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SHORT COMMUNICATION

Percentile Data Analysis of Snowfall in J&K and Saichen Glaciers Region

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ABSTRACT

The Indian Himalayas are located between eastings 72° to 96° and the northings 26° to 37° stretching to about 43000 km^2 area. There are five major ranges in this region, ie, Pir Panjal, Greater Himalayas, Zanskar, Laddakh, and Karakoram. Saltoro range is the major branch of widespread Karakoram ranges which falls in Indian territory. Saichen glaciers are located in Saltoro range. Percentile data of snowfall gives first-hand information about the snowfall pattern in Jammu and Kashmir and Saichen glaciers, the two distinguished areas of Indian Himalayas which would help in prediction of avalanche activity in these areas. Western disturbance originating from Caspian sea basically dictates the weather condition in this region. Western disturbance approaches from western side and hits Pir Panjal range and Greater Himalayan range first, and then either it moves to further north or towards north-eastern region. Western disturbance yields maximum precipitation during winter season over north-west Himalayas, but as it moves further, it looses the moisture content, hence reducing the solid snowfall quantity but stays for a longer duration due to extremely low temperatures observed in the region of Saichen glaciers. The data analysis shows that the snowfall takes place in Saichen glacier throughout the year whereas in Jammu and Kashmir area, snowfall takes place only during winter season. Change in snowfall pattern in these two regions is attributed to the variation in temperature in these regions, movement of weather system, and the difference in altitude. In the present study, four locations at varied altitudes from Jammu and Kashmir area and the complete Saichen glaciers region have been covered to analyse the snowfall pattern for the period from 1995-2000.

Keywords: Western disturbance, Saichen glaciers, Greater Himalayan range, Saltoro range, Korakoram range, Indian Himalayas, avalanche, snowfall pattern

1. 1NTRODUCTION

In spite of having various tools for avalanche prediction, it always falls short of input. Avalanches are predominant in hilly areas where at places snowfall is measured in meters and not in feet. The avalanches affect the routine life of personals of security forces deployed as well as civilians residing in these areas. Supplies of rations, fuel remains disrupted for days together, houses/shelters are damaged, and few loose their lives also, if the information about the likely avalanche triggering is not forecasted on time. Hence, the accurate prediction of avalanche activity is necessary.

Snow scientists all over the world have been working on this problem; various tools have been developed to help in accurate prediction of avalanches. Avalanche forecasting is carried out based on techniques, ie, by comparison of manual observatory data with various models, upper air observatory data, and so on. Improvement in forecast accuracy by mastering

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these techniques can be obtained but none of these techniques are full proof. The present study would provide a parameter, ie, pattern of snowfall over the Jammu and Kashmir region and the Saichen glaciers. By knowing, the data of fresh snowfall and having analysis of previous year data readily available, would help in accurate prediction of avalanche activity. Dimri[1], *et al*. have studied snowfall pattern and statistical analysis restricted to Jammu and Kashmir region for the period 1985-1994.

In this study, the snowfall data has been carried out of Jammu and Kashmir and the glacier region from 1995-2000. Criteria for selection of locations for the study is the variation in altitude of locations, secondly being the location of the surface observatory of Snow and Avalanche Study Establishment (SASE), Manali.

Altitude varies in respect of four locations considered for the study between 2500 m to 3100 m whereas the altitude variation in the locations considered in Saichen glacier region is between 4800 m to 6000 m. Snowfall in Jammu and Kashmir region is generally recorded during November to April, whereas in glacier region, snowfall takes place throughout the year, though scanty. The temperature in glacier region generally remains between – 5 ^{o}C to – 40 ^{o}C during winters and between 0 ^{o}C to – 20 ^{o}C during summer. In Jammu and Kashmir region, temperature is recorded in winter from 0 ^{o}C to – 14 ^{o}C and during the summers, temperature is recorded even above 30 ^{o}C at places.

2. AREA OF STUDY

In this study, four locations in Jammu and Kashmir area and complete glacier region have been covered, (Fig. 1) to analyse the snowfall pattern over the last five years (1995-2000). Analysis was based on the data collected by SASE observatories and the manually collected data. Locations considered for the study in Jammu and Kashmir region and the Saichen glacier area are described in Table 1.

