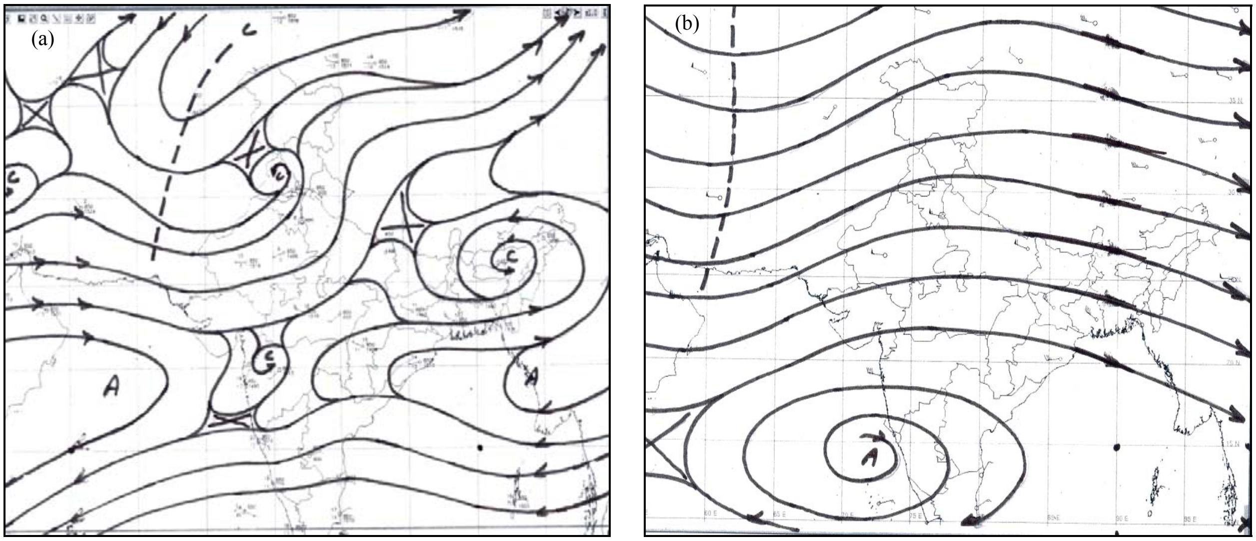
551.515.4 : 551.578.4 (235.243)

UNUSUAL SNOWFALL AND THUNDERSQUALLS OVER WESTERN HIMALAYAN REGION DURING 2012

1. A wide variety of weather systems such as monsoon circulations, tropical disturbances, western disturbances (WDs) and easterly waves affect the weather of Indian region. Western Himalayan region (WHR) experiences weather mainly due to WDs in winter season like strong winds, snowfall, rainfall and avalanches. Some weather events are severe in nature, which are associated with mainly active WDs and induced low pressure systems. Thunderstorm activities in pre-monsoon season and wind confluence with westerlies during monsoon season causes severe weather events like cloud bursts and heavy rainfall.

Many studies related to WDs and their impacts on Indian weather were carried out by many researchers. Agnihotri and Singh (1982) studied the WDs approaching northwest India & adjoining areas during winter period (November-March) with the help of satellite cloud imageries. Veeraraghavan and Nath (1989) studied about the temperature distribution of the top of the clouds

