Hydraulic Tomography: Estimating 3-D Hydraulic Conductivity in a DNAPL-Contaminated Fractured Rock Aquifer, Newark Basin, New Jersey, USA

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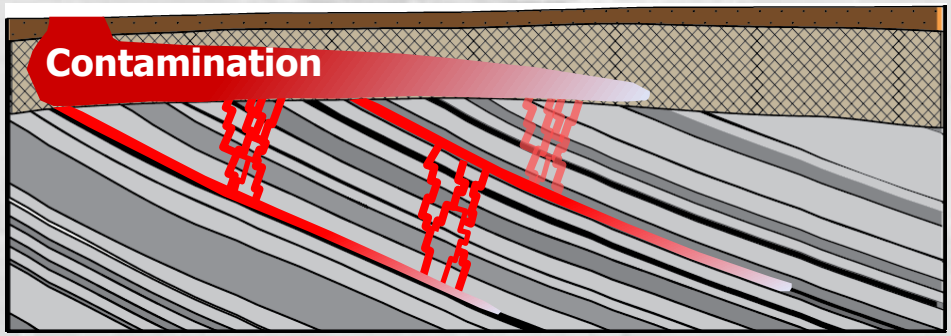
OUTLINE

- Motivation and Objectives
- Approach
  - Field
  - Modeling (Forward, Inverse)
- Results
- Next Steps

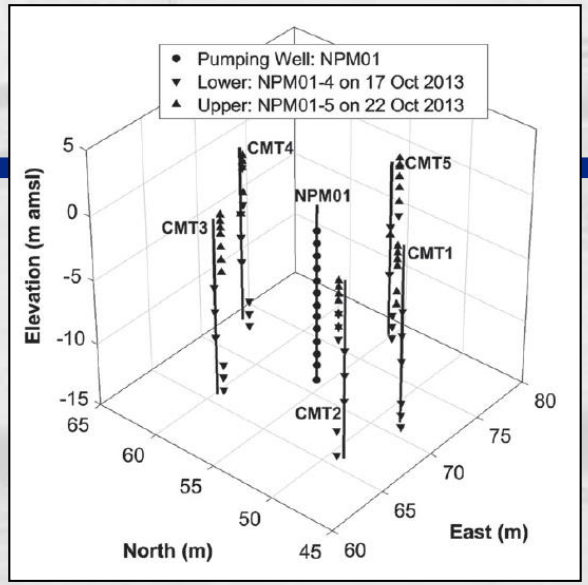
Motivation and Objectives

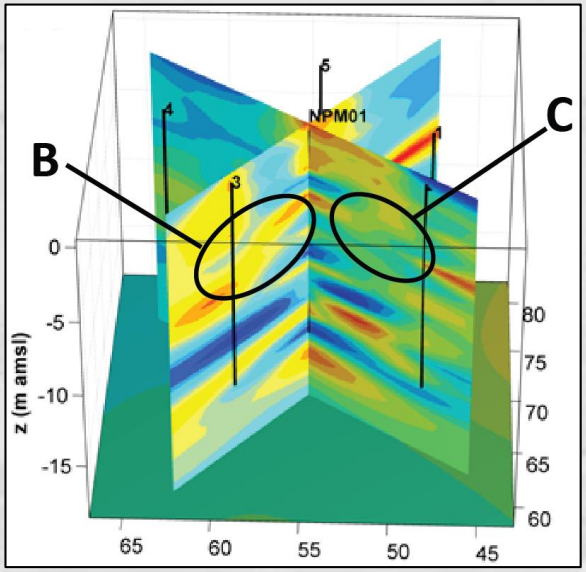
- In-Situ Remediation: Method selection, design, operation
- Issues: Extreme K heterogeneity, 3D fracture network
- Need:
  - Accurate modeling of flow and transport
  - Estimation of *actual* 3D K
  - Tractable field and modeling methods



Hydraulic Tomography (HT)

- Many pumping tests in discrete well intervals
- Monitor drawdown in all intervals





Hochstetler et al., 2016, Groundwater 54(2) 171-185.

Hydraulic Tomo

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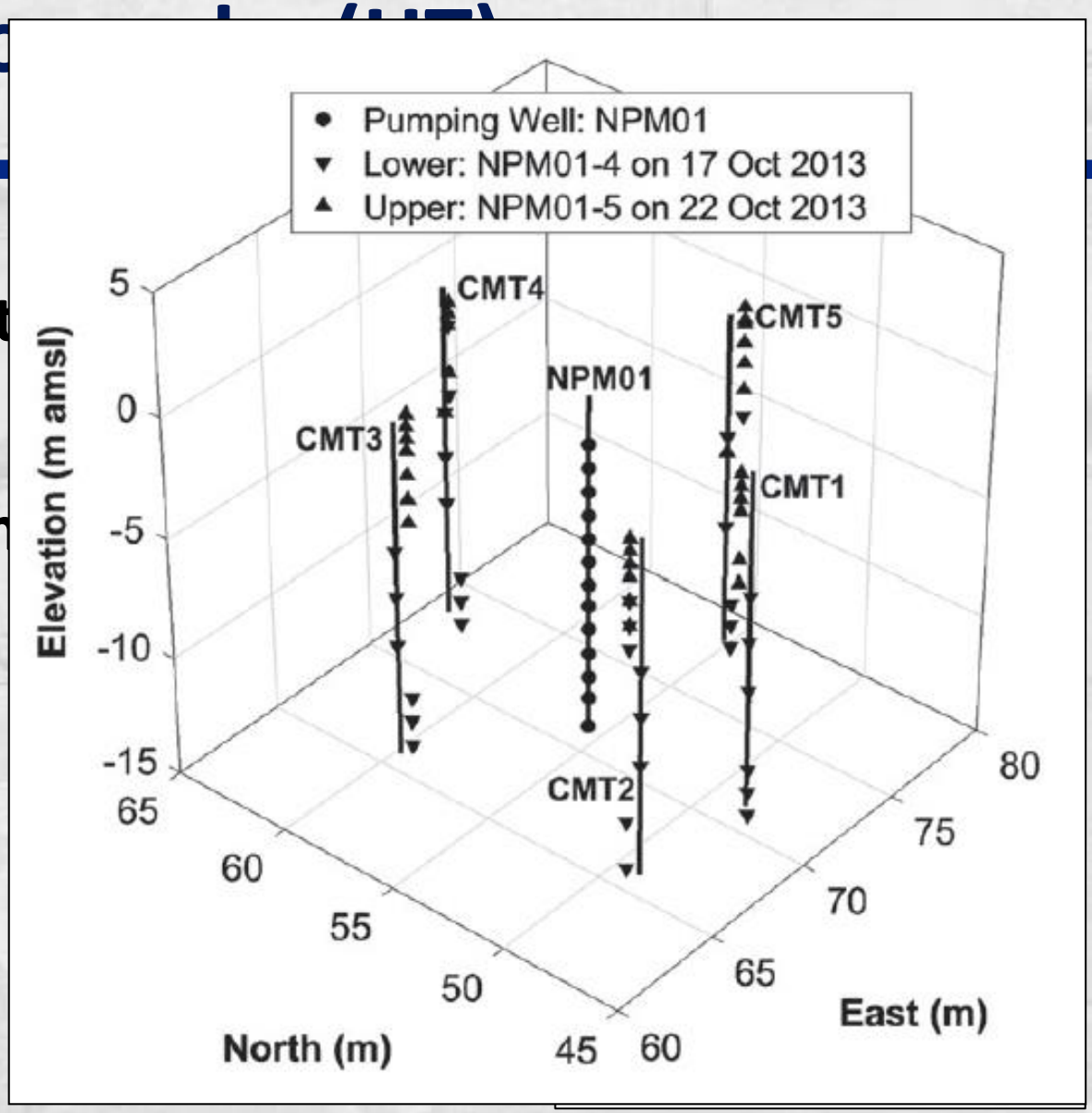

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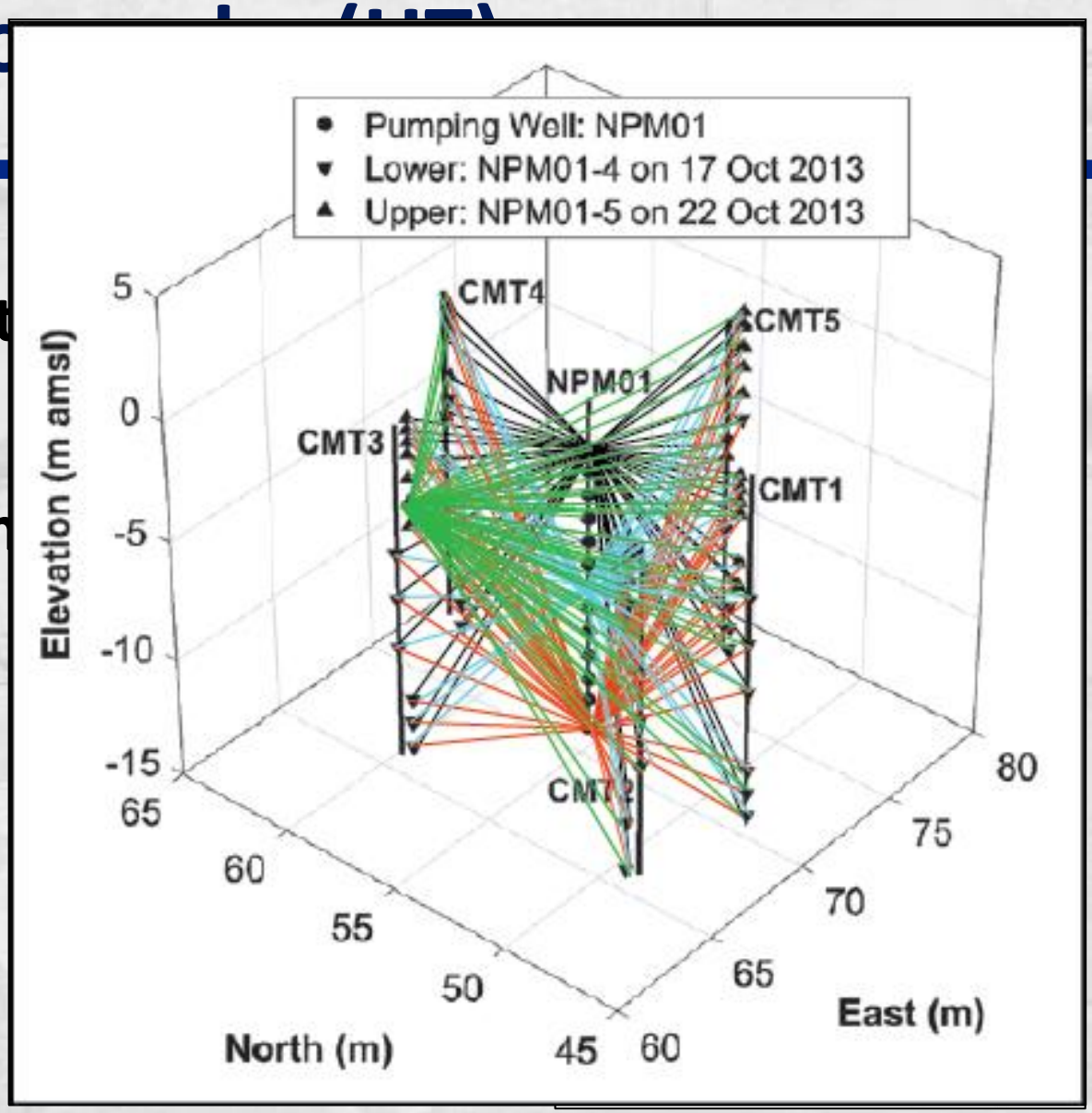

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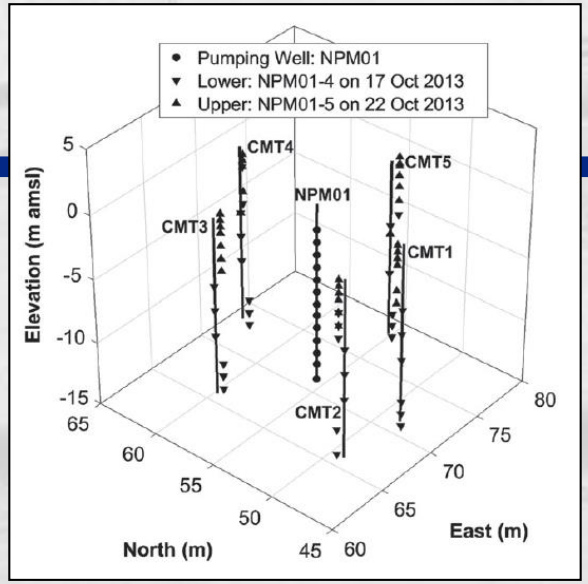
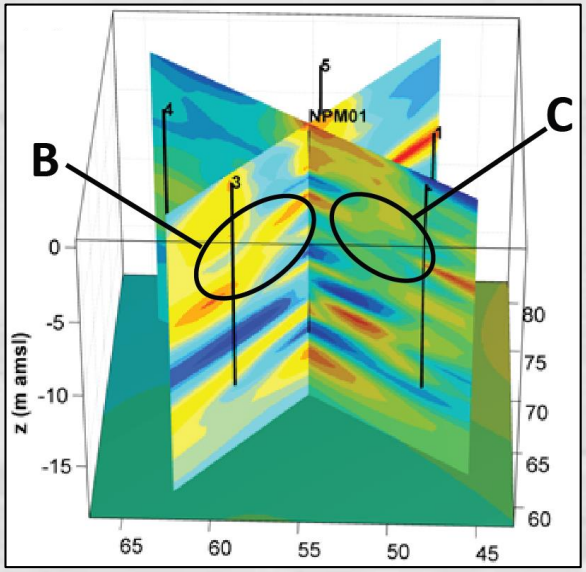
Hydraulic Tomography (HT)

- Many pumping tests in discrete well intervals
- Monitor drawdown in all intervals
- Simulate tests, run inverse modeling of all tests together
- Find 3D K, continuity-discontinuity





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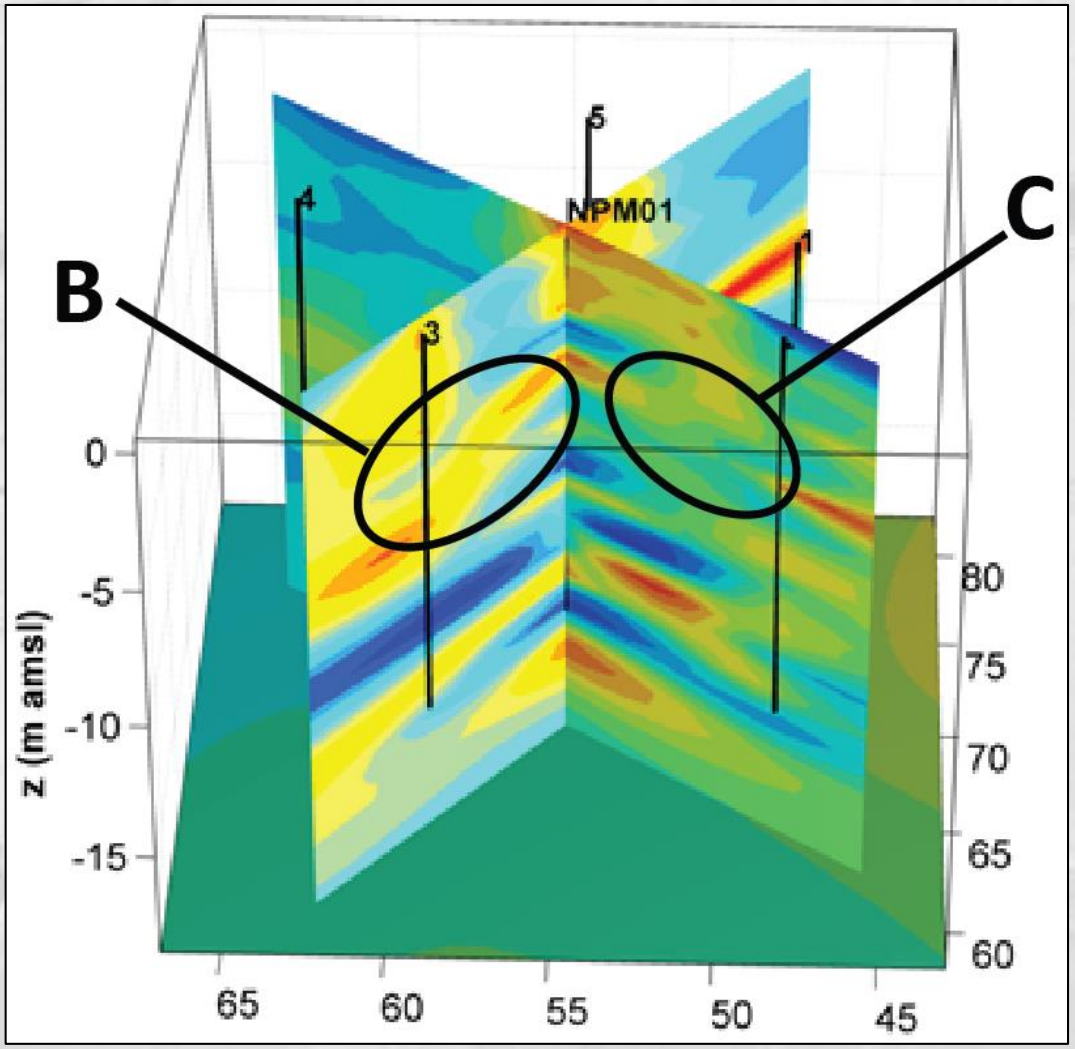
Hydraulic Tomography (HT)

