Mausam, (1995), **46**, 2, 149-154

551.509.324.2

Semi-quantitative precipitation forecasts for river Pun Pun by synoptic analogue method

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(Received 4 January 1993, Modified 8 April 1994)

सार — समकालिक एनालॉग विधि के उपयोग से, पुन पुन नदी के लिए अर्ध-मात्रात्मक वर्षण पूर्वानुमान (क्यू० पी० एफ०) जारी करने का प्रयास किया गया है। बारह वर्षों (1982-93) के आँकड़ों के आधार पर किए गए अध्ययन से पता चलता है कि विश्वसनीय रूप से अर्ध-मात्रात्मक वर्षण पूर्वानुमान जारी करना संभव है। पुन पुन नदी में आनेवाली भीषण बाढ़, गंगा नदी के अवरोधक प्रभाव के कारण पटना नगर के लिए समस्याएं उत्पन्न करती रहती है।

ABSTRACT. An attempt has been made to issue semi-quantitative precipitation forecasts for river Pun Pun by synoptic analogue method. Based upon twelve years' data (1982-93) the study reveals that it is possible to issue semi-quantitative precipitation forecasts with confidence. The severe floods in the river Pun Pun pose problems to Patna town due to blocking effect of Ganga.

Key words — Synoptic, Catchment, Quantitative Precipitation Forecast (QPF), Mean rainfall, Frequency, Range, Seasonal trough, Homogeneous, Rainstorm, Vigorous, Active, Oscillation.

1. Introduction

Rao (1973) applied the synoptic method for a selected area in northeast India for a period of 1961 to 1967 and identified four types of synoptic systems. Abbi *et al.* (1979) studied the movement of cyclonic storms/depressions/monsoon troughs for a period of 1960-76 with respect to Bhagirathi catchment and prepared analogue maps depicting the associated rainfall distribution. Lal *et al.* (1983) studied different types of synoptic situations and correlated them with their resulting rainstorms over Gomati river catchment in Uttar Pradesh based upon data of 1976-80 and prepared synoptic analogues for forecast range of areal rainfall. In the present paper, attempts have been made to identify the different synoptic systems and their locations which are accountable for average areal precipitation between the ranges 11-25, 26-50, 51-100 mm during the southwest monsoon period in the Pun Pun river catchment. The catchment area is meteorologically homogeneous.

River Pun Pun rises in the Chhotanagpur plateau at an elevation of 300 m and meets Ganga near Fatwah about 25 km east of Patna. The river has a total length of about 200 km and catchment area is 8530 sq km. The river has a number of tributaries, important among them are the Batane, the Madar, the Morhar and the Dardha. All these rivers rise in the Chhotanagpur plateau and are seasonal. The river flows in northeasterly direction through Aurangabad, Gaya, Jehanabad and Patna districts. The Pun Pun circumvents the city of Patna from south and east and heavily spills in this region, part of its spills travels towards Mokamah Tal and joins Ganga downstream of Patna (Fig. 1).

The Pun Pun catchment has seven raingauges located at Aurangabad, Palmerganj, Sherghati, Makhdumpur, Sripalpur, Patna and Hariharganj and three gauge & discharge stations, *viz.*, Kinjer, Palmerganj and Sripalpur.

2. Method and data

In order to apply synoptic analogue technique over the Pun Pun catchment, the area, lying between the parallels of latitude 20°-28°N and longitude 80°-90°E, has been selected and divided into following six zones comprising of meteorological sub-divisions as shown in Fig. 2.

(1) 20-24°N, 85-90°E	Gangetic West Bengal and adjoining areas of northwest Bay, Orissa, Bihar plateau and Bangladesh.
(2) 20-24°N, 80-85°E	East Madhya Pradesh and adjoining areas of Bihar plateau and Orissa.

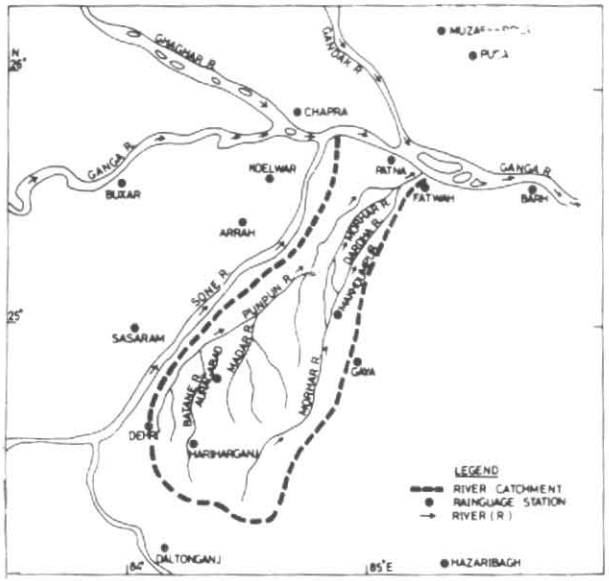

Fig. 1. Locater map of Pun Pun catchment

(3) 24-28°N, 80-84°E — East Uttar Pradesh and adjoining areas of east Madhya Pradesh.

