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The role of Western Disturbances in the production of weather over India during different seasons

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1. Introduction

The term 'Western Disturbances' has been generally used in India to connote depressions or low pressure areas on the surface chart as well as troughs in the upper air which move from west to east across northwest India. These exercise a significant influence on the Indian weather. Some of these disturbances induce lows either at sea level or upper level.

2. Widespread and locally heavy rain

Widespread rain is associated generally with western disturbances which move across India as depressions or shallow depressions. The areas which receive widespread rain most frequently are — Kashmir, Punjab (I) and northwest Uttar Pradesh. Active induced lows moving eastwards across Madhya Bharat, south Uttar Pradesh, Bihar, Bengal and Assam sometimes cause widespread rain in Uttar Pradesh, Vindhya Pradesh, east Madhya Pradesh and most parts of northeast India.

On examination of the data for the period 1945 to 1955, it is seen that while isolated or scattered heavy rain occurs sometimes over and near the hilly parts of north India in association with active western disturbances, the phenomenon of locally heavy rain is rare. During the aforementioned period only six occasions of locally heavy rain could be found. On most of these, heavy rain occurred over and near the hills of Punjab (I). The details of these occasions are given in Table 1.

The western disturbances which move across India differ considerably from extratropical depressions in that they generally do not always have well-marked cold or warm fronts either at surface or at upper levels. The mechanism of widespread rain in association with these two types of systems is, therefore, different. Western disturbances and their induced lows which move across India as depressions or shallow depressions cause marked or vigorous inflow of moist air from Arabian Sea and Bay of Bengal, generally upto levels from 5000 to 10,000 ft above sea level and consequently, convergence in lower levels and this contributes to the occurrence of widespread precipitation. From the fact that locally heavy precipitation

TABLE 1

Date	Region and local heavy rainfall	Synoptic situation
5-2-1949	*Northwest U.P.* Dehra Dun 4·2″ Roorkee 2·9″	An active western disturbance which lay over Punjab (I) as a low on the sea level chart on 4th morning moved away across the hills of Punjab (I) by 5th morning. It induced a low on sea level chart over southwest Uttar Pradesh and adjoining parts of Madhya Bharat and Vindhya Pradesh.
12-4-1949	*Sub-Himalayan West Bengal* Jalpaiguri 3·9″ Dhubri (Assam) 3·0″ Cooch Bihar 3·0″	A western disturbance moving across Punjab-Kumaon hills as a low on sea level chart induced a low over north Madhya Bharat, Vindhya Pradesh and adjoining parts of Uttar Pradesh on 11th, on sea level chart. By 12th morning, the induced low moved eastwards and was becoming unimportant.
1-1-1953	*The hills of Punjab (I)* Dalhousie 4·0″ Dharamsala 2·6″	The western disturbance which lay over north Rajasthan as a low on sea level chart on 31 December 1952 was causing an inflow of moist air into Punjab (I), Uttar Pradesh, and Rajasthan from the Arabian Sea and the Bay of Bengal. The disturbance moved away across the Punjab hills by 3rd morning.
31-1-1954	*The hills of Punjab (I) and Submontane parts* Dalhousie 2·6″ Pathankot 2·6″	A western disturbance lay over Rajasthan as a low on sea level chart on 30 January 1954 and was causing inflow of moist air into Punjab (I), Rajasthan and Uttar Pradesh from the Arabian Sea and the Bay of Bengal. While moving away northeastwards across the Punjab-Kumaon hills on 31st, it induced a low on sea level chart over Madhya Bharat and neighbourhood. The induced low became unimportant by the morning of 1 February 1954 but a fresh western disturbance lay over south Baluchistan, lower Sind and adjoining parts of Arabian Sea as a low on sea level chart. The western disturbance moved over to lower Northwest Frontier Province by 2nd morning and moved away northeastwards by 3rd morning.
2-2-1954	*The hills of Punjab (I)* Dalhousie 2·7″ Dharamsala 2·6″	
2-3-1955	*The hills of Punjab (I)* Dharampore 4·0″ Dalhousie 2·9″	The western disturbance and its well-marked induced low on sea level chart lay over Northwest Frontier Province and north Gujarat respectively on 28 February; these merged by the morning of 1 March and a deep trough lay over Punjab (I) and west Uttar Pradesh. This trough moved across Western Himalayas by 2nd morning.

in association with western disturbances is caused over and near the hills, one is led to conclude that orographic convergence plays the leading role in the production of locally heavy rain.

