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Hydrometeorological study of severe rainstorms of north Bihar

ASHIM K. GHOSH and K. PRASAD
Meteorological Office, Patna
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सार – यह अध्ययन गंडक, बूढ़ी गंडक, बागमती के जलग्रहण वाले उत्तर बिहार की भीषण तूफानी वर्षा का जल मौसम विज्ञान संबंधी विश्लेषण है। अधवारा समूह और कामला के जल ग्रहण वाले स्थान एवं मानसून अवदाबों/निम्नदाब क्षेत्रों के पथों के संदर्भ में तूफानी वर्षा के ढर्रे का अध्ययन किया गया है। इस अध्ययन से पता चलता है कि उपरोक्त क्षेत्र में भीषण तूफानी वर्षा अधिकांशतः सितम्बर महीने में होती है। इसकी सीमा 45° ऋणात्मक से 95° धनात्मक तक होती है और भारी वर्षा के केन्द्रों की दूरियां पिछले दिन के विक्षोभ के केन्द्र से 110 से 520 कि० मी० तक होती हैं।

ABSTRACT. The study contains hydrometeorological analysis of severe rainstorms of north Bihar comprising of the catchments of the *Gandak*, the *Burhi Gandak*, the *Bagmati*, the *Adhwara* group and the *Kamala*. Rainstorm pattern in relation to location and tracks of monsoon depressions/ low pressure areas has also been studied. This study has revealed that severe rainstorms in this area occur mostly in the month of September. Bearings range from *minus* 45 deg. to *plus* 95 deg. and the distances of heavy rain centre from that of the centre of the disturbance of the previous day range between 110 and 520 km.

1. Introduction

The role of hydrometeorogly in the evaluation of flood potentialities of a river basin and planning of flool control and other water management projects is well recognised. The most important hydrometeorological parameter required by the design engineer is the estimate of maximum precipitation over a given area. The reliable estimate of maximum precipitation are derived by the hydrometeorological analysis of past major rainstorms over that area, if adequate data are available. Numerous such studies have been conducted by various workers for different river basins of India. For the Bihar State, the work done by Raman and Dhar (1966), Banerji and Gupta (1966), Dhar and Rakhecha (1974) needs special mention. In this paper results of hydrometeorological study of the severe rainstorms since 1901, that occurred over the plains areas in north Bihar comprising of catchments of the *Gandak*, the *Burhi Gandak*, the *Bagmati*, the *Adhwara* group and the *Kamala* have been presented.

The present study is a part of the hydrometeorological studies of rainstorms of the region which are being undertaken by the Hydrometeorological Unit (Ganga Basin), Patna, for the preparation of a comprehensive flood control plan of the Ganga basin.

2. Ganga basin in Bihar — A brief introduction

The *Ganga* enters Bihar State in Bhojpur district and flows from west to east across the State dividing the plains of Bihar into two parts. As it enters the State it receives two important tributaries, the *Ghaghra* from the left at Chapra and the *Sone* from the right near Arrah. As it progresses eastwards, the *Gandak* another left bank tributary joins the *Ganga* just opposite the Patna township. It also receives the *Burhi Gandak* near Khagaria, the *Ghugri* (the combined channel of the *Kamala*, the *Bagmati* and the *Kosi* near *Kursela* and *Phulhar* branch of the *Mahananda* near Maniharighat on the left bank. The other important right bank tributaries of the *Ganga* are the *Pun Pun*, the *Kilu*, the *Chandan* and the *Gerua*.

(2) After the confluence with the *Phulhar* branch of the *Mahananda* near Maniharighat, the river swings about the Rajmahal hills and starts flowing almost southwards and enters West Bengal. Fig. 1 shows a map of the *Ganga* basin in Bihar.

