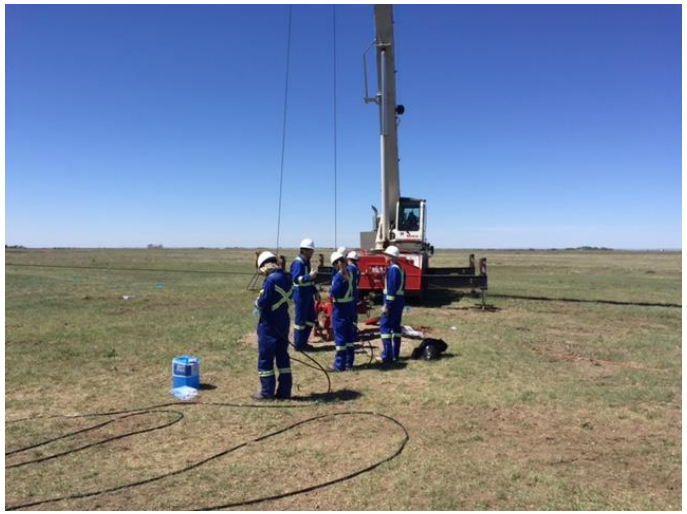
# VSP azimuthal travel time analysis at the Field Research Station near Brooks, AB.

Adriana Gordon, Don C. Lawton and David Eaton

# Outline

- Introduction and objectives
- Theory
- Case Study
- Results
- Conclusions
- Future work
- Acknowledgements



# Introduction

CMC Containment & Monitoring Institute + UNIVERSITY OF CALGARY

Field Research Station (FRS)

Objective

Facilitate and accelerate research and development leading to improved understandings and technologies for geological containment and storage of $CO_2$ and monitoring of fossil fuel production and environmental mitigation (Lawton et. al., 2014).

# Introduction


Field Research Station (FRS)

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Objective

Facilitate and accelerate research and development leading to improved understandings and technologies for geological containment and storage of $CO_2$ and monitoring of fossil fuel production and environmental mitigation (Lawton et. al., 2014).

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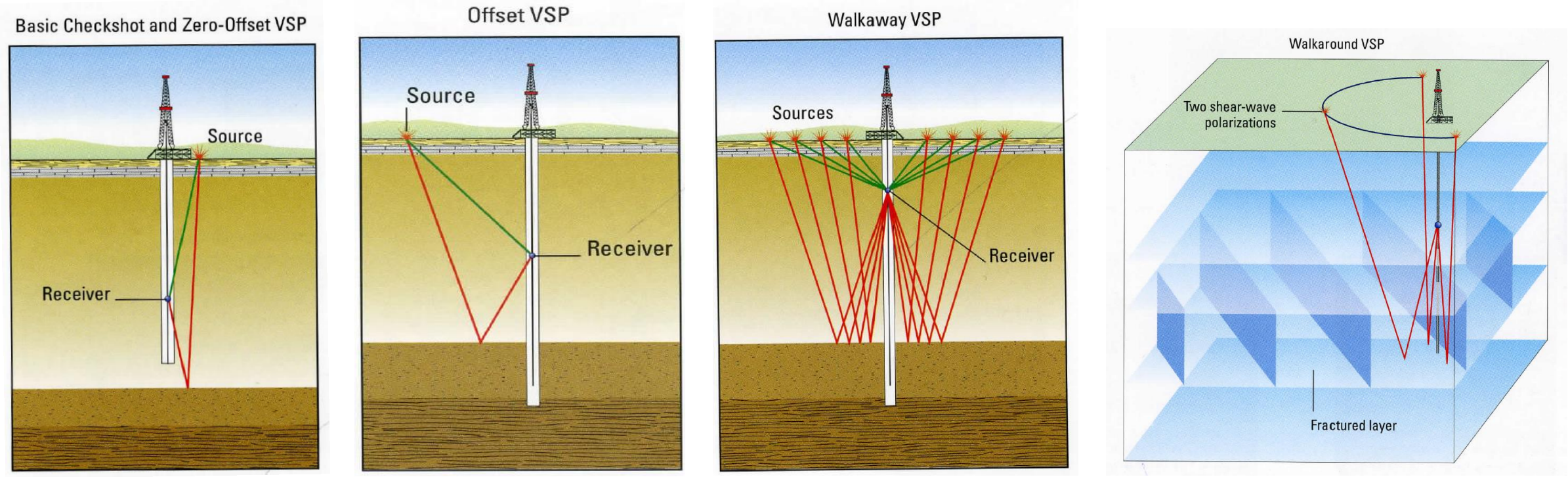
Identify azimuthal anisotropy at the FRS by analyzing the velocity changes

## Vertical Seismic Profile (VSP)

"A vertical seismic profile (VSP) is a measurement procedure in which a seismic signal generated at the surface of the earth is recorded by geophones secured at various depths to the wall of a drilled well" (Hardage, 2000).




Evans et. al., 2010.

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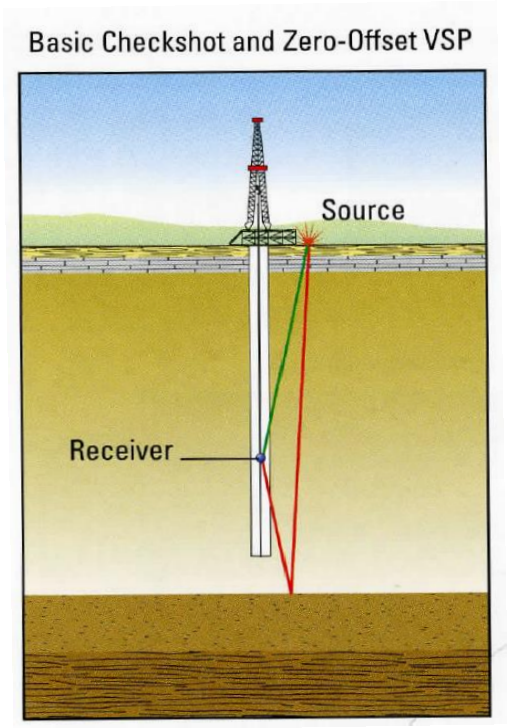
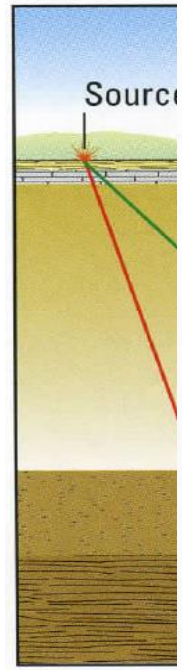
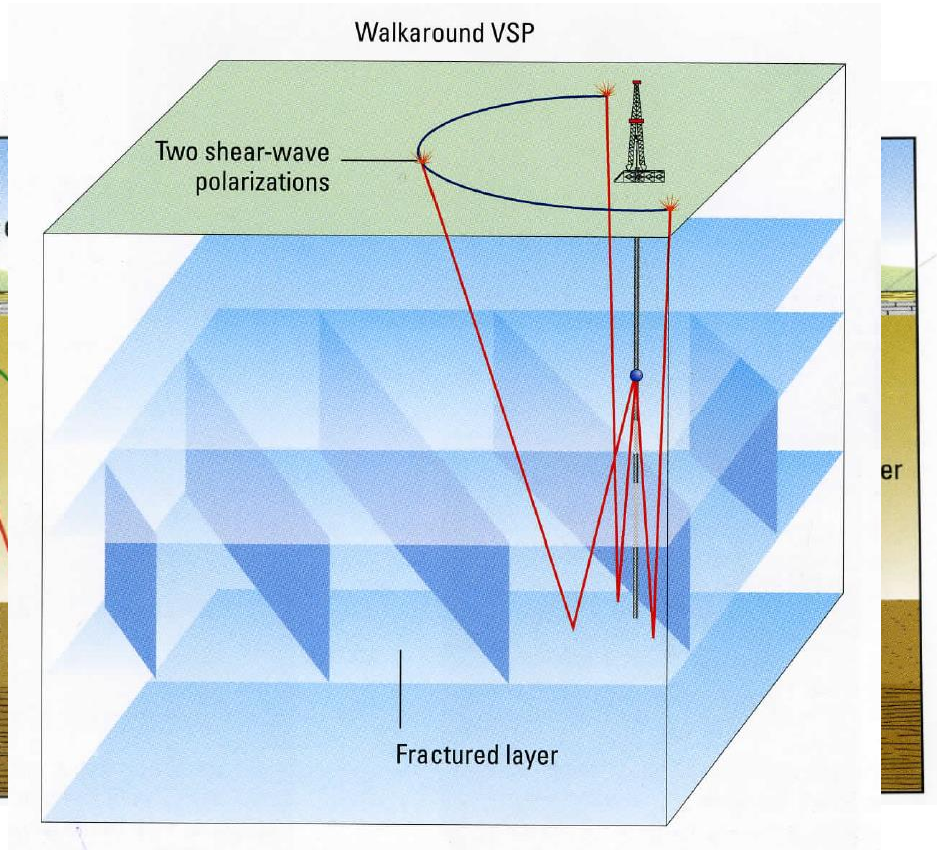
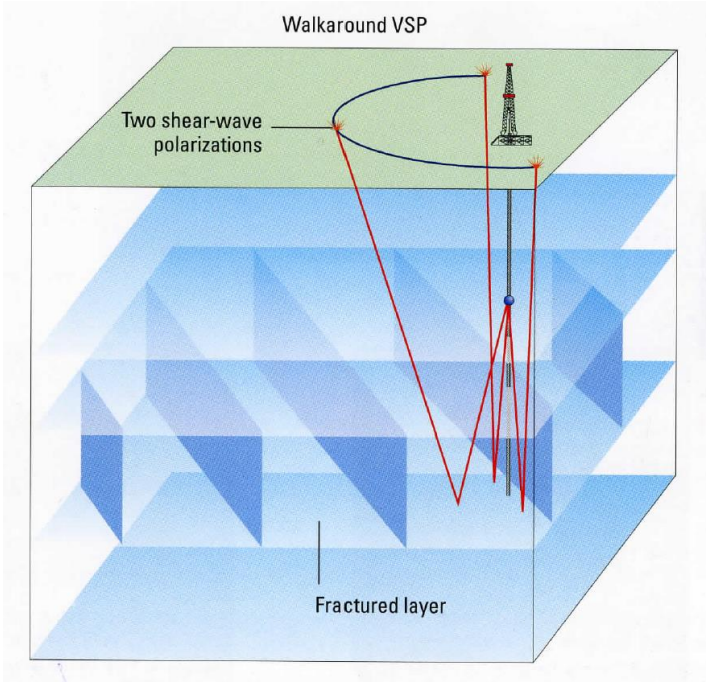


