FROST AND THE GROWING SEASON.[1]

By WILLIAM GARDNER REED.

(Review by C. F. Brooks.)

The appearance of a folio of colored maps marks the final outcome of an extensive investigation of the dates of killing frost in the United States initiated by Mr. O. E. Baker about six years ago. In 1913, 1914, and the first half of 1915, the Weather Bureau section centers and Central Office, and the Office of Farm Management were engaged in collecting and editing critically all the frost data available. The records for the period 1895-1914 were selected for the sake of homogeneity. In the latter half of 1915 these data from about 4,000 stations were mapped and the long records from about 600 stations were subjected to mathematical analysis. The results of this study are presented in detail by Mr. Reed in the Proceedings of the Second Pan American Scientific Congress (vol. 2, pp. 593-631, tables, 13 figs.). In this paper he describes not only the distribution of frost dates in the United States, but also presents tables of selected records and the details of the mathematical procedure used to obtain dates when the risk from spring or fall frost would be at a specified value. Several short papers, principally on the mathematics of the frost risk in farming, were published in 1916 by Mr. Reed independently, or jointly with Mr. H. R. Tolley (mathematician) and Prof. W. J. Spillman (then chief, Office of Farm Management).[2] Some of the frost maps have been published and briefly discussed in the National Weather and Crop Bulletin during the past three years.

In spite of these previous discussions, the publication under review is in no sense a repeater. The frost data of the United States are presented in detail by pleasing colored maps on a relief base; and selected records are strikingly portrayed in graphical form. The simple and well-written discussion goes into the geographical and agricultural aspects of frost and the growing season in the United States.

The study deals only with the occurrence of "killing frost" or its approximate equivalent, a temperature of 32° F. or lower. Thus we are concerned with the dates when widespread damage is done to vegetation by the cold and not with the formation of frost deposits. The last killing frost in spring limits the start of vegetation, and the first killing frost in autumn puts an end to most vegetative activity unless plants have already prepared for the winter. It is of considerable interest to the farmer to know when these critical frosts are most likely to occur, and to know just when a particular killing frost will come. From the weather map and from local signs, such forecasts are made. To illustrate killing frost weather types, 10 weather maps are reproduced. Warnings of killing frost are, however, of little use unless the farmer is prepared to meet them, either by actually protecting his endangered crops, or by having a surplus from previous successful years sufficient to cover his losses.

Latitude and altitude are of primary importance in determining the months of occurrence of killing frost. Relative altitude in rough country is for some localities more important than actual elevation above sea level. This frostiness of valley bottoms made it very difficult to draw the frost date lines in most of the highland regions of the United States.

[1] Atlas of American Agriculture, Advance sheets, 2, pt. II, sec. 1, issued, 1918. 48 by 34 cm. 12 pp., 12 colored maps, 10 weather maps, 10 graphs. Selected bibliography.
NOTE.—The rest of the climatic section has been ready for publication for some time and may reasonably be expected to appear in 1919.—EDITOR.

[2] Geogr. Rev., vol. 2, pp. 48-53; M. W. R. 44: 509-512, 197-200.

"The most noteworthy fact regarding these critical frost dates is their extreme irregularity." Nevertheless, by arithmetical averaging it is easy to get dates before and after which crops will be subject to killing frosts in about half the years. The maps of the average dates of last killing frost in spring and first killing frost in fall show the frost lines running mostly east and west in the eastern United States, bending northward near large bodies of water and over large valleys, and southward over the highlands. In the western United States, topography is the most important control other than that exerted west of the Sierra Nevada—Cascades by the Pacific Ocean. The map of the average "growing season" has much the same characteristics. In fact, all three differ only in details.

As corner inserts of these three double-page maps are small maps showing the areas covered by each general "wave" of last killing frost in spring and first in fall. A given frost may occur over a large area on one date, and another some time later over another region not coextensive with the first. Nine such overlappings are marked on the spring map and 8 on the autumn.

