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Decadal Cloud Characteristics in Association with Monsoon Rain in the Low and High Aerosol Regime in India

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Indian monsoon has been found to change its pattern (duration and intensity of extreme events) in the warming climate. Elucidating the causal pathway for these changes to greenhouse gas feedback and aerosols is critically important in order to predict the future climate. However, large discrepancy amongst the climate models to mimic the monsoon cloud distribution accurately continues to be the main challenge in resolving this issue. Partly, lack of a comprehensive observation-based cloud 3D structure is responsible for the limitation of robust evaluation of climate models. Passive remote sensing alone cannot provide the solution, especially in case of multi-layer clouds. We use ten years (2007-2016) of active radar measurement (CloudSat) to assess the 3D cloud distribution during the monsoon season in the Indian core monsoon region. The mean summer monsoon (June-July-August) season cloud occurrence in Indian subcontinent (latitude 5^0- 40^0North and 65^0– 100^0East), as seen from CloudSat data for individual cloud types, Cumulus, Stratus-Stratocumulus, Nimbostratus, Altostratus, Altocumulus, Deep-convective and Cirrus are 4.7%, 11.7%, 2.2%, 5.5%, 4.8%, 1.5%, and 5% respectively. Further, CloudSat-based climatology of individual cloud types is examined against climatology from passive sensors (ISCCP), another active sensor (CloudSat-CALIPSO joint product) and ground-based observations (EECRA). Changes in cloud vertical structure and associated microphysical properties (effective radius and water path for water and ice clouds) are analyzed as a function of rainfall intensity in the Indian landmass. The rainfall characteristics over the region for the decade mentioned are analysed using IMD high resolution (0.25^0X 0.25^0)gridded precipitation data. We found the average daily monsoon precipitation is around 6.29 mm with higher rain occurrence in North East and Peninsular India than in the western and central India. The structural and microphysical modifications of 3D cloud distribution with these changing precipitation characteristics are examined in a low and high aerosol regime (identified based on MODIS collection 6 aerosol product). Our analysis provides an observational framework to quantify precipitation susceptibility of monsoon clouds for the Indian summer monsoon. The strategic knowledge in terms of process understanding would facilitate refinement of weather and climate models through better representation of precipitating and non-precipitating clouds in the Indian monsoon region.

Keywords: CloudSat; Cloud types; 3-D Cloud climatology; IMD; Indian summer monsoon; Cloud properties.