Towards 4C FWI: DAS and 3C as complementary datasets

Matt Eaid and Kris Innanen

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Banff, Alberta

Outline

1. Motivation

2. FWI overview and outstanding challenges
   - 3C and DAS

3. Overview of CaMI Field Research Station
   - 2018, 3D Multi-Azimuth Vertical Seismic Profile

4. Modelling of four component dataset
   - Modeling CaMI field data from 3D VSP

5. Future work

Motivation

- Full waveform inversion, when applied to land data suffers from lack of low frequencies, narrow aperture, and sparse sampling.

- Acquisition using distributed acoustic sensors has the potential to provide data which correct for these shortcomings.

- Distributed acoustic sensor data introduces challenges associated with lack of directionality, and low signal-to-noise.

- DAS and 3C geophones from an FWI perspective are complementary and provide a 4C dataset that could improve our FWI result.

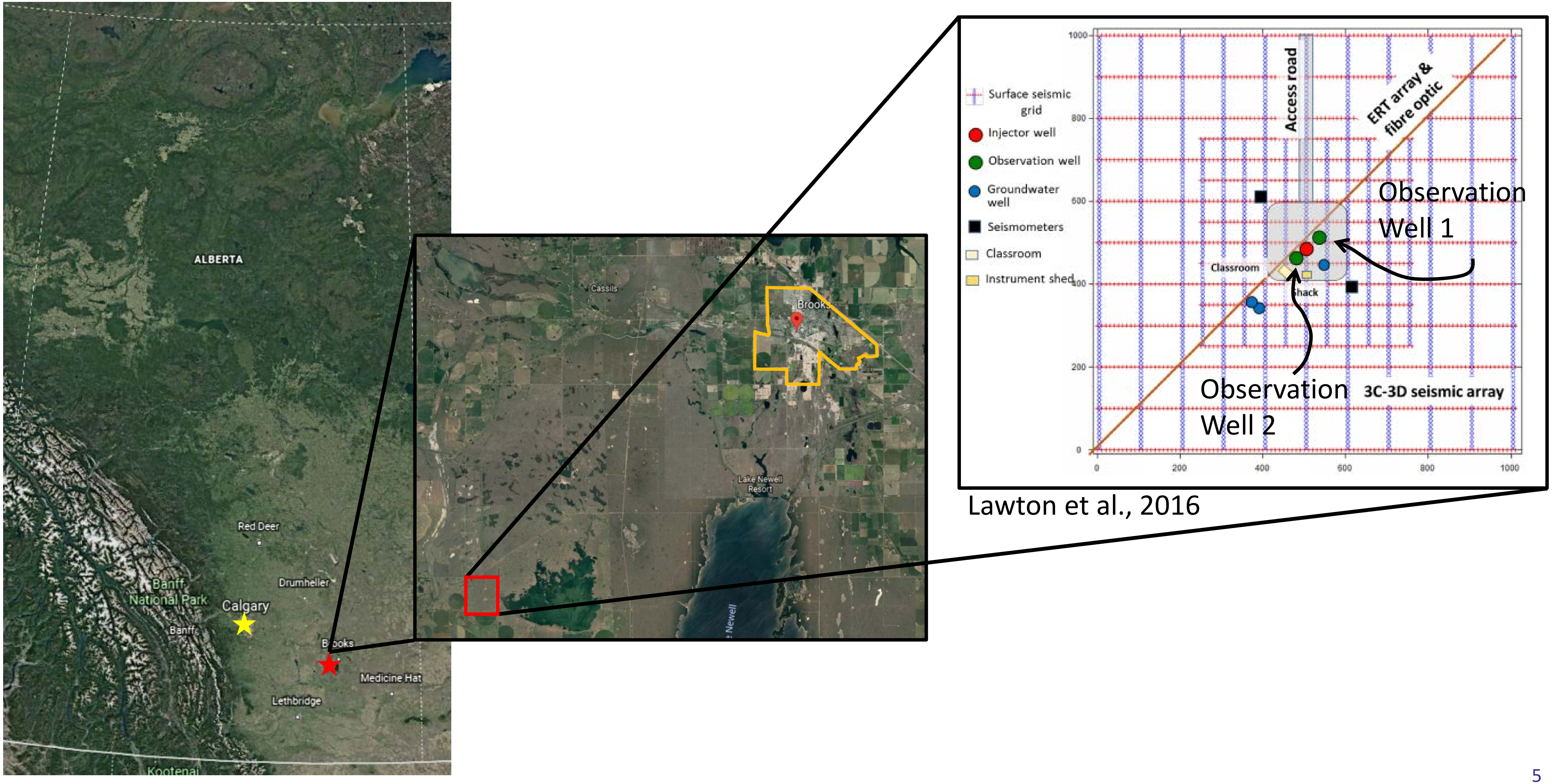
Full waveform inversion

Full waveform inversion attempts to find an estimate of the subsurface parameters by minimizing an objective function that usually depends on the L_2 norm of the data residuals.

$$f = \sum \|\delta \mathbf{d}\|_2^2$$

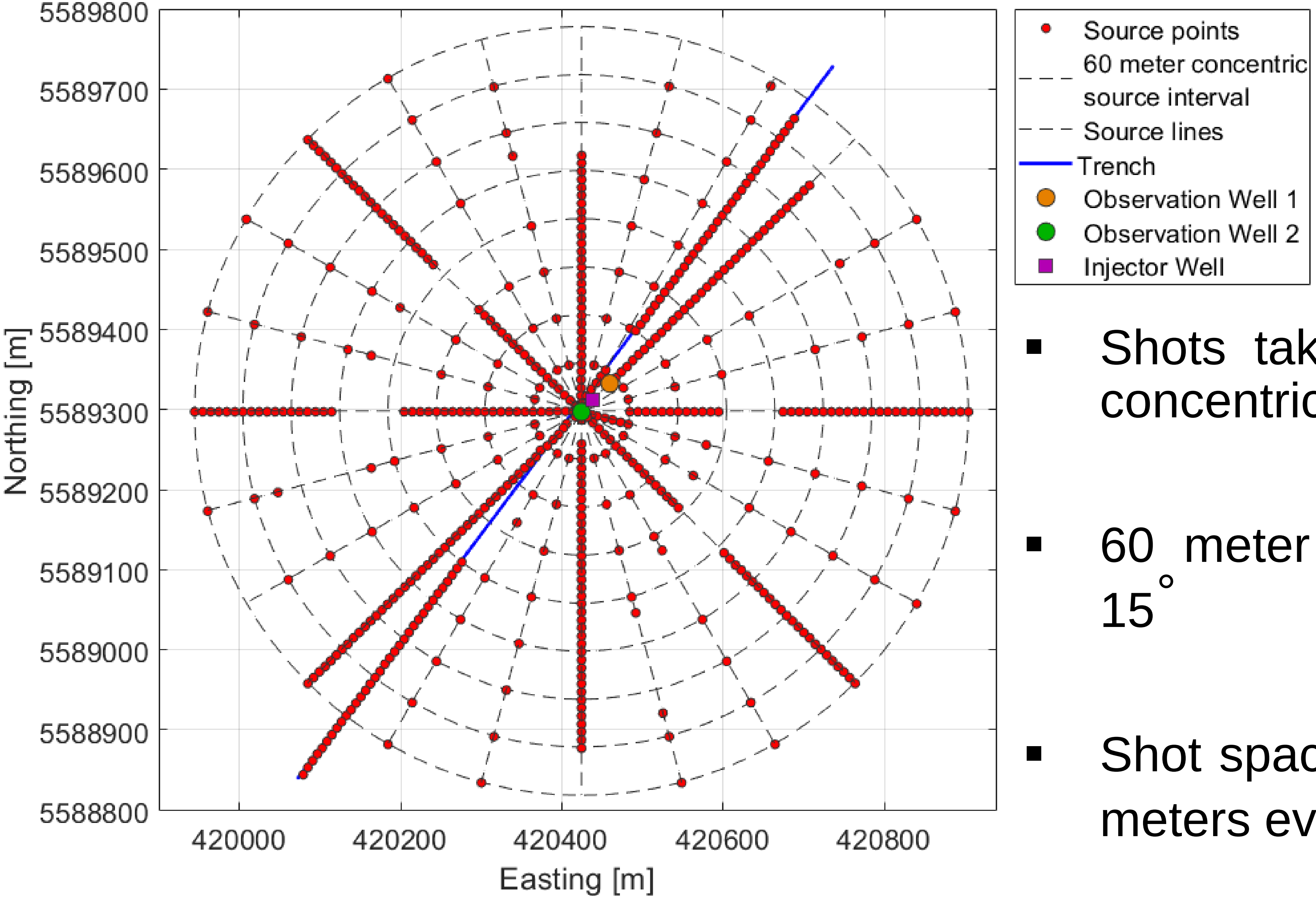
	3C Geophones	Distributed Acoustic Sensors
Dense Sampling	✗	✓
Low Frequency Recording	✗	✓
Multi-Component	✓	✗
High Signal-to-Noise	✓	✗