(4) 26-28°N, 84-90°E — Bihar plains and adjoining areas of Sub-Himalayan West Bengal.

(5) 24-26°N, 86-90°E — Bihar plains and areas of Gangetic West Bengal.

(6) 24-26°N, 84-86°E — Bihar plains.

Zone (6) covers the entire area of the Pun Pun catchment.

Synoptic systems responsible for active/vigorous monsoon conditions over the Pun Pun catchment have been identified and given below according to priority:

S_1 Cyclonic storm/deep depression/depression/land depression.

S_2 Low/well marked low pressure area either forming over sea or land.

S_3 Upper air cyclonic circulations.

S_4 Monsoon trough at mean sea level (msl) or at 0.9 km above sea level (asl).

S_5 North-south trough in lower levels/superimposed westerly trough in mid-tropospheric/higher levels.

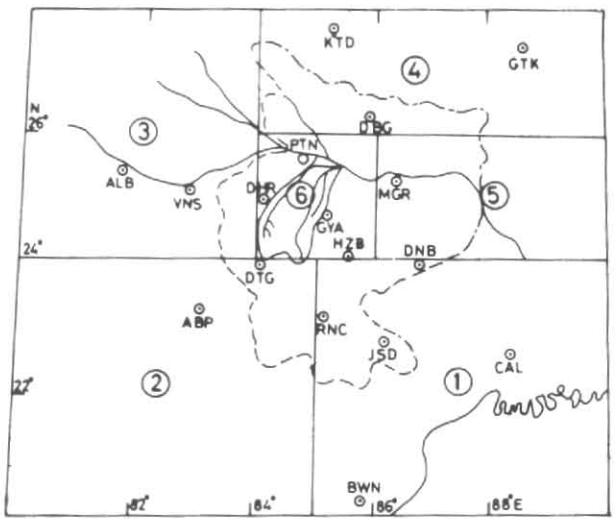

Fig. 2. Different zones in Pun Pun basin

According to the above classification the symbol $S_{2,2}$ stands for low pressure area over east Madhya Pradesh and adjoining areas of Bihar plateau or Orissa.

Flood meteorological work at Patna starts from 15 June every year. As such data under study have been used from 15 June to 30 September for the period 1982 to 1993. Synoptic situations based upon 0300 UTC, surface and 0000 UTC upper air charts responsible for the issue of quantitative precipitation forecasts between the ranges 11-25, 26-50, 51-100 and more than 100 mm and the realised average areal precipitation on the next day, have been collected datewise and monthwise. Also, those cases have been included where average areal precipitation was 2 cm or more, irrespective of the fact whether quantitative precipitation forecast was issued or not for the range 1-10 mm. All the values of average areal precipitation of the catchment have been collected against the particular synoptic condition situated in a particular zone monthwise and again weightage average rainfall have been calculated.

3. Results and discussion

Table 1 shows that synoptic code $S_{1,1}$ gave 20, 11, 9 and 4 mm rainfall in July, August, June and September respectively with frequencies 6, 24, 3 and 9 respectively. $S_{1,2}$ gave 43, 4 and 8 mm of rainfall in September, August and July respectively with frequencies 4, 8 and 3 respectively. $S_{1,6}$ gave 12 mm rainfall with frequency 3.