The area of this basin in Bihar is 1,43,961

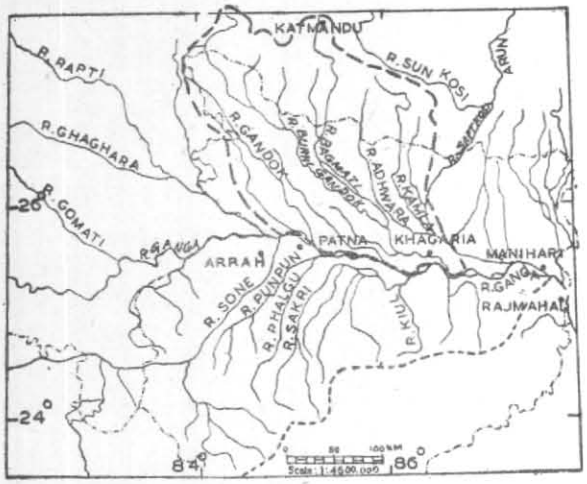

Fig. 1. Ganga basin in Bihar

sq. km which is approximately 16.7 per cent of the total area of the entire Ganga basin.

(3) *Synoptic situation of flood producing rainstorms and chief features of rainfall distribution in the Ganga basin in Bihar*

The Ganga basin in Bihar can be considered as comprising of two distinct sub-divisions, *viz.*, (*i*) the catchments of left bank tributaries towards the north and (*ii*) right bank tributaries towards the south of the *Ganga*. The southern sub-division is mainly affected by the Bay depressions and low pressure areas throughout the monsoon season. On the other hand the northern sub-division experiences the effect of not only depressions and low pressure areas but also of "*break*" monsoon situations.

The northern sub-division can be further subdivided according to synoptic situations mentioned above as they produce different rainfall patterns.

During the "*break*" monsoon situations the heavy rainfall is confined mostly in the mountainous region and along the foot-hills. On the other hand the area of heavy rainfall associated with monsoon depression/low pressure areas remains confined to the plain portion of the catchments under consideration and largely depends upon the tracks of the disturbances. Rainfall may occasionally extend into the Himalayan portion of the catchments depending upon the path of the system. Rainstorms associated with monsoon depressions/low pressure areas have a characteristic feature peculiar to them, *viz.*, concentrated heavy rainfall over smaller areas (Rao 1976). Due to differing characteristics of rainfall associated with the two types of synoptic situations it is only appropriate to categorise the rainstorms according to the central region of their occurrence, *viz.*, (*i*) the mountainous and the foot-hills region and (*ii*) the plains region, and carry out hydrometeorological analysis for each category separately. In the present study the rainstorms occurring in the plain region have been analysed.

3. Data used and procedure followed

Daily rainfall data since 1901 of all the raingauge stations available in the catchments have been used for this study.

Following the procedure given in the *Manual of Hydrometeorology*, Part-I (India Met. Dep., 1972) rainstorms of 1 to 4-day durations were selected for final analysis. The rainstorms selected for the individual catchments were composited and isohyetal charts prepared. As the interest was centred in obtaining maximum rain depths through envelopment, the number of rainstorms selected for final analysis was restricted to severe most rainstorms characterised by a high value of arithmetic average rainfall, a high maximum point rainfall and widespread occurrence of heavy rainfall. The number of storms selected were 20 of 1-day duration, 17 of 2-day duration, 6 of 3-day duration and 3 of 4-day duration. Out of these only 2 rainstorms were recorded in the month of June, 1 each in July and August, 2 in October and the rest 15 in September.

4. Depth-area-duration analysis of rainstorms

The depth-area-duration analysis of the rainstorms was carried out with rainstorm as a unit of study. It was seen that in majority of the cases the depth area curves exhibited the well known characteristics of a steep slope in the small area range and then becoming gradually flatter towards larger areas. The area covered by the rainstorms (area enclosed within the peripheral isohyets of 5 cm for 1-day storms) generally varied between 20,000 & 55,000 sq. km with two out of twenty cases having area less than 20,000 sq. km and one less than 10,000 sq. km.

Amongst depth area curves of 1-day duration, the curve of 11 September 1974 envelopes all other curves for the entire range of area except in respect of the central maximum point rainfall. For 2-day duration the curve of 5-6 October 1978 stands the highest. The envelope curves of 1 to 4-day durations have been drawn (Fig. 2) and maximum depth area statistics for standard areas upto 50,000 sq. km picked up from these curves are shown in Table 1.

