tures with respect to the line of best fit, and satisfactorily represent them on a larger scale. The line fluctuates above and below the line of 54.8 with a gradually decreasing range. In later years, however, there is a markedly abnormal departure of the line from the line of best fit. To what extent this represents a real departure from a linear, horizontal trend, or whether it is only a temporary departure, can not now be determined.

The fluctuations of the normals computed by methods (2) and (3) illustrate the characteristics previously pointed out. Those of (2) follow more closely the averages, with, however, a lag of variable amount, increasing with length of record.

The reason for regarding these values as the best available approximation to the normal lies in the fact that large departures of the averages from the computed normal, as in 1882, 1888, 1900, 1905, and 1916 are likely to be only temporary. In the case of the persistent departures above normal in the latter years we have no reason to assume that there will not be later on a return to averages below normal, and hence are not justified in disregarding the normal as computed. If, however, the abnormal conditions persist, the computed normals will gradually be adjusted to the change. The values by method (3), being more stable, should be regarded as the best approximation to the true normal.

The essence of the method consists in the assignment of relatively less weight to the latter values of a series, which insures greater stability. It must not be regarded, however, as an improvement on the ordinary method of averaging for a short series, or before the averages have become fairly stable.

HOURLY PRECIPITATION AT SYRACUSE, N. Y.

By MORGAN R. SANFORD, Meteorologist.

[Weather Bureau, Syracuse, N. Y.]

Popular interest in the study of rainfall distribution over the 24 hours of the day appears to be growing. Among other questions the following are being asked: "Does the total rainfall during the morning usually exceed that during the afternoon?" and "Is it more liable to be rainy in the morning or in the afternoon?" Careful examination of records covering several years has furnished considerable interesting information.

Pioneer work in this field was done by Blanford for Calcutta and by Draper for New York City.[1] Using seven-year periods prior to 1885, both of these found that the amount of rainfall was greater from noon to midnight than from midnight to noon. Fassig, using a 10-year period ending with 1902, has shown the same to be true regarding Baltimore.[2] He takes the months separately and shows the emphasis in the warmer months and the evident influence of the thunderstorm. Cox and Armington have shown the same true for Chicago over a 10-year period ending with 1911[3]. That there is considerable variation over the United States with respect to the relative amounts of daytime and nighttime rainfall has been shown by Kincer[4] in his study of a 20-year period ending with 1914. The rainfall from 8 p. m. to 8 a. m. over central New York, April to September, inclusive, he shows to be about 45 per cent of the total, while that over central Nebraska is 65 per cent of the total amount.

Hourly rainfall may be considered not only with respect to frequency and amount, but also with regard to duration, that is the length of time that rain may be falling during each of the 24 hours. Mindling has made a study of this latter subject for Philadelphia[5] and shown its importance in its direct relation to outdoor activity. Although both are important, attention is directed in this connection not to frequency nor duration of rainfall, but is confined solely to hourly amounts. Since some of of the precipitation during early April and late November at Syracuse, N. Y., is in the form of snow that interferes with the operation of the tipping-bucket rain gage, it has been thought best, for the sake of accuracy, to confine this study to the months from May to October, inclusive.

The rainfall for each of these months during the 20-year period, 1903–1922, has been considered separately, and the totals shown in the table and accompanying chart represent the accumulated depth in inches for each hour of the 24. The hourly totals for the six months are also indicated.

