

## Properties of interacting storms over Indian seas and their uses in forecasting

D. S. DESAI and N. B. THADE  
 Meteorological Office, Pune  
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**ABSTRACT.** Important properties of two interacting tropical cyclones over Indian seas are found here. These properties can be used in forecasting intensification and movement of two interacting tropical cyclones on day-to-day basis. In all six pairs of interacting tropical storms which are separated by about 1800 km are studied. Interaction is classified into two types for convenience. In the first type, the two interacting storms, one in the Arabian Sea and the other in the Bay of Bengal are studied. In the second type, the two interacting storms on either side of the equator near 6 to 8 deg. N/S and 80 to 95 deg. E are studied.

### 1. Introduction

Interaction between two storms has been studied by many authors. The first to study was Fujiwhara (1921-23) who treated the interaction between the cyclonic storms analogous to the interaction between vortices in hydrodynamics. He stated that the vortices either attract or repel each other when they come very close. The vortices rotate each other about centre of gravity located on a straightline or great circle connecting them. The centre of gravity of rotation depends upon the relative mass and intensity of the vortices. If both the vortices have equal strength, then they form a couple and rotate about the mid-point connecting the two (Reihl 1954).

Over the Indian seas, the interaction between the two storms is not frequent. It forms a most interesting part of the study, both from the synoptical and dynamical point of view. Studies so far done are mainly from the hydrodynamical or dynamical point of view and none from the synoptic point of view. Interaction between two storms over the Indian seas does not strictly follow the 'Fujiwhara' effect because of the following reasons, viz.,

(i) Fujiwhara effect is applicable when the strength of the two vortices are equal. This is a very rare case and in most of the cases the relative strengths of the vortices differ considerably.

(ii) Fujiwhara effect is mainly applicable to the storms which are over the open seas. Over Indian seas, the intervening peninsular India, perhaps contributes to the interaction of the storms. Therefore, in this paper, the properties of the interacting storms over the Indian seas which differ considerably from the famous 'Fujiwhara effect' are studied.

Interaction of two storms can be classified into two types for convenience. *The first type of interaction* is between two storms one in the Bay of Bengal and the other in the Arabian Sea. *The second type of interaction* is between two storms one in northern hemisphere near equator say 6 to 8 deg. N and other in southern hemisphere near equator between 6 to 8 deg. S.

The *tropical disturbance summary* from Washington, the *Gaum bulletins* and the *Daily Weather Charts* from Weather Central, Pune are used in this study. The tracks of the tropical storms from 1896 to 1979, the *Daily and Weekly Weather Reports* published by India Met. Dep. are also consulted for this study.

### 2. The first type of interaction

Four cases of storms which interacted each other one in the Bay of Bengal and the other in the Arabian Sea are studied here. The period of these storms are :

