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Oscillation of the eastern end of the monsoon trough

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सार — बारह वर्षों (1972–1983) की अवधि से सम्बन्धित जुलाई, अगस्त और सितम्बर के महीनों के देशान्तर 88° पूर्व के साथ-साथ दिन प्रति दिन की स्थिति के आलेखन द्वारा देशान्तर 83° पूर्व के पूर्व स्थित मानसून द्रोणी के उत्तर-दक्षिण दोलन गतियों का परीक्षण किया गया है। द्रोणी के अक्ष के उतार-चढ़ाव के प्रसार और वास्तविक प्रकृति तथा इसकी अनुकूलतम स्थितियों और माध्यस्थिति का पता लगाया गया है। उन याम्योत्तरों के साथ-साथ द्रोणी की वास्तविक और सापेक्ष उत्तर-दक्षिणी गतिविधियों के सम्बन्ध में जानने के लिये एक महीने के 84° पू०, 88° पू० और 92° पूर्व के तीन विभिन्न देशान्तरों के साथ-साथ द्रोणी की गतिविधियों की भी चर्चा की गई है।

सम्बन्धित सिनॉप्टिक स्थितियों सहित द्रोणी की विभिन्न स्थितियों से सम्बन्धित उत्तरपूर्वी भारत पर वर्षा के वितरण पर भी संक्षेप में विचार-विमर्श किया गया है।

ABSTRACT. In this study the north-south oscillatory motions of the monsoon trough lying east of Long. 83° E have been examined by plotting its day-to-day position along Long. 88°E for the months of July, August and September for a period of twelve years (1972-1983). The actual nature and the extent of fluctuations of the axis of the trough and its most favoured positions and mean position have been found out. The movements of the trough along three different longitudes of 84°E, 88°E and 92°E for one month have also been discussed for having an idea regarding the real and relative north-south movements of the trough along those meridians.

The distribution of rainfall over northeast India related to the various positions of the trough together with the associated synoptic situations have also been discussed in brief.

1. Introduction

It is well known to the meteorologists that during the northern summer, an intense heat low is established over Pakistan and adjacent land areas. An extension of this seasonal low into the Gangetic plains in north India is known as the 'monsoon trough'. It is regarded as the equatorial trough of the northern summer in Indian longitudes (Rao 1976). Actually the monsoon trough system covers a large area extending from western Sahara to China across Arabian peninsula, Iran, Pakistan and north India (Fig. 2; Ananthakrishnan *et al.* 1968). The axis of the monsoon trough is generally oriented from northwest to southeast with southwesterly to westerly winds to the south and easterly to northeasterly winds to the north of it.

The axis of the monsoon trough which runs, in its most favoured position, from Ganganagar to north Bay of Bengal, is not stationary but shows oscillatory movements towards north and south. This oscillatory movements of the monsoon trough has a vital bearing on the distribution of the seasonal rainfall. Although the axis of the monsoon trough is a zone of convergence, the precipitation on the trough axis is minimum due to subsidence around it (Ramage 1971). The maximum precipitation occurs to the south of the axis where tropical maritime air prevails up to a great depth (Rao 1976). When the trough shifts towards north and runs along the foothills of the Himalayas, the pattern of rainfall changes significantly. In this condition rainfall generally becomes heavy along the Himalayas, with heavier falls, along the Eastern Himalayas. Hence, Arunachal Pradesh, north Assam, Sikkim, Sub-Himalayan West Bengal and northern parts of Bihar plains get excessive rainfall. There is also an increase in rainfall in the southern Peninsula. On the other hand there is decrease in rainfall in the northern Peninsula and the central parts of the country. This is known as 'break monsoon' condition.

In this study an attempt has been made to examine the actual nature and extent of the fluctuations of the axis of the monsoon trough at its eastern end (*i.e.*, part lying to the east of Long. 83°E) and to find out its mean position. The distribution of rainfall over northeast India related to the various positions of the trough together with the associated synoptic situations have also been discussed.