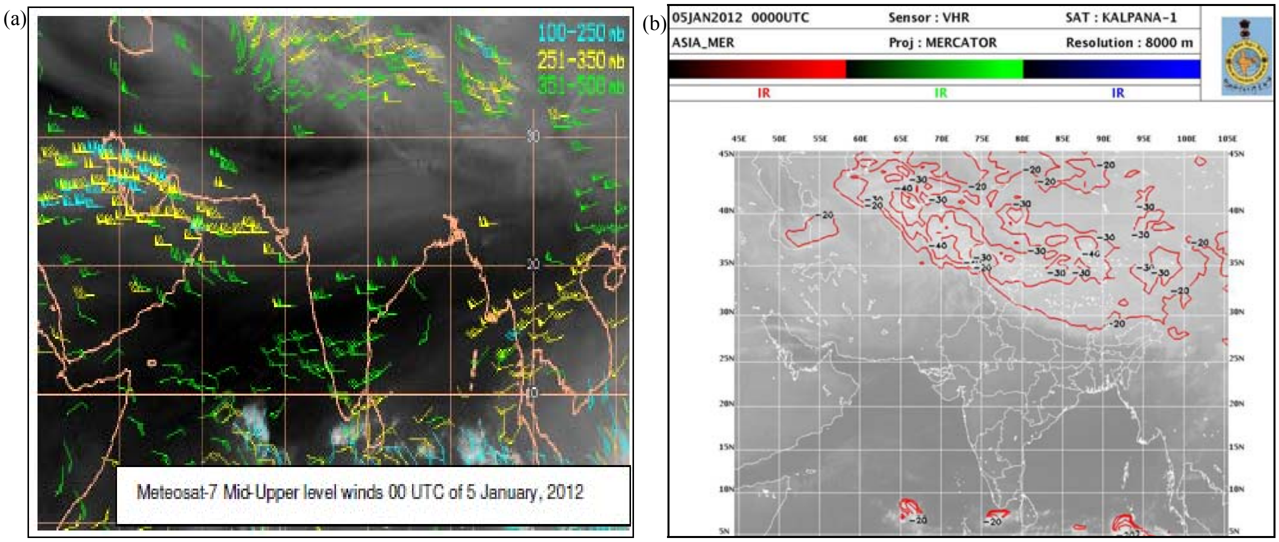


Figs. 1(a&b). Stream lines at (a) 850 hPa shows a deep trough over Pakistan and (b) 500 hPa a trough over Afghanistan and anticyclone over Arabian Sea at both levels of 0000 UTC on 5 January, 2012

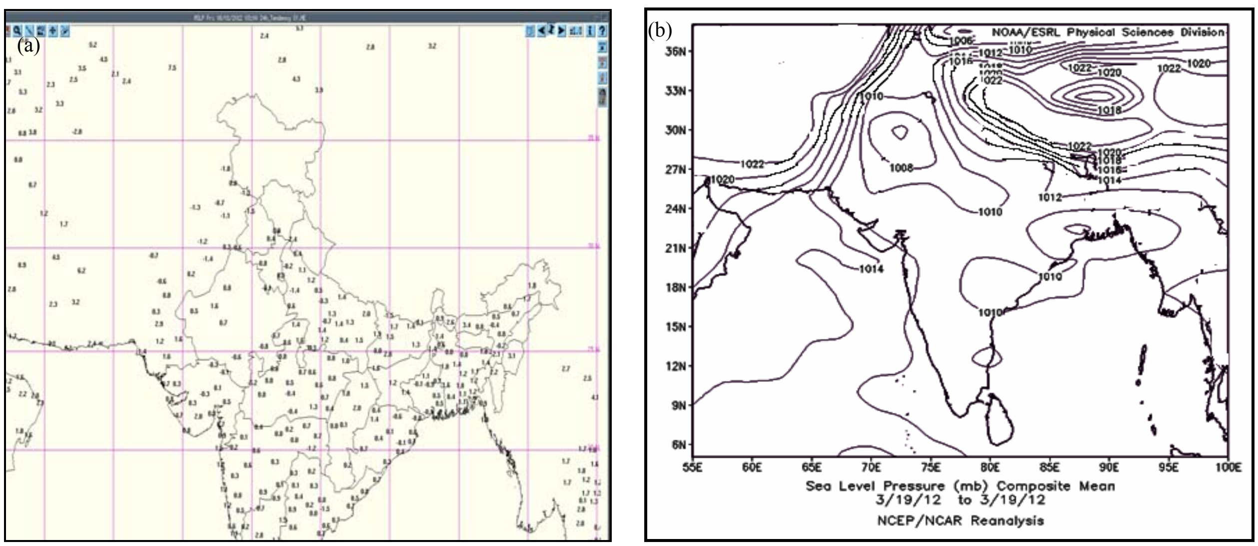
associated with the WDs as seen from the infrared satellite imageries and made an attempt to understand the relation between the CTT and the resultant rainfall. Rangachary and Bandyopadhyay (1986) have analysed the synoptic weather patterns associated with extensive avalanches over Western Himalayas due to western disturbances. Dimri and Mohanty (1999) studied the snowfall statistics of some Snow and Avalanches Study Establishment (SASE) field stations in Jammu & Kashmir, snowfall pattern and its frequency distribution using statistical means. They also studied the variation of snowfall spells to understand spatial and temporal changes in their distributions. Prediction of WDs and associated weather over Himalayan region were studied by Hatwar *et al.*, (2005). Dimri (2011) described in his study that whenever convergence peaks, a precipitation maxima occurs too. Moreover, temporal distribution shows a periodic 2-3 days association with convergence peak and precipitation maxima. Nandargi and Dhar (2012) made a detailed analysis of rainstorms that affected the northwest region of the Himalayas to assess the orographic effects of the Himalayas on precipitation in this region during past 135 years from 1875 to 2010. A study done by Ugnar (1999) indicates that the losses due to extreme weather events are increasing steeply especially in the last decade of the twentieth century. Kalsi and Hatwar (1992) made a study to understand interaction between tropics and mid-latitude through satellite observations. De *et al.,* (2005) listed the extreme weather events over India in past 100 years. Singh and Kumar (1977) carried out the detailed study of western disturbances and a book was published by Upadhyay (1995) about cold climate hydrometeorology associated with western disturbances.