CaMI Field Research Station



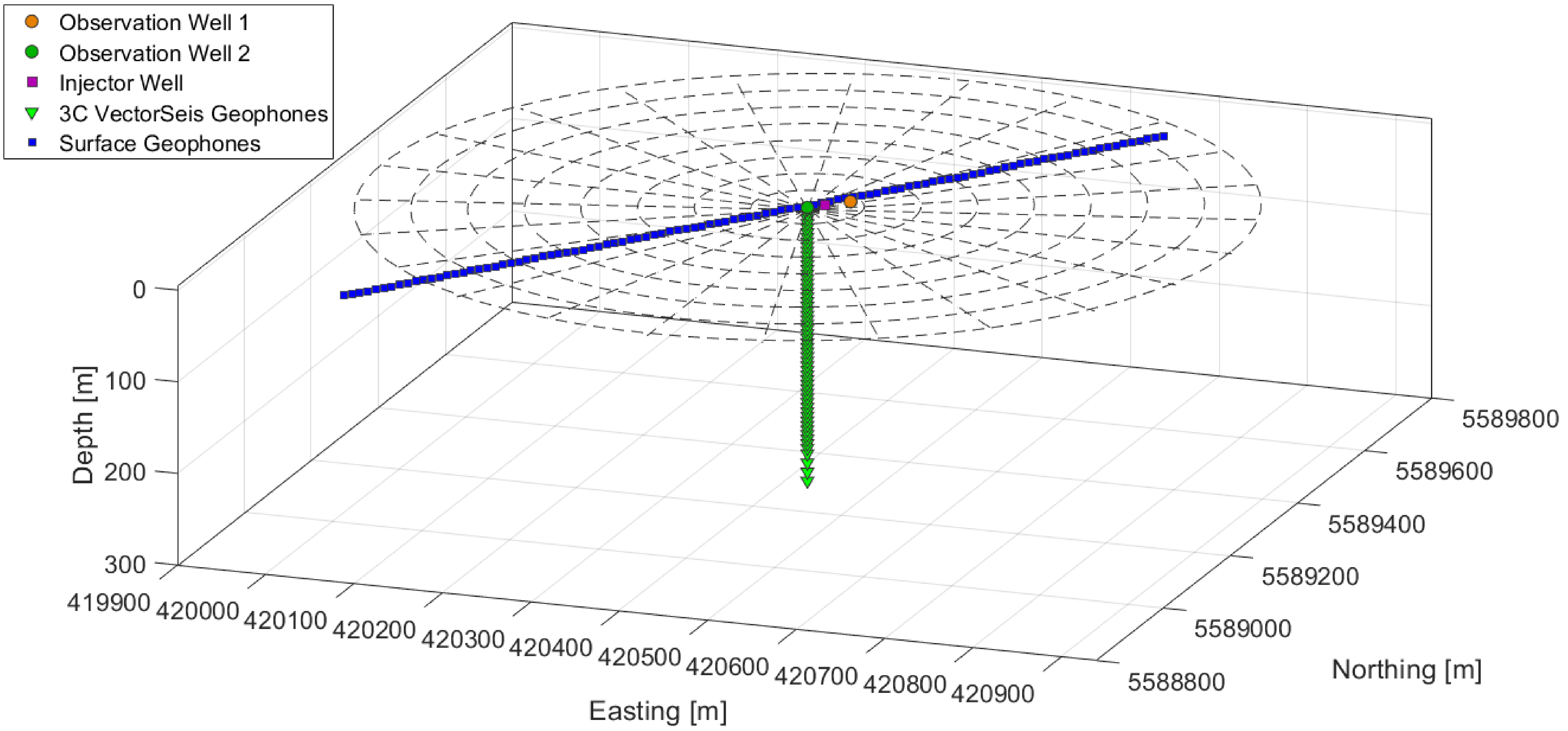
Lawton et al., 2016

2018 3D Multi-Azimuth VSP – source geometry

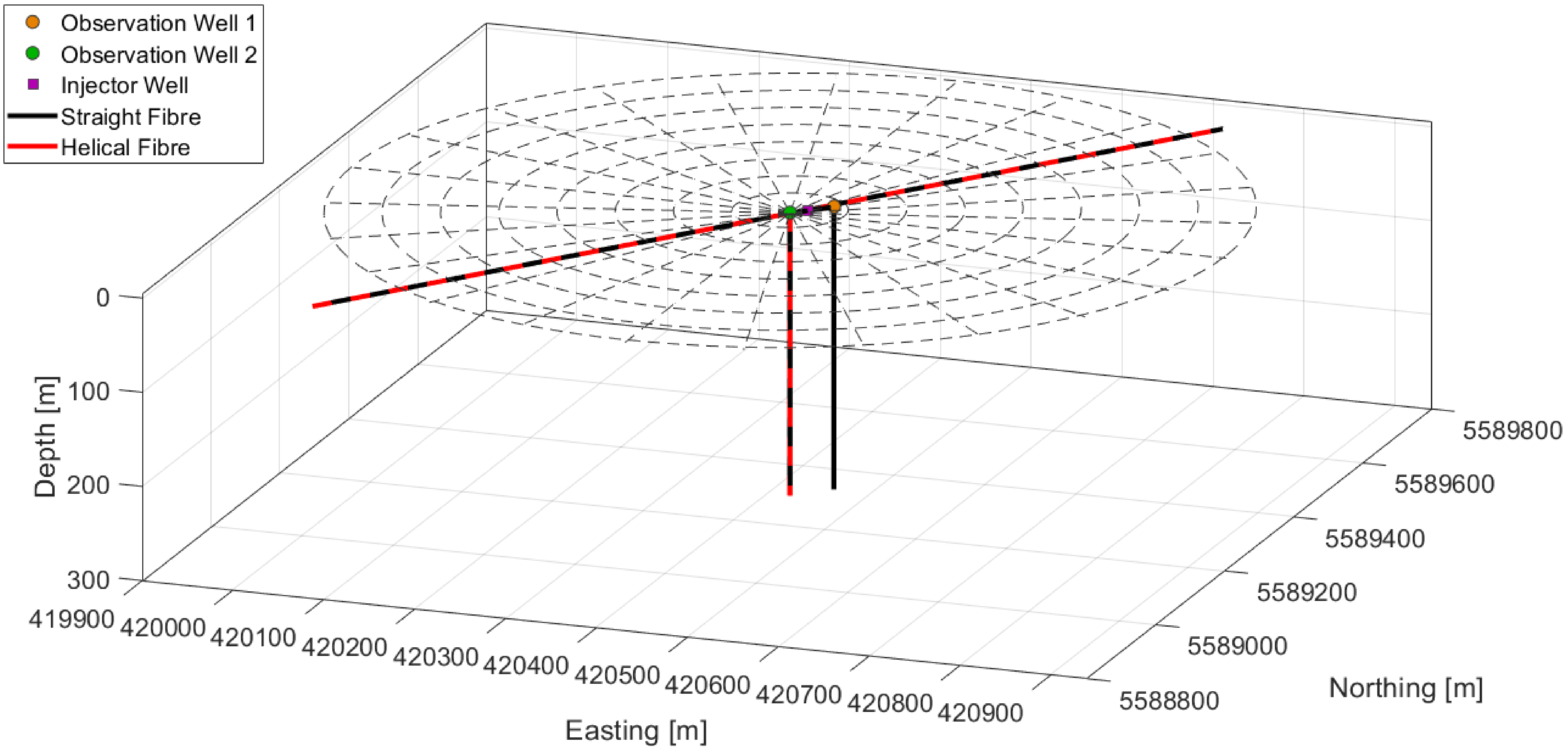


- Shots taken every 15° along concentric circles
- 60 meter shot spacing every 15°
- Shot spacing condensed to 10 meters every 45°

2018 3D Multi-Azimuth VSP – receiver geometry



2018 3D Multi-Azimuth VSP – fibre geometry



Velocity-stress finite difference

Velocity-stress finite difference simulations rely on computations of the particle velocity, and stress to propagate the wavefield.

