Dual- and triple-source in simultaneous mode – a solution for higher density seismic?

(EAGE papers 2015: Langhammer & Bennion + Liu et al.)

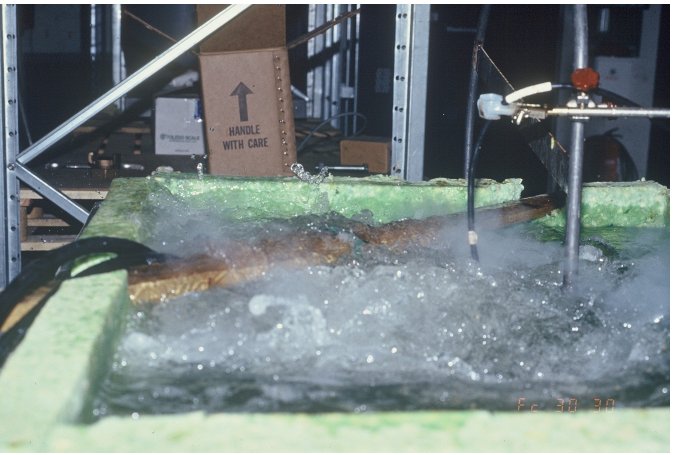
Jan Langhammer
ROSE meeting, NTNU

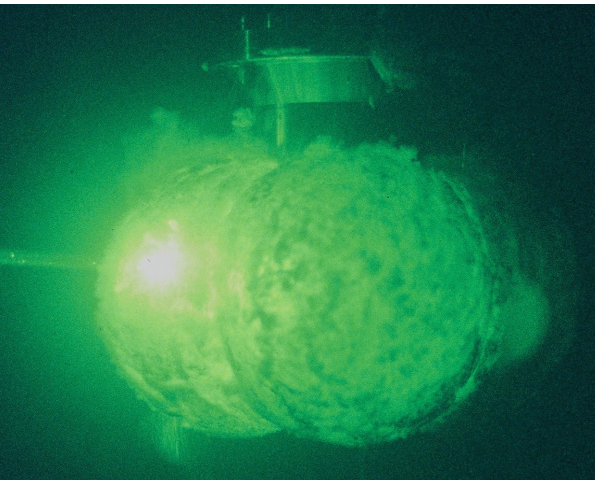
Tuesday 26th of April 2016

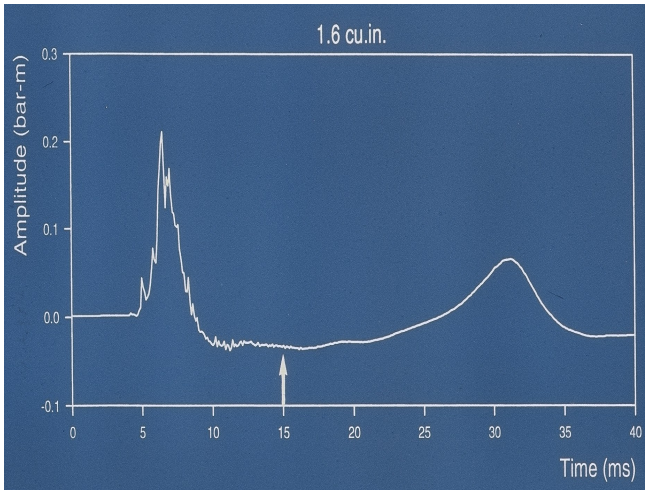
Outline

- Introduction
- Acquisition parameters and source details
- Test sequences
- Data examples and results
- Conclusions

Introduction (23 years ago!)







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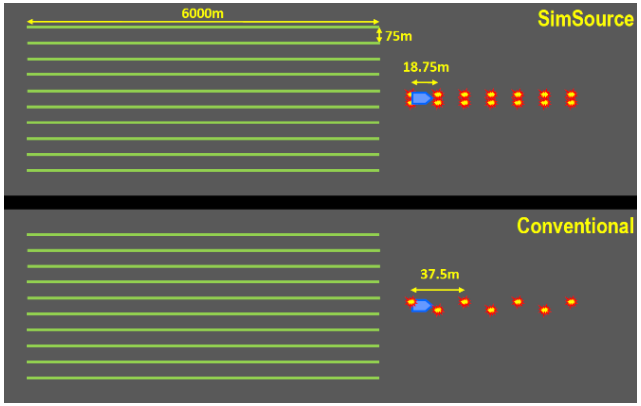
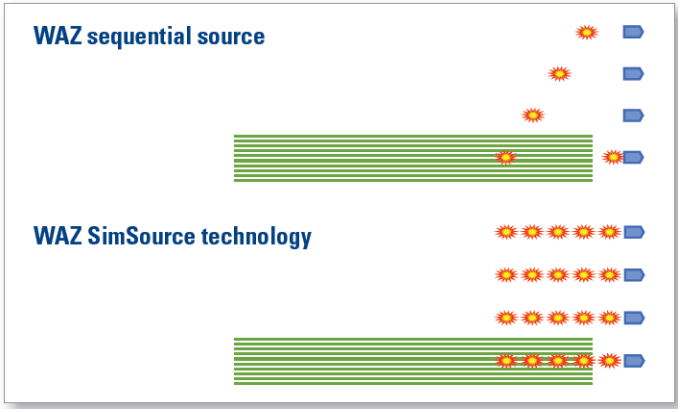
Introduction

- The concept of dual-source, in sequential mode, is the standard in 3D streamer acquisition
- Simultaneous sources has been introduced, both in various streamer and in ocean bottom acquisition concepts, for increased sampling and efficiency
- An increased need for better sampling in the crossline direction
  - Usually well sampled in the inline direction (6.25 m bin distance along streamers)
  - More sparse in x-line direction (18.75 m up to 50 m bin distance in between streamers)
- Why not revisit the use of triple-source in 3D streamer acquisition?
- Concept tested in the 1980's but without commercial success
- 2016: Low noise solid streamers, longer streamers, dynamic range is increased, continuous recording, deblending techniques available in processing

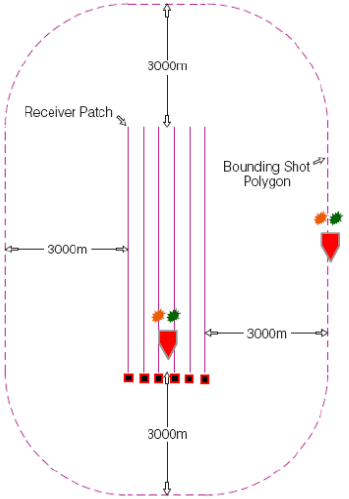
Introduction

- Higher fold and increased efficiency by the use of simultaneous/overlapping sources

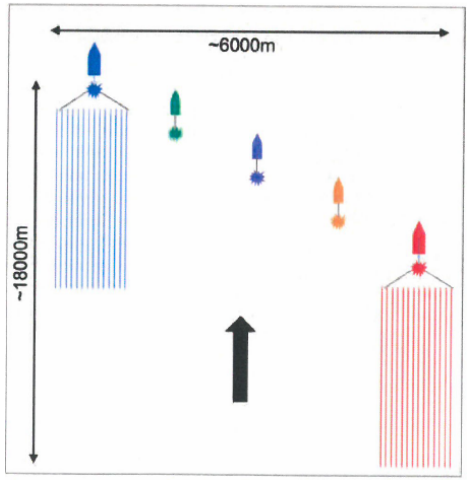




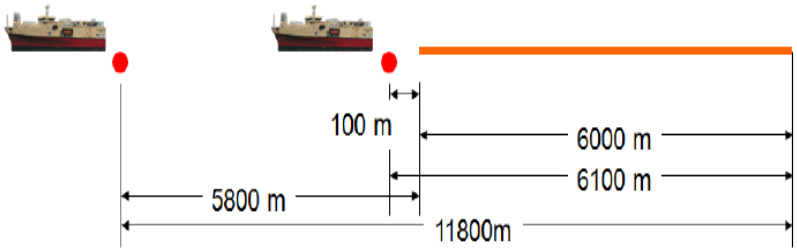
Courtesy WesternGeco



Courtesy BP



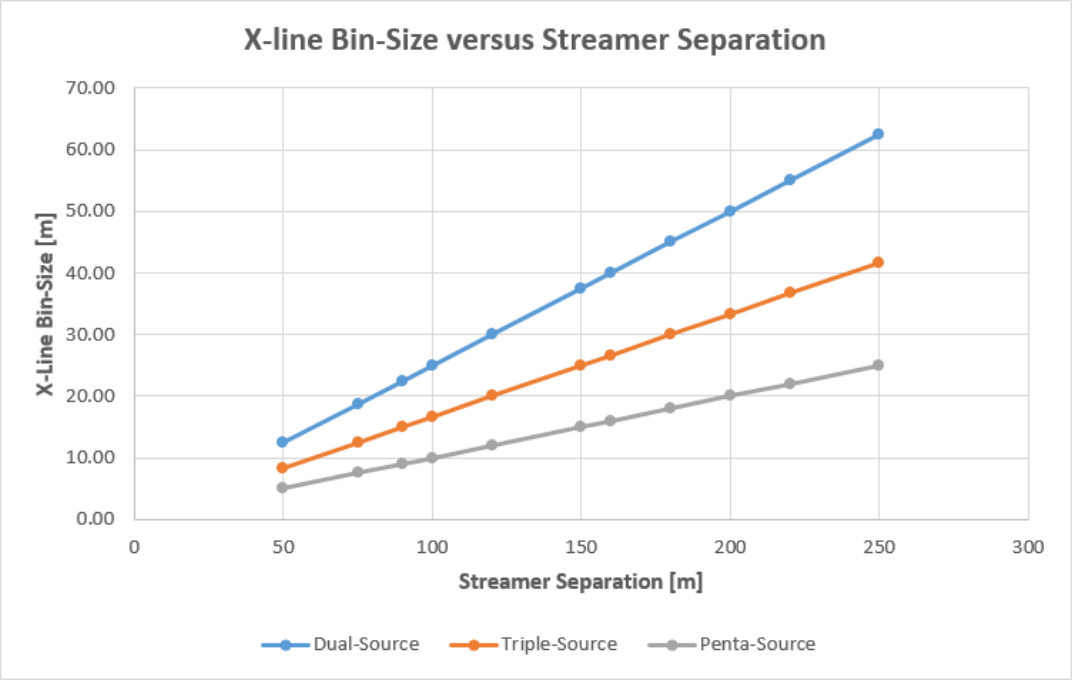
Courtesy CGG



Courtesy PGS

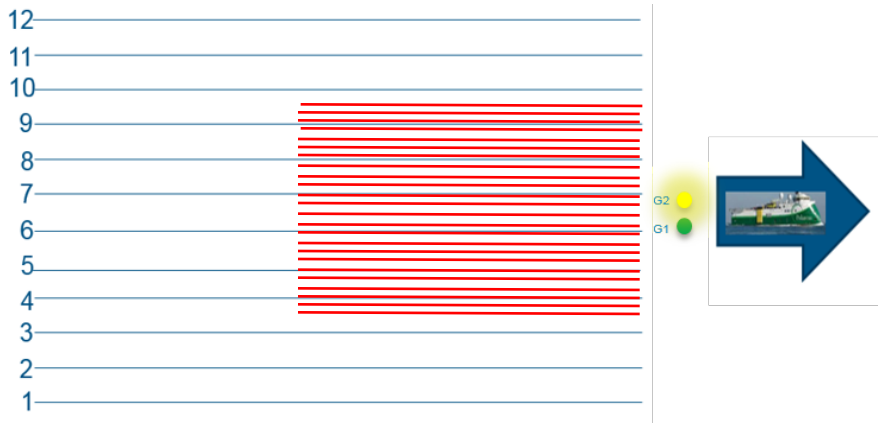
X-line bin-size

- Always a trade-off between size of streamer spread, i.e. efficiency, and good enough sampling, i.e. small enough x-line bin-size.

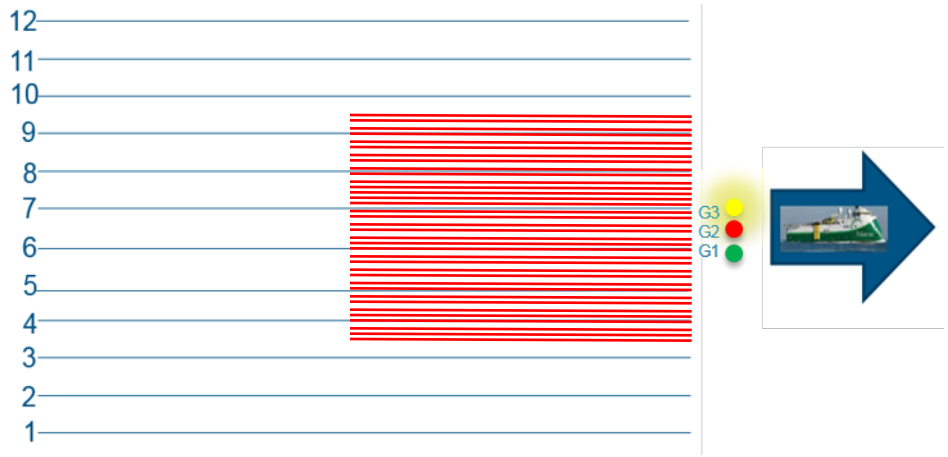


- Better spatial sampling will give better imaging of complex structures.

Re-configuration to triple-source



Conventional Dual-Source



Triple-Source Sequential

- ✓ An extra source will add more sub-surface coverage lines in between the streamers.
- ✓ No wave-field reconstruction, or interpolation, the extra coverage lines are actually measured.

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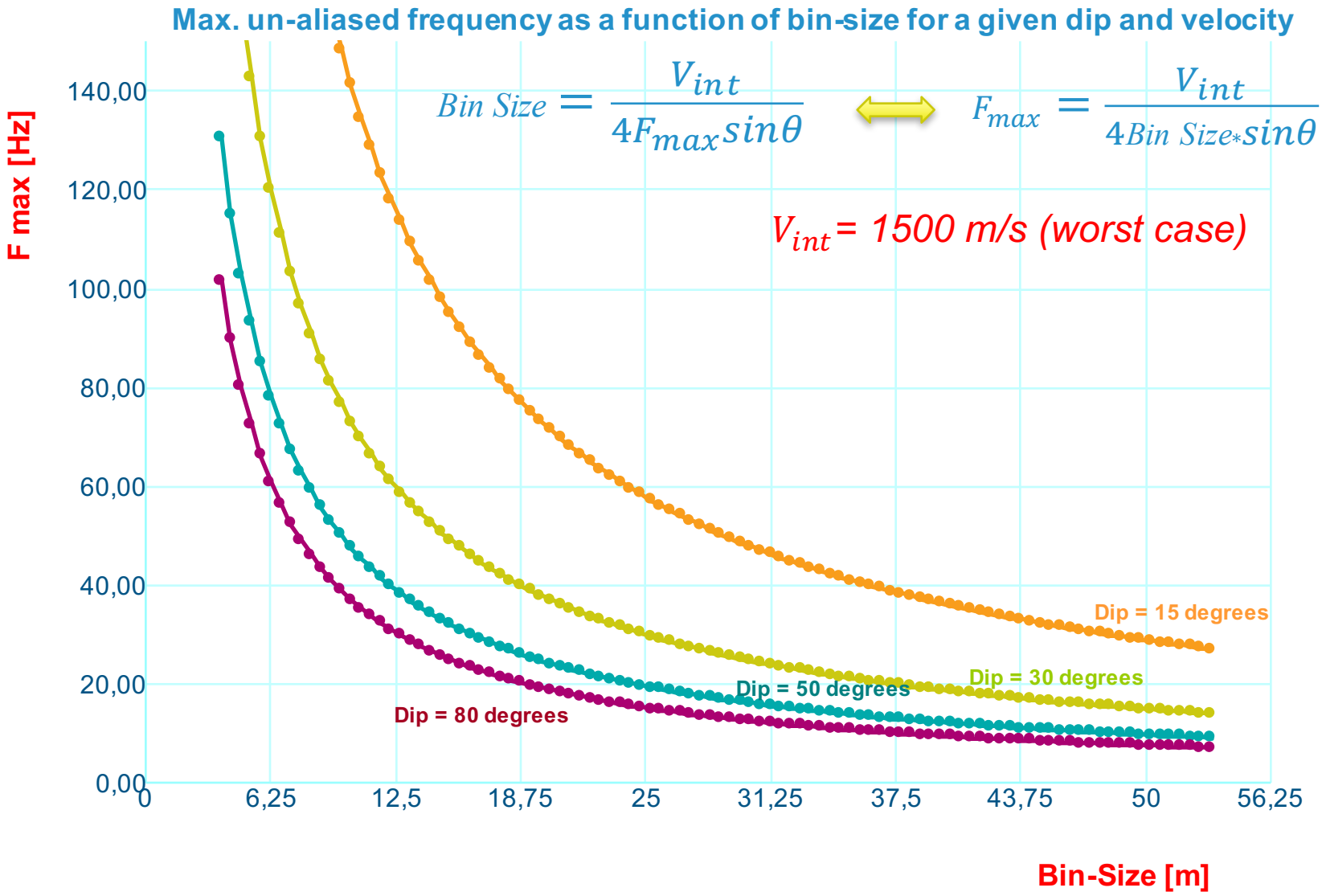
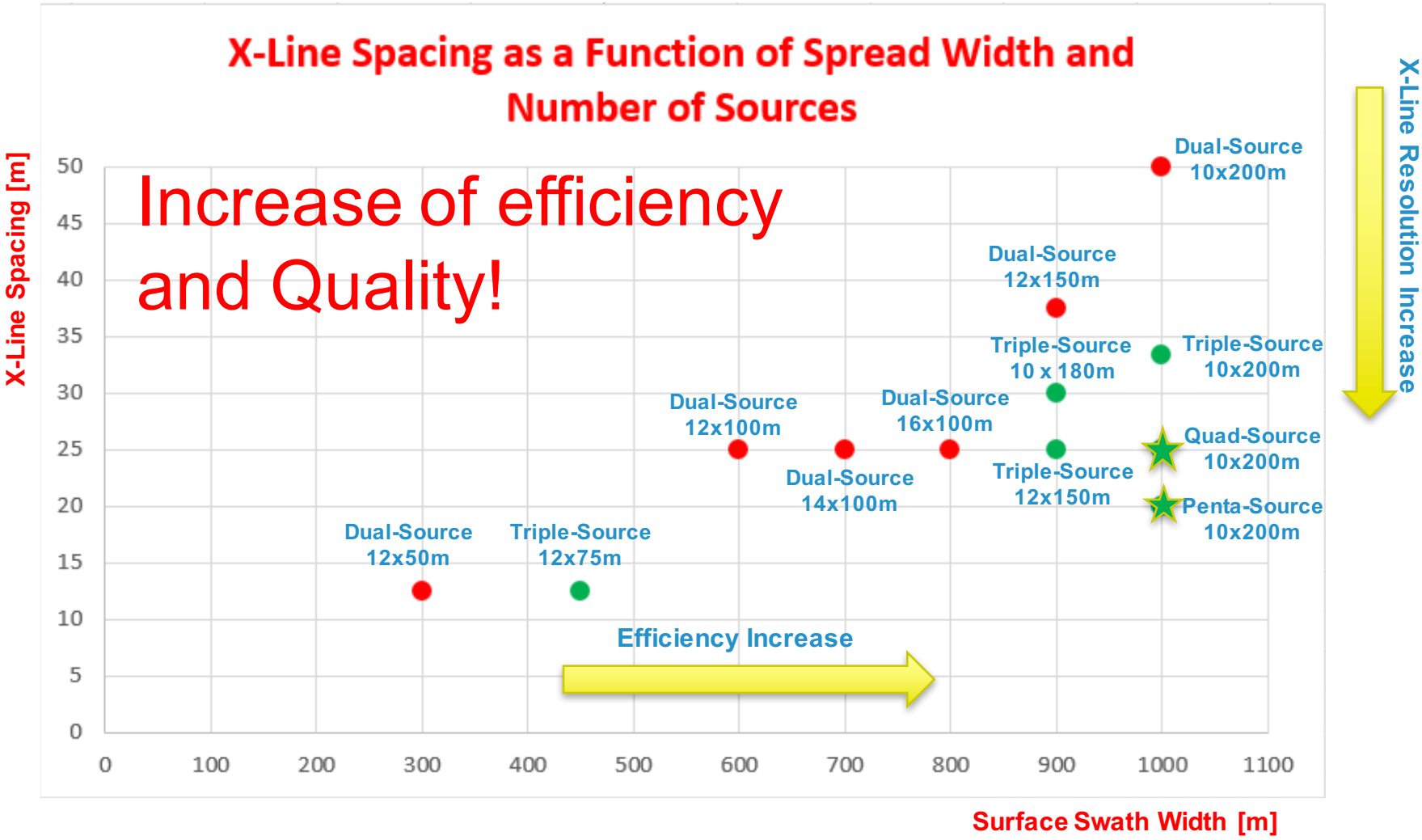
X-Line Bin-Size (worst case scenario)



Efficiency and resolution with no. of sources

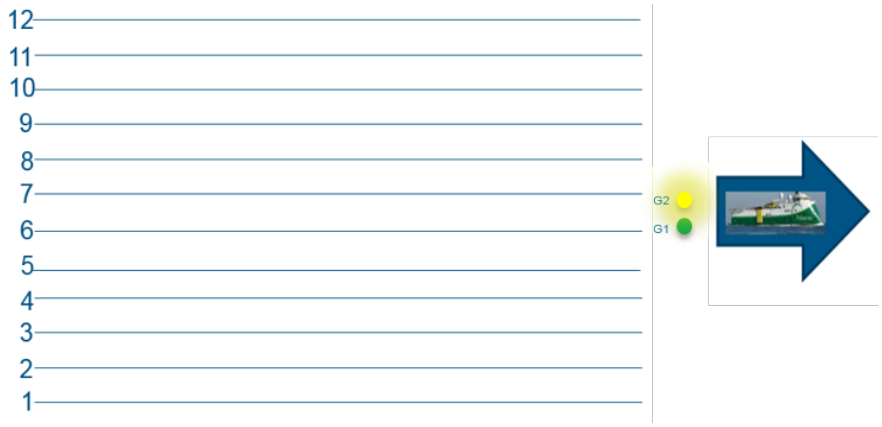


Why this test?

