Fibre trace registration by cross-correlations - can we successfully predict helically wound fibre pitch angle from recorded data?

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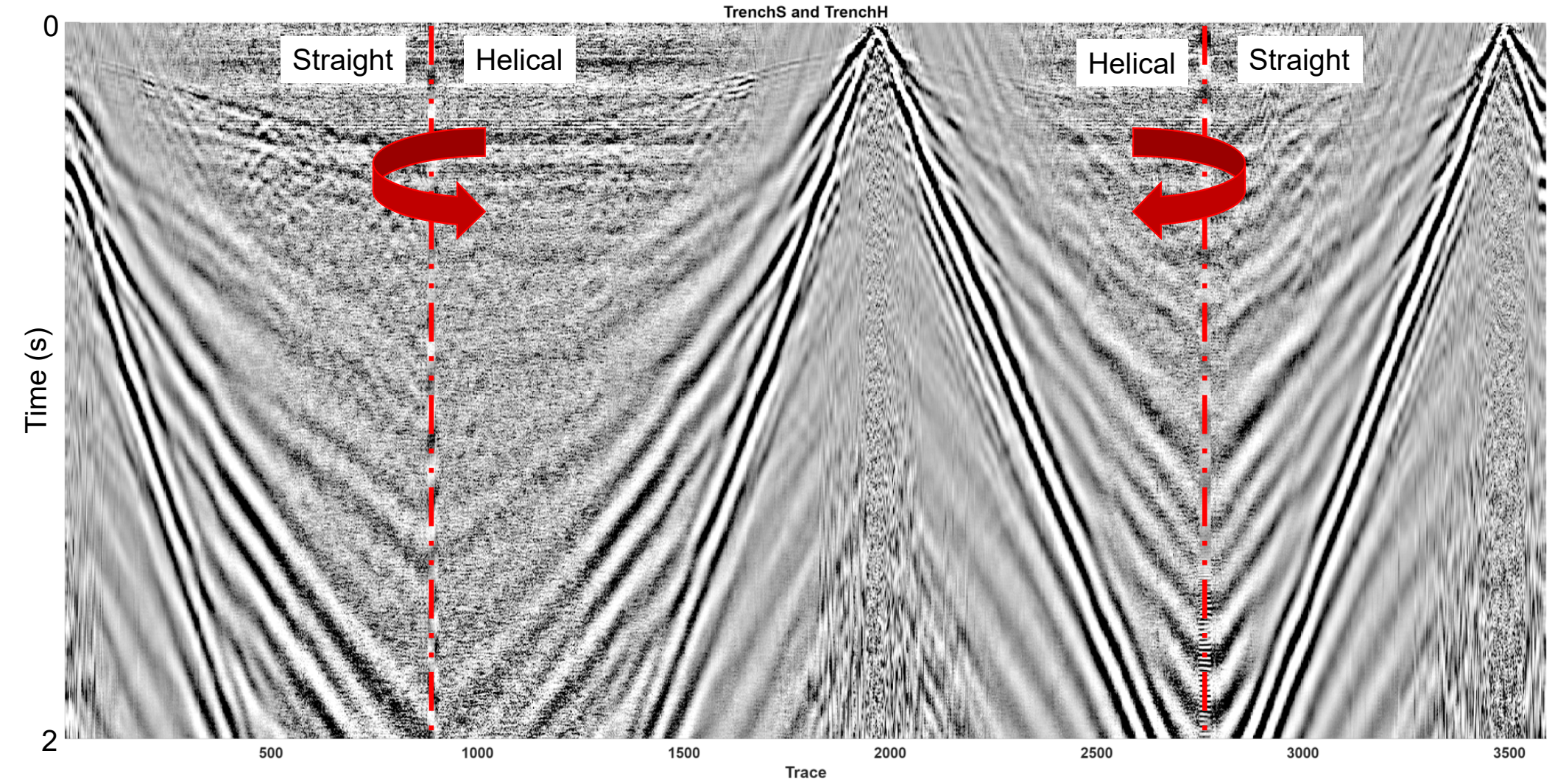
Motivation

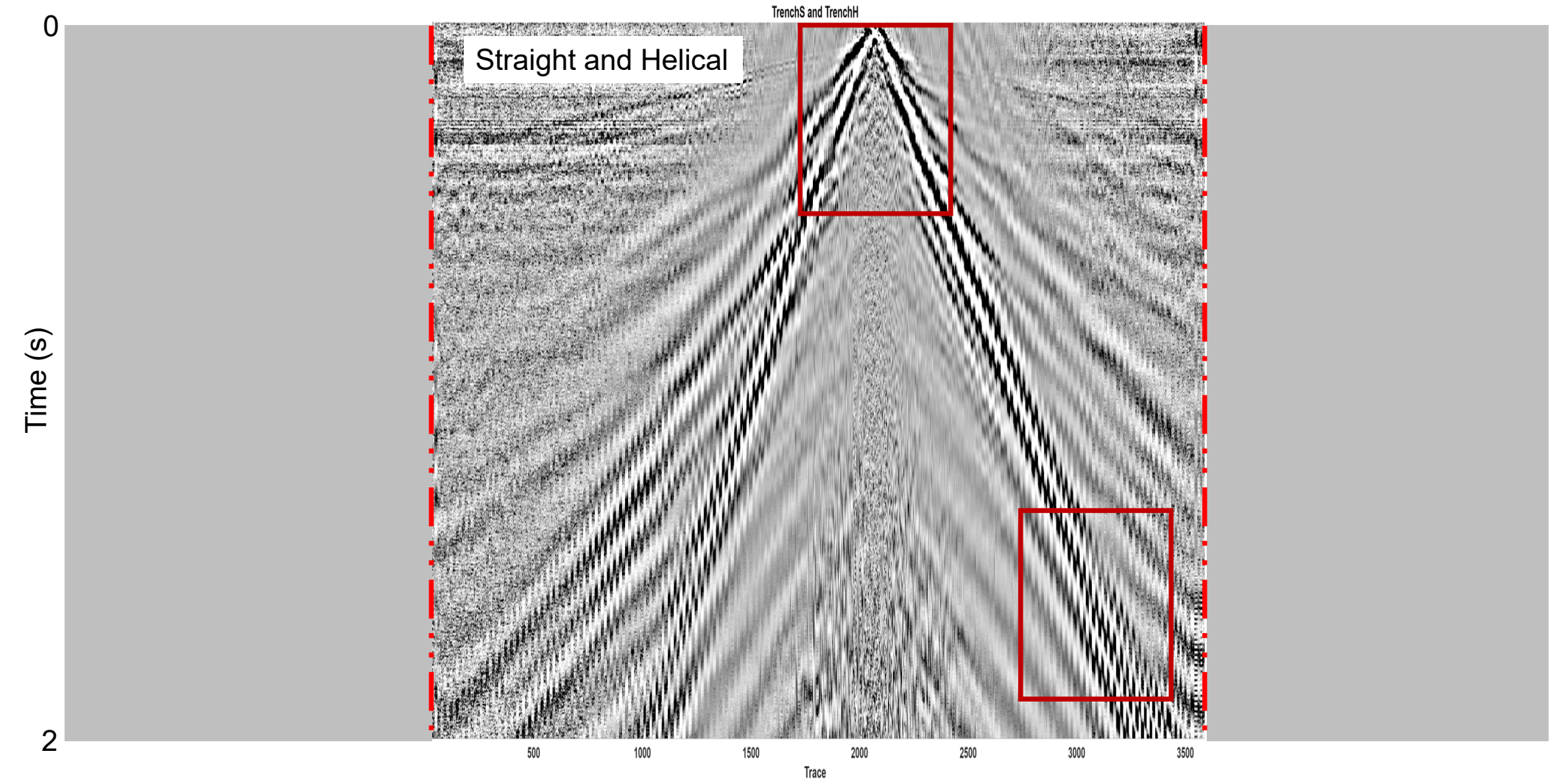
- Motivation: Helical/straight fibre data do not match after geometry assignment of interpolated helical/straight fibre trace co-ordinates (2019)
  - GPS/gyroscope surveys
  - Fibre length (well depth, trench length)
  - Straight fibre cable trace spacing assumption:
    - Software index of refraction (IR) == Fibre IR
  - Helical fibre cable trace spacing assumptions:
    - Software IR != Fibre IR, and nominal 30° pitch angle is correct

❖ Can we estimate pitch angle from seismic data?