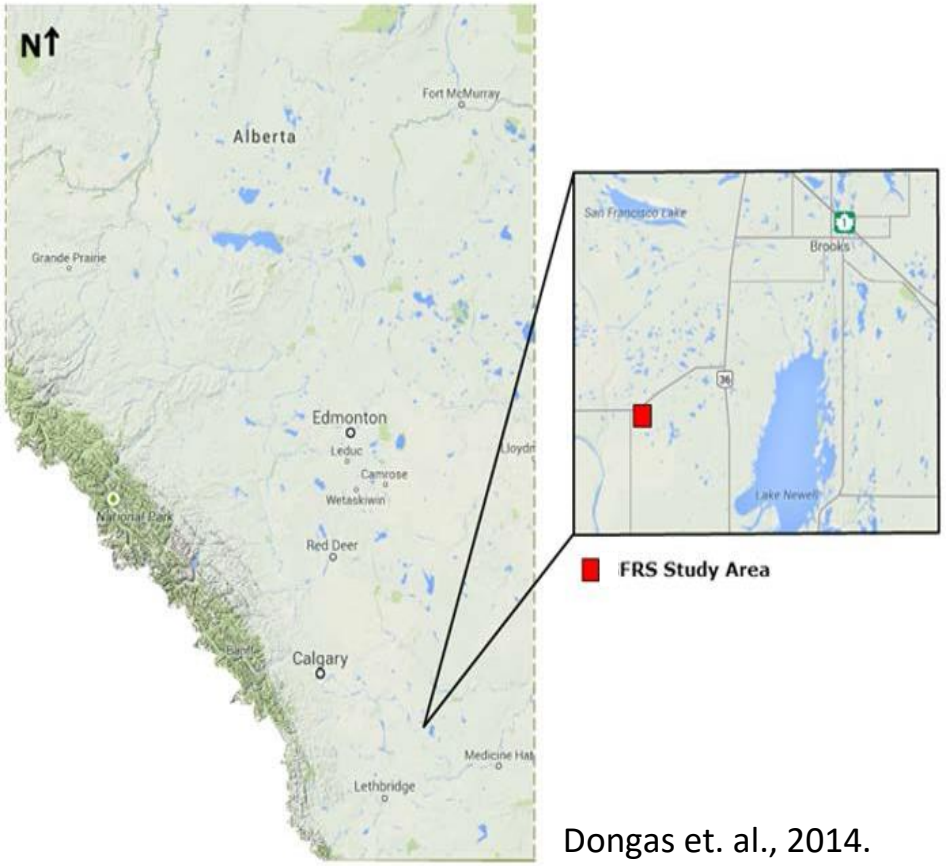




Evans et. al., 2010.

# Case study

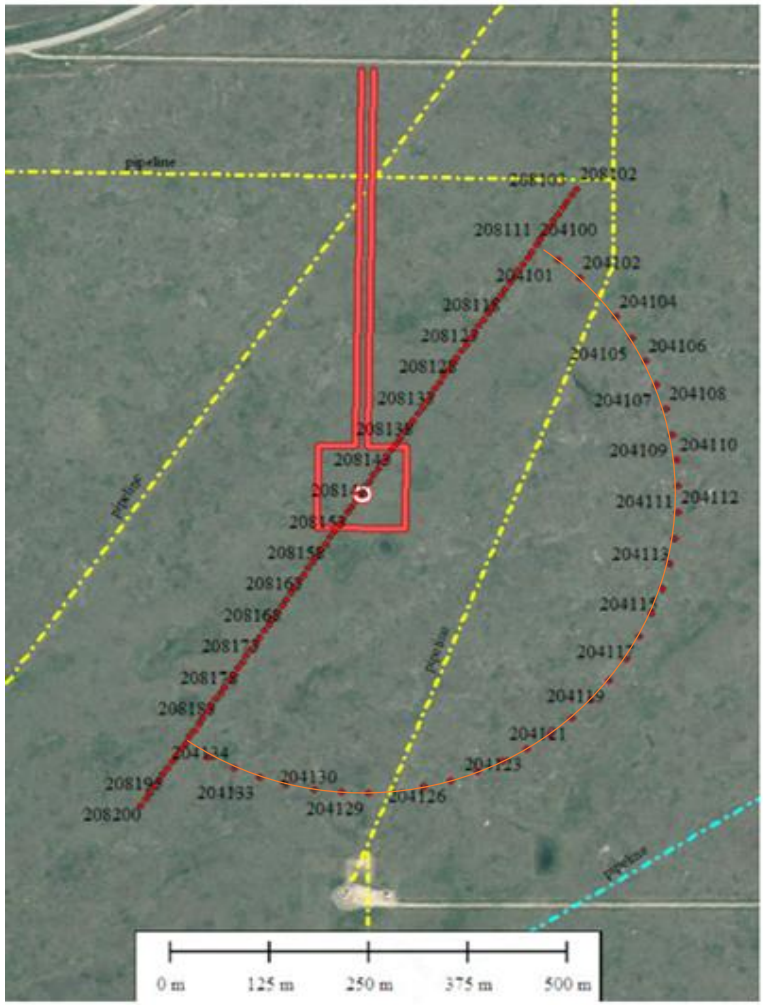
## Field Research Station (FRS) Location

189 km southeast of Calgary and 25 km southwest of Brooks




Dongas et. al., 2014.

Microseismic Industry Consortium



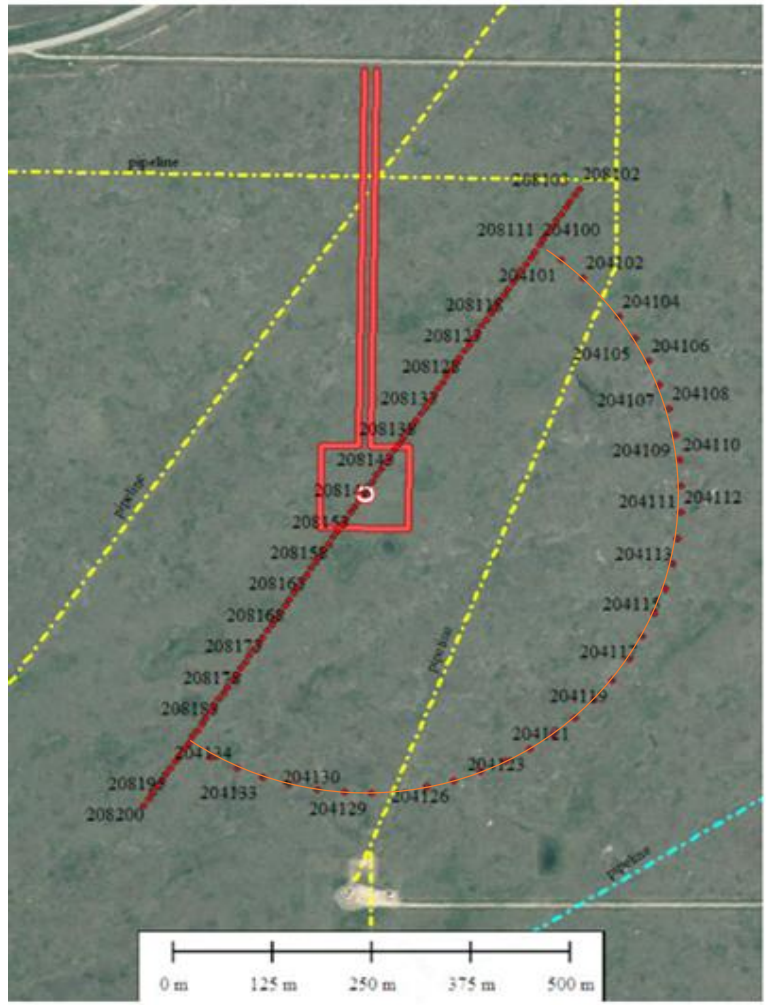

Hall et. al., 2015.

