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A mountain water resources monitoring and modelling framework using a temporal fusion of optical, lidar and radar image data sources at century to season scales

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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: a) understand historical runoff quantities from critical headwater regions so that we can (b) build better long-term forecasting capabilities, while (c) improving 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 using historical remote sensing imagery to track century-scale changes in key landcovers, while developing innovative seasonal lidar snowpack sampling routines. Combining oblique photos from the beginning of the 20th Century with air photos from the 1950s and contemporary high-resolution SPOT imagery (2015), we have mapped changes in tree cover and treeline in the upper Castle watershed (∼120km2). These changes are due to a combination of wildfire, forest harvesting, community and trail development, as well as natural migration of treeline. The temporal spatialization of forest cover changes are being used to support time-variant HRU definition within the ACRU model, to ensure long-term scenarios are not unduly biased by assuming static HRU properties. Since 2013, we have collected multiple 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. In combination with optimised lidar snowpack sampling, these relationships are exploited within a machine learning model to predict snowpack depth over the wider headwater areas. Lidar snowpack observations and simulations are being combined with high resolution HH and FQ mode synthetic aperture radar in an attempt to extend winter-time monitoring of snow covered area within mountainous environments. The major results thus far demonstrate that treeline is the most hydrologically high-yielding zone of these headwaters and that treeline itself has changed markedly over the last century due to various influences. The fusion of time-variant remote sensing platforms and data types utilised here is providing an innovative framework for climate and landcover change model parameterisation, as well as a cost-effective spatially explicit supplement to contemporary point-based snowpack sampling across sparse in situ hydrometric networks.