Distributed intelligent Heat Pulse Sensor (DiHPS)

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DiHPS: a Distributed intelligent Heat Pulse Sensor for the quantification of subsurface heat and water fluxes. Our mission is to develop a novel, distributed soil moisture and temperature monitoring network that will go beyond the currently available monitoring technologies, often based on data collection at isolated points in time and space. DiHPS will provide real-time, high-resolution spatially distributed data that enable effective and responsive decision making to deal with rapidly increasing demands in a changing climate. DiHPS will be based on combining Fiber Optics Distributed Temperature Sensor (FO-DTS) technology with distributed heat pulses sent along the fiber optics cable. The so-called Active DTS (A-DTS) allows observing flow-related heating and cooling patterns along the actively heated cable.

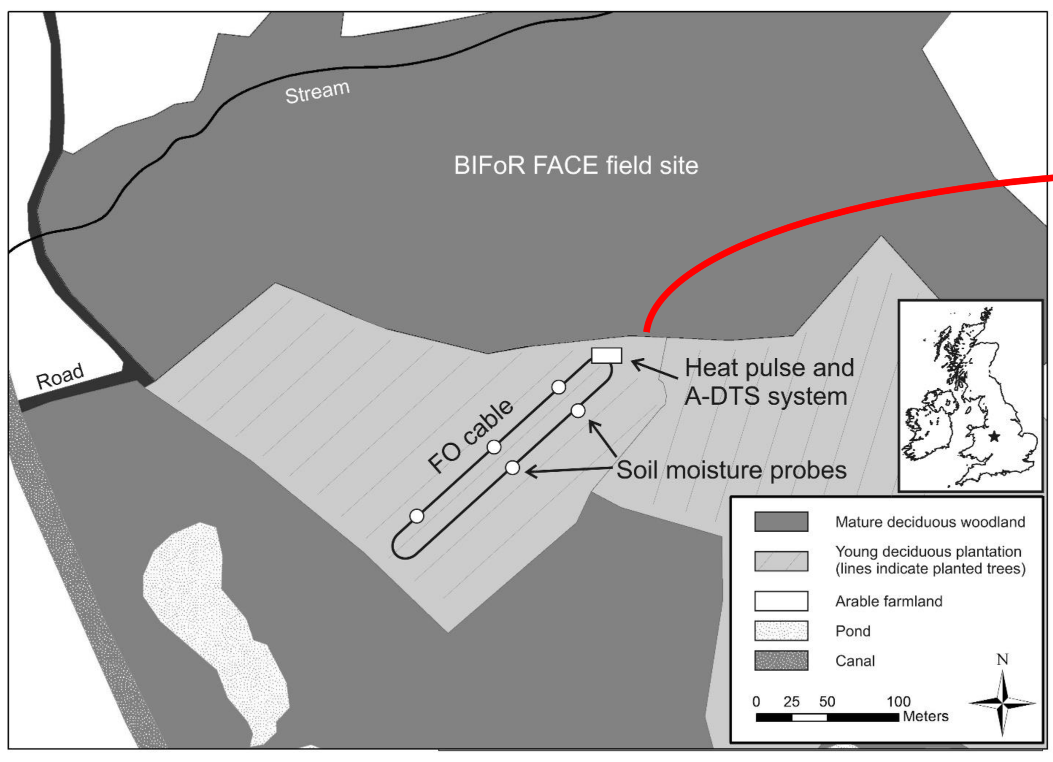
In a first stage DiHPS will focus on demonstrating its suitability to quantify parameters such as soil moisture content and thermal properties. A later stage will be instead devoted to DiHPS application in heat and water flux assessment.

