551.509.324.2 : 556.51

SEMI - QUANTITATIVE PRECIPITATION FORECAST FOR MIDDLE GANGA SUB - CATCHMENT BY SYNOPTIC ANALOGUE METHOD

1. Flood Meteorological Offices (FMOs) are established to provide meteorological support to Central Flood Forecasting Division (CFFDs) of Central Water Commission (CWC). In addition to the surface and upper air weather charts, FMOs prepare the rainfall analysis charts for catchments and sub-catchments as the case may be on map-scale 1 cm = 10 kms.

The technique of synoptic analogue is the most convenient method from the view of day-to-day operational forecasting. The dominant factor in forecasting qualitative precipitation amount is the synoptic meteorological situation. The Quantitative Precipitation Forecast (QPF), required for the determination of run-off, floods is, however, difficult for small catchment's areas by evaluating vertical velocity and moisture distribution in the upper atmosphere. Abbi *et al*. (1979) identified the movements of cyclonic storms/depressions 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 Gomti Catchment and prepared synoptic analogue of forecast range of real rainfall. Ram and Pangasa *et al*. (1999) attempted to predict quantitative rainfall in Ghaghara catchment by utilizing synoptic situations prevailing over Uttar Pradesh and neighbouring areas and rainfall data for the south-west monsoon period from 1991-98. Statement showing by Middle Ganga Division-II, Central Water Commission Lucknow in "Flood Appraisal Report, Monsoon season-2006". The details of maximum river level in meters at all forecasting site of river Middle Ganga (Gauge point Narora to Dalmau) (Table 1).

A method to issue semi-quantitative precipitation forecast for Middle Ganga (Narora to Dalmau) catchment by synoptic analogue method has been discussed based on analysis of rainfall data of monsoon for 12 years data (1994 to 2005) and the results were cross checked with the realized Average Areal Precipitation (AAP) of 2006 & 2007 flood season.

2. The river Ganga has its source from Gomukh near Gangotri which is at the elevation of 7010 meters from the top of middle Himalayas, where it is known as Bhagirathi. The River Alaknanda originates near the indo-Tibet border at the height of 7800 meters. Both the rivers Bhagirathi and Alaknanda meet at Dev Prayag, which is

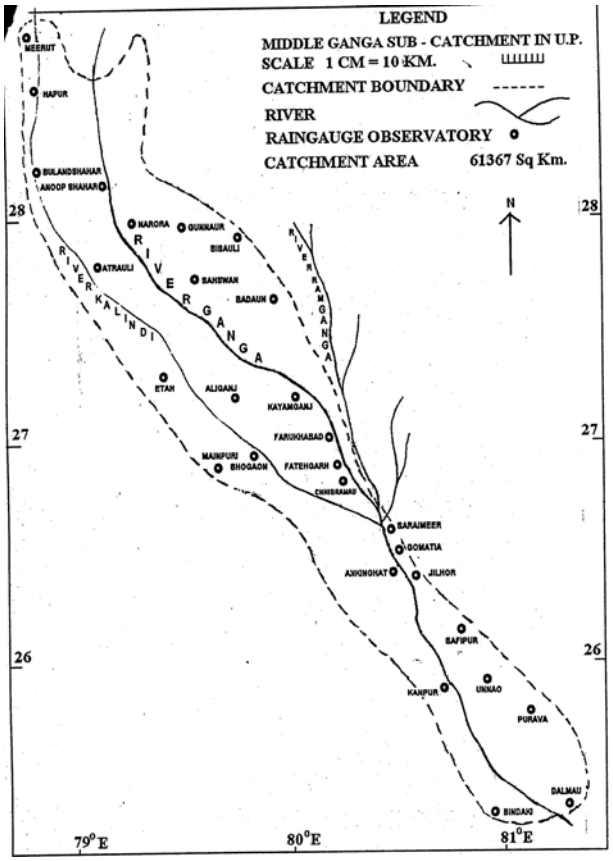

Fig. 1. Middle Ganga sub-catchment in U.P.

95 kms. Before Hardwar, and from that point, it is known as Ganga. On the upper level, two tributaries *viz*., Janhavi and Bhilangana near Tehri, supply water to Bhagirathi where as three tributaries *viz*., Dhauli Ganga, Pindar and Mandakini supply water to Alaknanda.

