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OBJECTIVE TEMPERATURE ESTIMATES FROM MEAN CIRCULATION PATTERNS [1]

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ABSTRACT

Two methods are developed for translating monthly mean circulation patterns into the accompanying surface temperature anomalies. Using a system of graphical correlation, temperature anomalies are deduced objectively from the curvature of isobars, pressure departure from normal, and air parcel trajectory on monthly mean 10,000-ft., or 700-mb. charts. The scheme is simplified by using the anomalies of flow and pressure as parameters. The results are extended for use on 5-day mean 700-mb. charts and further possibilities for improving the objective technique are considered.

INTRODUCTION

The preparation of long-range forecasts at the U. S. Weather Bureau involves first the construction of prognostic mean pressure and height charts and secondly the interpretation of these charts in terms of temperature and precipitation anomalies. In predicting circulation patterns, all available information of past behavior, including the weather associated with the observed circulation patterns, is considered. The second step of the forecast procedure has, in the past, been accomplished chiefly by a qualitative appraisal of the flow patterns.

The ability of forecasters to translate circulation prognoses into anomaly forecasts was investigated by Norton, Brier, and Allen [1]. In their experiment 3 experienced long-range forecasters were furnished observed sea level and 10,000-ft. pressure patterns and charts of weight between these levels, and were asked to draw the concomitant temperature and precipitation anomalies. It was found that a sizable portion of forecasting errors are apparently made subsequent to the completion of the prognostic pressure maps (that is, in the interpretation of the circulation patterns). In addition, the results obtained by different forecasters when interpreting flow patterns varied sufficiently that the need for an objective technique was clearly indicated. The hoped-for objectivity would have the effect of standardizing the interpretive processes and would lead to greater facility in applying and teaching the methods of extended forecasting.

It is recognized at the outset that there are two principal attacks to the problem of making better long-range forecasts. The difference lies in the order of operations: Whether the first attempts are for the improvement of the circulation prognosis or of the technique of interpreting the forecast. Much work has already been done on the former fundamental research problem with the expectancy that advances along these lines would be reflected in the anomaly forecasts. It is the present aim to develop the interpretive processes by a combined synoptic-statistical approach as was employed by Klein [2] in relating precipitation to upper level flow patterns.

Aside from the obvious practical advantages, it is clear that such an extensive empirical attack should cast a great deal of light on our fundamental knowledge of synoptic climatology.

PROCEDURE

In planning the work it was decided to divide the United States into broad geographical areas in which climatological influences are assumed to be uniform. These are shown in figure 1. These areas were chosen on the basis of experience gained by Namias and Clapp [3] and Smith [4]. Three cities were selected in each major subdivision by virtue of length of climatological record, and each of 4 researchers [2] was assigned one or more areas for study.

[2] J. F. Andrews, H. F. Hawkins, D. E. Martin, and K. E. Smith.

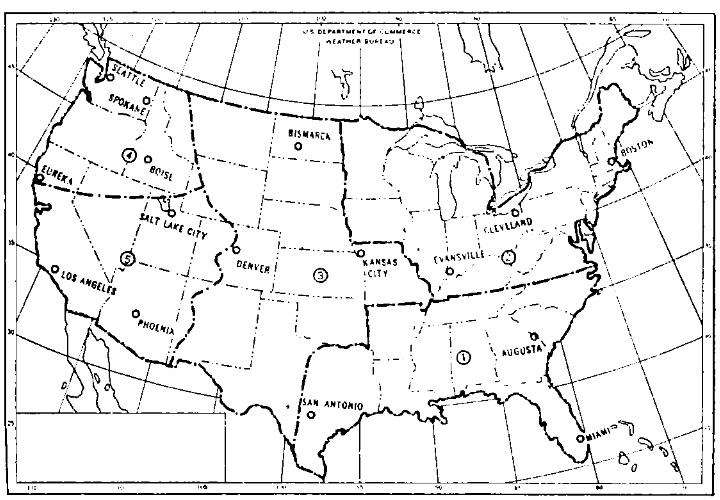

FIGURE 1.—Division of the United States into broad geographical zones of approximate climatic homogeneity for investigation of objective temperature forecasting techniques.

[1] A preliminary report on this subject was delivered at the annual meeting of the American Meteorological Society in Washington, D. C., on April 20, 1948, by Philip F. Clapp, Extended Forecast Section.

Upper level maps were used in preference to sea level maps because of their lesser complexity and the fact that they represent the primary consideration in our extended forecasting procedures. In considering the available data it was decided to make use of a 15-year historical series of mean monthly 10,000-ft. charts which had previously been prepared at the Extended Forecast Section. The decision to use these monthly data arose from the fact that 5-day means were available for only 6 years. Moreover, results obtained from this material would be directly applicable in the routine preparation of experimental mean monthly forecasts. Also it was believed that any method derived in this way could be adapted to usage in 5-day forecasting.

Monthly mean 10,000-ft. charts were constructed for the period from 1932 onward.[3] The first 13 years of data (from 1932 to 1945) were used in the investigational phases of the research problem. The last 2 years (1946 and 1947) were reserved for testing purposes

SELECTION OF PARAMETERS

On the basis of the experience of trained forecasters, and of theoretical as well as empirical studies, certain parameters were chosen. The first variable suggested as influencing the temperature field was the source region of the air expected at a given station. Air flowing from the north is generally associated with temperatures below normal, whereas above normal temperatures tend to result from southerly flow. Of course, topographical and geographical features would be expected to alter this simple relationship.

It is assumed that monthly mean 10,000-ft. charts are a good representation of the average stream flow during the month. A geostrophic wind computed from these charts should therefore approximate the resultant monthly wind velocity.

The mean trajectory of air parcels arriving at a station is assumed to coincide with the isobar through the station. The point of origin (see figure 2) is located by following the isobar upstream an arbitrary distance inversely proportional to the average gradient along the trajectory and depending on the season. For convenience in the computations, the length of the trajectory was determined as the travel distance at geostrophic speed for a period of 48 hours (except in June, July, and August, for which 72 hours was chosen as the time interval). It must be stressed that the time unit has no meaning other than utility in assuring that various synoptic situations yield a scattering of the points of origin while keeping these origins within the half-wave-length of the pressure system.

Trajectories were constructed in this manner for each station for each month. For Bismarck, for example, the points of origin were plotted on a North American base map along with the corresponding monthly mean surface temperature departure from normal at Bismarck. This geographical distribution of temperature anomalies was delineated according to the anomaly classes used in forecasting: much above and much below normal, each theoretically expected to occur ⅛ of the time; and above, near, and below normal, each expected ¼ of the time. The winter trajectory chart for Bismarck is shown in figure 3 and demonstrates the variability of temperature anomaly at that station according to the geographical distribution of the source of the trajectory.

