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Climatological features of tropical disturbances over the Indian Ocean - south of equator

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सार – इस शोध–पत्र में 17 वर्षों (1985–2001) के बेस्ट ट्रैक आँकड़ों के आधार पर भूमध्यरेखा के दक्षिण में हिंद महासागर पर उष्णकटिबंधीय विक्षोभों (अवदाब अवस्था और उसके बाद की अवस्था) के बनने, उनके क्षीण होने और संचलन जैसी विभिन्न विशेषताओं के संकलन करने का प्रयास किया गया है। इन विशेषताओं को भूमध्यरेखा से 40° द. और 35° पू. से 105° पू. के बीच से 2.5° × 2.5° अक्षांश/देशांतर की ग्रिड पर परिकलित किया गया है।

इस अध्ययन से दिसंबर 1991 के महीने में भूमध्यरेखा से 2.5° द. के बीच भूमध्यरेखा के समीप चक्रवात के बनने के रोचक लक्षण का पता चलता है। ग्रे द्वारा दी गई 8.4 की जलवायविक सामान्य के विपरीत उष्णकटिबंधीय विक्षोभों की वार्षिक बारम्बारता 11.9 पाई गई है। विशेष रूप से उष्णकटिबंधीय विक्षोभ भूमध्यरेखा से 5° द. तक क्षीण नहीं हुआ और इस अवधि में 27.5° द. से 40.0° द. तक देशांतरीय पट्टी में कोई विक्षोभ नहीं बना है। आगे यह भी पता चला है कि भूमध्यरेखा से 2.5° द. और 32.5° द. से 35.0° द. तक पश्चिमभिमुखी (पूर्वाभिमुखी) संचलन उष्णकटिबंधीय विक्षोभ कम (बढ़े) हुए। यह भी एक रोचक तथ्य है कि भूमध्यरेखा से 2.5° द. के बीच कोई उष्णकटिबंधीय विक्षोभ पूर्व दिशा की ओर संचालित नहीं हुआ है।

ABSTRACT. Based on 17 years (1985 to 2001) of best track data, an attempt has been made to compile the different characteristics *viz*, genesis, dissipation and movement of tropical disturbances (depression stage onwards) over the Indian Ocean south of equator. These characteristics have been computed over a grid of 2.5° × 2.5° of Lat./Long. from equator to 40° S and between 35° E to 105° E.

The study indicates an interesting feature regarding the formation of cyclone close to equator, between equator to 2.5° S in the month of December 1991. The annual frequency of tropical disturbances has been found to be 11.9 against the climatological normal of 8.4 as given by Gray . Interestingly, no tropical disturbance has been found to dissipate upto 5° S from equator and no disturbance has formed during the period in the latitudinal belt of 27.5° S to 40.0° S. It has been further seen that the frequency of westward (eastward) movement of tropical disturbances decreases (increases) from equator to 2.5° S and 32.5° S to 35.0° S. It is interesting to note that no tropical disturbance has shown eastward movement within equator to 2.5° S.

Key words – Genesis, Tropical disturbance, Modal frequency.

1. Introduction

The climatological information about tropical disturbance, depression stage onwards, have been well documented for the north Indian Ocean by India Meteorological Department in the publication "Tracks of storms and depressions in the Bay of Bengal and the Arabian Sea (1877-1970) and (1971-1990). Such reports are very useful for day to day forecasting work as well as to the climatologist. The International Indian Ocean Expedition (IIOE), which lasted from 1959 to 1965, did help in collecting large amount of climatological observations from ships land stations, aircrafts and satellites which were compiled and published in the form "Meteorological Atlas of the International Indian Ocean Expedition" (1972). The Annual Tropical Cyclone Report (ATCR) published by Joint Typhoon Warning Centre, Guam provides best track positions of the cyclones in the south Indian Ocean. Several scientists have studied the climatological features of tropical disturbances in the north Indian Ocean. According to Raghavendra (1973), the annual frequency of storms and depressions in the Bay of Bengal is 13 out of which 56 per cent occur in the monsoon season and 31 per cent occur in the post monsoon season. The hot weather and cold weather seasons contributions are 10 and 2 per cent only. Rao and

TABLE 1

Cumulative frequency of genesis/dissipation of tropical disturbances in Indian Ocean over Latitude 0° S - 40° S and Longitude 35° E - 105° E. Period (1985-2001)

