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A satellite study of an active western disturbance

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सार — नवम्बर 1986 के महीने में उत्तरी पाकिस्तान और जम्मू एवं कश्मीर से गुजरने वाले सक्रिय पश्चिमी विक्षोभ के अध्ययन को प्रस्तुत किया गया है। इस अध्ययन की महत्ता इस तथ्य पर निर्भर करती है कि इस पश्चिमी विक्षोभ द्वारा उत्पन्न कई स्थानों में व्यापक भारी वर्षा शुष्क माह नवम्बर में हुई। इस अध्ययन में प्रमुख बल अवरक्त उपग्रह चित्रों से देखे गए विक्षोभ से संबद्ध मेघ शीर्षों के तापमान के बंटन के संबंध में है। इसमें मेघ शीर्ष तापमानों और उनके परिणामस्वरूप होने वाली वर्षा के मध्य संबंध को समझने का प्रयास किया गया है। वर्षामापी स्टेशनों पर आधारित वास्तविक औसत वर्षा और आर्किन की विधि का प्रयोग करते हुए वर्षण अनुमान के मध्य तुलना की गई है। इसमें देखा गया है कि औसत वर्षा आकलन के लिए 235° K की सीमा-रेखा मेघ शीर्ष का तापमान (CTT) इस विशेष बौछार में अच्छे परिणाम नहीं देता है। इस विसंगति के कारणों को अभिग्रहित किया गया है।

ABSTRACT. The study of an active western disturbance which moved across north Pakistan and Jammu & Kashmir in the month of November 1986 has been presented. The importance of this study lies in the fact that this western disturbance, which had produced widespread precipitation with heavy falls at a number of places, has occurred in a relatively dry month, November. The main emphasis in this study is about the temperature distribution of the top of the clouds associated with the disturbance as seen from the infrared satellite pictures. An attempt has been made to understand the relation between the cloud top temperatures and the resultant rainfall. Comparison has been made between the rainfall estimate using Arkin's methodology and the actual average rainfall based on raingauge stations. It is seen that the threshold cloud top temperature (CTT) of 235° K to give an average rainfall estimate does not give good results in this particular spell. The reasons for this anomaly have been postulated.

1. Introduction

It is well known that disturbances which move from west to east in winter across Iran, Afghanistan, Pakistan and extreme northwest India, called western disturbances produce small but important precipitation over northwest India. This rainfall, though small, is very important for winter crops, especially wheat. Such western disturbances generally start affecting the weather over northwest India from the middle of December. The month of November generally remains dry over whole of India except extreme south Peninsula which gets rainfall due to northeast monsoon.

Agnihotri and Singh (1982) made a study of western disturbances approaching northwest India during November to March based on ten years satellite cloud pictures. According to them three distinct types of cloud masses could be detected, the most common being the overcast shapeless cloud mass. Their study was based on following the movement of overcast cloud masses as seen in satellite pictures.

