Dealing with Seismic Interference in a busy North Sea Season

by

Per Eivind Dhelie, David Harrison-Fox (PGS)

Espen Prytz Erlandsen, Muhammad Faheem Abbasi (Statoil)

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www.force.org

Outline

- Introduction – How large is the SI challenge in the North Sea?
- Method for removal of seismic interference
- Case study of SI
- Conclusions & recommendations

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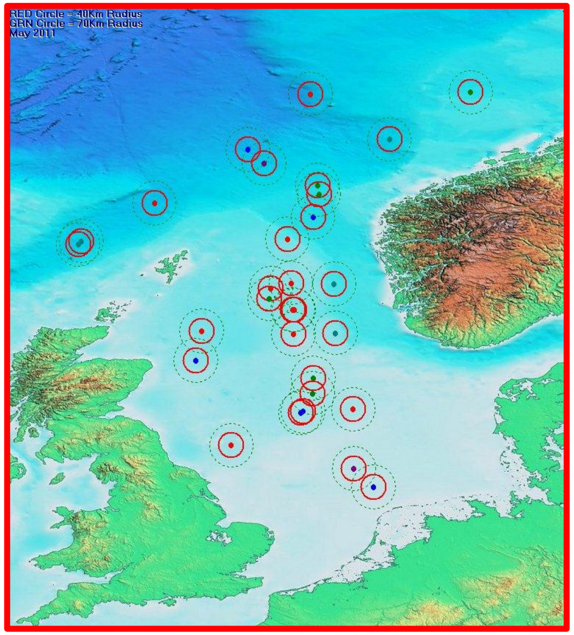
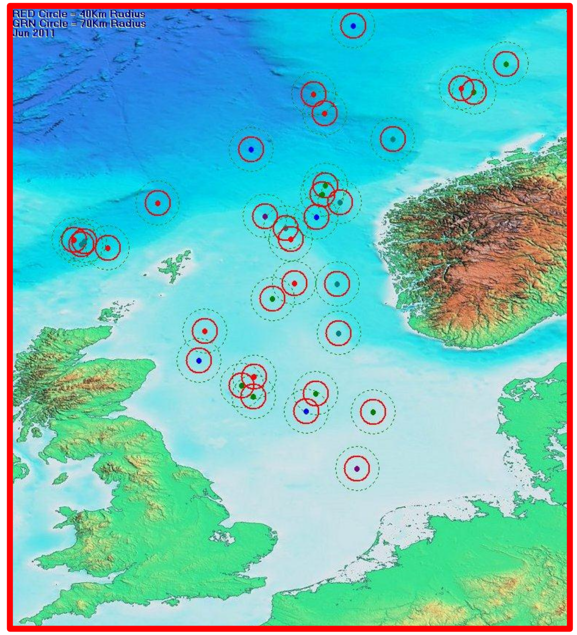
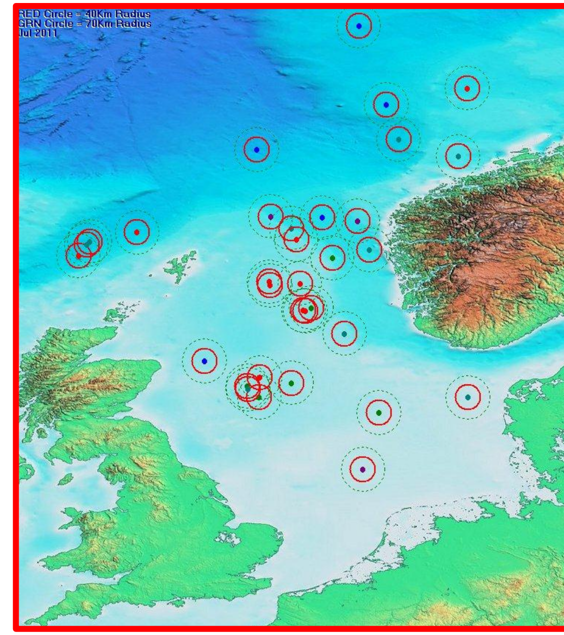
Active seismic vessels in the North Sea - 2011



May 2011



June 2011



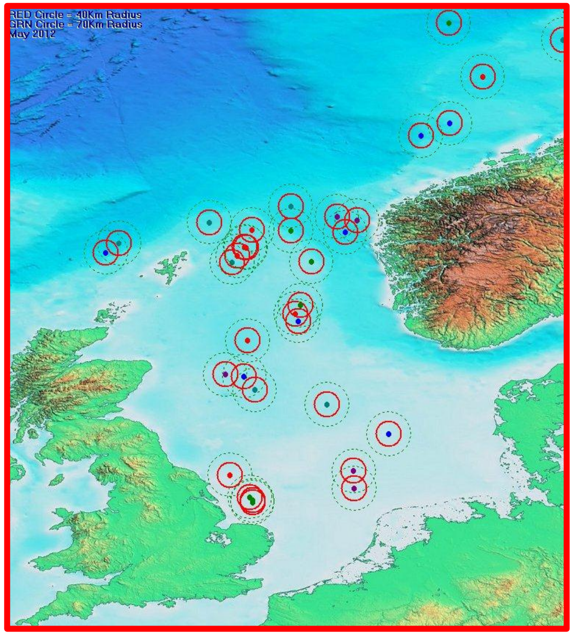
July 2011

= Radius of 40km
= Radius of 70km

With more than 20 seismic vessels operating in the North Sea during the summer of 2011, a lot of lost time is incurred whilst time-sharing

Source: NPD

Active seismic vessels in the North Sea - 2012



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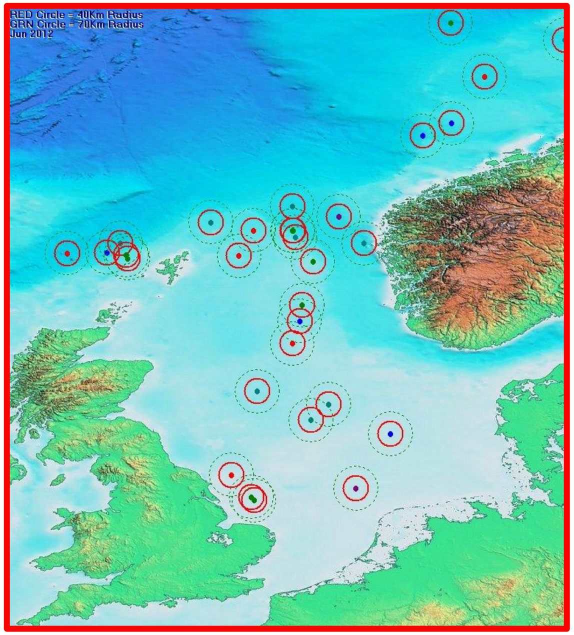

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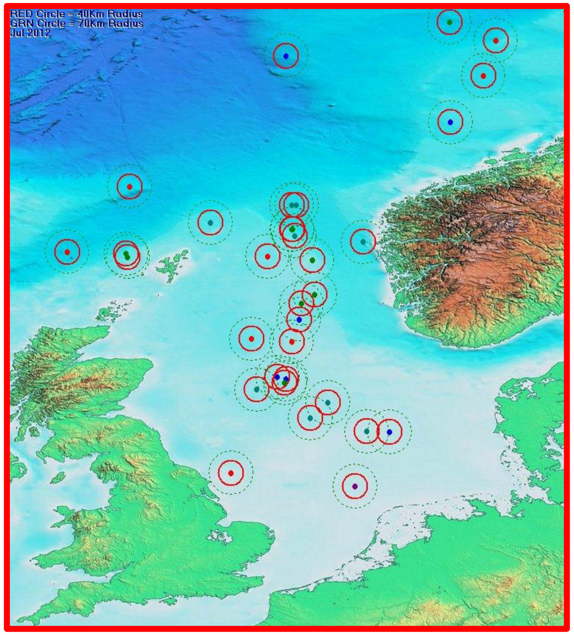

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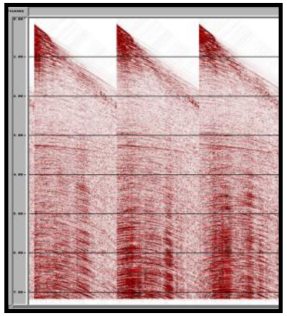
Method for removing seismic interference

- Current best practice for SI removal in production processing:
  - Pre-conditioning of shots (removal of random/swell noise)
  - Forward Tau-P transform on shots (CPU intensive)
  - Sort to common P (slowness) / FFID (shot) ensembles
  - Time and frequency dependent anomalous noise attenuation - using windowed anomalous amplitude detection followed by iterative F-X prediction to reconstruct coherent signal (SWOOP) (parameter testing)
  - Subtraction of filtered data from Tau-P input (isolate noise)
  - Sort back to Tau-P domain FFID gathers
  - Inverse Tau-P transform to give TX model of SI-noise (CPU Intensive)
  - Adaptive subtraction of SI-noise model from TX input data (parameter testing)

- For On-Board Processing line evaluation, SWOOP in common P traces followed by inverse Tau-P transform of results is proposed to save time (obtain 95% results)

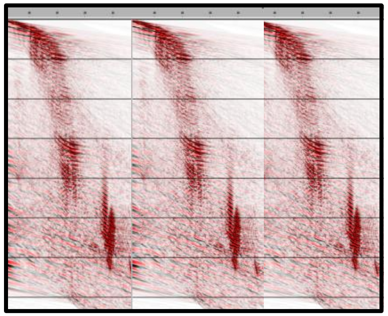
“Tau-P common-P” SI removal flow

T-X shot gathers



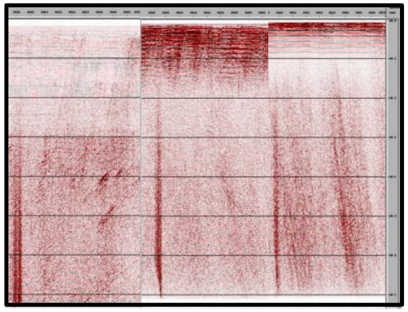
Transform using linear Radon and set a flag at the end of every shot cable pair

Tau-P shot gathers

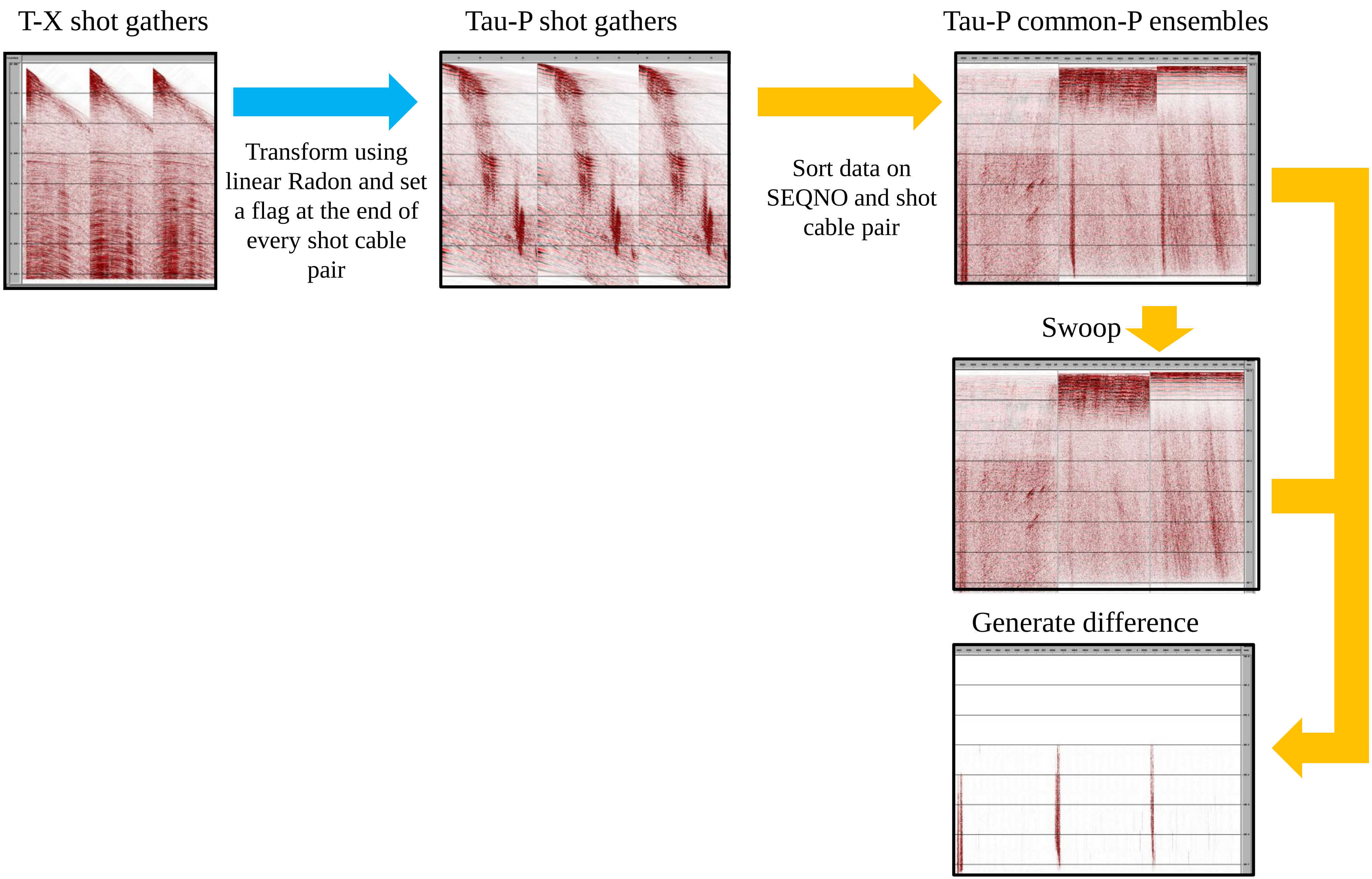


Sort data on SEQNO and shot cable pair

Tau-P common-P ensembles



“Tau-P common-P” SI removal flow



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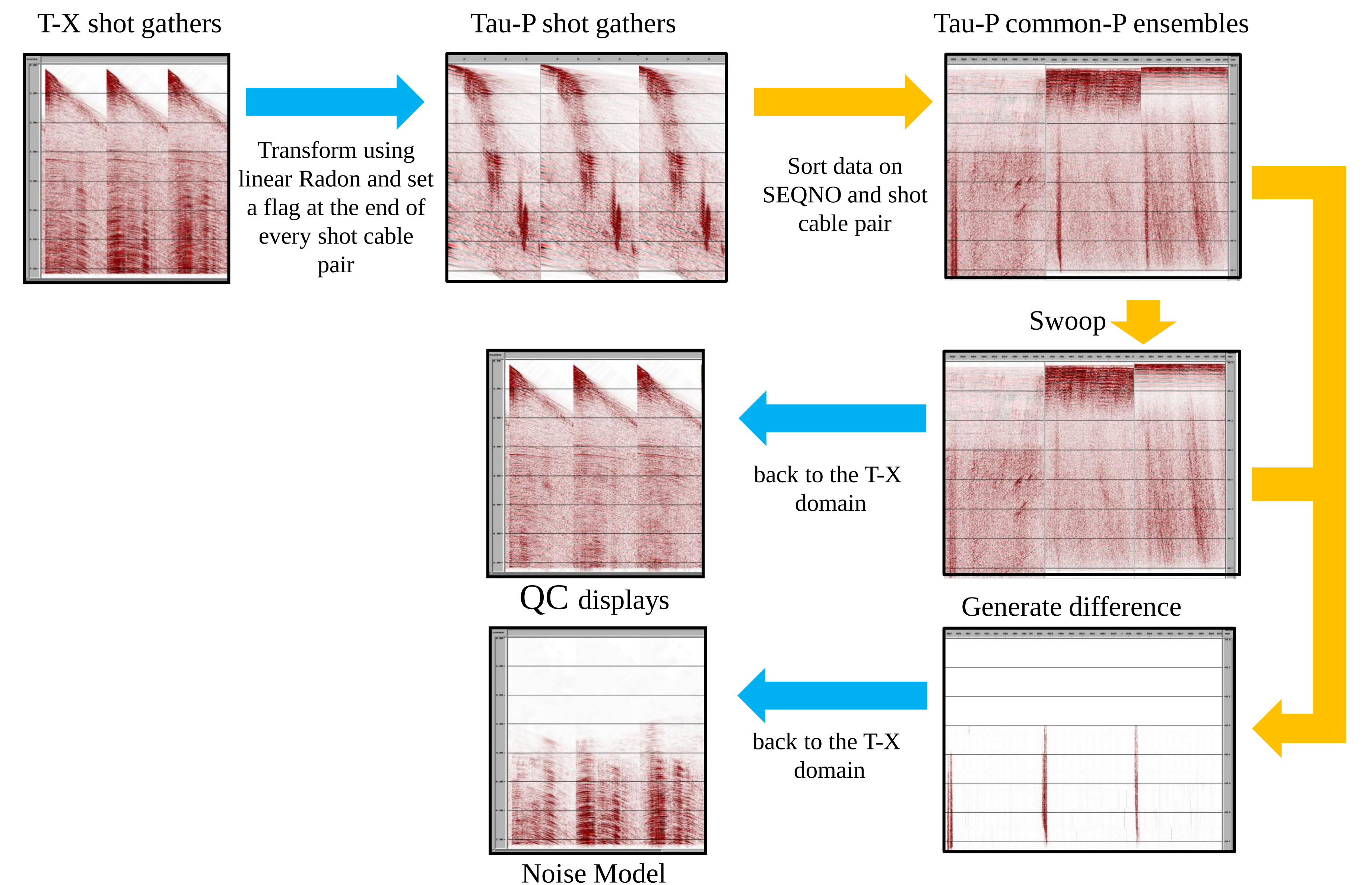
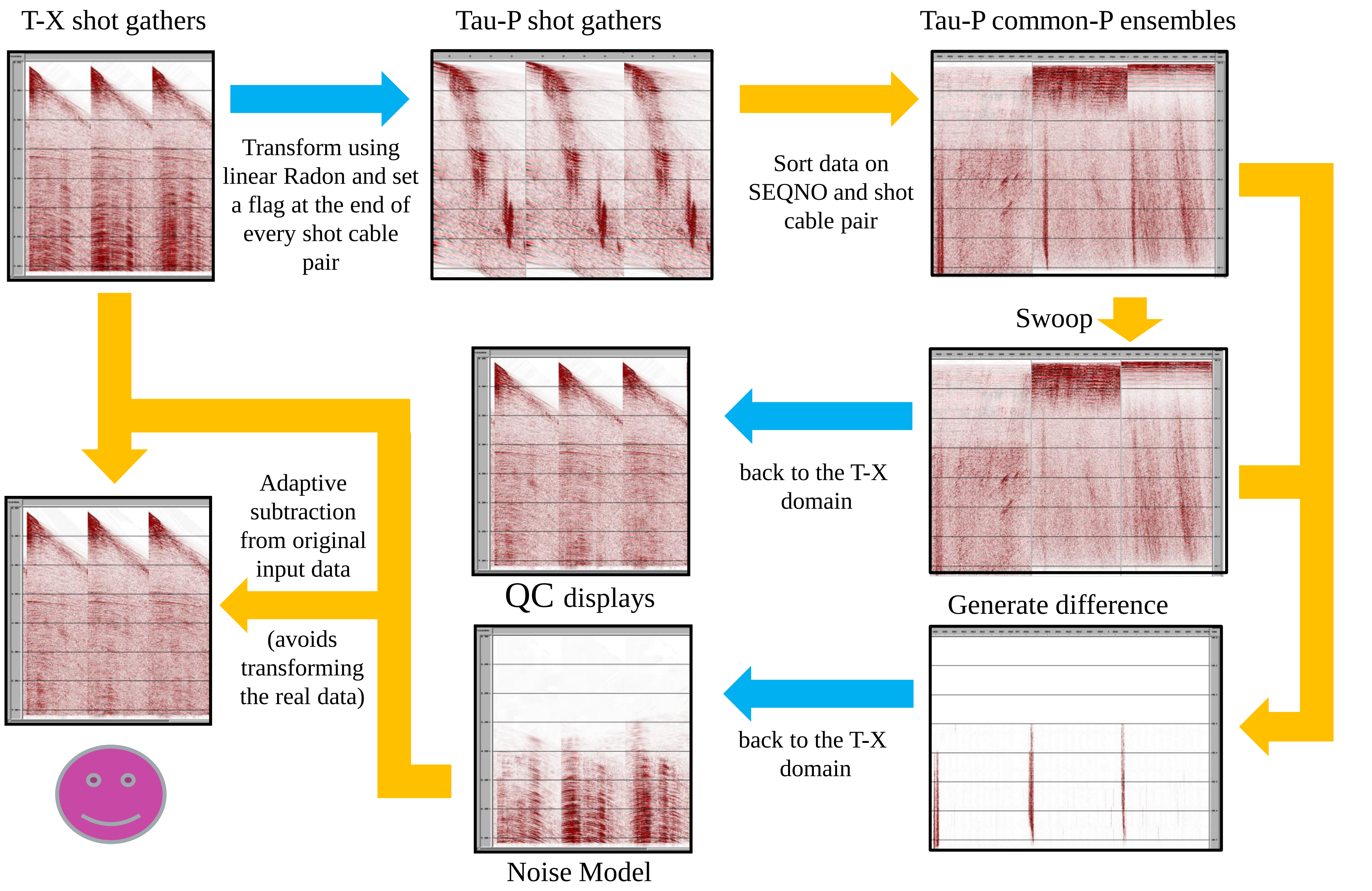
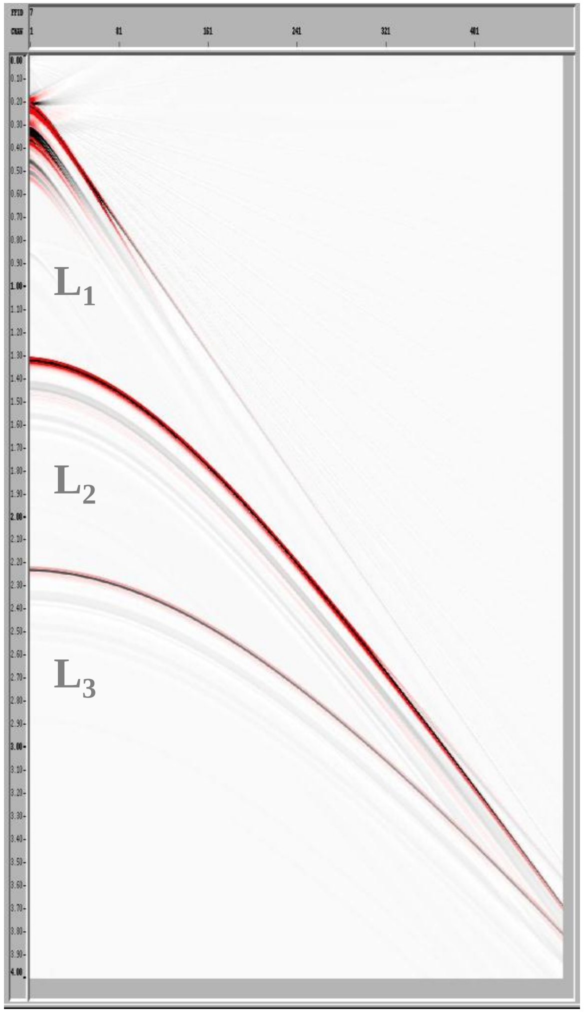