Recently, two WDs have caused unusual weather over WHR, the first during 3-9 January and second during 17-20 March, 2012. Considering the severity of the weather, a study has been undertaken to diagnose the synoptic and environmental conditions that caused unusual severe weather events over the region. To find out the synoptic and environmental conditions, conventional and automatic weather stations data, satellite products and numerical weather prediction model products have been utilized.

2. During winter months, weather of western Himalayan region and adjoining plains is very important for agriculture, horticulture and thermal plants etc. Over high reaches experience snowfall and low lying area including adjoining plains experience rainfall in general. During January and March 2012, there were two western disturbances which caused unusual weather one caused heavy snowfall at low latitudes and another thunderstorm accompanied with thundersqualls over the Srinagar Valley. To study these weather events synoptic situations, satellite imagery with cloud top temperatures (CTT), Meteosat derived winds, upper air charts, pressure change charts, rainfall and squalls *etc.* have been taken from Satellite division, National Weather Forecasting Centre & Meteorological Centre Srinagar of India Meteorological Department (IMD). Surface temperatures, wind shear, vector winds anomaly and vorticity charts have taken from NCEP/NCAR re-analysis data (Kalnay *et al*., 1996). The values of these parameters are the estimated values extracts from the images. GFS (T382) analysis winds have been also taken to study the weather events.

