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A Study on the Intricate Relationship between Aerosol Loading and Atmospheric Stability on Cloud Growth

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Cloud properties vary depending on aerosols and meteorological cloud-controlling factors. This study attempts to investigate the relationship between cloud growth and stability measured under different aerosol loading conditions. Different aerosol loading cases are classified based on Aerosol Optical Depth (AOD) data retrieved from the VIIRS Level 3 Deep Blue aerosol products on the Suomi National Polar orbiting Partnership (NPP) instrument. An AOD of less than 0.2 is defined as low aerosol loading, $0.2 \leq \text{AOD} \leq 0.5$ as moderate aerosol loading, and AOD greater than 0.5 as high aerosol loading. A measure of the inversion strength called Estimated Inversion Strength (EIS), introduced by Wood and Bretherton (2006), is used to estimate the stability of the atmosphere. Atmospheric stability controls the depth of the cloud. The height at which the rising air parcel gets saturated is defined as the Lifting Condensation Level (LCL) and is used as a reasonable estimate of the cloud base height. Temperature and humidity profiles retrieved from Suomi-NPP Cross-track Infrared Sounder (CrIS) data are used to estimate EIS and LCL. A varying relationship between LCL and EIS can be observed with respect to changes in aerosol loading. In high aerosol loading cases, the correlation coefficient between LCL and EIS is significant ($r = 0.61$), compared to lower values in low ($r = 0.44$) and moderate ($r = 0.47$) aerosol loading scenarios. This suggests that as aerosol loading increases, the impact of atmospheric stability on cloud properties becomes more pronounced. These findings have important implications for understanding cloud dynamics, improving weather prediction models, and assessing the impacts of aerosol-cloud interactions on climate.