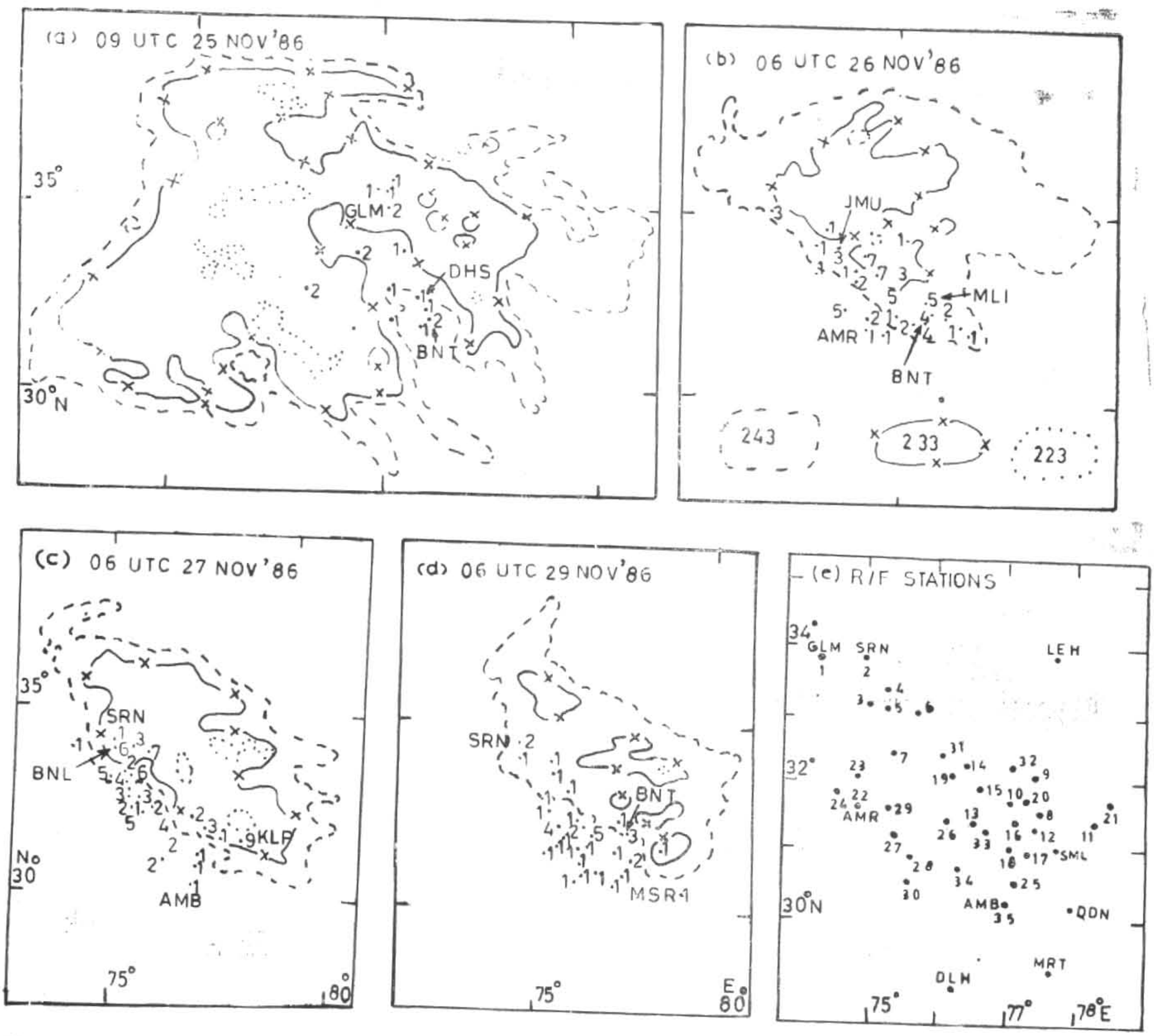
Sharma and Subramaniam (1983) while presenting the case study of a western disturbance of the winter season have shown the linkage of the western disturbance with a low in the lower tropospheric easterlies in the Arabian Sea off west coast of India. They concluded with the help of NOAA-6 satellite pictures that the linkage was responsible for the intensification of the western disturbance and the extension of precipitation far to the south.

Singh (1979) discussed the relationship between the approach of a developing upper level trough from the west and the consequent formation of two western disturbances, one in the southeast sector and other in northeast sector of the trough. He suggested that the appearance of western disturbances over India was mostly in this form and the southern one was generally stronger than the other.

In this paper the study of an active western disturbance which moved across north Pakistan and Jammu & Kashmir in the last week of November 1986 has been presented. The reason for undertaking this study is that this western disturbance has occurred in a relatively dry month and produced widespread precipitation with heavy falls at a number of places in the Western Himalayas. While synoptic charts prepared at the Northern Hemisphere Analysis Centre (NHAC), New Delhi have been studied in detail, the main emphasis in this study is about the temperature distribution of the top of clouds associated with the disturbance as measured from the infrared satellite pictures taken through INSAT-1B. The relation between the vertical extent of the clouds and resultant precipitation has also been examined.