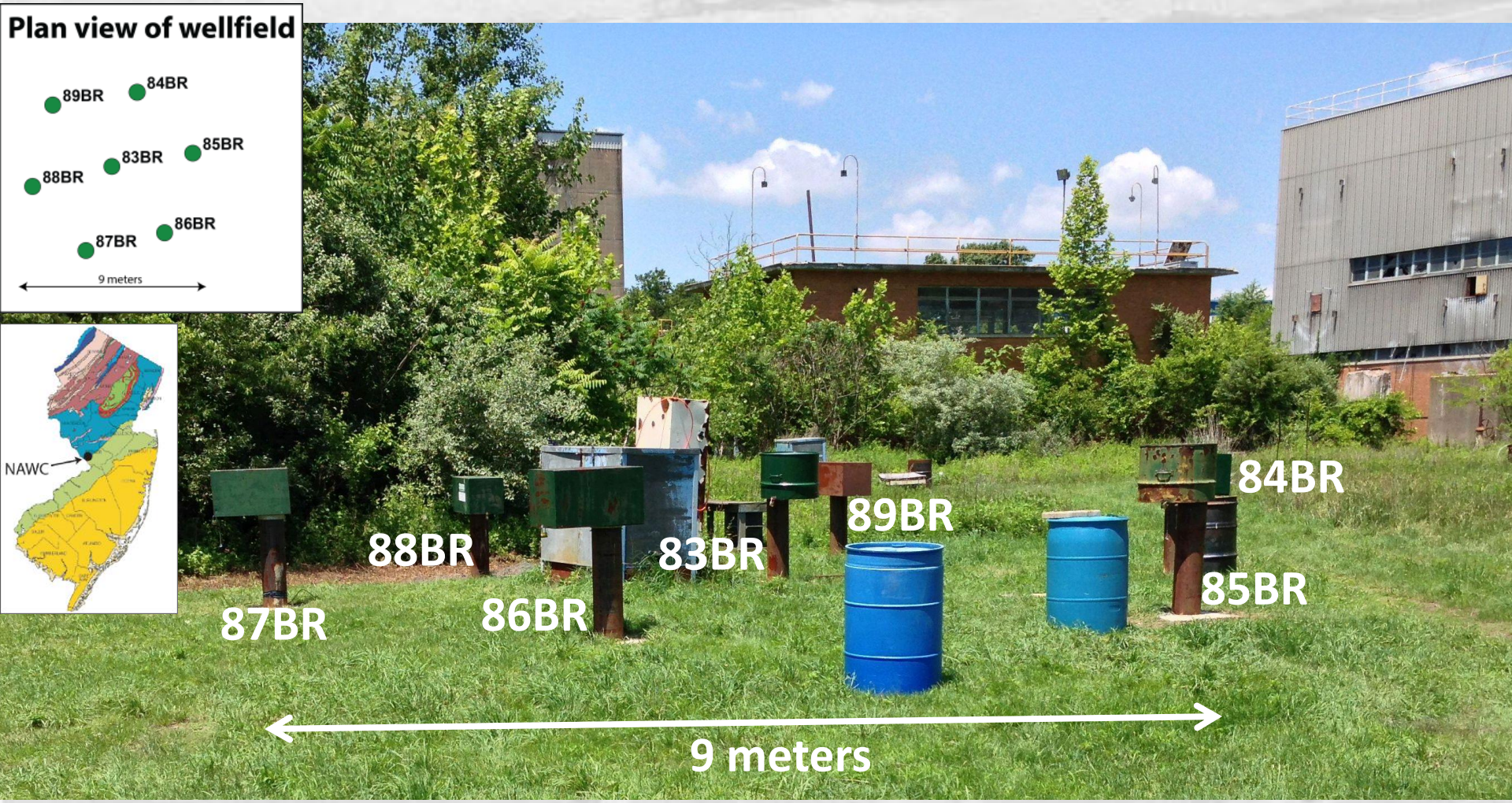
Clay to sd-grvl

- Continuity
- Discontinuity
- High contrast



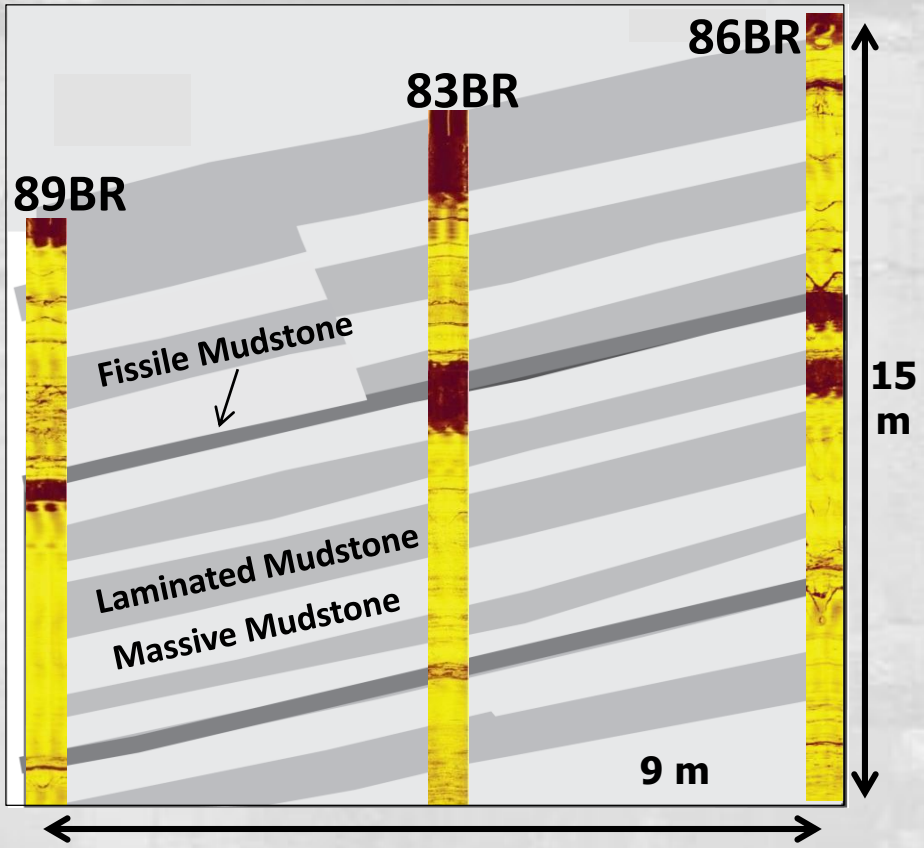
HT in a Fractured Aquifer

Former Naval Air Warfare Center (NAWC), New Jersey



HT testing in fractured aquifers

- Open wells – breakouts, zonation and packer configurations
- Pumping tests – Q range, high-resolution measurements



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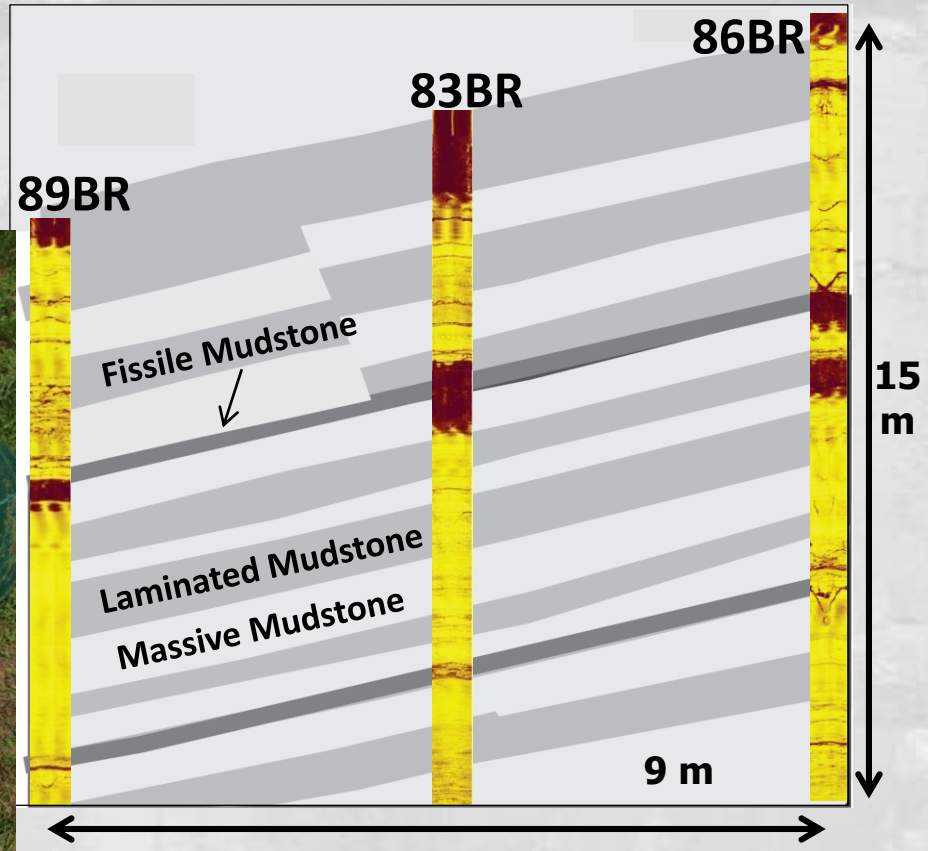
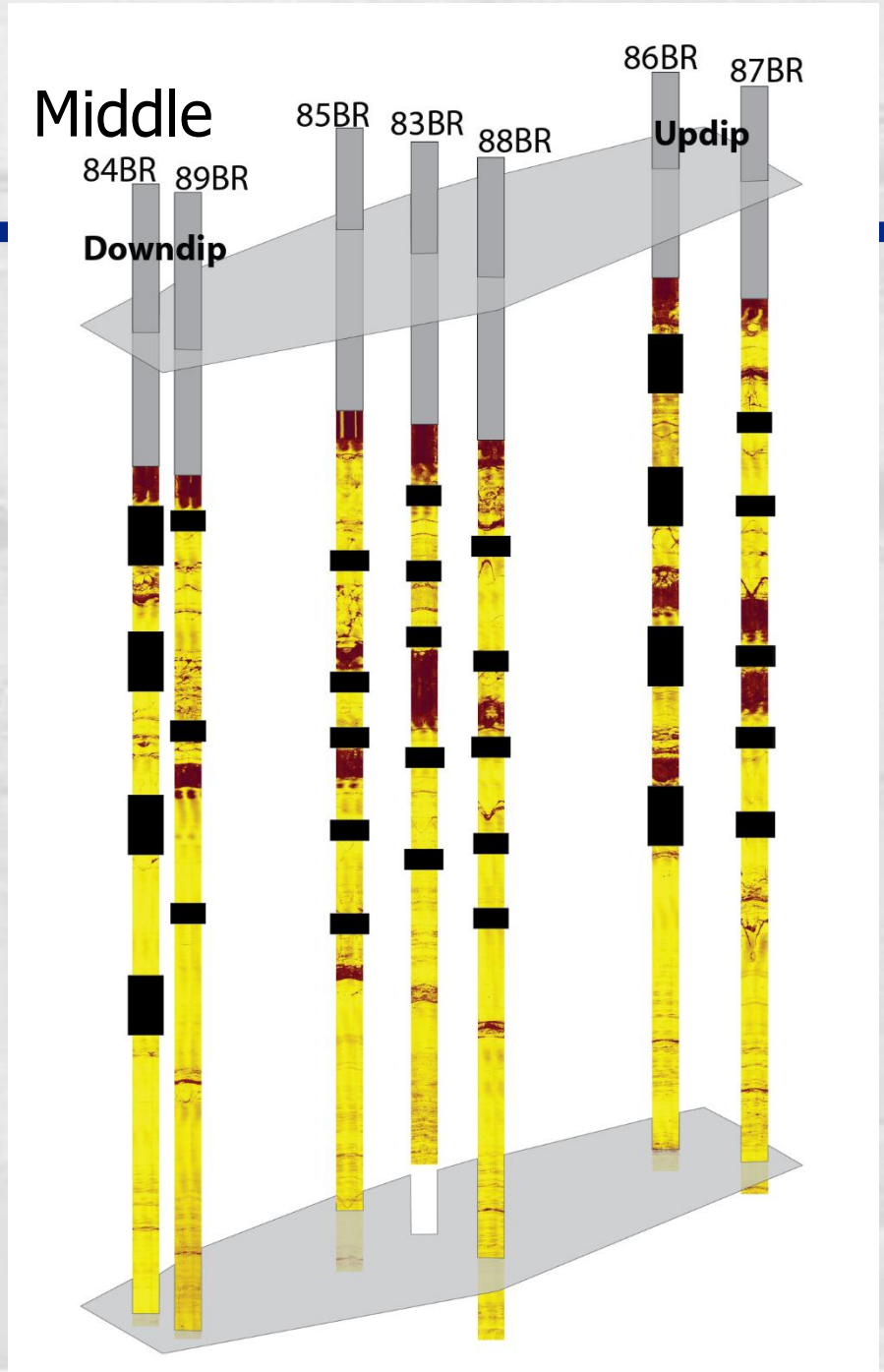
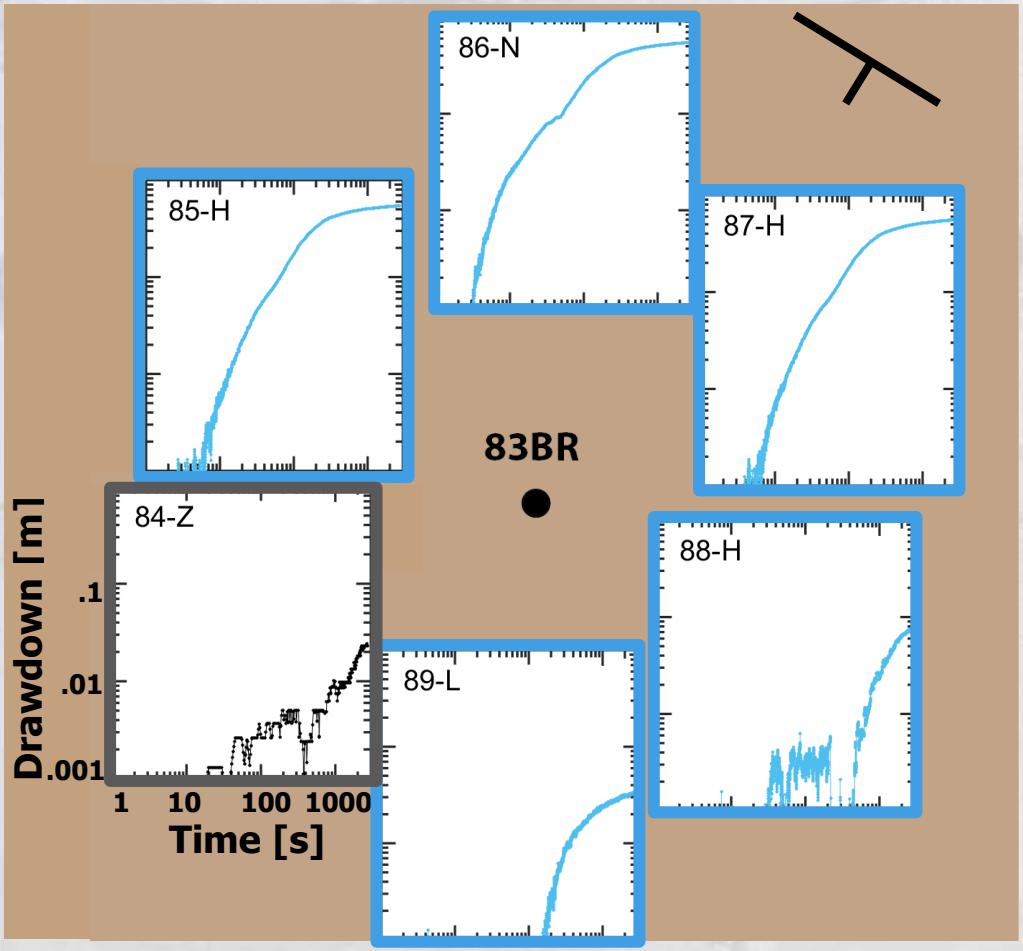


