The determination of the thermal conductivity of sands under varying density, moisture and drainage/wetting conditions

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Abstract. Soil thermal properties are required to conduct analysis and modeling associated with numerous agricultural, hydrological and industrial applications. In addition to characterizing the soil's physical and hydraulic properties, knowledge of the soil's thermal properties at finer spatial resolutions than what is needed in traditional soil physics applications is necessary for the analysis of heat and moisture flow in soils in the vicinity of a buried object in the shallow subsurface affected by the land/atmospheric boundary conditions. A clear understanding on how variations in water content, bulk density and soil wetting conditions affect the soil's thermal behavior is needed for the accurate detection of buried objects such as landmines, however, very few experimental data showing the effects of these variations are available. In this study, the effect of bulk density, soil moisture and soil hysteretic behavior on the thermal conductivity of some sandy soils was investigated. For this experimental investigation, a Tempe cell was modified to have a network of sampling ports, continuously monitoring water saturation, capillary pressure, temperature and soil thermal properties using a soil moisture sensor (Decagon Devices Inc., EC-5), tensiometer, temperature probe (Decagon Devices Inc., EC-T) and heat pulse probe (Decagon Devices Inc., customized KD-2 Pro), respectively. The water table was established at mid elevation of the cell and then lowered slowly, simulating the drainage cycle. The water table was then raised slowly to the original elevation and subsequently lowered again to establish the wetting and secondary drainage cycles. After liquid water drainage ceased, evaporation was induced at the surface to remove soil moisture from the sample to obtain thermal conductivity data below the residual saturation where it is expected to drop abruptly. For the test soils studied, thermal conductivity increased with increasing soil density and moisture content while thermal conductivity values were similar for soil drying/wetting behavior. Thermal properties measured in this study were then compared with independent estimates made using empirical models from literature. These soils will be used in a proposed set of experiments in intermediate scale test tanks to obtain data to validate methods and modeling tools used for landmine detection.

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