2. Satellite picture interpretation from 22 to 28 November 1986

The first indication of an approaching western disturbance in November 1986 was seen in the 0600 UTC satellite picture of 22 November 1986 when good cloudiness extending from north of Persian Gulf to south Caspian Sea was seen. The infrared picture of 0900 UTC (Fig. 2) of this day showed convective clouds extending to great heights from 30°N to 38°N and 48°E



Figs. 1 (a-e). Temperature (°K) contours of tops of clouds on different days and (e) locations of rainfall stations used in this study : Stations : 1. Gulmarg, 2. Srinagar, 3. Udhampur, 4. Quazigund, 5. Jammu, 6. Banihal, 7. Kathua, 8. Bhunter, 9. Manali, 10. Jogindernagar, 11. Kalpa, 12. Mandi, 13. Una, 14. Chamba, 15. Kangra, 16. Sunder Nagar, 17. Dharampur, 18. Nurpur, 19. Bilaspur, 20. Baijnath, 21. Kataula, 22. Amritsar, 23. Raya, 24. Tibri, 25. Chandigarh, 26. Hoshiarpur, 27. Kapurthala, 28. Ropar, 29. Batala, 30. Jagraon, 31. Dalhousie, 32. Dharamsala, 33. Hamirpur, 34. Samraula and 35. Ambala.

to 53° E. Other than this convective cloud mass, scattered medium and high clouds could be seen extending east and southeastwards up to 63°E. The VIS and IR pictures of 0630 UTC and 0900 UTC of 23 November showed a considerable extension of clouds northeastwards up to 68° E covering greater part of Afghanistan. While the clouds over eastern Iran and Afghanistan had extended to great heights, there was considerable thinning down of the clouds between Caspian Sea and Persian Gulf. This inference was made possible by the shadow cast by multilayered clouds over east Iran and Afghanistan on the relatively lower clouds south of Caspian Sea (WMO 1973). While there were a number of gaps in the clouds between Caspian Sea and Persion Gulf, it was almost overcast with multilayered clouds east of 55°E. On 24 November, there was further extension in the clouds northeastwards. The main cloudiness was between 60°E to 70°E and 30°N to 35°N with extension northeastwards into north Pakistan and Jammu & Kashmir where the clouds were generally medium to high. There was considerable decrease in cloudiness over Iran. From the main cloud mass we could see two to three finger type of clouds extending southeastwards into south and central Pakistan and adjoining Rajasthan, composed mainly of medium and high clouds. This was due to the development of an induced low over south Pakistan and adjoining Rajasthan at 0600 UTC (Fig. 4). It was interesting to note that while clouds over Iran had almost dissipated there was an extension from the main cloud mass southwestwards up to Persian Gulf. This extension was due to the formation of a low pressure area over south Iran and adjoining Baluchistan,