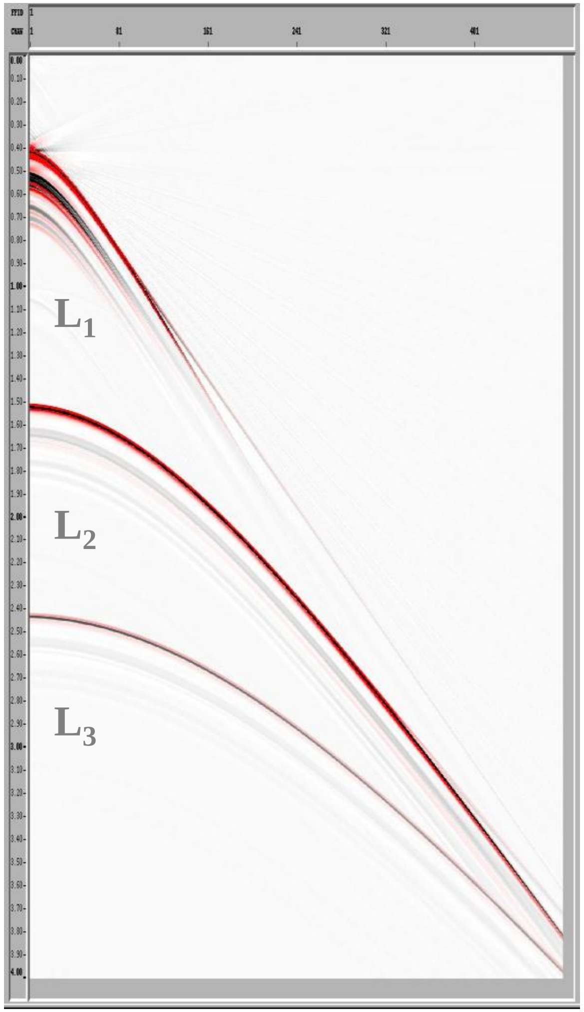
"*Tau-P common-P*" SI removal flow



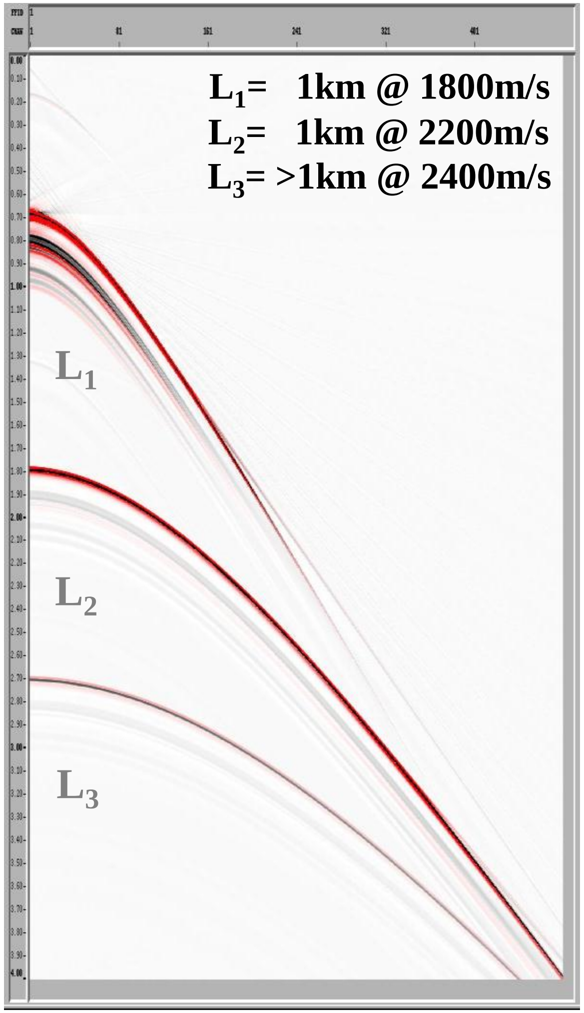
Modeling cases – No SI



150m water depth

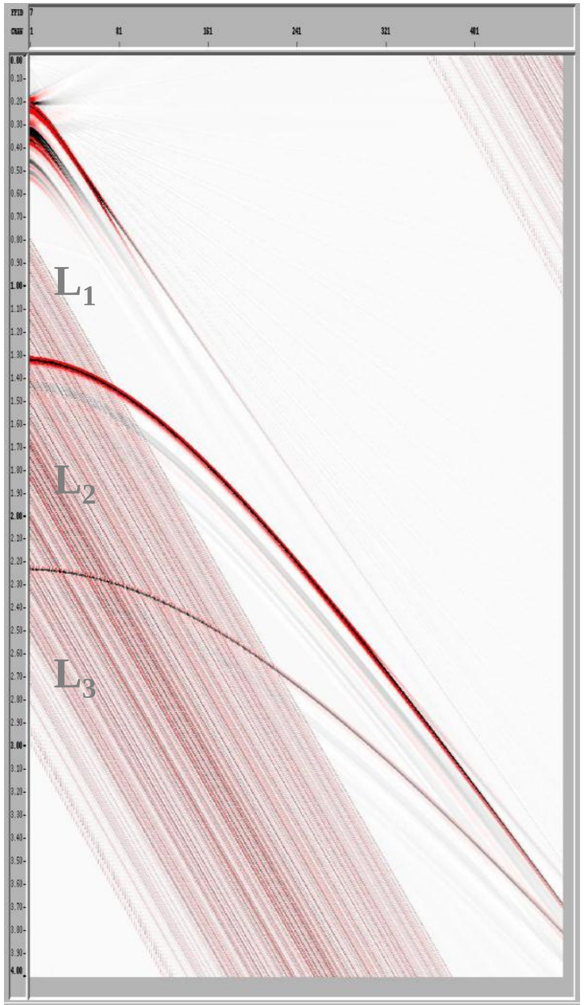


300m water depth

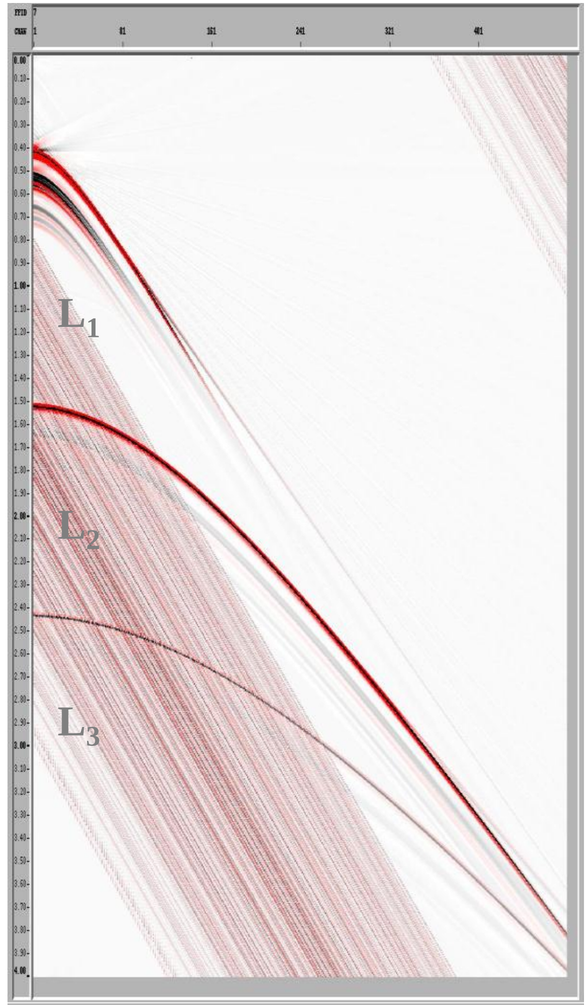


500m water depth

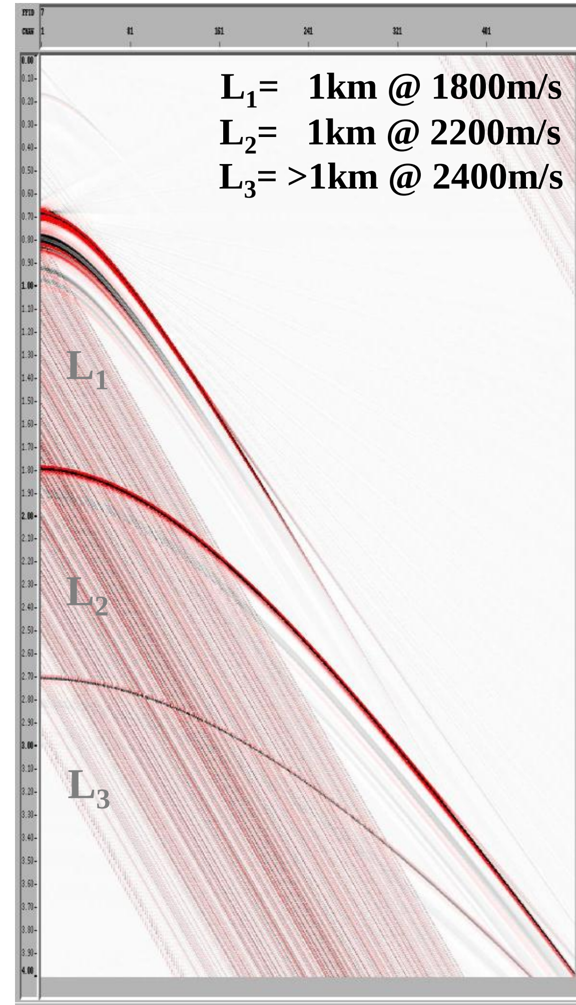
Modeling cases – SI ahead



150m water depth

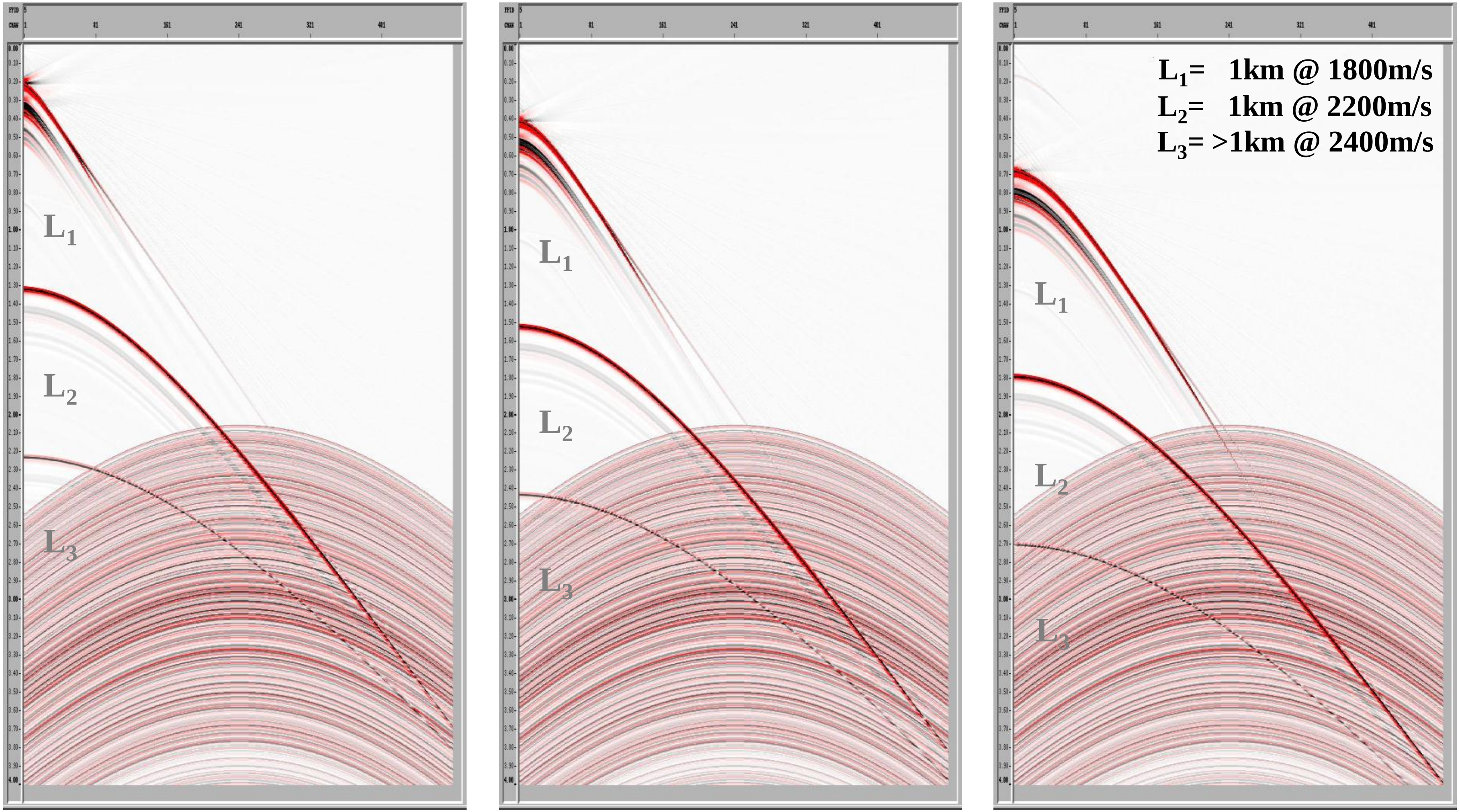


300m water depth



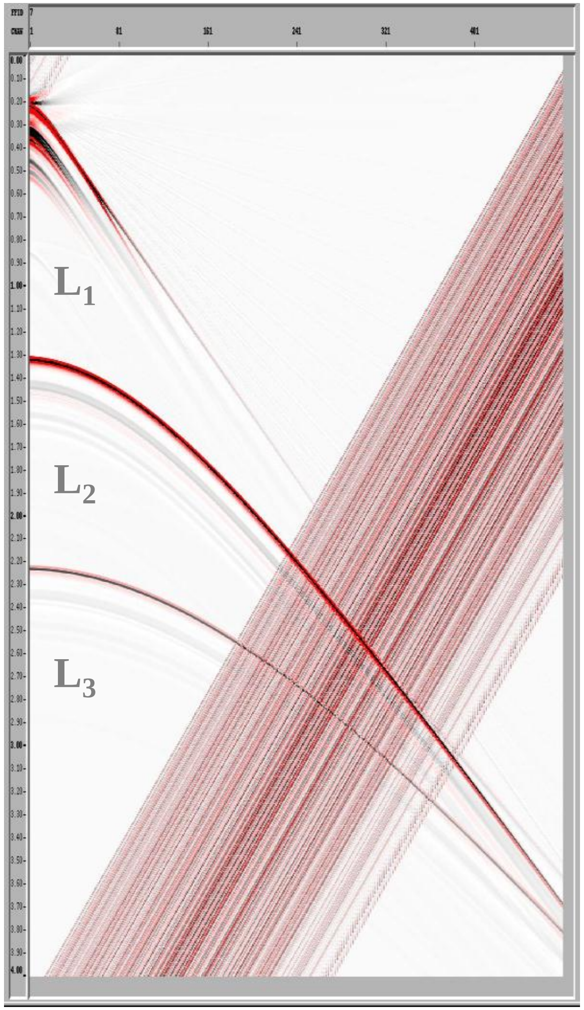
500m water depth

Modeling cases – SI abeam

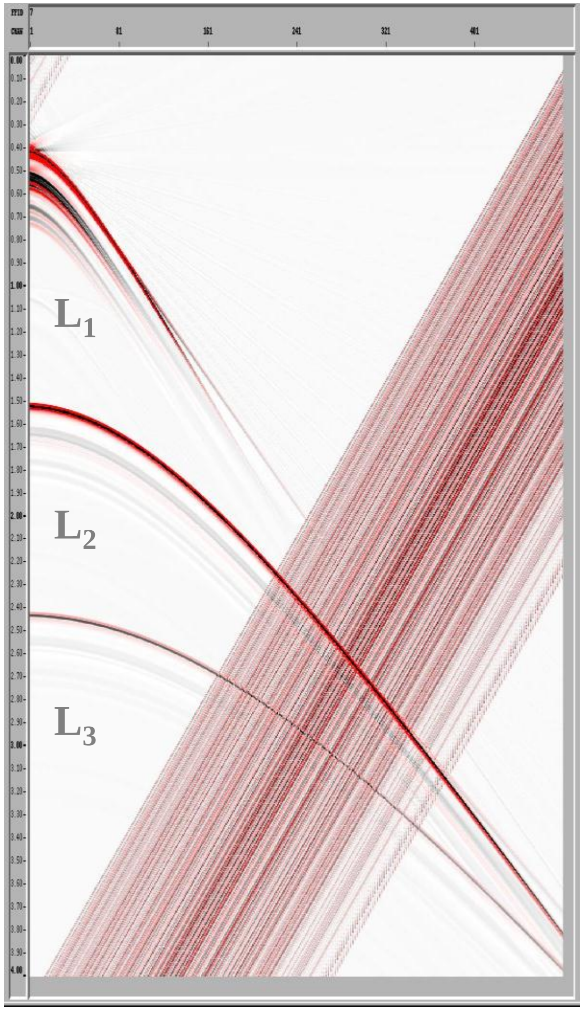


150m water depth 300m water depth 500m water depth

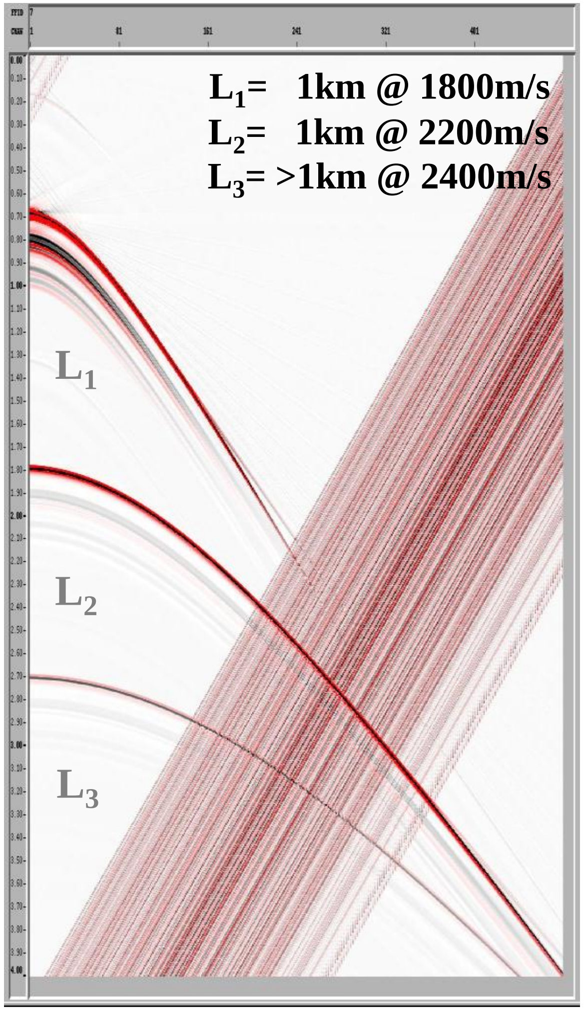
