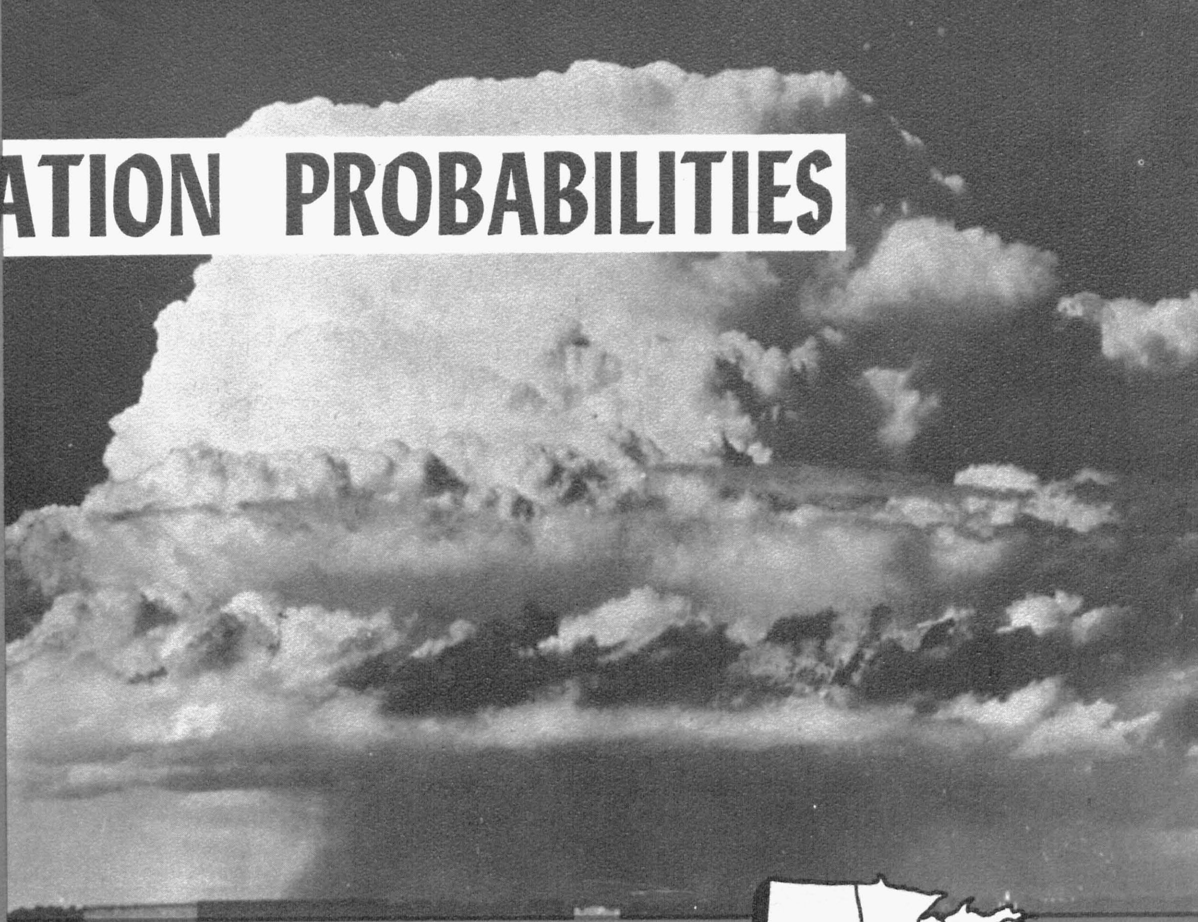
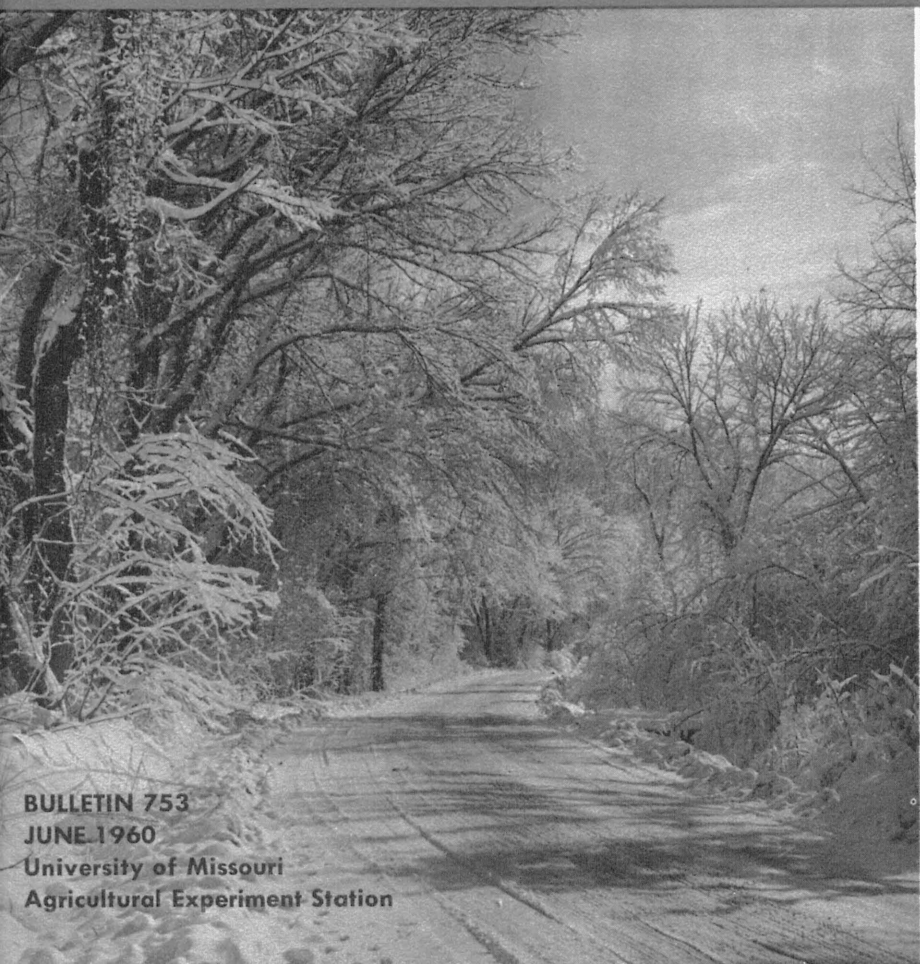
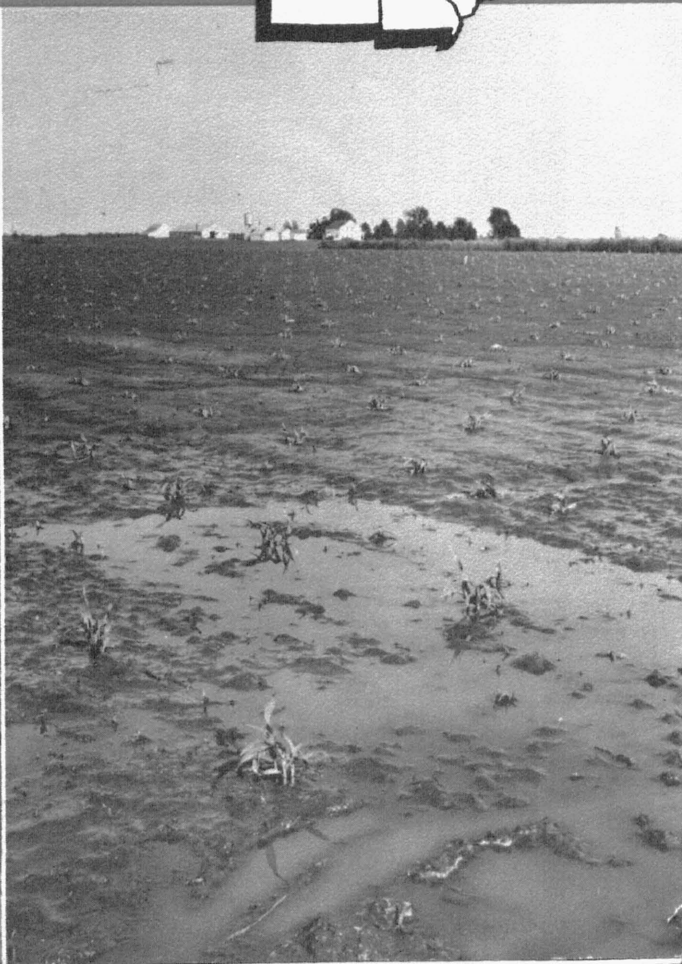
PRECIPITATION PROBABILITIES

In The NORTH CENTRAL STATES



NORTH CENTRAL REGIONAL PUBLICATION NO. 115. Agricultural Experiment Stations of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and the U. S. Department of Agriculture cooperating.





BULLETIN 753
JUNE 1960
University of Missouri
Agricultural Experiment Station

Cooperators

This report summarizes the precipitation probability study which was made under the direction of the North Central Regional Technical Committee, NC-26, on "Weather Information for Agriculture". Representatives of each state have assisted in the transfer of the original data to the punched cards used in this study. All members of the committee have furnished advice and assistance during the progress of the analysis. Special recognition is due W. L. Decker for supervising the publication of the bulletin.

Representatives of the following states and federal agencies participated in this study:

Representative	*State or Agency*	*Institution*
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R. H. Shaw	Iowa	Iowa State University
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R. F. Dale	U.S. Dept. of Commerce	Weather Bureau

Contents

PRECIPITATION PROBABILITIES IN THE NORTH CENTRAL STATES

BY ROBERT H. SHAW, GERALD L. BARGER AND ROBERT F. DALE[1]

The analysis of precipitation probabilities in a large area such as the North Central Region of the United States requires the handling of a large volume of data. To reduce this volume, certain decisions were necessary. How dense a network should be used? How long a period of record should be selected? What technique should be used? Questions such as these were resolved by the NC-26 Committee.

It was decided to use the 54-year period from March, 1901, through February, 1955, as the length of record. At some stations this length was not attainable; at others, a longer record was available and was sometimes used to increase the length of record or to substitute for missing years. The maximum length record used was 61 years, the minimum 25, but only 10 stations had less than 40 years of record, and only four had greater than 55 years. (2,3)

A network of approximately 10 stations in most states was believed to be adequate for regional analysis. The total number analyzed was 125 for the 12 states as shown in fig. 1.

Two alternatives for determining probabilities were considered:

1) Computing the probabilities directly from the tabulated frequencies.
2) Fitting a mathematical function to these tabulations and computing the probabilities from this function.

It was believed that the latter method would produce more accurate probabilities by bringing all the observed amounts into play and removing class interval bias resulting from observing and tabulating practices. The method of analysis selected involved the fitting of the incomplete gamma distribution to precipitation totals. [Thom (6, 7), Barger and Thom (1), Friedman and Janes (5) and Barger, Shaw and Dale (2, 3)]

In selecting the length of period to be used, there was considerable interest in a short period, such as 3 days. However, the distribution used does not adequately fit such periods, and precipitation totals for 1-, 2- and 3-week periods starting every week of the year were selected as those to be analyzed. The precipitation levels for which probabilities have been computed are: none or trace, at least 0.02, 0.06, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.4, 2.8, 3.2, 4.0, 6.0, 8.0 and 10.0 inches. Single copies of the complete results are filed with each cooperating State Agricultural Experiment Station and each State Climatologist, U. S. Weather Bureau, for his respective state, and for all 12 states at the National Weather Records Center, Asheville, North Carolina.

To conserve space, probabilities of only the following precipitation amounts were presented by Barger, Shaw and Dale (2), and the 1-, 2- and 3-week periods, respectively, were contiguous throughout the year, but not overlapping.

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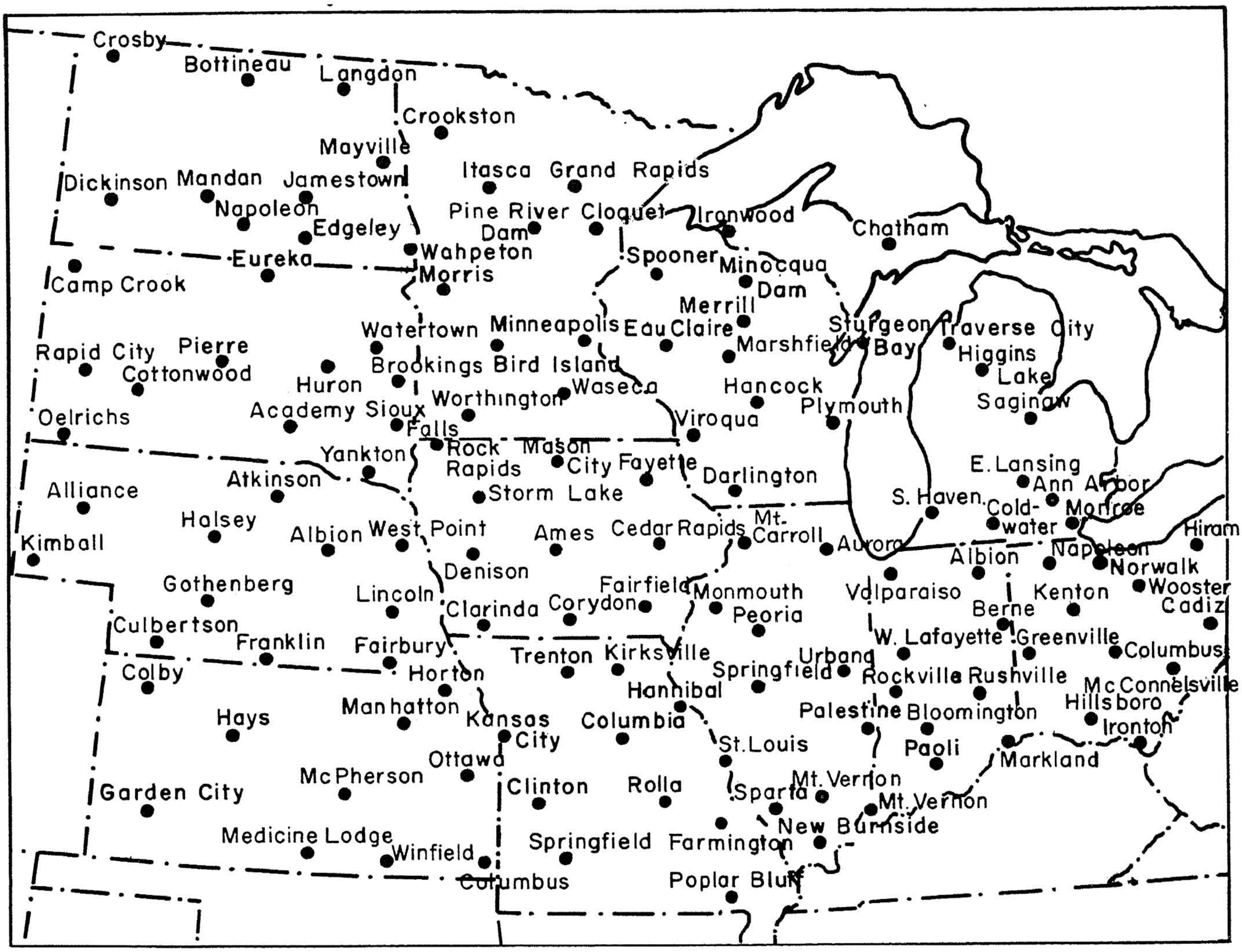

Fig. 1. Stations used in precipitation probability study.

1-week	2 - or 3-week
0 or T (less than 0.01)	0 or T (less than 0.01)
at least 0.1	at least 0.2
" 0.2	" 0.4
" 0.4	" 0.6
" 0.6	" 0.8
" 0.8	" 1.0
" 1.0	" 1.4
" 1.2	" 2.0
" 1.6	" 2.8
" 2.0	" 4.0
" 2.8	" 6.0
at least 4.0	at least 8.0

In total, there were 52, 26 and 17 sets for the 1-, 2- and 3-week periods, respectively, published in their tables.

These estimated probabilities are subject to error, of course, and the error is greater for 1-week totals than for 2- or 3-week totals. As a very rough approximation, the individual values published in (2) are correct within ±0.05 to 0.20 with an expectancy of 0.95. However, the smoothing techniques used in the regional analysis presented here will modify this somewhat and should reduce the overall magnitude of the errors. We emphasize though, that unsmoothed, empirical frequencies are subject to the same error, plus definite bias in individual class intervals because of the relatively short periods of record generally available in this country. Further, the fitted curve allows a small probability of experiencing amounts beyond the greatest precipitation total observed to date, and the parameters and nomograms in (3) can be used to estimate the probability of receiving any desired amount.

Constant Probability Analysis

The 1-, 2- and 3-week precipitation totals were analyzed for the probability of receiving a certain amount of precipitation, for example, 0.1 or 2.0 inches. They could also have been analyzed on a constant probability basis, which would have shown the amount of precipitation having a set chance of occurring during any given period. In fig. 2, we have presented two charts of this type. These show the amount of precipitation which is exceeded in 70% of the years during March 1-21 or June 28-July 18. Similar maps for any selected probability level for any 1-, 2- or 3-week period can be constructed from the data presented in (2).

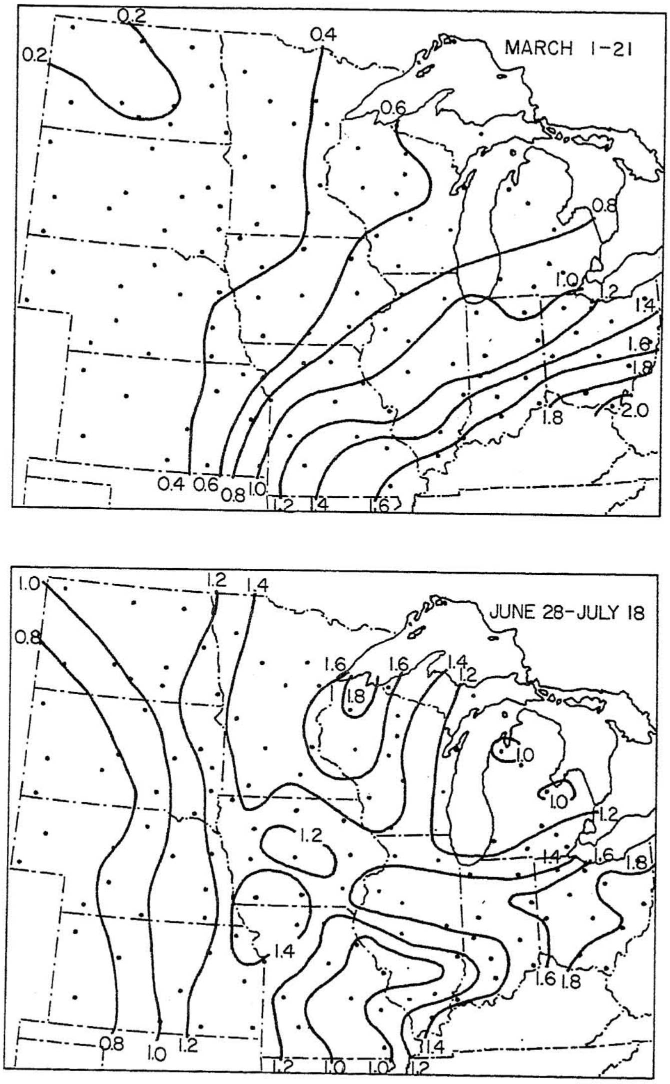

Fig. 2. 3-week precipitation totals (inches) exceeded 70 years in 100.

Constant Precipitation Amount Analysis

To characterize the annual pattern for each amount of precipitation, 10 stations stratified over the region were selected, and annual curves of their precipitation probabilities were plotted. Four of these stations—Alliance, Nebraska; Ames, Iowa; Urbana, Illinois; and Wooster, Ohio—provide a west to east transect across the region. These can be classified as representing the west central, central, east-south central and eastern areas of the region. Bottineau, North Dakota, was selected for the northwest, Garden City, Kansas, for the southwest, Spooner, Wisconsin, for the north central and Higgins Lake, Michigan, for the northeast area, although the latter does not represent the areas in the immediate vicinity of the Great Lakes. All eight of these stations will be shown in the figures to be presented. In addition, Pine River Dam, Minnesota, in the north central area and Springfield, Missouri, in the south central area were drawn but are not presented in the figures given here because addition of another curve to each set would make reading difficult and provide little additional information. They will be discussed in the short narrative accompanying each set of charts, however, when they give significant additional information. Hereafter, whenever an area is referred to, such as south central, it means the South Central portion of the North Central Region.

Plotting of the original data, i.e. the probabilities computed by fitting the gamma distribution (2, 3), showed considerable variability from week to week, and it was considered necessary to remove some of this variability in presenting a regional analysis of the data. The weekly computed probabilities of the selected amounts of precipitation were plotted against time (the beginning of the period) and a curve drawn through a series of three-point moving averages; that is, an average of three 1-week, three 2-week or three 3-week values, whichever were being studied. In fig. 3, a sample of this procedure is shown. The points plotted are the original computed

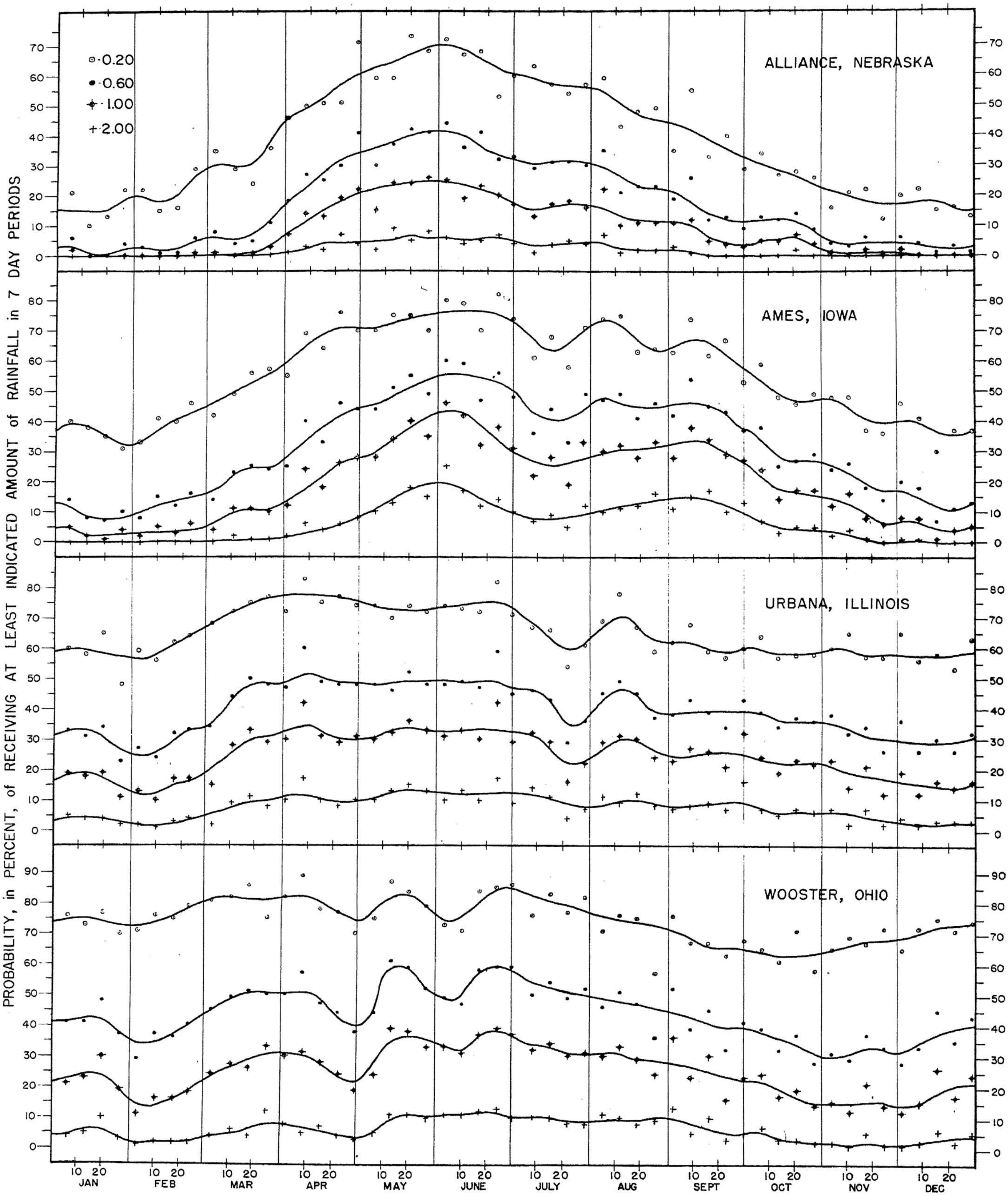

Fig. 3. Original data and smoothed curves for 0.2, 0.6, 1.0 and 2.0 inches of precipitation or more in 1-week periods at four stations.

values from the machine analysis (2). The curves shown are those drawn through the moving averages. Obviously this method is a compromise between fitting the curves mathematically and accepting the frequencies as they exist, with the short time singularities or random fluctuations, whichever they may be, present. Individual values which show considerable deviation from the average are smoothed out by this procedure, and the peaks or low points in the curve may not coincide exactly in time with individual high or low points, as three values determine each individual moving average. Thus, the longer period fluctuations are retained, but most of the short period singularities or random fluctuations are removed.

To show the regional pattern of precipitation, it is necessary to show regional maps for selected periods and amounts of precipitation. From the large number of maps which could be presented on the computed probabilities, it is necessary that a few be selected for publication, simply because of space and cost limitations. From a study of 52 weekly maps for several levels of precipitation, it appeared that six maps, selected out of the 52 possible for each amount of precipitation, would typify the yearly pattern fairly well and could be reduced to a single page and still be very legible. The beginning dates of these six maps are designated on the annual curves by arrows.

The dates selected were:

Beginning Date	Week No.	Beginning Date	Week No.
March 15	3	July 26	22
April 26	9	Sept. 13	29
June 14	16	Jan. 10	46

These weeks all include the 1st or 15th of a month and are based on the climatological year (2,3) starting March 1. The 2- and 3-week periods also begin with these dates.

The levels of precipitation selected for presentation were:

1-week

0 or trace
0.1 in. or more
0.2 in. or more
0.4 in. or more
0.6 in. or more
0.8 in. or more
1.0 in. or more
1.4 in. or more
2.0 in. or more
2.8 in. or more } (text only)
4.0 in. or more } (text only)

2-week

0 or trace
0.2 in. or more
0.4 in. or more
0.6 in. or more
1.0 in. or more
1.4 in. or more
2.0 in. or more
2.8 in. or more
4.0 in. or more
6.0 in. or more } (text only)
8.0 in. or more } (text only)

3-week

0 or trace
0.2 in. or more
0.6 in. or more
1.0 in. or more
1.4 in. or more
2.0 in. or more
2.8 in. or more
4.0 in. or more
6.0 in. or more
8.0 in. or more } (text only)
10.0 in. or more } (text only)

These amounts of precipitation were selected so that there was generally only a 10 to 15% change in the probability from one map to the next. To accomplish this, the interval between precipitation levels becomes greater as the precipitation increases. The highest amount for which maps are presented has a maximum probability in the Region near 20%, and this is usually confined to a small area for a short time. The higher precipitation amounts discussed only in the text have a low probability of occurrence.

In analyzing these maps, only intervals of 10% are drawn, except for 1 and 5% and 95 and 99%. Analyzing in greater detail is not very meaningful since the standard error of the computed probabilities is of the order of 0.10. For a discussion of the errors in the probability estimate, the reader is referred to Barger *et al.* (2) and Friedman and Janes (5). Individual stations which depart from the trend are smoothed out, except in the region of the Great Lakes. The purpose of the analysis presented here

TABLE 1--MONTHLY AND ANNUAL PRECIPITATION (AV. 1931-55) FOR 12 NORTH CENTRAL REGION STATIONS

STATION	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	ANNUAL
Urbana, Ill.	2.3	2.1	3.4	3.5	4.2	4.5	3.3	3.2	3.2	3.2	2.6	2.0	37.4
Albion, Ind.	2.2	1.6	2.3	2.6	3.2	3.8	3.4	3.5	2.9	2.9	2.4	1.8	32.7
Ames, Iowa	1.1	1.1	1.9	2.5	4.0	5.5	3.2	3.9	3.3	2.0	1.6	1.1	31.4
Dodge City, Kan.*	0.5	0.8	1.2	2.3	2.9	3.0	2.6	2.7	1.7	1.6	0.9	0.5	20.6
Higgins Lake, Mich.	2.1	1.6	2.0	2.5	2.9	3.5	3.3	3.0	3.6	3.0	3.0	2.1	32.5
Pine River Dam, Minn.	0.8	0.7	1.3	2.2	3.7	4.4	3.3	3.9	2.4	1.9	1.3	0.7	26.5
Springfield, Mo.	2.3	1.8	3.2	4.3	5.0	5.6	3.2	4.0	3.9	3.4	2.8	2.2	41.5
Alliance, Neb.	0.4	0.4	0.9	2.0	2.8	2.8	1.7	1.6	1.3	0.8	0.5	0.4	15.6
Bottineau, N. D.	0.5	0.4	0.7	1.0	2.0	3.8	2.6	2.6	1.4	0.8	0.4	0.4	16.4
Wooster, Ohio	2.8	2.0	3.3	3.1	3.8	3.9	3.8	3.5	2.7	2.3	2.2	2.2	35.6
Pierre, S. D.	0.4	0.6	1.2	1.5	2.4	3.2	1.7	2.0	1.1	0.9	0.5	0.5	16.0
Spooner, Wis.	0.8	0.7	1.4	2.2	3.3	4.4	3.8	3.9	3.2	1.9	1.6	0.9	28.1

*Dodge City substituted for Garden City.

is to show regional trends, not individual station variations within a small area. Further work is being done in the Region to develop physical explanation of the precipitation patterns found.

Mean Annual Precipitation

To many individuals, the precipitation pattern within their own state is well known, but very little is known about precipitation in surrounding states. For those unfamiliar with precipitation amounts in the North Central Region, table 1 gives the average monthly precipitation amounts for 12 stations based on the U. S. Weather Bureau 25-year means, 1931-55.

Bias in 0 or Trace Precipitation

Whenever the probability of 0 or trace is greater than 0, the charts of P(0, T) in figs. 4, 5, 22, 23, 40 and 41 include a significant upward bias because of the tendency for small amounts of precipitation to occur undetected and be recorded as 0 or trace at climatological substations at which observations are taken only once a day (4). Of the 125 stations used in this study, 115 are of this type; only 10 are first order Weather Bureau stations from which reliable estimates of probabilities of 0, trace and low amounts of precipitation can be made. Comparisons of 1-week estimates of P(0, T) from climatological substations with those estimated for the station on the basis of adjacent first order records for six independent comparisons showed an average bias for the year of 124% [P(0, T) cooperative station/P(0, T) first order]. This means that the individual 1-week values of P(0,T) for all substations should be multiplied by a factor of 100/124, or 0.8, to reduce them to more reasonable values. Correction of the probabilities is not so easily achieved, however, since there seems to be an annual trend in the bias, both by ratio (percent) and actual difference from the first order estimate, and the use of the average correction factor would overcorrect probabilities for some areas and seasons and undercorrect others. Although generally there is greater bias in the winter than in summer—presumably because of the additional observational difficulties with snowfall—the differences exhibited between the six individual comparisons available did not seem to warrant wholesale correction of the P(0,T) values on the basis of an average seasonal curve, and the size sample was not sufficient to delineate corrections geographically. Therefore, the charts have been drawn for the uncorrected data from the 115 substations, but the actual probabilities for the 10 first order stations have been included on the chart to provide an idea of the bias. The general patterns should remain the same, but the range would be reduced. For example, the P(0,T) values for the week January 10-16 (fig. 5), when the bias approaches 150%, should probably range downward from a high of above 40% in Nebraska and South Dakota rather than from above 60% as depicted by the chart.

Although the opportunity for low precipitation bias decreases with increasing length of period (and chance of receiving measurable precipitation) the bias still persists where the 2- and 3-week estimates of P(0,T) are greater than 0. For example on figures 23 and 41 in weeks January 10-23 and March 15-28 the plotted Pierre and Huron, South Dakota probabilities indicate the P(0,T) charts about 5-10% too high in this area, but the bias becomes negligible further east and generally so in the west during the summer months.

In order to check the effect of this P(0,T) bias on the computed precipitation probabilities, the probabilities were recomputed in selected cases of maximum bias substituting .02 for the weeks with biased amounts of 0 or trace. The new probabilities for amounts of precipitation greater than 0.2 inch were usually within 1% of those already computed. While one might expect the bias to be prorated over the entire distribution—the probability of n-week precipitation above x inches = [1-P(0,T)] F(x;b,g)—the light amounts of precipitation, measured as 0 or trace, cause an upward bias in the parameter gamma, and a downward bias in the parameter beta. This apparently largely compensates for the bias in the measured precipitation probability, 1-P(0,T). Therefore, very nearly all the P(0,T) bias is reflected in the P(.01-.09) interval, with little error in the probabilities for amounts greater than 0.1 inch.

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1-WEEK PRECIPITATION PROBABILITIES

The 1-week precipitation probabilities show the minimum probabilities in the winter and the maximum generally in the April-June period. In the west, the time of reaching the maximum probability at the northern stations is somewhat later than at the southern stations. As the precipitation amounts get higher during the winter there are long periods in the west when the probability is near 0.

In the eastern part of the region, the probability of any selected amount of precipitation shows a relatively small annual fluctuation. Because of this, the maximum and minimum probabilities are often not very pronounced, and the minimum for smaller amounts of precipitation frequently occurs in September-October, rather than during the winter. The annual range in the northeast also is small. In other parts of the region the annual range is greater and the maximum and minimum probabilities are more pronounced.

For lighter amounts of precipitation, the absolute maximum probability is generally in the east, but for amounts above ¾ inch the absolute maximum is in the central or south central area. Springfield, Missouri, shows a pattern similar to Urbana, with the probabilities for heavier amounts being somewhat higher and the maximum probability for heavier amounts of precipitation is located in this general area.

In the winter, the highest probability occurs in the east and northeast, the lowest in the west. For light amounts of precipitation, the highest probability in April is in the east and northeast, but for heavier amounts this shifts to the southeast and south central areas. By June the probability is relatively uniform over much of the region, with the lowest probability in the west. Most areas show a decrease in probability in July, and by mid-August the lowest probability is in the west, with the rest of the region relatively uniform. The probability in the west continues to decrease; in the east it remains relatively uniform. There is a September secondary maximum for some amounts of precipitation in the central and northeast areas, and the highest probability at that time generally occurs in those areas. After September the probability declines, except in the eastern area, until the winter pattern is reached.