$S_{2,1}$ occurred 15, 31, 34 and 44 times in June, September, July and August respectively with mean

TABLE 1

Different synoptic situations with location, frequency and mean rainfall (mm) monthwise from June to September (1982-93)

Synoptic code	June		July		August		September	
	Frequency	Mean rainfall (mm)	Frequency	Mean rainfall (mm)	Frequency	Mean rainfall (mm)	Frequency	Mean rainfall (mm)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$S_{1,1}$	3	9.0	6	19.7	24	10.7	9	4.3
$S_{1,2}$	—	—	3	4.0	8	4.0	4	43.0
$S_{1,3}$	—	—	—	—	1	6.0	—	—
$S_{1,5}$	—	—	1	26.0	—	—	—	—
$S_{1,6}$	3	12.3	—	—	—	—	—	—
$S_{2,1}$	15	17.2	34	11.9	44	10.9	31	13.3
$S_{2,2}$	9	14.2	15	8.3	21	5.8	18	16.9
$S_{2,3}$	4	10.3	14	11.0	7	12.4	12	10.8
$S_{2,4}$	1	14.0	—	—	—	—	—	—
$S_{2,5}$	—	—	2	21.0	9	21.2	1	61.7
$S_{2,6}$	4	18.7	8	28.3	7	22.3	6	24.7
$S_{3,1}$	—	—	6	9.1	8	17.7	2	10.0
$S_{3,2}$	1	4.0	1	12.3	2	25.5	2	12.0
$S_{3,3}$	—	—	9	13.0	2	12.0	2	16.0
$S_{3,4}$	—	—	—	—	—	—	—	—
$S_{3,5}$	—	—	8	17.0	4	26.7	—	—
$S_{3,6}$	—	—	8	14.7	2	11.0	3	9.0
$S_{4,2}$	1	6.0	18	11.7	9	15.7	10	12.2
$S_{4,3}$	—	—	1	1.0	—	—	—	—
$S_{4,4}$	—	—	31	21.3	12	13.1	2	9.5
$S_{4,5}$	—	—	—	—	—	—	—	—
$S_{4,6}$	16	11.0	66	14.9	33	15.1	16	10.4
$S_{5,2}$	—	—	—	—	—	—	1	13.0
$S_{5,3}$	—	—	1	12.5	1	7.0	—	—
$S_{5,5}$	2	2.0	—	—	—	—	1	12.0
$S_{5,6}$	1	3.0	—	—	—	—	1	14.0

rainfall of 17, 13, 12 and 11 mm respectively. $S_{2,2}$ occurred 18, 9, 15 and 21 times in September, June, July and August respectively with mean rainfall of 17, 14, 8 and 6 mm respectively. $S_{2,6}$ occurred 8, 6, 7 and 4 times in July, September, August and June respectively with mean rainfall of 28, 25, 22 and 19 mm respectively.

$S_{3,1}$ occurred 8, 2 and 6 times in August, September and July respectively with mean rainfall of 18, 10 and 9 respectively. $S_{3,6}$ occurred 8, 2 and 3 times in July, August and September respectively with mean rainfall of 15, 11 and 9 mm respectively.

$S_{4,4}$ occurred 31, 12 and 2 times in July, August and September respectively with mean rainfall of 21, 13 and 10 mm respectively.

$S_{4,6}$ occurred 33 and 66 times in August and July respectively and 16 times each in June and September with mean rainfall of 15, 15, 11 and 10 mm respectively.

TABLE 2

AAP more than 50 mm in the catchment due to synoptic systems in a single day

Synoptic code	Year	Date	AAP > 50 mm
$S_{4,6}$	1986	27 June	68.9
$S_{2,1}$	do.	30 ,,	69.1
$S_{1,1}$	do.	1 July	84.0
$S_{4,4}$	do.	5 ,,	66.4
$S_{2,6}$	1987	6 ,,	51.0
$S_{4,4}$	1989	11 ,,	95.5
$S_{4,4}$	1990	27 ,,	60.1
$S_{4,6}$	do.	28 ,,	62.2
$S_{2,6}$	1985	21 August	51.1
$S_{4,6}$	1987	11 ,,	74.3
$S_{4,6}$	do.	12 ,,	56.2
$S_{2,5}$	1993	25 ,,	69.3
$S_{2,2}$	1987	10 September	59.4
$S_{1,2}$	do.	11 ,,	66.3
$S_{1,2}$	do.	12 ,,	94.1
$S_{2,6}$	1984	4 ,,	55.1
$S_{2,5}$	1993	15 ,,	61.7

$S_{5,6}$, $S_{5,2}$ and $S_{5,5}$ synoptic codes occurred once each in September with mean rainfall of 14, 13 and 12 mm respectively.

Table 3 shows that depressions (S_1) alone contributed 22% of the seasonal average areal precipitation in the catchment, low pressures (S_2) 28%, upper air cyclonic circulations (S_3) 18%, oscillation of seasonal trough (S_4) 18% and S_5 14%. The combined contribution of all the systems was 17, 27, 24 and 33% of the seasonal rainfall in June, July, August and September respectively.

