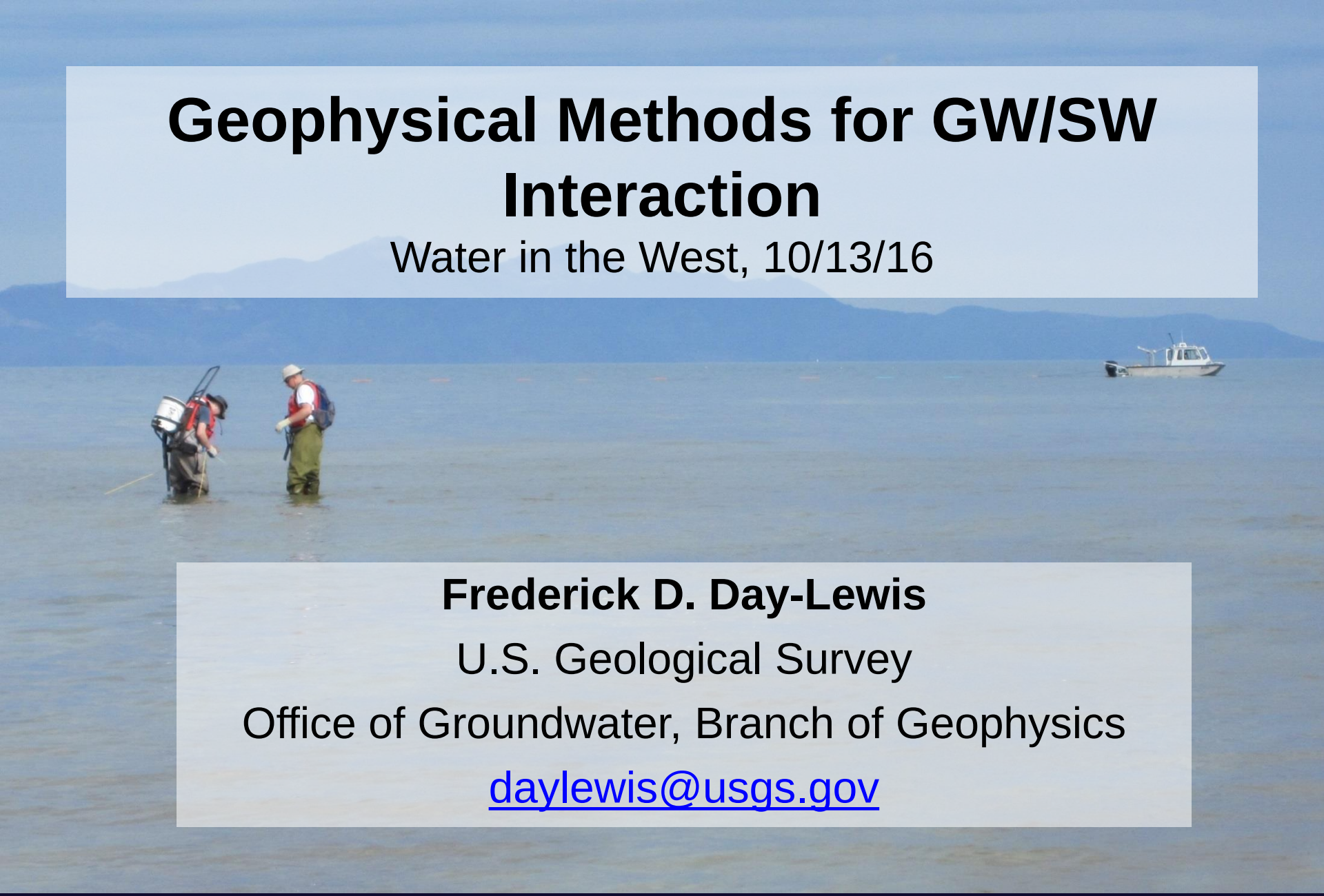
Geophysical Methods for GW/SW Interaction

