A comprehensive analysis of North Indian Ocean cyclonic activity and rainfall contribution over India during current and pre-warming climate

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This work provides an overview on climatology of cyclonic disturbances (CDs) and associated rainfall, with primary emphasis to North Indian Ocean (NIO). For this purpose, TC best track data provided by India Meteorological Department (IMD) over NIO region and rainfall product from IMD, several parameters like sea surface temperature (SST), air temperature (AT), surface level relative humidity (RH), mid-troposphere relative humidity (RH500), surface level wind (SW), evaporation factor from International Comprehensive Ocean-Atmosphere Data Set (ICOADS), NOAA CIRES, and Hadley centre considered. Robustness analysis of the best track data indicates that there is improvement over the years in terms of quality and availability over NIO. The determination of location and proper track of the CDs over NIO has improved during satellite era and the frequency of looping, southward moving, recurving CDs increased.

Based on annual SST anomaly variation, the period of study is divided into pre-warming (PWP; during 1880–1946) and current warming (CWP; 1947 onwards) with negative and positive anomalies respectively. A decreasing trend observed in total storms, cyclones and severe cyclones frequency during CWP for NIO region. CD activity over southern and northern BOB is decreasing sharply during CWP. Southern sector of BOB hosts mostly severe systems and middle sector most tropical cyclones. CD activity over the eastern sector of AS shows considerable enhancement during CWP. An increasing SST, SW, RH500 and potential evaporation factor are helpful in the formation of intensified storms during CWP. The activities during PWP were reverse compared to that of CWP. A large temperature anomaly difference between atmosphere and ocean also perceived to play a key role in modulating the enhanced intensity of CDs during CWP.

The impact of warming climate on landfall activity reveals that Bangladesh (BD), Andhra Pradesh (AP), and Tamil Nadu (TN) are more vulnerable to severe cyclones formed over BOB during the CWP. Among western coastal states, Gujrat (GJ) is prone to severe cyclones and Arabian Peninsula countries are vulnerable to cyclonic storms formed over the AS during the current warming climate as well. During CWP, BD and Myanmar are more vulnerable to CD landfall in pre-monsoon season, whereas in post-monsoon months, AP, TN and BD are more prone coastal areas of BOB. Gujrat is more vulnerable coastal area of AS. The enhanced genesis over southern and middle sector of BOB is mainly responsible for more landfall over AP, TN and BD. Changes in wind direction and increased meridional SST over BOB found to be encouraging the landfall activity near AP and TN coasts. The W-SW wind and zonally distributed SST supports landfall over Gujrat.
The rainfall rate associated with CDs (CDR) found to be increasing during post-monsoon season with a decreasing CD frequency both in PWP and CWP scenario (refer to the figure). During pre-monsoon, the CDR was increasing with CD frequency during both the epochs considered. Mostly eastern Indian states experienced heavy rainfall contribution by CDs during PWP. During CWP, the accumulated rainfall is higher over eastern and western coastal states during pre-monsoon and during post-monsoon season. Among eastern coastal states, the accumulated rainfall is higher over AP, TN, Odisha (OD) and southern West Bengal (WB) during both the seasons of PWP and CWP. Among western coastal states, Gujarat (GJ),

Karnataka (KA) and Kerala (KL) suffer maximum rainfall from CDs for the considered scenario. The overall rainfall contribution by CDs is observed to have a decreasing trend during both seasons of CWP and PWP. Owning to the stable rainfall trend along with decreasing CD frequency during post-monsoon season, the results indicate an increased amount of rainfall by CDs during CWP and PWP.

Keywords: North Indian Ocean, Cyclonic Disturbances, Warming Climate, Rainfall