Use of Strain Signature to Prevent Well to Well Communication

Environmentally Prudent Development FWP Task 25.2

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U.S. Department of Energy

National Energy Technology Laboratory
Resource Sustainability Project Review Meeting
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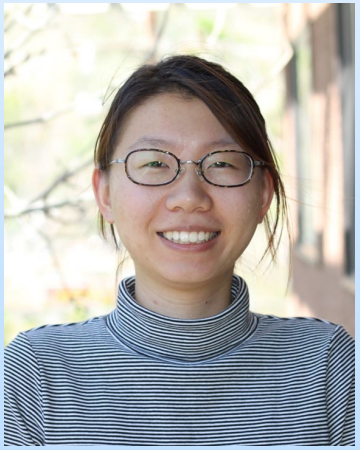
Project Overview

- Overall Project Performance Dates (2021-24)
- Project Participants – Colorado School of Mines
- Overall Project Objectives – To: 1) detect growing fractures; 2) estimate distance to growing fracture tip

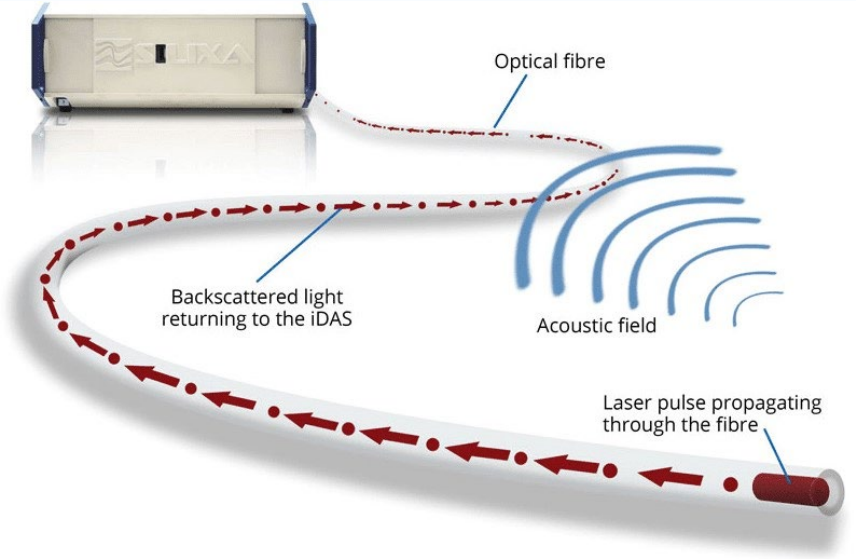


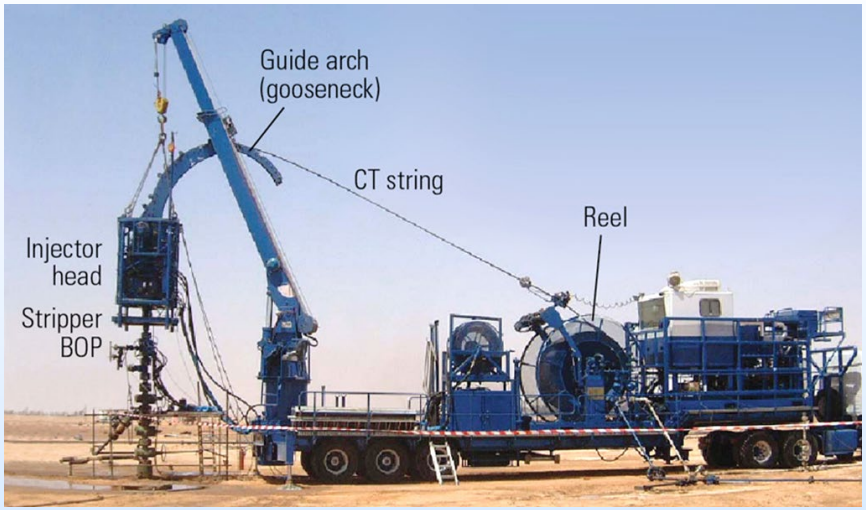
Ge Jin

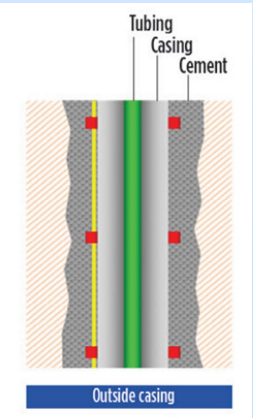
