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A method of forecasting the weather associated with western disturbances

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ABSTRACT. In the present study the authors have presented a method of forecasting the weather associated with western disturbances using the lower tropospheric wind flow pattern. For this purpose, the lower tropospheric winds over the country at two levels were studied - (*i*) the wind pattern at 0·9 km and (*ii*) the position of of subtropical ridge at 850 mb level. On the basis of the wind pattern at these two levels, the weather associated with western disturbances is divided into six broad categories. These are explained with the help of model diagrams. The conclusions have been drawn based on daily data for the months December to February 1960-1973.

This method is especially suitable when data over Pakistan, Afghanistan and neighbourhood are not available. It can also be used as an aid in forecasting the arrival of western disturbances and their associated weather over Indian region.

1. Introduction

There are several weather systems that cause rainfall over Indian region. Among these, western disturbances are of particular importance for the rabi crops in India. They also cause thunderstorm activity, widespread fog and cold wave conditions. Fog and thunderstorms are hazardous for transport and aviation while the cold wave conditions adversely affect human life and crops. In view of the above, it is of great importance to study western disturbances in detail especially in forecasting the weather associated with them.

When there are several consecutive days with sparse data over Pakistan, Afghanistan and adjoining areas, it becomes a major problem for a forecaster to detect western disturbances. Therefore, it will be an asset to formulate some method to forecast the weather associated with western disturbances with the aid of data obtained over Indian region. Rao *et al.* (1969) made some case studies and arrived at some valuable conclusions [for detailed bibliography refer to Rao *et al.* (1969)]. The present day forecaster in India heavily depends on the lower tropospheric wind field and moisture distribution to forecast the weather associated with western disturbances. Hence in the present paper, the authors attempted to classify the lower tropospheric wind patterns associated with western disturbances into a few types and associated a particular sequence of weather with each type.

2. Lower tropospheric winds and their association to western disturbances

Though western disturbances are lower tropospheric phenomena, both upper and lower tropospheric wind flow patterns over Indian region for the period 1960-73 (December to February) have been studied from daily working charts for completeness. The lower tropospheric wind flow pattern is found to be closely associated with western disturbances, in conformity with the findings of Rao *et al.* (1969).

Normally in winter, an anticyclonic flow pattern is seen upto 0·9 km level over northwest India. When an active western disturbance (associated with weather like rainfall etc) approaches nothwest India, the anticyclonic circulation over northwest India is replaced by a cyclonic circulation. In addition to this, another significant feature observed is that the extension of weather to a lower latitude is associated with a shift of the ridge line at 850 mb level to a lower latitude. In the present study, the features of the lower tropospheric flow pattern in association with the western disturbances and the resulting weather are presented.

The normal wind flow pattern over India in winter (January) at 0·9 km and 850 mb levels are shown in Fig. 1. The patterns of lower tropospheric winds that are associated with western disturbances are divided into six broad categories.

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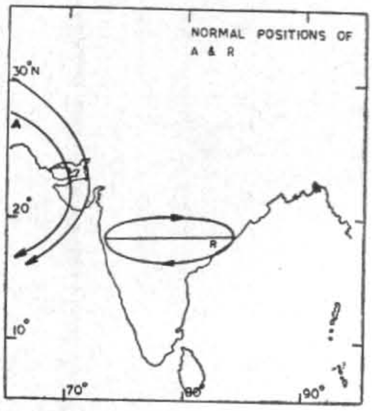


Fig.1

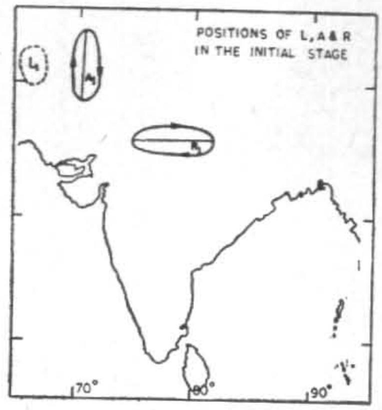
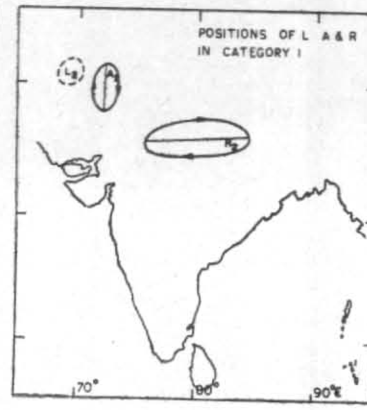