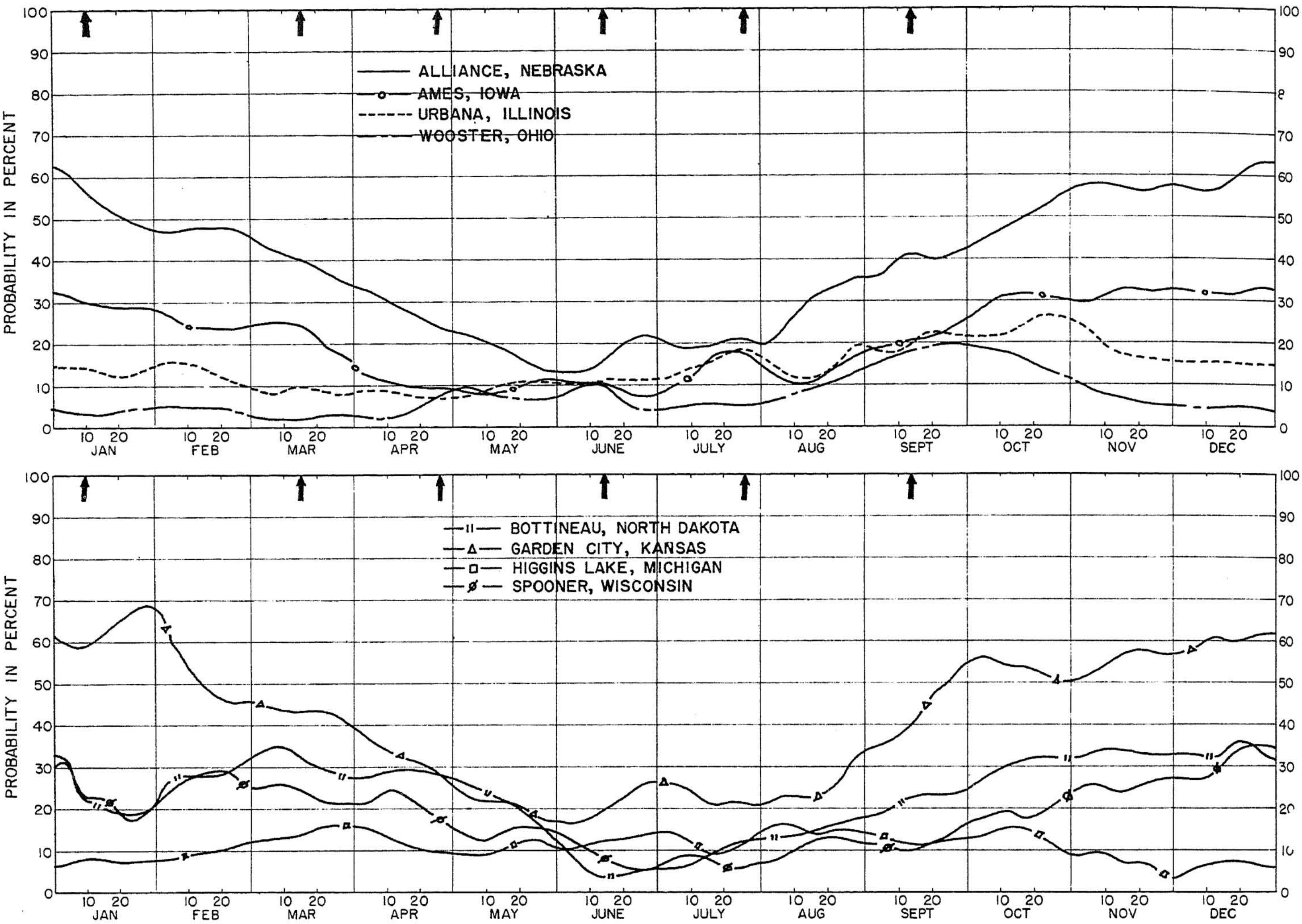

Fig. 4. Probability of receiving only 0 or trace precipitation in 1-week intervals at eight stations.

Probability of 0 or Trace

The probability of 0 or trace ranges from a maximum[2] of almost 70% to a minimum near 0. The extremes of probability range from near 0 to 20% at Wooster, near 5% to over 25% at Urbana, near 10 to 35% at Ames and less than 15 to 65% at Alliance. The maximum probability occurs in the winter months, except in the east, when it is in late September, and in the northeast, which has no definite maximum. The minimum generally occurs in June, except in the east and southeast, when it is in March-April, and in the northeast, when it is in late November.

In January, the probability ranges from less than 5% in the extreme east to over 60% in the southwest. The probability decreases throughout the region and ranges from 5 to 50% in mid-March. By late April the probability is near 10% in the eastern two-thirds of the region and near 20% in the west. There is little change in most areas by mid-June. By late July the probability ranges from near 10% over the eastern half to 30% in the southwest. After this date the probability increases, except in the north-east, and by mid-September ranges from 10 to 50% across the region. There is a continued increase in the probability, except in the east, until the winter pattern is reached in late October.

[2]See bias statement p. 13.

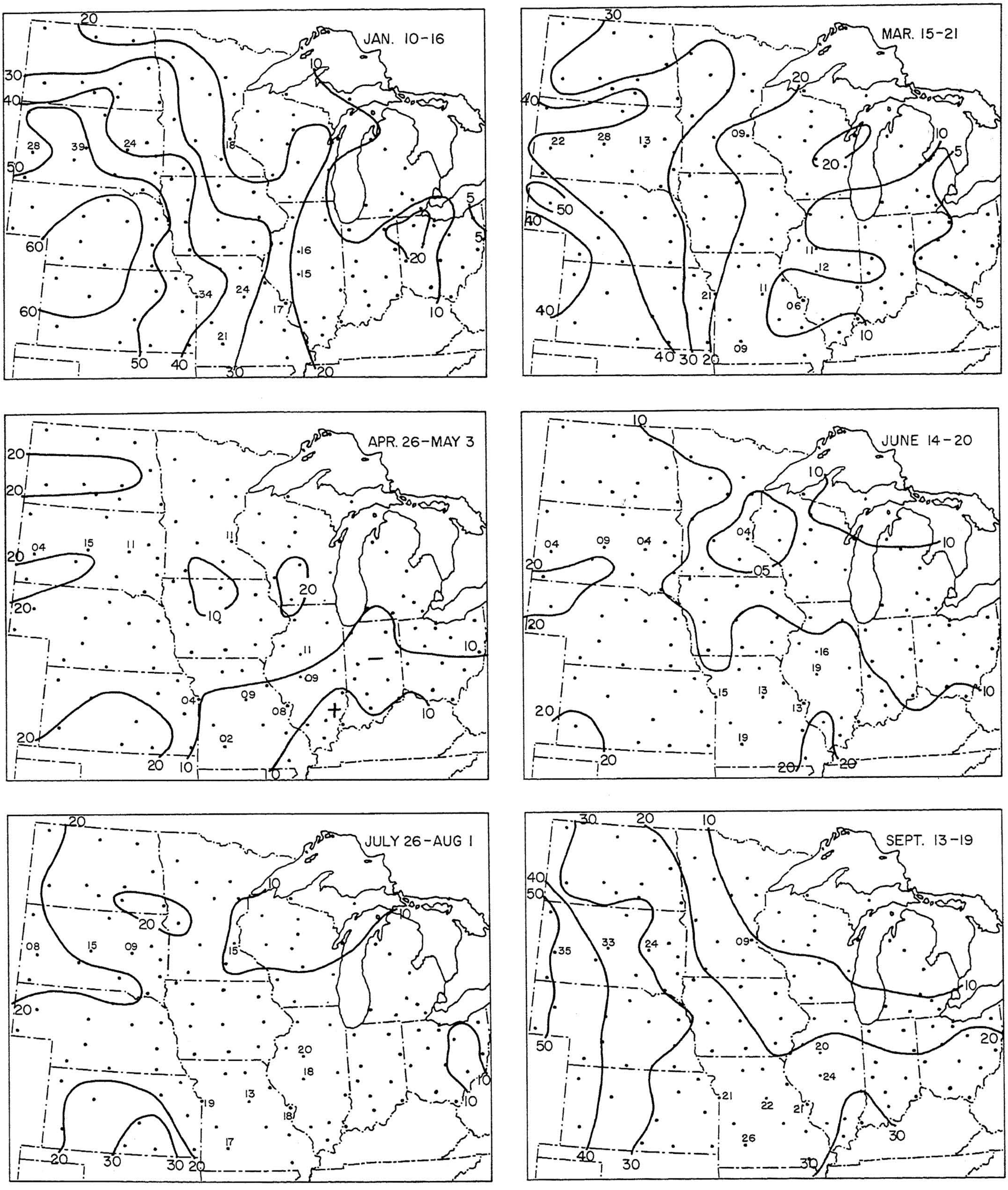

Fig. 5. Probability, in percent, of receiving only 0 or trace precipitation during 1-week intervals in six selected periods.

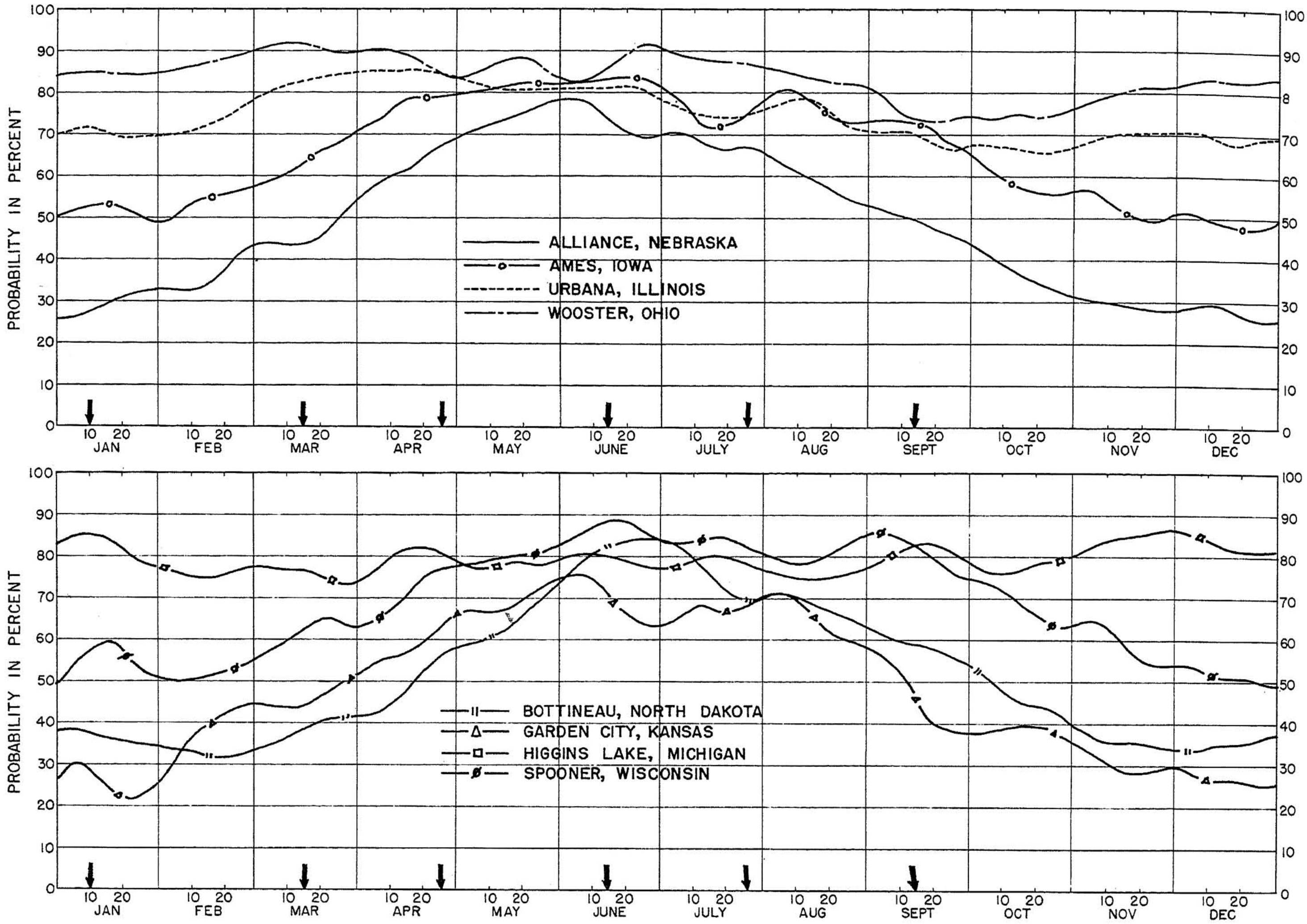

Fig. 6. Probability of receiving 0.1 inch or more precipitation in 1-week intervals at eight stations.

Probability of 0.1 Inch or More

The probability of receiving 0.1 inch or more ranges from 20% to over 90%. The extremes range from 75 to 90% at Wooster, 65 to 85% at Urbana, less than 50% to almost 85% at Ames and 25% to near 80% at Alliance. The minimum probability occurs in December-January, except in the east, where the minimum is in September-October, and in the northeast, where there is no definite minimum. The maximum probability is in June, except in the northeast, where there is no definite maximum, and in the south central, where the maximum is in April-May.

In mid-January, there is a definite west to east gradient with the probability ranging from 20% to over 80%. The probability in the west increases so that by early May much of the region is near 80%, ranging down to 60% in the northwest. In June, the probability over most of the region is 80-90%. With most of the region showing some decrease in July, the probability is generally 70-80% by late July. The western area continues to decline in probability, and by mid-September the probability over the region ranges from 40 to 90%, with the maximum probability in the Great Lakes area. There is a gradual decrease in probability in the west and little change in the east until the winter pattern is reached in November.

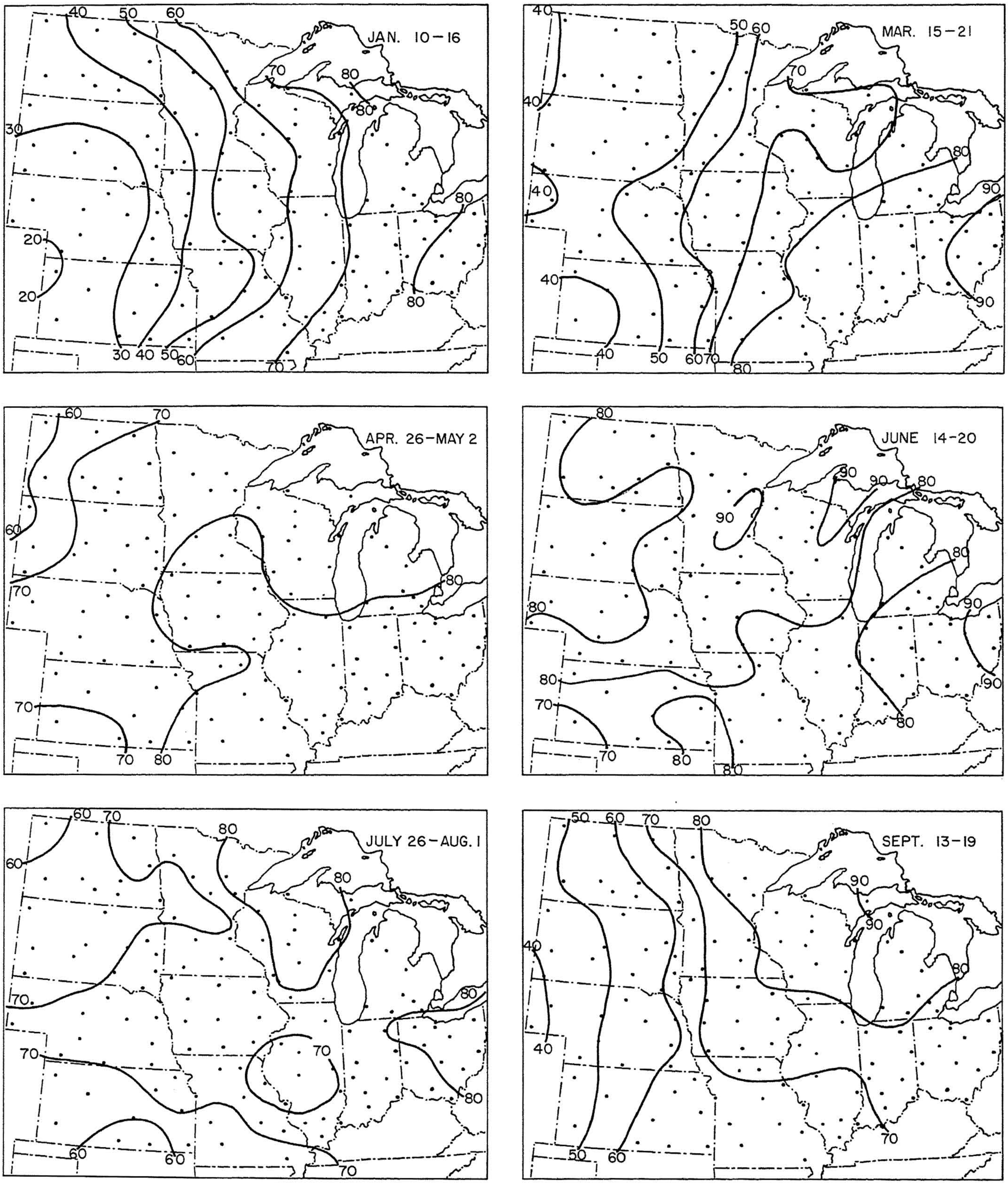

Fig. 7. Probability, in percent, of receiving 0.1 inch or more precipitation during 1-week intervals in six selected periods.

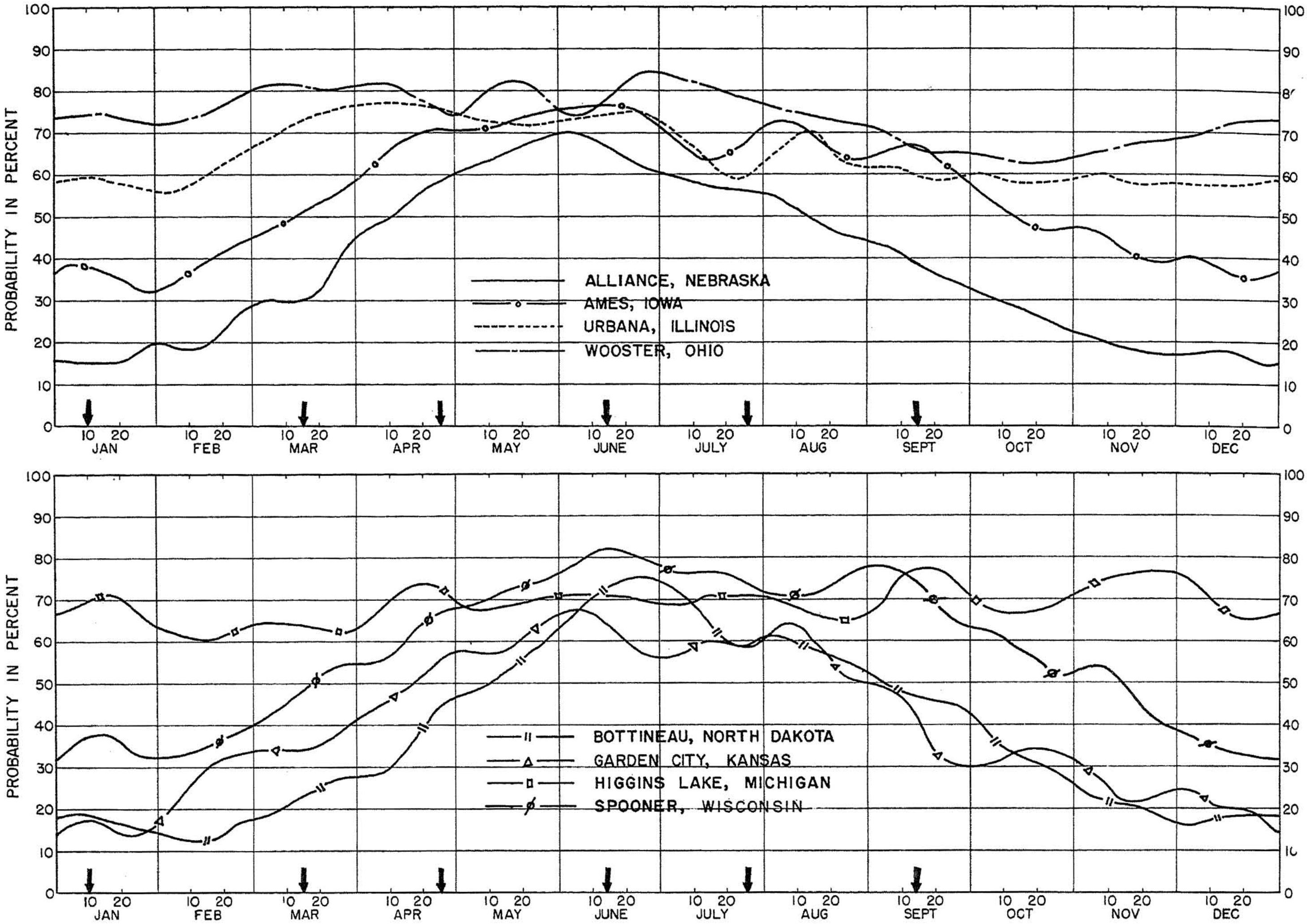

Fig. 8. Probability of receiving 0.2 inch or more precipitation in 1-week intervals at eight stations.

Probability of 0.2 Inch or More

The probability of receiving 0.2 inch or more ranges from 10% to over 80% across the region. The extremes range from 65 to 85% at Wooster, 55 to 80% at Urbana, 30 to 75% at Ames and 15 to 70% at Alliance. The minimum occurs in December-January, except in the northeast, which has no pronounced minimum, and in the east, where the minimum is in October. The maximum generally occurs in May-June, although it is not very pronounced in the east, and in the northeast it is in the fall.

The winter pattern shown for mid-January generally holds from mid-November to mid-February, when the probability generally increases. By mid-March it ranges from 30 to 80% across the region. The probability continues to rise, except in the east, and by early May ranges from 60 to 80%, with much of the region near 70%. By mid-June most of the region has a probability of 70-80%, with the maximum in the east and north central. There is a general decrease in the probability during July, and by late July it is near 70%, except for the western states where it is near 60%. The probability in the west continues to decrease and by mid-September ranges from 40 to 80% across the region, with the maximum in the northeast. The probability in the western half continues to decline, with some increase in the east and southeast, until the winter pattern is reached in mid-November.

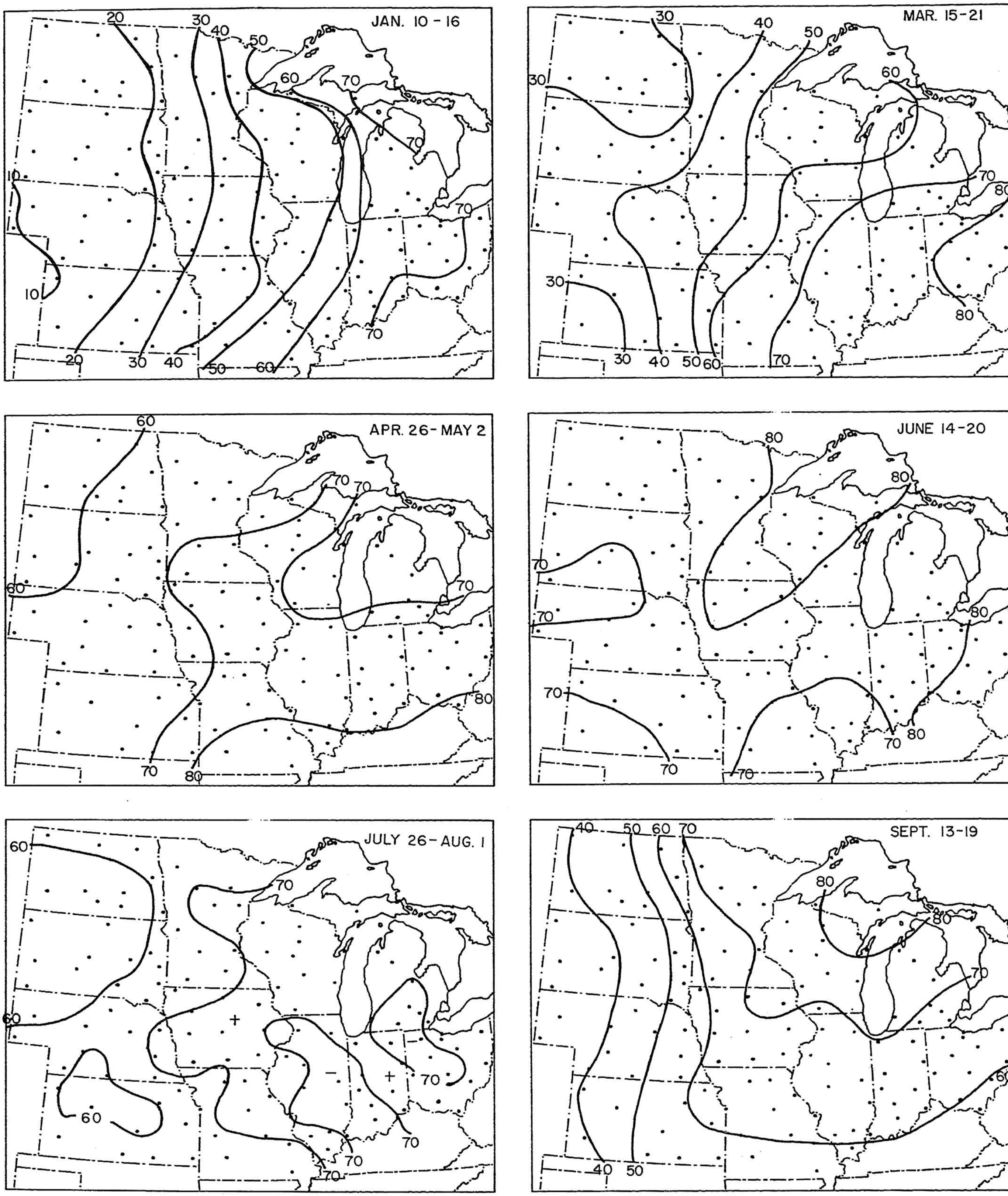

Fig. 9. Probability, in percent, of receiving 0.2 inch or more precipitation during 1-week intervals in six selected periods.

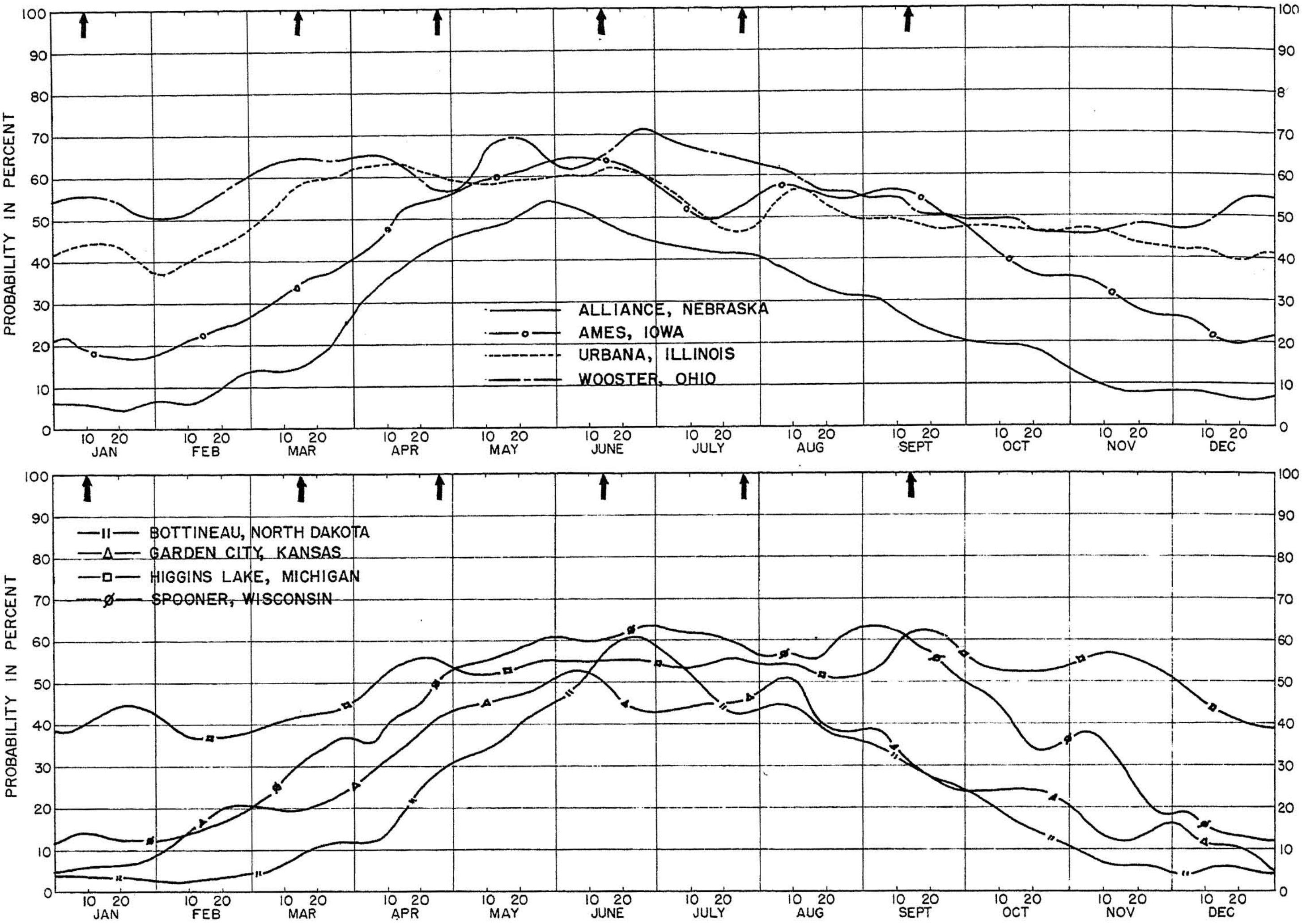

Fig. 10. Probability of receiving 0.4 inch or more precipitation in 1-week intervals at eight stations.

Probability of 0.4 Inch or More

The probability of receiving 0.4 inch or more ranges from less than 5% to over 70%. The extremes range from 45 to 70% at Wooster, 35 to 65% at Urbana, 15 to 65% at Ames and 5 to 55% at Alliance. The minimum probability occurs during the winter months, except in the extreme east, where it is in October-November. The maximum occurs generally in June, except in the south central area, where it is in April, and the northeast, where it is in September but is relatively uniform during the warm season.

The winter pattern holds from mid-November to mid-February, when the probability starts to increase, by mid-March ranging from 10 to 70% across the region, with the maximum still in the extreme southeast. By late April, the maximum of 70% has shifted to the south central area, and the probability has increased to 30% in the northwest and 50% in the southwest. With the probability continuing to increase in much of the region, except the south central, it ranges from 60 to 70% over most of the region in June. A general decrease occurs in July, and by late July the probability over most of the region is 50 to 60%. The probability in the west continues to decrease, but in the northeast shows some increase, and by mid-September the range across the region is 30 to 70% with the maximum in the northeast and a definite west to east gradient in the west. After this date, except for the extreme east and southeast, the probability declines until the winter pattern is reached.

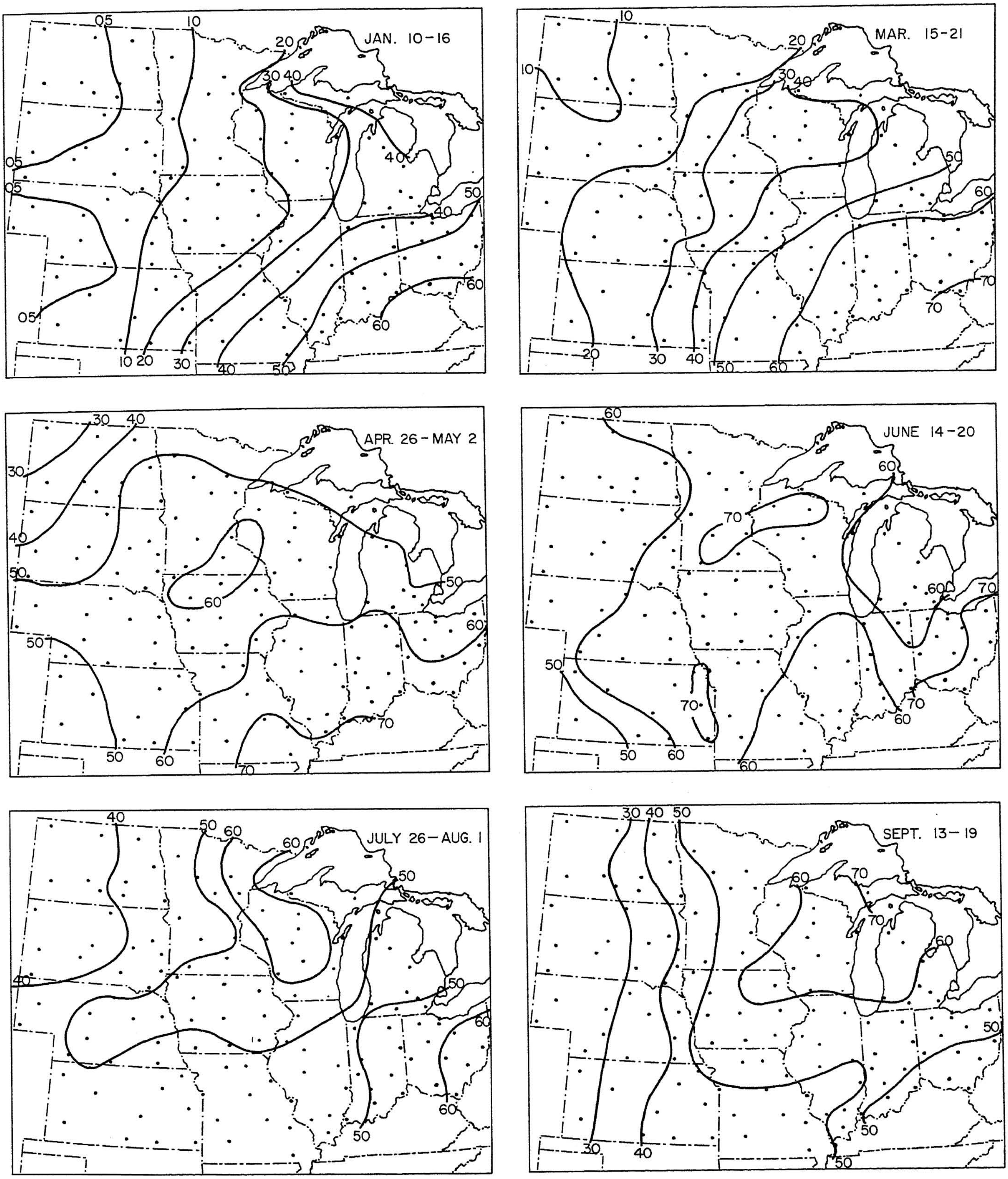

Fig. 11. Probability, in percent, of receiving 0.4 inch or more precipitation during 1-week intervals in six selected periods.

