



## A new low-cost approach to 3-D water temperature monitoring

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Water temperature is one of the key factors controlling aquatic ecosystems and influencing physical, chemical and biological processes. Detailed observations of spatial and temporal patterns in water temperature are important for assessing e.g. variations in thermal refugia, impacts of climate change and for developing appropriate management strategies. Freshwater temperatures are still mostly analysed based on single point measurements, but these do not reflect the spatial thermal variability within waterbodies (i.e. stream and lake) and therefore could lack information on thermal refugia. 2-D images of freshwater temperature in varying spatial resolution are increasingly obtained by space- and airborne methods such as UAV (unmanned aircraft vehicles). While these UAV methods offer the necessary spatial resolution at the surface, they require in situ measurements to obtain absolute temperature values and don't provide information on vertical thermal variability. Approaches that bridge this gap do exist (e.g. fibreoptic cables), but high demand on resources and high costs limit widespread use.

The aim of this work was to develop a low-cost, custom-build, fully flexible 3-D temperature sensor system that can be used for calibration and validation of thermal UAV observations, but also adds information on water temperature with depth. The design of our floating sensor system (with a maximum of 72 sensors) offers high flexibility in horizontal/vertical spacing and logging time intervals (ms to h). Here we present the first results of our prototype, which was calibrated using Solinst Leveloggers (accuracy  $\pm 0.05^{\circ}\text{C}$ ) and tested under various ambient conditions, both in the laboratory and in a lab-in-field experiment in a relatively shallow lake (maximum measurement depth of 1.50 m) in NE Scotland. We also evaluated the use of this system with UAV imagery at the lake.

The results show a quick response of the individual sensors to temperature changes and indicate suitability of the system for validating and calibrating thermal UAV images. For a set-up with 12 vertical arrays (6 sensors at different depths for each array) and arranged as a grid, preliminary data indicated the value for a 3-D approach as not all thermal patterns at depth were captured by surface measurements. Next, the transferability of the sensor system to a stream will be tested and applied to a stream water management case. Together with UAV thermal imagery, the new sensor system could have the potential for a wide range of research and management applications (e.g. thermal habitats, groundwater upwelling, infiltration of cooling water).