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Rainfall over central parts of India during the break monsoon conditions

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सार — भारत के मध्य भागों में, कभी-कभी ऐसे अवसर आते हैं जब इक्कादुक्का भारी वर्षा सहित सुविस्तीर्ण से दूर-दूर तक व्यापक वर्षा होती है हालांकि निम्न क्षोभ मंडलीय प्रवाह प्रतिमान मानसून में व्यवधान दर्शाता है। वर्तमान अध्ययन से पता चलता है कि 700 और 500 मि. बार स्तरों पर सार्थक साररूपी लक्षण की उपस्थिति होती है जिसका सम्बन्ध इस प्रकार की वर्षा की गति विधियों से हो सकता है। ऐसी अवधियों के दौरान विद्यमान तापीय प्रतिमानों (पैटर्नों) का भी अध्ययन किया गया है।

ABSTRACT. In the central parts of India, there are occasions when fairly widespread to widespread rains with isolated heavy falls occur although the lower tropospheric flow pattern exhibits break in monsoon. The present study brings out the presence of significant synoptic features at 700 and 500 mb levels that could be associated with such rainfall activity. The thermal patterns existing during such periods have also been studied.

1. Introduction

It is a well established feature of southwest monsoon that when the axis of the monsoon trough at sea level and at lower troposphere is located close to the foot-hills of the Himalayas or is not noticeable at all, there is generally a striking decrease of rainfall over large areas of the country. Such a synoptic situation is referred to as break in monsoon. Significant synoptic situations leading to these breaks have been investigated by many authors. Koteswaram (1950) connects 'break' with westward moving lows at low latitude (10° N) in the Bay which are prominently seen at 700 mb.

Pisharoty and Asnani (1958) discussed idealized flow pattern at 500 mb level in July during normal and break monsoon conditions. According to them, feeble cyclonic circulations over central parts of India seen on normal monsoon day shift to northeast India and the trough in the westerlies along Delhi meridian on normal monsoon is displaced to the east during break situation. Ramaswamy (1962, 1965) found that large amplitude troughs protrude into Indo-Pakistan area at 500 mb and aloft and remain quasi-stationary over north India when the break lasts for a week or more. The ridge in the rear of the trough causes extension of the anticyclone over northwest and central India and northern parts of Peninsula. Koteswaram (1958) has observed that during break in monsoon, the easterly jet is well marked and occupies a more northerly position than average. Ananthakrishnan and Ramakrishnan (1963) found that the area of strongest easterlies shifts from the normal position to 19° N during the 'break'.

Although the major parts of the country except northern areas extending from western Himalayas to Assam and, Tamil Nadu, are getting less rain during break situation, it is observed that sometimes central parts of the country also get fairly widespread rain with isolated heavy falls on some occasions in the month of July and first week of September. In the present study an attempt has been made to study the synoptic patterns at 700 mb and 500 mb during break monsoon and the resulting rainfall pattern observed over Madhya Pradesh and Vidarbha during the period 1978 to 1982. The widespread/fairly widespread rainfall distribution in the neighbouring sub-divisions around central parts of India except Uttar Pradesh is included in the last column of Table 1.

2. Method

The synoptic charts prepared in the Regional Meteorological Centre, Nagpur were examined for the monsoon months during the period 1978 to 1982 keeping in view the following aspects :

(*i*) Axis of the monsoon trough over mean sea level or in the lower troposphere upto 1.5 km a.s.l. has either shifted to the foot-hills of Himalayas or is not noticed at all.

(*ii*) Widespread to fairly widespread rainfall distribution in any meteorological sub-division of the the central region comprising Madhya Pradesh State and Vidarbha portion of Maharashtra State. The sub-divisions are : northwest, northeast, southwest & southeast Madhya Pradesh and east & west Vidarbha.

