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A synoptic study of a Monsoon Depression in the month of September 1963

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(Received 27 July 1964)

ABSTRACT. Synoptic features associated with the formation, intensification and movement of a Bay depression in the month of September 1963 are discussed in this paper. A low pressure system from the east moved into the Bay of Bengal where it concentrated into a depression. This occurred immediately after the weakening of a typhoon over the South China Sea. The depression intensified, moved westnorthwestwards and recurved over north India. Recurvature of this depression could be inferred from (1) the principle of high level steering (steering level at 300 mb), (2) the shift of the 700—500 mb thickness high from west to northeast and (3) the shift of the rain belt from the west to the north of the depression centre. The recurvature was also associated with very heavy rainfall under the influence of an upper tropospheric anticyclonic flow and a trough in the westerlies. The withdrawal of the monsoon took place from northwest India immediately after the breaking up of the depression.

1. Introduction

A sea level low pressure system with its central region near 12°N, 112°E, and an associated cyclonic circulation extending upto 500 mb was located over the South China Sea off the coast of Vietnam on 1 September 1963. Moving northwestwards, it came over land by the 4th and weakened. The circulation in the upper air, however, persisted and moved slowly westnorthwestward across Cambodia and Thailand. By 7 September, a well marked low pressure area at sea level developed over the Gulf of Martaban and adjoining north Andaman Sea. Moving northwestwards this concentrated into a depression by the 9th morning with centre near 17°·5N, 92°·5E. The depression moved in a westnorthwesterly direction, and showed some intensification on the 11th. Crossing coast near Balasore on the 11th it continued its westnorthwesterly course, and was centred near 21°·5N, 88°·5E on the 12th, and near 23°·5N, 80°·0E on the 14th. Thereafter, it recurved to a northnorthwesterly direction and broke up over the Uttar Pradesh Himalayas on 15th. The track of the disturbance for a period of 15 days is given in Fig. 1.

The main synoptic features associated with the formation, intensification and recurvature of this depression, and the subsequent withdrawal of the monsoon from northwest India are discussed in this paper.

2. Synoptic features favourable for formation of the depression

2.1. *Period of active cyclogenesis*

During the first two weeks of September 1963, three tropical storms/typhoons developed over the Western North Pacific near the Mariana-Guam Islands. These were—

(*a*) *Typhoon Faye.* This was located on 1 September as a tropical storm to the west of Guam Island with centre near 12°N, 138°E. It intensified into a typhoon by 2nd and moving westnorthwestwards crossed Vietnam coast near 107°E on 8th and subsequently weakened.

(*b*) *Typhoon Gloria.* This was located on 5 September as a tropical depression over the Mariana Island area with its centre near 18°N, 140°E. Intensifying into a typhoon by the 6th and moving westnorthwestwards, it crossed the coast of China near 120°E on the 12th and weakened.

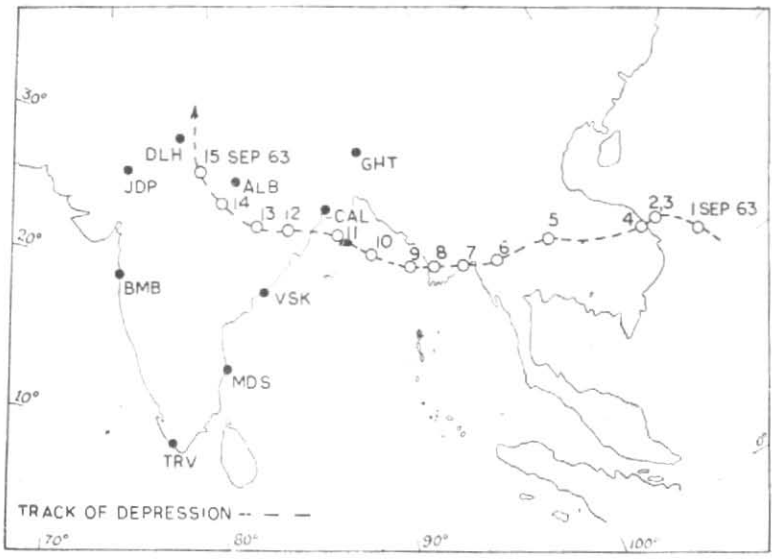

Fig. 1. Track of the depression — 1 to 15 September 1963

(*c*) *Storm Hester.* This was located as a depression on 10 September over the Mariana Islands with its centre near 16°N, 141°E. It intensified into a storm by the 11th, but subsequently weakened over the sea.