- Explore how easy it was in real life to change the available 6 sub-arrays onboard a 3D vessel from 3 sub-array dual-source into 2 sub-array triple-source configuration?
- What data quality would we obtain by changing the sources in this way?
- How to operationally manage triple-source in standard 3D acquisition?
- Can we use the triple-source configuration in future standard 3D acquisition AND can we fire all three sources off in simultaneous mode?
- How many sources can we separate/deblend and what about frequencies?

Acquisition Parameters and Source Details

Acquisition parameters



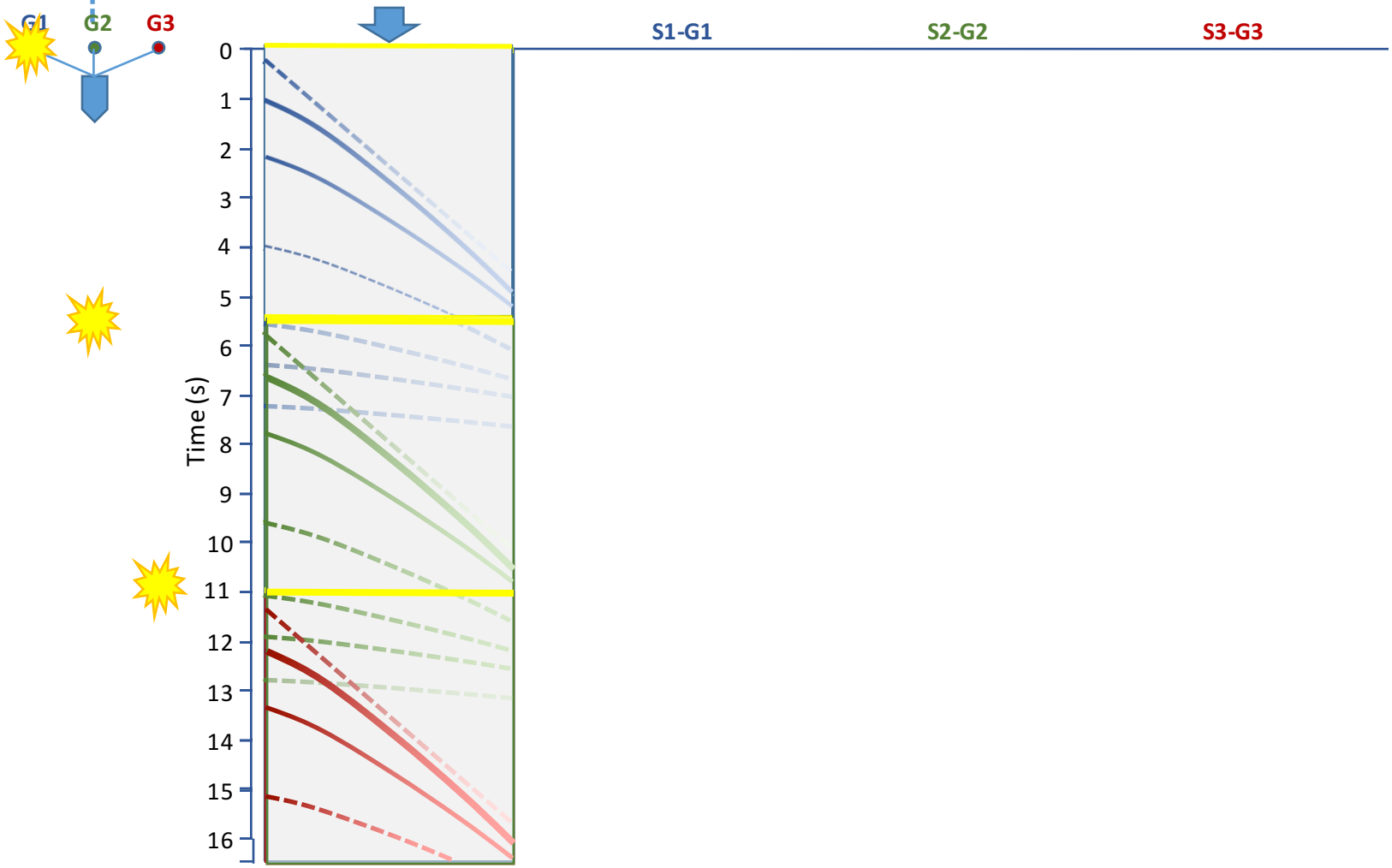
Conventional Dual-Source

- Streamers: 12 x 100 m x 6000 m
- Slant 12 m – 30 m
- Shot-point interval: 18.75 m (37.5 m)
- Timing for shots: Sequential
- Bin-size: 6.25 m x 25 m
- Source depth: 7 m
- Record length 8.2 seconds (cont. rec.)
- Fold: 80

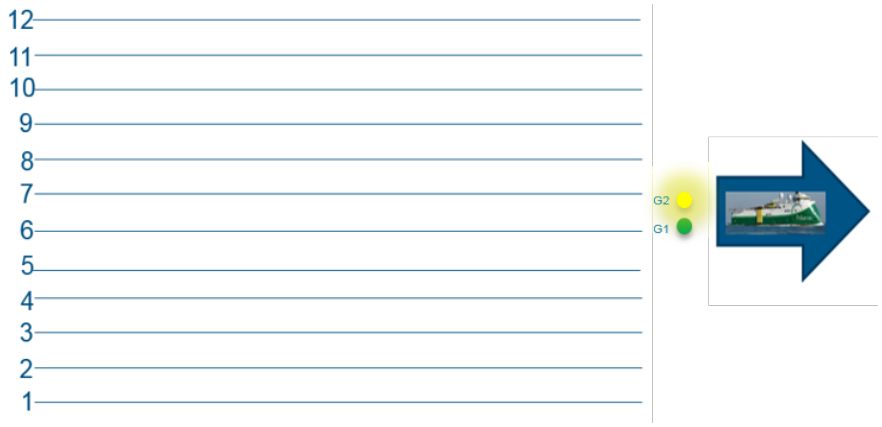
Dual-Source Simultaneous

- Streamers: 12 x 100 m x 6000 m
- Slant 12 m – 30 m
- Shot-point interval: 12.5 m
- Timing for shots: Dither: +/- 300 ms
- Bin-Size: 6.25 m x 25 m
- Source depth: 7 m
- Record length 5.4 seconds (cont. rec.)
- Fold: 240

FLIP-FLOP-FLAP



Acquisition parameters



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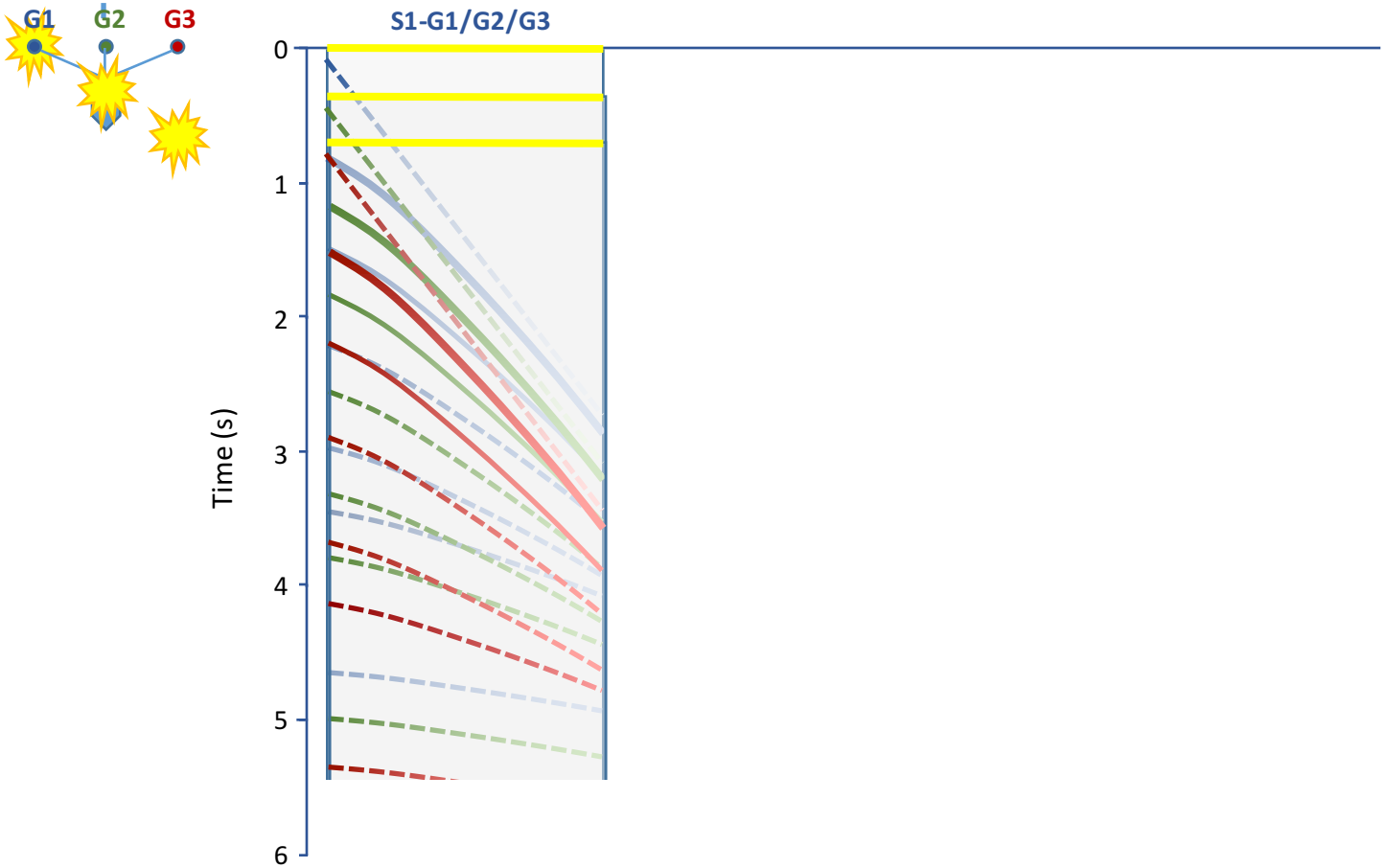
- Fold: 80

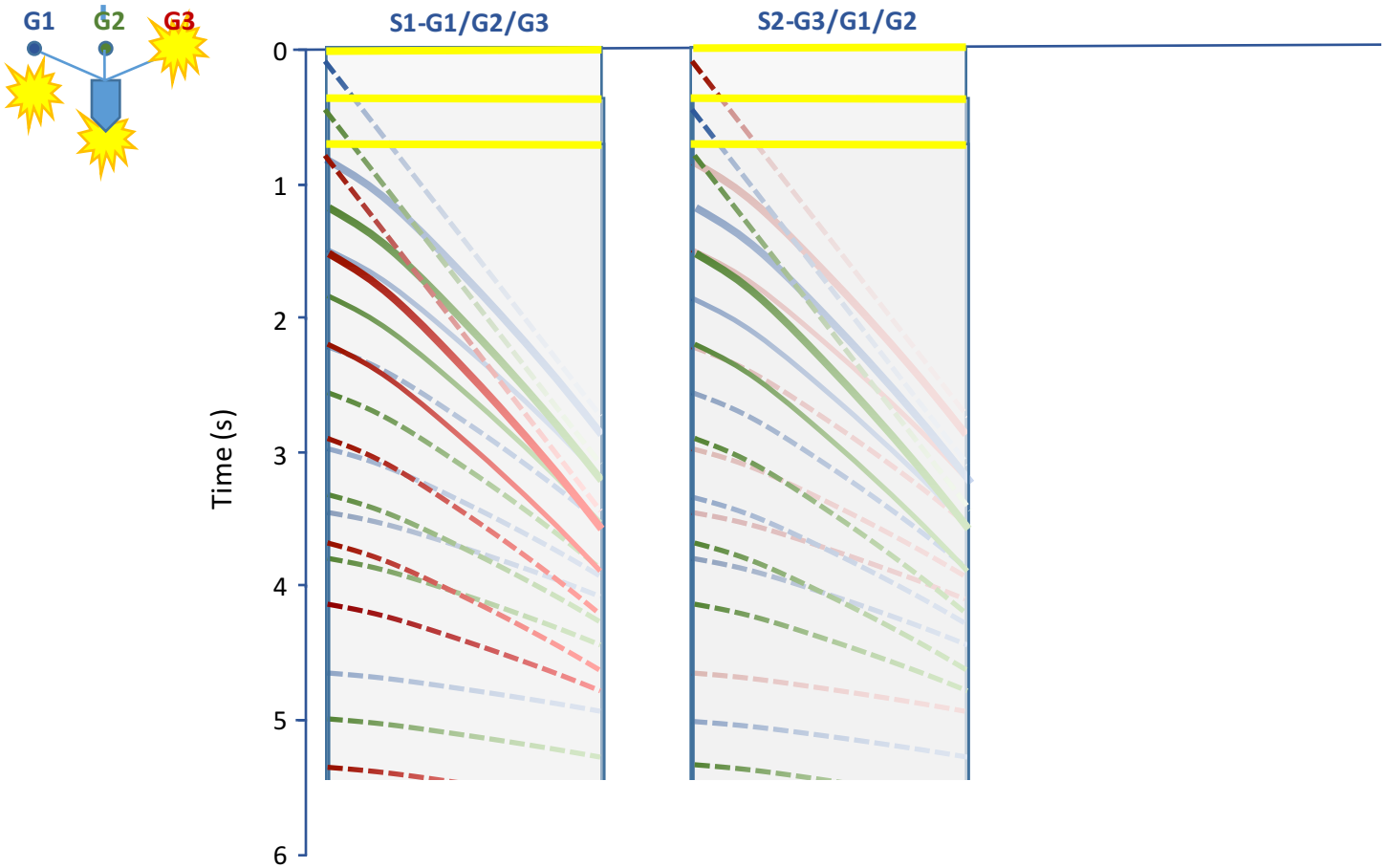
Triple-Source Sequential

- Streamers: 12 x 100 m x 6000 m
- Slant 12 m – 30 m
- Shot-point interval: 12.5 m (37.5 m)
- Timing for shots: Sequential
- Bin-Size: 6.25 m x 16.66 m
- Source depth: 7 m
- Record length 5.4 seconds (cont. rec.)
- Fold: 80

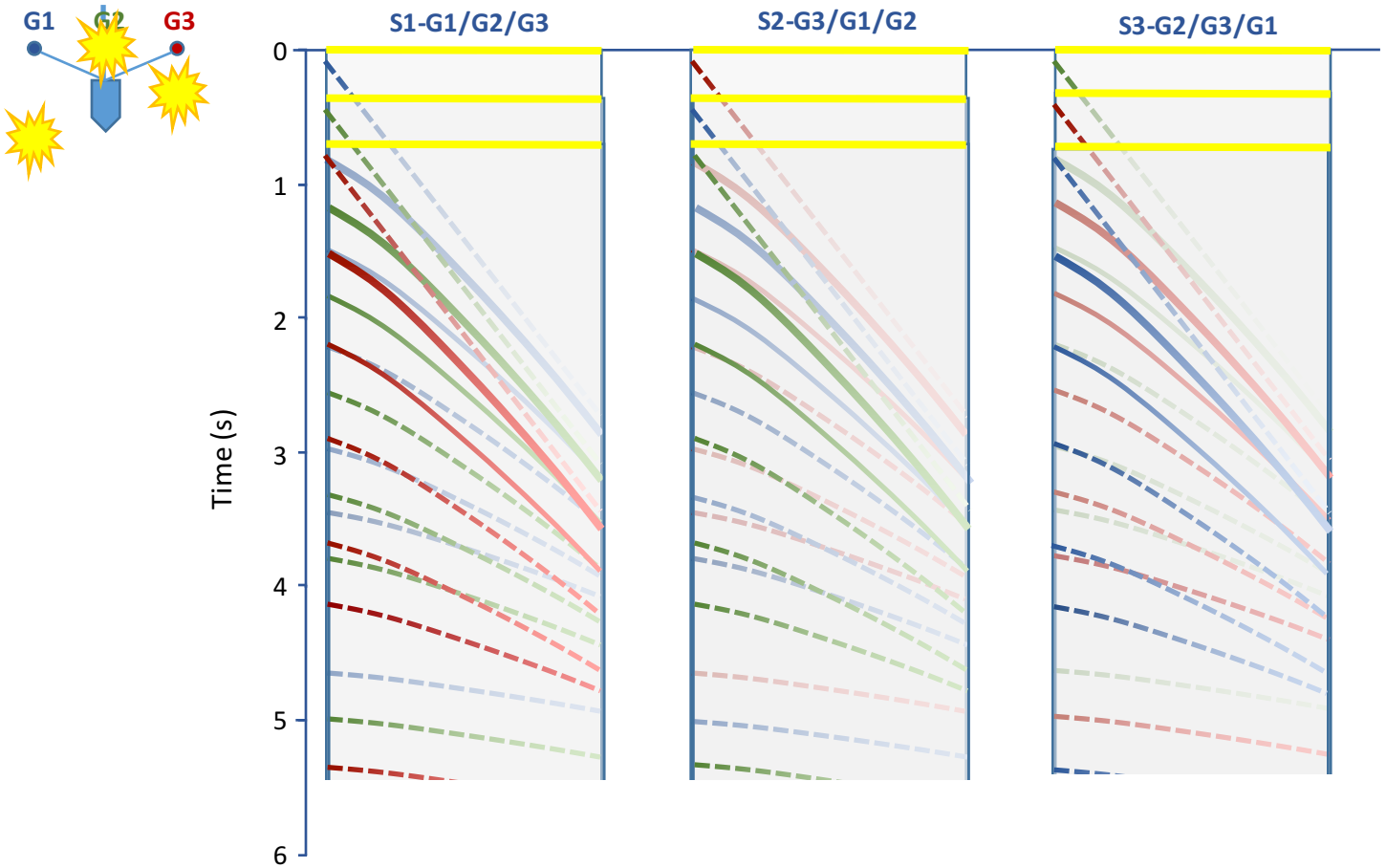
DITHERING 3-SOURCES RECORDING



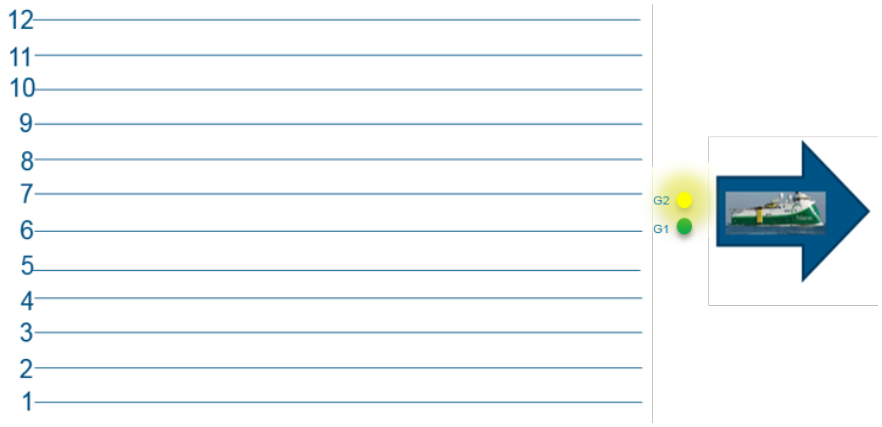
DITHERING 3-SOURCES RECORDING



DITHERING 3-SOURCES RECORDING



Acquisition parameters



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Triple-Source Simultaneous

- Streamers: 12 x 100 m x 6000 m
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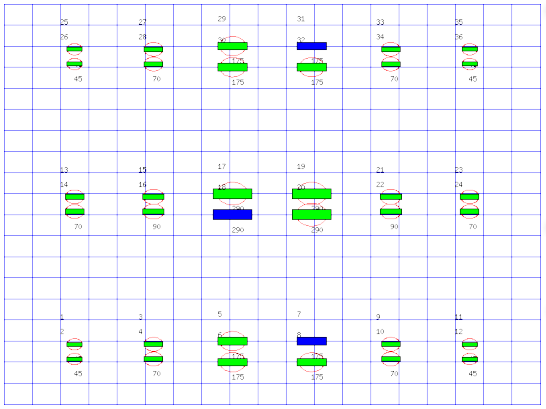
- Fold: 240

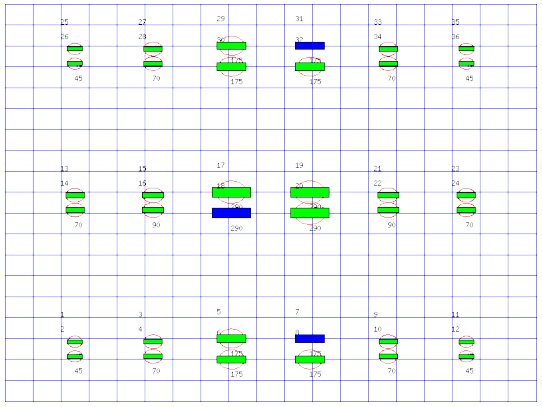
Re-configuration of sources

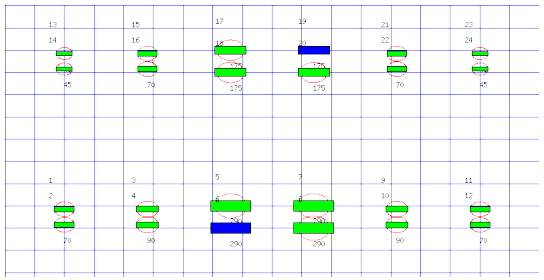
3480 cu.in.



