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NOAA Technical Report EDS 26

Temperature and Precipitation Correlations Within the United States

Asheville, N.C.
February 1978

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Data Service

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Juanita M. Kreps, Secretary

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TEMPERATURE AND PRECIPITATION CORRELATIONS WITHIN THE UNITED STATES

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ABSTRACT. Difficulties in long-range forecasting of weather and climate are fundamentally the difficulties associated with extraction of signals from a noisy background. Weather and climate are essentially the same phenomena measured over arbitrarily selected time scales. To some extent these may overlap.

Here, only one small phase of the multivariate problem is presented, the relationship of monthly temperature and the concurrent or subsequent precipitation within the United States within two separate time periods, 1906-1948 and 1949-1970.

Few good pattern signals are detected. One of the better ones is the relationship of June temperatures with September precipitation. In the region running from New Mexico to New England, the correlation pattern maximizes to -0.6 in Kansas. Other signals which may be worthy of study exist, though in general the charts in themselves can be considered to be noisy. The changing of correlation patterns with time, in near but not complete consonance with the change of long-wave patterns, implies that forecasting techniques must be continually updated and kept current.

INTRODUCTION

There has always been a close relationship of man's life and endeavors with weather and climate. With an ever increasing world population and essentially a finite source of energy, the problems associated with this relationship become more acute.

Weather and climate are complex entities in their own right, distinguished perhaps only by an arbitrarily chosen time scale discriminator. The usual time scale for weather ranges up to at most about 2 weeks with climate ranging onward from that point. Constancy is not a characteristic of either. There may be some overlap in the time scale from 1 to 3 weeks, but that is not important here. Here, monthly or longer time periods are discussed — climate time scales.

Accurate and precise weather and climate forecasts are indispensable tools or guides to meet the world's requirements. Long-range forecasts of the circulation pattern, no matter how accurate and precise, may not directly lead to accurate and precise temperature and precipitation forecasts. The low lag correlations on a month-to-month or season-to-season basis provide some but not much help. However, it is often assumed that simple relationships exist which would make solving the problem easy.

This paper presents correlations of temperature with precipitation within and between months and 2-month periods. The lags used are zero, one, two, and three. Due to the complex interaction of elements and patterns, description of the charts could be extensive and in some cases debatable. Therefore, only a few salient features of the entire ensemble are noted. The charts in themselves are instructive and quite revealing in demonstrating that the solution of the problems of long-range forecasting of weather and climate is not easy.

TEMPERATURE-PRECIPITATION RELATIONSHIPS

The relationship of one or more variables to one or more other variables is often called correlation. There are several procedures to obtain some idea of this correlation. One which is often used and which is used in this paper is the product moment correlation. The result is expressed as a number ranging from -1 to +1 as $-1 \leq \rho \leq +1$ where ρ is the correlation between two population variables.

Blair (1930) discussed the relationship of summer and autumn pressure anomalies and the subsequent winter temperature in the upper Mississippi Valley. Blair (1931a) examined the winter temperature-precipitation relationship within the United States. Regions of positive and negative relationships were found. In the Pacific Northwest and the Southwest to Northeast region extending through New Mexico and Maine, bounded on the northwestern flank by Oklahoma-Missouri-Wisconsin and on the southeastern flank by the extreme southwestern Appalachians to Pennsylvania, wet and warm or dry and cold winters occurred more than one-half of the time. When the temperature anomaly was 2°F (1°C) or more, more than three-fourths of the winters exhibited these characteristics. In the other regions, dry winters were warm and wet winters were cold. Later, Blair (1931b) discussed the work of Walker (1923) and presented some global relationships of pressure and the temperature-precipitation regimes.

Hamrick and Martin (1941), Gilman (1976), and Madden and Williams (1977) indicate that wet summers in the midwestern States are usually cool summers. This is associated with the fact that moisture has a damping effect, particularly with respect to maximum temperatures prior to rainfall and also with evaporative cooling after rainfall. Convection begins at an earlier time of day, preventing increasing surface temperatures. If sufficient moisture is available, clouds are formed and surface insolation is restricted. If still more moisture is available, precipitation is produced, the released latent heat of condensation and fusion are carried away, and the evaporating rain in the atmosphere and on the ground produces further cooling during the day.

Weightman (1941) in an excellent paper presents the difficulties facing those who attempt to deduce simple relationships from correlation fields to make long-range forecasts.

Crutcher (1960) used the first three harmonics of the annual marches of monthly temperature and cube roots of monthly precipitation and their correlations to cluster climates and to develop discriminant functions for these clusters. Cube roots of precipitation amounts were used to obtain a more symmetrical distribution more likely to be approximated by the normal distribution. The usual tests of significance for correlation coefficients assume underlying normality. Robustness of the tests, however, permit some departure from normality. Crutcher (1975) in an unpublished manuscript provided some correlations of temperature with temperature, precipitation with precipitation, and temperature with precipitation. Again, cube roots of precipitation amounts were used to provide consistency in technique. The charts were based on data for 40 locations over the period 1906-1948. The temperature-precipitation charts are presented here and are supplemented by extra charts for the period 1949-1970. There were 43 data pairs for each station during the first period and 22 data pairs during the second period.

The correlations shown do not exhibit large coefficients. In fact, the results are not promising for an easy solution to long-range forecasting. In essence, they point out that from these marginal combinations, the help obtained is not sufficient. Perhaps more than anything else, publication will help the reader understand why long-range forecasting is quite difficult.

Gilman and Riedel (1951) conclude from their studies that pairs of extremely dry sets of months respectively occur more often than chance would forecast. For pairs of extremely wet months, the subsequent occurrence is not significantly different than what chance would forecast.

RELEVANT WORK

Van Loon and Williams (1976) present isopleth charts of the slope of the regression line of winter mean temperature (°C/y), for 1900-1941, 1940-1954, 1950-1964, and 1942-1972. Figures 1 and 8 of their paper are reproduced here with permission as figures 1a and b of this paper. Attention is drawn to the U.S. portion of the Northern Hemisphere presentations. The sign of the slope must be the same as that of the correlation coefficient and if standardized data are used, then magnitudes must be equal. In figure 1, 1900-1941, the slopes are positive over all the country except for the northern inner montane range of the Rockies. The pattern reverses in the next 3 decades as indicated in 1942-1972 where the slopes are negative over all the country except for the inner montane region. Thus, it is seen that the slopes (correlations) may undergo a change over time. One inference that may be drawn is that as the long-wave circulation patterns move around the globe, the correlation patterns will move and/or change. The movements and changes of the circulation patterns may not be a one-to-one relationship with the long-wave patterns.

It is imperative that recognition be made of the fact that as time goes on, the correlations will change at a point or in an area or region within the weather and climate complex. This requires those who use long-range forecast equations based on linear regression to stay current with the situation. The prediction equation coefficients are always undergoing change. This becomes particularly important in the forecasting of weather, particularly that of precipitation over a season.

Such a forecast should carry with it a forecast of the variability within the season. That is, crops are dependent on temperature, and on precipitation with certain amounts at specified times of their development and no rain at other times. The paper by Madden and Williams (1977) indicates that over the period studied the spectral characteristics were essentially constant. This would provide some idea as to the variability of the precipitation process on a monthly basis. Further work should be done along this line over shorter time periods.

We computed correlation coefficients of temperature with temperature, precipitation with precipitation, temperature with precipitation, and precipitation with temperature within respective periods 1906-1948 and 1949-1970. The patterns do not show any consistently high correlations. The square of the correlation coefficient is a measure of the variance of the dependent variable explained by the independent variable. A correlation coefficient of 0.707 indicates that 50 percent of the variability of the dependent variable is explained by the independent variable. Few points reach significance and even fewer point correlations reach the value of 0.707.

The significance of a correlation coefficient is a function of the number of independent data pairs. For a smaller number of data pairs (say 22), the correlation coefficient has to be greater than for a larger number of data pairs (say 43). The respective coefficient magnitudes required are about 0.4 and 0.3 (Snedecor 1956). In a similar fashion, when 43 correlation coefficients are computed, one could expect two to reach significance simply by chance. When 102 correlation coefficients are computed and placed on a map, about five would reach significance by chance. Therefore, the existence of isolated points of significant correlation coefficients should be viewed with some suspicion. Though correlations between station data are not included in these charts, the space patterns of correlations on charts are important. Close proximity of significant correlations of opposite sign may indicate boundary conditions, such as land-water or mountain chains which act as barriers, or simple anomalous conditions within a short period of record. These are often recognizable features. Examination of the anomalous conditions will reveal whether these are real anomalies or are the results of data base contamination.

Because the correlations of the various combinations within station data are similar in their low resolution and often appear as noisy charts when plotted, only the temperature-precipitation combinations are shown here. Another reason is that with the exception of the precipitation-temperature combinations, the temperature-temperature and precipitation-precipitation relationships are available in the literature. Lags of zero, 1, and 2 months are shown for the first period, lags of zero, 1, 2, and 3 months are shown for the second period, and lags of zero, 2, and 3 are shown for 2-month combinations, where the lags are in terms of months.

Madden and Williams (1977) have presented seasonal data. To this extent, the 2-month zero lag data presentation approaches that of the seasonal data. Both presentations exhibit a decrease in the noise level, i.e., a smoothing of the contour patterns. This occurs because of the longer time periods producing more stable means.

Only a few salient features of the charts are discussed here.

MONTHLY DATA

In the respective periods 1906-1948 and 1949-1970, 40 and 102 stations were used. In the arid regions and in particular during the summer season of the west coast of the United States, there may be no rain in some months. The correlation coefficients have been computed with the zeros. If the zero combinations are not included, the coefficients will change. However, they do not change much and the loss of degrees of freedom requires a much higher coefficient for significance. For this area the uncertainty is indicated by the dashing of the isopleths in the region of the west coast. Though it is realized that in the mountainous regions the construction of representative isopleths is difficult, no marking or change of the isopleths is made to indicate this uncertainty.

The relationships noted by Blair (1931a) and by Madden and Williams (1977) hold. In the strip running from Texas to New England, wet summers are cool and dry summers are hot, while wet winters are warm and dry winters are cold. The transition seasons of spring and fall do not exhibit strong relationships.

The relationship of 1949-1970 June average temperatures with September precipitation is one of the stronger patterns shown. A negatively correlated area extends from southern Arizona to Michigan with a maximum of -0.6 in Kansas-Oklahoma. This is still not very good, for at best the temperature in June explains only about 40 percent of the variance in September precipitation. Positive correlations exist on the flanks in Idaho and in Georgia.

In July to October significant positive correlations exist in the mountain regions of the west. In August to November isolated significant positive maxima are found in Arizona, Texas, and Nebraska with negative areas in Illinois and southern Florida. In September to December significant negatively correlated areas are found in Nevada, Nebraska, Michigan, and in southern Louisiana, Mississippi, and Alabama.

For the December to March period significant negative correlations of -0.6 exist in Utah and Ohio.

TWO-MONTH DATA - PERIOD 1949-1970

The use of longer time periods for averaging or summing produces, in general, less noisy correlation patterns. That is, the areas of correlation will be greater and, in general, the magnitudes of the coefficients will be greater.

The charts for this period illustrate the correlation patterns of 2-month average temperatures with 2-month precipitation. Lag zero charts will again indicate correlations within the same time frame. Though coefficients were computed, lag 1 charts are not shown, for in this lag configuration the 2-month periods overlap. Lag 2 charts, for example, show correlations such as those for January-February temperatures with March-April precipitation. Lag 3 charts show, for example, the relationship of January-February temperatures with April-May precipitation.

In June-July the correlations reach a value of -0.7 in southwest Texas and in Kansas. This simply reaffirms the previous findings that wet summers are cool summers and dry summers are hot. In the July-August charts positive correlations begin to expand on the west coast and continue to expand inland over Nevada and Arizona through the September-October period, after which they move northward to Nevada-Idaho and northwestward through the December-January period.

In the May-June with August-September complex, as in the June with September relationship, negative relationships exist from Texas-Kansas to Michigan. However, these are weaker. A positively correlated area does appear on the southeastern coast in Georgia and South Carolina. The negative pattern is repeated in the June-July with the September-October complex but the field is displaced slightly northward, Oklahoma to Wisconsin. The remainder of the year is essentially noisy.

CONCLUSIONS

The National Weather Service issues long-range outlooks. Skill scores are not high, yet these are the best so far available. Verification of monthly temperature forecasts and precipitation forecasts within the categories used are, respectively, about 60-40 for temperatures and 55-45 for precipitation (Gilman 1974).

This paper presents, in an empirical and a subjective way, views of a limited number of marginal distributions of a multivariate problem. Here, only the arbitrarily chosen bivariate distributions of monthly temperatures with precipitation and 2-month temperatures with 2-month precipitation data are presented. These include the concurrent correlation as well as lagged correlations.

The author is reasonably certain that it has been adequately demonstrated through prior relevant work and with the comparison of two sequential period presentations that the long-range weather forecasting problem will be difficult to solve. This is, of course, not a new inference or conclusion. It is hoped that this presentation, negative in the general sense that no powerful technique has been found, will help the reader to understand a little as to why the problem is difficult, particularly if only simple linear relationships are used within the time periods involved.

Perhaps more important is the fact that correlations change with time and that not only the techniques but the coefficients used in the models should be continuously updated. This, of course, leads to the conjecture that these changing coefficients are closely related to the long-term or long-wave configurations.

In general, the charts are very noisy; that is, no significant and highly correlated feature persists long on any series of charts. The correlations, with few exceptions, indicate that temperature in a prior period can explain no more than 40 percent of the variability of precipitation in a data period. This implies that other variables or other sequences must be used if any better results are to be obtained.

The one series of charts that seems to promise some hope for good exploitation are those showing the relationship of May-June or July data with September or October data.

There are, of course, other leads embedded in the information presented which may be worthy of following. It is for this reason that so many charts are presented though with little or no discussion.

ACKNOWLEDGMENTS

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Thanks also go to Mr. Harry van Loon and Miss Jill Williams and to the American Meteorological Society for permission to use figures 1a and 1b, and to Professor Arnold Court for the suggestion that these charts be published.

REFERENCES

Blair, Thomas A., 1930: Summer and Autumn Pressure Anomalies Affecting Winter Temperatures in the Upper Mississippi Valley. Monthly Weather Review, Vol. 58, No. 2, pp. 53-58.

Blair, Thomas A., 1931a: Relations Between Winter Temperature and Precipitation. Monthly Weather Review, Vol. 59, No. 1, pp. 34-35.

Blair, Thomas A., 1931b: Two Series of Abnormal Winters. Monthly Weather Review, Vol. 59, No. 5, pp. 175-181.

Crutcher, Harold L., 1960: Statistical grouping of climates and the statistical discrimination among climate groups. Dissertation, Department of Meteorology and Oceanography, New York University. University Microfilms, Ann Arbor, Mich., 462 pp.

Crutcher, Harold L., 1975: Correlations of Temperature and Precipitation Within the United States. Unpublished manuscript, National Climatic Center, Asheville, NC, 2 pp. plus charts.

Gilman, Donald L., 1974: NOAA, National Meteorological Center, Washington, D.C., Personal communication.

Gilman, Donald L., 1976: NOAA, National Meteorological Center, Washington, D.C., Personal communication.

Gilman, C. S., and J. T. Riedel, 1951: Persistence of Extremely Wet and Extremely Dry Months in the United States. Monthly Weather Review, Vol. 79. No. 3, pp. 45-49.

Hamrick, A. M., and H. H. Martin, 1941: Fifty Years' Weather in Kansas City, MO, 1889-1938. Monthly Weather Review Supplement No. 44, 53 pp.

Madden, Roland A., and Jill Williams, 1977: The Relationship Between Temperature and Precipitation in the United States and Europe. Unpublished manuscript, National Center for Atmospheric Research, Boulder, CO, 10 pp. plus figures.

Snedecor, George W., 1956: Statistical Methods. The Iowa State College Press, Ames, Iowa, Fifth Edition, 534 pp.

Van Loon, Harry, and Jill Williams, 1976: The Connection Between Trends of Mean Temperature and Circulation at the Surface: Part I. Winter. Monthly Weather Review, Vol. 104, No. 4, pp. 365-380.

Walker, Sir Gilbert T., 1923: Correlation in Seasonal Variations of Weather, IX. A Further Study of World Weather. Memoirs, Indian Meteorological Department, Vol. XXIV, Part IV, pp. 275-332.

Weightman, Richard Hanson, 1941: Preliminary Studies in Seasonal Weather Forecasting. Monthly Weather Review Supplement No. 45, W. B. No. 1333, 100 pp.

