Session S07 – Poster 189

Modeling interactions between surface and subsurface temperature dynamics in floodplains

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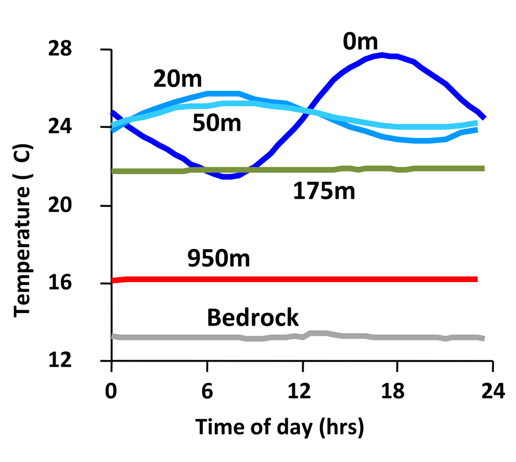
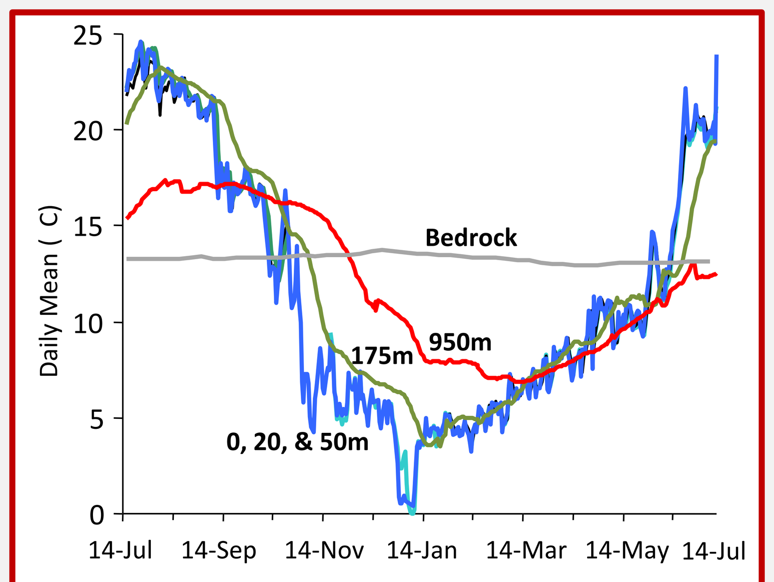
1. Objective: Add simulation of heat transport to a hydrologic model, to simulate influence of subsurface flow on water temperatures across floodplains.

Goal is to design a mechanistic model capable of simulating observed influence of different subsurface flow distances on water temperature dynamics.



Observed hourly temperature dynamics after different subsurface transport lengths during the summer



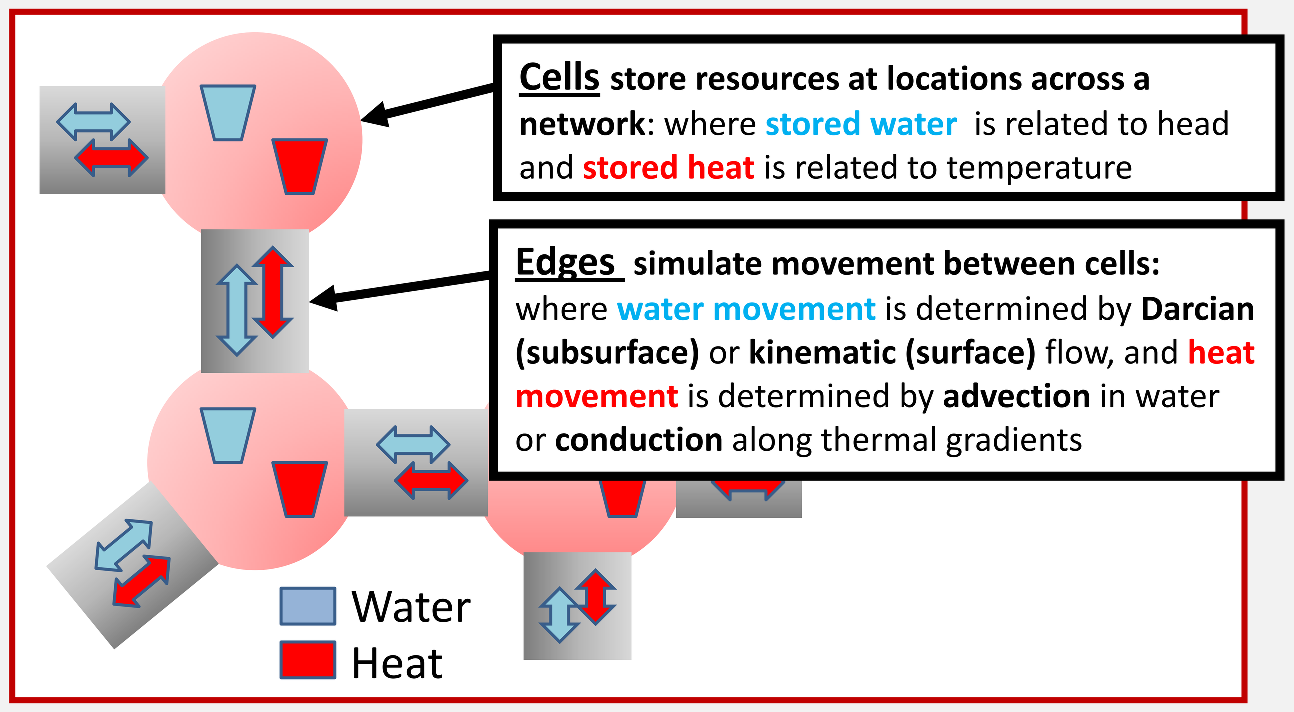
Observed seasonal temperature dynamics after different subsurface transport lengths

