



4D signal retrieval at Ula in the presence of severe SI – a case study

R.Milne (BP) J.Khan (CGGVeritas)

Outline



- Survey background
- SI characterization
- SI detection and removal
- 4D Results
- Ignore SI?
- Recommendations

Background



Background

Noise
Characterisation

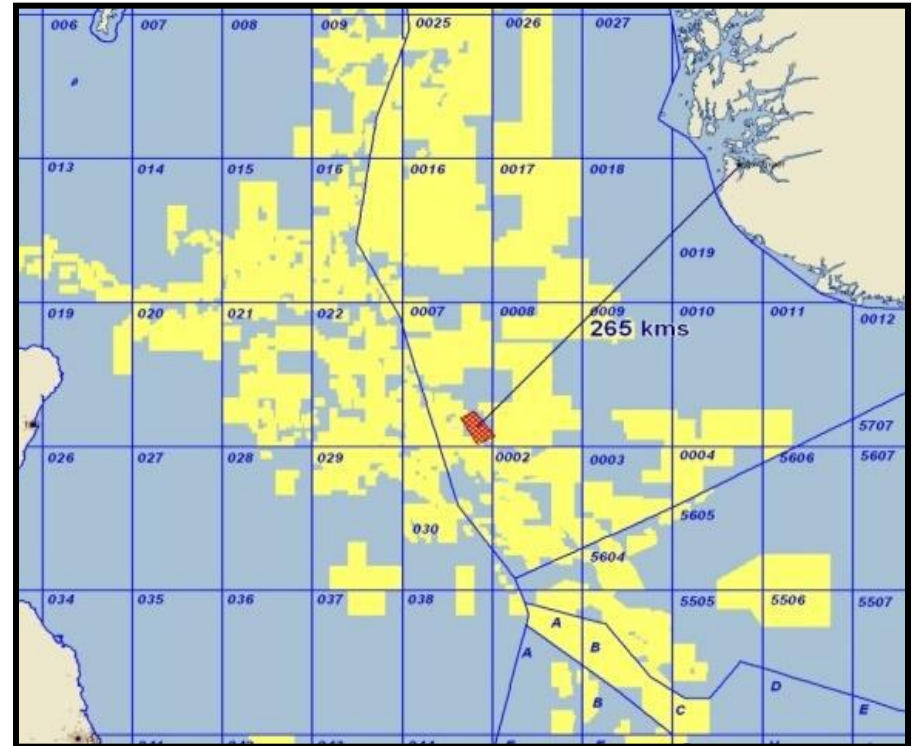
SI removal

4D Results

Ignore SI?

Summary

- Oil since 1986, WAG since 1998
- New 4D monitor in 2011, to match 1999 base
- Previous 4D in 2002
- Modelling predicts weak 4D
- Conservative noise acceptance limits for 2011 survey
- 2011 survey contaminated with severe S.I.
- Insight into impact of S.I.



Ula 2011 survey location

Ula 2011 survey



Background

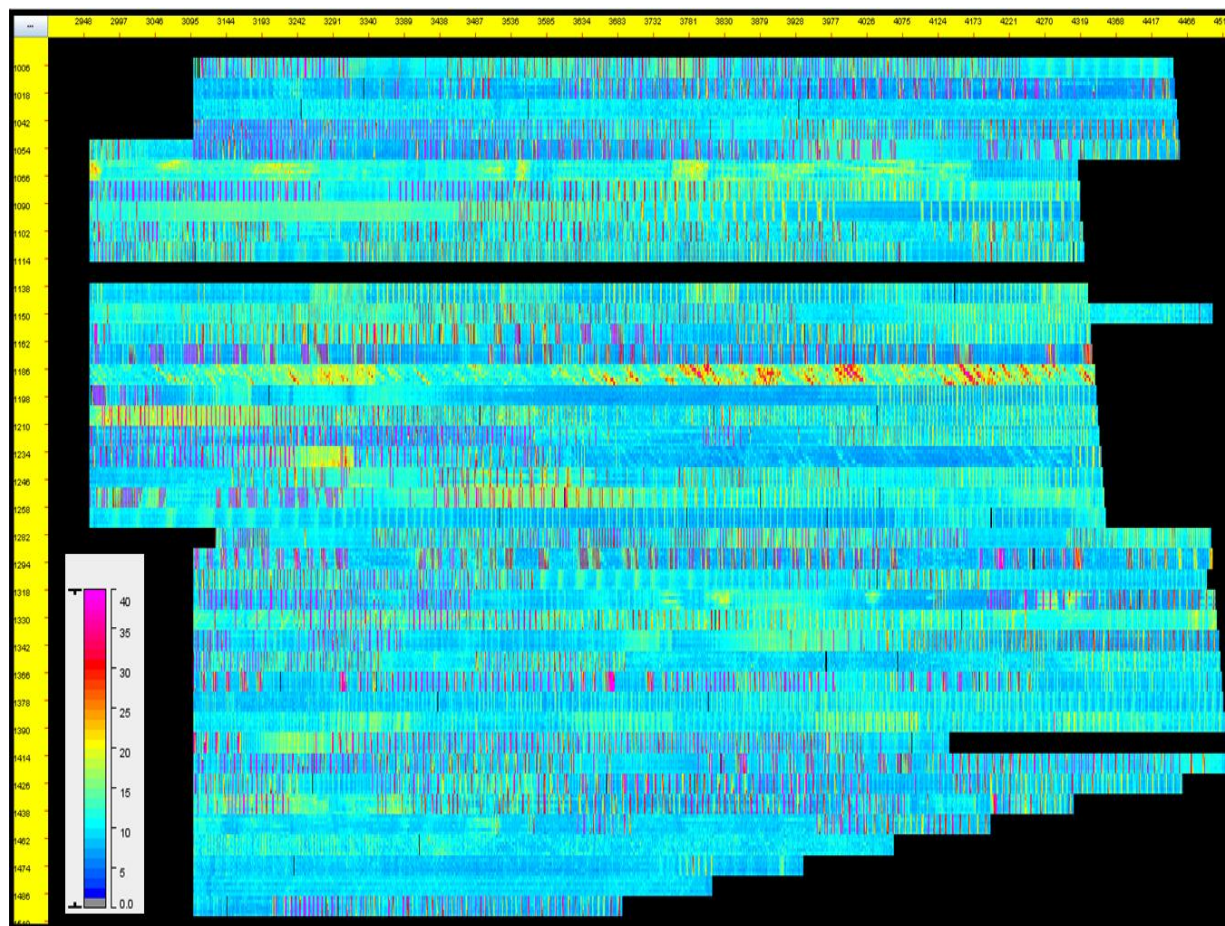
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



Sail-line RMS map, full window

- 83 sequences
- Only 8 unaffected
- S.I. near continuous for affected lines
- Typically 50-100 μ bar
- All affected lines exceeded pre-survey S.I. acceptance limits



- 4 main criteria
 - Synchronisation of interfering surveys, determined by shot intervals
 - Arrival window of noise; timing and duration
 - Relative move-out, determined by position of interfering source relative to receiving streamers
 - RMS noise level (Microbars)

