

## Influence of a cyclonic storm on another in Bay of Bengal, south China Sea and west Pacific

P. N. SEN, N. C. BISWAS and A. K. BANERJEE  
Meteorological Office, Pune

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**सारांश** — इस शोधपत्र में दो चक्रवाती तूफानों के बीच हुई अन्योन्य क्रियाओं की तीन घटनाओं को प्रस्तुत किया गया है और उस पर विवेचना की गई है। अन्योन्य क्रिया का चरण में तूफान अस्थायी रूप से एक सर्वनिष्ठ केन्द्र के चारों ओर घड़ी की सुई की दिशा में घूमता है जो कि सुविख्यात फुजिहारा प्रभाव की संकल्पना के विपरीत है। यहां इस असामान्य गमन की सिनाप्टिक व्याख्या प्रस्तुत करने का प्रयास किया गया है।

**ABSTRACT.** Three cases when a pair of cyclonic storms interacted with each other have been presented and discussed in this paper. During the interacting phase, the storms moved temporarily in a clockwise manner around a common centre which is reverse of what is postulated in the well known Fujiwhara Effect. A synoptic explanation for this unusual movement has been attempted.

### 1. Introduction

The pioneering work on the interacting vortices was done by Fujiwhara (1921, 1923) more than fifty years ago. He had shown that when two cyclonic storms come near each other and interact, they move anticlockwise around a common centre in the northern hemisphere.

Cyclonic storms are known for their destructive character. In recent years many useful techniques have been developed for predicting and forewarning movement of severe cyclonic storms to reduce loss of life and property. However, when two such intense systems appear on the same scene, on account of their mutual interaction, they may temporarily traverse in tracks quite different from the anticipated ones and elude satisfactory prediction. If one of them happens to be near to landfall during the interacting phase, reasonable forewarning about its movement through standard techniques may be difficult and in such situations, damage to life and property can be enormous. It is for these reasons that studies on the interaction between two cyclonic storms are gaining greater importance progressively in recent years. Mukherjee *et al.* (1979) were the first to study the 'Fujiwhara Effect' in the cyclonic storms of the Indian seas. Desai *et al.* (1981) studied the properties of the interacting storms.

One of the most active regions of cyclogenesis is the West Pacific where twenty to thirty tropical storms or typhoons develop every year. These disturbances generally move in a westnorthwesterly direction initially and take a northwesterly course at a later stage and a number of them even recurves northeastwards. The storms or typhoons, which take a more westward

course, enter south China Sea after crossing Philippines. Simultaneous occurrence of two storms over West Pacific is not uncommon.

Bay of Bengal is another region of cyclogenesis. The number of disturbances which develop in this region is, however, much less compared to that over the West Pacific. The Bay disturbances which intensify into cyclonic storms develop mainly during pre-monsoon period (March-May) or the post-monsoon period (October-December). Sometimes cyclonic disturbances are seen simultaneously both over the Bay of Bengal and the south China Sea.

An attempt has been made in this paper to find out whether two disturbances occurring simultaneously mutually interact and if so, the nature of their interaction.

### 2. Data utilised

For the present study, the tracks of the tropical storms over the Bay of Bengal and over the Pacific and south China Sea have been taken from the *Storm tracks* published by the India Meteorological Department (IMD) and *Typhoon* published by the Joint Typhoon Warning Centre (JTWC), Guam respectively. The tracks over the West Pacific and south China Sea have been taken from the best track published by JTWC. The analysed charts of the Indian Ocean and Southern Hemisphere Analysis Centre (INOSHAC) of IMD, Pune were utilised for synoptic study.

During the period 1972 to 1982 two cases have been identified when a cyclonic storm in the Bay of Bengal affected the normal course of a tropical storm or typhoon in the south China Sea and one case where

