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A MINIMUM TEMPERATURE FORECAST AID FOR RADIATIONAL COOLING SITUATIONS IN THE LOWER RIO GRANDE VALLEY OF TEXAS

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1. Introduction

The Lower Rio Grande Valley of Texas is known for its relatively mild winters. But nonetheless, the area is subject to freezes that can severely damage the citrus, winter vegetable, and sugar cane crops. Agricultural losses from major freezes may total many millions of dollars and may adversely affect the local economy for several years.

The devastating freeze of December 1983 resulted in a loss of more than half the citrus trees in the valley, and fruit production the following season was virtually zero. In 1982-83, the last complete production year prior to the freeze, total grapefruit and orange production value was more than $50 million (Texas Agricultural Extention Service, 1985).

Freezes in the valley may be classified as <u>advection</u> freezes or <u>radiation</u> freezes--or occasionally a combination of the two. Both are associated with outbreaks of arctic air. However, advection freezes are associated with wind (often strong) and perhaps clouds, while radiation freezes are characterized by clear skies and light or calm wind. With the advection freeze, the arctic high pressure center is usually still plunging southward from western Canada. With the radiation freeze, the arctic high is generally centered near or over the valley.

Advection freezes such as December 1983 are necessarily associated with <u>major</u> arctic outbreaks and are therefore (fortunately) quite rare. Radiation freezes, however, typically affect the valley one or more times each year. Because of the potential losses involved, a freeze (or freeze threat) brings tremendous pressure on the forecaster from not only the agricultural community but also the media. It is therefore imperative that the forecast be as accurate as possible.

This paper offers a forecast equation that is directed toward the radiation type of freeze and other non-freezing radiational cooling situations that affect the valley each year.

2. Data Used in the Study

Data consisted of monthly Local Climate Data (LCD's) for Brownsville from January 1971 to March 1985. Three-hourly observations and subsequent minimum temperatures were scanned, and 80 cases of near-maximum radiational cooling were identified. Each of the selected cases followed passage of a cold front and met the following criteria:

1. Clear skies or scattered cirrus during the late afternoon and night.
2. Calm or light wind (less than 5 mph) during the night.
3. Little or no advection, i.e., little change in dewpoint.

3. Development of the Forecast Equation

The forecast equation was developed using multiple linear regression. The equation was originally developed in 1978 and revised in 1979. At that time, 33 radiational cooling situations had been identified in the available data. The predictand (dependent variable) was the minimum temperature observed at the Brownsville airport during the Fruit-Frost season of November through March.

Landsberg (1958) discussed the use of afternoon values of wet-bulb and air temperature as predictors for nighttime minimum temperatures. Wet-bulb temperature is not readily available to the forecaster. However, it can be computed using known values of air temperature and dewpoint temperature. For simplification--and for more descriptive characteristics of the airmass at the station--it was decided to try afternoon values of air temperature and dewpoint temperature as predictors.

Using 3pm values of temperature and dewpoint as independent variables and minimum temperature as the dependent variable, correlation coefficients and lines of regression were computed. As indicated in Figures 1 and 2, the relationships were promising. Correlation coefficients were quite high, and both were determined to be highly significant--even for only 33 cases.