1. **Elastodynamic equation of motion**

$$\rho \frac{\partial \dot{u}_i}{\partial t} = \nabla \cdot \sigma + f_i$$

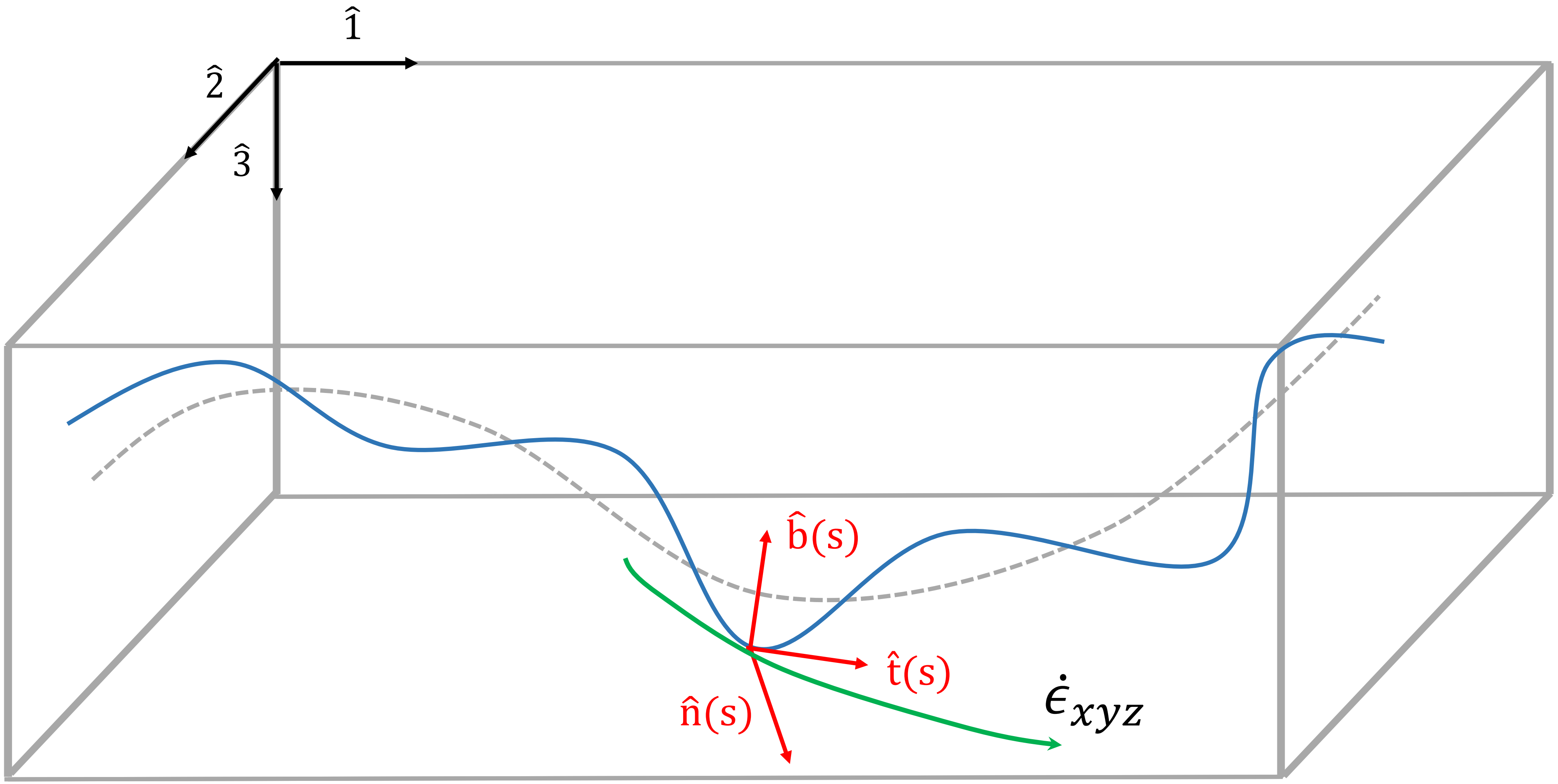
2. **Time Derivative of Hooke's Law**

$$\frac{\partial \sigma_{ij}}{\partial t} = C_{ijkl} \dot{\epsilon}_{kl}$$

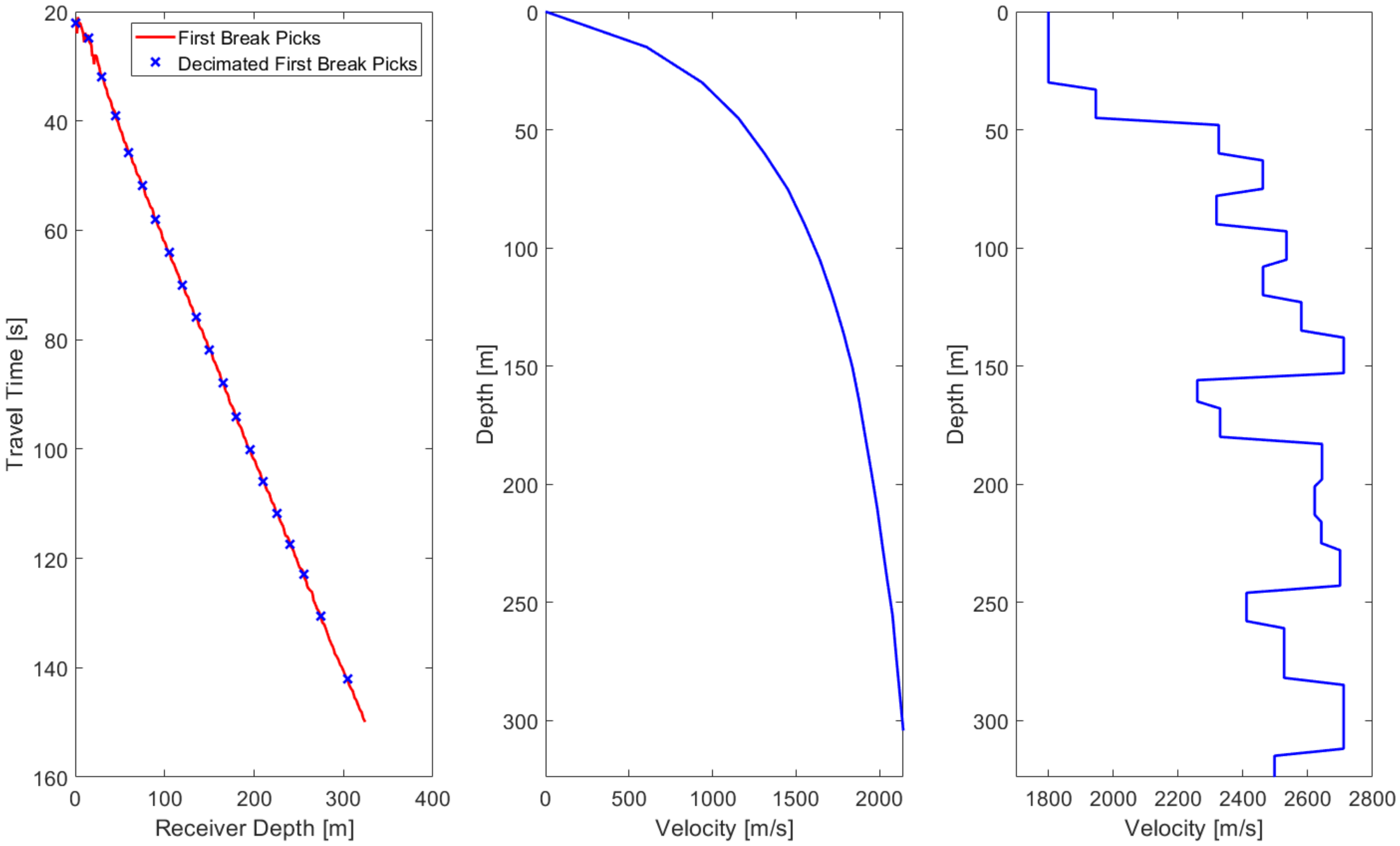
3. **Strain Rate Tensor**

$$\dot{\epsilon}_{kl} = \frac{\partial \epsilon_{kl}}{\partial t} = \left(\frac{\partial \dot{u}_k}{\partial x_l} + \frac{\partial \dot{u}_l}{\partial x_k} \right)$$

