

# Prediction of western disturbances and associated weather over Western Himalayas

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**Two cases of intense western disturbances which affected the northwest India have been investigated using the India Meteorological Department's operational limited area analysis and forecast system. The model results are compared with the synoptic observations, which have been enriched by additional stations installed under the national project 'Parwat'. The analysis shows that the 24-hour model forecasts are in good agreement with the observations both in respect of western disturbance's movement and intensification. Even the numerical model could predict the spatial distribution of precipitation with a high success rate and was found to be very useful in providing numerical guidance in day-to-day operational short range forecasts.**

DURING winter months, the Western Himalayas and adjoining northern parts of India experience cloudiness and rainfall/snowfall in association with weather systems commonly known as 'Western Disturbances' (WD). It is one of the most important weather systems that causes adverse weather conditions over northwest India and particularly over the Western Himalayan region. Analysis of synoptic charts shows that a WD originates usually over the Mediterranean Sea/Black Sea area as an extra-tropical frontal system, but its frontal characteristics are lost while moving eastward towards India across Afghanistan/Pakistan. However, even then an intense WD is capable of producing widespread heavy snowfall over the Western Himalayan region and rains over northern plains for a day or two and may lead to snow avalanches.

In an important work on winter weather systems, Rao and Srinivasan<sup>1</sup> have discussed some synoptic aspects of winter weather systems and the general weather pattern associated with the WDs. Recently Hatwar *et al.*<sup>2</sup> have carried out a study of heavy snowfall over the Western Himalayas during winter months.

India Meteorological Department (IMD) provides weather forecasts to different users in India, utilizing various techniques like synoptic, statistical and numerical weather prediction for day-to-day weather forecasting. However, lack of data, both surface and upper-air is a major problem in forecasting WD activities as the region across which a WD traverses has poor data network. In recent decades, satellite imageries and NWP products are found to be very useful in tracking

WDs. Also, efforts have been made to increase the surface and upper air data network over the Western Himalayan region under the 'Project Parwat', a joint national effort by IMD, DRDO (SASE), Army, Air Force and DST.

In the present study, the western disturbances that affected northwest India during the period 13–17 January 2002 and 5–8 February 2002 have been investigated using both synoptic and numerical model products. Special observations available under Project Parwat are also utilized in the study. Their utility in the analysis and forecast has been discussed. IMD's numerical model's forecasts have been compared with the available synoptic observations and verification/error statistics of operational forecast are presented.

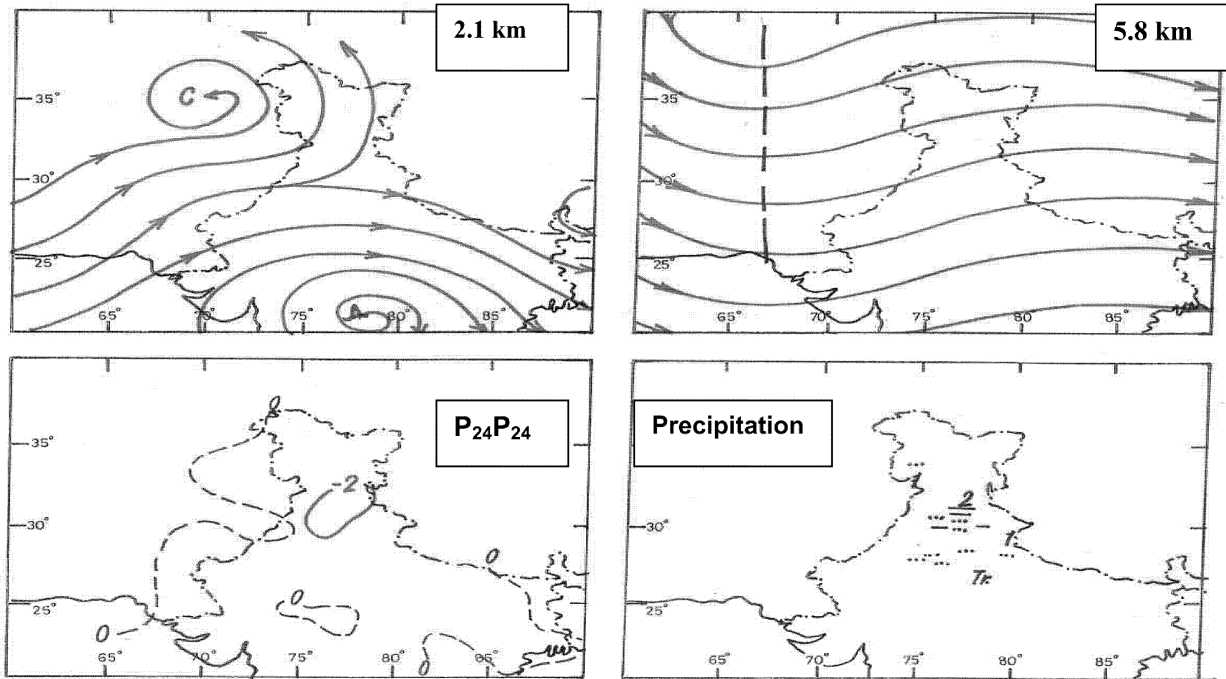
## Case-I (Western Disturbance, 13–17 January 2002)

This is an example of an intense western disturbance that affected mainly the Western Himalayan region and caused widespread snowfall with scattered heavy falls over the region.