The main tributaries of Ganga are, form north – Ram Ganga, Gomti, Ghaghara, Gandak, Boorhi Gandak, Kosi & Mahananda and from south are Yamuna, Tonse and Sone. The total length of Ganga is 2525 kms. The catchments area of Ganga is 8.61 Laces Sq kms which is includes Uttrakhand, Uttar Pradesh, Himanchal Pradesh, Haryana, Rajasthan, Madhya Pradesh, Bihar, West Bengal & Delhi. Flowing south-east wards through Narora, Fatehgarh, Ankinghat, Kanpur, Dalmau (Raebareli), it reaches Allahabad where its tributary Yamuna meets at Prayag (Sangam) at 2 kms. Upstream from Allahabad.

3. The two important parameters here are the synoptic situation and the corresponding average areal precipitation. The cases, which resulted in AAP of 10.5 mm (Rounded to 11 mm) and above only during the flood

TABLE 1

Details of all gauge sites of river Middle Ganga for flood forecasting purposes

Name of River/Site	District in which situated	Catchment area in sq km	Co-ordinate		Type of site	River length in km	Danger Level (m)	H.F.L/Year (m)
Middle Ganga			Latitude	Longitude				
1	2	3	4	5	6	7	8	9
Narora	Bulandshahar	32162	28°32′ 00N	78°16′ 00E	G(Gauge)	455	178.200	179.340/1998
Fatehgarh	Farukhabad	40096	27°24′ 00N	79°38′ 00E	GDSQ	630	138.600	138.060/1972
Ankinghat	Kanpur Dehat	82209	26°55′ 00N	80°05′ 00E	GDSQ	705	124.000	124.305/1978
Kanpur	Kanpur	87650	26°28′ 00N	80°23′ 00E	GDSQ	770	114.00	113.465/1967
Dalmau	Raibareli	91076	26°03′ 00N	81° 02′ 00E	G(Gauge)	865	99.360	99.840/1973

TABLE 2

Synoptic situation and rainstorm of total monsoon period affecting Middle Ganga (Narora to Dalmau) catchment during 1994 to 2005 flood season/month

Type of synoptic situation	Range of AAP (mm)	No. of rain storms along with their probabilities in month					Total no. during flood season (probability)
		June	July	August	September	October	
A	11-25	-	1(100%)	-	-	-	1(100%)
	26-50	-	-	-	-	-	-
	51-100	-	-	-	-	-	-
B	11-25	-	2(100%)	-	(100%)		3(100%)
	26-50	-	-	-	-	-	-
	51-100	-	-	-	-	-	-
C	11-25	8(100%)	12(80%)	18(82%)	14(67%)	1(100%)	53(79%)
	26-50	-	3(20%)	4(18%)	7(33%)	-	14 (21%)
	51-100	-	-	-	-	-	-
D	11-25	10(90%)	18(95%)	29(100%)	13(100%)	-	70(97%)
	26-50	1(90%)	1(5%)	-	-	-	2(3%)
	51-100	-	-	-	-	-	-
E^1	11-25	3(100%)	13(100)	22(100%)	11(100%)	2(100%)	51(100%)
E^2	26-50	1(100%)	3(100%)	3(100%)	5(100%)	-	12(100%)
E^3	51-100	-	1(100%)	-	-	-	1(100%)
F	11-25	1(100%)	8(100%)	-	1(100%)	-	10(100%)
	26-50	-	-	-	-	-	-
	51-100	-	-	-	-	-	-
G	11-25	-	6(67%)	5(83%)	-	-	11(73%)
	26-50	-	3(33%)	1(17%)	-	-	4(27%)
	51-100	-	-	-	-	-	-
H	11-25	-	-	1(100%)	1(100%)	-	2(100%)
	26-50	-	-	-	-	-	-
	51-100	-	-	-	-	-	-

season for the year 1994 to 2005 have been used. The available 18 stations rainfall data of departmental and State rain gauge, *viz*., Meerut, Hapur, Anoop Shahar, Narora, Atrauli, Sahaswan, Etah (T), Etah (C), Farukhabad, Fatehgarh, Mainpuri**,** Gumatia, Ankinghat, Safipur, Kanpur (IAF), Unnao, Dalmau distributed over the catchment, area as shown Fig. 1 have been used for determination of average areal rainfall over the catchment which has been derived by the method of arithmetic means to the catchment under study. The cases in which