When the trajectories were computed the winter data (December, January, and February) and the summer data (June, July, and August) were found to be sufficiently homogeneous to allow grouping on a seasonal basis. The spring and fall months, however, showed so much variability in wind speed and direction that they were treated individually by months.

It has been found (Namias [5]) that above normal pressure aloft and anticyclonic curvature of the isobars are associated with above normal temperature due to subsidence, and solar heating with clear skies. Cyclonically curved isobars and below normal pressures are usually related to convergence, cloudiness, precipitation, and a lack of solar radiation, leading to negative temperature anomalies at the surface. It was therefore decided to test the influence curvature and pressure departure from normal exert on the surface temperature.

The departures from normal of the 10,000-ft. pressures were obtained at 5-degree intersections of latitude and longitude for the mean monthly charts of the period studied. The 10,000-ft. monthly mean pressure departure from normal at each of the 15 originally chosen stations was correlated with the simultaneous monthly surface temperature anomaly at the same place. In addition,

[3] 700-mb. charts are currently employed. The conversion process for the objective method is straightforward and relatively simple.

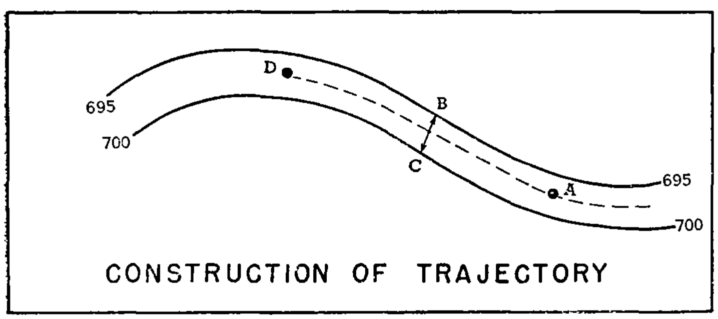

FIGURE 2.—Method of computing the point of origin of a trajectory:
a. Draw the intermediate isobar through the station (A) as an estimate of the course of the trajectory.
b. Measure the average gradient (BC) upstream and compute the geostrophic wind speed.
c. Proceed upstream along the trajectory a distance AD equivalent to the 48-hour travel of a parcel moving at the geostrophic wind speed. (Note: 72-hour travel is used in June, July, and August.)

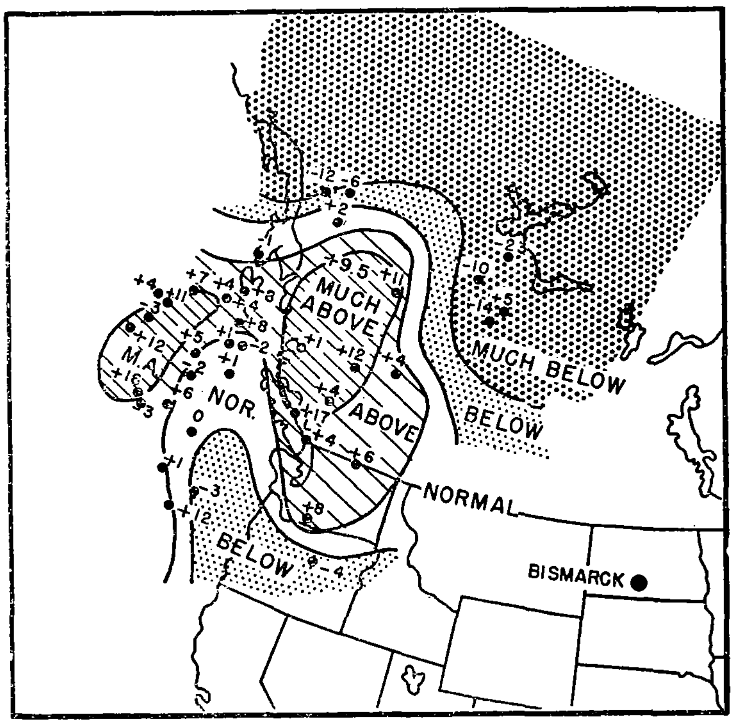

FIGURE 3.—Monthly mean temperature anomalies expected at Bismarck in winter according to the geographical location of the source of the 48-hour trajectory.

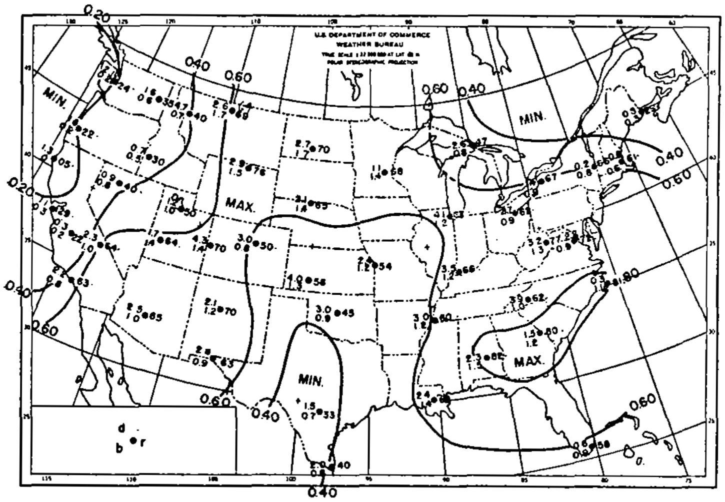

FIGURE 4.—Geographical distribution of correlation coefficients between surface temperature and 10,000-ft. pressure departure from normal for winter; upper left-hand figure at each station is "a" and lower left figure is "b" in the regression equation: $T=a+bP$; right-hand figure is the coefficient of correlation.

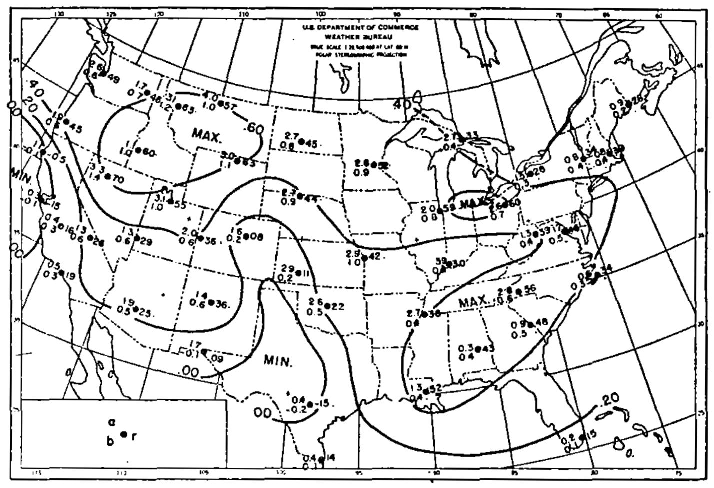

FIGURE 6.—Geographical distribution of correlation coefficients between surface temperature and 10,000-ft. pressure departure from normal for summer.