Ula 2011 SI classification – ASTERN



Background

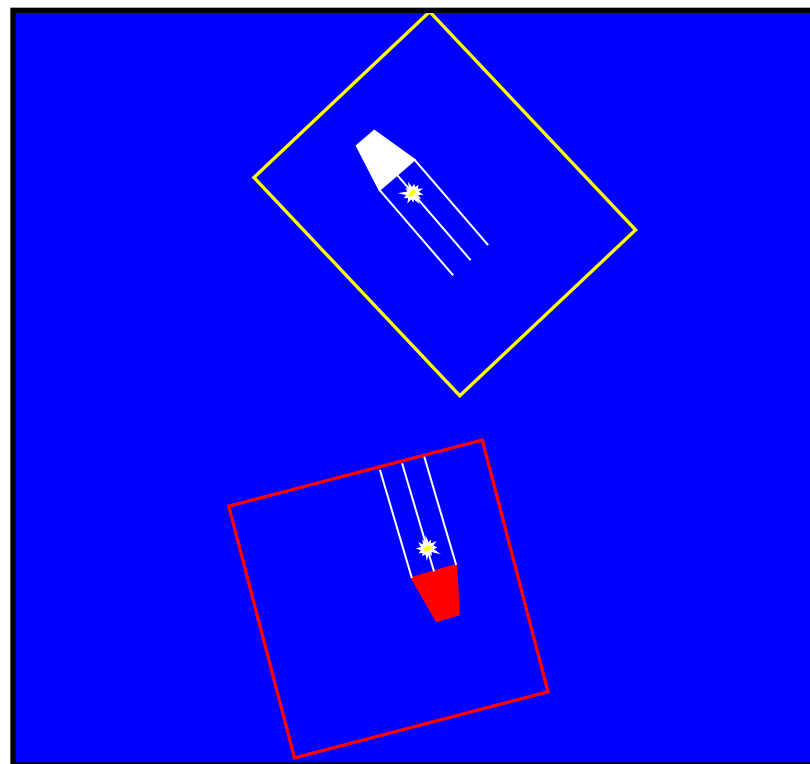
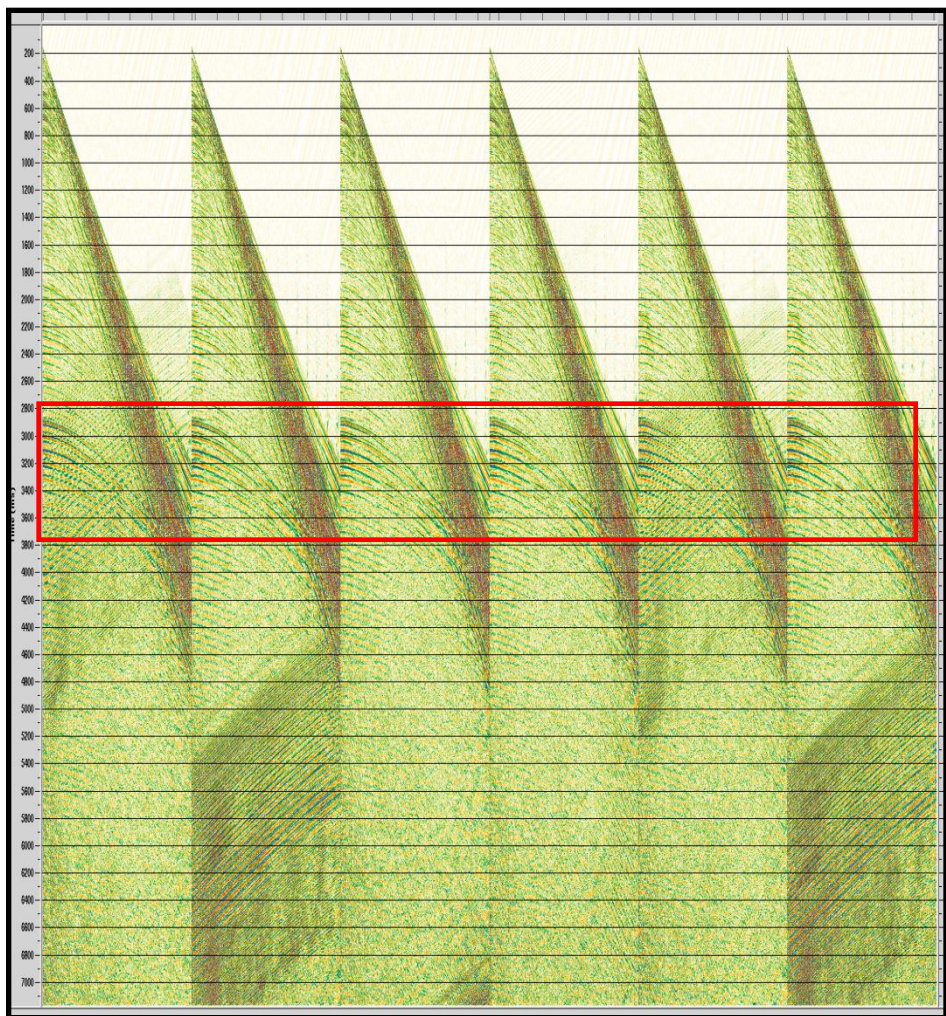
Noise
Characterization

SI removal

4D Results

Ignore SI?

Summary



Reservoir window

Ula SI classification – AHEAD



Background

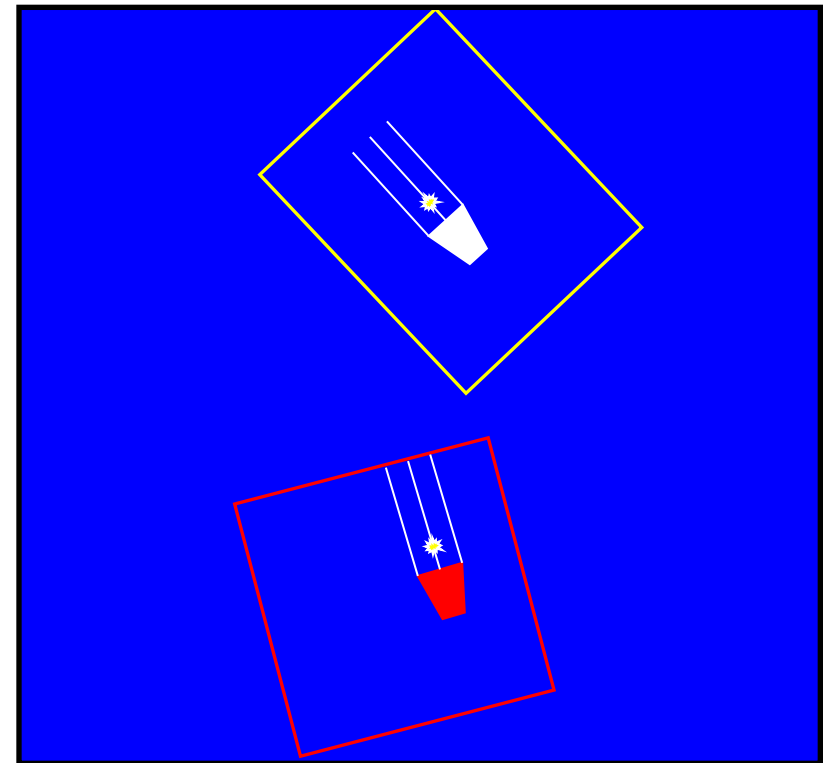
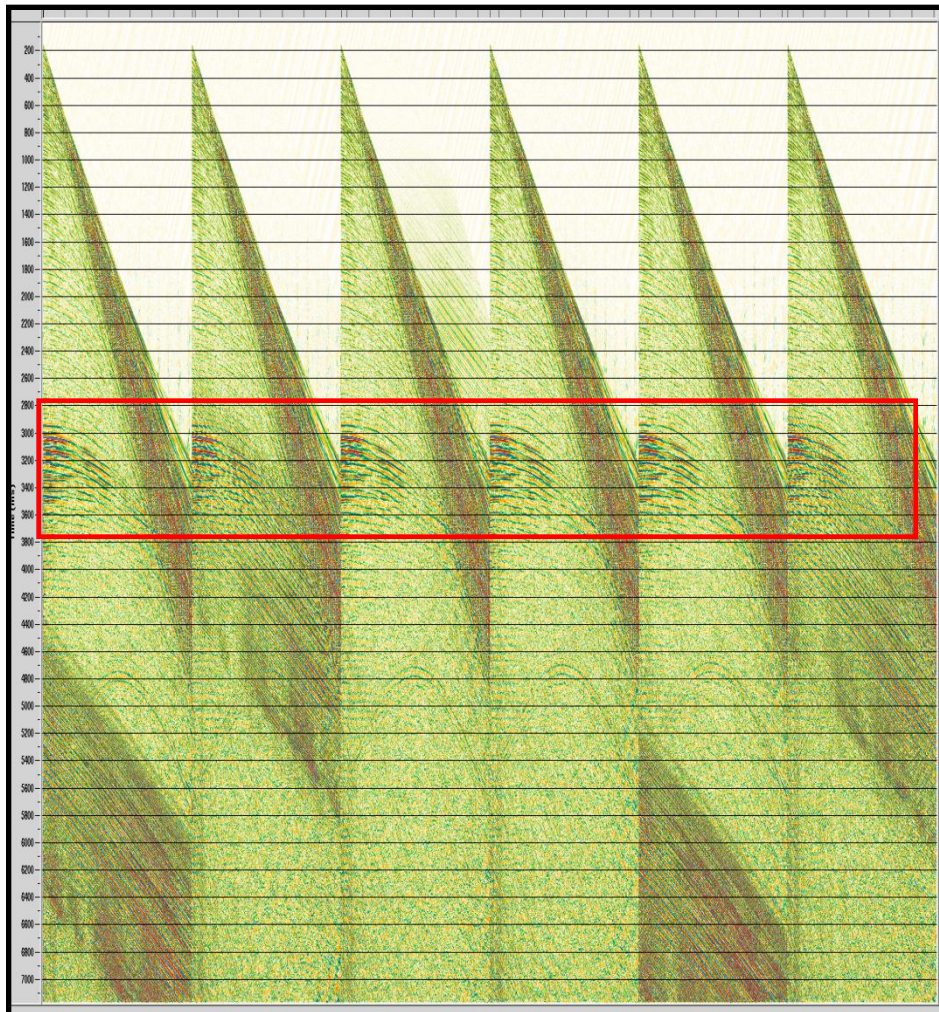
Noise
Characterization

