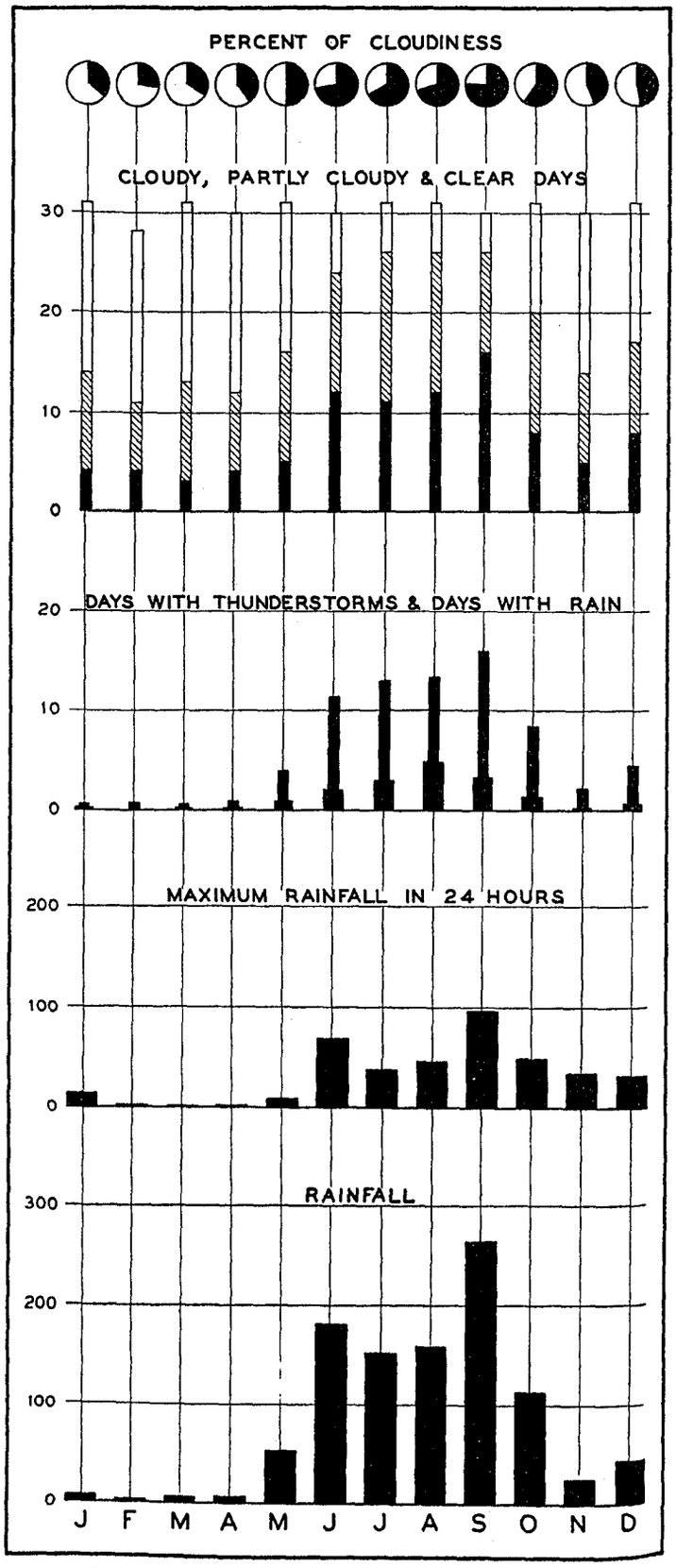

FIGURE 30.—Weather data for southern west coast rainfall province

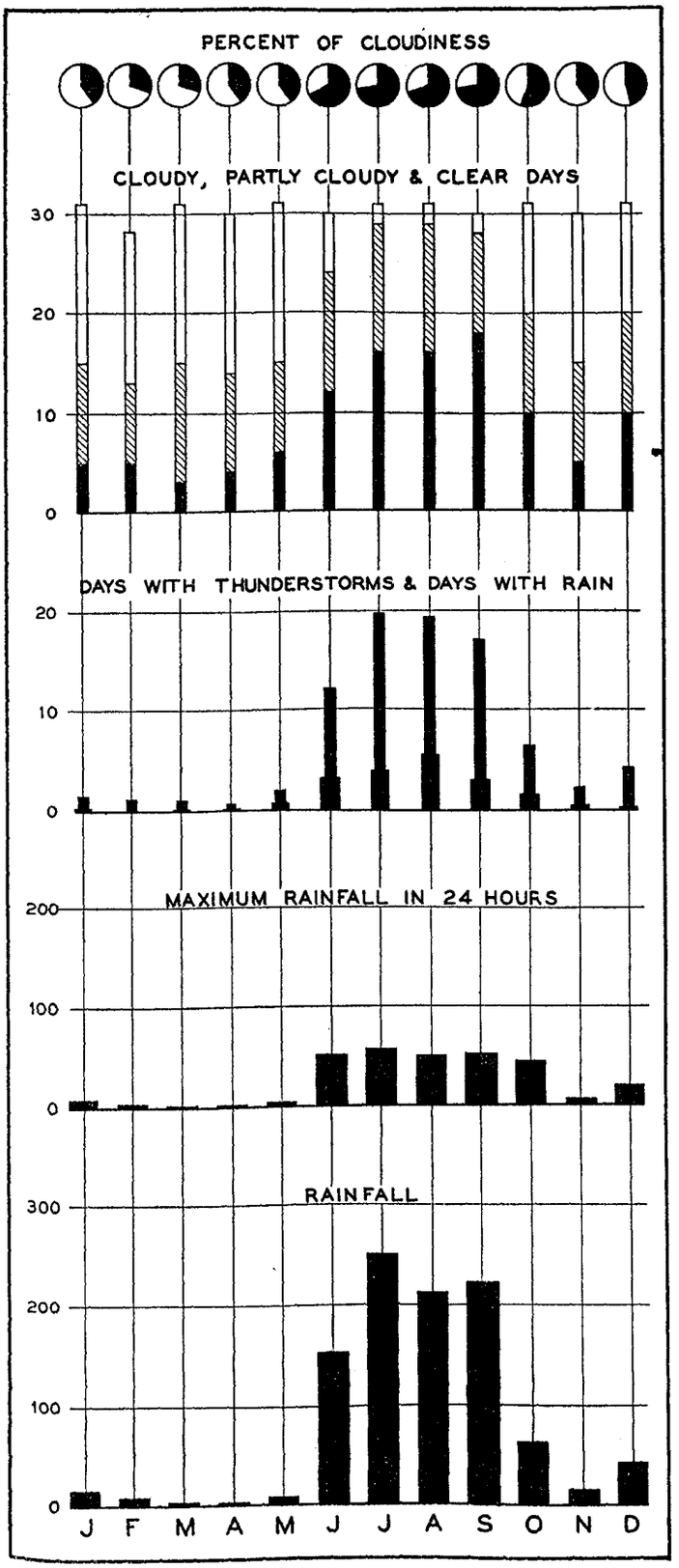

FIGURE 31.—Weather data for middle west coast rainfall province

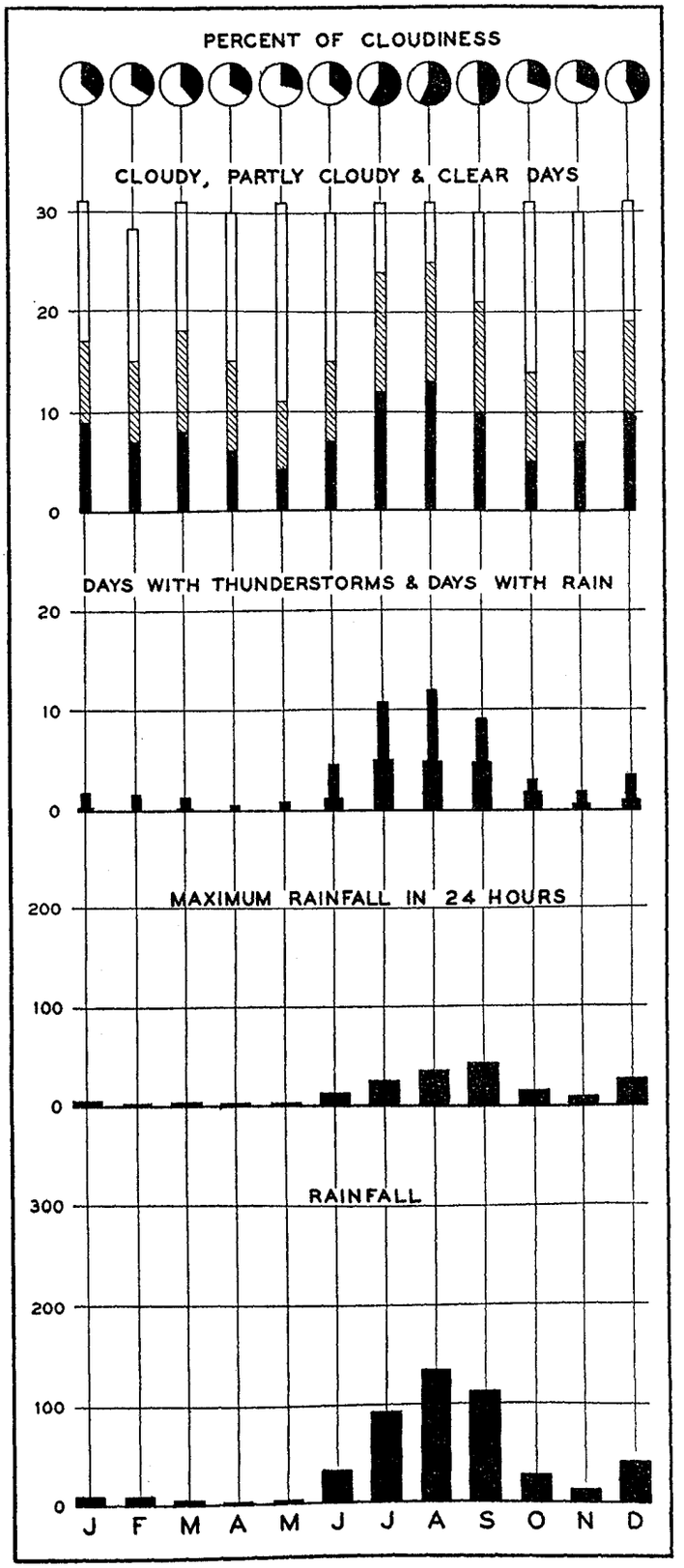

FIGURE 32.—Weather data for northern west coast rainfall province

tion north and south of the pressure belts, bringing this region under the control of cyclonic storms in winter and under the control of high pressure or northeast winds in summer.

The average rainfall for the region, based on records from three stations, along or very near the coast, is 295 millimeters, 6 millimeters of which come in the months of June to September. There are no records available for the highlands of the province, but as in southern California the rainfall is probably heavier than along the coast. Nelson (*54, p. 95*) reports that in the San Pedro Martir Mountains 3 to 4 feet of snow falls in winter. December is the month of maximum precipitation, though only slightly more than January or February. During each month of the year, on the average, about one-half of the total rainfall occurs in one 24-hour period.

December has the greatest number of days with rainfall, although all months have less than 10. December with an average of 9.7 and August with 0.7 are the extremes. August is the month with fewest cloudy days.

In July, August, and September there are more days with thunderstorms than days with rainfall. This may be accounted for by the fact that thunderstorm data were available only for San Diego, while days with rainfall were for San Diego as well as two Mexican stations. Another explanation is that thunderstorms occur in the mountains back of San Diego and give no rainfall at that station or else are "dry" thunderstorms; i. e., no rain reaches the ground.

Aside from December the months of maximum cloudiness and cloudy days do not coincide with the months of maximum rainfall. The maximum cloudiness and cloudy days come just after the rainy season, caused in part by the evaporation from the ground wet by winter's rain. July, August, and September are the clearest months, with an average of less than three cloudy days each.