Three ways to succeed

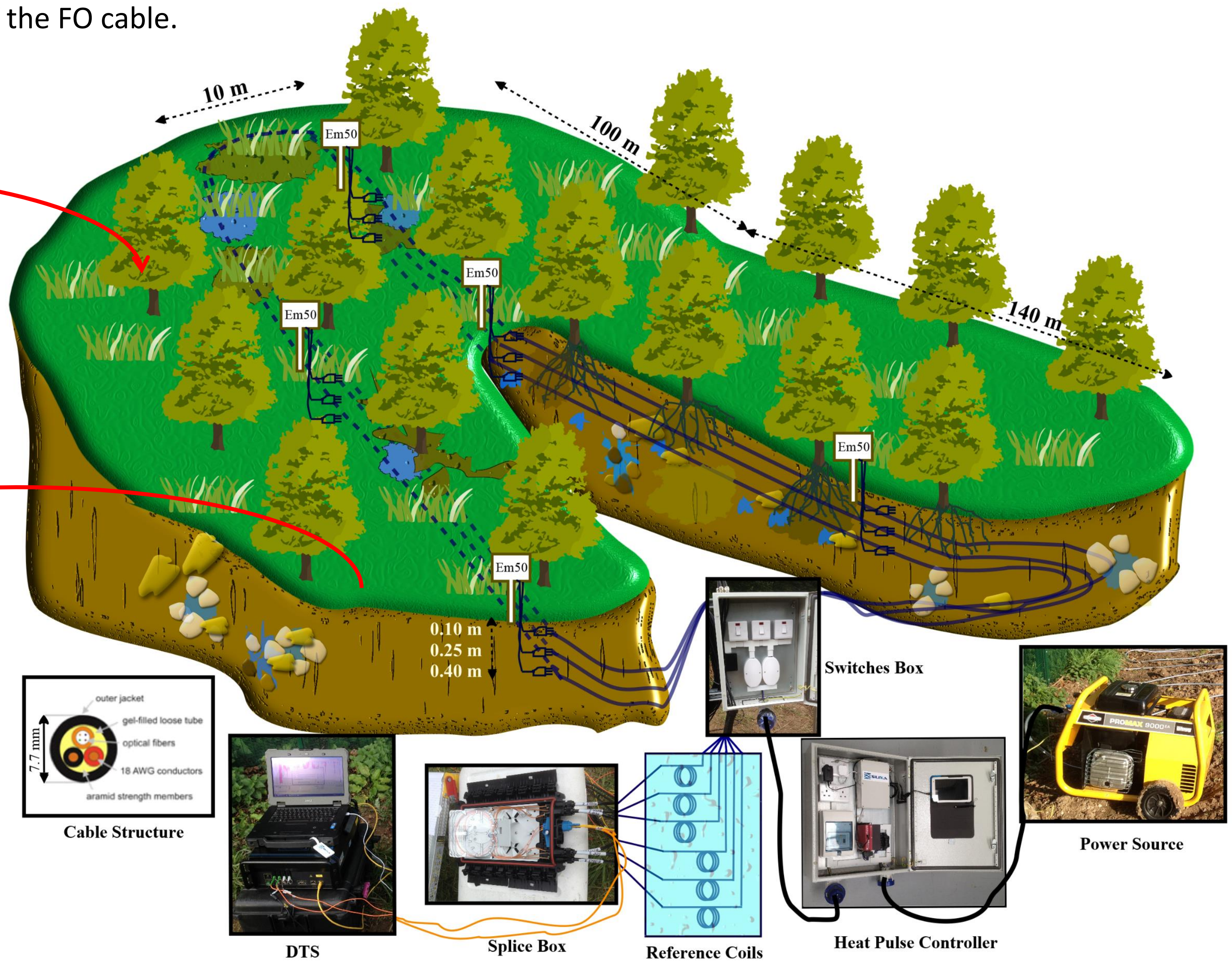
1. Increase spatial resolution of soil moisture content and thermal properties measurements to sub-centimetre scale using vertical A-DTS profilers (in preparation)
2. **Investigate the complexity introduced by real scenarios: the Mill Haft deployment (in progress)**
3. Achieve real-time and "intelligent" (autonomous) system operation. Internal (e.g. soil temperature based) and/or external (e.g. atmospheric conditions based) triggers able to automatically control initiation/cessation of the DTS active mode (in preparation)

Mill Haft deployment

SITE: FO cable buried (using a soil trencher) in a 3 overlapped loops configuration along a hillslope on the south side of the FACE field site. Heat pulse and A-DTS system deployed at the bottom of the hillslope.



