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INTERACTION BETWEEN TWO TROPICAL STORMS OVER WESTERN PACIFIC OCEAN

Fujiwhara (1921, 23) showed that when two cyclonic vortices in the atmosphere come close to each other, they rotate in an anticlockwise direction in the Northern Hemisphere around a common centre. Haurwitz (1951) confined his investigation on the rotation of the binary axis and found good correlation between observed and computed rate of rotation of the binary axis. Mukherjee *et al.* (1979) computed the angles of rotation of the binary axis based on two tropical cyclones over Indian seas during November 1977 and found good agreement with the observed angle of rotation. Using Brand's formula, Balasubramaniam and Jayanthi (1982) computed angular velocity of gyration of the two vortices of November 1977 over Indian seas and found that the computed values are higher than that of the observed ones. They concluded that this may be due to inaccuracies of their basic assumptions. An attempt has been made in this study to compute the angles of rotation of the binary axis for two pairs of tropical storms over Western Pacific Ocean during July 1981 and September 1979 using the method of Mukherjee *et al.*

2. The typhoon KELLY (Fig. 1) developed as a tropical depression on 28 June 1981 with centre near 13.0 deg. N/136.0 deg. E at 00 GMT. It became typhoon after crossing Philippines on 3 July centred at 16.9 deg. N/113.0 deg. E at 00 GMT and moved westnorthwestwards. It weakened into a depression on 051200 GMT after entering into North Vietnam.

The tropical storm LYNN (Fig. 1) was noticed as a depression over west Caroline islands on 1 July 1981. It became tropical storm on 030000 GMT centred near 12.2 deg. N/126.7 deg. E and moved northwestwards and crossed north Philippines on 4 July. It intensified again into a severe tropical storm on 060000 GMT over south China Sea.

2.1. The typhoon MAC (Fig. 2) developed from a weak surface circulation over west Caroline islands and became typhoon on 16 September 1979 by 1800 GMT. On 190000 GMT it was centred near 13.9 deg. N/121.4 deg. E as a tropical storm and moved northwestwards/northnorthwestwards. It weakened into a depression on 201200 GMT with centre near 17.6 deg. N/118.6 deg. E over south China Sea and again intensified into a tropical storm on 211200 GMT.

The tropical storm NANCY (Fig. 2) developed from a circulation over south China Sea and became a tropical storm on 19 September 1979 at 0600 GMT with centre near 18.6 deg. N/111.2 deg. E. After crossing Hainan it weakened into a depression on 201800 GMT centred near 17.9 deg. N/109.0 deg. E and moved southwestwards towards Vietnam.

3. Satellite tropical disturbance summary received from Washington, storm warning bulletin from Guam and daily weather charts prepared at Indian Ocean and Southern Hemisphere Analysis Centre (INOSHAC) have been used for this study. The position of the storm KELLY and LYNN at 00 GMT as received from Guam have been used except for 5 July where the centre of the storm KELLY has been determined based on data available from the storm fields and those for MAC and NANCY from Annual Typhoon Report (1979).

4. The computed and observed angles of rotation between the storm KELLY and LYNN and between MAC and NANCY are shown in Tables 1 and 2. From Table 1, it is observed that on 4 July the computed angle is higher than that of the observed one by only 3 deg. and on 5 July, there is no difference. But on 3 July the difference is more. It can be said that the Fujiwhara interaction between typhoon KELLY and tropical storm LYNN started on 4 July. Typhoon KELLY moved initially westwards and was forecasted to move northnorthwestwards or northwestwards from 3 July. But the intensification and movement of the storm LYNN has changed the course of KELLY. It moved westwards till it entered land over Vietnam and weakened. At the same time, LYNN moved northwestwards till it moved towards southeast China.

From Table 2, it is observed that on two days, the computed angles are more or less in agreement with the observed ones. On 19 and 20 September, the computed angles are within 5 deg. of the observed angle but on 21 September, the computed angle is almost double the observed angle. The Fujiwhara interaction between the storms started on 19 September. Sudden development of the tropical storm NANCY had modified the track of the typhoon MAC. MAC was originally forecasted to move westnorthwestwards, but with the development of NANCY it moved northnorthwestwards towards Hong Kong. NANCY initially moved westwards and then southwestwards till landfall over Vietnam. The possible explanation for the computed angle to be much higher than the observed

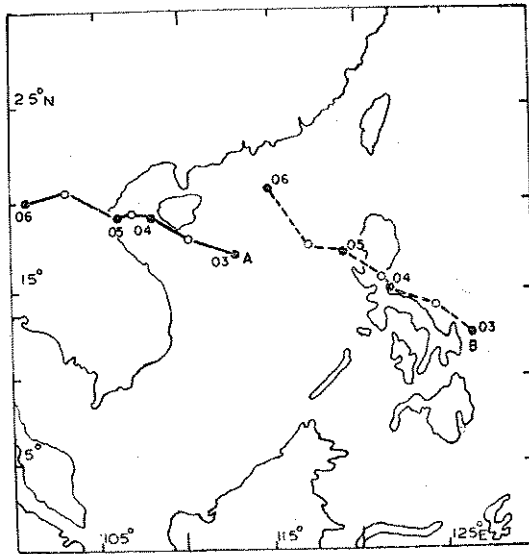


Fig. 1. Tracks of typhoon "KELLY" (A) and tropical storm "LYNN" (B) over Western Pacific Ocean during July 1981