Modeling cases – SI astern



150m water depth

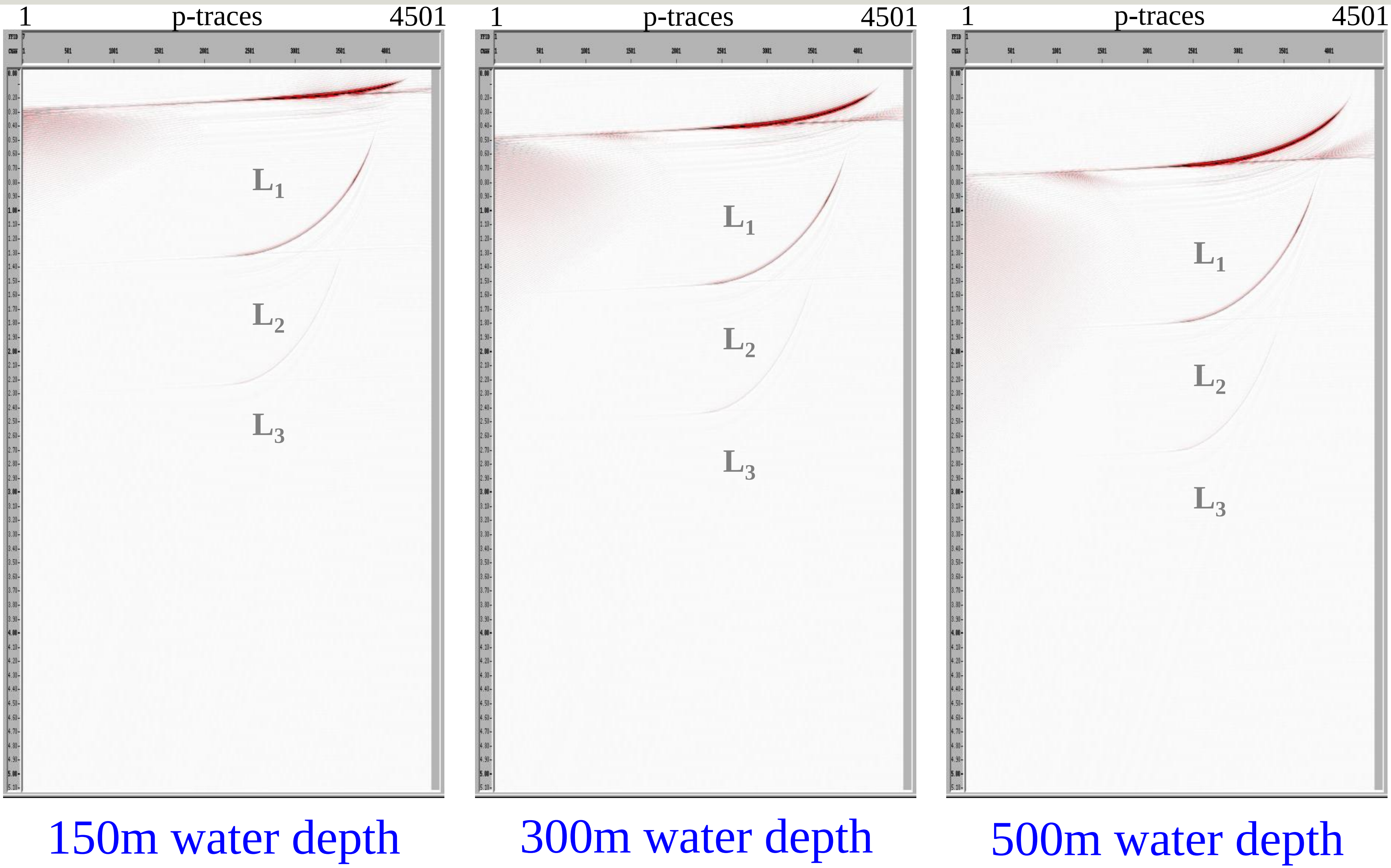


300m water depth



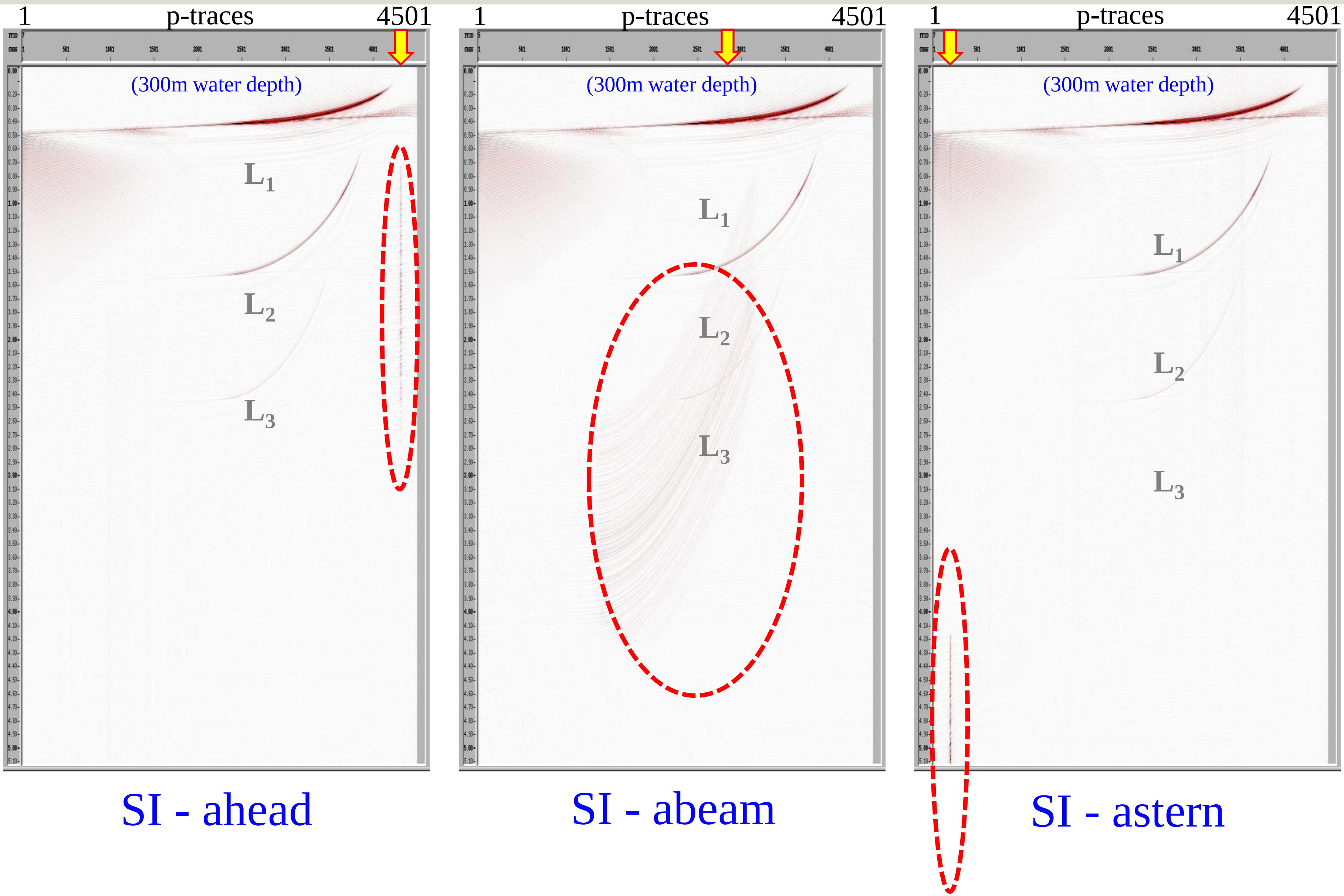
500m water depth

Modeling cases – Shots in tau-p domain – no SI

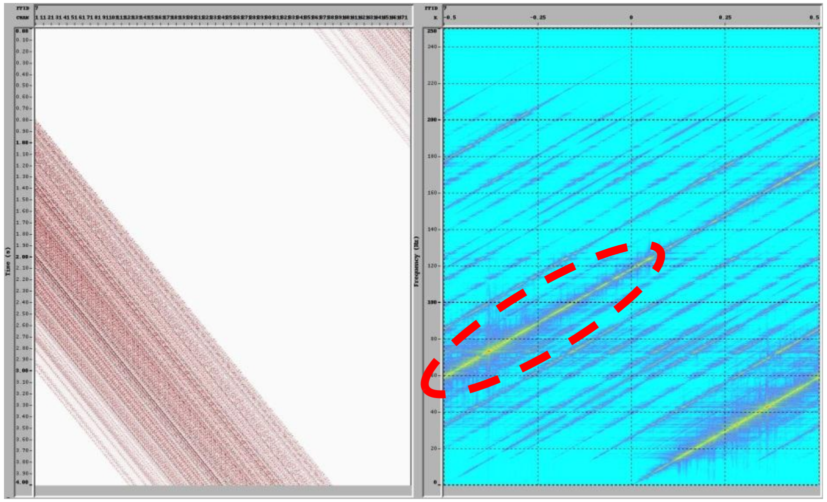


Linear tau-p transform – modeling 4501 p traces (slowness) at reference offset of 6100m.
Modeling range is -4500 to +4500ms (equivalent to +/- 1350m/s). Modeling 0-250Hz at 2ms

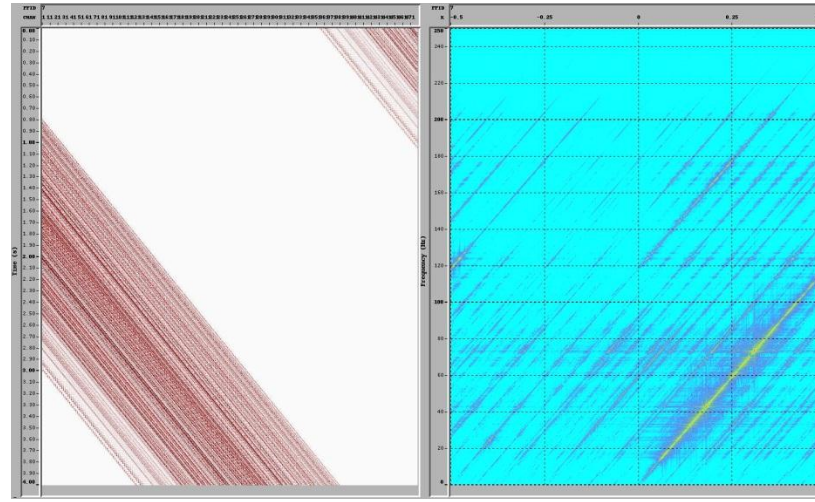
Modeling cases – Shots in tau-p domain – with SI



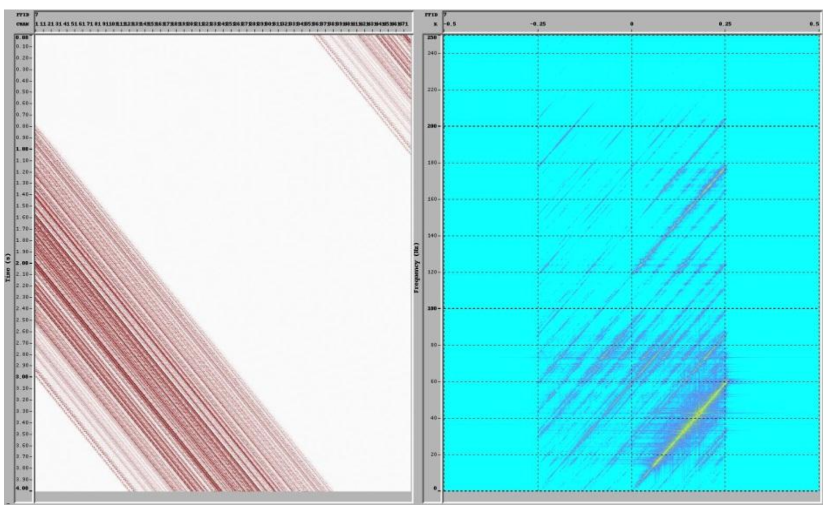
SI aliasing @ 1480m/s – at 60Hz with 12.5m groups