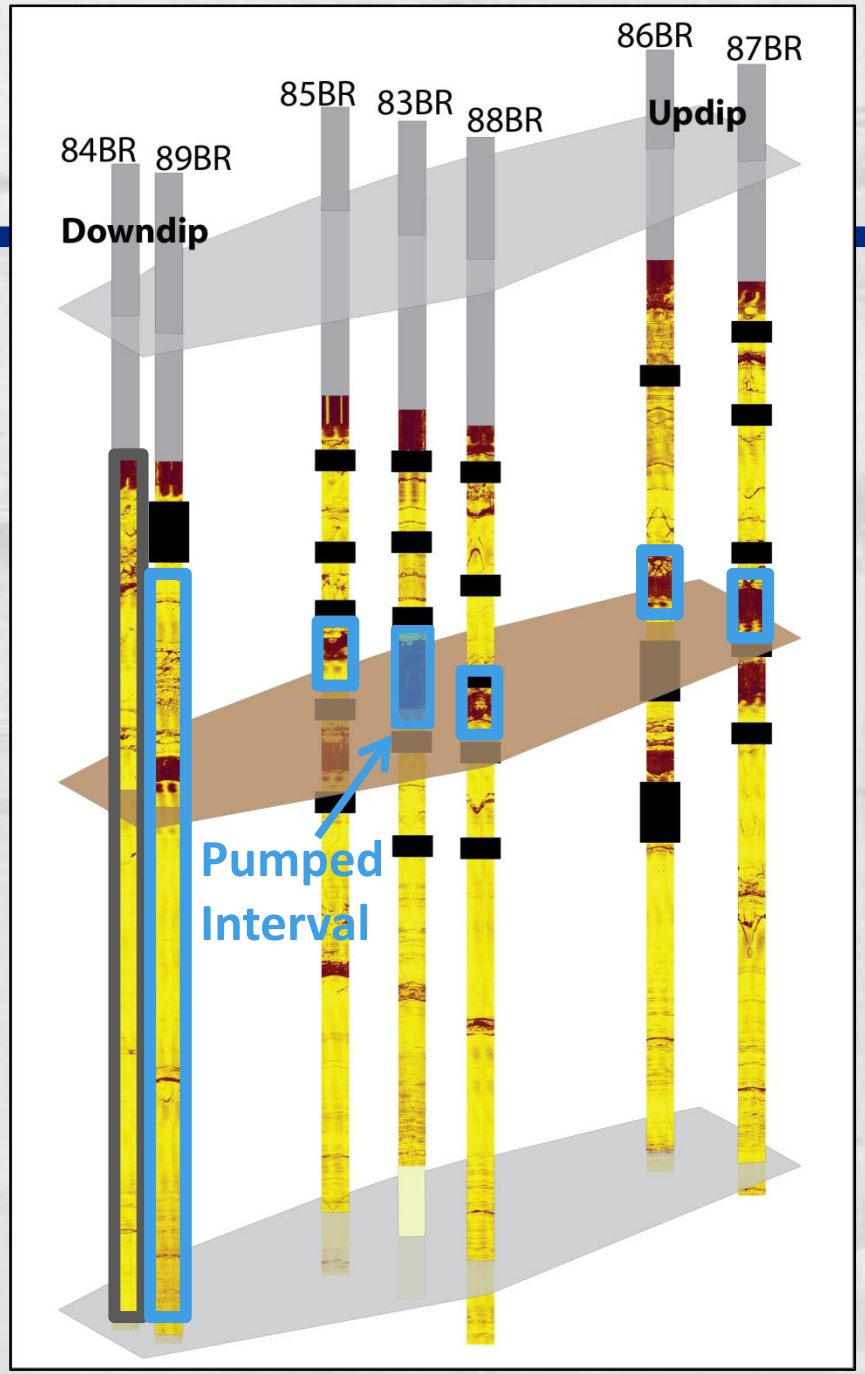
HT Testing 2015-2016

- 3 packer configurations
  - Some overlap, long zones
- 30-38 packed-off intervals
- Fracture zones vs rock matrix
- 48 pumping tests
- Pumping rates:
  - 0.04 – 7 L/min



Heterogeneity in Bedding Plane





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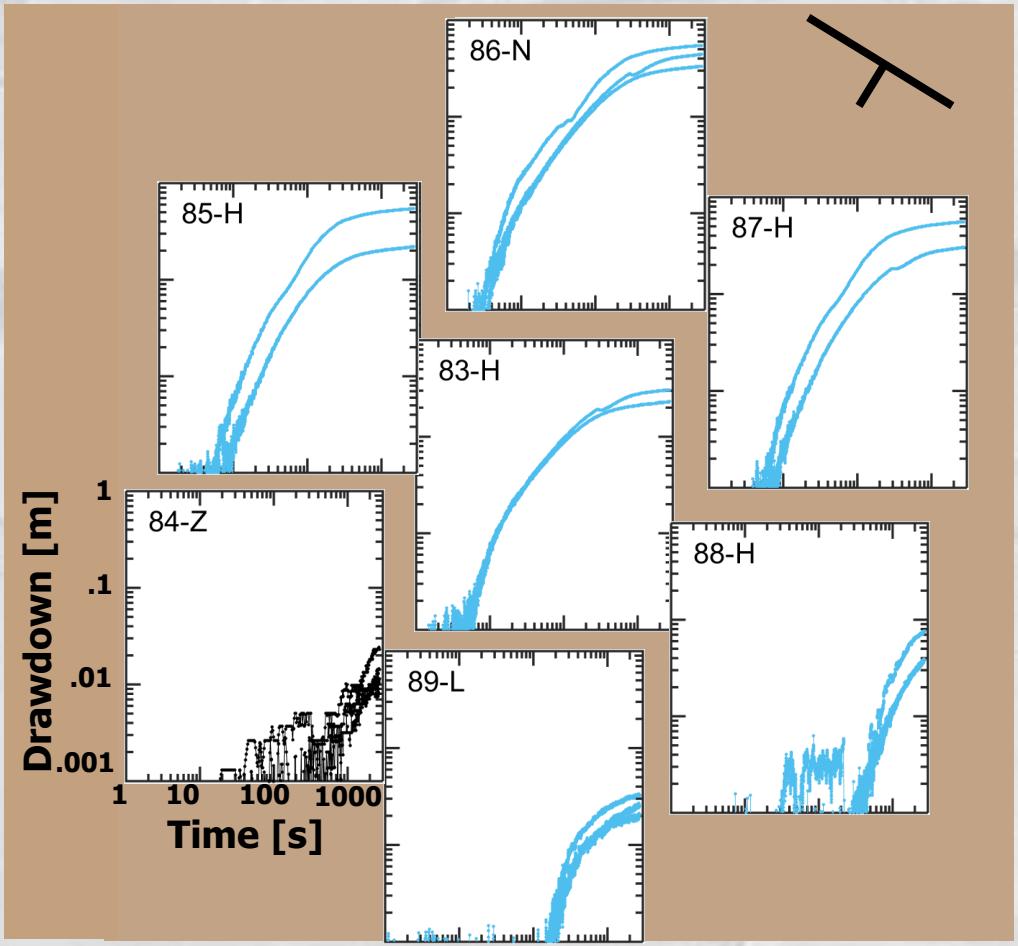
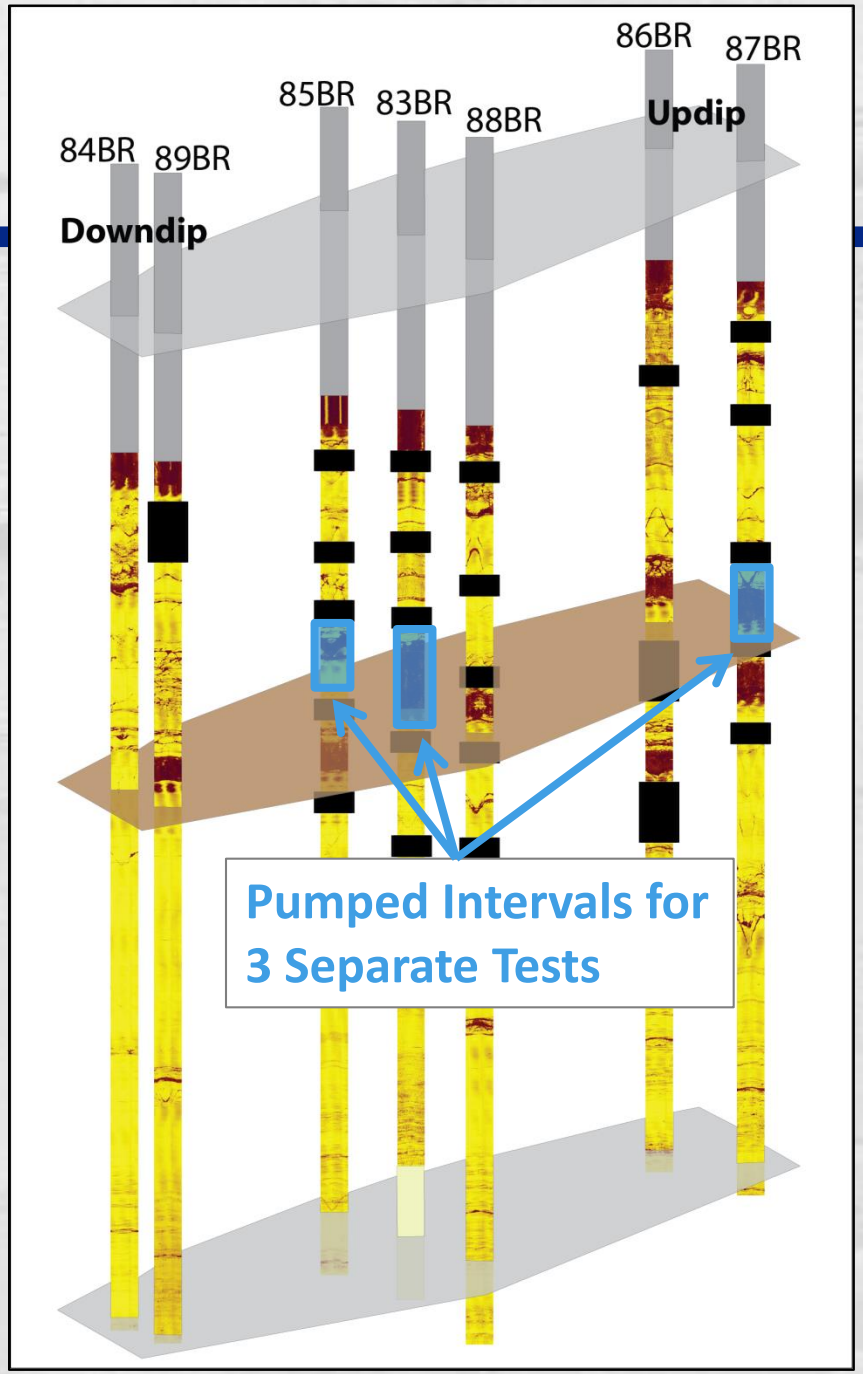
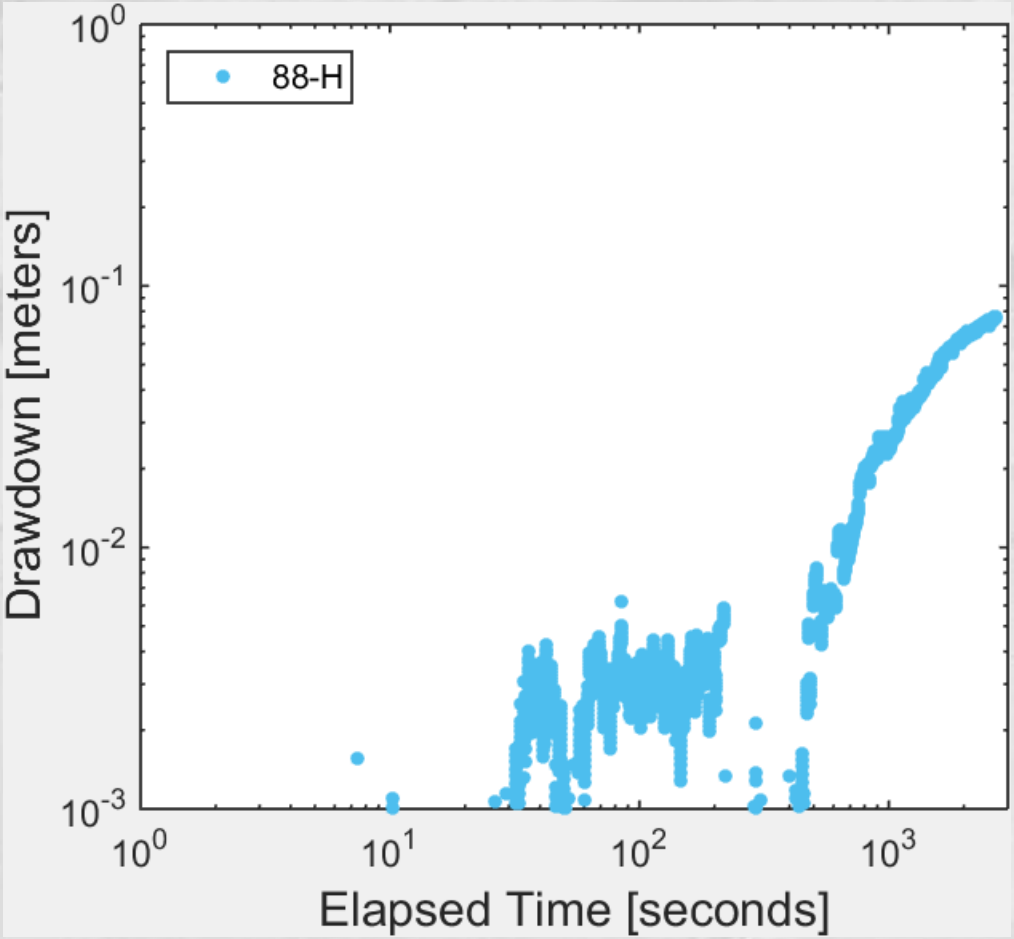
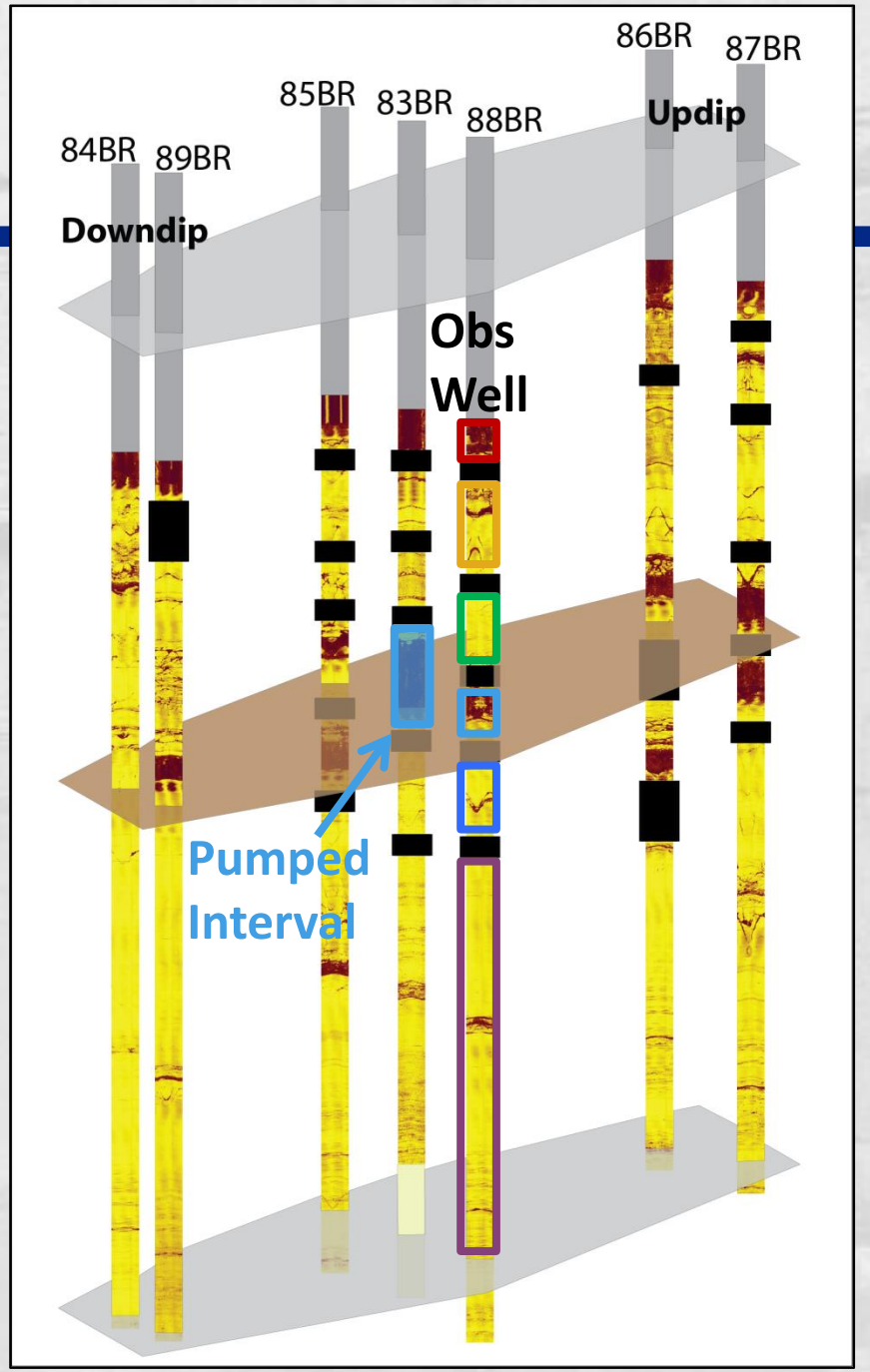


