Calibration of cosmic ray sensors for the measurement of snow water equivalent
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Introduction
Snow data is implemented by groups ranging from local residents, small- and large-scale businesses, and all levels of government. As such, it is vital that this data is as accurate as possible. The issue is that modern day measurement approaches are rooted almost entirely in point-scale techniques such as snow pillows and are not representative of an area, or extremely large-scale methods such as remote sensing which are subject to discrepancies related to sizable resolutions as well as cloud and canopy cover. An approach to measure snow at an intermediate scale that is representative of an area and not impacted by natural conditions is necessary to fulfill this intricacy.

In the past few years, modern approaches such as Unmanned Aerial Systems have seen some success measuring snow at a landscape scale, but issues such as continuous measurements, dependency on weather, and the physical need for the user to be at the site remain unresolved.

This research explores the potential of using cosmic rays sensors to accurately and continuously measure snow water equivalent with minimal concern from environmental or topographic variables.

Methods
- Acquire neutron counts measured by the sensors via an online portal.
- Calibrate for atmospheric water vapour, barometric pressure, and incoming temporal cosmic ray flux.
- Scale for site (adjust for latitude, longitude, elevation).
- Account for statistical noise.
- Validate results by conducting manual snow surveys.

Discussion
Unlike other studies, this research takes place at sites located in the Arctic and therefore possesses a unique set of environmental and topographic characteristics. In addition, this study uses a rural site that is easily accessible allowing the results between sites to be compared.

The maximum calculated SWE in this research is found to be ~38 cm in a deep shrub patch while a study by Schattan et al. (2017) was able to measure SWE up to 60 cm in the Austrian Alps. Earlier works calculated SWE to be between 7 and 12 cm (Desilets et al., 2010; Sigrin and Si, 2016). Other studies using the cosmic ray sensors are almost exclusively related to soil moisture measurements (Zreda et al., 2008; Chrisman and Zreda, 2013; Coopersmith et al., 2014; Wrona, 2016). Wrona (2016) is the only other study set in the Arctic, however, her soil moisture measurement results were inconclusive. Chrisman and Zreda (2013) used the 1000-B model in an attempt to measure soil moisture at a landscape scale in a moving vehicle, however, due to an extremely short pre-set time interval the results were flawed and soil moisture measurements were inconclusive.

Preliminary results indicate that both types of cosmic ray sensors are sensitive to SWE and exhibit the expected trends. Currently, due to the unique characteristics of the Trail Valley Creek sites, reformulations are necessary to the calibration equation in order to account for an extremely porous, organic, and high water content soil. Interestingly, this type of soil corresponds closer with standard glacial parameters than it does to a standard silty-loam soil in the calibration formulation.

This approach allows for the continuous & remote monitoring of SWE on an intermediate scale and in deep snow packs.

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References
• Dilshan, K., and Zreda (2013). A new model for cosmic ray neutrons: (A) many neutrons produced in ground escape to atmosphere, (B) some are blocked by snow, and (C) nearly all are blocked by snow. (Desilets et al., 2010).