Mausam, (1987), **38**, 1, 49-52

551.553.21 (545 : 547)

On development of a monsoon low over northwest India

S. K. GHOSH, K. PRASAD and S. K. SAHA

Meteorological Office, New Delhi

(*Received 20 February 1985*)

सार — जुलाई 1978 के दौरान राजस्थान और उसके आस पास मानसून निम्न दाब क्षेत्र के असामान्य निर्माण और उसकी असामान्य गतिविधि के मामले की जांच की गई है। निम्न दाब के विकास की रचना, उसकी ऊर्ध्वाधर संरचना और इससे सम्बन्ध वर्षा विशिष्ट मानसून अवदाब के समान है। यह विकास तब हुआ जब जम्मु और कश्मीर क्षेत्र से एक मध्य क्षोभमण्डलीय भ्रमिल दक्षिण दिशा की ओर बढ़ा और वह खाड़ी में अवदाब की गतिशीलता के कारण राजस्थान में गतिशील मानसून द्रोणी पर अधिस्थापित हो गया।

निम्न दाब, मध्य क्षोभमंडलीय भ्रमिल के नीचे की ओर फैलाव के रूप में इस ढंग से विकसित हुआ जो बंगाल की खाड़ी के शीर्ष पर विशिष्ट प्रकार के मानसून अवदाब की संरचना से मिलता जुलता था। निम्न दाब क्षेत्र के कारण राजस्थान में अत्याधिक वर्षा हुई। निम्न दाब आरम्भ में पूर्व दिशा की ओर असामान्य रूप में अग्रसर हुआ जिससे यह आभास हुआ कि यह मात्र पश्चिमी विक्षोभ हो, फिर पश्चिमी दिशा की ओर, और अन्त में दक्षिण-पश्चिमी दिशा की ओर अग्रसर हुआ। इस गतिशीलता का, उस क्षेत्र में ऊपर 200 मि. बार प्रवाह के संदर्भ में परीक्षण किया गया है।

ABSTRACT. A case of an unusual formation of a monsoon low pressure area over Rajasthan and neighbourhood during July 1978 and its unusual movement is investigated. The mechanism of development of the low, its vertical structure and the associated rainfall resemble a typical monsoon depression. Development took place when a mid-tropospheric vortex moved in a southerly direction from the Jammu & Kashmir region and was superposed on the monsoon trough which had moved into Rajasthan due to movement of a Bay depression. The low developed as a downward propagaton of the mid-tropospheric vortex in a manner resembling the formation of a typical monsoon depression over the head Bay of Bengal. The low pressure area caused excessive rainfall over Rajasthan. The low showed an unusual movement initially in an easterly direction giving the impression of being a western disturbance, then in a westerly direction and finally in a southwesterly direction. The movement is examined with reference to the 200 mb flow over the area.

1. Introduction

Usually, during the southwest monsoon season low pressure systems (monsoon lows/depressions) develop over north Bay of Bengal and move across northern and central parts of the country in some westerly direction. The low pressure systems are also known to develop in the monsoon trough over land areas and behave like their counterparts originating from Bay of Bengal. These are termed as land lows/depressions. Formation of monsoon lows/depressions over land is comparatively much less frequent. This type of lows usually form over land north of 22° N, mostly over Bihar, north Madhya Pradesh and south Uttar Pradesh. Their mode of formation is similar to the 'induced lows' in winter season, under the influence of troughs in middle latitude westerlies at mid and upper-tropospheric levels. Such lows develop on surface about 3 to 5 degrees longitude to the east of 500 mb trough. These lows tend to dissipate when the westerly system at higher latitudes moves away eastwards. Life period of these lows is about 2-3 days. The systems show slow movement eastward (Rao 1967). Rao *et al.* (1970) have reported one such case of the development of a sea level low over Punjab and Haryana under the influence of a westerly trough in July 1967. The role of extratropical wave disturbances in the development of monsoon depressions over Indian region has also been reported by some other workers (Sen Gupta 1971, Veeraraghavan & Ghosh 1974, Prasad and Krishna Rao 1974).