Water in the West, 10/13/16



Frederick D. Day-Lewis

U.S. Geological Survey

Office of Groundwater, Branch of Geophysics

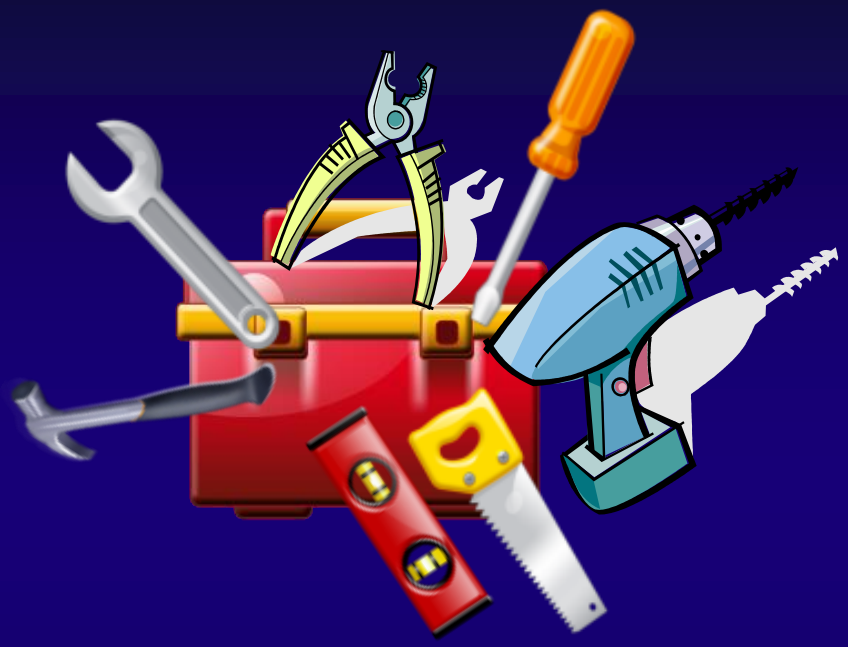
daylewis@usgs.gov

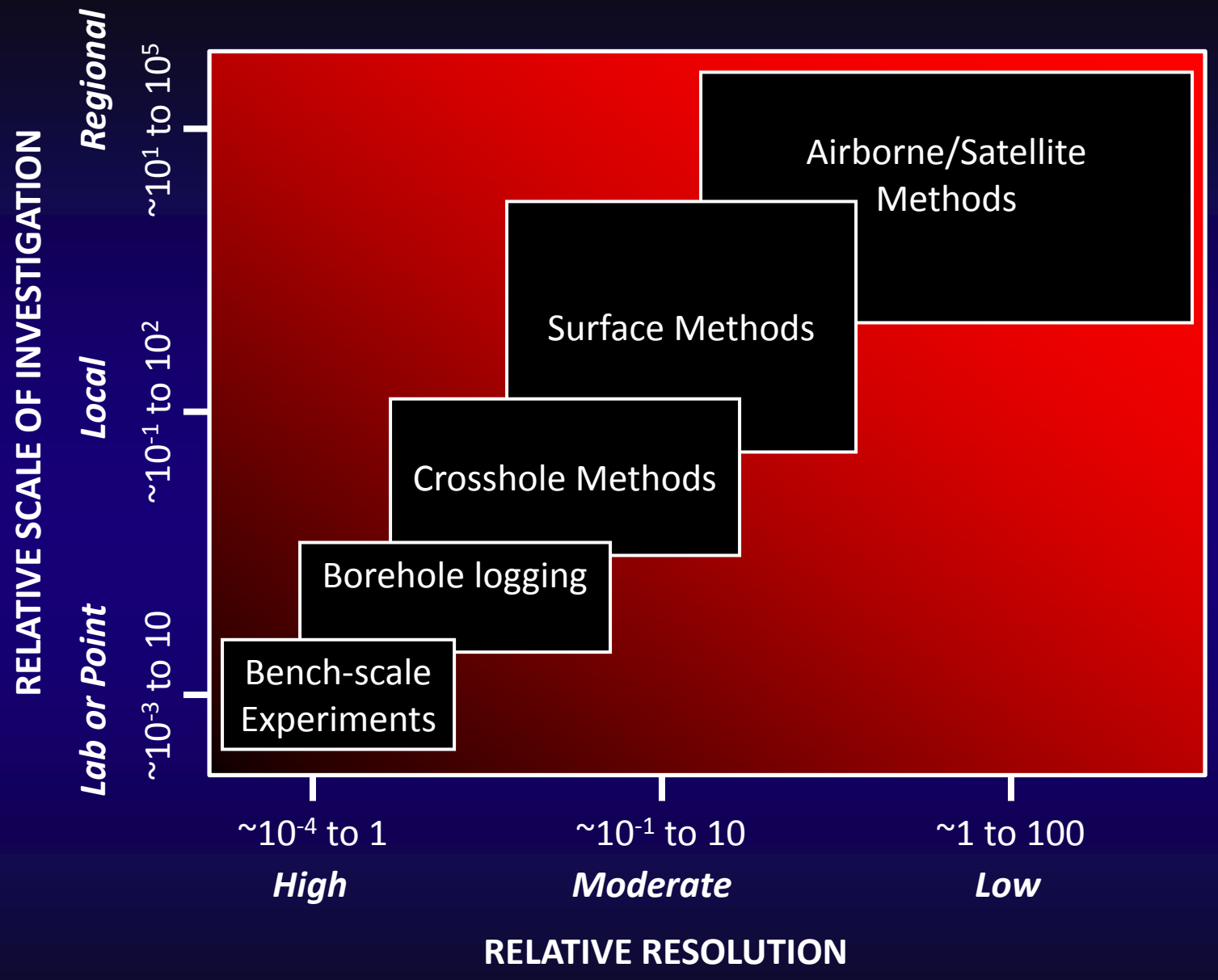
Outline

- Why geophysics?
- Why geophysics for GW/SW?
- Methods:
  1. Direct current electrical methods
  2. Electromagnetic Induction methods
  3. Temperature
- Conclusions

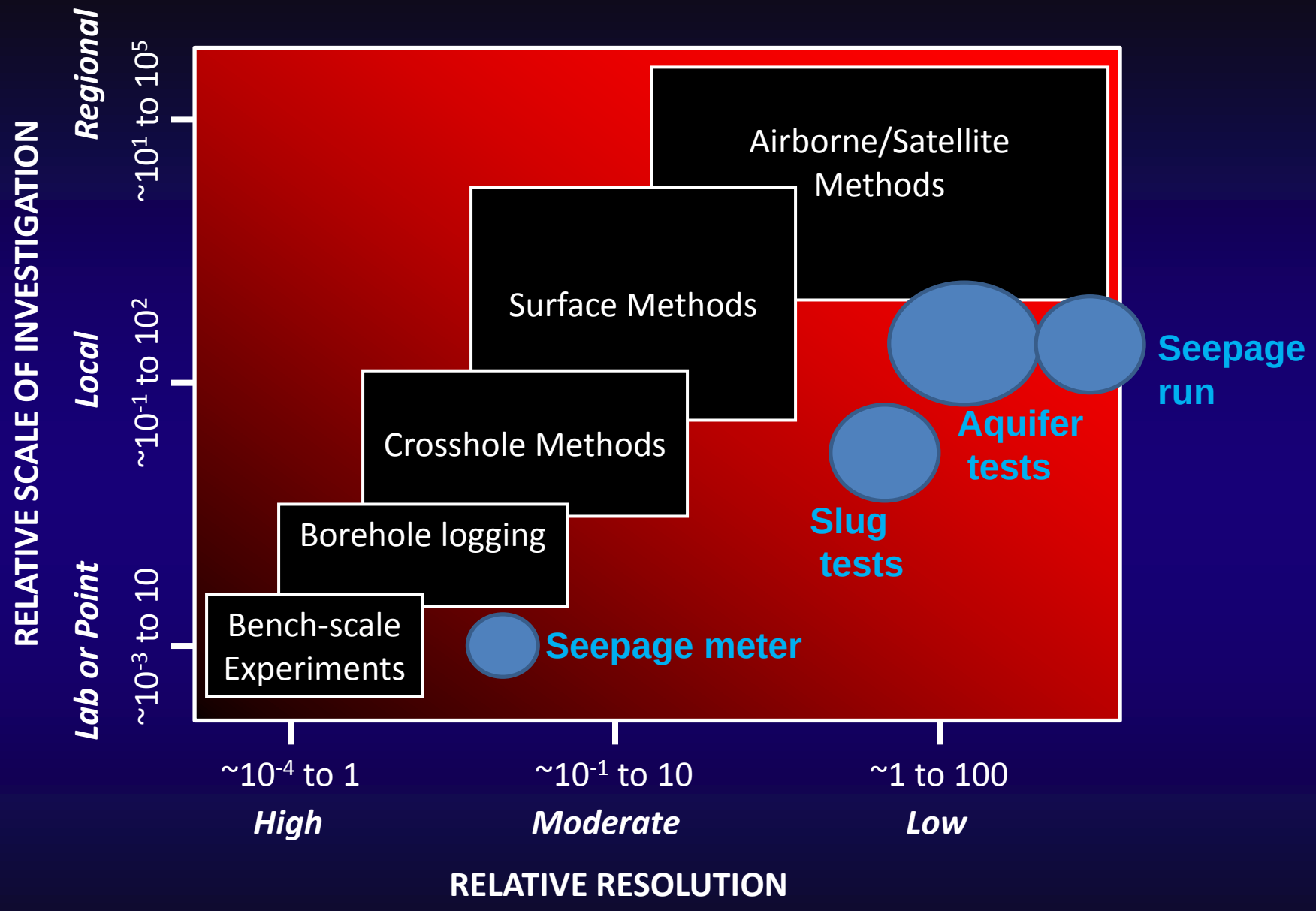
Why geophysics?

