

Distant effect of monsoon depressions — Part I : Effect of formation of depressions on rainfall activity along the west coast of India

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सार — उत्तर पश्चिमी या शीर्ष खाड़ी के ऊपर मानसून का अवदाब बनने के समय पूर्वानुमानकर्ता कोंकण-कर्नाटक के तटों पर भ्रामतौर पर भारी वर्षा का पूर्वानुमान व्यक्त करते हैं, किन्तु सभी मामलों में भारी वर्षा नहीं होती। इस शोध पत्र में हमने उत्तर-पश्चिमी/शीर्ष खाड़ी के ऊपर 1956-75 की अवधि में बने सभी 111 अवदाबों का विश्लेषण किया है। इस विश्लेषण का उद्देश्य उन दो प्रकार के अवसरो के बीच सिनोप्टिक अन्तर ज्ञात करना है जब खाड़ी के ऊपर बने मानसूनी अवदाबों से भारी वर्षा हुई और जब उन अवदाबों के कारण वर्षा नहीं हुई।

ABSTRACT. At the time of formation of monsoon depressions over northwest/head Bay forecasters generally issue heavy rainfall forecast for the Konkan-Karnataka coasts; but heavy rainfall is not realised in all cases. In this paper we have analysed all the 111 depressions that formed over northwest/head Bay during the period 1956-75 with a view to identify the synoptic differences between the occasions when the monsoon depression forming over the Bay, increases the rainfall activity over the Konkan-Karnataka coasts and when it does not.

1. Introduction

Forecasters are aware that when a monsoon depression forms over northwest Bay, there is a general increase in rainfall activity along the Konkan-karnataka coasts and even upto the western district of north Madhya Maharashtra. Krishnamurthy and Bhalme (1976) have observed that prior to the formation of monsoon depressions, there is a major intensification of the cross equatorial low level jet extending from east coast of Somalia towards India. Mukherjee and Shivaramakrishnan (1982) have pointed out that with the strengthening of wind in Arabian Sea at the time of formation of the depression, there is increase in the height of the swell waves over Bombay High area. Rangarajan and Subramaniam (1979) observed that there is a decrease in the concentration of radioactive tracer Radon at Bombay as a depression forms over the Bay. Mukherjee and Shyamala (1978) have found out that marked changes in the circulation pattern and rainfall activity occur west Rajasthan as a monsoon depression crosses coast and moves inland.

The above mentioned studies indicate that definite changes in the atmospheric conditions occur over

areas even far from the depression centre as a system forms over northwest/head Bay and moves inland. These effects in a general way have been termed as distant effects. In this paper we have attempted to study the monsoon depressions in their formative stage in relation to rainfall activity along the west coast in order to achieve better understanding of the phenomenon known for a long time.

2. Scope of the study

Five important synoptic systems normally cause increased rainfall activity over Konkan coast. They are (Srinivasan *et al.* 1972);

- (i) Trough of low pressure off west coast on the surface chart and in the low levels.
- (ii) Formation of depression or low over north Bay of Bengal.
- (iii) Presence of cyclonic circulation between 700 and 500 mb over northeast Arabian Sea and adjoining Saurashtra and Kutch with east-west trough at 700 mb.
- (iv) Cyclonic shear in the low level westerlies with strong winds to the south and weak winds to the north along the coast.

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- (v) Steep pressure gradient with a well marked seasonal trough.

The second situation listed above forms the main aspect of this study.

3. Data

All the 111 depressions that formed over northwest/head Bay during the period 1956-75 were studied in relation to rainfall activity along the west coast. The data were collected from the working charts of Forecasting Office, Colaba, Bombay and the *Indian Daily Weather Reports*

4. Observational aspects of depressions of July 1973

Let us consider the depressions that occurred during July 1973 as typical illustrations. There were 3 depressions during this month, the first during 3-9 July, the second during 11-14 July and the third between 18 and 24 July (Fig. 1).

4.1. Depression during 3-9 July 1973

A circulation between 850 and 500 mb lay over northwest Bay on 3 July. It developed into a well marked sea level low pressure area over northwest and adjoining westcentral Bay on 4th. It concentrated into a depression on 5th centred within half a degree of latitude 19.5 deg. N and longitude 89.0 deg. E. Moving westnorthwest, it crossed the Orissa coast between Puri and Paradeep on the morning of 7th. It weakened into a low on the evening of 9th over west Madhya Pradesh and merged with the seasonal trough on 10th (Fig. 1).

