MAUSAM, **64**, 3 (July 2013), 475-480

551.579 : 556.166 (541)

Probabilities of wet spells over North Eastern India leading to flood condition

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(*Received 8 July 2011, Modified 7 March 2012*)

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सार – भारी वर्षा के कारण ऊपरी जलग्रहण क्षेत्रों से नीचे की ओर बहने वाले जल के अत्याधिक तेज प्रवाहों को समाहित करने के लिए नदियों के तटों के अंदर की तरफ अपर्याप्त स्थान होने के कारण बाढ़ आती है। असम और मेघालय के उपखंडों और भारत के उत्तरी पूर्वी भागों के उपहिमालय पश्चिम बंगाल के क्षेत्र दक्षिण पश्चिमी मॉनसून ऋतु के समय बाढ़ से ग्रस्त रहते हैं। इस अध्ययन में असम और मेघालय के उपखंडों तथा उपहिमालय के पश्चिमी बंगाल के कुछ चुनिंदा जिलों में लगातार वर्षा वाले 2 और 3 सप्ताहों के सुनिश्चित थ्रेशोल्ड मान के आधार पर पहले क्रम के मार्कोव चेन मॉडल द्वारा आकलित किए गए संभावनाओं को बताने का प्रयास किया गया है। कुछेक विशेष क्षेत्रों के लिए भारी वर्षा की संभावना वाली अवधियों का पता लगाया गया है जब वर्षा का बौछारों की संभावनाएँ 80 प्रतिशत से अधिक होने पर उन क्षेत्रो में भारी वर्षा की चेतावनी और उनसे निपटने की योजना बनाई जा सकती है।

ABSTRACT. Floods are caused by the inadequate capacity within the banks of rivers to contain the high flows brought down from the upper catchments due to heavy rainfall. The sub-divisions Assam and Meghalaya and Sub-Himalayan West Bengal from northeastern parts of India are prone to flood conditions in the southwest monsoon season. In the present study an attempt has been made to give the probabilities computed by first order Markov chain model with certain threshold value for 2 and 3 consecutive wet weeks for selected districts of the sub-divisions Assam and Meghalaya and Sub-Himalayan West Bengal. The critical periods identified for certain region when probabilities of wet spells exceed 80% may lead to give awareness and planning for heavy rainfall in those areas.

Key words – Flood, Northeast India, Probability, Wet spells, SW monsoon.

1. Introduction

Floods are caused by the inadequate capacity within the banks of rivers to contain the high flows brought down from the upper catchments due to heavy rainfall. The long term changes in extreme rainfall over India has been studied by Guhathakurta *et al*. (2010) due to the occurrences of some exceptionally very heavy rainfall during recent years causing flash floods in many areas. One of the most significant consequences of global warming due to increase in green house gases would be an increase in magnitude and frequency of extreme precipitation events. Joshi & Rajeevan (2006) examined the trends in extreme rainfall indices over India.

In northeastern parts of India normal rainfall in southwest monsoon season in major parts exceeds 1000 mm. In some parts of Assam and Meghalaya and sub- Himalayan West Bengal, it exceeds 2500 mm. Floods are recurrent phenomena. Almost every year some parts of the country are affected by the floods of varying magnitude which cause serious nature of damages over the years.

Markov chain probabilities have been used in a number of applications. Gabriel and Neumann (1962) used a Markov chain model for daily rainfall occurrences at Tel Aviv. Robertson (1982) has applied Markov chain probabilities for 2 and 3 consecutive dry and wet spells in respect of drought and flood assessment. Chowdhury (1981) identified dry and wet spells over Bihar. Khambete and Biswas (1984) applied Markov chain model in determining drought proneness. Pandharinath (1991) applied Markov chain probabilities model to Andhra Pradesh. Gore (2000) made study of dry and wet spells over all meteorological sub-divisions of India. Gore and Thapliyal (2000) studied occurrence of dry and wet weeks over Maharashtra in detail.