TABLE 1

Association between rainfall and the main synoptic feature at 700 and 500 mb levels during break monsoon situation

Date	Synoptic situation on 700 mb chart	Simultaneous synoptic situation on 500 mb chart	Sub-divisions in Madhya Pradesh and Vidarbha getting widespread/fairly widespread rain	Adjoining Sub-division getting widespread/fairly widespread rain
(1)	(2)	(3)	(4)	(5)
16 Jul 1978	A trough in the westerlies extends from hills of west Uttar Pradesh to west Vidarbha	A trough in the westerlies extends from east Uttar Pradesh to northeast Madhya Pradesh	Northeast Madhya Pradesh and east Vidarbha	Bihar Plateau
28 Jul 1978	(1) A trough in the westerlies extends from northeast Rajasthan to Gujarat (2) A trough in the westerlies from Sub-Himalayan West Bengal to northwest Bay (By evening a circulation had developed over Bihar Plateau and neighbourhood)	A trough in the westerlies extends from east Uttar Pradesh to central parts of Madhya Pradesh (A circulation developed over Uttar Pradesh and northeast Madhya Pradesh by evening)	Northeast and adjoining central Madhya Pradesh	Bihar Plateau
19 Jul 1979	Cyclonic circulation over southeast Rajasthan and adjoining southwest Madhya Pradesh	Cyclonic circulation over central parts of north Madhya Pradesh	Northwest and east Madhya Pradesh	Bihar Plateau and Orissa
26 Jul 1979	East-west shear zone roughly along 17°N with embedded cyclonic circulation over : (1) east central Arabian Sea off Maharashtra coast (2) west central Bay off south Andhra coast	East-west shear zone from east central Arabian Sea to west central Bay with embedded cyclonic circulation over : (1) east central Arabian Sea off Karnataka coast (2) South Andhra coast	South Madhya Pradesh and west Vidarbha	Marathwada
27 Jul 1979	Cyclonic circulation over northeast Arabian Sea off Gujarat coast	East-west shear zone along 15°N with embedded cyclonic circulation over west central Bay off Andhra coast	West Vidarbha and southwest Madhya Pradesh	Marathwada
28 Jul 1979	Cyclonic circulation over northeast Arabian Sea off Gujarat State with trough extending upto east Vidarbha	East-west shear zone along 15-16°N with embedded cyclonic circulation over west central Bay off Andhra coast	West Madhya Pradesh and Vidarbha	Marathwada
2 Jul 1981	Trough in the westerlies extends from southeast Rajasthan to east central Arabian Sea off Maharashtra coast (A trough in the westerlies along 87°E north of 19°N. In the evening it lies along 85°E north of 15°N)	Trough in the westerlies extends from central parts of Uttar Pradesh to east central Arabian Sea off Maharashtra coast with embedded cyclonic circulation over north Gujarat State (Trough in the westerlies along 90°E north of 16°N in the evening it lies along 86°E north of 16°N)	Vidarbha	—
17 Jul 1981	Trough in the westerlies extends from Haryana to east central Arabian Sea off Maharashtra coast	Trough in the westerlies extends from Jammu & Kashmir to Marathwada	West Madhya Pradesh and Vidarbha	—
26 Jul 1981	Trough in the westerlies extends from east Uttar Pradesh to east Vidarbha	Trough in the easterlies extends from Rayalaseema to Bihar Plateau. Cyclonic circulation lies over east Uttar Pradesh and adjoining northeast Madhya Pradesh	East Madhya Pradesh and east Vidarbha	Telangana and Orissa
27 Jul 1981	Trough in the westerlies extends from east Uttar Pradesh to coastal Andhra Pradesh with embedded cyclonic circulation over southeast Madhya Pradesh	Trough in the easterlies extends from south interior Karnataka to east Uttar Pradesh	East Madhya Pradesh and Vidarbha	—
28 Jul 1981	Cyclonic circulation over central parts of Rajasthan with trough extending upto south Gujarat	A trough in the easterlies extends from north interior Karnataka to Bihar plains	East Madhya Pradesh and west Vidarbha	Marathwada

TABLE 1 (*contd*)