Another CYCIR developed over the northeast and adjoining east-central Arabian Sea and adjoining areas between 850 and 700 mb on 3 July. This circulation persisted upto 5th and on 6th it developed into a low pressure area over eastcentral Arabian Sea along and off north Maharashtra, south Gujarat coasts. On 7th it intensified into a depression centred within half a degree of latitude 20.0 deg. N and longitude 71.0 deg. E. It crossed coast and lay over Saurashtra and Kutch centred near Dwarka on 8th and weakened into a well marked low on 9th.

Before we discuss the actual synoptic charts, let us briefly review the normal pressure and wind condition over Konkan-Karnataka coasts during the monsoon season. The normal pressure gradient between Ahmedabad and Bombay is 3 mb while pressure gradient across Maharashtra coast is 4 mb. Figs. 2

and 3 represent the upper wind normal charts for the levels 850 and 700 mb for July (*IMD Upper Air Atlas 1972*). The heat low, one of the important components of the monsoon system is shallow and is seen at 850 mb, but extends upto 2.1 km only. At 850 mb, the monsoon trough is seen to extend from Delhi to northwest Bay across Paradeep.

In the 700 mb chart, the heat low is not seen but instead the subtropical anticyclonic ridge is seen. The 700 mb trough line runs along 22 deg. N.

Instead of discussing the charts of every day during the depression period, the changes in the pressure and wind conditions during the depression period have been discussed.

4.2. Pressure field

The heat low intensified from 1st July and the pressures fell considerably over Ahmedabad and Bombay by about 8 mb from 1 to 5 July. The corresponding pressure fall over Mangalore was 3 mb so that pressure gradient across Konkan-Karnataka coast increased from 0.7 mb on 1st to 6.0 mb on 5th even though no low pressure system was present at the surface. Subsequently a low developed over east central Arabian Sea and adjoining areas on 6th and pressure gradient increased further along the Konkan-Karnataka coast. With the weakening of the systems, the pressure gradient also weakened.

4.3. Wind field, vorticity distribution and rainfall

The lower tropospheric trough line at 850 and 700 mb was active on 1 and 2 July with the troughline along 20 deg. N with embedded cyclonic circulations. From Figs. 4 & 5 showing the wind field on 3 July we note that 2 circulations are observed, one over northwest Bay and the other over northeast Arabian Sea and adjoining Saurashtra and Kutch areas. At 850 mb another CYCIR over Madhya Pradesh is also seen in association with an earlier low pressure system over Madhya Pradesh which became unimportant on 3rd. The troughline is well defined at both 850 and 700 mb. Comparison of Fig. 4 and Fig. 2 shows marked changes in the 850 mb flow pattern.

Prior to the formation of the depression the winds over the west coast south of 15 deg. N were strong. From 3 to 5 July with a cyclonic circulation over northeast Arabian Sea and adjoining areas and strong pressure gradient across the Konkan-Karnataka coasts winds strengthened along these coasts, winds over