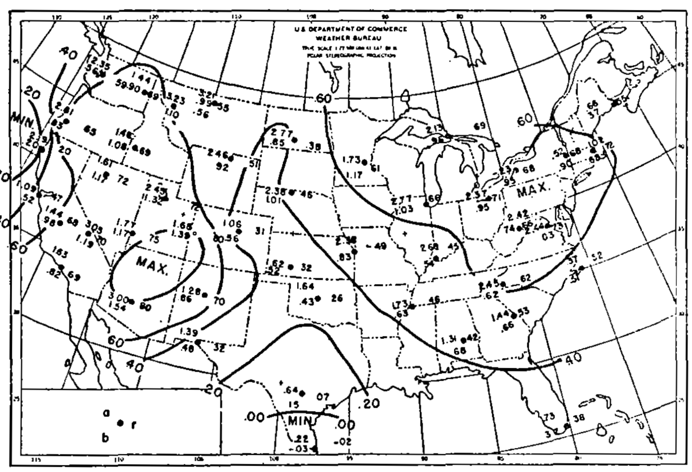

FIGURE 5.—Geographical distribution of correlation coefficients between surface temperature and 10,000-ft. pressure departure from normal for spring.

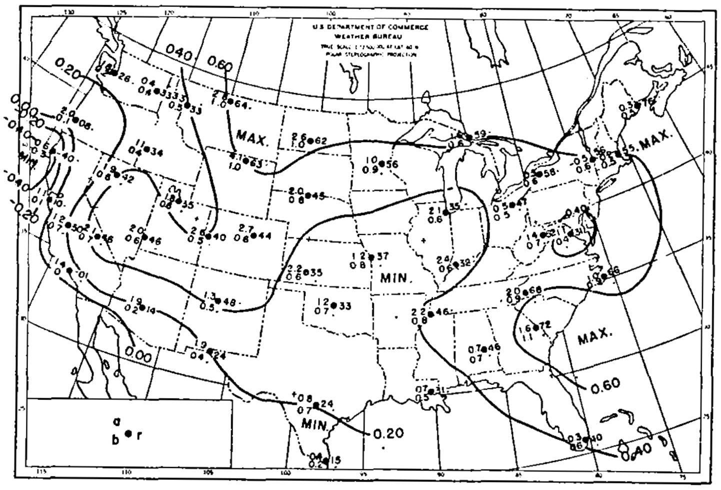

FIGURE 7.—Geographical distribution of correlation coefficients between surface temperature and 10,000-ft. pressure departure from normal for fall.

regression coefficients were also computed for these and other stations in each region. These coefficients of correlation and regression separated by seasons, were plotted on a map of the United States to discover the nature of their geographical distribution. (See figs. 4 through 7.) Isolines were drawn for the values of the correlation coefficient and areas of maximum and minimum correlation were marked.

In general, the correlations are good, the highest values being found in winter and spring and the lowest during the summer. The correlations inland are generally higher than those at coastal points, suggesting the existence of another important parameter along the coasts, perhaps surface wind direction.

At some of the stations where these correlation coefficients are lowest it was found that the curvature of the isobar is significant in determining the temperature anomaly. Usually, however, there is a pronounced relationship between curvature and pressure anomaly. As a result, curvature does not contribute markedly to the temperature anomaly after the effect of pressure departure from normal has been considered.

The actual measurement of curvature was neither as simple nor as direct as the measurement of the 2 parameters previously considered. Instead it was decided to determine a quantity analogous to the difference between the radius of a circle and the apothem of an inscribed polygon. In figure 8 the isobar QBHC passes through station H. The chord BC is constructed in such a way that its length is 10° of latitude, its end points are on the arc (isobar), and the chord is centered about the station. The perpendicular distance from the arc to the chord (positive for cyclonic curvature), HD, is measured in degrees of latitude and is the desired indication of curvature. It is apparent that this quantity increases in absolute value as the curvature becomes greater, either in the cyclonic or anticyclonic sense.

USE OF GRAPHIC METHOD

Having measured the parameters described above it becomes necessary to employ a facile technique of combination to yield a temperature anomaly forecast. It was felt that graphic correlation would be highly satisfactory in this respect.

The application of this method demands an increasing amount of data as the number of parameters is increased. With the few parameters involved in this study the

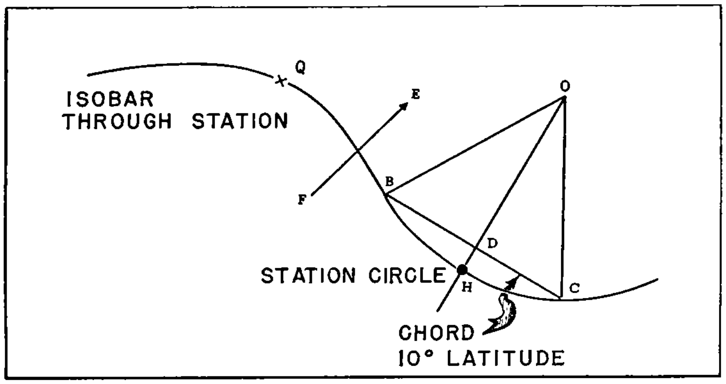

FIGURE 8.—Determination of curvature: a chord (BC) 10° of latitude in length is centered about the station (H) with its end points on the isobar (QBHC) through the station (H). The perpendicular distance between arc and chord (HD), measured in degrees of latitude, is the desired measure of curvature and is termed "radius minus apothem." Cyclonic curvature is considered positive.

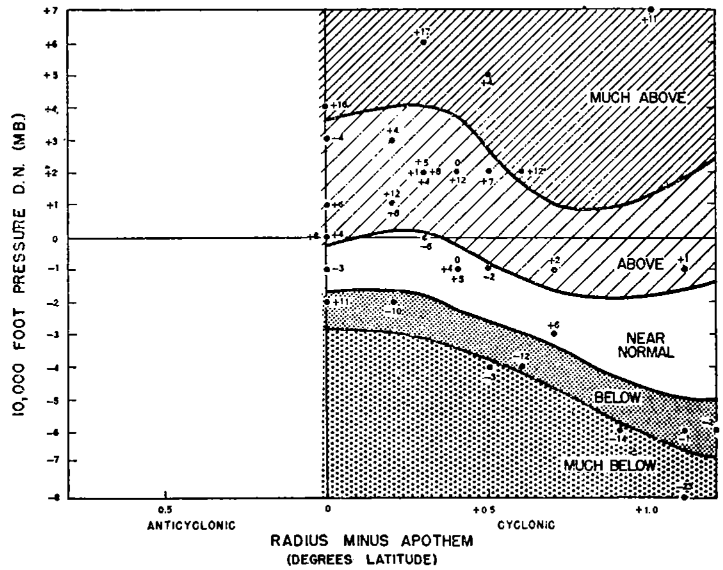

FIGURE 9.—Estimate of winter surface temperature anomaly at Bismarck on the basis of "radius minus apothem" curvature measure (abscissa) and 10,000-ft. pressure departure from normal (ordinate).

