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OBJECTIVE AIDS FOR FORECASTING MINIMUM TEMPERATURES AT RENO, NEVADA, DURING THE SUMMER MONTHS

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I. INTRODUCTION

Objective methods for relating meteorological parameters at some afternoon hour to forecast the subsequent minimum temperature are well known [1]. In the early 1960s staff members at Reno WSFO began using dry-bulb and dew-point temperature measurements taken at 2100 GMT as predictors of the minimum temperature for the following morning for a number of winter months. In this same vein, objective forecast aids for the summer months have now been developed with some additional refinements.

II. DISCUSSION

The HO-60 temperature dew point sensing equipment used by Reno WSFO is located at approximately the lowest elevation in a basin whose floor is at 4,400 ft. above sea level, sloping slightly downward to the north and east. To the west, the massive Sierra Nevada rise to elevations of nine- to eleven-thousand feet while to the east the Virginia Mountains reach six-to seven-thousand feet above sea level. As a result, weak drainage flow during the night is the general rule with the coldest air settling in the vicinity of the sensors by morning. Differences of ten or more degrees in morning temperatures have been noted between the primary HO-60 and standard minimum thermometers in the National Weather Service (NWS) shelter about one-fourth mile to the west. Minimum temperatures are very sensitive to low-level mixing and cloud cover during the night and especially near sunrise. However, during nonadvective conditions which are predominate over the Great Basin during the summer months, utilization of the 2100 GMT dry-bulb, dew-point measurements as gauges of the air-mass characteristics which govern the rate of radiational cooling was found to work quite well.

III. DEVELOPMENT OF THE FORECAST CHARTS

On an individual month-by-month basis for June through September, cases were singled out which met the following criteria: (a) skies were fair and no catabatic (or downslope) winds were occurring at the time the predictors were measured, (b) the subsequent morning had clear skies and surface winds were five knots or less from 0800 GMT through sunrise. In this study downslope winds are defined as winds having a sustained speed of ten knots or greater with a direction between 220 and 320 degrees and not associated with a cumulonimbus cloud or thunderstorm.

All the cases from the period 1963 through 1972 which met criteria (a) and (b) above were then used as a basis for developing scattergrams for each of the four months. It was found that for the months of August and September, a combination of this technique weighted equally with persistence yielded improved skill over the basic scattergram or simple persistence.

Cases where downslope winds, a common phenomena at Reno during the summer months, were occurring at the time the predictors were read were then examined. It was found that the forecast curves had an overall bias of a positive error in these instances and a refinement was developed for each month to compensate for this. The presence of downslope at the time the predictors are measured produces by adiabatic compression a dry-bulb reading that is higher than is actually representative of the air-mass characteristics. This is supported by the observation that if the winds develop later in the afternoon or during the evening, no such bias is evident.

The small percentage of cases where clouds or wind persisted through the night were then considered. No additional variables or criteria have been developed to compensate for the large negative bias given by the forecast scheme when applied to these cases. It was found, however, that adding nine degrees Fahrenheit yielded the largest reduction of error on the dependent data.

A. June:

Figure 1 is the resultant scattergram for June based on all cases which met criteria (a) and (b). Area B is the refinement for cases which fall in the downslope category. When the 2100 GMT dry-bulb and dew-point readings of a downslope case fall in area B, five degrees are subtracted from the value obtained from the curves to obtain the forecast minimum temperature. Interpreting areas A and B physically, it is noted that a dry-bulb temperature above 75 degrees (area A) depicts relative humidities below fifteen percent. As a result, the air mass is sufficiently dry that higher dry-bulb readings due to the downslope effect are of little consequence when the nocturnal radiation process begins. The normal or expected 2100 GMT dry-bulb temperature is slightly above 80 degrees. In view of this, area A below 75 degrees can be interpreted as often delineating cases where observed winds fit the downslope definition but in actuality are pressure driven or synoptic scale winds and an advection term is at work. If the winds have reached the surface indicating considerable mixing in the lower levels of the atmosphere and the dew point remains relatively high, this would indicate the air mass has sufficient moisture content to inhibit the normal radiational cooling process.

An alternate physical explanation can also be set forth. Downslope winds rarely commence as early as 2100 GMT at Reno unless the thermal surface trough is over the Great Basin. In these instances the pressure gradient force is enhancing the drainage of cold air from off the Sierra Nevada through the night. This would account for the positive bias given by the forecast curves.