3. Incidence of cold waves

The movement of a western disturbance across north India causes an inflow of warm and comparatively moist air from relatively southern latitudes ahead of the disturbance and of cold and dry air from relatively northern latitudes in the rear of the disturbance. This process in association with disturbances goes on during the winter period. In a very few cases in the rear of disturbances which are depressions, there is a flow into northwestern parts of India of markedly cold and dry air from considerably higher latitudes and this very cold air spreads to other parts of India as cold wave. If there is to be a free and rapid flow of very cold air

TABLE 2

Period	Highest negative dep. of min. temp. with area and date	Highest negative dep. of max. temp. with area and date	Highest negative dep. of pressure associated with the western disturbance	Areas affected by the cold wave
10 to 14 Jan 1945	12 to 16°F Cutch, Saurashtra, north Konkan, north Bombay Deccan, Rajasthan and south Punjab (I) on 11th	16 to 20°F Rajasthan, Madhya Bharat and Punjab (I) on 11th	10 to 11 mb on 8th	*Northwest India, Cutch, Saurashtra, Gujarat, north Bombay Deccan, north Konkan and †central parts of the country
4 to 9 Feb 1948	Mainly 12°F North Rajasthan, Madhya Bharat and adjoining parts of Madhya Pradesh and of Bombay Deccan on 7th	12°F South Rajasthan, south Madhya Bharat and adjoining parts of Bombay Deccan on 6th	10 to 11 mb on 3rd	Northwest India, Cutch Saurashtra, Gujarat, north Bombay, Deccan and the central parts of the country
13 to 17 Mar 1948	12°F Central parts of the country, Rajasthan, north-west Uttar Pradesh, Punjab(I) and north Hyderabad on 15th and 16th	12°F West Madhya Bharat, east Rajasthan, Punjab (I) and northwest Uttar Pradesh on 14th	6 to 7 mb on 10th evening	Northwest India, central parts of the country, north Bombay Deccan, Gujarat and northeast India outside Assam
6 to 9 Feb 1949	10 to 16°F North Bombay Deccan and west Madhya Pradesh on 7th	8 to 12°F North Hyderabad to Submontane parts of Bihar and in north-west Uttar Pradesh on 7th	10 to 11 mb on 4th	Cutch, Saurashtra, Bombay, Hyderabad, Madras, Deccan, north Madras coast, central parts of the country and northeast India‡
9 to 14 Feb 1950	16 to 20°F Rajasthan, Madhya Bharat, Cutch, Saurashtra and west Madhya Pradesh on 11th	20 to 24°F West Rajasthan and adjoining parts of east Rajasthan and of Gujarat on 9th	20 mb on 8th evening	Almost the whole of India north of Lat. 15°N
22 to 26 Jan 1954	15 to 17°F North Rajasthan on 22nd	8 to 12°F Madhya Bharat and south Uttar Pradesh on 22nd	12 to 13 mb on 19th	Northwest India, Cutch, north Gujarat, central parts of the country, Bihar, Chota Nagpur and the Gangetic West Bengal

* Northwest India consists of Jammu and Kashmir, Punjab (I), Rajasthan and Uttar Pradesh

† Central parts of the country consist of Madhya Pradesh, Vindhya Pradesh, Madhya Bharat and Bhopal

‡ Northeast India consists of Orissa, Chota Nagpur, Bihar, West Bengal and Assam

from considerably northerly latitudes it is necessary that the disturbance which is moving away across India should be deep, *i.e.*, the negative pressure departures from normal should be sufficiently large and there should be no disturbance in the rear affecting India and no disturbance to the north of India. The absence of a disturbance to the north of India for a few days will ensure flow of air from considerably northerly latitudes, while the absence of a following disturbance in the rear will ensure that there will be no inflow of warm air over northwest India from southerly latitudes. In other words, the absence of a disturbance to the north of India causes a marked cold wave over north and

central India and the absence of disturbances in the rear allows the intensity of the cold wave to be maintained for sufficient time. The cold waves generally affect the portion of India north of latitude 20°N. During the period 1945 to 1955 six cold waves affected India. Some important details in respect of these are given in Table 2 (p.255).