The period was thus one of considerable cyclogenetic activity over the tropical areas of the Western North Pacific.

2.2. *Systems moving from the east*

As indicated, the origin of the low pressure system was over the South China Sea or farther east in the Western North Pacific. Travelling westnorthwestwards, the system came over the Bay of Bengal and, under the favourable conditions discussed in subsequent paragraphs, concentrated into a depression and affected the northern parts of India.

2.3. *Weakening of the pressure system over the South China Sea*

The low pressure system which lay over the Gulf of Martaban and adjoining north Andaman Sea on 7th, shifted slightly westwards and concentrated into a depression over the East Central Bay between 8 and 9 September. It might be recalled that a typhoon (Faye) was moving over the South China Sea during this time; this typhoon crossed Vietnam coast on the 8th and weakened. Immediately afterwards, the system over the Bay of Bengal concentrated into a depression. The weakening of the pressure system over the South China Sea probably favoured the concentration of the disturbance to its west over the Bay of Bengal.

3. Intensification of the depression

A well marked anticyclonic circulation at 200-mb level lay over the North Bay and adjoining land areas on 10 September (Fig. 2). This high level anticyclonic outflow was favourable for the intensification of the depression by removing air ascending in the field of the depression (Dunn 1960). On 11 September, the depression showed some intensification, but by this time it was located close to Orissa Coast.

4. Recurvature of the depression

The depression had a general westnorthwestward movement upto the 14th.

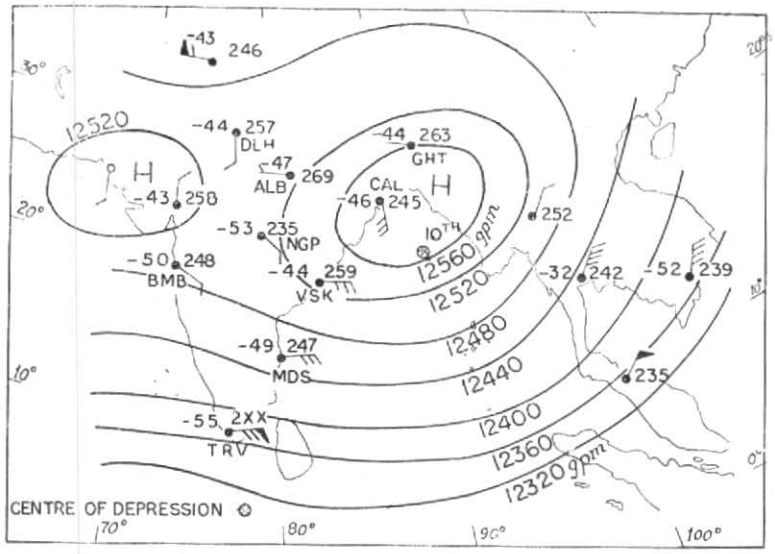

Fig. 2. Flow pattern at 200 mb at 00 GMT of 10 September 1963

The contours nave been drawn at an interval of 40 geopotential metres

Thereafter, it moved in a northnorthwesterly direction. This recurvature of the depression was one of special interest and importance from the point of view of forecasting the area of heavy rainfall.

4.1. *High level Steering*

According to the concept of 'high level steering' the wind at the steering level controls the motion of the disturbance. The steering level is defined as the height at which the cyclonic circulation associated with the system disappears (Dunn 1960). In the disturbance under study, cyclonic circulation on the 14th extended upto 500 mb. Aloft at 300 mb (Fig. 3) and also at 200 mb (Fig. 4) there were anticyclonic circulations over the sea level system. From the 300-mb flow pattern the recurvature of the depression from westnorthwest to northnorthwest could be easily inferred, whereas the 200-mb flow did not indicate any recurvature. The winds at 300 mb on 14 September afternoon (Fig. 5) of Nagpur, Allahabad and Delhi, however, became stronger southerlies compared to the morning observation, thereby suggesting further northwards steering of the depression.