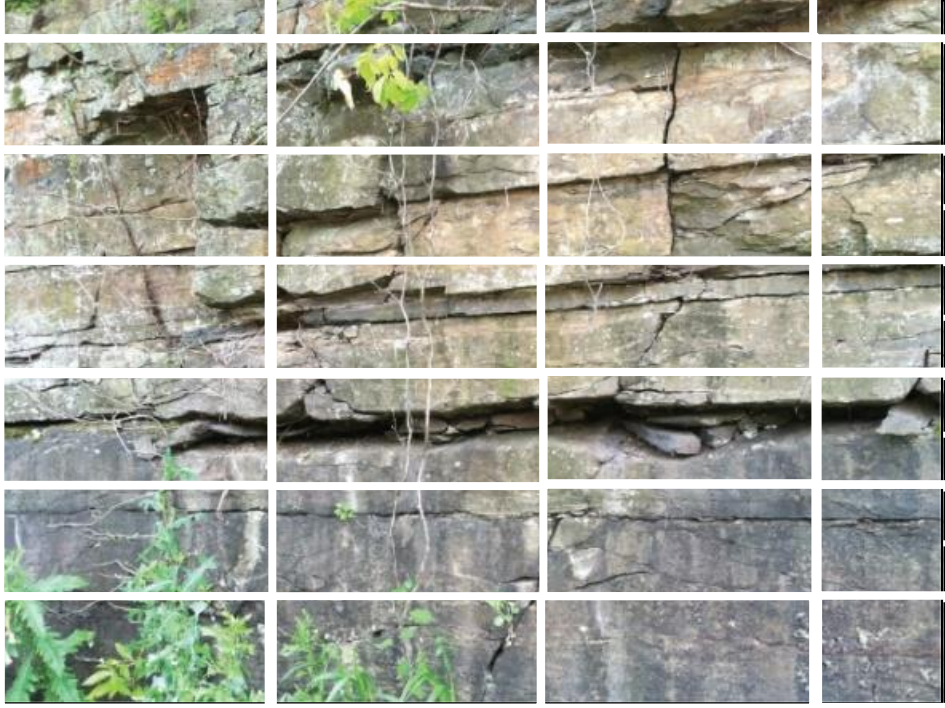


Hydraulic Connections across Beds





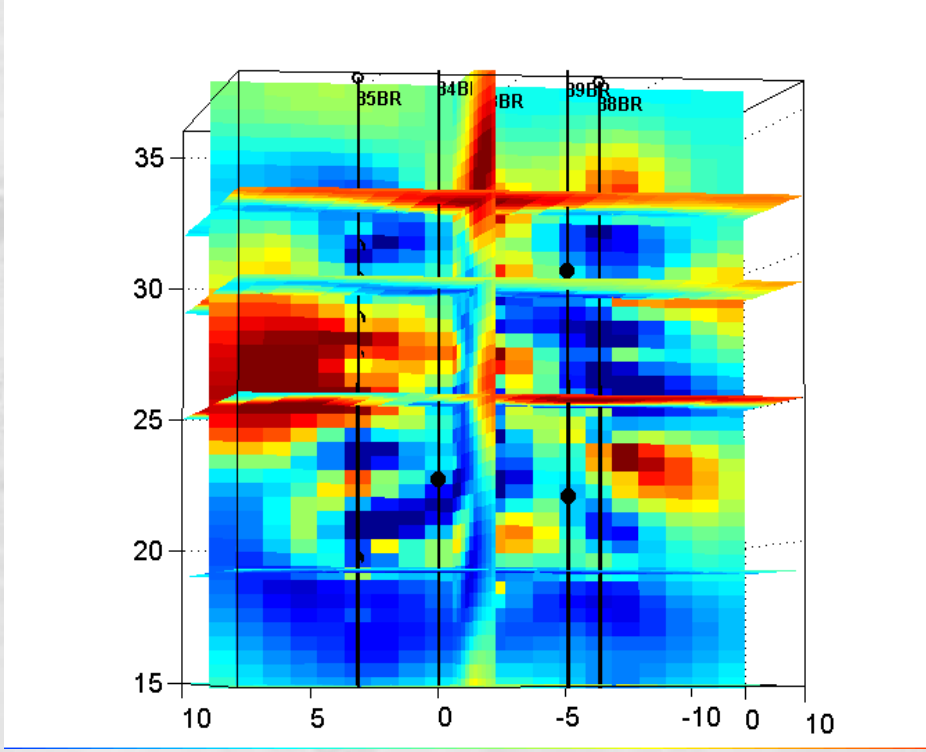
HT Modeling



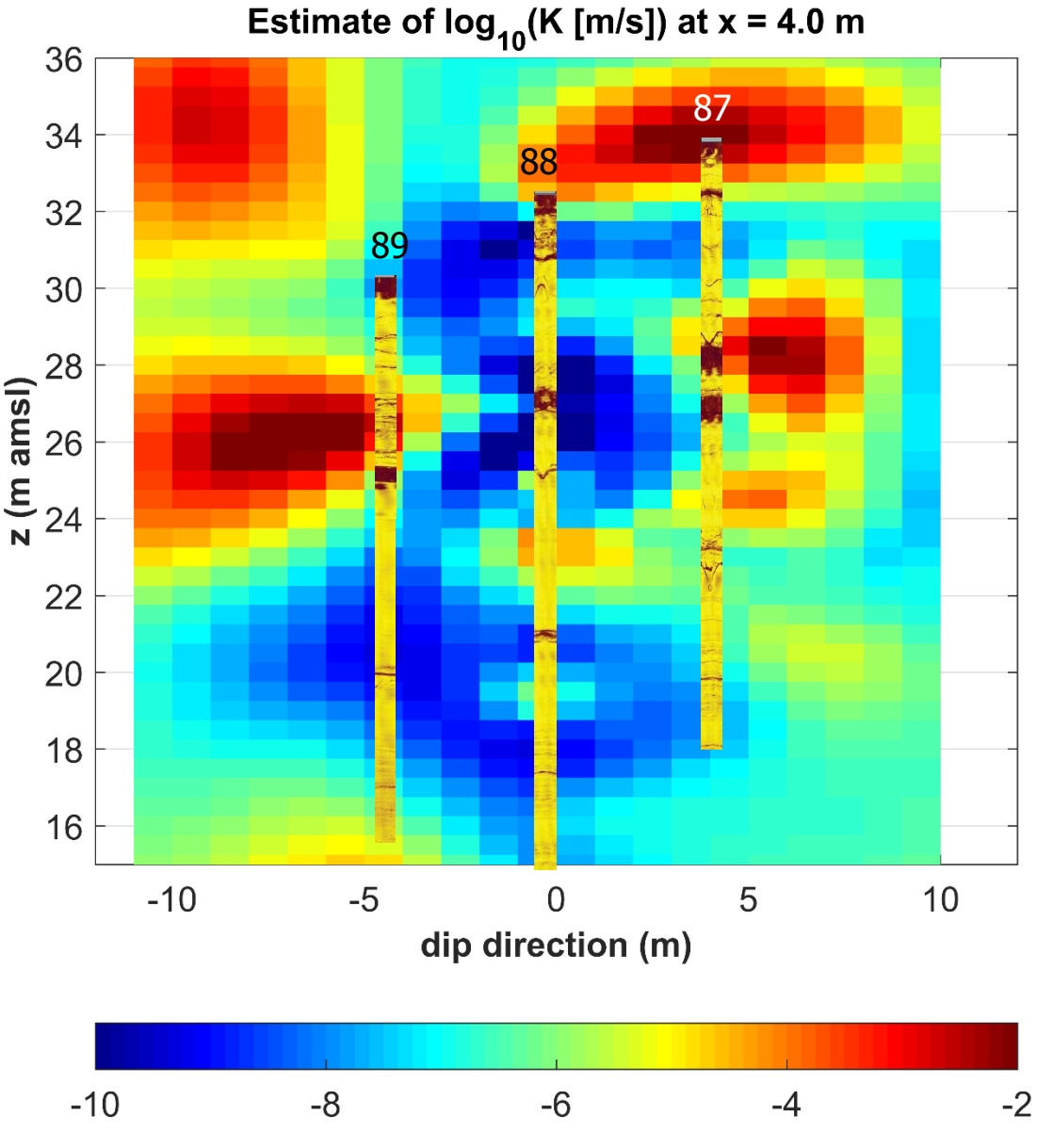
- Objectives:
  - 3D K distribution
- Approach:
  - Minimize assumptions – start with EPM (vs DFN)
  - Model fractures approximately
  - HT inversion - estimate K
    - (next add Q, Ss, finer discretization)

HT Modeling - Current Status

- Start with uniform K
- Estimate 3D K
- >K fractures:
  - Prominent, with details
- High-angle fault?
- <K fractures, connections
  - Less certain



Dip-view slices



Plan-view slices:
Top down

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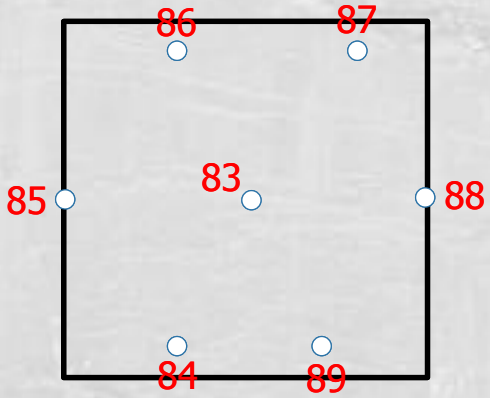

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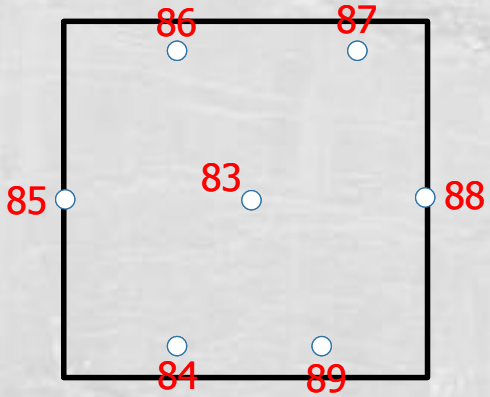

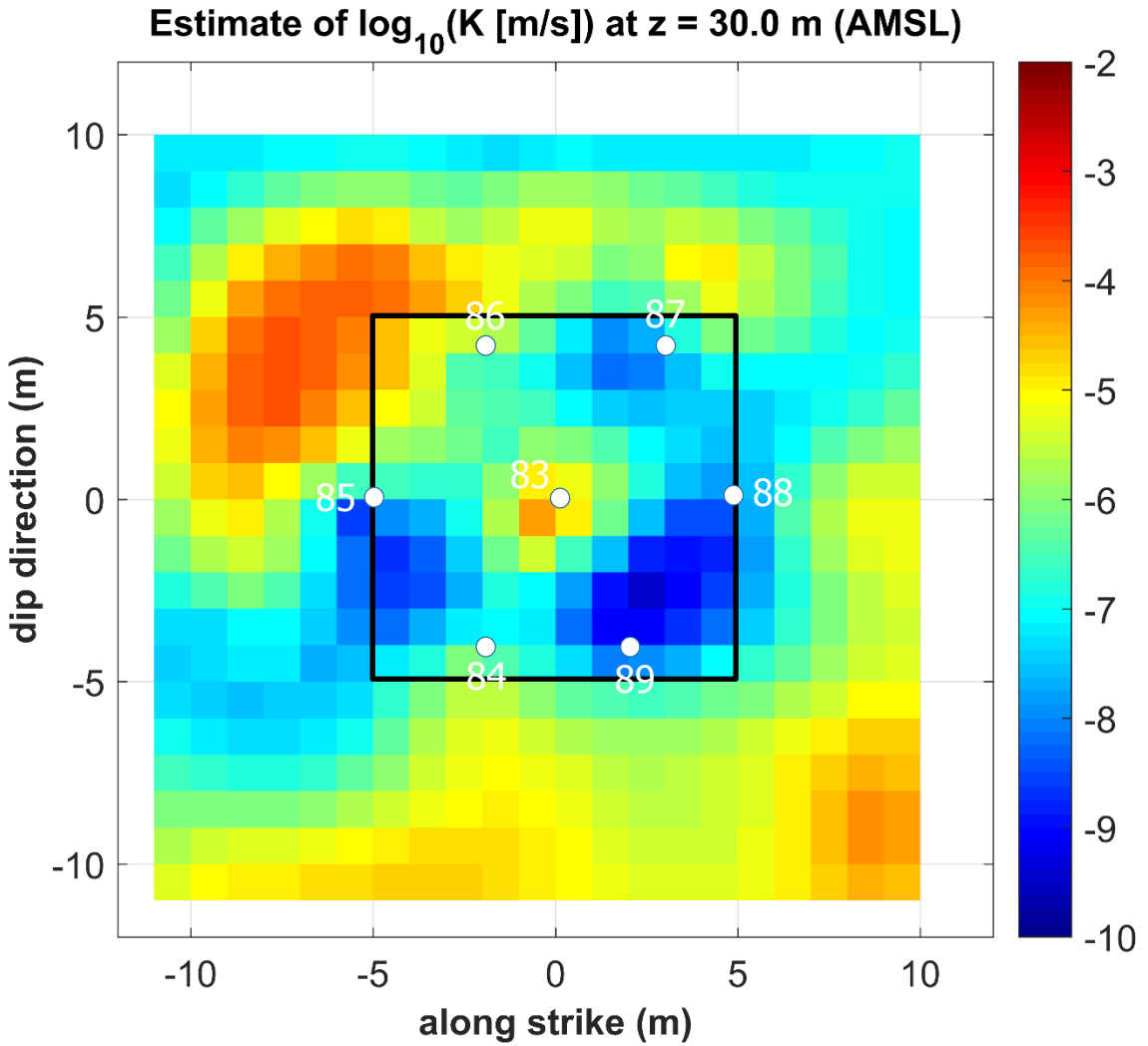

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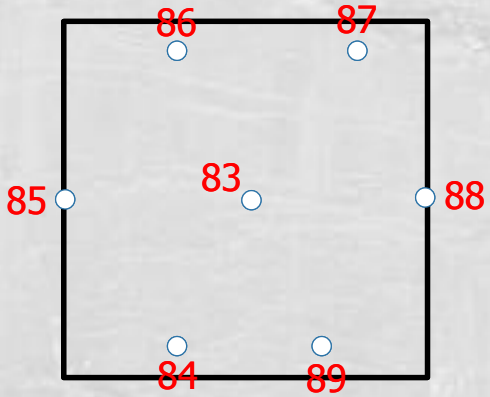