Observed data from: Poole, G. C., S. J. O'Daniel, K. L. Jones, W. W. Woessner, E. S. Bernhardt, A. M. Helton, J. A. Stanford, B. R. Boer, and T. J. Beechie (2008) Hydrologic spiralling: The role of multiple interactive flow paths in stream ecosystems. River Research and Applications 24: 1018-1031.

2. Approach: Network-based models

Added **fundamental processes controlling heat movement to an existing hydrologic model** built in Network Exchange Objects (NEO), an object-oriented modeling architecture for network-based systems.

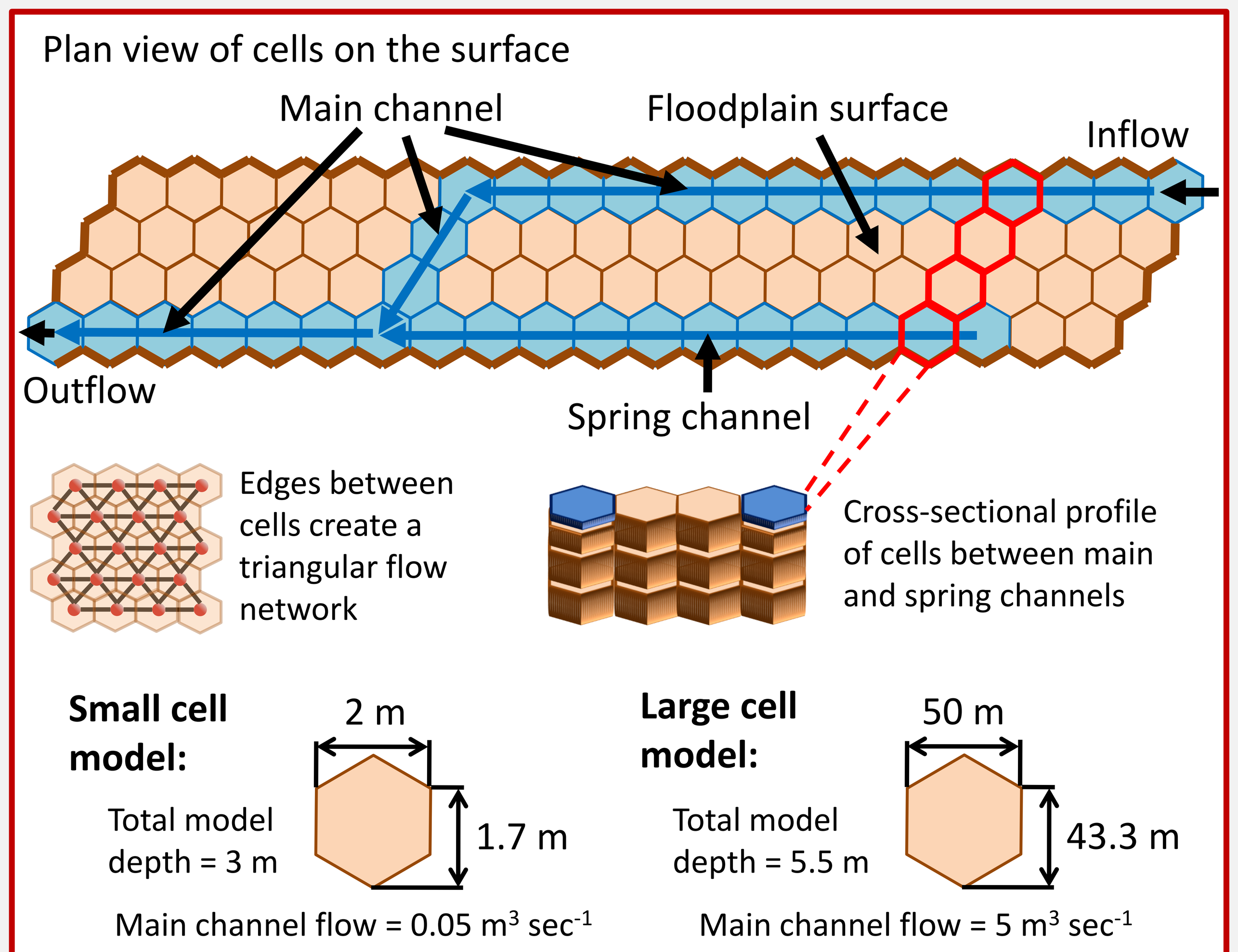
The network data structure acts as a distributed mass and energy balance, where storage is simulated in **cells** and movement is simulated across **edges**.



