Improved estimation of density enabled by PP–PS simultaneous inversion of multicomponent seismic data

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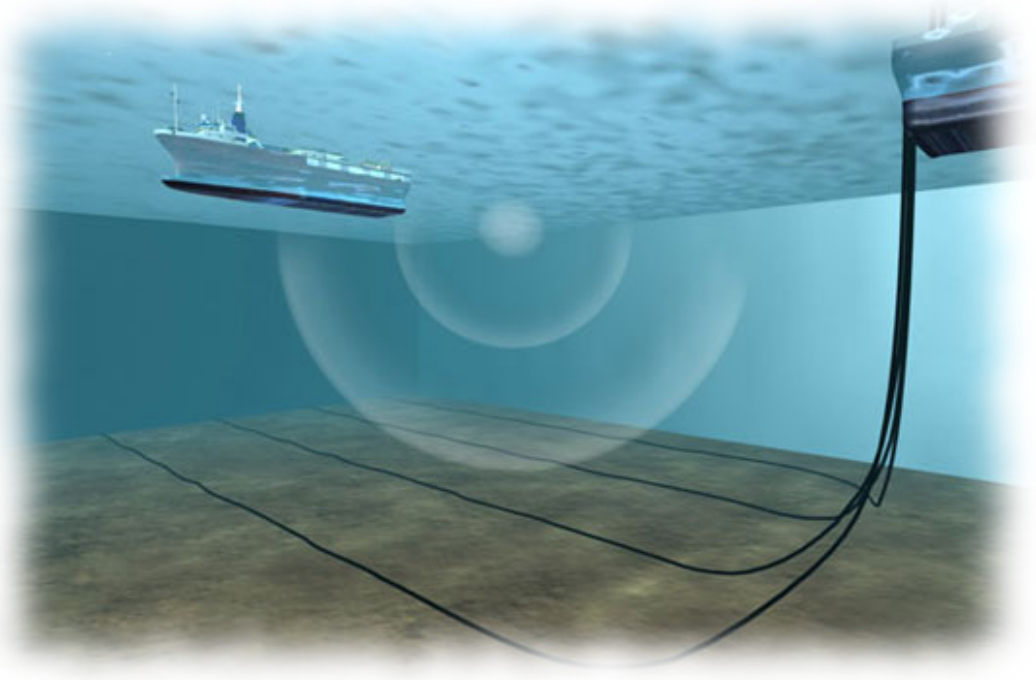
Roadmap

- Motivation
- Case study
  - Amplitude calibration
  - Event registration
  - Inversion results
- Lesson learned
- Recommendations for future work
- Q & A

Motivation

- OBS undergoing a renaissance
- Recent technical (efficiency) advances
  - Handling
  - Large sensor inventory
  - Battery life
  - Blended sources
  - Compressive sensing
- Reduction in unit cost of data
- High end PP–PS imaging and improving QI value proposition
  - New and existing data
  - Can address some common challenges in SEA
    - Gas obscured zones
    - Density as a proxy for gas saturation



Case study

- Production asset offshore peninsular Malaysia
- Density is observed to be a strong predictor of gas charge
- Difficult area for seismic
- Can a QI workflow accurately:
  - Map the PS data to the PP data to aid interpretation?
  - Tie blind well log data?
  - Produce stable and reliable density inversion results?

Input data

- Four wells
- PP and PS imaged anglestacks
- 14 anglestacks covering ~60 sqkm
- PP and PS RMS velocities
- PP horizons X 4
- PS horizons X 1
- Gamma field

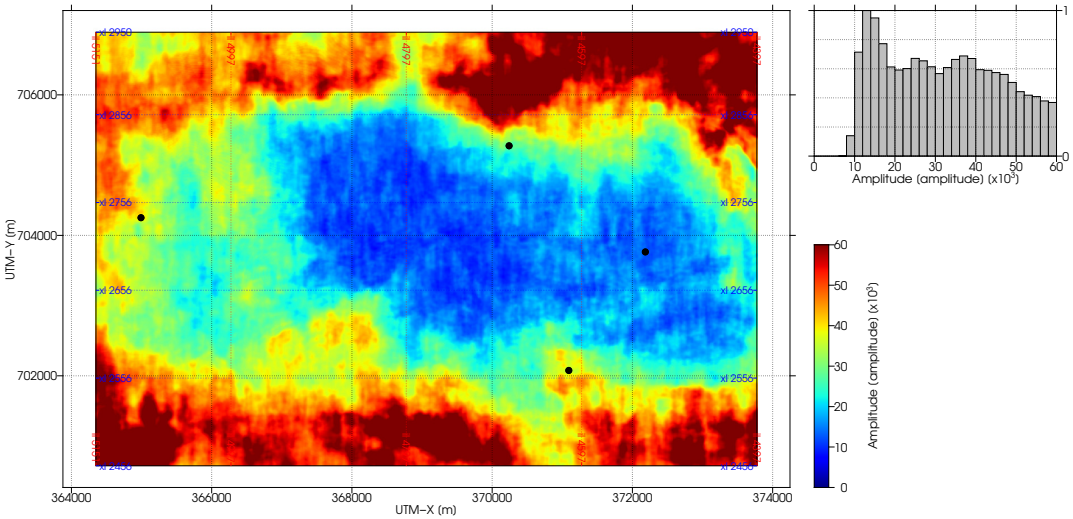
Key steps

- Preconditioning
  - Amplitude calibration
  - Event registration
  - Angle stack conditioning
- Inversion parameterisation
  - Angle ranges / weighting
  - Spatial and component weights per angle stack