2. Earlier studies

As the 'break' condition of Indian summer monsoon is a very important synoptic situation, a good number of workers have examined it. Malurkar (1950) pointed out that the axis of the monsoon trough shifted towards the foothills of the Himalayas when a depression had moved to the Himalayas and broken up there. From this he deduces that such movement of the seasonal trough may be due to an accentuation of the seasonal low pressure area in West China, presumably due to a more southerly travel of the extra-tropical disturbances

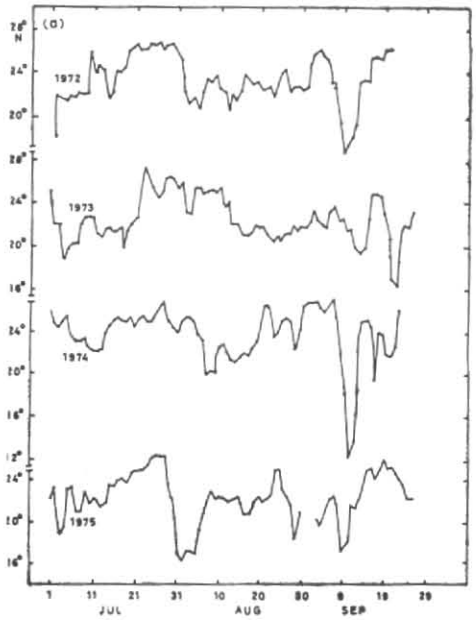

Fig. 1(a). Day-to-day position of monsoon trough along 88°E for 1972-1975

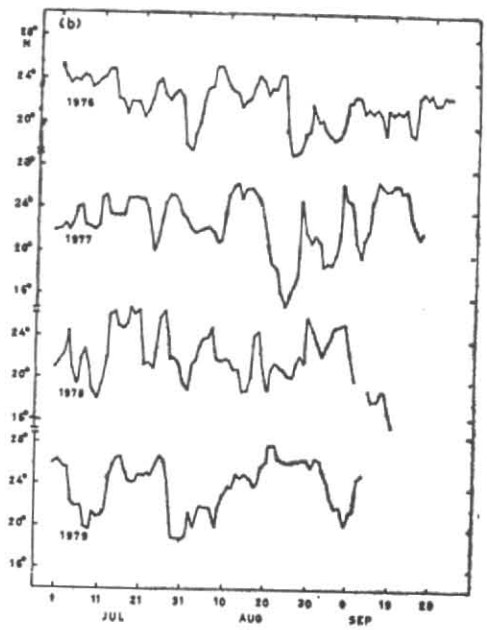

Fig. 1(b). Day-to-day position of monsoon trough along 88°E for 1976-1979

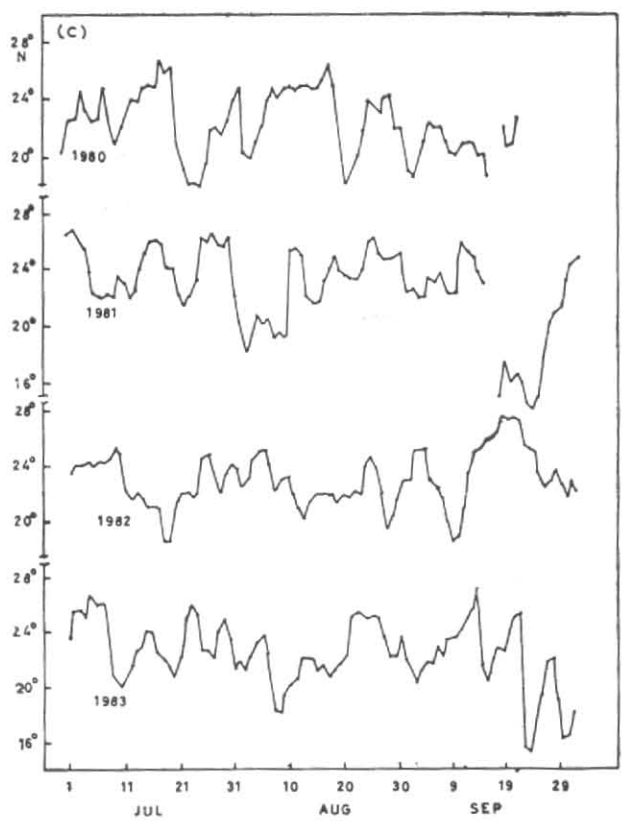

Fig. 1(c). Day-to-day position of the monsoon trough along Long. 88°E for 1980-1983

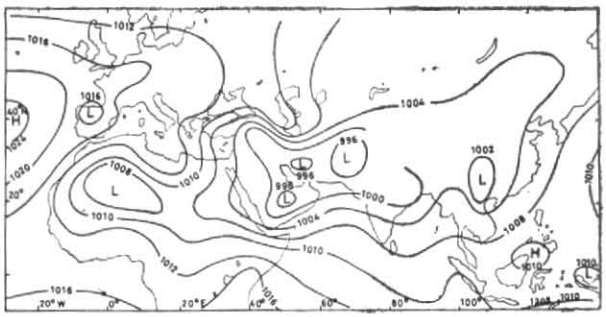

Fig. 2. Sea level pressure (mb) for July

than is usual for the season. He also assumed that the July 'breaks' are at least partly caused by the absence of monsoon 'pulses' crossing the equator from the south to the north over the Indian longitudes. Koteswaram (1950) related these breaks to the westward movement of low pressure areas in the equatorial easterlies in the middle troposphere across the south Bay of Bengal. Mukherjee and Natarajan (1968) had observed existence and westerly movement, simultaneous in pairs, of low pressure system in south Bay of Bengal and to the south of the equator. According to Raman (1955) when a depression or a typhoon in the China Sea moves to the north of Lat. 30° N the axis of the monsoon trough shifts to the Himalayas. The break does not occur if simultaneously there is a depression or a typhoon in the China Sea to the south of Lat. 30° N