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Spatiotemporal Variability of Snow Depth in Subarctic Environment Using Unmanned Aircraft Systems (UAS)

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Seasonal snow accumulation and melt dominates the hydrology in high latitude areas, providing water storages for both ecological and human needs. However, until recent years there has been a lack of cost-efficient way to measure the spatiotemporal variability of the snow depth and cover in high resolution. Unmanned aircraft systems (UAS) can offer spatial resolutions up to few centimeters, depending on the weather and light conditions, camera quality and drone specification. We used multiple different quadcopters and a fixed wing UAS to determine and analyze the spatiotemporal variability of snow depth and cover in three test plots with different land-cover types (forested slope, open peatland, and peatland-forest) in subarctic northern Finland, where weather and light conditions are challenging. Five measurement campaigns were conducted during winter 2018/2019 and a snow-free bare ground survey after snowmelt. Snow depth maps were constructed using Structure from Motion (SfM) photogrammetry technique and by differentiating the acquired models from snow-covered and snow-free surveys. Due to poor sub-canopy penetration with UAS-SfM method, tree masks were utilized to remove canopy effects prior to analysis. The snow depth maps produced with different UAS were compared to in situ snow course and an automatic ultrasonic measurement data. We highlight the difficulties of working in subarctic winter conditions and discuss the accuracy of UAS-derived snow depth maps. We show that the UAS-derived snow depth measurements agree well with manual snow survey measurements and UAS are suitable method for extending the spatial snow data coverage, whereas a continuous point snow depth measurement is unable to accurately present sub-catchment scale snow depth variability. Furthermore, the spatiotemporal variability of snow accumulation and melt between and within different land cover types is presented.