Monitoring Recharge with Time-Lapse Geophysics

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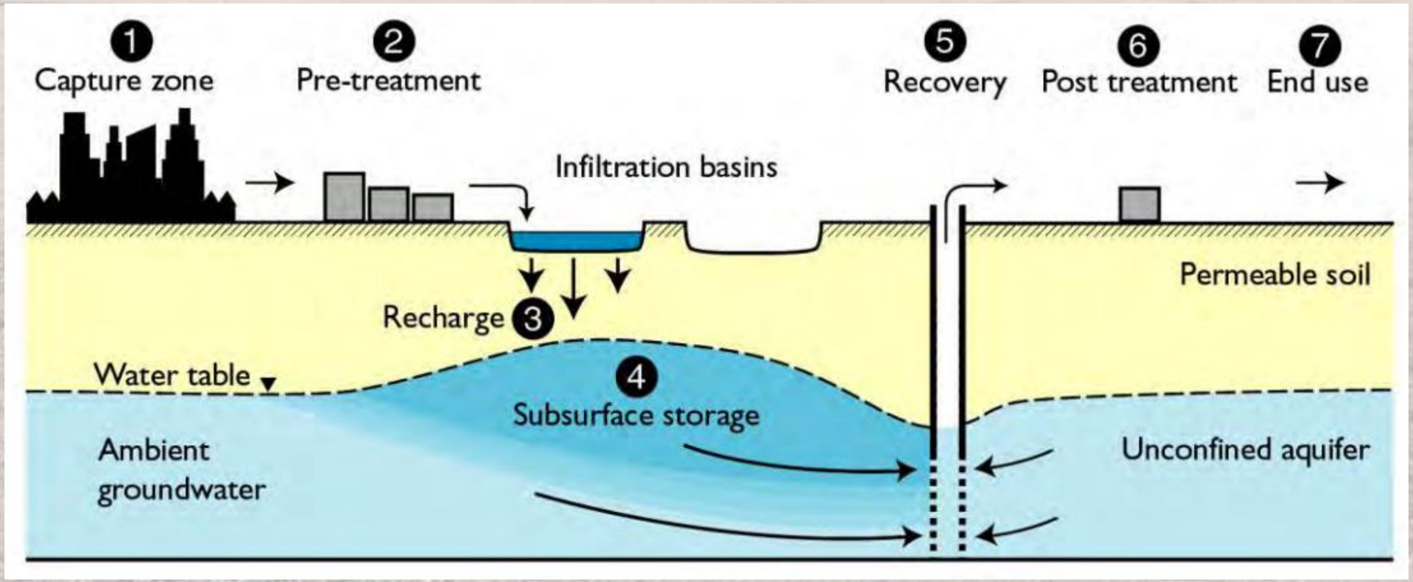
Engineered Groundwater Systems

Goals of MAR:

- Improve water quality
- Make water available at a later time



Graphic modified from: Peter Dillon, 2005

Engineered Groundwater Systems

Geophysics for Managed Aquifer Recharge

Key research questions:

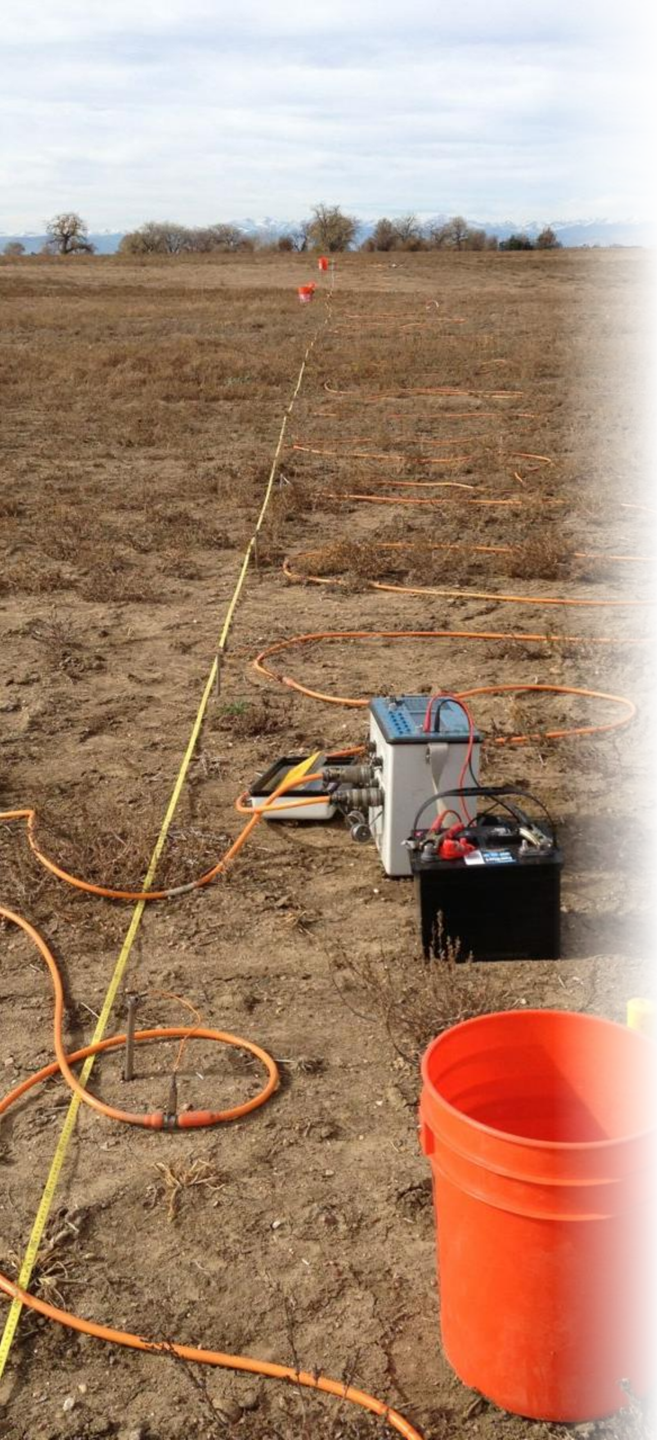
- Where does the water go after infiltration?
- How can extracted water quality and quantity be maximized?

Engineered Groundwater Systems

Geophysics for Managed Aquifer Recharge

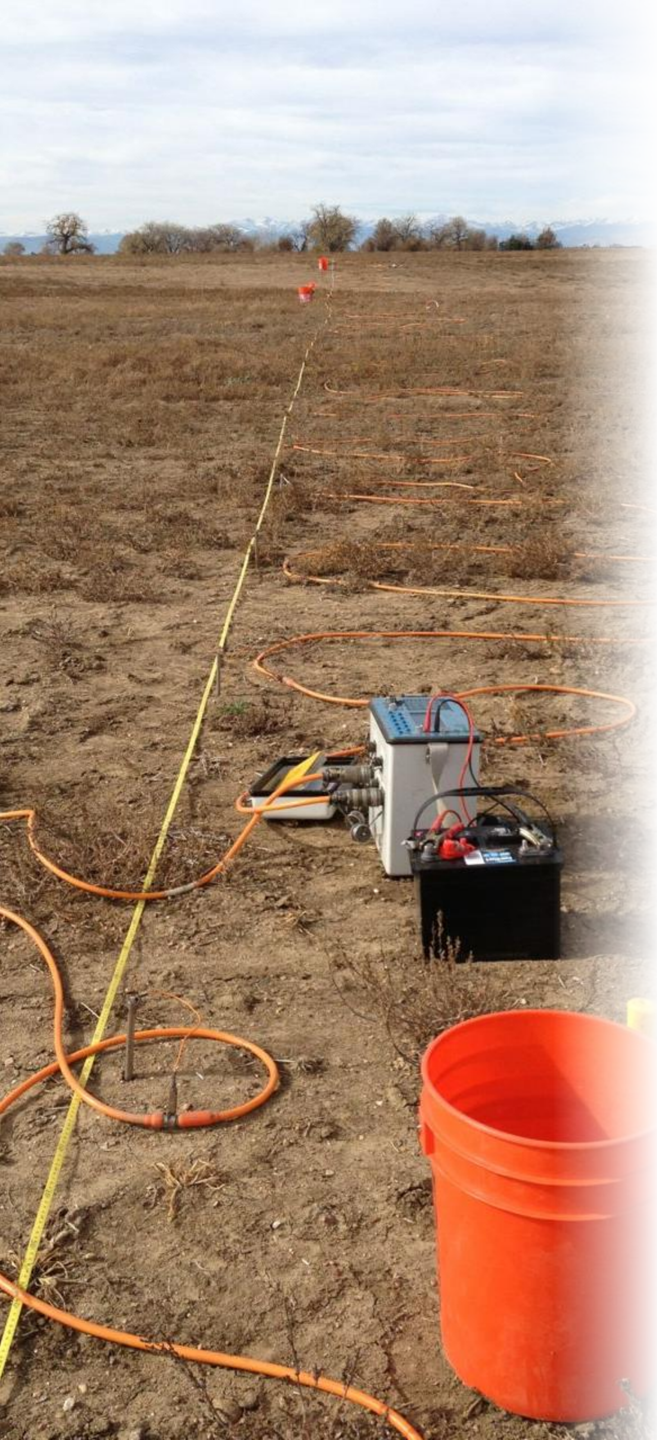
Key research questions:

- Where does the water go after infiltration?
  - *Lithology, permeable units, clay layers*
- How can extracted water quality and quantity be maximized?
  - *Optimized infiltration/extraction*



Why use geophysics?

Probing, drill cuttings, hydrologic observation, pumping tests, etc. can provide local information



Why use geophysics?

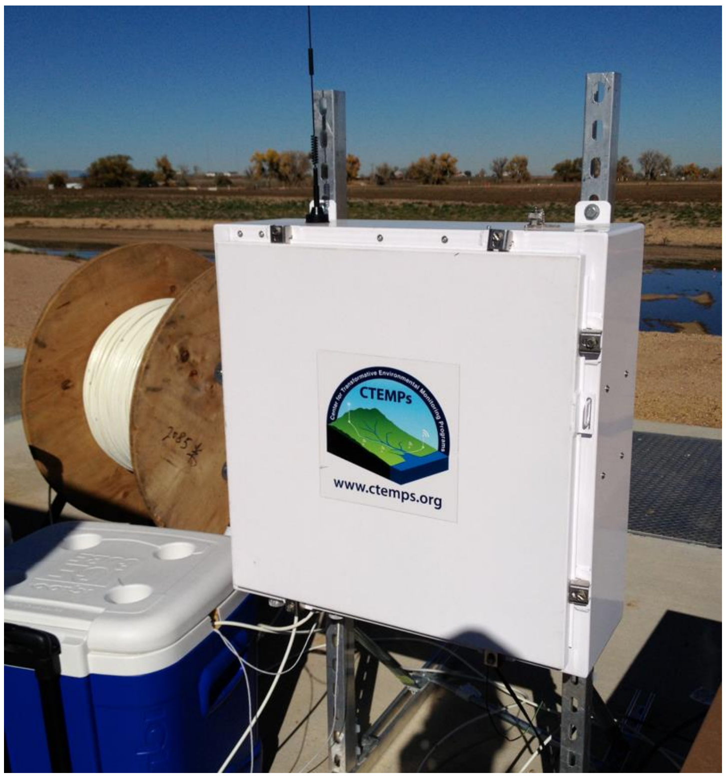
Probing, drill cuttings, hydrologic observation, pumping tests, etc. can provide local information

Geophysical measurements…

- extend observations over larger areas
- estimate parameters that are difficult to measure

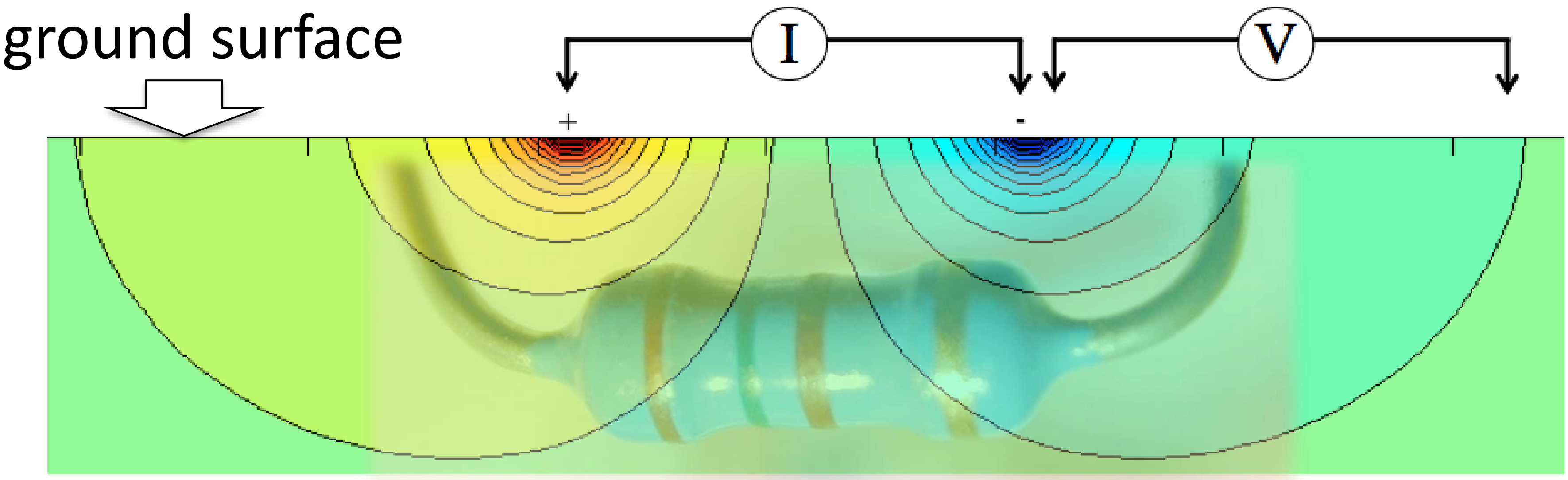
Brief Background of Geophysical Methods

Distributed Temperature Sensing (DTS)



Electrical Resistivity Tomography (ERT) Imaging

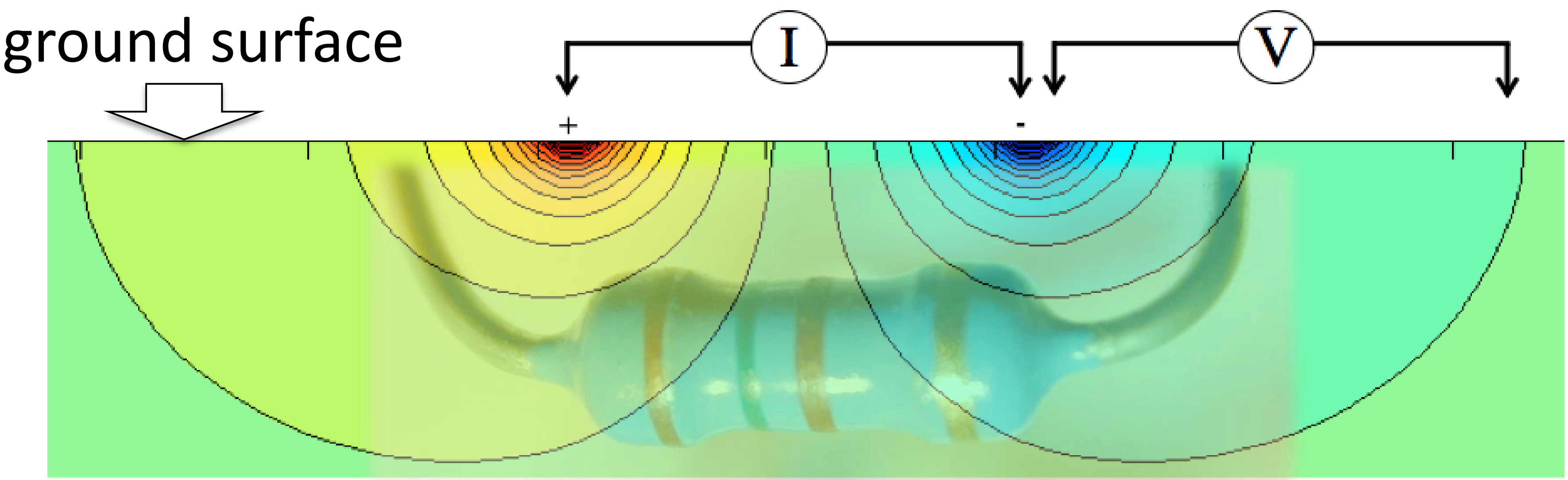
Electrical Resistivity Tomography (ERT)