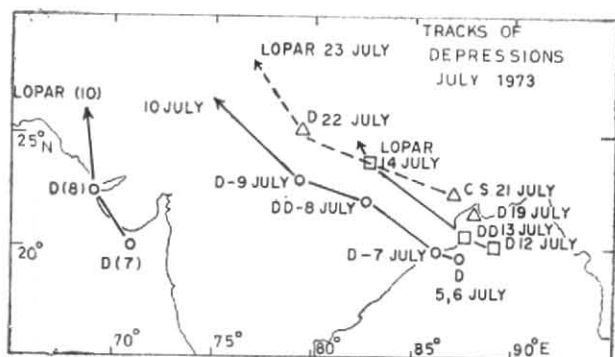


Fig. 1

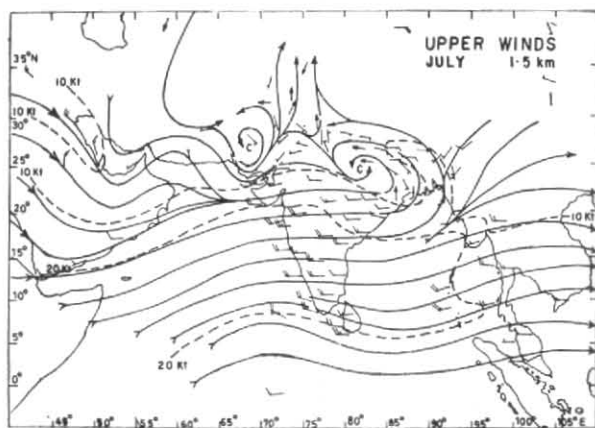


Fig. 2

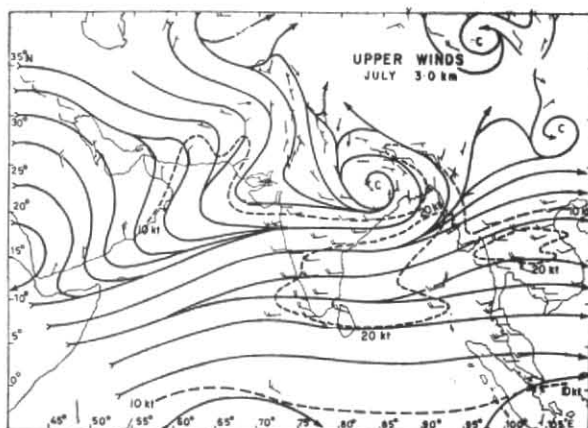


Fig. 3

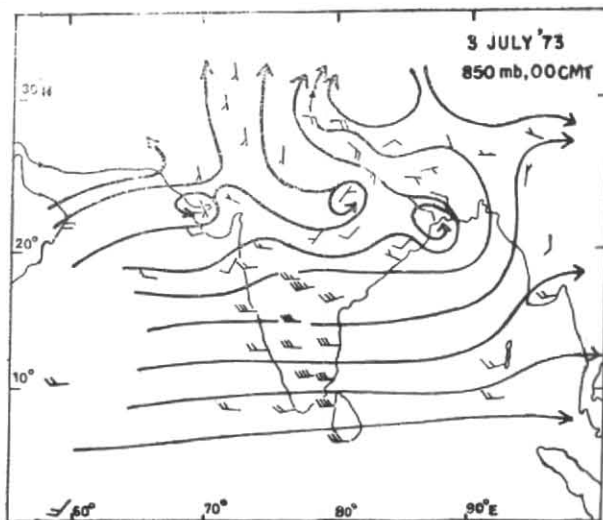


Fig. 4

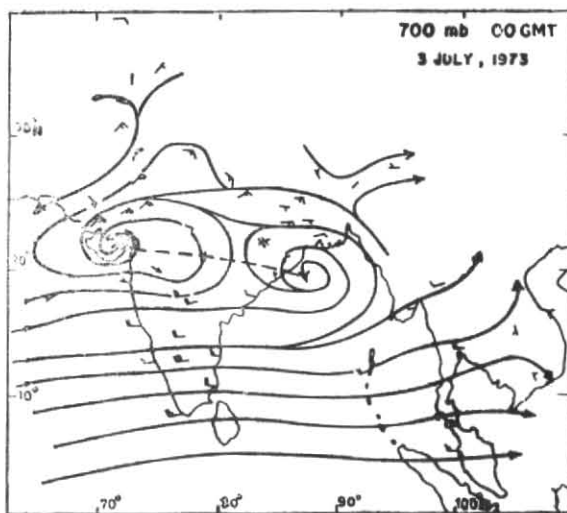


Fig. 5

South Karnataka coast were stronger as compared to Konkan and Kerala coasts. Calculation of the vorticity field by using the finite difference method and considering only the meridional variation of zonal wind as major component of vorticity in the monsoon season, the above wind distribution during 3-5 July resulted in cyclonic vorticity over Konkan-Karnataka coasts and anticyclonic vorticity over the Kerala coast. The rainfall values show increase along Karnataka-Konkan coasts while there is no change in the rainfall activity along the Kerala coast. Subsequently as the depression formed over the Bay on 5th there is further strengthening of winds along the Kerala coast. Vorticity values showed increase over Kerala, Karnataka and Maharashtra coasts upto 7th. As the system crossed coast and moved inland, the cyclonic vorticity decreased along the west coast.

