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AIDS FOR FORECASTING MINIMUM TEMPERATURE IN THE WENATCHEE FROST DISTRICT

Robert S. Robinson

National Weather Service Western Region
Salt Lake City, Utah
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Richard Frank, Administrator /
NATIONAL WEATHER SERVICE
Richard E. Hallgren, Director

This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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AIDS FOR FORECASTING MINIMUM TEMPERATURE IN THE WENATCHEE FROST DISTRICT

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I. INTRODUCTION

As in other fruit-frost districts, the Hygrometric Formula (Ellison, 1928) has been used in Wenatchee as an aid to forecasting minimum temperatures during the spring. However, this formula was developed for the Wenatchee key station and there is a wide variation in minimum temperatures across the district, averaging about 12°F between the warmest and coldest key stations during April and May. More importantly, due to the elevation differences and rugged terrain, there are no consistent relationships between frost key stations. While National Meteorological Center (NMC) guidance in the form of MOS minimum temperature forecasts is available for Yakima, experience has shown that it is not reliable enough for use as an aid in the fruit-frost forecasting in north-central Washington. Because of these factors, a semiobjective may-typing system has been used which is usually very helpful in determining minimum temperature distribution across the district and somewhat useful in obtaining absolute values. To complement this scheme, an objective aid was sought which would estimate the coldest minimum temperature to be expected among the key stations in the district on a given night.

II. PROCEDURE

As in other minimum-temperature studies, it was decided in the beginning to eliminate nights in which cloudiness was a factor. A review of past records indicated that cirrus of any amount, classified as thin, did not have any significant effect on minimum temperatures. Also, any cloud coverage of one-half or less was usually not enough to prevent at least one or two key stations in the district from achieving good nighttime radiation conditions. An examination of nights during five past seasons showed that 41 percent of all nights met this high-radiation criterion during April and May. Of these nights, 84 percent were cold (32°F or less at any key station) during April and 69 percent during May. Therefore, efforts were directed toward developing an aid which would indicate the coldest temperature in the district on nights with clear to scattered clouds or thin cirrus only. The sky-cover observations for 06Z, 09Z, and 12Z at Pangborn Field (EAT) near Wenatchee were used to measure the degree of cloudiness over the district.

Two types of forecasts are issued during the frost season for the Wenatchee district. Individual key station forecasts are made in the evening. However, a preliminary estimate of the lowest key station temperature expected in the district is issued in the morning for the following morning. Two aids were developed to utilize information available at these times of day. A number of variables which have been used in other minimum temperature forecast schemes (Dickey) and (Oard, 1977) were examined in developing the aid for use in the evening. These included 700- and 850-mb temperatures, maximum temperature, surface temperature at 00Z, relative humidity, 1000- to 500-mb thickness, 700- to 1000-mb thickness, dew point at 00Z, and cos N X day of the year (where N was any of a few tested integers*). The stepwise multiple regression technique used by Oard would have been the ideal method to handle the correlation of these variables and arrive at the most efficient regression equation. However, since the necessary computer facility was not availalbe, selection of variables was accomplished by manual computation of linear correlation coefficients on a small sample. While some of these variables showed good correlation with minimum temperature, most were eliminated because they were also highly correlated with either 1000- to 500-mb thickness or dew point. The independent variables finally chosen were a locally derived 1000- to 500-mb thickness and surface dew point, both taken at 00Z. The thickness was computed from the average of the 00Z surface pressures at EAT and Omak (OMK) and an average 500-mb height over the district. The dew point used was the lowest of Wenatchee WSO and OMK at 00Z. The cos 2 X day of the year was added to try to account for the shortening length of night during the season. The improvement in multiple correlation coefficient between variables and minimum temperature, reduction of variance, and standard error of estimate due to the addition of successive variables chosen is shown in Table 1. These were computed for 105 nights, 1964-1975, using a WANG programmable calculator on loan from Seattle WSFO. Verification on 79 nights during 1976, 1977, and 1978 (Table 2) showed no significant improvement due to the addition of cos 2 X day of the year (nor did any of the other values for N). Therefore, the final regression equation was formed using only the thickness and dew point as independent variables.

Selection of variables for an aid for the morning preliminary forecast followed the same procedure as outlined above. Variables tested were mainly from 12Z data in April and May 1972-1976. The final variables chosen were the 1000- to 500-mb thickness at Quillayute (UIL) at 12Z and cos 2 X day of the year (Table 3). Verification of the regression equation developed from these variables on the independent sample (1977-78) is shown in Table 4.