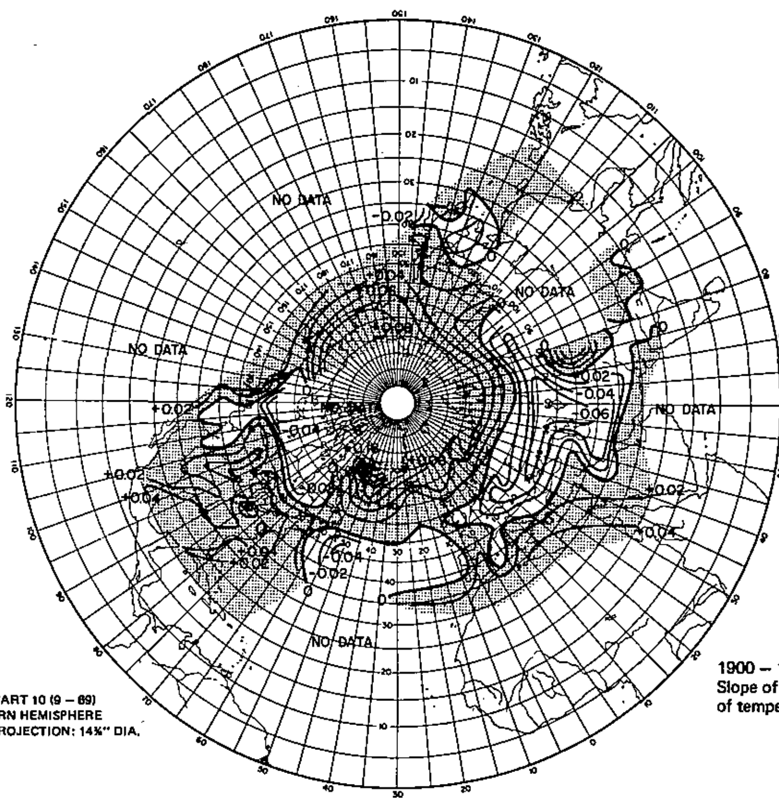


Figure 1a.--Isopleths of the slope of the regression line for winter mean temperature for 1900-1941 (°C yr^{-1}).

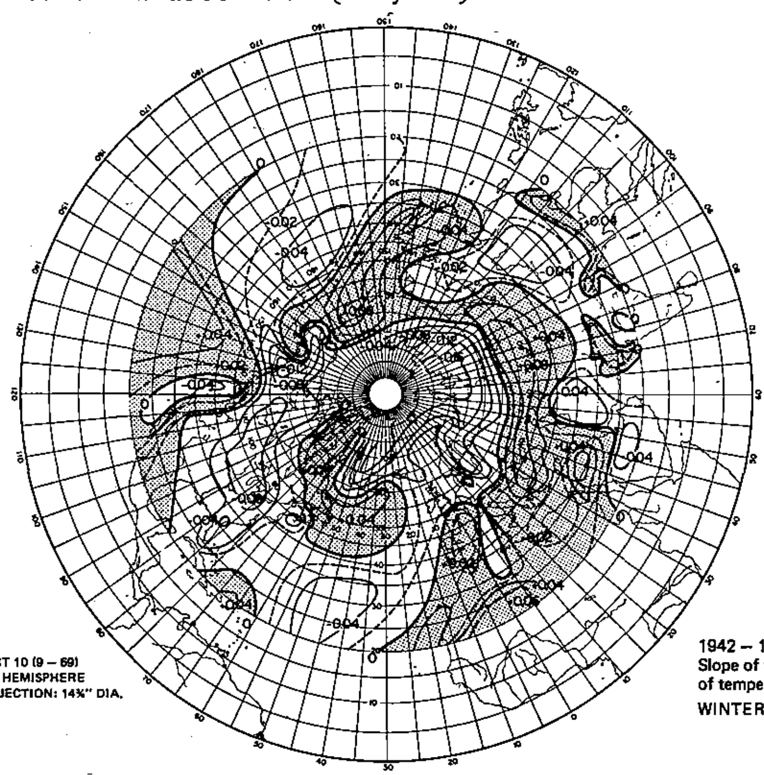


Figure 1b.--Isopleths of the slope of the regression line for winter mean temperature for 1942-1972 (°C yr^{-1}).

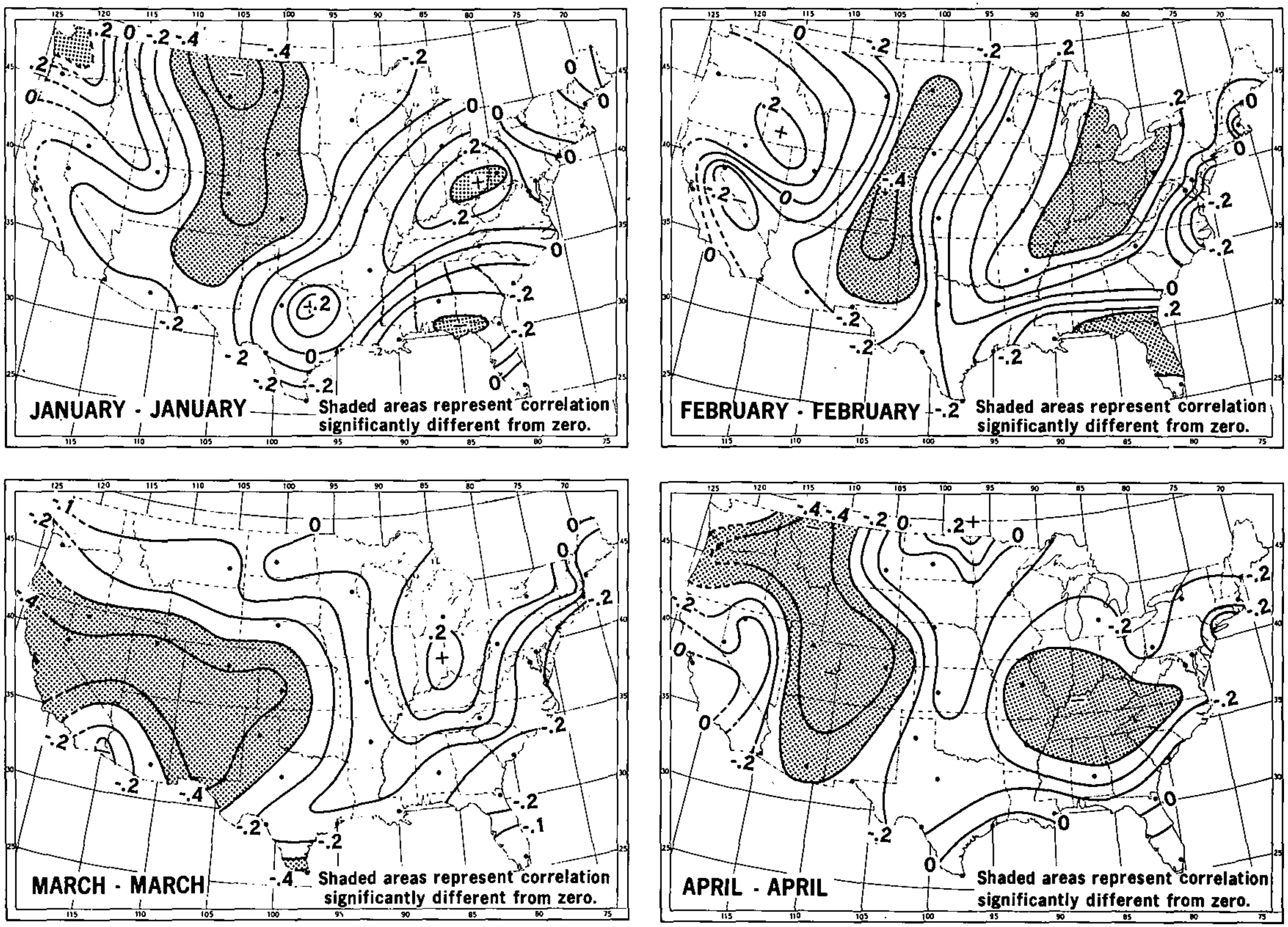


Figure 2a.--Isopleths of correlations, LAG 0, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 42 selected North American stations. Period: 1906-1948.

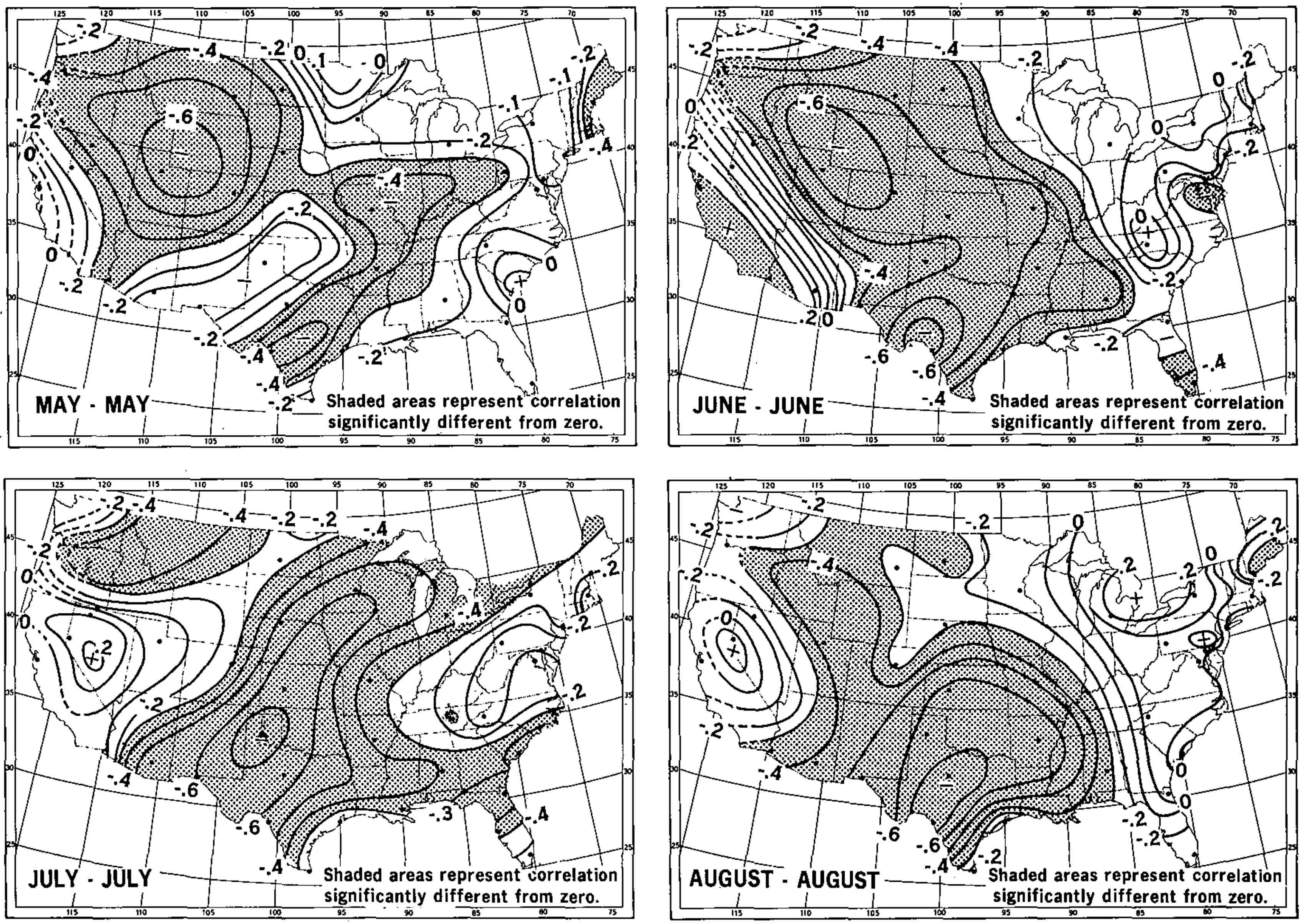


Figure 2b.--Isopleths of correlations, LAG 0, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 42 selected North American stations. Period: 1906-1948.

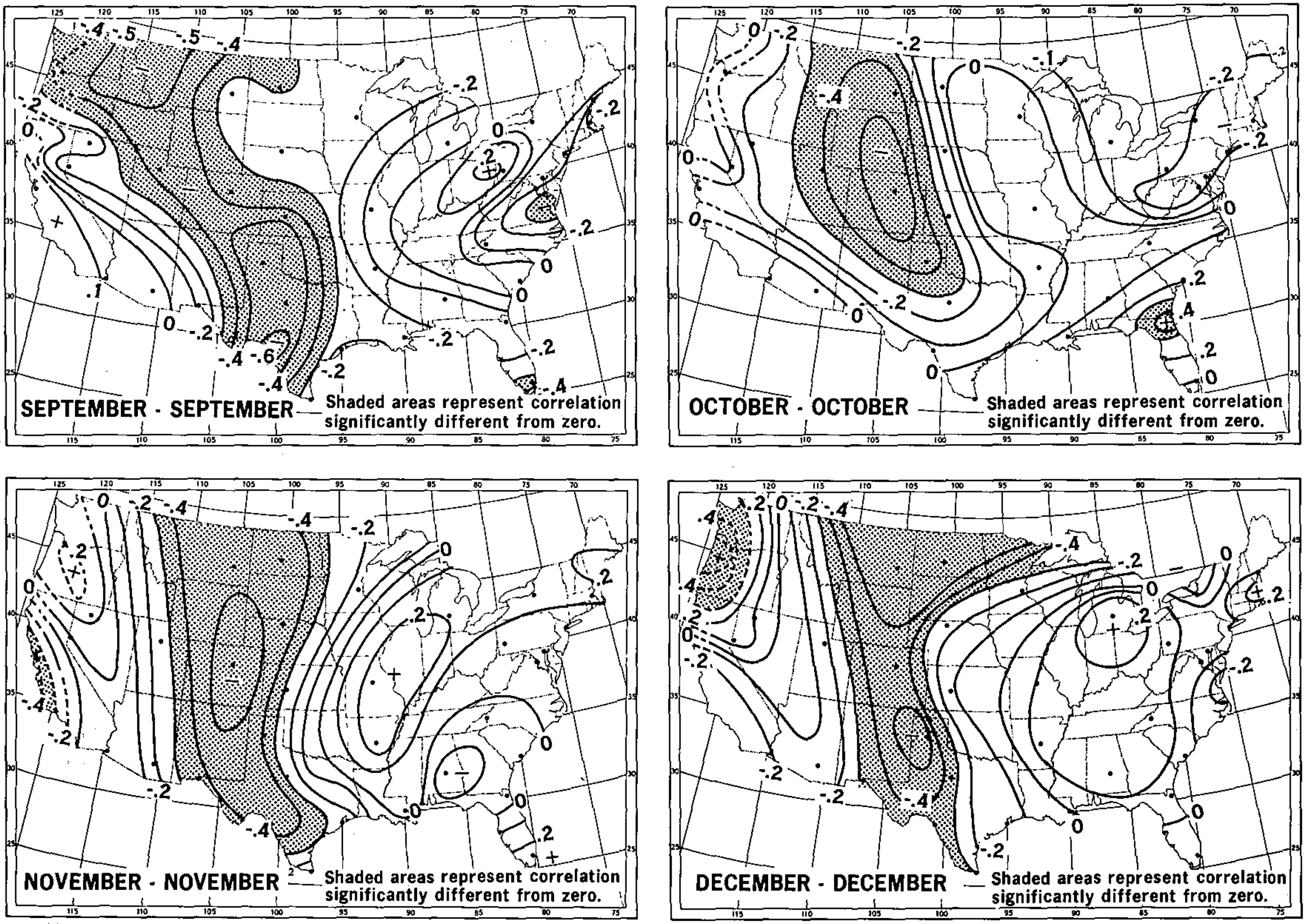


Figure 2c.--Isopleths of correlations, LAG 0, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 42 selected North American stations. Period: 1906-1948.

