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Daily Maximum and Minimum Temperature Forecasts and the Influence of Snow Cover

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NOTES AND CORRESPONDENCE

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ABSTRACT

Research into the relationship between snow cover and observed maximum and minimum temperatures is reviewed. An example of the importance of snow cover and forecasting max/min temperatures is presented for this past winter (1976–77). It is shown that there was a warm bias in the MOS temperature forecasts for the northern Great Plains following the receipt of a fresh cover of snowfall. It is proposed that snow cover be incorporated as a conditional predictor to be used only during specific synoptic conditions.

1. Introduction

The National Weather Service has been providing automated calendar day maximum and minimum temperature forecasts for the conterminous United States since 1965. Until early 1973, the forecast model consisted of the "Perfect Prog" method (Klein and Lewis, 1970). The Model Output Statistics (MOS) approach to forecasting max/min temperatures was implemented operationally during August 1973 (Glahn and Lowry, 1972; Klein and Glahn, 1974). Since that time, the National Weather Service has been providing automated centrally produced forecasts (with four forecast projections of 24, 36, 48 and 60 h after initial model time) of max/min temperatures for 228 stations in the conterminous United States.

This paper examines the research to date on the relationship between snow cover and max/min temperature forecasts. An example of a warm bias in forecasted temperatures, which is attributed to the presence of a fresh snow cover, is presented for this past winter (1976–77). Suggestions for the inclusion of snow cover as a predictor are also presented.

2. Snow cover and max/min temperature forecasts

During the early development and testing of a forecast model for max/min temperatures (Klein and Lewis, 1970 and Klein *et al.*, 1971) snow cover was considered as a possible predictor. Intuitively, it was assumed that snow cover should have a significant influence on observed temperatures, resulting in lower temperatures than would have occurred over bare ground. It has been argued that the lower maxima are caused by the higher albedo of the snow surface which reflects more of the incoming solar radiation than the darker bare ground. Lower minima are produced by enhanced nocturnal radiation over the snow cover which has a higher emissivity than bare ground. In addition, the snow cover can act as an insulting layer blocking the direct upward radiation of heat stored within the soil (assuming the soil to be unfrozen).

The results of screening max/min temperatures as a function of snow cover in binary form and previous surface temperatures (past 24 h observed maximum and minimum temperatures) at a network of 43 stations gave 1) the best single predictor of both maximum and minimum temperature is the field of previous minimum temperature (explaining about 70% of the temperature variance), and 2) inclusion of the previous day's maximum temperature field increases the reduction of variance by about 6% for forecasts of the maximum and 2% for forecasts of minimum, (Klein and Marshall, 1973). Snow cover as the only predictor explained 40% of the temperature variance but, when included with the temperature fields, was found to offer very little additional reduction of variance (1% for maximum forecasts and 3% for the minimum forecasts). These results were discouraging and, combined with the difficulty of obtaining adequate snow-cover data, led to a decision not to include snow cover as a predictor of max/min temperature in the Perfect Prog model.

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Shortly thereafter (in August 1973) the MOS technique of forecasting max/min temperatures became operational in the National Weather Service. The MOS equations included several additional factors which were not included in the earlier system and which had been only subjectively analyzed by the forecasters. Observed surface conditions at 0600 and 1800 GMT and forecast boundary layer and 850 mb wind speed and direction are examples of these new predictors. The number of stations included in the forecast model also increased from 131 to 228 cities in the conterminous United States. With these improvements, the accuracy of the automated forecasts continued to improve. As illustrated in Fig. 1, verification of forecasted max/min surface temperatures indicates that the overall mean absolute error in the 24 h projection is now less than 3.5°F (Hammons *et al.*, 1976).

It is significant to note that the MOS equations are based on synoptic-scale models which exclude important mesoscale features such as localized topographic influences, urban influences, atmospheric turbidity, fog from nearby water bodies or in low lying areas and *snow cover*. The importance and significance of these factors is left to the subjective interpretation of individual forecasters.

Despite the improving accuracy of max/min temperature forecasts, there were occasional incidents of a warm bias in temperature forecasts which were attributed to snow cover. The region most affected seemed to be the Great Plains area. Most noteworthy of the evidence concerning the alleged warm bias was a report coming out of National Weather Service Central Region (Curran and Ostby, 1974). Using data from the 1973–74 winter, Curran and Ostby noted that, during periods when there was a snow cover of 1 inch or greater, the automated temperature forecasts were usually too warm. It was also concluded that the forecast bias steadily increased in magnitude the higher the forecasted temperature.