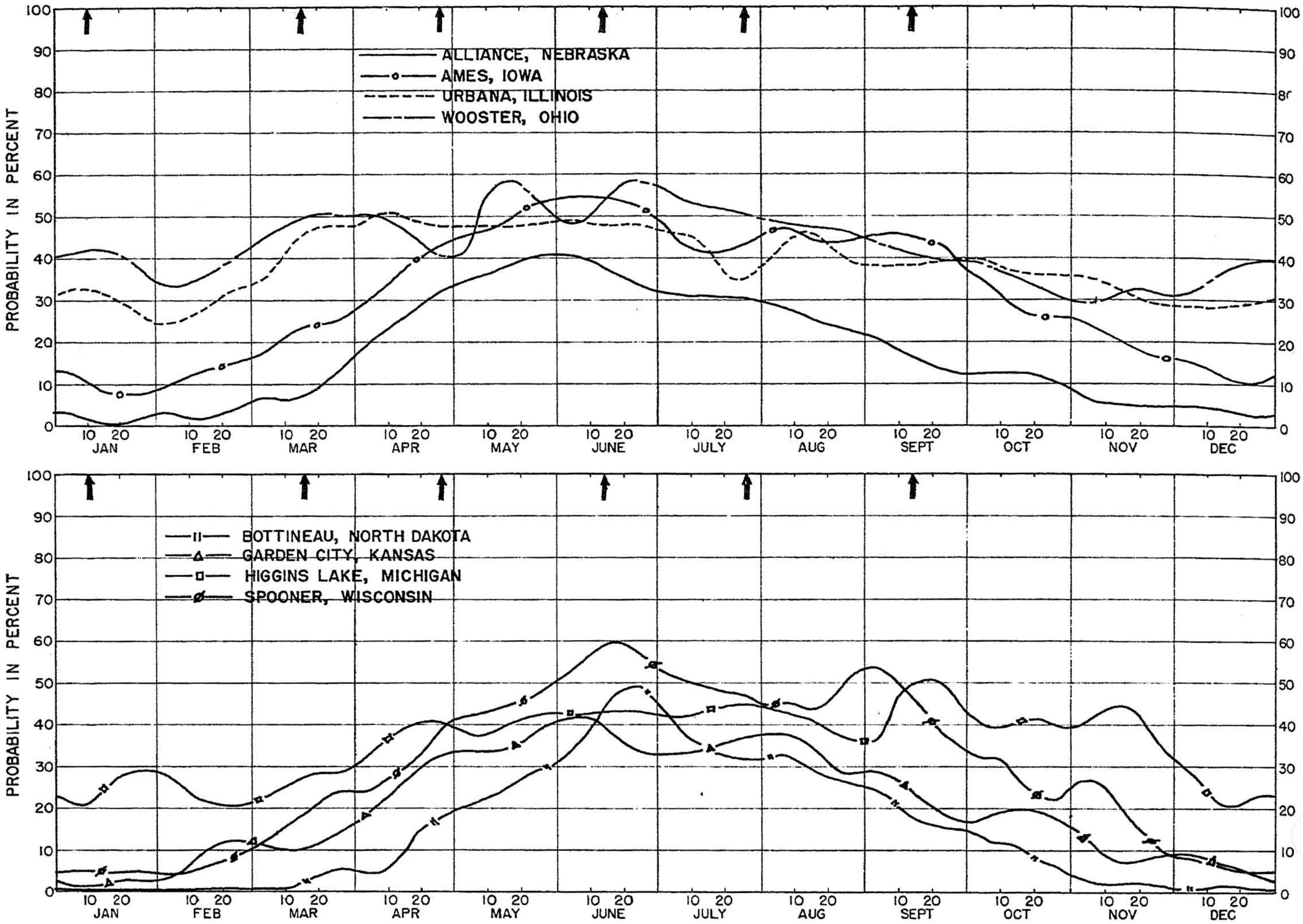

Fig. 12. Probability of receiving 0.6 inch or more precipitation in 1-week intervals at eight stations.

Probability of 0.6 Inch or More

The probability of receiving 0.6 inch or more ranges from near 0 to over 60%. The extremes range from 30 to 60% at Wooster, 25 to 50% at Urbana, near 10 to 55% at Ames and near 0 to 40% at Alliance. The minimum probability in all areas occurs during the winter months, while the maximum probability is generally in the May-June period, except in the south central area, which has an April-June maximum, and the northeast, which has a September maximum.

In mid-January, the probability ranges from near 0 to 50%, with the maximum in the southeast. The probability generally increases in February and by mid-March ranges from 10% to near 60% across the region. The probability continues to increase except in the east, and by late April ranges from 20% to over 60%, with the maximum in the south central area. After reaching its maximum at this time, the probability decreases in the extreme south central area, but increases in the north, so that by mid-June, except for the west, the probability is near 50% over the region. During July there is a general decrease, and by late July the probability ranges from 30 to 50% across the region with much of the region near 40%. The probability in the west continues to decrease. There is little change in the east, but an increase in the northeast, so that by mid-September the probability ranges from less than 20% to over 50%, with the maximum in the northeast. The probability remains relatively uniform in the east but decreases in the rest of the region until the winter pattern is reached in December.

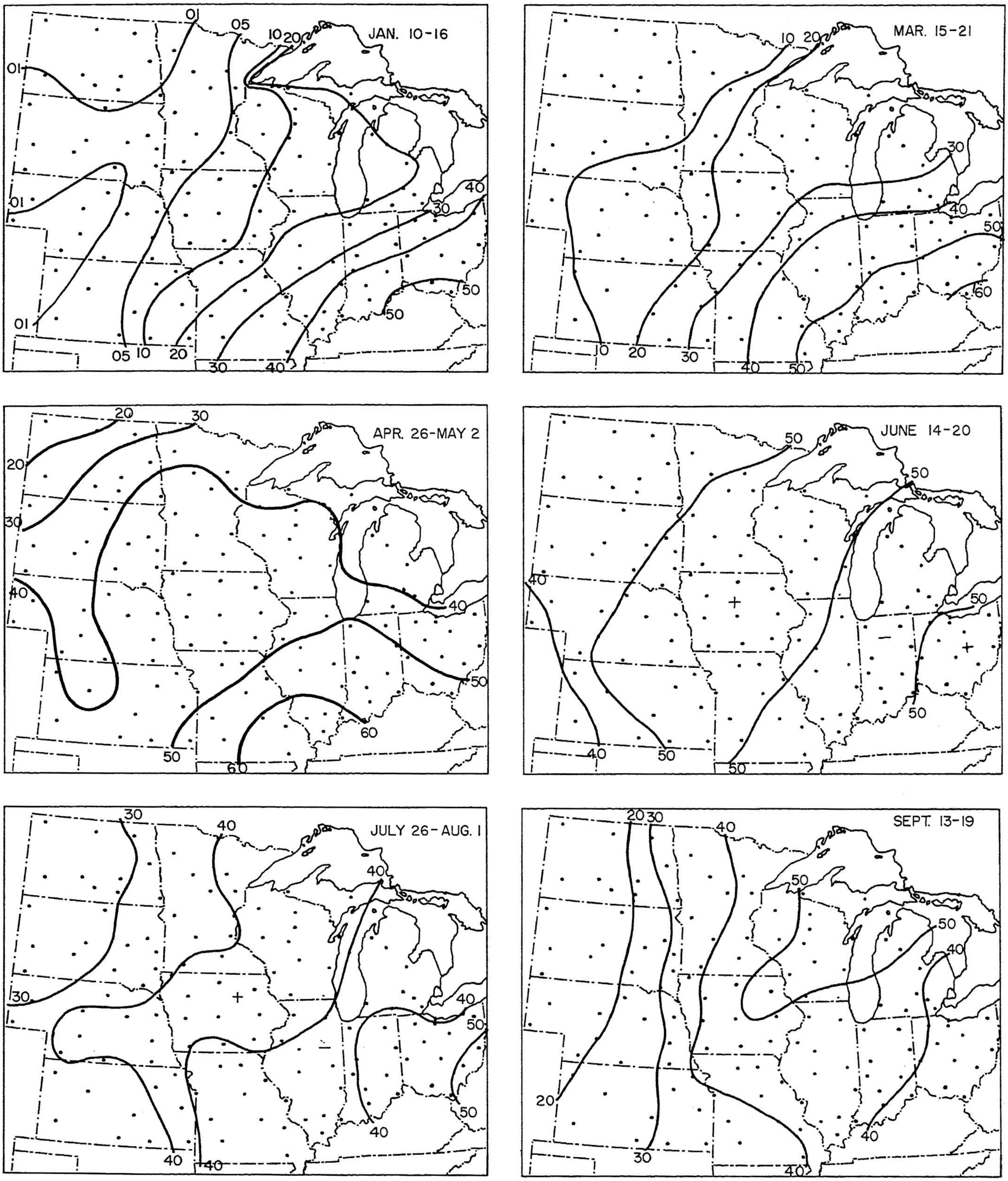

Fig. 13. Probability, in percent, of receiving 0.6 inch or more precipitation during 1-week intervals

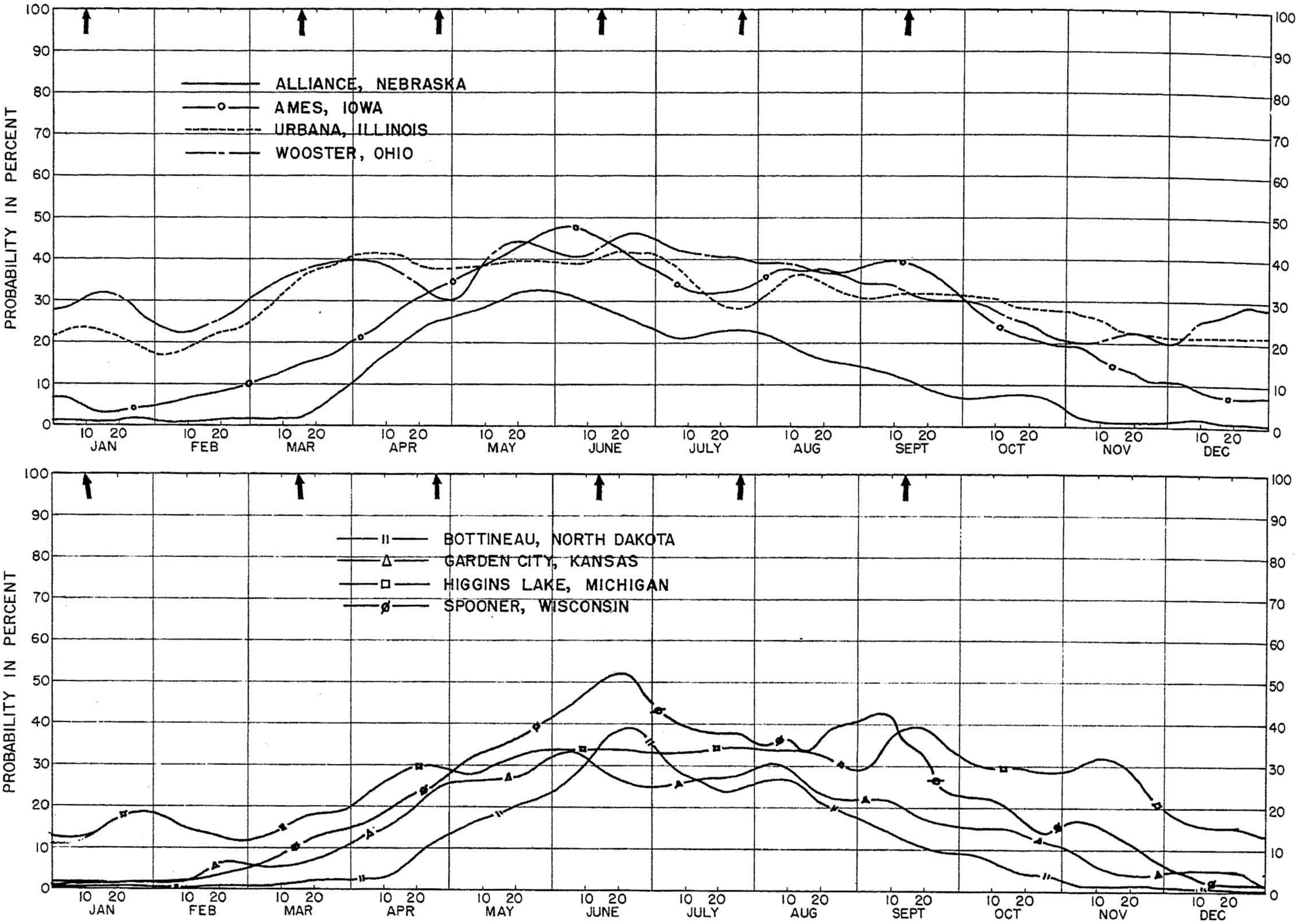

Fig. 14. Probability of receiving 0.8 inch or more precipitation in 1-week intervals at eight stations.

Probability of 0.8 Inch or More

The probability of receiving 0.8 inch or more ranges from 0 to over 50%. The extremes range from 20 to 45% at Wooster, less than 20% to over 40% at Urbana, 5% to near 50% at Ames and near 0 to near 35% at Alliance. The minimum occurs in the winter months, except in the east, where it is in November. The maximum generally occurs in May or June with a secondary maximum evident in September in the central to northeast area.

In January, the probability ranges from near 0 in the west to 40% in the extreme southeast. The probability increases slightly in February and early March. By late April the maximum has shifted to the south central area, and the probability ranges from 10 to 50% across the region. The probability continues to increase in the western and northern states and by mid-June ranges from 30 to 50% across the region, with the maximum near the Kansas-Missouri border. The probability generally decreases in July and in early August is near 30% over much of the region. In the west, the probability continues to decrease, while in upper Michigan, Wisconsin and northeast Iowa it increases in mid-September to 40%. After this date, except for the east and southeast, the probability decreases, and the winter pattern is reached by mid-November.

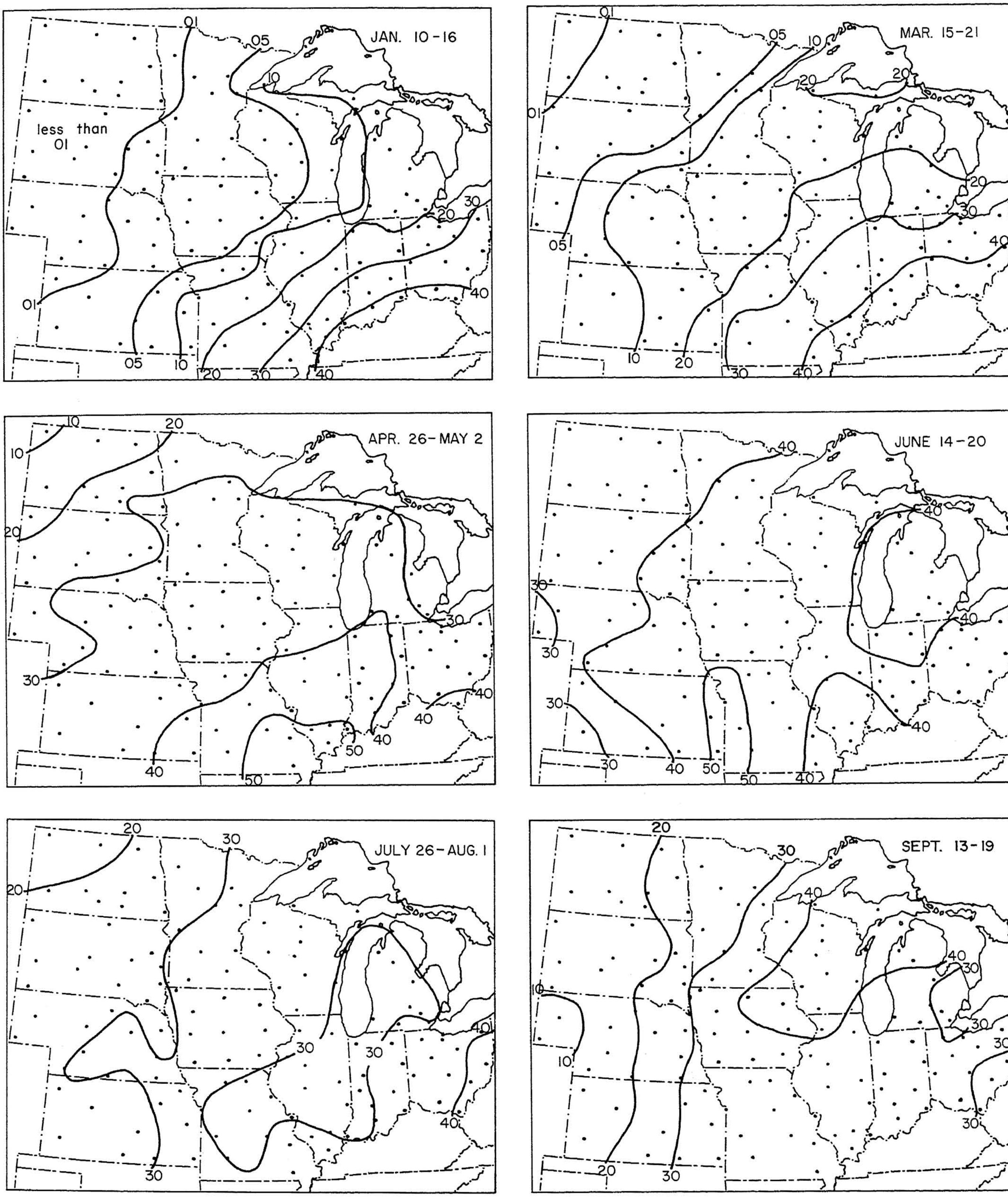

Fig. 15. Probability, in percent, of receiving 0.8 inch or more precipitation during 1-week intervals in six selected periods.

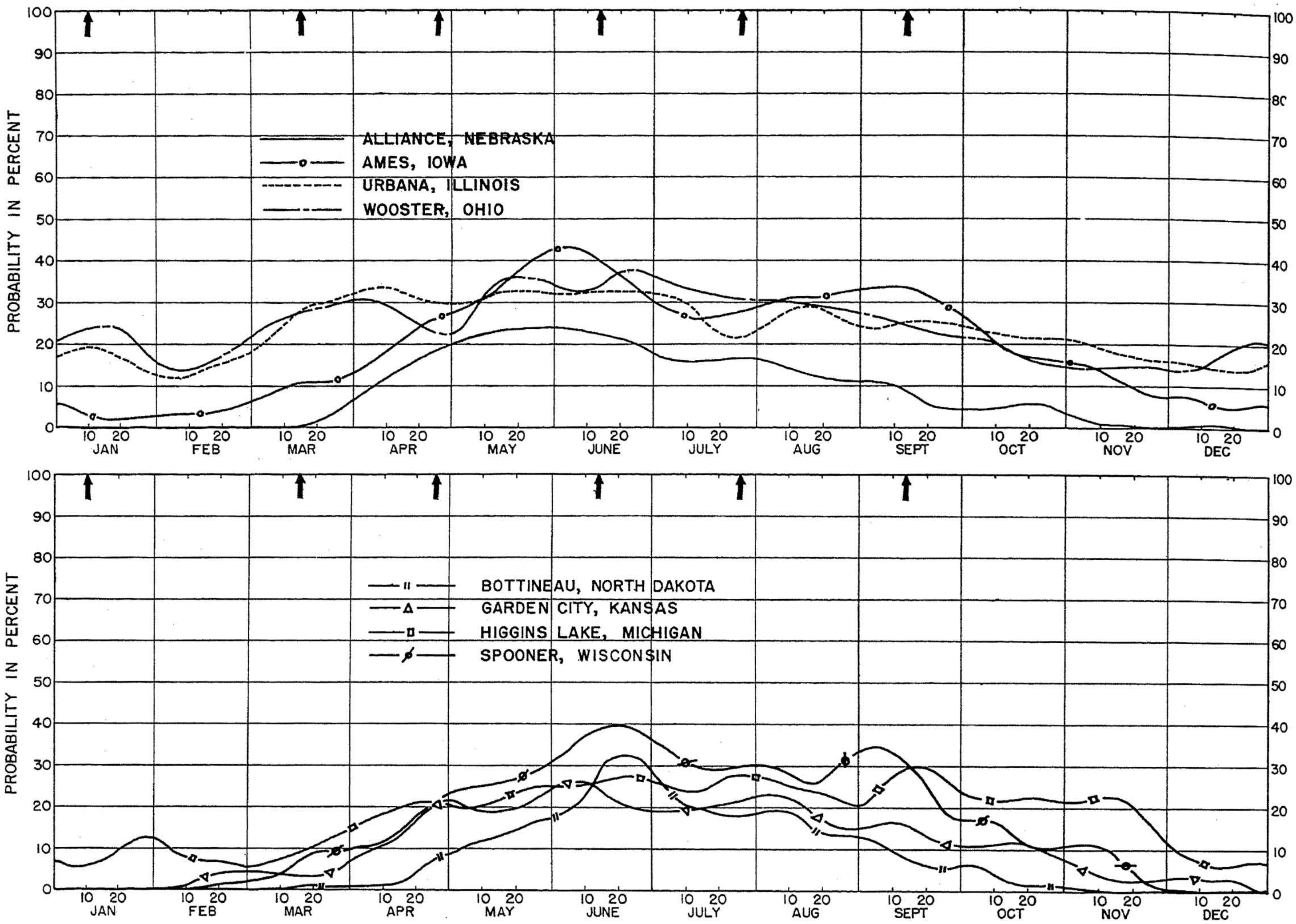

Fig. 16. Probability of receiving 1.0 inch or more precipitation in 1-week intervals at eight stations.

Probability of 1.0 Inch or More

The probability of receiving 1.0 inch or more varies from 0 to almost 45%. The extremes range from near 15 to 35% at Wooster, 10 to 35% at Urbana, near 0 to 45% at Ames and 0 to 25% at Alliance. The minimum occurs during the winter months throughout the region, and the maximum in late May and June, except in the northeast, where the September maximum is slightly higher than the June maximum. There is a dip in the probability in July in many areas and a secondary maximum in September in the north central part of the region.

In mid-January, the probability ranges from near 0 to 30% in the southeast. Except for the far west, there is an increase starting in February, and by mid-March the probability has increased over the region to 5 to 40%. The probability generally continues to increase and by early May ranges from 10 to 40%, with the maximum moving toward the south central area. By mid-June, over much of the region it is 30 to 40%. During July the probability generally decreases and in most areas is 20-30% by early August. The probability in the west continues to decrease, while it remains relatively constant in the east, by mid-September ranging from 10 to 30% with the maximum in the central and northeast areas. Except for the southeast, the probability declines after this date, and by mid-November the winter pattern is well established.

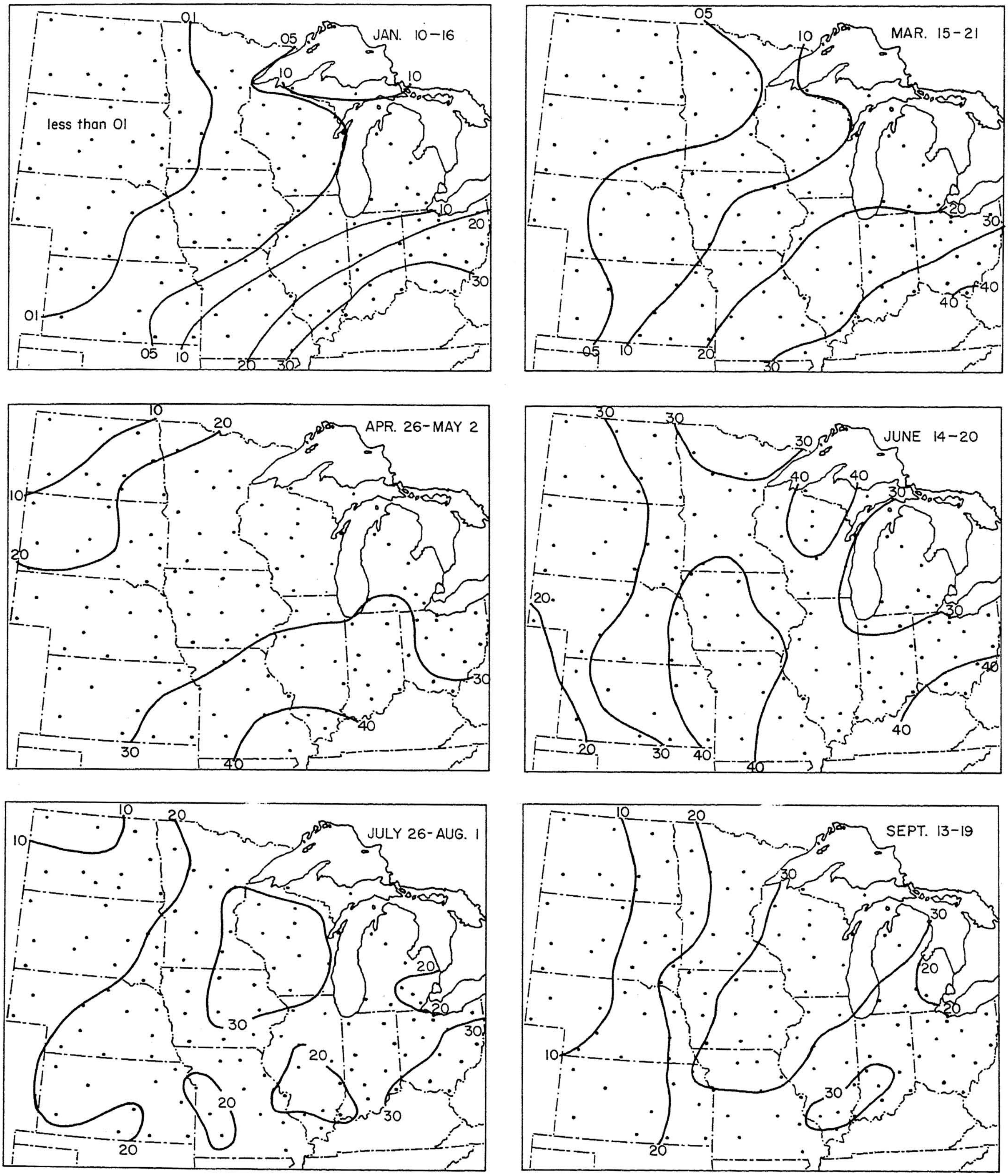

Fig. 17. Probability, in percent, of receiving 1.0 inch or more precipitation during 1-week intervals in six selected periods.

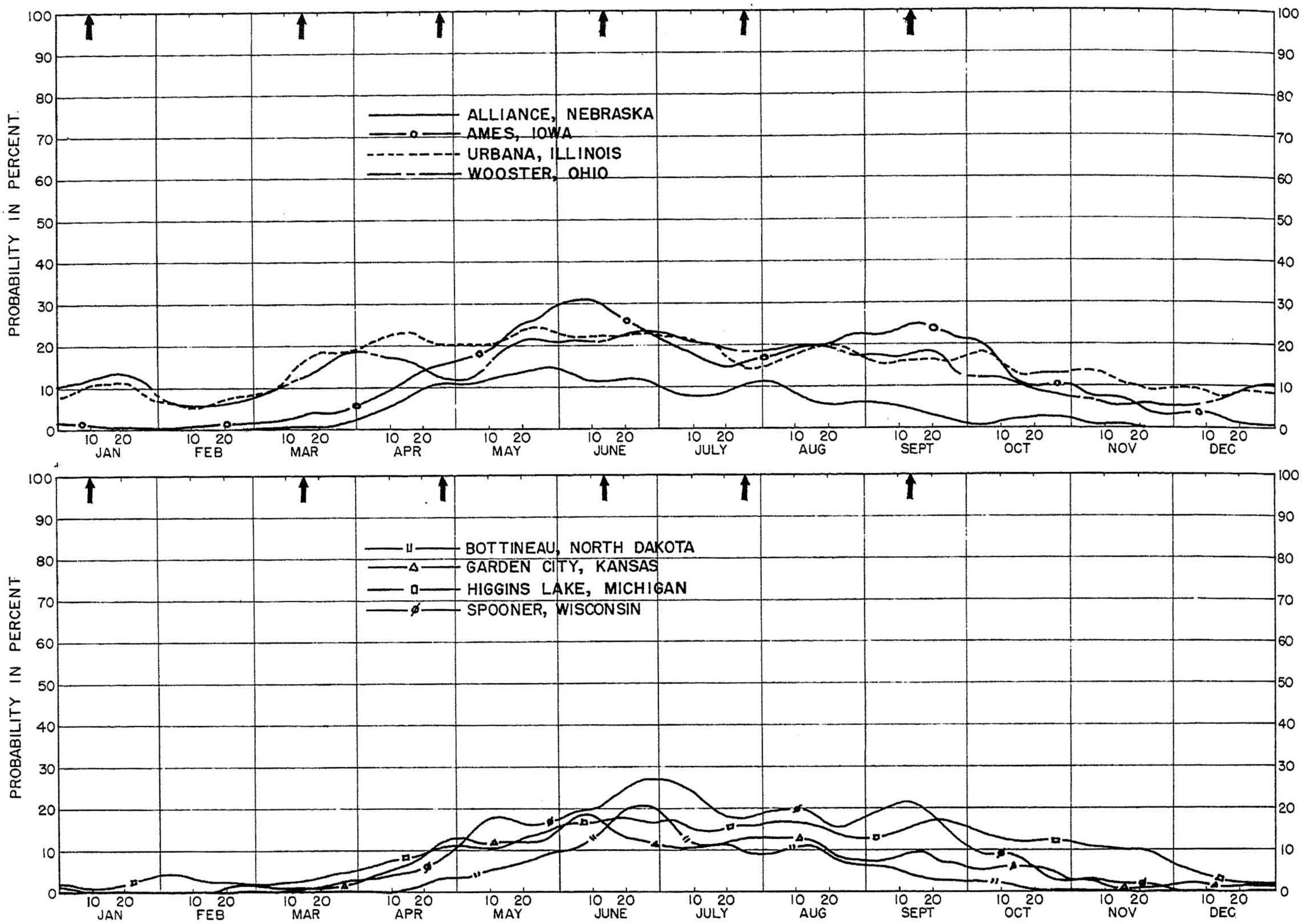

Fig. 18. Probability of receiving 1.4 inches or more precipitation in 1-week intervals at eight stations.

Probability of 1.4 Inches or More

The probability of 1.4 inches or more ranges from a maximum of over 30% to a minimum of 0. The extremes of probability range from 5% to nearly 25% at Wooster, 5 to 25% at Urbana, 0 to 30% at Ames and 0 to 15% at Alliance. The minimum probability occurs in the winter. The maximum probability generally occurs in May-June, with a secondary maximum evident in Iowa and Wisconsin in mid-September.

In January, the probability is near 0 in the western part of the region and ranges up to 20% in the southeast. There is a slight increase in the probability in most areas by mid-March, and by late April the probability ranges from 5% in the northwest to over 30% in southeast Missouri. By mid-June the probability is near 20% over much of the region, with the maximum over 30% in the south central area and the minimum under 20% in the west. The probability decreases slightly and by late July is between 10 and 20% over most of the region. Except for the area Missouri to Wisconsin, there is a further slight decrease, and by mid-September the probability ranges from a maximum of slightly over 20% to less than 5% in the northwest. The probability decreases after this date until the winter pattern is reached in November in the west and December in the east.

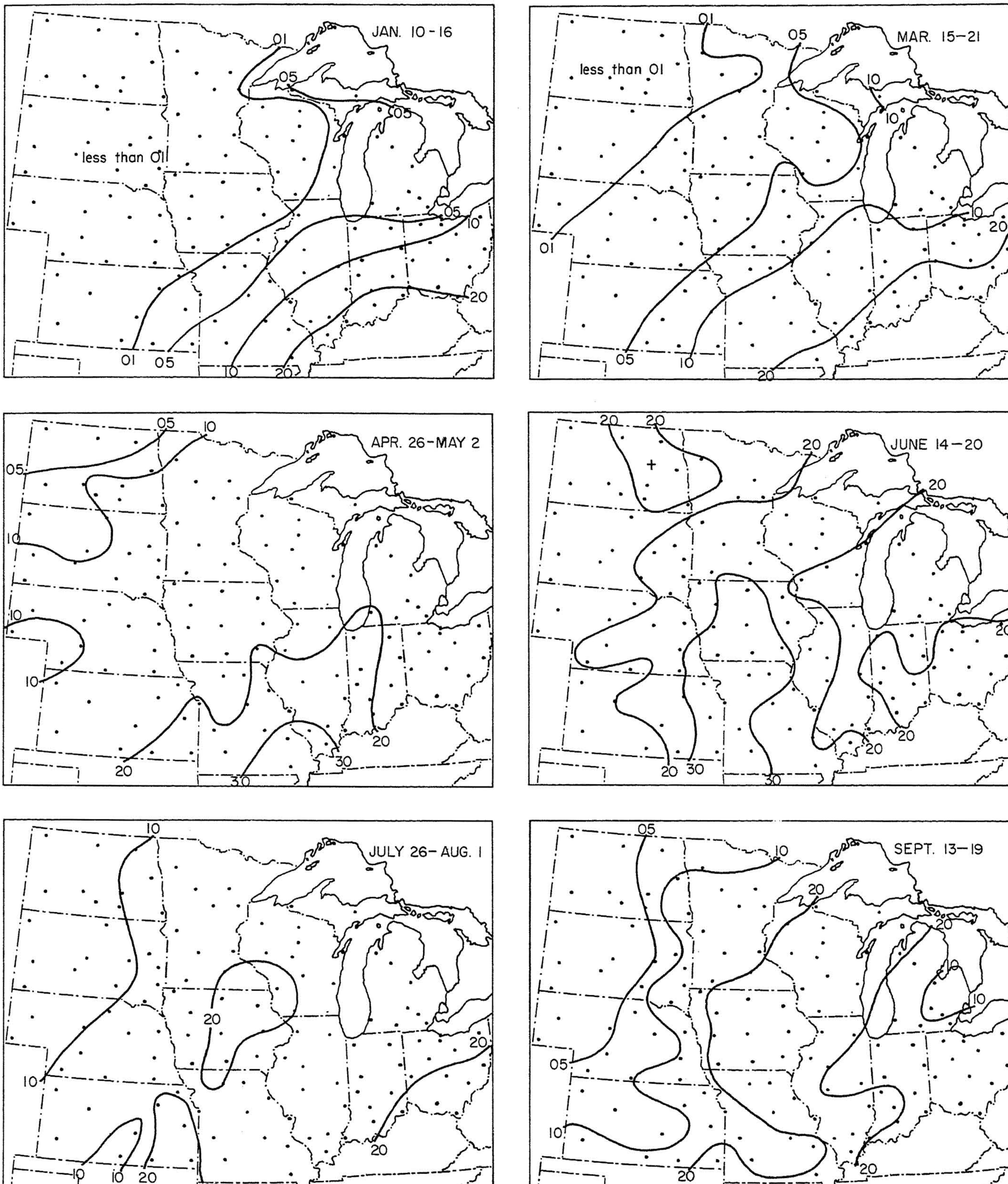

Fig. 19. Probability, in percent, of receiving 1.4 inches or more precipitation during 1-week intervals in six selected periods.

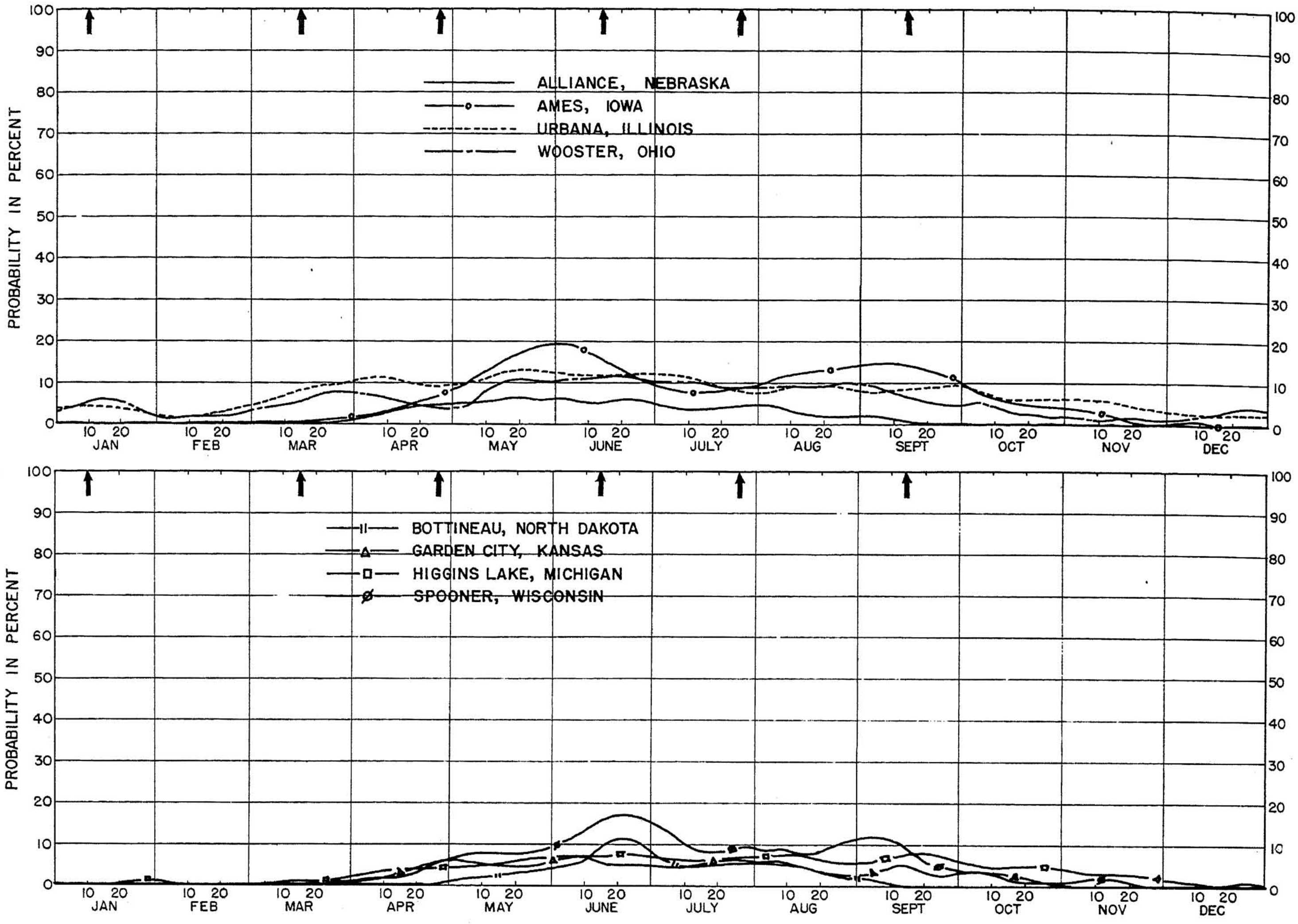

Fig. 20. Probability of receiving 2.0 inches or more precipitation in 1-week intervals at eight stations.

