

## Rainfall contribution of North Indian Ocean cyclonic disturbances over India in a warming climate

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Rainfall associated with cyclonic disturbances (CDs) poses mostly significant threat to the society. Such type of systems and their remnants are capable of producing heavy rainfall, which often produce flash flooding. The warming climate is considered from 1947 onwards based on sea surface temperature anomaly variation over North Indian Ocean (NIO) basin. Nearly 71.42% of CDs in pre-monsoon and 87.07% CDs in post-monsoon season crossed or gazed the Indian coast during 140 cyclone seasons of the warming climate. The trend for annual variation of CD rainfall (CDR) anomaly is decreasing along with CD anomaly during pre-monsoon season ( $P=4.89901E-15$ ). The trend for CDR anomaly is observed to be almost stable while the CD anomaly is decreasing drastically ( $P=1$ ) in the post-monsoon season, indicating increased amount of rainfall is contributed by CDs over India in this period.

Among eastern coastal states, Andhra Pradesh (AP), Tamil Nadu (TN), Mizoram, Tripura and among western coastal states, Kerala (KL), Karnataka (KA) and Gujarat (GJ) received most of the accumulated rainfall in pre-monsoon season. The rainfall contributed by CDs during pre-monsoon season is limited to the coastal districts of India only. However, the rainfall occurrences during post-monsoon season could penetrate up to very interior districts. During post-monsoon season, Odisha (OD), AP and TN received the highest rainfall contribution from CDs. Jharkhand, KL, KA, parts of Maharashtra (MH) and coastal GJ received significantly higher amount of rainfall in comparison to other interior places. Up to ~70% of rainfall is contributed by CDs over GJ, nearly 20-30% over AP and 15-18% over western Rajasthan during pre-monsoon (Figure 1). During post-monsoon season, considerable rainfall (60% of annual value) contribution is seen over all states. The trend in CD rainfall is observed to be increasing over western GJ, western Rajasthan, northeast AP and southeast OD during pre-monsoon months. The spatio-temporal trend of CD rainfall over Bihar, Jharkhand, northern OD, northern Chhattisgarh, eastern Madhya Pradesh, Sikkim and Meghalaya are observed to be increasing during post-monsoon months. The rainfall contributed by CDs over the border regions of AP and TN is observed to be decreasing. Among eastern coastal states, AP has received 200cm of accumulated rainfall contribution during pre-monsoon season. The corresponding values for TN, OD and WB are 180, 140 and 140cm respectively. During post-monsoon season, AP received 1100cm of rainfall, OD and TN with 900cm of rainfall each, and WB received 450cm of accumulated rainfall contributed by CDs. For western coastal states, during pre-monsoon season, the maximum amount of accumulated rainfall contributions over GJ, MH, KA and KL are about 85, 75, 110 and 160cm respectively. During post-monsoon season, the corresponding values are nearly 134, 145, 320 and 350cm. Comparing the trend for maximum and minimum rainfall received by a coastal state, it can be concluded that even though the maximum values for some years are slightly less in comparison to other years, the minimum contribution is quite significant for those particular years. The possible reason can be due to larger and faster moving storms those result in longer precipitation durations with greater area coverage.

Further, the association of such rainfall contributions with ENSO, MJO and IOD cannot be undermined and thus, analyzed using observations and modeling output. The preliminary results indicate relative dominance of MJO in determining the CDR over Indian region during pre-monsoon months. During IOD -ve, heavy rainfall is contributed by CDs over AP and TN. The explicit discussion regarding the same will

be included in the presentation.

Keywords: cyclonic disturbances, rainfall, North Indian Ocean, India

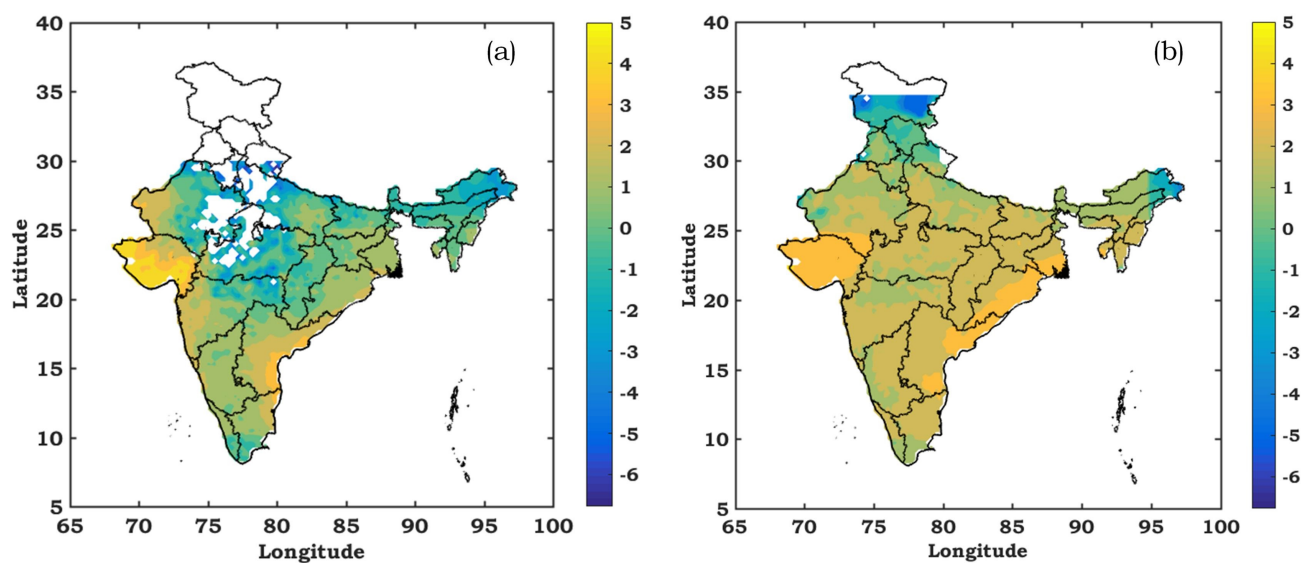


Figure 1: Percentage rainfall (cm) contributed by CDs formed over NIO during (a) pre-monsoon and (b) post-monsoon season respectively over India. Here, the percentage contribution of rainfall is shown in terms of logarithmic scale of actual value.