Electrical Resistivity Tomography (ERT)

Generally:

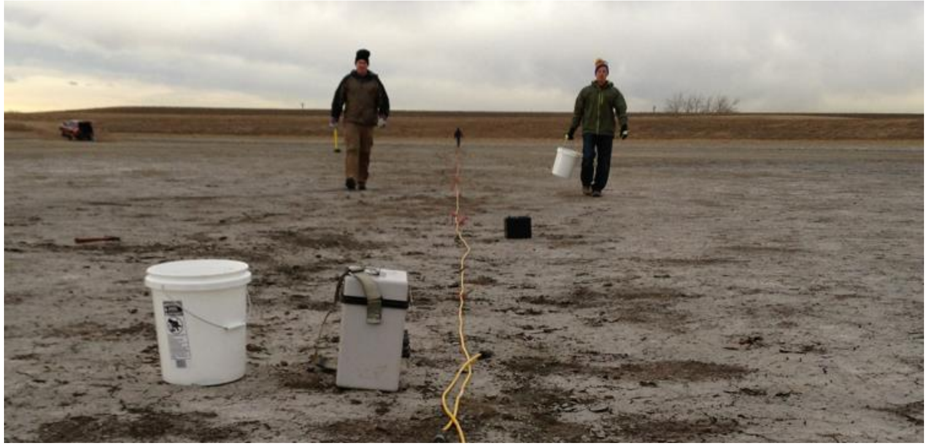
- *more resistive* sediments are drier
- *less resistive* sediments are wetter
- Repeated imaging through time reveals infiltration

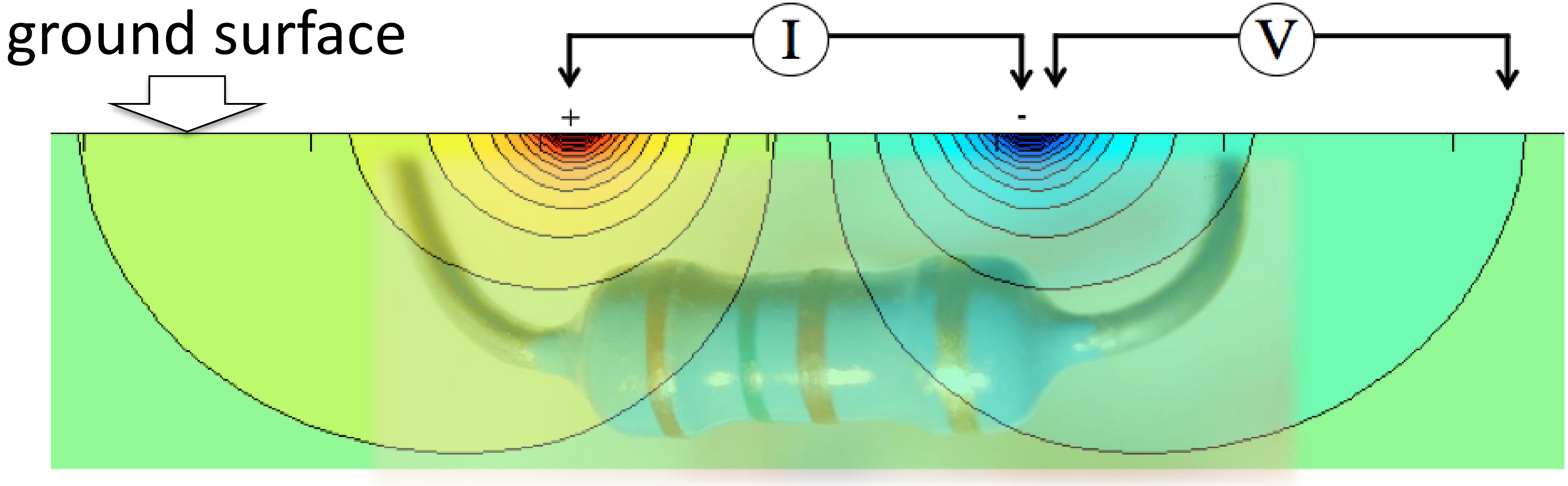


Electrical Resistivity Tomography (ERT)

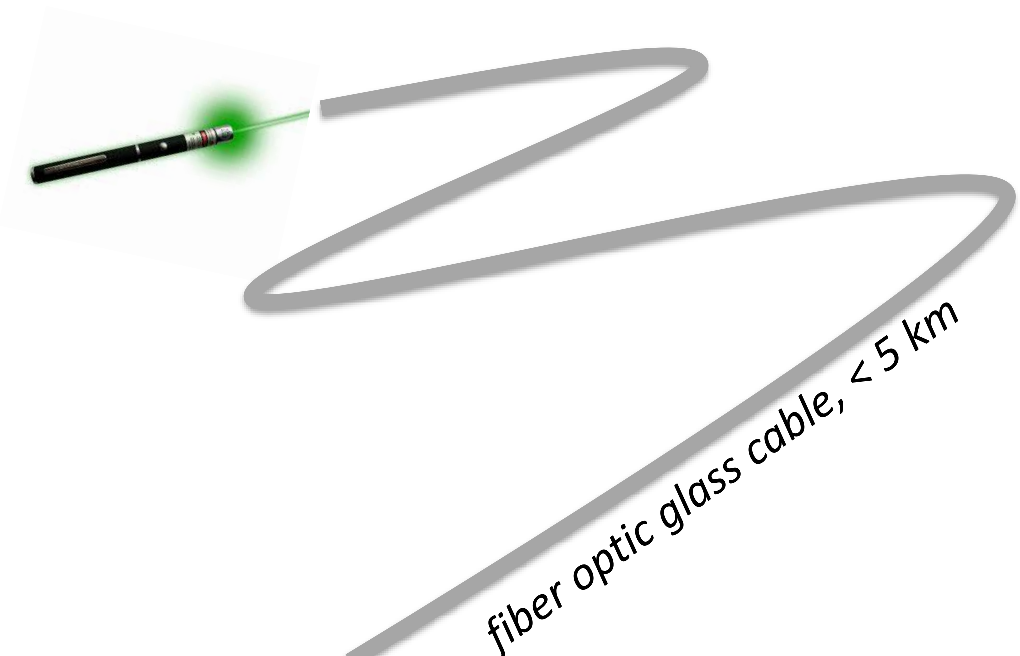
←Vertical probes

Surface cables →

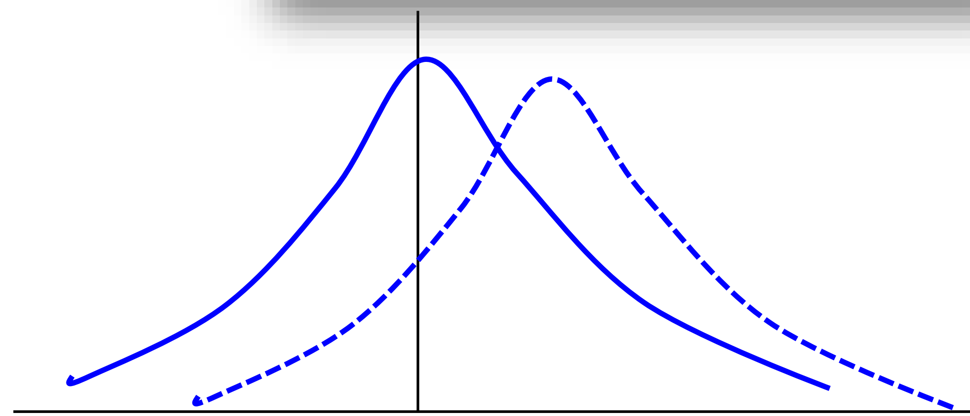




Distributed Temperature Sensor (DTS)