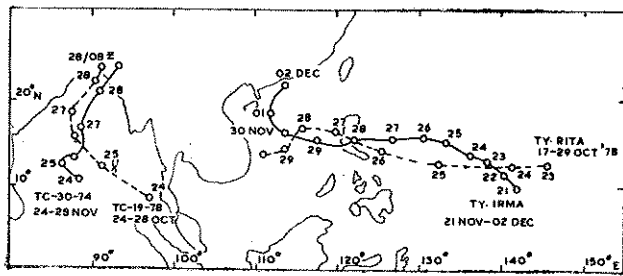


Fig. 1(a). Tracks of storms in the Bay of Bengal & south China Sea/Pacific Ocean

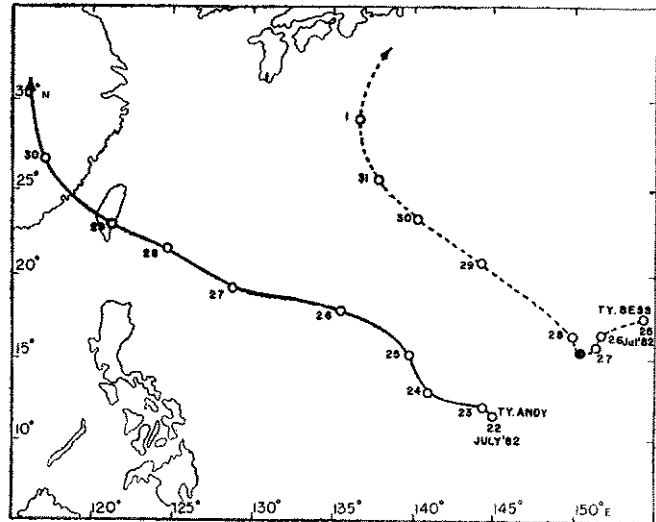


Fig. 1(b). Tracks of storms *Bess* and *Andy* over West Pacific

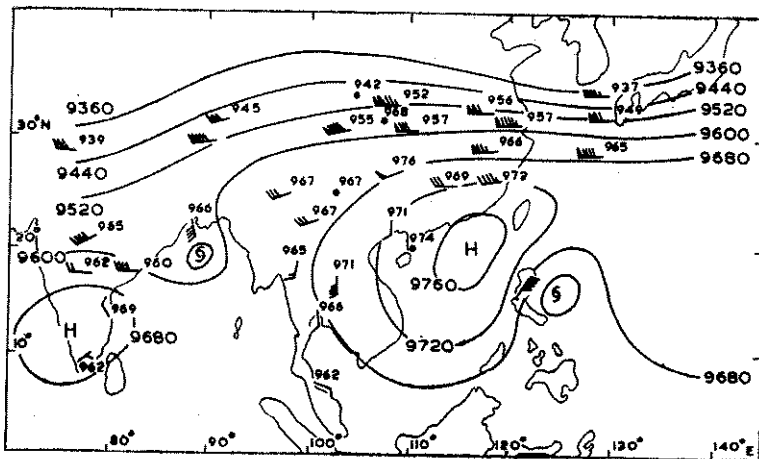


Fig. 2. Contour (gpm) analysis of 12 GMT, 300 mb level of 27 November 1974

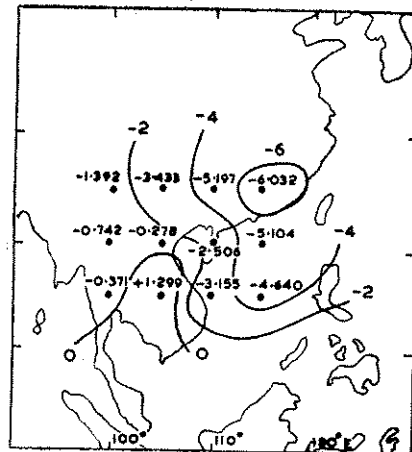


Fig. 3. Relative vorticity ( $10^{-5} \text{ sec}^{-1}$ ) distribution on 27 November 1974 at 12 GMT

the interaction took place between two storms over West Pacific. The tracks of the pair of storms are depicted in Figs. 1(a) and 1(b).

### 3. Case study

#### 3.1. Case 1—Interaction between TC 30-74 (24 to 28 November 1974) over the Bay of Bengal and typhoon *Irma* (21 November to 2 December 1974) over the West Pacific/south China Sea

Typhoon *Irma* developed as a tropical storm over east Caroline Islands in the West Pacific at 12 GMT of 21 November 1974. Initially it moved in a northwesterly direction till the 00 GMT of 26 November 1974 [Fig. 1(a)] when it lay centred at  $15.7^\circ \text{ N}$ ,  $130.8^\circ \text{ E}$ . Later it moved in a westerly direction till 00 GMT of 27 November 1974. Thereafter, it moved westsouthwest till 12 GMT of 28 November 1974 when

it lay centred at  $15.1^\circ \text{ N}$ ,  $119.5^\circ \text{ E}$ . Subsequently, it moved in a northwest direction till 1 December 1974 and then recurved [Fig. 1(a)].

At the time when the typhoon *Irma* developed in the West Pacific, another cyclonic system TC 30-74 formed in the Bay. It developed as a deep depression on the morning of 24 November 1974, 400 km west-southwest of Port Blair. It rapidly intensified into a severe cyclonic storm and lay at 12 GMT of 25 November 1974 at  $11.7^\circ \text{ N}$ ,  $87.6^\circ \text{ E}$ . Then it moved a little erratically for 36 hours and lay centred at 00 GMT of 26 November 1974 at  $13.5^\circ \text{ N}$ ,  $88.2^\circ \text{ E}$ . Under the influence of a middle and upper tropospheric trough in the westerlies it then moved in a north to northeasterly direction and crossed Bangladesh coast near Chittagong on the evening of 28 November 1974 and weakened by 29 November 1974 (Fig. 1a).