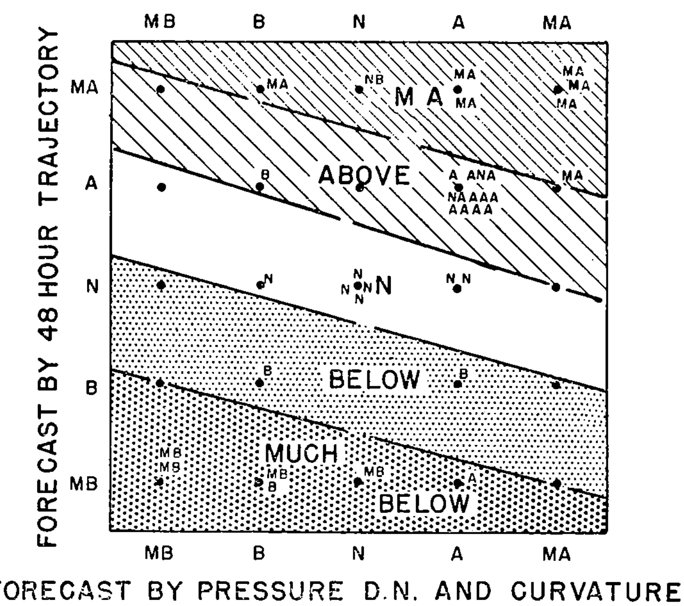

FIGURE 10.—Forecast of surface temperature anomaly at Bismarck in winter based on estimates from curvature-and-departure-from-normal graph (see figure 9) and trajectory source (see figure 3). Observed anomalies are plotted by letter at appropriate grid points.

utilization of the method is relatively simple. First, two of the variables are designated as coordinates of a graph at each point of which the dependent variable is entered as a function of the abscissa and ordinate. The graph is then analyzed in terms of the dependent variable.

Figure 9 is an example of the first step in the procedure. In this diagram temperature anomaly (for Bismarck) is plotted as a function of curvature (abscissa) and pressure departure from normal (ordinate). It can be seen that there is a definite grouping according to anomaly. Lines have been drawn to distinguish the several anomaly categories (much above normal, etc.) using the class limits for the station for this time of year.

It is perhaps surprising that figure 9 exhibits no cases with anticyclonic curvature. This fact and the appearance of inexplicable irregularities in the data are undoubtedly attributable to the strongly cyclonic normal curvature at Bismarck and to the limited data involved and the apparent abnormality of the period studied. These singularities have an important effect on the extension of the method to 5-day mean situations.

The next step of the graphic technique consists of obtaining a second estimate of the surface temperature anomaly from the location of the source of the trajectory. This is accomplished by the use of the type of chart shown in figure 3. A new graph is then derived using the curvature-departure-from-normal estimate of temperature as abscissa and the trajectory computation as ordinate. This new graph is analyzed in terms of observed temperature anomaly. For example, figure 10 shows this final graph for use in obtaining surface temperature anomalies for Bismarck. The value of the abscissa of this graph is derived from figure 9 and of the ordinate, from figure 3.

A set of graphs for each of the 15 stations investigated was prepared.

OPERATIONAL USE OF OBJECTIVE METHOD

Given a monthly mean circulation pattern and the set of graphs described above it becomes possible to estimate the surface temperature anomalies for a sufficient network of points to determine the temperature pattern for the United States as a whole. Since monthly data alone have been used in developing the method, however, it is necessary to apply corrective factors if results are desired with the use of 5-day material.

Five-day mean patterns are more variable than monthly patterns. This is true both for pressure at a point and for the resultant wind speed and direction. As the first step in allowing for this factor, the variability of pressure, as measured by the standard deviation, was computed for 5-day and monthly maps for a number of points scattered over the country. A similar operation was conducted for values of zonal wind index (as reflective of pressure gradients). These tests showed that the variability on 5-day charts is approximately 1⅗ times as large as the variability on monthly maps. This implies that the 5-day wind speed and pressure departure from normal must each be multiplied by ⅝ before being used in the graphs. It is to be noted that this method neglects the fact that highly abnormal situations occur in the short-term mean pressure patterns without any counterpart during the longer periods.

It is also necessary to convert the measurements made from constant pressure charts now in use (700-mb.) to units of constant level. This involves dividing height departures from normal by 40. Although these modifications allow for corrections of pressure and gradient measurement, no reduction for curvature is available. As mentioned above, curvature adds little to the pressure departure term, hence it was decided to eliminate measurements of curvature from the routine.

DISCUSSION OF RESULTS OF FIRST METHOD

On monthly data this method is limited somewhat by its unwieldiness, but is not hampered by the necessity for conversions. To test its usefulness in prognostication it was applied to 2 years of independent data and the results were compared to those that would be expected by chance.

Observed monthly mean charts for the winters of 1945–46 and 1946–47 and for the summers of 1946 and 1947 were interpreted by this objective system. Two mean maps were used for each calendar month (overlapping twice-monthly means were introduced to increase the amount of test data) yielding a total of 12 individual (but not completely independent) cases for each of the 2 seasons for each of 15 stations (180 cases in all).

Table 1 shows the results of this test in contingency form for winter and summer. An examination of the winter section of the table reveals that 36 percent of the time the temperature estimates were exactly correct; 81 percent of the time they were within one class. The skill scores[4] are 17 for zero-class errors (exactly right) and 54 for zero-plus-one-class errors (within one class), a definite improvement over chance forecasting.

Table 1.—Contingency tables showing results of applying first objective method to independent monthly data for all test stations, winter 1945–46 and 1946–47, and summer 1946 and 1947.

WINTER

FORECAST \ OBSERVED	MB	B	N	A	MA	TOTAL
MB	7	5	2	5		19
B	5	6	2	6	1	20
N	3	7	10	22	6	48
A		6	22	34	14	76
MA			5	5	7	17
TOTAL	15	24	41	72	28	180

	0-CLASS ERRORS	(0+1)-CLASS ERRORS
% CORRECT	36	81
SKILL SCORE	17	54

SUMMER

FORECAST \ OBSERVED	MB	B	N	A	MA	TOTAL
MB	1					1
B	2	4	4	6	1	17
N	3	6	23	10	3	45
A	6	11	12	25	11	65
MA	1	9	15	16	11	52
TOTAL	13	30	54	57	26	180

	0-CLASS ERRORS	(0+1)-CLASS ERRORS
% CORRECT	36	69
SKILL SCORE	17	22

In summer the zero-class errors remain the same (36 percent), but the zero-plus-one-class errors drop to 69 percent. The corresponding skill scores are 17 and 22. These scores are sufficiently high to suggest usefulness in preparing monthly temperature estimates.