In this paper an interesting case of the formation of a well marked low pressure area over Rajasthan and neighbourhood has been studied. The mode of formation, life period and movement of this low was entirely different from the usual 'induced low' type of formation ahead of a sinusoidal wave trough. The low developed over north Rajasthan on 18 July 1978 as downward propagation of a mid-tropospheric extratropical vortex much like the formation of a monsoon depression in Bay of Bengal. The mid-tropospheric vortex had moved from higher latitudes southward into north Rajasthan, where the monsoon trough had extended due to synchronous movement of a Bay depression into the area. The low pressure area moved erratically, initially in an easterly direction for some time, turned back westwards, and then moved southwest. Track of the low is shown in Fig. 1. The low pressure area caused heavy rainfall activity over Rajasthan and neighbourhood from 19 to 22 July upto 22 cm in a day.

Of particular interest in this study is the mechanism of formation of the low pressure area and its unusual movement.

2. Synoptic situation leading to the formation of low pressure area over Rajasthan

A depression moving from the Bay of Bengal passed across Rajasthan on 14 and 15 July 1978 and weakened into a feeble low pressure area over adjoining north

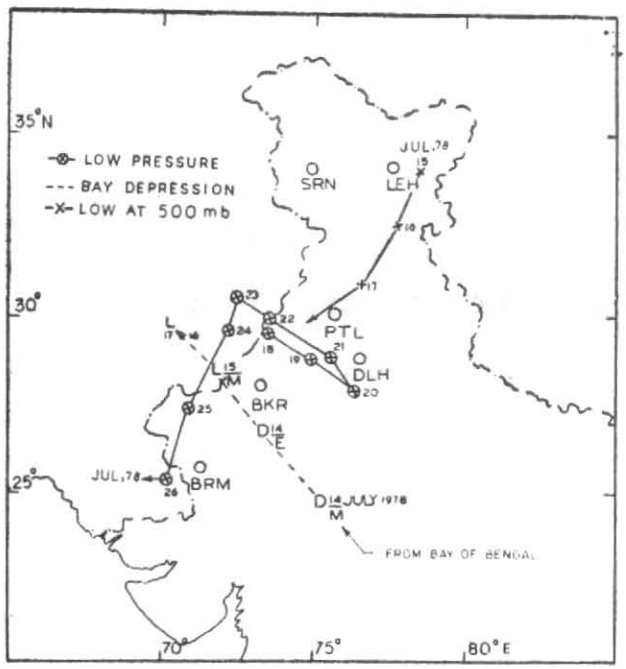


Fig. 1. Tracks of low (surface & 500 mb) and Bay depression

Pakistan, persisting there on 16 and17 July (Fig. 1). Due to the movement of this Bay depression northwestward the monsoon trough also shifted northward into the region.

A mid-tropospheric vortex appeared over the Ladakh area on 15 July 1978, centred around 35°N, 78°E. The vortex moved southsouthwestward during the subsequent three days. On 18 July the vortex lay over extreme north Rajasthan and adjoining Punjab and Haryana, centred around 30°N, 75°E. 500 mb charts from 15 to 18 July are shown in Fig. 2. From these charts it is clear that the vortex moved south as depicted in Fig. 2(d).

A low pressure area developed on sea level over north Rajasthan with its central region near Ganganagar on 18 July, near about the same location where the mid-tropospheric vortex lay [Fig. 2(d)]. The low moved southeast and became well marked on 19th, located about 90 km southwest of Hissar. It moved further southeast to be centred near Alwar on 20th. From this point it turned back moving northwestward upto 23 July. From there it took a southwesterly course, reaching west of Barmer on 26th. It filled up later. The surface charts from 18 to 26 July 1978 are presented in Fig. 3.

The circulation associated with the low was extending upto the mid-tropospneric levels throughout its life history, extending even higher on 20th.