4.2. *Warm tongue analysis*

Another technique in use for studying movement of tropical disturbances is the 'Warm tongue analysis'. The warm outflow from a tropical disturbance produces a belt of warm air ahead of the disturbance. The orientation of this warm tongue indicates the direction of the movement of disturbance for the next 24 hours (Dunn 1960). The thermal thickness of the 700–500 mb layer over the depression area was prepared for 13 and 14 September (Fig. 6). A thermal high (warm pool) was located to the west of depression centre on 13th. On 14th this was seen to the northeast of the centre indicating northward movement.

4.3. *Trough in mid-latitude westerlies*

On 14th at 300-mb level a trough in the westerlies lay along 72°E (Fig. 3). As already shown by Ananthakrishnan (1958) and other workers the location of this westerly trough to the northwest of the depression centre is a very favourable situation for recurvature.

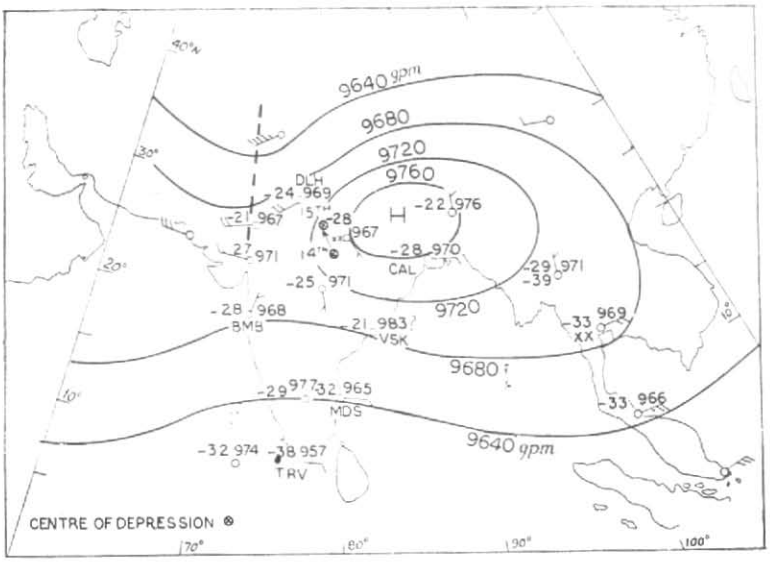

Fig. 3. Flow pattern at 300 mb at 00 GMT of 14 September 1963

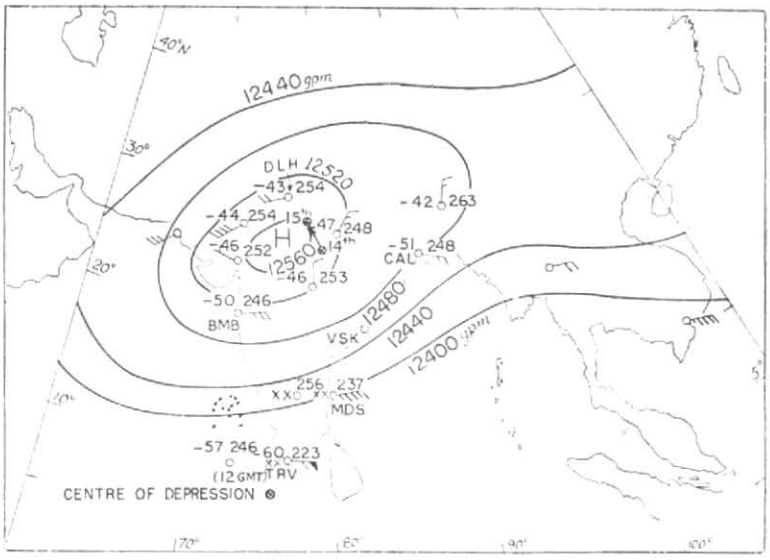

Fig. 4. Flow pattern at 200 mb at 00 GMT of 14 September 1963

