

Effect of monsoon depression of east coast at some distant region in west

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सार — मानसून के महीनों में तटीय क्षेत्रों में जब भी भ्रमिल अथवा हवा के कम दबाव का क्षेत्र या अवदाब के समूह बनते हैं, उस समय पश्चिमी तट पर भारी वर्षा होती है। भारी वर्षा की ऐसी घटनायें प्रायः सामान्य वर्षा से अधिक होती हैं। इस अध्ययन में उपग्रह से प्राप्त विम्बावलियों की सहायता से मानसून के महीनों में पूर्वी तरंग निर्देश को दशनि का प्रयास किया गया है। जब इन क्षेत्रों को तरंग की तीसरा सेक्टर प्रभावित करता है तो मध्य महाराष्ट्र और दक्षिण गुजरात में भारी और व्यापक वर्षा होने की संभावना होती है जैसा कि उपग्रह तरंग और अवदाब अथवा भ्रमिल को तरंग के पांचवें और छठे सेक्टर से प्रभावित दर्शाया गया है।

ABSTRACT. Whenever a vortex or system of low or depression forms over head bay during Monsoon months, the west coast experiences heavy rainfall. These heavy rainfall occurrences are usually higher than the normal rainfall. An attempt has been made in this study to visualise the easterly wave model during monsoon months with the help of satellite imageries. The rain is expected heavy and wide spread over Madhya Maharashtra and South Gujarat when third sector of the wave covers these areas, as visualised in satellite wave and depression or vortex lies in the 5th or 6th sector of the wave.

Key words — Easterly wave, Satellite imageries, Sinusoidal curve, Migratory, Precursor.

1. Introduction

Much have been discussed about the waves in the easterlies, and separately on the depressions or lows across the country from the Bay of Bengal. Whenever a vortex or system of low or depression forms over head bay during the monsoon months, the west coast experiences heavy rainfall. Especially, the western Maharashtra and Konkan regions receive about 15 cms of rainfall per day. Such heavy rainfall occurrences are quantitatively higher than the usually experienced heavy rainfall amounts during monsoon. This seems to be a sequel to the effect the synoptic system in the head bay causes on the other side of the western ghats of the peninsula. However, on such effects these systems produce over areas this far away, much less has been explored.

Sen and Sundar (1994) have derived an explanation for heavy rainfall over Pune, from the combined effect of the system from head bay moving over the central peninsula and the N-S trough off the west coast during the monsoon months. In the recent past Mukherjee and Shyamala (1985) have tried to explain the rainfall activity along the west coast during the formation stage of depressions over bay of Bengal. According to them, a monsoon depression over north-west bay is associated with increased rainfall activity over Konkan-Kerala coasts, along with an active trough line at 850-700 hPa level. This accompanies a cyclonic circulation over north-east Arabian sea between 1.5 and 3.0 kms asl.

The circulation pattern and rainfall over west Rajasthan gets inhibited as a ridge develops over NE Arabian sea and neighbourhood and depression moves inland according to Mukherjee (1978). Saxena (1988) while indexing the systems strengthening the monsoon activity over Madhya Maharashtra and Marathwada lists the monsoon depressions over bay and North-South troughs in the monsoon westerlies.

The waves in the easterlies have a sinusoidal appearance throughout their depth in some regions. These migratory waves give rise to close lows and depressions in lower levels which move as different entities, while the migratory easterly waves in mid and upper troposphere move away independently. Reed *et al.* (1977) postulated that the waves over west Africa and eastern Atlantic have a general wavelength of about 2500 kms - or roughly 25 longitude degrees, with a mean period of 3 to 4 days. The clouds and rain were maximum in the southwest sector of the wave near the centre. Properties of the waves as envisaged by Riehl (1954) indicate downward movement of air ahead of trough, with cumulus of above average development and scattered showers close to trough line but ahead of it, whereas over the trough and to the rear of it the cloud development is marked yielding heavier rainfall and decreasing farther to the east. The picture gets modified with orography and differential

