Thus in studying the two charts—one of temperature and one of precipitation—we see at once that the bulk of the precipitation occurs during the growing season. The distribution during this season is relatively uniform from month to month. There is sufficient late winter precipitation to form a surplus available when growth begins in the spring. There is probably snowfall to cover the soil, thereby ameliorating the soil temperature to some extent. From the second chart it is evident that the growing season lasts about six months during which the average temperature is about 55° or 60°, while the winters are severe, especially during December and January. There is a small spread in the range of annual temperature, and the mean annual temperature—roughly the center of the polygon—is about 42°.

To have two figures to deal with is rather awkward and entails considerable work, so that it has proved both feasible and practicable to unite them, as shown in Figures 2, 3, and 4, by superimposing the temperature polgyon upon that of precipitation. In order to keep these separate, the precipitation occurring during the growing season is cross hatched in order to differentiate it. It then becomes easy to separate the desired factors in the comparison of any two climates.

Figure 2 shows these climatographs for a few stations in southern California and indicates the uses which can be made of them. By a little study of many such figures as shown in Figure 3, it is possible to see the gradations between stations; how the temperature chart contracts, the precipitation chart increases, the development of the growing season, the distribution of the precipitation. With the correlation of the native vegetation with each climate, one can soon select the essential characteristics of the different localities and some of the limiting factors controlling distribution.

In compiling these data, it has been found that the ordinary 3 by 5 library card offers the best opportunity of comparing stations. The charts usually fit nicely upon these, except some stations where the winter precipitation is tremendous, and in such cases the amounts can be written upon the radii. The use of two colors brings out the precipitation and temperature data better than the one color, and obviates the necessity for so much crosshatching. Much more data can be put on these charts, making the division one of 10-day periods instead of months and, instead of mean temperatures, it is possible to use the mean maximum and mean minimum temperatures. The back of the cards offers an opportunity to make such notations as are desired, or to enumerate particular features about the station, such as its location, elevation, character of crops grown, prominent vegetation, proximity of bodies of water, and other similar information.

The use of this form of chart is not confined to the representation of temperature or precipitation alone, as it has been used also with humidity, pressure, evaporation, and other phenomena that one might desire to compare on a monthly basis.

THE USE OF CHARTS AND GRAPHS IN THE STUDY OF CLIMATE.[1]

By VERNA B. FLANDERS.

[Clark University, Worcester, Mass., August, 1922.]

When I first studied types of climate, I did so by steadfastly gazing at columns of figures for a given station and then reading a meager description in the text. No thought of comparison or contrast with my own environment occurred to me, few human responses to climate were suggested, and, altogether, no very definite mental picture of the different types remained with me. Perhaps this was just as well, since I was later to approach the subject from a much more interesting angle.

One of the greatest helps toward visualizing and understanding climatic data is the use of graphs and charts. I have chosen a number of contrasting types of climate from our own country and shall try to show how much information can be gained from two types of representation—the climatic chart (Goode) and climograph. A hasty glance at the accompanying diagrams reveals much of value, but the student will find added help if he will actually construct the charts himself and will experiment with graphs he finds most helpful. The knowledge needed, the care required, the interest in seeing how "it" is coming out, and finally the interpretation of the product—all lead to a new and absorbing interest in the subject.

On the climatic charts [2] is shown the following data for each station in so far as figures could be found: (1) Location, (2) elevation, (3) sunshine record, (4) wind-direction record, (5) average monthly relative humidity (8 a.m. and 12 m. readings average), (6) average monthly rainfall and total for year, (7) average monthl ytemperatures and yearly averages. These figures are entered in full on the back of each chart with additional data such as (1) average monthly and yearly vapor pressure (8 a. m. and 8 p. m. readings averaged), (2) average monthly wind velocity and yearly average.

It is of interest just here to note that all this information can be obtained from two publications of the United States Weather Bureau—Bulletin W and MONTHLY WEATHER. REVIEW SUPPLEMENT 6. They are available in some of our larger schools and libraries.