- (i) 29 September to 5 October 1966
- (ii) 8 November to 14 November 1966

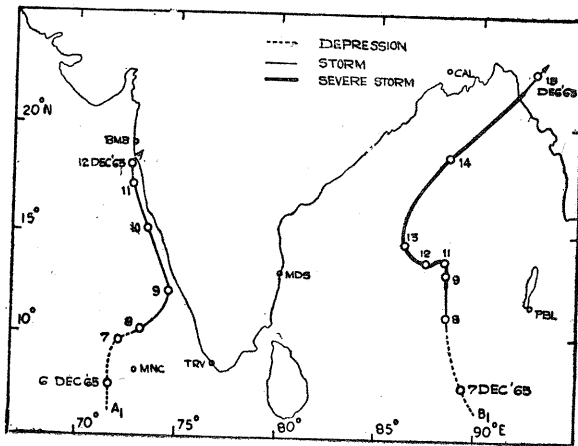


Fig. 1

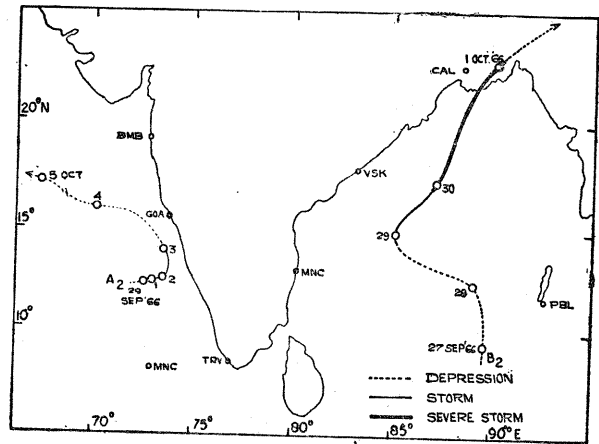


Fig. 2

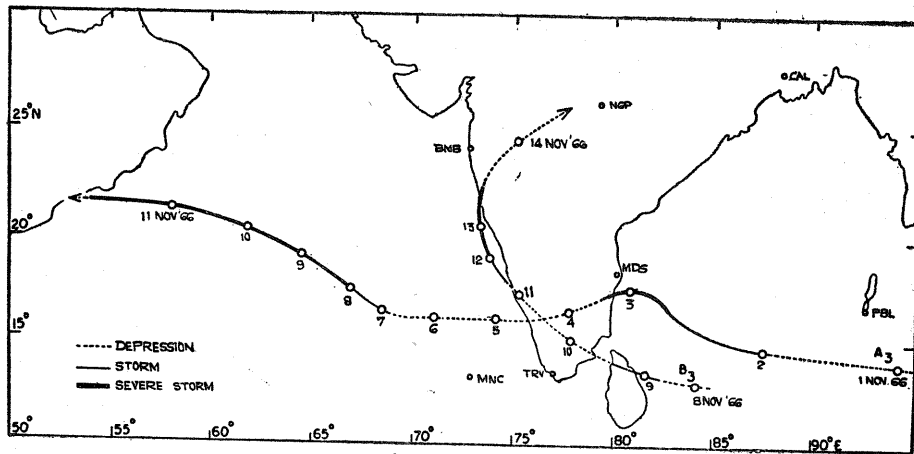


Fig. 3

(iii) 6 December to 12 December 1965

(iv) 8 November to 22 November 1977

Though, it was difficult to identify the condition under which two storms interacted, it was quite obvious from the behaviour of the two storms that they were interacting. On the day when interaction started, movements of both the systems were erratic and behaviour was irregular. It was difficult sometimes to keep continuity of the day-to-day centres of the storms both from satellite and conventional data. This is true for all the storms discussed in this paper. Storms interacted each other when they were separated by about 1800 to 2000 km away.

Intensification and movement of interacting storms mainly depend upon the relative strength, and the distance between them. When two storms form or exist simultaneously, then we should know relative strengths so that we can forecast the intensification and the movement of the system. When one of the two storms is very

much stronger than the other, then the conventional synoptic observations like—number of closed isobars, vertical extension of the system, pressure departure field, ships reports near the storms if available and the satellite pictures—will give conclusive evidence of their relative strengths in a qualitative way. Of the four storms discussed, three are of this type on the day when they interacted. As given in Figs. 1 and 3 we can see that on 8 December 1965 and 8 November 1966, the Arabian Sea storm was stronger than that over the Bay of Bengal and as in Fig. 2, on 29 September 1966 the Bay of Bengal storm was stronger than the one over the Arabian Sea. In this case, it has been found that the stronger of the two storms intensified first and moved; while the weaker one remained practically stationary without appreciable movement and intensification. The weaker one, intensified and moved only when the stronger one moved away from the field and dissipated completely. This property holds good when the stronger one continues to be stronger till it dissipated as it is the case in these