The 300 mb contour charts for the concerned area for 27 November 1974 is presented in Fig. 2 as an

example. The corresponding vorticity distribution pattern is presented in Fig. 3.

It has been observed that during the period from 26 to 28 November 1974 when the Bay storm took a northerly course, the anticyclone to its eastern flank gradually intensified. The contour values at the core of the anticyclone increased from 9720 to 9760 gpm. This is supported by the increase in the values of relative vorticity from  $-2 \times 10^{-5}/\text{sec}$  to  $-6 \times 10^{-5}/\text{sec}$  from 25 to 27 November 1974 (Fig. 3) in the neighbourhood of the core-region of the anticyclone. On 29 November 1974, the anticyclone became less intense and also the anticyclonic vorticity. It can thus be inferred that when the anticyclone gained sufficient intensity, it steered the typhoon *Irma* to a southerly course. After the dissipation of the cyclonic storm TC 30-74 over Bangladesh by 29 November 1974 the said anticyclone and the ridge over there weakened and re-adjustment took place to allow typhoon *Irma* to move in a northerly course. It may be interesting to note that under the influence of the Bay storm the sub-tropical anticyclone in the upper troposphere over Burma, Thailand and south China intensified to a reasonable degree so as to provide a strong northerly steering flow over the south China Sea resulting a southward movement of the storm in that area.

During the phase when typhoon *Irma* took a southerly course, the storm pair had a relative clockwise rotation and this may be due to a sort of three-body interaction between the two storms and the intervening anticyclone in the upper troposphere.

### 3.2. Case 2 — Interaction between TC 19-78 (26 to 28 October 1978) over the Bay of Bengal and typhoon *Rita* over the south China Sea

Typhoon *Rita* was the only super typhoon in the year 1978. It initially moved dead west because of the unusually strong mid-tropospheric ridge. Entering south China Sea across Philippines it weakened considerably and moved in a westnorthwest to northwest direction till 12 GMT of 27 October 1978, when it lay centred at  $17.0^\circ \text{N}$ ,  $117.4^\circ \text{E}$  (Fig. 1a). Afterwards *Rita* tended to move southward till 29 October 1978 and dissipated over the water off Vietnam coast.

Another cyclonic system TC 19-78 appeared in the Bay of Bengal during this period. The system developed into a cyclonic storm over the Bay of Bengal on the night of 25 October 1978. It initially moved northwestward till the morning of 26 October 1978. Then under the influence of a middle and upper tropospheric trough in the westerlies it moved north and then northeastwards and crossed Bangladesh coast in the afternoon of 28 October 1978. The 300 mb contour chart for the concerned area for 28 October 1978 is presented in Fig. 4 for example. The corresponding vorticity distribution pattern for this day is presented in Fig. 5.

It was seen that when the storm in the Bay started moving northeastwards from 27 October 1978 under the influence of a deep trough in the westerlies the anticyclone to its eastern flank began to intensify. On 27 October, the contour values near the core of the

anticyclone were around 9720 gpm but on the next day (28 October), they increased to 9760 gpm. Similarly the values of relative vorticity near the core region of the anticyclone increased from  $-2 \times 10^{-5}/\text{sec}$  on 27th to  $-3$  to  $-4 \times 10^{-5}/\text{sec}$  on 28th (Fig. 5). On 29 October, the anticyclone remained as intense as on 28th which can be seen from contour values near the core region remaining as high as 9760 gpm and values of relative vorticity remaining nearly  $-3 \times 10^{-5}/\text{sec}$ . But unfortunately, the typhoon (*Rita*) dissipated abruptly over the sea off the Vietnam coast on 29 October. Had *Rita* remained alive, she would have, in all probability, continued to follow a southwesterly course. Thus as in the previous case, in this case also the intensification of the anticyclone provided well-organised steering current for the typhoon to take a southwesterly course temporarily. As in case 1, here also a sort of three-body interaction took place between the two storms and the intervening anticyclone in the upper troposphere.

### 3.3. Case 3 — Interaction between Ty *Andy* and Ty *Bess* over South Pacific

As discussed in the earlier cases a similar interaction between Ty *Andy* and Ty *Bess* (Tracks shown in Fig. 1b) took place between 25 and 27 July 1982 in West Pacific through the intervening anticyclone. When Ty *Andy* started moving in a northerly course from 24 onwards to 26 July it intensified the anticyclone to its eastern flank which in turn governed the movement of the Ty *Bess* in a southerly course instead of moving polewards (Rossby 1949). After 26 July, Ty *Andy* took more westerly course and as a result the distance between the two systems increased, the intervening anticyclone became comparatively less intense and, therefore, was not in a position to influence the course of typhoon *Bess*. It took a northerly course which is in conformity with the general tendency of movement of a storm.