The cold wave of February 1949 did not effect northwest India. The cold wave of February 1950 was the severest. It profoundly affected the temperature conditions over India. A brief account of the same is given.

The western disturbance which lay over north Baluchistan as a low on sea level chart on 7 February 1950 moved northeastwards, intensified and lay as a depression over the Punjab (P) with its central region between Montgomery and Lahore on the morning of 8th. The depression lay over north Punjab (P) and adjoining parts of Kashmir on 9th morning. Cold and exceptionally dry air was sweeping over West Pakistan and adjoining parts of northwest India. Pressure gradient was steep over the region extending from Punjab (P) to Saurashtra and north Bombay Deccan. On 10th, the depression was filling up. The dust blown up into the atmosphere on account of the sudden outburst of the modified polar air spread as dust-haze over the different parts of the country. The cold wave had swept over northwest India and Saurashtra. By 11th, the dust-haze and cold wave had swept over the whole of north India, central parts of the country and some parts of the Peninsula. From 12th onwards, the cold wave and dust-haze started abating. The progress of the cold wave and dust-haze can be seen from the charts indicating the daily march of isotherms of minimum and maximum temperatures (Figs. 1—4), and the areas of dust-haze during the period 8 to 12 February 1950 (Fig. 5). Normal isotherms of minimum temperatures and maximum temperatures are also shown in separate maps (Figs. 6 and 7). By 14th, temperature rose markedly over northwest India when a western disturbance moved in and lay as a trough over Rajasthan and neighbourhood. On the 14th and 15th, the minimum temperature continued to be markedly below normal over most of northeast India and central parts of the country, although the maximum temperature was slightly below normal over these areas. During the regime of the cold wave the lowest minimum temperature recorded at a plain station was 27°F at Sikar and Sriganganagar (both in north Rajasthan) on 11th.

4. Induced disturbances and the upper air anticyclonic circulation over the central parts of the country and the adjoining parts of the Peninsula

The induced lows or troughs (both at sea level and at upper levels) which move eastwards or eastnortheastwards across the central parts of the country, Bihar, Orissa, Bengal and Assam, have the effect of displacing the anticyclonic circulation eastwards to north Bay and the Burma coast. As a result of this, conditions become favourable for an inflow of warm and moist air from the Bay of Bengal from relatively southern latitudes in the lower levels upto 5000 ft above sea level. Because of this injection of moist air, the secondary, when it comes to east Rajasthan and Madhya Bharat, gets rejuvenated. With further eastwards movement of the induced low or trough, the inflow of moist air extends to almost the whole of northeast India. This penetration of moist air sometimes causes widespread thunder-rain over the belt of the country from Punjab (I) and Rajasthan to Assam. An instance to illustrate this aspect is described below.

A well-marked western disturbance lay over northwest Rajasthan and adjoining areas of the Punjab (P) as a low on sea level chart on the morning of 14 January 1953. The upper air anticyclonic circulation which lay over south Madhya Pradesh and north Hyderabad at 5000 ft above sea level on 13th evening shifted eastwards to Orissa and adjoining parts of Madhya Pradesh by the 14th morning. Over Madhya Bharat, most parts of Madhya Pradesh, Vindhya Pradesh, west Uttar Pradesh, Punjab (1), the upper winds below 5000 ft above sea level had become southsoutheast to southwest but the speed was only 5 to 10 knots. By 15th morning, the