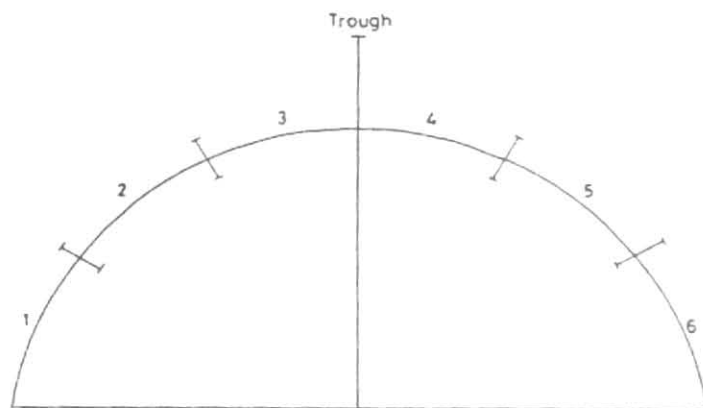


Fig. 1. Equi-distant sectors of wave shape

heating. Though the wave structure exists all the year round, these are more marked during northern summer.

The effect of the easterly waves leading to formation of depressions and lows over the bay of Bengal have already been propounded by Riehl (1965). This suggests the extension of a similar feature across the peninsular India, for a plausible explanation of increased rainfall over north Maharashtra coast and south Gujarat region with the formation and intensification and movement of a depression from head bay over land. The present study explores such a possibility.

Relatively feeble nature of the wave structure, and lack of uniformity in structure, and lack of data in the tropics and sea areas are some constraints in studying the features. Hence satellite data were chosen to study the relationship of rainfall over Maharashtra and south Gujarat with the relevant synoptic situation during the monsoon months.

2. Data and method

The days with marked lows and depressions over the bay of Bengal for a period of 3 years (1990-92) during June to September, amounting to 9 sequential instances, were chosen for an initial study. Data of rainfall for stations in Madhya Maharashtra and Gujarat were collected from the Indian Daily Weather Reports, (IDWR) for the duration of the system and also 2 days prior as well as later to that. On many days the cloud organisation exhibits a sinusoidal wavelike formation in a satellite imagery. The apparent Sinusoidal curve, as visualised in the satellite imageries of 0600 UTC from INSAT, was divided into six equi-distant-sectors each, the apex forming the divider of three sectors on either side and marking the trough as well (Fig. 1). The position of the synoptic systems as seen on the surface charts, that of the vortices seen on satellite imageries, the

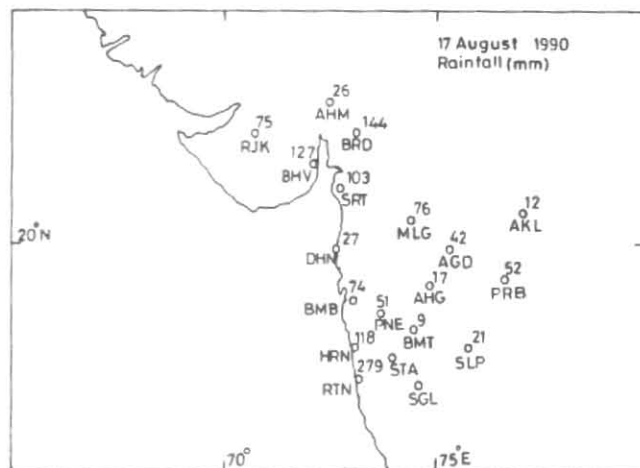


Fig. 2. Recorded rainfall (in mm) on 17 August 1990 over Gujarat and Maharashtra state

cloud formations on each sector and the rainfall reports were all analysed against this backdrop.

3. Results and discussion

(i) 1990

(a) A depression was at $22^{\circ}\text{N}/81^{\circ}\text{E}$ on 16th, August, and soon it became a low on 17th. On 15th Mumbai recorded 26 cms of rain; on 16th the rainfall was scattered over Madhya Maharashtra (MM) and was moderate to heavy. On 17th the rainfall increased everywhere, while on 18th South Gujarat (S-Guj) recorded heavy scattered rainfall (Fig. 2.)