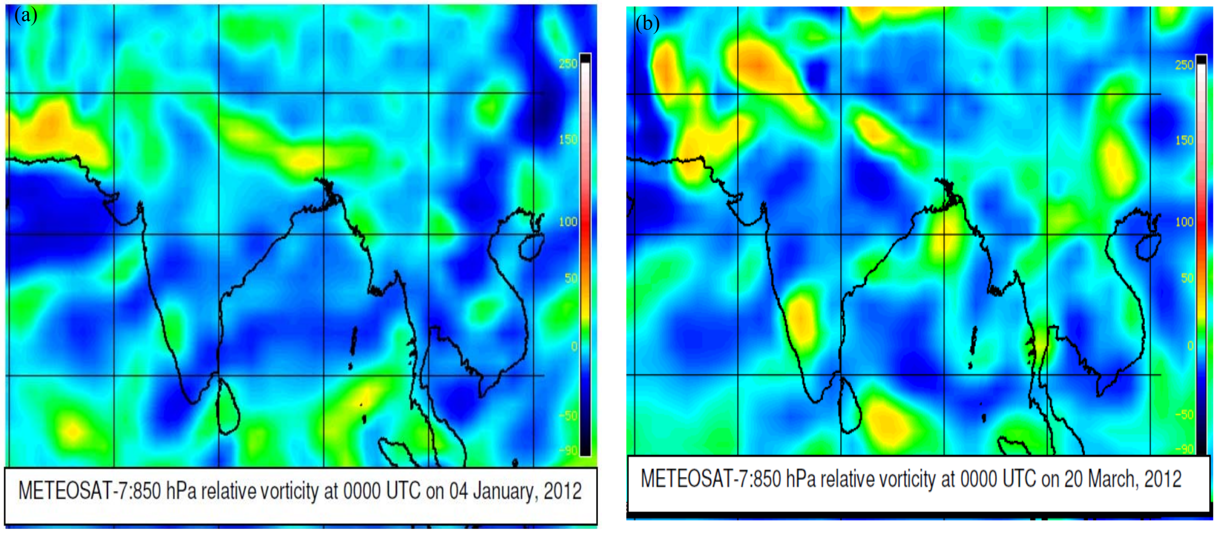


Figs. 2(a&b). (a) Meteosat derived winds between 80-100 kts, between 351-500 hPa levels of 0000 UTC and (b) Kalpana-1 infrared imagery of 0000 UTC with the CTT contours upto -50.0 °C over north Pakistan adjoining Jammu & Kashmir on 5 January, 2012



Figs. 3(a&b). (a) 24 hours pressure fall shows about 1.5-2.0 hPa over north Pakistan & adjoining western Himalayan region and (b) surface air temperature (°K) over the vast area including western Himalaya region on 5 January, 2012

3. Case-I (WD, 3-9 January, 2012) : On 3 January, a WD was seen as a trough in mid-latitude westerlies roughly along longitude 50.0° E and north of latitude 30.0º N. It moved eastwards and lay along long. 57.0° E and north of lat. 25.0° N on 4 January associated with an induced upper air cyclonic circulation over central Pakistan & neighbourhood in lower levels. It deepened and appeared as an upper air cyclonic circulation over north Pakistan and neighbourhood on 5 January [Figs. 1(a & b)]. There was good moisture incursion from Arabian Sea into the system. The wind maxima of the order of 80-100 kts was seen over north Pakistan & adjoining Jammu & Kashmir on the same day between 351-500 hPa levels [Fig. 2(a)]. On 6 January, the upper air cyclonic circulation laid over north Pakistan & adjoining western parts of western Himalayan region. The wind maxima shifted to eastwards and laid over Jammu & Kashmir and neighbourhood. Cloud top temperature



Figs. 4(a&b). Relative vorticity (a) at 850 hPa level is of the order of (30-40) $10^{-5}S^{-1}$ over western Himalayan region on 0000 UTC of 4 January and (b) at 850 hPa level is of the order of (40-50) $10^{-5}S^{-1}$ over north Pakistan and (10-20) $10^{-5}S^{-1}$ over western Himalayan region at 0000 UTC of 20 March, 2012

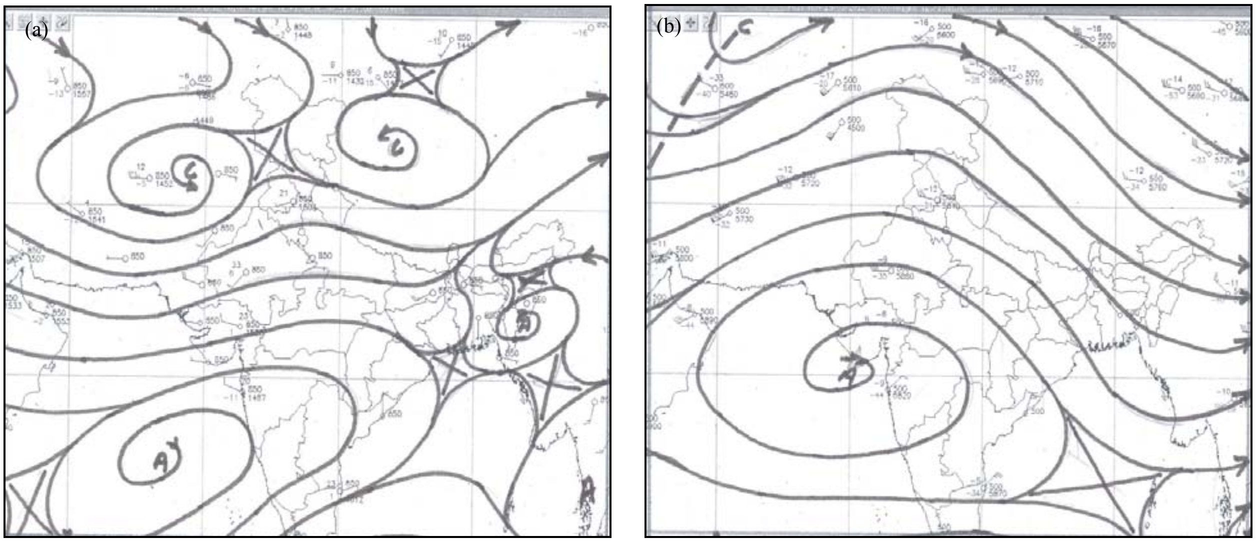
TABLE 1

Daily and cumulative precipitation (in mm) reported at stations over Jammu & Kashmir and Himachal Pradesh during 4 to 9 January, 2012