Cases which met the criteria for development of the scattergram comprised sixty percent of the total June cases on the ten years of dependent data and yielded an average absolute error of 2.6 degrees Fahrenheit. Positive or negative error bias was nonexistent with 43 percent of the cases having a positive error and 43 percent a negative error. Downslope cases comprised twenty percent of the total. Use of the five-degree correction when a downslope case fell in area B resulted in an average error of 2.5 degrees. The remaining twenty percent of the June cases were when clouds or winds persisted through the night and using the 9-degree correction yielded an average error of 3.1 degrees. Thus on the ten years of dependent data the total average absolute error for the month of June was 2.7 degrees.

B. <u>July</u>:

Figure 2 was derived in the same fashion as Figure 1. Seventy percent of the cases met criteria (a) and (b) and produced an average error of 2.9 degrees on the dependent data. It was found that for the 17 percent of the cases which fit the downslope category, a simple subtraction of four degrees from the value obtained from Figure 2 worked best. The fact that the correction is applicable throughout the entire spectrum of predictor values is an indication that the second physical explanation set forth in the previous section may be predominate during July. When the surface thermal trough is east of the Sierra Nevada, the pressure-gradient force aids in maximum drainage of cold air into the valleys of western Nevada.

The average error on the downslope cases is 2.5 degrees. Again the cases used to arrive at the scattergram showed a lack of bias in the error analysis with 41 percent positive and 42 percent negative; the remaining 13 percent of the total July cases were those where clouds or winds persisted through the night and the average error obtained using the plus 9-degree correction was 3.9 degrees Fahrenheit. The total average error for all cases was 3.0 degrees.

C. <u>August</u>:

The same procedure was followed as in the cases of June and July. However, the resultant scattergram showed much lower skill on the dependent data. It was found that a combination of the scattergram curves and persistence gave much better results. The cases where skies were fair and winds were light and variable at 2100 GMT followed by a night where skies were clear and winds were light comprised 79 percent of the dependent data. These were used to construct Figure 3 and yields an absolute average error of 2.9 degrees. Downslope cases were poorly correlated, possibly due to the introduction of another predictor. However, a blanket correction of minus two degrees for cases which met the criteria gave the largest reduction of error on the dependent data resulting in an average error of 3.9 degrees. The remaining 6 percent of the August cases were where skies remained cloudy or winds persisted through the night. The nine-degree correction gave an average error of 3.7 degrees on these cases. Thus the total average error for all August cases was 3.1 degrees.

To use Figure 3, enter the graph with the 2100 GMT dew point from the left and the dry-bulb temperature from the bottom. From the point where these two values intersect, follow parallel to the dashed guidelines up or down to the point opposite the value equal to the observed morning low temperature as indicated along the right side of the graph. At the intersection of the appropriate guideline and the morning low, interpolate the forecast minimum temperature from the labeled solid curves. For example, with a 2100 GMT dew point of 35 degrees, a dry-bulb reading of 85 degrees and a morning low of 36 degrees, the graph yields a forecast minimum of 40 degrees.

D. September:

Development of the forecast curves was the same as for the month of August. Seventy percent of the total dependent data met the previously established criteria necessary to be used in preparing the scattergram. Figure 4 is used in the same manner as Figure 3 and yields an average absolute error of 2.6 degrees on the developmental cases. On the 18 percent of the total which fit the downslope category, a blanket subtraction of three degrees produced an average error of 3.5 degrees. The remainder of the cases, where clouds or winds persisted through the night, gave an average error of 3.5 degrees with the plus nine-degree correction. Combining all September data yields an average error of 2.9 degrees.

IV. SUMMARY

The following table summarizes the performance of the forecast curves on the ten years of dependent data in terms of absolute average error and percent of total cases in parentheses.

TABLE I

MONTH	FAIR	DOWNSLOPE	CLOUDY	TOTAL
JUNE	(60) 2.6	(20) 2.5	(20) 3.1	(100) 2.7
JULY	(70) 3.0	(17) 2.5	(13) 3.9	(100) 3.0
AUGUST	(79) 2.9	(15) 3.9	(06) 3.7	(100) 3.1
SEPTEMBER	(70) 2.6	(18) 3.3	(12) 3.5	(100) 2.8
TOTALS	(70) 2.8	(18) 3.0	(12) 3.3	(100) 2.9

Figure 5 gives flow diagram of the use of objective aids.

