

LETTERS

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DECADAL VARIATIONS IN TRANSLATIONAL SPEED OF CYCLONIC DISTURBANCES OVER NORTH INDIAN OCEAN

1. Tropical Cyclones (TCs) are devastating weather events that cause extensive damages over coastal areas of the world. Even though TC dynamics are highly complex, forecasting TC movement, intensity & time and location of landfall based on climatology and persistence have been in vogue for long which served as crucial inputs for civil administrators and disaster managers. For forecasting TC intensity, the roles of two dominant factors that determine the extent of intensification, *viz.*, vertical wind shear and TC translational speed need to be understood clearly. Several studies relating shear and speed of movement to intensification of TCs have been reported for various oceanic basins worldwide. It has been shown that TC translational speed influences asymmetry in TC structure and rainfall distribution (Chen *et al.*, 2006). Regarding the role of translational speed on TC intensification, generally, it is understood that if TC movement is too slow, oceanic cooling due to turbulent mixing generated by whirling winds would disrupt the intensification process while on the other hand, if the TC movement is fast, the resulting asymmetric structure will also inhibit intensification.

2. India, having an extensive coastline, is also affected by the destructive features of TCs and hence improved knowledge of TC movement and intensity would help in greater accuracy in TC forecasting. For the oceanic basin of Western North Pacific, it has been shown that there is an increased frequency of intense TCs during the recent years due to changes in planetary atmospheric conditions (dynamic and thermodynamic - such as moist static energy related to air temperature which has been on the rise and zonal wind shear) that favour both formation and intensification of TCs (Chan, 2010). It is expected that climate change related atmospheric conditions would be reflected in the translational speeds of the cyclonic disturbances (CDs) also in decadal time scales. In the present study, decadal variations in the translational speeds of CDs, which include depressions and all categories of tropical cyclones over the North Indian Ocean (NIO) basin during the last five decades (1961-2010) are analysed and presented.

TABLE 1

Decadal frequencies of formation of CDs / SCS over BOB and AS during 1961-2010

Decade	BOB		AS	
	No. of CDs	No. of SCS	No. of CDs	No. of SCS
1961-1970	124	33	19	5
1971-1980	99	29	34	11
1981-1990	78	22	15	2
1991-2000	66	17	18	8
2001-2010	63	11	23	8

BOB: Bay of Bengal; AS: Arabian Sea;

CD: Cyclonic Disturbance (includes depressions and all categories of tropical cyclones); SCS: Severe Cyclonic Storm

(Source : Cyclone eAtlas - IMD, www.rmchennaieatlas.tn.nic.in)

3. Climatologically, the average annual frequency of TCs (Maximum Wind Speed (MWS) ≥ 34 knots) over the NIO basin is 5-6 per year out of which 2-3 TCs reach the intensity of Severe Cyclonic Storm (SCS, MWS ≥ 64 knots). The mean life of CDs over the Bay of Bengal (BOB) and the Arabian Sea (AS) are 4.2 and 4.4 days respectively and the normal speeds of movement of CDs over BOB and AS are 12.9 km/hr and 12.8 km/hr (Raj, 2012). It is observed that during the recent years, TC activity over the BOB has decreased but that over the AS region has been comparatively better. Table 1 presents decade-wise frequencies of CDs that formed over BOB and AS as well as the number that intensified into SCS during the period 1961-2010. Gradual decrease in the frequency of CDs/SCS over BOB is clearly seen as reported in earlier studies (Rajeevan *et al.*, 2000). However, over AS, the corresponding frequencies have improved during the recent two decades, 1991-2010.

4. The translation speeds of CDs over NIO are calculated based on the changes in the longitude and latitude positions at 6 hourly or 3 hourly intervals based on the availability of data taken from the International Best Track Archives (IBTrACS) of the National Climatic Data Centre, NOAA, USA (www.ncdc.noaa.gov) for the period 1961-2010. The IBTrACS contains the most complete global set of historical tropical cyclones available by combining information from various tropical cyclone datasets and hence provides storm data from multiple sources in one place. The IBTrACS archives for NIO basin has been prepared using best track data of the Regional Specialised Meteorological Centre (RSMC), New Delhi along with other datasets.