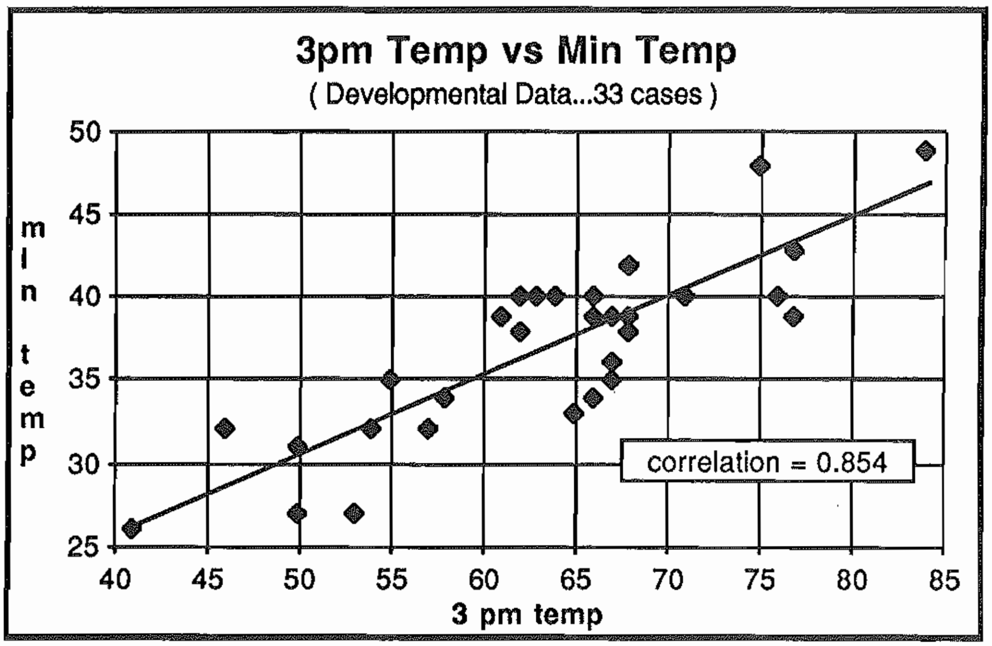

Figure 1.

Other predictors were considered. But since the data were already screened for similar conditions of wind, sky cover, and synoptic pattern, it was decided to introduce a seasonal characteristic as a third predictor. The function

cosine(day of year + 165)

was chosen so that similar values of temperature and dewpoint would be associated with lower minimum temperatures in January than in November or March. Since the cosine function has its minimum value at 180 degrees, the above function has its lowest value on January 15th. This matches the seasonal trend of minimum temperature at Brownsville. Figure 3 illustrates this function.

Using the above predictors and the 33 developmental cases, the following equation for minimum temperature was computed:

$$\text{min} = 0.2538\ T_3 + 0.2712\ Td_3 + 8.6296\ \cos(\text{day} + 165) + 21.1353$$

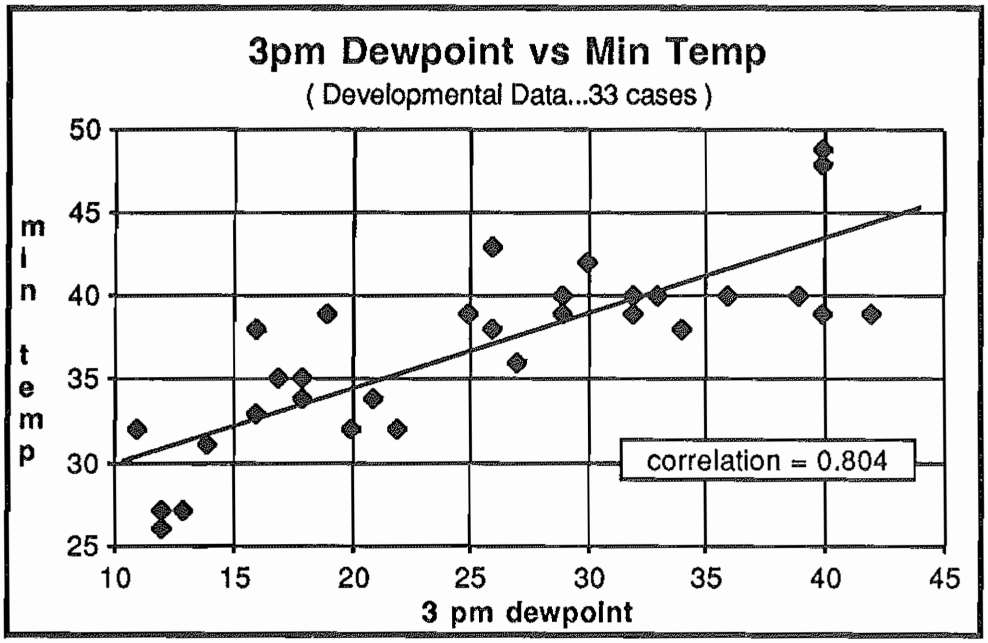

Figure 2.