From the envelope curves (Fig. 2) it is seen that there is a considerable difference in the magnitudes of enveloping rainfall depths for 1 and 2-day durations for the entire range of area. This difference decreases substantially from 2 to

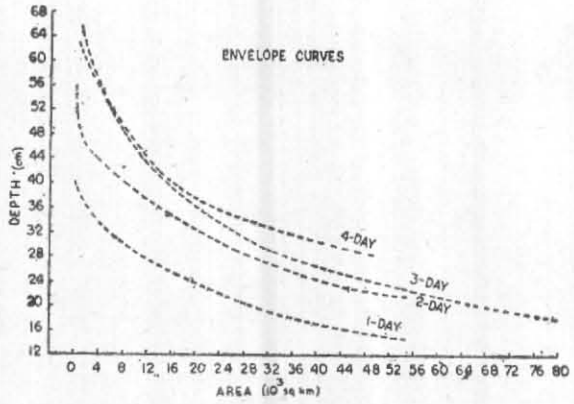

Fig. 2

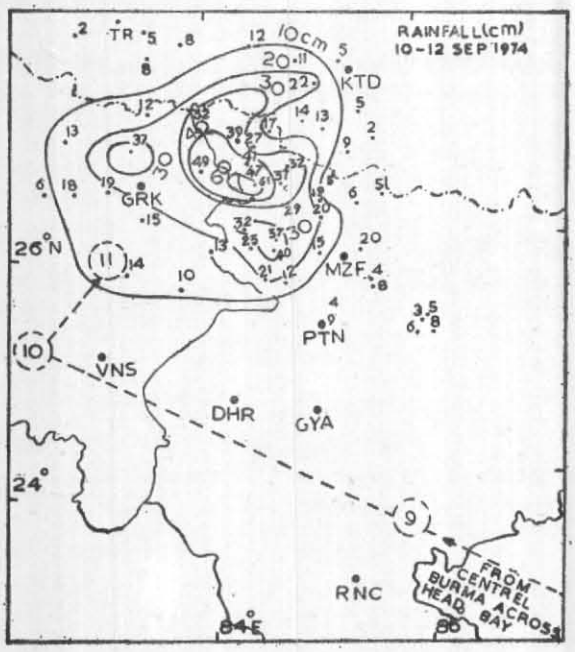

Fig. 3. Total storm isohyetal chart of 10-12 Sep 1974 & track of low pressure area, 9-11 Sep 1974

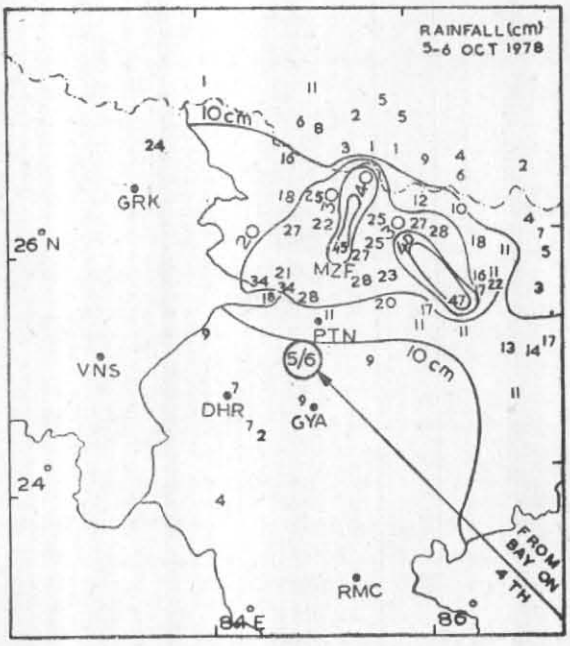

Fig. 4. Total storm isohyetal chart 5-6 Oct 1978 & track of depression, 4-6 Oct 1978