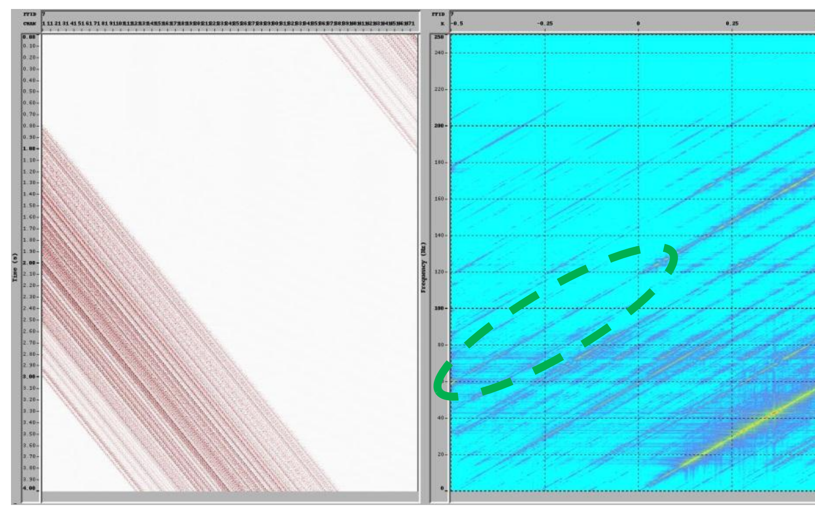
Aliased SI – 12.5m group spacing



Interpolate – 6.25m group spacing



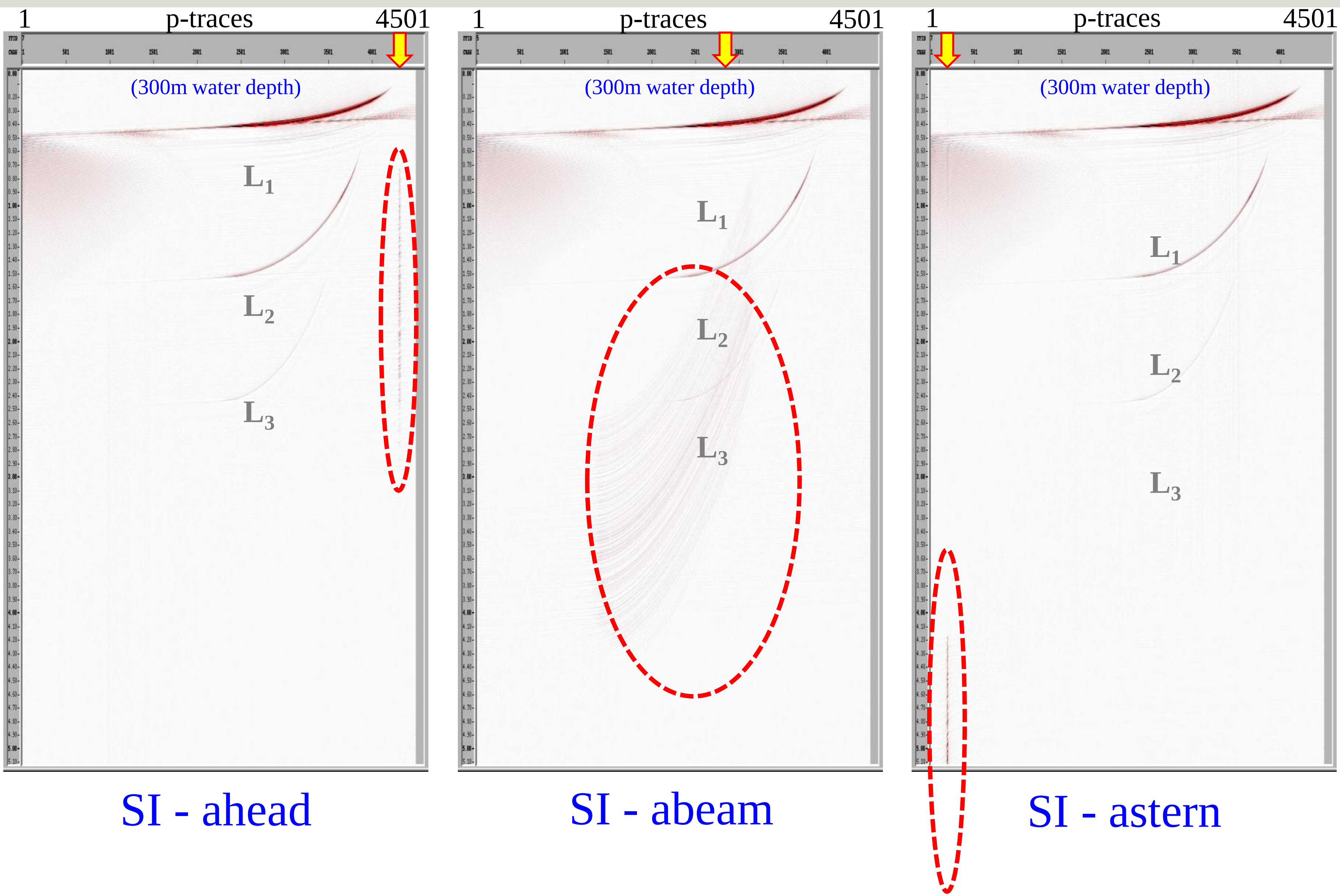
Spatial anti-alias filter



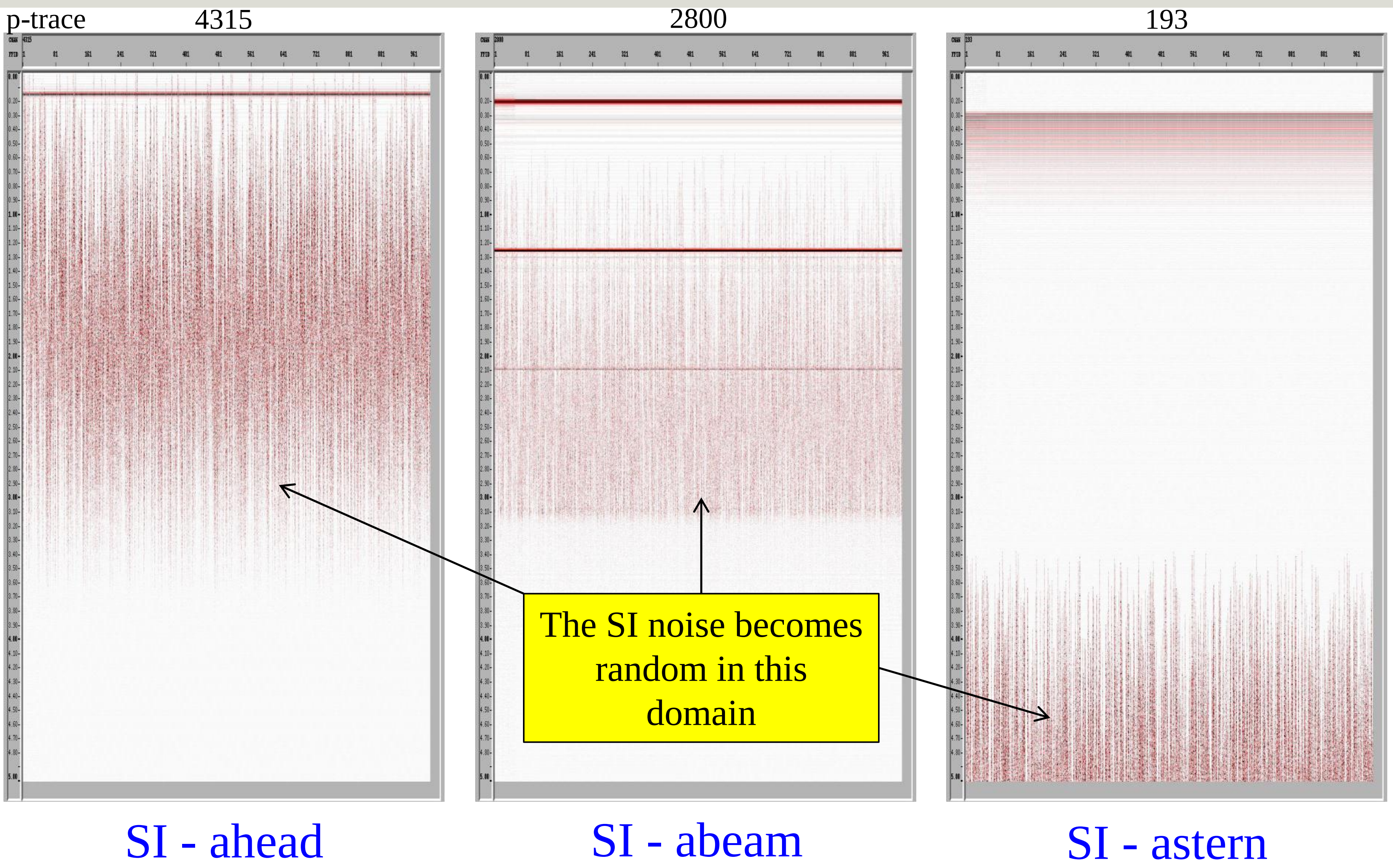
Drop traces – back to 12.5m spacing

SI aliasing is dependent on the apparent velocity of the SI hitting the receivers. 1480 is the worst case – astern or ahead. SI coming from abeam will have much higher apparent velocity and no aliasing problem

Modeling cases – Shots in tau-p domain – with SI

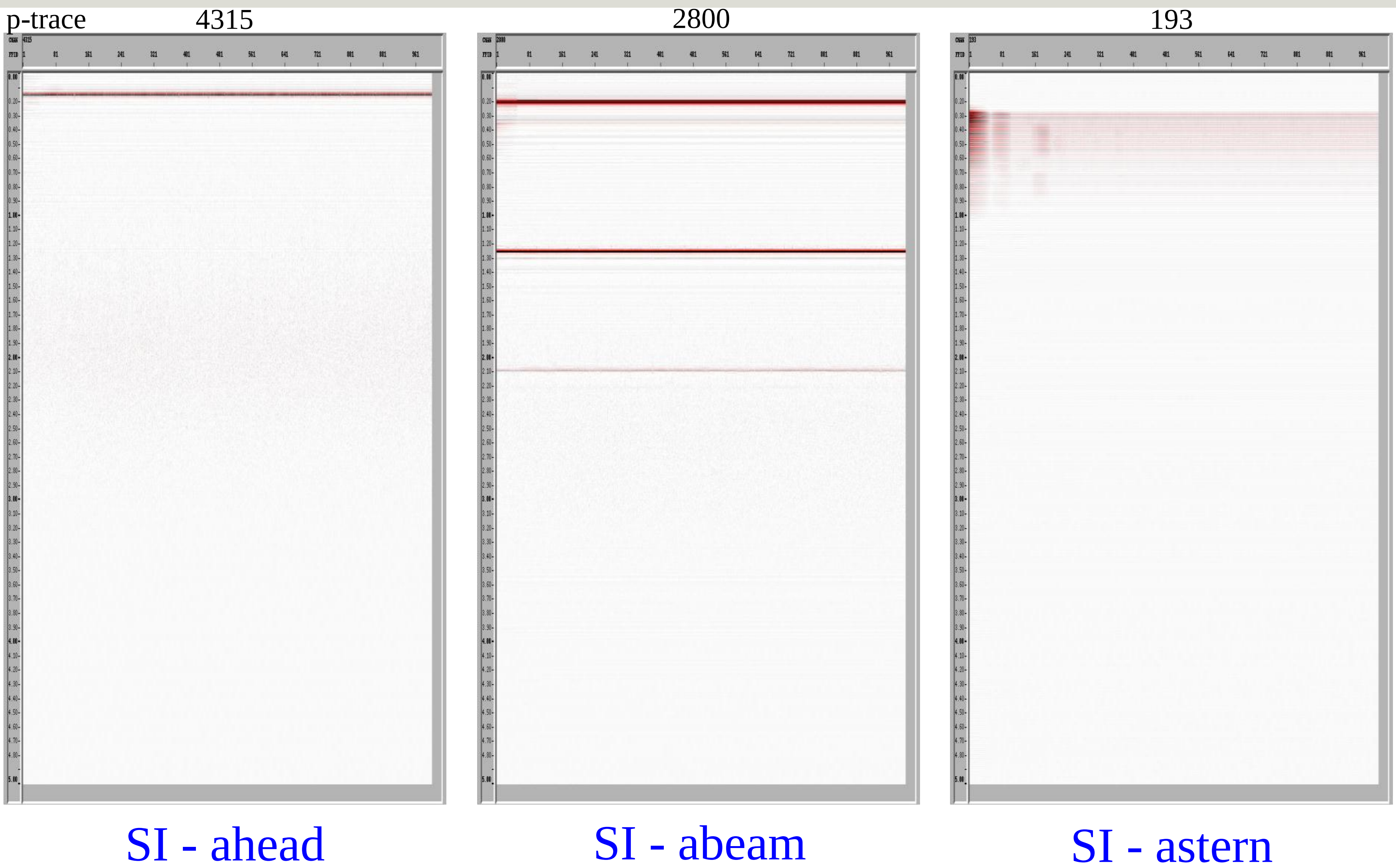


"Common p-plots" – with SI



NOTE: Showing only 3 p-traces (4315, 2800 & 193) out of a total of 4501

“Common p-plots” – after SI removal



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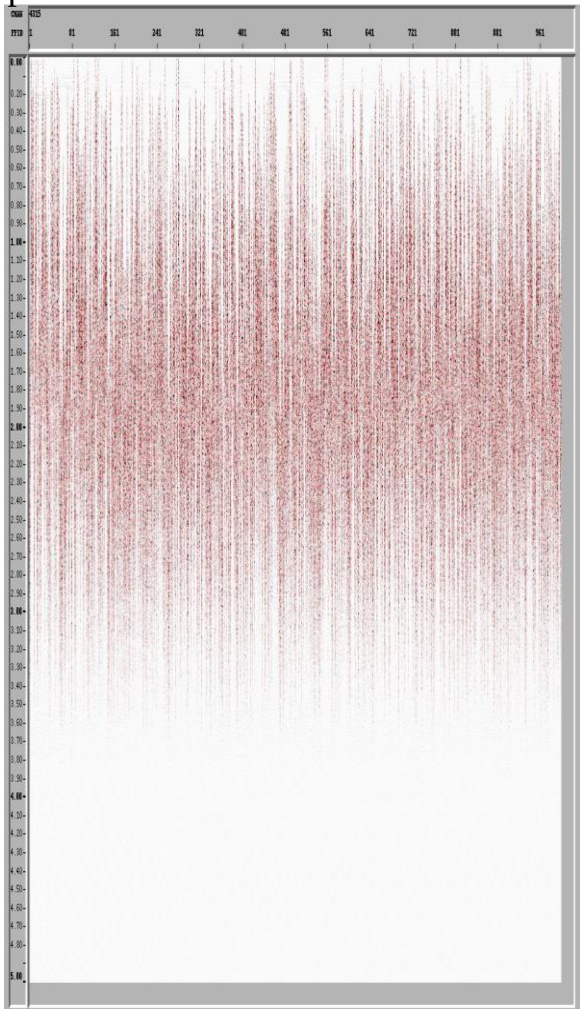
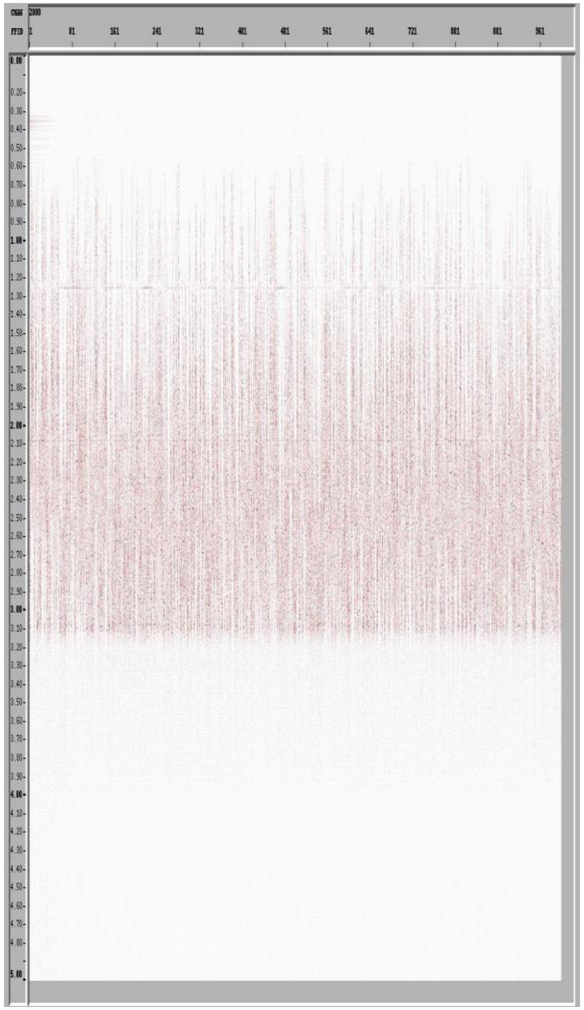
"Common p-plots" – difference before/after SI removal

