

Quantifying Surface Water-Groundwater Exchange Using Temperature Profile Inverse modeling in a Riparian Wetland

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Introduction



- Motivation:** understand how mining derived sulfate affects biogeochemical cycling in first order streams on Minnesota's iron range. The geochemical gradient is controlled by surface water-groundwater exchange (hyporheic flux) [Hayashi & Rosenberry 2002; Kurtz et al. 2007]

- Goal:** quantify hyporheic flux at a mining impacted stream using inverse temperature profile modeling
- Site:** Second Creek is a riparian wetland located in Minnesota's Iron Range

Methods

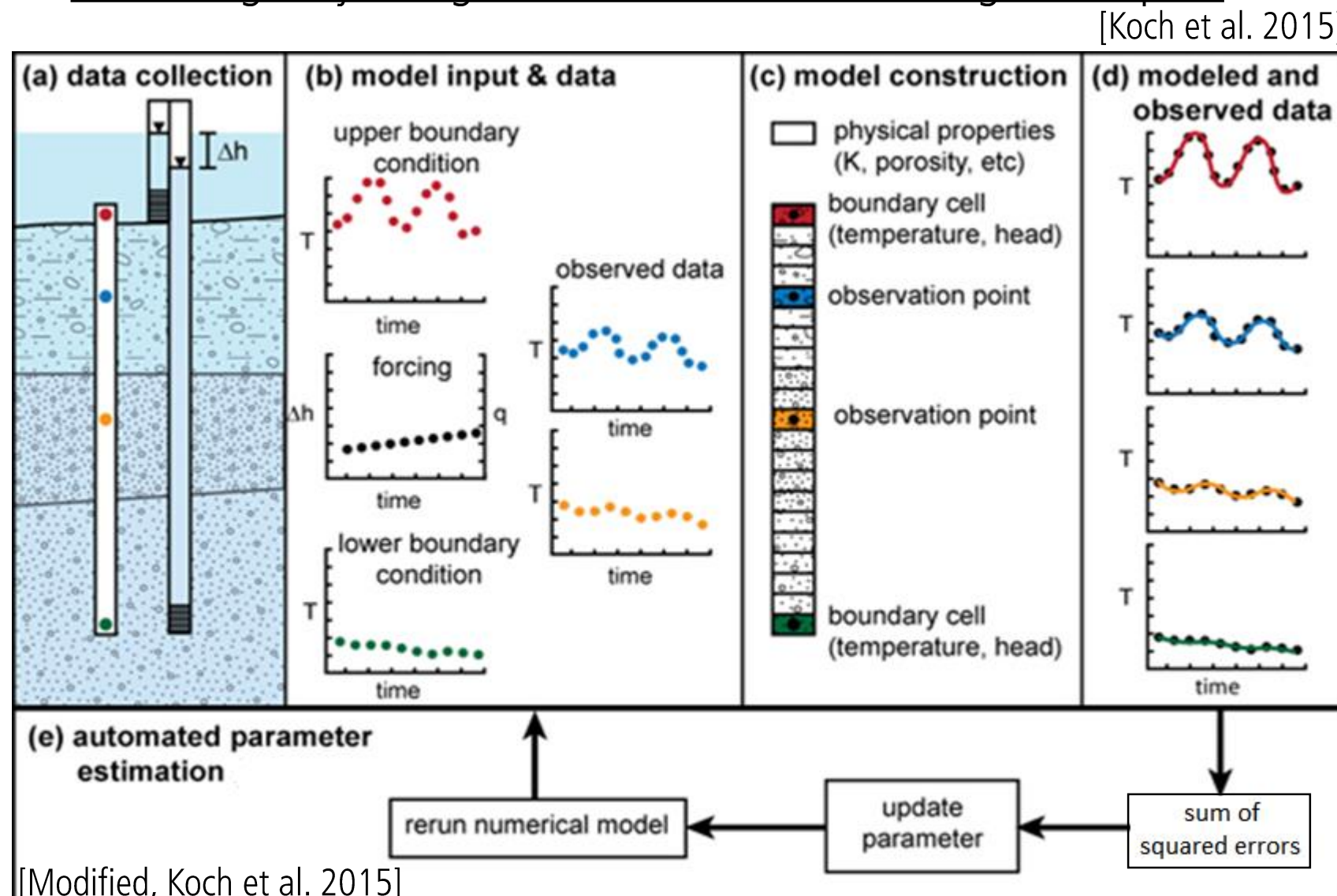
- Hydraulic conductivity is estimated by reducing the residual between an observed temperature profile and a modeled profile