Date	Synoptic situation on 700 mb chart	Simultaneous synoptic situation on 500 mb chart	Sub-divisions in Madhya Pradesh and Vidarbha getting widespread/fairly widespread rain	Adjoining sub-division getting widespread/fairly widespread rain
(1)	(2)	(3)	(4)	(5)
30 Jul 1981	Trough in the westerlies extends from west Rajasthan to Karnataka coast. East-west shear zone between 14 & 17°N	Trough in the westerlies extends from east Uttar Pradesh to south-east Madhya Pradesh	East Madhya Pradesh and east Vidarbha	Bihar Plateau and Telangana
1 Sep 1981	Cyclonic circulation over Saurashtra and Kutch	Trough in the westerlies extends from central parts of Uttar Pradesh to north Madhya Pradesh	East and southwest Madhya Pradesh	—
8 Jul 1982	Cyclonic circulation over north Gujarat and adjoining west Madhya Pradesh. East-west shear zone along 17°N	East-west shear zone along 12°N. Trough in the westerlies extends from southeast Madhya Pradesh to west central Bay	Vidarbha	Marathwada
9 Jul 1982	Cyclonic circulation over south Madhya Maharashtra	East-west shear zone along 15°N	West Madhya Pradesh and Vidarbha	—
25 Jul 1982	Trough in the westerlies extends from west Uttar Pradesh to east central Arabian Sea off north Maharashtra coast	Trough in the westerlies extends from Jammu & Kashmir to coastal Maharashtra	West Madhya Pradesh	—

After selecting the dates when the above features were present, charts of those dates were examined in detail to bring out the synoptic features that could have caused the rainfall activity. The thermal structure upto middle troposphere at standard levels, *viz.*, 850,700 and 500 mb was also studied by preparing thickness charts using wind shears and thickness values.

3. Discussion

During the period from 1978 to 1982, a total number of 16 cases were found to be associated with widespread to fairly widespread precipitation over central parts of India when synoptic conditions indicated setting in of the break monsoon. These occasions are shown in Table 1.

It may be stated that in the month of August, there was no instance of widespread to fairly widespread rains having occurred in any sub-division of Madhya Pradesh and Vidarbha on occasions when the axis of the seasonal trough lay near the foot-hills of Himalayas. This brings out the fact that the month of August witnesses real breaks in mosoon when the rainfall strikingly decreases over Madhya Pradesh and Vidarbha, but in other months, (*i.e.*, July and September break monsoon condition may temporarily appear on some occasions in low levels but widespread to fairly widespread rainfall activity may still occur in central parts. These are the situations when the forecaster has to be careful in assessing the rainfall potential.