p-trace 4315



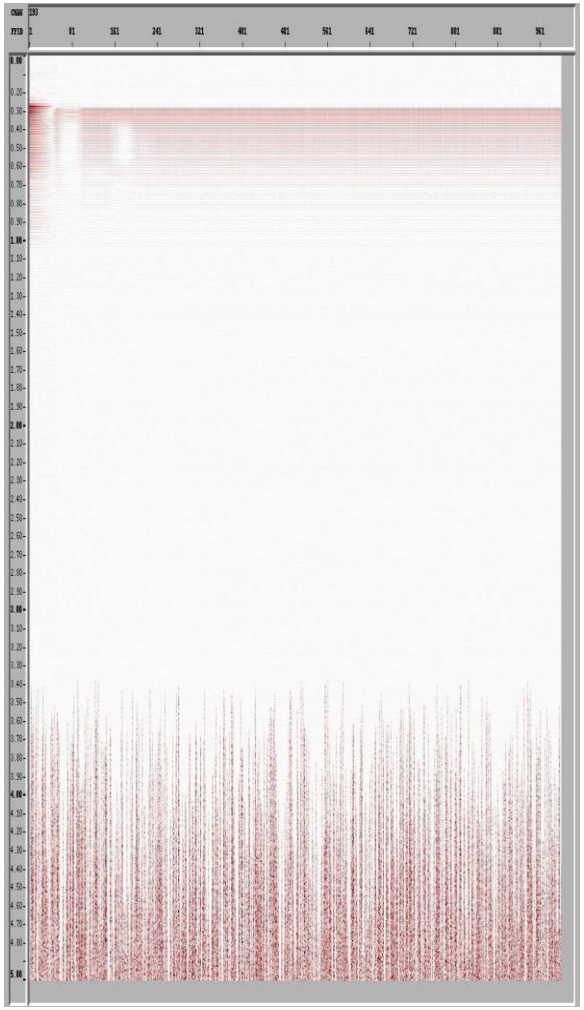
SI - ahead

2800



SI - abeam

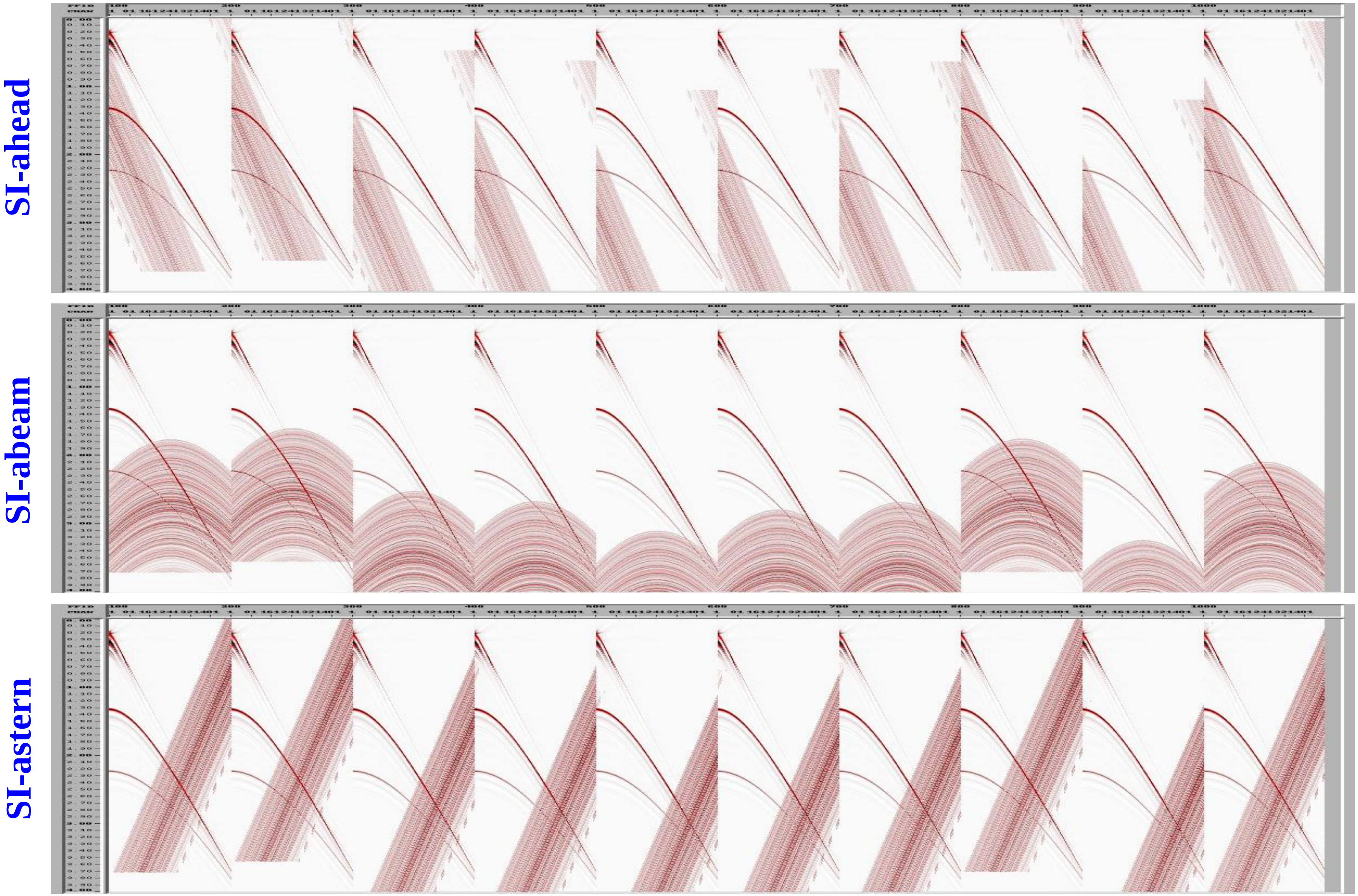
193



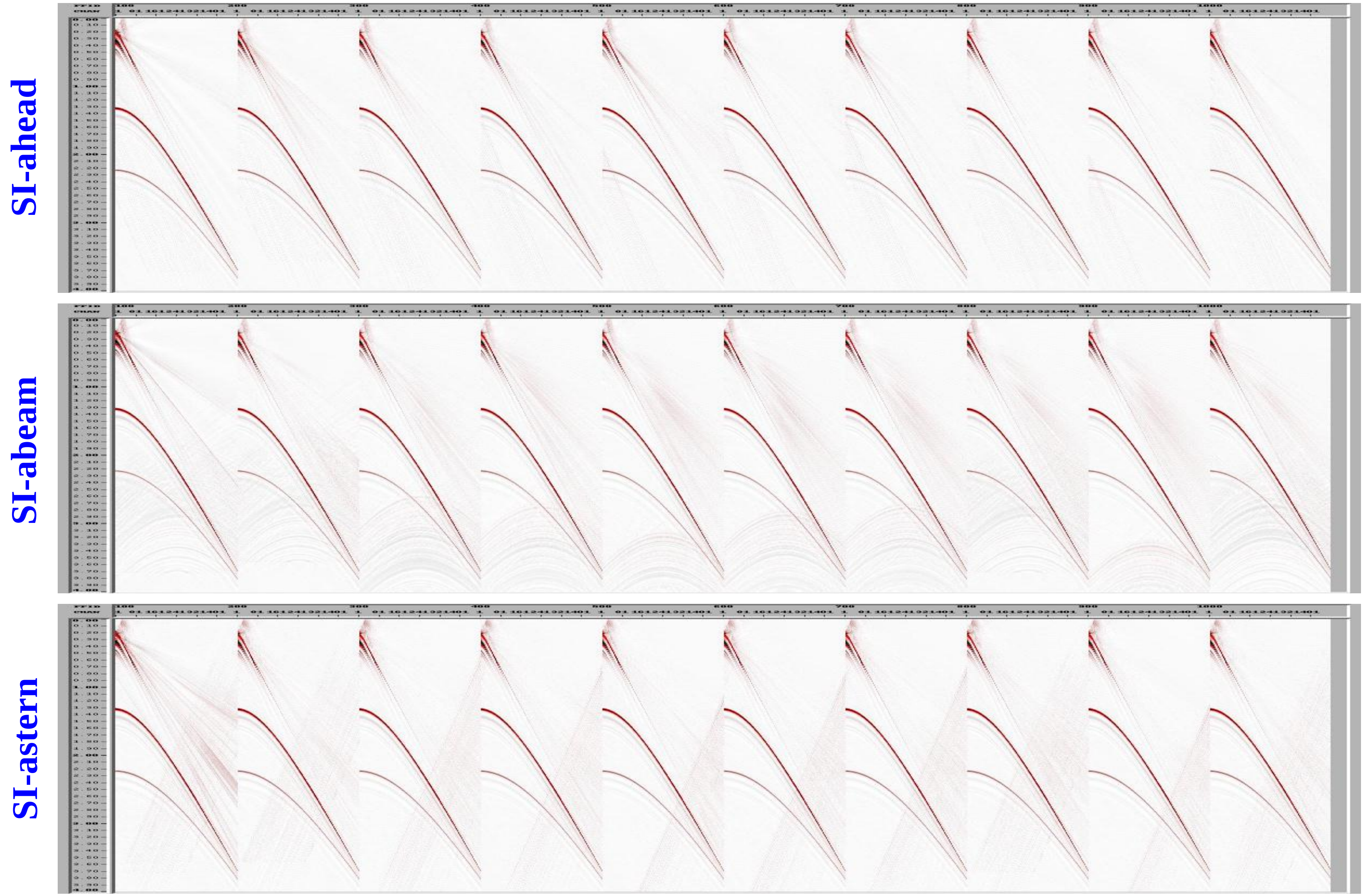
SI - astern

NOTE: Showing only 3 p-traces (4315, 2800 & 193) out of a total of 4501

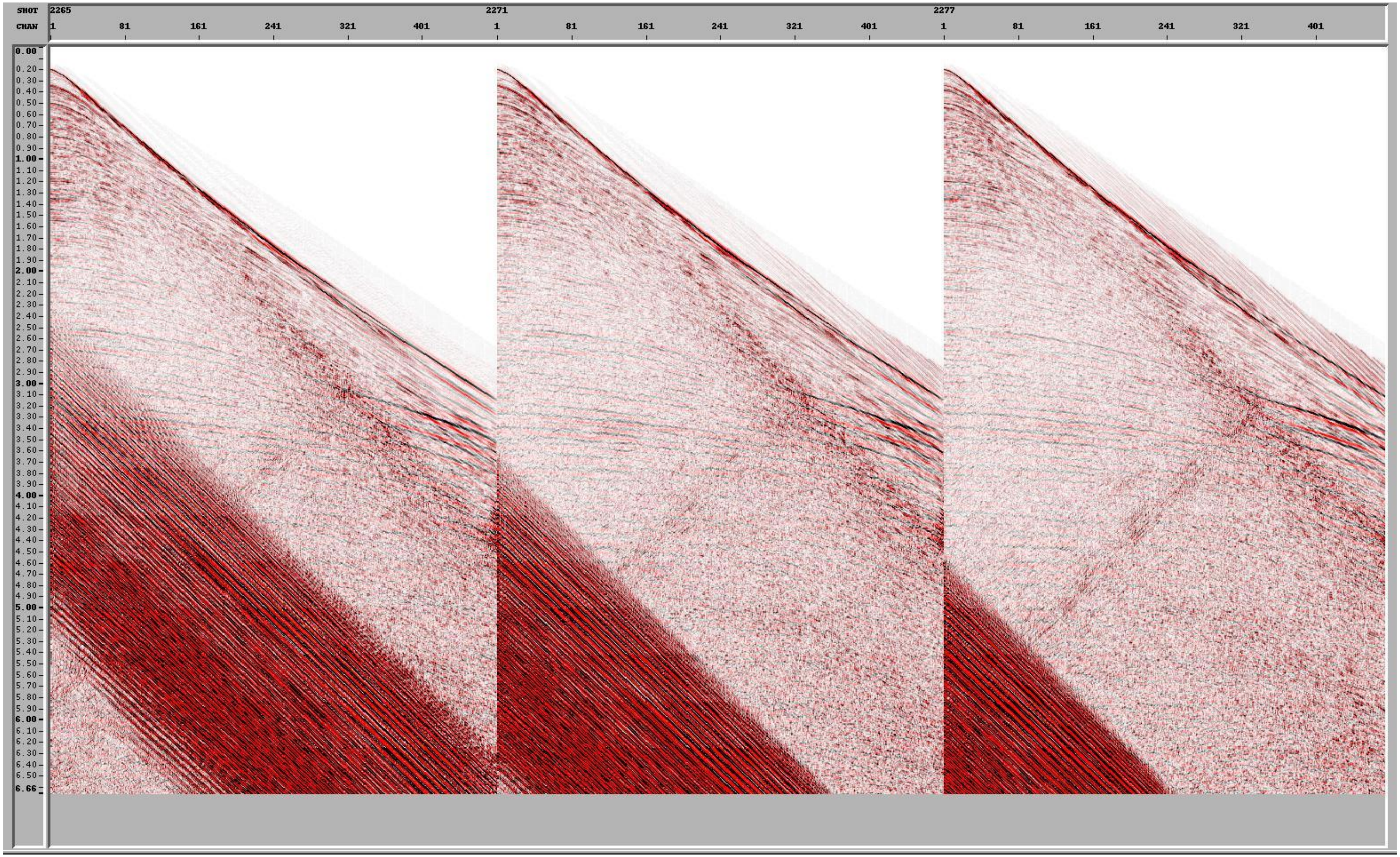
10 shots with SI – ahead – abeam & astern



10 shots after SI removal – ahead – abeam & astern



Real data – MC3D 2012 – 0-125 Hz Before SI removal



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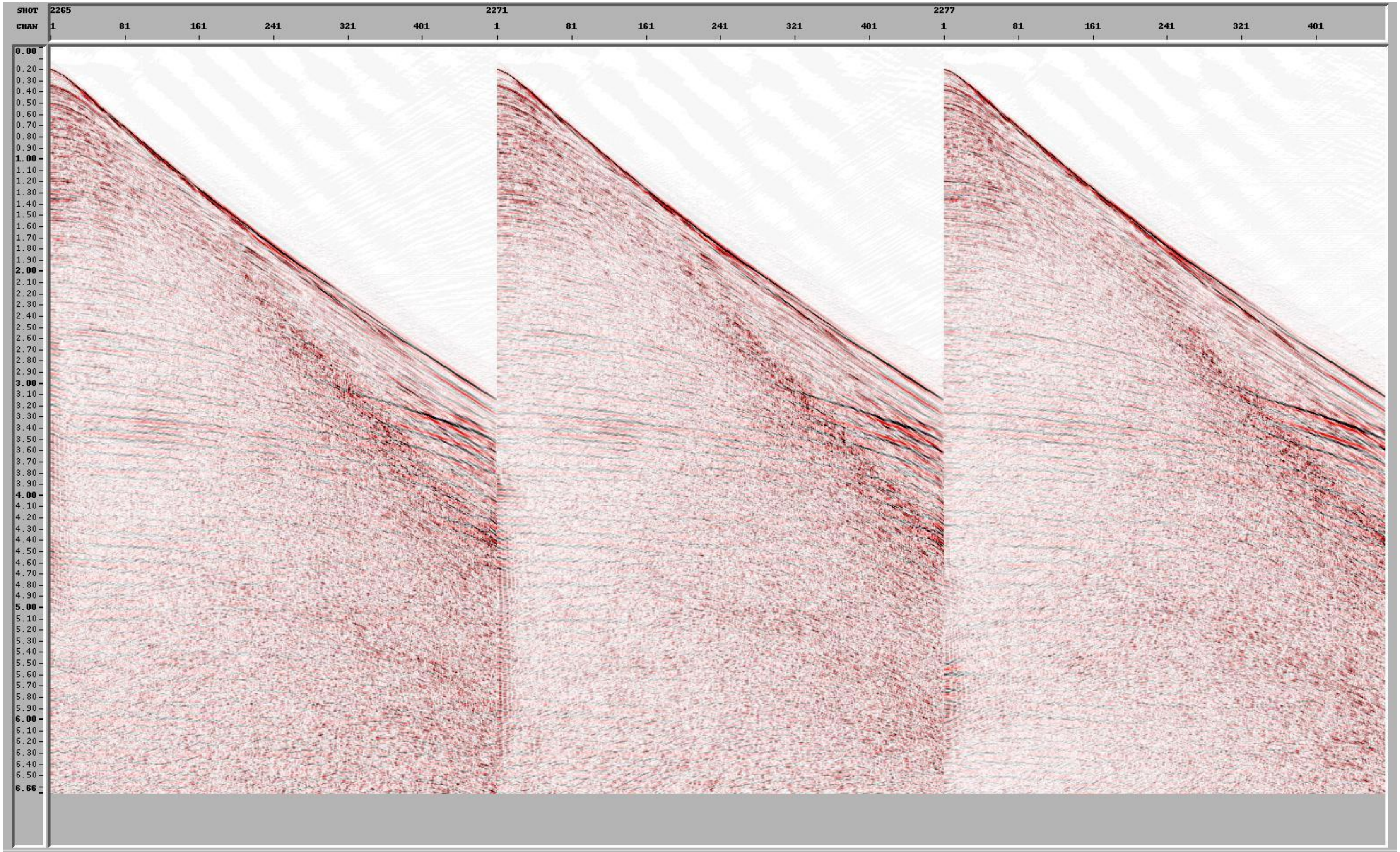
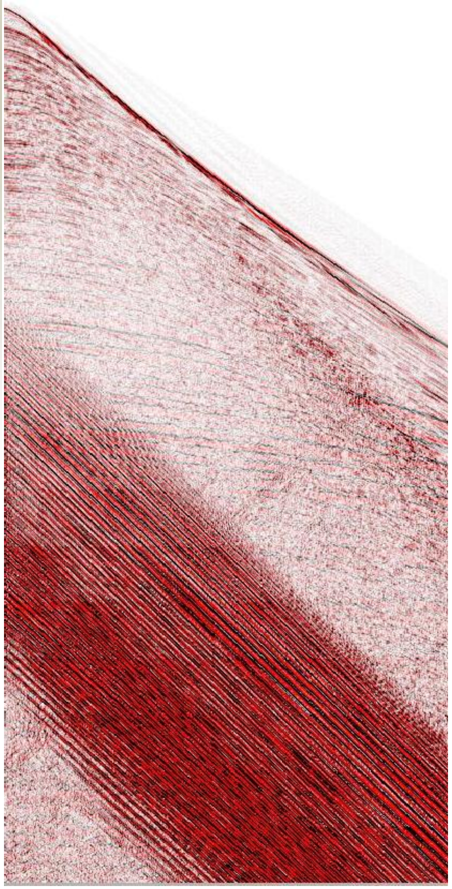
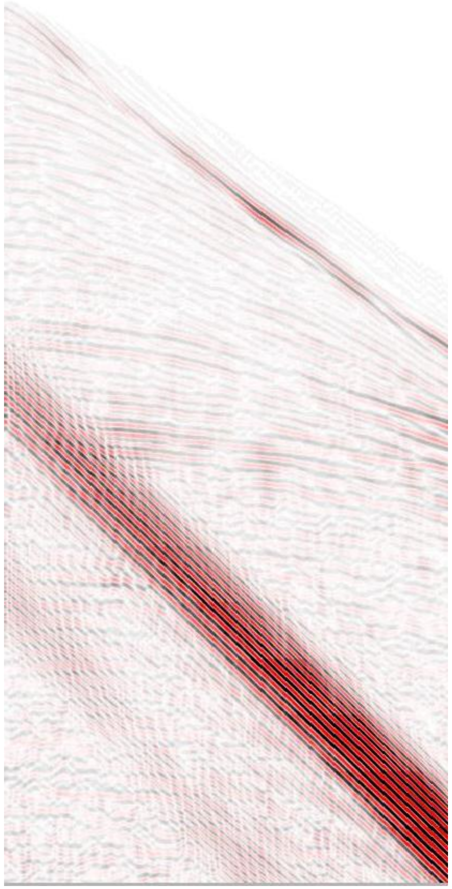