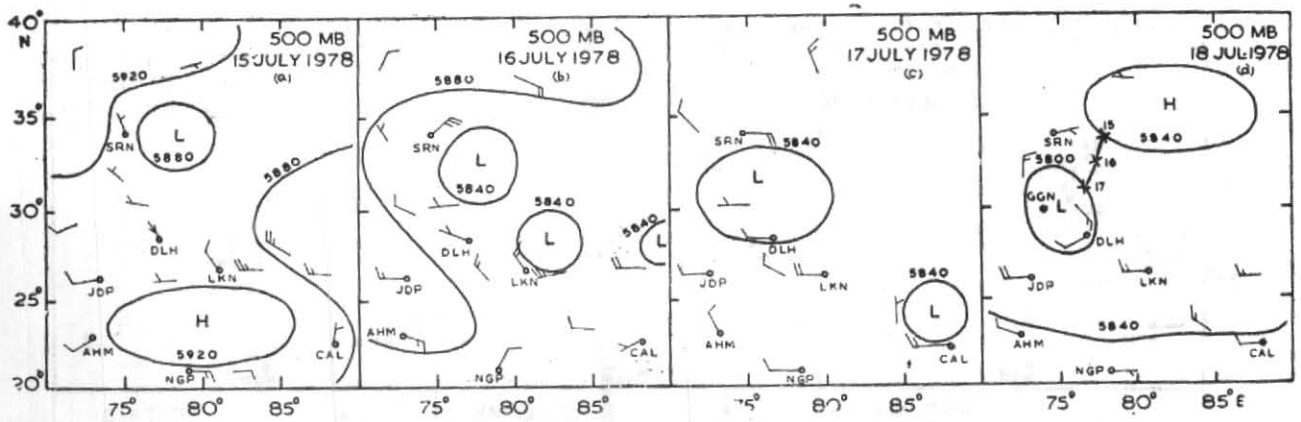
3. Discussion

It is evident from above that the formation of low pressure area under consideration over north Rajasthan took place as a downward propagation of the mid-tropospheric vortex over an area of pre-existing monsoon trough. Development on sea level took place when the mid-tropospheric vortex moving south from the higher latitudes was superposed over the trough. Mechanism of development resembled the formation of monsoon depressions over Bay of Bengal in a large number of cases, where a vortex first appears in middle troposphere and gradually builds up downwards.

The low pressure area, after formation, moved initially in an easterly direction against the westward movement normally followed by the monsoon low pressure systems, leaving aside the cases of recurvature. The eastward movement continued for two days. A low moving in an easterly direction over this part of the country would give an impression of it being a western disturbance to a synoptician. This tendency has, in fact, been observed in this particular case, where the low has been described as a western disturbance in the official publication (*Indian Daily Weather Report*). A closer examination of the vertical structure of the low and the thermal field around it, however, confirmed that the low was a monsoon low and did not possess any characteristics of a western disturbance. Upper air charts for 850, 700 and 500 mb levels composited together for 20 and 21 July are shown in Fig. 4(a). The RS/RW stations Delhi, Patiala and Jodhpur were within the field of influence of the low on these two days. It may be seen that the winds at Delhi and Patiala which are located to the east and north of the low are gently backing with height from 850 to 500 mb, while winds at Jodhpur, which is located to the west of the low centre are gently veering with height. This suggests a gentle slope of the low southward with height. The southward slope with height is characteristic of monsoon disturbances. A look at the temperature field around the low centre would show that the low pressure area has no well defined thermal core at any level.

It would appear from the foregoing facts that the low pressure area, which developed over north Rajasthan on 18 July 1978 was a monsoonal type of low, developing within the monsoon trough region and had no extratropical characteristics through the low developed basically under the influence of an extratropical system.