While there is some semblance of uniformity of meteorological condition in all the three parts of the glaciers (mentioned above), the conditions vary drastically from one area to another so far as avalanche activity is concerned. Wind activity plays a major role in the redistribution of snow at various locations. Entire glacier region remains covered with snow throughout the year and the temperature remains lower than in other Himalayan ranges located in Jammu and Kashmir and Laddakh areas.

3. SNOWPACK/TERRAINS BEHAVIOUR

3.1 Gulmarg

Snow in the formation zone altitude for few sites is estimated to be about 30 per cent more

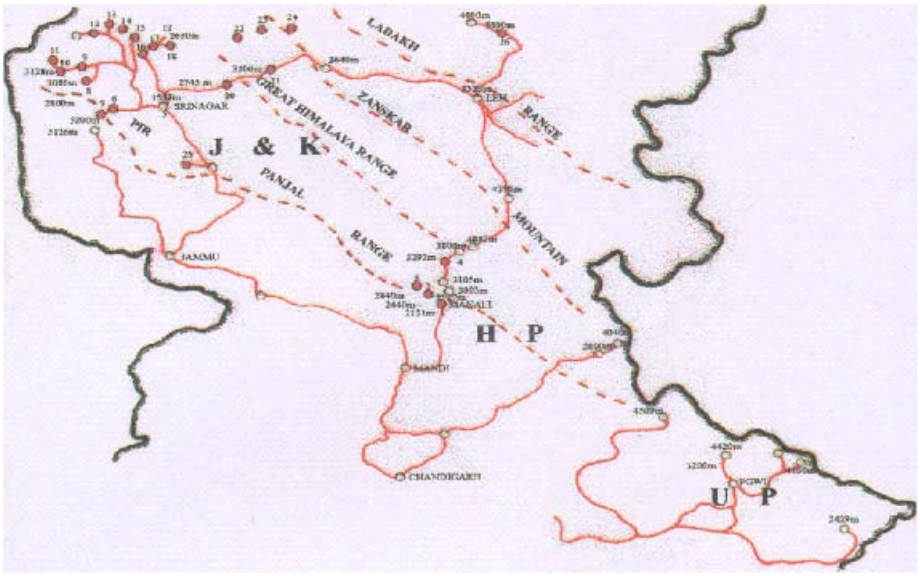

Figure 1. Area of study.

Table 1. Locations considered for the study in Jammu and Kashmir region and the Saichen glacier region

Location	Altitude (m)	Latitude	Longitude	Mountain range
Gulmarg	2800	34°04'	74°23'	Pir Panjal
Haddan Taj	3080	34°25'	74°03'	Pir Panjal
Kanzalwan	2440	34°35'	74°42'	Great Himalayas
Sonamarg	2745	34°18'11"	75°18'	Great Himalayas
North Glacier	4800-5995	35°28'	77°01'	Karakoram (Saltoro range)
Central Glacier	5320-5440	35°08'	77°05'	-do-
South Glacier	5040-5450	35°01'	77°03'	-do-

than the observatory at Gulmarg. Approximately 100 cm of standing snow is needed to cover the terrain irregularities in the formation zones. When snowpack (20-30 cm) is in temperature gradient (TG) regime, then only with small additional load, minor avalanche activity commences. Most avalanches trigger only after the height of standing snow at the formation zone exceeds 200-250 cm.

3.2 Haddan Taj

Snow in formation zone altitude is about 30 per cent more than at the base station. Approximately 80-100 cm standing snow is needed to cover the terrain irregularities in the formation zone. Avalanches trigger only after the estimated standing snow in formation zone exceeds 150 cm.

3.3 Kanzalwan

Kanzalwan station serves as an indicator station to base deductions on avalanche forecasting in the Gurez valley. Approximately 100 cm snow is required to cover the terrain irregularities.

3.4 Sonamarg

Formation zone of majority of avalanche sites receive approximately 40 per cent more precipitation than Sonamarg. 100–150 cm snow is required to cover the terrain irregularities of majority of the avalanche sites.