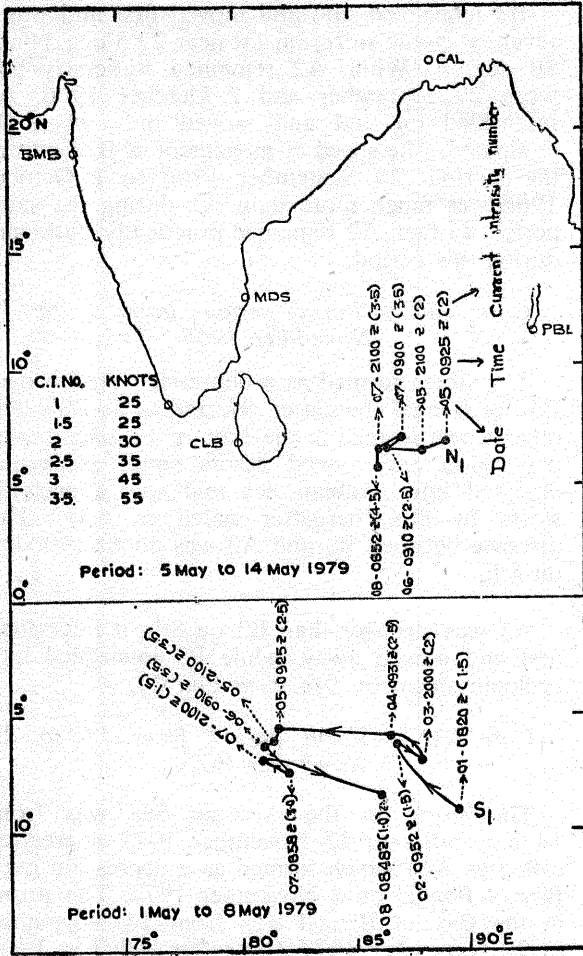


Fig. 4

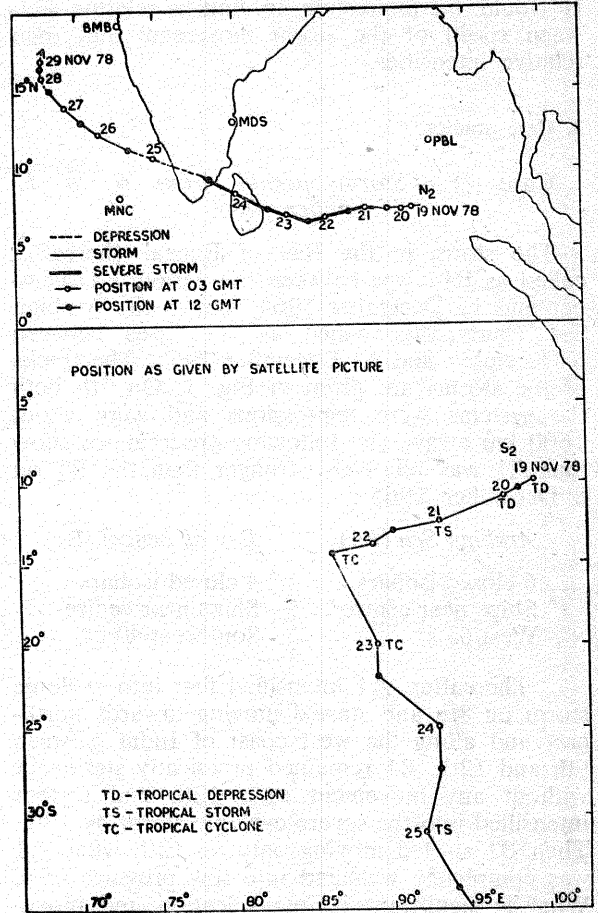


Fig. 5

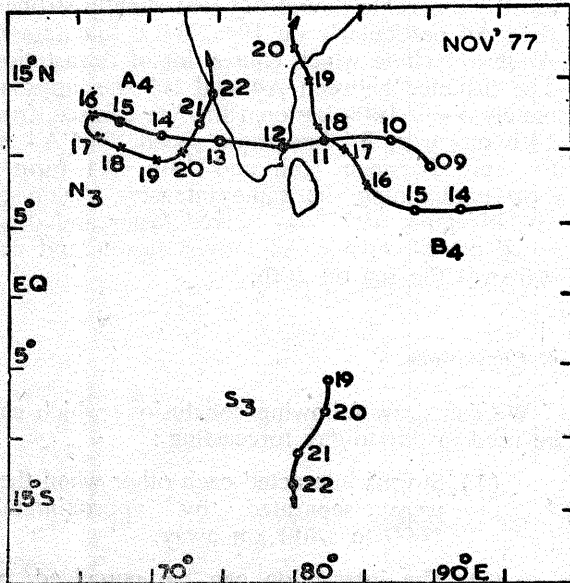


Fig. 6. Tracks of cyclone in the Indian Ocean during November 1977 (Diagram taken from the paper of Mukherjee *et al.* 1979)

three storms. When the interacting storms are of comparable intensity or strength (but not exactly equal, then they form a couple following a famous Fujiwhara effect) then convective data may not give conclusive evidence as to which one of them is stronger. Moreover, a stronger storm today may become weaker the next day relative to the other storm then also conventional data fail to identify their intensities. The storm during the period 8 November to 22 November 1977 as shown in Fig. 6 is a typical example of this type. Such cases are very rare and there is every possibility that we can understand which one is stronger. We can see the Fig. 6 where the tracks of the storm are given. Both the storms have almost comparable intensifies from 15 to 19 November 1977. Perhaps only on 19th that the Bay storm was little stronger than the Arabian Sea storm and as such Bay storm inland and dissipated earlier. It is worthwhile to mention here about the relative speed of the interacting storms. When one of them is stronger than the other, the stronger one moves with more speed than the weaker one; while both have the comparable intensities, then both move almost with equal

speed as in the case of November 1977 storm. It would be interesting to find a relation between speed of the storm movement and their relative intensities.