Xiaoyu (Rosie) Zhu

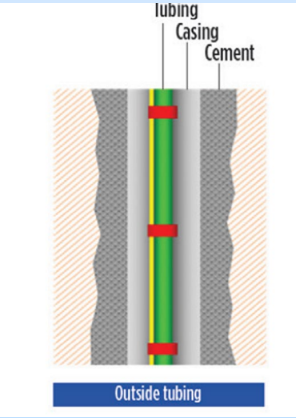
Peiyao Li

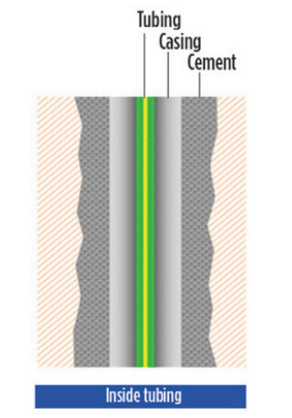
Technology Background

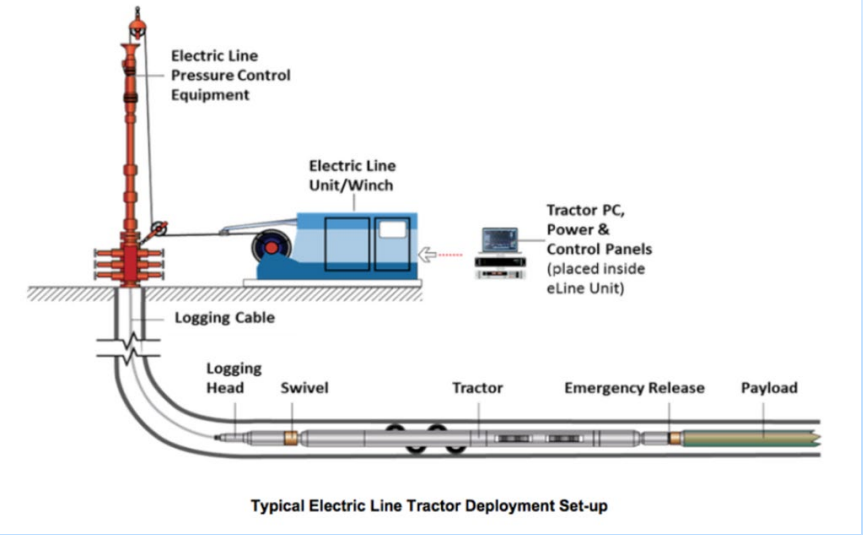








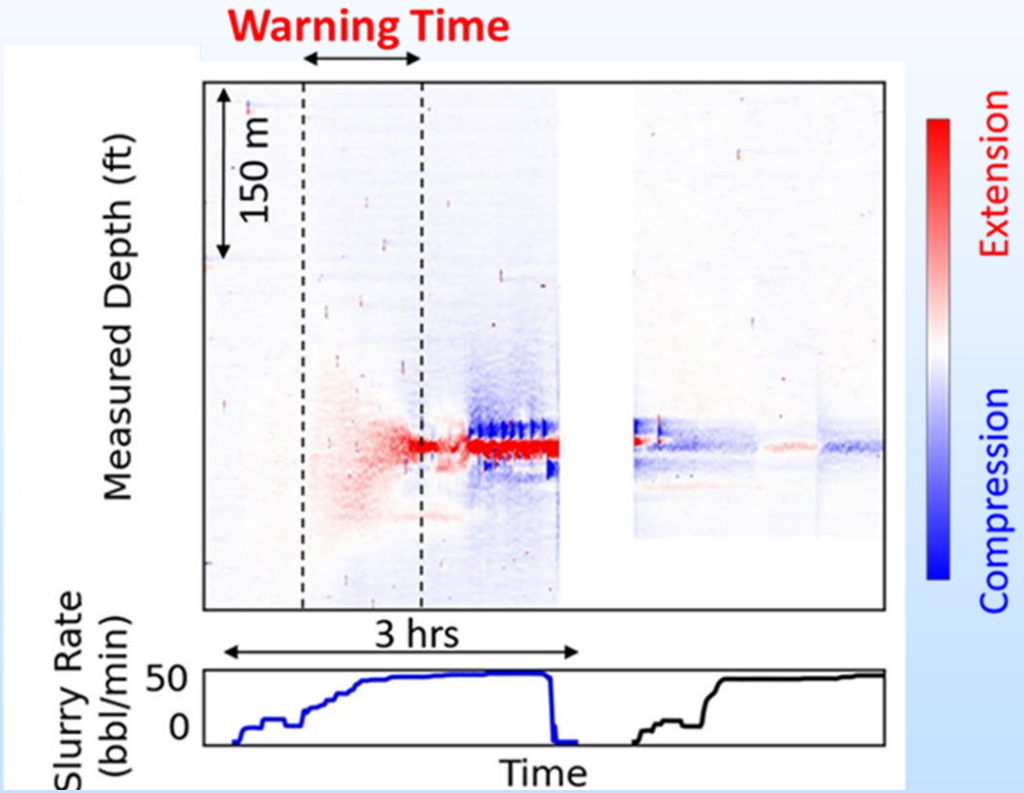




Images by Silixa

Technology Background – Past Work

- Task 1 Develop workflow to receive and condition Low-Frequency Distributed Acoustic Sensing (LF-DAS) data directly from the fiber optic cable interrogator
- Task 2 Develop and test machine learning workflows for the early, precise identification of impending frac hits
  - Random Forest (RF)
  - Artificial Neural Network (ANN)
  - Bagging Support Vector Machine (SVM)
  - *Convolutional Neural Network (CNN) – Chevron team*