V. CONCLUSIONS

An objective method for forecasting minimum temperatures at Reno during the summer months has been developed. The forecast aid performs satisfactorily during the predominance of cases where fair weather persists throughout the night. Objective methods compensating for downslope cases have also been incorporated into the aid. Cases where the radiational process is inhibited by clouds or surface wind must be treated subjectively; however, objective constants have been determined.

VI. REFERENCE

[1] SUTTON, O. G. *Micrometeorology*, 1953.

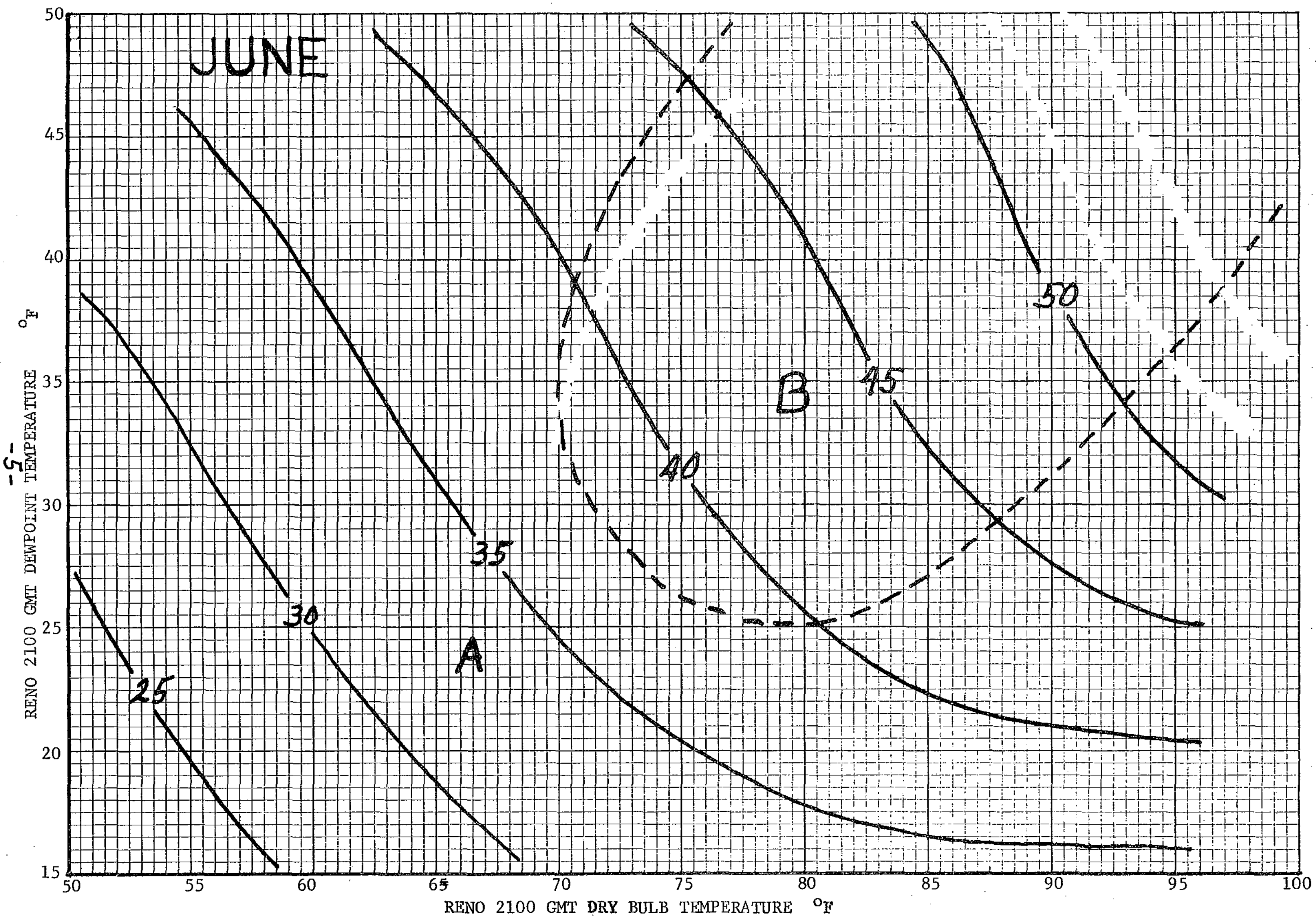

