Indian J. Met. Hydrol. Geophys. (1978), **29**, 1 & 2, 47-53

551.577 : 551.515 : 515.553.21 (544.6)

Distant effects of monsoon depressions on weather over west Rajasthan

A. K. MUKHERJEE and (Smt.) B. SHYAMALA

Meteorological Office, Bombay

ABSTRACT. Monsoon depressions are generally responsible for increased rainfall activity over northern and central parts of India during southwest monsoon season. That they also have some influence on the weather over places at quite some distance from the depression has been studied by some workers. One such effect mentioned by K.L. Sinha is that whenever monsoon depressions/lows form in the Bay of Bengal or interior and move in a westnorthwesterly direction, rain or thundershowers occur over Jodhpur. This phenomenon of distant effects of monsoon depression on weather over west Rajasthan has been studied for the 20-year period from 1956 to 1975. It is seen that on 70% of the occasions when monsoon depressions/lows formed in the northwest Bay and crossed the Orissa coast, distribution and activity of rainfall over west Rajasthan showed a prominent increase.

An explanation for the phenomenon has been offered in this study in terms of southward shift of the mid-tropospheric trough line. Those occasions when the depressions/lows were over or near west Rajasthan have been excluded in the study.

1. Introduction

Monsoon depressions are the most important synoptic systems that effect the weather over northern and central parts of India during the southwest monsoon season. The associated rainfall belt is normally confined to the zone of convergence between the easterlies to northeasterlies and the westerlies, the rainfall being heavy to the south of the trough with very heavy falls in the southwestern sector of the depression. But strangely it is also observed that monsoon depressions can also act as weather producing agents over places even at some distance from the depressions.

Three distinct distant effects of monsoon depressions have been observed :

(*a*) At the time of formation of the monsoon depressions in the head Bay, west coast gets very heavy rainfall,

(*b*) At the time of weakening of the depressions over Madhya Pradesh, Assam experiences weather, and

(*c*) Westnorthwest to northwest movement of the depressions/lows from the Bay of Bengal across the Orissa coast result in increased rainfall activity over west Rajasthan.

Sinha (1958) who studied the influence of distant monsoon lows on weather over Jodhpur has pointed out that when the monsoon lows lie on or near the line passing eastsoutheastwards from Jodhpur, and also when they have a tendency of movement towards westnorthwest, rain or thundershowers generally occur over Jodhpur. These lows disrupt the general westerly flow of the monsoon season over Jodhpur bringing in an easterly current and causing a convergency with the westerlies over Jodhpur resulting in thundershowers over the place.

West Rajasthan is a sub-division where monsoon advances last, by middle of July but withdraws first, by the beginning of September. The annual rainfall for the sub-division is 31·1 cm only. It is semi-arid and susceptible to high variability of rainfall. The value of the coefficient of variation of annual rainfall is as high as about 70 per cent for west Rajasthan. The position of the axis of the monsoon trough in the sub-division is also not favourable for good rainfall activity, because it runs from northern parts of Rajasthan and adjoining Punjab and Haryana to the head Bay and lies more frequently to the north of its "normal" position than to the south. Monsoon activity increases only under the influence of some synoptic

system. Thus weak monsoon conditions prevail over west Rajasthan during nearly two thirds of the monsoon period and is the predominant feature of the season for the sub-division. In the light of these adverse circumstances, arising out of the weak monsoon conditions any phenomenon that may cause even a slight increase in rainfall for west Rajasthan is very important and needs closer study.

A survey of the synoptic systems affecting northwest India during southwest monsoon indicates that active monsoon conditions prevail over northwest India (Rao *et al.* 1970) in association with—

(*i*) approach and movement of monsoon depressions/low pressure areas into the region,

(*ii*) intensification of the seasonal monsoon trough or its shift towards foot of the Himalayas, and

(*iii*) disturbances in the middle latitude westerlies moving from west to east across the estreme north of the country.