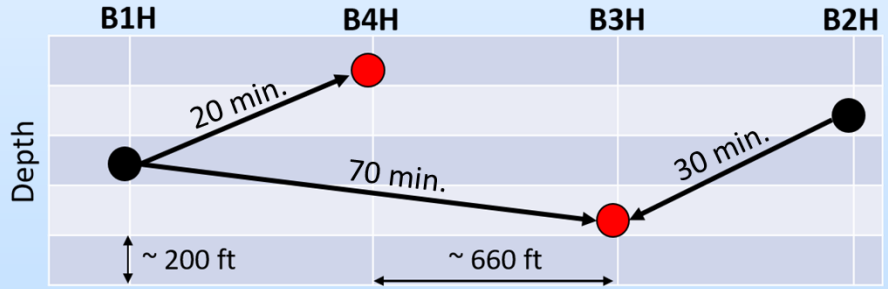


Technology Background – Past Work

Low-frequency DAS fracture-hit detection

Method	Accuracy	Frac-hit precision	Training time (s)	Predict time (s)
Random Forest	0.93	0.98	91.468	0.165
Bagging SVM	0.90	0.94	5833.670	5448.934
Neural Network	0.93	0.95	104.657	1.701

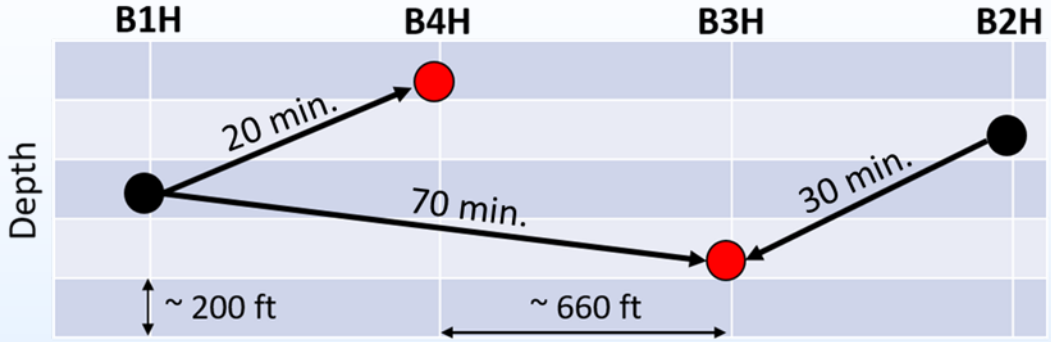
- Random Forest was the most accurate and precise, and had the shortest training and prediction times



Modified from Wang et. al., 2022

- Fiber optic warning time for frac hits at HFTS 2 was **at least** 20 minutes.
- Warning time was greater for longer well offsets and for downward fracture growth