# Case study

## Field Research Station (FRS) Location

Acquisition parameters

| | |
|---|---|
| 3C SuperCable | 3 different levels |
| Receiver positions | 106-496 m |
| Receiver spacing | 15 m |
| EnviroVibe | 10-200 Hz, 16 s |
| Walk-away shot interval | 10 m |
| Walk-around shot spacing | 5 ° |
| Walk-around offset | 400 m |

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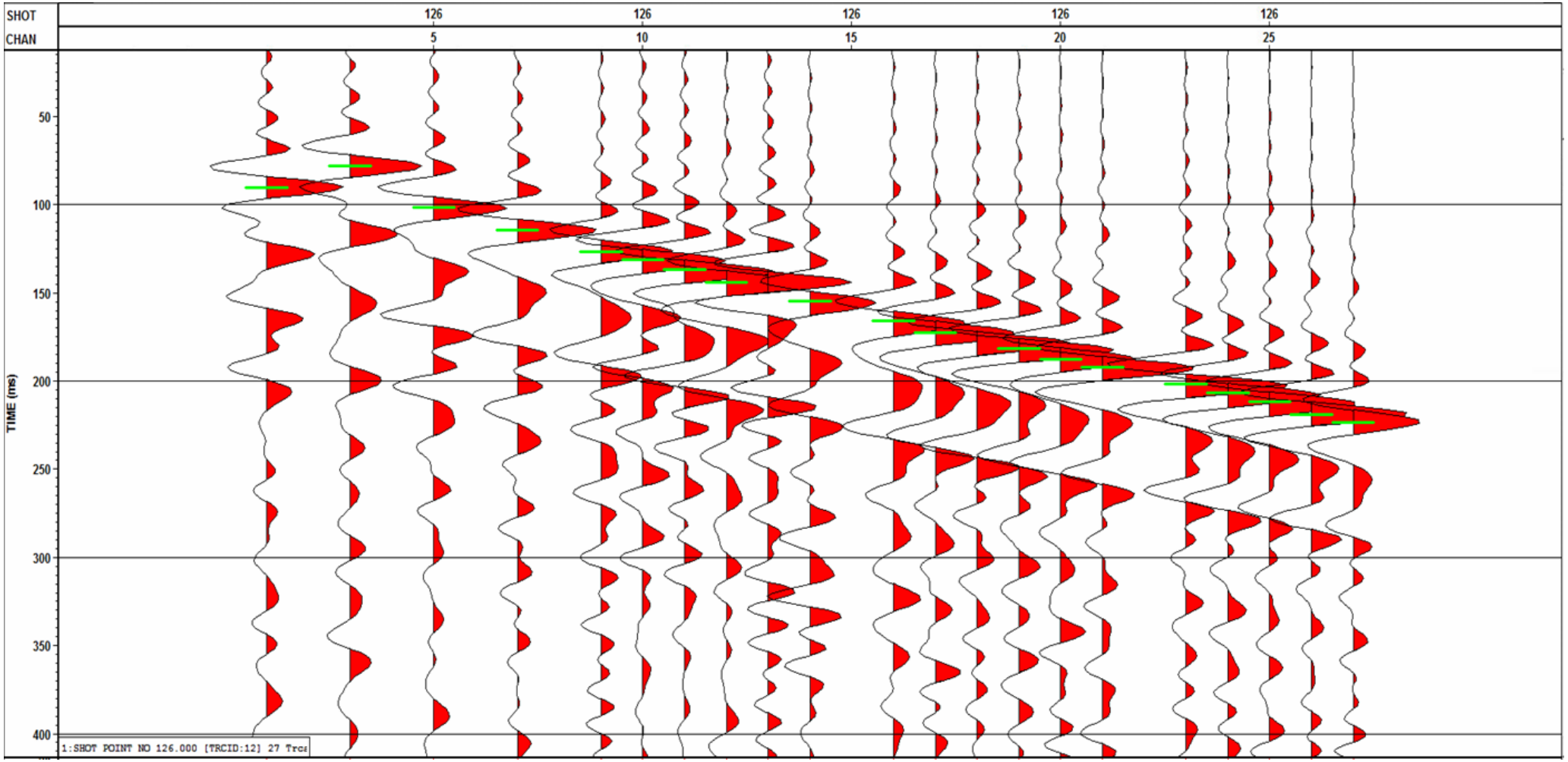
Hall et. al., 2015.

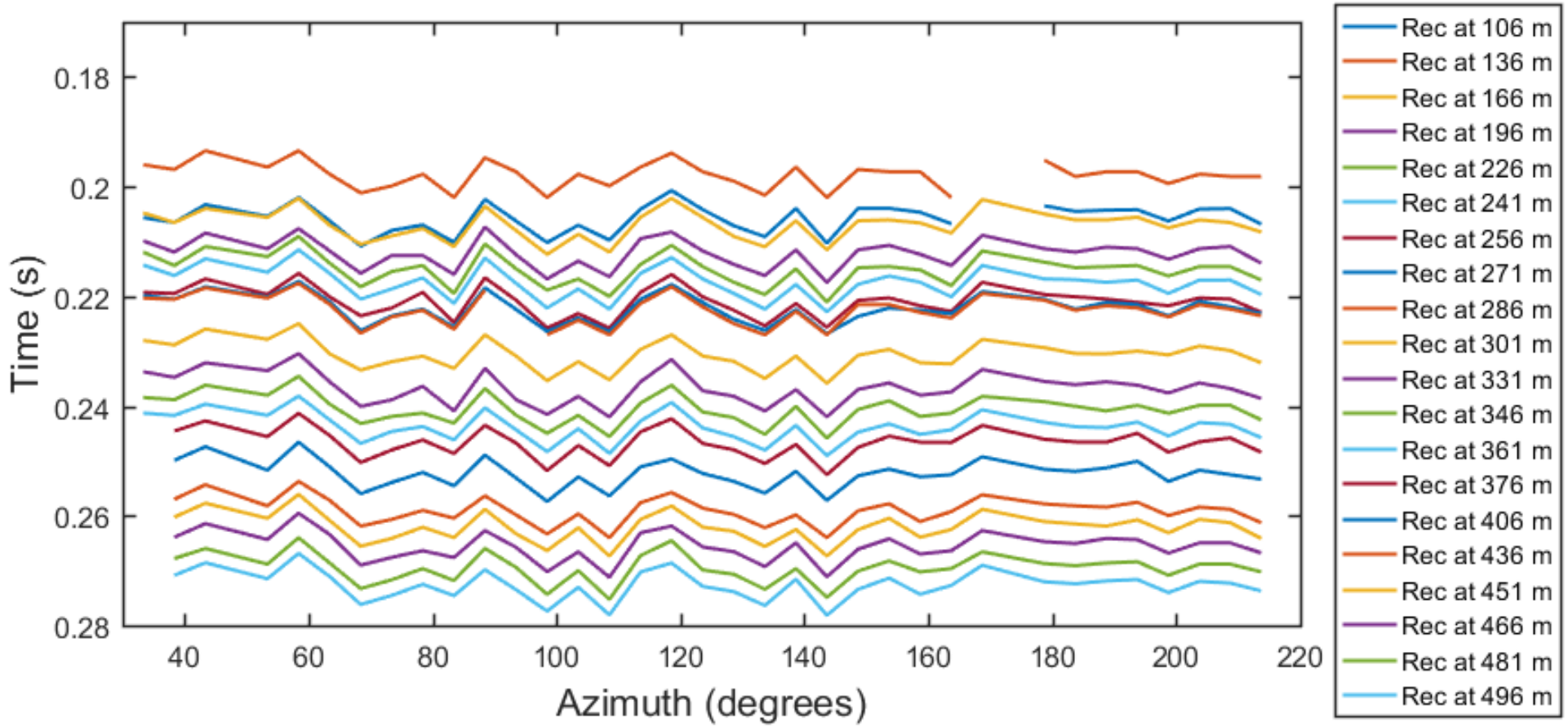
# Zero offset first break picks

## Walk-away shot line (line 208), shot 126



# First break travel time variation

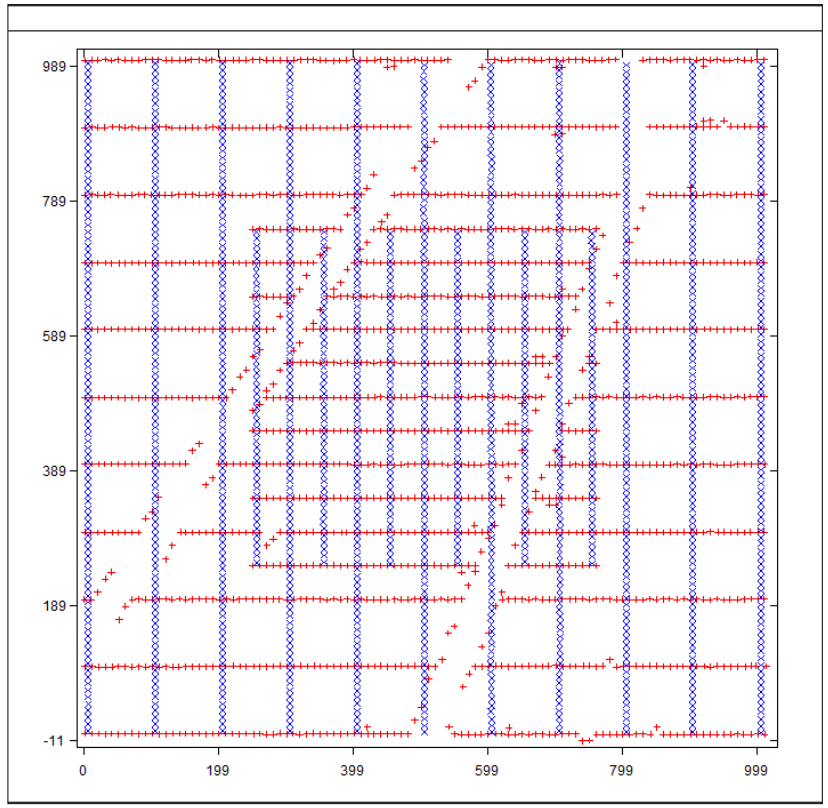
## Walk-around shot line (line 204)

