Actionable Science for Communities

Geophysical Methods for Groundwater - Surface Water Interactions – SHC 3.61.2

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Purpose/Utility of Research

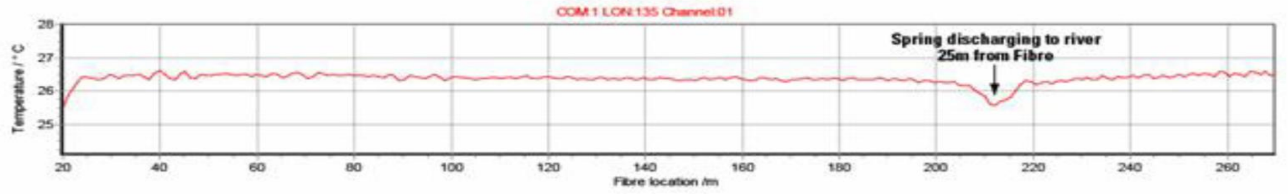
Purpose

- To help meet OLEM's research priority on groundwater characterization technologies and methodologies.
- To characterize contaminated groundwater routes of exposure for aquatic species via surface water bodies which threaten human health and the environment.
- To use non- and minimally- invasive geophysical methods to characterize and monitor groundwater-surface water (GW/SW).
- To provide Program Offices, Regions, Stakeholders, and others quantifiable modeling and analysis applications for understanding GW/SW interactions

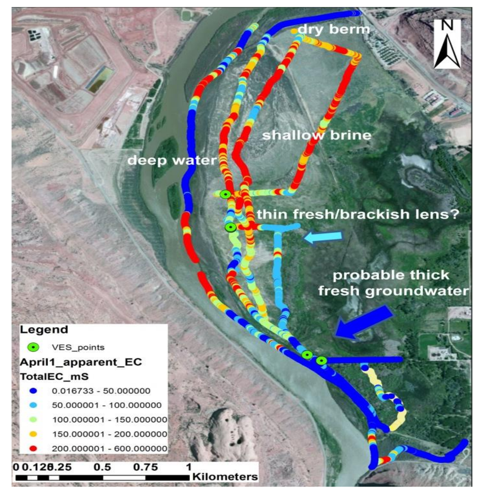
Utility

- Temperature and electrical gradients between GW/SW enables rapid large area coverage of these interactions
- Understanding GW/SW interactions:
  1. guides the placement of remediation or capture systems before surface water bodies are impacted
  2. can guide well placements
  3. monitor temporal variations as fluids move horizontally and vertically between this interface

- FO-DTS: Fiber-Optic Distributed Temperature Sensor
  - Strain
  - Temperature



Electromagnetic induction (EMI) for bulk earth conductivity

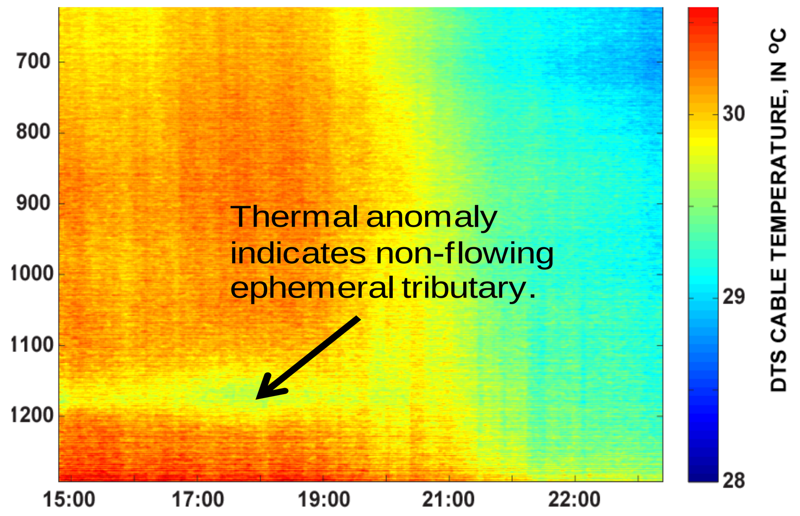


Electrical methods measure the electrical properties of the earth, which are a sum of the biogeochemical properties, reactions, and interactions