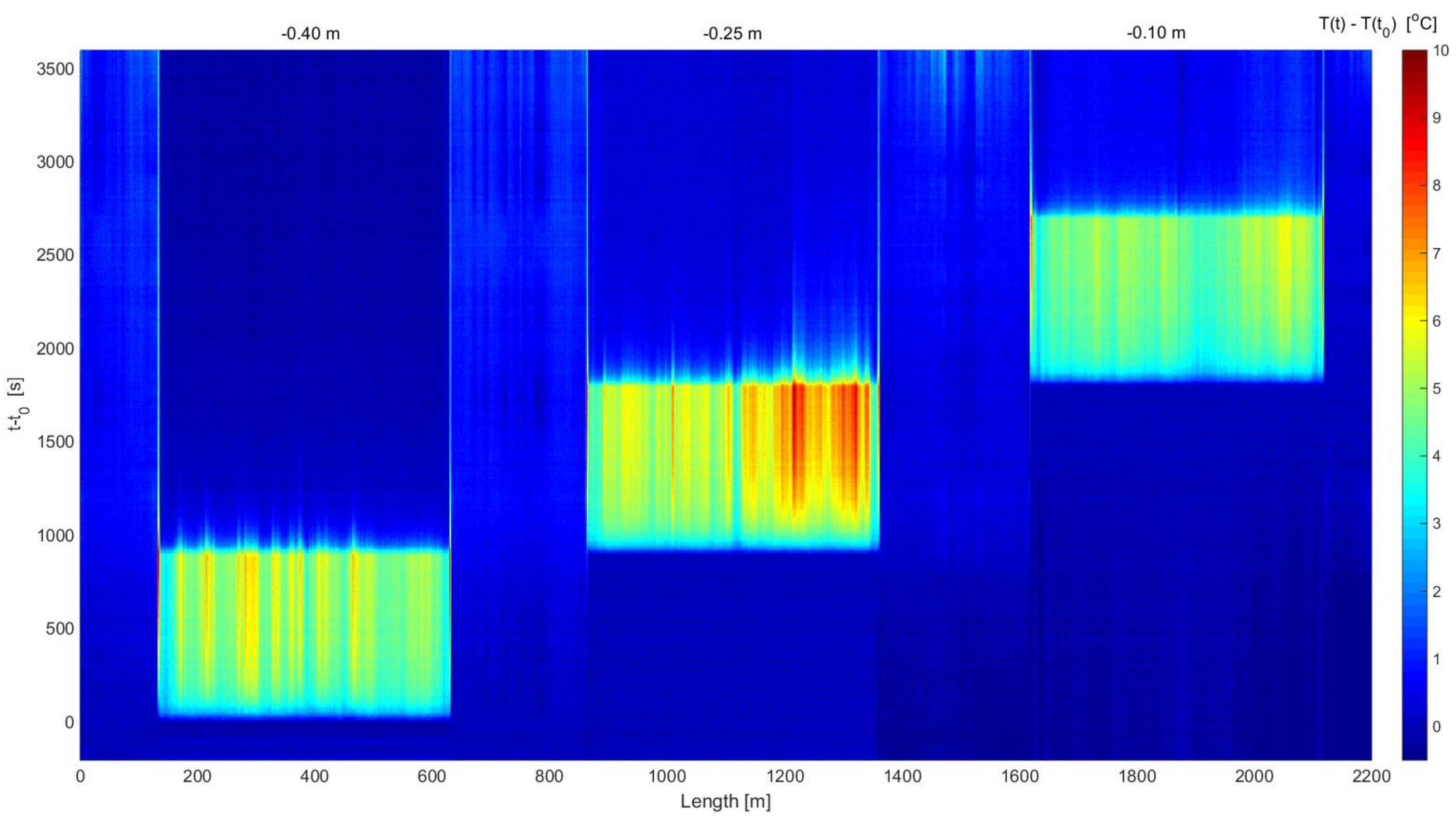
EQUIPMENT: A-DTS monitoring equipment and cross sectional view of the three FO cables at different depths. Soil-moisture point probes are buried in 5 locations (Em50) at the same depths of the FO cable.



MEASUREMENTS

Date	Heating Duration	Power Rate	Heating Sequence	DTS configuration	DTS sampling	DTS time interval
[dd/mm/yy]	[s]	[W/m]			[m]	[s]
28/10/15	900	3	Bot - Mid - Top	Double-Ended	0.25	20
09/06/16	900	3	Bot - Mid - Top	Double-Ended	0.25	10
09/06/16	900	4.8	Bot - Mid - Top	Double-Ended	0.25	10