The worthiness of this method as reflected in these results can, at least in part, be explained by physical reasoning. The correlations between pressure and temperature departures and the effects of curvature have already been discussed. There is, though, a further influence of the curvature factor. Cyclonic conditions imply the presence of a trough and northerly currents advecting cold air; conversely for anticyclonic curvature. Since the trajectory already allows for this factor, there is additional evidence in favor of eliminating curvature as a parameter.

An examination of the trajectory charts reveals certain general rules for determining the temperature anomaly. Throughout the year at almost all stations the temperatures average higher than normal when the trajectories originate below a critical (for that station) latitude, and lower than normal for the more northerly trajectories. The critical latitude is usually that of the station itself except for cities in the lee of the Rocky Mountains for which the critical point is farther north. It is obvious that currents from the north should produce lower temperatures than currents from the south. The mountain effect is introduced when downslope motion produces foehn warming. This is illustrated in figure 3 for Bismarck where westerly through west-northwesterly components undergo downslope warming. The more northerly trajectories result in the colder anomalies.

The direction of flow apparently is important at maritime stations where water temperatures are radically different from the air temperatures over the land areas. This is strikingly illustrated by figure 11 which shows the temperature anomalies for Los Angeles according to the location of the trajectory origin ("72-hour" point for summer). Here the separation between warm and cold anomalies is markedly parallel to and along the coast.

At many stations the speed of the wind, or the distance over the trajectory path, is as significant as the direction of the flow. This is partly explained by the geographical distribution of land and water bodies. At continental stations in summer, for example, increasingly long trajectories apparently allow for increased heating of the air parcels (usually southwest of the station) and higher temperatures.

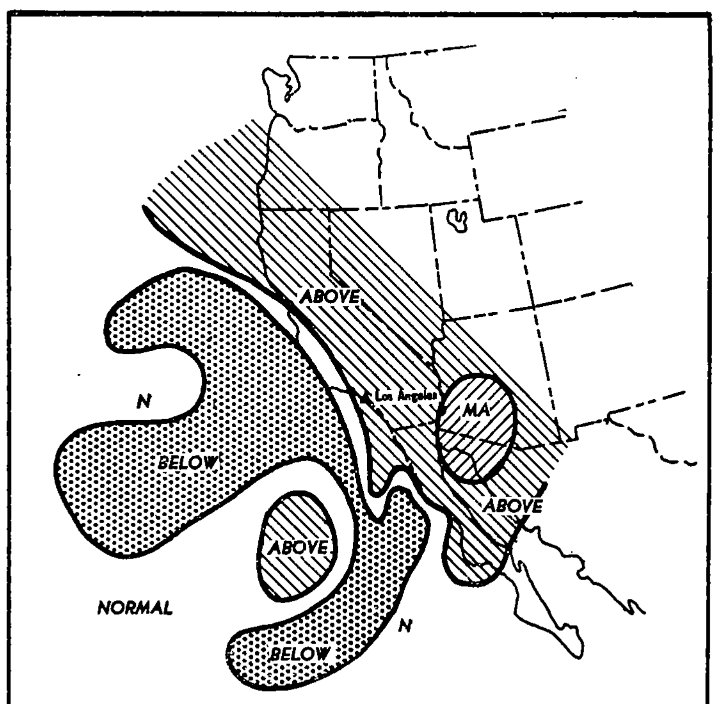

Figure 11.—Monthly mean temperature anomalies expected at Los Angeles in summer according to the geographical location of the source of the 72-hour trajectory.

[4] The skill scores were computed from the formula

$$S=\frac{\text{Number correct}-\text{Chance expectancy}}{\text{Total}-\text{Chance expectancy}}\times 100.$$

Chance expectancy is determined by the marginal totals of both predicted and observed classes. In a contingency table with subtotals P_i for predicted and O_i for observed and a total of N cases, the chance expectancy is