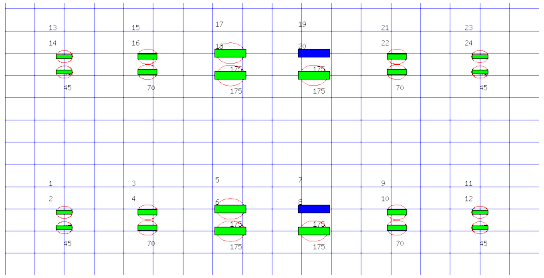
50 m

3480 cu.in.

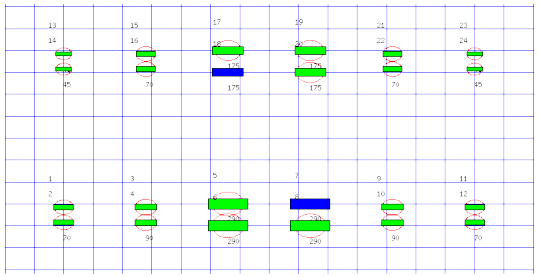




2495 cu.in.



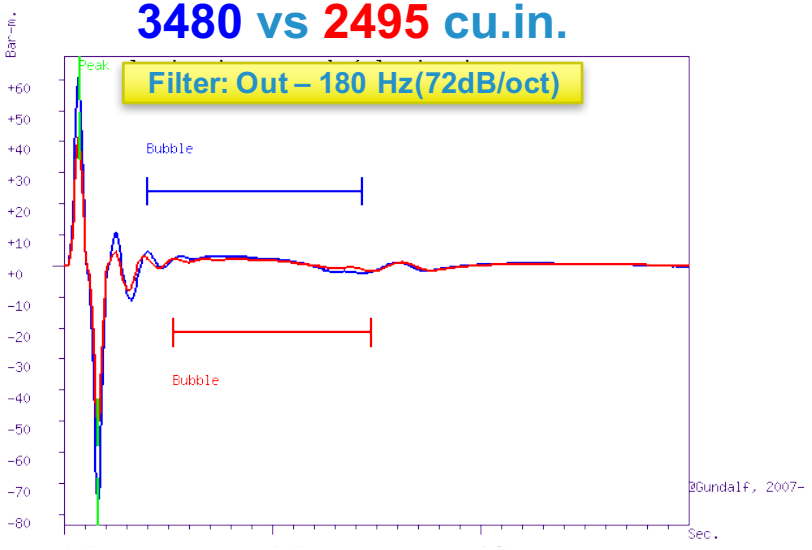
1970 cu.in.



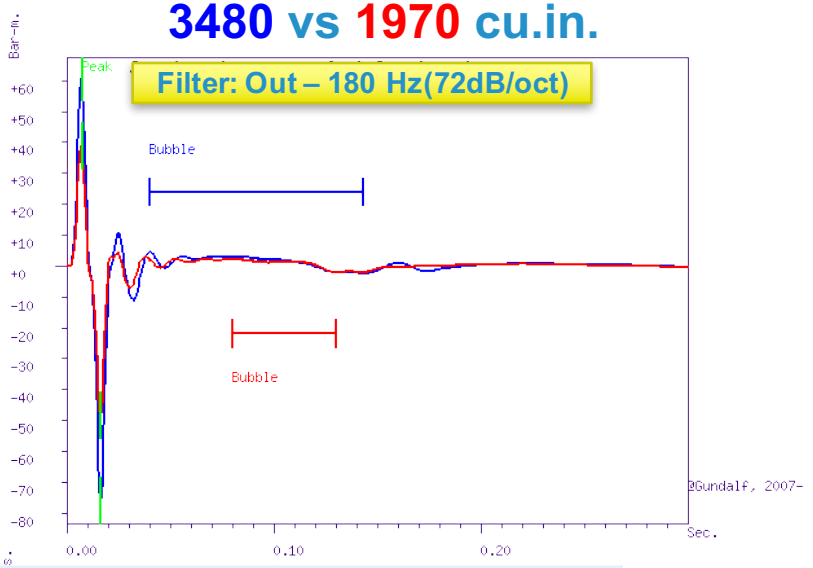
2495 cu.in.

Signatures and spectra

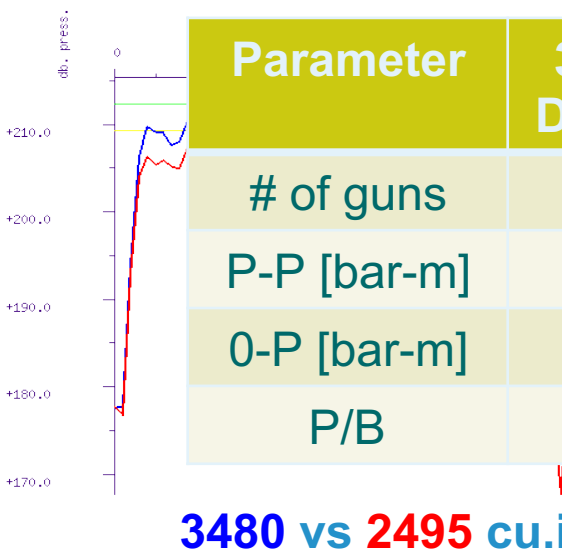
3480 vs 2495 cu.in.



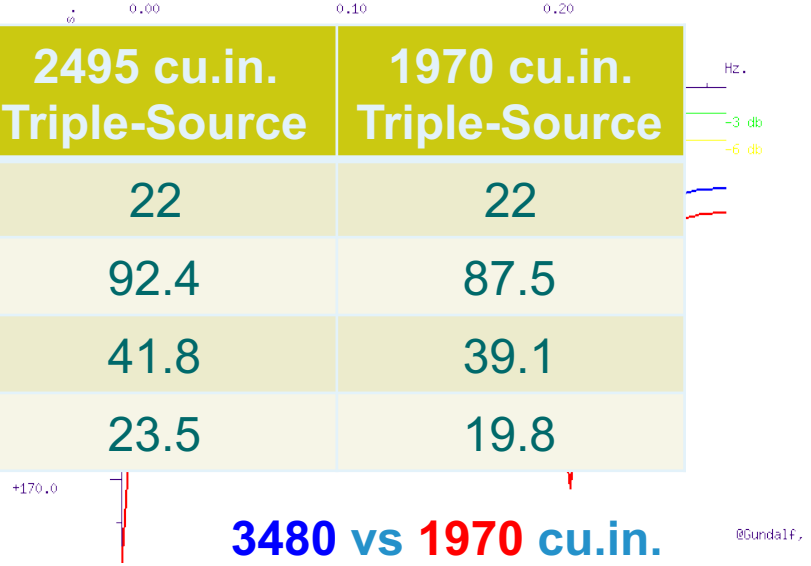
3480 vs 1970 cu.in.



Parameter	3480 cu.in. Dual-Source	2495 cu.in. Triple-Source	1970 cu.in. Triple-Source
# of guns	33	22	22
P-P [bar-m]	137.0	92.4	87.5
0-P [bar-m]	61.2	41.8	39.1
P/B	19.7	23.5	19.8

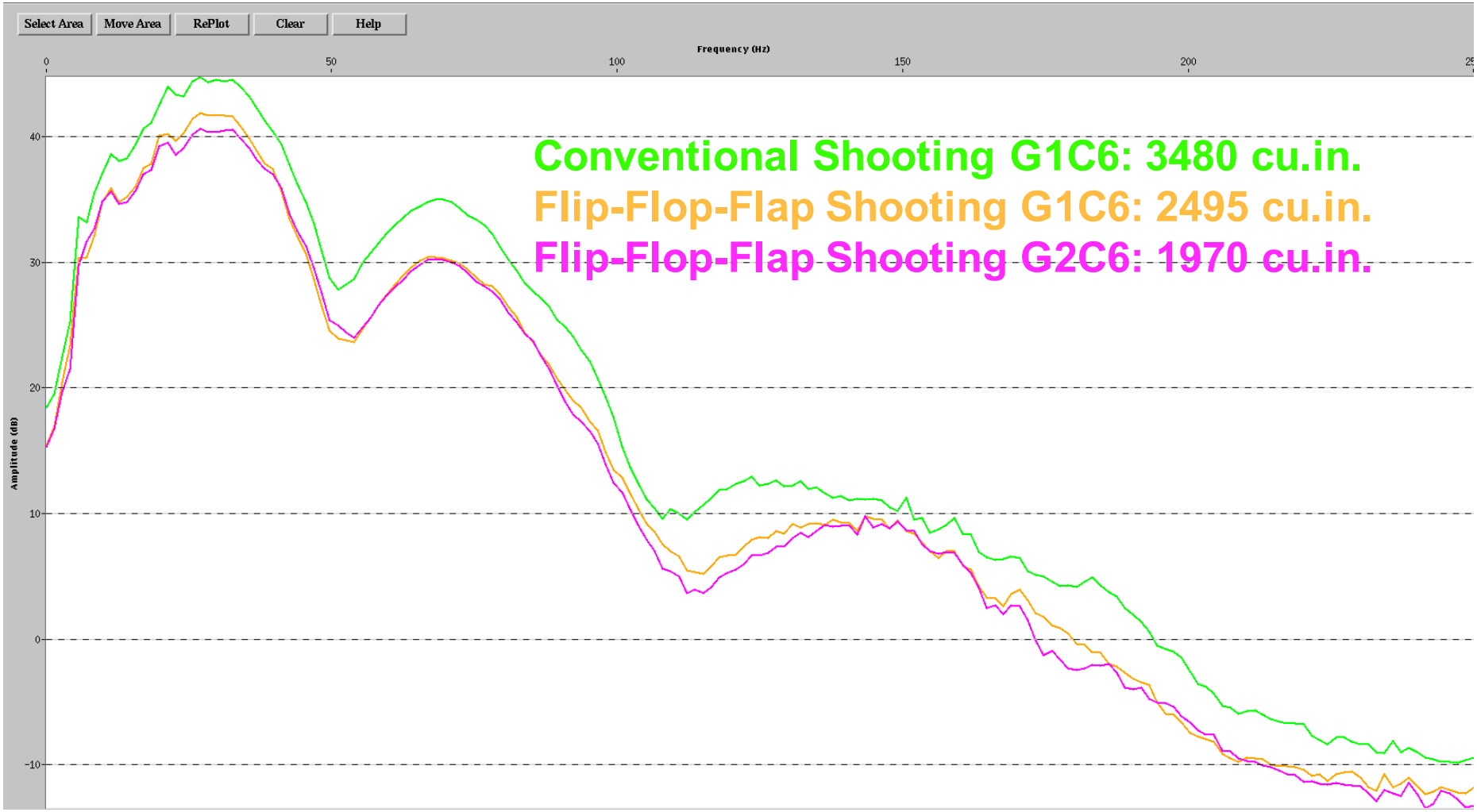


3480 vs 2495 cu.in.



3480 vs 1970 cu.in.

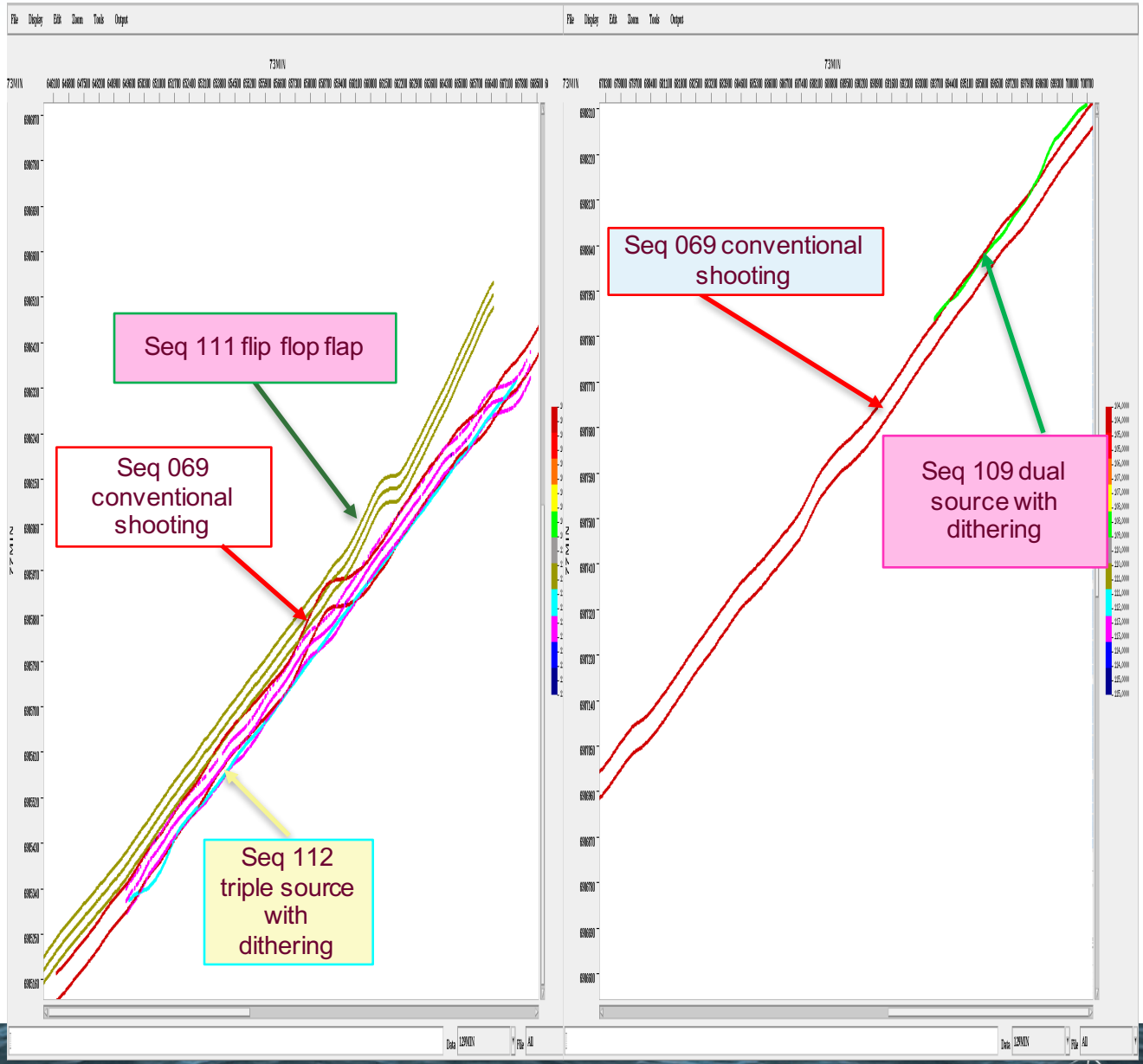
Power spectra



Test sequences

Test sequences

Sequence	Type	Sim Ops
69	Dual source, flip-flop	None
109	Dual source, flip+flop	Dithered
111	Triple source, flip-flop-flap	None
112	Triple source, flip+flop+flap	Dithered



Summary table

Seq.	Config.	Sim. Source	Mode	SP Int. [m]	Source size [cu.in.]	Fold
069	Dual	No	Flip-Flop	18.75	3480	80
109	Dual	Yes (Dither +/-300 ms)	Flip+Flop	12.50	3480	240
111	Triple	No	Flip-Flop-Flap	12.50	2495 & 1970	80
112	Triple	Yes (Dither +/-300 ms)	Flip+Flop+Flap	12.50	2495 & 1970	240

Deblending: Enhanced Adaptive Subtraction method (EAS)

Liu, Z., Wang, B., Specht, J., Sposato, J. and Zhai Y. [2014] Enhanced adaptive subtraction method for simultaneous source separation, 84th Annual International Meeting, SEG Expanded Abstracts, 115-119

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Liu, Z., Wang, B., Langhammer, J., Specht, J., Egger, C. and Zhai Y. [2015] A Case Study of Simultaneous Data Separation with Enhanced Adaptive Subtraction Method: Offshore West of Shetland Island, 77th EAGE Conference & Exhibition.

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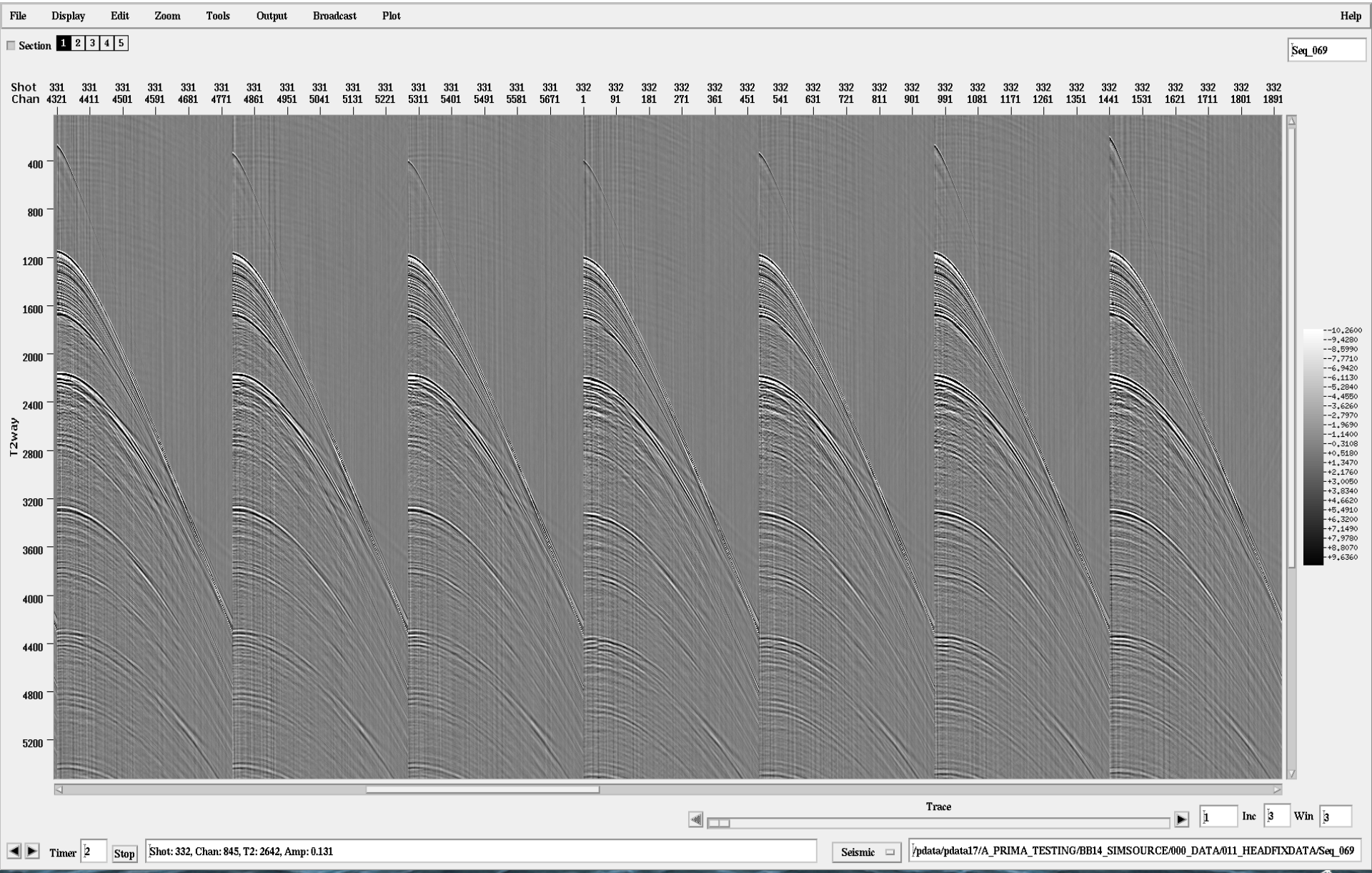
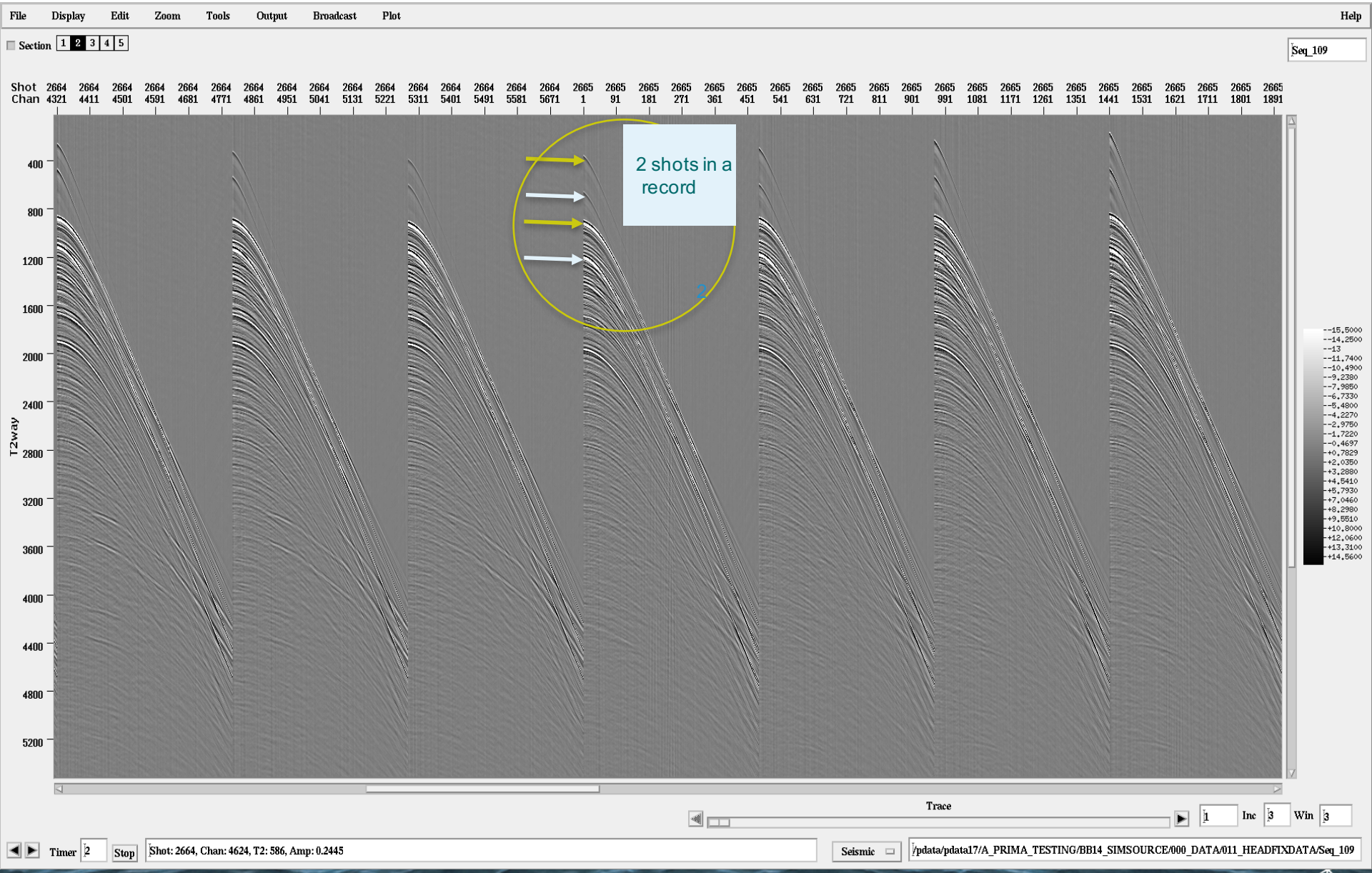
Data examples and results