- Filling in gaps in space
  - Large areal coverage /$
  - High resolution /$
- Filling in gaps in time
  - Long-term continuous monitoring
- Limitations:
  - Indirect
  - Need multiple methods
  - Not a substitute for direct measurements





[Modified from Hubbard and Rubin, 2005]



[Modified from Hubbard and Rubin, 2005]

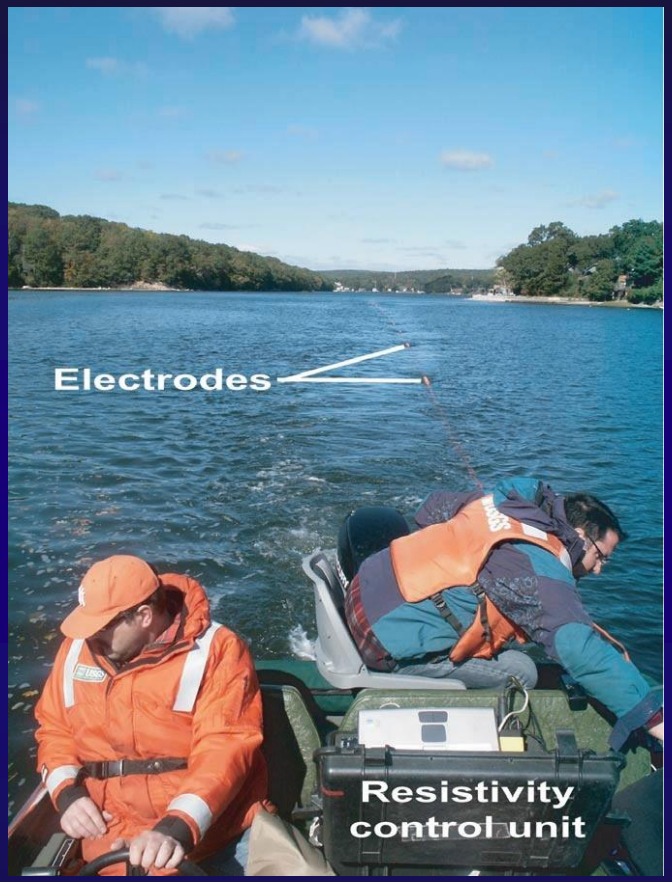
Why geophysics for GW/SW?

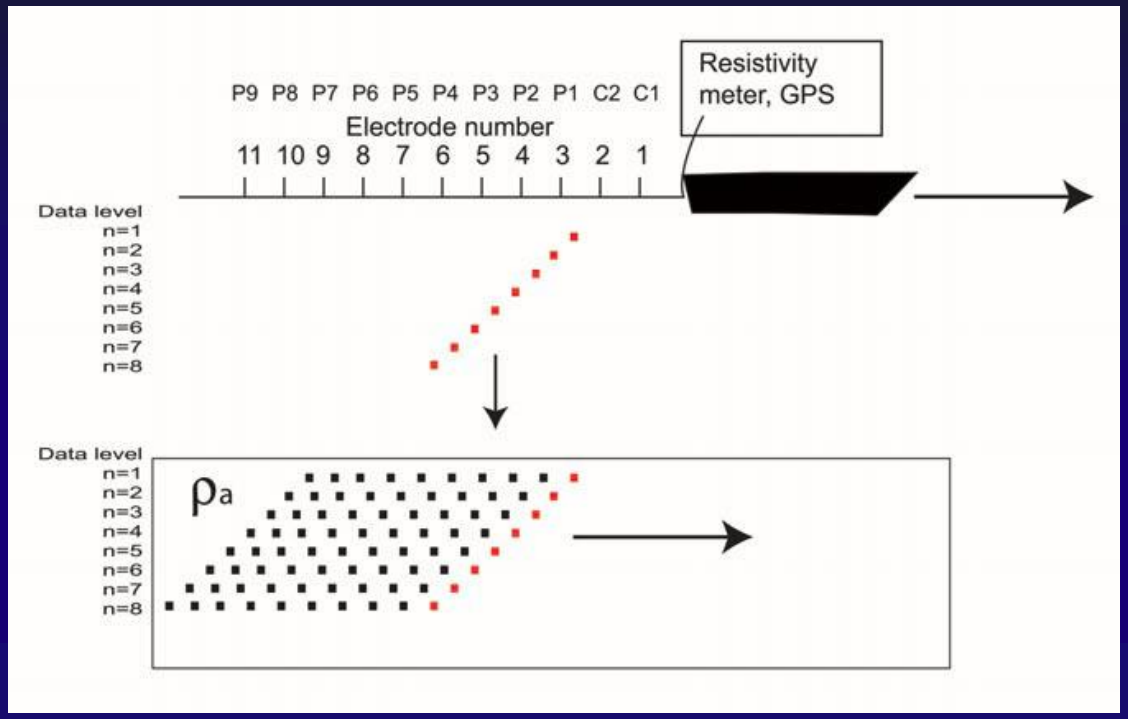
- Reconnaissance
  - Mapping bed materials (electrical, EM, seismic, GPR)
  - Mapping groundwater salinity (electrical, EM)
  - Mapping relative exchange (thermal imaging, fiber optic temperature, time-lapse electrical)
- Quantifying fluxes (temperature)
- Monitoring (fiber optic temperature, electrical)

(1) Electrical Resistivity

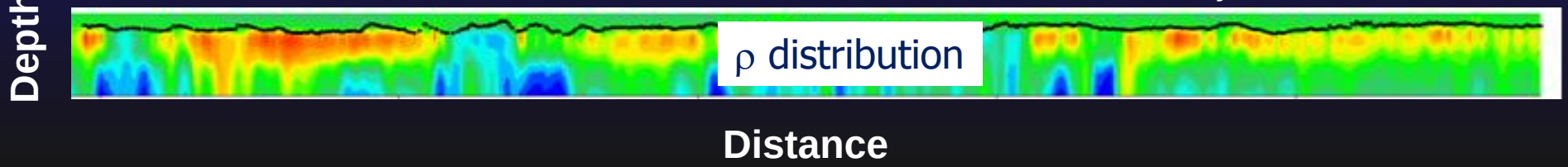
- **Mapping subsurface resistivity**
  - →Geology/structure
  - →Salinity
- Performed from land, on stream bed, or from boat
- Requires electrodes in contact with ground or water