$$\frac{\Sigma[P_i \times O_i]}{N}.$$

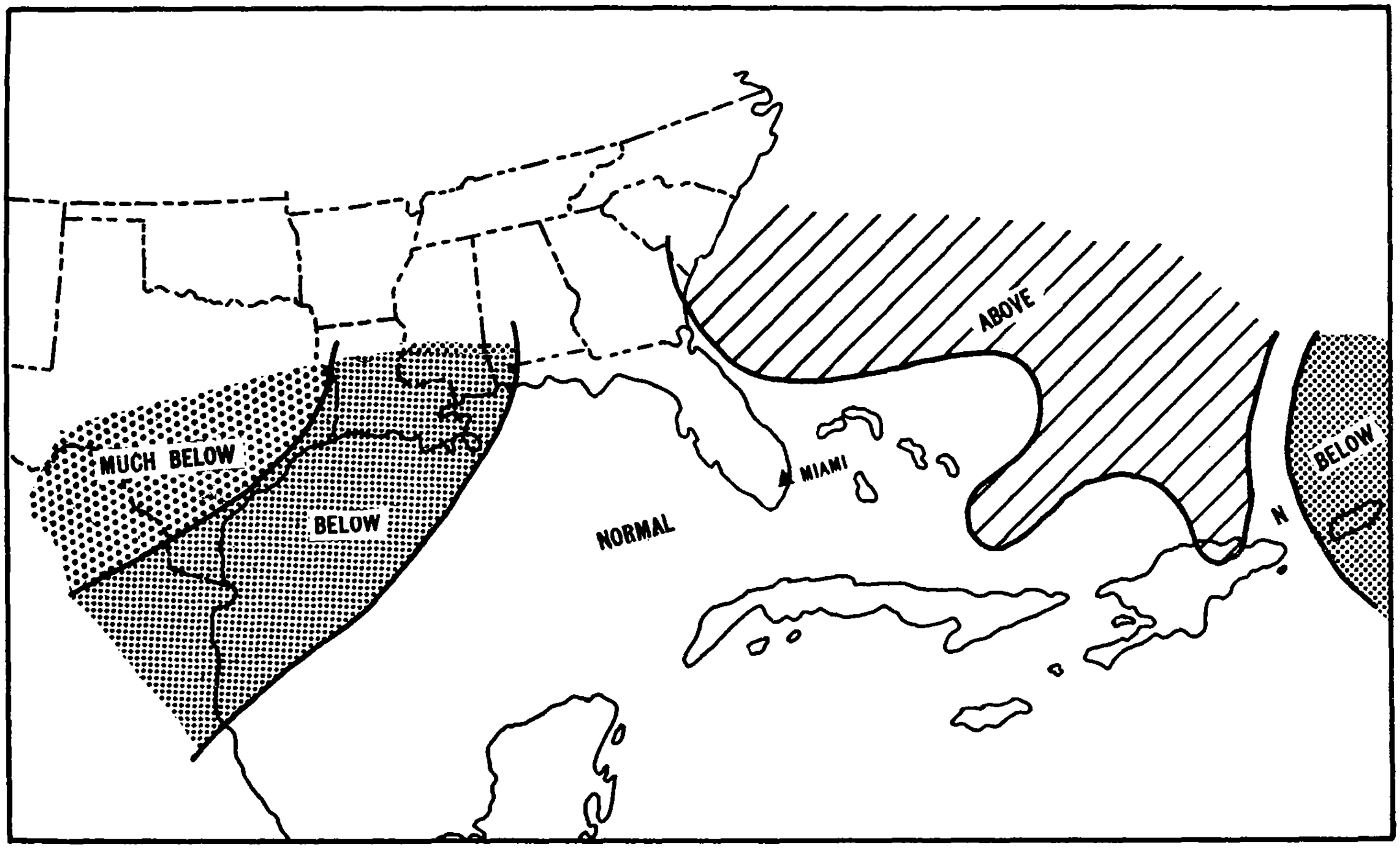

FIGURE 12.—Monthly mean temperature anomalies expected at Miami in summer according to the geographic location of the source of the 72-hour trajectory.

In addition to general rules on the relationship between temperature and trajectory, specific explanations can be found for individual graphs. At Miami in summer (see figure 12) air from the east circulates around the subtropical high cell and above normal temperatures are observed. Westerly trajectories are associated with lower pressure and trough conditions, and the temperatures fall below normal.

These graphs evidently afford a synoptic climatology for each station and afford a value beyond the usefulness of the objective method for forecasting. A study of these charts can give the subjective forecaster an excellent background for preparing temperature estimates by demonstrating the effects of geography and topography at each station.

REVISION OF METHOD

It has been pointed out that the measurement of curvature is cumbersome and does not lend itself to conversion for use with 5-day material. Furthermore, little knowledge is gained from the use of curvature after the effects of the pressure anomaly and air parcel trajectory have been considered. Accordingly it was deemed advisable to eliminate curvature measurements from the objective process.

An additional argument against the technique as developed to this point was the length of time required to prepare an anomaly estimate of temperature for the entire United States. It was therefore decided to shorten the procedure while salvaging those aspects which showed the most promise. The best parameters seemed to be the direction and magnitude of the flow near the station and the pressure departure from normal.

As a first step in the revision of the procedure it was decided to consider the mean wind speed and direction in the neighborhood of the station as a substitute for the elaborate computation of the trajectory. If departures from normal in speed and direction are used instead of the absolute (geostrophic) quantities, it is found that a single pressure anomaly chart contains information about all the desired parameters. The value of the pressure-departure chart has previously been recognized, and forecasters have utilized the data of this chart in forecasting the mean temperature field. Namias [5] states: "For the temperature anomalies one of the most important considerations is the comparison of flow patterns at sea level and aloft with the normal. This may be done by direct visual comparison, or perhaps better, by constructing pressure and height anomaly isograms."

Examination of a pressure anomaly chart (figure 13) shows that qualitative conclusions can be drawn immediately. In the northwest, for example, above normal pressures and flow more southerly than normal should be expected to lead to above normal temperatures. The goal is the reduction of this type of subjective reasoning to quantitative objective terms.

The pressure anomaly at any point of the chart can be determined by inspection once the isanomalous lines have been drawn. The measurement of geostrophic wind direction and speed (relative to normal) can be obtained by vector measures, and the vectors, in turn, can be

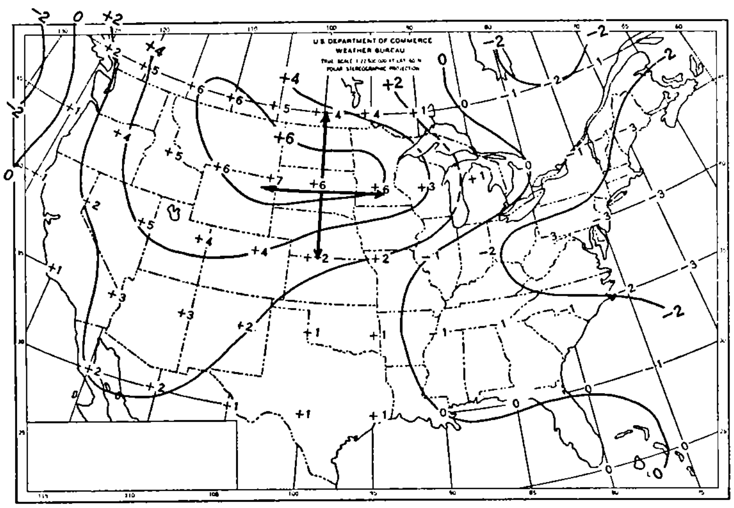

Figure 13.—Monthly 10,000-ft. pressure departures from normal for January 1942. Arrows indicate points for objective measurements.

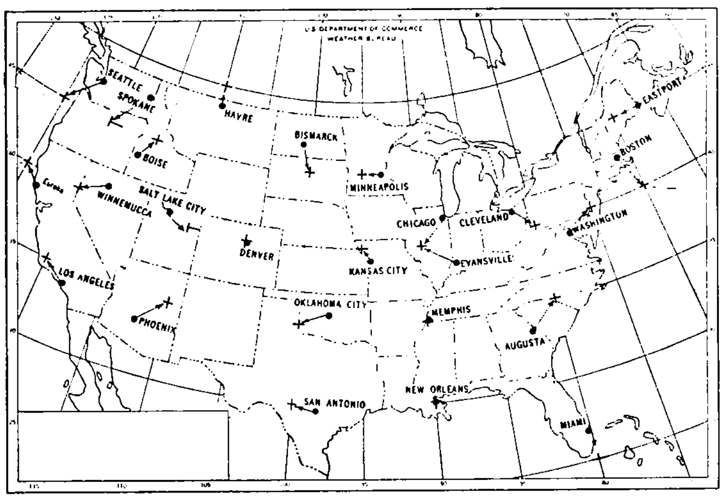

Figure 14.—Grid of points used in computing components of the geostrophic wind relative to normal.

broken into their north-south and west-east components. Finally, these components are directly proportional to the anomaly gradient, or to the anomaly difference across the unit length. Hence the pressure anomalies due north, east, south, and west of the station (or reasonably near) determine completely the direction and force of the geostrophic wind relative to normal at the station.