But an analysis of the percentage of various active monsoon days over northwest India associated with each of the 3 synoptic situations mentioned above, shows that lows/depressions and their movement and approach towards west Rajasthan contributes a large percentage of synoptic situations causing active monsoon conditions over the sub-division. Occurrence of weather due to a system over or near Rajasthan is a well-known feature. But this aspect of the movement of the systems from the east and their influence on the weather over west Rajasthan even when there is some intervening distance between them is very significant in view of the fact that Rajasthan is a semi-arid area with scanty annual rainfall. In the present paper, this effect has been studied.

2. Data

Data for the 20-year period 1956-1975 for the months July and August for west Rajasthan have been carefully analysed so as to see whether any increase in distribution of rainfall took place in the sub-division in association with a system to the east. July and August have been chosen for the study since they are the months when Rajasthan is under the sweep of the monsoon current. Those occasions when the rainfall increased due to a system over or near west Rajasthan have been excluded. Table 1 gives the list of all the monsoon depressions that crossed Orissa coast during the period 1956-75 (July and August) and their effect on the weather over west Rajasthan. Data for the distribution of rainfall have been collected from the Weekly Weather Reports and the Indian Daily Weather Reports.

It is important to note that on 70 per cent of the occasions, distant effect of monsoon depression/lows over weather in west Rajasthan is seen.

The different cases listed in the table where rainfall occurred in atleast 50 per cent of the stations in the sub-division are presented below in slightly greater detail.

(*a*) A shallow depression developed in the Bay on 3 July 1959 with its centre near 19·5°N and 89·0°E. It moved westwards and crossed the Orissa coast between Puri and Gopalpur by midnight of 4-5 July. Weakening as it moved westwards and then northwards, it lay as a low over Punjab and adjoining parts of west U. P. on 8 July.

The rainfall distribution for the week 2-8 July for west Rajasthan is given below. (Sc and L denote scattered and local rainfall respectively).

Jul 2	3	4	5	6	7	8
—	Sc	—	—	L	L	Sc

It is important to note that west Rajasthan was dry on 4 and 5 July while on 6 and 7 July, 50 per cent of the stations in the sub-division received rainfall.

(*b*) A low pressure area developed over northwest angle of the Bay in the evening of 29 June 1960. By next morning it concentrated into a depression with central region about 150 km east of Chandbali. Intensifying further, it lay as a deep depression centred about 100 km eastnortheast of Puri on the morning of 2 July. Crossing the Orissa coast on 2nd evening, it moved westnorthwestwards and weakened. It merged into the seasonal trough over the Gangetic plain by 5th morning.

The rainfall distribution for west Rajasthan for the week 30 June to 6 July is as follows :

Jun 30	Jul 1	2	3	4	5	6
—	Sc	—	L	L	L	Sc

TABLE 1

S. No.	Year	Total No. of depressions crossing Orissa coast during July and August	Week during which the disturbance occurred	Effect of the depression over weather in west Rajasthan after crossing coast	Remarks—whether distant effect is seen or not
1	1956	1	28 Jun-4 Jul	Sc Rainfall	Seen
2	1957	*Nil*			
3	1958	1	17-23 Jul	Sc Rainfall	Do.
4	1959	1	2-8 Jul	Local Rainfall	Do.
5	1960	1	30 Jun-6 Jul	Local Rainfall	Do.
6	1961	3	29 Jun-5 Jul	Sc Rainfall	Do.
			20-26 Jul	Sc Rainfall	Do.
			24-30 Aug	Sc Rainfall	Do.
7	1962	1	12-18 Jul	Local Rainfall	Do.
8	1963	3	24-30 Jul	No increase in rainfall	Not seen
			8-14 Aug	Local Rainfall	Seen
			15-21 Aug	Isol. Rainfall	Do.
9	1964	5	2-8 Jul	Sc Rainfall	Do.
			6-12 Aug	No increase in rainfall	Not seen
			13-19 Aug	Sc Rainfall	Seen
			20-28 Aug	Isol. Rainfall	Do.
10	1965	3	15-21 Jul	Fw	Do.
			22-28 Jul	No increase	Not seen
			19-25 Aug	Isol. Rainfall	Seen
11	1966	*Nil*			
12	1967	*Nil*			
13	1968	*Nil*			
14	1969	2	11-16 Jul	Sc	Seen
			31 Jul-6 Aug	Mainly dry	No increase in rainfall
15	1970	1	23-29 Jul	No increase	Not seen
16	1971	*Nil*			
17	1972	*Nil*			
18	1973	2	5-11 Jul	No increase	Do.
			12-18 Jul	No increase	Do.
19	1974	2	13-19 Jul	No increase	Do.
			8-14 Aug	Isol. Rainfall	Seen
20	1975	2	14-20 Aug	Fw Rainfall	Do.
			21-27 Aug	No increase	Not seen