3. A recent example of the influence of snow cover on observed temperatures

A late winter snowstorm struck the Great Plains on 3–4 March 1977. The resultant snow cover after this storm is illustrated in Fig. 2. Combined with the fact that the snowfall had been below normal in the area during the winter, the late winter snow fell for the most part on bare ground. The synoptic pattern of the week following the snowfall was dominated by the slow eastward movement of a large anticyclone (central pressure 1029.5 mb) across the mid portion of the United States. Mostly clear skies with light winds existed throughout the Great Plains region for over five days following the snowstorm. These conditions presented an ideal opportunity to examine the performance of our automated max/min temperature forecasts for adjacent snow-covered and non-snow-covered areas in the center of the country. Due to a lack of frontal activity and cloudiness during the post snowfall period (as revealed in an examination of the hourly data and 3 h surface charts of the region) as well as the geographic character of this region (lack of significant orographic and urban influences), it was assumed that any mesoscale variation in observed temperatures should be strongly related to the presence of the new snow cover.

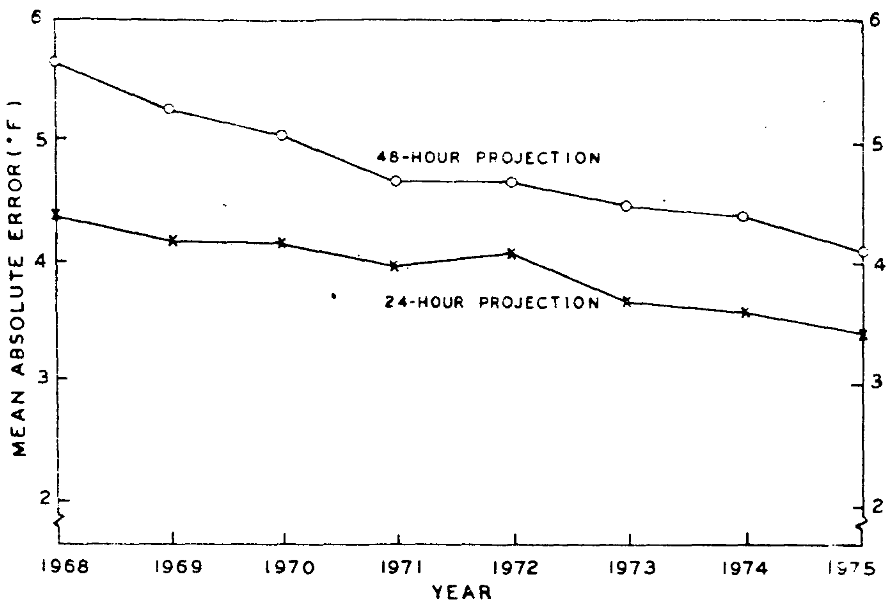

FIG. 1. Verification of automated forecasts of maximum and minimum surface temperatures produced as nationwide guidance on an operational basis in the National Meteorological Center. (From Hammons *et al.*, 1976.)

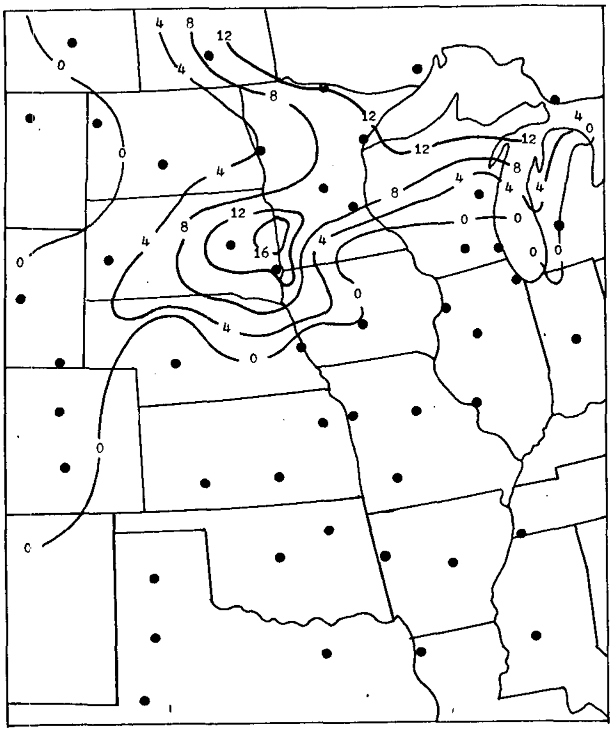

FIG. 2. Snow cover (inches) 1200 GMT 5 March 1977. Solid circles indicate MOS max/min stations, snowfall data are from NMC facsimile chart N74.