TABLE 1

Envelope rain depths for standard areas

Area (sq. km)	Average rain depths (cm)			
	1-day	2-day	3-day	4-day
Point	39.5	56.0	63.5	67.0
500	39.0	52.0	63.0	66.0
1,000	38.0	48.0	62.0	65.0
2,000	36.4	46.0	60.0	62.0
5,000	32.8	43.2	54.0	54.5
10,000	28.8	39.2	45.5	46.0
25,000	22.0	30.0	33.0	35.2
50,000	15.6	22.0	23.5	28.0

3-day and 3 to 4-day durations. The envelope curves of 3 and 4-day durations, in fact overlap each other for a certain extent of area in the smaller range thereby showing that in this region, heavy rain spells associated with monsoon disturbances are generally of three to four day duration only.

5. Isohyetal patterns of September 1974 and October 1978 rainstorms

The rainstorms of September 1974 and October 1978 were found to be the severemost in this region causing serious flooding in the *Burhi Gandak* and *Adhwara* group of rivers respectively. The total storm isohyetal patterns of the rainspells of 10 to 12 September 1974 and 5 to 6 October 1978 are shown in Figs. 3 and 4.

TABLE 2

Severe rainstorms and their distribution relative to locations and tracks of disturbances

S. No.	Rainstorm date	Location of heavy rain centre	Max. pt. rainfall at centre (cm)	Associated synoptic situations	Direction of movement*	Bearing (o) of the heavy rain centre†	Distance of heavy centre** (km)
1	18 Sep 1913	About 40 km west of Muzaffarpur	23	Low centred between Ranchi & Purulia	NW	30°	330
2	12 Sep 1915	About 40 km west of Raxaul	36	Low centred between Umaria & Satna	N	45°	520
3	8 Sep 1918	Near Patna	31	Depression near Hazaribagh	N	—10°	170
4	15 Sep 1921	About 65 km north of Balia	27	Low southwest of Dehri	WNW	70°	200
5	23 Jun 1922	About 55 km east of Motihari	17	Low southwest of Dehri	N	30°	270
6	18 Sep 1924	About 50 km east of Motihari	32	Low between Jamui & Dhanbad	NNW	50°	260
7	25 Sep 1926	Near Darbhanga	29	Low between Allahabad & Varanasi	ENE	40°	400
8	17 Sep 1930	About 50 km west of Raxaul	24	Low between Fatehpur & Faizabad	E	—20°	320
9	30 Sep 1942	About 40 km northeast of Darbhanga	40	Low north of Gaya	N	25°	200
10	16 Sep 1956	About 40 km west of Raxaul	29	Low west of Balia	ENE	—45°	265
11	1 Oct 1961	Between Jamui and Bhagalpur	16	Depression south of Daltonganj	NNE	—30°	330
12	2 Oct 1961	Between Gaya and Jamui	42	Depression close to Daltonganj	ENE	—15°	165
13	3 Oct 1961	Near Begusarai	37	Depression southwest of Gaya	ENE	—35°	140
14	23 Sep 1962	Near Monghyr	23	Depression near Purulia	NW	45°	280
15	28 Sep 1963	About 50 km northwest of Dhanbad	21	Depression between Chaibasa & Baripada	NNW	15°	240
16	20 Sep 1963	Near Begusarai	23	Depression near Hazaribagh to the southeast	NNW	25°	235
17	24 Sep 1965	About 75 km northeast of Gaya	42	Depression near Ambikapur	NE	0°	365
18	25 Sep 1965	Near Bhagalpur	35	Depression east of Gaya	NE	25°	165
19	30 Jul 1965	Near Raxaul	26	Depression near Gaya & Dhanbad	WNW	70°	260
20	20 Sep 1967	Near Patna	27	Low near Gaya	N	0°	110
21	21 Sep 1967	About 40 km northwest of Darbhanga	32	Depressoion near Patna	N	30°	140
22	18 Sep 1970	Near Motihari	18	Depression northwest of Ballia	NE	0°	115
23	10 Sep 1974	Near Motihari	20	Low between Hazaribagh & Dhanbad	WNW	50°	375
24	11 Sep 1974	About 85 km northeast of Motihari	39	Low between Allahabad & Varanasi	NE	0°	260
25	26 Sep 1975	About 85 km east of Gaya	27	Depression near Midnapur	NW	15°	330
26	27 Sep 1975	About 70 km south of Darbhanga	23	Depression between Gaya & Hazaribagh	WNW	95°	165
27	5 Oct 1978	Near Monghyr	23	Cyclonic storm between Contai & Calcutta	NNW	15°	400
28	6 Oct 1978	Near Sonbarsa on Indo-Nepal border	30	Depression north of Gaya	Stationary	—	240

