Retrieving Snow Density from Ground-Based Radar and Airborne Lidar Observations and Spatial Prediction for Distributed Snow Water Equivalent in Sub-Alpine Mountain Environments

TATE G. MEEHAN[1], SHAD O'NEEL[1], H.P. MARSHALL[2], ELIAS J. DEEB[1], AHMAD HOJATIMALEKSHAH[2], ZACHARY KESKINEN[2], AND BRENT WILDER[2]

ABSTRACT

Constraining snow depth from repeated airborne lidar acquisitions enables the retrieval of snow density from radar travel-time along transects at 1-m resolution. These inferred observations of bulk snow density illustrate spatial patterns and features that are not captured by sparse manual measurements. We combine ground-penetrating radar (GPR) surveys and airborne lidar acquisitions in subalpine environments, covering a range of terrain and ecological parameters such as elevation, slope, aspect, forest canopy, and burned forest area, which captured variability in snow density due to differences in surface energy balance and wind exposure. These terrain and vegetation parameters can be derived from airborne lidar acquisitions and serve as the basis of features within a supervised learning framework to extrapolate snow density estimates across the study regions. Several machine learning models of snow density are compared, but the choice of a best model is difficult to quantitatively assess, as outputs have similar statistical representations but differing spatial patterns. Estimates of the snow water equivalent (SWE) are calculated, using the density map and lidar snow depths, at a scale of tens of square kilometers. The total SWE estimated by any choice of density model is similar in bulk value. This work implores a deepened focus on the meteorological, terrain, and ecological variables controlling the densification of snow in subalpine mountain watersheds with the intent of studying predictor importance and model applicability. An improved observational comprehension of the influences of snow densification will enable snow scientists to better assess and improve physically modeled snow density.

[1] U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, USA

[2] Boise State University, Boise, ID, USA

Corresponding author: tate.g.meehan@erdc.dren.mil

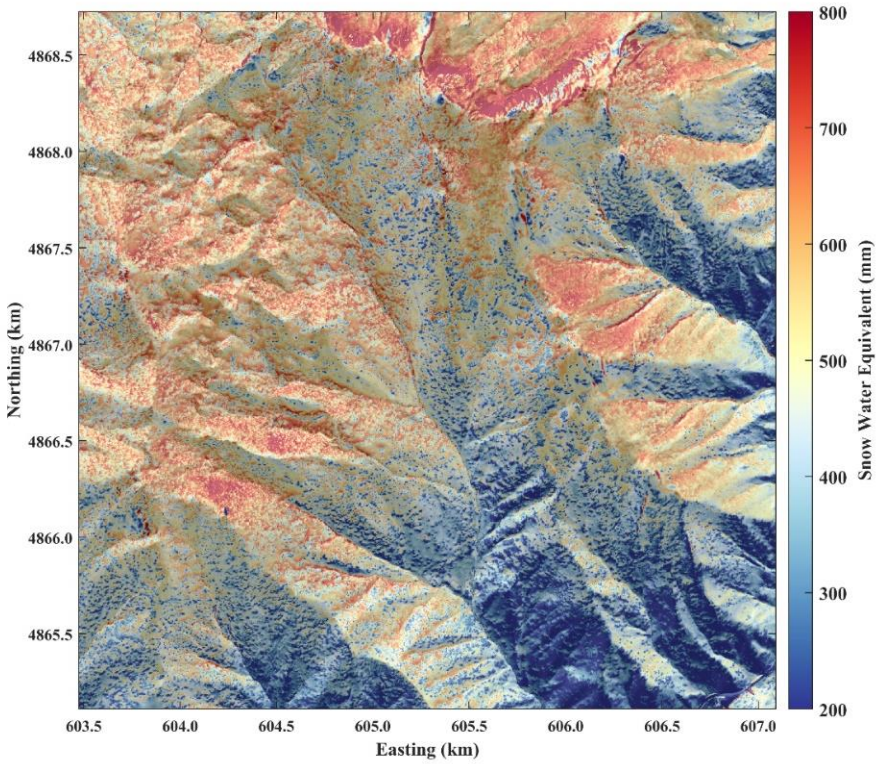

Figure 1. Snow water equivalent of Mores Creek Summit, Idaho was estimated from helicopter-borne lidar acquisitions and density spatially distributed via artificial neural networks.