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A new method using evaporation for high-resolution measurements of soil thermal conductivity at changing water contents

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The thermal conductivity of soils is a key parameter to know if their use as heat source or sink is planned. It is required to calculate the efficiency of ground-source heat pump systems in combination with soil heat exchangers. Apart from geothermal energy, soil thermal conductivity is essential to estimate the ampacity for buried power cables.
The effective thermal conductivity of saturated and unsaturated soils, as a function of water transport, water vapour transport and heat conduction, mainly depends on the soil water content, its bulk density and texture.

The major objectives of this study are (i) to describe the thermal conductivity of soil samples with a non-steady state measurement at changing water contents and for different bulk densities. Based on that it is (ii) tested if available soil thermal conductivity models are able to describe the measured data for the whole range of water contents.

The new method allows a continuous measurement of thermal conductivity for soil from full water saturation to air-dryness. Thermal conductivity is measured with a thermal needle probe in predefined time intervals while the change of water content is controlled by evaporation. To relate the measured thermal conductivity to the current volumetric water content, the decrease in weight of the sample, due to evaporation, is logged with a lab scale.

Soil texture of the 11 soil substrates tested in this study range between coarse sand and silty clay. To evaluate the impact of the bulk density on heat transport processes, thermal conductivity at 20°C was measured at 1.5g/cm^3; 1.7g/cm^3 and 1.9g/cm^3 for each soil substrate.

The results correspond well to literature values used to describe heat transport in soils. Due to the high-resolution and non-destructive measurements, the specific effects of the soil texture and bulk density on thermal conductivity could be proved.
Decreasing water contents resulted in a non-linear decline of the thermal conductivity for all samples. Especially for coarse textured soils a rapid decrease of the thermal conductivity was observed, when the volumetric water content drops under a critical level.
Higher bulk densities increased the heat transport parameters for soil samples with the same texture. This effect becomes significant at high water saturations.

The method used in this study allows easy to use non-steady state measurements of the soil thermal conductivity with a high data resolution and for continuously decreasing water contents.
In further studies these measured data will be used to enhance existing pedotransfer functions and models and improve the prediction of soil thermal properties for application-oriented requirements.