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Using Actively Heated Fibre Optics (AHFO) to determine soil thermal conductivity and soil moisture content at high spatial and temporal resolution

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Optical fibre distributed temperature sensing (DTS) is increasingly used in environmental monitoring and for subsurface characterisation, e.g. to obtain precise measurements of soil temperature at high spatio-temporal resolution, over several kilometres of optical fibre cable. When combined with active heating of metal elements embedded in the optical fibre cable (active-DTS), the temperature response of the soil to heating provides valuable information from which other important soil parameters, such as thermal conductivity and soil moisture content, can be inferred. In this presentation, we report the development of an Actively Heated Fibre Optics (AHFO) method for the characterisation of soil thermal conductivity and soil moisture dynamics at high temporal and spatial resolutions at a vegetated hillslope site in central England.

The study site is located within a juvenile forest adjacent to the Birmingham Institute of Forest Research (BIFoR) experimental site. It is instrumented with three loops of a 500m hybrid-optical cable installed at 10cm, 25cm and 40cm depths. Active DTS surveys were undertaken in June and October 2016, collecting soil temperature data at 0.25m intervals along the cable, prior to, during and after the 900s heating phase. Soil thermal conductivity and soil moisture were determined according to Ciocca et al. 2012, applied to both the cooling and the heating phase. Independent measurements of soil thermal conductivity and soil moisture content were collected using thermal needle probes, calibrated capacitance-based probes and laboratory methods.

Results from both the active DTS survey and independent in-situ and laboratory measurements will be presented, including the observed relationship between thermal conductivity and moisture content at the study site and how it compares against theoretical curves used by the AHFO methods. The spatial variability of soil thermal conductivity and soil moisture content, as observed using the different methods, will be shown and an outlook will be provided of how the AHFO method can benefit soil sciences, ground source heat pump applications and groundwater recharge estimations.

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Ciocca F., Lunati I., van de Giesen N., and Parlange M.B. 2012. Heated optical fiber for distributed soil-moisture measurements: A lysimeter experiment. Vadose Zone J. 11. doi:10.2136/vzj2011.0177