Mausam, (1982), 33, 4, 495-498

551.515.1 : 551.553.21 (267)

Characteristic features of monsoon depressions of the Bay of Bengal — An observational study

KAILASH SINGH, S. V. DABEER, FLT LT L. V. MOHANDAS* and R. K. DATTA

India Meteorological Department, New Delhi

(*Received 27 June 1981*)

सार – प्रस्तुत अध्ययन मानसून के दौरान बंगाल की खाड़ी के अवदाबों के तीन पहलुओं का अध्ययन हैं : (1) विक्षोभों की संभावित उत्पति का पता लगाना, (2) निर्माण, प्रौढ़ और ह्रासी अवस्थाओं की अवधि में उर्ध्वाधर संरचना, (3) खाड़ी में अवदाबों का तीव्रीकरण और निम्न स्तरी क्षोभमंडलीय पश्चिमी जेट एवं उच्चस्तरी क्षोभमंडलीय पूर्वी जेट प्रबलता के बीच अन्तर-संबंध का परीक्षण। इसमें 1970 से 1979 तक के दशक के मानसून अवदाबों के 64 मामलों का अध्ययन किया गया है।

यह देखा गया है कि (1) पूर्व से या दक्षिण-पूर्व से अभिवहित प्रणालियों की कुल संख्या का 82% (2) ऊँचाई के साथ परिसंचलन का झुकाव उस दिशा में रहा जहां से प्रणालियां निर्माणावस्था में अभिवहित होती है। प्रौढ़ाव स्था में सामान्यतः कोई झुकाव नहीं था और ह्रासी अवस्था में भी कोई सुविख्यात प्रतिदर्श दिखाई नहीं पड़ा। (3) लगभग 55% मामलों में अधिकतम तीव्रीकरण से 1–2 दिन पूर्व निम्न स्तरी पश्चिमी जेट प्रबल हो गया जब कि कुल संख्या का 75% मामलों में उच्चस्तरीय पूर्वी जेट का प्रबलीकरण और अधिकतम तीव्रीकरण एक साथ होता रहा।

ABSTRACT. The present study deals with three aspects of Bay of Bengal depressions during the monsoon period (*i*) to trace the possible origin of the disturbances, (*ii*) vertical structure during the formative, mature and decaying stages, and (*iii*) examination of the inter-relation between the intensification of depressions in the Bay and the strengthening of the lower tropospheric westerly jet and tropospheric upper level easterly jet. In all, 64 cases of monsoon depressions which formed in the decade from 1970 to 1979 have been studied.

It is observed that (*i*) 82 per cent of the total number of the systems advected either from east or southeast, (*ii*) the tilt of the circulation with height, was in the direction from which the systems advected in the formative stage. In the mature stage, there was practically no tilt and during the dissipating stage, no well-defined pattern was observed and (*iii*) the lower level westerly jet strengthened 1-2 days prior to the maximum intensification in about 55 per cent cases, whereas the strengthening of upper level easterly jet and maximum intensification were simultaneous in about 75 per cent of the total number of the cases.

1. Introduction

Depressions formed in the Bay of Bengal are one of the important synoptic scale phenomena and a topic of interest for several researchers. Cyclones/depressions in the Bay and their three dimensional structures are among the scientific objectives of summer Monex-79. The present study investigates the following aspects of the monsoon depressions over the Bay of Bengal:

(*a*) To find the possible origin of the disturbances, *i.e.*, to investigate whether the disturbances form *in situ* in the Bay or the source of the disturbances lies in the east/southeast China Sea.

(*b*) To examine the vertical structure of the disturbances during the formative, mature and decaying stages, *i.e.*, to see the tilt of the upper-air circulation with respect to the surface in different stages of development the system and

(*c*) To examine the role of depressions over the Bay of Bengal in strengthening the lower level westerly jet (LLJ) and upper level easterly jet (TEJ) and *vice-versa*.

It has been a matter of debate amongst the meteorologists as to which is the cause and which is the effect. The present study endeavours to find an answer to this very important problem.

