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# Research on Variation of Cloud Temperature, Closed Loop Cycle, Predication of Cyclone Track Over Ocean Basins

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**ABSTRACT:** The one-day variation of the pall cover area & Temperature during Tropical Cyclone (TC) in the Bay of Bengal and Arabian basins are studied using thermal infrared brilliance temperature. Position and intensity data from the International Best Track Archive for Climate Stewardship are combined with global, gridded rush estimates from the Tropical Rainfall Measuring Mission (TRMM) Multi satellite Rush Analysis (TMPA) for the period 2013-2016 to study the quotidian cycle of area in tropical cyclones. The comprehensive global content and large sample size swung by the two datasets allow robust statistical analysis of storm- equaled quotidian variations and permit position of the data in colorful ways. The quotidian variation of mean Pall area of deep cold shadows is maximum during the morning while the mean Clod area of cold shadows is maximum in the autumn for an inner and external region of TCs. Perfecting the Tropical cyclone (TC) vaticination is always an important exploration area and grueling task to the meteorologists since it poses a major impact on mortal life, parcels and countries frugality. The functional and exploration centres around the globe have been working to more understand the multiscale relations involved to advance the TC prognostications.

**KEYWORDS:** Tropical cyclone; Cloud; Track;

## I. INTRODUCTION

Tropical cyclones pose a significant risk to health and safety for large numbers of people around the globe. Accurate forecasts of hurricane position and intensity are critical for issuing timely storm warnings and evacuation advisories. Hurricane track forecasting has improved substantially in recent years, but improvements in intensity forecasts have come more slowly (Gall et al. 2013). Continuing increases in forecast model resolution and in the representation of physical processes within models will undoubtedly lead to further improvements in forecast skill, but better understanding of the underlying physical processes in tropical cyclones will help to focus research and development efforts in the most promising areas.

One potentially important and predictable component of precipitation variability in tropical cyclones is the diurnal cycle. Precipitation over the oceans in general is known to have a climatological diurnal cycle with maximum rain rates occurring in the early morning hours (Kraus 1963; Gray and Jacobson 1977; Serra and McPhaden 2004; Collier and Bowman 2004; Bowman et al. 2005), although some results are at variance with this. Nesbitt and Zipser (2003) sorted precipitation feature by size and intensity using data from the Tropical Rainfall Measuring Mission (TRMM) satellite and found diurnal signals in many characteristics, including an early morning peak in the rain rate. In their analysis of extreme convective events over the ocean near the Indian subcontinent, Romatschke et al. (2010) found that wide convective cores and broad stratiform regions have a broad peak beginning in early to late morning hours, respectively, and extending into the early afternoon.

The Tropical Cyclones (TCs) are termed differently in different parts of the globe. Over the Atlantic and Eastern Pacific, they are termed as 'Hurricane' and in western Pacific as 'Typhoon'. In the North Indian Ocean (NIO) region, they are named as 'Tropical Cyclone'. The NIO contributes 5-6 TCs every year (~7% of the world's TCs) (Mohanty and Gupta, 1997). Though the percentage of frequency over the NIO basin is less relative to any other global basins, annual frequency rate is often stable with an average disparity of  $\pm 7\%$ . Every year, about 80 TCs causes an average number of 20,000 deaths and a total economic loss of \$6-7 billion (Mohanty et al., 2015). Almost all the TCs form within 25° latitudes on both sides of the equator except in the equatorial region of 5° S to 5° N due to negligible Coriolis force.



The goal of this study is to determine whether a diurnal cycle of precipitation rates exists in tropical cyclones and to establish statistical estimates of its magnitude and timing. In this study we combine a 15-yr record of 3-hourly satellite precipitation estimates with tropical cyclone track data to estimate the amplitude and phase of the climatological diurnal and semidiurnal harmonics of precipitation in tropical cyclones. The large sample size provided by the global satellite coverage allows us to make firm error estimates, to stratify the data by storm intensity and by ocean basin, and to evaluate the influence of nearby land surfaces on the diurnal cycle.