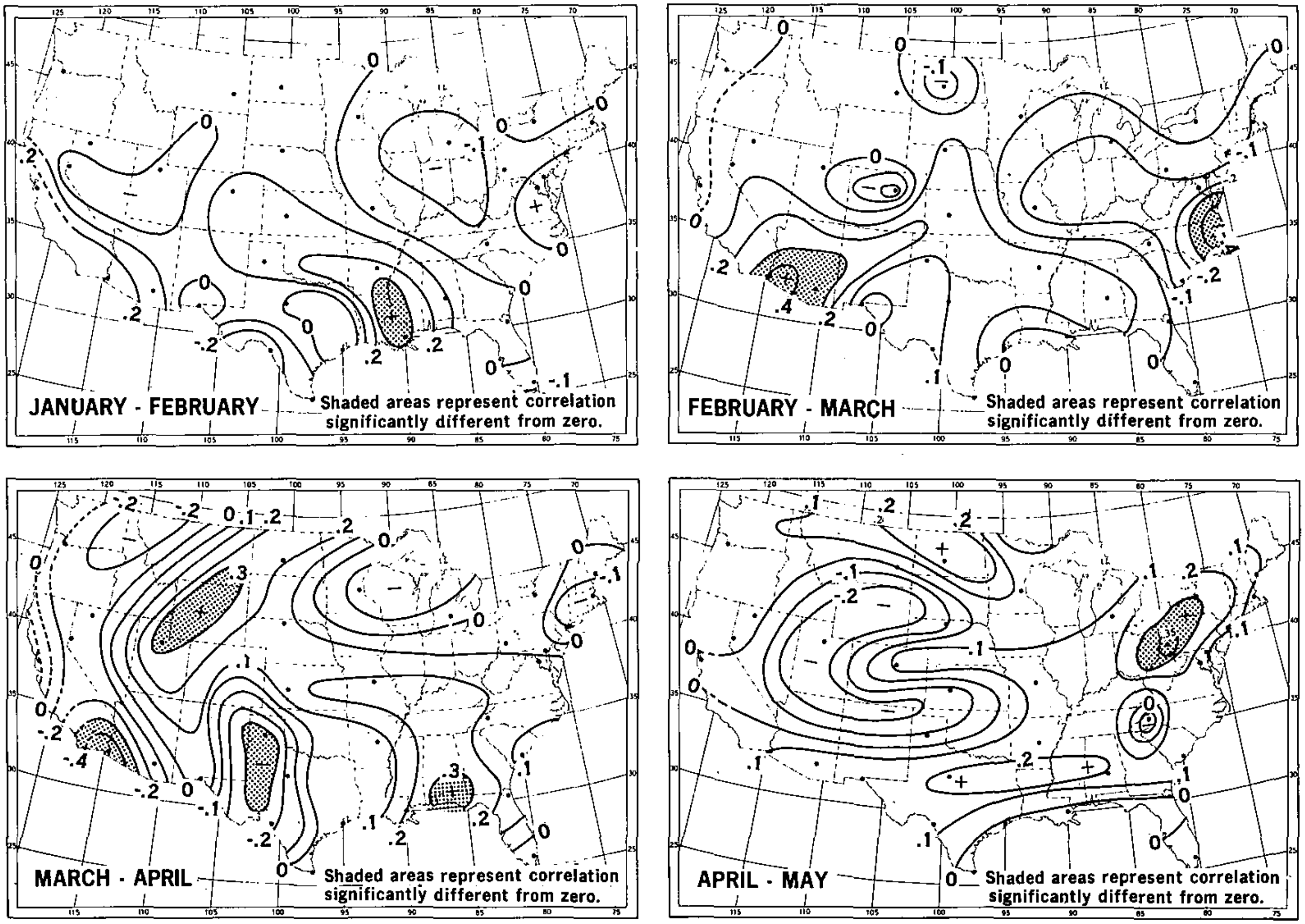


Figure 3a. Isopleths of correlations, LAG 1, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at selected North American stations. Period: 1906 – 1948.

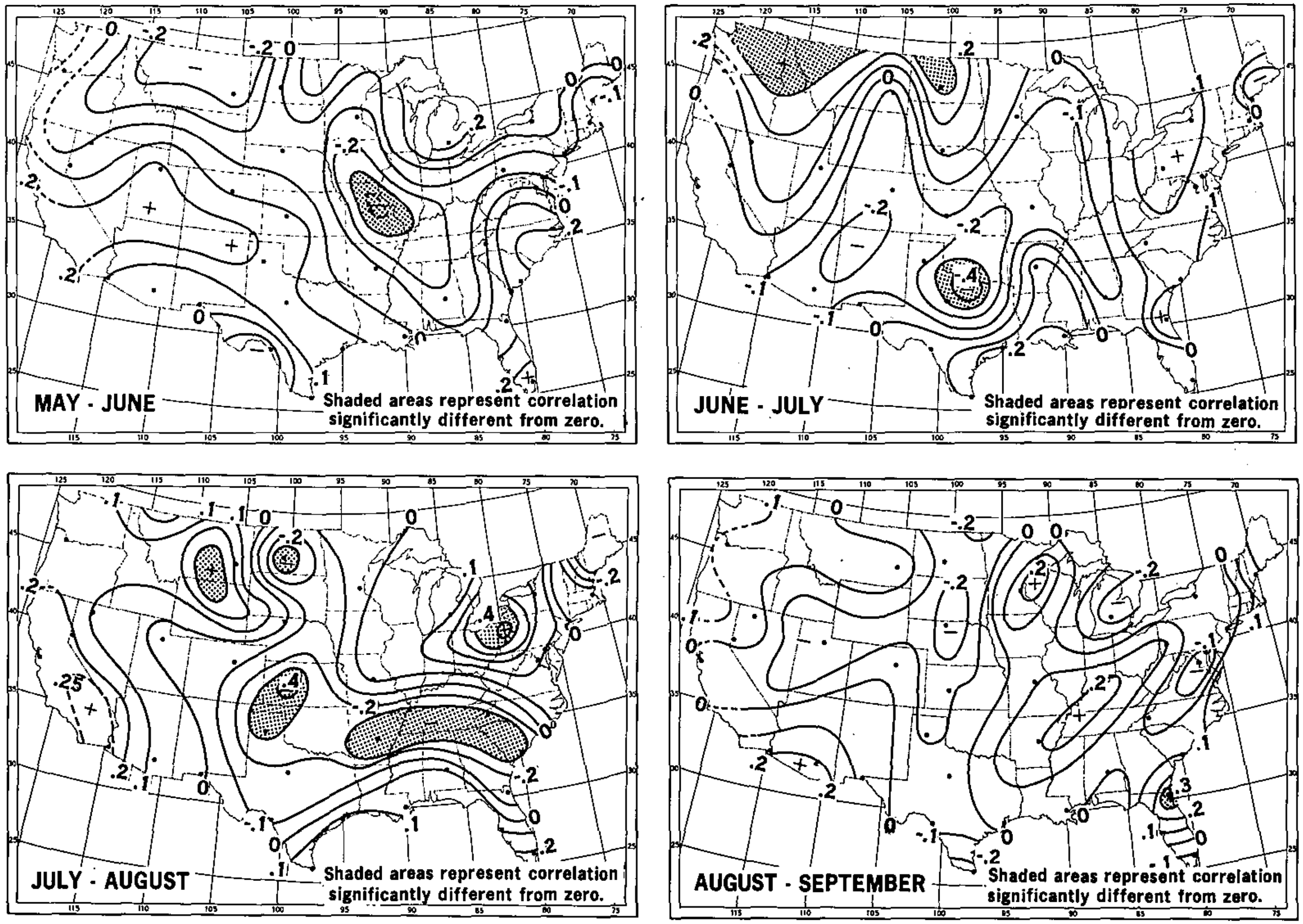
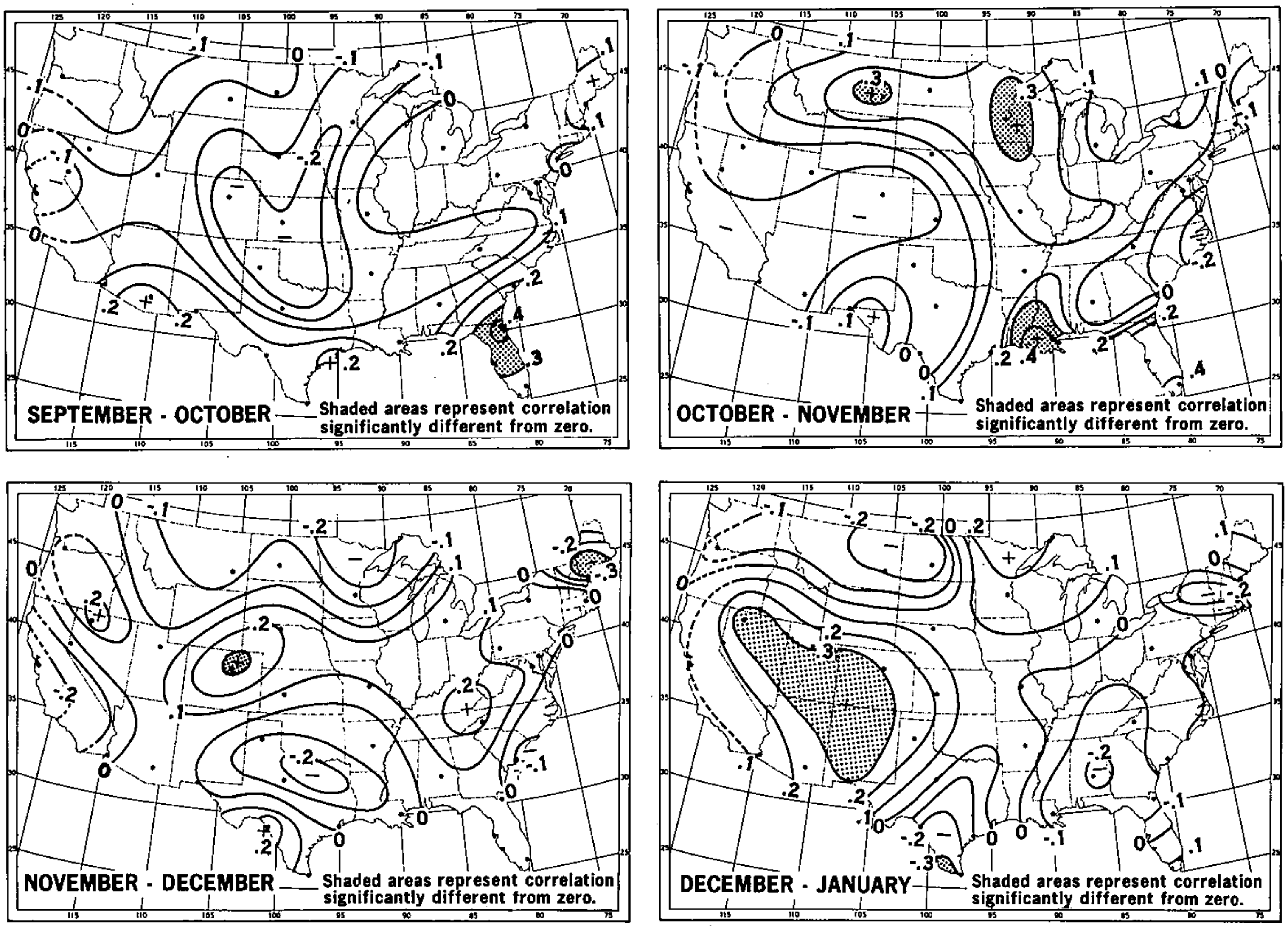


Figure 3b. Isopleths of correlations, LAG 1, between monthly average temperature (°F) and monthly total precipitation, $(\text{inches})^{1/3}$ at selected North American stations. Period: 1906 – 1948.



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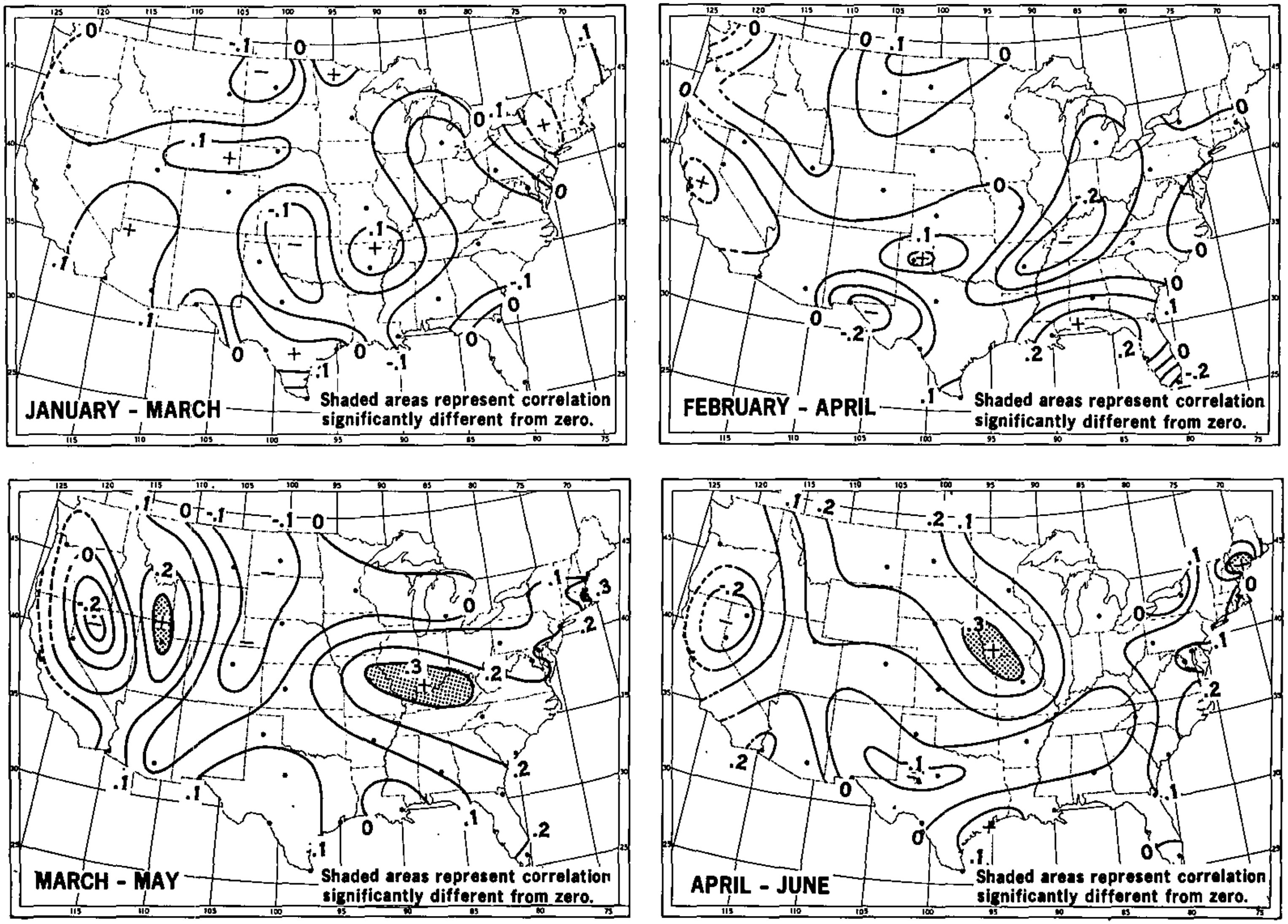


Figure 4a. Isopleths of correlations, LAG 2, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at selected North American stations. Period: 1906 – 1948.

