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Effects of Topography and Background Wind on Rainfall over the Lanyang Plain: Surface Meteorological and UAV Observations

Abstract

During the winter season, the southern Lanyang Plain of Yilan county frequently experiences heavy rainfall. However, due to the lack of comprehensive investigation with field experiments over the past thirty years, the three-dimensional structure of atmospheric conditions associated with this heavy rainfall phenomenon remains unclear. The Yilan Experiment of Severe Rainfall (YESR), initiated in 2020, provided intensively vertical observation data from UAVs, radiosondes, radar, and wind profilers, which help to explore the mechanism of rainfall in Yilan. This study utilizes data from meteorological observation stations of the Central Weather Bureau from autumn and winter of 2018 to 2024, along with data from three UAV intensive observation periods during YESR, encompassing a total of 65 sorties, to study the effects of topography and wind on rainfall over the Lanyang Plain.

The assessment of rainfall climatology suggests that the hotspots of rainfall differ under three background winds: north, northeast, and east. During periods of northerly winds, the rainfall hotspot is located in the mountainous area on the southern Lanyang Plain. Under northeasterly wind conditions, the hotspot extends approximately 10 km upstream from the southern mountainous area. Lastly, rainfall is more uniformly distributed across the Lanyang Plain under easterly wind conditions. The moist Froude number (F_r) was calculated using UAV data obtained from the YESR's experiments to explain the wind flow characteristics in association with rainfall. Results revealed that during north wind conditions, the relatively high wind speed throughout surface to 1.5km height causes the value of $F_r > 0.354$ and convection to remain quasi-stationary over the mountainous peaks in the southern Lanyang Plain. For easterly wind conditions, the near-surface wind field in the central and southern Lanyang Plain displays orographic-induced wind that converges with the background wind field, triggering convection, which then moves towards Yilan. In the context of northeasterly wind conditions, the reduced wind speed results in the formation of convection on the windward side, which subsequently moves towards the upstream direction. Meanwhile, the near-surface orographic-induced wind generates rainfall patterns shows similar to those observed under easterly wind conditions.

Overall, the UAV observations provide a new insight on rainfall in the southern Lanyang Plain, which is primarily contributed by orographic lifting on the windward side and convection from the interaction between orographic-induced wind and the background wind field.

Keywords

Orographic-induced wind
Moist Froude number