### 3. Case studies

#### *Case (i) — Storm period from 6 to 12 December 1965*

The storm in the Bay of Bengal (hereafter called as B1) was between the period 7 December and 15 December 1965, and in the Arabian Sea (hereinafter called as A1) was between 6 December and 12 December 1965. The tracks of the storms are given in Fig. 1. On 7th both the systems were depressions and were about 1600 km away. The following observations show that A1 was relatively stronger than the B1 on 8 December 1965 :

<i>Arabian Sea (A1)</i>	<i>Bay of Bengal (B1)</i>
6 closed isobars	4 closed isobars
Ships near centre	Ships near centre
West/65 kt	Southeast/40 kt

Thereafter, A1 intensified first into cyclonic storm on 8th and started moving towards north-east and along the west coast of India between 9th and 12th. B1 remained practically stationary without any movement upto 12th and further intensified into the severe cyclonic storm by 12th. Then B1 started moving only on 12th when A1 was completely weakend into low pressure area. What is significant is intensification and movement of A1 on 8th and its dissipation by 12th while B1 remaining practically stationary between 8th and 12th and start moving later only. Speed of movement of A1 between 8th and 12th is much more than B1 during the corresponding period.

#### *Case (ii) — Storm period from 29 September to 5 October 1966*

The period of the storm in the Bay of Bengal was between 27 September and 1 October 1966 (hereafter called as B2) and in the Arabian Sea was between 29 September and 5 October 1966 (hereafter referred as A2). The tracks of the storms are given in Fig. 2. B2 formed as depression on 27th and remained so upto 29th while A2 formed as a depression on 29th only. Both the systems on 29th were about 1400 km away and the following observations of 29th show that B2 was stronger than A2 :

<i>Arabian Sea (A2)</i>	<i>Bay of Bengal (B2)</i>
Two closed isobars	Three closed isobars
Max. winds reported by ships near centre	Max. winds reported by ship near centre
West/15 kt	Northnortheast/30 kt, Southsouthwest/30 kt.

B2 intensified first and moved first and was a severe cyclonic storm on 1st near 22.5 deg. N and 90 deg. E. While A2 remained stationary between 29 September and 2 October 1966. A2 intensified on 2nd and moved only when B2 dissipated. The speed of movement of B2 between the period 29 September 1966 to 1 October 1966 was much more than A2 during the same period. In fact, A2 remained practically stationary during this period.

#### *Case (iii) — Storm period from 1 to 14 November 1966*

The storm formed as a depression on 8th over Bay of Bengal (hereafter referred to as B3). The other storm formed in the Bay on 1 November as depression and moved across south peninsula, emerged into Arabian Sea and was a cyclonic storm by 8th (hereafter called as A3). The distance between B3 and A3 was about 1900 km on 8th.

A3 was stronger than B3 on 8th, it intensified first and moved away, while B3 intensified into cyclonic storm on 9th (See Fig. 3).

#### *Case (iv) — Storm period from 14 to 22 November 1977*

The storm in the Arabian Sea was from 14 November to 22 November 1977 (hereafter called as A4) which formed as a depression over Bay of Bengal on 8 November 1977. The storm in the Bay of Bengal was from 14 November to 20 November 1977 (hereafter called as B4).

The tracks of the storms are given in Fig. 6. In this case, the strengths of A4 and B4 were most comparable though B4 was slightly stronger than A4 particularly on 19th, B4 is that famous Andhra cyclone which caused lot of devastation. The distance between A4 and B4 was approximately about 1600 km on 18th. We can see, from 14th onwards, B4 had more speed than A4 till the end. Between 16th and 18th, A4 form a loop maintaining the same intensity. Again on 19 November 1977, B4 moved faster and dissipated on 20th while A4 moved slower and was still over the sea on 20th.

### 4. Conclusions

We can draw following conclusions which can be used in day-to-day forecasting :

- (1) Storms interacted each other when they were separated by approximately 1600 to 1800 km away.
- (2) The interaction can be perceived by the erratic behaviour and irregular movement of either or both of the storms.

- (3) The stronger of the two storms, intensifies first and moves away while the weaker one remains without appreciable movement and intensification.
- (4) The weaker one intensifies and moves only when the stronger one moves away and dissipates completely.
- (5) Speed of movement of the storm depends upon the relative intensities of storms.