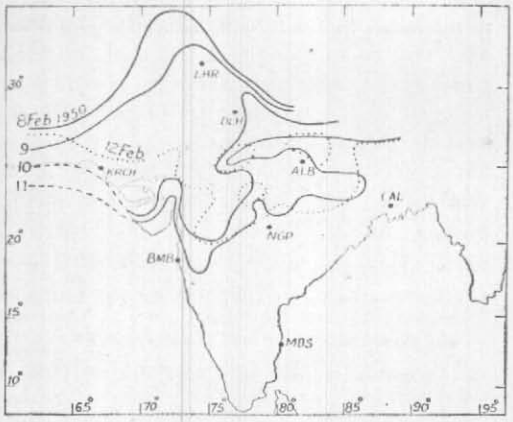

Fig. 1. Advance of cold wave as indicated by the daily march of the isotherm of minimum temperature 40°F during the period 8—12 February 1950

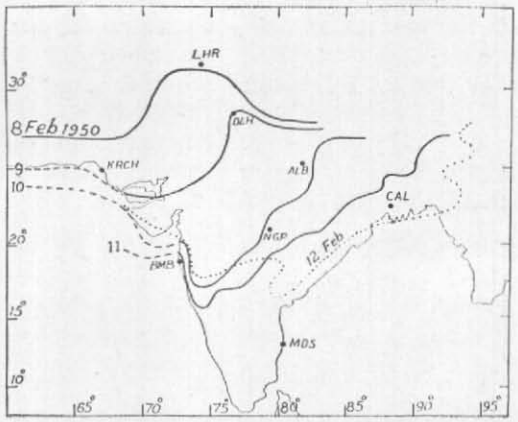

Fig 2. Advance of cold wave as indicated by the daily march of the isotherm of minimum temperature 50°F during the period 8—12 February 1950

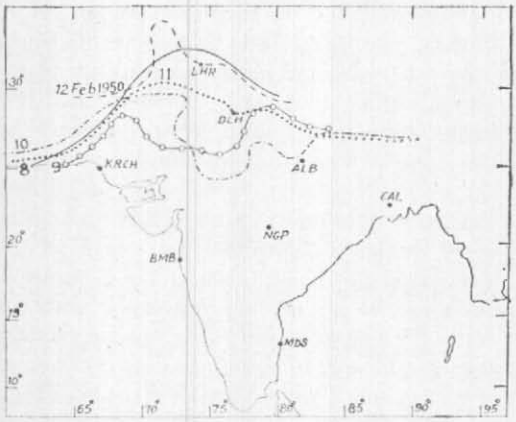

Fig. 3. Advance of cold wave as indicated by the daily march of the isotherm of maximum temperature 60°F during the period 8—12 February 1950

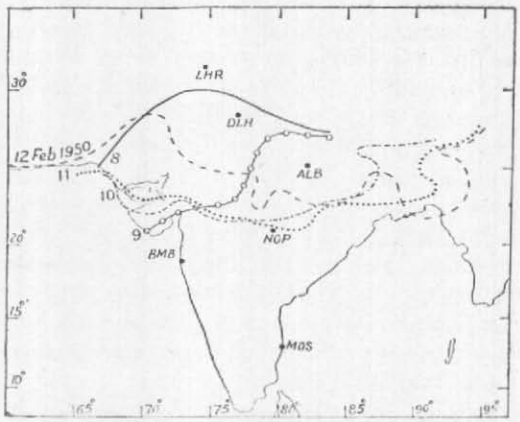

Fig. 4. Advance of cold wave as indicated by the daily march of the isotherm of maximum temperature 70°F during the period 8—12 February 1950

western disturbance moved over to north Punjab (P) and adjoining parts and had induced a low in the upper air over north Madhya Bharat. The anticyclonic circulation had shifted to north Bay, the winds over the region extending from Punjab (I) and Uttar Pradesh to south Madhya Pradesh strengthened to 15–20 knots (being even 25/30 knots at a few places). A marked inflow of moist air had commenced. By evening, the anticyclonic circulation shifted eastwards and inflow of moist air extended to Bihar, Orissa, Chota Nagpur, and western parts of Gangetic West Bengal. By 16th morning, the western disturbance moved away across the Punjab hills, the induced low lay over Chota Nagpur and adjoining parts, the anticyclonic circulation had shifted further eastwards to coastal Burma and neighbourhood and the moist feed was getting cut off. By evening, the anticyclonic circulation shifted further eastwards and lay over Siam and adjoining parts of Burma and of Indo-China, and the moist feed was cut off completely. The induced low moved away eastnortheastwards rather rapidly