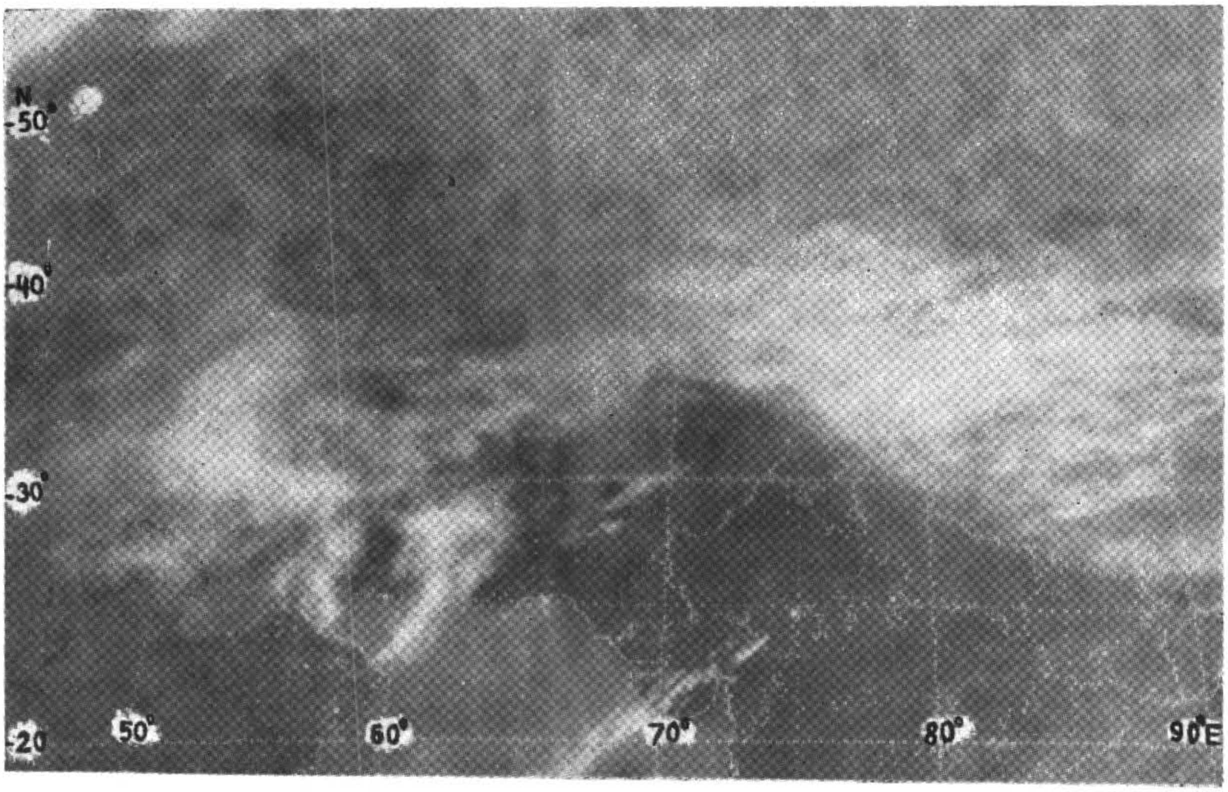


Fig. 2. INSAT-1B (IR) picture of 22 November 1986 at 0900 UTC

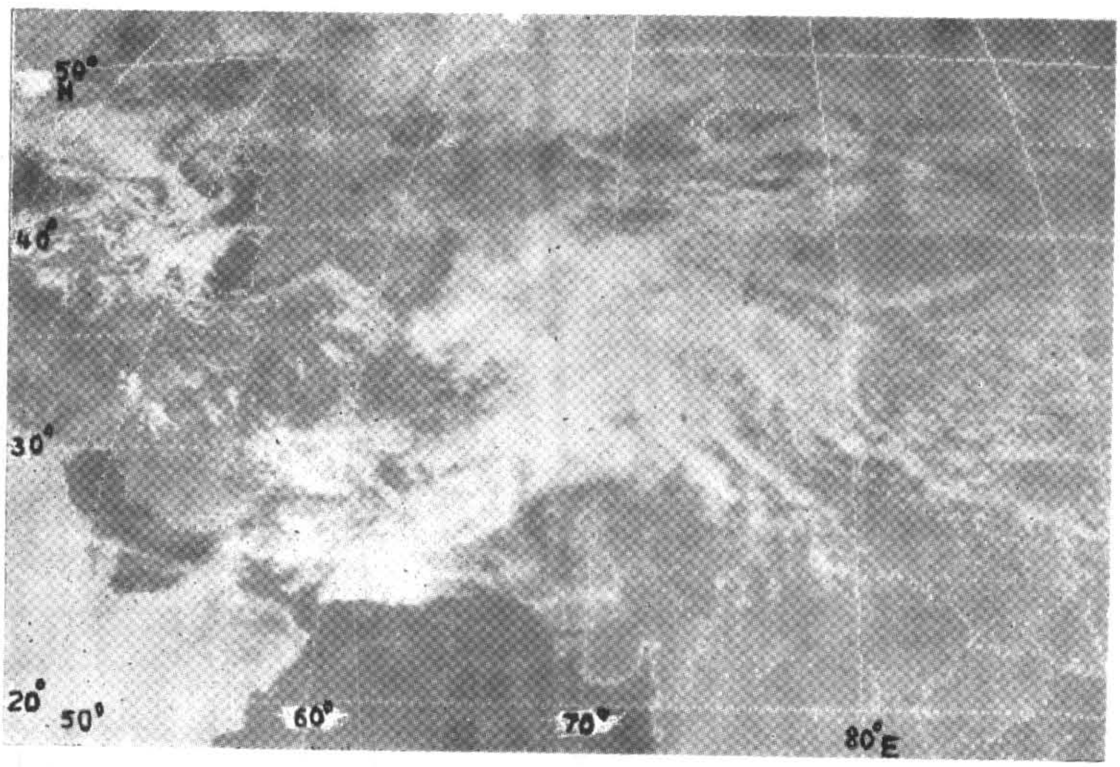


Fig. 3. INSAT-1B (VIS) picture of 25 November 1986 at 0900 UTC

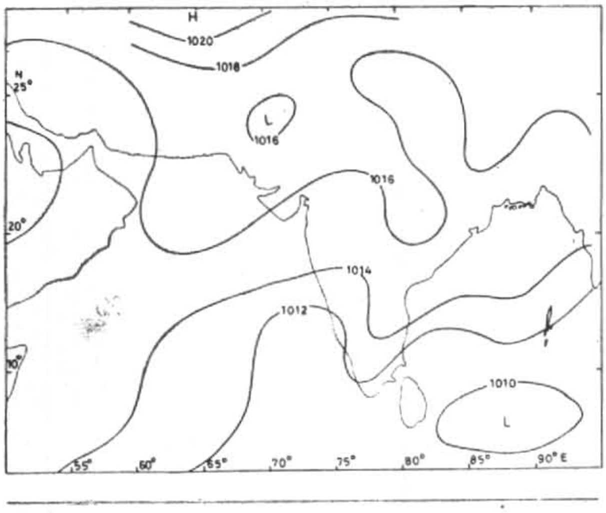


Fig. 4. 0600 UTC isobaric chart of 24 November 1986

There was a marked increase in cloudiness from 24th to 25th as seen in 0900 UTC VIS satellite picture. The main thick multi-layered clouds extending up to great heights were seen in the IR picture from 28°N to 40° N and between 65°E & 75°E. There was an increase in cloudiness over Jammu & Kashmir and also in the extension southwestwards over Baluchistan and south Iran. The extension southwestwards up to Persian Gulf was due to formation of a low pressure area over southeast Iran and adjoining Baluchistan on the sea level chart of 24th morning as seen from NHAC charts. Finger type of clouds extending southeastwards seen on the previous day were also noticeable on 25th. Two such finger clouds composed mainly of *Cu* and *Cb* clouds extended over Haryana, north Rajasthan and west Uttar Pradesh. The cloudiness associated with the western disturbance was at its maximum on this day (0900 UTC visible picture of 25 Nov 1986—Fig. 3). On 26th, the main cloudiness was over Jammu & Kashmir, Himachal Pradesh, Punjab and north Pakistan covering the area between 30° N to 40° N and 70°E to 80° E. There was extension southwards up to 27°N. Two finger type of clouds continued to extend eastwards up to 85°E. In the areal extent, there was decrease in cloudiness from 25th to 26th.

On 27th, multilayered clouds were confined to Jammu & Kashmir, Himachal Pradesh and Punjab. There was very little extension south of 30° N and Pakistan was completely clear. One finger type of cloud could still be seen extending southeastwards up to 30° N, 82°E. This extension southeastwards coincided with the wind discontinuity at 0.3 km a.s.l. passing through Peshawar, Lahore, Ambala, Agra and Hardoi (U.P.).

On 28th, there was considerable decrease in cloudiness over Jammu & Kashmir and Himachal Pradesh compared to 27th. There was an extension of cloudiness northeastwards into Tibet. The heights of the clouds had also considerably decreased as seen from the VIS and IR pictures, thereby meaning that the system was weakening and moving away northeastwards across Western Himalayas.