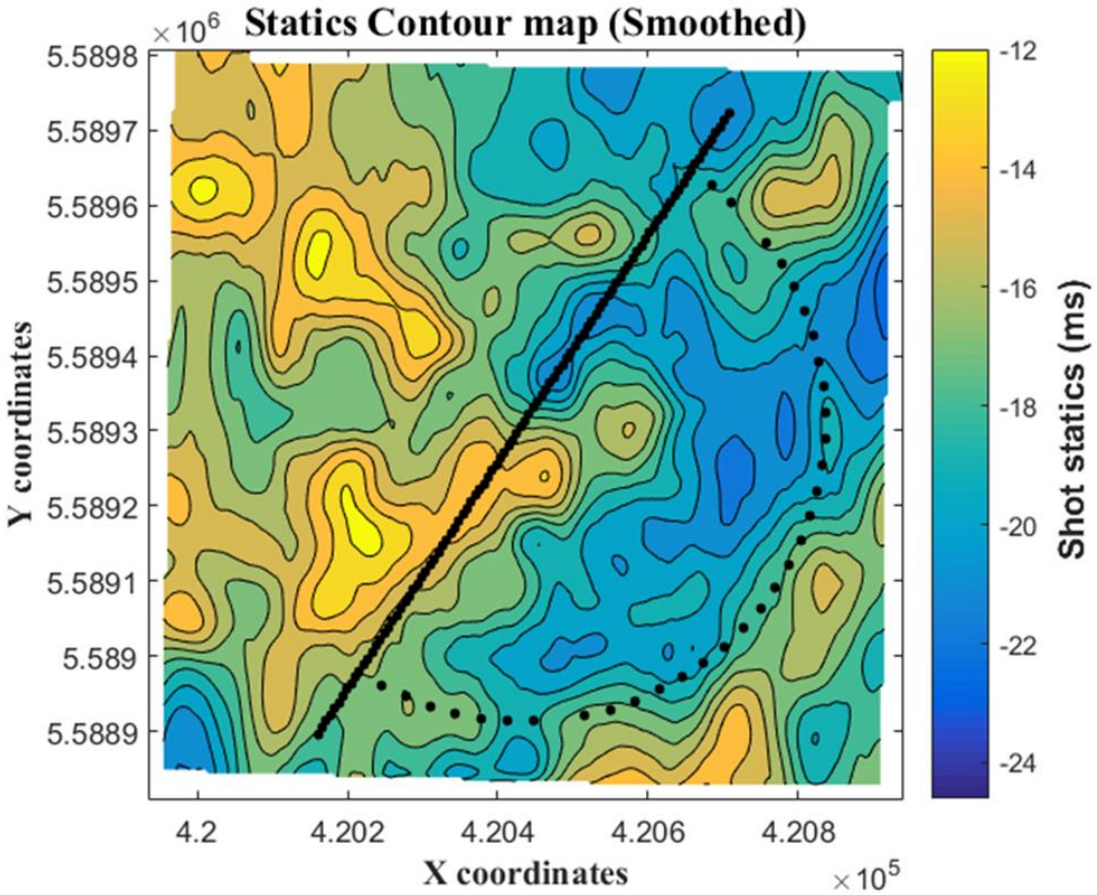


# Statics correction

## Shot statics from 3D seismic survey

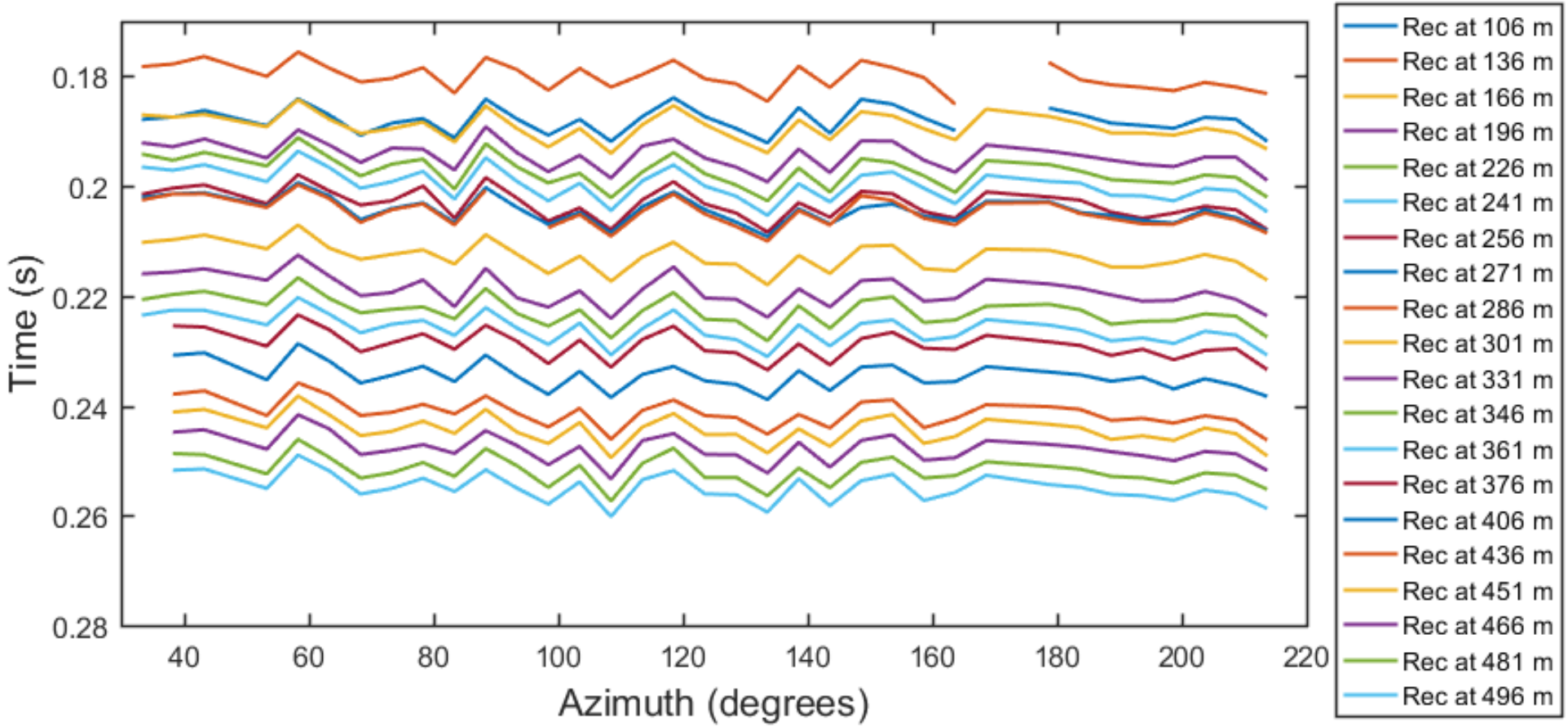
3D acquisition geometry



# Statics correction

## After shot