Fig. 2



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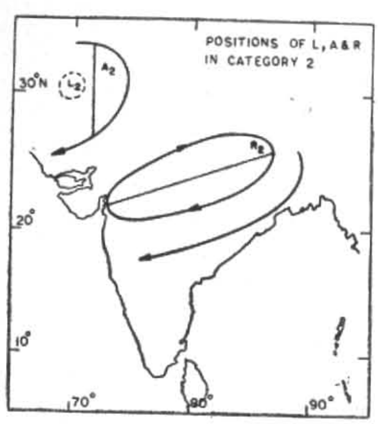

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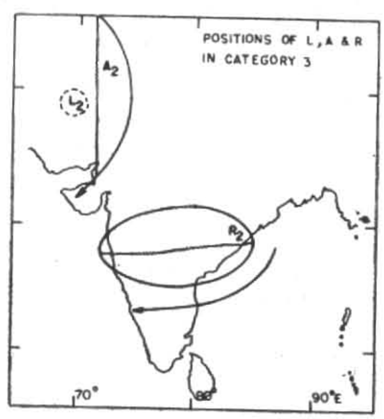

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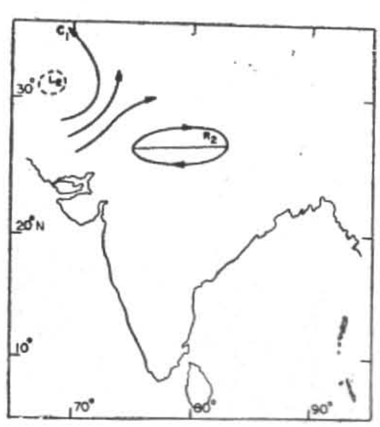

Fig. 6(a)

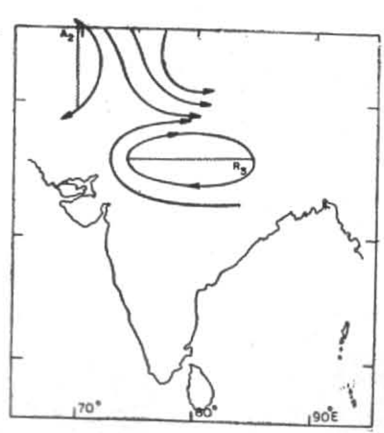

Fig. 6(b). Later stage

Fig. 6. Positions of L, A, C and R in category 4

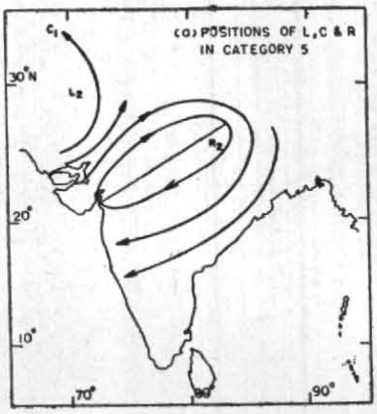

Fig. 7(a)

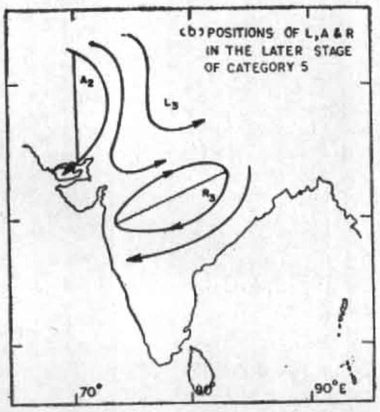

Fig. 7(b)

These are explained along with model diagrams as follows:

The symbol L denotes the surface low associated with western disturbance. A (or C) denotes the anticyclonic (or cyclonic) flow at 0·9 km and R the ridge at 850 mb level. A (or C) does not refer to the centre of the system but are used only to indicate anticyclonic (or cyclonic) flow.

