The Lagrangian Evolution of Water Budget and Precipitation Efficiency of an Idealized Squall Line as Interacting with Terrain

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Abstract

In this study, idealized simulations of squall line traversing a bell-shape mountain in a three-dimensional framework are conducted using the Weather Research and Forecasting (WRF) model, version 3.2.0, with 2-km horizontal grid size and 60 vertically stretched layers. Water vapor and condensate budgets are examined, and the temporal variations of four microphysics ratios, including precipitation efficiency (PE), condensation ratio (CR), deposition ratio (DR), and evaporation ratio (ER) are investigated as the simulated squall line interacts with the terrain. Results show that as the simulated leading convective line climbs over the mountain, the horizontal flux convergence of water vapor is increased as a result of flow convergence over the terrain. When the leading line moves to the leeside slope, downslope subsidence reduces the depth of cold pool, and the raindrop evaporation and ice-phase deposition processes become more important compared to those over the upwind slope. Twenty simulations are performed with different combinations of terrain peak heights and environmental wind speeds. For squall lines encountering increasingly higher mountain peaks but with the same environment wind, there are optimal maximum changes on horizontal vapor-flux convergence and precipitation efficiency due to terrain lifting. Similarly, for squall lines moving across the same terrain but with increasingly stronger environmental wind speeds, there are also optimal wind speeds to have the greatest enhancement of vapor flux convergence and precipitation efficiency over the windward slope. Terrain enhancement of water budget and precipitation efficiency is thus a nonlinear response to the increase of Froude number.