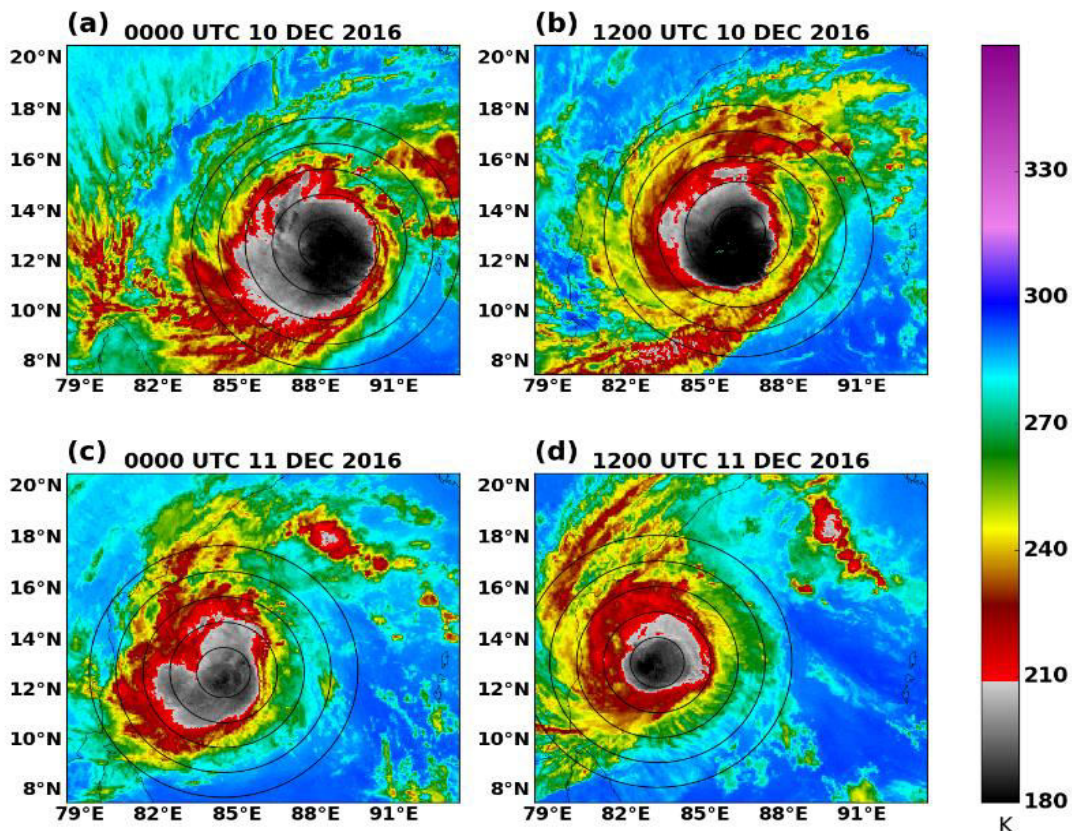
**II. DATA AND METHODS**

The International Best Track Archive for ClimateStewardship (IBTrACS) is a global record of tropicalcyclone track and intensity information maintained byNOAA’s National Climatic Data Center (2014; Knapp et al. 2010). Records are compiled from analyses by a number of meteorological agencies around the world. Storm parameters are typically recorded at 0000, 0600, 1200, and 1800 UTC, although some observations are available at special times because of unique conditions of the storm. In this study we use the 6-hourly observations for the period 1998–2012 from the IBTrACS-All database. The availability of satellites and other modern observing systems throughout the selected period make the track data relatively homogeneous and of good quality.

Mission/ Instrument	Product	Source
INSAT-3D Imager	L1B-STD, Brightness temperature	<a href="http://www.mosdac.gov.in">www.mosdac.gov.in</a>
IMD	Three-Hourly Best track data	<a href="http://www.rsmcnewdelhi.imd.gov.in">www.rsmcnewdelhi.imd.gov.in</a>

