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National Weather Service

Prediction of Surface Dew Point Temperatures

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PREDICTION OF SURFACE DEW POINT TEMPERATURES

R. C. Elvander

Compliments of the author

Systems Development Office
Techniques Development Laboratory

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PREDICTION OF SURFACE DEW POINT TEMPERATURES

R. C. Elvander

ABSTRACT. Screening regression is used to obtain relationships between predictands consisting of surface dew point temperatures, and predictors consisting of the predictand values a day earlier and upper air parameters analyzed at selected gridpoints on the same day. The dependent data are stratified by bimonthly periods, July-August and November-December, and consist of 10 years of surface observations, 1951-60, taken at 1400 LST at 89 cities in the United States. The upper air predictors are obtained from twice daily values of 700- and 1000-mb heights on a diamond grid which covers most of North America and the adjacent oceans.

By-products of the screening regression runs are used to develop a climatology of the 1400-LST dew point temperature. Correlation fields illustrating the large-scale relationships between the predictors and predictands are shown.

The resulting equations for November-December are used to obtain dew point temperature forecasts by applying them to numerical prognostic maps. Comparison of these with dew point temperatures forecast with a generalized equation useful over the Eastern United States is made. Also, forecasts of low-level dew point temperatures based on a three-dimensional Lagrangian technique are compared with the statistical forecasts developed in this study.

INTRODUCTION

This report is concerned with research done during the past 2 years on forecasting surface dew point temperature at 89 cities scattered throughout the conterminous United States. The main purpose of the research is to eventually enable nationwide forecasts (at 89 cities) of surface dew point temperature at 1400 LST to be produced centrally at the National Meteorological Center (NMC) in Suitland, Maryland. The implementation of such forecasts would follow the guidelines established in the Federal Plan for a National Fire Weather Service (1967):

> ". . . Development of techniques for interpreting the National Meteorological Center's prognostic charts in terms of fire weather elements such as maximum temperature, minimum relative humidity, wind speed and direction, surface turbulence, and fuel moisture."

Forecasts of the 1400-LST dew point temperatures are particularly valuable to fire weather forecasters and fire planning personnel. This time of day is usually the warmest and driest. Estimates of the relative humidity and atmospheric moisture can be established from dew point temperature forecasts. Hence, these forecasts will be useful in delineating the possible danger of the fuel-weather situation under adverse fire weather conditions. These forecasts could also be useful to agricultural and aviation forecasters.

The dew point temperature prediction problem amounts to future knowledge of the low-level moisture field, since the dew point temperature is directly related to the mixing ratio. It was thought that using height fields at 700 and 1000 mb and observations of yesterday's dew point temperatures as predictors in a statistical method would be fairly successful. The height data would represent the low-level flow near the station in the sense of to-or-from source regions; the values observed yesterday would represent persistence or upstream values brought to the station by the low-level flow.

The statistical method was adopted for this study over any dynamical method because the data were amenable to this approach, and the application of dynamical methods in mountainous areas is a special problem by itself, with much work needed before applications such as dew point temperature forecasting should be attempted. Also, it was hoped that this work could be finished in a relatively short period and a useful forecasting method obtained from the study.

A screening multiple regression program has been applied to two bimonthly sets of data, July-August and November-December, to develop 89 individual dew point temperature prediction equations. A generalized equation to predict the dew point temperature was developed by Glahn and Lowry of TDL in conjunction with their studies involving the subsynoptic advection model (SAM) (Glahn, Lowry, and Hollenbaugh, 1969). Forecasts for 28 of the 89 stations made by this method are compared with the single station forecasts.

A three-dimensional Lagrangian trajectory technique, developed by Reap (1968) produces dew point temperatures at four levels: 500, 700, 850, and 1000 mb. Only 9 days were available for a comparison between the forecasts made by this method and those produced by the equations derived in this paper.

Results of the test forecasts made by these methods and their comparisons with persistence will be discussed. In addition, some by-products of interest will be described. These include results of screening on dependent data using different predictor combinations, charts of the natural variance of the dew point temperature observed at 1400 LST, and correlation fields of predictors versus predictands.

THE DATA USED IN THIS STUDY

The Surface Data

Ten years of surface data at 89 stations within the conterminous United States were made available to TDL by the Fire Research Laboratory of the U. S. Forest Service at Riverside, California. These data were assembled

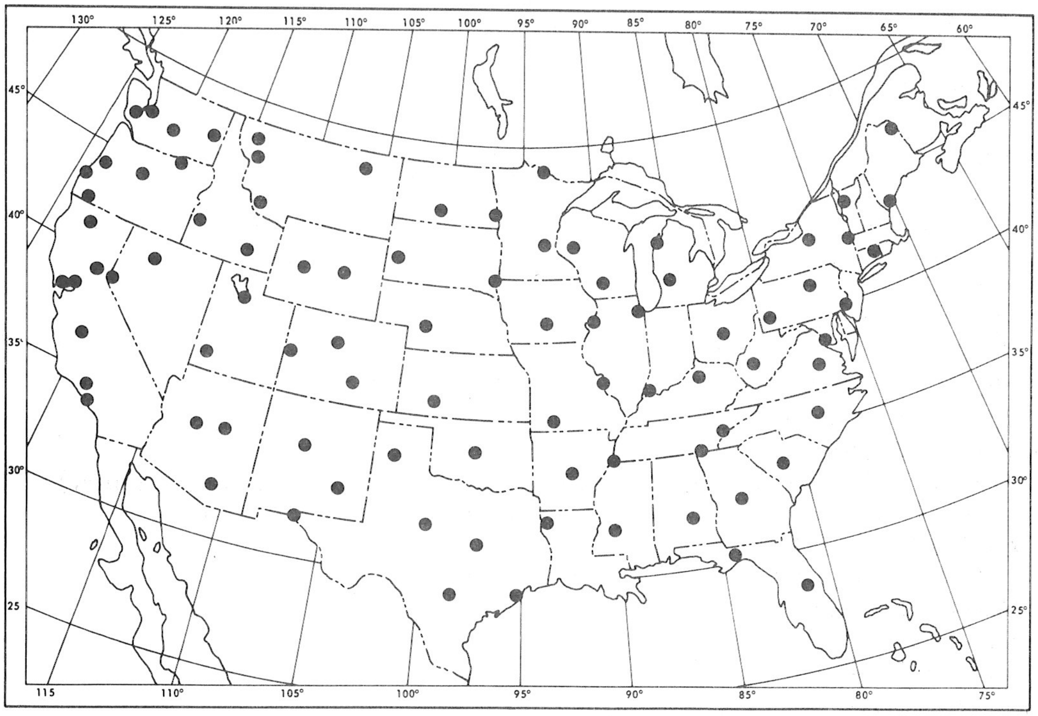

Figure 1 - Location of the 89 stations used in this study for which surface data were available.

by Schroeder, et. al. (1964) for a study prepared for the Office of Civil Defense, entitled "Synoptic Weather Types Associated with Critical Fire Weather." Other studies based on the data are those of Hull, O'Dell, and Schroeder (1966) and Huschke (1966). The former deals with critical fire weather patterns, their frequency, and levels of fire danger for 14 areas; the latter with the burning of wildland due to a nuclear attack.

Because of the original purpose of the data, the stations, shown in figure 1, are not scattered uniformly throughout the mainland United States. They were selected on the basis of homogeneity of weather. Hence, east of the Rockies, they are spaced fairly widely apart, especially throughout the Plains. From the Rockies westward, they are placed closer together to account for the topographic effect on the weather. The 89 cities are listed in the appendix.

Table 1 lists the elements on the data tape assembled by Schroeder from information available at the National Weather Records in Asheville, N.C. Elements 15 and 17 to 23 are derived from the basic observations. These parameters are used daily for fire weather purposes. The responsibility of the National Weather Service (NWS) is to forecast the basic elements. The foresters can then use this information to calculate expected values of the various fuel indices mentioned in table 1. However, beginning in 1969, the NWS has issued a daily Fire Spread Index Chart developed from observations (Technical Procedures Branch 1969). This is a measure of the windspeed and fine fuel moisture.

Table 1. Parameters included in the 89-station data

1. Station number
2. Year
3. Month
4. Day
5. Hour of observation
6. Dew point temperature
7. Wind direction
8. Wind speed (mph)
9. Dry bulb temperature
10. Wet bulb temperature
11. Relative humidity
12. Cloud amount
13. Average wind speed (Observation hour and two previous hours)
14. Precipitation (24-hour amount at previous midnight)
15. Fuel stick moisture
16. Previous day maximum relative humidity
17. Timber buildup
18. Fine fuel moisture
19. Spread index
20. Timber intensity index
21. Timber burning index
22. Fire ignition index
23. Fire load index

The Upper Air Data

TDL has on file 1000- and 700-mb heights obtained from the Extended Forecast Division of NMC. These data were interpolated from synoptic analyses onto a 130-point diamond grid extending from longitude 50° West to 175° West and from latitude 25° North to 70° North. The location of most of the 130 points, numbered from northeast to southwest, and the locations of the 89 cities, black squares and open circles, respectively, are illustrated in figure 2.

The 130-point height data along with other surface data were used by Klein et al. (1967, 1969) in the development of a successful objective maximum-minimum temperature forecasting technique in use operationally at NMC. The same upper air data were used by Klein (1968) in a study on forecasting precipitation in the Tennessee and Cumberland Valleys.

THE SCREENING MULTIPLE REGRESSION PROGRAM

The height data and surface data just described are used to develop prediction equations of the dew point temperature measured today (at the 89 stations) in terms of surface parameters, usually dew point temperatures, measured yesterday, and upper air data analyzed onto a 130-point diamond grid. (Note figure 2).

The prediction equations are developed by means of a screening multiple regression program written by Mr. Frank Lewis (unpublished) of TDL. This

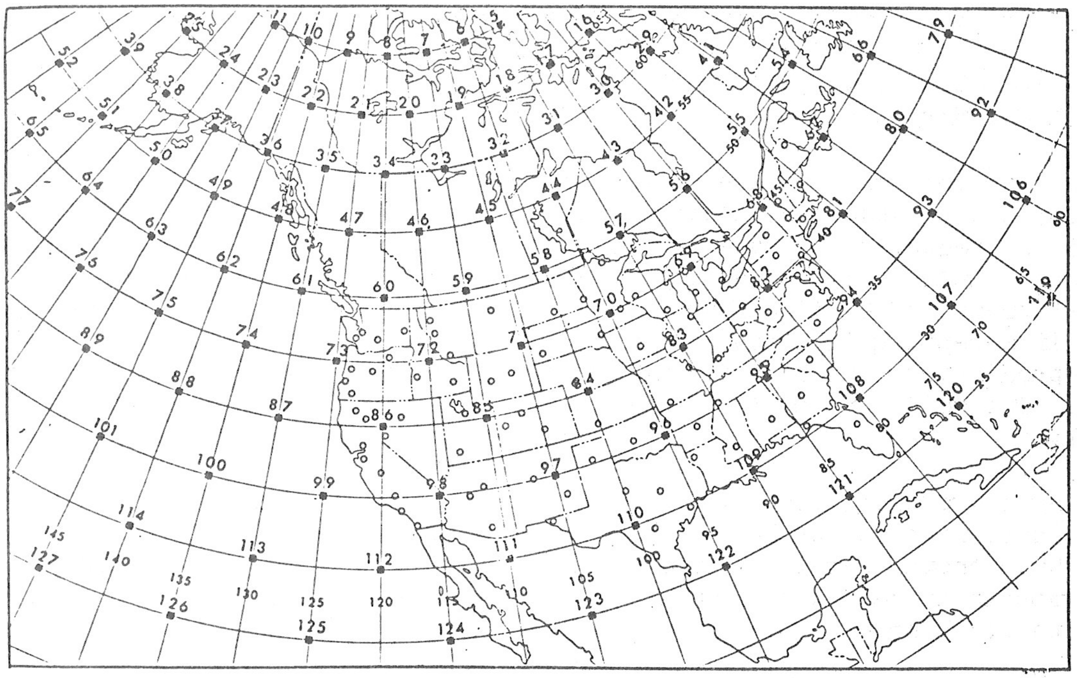

Figure 2 - Location of part of the diamond grid with respect to the 89 stations. The diamond grid is represented by the black squares, the 89 stations by the open circles.

program, a modification of the original work by Miller (1958) of the Travelers Research Center, has been used by Klein et al. (1967, 1969) in their studies on maximum-minimum temperature forecasting. In this modified program, every possible pair of predictors is examined, and the pair explaining most of the variability of the predictand is selected. The better predictor of this pair is retained in the regression equation, and the other one is dropped. Each remaining pair, including all combinations with the predictor just dropped, is then reexamined for its effect in conjunction with the predictand and the other predictor(s) retained. As before, only the better predictor of the pair is retained for inclusion in the multiple regression equation. The routine is continued through the selection of ten predictors.

The output of the screening regression program contains ten equations for each predictand, in order of increasing number of predictors. The multiple correlation coefficients, the reductions of variance, and information on the other predictor of the pair having the highest joint correlation with the predictand is also contained in the output for each of the predictors.

The surface and upper air data are assembled in bimonthly groups onto a master tape in a convenient order. The predictors and predictands to be used in a specific experiment are selected by means of control cards used in the screening regression program. The predictands, surface dew point temperatures at the 89 stations, were divided arbitrarily into two groups by the 100° West longitude. This results in 48 stations in the eastern United States and 41 in the western United States, including all of the intermountain west. The screening regression program can accommodate 190 predictors and 50 predictands.

If the program is used at capacity, it takes about 10 minutes running time (in core) on a CDC-6600 computer using a SCOPE monitoring system when 610 sets of data are utilized. (This machine is located in the NOAA Computer Division at Suitland, Maryland.)