(b) Again from 21st to 24th another depression moved from $19^{\circ}\text{N}/89^{\circ}\text{E}$ to Rajasthan. From 23rd and 24th rainfall increased and was scattered on 23rd and 24th. Ahmedabad recorded 24 cms on 24th, and Surat 11 cms on 25th. The rainfall was moderate upto 26th in the region.

Interpolating the wave pattern as discussed above with the aid of satellite pictures indicates that the wave trough can be located over $22^{\circ}\text{N}/75^{\circ}\text{E}$, with the ridge to ridge extent being about 26° along the equatorial latitude (Fig. 3). The clouds were low or medium type in 1st and 2nd sectors, with occasional convective clouds in 2nd. Moderate convective clouds occupied sectors 3,4 and 5, with some medium level clouds in 3rd sector. Intense cloudings were seen in 4th sector on 22nd and 23rd, while in sector 5, the intensity was more on 20th and 21st, in conjunction with the movement of the system.

The wavelength of the wave ranged from 23° to 30° , mostly extending to 26° . The trough moved from 85° to 77°E between 17th and 20th -along 22°N . But it moved from 78° to 72°E between 21st and 24th, descending southward from 25°N on 21st to 20°N on 22nd and again rising



Fig. 3. Location of wave pattern superimposed on visible satellite imagery of 0600 UTC, 21 August 1990

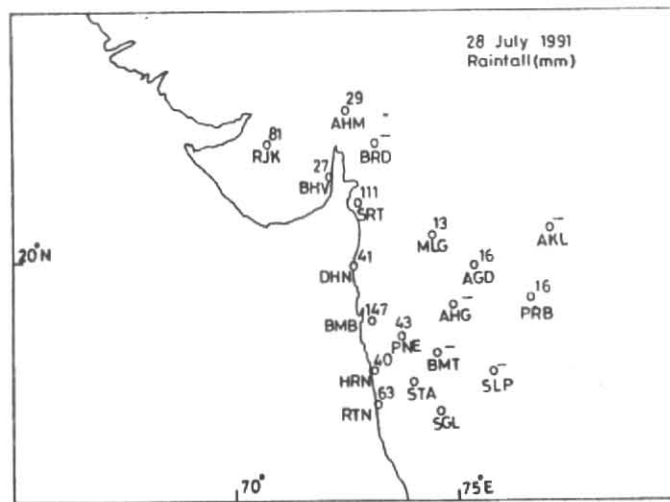


Fig. 4. Recorded rainfall (in mm) on 28 July 1991 over Gujarat & Maharashtra state

northward upto 27°N on 25th. The vortex on imagery, however, progressed westward sequentially from 6th sector to 3rd sector. The effect of the depression on the end of the 5th sector with region falling under 2nd and 3rd sectors was noticeable on 21st; on 23rd & 24th the region was under 3rd or 4th sector, with the depression over Madhya Pradesh

(MP), just north of the wave's arm or near the trough. The distant effect was again noticeable on 25th.

(ii) 1991

(a) A depression formed on 27th July, at $20^{\circ}\text{N}/89^{\circ}\text{E}$ and moved upto Rajasthan on 31st, intensifying into a deep

