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Mapping snow depth in alpine terrain with remotely piloted aerial systems and structure-from-motion photogrammetry – first results from a pilot study

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Detailed information on the spatio-temporal distribution of seasonal snow in the alpine terrain plays a major role for the hydrological cycle, natural hazard management, flora and fauna, as well as tourism. Current methods are mostly only valid on a regional scale or require a trade-off between the data‘s availability, cost and resolution. During a one-year pilot study, we investigated the potential of remotely piloted aerial systems (RPAS) and structure-from-motion photogrammetry for snow depth mapping. We employed multi-copter and fixed-wing RPAS, equipped with different low-cost, off-the shelf sensors, at four test sites in Austria and Switzerland. Over 30 flights were performed during the winter 2014/15, where different camera settings, filters and lenses, as well as data collection routines were tested. Orthophotos and digital surface models (DSM) where calculated from the imagery using structure-from-motion photogrammetry software. Snow height was derived by subtracting snow-free from snow-covered DSMs. The RPAS-results were validated against data collected using a variety of well-established remote sensing (i.e. terrestrial laser scanning, large frame aerial sensors) and in-situ measurement techniques. The results show, that RPAS i) are able to map snow depth within accuracies of 0.07-0.15 m root mean square error (RMSE), when compared to traditional in-situ data; ii) can be operated at lower cost, easier repeatability, less operational constraints and higher GSD than large frame aerial sensors on-board manned aircraft, while achieving significantly higher accuracies; iii) are able to acquire meaningful data even under harsh environmental conditions above 2000 m a.s.l. (turbulence, low temperature and high irradiance, low air density). While providing a first prove-of-concept, the study also showed future challenges and limitations of RPAS-based snow depth mapping, including a high dependency on correct co-registration of snow-free and snow-covered height measurements, as well as a significant impact of the underlying vegetation and illumination of the snow surface on the fidelity of the results.