statics from 3D seismic survey



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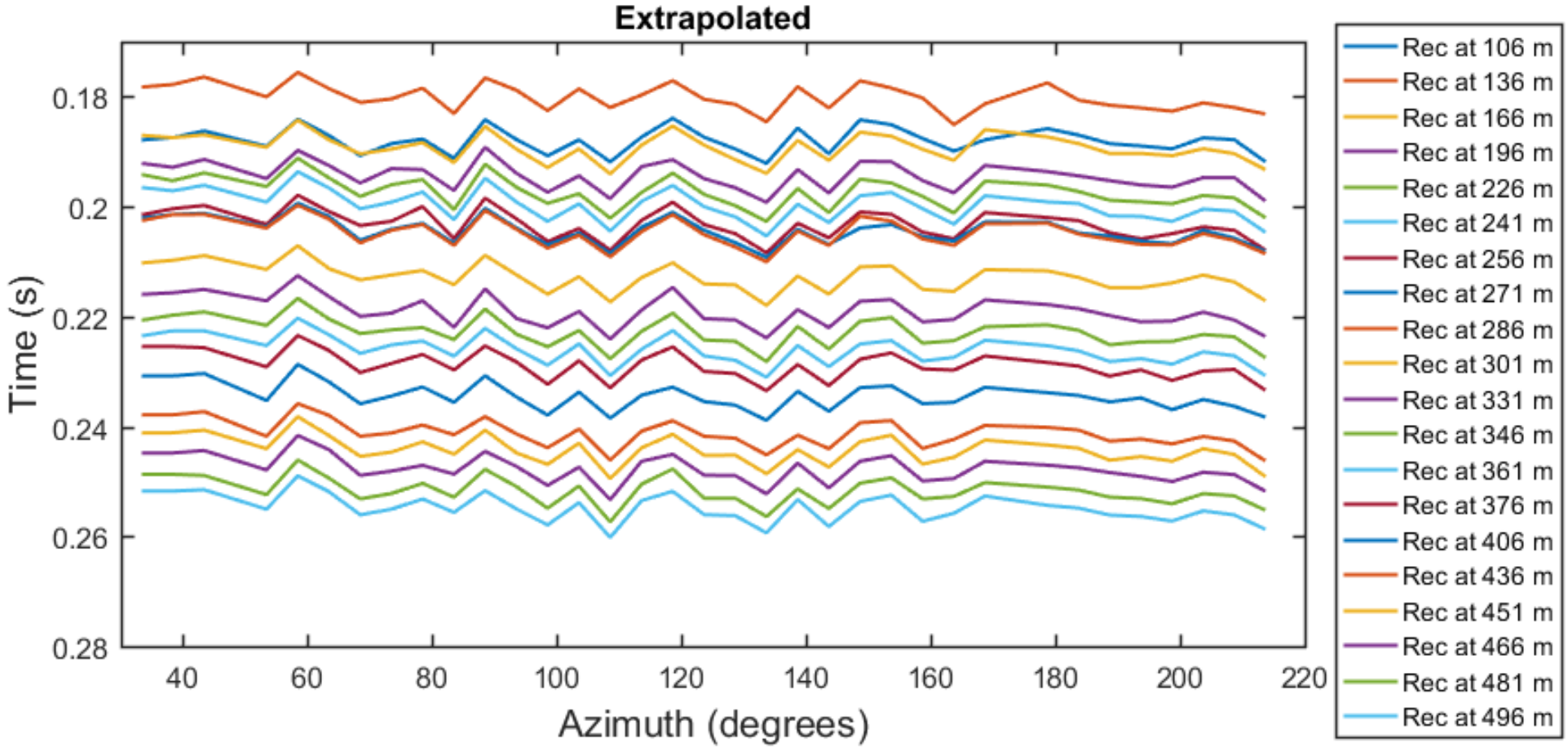
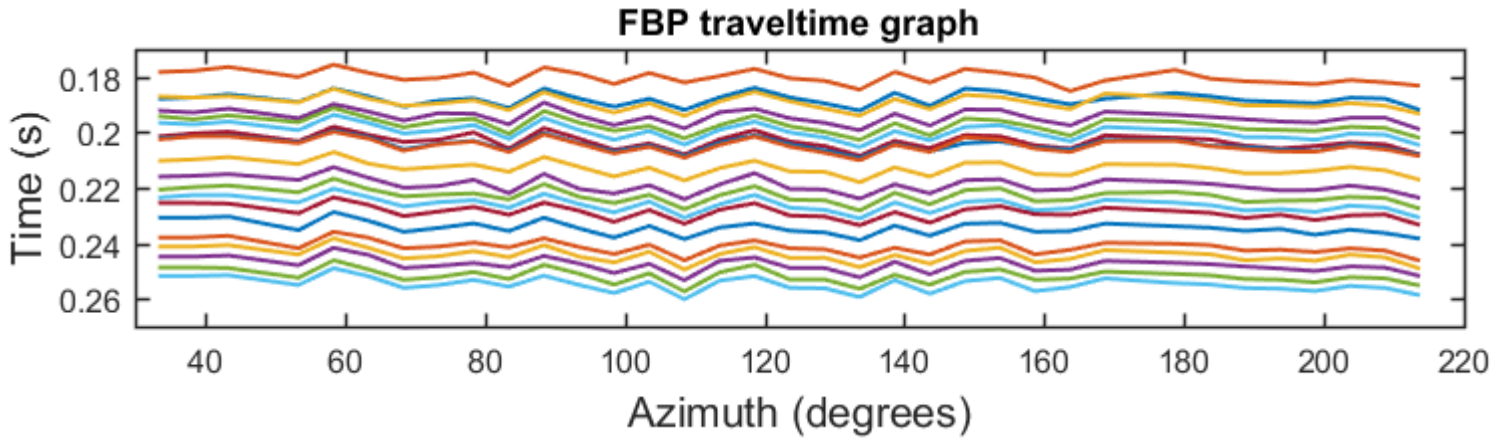
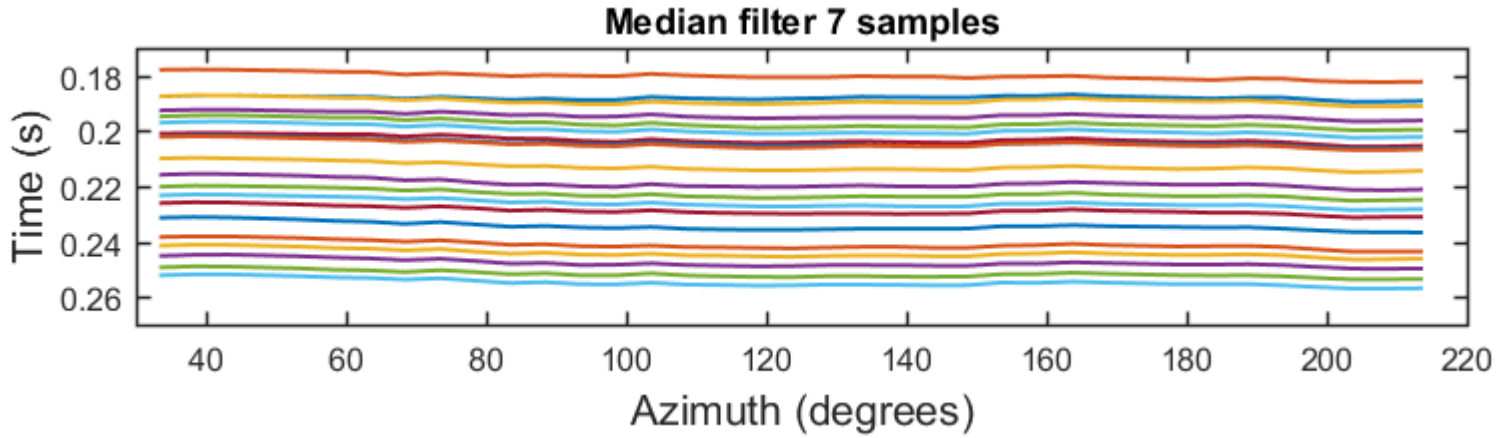


