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# Snowfall Statistics of Some SASE Field Stations in J&K

A.P. Dimri
*Snow & Avalanche Study Establishment, Manali*-175 103.
and
U.C. Mohanty
*Indian Institute of Technology, New Delhi*-110 016.

**ABSTRACT**

North-west Himalayan region comprises five mountain ranges. Their orientation and complex terrain influence the weather over the region. Sudden altitudinal changes also affect the weather systems to a considerable extent . Due to the prevailing inhomogeneous topography, various dynamic and thermal processes take place at mesoscale level. In synoptic scale, during winter seasons, weather systems, named, western disturbance (WD), take their southerly track and travel over J&K, HP and hills of western UP, and yield considerable amount of precipitation. On the basis of past historical data collected over J&K region, the pattern of snowfall and its frequency distribution was studied using statistical means. Variation of these snowfall spells was also studied to understand spatial and temporal changes in their distribution. A brief case study of a WD has been carried out to estimate moisture flux inflow over Himalayas.

## 1. INTRODUCTION

The western Himalayan ranges cover most parts of J&K, HP and the hills of western UP over north India. These ranges have high elevations and run from north-west to south-east and exert considerable influence on the weather and climate of north India[1] Due to the complexity of terrain and inaccessibility to several areas in the Himalayan region, knowledge of climate, characteristics of snowfall and other hydrometeors, their frequency of occurrence, intensity and duration, and also their variation in time and space is limited. Snowfall occurs over western Himalayas mainly during November to April in association with eastward-moving low pressure systems, known as western disturbances (WDs). These disturbances are often observed as closed lows on the mean sea level weather charts or as troughs in the upper levels over the Indo-Pakistan region, and generally move ENE wards across north India, causing widespread precipitation over north India. Generally, 6-7 such disturbances move across western Himalayas in a month during the winter months. Of these, 1-2 remain of severe intensity, causing extensive cloudiness, heavy precipitation, strong winds, severe cold conditions and at times blizzards. Ahead of these disturbances, there is general warming of the lower troposphere followed by cold to very cold wind in the rear. To understand the variability of winter precipitation, past historical data at a few places in J&K was considered for this study.

## 2. DATA & ANALYSIS PROCEDURES

This study presents a preliminary analysis of daily snowfall data recorded at four Snow & Avalanche

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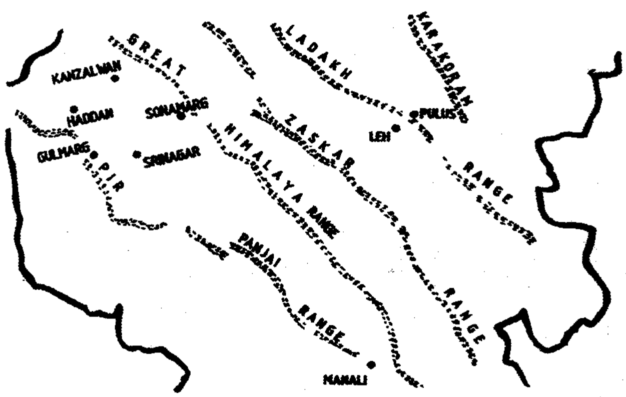



**Figure 1. Location of SASE field observatories taken for study**

Study Establishment (SASE) stations in north-west J&K, viz., Haddan (long: 74°02′42″, lat: 34° 18′43″ and alt: 3080 m), Gulmarg (long: 74°23′00″, lat: 34°03′42″ and alt: 2800 m), Kanzalwan (long: 74° 42′06″, lat: 34° 38′39″ and alt: 2440 m) and Sonamarg (long: 75°17′57″, lat: 34°18′11″ and alt: 2745 m), from November to April covering a period of 10 years from 1985-1994. Twenty four hour cumulative precipitation was used for making snowfall climatology for the J&K region. These four stations, shown in Fig.1, are located at the high mountainous regions of western Himalayas with their altitudes varying from about 2500-3100 m and lie within a range 50-100 km from each other.

## 3. OCCURRENCE OF SNOWFALL SPELLS OF DIFFERENT DURATIONS & THEIR VARIATIONS

Snowfall spells were divided into seven categories in terms of duration (in days) of snowfall occurrence at a station. These were spells of durations 1 day, 2 days, 3 days, 4 days, 5 days, 6-10 days and more than 10 days. The last two categories were chosen considering the fact that the frequency of snowfall spells of durations exceeding 5 days is not large.