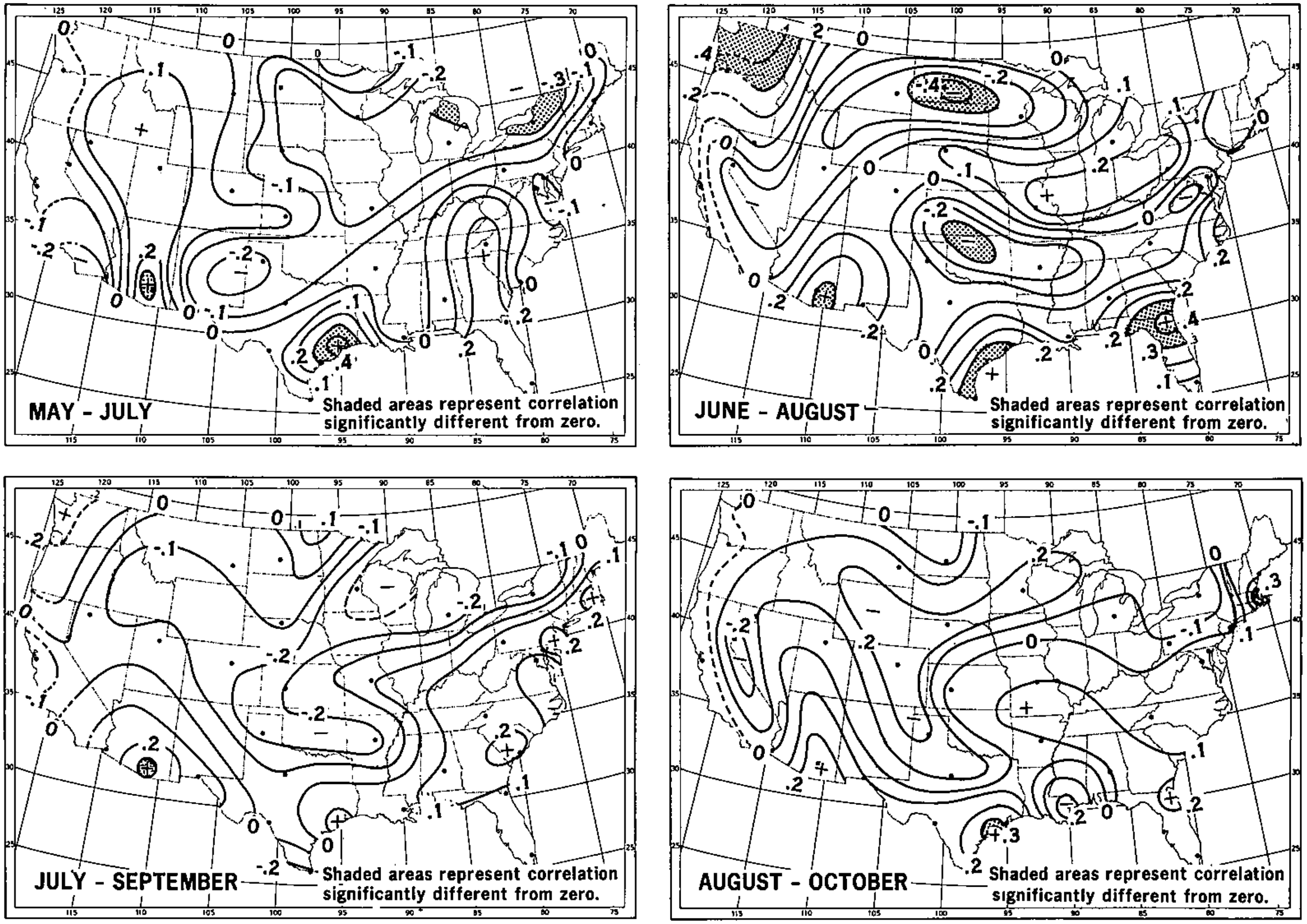
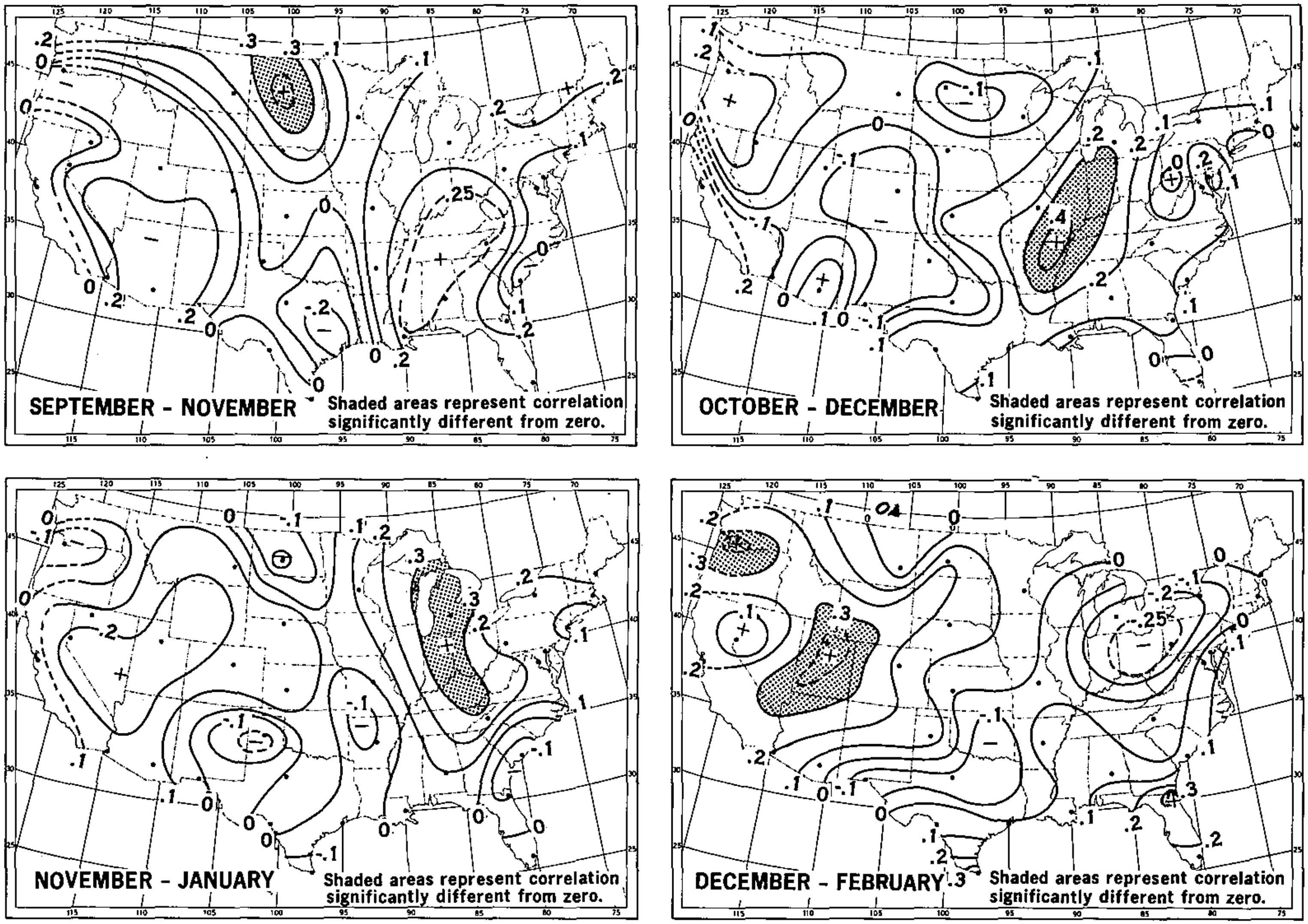


Figure 4b. Isopleths of correlations, LAG 2, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at selected North American stations. Period: 1906 – 1948.



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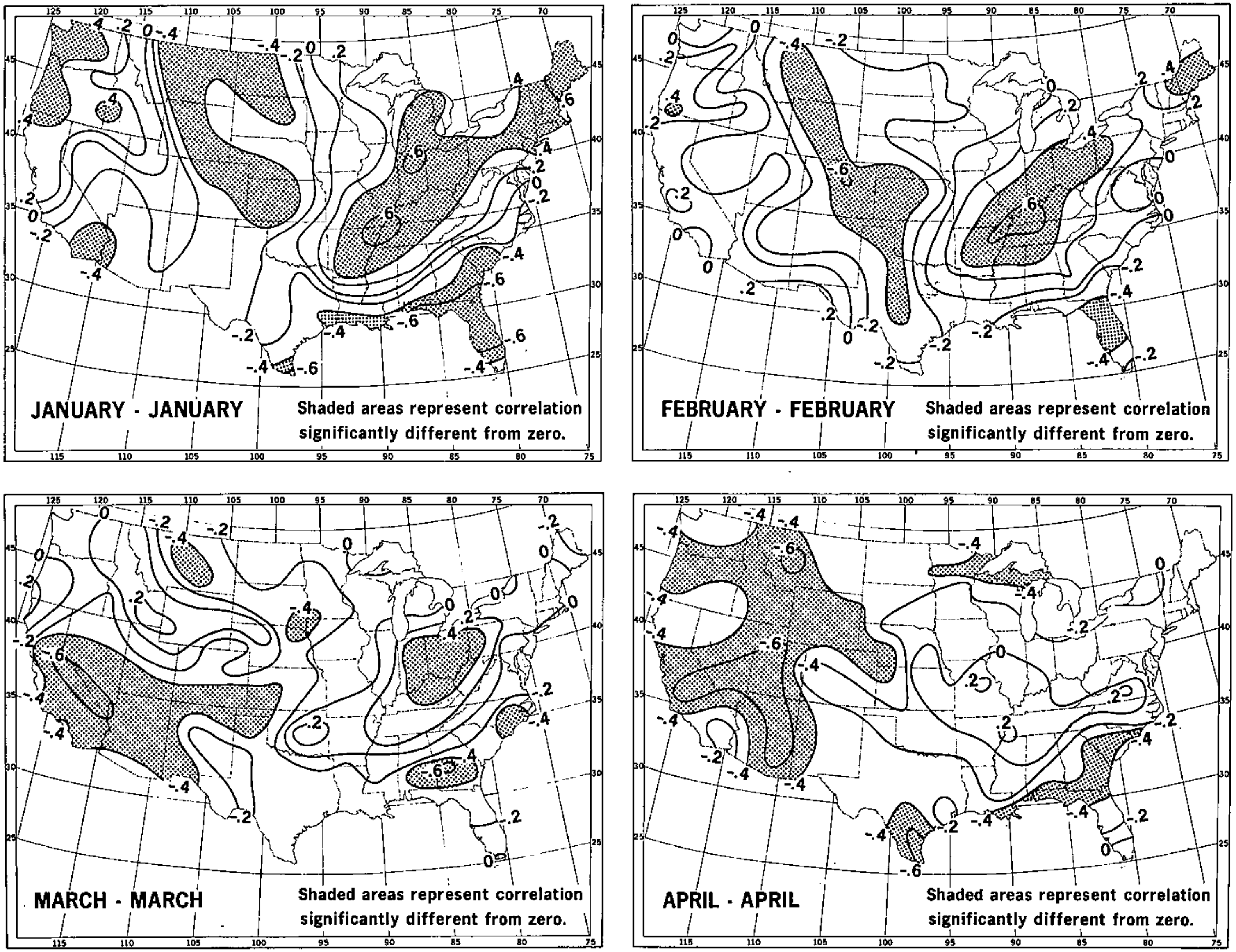

Figure 5a. Isopleths of correlations, LAG 0, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

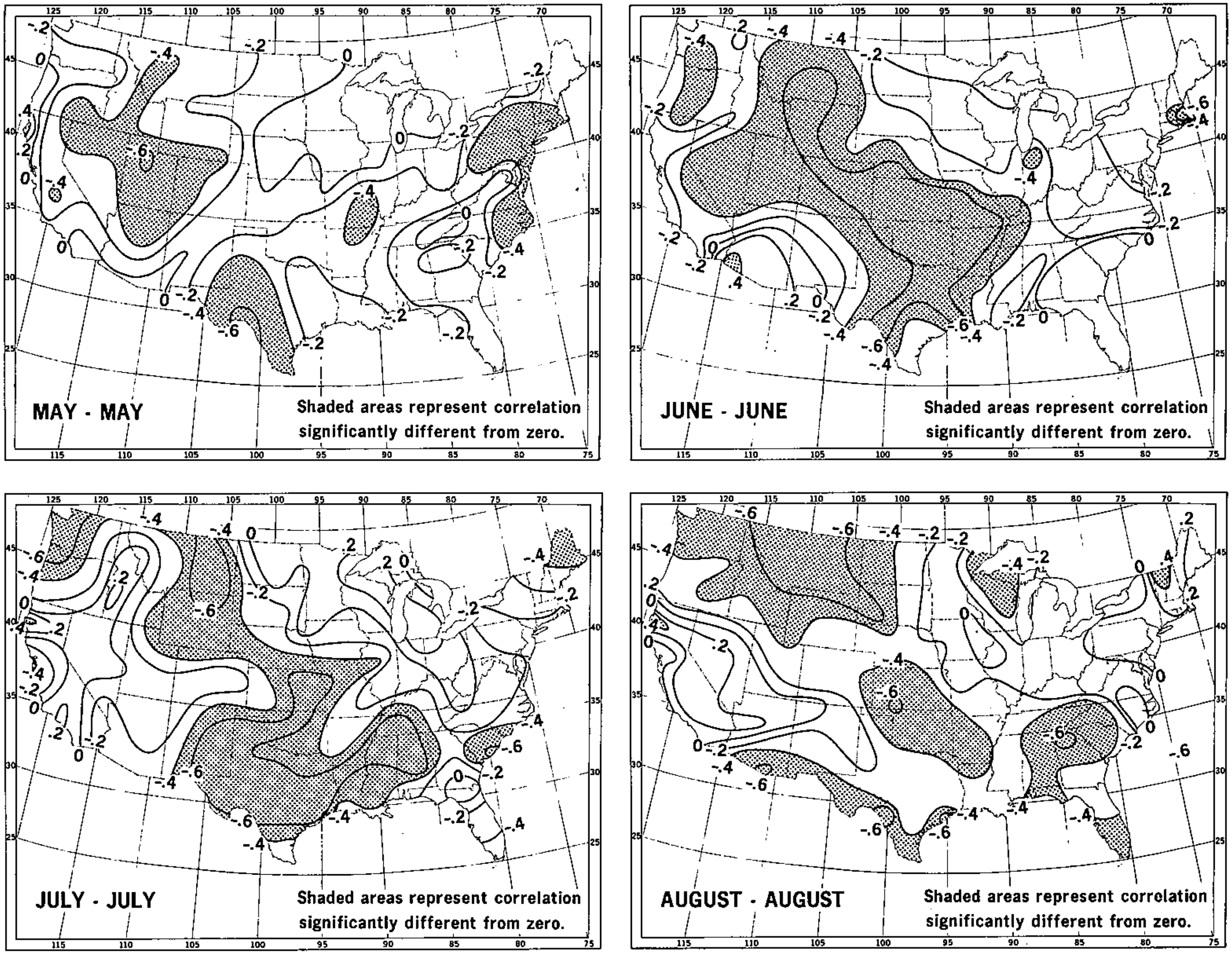

Figure 5b. Isopleths of correlations, LAG 0, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

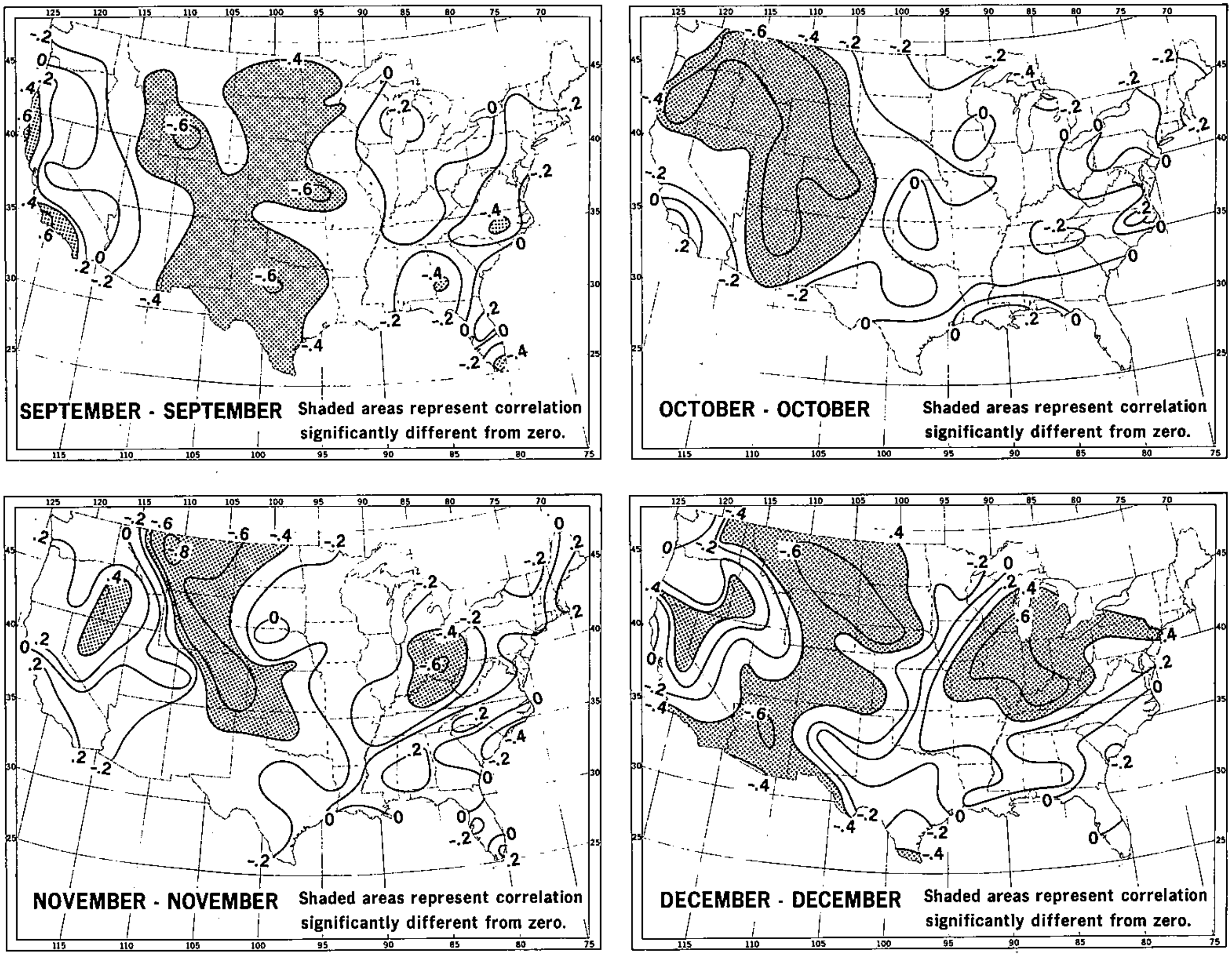

Figure 5c. Isopleths of correlations, LAG 0, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