Forward model governing equation

$$(\lambda_s + q_z \alpha C_w) \frac{\partial^2 T}{\partial z^2} - q_z C_w \frac{\partial T}{\partial z} = \frac{\partial T}{\partial t} (\phi C_w + (1 - \phi) C_s)$$
$$q_z = -K \frac{dh}{dz}$$

[Healy, R.W., and A.D. Ronan. 1996]

Estimating K by fitting model to observations using 1DTempPro

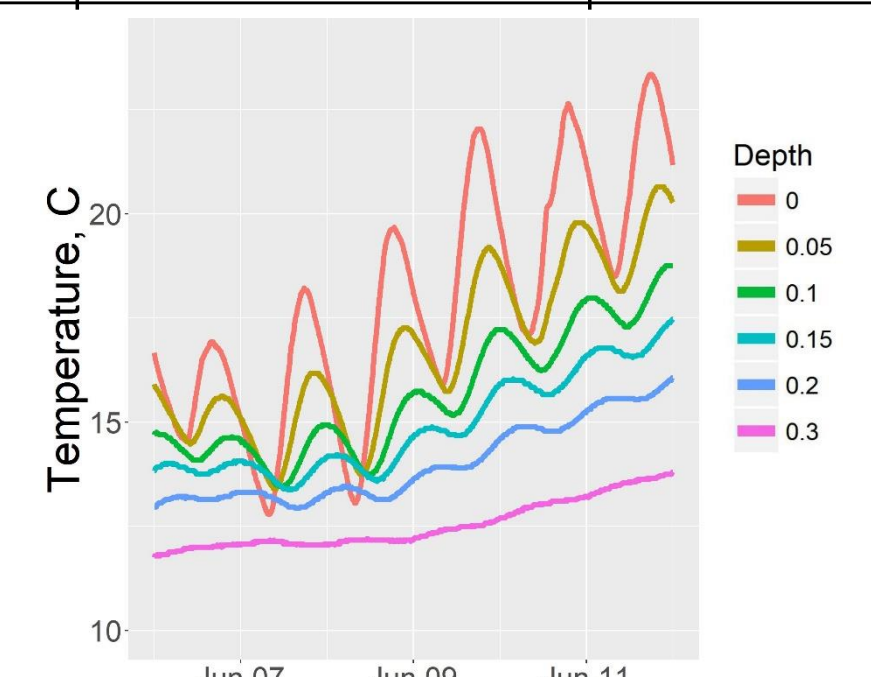


Parameter	Symbol
Hydraulic conductivity	K
Porosity	ϕ
Saturated thermal conductivity	λ_s
Sediment heat capacity	C
Water heat capacity	C_w
head	h
Dispersivity	α
Hyporheic flux	q_z
Temperature	T