HEATING RESULTS



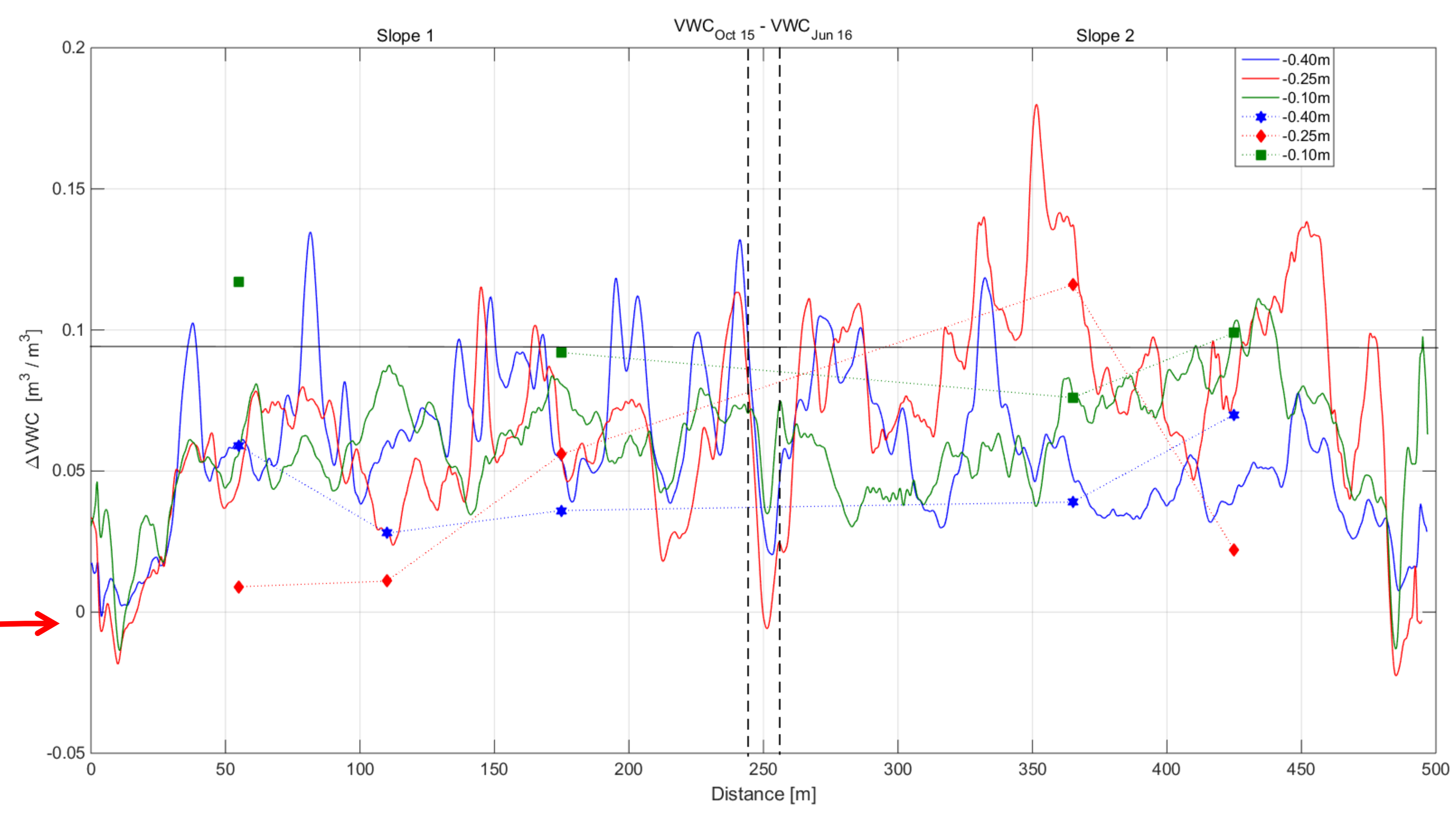
Thermal map of heat pulse from June 2016. Heating starts at t_0 = 0 s (bot), 900 s (mid), 1800 s (top). $T(t_0)$ are 200 seconds averaged T before the respective t_0.

ANALYSIS

$$T_{cum}(x) = \int_{t_0}^{t_H} \Delta T(x) \cdot dt$$

Integral approach by *Sayde et al, WRR, 2010* is applied. Cumulative temperature T_{cum} is a robust and strongly soil moisture dependent variable

SOIL MOISTURE VARIATIONS: Linearly normalized delta of T_{cum} (solid lines) and soil moisture point probes between October 2015 (wetter soil) and June 2016 (drier soil).



PRELIMINARY CONCLUSIONS: 1) A-DTS system working correctly; clear distributed temperature patterns 2) General soil drying between October 15 and June 16 captured; qualitative agreement with soil moisture point probes at almost all locations. 3) Necessary more soil moisture variability and better normalization.

OUTLOOK: *a) Start tests on vertical profilers in Silixa's premises to investigate sub-centimetre vertical resolution b) Perform more measurements in Mill Haft to improve empirical relation between T_{cum} and soil moisture; include thermal conductivity measurements*

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