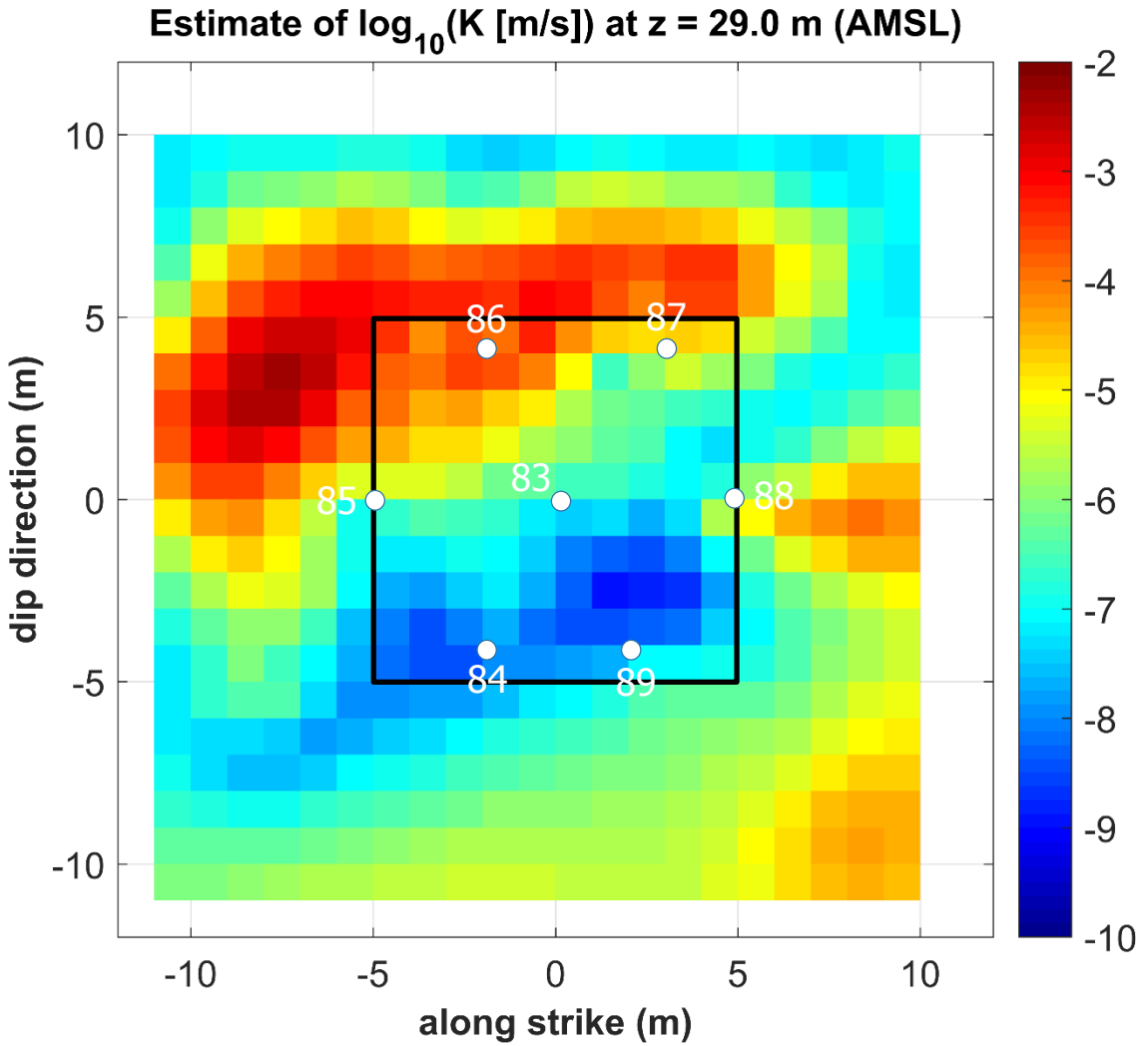

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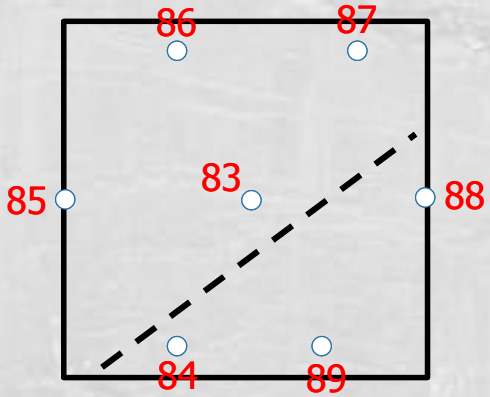

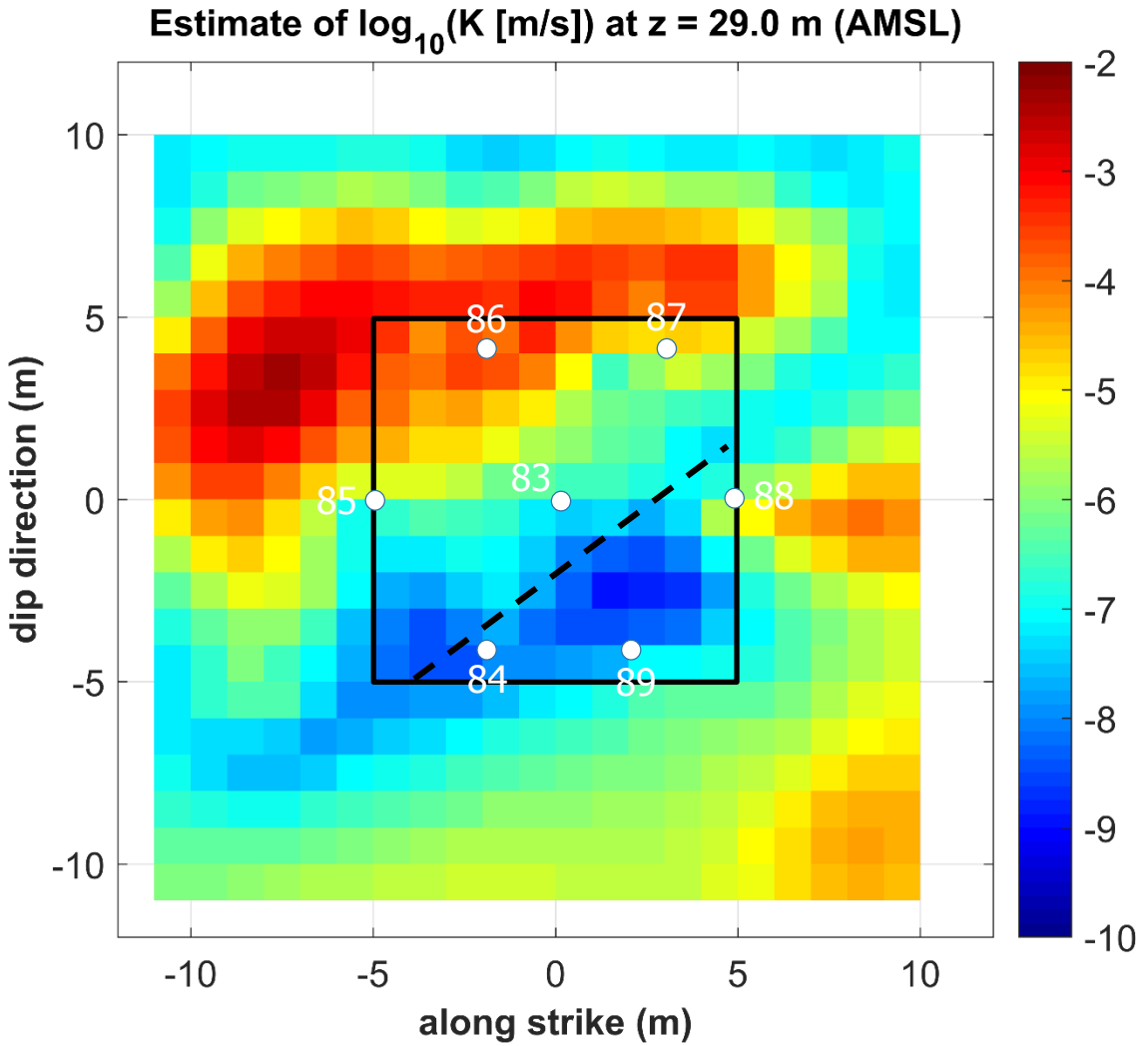

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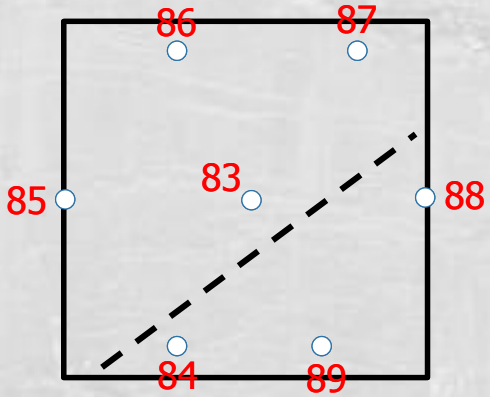

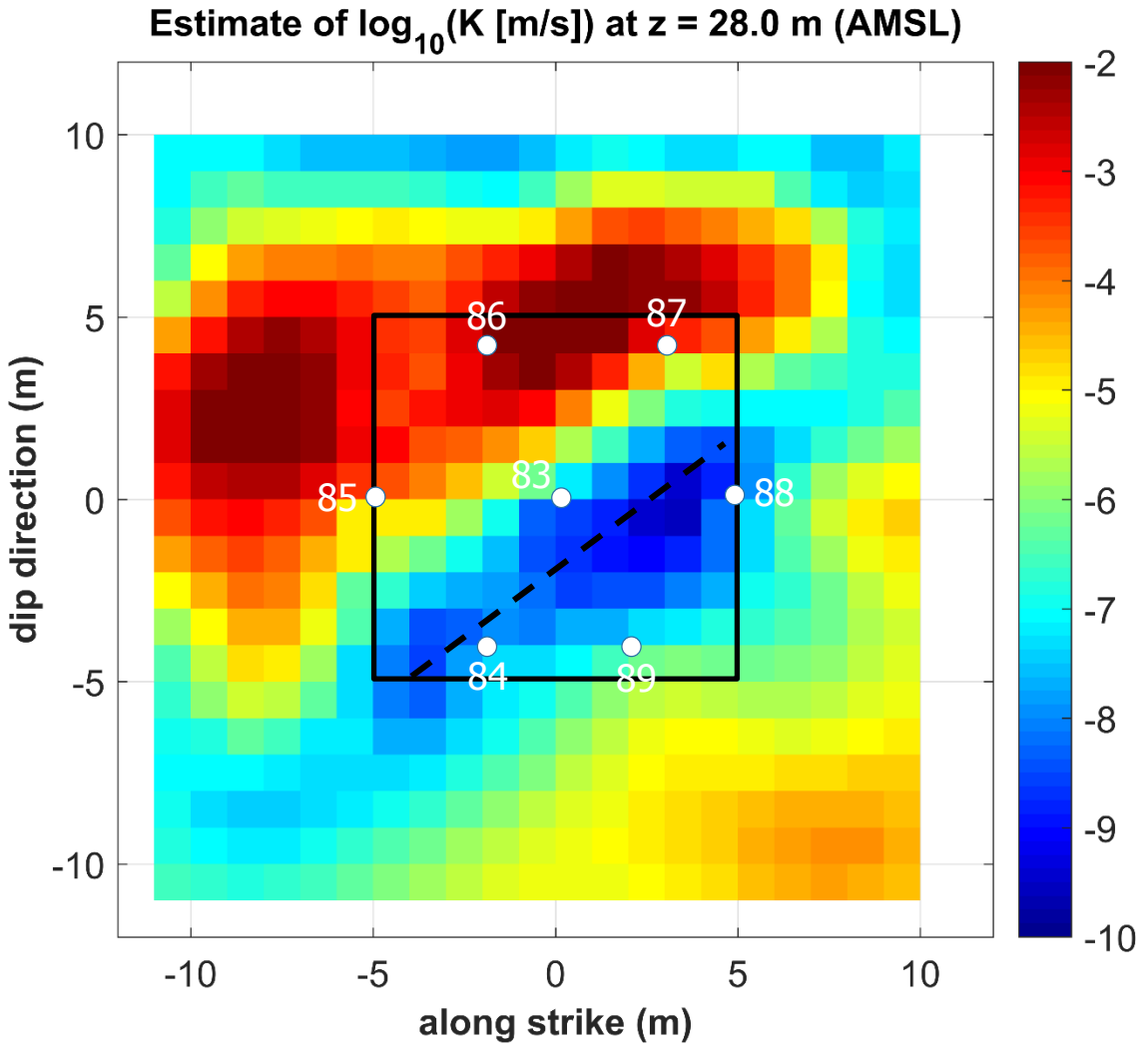

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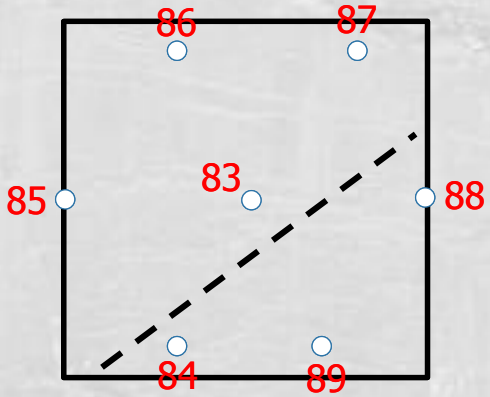

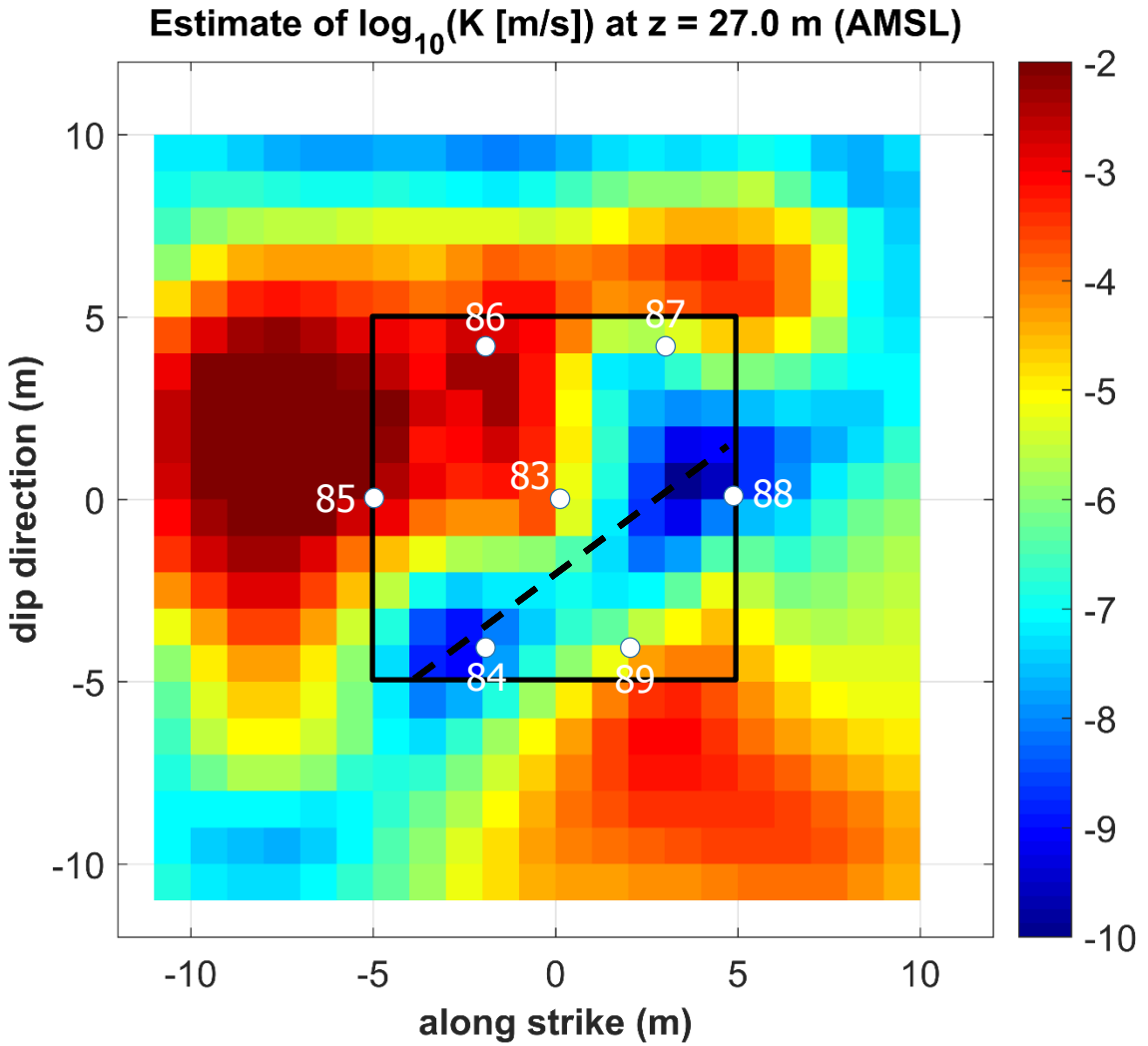

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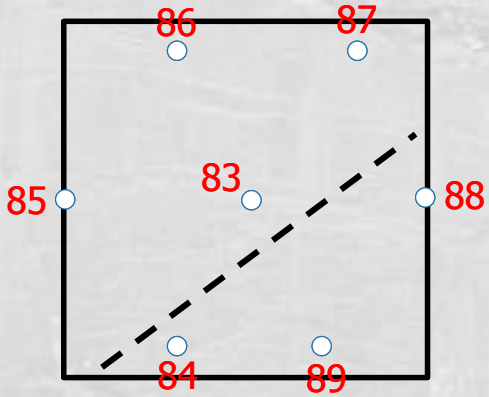