The determination of the number of predictors to be used in a prediction equation is done quasi-objectively. If the addition of two predictors increased the reduction of variance of the predictand by 2 percent or more, they were both retained (in the appropriate equations). If this test was negative, the next predictor by itself was checked for acceptance into the final equation. If accepting it added 1 percent or more to the reduction of variance of the predictand, and it appeared to make meteorological sense, it was retained. The selection of the appropriate equation by this method was done manually.

Many regression screening programs use some form of the statistical "F" test to determine the number of acceptable predictors. Studies by Klein (1965) have shown that the simpler method used in this study is reliable if large amounts of data are used to derive the equations; that is, the relationships are stable.

EXPERIMENTAL RESULTS FROM DEPENDENT DATA

The Standard Deviation of the 1400-LST July-August Dew Point Temperature

Maps of the standard deviation of the dew point temperature were construed from the output of the screening regression program. I selected the standard deviation map for inclusion in this study because it demonstrates well the climatology of the dew point temperature.

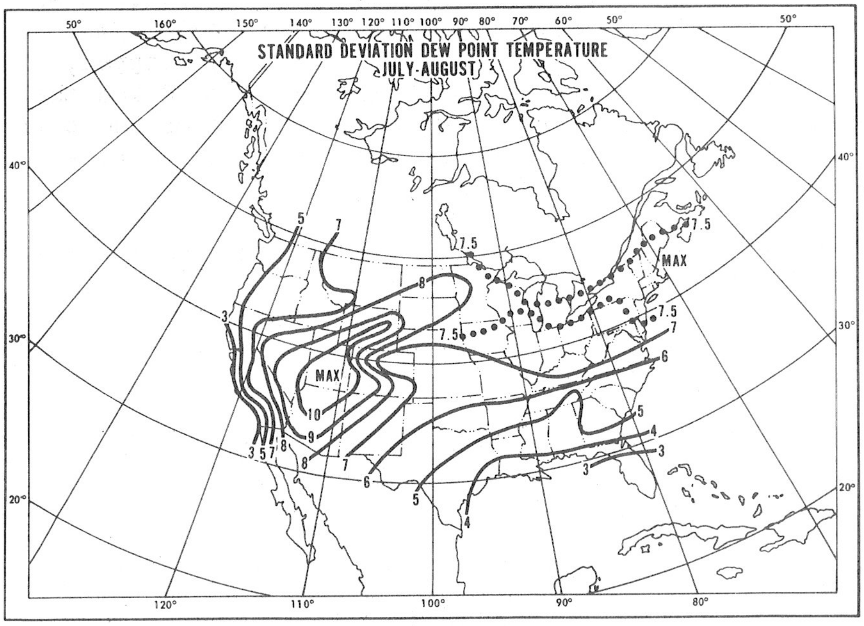

Figure 3 - Chart depicting isopleths of the standard deviation of the 1400-LST dew point temperature for July-August 1951-60 (°F).

Figure 3 illustrates the July-August map of the standard deviation of the surface dew point temperature at 1400 LST based on records at the 89 stations. Note the low variability of the dew point temperature in the southeastern United States and along the Pacific coast. This can be attributed to the semipermanent nature of the prevailing pressure patterns and adjacent moisture sources. The large variance in the Plateau area is due to frequent intrusions of moisture-laden air from the Gulfs of Mexico and Baja California replacing drier air resulting from subsidence in the semipermanent eastern Pacific high pressure area during this season. The gradual increase in the standard deviation, as one goes further north, in the eastern and central United States is due to the alternate passage of air masses of polar and maritime origins.

The Standard Deviation of the 1400-LST November-December Dew Point Temperature

Figure 4, illustrating the standard deviation of the November-December dew point temperature, indicates the larger variability found over most of the country during the late fall season. The November-December values of the standard deviation of dew point temperature are more than twice as large as the July-August values in the eastern and central United States. However, the plateau area has slightly smaller values during this season.

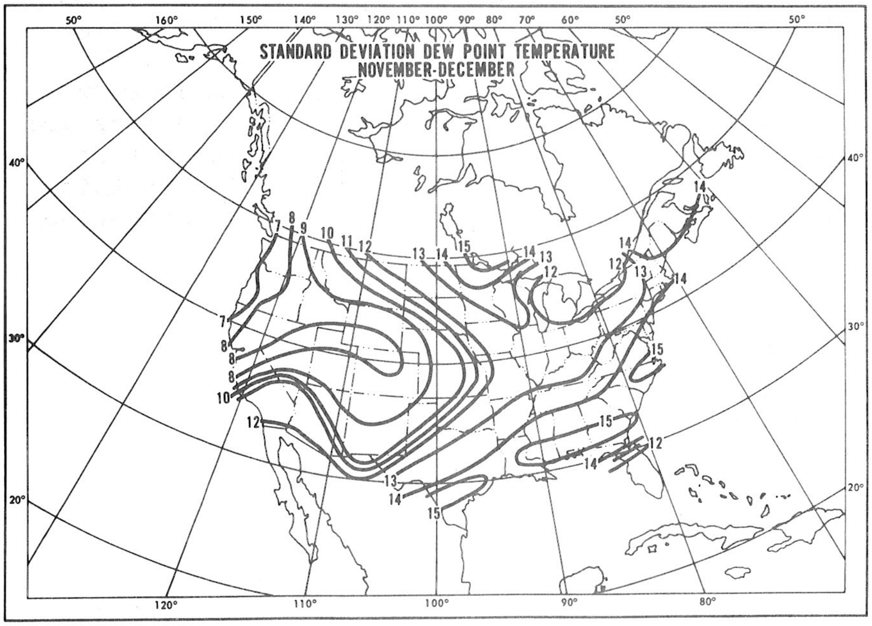

Figure 4 - Chart depicting isopleths of the standard deviation of the 1400-LST dew point temperature for November-December 1951-60 (°F).

East of the Rocky Mountains, the controls appear to be the rapid succession of moist and dry (warm and cold) air masses. Note the relative minimum close to the Great Lakes and the maximum along the Gulf and Atlantic coasts in the southeastern United States. This area is roughly the location of the polar front during the late fall season. West of the Rocky Mountains, the control is the combination of strong westerlies and the Pacific Ocean.

Notice how the values of the standard deviation decrease as one gradually approaches the Pacific coast.

These maps can be added to the interesting studies of Dodd (1965) and Gringorten et al. (1966) concerning the distribution of atmospheric moisture.

Correlation Fields Between Dew Point Temperature and Selected Parameters

In his study on the applications of synoptic climatology to weather prediction, Klein (1965) constructed fields of correlation coefficients between five-day mean temperatures and precipitation and the 5-day mean anomalies of the 700-mb height fields. The output of the screening regression program used in this study allows similar maps to be plotted between any predictand and set of predictors.

Klein (1965) discussed the statistical problems associated with the construction of these charts. In his study, he had only 140 cases of dependent data in most instances. In this study, I have at least 610 cases of dependent data to work with. This larger number of data sets allows rejection of the null hypothesis (the actual correlation coefficient is zero) at the 95-percent and 99-percent levels, when sample correlation coefficients as low as 0.088 and 0.115, respectively, are obtained. Also, the 95-percent confidence belt for the correlation coefficients obtained with 610 cases is about ± 0.05. (These values were obtained from standard statistical tables found in Crow et al. 1960.) Of course, one must remember that day-to-day data records are not independent and the normality of the predictors and predictands has not been demonstrated. In any case, I feel that the examples presented in this study are realistic and useful in presenting the dominant controls affecting the dew point temperature.

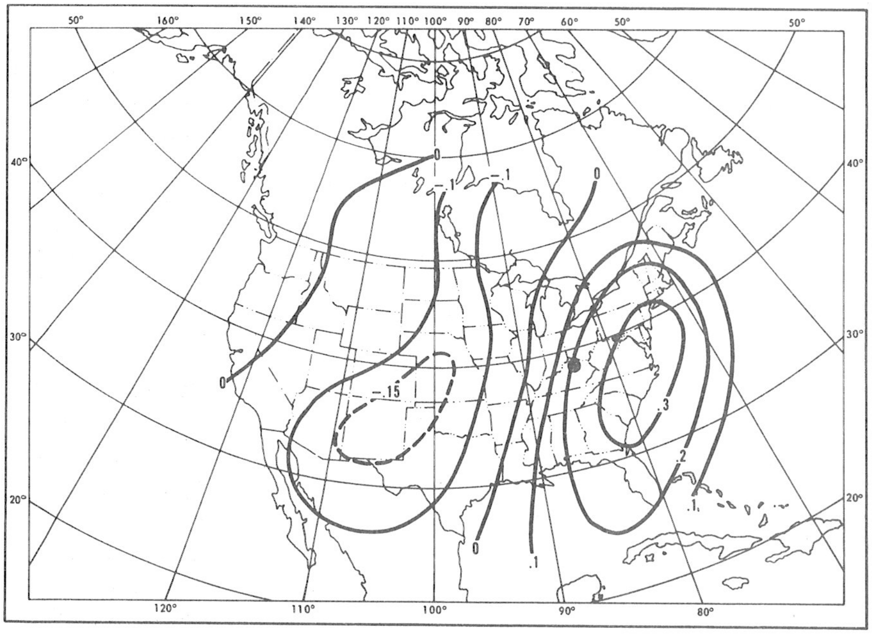

Figure 5 - Chart depicting the correlation field between the 1400-LST dew point temperature at Lexington, Kentucky, and the 700 mb-height field for July-August 1951-60.

Maps of the correlation fields between the 1400-LST (1900-2200Z) dew point temperatures and 1000- and 700-mb heights at 1200Z the same day have been constructed for the July-August and November-December sets of data. Figure 5 shows the correlation field of the 700-mb heights at 1200Z and the 1400-LST dew point temperature at Lexington, Kentucky during July-August 1951-60. Positive values range as high as +0.30 and negative values as low as -0.18. If the isopleths of correlation are treated as isopleths of the height anomaly (Klein 1965), then it is apparent that a southerly flow at 700 mb would raise the dew point temperature at Lexington.

The corresponding correlation field between the 1000-mb 1200Z heights and the 1400-LST dew point temperature at Lexington is shown in figure 6. The largest positive value is less than that in figure 5, but the negative values are much larger in this figure. The position of the gradient in figure 6 indicates well a source region for moisture at Lexington to be the Gulf of Mexico. A westward extension of the Bermuda-Azores high will produce high dew point temperatures at Lexington. The gradient in this figure appears stronger than that in the preceding figure for 700-mb indicating possibly the 1000-mb flow to be more important for production of high dew point temperatures at Lexington in July-August than the 700-mb flow.

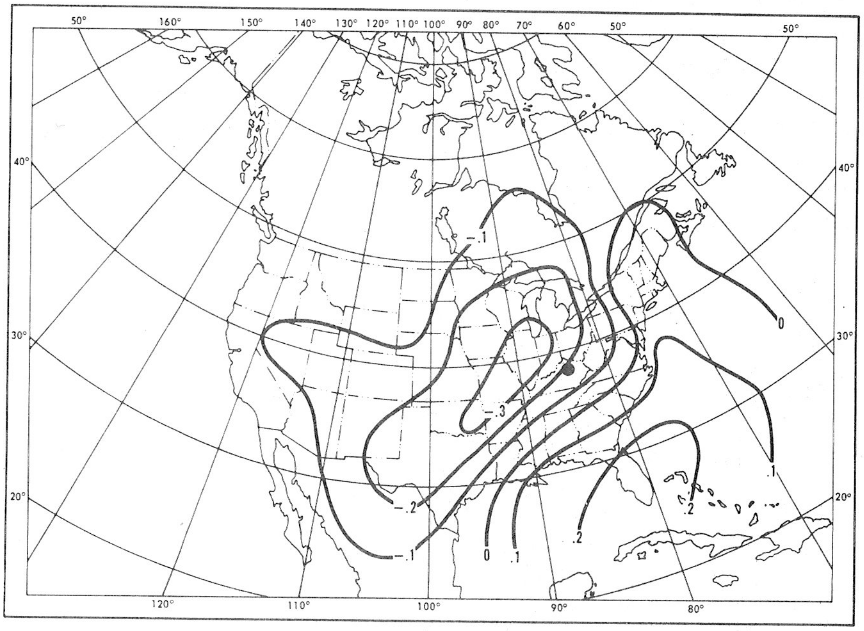

Figure 6 - Chart depicting the correlation field between the 1400-LST dew point temperature at Lexington, Kentucky, and the 1000-mb height field for July-August 1951-60.

The correlation field between the 1400-LST dew point temperature observed today at Lexington and those observed yesterday at many eastern cities is pictured in figure 7. The largest value, around 0.65, is found to the west of Lexington, indicating perhaps a regime of weak westerlies during the summer. Also, the circular character of the isopleths indicates a fairly even distribution of dew point temperatures exist during July-August.

Maps plotted for similar data from the November-December set are illustrated in figures 8, 9, and 10. The larger natural variance of the dew point temperature in the eastern United States documented earlier in this study

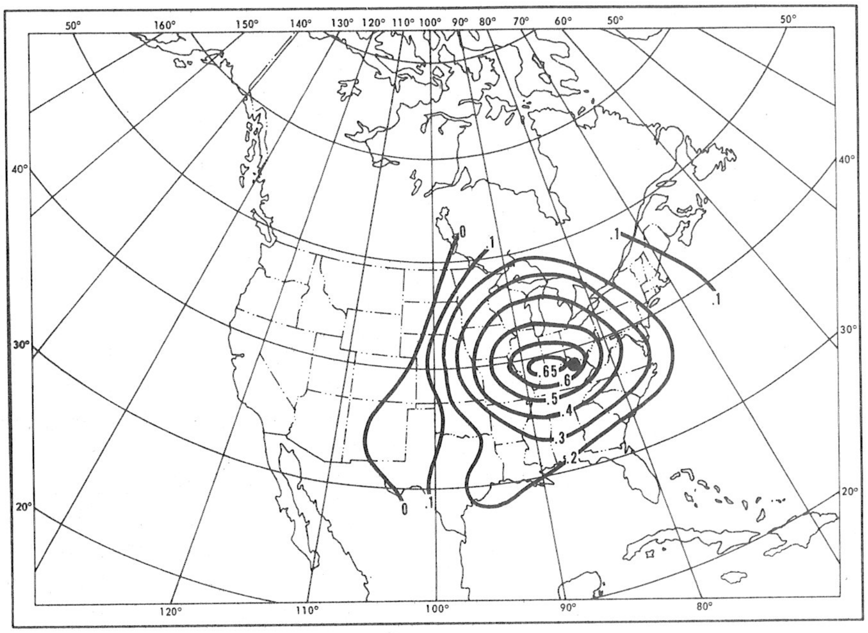

Figure 7 - Chart depicting the correlation field between the 1400-LST dew point temperature at Lexington, Kentucky, and 1400-LST dew point temperatures observed yesterday at selected stations for July-August 1951-60.

