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12-hourly changes in vorticity and forecasting of rainfall over Bhagirathi catchment

D. V. L. N. RAO, K. K. SRIVASTAVA, H. C. MEHRA and B. R. BANSAL

Meteorological Office, New Delhi

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सार — भागीरथी जलग्रहण क्षेत्र में वर्षा के पूर्वानुमान के लिए सिनॉप्टिक प्रकारों से संबद्ध अन्य मौसम सबंन्धी प्राचलों को साथ मिलाकर धनात्मक भ्रमिलता में परिवर्तन के क्षेत्रों का पता लगाने की दृष्टि से भागीरथी जलग्रहण क्षेत्र में तूफान आने से एक दिन पूर्व की तूफान वर्षा की स्थितियों के लिए पवन क्षेत्र और परम भ्रमिलता से प्रति 12 घंटे के परिवर्तन का परीक्षण किया गया है ।

21°- 26° उ॰ एवं 84°-92° पू॰ से घिरे भागीरथी जल ग्रहण क्षेत्र के धनात्मक भ्रमिलता परिवर्तनों से पता लगने वाले अभिसरण प्रारूप को आलेखित किया गया है और उसका अगले दिन तीन बजे (ग्री॰ मा॰ स॰) की प्रेक्षित वर्षा के समवर्षण प्रारूपों से मिलान किया गया है । अध्ययन से पता चला है कि दोनों प्रारूपों में परस्पर काफी समानता है ।

सूझाव है कि सिनॉप्टिक स्थितियों से निर्धारित वर्षण क्षेत्र के पूर्वानुमान में संभावित पार्श्व स्थानांतरण को ध्यान में रखते हुए वर्षण क्षेत्र का पूर्वानुमान 12 से 15 घंटे पहले करने के लिए कुल धनात्मक भ्रमिलता परिवर्तनों के क्षेत्रों को पथप्रदर्शक माना जा सकता है ।

ABSTRACT. The wind field and 12-hourly change in absolute vorticity have been examined for a few rainstorm situations in the Bhagirathi catchment one day in advance to the storm with a view to locating areas of positive vorticity changes as one of the criteria in conjuction with other meteorological parameters associated with synoptic types for forecasting rainfall over Bhagirathi catchment.

Convergence patterns as revealed by positive vorticity changes over the area bounded by Lat. 21-26 N and Long. 84-92 E containing Bhagirathi catchment have been plotted and compared with the isohyetal patterns of observed rainfall at 03 GMT of the next day. The study shows that there is resemblance between the two patterns.

It is suggested that the areas of positive total vorticity changes may be taken as a guide to forecast areas of precipitation 12 to 15 hours in advance keeping in view the likely lateral shift of the forecast areas of precipitation as judged by synoptic situation.

1. Introduction

In the study on the forecasting of heavy rainfall over Delhi and neighbourhood Ghosh (1970) considered convergence pattern over Delhi in conjuction with the passage of wave troughs and concluded that rise in rate of convergence in the lower levels and the passage of a wave trough over Delhi 24 to 36 hours earlier was conducive to heavy rainfall over Delhi.

Sarma (1970) considered evaluating vertical velocities over small areas for forecasting heavy rainfall.

Banerji and Rao (1966) computed rates of precipitation over catchment areas making use of various methods.