TABLE 3

Testing of synoptic analogue of QPF for Middle Ganga catchment for 2006 monsoon season

S. No.	Date	Synoptic situation (Type)	QPF range as per analogue (mm)	AAP (mm)	Verification	
					Correct	Out by one stage over/under estimation
1	29 June 2006	E^1	11-25	18	Yes	-
2	09 July 2006	C	26-50	36	Yes	-
3	10 July 2006	G	11-25	20	Yes	-
4	15 July 2006	D	11-25	21	Yes	-
5	19 July 2006	F	11-25	12	Yes	-
6	20 July 2006	D	26-50	13	-	Over
7	27 July 2006	E^3+G	51-100	60	Yes	-
8	23 August 2006	G	26-50	14	-	Over
9	02 September 2006	D	26-50	20	-	Over
10	03 September 2006	E^1	11-25	20	Yes	-
11	05 September 2006	E^1	11-25	11	Yes	-

Percentage of correct forecast = (8/11) × 100 = 73%

AAP was lower than 10.5 mm are neglected, since during monsoon, light rainfall can occur on any day even without significant synoptic system in this reason.

For synoptic situation corresponding to rain storms, the daily weathers charts available in the Meteorological Centre, Lucknow have been utilized after plotting of important missing data where-ever necessary. It is observed that weather systems within a range of about 500 kms from the central area of the catchments contribute appreciably to the average rainfall over the catchments and the systems beyond that range have very little effect. As such the synoptic situations have been identified accordingly. Generally the rain storms greater than 11 mm leads to floods in the catchment. The rainfall amount for higher ranges of rainfall *viz*., 11-25 mm, 26-50 mm, 51-100 mm and more than 100 mm have been considered for matching with different categories of synoptic situations.

3.1. The synoptic situations which gave average rainfall over the catchment are classified into following categories:

A. A low pressure area/upper air cyclonic circulation located out side the catchments over Gangetic West Bengal.

B. A low pressure area/upper air cyclonic circulation located out side the catchment over Bihar planes and adjoining areas.

C. A low pressure area/upper air cyclonic circulation located out side the catchment over South Uttar Pradesh and North Madhya Pradesh.

D. A low pressure area/upper air cyclonic circulation located near and moving towards the catchment.

E^1. An upper air cyclonic circulation (CYCER) located over the catchment.

E^2. A low pressure area (LOPAR) located over the catchment.

E^3. A well marked LOPAR/DEPRESSION located over the catchment.

F. An elongated axis of monsoon trough with embedded upper air cyclonic circulation south of the catchment.

G. An elongated axis of monsoon trough with embedded upper air cyclonic circulation passing through the catchment.

H. An elongated active monsoon trough with embedded upper air cyclonic circulation, close to the foot of Himalayas.

TABLE 4

Testing of synoptic analogue of QPF for Middle Ganga catchment for 2007 monsoon season

S. No.	Date	Synoptic situation (Type)	QPF range as per analogue (mm)	AAP (mm)	Verification	
					Correct	Out by one stage Over/Under Estimation
1	08 July 2007	B	11-25	11	Yes	-
2	17 July 2007	B	11-25	20	Yes	-
3	18 July 2007	D	11-25	25	Yes	-
4	25 July 2007	E^1	11-25	12	Yes	-
5	27 July 2007	E^2	26-50	43	Yes	-
6	28 July 2007	E^3	26-50	52	-	Under
7	02 August 2007	D	11-25	20	Yes	-
8	03 August 2007	D	11-25	20	Yes	-
9	15 August 2007	H	11-25	14	Yes	-
10	29 August 2007	C	11-25	11	Yes	-

Percentage of correct forecast = (9/10) × 100 = 90%

4. The total no 236 rain storms have been issued over the catchment with AAP falling in 11-25 mm and higher ranges and no rainstorm of rainfall >100 mm observed during the period under consideration.

