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Inferring permafrost thermal properties from freeze-thaw column experiments and numerical modelling

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Cold-regions contain a vast pool of organic carbon in permafrost, which is currently immobilized. As the global air temperatures rise, permafrost active layer depths are increasing. The deepening of the active layer reactivates groundwater transport processes, leading to the release of solutes such as dissolved carbon to streams and the atmosphere. In order to make predictions of the rates of permafrost thaw based upon numerical modeling, we need accurate data on active layer thermal properties.

Active layer thermal properties, thermal conductivity and heat capacity, are strongly coupled to geological properties such as water content, and organic matter content and are therefore highly heterogenous in natural systems. Furthermore, the effective thermal properties vary as a function of temperature through ice-content, especially across the freeze-thaw interval near 0 ^{o}C. Direct in-situ observations of active-layer thermal properties are rare because in-situ measurements involves sampling of frozen samples and analysis in a laboratory.

This study uses soil column (1 m high x 0.31 m diameter) experiments to investigate the relation between soil physical properties and thermal properties. A total of nine samples were synthesized using a range of grain sizes and organic matter contents, and were fully saturated with water. The columns were insulated on the sides and top, aiming to create a fully 1D thermal system allowing only vertical heat transport. The columns are subjected to one freeze-thaw cycle, lasting about 20 weeks. Resulting temperature observations were analyzed using a numerical heat transfer model. By fitting the temperature observations to the heat transfer model, thermal properties can be inferred. Initial data shows differences in heat propagation through the soil column, indicating differences in thermal conductivity and heat capacity as a result of varying soil grain size and organic matter content. This research will help to link permafrost soil physical properties to thermal properties, and increase understanding at the dynamic freeze-thaw interval.