Sc—scattered; Isol—isolated; Fw—fairly widespread

West Rajasthan had a marked increase in rainfall on 3 and 4 July due to the system to the east-crossing the Orissa coast on 2nd evening.

(*c*) A low pressure area developed over the head Bay on 8 August 1963. It concentrated into a depression with centre at 0830 IST on 8 August within half a degree of Lat. 20·5°N and Long. 89·5°E. It moved inland and lay centred at 0830 IST on 10 July at about 50 km west of Midnapur.

Rajasthan was mainly dry on 8th, 9th and 10th but as recorded at 0830 IST of 11 July, 50 per cent of the stations in the sub-division received thundershowers. Ganganagar continued to receive 4 cm of rain on 11th also.

(*d*) A well marked low pressure area developed in the head Bay on 3 July 1964. It concentrated into a depression and became deep and lay at 0830 IST on 4 July within half a degree of Lat. 21·5°N and Long. 89°E. It crossed Orissa coast between Chandbali and Contai and weakened and lay as a depression at 0830 IST of 5th, 100 km west of Ranchi and on 6th, 50 km to the southeast of Allahabad. Weakening further, it merged with the seasonal low on 8 July.

Rajasthan was dry on 3 and 4 July but as reported on 5th morning Bikaner had 0·5 cm of rainfall and Phalodi 1·6 cm. The rainfall continued to be scattered upto 7 July.

(*e*) A cyclonic circulation over the head Bay formed on 13 August 1964 extending upto 5 km. Under its influence, a depression formed over northwest angle of the Bay with centre near Lat. 20·5°N and Long. 87·5°E at 0830 IST on 15 August. Moving northwest, it crossed the Orissa coast near Balasore on 15th evening. On 16th, 0830 IST, it lay over Bihar plateau and adjoining northeast M.P. It weakened into a low pressure on 18th and merged with the seasonal trough. Rajasthan was mainly dry on 15th and 16th but as reported at 0830 IST on 17th, Barmer received 1·1 cm of rainfall and Jodhpur had 0·3 cm. The rainfall continued on 17th also and as reported at 0830 IST of 18th, Ganganagar had received 1·6 cm and Jodhpur 9·3 cm.

(*f*) A well marked low pressure area formed over northwest Bay and adjoining parts of Gangetic West Bengal and Orissa coast on 12 July 1965. It concentrated into a depression on 13th at 0830 IST near Lat. 19·5°N and Long. 87·5°E. It moved slowly westwards and intensified into a deep depression and was centred at 0830 IST on 14th within half a degree of Lat. 19°N and Long. 85·5°E. It moved westwards and crossed Orissa coast near Gopalpur and was centred at 0830 IST on 15th near Lat. 19·5°N and Long. 81°E. On 16th it lay over west M.P. and the system merged with the seasonal trough on 17th. West Rajasthan was dry upto 15th but on 16th rainfall was isolated and on 17th, it was Fw with Ganganagar receiving 2·1 cm, Jodhpur 1·2 cm and Barmer 5·1 cm. There was a marked decrease in rainfall as reported on 18th (0830 IST) with only Barmer reporting 0·8 cm of rainfall.

