551.557.2 : 551.577.3 "1966"

Spells of heavy rainfall in association with western disturbances over Northwest India during the monsoon of 1966 — A quantitative approach

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(*Received 28 July 1967*)

ABSTRACT. Three spells of heavy rainfall which occurred over northwest Uttar Pradesh, Himachal Pradesh and the Punjab in association with western disturbances moving across extreme northwest India during the monsoon of 1966 were studied.

It has been shown quantitatively that the increase in convergence at 900 m a. s. l. occurred over northwest India with approaching western disturbances and areas of very heavy rainfall had marked convergence at 900 m level, superimposed by marked divergence at 9.0 km a.s.l

1. Introduction

Heavy rainfall over northwest India during monsoon is usually associated with the depressions approaching from the east and moving westnorthwestwards. Heavy rainfall also occurs over extreme northwest India whenever the axis of the monsoon trough runs close to the foot of Himalayas and consequent break in the monsoon over the plains.

There had been three spells of heavy rainfall over northwest India during the monsoon of 1966 which were neither associated with the eastern depressions nor with the break monsoon conditions. The periods of these spells were—(1) 24 to 27 July, (2) 5 to 7 August and (3) 15 to 19 August.

The first one was the heaviest spell. It caused severe damage to railway track and also took toll of many lives in Dehra Dun valley. In all the three cases, a western disturbance was moving across northwest India.

Mooley (1957) has described that the increase in activity of the monsoon over the Punjab (I) and west Uttar Pradesh is associated with the passage of western disturbances across extreme north India. Pisharoty and Kulkarni (1956) have shown that zones of heavy rainfall in monsoon can be associated with marked divergence in the mid and upper troposphere.

It is well known that the areas where low level convergence is superimposed by mid/upper tropospheric divergence are the most favoured areas for marked vertical velocity. Heavy precipitation areas are where sustained vertical velocity occur for considerable length of time. It was, therefore, thought worthwhile to consider quantitatively the magnitude of day-to-day lower level convergence and upper tropospheric divergence—their comparative values and progressive variations—on the days of heavy rainfall. To evaluate progressive variations, one day preceding and succeeding the period of heavy rainfall was also included in the heavy rainfall spell.

In this note, a detailed study of the heaviest spell has been made which occurred from 24 to 27 July 1966. The other two spells have been briefly described. Attempts have been made to find out whether the occurrence of heavy rainfall in northwest India is associated with increase in lower level convergence at 900 m and upper tropospheric divergence at 9·0 km under the influence of western disturbance moving across north India.

2. Evaluation of divergences

The divergence of horizontal wind field may be expressed as—

$$\text{Div } V = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} - \frac{V \tan \phi}{R}$$

where u and v are the components of horizontal wind V, R is the radius of curvature of the earth and ϕ, the latitude. Neglecting the last term which is of a small order of magnitude, we have —

$$\text{Div } V = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

The u and v components of wind field were computed from the radiosonde/rawin and pilot balloon data. Due to paucity of wind observations at 9·0 km the components at some stations and grid points were computed from