The chart for New York (fig. 1) shows the city's moderate, evenly distributed rainfall, the fairly large range of temperature, moderately high relative humidity, and the delayed maximum and minimum temperatures—all evidences of our littoral type of climate in middle latitudes. Such questions as—Why has February such a low temperature? Why is the relative humidity highest in winter? Why do prevailing winds in June and July come from the southwest? Account for the evenness of the rainfall distribution—stimulate thought and investigation and direct the pupil's study of the charts.

Savannah exhibits in its summer rainfall an almost monsoon tendency. How can we account for the considerable rainfall in winter? Why has it a smaller range of temperature than New York? Why has it a greater range of temperature than Los Angeles?

Continental influences show in St. Louis's chart (fig. 1) in the increased range of temperature and the early summer maximum of rainfall. Williston is more markedly continental in a higher latitude.

[1] Thesis submitted in course on climatic environments, Clark Summer School, Worcester, Mass., August, 1922.

[2] The charts here referred to are drawn on the well-known Goode base climatic chart No. 80. Lack of space prevents the reproduction of all of them, but we have combined the essential features of four of them so as to give a cross section of the United States about latitude 40 N. and present it in fig. 1. The climographs appear in fig. 2.—ED.

Denver (fig. 1) shows the influence of increased elevation as well as an interior position in the continent. It shows clearly a light rainfall with a spring maximum, low relative humidity, and a marked seasonal temperature range.

Phoenix is a type of our middle latitude arid regions and its extremely low relative humidity, great temperature range and meager rainfall are striking. Why has it a greater temperature range than Los Angeles? Smaller than Williston? Account for the winter rainfall.

Our Pacific coast furnishes examples of the marine type in San Francisco (fig. 1) and of the Mediterranean type in Los Angeles. Both show the winter maximum of rainfall and small temperature ranges. Why does Los Angeles have so much less rainfall? Why are its temperatures higher? Why is its relative humidity lower? Why is not June the hottest month in each case?

A chart for each type of climate to accompany the climatic regions map (Jones and Whittlesey) illuminates the text for beginners in climate study.

The climograph has lately been developed and put to use by Dr. Griffith Taylor, an Australian geographer in his study of The Geographic Representation of the Effect of Climate on Man and The Control of Settlement by Humidity and Temperature.[3]

He plots in graph form the wet-bulb temperature readings (average monthly) and the average monthly relative humidity for the given station. The resulting figure falls into the classification of scorching, muggy, keen or raw, according to its position on the diagram. (See fig. 2).

While this form is graphic, easily readable, and offers opportunity for comparison of stations, it is critized on several counts. First, it seems that *wet-bulb* readings combined with relative humidity give too great prominence to the moisture element in climate. Second, the terms "muggy," "keen," "raw," and "scorching" are relative terms. They mean different degrees to different persons, and, for instance, would doubtless have a slightly different interpretation with us than with an Australian. Third, since climographs for a single place differ from year to year, they might be more valuable for short-term observations—in short, as a help for weather observations rather than for climatic study. Fourth, these graphs take no account of wind velocity, an element that influences greatly the cooling power of the air.

Their chief value seems to be the opportunity they afford for comparison and contrast of different stations. They may be made one of the criteria for determining the limits of a *climatic region.*

A hythergraph (fig. 2, upper left) shows average monthly rainfall and average monthly temperatures. I have chosen five of our eight United States stations to