3. Model structure: Spring channels

Spring channels drive **stream-subsurface exchange across floodplains** and are common features of anabranched channel networks.

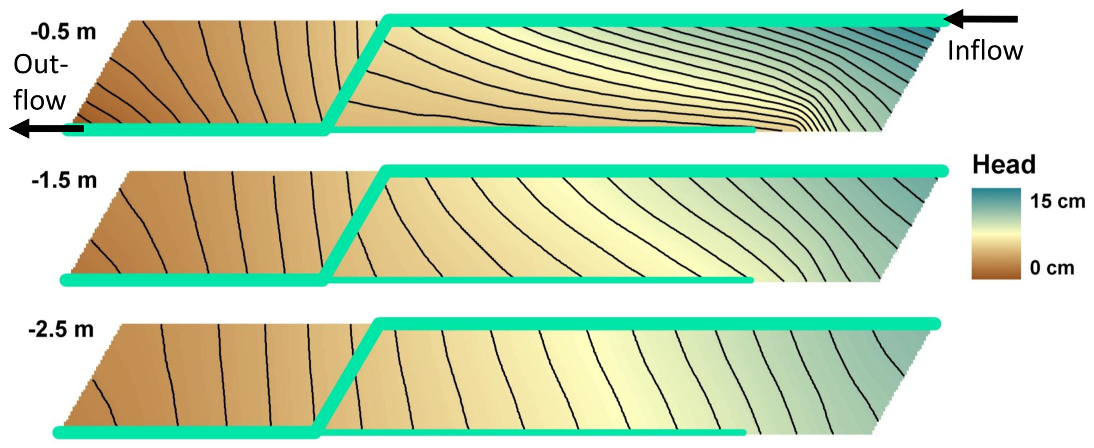
Spring channel models **of two different sizes** were built from hexagonal surface and subsurface cells.



Parameters used at both scales: horizontal hydraulic cond. = 0.008 m sec^{-1}, vertical hydraulic cond. = 0.0008 m sec^{-1}, porosity of substrate = 0.2, specific heat of substrate = 0.84 kJ kg^{-1} °C^{-1}, all external boundaries are no-flow except main channel inflow and outflow