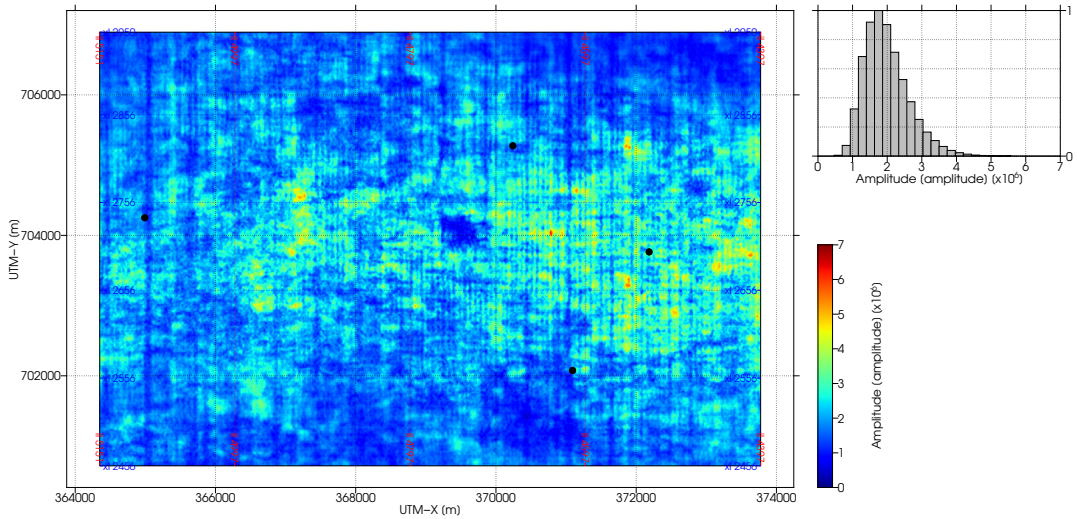
Case study – preconditioning

Effect of shallow gas on reservoir amplitudes

PP fullstack



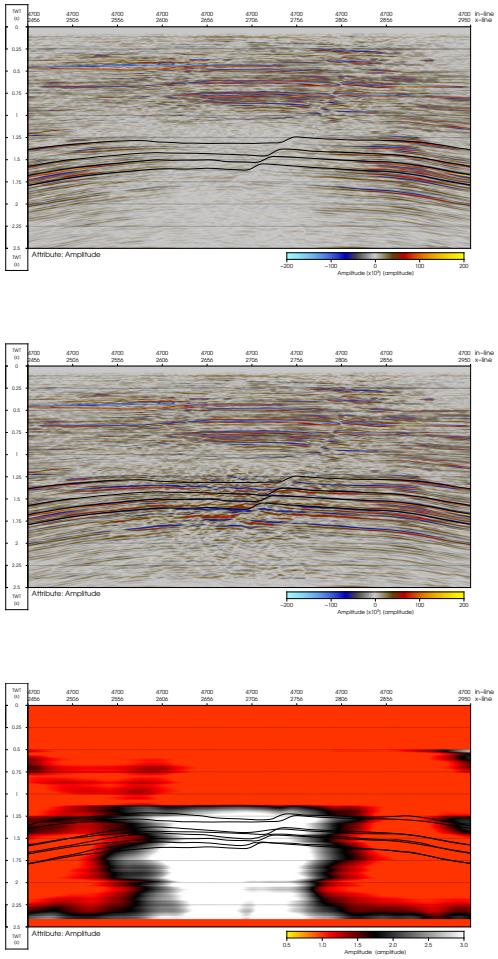
PS fullstack



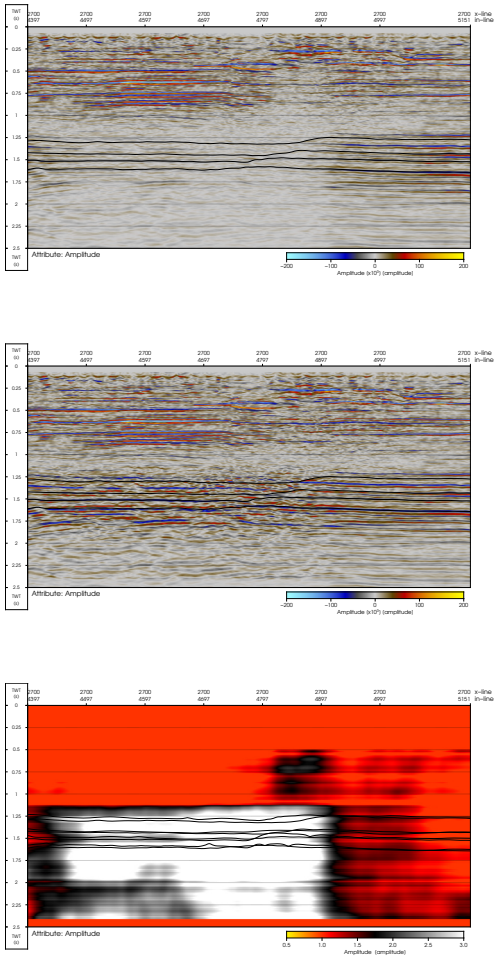
Case study – preconditioning

Full stack amplitude calibration

inline 4700 PP



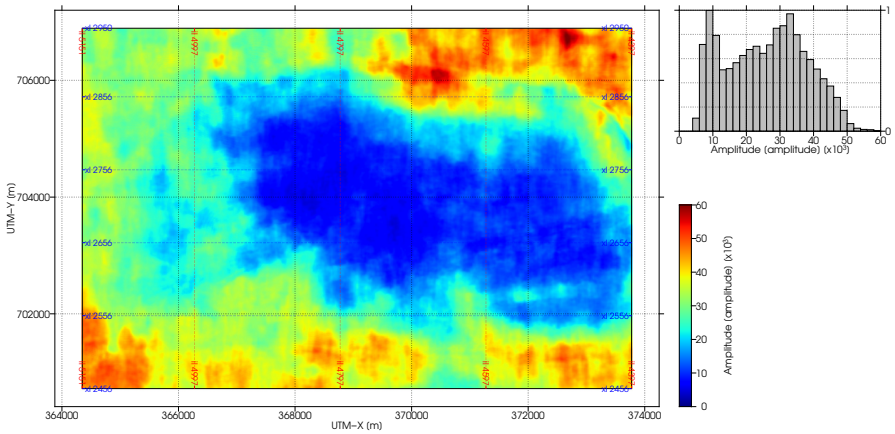
crossline 2700 PP



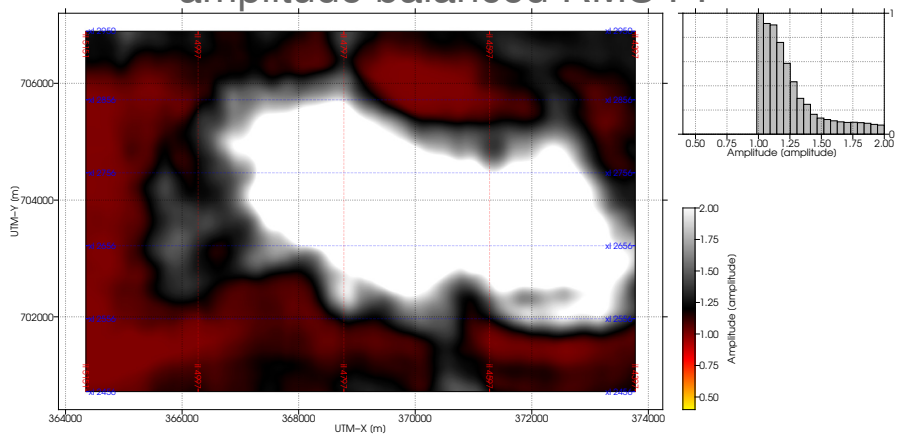
Case study – preconditioning

Full stack amplitude and spectral balancing