This province then is relatively dry, with much sunshine, little cloudiness, few rainy days, and often hazy during the summer months.

The plateau rainfall types (figs. 35–37), too, are characterized by their seasonal distribution of rainfall, although the seasonal differentiation is not so marked as on most of the Pacific coast. The rainfall in some respects is similar throughout the plateau. Most of the rainfall comes in the four months, June to September, but the percentage occurring in these four months is greater in the south, the northern part being far enough north to get considerable winter rainfall. In the southern and middle sections of the plateau there are four months of about equal amounts, while to the north the number is reduced to three and the total amount is considerably less.

Another character of the whole plateau is that the month just before and the month just after the rainy season have about equal amounts and show their transition character.

The month of maximum rainfall in the plateau is June or July, depending on the province.

The interseasonal contrasts of cloudiness are more marked in the south and become increasingly less toward the north. Throughout the plateau thunderstorms occur in every month of the year, on the average, but are much more numerous in the rainy season. Days with any rainfall decrease greatly from south to north.

The southern plateau rainfall province (fig. 28, J) has plentiful summer but meager winter rainfall. The year in this province may be divided into two seasons: a rainy season from June to September, with 75 per cent of the total, a dry season from November to April, with 10 per cent, while May and October, with 15 per cent are transition months. Throughout the province July is wettest, though the other three months of the rainy season have about equal amounts and only slightly less than that of July. (Fig. 35.)