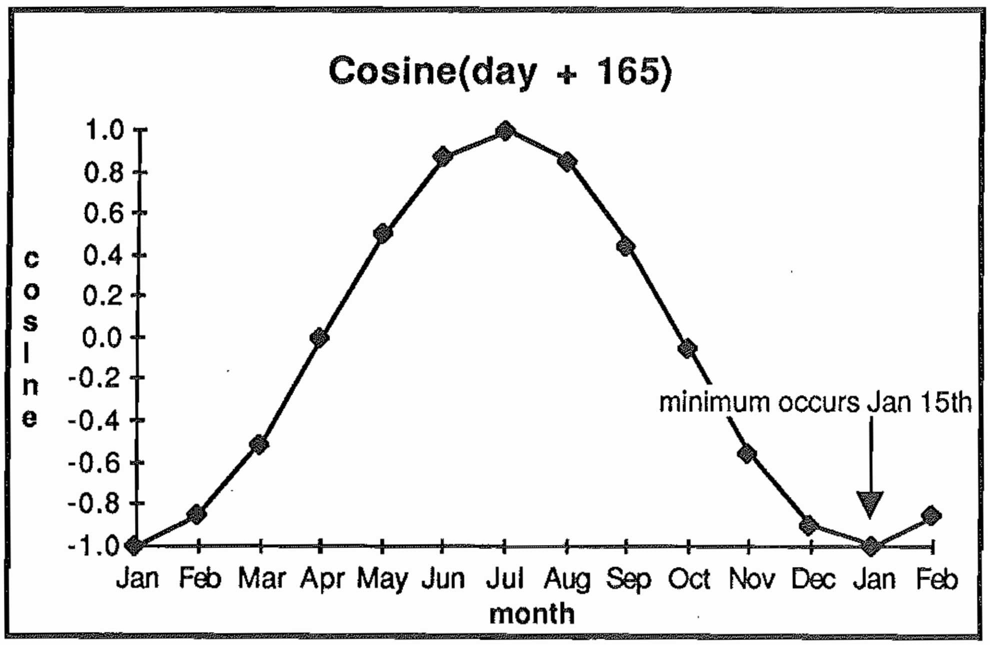

Figure 3.

where T_3 is 3pm temperature and Td_3 is 3pm dewpoint. It should be emphasized that the cosine function is expressed in degrees. To convert to radians (as used by most computer languages), the cosine function must be multiplied by 0.0175.

Results of the regression calculations are summarized in Table 1. The coefficient of determination, R^2, statistically suggests that 91% percent of the variance in minimum temperature can be explained by the regression. Also, the standard error of estimate suggests that about 67% of the errors should be within 1.6 degrees.

variables	correlation
3pm temp & min temp	0.8539
3pm dewpoint & min temp	0.8040
cos(day + 165) & min temp	0.5400
3pm temp & cos(day + 165)	0.4110
3pm dewpoint & cos(day + 165)	0.1820
3pm temp & 3pm dewpoint	0.6130
multiple correlation coeff,	R = 0.9562
coeff of determination,	$R^2 = 0.9142$
std error of estimate =	1.64

Table 1.

Using the above equation and the developmental data, forecast minimum temperatures were computed. The forecast and observed temperatures and statistics on the resulting errors are summarized in Figure 4. As indicated by deviations from the least-squares line of best fit, the equation obviously worked quite well on the developmental data. The correlation between forecast and observed temperature (0.951) compares closely with the multiple correlation coefficient (0.956) in Table 1. Also, 85% percent of the errors were within 2 degrees.