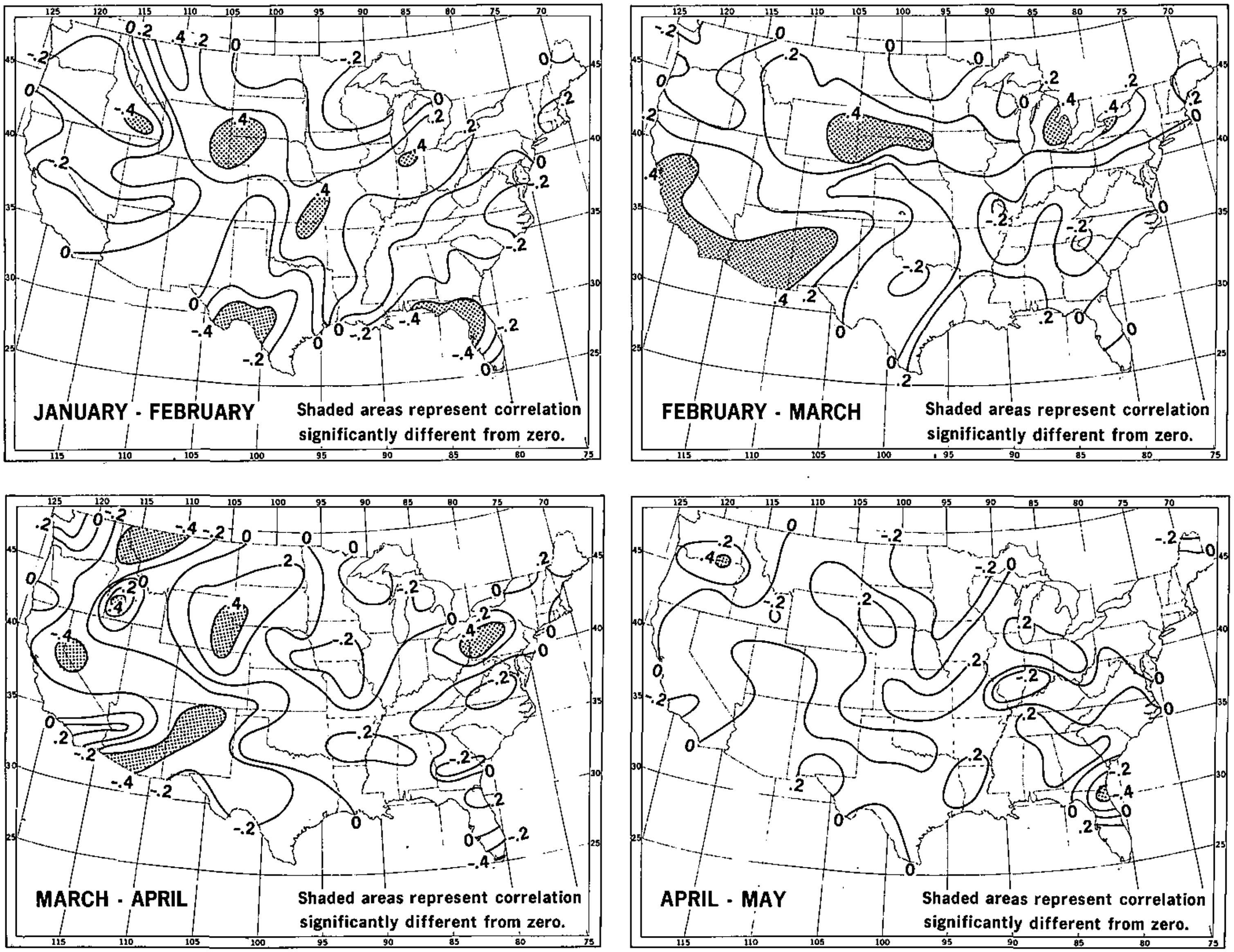

Figure 6a. Isopleths of correlations, LAG 1, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

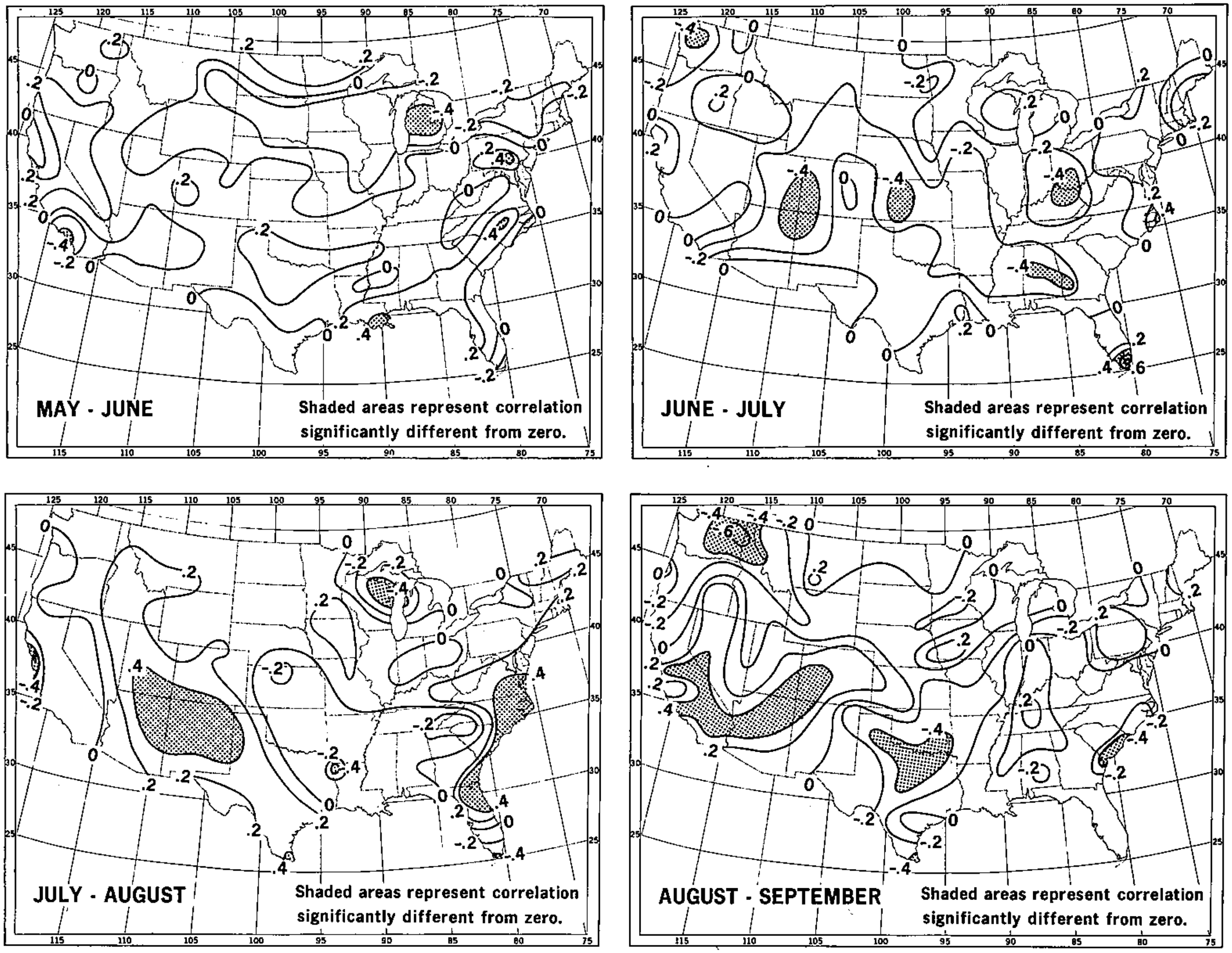

Figure 6b. Isopleths of correlations, LAG 1, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

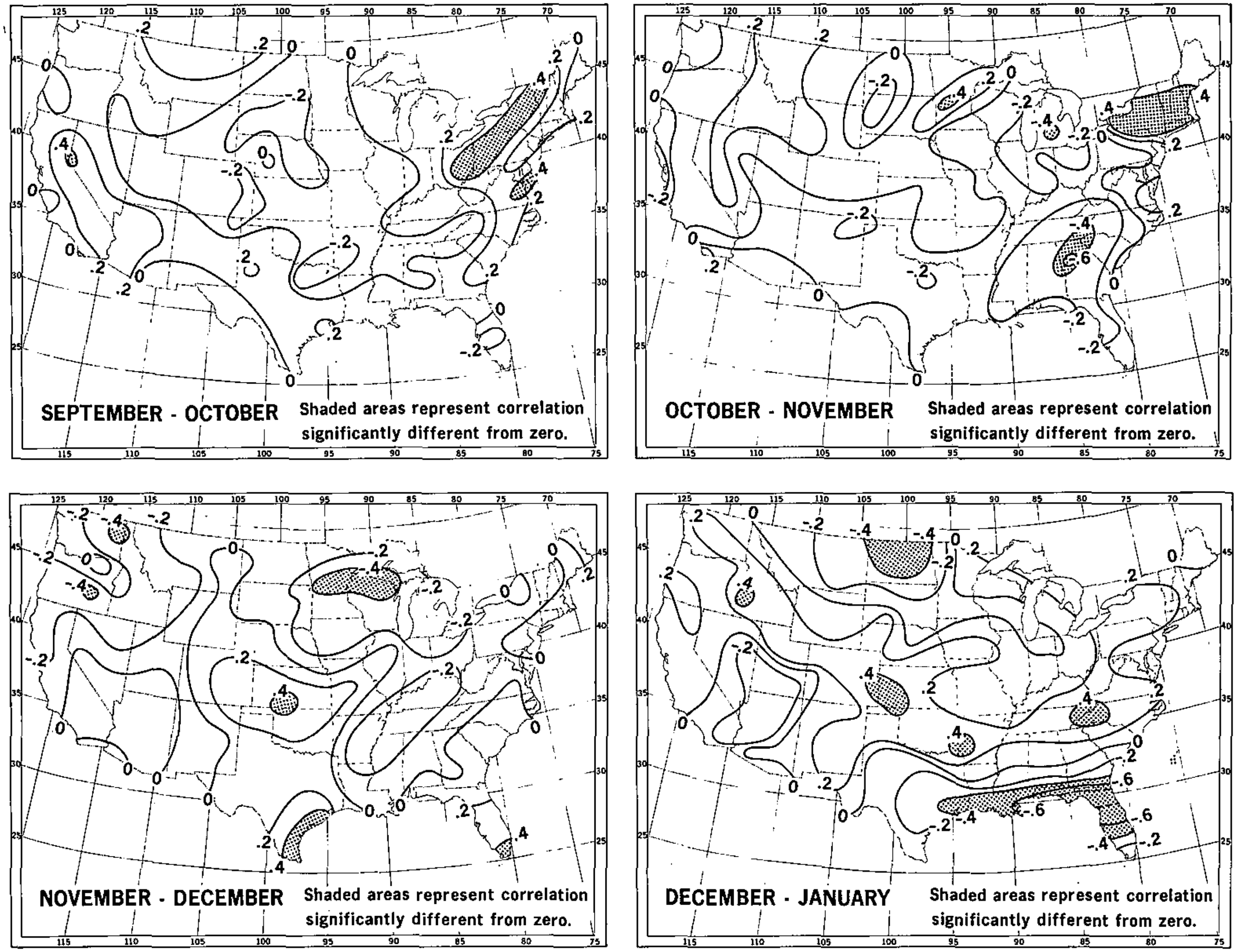

Figure 6c. Isopleths of correlations, LAG 1, between monthly average temperature (°F) and monthly total precipitation (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

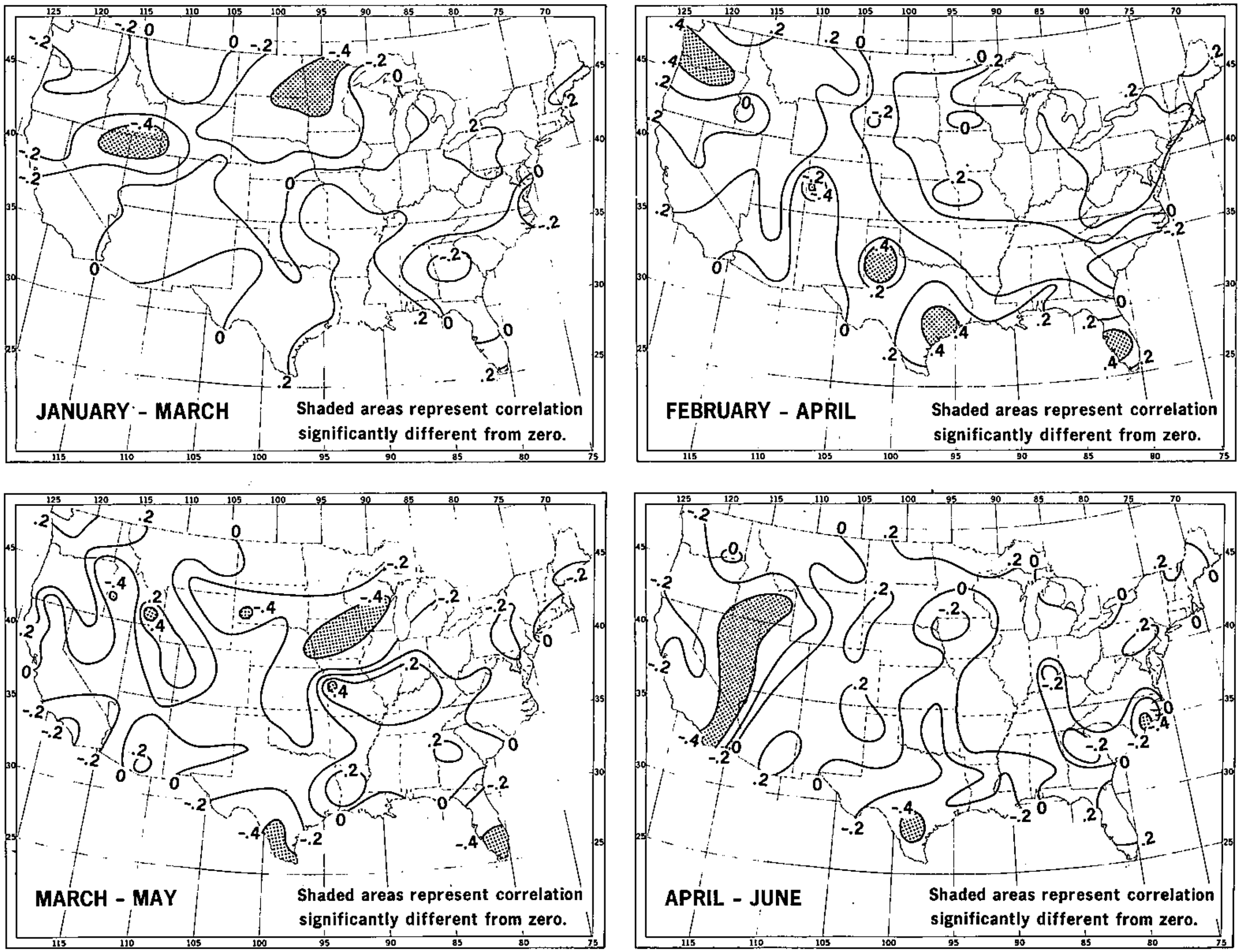

Figure 7a. Isopleths of correlations, LAG 2, between monthly average temperature (°F) and monthly total precipitation, $(\text{inches})^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

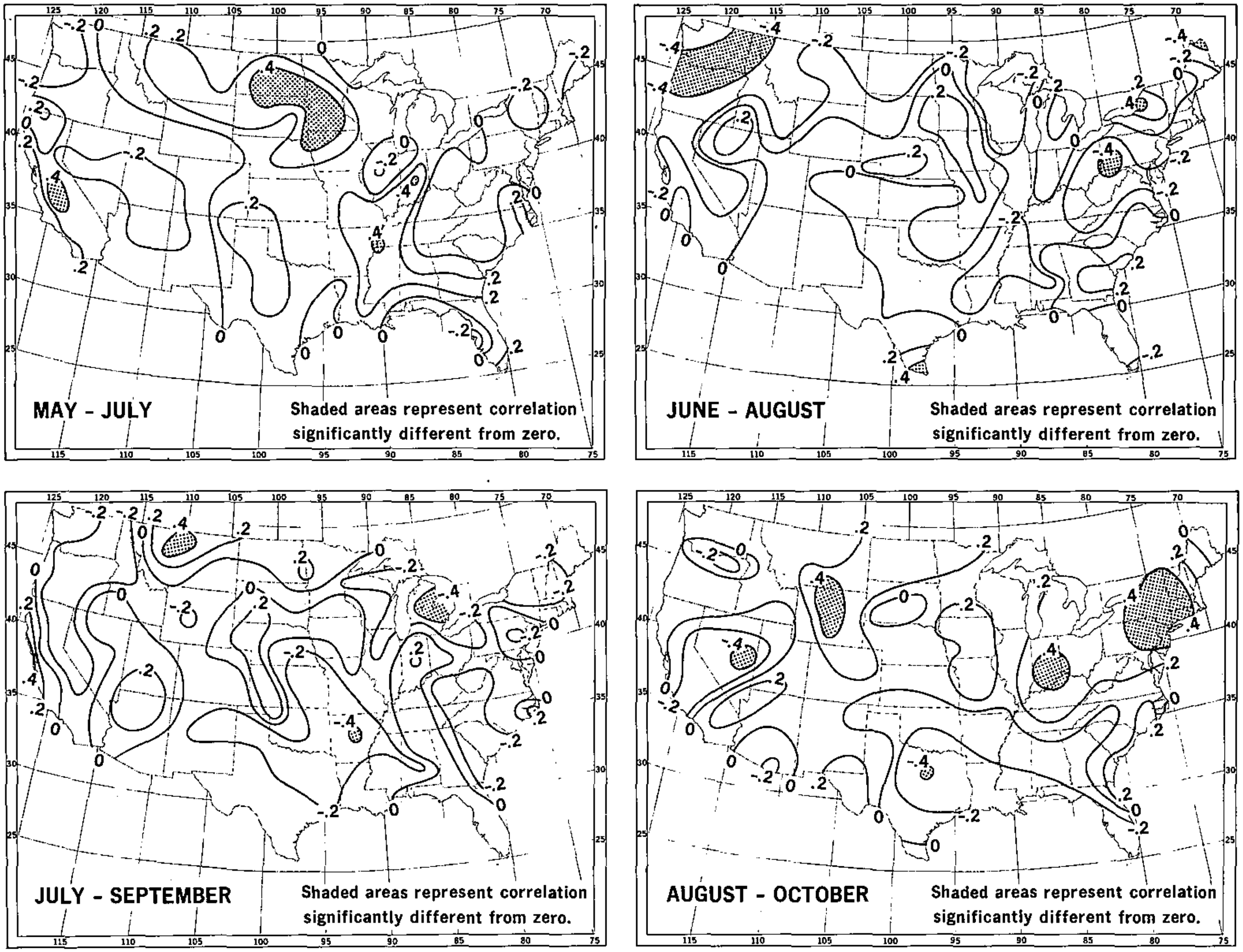

Figure 7b. Isopleths of correlations, LAG 2, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