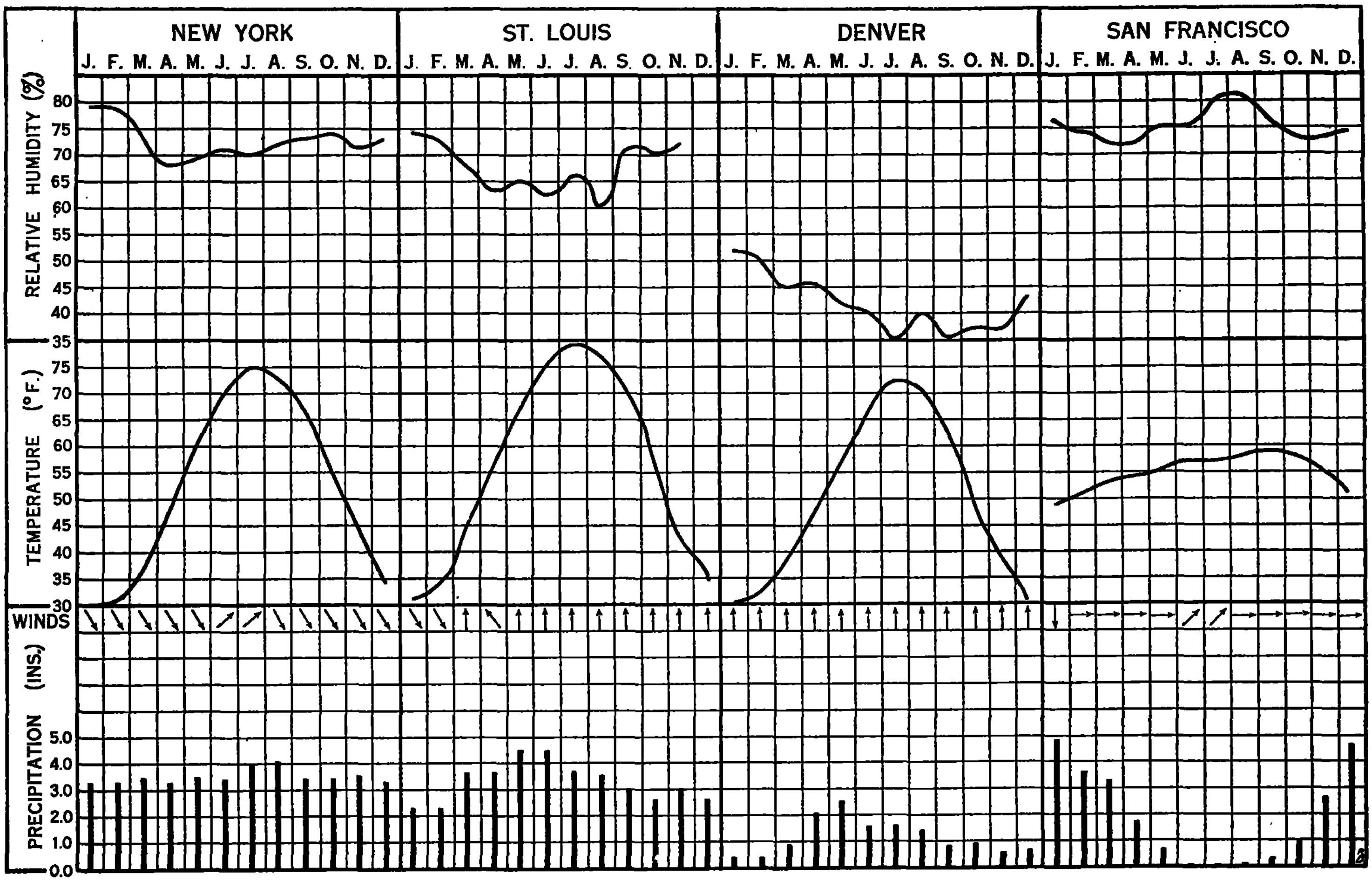

FIG. 1.—Climatic charts of New York City, St. Louis, Denver, and San Francisco. These charts were originally drawn on the Goode base, but, for facility of reproduction have been redrawn.

[3] cf Mo. WEATHER REV., September, 1919, 48, 490-495; September, 1920, 49, 495-497.

