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Heat as a tracer to study groundwater upwelling: field data and benchmarking integrated hydrological modelling

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Introduction

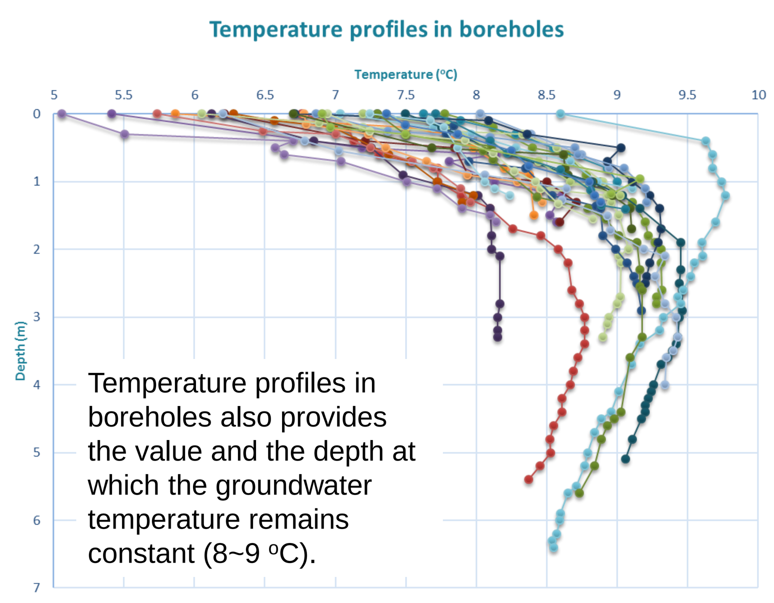
Temperature depth profiles, Fiber Optic Distributed Temperature Sensing (FO-DTS) and the use of airborne thermal imaging have the capability of using heat to recognize surface water – groundwater exchange processes. However, the uncertainty in both the field instrumentation location and the selection of heat parameters that go into models used to estimate water exchange fluxes can lead to a wide range of possible results for the same study area ([1], [2], [3]).

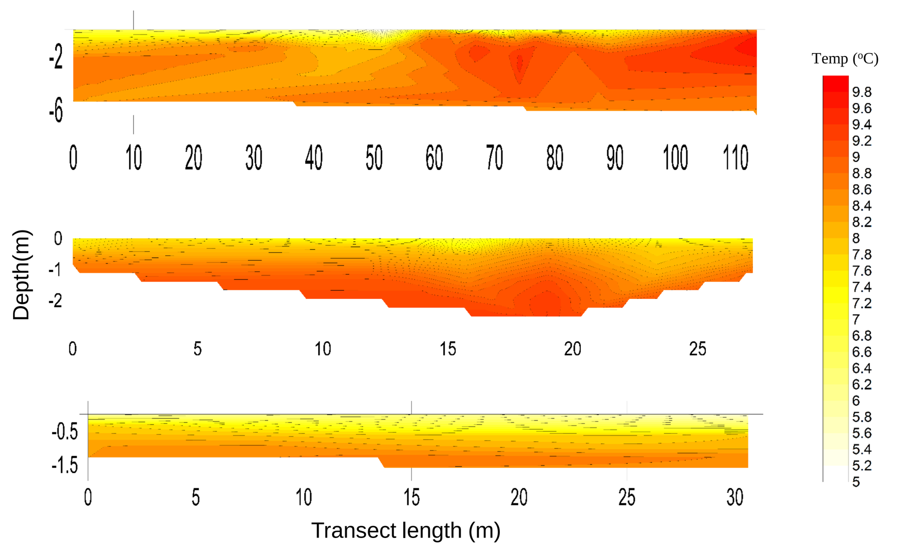
We are specifically interested in groundwater upwelling to the land surface in wetland areas and subsequent overland flow; the combination of field techniques and Integrated Surface and Subsurface Hydrological Models (ISSHM) can provide a way to study such areas at the scale of a catchment.

Objectives

- Understand surface water – groundwater interaction processes (upwelling) in stream-wetland areas.
- Define applicability of temperature profiling, DTS and airborne thermal imaging to locate water exchange areas.
- Investigate the temperature dynamics at the ground surface, its correlation with the subsurface temperature distribution and the model parameter sensitivity on such dynamics and correlations.