3. Relationship between rainfall and cloud top temperatures

This western disturbance which moved northeastwards across Jammu & Kashmir on 28th gave widespread rain or snow over Jammu & Kashmir from 26th to 28th, over Himachal Pradesh on 27th and 28th, and scattered rain or snow over the hills of west Uttar Pradesh on 27th and 28th and scattered rain or thunderstorms over Punjab on 27th and 28th. In order to understand the relationship between the rainfall and the vertical extent of clouds, temperature contouring of the tops of clouds for 0900 UTC of 25th (0600 UTC picture of 25 November 1986 was not available) and 0600 UTC of 26, 27 and 29 November 1986 are presented in Figs. 1 (a-d). The 24-hour precipitation amount (cm) ending at 0830 IST of 26, 27, 28 and 30 November were also plotted in the corresponding temperature contour maps for easy comparison. A map showing the rainfall stations, whose rainfall had gone into this study, could be seen at Fig. 1(e). Isotherms of cloud top temperature (CTT) were taken from the infrared pictures for these four days at 0° C, —30° C, —40° C, —50° C and —60° C. The cloud top temperature analyses gave the following information :

On 25 November at 0900 UTC, the 233°K (—40° C) temperature contour covered greater part of Jammu & Kashmir except southwestern part and Ladakh area. A tongue from this also extended into Himachal Pradesh. However, the coldest temperatures were in Pakistan, the coldest temperature being 218°K (—55° C). In Jammu & Kashmir there was no area where the temperature was less than 233° K while a very small area in north Himachal Pradesh had a cloud top temperature of 221° K.

On 26th, most of the area bounded by the 233° K isotherm lies over western Jammu & Kashmir. The lowest temperature of 220°K (—53°C) also lay here, while 227° K (—46°C) was in eastern Jammu & Kashmir (Ladakh).

On 27th, the area bounded by 233°K was more than that of 26th. This extended southeastwards into Himachal Pradesh where lowest temperature of 220° K was observed. There were five small closed areas bounded by 223° K, three of which were in eastern Jammu & Kashmir, one in Himachal Pradesh and one on the border between Jammu & Kashmir and Himachal Pradesh.

Table 1 gives the normal upper air temperatures (°C) and heights (km) corresponding to standard millibaric levels of New Delhi and Srinagar for the month of November.

The cloud top heights (CTH) corresponding to cloud top temperatures (CTT) for the various values given in the previous paragraph could be approximately worked out from the above table.

At 0600 UTC of 28th, cold areas bounded by 223° K shifted to the northeast of Jammu & Kashmir into the Tibet region. Even the 243° K (—30°C) isotherm passed through extreme northeast portion of Ladakh.

On 29th, the 243° K isotherm covered most of Jammu & Kashmir and greater half of Himachal Pradesh. Two fairly big areas enclosed by 233°K were in Jammu & Kashmir and two smaller areas of the same temperature were in Himachal Pradesh. This probably accounted for widespread precipitation over Jammu & Kashmir and Himachal Pradesh on 30th after a day of practically no rainfall on 29th.

TABLE 1

Standard levels (mb)	Height (km) and temp. (°C)	
	New Delhi (km/°C)	Srinagar (km/°C)
850	1.5/15.0	—
700	3.1/5.0	3.1/0.0
500	5.8/—11.9	5.7/—17.8
300	9.5/—36.4	9.4/—43.5
200	12.2/—52.5	12.0/—55.0
150	14.1/—61.3	13.8/—59.3
100	16.5/—68.6	16.3/—62.0
50	20.7/—59.7	—
30	24.0/—52.7	—

TABLE 2

Distribution of rainfall stations in various CTT zones

Date (Nov 86)	Within 233° K	Between 233°&243°K	Outside 243°K	Total
25	5 (42%)	3 (25%)	4 (33%)	12
26	6 (22%)	16 (60%)	5 (18%)	27
27	7 (27%)	5 (19%)	14 (34%)	26
29	—	8 (31%)	18 (69%)	26
Cumulative based on 4 days	18 (20%)	32 (35%)	41 (45%)	91