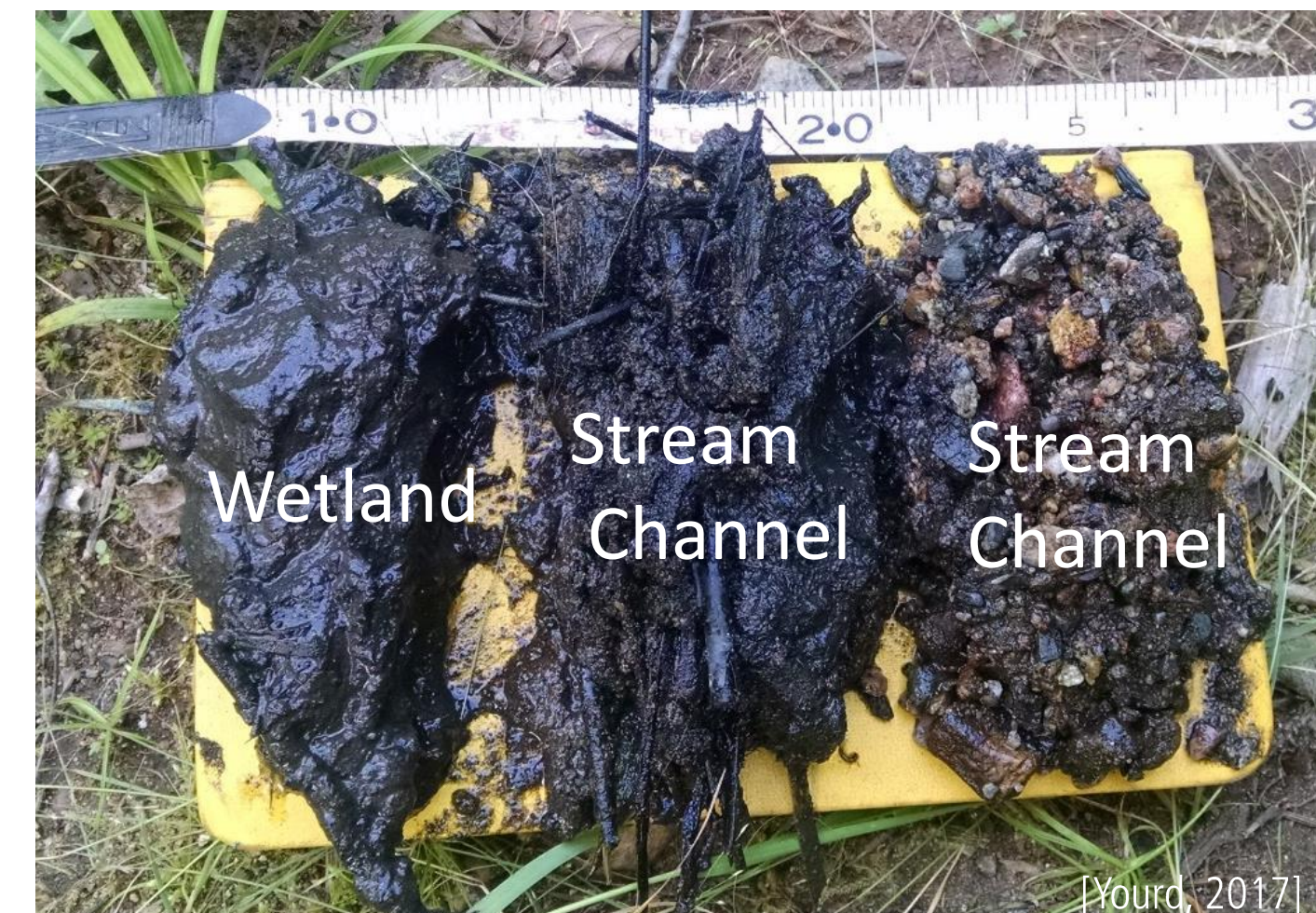
Data collection

- Three temperature probes were collocated with piezometers across the site
- Pressure and temperature were measured at 15 minute intervals to capture diurnal variability over the summer
- Data was collected using low cost, open source data loggers developed in house [Wickert, 2014]