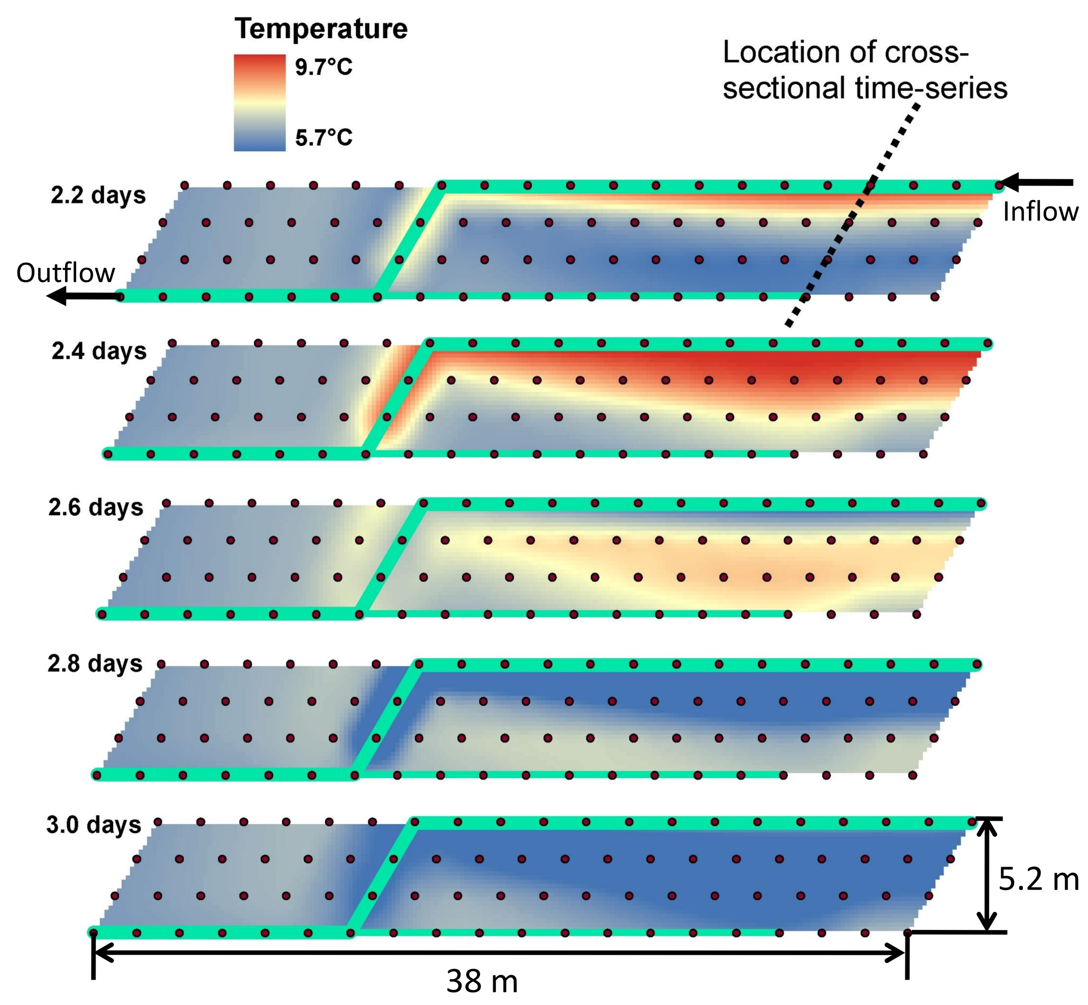
4. Small cell model: Simulation of temperature dynamics over short subsurface travel distances

Hydraulic head at 3 depths in substrate (each layer of cells):
Hydraulic gradients in shallower substrate tend to move water from the main channel to the spring channel.
Gradients in deeper substrate tend to move water down-valley.