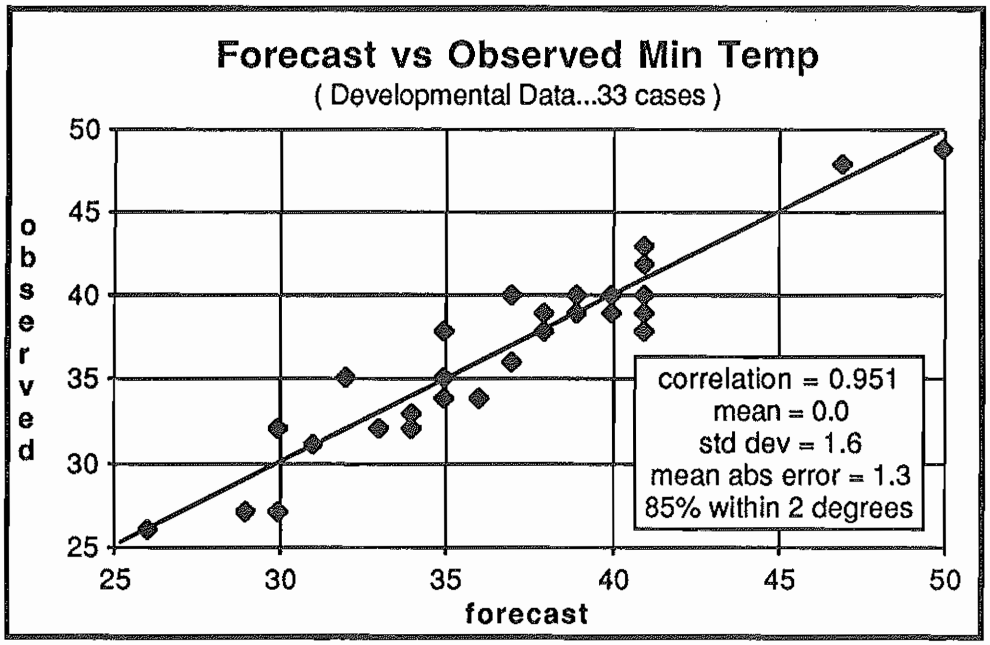

Figure 4.

4. Test of the Equation on Independent Data

As pointed out by Panofsky and Brier (1968), relationships between meteorological variables occur in regimes. The best test of a forecast equation is therefore how well it performs on independent data. Since the equation was developed in 1979, it has been tested on 47 additional radiation situations--the most recent in March of 1985. The results are indicated in Figure 5.

The equation performed amazingly well on the independent data. The mean absolute error was 1.5 degrees, and 79 percent of the errors were within 2 degrees.

In fact, the maximum error among the 47 independent cases was 3 degrees. A comparison of Figures 4 and 5 reveals almost no difference in forecast accuracy between the developmental and independent data. The forecast equation appears to be quite stable.

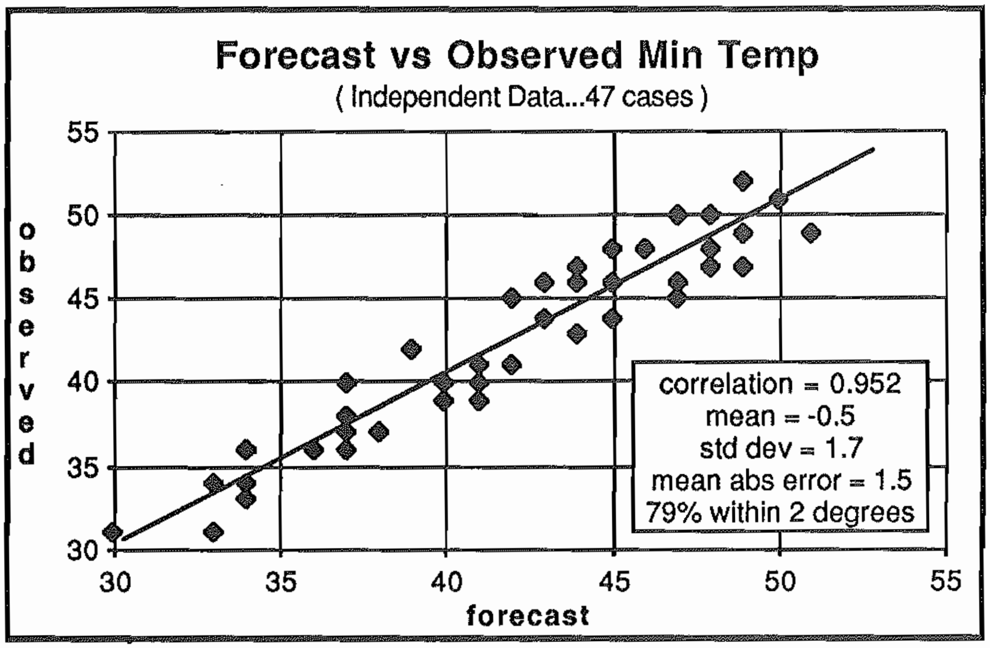

Figure 5.