FIGURE I. JOINT RELATIONSHIP IN JUNE BETWEEN PREDICTORS (RENO 2100 GMT DRY-BULB AND DEW-POINT TEMPERATURES) AND THE RENO MINIMUM TEMPERATURE OCCURRING THE FOLLOWING MORNING. IF 2100 GMT WIND IS ≥ 10 KNOTS FOR 220 TO 320 DEGREES AND POINT DETERMINED BY DRY-BULB AND DEW-POINT TEMPERATURE FALLS IN AREA B, SUBTRACT 5 DEGREES FROM VALUE GIVEN BY ISOLINES.

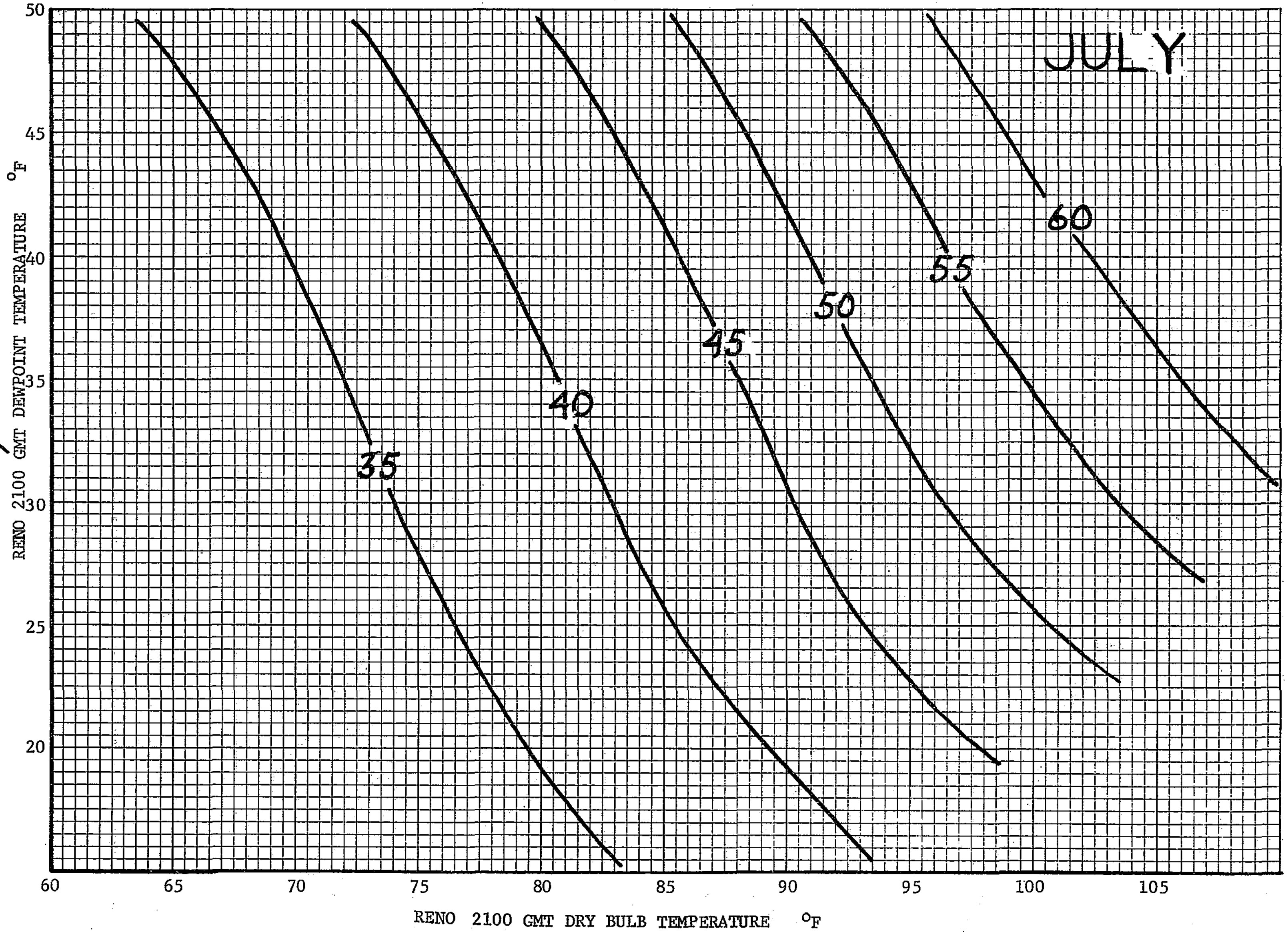

FIGURE 2. JOINT RELATIONSHIP IN JULY BETWEEN PREDICTORS (RENO 2100 GMT DRY-BULB AND DEW-POINT TEMPERATURES) AND THE RENO MINIMUM TEMPERATURE OCCURRING THE FOLLOWING MORNING.

