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SHORT COMMUNICATION

Estimation of Minimum Surface Temperature at StageII

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ABSTRACT

Forecasting minimum surface temperature at a station, StageII, located in mountainous region requires information on the meteorological fields. An attempt has been made to develop a statistical model for forecasting minimum temperature at ground level using previous years' data. Surface data were collected at StageII (longitude 73 °E, latitude 34 °N, and altitude 2650 m). Atmospheric variables are influenced by complex orography and surface features to a great extent. In the present study, statistical relationship between atmosphere parameters and minimum temperature at the site has been established. Multivariate linear regression analysis has been used to establish the relationship to predict the minimum surface temperature for the following day. A comparison between the observed and the calculated forecast minimum temperature has been made. Most of the cases are well predicted (multiple correlation coefficient of 0.94).

Keywords: Minimum surface temperature forecasting, avalanche hazard, snowpack stability, snow studies, temperature forecasting models

1. INTRODUCTION

The western Himalayan region mainly remains covered with snow during winter months (December to April) due to significant amount of precipitation yield shaded by eastward moving low pressure weather systems known as western disturbances. Local orography influences these systems and hence modifies the existing meteorological fields. Knowledge of minimum surface temperature in advance is important to assess snowpack stability for avalanche hazard. Sometimes, intense weather inversions due to low minimum temperature are also of importance. One of the obvious reasons for this is the phenomenon of cold and dry day, which is an important event during winter season.

In the present study, an attempt has been made to evolve an objective forecasting method based on multivariate statistical technique to forecast the minimum temperature in the winter season at StageII, required to assess avalanche threat and is useful for defence personnel operating in Jammu and Kashmir region. To achieve the objective, snow and meteorological data sets of past years have been taken into account. A minimum surface temperature value of the following day at StageII has been correlated with these data sets. Using forward screening technique, potential predictors were selected and linear regression equation generated. Verification of the developed model set has been carried out on an independent data set for prediction of minimum surface temperature for the following day.

In India, researchers have studied various techniques for forecasting maximum and minimum temperatures. Development of forecasting technique of maximum temperature at Ozar (Maharashtra) was carried out by Mohan[1], *et al.* Regression techniques were used by Raj[2] for developing a scheme for

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predicting minimum surface temperature at Pune. Attri[3], *et al.* used multiple regression method for forecasting minimum temperature at Gangtok.These studies mainly considered dew point temperatures,amount of cloud and the maximum and minimum temperatures on the previous day. Raj[4] had developed forecasting scheme based on statistical techniques for development of forecasting daily summer (March–May) maximum temperature of Chennai.

2. DATA & ANALYSIS PROCEDURE

For predicting minimum surface temperature at StageII, data sets of 1992 (January to April and December) and of 1993 (January to April) have been utilised. The performance of model was verified with independent data set of December 1995.

In general, at StageII, the lowest of minimum temperatures is associated with cold waves and clear nights. After the passage of western disturbances, nocturnal cooling over the region and heat exchange between ground surface and adjacent atmosphere, formation of mist and fog over the ground surface is a phenomenon to be understood.

These temperature variations are a major contributing factor for forming surface hoar over the snow surface, which are weak bonds to withhold the snow mass, hence, avalanche release. Prediction or knowledge of minimum surface temperature enables one to understand these physical processes.

For evolving the equation for minimum surface temperature, surface observation corresponding to 0830 IST and 1730 IST at StageII were utilised. The lead-time for prediction of minimum surface temperature on the basis of availability of data and operational requirements has beeen kept at 24 hr and the same is issued at 0830 IST.

Missing observations in data sets were closed using linear interpolation of the previous and subsequent observation of meteorological parameters and also by using consistency of time, space and synoptic conditions. However, data of the predictand, viz., minimum surface temperature of StageII, were all observed values only.

3. DEVELOPMENT OF MODEL

Multiple regression technique was used, in which a linear composite of explanatory variables (predictors) formation has been done in such a way that it has maximum correlation with a criterion variable (predictand). The main objective of using this technique is to predict the variability of the dependent variable based on its covariance with all the independent variables. The given levels of independent variables (meteorological parameters at StageII) define prediction of the level of the dependent phenomenon, i.e., variation in minimum temperature at StageII. Stepwise regression method is utilised for the selection of statistically significant predictions.

