Mausam, (1994), **45**, 1, 87-98

Letters to the Editor

551.509.314 : 551.577.21

APPLICATION OF A STATISTICAL SYNOPTIC METHOD FOR QPF FOR NARMADA AND TAPI BASINS

1. In this study an attempt has been made to formulate a statistical synoptic method for issuing QPF, using contingency table in respect of Narmada and Tapi basins. Lahiri (1979) and Basu & Khamrui (1989) studied heavy rain and floods using contingency tables in respect of other basins. QPF refers to the quantity of rainfall expected at a point in a catchment during the specific duration, say, 24 hours or 48 hours. Abbi *et al.* (1970, 1971 and 1972) have studied some hydrological aspects of Narmada and Tapi basins.

Narmada catchment experiences a mean annual rainfall of about 123 cm of which about 90% is recorded during the southwest monsoon season (June to September). Tapi catchment receives an average of 81 cm of annual rainfall of which as much as 86% is contributed by the southwest monsoon.

2. The data of four months of principal flood season, June to September, for the period 1983 to 1989, have been used. The weighted average rainfall has been derived by Thiessen Polygon method with all available stations. For the present study, the Narmada basin is divided into three regions, upper, middle and lower sub-basins shown in Fig. 1 (a). Similarly, Tapi catchment is divided into two regions, upper and lower sub-basins shown in Fig. 1 (b). The storms with 15 mm or more of Weighted Average Rainfall (WAR) have only been considered. Synoptic systems which are primarily responsible for rainfall over Narmada and Tapi basins were identified from *Indian Daily Weather Reports* (*IDWR*) and from analysed weather charts.

3. The synoptic situations which are responsible for significant rainfall over Narmada and Tapi basins were identified. They can be mainly categorised into five classes given below :

(A) Low pressure area/depression over northwest Bay and adjoining Orissa.

(B) Low pressure area/depression over east Madhya Pradesh and adjoining Vidharbha/Orissa.

(C) Low pressure area/depression over west Madhya Pradesh.

(D) Low pressure area/depression over northwest Madhya Pradesh and adjoining southeast Rajasthan and Gujarat region.

(E) Low pressure area/upper air cyclonic circulation over Gujarat/Saurashtra/Kutch/the trough of low pressure on sea level chart off Gujarat coast.

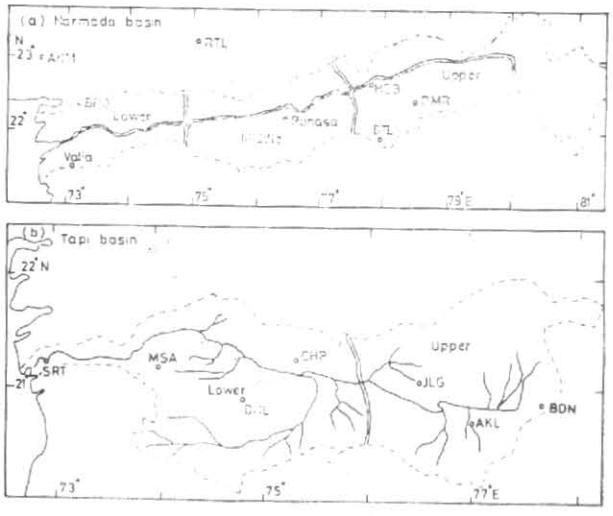
In this connection it may be stated that the role of Arabian Sea current cannot be ruled out for the low pressure area/depression moving west/westnorthwestwards. Because of this current, at times, systems get strengthened and cause intense rainfall over this area.

The WAR values are categorised into three different classes, namely, 15-25, 26-50 and more than 50 mm. Frequency of weighted average rainfall in different categories of synoptic weather situations are arranged into 3×5 contingency table (Table 1). From this table it can be seen that in Narmada and Tapi basins most preferred synoptic situation for high intensity precipitation is low pressure area/depression over east M.P. and adjoining area. When depression is over east M.P. and Vidarbha and moving in a west/westnorthwestwards causes widespread, high intensity rainfall in the southwest sector about two to three degree away. A second rainfall belt often develops outside the depression field to the west fairly distinct from the southwest sector, due to convergence between northwest, northeasterly flow around the depression and westerly to the south in the lower troposphere. Dubey and Balakrishnan (1992) found that depression/low pressure area over east M.P. and adjoining area contributes maximum intensity and frequency of heavy rainfall over central M.P. The synoptic situations D and E, *i.e.*, the low pressure over Gujarat region, trough over sea level chart along west coast and low pressure area over northwest M.P. adjoining southeast Rajasthan do not contribute rainfall more than 50 mm over Narmada basin, but only over Tapi upper sub-basin. Table 2 shows mean WAR and standard deviation with different categories of synoptic situations.

To measure the intensity of association for the particular synoptic situation, we calculated the Yule's coefficient and Tschuprow's coefficients by reducing the original contingency table into a number of 2×2 contingency tables. Yule's coefficient of association for 2×2 contingency table is given by :

$$Y = \frac{A_{11} A_{22} - A_{21} A_{12}}{A_{11} A_{22} + A_{21} A_{12}}$$

where, A_{ij} is the frequency of rainfall in ith range and jth synoptic situation. For further details, Basu and Khamrui (1989) may be referred to.