The average for the region is about 700 millimeters. There is, however, considerable local diversity in the rainfall. Toluca receives the average for the region, while Valle de Bravo and Justlahuaca with 1,386 and 217 millimeters, respectively, are the recorded extremes. During the rainy season the average maximum rainfall in 24 hours is about one-fourth the total amount, most of the stations at some time having received 75 millimeters and some 100 millimeters in a 24-hour period.

The rainfall here fluctuates less from year to year than in any other part of Mexico and comes at the most advantageous season for an agricultural people.

The annual course of cloudiness, cloudy days, days with thunderstorms, and days with any precipitation follow closely that of the total rainfall.

In the rainy season some rain falls on about 20 days per month. Much of the rain comes in the local afternoon thunder showers of short duration, at times accompanied by violent thunder and lightning as well as hail. The sudden downpours are helpful in cleaning the streets and clearing the atmosphere. Rapid evaporation under bright sunshine after the shower dries the surface in a short time.

The dry season in contrast with the rainy is typified by many bright, clear, sunny days. During this season Popocatepetl and Ixtacihuatl, the two permanently snowcapped peaks towering above the Valley of Mexico, are often visible from Mexico City, while in the rainy season they are seldom seen. They are obscured in the early morning hours by fog and haze and later in the day by clouds.

Snowfalls are rare in this province except on the higher mountain peaks, some of which remain permanently snowcapped.

The northern plateau rainfall province (fig. 28, D) is almost a desert. Areas within this province are deserts, as the Bolson de Mapimi, where less than 250 millimeters of rain falls. The extreme aridity of parts of this region was a problem of great concern in the recent revolution.

The province has a seasonal differentiation of rainfall, which, however, is not so pronounced as in the northern west coast province immediately adjacent. July to September are the rainy months and June and October the transitions. Some rain, however, falls in all months. July, with 85 millimeters, is the rainiest and January to May each has about 10 millimeters. Much of the rain which this region receives in winter comes with the extratropical cyclones which take a southerly course across North America. Some of the winter precipitation comes as snow. The summer rainfall is produced by afternoon convection, often accompanied by thunder and lightning.

On the average a half to a third of all the rainfall comes in one heavy shower each month.

In a province so large and so mountainous as this, local diversity is the rule. It is, however, a basin and therefore dry. The mountains to the the west are too high and continuous to permit the importation of much vapor from the Pacific. The mountains to the east, while less elevated, are a considerable barrier to moisture from the Gulf of Mexico.

This is a sunny province with a few cloudy or rainy days. There are only 70 days in the year with any rainfall, and half of these are in July, August, and September.

