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Characteristics and formation mechanism of clouds below the lifting condensation level over a semi-arid Western-Indian region

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The lifting condensation level (LCL) provides an estimate of the convective cloud base height (CBH) and is a crucial parameter influencing many meteorological processes. Typically, the CBH coincides with or is above the LCL in the atmosphere. This study aims to investigate the atmospheric conditions that lead to the formation of clouds below the LCL in a semi-arid region of western India. An analytical expression to estimate the LCL using surface parameters like temperature and relative humidity was derived and compared with the established LCL expression, showing minimal bias when tested against radiosonde observations. The correlation for various methods was similar (~0.84), though root mean square errors differed. The study also investigated the diurnal and seasonal variations in the LCL over the Ahmedabad region. LCL was found higher during the daytime, peaking between 9:00 and 11:00 UTC, and lower during the nighttime. This daytime peak is attributed to higher surface temperatures and lower relative humidity. The LCL is highest during the pre-monsoon season and lowest during the monsoon season, peaking at 3.3 km in May and dropping to 750 m in July. This low LCL during the monsoon is critical for the formation of low-level clouds that bring precipitation over the study region. Clouds below the LCL were found in the well-mixed boundary layer during the afternoon hours of winter, as well as the pre- and post-monsoon periods. These clouds, occurring beneath the LCL, were observed to emerge between 6:00 and 12:00 UTC. Conditions for cloud formation below the LCL are prevalent when the LCL is above the BLH, with moderate relative humidity (20-50%) near the surface, and increased surface sensible heat flux. A better understanding of these cloud formation processes will provide valuable insights into meteorological and atmospheric dynamics within the boundary layer.

Keywords: Lifting Condensation Level, Cloud Base Height, Atmospheric Boundary Layer, Sensible Heat Flux.