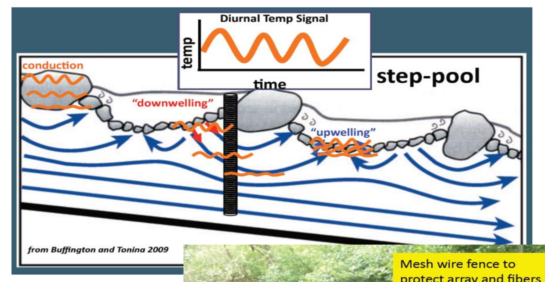
Highlights

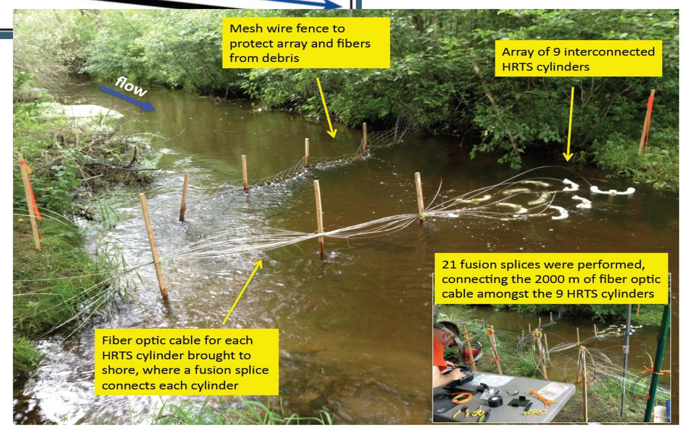
Using geophysics to efficiently characterize GW/SW exchange in zones of contamination

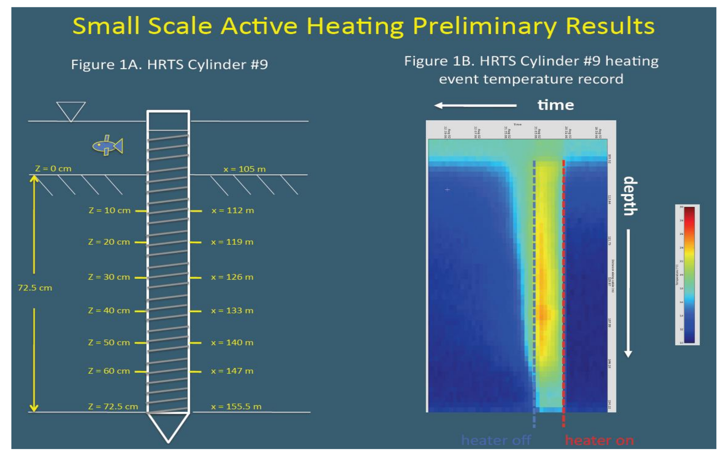
Temperature variance used to guide fate & transport decision making

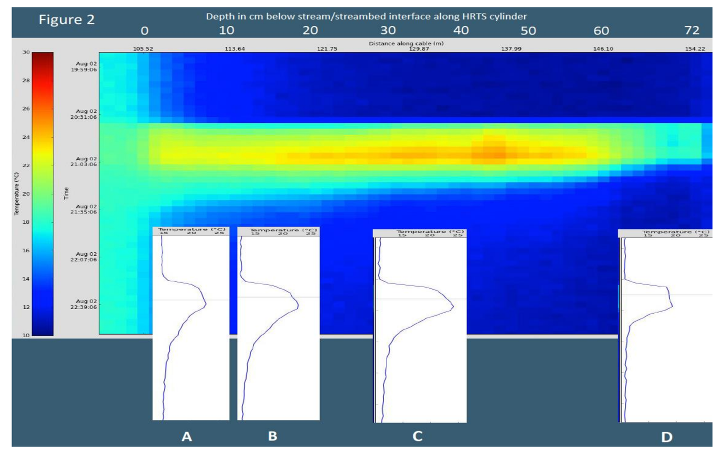


- Vertical component being developed for groundwater flux measurements
- Used to quantify vertical groundwater flux which is a function of heat decay from an active heated probe[2]