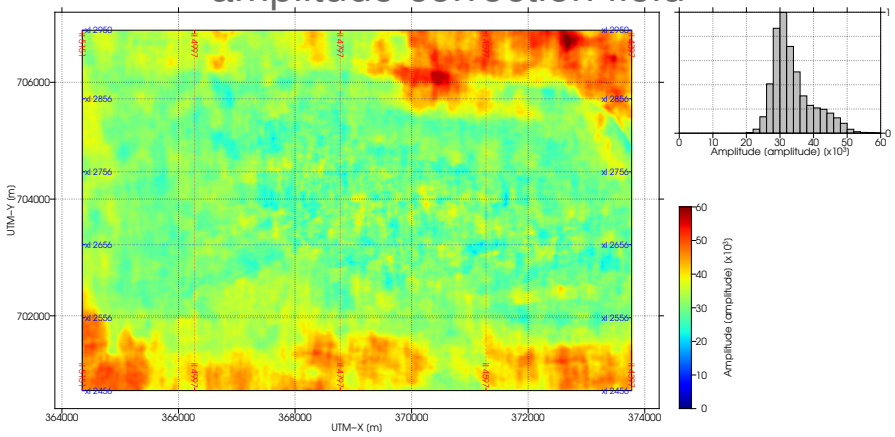
raw RMS PP



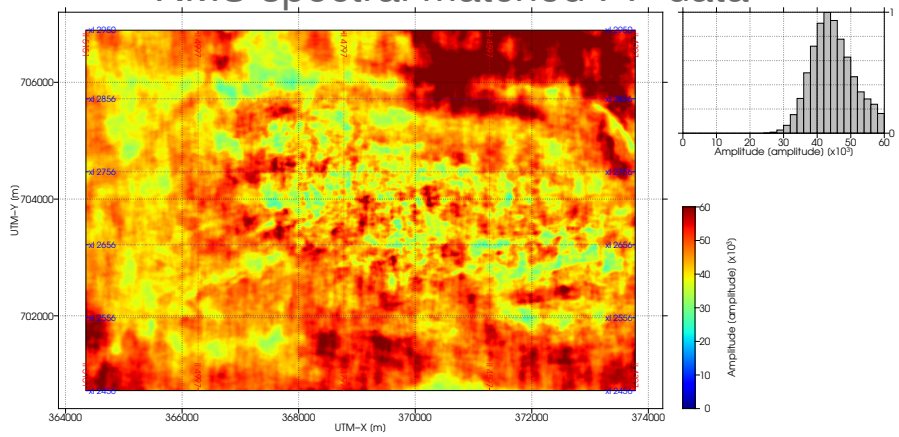
amplitude balanced RMS PP



amplitude correction field

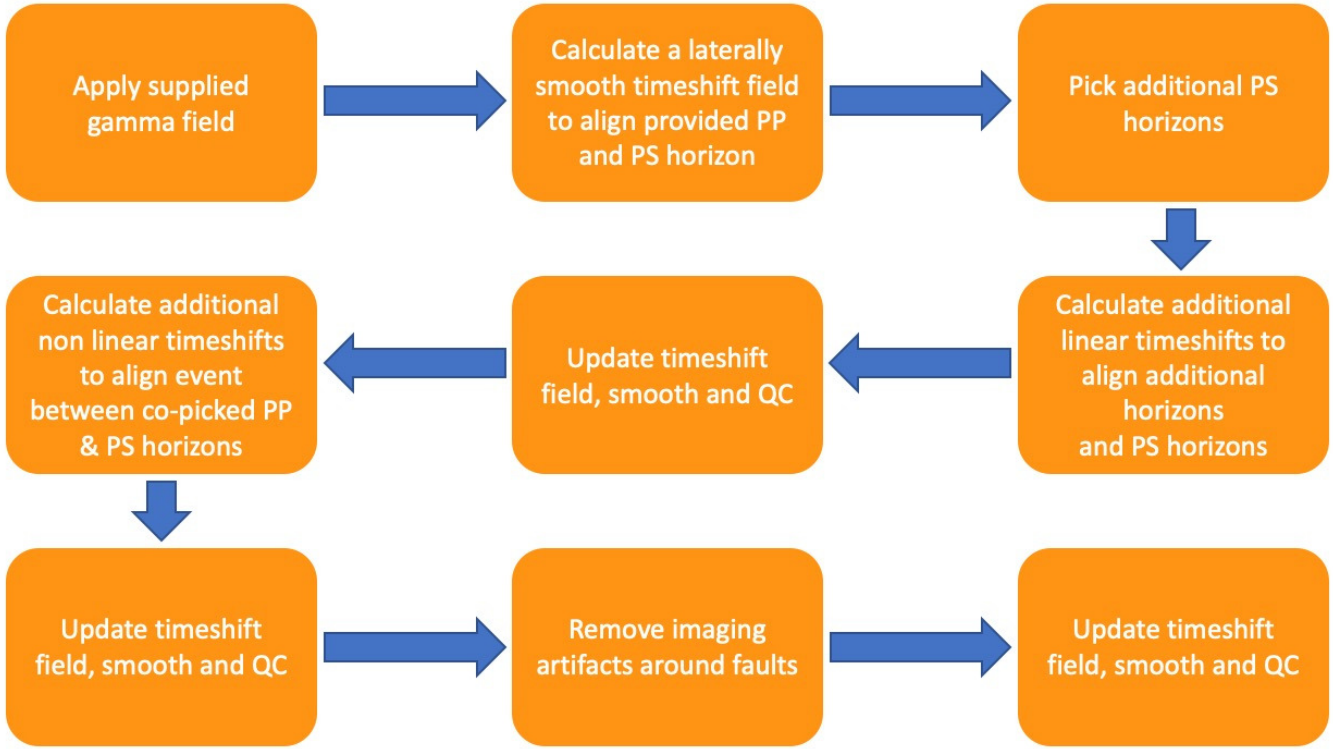


RMS spectral matched PP data



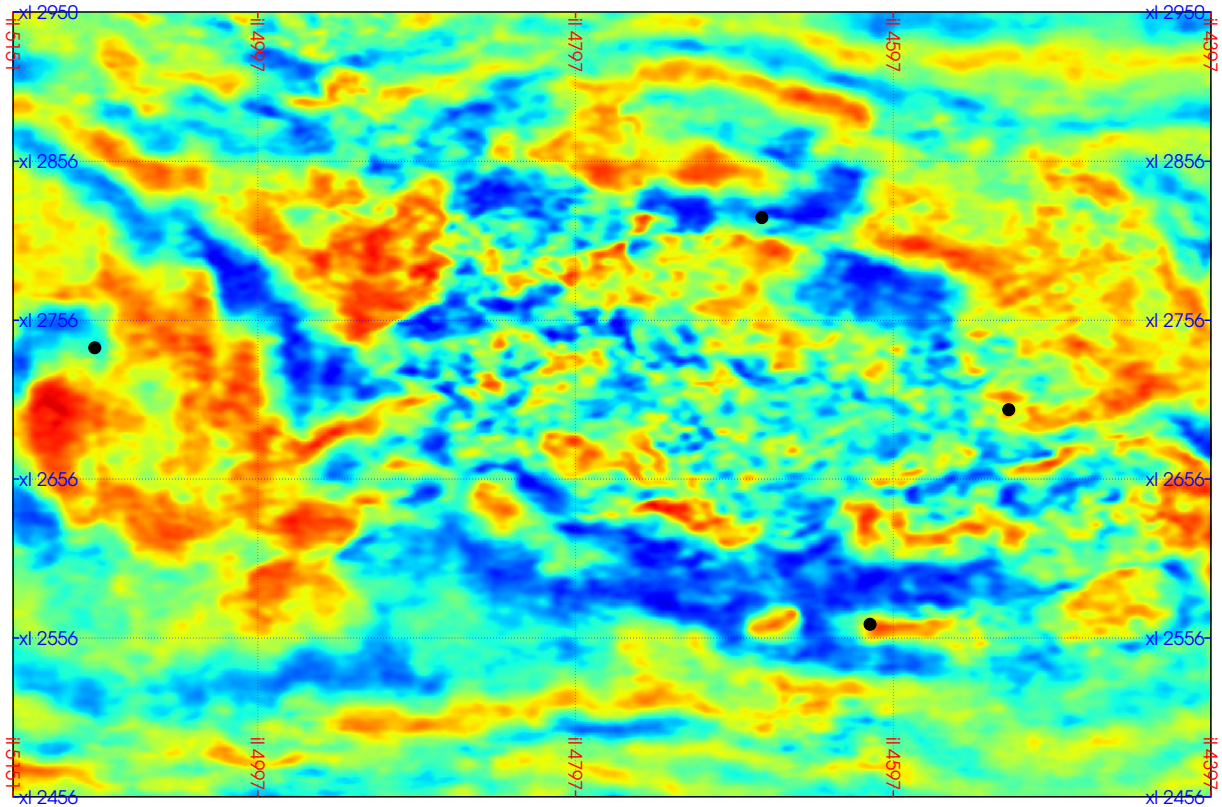
Case study – preconditioning

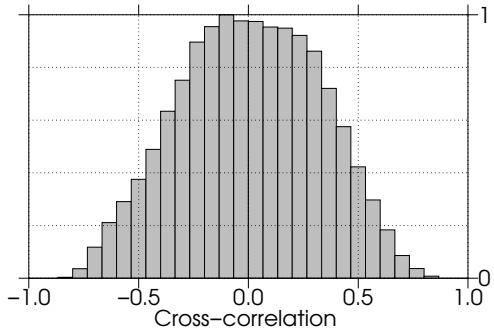
Event registration

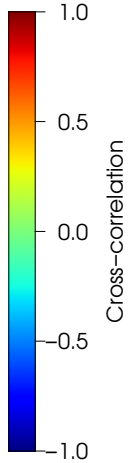


Case study – preconditioning

Cross correlation PP to PS (in PS time)