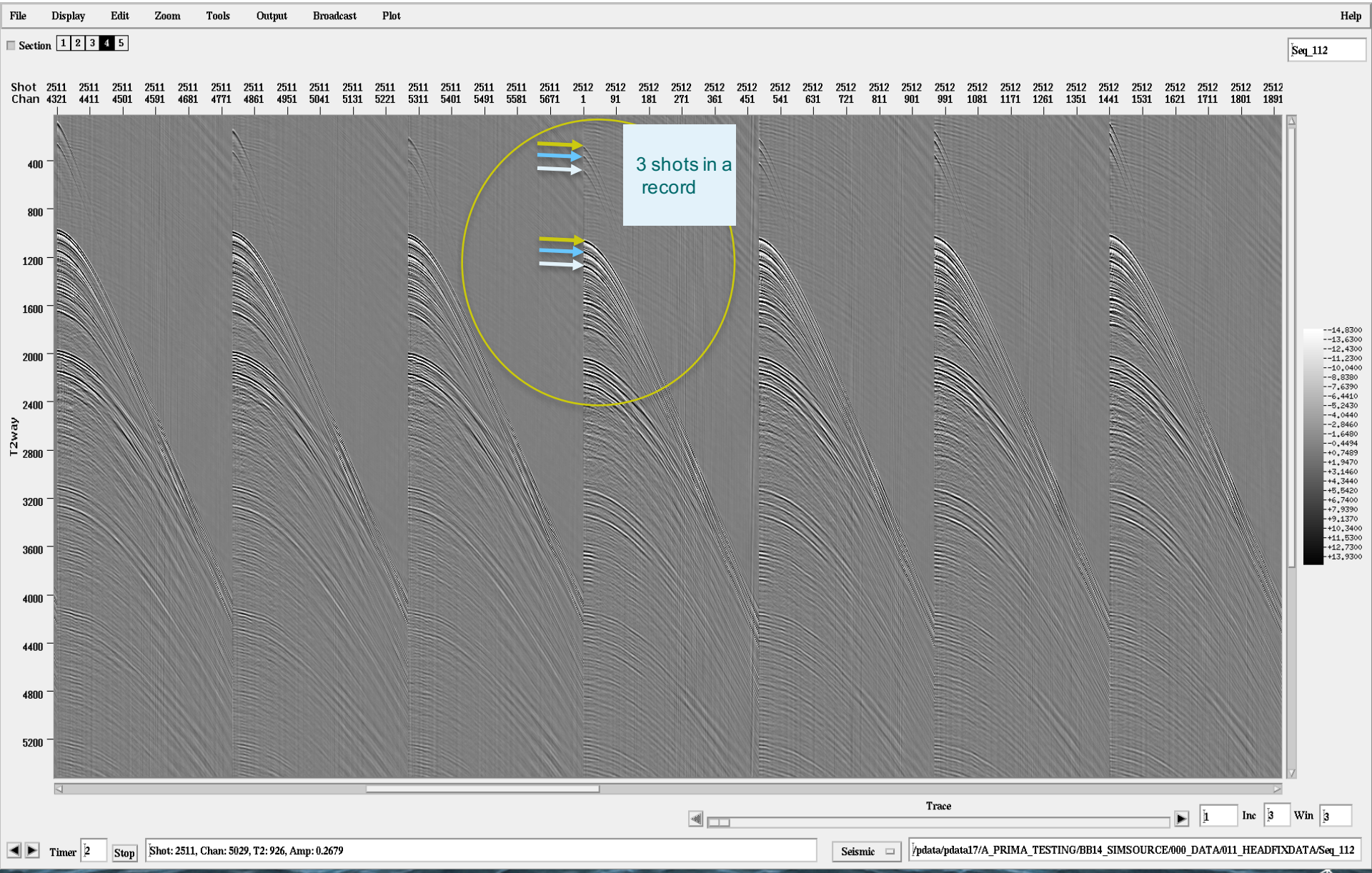
Seq. 069 Example of shots conventional shooting (flip-flop)



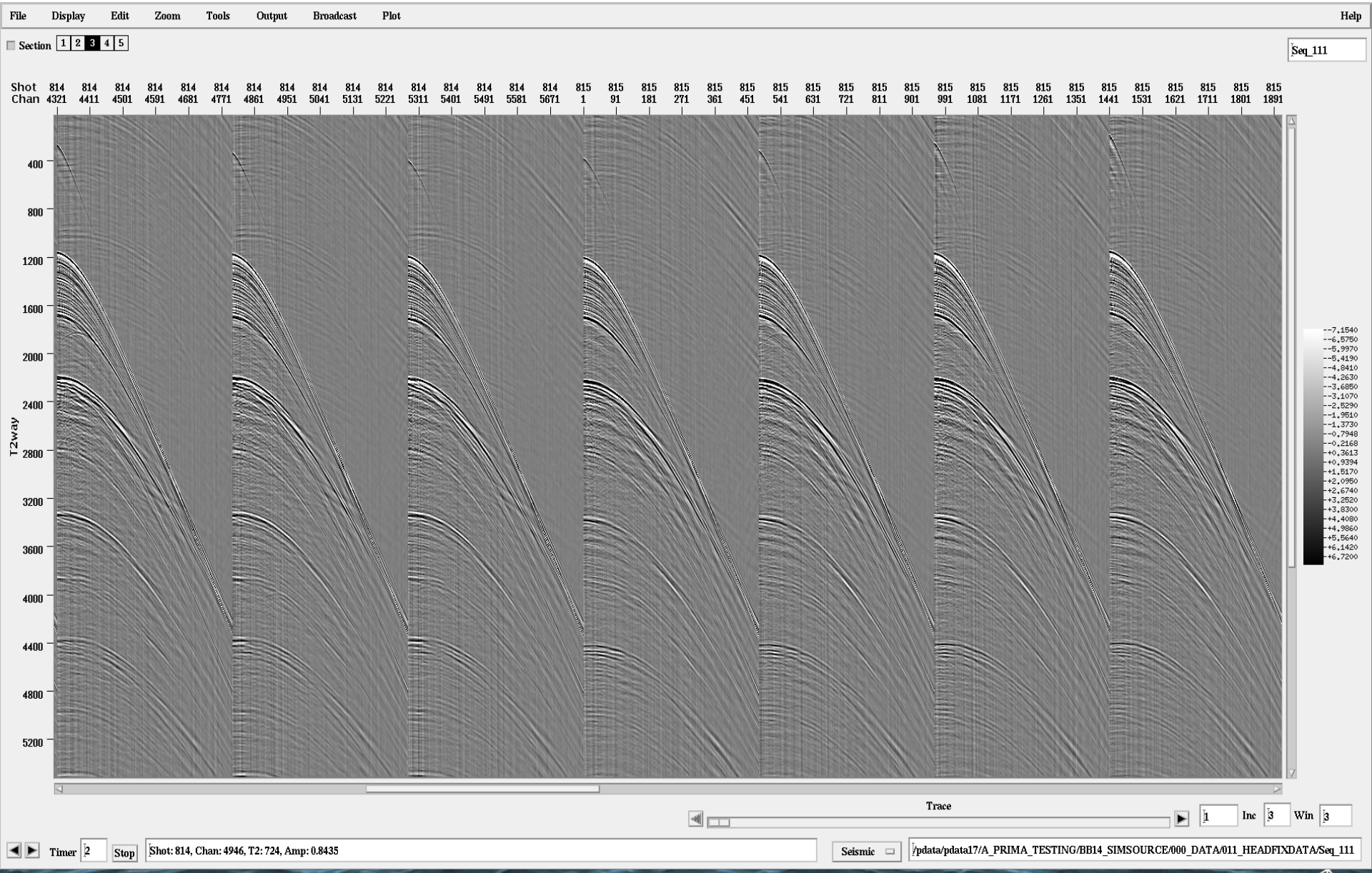
Seq. 109: Example of shots dual-source with dithered time (+/- 300 ms)



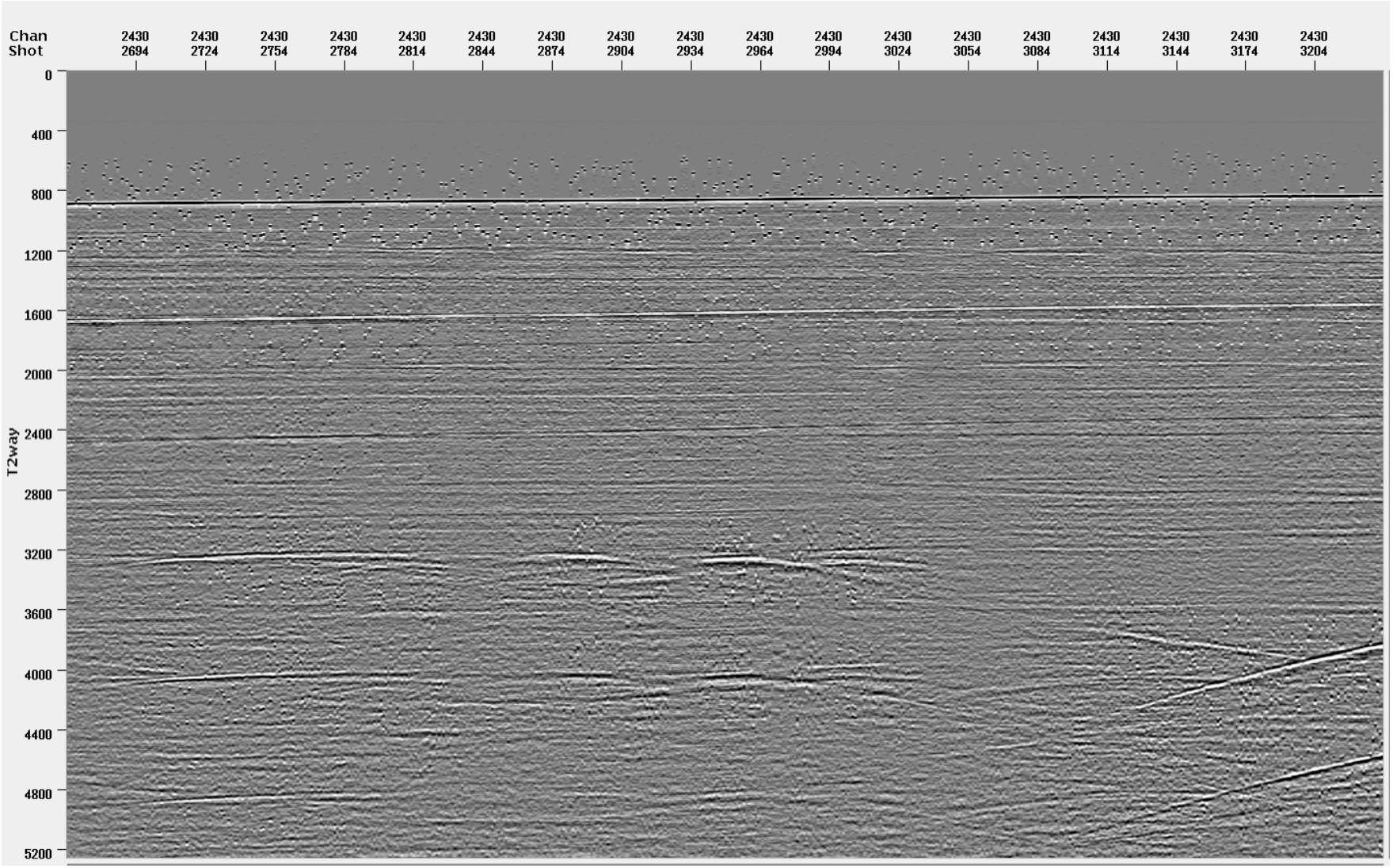
Seq. 112: Example of shots triple-source with time dithered (+/-300 ms)



Seq. 111: Example shots of triple-source flip-flop-flap



Seq, 109: Common offset gather dual-source sim.



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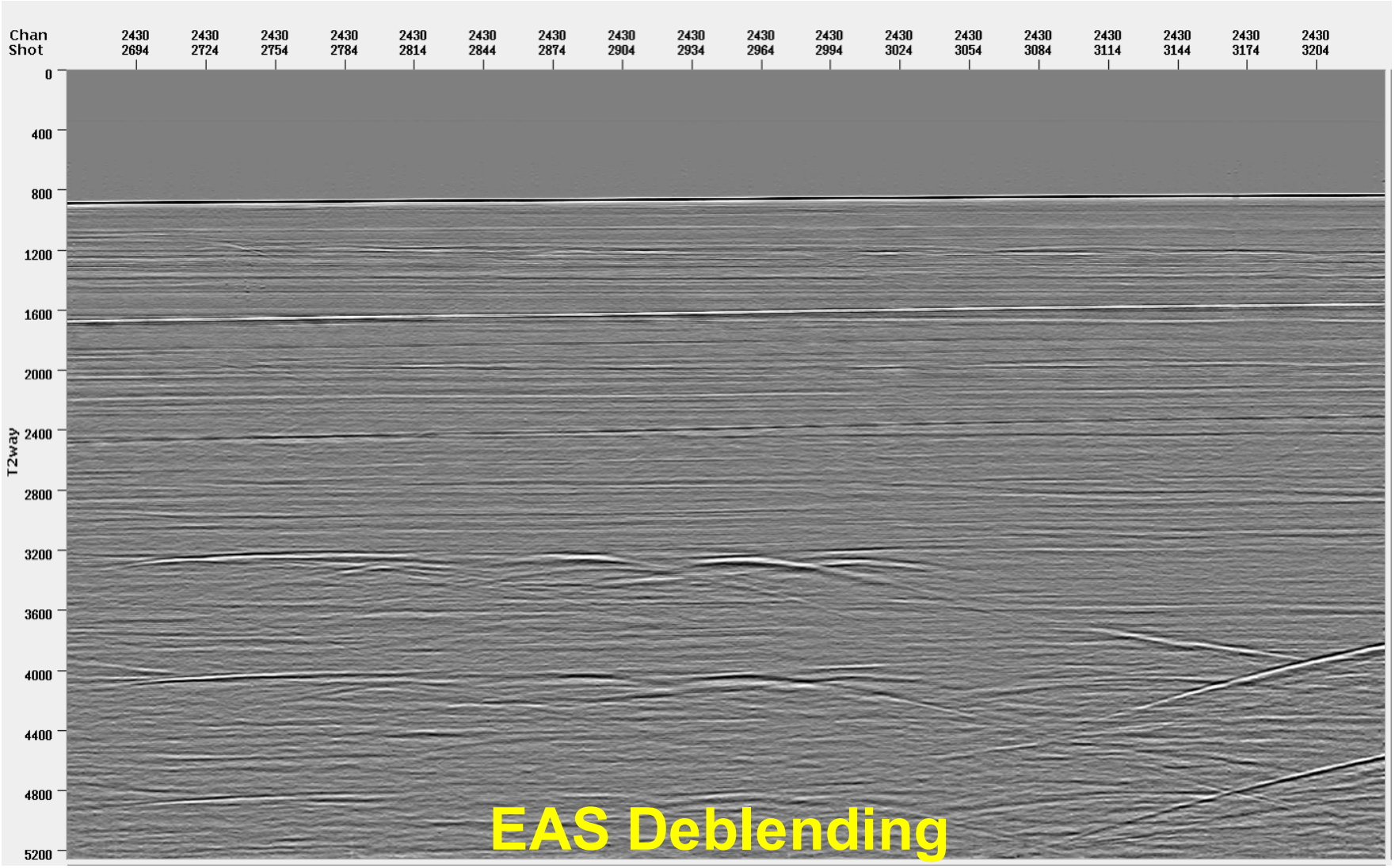

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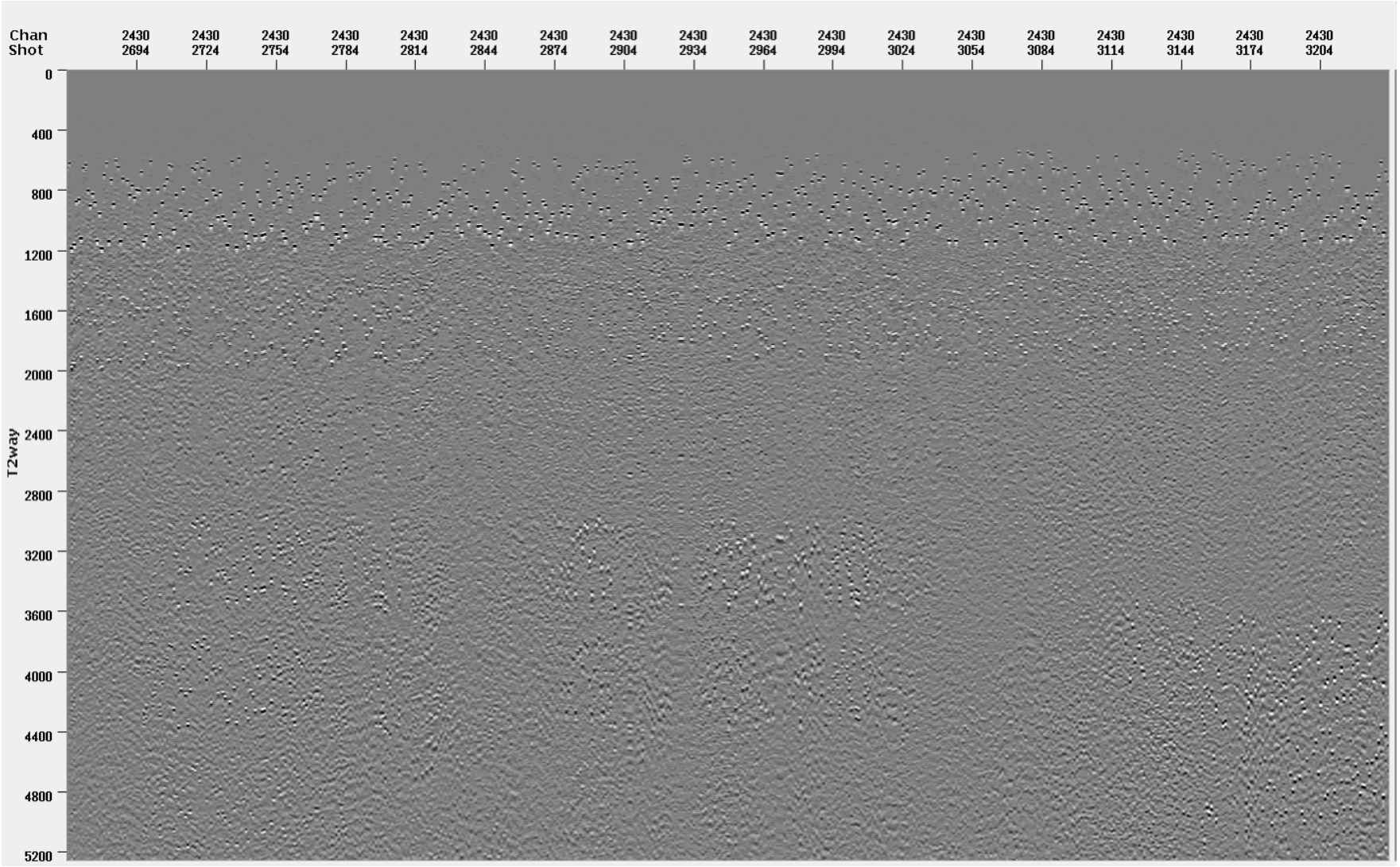
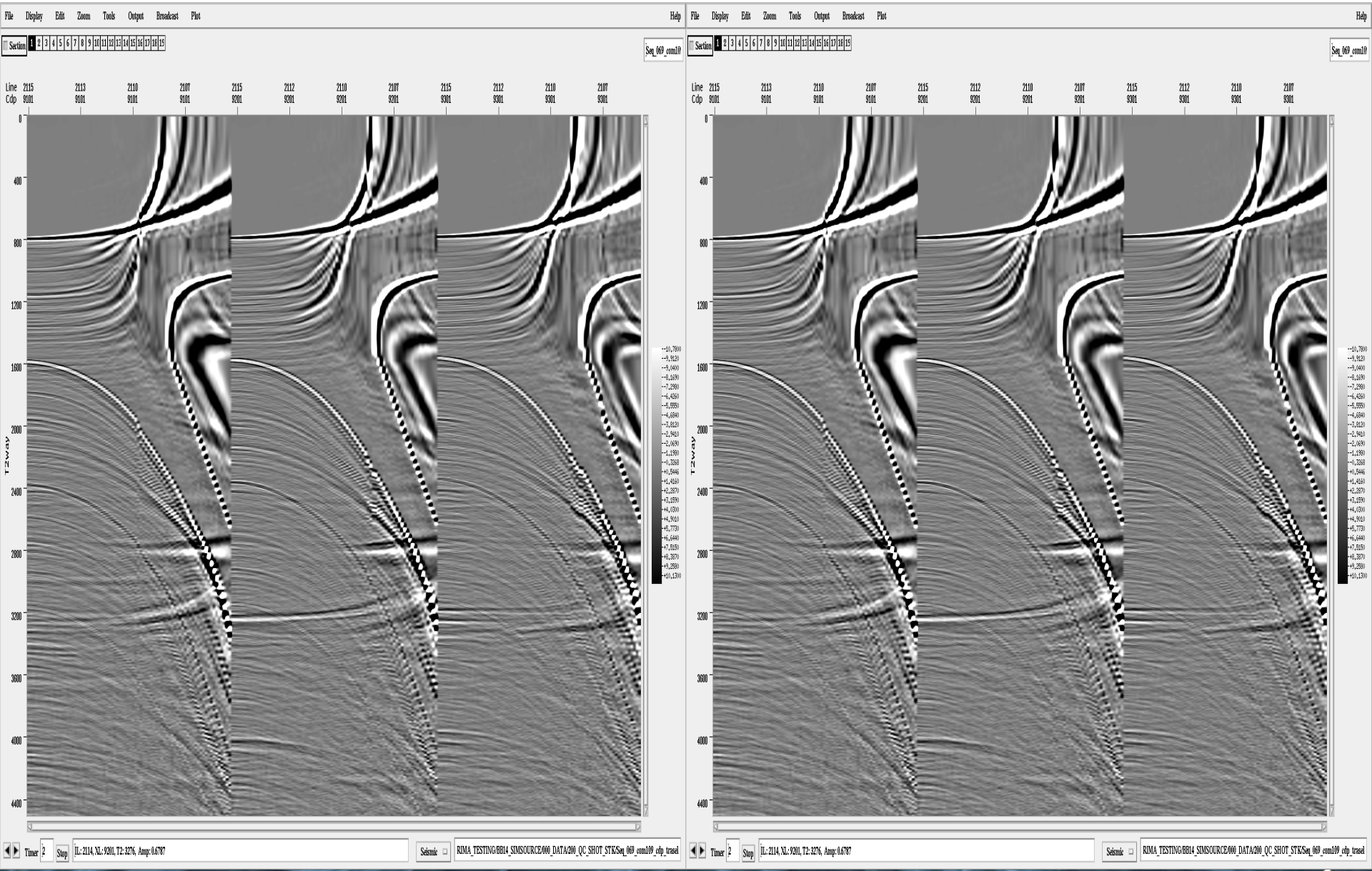
Seq. 109: Difference