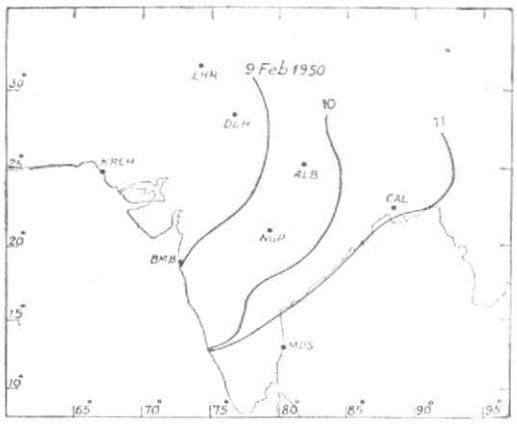

Fig. 5. Advance of dust-haze during the period 9—11 February 1950

across the sub-Himalayan West Bengal by 17th morning, while the anticyclonic circulation lay over coastal Burma and adjoining Bay at 5000 ft and over Central Bay below that level. On the 17th evening, the anticyclonic circulation was practically over Central Bay and by 18th morning it shifted back to south Madhya Pradesh, north Hyderabad and adjoining parts of coastal Andhradesa.

Under the combined influence of the western disturbance, the induced low and the anticyclonic circulation, widespread rain accompanied by thunder at a number of places occurred in Punjab (I) and west Uttar Pradesh with locally rather heavy falls in Punjab (I) by 15th morning; in Punjab (I), Uttar Pradesh, Vindhya Pradesh, Chota Nagpur, Bihar and sub-Himalayan West Bengal with locally rather heavy falls in Punjab (I) and Uttar Pradesh by 16th morning; and in Kumaon hills, Chota Nagpur, West Bengal and Assam by 17th morning.

5. Absence of western disturbances or movement of weak disturbances and spell of hot weather in winter months

The movement of western disturbances across north India with the consequent flow of cold air at intervals, is essential for the maintenance of the cold season. The disturbances exert a moderating influence on the maximum temperature on account of the cloudiness which they produce. The absence of western disturbances or movement of weak disturbances over a sufficiently long period, therefore, leads to stagnation of air masses and warming up of air. The heating of the stagnant air goes on uninterrupted during day-time and radiational cooling of the air during night is not prevented. This ultimately results in maximum temperature reaching values considerably above normal but minimum temperature reaching value above normal to a comparatively much smaller extent.

There are, however, cases when even moderately active western disturbances following one another in rapid succession do not allow the warmed up air to cool down as a result of which hot spells are experienced. The hot spell in these cases are, of course, not so well-marked.

During the period 13 February to 19 March 1953, there were only a few feeble western disturbances which moved across northwest India. This period was characterised by very warm weather over northwest India, Cutch, Saurashtra, Gujarat, north Bombay Deccan, central parts of the country and Chota Nagpur. This can be clearly seen from the chart (Fig. 8) which indicates the mean daily departure of maximum temperatures from normal for the five-week period. Maximum temperatures were markedly above normal over Punjab (I),east and southwest Rajasthan, north Madhya Pradesh and some parts of west Uttar Pradesh. During this period there were a few short-period severe hot spells over certain parts of the country. A severe hot spell was affecting north Rajasthan, Punjab (I) and adjoining parts of west Uttar Pradesh during the short period 5 to 9 March 1953, the mean daily departure of maximum temperature from normal being 13° to 16° F above normal (Fig. 9). The five-week warm spell started abating after 19 March. The western disturbance which was affecting Baluchistan on the 21st moved over to north Baluchistan and neighbourhood by 22nd morning, and lay there as a low on sea level chart. After remaining over the Punjabs and neighbourhood on 23rd and 24th