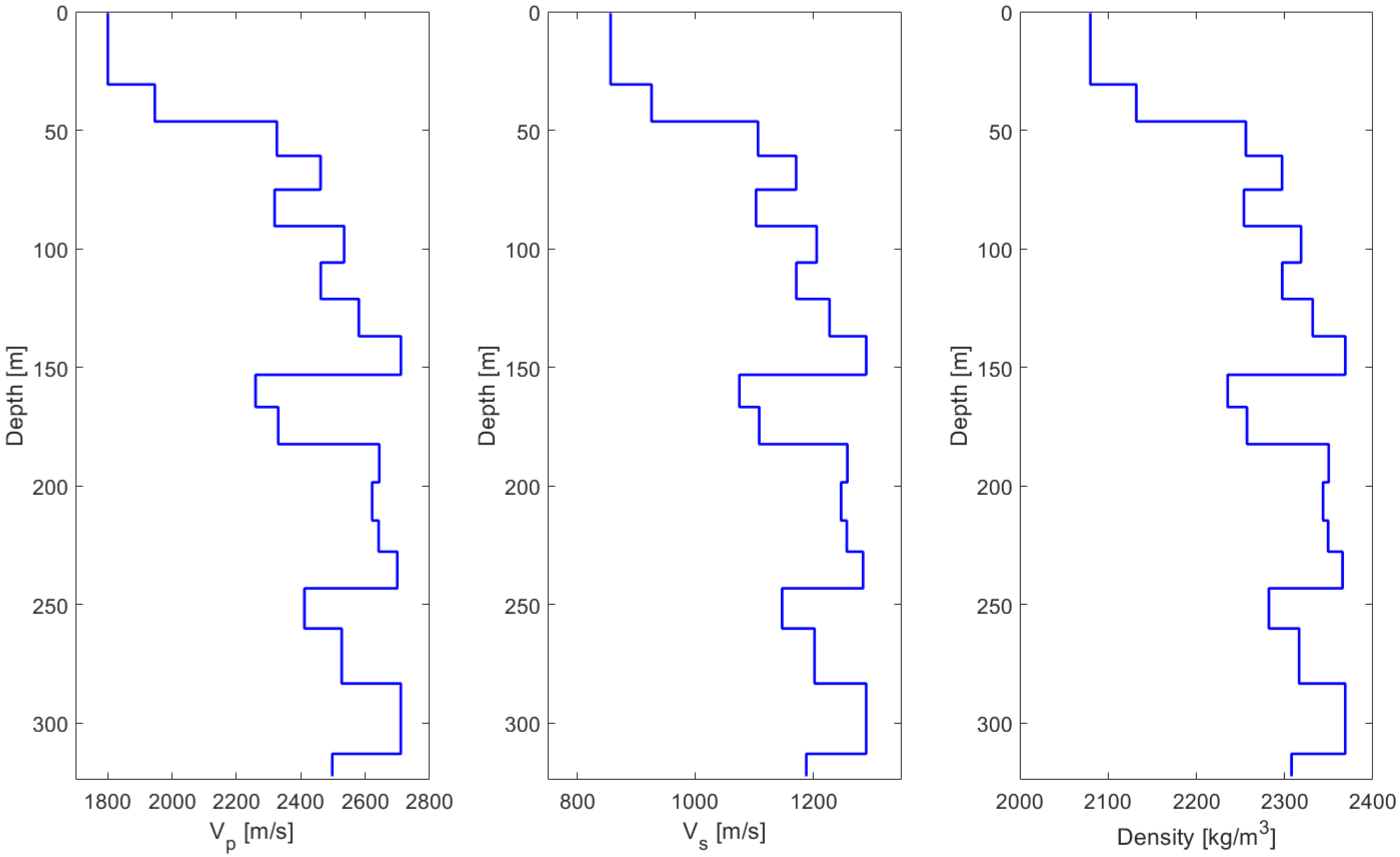
Distributed acoustic sensors are only sensitive to wavefields causing tangential strain along the fibre axis.