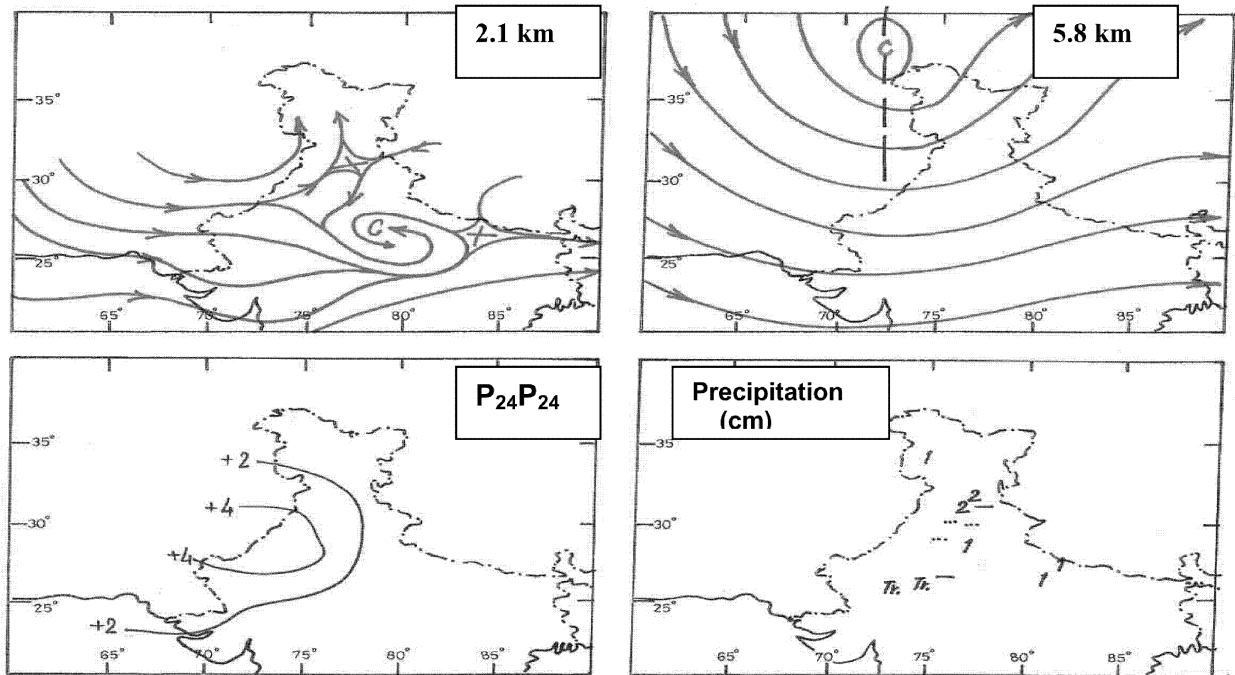
### Synoptic situation

On 12th morning, a western disturbance was seen as a low pressure area over Pakistan and adjoining Afghanistan with the upper air cyclonic circulation extending up to 2.1 km above sea level. An induced low was also formed on 13th morning between longitudes 58°E to 63°E and latitudes 25°N to 30°N with circulation extending up to 0.9 km above sea level. Both the main as well as induced lows moved eastwards along Jammu & Kashmir and West Rajasthan respectively, for the subsequent two days. On 15th and 16th, the main low pressure area persisted over the same area with slight eastward movement while the induced low pressure area moved eastwards faster than the main low (Figures 1 and 2). With the arrival of WD, the pressure fall of 1–2 hPa over the Western Himalayas and 3–4 hPa over adjoining parts of Pakistan was observed on 12th and a fall of 3–4 hPa over the Western Himalayas, West Rajasthan and neighborhood was seen in the subsequent two days. On 15th, the surface pressure fell only 1–2 hPa over the domain. On 16th morning, there was no further fall over the Western Himalayas and as the WD weakened and moved away eastwards, a rise in surface pressure by 3–4 hPa was seen over Rajasthan and neighborhood on 17th. The pressure rise was also observed over the Western Himalayan region.

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**Figure 1.** Stream line analysis at 2.1, 5.8 km and pressure change (hPa) based on synoptic analysis and rainfall (cm) based on 03 UTC synoptic observations on 15 January 2002.