Seq. 069: CDP's NMO corrected dual-source sequential



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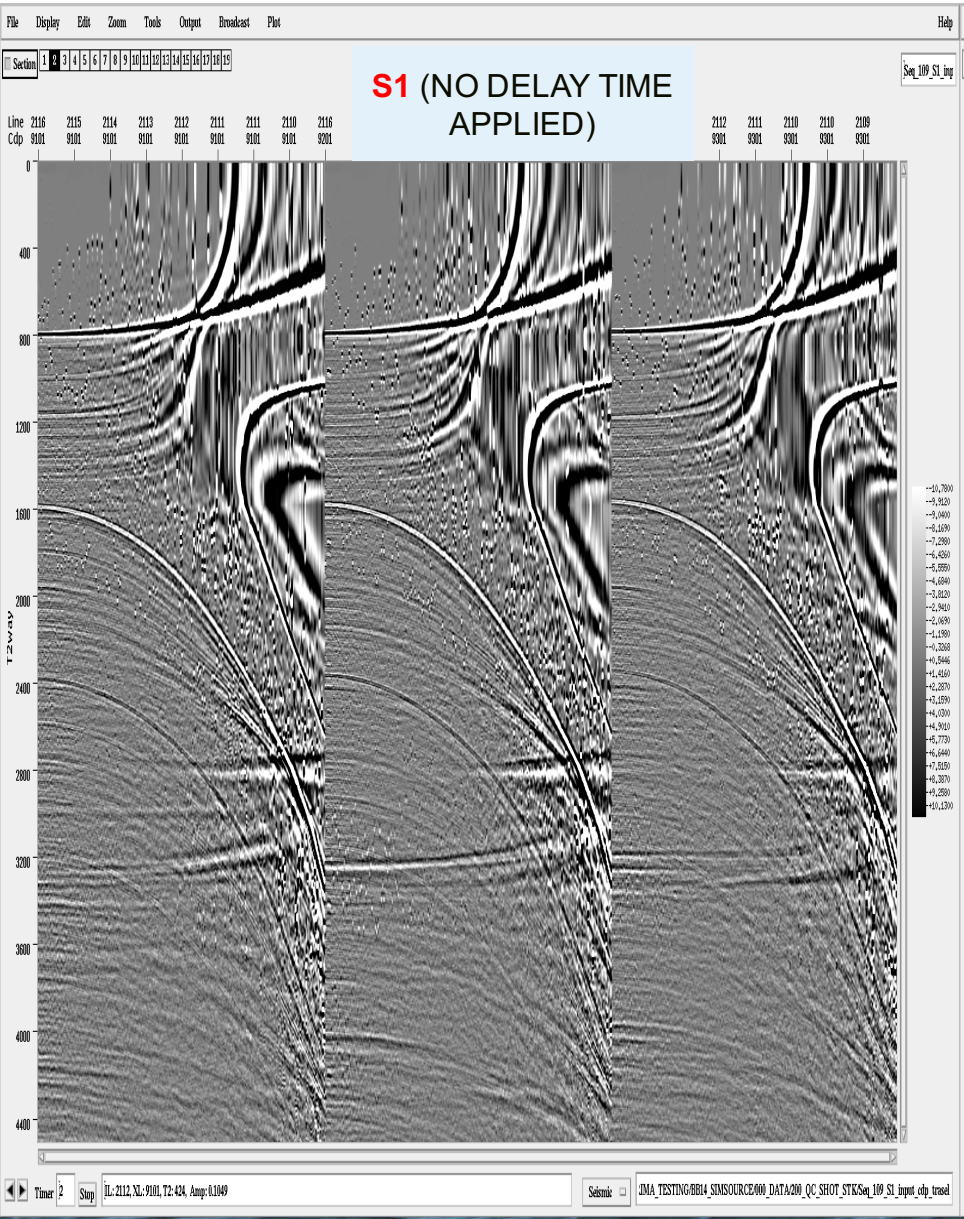
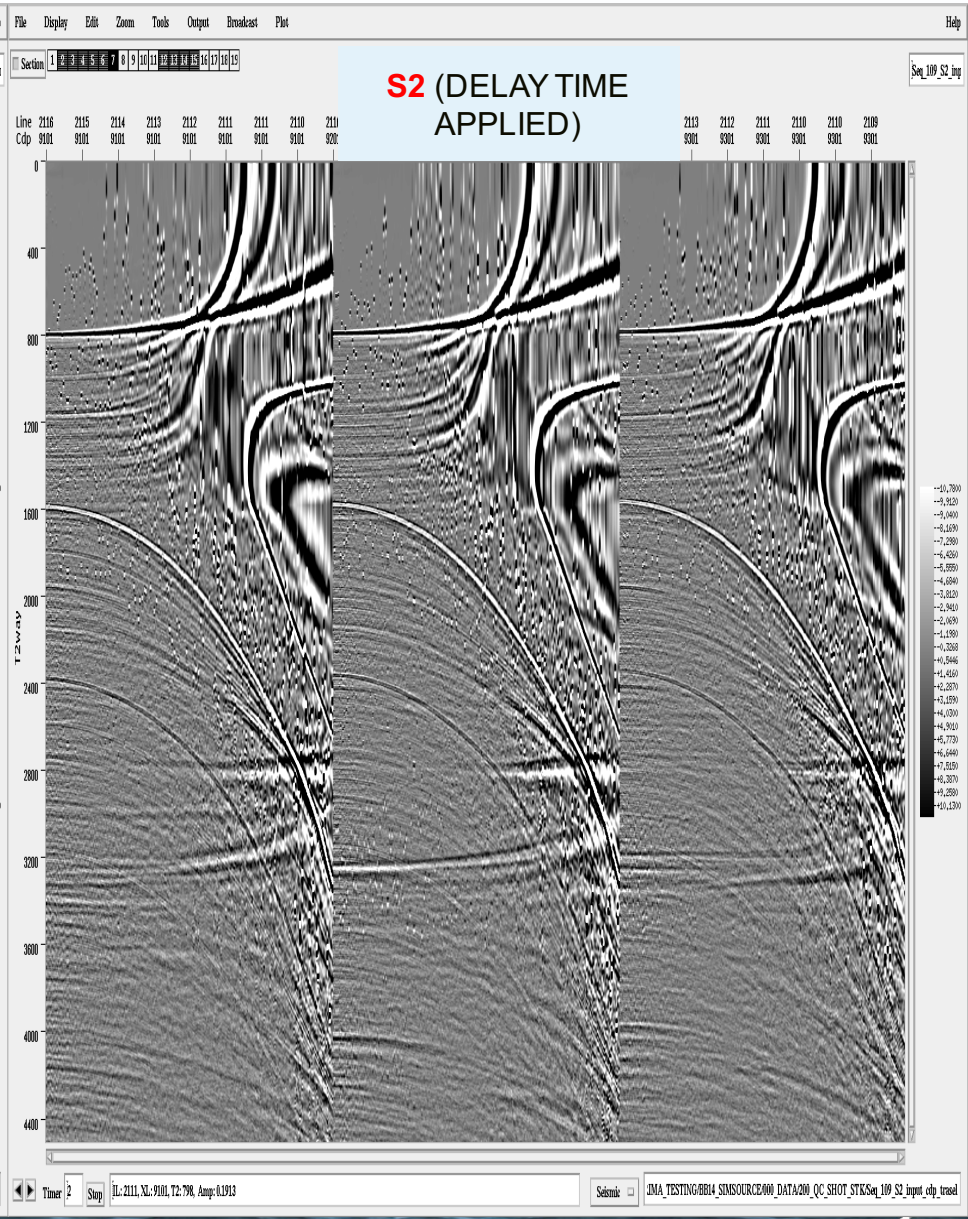
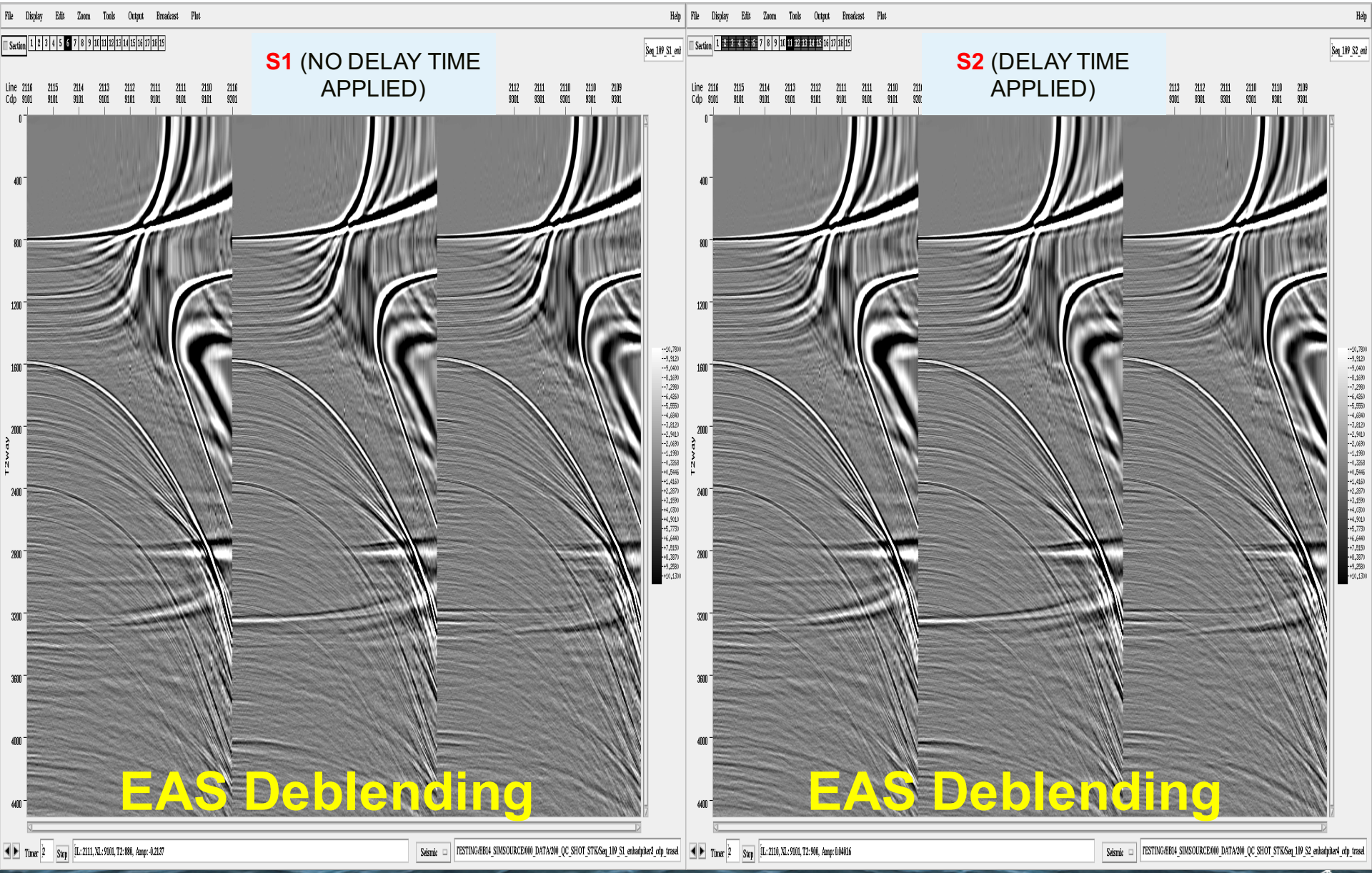
Seq. 109: CDP's NMO corrected dual-source simultaneous

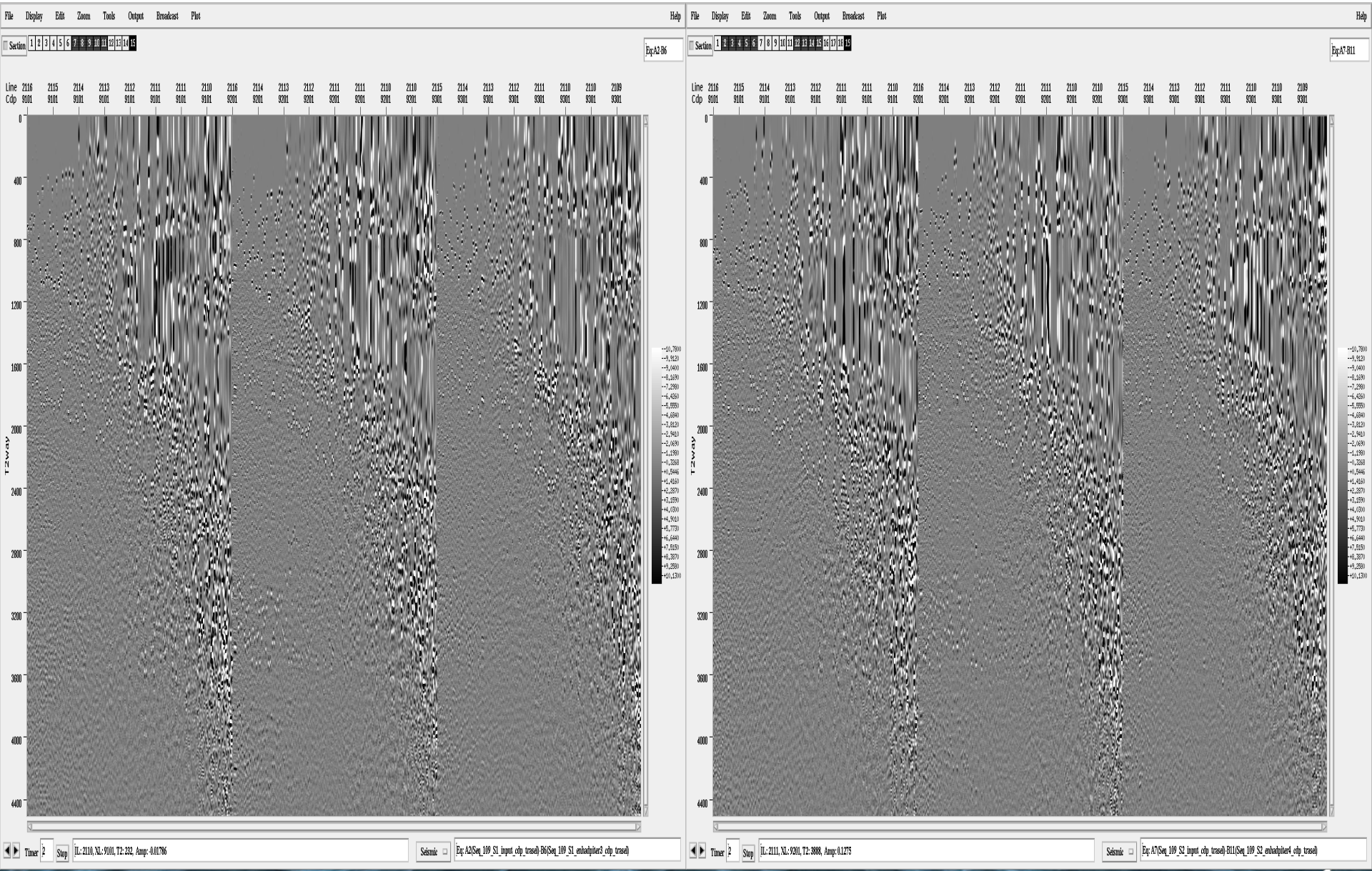




Seq. 109: CDP's NMO corrected dual-source simultaneous



Seq. 109: Difference between input and deblended data



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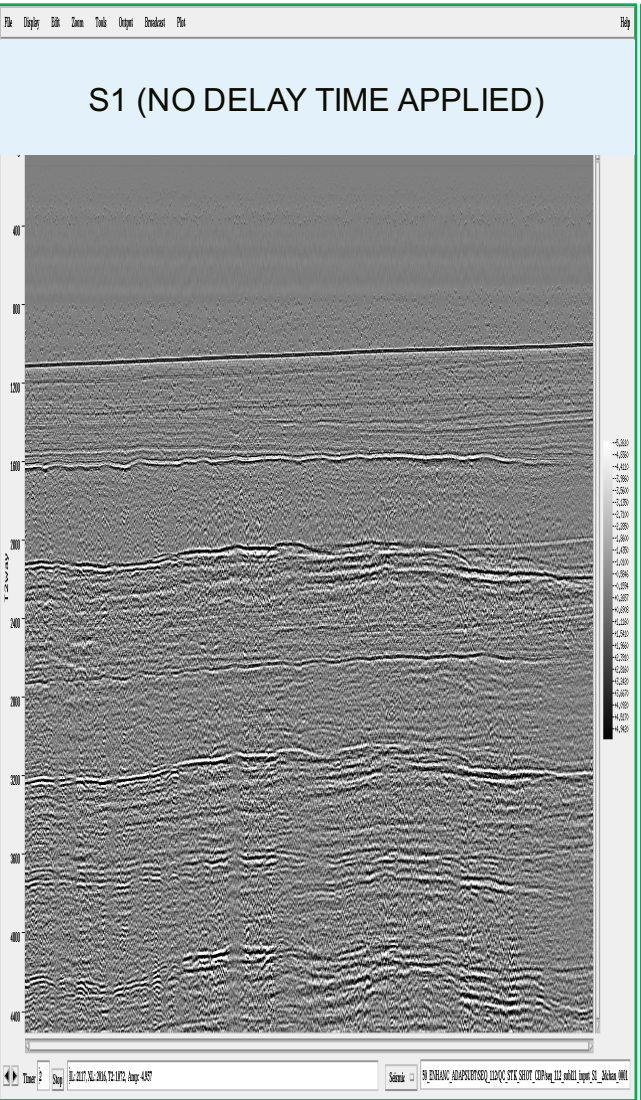
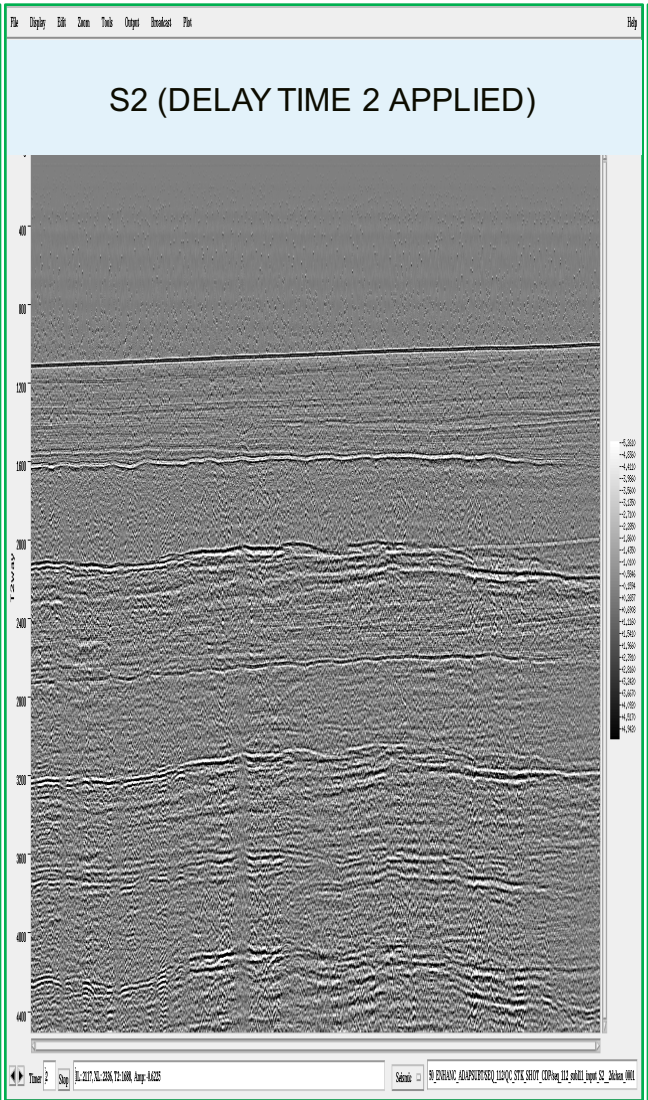
Seq. 112: Near channel input data (Sim. triple)