The movement of the low pressure in this case was very unusual. The synoptic explanation for the peculiar movement is not easy. Nevertheless, an attempt has been made to look into the possible causes of the erratic movement. It is known that the movement of the monsoon low pressure areas/depressions in India is guided by the basic upper easterly flow which prevails to the south of the subtropical anticyclone over Tibet in this season. Cases of unusual behaviour of the monsoon lows/depressions have been reported, where the upper steering flow gets distorted due to shifting of the subtropical ridge line southward, pushed by a westerly wave moving across to the north of the country (Prasad and Sen Sarma 1978). The 200 mb flow overlying the low pressure area was, therefore, examined to see if any such situation prevailed during the period. 200 mb level was chosen because the flow at lower levels 300 and 250 mb was occasionally disturbed by the circulation of the low. 200 mb winds at Delhi and Patiala at the nearest RS/RW stations in the field of the low from 18 to 25 July 1978 are shown in Fig. 4 (b). It is seen that the 200 mb



Figs. 2(a-d). 500 mb charts from 15 to 18 July 1978

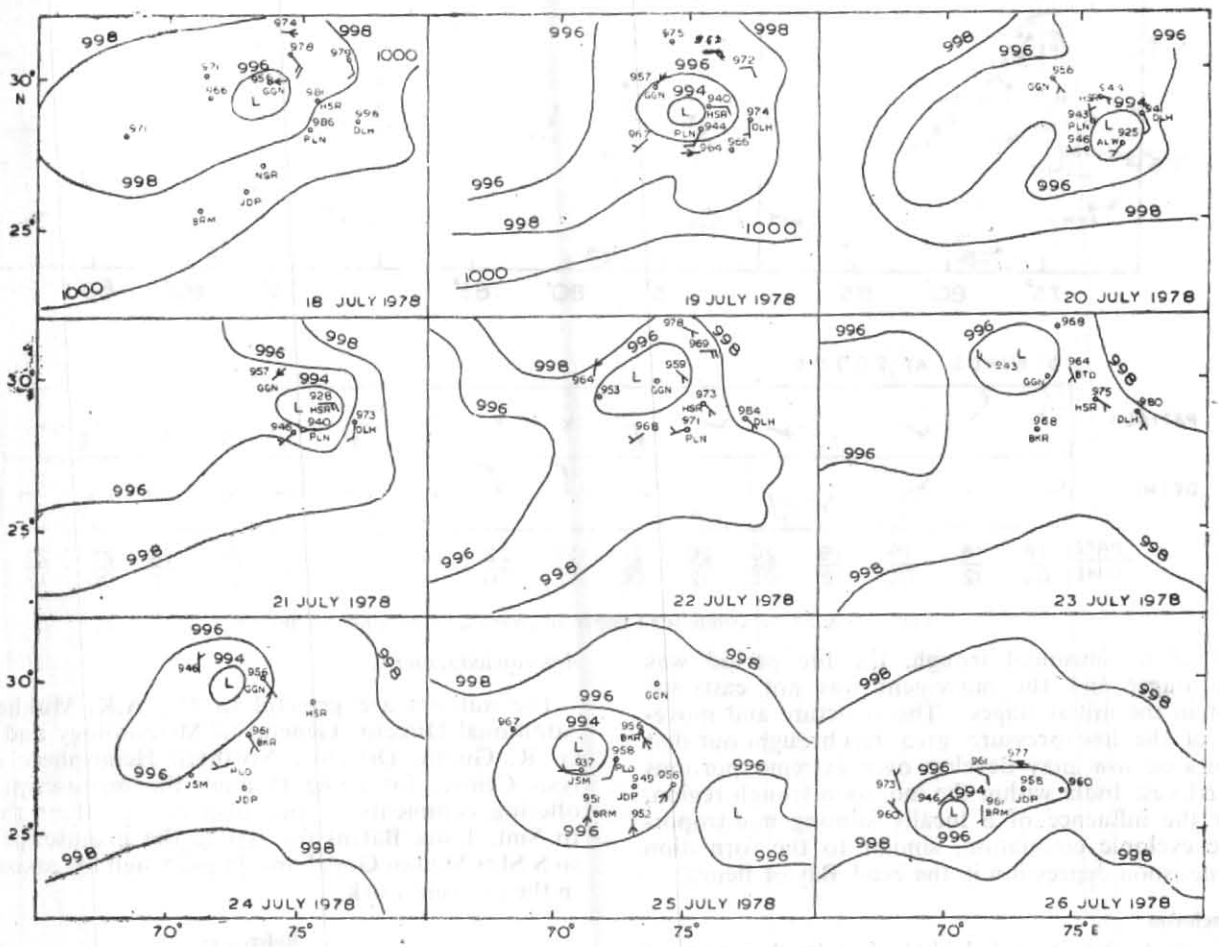
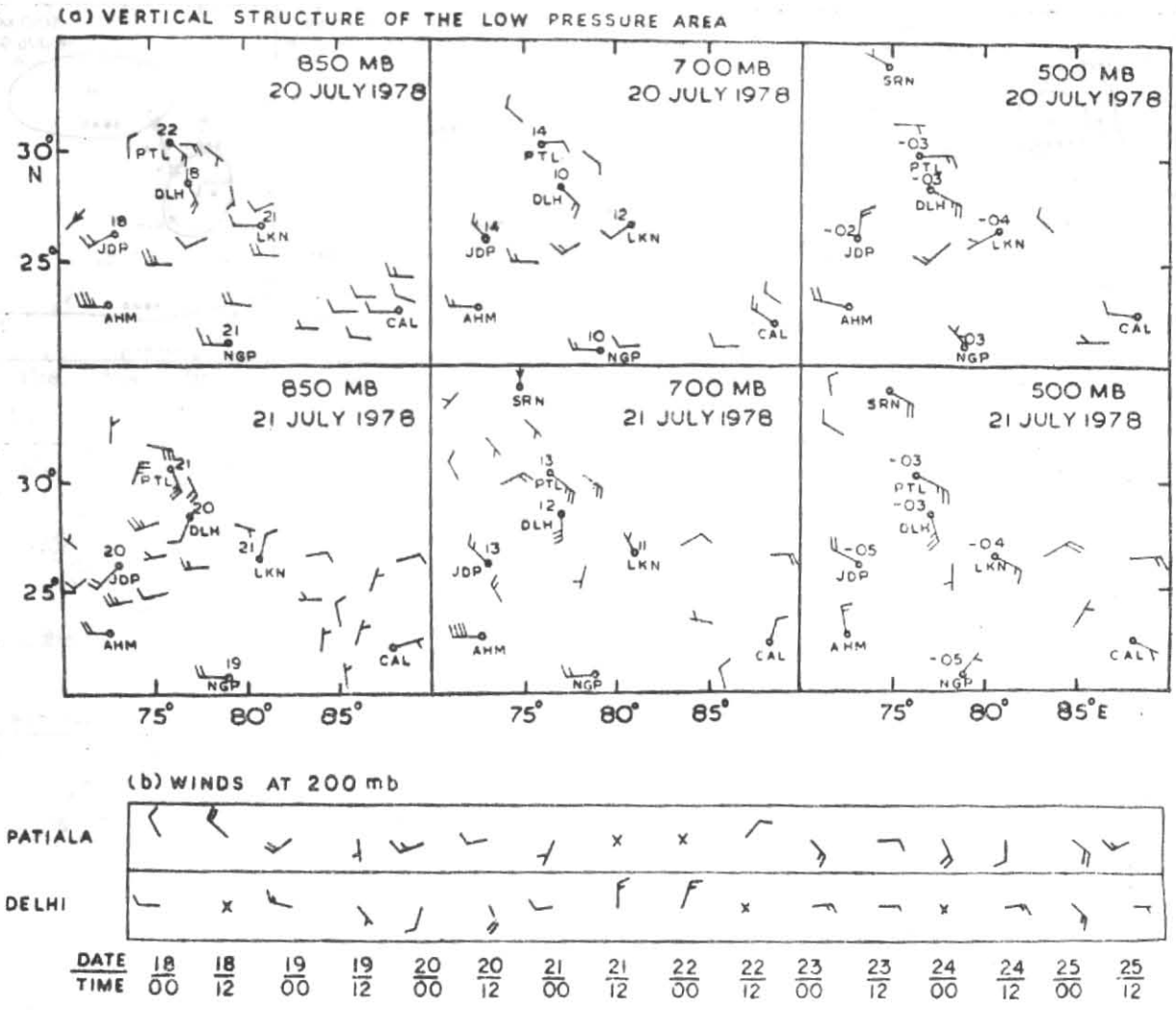


Fig. 3 Surface charts, 18-26 July 1978

winds from 18/00 GMT to 19/00 GMT are from a westerly direction at Delhi and Patiala both, signifying that the 200 mb ridge was passing south of Delhi. From 19th evening to 22nd evening the ridge was meandering between Delhi and Patiala latitudes passing over the low level circulation as evident from the changes in winds. From 23/00 GMT onward a perceptible change occurred in the position of the anticyclone, which shifted to its normal position over Tibet. This is evident from the steady winds between easterly to southerly direction at Delhi and Patiala after 23rd.