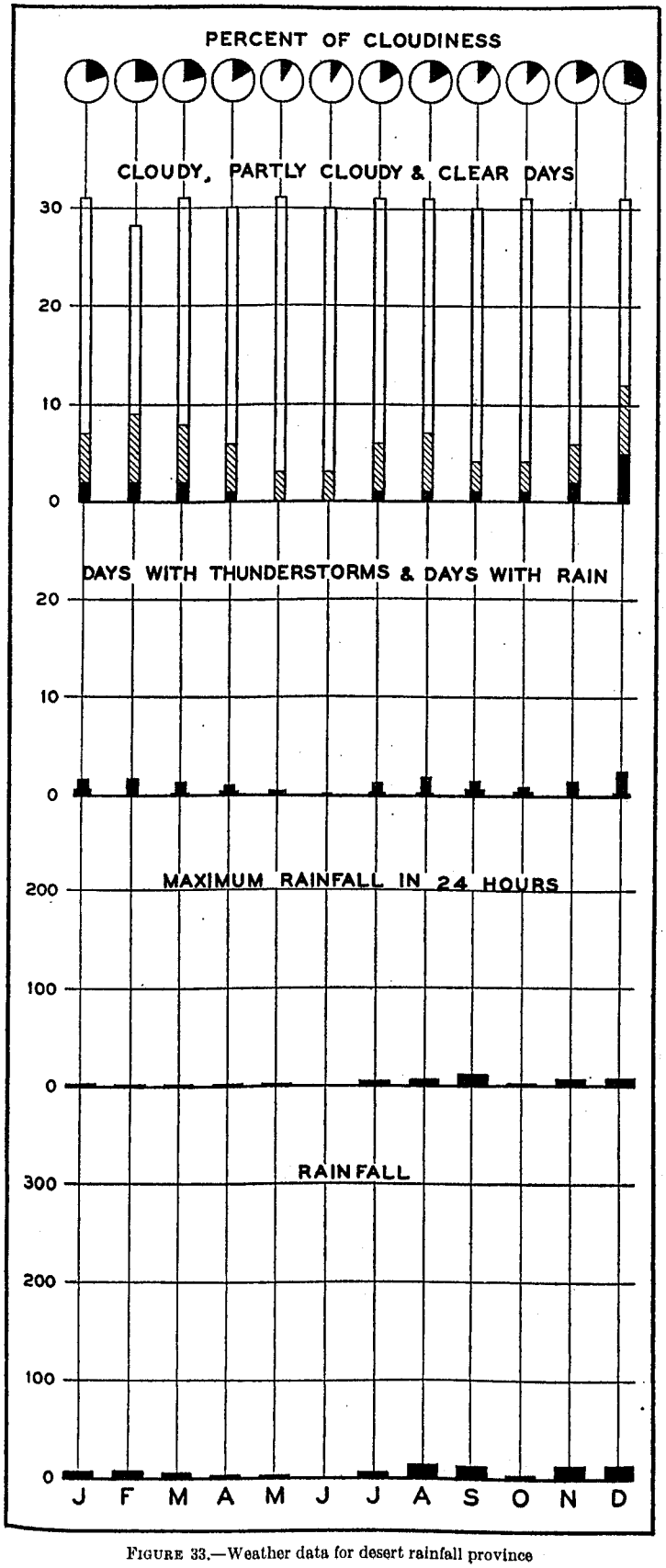

FIGURE 33.—Weather data for desert rainfall province

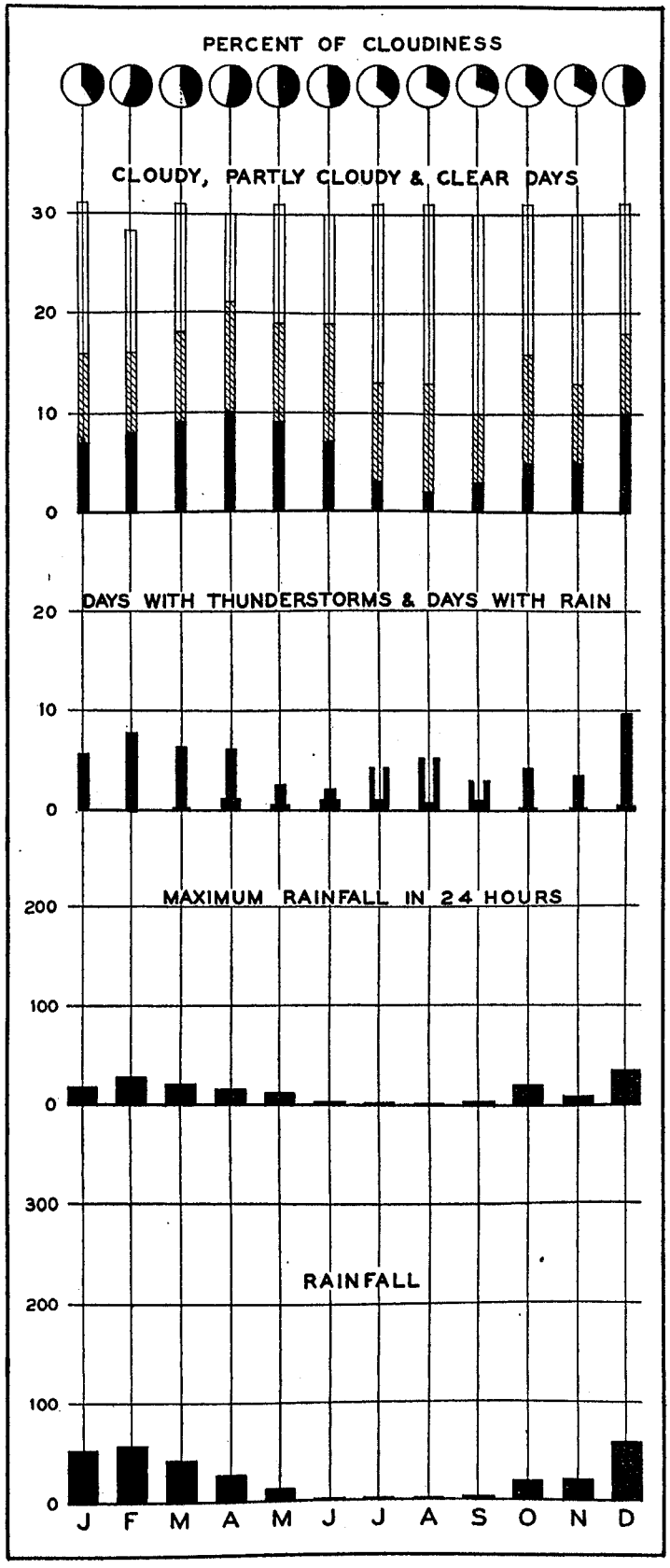

FIGURE 34.—Weather data for Mediterranean rainfall province

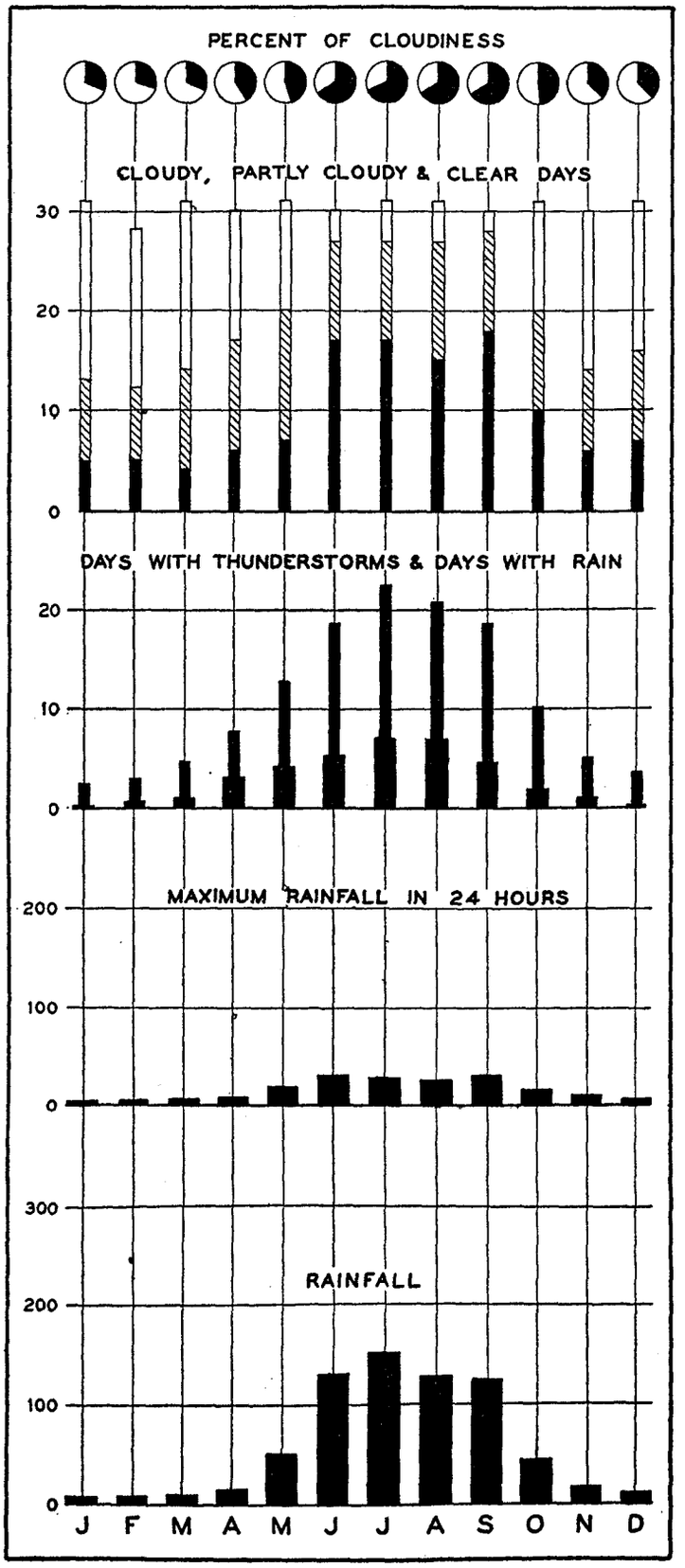

FIGURE 35.—Weather data for southern plateau rainfall province

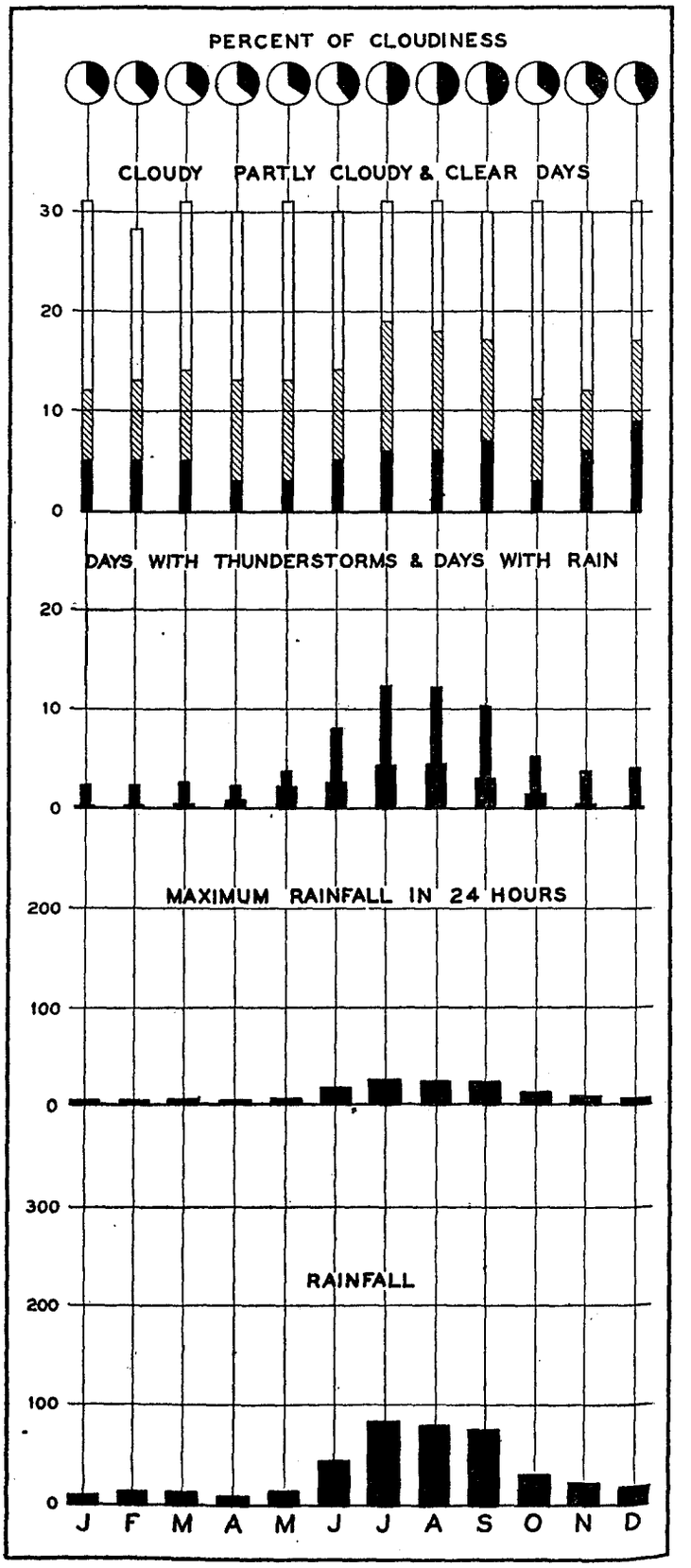

FIGURE 36.—Weather data for northern plateau rainfall province

The middle plateau rainfall province (fig. 28, G) differs from the northern plateau province in amount and monthly course of rainfall, and from the southern plateau province in monthly course rather than amount of rainfall. It, like the southern plateau rainfall province, is a region of plentiful summer but meager winter rainfall. (Fig. 37.) June to September are the rainy months, while May and October are transition months. The other six months have little rainfall. June is the month of maximum rainfall, while a secondary maximum falls in September. The number of days with rainfall and days with thunderstorms are considerably less than in the southern plateau province, while the amount of rainfall is about the same, a combination of which indicates that the rainfall per rainy day is heavier than to the south.

As far as cloudiness is concerned this province may be considered as a transition region between the plateau to the north and the plateau to the south.

Everywhere on the Gulf coast, from Rio Grande to Yucatan, summer or fall is the season of maximum rainfall. The winters, though distinctly less wet than these seasons, are rainier than any other part of Mexico, save northwestern Lower California. The Gulf coast region receives its rainfall from tropical and extratropical cyclones, convection, relief, and northers. The middle and southern Gulf slopes have the greatest annual rainfall, the heaviest 24-hour rainfall, and the greatest number of days with rain in Mexico. To the north as well as to the east of these provinces a considerable decrease in amount of rainfall, days with rainfall, and average maximum rainfall in 24 hours is found. There are enough differences in amount and monthly course of rainfall to warrant the delimitation of four rainfall provinces. (Figs. 38–41.)

The Yucatan rainfall province (fig. 28, M) embraces the States of Yucatan and Campeche, and the Territory of Quintana Roo. It has considerable rainfall all through the year but has much heavier rainfall in the months of June to October. (Fig. 38.) March, with 22 millimeters is driest and June, with 160 millimeters, is wettest.