Probability of 2.0 Inches or More

The probability of 2.0 inches or more ranges from 0 to over 25%. The extremes range from near 0 to 10% at Wooster, near 0 to over 10% at Urbana, 0 to 20% at Ames and Springfield and 0 to over 5% at Alliance. The minimum occurs in the winter months, and in the west near 0 probability persists for over 6 months. The maximum generally occurs in late May or June, but because of the small annual range in many areas is often not very pronounced.

In January, the probability ranges from near 0 over most of the region to 10% in the southeast. There is a slight increase by mid-March, but the range is still near 0 to 10%. Except for the east, the probability increases during April, and by late April it has reached the maximum of 10% in the south central area and ranges down to 1% in the northwest. There is a small, but general increase in probability in May and early June, except in the southwest, and by mid-June the probability in much of the region is between 10 and 20%, with the maximum in the south central area where some individual stations at this time have a probability over 25%. A general decrease in the probability occurs in July, and by early August the probability is near 5% in the west and near 10% in the rest of the region. Probability in both the west and east shows a decrease in August and early September, and by mid-September the maximum of near 10% occurs in the central sector. Except for the east and southeast, the probability decreases after mid-September, and by late October the winter pattern is well established.

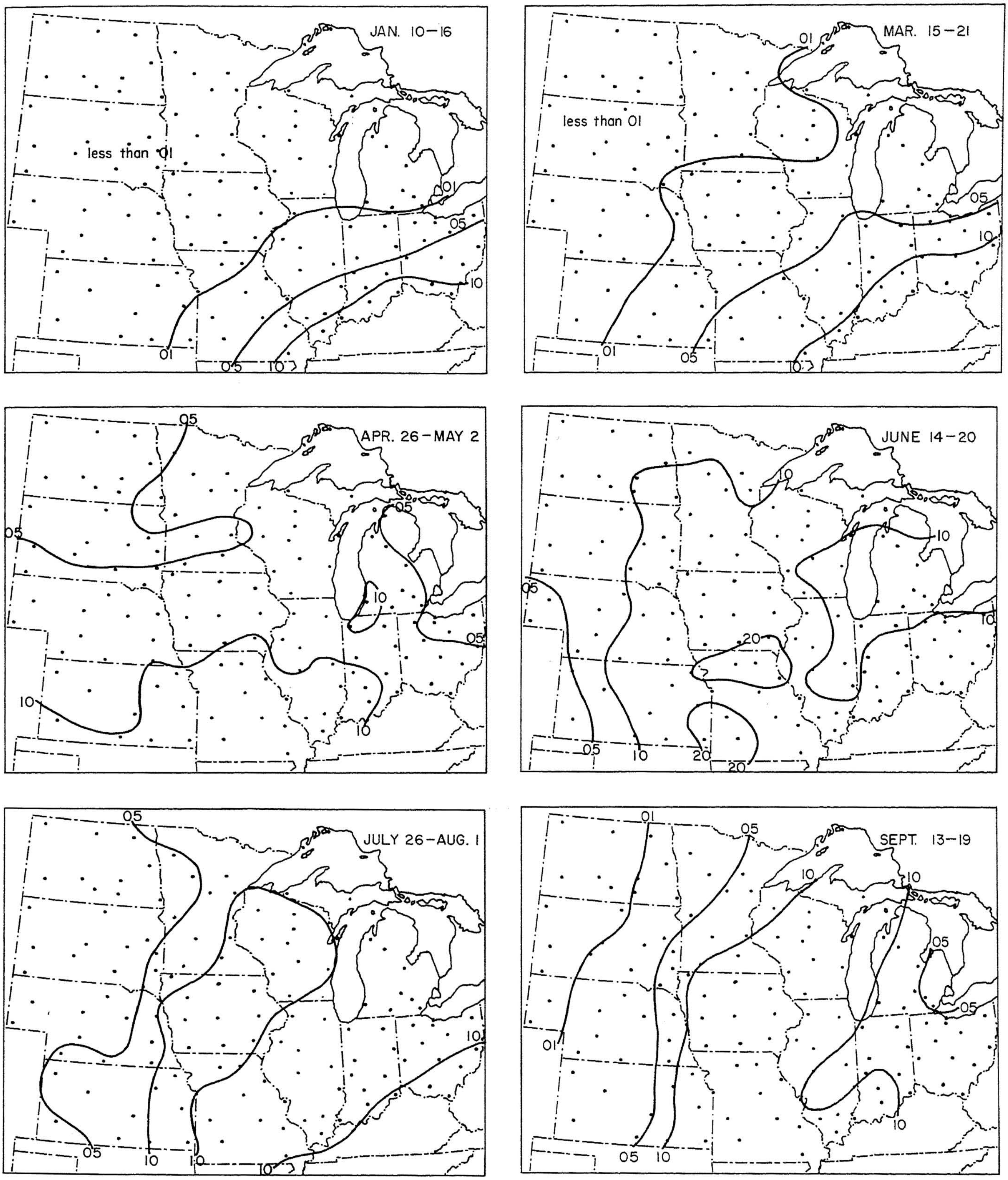

Fig. 21. Probability, in percent, of receiving 2.0 inches or more precipitation during 1-week intervals in six selected periods.

Probability of 2.8 Inches or More

The probability of receiving 2.8 inches or more is very low over much of the region most of the year. It reaches a maximum of over 15%, in June, in southeast Kansas.

In January, the probability is near 0 over most of the region, and reaches 5% in the extreme southern parts of Missouri, Illinois, Indiana and Ohio. The pattern in mid-March is very similar, with the maximum probability approaching 10% in these areas, and ranging down to 1% in the northern parts of these states, plus southern Wisconsin, southeastern Iowa and eastern Kansas. The probability gradually increases in the west, and by early May is 1 to 3% over much of the region, with the maximum of just over 5% in the south central area. By mid-June there has been a small general increase in the probability, with the south central area having a probability over 10%, with a maximum near 15% in southeast Kansas; and with the rest of the region, except for the northern and eastern borders, being between 5 and 10%. The probability in July generally declines, and by early August is 2-3% over most of the region, with a few small areas in southern Missouri and southeast Ohio over 5%. Except for the west, there is a small increase in the probability in late August-early September, and by mid-September the probability is near 10% from southwest Wisconsin to northeast Kansas, and gradually decreases to near 0 in the west and extreme east. The probability decreases rapidly after September over most of the region, bringing a return of the winter pattern over the region by early November.

Probability of 4.0 Inches or More

The probability of 4.0 inches or more is very low over most of the region. The maximum reached is between 5 and 10% in the south central area.

In January, the probability is near 0, except in extreme southern Indiana and Illinois and southwest Ohio and southeast Missouri, where it is near 1-2%. A similar pattern is true through March. By early May the south central states have a probability of 1-2%, the rest of the region is near 0. There is little change until early June, when the probability on the Missouri-Kansas border is over 5%, with the rest of the region between 2-4%, except the east and west borders where it is 1% or less. The probability decreases in early July to less than 5% in all areas, and by August the probability in the western states is near 0 and near 1% in the rest of the region. There is some increase in the probability in September, as it approaches 5% in the south central sector and ranges down to near 0 on the eastern and western margins. After this date the winter pattern is very quickly reached.

2-WEEK PRECIPITATION PROBABILITIES

The 2-week precipitation probabilities show a pronounced west to east pattern. In the west, the probability is low in the winter and reaches a maximum generally during the May-June period. In the east, the level of probability is more uniform throughout the year. The east has a higher winter probability than the west. For the lower amounts of precipitation, the highest probability at any given time is generally in the east or northeast. With heavier amounts of precipitation, the winter probability is higher in the east, but in the spring and summer the highest probability is generally in the central and south central area. Except for the northeast and in much of the western area, there is a definite decrease in the probability in July, and in areas where a secondary maximum occurs in September, a midsummer, secondary minimum results in July. During this period the probability at Springfield runs slightly higher than at Urbana. For amounts from 0.6 inch to about 2 inches there is a secondary maximum around September in northeast Iowa, Wisconsin and upper Michigan; the highest probability at that time occurs in that area. For heavier amounts, the September maximum is less pronounced. There are also indications of a midwinter (January) peak in the probability in the east, northeast and southeast, except for low amounts of precipitation.

For light amounts of precipitation (0.2 inch) the probability is near 100% in the summer, but ranges down to 30% in the winter. For 0.6 inch the probability ranges from near 5% in the west in the winter to 90% or over in the southeast area in March and south central area in late May. For 1.0 inch the probability is near 0 in the west in the winter and reaches over 70% in the east in March and south central area in early May. For 2.0 inches the probability is near 0 in the western area in the winter and reaches a maximum near 50% in the south central area in May and June. For 2.8 inches the probability is near 0 in most of the region in the winter, and reaches a maximum near 35% in the south central area in June. The probability of receiving 4.0 inches or more is near 0 in the winter over most of the region, and reaches a maximum of 20% in the south central area in June. The maximum probability of receiving 6.0 inches is 10%, and 8.0 inches only 5%.

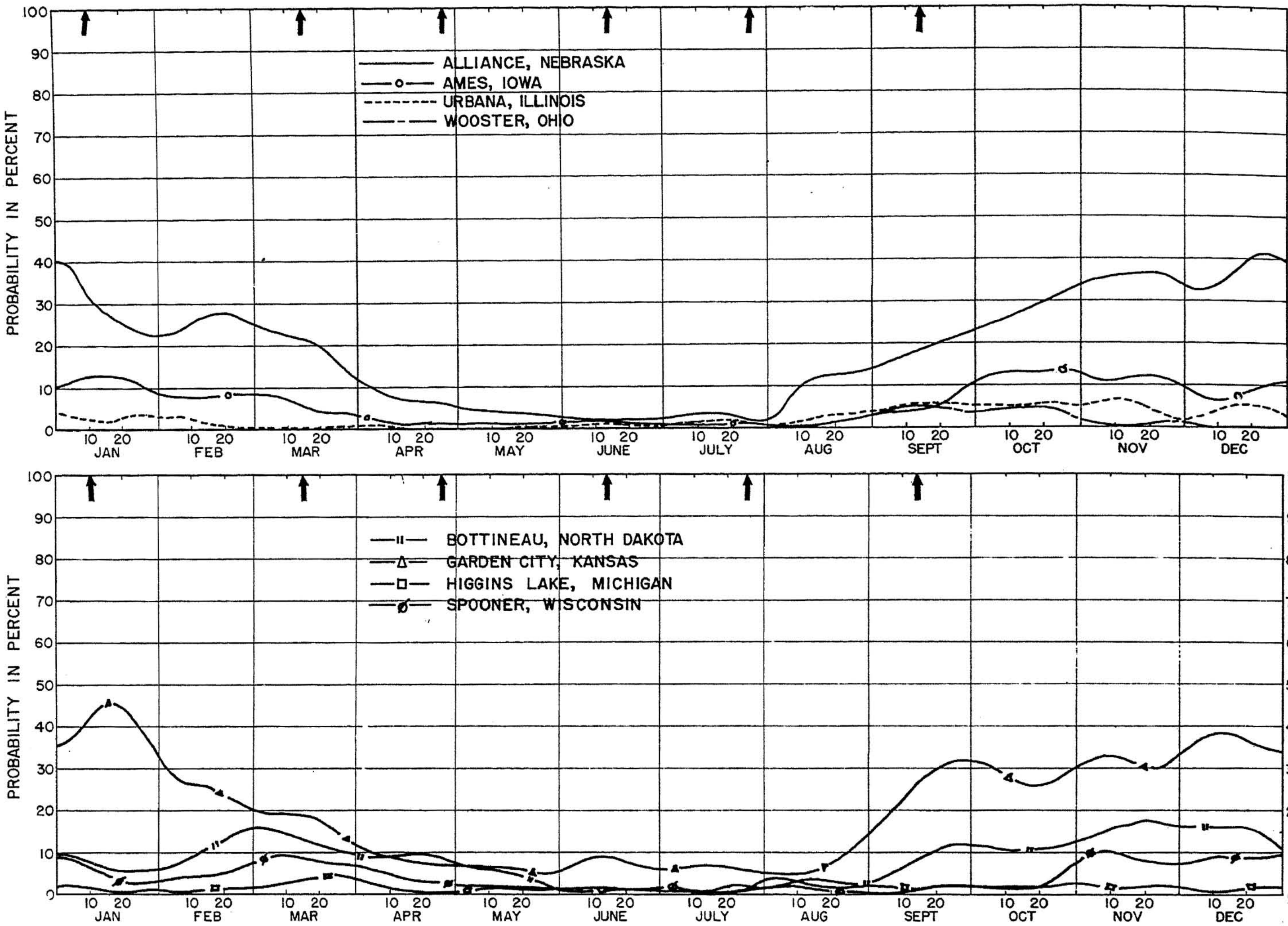

Fig. 22. Probability of receiving only 0 or trace precipitation in 2-week intervals at eight stations.

Probability of 0 or Trace

The probability of 0 or trace ranges from a maximum of over 45% in the southwest in late January to a minimum of 0. The extremes of probability range from 0 to 5% at Wooster, 0 to near 5% at Urbana, 0 to almost 15% at Ames, and near 0 to over 40% at Alliance. The maximum probability occurs in the winter months, except in the east when it is in the fall, while the minimum probability occurs in the summer period.

In January, the probability ranges from near 0 in the east to over 40% in the southwest. There is generally a decrease after this date and by mid-March the range is from 1% in the east to 20% in the southwest. A continued decrease in probability takes place in the west, and by early May the probability is less than 5% over the region, and less than 1% over much of the region. There is relatively little change until early August, when the probability is less than 5% over most of the region. A gradual increase takes place after this date, in most areas and by mid-September the probability ranges from 1% in the northeast to 30% in the southwest. The mid-winter pattern is well established by October.

To provide an idea of the bias[3] the actual observed P(0,T) for the first order stations are given on each map in fig. 23. Except for the higher probabilities the absolute difference between the estimates for cooperative stations and those for first order stations appears to be very small.

[3]See page 13.

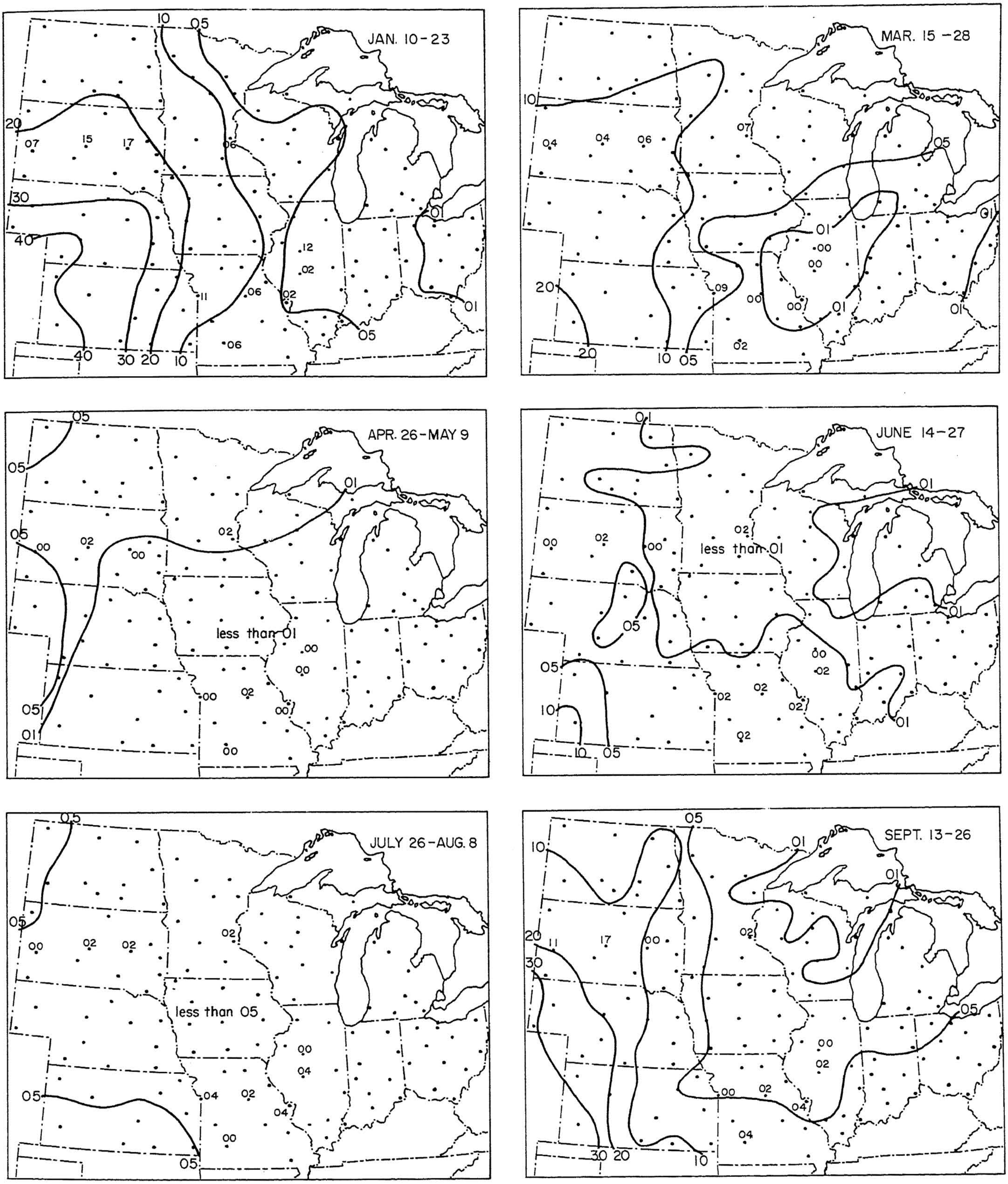

Fig. 23. Probability, in percent, of receiving only 0 or trace precipitation during 2-week intervals in six selected periods.

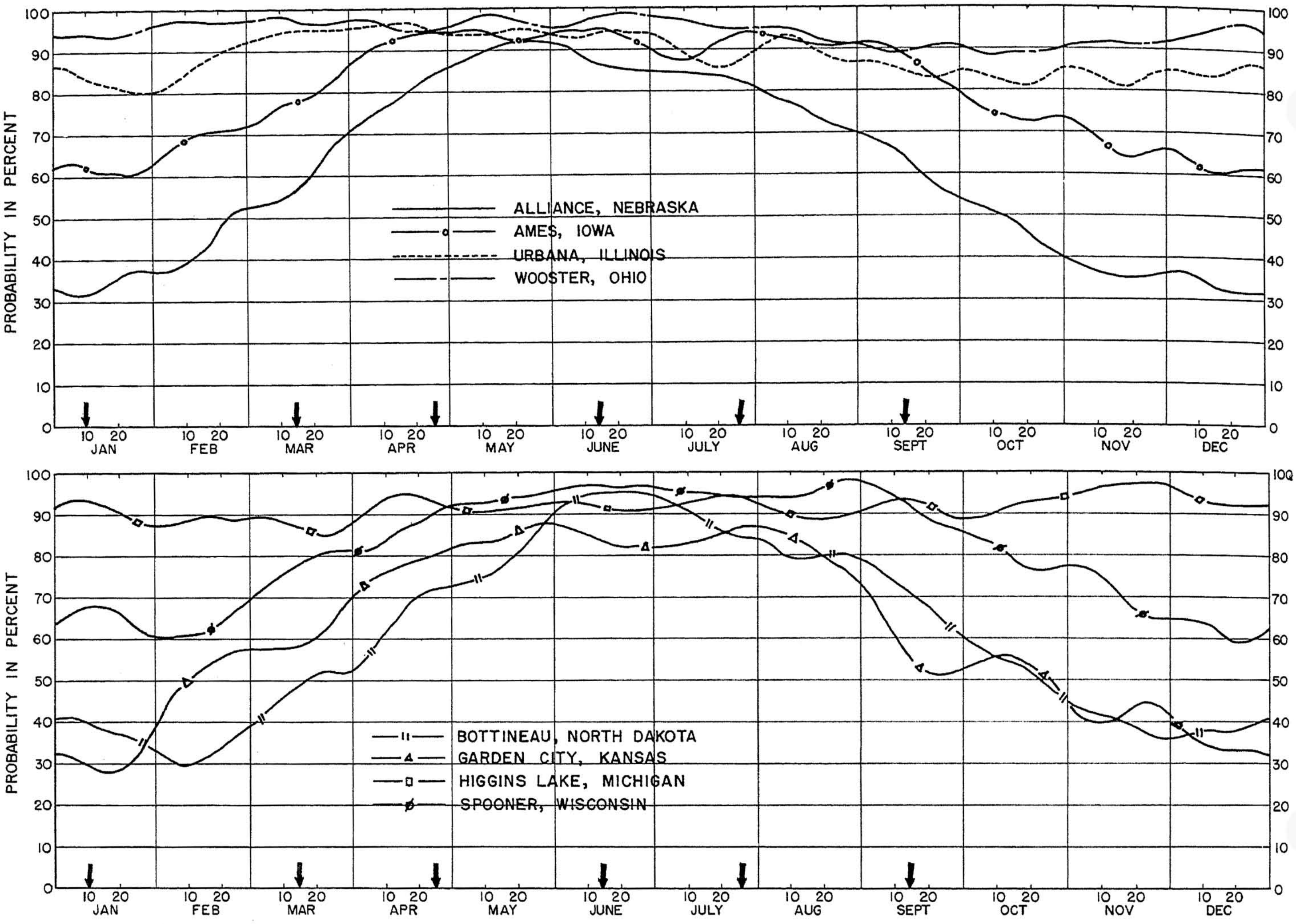

Fig. 24. Probability of receiving 0.2 inch or more precipitation in 2-week intervals at eight stations.

Probability of 0.2 Inch or More

The probability of receiving 0.2 inch or more ranges from a low near 30% to a high near 100%. The extremes of probability range from near 90% to near 100% at Wooster, from 80% to over 95% at Urbana and Springfield, 60 to 95% at Ames and near 30% to over 90% at Alliance. The minimum probability occurs during the winter months except in the east and northeast; the maximum occurs in May or June, except in the south central area, where it occurs in April and in the east and northeast, where there is little annual range.

In January, the probability ranges from near 30% in the west to over 90% in the east. By mid-March there is a slight increase in the east and southeast and a large increase to 60% in the west. The probability continues to increase, until by early May it ranges from 80% to over 95%, and by mid-June is 90 to 99% over the region with the minimum probability in the southwest and south central areas. By early August, the probability has declined to 80% in the west and near 90% in the rest of the region. The probability in the west continues to decline through September until the winter pattern is reached in December. In the east there is little change during this period, while in the central area the probability remains around 90% through mid-September and first reaches the winter minimum from mid-November to mid-December.

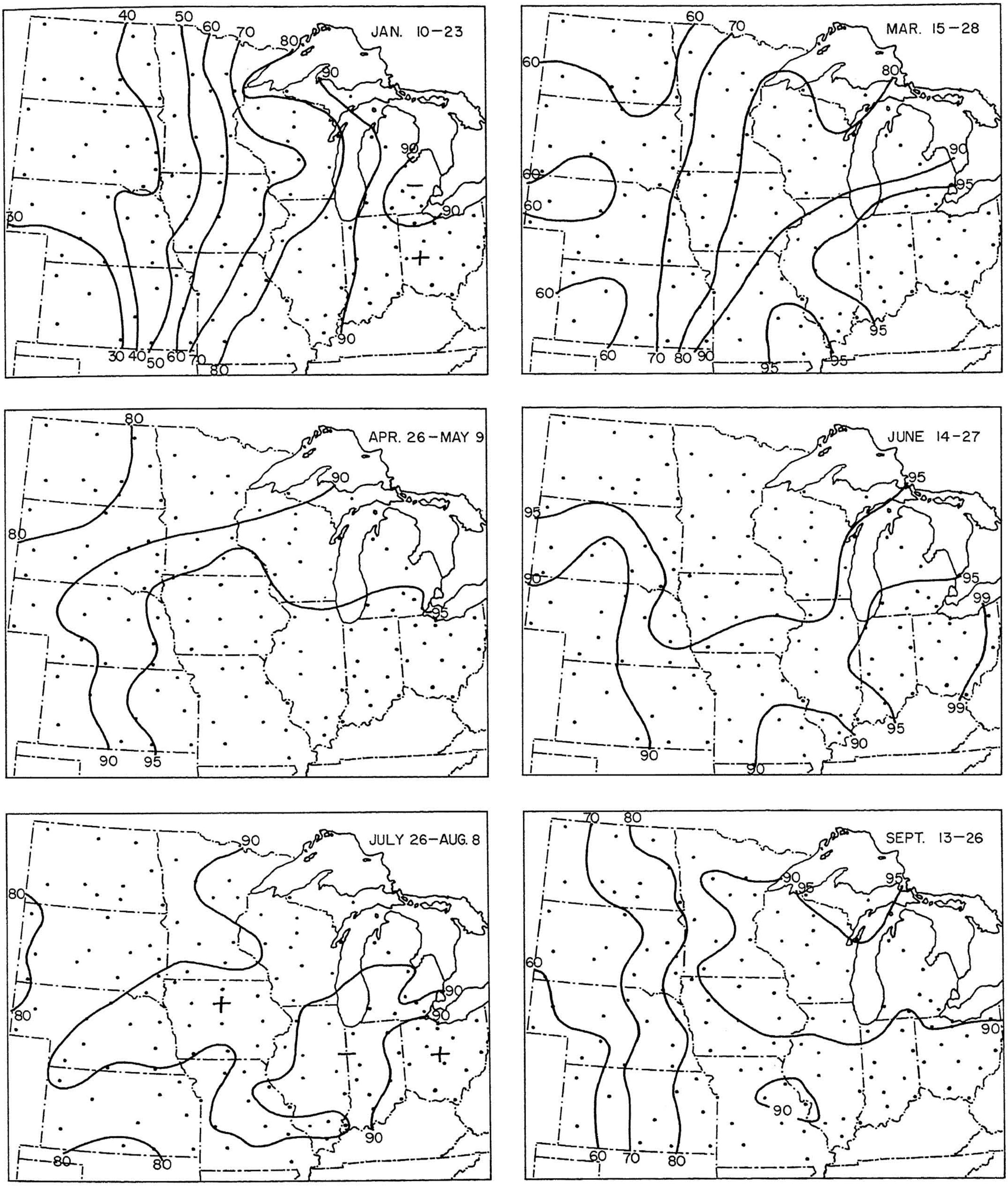

Fig. 25. Probability, in percent, of receiving 0.2 inch or more precipitation during 2-week intervals in six selected periods.

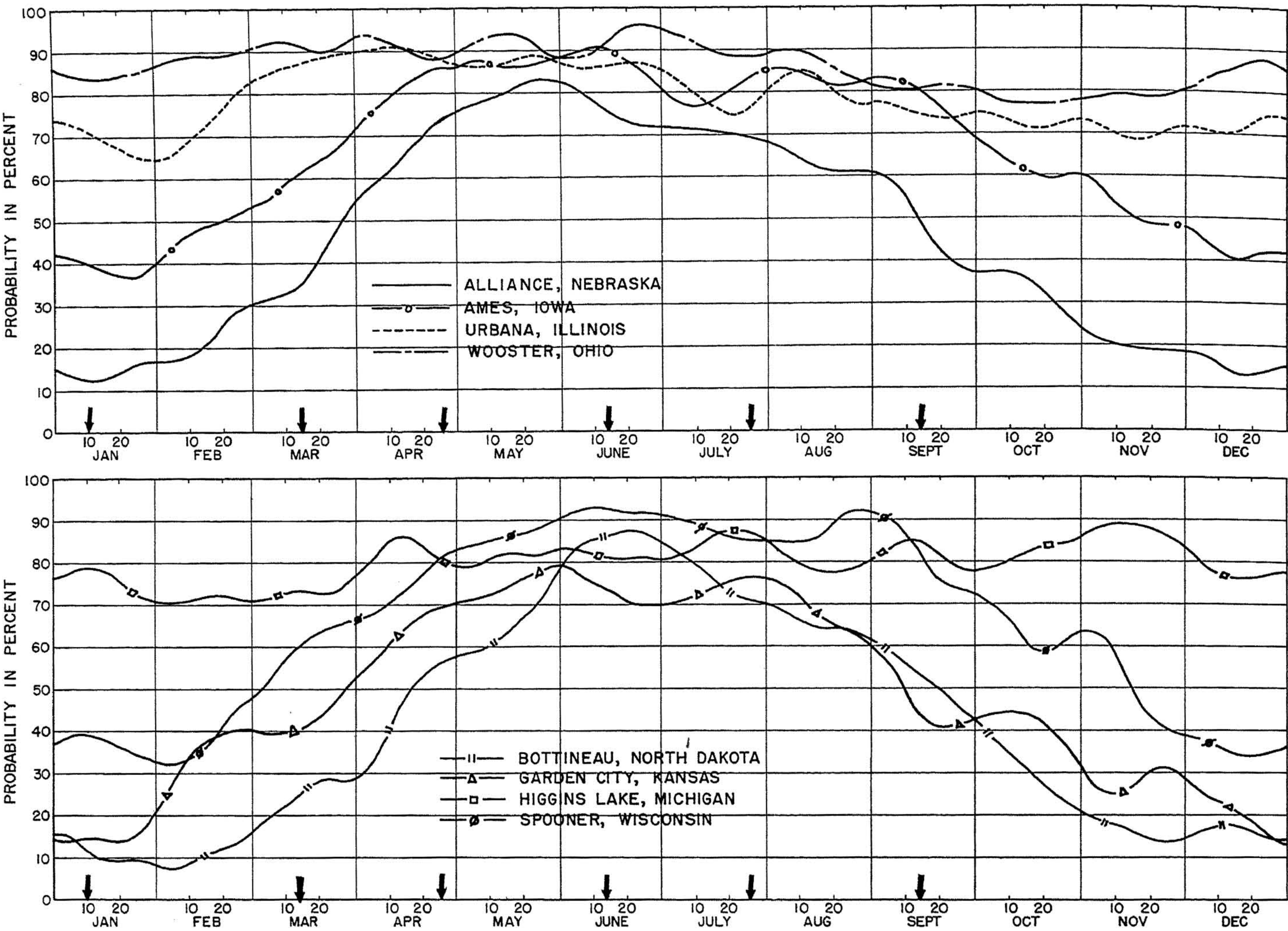

Fig. 26. Probability of receiving 0.4 inch or more precipitation in 2-week intervals at eight stations.

Probability of 0.4 Inch or More

The probability of receiving 0.4 inch or more ranges from a low of less than 10% in the northwest to a high near 95% in the extreme east The extremes range from 75 to 95% at Wooster, 65 to 90-95% at Urbana and Springfield, 35 to 90% at Ames and 10 to near 85% at Alliance. The minimum probability at Wooster is in October; at Higgins Lake in February-March and in the rest of the region during the winter months. The maximum generally occurs in the south central and eastern areas in April, while in the west and north it occurs in May or June.

In January, the probability ranges from near 10% in the west to 80% in the east. It increases during February and by mid-March ranges from 30 to 90%. By early May the probability in the west has increased to 60-70% with little change in the east and by mid-June has increased to 70-80% in the west to 95% in the extreme east. Except for the northeast, the probability generally declines in early July and by early August is near 80% across the region, except for the extreme west, where it is near 70%. Starting in August there is a gradual decrease in the probability in the west so that by mid-September the probability ranges from 50 to 90% across the region, with the maximum in the upper Great Lakes Region. Except in the east, there is a gradual decrease in the probability until the winter pattern is reached in late November-early December.

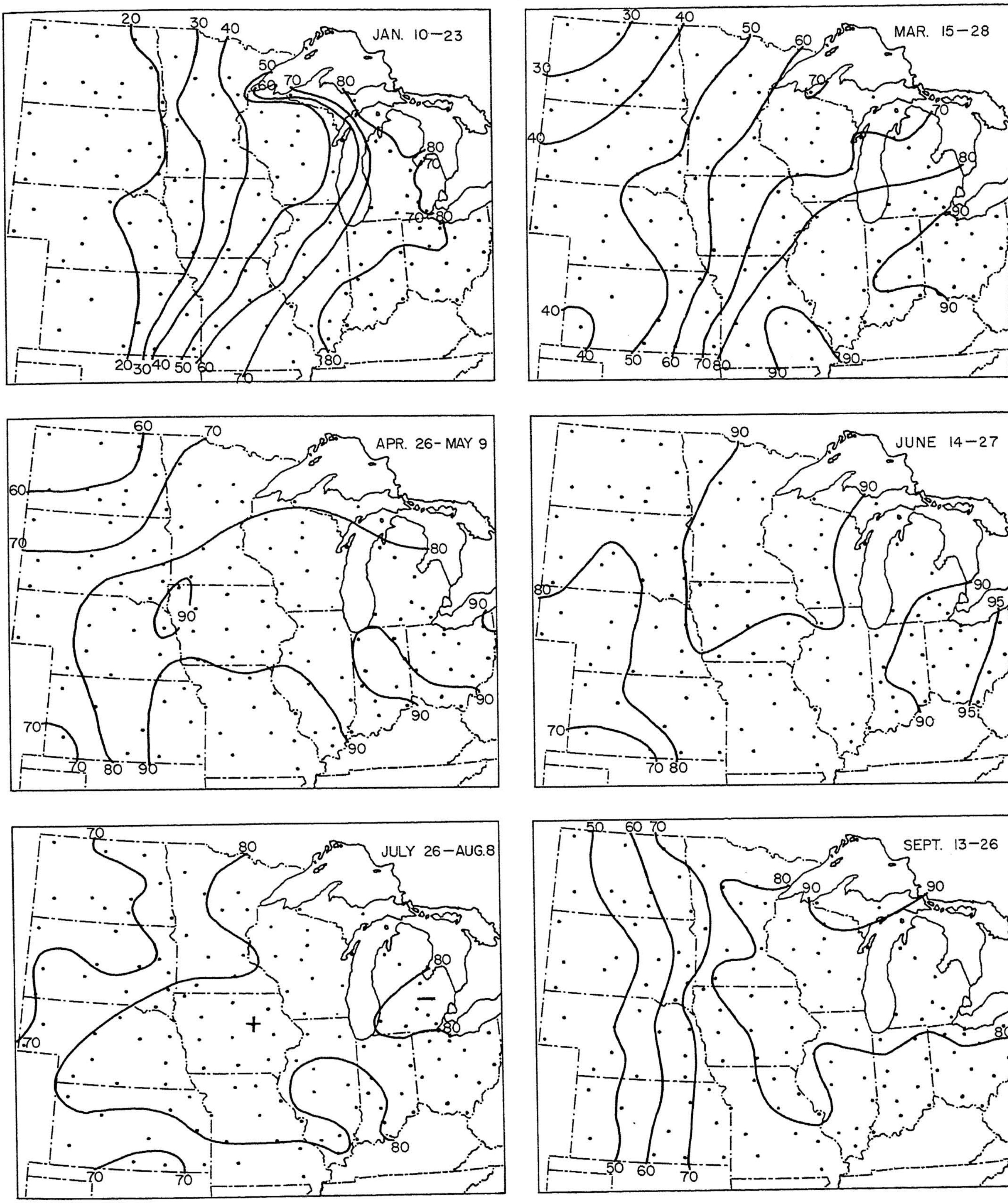

Fig. 27. Probability, in percent, of receiving 0.4 inch or more precipitation during 2-week intervals in six selected periods.