III. RESULTS

Test results in Tables 2 and 4 show that both aids can provide useful forecasts of minimum temperature providing the amount of cloudiness can be properly assessed. Graphical solutions to the regression equations were prepared (Figures 1 and 2) for operational use. The utility of the morning forecast aid has been increased by recognizing the ability of the LFM model to forecast with reasonable accuracy the 1000- to 500-mb

*Editor's Note: Normally cos N X day of year, where N=1, is used in such studies. This study, however, is only over a two-month period (April and May), not the full 360-day period of the complete cycle of cos 1 X day of year, so other N values were tested as well.

thickness in the vicinity of UIL. Based on experience with the facsimile output of the LFM thickness prog on the 12Z run, the accuracy is less than useful beyond 24 hours. As indicated in Table 5, however, the thickness forecast by the LFM at 24 hours is very good. The average error in the thickness forecast over UIL during the 1976 and 77 seasons was less than 25 meters during April and May. When this is applied to the morning forecast aid, it results in a variation of less than one degree F. This should allow a forecaster to make a more accurate assessment of the potential district minimum temperature about 48 hours in advance.

Several shortcomings have also been identified. Strong warm advection causes both equations to forecast temperatures too high. When an increase in the 1000- to 500-mb thickness occurs at this time of year, it more often acts as a stabilizing factor, capping cooler air at low levels. Strong cold advection on the other hand doesn't seem to introduce any significant bias. While wind is a factor governing minimum temperatures, the topographical makeup of the district is such that wind lulls will occur during the early morning allowing temperatures to fall to near values forecast by the aids at some station within the district. One exception to this occurs when the amount of cloudiness is just within the specified limits on windy nights. Verification of equation 1 indicated that on the average the mean 1000- to 500-mb thickness at 00Z between UIL and Spokane (GEG) may be used in place of the locally derived value without greatly impairing accuracy. Sufficient data of this kind were not available for the development of the equation.

IV. SUMMARY

Regression equations and their graphical solution were developed as aids for forecasting the lowest minimum temperature among frost key stations in the Wenatchee frost district on a given night during the spring. Two aids were developed, one based on morning data for the preliminary frost forecast and one based on evening data for the primary forecast. Both require that nights have no more than scattered clouds or thin cirrus. Verification on independent data showed both equations to be quite useful. To further improve their usefulness, more study is needed to objectively determine whether or not sufficient cloudiness will be present to affect minimum temperatures.

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TABLE 1

Equation 1

SUMMARY OF REGRESSION ESTIMATE OF MINIMUM TEMPERATURE FOR 105 NIGHTS, 1964 - 1975

VARIABLES USED	MULTIPLE CORRELATION COEFFICIENT	REDUCTION OF VARIANCE	STD. ERROR OF ESTIMATE
1000- to 500-mb Thickness	0.7802	0.6087	2.5672
1000- to 500-mb Thickness and 00Z Dew Point	0.8408	0.7070	2.3222
1000- to 500-mb Thickness 00Z Dew Point, and cos 2 X day of year	0.8631	0.7450	2.1336

TABLE 2

Equation 1

VERIFICATION ON THREE YEARS OF DATA, 79 NIGHTS, 1976-77-78

VARIABLES USED	MEAN ABSOLUTE ERROR	STD. ERROR OF ESTIMATE
1000- to 500-mb Thickness	2.0534	2.5715
1000- to 500-mb Thickness and 00Z Dew Point	1.7020	2.1250
1000- to 500-mb Thickness, 00Z Dew Point, and cos 2 X day of year	1.6959	2.2201

TABLE 3

Equation 2

SUMMARY OF REGRESSION ESTIMATE OF MINIMUM TEMPERATURES FOR 99 NIGHTS, 1972 - 1976

VARIABLES USED	MULTIPLE CORRELATION COEFFICIENT	REDUCTION OF VARIANCE	STD. ERROR OF ESTIMATE
UIL 1000- to 500-mb Thickness	0.6981	0.4874	3.1725
UIL 1000- to 500-mb Thickness, and cos 2 X day of year	0.7563	0.5719	2.9133

TABLE 4

Equation 2

VERIFICATION ON 1977 and 78 SEASONS, 63 NIGHTS

VARIABLES USED	MEAN ABSOLUTE ERROR	STD. ERROR OF ESTIMATE
UIL 1000- to 500-mb Thickness	2.3657	3.1027
UIL 1000- to 500-mb Thickness, and cos 2 X day of year	2.001	2.5947