# Smoothing

## Median filters of 3, 5, 7, 9 and 11 samples



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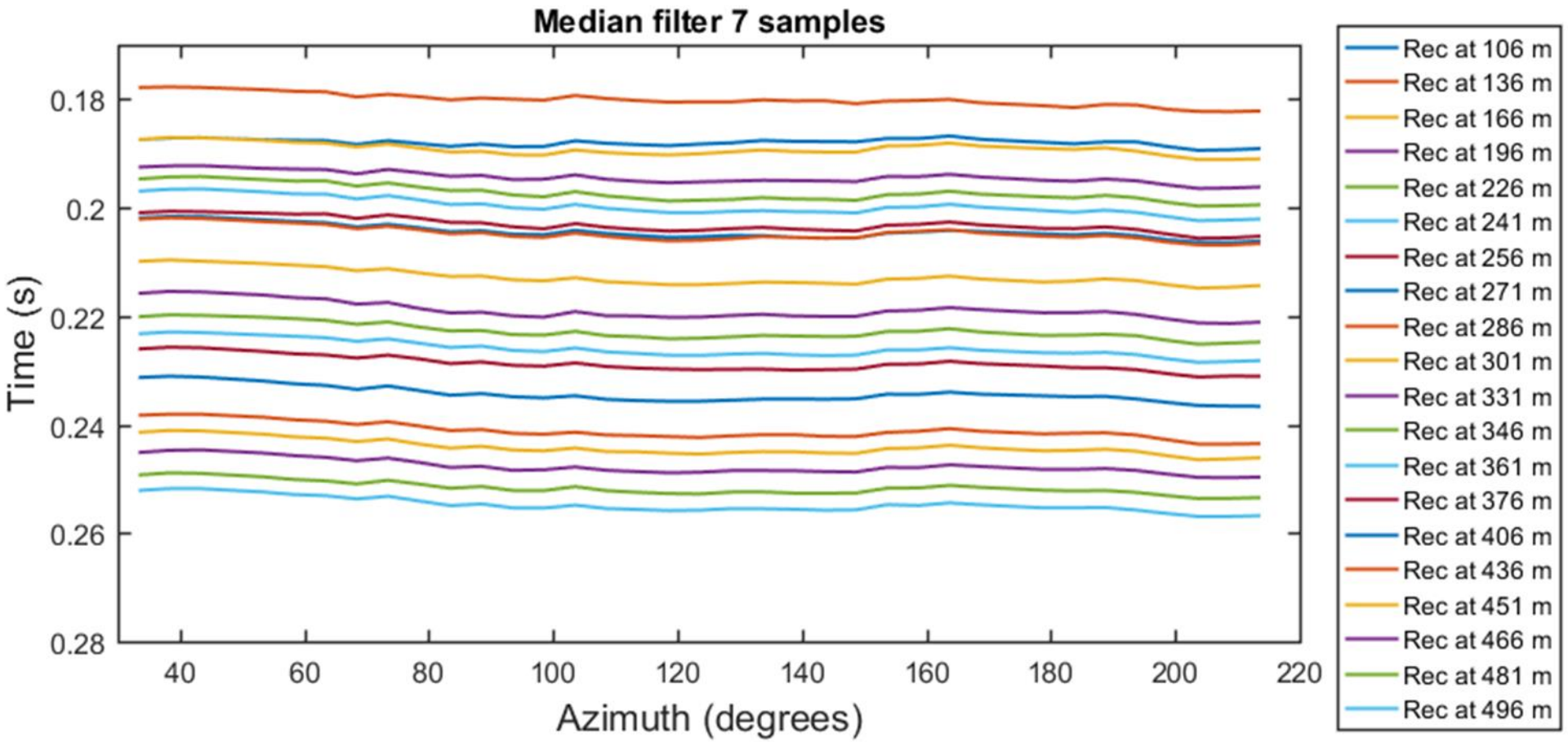
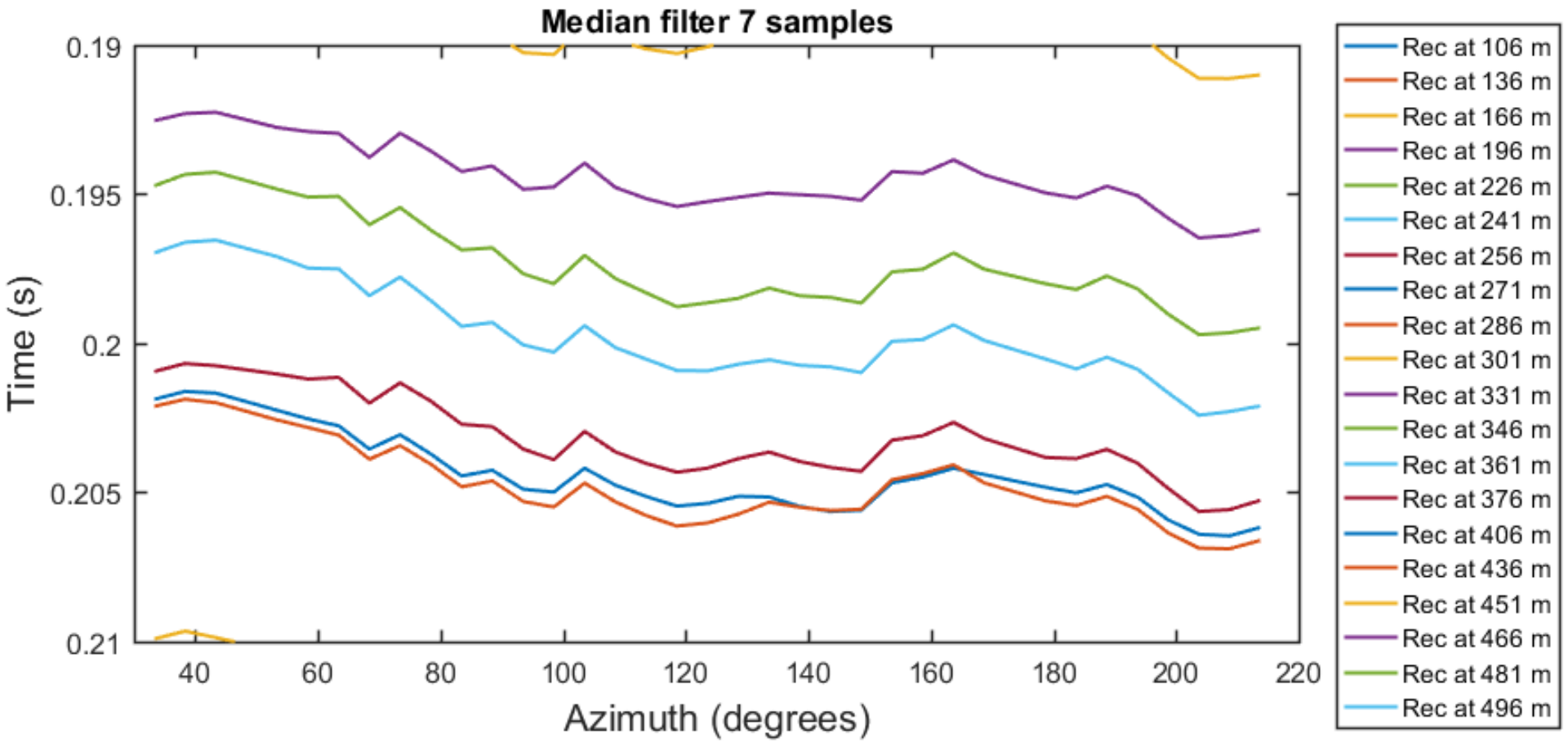