SI removal

4D Results

Ignore SI?

Summary



Reservoir window

Ula 2011 SI classification – ABEAM



Background

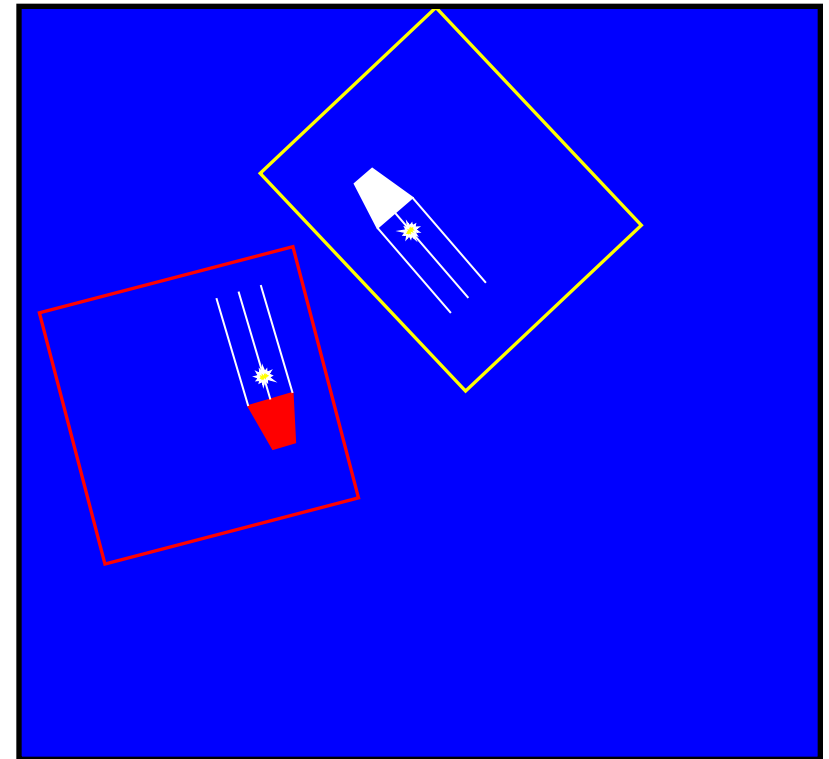
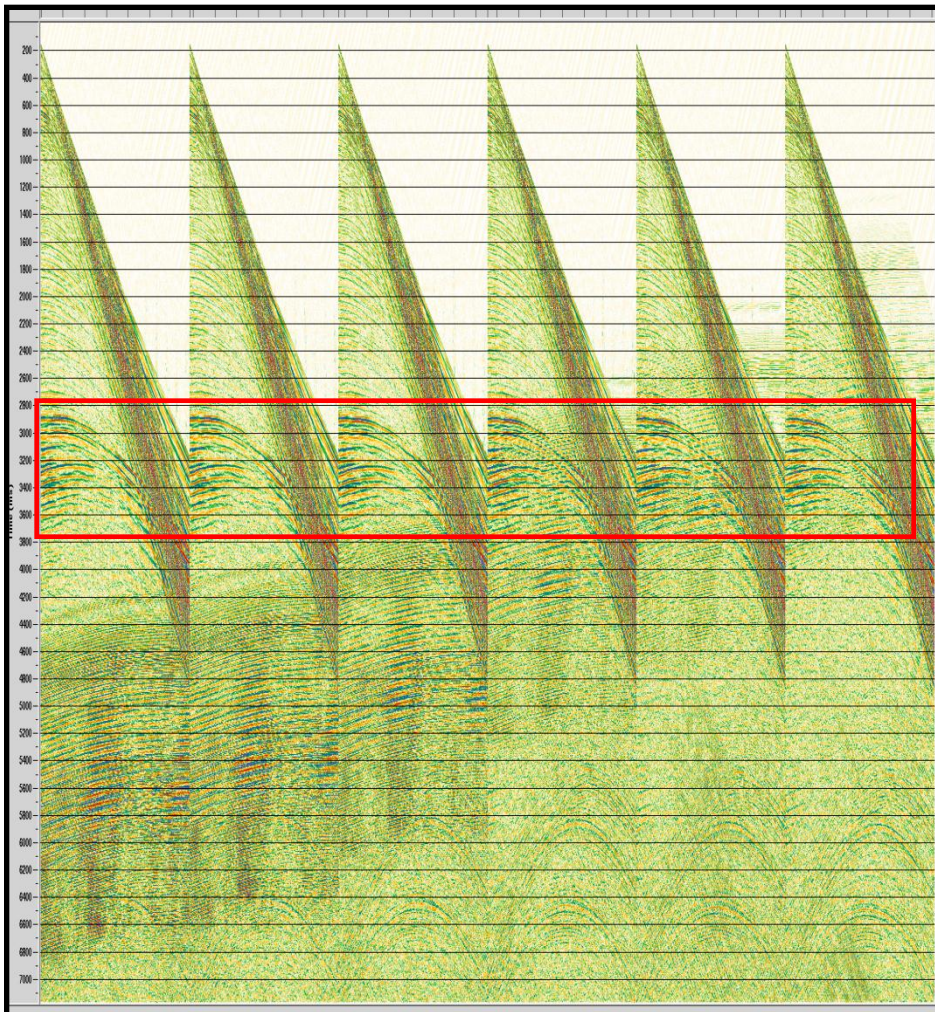
Noise
Characterization

SI removal

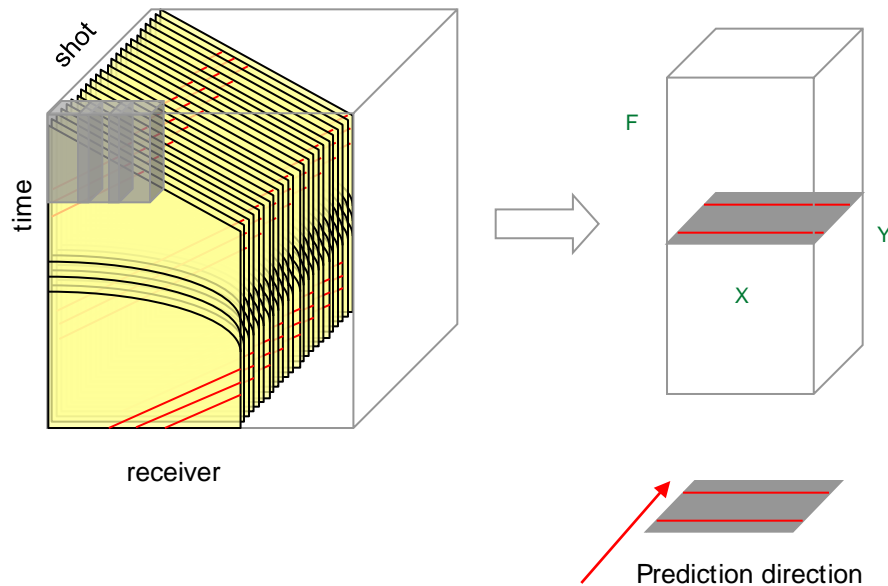
4D Results

Ignore SI?