From Figs. 1 (a-d) we noticed that even in areas not covered by 243° K CTT contour, moderate precipitation had occurred. If we take the intensity and precipitation as a parameter, rather heavy precipitation (4-6 cm in 24 hours) had occurred in areas bounded by 233°K contour as well as in areas where the temperature of the cloud top was warmer than 243°K. This could be seen over Punjab and adjoining Himachal Pradesh in Figs. 1 (c & d). While the 0600 UTC CTT configuration might be expected to present the maximum convection, it was to be understood that there need not be one to one correspondence between the CTT field, thus derived and the 24-hour cumulative rainfall ending at 0830 IST of the next day. This was because of the simple reason that the clouds associated with a system like a western disturbance were continuously forming/dissipating and moving and, thus, the temperature field at any particular time would not represent cumulative rainfall.

4. Arkin's method

Arkin and Richards (1981) proposed a simplified rainfall estimation model using only one parameter, namely, area of clouds colder than a chosen threshold (235° K). They found that the correlation between radar estimated rainfall and the mean fractional cloud coverage over an area improved (often exceeding 0.8) if the area and duration of the areal and temporal averaging were increased. They observed that the correlation was maximum when the spatial average was done over an area of 2.5 degree square with temporal average of 24 hours. According to them the fractional cloud coverage for a given hour was comparable with the rainfall accumulated over the preceding hour. Thus, they concluded that there was a built in lag of 30 minutes between cloud coverage and rainfall. While Arkin's method of rainfall estimation used only one temperature threshold, *viz.,* 235° K, we while studying western disturbances, mapped the cloud top temperature (CTT) field over Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh hills, Punjab and ajdoining areas corresponding to 243°K, 233°K and 223° K. The contour maps for 25, 26, 27 and 29 November 1986 could be seen in Figs. 1 (a-d).

Table 2 gives the daily number of rainfall stations that reported rainfall, which lay in various cloud top temperature (CTT) intervals. Statistics based on the 4-day 25-27 and 29 November 1986 rainfall is also given.

It is seen from the table that nearly 45% of stations which reported rainfall on 25, 26, 27 and 29 November 1986 lie in the area where CTT are warmer than 243°K, about 35% of them lie in the region where CTT are between 243°K and 233° K, and the rest of 20% in the area having CTT colder than 233° K.

This will mean that in the area comprising of Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh hills and neighbourhood even warm clouds whose CTT are of the order of 243°K contribute considerably to the precipitation. This is to be expected as we are dealing with an orographic region, whereas Arkin's single parameter model is for an oceanic area.

5. Summary and conclusion

In this paper, a new method has been demonstrated for the study of a western disturbance with the help of cloud top temperature (CTT). The relationship between the CTT and the resultant rainfall has been studied using a methodology similar to Arkin's. The detailed study of western disturbances using the above methodology has been taken up recently. It is hoped that with the study of a number of western disturbances we may be in a position to evolve the relationship between rainfall and the CTT field.

References

Agnihotri, C.L. and Singh, M.S., 1982, Satellite study of western disturbances, *Mausam,* 33, 2, pp. 242-254.

Arkin, P. and Richards, F., 1981, On the relationship between satellite observed cloud cover and precipitation, *Mon. Weath. Rev.,* 109, 1081-1093.

Rao, Y.P. and Srinavasan, V., Winter western disturbances and their associated features. Forecasting Manual Report No. III-1.1, India Met. Dep.

Sharma, R.V. and Subramaniam, D.V., 1983, The western disturbances of 22 December 1980 : A case study, *Mausam,* 34, 1, pp. 117-120.

Singh, M.S., 1979, Westerly upper air troughs and development of western disturbances over India, *Mausam,* 30, 4, pp. 405-414.

WMO, 1973, Use of satellite pictures in weather analysis and forecasting; WMO Tech. Note No. 124.