## 4. Discussion

In all the three cases discussed above, it is observed that the pair of cyclonic storms had some sort of interaction between them through the intervening anticyclone in the upper troposphere. But their relative movement during the phase of interaction was reverse of that postulated by Fujiwhara (*loc. cit.*). That is, they formed a couple and moved in a clockwise direction around a common centre. During the interacting phase in the first two cases the storms in the west moved in northnortheast direction under the influence of well marked upper/middle tropospheric troughs in the westerlies which lay north of the storms. In the anticyclonic flank of these westerly troughs, well marked anticyclones or elongated ridge invariably developed at 300 mb/200 mb, which generated steering current conducive for the storms to the east to move southwards. In the third case the storm to the west while moving in a northerly direction intensified the anticyclone in the middle/upper troposphere to its eastern flank which in turn steered the storm to the east in a southerly course.

Evidences show that well marked anticyclone/ridge in the anticyclonic sector of the westerly troughs

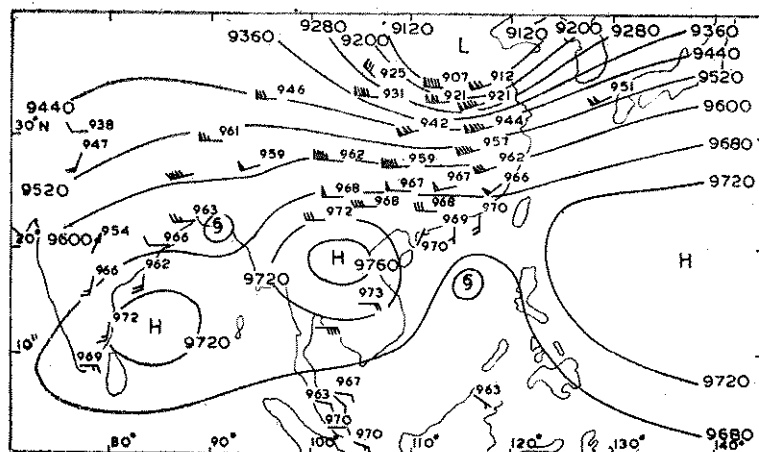


Fig. 4. Contour (gpm) analysis of 00 GMT, 300 mb level of 28 October 1978

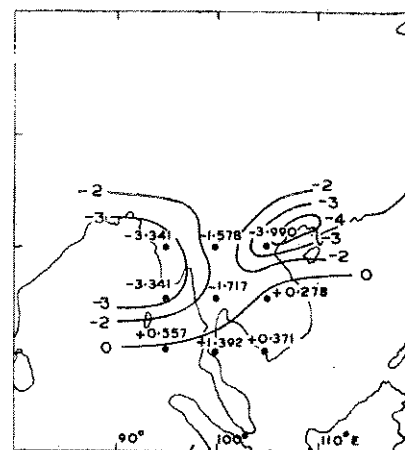


Fig. 5. Relative vorticity ( $10^{-5} \text{ sec}^{-1}$ ) distribution on 28 October 1978

develop under the influence of the cyclonic storms when the latter lie south of the westerly troughs. In such conjunctions, it may be argued that the inward pressure gradient in the cyclonic storm decreases with height and a reversal takes place at some level in the upper troposphere causing outflow from the eye wall leading to a well developed anticyclone in the upper troposphere. Riehl (1950) also postulated a similar process and incorporated in his model on hurricane formation. Similar situations have been encountered in the first two cases of interaction which have been discussed in the previous section.

## 5. Conclusions

(i) When a cyclonic storm moves north to north-eastwards under the influence of a moving middle and upper tropospheric trough in the westerlies, the anticyclone/ridge to its eastern flank often intensifies.

(ii) If another storm or typhoon appears to the east of it then the two at times interact with each other temporarily through the anticyclone mentioned above. During the phase of interaction of the two storms, which is short-lived, the normal course of the storm to the east, is often changed into a southerly course. The two storms then tend to move in a clockwise direction around a common centre which is opposite of what is postulated in Fujiwhara Effect.

(iii) On pure hydrodynamic considerations, Fujiwhara (*loc. cit.*) concluded that when a storm interacts with another in its vicinity, the two should move in an anticlockwise direction around a common centre. In the present study, the temporary clockwise movement around a common centre witnessed in case of three

pairs of storm seems to be due to synoptic perturbation. The source of the synoptic perturbation appears to be a well-organised anticyclone embedded between the two storms in the upper troposphere which gets temporarily intensified by the north/northeasterly moving storm. The interacting phase, when the pair of storms displays clockwise movement, is thus short-lived as the anticyclone reverts to its normal intensity after the dissipation of the storm on the western side over land. Though such phenomena may be explained with the help of steering current concept, as can be seen from the case presented in the paper that a three-body interaction is also responsible for such movement.

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