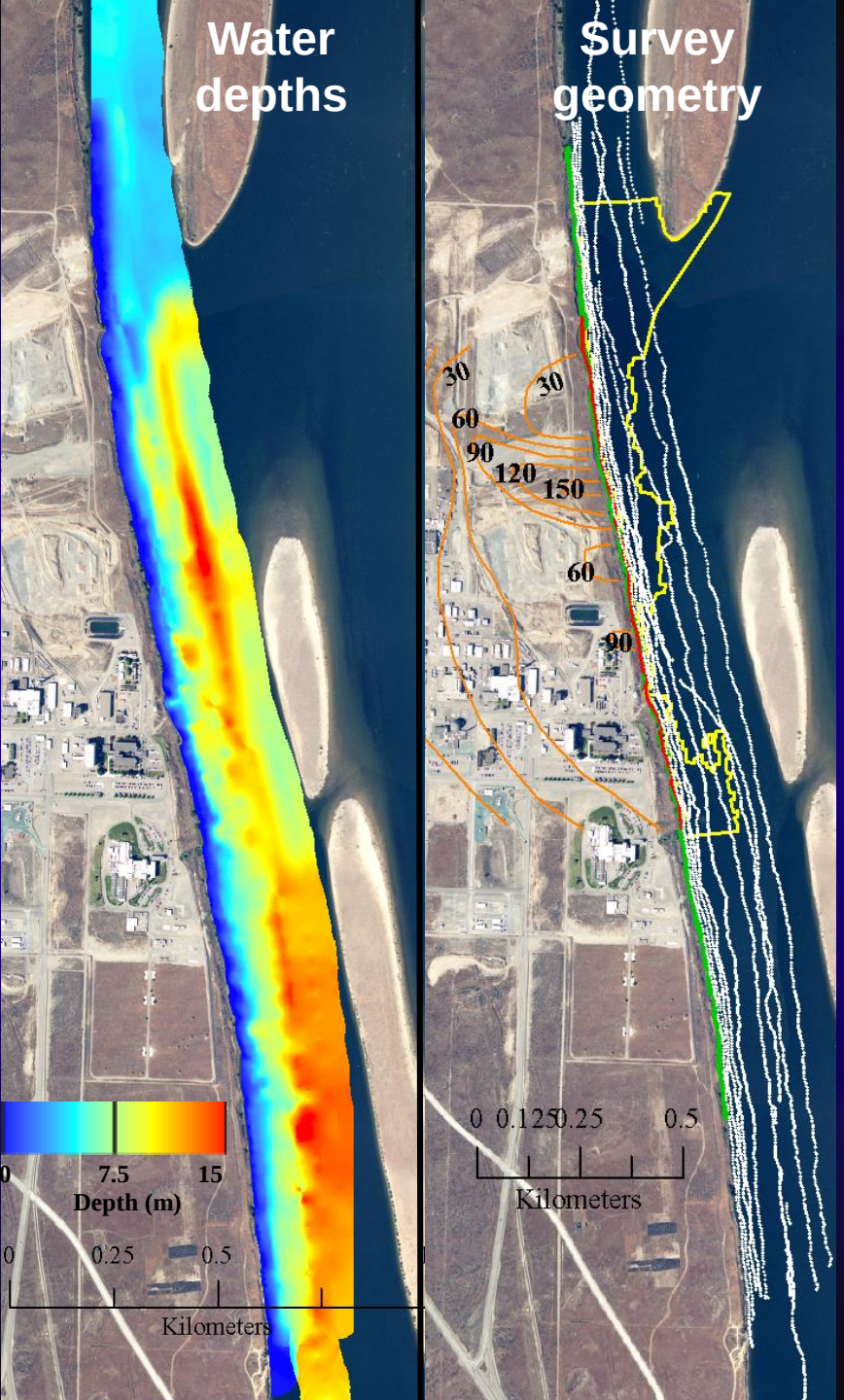
Continuous Resistivity Profiling





Numerical methods + **Inverse modeling** [with appropriate constraints on water layer thickness and conductivity



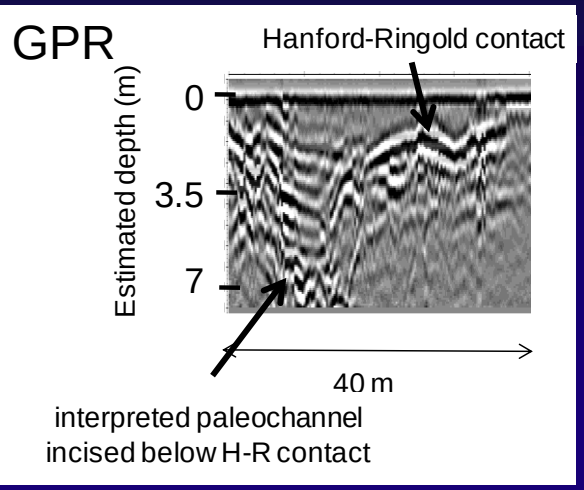


CRP Example: Columbia River, WA

- 30 km of waterborne electrical line
- Water depths varied from 1-14 m (in channel)
- Focus on near shore where water depth of a few meters only
- Chargeability stronger indicator of lithology at this site than resistivity
- *Also waterborne seismic and GPR, land-based electrical; DTS; 1D vertical temp,* ***<u>not shown here</u>***

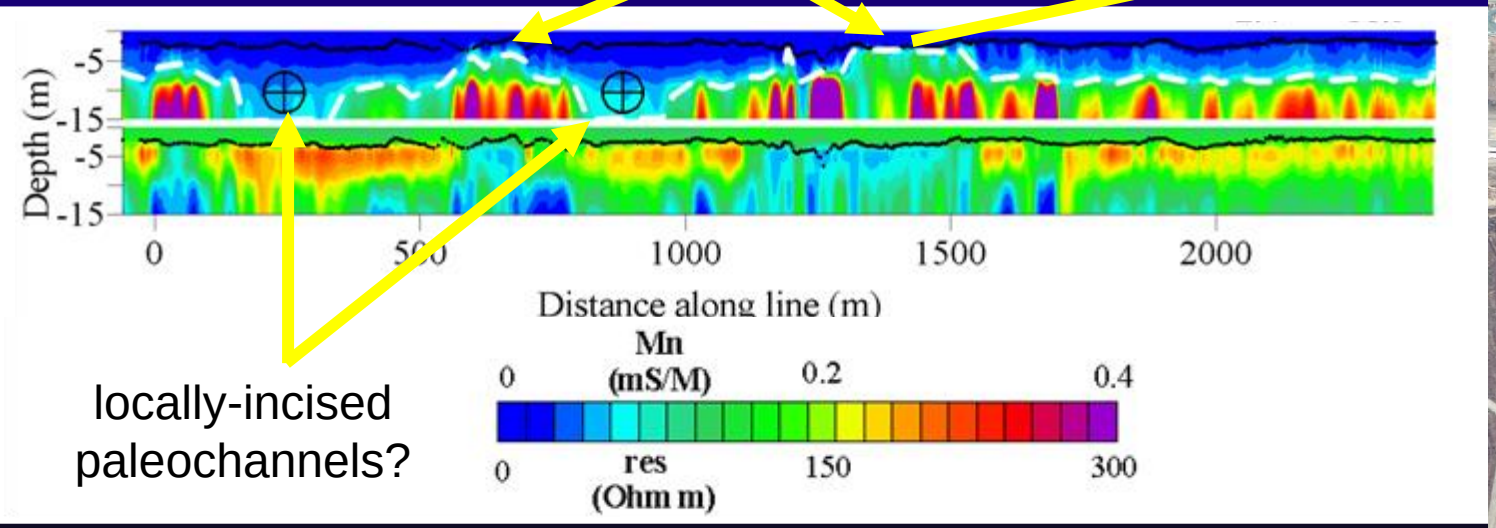
Res/IP
DTS
Contributing area?