Technology Background – Past Work



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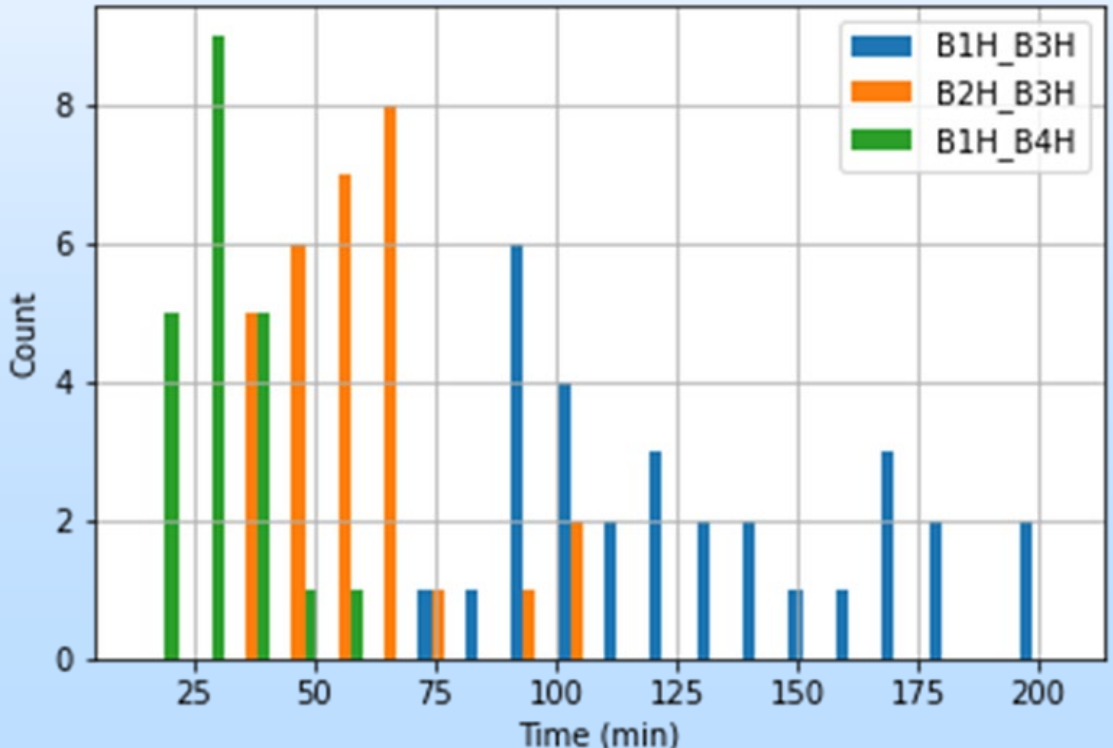
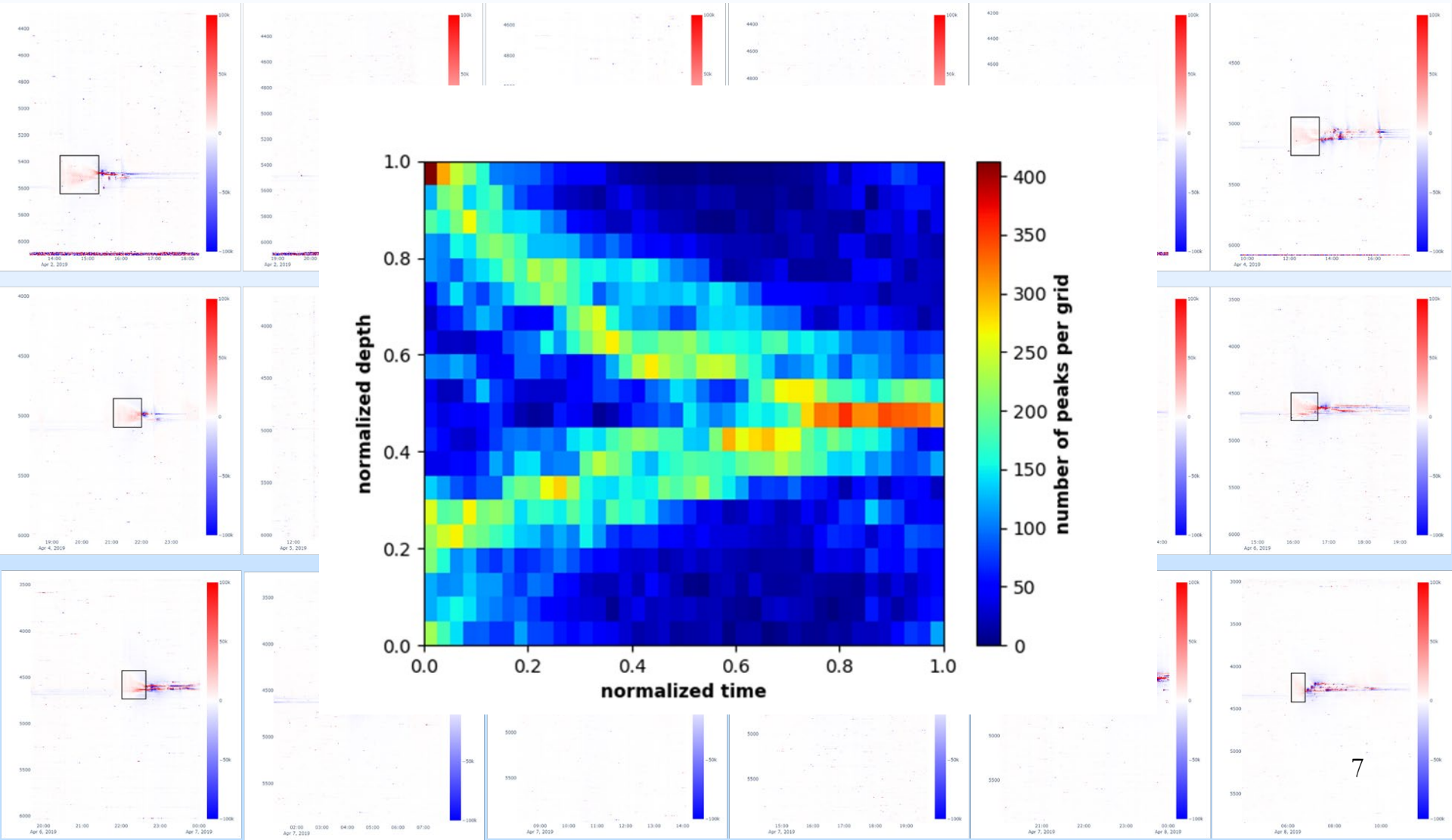


