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Letter to the Editor

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HEAVY RAINFALL IN NORTHWEST INDIA DURING WINTER AND ADVECTION OF VORTICITY AT 300-MB LEVEL

1. Rainfall in northwest India during winter is associated with the western disturbances which are perturbations on the middle latitude westerlies and are usually more active during the winter as the westerlies come down to north Indian latitudes. Heavy precipitation in northwest India during winter invariably occurs in association with well marked western disturbances with deep upper air troughs. Pisharoty and Desai (1956) state that western disturbances occasionally deepen when they come over Rajasthan and the Punjab. The occasional deepening of the sea level 'low' may be connected with marked diffluence in the upper air flow patterns at the 300-mb level and aloft prevailing over the sea level 'lows'. Therefore, it is considered that heavy rainfall in winter over northwest India may be associated with the marked divergence at 300-mb level.

2. An attempt has been made to determine the areas of marked upper air divergence at 300 mb from the vorticity patterns and to consider these as the probable areas of heavy precipitation during winter.

3. Isobaric divergence is related to the advection of absolute vorticity by the equation:

$$\nabla_p . V = -\frac{1}{\zeta_a} V \frac{\partial \zeta_a}{\partial s}$$

Thus the areas, where vorticity decreases downstream will be divergent. In other words, the area of positive vorticity advection coincides with the divergent area. The geostrophic relative vorticity may be substituted for relative vorticity and can be computed by finite difference approximations:

$$\zeta_g = \frac{4g}{fd^2} (\overline{Z} - Z_0)$$

where $\overline{Z} = (Z_1 + Z_2 + Z_3 + Z_4)/4$, is the space averaged contour height, Z_0 is the observed contour height at the grid centre and d, the grid length = 6° latitude. Since the factor $4g/fd^2$ varies only slowly in the north-south direction on the map, the isopleths of $(\overline{Z} - Z_0)$ may be taken to be the isopleths of vorticity. As the change in f along the contours of upper air isobaric chart is generally small, the absolute vorticity patterns will not be much different from the patterns of geostrophic relative vorticity as obtained from $(\overline{Z} - Z_0)$.

4. To examine quantitative relationship between positive vorticity advection and heavy rainfall in winter, vorticity patterns at 300-mb level at 00 GMT for various days were prepared as follows.

(*i*) The values of $(\overline{Z} - Z_0)$ were calculated at each 5-degree grid point between the longitudes 65° E and 90°E and latitudes 40° N to 25°N by using finite difference grid.

(*ii*) The isopleths of $(\overline{Z} - Z_0)$ at 10 gpm intervals were drawn. These could be considered as isopleths of relative vorticity.

5. On the 300-mb charts for 00 GMT reproduced in Figs. 1 and 2 contour lines are drawn at intervals of 80 gpm and isopleths of $(\overline{Z} - Z_0)$ at 10 gpm which have been taken as isopleths of relative vorticity. Rainfall amounts of 3 cm or more have also been plotted on the corresponding charts.

6. The magnitude of the advection of relative vorticity may be measured from the maps if we consider the size of the quadrilateral formed by the two consecutive contour lines and two consecutive isopleths of vorticity considering the following points:

(*i*) Advection of vorticity may be taken to be inversely proportional to the area of the quadrilateral formed by the intersection of the two consecutive contour lines with the consecutive isopleths of relative vorticity.

(*ii*) Advection of vorticity along stream lines varies directly with the wind speed.

The charts for 9 and 10 March 1963 are shown in Figs. 1 and 2 respectively. In both the cases the heavy rainfall had occurred in the zones of positive vorticity advection.

R. K. S. SAXENA
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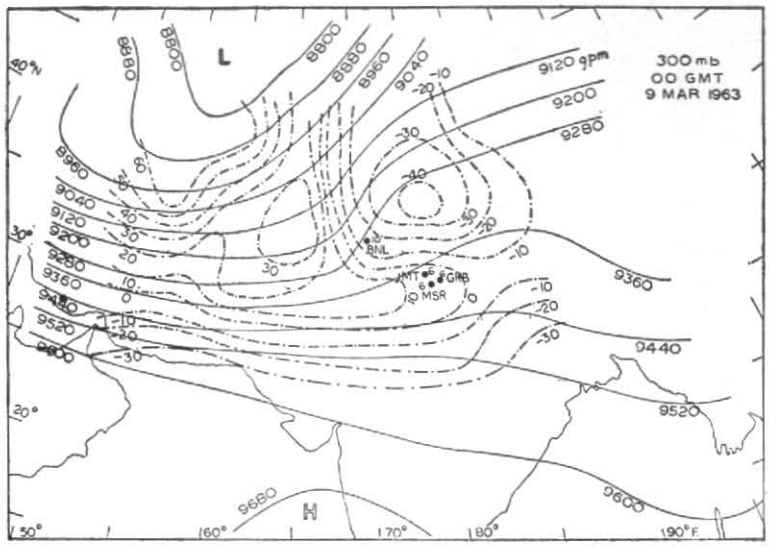

Fig. 1

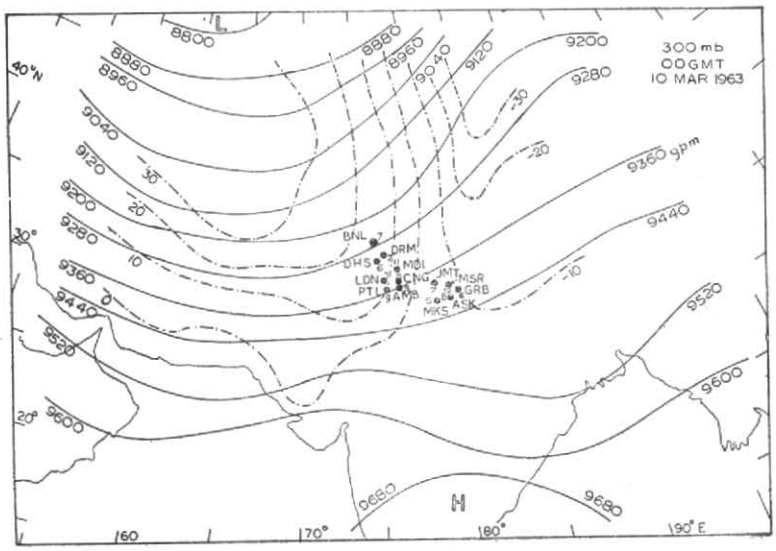

Fig. 2

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