

Fractal distribution of snow depth from LiDAR data

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Abstract. Snowpack properties vary dramatically over a wide range of spatial scales, from crystal microstructure to regional snow climates. Knowledge of snow depth variability in subalpine and alpine environments is important for understanding and modeling hydrologic, ecologic, and avalanche processes. Additionally, knowledge of how snow depth variability changes with the scale of observation has ramifications for sampling, modeling, and hydrologic or avalanche forecasting. The scaling properties of variability derive from the scale dependencies of the physical processes that interact to create the observed snow depth distributions. The driving forces of wind and energy balance interact with topography and vegetation to dominate snow depth variability at horizontal scales from 1 to 1000 meters. Despite the apparent and intuitive relation of snow depth to topography at the slope scale, efforts to relate topographic parameters to variability in snowpack properties have left room for improvement.

The measure of the fractal dimension of surfaces, i.e. land surface, vegetation, or snow cover, shows promise as a tool for assessing the complexity of the interrelated surface morphologies. Fractal dimension is an index of the roughness and self-similarity of an object derived from its scaling properties. This study uses LiDAR-derived land surface elevation, vegetation surface elevation, and snow depth data collected at the Buffalo Pass, Walton Creek, and Alpine Intensive Study Areas as part of the NASA Cold Land Processes Experiment (CLPX) in April and September, 2003. Fractal dimensions are estimated from the slope of a log-transformed variogram, and demonstrate scale-invariant, fractal behavior in the elevation, vegetation, and snow depth datasets. The snow depth data show a distinct scale break around 15-40 meters, depending on the site. Directional differences in the fractal dimensions are also present at multiple scales.