TABLE 2

Decade-wise mean speeds of movement and standard deviations

Decade	BOB			AS		
	N	Mean (km/hr)	S. D. (km/hr)	N	Mean (km/hr)	S. D. (km/hr)
1961-70	2005	12.64	7.55	659	12.03	7.56
1971-80	1367	12.86	7.7	798	12.55	6.84
1981-90	655	14.74	7.18	246	14.82	7.46
1991-00	1254	16.3	12.4	691	15.86	11.8
2001-10	1379	16.64	12.3	752	16.32	14.3

N: Sample size; S.D. : Standard Deviation: BOB & AS : As in Table 1

5. Table 2 presents the decade-wise mean speeds of movement and standard deviations (S.D.) for CDs of BOB and AS during the period 1961-2010 along with the sample size (N). It may be noted that the mean speeds of movement over BOB and AS are consistent at 12-13 km/hr during the first two decades 1961-70 and 1971-80 over both BOB and AS. Thereafter, there is a gradual increase in the speeds of movement during the period 1981-2010 over both BOB and AS. The S.D.'s have been consistent around 6-7 km/hr during the first three decades, 1961-1990. However, there is a sharp increase in the S.D.'s to 12-14 km/hr during the recent two decades for both BOB and AS indicating greater deviations from the mean speeds during the recent decades.

6. The Probability Density Functions (PDFs) of the speed of movement of CDs over BOB and AS for the recent five decades 1961-70, 1971-80, 1981-90, 1991-2000 and 2001-10 are shown in Fig. 1. These PDFs were generated using the criteria, Bin width = $2 \times \text{Inter Quartile Range} \times N^{-1/3}$, where N is the sample size (Wilks, 1995). The bin widths have been fixed at 1.6 km/hr and 2 km/hr for BOB and AS respectively based on the sample size for the first decade. It may be noted that the PDFs display skewed distribution with secondary modes as well as to 1980 for BOB and up to 1990 for AS. For the recent decades, the distributions have considerably flattened and have tertiary modes too. The modal values of translation speed of CDs of BOB during the recent five decades are:

Decade	Modal values
1961-1970	6.4 km/hr (9.3%), 11.2 km/hr (9.2%)
1971-1980	9.6 km/hr (9.8%), 12.8 km/hr (9.5%)
1981-1990	9.6 km/hr (11.3%), 14.4 km/hr (9.9%), 17.6 km/hr (9%)

1991-2000 9.6 km/hr (10.2%), 19.2 km/hr (7%)

2001-2010 17.6 km/hr (8%), 25.6 km/hr (4%) & 9.6 km/hr (3%).

Similarly for AS, the modal values of translation speed of CDs during the recent five decades are:

Decade	Modal values
1961-1970	14 km/hr (12%), 10 km/hr (11.8%)
1971-1980	8 km/hr (11.7%), 18 km/hr (11.1%)
1981-1990	14 km/hr (13.4%), 10 km/hr (13%)
1991-2000	10 km/hr (10.3%), 14 km/hr (9.6%), 18 km/hr (9%)
2001-2010	6 km/hr (9.4%), 10 km/hr (9.4%), 16 km/hr (6.8%)

7. Over BOB, the most probable speed of movement of CDs during the first four decades has been in the range 6.4-9.6 km/hr. This has increased to 17.6 km/hr during the recent decade of 2001-2010. However, for the AS, the most probable speed of movement of CDs has decreased from about 8-14 km/hr during 1961-2000 to 6-10 km/hr during the recent decade of 2001-2010. It has been shown for the Australian region that intense TCs develop over a narrow range of translational speeds (3-6 m/s) and there is a clear trend towards weaker cyclones as the speed of movement increases (Wang and Wu, 2010). The present study for the NIO region has shown that CD movement over BOB is faster and that over AS is relatively slower during the recent decade. This might have had an impact, along with other factors, on the decreased TC activity over BOB and a somewhat increased intense TC activity over AS during the recent decade.

8. The present study shows that the most probable translational speed of CDs over BOB (AS) has increased (decreased) during the recent decade (2001-2010) as compared with the earlier four decades (1961-2000). TC translational speed is a dominant factor determining TC rainfall asymmetry under weak environmental shear (Chen *et al.*, 2006). Further studies relating translational speeds and asymmetric structure of TCs would throw more light on decadal variability of TC rainfall asymmetry in the context of changes in translational speeds which may lead to reliable quantitative precipitations forecasts for TCs of NIO.