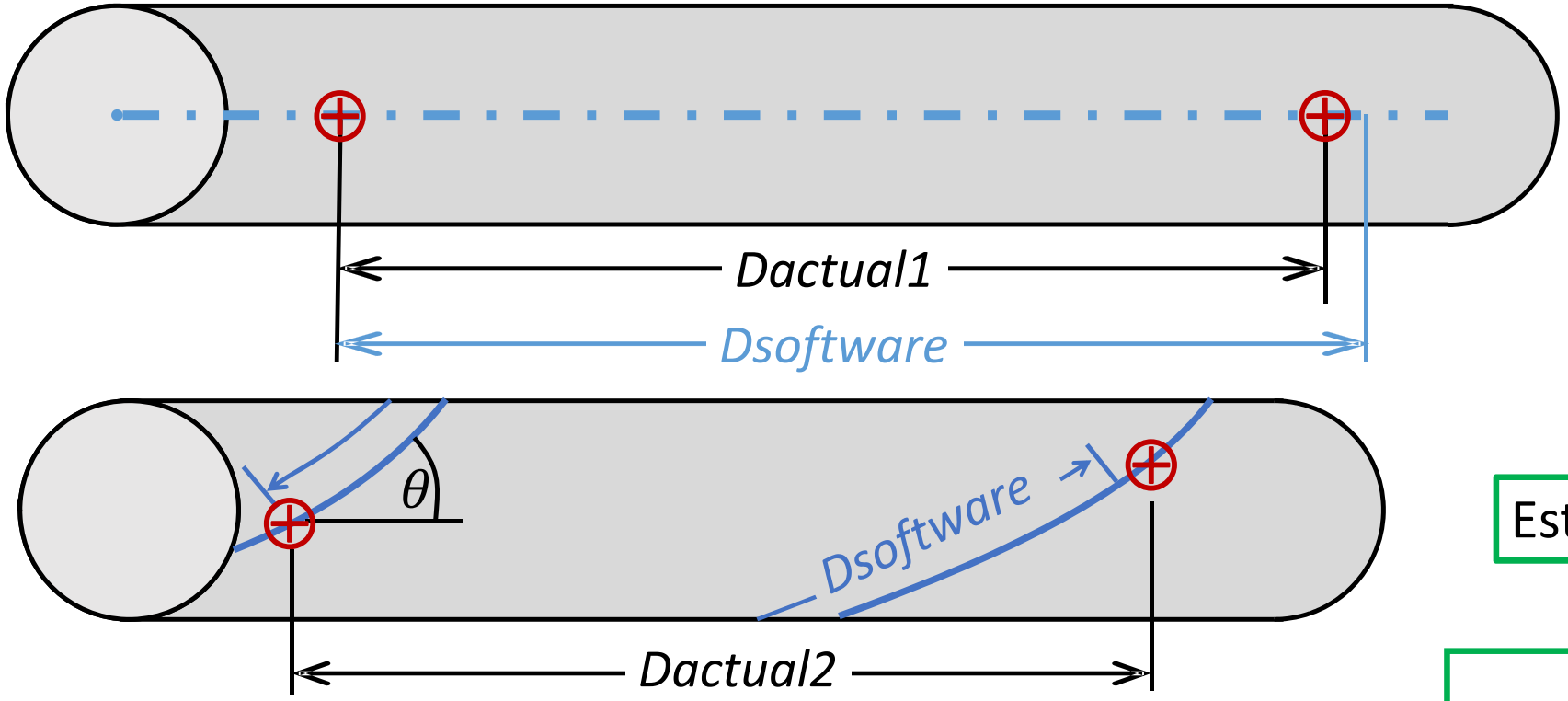
Motivation: Trench data example



Motivation: Trench data example - 30° pitch angle; no IR correction



Theory: Pitch angle and pseudo-pitch angle estimation



Straight Fibre

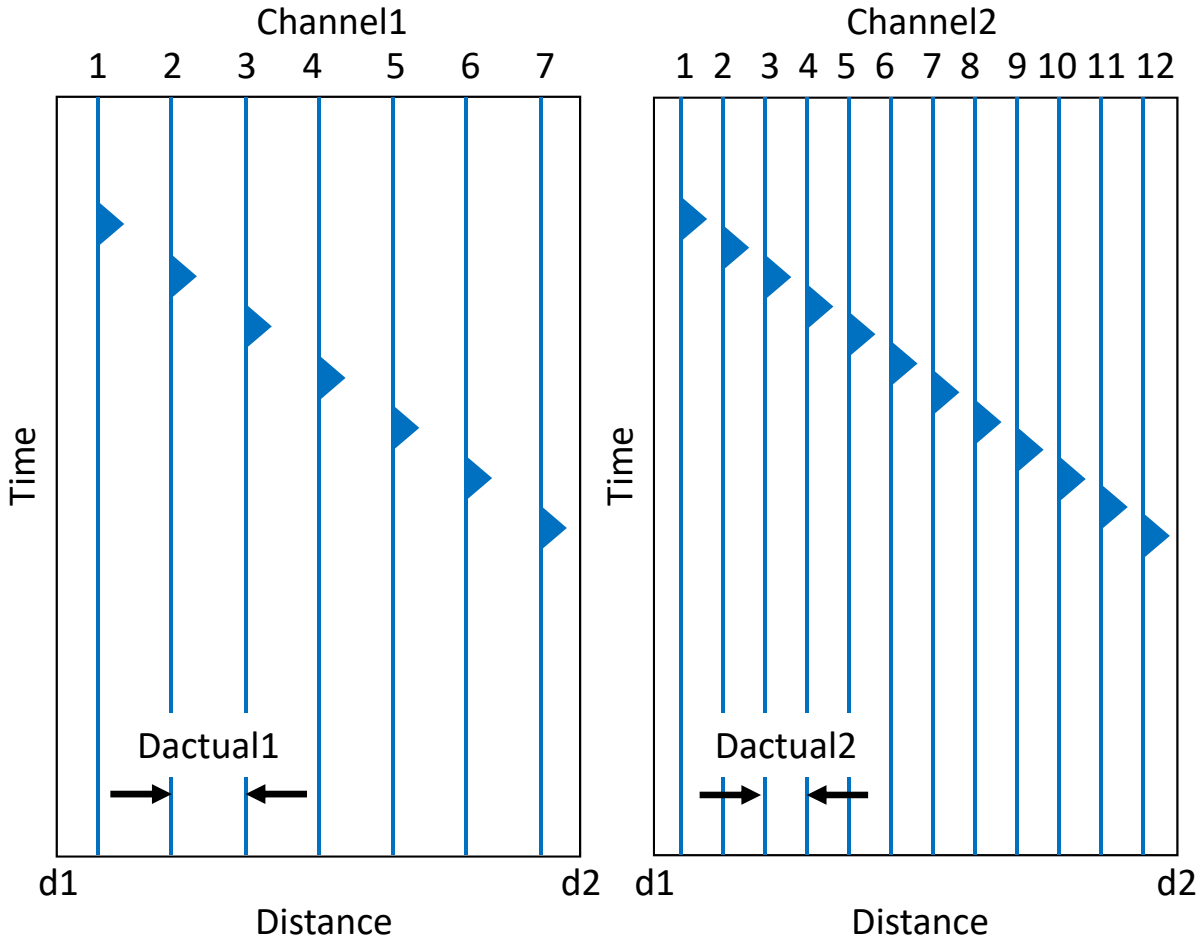
Helical Fibre

Trace Location

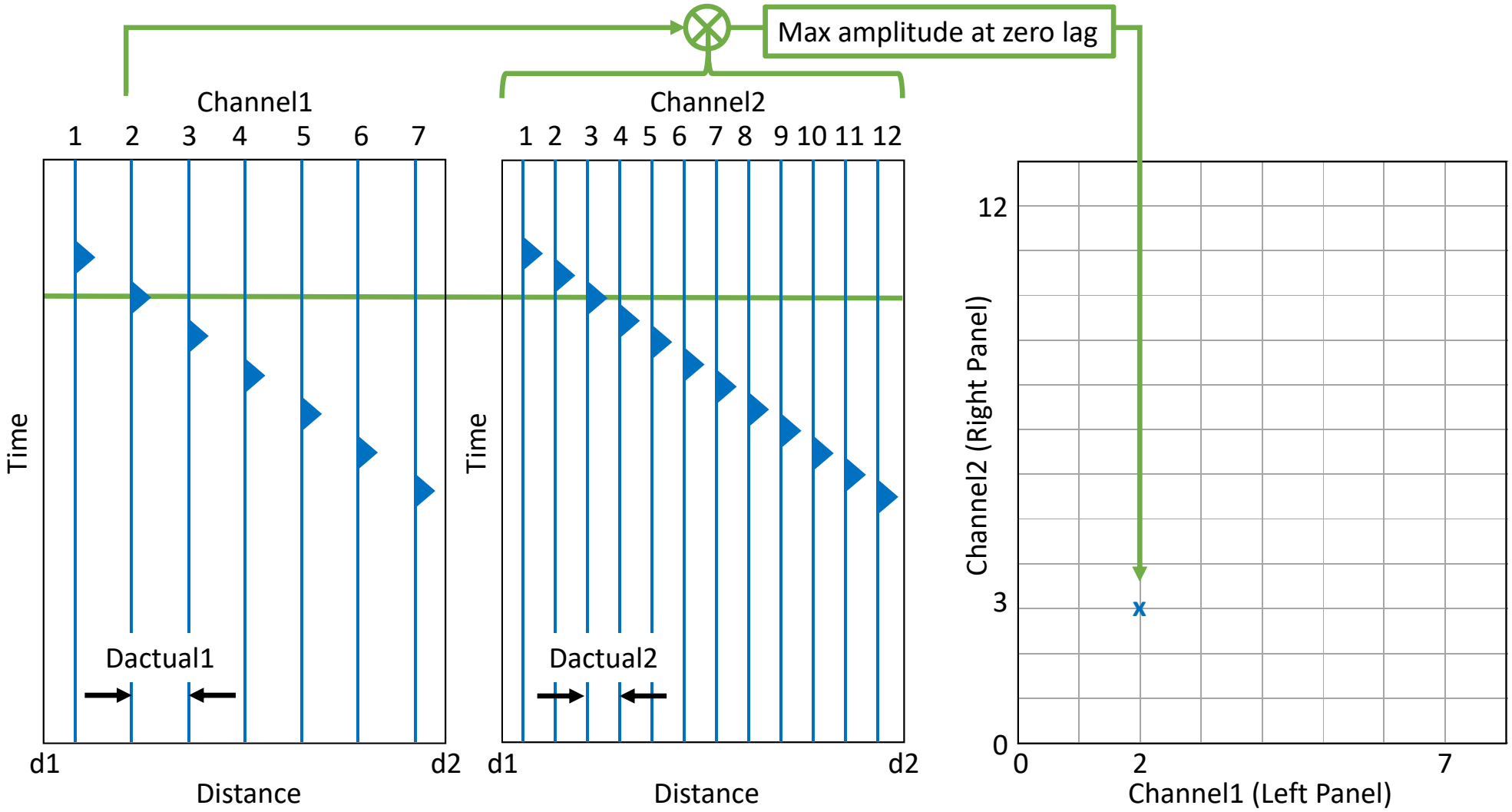
Estimate this

$$\theta = cos^{-1}\left(\frac{Dactual2 * IRactual2}{Dactual1 * IRactual1}\right), \qquad \varphi = cos^{-1}\left(\frac{Dactual2}{Dactual1}\right)$$