The ease of operation of this method permits an expansion of the study to include more points. Twenty-five stations were considered (including the earlier 15) and the 5-degree intersections of latitude and longitude most closely surrounding each station were selected as the grid points for pressure anomaly measurements. The resultant components of flow should approximate the results obtainable by using a grid of points removed exactly 5° from the station (which is not usually located on a 5° intersection of latitude and longitude). The network of points, shown in figure 14, has been reproduced on a transparent overlay which facilitates the measurements.

From examination of figure 13, it is seen that at Bismarck the pressure 5° to the west is 7 mb. above normal and 5° to the east only 6 mb. above normal. This indicates a flow at the station more northerly than normal, its strength shown on a relative basis by the magnitude of the difference (1 mb. in this case). Similarly the difference between the pressure anomalies 5° north and 5° south of Bismarck indicates a more easterly flow than

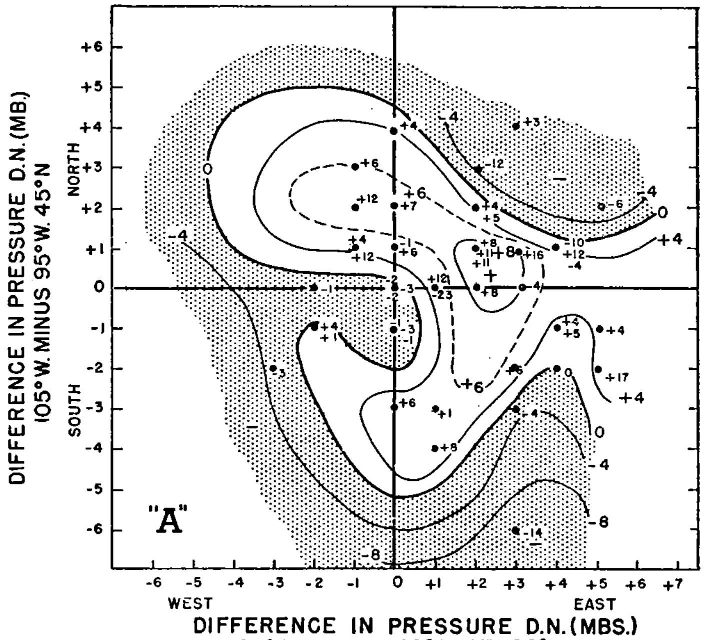

Figure 15.—Monthly mean temperature anomalies (in degrees F.) expected at Bismarck in winter according to the strength of the west-east wind component relative to normal (as abscissa) and the relative north-south component (as ordinate).

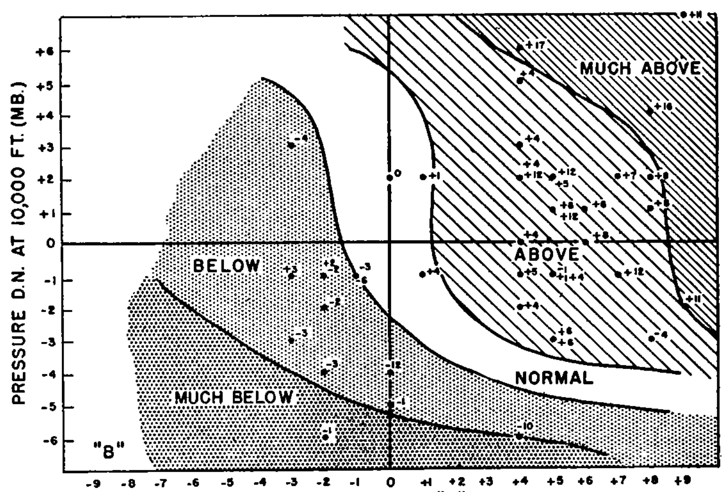

Figure 16.—Final forecast of temperature anomaly at Bismarck in winter on the basis of estimate from wind components (see figure 15) and 10,000-ft. pressure departure from normal (ordinate).

normal in proportion to the anomaly difference (2 mb.). Combination of the 2 components shows that the flow relative to normal is from the northeast. This is apparent graphically since the flow relative to normal obeys the same relationship to pressure departure from normal as does the geostrophic wind with respect to the pressure field.

OPERATIONAL USE OF REVISED METHOD

As in the earlier study (involving curvature), a graphic technique was employed to translate wind and pressure anomalies into temperature anomalies. The preliminary graph (e. g., figure 15) now charts the north-south and the west-east components of the relative wind as coordinate independent variables and the resultant of this graph is applied as the abscissa of the final estimating graph (figure 16). With the pressure departure from normal at the station as ordinate the final temperature estimate can be determined. Once again there are singularities in the work graphs which cannot be simply explained by theory. It is expected that these wiggles would disappear if the size of the work sample were increased sufficiently to insure complete representativeness of the data.

As an illustration, figure 13 shows that the north-south component relative to normal at Bismarck is +1 and that the west-east component is +2. Entering the preliminary graph for Bismarck (winter), figure 15, with these values as ordinate and abscissa, respectively, gives +8 from the parametric lines. This value is now the abscissa for use in the final graph, figure 16, and the ordinate is the pressure departure from normal at Bismarck itself, approximately +6 from figure 13. The temperature estimate for Bismarck is then "much above normal."

This method of preparing objective temperature estimates from wind components was evolved for use on monthly mean constant level charts. As with the first method derived, it is necessary to apply conversion factors if the technique is to be used with constant pressure or 5-day mean charts. For monthly mean 700-mb. charts the values of the height gradients and the height anomalies are divided by 40 to translate height units to pressure units. Five-day mean heights must be divided by 60 in order to account for the change-over to pressure units as well as the increased variability introduced by the use of 5-day data.

EVALUATION OF REVISED METHOD

The revised, component method was tested on the independent monthly winter data of 1945–46 and 1946–47, and the results for the 90 cases were compared with the results obtained using the first method. Table 2 shows the contingency distributions for the 2 methods. The older method was exactly correct 34 percent of the time and within one class 84 percent of the time. The skill score above chance is 16 for zero-class errors and 62 for zero-plus-one.

The component method shows a zero-class average of 60 percent correct and a 96 percent average for zero-plus-one-class errors. The skill scores are, respectively, 49 and

TABLE 2.—Contingency tables showing comparison between first and revised objective methods of forecasting. Independent monthly data for all test stations, winter 1945–46 and 1946–47.