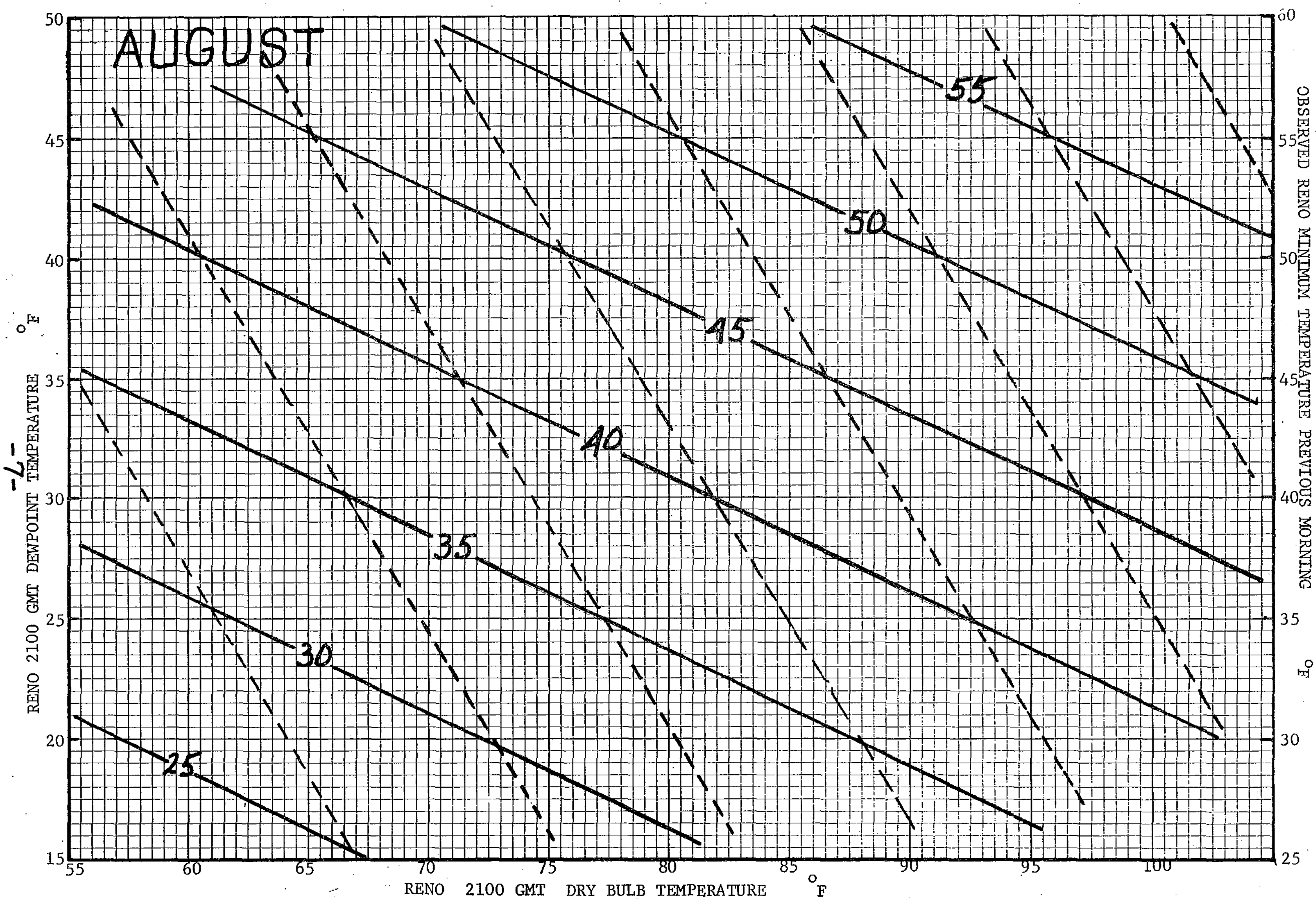

FIGURE 3. JOINT RELATIONSHIP IN AUGUST BETWEEN PREDICTORS (RENO 2100 GMT DRY-BULB AND DEW-POINT TEMPERATURES AND PREVIOUS MORNING MINIMUM TEMPERATURE) AND THE RENO MINIMUM TEMPERATURE THE FOLLOWING MORNING.