3. Categorisation of lower tropospheric winds and their associated weather

The initial stage when western disturbance (hereafter referred as WD) is over Pakistan and the adjoining areas is represented by Fig. 2 in which L_1 represents surface low. The anticyclonic flow and ridge positions at 0·9 km and 850 mb levels are represented by A_1 and R_1 (north of its normal position) respectively.

As WD approaches northwest India, the anticyclonic flow over northwest India in lower troposphere (0·3 km to 0·9 km levels) :

Category 1 — Persists and the lower tropospheric ridge line (850 mb level) is observed with east-west orientation to the north of normal position. This is shown in Fig. 3, where L_2, A_2 and R_2 are the respective positions of L_1, A_1 and R_1 as seen in Fig. 2. In this case, the weather over Indian region will be dry, but slight night temperature fall will be seen over extreme northwest India behind the WD.

Category 2 — Persists and the ridge (850 mb level) is observed with SW to NE orientation north of its normal position. Here the orientation of the ridge is important. Fig. 4 shows this pattern in which L_2, A_2 and R_2 are the respective positions of L_1, A_1 and R_1 as shown in Fig. 2. Cold wave conditions starts behind WD after it moves eastward across north India as the winds (cold northerlies) are favourable for temperature fall. Moderate cold wave conditions may exist occasionally over northwestern parts of India.

Category 3 — Persists and the ridge moves to the normal or south of its normal position. This is explained in Fig. 5, where L_2, A_2 and R_2 are the respective positions of L_1, A_1 and R_1 as shown in Fig. 2. Cold wave condition starts behind WD over north India after it moves eastwards across India and likely to exist even upto the ridge position and moderate to severe cold wave condition prevails behind WD occasionally (Higher minimum temperature fall being in central India).

Category 4 — Is replaced by cyclonic flow upto 0·9 km level and the ridge is observed with east-west orientation, north of its normal position. This can be seen in Fig. 6(a). In this case, isolated rainfall/snow will be observed over Jammu and Kashmir. When WD crosses the Indian region, the positions of L_2, C_1 and R_2 are shown in Fig. 6(b) by L_3, A_2 and R_3 respectively. When the cyclonic flow shown by C_1 (Fig. 6 a) is replaced by anticyclonic flow shown by A_2 (Fig. 6 b), the cold wave condition (slight night temperature fall) starts behind WD due to cold northerlies. This is confined to the extreme north of northwest India. In this case WD in its eastward movement may also cause scattered to isolated weather over extreme north India (more occasionally over northern parts of northeast India).

Category 5 — Is replaced by cyclonic circulation and the ridge is observed with SW to NE orientation north of its normal position (here the orientation of the ridge is of importance). This is shown in Fig. 7 (a) where L_2, C_1 and R_2 are the respective positions of L_1, A_1 and R_1 shown in Fig. 2.

In this case, scattered to fairly widespread rainfall will be observed over northwest India and scattered snow over extreme northwest India. If the ridge R_2 extends into Arabian Sea, there is a possibility of formation of airmass discontinuity in association with the low level trough associated with the induced low* (if developed) or of western disturbance over northwestern side of the ridge. On some occasions the difference in dew point temperature on either side of the airmass discontinuity line is of the order of 10°C, *i.e.*, on trough side low dew point temperatures and on the ridge side high dew point temperatures. This is seen more conspicuously in categories 6(*ii*) and 6(*iii*). In this case thunderstorm activity and rainfall will be observed along the line of airmass discontinuity.