Lat. Belt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Amount
EQ	0(0)	0(0)	1(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	1(0)
2.5 S	1(0)	2(0)	2(0)	2(0)	0(0)	0(0)	4(0)	0(0)	0(0)	2(0)	0(0)	2(0)	15(0)
5.0	3.5(1)	9.0(1)	4.0(2)	2.5(0)	0(0)	3.5(0)	1.5(0)	1(0)	0(0)	2(2)	1(0)	2(1)	30(7)
7.5	4.5(3)	4.5(0)	4.0(0)	12.0(0)	6(0)	6(0)	2.5(0)	1(0)	2(0)	1(1)	1(2)	2(3)	46.5(9)
10.0	1.0(l)	2.5(2)	6.0(0)	12.5(2)	11(1)	6.5(0)	9.5(3)	2(3)	0(2)	0(0)	1(0)	1(0)	53(14)
12.5	0(3)	0(4)	0(3)	4.0(5)	10(5)	11.5(2)	1.5(4)	0(0)	0(0)	0(1)	0(0)	0(0)	27(27)
15.0	0(2)	0(1)	0(3)	4.0(1)	9(2)	4.5(3)	2.0(4)	0(1)	0(0)	0(1)	0(0)	0(0)	19.5(18)
17.5	0(0)	0(4)	0(2)	2(2)	3(4)	0(4)	0(4)	0(0)	0(0)	0(0)	0(0)	0(0)	5(20)
20.0	0(0)	0(I)	0(1)	2,0(4)	1(4)	0(5)	0(3)	0(0)	0(0)	0(0)	0(0)	0(1)	3(19)
22.5	0(0)	0(1)	0(2)	0(5)	1(4)	0(3)	0(2)	0(2)	1(0)	0(0)	0(0)	0(0)	2(19)
25.0	0(0)	0(0)	0(1)	0(6)	0(6)	0(8)	1(1)	0(0)	0(0)	0(0)	0(0)	0(0)	1(22)
27.5	0(0)	0(0)	0(0)	0(4)	0(3)	0(6)	0(1)	0(0)	0(0)	0(0)	0(1)	0(0)	0(15)
30.0	0(0)	0(0)	0(0)	0(5)	0(3)	0(3)	0(2)	0(0)	0(0)	0(0)	0(0)	0(0)	0(13)
32.5	0(0)	0(0)	0(0)	0(3)	0(4)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(7)
35.0	0(0)	0(0)	0(0)	0(2)	0(2)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(6)
37.5	0(0)	0(0)	0(0)	0(1)	0(1)	0(1)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)	0(3)
40.0	10.0	18.0	17.0	41.0	41.0	32.0	22.0	4.0	3.0	5.0	3.0	7.0	203
Total	(10)	(14)	(14)	(40)	(39)	(36)	(25)	(6)	(2)	(5)	(3)	(5)	(199)
Average	0.6	1.1	1.0	2.4	2.4	1.9	1.3	0.2	0.2	0.3	0.2	0.4	11.9
	(0.6)	(0.8)	(0.8)	(2.4)	(2.3)	(2.1)	(1.5)	(0.4)	(0.1)	(0.3)	(0.2)	(0.3)	(11.7)

Genesis ← X(y) → Dissipation

Jayaraman (1958) found the annual frequency of storms and depressions in the same region as 12.6. Based on 17 years (1985-2001) of record of best tracks of cyclones collected form ATCR, an attempt have been made by the authors to compile information and present results about the genesis, dissipation and movement of tropical cyclones in the Indian Ocean area bounded by longitude 35° E to 105° E and latitude equator to 40° S.

2. Data source and methodology

The best track positions of the Indian Ocean tropical cyclones in the southern hemisphere are obtained for the 17 years period (1985-2001) from the Annual Tropical Cyclone Reports for the compilation of frequencies pertaining to genesis, dissipation and tracks. Following methods have been adopted :

(*i*) The Indian Ocean region between equator to 40°S and between 35° E to 105° E have been divided into a number of grids each with the dimensions 2.5° × 2.5° of Lat./Long.

(*ii*) If the genesis / dissipation point, falls within a grid point, the frequency has been taken as one.

(*iii*) If a genesis / dissipation point falls on or lies either on latitude or on a longitude line forming the grid, the frequency have been taken as 0.5 for each of the grid involving that particular latitude or longitude.

(*iv*) The movement of a tropical disturbance within a grid has been first considered for 16 points of compass and later frequency for westward and eastward moving system have been compiled. The movement of a tropical disturbance between 45° - 135° and 225° - 315° of compass have been considered as eastwards and westwards movement respectively.