Data on monthly distribution of snowfall spells of different durations (in days) at Haddan, Gulmarg, Kanzalwan and Sonamarg are given in Table 1. At these stations, the frequencies of snowfall spells of 1day duration vary from 40-52 per cent and these decrease as the duration of the spell increases. The frequencies of occurrence of snowfall spells of more than 3 days′ duration, however, are found

**Table 1. Monthly distribution of average number of snowfall spells of different durations (in days) based on 10 year (1985-94) data**

**(a) Haddan (long: 740° 2′42″, lat: 34°18′43″ and alt: 3080 m)**

| Month | Spell duration (days) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6-10 | >10 |
| November | 6 | 7 | 0 | 3 | 0 | 0 | 0 |
| December | 14 | 8 | 4 | 2 | 1 | 2 | 0 |
| January | 18 | 18 | 6 | 7 | 0 | 2 | 0 |
| February | 16 | 7 | 10 | 0 | 3 | 3 | 1 |
| March | 25 | 13 | 10 | 3 | 1 | 2 | 1 |
| April | 15 | 8 | 8 | 4 | 1 | 0 | 0 |

**(b) Gulmarg (long: 74°23′00″, lat: 34°03′42″ and alt: 2800 m)**

| Month | Spell duration (days) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6-10 | >10 |
| November | 7 | 0 | 1 | 1 | 0 | 0 | 0 |
| December | 13 | 4 | 5 | 1 | 1 | 0 | 0 |
| January | 16 | 10 | 4 | 4 | 1 | 1 | 0 |
| February | 9 | 7 | 11 | 4 | 2 | 3 | 0 |
| March | 14 | 13 | 8 | 4 | 2 | 2 | 1 |
| April | 6 | 4 | 3 | 1 | 0 | 0 | 0 |

**(c) Kanzalwan (long: 74°42′06″, lat: 34°38′39″ and alt: 2440 m)**

| Month | Spell duration (days) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6-10 | >10 |
| November | 5 | 2 | 3 | 2 | 0 | 0 | 0 |
| December | 15 | 6 | 2 | 3 | 2 | 0 | 0 |
| January | 14 | 11 | 2 | 7 | 1 | 2 | 0 |
| February | 10 | 7 | 7 | 1 | 2 | 3 | 1 |
| March | 21 | 12 | 7 | 1 | 2 | 3 | 0 |
| April | 8 | 9 | 4 | 1 | 1 | 0 | 0 |

**(d) Sonamarg (long: 75°17′57″, lat: 34°18′11″ and alt: 2745 m)**

| Month | Spell duration (days) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6-10 | >10 |
| November | 7 | 0 | 0 | 2 | 0 | 0 | 0 |
| December | 19 | 2 | 1 | 2 | 2 | 1 | 0 |
| January | 17 | 13 | 2 | 2 | 2 | 0 | 0 |
| February | 16 | 14 | 3 | 0 | 4 | 0 | 0 |
| March | 22 | 16 | 2 | 5 | 3 | 1 | 1 |
| April | 13 | 5 | 2 | 0 | 1 | 0 | 0 |

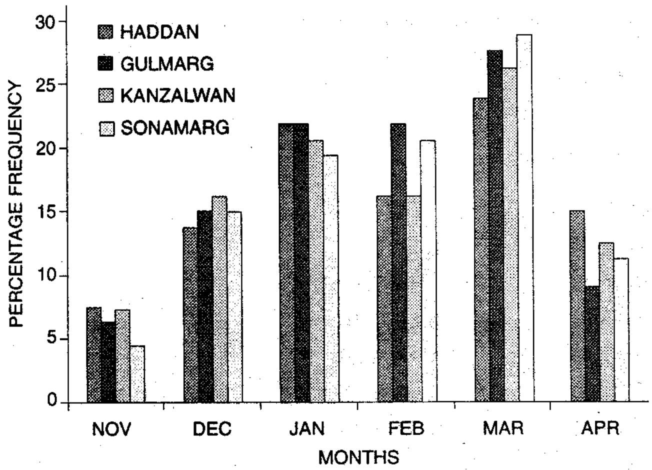



**Figure 2. Monthly percentage frequency of snowfall spells of all categories.**

to be less than 10 per cent. The probability of occurrence of a spell exceeding 10 days is very small (0.01). The frequencies of all snowfall spells having duration 1-3 days, taken together, lie between 80 per cent and 85 per cent, indicating that spells of up to 3 days' duration are most frequent over the western Himalayas. However, snowfall spells of more than 3 days' duration do occur, though their frequency is low.