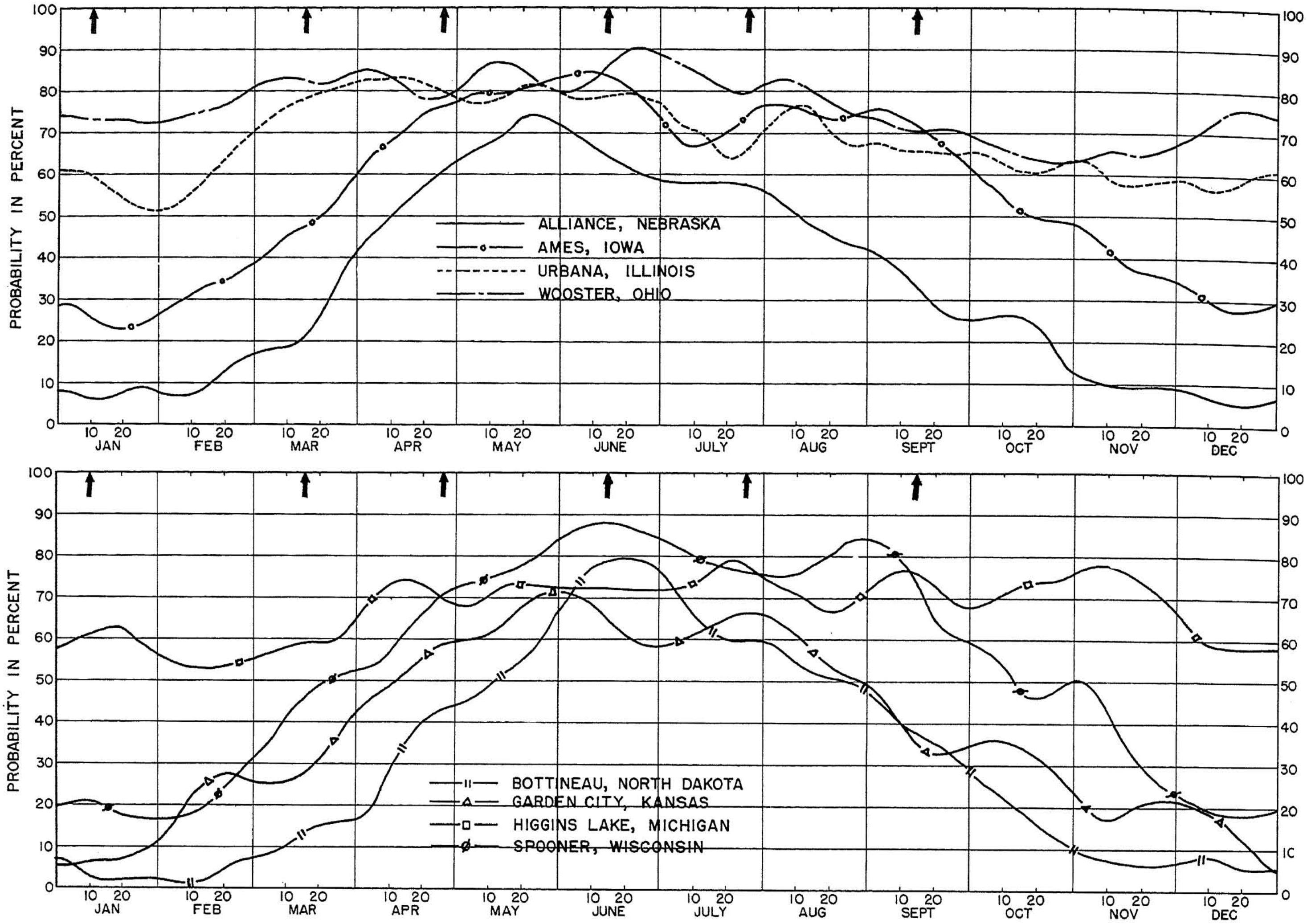

Fig. 28. Probability of receiving 0.6 inch or more precipitation in 2-week intervals at eight stations.

Probability of 0.6 Inch or More

The probability of receiving 0.6 inch or more during a 2-week period ranges from a low of near 0 in the northwest to a high of 90% in the east in late June and south central area in late April. The extremes of probability range from 65 to 90% at Wooster, 50% to near 85% at Urbana, 50 to 90% at Springfield, 25 to 85% at Ames and 5 to 75% at Alliance. The minimum probability occurs in the winter in most areas, except in the east, where it is in October-November at Wooster, and in Urbana which has a secondary minimum during that time. The maximum probability at most stations occurs in May or June, except for Springfield which has an April maximum and Higgins Lake which has a flat April-November maximum. Spooner and Pine River Dam have secondary maxima in August-September.

In January, the probability ranges from 5 to 80% across the region. There is a gradual increase in probability during late winter, and by mid-March the probability ranges from 20 to 90% across the region. The probability in the west continues to increase, a slight decrease occurs in the east, and by early May the maximum probability of over 90% occurs in southwest Missouri. By mid-June the probability over much of the region is 80-90%. During July the probability decreases in most areas and by early August is near 70% in much of the region. The probability in the west continues to decrease and by mid-September ranges from 40 to 80% across the region, with the maximum probability in Wisconsin and upper Michigan. There is a gradual decrease in the probability, except in the extreme east, and by late November the winter pattern is evident.

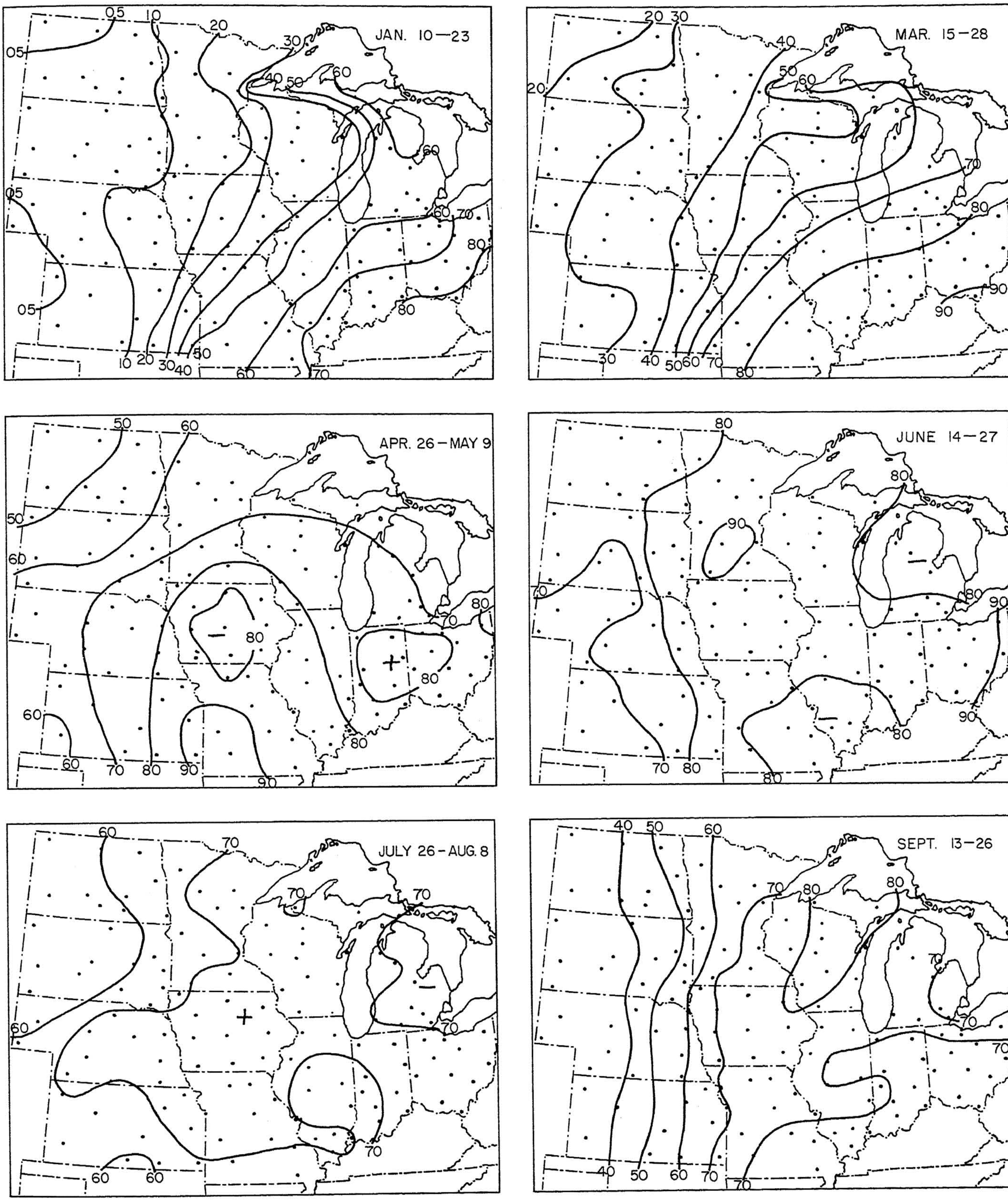

Fig. 29. Probability, in percent, of receiving 0.6 inch or more precipitation during 2-week intervals in six selected periods.

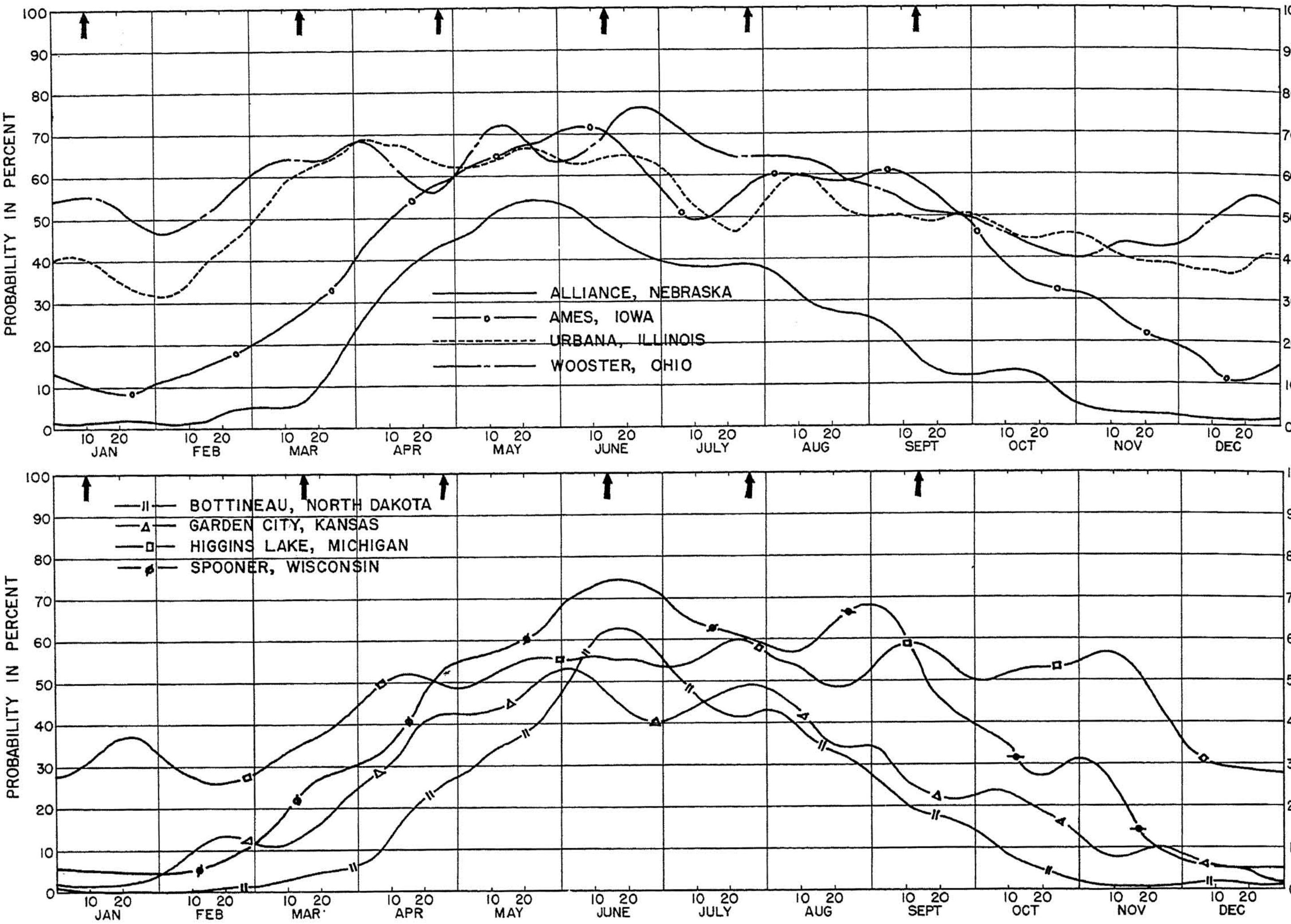

Fig. 30. Probability of receiving 1.0 inch or more precipitation in 2-week intervals at eight stations.

Probability of 1.0 Inch or More

The probability of receiving 1.0 inch or more ranges from near 0 in the west to over 75% in the east in June and south central area in late April. The extremes of probability range from 40 to 75% at Wooster, 30 to 70% at Urbana, 30 to 75% at Springfield, 10% to over 70% at Ames and near 0 to 55% at Alliance. The minimum probability occurs in the winter months, except at Wooster, where it occurs in late October-early November. The maximum occurs in late May at Alliance, and June in the rest of the region, except at Urbana and Springfield, where it is in April, Higgins Lake where it is in July but relatively uniform April through July, and Spooner, where a secondary maximum occurs in early September. A definite dip in the probability curve occurs in mid-July at Urbana, Springfield, Ames and Spooner.

In January, the probability ranges from near 0 to 60% across the region. The probability starts to increase in early February at the southern stations and in late February at the northern stations, by mid-March ranging from 10 to 70% across the region and by early May ranging from 30% to over 70% across the region. The area of maximum probability shifts from the extreme southeast part of the region to southern Missouri. By mid-June the probability is 60 to 70% over much of the region. A general decline in probability occurs during July; by early August it is 50 to 60% over much of the region. A continuing decline in the probability in the west results in a pronounced west-east gradient by mid-September with maximum probability in the northeast. By late November the pattern is very similar to that in mid-January.

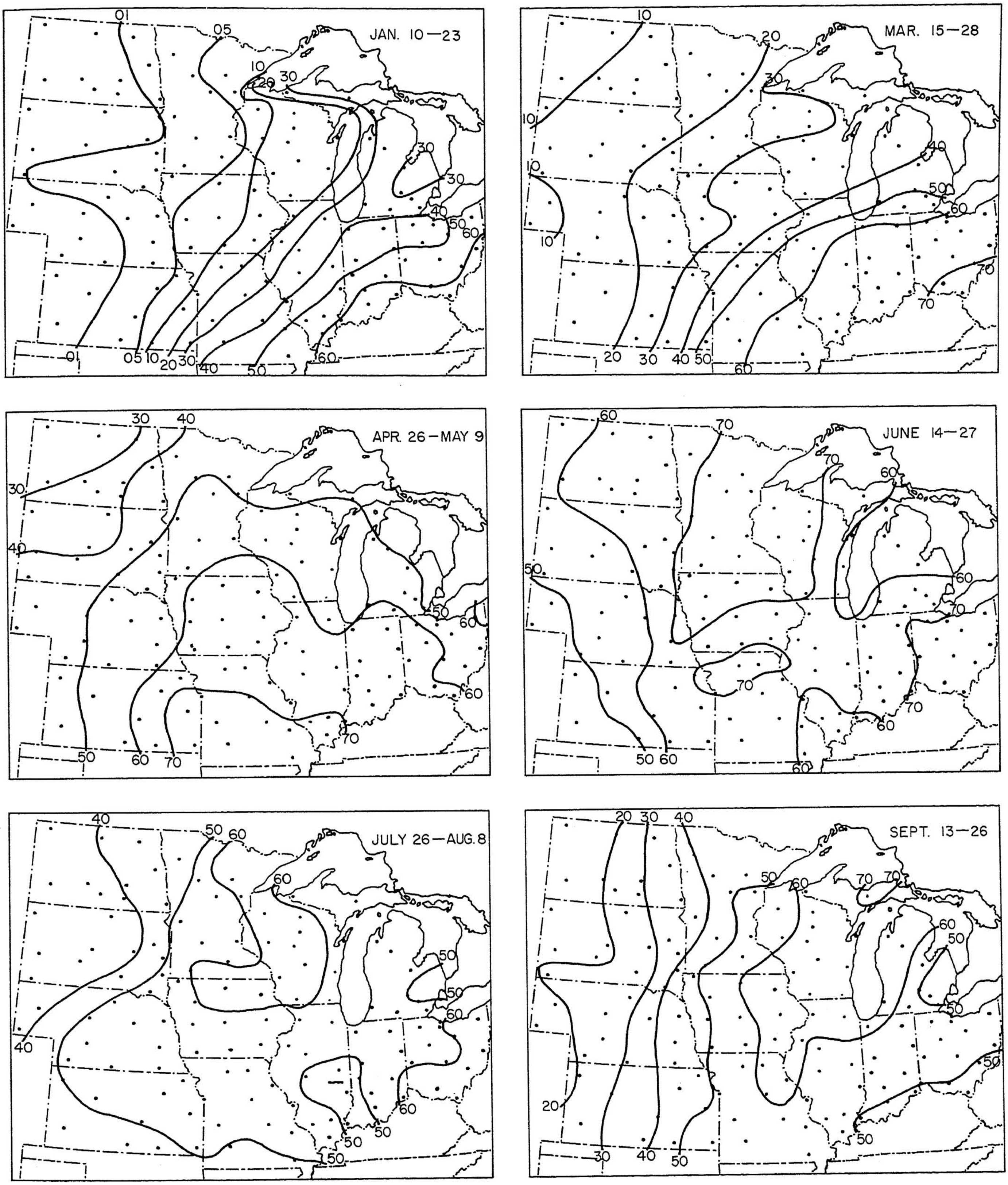

Fig. 31. Probability, in percent, of receiving 1.0 inch or more precipitation during 2-week intervals in six selected periods.

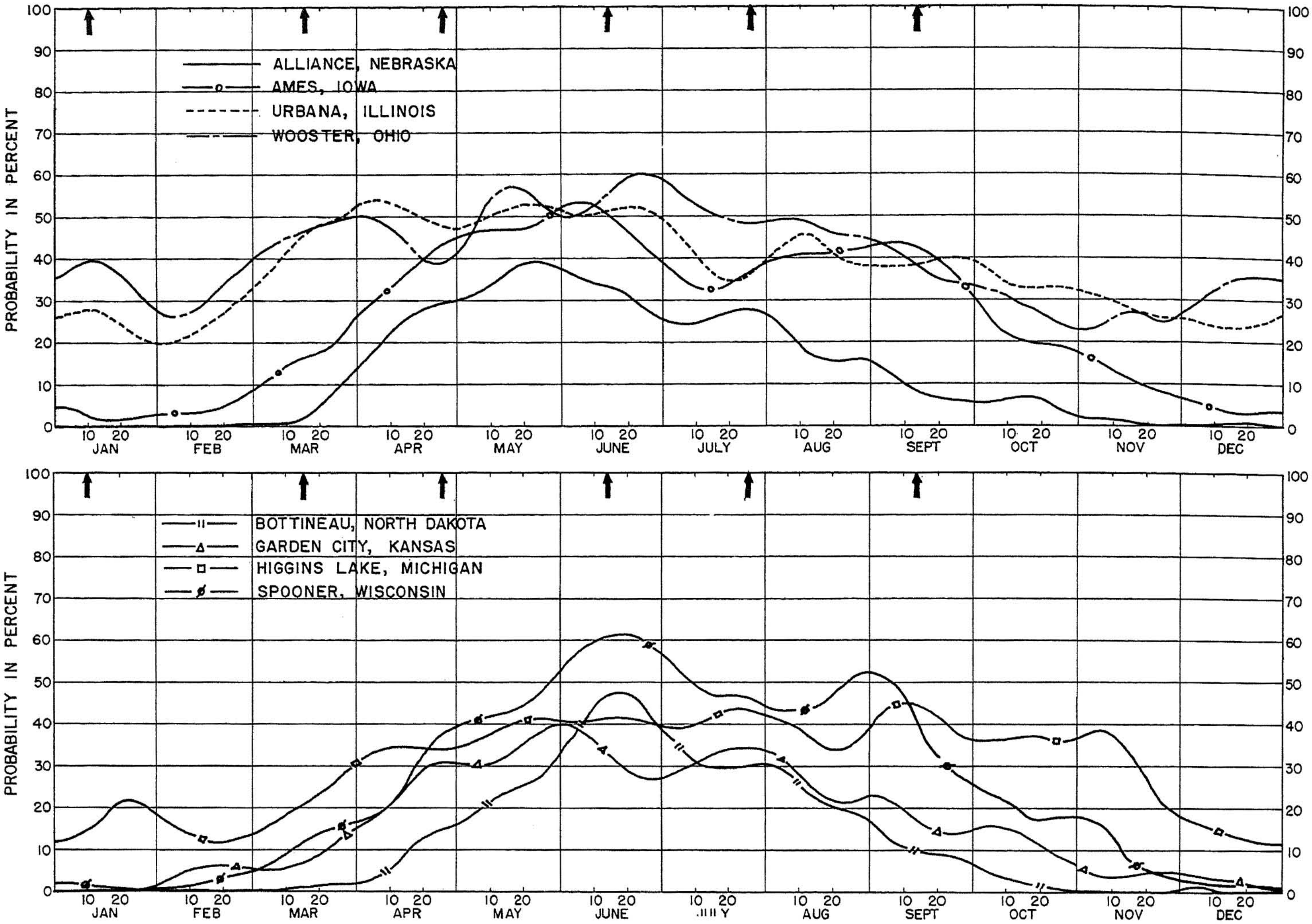

Fig. 32. Probability of receiving 1.4 inches or more precipitation in 2-week intervals at eight stations.

Probability of 1.4 Inches or More

The probability of receiving 1.4 inches or more ranges from 0 in the west during the winter to over 60% in the south central area in late April and the north central area in June. The extremes of probability range from 25 to 60% at Wooster, 20 to 55-60% at Urbana and Springfield, near 0 to over 50% at Ames and 0 to 40% at Alliance. The minimum probability occurs during the winter months throughout the region. The maximum occurs in May or June in much of the region, with northern areas having the later dates. At Springfield and Urbana the maximum is in April, but the April through June period is relatively constant. At Higgins Lake the maximum is in September, but the period May through mid-November is quite constant.

In January, the probability ranges from 0 to 50%. In late February and early March the probability generally starts to increase, and by mid-March it has increased slightly to 5 to 50% across the region. By early May it ranges from 20% to over 60% with the maximum centered in southern Missouri. By mid-June the probability is 50 to 60% in much of the region, but in the west is only 30%. In the central portion of the region (Spooner, Ames, Springfield, Urbana) there is a mid-July decrease in the probability. By early August the probability is 40 to 50%, except in western areas, where it ranges down to 20%. There is little change in the east (except extreme southeast) but some decrease in the west during August, and by mid-September the probability is down to 10% in western Nebraska with the maximum in the northeast. The probability generally declines until by mid-November the winter pattern is well established.

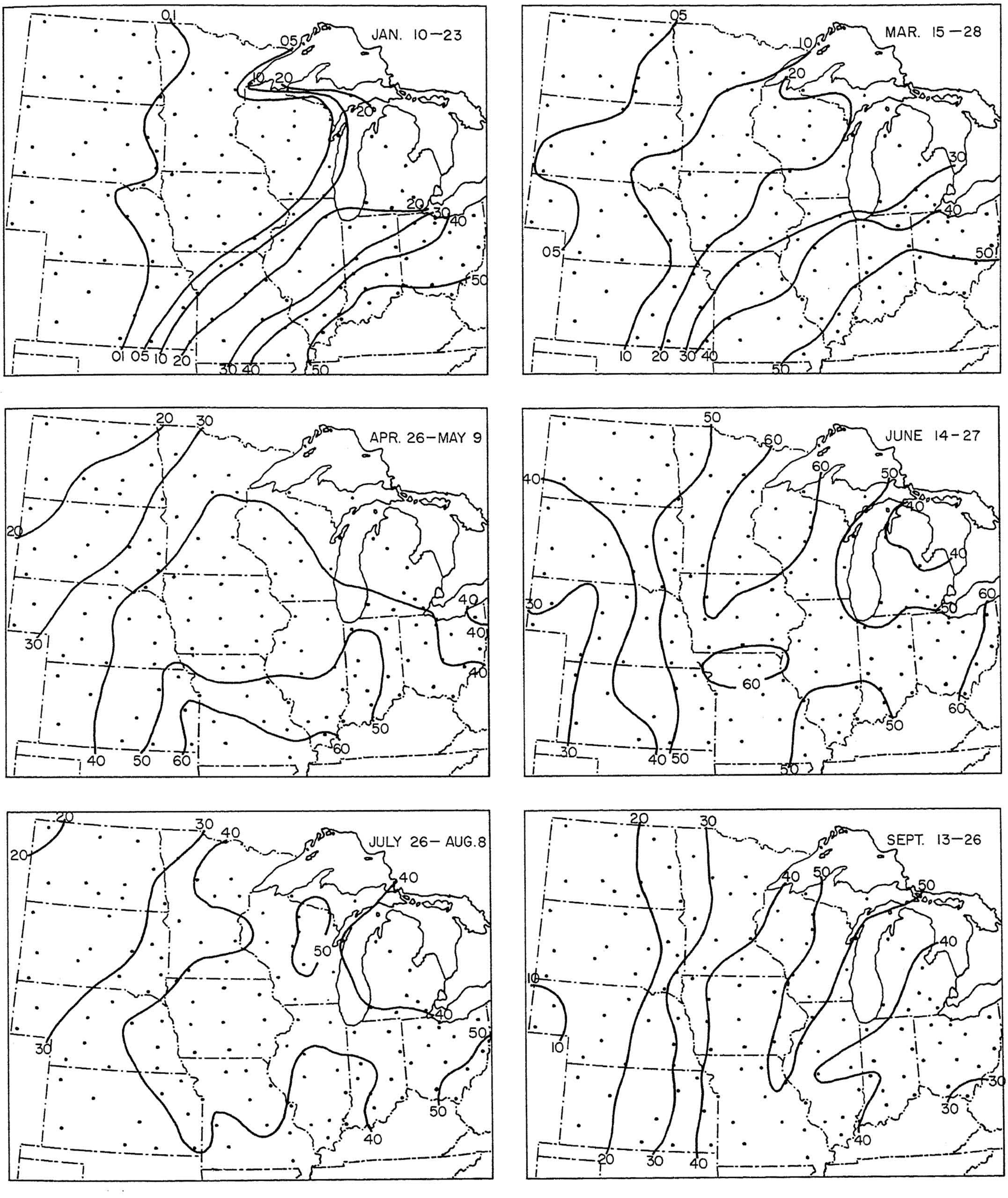

Fig. 33. Probability, in percent, of receiving 1.4 inches or more precipitation during 2-week intervals in six selected periods.

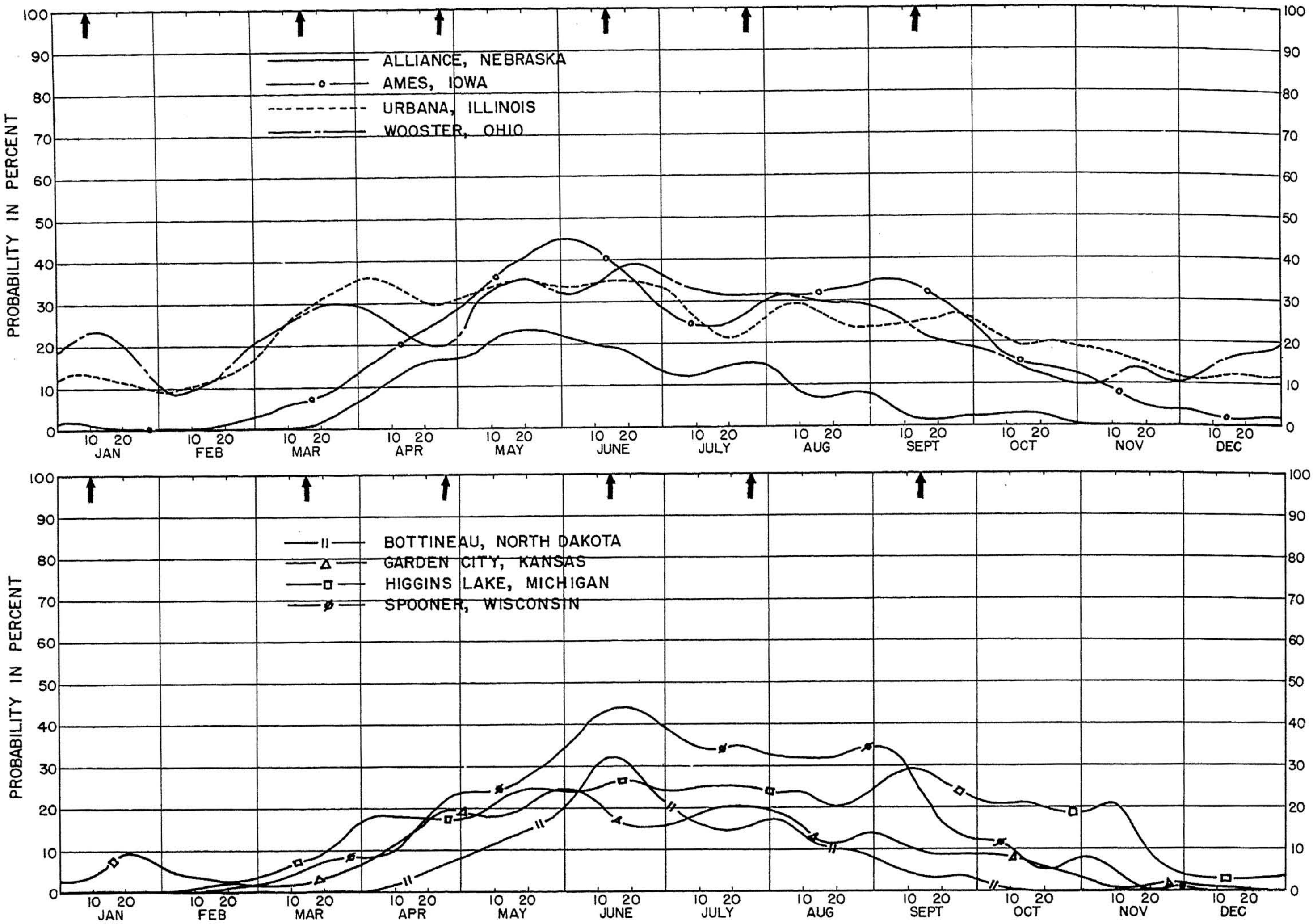

Fig. 34. Probability of receiving 2.0 inches or more precipitation in 2-week intervals at eight stations.

Probability of 2.0 Inches or More

The probability of 2.0 inches or more ranges from 0 in the west to almost 50% in the south central area in May and June. The extremes of probability range from 10 to 40% at Wooster, 10 to 35% at Urbana, 0 to 45% at Ames and 0 to 25% at Alliance. The minimum occurs during the winter period at all locations. The maximum in much of the area occurs in late May or June, except at Urbana and Springfield where it is relatively constant from April through June, and at Higgins Lake, where the maximum is in September, although the April through early November period is relatively constant.

In January, the probability ranges from 0 to 40%. There is generally a slight increase in the probability by mid-March, but the range is still near 0 to 40%. By early May, the maximum probability of 40% is in southern Missouri, and it ranges down to 10% in the extreme northwest section. By mid-June the central section has a probability near 40%, which ranges down to 20% in the southwest section. There is a general decrease in the probability after mid-June, and in most of the region it is 20 to 30% from late July through mid-September, except for the western states. The probability in all areas, except the southeast, declines during the fall period, and the winter pattern is reached in the west by early November. The probability in the extreme southeast increases in early December and January (see Wooster curve) to 30-40%.

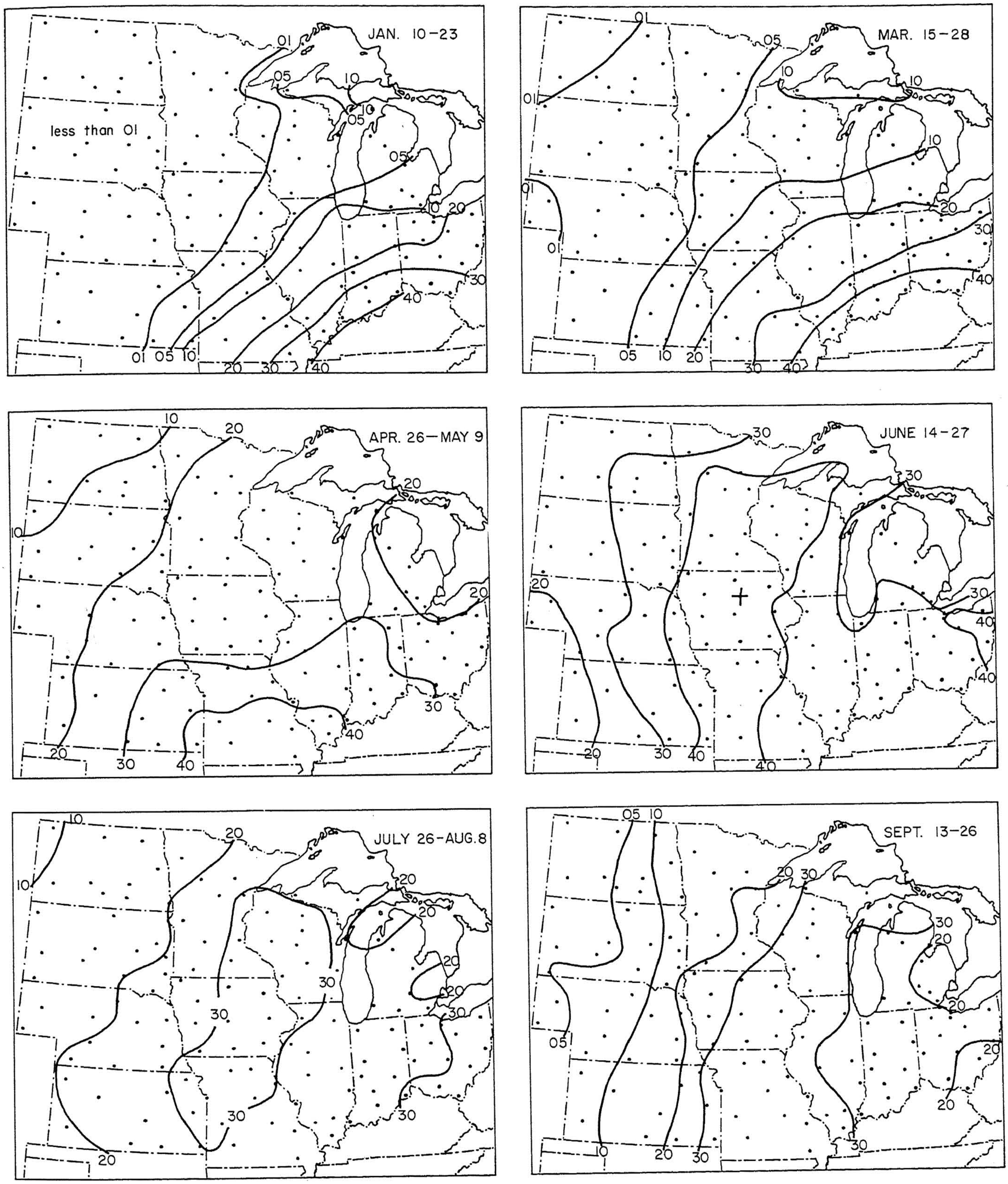

Fig. 35.Probability, in percent, of receiving 2.0 inches or more precipitation during 2-week intervals in six selected periods.