P-wave velocity model from first breaks



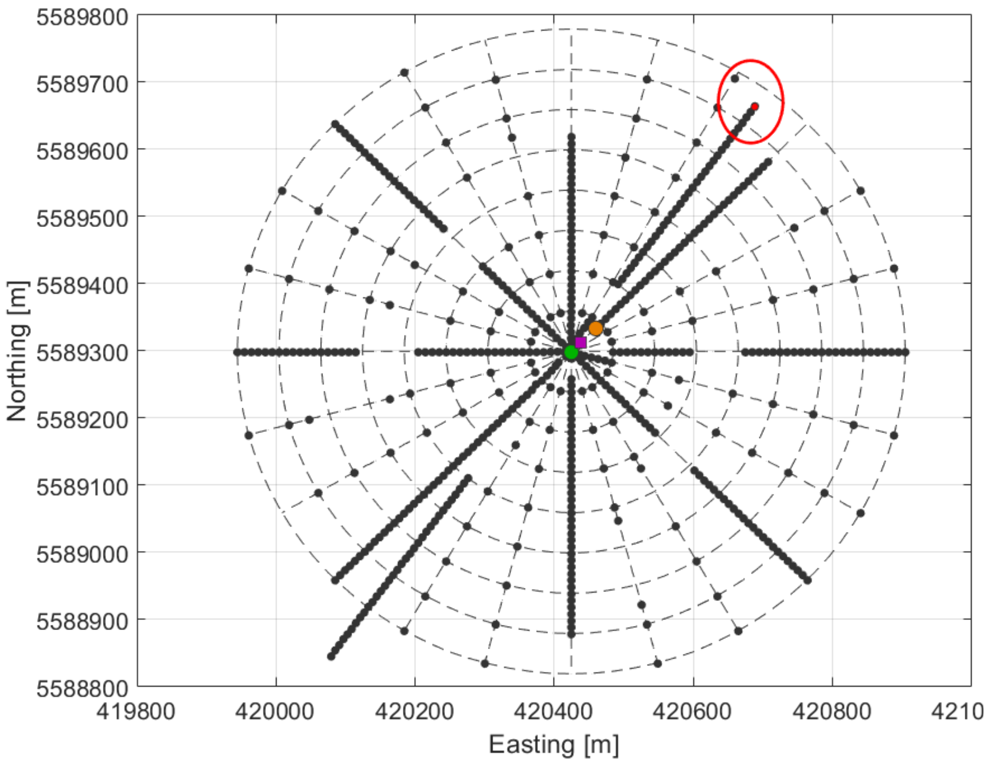
Field Research Station elastic models

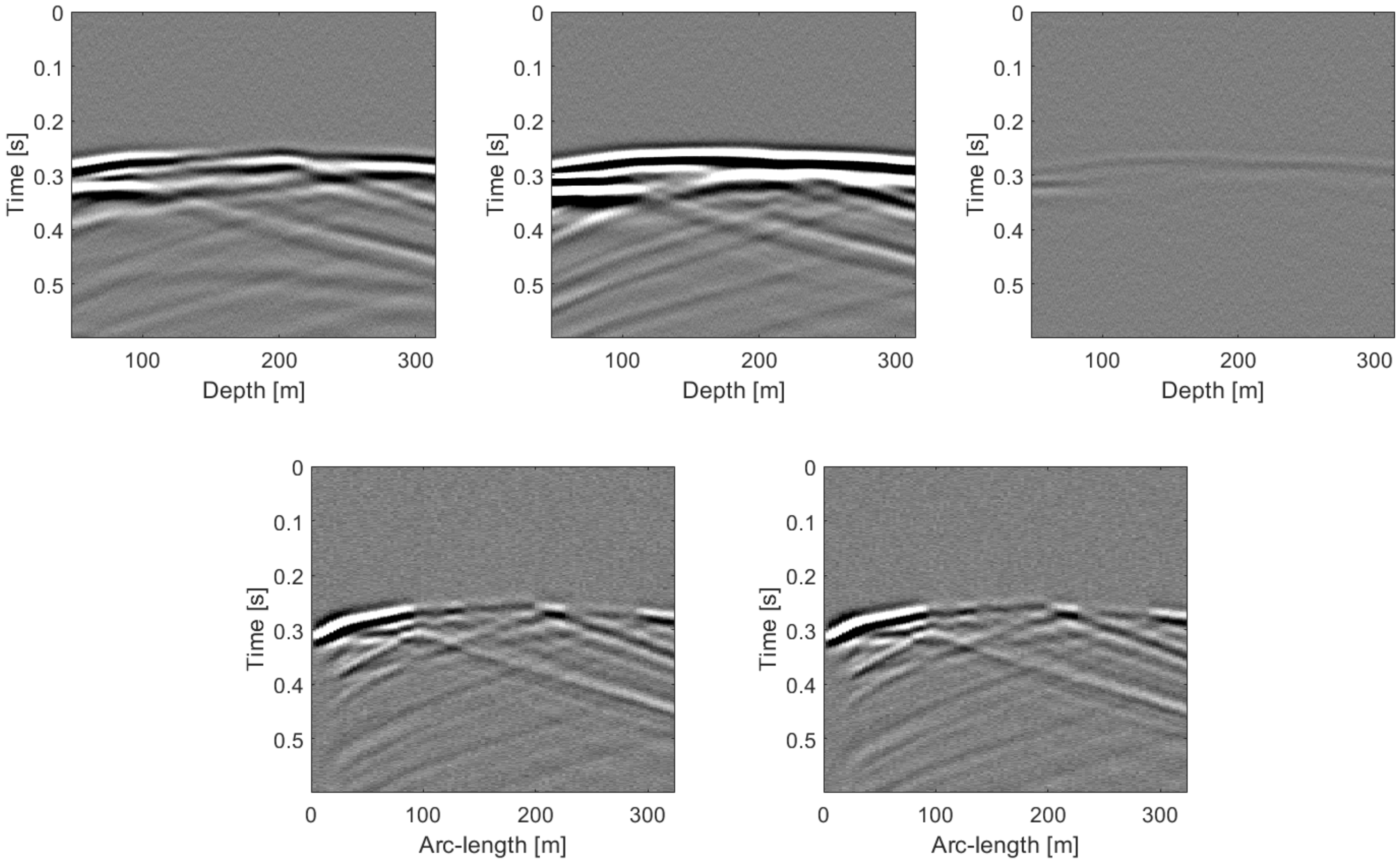


Modelled data processing

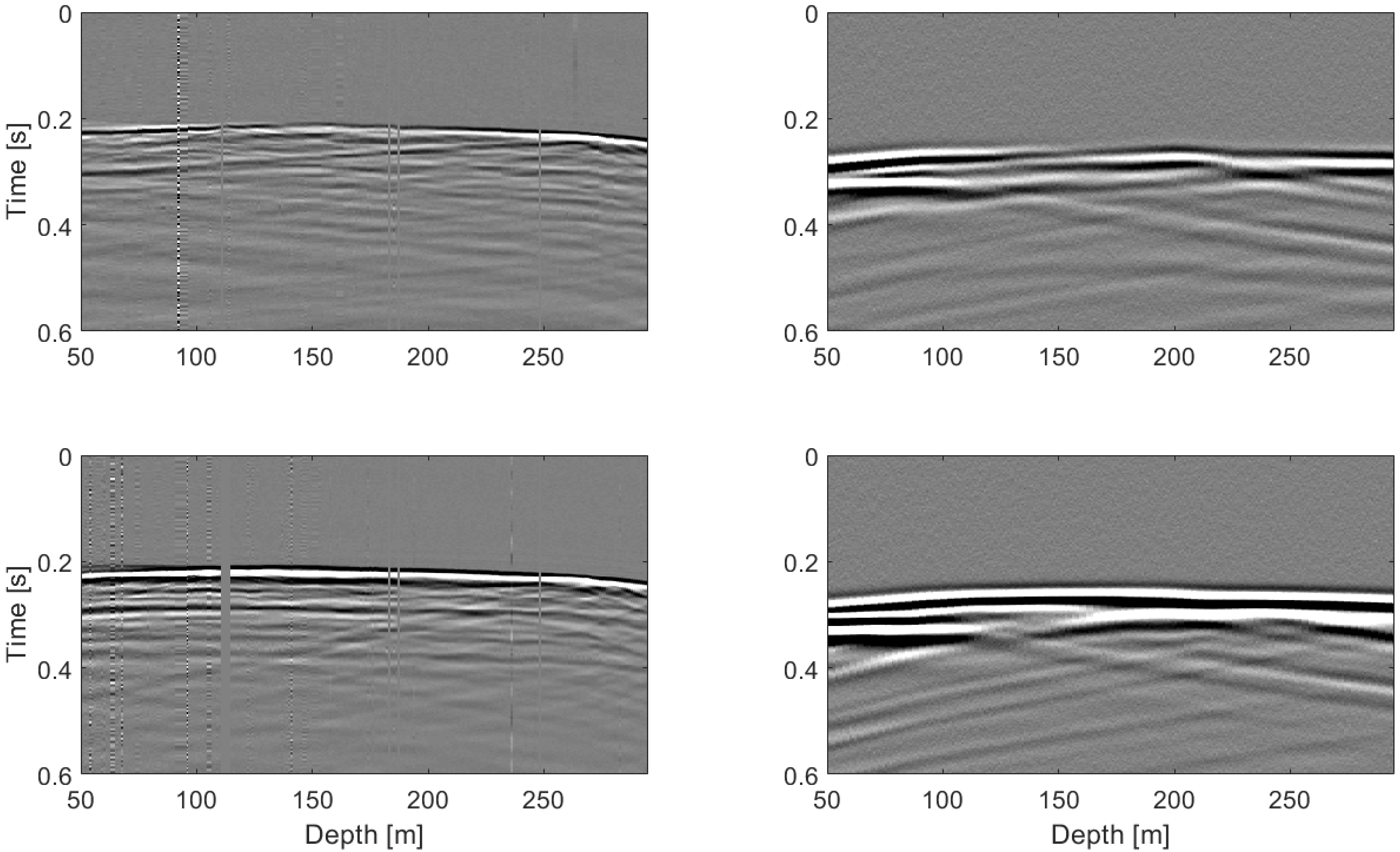
- The modelled data was then processed to emphasize the complementary aspects of each dataset
- Random noise was added to both 3C and DAS data, highlighting the inferior signal to noise of DAS
- The geophone data was then band pass filtered from 10-150 Hz simulating geophone data
- The DAS data was filtered from 0-150 Hz