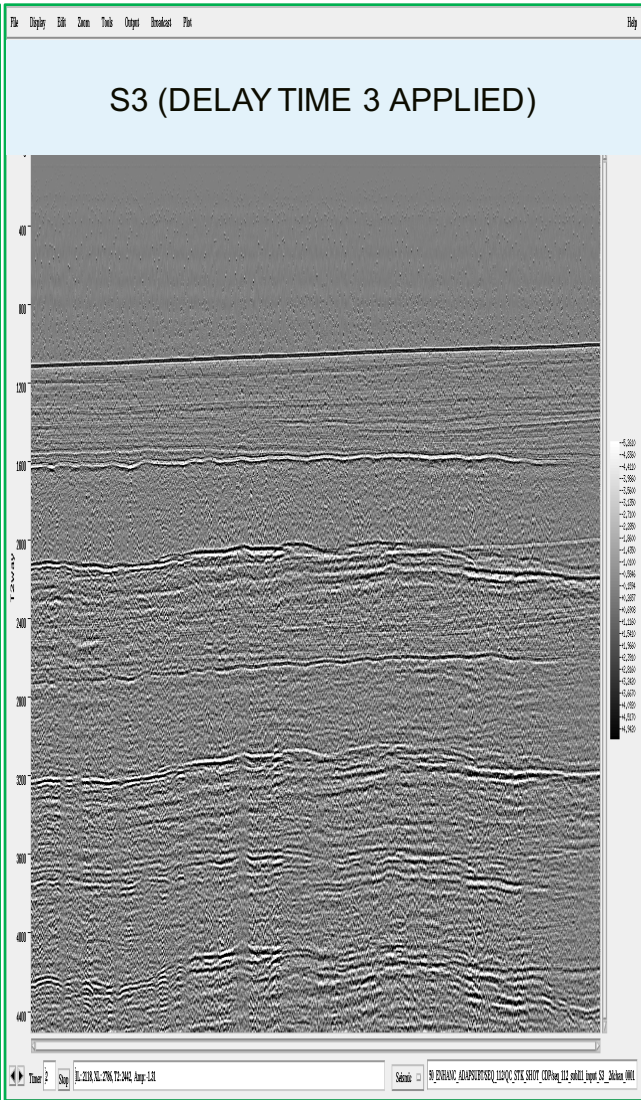
S1 (NO DELAY TIME APPLIED)



S2 (DELAY TIME 2 APPLIED)

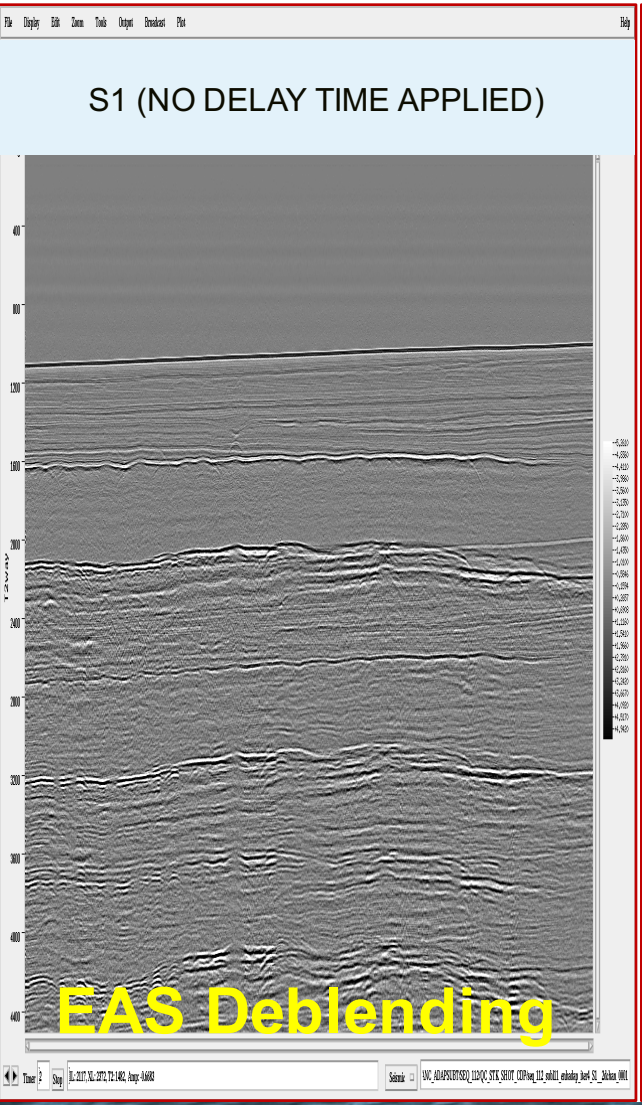


S3 (DELAY TIME 3 APPLIED)

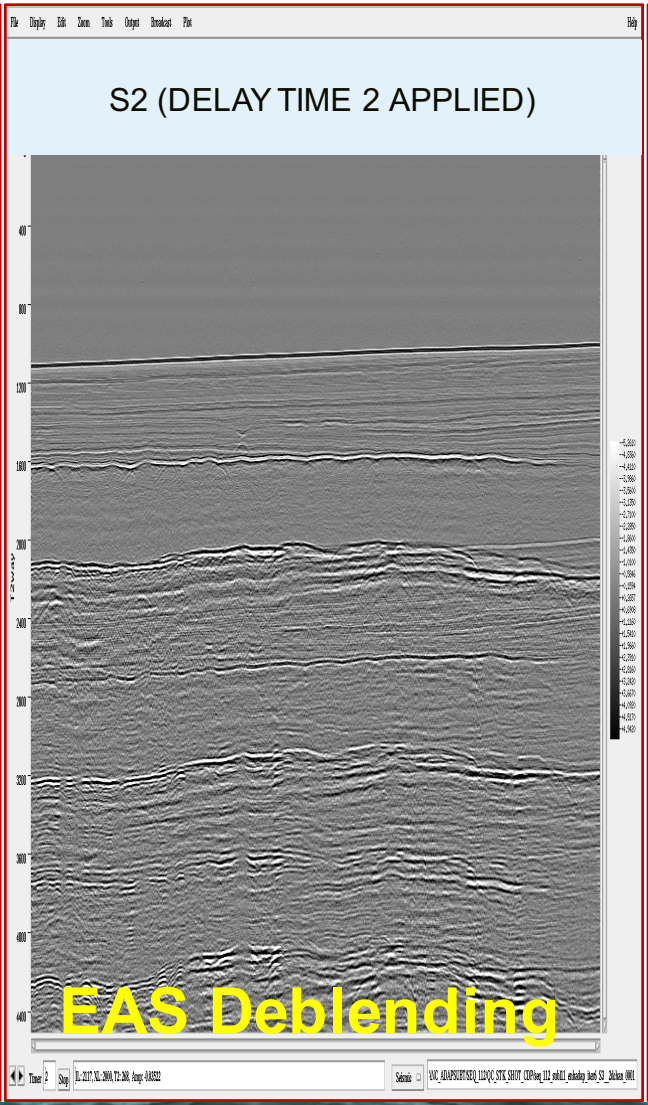


Seq. 112: Near channel deblended (Sim. triple)

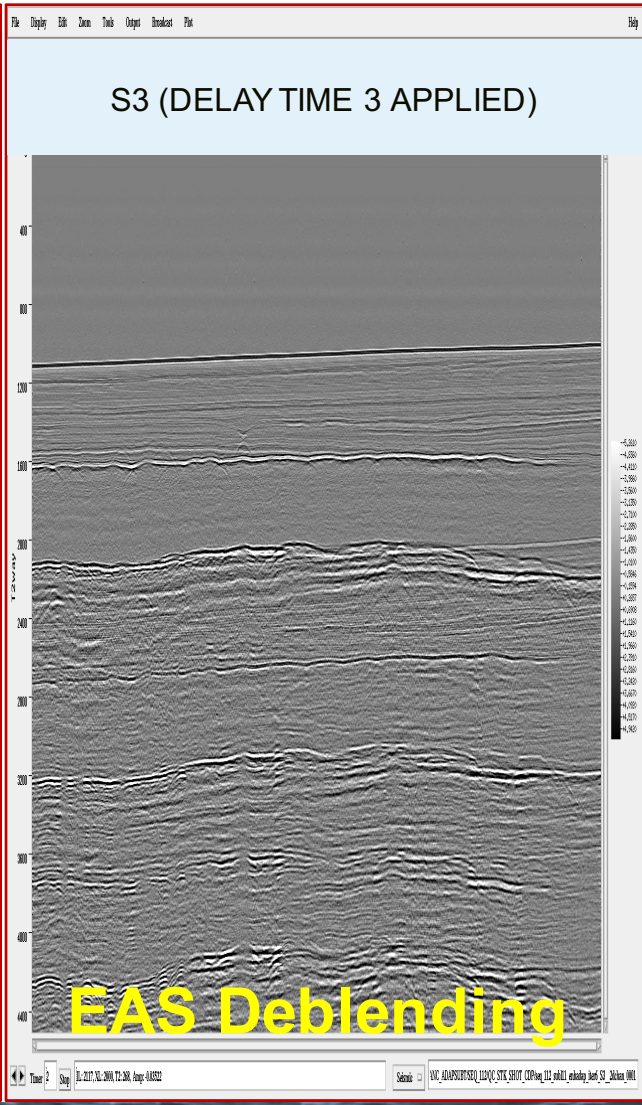
S1 (NO DELAY TIME APPLIED)



S2 (DELAY TIME 2 APPLIED)

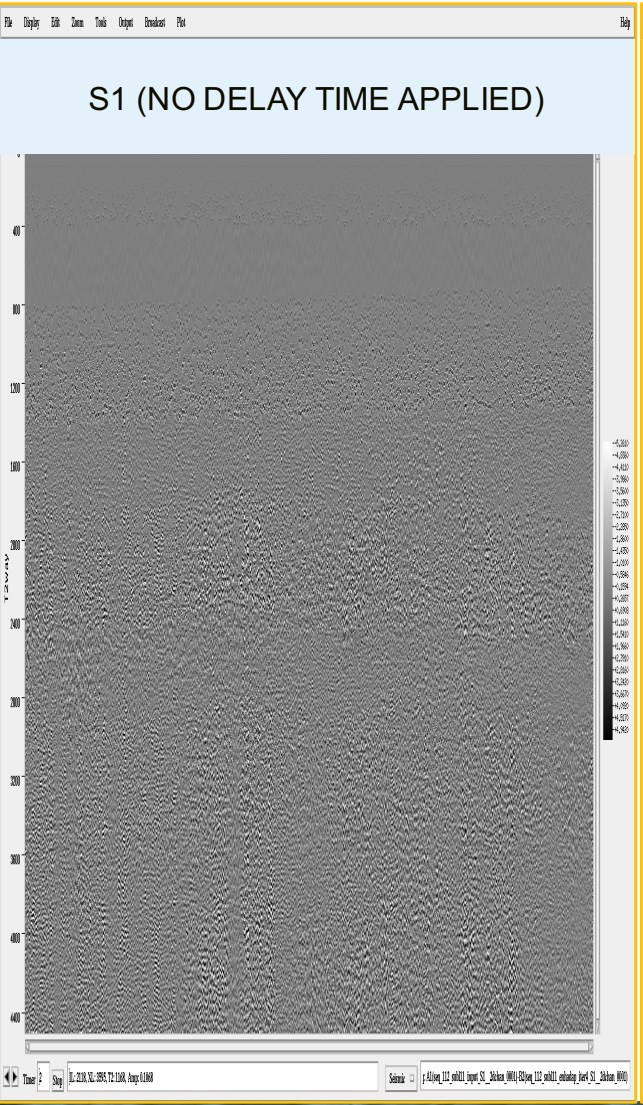


S3 (DELAY TIME 3 APPLIED)

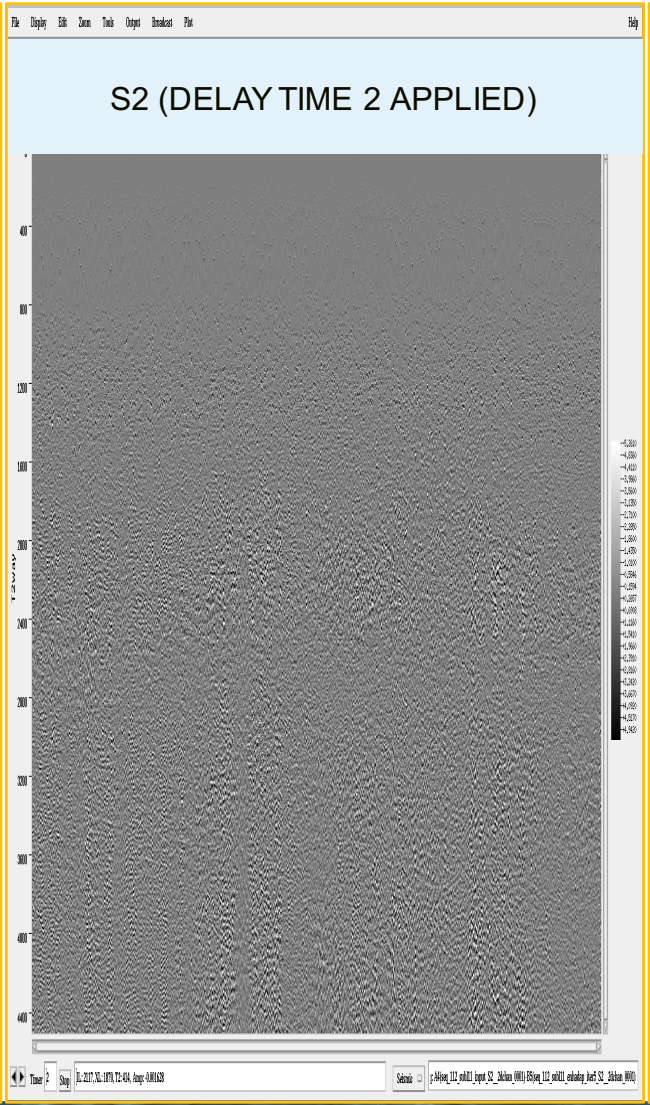


Seq. 112: Difference (Sim. triple)

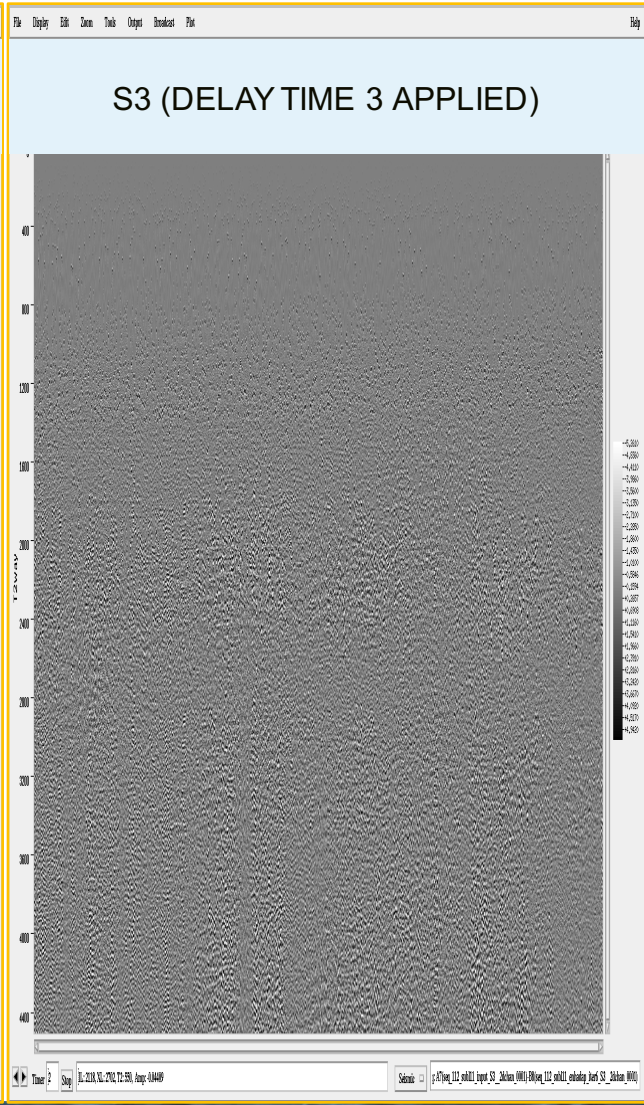
S1 (NO DELAY TIME APPLIED)



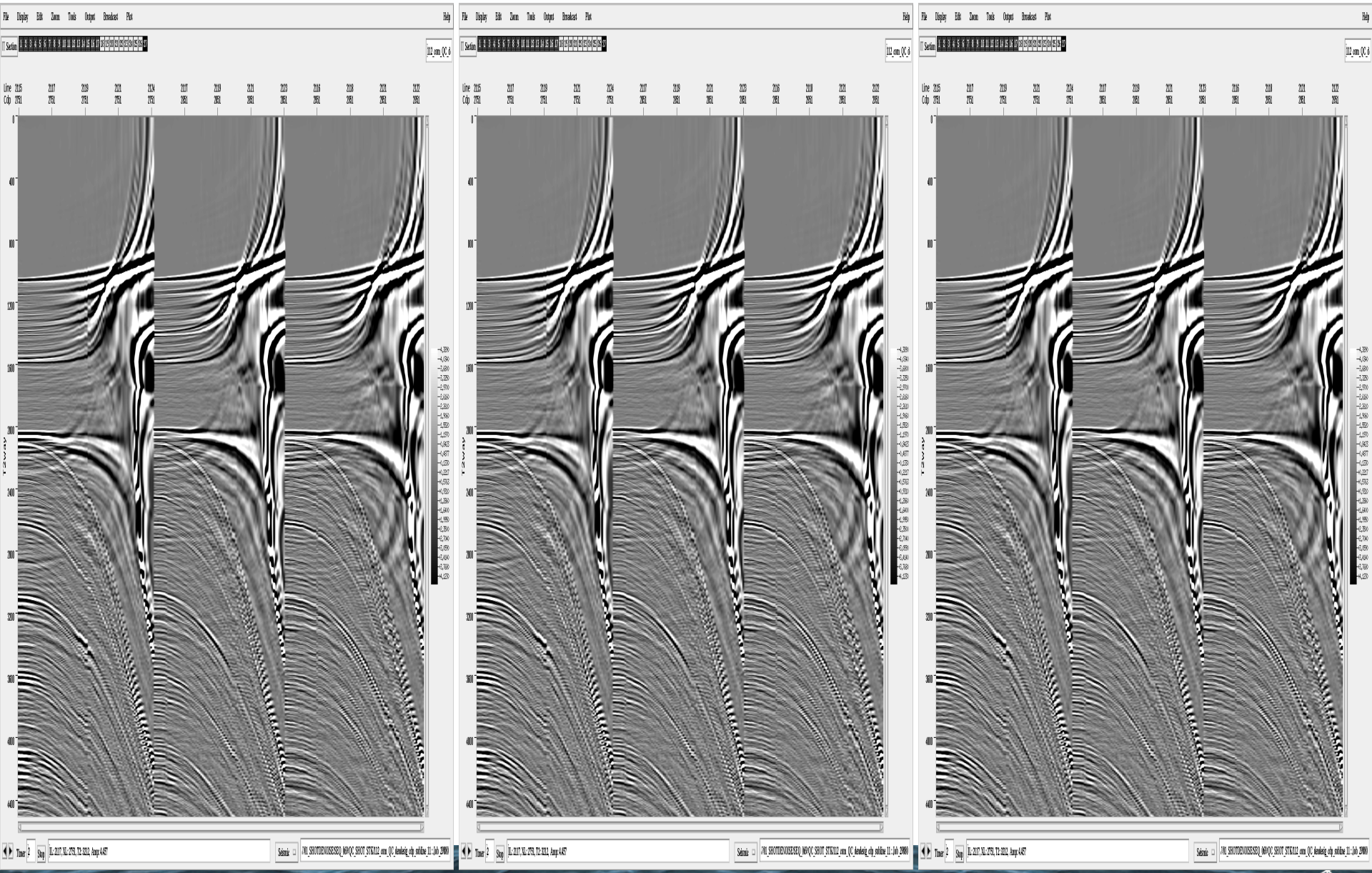
S2 (DELAY TIME 2 APPLIED)