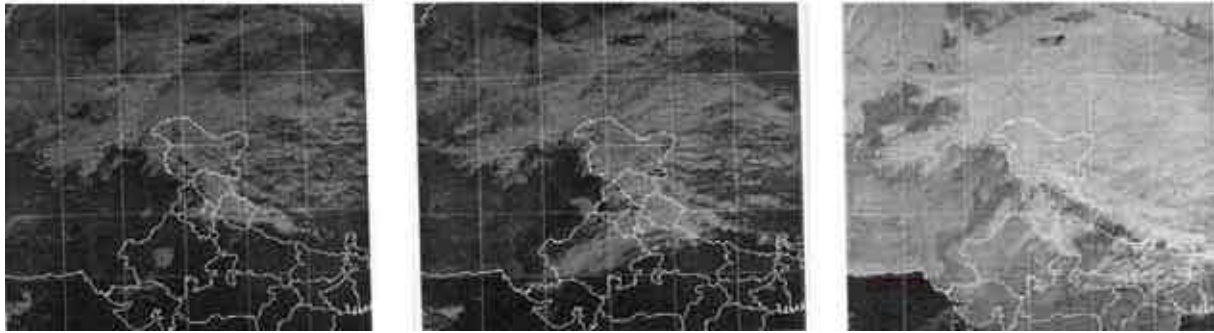


**Figure 2.** Stream line analysis at 2.1, 5.8 km and pressure change (hPa) based on synoptic analysis and rainfall (cm) based on 03 UTC synoptic observations on 16 January 2002.

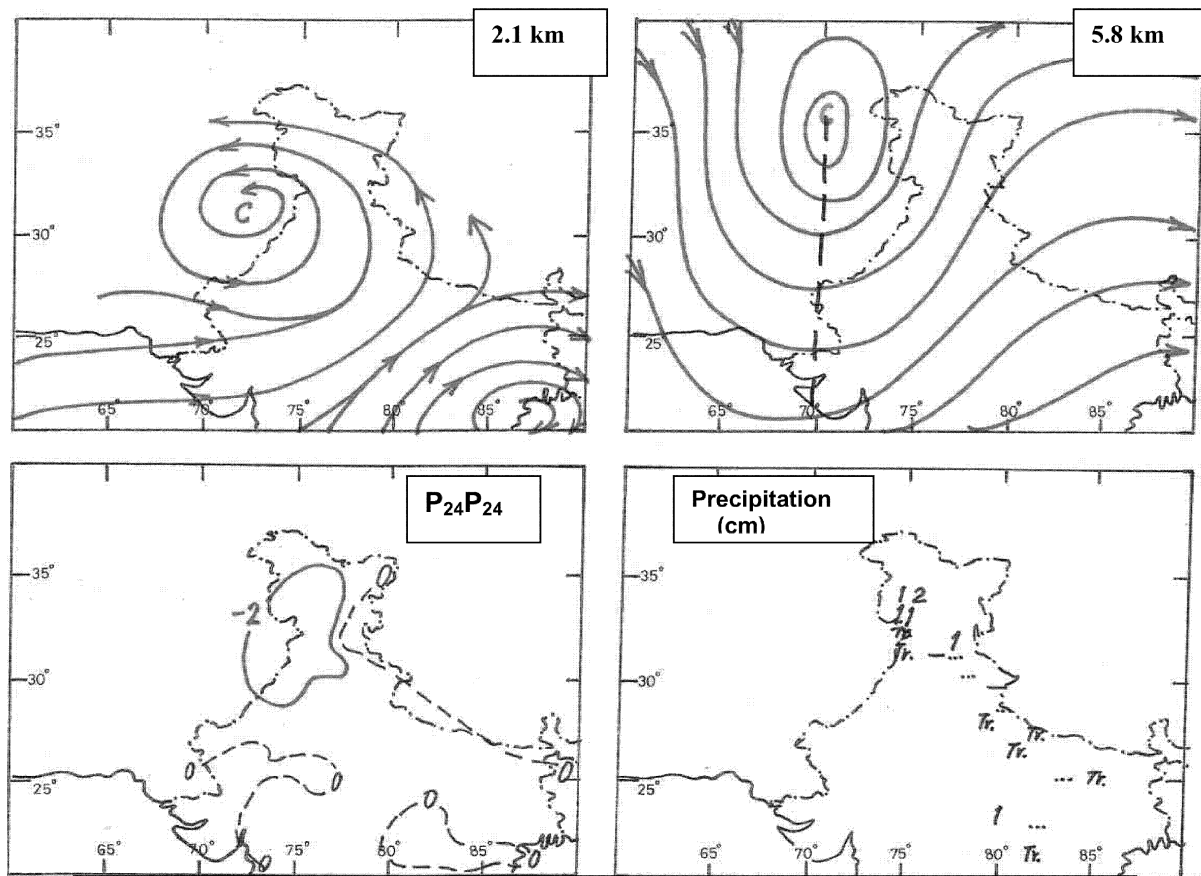
*Mid tropospheric westerly trough*

On 15th morning, there was a well-marked trough at 500 hPa in the mid tropospheric westerlies nearly along longitude 66°E and north of latitude 25°N. This trough moved east-

wards and was seen along longitude 72°E and 75°E and north of latitude 30°N on 16th and 17th respectively (Figures 1 and 2). With the eastward movement of the system in the lower levels, the mid-tropospheric westerly trough also moved further eastwards on 18th morning.