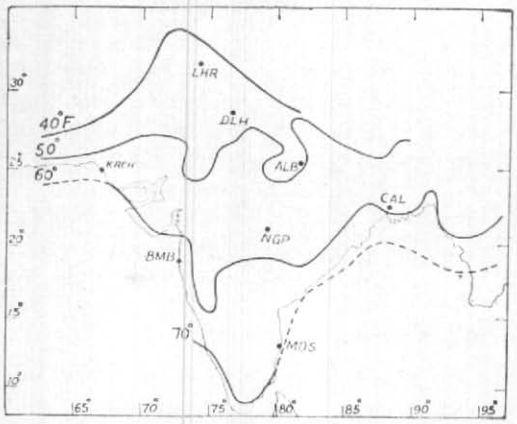

Fig. 6. Isotherms of normal minimum temperature (8—12 February)

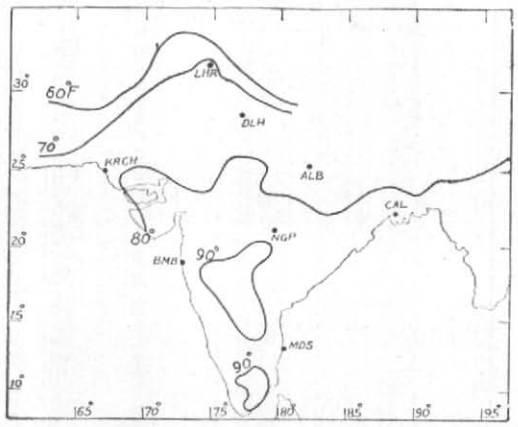

Fig. 7. Isotherms of normal maximum temperature (8—12 February)

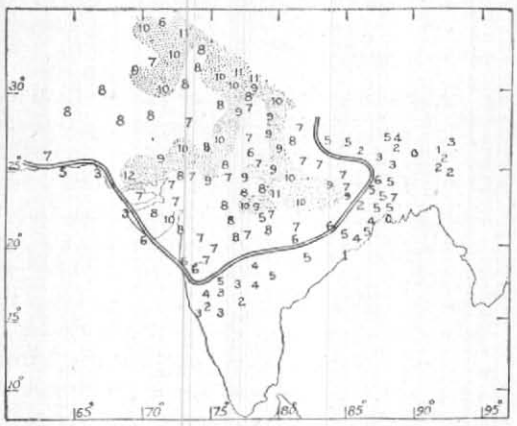

Fig. 8. Mean daily departure of maximum temperature from normal for the period 13 Feb to 19 Mar 1953

Area with temperature markedly above normal is shaded. Area within double line has maximum temperature appreciably above normal

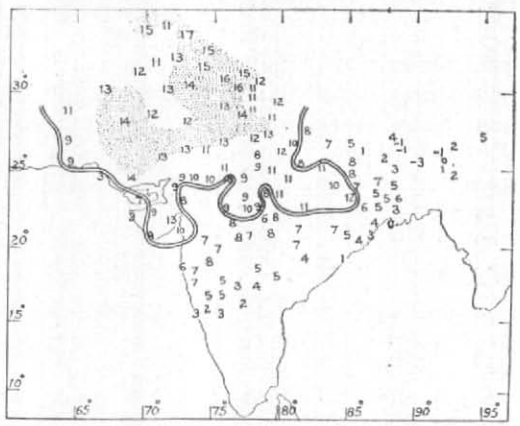

Fig. 9. Mean daily departure of maximum temperature from normal for the period 5—9 March 1953