Further, short range, location specific and time specific deterministic prediction of surface weather elements is one of the intricate problems of weather forecasting. Secondly, orography and topography makes the prediction more difficult. Since the objective of the study is to forecast minimum surface temperature at StageII in 24 hr in advance, the inputs consists of observational data available at the time of forecast and are expressed as

$$Y_t = f\,(X_0) \tag{1}$$

where Y_t is the forecast value of the predictand (minimum surface temperature) at time t (24 hr in the present case) and X_0 is observational data at time 0 or available at that time. All the predictors, as given in Table 1, are subjected to screening for the forecast of minimum surface temperature. Some of these parameters are intercorrelated and also

Table 1. List of potential predictors used

	Predictors and their notations	Station	Total
Surface	Ambient surface temperature (t_a) maximum surface temperature (t_x) minimum surface temperature (t_n) snow surface temperature (t_w) fresh snowfall (h_n) standing snow (*hs*) snowfall intensity (s_{in}) sunshine duration (*ss*)	StageII	08
Persistence	Minimum surface temperature (T_{min})	StageII	01
Total			09

are measured with certain degree of observational error. Hence, only few of the potential predictors are selected which can explain most of the variance of the predictand. As a result, only small number of predictors get selected which define linear relation of information wrt predictand. In this study, F-test is utilised to select significant predictors with 95 per cent confidence level. The stepwise procedure continues by adding one predictor at a time to the model. After each step, selection of predictors is verified and insignificant predictor from regression point of view is rejected. This process goes on until no significant improvement in variance value is found.

4. RESULTS & DISCUSSION

Detailed statistical analysis of minimum surface temperature (predictand) at StageII was carried out before establishing their relationship with meteorological parameters. The basic statistics, such as mean and standard deviation and range were computed monthwise and for the whole season, based on the data of development period.

To examine the seasonal variation further, daily normal values were computed based on dependent data, for StageII and was smoothed. Mean of minimum surface temperature at StageII decreased with advancement of the winter season. Frequency distribution for the predictand manifests slight negative skewness. Predictand series are not stationary in character and contain a prominent seasonal component. The mean values were not exactly representative of the month/season from whose data they have been computed. The multiple correlation coefficient between daily minimum surface temperature and selected potential predictors is 0.94. Minimum surface temperature equation for 24 hr forecast and the variance explained by individual predictors and cumulative variance is given in Table 2. A 24 hr forecast equation consists of four predictors. Selected predictors indicate a strong relationship with predictand. Precipitation over StageII is positively correlated with minimum surface temperature, and hence indicates that increase in snow yield (moisture) leads to increase in minimum surface temperature, whereas variation in standing snow at StageII is inversely correlated with minimum surface temperature at StageII.

Table 2. Twenty-four hour forecast issued at 0830 IST for minimum surface temperature forecast; equation, predictors and variances

S. No	Predictors	Time (IST)	Level	VE	CVE
A1	T_{min}	0830	Surface	85.95	85.95
A2	*ss*	0830	-do-	01.36	87.51
A3	S_{in}	0830	-do-	00.04	87.56

Y = – 0.5613 + (0.9403 × A1) + (0.1568 × A2) – (0.0887 × A3)

VE = Variance explained, CVE = Cumulative variance explained, MCC = Multiple correlation coefficient

The 24 hr forecast along with actual values for December 1995, i.e., verification data set, are represented in Figs 1 and 2. It is seen that model responds very well to the variation in the actual minimum surface temperature at StageII. As apparent from Figs 1 and 2, 60 per cent to 70 per cent of the forecasts are correct to within

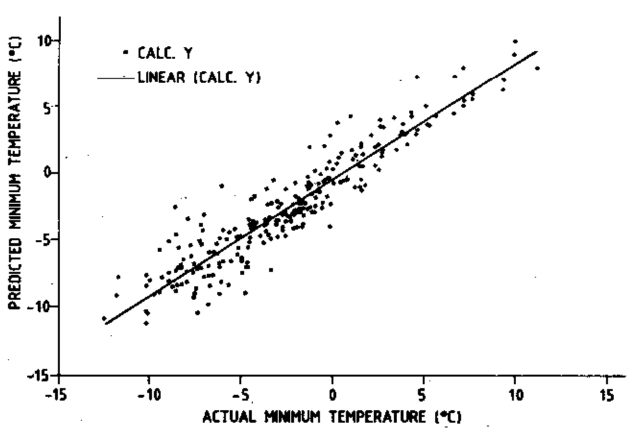

Figure 1. Actual and predicted minimum temperature at StageII.

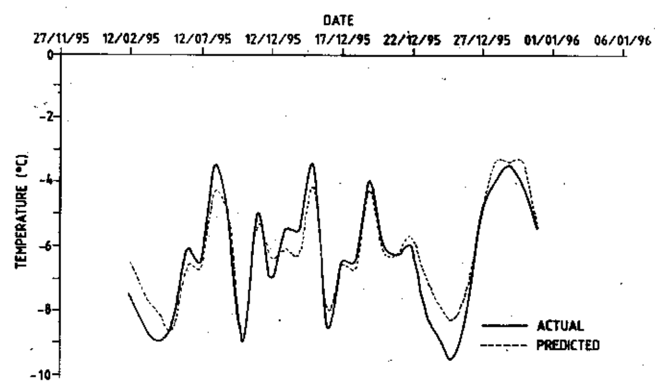

Figure 2. Verification of predicted minimum temperature with independent data set of December 1995 at StageII.

± 1°C and about 80 per cent to 90 per cent of the forecasts are correct to within ± 2°C of the actual value. Some cases having large deviation in forecasted values are found. Detailed studies for understanding these cases are in progress.

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