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On the structure of monsoon low over the Bay of Bengal

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सार — 3 से 6 जुलाई 1979 तक बंगाल की खाड़ी पर और 9 जुलाई 1979 को भूमि पर मानसूनी अल्प दाब क्षेत्र की संरचना का पवन, तापमान, ऊर्ध्वाधर झुकाव, आपेक्षिक आर्द्रता, आपेक्षिक भ्रमिलता और सृति के संदर्भ में अन्वेषण किया गया है । जब 7 एवं 8 जुलाई को खाड़ी पर अल्प दाब सांद्रित होकर अवदाब में बदल गया, तब इन्हीं प्राचलों के अवदाब की संरचना का भी विश्लेषण किया गया । दोनों संरचनाओं में कुछ समताएं एवं विषमताएं देखी गई, अतः पूरी प्रणाली के सांद्रीकरण की अवधि में प्रेक्षित प्रमुख अभिलक्षणों का विवेचन किया है ।

ABSTRACT. The structure of a monsoon low over the Bay of Bengal during 3-6 July 1979 and over the land on 9 July 1979 has been investigated in respect of wind, temperature, vertical tilt, relative humidity, relative vorticity and vergence. The structure of the depression of the respective parameters was also analysed when the low concentrated into a depression on 7 and 8 July over the Bay. Certain similarities and dissimilarities between their structures have been noticed and the important features observed during the intensification of the system have been described.

1. Introduction

Out of the different synoptic systems appearing over the Indian seas and land areas during the summer monsoon season, the low pressure areas are not so intense enough as depressions or tropical cyclones. But these low pressure areas appear in the same region and the same season as the strong circulations, although the low pressure areas are rather weak systems. In a recent study by Bhattacharya and Chanda (1982), it was found that the low pressure areas have a strong potentiality for production of significant monsoon rainfall in a good number of sub-divisions in India. Earlier studies (Murakami 1976) also revealed some similarities between low and depression and suggest that under favourable conditions, the low pressure area might develop into a depression. His study was related to low pressure systems mainly over the land. During the monsoon season, the genesis of these lows generally starts over the sea areas, and their intensification from a shallow low to a well-marked low generally takes place over the sea. Due to paucity of data it is difficult to study the monsoon lows over the Bay of Bengal. The MONEX Data Set of 1979 has given the opportunity to study the low pressure system developed over the north Bay of Bengal.

The structure of monsoon depressions have been studied by a number of investigators (Krishnamurti *et al.* 1976, Godbole 1977, Sikka 1980, Shukla 1981 etc), but studies on monsoon lows are few and far between. Murakami (1978), by spectrum analysis did some studies on the monsoon lows. Sharma and Paliwal (1982), have recently investigated the mean structure of inland monsoon low. The structure of such low pressure areas over the Indian sea areas have not yet been thoroughly investigated, although reference to the low pressure areas were made in their studies on depressions. During MONEX '79 only one system in the Arabian Sea (14-18 June) and another over the Bay of Bengal (3-9 July), could be investigated thoroughly by dropsonde data. In the present study, a critical analysis of the monsoon low over the Bay of Bengal and over the adjacent land areas has been made.

2. Data

The data for the low/depression were collected from the MONEX Data Set No. 2.1 (Aircraft data) together with the aerological data for July 1979 published by India Met. Dep. Since the aircraft flights were carried out mainly during the morning hours of the day, the aerological data at 00 GMT were only utilized. In addition to these the satellite imageries were also consulted.

3. Surface features of the system

The low pressure area under study originated from a tropical disturbance over Vietnam, moved across Burma and emerged into the Bay of Bengal across Arakan coast as an upper air cyclonic circulation on 3 July 1979. During 3, 4 and 5 July the system got organised and finally on 6th it became a well marked low. From satellite imageries it was found that the cloud clusters appeared over north Bay on 3 July, increased on 5 July and continued to increase thereafter. The system concentrated into a depression on 7 July and crossed Orissa coast on 8 July. Moving