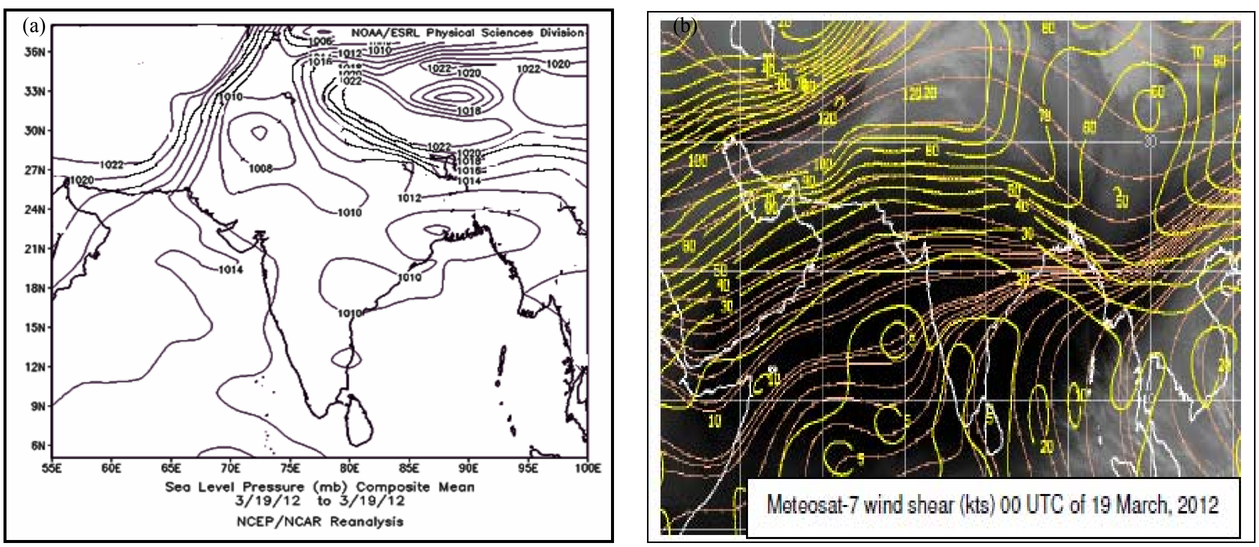
Date /stn.	1. BANIHAL TOP(J&K)	2. GULMARG(J&K)	3. HADDAN TAJ(J7K)	4. STAGE-II (J&K)	5. PHARKIYAN (J&K)	6 KANZALWAN J&K)	7-Z-GALI (J&K)	8. DRASS (J&K)	9. PUTTAKHAN (J&K)	10. RAGNI (J&K)	11. SONAPINDI (J&K)	12. NIRU (J&K)	13. DAWAR (J&K)	14. SONMARG (J&K)	15. BIMBAT LC (J&K)	16. FIRM BASE (J&K)	17. GUGALDAR (HP)	18. BHANG (H.P)	19. SOLANG (H.P)	20. DHUNDI (H.P)	21. PATSIO (H.P)
4 January, 2012	0	0	0	0	0	0	0	0	0	0	0	6	4	0	0	0	-	0	0	0	0
5 January, 2012	9	0	6	11	4	7	2	0	10	40	10	-	-	3	4	6	6	2	16	15	1
6 January, 2012	34	20	24	2	4	19	24	9	5	35	28	-	-	6	45	7	4	0	3	3	0
7 January, 2012	0	5	15	16	12	0	5	0	15	18	6	-	-	3	5	1	4	22	13	0	7
8 January, 2012	0	1	0	3	2	0	3	0	8	0	3	0	0	1	-	-	0	21	17	0	2
9 January, 2012	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0	2	-	21	20	22	-
Cumulative precipitation (in mm)	43	26	45	32	22	26	34	9	38	93	45	6	4	13	54	16	14	66	69	40	10

(CTT) was upto -40.0 °C at 0000 UTC on 4 and it further reduced to -50.0 °C at 0000 UTC on 5 January over Jammu & Kashmir region [Fig. 2(b)].

