In Situ Determination of Dry and Wet Snow Permittivity: Snow Water Equivalent Algorithm Development for Low Frequency Radar Applications

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Extensive efforts are made to observe the accumulation and melting of seasonal snow. However, making accurate observations of snow water equivalent (SWE) at the global scale remains elusive. Active radar systems show promise, provided the dielectric properties of the snowpack are accurately understood. The dielectric relative permittivity (k) determines the velocity of the radar wave through snow. Equations used to estimate k have been validated only for specific conditions with limited in situ validation for seasonal snow applications. The goal of this work is to further understand the dielectric permittivity of seasonal snow under dry and wet conditions. We utilize extensive in situ observations of k with snow density and liquid water content (LWC) observations to: (1) Test current permittivity equations for dry snow conditions, (2) Test current permittivity equations for wet snow conditions, and (3) Determine if any improvements to current permittivity equations are necessary. Data were collected in the Jemez Mountains, NM; Sandia Mountains, NM; Grand Mesa, CO; and Cameron Pass, CO from February 2020 to May 2021. We will present empirical relationships based on 146 snow pits for dry snow conditions and 92 LWC observations in naturally melting snowpacks. Regression results have r^2 values of 0.57 and 0.37 for dry and wet snow conditions, respectively. Our results in dry snow showed large differences between our in situ observations and commonly applied equations. We attribute these differences to assumptions in shape of the snow grains that may not hold true for seasonal snow applications. Different assumptions, and thus different equations, may be necessary for varying snowpack conditions in different climates, though further testing is necessary. When considering wet snow, large differences were found between commonly applied equations and our in situ testing. Many previous equations assume a background (dry) k that we found to be inaccurate, as previously stated, that is the primary driver of resulting uncertainty. Our results suggest large errors in SWE or LWC estimates based on current equations. The work presented here could prove useful for making accurate observations of changes in SWE using future remote sensing opportunities such as NISAR and ROSE-L.