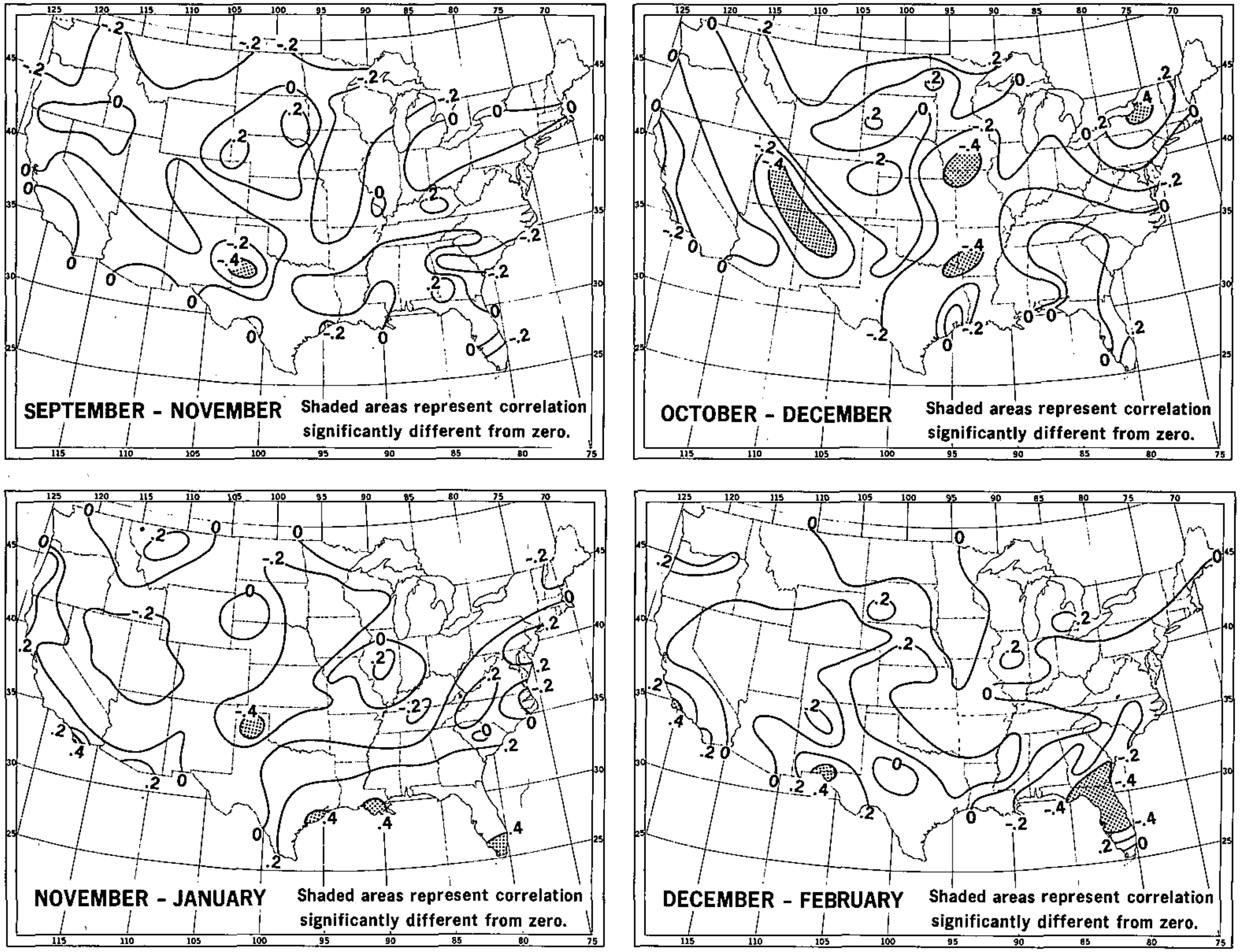

Figure 7c. Isopleths of correlations, LAG 2, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

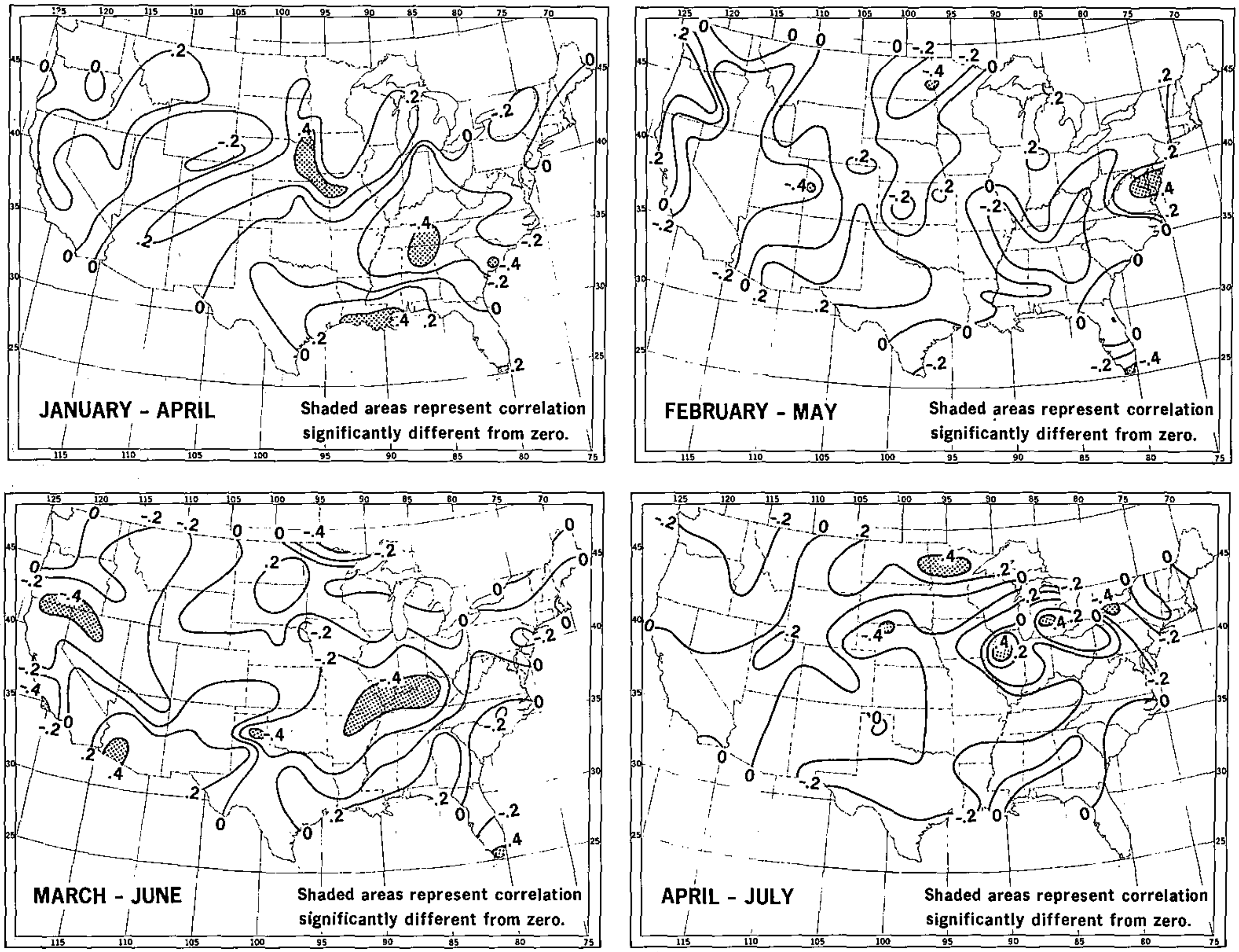

Figure 8a. Isopleths of correlations, LAG 3, between monthly average temperature (°F) and monthly total precipitation (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

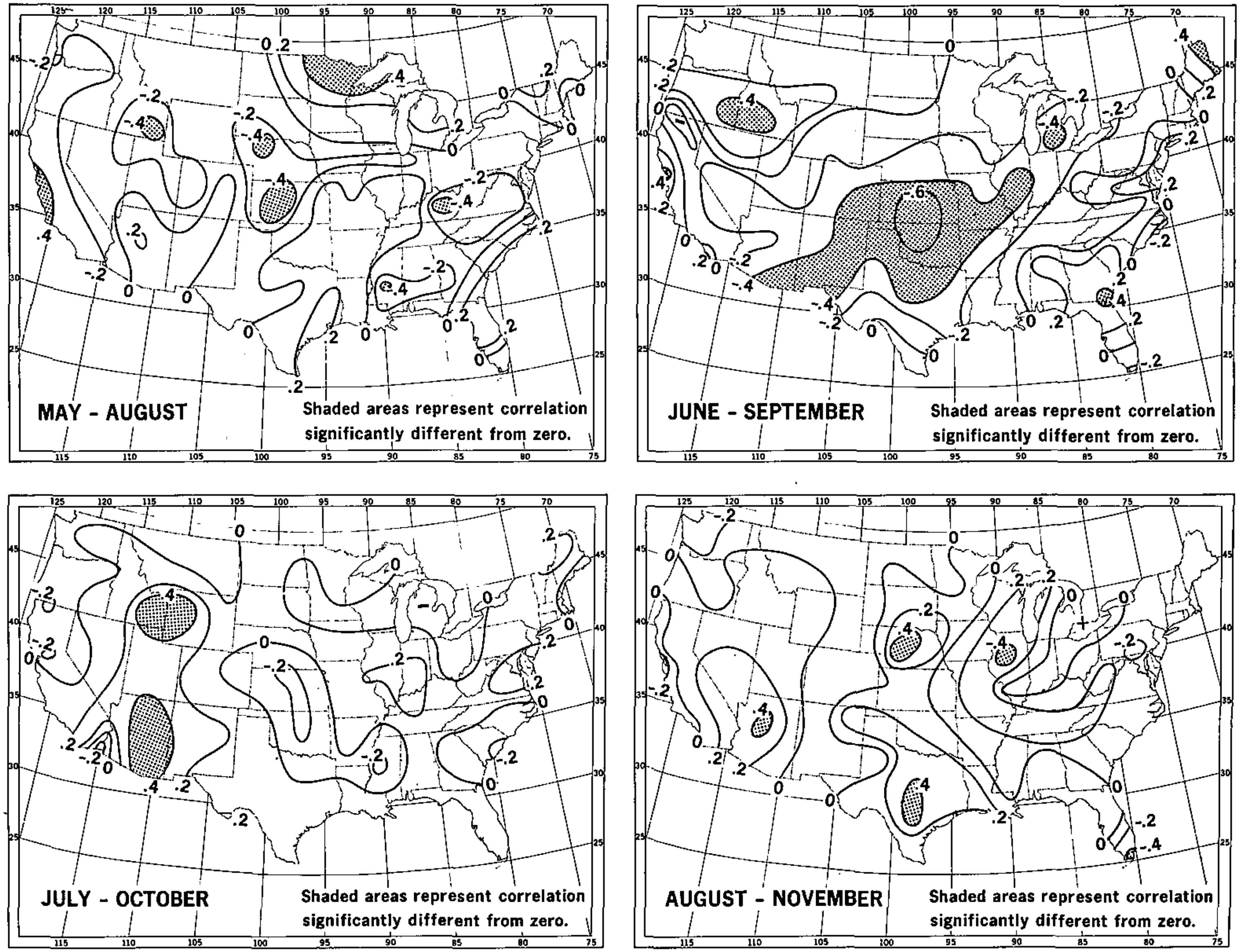

Figure 8b. Isopleths of correlations, LAG 3, between monthly average temperature (°F) and monthly total precipitation (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

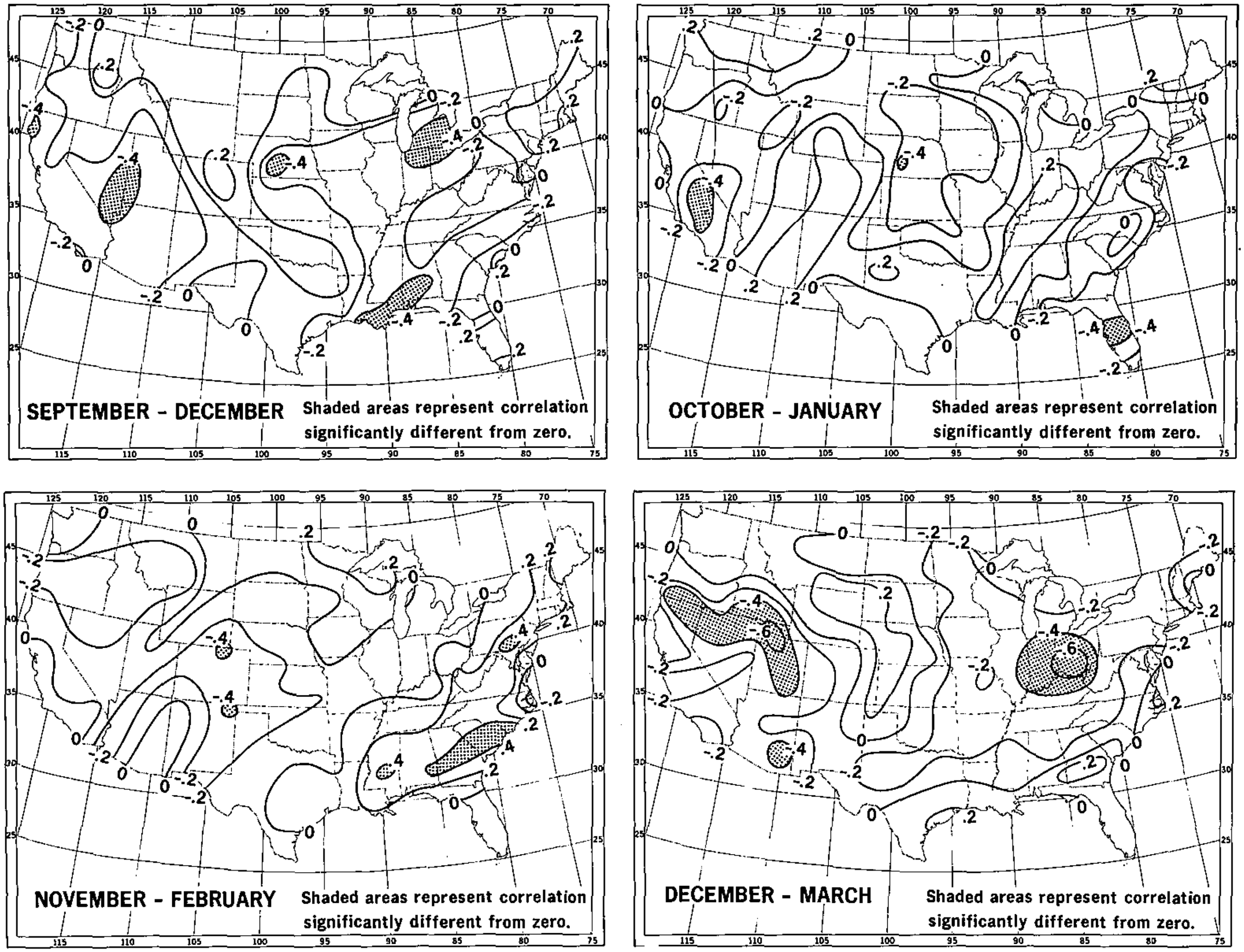

Figure 8c. Isopleths of correlations, LAG 3, between monthly average temperature (°F) and monthly total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