TABLE 1.—*Total hourly rainfall, 1903 to 1922, Syracuse, N. Y.*

	May to October, inclusive.											
	1	2	3	4	5	6	7	8	9	10	11	12
May:												
A. M.	3.69	2.07	2.15	2.29	1.66	2.04	2.77	2.08	1.91	1.40	2.08	2.27
P. M.	1.54	1.84	2.04	2.68	3.20	3.37	3.52	3.19	2.51	2.74	2.57	2.26
June:												
A. M.	1.82	2.54	2.43	2.33	2.49	3.43	3.74	2.95	3.10	2.21	2.49	2.97
P. M.	2.66	5.28	3.91	4.71	8.20	4.26	3.65	3.97	4.80	3.70	3.30	2.54
July:												
A. M.	1.10	0.92	1.47	1.84	1.90	1.90	2.16	1.81	2.25	1.58	2.00	3.42
P. M.	3.29	3.10	5.21	4.07	3.86	6.05	5.63	6.25	2.22	2.47	1.27	1.47
August:												
A. M.	1.77	2.66	3.02	2.75	2.16	2.64	2.78	2.00	1.37	1.56	2.47	2.18
P. M.	1.54	4.31	4.63	3.64	2.50	4.52	2.82	4.33	2.36	1.25	1.93	1.54
September:												
A. M.	2.67	2.37	1.73	3.73	2.06	1.88	2.15	2.22	1.54	1.24	1.22	1.02
P. M.	1.61	1.76	1.40	1.96	2.36	2.67	3.23	3.33	2.80	1.70	2.21	1.91
October:												
A. M.	2.00	2.27	2.11	2.41	2.70	1.97	2.22	3.08	2.18	2.38	1.68	1.61
P. M.	1.62	2.21	1.87	2.05	1.68	2.98	3.47	3.14	3.11	3.18	2.05	1.66
Totals:												
A. M.	13.0	12.8	12.9	15.4	13.0	13.9	15.8	14.1	12.4	10.4	11.9	13.5
P. M.	12.3	18.5	19.1	19.1	21.8	23.8	22.3	24.2	17.8	15.0	13.3	11.4

Two facts are brought out clearly in this chart of the hourly distribution of rainfall. In the first place there is an afternoon maximum and a late forenoon minimum; and secondly, this feature is emphasized in the warmer and fades out in the cooler months. Something similar

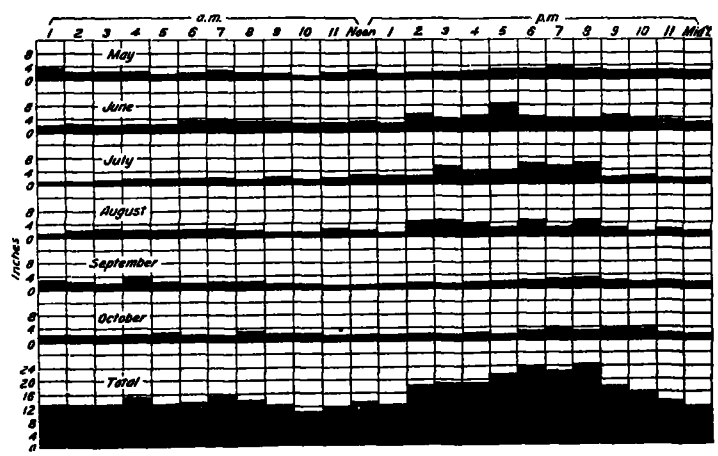

FIG. 1.—Accumulated depths of rainfall for each hour and for each month, May to October, at top and for the six months at bottom.

[1] American Weather, by Gen. A. W. Greely, p. 155.
[2] Oliver W. Fassig in Maryland Weather Service, Vol. II, p. 165.
[3] The Weather and Climate of Chicago, by Prof. Henry J. Fox and J. H. Armington, p. 203.
[4] Joseph Burton Kincer, MO. WEATHER REV., November, 1916, 44: 628–633.
[5] George W. Mindling, MO. WEATHER REV., November, 1918, 46: 517–520.

has also been shown by Nunn to be true in the rainfall of Nashville, Tenn.[6] Though on a slightly different basis, these Syracuse results agree closely with Kincer's calculation. The amount of rainfall over this period for the 12 hours ending at 8 a. m. is 45 per cent of the total, but for the 12 hours, midnight to noon, only 42 per cent of the total amount. Considering individual hours it is found that the hour ending at 10 a. m. receives the least amount and the hour ending at 8 p. m. the greatest, 2.2 times as much as the former. The three hours ending at 8 p. m. receive twice as much as the three hours ending at 11 a. m.

These results are what are naturally to be expected as effects of the forenoon warming and afternoon cooling combined with the occurrence of thunderstorms. In general, the month with the greater number and the more energetic thunderstorms has the greater afternoon rainfall. The hump shown in the June record is due in part to a violent storm on the 17th in 1922, when 2½ inches of rain fell between 4 and 5 p. m.

[6] Roscoe Nunn, Mo. WEATHER REV., April, 1922, 50: 180–184.

In marked contrast with the preceding summer is that of 1923, with a few thunderstorms and those of little energy, frequently with faint thunder and light rainfall. The total rainfall during six separate thunderstorms in August was 0.30 inch, and the greater portion of the rainfall during the summer months came during the forenoon hours, this being 58 per cent of the total amount.

