Abstract

Deep convective clouds play an important role in global energy balance through vertical transport of water vapor, momentum and energy, altering radiation and also influence hydrological cycle via precipitation. These clouds are organized mainly at Synoptic scale (~1000 km), Mesoscale (~100 km) and storm-scale (~10 km) and involve interactions from micro-scale (e.g., cloud condensation nuclei and droplets) to planetary scale. Physical processes associated with such clouds are the largest sources of uncertainty in atmospheric weather and climate models. Clouds involve rich physics and therefore, studying and understanding of convective clouds is an important research area in weather and climate sciences.

In present work, the mesoscale and storm scales of convective cloud systems are addressed using spacebrone and ground based Doppler weather (conventional and polarimetric) radars. The work started with the analysis of cloud systems over Tibetan Plateau. These cloud systems are observed to be very deep in nature. After finding the underestimation of radar reflectivity especially in convective regime, analysis is further extended in entire latitudinal belt of 38°N-38°S. The coincident data collected with the precipitation radar (PR) onboard TRMM (Tropical Precipitation measuring Mission) satellite and profiling radar (CPR) onboard CloudSat satellite is used. It is shown the PR measures properties of convective part but it misses portions of the anvil part of mesoscale convective cloud systems (MCSs). CPR measures the full spatial extent of MCSs however its reflectivity values are very low due to the strong attenuation suffered by the radar beam while passing through a precipitating convective cloud. CPR beam gets attenuated severely during convective rain episodes especially below 6 km height. While going by their technical specification, we can expect substantial overlap in the radar reflectivity factor for convective clouds, very little overlap is observed. One should be very careful while drawing conclusions on the cloud characteristics measured with the PR and CPR. I felt that it is better to study the cloud properties using ground radars, hence, most of the results reported in the thesis are based on ground radar data.

As part of the Continental Tropical Convergence Zone (CTCZ) program of the Ministry of Earth Sciences, Govt. India, India Meteorological Department (IMD) made available its

Doppler weather radar (DWR) data for the years 2012 and 2013 to researchers within the country. Using IMD DWR data, life cycle of monsoonal MCSs over Indian monsoon zone and properties of storms embedded within MCSs are studied at five locations, namely, Kolkata, Hyderabad, Nagpur, Patiala and Delhi. Stages in the lifecycle of MCSs have been explored including convective area and precipitation fractions. It was observed that intense precipitation within an MCS is confined to several pockets having areas much smaller than that of an MCS. Those convective cells are called storms in this work. Storm is a precipitating convective cloud having a volume of more than 50 km^3 of connected pixels with radar reflectivity factor of at least 30 dBZ. The results of storm properties are reported for the first time using the DWR data for the Indian subcontinent. It is observed that the growth phase of an MCS is characterized by a rapid increase in the number of storms. An MCS can have more than one growth and decay phases during its lifetime. MCS may contain few or large number of storms depending upon geographic location and life phase. Average area of storms varies from less than 20 to more than 250 km^2, while average storm height lies typically between 6 and 10 km. In one extreme case, it is found even 17 km. Average convective precipitation fraction (CPF) is 40% or less, highest at Kolkata, Hyderabad, Patiala and Delhi (~40%) and the least at Nagpur (13%). Average convective area fraction (CAF) is less than 15% at all locations. The maximum CAF and CPF can go higher up to 45% and 90% respectively. The most intense convective clouds are observed over Patiala and Delhi where 30 dBZ radar echoes are found above 10 km. These locations lie near Himalayan foothills. According to previous studies, this region experiences intense convective systems due to high degree of potential instability caused by high moisture flux from low-level air flow from Arabian Sea to over foothills of Himalayas which interacts with extra moisture supplied from soil wetted from earlier precipitation. The vertical structure of MCSs is different at each radar location. These differences appear remarkably below 5 km and above 10 km altitudes. The final part of the thesis is based on the analysis of data from a polarimetric DWR located at Delhi. Using polarimetric DWR radar reflectivity data at Delhi (a land Indian region), the three prominent features of an MCS (Severe precipitation (below 4 km), melting band (at ~4 km) and anvil structures at higher altitudes (~12 km) are captured in vertical distributions of convective and stratiform echoes. Convective clouds are very deep over the Delhi region, many of them extended beyond 16 km. The typical storm duration is an hour while few exceed 3½ hours. Storms those have large average areas and long durations contribute more in precipitation amount. The average precipitation rate (*R*) of storms is estimated in between 5 and 34 mm hr^{-1}. The total accumulated precipitation (P_{acc}) derived from polarimetric variable (K_{dp}) is as large as 250 mm in 6 days at Delhi. The cloud liquid water content (*M*) is derived using horizontal radar reflectivity (Z_h, property of cloud volume observed by the radar beam which is which is proportional to the 6^{th} moment of the diameter of hydrometeors) and specific differential phase (a measure of phase difference between horizontally and vertically polarized waves). The mean of cloud liquid water content derived from Z_h (~1 gm m^{-3}) is just half of that derived from K_{dp}. However, their maximum bound (~4.2 gm m^{-3}) are found similar but have different frequencies. At each altitude, values of *M* vary largely which reflects the natural variability in clouds. One of the important finding is that the P_{acc} and *M* estimates are found to be more realistic when derived using polarimetric variable.