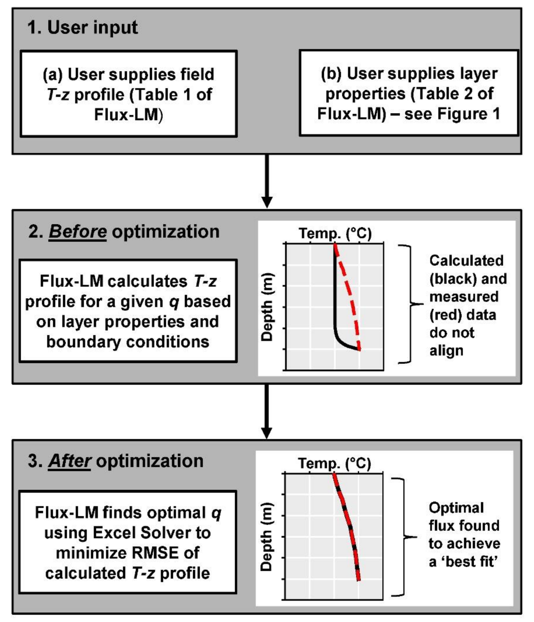
Heat decaying more rapidly at depth

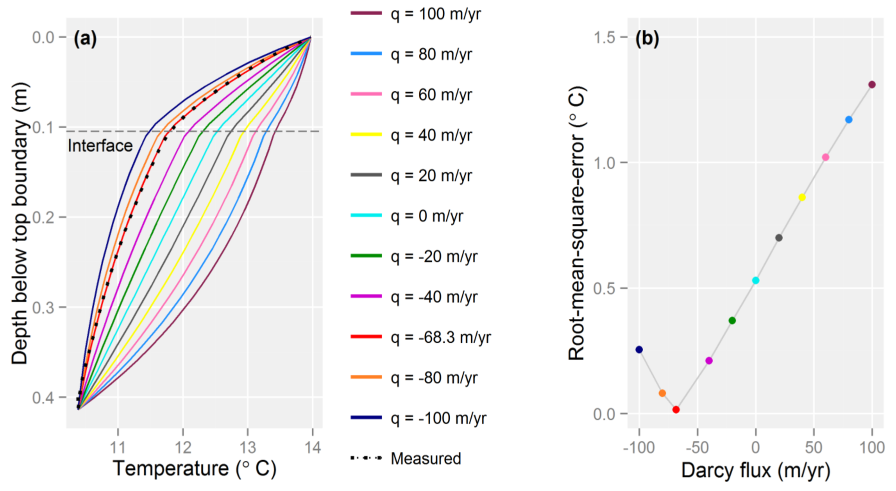
Application & Translation

- analytical software (Flux-LM[1] and 1DTempPro[3]) to assess GW/SW interactions from hydrogeophysical data (e.g., temperature and electrical resistivity)
- a module for the Geophysical Toolbox Decision Support System (GTDSS) to guide the selection of geophysical methods and to design of surveys for effective application to GW/SW problems. {see GDSS poster}

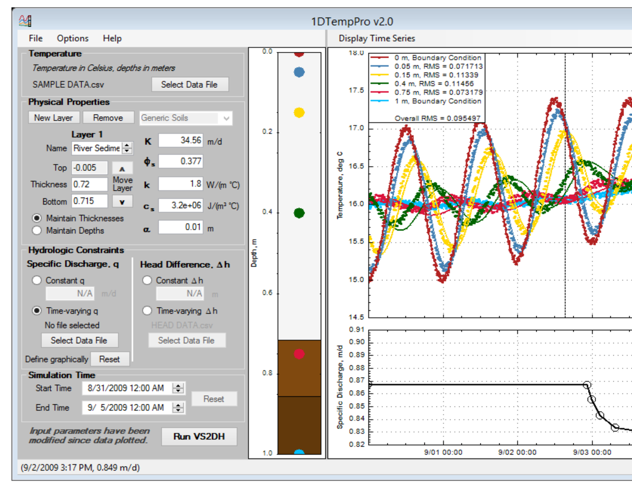
Flux-LM[1] workflow:

1. layer and measured temperature-depth (*T-z*) data
2. *T-z* profile is calculated
3. Optimal Darcy flux is found by adjusting the flux to minimize the RMSE of the calculated *T-z* profile





(a) Temperature profiles from field HRTS measurements (black dashed line) and those calculated with Flux-LM[1] (colored solid lines)
(b) RMSE between measured and calculated temperature profiles for each Darcy flux value. Lowest RMSE = best flux



- Main window of 1DTempPro V2[3]
- Parameter input, model estimation

Intended End users

- Characterization and monitoring of GW/SW interaction zones serves many of the Program Offices, Regions, Stakeholders, other Agencies (i.e., Fish and Wildlife, USGS), and other investigator needs
- Any user requiring an understanding of subsurface processes (e.g., fate and transport and remediation effectiveness) and interactions with surface water bodies.

Lessons Learned

- Geophysical methods can efficiently guide data collection, put precise point measurements into system-scale context, and build process-based understanding of GW/SW exchange dynamics in zones of contamination.

Electrical methods (e.g., resistivity, EMI)

Strengths:

- Identify controlling geologic structure
- Provide a snapshot and time-lapse monitoring
- Fluid mapping
- Monitoring

Limitations:

- Non-unique interpretations due to geology, porosity, fluid dynamics, stream bed conductivity
- Contaminant of interest may not have an observable electrical signature
- EMI is subject to drift and infrastructure interference

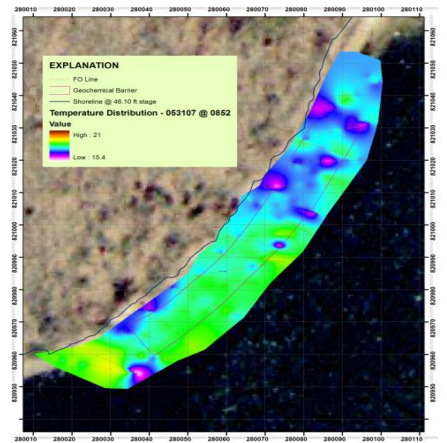
Fiber-optic distributed temperature sensors

Strengths:

- High spatial resolution (~0.5 to 1 m) and high precision (0.01 °C)
- Large scale (10's of km possible, <5 km common)
- Continuous measurement (in time and space)
- Long-term installation possible

Limitations:

- Fiber is glass – can be damaged
- Deployment can be labor-intensive
- DTS systems are costly ($25-100K)
- Require calibration and field verification



References

1. Kuryluk,B.L., Irvine,D.J., Carey, S.K., Briggs,M.A., Werkema,D.D., Bonham,M., Heat as a hydrologic tracer in shallow and deep heterogeneous media: analytical solution, spreadsheet tool, and field application, *Water Resources Research*, In Review. 2016
2. Briggs, M.A., Buckley,S.F., Bagtzoglou,A.C., Werkema, D.D, and Lane Jr., J.W., Actively heated high-resolution fiber-optic distributed temperature sensing to quantify vertical and horizontal flow in streambeds, *Water Resources Research*, In Press. 2016
3. Koch, F.W., Voytek,E.B., Day-Lewis,F.D., Healy,R., Briggs,M.A., Werkema, D.D. , Lane Jr.,J.W., 1DTempPro V.2: New features for parameter estimation, heterogeneity, and time-varying exchange, Groundwater, 54, no. 3: 434-439, doi:10.1111/gwat.12369. 2015