



Changing monsoon intraseasonal variability and its relation with extreme events over India

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Indian summer monsoon rainfall (ISMR) possesses a prominent and unique intraseasonal character manifested by active and break phases associated with certain oscillatory modes (intraseasonal oscillations, ISOs). Understanding the changing nature of these ISO modes and their relationship with extreme rainfall events are necessary for better prediction and essential in dealing with the climate-related risks in a warming environment. Here, using comprehensive mathematical and statistical techniques, we show that the relative strength of the dominant northward propagating low-frequency intraseasonal (20-60 days) modes have a significant decreasing trend possibly attributed to the weakening of vertical shear of zonal winds in the monsoon region. This reduction is compensated by a gain in synoptic-scale variability. Using a percentile-based threshold for extreme events, we find a significant increasing trend of extreme events over India. Preferentially, these extremes occur in tandem with the active phase of low-frequency ISO modes. However, we show that there exists a significant decreasing trend in the percentage of extreme events that occur in active phase. Consequently, significant increasing trends are present in break and transition periods counterparts. The changes of occurrence of extreme events in different phases of ISO is most prominent over central India and monsoon trough region. The observed trends are important for medium-to long-range forecasts of extreme events and relevant for hydrological planning and disaster management in the region.