**Figure 3.** INSAT-1D cloud picture (visible) 06 UTC of 14, 15 and 16 January 2002.



**Figure 4.** Stream line analysis at 2.1, 5.8 km and pressure change (hPa) based on synoptic analysis and rainfall (cm) based on 03 UTC synoptic observations on 7 February 2002.

*Satellite imageries*

The cloud mass associated with this system was seen over Iran, Afghanistan and parts of Pakistan on 12th, which moved eastwards and was seen over Pakistan and Jammu & Kashmir on 13th. From 14th to 16th, intense convective clouds associated with the system were observed (Figure 3) over the Western Himalayas and low and medium clouds over adjoining plains of northwest India, which moved away eastwards on 17th and 18th.

*Precipitation*

Precipitation belt was confined mainly over the Western Himalayan region, Jammu & Kashmir and Himachal Pradesh as only very light rainfall was recorded over plains of north-west India. On 13th morning, moderate snowfall was recorded at most places over the Western Himalayas. On 14th and 15th, the intensity increased and widespread snowfall was recorded over the Western Himalayan region with scattered heavy to very heavy falls on 15th. The highest amounts

(water equivalent) recorded on 15th were 14 cm at Gugaldhar, 10 cm each at N. C. Pass and Stage-II and 9 cm each at Pharkyan and Kanzalwan over Jammu & Kashmir sector and 8 cm at Dhundi over Himachal Pradesh sector of the Western Himalayas and additional observed rainfall (cm) data over the plains of northwest India are given in Figure 1.

**Case-II (Western disturbance, 5–8 February 2002)**

This is an example of a western disturbance, which gave precipitation over the Western Himalayas, Jammu & Kashmir, Himachal Pradesh, Uttaranchal and also over central parts and Gangetic plains of India.

*Synoptic situation*

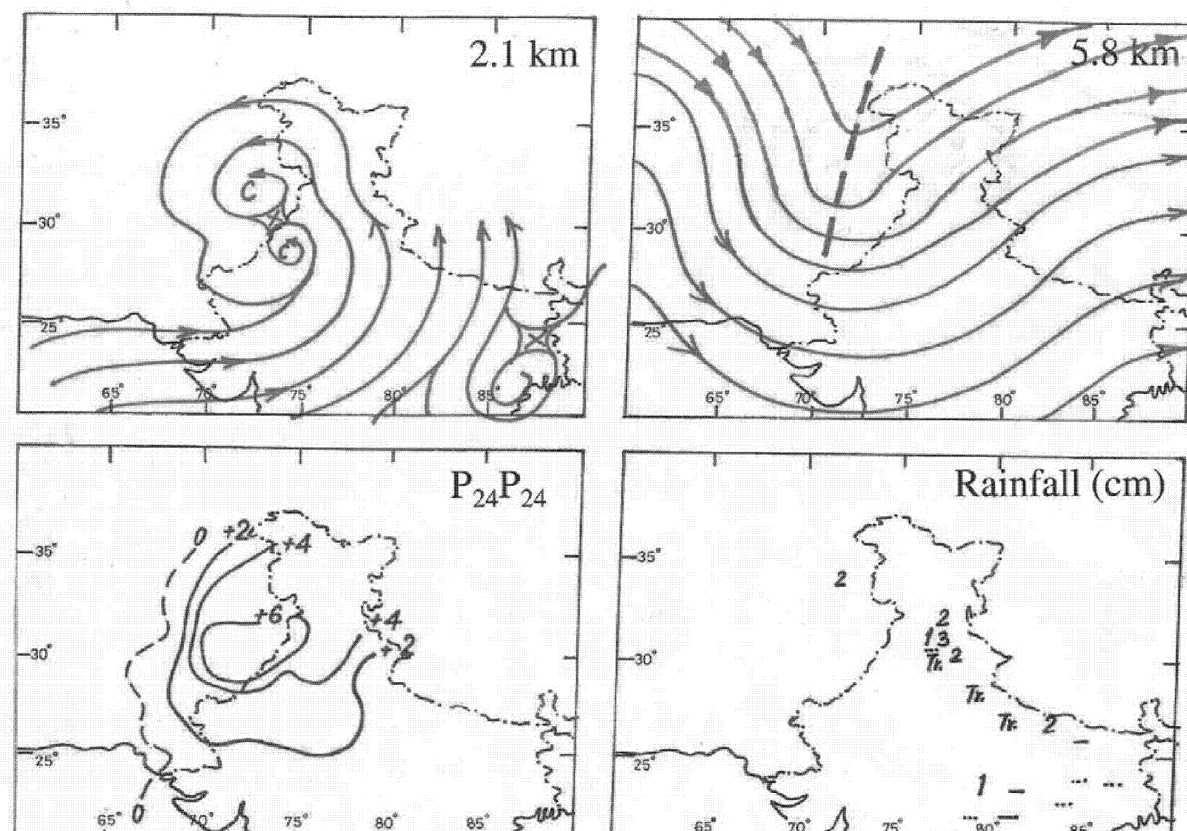
Its entry into the Indian sub-continent has been a little more to the south than most cases, near latitude 25°N–30°N. This system could be seen as a surface low over extreme southern parts of Iran on 4th with low level cyclonic circulation over north Pakistan and neighbourhood extending up to 4.5 km. An induced low pressure area formed over central parts of Pakistan and adjoining west Rajasthan on 5th with associated low level circulation extending up to 2.1 km. The main system moved eastwards and was seen over Jammu & Kashmir and neighbourhood on 6th whereas the induced