Electrical cross sections

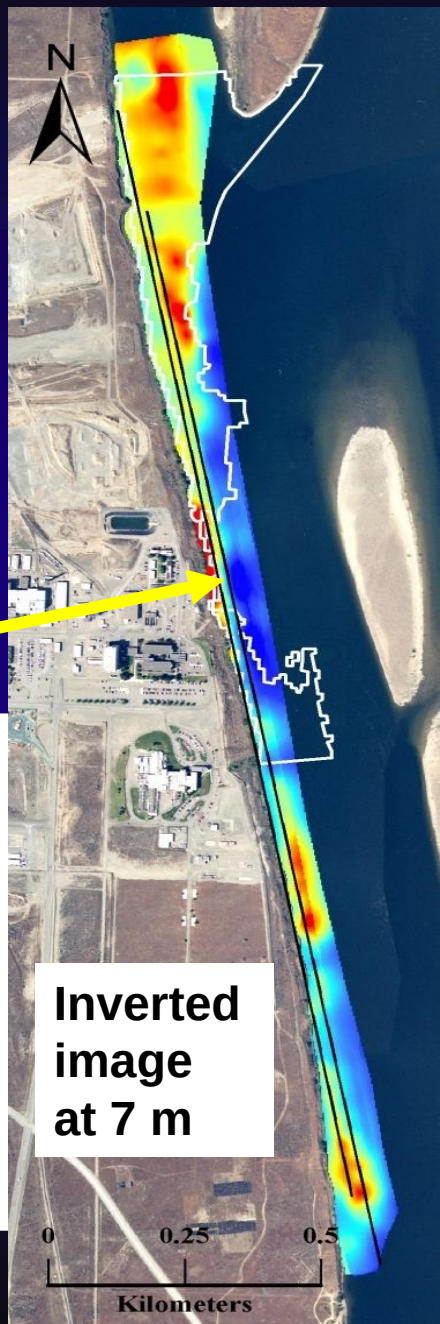


Hanford-Ringold contact defined along river corridor

Ringold daylights



locally-incised paleochannels?



Inverted image at 7 m

Line 20 (20 m from shore)

(2) Electromagnetic Induction

- **Many tools/platforms for different target depths and scales of investigation**
  - →Geology/structure
  - →Salinity
- No electrode-contact required

Mapping fresh water discharge to the CO River

Current fresh groundwater discharge estimate based on a zone of constant thickness across the wetland area…

USGS

- *Unpublished results*

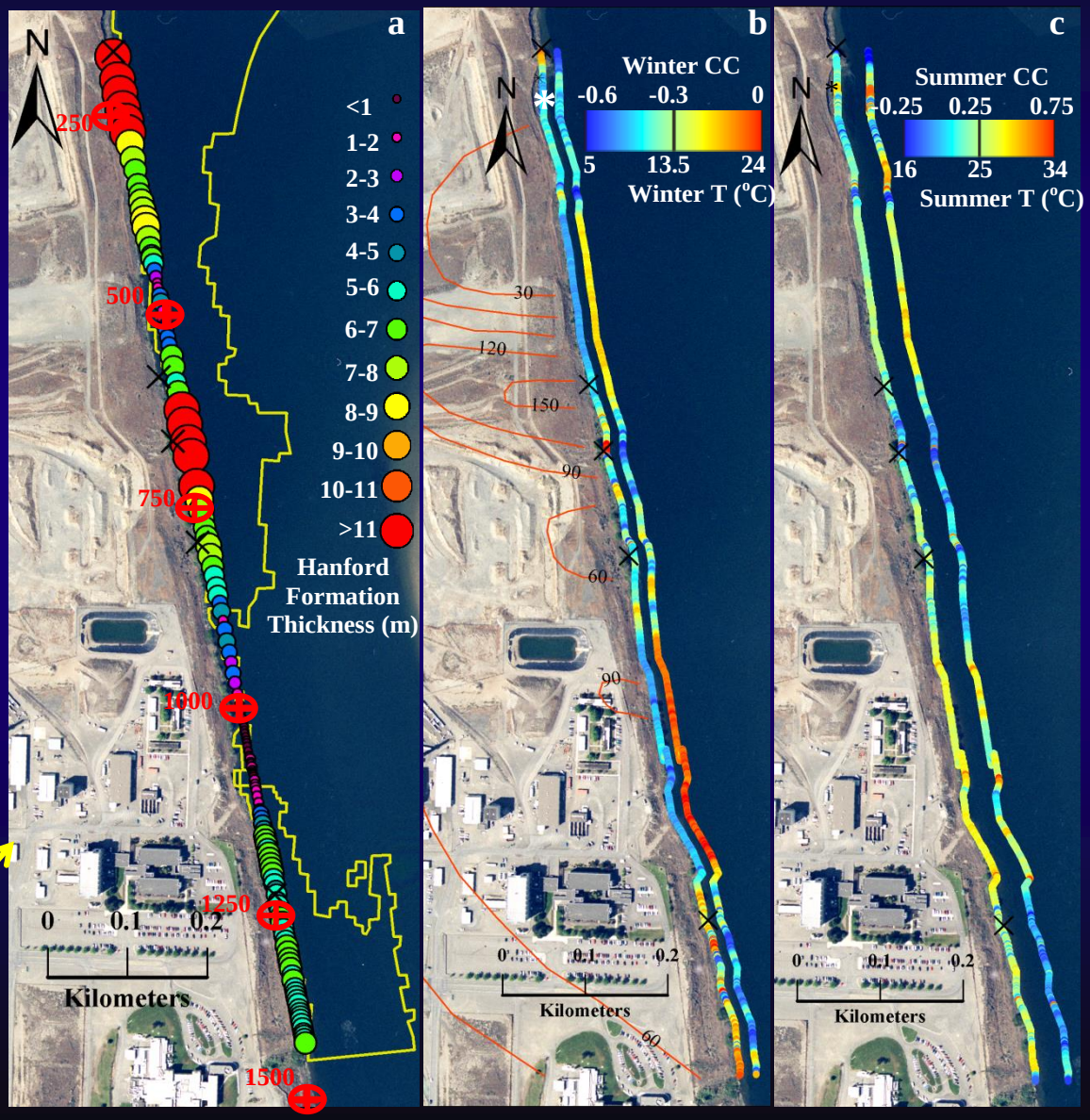
(3) Temperature Methods

- Conventional 1D Vertical profiles
- Fiber-optic distributed temperature sensing
- Thermal imaging

