Modeling Snowpack Bulk Density using Snow Depth, Cumulative Degree Days, and Climatological Predictor Variables

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ABSTRACT

Snowpack water equivalent (SWE) is a key variable for water resource management in snow-dominated catchments. While it is not feasible to quantify SWE at the catchment scale using either field surveys or remotely sensed data, technologies such as airborne LiDAR support the mapping of snow depth at scales relevant to operational water management. To convert snow depth to water equivalent, models have been developed to predict SWE or snowpack density based on snow depth and additional predictor variables. This study builds upon previous models that relate snowpack density to snow depth by including additional predictor variables to account for (1) the effect of annually varying meteorological conditions on densification through a cumulative degree-day index derived from North American Regional Reanalysis products, and (2) long-term climatologies that describe the prevailing conditions influencing regional snowpack properties. A non-linear model was fit to 114,506 snow survey measurements spanning 41 years from 1,166 snow courses across western North America. Under spatial cross-validation, the predicted densities had a root-mean-square error of 47.1 kg m^{-3}, a mean bias of -8 x 10^{-3} kg m^{-3}, and a Nash-Sutcliffe Efficiency of 0.70. Compared to a similar regression-based model reported in the literature, the two models had similar overall performance, but the model developed in this study had reduced seasonal biases. When applied to predict SWE from simulated depths determined from aerial platforms (LiDAR or Structure-from-Motion), 50% of the SWE estimates for May and June fell within -55 to 59 mm of the observed SWE, representing prediction errors of -15 to 23%.

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