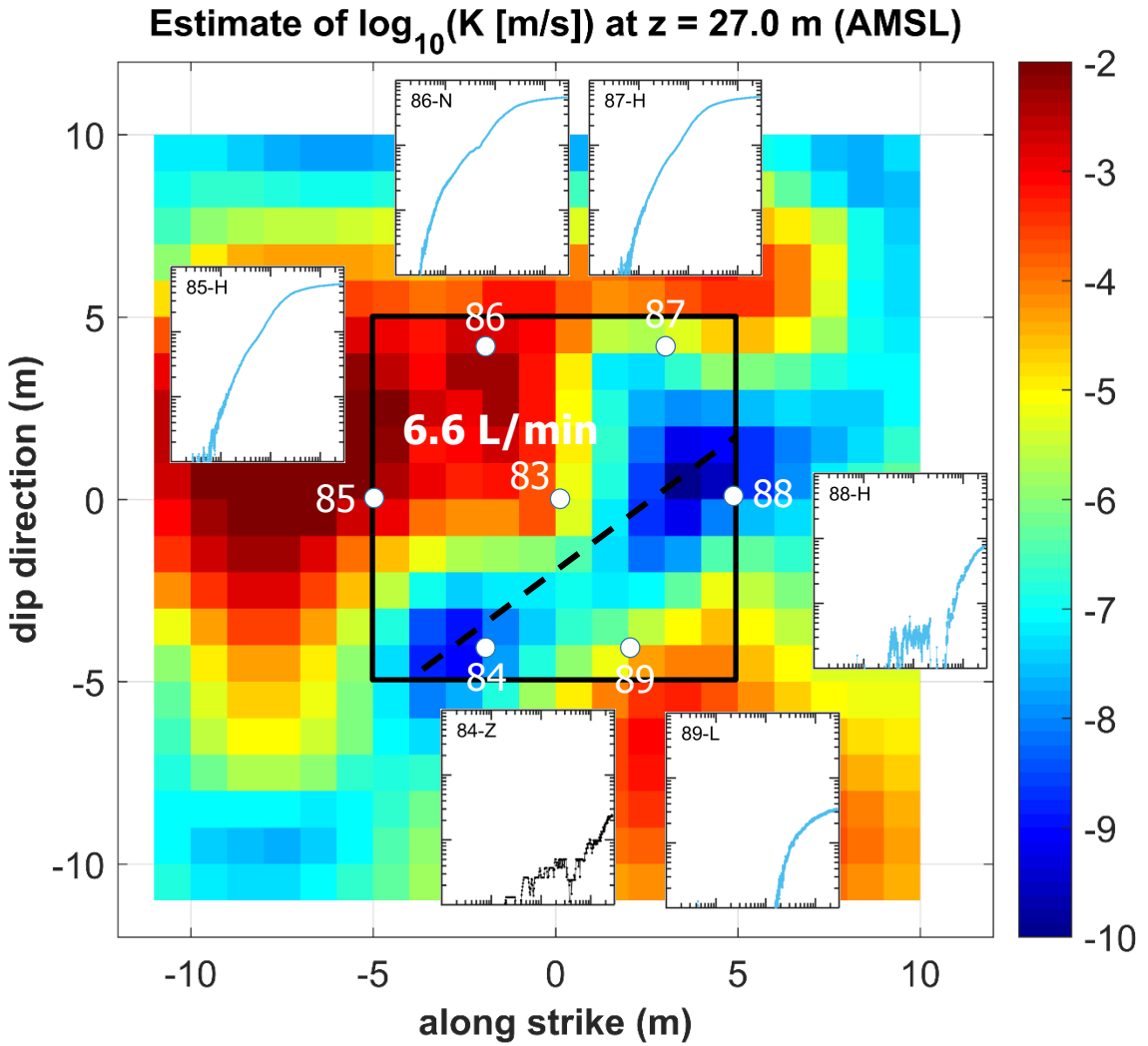

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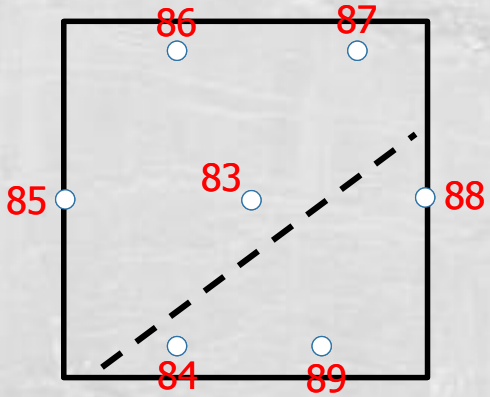

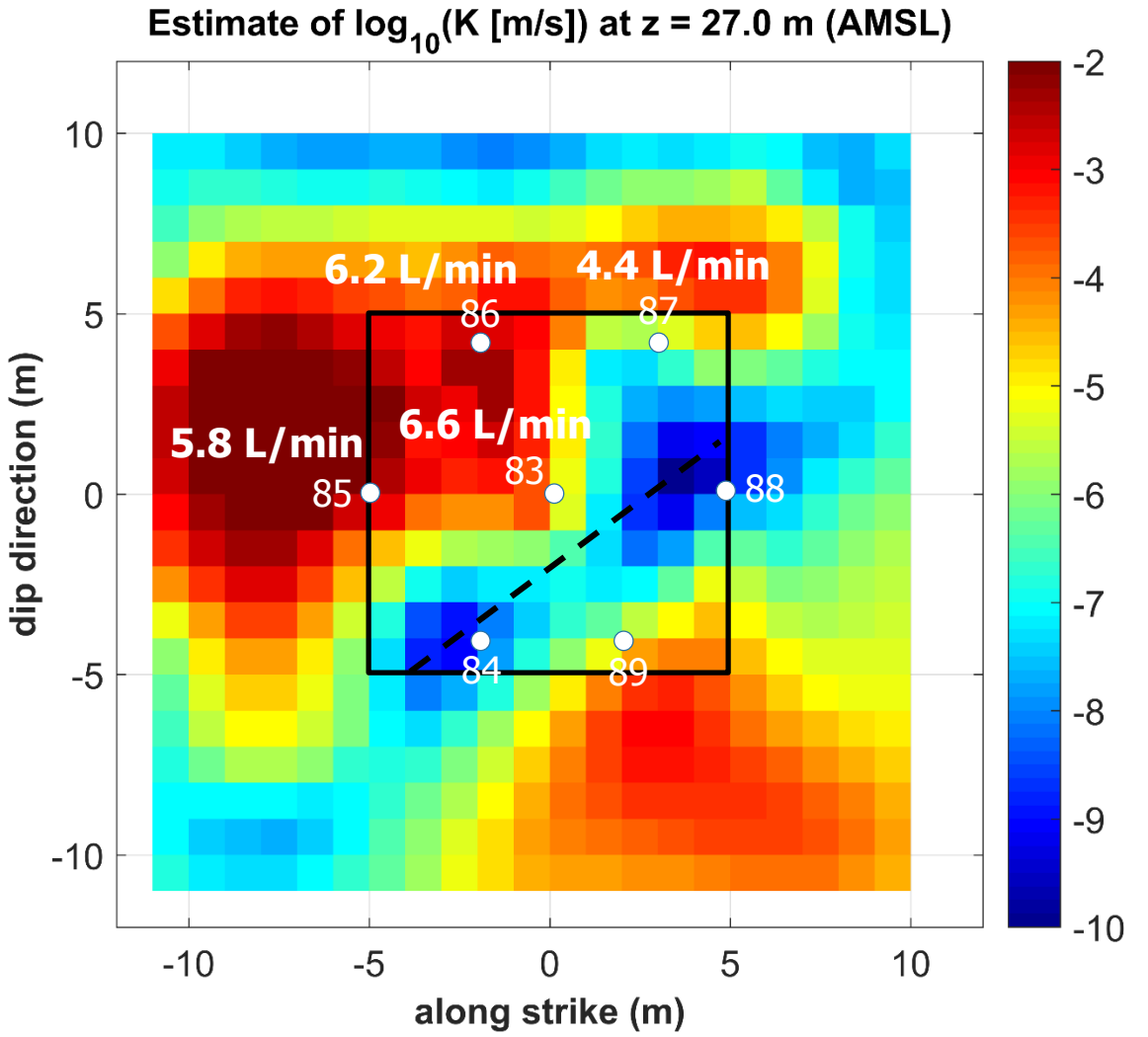

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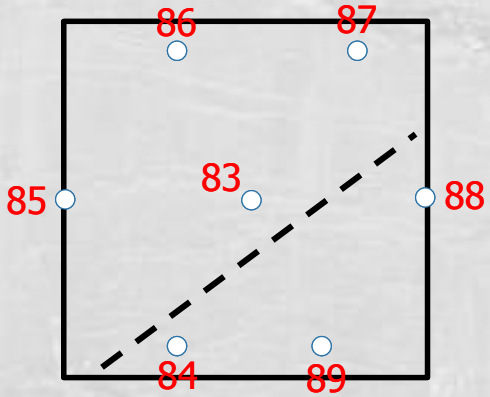

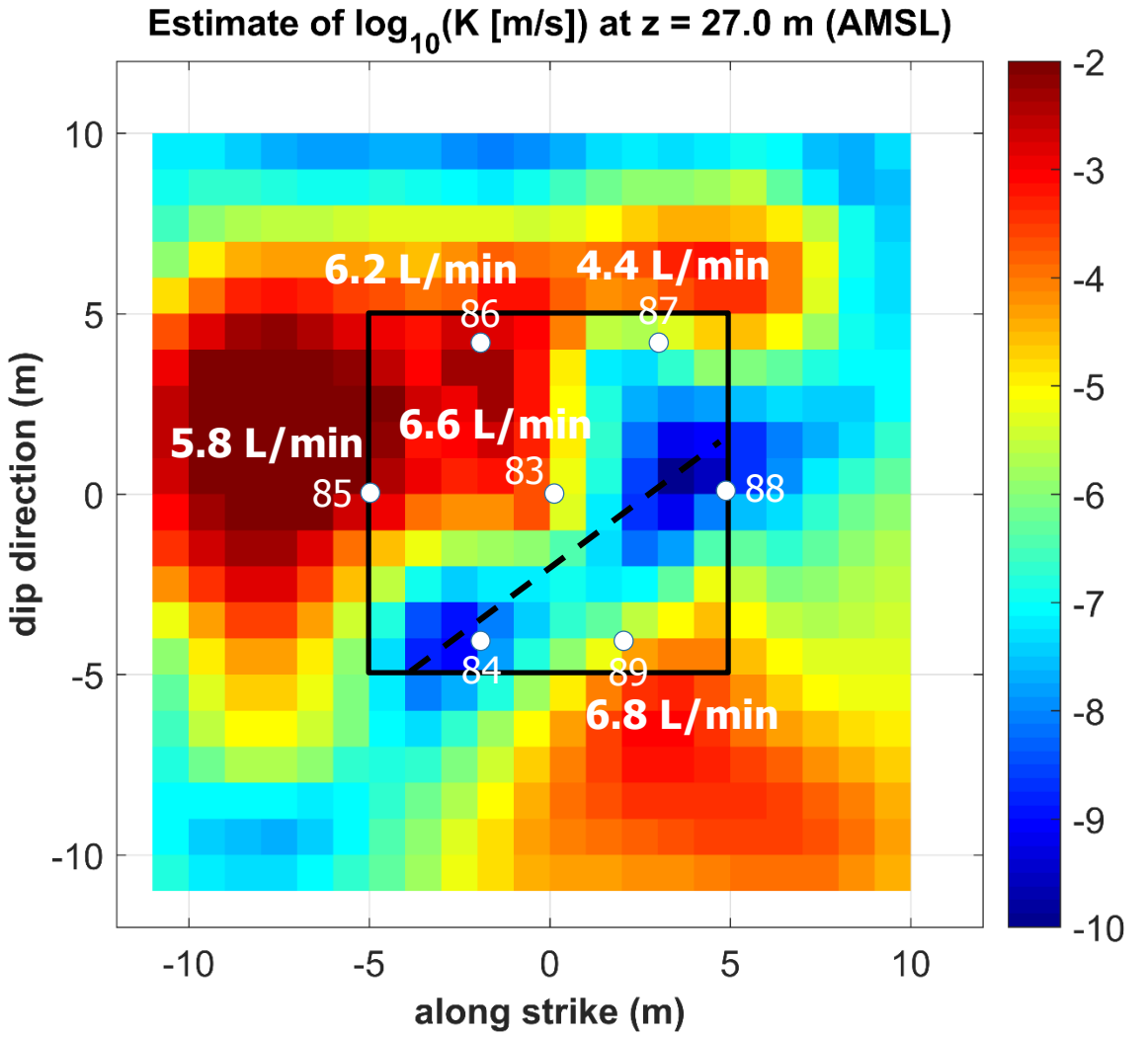

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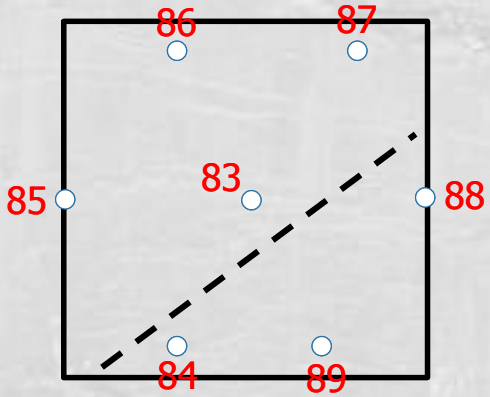

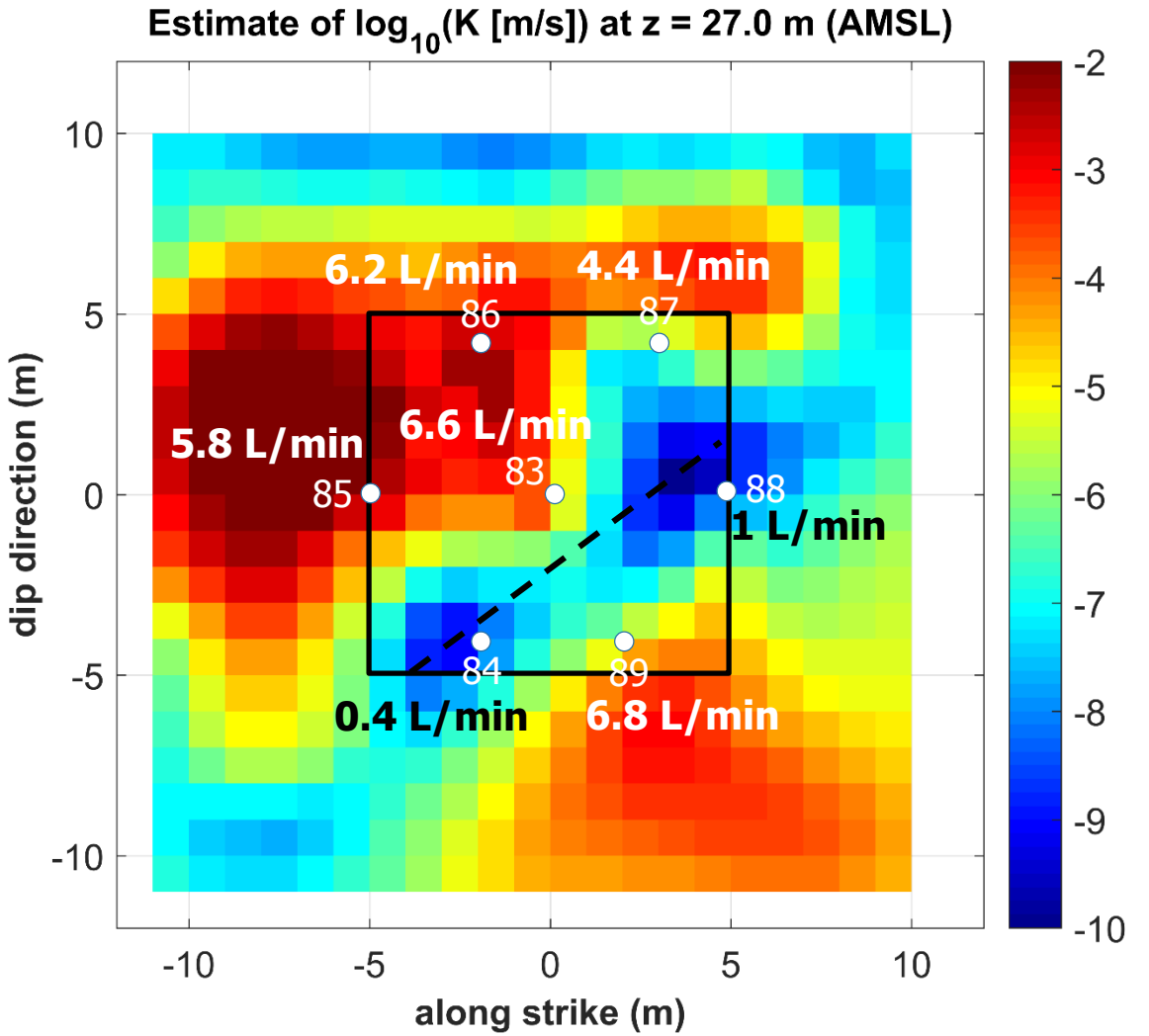

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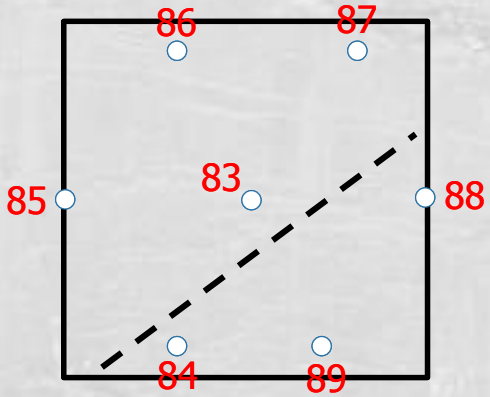