Frequencies of snowfall spells increase rapidly from November to January at all the four stations (Fig. 2). However, these do not show any significant change from January to February, but again increase in March, when the occurrence of snowfall spells is the highest over the region. There is, however, a sharp decrease in the frequencies of spells from March to April. About 80 per cent of the snowfall spells of various durations occur during November to April.

## 4. SNOWFALL DAYS OF DIFFERENT INTENSITIES & THEIR VARIATIONS IN TIME & SPACE

The total number of snowfall days of different intensities occurring at a station in each month have been determined and their variations in time and space studied. The intensity of a snowfall day is defined in terms of fresh snowfall amount recorded in 24 hr. To work out the number of days having different amounts of snowfall, these are divided into five class intervals, viz., 0-12 cm, >12-24 cm, >24-48 cm, >48-96 cm and <96 cm, representing categories of very light, light, moderate, heavy and very heavy intensities of snowfall day, respectively. Days having no snowfall have not been considered.

It is seen from Table 2 that over a station the least number of snowfall days in most of class intervals fall in November. The snowfall days show an increase in different class intervals from November to March with the advancing of winter, but decrease sharply in April. The highest number of days in the moderate (>24-48 cm) and heavy (> 48-96 cm) categories of snowfall intensities are found over a station in February/March. In the category of very heavy intensity (>96 cm) of snowfall in a day, the average number of snowfall days at a station are found to be only 0.1-0.2 occurring from December to March.

Data on frequencies of days in the five class intervals of snowfall amounts of > 0-12 cm, >12-24 cm, >24-48 cm, >48-96 cm and >96 cm are plotted in Fig.3. On about 50 per cent occasions in the six-month period, snowfall days are of very light intensity (0-12cm); on about 40 per cent occasions, these are of light to moderate intensity (>12-48 cm) and on only about 10 per cent days, the snowfall was of heavy to very heavy intensity (> 48 cm). The probability of occurrence of very heavy snowfall intensity over a station during the period is very small, i.e., 1 per cent or less. It can be seen that there is an almost exponential decrease in the frequency of days as one goes towards higher ranges.

Frequencies of snowfall days of all intensities taken together are the highest in March and the lowest in November (Fig. 4). It is noticed that the occurrence of snowfall days increases by 2-3 times from November to December at all the four stations. Among the stations, Gulmarg and Sonamarg have the maximum occurrence of snowfall days in March. Thirty per cent of the total number of snowfall days during the six months occur in this month at these two stations. Considering December to March as the winter period for the western Himalayan region, about 80 per cent of the total snowfall days of all intensities fall within the above four months.

**Table 2. Average monthly frequency of snowfall days in respective ranges (percentage frequency of snowfall days taken together),**

**(a) Hadden (long: 74° 02′ 42″, lat: 34° 18′ 43″ and alt: 3080 m)**

| Month | Intensity (cm) | | | | |
|---|---|---|---|---|---|
| | 0-12 | >12-24 | >24-48 | >48-96 | >96 |
| November | 1.9(51.5) | 0.8(21.2) | 0.7(21.2) | 0.20(6.06) | 0(0) |
| December | 3.1(50.0) | 1.4(23.2) | 1.0(16.1) | 0.44(7.10) | 0.22(3.6) |
| January | 6.1(56.5) | 2.4(22.2) | 1.5(13.9) | 0.80(7.40) | 0(0) |
| February | 5.9(51.8) | 2.3(20.2) | 2.0(17.5) | 1.10(9.60) | 0.10(0.9) |
| March | 6.2(50.0) | 2.5(20.2) | 2.7(21.8) | 1.00(8.10) | 0(0) |
| April | 4.5(59.2) | 2.1(27.6) | 0.7 (9.2) | 0.30(3.90) | 0(0) |

**(b) Gulmarg (long: 74° 23′00″, lat: 34° 03′42″ and alt: 2800 m)**

| Month | Intensity (cm) | | | | |
|---|---|---|---|---|---|
| | 0-12 | >12-24 | >24-48 | >48-96 | >96 |
| November | 1.6(86.7) | 0.13(6.7) | 0.13 (6.6) | 0(0) | 0(0) |
| December | 2.6(50.0) | 1.0(18.2) | 0.90(15.9) | 0.75(13.6) | 0.13(2.3) |
| January | 4.5(53.2) | 2.0(23.4) | 1.80(20.8) | 0.22 (2.6) | 0(0) |
| February | 6.1(55.6) | 1.9(17.2) | 2.00(18.2) | 1.00 (9.1) | 0(0) |
| March | 5.8(47.3) | 3.6(29.1) | 2.10(17.3) | 0.80 (6.4) | 0(0) |
| April | 2.3(77.8) | 0.6(18.5) | 0.11 (3.7) | 0(0) | 0(0) |