Modelled data in observation well 2





Comparison of field to modelled data



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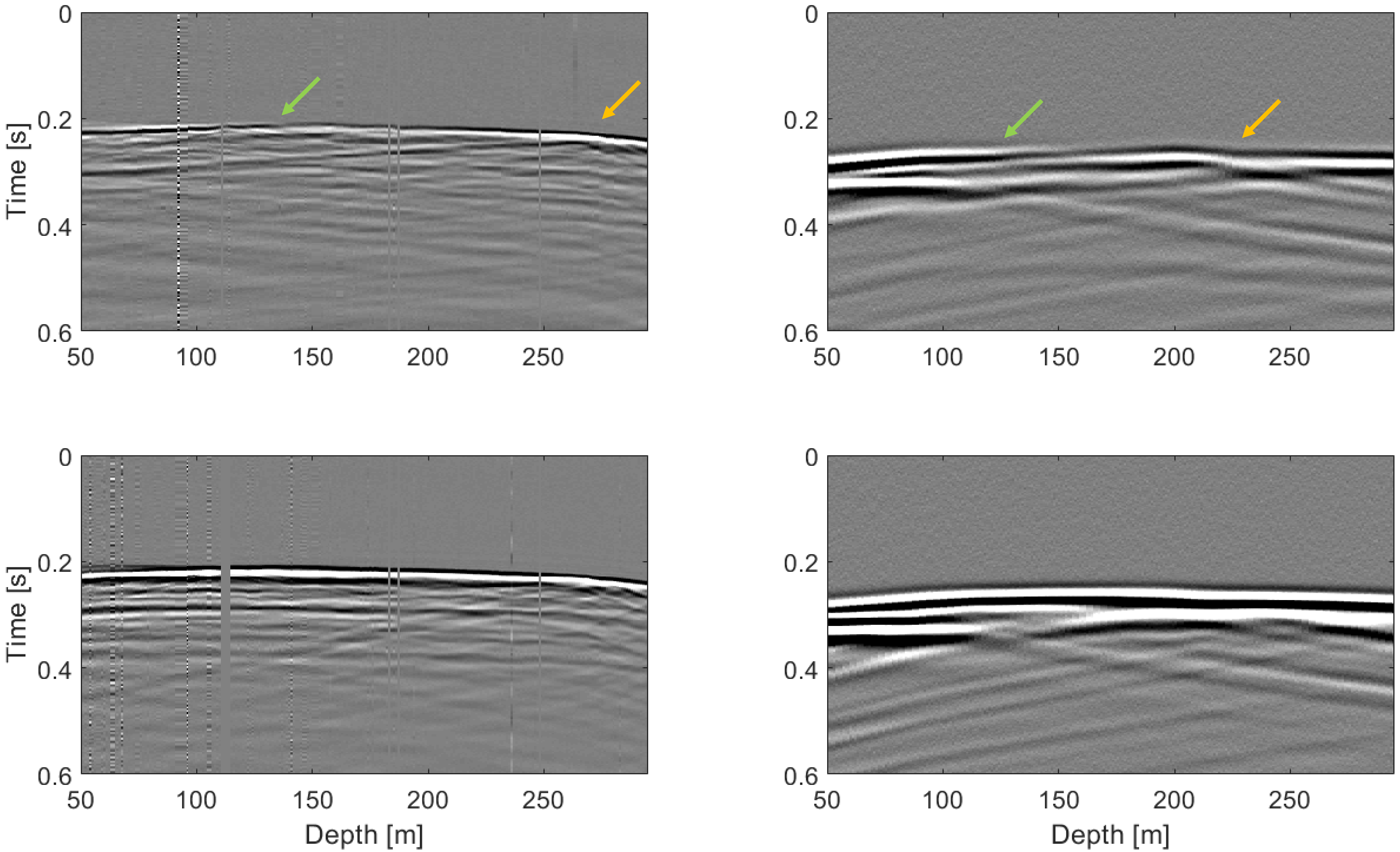
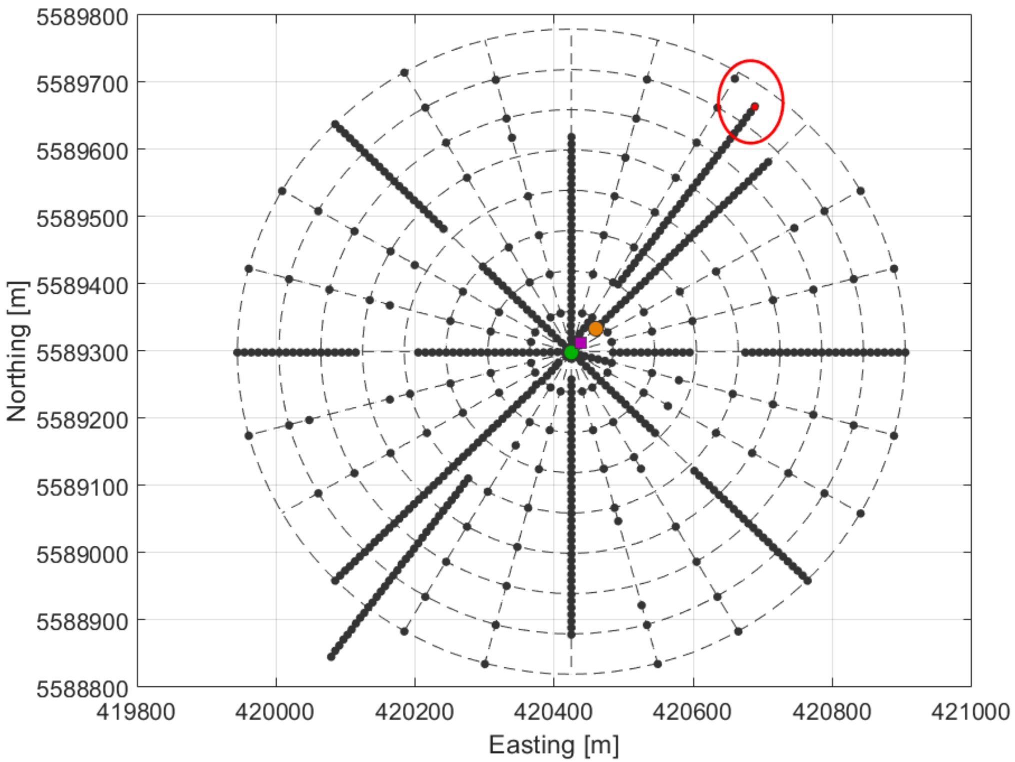
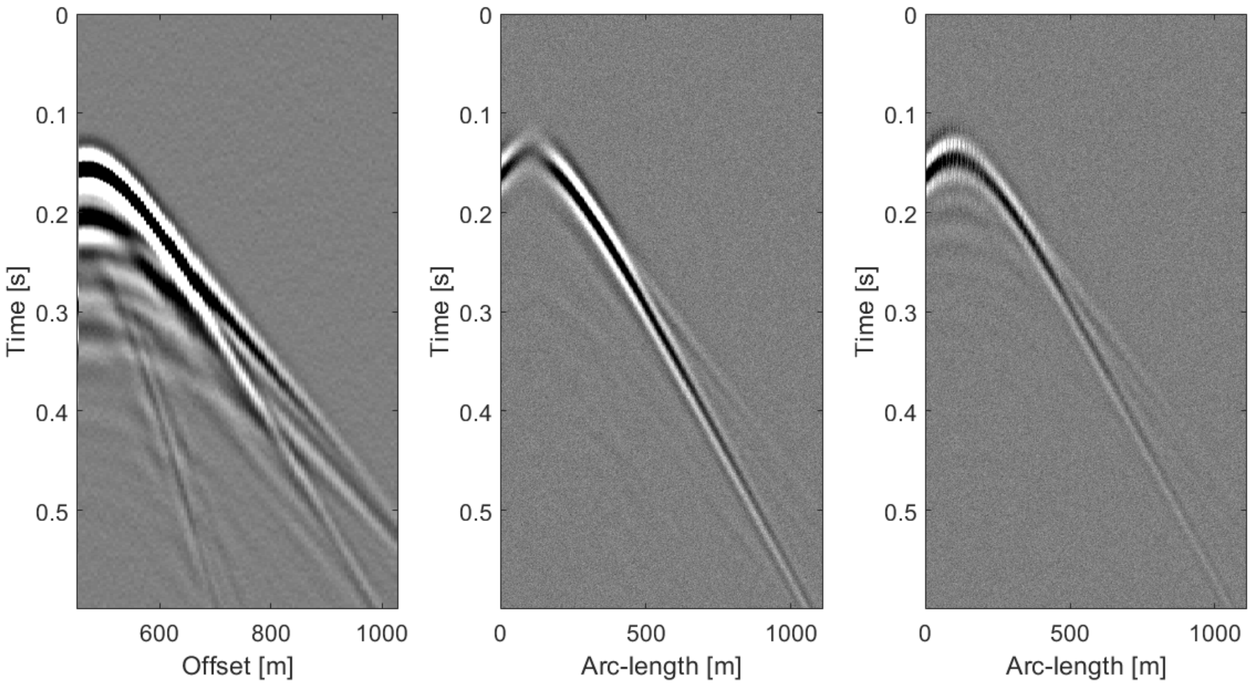
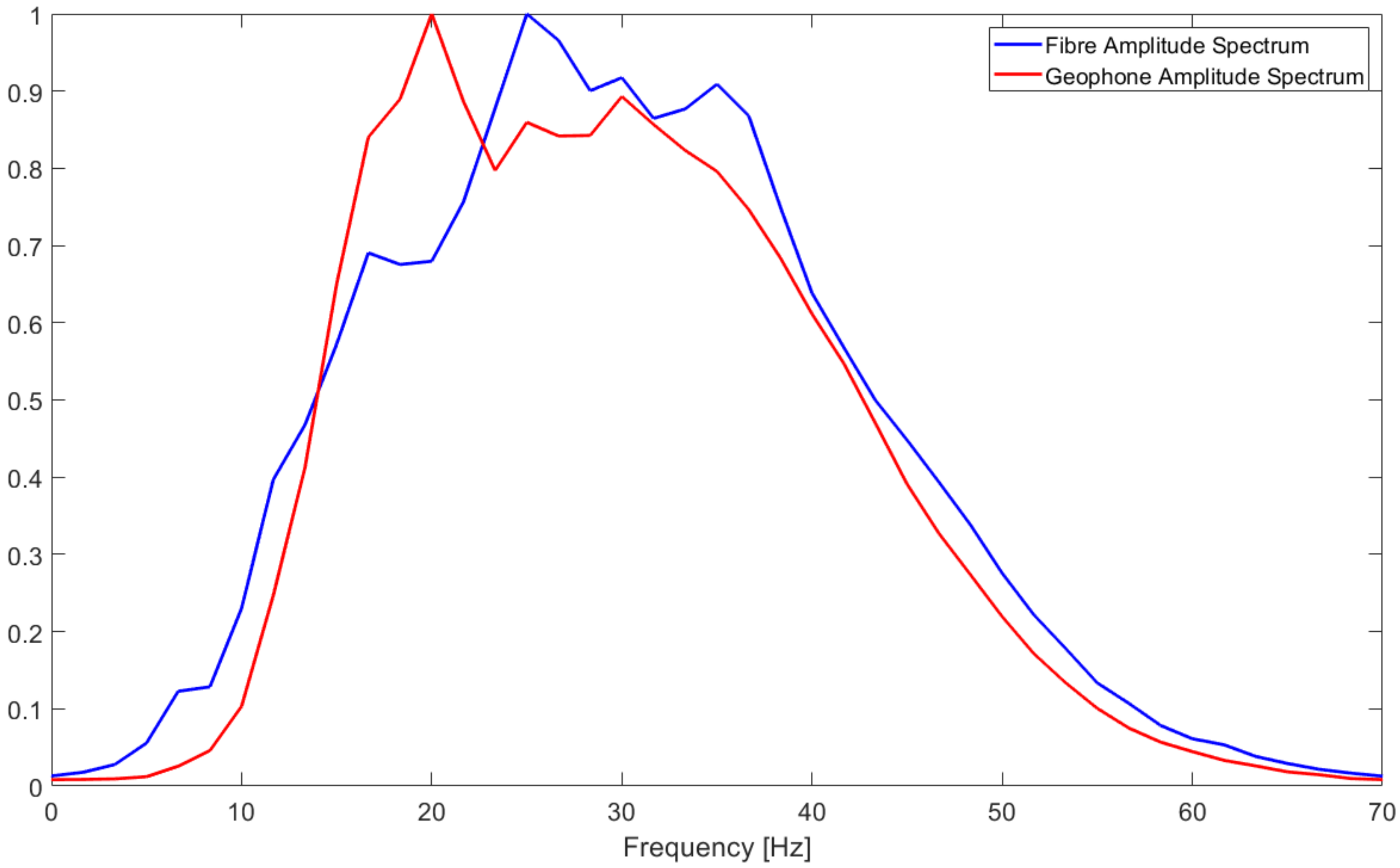