or unsettled conditions prevail in the Bay of Bengal or a depression lies in the Indan seas. A western disturbance or westerly wave moving across the extreme north of the country and eastern Himalayas also helps the monsoon trough to shift to the foot of the Himalayas (Kulkarni 1956, Mooley 1957, Chakraborty and Basu 1957). The role of westerly waves in causing flood producing storms in parts of northwest India have been discussed by Changrany (1966). Chaudhury (1966) had shown that the passage of the westerly waves across Eastern Himalayas could cause heavy rain as far south as in Santhal Parganas and adjoining Ajoy catchment areas. Oscillation of the monsoon trough within the belt of Longs. 72.5°-92°E during the peak monsoon months of July and August has been studied by Paul and Sikka (1976) based on 20 years daily weather charts (1946-65). A few other workers have studied the oscillatory characteristics of the monsoon system as a whole (Krishnamurti & Bhalme 1976, Murakami 1976).

3. Methodology and data used

Twelve years (1972-1983) data for the months of July, August and September have been used in this study. Day to day weather charts of Area Cyclone Warning Centre, Calcutta and the data and maps of *Indian Daily Weather Report* and *Weekly Weather Report* etc., published by India Met. Dep. have also been used for the purpose.

As the north-south movements at different points of the monsoon trough are neither uniform nor in the same phase at any particular time, we selected Long. 88°E for studying the swinging of the monsoon trough along it. The points of intersection of the trough with Long. 88°E at 0830 IST everyday from 1 July to 30 September were plotted on the graphs taking latitudinal extent as ordinate against dates along abscissa and successive points were joined by freehand (Fig. 1a-c).