Variations in the dates of spring or fall frost by 10 days or more from the average are common (i. e., over 5 times in 20), where frosts may not occur every spring or fall, as along the Gulf coast, and where the effect of topography varies with the type of weather as in the mountainous region of the West. The maps of security from killing frost show the dates on which the chance of killing frost in spring (autumn) falls (rises) to 10 per cent. These maps are practically the same as the average date maps, but the dates are 10 to 30 days later in spring and earlier in fall. "The areas in which the chance of spring [(autumn)] frost is greater than 10 per cent on June 1 [(Sept. 1)] include the region along the northern boundary of the United States, elevated areas in the Appalachian Mountains, and the greater part of the higher altitudes of the West."

The maps of the growing season are the most important from the agricultural point of view. The large double-page map of the average length of the "growing season" shows detailed lines for every 10 days in the eastern United States and for every 30 days from the Rockies westward. "Throughout most of Florida, along the coast of the Gulf of Mexico, and in favored localities in Arizona and California, the average season without killing frost is more than 260 days. Along the northern margin of the cotton belt it is about 200 days, along the northern margin of the corn belt from 140 to 150 days, in northern Maine and northern Minnesota, where hay, potatoes, oats and barley are the principal crops, it is about 100 days, and in the higher regions of the West it is less than 90 days." If a farmer were to raise crops requiring the average length of the growing season to mature he would not get a harvest in more than a third of the years.

The map showing the available growing season in four-fifths of the years shows a period 15 to 50 days shorter than the average "growing season." "In the region having 90 days or less without frost in four years out of five, general farming is limited largely to small grains, grasses, and potatoes; and, in general, the area is much the same as that in which the average period without killing frost is less than 90 days, although, of course, somewhat greater in extent. The longest growing season is found in the States bordering the Gulf of Mexico, in southern Arizona, and portions of California. The safe growing season in the eastern United States varies from about 240 days along the Gulf of Mexico to 100 days or less in Minnesota and the Dakotas, and 90 days or less in parts of the Appalachian Mountains and the higher altitudes in New York and New England. In the more elevated regions of the West the safe season is less than 90 days. This map represents, in general, the number of days expected to be available for the growth of crops in a sufficiently large proportion of the years to enable the organization of farm enterprises on that basis with a reasonable chance of success." In the selection of suitable planting dates, the chance of spring frost damage, the advantages of maturity for early markets, and the length of the growing period of the crop must all be considered. Greater risk can be taken with some crops than with others.

HOURLY DURATION OF PRECIPITATION AT PHILADELPHIA.

By GEORGE W. MINDLING.

[Dated: Weather Bureau Office, Philadelphia, Pa., Dec. 19, 1918.]

What information can we give to business men as to the amount of time likely to be lost at different times of the day at various seasons of the year on account of stormy weather? What facts of diurnal distribution of rainy weather can be brought out that may prove helpful in the preparation of either State or local forecasts? Is there a diurnal periodicity in the occurrence of rainfall such that we may depend on certain parts of the day to be more likely to give rain than others, or, more particularly, a greater duration of rainfall than others?

If the periodicity is sufficiently marked, a knowledge of its character ought to enable one to say with some assurance at what hours it will be most likely to rain, especially under conditions of somewhat unsettled weather when the prospects of precipitation are doubtful. Also such knowledge should aid in enabling one to say when a storm of moderate severity may be expected to abate.

The total duration of precipitation in Philadelphia has been found to average 928 hours per year, which is equivalent to more than five weeks of continuous precipitation. The duration of precipitation is nearly as great or greater in most of our highly developed industrial centers, especially those surrounding the Great Lakes and in the northeastern part of the country, as may reasonably be inferred from the average annual number of days with 0.01 inch or more of precipitation. Such averages for the ten years beginning with 1907 are as follows: Philadelphia, 122; Albany, 127; Boston, 114; Buffalo, 163; Chicago, 123; Cincinnati, 127; Detroit, 136; New York, 121; Pittsburgh, 149. Obviously, then, if the diurnal distribution of precipitation is not too haphazard, it must be deserving of careful study, especially in regions where some form of precipitation is occuring more than one-tenth of the time, as is true in Philadelphia.