*Movement of the disturbance during next 24 hours

†Bearing of the heavy rain centre with respect to the track of disturbance from previous date to the date of rainfall (—*ve* left of the track, +*ve* right of track)

**Distance of heavy rain centre is from the disturbance centre (on previous date)

The rainstorm of September 1974 had its central region in the plains of northwest Bihar and adjoining east Uttar Pradesh. It was caused in association with a low pressure area whose detailed account is given by Prasad (1977). This rainstorm was responsible for causing floods of an unprecedented magnitude in the *Burhi Gandak*, which surpassed the highest flood levels at some gauging sites and nearly touched at other sites.

The rainstorms of 5 and 6 October 1978 occurred in association with a deep depression which originated over Bay of Bengal and crossed the West Bengal coast as a cyclonic storm on the 4th and was centred over Bihar plains about 50 km southwest of Patna on 5th and 6th. The storm isohyets covered the central parts of plains of north Bihar with rainstorm centre near Sonbarsa in the Upper Adhwara sub-catchment. The *Adhwara* group of rivers experienced a high flood wave due to this rainstorm surpassing the highest flood level at Sonbarsa.

6. Rainstorm patterns relative to the tracks of disturbances

Most of the severe rainstorms occurring in the region were found to be associated with monsoon depressions/low pressure areas (two were, however, found to be associated with *"break"* monsoon situations). It was, therefore, decided to study day to day distribution of storm rainfall over this region with respect to tracks of disturbances and distance between heavy rain and pressure centres.

For this purpose the tracks of monsoon depressions/low pressure areas were superimposed on the 24 hours isohyetal charts. Then the distances of the heavy rainfall centres from the centre of the low pressure system on previous day and their bearings relative to the tracks of the disturbances during the preceding 24 hours were measured. The results are shown in Table 2.

It is seen that in the majority of cases the heavy rainfall centres lie ahead of the pressure systems and towards the right of their track. The bearings of the heavy rain centres with respect to the tracks range between *minus* 45 deg. to *plus* 95 deg. (*negative* sign for the centre on the left of the track and *positive* to the right). The distances of these centres from the centre of the pressure systems ranged between 110 and 520 km. A frequency classification of bearings and distances showed that the maximum number of cases were in the class interval of 0 to 20 deg. and 250 to 300 km respectively.

An interesting fact that emerged from the above study is that the rainstorms occurred to the right side of the track not only during N/NE movements of the disturbance but also during NW/WNW movement. This is in sharp contrast to the rainfall pattern commonly observed with depressions of mid monsoon months.

7. Conclusions

The investigation has revealed that majority of severe rainstorms over the plains region of the Ganga basin in north Bihar comprising of the catchments of the *Gandak*, the *Burhi Gandak*, the *Bagmati*, the *Adhwara* group and the *Kamala* occur in the month September. The occurrence in other months of monsoon season are only isolated. The rainstorms are mostly associated with monsoon depressions/low pressure area.

The study has further revealed that the heavy rainfall centres occurring in the above month lie mostly in front and to the right side of the track of the pressure systems. The bearings of the heavy rain centres relative to storm tracks range from *minus* 45 deg. to *plus* 95 deg. and the distances of these centres range between 110 and 520 km. These observations are of vital importance for flood forecasting and reservoir management.

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