Sample west streambed temperature data



Sediment characterization



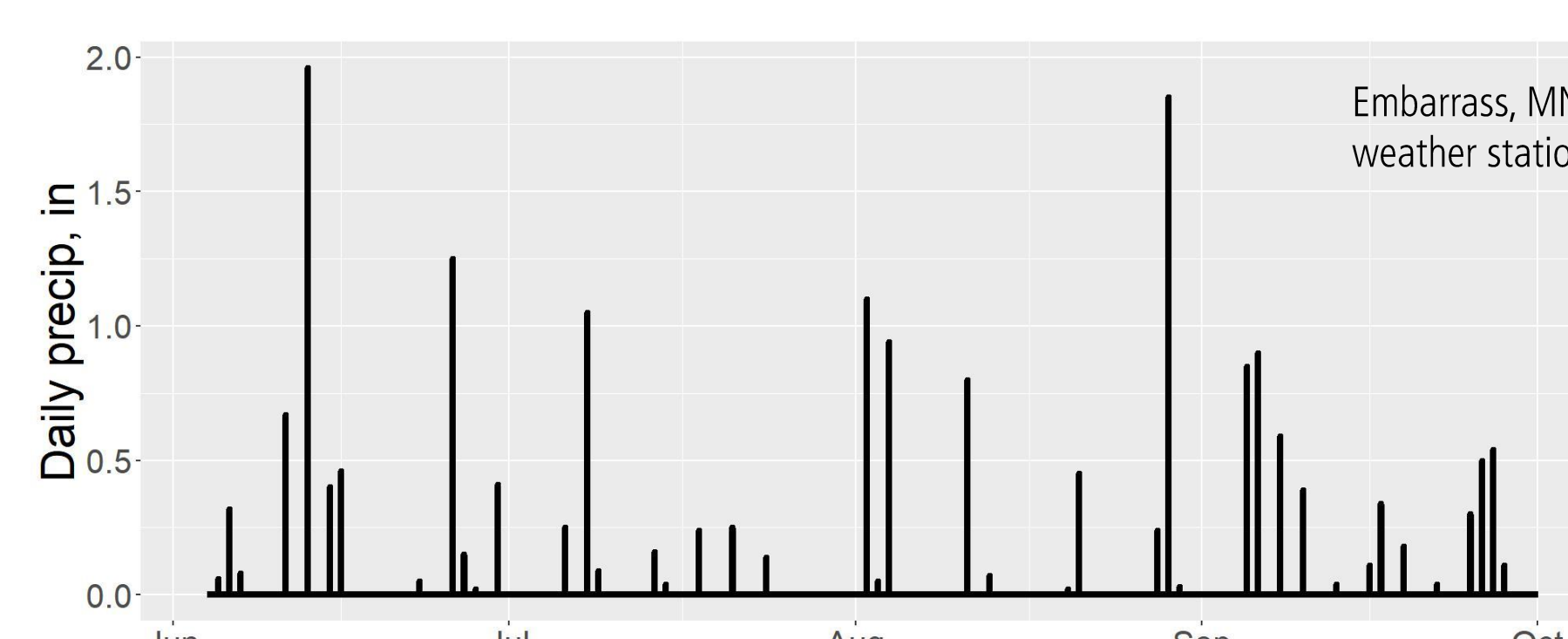
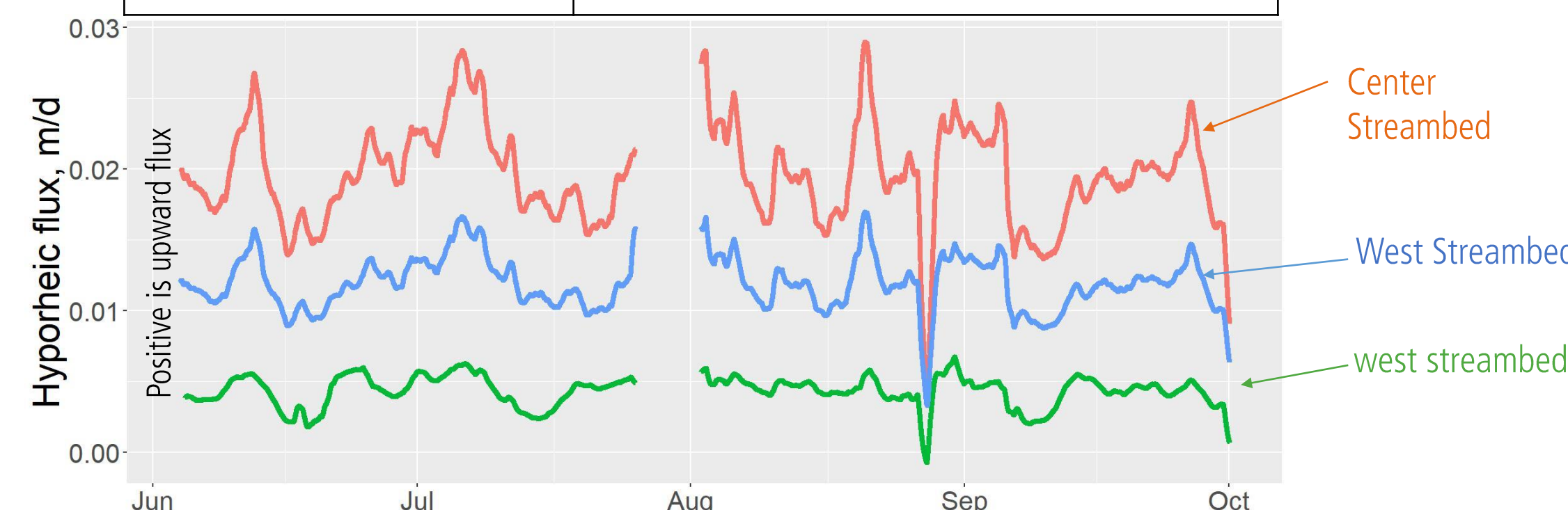
- Thermal properties of the streambed and wetland sediment are required for modeling the temperature profile
- Site sediment is characterized by high organic content, low dry bulk density, high porosity [Mybro, 2013]
- Measured dry bulk density from [Mybro, 2013] used to estimate the fraction of silicate and soil organic matter
- 80-90% SOM, 10-20% silicate
- Thermal conductivity and sediment heat capacity constrained by computing upper and lower bounds based on [Farouki, 1961]

$$\lambda_{min} = \frac{x_{Si}}{\lambda_{Si}} + \frac{x_{Som}}{\lambda_{Som}} \quad \lambda_{max} = x_{Si} \lambda_{Si} + x_{Som} \lambda_{Som}$$