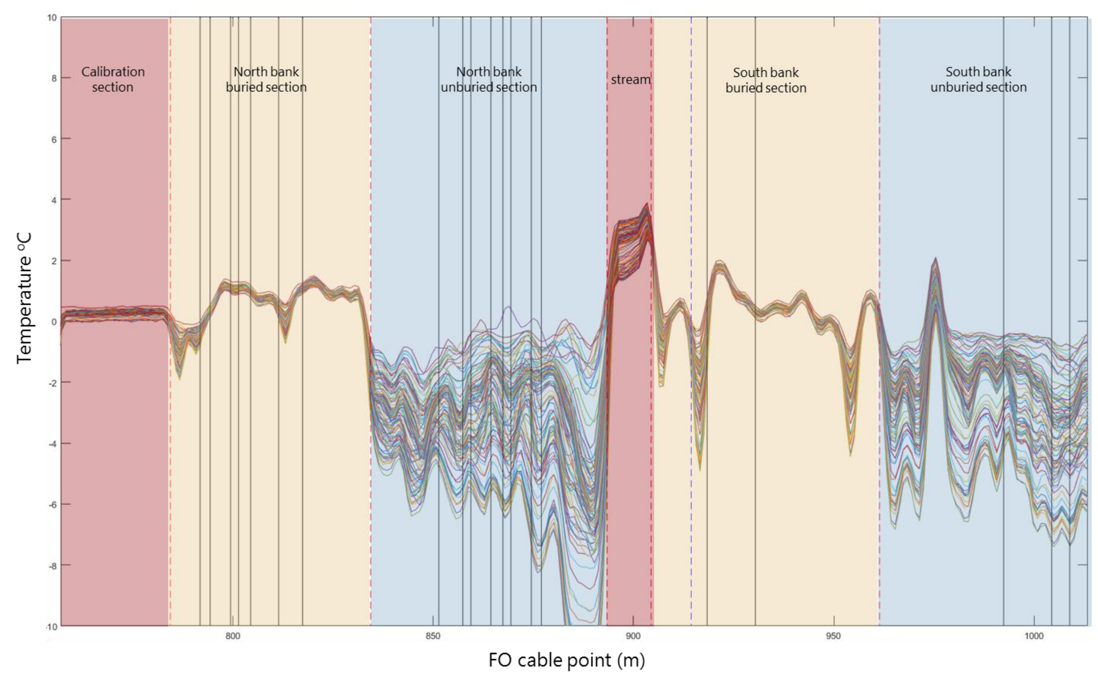
Field Data

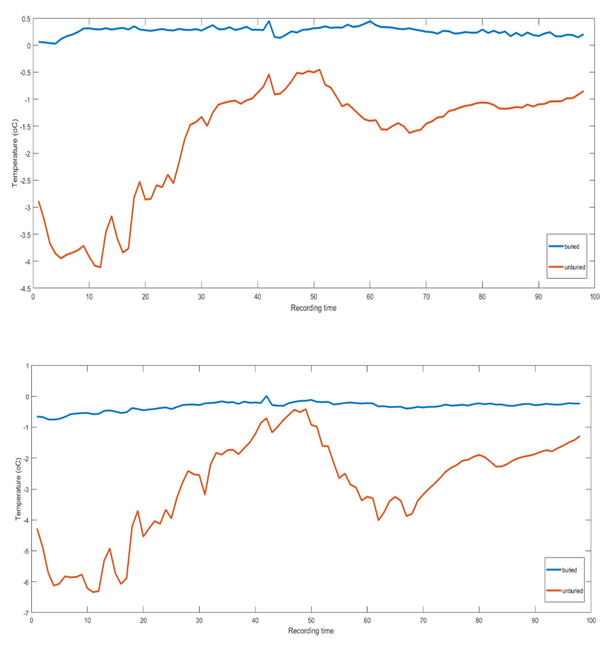




Temperature depth profiles to map groundwater temperature

- Locate potential upwelling areas
- Compare with model results





FO-DTS on land and ~20 cm in depth

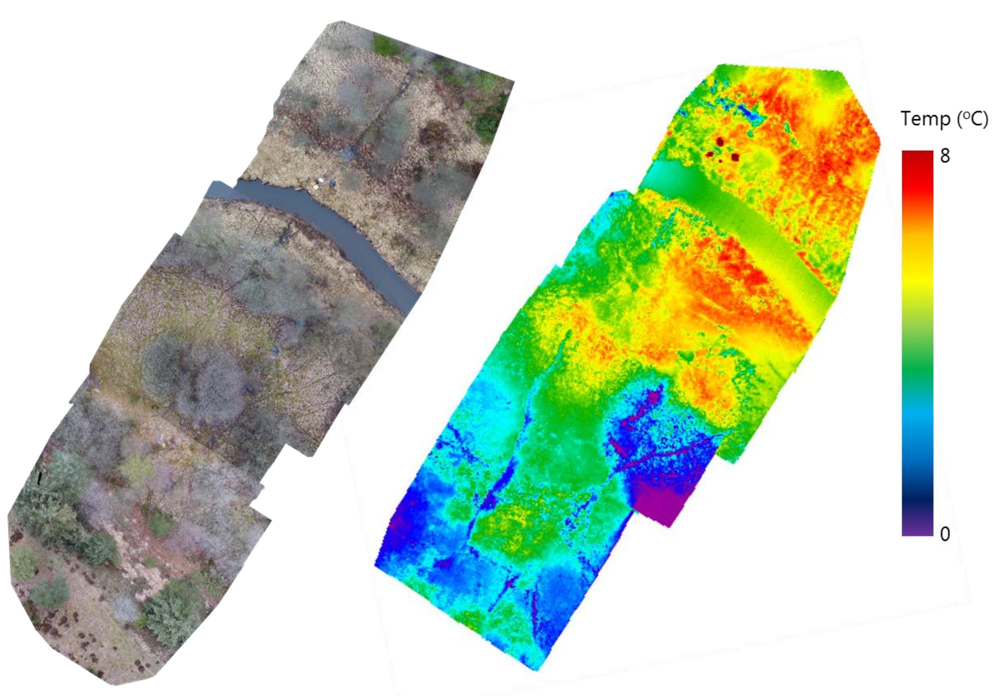
- Surface + Near-Surface temperature data
- Time series along a transect

Thermal infrared images (TIR)

- From drone flights
- Snapshot of surface temperature distribution
- Seasonal evolution of surface temperature

FO-DTS + TIR

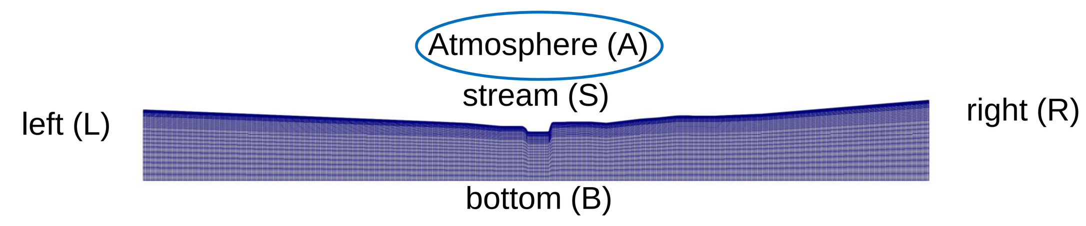
- Calibration of ISSHM
  - Quantification of groundwater upwelling fluxes