DTS Example – Columbia River

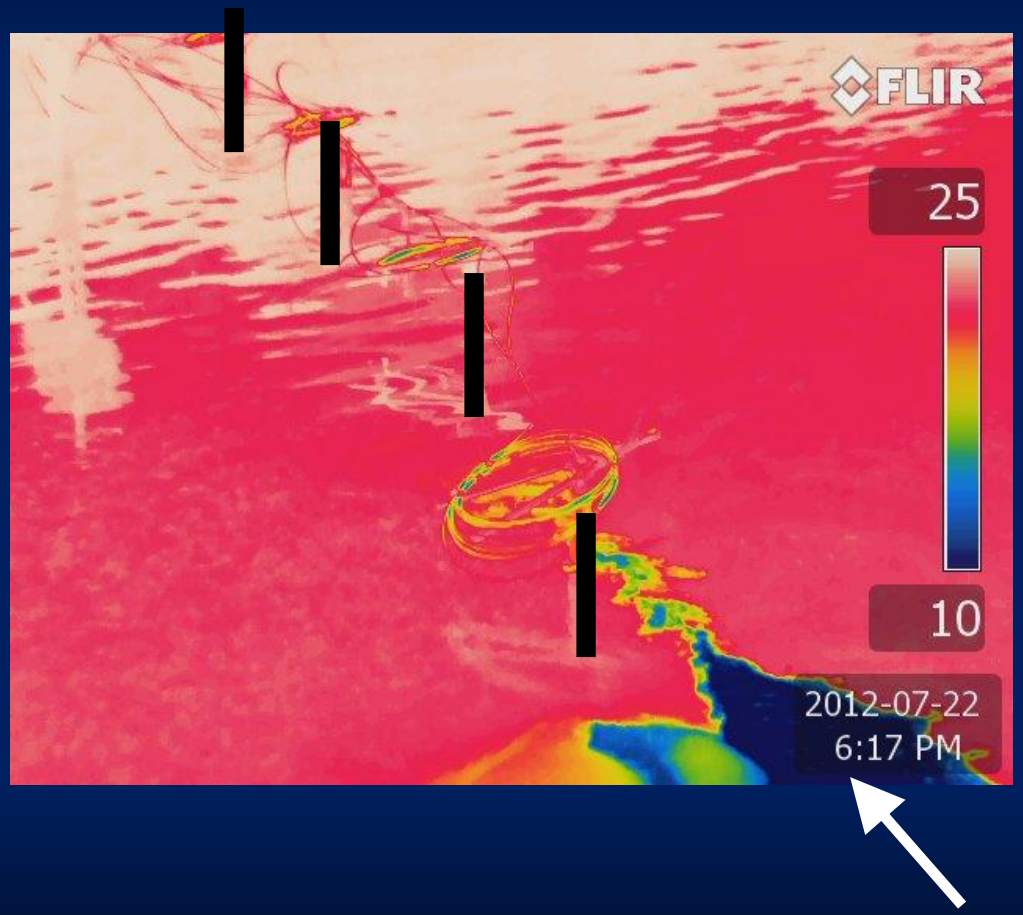
Slater et al., 2007
Mwakanyamale et al., 2012
Mwakanyamale et al., 2013

- DTS provides high-resolution in space and time
- Temperature anomalies coincide with known uranium seeps, *but there are many additional temperature anomalies/seeps*
- DTS results consistent with electrically estimated Hanford thickness



Estimated variation in thickness of uranium contributing area from IP

FLIR & 1D Temp. Example – Delaware R.