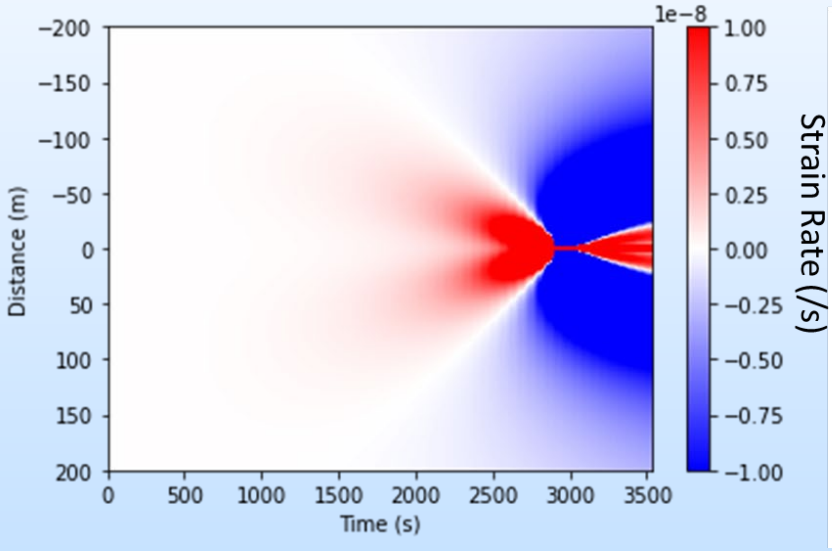
Technology Background – Current Work



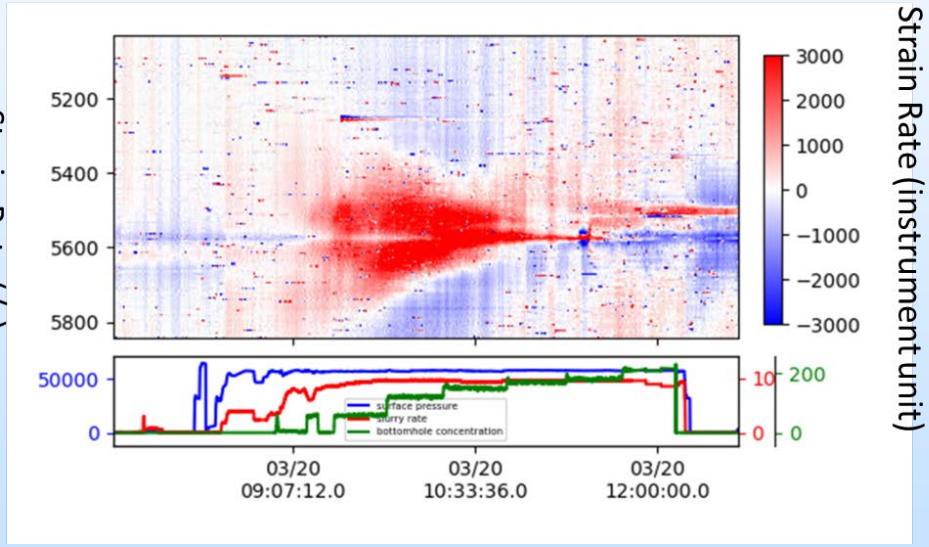
Technology Background – Current Work

- Heart-shape extensional strain signal is generated ahead of the fracture tip, and can be captured by cross-well strain measurement.