The rainfall activity over Bombay increased from 0.3 on 2nd to 9 cm on 6th (Fig. 6). Subsequently the rainfall increased to 15 cm on 8th as the circulation over northeast Arabian Sea also intensified into a depression on 7th. The rainfall activity decreased later. The Ghat stations showed similar rainfall distribution with higher amounts of rainfall recorded. The rainfall over Mangalore showed the same trend while rainfall activity along the Kerala coast did not show any significant change.

All the 111 depressions that formed during the period 1956-1975 were analysed for the occurrence of active/vigorous monsoon conditions over the west coast. It was seen that in 70% cases the following sequence of weather development was observed :

- Formation of depression over north/head Bay.
- Strengthening of monsoon over Arabian Sea leading to development of belt of strong westerlies in the lower troposphere over Arabian Sea, west coast and Peninsula south of 15 deg. N.
- Development of a cyclonic circulation more or less simultaneously over northeast Arabian Sea and adjoining areas between 850 and 700 mb levels. The circulation rarely descends down to form a surface low.
- Persistence of the circulation mentioned in (c) till the Bay system crosses coast and moves inland.
- Strengthening of the pressure gradient and winds north of 13 deg. N along the west

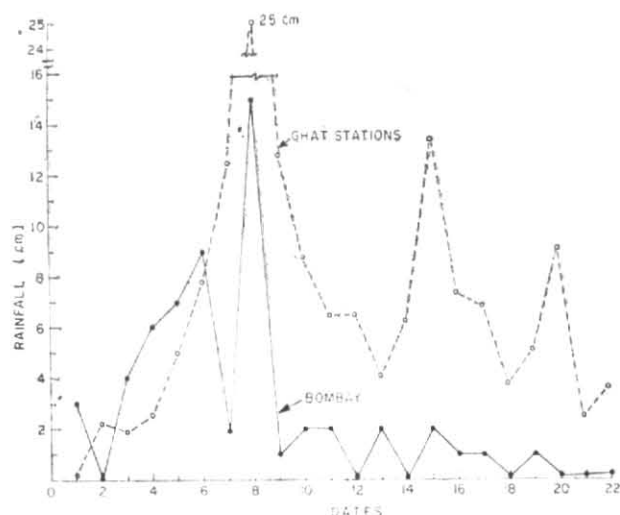


Fig. 6. Rainfall (cm) during 1-22 July 1973

coast with stronger winds over south Karnataka coast.

- Increase in cyclonic vorticity and rainfall along Karnataka-Maharashtra coasts.
- Increase in rainfall activity over the Ghats due to strengthening of winds.
- No change in rainfall activity over Kerala coast.
- Movement of the cyclonic circulation over northeast Arabian Sea and adjoining areas, towards north as the Bay system crosses coast.
- Weakening of the cyclonic vorticity, winds and rainfall along the Konkan-Karnataka coasts as the Bay system moves inland.

The development of a cyclonic circulation between 850 & 700 mb over northeast Arabian Sea and adjoining areas more or less simultaneously with the initial stage of development of the depression in the Bay has been found to be the key factor forecaster may look for, in connection with issue of heavy rainfall warnings over Konkan-Karnataka coasts at the time of formation of a depression. This situation is accompanied by increased pressure gradient and strengthening of lower tropospheric winds increased cyclonic vorticity and increased rainfall activity over the Konkan-Karnataka coasts and Ghat stations. There is no change in the rainfall activity along the Kerala coast.

In 77 cases out of 111 cases, the above features were noticed. 5 cases out of 111 did not confirm with the above even though a CYCIR developed over northeast Arabian Sea and adjoining areas at the time of