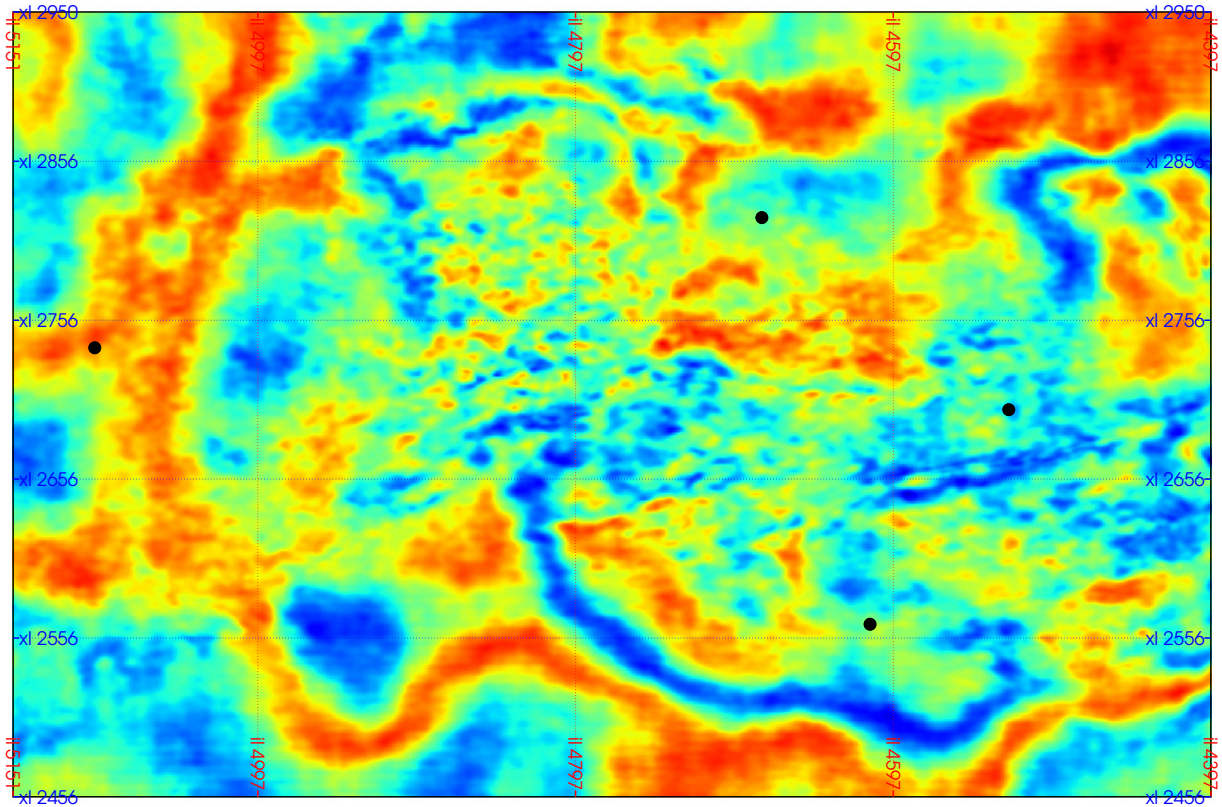


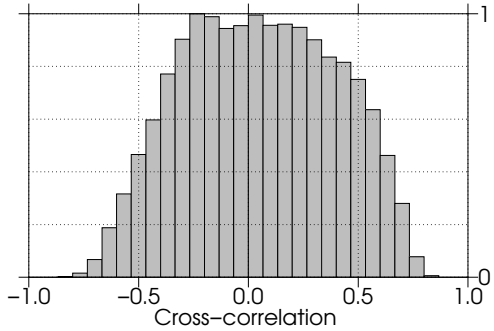


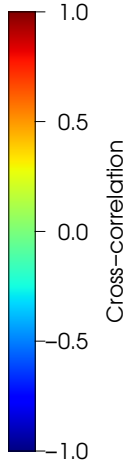


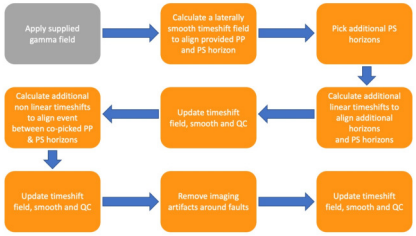
Case study – preconditioning

Cross correlation PP to PS (in PP time from supplied gamma)



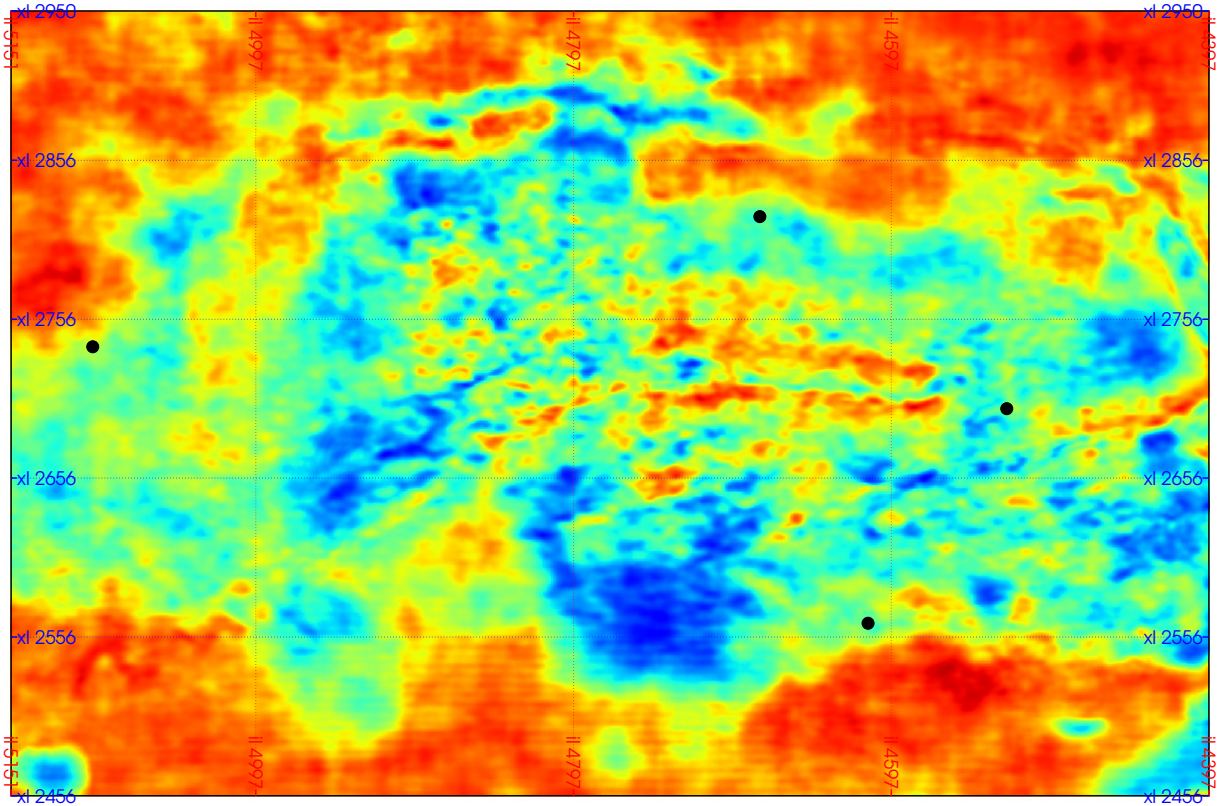


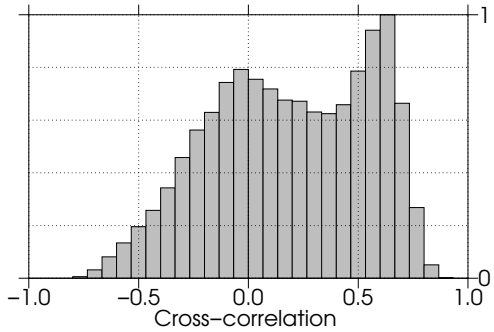


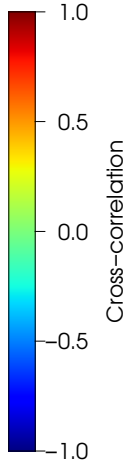


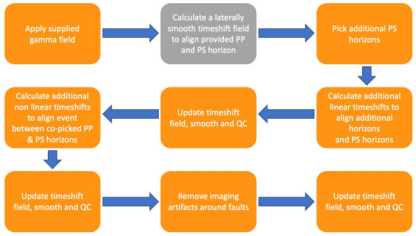
Case study – preconditioning

Cross correlation PP to PS (gamma plus residual alignment using supplied PS horizon)