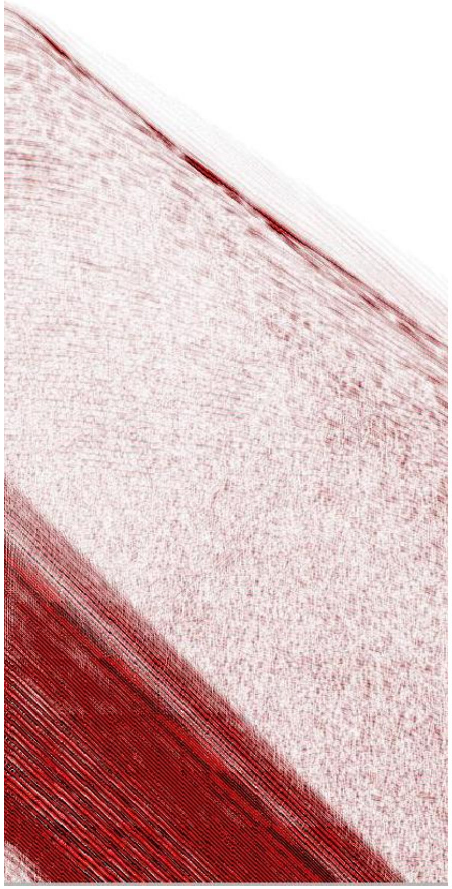
Before SI removal



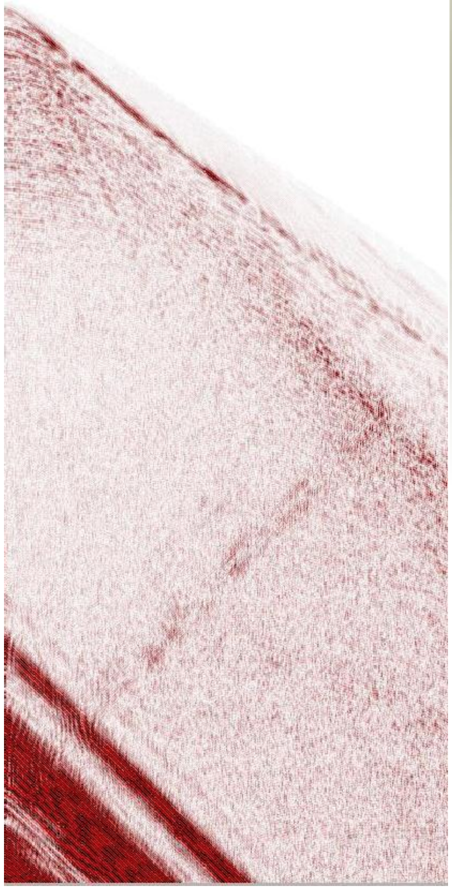
0-125Hz



0-15Hz

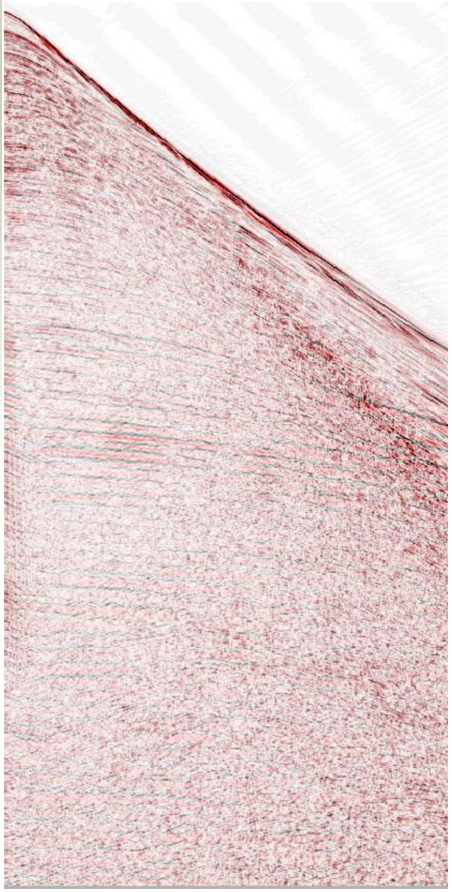


15-40Hz

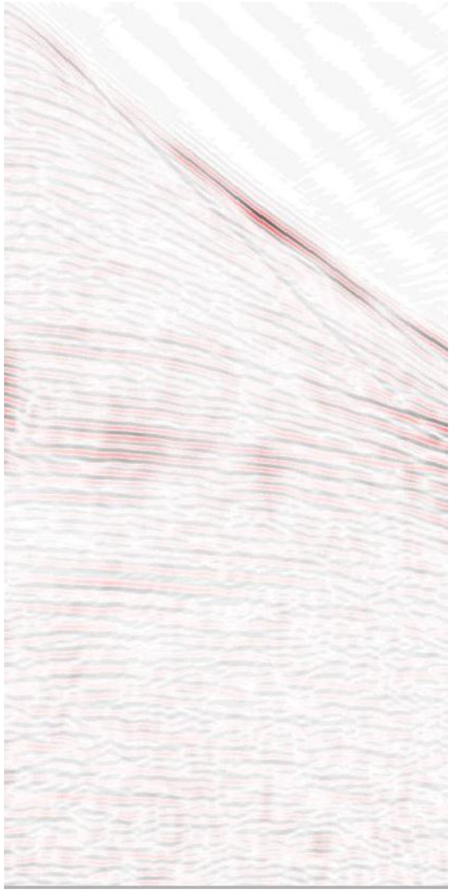


40-125Hz

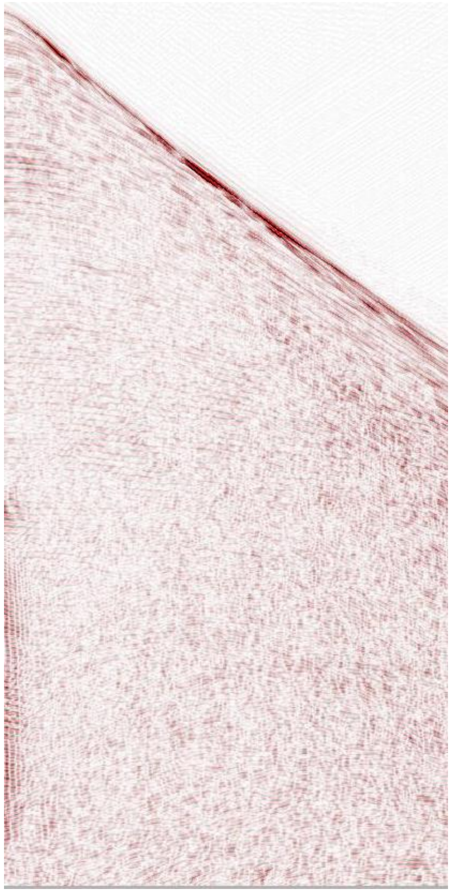
After SI removal



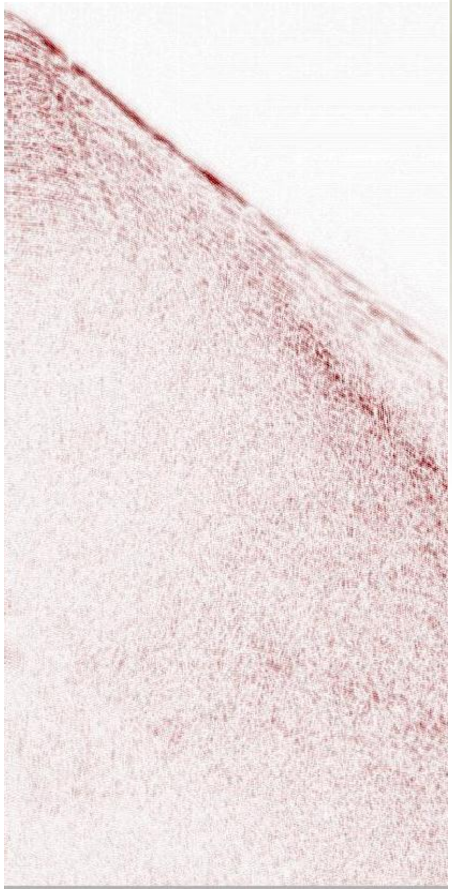
0-125Hz



0-15Hz



15-40Hz



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A real field trial of Seismic Interference

1. Pre-study – Demonstrate the SI removal toolbox – and define a plan and procedure including a set processing flow for on-board-processing to evaluate and eliminate SI

2. Field trial – Shoot one single full sail line of data with and without SI and prove you can remove the SI to an acceptable limit – is there a limit – and what is that limit – microbars/distance/direction – define the SI acceptance criteria for the rest of the survey

3. Shoot two large commercial seismic surveys “on top of each other” using the new acceptability criteria and on-board processing SI removal flows – whilst minimizing the need for time-sharing

Shoot more – wait less – save money

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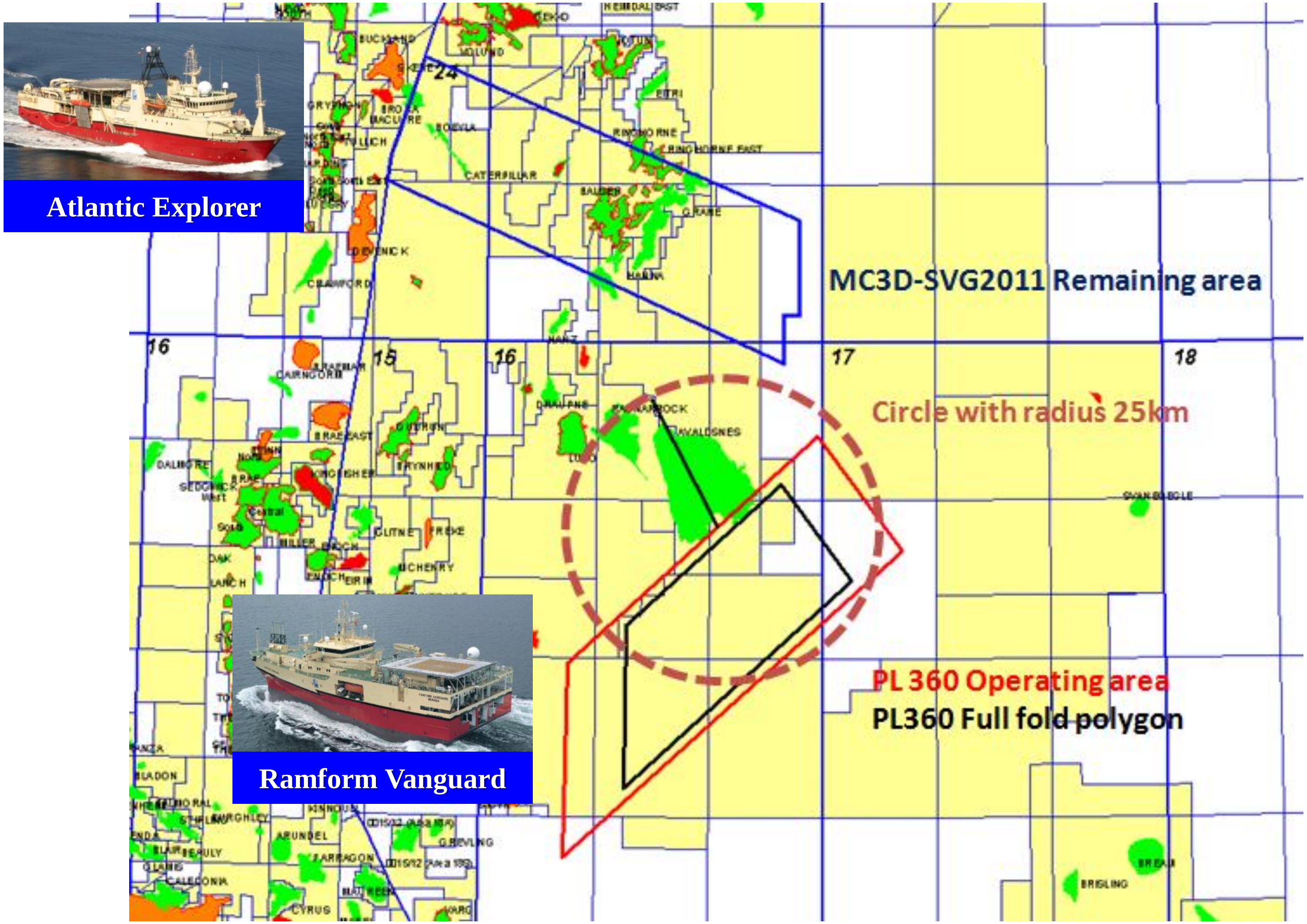
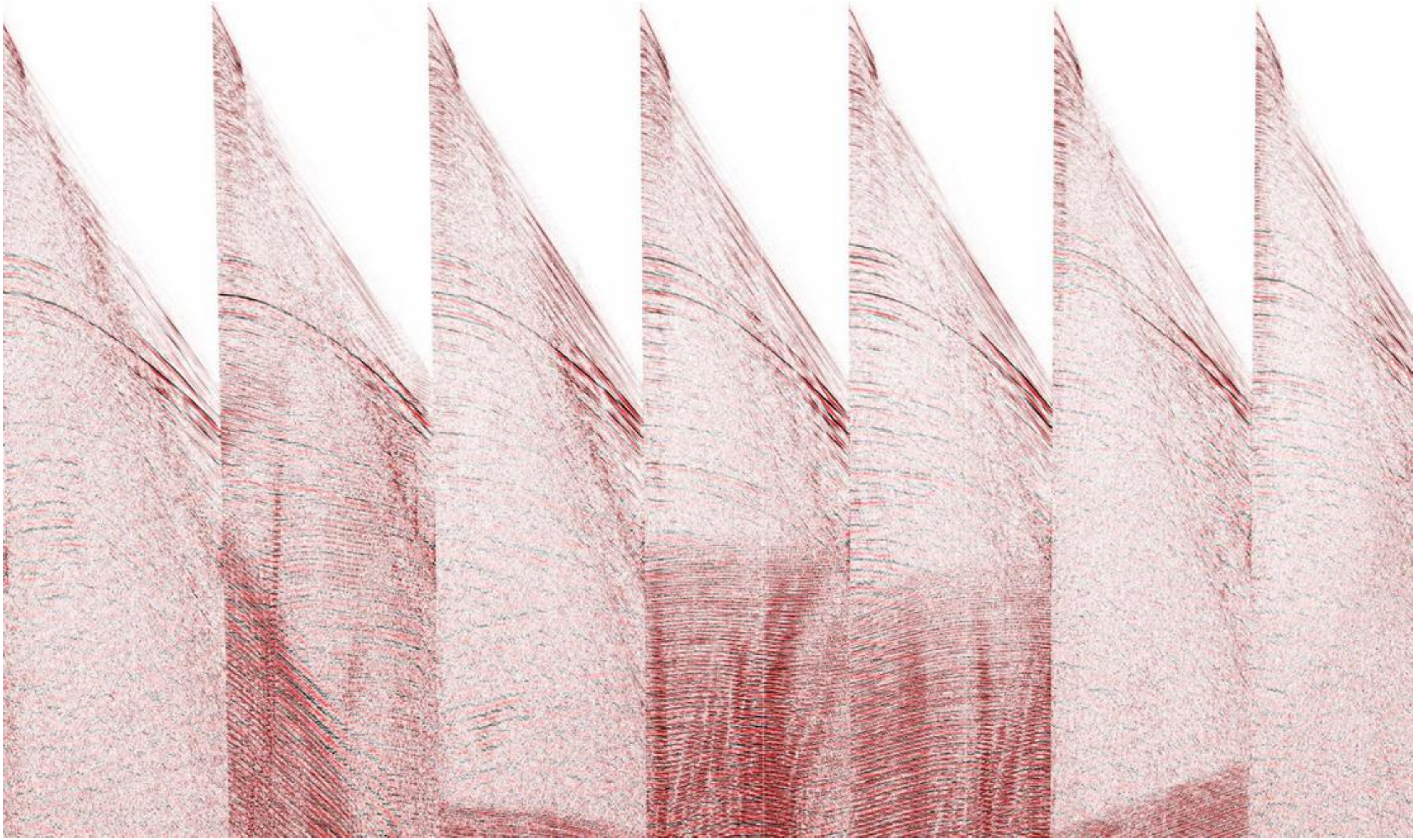
The field trial – location – North Sea



PL360 Lupin West and MC3D-SVG2011

Pre-study – MC3D-NVG2010 – Input data



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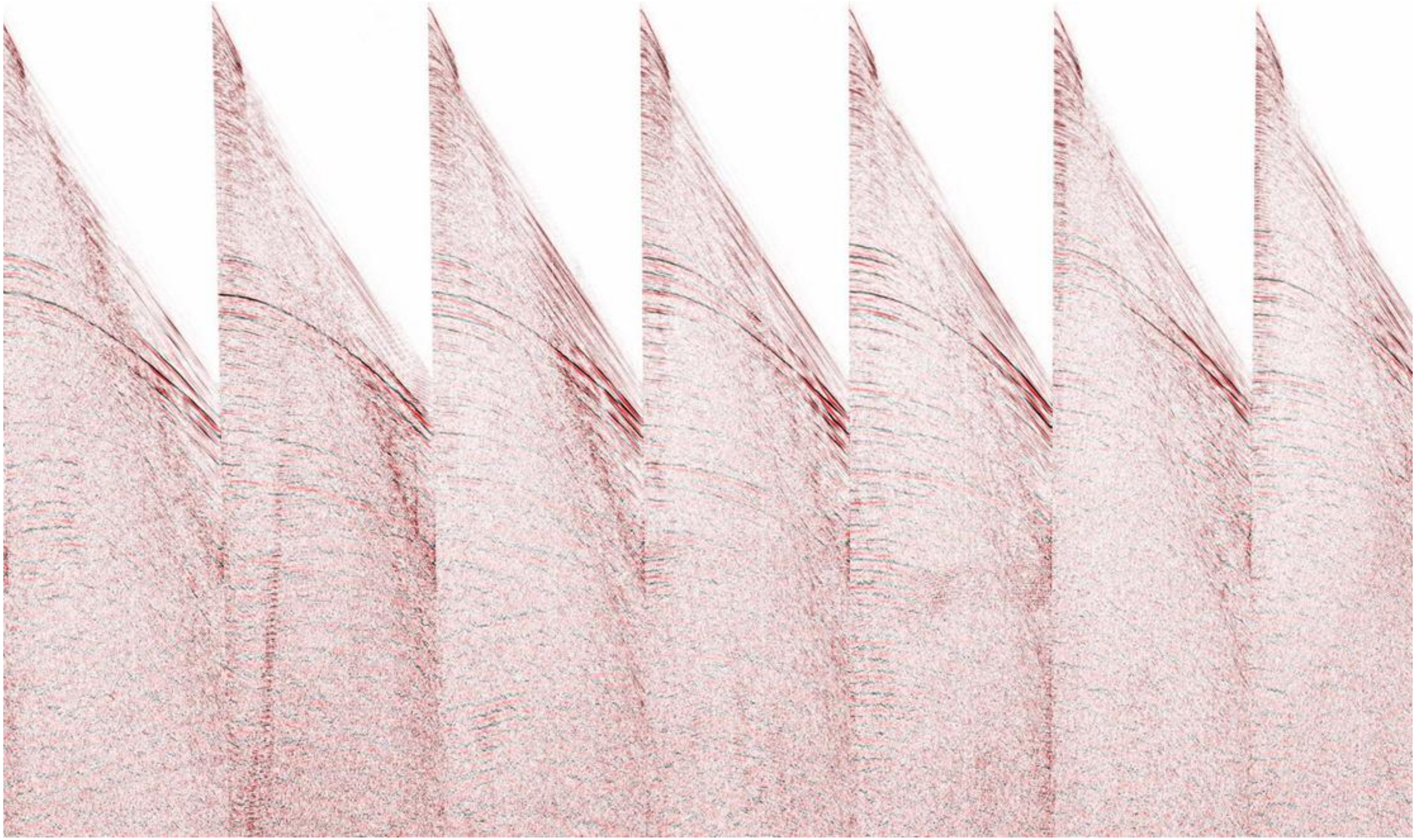
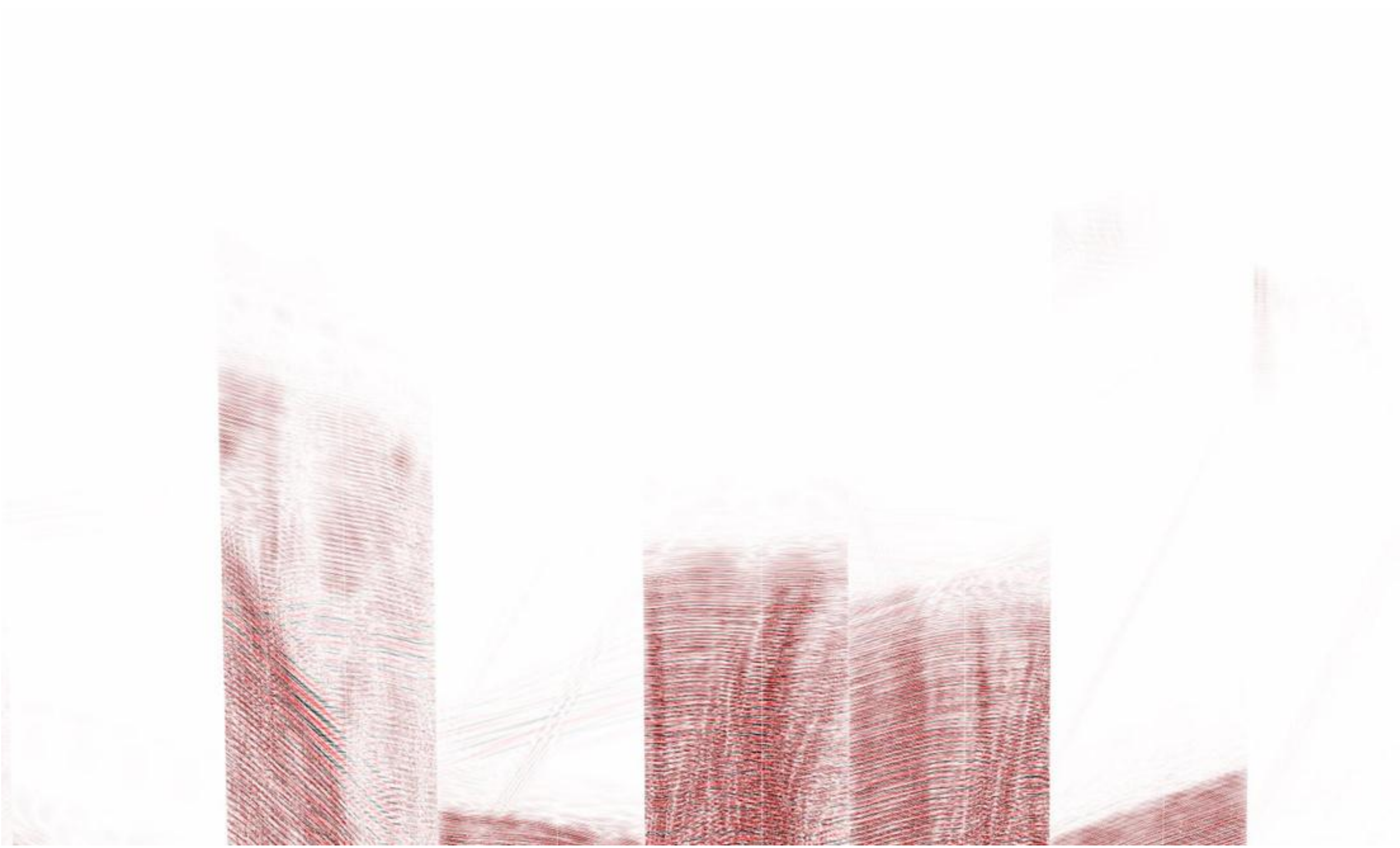
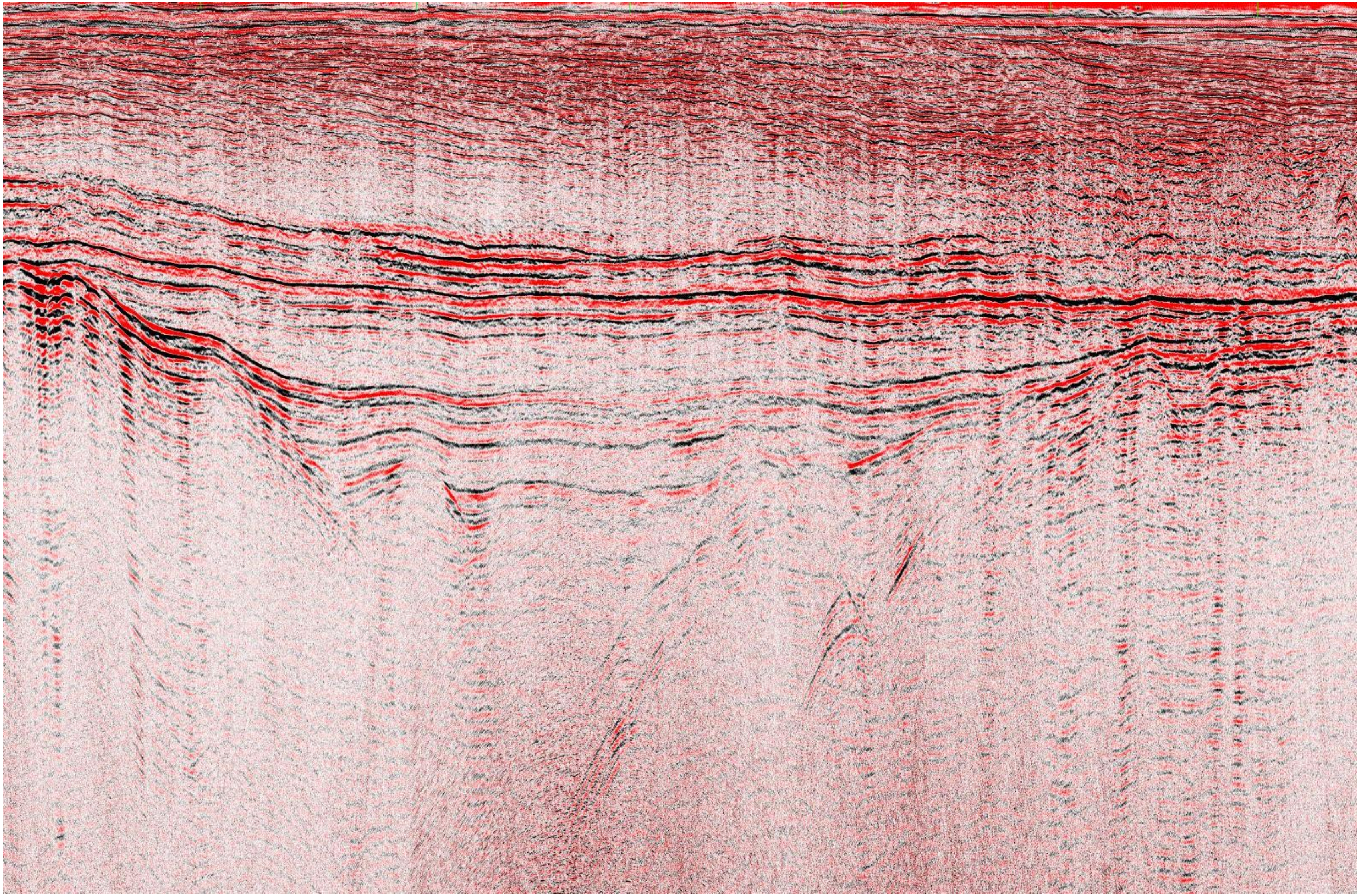