These results have led the writer to two definite conclusions: In the first place, that the summers of 1922 and 1923 show opposite extremes in convectional and electrical conditions as well as in rainfall amount and hourly distribution; and secondly, that a period much longer than 20 years should be covered in order to make possible any satisfactory discussion of rainfall.

EFFICIENCY OF SMOKE SCREENS AS A PROTECTION FROM FROST.

By H. H. KIMBALL, Meteorologist, Weather Bureau, and B. G. MACINTIRE, U. S. Chemical Warfare Service.

[Washington, August 23, 1923.]

SYNOPSIS

At Edgewood Arsenal, Md., a field was covered with dense smoke, by burning white phosphorus, on nights when conditions favored frost. The temperatures were carefully measured under and in the smoke, and also in a similar nearby field that was free from smoke. Also, the rate at which heat was radiated from a blackened surface exposed horizontally was measured both under and outside the smoke cloud.

The results show that while the smoke cloud decreased the rate of cooling of the blackened surface about one half, it had little effect upon the air temperature, probably because of an interchange between the air under the smoke and that outside. The slight increase in temperature noted under and in the smoke apparently was due principally to heat imparted to the air by the hot particles constituting the smoke.

The experiments confirm previous conclusions that the most efficient and economical method of frost protection is to heat the lower layers of the air by burning some form of cheap fuel.

The cost of maintaining a dense smoke cover over a field by burning white phosphorus, or by any other known chemical means, is greater than the cost of heating the air in the field by burning crude oil.

INTRODUCTION.

Since the close of the World War numerous inquiries have been addressed to both the Weather Bureau and the Chemical Warfare Service relative to the practicability of utilizing a smoke cloud, such as is used to hide the movement of troops, in protecting orchards and tender vegetation generally from frost. There seems to be a conviction in the minds of many who have had to do with smoke screens that a chemically produced smoke cloud would furnish a cheaper, cleaner, and, perhaps, more effective, frost protection than is obtained from the combustion of crude oil or other fuels.

The Weather Bureau has already made a study of the part played by smoke from burning crude oil in protecting vegetation from damage by frost.[1] The conclusion reached was that "The retardation of nocturnal radiation by the smoke cloud plays an insignificant part in frost protection."

DETAILS OF THE PROJECT.

In the above study by the Weather Bureau it was difficult to completely separate the effect of the smoke cloud in retarding nocturnal cooling from the heating effects of the combustion of the oil. Therefore, the Weather Bureau very gladly availed itself of the privilege extended to it by the Chemical Warfare Service of utilizing the facilities of the Edgewood Arsenal, Edgewood, Md., in conducting jointly with that Service experiments on the efficiency of smoke in retarding nocturnal cooling.

[1] Kimball, Herbert H., and Young, Floyd D.: Smudging as a protection from frost. Mo. WEATHER REV., August, 1920, 48: 461–462.

This cooperative project called for the maintenance by the Chemical Warfare Service of a dense smoke cloud for a period of about four hours over an area of approximately five acres on a night with little or no wind and a clear sky. The cloud was to be produced by such material as would most economically give the desired results, and in such a manner that the heating of the air by the combustion of material would be a minimum.

On its part the Weather Bureau was to determine the extent to which nocturnal cooling was retarded by the smoke cloud on nights when the meteorological conditions were favorable for frost formation.

EXPERIMENTAL FIELD SELECTED.

The field used in carrying out the tests was selected from the standpoint of convenience in handling the equipment and raw material required and is designated "M" field. The "M" field is located on the Gunpowder River, surrounded by woods on three slides. Two areas, of a few acres each, separated by a few trees and located about one quarter mile from the water front on "M" field, were selected for the installation of the instrument shelters to be referred to later.

SOURCE OF SMOKE.

White phosphorus was used as the smoke-producing material in all tests, as white phosphorus was readily available in sufficient quantities and as it had the property of producing more smoke per unit weight than other materials.

When phosphorus is burned in the presence of air or oxygen, phosphorus pentoxide, a solid substance, is produced, which in turn readily unites with atmospheric moisture, producing meta phosphoric acid, a liquid. A phosphorus smoke cloud consists of a mixture of the two substances, (phosphorus pentoxide and meta phosphoric acid) the ratio of the two being dependent on the humidity of the atmosphere and the rapidity with which the phosphorus is burned.