In association with the passage of WD over northwest India when the cyclonic flow over northwest India in lower levels is replaced by anticyclonic flow (Fig. 7b), moderate to severe cold wave condition sets in behind the WD. The cold wave condition is confined to the region in between A_2, L_3 and R_3. This condition will persist until the anticyclonic flow is replaced by cyclonic flow over northwest India, *i.e.*, due to the approach of a fresh WD. During its eastward movement the WD will give rain over areas north of the ridge (*i.e.*, northern part of India).

Category 6 — Is replaced by cyclonic circulation and the ridge moves to the normal or south of its normal position, then widespread rainfall will occur over north and central parts of India; some times even the Peninsula is also affected if the ridge moves far south. This is shown in Fig. 8 (a) where L_2, C_1 and R_2 are the positions of L_1 A_1 and R_1 respectively.

In the later stage there are some variations in this pattern. They are :

Category 6(i) — As the WD moves eastward across north India, the Cat. 3 flow will be seen bahind WD and moderate to severe cold wave conditions follow the rear of WD. This is shown in Fig. 8 (b). This pattern will persist until another WD approaches the northwest India and thereby the anticyclonic flow over northwest India is replaced by cyclonic flow in the lower levels.

Category 6 (ii) — In almost all days in winter a semi-permanent easterly trough (T_2, Fig. 8 c) is seen anchored over west coast of India. When the *induced low*† with its associated low level trough (T_1, Fig. 8 c) moves to a lower latitude (during its eastward movement), it sometimes merges with the trough T_2 and forms a well marked trough (T_3) and by which the ridge position (R_4, Fig. 8 c) shifts in to Bay of Bengal (R_5, Fig. 8(d) and an airmass discontinuity forms as shown in Fig. 8 (d). This gives rise to thunderstorm activity and rain along the line of airmass discontinuity.

Category 6 (iii) — When once the trough moves away from central India, the ridge line (R_5, Fig. 8 d) also shifts to north (R_6, Fig. 8 e). In this stage, the semi-permanent trough (T_4, Fig. 8 e) seen along the foothills of Himalayas (roughly at 85°E) acts with this ridge which is in Bay of Bengal and forms an airmass discontinuity line shown in Fig. 8(e) and causes thunderstorms and rain over northeast India. It is a must, whenever (*ii*) appears over central India (within one or two days). This case will also occur without the association of (*ii*), when WD does not move to a far south latitude.

Category 6 (iv) — According to Rao *et al.* (1969) that "a depression in south Bay of Bengal or Arabian Sea seems unfavourable for activity of WD over north India".

(*a*) When there is a strong disturbance (D) in Bay of Bengal north of 5°N Lat. the ridge in the lower troposphere shifts to northwestwards and thereby WD (if any) weakens. Figs. 8 (f) and 8 (g) respectively represent the patterns before and after D in Bay of Bengal crosses the 5°N latitude.

(*b*) When D is in Arabian Sea the ridge shifts into Bay of Bengal and helps in the development of case (*iii*) condition and by which scattered to fairly widespread rainfall will be observed over north India. Figs. 8 (h) and 8 (i) respectively represent the patterns before and after D crosses the 5°N latitude.

D in Arabian Sea or Bay of Bengal south of 5°N latitude do not affect WD over Indian region.

4. Frequency of occurrence of WDs in different categories and their associated weather

From the daily data (working charts) of 1960 to 1973 (December, January and February months) the frequency of occurrence of WDs in different categories are obtained and are given below :

Category	1	2	3	4	5	6
Frequency	34	25	50	69	58	65

It is seen from this table that 33 per cent of the WDs are of categories 1 to 3, associated with the dry weather. Therefore categories 1 to 3 are

*Induded lows are developed in association with the WD at a lower latitude than the position of WD

†Induced low formation is more frequent in this case, while in the case of Cat. 5 rarely it develops