(see figure 4) is well demonstrated in these figures. The 700-mb heights at 1200Z have much larger centers of correlation with the 1400-LST dew point temperature at Lexington, in November-December than in July-August, as high as 0.60 and as low as -0.34. Also, the isopleths form a tighter gradient. Klein's models for warm temperatures and heavy precipitation documented in the

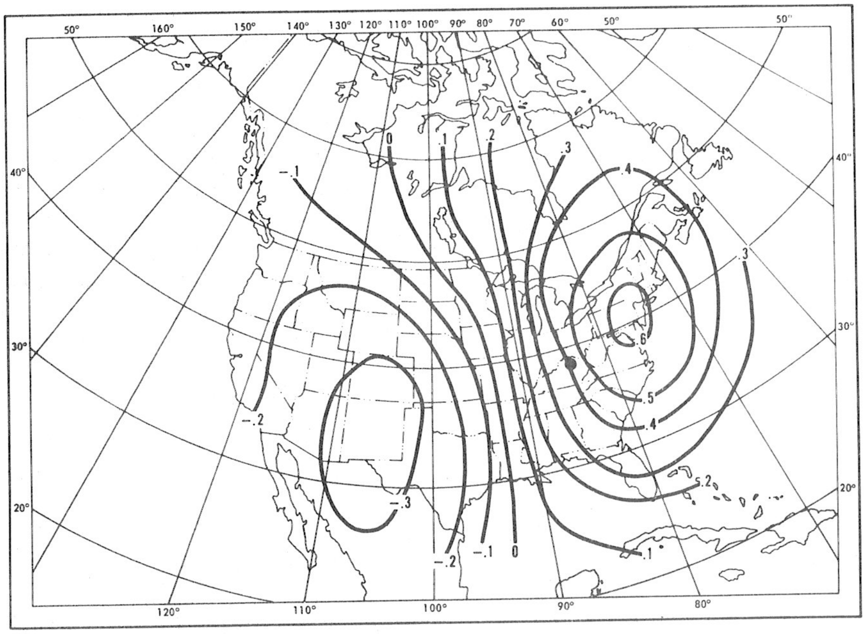

Figure 8 - Chart depicting the correlation field between the 1400-LST dew point temperature at Lexington, Kentucky, and the 700-mb height field for November-December 1951-60.

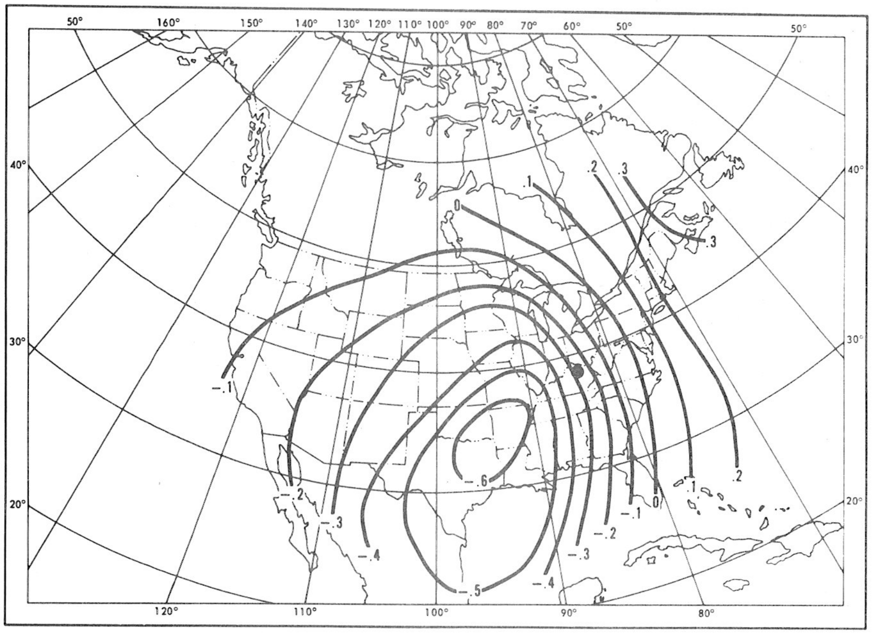

Figure 9 - Chart depicting the correlation field between the 1400-LST dew point temperature at Lexington, Kentucky, and the 1000-mb height field for November-December 1951-60.

aforementioned study on synoptic climatology (Klein 1965) emerge when the isopleths of correlation are treated as isopleths of anomalies. That is, a ridge in the eastern coast area and a trough in the Mississippi Valley contribute to warmer temperatures and heavy precipitation in the Lexington area. In this case, they contribute to higher dew point temperatures.

Figure 9, illustrating the correlation field between the 1200Z 1000-mb heights and the 1400-LST dew point temperature at Lexington for November-December, also shows a stronger gradient than the corresponding summer situation. Values of correlation range from -0.64 to 0.30. These are similar to those found on figure 8, perhaps indicating that both levels are equally important for determining the value of the dew point temperature at Lexington. The negative values are larger in November-December than in July-August, perhaps indicating the importance of cyclones in the late fall for bringing moist air to Lexington. The summer situation is more stagnant than the late fall, with the high pressure area in the southeastern United States being the dominant influence.

The correlation field between yesterday's dew point temperature observations at 1400 LST at selected stations and today's observations at Lexington for November-December is illustrated in figure 10. The center of the largest correlation, about 0.70, is located farther west than in figure 7, illustrating the July-August data. Also, the configuration of the isopleths is much different. The pattern can be interpreted to indicate the stronger westerlies of this season, and the concomitant passage of cyclones and anti-cyclones with their inherent dew point temperatures.

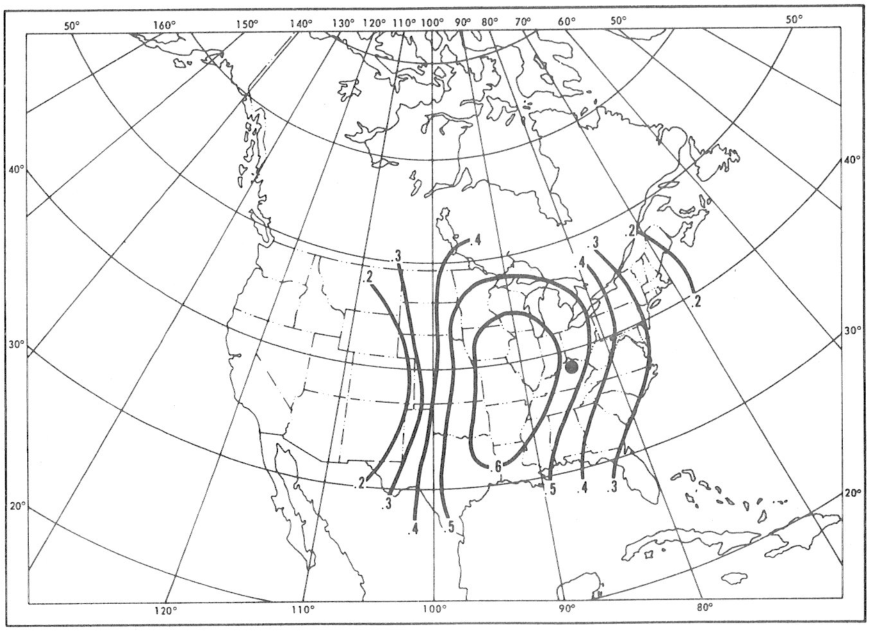

Figure 10 - Chart depicting the correlation field between the 1400-LST dew point temperature at Lexington, Kentucky, and 1400-LST dew point temperatures observed yesterday at selected stations for November-December 1951-60.

Table 2. Symbolic notation used in the following tables describing the Screening Regression Experiments

Symbol	Description of the symbol
Z_7	700-mb height
Z_{10}	1000-mb height
H	1000-700 mb thickness
T	Dry bulb temperature (surface)
T_w	Wet bulb temperature (surface)
T_d	Dew point temperature (surface)
$(\ )^{00,12}$	Height data observed at 0000 or 1200Z
$(\ )^{-1}$	Surface data observed at 1400 LST Yesterday

Table 3. The results of the screening regression experiments on the July-August Set of Data. (The predictand is the dew point temperature at 1400-2200Z, today)

Experiment	Predictors	Area	Standard error of estimate (°F)	Reduction of variance (%)
1	$(H,Z_7,Z_{10})^{12}$	East	4.78	41.7
2	$(H,Z_7,Z_{10})^{12},T_w^{-1}$	East	4.43	50.3
3	$(H,Z_7)^{12},(T,T_w)^{-1}$	East	4.39	51.7
4	$(H,Z_7)^{12},(T,T_w)^{-1},T$	East	4.26	55.0
5	T_d^{-1}	East	4.68	46.4
		West	5.49	40.3
		All	5.05	43.6
6	$(Z_7,Z_{10})^{00},T_d^{-1}$	East	4.30	54.7
		West	5.25	45.6
		All	4.74	50.5
7	$(Z_7,Z_{10})^{12},T_d^{-1}$	East	4.26	54.1
		West	5.24	45.6
		All	4.71	50.2
8	$(Z_7,Z_{10})^{24},T_d^{-1}$	East	4.20	55.5
		West	5.28	44.8
		All	4.69	50.5

Screening Regression Results Based on Dependent Data

July-August Results

Table 2 lists the symbols used to describe the results of screening regression experiments on the specification of the dew point temperature from the bimonthly sets of data. Z_7 and Z_{10} refer to 700- and 1000-mb heights, respectively, H describes the 1000- 700-mb thickness, and T, T_w, and T_d the dry bulb, wet bulb, and dew point temperatures. When height data are superscripted, the superscript is the GMT, 0000, 1200, or 2400Z; when the surface data are superscripted, the meaning is -1 for yesterday's observation at 1400 LST, and blank for today's data.

Table 3 lists the results from the experiments made for specification of the dew point temperature in July-August. These results were obtained using the cutoff criteria previously discussed, from the results averaged over 48 stations in the eastern group and 41 stations in the western group. Interestingly, using all three upper air parameters as predictors, experiment 1, resulted in less reduction of variance of the dew point temperature (over the eastern group of stations) than the case, experiment 5, when the observed dew points yesterday are the sole predictors. Further examination of table 3 reveals that use of surface predictor information in addition to height information increased the reduction of variance of the dew point temperatures in the east from 8 to 14 percent. Adding yesterday's wet bulb temperature to the height predictors increased the reduction of variance 8.4 percent, experiment 2. When yesterday's dry bulb temperature was added to the same set, experiment 3, the reduction of variance was only 1.4 percent more; and, when today's dry bulb temperature was added to this set, experiment 4, the reduction of variance was increased by only 3.4 percent. This illustrates well the independence of the 1400-LST dry bulb temperature and the 1400-LST dew point temperature in July-August. This is to be expected since a dominant control on the summer dry bulb temperature maximum is the amount of insolation, which is not a direct function of the dew point temperature.

After some experimentation, I decided to include only surface dew point temperatures as station predictors, for the following reason: a forecast for tomorrow's dew point temperature at 1400 LST would be more simplified if the only station information needed was today's dew point temperature, already forecast. As seen in table 3, the combination of yesterday's dew point temperatures and height data at 00, 12 and 24Z were used as sets of predictors in experiments 6, 7, and 8. Little difference is noted in the reduction of variances obtained in these experiments, all having values of about 50 percent. These are almost as high as those in experiment 4, which included today's dry bulb temperature. If these equations were used in a forecast procedure, predictions made with experiment 6, using actual observed data would most likely yield the best results.

I made some tests using monthly data alone (not shown) and obtained slightly higher reductions of variance. Also, I compared sets of predictors using all three highest predictors and combinations of two of the three. Results (not shown) indicate only two of the three height predictors are necessary, the third being redundant.

November-December Results

The experimental results of screening regression for the specification of the dew point temperature in November-December are listed in table 4. It was found that the larger natural variability of the dew point temperature in November-December relative to July-August resulted in a larger reduction of variance of the predictand when similar predictors were used. The mean November-December dew point temperature data has almost twice the variance of July-August data, and the reduction of variance, averaged over all 89 stations, is 18 percent more, using the best set of predictors, than in the July-August set. However, the standard errors of estimate are higher in the November-December set.

Experiment 1, in table 4, in which the predictor is yesterday's dew point temperature, yielded a reduction of variance 11 percent greater than the same set, experiment 5 in table 3, for July-August. Addition of height information increased the reduction of variance significantly only when today's 1200Z data were used, as in experiment 3. When 0000Z and 2400Z (0000Z tomorrow) data were used in conjunction with yesterday's dew point temperatures, experiments 2 and

Table 4. The results of the screening regression experiments on the November-December data (The predictand is the dew point temperature at 1400 LST)

Experiment	Predictors	Area	Standard error of estimate (°F)	Reduction of variance (%)
1	T_d^{-1}	East	8.37	59.6
		West	6.30	48.8
		All	7.42	54.6
2	$(Z_7,Z_{10})^{00}, T_d^{-1}$	East	8.28	60.7
		West	6.37	47.8
		All	7.40	54.6
3	$(Z_7,Z_{10})^{12}, T_d^{-1}$	All	6.16	66.8
4	$(Z_7,Z_{10})^{24}, T_d^{-1}$	East	8.15	61.8
		West	6.23	49.7
		All	7.27	56.2

4, the reductions of variance were much less. Experiment 4, in which the height information was observed only 2-5 hours later (at 2400Z today) than the surface dew point temperatures (1900-2200Z or 1400 LST), yielded a reduction of variance only slightly better than using the dew point temperature observed yesterday alone, experiment 1. The use of 0000Z height information along with yesterday's dew point temperatures, experiment 2, did not increase the reduction of the variance over that of experiment 1. Experiment 3, using the combination of 1200Z height information and yesterday's dew point observations for the predictor set, is the set of equations which has been tested on independent data during November-December 1968.