low remained stationary. On 7th both main as well as induced system became more intense with strong surface winds. There was moisture incursion from the Arabian sea due to southerly/southwesterly winds and also from Bay of Bengal in association with a anticyclonic circulation over the area. By 8th both main as well as the induced systems weakened and were seen as low level cyclonic circulations extending up to 2.1 and 0.9 km respectively (Figures 4 and 5).

With the approach of the WD, a pressure fall of 2–4 hPa was observed over north India on 4th and 5th and a similar tendency in pressure change was observed during the subsequent two days (Figure 6). The pressure rise of 4–5 hPa was observed over the Western Himalayas and adjoining plains of northwest India on 8th with the weakening and movement of the system eastwards.

*Mid-tropospheric westerlies*

With the passage of the system, the mid-tropospheric westerly trough at 500 hPa was seen nearly along longitude 55°E to the north of latitude 25°N on 4th and subsequently it shifted eastwards to 62°E and 65°E on 5th and 6th. With the strengthening of the system on 7th, the extension of trough into south was seen up to 20°N along 70°E and on 8th it moved northeastwards and was over 72°E north of 30°N (Figures 4 and 5).



**Figure 5.** Stream line analysis at 2.1, 5.8 km and pressure change (hPa) based on synoptic analysis and rainfall (cm) based on 03 UTC synoptic observations on 8 February 2002.

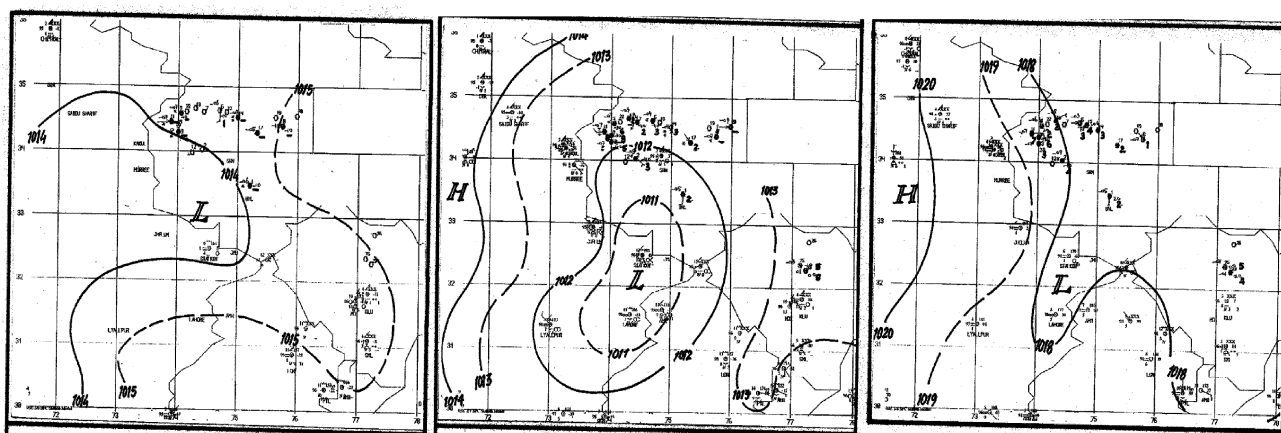


Figure 6. Mean sea level pressure analysis for 03 UTC of 5, 6 and 7 February 2002.