TABLE I

Date (July 1979)	Stage	Central region of low/centre of depression at sea level	850 mb: Circulation centre	850 mb: Maximum wind in Westerlies	850 mb: Maximum wind in Easterlies	700 mb: Circulation centre	700 mb: Maximum wind in Westerlies	700 mb: Maximum wind in Easterlies
3	Upper air low	—	20° N, 92½° E	W 40K 5° to the south of central region	Nil	19½°N, 92°E	W 25/30K 5° to the south of central region	NE 10K close to the central region
4	—	No drop-sonde data	—	—	—	—	—	—
5	Low	19°N, 92°E	20½°N, 92°E	W 40 K 5° to the south of central region	SE 10K 3°-4° to the north of central region	20½°N, 92°E	W 25/30K 5° to the south of central region	SE 10K 3° to the north of central region
6	Low	19°N, 90°E	19°N, 90½°E	W45K 5° to the south of central region	E 20K 1° to the north of central region	19°N, 90½°E	WSW 40K 5° to the south of central region	E 20K 1° to the north of central region
7	Dep-ression	20°N, 88°E	19½°N, 88°E	W 20K 1° to the south of centre W 30K 4° to the south of centre	ENE 35 K about 2½° N of centre	18½°N, 88°E	W 25K 2° to the south of centre, W30K 5° to the south of centre	ENE 30K about 20° N of centre
8	Dep-ression	20°N, 86½°E	19½°N, 86½°E	SW 20K close to the south of centre, 45K about 4° S of centre	NE 40K close to the north of centre, E30K 3½° N of centre	18°N, 84½°E	SW 25K about 2° S of centre	E 30K 2½° N of centre, E 40K 4½° N of centre
9	Low	22°N, 83°E	22°N, 83°E	W 30K 5° S of central region	E 15K about 3° N of central region	20°N, 79°E	W 20/25K 3° S of central region	E 15K about 2½° N of central region

Date (July 1979)	Stage	Central region of low/centre of depression at sea level	500 mb: Circulation centre	500 mb: Maximum wind in Westerlies	500 mb: Maximum wind in Easterilies	Tilt: 850—700 mb	Tilt: 700—500 mb
3	Upper air low	—	—	—	—	½°S ½°W	—
4	—	No drop-sonde data	—	—	—	—	—
5	Low	19°N, 92°E	20°N, 91½°E	W 20/25K 5° to the south of central region	—	No Tilt	½°S, ½°W
6	Low	19°N, 90°E	19°N, 90°E	W 20/25K 5° to the south of central region	ESE 20K 3° to the north of central region	No Tilt	½° W
7	Dep-ression	20°N, 88°E	18°N, 86½°E	Light westerly wind close to the centre, W15 K about 6° south of centre	E 30K about 2½° north of centre	1° S	½°S, 1½°W
8	Dep-ression	20°N, 86½°E	16½°N, 83E°	W 15K about 3°S of centre	E 10K 2° N of centre, E 25/20K 4° N of centre	1½° S, 2° W	1½° S, 1½° W
9	Low	22°N, 83°E	18°N, 77°E	W 15/20K about 4° S of central region	E 15K about 3° N of central region	2°S, 4° W	2°S, 2°W