(*g*) A low pressure area formed over north Bay of Bengal on 25 July 1965. It concentrated into a depression centred at 0830 of 26th within half a degree of Lat. 21°N and Long. 89·5°E. It intensified into a deep depression and was centred at 0830 of 27th within half a degree of Lat. 21°N and Long. 88·0°E. It crossed north Orissa coast near Balasore on 27th evening and was centred at 0830 of 28th about 30 km eastsoutheast of Jamshedpur. It lay as a low pressure area over Bihar on 29th.

The rainfall distribution in Rajasthan was isolated from 23rd to 28th but became Fw as the depression crossed the Orissa coast with Ganganagar getting 2·05 cm, Bikaner 1·7 cm, Jaipur 1·3 cm, Phalodi 0·2 cm and Barmer 2·6 cm.

(*h*) A low developed over the north Bay on 16 August 1975. It concentrated into a depression on 17th, became deep on 18th with its centre close to Contai. It moved northwest crossing the north Orissa and adjoining West Bengal coast and lay at 0830 of 19th over west Bihar and neighbourhood with its centre between Delhi and Daltonganj.

West Rajasthan had Fw rainfall on 18th as reported on 19th at 0830 IST.

3. Analysis

The last synoptic situation has been selected for a detailed study of the phenomenon. The relevant Weekly Weather Reports, Indian Daily Weather Reports, and the actual working charts of both Colaba and Santacruz were analysed. The salient features of the situation are as follows :

(*i*) *16 August 1975 (0830 IST)*

A low pressure area formed over north Bay of Bengal on 16 August 1975 with associated upper air cyclonic circulation extending upto 5·8 km. The axis of the monsoon trough on the sea level chart passed through Bikaner, Gwalior, Balia, Asansol and thence through Balasore and dipping into the head Bay.

The 24-hr pressure tendencies were positive for west Rajasthan.

(*ii*) *17 August 1975 (0830 IST)*

The low pressure area concentrated into a depression and lay centred at 0830 on 17th near Lat. 17°N and Long. 89·0°E. The axis of the monsoon trough at 0·9 km passed through Bikaner, Sultanpur, Gaya and Contai while at 700 mb, it passed through Sandheads, Jodhpur and Naliya. The 24-hr pressure tendencies were positive.

(*iii*) *18 August 1975 (0830 IST)*

The depression became deep on 18th morning. It lay over north Orissa coast with its centre

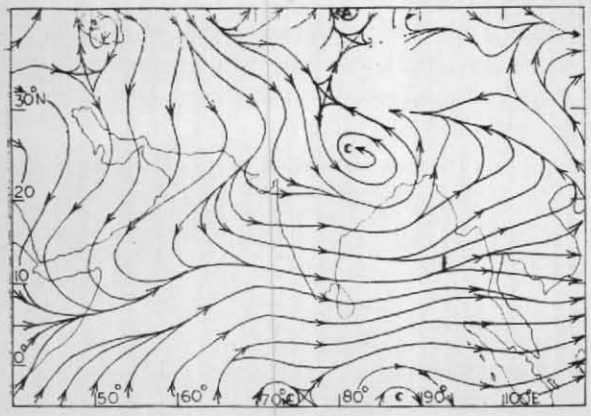

Fig. 1. Normal—August (700 mb)