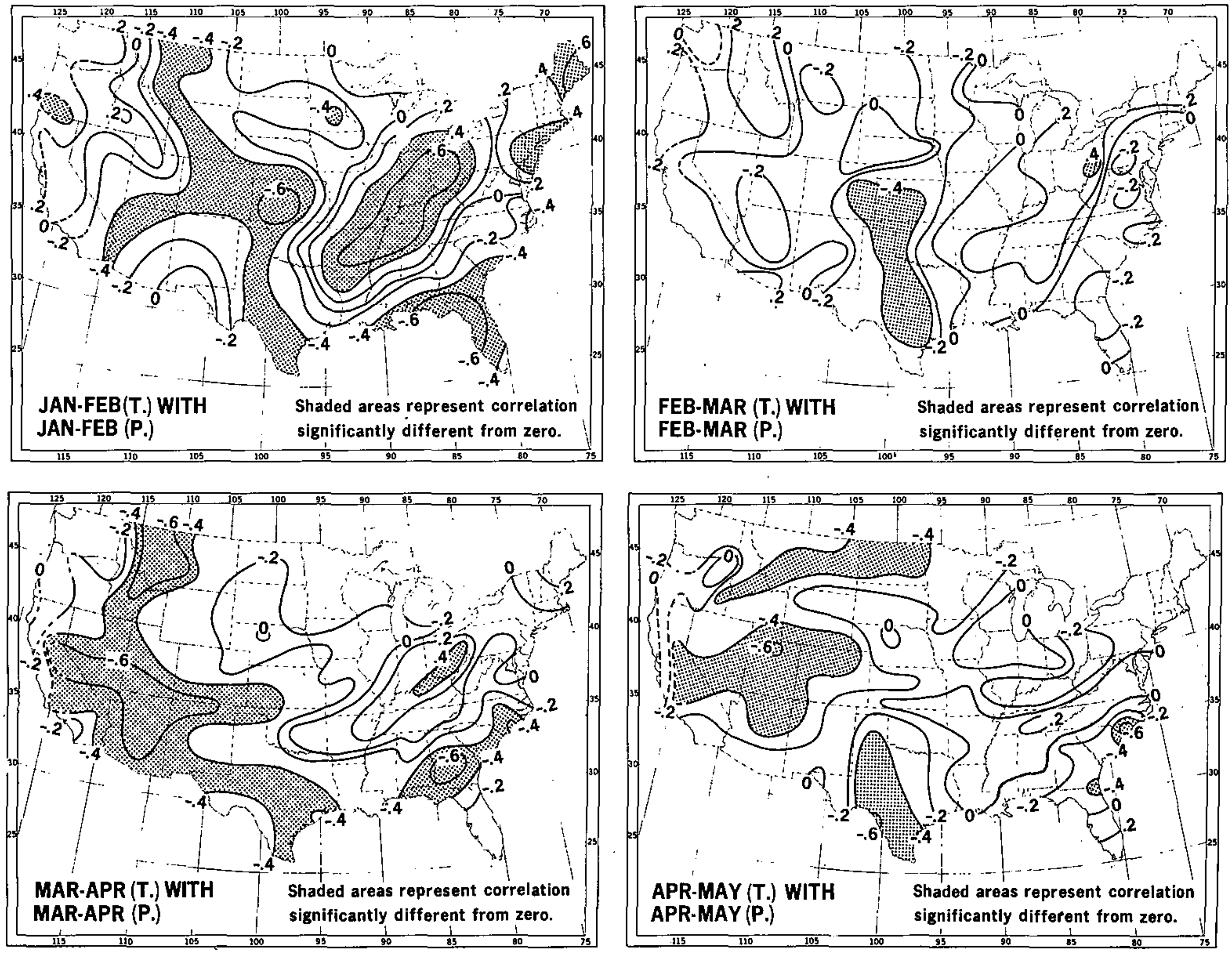

Figure 9a. Isopleths of correlations, LAG 0, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

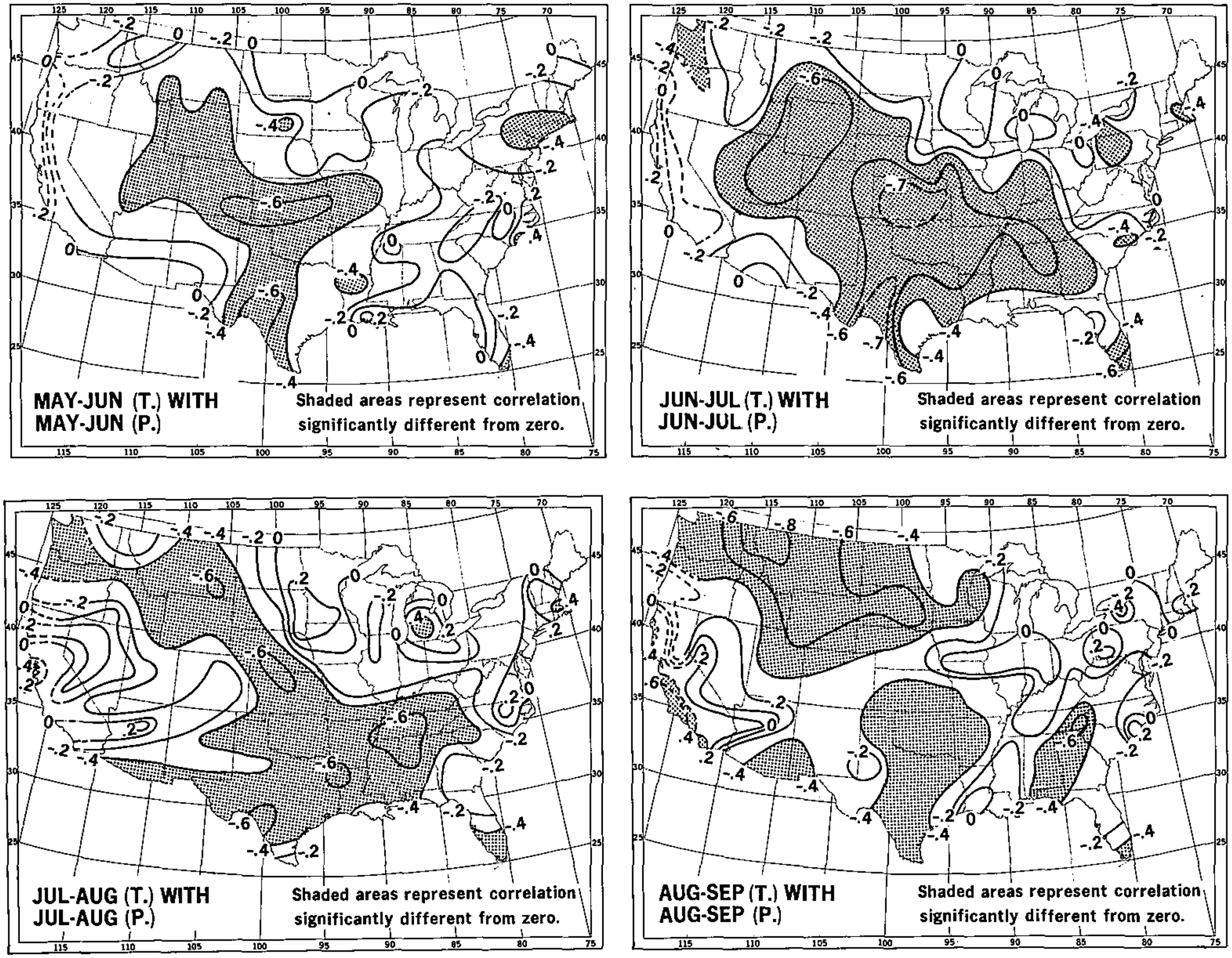

Figure 9b. Isopleths of correlations, LAG 0, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

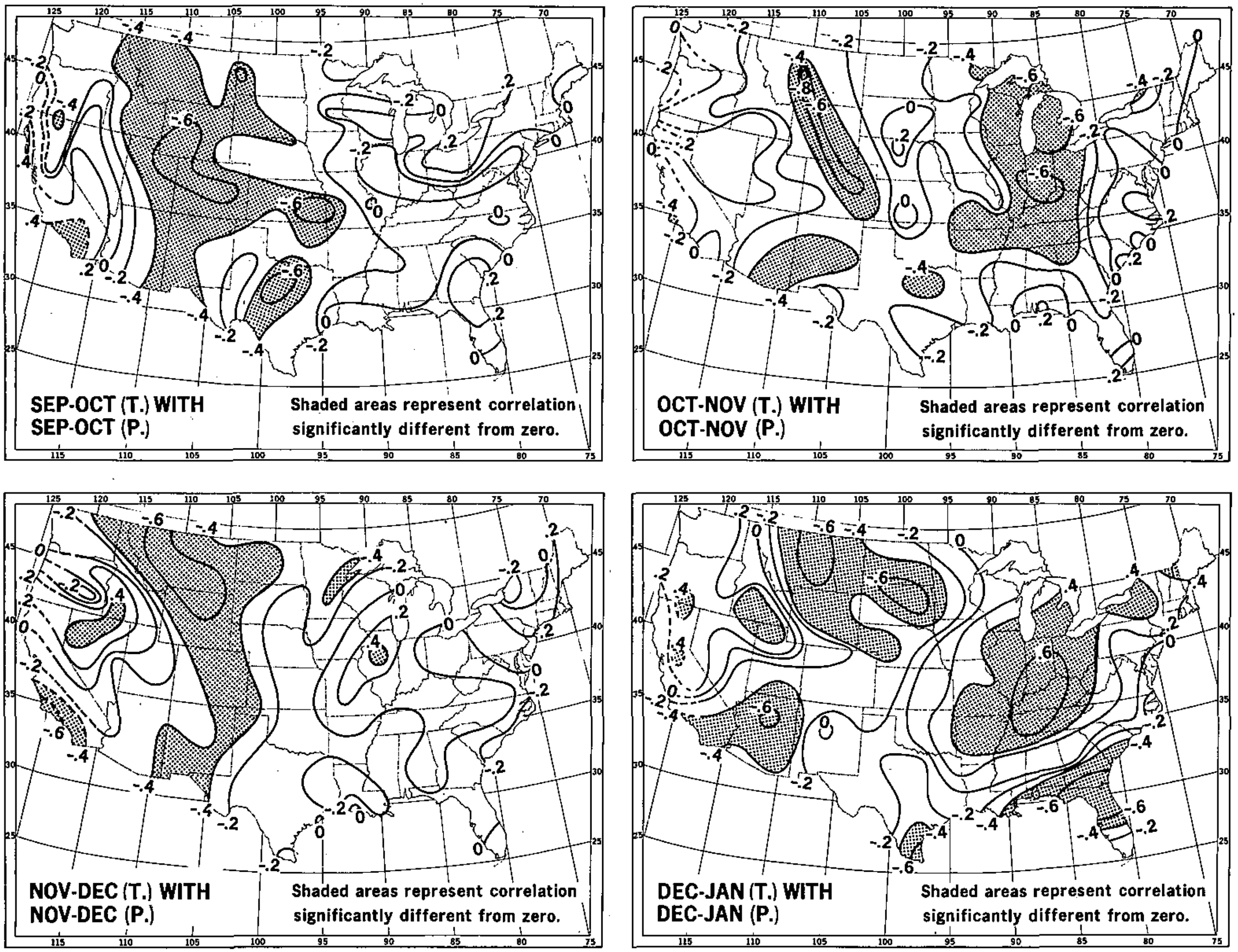

Figure 9c. Isopleths of correlations, LAG 0, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

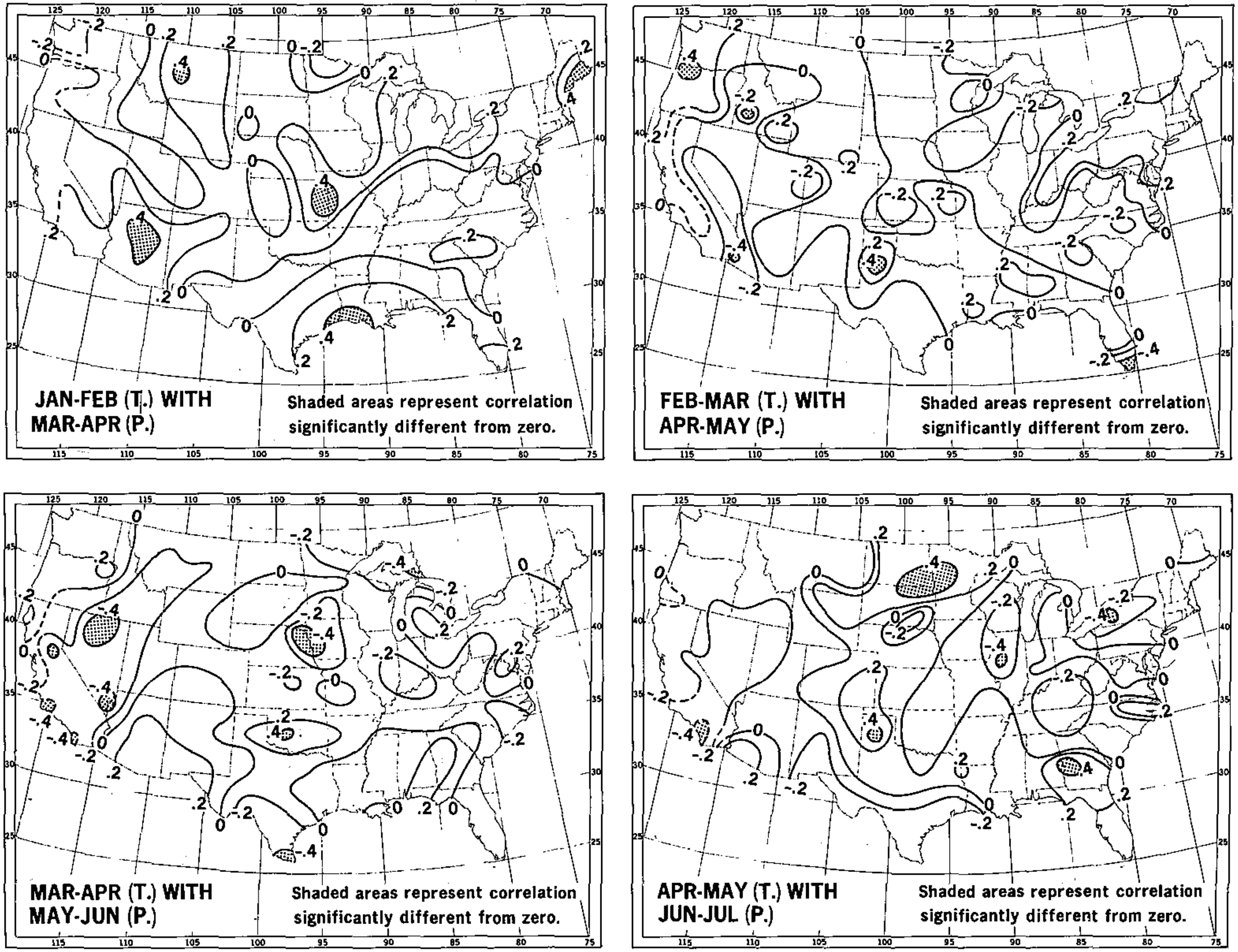

Figure 10a. Isopleths of correlations, LAG 2, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

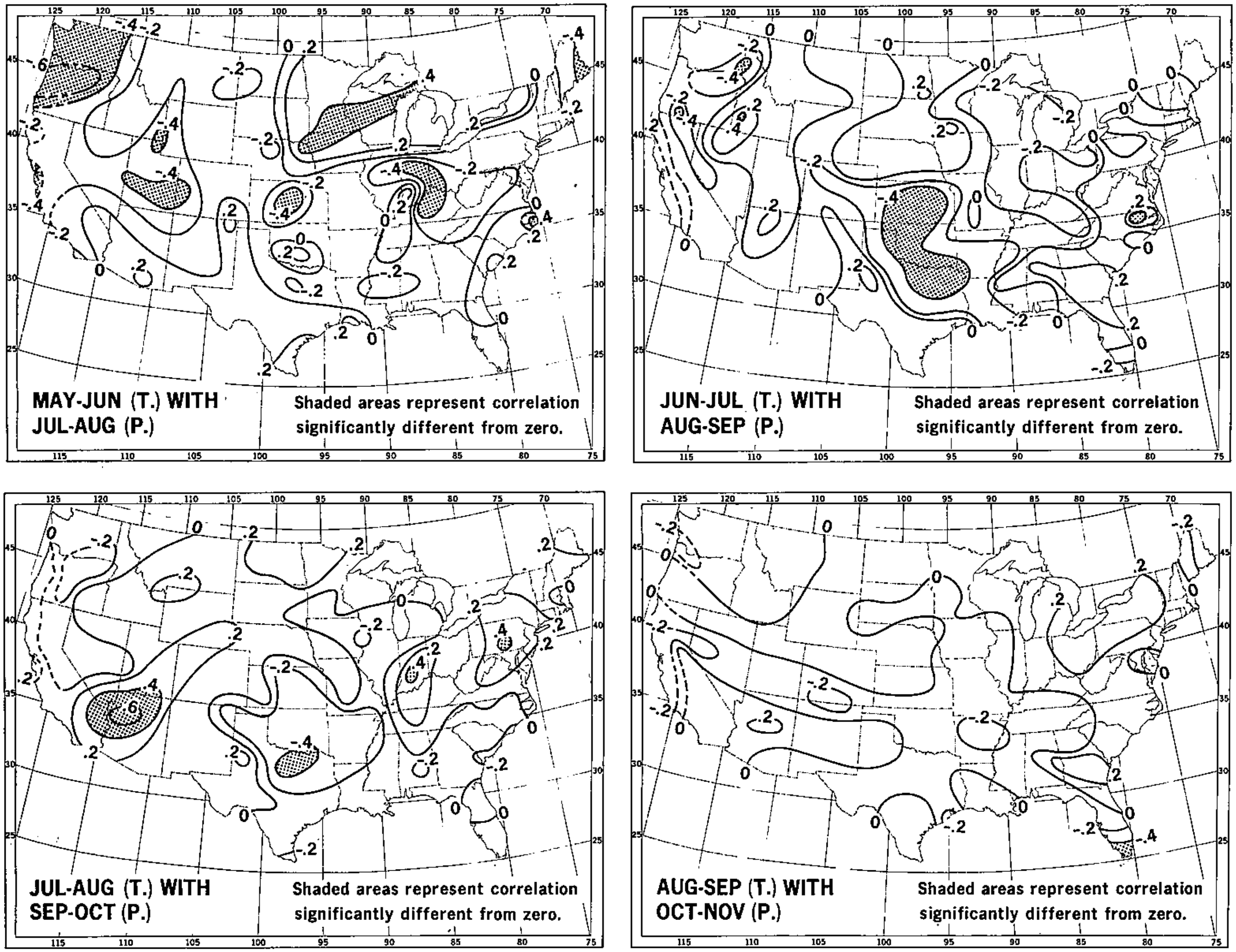

Figure 10b. Isopleths of correlations, LAG 2, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