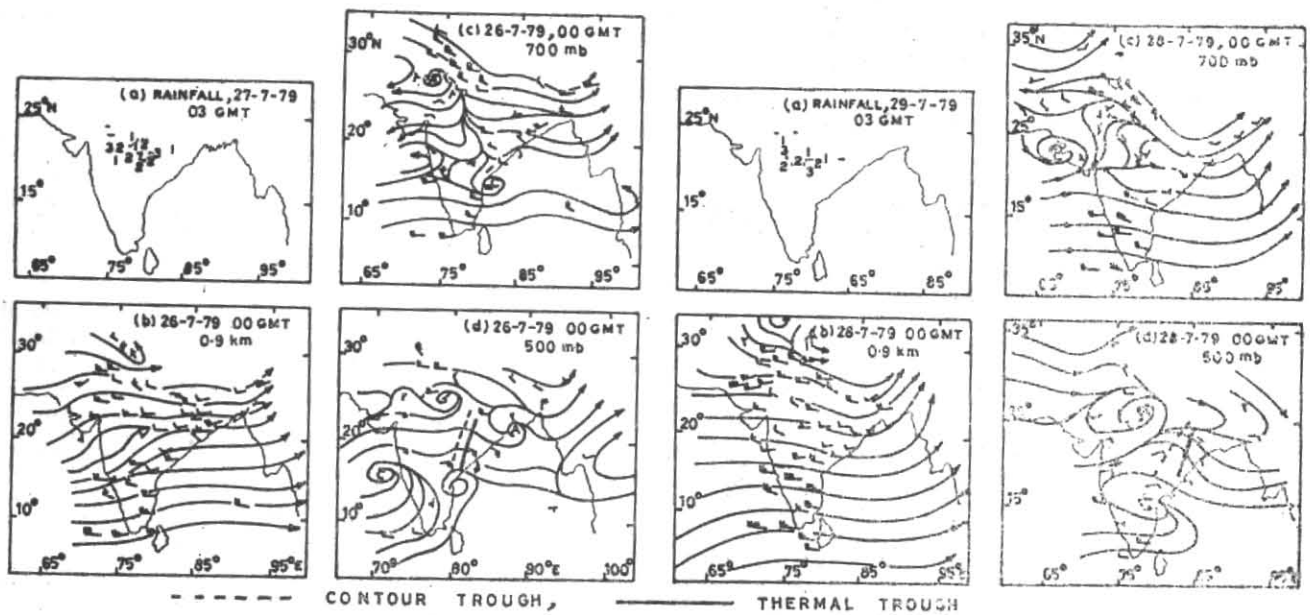
3.1. *Flow pattern over* 700 *mb level*

As the break in mosoon starts setting in, axis of the monsoon trough at sea level and in the lower troposphere starts shifting northwards. It is observed in this study that on some of these occasions axis of the monsoon trough at sea level and in the lower troposphere upto 1.5 km reaches the foot-hills of the Himalayas but the wind pattern at 700 mb does not necessarily conform to the idealized break situation simultaneously. That is to say that the usual east-west shear line may be absent but trough or cyclonic circulation develops either in the eastern or western parts of the region and the adjoining areas which leads to precipitation over Madhya Pradesh and Vidarbha. The synoptic situation of 700 mb chart leading to precipitation over Madhya Pradesh and Vidarbha are summarized in Table 2.

From Table 2, it will be seen that a large number of troughs in westerlies or cylonic circulations develop over western part of the region and adjoining areas of Rajasthan, Gujarat and Madhya Maharashtra which can cause fairly widespread rainfall activity over west Madhya Pradesh and west Vidarbha. The frequency of such systems comes out to be 67%. The eastern parts of the central region are also affected by the trough in westerlies or cyclonic circulations which develop over east Madhya Pradesh and adjoining areas of Bihar, Orissa, coastal Andhra Pradesh. These systems bring fairly widespread rains over east Madhya Pradesh and east Vidarbha. For instance, such a case was observed on 28 July 1978 when a trough in westerlies extended from Sub-Himalayan West Bengal to northwest Bay at 700 mb. By evening a cyclonic circulation had developed over Bihar plateau and neighbourhood causing widespread to fairly widespread rains over northeast and adjoining central Madhya Pradesh and Bihar plateau. The east-west shear zone was observed only in 14% of the occasions. On all these occasions this shear zone was confined between 14° and 17° N and caused fairly widespread rainfall activity over south Madhya Pradesh and Vidarbha.

TABLE 2

Synoptic situation	No. of occasions	
	700 mb	500 mb
Trough in the westerlies over western parts of the region and adjoining areas	6	5
Trough in the westerlies over eastern parts of the region and adjoining areas	3	3
Trough in the easterlies over the eastern parts of the region and adjoining areas	—	3
Cyclonic circulation over the western parts of the region and adjoining areas	8	3
Cyclonic circulation over the eastern parts of the region and adjoining areas	1	4
East-west shear zone	3	5
Total	21	23



Figs. 1(a-d) Figs. 2(a-d)

Figs. 1 & 2. (a) Rainfall on 27th and 29th, (b) 0.9 km streamline chart, (c) 700 mb streamline chart and (d) Thermal trough between 800 mb and 500 mb of the previous day

3.2. *The flow pattern over 500 mb level*

The charts of 500 mb were also examined to find out any typical situation that is also present on these occasions of break monsoon condition. The synoptic systems that affected the central region have also been given in Table 2. It will be seen that the most prominent feature at this level is the trough in the westerlies or cyclonic circulation over west Madhya Pradesh and adjoining areas. Their frequency comes out to be 35%. The other important feature is the presence of the trough in the westerlies or cyclonic circulation, over east Madhya Pradesh and adjoining areas which has a frequency of 30%. It may be mentioned that these cyclonic circulations have mostly appeared as embedded cyclonic circulation on the east-west shear zone. The east-west shear zone has a frequency of 22% out of the total synoptic systems observed. This shear zone is located between 12° and 16° N. The trough in the easterlies over the eastern parts of the region is also affecting the region, which has a frequency of 13%.