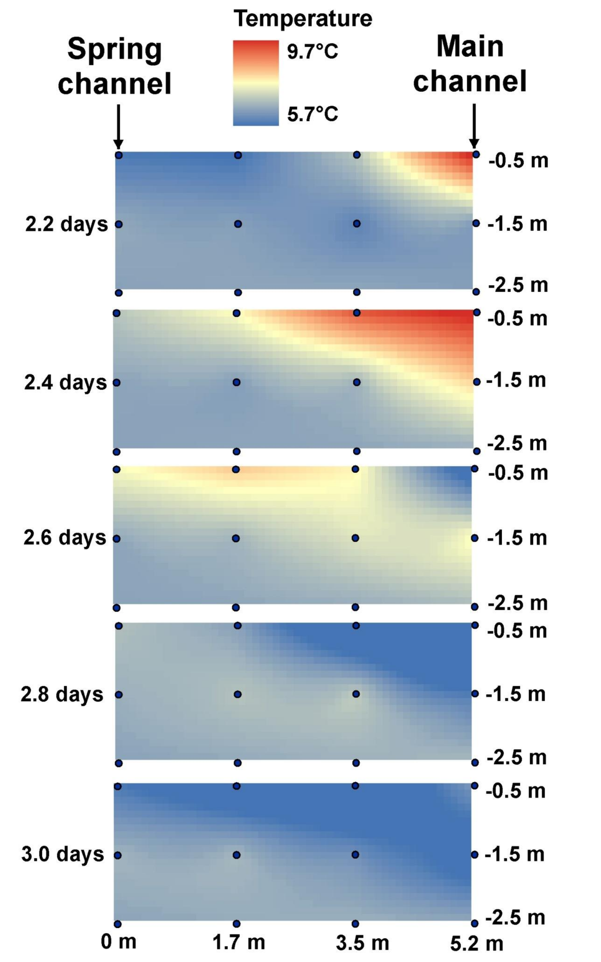


Temperature dynamics in the subsurface driven by temperature dynamics in the main channel inflow (simulated as a diel period sine wave):
Pulses of warmer and cooler water are transported across the floodplain, from the main channel to the spring channel.
While in transport, pulses of warmer water are cooled and pulses of cooler water are warmed by mixing with deeper subsurface water.

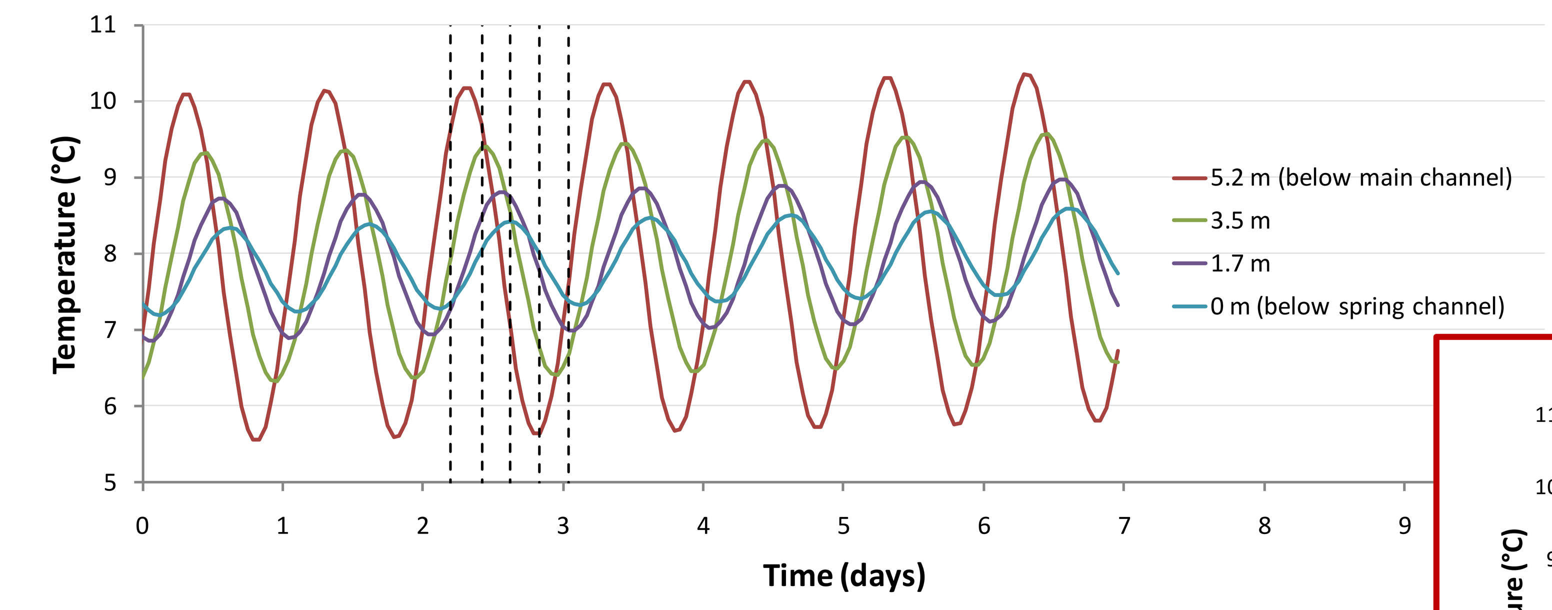
Plan views of subsurface temperatures in top layer through time



