Fine-Scale Characterization of Snowpack Evolution using Unpiloted Aerial System Lidar and SfM Photogrammetry

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ABSTRACT

Unpiloted aerial systems (UAS) equipped with lidar and structure-from-motion (SfM) photogrammetry have emerged as viable methods to map snow depths at fine resolutions. In this study, eight UAS lidar/SfM snow depth maps were collected during the 2020/2021 winter season in Durham, NH, USA with the objectives of: (1) validating UAS snow depth retrievals using multiple *in situ* measurement techniques (Magnaprobe and field cameras), (2) conducting a quantitative comparison of lidar and SfM snow depths (< 35 cm) throughout the winter, and (3) better understanding a spatial structure of snow depth and its relationship with terrain features. The surveys were conducted over approximately 0.35 km^2 including large open and mixed forested areas. Results showed that lidar outperformed SfM compared to *in situ* observations, especially at forested sites. In the field, lidar had a lower mean absolute error (MAE) than SfM compared to the Magnaprobe (lidar = 3 cm, SfM = 5 cm) and field cameras (lidar = 3 cm, SfM = 14 cm). The same was true in the forest compared to the Magnaprobe (lidar = 7.2 cm, SfM = 32 cm) and cameras (lidar = 2.7 cm, SfM = 45 cm). The difference between lidar and SfM was much greater in the forest, with SfM overestimating snow depths at most locations. We also found differences between the *in situ* measurement techniques used for validation. However, the differences had only a modest impact on snow depth validation. The spatial structures of snow depth captured by lidar were generally consistent throughout the period indicating that static land characteristics such as slope, vegetation, and soil properties, may control the spatial variability.

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