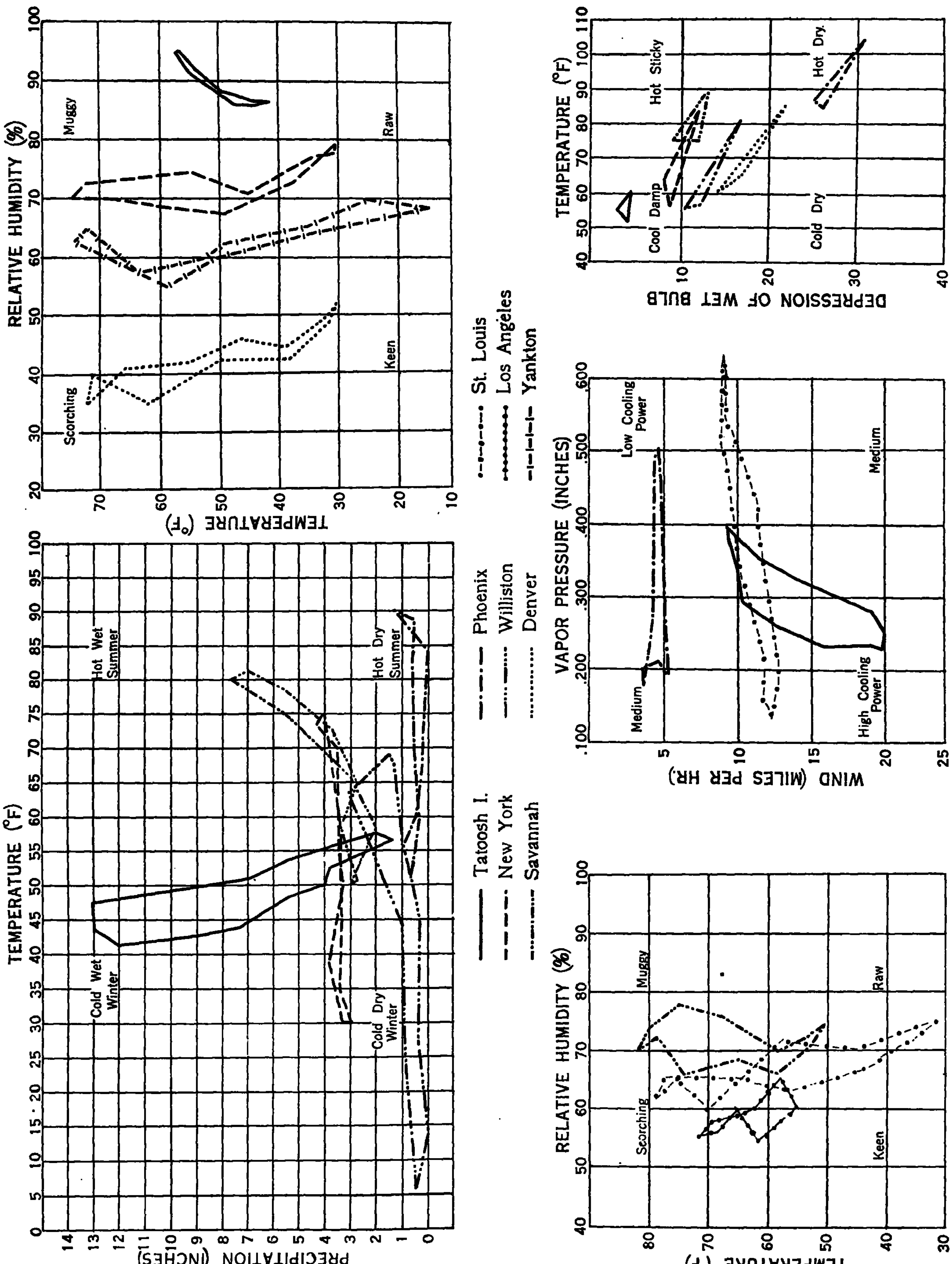

FIG. 2.—Climographs for various cities in the United States.

show how the information given on the charts may be grouped for comparison. Obviously breadth from left to right in a figure denotes great temperature range while length from top to bottom shows uneven distribution of rainfall. New York shows its marked evenness of rainfall, as Tatoosh Island shows small range of temperature. Savannah's heavy July rainfall is easily recognized and irregularity of its figure with crisscrossing lines suggests cyclonic influences and perhaps the effect of local controls.

Four stations, Tatoosh Island, New York, Yankton, and Denver, in approximately the same latitude were chosen to show reading from right to left the decrease in marine influence and the increase in elevation above sea level (fig. 1, upper right).

Los Angeles, St. Louis, and Savannah in approximately the same latitudes (fig. 2, lower left) show clearly from left to right the typical Mediterranean type, the continental type and the littoral type in low middle latitudes.