The low was very close to the upper tropospheric ridge line at 200 mb between 18 & 22 July. It has an eastward component of movement as long as the ridge line was to the south of it. As the ridge shifted north, the low reversed its course and moved westwards. The behaviour of the low upto this point was similar to the one reported by Veeraraghavan and Ghosh (1974). After 23rd when the anticyclone shifted to Tibet, the low fell in the 'Col' region between Tibetan anticyclone and the one over Iran-Afganistan area. It moved southsouthwestwards at this stage.

The above description shows that the characteristics of the low under investigation differed from the usual characteristics of an 'induced low', in that the low developed under a mid-tropospheric vortex as against



Figs. 4(a & b). (a) composited upper air charts and (b) winds at 200 mb

ahead of a sinusoidal trough, the life period was much longer and the movement was not eastward except in the initial stages. The structure and movement of the low pressure area has brought out that a monsoon low may develop over extreme portions of northwest India within the monsoon trough region, under the influence of a locally forming mid-tropospheric cyclonic circulation, similar to the formation of a monsoon depression in the head Bay of Bengal.

4. Conclusion

The study has revealed that the development of a monsoon low *in situ* as far inland as Rajasthan is possible within the monsoon trough in a manner similar to the formation of monsoon depressions over head Bay of Bengal, under the influence of a mid-tropospheric low. The vertical structure of the the system was also like a monsoon depression. The rainfall associated with the low was as intense as usually occurs with a monsoon depression. Movement of the low over this area may be unusual due to absence of a steady and well defined steering flow. A system moving eastward over this area may not always be a western disturbance and should be identified with reference to its mechanism of formation and vertical structure. A proper identification of the system and its possible motion having a westerly/southerly component is necessary for issuing heavy rainfall warnings.

Acknowledgements

The authors are grateful to Dr. A.K. Mukherjee, Additional Director General of Meteorology and Shri G. R. Gupta, Director, Northern Hemisphere Analysis Centre, for going through the manuscript and offering comments. They also convey their thanks to Smt. Usha Balani for typing the manuscript and to S/Shri Madan Gopal and Jaipal Singh for assistance in the drawing work.

References

India Meteorological Department, 1978, *Indian Daily Weather Report*, July-September 1978.

Prasad, K. and Krishna Rao, D., 1974, 'Case studies of westerly waves in the development of monsoon depressions', *Indian J. Met. Geophys.*, **25**, pp. 265-268.

Prasad, K. and Sen Sarma, A.K., 1978, 'A synoptic study of July 1971 and August 1975 floods in river *Sone*', *Indian J. Met. Hydrol. Geophys.*, **29**, pp. 752-754.

Rao, M.S.V., Srinivasan, V. and Raman, S., 1970, 'Southwest monsoon typical situations over northwest India', India Met. Dept. FMU, Rep. No. III-3.3 (September 1970), 29 pp.

Rao, Y.P., 1976, '*Southwest Monsoon*' Met. Monograph, Synoptic Meteorology No. 1/1976, 9.2.3, pp. 201-208.

Sen Gupta, S., 1971, 'Exceptionally heavy rain in and around Patna city in September 1967—A case study of mid-tropospheric interaction between an easterly wave and a westerly wave', *Indian J. Met. Geophys.*, **22**, pp. 599-600.

Veeraragahavan, K. and Ghosh, S.K., 1974, 'Unusual formation and movement of a deep depression over Rajasthan during the monsoon season', *Indian J. Met. Geophys*, **25**, pp. 399-402.