In March and April little rain falls. These are the months of lowest relative humidity, because the rise of temperature from winter to summer is more rapid than the rise of relative humidity. By the latter part of May convectional rains begin and continue through the summer, apparently reaching their maximum in June, with a decrease in July, when the center of lowest pressure has shifted to northern Mexico. With the occurrence of tropical hurricanes in the late summer and early fall the rainfall is again brought to a maximum in September. This fall maximum is most pronounced in the eastern part of the peninsula, where the tropical storms can be most felt.

There are no records in the southern part of the peninsula, but because of its more southerly location and from the more luxuriant vegetation it seems likely that the rainfall is somewhat heavier than in the northern and eastern parts. The average rainfall for the province is 950 millimeters, falling on the average, on 125 days of the year. Each of the months from June to October has about 15 days with some rainfall, and days with heavy rainfall are not lacking. June and October each has more than 40 millimeters as the average maximum rainfall in 24 hours.

Thunderstorms are not infrequent in Yucatan during the rainy season. July, August, and September each has about three, and every month has reported them. The partly cloudy days exceed in number those clear or cloudy in every month of the year, and the number varies little from month to month. There is likewise little monthly range in percentage of cloudiness. March, with 4.6, and June, with 6.3, are the extremes.

To the west of the Yucatan rainfall province a considerable increase in rainfall is encountered. The southern Gulf coast rainfall province (fig. 28K) has the heaviest recorded rainfall of any province in Mexico. It has in it the station of greatest recorded rainfall in the country, that of Teapa, in Tabasco, with 4,638 millimeters. The data for this station were not used in constructing the composite graph of the province, because this very heavy rainfall seems to be more local than general. The average for the region is, however, over 2,000 millimeters. The lowest recorded amount is 950 millimeters, at Frontera, in Tabasco. April, with 44 millimeters, is the month of minimum rainfall, while October, with 342 millimeters, is the month of maximum. (Fig. 39.) Winter rains are abundant, being produced in part by the northers. The heavy rainfall of summer is a result largely of convection, while the still heavier rainfall of September, October, and November results from tropical storms, convection, and northers.