The Dew Point Temperature Prediction Equations

The equations derived in experiment 3, table 4, form the basis of the test of the method developed in this paper for prediction of dew point temperature. The results of this test will be discussed later.

Pertinent facts on these derived equations are listed in table 5. The average reduction of variance, over all 89 stations, using the 1000- and 700-mb heights at 1200Z and the dew point temperatures observed yesterday at 1400 LST as the predictor set, was 67 percent (line 1). The mean standard error of estimate, line 2, is 6.16°F. The natural variance, represented by the mean standard deviation of the dew point temperature, line 3, is 11.2°F. The mean dew point temperature for this period is 29.3°F. Line 5 indicates that an average of 4.77 predictors were used. The composition of these predictors is interesting; the most common predictor was yesterday's dew point temperature followed by the 1000- and 700-mb heights. Fifty-three of the 89 stations selected the local observed dew point temperature yesterday as one of the predictors included in its prediction equation. Lines 7 and 8 in table 5 describe the composition of the first and second predictors selected in the screening regression procedure. The first predictor selected is generally a dew point temperature, the second, a 700-mb height. The screening procedure selected the dew point temperature observed yesterday at the predictand station as the first predictor 24 times out of the 53 cases when it was selected as a predictor. Persistence is well documented in this case, although it will be demonstrated later that the other predictors are quite important.

Table 5. Pertinent facts concerning the November-December dew point temperature prediction equations (Based on dependent data from 1951-60)

Line			
1	Mean reduction of variance (%)		66.8
2	Mean standard error of estimate (°F)		6.16
3	Mean standard deviation (°F)		11.20
4	Mean dew point temperature		29.3
5	Mean number of predictors		4.77
	Composition	dew point temperature yesterday at 1400 LST	1.89
		1000-mb height	1.63
		700-mb height	1.25
6	Number of stations selecting own dew point temperature observed yesterday at 1400 LST		53
7	First predictor composition		
		dew point temperature yesterday at 1400 LST	51
		1000-mb height	21
		700-mb height	17
8	Second predictor composition		
		dew point temperature yesterday at 1400 LST	13
		1000-mb height	34
		700-mb height	42

The complete statistics for each equation and the equations themselves can be found in the appendix. Maps illustrating the fields of the standard error of estimate and the reduction of variance of this set of prediction equations are shown in figures 11 and 12.

Comparing figure 11, which depicts the standard error of estimates, and figure 4, the standard deviation of the November-December dew point temperature, it is seen that the patterns are quite similar in Eastern United States. However, in the western part of the country, the patterns do not seem to have

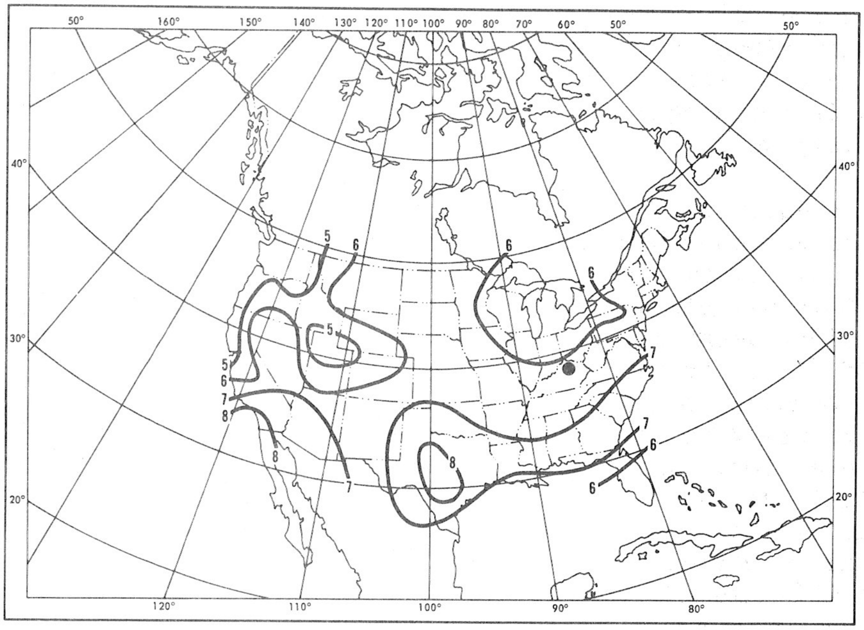

Figure 11 - Chart depicting the isopleths of the standard error of estimate (°F) of the 1400-LST dew point temperature at the 89 stations as specified by the 1200Z 1000- and 700-mb height fields and the 1400-LST dew point temperature observed yesterday, during November-December 1951-60.

the same relationship to each other, relatively speaking, as they do in the East. This is well represented in figure 12, which depicts the reduction of variance of the 1400-LST dew point temperature using the described set of predictors. Eastern United States has a relatively smooth pattern of values between 70 and 85 percent. These values decrease steadily toward the central Rocky Mountains, where the reduction of variance at Pueblo is only 27 percent. Values farther west are low, between 40 and 60 percent, increasing to about 70 percent in the northern mountains. The larger reduction of variance in the East may be attributed to the rapid succession of cold, dry air masses and warm,

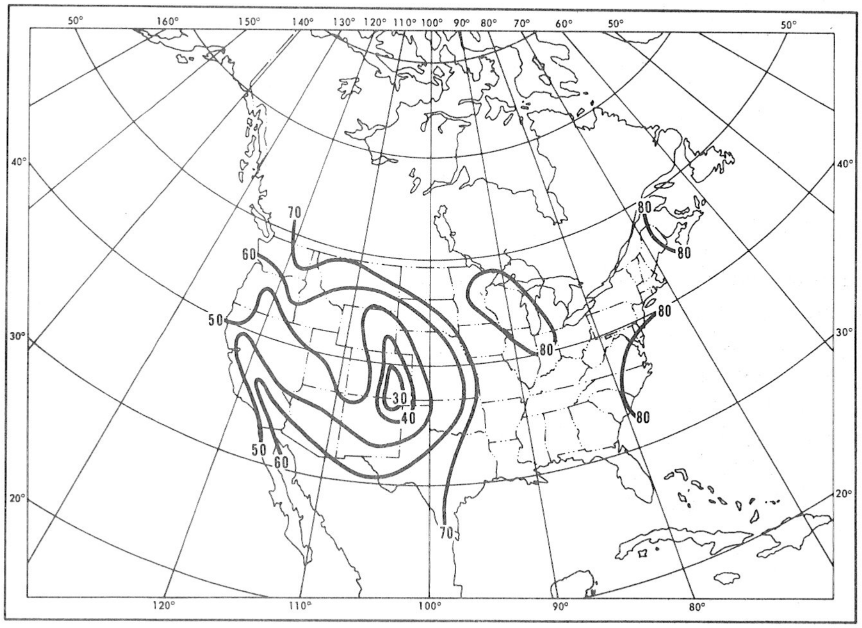

Figure 12 - Chart depicting the isopleths of the reduction of variance (%) of the 1400-LST dew point temperature at the 89 stations as specified by the 1200Z 1000- and 700-mb height fields and the 1400-LST dew point temperatures observed yesterday, during November-December 1951-60.

moist air masses, which are fairly well represented by flow patterns at 1000- and 700-mb. On the other hand, the weather in the intermountain plateau is well documented as being of a more complex nature, with the result that the set of predictors used in these equations cannot describe the variation in the dew point temperature very well.

A sample prediction equation from this set is illustrated in figure 13. This equation is for the November-December period at Little Rock, Ark. The predictors are five in number, two dew points measured yesterday at Little Rock and Waco, two 1000-mb heights located northwest and southeast of Little Rock, suggesting a gradient amenable to southwest flow, and one 700-mb height located to the north of Little Rock. The first predictor selected was the 1000-mb height to the northwest of Little Rock, the negative sign indicating higher dew point temperature with lower heights. The other predictors are labelled in order of selection. The figure to the left of the circle is the standard error of estimate at each step of the screening process, and the figure below the circle is the corresponding reduction of variance. Using all give predictors, a total reduction of variance of 76.4 percent with a standard error of estimate of 6.6 °F is obtained.

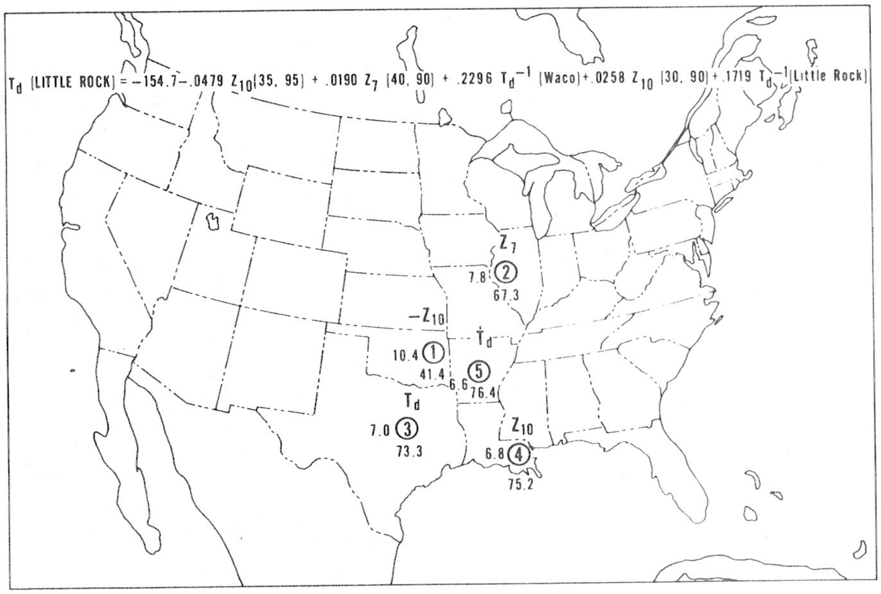

Figure 13 - The November-December dew point temperature prediction equation for Little Rock, Ark., as derived in this study. The numbered circles refer to the location and order of selection of a predictor. The numbers to the left and below the circle refer to the standard error of estimate and the reduction of variance of the predictand up to and including that predictor. Z_7, Z_{10}, and T_d^{-1} refer to 1200Z heights and the dew point temperature observed yesterday afternoon at the location in parentheses.

Other Possible Predictors

A pertinent question to ask is why derived predictors such as vorticity and vorticity advection, as used by Veigas and Ostby (1963) have not been used in this study? The evidence from other studies is not encouraging in this respect. Glahn (personal communication 1969) has experimented with this type of predictor in connection with weather specification from the SAM and PE models. These derived predictors were not found to be of much utility. Similarly, in Klein's study of rainfall forecasting for the Tennessee and Cumberland Valleys (1968), he found that higher reductions of variance were obtained from the basic height data than from derived predictors.

In a related study on objective temperature forecasting in Canada, Yacowar (1968) used derived predictors such as vorticity, vorticity advection and thermal vorticity advection. His results, based on one winter's data, using a regression method similar to that adopted in this paper, show reductions of variance that are overall less than the simpler method of Klein et al. (1969). The limited testing by Yacowar also indicates similar results to those of Klein et al. The complex predictors were only once selected as high as the second term in the regression equation; they were usually found in the fourth or fifth terms.

Miller et al. (1968), in a study on forecasting hurricane movement, have shown that this type of predictor generally adds only little to the basic height information.

In view of these results and others by Klein (1965), I decided to forego using derived predictors in this study. More discussion of this problem will be found in the summary and conclusion.

OTHER FORECAST METHODS USED IN THE TEST

The Reap Three-Dimensional Trajectory Technique

Two additional forecast methods, as well as persistence, were used in a test of the dew point prediction equations developed in this study during November-December 1968. Both methods are part of forecast models developed recently in TDL. One utilizes output from the PE model in a purely physical approach, the other in a physical-statistical approach.

The physical model is a three-dimensional Lagrangian trajectory technique developed by Reap (1968). The data used in the model consists of initial radiosonde information and wind forecasts produced operationally by the PE model at NMC. The trajectories computed over an area slightly larger than the continental United States, are tracked backwards from the end points (part of the NMC 1977-point grid) to the origin points by means of two-hourly winds, both vertical and horizontal, interpolated from the six-hourly data on the PE history tape. Thermodynamic parameters of interest are analyzed at the origin points according to a scheme different from that in use at NMC, favoring along-stream reports over cross-stream reports. The parcels are then tracked back to the end points. However, saturation effects are built into them and an improved terrain is introduced into the western United States with a concomitant modeling of the flow over the Rocky Mountain Barrier.

The output at the end points, part of the NMC 1977-point grid, consists of dry bulb and dew point temperature, relative humidities, dew point depressions, and vertical parcel displacements ending at four levels: 1000 mb (or surface, if higher than 1000 mb), 850, 700, and 500 mb. An interpolation scheme will assign values to specific stations from the grid point data. The dew point temperatures at 1000 mb in the Eastern United States and 850 mb in the Western United States were qualitatively compared with the single station forecasts for a small set of nine similar forecasts.