The sub-divisions Assam and Meghalaya and Sub-Himalayan West Bengal from northeastern parts of India are prone to flood conditions in the southwest monsoon

TABLE 1

Threshold rainfall amount based on Co-efficient of Variation (C.V.) of the seasonal monsoon rainfall

S. No.	C.V. (%)	Rainfall Amount (mm)
1.	< 20%	50
2.	20 - 30%	40
3.	30 - 40 %	30
4.	40 - 50 %	20
5.	> 50%	10

season. In the present study an attempt has been made to give the probabilities for 2 and 3 consecutive wet weeks for selected districts of the sub-divisions Assam and Meghalaya and Sub-Himalayan West Bengal computed by first order Markov chain model with specified threshold value [based on coefficient of variation (C.V.)] of rainfall for the monsoon season recommended by Annual Monsoon Review Meeting (AMR 1997). The simple and conditional probabilities of wet weeks for the standard weeks from 23rd to 39th during the southwest monsoon season, would help to identify the ciritical periods in which the probabilities of 2 or more consecutive wet weeks are exceeding 80 to 90% in certain districts of Assam and Meghalaya and Sub-Himalayan West Bengal creating worst flood conditions.

2. Data and methodology

A criteria for a wet week for a district is defined when the amount of rainfall for that week is more than specified threshold value based on Coefficient of Variation (C.V.) of rainfall for the southwest monsoon season. The details of the threshold rainfall amount based on C.V. (Recommended by Annual Monsoon Review Meeting, 1997) are given in Table 1. A normal seasonal rainfall, C.V. (%) for June to September and threshold rainfall values for defining a wet week for various districts of Assam and Meghalaya and Sub-Himalayan West Bengal are tabulated in Table 2. The threshold rainfall for various districts as shown in Table 2 varies from 40-50 mm, whereas C.V. varies from 10-30%.

The initial and conditional probabilities for dry and wet week of Markov chain model of 1st order as given in WMO (1982) are as below:

$$P(D) = F(D) / n$$

$$P(D/D) = F(D/D) / F(D)$$

$$P(2D) = P(D)w1 \times P(D/D)\ w2$$

$$P(3D) = P(D)\ w1 \times P(D/D)\ w2 \times P(D/D)\ w3 \quad (1)$$

$$P(W) = F(W) / n$$

$$P(W/W) = F(W/W) / F(W)$$

$$P(2W) = P(W)\ w1 \times P(W/W)\ w2$$

$$P(3W) = P(W)\ w1 \times P(W/W)\ w2 \times P(W/W)\ w3$$

Where,

P(D) → Probability of the week being dry

P(D/D) → Conditional probability of dry week preceded by a dry week

P(2D) , P(3D) → Probabilities of 2 and 3 consecutive dry weeks respectively starting with the week

P(W) → Probability of the week being wet

P(W/W) → Conditional probability of the wet week preceded by a wet week

P(2W), P(3W) → Probability of 2 and 3 consecutive wet weeks respectively starting with the week

N → Number of years of data

w1, w2, w3 → Indicate 1st, 2nd and 3rd consecutive wet/dry week respectively

F(D) → Number of dry weeks

F(D/D) → Number of dry weeks preceded by dry week

F(W) → Number of wet weeks

F(W/W) → Number of wet weeks preceded by wet week

TABLE 2

Rainfall variability over Assam & Meghalaya and Sub-Himalayan West Bengal in SW monsoon season

S. No.	District	No. of Stations	Normal R/F (mm)	C.V. (%)	Threshold value of R/f (mm)
			Assam and Meghalaya		
1.	Nowgong	13	1174	20 - 30	40
2.	Sibsagar	12	1412	< 20	50
3.	Garohills	03	2027	20 - 30	40
4.	Lakhimpur	12	1996	< 20	50
5.	Dibrugarh	02	1793	10 - 20	50
6.	M.N. Cachar	04	1759	20 - 30	40
7.	Cachar	16	2036	< 20	50
			Sub-Himalayan West Bengal		
1.	Coochbehar	05	2534	20 - 30	40
2.	Darjeeling	07	2370	< 20	50
3.	Malda	03	1144	20 - 30	40
4.	Jalpaiguri	06	3013	< 20	50
5.	West Dinajpur	05	1268	20 - 30	40

TABLE 3

Period in standard weeks for the simple and conditional probabilities of wet weeks ≥ 80%