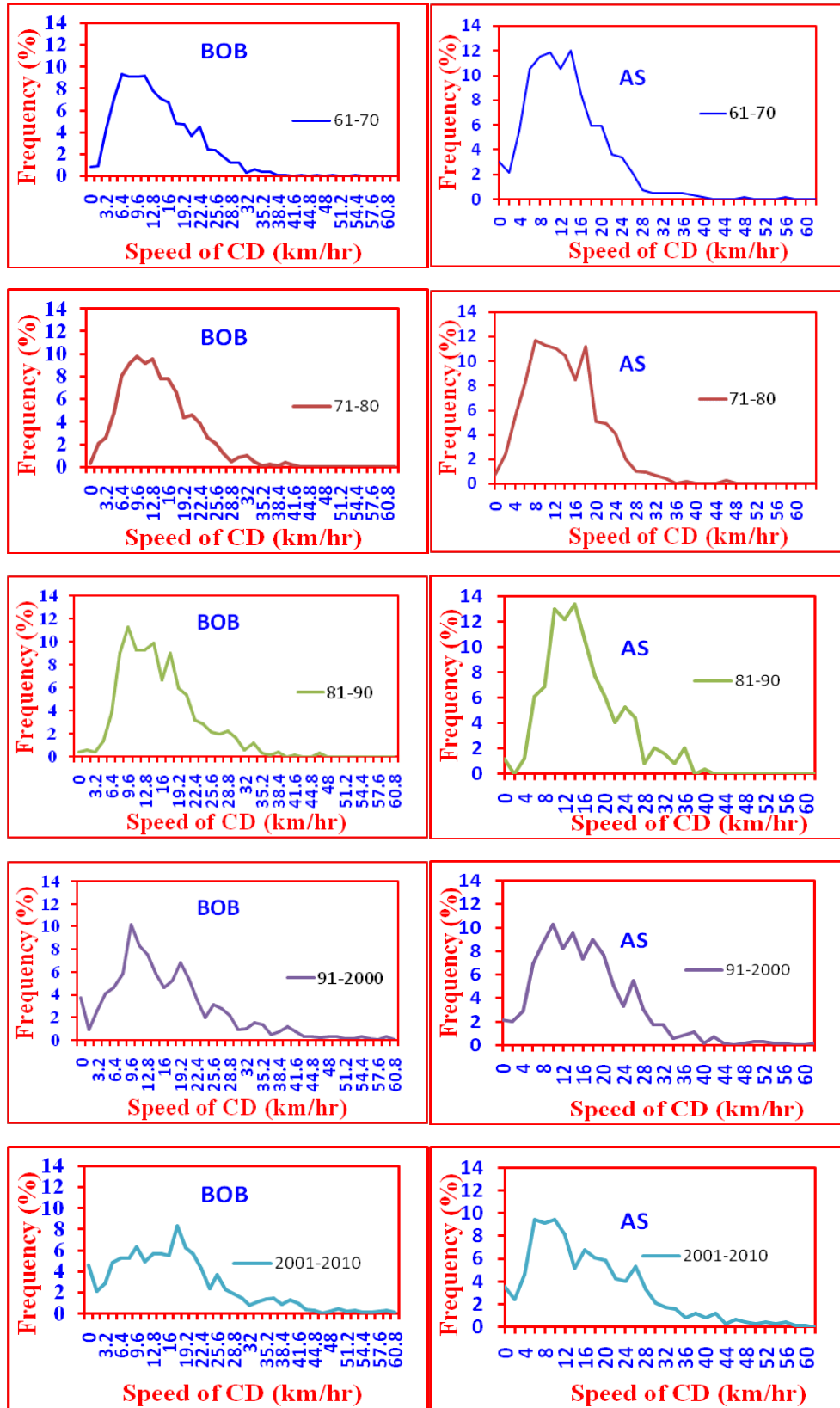


Fig. 1. Probability density function of speed of movement of CDs (in km/hr) over BOB and AS for the decades 1961-1970, 1971-1980, 1981-1990, 1991-2000 and 2000-2010.

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