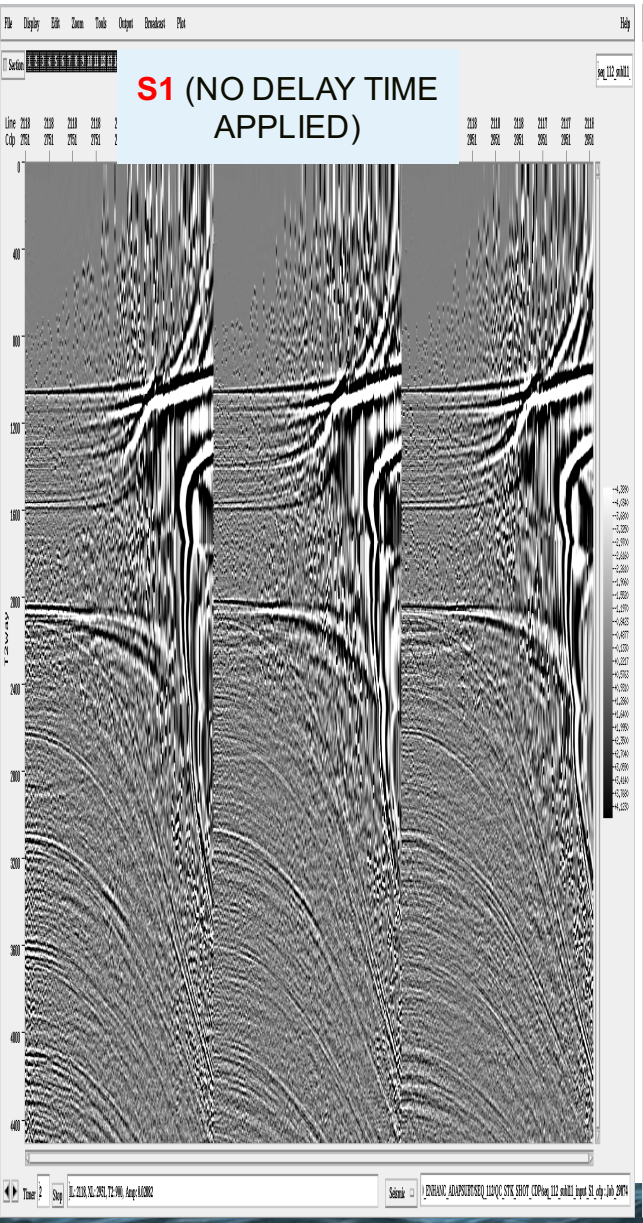
S3 (DELAY TIME 3 APPLIED)

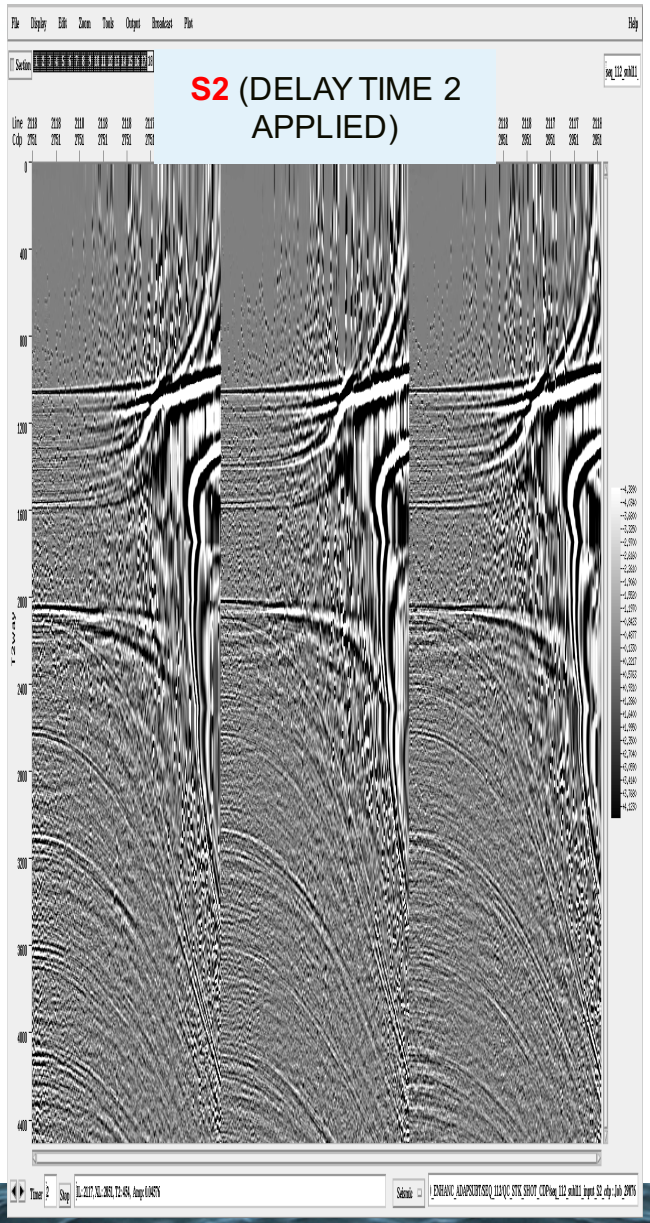


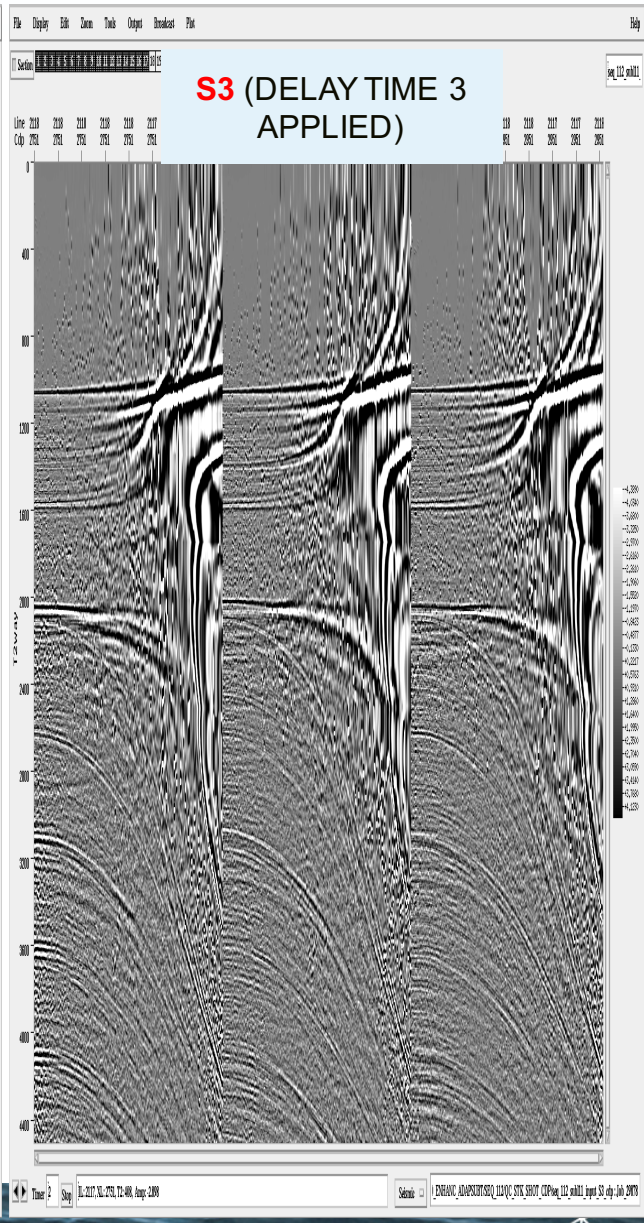
Seq 069: CDP's NMO corrected dual-source sequential



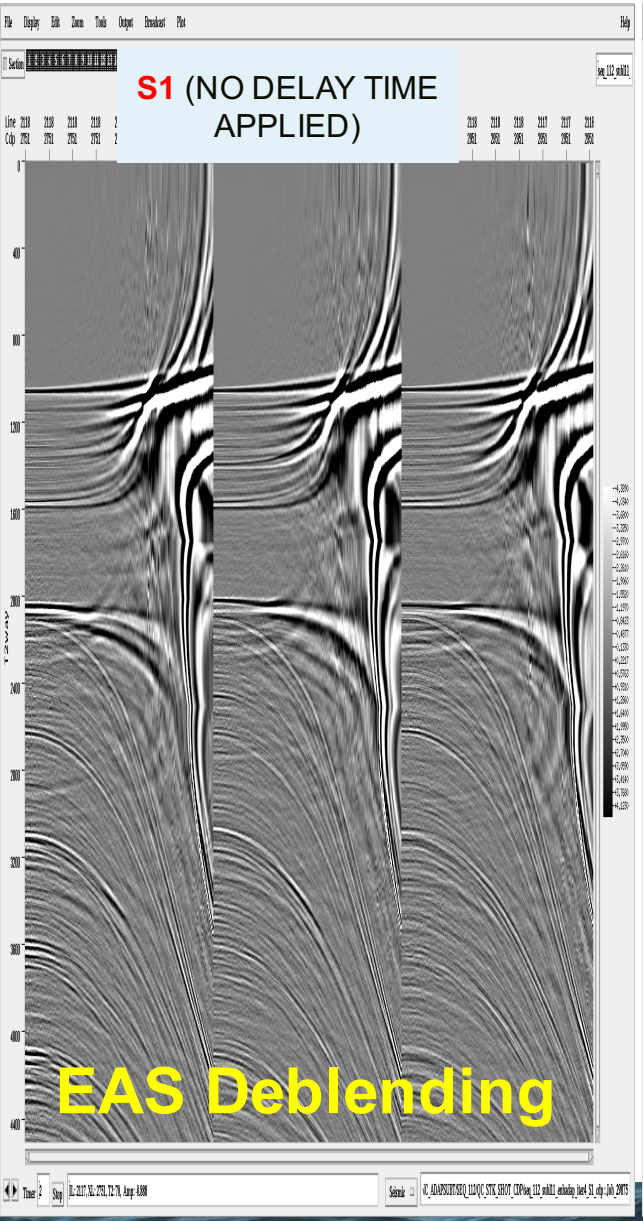
Seq 112: CDP's NMO corrected triple-source simultaneous