The Glahn-Lowry Generalized Equation

The other forecast model used in the test is part of the SAM model (Subsynoptic Advection Model) developed by Glahn, Lowry, and Hollenbaugh (1969). The model uses output from the PE forecasts at 500 mb and surface analyses at 07Z to develop 1000- to 500-mb thickness and surface pressure forecasts in three-hour stages to 00Z. Statistically derived forecast equations are used to predict various meteorological parameters of interest at 100 stations in the Eastern United States. The predictors in these equations are products of the PE and SAM models interpolated to the station and 07Z station data. The approach is to develop one equation valid for all 100 stations. A subset of 28 of the 100 stations was included in the 89 stations used in the present study to develop single station prediction equations.

Dew point prediction equations were developed from the dependent data for valid times of 18Z and 21Z. The average of these two forecasts was used as the prediction valid at 19.5Z. According to Dodd (1965), the value of the dew point temperature changes little over a half-hour in the Eastern United States during this season; hence, the values at 19.5Z were assumed to be representative of 1400 LST for the test.

The dependent data sample consisted of 12,445 sets of data from 139 days at 100 stations between October and March 1967-68. Screening multiple regression was used to develop the prediction equations valid at 18Z and 21Z. The first predictor selected was the observed dew point temperature at 07Z in both equations. The linear correlation of the 18Z and the 07Z dew point temperatures was 0.90. In the 89-station study discussed earlier, the multiple correlation of yesterday's and today's 1400-LST dew point temperatures was 0.71. This illustrates well the importance of later data. However, the period of record is October to March, and part of the larger correlation may be due to a seasonal trend in the data. The second and third predictors were also the same for the two equations, namely the 24-hour forecasts by the PE model of the 1000-mb temperature and the mean relative humidity. The fourth predictors in the two equations were the 1000-mb south wind speed at 15Z and 18Z as forecast by SAM. The remaining predictors selected in the equations were forecasts of saturation deficit produced by the SAM model and mean relative humidity produced by the PE model.

The resulting averaged equation is listed in table 6. The standard errors of estimate for the 18Z and 21Z forecast equations are 5.85 and 6.15 degrees F, respectively. The larger variability with time indicates possibly a larger natural variability in the dew point temperature during the later afternoon and/or difficulty in specification due to deterioration in the PE and SAM forecast models.

Using prognostic data to develop forecast equations is an interesting approach in statistical forecasting. The main disadvantage appears to be the necessary rederivation of equations from time to time as alterations are made in the basic prognostic models. Another disadvantage is possibly the necessity of using the generalized equation approach due to small samples of numerical forecasts.

THE TEST ON INDEPENDENT DATA

The Test Period

The period of the test on independent data extended from November 15 to December 31, 1968. Surface dew point temperatures at the 89 stations were collected from Service A of the Federal Aviation Agency airways teletype network during the period. Subjective interpolations of dew point temperatures to one or more of the stations were made on some of the days of the test period because of missing data.

Table 6. The generalized operator dew point temperature prediction equation

	Coefficient	Predictor
Dew point temperature (19.5Z) =	9.2990	
	+ 0.61950	Observed dew point temperature (07Z)
	+ 0.44700	PE 1000-mb temperature (24Z)
	+ 0.09143	PE mean relative humidity (24Z)
	+ 0.03826	SAM 1000-mb south wind speed (15Z)
	+ 0.04412	SAM 1000-mb south wind speed (18Z)
	- 0.00645	SAM saturation deficit (18Z)
	- 0.04482	PE mean relative humidity (18Z)
	- 0.02771	PE mean relative humidity (12Z)
	- 0.00542	SAM saturation deficit (21Z)

The appropriate height prognoses for the 1000- and 700-mb fields as predicted by the PE model are routinely saved on magnetic tape at the National Meteorological Center in Suitland, Md. These forecasts were extracted from those tapes for use in the test of the forecast equations derived in this paper. The collected surface data were put onto punched cards and a program was written which made forecasts of the dew point temperatures at the 89 stations based on the equations in the appendix. Forecasts were made for 47 days during the test period.

On 44 days of the test period, dew point temperature forecasts were made using the generalized equation developed by Glahn and Lowry for stations in the Eastern United States. Unfortunately, the SAM model failed to run on three days because of data collection problems at NMC. Twenty-eight of the stations where forecasts were made using the generalized equation are included in the 89 stations, for which single station forecast equations were derived. Forecasts by the two methods for the 28 stations are compared later in this paper. Reap's trajectory model ran only 9 days during the same period.

The Format of the Forecast Methods

Figure 14 is an illustration of the format for the different forecasts. The prediction equations derived in this study have an input surface data from 1400 LST yesterday and PE prognoses based on 00Z initial data valid at 12Z today to make a forecast of the dew point temperature valid at 1400 LST today. The generalized equation forecast and the SAM model use prognoses from the same initial PE forecast. The SAM model also utilizes surface data from 07Z. The valid time of the forecasts using the generalized equation is 19.5Z. The trajectory program uses the entire PE forecast over 24 hours to produce forecasts valid at 00Z.

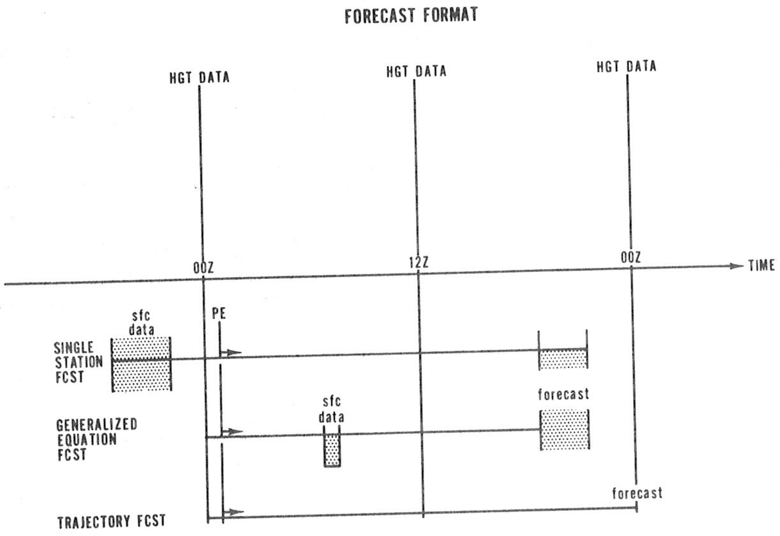

Figure 14 - Depiction of the forecast format of the various prediction methods.

The prediction equations derived in this paper can use any height data, forecast or observed, valid at 12Z. Of course, the better forecast will result from the observed data. When 12-hour-PE prognoses are used based on 00Z initial data, in the single station equations, the acronym SS1 or SS2 will be used to describe results. SS1 refers to the subgroup of 28 of the eastern stations, the results of which are compared with those from the generalized equation forecasts. SS2 refers to all 89 stations. Forecasts were also made using 24-hour PE prognoses and yesterday's 1400-LST dew point temperatures to predict today's dew point temperatures. These forecasts are labeled SS3.

As stated earlier, one of the reasons for using only the dew point temperatures from the surface data predictor set was to enable longer range predictions of the dew point temperature to be produced easily. Forecasts for tomorrow's 1400-LST dew point temperatures were made using forecasts of today's dew point temperatures from the SS2 system and 36-hour PE prognoses valid at 12Z tomorrow. These predictions are called SS4. The generalized equation forecasts are labeled SAM.

Comparisons of different prediction models are difficult to make when the forecasts are of different length. If the initial time of the forecast model is when the latest data is introduced, then the generalized equation method is a 12.5-hour forecast (average of 11-and 14-hour forecasts), the single station methods are 19-22, 24, and 43-46-hour forecasts, Reap's trajectories are 24-hour forecasts, and persistence, 24- and 48-hour forecasts. The latest input data to SAM is the 07Z surface reports. When 12-hour PE prognoses are input to the single station equations (SS1, SS2), the latest data is 00Z; when 24-hour PE prognoses are used (SS3), the latest data is 19-22Z surface dew point temperatures. When 36-hour PE prognoses are used in conjunction with forecasts of today's dew point temperatures (from SS2) as in SS4, the latest data is 00Z yesterday.

Results of the Test

All of the forecasts produced by the various prediction models have been verified. Table 7 lists the results of the verification for all models except the three-dimensional trajectory model, which only had nine cases for comparison. Table 8 summarizes comparison of the nine cases of the Reap trajectory model with the single station approach.

The mean algebraic error results listed in table 7 indicate that all of the methods have a positive bias. According to Green (1969), the conterminous United States was colder than a 30-year normal during December 1968. Two-thirds of the test are comprised of that month. If the dry bulb temperature is used as an upper limit of the dew point temperature, then it is likely that the dew point temperatures were also below normal during that period. If so, then a reasonable explanation of the positive bias has been given. A larger developmental sample that included colder, hence drier, months might have yielded regression equations that could have better handled this situation.

Table 7. Verification results of the test period November 15-December 31, 1968, for the various dew point forecast methods used (°F where temperatures are implied)

Forecast Method	SAM	SS1	SS2	SS3	PERS1	SS4	PERS2
Mean observed	29.3	29.3	26.1	26.1	25.9	25.9	25.7
Standard deviation	13.9	13.9	11.7	11.7	11.6	11.6	11.6
Mean forecast	29.8	30.2	27.1	27.5	26.4	28.4	26.6
Standard deviation	12.7	12.9	9.8	10.2	11.4	9.8	11.1
Mean algebraic error	.5	.9	1.0	1.4	.5	2.5	1.0
Standard deviation	5.9	6.7	6.3	6.7	10.5	7.5	14.0
Mean absolute error	4.8	5.6	5.1	5.5	8.0	6.5	11.2
Standard deviation	3.6	4.3	4.2	4.6	6.8	5.4	8.5
Root-Mean-Square error	6.1	7.1	6.6	7.2	10.6	8.4	14.1
Correlation	.909	.880	.822	.805	.571	.750	.240
Number of cases	44	44	47	47	46	46	45

Forecast description:

SAM........11-14 (12.5)-hour forecast for 28 stations in Eastern United States
SS1........19-20 -hour forecast for 28 stations in Eastern United States
SS2........19-22-hour forecast for 89 stations in the adjacent conterminous United States
SS3........24 -hour forecast for 89 stations in the adjacent conterminous United States
SS4........43-46-hour forecast for 89 stations in the adjacent conterminous United States
PERS1......24-hour persistence of yesterday's dew point temperature at 89 stations
PERS2......48-hour persistence of yesterday's dew point temperature at 89 stations

In any case, the results listed in table 7 are quite encouraging. In the original derivation, the average standard error of estimate of the 89 single station equations was 6.2 degrees (table 5). The same statistic for the generalized equation (not shown) for the Eastern United States was 5.85 degrees for a forecast valid at 18Z and 6.15 for a forecast valid at 21Z. The root-mean-square (RMS) errors of the test are not much larger than these figures, 6.1 °F for the generalized equation (SAM) and 7.1 °F. for the single station equations for 28 stations in the Eastern United States (SS1). These forecasts (SS1) used 12-hour PE prognoses. However, the 89-station average rms error using 12-hour PE prognoses (SS2) was only 6.6 °F, indicating lower rms errors in the Western United States.

The single station model utilizing 24-hour PE prognoses (SS3), valid at 12Z today, had rms error of 7.2 °F. Forecasts of tomorrow's dew point temperature made using the single station equations (SS4) have as input forecasts of today's dew point temperatures from SS2 and PE prognoses of 36 hours length. The rms error of these 43-46-hour forecasts was 8.4 °F. Compared with persistence forecasts of 24 hours (PERS1) and 48 hours (PERS2), the forecast models performed very well. The rms errors of PERS1 and PERS2 were 10.6° and 14.1°, respectively.

Other encouraging statistics in table 7 are the correlation coefficients and the standard deviations of the observed and forecast dew point temperatures. The latter are quite similar to each other, indicating the statistical model can demonstrate the same amount of variability as the atmosphere.

The results listed in table 7 also demonstrate very well the importance of late data to a forecast system. The shortest forecasts, those produced by the generalized equation using SAM and PE input, have a one degree less rms error than the single station forecasts for the same 28 stations (SS1). The generalized equation forecasts are about seven hours shorter in time. This feature is again demonstrated by the results of the SS2, SS3, and SS4 test forecasts. The SS2 forecasts, using 12-hour PE prognoses, had a rms error of 0.6 degrees less than the SS3 forecasts, using 24-hour PE prognoses. The longer range SS4 forecasts had an increase of 1.4 degrees rms error over the SS3 forecasts.

The surprisingly good results of the SS4 forecasts demonstrates the ability to produce long-range forecasts of dew point temperature not currently produced operationally. Producing useful dew point temperature information this far in advance would be particularly beneficial to fire weather forecasters and fire fighting planning teams. Dew point temperatures within a certain range are necessary information for slash burning procedures and fire weather warnings.

A "t" test was made on the results of the differences SS1-OBS and SAM-OBS, where OBS is the observed temperature, for each day in the test period. The hypothesis was that the differences are the same. If the test failed, it could be considered as indicative of the performance of one method compared to the other. The formula used was:

$$t = \frac{\bar{D}\,(N(N-1))^{1/2}}{\sum_{i=1}^{n} D_i^{2} - N\bar{D}^{2}}$$

where

$$D = \frac{\sum_{i=1}^{n} D_i}{N} = \sum_{i=1}^{n} \frac{((SS1-OBS)_i - (SAM-OBS)_i)}{N}$$

N being the number of forecasts.

The value of "t" determined by this formula was 3.46 for the last 15 days of November and 6.14 for December, with N being 448 and 784, respectively. These results indicate the hypothesis can be rejected at the 99.9-percent level. The verification results in table 7 validate these results. However, it must be remembered that the generalized equation forecasts benefit from a much later data input.

Unfortunately, Reap's trajectory model ran on only 9 days of the test period. These 24-hour forecasts are compared with the 19- to 22-hour forecasts made using the single station equations (SS2) in table 8. The SS2 forecasts have a rms error of 5.4 degrees. Reap's forecasts at the 1000-mb level have a rms error of 5.2 degrees in the Eastern United States and 9.7 degrees in the Western United States. However, there are only a few stations at the 1000-mb level in the Western United States and the physical model has inherent problems due to the mountains. At 850 mb, the rms error is reduced to 5.7 degrees in the West. This value at 850 mb is probably more realistic than the 1000 mb value in the West. In the East, it increases to 6.5 degrees.