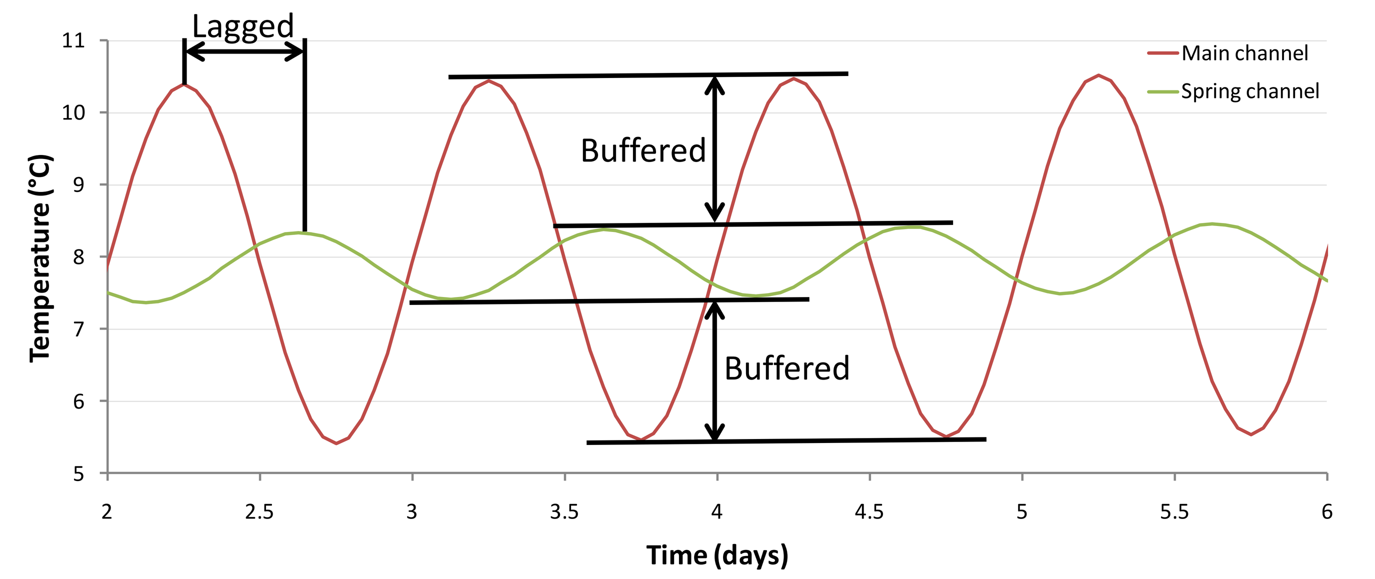
Cross-sectional profiles of subsurface temperatures through time



Subsurface water temperatures in top layer, along cross-section indicated above



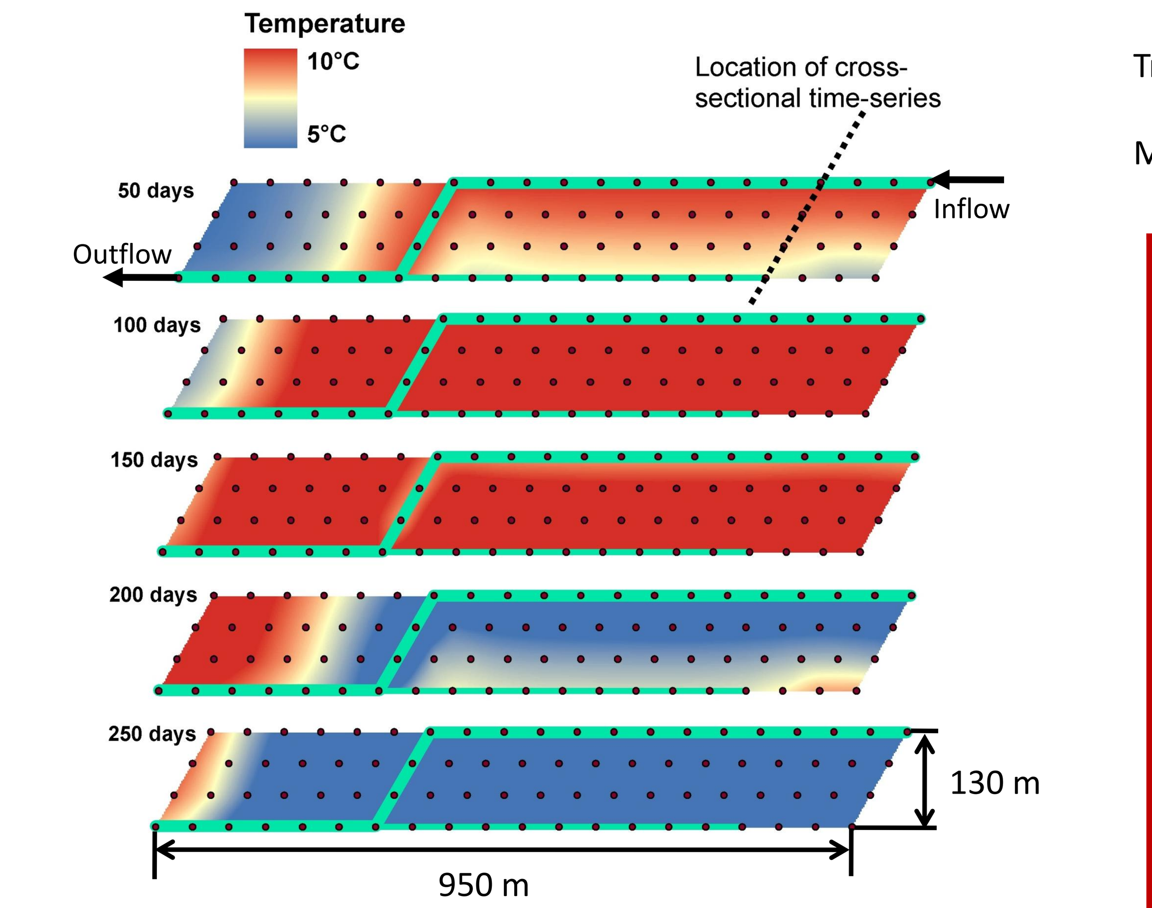
Temperature time-series across the floodplain:
Dashed lines represent the snapshots in time pictured in the plan and profile series above.
Mixing of main channel water and longer-residence-time, deeper subsurface water results in delay and attenuation of the main channel temperature signal in transport across the floodplain.



