PRECIPITATION PROBABILITY AT DENVER RELATED TO LENGTH OF PERIOD

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ABSTRACT

The variation of precipitation probability or expectancy at Denver as related to length of period is considered. Periods of 1 minute to 15 days are tabulated. Graphs are drawn to permit easy interpolation for periods of intermediate length

1. INTRODUCTION

Precipitation is a discontinuous meteorological element. The problem of occurrence or non-occurrence of a discontinuous element during a period of specified time-length is dependent on the length of time specified, as well as on other variables such as location, season, time of day, etc. Thus, a brief shower of rain of only a few minutes duration can verify the occurrence of precipitation during any time-length specified, whether it be an hour or several days. This paper deals with the variation of precipitation probability at Denver, Colo., during time-length periods varying from 1 minute to 15 days.

Study of the probability or expectancy of precipitation lies within the realm of climatology. Landsberg [1] states that "quantity" is an incomplete description of precipitation and he lists "frequency" as additional desirable information. Partial studies of precipitation probability have been made for many years. A tabulation of the number of days with 0.01 in. or more during a month is part of most local climatological studies. Measurement of precipitation at 12-hr. intervals during early days of the Weather Bureau, and the issuance and verification of forecasts using the same time interval, resulted in studies of precipitation probability for the 12-hr. interval. Blair [2] found that the winter precipitation probability at Dubuque, Iowa, was 24 percent for the 12-hr. period, and rose to 45 percent for the 24-hr. period. When he used only those periods having measurable precipitation (0.01 in. or more) the result was a probability of 11 percent for the 12-hr. period and 22 percent for the 24-hr. period. Conrad [3] found the probability of precipitation for the 2-hr. period at Blue Hill Observatory to be 17 percent in winter and 11 percent in summer. Belden [4] compiled data giving the mean monthly duration of precipitation at St. Joseph, Mo. This mean duration when divided by the total time gives the probability of precipitation during any random minute. The Extended Forecast Branch of the Weather Bureau has published the probability of no precipitation for 5-day periods for many stations in western United States during certain months. The present paper attempts to show a relatively complete spectrum of precipitation probability for Denver, Colo.

2. METHOD

Data for this study included the years 1949 through 1958. The entire body of data was used in studying periods of 1 minute to 12 hours. For periods of 1 day to 15 days all months were adjusted to 30-day length. This was done by using the first 30 days of all months, omitting the last day of 31-day months. February was lengthened to 30 days by extending it one or two days into March as necessary. This adjustment to 30-day length was made in order that the same precipitation would be used in periods of all lengths. The 30-day month is exactly divisible by all time period lengths studied. This results in all periods being mutually exclusive except the last period of February, which extends into the first period of March. The last period of February and the first period in March can include some of the same precipitation.

Percentage of 1-minute periods having precipitation was found by compiling the total duration of precipitation and dividing this by the total time and multiplying by 100. This value appears only in tables and graphs of a trace or more, as in most cases the fall of 0.01 in. is the accumulation of previous minutes. Since the method of obtaining the probability from 1 minute periods differs from the method used in the rest of the study it does not properly belong in the same series; moreover, because of diurnal variations, none of the probabilities for periods less than 1 day properly belongs to the series for longer periods. But the data for these periods are included because of their value for some of the purposes of this study. Extension of this study to time periods longer than 15 days was considered, but this was abandoned when it was found that for the 15-day period the probability of a trace or more had reached 95 percent or more for all seasons, and the probability of 0.01 in. or more had reached 85 percent or more.

For periods of 1 hour or more the 30-day period was divided into the appropriate time-length periods by beginning at 0000 MST of the first day. Thus, for 3-hr. periods the first period was 0000 MST to 0300 MST, the second period 0300 to 0600 MST, etc. The occurrence of a trace or more or of 0.01 in. or more during each period was tabulated. The total of occurrences of each type was divided by the total number of periods of that time length. This was multiplied by 100 to give a percentage value of the probability.