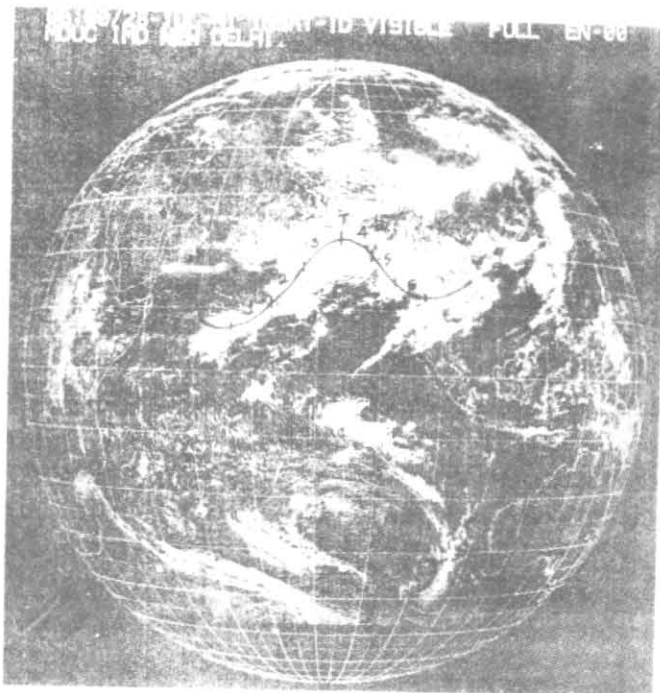


Fig. 5. Location of wave pattern superimposed on visible satellite imagery of 0600 UTC, 28 July 1991



Fig. 6. Location of wave pattern superimposed on visible satellite imagery of 0630 UTC, 21 August 1991



Fig. 7. Location of wave pattern superimposed on visible satellite imagery of 0600 UTC, 24 August 1991

depression between 28th and 30th. Off-shore trough near the west coast was also seen on 27th. The cycir extended upto mid tropospheric levels. Another cycir was seen over Gujarat on 27th and 28th, and moved over Rajasthan and adjoining Pakistan on 29th.

On 27th Mumbai recorded 18 cms of rainfall and Ratnagiri 17 cms. The rainfall area widened on 28th and the quantity was moderate. Rajkot had 8 cms, Ahmedabad and Bhavnagar 3 cms each, Surat 11 cms, Harnai 4 cms, Mumbai 15 cms, Pune 4 cms, Aurangabad 1.6 cms, Malegaon 1.3 cms, Parbhani 1.6 cms and Solapur 0.7 cms (Fig. 4). After that there was general decline of rainfall, as the depression moved inland upto north-west Madhya Pradesh.

The wavelength was approximately 28° across. The trough moved from $23^\circ\text{N}/85^\circ\text{E}$ on 28th to $22^\circ\text{N}/77^\circ\text{E}$ on 31st. The cloud organisation was not well poised on 27th. While light to moderate medium clouds occupied 2nd and 3rd sectors, 4th and 5th sectors were dominated by large convective clouds; 6th sector had moderate low clouds. On 28th the cloudings was intense in 3rd, 4th and 5th sectors (Fig. 5).

On 28th when the region was in the verge of the 2nd sector, the rainfall increased with the depression moving north of the wave's arm, and subsequently north of the

trough. The decreasing effect is evident in the decreasing trend of the rainfall in the region.

(b) A low formed at $18^\circ\text{N}/90^\circ\text{E}$ in north bay on 21st August extending upto 700 hPa and with trough at 500 hPa over bay. Another cycir was centred at $24^\circ\text{N}/77^\circ\text{E}$ at 850 and 700 hPa. The overlying wave pattern in satellite imagery could be positioned with the trough at $25^\circ\text{N}/77^\circ\text{E}$ and the wave length extending over 28° of longitude (Fig. 6). The cloud organisation was not well marked. The rainfall over west-coastal region were moderate on 21st. On 22nd the low became a depression at $21^\circ\text{N}/88^\circ\text{E}$ and moved upto $28^\circ\text{N}/77^\circ\text{E}$ on 26th. The cloud organisation was moderate and the wave length varied between 23° and 27° (Fig. 7). On 23rd the trough was at $23^\circ\text{N}/77^\circ\text{E}$ and it moved slowly north along the longitude, ending up at 27° on 27th. The clouds were light and scattered low and medium types in second sector. Convective clouds occupied 3rd and 4th sectors; Moderate convective clouds were seen in 5th and 6th sectors. The rainfall decreased on 22nd and increased substantially from 23rd to 25th before decreasing again. On 22nd, the wave had the region midway of its 1st and 2nd sectors, with depression in the 5th sector. The movement of the system north of the wave may have to be taken into consideration for the decrease in rainfall (Fig. 8).