Summary



Reservoir window



Entire cube

Subset for
processing in FXY

- Exploits randomness of interference in common channel direction
- Small overlapping cubes transformed to FXY domain
- Analysis on frequency slices
- Noise is detected using amplitude analysis on frequency slices
- Noisy samples are first killed with plane wave killer in common shot direction and then are replaced with predicted values through FX spatial prediction filters in common channel direction.

Reference: Gulunay, N., Magesan, M. and Baldock, S., 2004. Seismic interference noise attenuation. S.E.G. 74th Ann. Internat. Mtg., Expanded abstracts

Tau-p domain application - AHEAD



Background

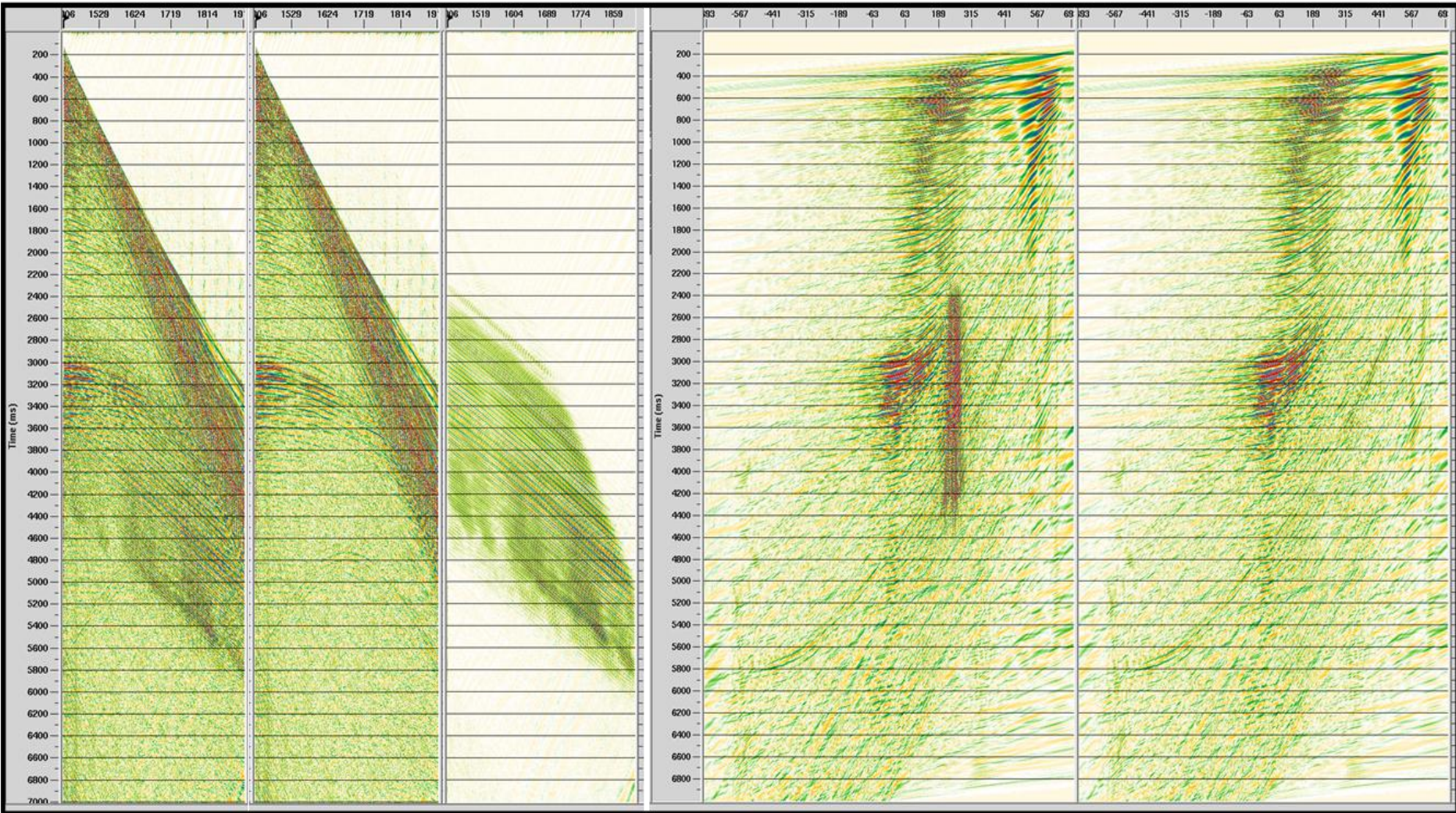
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



Tau-p domain application - ASTERN



Background

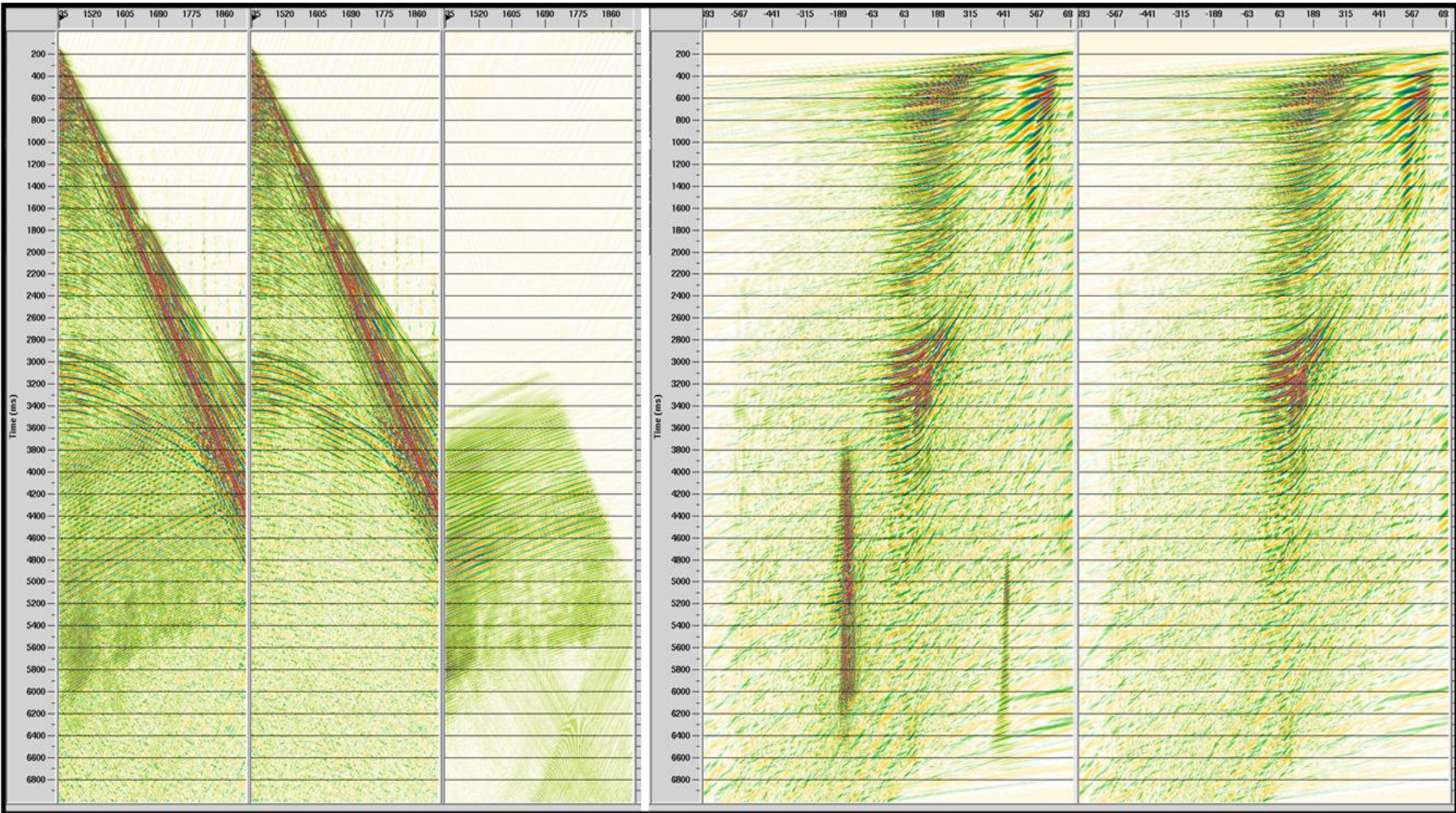
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



