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Freeze-thaw dynamics in synthetic permafrost soil columns with variable organic carbon content

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Cold-regions hold a pool of organic carbon that has accumulated over many thousands to millions of years and which is currently kept immobile by permafrost. However, in a warming climate, a deepening of the active layer results in the release of greenhouse gasses CO_2 and CH_4 into the atmosphere from this carbon pool. Additionally, due to the degradation of deeper permafost, soil hydraulic properties and associated groundwater flow paths are shifting rapidly as a result of which also organic carbon in deeper permafrost is being dissolved into groundwater, which can then reach the surface environment via groundwater flow. This provides an additional mechanism by which permafrost carbon can be mobilized in a warming climate, and one which is likely increasingly important for progressive surface warming.

Although the process of carbon leaching from thawing organic rich permafrost layers into the groundwater is an increasingly important part of the carbon cycle of cold-regions, it is notoriously difficult to measure in situ or incorporate into numerical model assessments due to the highly heterogeneous properties of the permafrost, and lack of process knowledge. In particular, the crucial understanding of the influence of different soil physical properties such as soil grain size and organic matter content on permafrost thawing processes is missing, as well the precise release mechanisms of organic matter into pore waters in thawing soils.

This study employs lab soil column experiments to investigate the interplay between soil physical properties and thawing dynamics of permafrost. One meter high soil columns are frozen to create controlled permafrost conditions. A range of sand grain sizes (0.1 to 0.8mm) and organic matter contents (1 to 10 wt%) representative for sedimentary permafrost are used. The column is thermally insulated on the sides and top, exposing only one face to ambient temperature in the climate chamber. In this way one-dimensional heat flow conditions are created. So far, the columns are equipped with arrays of temperature sensors. Experiments consist of a cycle of freezing and thawing. Our initial data and analysis illustrate how a fast evolving thawing front develops through the frozen soil column including the effects of latent heat at the thawing front. Numerical modeling allows to infer the soil thermal properties relevant to model the permafrost thawing process.