Table 2 shows that the catchment received average areal precipitation of 5 cm or more on 17 occasions within twelve years and on three consecutive days in September 1987. Seven cases were due to oscillations of S_4 towards north from normal position, three due to S_1 and seven due to S_2. All the above systems were responsible for active monsoon condition in the catchment and there were heavy downpours on 11 July 1989 and the catchment received highest average areal precipitation of 95.5 mm. Again, on 12 September 1987, the catchment received 94.1 mm rainfall. In the first case, it was due to $S_{4,4}$ and in the second due to $S_{1,2}$. Such occasions occurred due to active monsoon conditions in the catchment and 1986 & 1987 were the favourable monsoon years.

TABLE 3

Amount of average areal precipitation (mm) and percentage in the catchment by different synoptic systems monthwise (1982-93)

Synoptic system	June	July	August	September	Total
Depression (S_1)	10.6	16.6	6.8	23.6	57.6
	(6)	(10)	(33)	(13)	(22%)
Low pressure (S_2)	14.9	16.1	14.5	25.5	71.0
	(33)	(73)	(88)	(68)	(28%)
Upper air cyclonic circulations (S_3)	4.0	13.2	18.6	11.7	47.5
	(1)	(32)	(18)	(9)	(18%)
Seasonal trough (S_4)	8.5	12.2	14.6	10.7	46.0
	(17)	(116)	(54)	(28)	(18%)
North-south trough/mid & upper air westerly trough (S_5)	2.5	12.5	7.0	13.0	35.0
	(3)	(1)	(1)	(3)	(14%)
Total	40.5	70.6	61.5	84.5	257.1
	(17%)	(27%)	(23%)	(33%)	

N.B. Monthwise frequencies are given in brackets.

TABLE 4 (a)

Frequency of different synoptic systems which contributed AAP between the ranges 11-25 & 26-50 mm

Synoptic code	June		July		August		September	
	11-25 mm	26-50 mm	11-25 mm	26-50 mm	11-25 mm	26-50 mm	11-25 mm	26-50 mm
$S_{1,1}$	1	—	1	—	9	1	1	—
$S_{1,2}$	—	—	—	—	1	—	1	—
$S_{1,5}$	—	—	—	1	—	—	—	—
$S_{1,6}$	3	—	—	—	—	—	—	—
$S_{2,1}$	5	2	11	5	11	6	9	5
$S_{2,2}$	1	2	6	—	4	—	10	3
$S_{2,3}$	2	—	3	1	2	1	6	1
$S_{2,4}$	1	—	—	—	—	—	—	—
$S_{2,5}$	—	—	1	1	5	1	—	—
$S_{2,6}$	2	1	4	2	3	2	1	2
$S_{3,1}$	—	—	2	—	4	1	1	—
$S_{3,2}$	—	—	1	—	1	1	1	—
$S_{3,3}$	—	—	3	2	1	—	—	—
$S_{3,4}$	—	—	—	—	—	—	—	—
$S_{3,5}$	—	—	4	1	—	1	—	—
$S_{3,6}$	—	—	4	1	1	—	1	—
$S_{4,2}$	—	—	9	1	1	1	3	2
$S_{4,4}$	—	—	18	2	4	2	1	—
$S_{4,6}$	5	1	24	8	17	1	7	2
$S_{5,2}$	—	—	—	—	—	—	1	—
$S_{5,3}$	—	—	1	—	—	—	—	—
$S_{5,6}$	—	—	—	—	—	—	1	—

Table 4(a) shows the frequencies of different synoptic systems that were responsible for Areal Average Precipitation (AAP) between 11-25 and 26-50 mm. The frequencies of $S_{1,1}$ were 1, 1, 9 and 1 in June, July, August and September respectively between 11-25 mm. $S_{1,1}$ occurred once between 26-50 mm in August. $S_{1,6}$ occurred 3 times in June between 11-25 mm.

$S_{2,1}$ occurred 5, 11, 11 and 9 times in June, July, August and September respectively between 11-25 mm. It occurred 2, 5, 6 and 5 times in June, July, August and September respectively between 26-50 mm. $S_{2,6}$ occurred 2, 4, 3 and 1 time in June, July, August and September respectively between 11-25 mm. It occurred 1 and 2 times each in June, July, August and September respectively between 26-50 mm.

$S_{3,6}$ occurred 4, and 1 time each in July, August and September respectively between 11-25 mm and 1 time in July between 26-50 mm.