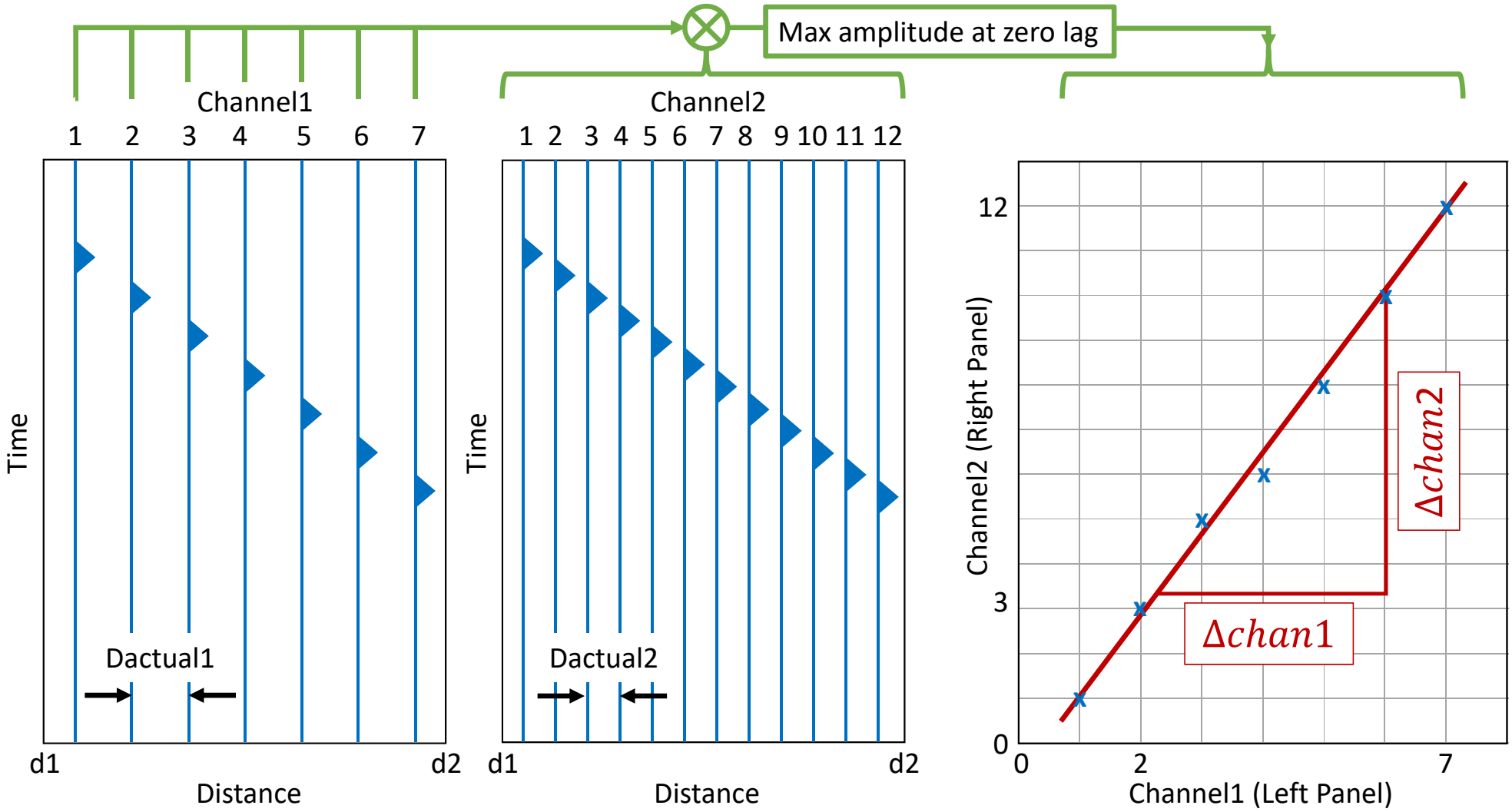
Theory: *Dactual2/Dactual1 estimation*



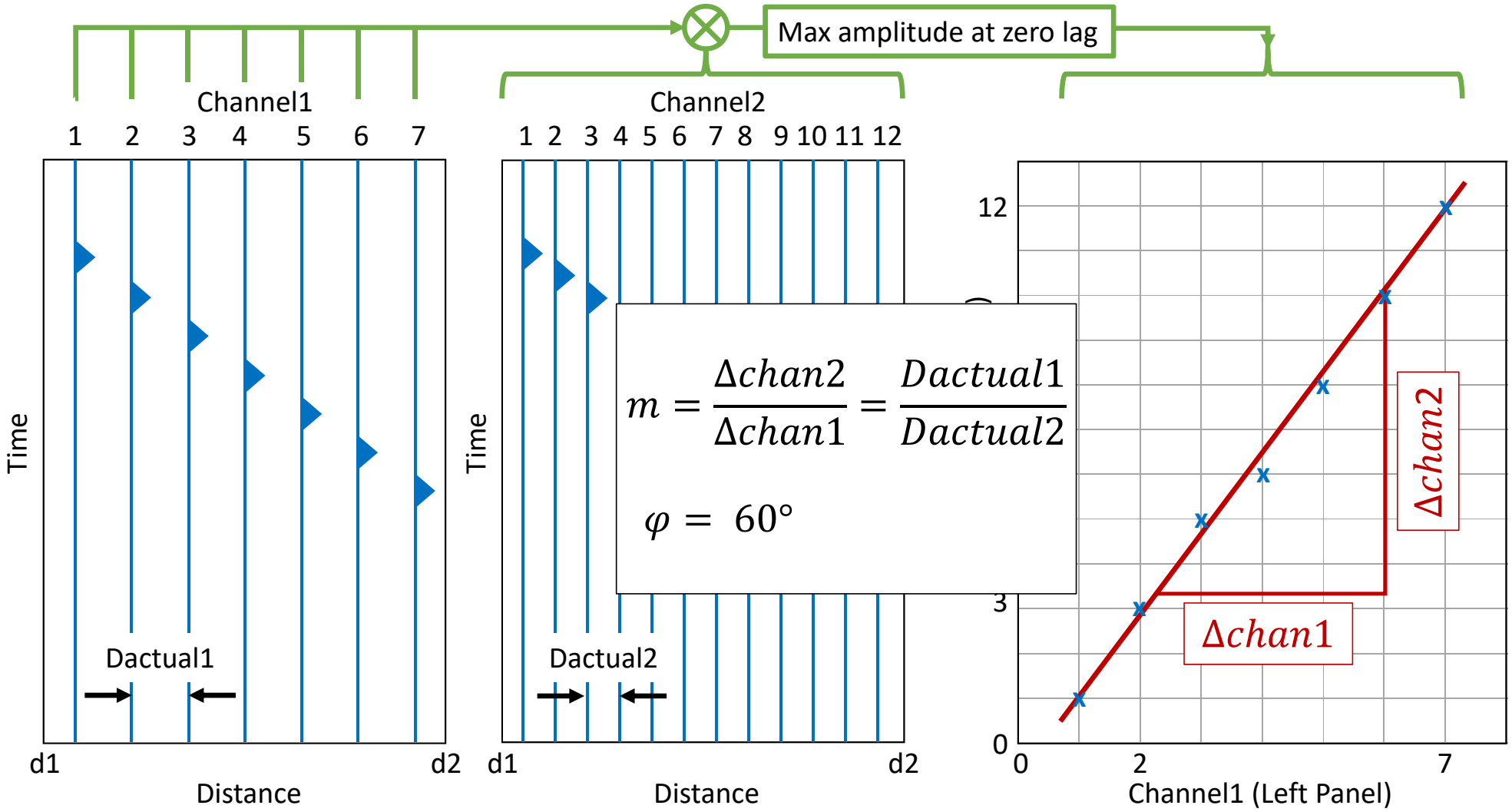
Theory: *Dactual2/Dactual1 estimation*



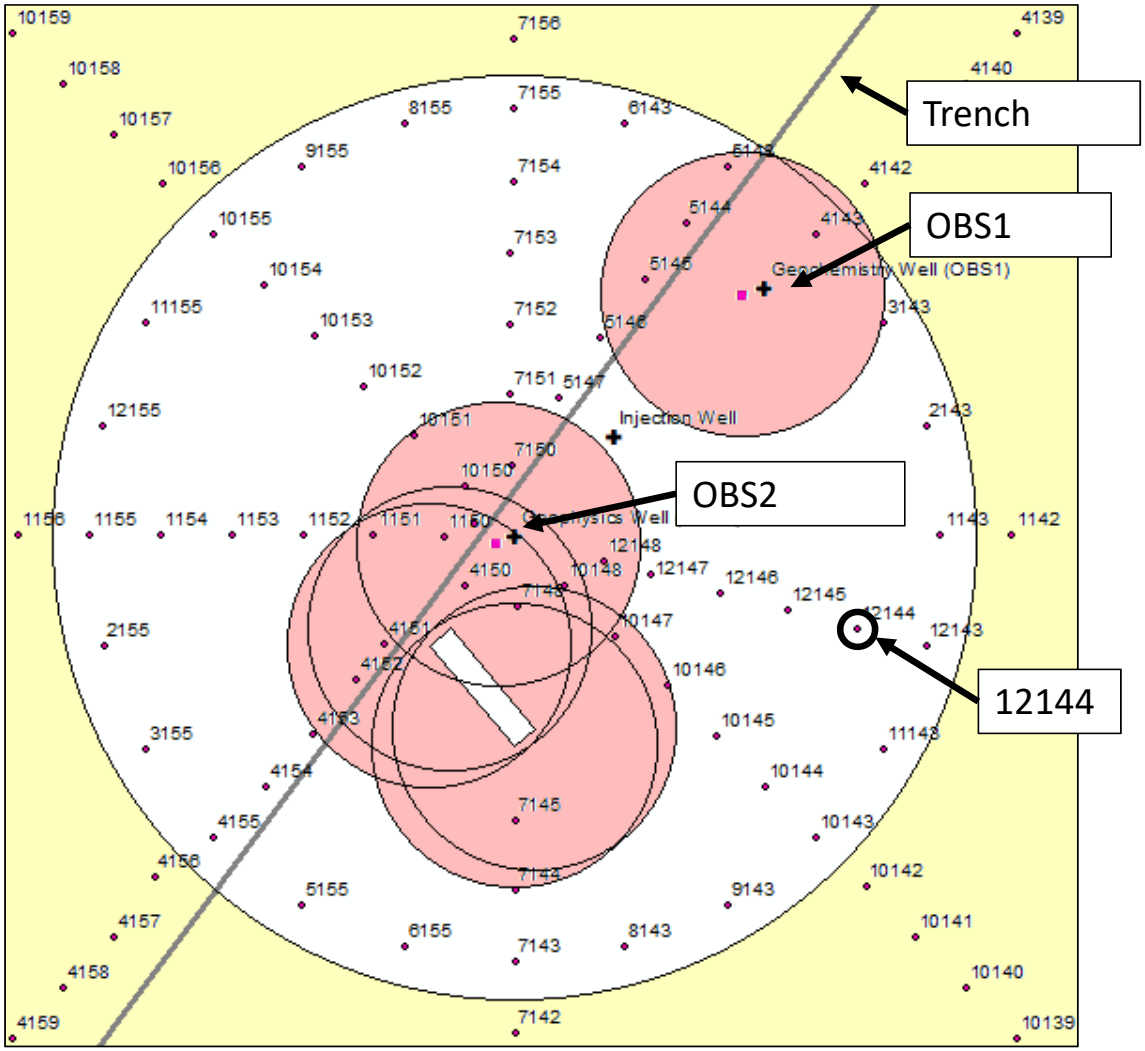
Theory: *Dactual2/Dactual1 estimation*



Theory: *Dactual2/Dactual1 estimation*



Testing: 2018 VSP (Snowflake) data selection



N

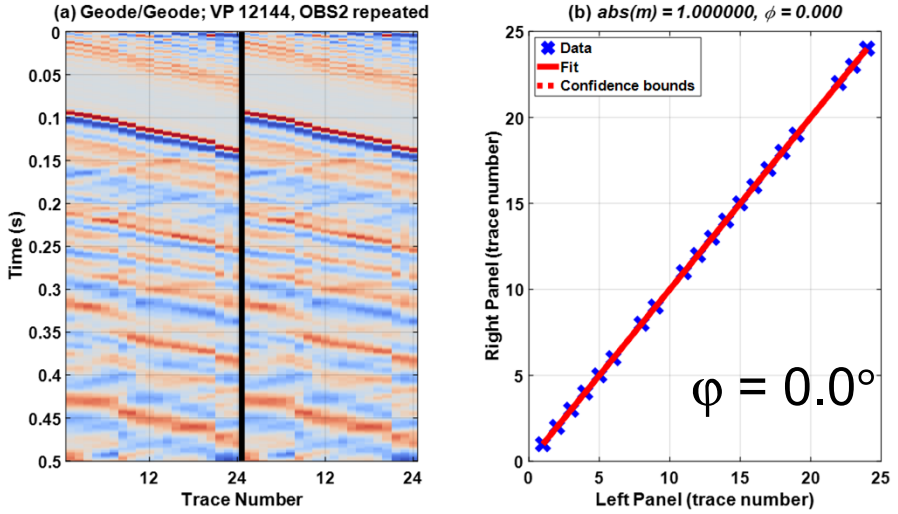
20 m

Exclude:
- VP > 65 m from OBS2 (yellow)
- VP < 20 m from Junction boxes (pink)
- VP < 20 m from classroom corners (pink)