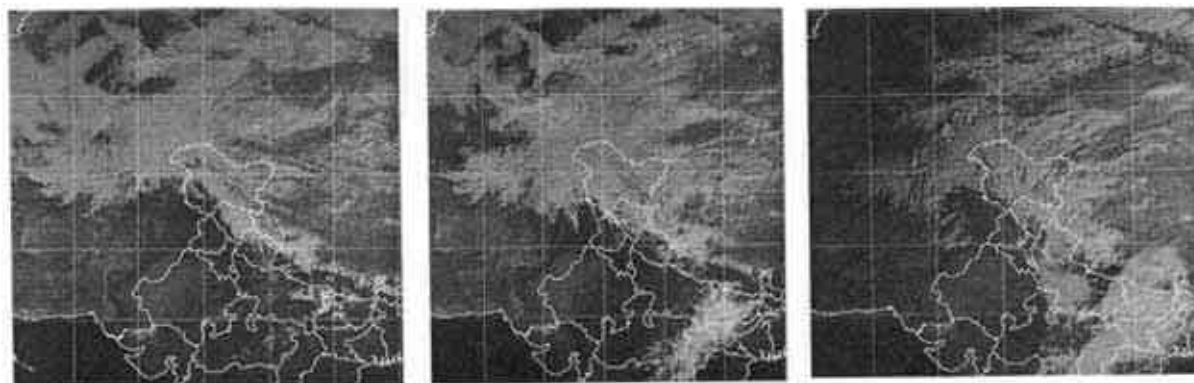


Figure 7. INSAT-1D cloud picture (visible) 06 UTC on 6, 7 and 8 February 2002

### Satellite cloud imageries

The cloud mass associated with system was seen over Afghanistan and neighbourhood on 4th, which moved eastwards and was seen over Pakistan and Jammu & Kashmir on 5th. The system further moved eastwards slowly and the associated cloud mass was seen over Jammu & Kashmir and adjoining north Pakistan on 6th and 7th morning. On 8th, low/medium clouds could be seen over eastern parts of Jammu & Kashmir and adjoining plains extending up to central and northeast parts of India (Figure 7).

### Precipitation

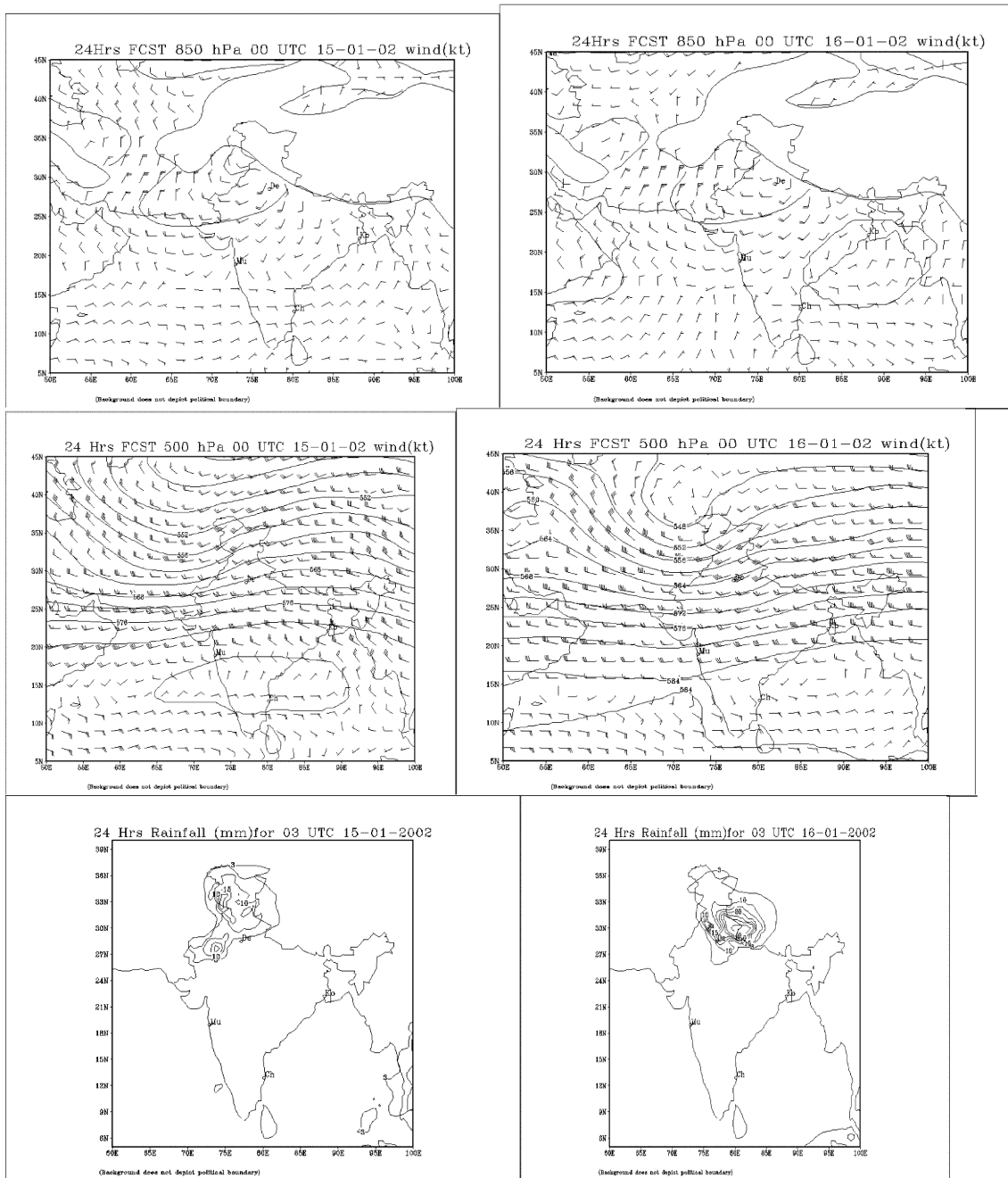
During the passage of this system, the precipitation belt shifted from the Western Himalayan region to central parts and Gangetic plains of India. On 6th fairly widespread light precipitation was recorded over the Western Himalayas and adjoining plains. On 7th and 8th, widespread moderate snowfall with isolated heavy falls was recorded over Western Himalayas and moderate rainfall over central parts and Gangetic plains of India. The highest amounts recorded on the 7th were 8 cm each at N. C. Pass and Stage-II