3.5 Northern Glacier

The avalanche activity on northern group of glaciers is restricted to its tributary glaciers and that too in only few areas. A few avalanches on main glacier go generally unnoticed, as these do not reach the pedestrian track. The avalanches fall mainly in the rare category and follow well-defined path. Ice avalanches are also known to occur in this area. Chances of avalanche occurrence increases if > 60 cm snow falls in a short duration of 24 h to 36 h. Small spells of 5 cm to 10 cm get relocated.

3.6 Central Glacier

Central glacier is known for its hazard potential. A large number of avalanches have high frequency and affect pedestrian traffic. Some of the sites are notoriously known for their hazard potential. Smooth rocky surface requires less snow to release avalanches. Possibility of avalanche increases if more than 50 cm snowfall occurs later in 24 h to 36 h. Wind direction and wind velocity play major roles in relocation of snow.

3.7 Southern Glacier

The southern group of glaciers is also known for its avalanche activity. It has glaciated and rocky terrain. In comparison to northern and central glaciers, the temperature remains relatively high on this part of the glacier. Steep peaks, glaciated valleys, and rugged terrain characterise whole of the glacier region. Extreme cold climate makes it most inhospitable area in Himalalayas in comparison to Jammu and Kashmir area. The climatic conditions are closer to polar conditions. Snowfall in this zone is generally scantly but extends almost throughout the year. Snow is mostly dry and bonds poorly with the glaciated surface or with the old snow. Due to loose bonding, the redistribution is due to wind activity.

4. OCCURRENCE OF SNOWFALL SPELLS

Snowfall in these regions was divided into seven categories for the purpose of analysis in terms of duration (in days) of snowfall occurrence at a particular station. The spells considered into the seven categories like 1 day, 2 days, 3 days, 4 days, 5 days, 6 to 10 days, and >10 days. Categories of 6 to 10 days and >10 days have been counted at one place since the frequency of such spells is quite low. (Annual data of Siachen glacier and Jammu and Kashmir region is available in annual technical reports of SASE). Snowfall taking place during November to April has been compared for Jammu and Kashmir region, since during this period, maximum snowfall occurs in Jammu and Kashmir region. A comparison has been made to show the snowfall during winter and summer in glacier region.

The analysis shows that there is a drop in snowfall in Jammu and Kashmir region during 1995 to 2000 in comparison to the period (1985-1994) as seen in the analysis of data carried out by Dimri[1], *et al.* for the same locations. Frequency of all the categories of spells was reduced; 1-day duration spells varied from 30-46 per cent during (1995-2000) in comparison to previous data of 1985-1994 where it was 40-52 per cent. In glacier area, 1-day spell percentage was observed between 2 per cent to 5 per cent and the percentage of spells of > 1-day duration increased and maximum snow-spell days fell between 3 days to 10 days, whereas percentage of snow spell of days (6 or more) in Jammu and Kashmir region was between 1 per cent to 2.5 per cent only. Table 2 contains summary of 10 year data (1985-1994) of Jammu and Kashmir region (previously analysed) by Dimri[1] and others. Table 3 contains five-year data of Jammu and Kashmir region and the Saichen glacier region (presently analysed) for the period between 1995-2000.

Frequency of occurrence of a spell exceeding 10 days was found to be 0.01 per cent while analysing data of 1985-1994, but no spells during the period 1995-2000 (present study). The frequency of snow spells of 1 to 3 days taken together lie between 85 per cent to 95 per cent. However, though snow spells of more than 3 days do occur; their frequency is very low.

