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Comprehensive observational evidence for the effect of clouds in the diurnal evolution of atmospheric boundary layer

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Atmospheric boundary layer (ABL) is the lower part of the troposphere which directly responds to the instantaneous changes in surface forcing within a typical time scale of less than an hour. The turbulent eddies provides a major pathway for the vertical mixing of aerosols, water vapour and pollutants in the ABL and vertical flux of energy and momentum which make ABL distinct from the other atmospheric layers. ABL is characterized by the remarkable strong diurnal variation of its vertical extent, turbulent intensity and meteorological parameters which is mainly driven by surface energy balance arising from incoming solar flux, emitted thermal radiation, heat transfer and the ground energy flux. The diurnal evolution of ABL is also significantly modulated by the background meteorological conditions and geography of the region. The boundary layer height (BLH) is a key parameter that determines the vertical extent of mixing and dispersal of atmospheric constituents. Even though various techniques exist for measuring BLH, they are not sufficient to study the diurnal evolution of BLH (due to the rapid development of convective boundary layer) under all-weather conditions (due to cloud cover). Microwave Remote sensing serves as the best method for studying diurnal cycle of BLH under clear and cloudy conditions since microwaves are capable of penetrating clouds.

Studies on the diurnal evolution of ABL and its characteristics has been extensively carried out over the tropical coastal station Thumba using different in-situ and remote sensing techniques. However, studies on the diurnal evolution of BLH under contrasting meteorological conditions (clear and cloudy sky) are not addressed so far. This study mainly focusses on the technique for identifying clear and cloudy conditions and the diurnal evolution of BLH under both conditions. The results on a monthly mean basis are quantified based on the multi-year microwave radiometer profiler (MRP) observations (April 2010 to October 2017) over the tropical coastal station Thiruvananthapuram (8.5°N, 76.9°E) located at the southwest peninsular India and are presented in this paper. Continuous high resolution multifrequency ground based passive MRP observations of atmospheric temperature and humidity profiles along with the thermal infrared brightness temperature (IRT_b) provides a unique opportunity for determining the diurnal evolution of BLH and their distinct variability under clear and cloudy conditions.

Temporal coherence method has been used to identify the time periods corresponding to clear and cloudy conditions. The limits with IRT_b <= 265 K with IRT_b rms <= 3 K and also with 275 K <= IRT_b > 265 K with IRT_b rms <= 1.5 K are identified as periods corresponding to clear sky and all the points falling outside the clear sky limit are identified as cloudy periods. Parcel method has been used to determine BLH from the MRP derived virtual potential temperature profiles. The BLH exhibited strong diurnal evolution during clear and cloudy conditions with rapid growth of BLH during ~ 08-11 IST and a slow growth or steady state till ~ 14 IST. The post-noon session is characterized by a slow decrease in BLH till ~ 17 IST and a rapid fall during 17-18 IST. The BLH is below ~ 250 m almost throughout the night time. In general the daytime peak of BLH is largest in January-February (~ 900 m) and least during the summer monsoon season (< 700 m). The difference in the BLH during clear and cloudy conditions shows distinct diurnal variability in all months. The daytime BLH during the cloudy conditions are always less (~ 150-250 m) compared to the clear conditions. This difference maximizes during ~ 09-10 IST and is largest during November- January and least during July- September.