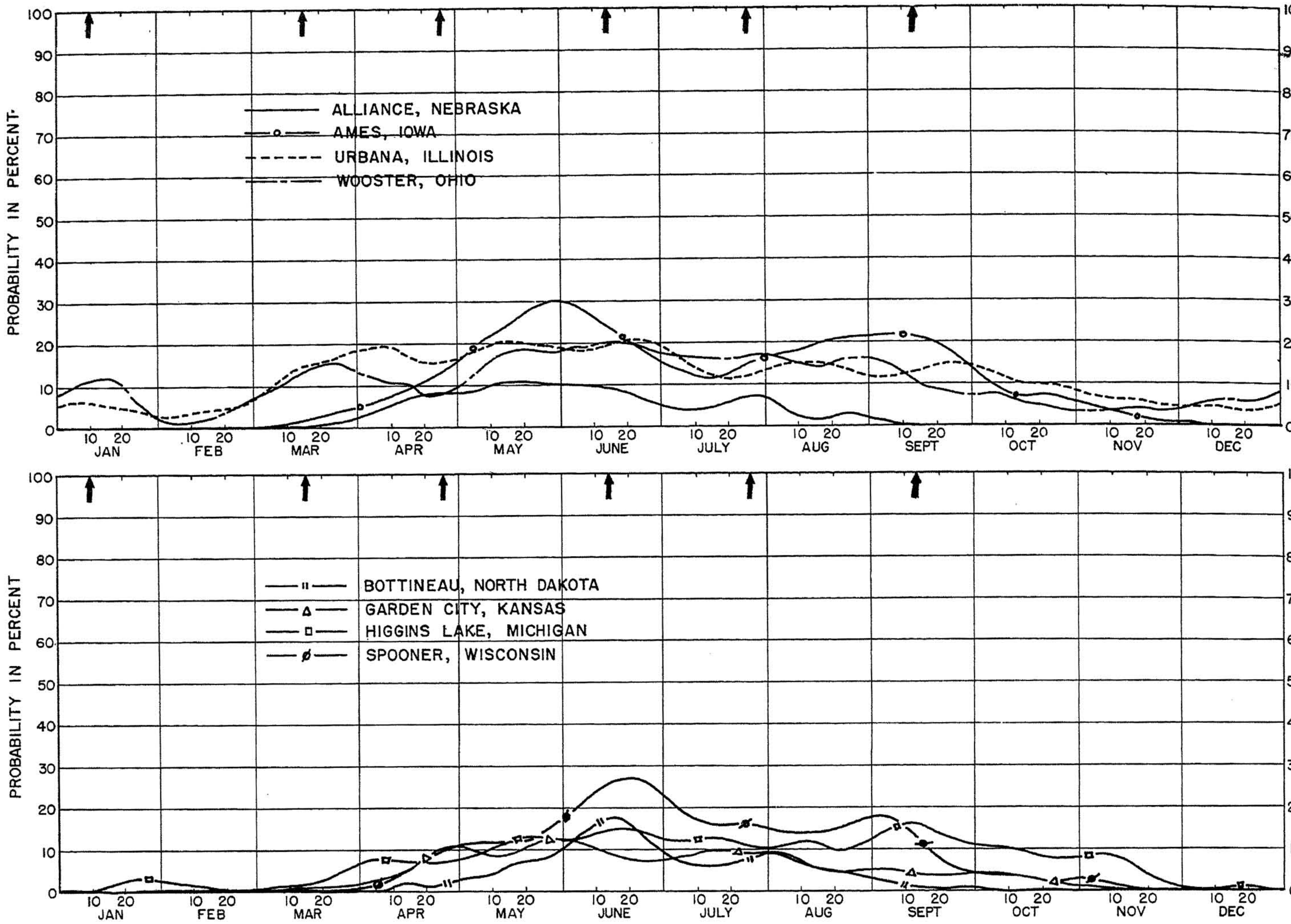

Fig. 36. Probability of receiving 2.8 inches or more precipitation in 2-week intervals at eight stations.

Probability of 2.8 Inches or More

The probability of receiving 2.8 inches or more varies from 0 in much of the region in the winter to near 35% in the south central area in June. The extremes of probability range from near 0 to 20% at Wooster, 5 to 20% at Urbana, 5 to 30% at Springfield, 0 to 30% at Ames and 0 to 10% at Alliance. The minimum occurs during the winter period. The maximum is in late May or June, except at Higgins Lake, where the maximum is in September, although the mid-May through September period is relatively constant, and at Wooster, where the maximum is in June, but the mid-April through early September period is relatively constant.

In January the probability ranges from 0 to 20%, showing little increase by mid-March. By early May, there is some increase in the west, and the maximum probability of 20% occurs in southern Missouri and Illinois. There is a general increase in the probability during the late spring, and by mid-June much of the region is near 20%, with a maximum of 30% in Missouri (35% in extreme southwest Missouri and southeast Kansas) and a minimum of 10% in the west. There is a general decrease in the probability from the spring maximum, and by early August the probability over most of the region is near 10%. (Ames and Springfield show a definite July minimum.) The probability in the west decreases during August and early September, but in the central area (Ames) there is a secondary maximum in mid-September. There is a gradual decrease in the probability after mid-September, and by early November the pattern is very similar to that in January.

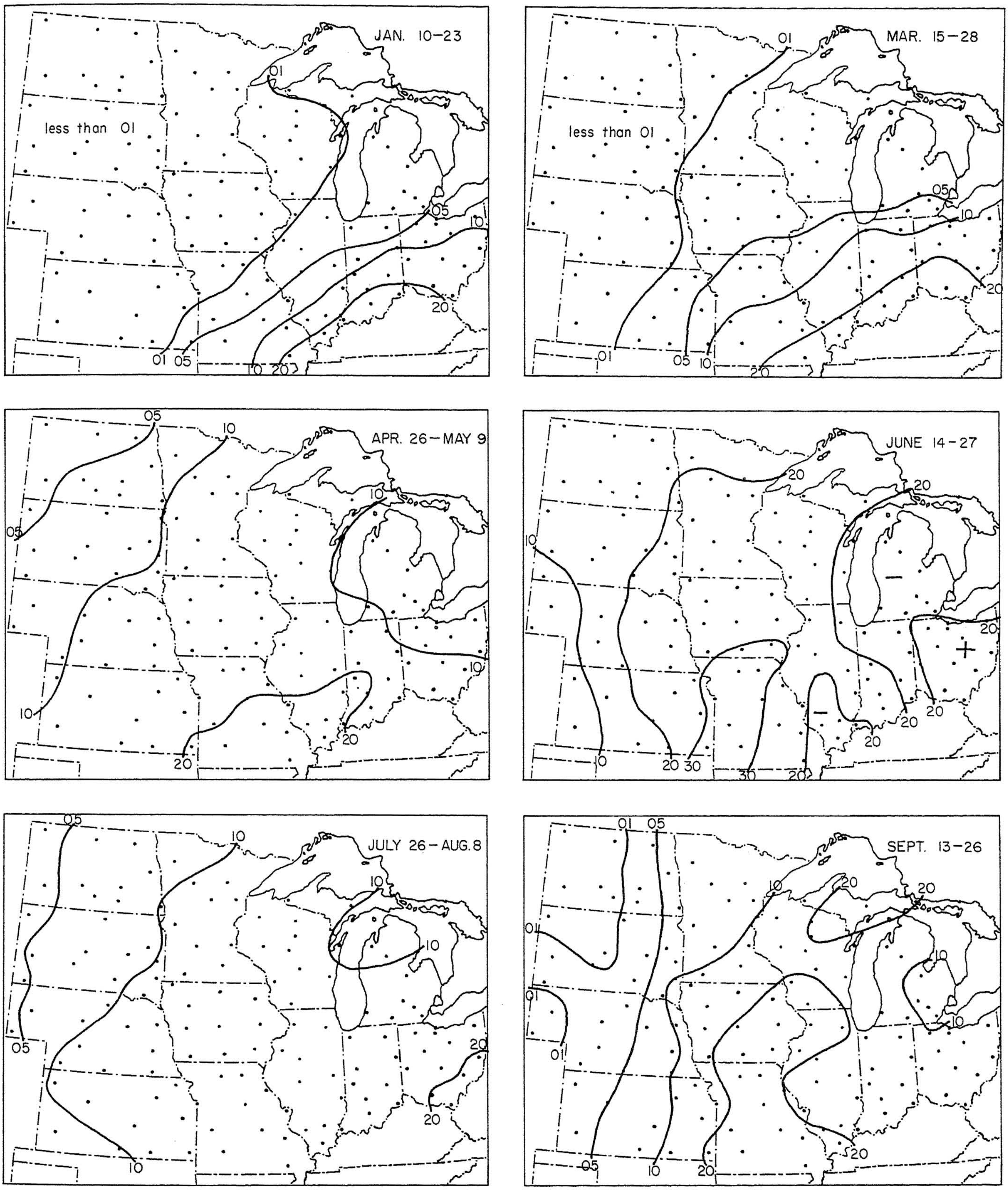

Fig. 37. Probability, in percent, of receiving 2.8 inches or more precipitation during 2-week intervals in six selected periods.

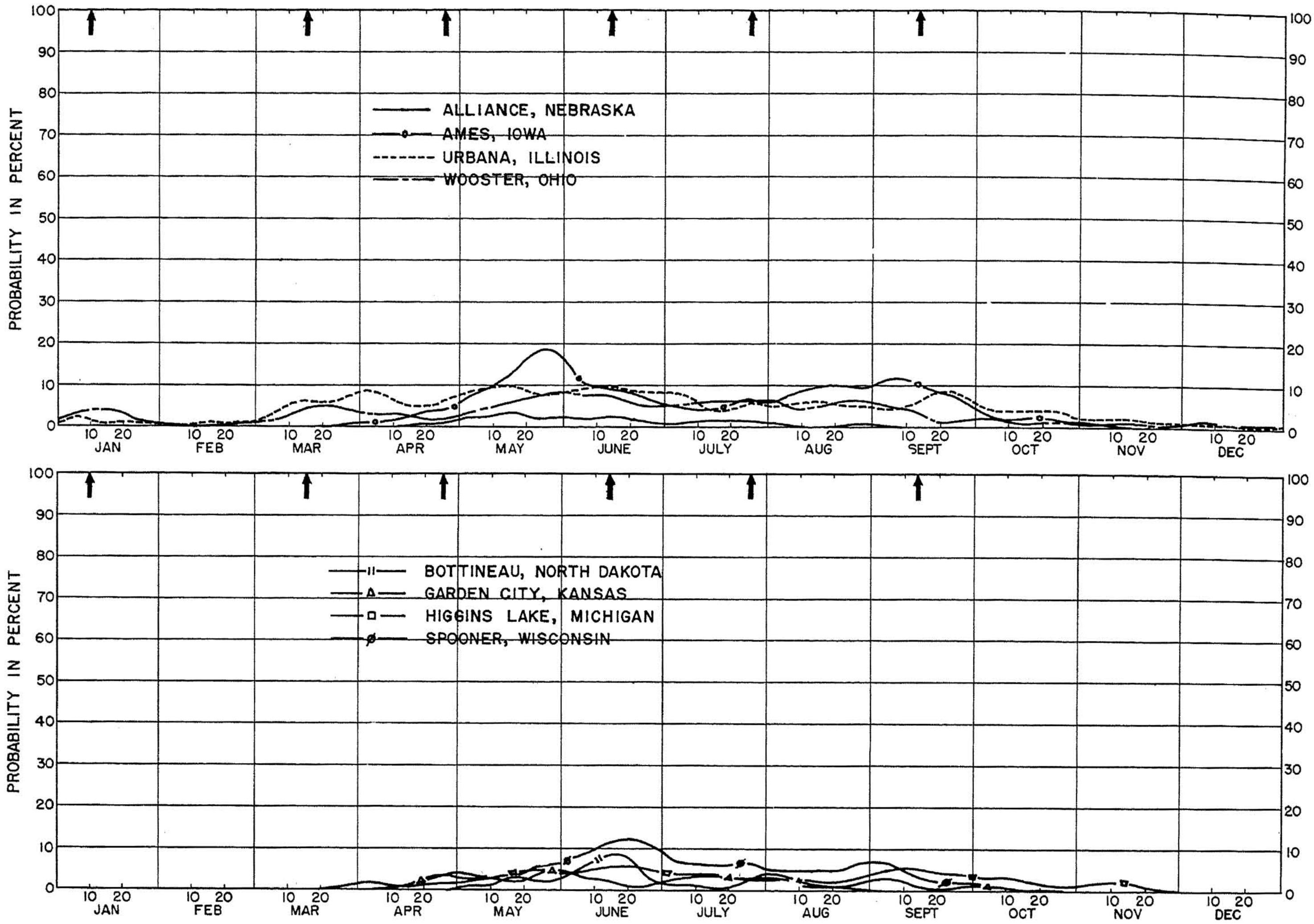

Fig. 38. Probability of receiving 4.0 inches or more precipitation in 2-week intervals at eight stations.

Probability of 4.0 Inches or More

The probability of receiving 4.0 inches or more ranges from 0 in the winter to 20% in the south central area in June. The extremes of probability range from 0 to almost 10% at Wooster, 0 to 10% at Urbana, 0 to near 20% at Ames and Springfield and 0 to less than 5% at Alliance. The maximum probability occurs generally in the May-June period although most stations show only a small annual range. In January the probability is less than 1% in all of the region, except southern Missouri, southern Illinois and Indiana and Ohio. By mid-March it has increased slightly, but still is less than 5%, except for the southern parts of Illinois, Indiana, Missouri and Ohio. By early May the probability is near 5%, except in southeast Missouri, where it is 10%, and the western border, where it is near 1%. By mid-June the probability is over 10% in Iowa and Missouri and the adjacent areas and near 5% in the eastern and western sectors. The highest probability occurs in extreme southeast Kansas and southwest Missouri. The peak shown for Bottineau is not shown by surrounding stations and therefore is not shown on the June 14-20 map. In early August the probability is near 5% in much of the region, although it is less than 1% in the extreme west. By mid-September there is an increase to 10% in the south central sector, but in the east the probability remains near 5% and is near 1% in the western states. By November the winter pattern is reached.

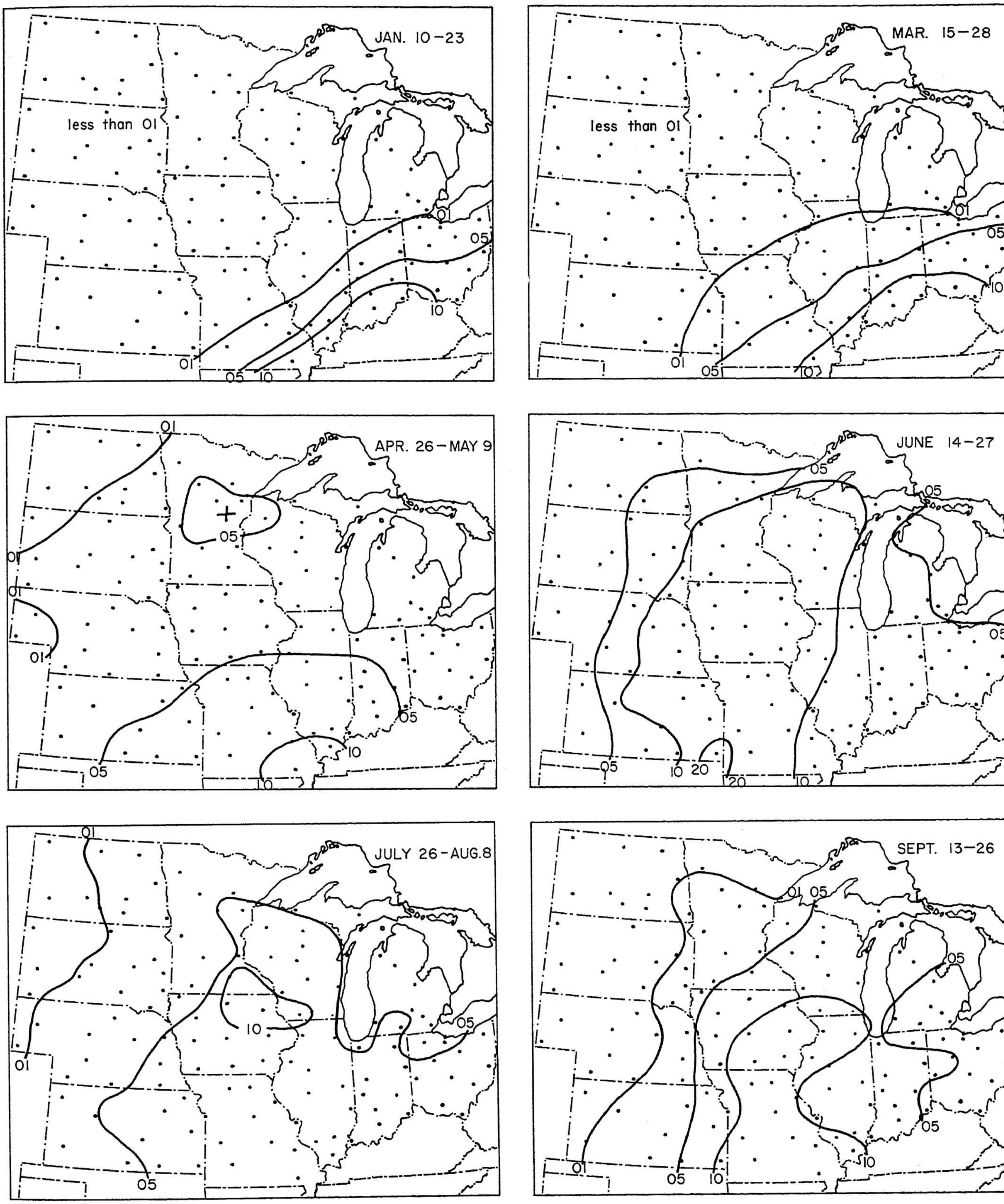

Fig. 39. Probability, in percent, of receiving 4.0 inches or more precipitation during 2-week intervals in six selected periods.

Probability of 6.0 Inches or More

The probability of 6.0 inches or more ranges from 0 to near 10%. In all areas it is near 0 during the winter season. In the west it is near 0 throughout the year, while in the east it reaches only 1-2% from late May to August and is near 0 the rest of the year. In the central sector the maximum probability of 3-4% is reached in late May or early June. In the south central area the maximum probability occurs during late May and early June and for a short period reaches almost 10% in southwest Missouri and southeast Kansas.

Probability of 8.0 Inches or More

The probability of 8.0 inches or more ranges from 0 to only 5%. It is near 0 in January, except in the extreme southeast where the probability is 1-2%. In mid-March the probability is near 0 over the region. Again in late April the probability is near 0, except in the extreme southeast where it is 1-2%. By mid-June, except for the area extending from Wisconsin (1-2%) to Missouri (3-4%), the probability is near 0. The probability in late July is near 0 except in western Missouri-eastern Kansas where it ranges from 1 to 5%. By mid-September the probability is 1-2% in Iowa, Missouri and Illinois, and near 0 elsewhere.

3-WEEK PRECIPITATION PROBABILITIES

The 3-week precipitation probabilities follow a pattern similar to that of shorter periods, with the minimum generally occurring during the winter period and the maximum generally during the April-June period. The maximum tends to be later with increasing latitude. For lighter amounts of precipitation, the absolute maximum is generally in the east. For heavier amounts of precipitation, it is in the south central area with Columbus, Kansas, and Clinton, Missouri, most frequently showing the greatest probability. These localized station values are frequently smoothed out of the maps because of the intent to represent general regional patterns. The minimum generally occurs in the west throughout the year. The shape of the curve at Springfield, Missouri, is similar to that at Urbana, except the spring maximum is much more peaked.

In the winter the maximum is in the southeast or east. In April-May the maximum is generally in the south central area, particularly for heavier amounts of precipitation. In June the maximum is most frequently in the east, but the probability at that time of year is relatively uniform throughout most of the region. The maximum September probability frequently occurs in the northeast or central area.

The annual curves for stations in the central and south central sector frequently show a July dip in the probability and a secondary September maximum.

For light amounts of precipitation (0.2 inch) the probability is near 100% in the summer, but ranges down to 40% in the winter. For 1.0 inch the probability is near 0 in the west in the winter but ranges up to 90-95% in the east, south central and central areas in the April-June period. For 2.0 inches the probability is near 0 in much of the region during the winter and reaches 60-70% in the east and central area in May or June. For 4.0 inches the winter probability is near 0 in most of the region, reaching a maximum near 40% in the south central areas in June. The maximum probability of receiving 6.0 inches is near 25% in late May-early June in the south central area at individual stations, although most stations in this area peak near 15%.

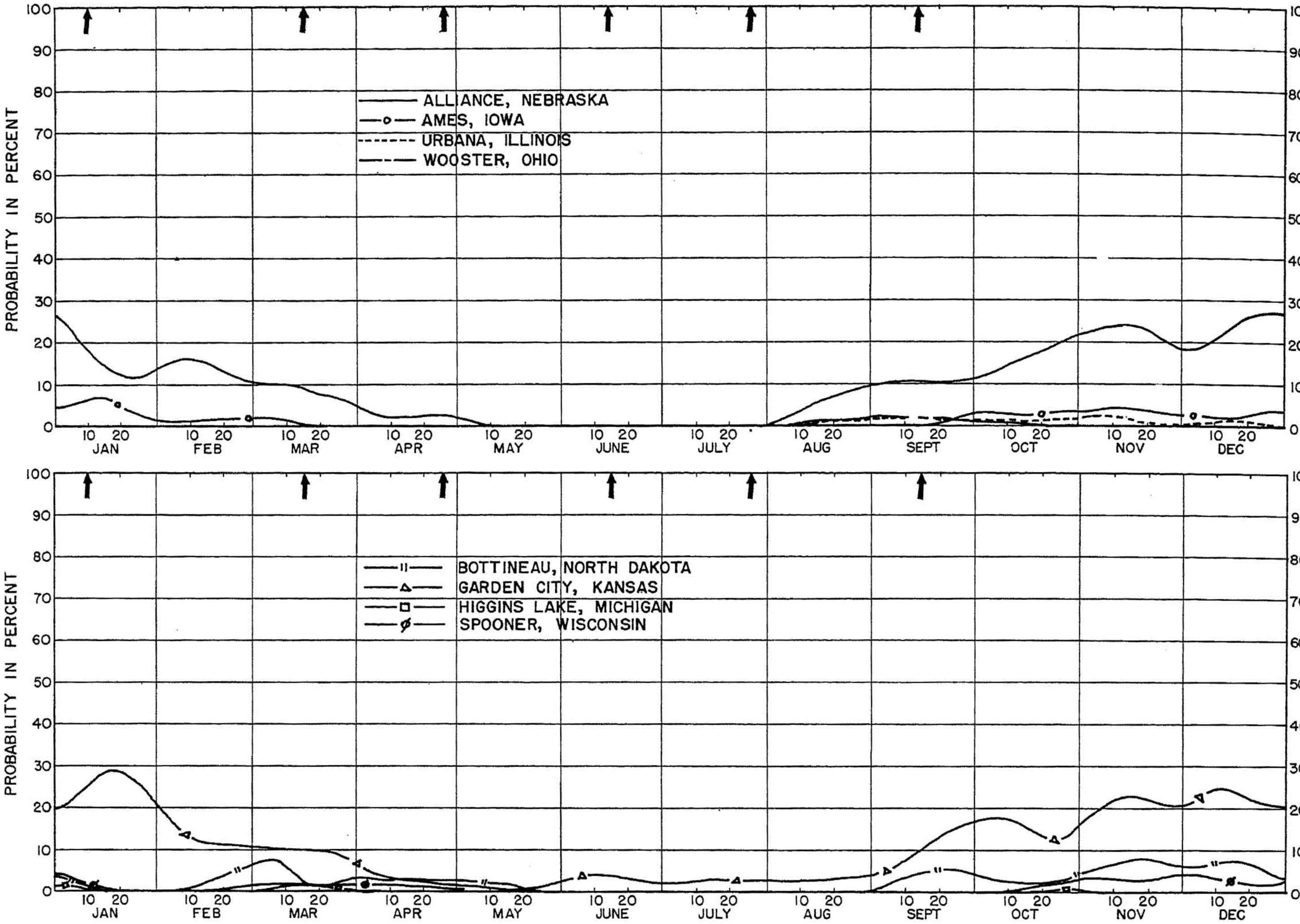

Fig. 40. Probability of receiving only 0 or trace precipitation in 3-week intervals at eight stations.

Probability of 0 or Trace

The probability of 0 or trace in a 3-week period ranges from 0 to near 30%. The maximum probability occurs during the late fall or winter months, the minimum during May to August.

In January the probability ranges from near 1% in the east to 30% in the southwest. The probability in the west decreases and by mid-March is down to 10% in the southwest. By late April, except for individual stations, the probability is 1% or less, and remains near that level through July. In August the probability increases in the west, and by mid-September ranges from near 1% in the east to 10% in the southwest. By mid-November the winter pattern is well established.

To provide an idea of the bias[4] the actual observed P(0,T) for the first order stations are given on each map in fig. 41. Except for the higher probabilities, the absolute difference between the estimates for cooperative stations and those for first order stations appears to be very small.

[4]See page 13.

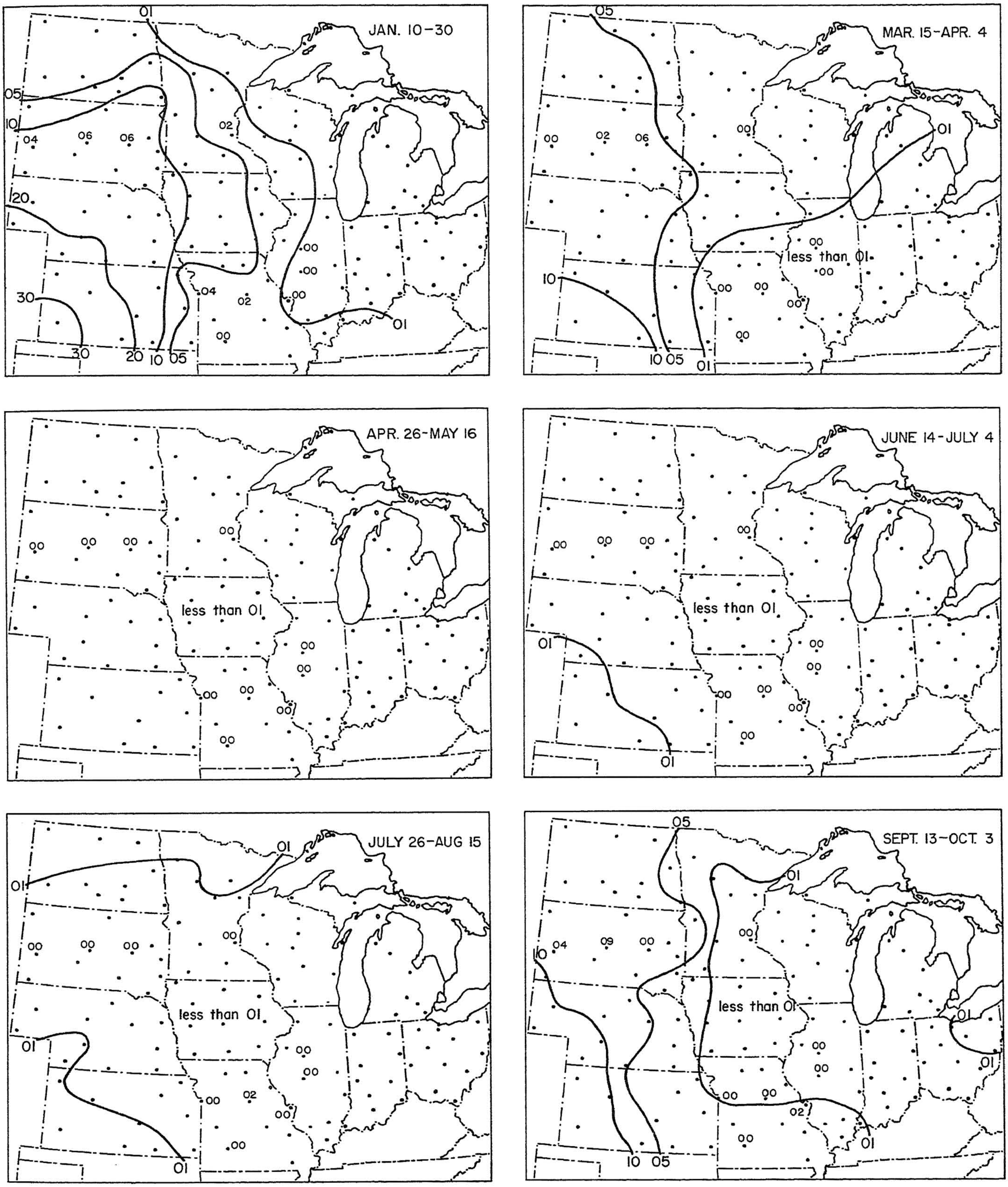

Fig. 41. Probability, in percent, of receiving only 0 or trace precipitation during 3-week intervals in six selected periods.

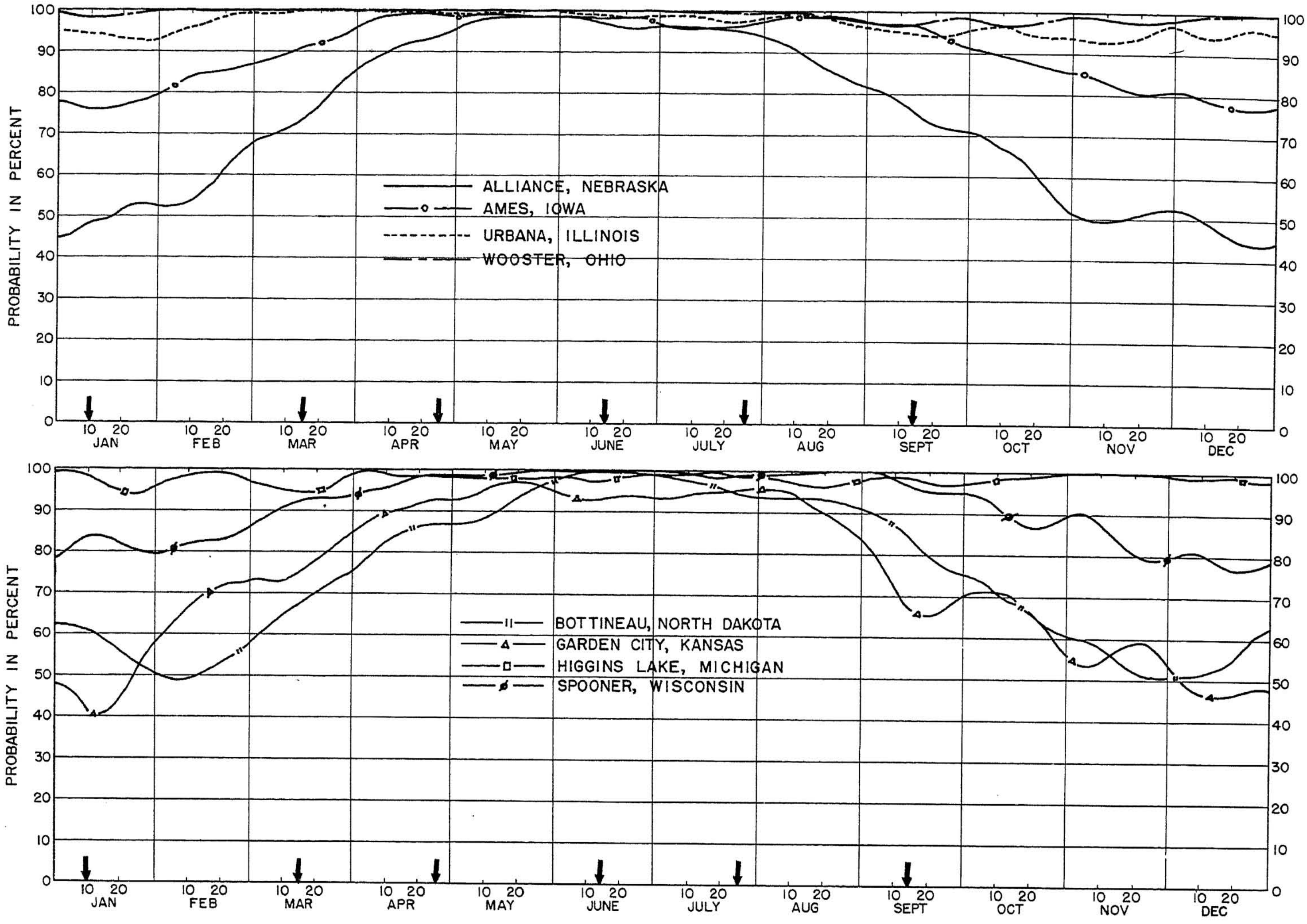

Fig. 42. Probability of receiving 0.2 inch or more precipitation in 3-week intervals at eight stations.

Probability of 0.2 Inch or More

The probability of 0.2 inch or more ranges from a low slightly less than 40% in the southwest during mid-January to a high near 100% in most areas during the summer. The extremes of probability range from a low of 90-95% to a high of 100% in the east, northeast and south central sections, 70-80 to 100% in the central area and near 45 to 100% in the western areas.

In January, the probability ranges from 40% in the southwest to 99% in the extreme east. The minimum generally occurs in mid-January, except at Bottineau where there are minima in late November-early December and again in February. The probability rapidly increases in the west after January and by mid-March the range across the region is from 70% to over 95%, by early May is 90% to near 100% and by mid-June 95% to near 100%. The probability decreases slightly by early August to 90% to over 95% across the region. By mid-September the probability in the west decreases to 70% and continues to decrease until the winter pattern is reached in late November-early December.