3. RESULTS

Table 1 shows the probability of a trace or more of precipitation at Denver, Colo., for periods varying in length from 1 minute to 15 days, by months, by seasons, and for the year. Table 2 shows the same data for precipitation of 0.01 in. or more. Figures 1 and 2 show for each season the precipitation probability as plotted against time periods of different length. A smooth curve has been drawn through the points for each season. The

TABLE 1.—*Percent of periods of various length in which a trace or more of precipitation occurred, 1949–1958, Denver, Colo.*

	Minute	Hours						Days						
	1	1	2	3	4	6	12	1	2	3	5	6	10	15
Dec.	6	7	9	9	10	12	16	23	36	42	58	62	77	90
Jan.	11	12	14	15	16	18	23	32	49	62	77	82	87	95
Feb.	10	11	13	14	15	18	23	33	51	66	80	86	100	100
Winter	9	10	12	13	14	16	21	29	45	57	72	77	88	95
Mar.	14	16	18	19	21	24	32	42	62	70	85	88	93	100
Apr.	13	17	19	22	24	28	35	48	66	77	93	94	97	95
May	12	16	20	22	25	29	39	57	70	80	92	94	100	100
Spring	13	16	19	21	23	27	35	49	66	76	90	92	97	98
June	7	11	14	17	19	24	34	53	75	82	97	94	100	100
July	6	10	14	18	20	26	36	59	78	90	100	100	100	100
Aug.	4	9	13	16	19	24	36	58	78	92	97	98	100	100
Summer	6	10	14	17	20	24	36	57	77	88	98	97	100	100
Sept.	4	6	8	9	10	14	21	32	50	64	78	86	97	100
Oct.	6	8	9	10	11	13	18	27	40	49	70	72	90	95
Nov.	9	11	12	13	14	16	22	27	43	52	67	76	90	95
Autumn	6	8	10	11	12	14	20	29	44	55	72	78	92	97
Year	8	11	13	15	17	20	28	41	58	69	83	86	94	98