S. No.	Name of District	P(W)	(P(W/W)	P(2W)	P(3W)
			Assam & Meghalaya weeks for ≥ 80%		
1.	Nowgong	24 - 36	22 - 35	24 - 30, 32	24, 25, 27, 28
2.	Sibsagar	23 - 36	22 - 36, 38	24 - 30	25, 27
3.	Garohills	22 - 34, 36 37	22 - 34, 36, 37	24 - 26	24
4.	Lakhimpur	22 - 37	22 - 36	23 - 32	23 - 30
5.	Dibrugarh	24 - 31	23 - 28, 30	-	-
6.	M. N. Cacher	23 - 29, 31 - 35	22 - 28, 30 - 34	24 - 26	-
7.	Cacher	23 - 35	23 - 34, 36	23 - 30, 32	23 - 27
			Sub-Himalayan West Bengal		
1.	Coochbeehar	23 - 29, 32, 37	22 - 28, 31, 36	-	-
2.	Darjeeling	23 - 38	22 - 37	23 - 35	23 - 33
3.	Malda	27, 32	23, 25 - 28, 31, 34	-	-
4.	Jalpaiguri	23 - 38	22 - 37	23 - 32, 35	23 - 26, 29
5.	West Dinajpur	26 - 28, 32	23 - 27	-	-

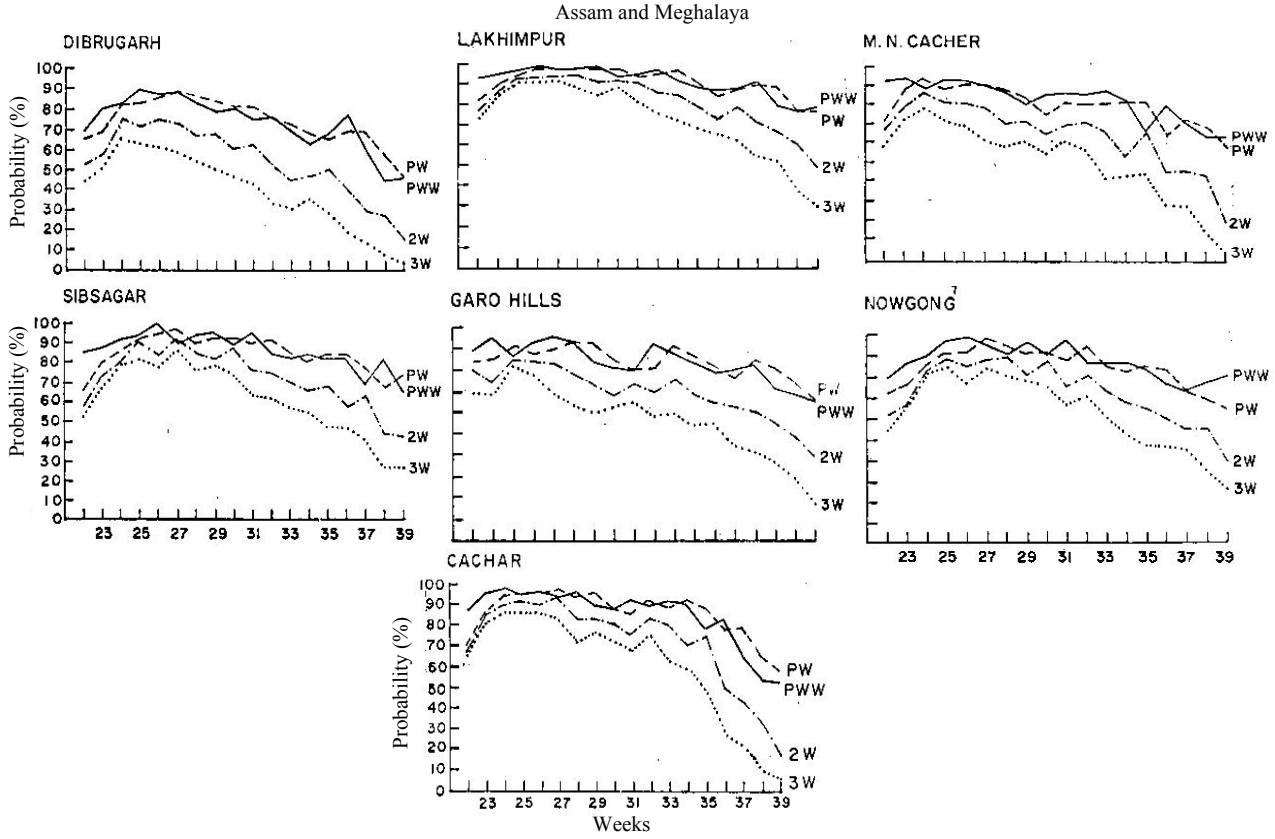

Fig. 1(a). Probability of wet spells by Markov Chain model for the districts of Assam and Meghalaya sub-division