and 6 cm at Pharkyan over the Jammu & Kashmir and 5 cm each at Dhundi and Solang over Himachal Pradesh. On 8th 4–6 cm were recorded at some of the stations over the Western Himalayas, 2 cm at Gorakhpur in East Uttar Pradesh and 1 cm at Jabalpur in East Madhya Pradesh.

### Numerical model results

In recent decades with the advances in the observational technology and numerical techniques, significant progress has been achieved in weather forecasting by numerical models. The success is more spectacular in respect of extra-tropical weather systems and numerical model forecasts have become one of the useful tools for operational forecasters.

The IMD limited area analysis forecast system consists of real-time data decoding, multivariate optimum interpolation analysis covering for limited area horizontal domain of 30°S to 60°N; 0° to 150°E and 12 sigma levels from 1.0 to 0.05 in the vertical and 1° × 1° horizontal lat./long. grid. Forecast model for the operational short-range prediction is a multi-level, semi-Lagrangian, semi-implicit primitive equation regional model with horizontal resolution of 0.75° lat./long. and 16 sigma levels in vertical. Its horizontal domain



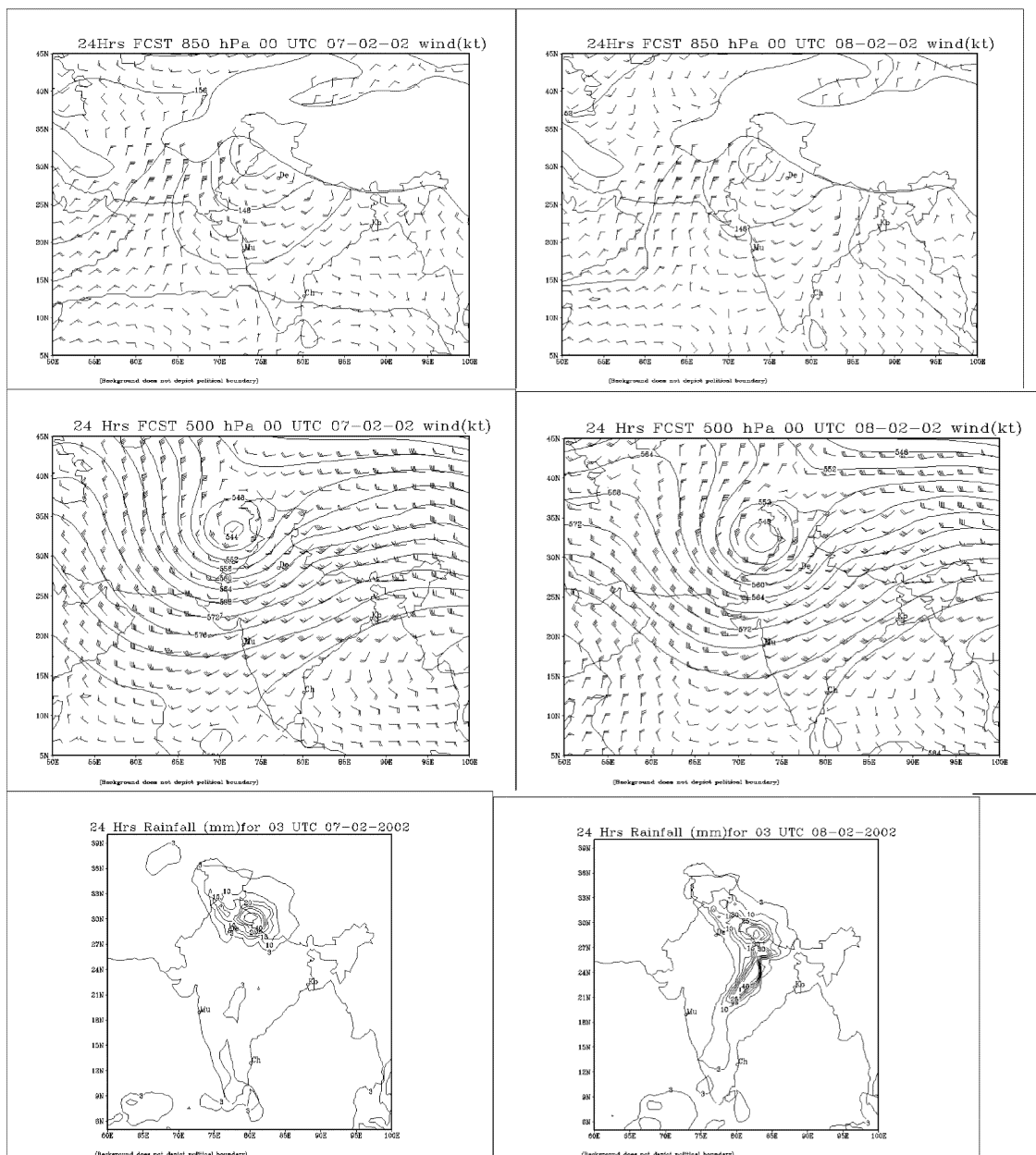
**Figure 8.** LAM 24 h forecast wind and height fields at 850, 500 hPa and rainfall (mm: CI 5, 10, 15, ... , 45) left: 15 and right: 16 February 2002.