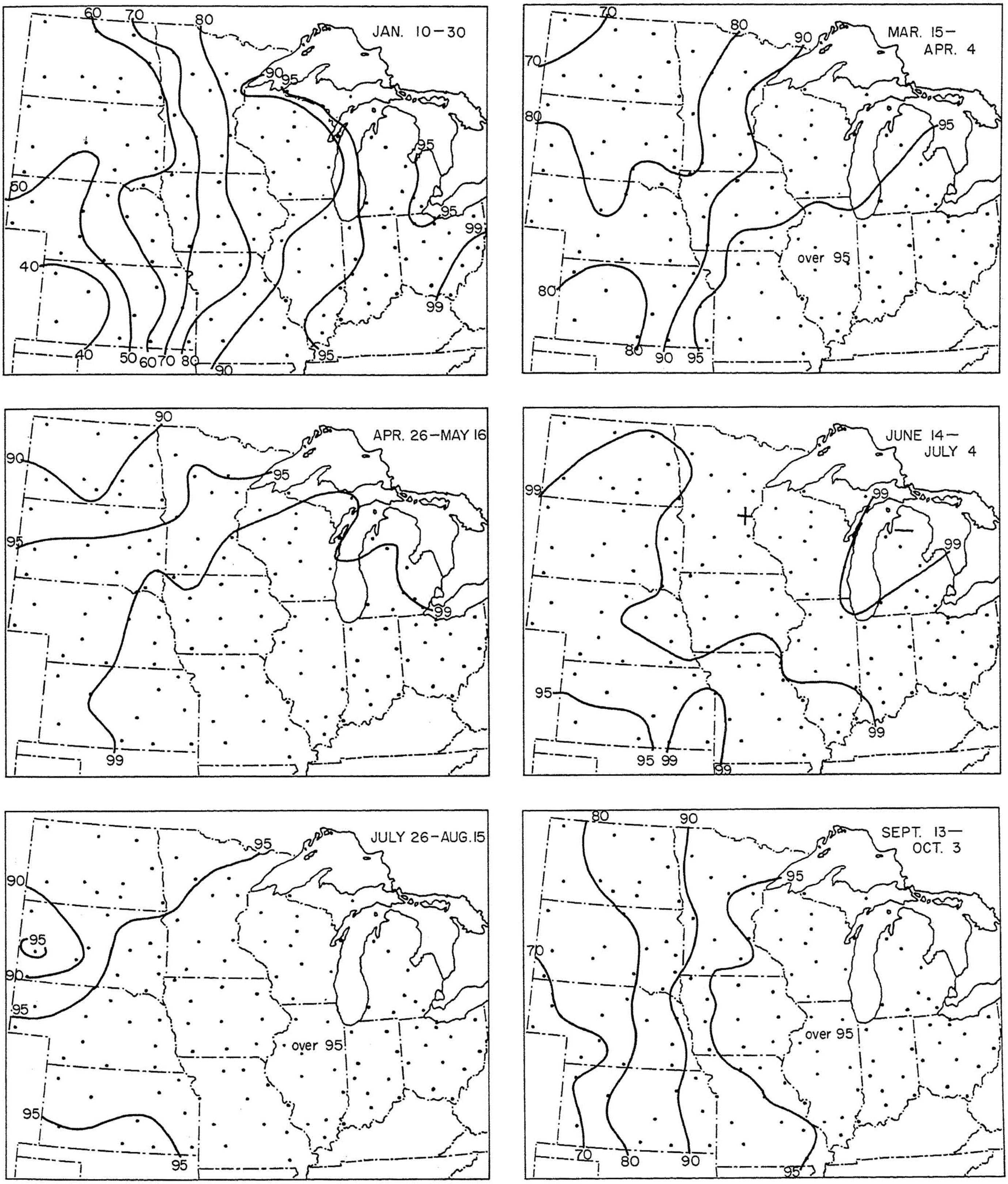

Fig. 43. Probability, in percent, of receiving 0.2 inch or more precipitation during 3-week intervals in six selected periods.

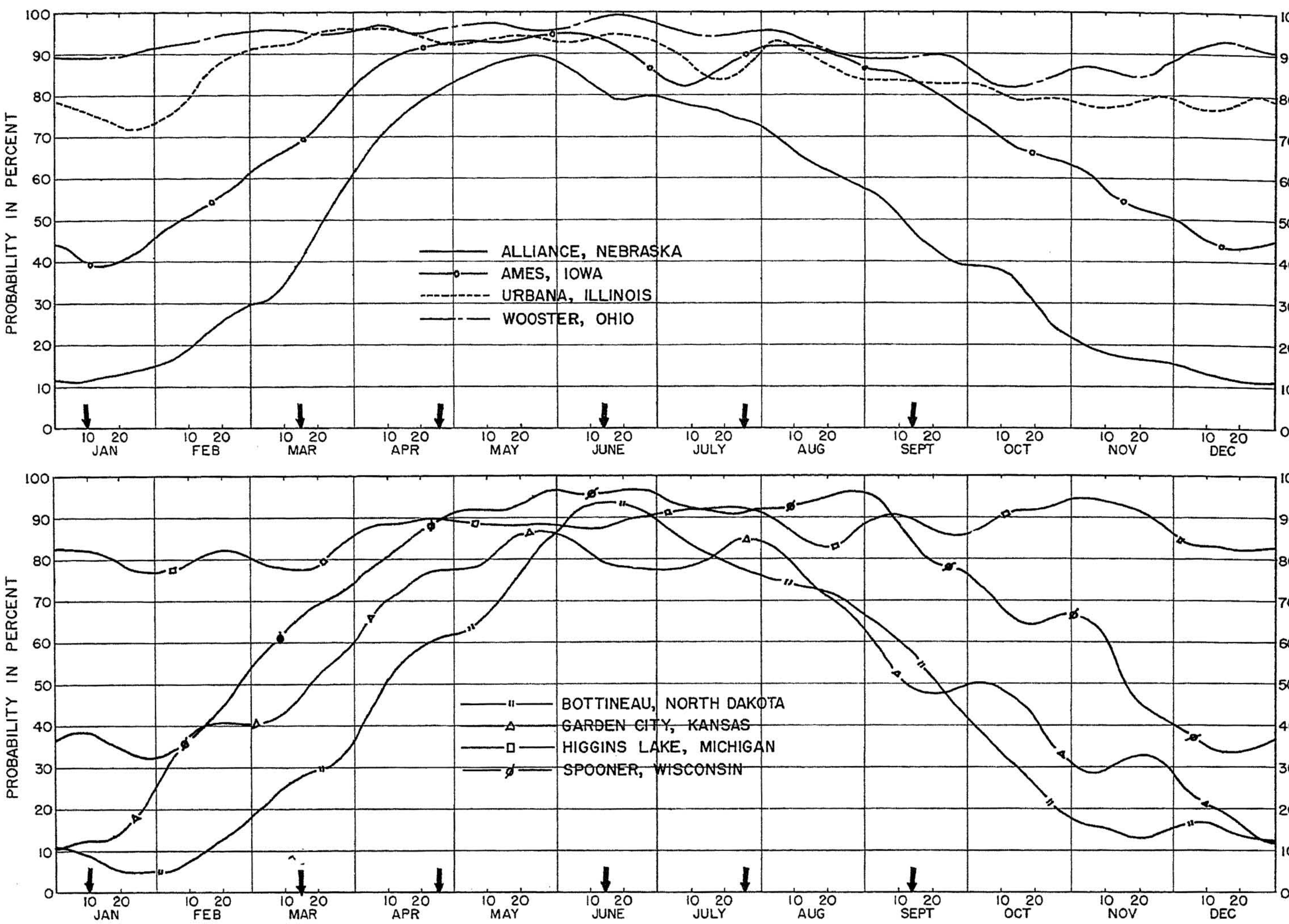

Fig. 44. Probability of receiving 0.6 inch or more precipitation in 3-week intervals at eight stations.

Probability of 0.6 Inch or More

The probability of receiving 0.6 inch or more ranges from a low near 5% in late January in the northwest to a high near 100% in the east in June. The extremes of probability range from 80% to near 100% at Wooster, 70 to 95% at Urbana, 40 to 95% at Ames and near 10% to near 90% at Alliance. The minimum generally occurs in the December-January period, although at Higgins Lake it is January-March, and in the east it is during October-November. The maximum probability in the west and central areas is in the May-June period, while in the southeast it is during April-May, and in the east and northeast there is a broad, relatively uniform period of high probability from April through July.

During mid-January, the probability ranges from less than 10 to 90% across the region, with a pronounced west to east gradient. The probability increases rapidly after this date in the west and a small amount in the east so that by mid-March it ranges from 30 to 95% across the region and by early May is 60 to 95%, with the lowest probability in the northwest. By mid-June the probability is 90-95% over most of the region. Probabilities in the extreme west decrease in July, and by early August the range is 70 to 95% across the region. In mid-September the maximum probability occurs in the Wisconsin-upper Michigan area, with other areas having decreased since early August, particularly in the west and extreme east. Except for the extreme eastern area, the probability decreases, particularly in the west, and the winter pattern is reached by early December.

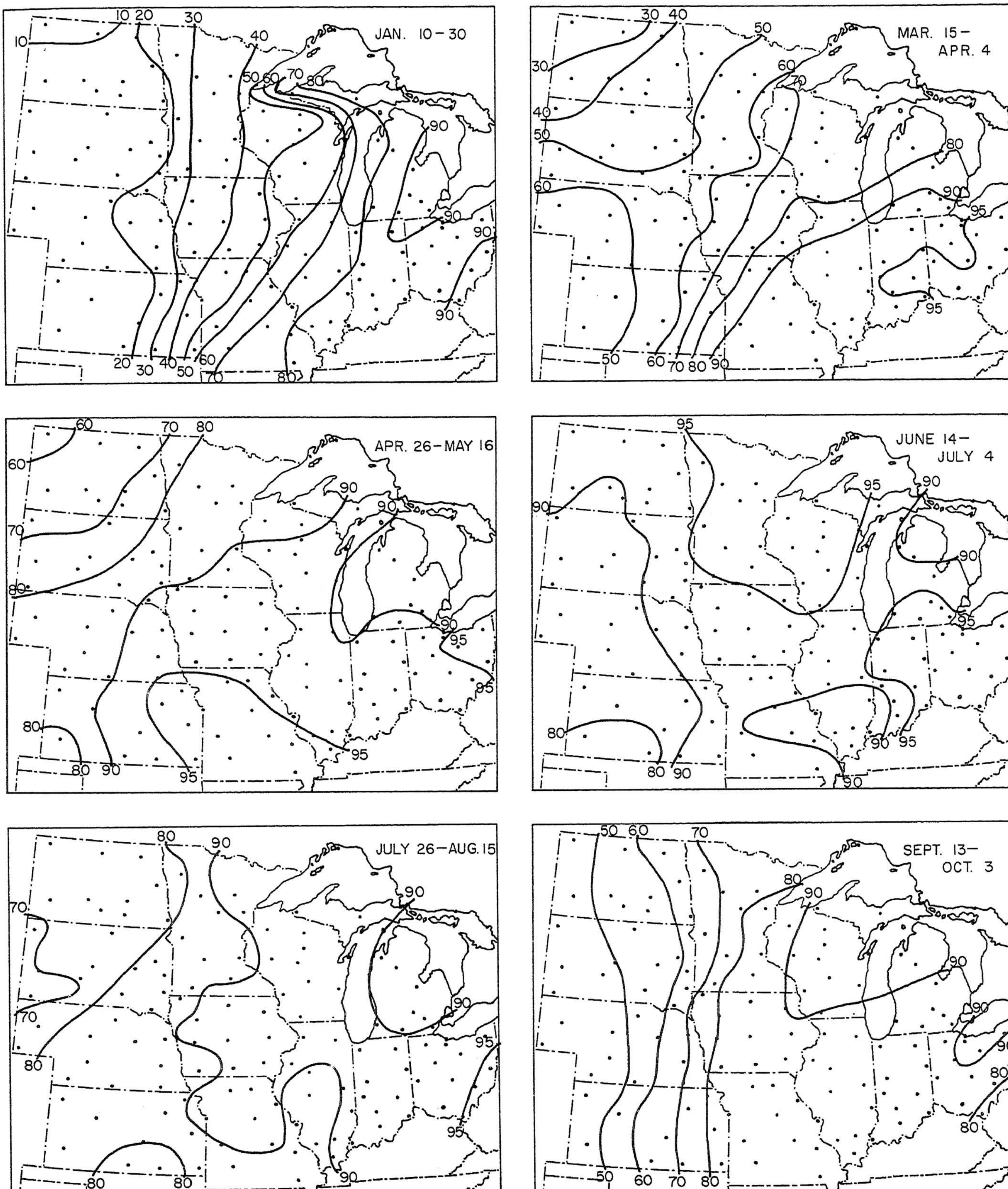

Fig. 45. Probability, in percent, of receiving 0.6 inch or more precipitation during 3-week intervals

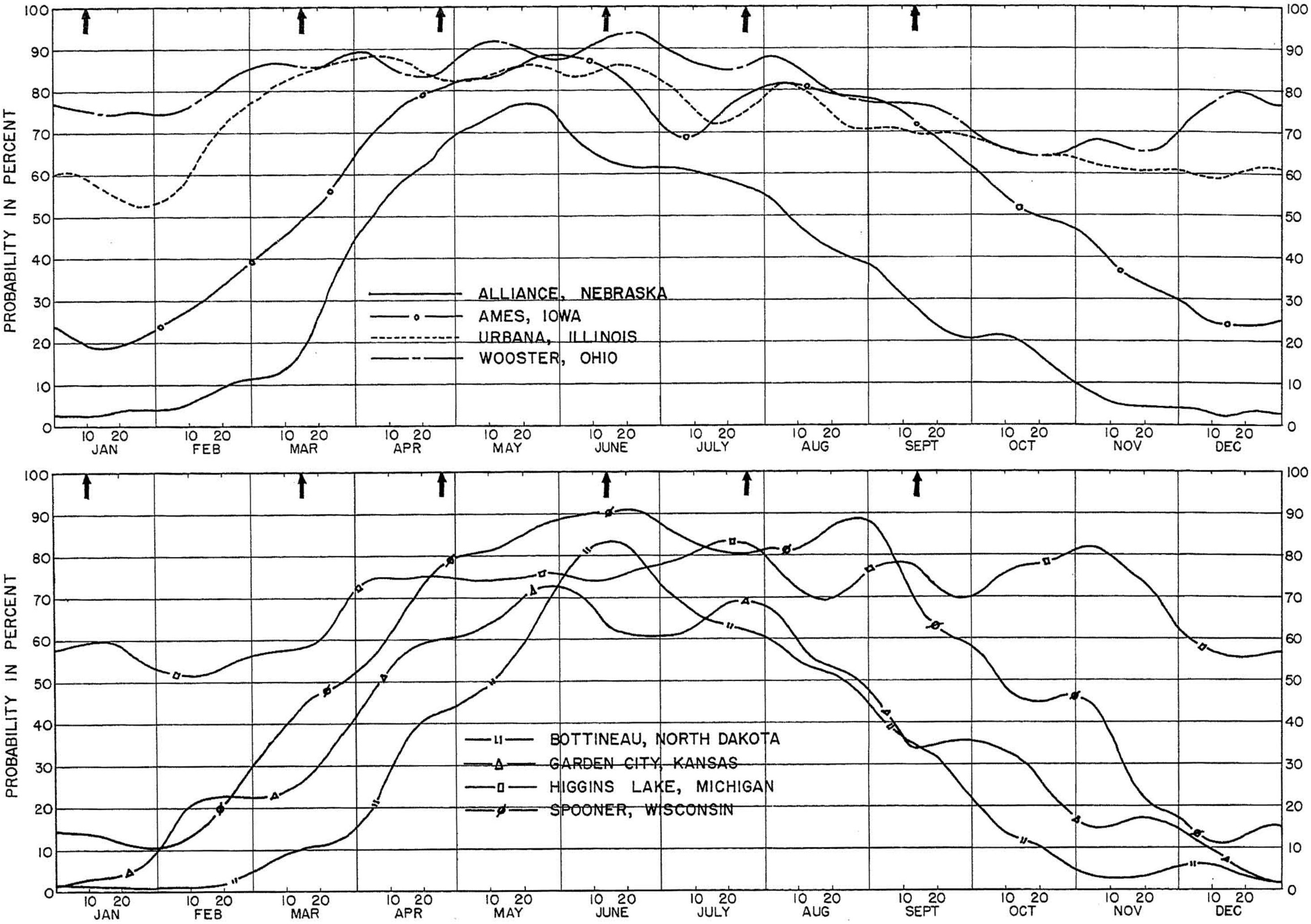

Fig. 46. Probability of receiving 1.0 inch or more precipitation in 3-week intervals at eight stations.

Probability of 1.0 Inch or More

The probability of receiving 1.0 inch or more ranges from near 0 in the west to near 95% in the south central area in April and in the east in June. The extremes of probability range from 65 to 95% at Wooster, 50% to near 90% at Urbana, 20 to 90% at Ames and near 0 to 75% at Alliance. The minimum occurs generally in December or January, except in the east, where it is October-November at Wooster. The maximum occurs in May or June in much of the region, although it is in April in the southeast and south central, and in July at Higgins Lake. A definite decrease in the probability is evident in the south central and central areas in July.

In January, the probability varies from near 0 in the northwest to near 80% in the southeast. The probability generally starts increasing in February, and by mid-March the range is 10 to 90% across the region. By late April-early May the maximum probability has shifted to the south central area and the range across the region is 40 to 90%. The probability in the west continues to increase, and by mid-June it is 80 to 90% across much of the region. By this time the probabilities in the west have passed their maximum value. The probability in the west continues to decline to 60 to 70% by early August, while the probability in the rest of the region varies from 80 to 90%. There is a general decrease in the probability after this time, particularly in the west, and by mid-September the probability is 30 to 80% across the region. Except for the extreme east, the probability continues to decrease until by early December the winter pattern is established.

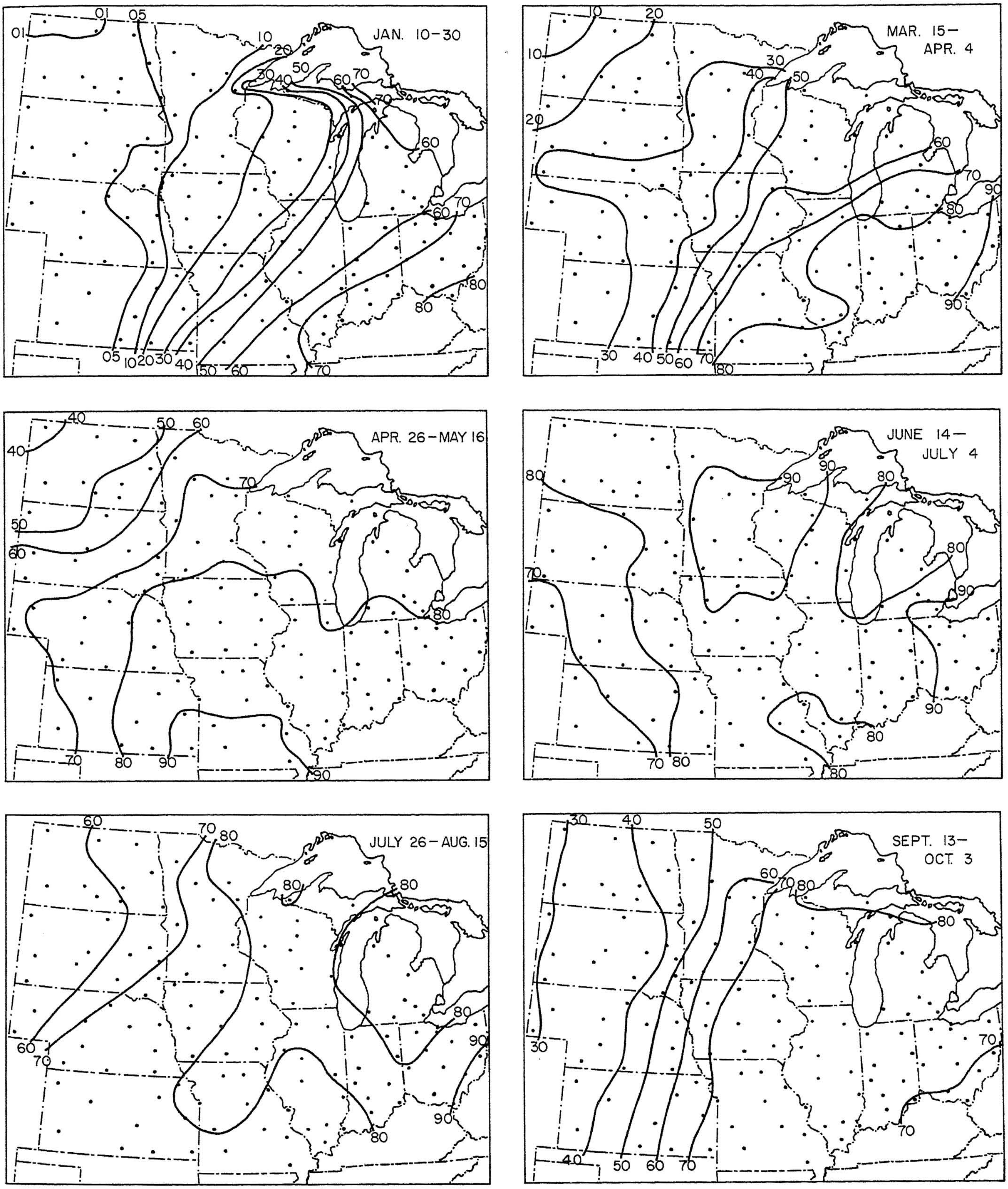

Fig. 47. Probability, in percent, of receiving 1.0 inch or more precipitation during 3-week intervals in six selected periods.

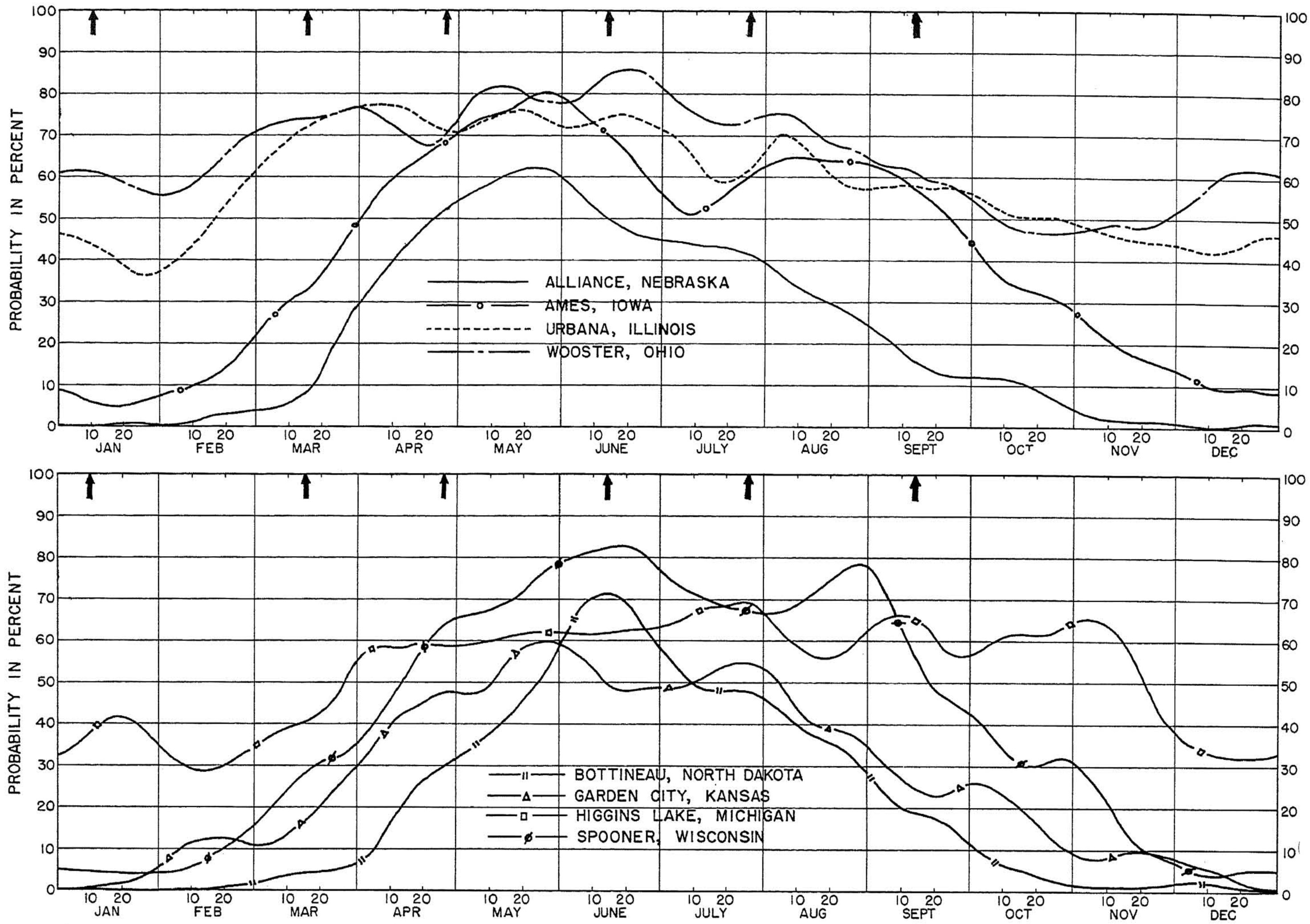

Fig. 48. Probability of receiving 1.4 inches or more precipitation in 3-week intervals at eight stations.

Probability of 1.4 Inches or More

The probability of 1.4 inches or more ranges from 0 in the west to over 80% in the south central area in April and the east in June. The extremes range from 45 to 85% at Wooster, 35 to 75% at Urbana, 5 to 80% at Ames and 0 to over 60% at Alliance. The minimum probability generally occurs in December-January, with a longer duration in the west. In the extreme east, the minimum occurs in October-November. The maximum occurs generally in May or June with a later maximum in the northern locations. In the south central area the maximum occurs in the April-May period, while in the northeast it is in July. Except in the northeast, there is a rapid decrease in the probability after the maximum, and in the central and south central areas a definite July dip in the probability is evident.

In January, the probability ranges from near 0 to 70% across the region. In February, the probability increases in most areas, and by mid-March the range is 5 to 80%. By late April the maximum probability has shifted to the south central area and ranges from 30 to 80% across the region. Some areas have already passed their maximum probability by mid-June, and in most areas the probability is 60 to 80%. By early August the probability has decreased to 40% in the west, and much of the region has a probability of 60 to 70%. The probability continues to decline, particularly in the west, and by mid-September ranges from 20 to 70%; and continues to decline after this date, except in the east, reaching the winter pattern by early December.

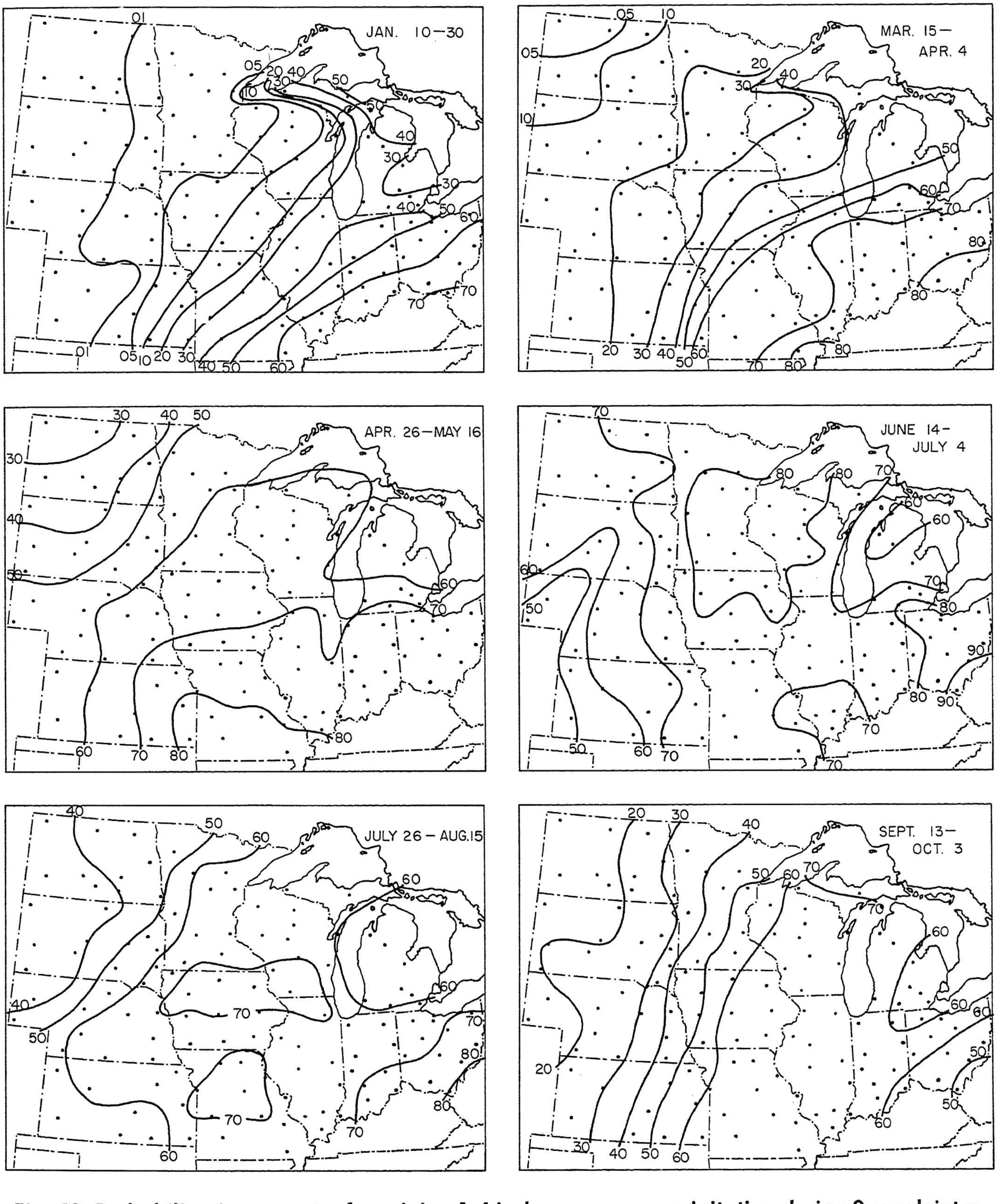

Fig. 49. Probability, in percent, of receiving 1.4 inches or more precipitation during 3-week intervals in six selected periods.

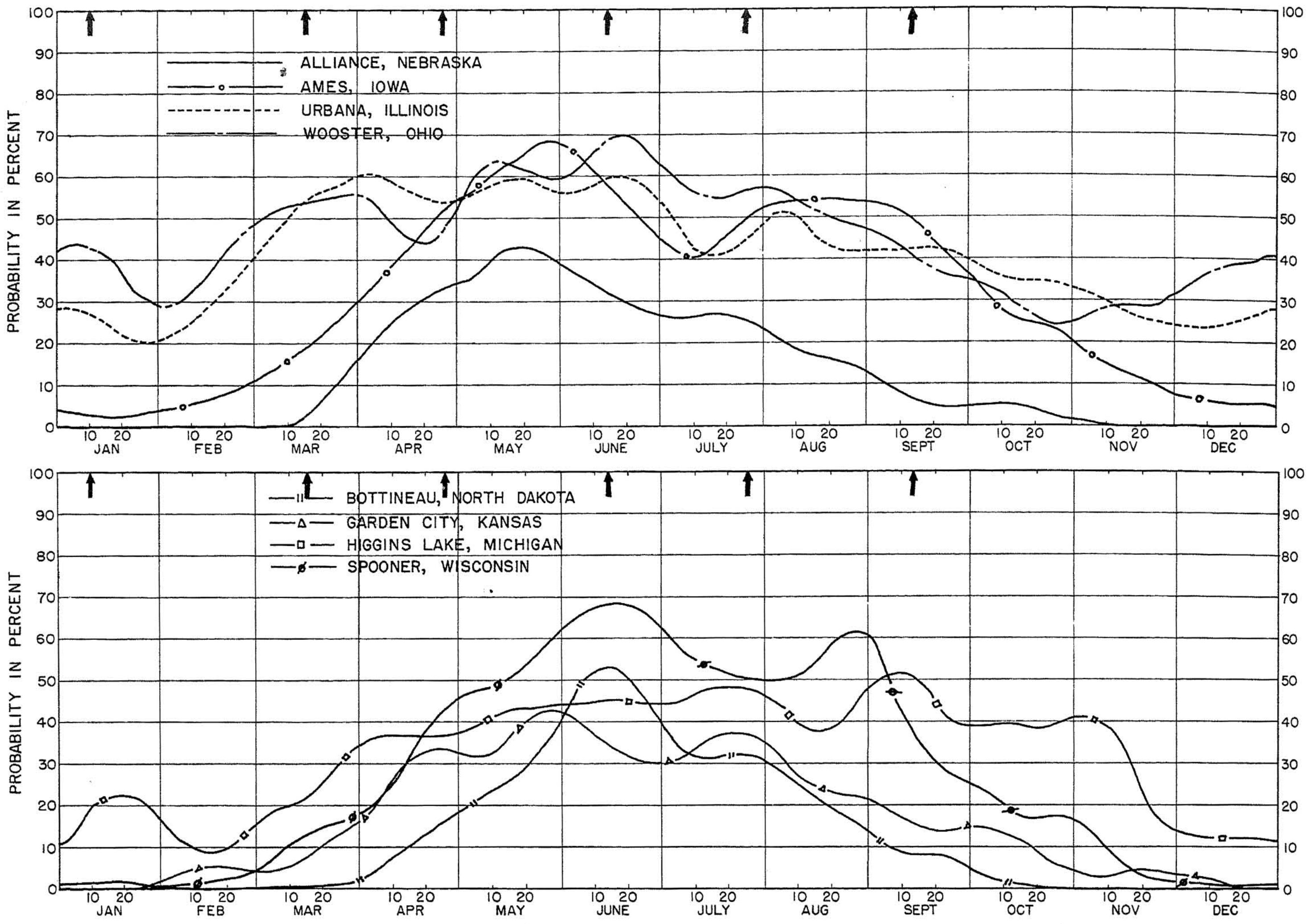

Fig. 50. Probability of receiving 2.0 inches or more precipitation in 3-week intervals at eight stations.

Probability of 2.0 Inches or More

The probability of 2.0 inches or more varies from 0 to over 70%. The extremes range from 20-25% to 60-70% in the east and southeast, near 0 to 60-70% in the central area and 0 to 45-55% in the west. The minimum probability generally occurs during the winter, with western areas having a longer minimum period. In the east, the minimum is in late October. The maximum occurs generally from late April to mid-June, being later at the northern stations. At Higgins Lake, the maximum is in September, although the April through October period is relatively flat. Except for the west and northeast, there is a secondary minimum in the probability during July.

The probability in January ranges from near 0 to 50% across the region. Except in the west the probability increases during February, by the middle of March ranging from 5 to 70% across the region. By late April the maximum probability has shifted to the south central area and the probability has increased to 20% in the northwest. By mid-June the maximum probability has been passed in many areas, and the probability ranges from 50 to 70% over much of the region. The probability in nearly all areas decreases after June and by early August ranges from 40 to 50% over much of the region. In the central area there is some increase during August, while the east and west have a decreasing probability. Nearly all areas show a decrease in September. The highest September probability occurs from Missouri to upper Michigan. After September, the probability in most areas decreases, and by early November the winter pattern is reached.