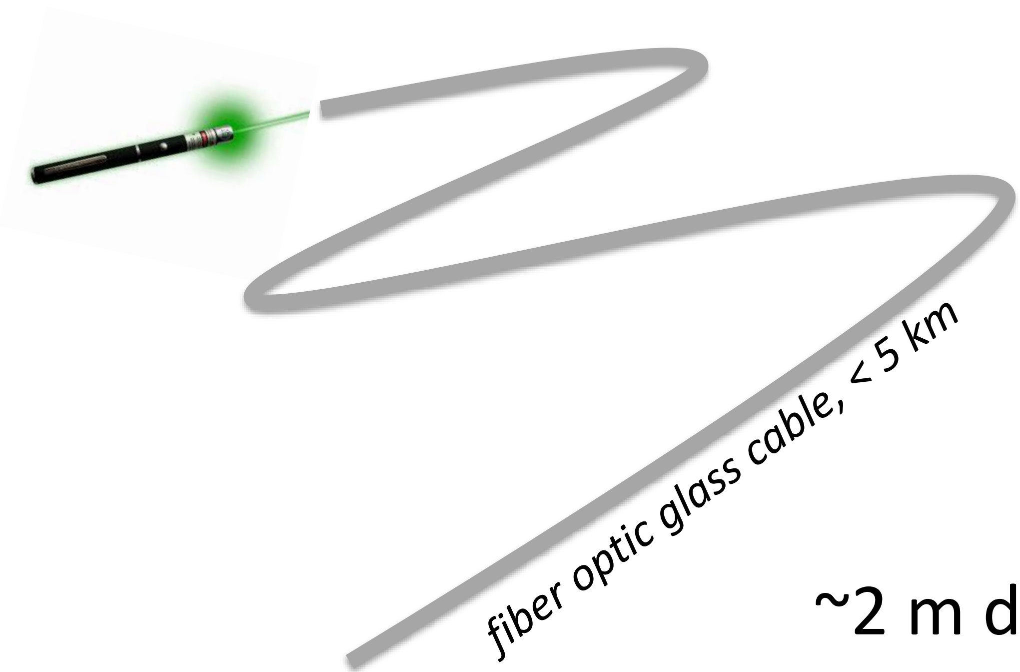


Time-of-flight:
<u>distance along cable</u>



Backscattered light phase shift: <u>temperature</u>

Distributed Temperature Sensor (DTS)



~2 m distance resolution

< 0.1 C temperature resolution

~5 min time resolution

Tracking thermal 'tracer' vertically over time gives infiltration rate

Example: Tracking water movement

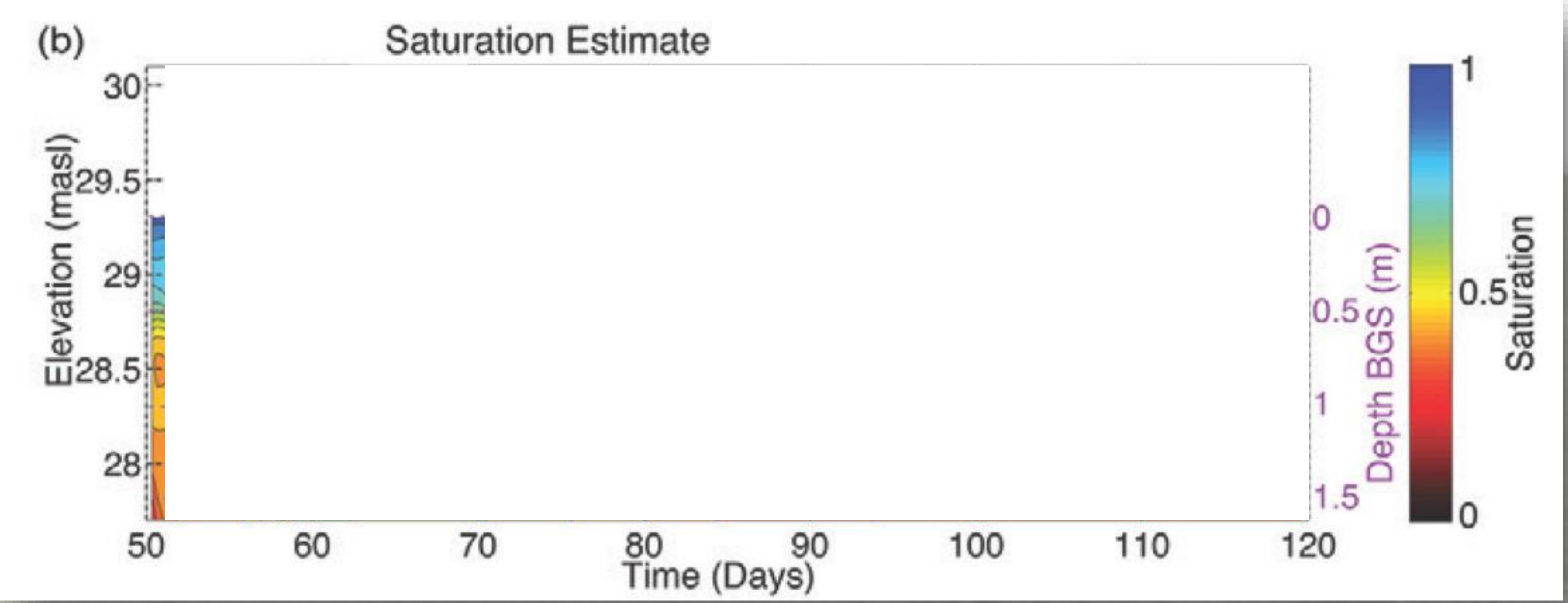
Why? Want to know where water goes after infiltration.

How? Time lapse resistivity probes.

Installing vertical resistivity probe in MAR basin

Example: Tracking water movement

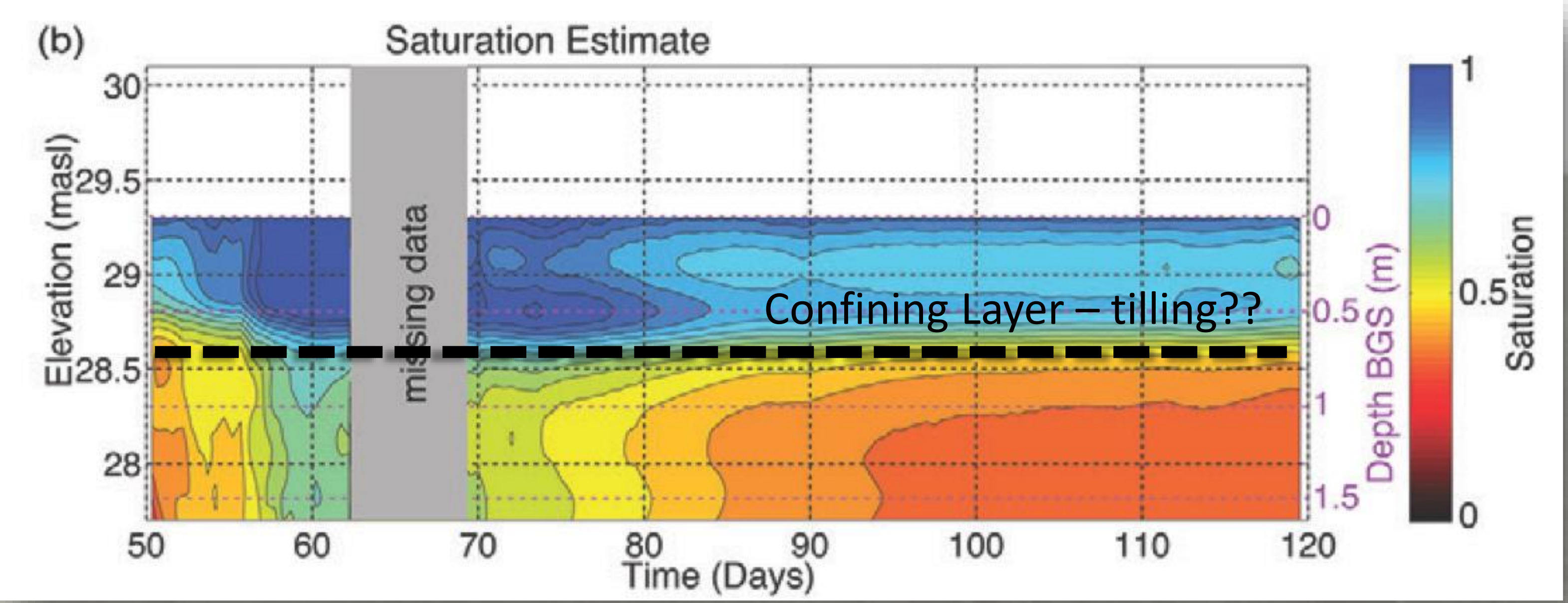
Vertical electrical resistivity probe



Pidlisecky et al., 2012 (VZJ)