Use:
- OBS2 Well
  - Geophone data (Geode)
  - Accelerometer data (Scorpion)
  - Helical fibre data (Fotech)
  - Straight fibre data (Fotech)
- OBS1 Well
  - Straight fibre data (Fotech)
- Trench
  - Geophone data (Aries)
  - Helical fibre data (Fotech)
  - Straight fibre data (Fotech)

Testing: OBS2 - Geo/Geo, Accel/Accel, Hel/Hel, Str/Str

a)



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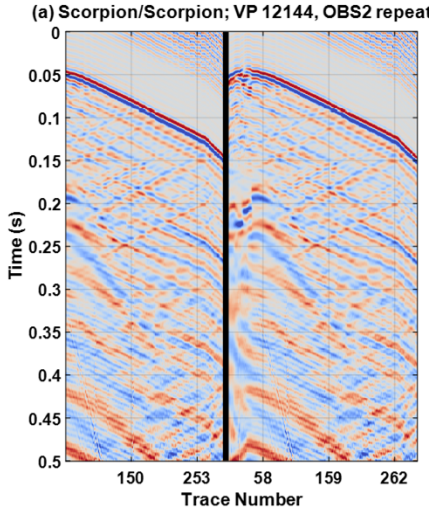

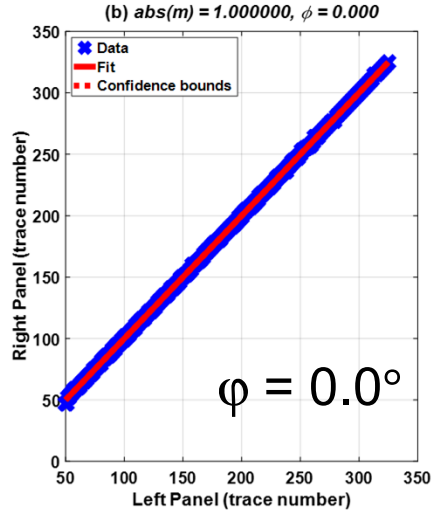

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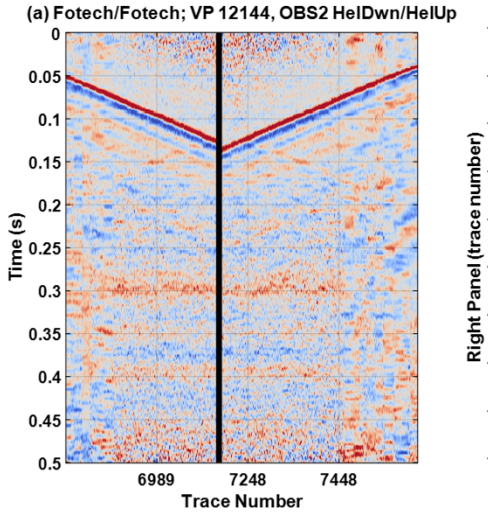
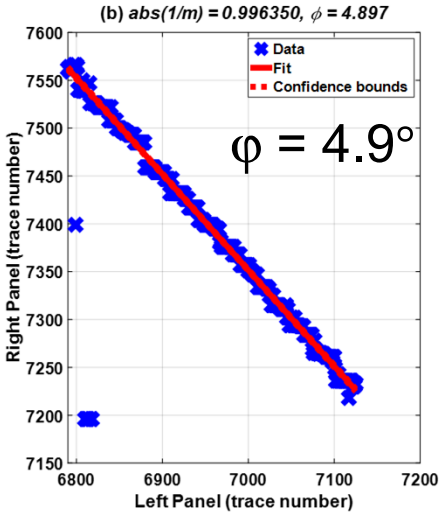
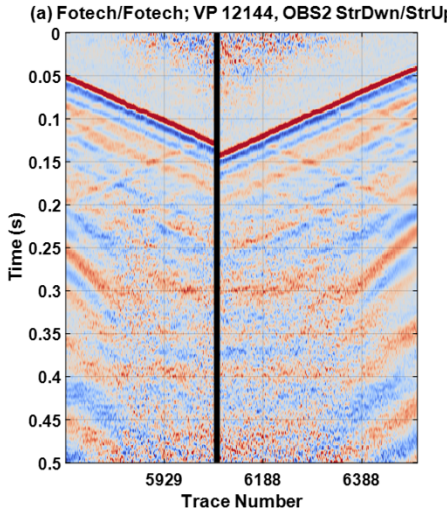
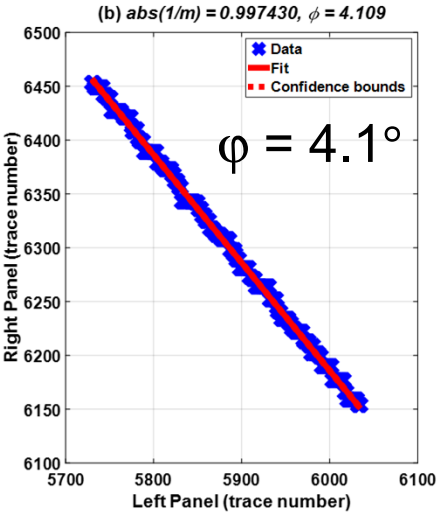


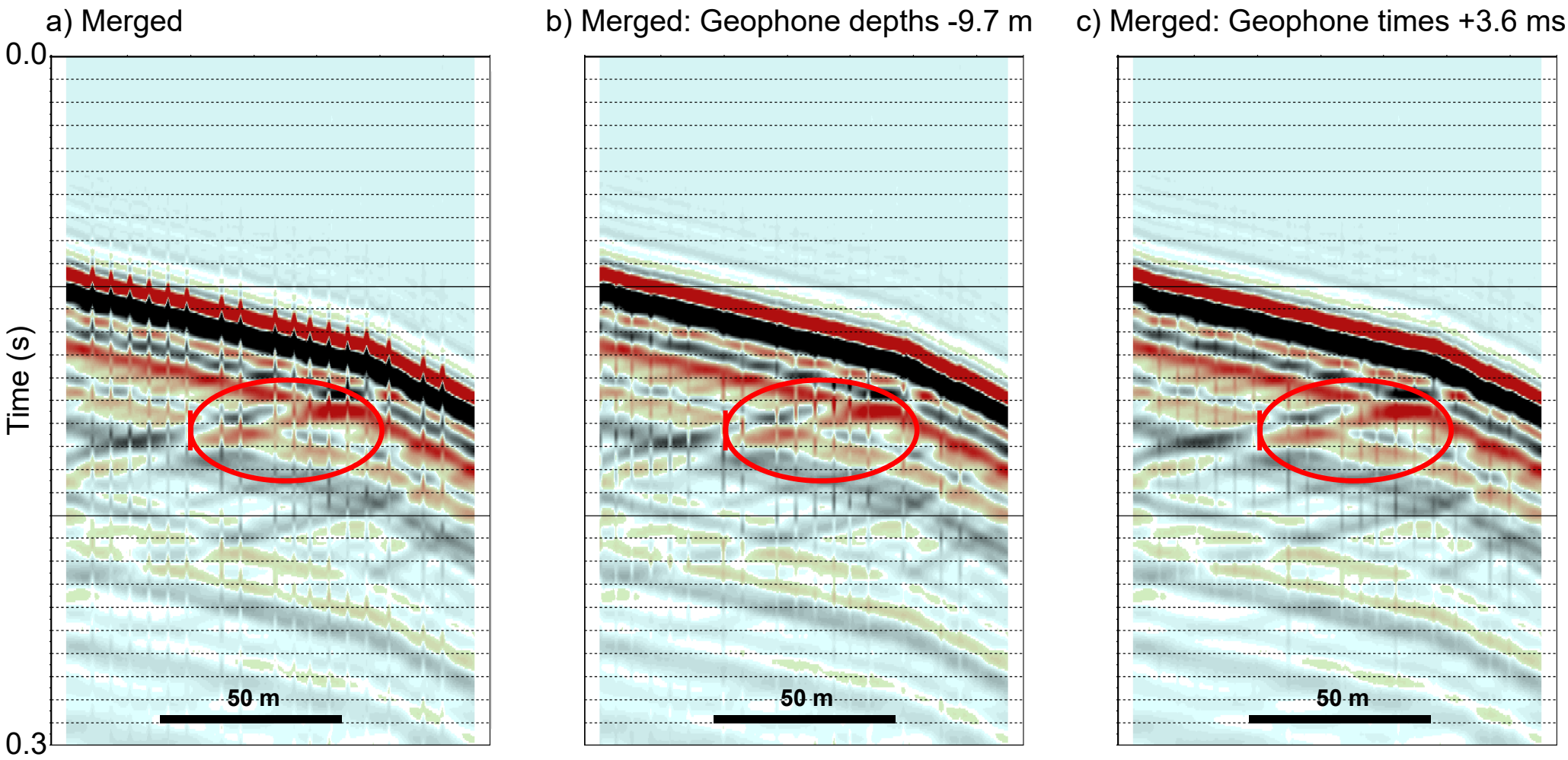


d)