Table 8. Verification results for the dew point temperatures forecast by the single station method and the trajectory method (°F where temperatures are implied)

(Nine cases)

(Forecast method)	SS2	Trajectory			
		1000 mb		850 mb	
		East	West	East	West
Mean absolute error	4.30	4.12	7.89	5.09	4.34
Root-mean-square error	5.40	5.23	9.72	6.51	5.72
Verifying Time	19-22Z	00Z		00Z	

These few results indicate that the physical-dynamical model of Reap is comparable in the East to the statistical models, if not better. In the West, the statistical model is probably better because of the mountains. However, only more complete comparisons will adequately evaluate the techniques.

Maps illustrating the rms error patterns of forecasts produced by the generalized equation over the Eastern United States and by the SS2 equations over all 89 stations are shown in figures 15 and 16. (Verification statistics for individual stations from the SS2 test forecasts can be found in table 12 of the appendix.)

The pattern in figure 15 indicates that the generalized equation fares worst in the southeastern United States. Two reasons can be offered for this result. One, the authors combined data from throughout the Eastern United States, perhaps not including enough southern stations. The second source of error is most likely the inadequate forecasts produced by the PE, and hence, the SAM model in this area of the country.

Reexamination of figure 11, the standard error of estimate of the dew point temperatures from the dependent data set for the prediction equations, is useful for interpretation of the rms error of the test with these equations, as drawn in figure 16. In the Eastern United States, the patterns are very similar. On both figures, there is a relative minimum near the Great Lakes and a relative maximum in the southeastern United States. However, the values close to the gulf coast appear too high in figure 16. In the Western United States, the pattern is again similar. There is a relative minimum in the plateau area and low values along the Pacific coast. The central United States, between 90 and 105 degrees West, is the major location of disagreement between the figures. The values in figure 16 appear excessively large throughout the plains area, particularly in the Texas area.

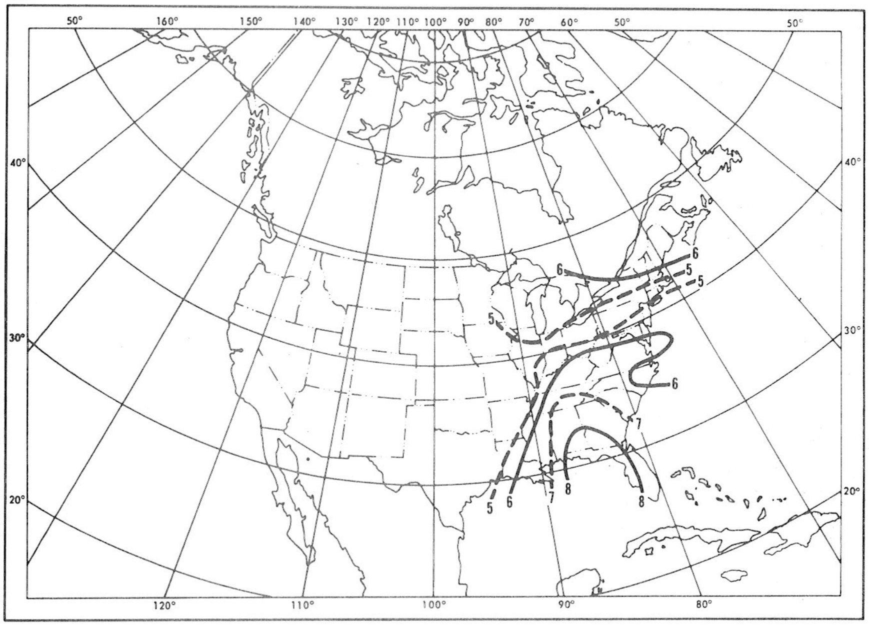

Figure 15 - The root-mean-square error isopleths (°F) of dew point forecasts produced by the generalized equation developed by Glahn and Lowry for 28 stations in the Eastern United States during the test period November 15-December 31, 1968.

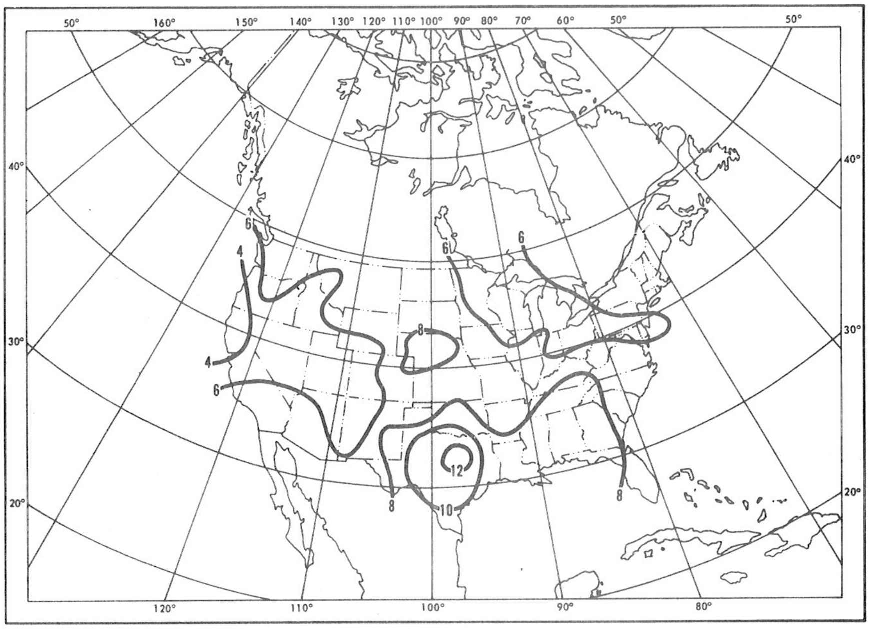

Figure 16 - The root-mean-square error isopleths (°F) of dew point forecasts produced by the equations developed in this study for the test period November 15-December 31, 1968.

Reference to figure 12, which depicts the reduction of variance of the predictand, dew point temperature, in the developmental data, indicates values between 60 and 80 percent in this area. As aforementioned, most of the forecast areas obtained very reasonable rms errors in the test, in light of the results from dependent data. It appears that the anomalous error pattern in the central, especially the south central, United States can best be ascribed to the inability of the PE numerical model to produce adequate low-level forecasts of heights.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDY

Conclusions from This Study

The results of this study clearly demonstrate the ability to forecast reasonably well the surface dew point temperature by means of relatively simple statistical models. It has also been shown that a physical-dynamical model utilizing Lagrangian trajectories can produce comparable forecasts, at least for 24 hours, over the Eastern United States.

The single station equations developed in this study would be particularly useful in Western United States, where the mountainous terrain defies the application of dynamical methods to a large extent. It has been indicated in this study that these equations are useful for longer range forecasts (43-46 hours). For this purpose, implementation of the forecast equations would probably be most useful.

The study demonstrated well the importance of later data input into a forecast scheme. Results of a test using a generalized equation over the Eastern United States indicated the superiority of this shorter forecast, which used seven hours later input data, over the single station equations developed in this study. Other forecasts made with different input to the single station equations reinforced the importance of later data.

Recommendations for Future Research

The data used in this study restricted the selection of predictors somewhat. The surface parameters included wind speed and direction, dry bulb temperatures, etc., but the means of predicting these parameters are not presently very good and the forecasts would most likely negate any large reductions of variance attributable to them. The height fields used in the study were from a coarse grid which disallowed any introduction of complex predictors based on the data.

However, these suggestions for future study should be mentioned. None of the predictors developed for this study were of the binary type where a value of 0 or 1 is assigned to the predictor if certain criteria are met. Examples of such predictors would be the range of the dew point temperature, the strength of gradients in the height fields near the station, changes of the dew point temperature over certain ranges, etc. The availability of more comprehensive data fields aloft would allow more complex predictors, such as thickness advection between 1000 and 850 mb, to be developed. Certainly parameters related to moisture should be important to this problem.

Gentille (1955) has shown an excellent relationship between the dew point temperature in the morning and the minimum temperature,in nonmountainous areas. The importance of the dew point temperature information at this time is seen in the generalized equation developed by Glahn and Lowry tested in this study. If the data sample included such information as maximum and minimum temperatures, perhaps larger reductions of variance could have been achieved.

In any case, until developments in numerical forecasting by dynamical models improves considerably, useful surface dew point temperature forecasts can be made utilizing the single station equations developed in this study, particularly for longer ranges and in the Western United States.

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APPENDIX

This appendix contains additional information concerning the equations derived in the text for prediction of the 1400-LST dew point temperature at 89 cities in the conterminous United States. The procedure is discussed in the text. Table 9 lists the 89 cities for which surface data were available.

Table 10 lists results of the screening regression for each of the 89 stations on the dependent data set. The predictors are 1200Z 1000- and 700-mb heights at selected gridpoints and the dew point temperature observed yesterday at 1400 LST at the 89 stations. Figure 1, in the text, illustrates the location of the 89 stations and figure 2, the location of part of the gridpoints for which upper air data were available. Note that the gridpoints are numbered in figure 2.

Table 11 lists each of the 89 equations derived from the dependent data set, November-December 1951-60. In these equations, A7 and A10 refer to 700- and 1000-mb heights observed at the gridpoint in parentheses. As stated before, figure 2 illustrates the location of these gridpoints. DP and DPY refer to the dew point temperature observed today and yesterday at 1400 LST at the 89 stations. The numbers in parentheses can be referred to in table 9.

For example, the first equation in table 11 is for predicting the 1400-LST dew point temperature at Macon, Ga. The predictors selected are the 1000-mb heights at gridpoint 109, the 700-mb height at gridpoint 94, and yesterday's 1400-LST dew point temperature at Memphis, Tenn. and Macon. According to figure 2, gridpoints 94 and 109 are located at 35° North, 75° West, and 30° North, 90° West. This would place gridpoint 94 to the northeast of Macon and gridpoint 109 to the southwest of Macon. The coefficient of the 1000-mb height, located to the southwest of Macon, is negative; that of the 700-mb height, located to the northeast of Macon, is positive. This appears to be meteorologically reasonable, for a 700-mb ridge to the east of Macon and lower 1000-mb heights to the west of Macon normally would indicate southerly flow and higher surface temperatures. The combination of the southerly flow and higher surface temperatures should mean higher dew point temperatures at Macon. Similarly, the terms in the other 88 equations are easy to obtain from the tables.

These equations were tested in a semioperational trial November 15-December 31, 1968. The general results of the test period are described in the text. Table 12 lists the statistics obtained at each of the 89 stations for the SS2 forecast procedure. The SS2 forecasts used 12-hour PE height prognoses and yesterday's observed dew point temperatures to predict today's 1400-LST dew point temperature at the 89 stations. All the results are in degrees Fahrenheit. The correlation coefficients are between the observed and predicted dew point temperatures. The average reduction of variance is 63.7 percent. This is close to that obtained using the dependent data, 66.8 percent, indicating that the equations are stable.

TABLE 9

List of the 89 Stations Used in this Study.

Number	City	Number	City
1	Macon, Ga.	46	El Paso, Tex.
2	Orlando, Fla.	47	Amarillo, Tex.
3	Houston, Tex.	48	Albuquerque, N. Mex.
4	San Antonio, Tex.	49	Eagle, Colo.
5	Raleigh, N. C.	50	Grand Junction, Colo.
6	Philadelphia, Pa.	51	Tucson, Ariz.
7	Richmond, Va.	52	Los Angeles, Calif.
8	Washington, D. C.	53	Prescott, Ariz.
9	Charleston, W. Va.	54	Reno, Nev.
10	Chattanooga, Tenn.	55	Sandberg, Calif.
11	Columbia, S. C.	56	Winslow, Ariz.
12	Knoxville, Tenn.	57	Blue Canyon, Calif.
13	Memphis, Tenn.	58	Oakland, Calif.
14	Montgomery, Ala.	59	Sacramento, Calif.
15	Jackson, Miss.	60	Bismarck, N. Dak.
16	Shreveport, La.	61	Lander, Wyo.
17	Waco, Tex.	62	North Platte, Nebr.
18	Abiline, Tex.	63	Casper, Wyo.
19	Little Rock, Ark.	64	Rapid City, S. Dak.
20	Oklahoma City, Kans.	65	Salt Lake City, Utah
21	Dodge City, Kans.	66	Winnemucca, Nev.
22	Saint Louis, Mo.	67	Boise, Idaho
23	Springfield, Mo.	68	Dillon, Mont.
24	Caribou, Maine	69	Kalispell, Mont.
25	Albany, N. Y.	70	Missoula, Mont.
26	Hartford, Conn.	71	Pendleton, Oreg.
27	Burlington, Vt.	72	Pocatello, Idaho
28	Portland, Maine	73	Spokane, Wash.
29	Syracuse, N. Y.	74	Mount Shasta, Calif.
30	Williamsport, Pa.	75	Eugene, Oreg.
31	Chicago, Ill.	76	Medford, Oreg.
32	Columbus, Ohio	77	Olympia, Wash.
33	Detroit, Mich.	78	Redmond, Oreg.
34	Grand Rapids, Mich.	79	Yakima, Wash.
35	Madison, Wisc.	80	Seattle, Wash.
36	Sault Ste Marie, Mich.	81	North Bend, Oreg.
37	Traverse City, Mich.	82	Pueblo, Colo.
38	Fargo, N. Dak.	83	Cedar City, Utah
39	Int'national Falls, Minn.	84	Fresno, Calif.
40	Minneapolis, Minn.	85	Tallahassee, Fla.
41	Moline, Ill.	86	Evansville, Ind.
42	Des Moines, Iowa	87	Lexington, Ky.
43	Sioux Falls, S. Dak.	88	Glasgow, Mont.
44	Eau Claire, Wisc.	89	Pittsburgh, Pa.
45	Roswell, N. Mex.		