The 24 hours surface pressure fell by 1.0-1.5 hPa over north Pakistan & adjoining western Himalayan region on 5 January, 2012 [Fig. 3(a)] and on 6 onward it rose by 2.0-2.5 hPa. The surface temperature was less than 1.0 °C over the most parts of WHR on 5 January [Fig. 3(b)] and expands over to more areas on 6 January. The relative vorticity at 850 hPa level was about (40) $10^{-5} S^{-1}$ on 4 January [Fig. 4(a)] and it became about



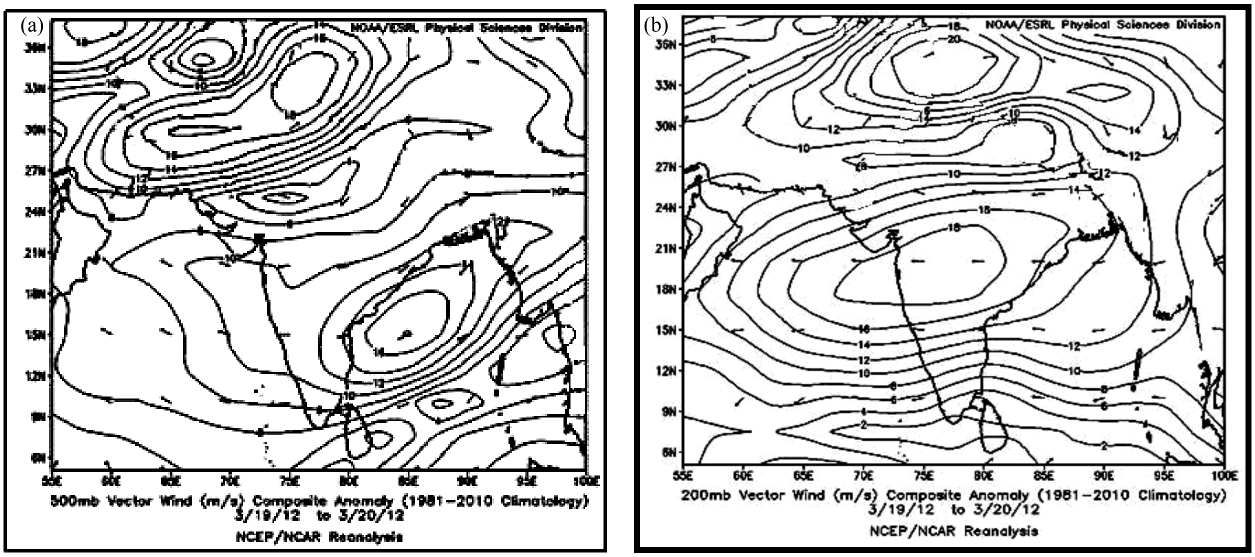
Figs. 5(a&b). Stream lines (a) at 850 shows cyclonic circulations east-west of western Himalayan region and (b) at 500 hPa a deep trough around longitude 60.0° E of 0000 UTC on 19 March, 2012