Example: Tracking water movement

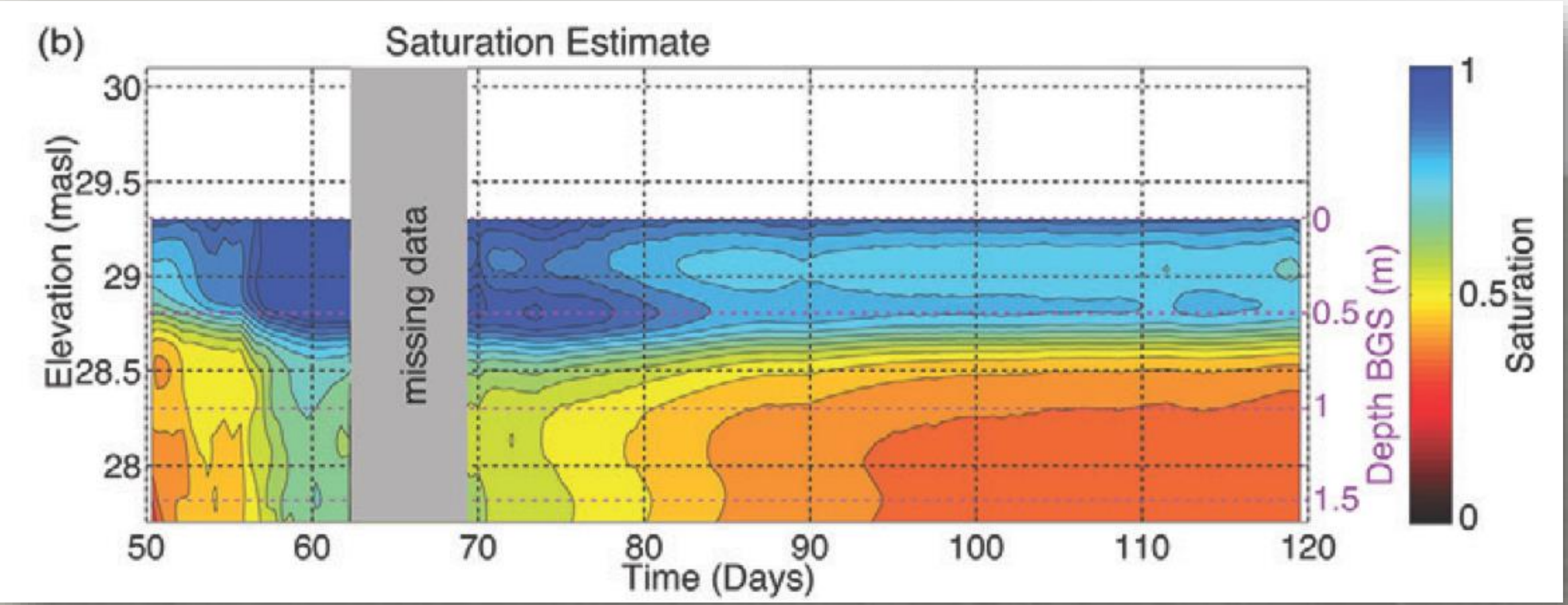
Vertical electrical resistivity probe



Pidlisecky et al., 2012 (VZJ)

Example: Tracking water movement

Vertical electrical resistivity probe

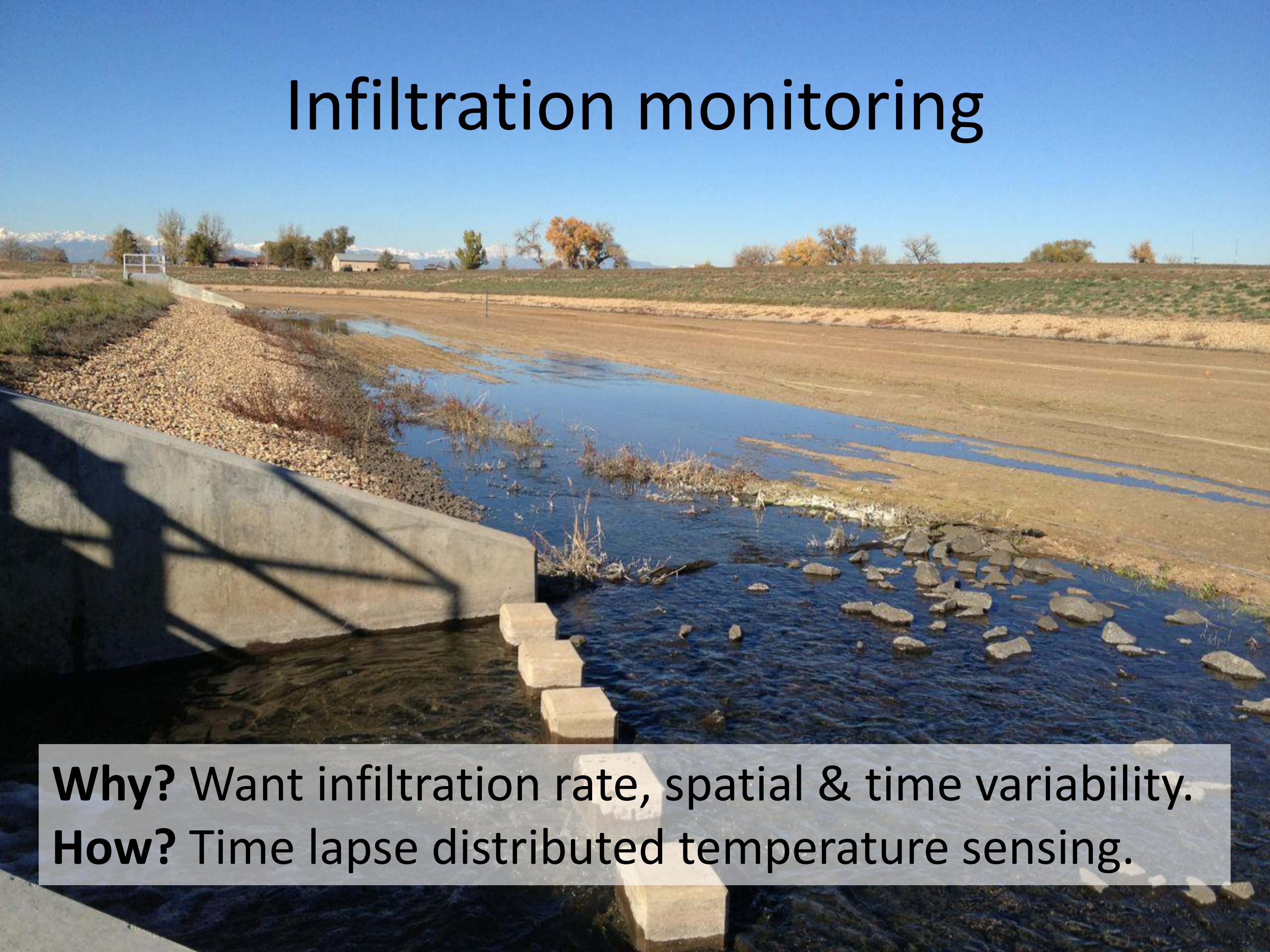


RESULTS:

- Identify barriers to flow
- Estimate residence time
- Visualize vertical water movement

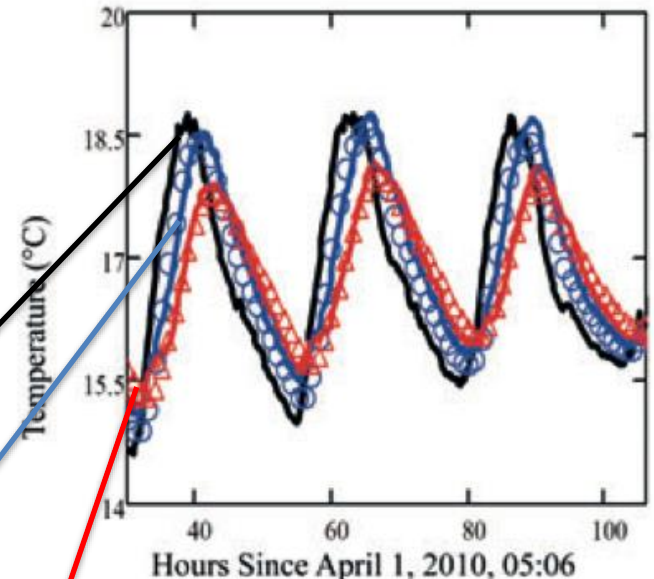
Pidlisecky et al., 2012 (VZJ)

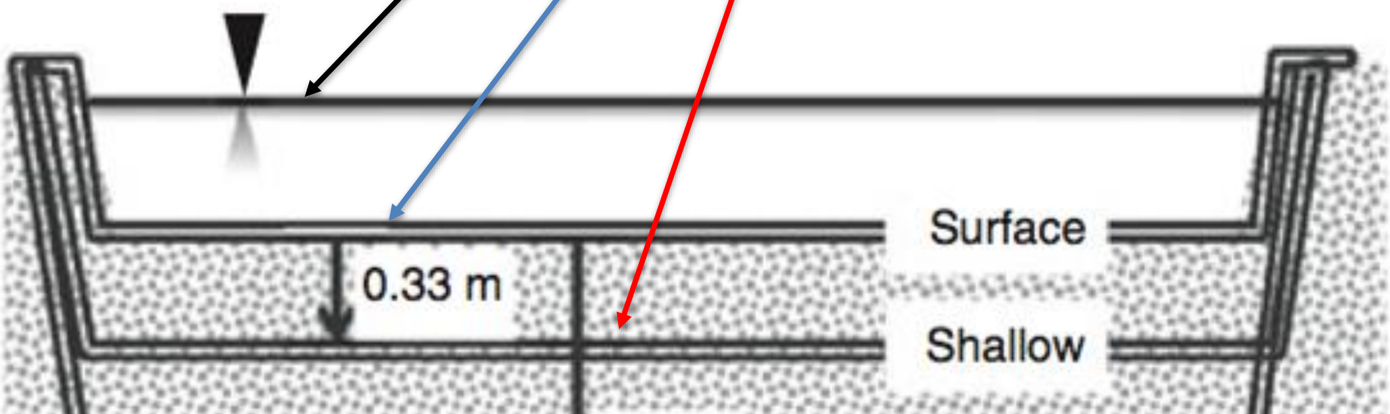
Infiltration monitoring



Why? Want infiltration rate, spatial & time variability.
How? Time lapse distributed temperature sensing.

Infiltration monitoring with DTS

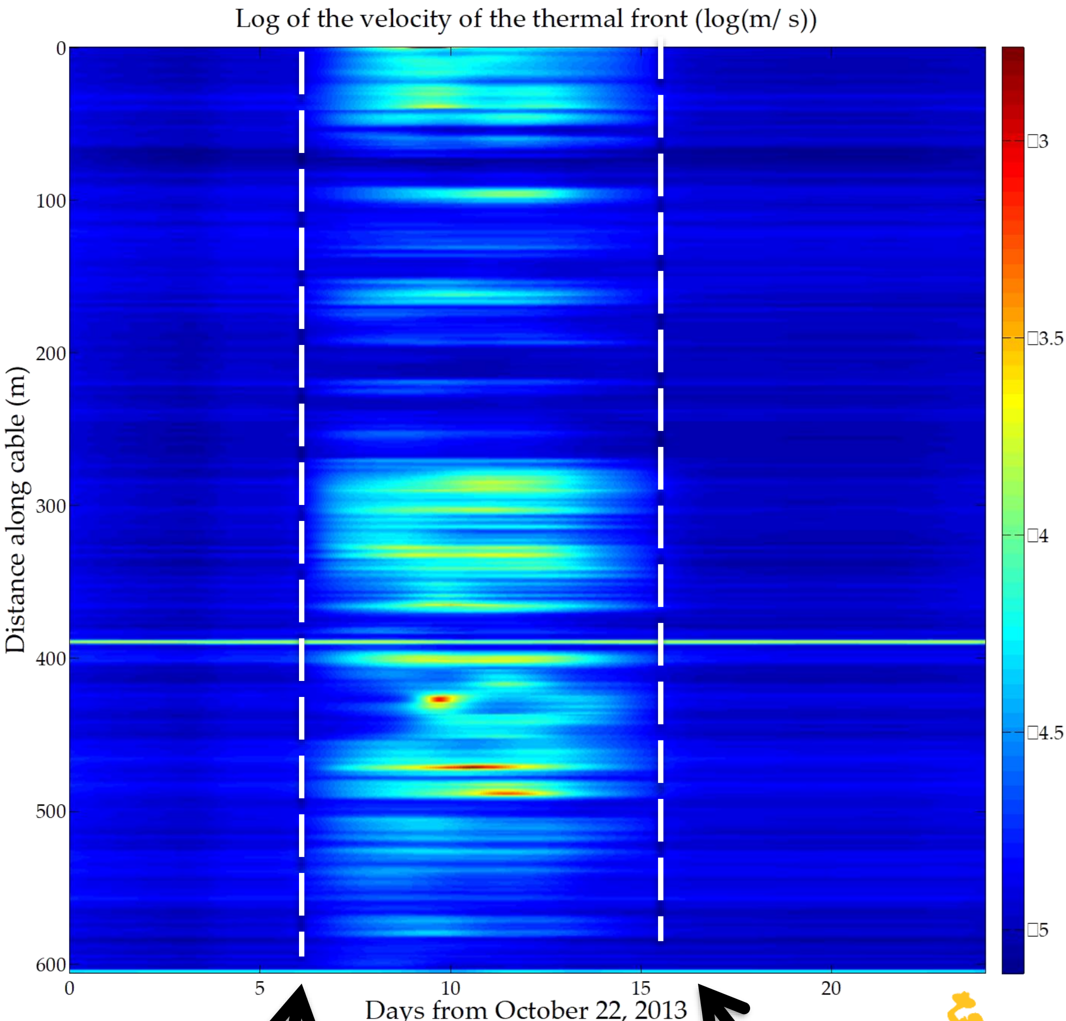




Becker et al., 2013 (Groundwater)