TABLE 10

Individual station statistics concerning the November-December dew point temperature prediction equations. (The temperature values are in °F, the reduction of variance in %.)

Station	Mean value	Standard deviation	Reduction of variance	Standard error	Number of predictors
Macon	38.4	15.2	74.3	7.7	4
Orlando	54.4	11.4	74.3	5.8	5
Houston	47.8	14.9	78.4	6.9	4
San Antonio	42.1	15.2	70.2	8.3	4
Raleigh	34.4	15.2	80.0	7.1	4
Philadelphia	30.5	14.1	78.4	6.5	4
Richmond	33.7	14.2	80.0	6.3	4
Washington	30.3	14.1	79.8	6.3	4
Charleston	30.1	13.2	72.9	6.9	4
Chattanooga	35.1	13.6	78.5	6.3	6
Columbia	38.3	14.6	77.3	7.0	4
Knoxville	35.0	12.5	78.8	5.8	5
Memphis	35.6	13.9	80.4	6.1	7
Montgomery	40.7	14.5	76.4	7.0	5
Jackson	39.4	15.6	77.5	7.4	6
Shreveport	40.4	14.5	75.4	7.2	5
Waco	41.0	13.6	71.3	7.3	5
Abilene	31.1	13.0	61.4	8.1	5
Little Rock	36.0	13.6	76.4	6.6	5
Oklahoma City	30.9	11.9	62.6	7.3	6
Dodge City	25.0	9.3	52.7	6.4	6
Saint Louis	29.6	12.7	76.7	6.1	5
Springfield	31.6	12.4	72.2	6.5	5
Caribou	20.2	14.8	82.5	6.2	6
Albany	26.5	13.1	76.1	6.4	4
Hartford	27.9	13.3	74.9	6.7	4
Burlington	24.2	14.2	77.5	6.7	3
Portland	27.2	13.8	76.5	6.7	4
Syracuse	27.8	12.0	73.6	6.2	4
Williamsp't	27.5	12.3	78.3	5.7	5
Chicago	27.0	12.9	80.5	5.7	5
Columbus	30.4	12.4	77.0	5.9	4
Detroit	27.4	11.8	79.8	5.3	7
Grand Rapids	28.1	10.9	75.2	5.4	5
Madison	24.0	13.1	80.7	5.8	4
Sault Ste M	24.0	12.0	77.0	5.8	5
Traverse Cty	26.9	10.5	75.6	5.2	5
Fargo	17.4	14.3	77.7	6.8	3
Int'l Falls	14.1	15.3	79.1	7.0	5
Minneapolis	20.8	13.1	83.1	5.4	4
Moline	26.3	12.9	80.3	5.7	5
Des Moines	25.1	12.4	74.5	6.2	4
Sioux Falls	19.2	12.6	71.3	6.7	4

Table 10 (Continued)

Station	Mean value	Standard deviation	Reduction of variance	Standard error	Number of predictors
Eau Claire	19.9	13.2	83.4	6.7	4
Roswell	24.1	9.7	49.7	6.9	8
El Paso	25.5	9.5	55.0	6.3	5
Amarillo	23.1	9.4	41.4	7.2	5
Alb'q'que	20.5	8.6	49.7	6.1	5
Eagle	20.4	7.9	54.1	5.3	4
Grand Jct	21.0	8.5	61.0	5.3	5
Tucson	26.8	11.3	59.0	7.3	3
Los Angeles	43.9	11.7	51.2	8.2	6
Prescott	21.2	11.3	56.9	7.4	7
Reno	24.5	8.3	47.0	6.1	4
Sandberg	23.8	11.8	63.4	7.1	4
Winslow	19.1	9.8	51.0	6.9	5
Blue Canyon	27.0	8.9	37.4	7.0	5
Oakland	43.1	8.1	57.6	5.3	7
Sacramento	41.6	8.1	63.6	4.9	5
Bismarck	18.9	12.6	76.0	6.2	5
Lander	17.8	8.2	54.7	5.6	6
North Platte	22.6	9.3	56.3	6.1	4
Casper	18.7	8.1	43.9	6.1	7
Rapid City	20.8	9.4	54.4	6.3	3
Salt Lake	26.5	7.4	58.0	4.8	5
Winnemucca	25.0	8.4	49.7	6.0	5
Boise	27.8	8.2	60.0	5.2	5
Dillon	19.1	9.3	53.1	6.4	4
Kalispell	23.7	9.9	69.9	5.4	5
Missoula	23.4	10.2	68.1	5.8	5
Pendleton	31.4	8.3	65.7	4.9	4
Pocatello	24.6	8.2	59.0	5.2	5
Spokane	28.6	8.7	71.7	4.6	5
Mt Shasta	30.5	7.8	53.2	5.4	5
Eugene	40.5	7.1	59.0	4.6	5
Medford	36.8	6.9	59.8	4.4	4
Olympia	38.7	7.5	58.1	4.9	5
Redmond	28.2	11.2	50.0	5.7	5
Yakima	28.8	8.0	66.8	4.6	4
Seattle	40.2	7.1	60.0	4.5	5
North Bend	44.8	6.4	55.9	4.3	5
Pueblo	19.6	8.1	27.3	6.9	4
Cedar City	22.8	8.1	46.4	5.9	5
Fresno	40.3	7.4	56.6	4.9	2
Tallahassee	45.8	14.6	76.6	7.1	5
Evansville	32.2	13.0	78.0	6.1	4
Lexington	31.5	12.9	72.9	6.7	5
Glasgow	18.9	12.0	73.1	6.2	5
Pittsburgh	28.1	12.6	72.6	6.6	4
Average	29.3	11.2	66.8	6.2	4.77

TABLE 11

The dew point temperature prediction equations for each of the 89 stations. (Refer to the text in the appendix for the explanation of the equations.)

```
DP(1)=-200.055+.0241*A7(94)-.0385*A10(109)+.2599*DPY(13)+.1859*
DPY(1)
DP(2)=-329.7273+.0235*A7(108)-.057*A10(121)+.0168*A7(94)-.1275*
DPY(6)+.1421*DPY(14)
DP(3)=-174.5413-.0683*A10(110)+.0223*A7(96)+.3301*DPY(3)+.0333*
A10(109)
DP(4)=-200.6529-.06*A10(110)+.0243*A7(96)+.3456*DPY(18)+.033*
A10(109)
DP(5)=-241.7699+.4325*DPY(87)+.0172*A7(94)-.0329*A10(95)+.0109*
A7(81)
DP(6)=-183.6837+.4391*DPY(33)+.0219*A7(81)-.0173*A10(95)-.0096*
A10(82)
DP(7)=-249.6987+.372*DPY(87)+.0179*A7(81)-.0365*A10(95)+.0115*
A7(95)
DP(8)=-168.0074+.0199*A7(81)-.025*A10(95)+.3059*DPY(34)+.2366*
DPY(87)
DP(9)=-198.9077+.0239*A7(82)-.0477*A10(95)+.2934*DPY(87)+.0216*
A10(108)
DP(10)=-202.2607+.0239*A7(82)-.0215*A10(95)+.1581*DPY(15)+.0392*
A10(121)-.0329*A10(109)+.1895*DPY(87)
DP(11)=-254.5535+.0289*A7(94)-.0296*A10(95)+.2652*DPY(15)+.175*
DPY(11)
DP(12)=-238.1304+.0122*A7(82)-.0459*A10(95)+.3008*DPY(87)+.0161*
A10(94)+.016*A7(95)
DP(13)=-206.1217-.0493*A10(96)+.0115*A7(95)+.2029*DPY(23)+.1693*
DPY(15)+.0214*A10(121)+.0124*A7(83)+.0116*A10(97)
DP(14)=-278.2473-.0667*A10(109)+.0221*A7(95)+.2727*DPY(15)+.0341*
A10(121)+.0104*A7(93)
DP(15)=-72.9044-.0436*A10(110)+.2999*DPY(3)+.0163*A7(82)+.0108*
A10(85)+.2054*DPY(23)-.0057*A7(42)
DP(16)=-167.3079-.023*A10(110)+.0207*A7(83)+.32*DPY(3)+.0282*
A10(121)-.0239*A10(96)
DP(17)=-218.5119-.0369*A10(110)+.0262*A7(96)+.3157*DPY(18)+.0282*
A10(109)-.0194*A10(96)
DP(18)=-288.8041-.0333*A10(97)+.0218*A7(84)+.2162*DPY(18)+.0112*
A7(83)+.1927*DPY(45)
DP(19)=-154.7375-.0479*A10(96)+.019*A7(83)+.2296*DPY(17)+.0258*
A10(109)+.1719*DPY(19)
DP(20)=-128.6383+.0149*A7(83)+.2691*DPY(20)-.0216*A10(97)+.2283*
DPY(88)+.0139*A10(122)+.164*DPY(45)
DP(21)=-93.073+.3404*DPY(21)-.0066*A10(84)+.0111*A7(84)-.0094*
A10(85)+.1871*DPY(88)+.008*A10(95)
DP(22)=-184.3175-.0407*A10(96)+.0216*A7(83)+.2244*DPY(38)+.1992*
DPY(3)+.0192*A10(122)
DP(23)=-180.1579-.0379*A10(96)+.0214*A7(83)+.228*DPY(23)+.0205*
A10(109)+.1475*DPY(60)
DP(24)=-309.5878+.0225*A7(55)-.0288*A10(55)+.0129*A7(67)+.2169*
DPY(24)-.0072*A10(68)+.1878*DPY(36)
DP(25)=-104.25+.3056*DPY(33)+.0124*A7(67)-.0112*A10(82)+.3391*
DPY(35)
DP(26)=-127.5442+.2897*DPY(33)+.0153*A7(67)-.0132*A10(82)+.2632*
DPY(35)
```