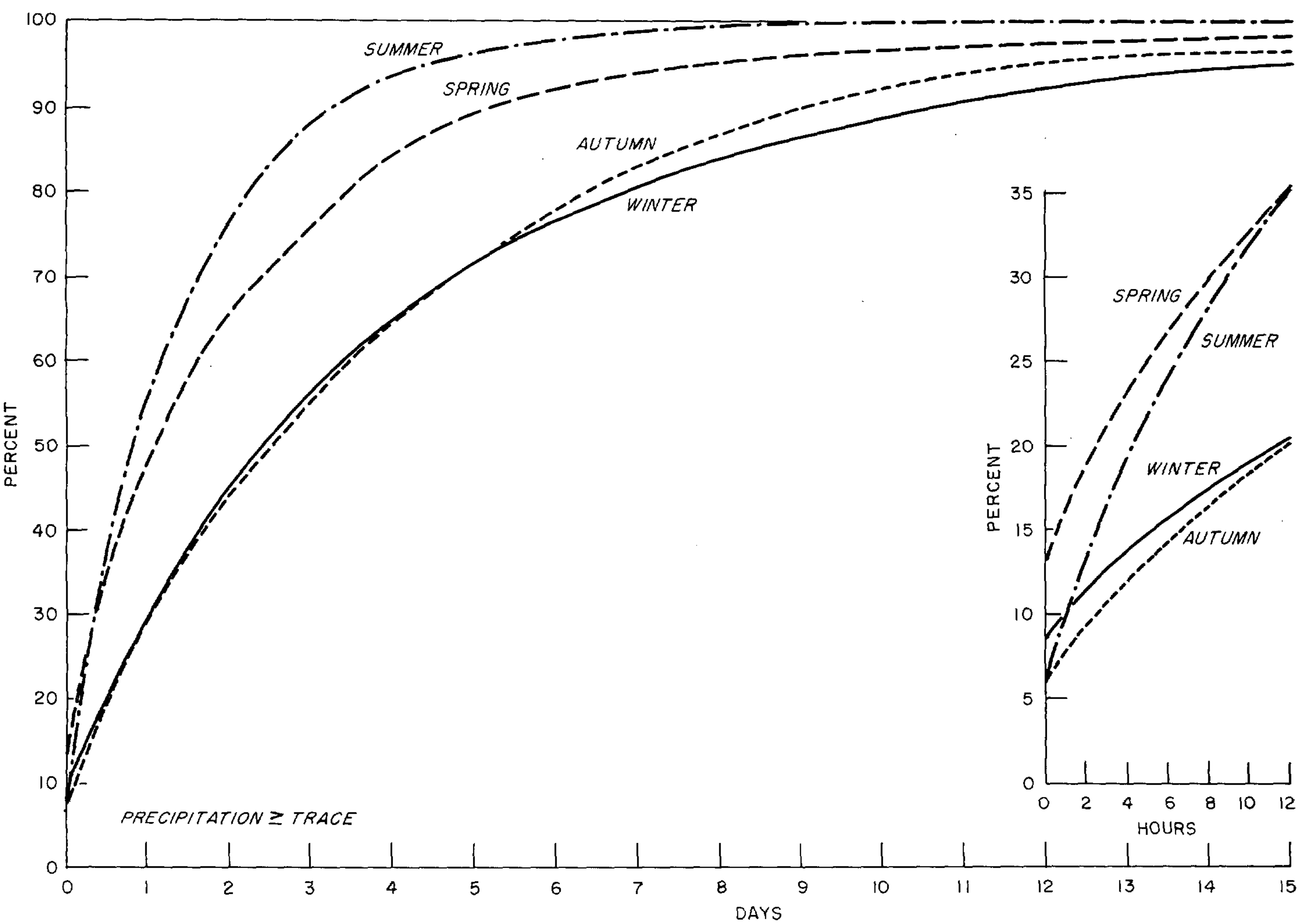

FIGURE 1.—Climatological probability of precipitation (trace or more) for periods of different length. Insert gives curves on expanded scales for 12-hr. or shorter periods.

TABLE 2.—*Percent of periods of various length in which 0.01 in. or more of precipitation occurred, 1949–1958, Denver, Colo.*

	Hours						Days						
	1	2	3	4	6	12	1	2	3	5	6	10	15
Dec	3	3	4	4	5	8	13	22	28	38	46	60	85
Jan	4	5	6	7	8	11	19	30	38	55	58	80	85
Feb	4	5	6	7	8	12	19	31	41	58	64	83	95
Winter	3	4	5	6	7	10	17	28	36	51	56	74	88
Mar	6	7	9	10	12	17	26	43	53	67	78	87	95
Apr	7	9	11	12	15	22	33	50	60	77	80	87	90
May	8	10	12	13	15	22	33	47	63	77	78	97	100
Spring	7	9	11	12	14	20	31	47	59	73	79	90	95
June	4	6	7	9	11	18	33	47	61	82	84	97	100
July	4	5	7	8	11	17	31	50	62	85	84	100	100
Aug	3	4	6	7	9	15	27	46	59	75	76	97	100
Summer	3	5	6	8	10	17	30	48	61	81	81	98	100
Sept	2	3	4	4	5	9	16	25	33	47	50	70	90
Oct	3	4	5	5	7	10	15	25	31	43	50	67	80
Nov	4	6	7	7	9	13	19	30	40	50	60	77	90
Autumn	3	4	5	6	7	11	17	27	35	47	53	71	87
Year	4	6	7	8	9	14	24	37	47	63	67	83	93

probability of precipitation for periods intermediate to those computed can be estimated from these curves. On figure 2, the points for 5- and 6-day periods for summer failed to fit a smooth curve. Their position off the curve is indicated. It was felt that this poor fit was due to the chance nature of summer thundershower activity and the limitations of a 10-year sample, and that the drawing of a smooth curve was justified.

An attempt was made to fit a portion of the hyperbola to the data, but the fit was not sufficiently close throughout to warrant inclusion in this paper. In the meantime, in reviewing the original manuscript, Caskey [5] found that the curves in figures 1 and 2 are closely approximated by a simple Markov chain probability model. The results of his analysis are contained in a note following this paper.

The determination of the diurnal variation of precipitation probability was not attempted in this study, though it is known that during summer months this is an important factor in Denver. Cook [6] made a rather exhaustive study of diurnal variation of summer precipitation for Denver for the years 1919–1938. Using his data for total hours with precipitation during any hour by the clock, the percentage probability of precipitation was computed for each hour of the day. These percentage

