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Avalanche forecast using numerical weather prediction in Indian Himalaya

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Abstract

The integration of a nearest-neighbours method based avalanche forecast model with a mesoscale weather forecast model (MM5) has been attempted for avalanche forecasting in Indian Himalaya. The MM5 model simulates weather parameters up to day-4 over the entire western Himalaya. The paper describes the methodology of using MM5 model predictions and some empirical relations, to find the probability of avalanche occurrence up to day-4 at a spatial resolution of 5 km by applying the nearest-neighbours method. The nearest-neighbours model uses Euclidean weighted distance metric to find 10 nearest neighbours from the past data in terms of snow and weather parameters. Based on the avalanche occurrences associated with nearest-neighbours, an a priori probability of avalanche occurrence is derived. This approach has been tested for forecasting of avalanches in Chowkibal–Tangdhar road axis in Indian western Himalaya.

Keywords: Avalanche forecasting; Avalanches; Nearest neighbours method; Numerical weather forecast; Himalaya

1. Introduction

Some earlier attempts of using the nearest-neighbours (NN) method for avalanche prediction include Buser (1983), McClung and Tweedy (1994), and Kristensen and Larsson (1994). Lately many new versions and features have been introduced, e.g. by Gassner et al. (2000), Brabec and Meister (2001), Purves et al. (2003), McCollister et al. (2003), and Singh and Ganju (2004). However, they are used generally in nowcasting mode only, i.e. the effective forecast period is limited to 12 to 24 h in the future from the time of observation of the input data.

A NN method based model is operational at the Snow and Avalanche Study Establishment (SASE) for avalanche prediction for the current day (day of observation of input data). It uses an euclidean weighted distance metric and provides an avalanche occurrence probability for the current day based on the avalanche occurrences associated with the 10 nearest-neighbouring days from the past. The data used are snow and weather variables observed at 0830 h on the current

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day and some other variables derived from the observations of the past three days. The variables were chosen since they were believed to be critically connected with avalanche occurrences as suggested in previous studies (Perla, 1970; Föhn et al., 1977; Obled and Good, 1980; Buser, 1983; McClung and Tweedy, 1993) (Table 1).

We wanted to extend the effectiveness of NN method based avalanche forecasting from current day (day-1) to future days (day-2, -3 and -4). The main requirement for this task was to have forecasted input variables for day-2 to day-4. We have attempted to accomplish this task through the use of a mesoscale weather simulation model MM5 (Grell et al., 1994) for weather variables and some empirical relations for snow variables. According to Roeger et al. (2001), the combination of weather forecast and avalanche prediction requires the combination of two different scales. This task implies the use of some extrapolations and simplifications, which in turn may affect the accuracy of avalanche forecasting. However, their attempt to test the forecasted weather parameters as input for avalanche forecasting with the help of statistical correction methods was very encouraging. Therefore a huge potential exists in deriving avalanche forecast far in the future through the use of weather forecast models. The present study is an attempt in the same direction and combines weather and avalanche forecasts at mesoscale level.

Table 1
Nearest neighbours model input variables, their units, characteristic periods/time (as on any day-t), and weights used for Chowkibal–Tangdhar road axis

No	Variable (P_i)	Unit	Characteristic period/ time	Weight
1	Air temperature	°C	At 0830 h (t)	1
2	Snow surface temperature	°C	At 0830 h (t)	2
3	Air temperature change	°C	$T_{0830\ h\ (t)} - T_{0830\ h\ (t-1)}$	2
4	New snow in 24 h	cm	0830 h (t-1) to 0830 h (t)	5
5	New snow in 48 h	cm	0830 h (t-2) to 0830 h (t)	4
6	New snow in 72 h	cm	0830 h (t-3) to 0830 h (t)	3
7	Snowpack depth	cm	at 0830 h (t)	4
8	Snowpack water equivalent	mm	at 0830 h (t)	2
9	Wind speed	m/s	at 0830 h (t)	1
10	Ram penetration	cm	at 0830 h (t)	3

The paper describes the strategy followed and the implementation for the prediction of avalanches along Chowkibal–Tangdhar road axis in Indian western Himalaya. The results for the winter of 2002/03 are presented and discussed.

2. Mesoscale weather forecast

The regional mesoscale weather simulation model MM5 operational at SASE is based on a versatile mesoscale model developed jointly by National Centre for Atmospheric Research (NCAR), USA and Pensylvania State University (PSU), USA. The model was first documented by Anthes and Warner (1978). Since then, many changes have been made to broaden its usage. These include multiple-nest capability, non-hydrostatic dynamics and a four dimensional data assimilation capability.

In our case, the initial meteorological fields are taken from the global analysis made available by the National Centre for Medium Range Weather Forecasting (NCMRWF) through T-80 global spectral model (http://www.ncmrwf.gov.in/bdgsm.jpg). The global analysis is at 1.5 degree horizontal resolution and at 12 standard levels in vertical. The T-80 global model forecast fields up to 4 days at 24 h interval are also used to specify appropriate boundary conditions for the MM5 model. The initial global analysis fields are further enhanced using the additional surface and upper air observations collected at various places over the western Himalayan region. Numerical simulations are performed for up to 96 h. For this, a coarse domain (mother domain) with 101×81 horizontal grid points with grid spacing of 30 km, centered at 75°E longitude and 35°N latitude has been considered. Further, a nest domain of 91×91 horizontal grid points with a grid spacing of 10 km, covering western Himalaya has been considered for fine simulation (Fig. 1). Vertically 11 standard pressure levels have been considered for both mother and nest domain, where the top of the model is considered as 50 mbar. Work is under progress to further improve the forecast resolution spatially by including a sub-nested grid of spacing 5 km, as more surface observatories are being established in the area. The other relevant details about the