5. Summary of Forecast Equation and its Application

The minimum temperature forecast equation is for the Brownsville airport and is valid during the Fruit-Frost season which includes the months of November through March. The equation may be expressed with the cosine function in degrees as

$$\text{min} = 0.2538\ T_3 + 0.2712\ Td_3 + 8.6296 \cos(\text{day} + 165) + 21.1353$$

or with the cosine function in radians as

$$\text{min} = 0.2538\ T_3 + 0.2712\ Td_3 + 0.1510 \cos(\text{day} + 165) + 21.1353$$

where

T_3 = 3pm temperature
Td_3 = 3pm dewpoint
day = day of year (expressed as integer from 1 to 365).

The required criteria for using the equation are:

1. A cold front has passed and high pressure is expected to settle near or over the valley.
2. Clear skies or scattered cirrus is expected during the late afternoon and night.
3. Wind is expected to remain less than 5 mph during the night.
4. Little or no advection is expected.

The cosine function gives the equation a seasonal characteristic so that the forecast temperature will correspond to the climatological trend in minimum temperature. As indicated in Figure 6, forecast temperatures based on the same 3pm temperature and dewpoint will vary considerably from November through March.

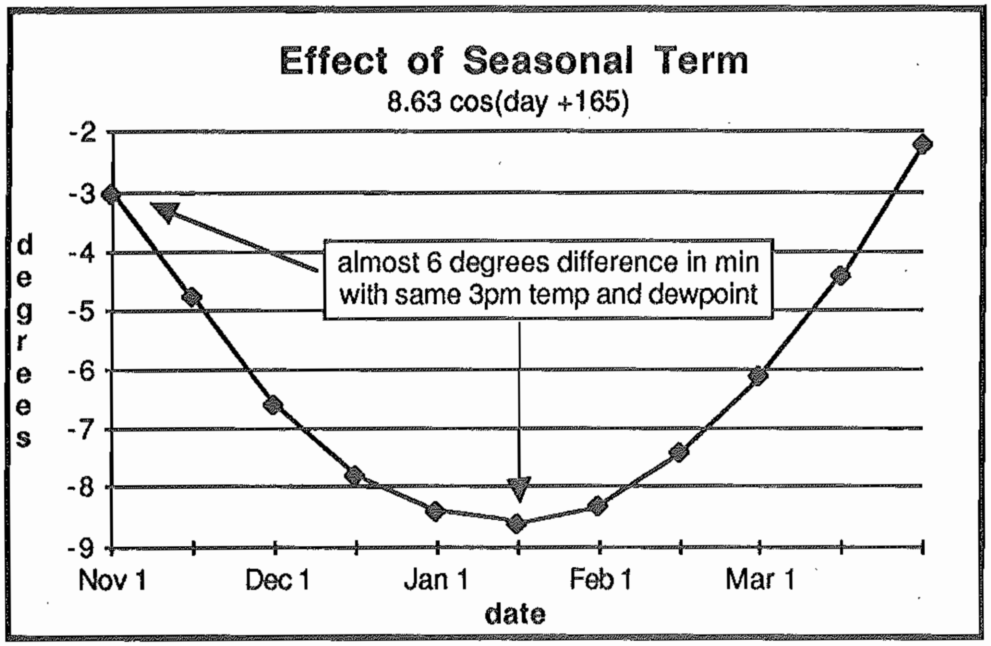

Figure 6.

6. Conclusion

This paper has presented a minimum temperature forecast equation that has performed well for 47 independent radiational cooling situations during the past six years. It is an objective technique that is intended to supplement rather than replace other guidance that is available to the forecaster.

Although the forecast equation is only for Brownsville, the same predictors might lead to similar equations for other locations where minimum temperature forecasts are critical.

Acknowledgements

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