**(c) Kanzalwan (long: 74° 42′06″, lat: 34° 38′39″ and alt: 2440 m)**

| Month | Intensity (cm) | | | | |
|---|---|---|---|---|---|
| | 0-12 | >12-24 | >24-48 | >48-96 | >96 |
| November | 2.3(62.0) | 0.7(19.0) | 0.6(15.0) | 0.14 (3.8) | 0(0) |
| December | 4.4(56.4) | 1.6(20.0) | 0.6 (7.3) | 1.14(14.5) | 0.14(1.8) |
| January | 5.3(46.7) | 2.3(20.0) | 2.9(25.6) | 0.90 (7.8) | 0(0) |
| February | 4.4(37.2) | 2.5(21.3) | 3.3(27.7) | 1.60(13.8) | 0(0) |
| March | 5.0(39.2) | 3.9(30.4) | 2.6(20.6) | 1.30 (9.8) | 0(0) |
| April | 4.5(76.6) | 1.3(21.3) | 0.12(2.1) | 0(0) | 0(0) |

**(d) Sonamarg (long: 75° 17′57″, lat: 34° 18′11″ and alt: 2745 m)**

| Month | Intensity (cm) | | | | |
|---|---|---|---|---|---|
| | 0-12 | >12-24 | >24-48 | >48-96 | >96 |
| November | 1.60(61.6) | 0.6(22.2) | 0.42(16.7) | 0(0) | 0(0) |
| December | 3.14(39.3) | 2.0(25.0) | 1.7 (21.4) | 0.86(10.7) | 0.30(3.6) |
| January | 4.10(47.1) | 1.4(15.7) | 2.4 (27.1) | 0.90(10.0) | 0(0) |
| February | 4.30(39.5) | 2.6(24.4) | 2.1 (19.8) | 1.60(15.1) | 0.13(1.2) |
| March | 5.90(40.5) | 3.6(25.0) | 3.0 (20.7) | 1.80(12.1) | 0.30(1.7) |
| April | 2.40(54.3) | 1.4(31.4) | 0.40 (8.6) | 0.30 (5.7) | 0(0) |

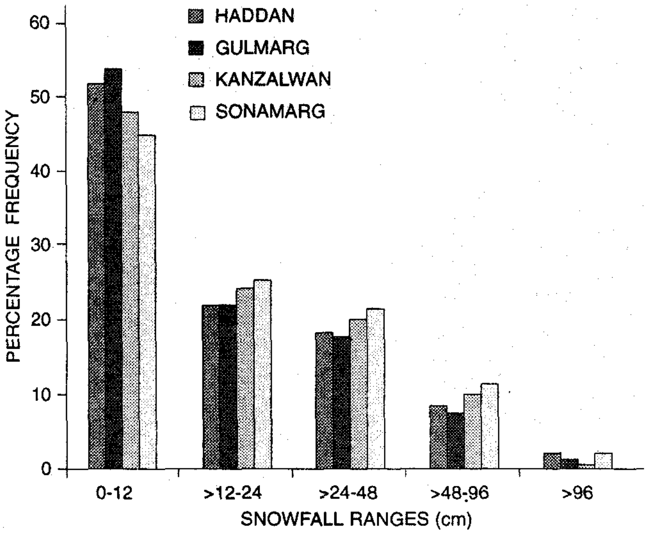



**Figure 3. Percentage frequency of snowfall days in different amount ranges.**

## 5. HIGHEST CUMULATIVE SNOWFALL AMOUNTS IN SPELLS OF DIFFERENT DURATIONS

Data on the highest snowfall amounts recorded in spells of different durations are presented in Fig. 5. It is seen that generally with increase in the duration of the snowfall spell, the amount of snowfall recorded at a station also increases. However, there are a few exceptions. For example, at Kanzalwan, the highest snowfall recorded during a spell of >10 days was 249 cm, which is much less than the amount recorded at the same station during a spell of 6-10 days. Similar distributions were observed at Haddan and Gulmarg, where the snowfall amounts received during a 4 days′ spell is less than those occurring during a spell of 3 days′ duration. The highest amount of snowfall was 486 cm recorded at Sonamarg in a spell of >10 days during 10 years.