Integrated hydrological model

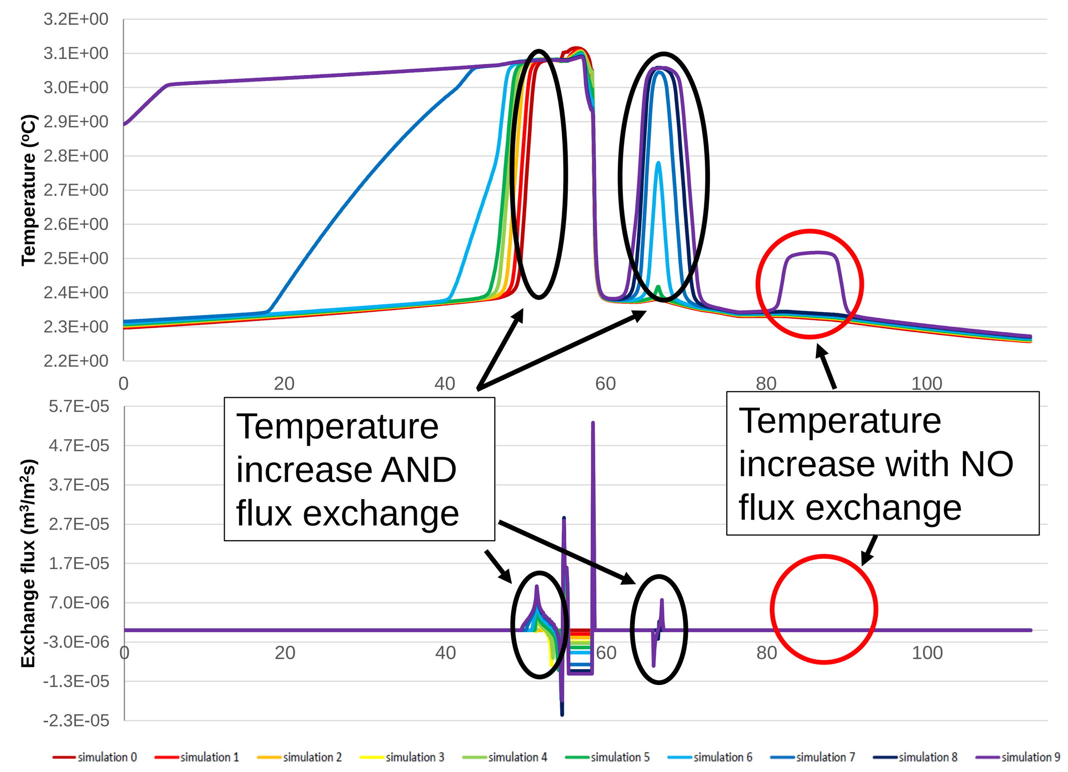
Benchmarking problem

- 2D homogeneous ISSHM
- Application of different sets of boundary conditions
- Thermal response of porous media and land surface domains



In this example:

- A conditions are fixed for all simulations
- S head constant for all simulations
- B temperature constant for all simulations
- L and R heads increasing simulation after simulation
- Simulation 0 is the base case
  - S, L and R heads have the same value.

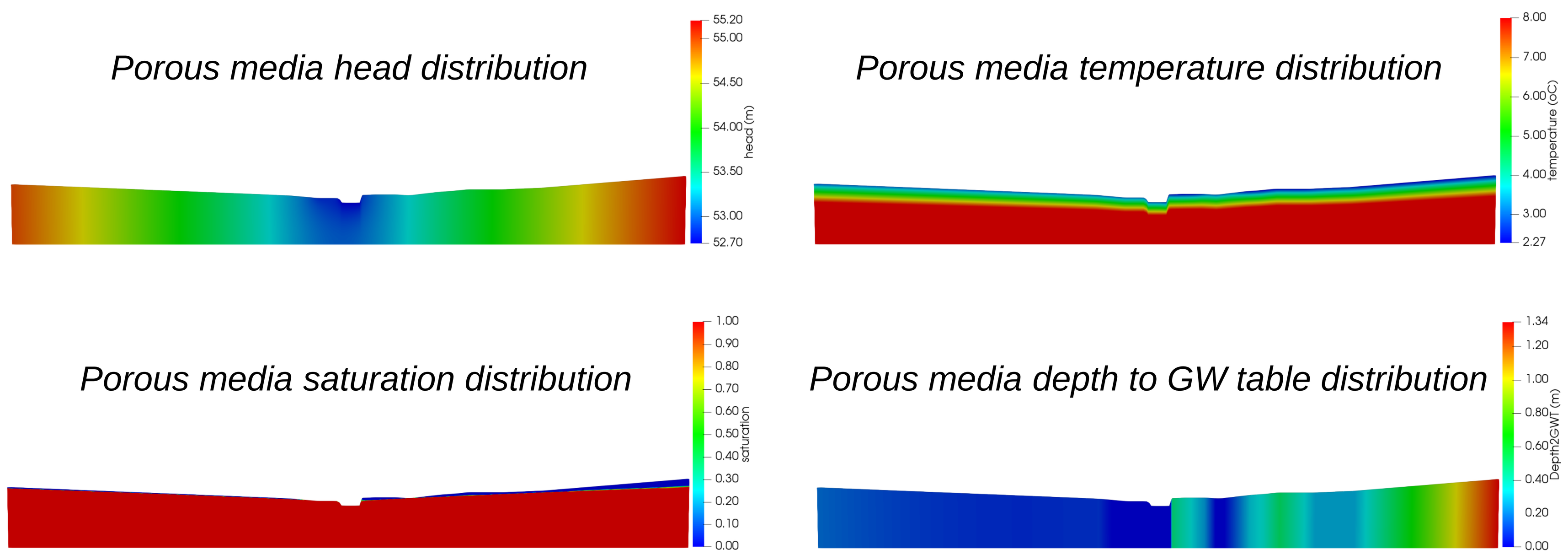


Subsurface-Surface water exchange areas

- Increase in surface temperature
- The higher L and R heads the higher the flux exchange and the temperature

"False Positive"

- No subsurface-surface water exchange but surface temperature increase
- Proximity of groundwater table to surface (Heat conduction)



Porous media results simulation 9 (Higher L and R heads)

- Saturation profile showing groundwater table – surface proximity
- Groundwater table intersecting surface: flux exchange
- Temperature profile results can be compared with field data

Conclusions

- Temperature profiles, FO-DTS and TIR provide valuable temperature distribution data from the surface and the subsurface both in time and space.
- ISSHM allows us to understand and predict under which conditions there is potential for groundwater upwelling processes and the effect of these processes on the surface and subsurface temperature distribution.
- Combination of thermal field data and ISSHM has the potential to study groundwater upwelling processes in stream valleys based on thermal imaging methods.

References

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