The Potential of Satellite Data to Identify and Quantify Permafrost Presence and Change

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Satellite data can only indirectly reveal changes in permafrost, in sub-ground conditions. The application potential differs with respect to the actual target parameter. International programs and initiatives define usually one or several of the following parameters as essential for monitoring of permafrost on a global scale: ground temperature, permafrost extent, and/or active layer thickness. These listings form the basis for, e.g., the European Space Agency Climate Change Initiative. Spatially continuous information on these parameters can be only obtained through modelling. Due to the nature of relevant satellite observations, data gaps are common and limit their applicability in this context. In addition, data for calibration is needed which is scarcely existing in a sufficient quality and quantity. Further on, in order to capture actual climate change impacts, satellite records are usually too short. Thus, satellite data are currently mostly used to capture variations of permafrost proxies (impacts of ground thaw on the landscape) or drivers (observables related to ground temperature). This aids process understanding and regional inventories. Landcover change monitoring is a frequent strategy as it is technically feasible to implement with satellite data. Analyses across landscape gradients opens the way for space for time concepts, but its utility for permafrost research is rarely explored. This contribution reviews recent achievements based on satellite data on circumpolar scale and along permafrost landscape gradients. Examples are shown for the utility of radar techniques, including surface status observations as proxy for permafrost in comparison to other approaches, specifically considering products available from ESA CCI+ Permafrost (covering 1997-2019). Constraints due to limited availability of in-situ observations are discussed in addition.

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Using Arcticdem and Shallow Boreholes to Quantify Mass Wasting Sediment Loss Of Retrogressive Thaw Slumps in the Eureka Sound Lowlands, Canadian High Arctic

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Retrogressive thaw slumps (RTSs) are mass wasting features that form in degrading ice-rich permafrost, including local erosional processes such as gullying, and regional processes such as increasing summer air temperatures. These features are typically horseshoe shaped with an ablating headwall that feeds fluidized sediment downslope. RTS occurrence and activity is controlled by multiple factors including climate, slope, RTS geometry and ground-ice content. Study of RTS typically relies on 2D satellite imagery and the availability of extensive ground-ice datasets is limited. We use summer digital elevation models (DEM) between 2009 and 2017 generated by the ArcticDEM project to quantify total volume loss by RTS initialization and retreat in the Eureka Sound Lowlands in west-central Ellesmere Island and southeastern Axel Heiberg Island, Canada. A map of biophysical regions and shallow borehole dataset was used to estimate ground-ice content by surface cover to partition sediment and ice amounts lost by RTS activity. ~200 RTSs were identified, including both newly initialized RTS in undisturbed terrain and active RTS that initiated prior to 2009. Overall mean depth of material loss is 1.9 m (standard deviation is 0.79 m) and mean maximum depth was 4.6 m (standard deviation is 2.35 m). Mean total volume loss for individual RTS was 9,000 m^3 (standard deviation is 17,000 m^3). Mean ground-ice content for all cores was 49% in the upper 1 m of the ground surface. The incorporation of DEM differencing in RTS studies will compliment previous 2D analysis, furthering our understanding of RTS dynamics and allows for the measurement of volume loss by RTS activity.