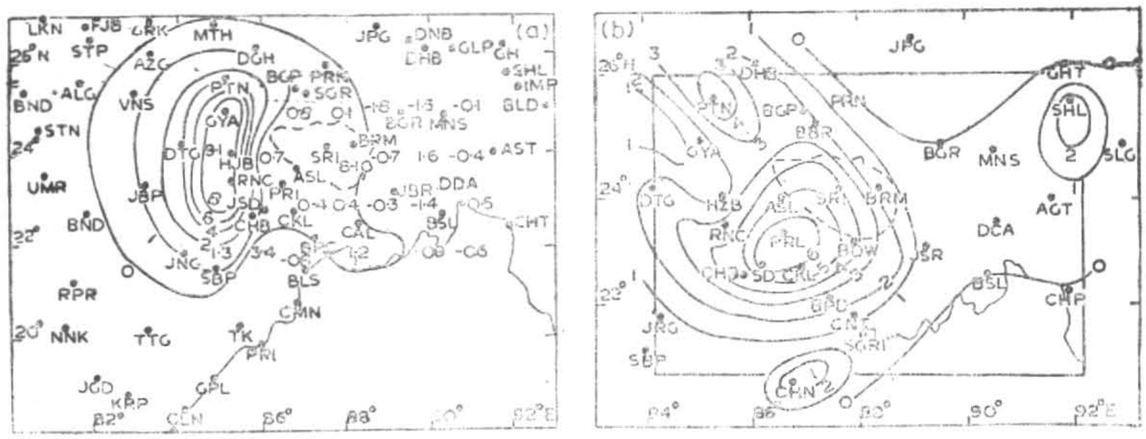
Knowing that one of the mechanisms of heavy rainfall is due to the convergence in the lower levels and divergence at higher levels, changes in absolute vorticity over Bhagirathi catchment and neighbourhood at lower levels 12 to 15 hours in advance of a few rainstorm situations have been studied in this paper with a view to aid heavy rainfall forecasting.

Bhagirathi catchment lies in the border areas of Bihar Plateau and Gangetic West Bengal. It has a total area of about 25,000 sq. km and lies in homogeneous rainfall zone. The annual rainfall over the catchment as a whole is 136 cm of which 85 per cent occurs during the months of June to October.

Three cases of one-day rainstorms of 3 & 21 August and 23 September 1962 having coverage depths of precipitation as 4.1, 4.0 & 4.0 cm respectively were finally selected for the study.

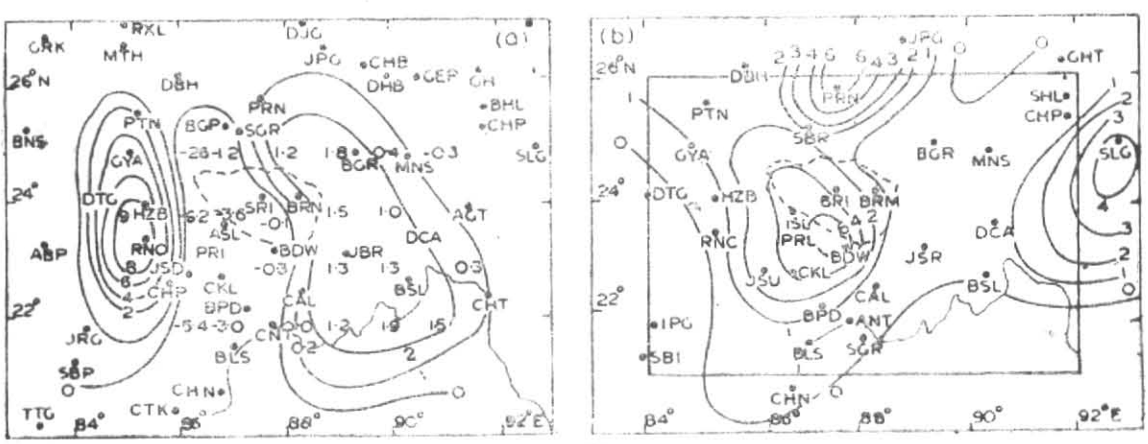
2. 12-hourly changes in total vorticity

The basis of this is a study by Peterson *et al.* (1960) in which it was shown that convergence develops after cyclonic vorticity has appeared and reaches its maximum down stream from the maximum cyclonic vorticity and that the time lag was of the order of a few hours. This observation of Peterson and others has been extended to locate rainfall maxima. Theoretically the changes in geostrophic



CATCHMENT BOUNDARY, ISOHYETS (cm), AREA UNDER CONSIDERATION, RAINGAUGE STATION

Fig. 1. (a) 12-hr total vorticity change in 10^{-5}/sec between 12 and 00 GMT of 2 August 1962 and (b) Observed rainfall (cm) on 3 August 1962



CATCHMENT BOUNDARY, ISOHYETS (cm), AREA UNDER CONSIDERATION

IMPORTANT RAINGAUGE STATION

Fig. 2. (a) 12-hr total vorticity change in 10^{-5}/sec between 12 and 00 GMT of 20 August 1962 and (b) Observed rainfall (cm) on 21 August 1962

vorticity can take place either as a result of changes in shear term or in the curvature term. The location and intensity of rainfall, therefore, can be related in the first instance in a quantitative way to the duration and amplitude of the geostrophic vorticity.