Iyer (1938) in his classical paper postulated that most of the depressions which form over the Bay of Bengal have their genesis associated with the disturbances in the Pacific or China Sea. In recent paper, Saha and Shukla (1980) have found that about 87 per cent of the lows and depressions that formed in the Bay of Bengal during July and August over a ten years period (1969-1978) had their predecessors coming from the east. George and Datta (1965) studied a monsoon depression of September 1963 having formed out of the remnants of a typhoon from the Pacific

*Indian Air Force, New Delhi

TABLE 1

Month	Origin		Westerly jet			Easterly jet		
	No. of cases studied	% of systems from E to SE	% of cases in which wind strengthened 1-2 days prior	Simultaneous strengthening (%)	Max. wind speed (kt) (average)	% of cases in which jet strengthened 1-2 days prior	Simultaneous strengthening (%)	Max. wind speed average (kt)
May	7	90	50	10*	35-40	50	50	50-55
Jun	12	75	40	60	45-50	40	60	60-65
Jul	15	83	67	33	45-50	30	70	60-70
Aug	17	87	60	40	40-45	20	80	55-60
Sep	13	75	50	50	40-45	25	75	50-55

*Rest of the 50% cases inconclusive

Ocean under upper level divergence at 200 mb anticyclone. Ramanna (1965) found that about 17 per cent depressions are formed out of the remnants of Pacific typhoons.

Srinivasan *et al.* (1972) traced the centre of depression southwards with height. Choudhary and Appa Rao (1976), Godbole (1977) and Mandal *et al.* (1979) also analysed the vertical structure of the disturbances. Many authors have investigated the interaction between the disturbances and the strengthening of LLJ & TEJ. Koteswaram and George (1958) relate the formation of the depressions with troughs in upper tropospheric easterlies and strengthening of the easterly jet. Joseph and Raman (1966) found that the low level jet stream in July has a core of about 1.5 km and speed upto 40-60 kt. The present study is an examination of some of these aspects, for the monsoon depressions for the decade 1970-1979.

2. Data and method of analysis

In all 64 cases of monsoon depressions which formed during the decade from 1970 to 1979 in the months of May to September have been studied. Daily synoptic charts plotted by NHAC, New Delhi were used. Synoptic charts prepared at Meteorological Office, Safdarjung, New Delhi, were also referred to. Data sets of Monex-79, Monsoon-77 and ISMEX-73 were also extensively used.

To trace the origin of the systems, synoptic charts a few days prior to the formation of the low pressure area (LPA) in the Bay of Bengal were studied. Besides well-defined low pressure systems moving westwards, the pressure changes and the rainfall pattern were also considered to trace the source of the systems which intensify in the Bay.

To find the vertical structure of the disturbances, centres of cyclonic circulations at standard levels were taken from the analysed synoptic charts.

In order to find out the role of LLJ, vertical time sections of the winds at the following three latitudinal belts were prepared:

(*i*) 8° N — Cochin, Trivandrum, Columbo,
(*ii*) 13° N — Mangalore, Bangalore, Madras and
(*iii*) 18° N — Bombay, Hyderabad, Visakhapatnam.

Wind data for 00 GMT for the above mentioned stations at 850-700 mb were used for studying the LLJ. For studying the interactions of TEJ with the disturbances, vertical time section of the winds at Calcutta and Agartala at 200 and 100 mb were prepared. In a few cases when 00 GMT data were not available, 12 GMT data were used.

3. Discussion and results

3.1. *Source region of monsoon depressions*

Table 1 gives the monthwise classification of the cases studied. The frequency of the systems was highest in August, followed by July, September, June and May.

About 82 per cent of total number of disturbances seem to have their sources either in east or southeast. Some of the disturbances could be distinctly seen, as originated from the remnants of Pacific typhoons. Very few, *i.e.*, about 15-20 per cent of the total disturbances formed *in-situ*. Pressure departure and the pressure change charts are being plotted routinely in the India Meteorological Department have been extensively used for the study.

3.2. *Vertical tilt of monsoon depressions*

During the formative stage, the tilt of the wave axis was generally towards the direction of advection. In the mature stage, there was no tilt in the associated upper air cyclonic circulation. In the weakening stage, the pattern was not well defined. However, the associated upper air circulation at 300-250 mb, whenever