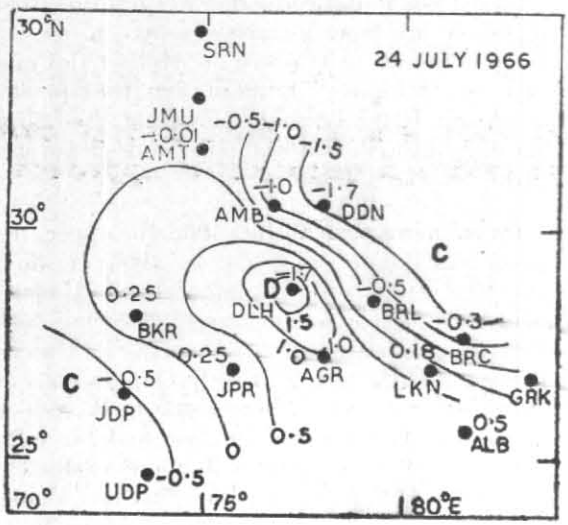


Fig. 1(a). Pattern of divergence at 900 m a.s.l. 0230 GMT on 24 July 1966

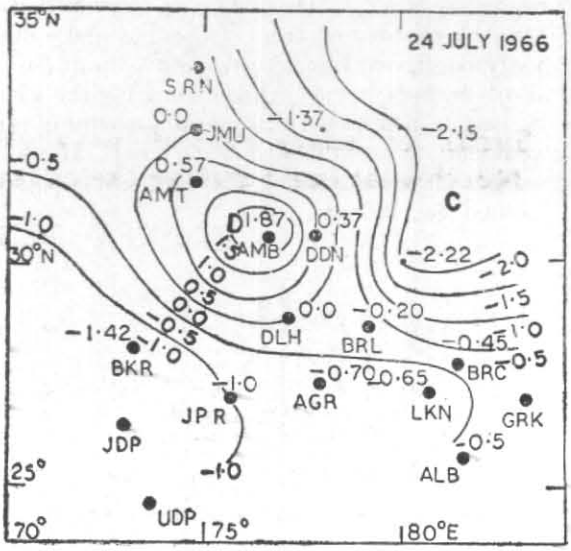


Fig. 1(b). Pattern of divergence at 9·0 km. a.s.l. 00 GMT on 24 July 1966

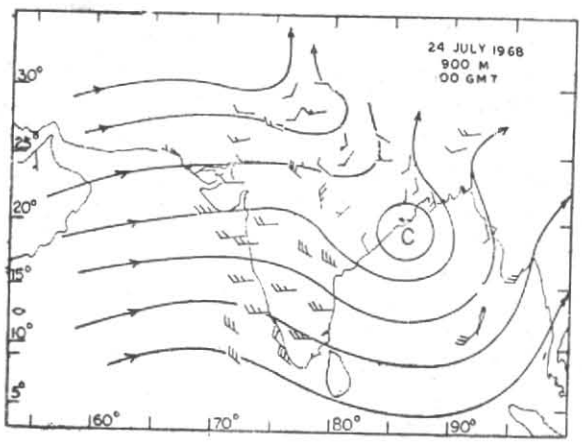


Fig. 1(c)

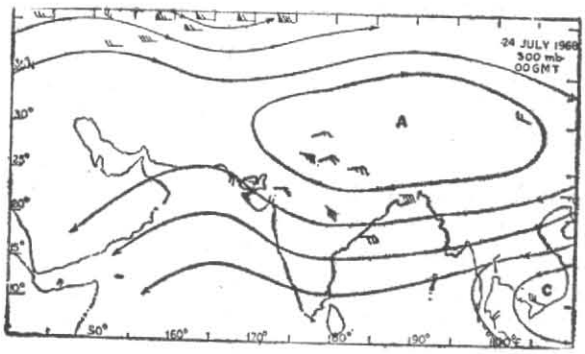
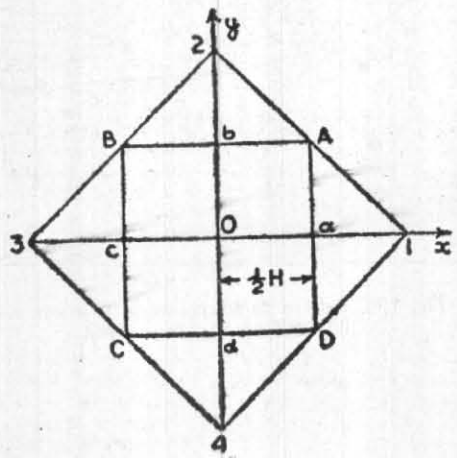


Fig. 1(d)

estimated winds. The values of estimated wind have been obtained from streamline and isotach analysis. In addition, geostrophic assumption has also been kept in view while estimating the winds. It may be mentioned that certain amount of error would have entered in estimating winds. However, under the circumstances, this is the best possible method to estimate winds.