Heavy rains in a 24-hour period are recorded in every month of the year, on the average, though April, with 18 millimeters, and November, with 98 millimeters, are the extremes. More than half of the days from July to October have some rainfall. Even in December and January the days with some rainfall are 12 and 11, respectively. Days with thunderstorms are about one-third as numerous as days with any rainfall.

Cloudiness varies little from month to month, more than half of the sky being covered on the average by clouds during all months. The percentage of cloudiness may not, however, be very representative of the whole region, since it is for the one station of Puerto, Mexico.

To the northwest, along the Gulf coastal plain and foothills of the Sierra Madre Oriential the amount of rainfall does not change appreciably, but the course through the year does change to the middle Gulf coast type. (Fig. 28, H.) Like the southern gulf coast, this province has condiderable winter rainfall, but less than to the southeast. The month of maximum rainfall in this province is September. There is a secondary in June. The province has a more marked seasonal distribution of rainfall than the southern Gulf coast rainfall province. Much cloudiness, few clear days at any season, although a maximum in winter and spring, characterize this province. (Fig. 40.) During the winter and spring Mount Orizaba may be seen quite frequently from Vera Cruz and, under very favorable conditions, from 50 miles at sea. But during the rainy season it is not visible for a great distance and at times can not be seen from Orizaba City.

Many rainy days are the rule in this province. Much of the rainfall along the mountain slopes comes as a kind of mist which may change into heavy downpours. The dense tropical and semitropical forest along the slopes of the Sierra Madre Oriental bespeaks the abundant rainfall.

The lower Rio Grande rainfall province (fig. 28, E) differs from the middle Gulf coast in amount rather than monthly distribution of rainfall, for it too has a September maximum and a June secondary maximum. But it has less than one-third as much rain fall as the middle Gulf coast rainfall province. (Fig. 41.) The lower Rio Grande province is far enough north to receive considerable winter rainfall from the extratropical cyclones when they take their most southerly course across North America as well as from the cyclones which originate in the western part of the Gulf of Mexico.