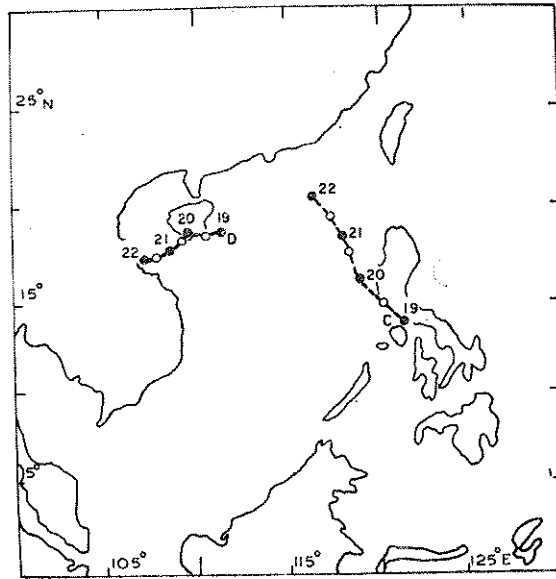


Fig. 2. Tracks of typhoon "MAC" (C) and tropical storm "NANCY" (D) over Western Pacific Ocean during September 1979

TABLE 1

Date (July '81)	Position at 00 GMT	r (km)	r' (km)	P (mb)	P' (mb)	$M_i \times 10^{10}$ (cm ² /sec)	r_{12} (km)	Angle(α)	
								Computed (°/day)	Observed (°/day)
Typhoon KELLY									
03	16.9N/113.0E	200	330	1002	1004	3.395			
04	19.1N/108.3E	180	310	1000	1002	2.863			
05	19.0N/106.0E	150	290	1000	1000	2.361			
Tropical storm LYNN									
03	12.2N/126.7E	200	370	1002	1004	3.354	1620	12.7	<2.0
04	14.9N/121.8E	160	240	1004	1006	3.245	1570	12.2	9.5
05	16.9N/119.3E	150	260	1004	1006	2.645	1480	11.3	11.5

Angle (α) is between 00 GMT of the day and 00 GMT of the next day.

TABLE 2

Date (September '79)	Position at 00 GMT	r (km)	r' (km)	P (mb)	P' (mb)	$M_i \times 10^{10}$ (cm ² /sec)	r_{12} (km)	Angle(α)	
								Computed (°/day)	Observed (°/day)
Typhoon MAC									
19	13.9N/121.4E	140	220	1006	1008	2.812			
20	16.1N/119.1E	170	270	1006	1008	3.150			
21	18.4N/118.1E	200	300	1004	1006	3.674			
Tropical storm NANCY									
19	18.8N/111.6E	130	360	1006	1008	1.730	1240	14.6	11.5
20	18.7N/109.7E	180	320	1004	1006	2.863	1100	24.6	20.0
21	17.7N/108.7E	200	310	1002	1004	3.580	1055	32.3	17.5

Angle (α) is between 00 GMT of the day and 00 GMT of the next day.

angle on 21 September is that MAC and NANCY weakened considerably into depression by 210000 GMT. Though NANCY remained depression till land-fall over Vietnam, MAC intensified into tropical storm by 211200 GMT and remained so till it moved towards southeast China.

Brand (1970) showed that the mutual interaction became apparent at a separation distance of about 1400 km atleast for north Pacific Ocean Tropical cyclones. This separation distance again probably depends upon the intensity of the storms. Based on this study, the interaction between typhoon KELLY and tropical storm LYNN was effective when they were at a separation distance ~ 1500 km; in case of typhoon MAC and tropical storm NANCY this distance was 1250 km.

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References

- Balasubramaniam, V. and Jayanthi, N., 1982, *Mausam*, 33, p. 207.
Brand, S., 1970, *J. appl. Met.*, 9, p. 433.
Fujiwhara, S., 1921, *Quart. J. R. Met. Soc.*, 47, p. 287.
Fujiwhara, S., 1923, *Quart. J.R. Met. Soc.*, 49, p. 75.
Haurwitz, B., 1951, *Archiv. Met. Geophys. Bioklim.*, 4, p. 73.
Joint Typhoon Warning Centre, Guam, 1979, Annual Typhoon Report.
Mukherjee, A.K., Gupta, H.V. and Gurunadhan, G., 1979, *Mausam*, 30, p. 457.
U.S. Dept. of commerce, NOAA, 1980, *Mar. Wea. Log.*, 24, p. 12.

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