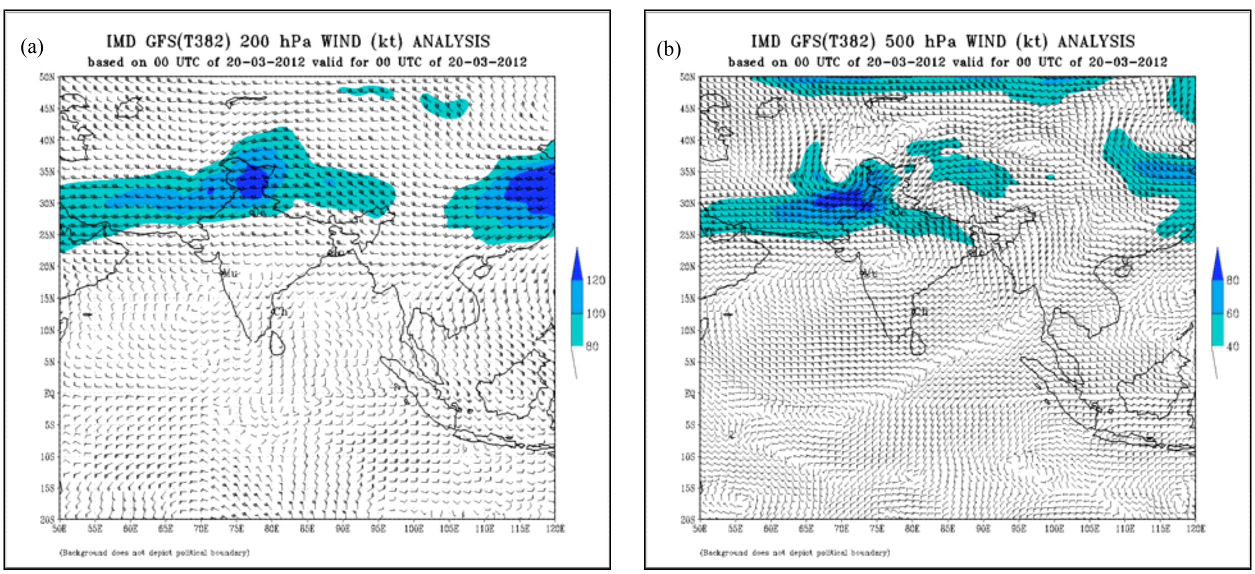
Figs. 6(a&b). (a) Meteosat 7 wind shear (kts) 19 March, 2012 and (b) NCEP/NCAR re-analysis plot of surface pressure of 19 March, 2012

(-30)10^{-5} S^{-1} on 9 January, that means a significant change in flow pattern from cyclonic to anti-cyclonic. According to Upadhyay (1995), the surface air temperature less than 2.0 °C is favourable for snowfall. As the water droplets passing through the environment of 2.0 °C or less temperature, droplets temperature reach to freezing point or less.

3.1. Due to this WD, fairly widespread snowfalls with isolated heavy falls were observed over WHR during 4-6 January, 2012 with its peak weather on 5 January. Widespread precipitation (rainfall/snowfall) activity was observed over high reaches of western Himalayan region and fairly widespread over low lying area upto Pathankot (Punjab) and Kangra Valley in Himachal Pradesh, these areas were unusual for snowfall. The highest cumulative precipitation was recorded at Ragni 93 mm, followed by Bimba (LCT) 54 mm in Jammu & Kashmir, Solang 69 mm and Bhang 66 mm in Himachal Pradesh. The significant amounts of precipitation recorded at India Meteorological Department (IMD) observatories are given in Table 1.



Figs. 7(a&b). Vector winds anomaly at (a) 500 hPa shows negative anomaly over northern plains of the country and positive anomaly far northwest of India and (b) 200 hPa negative anomaly over east Nepal and China and positive over far northwest of India on 19 & 20 March, 2012



Figs. 8(a&b). GFS (T382) wind Analysis at (a) 500 hPa & (b) 200 hPa, shows winds maxima over western Himalayan region and adjoining plains on 20 March, 2012

3.2. Case-II (WD, 17-20 March, 2012) : On 17 March, the WD appeared as a trough in mid-latitude westerlies roughly along longitude 57.0^{o} E and north of latitude 25.0° N. It moved eastwards and laid along longitude 62.0° E and north of latitude 25.0° N with an induced cyclonic circulation over central Pakistan & neighbourhood on 19 March [Fig. 5(a&b)]. The surface pressure fell by 2-3 hPa over the WHR. Steep pressure gradient (about 12 hPa) was observed between northeast Afghanistan and eastern parts of WHR on 19 March, such steep pressure gradient contribute in enhancing windflow over the region [Fig. 6(a)]. Wind shear was between 80-120 kts over the region on 19 March [Fig. 6(b)], which enhanced vertical velocity over the region. Positive wind anomaly of the order of 10-15 m/s was observed over WHR at higher levels (500 & 200 hPa) on 20 March [Fig. 7(a & b)] and wind maxima at higher levels [Fig. 8(a&b)]. The relative vorticity at 850 hPa level was (60) 10^{-5} S^{-1} at 0000 UTC on 16 March and it decreased to (-30) 10^{-5} S^{-1} at 0000 UTC on 20 March [Fig. 4(b)] with an increase of wind shear and was of the order about 85 kts over the region and about 100 kts over the Valley area on 20 March, 2012.

