551.585.7 ; 551.524.36

ANALYSIS OF MAXIMUM AND MINIMUM TEMPERATURE IN VIEW OF AVALANCHE ACTIVITIES OVER NORTH-WEST HIMALAYAS

1. Snow climate of Indian Himalaya being very diverse, the characteristics of the snow pack are entirely different on different regions. The snow climatology (Sharma and Ganju, 2000) of the Himalaya reveal that the lower Himalayan zone is characterized by mild temperatures, heavy precipitation during winter and deep snow pack whereas middle Himalayan zone by cold temperatures, relatively low precipitation and shallow snow pack. Average altitude of different mountain ranges in lower Himalayan zone is 2000 to 4000 m and that in middle Himalayan zone 3500 to 5300 m. In the lower and middle Himalayan climatic zones, because of the diversity of meteorological conditions, snow pack properties and hence avalanche climatology of these zones differ. During winter both in the lower and middle Himalayan zone frequent snow avalanche is a common phenomenon that affects transport, tourism, army and the inhabitants of the region very badly.

A snow avalanche is sudden downward release of snow mass on a mountain slope. It is directly related to the cohesion of the snow grains within snow pack which in turn depends on the size and shape of the snow grains. The size and shape of snow particles at the time of precipitation is strongly affected by the prevailing temperature because it determines the temperature of the accumulated fresh snow. Snow temperature is one of the significant contributory factors towards avalanche because the snow crystal morphology (Fig. 1) that characterizes snow pack layers depends on temperature and supersaturation in a complex manner. Cold temperature during a snow storm slows the formation of bonds allowing weakness to persist and warm temperature produce snow that often stabilizes in place (McClung and Scherer, 1993). The lack of coordination among snow grains result in the formation of a weak layer that can cause an avalanche.

To understand snow crystal morphology Nakaya in 1930 performed first in-depth laboratory study of snow crystal growth and observed different growth morphologies that appeared at different temperatures and supersaturations and combined these observations into what is called snow crystal morphology diagram, shown in Fig. 1. This diagram refers to snow crystals growing in air at a pressure near 1 atm, so applies to natural snow crystals. These observations reveal a surprisingly complex dependence of crystal morphology on temperature and supersaturation. Just below freezing, at temperatures near T = - 2° C, the growth is plate like, with thick plates at lower supersaturations. For temperatures near T = - 5° C, the growth is columnar, with stout columns at the lower supersaturations, hollow columns at intermediate supersaturations, and clusters of thin needle-like crystals at higher supersaturations. Colder still, near T = - 15° C, the growth again becomes plate-like. Finally at lowest temperatures the growth becomes a mixture of thick plates at low supersaturations and columns at higher supersaturations. The morphology diagram in Fig. 1 is not necessarily indicative of all natural snow crystals which are dominated by polycrystalline forms, but rather it reflects the growth of ice-single-crystal (Nakaya, 1954). For natural crystals it is also important to note that the ice growth is enhanced when air flows over a growing surface (Keller and Hallett, 1982).

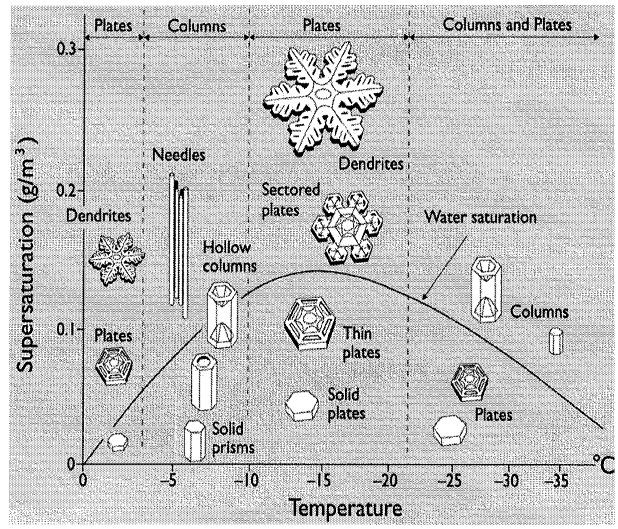

Fig. 1. Snow crystal morphology diagram

2. Present study is a part of the development of an avalanche forecasting model for N-W Himalaya. In this study two of the model input parameters (maximum and minimum temperature) are analyzed to find out avalanche prone ranges of the parameters. This study thus provides the most probable temperature ranges that contribute towards avalanche. the study is carried out at four places of the North-West Himalaya, two of which (STAGE II in J&K & DHUNDI in HP) fall on lower Himalayan zone and rest two (DRASS in J&K & PATSEO in HP) in the middle Himalayan zone. The database consists of a record of maximum temperature, minimum temperature and avalanche activities of 12 winters (1993-2004). Days with standing snow greater than zero (*i.e.*, snow is present at the observatory site) only are considered. Since there is mismatch in the recording time of maximum and minimum temperatures, to analyze them simultaneously,

Fig. 2. Index of avalanche for various ranges of maximum and minimum temperature on different regions of the lower and middle Himalayan climatic zones

TABLE 1

Index of avalanche for different ranges of maximum and minimum temperature at STAGE II, DHUNDI, DRASS and PATSEO