Time Lapse Infiltration Data

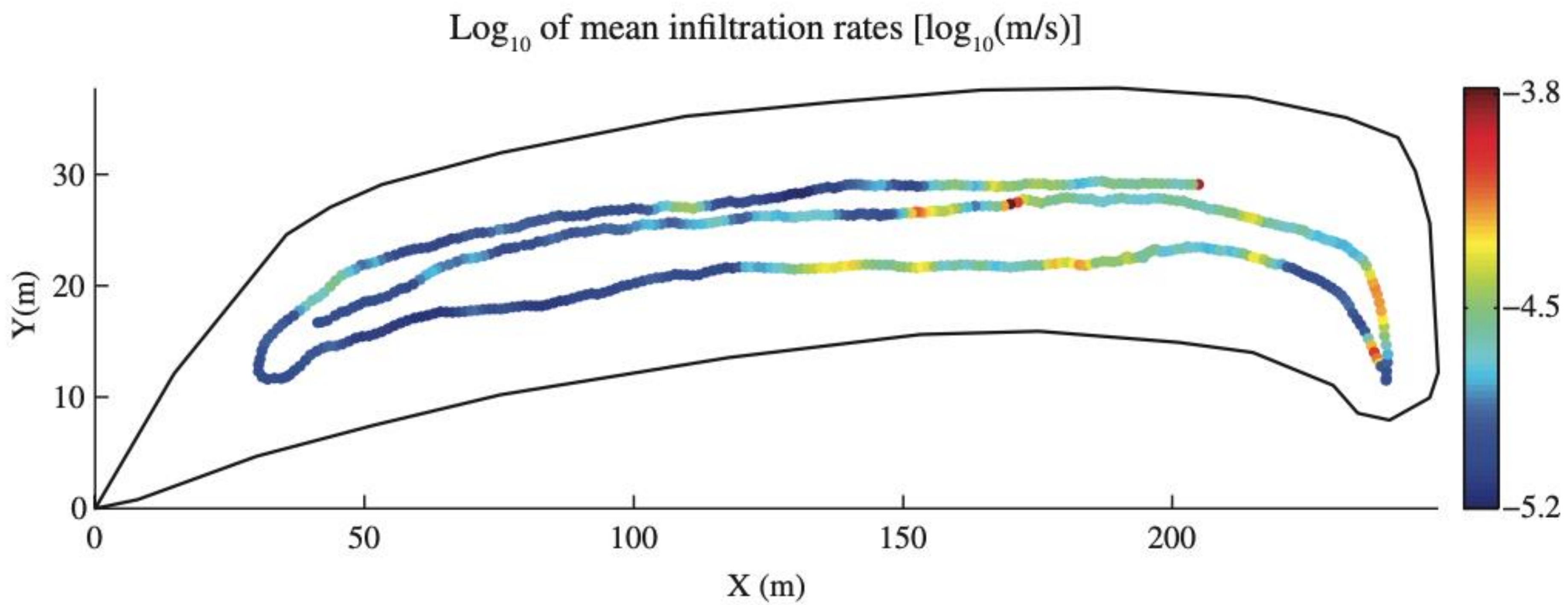
Installing fiber optic cable



start filling basin

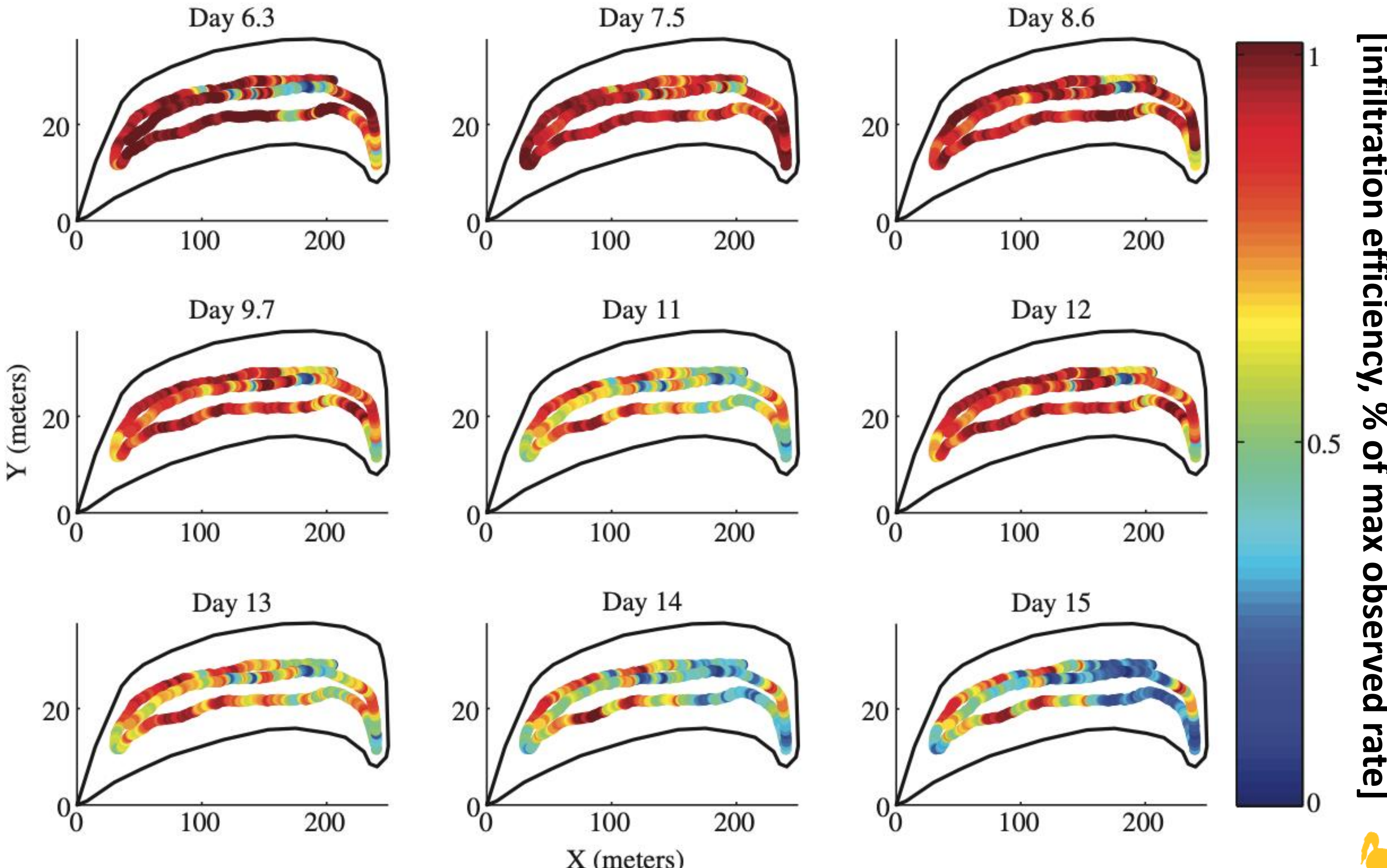
drain basin

Infiltration rate spatial heterogeneity



Mawer, Parsekian, et al., *2016*

Tracking infiltration over time



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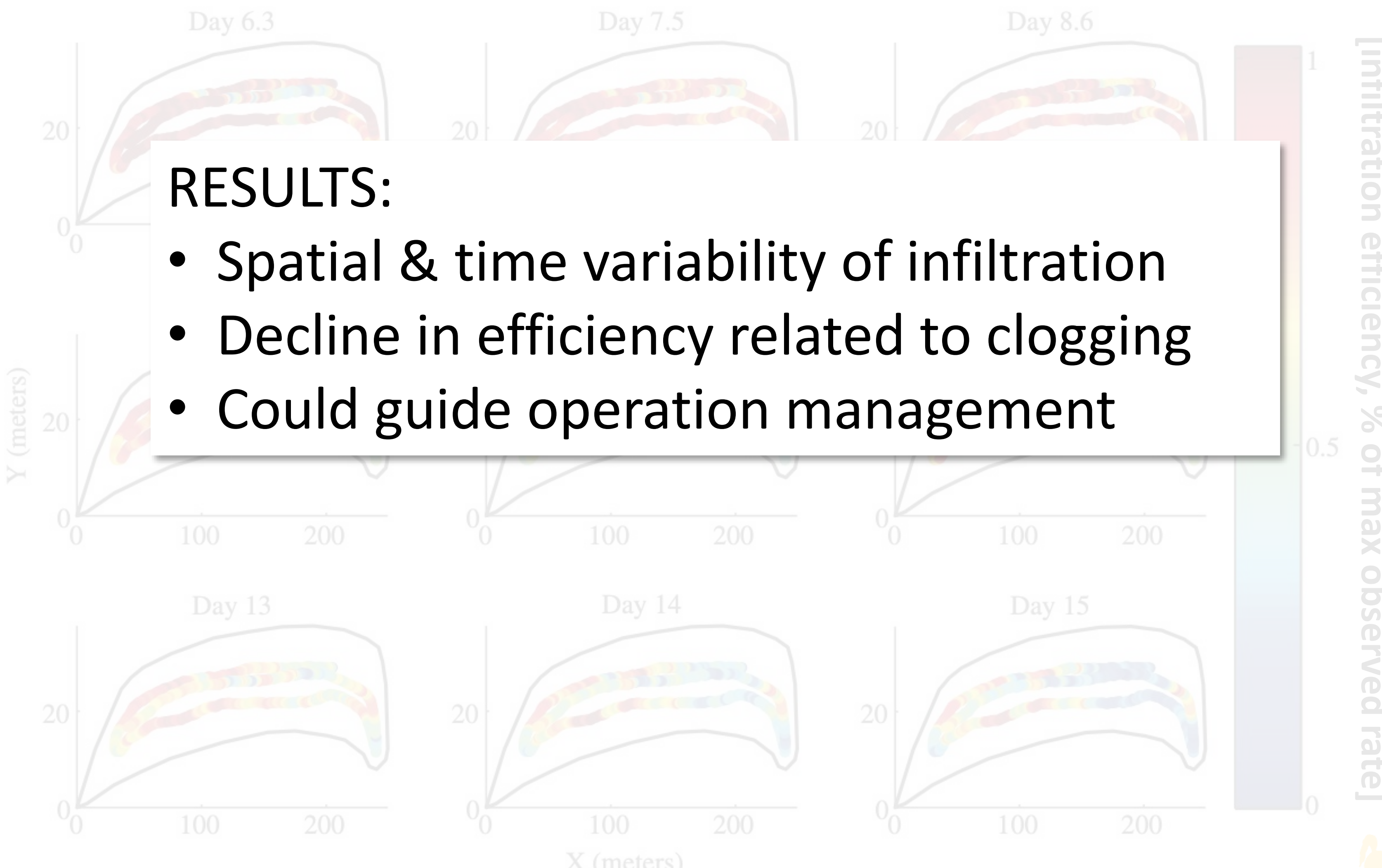
Tracking infiltration over time

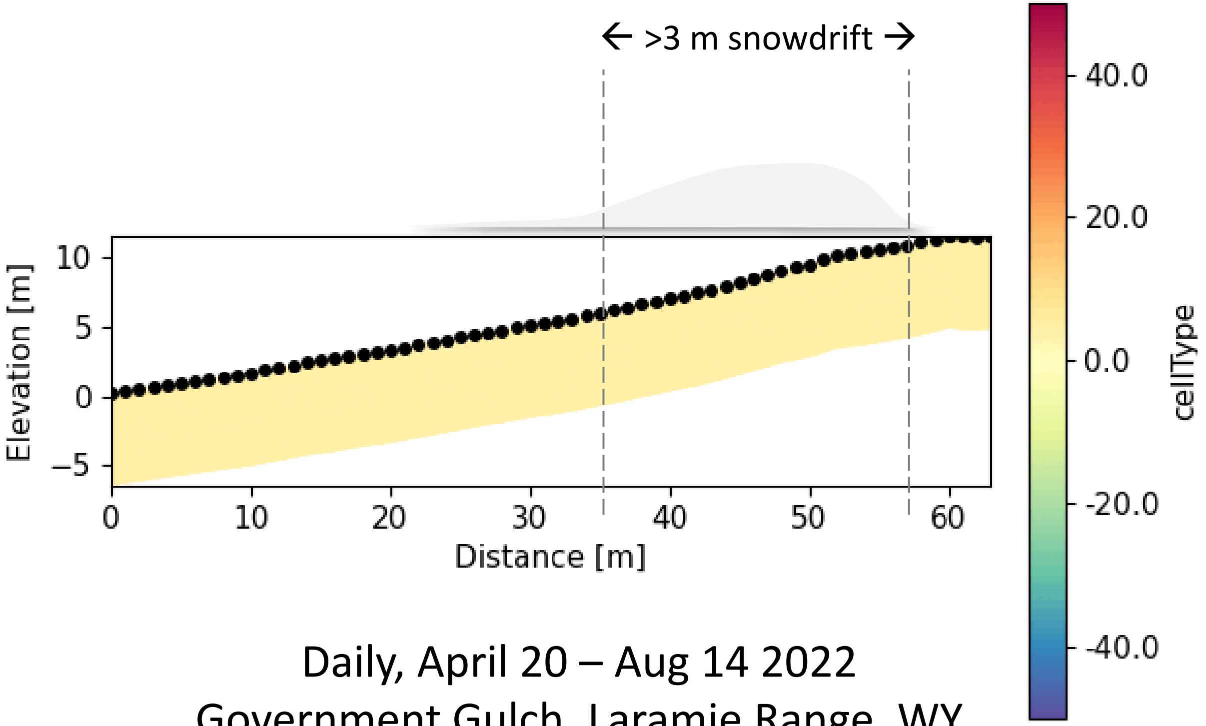


RESULTS:

- Spatial & time variability of infiltration
- Decline in efficiency related to clogging
- Could guide operation management

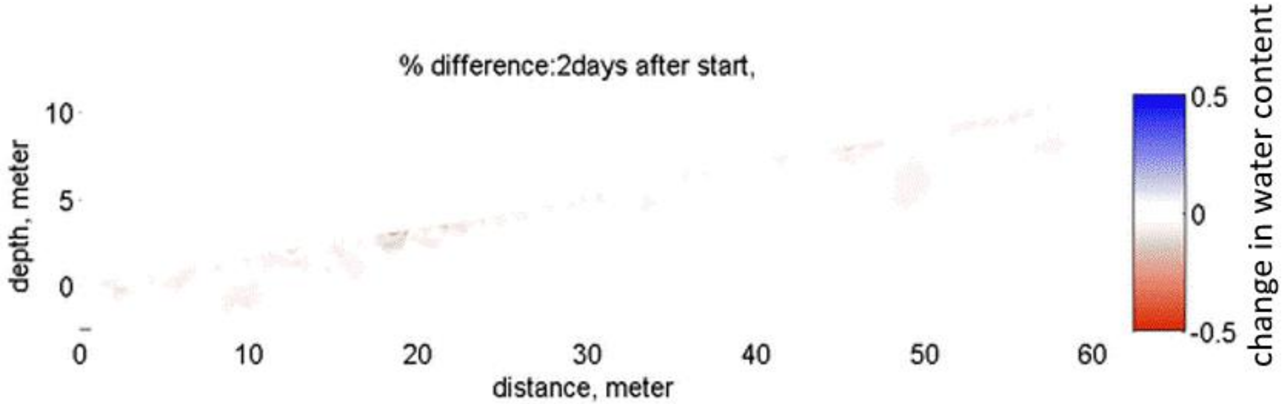
Mawer, Parsekian, et al., *2016*

“Low-cost” electrical imaging



Daily, April 20 – Aug 14 2022
Government Gulch, Laramie Range, WY

“Low-cost” electrical imaging



Kotikian, M., Parsekian, A. D., Paige, G., & Carey, A. (2019). Observing heterogeneous unsaturated flow at the hillslope scale using time-lapse electrical resistivity tomography. *Vadose Zone Journal*, *18*(1), 1-16.

Headquarters, Laramie Range

Let’s tie together these results

RECALL:

Key research questions:

- Where does the water go after infiltration?
  - DTS → where water enters the subsurface
  - ERT → subsurface flow rate, direction
- How can extracted water quality and quantity be maximized?
  - DTS → track infiltration efficiency
  - ERT/ER Probes → saturation/residence time

Thanks!

- NSF ReNUWIT Engineering Research Center
- Stanford UPS Research Fund

- **[Stanford]** Rosemary Knight, Chloe Mawer, Harry Lee, Dave Cameron, Nick Odlum
- **[CSM]** Jörg Drewes, Julia Regnery
- **[U Calgary]** Adam Pidlisecky
- **[Aurora Water]** Jason Lee, Ted Hartfelter
- **[CTEMPS/U. Nevada-Reno]** Scott Tyler

Collaborators

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