The u and v components of wind field were separately plotted and isopleths of speed were drawn. The values of divergence at various points were calculated by finite difference grid given below —

$$\text{Div } V = \frac{u_a - u_c + v_b - v_d}{H}$$

$$bd = ac = BC = AD$$

Taking H=400 km at 30° N (Scale 1 : 10×10^6) on mercator projection, the divergence patterns were obtained by drawing isopleths in units of 10^{-5} sec^{-1}. The changes in divergence in 24-hr at various points were obtained by taking the difference in the values of divergence on two consecutive days. The isopleths of changes in divergence were then drawn.

3. Discussion

On 24 July 1966 only light to moderate rain occurred which was scattered in Himachal Pradesh, the hills of the Punjab and of west Uttar Pradesh.

On the morning of 25 July 1966 the seasonal low over West Pakistan and adjoining Punjab was observed to be more marked and upper air trough lay between 2·1 and 4·5 km a.s.l. over these areas.

Under the influence of this western disturbance monsoon suddenly became vigorous in northwest Uttar Pradesh and active in Himachal Pradesh and the Punjab. Rainfall was widespread in northwest Uttar Pradesh, Himachal Pradesh and the hills of the Punjab and fairly widespread in the plains of the Punjab.

On the morning of 26 July 1966, the upper air cyclonic circulation extending to about 4 km lay over the Punjab and neighbourhood. Under its influence monsoon was vigorous in the plains of the Punjab and continued to be active in Himachal Pradesh and the hills of the Punjab and was only active in northwest Uttar Pradesh. Rainfall was widespread in Himachal Pradesh and the hills of Punjab, fairly widespread in Jammu and Kashmir, plains of the Punjab and northwest Uttar Pradesh.

On the morning of 27 July 1966, the upper air cyclonic circulation was moving away eastwards across the hills of the Punjab and of Uttar Pradesh as an upper air trough. In general, activity of the monsoon decreased later in the Punjab, Himachal Pradesh and west Uttar Pradesh. However, the monsoon was active in east Uttar Pradesh. Rainfall has been widespread in the hills of west Uttar Pradesh, fairly widespread in Himachal Pradesh and the Punjab.

The divergence patterns and upper wind charts at 900 m and 9·0 km at 0000 GMT of 24 to 26 July are prepared and only the charts pertaining to 24 July 1966 are shown in Figs. 1(a), 1(b), 1(c) and 1(d) respectively. It is evident from Fig. 1(a) that the convergence is maximum over northwest Uttar Pradesh and the adjoining hills of the Punjab. At 9·0 km. the divergence is maximum over the plains of Punjab. It is seen that areas of convergence at 900 m a.s.l. do not correspond to the areas of divergence at 9 km a.s.l.

Similar divergence patterns at 0000 GMT of 25 July at 900 m and 9·0 km a.s.l. were prepared (not shown) and the corresponding 24-hr change in divergence from 24 to 25 July shown in Figs. 2(a) and 2(b) respectively.

It is seen that in the morning of 25 July whole of northwest India at 900 m a.s.l. has turned into convergent area. The maximum convergence is over northwest Uttar Pradesh. At 9·0 km a.s.l. there has been increase in the magnitude of divergence over Uttar Pradesh, Himachal Pradesh and the hills of the Punjab. The maximum increase in divergence has occurred over northwest Uttar Pradesh and maximum fall over the south Punjab as is obvious from Fig. 2(b). By the morning of 25 July, Uttar Pradesh and Himachal Pradesh