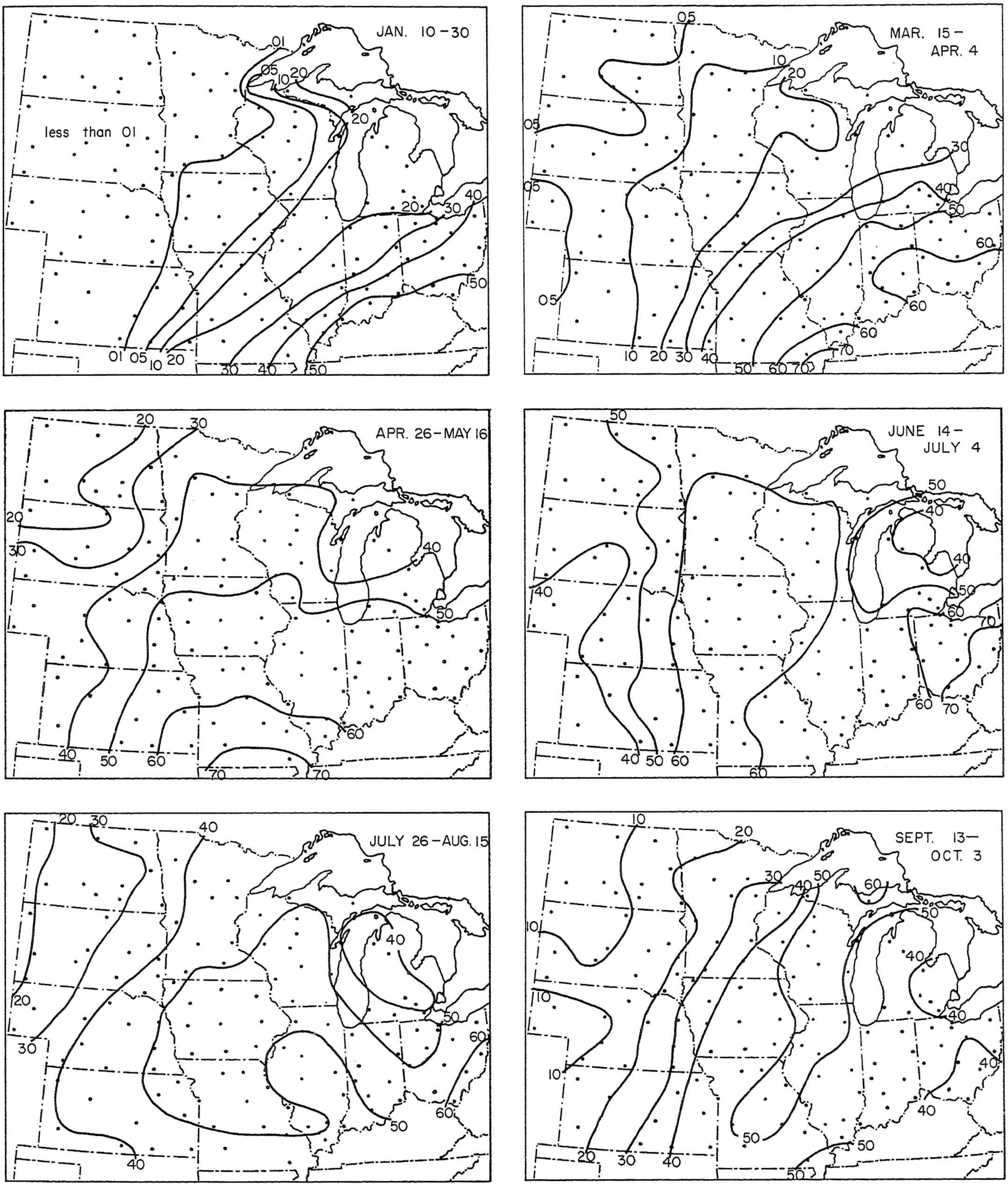

Fig. 51. Probability, in percent, of receiving 2.0 inches or more precipitation during 3-week intervals in six selected periods.

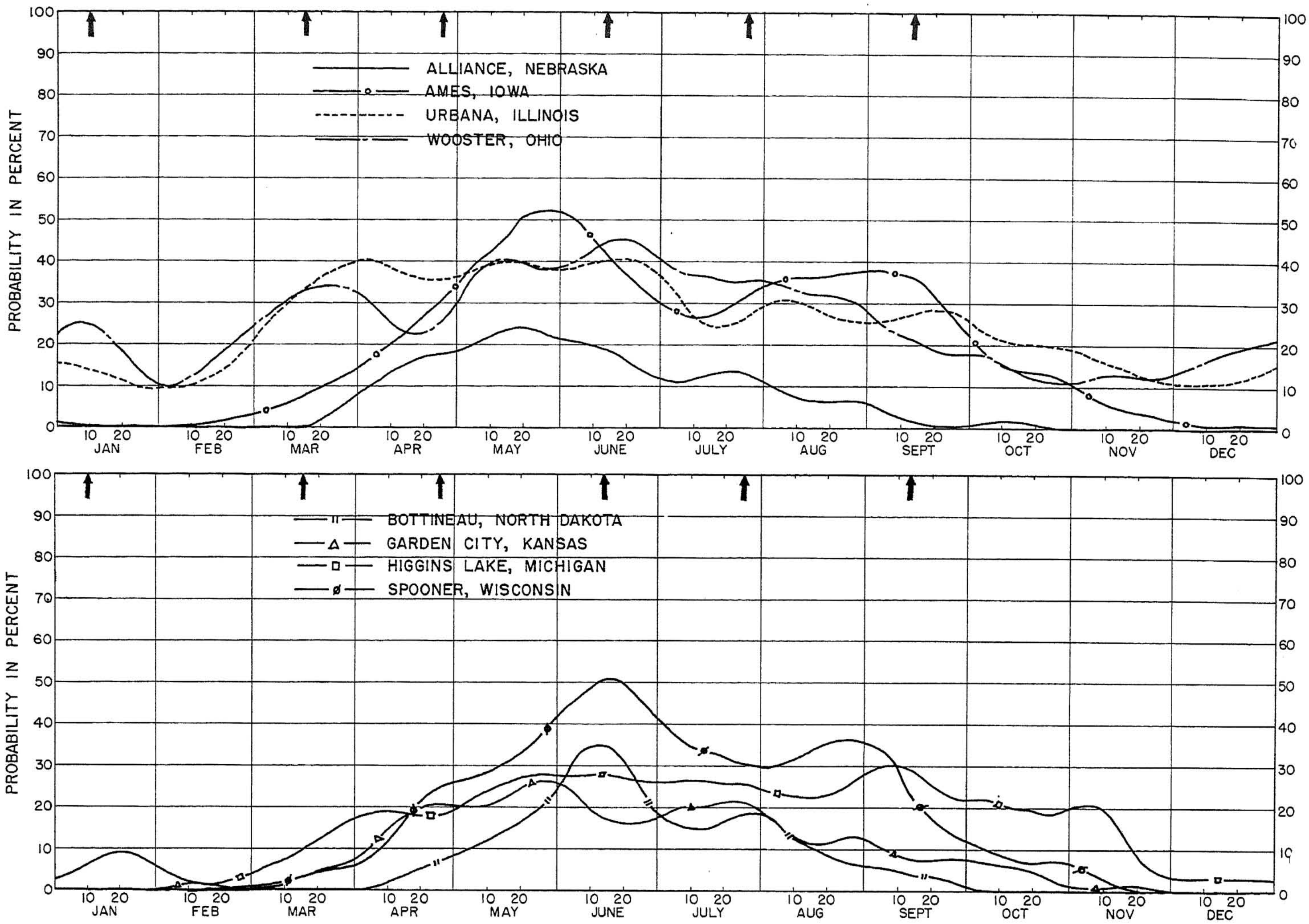

Fig. 52. Probability of receiving 2.8 inches or more precipitation in 3-week intervals at eight stations.

Probability of 2.8 Inches or More

The probability of 2.8 inches or more in a 3-week period varies from 0 in the western part of the region in the winter to over 50% in the south central area in April and in the central area in June. The extremes range from 10 to 45% at Wooster, 10 to 40% at Urbana, 0 to 50% at Ames and 0 to 25% at Alliance. The minimum probability occurs during the winter months and lasts over 5 months in the west. In the east the minimum is in November and there is a January secondary maximum in the probability curve. The maximum generally occurs from April through June, except in the northeast, where it is in September, although it is relatively uniform from May through November. The maximum tends to be earlier in the south. The central area shows a July dip in the probability curve resulting in a late August-early September secondary maximum in these areas.

In January, the probability ranges from 0 to 40% across the region, with the western half of the region near 0. By late February the probability is increasing in much of the region, and by mid-March, although the range is still near 0 to 40%, there has been some increase in the probability in most areas. Except in the east the probability continues to increase (note the late April dip in the curve at Wooster), and by early May the probability ranges from 10 to 50%, with the maximum in the south central area. By mid-June the probability over much of the region ranges from 30 to 50%. The probability generally declines in July, and by early August is near 30% in much of the region, although it ranges down to 10% in the northwest. The secondary maximum in the central area in August-September results in the highest probability in mid-September, near 30%, being in that area. The winter pattern is established by early November.

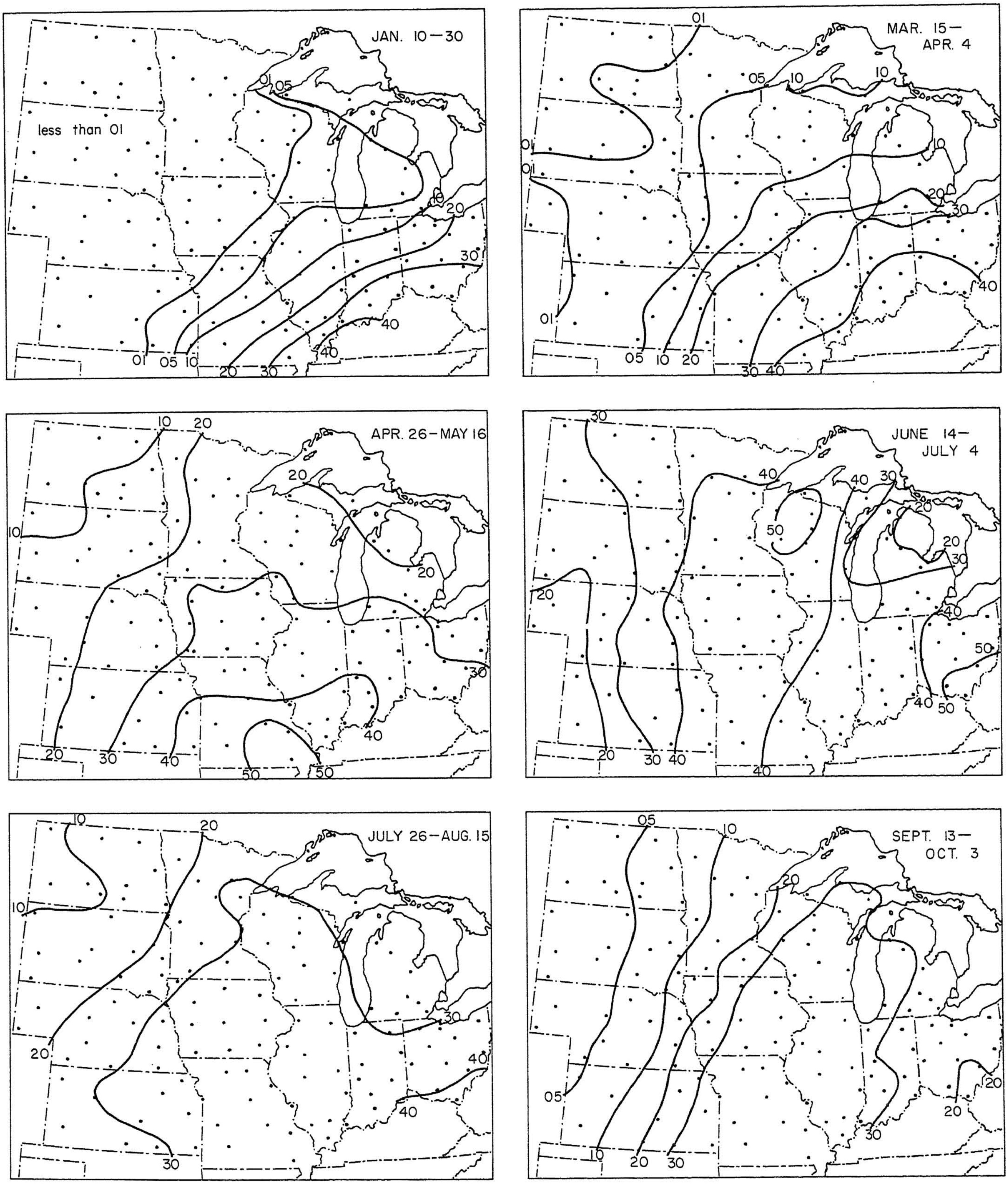

Fig. 53. Probability, in percent, of receiving 2.8 inches or more precipitation during 3-week intervals in six selected periods.

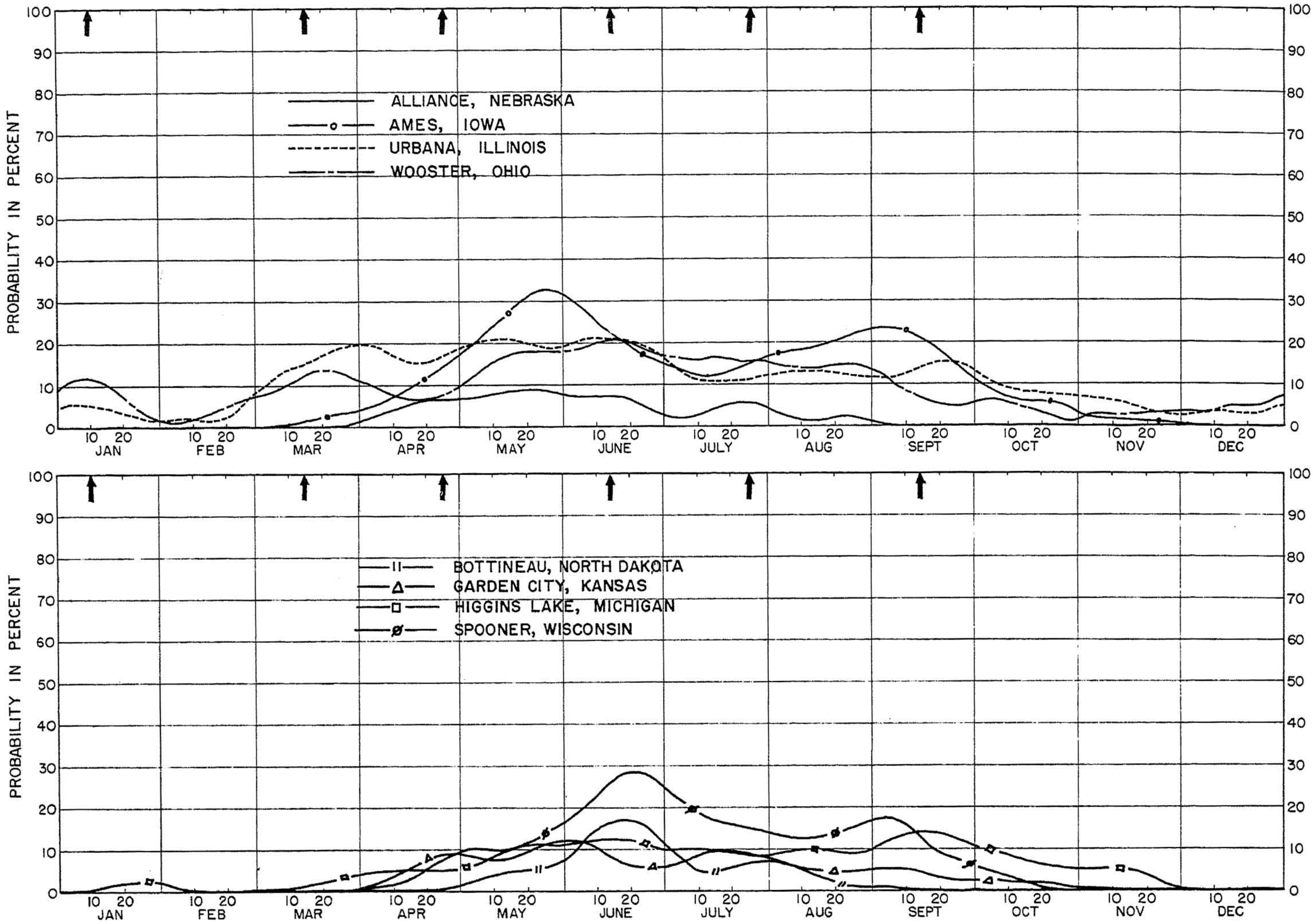

Fig. 54. Probability of receiving 4.0 inches or more precipitation in 3-week intervals at eight stations.

Probability of 4.0 Inches or More

The probability of receiving 4.0 inches or more ranges from 0 over wide areas, to near 40% at Columbus, Kansas, in June. The minimum is 0 or near 0 in all areas. The maximum in the east is 15 to 20%, 25% to over 35% in the central area and only 10% in the west. The minimum probability occurs in the winter season and lasts up to 7 months in the west. In the east and southeast there is a January peak in the probability. The maximum generally occurs in late May or early June, although in the east it occurs in late March. There is a secondary maximum in September in the central area following the July decrease in probability.

In January, the probability in most of the region is near 0 although in the extreme southeast it reaches 20%. There is little change by mid-March. By early May the maximum probability of 20% has shifted to the south central part of the region, and some increase in probability has occurred in most of the region. By mid-June the probability in much of the region is 20 to 30%, with the maximum in the south central area. There is a general decrease in probability during July, and in early August the probability is 15-20% in the southern area and 10% or less in the northern and western areas. The secondary maximum in the central region results in the maximum of 20% in mid-September being in that area. The probability in the west is declining, and the winter pattern is established in October in the west and over the entire region in November.

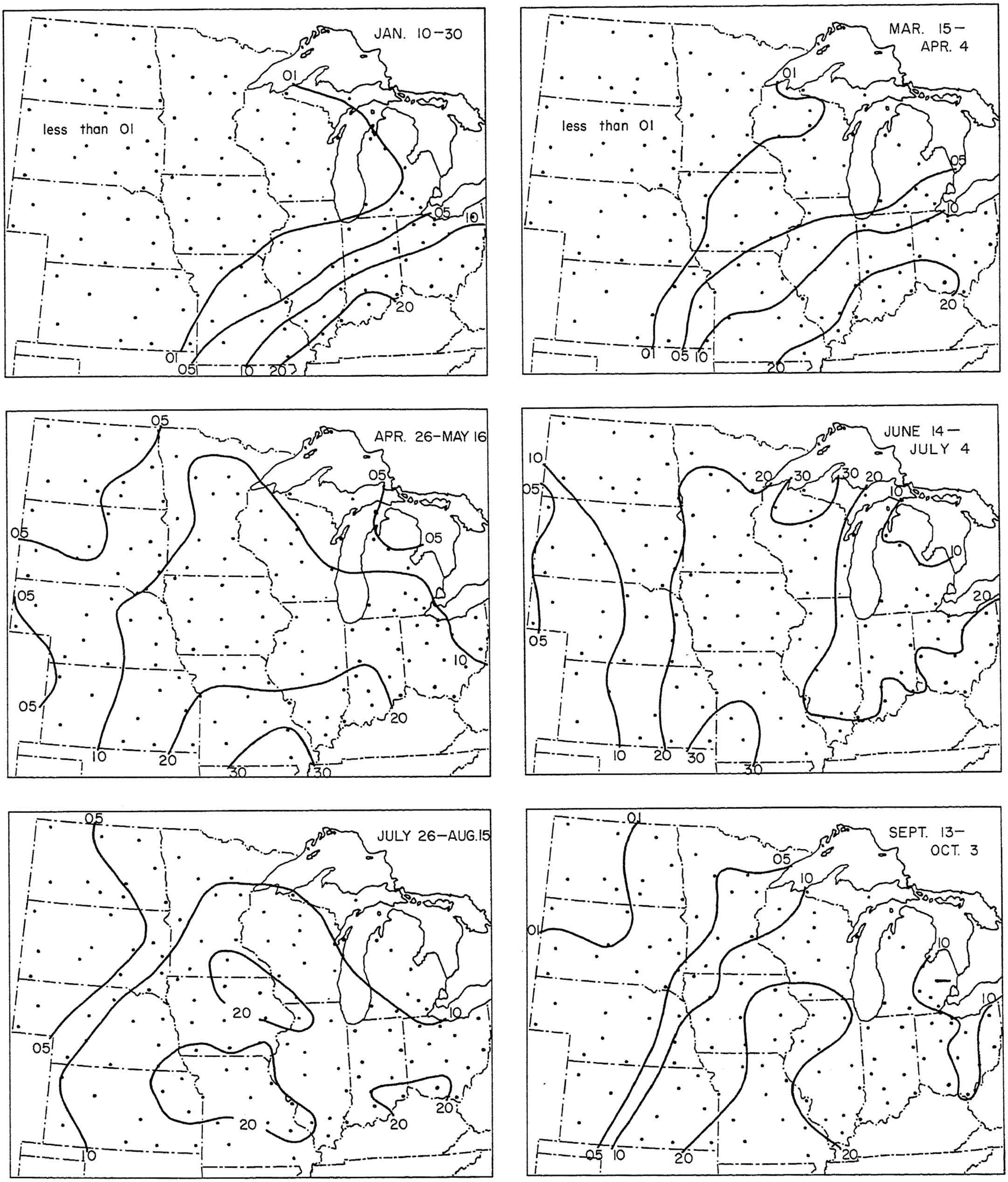

Fig. 55. Probability, in percent, of receiving 4.0 inches or more precipitation during 3-week intervals in six selected periods.

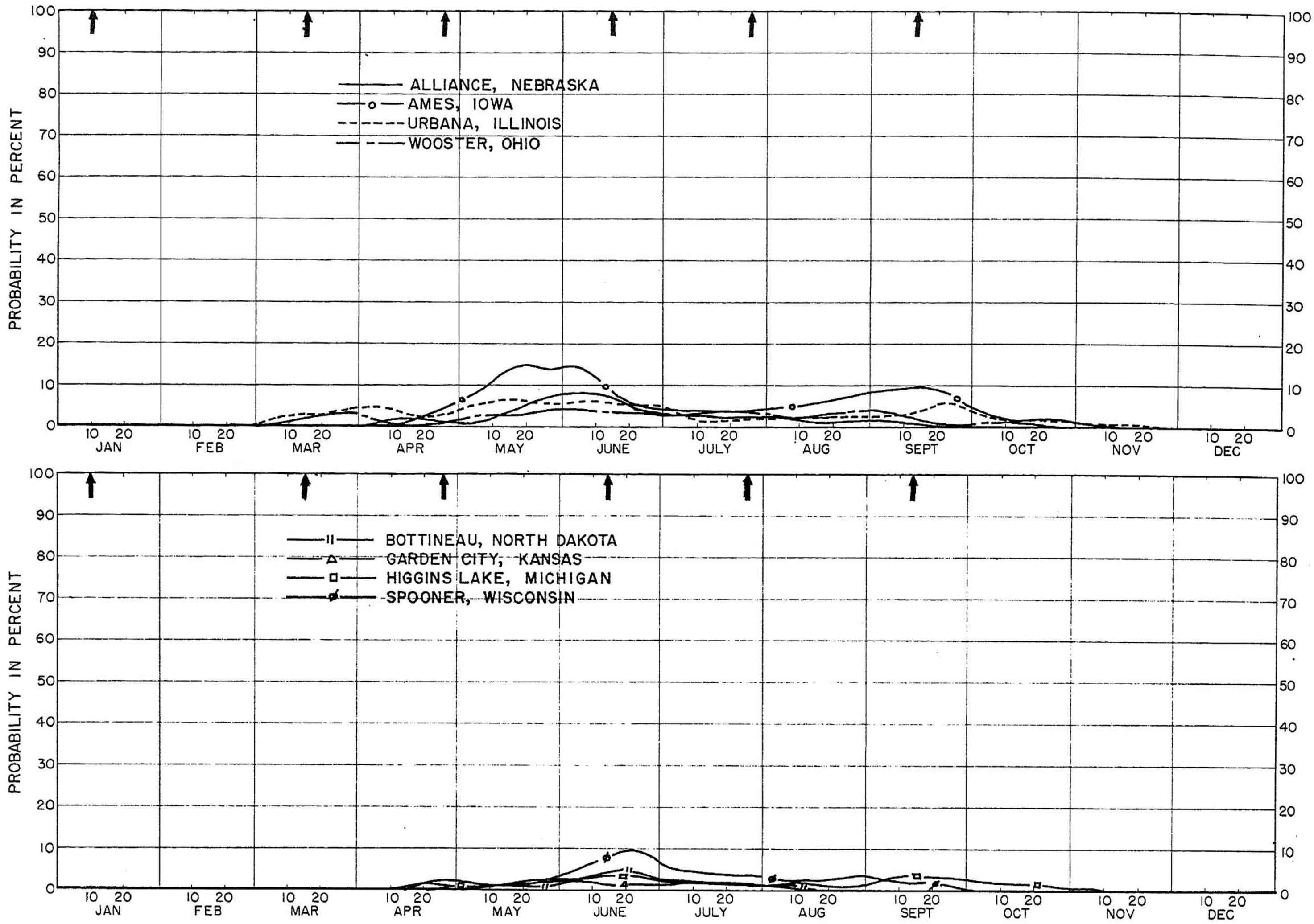

Fig. 56. Probability of receiving 6.0 inches or more precipitation in 3-week intervals at eight stations.

Probability of 6.0 Inches or More

The probability of receiving 6.0 inches or more in a 3-week period is generally low over most of the region. The maximum probability of near 25% is reached in late May-early June in local areas in southeast Kansas and southwest Missouri, although most stations in this area peak near 15%. The extremes range from 0 to 5% at Wooster, 0 to 7% at Urbana, 0 to 16% at Ames and Springfield and 0 to 3% at Alliance.

In January, the probability is near 0, except in the extreme southeast area, where it reaches 10% at individual stations. By mid-March it is near 0 in most areas and reaches only 5% in the southeast. In early May, the probability is near 1% in most of the region and reaches a maximum of 10% in the south central area. By June there is a sector through the central area, Wisconsin to Missouri, where the probability is near 10%, with a small sector over 20% in southeast Kansas and southwest Missouri in early June. By mid-June the probability in this area is less than 20%. The probability is near 5% in the rest of the region. By early August the probability is a maximum of 5% in the south central area. By mid-September the probability is still 5% in the south central sector with a maximum of 10% in southern Missouri and is less than 5% in the rest of the region. By mid-October the probability is near 0 over most of the region.

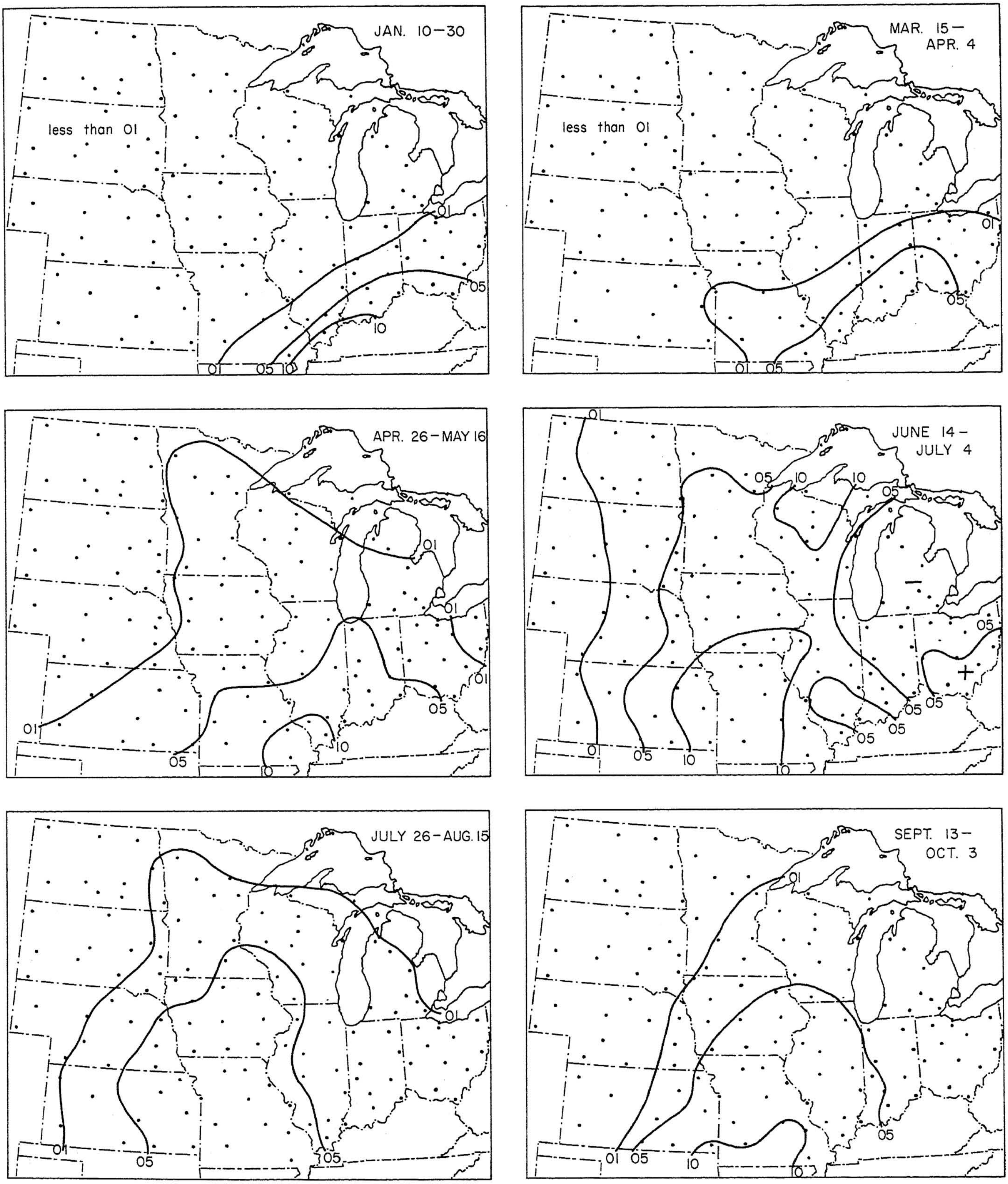

Fig. 57. Probability, in percent, of receiving 6.0 inches or more precipitation during 3-week intervals in six selected periods.

Probability of 8.0 Inches or More

The probability of receiving 8.0 inches or more ranges from 0 over wide areas, to over 10% in late May. The probability remains near 0 in the west throughout the year. In January the probability is near 0, except in the extreme southeast where it is 1-2%. There is little change by mid-March. By late April-early May the probability has reached 5% in the south central area. The maximum probability in the region is reached in late May in the south central area and by mid-June is 7-8% in the south central area and 1-3% in the central area. By early August the probability is a maximum of 3% in the south central area. In mid-September the maximum is over 5% in the south central area, with much of this area having a probability of 2-3%.

Probability of 10.0 Inches or More

The probability of receiving 10.0 inches or more varies from 0 to near 4%. In January the probability is near 0, except in the extreme southeast, where it is 1-2%. There is little change until April when the probability is near 0 except from eastern Kansas to southern Indiana where local areas have probabilities of 1-2%. By mid-June much of the area from Wisconsin to Missouri and eastern Kansas has a probability of 1-2%, with local areas in Missouri up to 4%. By late July only areas in eastern Kansas and Missouri show probabilities other than 0, and these are 1-4%. In mid-September the probability is 1-2% from southern Wisconsin, through Illinois, Iowa and Missouri.

USE OF PRECIPITATION PROBABILITIES

These probabilities can be used in planning various agricultural operations. For example, at least 1 inch has often been used as the amount of water which should be added to a sandy soil each week, during the peak use period, to get high corn yields. This assumes that there is also some moisture reserve. What are the chances of getting at least this amount each week through June and July? Referring to figs. 16 and 17 we find that at Wooster the probability of this amount is 35% in the middle of June and 30% in early August, at Ames 40% and just under 30% and at Alliance 22 and 17%. The difference between these and 100% is the frequency with which irrigation would be necessary. If we were interested in some station not given on the eight annual curves we could determine its relation to the nearest station and estimate from the curves. For example, in eastern Nebraska the probability in mid-June is about 10% less than Ames, and in early August still about 10% less. At any time during this period we would estimate a value for eastern Nebraska by subtracting 10% from the Ames curve. On heavier soils we might set the requirement as 2 inches of precipitation occurring anytime during each 2 week period. We would use the information on figs. 34 and 35 to determine these probabilities. In early August the probability of receiving this at Wooster and Ames is 32% and at Alliance, less than 15%. A large part of the time this amount is not received in what is considered the optimum corn producing area! Actually, due to soil moisture storage from precipitation greater than the required amount with no requirement set on the 1-week distribution, there is a carryover which reduces the need of irrigation below that indicated from the charts.

The precipitation probabilities could provide us with some information on the feasibility of using wide row corn to establish meadow. In using this practice, the meadow is usually seeded during June in the central part of the region. Will there be enough rainfall to establish the seeding? Rainfall is needed to provide moisture for the crop and moisture for evaporation to help keep the soil cool. The soil temperatures are very important. The critical time seems to be after the seeding has started to grow. For our purpose we'll use 0.6 inch as the required precipitation each week (fig. 13). The chances of getting this amount are a little over 50%. Toward the south due to greater evaporation more would probably be needed, reducing the probability. In Wisconsin, less would be needed, increasing the probability of success.

These are only two examples of many which could be used. To use these probabilities, it is necessary to determine a critical amount of precipitation for the problem under consideration, then determine its probability of occurrence from the proper figures. In most cases, the difficult problem will be to determine the critical precipitation level for the operation or problem under consideration.

These data can also be used to answer more general questions such as, "What is the main difference between the precipitation probability from east to west?" Any or all of the amounts of precipitation presented could be examined, but for illustrative purposes here, we'll use the probability of 1.0 inch or more in a 1-week period. Figures 16 and 17 present this information. During the warm season, except for the extreme west, the probability is relatively uniform, but in the winter and spring months the probability is much higher in the east and southeast. From the standpoint of a soil moisture reserve, this means that in these areas, the usual occurrence would be a saturated or near saturated soil profile in the spring. The further west, the less likely the profile will be saturated by late spring. The difference in the winter and spring precipitation results in a difference in the expected soil moisture reserve.

As shown by the above examples, the study is primarily in the direction of agricultural water use applications and drought probabilities, not for hydrologic or soil erosion studies. The week is the smallest unit of time, and a weekly total of 1 inch precipitation could have fallen in 30 minutes, or gently over several days. It should be pointed out that the regional charts of probabilities are drawn to data based on occurrences at individual stations since it was believed that the greatest application of these probabilities would be on an individual farm planning basis. Where the charts indicate a probability of 1.8 inches or more rainfall to be 5%, this pertains to any specific location and not for a large area. The probability of 1.8 inches or more occurring at any place within a state would be considerably larger, i.e., amounts which have a small probability of occurring at a specific station, occur at some place within a state with much greater frequency than indicated on the charts.

EXTENSION OF PROBABILITIES TO LONGER PERIODS

In certain problems we may be interested in rainfall during periods of 4 weeks, 6 weeks, or longer. The gamma distribution parameters, published in (3), can be used to obtain this information. In using these parameters the parameter β can be averaged over two periods of, say, 3 weeks, to obtain an average β for the 6-week period. The parameter γ is estimated for the 6-week period by summing the estimates of γ for the two 3-week periods. The mean precipitation for the 6-week period is, of course, the sum of the two 3-week means. The nomograms provided in (3), can be used to compute the probability for the longer period. Limited copies of the parameters for all states were printed, but each state representative on Project NC-26 was furnished 100 copies of the parameters for his state and the graphs and instructions needed in computing probabilities for longer periods.

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