Modelled data along trench

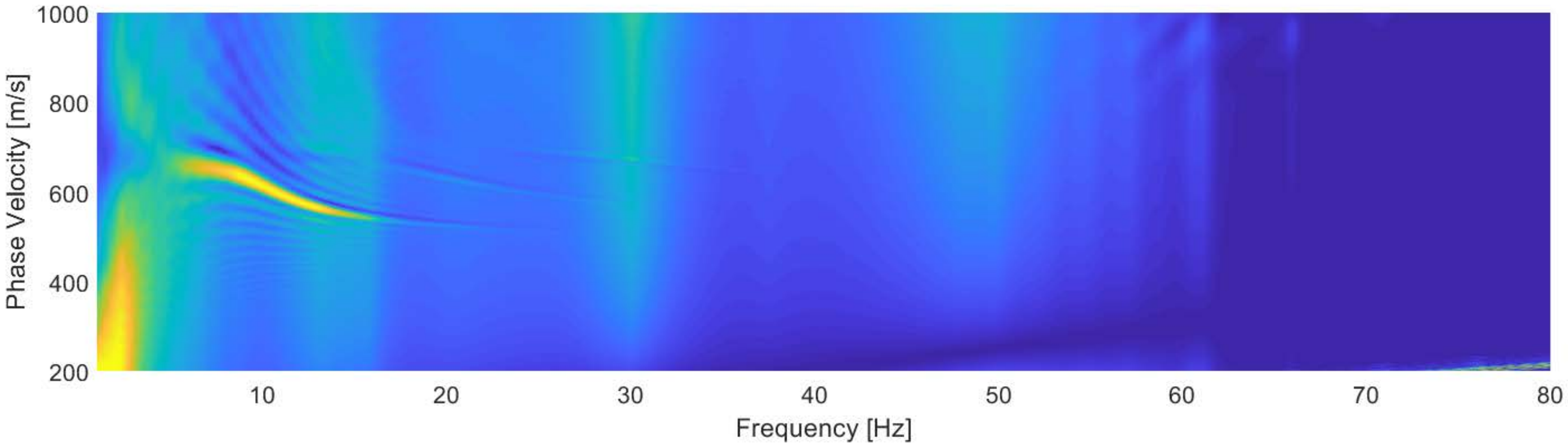




Amplitude Spectrum Comparison



Dense sampling – surface waves



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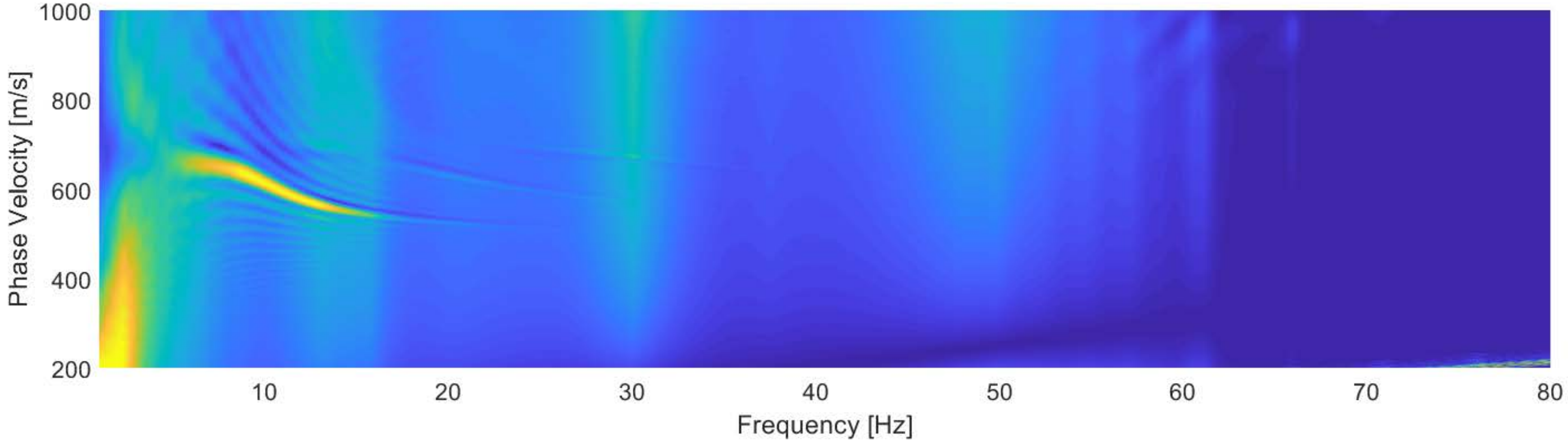