In Figs. 3 and 4, the contours have been drawn at an interval of 40 gpm

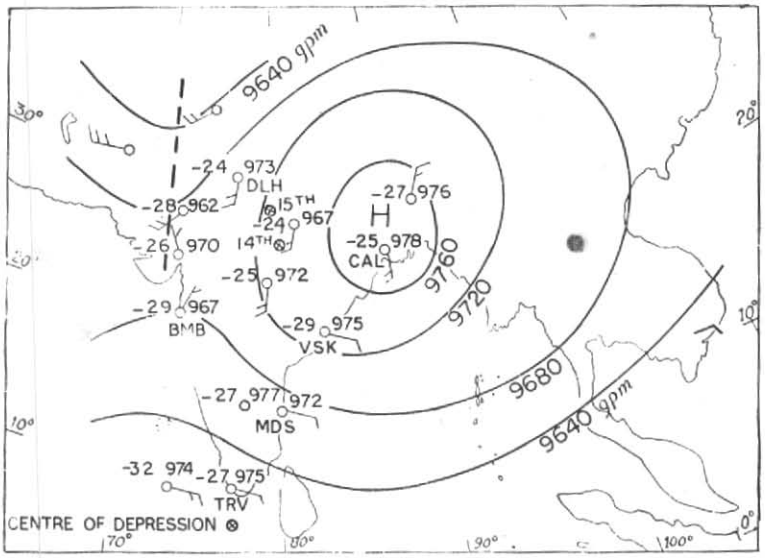

Fig. 5. Flow pattern at 300 mb at 12 GMT of 14 September 1963
The contours have been drawn at an interval of 40 gpm

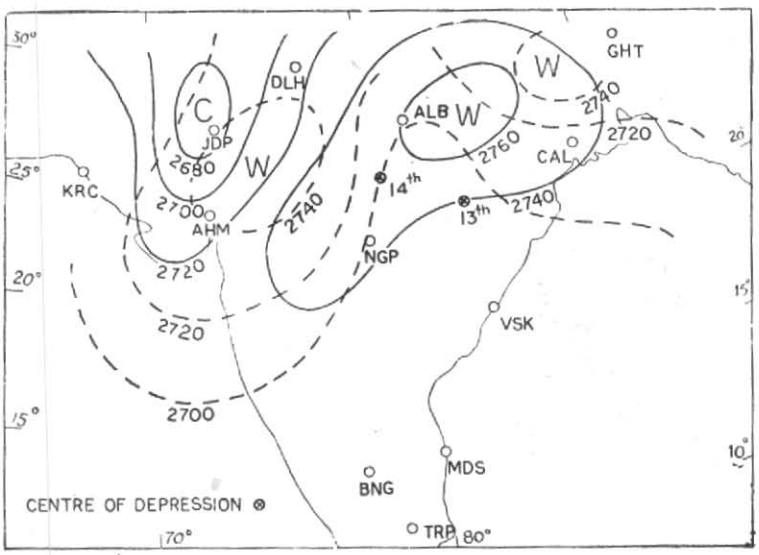

Fig. 6. Thermal thickness 700—500 mb
— — — — Thermal thickness at 00 GMT of 13 September 1963
———— Thermal thickness at 00 GMT of 14 September 1963

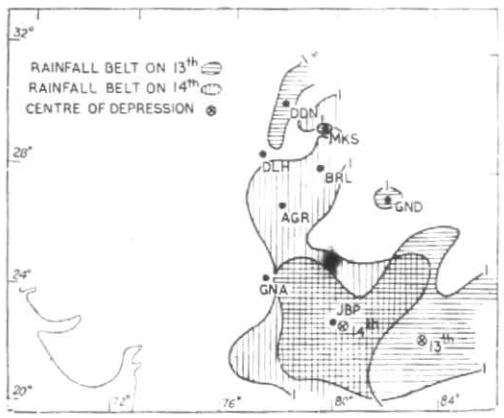

Fig. 7. Rainfall belt on 13 and 14 September 1963

4.4. *Rainfall belt*

Synoptic experience shows that the belt of heavy rainfall in westward moving monsoon depression is in the southwest sector. When the depression recurves and assumes extra-tropical features, the belt of heavy rainfall shifts to the front portion, which is to the right of the line of movement of the depression centre. The rainfall belt of amount more than 1 cm on the 13th and 14th mornings around the depression are given in Fig. 7. On 13th the rain belt was extending westwards, while on the 14th it was seen extending northwards. This shift was also indicative of recurvature.