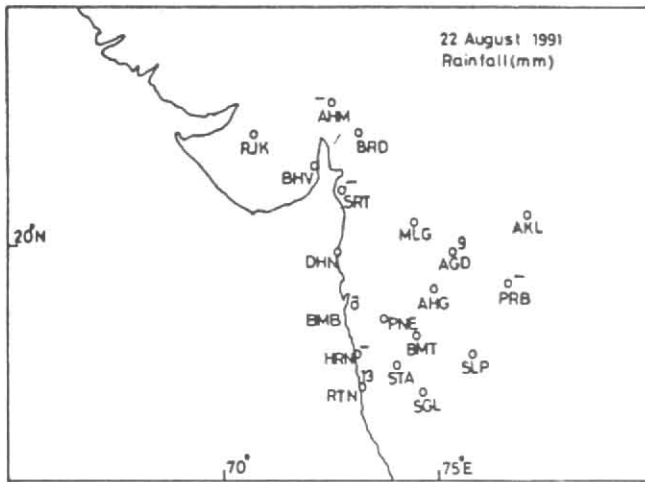


Fig. 8. Recorded rainfall (in mm) on 22 August 1991 over Gujarat & Maharashtra state

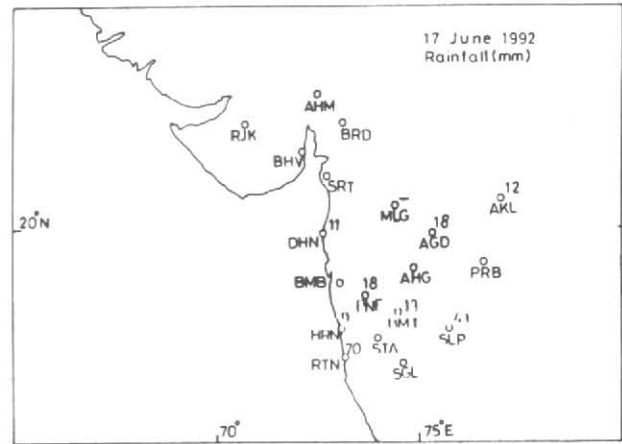


Fig. 9. Recorded rainfall (in mm) on 17 June 1992 over Gujarat & Maharashtra state

(iii) 1992

Though the effects in June were similar to July and August months, the clouding in June is however dependent mostly on the northward advancing of cloud pulses. Hence the distant effect of monsoon depression is less pronounced in June.

(a) A depression formed over $19^{\circ}\text{N}/88^{\circ}\text{E}$ on 17th June, and lasted upto 20th at $21^{\circ}\text{N}/78^{\circ}\text{E}$ with cycir upto 700 hPa. On 17th the region was on the verge of 2nd sector. However, the movement of trough was such that the region was left out of its seige on 18th & 19th. On 17th June a trough was seen over $17^{\circ}\text{N}/85^{\circ}\text{E}$ and moved upto $22^{\circ}\text{N}/77^{\circ}\text{E}$ on 20th. Wavelength was 25° on 18th & 19th. There were light to moderate convective clouds in 2nd and 6th sectors. The clouding increased in sectors 3,4 and 5, with moderate to intense convection. On 17th the rainfall recorded a steep increase throughout the region (Fig. 9).

(b) Between 6th and 8th, when there was a cyclonic circulation over south-west bay, the effects were not evident, probably due to lack of advancement of southwesterly current upto the area concerned to provide the necessary moisture. The monsoon arrived over the region only on 21 June, 1992.

The rainfall increased after 11th, with widespread rainfall over the region on 13th. Jalgaon and Parbhani reported 5 cms, Pune 3 cms, and Aurangabad 2 cms.

(c) A depression at $21^{\circ}\text{N}/87^{\circ}\text{E}$ on 26th July, moved upto Rajasthan on 30th and crossed over to Pakistan on 31st as a low, with the cycir extending upto 500 hPa on most of the days. Another cycir moved ahead of this cycir, from Rajasthan to Pakistan between 850 and 700 hPa. The trough position shifted gradually from $24^{\circ}\text{N}/83^{\circ}\text{E}$ on 23rd to

$25^{\circ}\text{N}/76^{\circ}\text{E}$ on 25th and another trough from $18^{\circ}\text{N}/83^{\circ}\text{E}$ on 26th to $28^{\circ}\text{N}/75^{\circ}\text{E}$ on 31st. The wavelength was 25° of longitude on most of the days. The vortex on satellite pictures was stationed at 5th sector of the wave on 23rd, 24th and 25th and moved upto 3rd sector on 30th, and was over Pakistan on 31st in the 2nd sector (Fig. 10).

