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SoilDTS: Estimating soil moisture from passive Distributed Temperature Sensing

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SoilDTS is an advanced technique for monitoring soil moisture and temperature in the vadose zone based on distributed temperature sensing (DTS). Using fibre-optic cables, temperatures are measured with a horizontal resolution of 1-2m over cables up to 10km in length. Due to the dependence of soil thermal properties on soil moisture, observations of temperature dynamics in the thermally active zone can yield information about soil moisture content. By providing high-resolution observations over a large area, this innovative technique can be used to bridge the gap in space-time resolution between observations of soil moisture from remote-sensing data (e.g. SMOS) and from conventional in-situ methods. It also allows us to investigate how soil moisture and temperature control hydrological fluxes at different spatial and temporal scales.

We recently demonstrated the feasibility of using SoilDTS to estimate soil moisture using an inversion approach. That study also highlighted a number of theoretical and practical challenges. Here, we will present more recent research in which we address each of these challenges.

The main practical problems were uncertainty in the cable depths as well as disturbance of the soil. Both of these problems have been addressed by revising the plough design to ensure a smoother installation with minimal soil disturbance.

Many of the theoretical problems can be dealt with by using a data assimilation approach in which observations are merged, in an optimal way, with a model. A dual state-parameter ensemble Kalman filter was used to estimate temperature as a state and soil moisture as a parameter of a coupled heat and moisture model. Using the ensemble Kalman filter means that the model is only run in the forward direction, so we can avoid having to infer soil moisture from thermal diffusivity. The EnKF has a modular structure and the model adjoint is not needed. Therefore, it is easy to include additional terms (e.g. advection, source/sink terms) in the soil/heat model. Use of an ensemble method also allows us to include information on uncertainty in the model parameters and forcing data. Data assimilation results from data collected at Monster (the Netherlands) in 2008 will be presented. We will conclude with an outline of additional planned SoilDTS installations.