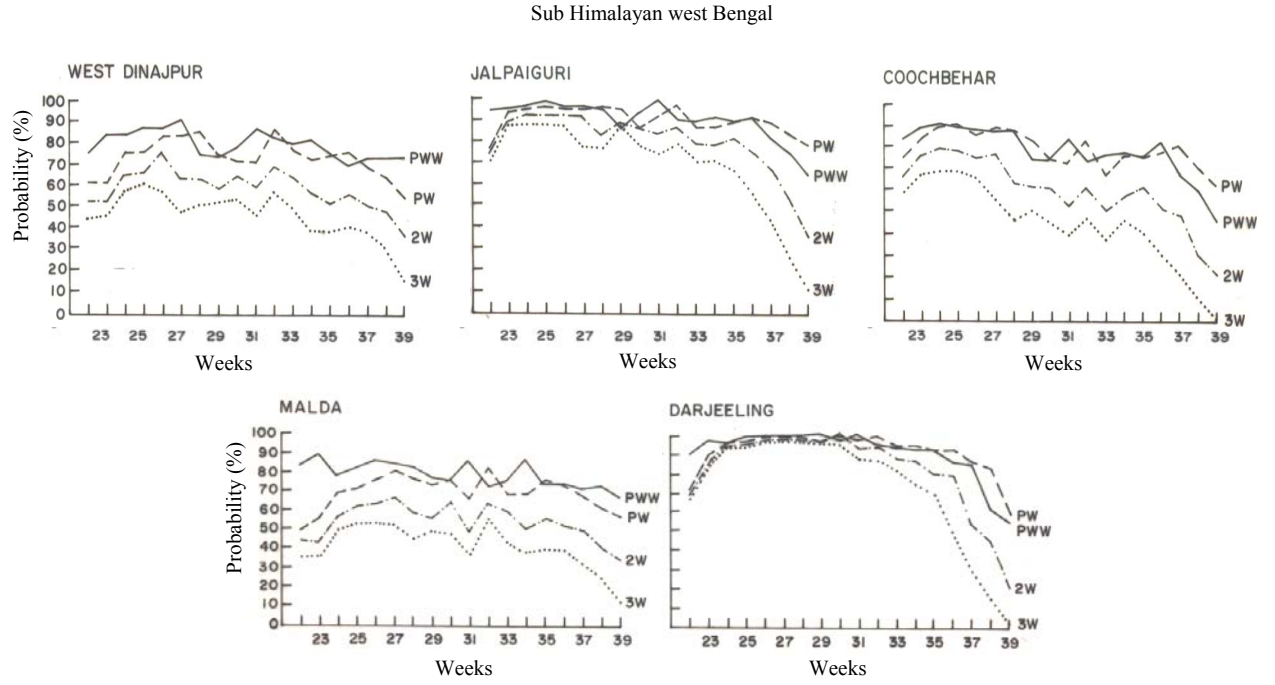

Fig. 1(b). Probability of wet spells by Markov Chain model for the districts of Sub-Himalayan West Bengal. (PW - Probability of wet week, PWW – Probability of wet week preceded by wet week, 2W & 3W – Probability of 2 and 3 consecutive wet weeks respectively)

The initial and conditional probabilities for dry and wet weeks for selected districts of Assam and Meghalaya and Sub-Himalayan West Bengal have been considered from the publication, Met. Monograph, Hydrology No. 12/2000 by Gore (2000) entitled, "Study of dry and wet spells for meteorological sub-divisions of India". A daily rainfall data for 90 years (1901-1990) has been used from National Data Centre, Pune. The probabilities are categorized in 4 classes, *viz*., high (> 70%), moderate (51-70%), low (30-50%) and very low (< 30%).