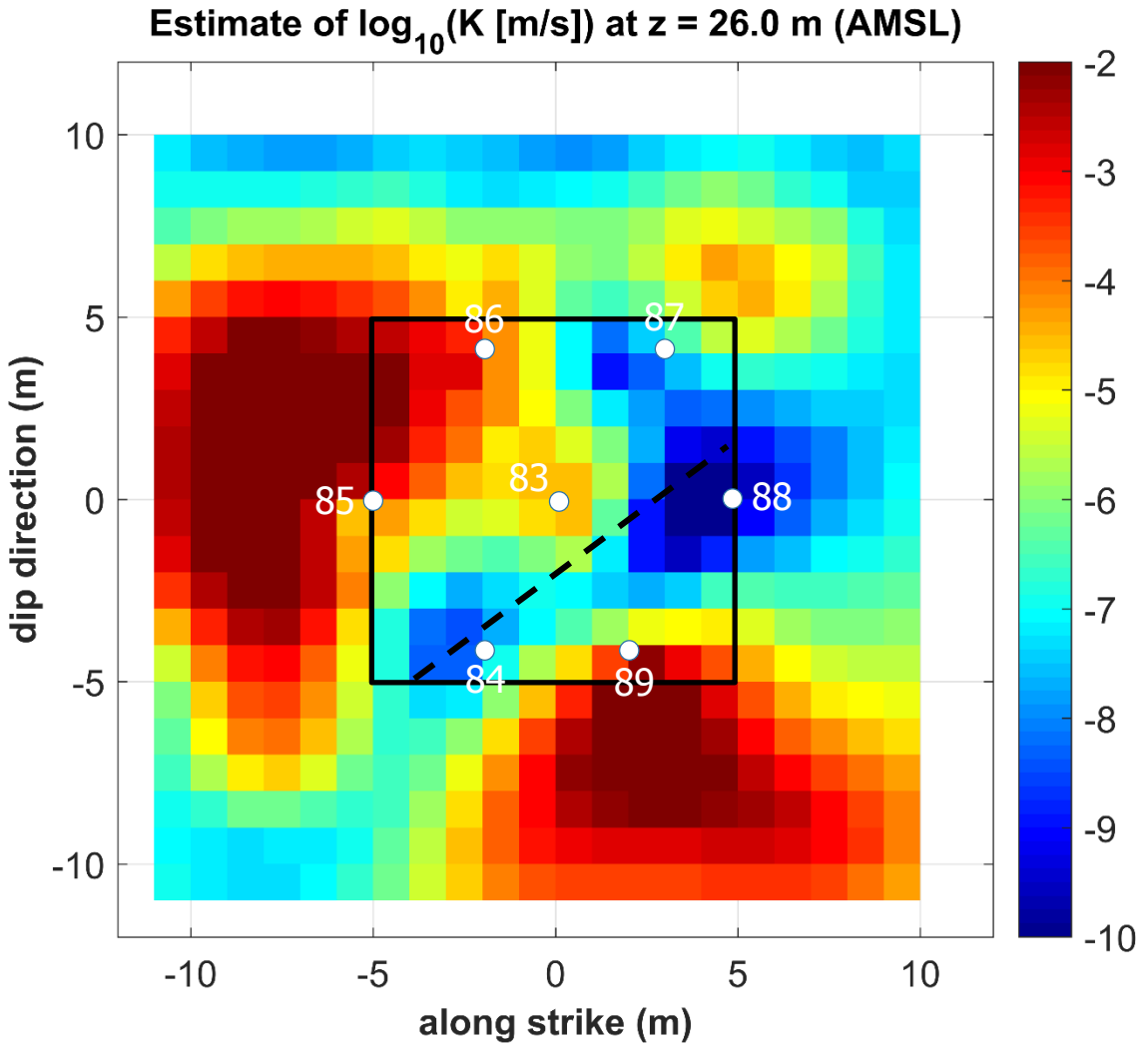

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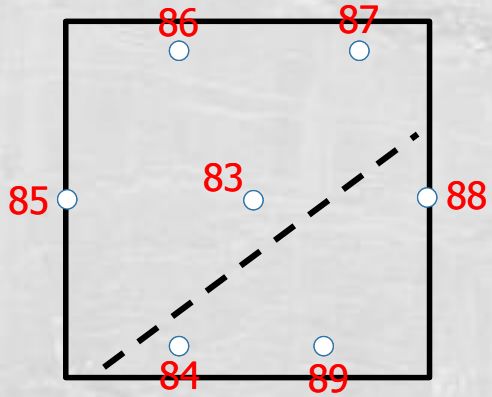

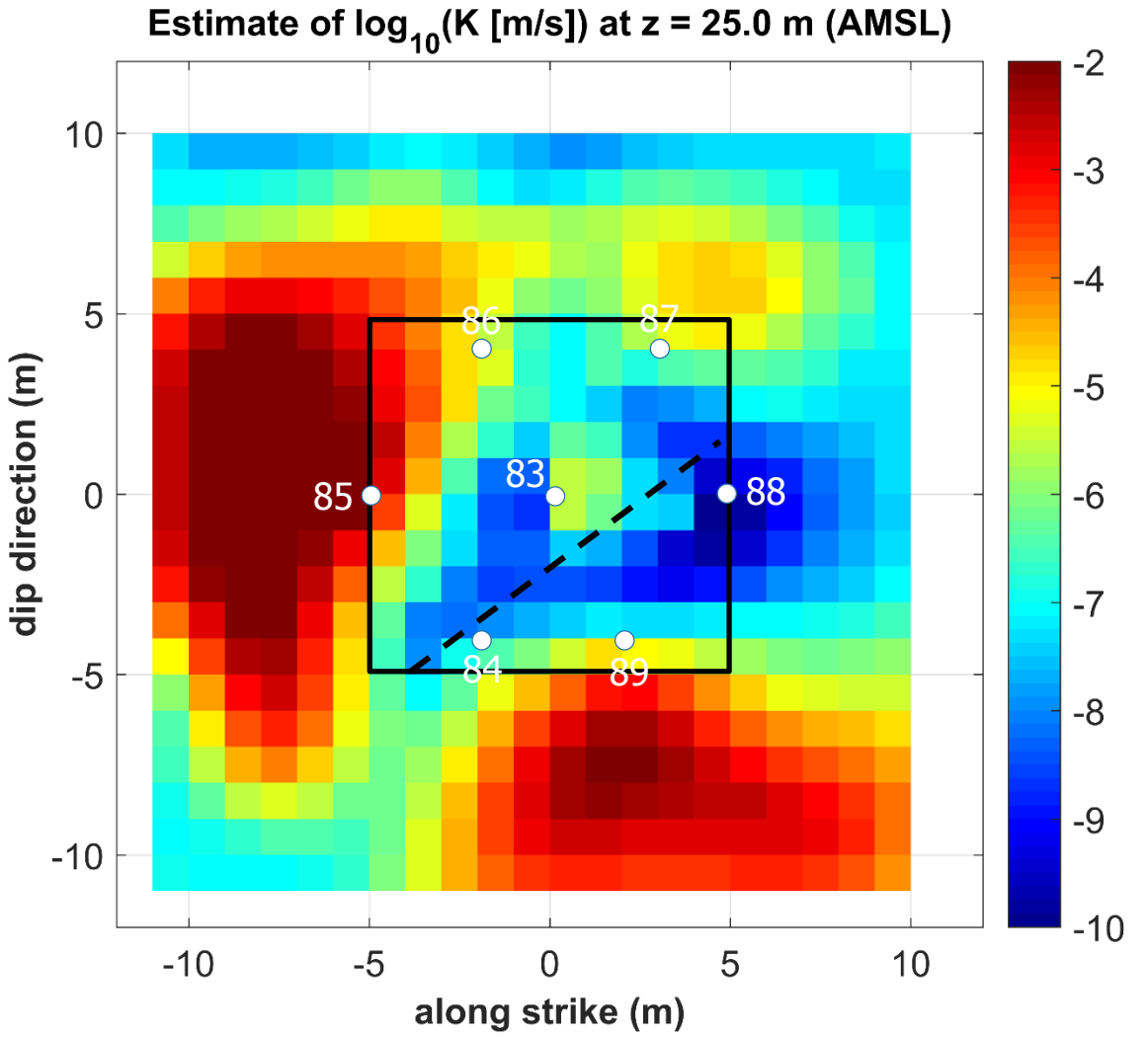

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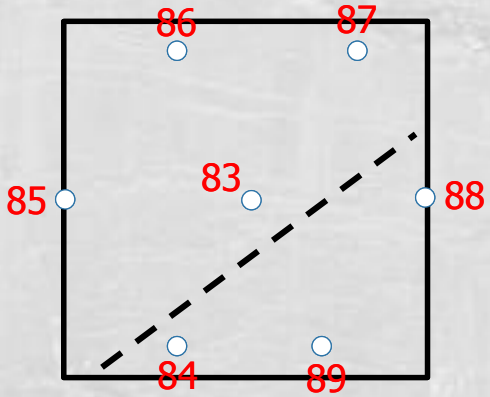
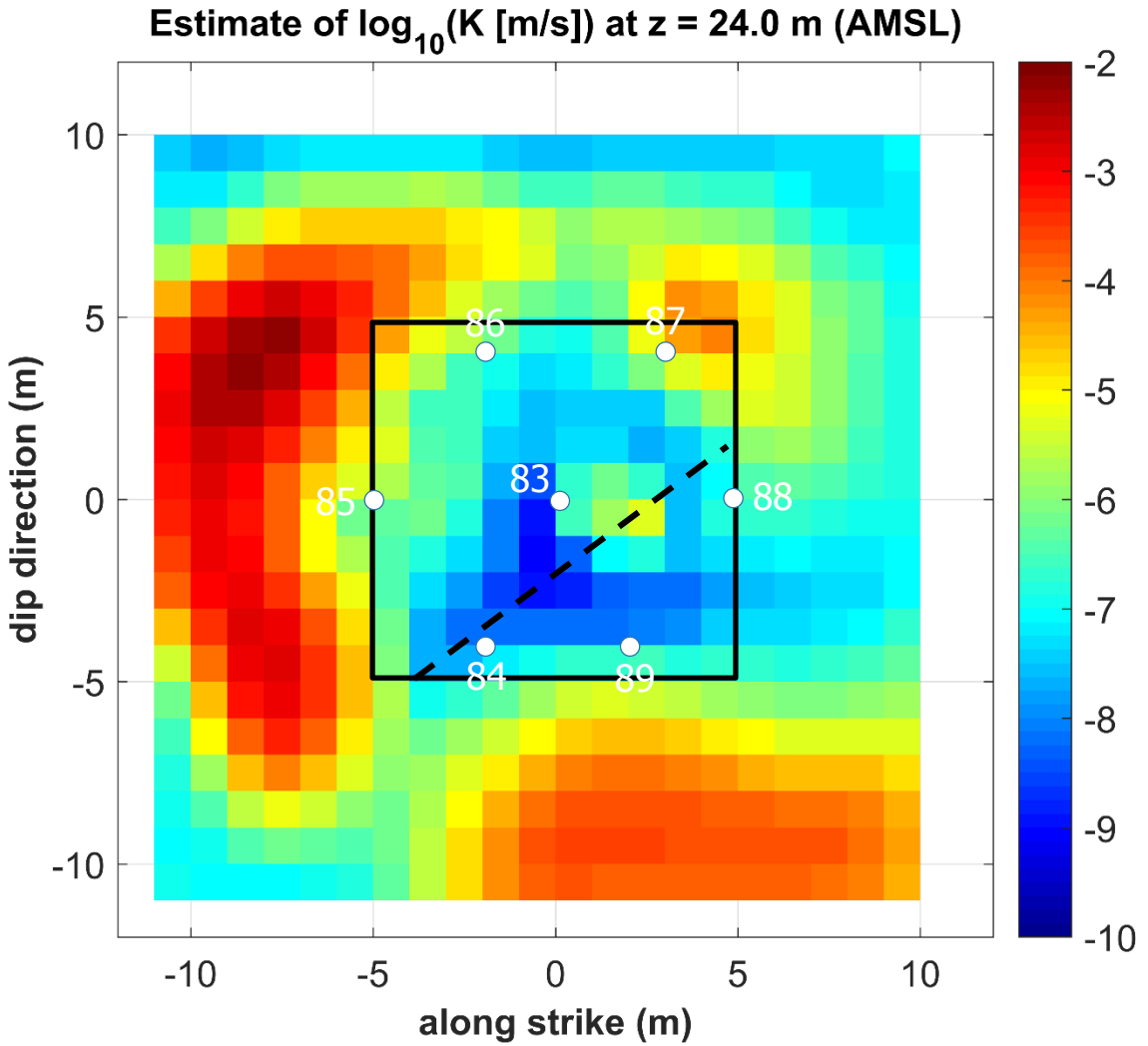
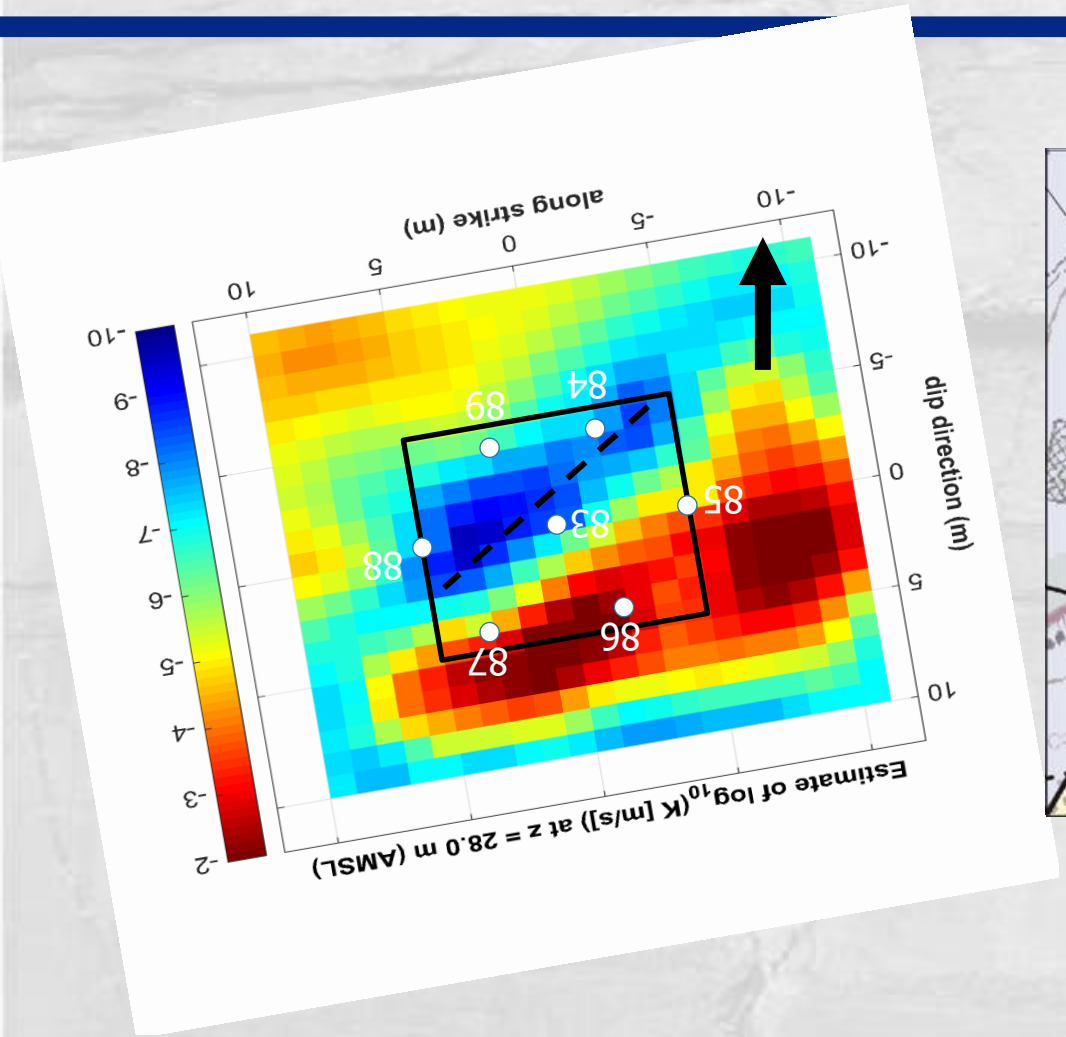
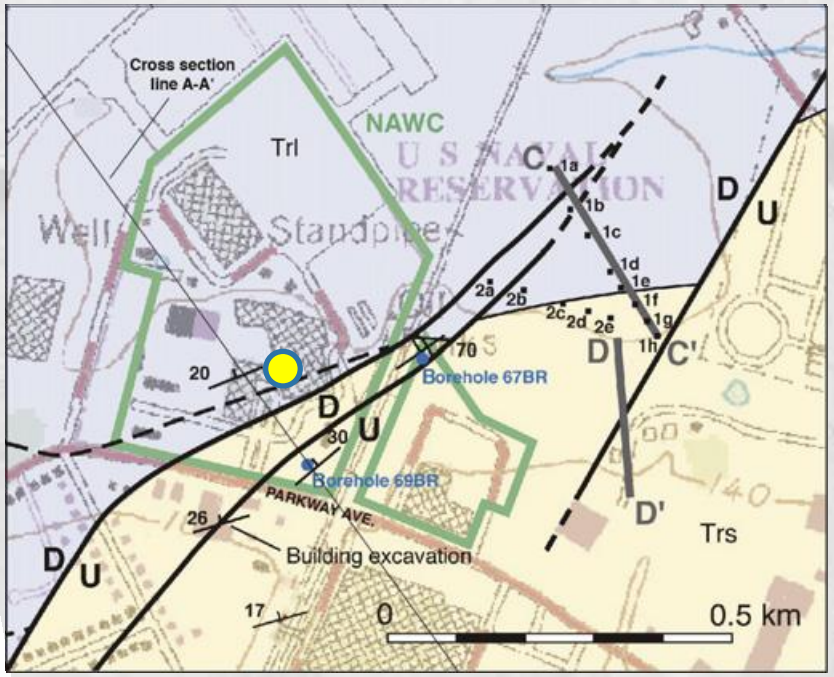