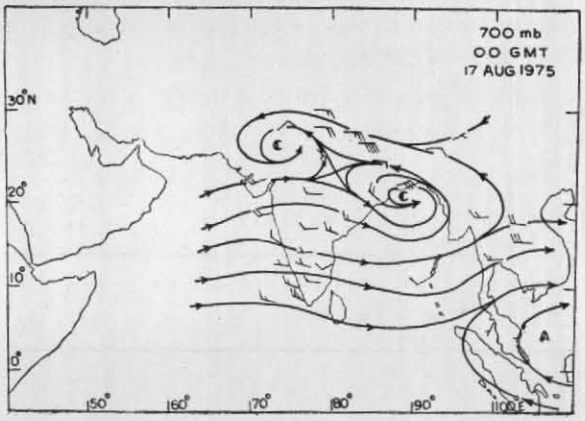

Fig. 2

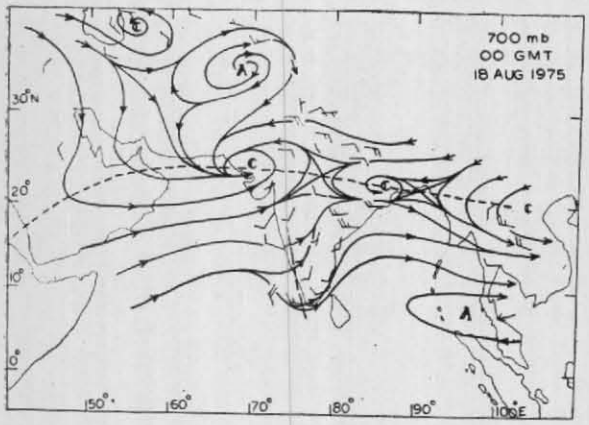

Fig. 3

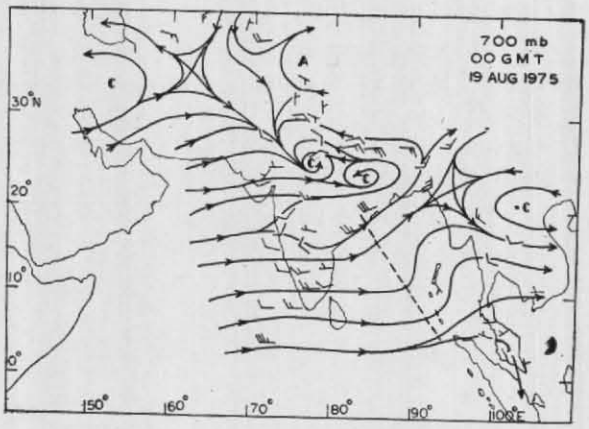

Fig. 4

near Contai and associated cyclonic circulation extending upto 9·5 km. The axis of the monsoon trough on the sea level chart passed through Anupgarh, Banda, Jamshedpur and thence through the centre of the depression. At 700 mb the trough line passed through Dwarka, Ahmedabad, Saugor and Balasore. The 24-hr pressure tendencies were still positive. It is significant to note that the trough line at 700 mb has started shifting southwards bringing west Rajasthan into the zone of convergence between the seasonal westerlies and the moist easterlies. Phalodi reported 5 cm rainfall.

(*iv*) *19 August 1975*

The deep depression moved northwestwards and lay over Bihar Plateau with its centre between Dhanbad and Ranchi, with associated upper air cyclonic circulation extending upto 7·6 km a.s.l.

The axis of the seasonal trough at sea level passed through Gangapur, Agra, Allahabad and thence through the centre of the depression. At 700 mb, the trough line passed through Anupgarh, Jaipur, Saugor and Ambikapur.

The rainfall recorded at 0830 IST of 19th was Fw for the subdivision with Bikaner getting 3·6 cm, Ganganagar 0·6 cm, Jodhpur 0·4 cm and Phalodi 0·2 cm. The 24-hr pressure tendencies were negative for most of the stations in the sub-division.

(*v*) *20 August 1975*

The deep depression lay over west Bihar State and adjoining northeast Madhya Pradesh and southeast Uttar Pradesh with centre at 0832 IST of 20th between Daltonganj and New Delhi with associated upper air cyclonic circulation extending upto 7·6 km. The axis of the seasonal trough on the sea level chart passed through Ganganagar, Banda, centre of the depression and thence through Calcutta. The trough line on the 700 mb chart moved northwards.

Pressures started increasing and the rainfall in the sub-division was scattered as reported at 0830 IST on 20 August.

Table 2 gives the spatial distribution of rainfall over west Rajasthan for the week 14 to 20 August 1975.

TABLE 2

Aug. 1975	14	15	16	17	18	19	20
Rainfall	Sc	Sc	Sc	Sc	Sc	Fw	Sc

It is significant to note that—

(*a*) The rainfall activity over west Rajasthan from 14th to 17th is in association with a system near and over west Rajasthan which merged with the seasonal low on 18th and became unimportant.