TABLE 2

Cumulative frequency of movement of tropical disturbances in Indian Ocean over Latitude 0° S - 40° S and Longitude 35° E - 105° E. Period (1985-2001)

Lat. Belt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total movement	Total movement (%)
0.0 E														
	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	(0)
	W-0	W-0	W-2	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-2	(100 %)
2.5 S														
	E-0	E-1	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-0	E-1	E-2	(11%)
	W-1	W-2	W-2	W-1	W-1	W-0	W-4	W-0	W-0	W-3	W-0	W-2	W-16	(89%)
5.0														
	E-2	E-2	E-1	E-1	E-0	E-0	E-0	E-0	E-0	E-0	E-2	E-1	E-9	(10%)
	W-7	W-18	W-11	W-7	W-0	W-4	W-7	W-2	W-0	W-11	W-4	W-11	W-82	(90%)
7.5														
	E-6	E-1	E-6	E-8	E-0	E-5	E-4	E-5	E-0	E-2	E-0	E-1	E-38	(18%)
	W-22	W-21	W-26	W-15	W-11	W-7	W-19	W-6	W-4	W-8	W-7	W-27	W-173	(82%)
10.0														
	E-3	E-4	E-7	E-11	E-9	E-4	E-9	E-8	E-2	E-1	E-2	E-0	E-60	20%
	W-18	W-24	W-28	W-44	W-37	W-27	W-39	W-8	W-4	W-2	W-1	W-9	W-24	80%
12.5														
	E-3	E-3	E-9	E-12	E-12	E-15	E-9	E-3	E-0	E-4	E-0	E-0	E-70	19%
	W-6	W-24	W-46	W-45	W-54	W-82	W-37	W-6	W-0	W-1	W-0	W-4	W-305	81%
15.0														
	E-0	E-3	E-01	E-9	E-18	E-9	E-6	E-4	E-0	E-1	E-0	E-0	E-51	16%
	W-0	W-11	W-35	W-60	W-62	W-72	W-31	W-3	W-0	W-2	W-0	W-2	W-278	84%
17.5														
	E-0	E-1	E-1	E-11	E-18	E-12	E-6	E-7	E-0	E-0		E-0	E-56	23%
	W-0	W-9	W-11	W-49	W-78	W-23	W-11	W-6	W-0	W-0		W-0	W-187	77%
20.0														
		E-0	E-2	E-9	E-12	E-9	E-8	E-7	E-0	E-0		E-0	E-47	34%
		W-2	W-2	W-37	W-26	W-20	W-3	W-2	W-0	W-0		W-0	W-92	66%
22.5														
		E-0	E-0	E-5	E-10	E-9	E-4	E-3	E-0				E-31	32%
		W-1	W-0	W-26	W-25	W-10	W-3	W-0	W-4				W-65	68%
25.0														
		E-0	E-0	E-10	E-11	E-16	E-4	E-0	E-0				E-41	59%
		W-0	W-1	W-11	W-8	W-3	W-2	W-0	W-0				W-29	41%
27.5														
		E-0	E-0	E-12	E-10	E-9	E-6	E-0	E-0				E-37	82%
		W-0	W-0	W-2	W-5	W-1	W-0	W-0	W-0				W-8	18%
30.0														
			E-0	E-13	E-14	E-10	E-8						E-45	96%
			W-0	W-2	W-0	W-0	W-0						W-2	4%
32.5														
				E-8	E-12	E-5	E-0						E-25	100%
				W-0	W-0	W-0	W-0						W-0	0%
35.0														
				E-5	E-5	E-3	E-0						E-13	
				W-0	W-0	W-0	W-0						W-0	100%
37.5														
				E-2	E-6	E-3	E-0						E-11	
				W-0	W-0	W-0	W-0						W-0	100%
40.0 S														

3. Results and discussion

3.1. *Features associated with genesis of tropical disturbances in the Indian Ocean region south of equator*

The monthly cumulative frequencies of genesis and dissipation of tropical disturbances during October to September along various latitudinal belts at 2.5° apart upto 40° S from equator is shown in Table 1 for the 17 years (1985-2001) record. The monthly average figures have been worked out. The figures in bracket indicate dissipation frequencies. Following are the chief features of the table.

(*i*) The cumulative frequency on the right side of the table in the last column, indicate that the cumulative frequency of genesis increases rapidly (at the rate of 15 percent 2.5° Lat.) from equatorial region upto 10° S. The modal frequency occurs in the latitudinal belt of 10° - 12.5° S. The frequency decreases rapidly and is zero in the latitudinal belt of 27.5° - 30.0° S.