**III. RESULTS**

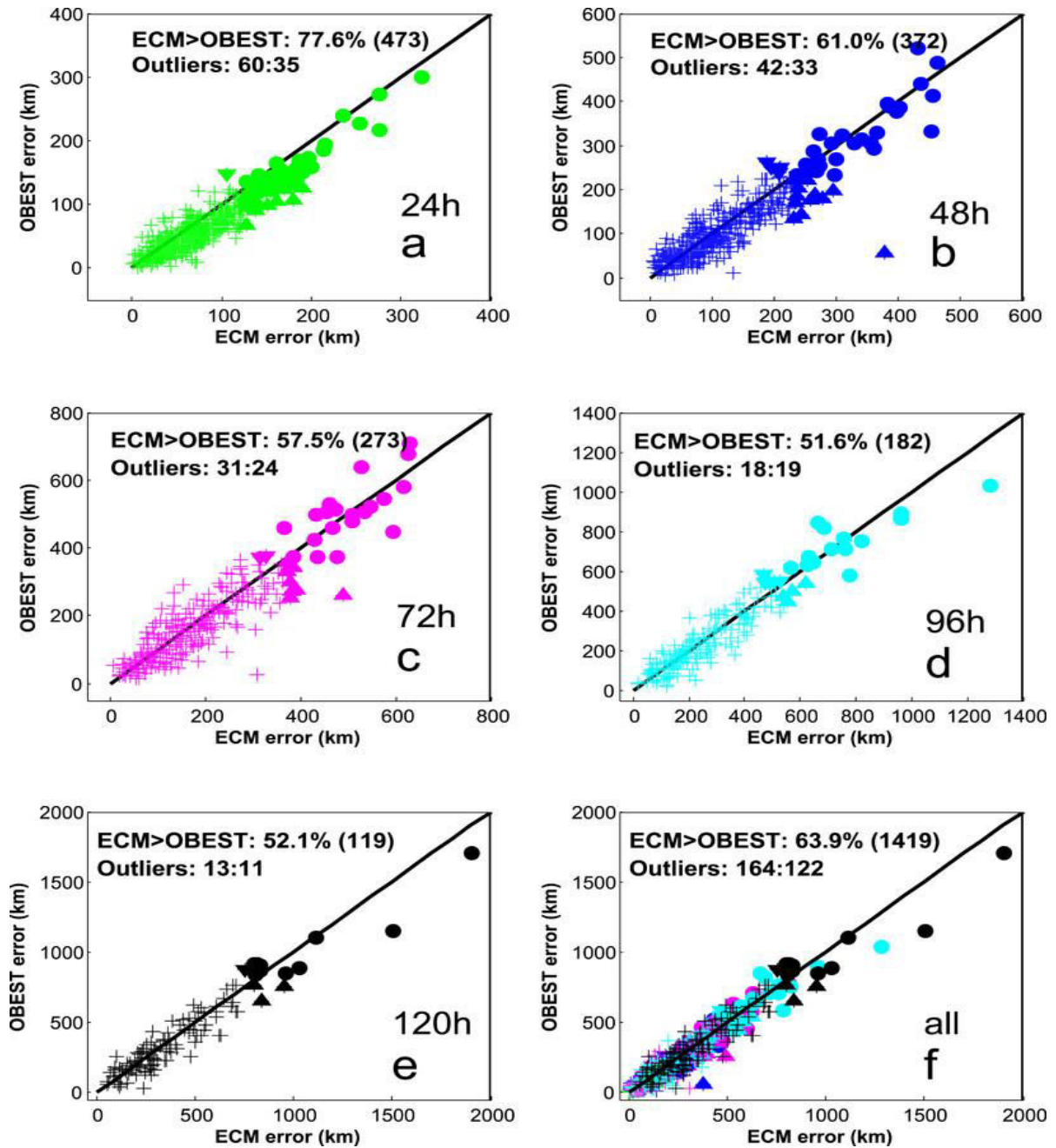
In order to observe diurnal variations of the spatial distribution of the cloud top temperature and cloud covered area during cyclone the TIR-BT plots during cyclone is shown in Fig.1



**Figure 2:** TIR enhanced brightness temperature showing Vardha Cyclone (a,b) 0600 IST and 1800 IST 10<sup>th</sup> Dec. 2016 and (c,d) 0600 and 1800 IST 11<sup>th</sup> Dec. 2016.



The TIR-BT enhanced images of Vardha Cyclone (Fig.2) shows that the areal extent of deep cold clouds decreases from 500 km to 300 km during day-time (0600-1800 IST) while it increases rapidly from 300 km to 500 km during night-time (1800-0600 IST). The areal extent of relatively warm clouds increases during day-time but decreases during the night-time. In the case of cyclone Vardha, most of the areas of cloud within 200 km radius of the TCs centre were covered with clouds colder than 220 K.