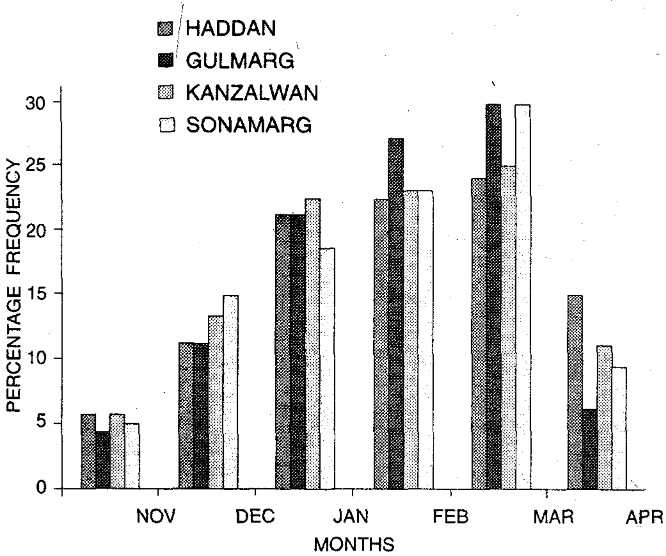



**Figure 4. Monthly percentage frequency of all amount ranges taken together.**

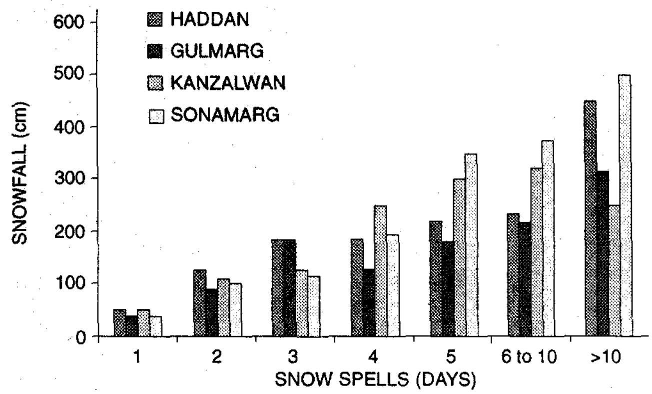
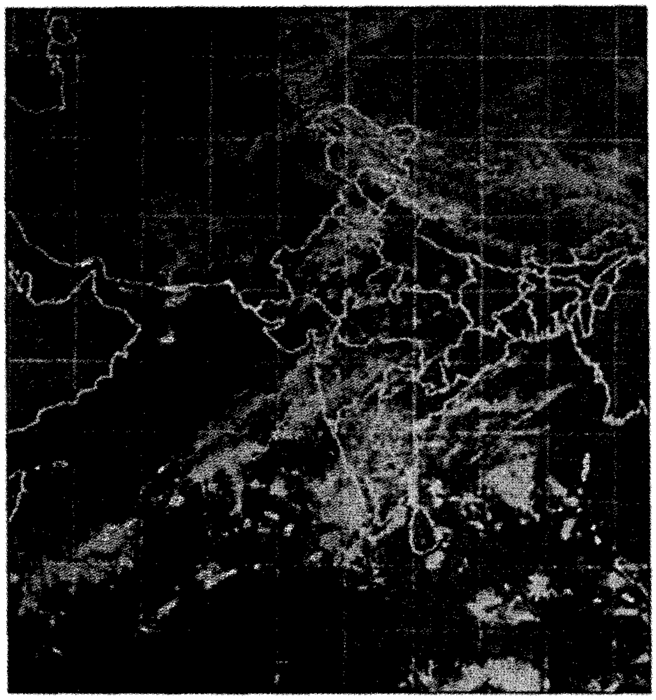