TABLE 1

Date	Position of the Western Disturbance	Weather caused	Remarks
	Second Spell — 5 to 7 August 1966		
5 Aug 1966	An upper air trough was traced on 1200 GMT charts over West Pakistan and adjoinging areas extending upto 2·1 km a.s.l.	Monsoon had been active in west Rajasthan; fairly widespread rain in Rajasthan, Himachal Pradesh, hills of the Punjab and the plains of west Uttar Pradesh	
6 Aug	The seasonal low pressure area over West Pakistan and adjoining Punjab was well marked and upper air trough was extending between 3·0 and 6·0 km a.s.l. over northern divisions of West Pakistan and adjoining Jammu and Kashmir	Monsoon had been active in east Uttar Pradesh. Fairly widespread rain in Himachal Pradesh, the hills of the Punjab and Uttar Pradesh	A low pressure area had formed over Gangetic West Bengal and neighbourhood. Associated upper air cyclonic circulation extending upto about 7·0 km a.s.l.
7 Aug	The seasonal low pressure area over Pakistan and adjoining Punjab continued to be well marked. The upper air trough is also persisted over northern divisions of West Pakistan and adjoining Jammu and Kashmir between 4·0 and 7·0 km a.s.l.	Monsoon had been active in northwest Uttar Pradesh and the plains of the Punjab. Fairly widespread rain in northwest Uttar Pradesh, the Punjab and Himachal Pradesh	Low pressure area lay over Bihar plateau and neighbourhood with associated upper air cyclonic circulation extending up to 7·0 km a.s.l. By 8th morning the low pressure area moved over to south Uttar Pradesh and adjoining Madhya Pradesh and seasonal low became less marked.
	Third Spell — 15 to 19 August 1966		
15 Aug	A western disturbance lay as an upper air trough over West Pakistan and adjoining areas extending up to 4·5 km a.s.l.	Monsoon had been active in west Uttar Pradesh where widespread rain occurred. Fairly widespread rain in Himachal Pradesh, hills of the Punjab and east Uttar Pradesh	
16 Aug	The western disturbance lay as an upper air cyclonic circulation extending upto about 2·0 km a.s.l. over the Punjab	Monsoon had been vigorous in the plains of the Punjab. Widespread rain in west Uttar Pradesh, fairly widespread in the plains of the Punjab	
17 Aug	The upper air cyclonic circulation persisted over the Punjab and extended upto about 4 km a.s.l.	Scattered rain in Jammu and Kashmir, Himachal Pradesh, the hills of the Punjab and Uttar Pradesh	
18 Aug	The upper air cyclonic circulation lay over the Punjab and neighbourhood and extended upto 3·0 km a.s.l.	Fairly widespread rain in Himachal Pradesh and the hills of the Punjab	
19 Aug	The upper air cyclonic circulation was moving across the hills of the Punjab and of west Uttar Pradesh as an upper air trough	Widespread rain in the hills of west Uttar Pradesh	

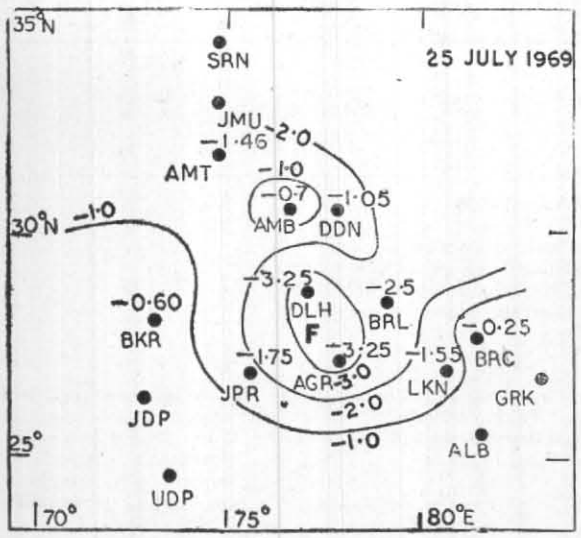


Fig. 2(a). Changes of divergence at 900 m a.s.l., 00 GMT, from 24 to 25 July 1966