**Figure 3:** Scatterplots of consensus track errors from OBEST with EC-EPS vs those from ECM for all valid forecast samples for 2012 and 2013 at different forecast hours: (a) 24, (b) 48, (c) 72, (d) 96, and (e) 120 h, as well as (f) all five times (numbers in the parentheses are the total number of samples). The number of outliers at each lead time, and the percentage of samples where ECM error is greater than OBEST, are marked in each panel. Solid dots indicate that both ECM and OBEST errors are outliers, upward (downward)-pointing triangles are used when only



ECM(OBEST) error is an outlier, and crosses are for forecasts where neither ECM nor OBEST is an outlier.

Figure 3 shows scatterplots of track errors from OBEST versus those from ECM for all valid forecast samples at different forecast hours for 2012 and 2013 [different from Fig. 3b in which CMA best-track estimates were used, the results displayed in Fig. 3 are derived using the JMAbest-track estimates]. At 24h (Fig. 3a), OBEST provides a more accurate forecast than ECM by a large margin (specifically, OBEST has a smaller error in over 77.6% of all 24-h forecast samples). At forecast hours 48 and 72 (Figs. 3b,c), OBEST is more accurate than ECM approximately 60% of the time. At the longest lead times (96 and 120h; see Figs. 3d and 3e, respectively) OBEST outperforms ECM in just over 50% of all cases. The decreasing advantage of OBEST at increasingly longer lead times is a sign of nonlinear error growth and saturation when initially small-scale and/or small-amplitude initial condition or forecast model errors begin to alter the larger-scale environmental flow that can significantly affect the track forecasts (Lorenz 1969; Zhang et al. 2007; Gilmour et al. 2001). Nevertheless, at both these two long lead times, OBEST has noticeably smaller track errors for the ECM forecasts that have extremely large forecast errors (subjective thresholds at 800km for the 96-h forecast and at 1000km for the 120-h forecast). Combining all five of these lead times results in better performance of OBEST (compared with ECM) for 63.9% of the total 1419 valid forecast samples (Fig. 3f). Moreover, if we consider any forecast by either OBEST or ECM to be an outlier (very bad forecast) when it exceeds the 95th percentile threshold value out of the total combined forecast error samples at each respective lead time, the percentage of outliers is larger for ECM than OBEST at almost all lead times (except for at 120 h). The sum of the outliers for all five lead times is 164 for EC Mand 122 for OBEST (Fig. 3f).

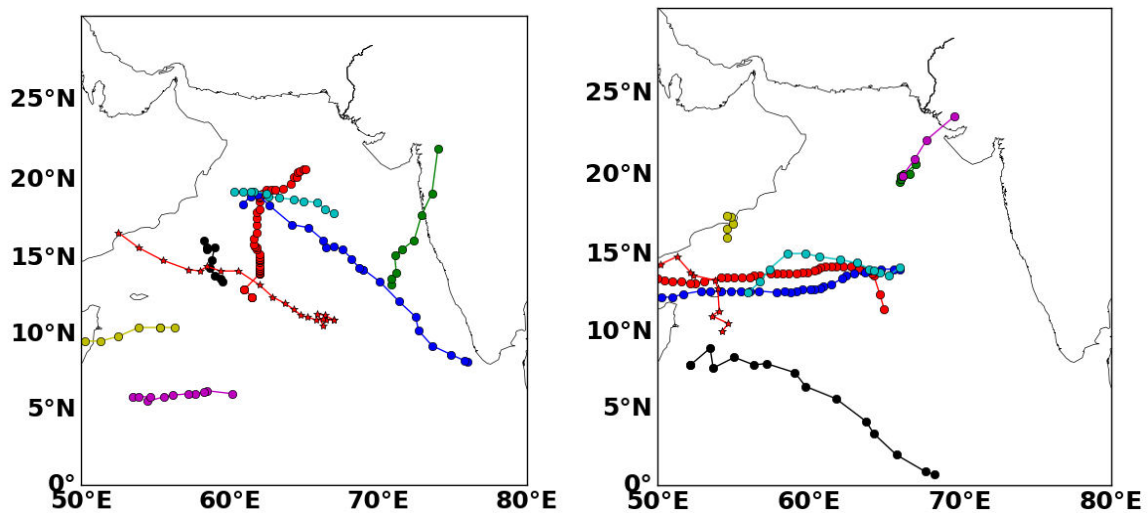


Figure 4: Observed track of Tropical Cyclone Post monsoon a) Over East ARB, b) Over West Basins