Table 11 - Continued

```
DP(27)=-174.8959+.5617*DPY(36)+.0198*A7(67)-.0137*A10(68)
DP(28)=-177.0106+.0205*A7(57)-.0146*A10(68)+.3589*DPY(36)+.1576*
DPY(28)
DP(29)=-112.1593+.321*DPY(37)+.0132*A7(81)-.0128*A10(82)+.3005*
DPY(35)
DP(30)=-109.9877+.3225*DPY(33)+.0141*A7(68)-.0102*A10(82)+.2213*
DPY(35)-.0117*A10(95)
DP(31)=-223.0952+.0272*A7(69)-.0144*A10(96)+.242*DPY(42)-.0089*
A10(69)-.0096*A10(83)
DP(32)=-175.4911+.3309*DPY(31)+.0216*A7(82)-.0165*A10(96)-.0129*
A10(82)
DP(33)=-187.5941+.1051*DPY(40)+.0079*A7(68)-.0063*A10(96)-.0102*
A10(69)+.0151*A7(69)+.2058*DPY(36)-.0093*A10(83)
DP(34)=-183.5043+.0223*A7(69)-.0126*A10(69)+.1914*DPY(42)-.0098*
A10(83)+.1401*DPY(36)
DP(35)=-163.8811+.0194*A7(59)-.018*A10(70)+.2482*DPY(38)+.2205*
DPY(42)
DP(36)=-151.6282+.186*DPY(39)+.0111*A7(69)-.0186*A10(57)+.2401*
DPY(35)+.0073*A7(56)
DP(37)=-161.1721+.0197*A7(69)-.0117*A10(69)+.1873*DPY(40)-.0079*
A10(70)+.1629*DPY(36)
DP(38)=-282.4355-.0402*A10(58)+.0328*A7(58)+.2972*DPY(38)
DP(39)=-349.9893+.0285*A7(57)-.0275*A10(58)+.2484*DPY(39)+.0118*
A7(45)-.0167*A10(57)
DP(40)=-317.3907-.0384*A10(70)+.0249*A7(70)+.2005*DPY(38)+.0118*
A7(57)
DP(41)=-259.6676+.0106*A7(59)-.0228*A10(70)+.2865*DPY(42)+.0203*
A7(70)-.0145*A10(96)
DP(42)=-263.8667-.0263*A10(70)+.0309*A7(70)+.2685*DPY(42)-.0091*
A10(84)
DP(43)=-229.5912-.032*A10(70)+.0263*A7(70)+.3488*DPY(88)+.0069*
A10(69)
DP(44)=-298.5315-.0334*A10(70)+.0138*A7(57)+.2491*DPY(38)+.0145*
A7(70)+.006*A7(82)
DP(45)=-180.5594+.3724*DPY(45)+.0133*A7(84)-.0103*A10(98)+.2435*
DPY(53)+.0069*A7(73)-.0068*A10(72)-.1952*DPY(48)+.154*DPY(82)
DP(46)=-71.346+.3855*DPY(46)-.0193*A10(98)+.0095*A7(84)+.1907*
DPY(53)-.0795*DPY(43)
DP(47)=-53.8559+.3069*DPY(47)+.0171*A7(84)-.0097* A7(98)+.2375*
DPY(63)-.0102*A10(97)
DP(48)=-91.4899+.1814*DPY(53)+.2356*DPY(48)+.0105*A7(84)-.0082*
A10(85)+.1886*DPY(83)
DP(49)=-230.9011-.0279*A10(85)+.0258*A7(85)+.2116*DPY(49)+.1638*
DPY(83)
DP(50)=-124.9776+.4021*DPY(50)-.0131*A10(85)+.0137*A7(97)+.1882*
DPY(83)+.1096*DPY(68)
DP(51)=-65.8946+.6439*DPY(51)-.0171*A10(98)+.0083*A7(98)
DP(52)=-88.1721+.3242*DPY(52)-.0276*A10(86)+.0121*A7(98)+.2278*
DPY(46)-.1252*DPY(3)+.247*DPY(81)
DP(53)=67.4882+.4971*DPY(53)-.021*A10(86)+.0351*A10(111)-.017*
A10(98)+.0133*A7(86)-.0185*A7(112)+.1564*DPY(57)
DP(54)=3.5923+.2802*DPY(54)-.0099*A10(87)+.3284*DPY(81)+.1697*
DPY(57)
DP(55)=13.5698+.4048*DPY(55)-.0261*A10(86)+.2926*DPY(57)+.0179*
A10(111)
DP(56)=22.2255+.4055*DPY(56)-.0102*A10(86)+.0071*A7(84)+.24*
DPY(83)-.0079*A7(112)
DP(57)=-50.4517+.2323*DPY(74)-.0111*A10(73)+.2465*DPY(57)+.0062*
A7(85)+.0134*A10(112)
DP(58)=-122.6043+.2414*DPY(81)-.0087*A10(87)+.2166*DPY(58)+.0146*
A7(98)-.0135*A10(86)+.0146*A10(112)+.1157*DPY(48)
DP(59)=14.7254+.4759*DPY(59)-.0083*A10(87)+.0201*A10(98)+.2233*
DPY(74)-.0097*A10(86)
DP(60)=-232.2572-.0266*A10(58)+.0271*A7(58)+.2892*DPY(88)-.0113*
A10(59)+.0078*A10(72)
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Table 11 - Continued

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DP(61)=-199.221+.176*DPY(68)+.0106*A7(97)-.0086*A10(71)+.2558*DPY(
61)+.0111*A7(72)-.0089*A10(72)
DP(62)=-180.0529-.0242*A10(71)+.0209*A7(71)+.2548*DPY(62)+.1444*DP
Y(63)
DP(63)=-116.273+.0497*DPY(68)+.2954*DPY(63)-.0093*A10(72)+.0131*
A7(72)-.0086*A10(71)+.0063*A10(96)+.1634*DPY(66)
DP(64)=-207.9282-.0248*A10(71)+.0239*A7(71)+.2765*DPY(64)
DP(65)=-99.9705+.3046*DPY(65)+.0112*A7(97)-.0054*A10(72)+.2081*DPY
(66)+.1261*DPY(68)
DP(66)=-4.7702+.364*DPY(66)+.2819*DPY(81)-.0050*A10(73)+.0130*
A10(111)+.1946*DPY(54)
DP(67)=-72.5977+.3239*DPY(77)+.2323*DPY(66)-.006*A10(73)+.0076*
A7(98)+.2636*DPY(67)

DP(68)=-137.6684+.3158*DPY(68)+.0143*A7(85)-.009*A10(60)+.2675*DPY
(80)
DP(69)=-141.8214+.3752*DPY(69)+.0155*A7(72)-.0098*A10(60)-.0065*
A10(46)+.2403*DPY(77)
DP(70)=-159.1063+.3855*DPY(77)+.313*DPY(70)-.0111*A10(60)+.017*
A7(72)-.0077*A10(71)
DP(71)=-17.2566+.3456*DPY(77)+.4175*DPY(71)-.0083*A7(47)+.0101*A7(
72)
DP(72)=-115.904+.2846*DPY(72)+.0128*A7(85)-.0095*A10(72)+.2058*DPY
(78)+.2037*DPY(66)
DP(73)=-126.6726+.3157*DPY(77)-.0084*A10(60)+.0141*A7(72)+.3097*DP
Y(73)-.0059*A10(61)
DP(74)=-.6135+.3107*DPY(74)+.3603*DPY(81)-.0072*A10(87)+.0091*A10(
98)+.1677*DPY(57)
DP(75)=-127.2697+.2983*DPY(81)-.0066*A10(61)+.011*A7(99)+.273*DPY
(77)+.0034*A7(83)
DP(76)=-21.8401+.3122*DPY(81)+.373*DPY(76)-.0099*A7(73)+.0128*
A7(86)
DP(77)=-96.415+.4825*DPY(77)+.0116*A7(72)-.0093*A10(61)+.0056*A10(
100)
DP(78)=-104.4358+.2388*DPY(81)-.0096*A10(73)+.0111*A7(86)+.2165*
DPY(78)+.1981*DPY(80)
DP(79)=-81.5035+.3882*DPY(79)-.0086*A10(61)+.0089*A7(72)+.3140*
DPY(80)
DP(80)=-169.8201+.3647*DPY(77)+.014*A7(72)-.0062*A10(61)+.0059*
A7(100)-.0052*A10(60)
DP(81)=-154.015+.3881*DPY(81)+.0116*A7(86)-.0046*A10(61)-.0094*
A10(87)+.0069*A7(100)
DP(82)=-56.9996+.2941*DPY(82)+.1992*DPY(63)-.014*A10(98)+.0074*
A7(72)
DP(83)=-51.0367+.3759*DPY(83)+.1585*DPY(57)+.1264*DPY(53)+.0061*
A7(97)-.0063*A10(86)
DP(84)=8.821+.4063*DPY(59)+.3581*DPY(84)
DP(85)=-372.2253+.022*A7(94)-.065*A10(109)+.2267*DPY(15)+.0211*
A7(109)+.0131*A10(96)
DP(86)=-119.8288-.0252*A10(96)+.0157*A7(82)+.2513*DPY(23)+.1556*
DPY(40)
DP(87)=-122.9053+.196*DPY(22)-.0347*A10(96)+.0157*A7( 82)+.0132*
A10(97)+.1897*DPY(87)
DP(88)=-123.5204+.395*DPY(83)-.027*A10(59)+.0177*A10(72)+.0135*
A7(58)+.2182*DPY(77)
DP(89)=-203.3086+.319*DPY(31)+.0245*A7(82)-.0224*A10(95)-.0114*
A10(82)
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TABLE 12

Verification results using the SS2 procedure from the test period November 15-December 31, 1968 for each of the 89 stations. (°F)

Station	Mean obs	Stand dev	Mean fcst	Stand dev	Mean alg E	Mean abs E	RMSE	Corr coef
Macon	32.4	14.8	35.5	15.2	3.1	6.3	8.5	.860
Orlando	48.4	15.4	50.8	12.0	2.4	5.4	7.6	.832
Houston	44.4	15.0	50.8	14.3	6.4	7.8	9.8	.872
San Antonio	39.3	13.8	44.6	14.5	5.2	8.6	11.7	.727
Raleigh	30.4	15.8	30.0	15.6	-.4	5.6	6.6	.913
Philadelphia	25.9	14.6	25.1	15.0	-.8	4.6	5.6	.925
Richmond	29.1	16.0	28.9	14.2	-.3	5.8	6.9	.904
Washington	27.0	14.6	24.8	13.7	-2.2	4.7	5.7	.932
Charleston	27.8	12.9	28.4	13.0	.6	5.7	6.7	.866
Chattanooga	31.3	14.0	34.2	13.2	3.0	6.7	8.3	.839
Columbia	33.4	15.2	34.7	15.2	1.3	5.9	7.9	.869
Knoxville	29.1	13.1	32.5	13.1	3.4	6.6	8.5	.823
Memphis	33.1	13.1	37.4	13.7	4.3	6.3	8.0	.875
Jackson	38.7	13.4	39.4	16.7	.7	6.9	8.2	.874
Shreveport	38.2	13.4	39.4	14.4	5.2	7.3	9.4	.843
Waco	37.1	14.1	43.2	13.0	6.2	8.5	12.4	.688
Abilene	31.6	13.9	28.1	10.3	-3.4	8.9	11.4	.627
Little Rock	34.3	13.9	36.9	13.8	2.6	4.8	6,4	.911
Oklahoma City	28.6	11.9	26.8	10.2	-1.8	6.9	8.7	.708
Dodge City	21.7	9.0	22.5	6.9	.9	5.0	6.2	.732
Saint Louis	28.4	13.1	28.6	11.9	.2	4.8	6.2	.883
Springfield	26.5	13.9	30.2	11.6	3.7	5.3	6.9	.909
Caribou	16.3	12.8	15.5	11.4	-.7	4.6	6.0	.886
Albany	19.0	13.8	21.1	11.0	2.1	5.0	7.0	.881
Hartford	21.0	14.9	22.3	11.1	1.3	5.5	6.8	.909
Burlington	14.6	14.8	17.0	12.9	2.4	5.7	7.6	.875
Portland	19.6	14.8	20.5	12.1	.9	5.3	6.7	.897
Syracuse	26.2	12.3	22.3	10.5	-3.7	6.0	6.7	.890
Williamsport	25.9	12.7	23.5	10.4	-2.4	5.4	6.5	.884
Chicago	25.1	13.2	25.3	11.3	.2	5.5	7.4	.830
Columbus	26.6	12.6	29.6	10.8	3.1	4.5	5.8	.922
Detroit	25.4	10.5	25.1	9.9	-.3	4.3	5.5	.856
Grand Rapids	24.7	9.9	25.4	8.5	.7	3.8	4.8	.876
Madison	22.9	12.5	21.2	11.5	-1.7	4.3	5.4	.912
S. S. Marie	18.2	12.4	20.4	9.2	2.2	4.8	6.3	.889
Traverse City	22.2	9.3	24.8	8.2	2.6	4.3	5.7	.836
Fargo	14.7	15.5	14.7	12.9	.0	5.0	6.2	.919
Intern'l Fs	12.3	13.5	12.0	11.6	-.3	4.5	5.2	.924
Minneapolis	18.4	15.2	18.8	11.2	.4	4.8	5.8	.950
Moline	23.3	13.6	24.3	11.5	1.1	4.5	5.8	.901
Des Moines	19.3	13.2	21.8	10.2	2.5	4.9	6.2	.913
Sioux Falls	16.3	13.7	15.6	11.8	-.7	4.6	6.0	.903
Eau Claire	16.9	15.1	18.6	11.5	1.7	4.5	5.9	.944
Roswell	20.0	11.1	19.3	7.3	-.7	7.0	9.3	.554
Montgomery	38.1	16.1	41.5	14.2	3.4	7.3	9.3	.845

Table 12 - Continued

Station	Mean obs	Stand dev	Mean fcst	Stand dev	Mean alg E	Mean abs E	RMSE	Corr coef
El Paso	24.8	9.0	23.2	5.8	-1.6	4.8	6.2	.761
Amarillo	20.1	8.4	20.7	6.4	.5	5.0	6.3	.673
Albuquerque	18.6	6.7	18.2	4.9	-.4	3.7	5.0	.679
Eagle	16.6	6.2	16.6	5.3	.0	3.9	4.7	.679
Grand Jct	17.1	6.7	17.4	5.6	.3	3.7	4.7	.727
Tucson	24.7	9.8	24.8	7.0	.1	5.6	7.5	.642
Los Angeles	41.3	11.8	42.9	8.0	1.7	6.2	7.7	.777
Prescott	18.7	9.4	20.1	6.5	1.4	5.2	6.8	.703
Reno	25.9	8.3	24.8	5.4	-1.1	4.0	5.2	.807
Sandberg	20.3	11.8	23.4	6.9	3.1	6.7	8.5	.763
Winslow	16.1	7.8	16.0	5.2	-.1	3.9	5.1	.765
Blue Canyon	25.1	9.3	27.6	5.3	2.4	6.0	7.8	.611
Oakland	45.1	7.1	44.2	6.2	-.9	3.4	4.4	.798
Sacramento	42.6	6.7	43.3	5.8	.7	3.2	3.9	.826
Bismarck	12.3	15.1	15.0	12.7	2.7	5.3	6.9	.909
Lander	11.9	10.2	14.2	7.0	2.3	5.1	6.6	.804
North Platte	14.4	10.2	17.9	7.9	3.5	6.1	8.1	.697
Casper	15.5	10.0	16.6	6.6	1.1	5.1	7.7	.653
Rapid City	14.3	11.6	16.9	8.2	2.6	5.2	7.7	.783
Salt Lake Cty	23.5	5.8	24.9	5.5	1.3	3.5	4.2	.748
Winnemucca	26.6	6.9	26.6	5.7	.0	3.8	4.8	.729
Boise	28.4	8.2	27.6	6.8	-.7	3.4	4.4	.849
Dillon	18.3	9.9	16.2	8.4	-2.1	4.8	6.0	.826
Kalispell	17.3	15.5	18.8	11.8	1.5	4.8	6.6	.925
Missoula	20.4	10.6	20.2	9.9	-.3	3.4	4.4	.911
Pendleton	29.3	12.7	29.2	9.1	.0	4.3	6.2	.891
Pocatello	19.8	8.1	23.7	6.7	3.8	4.7	6.1	.804
Spokane	24.1	14.0	26.0	10.2	1.9	4.5	6.7	.906
Mt Shasta	29.1	7.0	30.1	5.6	1.0	3.1	3.8	.854
Eugene	40.9	7.4	39.7	6.2	-1.2	3.4	4.4	.820
Medford	34.5	6.7	36.1	5.3	1.6	3.9	4.8	.744
Olympia	37.1	9.6	36.1	7.7	-1.0	3.9	5.1	.858
Redmond	26.0	10.3	26.1	6.4	.0	4.1	6.5	.793
Yakima	27.4	13.5	25.9	9.7	-1.6	4.6	6.3	.911
Seattle	35.7	10.5	37.4	7.3	1.8	4.4	6.1	.849
North Bend	43.7	6.1	43.9	5.7	.2	2.9	3.8	.799
Pueblo	15.3	8.6	15.4	4.6	.1	5.8	7.5	.475
Cedar City	17.7	6.4	19.6	4.8	1.9	4.6	5.4	.620
Fresno	43.2	6.4	41.6	4.6	-1.7	3.7	4.8	.711
Tallahassee	40.9	17.7	43.8	15.3	3.0	6.3	8.6	.890
Evansville	31.3	12.6	31.4	13.1	.2	5.4	6.9	.854
Lexington	29.0	11.8	32.0	12.0	3.0	5.9	7.2	.849
Glasgow	12.4	15.7	14.6	13.1	2.2	4.8	7.0	.910
Pittsburgh	25.0	12.5	25.0	11.6	.0	3.8	4.9	.920
89-Station Average	26.1	11.7	27.1	9.8	1.0	5.1	6.6	.822

Average Reduction of Variance 63.7 %

(Continued from inside front cover)

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