4. Results and discussions

From the graphs (Fig. 1) it is seen that the position of the monsoon trough on Long. 88°E varies day to day between latitudes 16.0°N and 27.5°N though in extreme cases it has been found to vary between Lat. 12°N and 28° N. When the orientation of the trough is in a north-south direction, it may not cut the 88°E line and in that case the trough lies west of the said meridian. This condition is more frequent in the later-half of September.

It is seen that the north-south movement of the trough is not regular or periodic (Fig. 1). Sometimes it moves very slowly remaining quasi-stationary for a few days while on other occasions its movement is quite fast, covering 6 or 7 degrees latitude in 24 hours. It will be evident from later discussions that such a rapid movement of the trough is associated either with the northwesterly/northnorthwesterly movement of a depression/cyclonic storm along the trough from the Bay of Bengal occasionally paired with easterly movements of some westerly system across the Himalayas or with the rapid development of a monsoon cyclonic disturbance in the Bay of Bengal. In the former case the movement is towards the north while in the latter one it is towards the south.

If we consider the percentage frequency of the positions of the trough at or in the neighbourhood (*i.e.*, within ± 15′) of a particular point on Long. 88°E, we see that it is maximum around Lat. 22°N. This position has been described by the Indian meteorologists as the normal position of the monsoon trough on the said meridian. This is, perhaps, due to the fact that most of the monsoon disturbances are formed in the Bay when the trough is at this favoured position. Table 1 shows the percentage frequency position of the monsoon trough crossing Long. 88°E around Lat. 22° N (O) and to the north (N) and south (S) of it. The north-south positions of the monsoon trough not crossing Long. 88°E or, when it is diffuse, have been shown as NST in Table 1. From Table 1 it is seen that the average percentage frequency (PF) at O position is 15 in July, 18 in August and 9 in September and 14 during the period July-September. The PF of occasions when the trough passes through the north of O position is 51 against that of 27 when it passes through the south. This suggests that the mean position of the trough along Long. 88°E is somewhere to the north of Lat. 22° N. In order to find out the mean position of the trough along Long. 88°E we examined the mean wind of different stations situated along and near Long. 88°E taking 0830 IST and 1730 IST data for a period of 30 years as contained in the *Climatological Tables of Observatories in India*: 1931-1960 (India Met. Dep. 1983). The position of the trough was considered to the south of a station having N/NE/E/SE'ly winds and to the north with S/SW/W/NW'ly winds. It is noticed that, in its mean position, the trough

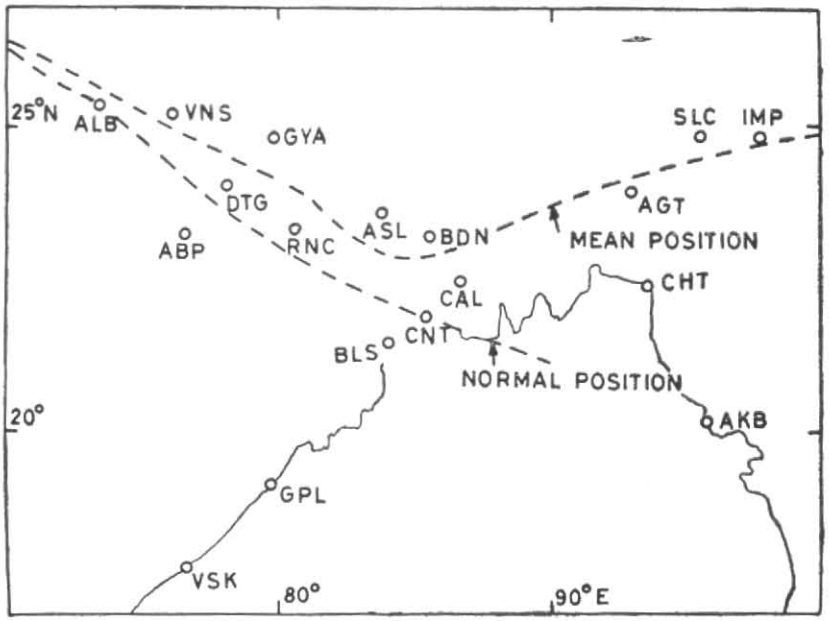

Fig. 3. Normal and mean positions of the monsoon trough

TABLE 1

Percentage frequency (PF) of different positions of monsoon trough along Lat. 22°N