Figs. 1 (a & b). (a) Narmada and (b) Tapi basin

TABLE 1

Frequency of weighted average rainfall in different categories of synoptic weather situations over Narmada and Tapi basins during the seven-year period (1983-1989)

Range (mm)	A	B	C	D	E	Total
			(a) **Upper Narmada basin**			
15-25	9	11	6	5	5	36
26-50	1	7	4	1	4	17
⩾51	4	10	0	0	0	14
Total	14	28	10	6	9	67
			(b) **Middle Narmada basin**			
15-25	3	7	2	2	5	19
26-50	2	12	4	3	3	24
⩾51	1	8	3	0	0	12
Total	6	27	9	5	8	55
			(c) **Lower Narmada basin**			
15-25	3	5	5	6	4	23
26-50	2	9	2	3	7	23
⩾51	0	2	2	0	0	4
Total	5	16	9	9	11	50
			(d) **Upper Tapi basin**			
15-25	4	11	3	2	4	24
26-50	3	9	5	3	5	25
⩾51	0	2	0	0	0	2
Total	7	22	8	5	9	51
			(e) **Lower Tapi basin**			
15-25	2	4	4	4	13	27
26-50	1	4	4	2	5	18
⩾51	1	3	1	1	3	9
Total	4	11	9	7	21	54

The study reveals the following facts in respect of Narmada and Tapi basins :

(a) *Lower Narmada basin* — The WAR ranges greater than 50mm, 26-50 mm and 15-25 mm have the highest association of 91%, 33% and 36% for the categories B, E, and D respectively.

(b) *Middle Narmada basin* — The WAR ranges greater than 50 mm, 26-50 mm and 15-25 mm have got highest association of 47%, 15% and 48% in C, D and E categories respectively.

(c) *Upper Narmada basin* — The WAR ranges greater than 50 mm, 26-50 mm and 15-25 mm have the highest association of 59%, 57% and 47% in B, E and D categories respectively.

(d) In lower Tapi basin the WAR ranges greater than 50 mm, 26-50 mm and 15-25 mm have got the highest association of 55%, 40% and 38% in A,C and E categories respectively.

(e) Similarly, in upper Tapi basin for same ranges the corresponding values are 61%, 17% and 10% in B, C and B categories respectively.

Probability of association of WAR ranges of 15-25 mm and 51 mm or more in upper Narmada basin is 95% or more for category B synoptic systems. In lower Narmada basin the similar association is existing for range 51 mm or more in categories B and C systems.

4. The chances of occurrence or non-occurrence of of the particular category of rainfall ranges due to the corresponding category of synoptic situation can be decided using Table 1 and Yule's coefficient of association. The actual rainfall category can be decided by using Table 2 for each sub-basins. The synoptic statistical method was developed and tested for issuing QPF in case of monsoon seasons 1990 and 1991 and the method displayed fairly good accuracy. The results are shown in Table 3.

5. The following conclusions can be drawn from this study :

(*i*) The significant rainfall over Narmada and Tapi basins is caused mainly due to the low pressure systems forming over northwest Bay and moving westnorthwestwards across the basins.

(*ii*) Frequencies of occurrence of rainfall category more than 50 mm is more over Narmada basins than Tapi basins.

(*iii*) In upper, lower and middle Narmada basins the WAR range greater than 50 mm is highest for category B, *i.e.*, Low pressure area/depression situated over east Madhya Pradesh and adjoining areas with associated upper air cyclonic circulation extending up to middle tropospheric level.

TABLE 2

Mean WAR and standard deviation with different categories of synoptic situations

Synoptic features	24 hours rainfall (mm) Upper sub-basin Mean/SD ($\bar{X}$ / σ)	Middle sub-basin Mean/SD ($\bar{X}$ / σ)	Lower sub-basin Mean/SD ($\bar{X}$ / σ)	Range for 24 hours QPF for the concerned sub-basin considering positive side of ($\bar{X} + 2\sigma$) Upper	Middle	Lower
			(a) Narmada basin			
A	35.7/6.2	29.3/7.3	26.8/4.8	26-50	26–50	26-50
B	48.9/7.1	44.7/3.9	38.5/5.7	⩾51	⩾51	26-50
C	24.2/2.3	43.0/4.1	45.5/12.9	26-50	⩾51	⩾51
D	21.7/1.6	23.5/2.1	20.9/2.3	11-25	26-50	11-25
E	28.8/3.7	25.9/3.8	30.9/2.6	26-50	26-50	26-50
			(b) Tapi basin			
A	27.9/3.4		35.7/7.6	26-50		⩾51
B	30.2/3.4		37.4/5.8	26-50		26-50
C	27.2/1.9		33.1/6.3	26-50		26-50
D	38.7/12.1		27.6/4.8	⩾51		26-50
E	29.0/2.9		32.1/5.0	26-50		26-50

TABLE 3

Verification of QPF issued for Narmada and Tapi basins during monsoon season 1990 and 1991

Realised rainfall category (mm)	Forecast rainfall category 11-25 (mm)	26-50 (mm)	⩾50 (mm)
11-25	22	14	2
26-50		45	5
>50		**15**	**8**
Total	22	74	15

(*iv*) In lower and upper Tapi basins the WAR range greater than 50 mm is highest for categories A and B, *i.e.*, low pressure area/depression over northwest Bay and adjoining Orissa and low pressure area/depression over east Madhya Pradesh respectively.

(*v*) Verification of quantitative precipitation forecast issued for the monsoon seasons, 1990 and 1991 showed fairly good accuracy of the method.

It is necessary to update the present study using data of some more years to make the results more valid.

6. The authors are grateful to Shri S. P. Saxena, Director, Meteorological Centre, Ahmedabad for his constant encouragement and guidance. Useful suggestions and help from Shri G.K. Kapoor, Meteorologist Gr. I and Sh. R. C. Gupta, Meteorologist Gr. II are thankfully acknowledged.

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4 April 1991, Modified 9 July 1993