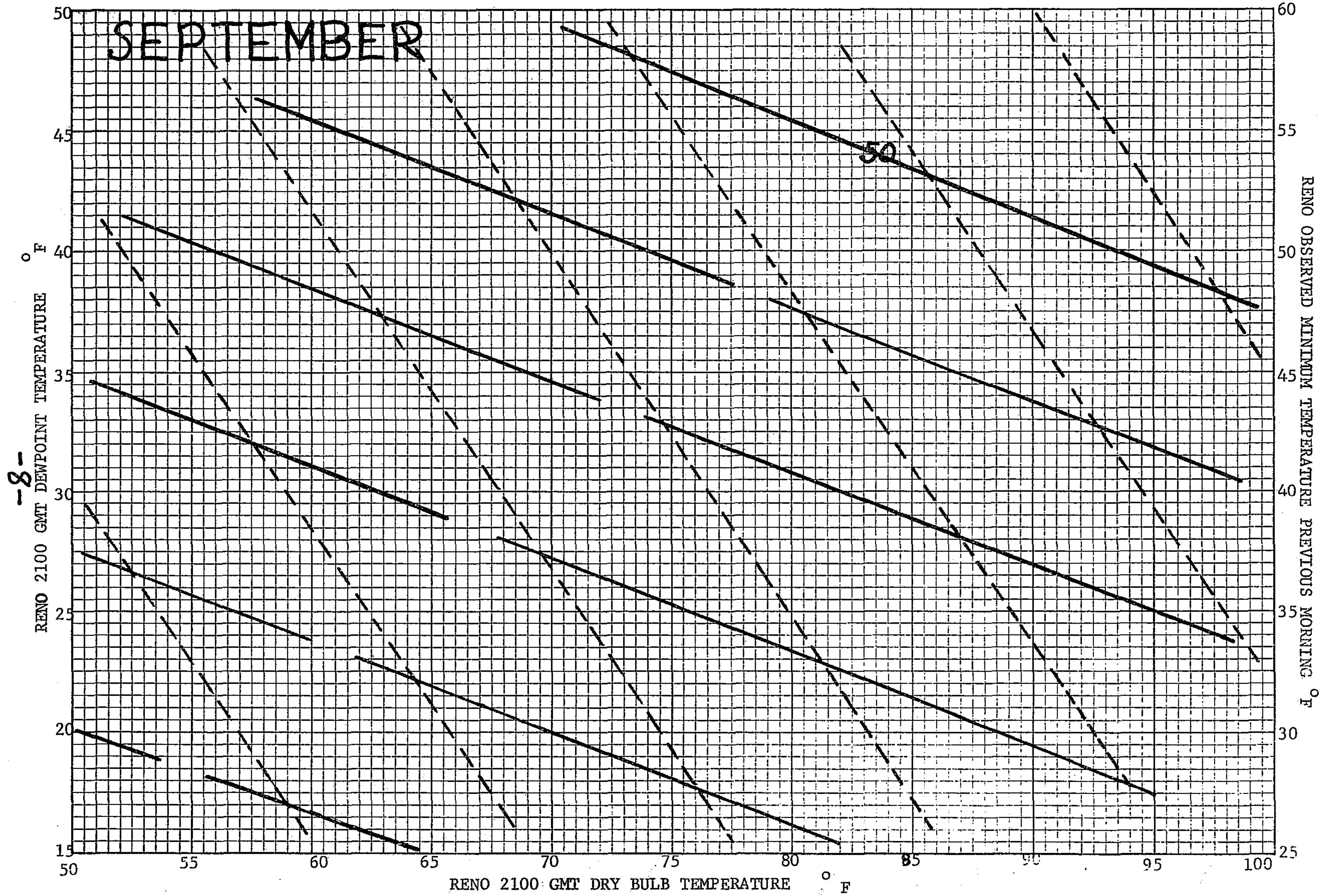

FIGURE 4. JOINT RELATIONSHIP IN SEPTEMBER BETWEEN PREDICTORS (RENO 2100 GMT DRY-BULB AND DEW-POINT TEMPERATURES) AND THE RENO MINIMUM TEMPERATURE THE FOLLOWING MORNING.