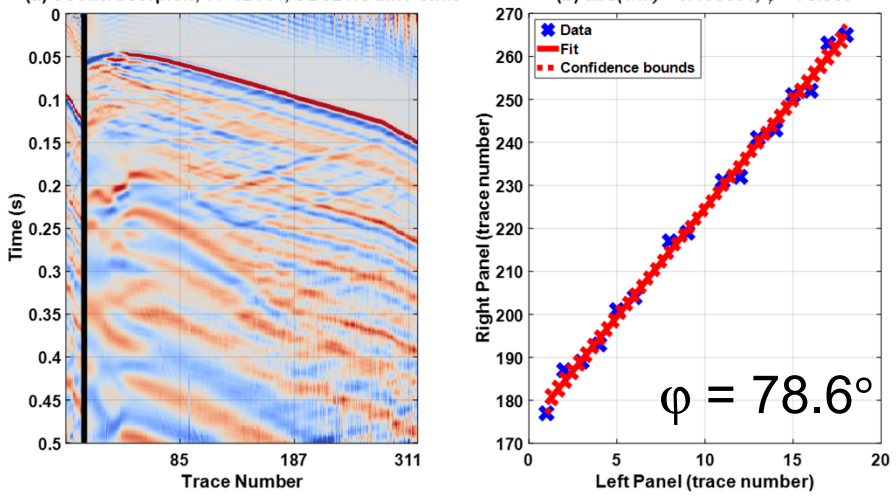


Testing: OBS2 - Geo/Accel; Time-zero mismatch



Testing: OBS2 - Geo/Accel; Time-zero mismatch

a)



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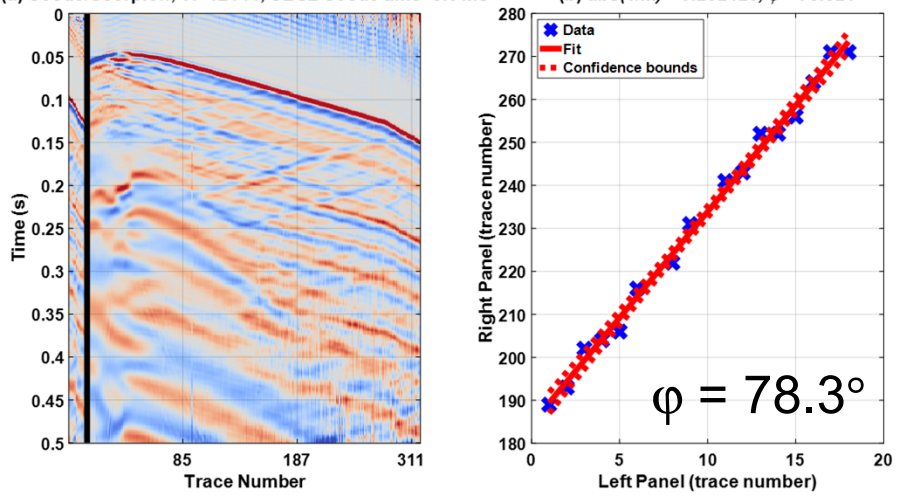

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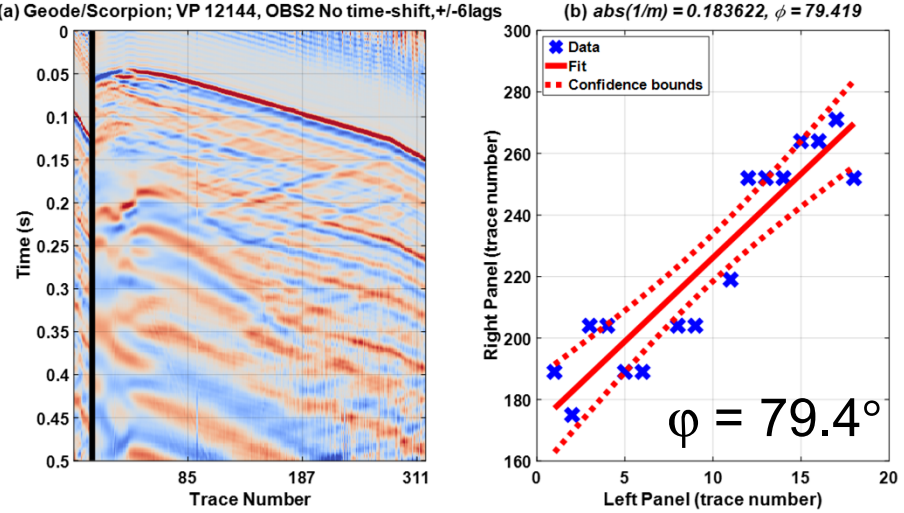

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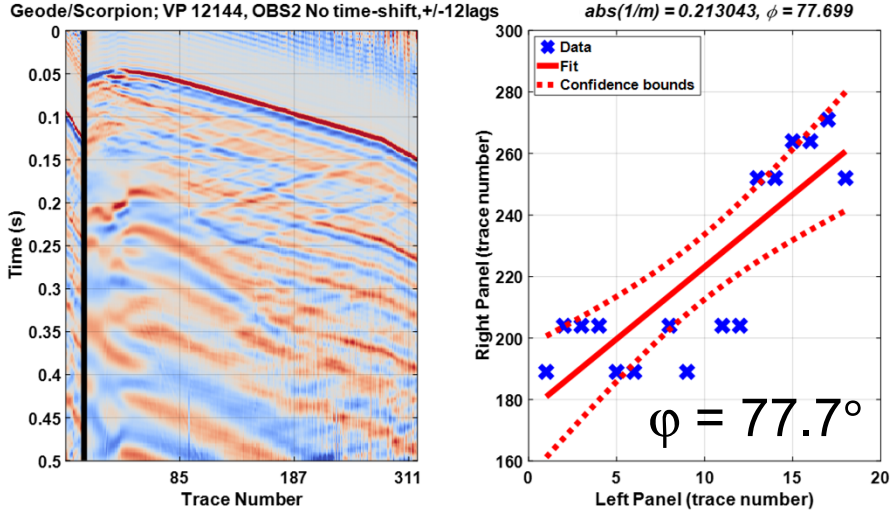
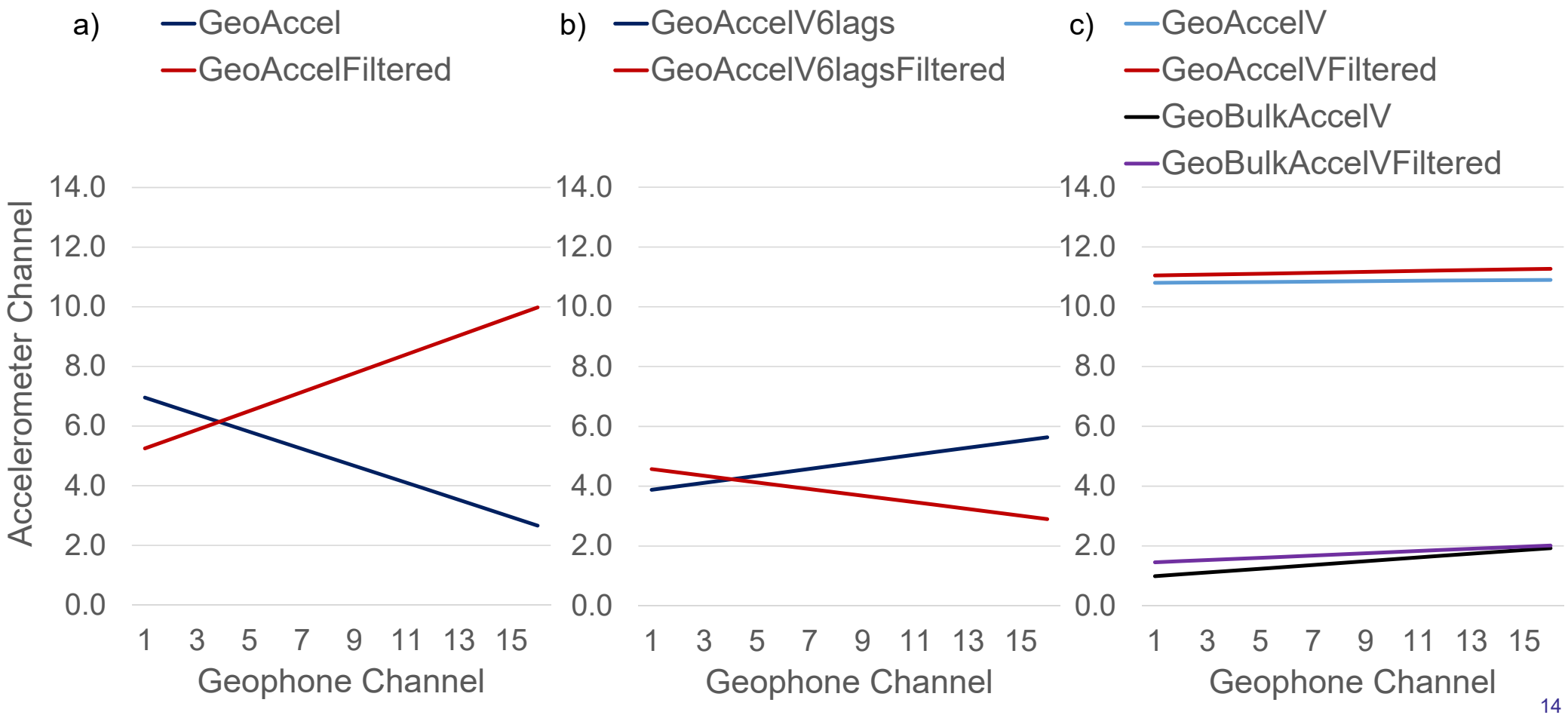


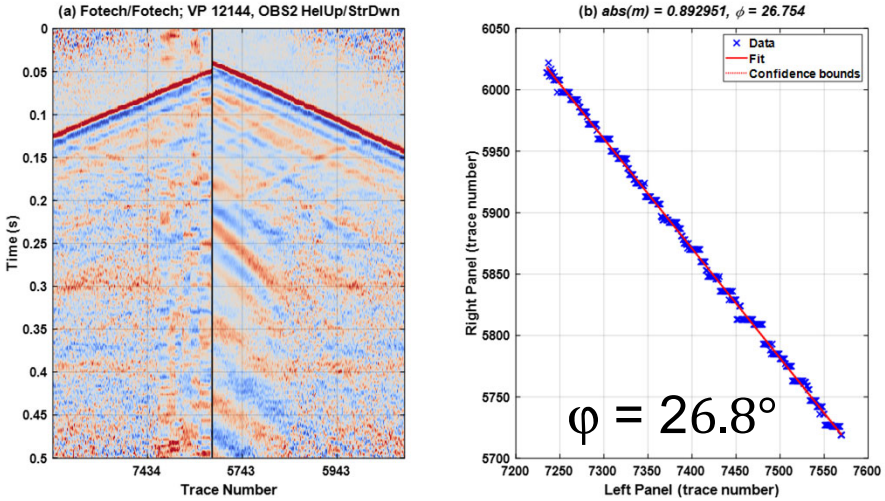
Testing: OBS2 - Geo/Accel; Multi-lag search and data domain

Accelerometer channel difference (Actual – Estimated)



Results: OBS2 – Psuedo-pitch angle estimate

a)