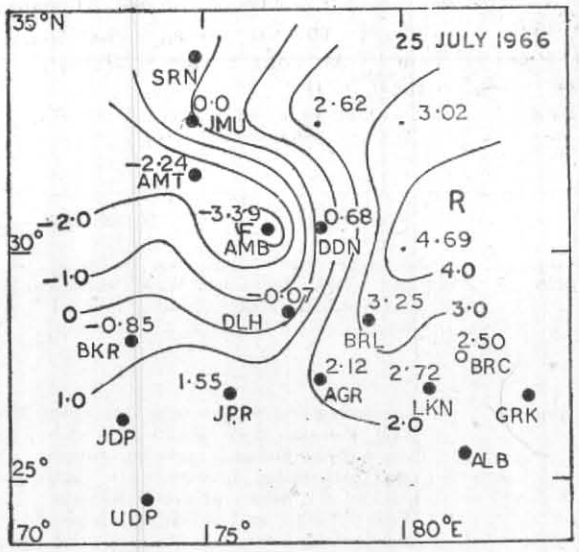


Fig. 2(b). Changes of divergence at 9·0 km a.s.l., 00 GMT, from 24 to 25 July 1966

the hills of the Punjab, Kashmir and south Rajasthan have become divergent, the maximum divergence being over northwest Uttar Pradesh.

It may be noted that northwest Uttar Pradesh where heaviest rain occurred was also the area where maximum covergence at 900 m a.s.l. and maximum divergence at 9·0 km a.s.l. is observed. The other areas of heavy rainfall except in the plains of the Punjab also show similar correspondence between convergence at 900 m a.s.l. and divergence at 9·0 km a.s.l.

It is seen from the 00 GMT change chart of 26 July that there has been general decrease in convergence over west Uttar Pradesh, Himachal Pradesh and Jammu and Kashmir and increase over west Rajasthan and adjoining Punjab at 900 m a.s.l.

The whole of northwest India continued to be convergent even on 26 July at 900 m a.s.l., the maximum convergence being over southwest Uttar Pradesh.

At 9·0 km a.s.l. divergence has in general decreased over west Uttar Pradesh, Jammu and Kashmir, Himachal Pradesh and the hills of the Punjab and increased over the plains of the Punjab, and Rajasthan ; Himachal Pradesh, the hills of the Punjab and of west Uttar Pradesh, southwest Uttar Pradesh and Rajasthan continue to be divergent but less marked. Though areas of heavy rainfall over the hills are also the areas where convergence at 900 m a.s.l. is superimposed by the divergence at 9·0 km a.s.l., yet the plains of the Punjab and of northwest Uttar Pradesh which fall in the areas of marked convergence at 900 m a.s.l. correspond to the slightly convergent or flat region at 9·0 km a.s.l.

It is clear from the 00 GMT change chart of 27 July, that there has been general decrease in convergence except in west Rajasthan and east Uttar Pradesh where slight increase in the magnitude of convergence has occurred.

The whole of northwest India continues to be convergent at 900 m a.s.l. except south Rajasthan, the maximum convergence being over east Uttar Pradesh, north Rajasthan and the adjoining plains of the Punjab.

At 9·0 km a.s.l. there has been increase in divergence over Jammu Province, Kashmir, Himachal Pradesh, the Punjab and east Uttar Pradesh and from the charts prepared it is seen that north Punjab, Himachal Pradesh, Jammu and Kashmir, south Rajasthan and southwest Uttar Pradesh are divergent.

East Uttar Pradesh, the area of heaviest rainfall, is also the area of maximum convergence at 900 m a.s.l. However, at 9·0 km a.s.l., this corresponds to a slight convergent field.

The other two spells of heavy rainfall are described briefly in Table 1. In both the cases it may be easily inferred that the activity of monsoon over northwest India has increased under the influence of the western disturbances.

4. Conclusion

1. Activity of the monsoon increased over Himachal Pradesh, the Punjab and west Uttar Pradesh with the passage of the western disturbances across northwest India.

2. Increase in convergence at 900 m a.s.l. over northwest India occurred with the approach of the western disturbance.

3. The heaviest rainfall occurred in the areas where marked divergence at 9·0 km a.s.l. was superimposed over marked convergence at 900 m a.s.l.

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Pisharoty, P. R. and Kulkarni, S. B.	1956	*Ibid.*, **7**, 2, pp. 103 112.