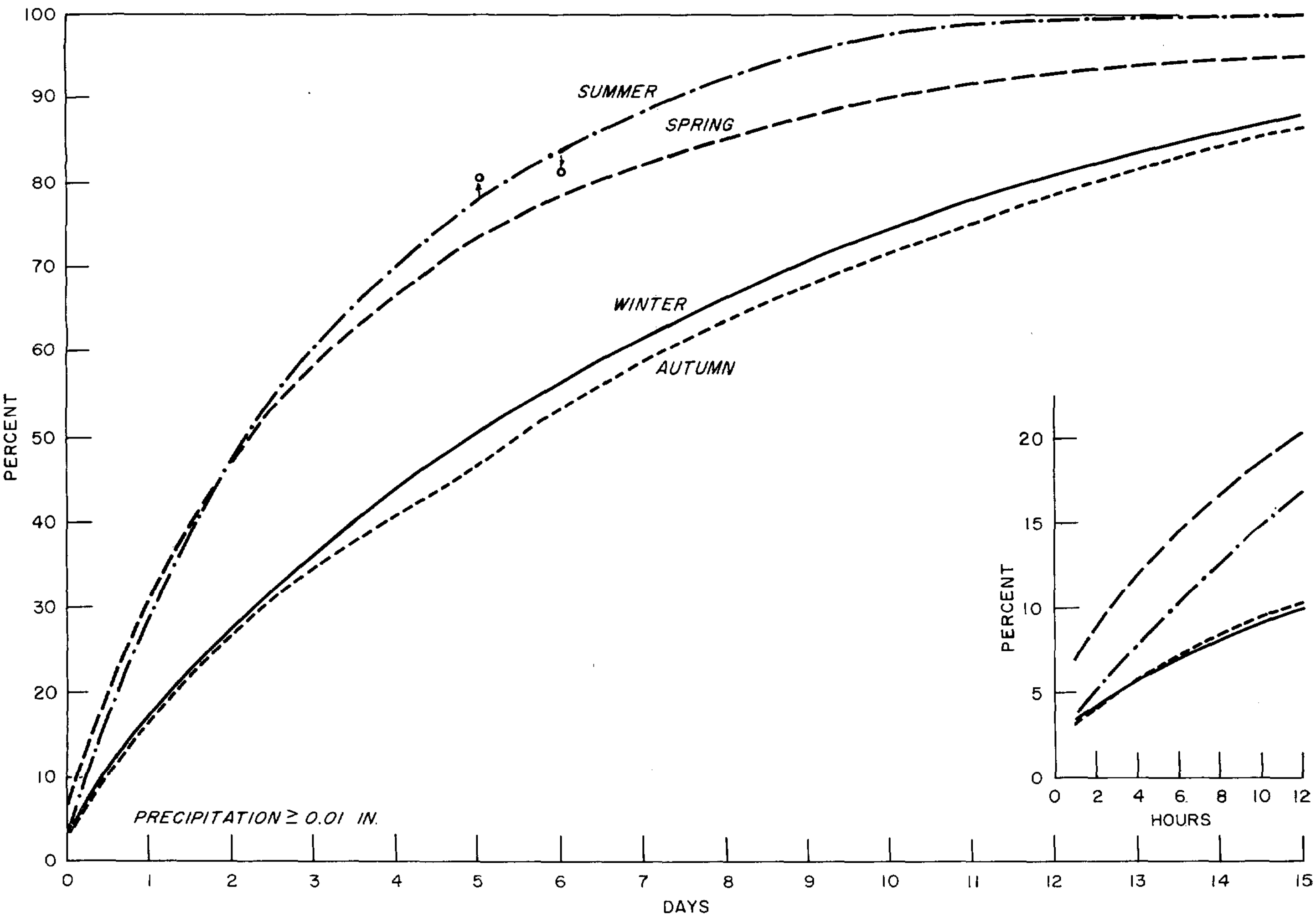

FIGURE 2.—Climatological probability of precipitation (0.01 in. or more) for periods of different length. Insert gives curves on expanded scales for 12-hr. or shorter periods.

TABLE 3.—*Precipitation probability during summer at Denver, Colo., for hour (MST) ending:*

	a.m.												p.m.											
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	12
Trace or more	3.5	3.6	3.2	2.6	2.7	3.5	3.3	2.5	2.4	1.9	2.2	5.1	8.5	13.1	15.3	15.2	21.9	20.7	19.3	15.4	14.0	10.5	8.4	6.0
0.01 in. or more	2.1	2.0	1.9	1.5	1.0	1.1	0.8	0.9	0.9	1.0	0.9	1.1	1.9	4.4	4.9	5.4	7.4	8.3	6.5	6.0	5.8	5.1	4.1	2.5

probabilities for a trace or more and for 0.01 in. or more appear in table 3. Figure 3 shows the precipitation probability for any one hour as plotted against the time of day during the summer months at Denver.

4. DISCUSSION

There are several possible uses of climatological probabilities. In the case of precipitation forecasting, for periods of more than a few days in the future, the climatological probability is often the best forecast that can be made. The climatological probability of precipitation for a 1-day period has long been available, but this may not be the length of period that is desired. A farmer may feel that his "cut hay" must lie in the field to dry for two or more days, or the farmer may wish to know the probability of his ripe grain being rained upon before he can harvest it. This requires information on rainfall probability for periods of two or more days in length. This information is not simply related to the 1-day probability, for as indicated in table 2, the precipitation probability in summer for a 1-day period is 31 percent, for a 2-day period 48 percent, for a 3-day period 61 percent, etc. In the case of sports or other outdoor activities, shorter-period probabilities may be useful. It would not be the best forecast to use the 1-day probability of 31 percent as the likelihood of getting measurable precipitation during a spring baseball game which is completed in 3 hours and so has a precipitation probability of only 11 percent.