3.3. Due to this WD, fairly widespread precipitation and severe thunderstorm activity have been observed on 19 & 20 March, 2012 over WHR mainly over Srinagar, Bandipur and Jammu areas. The maximum damage was were injured, hundreds of rooftops were blown away, scores of trees uprooted and damaged power infrastructure (Media reports of 20 March, 2012). IMD observatories over Srinagar area have reported wind 75-88 kmph from southeasterly direction in Srinagar at around 1500 hours IST, 40-50 kmph in Kokarnag and 48-55 kmph in Qazigund from southeasterly direction on 20 March, 2012, such type of severe thundersquall activity in Srinagar valley is categorised unusual.

(a) In first WD, unusual snowfall occurred in association with high winds in the order of about 100 kts along with intense convective clouds over Pakistan & adjoining Rajasthan in middle & upper tropospheric levels. Also, the surface air temperatures were less than 1.0 °C over most parts of the region that caused unusual snowfall in lower latitudes

(b) In second WD, severe thunder squalls were caused due to mainly strong wind shear about 100 kts and high pressure gradient about 10 hPa over the region. The westerly jet was also very favourable, which led to development of dynamic instability in the atmosphere.

(c) Relative vorticity over western Himalayan region was positive in the advance phase of first WD (upto 5 January, 2012) and negative afterwards, in second WD it was positive till 19 March, 2012 and negative afterwards.

References

Agnihotri, C. L. and Singh, M. S. 1982, "Satellite study of western disturbances", *Mausam,* **33,** 2, 249-254.

Dimri, A. P. and Mohanty, U. C. 1999, "Snowfall statistics of some SASE field stations in Jammu & Kashmir and a case study of western disturbances", *Defence Sci. J.*, **49**, 5, 437-445.

Dimri, A. P., 2011, "Atmospheric water budget over the western Himalaya in a regional climate model", *Journal Earth System Science,* **121**, 4, 963-973, DOI: 10.1007/s12040-012-0204-8.

De, U. S., Dube, R. K. and Rao, G. S. P., 2005, "Extreme weather events over India in the last 100 years", *J. Ind. Geophys. Union*, **9**, 3, 173-187.

Hatwar, H. R., Yadav, B. P and Rama Rao, Y. V. 2005, "Prediction of western disturbances and associated weather over Western Himalayas", *Current Science*, **88**, 6, 913-920.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White, G., Woollen, J., Zhu, Y., Chelliah, M., Ebisuzaki, W., Higgins, W., Janowiak, J., Mo, K. C., Ropelewski, C., Wang, J., Leetmaa, A. Reynolds, R., Jenne, R. and Joseph, D., 1996, "The NCEP/NCAR 40-Year Reanalysis Project". *Bulletin of the American Meteorological Society* **77**, 3, 437-471.

Kalsi, S. R. and Haldar, S. R., 1992, "Satellite observations of interaction between tropics and mid latitude", *Mausam*, **43**, 1, 59-64.

Nandargi, S. and Dhar, O. N., 2012, "Extreme Rainstorm Events over the Northwest Himalayas during 1875-2010", 13, 4, 1383-1388.

Rangachary, N. and Bandyopadhyay, B. K. 1986, "An analysis of the synoptic weather pattern associated with extensive avalanching in Western Himalaya", *IAHS Publ. No.* ***162,*** 311-316.

Singh, M. S. and Kumar, S., 1977, "Study of a western disturbance", *Mausam*, **28**, 2, 233-242.

Upadhyay, D. S., 1995, "Cold climate hydrometeorology", New age international (p) Ltd. publisher India".

Ugnar, S., 1999, "Is strange weather in the air?, A study of U>S> national network news coverage of extreme weather events", *Climate Change*, **41**, 2, 133-150.

Veeraraghavan, K. and Nath, T. A., 1989, "Satellite study of an active western disturbance", *Mausam*, **40**, 3, 303-306.

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