4.1. The detail analysis of synoptic situation and no of corresponding rainstorms in different months and flood season along with probabilities are given in Table 2.

4.1.1. The synoptic situation A, B, F, G & H when the low pressure area / upper air cyclonic circulation lies outside the catchment and monsoon trough lies near or passes through the catchment, AAP is mostly the range of 11-25 mm.

4.1.2. The synoptic situation C, D & E when the low pressure area/upper air cyclonic circulation is either over or near the catchment, AAP is observed in all the three ranges 11-25 mm, 26-50 mm & 51-100 mm. Generally the forecast is given corresponding to maximum probability.

4.1.3. The middle Ganga sub catchment received AAP in the range of 11-25 mm, 26-50 mm & 51-100 mm on 201 (85.2%), 32 (13.5%) and 3 (1.3%) occasions respectively. This shows that the middle Ganga sub catchment generally receives rainfall in the range of 11-25 mm & occasionally gets very heavy rainfall in the range of 51-100 mm which is associated with strong systems near or over the catchment.

4.2. The analysis has been verified for the year 2006 & 2007 flood season, the results are given in the Tables 3 & 4 respectively. It is mentioned here that no QPF was issued during flood season 2006 as the river was flowing well below danger level and no flood alert was issued at any of the gauge points. During flood season 2007, the river was under flood alert *w.e.f.* 08 August 2007 to 31 August 2007 & 06 September 2007 to 13 September 2007 and QPF was issued as NR (No Rain), 01-10 mm & 11-25 mm at some gauge points. The realization of the same was NR, 01-10 mm on some days. Therefore, these scales are not considered in synoptic analogue, only 11-25 & above are considered in the synoptic analogue. It has been observed that QPF forecast based on only analogues gives 73% & 90% correct forecast for the year 2006 & 2007 respectively. For better results, the forecaster has to use his experience and detailed analysis of synoptic situation in addition to analogues for forecasting QPF.

5. The above study concludes that the synoptic systems which are far away from the river catchment generally produce rainfall in lower range of 11-25 mm. The system likes low pressure area/upper air cyclonic circulation located over the catchments area and neighborhood, located near or moving towards the catchments area and neighborhood and active monsoon trough over the catchment area with a tendency to move towards North produces the rainfall generally in the higher ranges. Thus on the basis of this study the synoptic

analogue technique is fairly accurate in issuing quantitative precipitation forecast by the forecaster in 24 hours advance for middle Ganga catchment. Further if a careful watch is kept on the weather situation and the more frequent observation or collect for during the movement of low pressure area/cyclonic circulation a reasonable success can be achieved by the forecaster in issue of an advance warning show necessary for flood disaster preparedness and mitigation. Considering the various hazardness aspects of floods it is imperative to issued the advance flood warning for various flood affected towns and agricultural field in order to provide timely relief and rescue operations to the flood victim.

6. The authors are thankful to Dr. O. P. Singh, Scientist "F' & DDGM RMC New Delhi, Dr. (Mrs.) S. Kaur Scientist "F' for encouragement and also thankful to FMO staff and Shri Bikram Sen S.A. & Shri Ajay Shakti Mech. Gr- I, M.C. Lucknow for collection of valuable data and typing of manuscript.

References

Abbi, S. D. S., Singh, Rajender and Katyal, K. N., 1979, "A case study of heavy rainfall in Bhagirathi catchment in association with September 1978 Bay depression", *Vayumandal*, **9**, 1 & 2, 16-22.

Lal, J., Day, J. S. and Kapoor, K. K., 1983, "Synoptic Analogue method for issue of semi-quantitative precipitation forecast for Gomati catchment", *Mausam*, **34**, 3, 309-312.

Ram, L. C. and Pangasa, N. K., 2000, "Semi quantitative precipitation forecast for Ghaghara catchment by synoptic analogue method for Ghaghara catchment", *Mausam*, **51**, 1, 85-88.

J. P. GUPTA
MANNU RAM*
MOTI LAL

Meteorological Centre, Lucknow, India
(*Received 13 April 2010, Modified 30 November 2011*)
***e mail : mannu.ram@imd.gov.in**