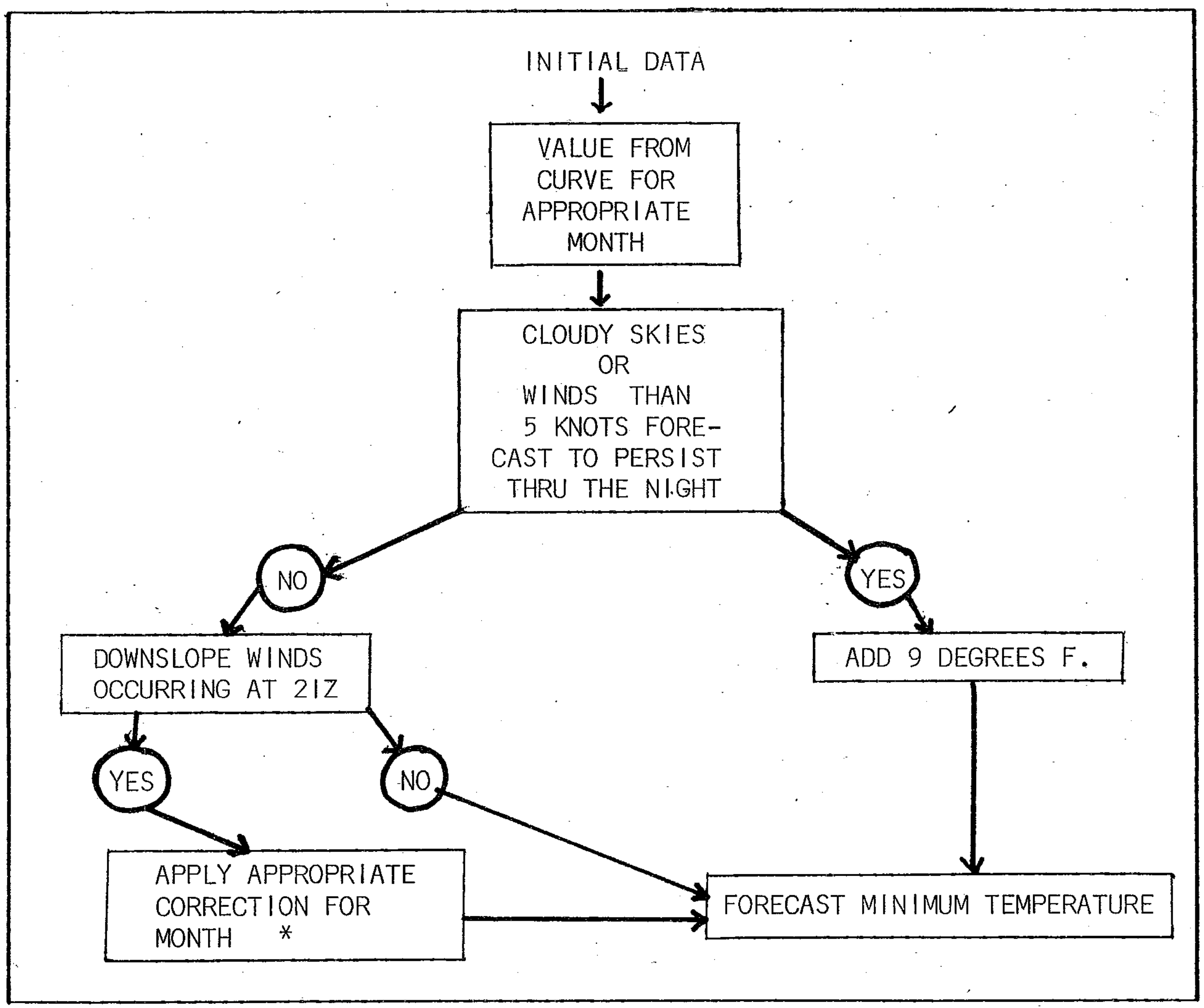

FIGURE 5. FLOW DIAGRAM SUMMARIZING THE USE OF THE OBJECTIVE AIDS.

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