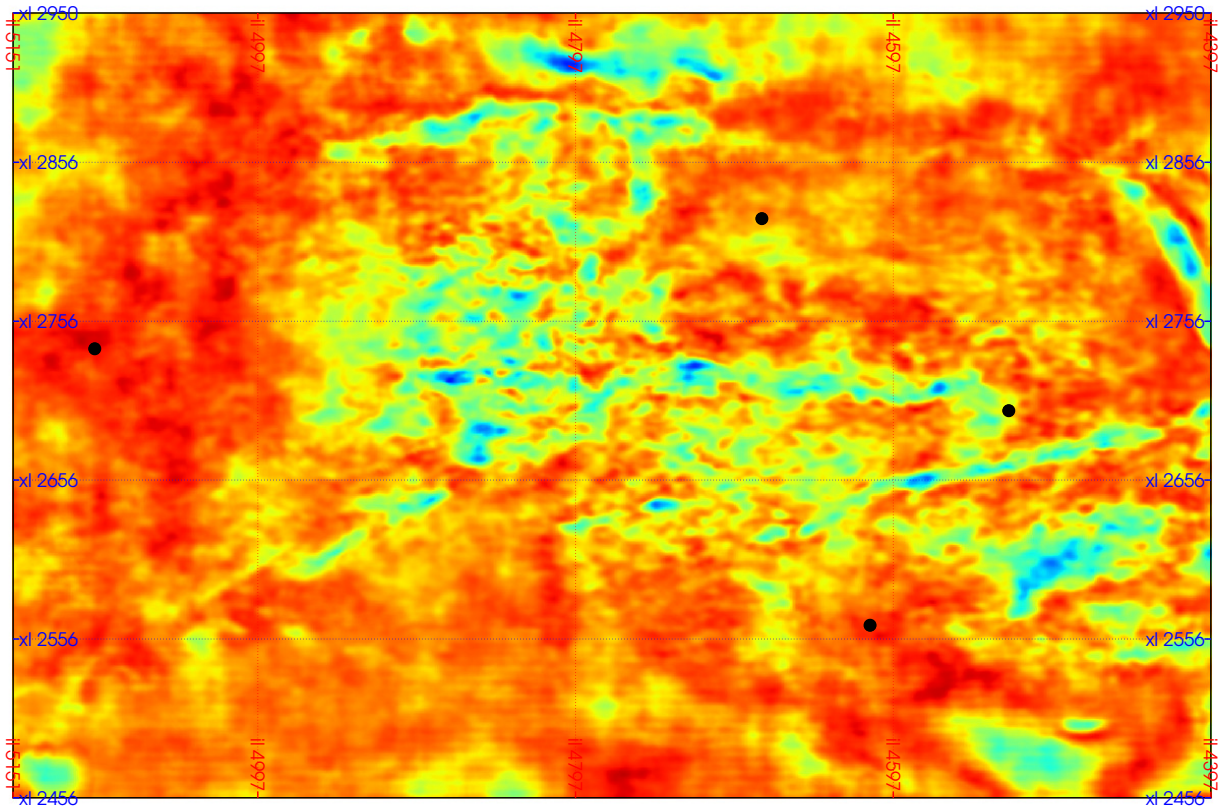


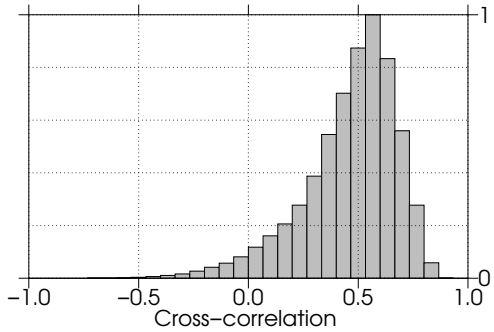


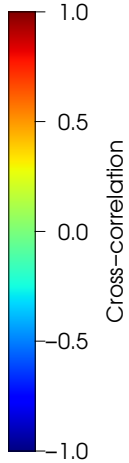


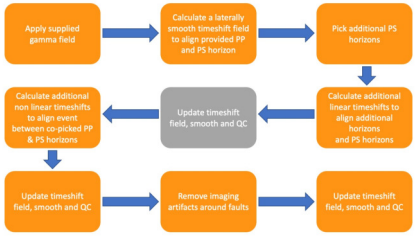
Case study – preconditioning

Cross correlation PP to PS (gamma plus residual alignment using picked PS horizons)