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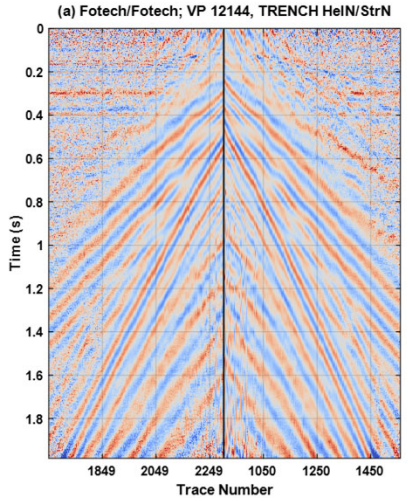

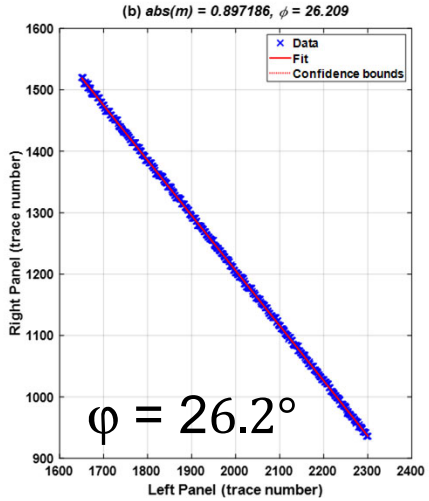

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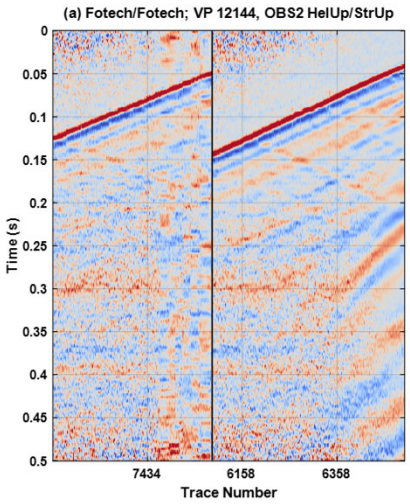

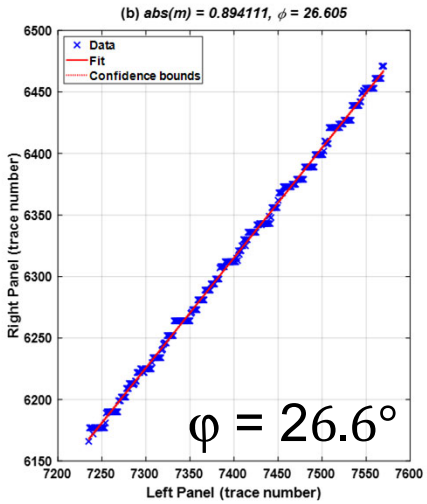

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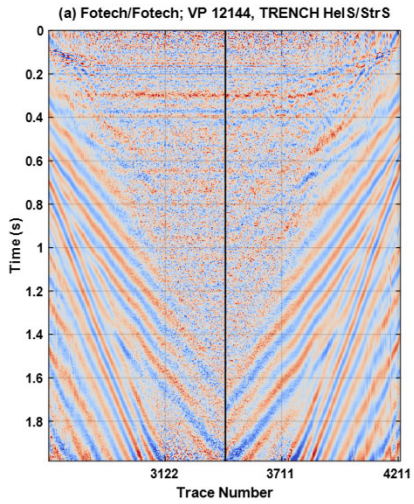
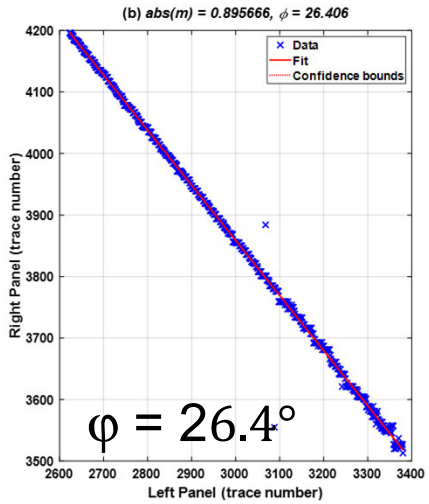
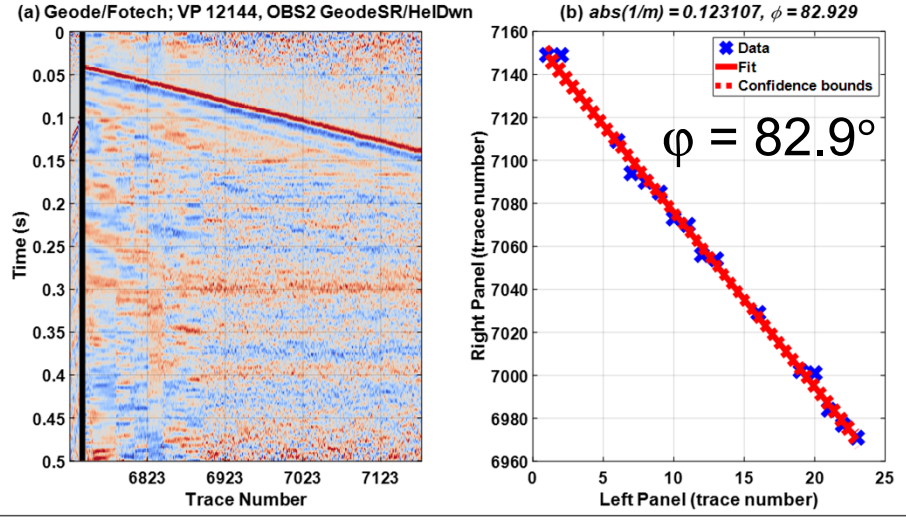




Results: OBS2 - Geo/Hel, Geo/Str, Accel/Hel, Accel/Str

a)



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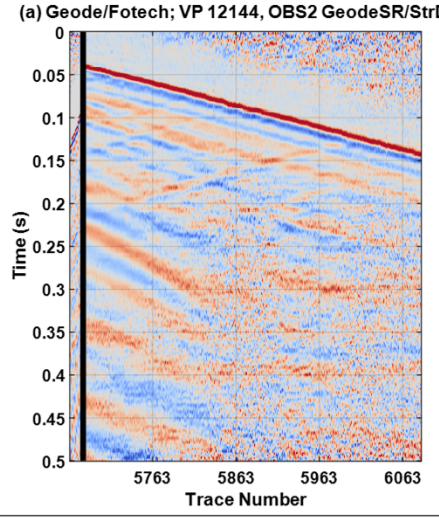

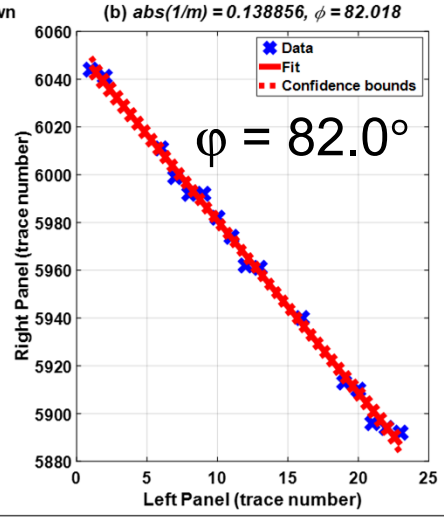

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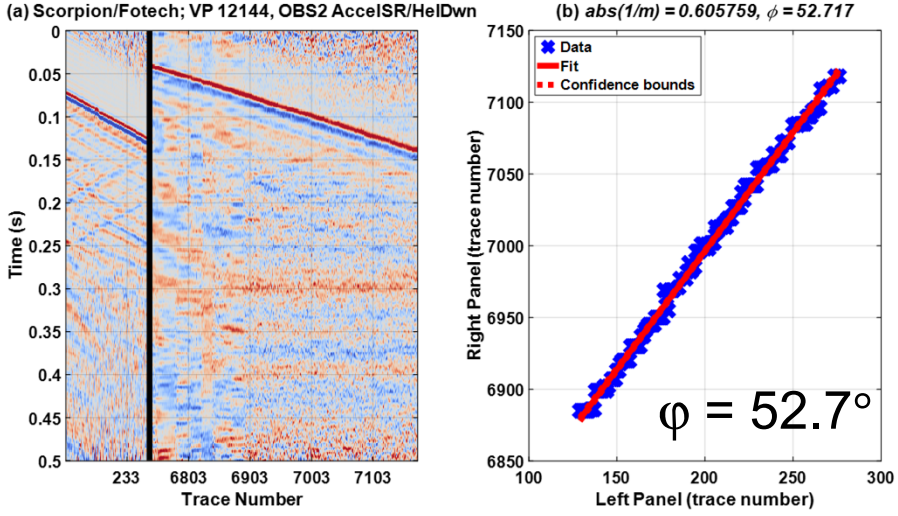

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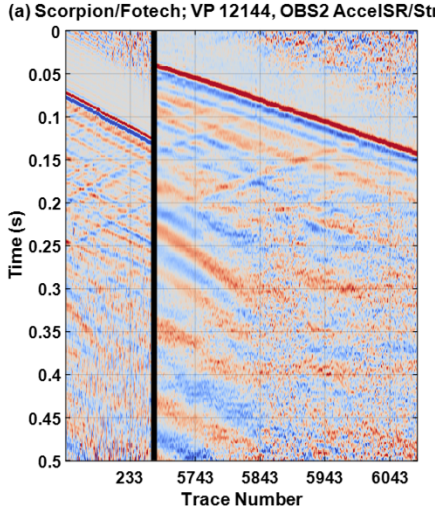
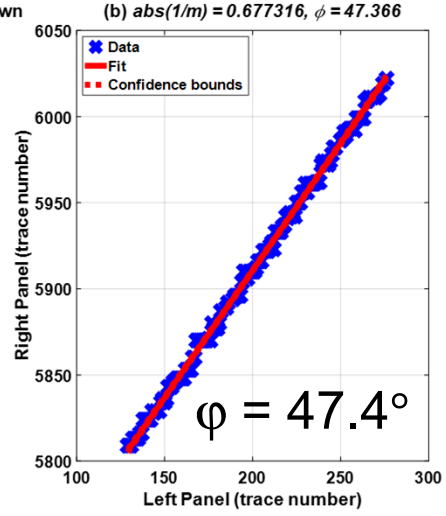
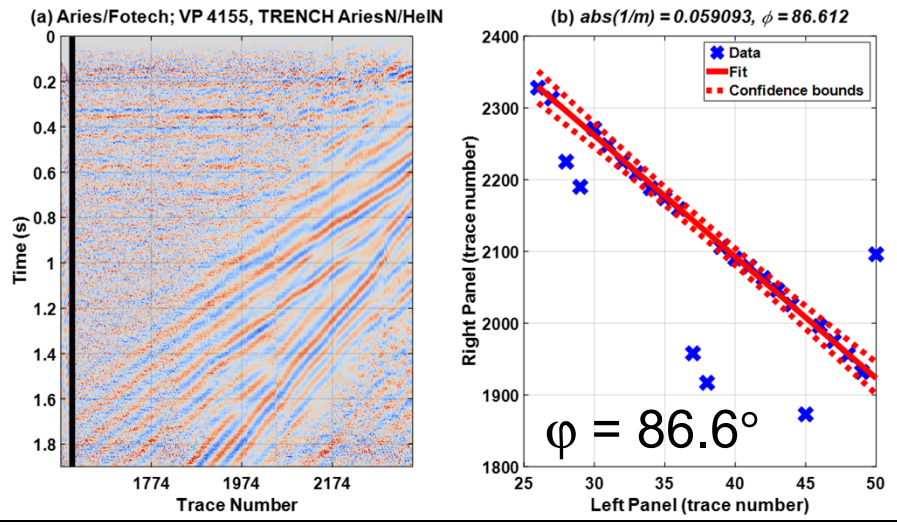