All the available upper air data from 18 stations, pilot balloon as well as RS/RW data within the area, 21-26 N and 84-92 E, were collected from the *Indian Daily Weather Reports* and *Aerological Data* published by India Met. Dep. for the relevant dates.

A computer programme was used to resolve the wind into u and v components and to compute weighted averages of these components by Cressmen's technique at one degree grid points within the area under study. Vorticity was calculated at each grid point by the usual expression :

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

ζ is expressed in 10^{-5}/sec at each level. Total vorticity from surface upto 500 mb level was then calculated at each grid point for 0000 and 1200 GMT on the day previous to the occurrence of rainstorm.

The total vorticity changes were calculated by using the well-known expression :

$$\frac{d}{dt}\,(\zeta+f) = -(\zeta+f)\,\nabla\cdot\mathbf{V}$$

neglecting vortex tube term and solenoidal term from the vorticity equation.

Isopleths of 12-hourly changes in the total vorticity were then plotted to demarcate areas of positive and negative vorticity changes. The pattern of isopleths thus plotted were compared with the isohyetal patterns of observed storm rainfall at 03 GMT of the next day. Negative vorticity changes are taken to be associated with subsidence and consequent no rain whereas positive vorticity changes are taken to be associated with heavy rainfall cases.

3. Discussion of results of individual cases

Case 1: *Rainstorm of* 3 *August* 1962

The isopleths of 12-hourly changes in vorticity between 00 & 12 GMT of 2 August 1962 (Fig. 1 a) show a centre of marked positive vorticity change over northeastern parts of Orissa and adjoining areas of Bihar and Bengal.

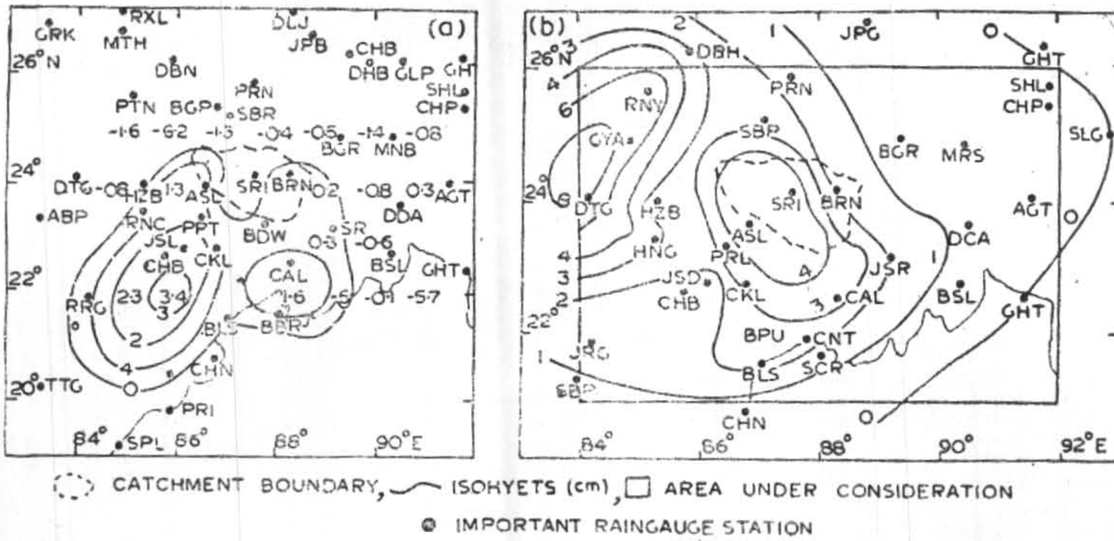


Fig. 3. (a) 12-hr total vorticity change in 10^{-6}/sec between 12 and 00 GMT of 22 September 1962 and (b) Observed rainfall (cm) on 23 September 1962

The isohyetal pattern of observed rainfall at 03 GMT on 3 August 1962 (Fig. 1 b) shows an area of heavy rainfall over eastern parts of Bihar and adjoining Gangetic West Bengal.

