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Integrating airborne laser and in situ LED ranging for snowpack monitoring

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Communities and agricultural operations in the arid Prairies of western Canada are largely dependent on seasonal snow melt from the high-yielding upstream mountainous headwaters for water supply, irrigation and energy generation. With changing climatic and land cover patterns, combined with increasing demands for food production and urban development, there are increasing needs to improve our monitoring of the critical seasonal snowpack resource. As part of a multi-faceted water resources reconstruction and simulation study in the headwaters of the Oldman River, Alberta, Canada, we are developing innovative snowpack sampling and mapping routines that combine occasional airborne lidar sampling, in situ proof-of-concept leddar (light emitting diode detection and ranging) profiling and satellite-based synthetic aperture radar (SAR) snow cover mapping. Since 2013, we have collected seven airborne lidar images during summer and winter months to enable snowpack depth mapping across the Castle headwaters. These data are being used to discern primary, secondary and tertiary in-situ and proximal driving mechanisms for snow depth distributions, while also establishing whether or not drivers remain constant during the transition from early to mid-winter accumulation through to spring melt periods. These spatially distributed snowpack depth sampling observations are being combined with in situ time series leddar depth profile data and wide area SAR-based snow cover data to develop a spatio-temporal snowpack mapping framework for mountainous environments. The study is one year away from completion but major results thus far demonstrate that: a) treeline is the most hydrologically high-yielding zone of these headwaters; b) machine learning is an effective method of spatially extending snow depth information into areas with no observation data; c) leddar depth profiling accurately illustrates localised variations and is a superior method of in situ collection compared to more traditional point-based methods. SAR-based snow cover mapping is challenged by terrain and forest cover, and is sensitive to seasonal snow moisture characteristics but high resolution lidar terrain and canopy data are useful in overcoming some of these challenges. The fusion of time-variant remote sensing platforms and data types utilised here is providing a cost-effective spatially explicit supplement to contemporary point-based snowpack sampling across sparse in situ hydrometric networks.