Table 2. Statistical data (1985-94) from annual reports of SASE

Month	Spells duration (days)						
	1	2	3	4	5	6-10	>10
Gulmarg							
NOV	7	0	1	1	0	.0	0
DEC	13	4	5	1	1	0	0
JAN	16	10	4	4	1	1	0
FEB	9	7	11	4	2	3	0
MAR	14	13	8	4	2	2	1
APR	6	4	3	1	0	0	0
Total	65	38	32	15	6	6	1
Haddan Tai							
NOV	6	7	0	3	0	0	0
DEC	14	8	4	2	1	2	0
JAN	18	18	6	7	0	2	0
FEB	16	7	10	0	3	3	1
MAR	25	13	10	3	1	2	1
APR	15	8	8	4	1	0	0
Total	94	61	38	19	6	9	1
Kanzalwan							
NOV	5	2	3	2	0	0	0
DEC	15	6	2	3	2	0	0
JAN	14	11	2	7	1	2	0
FEB	10	7	7	1	2	3	1
MAR	21	12	7	1	2	3	0
APR	8	9	4	1	1	0	0
Total	73	47	25	15	8	8	1
Sonamarg							
NOV	7	0	0	2	0	0	0
DEC	19	2	1	2	2	1	1
JAN	17	13	2	2	2	0	0
FEB	16	14	3	0	4	0	0
MAR	22	16	2	5	3	1	1
APR	13	5	2	0	1	0	0
Total	94	50	10	11	12	2	2

In the case of Saichen glacier, it is rare to observe 1 to 2 days' snow spell as mentioned above. The snow spell is only 2 per cent to 5 per cent. This is approximately 85-95 per cent. Percentage of, snow spell of >10 days lies between 7 per cent to 12 per cent. The variation in temperature and the difference in altitude causes snowfall throughout the year, whereas due to rise in temperature in Jammu and Kashmir region, the snowfall is restricted to winter months only, ie, from November to April. Snowfall in the Jammu and Kashmir region is of short spells but of high intensity. In Saichen glacier, the snowfall is of low intensity but of longer duration. Since the snow stays throughout the year and snowfall also continues, even small addition of fresh snow

Table 3. Statistical data (1995-2000) from annual reports of SASE

Month	1	2	3	4	5	6-10	>10
Gulmarg							
NOV	5	3	3	0	0	0	0
DEC	7	4	1	1	0	.0	0
JAN	8	10	2	3	1	1	0
FEB	7	10	7	2	0	0	0
MAR	15	12	1	1	0	2	0
APR	5	0	0	1	0	0	0
Total	47	39	14	8	1	3	0
Haddan Taj							
NOV	9	1	2	0	0	0	0
DEC	8	7	0	0	0	0	0
JAN	7	8	7	1	1	2	
FEB	11	6	5	2	1	1	0
MAR	17	17	6	3	0	0	0
APR	11	3	0	2	0	0	0
Total	63	42	20	8	2	3	0
Kanzalwan							
NOV	4	5	4	0	0	0	0
DEC	3	8	3	1	1	0	0
JAN	6	3	7	4	1	1	0
FEB	7	12	6	2	1	0	0
MAR	9	14	5	1	0	2	0
APR	8	2	0	0	1	0	0
Total	37	44	25	8	4	3	0
Sonamarg							
NOV	3	1	2	0	0	0	0
DEC	8	5	1	0	0	0	0
JAN	7	13	2	0	1	1	0
FEB	12	9	4	0	0	0	0
MAR	14	13	7	0	0	0	0
APR	4	2	0	4	0	0	0
Total	48	43	16	4	1	1	0
Northern Glacier							
NOV	0	0	1	3	4	7	0
DEC	1	5	1	4	2	2	1
JAN	0	1	3	1	1	4	1
FEB	0	1	2	1	3	0	1
MAR	0	0	1	3	3	2	1
APR	2	2	3	3	2	3	1
Total	3	9	11	15	15	18	5
Central Glacier							
NOV	1	0	1	0	3	2	a
DEC	0	0	0	2	1	0	1
JAN	0	0	2	0	0	6	0
FEB	0	0	1	1	2	1	1
MAR	0	0	0	1	1	1	1
APR	1	0	2	4	2	2	1
Total	2	0	6	8	9	12	4
Southern Glacier							
NOV	0	0	1	2	1	2	1
DEC	0	2	0	3	1	0	1
JAN	0	0	1	0	0	6	0
FEB	0	1	2	1	2	0	1
MAR	0	0	0	1	2	1	1
APR	1	1	2	2	1	2	1
Total	1	4	6	9	7	11	5

causes the avalanche. This point is also clarified above in the terrain analysis.

