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Assessing the efficiency and detection limits of Fiber-Optic Distributed Temperature Sensing in environmental applications

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The use of Fiber-optic Distributed Temperature Sensing (FO-DTS) for the temporal and spatial measurement of transient/discrete changes in temperature continuously has seen a substantial increase in the environmental and hydrological sector. Popular hydrological applications of FO-DTS involve the monitoring of stream or streambed temperature dynamics, groundwater inflow patterns and stream/groundwater interaction.

The temperature and sampling resolution of currently available FO-DTS instruments typically vary between 1-2m and 0.01ºC with the most advanced systems providing spatial measurement resolutions of 0.25m. Temporal resolutions vary upwards from fractions of a minute (when a standard communication fiber-optic cable is used) for cable lengths of up to 30,000 m.

FO-DTS technology has been applied to the measurement of both, continuous temperature changes over larger scales as well as discrete hot- or cold spots at small scales. For accurately measuring temperatures by FO-DTS, it is important to account for the aforementioned limitations during the monitoring set up. In order to ensure that the actual signal size and location are accurately reflected by the FO-DTS measurements, it is essential to prove that the spatial extent of the investigated signal variation can be captured by the DTS methodology. If detection limits and uncertainties are not considered thoroughly during the monitoring set up, the resulting errors can fundamentally affect the interpretation of the results. As such, it is essential that the spatial dependency of FO-DTS signal accuracy is understood (i.e. its ability to predict the actual magnitude temperature as well as the relative spatial location of the signal) in order to provide data which are reliable and comparable with other methods for temperature monitoring.

This study presents an analysis of FO-DTS measurement precision based on the prediction of signal strength and location in relation to signal size and measurement set up. Using a DTS instrument with a spatial sampling resolution of 2m and a standard fibre-optic cable set up, measurements of 'warmer' (40±4oC) and colder (0±3oC) water bath temperatures were made in comparison to ambient 25oC. Spatial measurement increments ranged between 0.25m and 15m and the results investigated for accuracy in their prediction of magnitude (temperature) and location.

The results showed that signals of the size of up to 3-times of the sampling interval would still be captured with substantial uncertainties in the signal magnitude (i.e. temperature). Although FO-DTS technology, and in particular spatial resolution of measurements, are fast advancing, the results prove that care is needed when interpreting discrete signal changes with spatial extents close to the sampling resolution. Ultimately, any limitations in the instrument precision and in the monitoring set up may limit the applicability of this exciting technology for precisely predicting small signal changes at small scales.