SI attenuation – common channel QC



Background

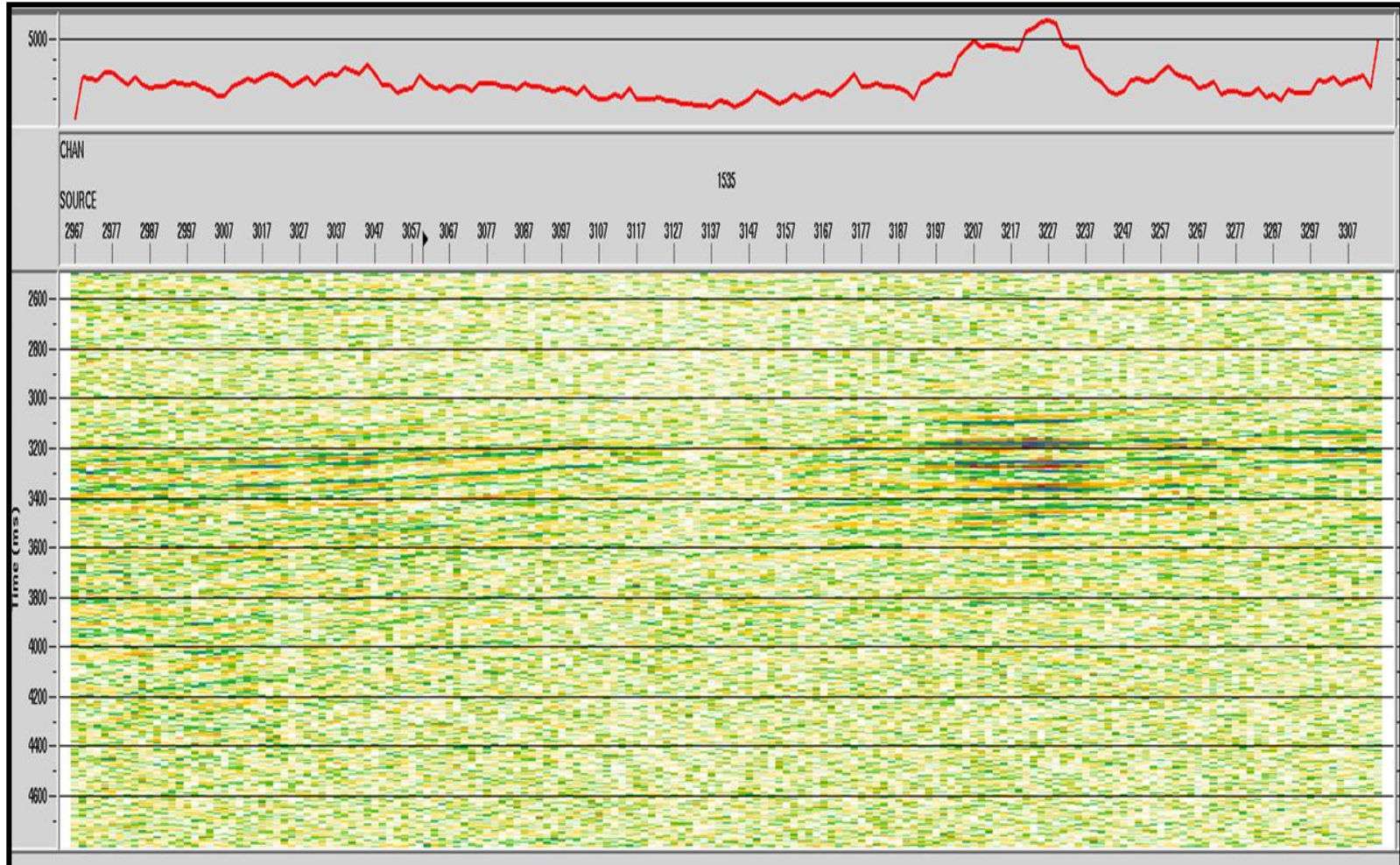
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



SI attenuation – Shot vs Channel RMS maps



Background

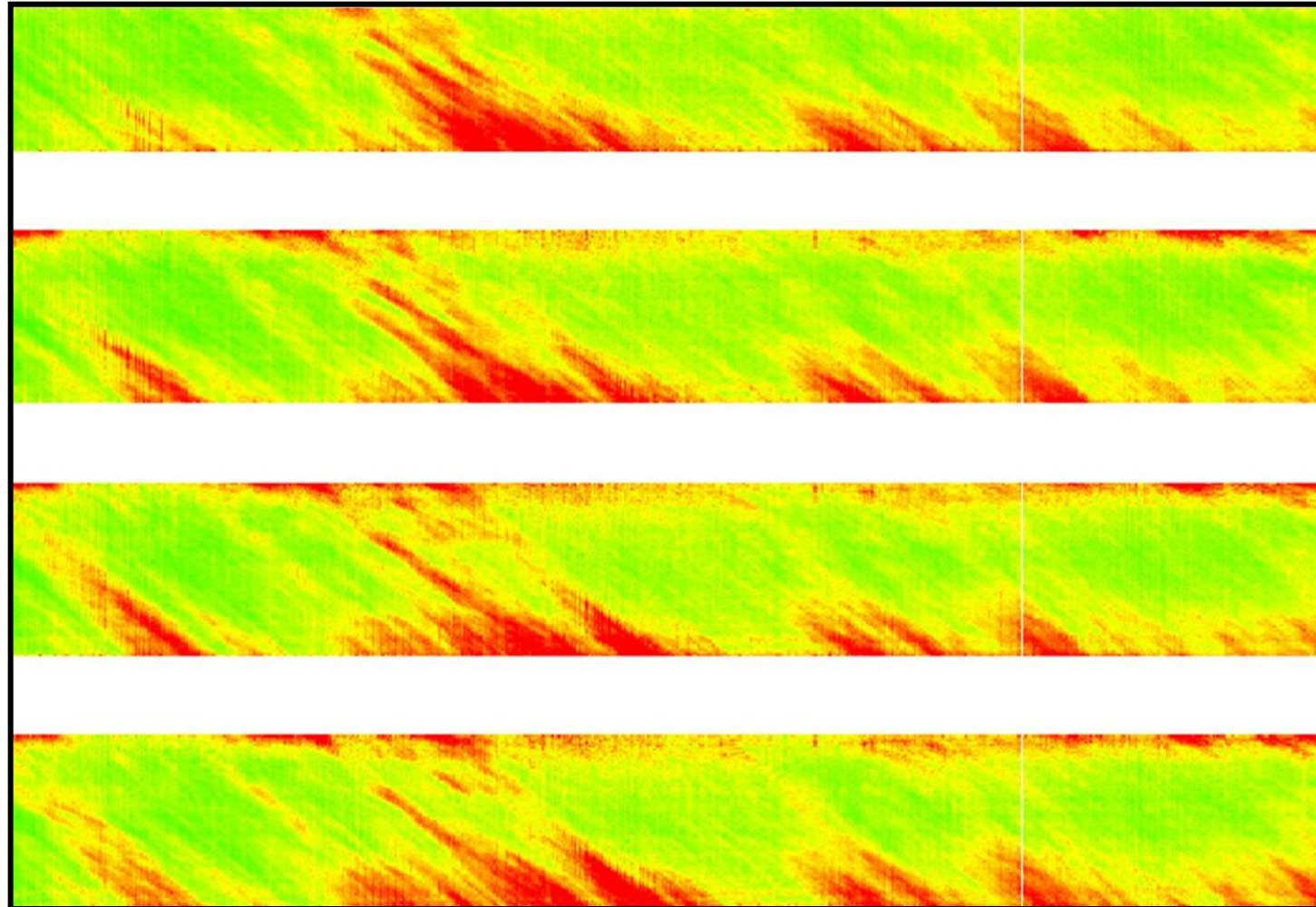
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