In Assam and Meghalaya the probabilities of wet weeks and conditional probabilities of wet preceding wet weeks are mostly high for all the districts. The probabilities for 2 consecutive wet weeks are moderate to high. The probabilities of 3 consecutive wet weeks are moderate or moderate to high. The probabilities of dry weeks are very low for all the districts. The conditional probabilities for dry preceding dry weeks are very low to low. The probabilities of 2 and 3 consecutive dry weeks are very low.

In Sub-Himalayan West Bengal and Sikkim the probabilities of wet weeks and conditional probabilities of wet preceding wet weeks are mostly high for all the districts. The probabilities for 2 consecutive wet weeks are moderate and those for districts Darjeeling and Jalpaiguri are high. The probabilities of 3 consecutive wet weeks are low to moderate and those for districts Darjeeling and Jalpaiguri are high. The probabilities of dry weeks are very low for all the districts. The conditional probabilities for dry preceding dry weeks are very low to low. The probabilities of 2 and 3 consecutive dry weeks are very low.

3. Results and discussion

The variability of the Markov chain probabilities during the southwest monsoon season for various districts in Assam and Meghalaya and Sub-Himalayan West Bengal is depicted in Fig. 1. Table 3 shows the period in standard weeks for various districts for which the simple and conditional probabilities for wet weeks exceed 80%. It can be seen from Table 3 that the probabilities of wet weeks equal to 80% or more are noticed for most of the period during the southwest monsoon season over the major area of Assam and Meghalaya. In case of Assam and Meghalaya, there is 80% or more probability of 2 consecutive wet weeks with rainfall more than 50 mm during the weeks from 4th June to 29th July and 6th August to 12th August for Cachar, from 11th June to 29th July for districts Nowgong and Sibsagar. During 6th to 12th August, again, the probability of 2 consecutive wet weeks is more than 80% for Nowgong. The probability of 2 consecutive wet weeks is more than 80% from 4th June to 12th August for Lakhimpur, while the probabilities exceed 80% for Garo Hills and M. N. Cacher only from 11th June to 1st July. The district Cacher shows the probability of 3 consecutive wet weeks exceeding 80% from 4th June to 8th July, while, the district Nowgong shows the probability of 3 consecutive wet weeks exceeding 80% from 11th June to 24th June and from 2nd July to 15th July. The district Lakhimpur has the largest period from 4th June to 29th July for the probability of 3 consecutive wet weeks exceeding 80%.

In Sub-Himalayan West Bengal, the districts Darjeeling and Jalpaiguri show the probabilities of wet weeks exceeding 80% and persistent rainfall during the southwest monsoon season. The probability of 2 consecutive wet weeks more than 80% is noticed from 4th June to 2nd September for Darjeeling and from 4th June to 12th August and from 27th August to 2nd September for Jalpaiguri. The probability of 3 consecutive wet weeks with the probability exceeding 80% is from 4th June to 19th August for Darjeeling, from 4th June to 1st July and from 16th July to 22nd July for Jalpaiguri.

4. Conclusions

(*i*) The districts Cacher, Nowgong, Sibsagar and Lakhimpur from Assam and Meghalaya show a large period of persistent rainfall during the southwest monsoon with a probability for 2 and 3 consecutive wet weeks exceeding 80%.

(*ii*) The districts Darjeeling and Jalpaiguri from Sub-Himalayan West Bengal show a large period of persistent rainfall during the southwest monsoon with a probability for 2 and 3 consecutive wet weeks exceeding 80%.

(*iii*) Such a persistent rainfall may create a flood situation in northeastern parts of India, during the southwest monsoon season. For most of the high hilly districts like Darjeeling etc. the flood last for a shorter duration because water moves down fast over those regions. The critical periods identified for different districts when the probabilities of wet spells exceed 80%, may lead to give awareness and heavy rainfall warning in those areas.

Acknowledgement

The authors are grateful to Dr. A. L. Koppar, DDGM(C) and Dr. A. B. Mazumdar, LACD ADGM (R) for the encouragement and support. Thanks are due to Shri R. S. Wayal for preparation of diagrams. Thanks are due to Mrs. U. J. D'Souza for typesetting.

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