TRAJECTORY METHOD

FORECAST \ OBSERVED	MB	B	N	A	MA	TOTAL
MB	4	2	1	2		9
B	2	5	1	1		9
N	1	5	3	9	2	20
A		4	12	14	10	40
MA			3	4	5	12
TOTAL	7	16	20	30	17	90

	0-CLASS ERRORS	(0+1)-CLASS ERRORS
% CORRECT	34	84
SKILL SCORE	16	62

WIND COMPONENT METHOD

FORECAST \ OBSERVED	MB	B	N	A	MA	TOTAL
MB	3	2		1		6
B	3	9	2	1		15
N	1	5	11	5		22
A			6	22	8	36
MA			1	1	9	11
TOTAL	7	16	20	30	17	90

	0-CLASS ERRORS	(0+1)-CLASS ERRORS
% CORRECT	60	96
SKILL SCORE	49	89

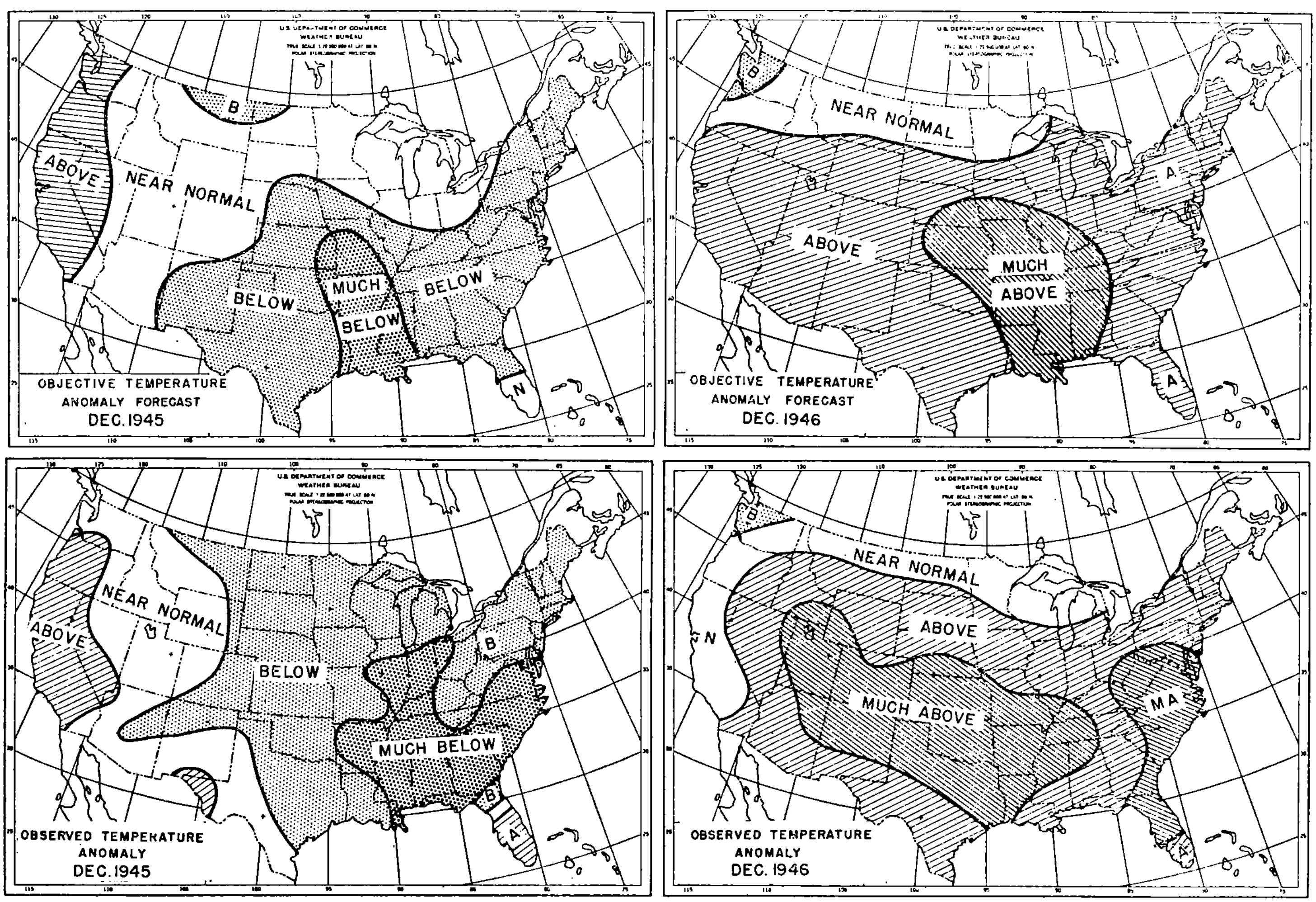

FIGURE 17.—Comparison of temperature anomalies forecast by objective method involving wind component and pressure departure from normal (upper charts) with the observed anomalies (lower charts) for December 1945 and December 1946.

89. It is perhaps surprising that the new method shows such an improvement over the old although the parameters are essentially the same in both methods. The difference may be partly due to sampling errors and errors in measurement. Not only is the later method quicker, but it is also more objective in application and less conducive to errors. It is certainly a better method in terms of efficient operation and effective results. Figure 17 depicts the operational value of this objective technique by comparing objective results with the observed anomalies for December 1945 and December 1946.

SUMMARY AND CONCLUSIONS

The technique of graphical correlation has thus yielded systems for objective interpretation of monthly mean 700-mb. charts in terms of surface temperature anomalies. Using observed monthly data, height anomaly charts have been correctly translated into temperature fields 60 percent of the time (96 percent for hits within one class). The final technique is simple to apply and is currently used in the monthly and 5-day forecasting routines as a forecasting device and also as a consistency check.

The prognostic usefulness of the objective methods has been tested elsewhere (Leight-Sartor [6]; Leight [7]). The results indicate that further investigation is necessary before objective forecasts can be used automatically without correction. However, the objective forecasts are of use to the monthly and 5-day forecasters as indications of expected conditions. The graphs from which the forecasts are obtained are helpful in affording a synoptic climatology for each of the 25 stations studied.

During the winter season 1947–48 it became apparent that the 5-day mean upper level maps did not completely explain the surface temperatures that were observed. Cold highs occasionally appeared at the surface under and ahead of trough conditions aloft on 5-day mean maps. Since comparable situations do not exist on mean maps of longer duration, the graphs, having been derived with the use of monthly data, did not yield the correct interpretations. This strongly suggests the necessity of utilizing another parameter in addition to height anomaly and vector flow. It has been recommended that changes from the initial temperature field or the thickness anomaly at the source of the trajectory must be considered for shorter-term forecasts.

A study to incorporate these and other factors into the objective procedure is currently in progress. To eliminate the necessity for conversion and resultant loss of reliability 5-day data are now being employed as source material. Intensive research is being directed toward identifying the key centers of action for determining the temperature anomaly for various locales; it has been discovered that broad features of the circulation are more effective than local phenomena in producing anomalous situations. A report will be forthcoming upon the completion of the newer work. The feasibility of objectivity in estimating temperatures has been demonstrated, and it is hoped that refinements of the technique will lead to greater efficiency in forecasting.

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