Large convective clouds occupied 3rd to 5th sectors and light to moderate low an medium clouds in 2nd sector. Moderate convective clouds were seen in 6th sector also. From widespread rainfall on 22nd, the activity decreased and became widespread again on 26th. The quantities were however lower on 26th. It was intense over south Gujarat on 25th. The region was under the influence of 2nd sector on 23rd & 24th and of 3rd on 25th. The trough and there by the wave occupying lower latitudes from 26th leaving out Gujarat and Madhya Maharashtra may be attributed as reason enough for lack of the effect of the system. Only the 29th the region came under the trough and depression was also near the wave trough.

From above analysis of individual instances, the following observations emerge :

- (i) At the formation stage of the synoptic system and on the day of its formation, rainfall activity over the designated area along the west coast of Maharashtra and over south Gujarat increases as a precursor to the systems at the eastern end of the wave.
- (ii) As system moves inland, and lies over north Andhra Pradesh or Orissa, the rainfall activity in the west decreases significantly.
- (iii) When the trough position at the northern limit of the wave lies close to the west coast, the rainfall increases markedly over the region, which incident-



Fig. 10. Location of wave pattern superimposed on visible satellite imagery of 0600 UTC, 31 July 1992

tally lies in the 3rd sector of the wave structure. When the area over west coast falls under the 3rd and 4th sectors of the wave there is an increase of rainfall there.

- (iv) When this trough and the overlying vortex shifts northward, there is an overall decrease of rainfall over the area (MM & S- Guj). This decrease in rainfall is noticeable even when the synoptic vortex shifts northward.
- (v) In most of the cases the synoptic low or depression forms over the 5th or 6th sector of the trough. When the wave structure on the satellite picture is seen to be well marked, it can be inferred that the system formation is favourable. However, the system moves independently as a separate entity, and not necessarily along the wave pattern. The synoptic systems are faster than the wave.
- (vi) Maximum clouding increase from 3rd to 5th sector and extends upto the 6th sector. The cloudiness in 1st and 2nd sectors is minimal; thereby the weather is also minimal or nil.

- (vii) Wavelength measured from ridge to ridge of easterly wave, as seen from satellite, varies between 23° to 30° of longitude in the Indian region. Average wavelength is about 26° of longitude.

The study was limited to a few years and the region selected for study was small. There is possibility for widening the time frame as well as area for visualising similar effects of wave nature and the effects, the systems produce on far away domains, and thereby effecting improvements in short term synoptic forecasts.

4. Conclusion

It can be inferred that the depressions or lows in the north-west bay of Bengal cast their spell as far as MM and S-Guj. Depending on their intensity and the easterly waves extent and position, the quantity of rainfall over the region varies from moderate to heavy, and from scattered to widespread. The rainfall is particularly intense and widespread when the 3rd sector of the wave as can be visualised in the satellite imagery covers MM & S- Guj, with the depression in the 5th or 6th sector of the wave. Thereafter, there is a general decrease of the rainfall in space and quantity, when

the system moves north of the wave as a separate entity. If the system chances to move along the wave's arm upto its culminating trough, with the other arm still covering the designated region, the rainfall continues over the region or intensifies. While the system is well poised in the 5th or 6th sector of the wave, if the trough is in the lower latitude, or in a more easterly position, with the right arm of the wave away from the MM and S-Guj regions, there is lack of effect of the system on the rainfall activity over the area, either for occurrence or for increase as the case may be. Thus the visualisation of the easterly wave structure with the help of satellite imagery may pave way for effective reckoning of rainfall in MM & S-Guj region and for improving forecast of areal and quantitative rainfall over the region.

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