**Figure 5. Highest amount of cumulative snowfall occurring in spells of different durations.**

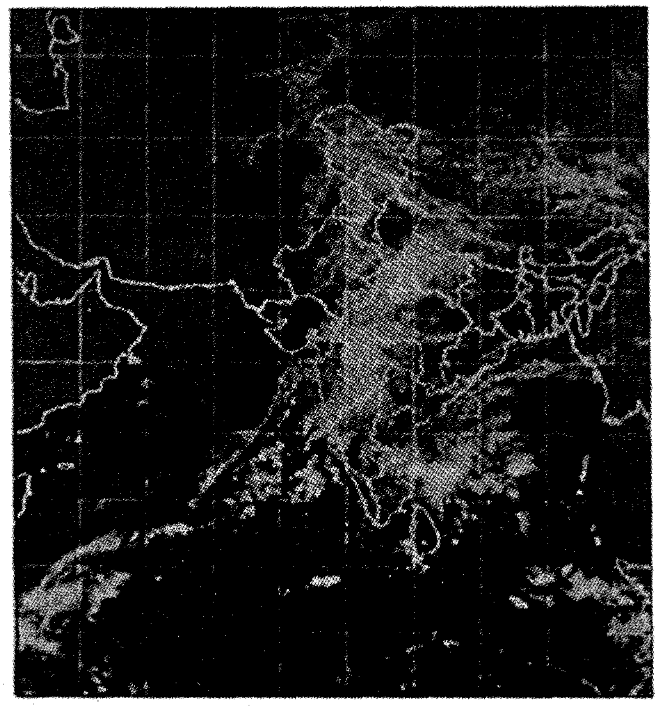
## 6. CASE STUDY OF A WESTERN DISTURBANCE

The synoptic situation of a WD was examined as a case study. A WD, as an upper air cyclonic system moved across north-west India during 7-10 December 1997. This was a very active disturbance and caused rain or snow at almost all places in HP, hills of western UP and a few places in J&K.

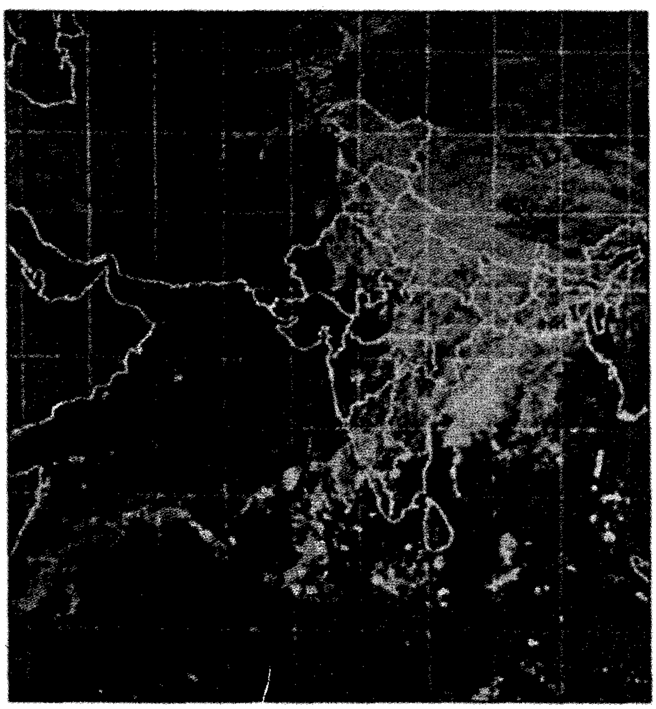
INSAT imageries at 0600 UTC (visible channel) of all these days are reproduced in Fig.6. From surface features it is noticed that the two cyclonic circulations at 850 hpa, one close to north Gujarat and the other over Punjab, moved slowly north-eastwards towards the hills of HP and western UP. At 300 hpa, a north-south-oriented upper air trough persisted at 70-75°E and north of 25°N during 7-9 December 1997. It moved towards north east on 10 December 1997 and lay along 80°E. The satellite pictures indicate advection of clouds and hence the moisture from the Arabian sea into the region of low level cyclonic circulations or to their east and concentrating over the region of Punjab, Harayana, HP, hills of western UP and J&K. Presence of westerly trough at upper level had intensified the system, causing widespread