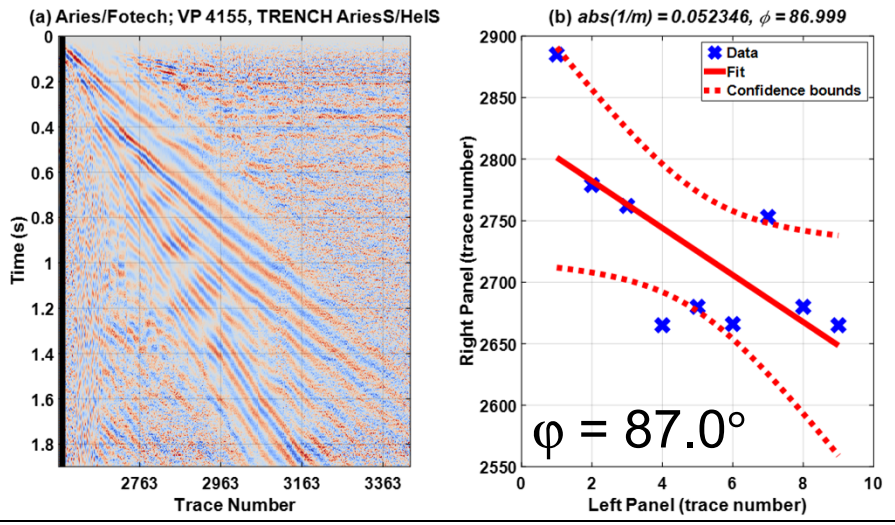


Results: Trench – Geo/Hel, Geo/Str

a)



b)



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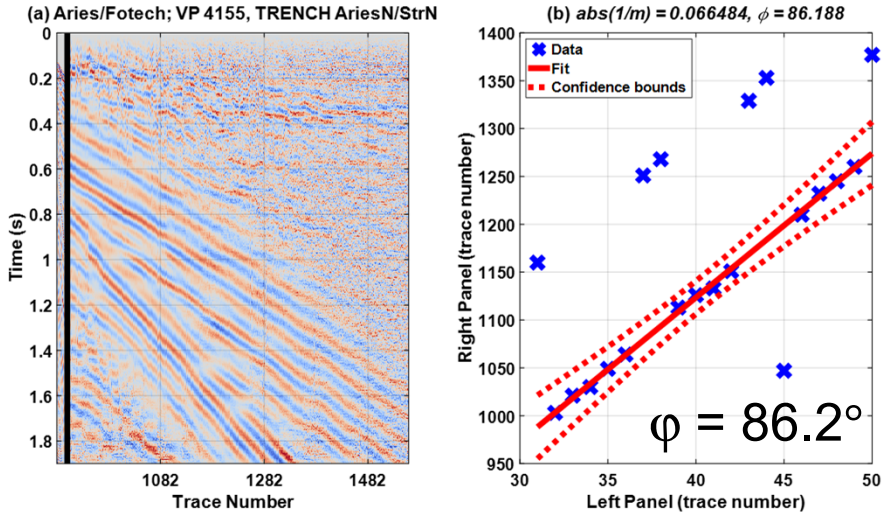
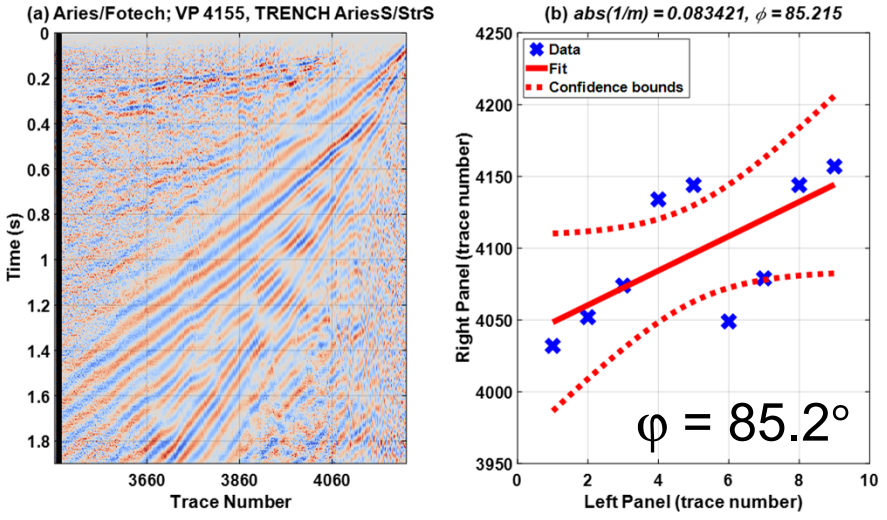


d)



Results: Summary of pitch angle estimates

Table 1. Averaged results from OBS2 and Trench.

	nVP	*m*	φ (deg)	θ (deg)
OBS2 Average	20	0.888	27.3	29.6
Trench Average	19	0.897	26.2	28.5

Table 2. Helical cable trace spacing results for OBS2 and Trench.

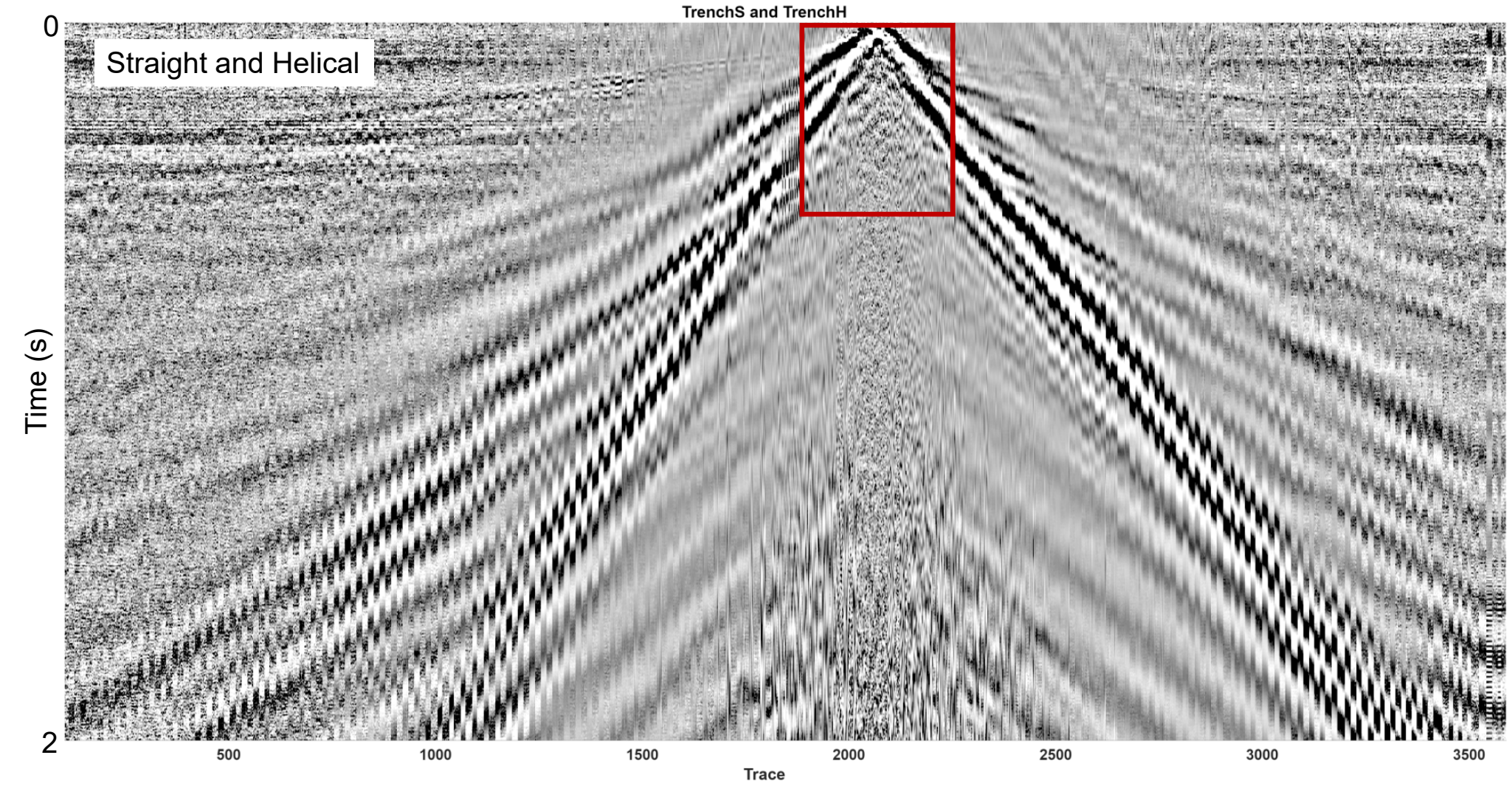
	θ (deg)	φ (deg)	*m*	Dactual (m)	deltaD (m)	TD (m)	Ntraces
Nominal θ	30.0	30.0	0.866	0.577	0.089	300	520
Nominal φ after IR correction	30.0	27.8	0.885	0.590	0.077	300	509
OBS2 *m* estimate	29.6	27.3	0.888	0.592	0.075	300	507
Trench *m* estimate	28.5	26.2	0.897	0.598	0.069	300	502