In this connection, it may be pointed out that this depression caused exceptionally heavy rainfall during its recurvature phase on 15 and 16 September. The isohyetal patterns for the period 13 to 16 September 1963 are presented in Fig. 8. Isohyets shown are for 1 cm and above.

The anticyclonic outflow in the upper troposphere namely at 300 and 200 mb (Figs. 3, 4 and 5) helped to maintain the continued ascent of air in the field of the depression. By 15th, the depression came under the influence of the westerly trough referred to earlier in para 4·3 (Parthasarathy 1958). These factors would account for the exceptionally heavy rainfall of 15 and 16 September.

5. Withdrawal of monsoon

With the breaking up of the depression on the Himalayas the monsoon trough shifted to the foothills of the Himalayas bringing in 'break-monsoon' conditions. The upper air flow also rapidly changed. A well-marked trough in westerlies at 500 mb lay over northwest India on 16 September bringing westerlies right upto 25°N. Weather rapidly cleared over northwest India. The monsoon subsequently withdrew from the Punjab and west Rajasthan on 18 September 1963. A series of westerly troughs affected northern parts of India in quick succession thereafter.

Taking the air flow in the upper troposphere, it is found that under the influence of the trough in the westerlies, the anticyclone at 300 mb (a good approximation for the steering level) shifted eastwards. Obviously it indicates that any subsequent depression developing over the Bay of Bengal would recurve near the Head Bay, and would not affect the weather over northwest India. The 300-mb flow of 20 September (Fig. 9) brings out this feature. On 25 September 1963, a depression developed over the Bay and it recurved and broke-up over the eastern Himalayas.

6. Summary and conclusions

The disturbance under study moved into the Bay of Bengal from the east across the Indo-China Peninsula during a period of active cyclogenesis over the Western North Pacific. It concentrated into a depression immediately after the weakening of a typhoon over the South China Sea. The depression intensified before crossing coast while located directly below a 200-mb anticyclone. Its recurvature over north India was seen from (1) the principle of high level steering (300-mb flow), (2) the shift of the 700–500 mb thickness high from the west to northeast and (3) the shift of rain belt from west to north of the depression centre. The