The examination of the 500 mb flow pattern also brings out the existence of an anticyclonic flow over central Rajasthan or Gujarat. At times it shifts to northeast Arabian Sea and north Madhya Maharashtra also.

3.3. *Thermal pattern*

During the break monsoon period, it is observed that a thermal high develops over northeast India and east Uttar Pradesh. It is well known that the trough in the upper air flow pattern intensifies if the thermal trough lags behind the trough in the streamline pattern. The case studies on 26 and 28 July 1979 show that thermal troughs are lagging behind the trough in the streamline pattern. Positions of these troughs are shown in Figs. 1(d) and 2(d).

The rainfall chart on 27th and 29th and 0.9 km and 700 mb streamline and position of 500 mb trough and thermal trough between 850 mb and 500 mb of the previous day, *viz.*, 26th and 28th are shown in Figs. 1 (a-d) and 2 (a-d) respectively.

4. Conclusion

(1) There are occasions during the southwest monsoon season, when the position of the axis of the monsoon trough over sea level or in the lower troposphere indicated break in monsoon but fairly widespread to widespread rains occur in some sub-divisions of the central India.

(2) During the initial stages of break conditions the flow pattern at lower middle or middle troposphere may exhibit significant synoptic systems.

(3) The most significant synoptic systems seen at 700 mb are :

(i) Cyclonic circulation or trough in the westerlies over western parts of the region and adjoining area of Rajasthan, Gujarat and Madhya Maharashtra giving fairly widespread to widespread rain over west Madhya Pradesh and west Vidarbha.

(*ii*) Cyclonic circulation or trough in the westerlies over eastern parts of the region and adjoining area of Bihar, Orissa and coastal Andhra Pradesh giving fairly widespread to widespread rainfall over east Madhya Pradesh and east Vidarbha.

(4) The most significant synoptic systems seen at 500 mb are :

(*i*) East-west shear zone between 12° &16°N giving fairly widespread to widespread rainfall over south Madhya Pradesh and Vidarbha.

(*ii*) Trough in the westerlies or cyclonic circulation over west Madhya Pradesh and adjoining areas giving fairly widespread to widespread rainfall over west Madhya Pradesh and west Vidarbha.

(*iii*) Trough in the westerlies or cyclonic circulation over east Madhya Pradesh and adjoining areas giving fairly widespread to widespread rainfall over east Madhya Pradesh and east Vidarbha.

(5) An anticyclonic flow also develops over northwest India which sometimes shifts to northeast Arabian Sea off north Madhya Maharashtra.

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References

Ananthakrishnan, A. and Ramakrishnan, A.R., 1963, Perturbation of the general circulation over India and neighbourhood, Proc. Symp. Tropical Meteorology, Rotorua, pp. 114-159.

Koteswaram, P, 1950, 'Upper level lows in lower latitude in the Indian area during southwest monsoon season and breaks in the monsoon', *Indian J. Met. Geophys.*, **1**, pp. 162-164.

Koteswaram, P., 1958, 'The Easterly Jet Stream in the Tropics, *Tellus*, **10**, pp. 43-57.

Pisharoty, P.R. and Asnani, G. C., 1958, 'Flow pattern over India and neighbourhood at 500 mb level during monsoon', Symposium on Monsoon of the world, pp. 112-117.

Ramaswamy, C., 1962, 'Breaks in the Indian Summer monsoon as a phenomenon of interaction between the easterly and subtropical westerly Jet-streams', *Tellus*, **14**, pp. 337-349.

Ramaswamy, C., 1965, On synoptic methods of forecasting the vagaries of southwest monsoon over India and neighbourhood countries, Proc. Symp. Met. Results of IIOE, pp. 317-327.