TABLE 5

LFM 1000- to 500-MB THICKNESS FORECASTS, 12Z 24-HOUR PROG - 1976-77 (Decameters)

VARIABLES USED	MEAN ABSOLUTE ERROR	STD. ERROR OF ESTIMATE
April	2.4400	3.1559
May	2.1452	2.8933
COMBINED	2.2768	3.0133

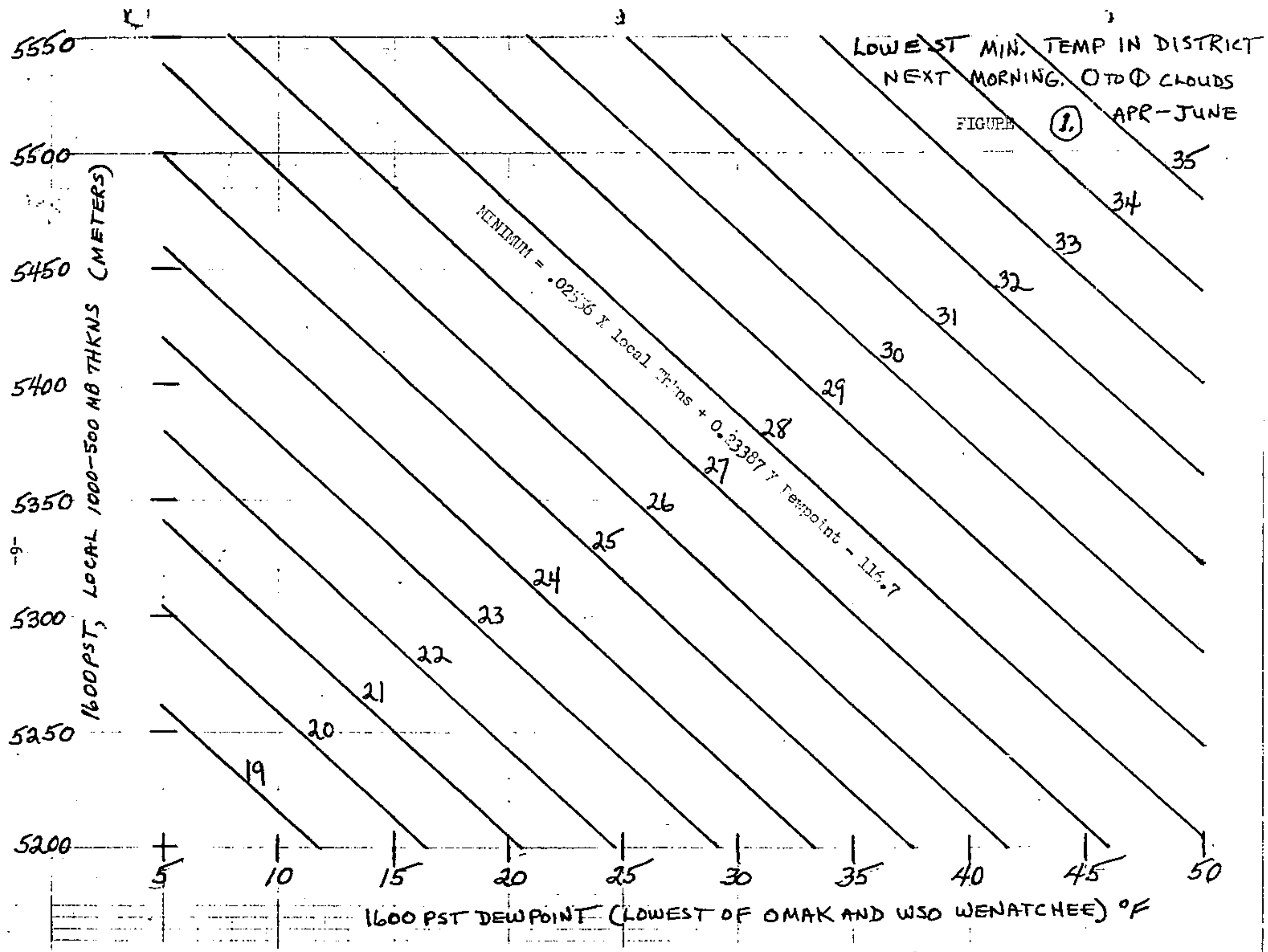

FIGURE 1. LOWEST MINIMUM TEMPERATURE FORECAST NOMOGRAM FOR THE DISTRICT ON THE NEXT MORNING USING 1600 PST DEW POINT AT OMAK OR WENATCHEE (WHICHEVER IS LOWER) AND THE 1600 PST INTERPOLATED 1000-500 MB THICKNESS.