#### 5. Second type of interaction

For studying the interaction between two storms one in northern hemisphere and other in southern hemisphere on either side of the equator, the following three cases are studied. The periods of these storms were (1) 1 to 14 May 1979, (2) 19 to 29 November 1978, (3) 8 to 22 November 1977 (this is common for both the types). From the study of these storms, we can see that all the conclusions under 4 hold true for these interacting storms more accurately, for storms 1 to 14 May 1979 and 19 to 29 November 1978 as in Figs. 4 and 5.

*Case (v)* — The storm period in northern hemisphere was from 5 to 14 May 1979 (hereafter called as N1) and the corresponding in southern hemisphere was from 1 to 8 May 1979 (hereafter referred as S1). Tracks of the system as given in Fig. 4 by satellite picture and Gaum bulletins are drawn as the conventional data over the sea areas was sparse. On 5th N1, was a depression so also S1 separated by about 1500 km away. Behaviour of N1 and S1 were very much erratic throughout upto 8th. S1 was stronger than N1 upto 6th at 0910 GMT as per the current intensity number given by satellite clouding. Between 6th 0910 GMT and 7th 2100 GMT both S1 and N1 detoured and formed a loop simultaneously as shown by satellite pictures. At 7th 2100 GMT, N1, became more intense than S1 according to satellite current intensity number. Further on 8th 0848 GMT, N1 further intensified while S1 became very much weak. By 9th, N1 moved northwest and S1 moved southeast.

*Case (vi)* — The storm period in northern hemisphere was from 19 to 29 November 1978 (hereafter called N2) and other from 19 to 27 November 1978 (hereafter called S2). The tracks of the storms are shown in Fig. 5. Both the systems were about 2000 km apart between 19th morning to 22nd evening. N2 intensified into severe cyclonic storm on 20th evening while S2 remained tropical storm. Between 21st and 22nd evening, N2 and S2 moved almost parallel in a westsouthwesterly direction. Later N2 moved in a northwesterly direction and S2 in a southeasterly direction.

*Case (vii)* — The storm in northern hemisphere was from 14 November to 22 November 1977 in the Arabian Sea (say N3) and in southern hemisphere was between 19 and 22 November 1977 (say S3). The tracks of the storms are given in Fig. 6. What is most interesting to see is on 19 November 1977 all the three storms were interacting, perhaps a very rare phenomenon. Both the storms N3 and S3 repelled each other and moved away. Other conclusions do not hold good here.

An interesting finding which emerged out of this study is that a low pressure system near the equator in northern hemisphere (say south of 10 deg. N) can intensify into a cyclonic storm when there is an interacting low pressure system near the equator in southern hemisphere (say north of 10 deg. S). That means the two systems near the equator one each in northern hemisphere and southern hemisphere can form, intensify into cyclonic storm simultaneously. Dynamically, it is difficult to explain the formation of cyclonic storm near the equator as the wind flow becomes mainly cyclostrophic in the absence of coriolis force. For a synoptic scale of systems, the value of the centrifugal force (which balances the pressure gradient force in a cyclostrophic flow) is less and wind strength does not increase to required 34 kts to form a cyclonic storm. But, in the case of the two interacting storms near the equator on either side, the westerly wind strength is maintained and systems can intensify into cyclonic storm. The recent Andhra cyclone (between 6 to 14 May 1979 which crossed Andhra coast on 12th evening is a typical case of illustration. The tracks of the storm is given in Fig. 4. The system intensified into cyclonic storm at 6 deg. N in association with another interacting storm at 6 deg. S.

It is also worthwhile to see the movement of the interacting storms on either side of the equator. Of particular interest is case 4 as given in Fig. 4. Mukherjee *et al.* (1979) hypothesised that the two interacting storms on either side of the equator have a tendency to move eastwards. They explained their hypothesis on the basis of the vorticity of moving parcel across the equator. When we examine the storm tracks as in Fig. 4, we find that both the storms started interacting from 5 May 1979 at 0925 GMT as given by satellite disturbance summary. On 6th at 0910 GMT both the storms moved towards east before forming a loop. Thus, this case illustrates clearly the hypothesis of Mukherjee *et al.* (1979).

#### 6. Conclusions

- (1) All the conclusions drawn for the first type of interaction under 4 also hold here.
- (2) An interesting finding is two low pressure system on other side of the equator very close to each other (say south of 6 deg. N or north

of 6 deg. S) can intensity into cyclonic storms when both of them are interacting each other. This cannot be otherwise explained dynamically.

(3) Interacting storms on either side of the equator have a tendency to move towards east. This hypothesis by Mukherjee *et al.* (1979) is nicely illustrated by the storms from 5 to 14 May 1979.

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