Differences between main and spring channel temperatures:
Subsurface transport times cause a lag between the main and spring channel diel temperature signals.
Mixing with deeper subsurface water buffers the amplitude of the main channel signal before arrival in the spring channel.

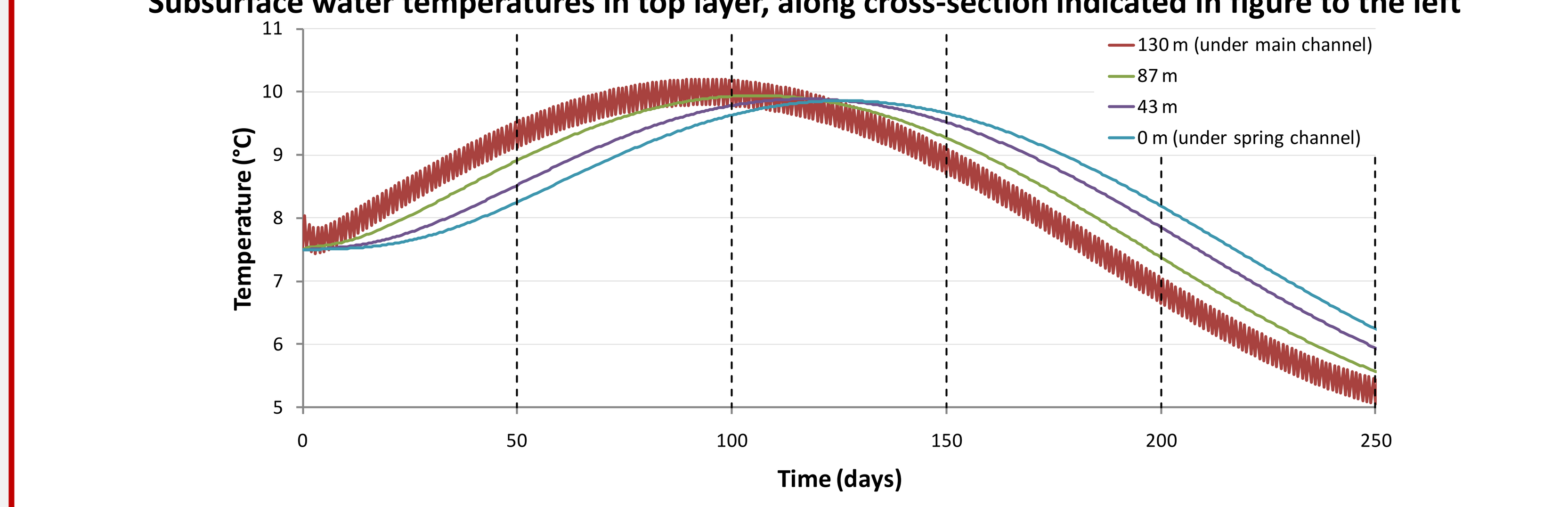
5. Large cell model: Simulation of temperature dynamics over long subsurface travel distances