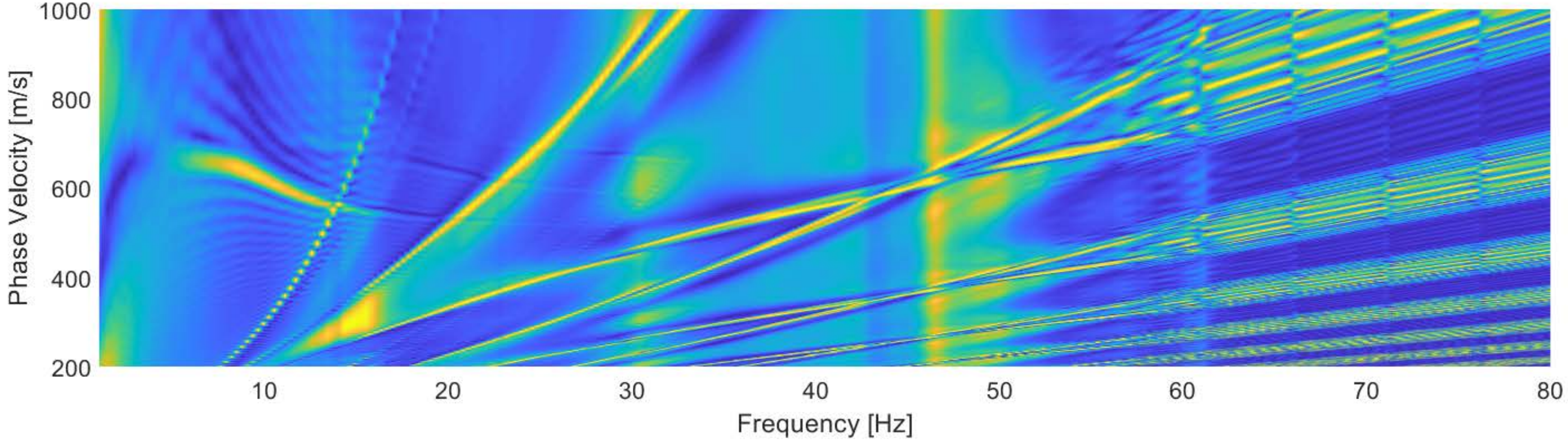

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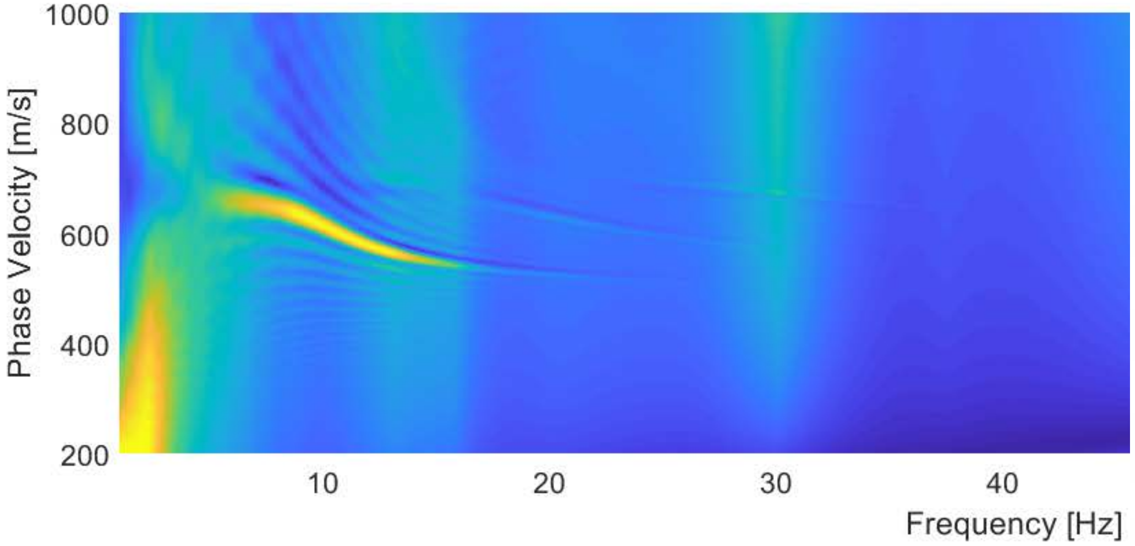
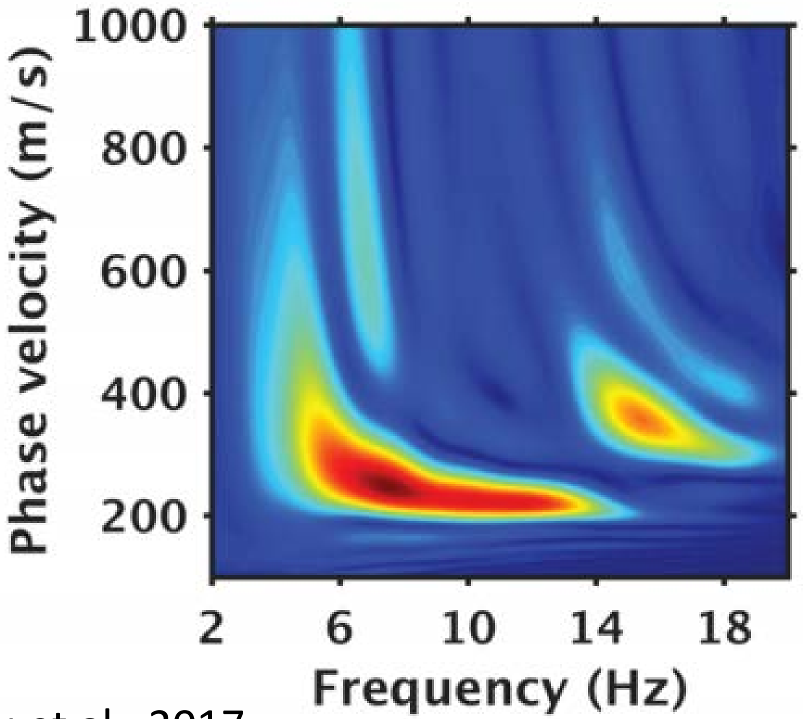
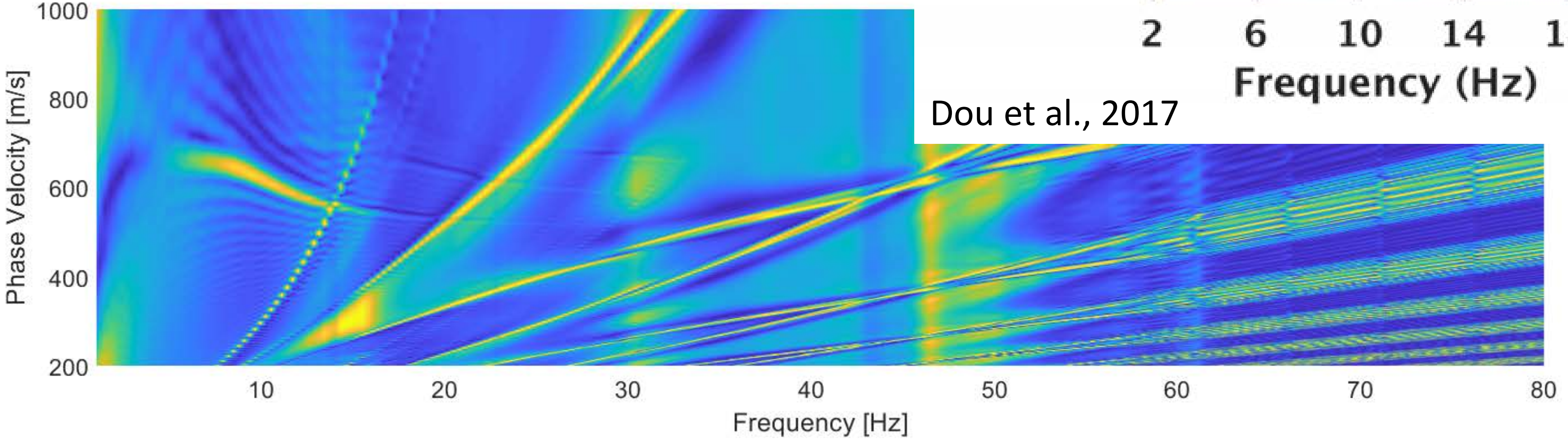




Dou et al., 2017



Conclusions and Future Work

Conclusions:

- Complementary aspects of DAS and 3C were discussed, and a means of forward modelling both datasets was presented.

Future Work:

- Development of a simultaneous FWI framework that leverages the complementary aspects of DAS and 3C recording.

- Using this framework the data from the 3D multi-azimuth VSP will be inverted to provide an initial model for the FRS.
    - Could be used for 4D seismic studies in the future.

Acknowledgments

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Questions?