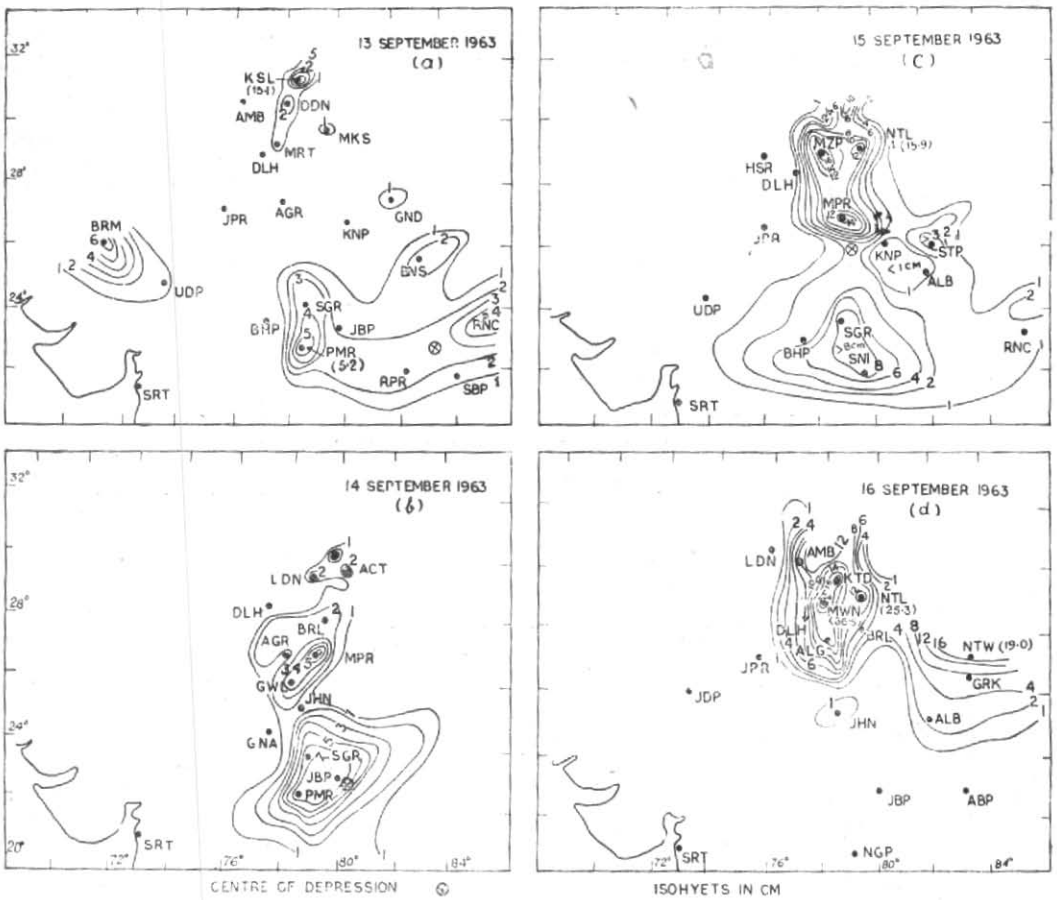

Fig. 8. Rainfall pattern for the period 13—16 September 1963

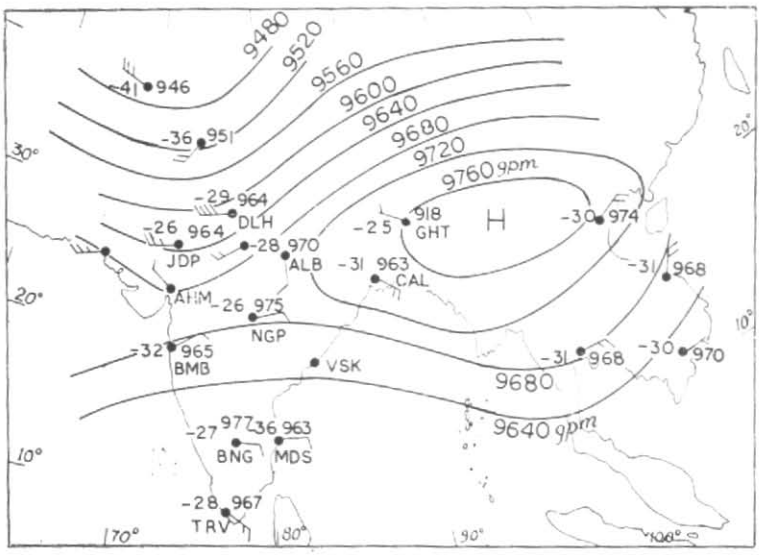

Fig. 9. Flow pattern at 300 mb at 00 GMT of 20 September 1963
The contours have been drawn at an interval of 40 gpm

depression caused exceptionally heavy rainfall (1) being located under an anticyclonic upper tropospheric flow which provided an effective mechanism for out-flow and (2) under the influence of a westerly trough. Soon after the breaking up of the depression, the monsoon withdrew from northwest India.

The monsoon depression discussed in this note revealed certain synoptic features from which different aspects of its subsequent behaviour could be forecast. Further studies of monsoon depression in the light of the above results would be useful for forecasting the movement of these depressions.

7. Acknowledgement

We are extremely grateful to Dr. P. K. Das, Director, Northern Hemisphere Analysis Centre for giving us valuable guidance and encouragement in this study. We are also thankful to Shri P. K. Raman, Meteorologist for useful suggestions in the course of this study.

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