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Soil moisture estimation by Passive Distributed Temperature Sensing (DTS) using data assimilation

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Soil moisture is a key parameter for hydrology and climate processes modeling. However, the gap between footprint and point scale measurements limits not only the model performance but also the utilization of satellite soil moisture products. DTS (distributed temperature sensing) is a newly developed technique for measuring environmental temperature with high resolutions (spatial < 1m and temporal < 1 min), over cables kilometers in length. Soil with different moisture will present a different thermal diffusivity at a given net radiation. The thermal response of a soil column to incident net radiation depends on the soil's thermal properties, which in turn depends on the soil moisture content of the soil. Previous studies indicated that soil moisture information could be obtained from Passive DTS, where the soil temperature profile is measured with DTS. They also highlighted the challenges in retrieving soil moisture from passive DTS, notably the influence of uncertain cable depth and the non-uniqueness of the relationship between thermal conductivity and soil moisture.
This study uses a combination of synthetic data, and real observations to compare three techniques to retrieve soil moisture from soil temperature profile information such as that obtained using DTS. We will demonstrate that both a dual state-parameter estimation (data assimilation) approach as well as an "inversion" approach can yield reasonable estimates of soil moisture. We will also show that including knowledge on the vertical profile in thermal properties improves estimation of both thermal properties and soil moisture. The accuracy of the temperature observations themselves also influences the RMSE in soil moisture and thermal properties. Cable depth could be estimated by either data assimilation or using the amplitudes of the daily temperature cycle, and the accuracy of the cable depth estimate is also determined by the temperature observation error.