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Mapping snow depth from Ka-band interferometry over a mountainous basin

Konstantinos Andreadis (1), Delwyn Moller (2), Kat Bormann (1), Scott Hensley (1), and Thomas H Painter (1)

(1) Jet Propulsion Laboratory, Pasadena, United States (konstantinos.m.andreadis@jpl.nasa.gov), (2) Remote Sensing Solutions, Inc

Mapping snow depth and water equivalent from remote sensing becomes very challenging over mountains where complex topography drives extremes in orographic precipitation, snow redistribution, and snowmelt gradients. Traditionally, attempts to remotely map snow properties have focused on passive/active microwave sensors that either use regression relationships or radiative transfer modeling as the retrieval algorithm. However, these approaches are hindered by issues such as penetration into the snow volume, presence of liquid water, vertical heterogeneity in grain size and density among others. Recently, an alternate approach has been demonstrated whereby SWE is estimated by merging modeled density with a direct measurement of snow depth. The NASA Airborne Snow Observatory (ASO) provided the first distributed mapping of mountain SWE across entire basins using an airborne scanning lidar for the accurate measurement of topography and retrieval of depth. Lidar may hold a path to space but it suffers from scattering by cloud cover at very small optical depths. Single-pass interferometric synthetic aperture radars may hold the key to overcoming this issue while making accurate topographic maps. We present the first demonstration of mm- wave single-pass interferometric synthetic aperture radar (InSAR) for snow-depth mapping. Maps are presented over the Tuolumne River Basin region of the Sierra Nevada, CA, USA and compared with those collected by ASO for the same region on the same snow day. Despite the rugged terrain, heavy tree-cover, very low snow-volume, and wet conditions depth maps had a relative mean error of 0.5% (or 0.0073 m) with the largest differences occurring on slopes exceeding 40^{o}. While additional evaluation is needed with demonstration of the InSAR capability over a greater range of conditions and terrain, these results are promising. InSAR for snow-depth mapping holds significant advantages for a spaceborne mission if proven viable as it can operate through cloud cover, day or night and measure snowpack when wet or melting.