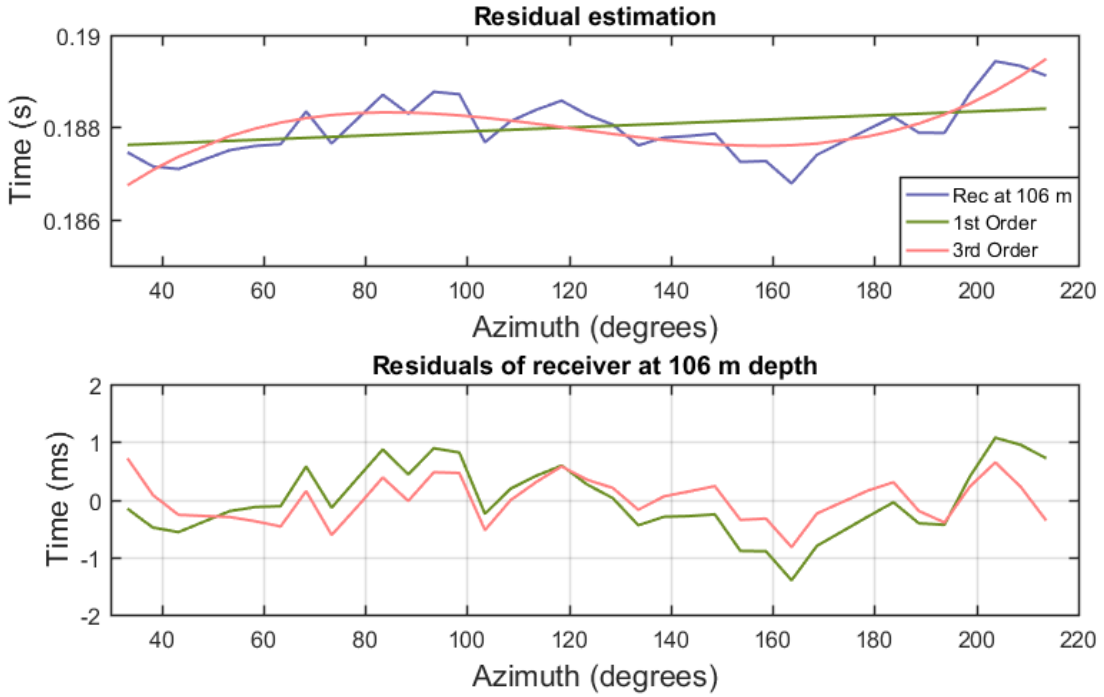
# First break travel time variation

## After static correction and smoothing

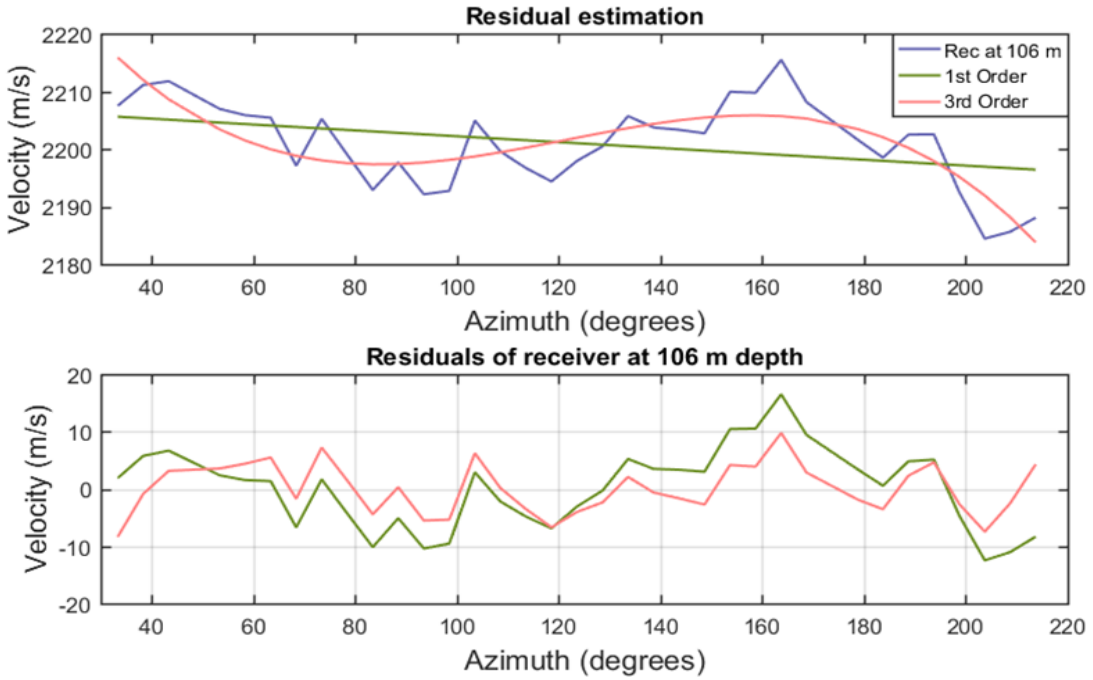


# Residual calculation

## Travel time variation




## Velocity variation



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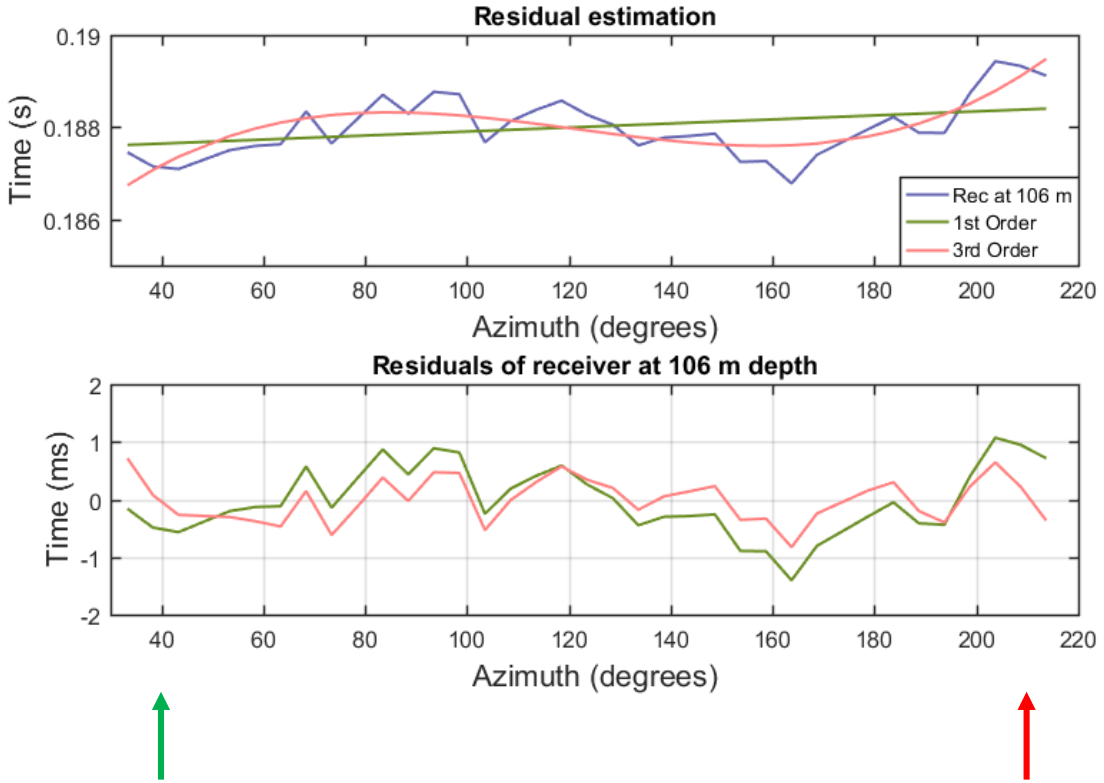
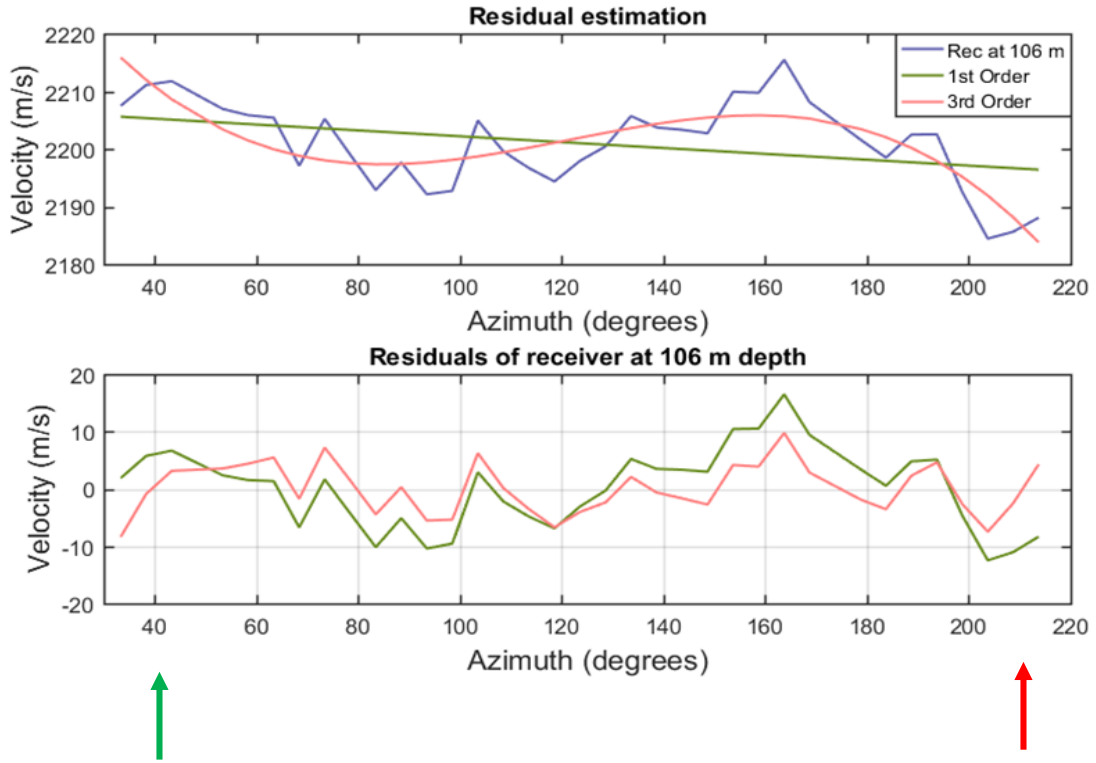


