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Response of Orographic Precipitation to Subsaturated Low-Level Layers

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Orographic precipitation is, on the one hand, an important source of fresh water, and on the other hand, a potential cause of floods and other disasters. Previous studies have focused on the situation where the whole atmosphere is saturated and nearly moist-neutral. However, there are times when subsaturated low-level layers are observed to be below saturated, nearly moist-neutral, upper-level layers.

A series of idealized two-dimensional simulations are performed here to investigate the impact of this subsaturated low-level layer on orographic precipitation. It is found that the impact is mainly controlled by a nondimensional parameter and two competing effects. The nondimensional parameter is $N_2 z_t / U$, where N_2 and z_t are, respectively, the dry Brunt-Väisälä frequency and depth of the subsaturated low-level layer, and U the cross-mountain wind speed. When the nondimensional parameter exceeds a critical value, the decelerated region on the upwind side of the mountain moves upwind, resulting in weak surface precipitation near the mountain peak. When it is smaller than the critical value, surface precipitation occurs near the mountain peak.

The two competing effects are: 1) the vapor-transport effect, meaning that increasing z_t decreases the amount of vapor transported to the mountain, and hence tends to decrease surface precipitation; and 2) the updraft width effect, meaning that increasing z_t enhances flow blocking, producing a wider updraft over the upwind slope, and hence tends to increase surface precipitation. When the vapor-transport effect dominates, surface precipitation decreases with z_t . When the updraft-width effect dominates, surface precipitation increases with z_t .