↑
CABLE /
CHANNEL



increasing SHOT

SI attenuation – method breaks down



Background

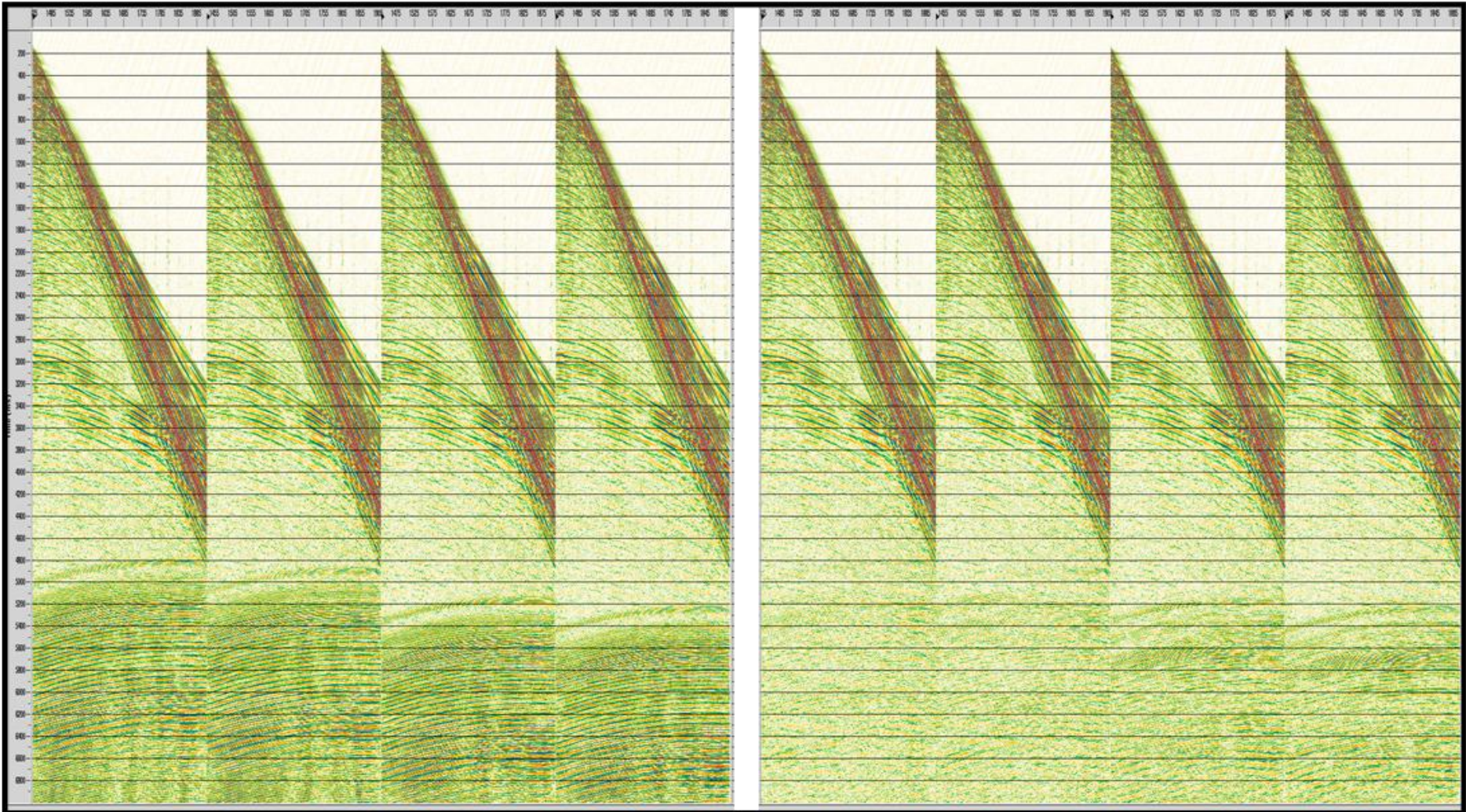
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



4D Results



Background

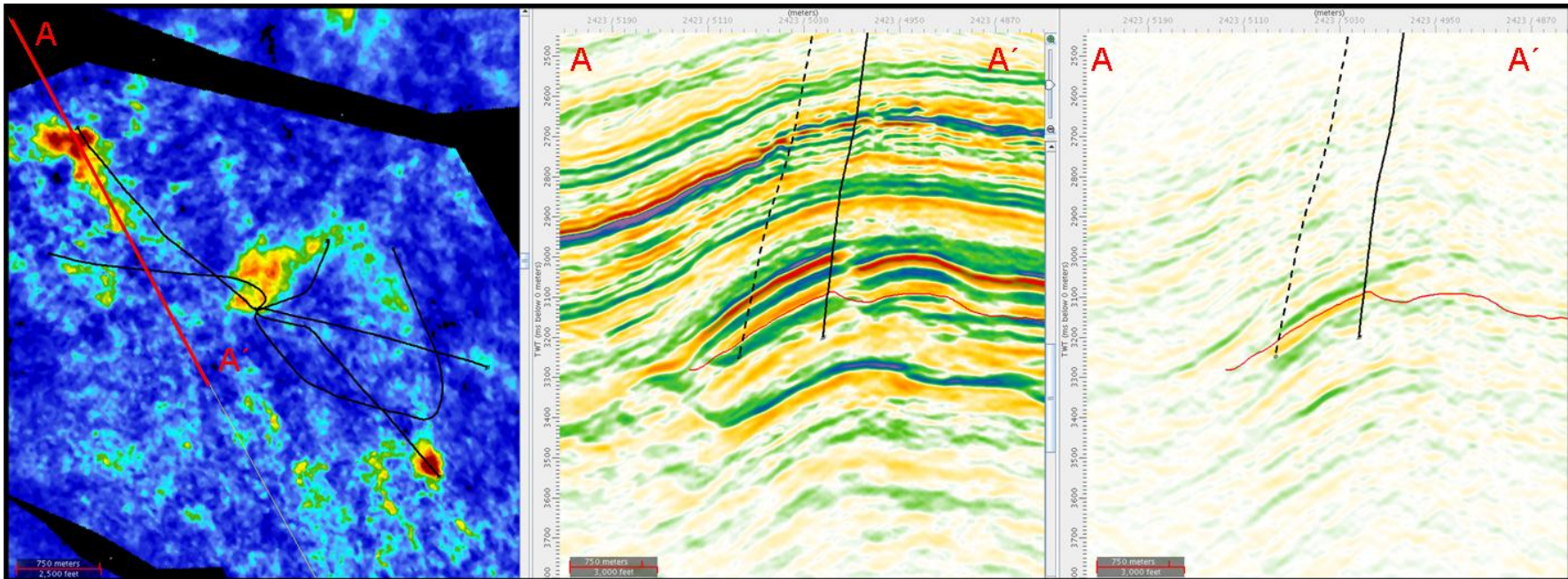
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



SNA Top Ula + 40ms from C.I.
4D difference 2011-1999

2011 C.I. Volume

CI 4D difference 2011-1999

- Amplitude softening signal, up-dip from the 3 most prolific WAG injectors
- Indicative of elevated gas saturation

Further tests – ignore the S.I.