Shaded area has got maximum temperature 13°F and more above normal. Area within double line has temperatures markedly above normal

the western disturbance was moving away across extreme north of the country on 25th and a fresh disturbance lay over north Baluchistan and neighbourhood as a low on sea level chart. The fresh disturbance moved away across extreme north of India on 27th and there was a well-marked incursion of cold dry air causing a marked fall in maximum and minimum temperatures over northwest India and north Gujarat on 28th. Temperatures fell appreciably over the region extending from Punjab (I) to north Deccan (Desh) and west Hyderabad on 29th and they were generally below normal over the belt of the country extending from Punjab (I) and Rajasthan to north Hyderabad and southeast Madhya Pradesh. On 29th, the maximum temperatures were markedly below normal over Rajasthan, Cutch, Gujarat and adjoining parts of Saurashtra and over west Madhya Bharat.

6. The role of western disturbances during monsoon

(*i*) *Extension of moist current to Punjab (I) and Kashmir during June*—By the middle of June, monsoon is normally established

over east Uttar Pradesh. With western disturbances moving across northernmost parts of India, there is sometimes a temporary extension of monsoon current over Punjab (I), west Uttar Pradesh and Kashmir and this effect is rather marked over the hills and submontane parts. Even before the monsoon has arrived over east Uttar Pradesh, there is occasionally an extension of moist current from the Bay of Bengal when a disturbance is moving across northwest India. This incursion of moist air, on a few occasions, causes widespread thunder-rain in Punjab (I) and west Uttar Pradesh.

(*ii*) *Enhancement of the activity of the monsoon*—Activity of the monsoon over Punjab (I) and west Uttar Pradesh is sometimes increased with the passage of disturbances across extreme north India. This will be clear from the following example.

On the morning of 9 July 1953, a low was lying over upper Northwest Frontier Province and neighbourhood and this moved over to Punjab (P) and neighbourhood on 10th morning. Under its influence monsoon suddenly became vigorous over Punjab (I) and northwest Uttar Pradesh where widespread and locally heavy rain occurred by 10th morning. The low had moved away eastwards across the extreme north of the country by 11th morning. Monsoon continued to be vigorous over the Punjab (I) and the northwest Uttar Pradesh on 11th also. The activity of the monsoon over these parts decreased considerably on 12th. It may be mentioned that only isolated light rain had occurred over the plains of Punjab (I) by 8th morning and scattered light rain by 9th morning. But on 10th and 11th morning widespread rain with locally heavy falls was reported from the plains. The following are heavy to very heavy falls which were reported from Punjab (I) and northwest Uttar Pradesh on 10th and 11th.

On 10th morning

Pathankot 7·5″, upper Dharamsala 6·5″, Jind (PEPSU) 5·6″, Patiala 5·4″, Ambala 4·6″, Karnal 3·7″, Aligarh 2·8″, Nainital 2·7″, Meerut 2·6″.

On 11th morning

Sangrur (PEPSU) 7·4″, Rohtak 7·0″, Dharamsala 4·9″, Ludhiana and Delhi (Palam) 4·6″ each, Ferozepur 4·3″ and Amritsar 2·6″.

(*iii*) *Shift of the axis of the monsoon trough to foot-Himalayas*—The westward movement of lows coming from Burma and of lows and depressions which form in the Bay of Bengal are able to keep the monsoon trough in the normal position, *i.e.*, over the plains of north India. But on some occasions when there is an absence of these lows and depressions and if there is a western disturbance moving across extreme north of the country and Eastern Himalayas, the monsoon trough easily shifts to foot-Himalayas. Under this situation there is a general break in the monsoon rains over the country, although, over the hills and adjoining parts fairly widespread moderate to heavy rain occurs. This role of the western disturbances in shifting the monsoon trough to foot-Himalayas can be considered as passive. During the period 18 to 22 July 1949, the monsoon trough remained close to foot-Himalayas. A low was affecting the extreme north of the county during the period 18th to 22nd. This had moved away eastwards by 23rd morning. The appearance of a low over Gangetic West Bengal on 22nd morning started the southward shift of the monsoon trough. Western disturbances do, however, play sometimes the active role in shifting the western end of the monsoon trough to the foot-Himalayas.