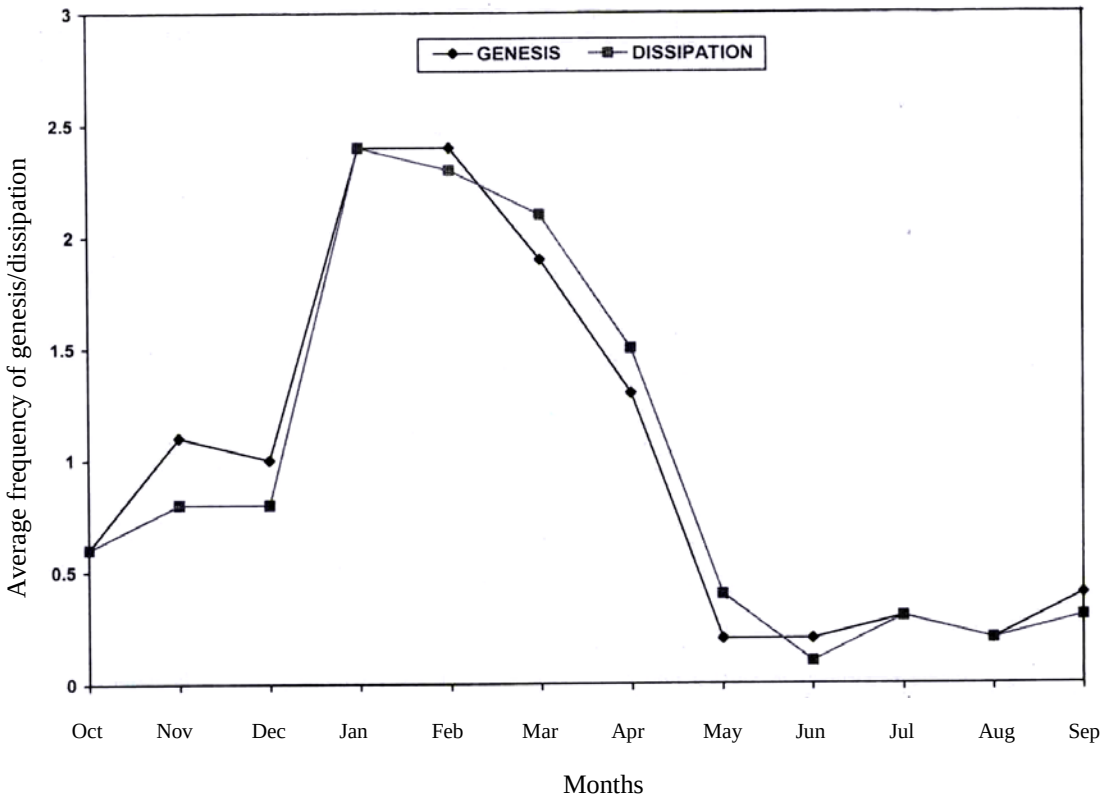

Fig. 1. Monthly variability of frequency of genesis/dissipation of tropical disturbances in the Indian Ocean region south of equator (1985-2001)