Background

Noise
Characterisation

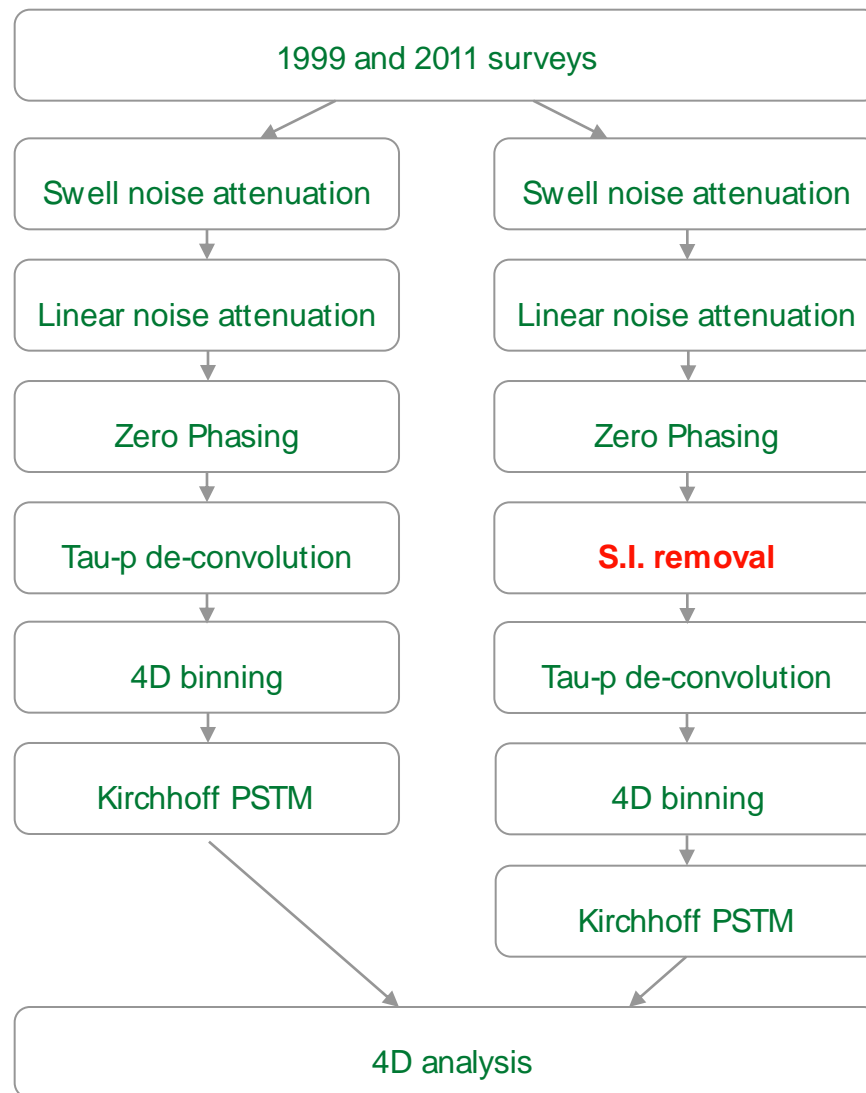
SI removal

4D Results

Ignore SI?

Summary

- Pre-stack migration and common mid-point (CMP) stacking have a significant impact on signal-to-noise
- Energy must originate from the same subsurface point to contribute to an image during migration
- Dipping noise will sum out during CMP stack
- Processing trial designed to assess the impact of doing nothing to remove S.I.



Further tests – ignore the S.I.



Background

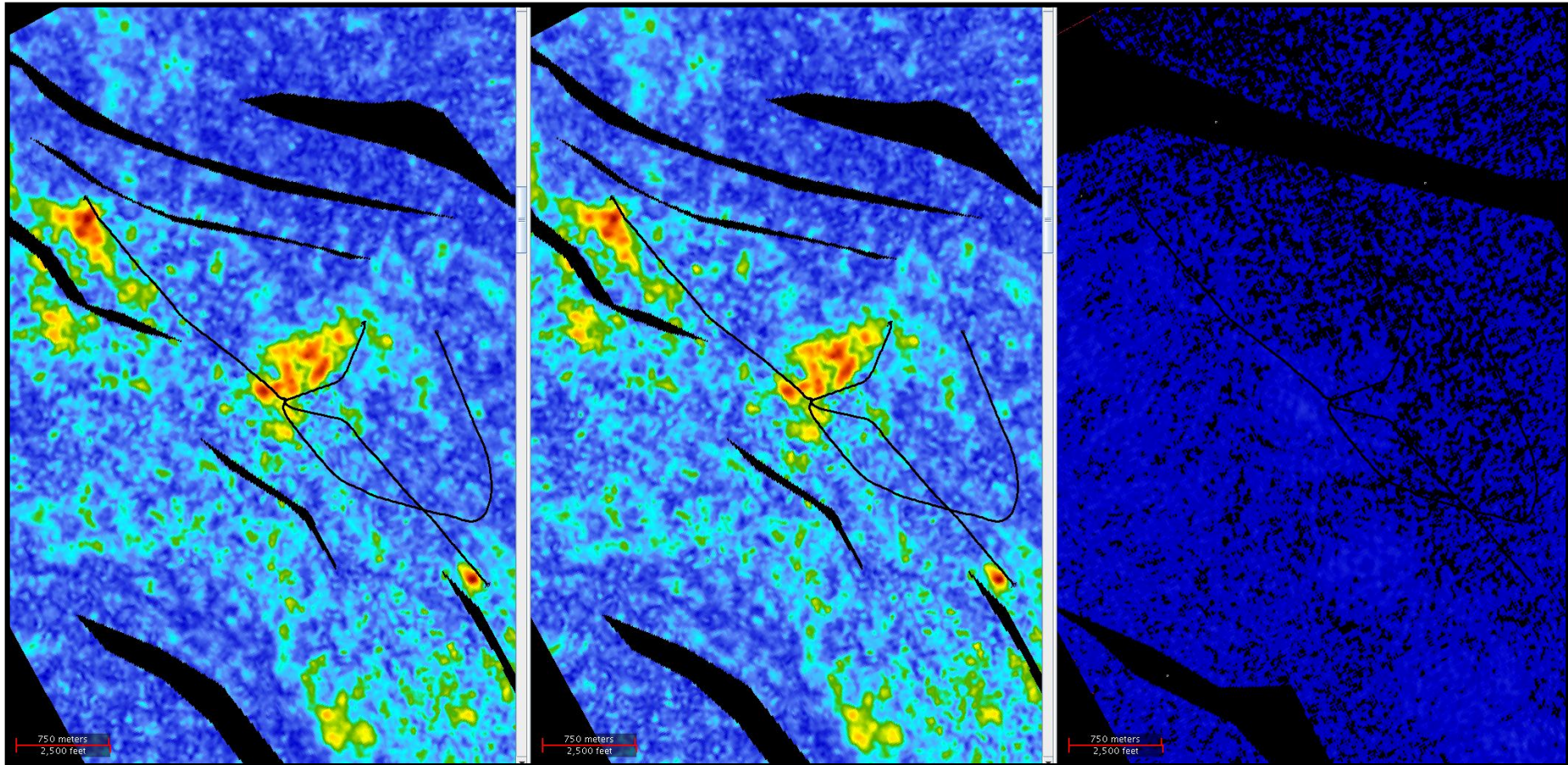
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



1) SI removed

2) SI remains

3) (1-2)

Further tests – ignore the S.I.



Background

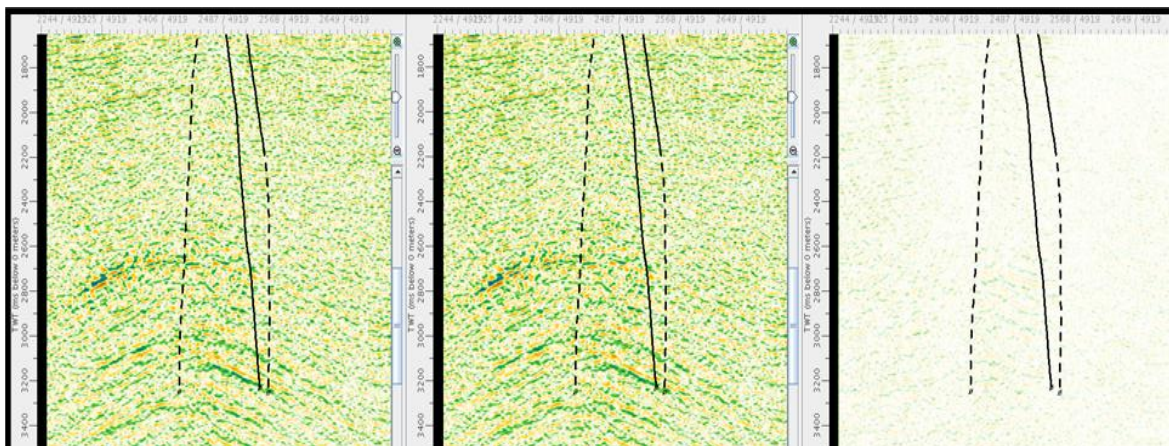
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary