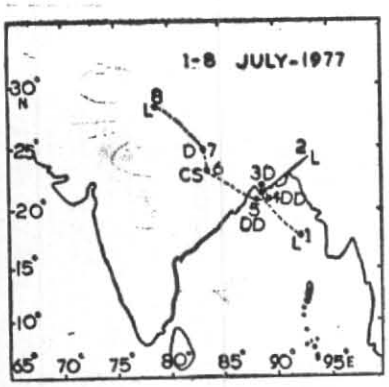


Fig. 1. Track of the cyclonic storm

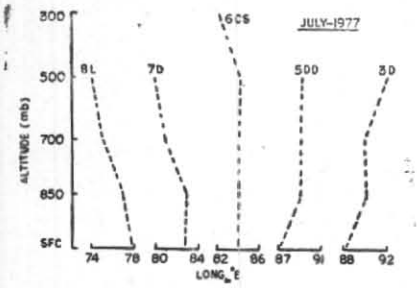


Fig. 2. Tilt of the circulation with height

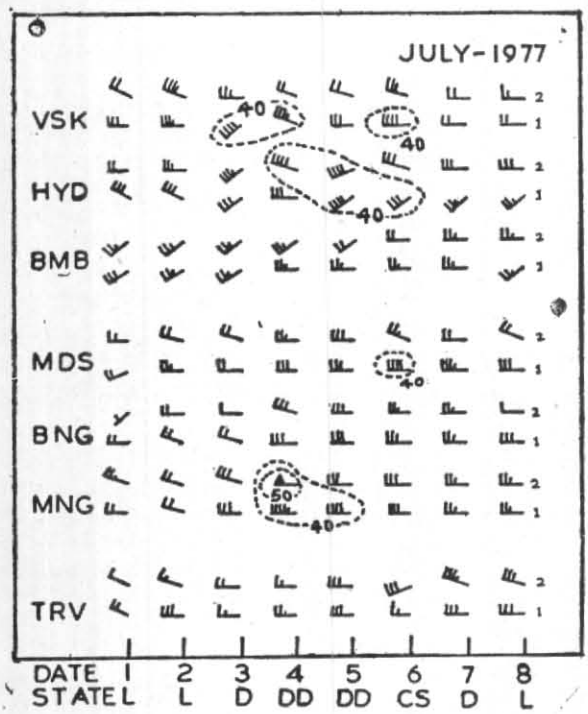


Fig. 3. Lower tropospheric westerlies : (1) 850 mb, (2) 700 mb

it extended upto that, showed a southwestward tilt regardless of the stage of the system. The systems in the formative stage generally had a cyclonic circulation upto 500 mb, whereas in the mature stage, deep depression (DD) and

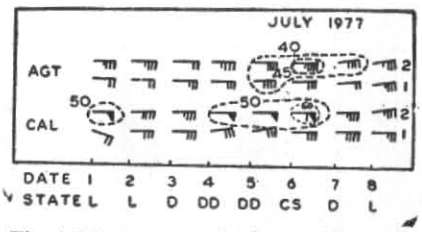


Fig. 4. Upper tropospheric easterlies (1) 200 mb, (2) 100 mb

cyclonic storm (CS), it extended upto 300 mb level. In a few cases, the upper air circulation extended upto even 250 mb. In general, the area of the cyclonic vortex shrinks with the height and changes to anticyclonic circulation around 250-200 mb levels.

3.3. *Low level westerly jet (LLJ) and the monsoon depressions*

Of the vertical time sections drawn for the three latitudinal belts, the southern belt comprising of Cochin, Trivandrum and Colombo generally showed higher winds. The winds strengthened gradually during the formative stage. In most of the cases, there was a strengthening of the LLJ 1-2 days prior to the maximum intensification of the system (Table 1). In a majority of the cases, the LLJ weakened in the decaying stage. However, persistence of higher winds could be seen in the mature stage. The strength of the jet was more in June and July compared to that in August and September.

3.4. *Upper tropospheric easterly jet (TEJ) and the monsoon depressions*

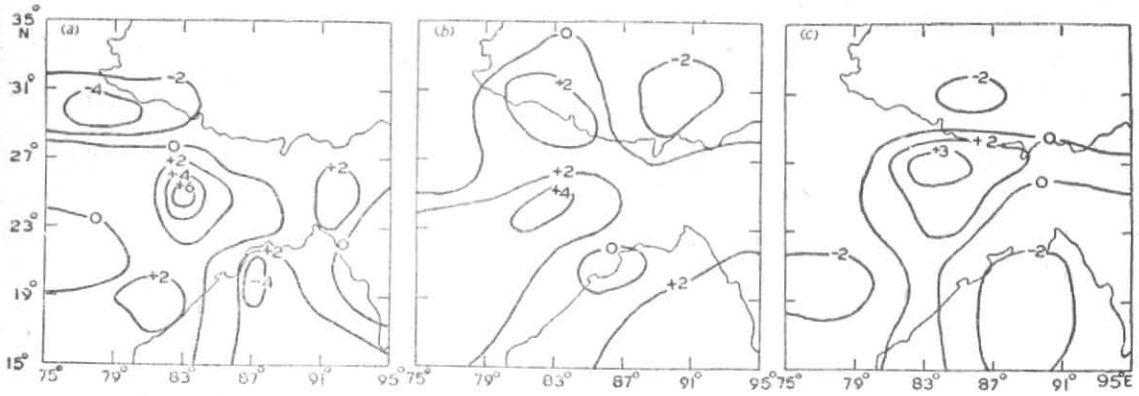
The TEJ as shown by Calcutta and Agartala winds strengthened gradually with the intensification of the system in about 75 per cent cases. The TEJ weakened as the system dissipated over land.