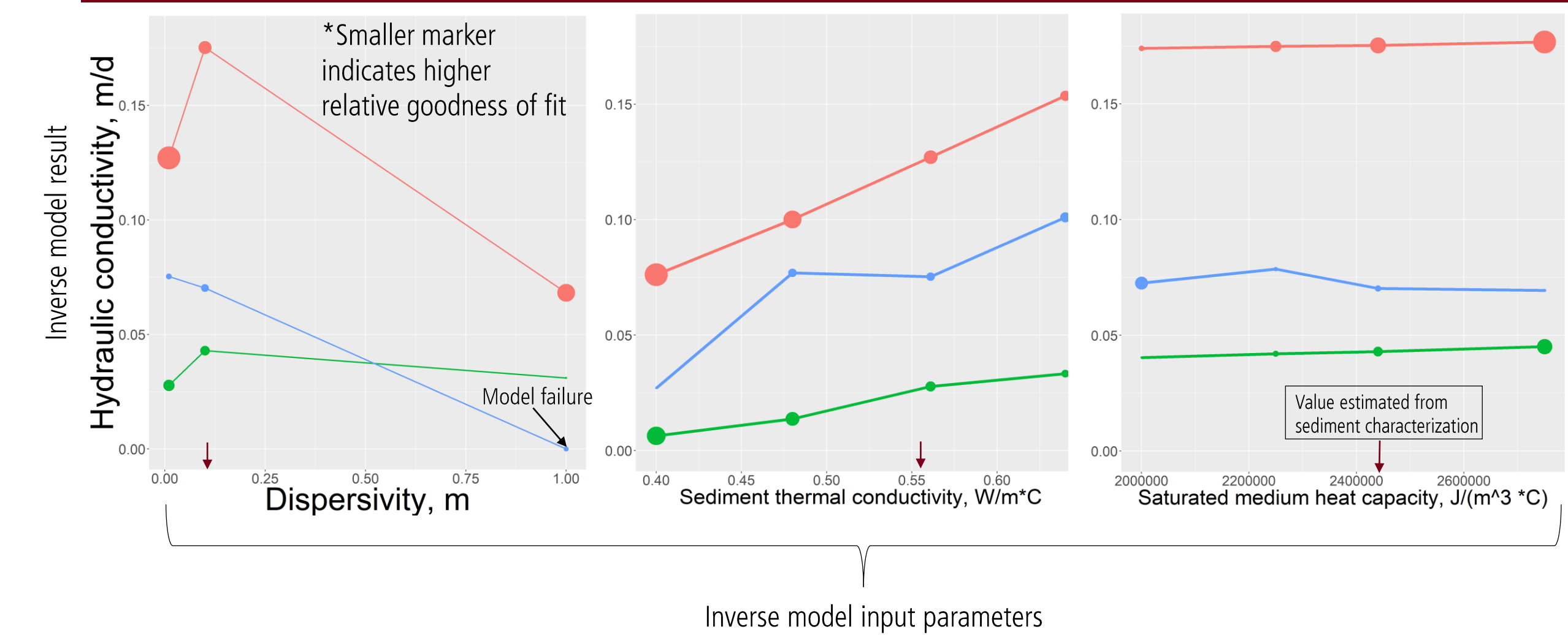
- Dispersivity estimated from the range provided in [Zheng & Bennet, 1995]

Results

Location	Hydraulic conductivity, m/d
West wetland	0.07
Stream west	0.04
Stream center	0.18



Model fit and sensitivity analysis



- Models fit the observed profiles well with average error between 0.09 and 0.17 degrees C.
- Input parameter values were chosen to minimize model misfit.
- Sensitivity testing matched intuition for dispersivity and thermal conductivity:
 - At high dispersivity, low upward flux is required and dispersivity is the dominant mode of heat transport.
 - As thermal conductivity increases, larger upward flux is required to counteract downward heat diffusion
- Saturated heat capacity is relatively insensitive compared to site variability

Conclusions

- Flux in the hyporheic zone is consistently upward throughout the summer so groundwater influences geochemistry in the streambed
- Flux is spatially variable due to sediment heterogeneity
- The lowest magnitude of flux occurs in the stream channel rather than the wetland.
- The influence of precipitation on hyporheic flux is seasonally dependent

Future work

- Similar data with higher spatial resolution, and longer collection time (May–October) was collected in 2017
- 2017 data includes a long term flux reversal and could improve heterogeneity resolution
- 2018 field campaign potential: unique parameterization based on sediment collected at each probe location

References

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