It was observed from the analysis that in Jammu and Kashmir region, snowfall spells increase rapidly from November to March and decline during April (mainly due to variation in temperature). In Jammu and Kashmir region, approximately 88 per cent to 92 per cent of the snowfall spells of various duration occurred during November to March and only 8 per cent to 12 per cent during April. In Saichen glacier region, 72-78 per cent snowfall occurred in winter season in different spells from November to March. During April, frequency of various duration spells observed was 22-28 per cent, reflecting big difference between the snowfall patterns in Jammu and Kashmir and the Saichen glacier region. System stays for longer duration in glaciated regions (Table 4).

This phenomenon can be explained on the basis that as the vapour rises from the earth's surface, it is constantly diffusing upwards and this state continues until it attained the state of equilibrium represented by Dalton's Law but the temperature falls as the altitude increases and it reaches to the saturation point at a certain altitude. The vapour is partially condensed into cloud or rain much before the barometric equilibrium is attained.

Evidently, glacier region frequently encounters spells of 7 days or more in Jammu and Kashmir region; this phenomenon is not seen in data analysis of 1995-2000. There were few spells of 6 days or more during 1985-94 (Dimri[1], *et al.*). It was observed that amount of snowfall during winter season (Nov-April) remained almost the same in Jammu and Kashmir region and the Saichen glacier region (Fig. 2).

In general, snow spells are of shorter duration but snowfall is more in Jammu and Kashmir region in comparison to Saichen glacier region. However, frequency of larger number of snow-spell days in glacier region compensates the amount of snowfall (Figs 3 and 4). Average snowfall during winter and summer in glacier region during a year is shown in Fig. 5. Percentage of snowfall days during November to April and May to October is shown in Fig. 6 and Table 5. It was observed that ratio of snowfall in two seasons is approximately 45 per cent to 55 per cent, that is why the glacier remains covered with snow throughout the year. In Jammu & Kashmir region, 90 per cent to 95 per cent of total snowfall takes place between November

Table 4. Percentage of monthly snowfall and percentage of monthly snowfall day

Month	Gulmarg	HaddanTaj	Kanzalwan	Sonamarg	Northern Glacier	Central Glacier	Southern Glacier
Percentage of monthly snowfall							
NOV	9	7	7	5	19	20	14
DEC	8	6	11	11	16	8	14
JAN	34	30	32	35	1,8	15	13
FEB	24	25	21	19	16	10	10
MAR	22	24	25	22	13	19	25
APR	3	0.8	4	8	18	28	24
Percentage of monthly snowfall day							
NOV	10	9	11	5	17	16	16
DEC	12	11	13	12	23	10	16
JAN	22	19	18	21	14	20	16
FEB	23	19	23	22	14	12	17
MAR	27	30	26	31	11	10	11
APR	6	12	9	9	21	32	24