4. A typical illustration

A typical case of a cyclonic storm which formed in the month of July 1977 is presented below:

A low pressure area (LPA), formed on 1 July 1977 at 18°N and 92°E, moved northwestward and intensified into a cyclonic storm on 6th. It is evident from the pressure departure charts, one to two days prior to the formation of LPA, over the east central Bay, that it was formed as a result of the passage of the lower level easterly low pressure wave from the western Burma coast and adjoining area.

The circulation in the formative stage (3 to 5 July 1977) extended upto 500 mb and showed a marked eastward tilt, that is, in the direction from which the system advected (Fig. 2). On



(a) 5 July 1977 (b) 6 July 1977 (c) 7 July 1977

Fig. 5. Upper level divergence at 200 mb

the day of maximum intensification (6 th), there was no tilt in the upper air circulation upto 500 mb but at 300 mb, southwestward tilt could be seen. In the weakening stage of the system (7 & 8th) the circulation extended upto 500 mb and a westward tilt with height was observed. This conforms to our earlier observation in the section 3.2.

The LLJ strengthened gradually and attained its maximum intensity on 4th and 5th, *i.e.*, 1-2 days prior to the maximum intensification of the system. Wind speed upto 50 kt was observed at Mangalore (13°N, 75°E) at 700 mb on 4th. The second and the third latitudinal belts specially showed a marked increase a day or two prior to 6th, the day of maximum intensification of the system (Fig. 3).

Figs. 5 (a-c) depict the vergence field at 200 mb on 5, 6 and 7 July 1977 respectively. There was an upper level divergence of the order of 6×10^{-5}/s on 6th in the northwest sector of the system at lower levels. A divergence of about 4×10^{-5}/s could be seen on 6th in the northwestern sector of the depression. On 7th as the lower level system weakened, the upper level divergence in the north of the depression also reduced to about 3×10^{-5}/ s. The upper level divergence started from 300 mb level in the formative and weakening stages, whereas, in the mature stage, it started at 200 mb. Computations of divergence at all standard pressure levels have been made but not presented here for economy of space.

5. Conclusions

(*i*) 82 per cent of the systems advected either from east or southeast confirming the postulate of Iyer (1938).

(*ii*) The tilt of the wave axis was in the direction from which the systems advected in formative stage. In the mature stage, no such tilt was observed. In the weakening stage no well-defined pattern was found. The area of cyclonic vortex decreased with height.

(*iii*) The lower level westerly jet strengthened 1-2 days prior to the maximum intensification in 55 per cent of the total cases, whereas, the strengthening of the upper level easterly jet and maximum intensification were simultaneous in 75 per cent cases.

Acknowledgements

The authors thank the Director General of Meteorology for providing necessary facilities. Two of the authors, Sarvashri S.V. Dabeer and Kailash Singh thank the Monex Directorate for financial assistance. We are thankful for the staff of NHAC, New Delhi for providing the necessary charts. Our thanks are also due to Sergent Sharma, N. C. and Corporal Ajit Singh for their help in various stages of the project.

References

Choudhary, A. and Appa Rao, G., 1976, Proc. Symp. on Tropical Monsoon, (8-10) Sep 1977, 142-150, IITM, Pune.

George, C. J. and Datta, R.K., 1965, *Indian J. Met. Geophys.*, **16**, p. 213,

Godbole, R.V., 1977, *Tellus*, **29**, pp. 25-41.

Iyer, V., Doraiswamy, 1935, IMD Memoirs, Vol. XXVI, p. 193.

Joseph, P.V. and Raman, C.R.V., 1966, *Indian J. Met. Geophys.*, **17**, pp. 407-410.

Koteswaram, P., 1958, *Tellus*, **10**, pp. 43-57.

Koteswaram, P. and George, C.A., 1958, *Indian J. Met. Geophys.*, **9**, pp. 9-22.

Mandal, *et al.*, 1980, India, Met. Dep. Tech. Note.

Ramanna, G. R., 1969, *Indian J. Met. Hydrol. Geophys.*, **26**, pp. 140-150.

Saha, K.R. and Shukla, J., **1980**, Results of Summer Monex field phase research (Part I), 23-3.

Srinivasan, *et al.*, 1972, India Met. Dep. FMU Rep. III, 3-6.