Normalized temperature ranges	STAGE II		DHUNDI		DRASS		PATSEO	
	IA for maximum temperature	IA for minimum temperature	IA for maximum temperature	IA for minimum temperature	IA for maximum temperature	IA for minimum temperature	IA for maximum temperature	IA for minimum temperature
0 to 0.1	*	*	*	*	*	0.39	*	*
0.1 to 0.2	0.28	0.11	0.05	*	0.03	0.08	0.08	0.04
0.2 to 0.3	0.34	0.10	0.03	0.06	*	0.05	0.04	0.05
0.3 to 0.4	0.27	0.10	0.05	*	0.09	0.08	0.05	0.05
0.4 to 0.5	0.13	0.15	0.03	0.03	0.10	0.07	0.03	0.03
0.5 to 0.6	0.07	0.17	0.02	0.03	0.15	0.10	0.01	0.03
0.6 to 0.7	0.07	0.24	0.02	0.04	0.20	0.20	0.01	0.02
0.7 to 0.8	0.08	0.10	0.04	0.03	0.13	0.23	*	0.03
0.8 to 0.9	0.20	0.21	0.11	0.02	0.16	0.36	*	*
0.9 to 1.0	*	0.20	*	*	0.10	0.38	*	*

(‘*’ represent no avalanche in the corresponding range of the temperature)

maximum temperature of previous day is analyzed with the minimum temperature of the current day. Initial step to analyze maximum and minimum temperature is to normalize them by using the relation:

$$X_{\text{normalized}} = (X - X_{\min})/(X_{\max} - X_{\min}) \qquad (1)$$

Where, $X_{\max}$ and $X_{\min}$ represent maximum and minimum value of the temperature X.

The normalized parameters then categorized into ten equal ranges (between 0 and 1, since all the normalized values lie in this range). For each of the ranges ‘i’ an Index of Avalanche (IA) is calculated by using the relation:

$$(\text{IA})_i = n_i/N_i \qquad (2)$$

Where,

n_i = number of avalanche days in i^{th} range

N_i = total days in i^{th} range

IA is nothing but the likelihood of avalanche for any range of a parameter.

3. Index of avalanche for different ranges of maximum and minimum temperature at STAGE II, DRASS, DHUNDI and PATSEO is summarized in Table 1 and plotted in Fig. 2. Avalanche activities observed in different ranges of maximum and minimum temperature during winter 2006-08 are compared with the results of present study.

Present study reveals that in the lower Himalayan zone at STAGE II in J&K the temperature range (-2 to 0) is most prone to avalanche for both maximum and minimum temperature and that at DHUNDI in HP is (12.5 to 15) for maximum temperature and (-10 to -8) for minimum temperature. In the middle Himalayan zone at DRASS in J&K, the avalanche prone temperature range of minimum and maximum temperature are (-3 to 0) and (0 to 3) respectively. Thus in J&K on both of the climatic zones most of the avalanche activities take place in the maximum and minimum temperature range close to zero. In the middle Himalayan climatic zone avalanche prone temperature range in HP for maximum temperature are (-13.5 to -10.8) and that for minimum temperature (-21 to -15). Though these temperature ranges are prone to avalanches, other ranges can have more avalanche occurrence events. Observations during winter 2006-08 at STAGE II reveal that 32 (65%) out of 49 avalanches triggered during the maximum temperature range (-2.5 to 2.5) and 23 (47%) out of 49 triggered during minimum temperature range (-7.5 to -2.5). These observations match with the results shown in Fig. 1. At DHUNDI there are total 11 avalanches occurred during winter 2006-08 out of which 3 (27%) activities took place in the maximum temperature range (10 to 12) and 4 (36%) out of 11 in the minimum temperature range (-6 to -4). These observed ranges though slightly less prone to avalanches yet contribute appreciably towards avalanche. In the middle Himalayan zone 57% avalanche activities (31 out of 54) at DRASS are observed in the maximum temperature range (-3 to 3) which matches well with the results. In the case of minimum temperature 25 (46%) activities took place in the temperature range (-12 to -3). These ranges also contribute appreciably (Fig. 2) towards avalanche. At PATSEO out of total 10 activities, 7 (70%) took place in the minimum temperature range (-15 to -21) which is in agreement with the avalanche prone range of the results. There is only mismatch of maximum temperature range at PATSEO where all the observed avalanches took place in the temperature range (-2.5 to 2.5) whereas results show (-13.5 to -5.4) as avalanche prone ranges. Thus as far as the test data of winter 2006-08 is concerned the observed avalanche prone range of maximum and minimum temperatures match appreciably (except maximum temperature at PATSEO) with the results of present study.

4. The study can be summarized into the following paragraph:

In the lower Himalayan zone the avalanche prone range of maximum and minimum temperature at STAGE II in J&K is (-2.5 to 2.5). 65% of the observed avalanche activities during winter 2006-08 took place in this range only. At DHUNDI in HP avalanche prone maximum temperature range is (12.5 to 15) as well as (0 to 2.5) whereas minimum temperature ranges (-10 to -8) and (-2 to 0) are found prone to avalanche. In the middle Himalayan zone at DRASS in J&K both for maximum and minimum temperature, (-3 to 3) is the temperature range found prone to avalanche and at PATSEO in HP, minimum temperature range (-21 to -15) found most probable for avalanche. More precise avalanche prone temperature ranges can be achieved by using larger database. The results may deviate slightly with the choice of different temperature ranges.

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