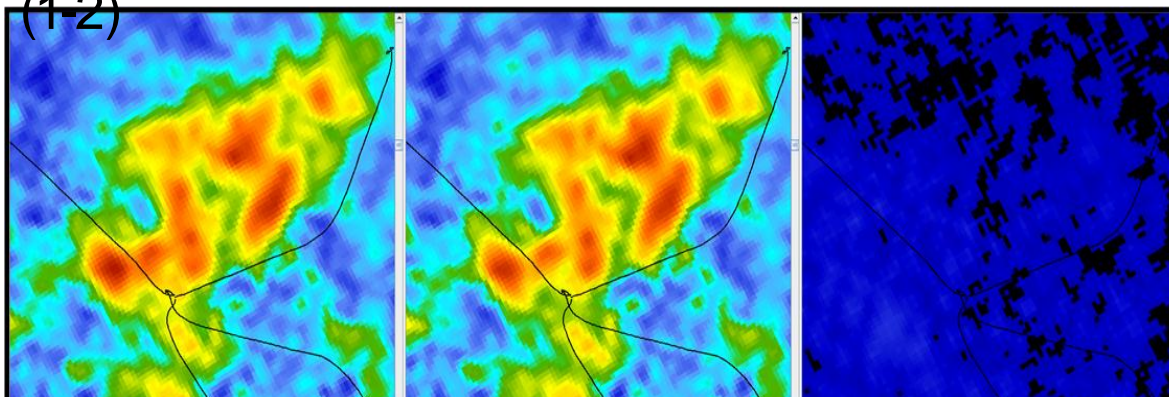
Coloured Inversion 4D difference 11-99

1) SI removed

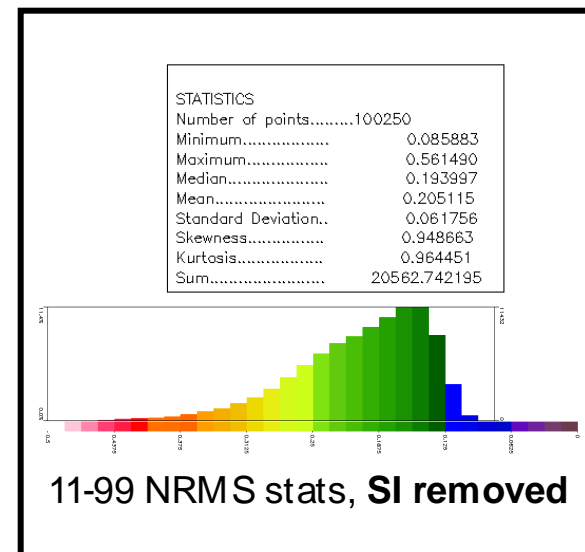
2) SI remains

3)

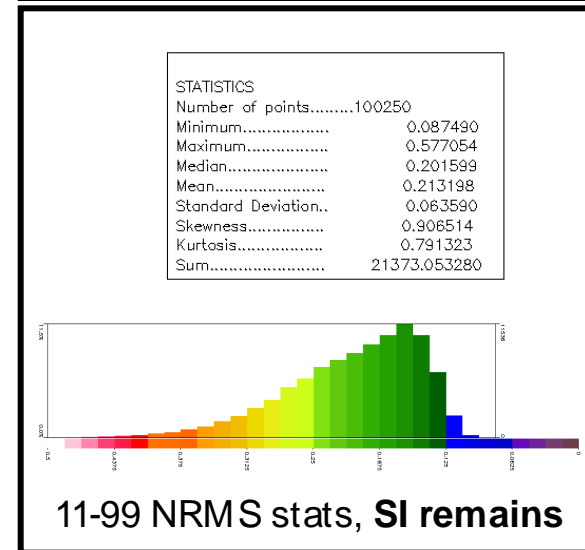
(1-2)



SNA Top Ula + 40ms from C.I. 4D difference 11-99



11-99 NRMS stats, **SI removed**



11-99 NRMS stats, **SI remains**

Recommended onboard QC flow



Background

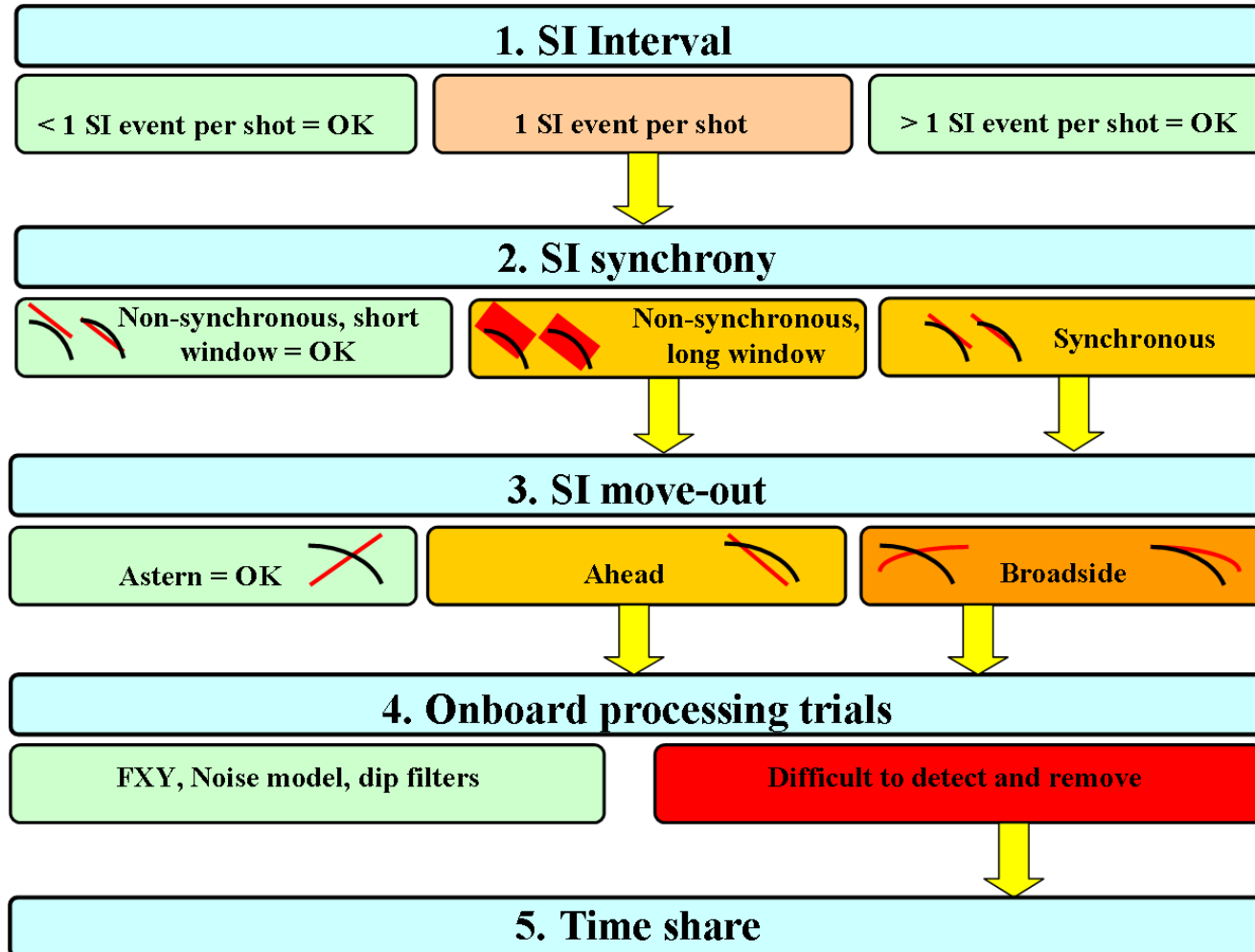
Noise
Characterisation

SI removal

4D Results

Ignore SI?

Summary





- Ula 2011 survey: a large proportion of incoming S.I. events were unsynchronised from shot to shot
- Similar observations on other surveys show that this is typical
- Modern processing techniques can effectively remove most trends of S.I.
- The 4D signal at Ula is robust, even if S.I. is not targetted during processing.
- An onboard S.I. assessment flow is proposed, with time-sharing representing the last resort.

Acknowledgements



- Co-author, Jamshade Khan
- CGGVeritas, Terje Weisser, Henning Hoeber, Aberdeen BP in-house team
- BP Norway and Ula field partners Dong E&P AS
- BP Technical support; Darrell Stanley, Steve Campbell, Einar Kjos