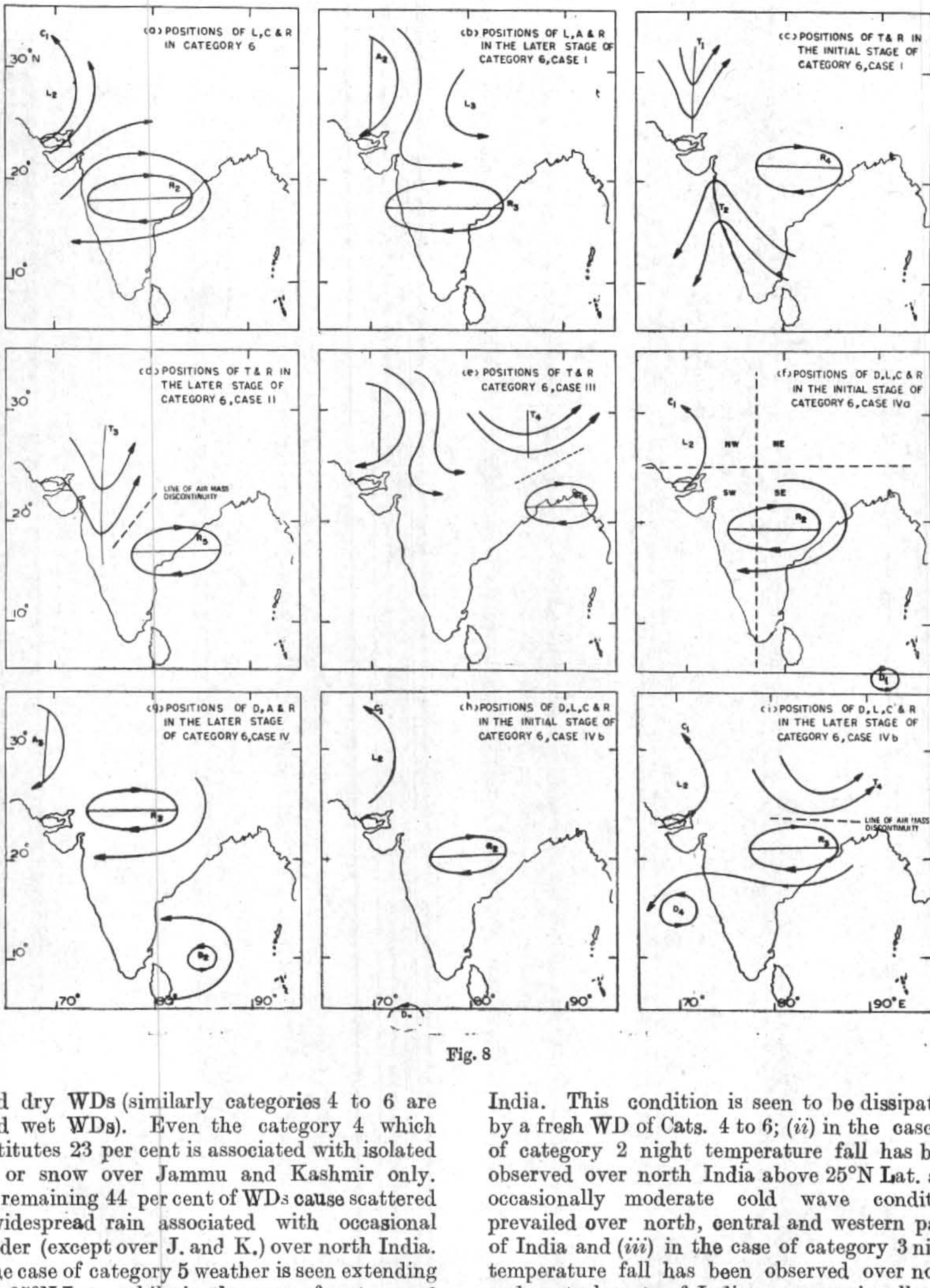

Fig. 8

called dry WDs (similarly categories 4 to 6 are called wet WDs). Even the category 4 which constitutes 23 per cent is associated with isolated rain or snow over Jammu and Kashmir only. The remaining 44 per cent of WDs cause scattered to widespread rain associated with occasional thunder (except over J. and K.) over north India. In the case of category 5 weather is seen extending upto 25°N Lat., while in the case of category 6 it extends upto central parts of India and occasionally it extends even up to 10°N Lat. When a dry WD passes over Indian region, behind WD : (*i*) in the case of Cat. 1 slight night temperature fall has been observed over extreme northwest India. This condition is seen to be dissipating by a fresh WD of Cats. 4 to 6; (*ii*) in the case of of category 2 night temperature fall has been observed over north India above 25°N Lat. and occasionally moderate cold wave condition prevailed over north, central and western parts of India and (*iii*) in the case of category 3 night temperature fall has been observed over north and central parts of India even occasionally extending upto 10°N Lat. and moderate to severe cold wave condition prevailed occasionally over central parts of India (*i.e.*, west Madhya Pradesh and adjoining areas). Whenever categories 2 and 3 prevail it persists for longer period unless another

TABLE 1

Category	Anticyclonic flow over NW India in lower troposphere (0·3 to 0·9 km)	Ridge position at 850 mb	Associated weather	Examples
1	Persists	North of its normal position with east-west orientation	No effect on Indian weather	23-26 Jan 1962 19-23 Dec 1968
2	Persists	North of its normal position with SW to NE orientation	Cold wave condition may exist over extreme NW India	16-18 Dec 1960 1-3 Dec 1964
3	Persists	Normal or south of its normal position	Cold wave condition may exist over north India and occasionally moderate to severe cold wave conditions likely to exist upto the ridge position.	7-16 Jan 1967 6-15 Dec 1961
4	Replaced by cyclonic flow	North of its normal position with east-west orientation	Isolated to scattered weather over NW India and cold wave conditions in the wake of the WD upto the ridge position	7-10 Feb 1960 26-28 Dec 1960
5	Replaced by cyclonic flow	North of its normal position with SW to NE orientation	Scattered to fairly widespread weather over NW India. Moderate to severe cold wave conditions likely to persist upto the ridge position in the wake of WD	9-14 Jan 1962 10-16 Feb 1961