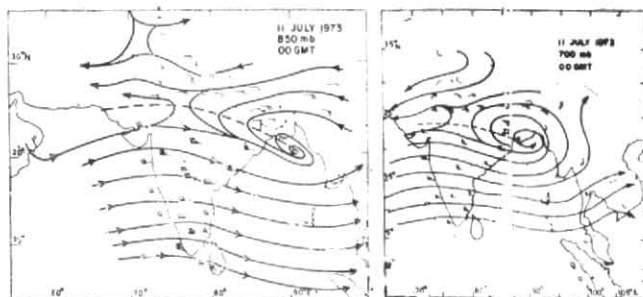


Fig. 7

Fig. 8

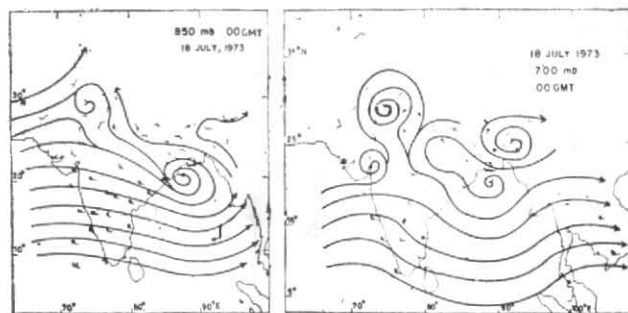


Fig. 9

Fig. 10

formation of the depression, but no increase in rainfall occurred.

5. Depression during 11-14 July 1973

A low pressure area developed over north Bay on 11 July. It concentrated into a depression on 12th morning about 300 km south of Calcutta. Moving westnorthwest, it became deep on 13th and crossed coast near Chandbali that afternoon and weakened into a low over north Madhya Pradesh on 14th (Fig. 1).

As the cyclonic circulation over north east Arabian Sea on 3 July and adjoining areas developed into a surface system and moved inland by 9 July, pressures started rising over west coasts and by 4.2 mb over Bombay on 11th and the anticyclonic ridge pattern which is normally observed over Kerala coast progressively extended northwards along the entire west coast at 850 mb and 700 mb (Fig. 7 & Fig. 8). With this wind flow, eventhough a depression formed over north Bay and the belt of strong wind was present all along the west coast, cyclonic circulation did not develop over the northeast Arabian Sea and adjoining areas. In the absence of CYCIR and therefore cyclonic vorticity there was no increase in the rainfall activity along the Konkan-Karnataka coasts while the Ghat stations continued to receive about 6 cm of rainfall.

In the case of 22 depressions out of 111 depressions, it was seen that the development of ridge pattern along the west coast extending from Kerala coast to east M.P. across the Konkan-Karnataka coasts inhibited the development of the CYCIR over northeast Arabian Sea and adjoining areas in the lower tropospheric levels especially at 850 mb. On these occasions no increase in rainfall activity was observed along the west coast at the time of formation of depression over north Bay.

6. Depression during 18-24 July

A low pressure area developed over northwest Bay of Bengal on 18 July. It concentrated into a depression on 19th morning near Sandheads. Moving west-northwest it rapidly intensified into a cyclonic storm on 19th night and crossed coast near Contai and lay near Midnapore on 20th morning. It weakened into a depression on 22 July near Madhya Pradesh (Fig. 1).

From Figs. 9 & 10 we see that the anticyclonic flow over west coast and the strong winds along the west coast continued on 18th. The same conditions prevailed on 19th also so that in the absence of the development of the CYCIR over northeast Arabian Sea and adjoining areas no cyclonic vorticity was present and

no increase in rainfall was registered along the coastal stations. A noticing feature during this situation was the presence of a closed intense anticyclonic cell in the lower troposphere over northern parts of our country. Otherwise this depression is similar to the one that occurred during 11-14 July, 4 cases of 111 belonged to this category.

7. Conclusions

The 2 important findings from this study are :

- (a) A monsoon depression forming over north-west/head Bay is associated with increased rainfall activity over Konkan-Karnataka coasts only when an active troughline is observed from 850-700 mb level. In this condition, a cyclonic circulation develops over northeast Arabian Sea and adjoining areas between 850-700 mb. The pressure gradient steepens along these coasts associated with strengthening of winds. Strong winds coupled with cyclonic vorticity results in increased rainfall activity over Konkan-Karnataka coast and the Ghat stations. No

change in rainfall activity is noticed along the Kerala coast.

- (b) The presence of anticyclonic ridge along the west coast inhibits the development of the cyclonic circulation to the north. In the absence of cyclonic vorticity, no increase in the rainfall activity is observed along the coast while Ghats continue to receive moderate rainfall.

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