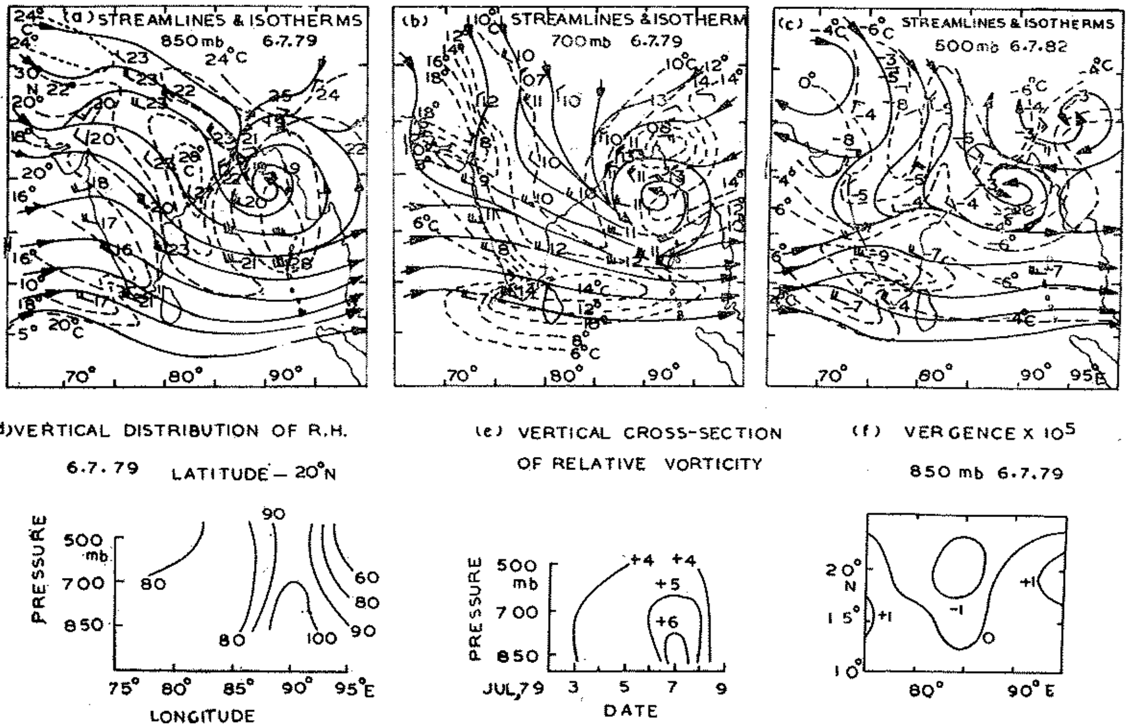

Fig. 1

westwards, the depression weakened into a low pressure area over northwest Madhya Pradesh on 9 July and merged with the seasonal trough on 10 July. The system considered, continued as low for 4 days during the pre-depression period and one day during the post-depression period. The low concentrated into a depression very close to the coast and crossed the coast the next day. The life of the depression stage was thus short, it only existed for two days.

The position of the central region of the low/depression on different dates are given below :

Date (July 1979)	Position Lat. (°N)	Position Long. (°E)	Stage
3	20	92.5	Upper air low
4 No aircraft flight			
5	19	92	Surface low
6	19	90	Do.
7	20	88	Depression
8	20	86.5	Do.
9 Over Madhya Pradesh			Surface low
10 Merged with seasonal trough			

4. Methodology, computation and presentation of data

The structure of the monsoon low was studied with reference to streamlines (wind field), thermal field, moisture field, vorticity and convergence/divergence at different pressure levels. Since the low pressure system concentrated into a depression the structure of the depression was also evaluated on the same basis for the sake of continuity and comparison.

The dropsonde data mostly originated from 400-500 mb level; for this reason, the data for the different parameters studied were evaluated for three pressure levels, 500, 700 and 850 mb.

Upper winds for the area bounded by Lats. 5 deg.-30 deg. N and Longs. 65 deg.-110 deg. E were plotted for 850, 700 and 500 mb together with the air temperatures. Streamlines and isotherms at an interval of 2 deg. C were drawn over these charts. Thus, the wind circulation at the field of the low/depression and the associated temperature field were clearly delineated. The relative humidity at each level was computed from the dry bulb temperature and dew point temperature, plotted at each level and were analysed by drawing isopleths. The vertical distribution of relative humidity roughly along the axis of movement of the system were also plotted, from which the vertical build up of moisture on different days could be clearly assessed. Each wind was resolved into u component (from west to east) and v component (from south to north). The relative vorticity and convergence/divergence were calculated by finite difference method for the area bounded by Lats. 10 deg.-25 deg. N and Longs. 65 deg.-95 deg. E.

The details of the upper winds are shown in tabulated form (Table 1). Tables 2 and 3 give temperature anomaly and maximum relative vorticity respectively. The streamlines and isotherms at three levels, vertical distribution of relative humidity and vergence at 850 mb when the system developed as a well marked low (6 July) was considered as a representative one and depicted in Fig. 1. This figure also contains the vertical time scale of maximum relative vorticity during the entire period (3-9 July).

TABLE 2

Temperature anomaly at different levels

Date (July' 79)	Temperature anomaly (°C)		
	850 mb	700 mb	500 mb
5	—3.16	—1.8	+3.7
6	—2.2	—0.4	+2.7
7	—0.4	+2.2	+3.0
8	—0.9	+0.3	+2.0
9	—0.7	+0.23	+1.0

TABLE 3

Maximum relative vorticity at different levels

Date (July '79)	Maximum relative vorticity ($\times 10^{-5}$ per sec)		
	850 mb	700 mb	500 mb
3	4	4	—
5	4	4	4
6	4	5	4
7	>6	5	4
8	5	5	4
9	3	3	3

5. Analysis and discussion of results

(*i*) *Wind field*

The low pressure area had a region of strong westerlies winds of 40-45 kt approximately 5 degrees to the south of the central region at 850 mb on 6 July and the speed gradually reduced with height. At 700 mb, the speed of westerlies was lower by 5-10 kt though the region of strong westerlies remained almost the same and further reduction of speed was noticed at 500 mb. When the low pressure area was formed over the land due to the decay of the depression over the Bay, the speed of westerly wind reduced to 30 kt.

