The role of low-level blocked flow on orographic precipitation enhancement in the Cascade Mountains

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Abstract

During the cool season, extra-tropical cyclones develop over the North Pacific Ocean and make landfall along the United States’ west coast. Precipitation is enhanced by interactions of the low-level flow and moisture from these storms with the topography of the coastal and interior mountain ranges. This study uses operational scanning radar and a vertically-pointing radar at Portland, Oregon, as well as upper air soundings from Salem, Oregon obtained during several cool seasons to examine the environmental conditions and precipitation structures of storms affecting the interior Cascade Mountains. Orographic precipitation in this region typically occurs during conditions of near neutral stability and lasts longer than 12 hours. Large storm total rainfall and flooding in this region are associated with long persistence of light to moderate precipitation (< 10 mm/hr) rather than short periods of intense rainfall.

Strong cross-barrier winds, enhanced vertically-integrated water vapor, a high 0 °C level, and storm durations > 24 hours were necessary but not always sufficient conditions for flooding. Flooding storms more often occurred when an additional condition of two-layer flow was present, defined as a difference of at least 10 m/s between the layer-average cross-barrier wind speed from 0 to 1.2 km altitude compared to 1.2 to 2.2 km altitude upstream (west) of the Cascades. Two-layer flow is created by partial or complete blocking of low-level flow by the Cascades. During two-layer flow conditions, the effective barrier width and the associated area of orographic precipitation enhancement widens to the west to include part of the valley. While blocked flow has primarily been studied in relation to the stability of the incoming air mass, other conditions related to three-dimensional flow near and over terrain can yield analogous low-level blocked flow. These conditions include down-valley flow within narrow valleys resulting from cooling of the air by melting and evaporating precipitation particles, which increases the low-level stratification and the potential for blocking.

We examine the vertical and horizontal structures of the radar echo relative to the terrain as well as cell tracking to address the associations between precipitation enhancement and the development of two-layer flows. These results point to the importance of the representation of low-level blocked flows in predicting orographic storm total rainfall accumulations, which has implications for numerical modeling in short-term forecasting and climate applications.