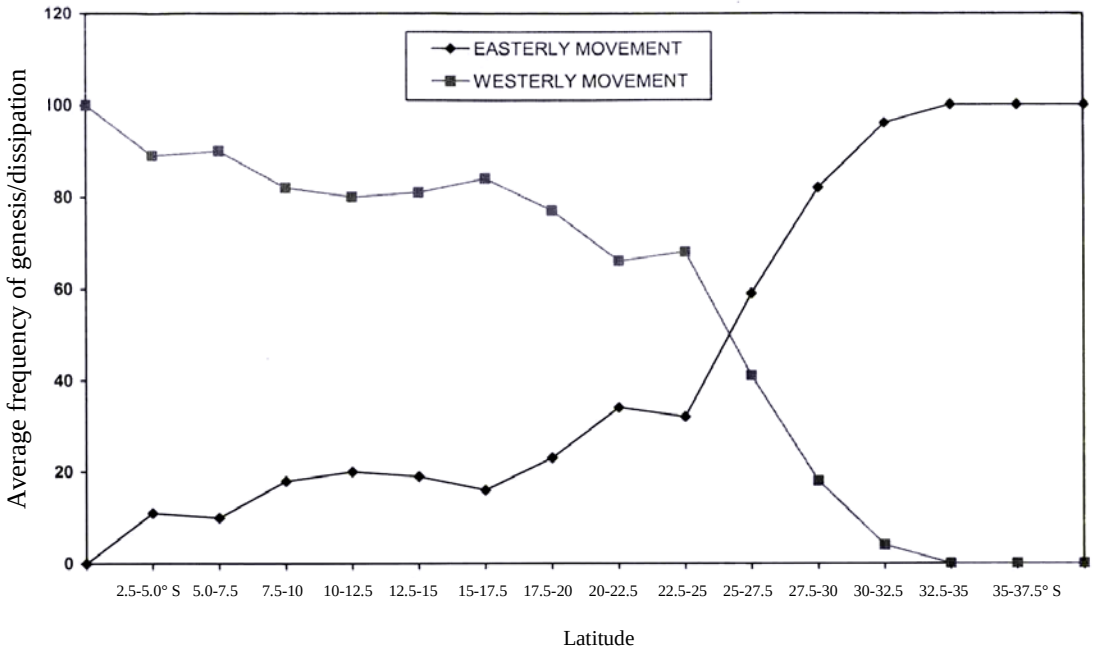

Fig. 2. Latitudinal variation of movement (eastward/westward) of tropical disturbances (1985-2001)

(*ii*) The table also indicates formation of a tropical disturbance (ATCR, 1992) within equator to 2.5° S which occurred in December 1991 which is clearly shown in Fig. 3. Such genesis closer to equator is unusual but significant for the climatologist.

(*iii*) On an average, about 12 (11.9) number of tropical disturbances form per year. The genesis frequency is minimum at 0.2 to 0.3 during May and August, which rises to maximum of 2.4 in the month of January and February both. A comparison of annual frequency from Gray (1979) which is 8.4, indicates a rise in annual frequency during the period 1985 to 2001.

(*iv*) The genesis beyond 27.5° S towards the higher latitude is zero which is obvious due to seasonal fluctuation of Inter Tropical Convergence Zone in the southern hemisphere.

3.2. *Features associated with the dissipation of tropical disturbances*

In Table 1, along with genesis, cumulative frequency of dissipation of tropical disturbances are also shown in brackets. Following are the chief features regarding dissipation of tropical disturbances.

(*i*) The cumulative frequency given on right side of Table 1 in the last column in the brackets, indicate that no disturbance dissipates within 5° S of the equator. The dissipation frequency increases southwards and its mode generally lies in the latitudinal belts of 12.5° - 15.0° S and 25.0° - 27.5°.

(*ii*) On an average 12 (*i.e.*, 11.7) tropical disturbances dissipate per year. The dissipation frequency increases continuously from September and reaches maximum of 2.4 in January followed by February (2.3).

3.3. *Latitudinal variations in genesis and dissipation of tropical disturbances*

The Fig. 1 indicates variation in cumulative genesis/ dissipation frequencies against latitudinal belts from equator - 2.5° S to 37.5° - 40.0° S. It shows that the frequency of genesis dominates over dissipation frequency between equator and 17.5° S while it is reversed between 17.5° and 40° S.

3.4. *Features associated with movement of tropical disturbances in the Indian ocean region south of equator*

Table 2 contains cumulative (monthly) frequency of movements of tropical disturbances from October to September. The last column on the right side also gives percentages frequency of eastward and westward movement over each latitudinal belt of 2.5° which is also shown in the Fig. 2 indicates that the frequency of eastward moving tropical system increases from equator to the latitudinal belt of 30° - 32.5° S and thereafter frequency remains at 100 percent. For the westward moving systems, the frequency decreases from 100 percent equatorial region to zero percent across latitudinal belt of 32.5° - 35° S and thereafter it remains at zero. The frequencies of eastward and westward moving systems are reversed or in opposite phase between equator and 40° S. After weather disturbances cross 22.5° - 25.0° S belt, the change in their frequencies are very rapid.

4. Conclusions

The following inferences are noteworthy from the study of 17 years of data.

(*i*) A tropical disturbance may form between equator to 2.5°S but does not dissipate within 5° S of the equator.

(*ii*) The annual frequency of tropical disturbance has been found to be 11.9 against 8.4 (Climatological normal).

(*iii*) The maximum frequency of genesis and dissipation both occurs during January and February.

(*iv*) The frequency of westward (eastward) moving tropical disturbances decreases (increases) from region of equator to 2.5° S and 32.5° S - 35.0° S latitudinal belt.

(*v*) No tropical disturbance moves eastward close to the equator *i.e.*, between equator to 2.5° S.

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