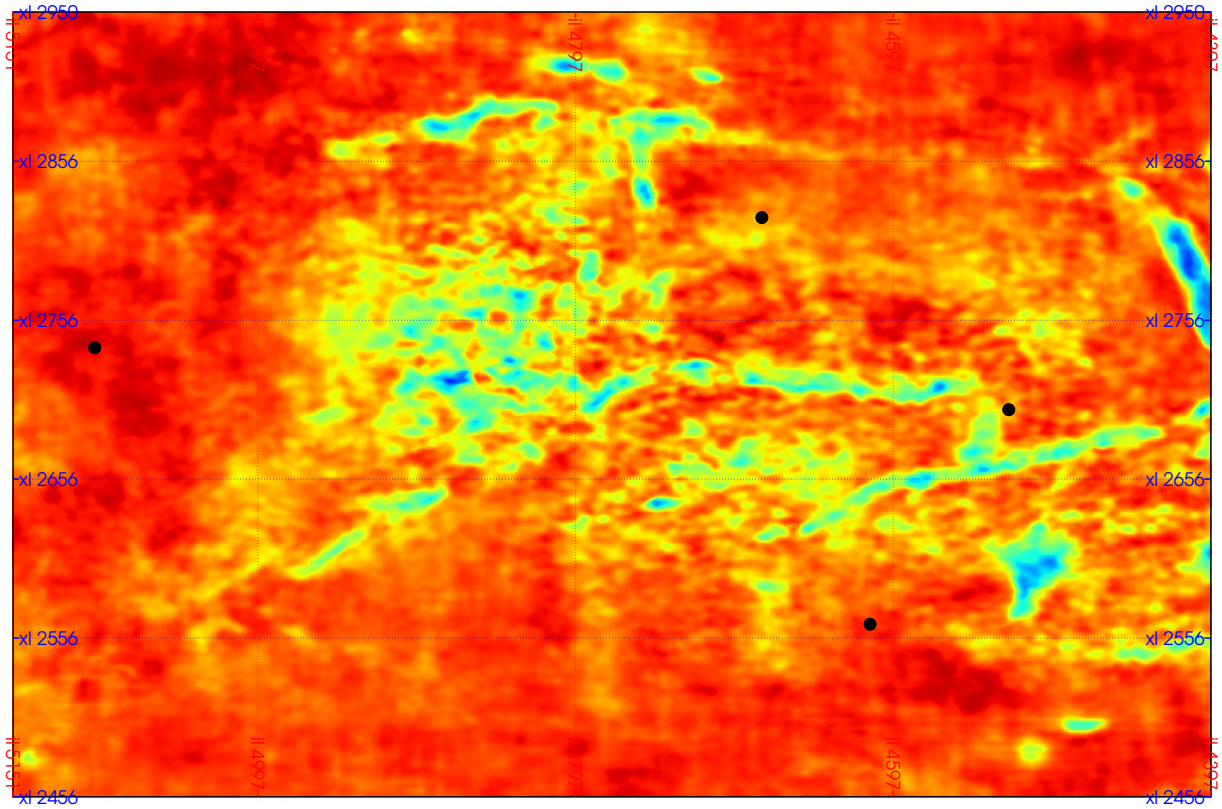


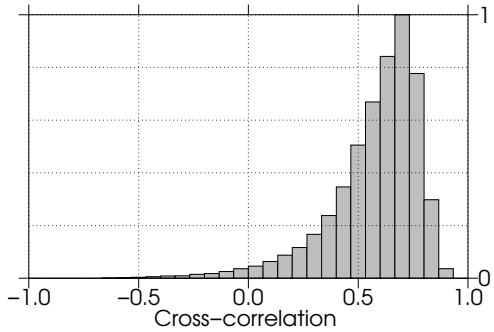


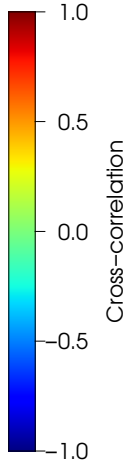


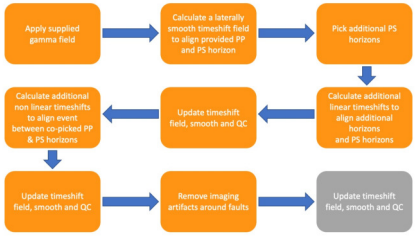
Case study – preconditioning

Cross correlation PP to PS (after final event registration)