Pre-study – MC3D-NVG2010 – Difference plot



Pre-study – MC3D-NVG2010 – Input data



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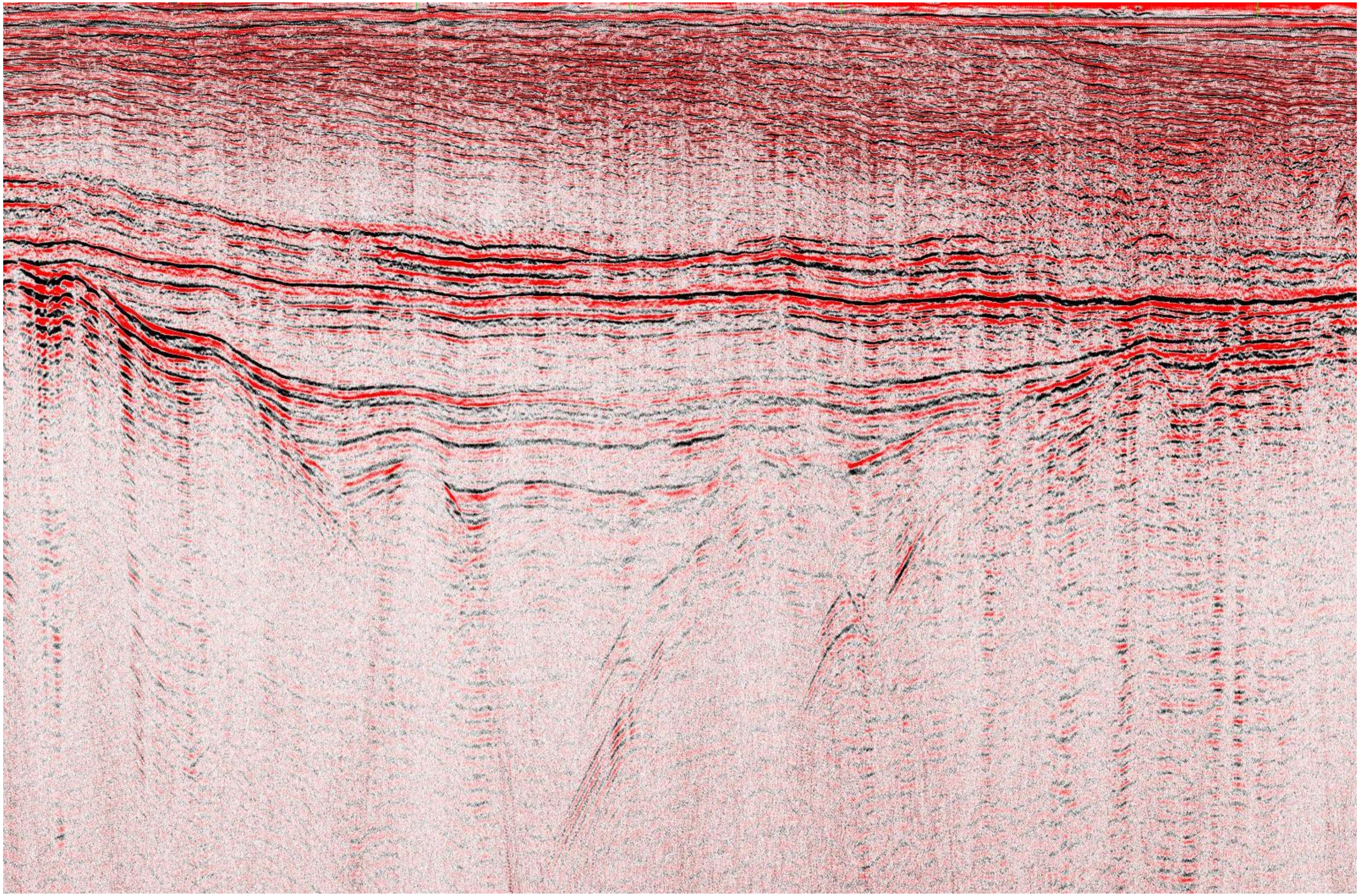

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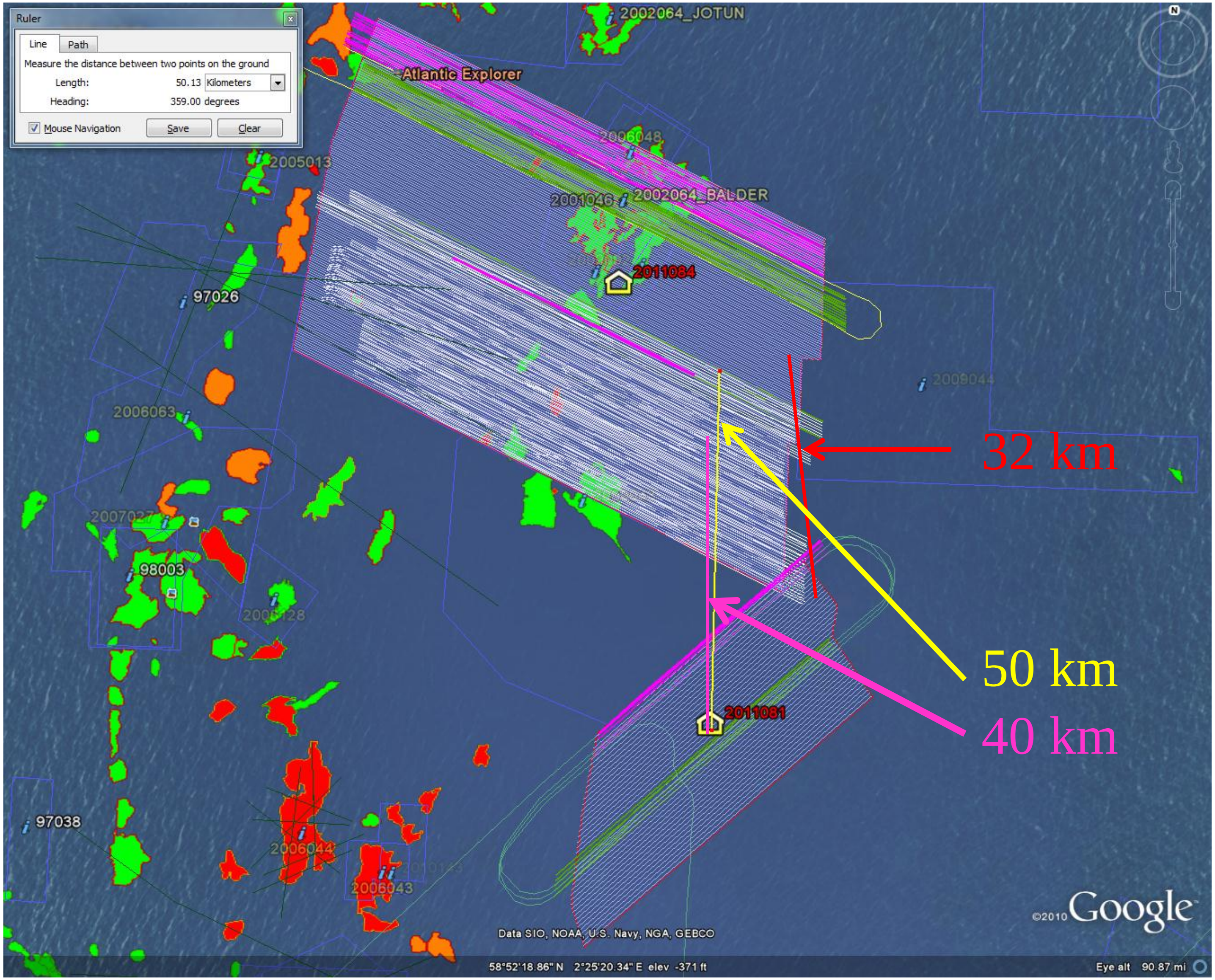
Distances 50, 40 and 32 km

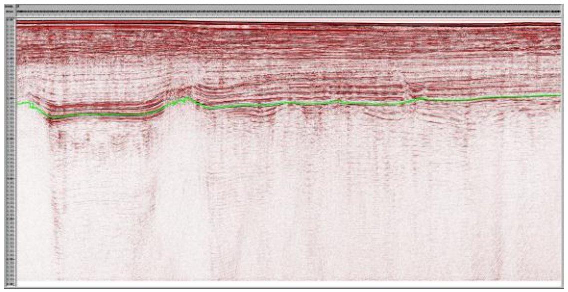
50km min distance:
Time-share, maybe not 100%, but close

40km min distance.
Limited amount of time-sharing, if good forward planning is in place to optimize each line between the 2 vessels.

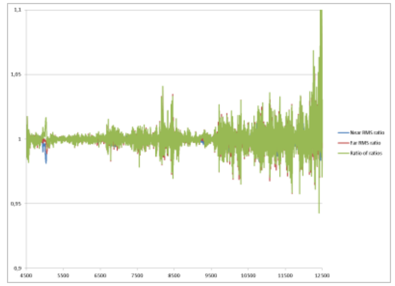
32km min distance:
Both vessels could more or less shoot unaffected by each other.