Year	July				August				September				Total			
	N	O	S	NST	N	O	S	NST	N	O	S	NST	N	O	S	NST
1972	65	23	13	—	65	16	19	—	47	—	17	36	59	13	16	12
1973	48	13	39	—	42	26	32	—	40	13	30	17	43	17	34	5
1974	94	6	—	—	70	10	20	—	50	10	13	27	72	9	11	8
1975	71	13	16	—	35	23	42	—	37	17	33	13	48	17	31	4
1976	61	23	16	—	55	10	35	—	27	13	60	—	48	15	37	—
1977	77	10	13	—	39	22	39	—	47	10	30	13	54	14	28	4
1978	45	16	39	—	29	23	48	—	27	—	30	43	34	13	39	14
1979	65	6	29	—	71	13	16	—	23	7	10	60	53	9	18	20
1980	61	10	29	—	61	13	26	—	7	10	50	33	43	11	35	11
1981	71	26	3	—	62	3	35	—	40	7	—	53	58	12	13	17
1982	55	19	26	—	42	35	23	—	80	7	13	—	58	21	21	—
1983	68	10	22	—	35	23	42	—	40	10	43	7	48	14	36	2
Average	65	15	20	—	51	18	31	—	38	9	27	26	51	14	27	8

O=Trough on and around Lat. 22°N (*i.e.*, 22°N±15′); N=Trough north of Lat. 22°N
NST=North-south oriented trough not cutting Long. 88°E; S=Trough south of Lat. 22°N

passes through Krishnagar keeping Burdwan to the north of it (Fig. 3).

It is evident from Fig. 1, that the monsoon trough has a second favoured position around Lat. 25°N. The average percentage frequency of the trough position around Lat. 25°N is 11 against that of 14 around Lat. 22° along Long. 88°E.

5. Movement of the trough during July 1980

In this section we shall discuss the day-to-day movements of the monsoon trough along three different longitudes of 84°E, 88°E and 92°E for a month in order to get an idea about the real and relative north-south movements of the trough along those meridians.

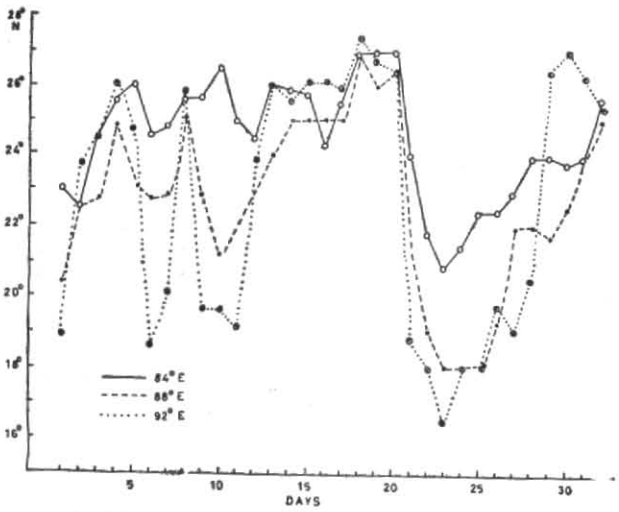

Fig. 4. July 1980 position of monsoon trough on Longs. 84°E (Solid lines), 88°E (broken lines) and 92°E (dotted lines)

Fig. 4 shows the movement of the trough in July 1980 along Longs. 84°E (solid lines), 88°E (broken lines) and 92°E (dotted lines).