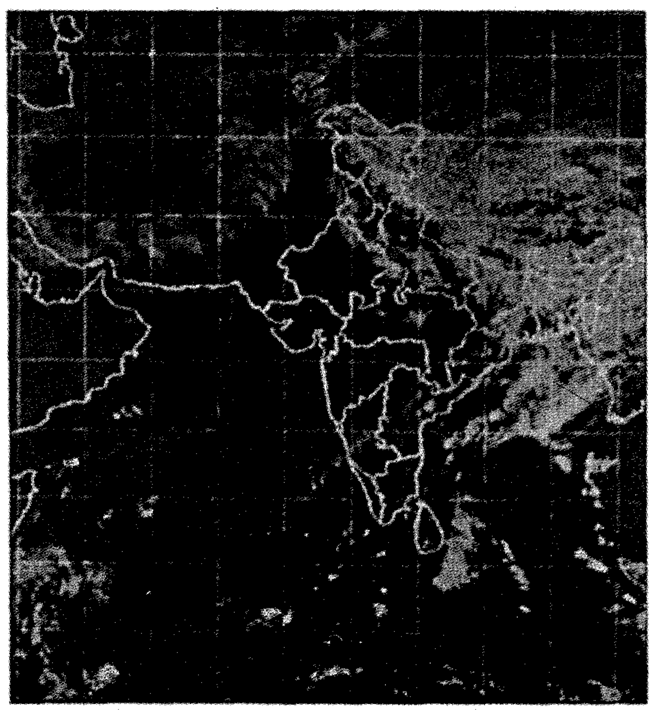
07 December 1997: 0600 UTC



08 December 1997: 0600 UTC



09 December 1997: 0600 UTC



10 December 1997: 0600 UTC

**Figure 6. Visible INSAT cloud imageries for storm period 07-10 December 1997**

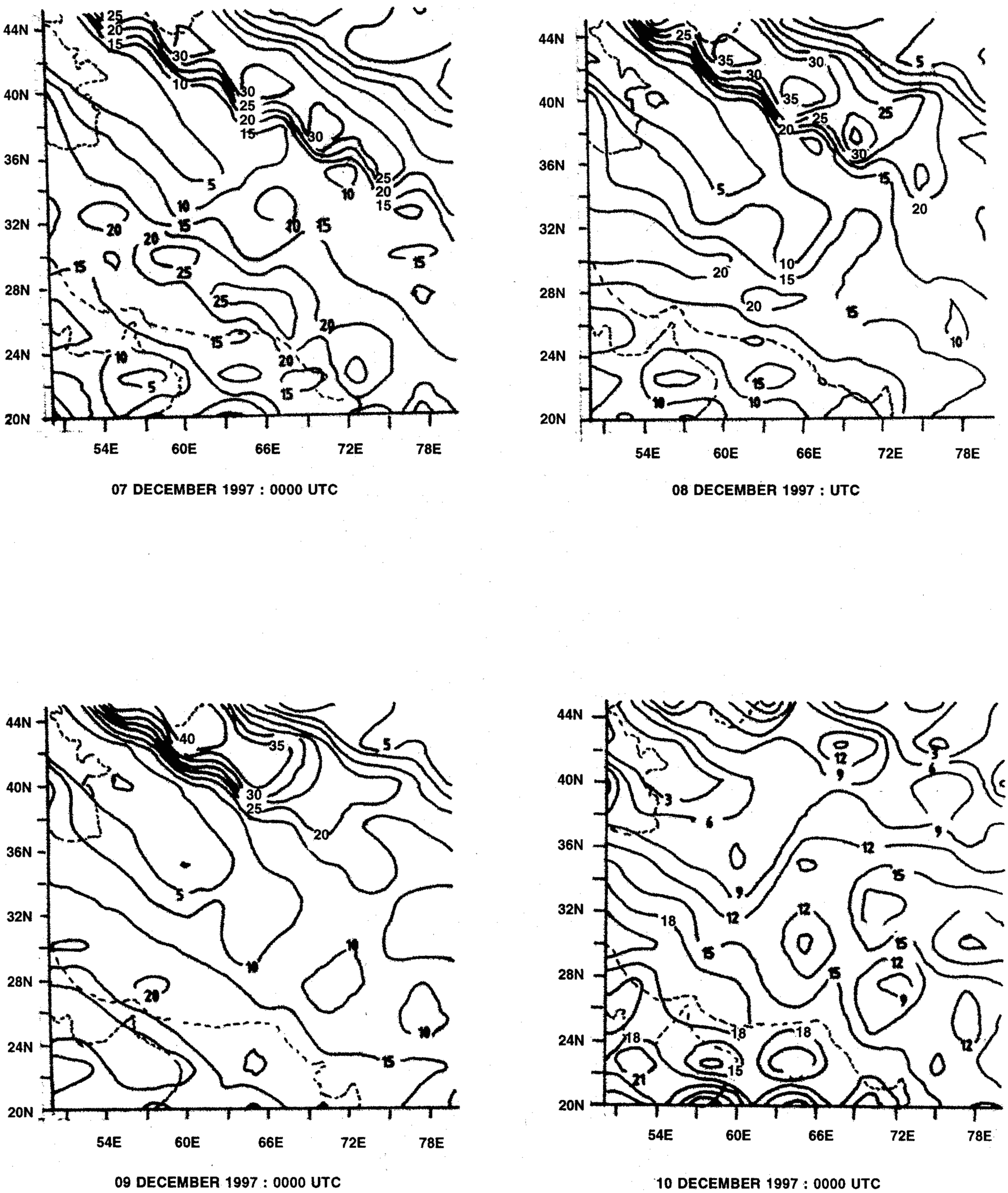



**Figure 7. Total precipitable water content (g/cc) for storm period 07-10 December 1997**

precipitation. The trough was formed due to medium and high level clouds forming ahead of the westerlies[2]. These south-west and north-east medium and high level clouds over the region are baroclinic in nature and are the main cause of lifting of moisture from the Arabian sea. During the storm period, the sky remained overcast with low and medium clouds[3,4]. The Himalayan mountain ranges modify the synoptic scale weather system approaching the Indian longitudes from the west. Surface observation of snow-meteorological parameters show that WD sometimes get intensified and at times slow down their movement in the vicinity of the Himalayas and thus cause local heavy snowfall over the hilly areas of J&K, HP and western UP.

Intensification of a WD is seen to be generally accompanied by incursion of warm moist air from bay of bengal or the Arabian sea into low pressure induced by development in the westerlies. To investigate the accumulation of moisture during the period of storm that sustained the WD and caused widespread precipitation, National Centre, for Atmospheric Research (NCAR), USA, daily re-analysis of total precipitable water content of the atmosphere at 00 UTC during 7-10 December 1997 is considered; the calculated values of moisture content are shown in Fig.7. It is seen that the calculated values are in conformity with clouds shown in Fig. 6. Two belts of maximum precipitable water content (g/cc), one extending from Arabian sea to north-west China and the other from south Iran to Gujarat in India, persisted during 7-9 December 1997. In between these two belts of maxima of total precipitable water content, a relatively dry belt of moisture was observed running from south Caspian sea to northern Rajasthan. On 10 December 1997, the northern belt of maximum precipitable water content weakened considerably and shifted north-eastwards and the southerly belt shifted further southwards into the Arabian sea. Widespread and heavy rainfall over J&K, HP and western hills of UP was recorded during 7-9 December 