Results: Summary of pitch angle estimates

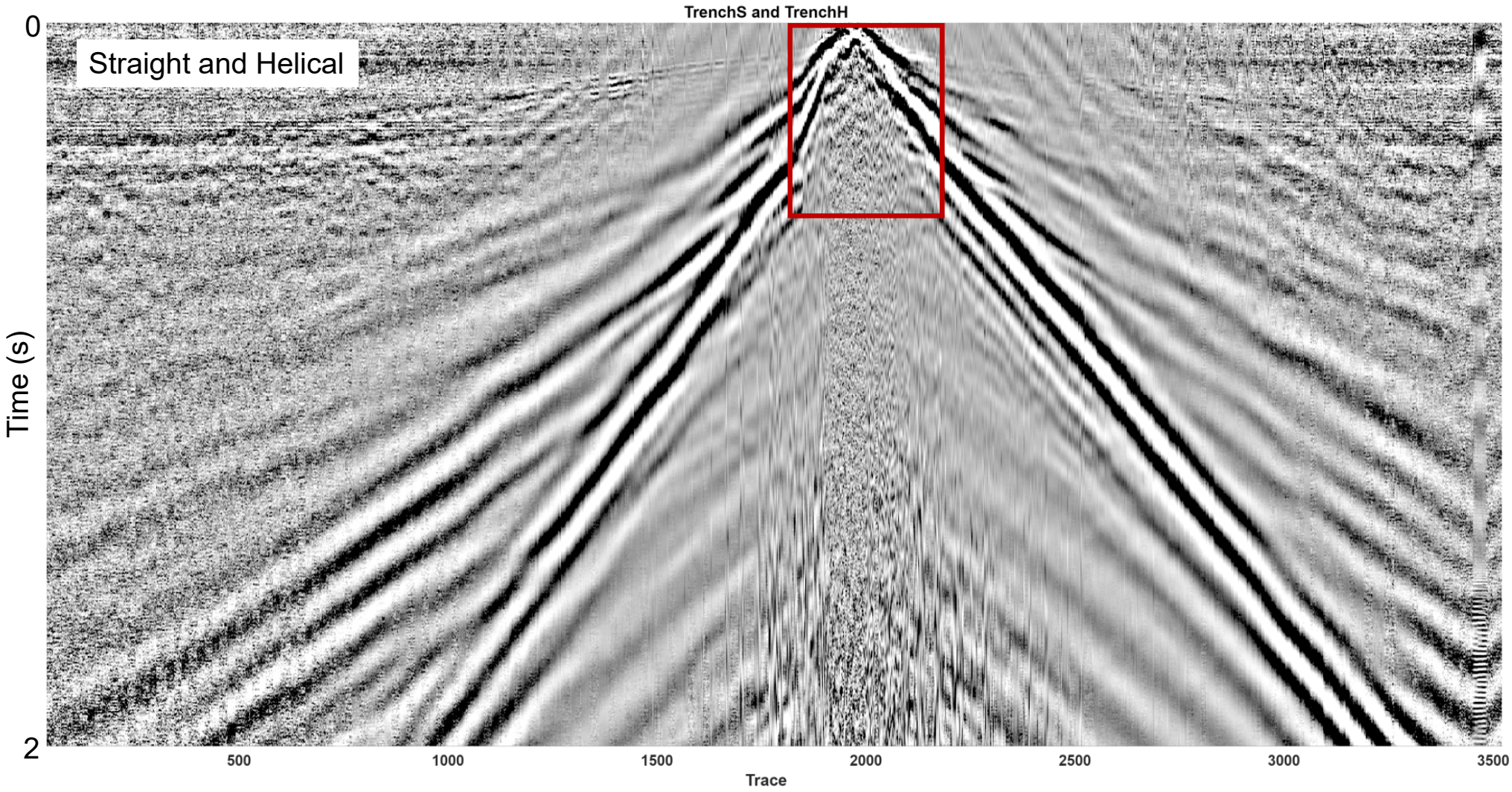
Table 3. Averaged results from OBS2 and Trench.

	nVP	Nom. *D1* (m)	Nom. *m*	Est. *m*	Nom. *φ* (deg)	Est. φ (deg)	*Dactual* (m)	Est. *D2* (m)	Δ*D2* (m)
GeoSR HelDwn OBS2	26	5	0.118	0.122	83.2	83.0	0.592	0.610	0.018
AccelSR HelDwn OBS2	25	1	0.592	0.596	53.7	53.4	0.592	0.596	0.003
GeoSR Hel NorthTrench	19	10	0.060	0.060	86.6	86.6	0.598	0.599	0.001

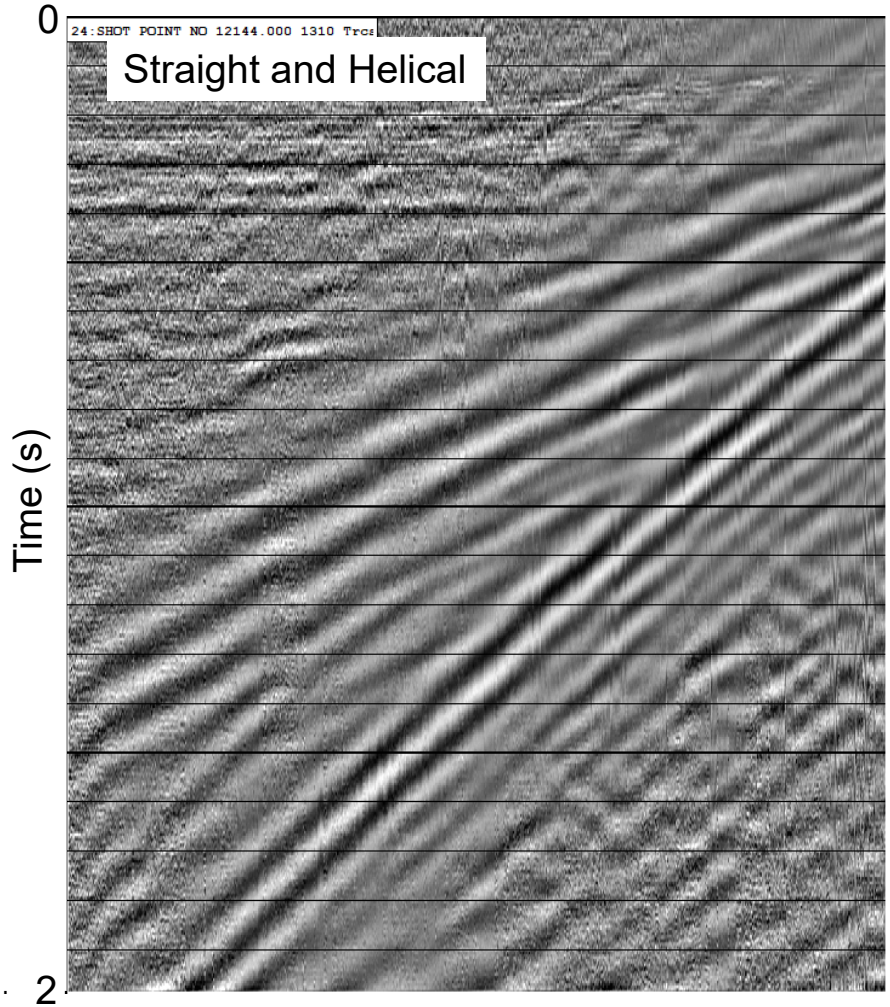
Results: Trench data interleaved - 30° pitch angle; no IR correction

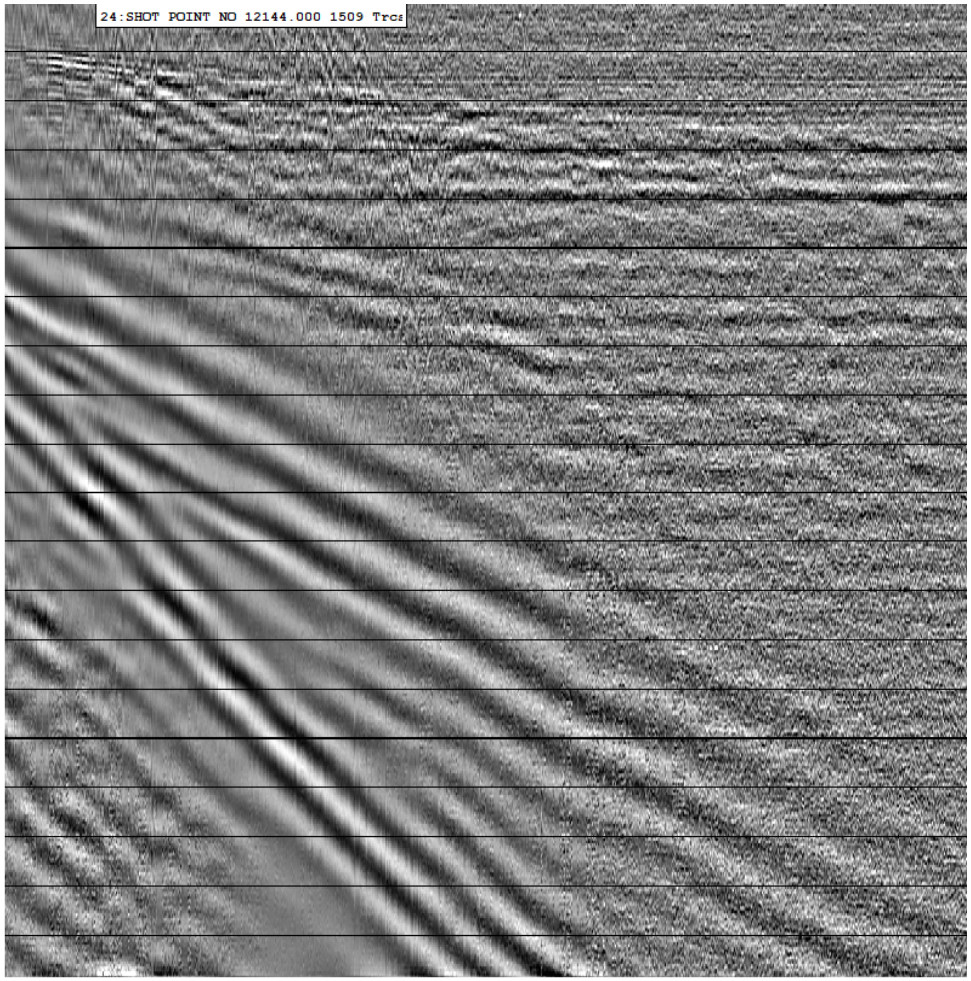


Results: Trench data interleaved - 26.2° pitch angle; no IR correction



Results: Trench data interleaved - 26.2° pitch angle; y=mx+b





Discussion

- We can estimate pseudo-pitch angle (φ) from recorded data
  - We do not need to know software or fibre IR
  - We can apply IR corrections for comparison to nominal pitch-angle
- We can use φ to calculate helical cable trace spacing
  - We can do this when comparing helical fibre data to straight fibre, geophone, and accelerometer data

Future Work

- Confirm Geo/DAS and Accel/DAS time-zero
- Test data from other interrogators
  - Do we get the same answer?
- Geometry assignment
  - Use linear relationship to find anchor traces
  - Assign interpolated co-ordinates based on estimated helical cable trace spacing

Acknowledgements

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- Halliburton
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- CaMI.FRS JPI subscribers

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