Fig. 3 illustrates the 5–9 March average departure of the observed temperatures (T_0) from the predicted temperatures (T_p) for the maximum temperatures and Fig. 4 for the minimum temperatures. The forecast max/min temperatures for the period were 24 h forecast values, and verification was achieved by comparison with observed temperatures which were reported to the National Meteorological Center and stored on computer tape. Table 1 is presented to indicate the daily departures ($T_p - T_0$) which occurred at two National Weather Service stations in South Dakota (near the center of the observed warm forecast bias).

It can be seen from Figs. 3, 4 and Table 1 that there was a significant warm bias in the MOS forecasts of max/min temperatures for the period 5–9 March. The largest average departure exceeded 17°F, almost five times the average departure illustrated in Fig. 1. However, the magnitude of the warm bias on some days was even larger, as illustrated for Sioux Falls and Huron, S. D. The largest forecast error occurred at Huron on 7 March (+23°F). The max forecasts errors for the region of the warm bias were consistently larger than the min errors for each 24 h forecast period. The reason for this difference in forecast error magnitude is probably related to the importance of solar radiation at this time of year. The solar input during March is considerably greater than in December; therefore, the strong contrast in albedo when comparing dark soil and snow-covered surface manifests itself in relatively little heating of the air near the snow surface. Had this synoptic occurrence taken place in early January, it is anticipated that the reduced importance of solar input would have resulted in approximately equal maximum and minimum temperature forecast errors.

An interesting feature of the two verification maps (Figs. 3 and 4) is the lack of a warm forecast bias toward the northern portion of Minnesota. Since the snow cover extended through this region, it might seem unusual that a significant warm bias did not exist here as well. If one considers the climatology of the area and the nature of the derivation of the forecast equations, this is not really unexpected. If an area is normally snow covered, the data upon which the forecast equations are derived will reflect this. The forecast equations have been derived for individual stations; therefore, any climatologically normal phenomenon (for example, a persistent snow cover and relatively lower temperatures) will automatically be incorporated into the equation. The fresh fall of snow and subsequent five-day snow cover was a climatologically normal phenomenon during this time of year for the northern portion of the region. This meant that forecast errors due to the presence of a snow cover were not to be expected in northern Minnesota.

4. Conclusions

In conclusion, this note is not intended to provide a final definitive statement on the influence of snow

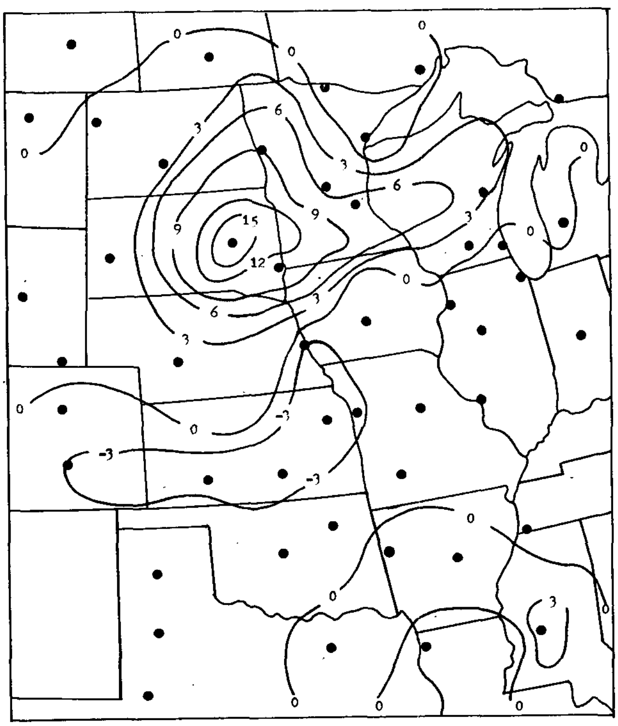

FIG. 3. Average maximum temperature forecast error $T_p - T_0$ (°F), 5–9 March 1977.

cover on maximum and minimum temperatures. Instead, it is presented to demonstrate partial evidence for the inclusion of snow cover as a predictor in automated max/min temperature forecasts. It is unlikely that the incorporation of snow cover as a predictor will lead to a significant reduction in variance for regions where a snow cover is a persistent phenomenon during the winter. Nor should the inclusion of snow cover as a predictor result in a large reduction of variance during all synoptic conditions.