Synthetic Model

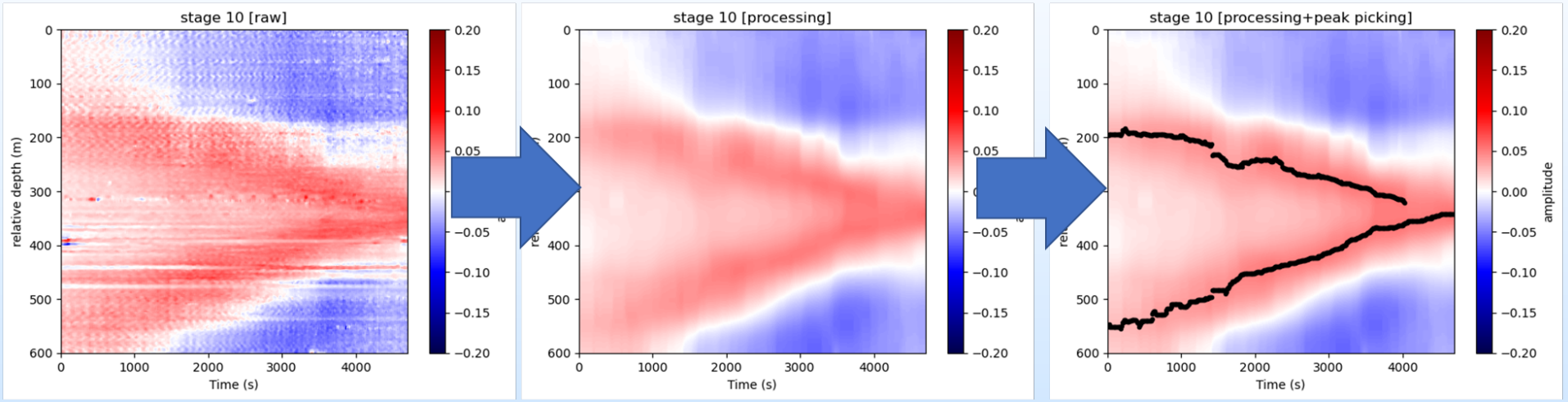


Field Data (HFTS2)



Technology Background – Current Work

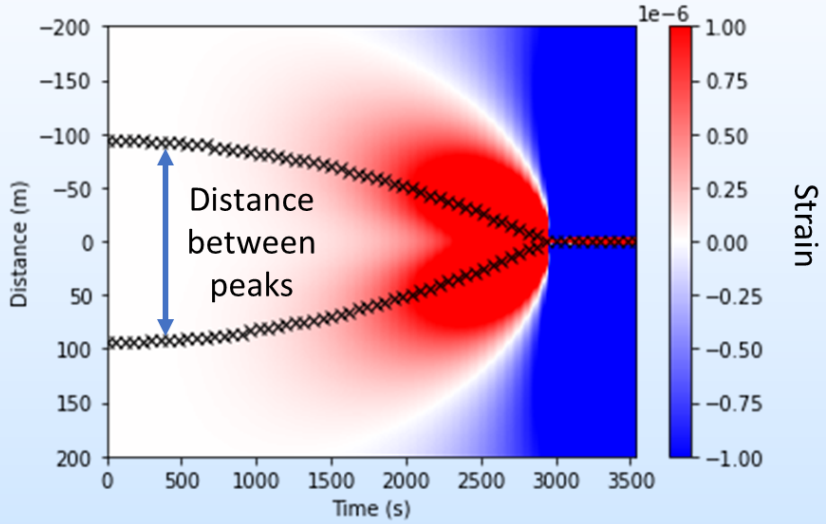
Signal processing and peak picking

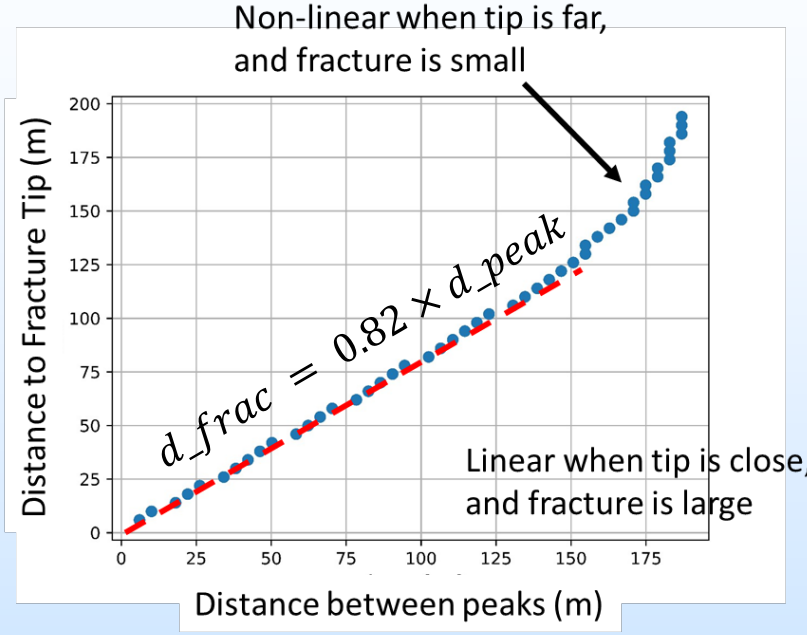


Through the developed signal processing algorithm, local spatial maximums of the heart-shape signal can be picked at each time step in the field data.