The easterly wind to the north of the low pressure area was first noticed on 6 July when the low pressure became well marked and its speed was 20 kt. During post-depression low, easterly wind of 15 kt was noticed at about 2½-3 degrees to the north of the low.

During the depression phase (7 and 8 July) strong westerlies were also present at about 4 degree to the south of the depression centre but its speed reduced to about 30 kt. The most striking feature of the wind field was the sudden increase of the easterly component of wind when the low pressure area concentrated into a depression on 7 July. Winds from eastnortheast and speed reaching 35 kt at 850 mb were observed at 2½ degree to the north of the depression centre. The speed of the easterlies dropped again when the depression crossed the coast and lay as a low pressure area on 9 July.

(*ii*) *Relative vorticity*

The region of maximum vorticity coincided with the central region of the low pressure area over the Bay of Bengal. The relative vorticity was $4 \times 10^{-5} s^{-1}$ on 3 July at 850 and 700 mb levels. The same order of vorticity continued at all levels (850, 700 and 500 mb) throughout the low pressure stage except for 700 mb on 6 July when relative vorticity slightly increased to 5 units. When the depression weakened into a low pressure area over the land on 9 July, the relative vorticity decreased to only 3 units at all the three levels. With the intensification of low to a depression on 7 July the relative vorticity rapidly increased in amount and attained a value of greater than 6 units at 850 mb but decreased to 5 and 4 units at 700 and 500 mb respectively. On 8 July the relative vorticity was 5 units at 850 and 700 mb. This weakening of relative vorticity on 8th reflected the decay of depression soon after its formation. At 500 mb relative vorticity was same throughout the period of well marked low and depression.

(*iii*) *Convergence*

The zone of maximum convergence was situated to the western and southwestern sector of the low pressure area during 3, 5 and 6 July. This zone developed between the monsoon westerlies and deflected easterlies and northeasterlies about 5 degree away from the centre (Bedekar and Banerjee 1969). During the post-depression stage, when the system lay as a low on 9 July, the zone of convergence became less prominent. The maximum values of convergence/divergence were only of the order of 2×10^{-5} /sec, during the entire life period of the system.

(*iv*) *Vertical tilt*

The relative vorticity field showed no tilt on 5 and 6 July at any level. On 9 July when the depression decayed to a low pressure area over the land, the circulation centre of the low pressure area showed considerable vertical tilt. It was about 400 km to the westsouthwest between 850 and 700 mb and about 280 km to the southwest between 700 and 500 mb. As regards vorticity field, the tilt was to the western sector on 9 July. So, when the vorticity maxima had sufficient vertical coupling at different levels, the disturbance intensified and it decayed with the growing vertical tilt (Shukla 1981).

(*v*) *Thermal field*

From the plot of isotherms at different levels and from Table 2 which shows the temperature anomaly, it reveals that during the low phase (5-6 July) temperature at the central region of 850 and 700 mb levels were colder than the surroundings while at 500 mb level these were warmer. The cold anomaly continued upto 700 mb on 6 July, but with reduced amplitude. During the depression stage while at 850 mb level the central region was colder but at 700 and 500 mb levels it was warmer than the surroundings. Thus the thermal structure of colder lower troposphere and warmer upper troposphere agreed well with the results obtained by Murakami (1978) and Godbole (1977), with the exception than during the monsoon low over Bay cold anomaly extended upto 700 mb. The same characteristics as observed during depressions also prevailed on 9 July (post-depression low). The maximum amplitude of cold anomaly (—3.16 deg. C) was observed on 5 July at 850 mb and that of warm anomaly(+ 3.7 deg. C) was also observed on the same day at 500 mb. At 850 mb it was observed that the area ahead of the central region of the low was much warmer than the surroundings. This may be due to the flow of the warm northwesterlies from the desert regions of Rajasthan (Godbole 1977).

(*vi*) *Moisture field*

The central region of the low pressure area at 850 and 700 mb was found to be very moist with relative humidity of 100 p.c. or very nearly equal to it. The area to the west of this region was much dry while the eastern sector, where the southerlies dominate, was very moist.

At 500 mb, although the land areas to the west Long. 85 deg. E remained comparatively dry on 5 and 6 July, with the intensification of the system to depression stage, the moisture field became rather uniform around Lat. 20 deg. N from Burma coast through north Bay of Bengal to Long. 72 deg. E. On 9 July, during the post-depression low, the relative humidity near the central region of the low became only 80 to 90 p.c.