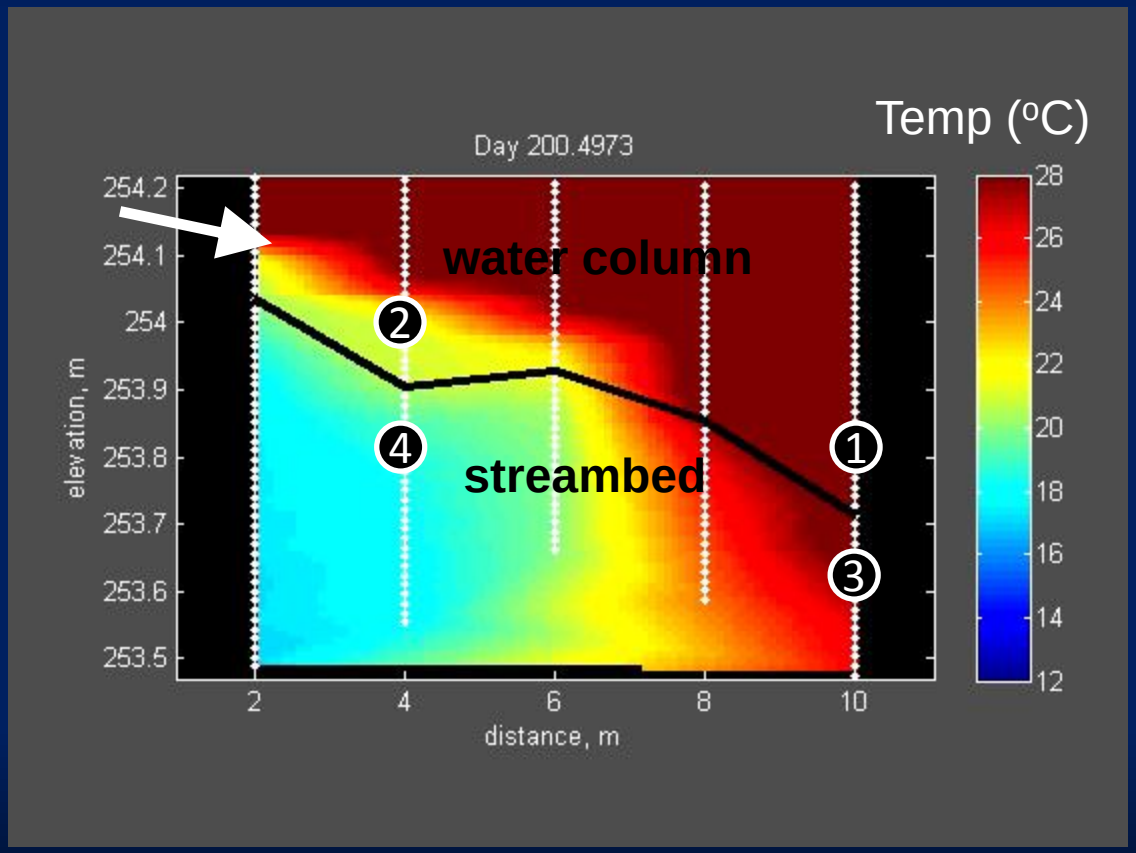


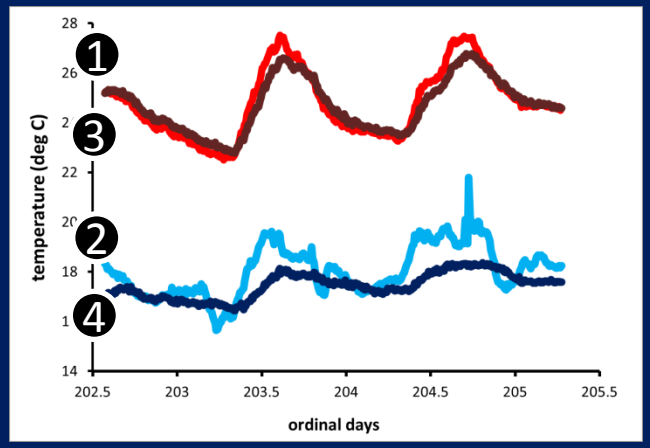
- **Probes installed in transect vertically through water column and into streambed**
- **Data calibrated using various models include 1DTempPro (USGS)**
- **Study of dwarf wedge mussel cold water refugia**

USGS

Briggs et al., ES&T, 2013

HRTS: Delaware River cold water plume

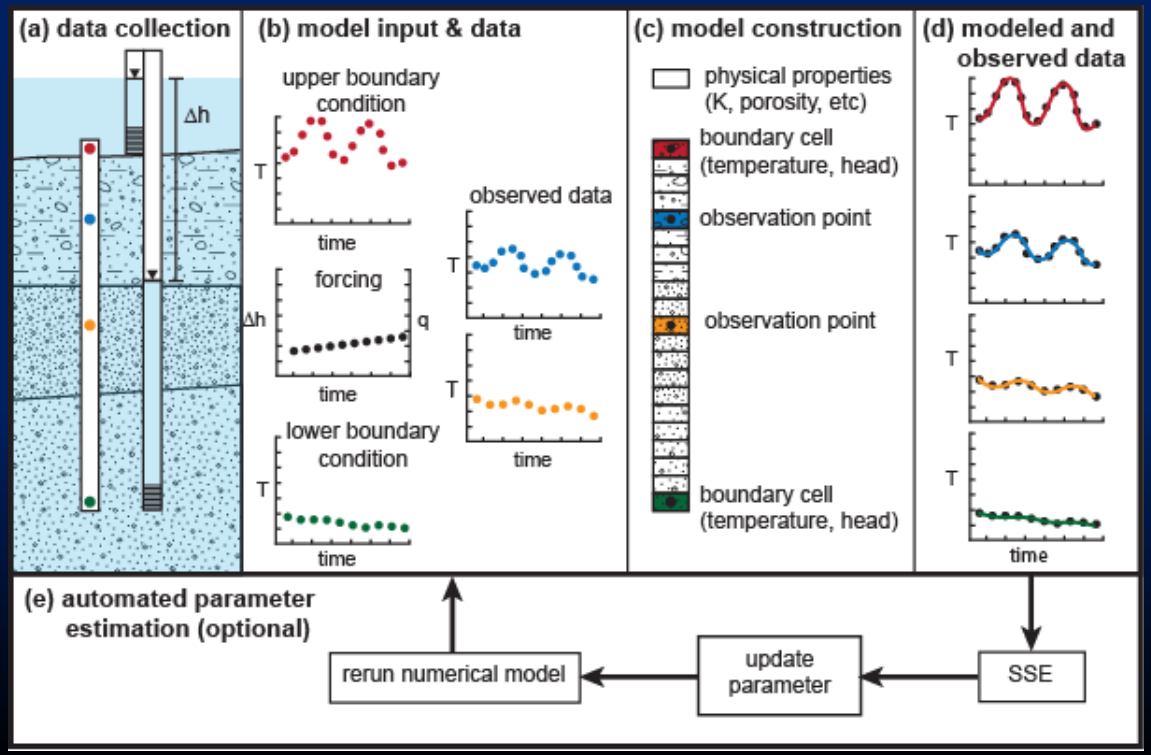


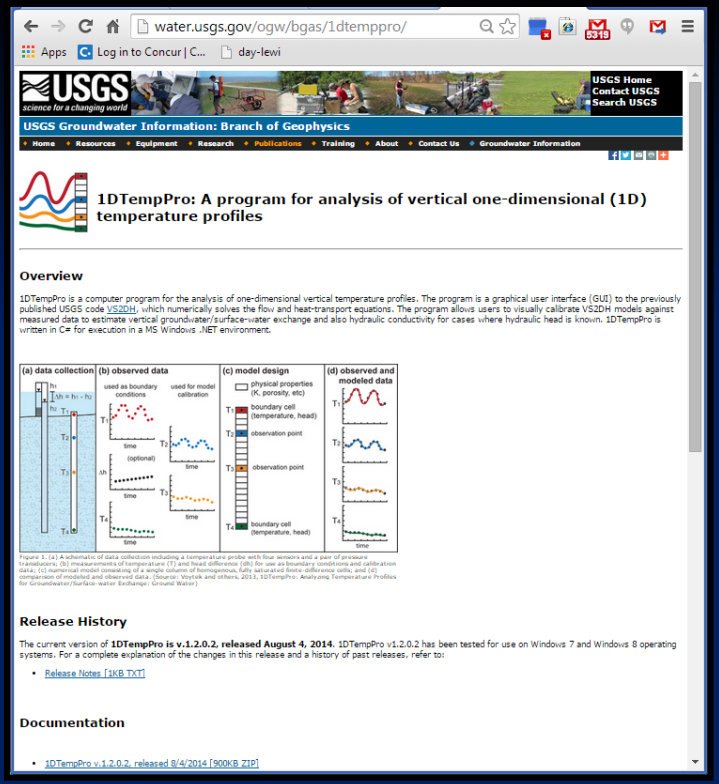


Briggs et al., ES&T, 2013

1DTempPro V2

- USGS software
- Calibrates heat transport model to determine vertical exchange
- Used VS2DH numerical model
- Exploring extension to unsaturated zone
- *http://water.usgs.gov/ogw/bgas/1dtemppro*