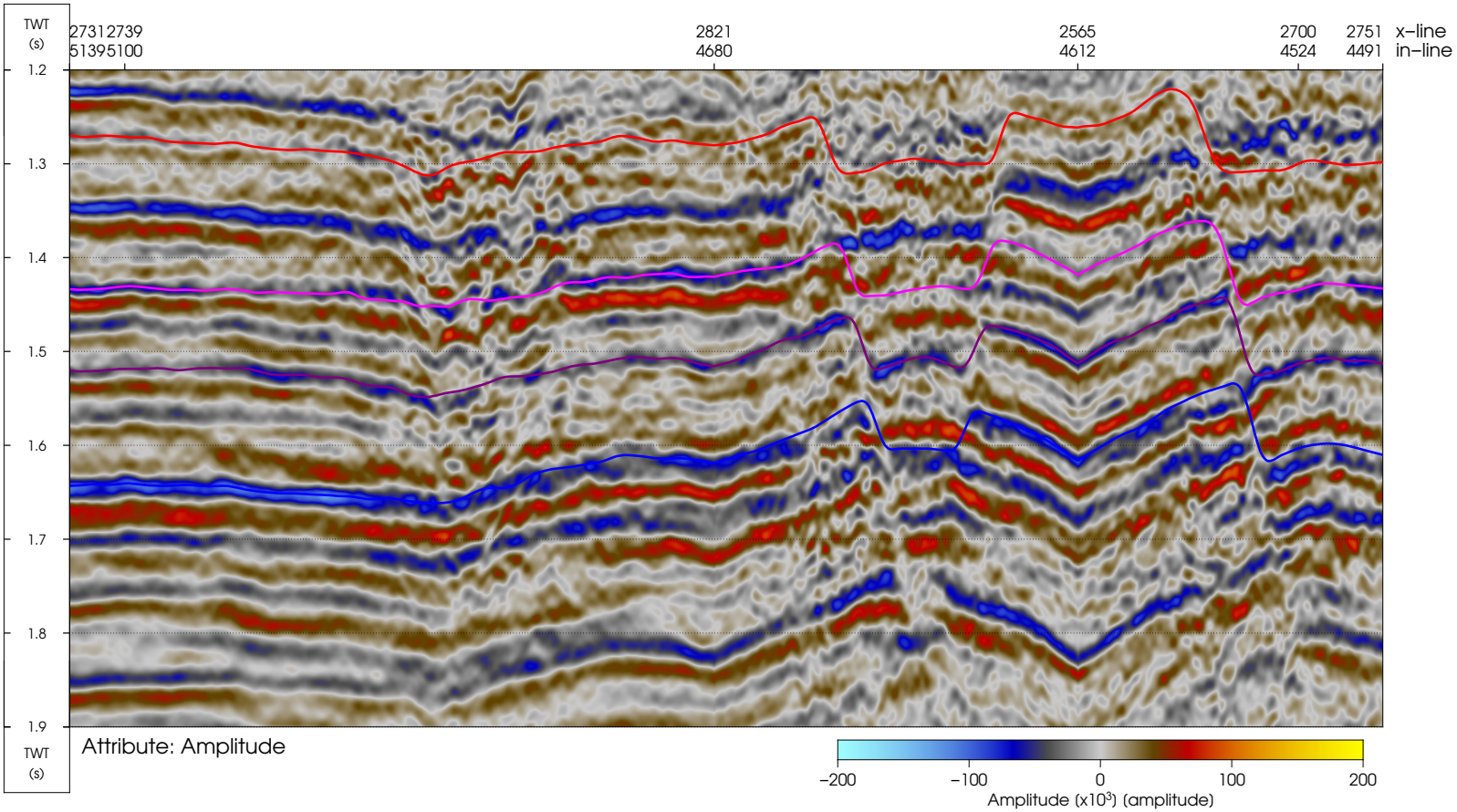






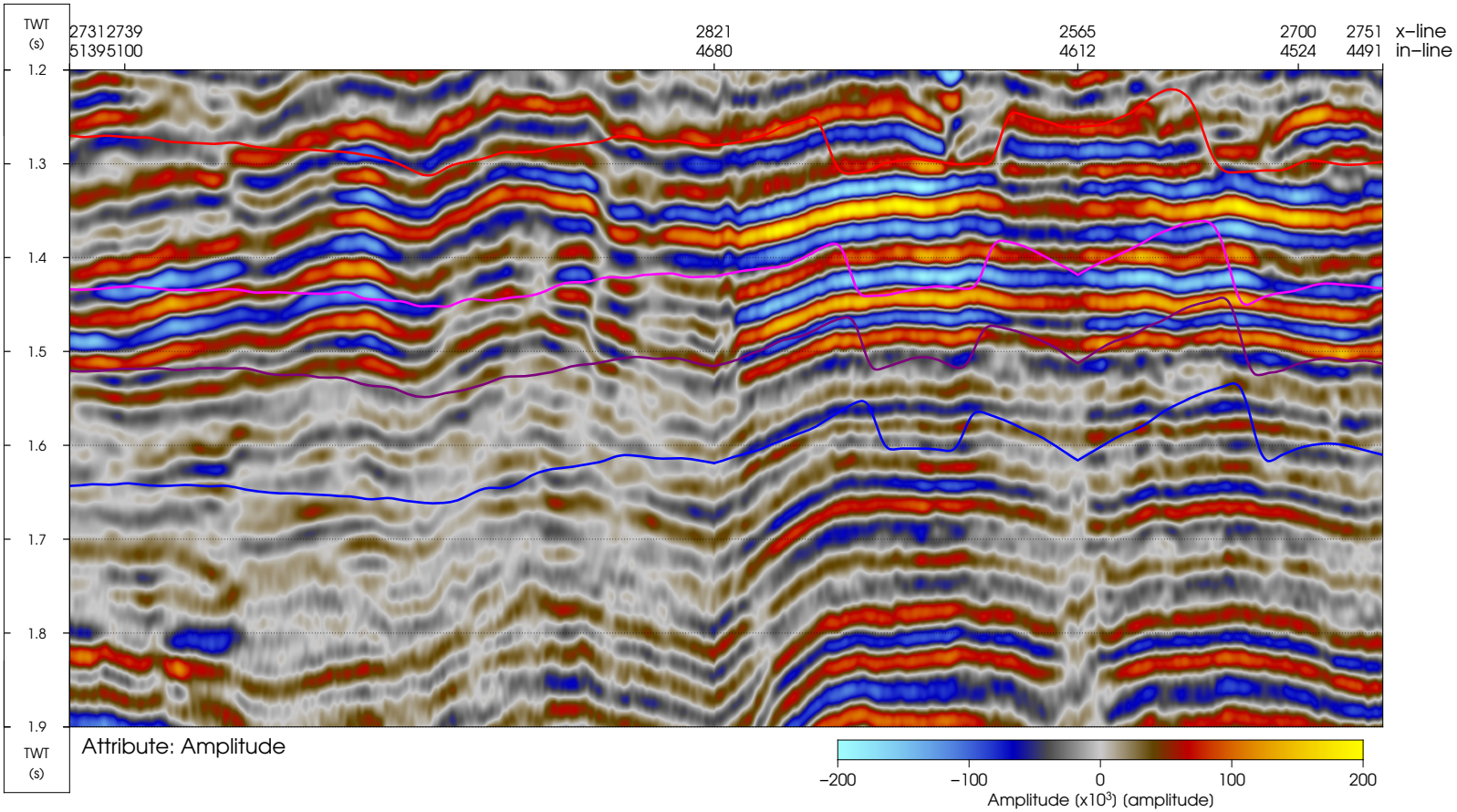
Case study – preconditioning

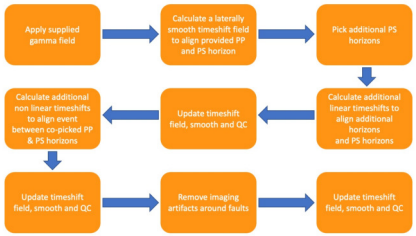
PP seismic section (reference)