A study of the vertical distribution of relative humidity has been made. On 6th there was a vertical build up of 100 p.c. relative humidity near the central region of the low, which was most prominent of all days under consideration (Fig. 1).

It was interesting to note that the southern region of the Bay of Bengal was much dry, compared to the southern areas of the Arabian Sea.

(*vii*) *Effect of storms in the China Sea*

When the low pressure area under study emerged in the northeast Bay of Bengal and was organizing itself, two tropical storms were in existance in the far east. The first one (Ellis) weakened over China coast near Lat. 22 deg. N and Long. 110 deg. E on 6 July and the second one (Faye), which remained stationary at Lat. 14.5 deg. N, Long. 132 deg. E on 6 July without intensification, rapidly dissipated on 7 July. The low pressure area over the northeast Bay became well marked on 6 July and concentrated into a depression on 7 July. It, therefore, appears that a teleconnection existed between the dissipation of the two tropical storms in the far east and the intensification of the low pressure system in the Bay of Bengal.

6. Summary and remarks

The low pressure system which developed over the Bay of Bengal from 3-6 July 1979, intensified into a short-lived depression during 7-8 July, crossed the coast on 8 July near Paradeep in Orissa coast and dissipated as low again on 9 July over the land area. This system was analysed with emphasis on the structure of the low pressure system during pre and post depression periods. The wind field, relative vorticity, vergence, thermal field and relative humidity were evaluated on all days (except 4 July for which there was no aircraft flight) at three pressure levels (850, 700, 500 mb). From the analysis of data the following observations can be made :

6.1. (*i*) The upper wind westerlies were strongest at 850 mb and were approximately in the region of 5 degree south of centre of lows and 4 degree south of depression centre. The westerlies were stronger when the low was well marked compared to the depressions stage.

(*ii*) During the formative phase of the low there was practically no existence of easterly. It almost suddenly appeared when the low became well organised and became stronger when the low concentrated into a depression.

6.2. The region of maximum relative vorticity generally coincided with the central region of the low pressure area. During the period when the system organised into a well marked low pressure system, relative vorticities were same at all levels (850, 700, 500 mb). During the depression stage the relative vorticities were much higher at the lower level and it gradually decreased with height. When the system decayed as a low on 9 July, the relative vorticities were again same at all levels although its value was one unit less than initial low pressure system.

6.3. The features of the wind field and relative vorticity field confirm that the system was coupled vertically.

A comparison of the vertical tilts between low pressure area on 5 and 6 July with that in the depression stage on 7 and 8 July shows that the tilt started at all levels from 7 July and gradually increased as the system began to weaken. This is because the depression was short lived and started to weaken soon after its intensification. During the decaying phase the middle tropospheric system moved rapidly in comparison with the lower tropospheric circulation. The tilt indicates a decoupling of the system resulting from the movement of vorticity maximum with different speeds at different levels.

6.4. The zone of maximum convergence was to the western sector of the low. It was less noticed when the low was over the land and in the process of decay.

6.5. There was a cold anomaly of temperature at 850 and 700 mb and warm anomaly at 500 mb when the system was lying as a low on 5 and 6 July. During the depression stage (7 and 8 July) there was cold anomaly at 850 mb and warm anomaly at 700 and 500 mb.

6.6. The zone of maximum relative humidity was over the central region of the low pressure area and 100 p.c. relative humidity was observed over the sea and the relative humidity was slightly less over the land.

6.7. The low intensified to a depression on 7 July. Certain features were observed during the phase of intensification :

(*i*) Easterlies which were non-existant earlier, appeared on 6 July.

(*ii*) The low pressure system under consideration, migrated to the Bay of Bengal from the east. During this period there were two tropical storms, one near the China coast (Ellis) which weakened on 6 July and the other (Faye, Lat. 14.5 deg. N and Long. 132 deg. E) dissipated on 7 July.

(*iii*) Cold anomaly at 700 mb level changed to warm anomaly during the intensification of the low into the depression stage.

(*iv*) The vertical growth of moisture was most prominent on 6 July when the low pressure area became well marked and began to intensify as a depression.

Form the limited study it appeared that the structures of monsoon lows and monsoon depressions are similar in many respects. The similarity of the two systems seems to suggest that monsoon depressions might develop from monsoon lows under favourable conditions. The conditions responsible for their growth are, however, not yet fully understood. Further study of a number of similar situations are needed for understanding and identification of these conditions.

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