



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

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Background

- Water temperature is important for aquatic ecosystems
- 2. Single point measurements do not reflect on spatial thermal variability
- Space- and airborne methods such as UAV (unmanned aerial vehicles) require in situ measurements to obtain absolute temperature values and only provide 2-D data information. Hence they don't provide information on vertical thermal variability





Thermal UAV survey including calibration measurements

Aim









Design

- Sensor system (Array)
- Low cost
- Real-time clock for timestamps
- Up to 84 sensors
- high flexibility in horizontal/vertical spacing
- high flexibility in logging time intervals (s to h)



Sensors

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- Maximum Accuracy Digital Temperature Sensor (MCP9808)
- Typical accuracy ±0.25°C
- User-Selectable Measurement Resolution: - +0.5°C, +0.25°C, +0.125°C, +0.0625°C



Sensor temperature accuracy according to Microchip Technology Inc.

Calibration



84 sensors have been individually calibrated in a water bath over defined temperature range (3°C - 20°C) using a high accuracy water level datalogger





Setup for calibration experiment

Calibration

Sensors are showing in general a linear response but are underestimating the temperature slightly. This needs to be addressed in calibration equations.



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Example of calibration dataset for one sensor

Calibration



As all slopes are close to 1 and are therefore negligible only the intercept needed to be addressed in the equation. This was done

individually for each sensor.

Statistics for all sensors Intercept [°C] slope Maximum 0.95 1.02 Minimum 0.14 0.95 Average 0.57 1.01 0.21 0.11 Standard deviation Coefficient of 0.36 0.11 variation

Testing



The arrays have been tested in a range of different environments.

A selection of the

collected datasets are

presented in **Data**.









Testing in garden



Testing in stream

Testing

As the arrays are easy to identify/locate in thermal UAV data they can be used to calibrate aerial data. A preview is

available here.





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Data

The lake data-set shows

significant temperature

differences with depth during daytime and

strongest diurnal

temperature variations at

the surface.



Temperature timeseries of 1 array during testing in lake



Data

The stream data-set 6.5 shows significant surface 6.0 temperature [C] temperature variations within a short timescale and generally higher 4.5 temperature readings at 4.0 the surface.



Temperature timeseries of 1 array during testing in stream

Results & Outlook

The collected datasets is used to analyse thermal variability in a Scottish lake as well as a Scottish stream. The surface array data was used to calibrate and validate simultaneously collected thermal UAV imagery. As a final step UAV and array data will be combined for a 3D-analysis of the thermal variability within both environments.





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3-D visualisation of array data in a lake in combir with UAV thermal imagery at the surface