6	Replaced by cyclonic flow	Normal or south of its normal position with east-west orientation	Fairly widespread to widespread weather over north and central parts of India. The weather also shifts southwards as the ridge moves southwards. Moderate to severe cold wave condition in the wake of WD	15-19 Dec 1961 14-20 Feb 1962 7-14 Dec 1968 (6,iv) 24-30 Dec 1968

intense WD of categories 5 or 6 cross over Indian region. This can be seen in December 1961. An intense system over Bay of Bengal will only help for the dissipation of cold wave condition over southern portions and the cold wave condition north of 27° Lat. will persist. This can be seen during December 1965. If WD passes over Indian region in succession at intervals of less than 2 days, the cold wave condition will not develop only slight temperature fall is seen occasionally). This can be seen during the last week of January to 2nd week of February in 1961. The cold wave conditions behind the wet WDs are seen to be relatively more severe than those associated with dry WDs. In brief the weather associated with each type of flow pattern is presented in Table 1.

Whenever there is a D over Bay of Bengal the WDs are weakened and the associated weather is seen to be dry. Whenever there are simultaneously two intense disturbances respectively one each in Bay of Bengal and Arabian Sea, the weather associated with WDs are seen to be dry over north India. This can be seen in December 1965.

5. Conclusions

(*i*) An attempt has been made to classify the low level wind flow associated with western disturbances into a few typical patterns and associated each typical pattern with a particular type of weather distribution and sequence. This will be very useful to the forecasters in their daily work.

(*ii*) In the absence of data over Pakistan and neighbouring areas, the criteria presented in this paper will help in forecasting the weather associated with western disturbances over Indian region.

(*iii*) An active tropical disturbance in the Bay of Bengal north of 5°N latitude, inhibits western disturbance activity over Indian region; but an active disturbance in the Arabian Sea north of 5°N latitude will be favourable for increased rainfall over north India. The disturbances in the Arabian Sea or Bay of Bengal south of 5°N latitude are of no significant importance to affect western disturbance over Indian region.

REFERENCE

Rao, Y. P. and Srinivasan, V. 1969 *Western disturbances and their associated features*, FMU Report No. III-1·1, India met. Dep.