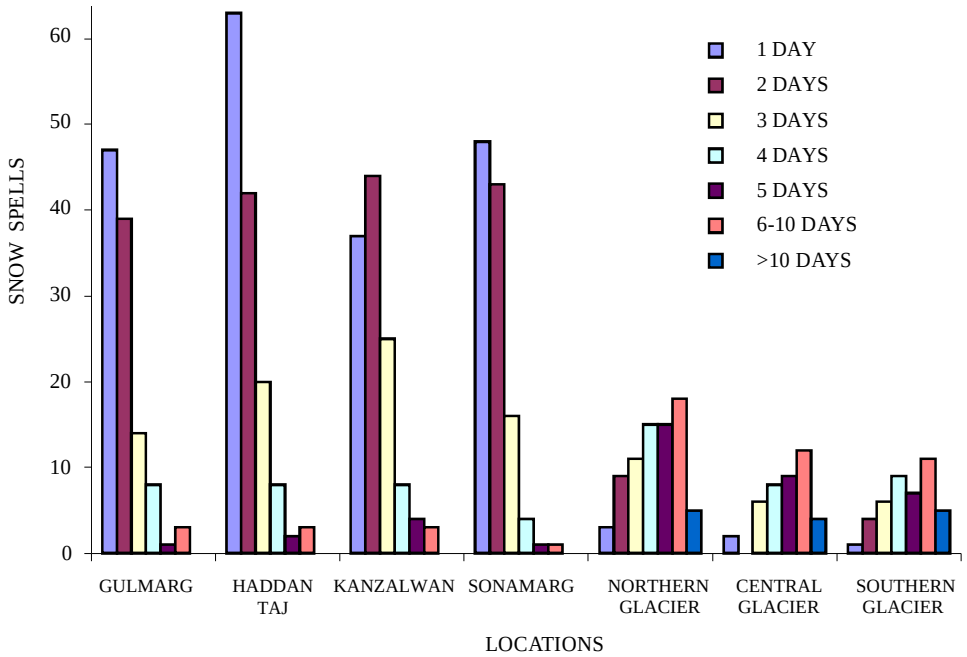

Figure 2. Snow spells of various duration in winter season (Nov-Apr).

to April, hence, the higher reaches of mountain tops get cleared during summer season.

5. CONCLUSIONS

Total snowfall in Karakoram range remains relatively high in comparison to the other Himalayan ranges since it receives snowfall throughout the year because of being in low temperature and high altitude region. Western disturbance after entering the Indian territory hits Himalayan ranges and causes precipitation. The weather system moves towards either northwards or eastwards. The moisture content reduces as it proceeds further during winter months although same weather system gives precipitation in the form of rain in Jammu and Kashmir region during summer months. The percentile data analysis would provide first-hand information to the snow scientists about the pattern of snowfall in Jammu and Kashmir region as well as in Saichen glacier region which would help them in the prediction of ensuing the avalanche activity.

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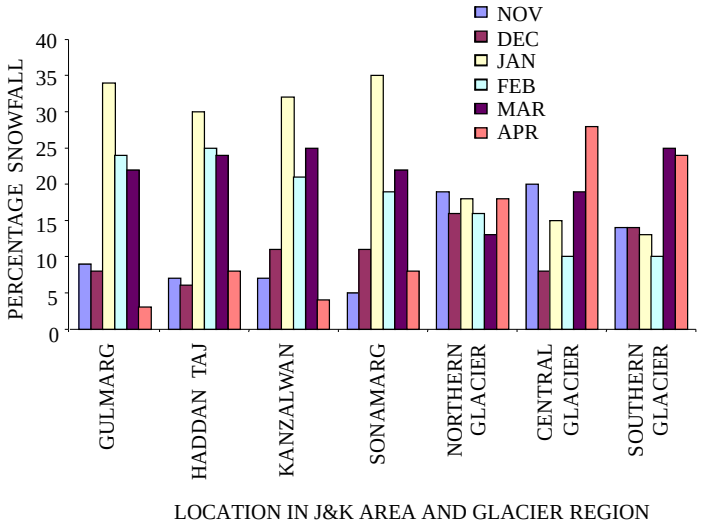

Figure 3. Percentage monthly snowfall.

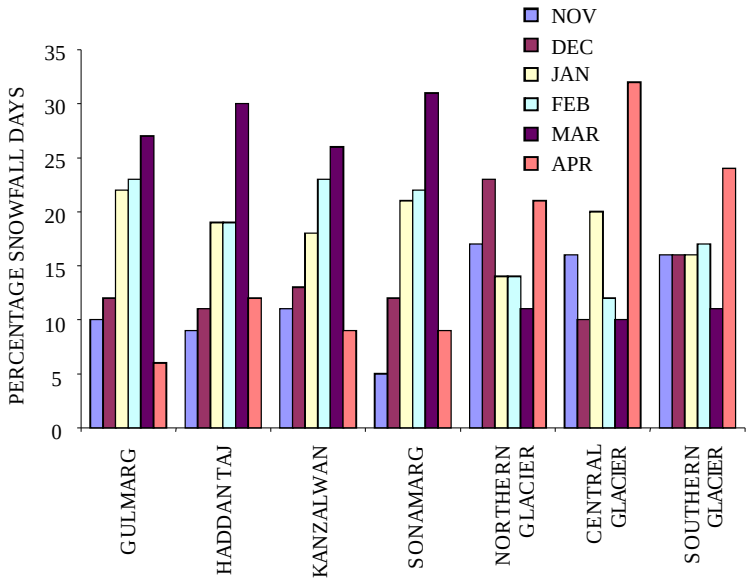

Figure 4. Percentage monthly snowfall days.

