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small-scale updrafts and snow growth in stratiform orographic clouds

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Stratiform clouds over mountains are subject to locally strong updrafts that impact snow growth. These vertical drafts occur at a range of horizontal scales and depth, and include vertically propagating gravity waves, shallow terrain-driven (evanescent) waves, embedded convection, and shear-driven overturning cells. The latter essentially are Kelvin-Helmholtz (KH) waves; we find them to be remarkably common in deep stratiform precipitation systems associated with frontal disturbances over complex terrain, as is evident from transects of vertical velocity and 2D circulation, obtained from a 3-mm airborne Doppler radar. The high range resolution of this radar (~40 m) allows detection and depiction of KH waves in fine detail. These waves are observed in a variety of wavelengths (<100 m to > 1 km), depths, amplitudes, and turbulence intensities. Proximity rawinsonde data confirm that they are triggered in layers where the Richardson number is very small. Complex terrain may locally enhance wind shear, leading to KH instability. In some KH waves, the flow remains mostly laminar, while in other cases it breaks down into turbulence. KH waves are frequently locked to the terrain, and occur at various heights, including within the free troposphere, at the boundary layer top, and close to the surface. They are observed not only upwind of terrain barriers, as has been documented before, but also in the wake of steep terrain, where the waves can be highly turbulent. Doppler radar data and flight-level cloud probe data are used to explore the dynamics of KH waves and the response in terms of droplet growth, ice initiation, and snow growth.