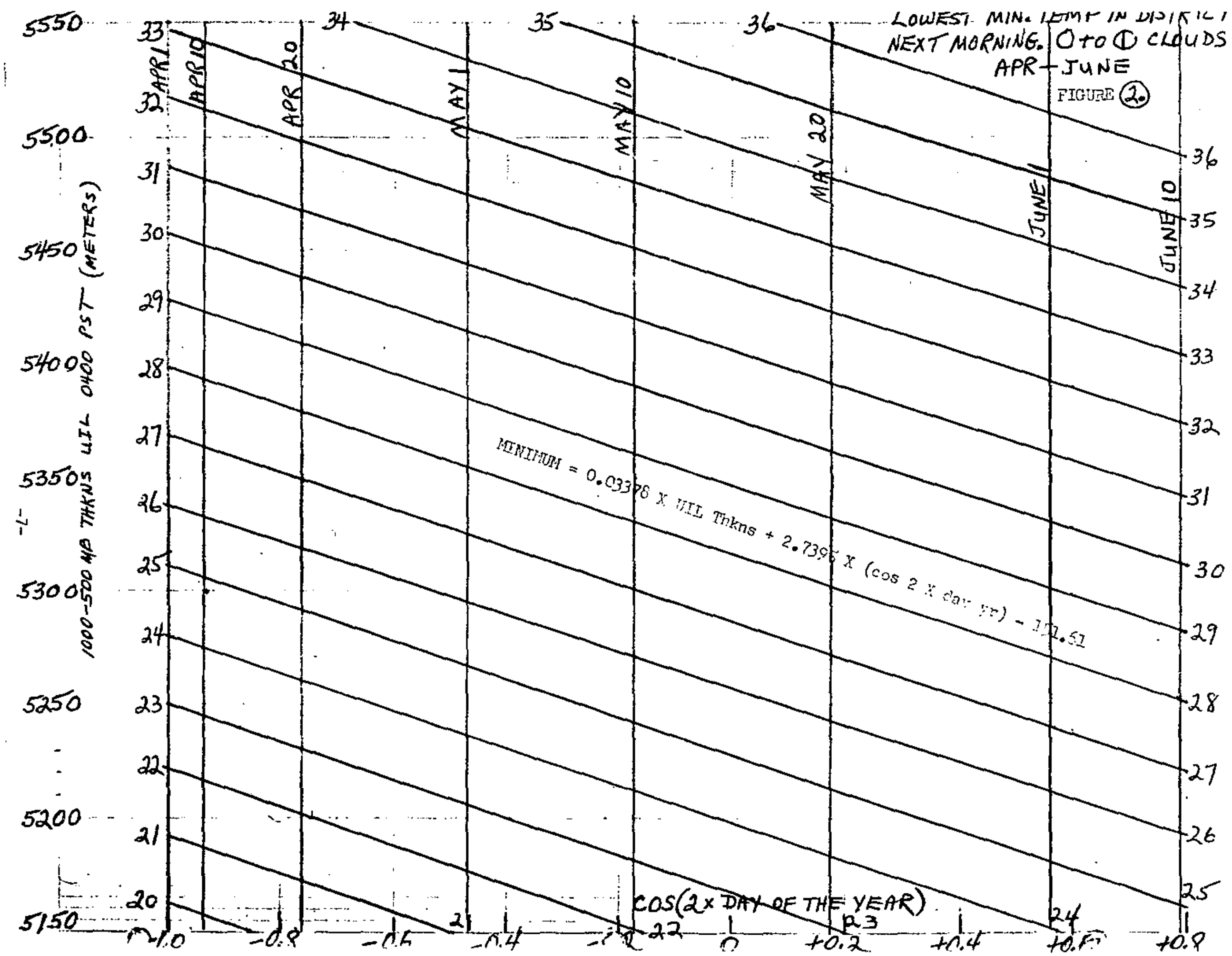

FIGURE 2. LOWEST MINIMUM TEMPERATURE FORECAST NOMOGRAM FOR THE DISTRICT ON THE NEXT MORNING USING COS (2 X DAY OF THE YEAR) AND 0400 PST 1000-500 MB THICKNESS AT QUILLAYUTE.

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