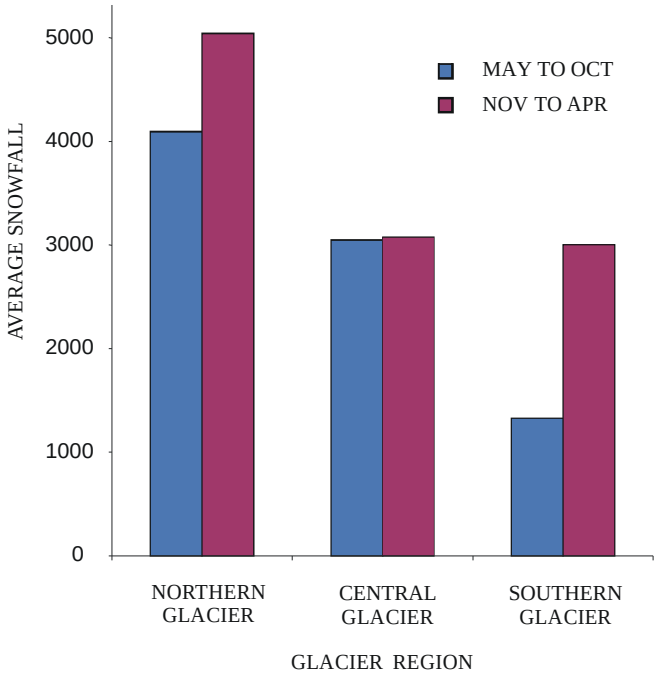

Figure 5. Snowfall during winter and summer.

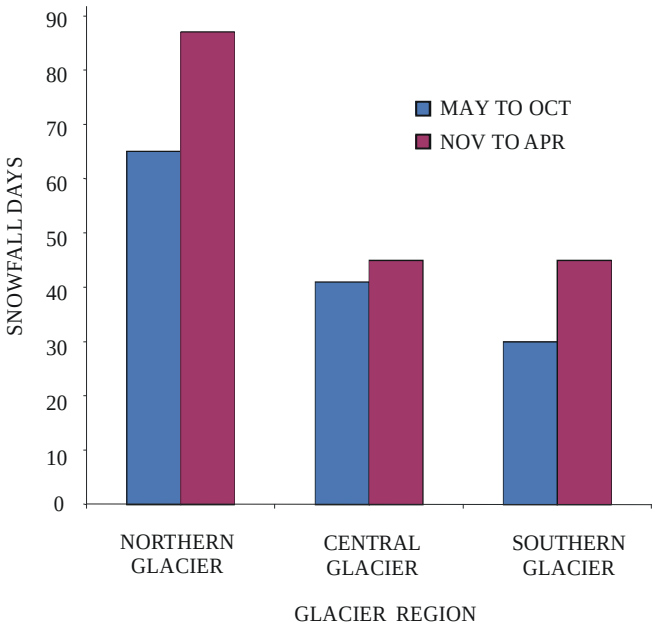

Figure 6. Snowfall days during winter and summer.

Table 5. Average snowfall in glacier area during summer and winter season

Season	Northern Glacier	Central Glacier	Southern Glacier
Average snowfall			
May to Oct	4094	3048	1325
Nov to Apr	5039	3075	3002
Percentage of snowfall			
May to Oct	65	41	30
Nov to Apr	87	45	45

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REFERENCES

1. Dimri, A.P. & Mohanty, U.C. Snowfall statistics of some SASE field stations in J&K and a case study of western disturbance. *Def. Sci. J.*, 1999, **49**(5), 437-45.

2. Dimri, A.P. & Mohanty, U.C. Simulation of heavy precipitation associated with an intense western disturbance over western Himalayas. Natural hazard, SASE, Manali, 2004. Pub. No. SASE No. 66.

3. Atkinson, E.T. Geology of the Himalayas. Cosmo Publications, New Delhi, 1882.

4. Snow and Avalanche Study Establishment, J&K (1995-2000), Glacier region (1995-2000). SASE Annual Report 1995-2000.

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