$S_{4,6}$ occurred 5, 24, 17 and 17 times in June, July, August and September respectively between 11-25 mm. It occurred 1, 8, 1 and 2 times in June, July, August and September respectively between 26-50 mm.

The results so derived were verified during 1992 flood season for each rainstorm with actual average areal rainfall of 10mm or more and the results are shown in Table 4(a). Out of 21 such cases, three cases were out by one stage, one case on 6 August 1992 was out by more than two stages on three occasions. Quantitative Precipitation Forecasts (QPF) were not issued due to the below warning levels of the river and the actual rainfall matched well with the QPF range based on synoptic analogues in 14 cases. Results can be improved if one or two upper stations are opened in north Bihar.

The study by synoptic analogue technique of the Pun Pun catchment reveals that it is possible to issue semi-QPF with confidence by locating main synoptic systems in different zones in and around the catchment areas for the day-to-day operational requirements are shown in Table 4 (b).

The month of August witnessed the maximum number of low pressure areas on sea level charts

TABLE 4 (b)

Verification of synoptic analogues of QPF for Pun Pun catchment during 1992 flood season

S. No.	Date	Actual average areal rainfall (mm)	Associated synoptic systems zonewise	QPF issued
1.	27 June	32	$S_{4,6}$	—
2.	27 „	15	$S_{3,5}$	—
3.	10 July	17	$S_{2,6}$	01-10
4.	11 „	21	$S_{2,3}$	11-25
5.	12 „	11	$S_{2,3}$	11-25
6.	15 „	10	$S_{4,6}$	01-10
7.	16 „	12	$S_{5,3}$	11-25
8.	20 „	24	$S_{3,5}$	01-10
9.	21 „	10	$S_{2,5}$	01-10
10.	22 „	10	$S_{3,2}$	01-10
11.	24 „	17	$S_{3,5}$	11-25
12.	25 „	25	$S_{2,1}$	11-25
13.	26 „	11	$S_{1,1}$	11-25
14.	6 August	57	$S_{3,5}$	01-10
15.	7 „	19	$S_{3,3}$	11-25
16.	9 „	11	$S_{4,6}$	11-25
17.	25 „	30	$S_{5,3}$	—
18.	26 „	46	$S_{3,2}$	11-25
19.	27 „	12	$S_{2,1}$	11-25
20.	11 September	17	$S_{2,2}$	11-25
21.	27 „	22	$S_{2,1}$	11-25

affecting the catchment. Then comes July, September and June respectively contributing 28% of the seasonal rainfall in the catchment. Semi-QPF can be issued safely between 1 to 3 cm of rainfall especially under influence of those systems when associated upper air cyclonic circulations are 6 km and above.

S_1 type weather occurs maximum number of times in August but contributes maximum areal average precipitation in September with seasonal contribution of 22%. The monsoon is in retreating phase in September and it gives maximum rainfall in the catchment and semi-QPF can be issued between 11-25 mm in June, July and August and in September between 26-50 mm in majority of cases specially when recurvatures take place.

S_3 system contributes 18% of the seasonal average areal precipitation and occurs maximum in July and then in August and September. QPF can be issued between the range of 11-25 mm if the system is located in central Bihar on the catchment and upper air cyclonic circulations are beyond 6 km asl.

S_4 system, due to its oscillations from normal position, contributes 18% of seasonal average areal precipitation in the catchment and maximum oscillations take place in July and next in August. QPF can be issued in the range of 11-25 mm in majority of the cases, when the oscillation takes place in the northern side from normal position or during break monsoon condition when the monsoon trough is very close to foothills of the Himalayas.

S_6 contributes 14% of seasonal average areal precipitation in the range of 11-25 mm QPF can be issued during July, August and September.

There are occasions when average areal precipitation exceeds 5 cm. Such occasions occur due to active/vigorous monsoon conditions in the catchment created either by well-marked low pressures over or very close to the catchment or due to presence of S_1 over or very close to catchment and its recurvature specially in September. These also occur due to oscillation of seasonal trough in the catchment or north of the catchment from normal position and very close to foothills during break situation, and also during superimposed upper air monsoon trough and in such cases semi-QPF can be issued between the range 51-100 mm safely.

Acknowledgement

The authors are grateful to Shri P.K. Mishra, Dy. Director General of Meteorology, Regional Meteorological Centre, Calcutta and Shri J. Lal, DDGM (Hydrometeorology), New Delhi for encouragement and thankful to Shri A. Prasad of Meteorological Centre, Patna for typing the manuscript.

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