It is proposed that there are specific synoptic conditions (as illustrated above) where snow cover will provide a significant reduction of variance in max/min temperature forecasts. Therefore, I intend to attempt to isolate those types of synoptic conditions in which snow cover appears to be a significant predictor. Through an examination of max/min forecast errors in conjunction with the surface charts, I anticipate that snow cover will be shown to be an important predictor 1) in the central portion of the United States (where snow cover occurs periodically during the winter season) and 2) primarily during periods of extensive clear skies and light winds (cloudiness, precipitation and strong winds should have a tendency to ameliorate any relative temperature differences). The final product produced by this research effort will be modified max/min temperature forecast equations which will include snow cover as a predictor and which will be utilized only in selected geographic areas when snow cover exists, as well as only when specific synoptic criteria are satisfied.

TABLE 1. Max/min temperature verification (5–9 March 1977) for Sioux Falls and Huron, S. D. All values °F.

	Sioux Falls (FSD)		Huron (HON)	
	Max	Min	Max	Min
5 March				
T_p	38	18	41	18
T_0	28	7	28	3
$T_p - T_0$	+10	+11	+13	+15
6 March				
T_p	42	13	44	14
T_0	31	8	28	0
$T_p - T_0$	+11	+5	+16	+14
7 March				
T_p	54	20	60	22
T_0	40	11	37	13
$T_p - T_0$	+14	+9	+23	+9
8 March				
T_p	59	33	60	28
T_0	45	18	41	23
$T_p - T_0$	+14	+15	+19	+5
9 March				
T_p	56	25	59	29
T_0	48	27	41	23
$T_p - T_0$	+8	−2	+18	+6
Average 5–9 March	+11.4	+7.6	+17.8	+9.8

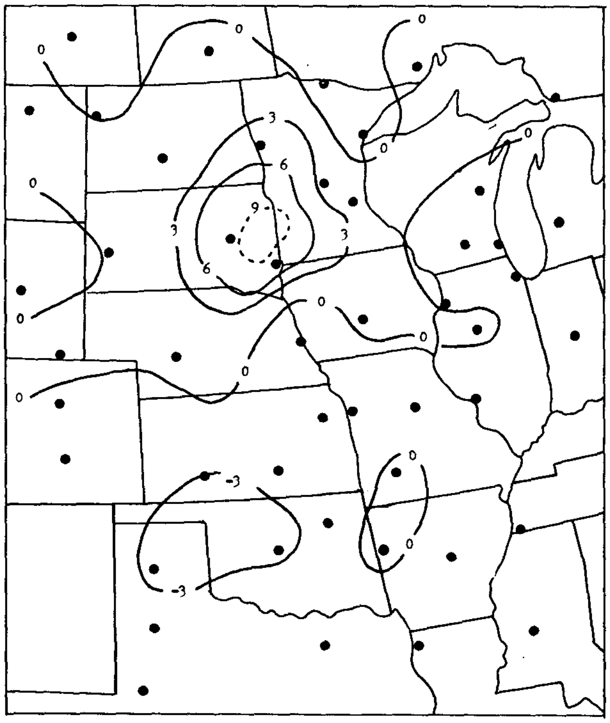

FIG. 4. Average minimum temperature forecast error $T_p - T_0$ (°F), 5–9 March 1977.

REFERENCES

Curran, J. T., and F. P. Ostby, 1974: Bias of NMC objective surface temperature forecasts. Central Region Tech. Attachment 74–1, National Weather Service, Kansas City, Mo. 4 pp.

Glahn, H. R., and D. A. Lowry, 1972: The use of model output statistics (MOS) in objective weather forecasting. *J. Appl. Meteor.*, **11**, 1203–1211.

Hammons, G. A., J. P. Dallavalle and W. Klein, 1976: Automated temperature guidance based on three-month seasons. *Mon. Wea. Rev.*, **104**, 1557–1564.

Klein, W. H., and F. Lewis, 1970: Computer forecasts of maximum and minimum temperatures. *J. Appl. Meteor.*, **9**, 350–359.

——, and H. R. Glahn, 1974: Forecasting local weather by means of model output statistics. *Bull. Amer. Meteor. Soc.*, **55**, 1217–1227.

——, and F. Marshall, 1973: Screening improved predictors for automated max/min temperature forecasting. *Preprints 3rd Conf. Probability and Statistics*, Boulder, Amer. Meteor. Soc., 36–43.

——, F. Lewis, and G. A. Hammons, 1971: Recent developments in automated max/min temperature forcasting. *J. Appl. Meteor.*, **10**, 916–920.