Assessing satellite-based radar capabilities for orographic snowfall process studies

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Satellite-borne radar is potentially one of the most capable observing methods for examining orographic snowfall processes, particularly in areas of remote or rugged terrain. Unlike lidar or passive instruments, radar can often penetrate snowing clouds and the snowing columns below cloud base, allowing for measurements with vertical resolution, a key factor for precipitation process studies. In addition, satellite-based measurements allow sampling in these remote or rugged areas for extended time periods, sampling that typically isn't accomplished with ground-based instruments or with limited-duration field experiments. These advantages give way to a number of tradeoffs, however: 1) ground clutter, which is often worsened by irregular terrain, and 2) balances between sensitivity, spatial resolution, and attenuation that are made difficult by satellite-borne hardware limitations. These tradeoffs are exacerbated in orographic snowfall, which can be highly spatially variable and often shallow.

This work examines these tradeoffs in two ways. First, comparisons of observations of orographic snowfall by the Cloud Profiling Radar and the Dual-frequency Profiling Radar (DPR) illustrate differences in detection and quantification of orographic snowfall on a global basis. Although detections of orographic snowfall by the DPR are susbstantially less frequent than are those by the CPR, the DPR's globally averaged annual orographic snowfall accumulation is almost 50% larger than the CPR's. The cause lies in differences in the snowfall intensities observable by the two instruments, differences ultimately resulting from attenuation and sensitivity limits that differ between the two radars.

Second, modeling studies quantify the ability of various radar configurations to determine bulk microphysical process parameters for orographic snow events. Simulations by the Regional Atmospheric Modeling System are evaluated to quantify each event's snowfall occurrences and precipitation efficiencies (PEs) and then are used in conjunction with QuickBeam to simulate reflectivity profiles at W-, Ka-, and Ku-band. Using thresholds for blind zone depth and sensitivity, errors in occurrence and PE are evaluated for a number of hypothetical satellite-borne radars. For deep, intense events, errors in PE can be smaller than 10%, even with 2000-m deep blind zones. For less intense events, poor detection leads to errors larger than 90%, even when no blind zone is present.