At the beginning of the month of monsoon trough lay slightly south of its normal position with a well marked low pressure area over the northwest Angle Bay and adjacent north Orissa with associated cyclonic circulation extending up to mid-tropospheric levels. The trough shifted to the north and on 4th, it lay between Lats. 25° and 26°N. This northward shift was associated with movement of the low pressure area towards west-northwest along the trough and the eastward movement of an upper air westerly system across the Himalayas.

The monsoon trough began to shift towards south with the appearance of a low pressure area over north-west Bay on 5th and came almost to its normal position, by 6th morning. As the lopar moved westnorthwestwards, another low pressure area appeared over Angle Bay and adjacent land areas on 7th. This lopar moved towards NW very fast to western parts of Bihar by 8th drawing the trough to the north of Lat. 25°N by that time. At the same time a trough in mid and upper tropospheric westerlies extended from Tibet to central Uttar Pradesh. The monsoon trough again had been at its normal position during the period from 9th to 11th when a low pressure area formed over the northwest Bay. Consequent upon its northwesterly movement, the trough moved to the north of its normal position after 11th and shifted to the north of Lat. 25°N by 14th. A few lopars which formed *in situ* over Bihar plains and adjacent West Bengal and east Uttar Pradesh between 14th and 16th caused little northward movement of the monsoon trough.

With the development of a lopar over northwest Bay with well marked associated cyclonic circulation extending up to mid-tropospheric levels, the monsoon trough shifted southwards and lay slightly south of its normal position on 21st. The lopar concentrated into a depression on 24th with its centre at 0830 IST near Lat. 13.5°N, Long. 86.5°E and after crossing the coast it weakened into a lopar on 25th morning with its central area near Gopalpur. The lopar moved westnorthwestwards and lay over northeast Madhya Pradesh and adjoining east Uttar Pradesh on 27th. The monsoon trough did not move towards north and remained at its normal position up to 29th due to the formation of another low over north-west Bay and adjoining land areas of Orissa and West Bengal. The trough again started moving towards north with the movement of this low towards westnorthwest and shifted to the north of Lat. 25°N by 31st when there was no other easterly system or lopar over the north Bay of Bengal and adjoining areas.

From Fig. 4 it can be easily visualised that neither the north-south movements of the eastern end of monsoon trough at the different points are regular, nor they are in the same phase at any particular time or period. The latitudinal extent of the movement of the trough is maximum along Long. 92°E and minimum along Long. 84°E.

6. Rainfall

Rainfall was found to be widespread over coastal West Bengal and Orissa during the formative periods of cyclonic disturbances at the north Bay of Bengal. Distribution of rainfall did not change appreciably so long such disturbances remained over the sea. Rainfall was widespread and moderate to heavy around the trough, particularly to its southern side during the movement period of low/depression over the affected area. It was also widespread over the area swept by the trough during its north-south movement. Widespread and moderate to heavy rainfall occurred in Assam & adjoining States, Sub-Himalayan West Bengal & Sikkim and sub-montane districts of Bihar plains when the monsoon trough lay north of Lat. 25°N.

7. Conclusion

From the above observations it is evident that :

(a) the north-south oscillation of the monsoon trough is neither periodic nor regular. Sometimes it moves very slowly remaining quasi-stationary for a few days while on other occasions its movement is quite fast covering 6 or 7 degrees latitudes in 24 hours.

(b) the trough has two favoured positions of stay along Long. 88°E, one around Lat. 22°N (PF 14) and the other around Lat. 25°N (PF 11), the former being known as the normal position of the trough.

(c) the monsoon trough moves towards north with the movement of monsoon disturbances from north Bay of Bengal towards westnorthwest/northwest along the trough when there is no fresh disturbance in the Bay.

(d) the presence of moving troughs in middle and upper tropospheric westerlies over the Himalayan region also helps/accelerates the shift of the monsoon trough towards north.

(e) the trough shifts towards its normal position or the break condition terminates as soon as an easterly disturbance enters the north Bay of Bengal and a low pressure area forms there.

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