These two climographs were plotted with dry-bulb readings and relative humidity.

Climograph (fig. 1, lower right) shows the average maximum temperatures (dry-bulb) for April, July, and October with the average depression of the wet-bulb from that maximum for the same months. A study of these figures shows a complete gradation from Tatoosh Island with its air showing the least drying power, if there were no wind, through Savannah, inclining, in summer toward the hot sticky type, to Phoenix with its hot, drying atmosphere.

In Figure 1, lower center is shown the result of an experiment to plot wind velocity with vapor pressure. The three stations, Phoenix, St. Louis, and Tatoosh show a difference in cooling power of the air based on these two factors. Perhaps this form of climograph may supplement the information given by the relative-humidity dry-bulb type of graph.

The construction of these graphs offers an opportunity for endless surmisses and possibilities as to different combinations of factors. The study can not fail to stimulate clear thinking and promote intense interest in this phase of climatology.

DRY MONTHS IN THE UNITED STATES.

By ALFRED J. HENRY.

[Weather Bureau, Washington, D. C., October 28, 1922.]

The wide-spread and rather severe drought which prevailed during the month, as elsewhere noted in this REVIEW leads the Editor to briefly summarize the meteorological conditions associated with prolonged dry weather. His previous studies of the subject [1] have shown that local droughts prevail in some part of the country in practically every year. General droughts, however, are not of such frequent occurrence and are less easily discussed in their true perspective. It would seem, however that they are due to changes in the pressure distribution over considerable portions of the continents and oceans which, in turn, lead to modifications in the general winds of the drought-affected regions.

The data used.—In this study the data used are the monthly departures from the normal precipitation for each climatic district as published in Table 1 of the MONTHLY WEATHER REVIEW. These data are available back to 1881, thus covering a span of 41 years. Table 1, with which readers of the REVIEW are familiar, contains in full-face type the mean temperature, mean precipitation and other data for the respective districts in the United States. The procedure was to tabulate the number of districts for each month of the period for which precipitation was above, below, or exactly equal to, the normal for the month in question, regardless of the amount of the abnormality. This method gives, therefore, qualitative results only.

Checking the qualitative against quantitative results shows good agreement; it is felt, therefore, that the method followed in the work has given worth-while results.

In the tabulation was given the percentage for each month of the period. These percentages may be considered as roughly indicating the percentage of the total area for which precipitation was exactly normal or above normal. The climatic districts are not of equal area, hence the results must be only an approximation.

If precipitation should be above normal in all of the 21 districts the percentage for that month would be of course 100. The tabulation showed that the nearest approach to that figure was in December, 1884, when 95 per cent of the districts had precipitation above the normal. In but 8 of the 492 months in the entire period was the area of excess of precipitation as much as 80 per cent or more of the total. It may also be noted that the months of widely distributed normal rains occur mostly in the spring, never in the summer and autumn and rarely in winter. On the other hand there were four months during which precipitation was below normal in all districts, viz, January, 1902; March and December, 1910; and November 1917.

With the object of increasing our knowledge of the general weather conditions which prevail during dry weather in the United States the above-mentioned months have been considered separately and collectively.

DRY MONTHS.

Atmospheric pressure seems to be the one element that is definitely related to the amount and frequency of precipitation. The distribution of pressure is, however, conditioned upon the paths followed by traveling cyclones and anticyclones; inasmuch as the latter are not available for large portions of the globe, particularly in the Arctic region, the avenue of approach to the problem through the frequency of cyclones and anticyclones is shut off. Brooks and Glaspoole [2] have shown that droughts in the British Isles are associated with low pressure in the Arctic.

The same conclusion is apparent in this brief study. March, 1910, one of the months studied, was one of the driest of that name in the United States within a century. There was in that month a pronounced diminution in mean pressure in the neighborhood of Iceland and thence westward across the continent of North America and increased pressure over the British Isles and northern Europe. (See the statistics of *Reseau Mondial*, 1910.)

[1] *Bulletin Q*—Climatology of the United States pp. 51-58.

[2] Quart. Jour. XLVII, p 139-166.