On comparing these two patterns, it is noticed that the central area of positive vorticity was found to be located west about 2 degrees to give heavy rainfall over eastern parts of Gangetic West Bengal, parts of Bhagirathi catchment and neighbourhood.

The streamline patterns of 00 GMT and 12 GMT of 2 August 1962 and 00 GMT of 3 August 1962 support the convergence over the area under study upto 700 mb.

Case 2 : *Rainstorm of* 21 *August* 1962

The isopleths of 12-hourly change in vorticity between 0000 GMT and 1200 GMT of 20 August 1962 (Fig. 2 a) show two areas of positive change in vorticity, one over Bihar Plateau and the adjoining areas of northeast Madhya Pradesh and north Orissa and the other over Bangla Desh separated by an area of negative vorticity change running north-south through Bhagirathi catchment. The isohyetal pattern of observed rainfall at 03 GMT of 21 August 1962 (Fig. 2 b) shows two areas of high rainfall, one over east Bihar and adjoining parts of Bengal and the other over eastern parts of Bangla Desh and adjoining areas of Nagaland, Manipur, Mizoram and Tripura separated by an area of scanty rainfall.

On comparison with the isopleths of 12-hourly vorticity change at 12 GMT of the previous day, it is noticed that high rainfall area over east Bihar and adjoining parts of West Bengal has appeared over areas 2½ deg. E of the areas of positive vorticity change. Similarly, the area of high rainfall over eastern parts of Bangla Desh and neighbourhood had appeared 1½-degree towards the northeast of the area of positive vorticity change of the previous evening. The area of negative change has appeared as an area of scanty rainfall in between the areas of high rainfall which is in agreement with assumptions made.

Case 3 : *Rainstorm of* 23 *September* 1962

Isopleths of 12-hourly vorticity change in 22 September 1962 (Fig. 3 a) show maximum positive vorticity change over south Gangetic West Bengal and neighbouring areas of east Bihar and adjoining parts of Bangla Desh where centres of high rainfall may be expected surrounded by areas of negative vorticity change embedded in the general area under study.

On comparison with the centres of high rainfall in the isohyetal pattern of observed rainfall at 03 GMT of 23 September 1962 (Fig. 3 b), it is seen that there is an area of high rainfall over Gangetic West Bengal and east Bihar, coinciding with the area of positive vorticity though with a shift of 2-degree to the northeast. Another centre of high rainfall over west Bihar and adjoining areas of southeast Uttar Pradesh in the observed pattern of rainfall has no counter part in the 12-hourly positive change of absolute vorticity. In fact this area is shown as an area of negative vorticity change where no rainfall was expected.

4. Conclusions

From the study of the wind field over the catchment and neighbouring areas under favourable synoptic situations, a plot of change in vorticity at 12 GMT of the day, it seems that likely areas of precipitation can be forecasted 15 hours in advance. The shift is areas of precipitation in relation of vorticity changes is to be expected since in a dynamic situation the pressure field is constantly changing.

This study at present gives a qualitative but objective forecast of the likely areas of precipitation, and can be a useful tool for forecasting offices.

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References

Banerji, S. and Rao, D.V.L.N., 1966, Rational attempt at quanttative precipitation forecasting,' *Indian J. Met. Geophys.*, **17** (Spl. No.), p. 307.

Ghosh, Ashim K., 1970, Forecasting heavy rainfall over Delhi and neighbourhood, *Indian J. Met. Geophys.*, **21**, 1, p. 65.

Peterson, K.R., Cochrane, C.W. and Molansky, S., 1960, N.H.R.P. Rep. No. 33 on Q.P.F., U.S. Weath. Bur.

Sarma, V.V., 1970, A simple method of evaluating vertical velocity over small areas for forecasting heavy rainfall, *Indian J. Met. Geophys.*, **21**, 1, p. 87.