1997. It is probable that a relatively dry air belt between two very moist belts, coupled with synoptic disturbances and topography caused considerable instability, particularly on the Himalayan ranges and hence widespread and heavy precipitation. From 10 December 1997, when the two moist and dry belts became less marked, the precipitation belt decreased and moved eastwards.

## 7. CONCLUSIONS

From statistical trends of WD of the past 10 years, it is seen that weather associated with a WD lasts for 2-4 days, but the disturbed weather conditions persist for 5 days or even more. Such a situation normally occurs when WDs approach north-west India one after the other in quick succession at intervals of 1-2 days. Also, slow moving or stationary disturbances may cause adverse weather conditions for much longer duration over the hilly regions.

It may be concluded from the case study that a slow moving WD coupled with a well-marked upper level trough at 300 hpa and above moved into the hills from southern Rajasthan, Punjab/ Haryana regions. Two belts of very high total precipitable water content with a relatively dry belt with much less precipitable water content in between were observed.

## ACKNOWLEDGEMENT

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**Contributors**

**Mr AP Dimri** obtained his MSc (Tech) in Geophysics (Meteorology) from the Banaras Hindu University, Varanasi, in 1992. In 1994, he compeleted his MPhil in Environmental Sciences from Jawaharlal Nehru University, New Delhi. In the same year, he joined DRDO at the Snow & Avalanche Study Estt, Manali. Presently, he is involved in weather forecasting at some of the stations in J&K and HP using statistical and dynamical methods.

**Prof UC Mohanty** obtained his PhD (Tropical Meteorology) from USSR in 1978. Presently, he is working as Professor and Head of the Centre for Atmospheric Sciences at the Indian Institute of Technology (IIT), New Delhi. He is having more then 26 years of research and teaching experience in atmospheric sciences. He has been honoured with several awards, including *Shanti swaroop Bhatnagar Award,* (1993). He has published more than 70 papers in international/national journals. He is a member of many professional societies related to atmospheric sciences. His fields areas of specialisation are: tropical meteorology, numerical weather prediction, monsoon dynamics and climate modelling.