Technology Background – Current Work

Synthetic modelling



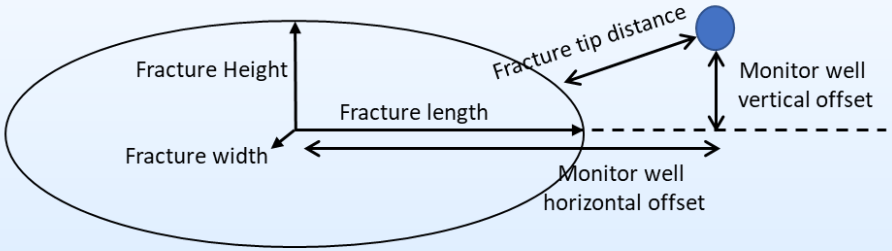


Synthetic model demonstrates that the distances between peaks for each time step are strongly correlated with the distance between the fracture tip and monitor well.

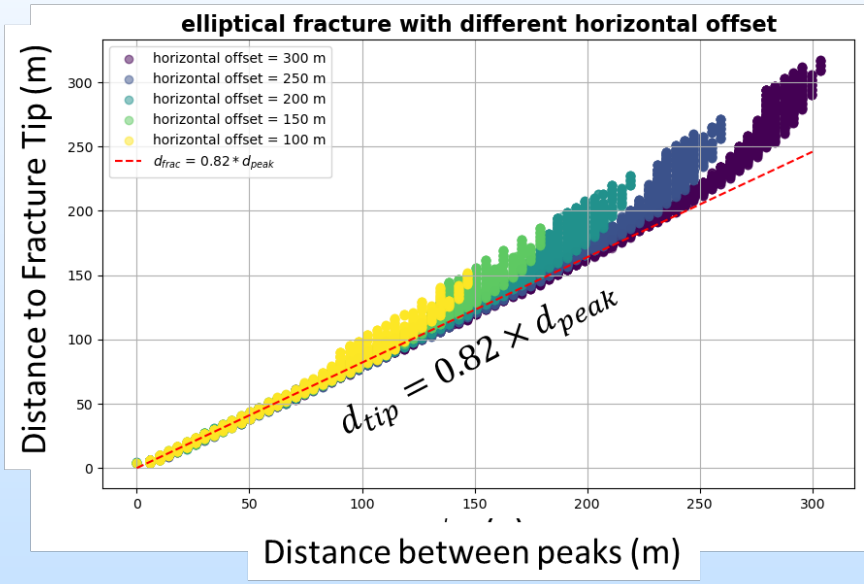
3D Displacement Discontinuity Method (DDM)

Technology Background – Past Work

Peak distance to fracture distance

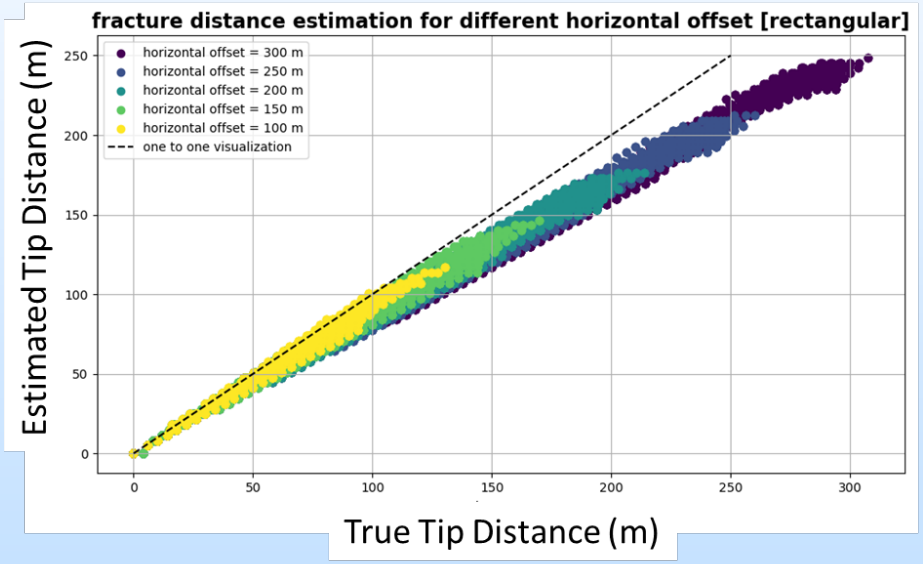


Elliptical fractures: 405 different models
Fracture length: 0 - 240 m
Width/length ratio: 4.17e-6, 4.17e-5, 4.17e-4
Height/length ratio: 0.125, 0.25, 0.375
Monitor well vertical offset: 0, 15, 30, 45, 60, 75, 90, 105, 120 m
Horizontal offset: 100, 150, 200, 250, 300 m