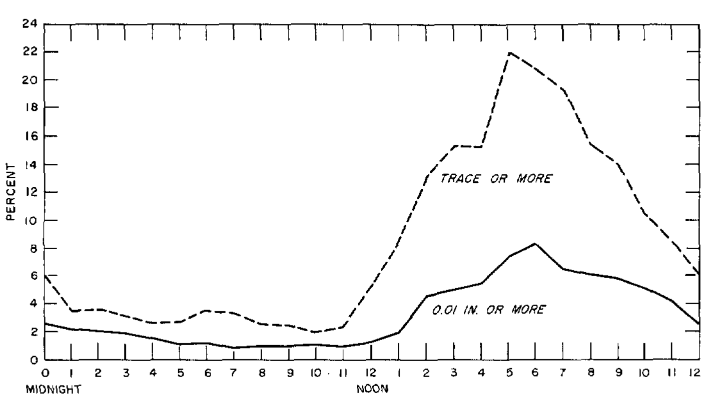

FIGURE 3.—Probability of precipitation during any hour* of the day in summer (June, July, August) 1918–1938 (data from A. W. Cook [6]). (*For hour ending at time indicated on abscissa.)

Climatological probability is an important forecast tool and becomes embedded in that vast fund of knowledge often referred to as a forecaster's experience. This knowledge, like other tools, must be used correctly or it may result in incorrect conclusions. An incorrect use of precipitation probability results when forecast periods are combined for comparison with other forecasts of different length. This is incorrect because the climatological probability for the original length of period was one of the tools used in making the forecast, and if the forecaster had known that the periods would be combined for verification he would have used the climatological probability for the longer period and might have issued a different forecast. Thus Beebe [7] should not have combined 12-hr. period forecasts made by Weather Bureau forecasters for comparison with 24-hr. forecasts made by an objective system which had automatically incorporated a 24-hr. probability. As can be seen from table 2 (had these forecasts been made for Denver), for the summer season at Denver the 12-hr. forecasts would have been made with only a climatological probability of 17 percent, and this is the probability the forecaster would have incorporated in his forecast. The objective system, in making a forecast for a 24-hr. period, would have a climatological probability of 31 percent, and thus would have an unfair advantage at that length of period.

This also indicates the advantage of developing objective aids to forecasting for periods of the same length as the period the forecaster must use. If an objective aid forecasts precipitation during a period that is two or more times as long as the regular forecast period, the forecaster must still decide which, if any, of the subperiods will have more than a 50-percent chance of precipitation, as the probability of a longer period may not be divided simply into two or more shorter periods.

When forecasts are verified on the sliding system, that is, when the forecaster is allowed to include precipitation that falls on one or two days on either side of his forecast date in verifying his precipitation forecast, the climatological probability of success increases greatly. Using measurable precipitation (0.01 in. or more) in spring, the 1-day probability of precipitation is only 31 percent. If the forecaster is allowed an additional day on either side of his forecast date, this 3-day probability is 59 percent, while 2 days on either side results in a 5-day probability, or 73 percent. A long-range soothsayer who claims about 75 percent accuracy but asks for a day or two leeway in verification of his forecasts may be claiming no more than climatological probability, though to his followers he appears very skillful.

5. CONCLUSION

This study shows the variation in percentage probability of precipitation at Denver, Colo., ranges from around 10 percent or less for time periods of an hour or less, to around 90 percent as the length of the time period is extended to 15 days. This information can be used in estimating the expectancy of precipitation for different length time periods that are so far in the future as to be beyond the scope of synoptic methods.

The use of the probabilities by months (tables 1 and 2) instead of by seasons (figs. 1 and 2) is recommended since there are some marked changes in values from one month to another within the same season. However, because the number of cases of 10- and 15-day periods contained in only 10 years of monthly data is small, it would be desirable to base the probability estimates on a longer record, say 30 years, in order to improve their reliability. The magnitude of the work required suggests that a computer program be prepared to do the job. The use of a high-speed computer not only would make it practicable to process more than 10 years of data by months but would provide a way for efficiently performing this kind of analysis of precipitation probabilities for all first-order Weather Bureau stations.

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