(*b*) 50-75 per cent of the stations in west Rajasthan received rainfall on 18th as reported at 0830 IST on 19th as the depression crossed the Orissa coast and started moving in a westnorthwesterly direction.

(*c*) The midtropospheric trough line at 700 mb shifted to a more southerly position during 18th and 19th morning extending the zone of convergence to west Rajasthan in the vertical.

Figs. 1, 2, 3 and 4 illustrate this feature.

(d) There is no apparent change in the position of the axis of the monsoon trough on the surface chart. Circulation patterns above 500 mb also do not show any change.

(*e*) With the northward shift of the midtropospheric trough line on 19th, the rainfall activity has again decreased during 19th-20th over west Rajasthan.

5. Conclusion

Similar studies of the other synoptic situation mentioned above, also decisively prove that monsoon depressions do exert a pronounced influence on the rainfall activity over west Rajasthan, whenever they cross Orissa coast and move in northwest/westernorthwesterly direction. It is apparently due to the fact that these depressions extending upto the middle troposphere act upon the circulation pattern on a bigger scale and bring about a southward shift of the midtropospheric trough line and a lowering of the zone of convergence to extend over west Rajasthan resulting in increased rainfall activity for the sub-division. The effect is not so clearly found at lower levels nor at levels above 500 mb level.

REFERENCES

Sinha, K. L.	1958	*Indian J. Met. Geophys.*, **9**, pp. 251-254.
Rao, M. S. V., Srinivasan, V. and Raman, S.	1970	Forecasting Manual, No. III. 3.3, pp. 7-8. India met. Dep. Publ.

DISCUSSION

(Paper presented by Smt. B. Shyamala)

K.N. RAO : In connection with this paper, the following monthly rainfall inter-correlations between Orissa and the western sub-divisions may be of interest.

Sub-division	CCs between Orissa and sub-divisions in Col. 1 (1901-50)				Average rainfall (cm) (1901-50)			
	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
West Rajasthan	.42	·35	·61	·33	3	10	11	4
East Rajasthan	·63	·35	·60	·51	7	24	23	11
West Madhya Pradesh	·80	·42	.61	·64	13	35	29	18
Gujarat region	·23	·28	·61	·59	13	40	24	16
Saurashtra and Kutch	·29	·39	·51	·47	7	21	10	7
Orissa					21	35	34	24

August rainfall CCs between Orissa and the western sub-divisions is of the order of 0·6 (except for Saurashtra and Kutch). July rainfall CCs are significantly lower.

The data used in the paper cover a period of 20 years and analysis for a longer period seems necessary for finding stabler probability values.

Monthly correlations unless very high, do not reflect short period association. There is, therefore, no variance between the results in the paper and the table. The table adds information on how the correlations vary when periods of a month are considered and rainfall amounts of sub-divisions (utilising data of all raingauges in each of the sub-divisions) are correlated.

It has been our experience in studies on long-range forecasting that significant short period correlations are not often maintained and there have been changes in sign too, when data for longer periods are considered.

AUTHOR : The remarks regarding a low correlation coefficient in the months of July and a fairly high correlation coefficient in the month of August agree well with our findings. But it may be mentioned here that a high mean monthly correlation coefficient does not necessarily indicate the simultaneous occurrence of the two events since it can even mean that in August, depressions affect Orissa coast first and west Rajasthan subsequently. Similarly a low coefficient in the month of July can mean that the depression affect Orissa but not west Rajasthan.

The purpose of our study was completely different — to establish the simultaneous occurrence of rainfall in Orissa and west Rajasthan, *i.e.*, as Orissa is affected by the depressions crossing the coast, simultaneously west Rajasthan is also affected although it is about one thousand km away from the system.

Analysis of 20 year data also, can provide useful hints to the synoptician in forecasting. Of course a longer period analysis will naturally increase his confidence.