Technology Background – Current Work

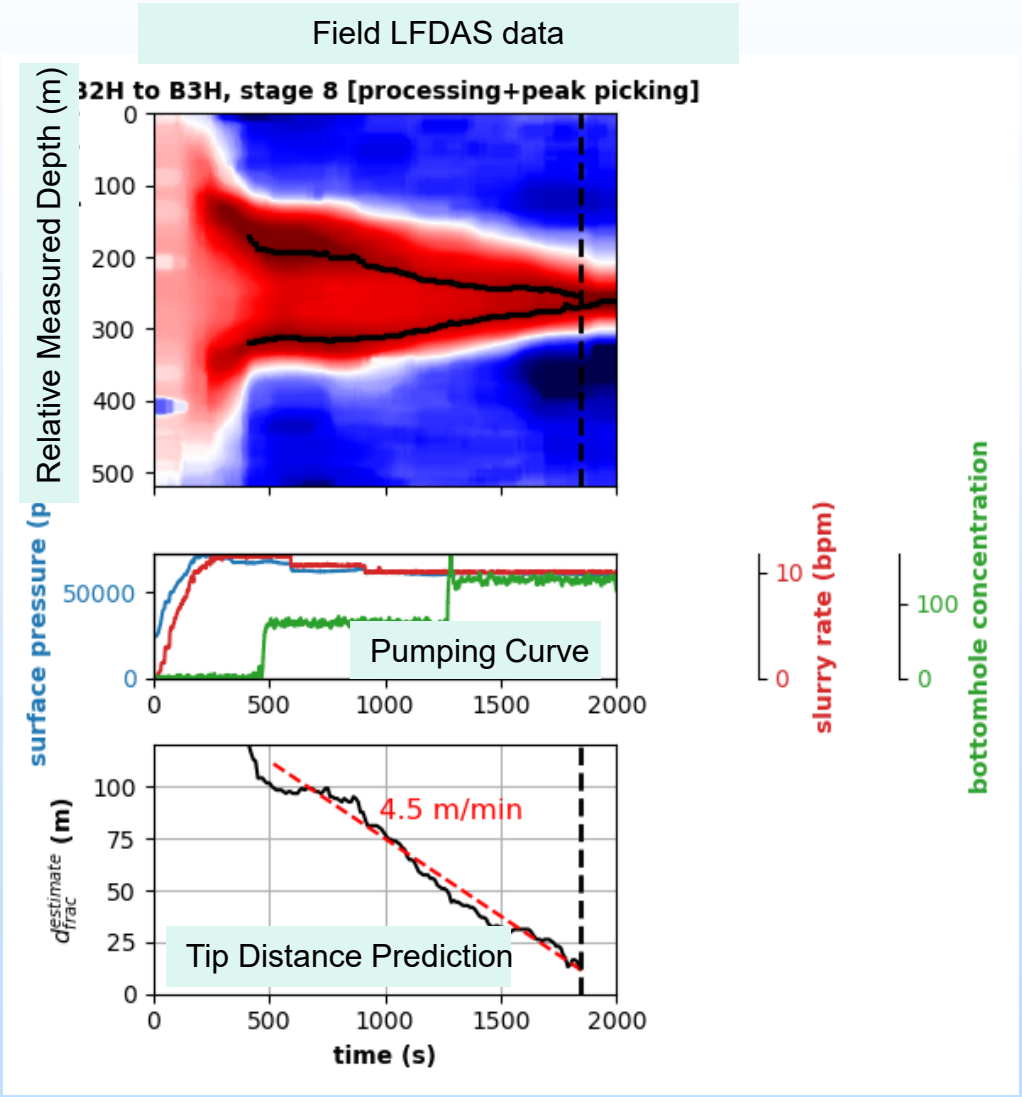
Estimation error on rectangular fractures



If we use the relation obtained from elliptical fracture to predict rectangular fracture, up to 15% systematic bias can be observed.

The shape of actual fractures should be between elliptical and rectangular. This represents the worst-case scenario.

Technology Background – Current Work



- Well offset is 205 m; therefore, fracture tip distance can be estimated up to 123 m.
- Fracture propagation initially occurs rapidly and then decelerates.
  - 12 m/min for the first 7 minutes
  - 4.5 m/min afterward until fracture hits
- Estimating fracture tip distance in real-time enables field operators to adjust pumping strategies to prevent fracture hits.

Plans for future testing/development/ commercialization

Technology transfer:

a. Real-time LF-DAS processing on GitHub
   https://github.com/DASDAE/DASLowFreqProcessing
b. Real-time ML recognition of fracture strain signature - to be published on GitHub
c. Real-time calculation of fracture tip distance – submitted to SPE Journal

Summary Slide

Permanent or deployable fiber optic cables can be used to:

1. Monitor frac hits in real time
2. Warn of impending frac hits in adequate time to implement an intervention strategy
3. Estimate distance to growing fracture tip