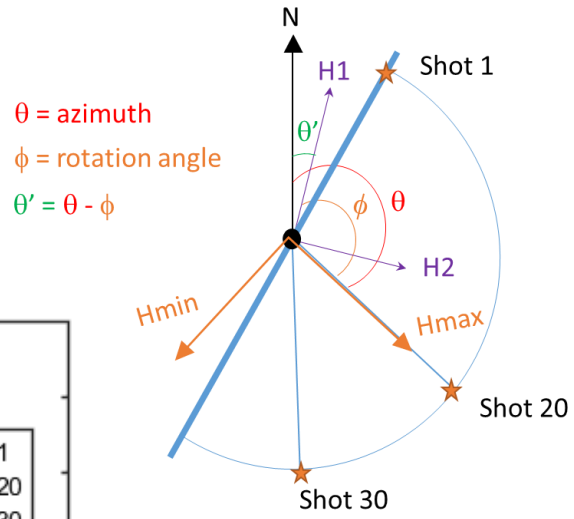

## Velocity variation



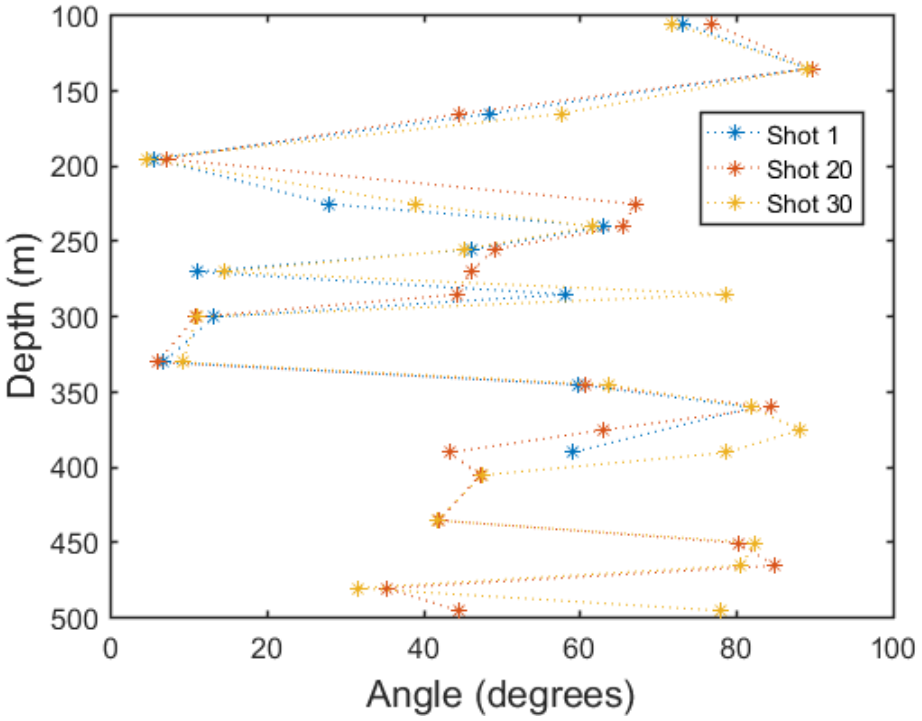

**Epsilon (ε) estimation** Receivers at 106, 301 and 496 m depth **ε = 2%**

# Data rotation

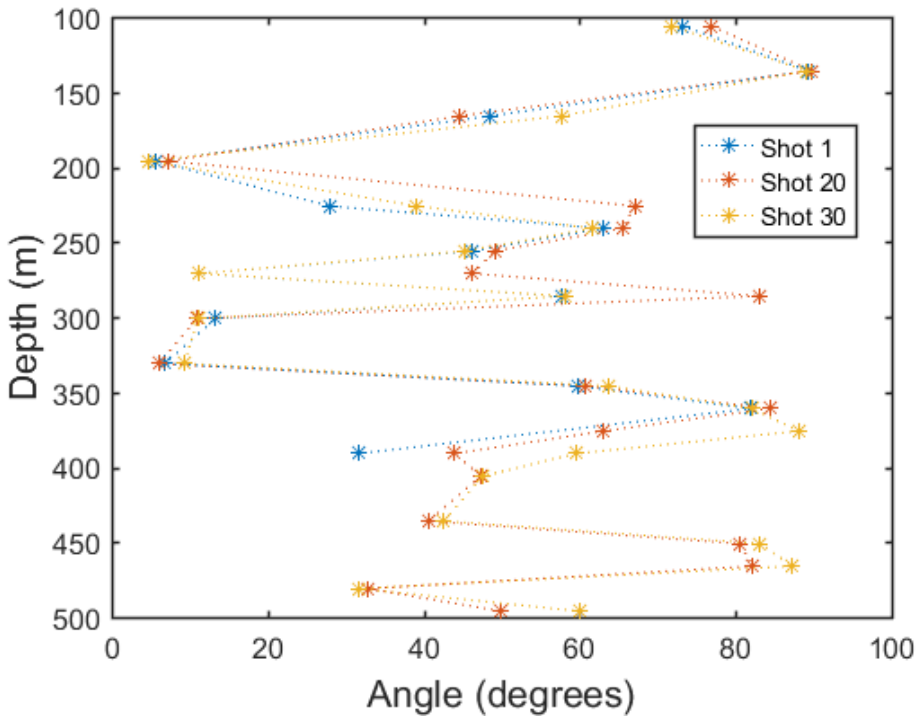
## Rotation of H1 and H2 to Hmax and Hmin




Vista

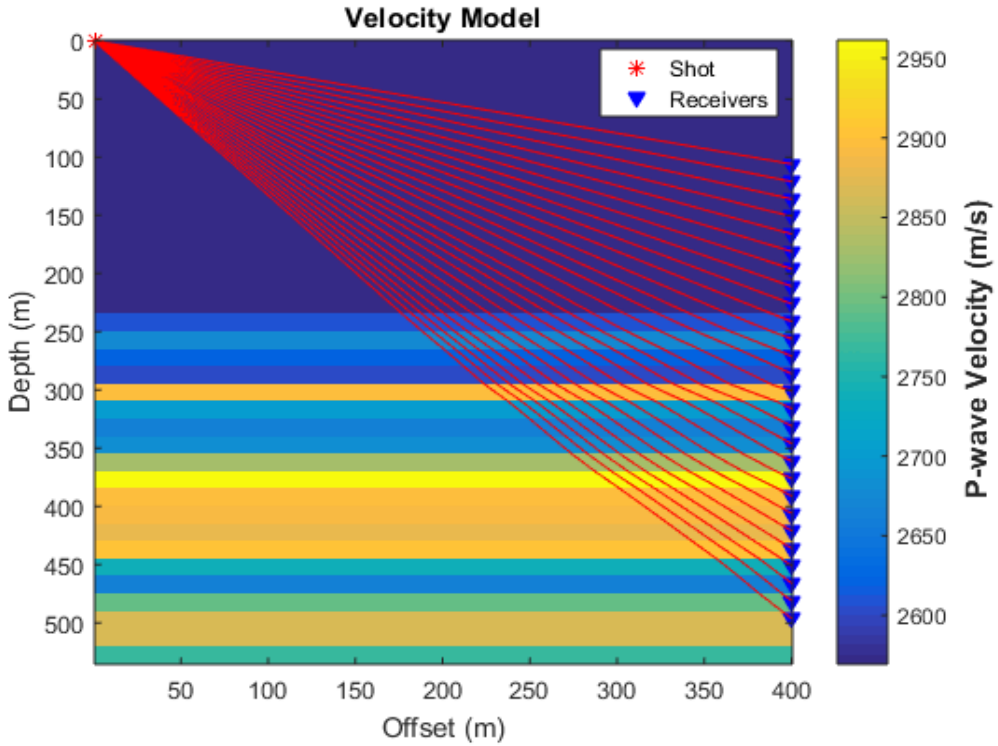


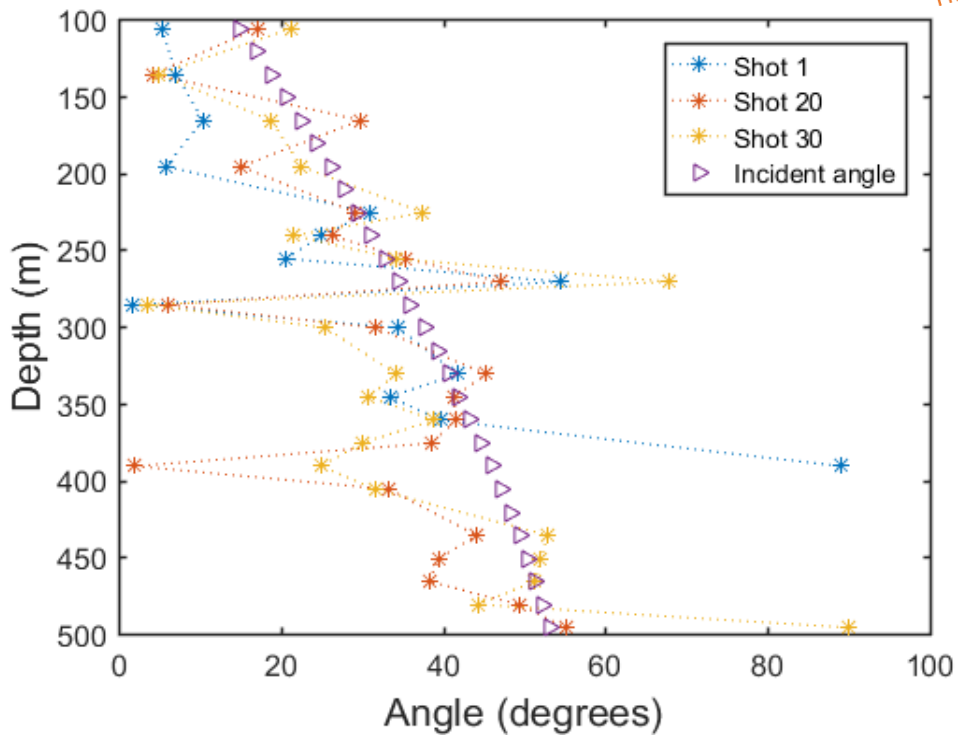

Matlab

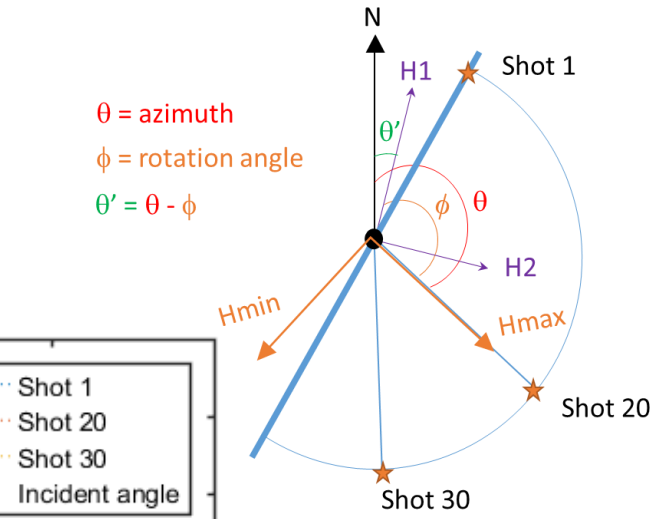


# Data rotation

## Rotation of Z and Hmax to Z’ and Hmax’



# Conclusions

- A sinusoidal trend is noticeable for the traveltime variation, indicative of weak azimuthal anisotropy (HTI). The fast direction (NE) is similar to the Western Canada stress orientation.

- With the traveltime and velocity variations we were able to estimate an approximate value of epsilon equal to 2%.

- Accurate results were obtained with Vista and Matlab for the first rotation. The receivers showed a similar orientation with small variations that needs further analysis.

- For the second data rotation, the incidence angle was calculated with two methods that yield similar results. Although there are several outliers in the hodogram approach that needs further analysis.

# Future work

- Continue the azimuthal analysis and the processing flow for the VSP walk-around data in order to obtain imaging results.

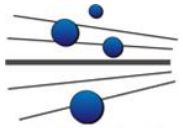
- Estimate the anisotropy parameters using a relation between the residual functions applied to the data and weak anisotropy approximations (WAA) introduced by Thomsen (1986) and Alkhalifah-Tsvankin (1995).

- Develop a velocity model using the software NORSAR-2D Ray Modelling package would be useful to obtain the incidence angles and compare the results to those presented in this paper.

# Acknowledgments


- CREWES sponsors
- CMC
- NSERC (grant CRDPJ 461179-13)
- Microseismic Industry Consortium
- CREWES faculty, staff and students
- Schlumberger for Vista software



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