Plan views of subsurface temperatures in top layer through time

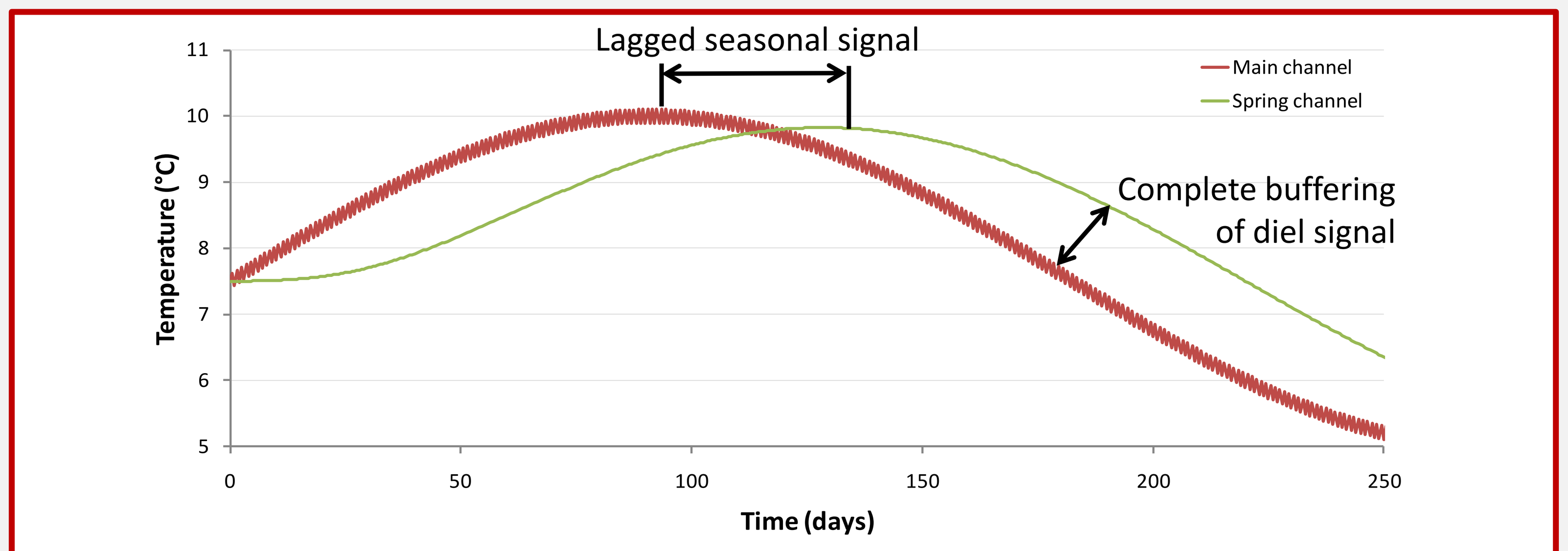


Temperature dynamics in the subsurface driven by temperature dynamics in the main channel inflow (simulated as a diel period sine wave on top of an annual period sine wave):
Travel times are slower relative to the seasonal change in temperature, resulting in more complete heating and cooling of the floodplain than the small cell model.
More complete heating and cooling results in less spatial variability in temperature between the main and spring channels, relative to the total annual variability in temperature.

Subsurface water temperatures in top layer, along cross-section indicated in figure to the left



Diel variability is quickly attenuated in the large cell model, but there is little attenuation of the annual variability due to more complete heating and cooling of the floodplain.



Differences between main and spring channel temperatures:
Diel temperature signals in the main channel are not transported to the spring channel.
Long subsurface transport times cause a lag between the seasonal variability in the main channel and spring channel.

6. Conclusions and future work

Spring channels provide a useful testing platform for hyporheic influences because hyporheic discharge can be assessed before mixing with the main channel.
Model results are consistent with current hypotheses about influences of multi-scaled hyporheic flow on temperature.
Model is ready for testing more complex energy balance interactions, such as the added influence of radiation and air-water energy exchanges.
Ultimately, this heat transport code will be used in full-scale models, to test system-level hypotheses about the controls of temperature distribution across floodplains.