is 25°E–130°E and 30°S–50°N. The model employs a semi-Lagrangian advective combined with semi-implicit time integration scheme and includes detailed physics and initialization processes. The first guess and boundary data fields are obtained from the global forecasts of the National Centre for Medium Range Weather Forecasting, New Delhi. The model is run on operational mode twice a day using 00 UTC and 12 UTC observations. The detailed description of model formulation, horizontal and vertical discretization and time integration scheme of the model has been described in de-

tail by Krishnamurti *et al.*<sup>3</sup> and Prasad *et al.*<sup>4</sup>. In the present study the limited area model forecasts are compared with the observed synoptic features for the western disturbances over the Western Himalayas.

**Case-I**

The LAM 24 h forecast valid for 15th shows (Figure 8) that a trough in the westerlies was located over Pakistan and



**Figure 9.** LAM 24 h forecast wind and height fields at 850, 500 hPa and rainfall (mm: CI 5, 10, 15, ... , 45) left: 7 and right: 8 February 2002.

adjoining area at 850 hPa and at 500 hPa the trough was located at 67°E extending up to 30°N. On 16th the low level circulation moved eastwards, was located over Punjab, Haryana and adjoining area and at 500 hPa a deep trough lies over 70°E extending up to 25°N. These forecast fields are consistent with the observed features.

The model rainfall forecast on 15th shows widespread precipitation over the Western Himalayas and Jammu & Kashmir and on 16th with the movement of the system eastwards the heavy rainfall belt also shifted to east UP. The model predicted precipitation distribution compares well with the observed precipitation pattern.

### Case-II

The 24-hours forecast valid for 7th (Figure 9) shows a trough in the westerlies at 850 hPa over Pakistan and adjoining Punjab and Haryana and the trough at 500 hPa level was located at 72°E extending up to 25°N. On 8th the low level circulation further moved eastwards to lie over east UP and at 500 hPa the trough moved northeastwards.

The 24-hours forecast by the model was able to capture the observed flow fields (Figures 4 and 5) and the model-predicted rainfall shows the movement of the rainfall belt from the Western Himalayas on 6th to over East UP along with

**Table 1.** Verification of synoptic forecast (24 h rainfall) for the Western Himalayan Region

Month Accuracy	January 2002	February 2002	March 2002
Accurate	65	63	74
Correct	90	89	97
Incorrect	10	11	03

Accurate, as per forecast; Correct, one stage out; Incorrect, two stage out.

Punjab, Haryana, Uttaranchal on 7th, and on 8th the rainfall belt further moved eastwards extending the heavy rainfall belt to central parts of India.

### Forecast verification

In Table 1 the verification statistics in respect of 24-hours rainfall forecasts issued on operational basis over the Western Himalayan region during the winter season was presented. The verification is done with observed available station data and the forecast issued for spatial distribution of precipitation under different categories, such as, (i) Isolated (up to 25% of forecast area), (ii) Scattered (26 to 50%), (iii) Fairly widespread (51 to 75%) and (iv) Widespread (more than 75%). In addition warnings for heavy precipitation was also issued. The figures in the table indicate the percentage of success of forecast of the event in a particular month. The results show that in 90–95% cases the forecast was correct out of which it was accurate in 60–70% cases.

### Conclusions

The verification of model forecasts shows that predicted flow fields generally agree well with the observed flow patterns. The 24-hour predictions in respect of winter weather systems show a good success rate and the model predicts their movement and intensification/weakening with reasonable

accuracy and the forecasts are found to be useful in the day-to-day operations. The 24-hour model precipitation forecast also compares spatially well with the observed pattern. However, the model generally under-predicts the heavy precipitation amounts observed over the region. Further improvement in the model resolution, orography in the model, especially suitable for high mountainous region and assimilation of satellite data in the analysis system are expected to improve the forecast accuracy further.

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