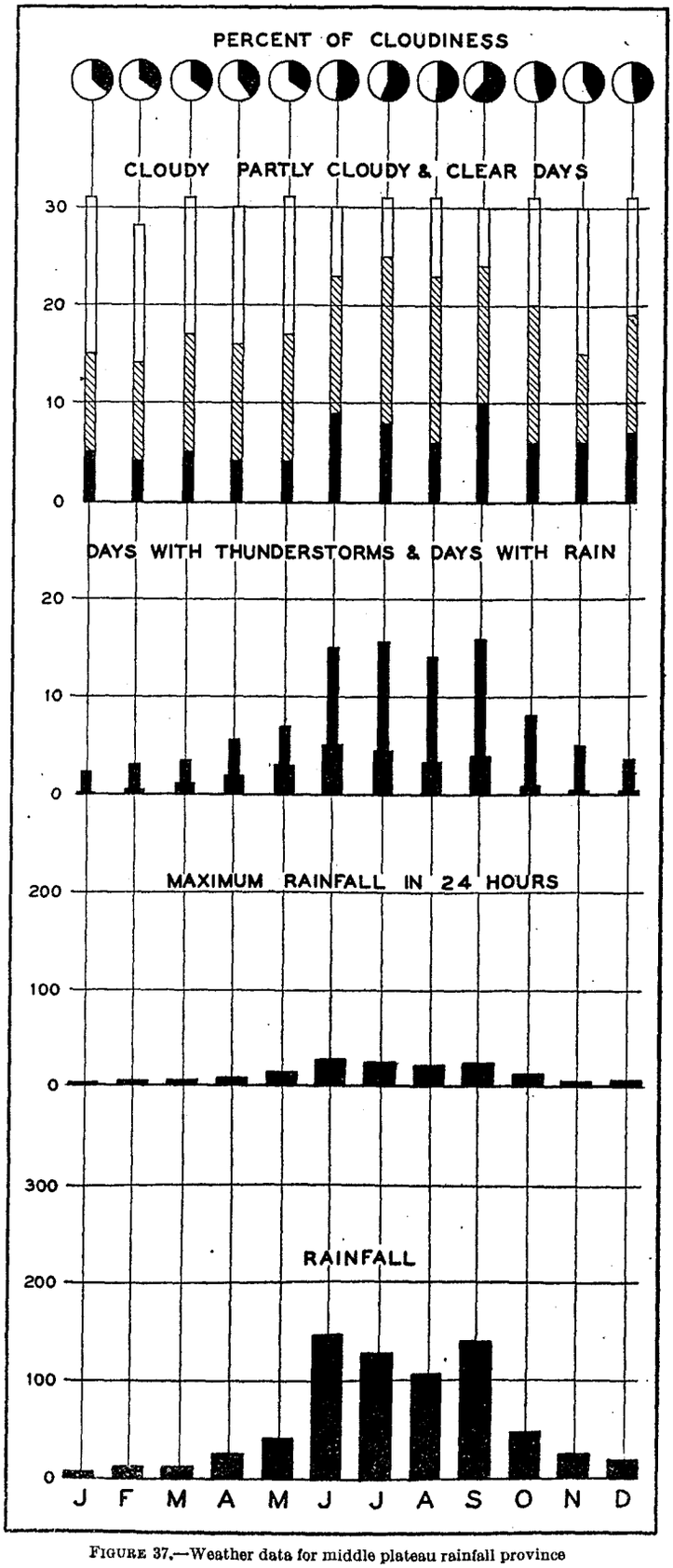

FIGURE 37.—Weather data for middle plateau rainfall province

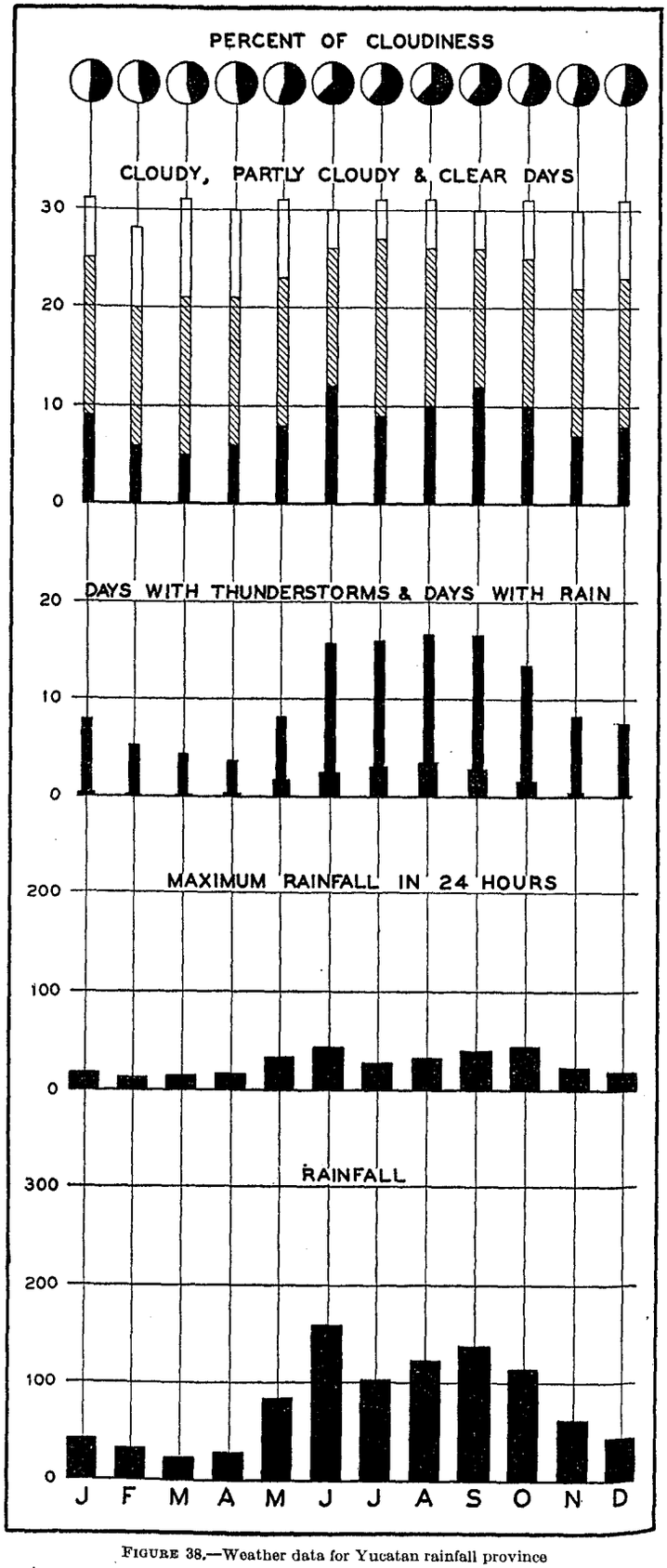

FIGURE 38.—Weather data for Yucatan rainfall province

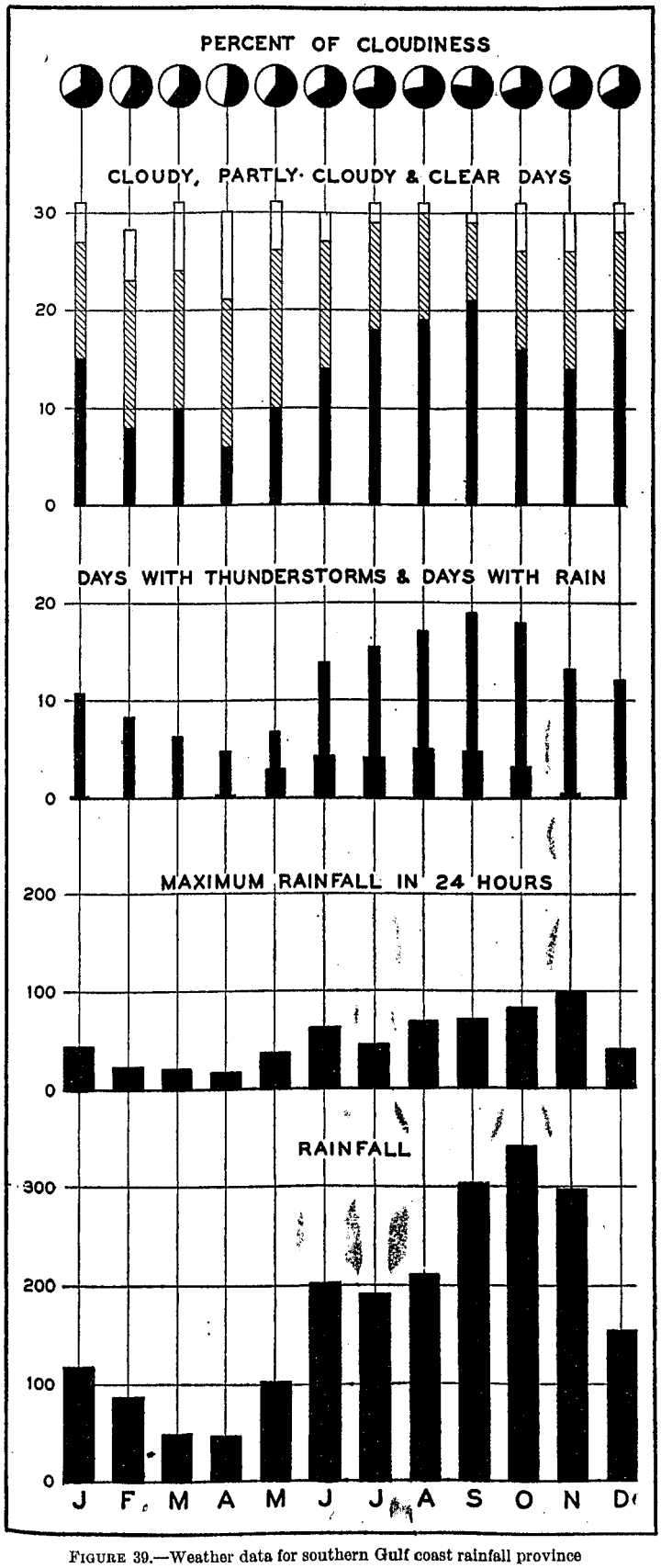

FIGURE 39.—Weather data for southern Gulf coast rainfall province

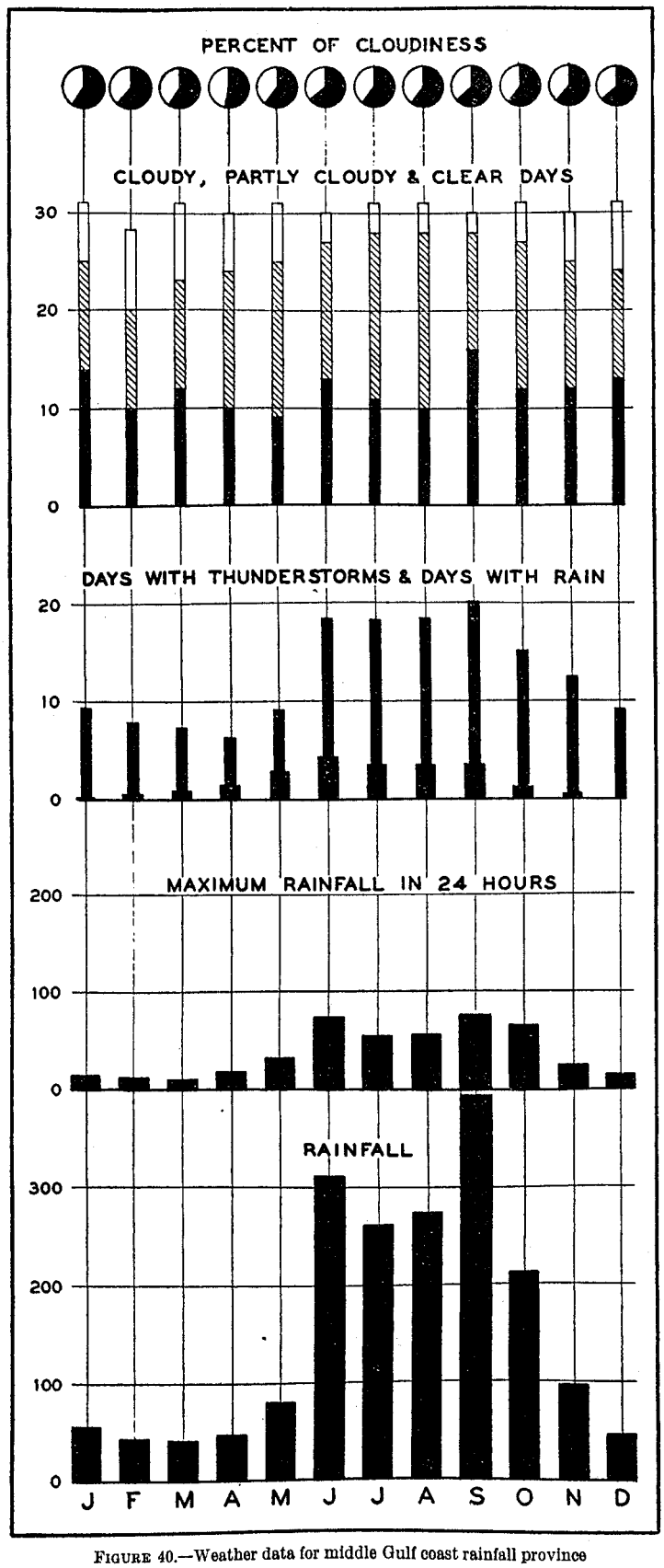

FIGURE 40.—Weather data for middle Gulf coast rainfall province

A characteristic of this province is that it has its maximum cloudiness from November to May when it is having

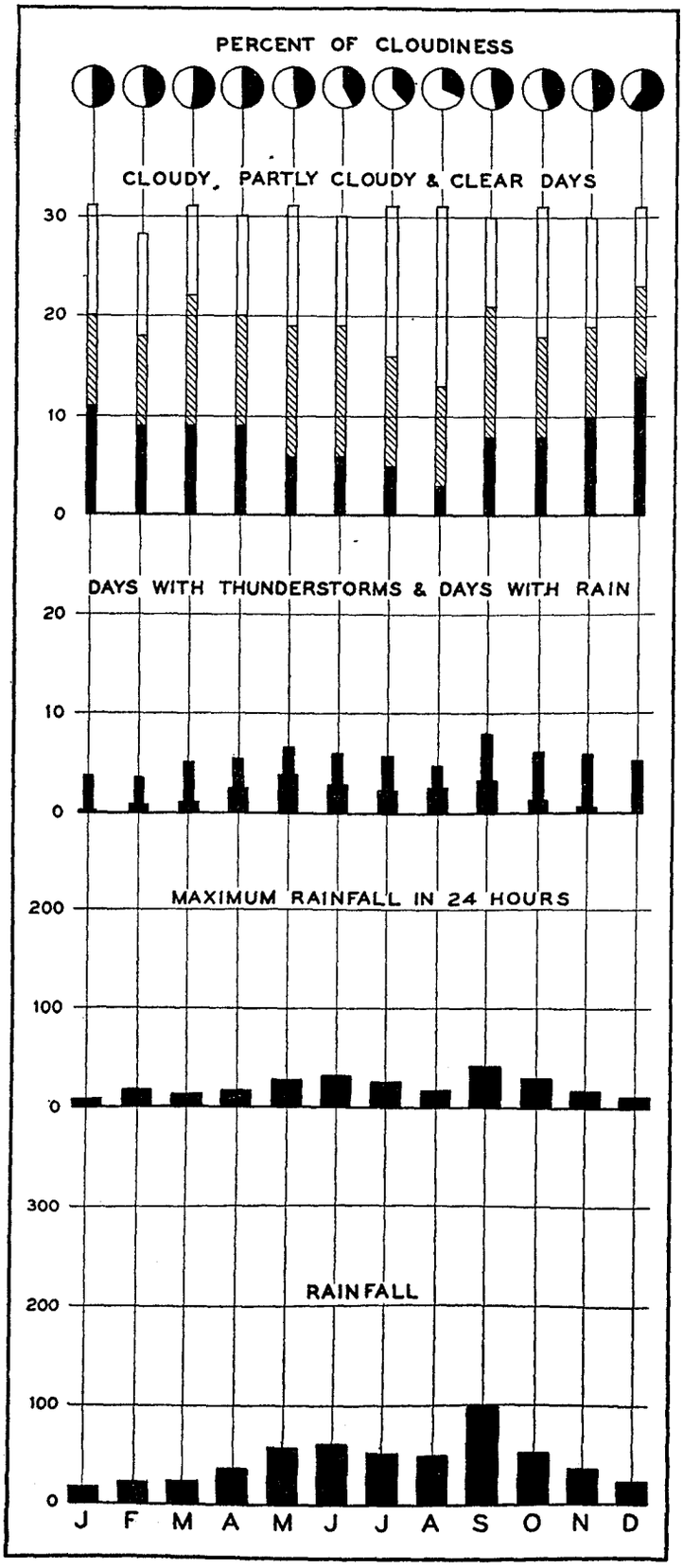

FIGURE 41.—Weather data for lower Rio Grande rainfall province

its smallest amount of rainfall. This anomaly results from the greater frequency and more southerly course of cyclonic storms at this season. Days with thunderstorms are almost as frequent as days with rainfall. All in all, this is a province with few cloudy days, fewer rainy days, and a low total rainfall. The september rainfall is conspicuous by its relatively great amount, probably caused by tropical storms which at times deluge this valley.

SUMMARY

Thus Mexico, though only three times the size of Texas, can be thought of as a country of marked local diversities in all of its climatic elements. It has prevailing winds from every point of the compass. In temperature it ranges from hot, humid conditions of the tropical lowlands to permanently snowcapped heights. In mean annual rainfall it varies from 55 to 4,638 millimeters. Some places are said to receive no rainfall in some years. The number of days with rainfall varies from 15 to more than 200.

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