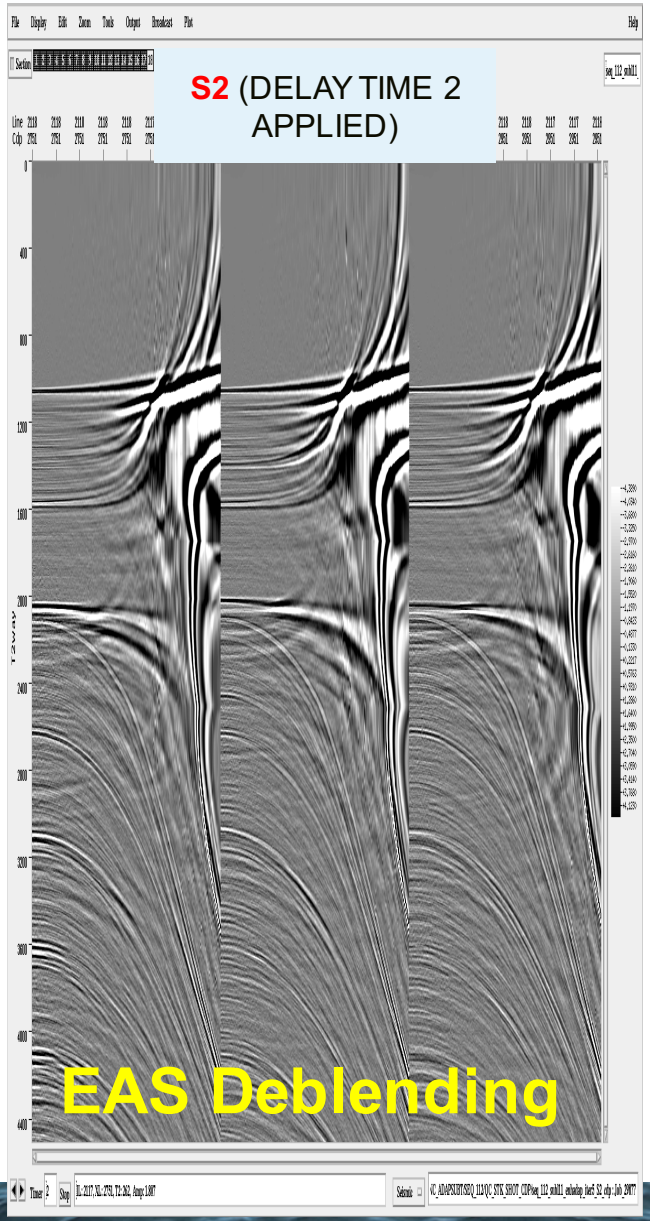


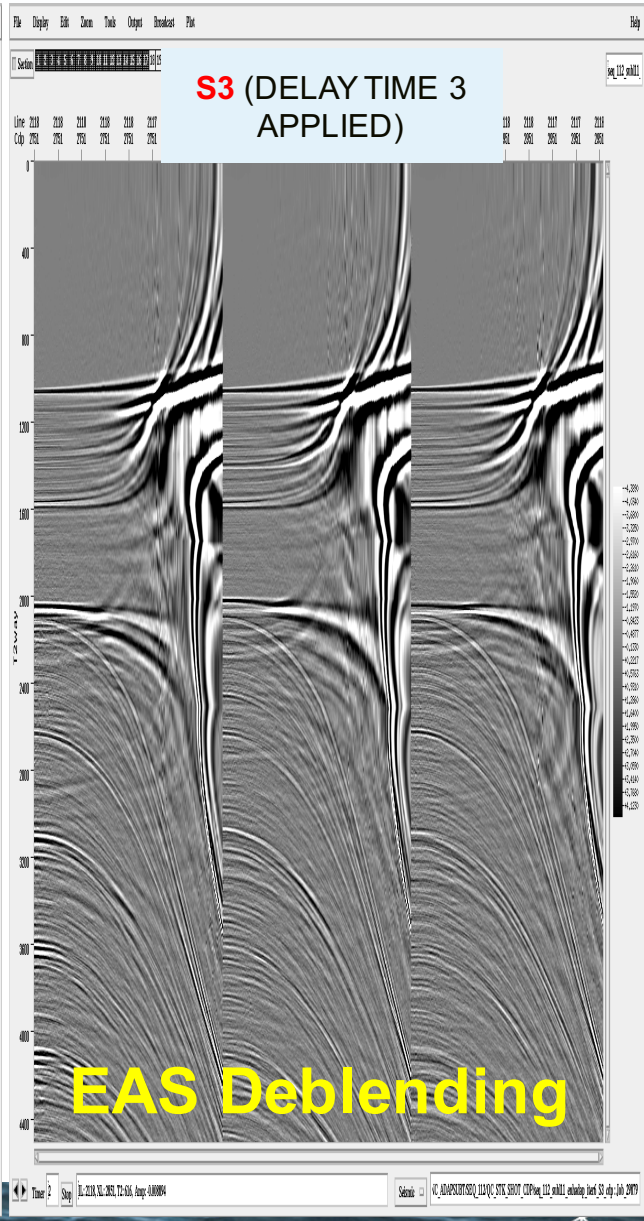




Seq 112: CDP's NMO corrected triple-source simultaneous





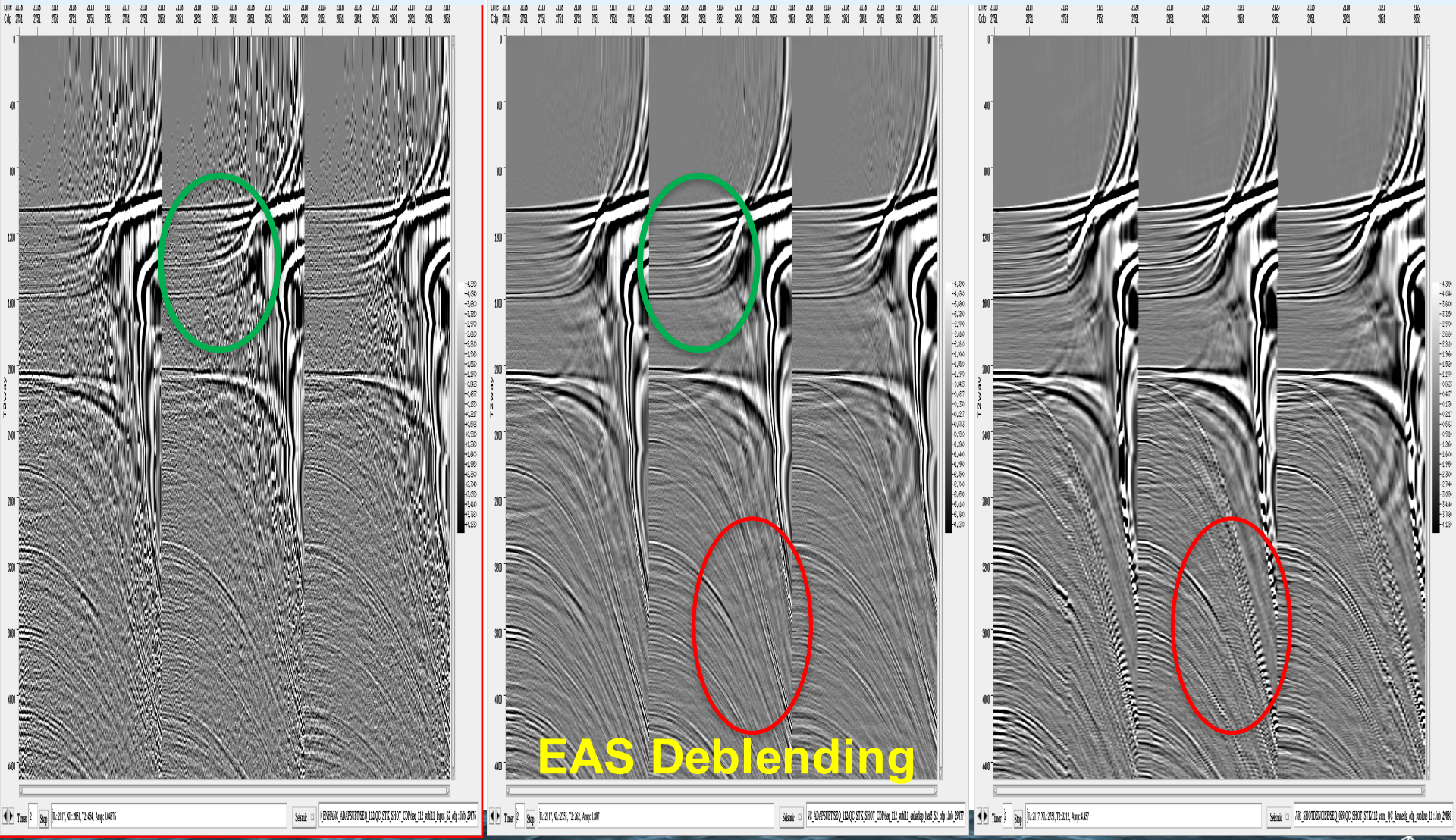


Simultaneous source increases fold, reduces aliasing

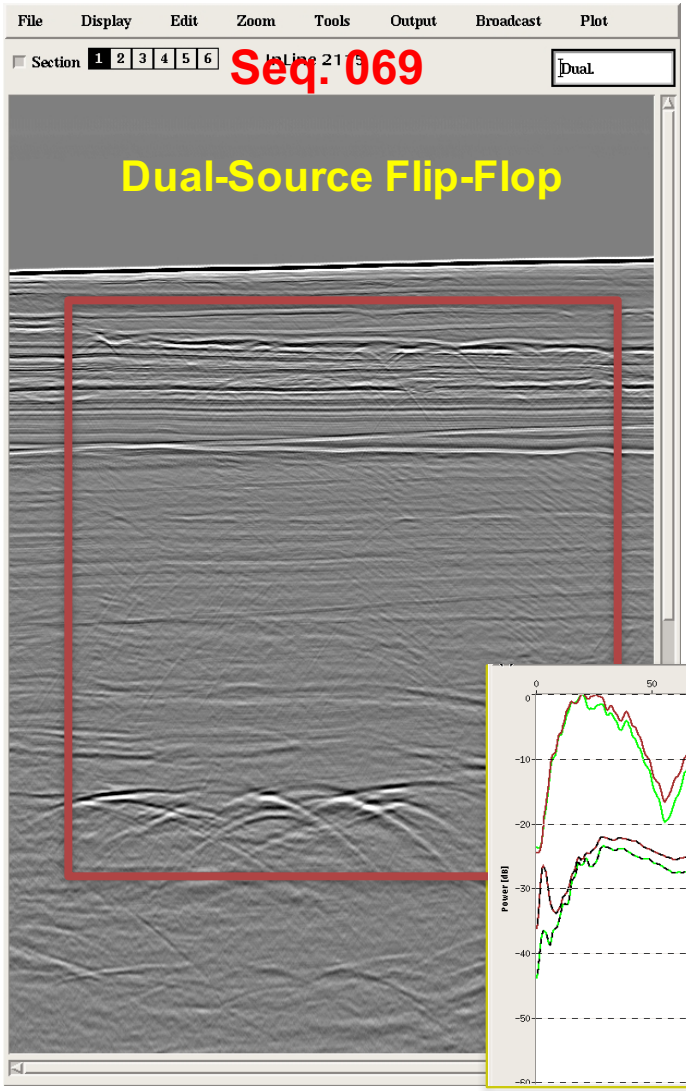
Triple-Source, Dithered

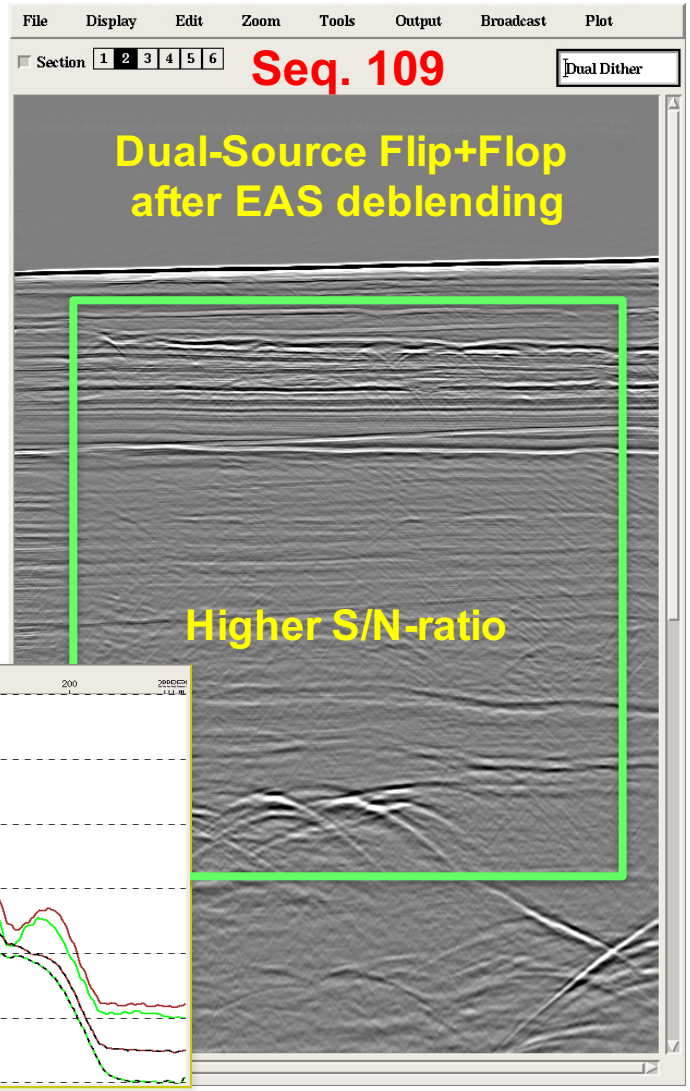
Triple-Source, after deblending

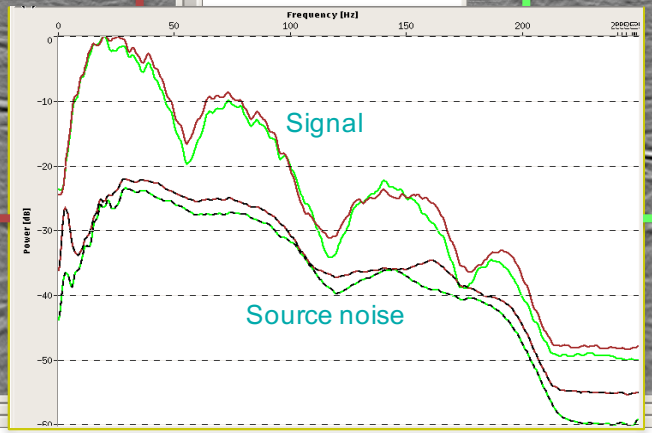
Conventional Dual-Source



Dual-source sequential vs dual-source simultaneous

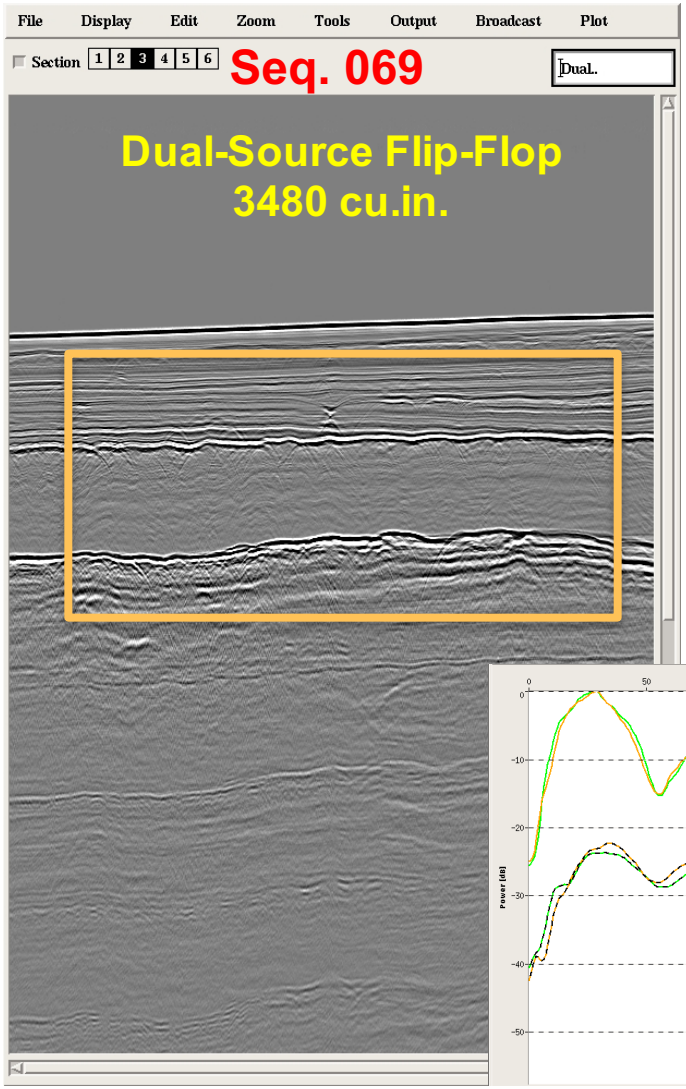




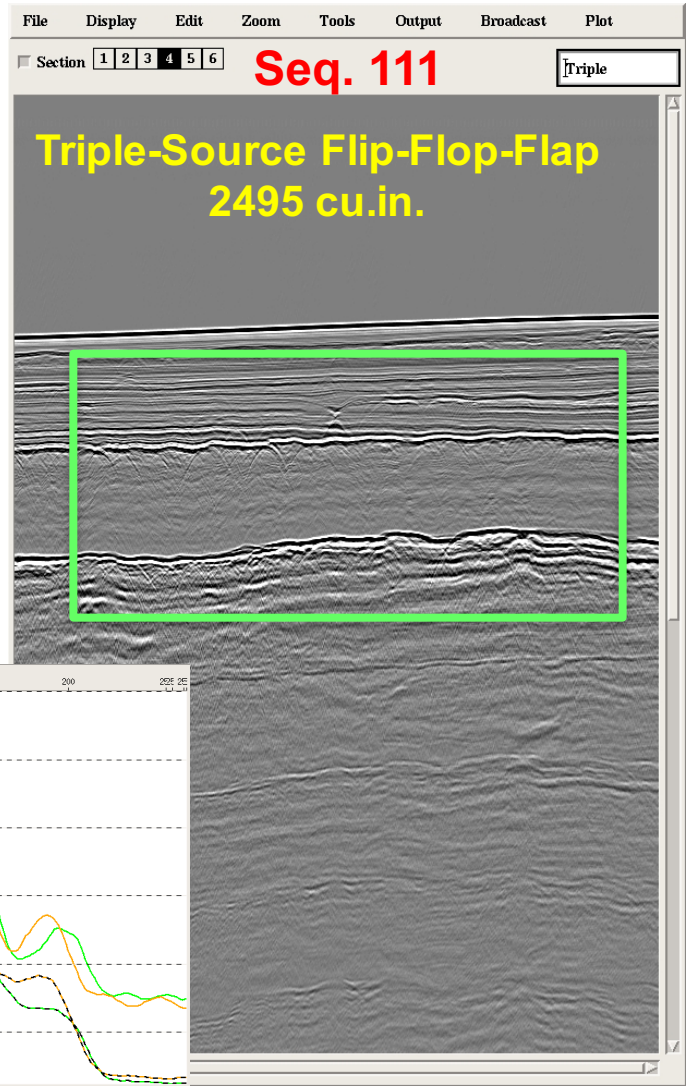


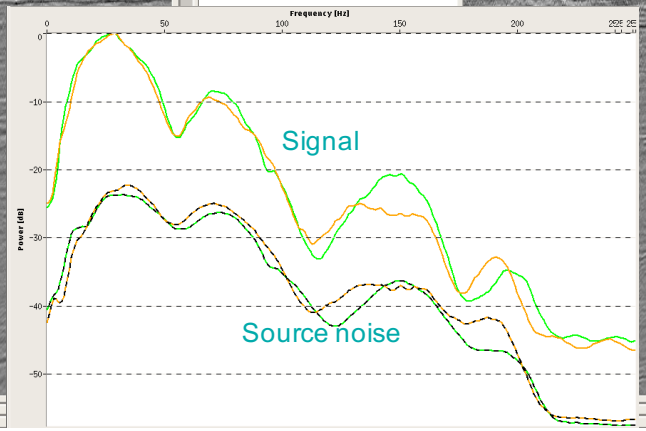
TGS

Dual-source vs triple-source sequential shooting



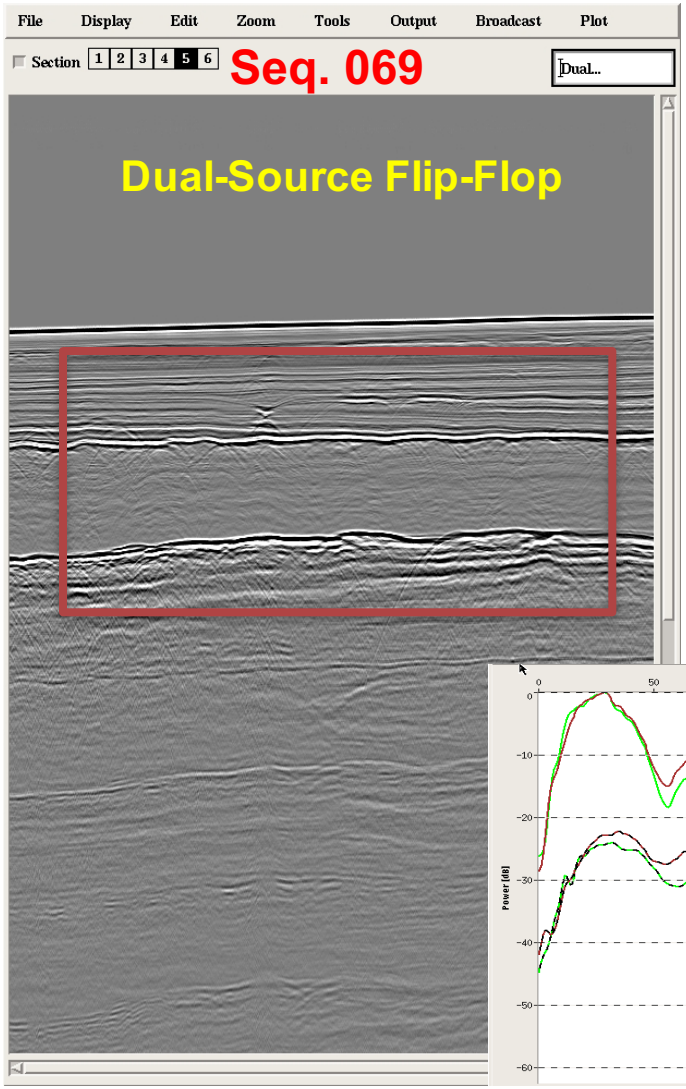
Same s/n ratio

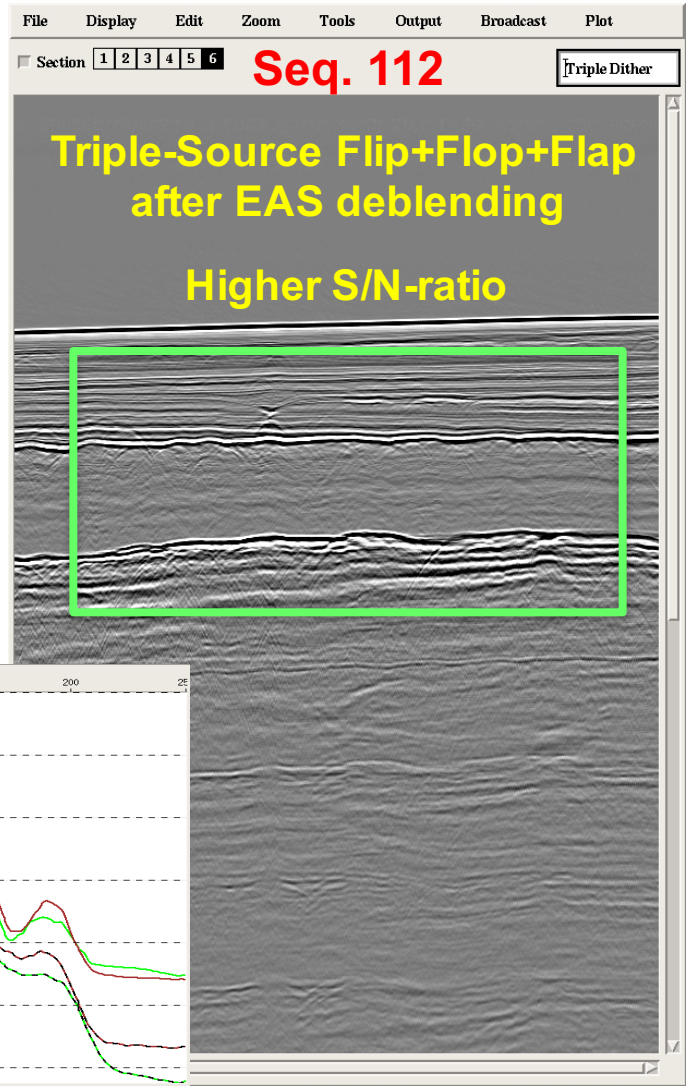


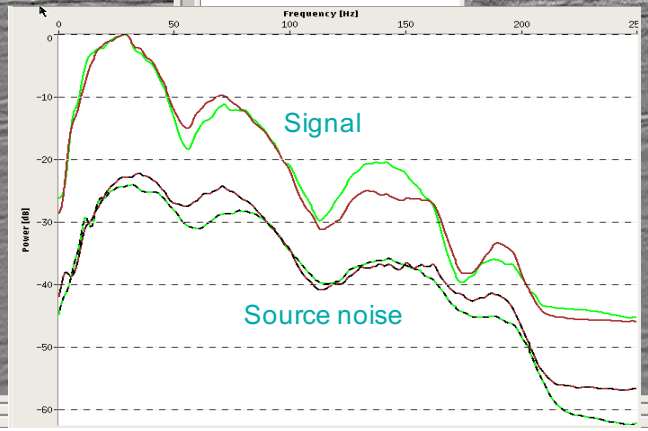


TGS

Dual-source sequential vs triple-source simultaneous







Conclusions

- Successful reconfiguration and operation of a triple-source setup, in both sequential and simultaneous source mode
- When compensating for signature differences, data quality from a dual-source and a triple-source configuration, is similar.
- Simultaneous shooting, or overlapping records, will give us higher fold and less aliasing in pre-stack domain
- EAS flow for deblending simultaneous source data, performs very good on data from both dual- and triple-source mode

Why stop at three sources, we could do with more ?

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- Adriana Thames
- Zhaojun Liu
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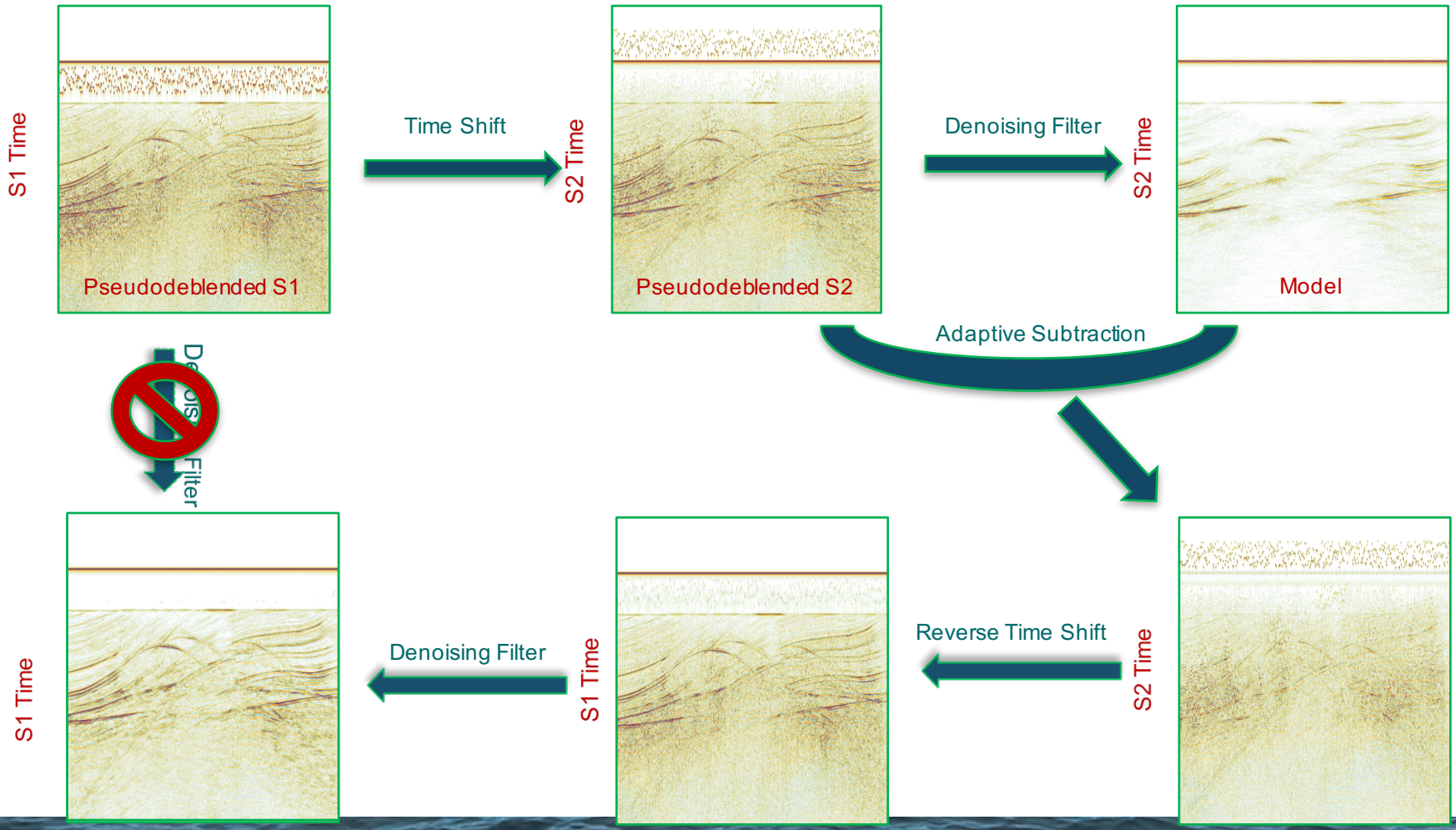
- Henrik Roende
- Nick Woodburn

Thank You!

Adaptive Subtraction: Young Kim et al. 2009



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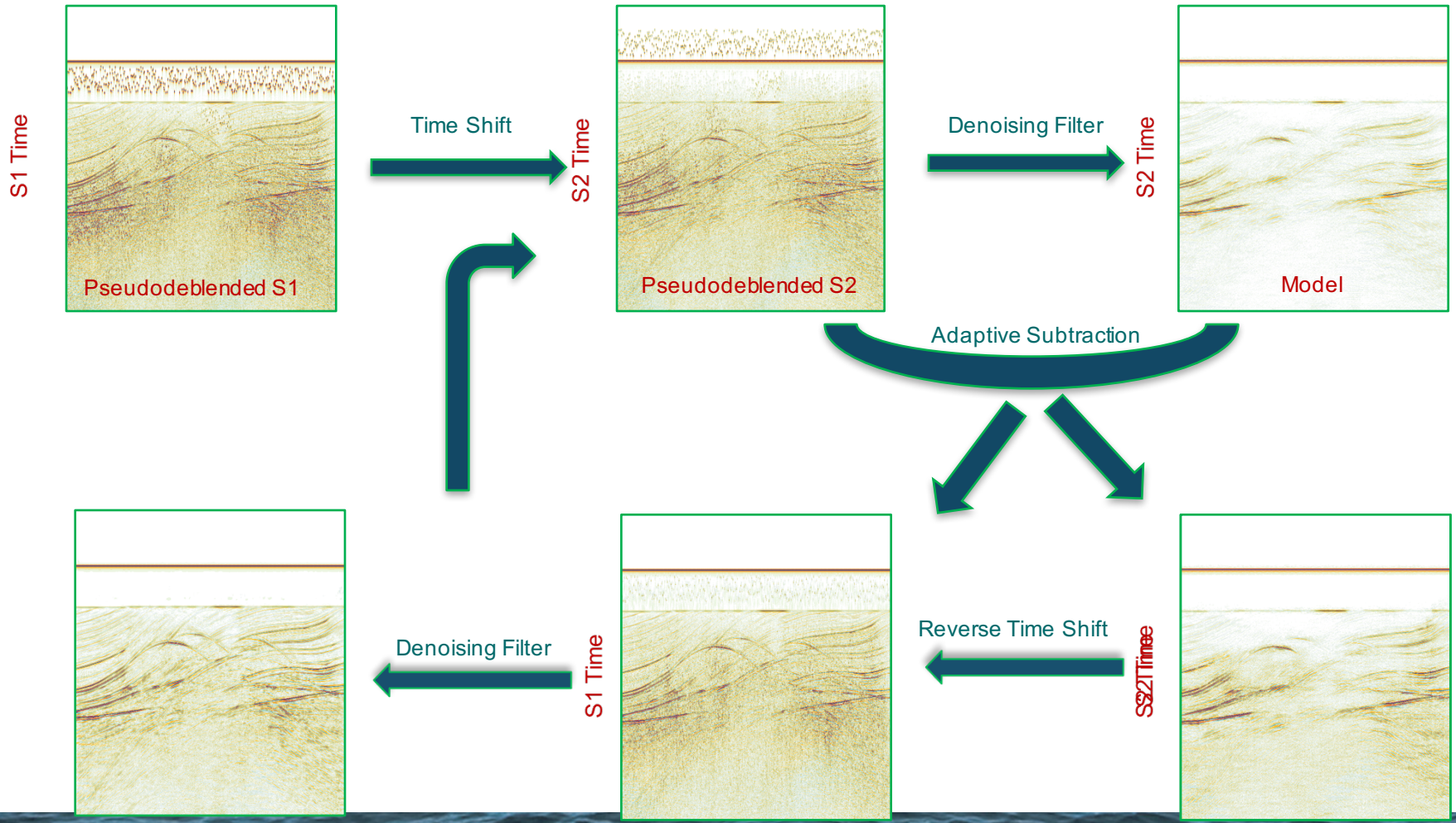
Enhanced Adaptive Subtraction (EAS): Liu 2015



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