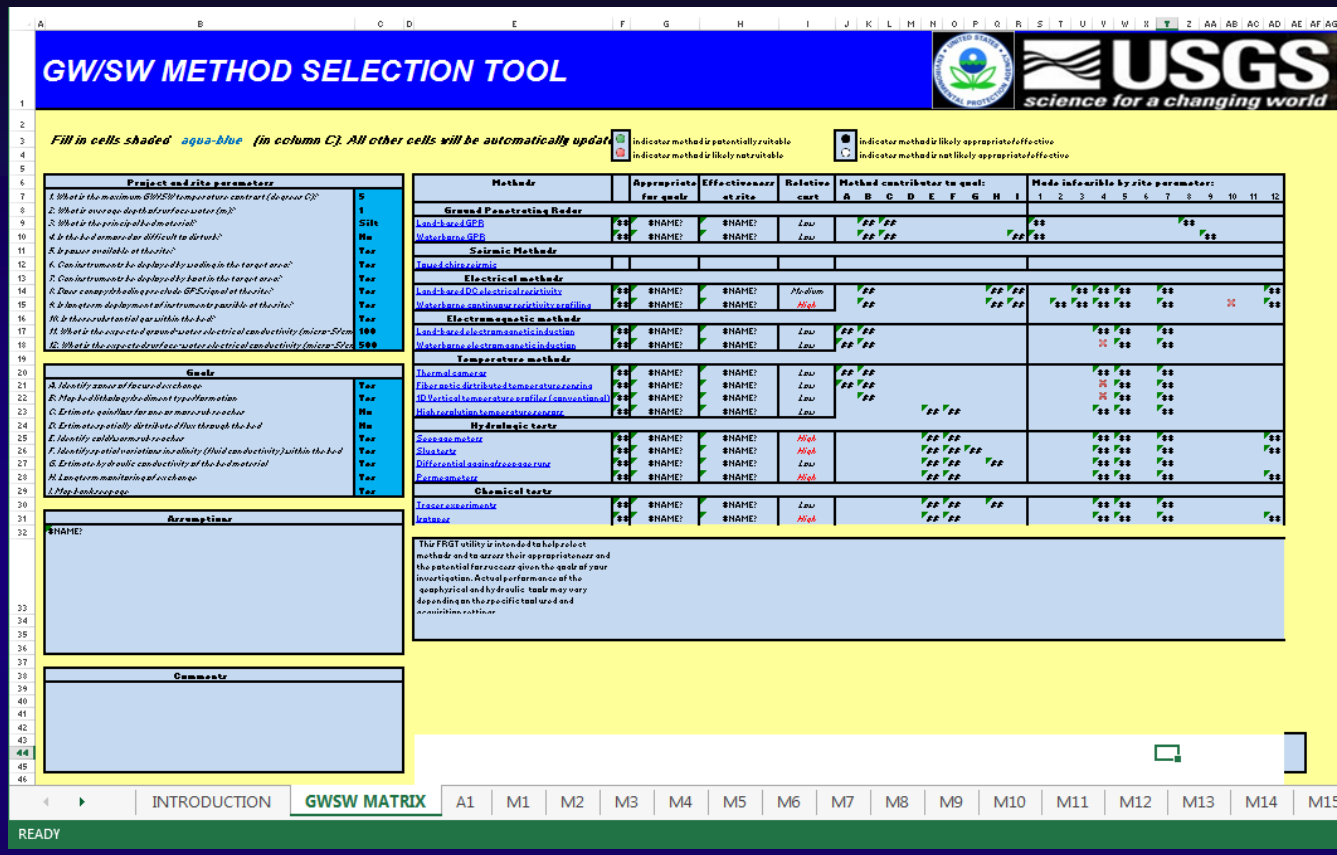




Koch et al., Groundwater, 2015

GWSW-MST

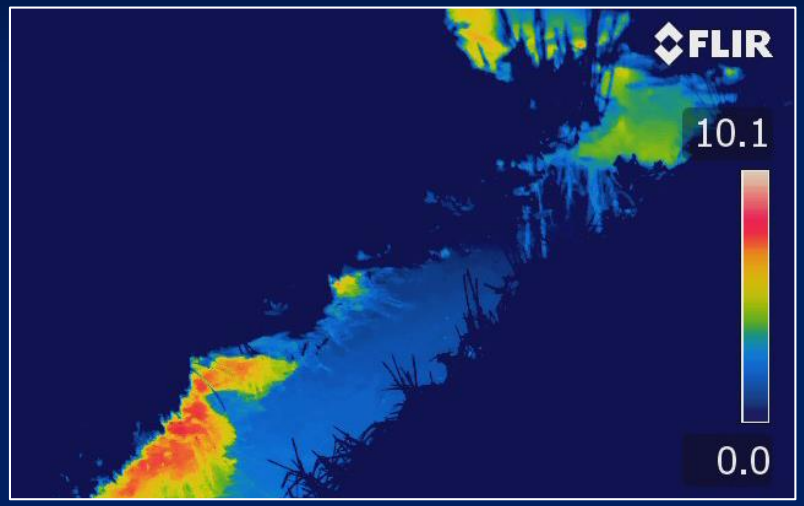
- Groundwater/ Surface Water Method Selection Tool
- Excel-based Decision Support System
- **Still in active development**

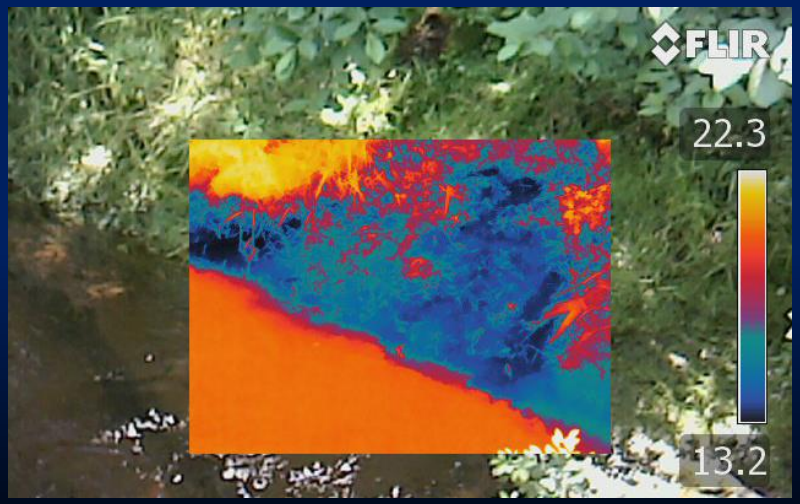


Similar to the Fractured Rock Ggeophysical Toolbox Method Selection Tool (*Day-Lewis et al., 2016, Groundwater*)

Conclusions

- Geophysical methods can contribute:
  - Qualitative and recon information for early conceptual system understanding
  - Higher resolution and greater coverage → gaps in space
  - Repeat snapshots or continuous monitoring → gaps in time
  - Quantitative information for fluxes, in the case of temperature
  - Thermal imaging – powerful technology amenable to UAS deployment
- http://water.usgs.gov/ogw/bgas





Acknowledgements

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