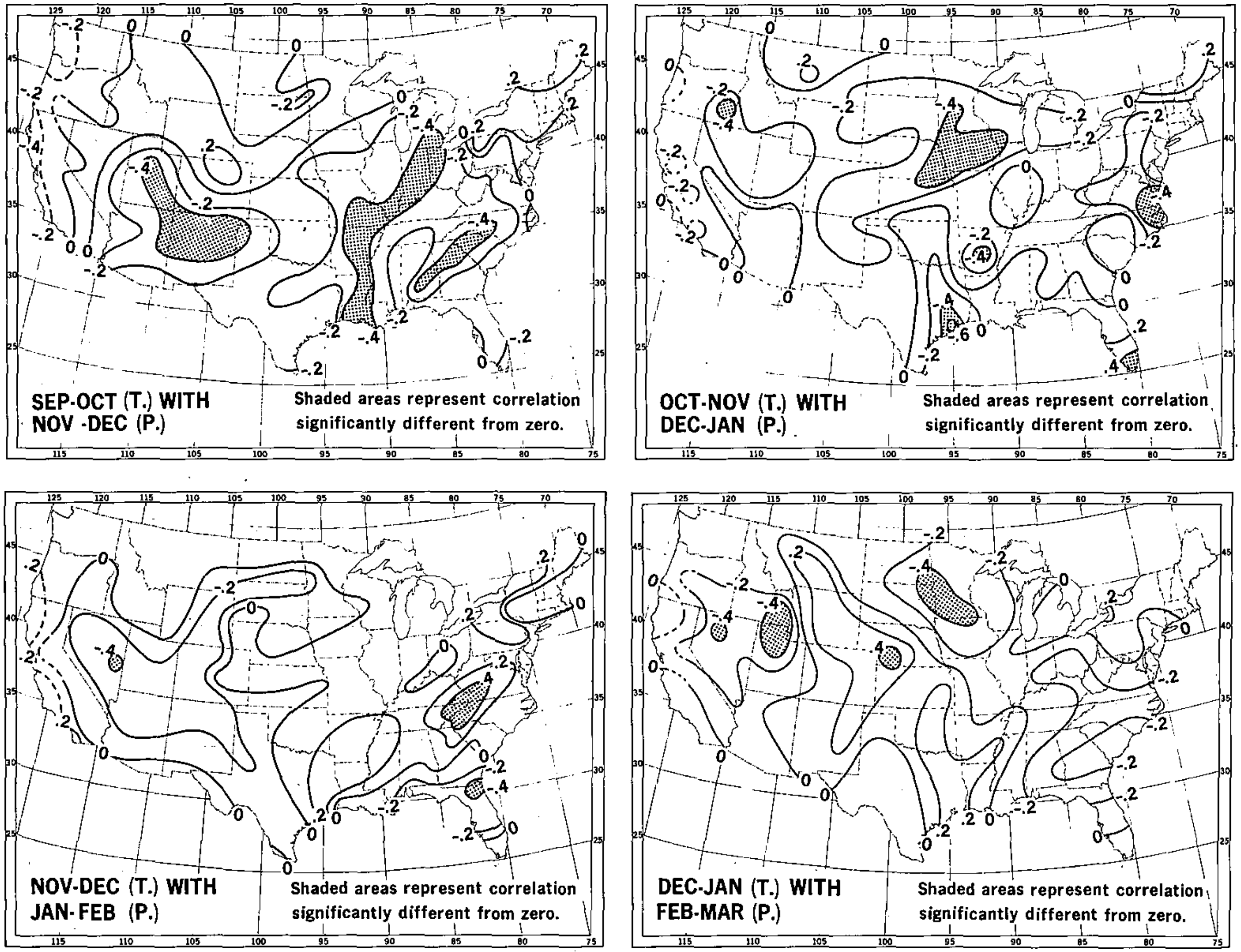

Figure 10c. Isopleths of correlations, LAG 2, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

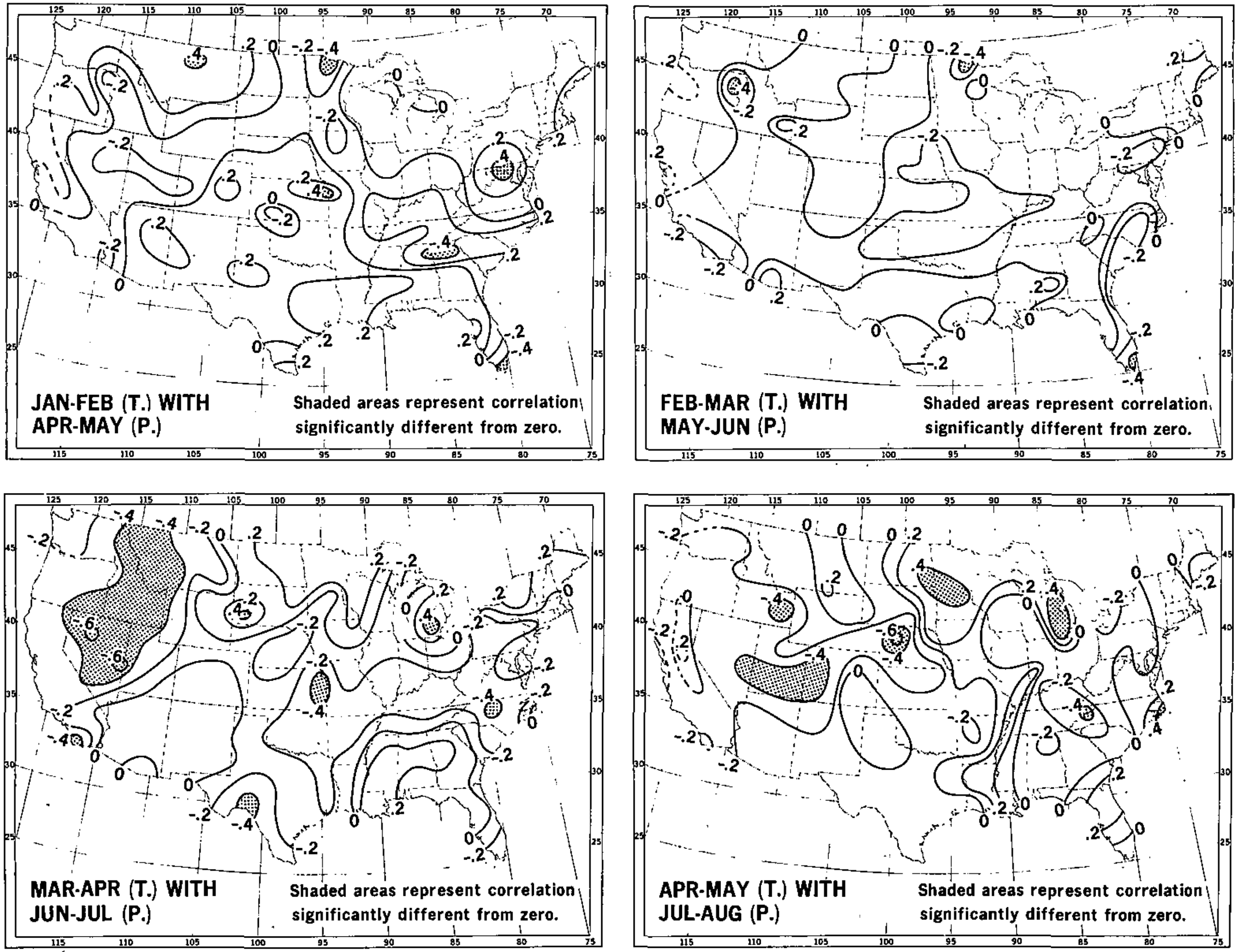

Figure 11a. Isopleths of correlations, LAG 3, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

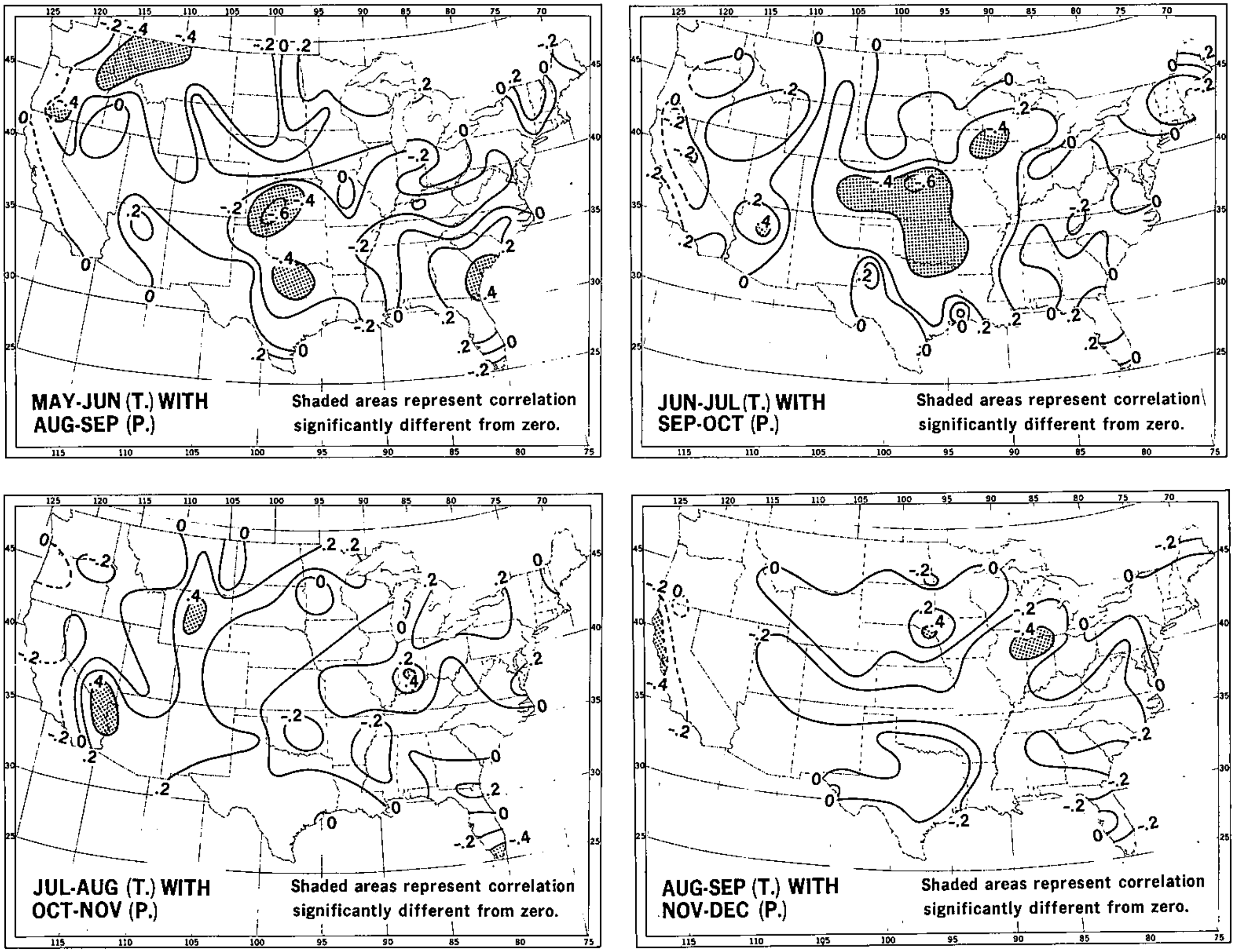

Figure 11b. Isopleths of correlations. LAG 3, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.

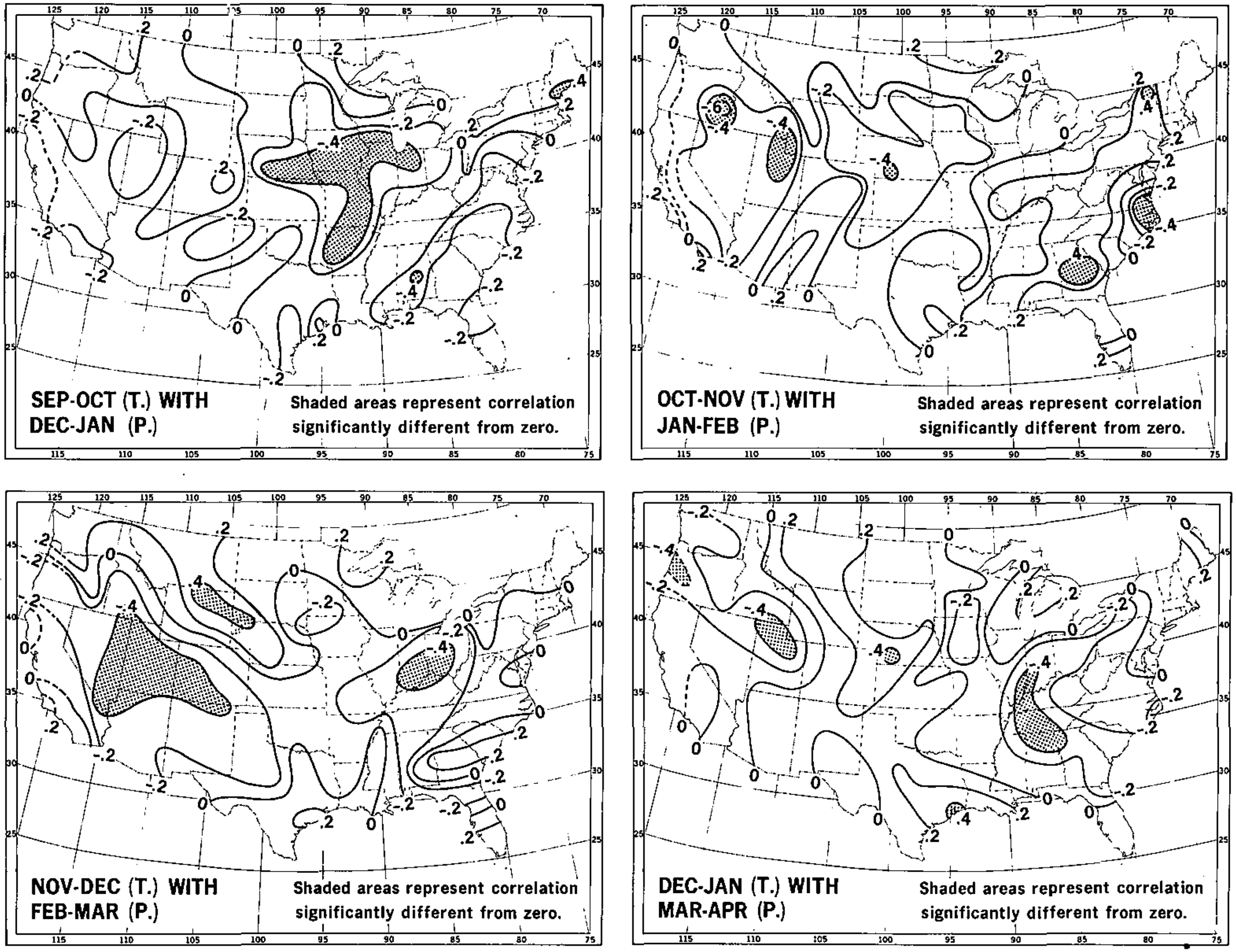

Figure 11c. Isopleths of correlations, LAG 2, between two-month average temperature (°F) and two-month total precipitation, (inches)$^{1/3}$ at 102 selected North American stations. Period: 1949 – 1970.