It could not be out of place in connection with a study of this kind, to make some references to studies of the average amount and frequency of precipitation for the different hours of night and day.

1. The pronounced diurnal period in the relative amounts and frequency of rainfall in tropical countries suggested to Dr. Fassig a study of these matters in his work on "The Climate and Weather of Baltimore." (See Maryland Weather Service, Vol. II, pp. 165–170.)

In his studies of the average hourly amounts of precipitation for a ten-year period, he found the winter and spring months characterized by a rather uniform distribution of precipitation throughout night and day, while summer rains were generally light in the forenoon, increasing rapidly about the middle of the day and more slowly in the afternoon with a maximum about 5 p. m. The uniformity observed in winter and spring he attributed to the general dependence of precipitation in those seasons on the "more or less regular succession of the cyclonic disturbances of the middle latitudes whose eastward progress is but slightly, if at all, affected by the diurnal variations of temperature and pressure." The influence of thunderstorms was distinctly seen in the large average amounts of rainfall for summer afternoons.

His investigation of the hourly frequency of precipitation was based on compilations of the total number of days in each month for 10 years on which precipitation occurred in the various 24-hour periods. Thus, between 4 p. m. and 5 p. m. in the month of March precipitation occurred on 61 days during the 10 years. This was the hour of the greatest frequency. The hour of least frequency was from 4 a. m. to 5 a. m. in August, the total number of days with precipitation being only 9. For the year as a whole, the average frequency was least about 2 a. m. to 4 a. m. and greatest about 4 p. m. to 6 p. m. The July curve exhibited the strongest periodicity; that of March, the greatest uniformity.

2. Similar studies of Chicago records were made by Cox and Armington. (See Weather and Climate of Chicago, pp. 203–208.) Owing to the severity of the Chicago winter climate, which makes continual use of the tipping-bucket rain gage impossible, it was necessary to limit the study of hourly amounts of precipitation to the period of April to October, inclusive. The results showed considerably less symmetry than those obtained at Baltimore, yet there was, "in general, a relation to be seen between the times of greatest hourly rainfall and the times of occurrence of thunderstorms."

Much greater regularity was found in the mean hourly frequency of precipitation, but the rather distinct early morning minimum and afternoon maximum observed at Baltimore were hardly discernible at Chicago. In other respects there was similarity in the conditions observed at the two places.

3. Records made at a number of places in the interior of Europe show greatest frequency of precipitation in the morning hours in winter, in afternoon hours in summer. The diurnal variation in amount is discussed by Hann (Lehrbuch der Meteorologie, 3d ed., p. 343 and following) somewhat as follows:

> The diurnal variation in precipitation is a rather complicated phenomenon. In the course of the day there occur in most places two maxima and minima, frequently three. Not infrequently it is scarcely possible to recognize any sort of regular trend in the hourly averages. Studies of available records do not warrant making a concise statement of the general characteristics of diurnal variation in intensity of rainfall; one can only present some of the more distinct types. * * * In the continental type of the temperate zone, there is a principal maximum in the afternoon and a lesser maximum in the early morning hours, while the prominent minimum occurs between midnight and 4 a. m., and a secondary minimum between 8 a. m. and noon. In the oceanic type, the times of principal maxima and minima are the reverse of those in the continental type.

4. Kincer has shown that during the season of April to September, inclusive, there is a marked predominance of daytime precipitation over nighttime precipitation in the States along the Gulf of Mexico as far west as Galveston, Tex., and an equally pronounced excess of nighttime precipitation in the Central Plains region. (See vol. 44 of this REVIEW for 1916, pp. 628–633.) Whether considered with respect to the amount, frequency, or total duration of the precipitation, the dominance of daytime rains in the