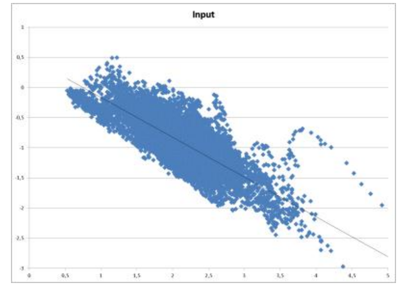
Field trial – attribute plots



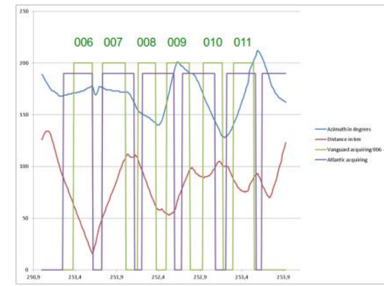
Full offset stack – pick horizon



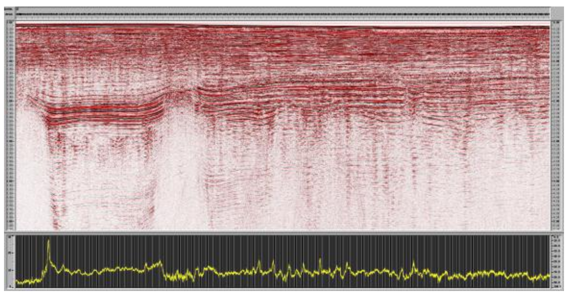
Ratio of ratio RMS in/out



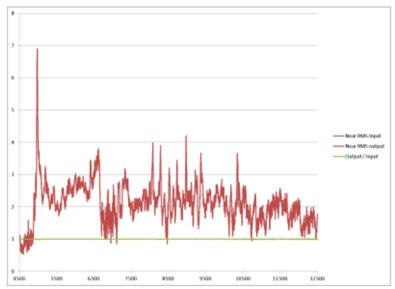
X-plot near vs. far before SI



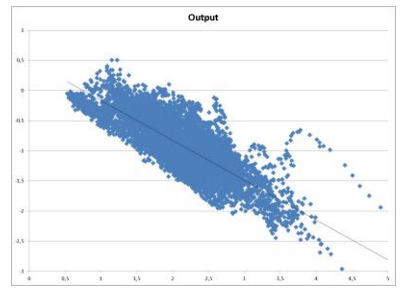
Distance & azimuth



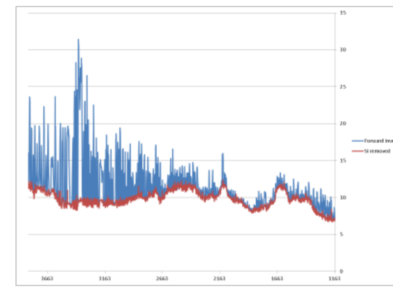
Near offset stack – RMS / SI



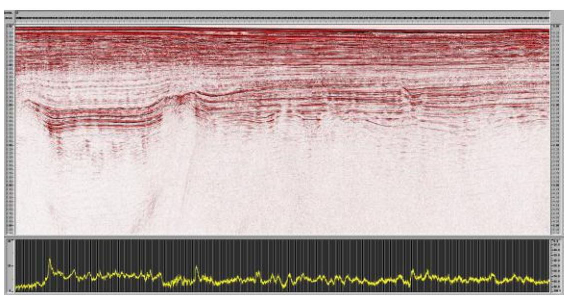
Near RMS in/out & ratio



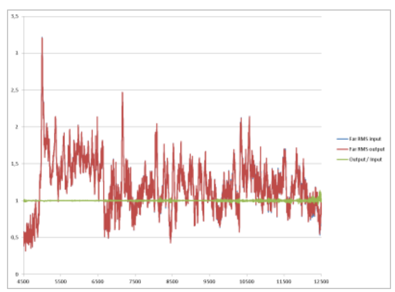
X-plot near vs. far after SI



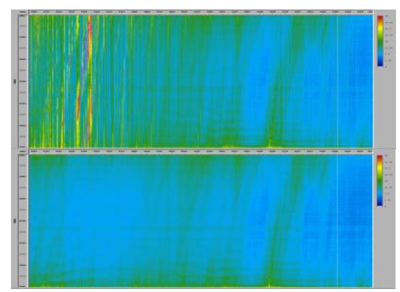
Deep window RMS bef/aft



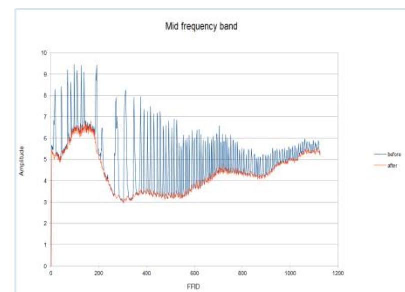
Far offset stack – RMS / SI



Far RMS in/out & ratio

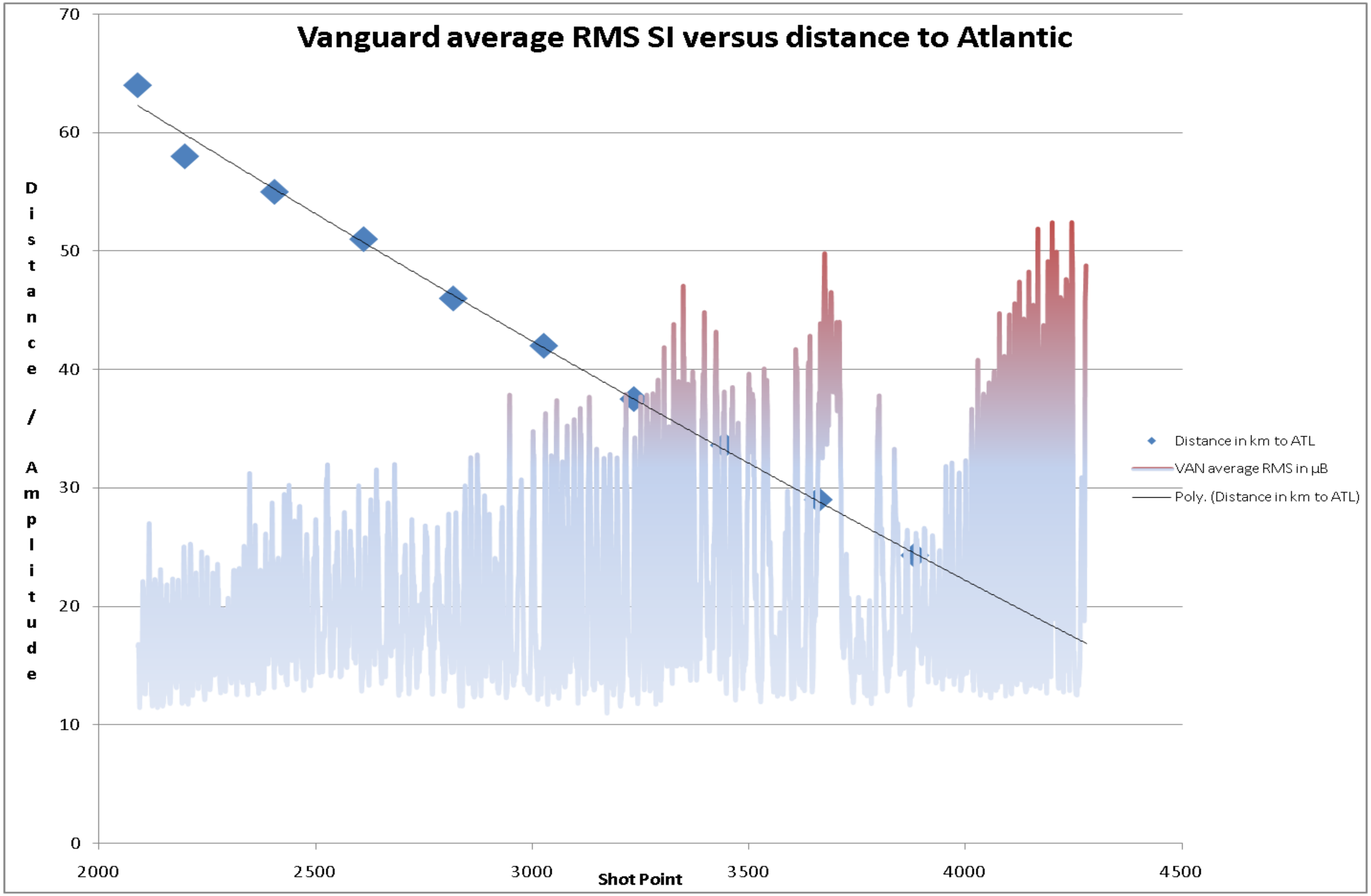


Deep window RMS bef/aft



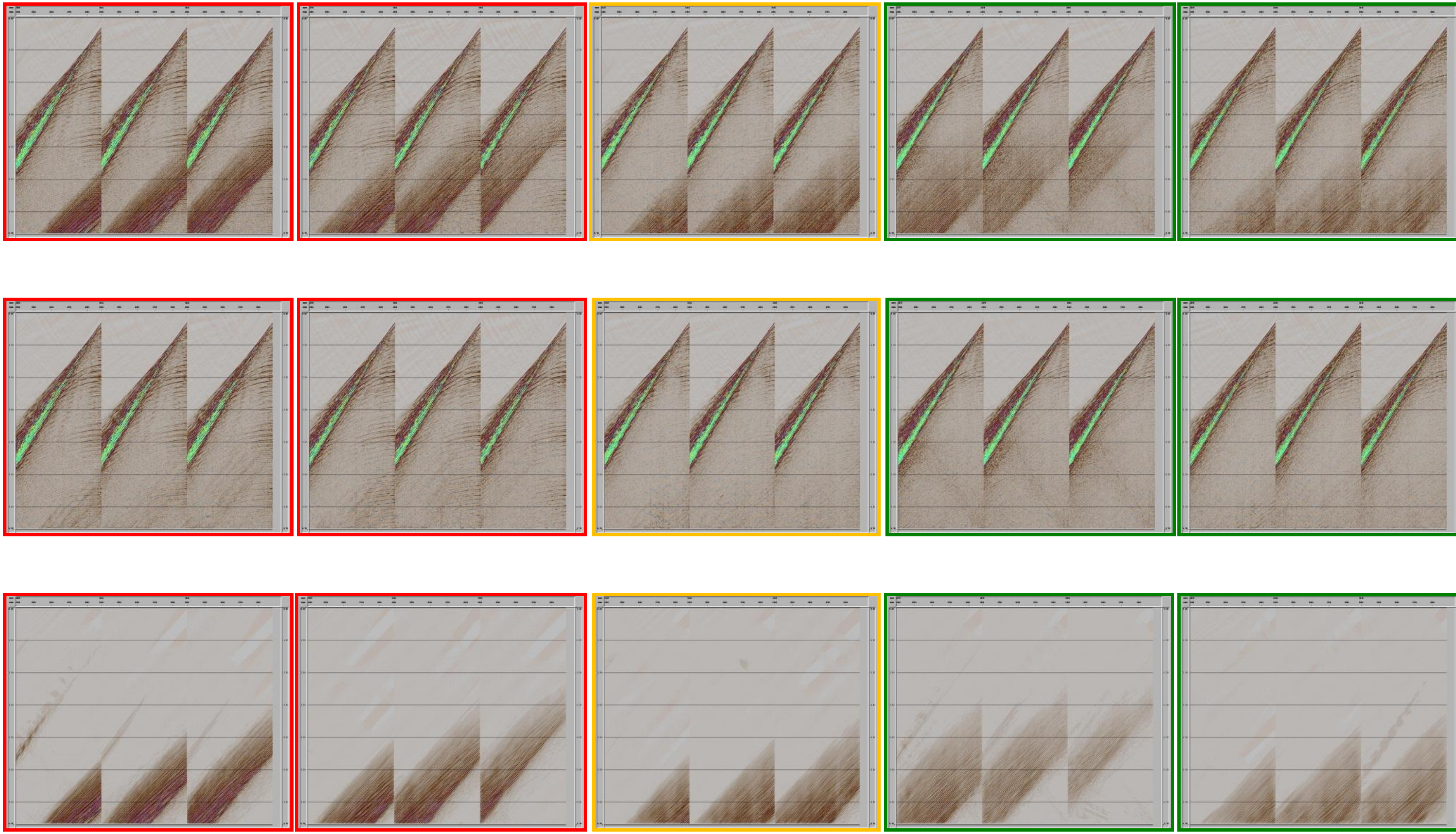
Mid frequency amp bef/aft

RMS SI levels vs. distance between vessels



Seismic Interference vs. distance between vessels

30km | 35km | 40km | 45km | 50km



Too strong

Acceptable

We agreed 40-50km would be conservative and acceptable

Low levels

A real field trial of Seismic Interference

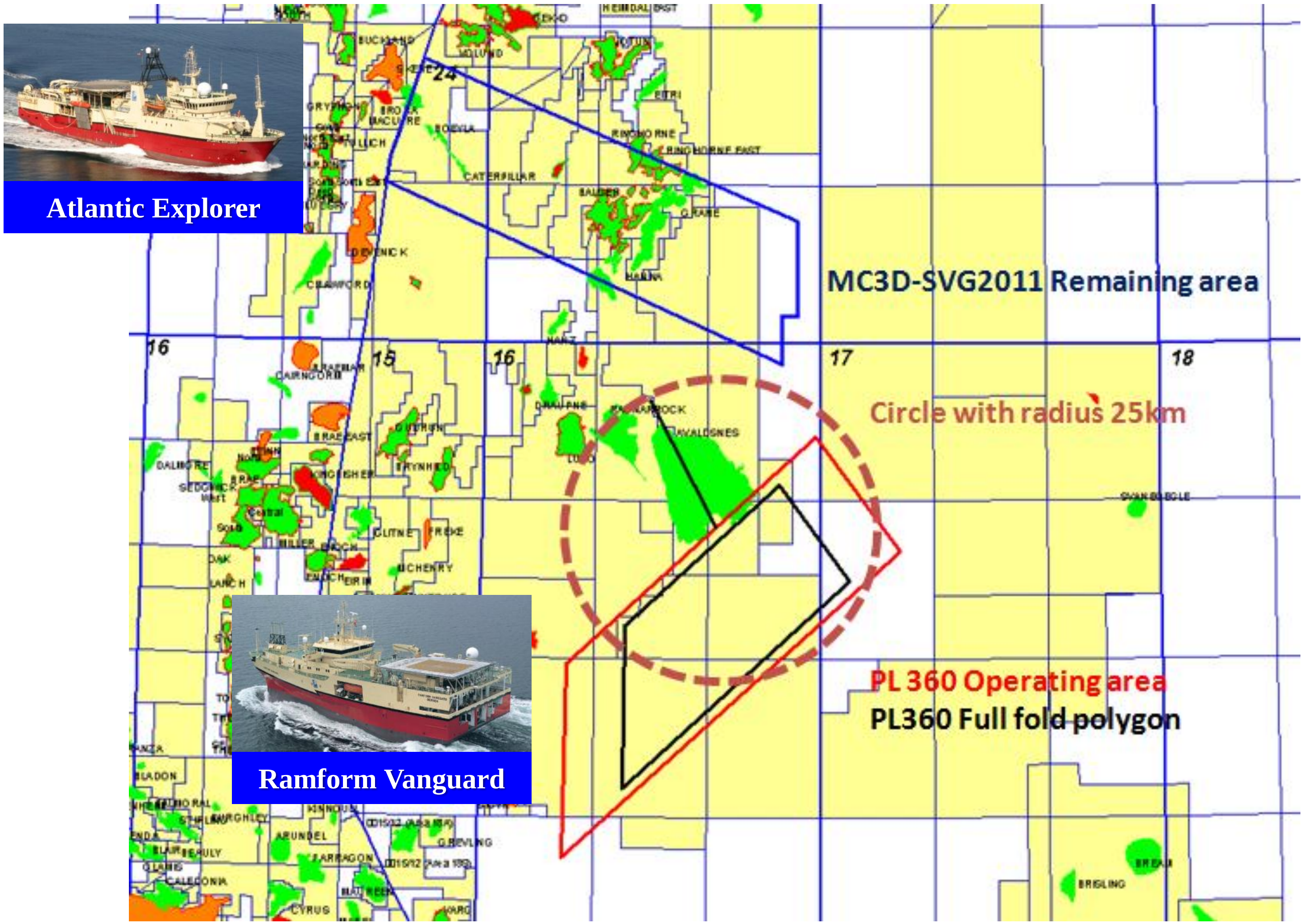
1. Pre-study – Demonstrate the SI removal toolbox – and define a plan and procedure including a set processing flow for on-board-processing to evaluate and eliminate SI

2. Field trial – Shoot one single full sail line of data with and without SI and prove you can remove the SI to an acceptable limit – is there a limit – and what is that limit – microbars/distance/direction – define the SI acceptance criteria for the rest of the survey

3. Shoot two large commercial seismic surveys "on top of each other" using the new acceptability criteria and on-board processing SI removal flows – whilst minimizing the need for time-sharing

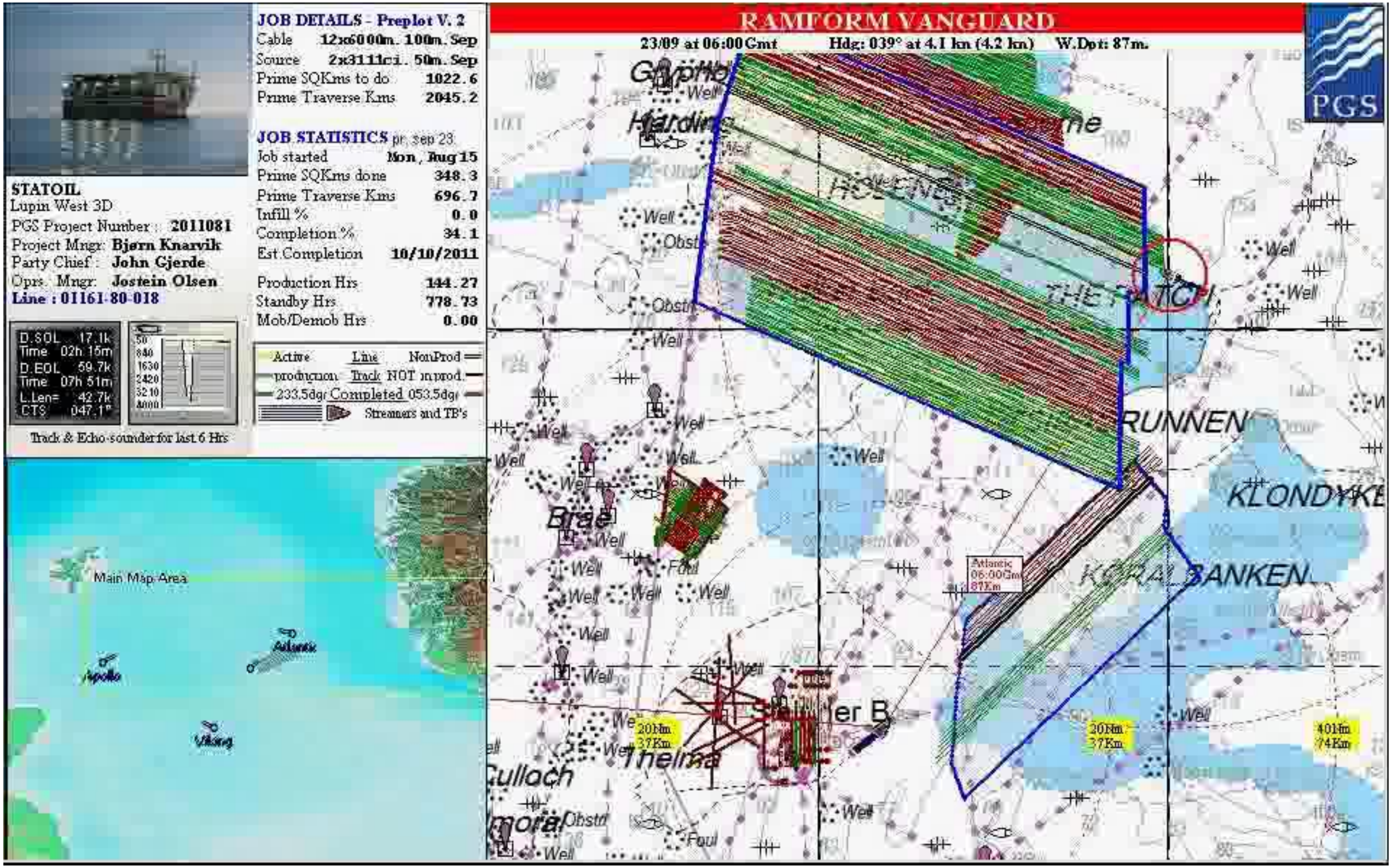
Shoot more – wait less – save money

Shooting two surveys with min. distance ~20km



PL360 Lupin West and MC3D-SVG2011

Video of how the two vessels optimized production



This is a 2min video: Click on the picture to start the video.

Outline

- Introduction – How large is the SI challenge in the North Sea?
- Method for removal of seismic interference
- Case study of SI
- Conclusions & recommendations

Conclusions & recommendations (1 of 3)

- The “Tau-P common-P” SI removal technique has been demonstrated to work very efficiently
- The method uses no a-priori information and can handle SI from several vessels at the same time
- There are some pitfalls in the flow (aliasing/wraparound/swell noise) – that must be avoided – and good QC is essential
- The method is capable of removing very large amounts of SI – but will reach a point when we can no longer recover the underlying signal
- From the case study we are able to demonstrate that the SI and SI removal has no discernible effect on attributes of the data, such as near vs. far – high vs. low frequency etc.
- From the case study we found that direction had little impact on the SI removal – as expected from the modeling (limited exposure)
- We also found that distance and microbars is an effective measure for planning and steering the seismic operations to minimize the impact of SI and time-sharing

Conclusions & recommendations (2 of 3)

- A pre-study in close collaboration with the clients is highly recommended. This will sharpen all pencils.
- Random swell noise removal is a pre-requisite for the tau-p common p flow to work. High amplitude low frequency bursts will smear in the tau-p domain and cause artifacts and wraparound effects.
- You are able to remove quite large amounts of SI without degrading the overall quality of your seismic data.
- Timing is crucial for line acceptance – therefore you need pre-defined workflows and highly skilled OBP staff to run them and also to generate material that can be used to make the final call. Consider having extra on-shore staff to assist the OBP teams during the SI QC process.

Conclusions & recommendations (3 of 3)

- This SI project was a success:
  - Two surveys acquired almost simultaneously in close proximity
  - SI removal and OBP line acceptance kept up with production
  - Reduced distance between vessels from ~70km down to ~40km (40μbar)
  - 5 weeks simultaneous acquisition incurred only 8 hours of SI standby time
  - Saved 3-4 days production time for both vessels
  - Experience from production processing of PL360 was that there were challenges especially with swell and SI. Both were handled successfully and data result is of very good quality. Removal of swell noise was very important for removal of SI
  - Method will be used for further surveys where SI may be a challenge

Acknowledgment

- FORCE group for inviting me to present the work
- Statoil and PGS for permission to publish this work
- My co-authors for all their valuable help and input
- Liw and Taha onboard the vessels for testing all the SI removal flows
- Terje for his vessel monitoring
- Magnus for the SI modeling work
- A lot of hard working people in Data Processing for coming up with new “cool” tools to effectively remove Seismic Interference