Fault? Geology

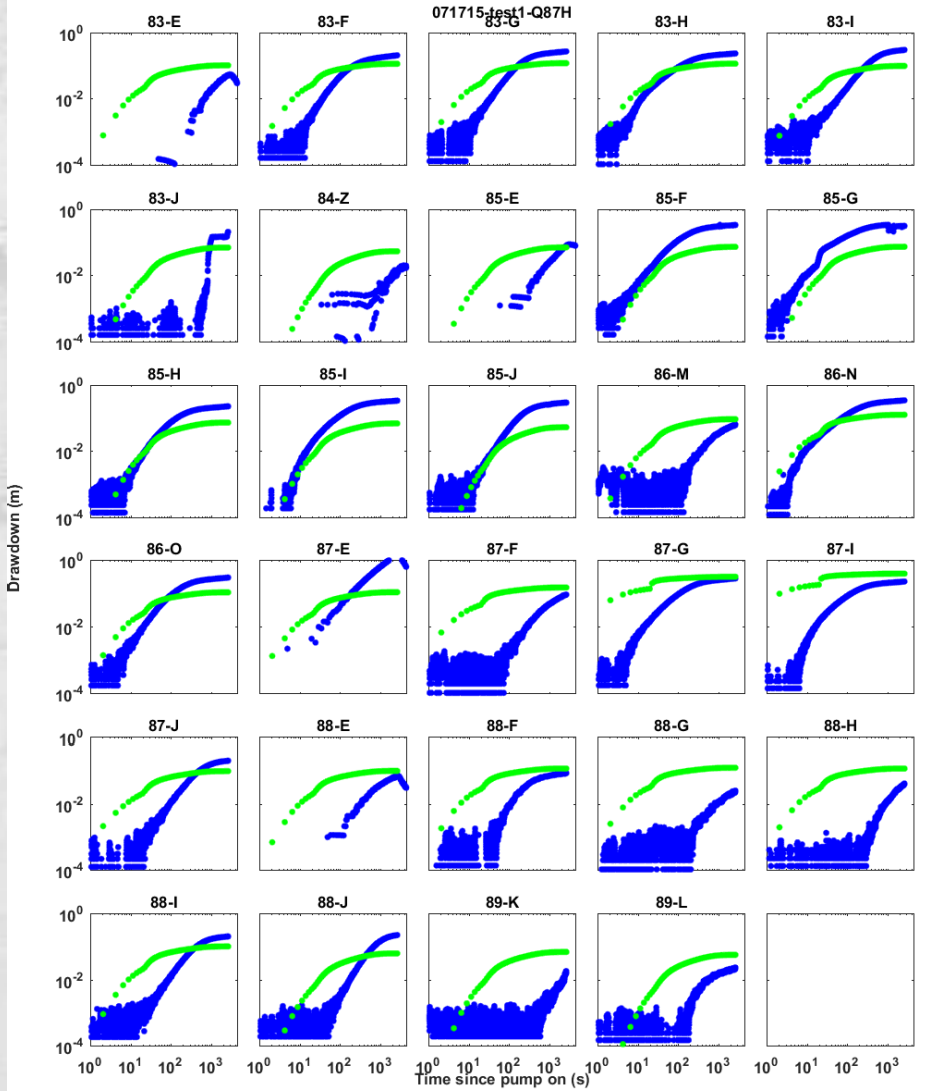




Ellefson et al., 2012, J Applied Geophysics 79: 71-81.

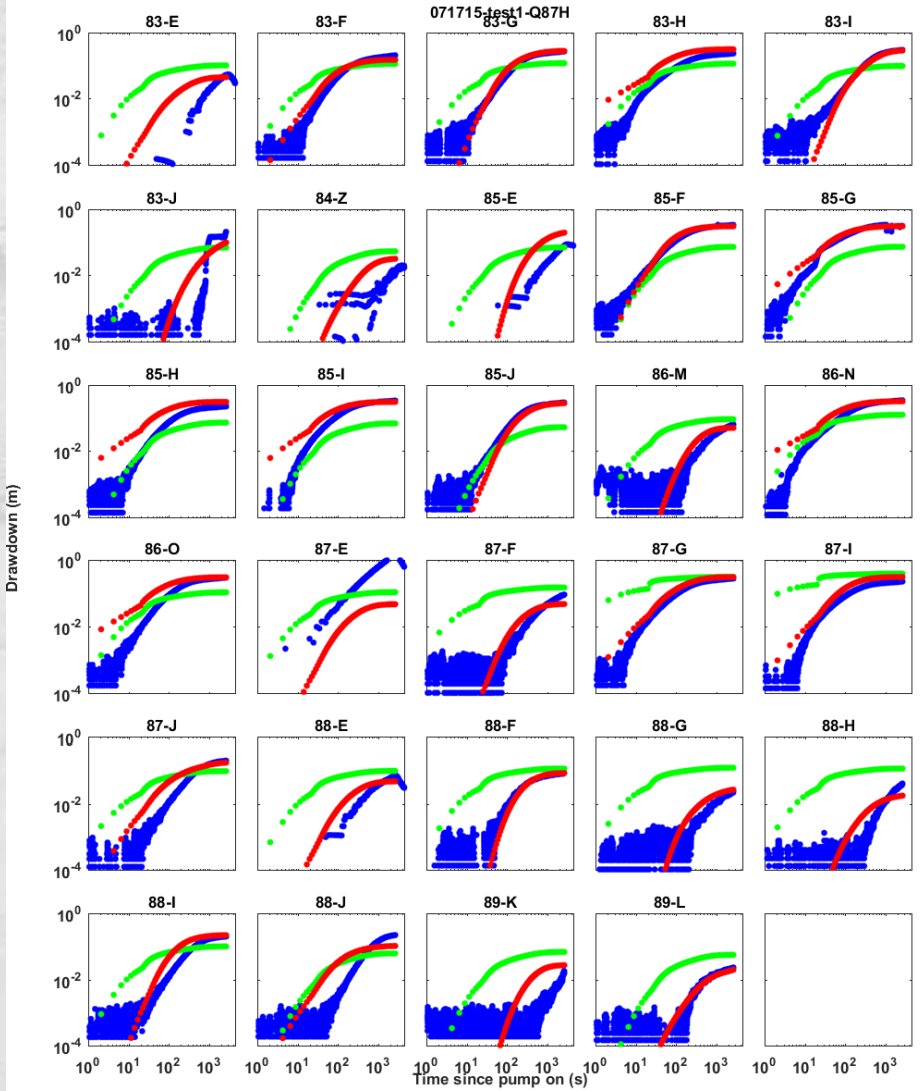
Assessment: Calibration Quality

- Homogeneous starting model
  - Pump from >K major fracture



Assessment: Calibration Quality

- Using current HT 3D K results
  - Pump from >K major fracture



Assessment: Calibration Quality

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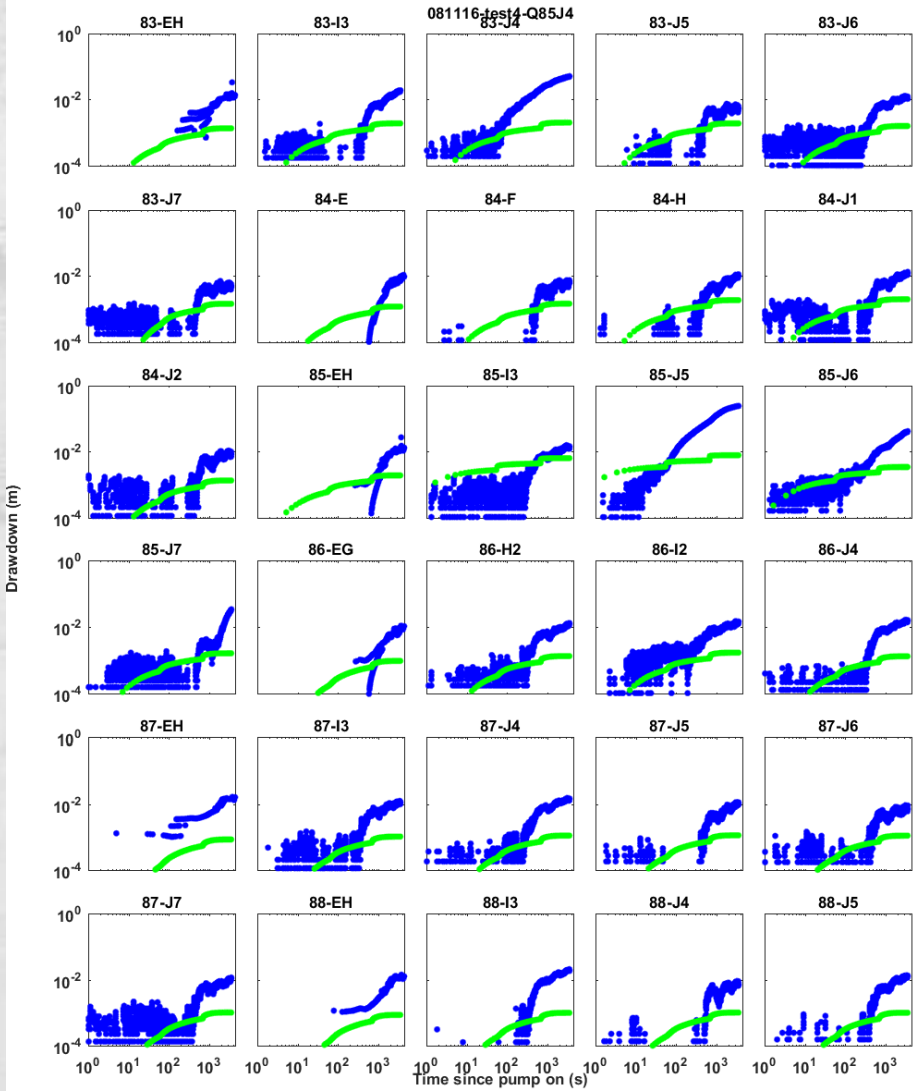
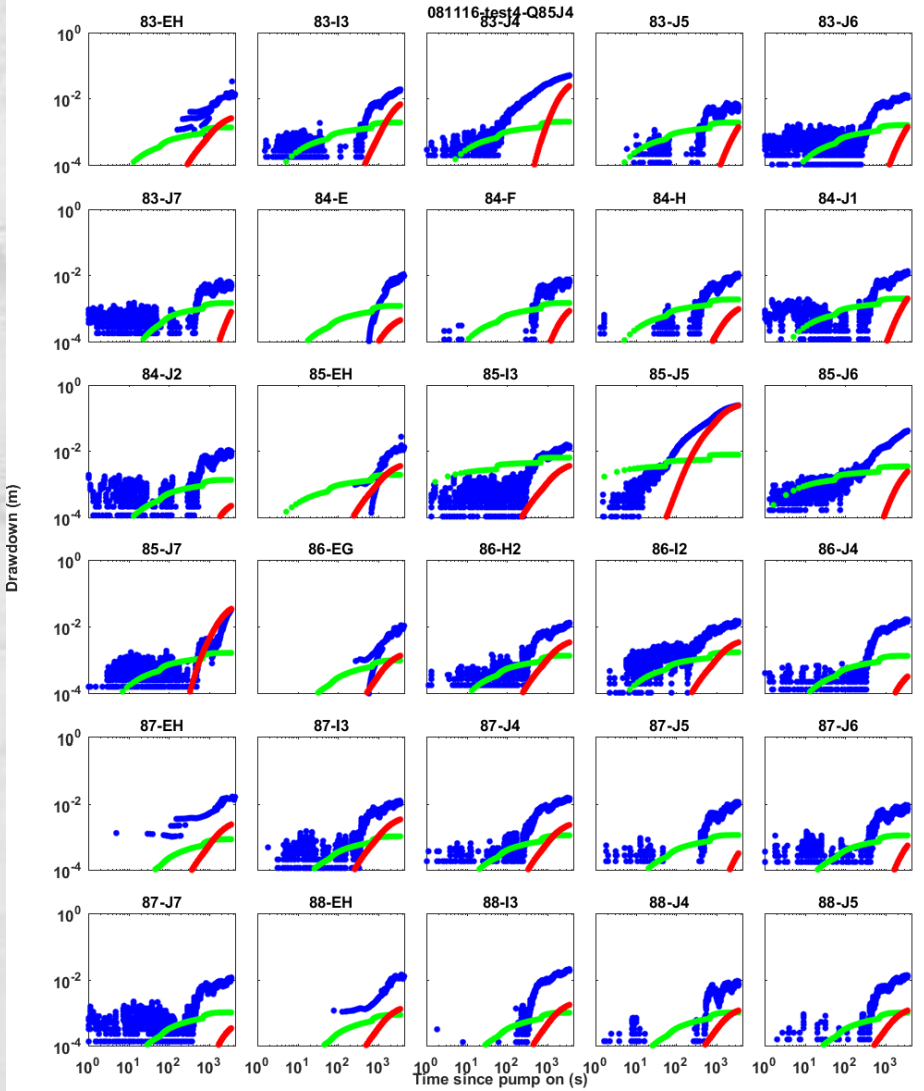
  - Pump from <K deep region



Assessment: Calibration Quality

- **Using current HT 3D K results**
  - Pump from >K major fracture
  - Pump from <K deep region
- **Improved fits – but details yet to find**



Summary and Next Steps

- HT in fractured rock aquifer
- Adapt approach used in sediments
- Finding >K fractures ± <K fractures, fault?
  - Complete initial (most-general) inversion
  - Repeat: Estimate (a) early Q and (b) Ss
  - Finer discretization (.5 x .5 x .5 m vs 1 x 1 x .5 m)
- Methods to better represent fractures
- R&D with in-situ remediation

Thank you!