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Precipitation top heights of orographic heavy rainfall in the Asian monsoon regions

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In contrast to the dominant view that heavy rainfall results from deep clouds, the Tropical Rainfall Measuring Mission (TRMM) precipitation radar (PR) frequently observed heavy, but shallow orographic rainfall over coastal mountain ranges of the Asian monsoon regions. The low-level horizontal winds, leading to topographic forced upward motion on the windward slopes, are dynamically important for its occurrence. This paper focuses on the thermodynamic character of the atmospheric environment associated with shallow orographic heavy rainfall. The precipitation-top heights of orographic heavy rainfall generally decrease with low- and mid-level relative humidity especially for coastal mesoscale mountain ranges during summer monsoon. This differs from what has been observed for convection over the tropical ocean in previous studies, but is consistent with abundant shallow convection during the moist summer monsoon season. In contrast, the precipitation-top heights over Annam Cordillera during the transition phase from boreal summer to winter monsoon seasons, facing the prevailing northeasterly, increase with low-level and mid-level relative humidity, demonstrating that convection depth is not a simple function of humidity. The precipitation-top heights of orographic heavy rainfall decrease with the low-level stability for all regions considered in this study as well as Annam Cordillera during the transition phase from boreal summer to winter monsoon seasons. Therefore, low-level static stability, which inhibits cloud growth and promotes cloud detrainment, is inferred to be an equally important parameter in determining the precipitation-top heights.