The NIO basin comprised of Bay of Bengal (BoB) and Arabian Sea (AS), also commonly referred as Indian seas, is unique in its nature than any other global basins, as far as the genesis and season are concerned. Mohanty et al. (2011) suggest that the BoB and AS contributes ~76% and ~24%, respectively to the total number of TCs. In other ocean basins, TCs occur around late summer to early fall. However, the genesis of TCs over the NIO basin is very seasonal with primary maxima in post monsoon season (October-December) and secondary maxima during pre-monsoon season (April-May) (Mohanty, 1997). The TCs over the NIO move usually to the west, north-west and northward, sometimes, recurve towards north-east or east [Figs. 4(a&b)].

About 85% of the post-monsoon TCs move westward, out of which 30% is in October [Fig. 1(b)]. Northward moving TCs are also primarily seen in post monsoon season. The north-eastward moving / recurving TCs that cross Myanmar are common in the pre-monsoon season [Fig. 1(a)]. During the pre-monsoon season, inter tropical convergence zone (ITCZ) is located sufficiently over the open waters of the Indian seas which trigger low pressure system and its development into a stronger cyclone (Lee, 1989). As the storm gets intensified, it passes through several stages. Based on pressure drop and maximum sustainable surface wind, the World Meteorological Organization (WMO) classified the TCs over the NIO broadly into seven categories



### III. DISCUSSION & CONCLUSIONS

From the above results and discussions, the following broad conclusions are drawn:

- (i) There are large number of efforts made from last three decades to progress the prediction of TCs over NIO using various NWP models and assimilation techniques.
- (ii) Especially, high resolution meso-scale models (WRF and HWRF) have shown their credibility in predicting TC tracks when compared to the other global models.
- (iii) The HWRF model was efficacious in providing intensity forecast guidance well in advance. The mean error and RMSE of intensity (10 m maximum wind speed) up to 96 h forecast length is considerably less in HWRF predictions whereas ARW model not shown the same.
- (iv) The improvement in prediction of track and intensity has also led to improve in storm surge prediction well in advance of 3-4 days.
- (v) Further improvements can be achieved by the incorporation of improved land surface parameters, coupled modeling systems, advanced data assimilation, etc.

This study combines track data from the International Best Track Archive for Climate Stewardship (IBTrACS) database and eight-times-daily gridded precipitation estimates from the TRMM Multisatellite Precipitation Analysis to investigate the diurnal cycle of precipitation in tropical cyclones. The 15-yr global record of precipitation from the TMPA includes over 85 000 observations of individual tropical cyclones. With the large sample size, a robust statistical analysis of the properties of the climatological diurnal cycle in tropical cyclones is possible.

Average rainfall rates in tropical cyclones vary by a factor of 2 among the different ocean basins. With the exception of the South Atlantic basin, where the number of storms in the data record is too small to allow statistical analysis, tropical cyclones exhibit a diurnal cycle with a morning maximum in all of the major ocean basins. Based on stratifying the data by basin and by storm intensity, there is evidence that the amplitude of the diurnal cycle increases as the mean rainfall rate increases, but that result is not statistically significant.

During this analysis, the CCA of deep cold clouds decreases during the daytime while increases during the nighttime, but the variation is opposite in the case of cold clouds. Similar trends are also found in the outer region of TCs for the cold and warm clouds. But in the case of CTT 3-hr lag is observed. If CTT is maximum, then CCA is minimum at a particular time. The diurnal variation of mean CCA of deep cold clouds is maximum during the morning while the mean CCA of cold clouds is maximum in the afternoon for the inner and outer regions of TCs. The cold cloud had minimum mean CTT during the morning while the warm cloud had minimum mean CTT during the afternoon for the inner and outer region of TCs.

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