Case study – preconditioning

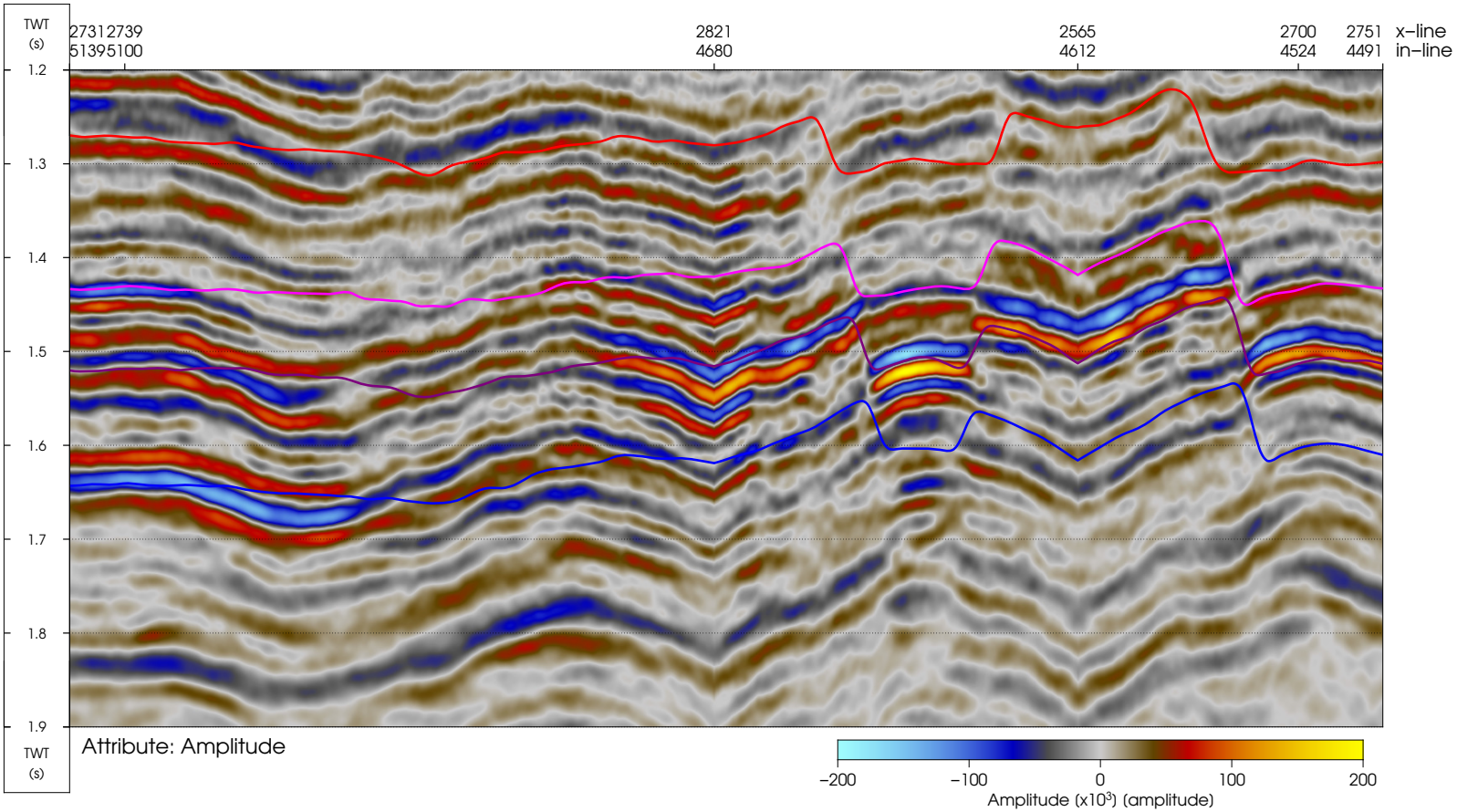
PS seismic (raw)

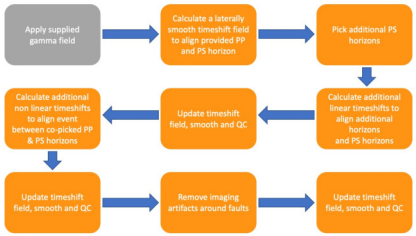




Case study – preconditioning

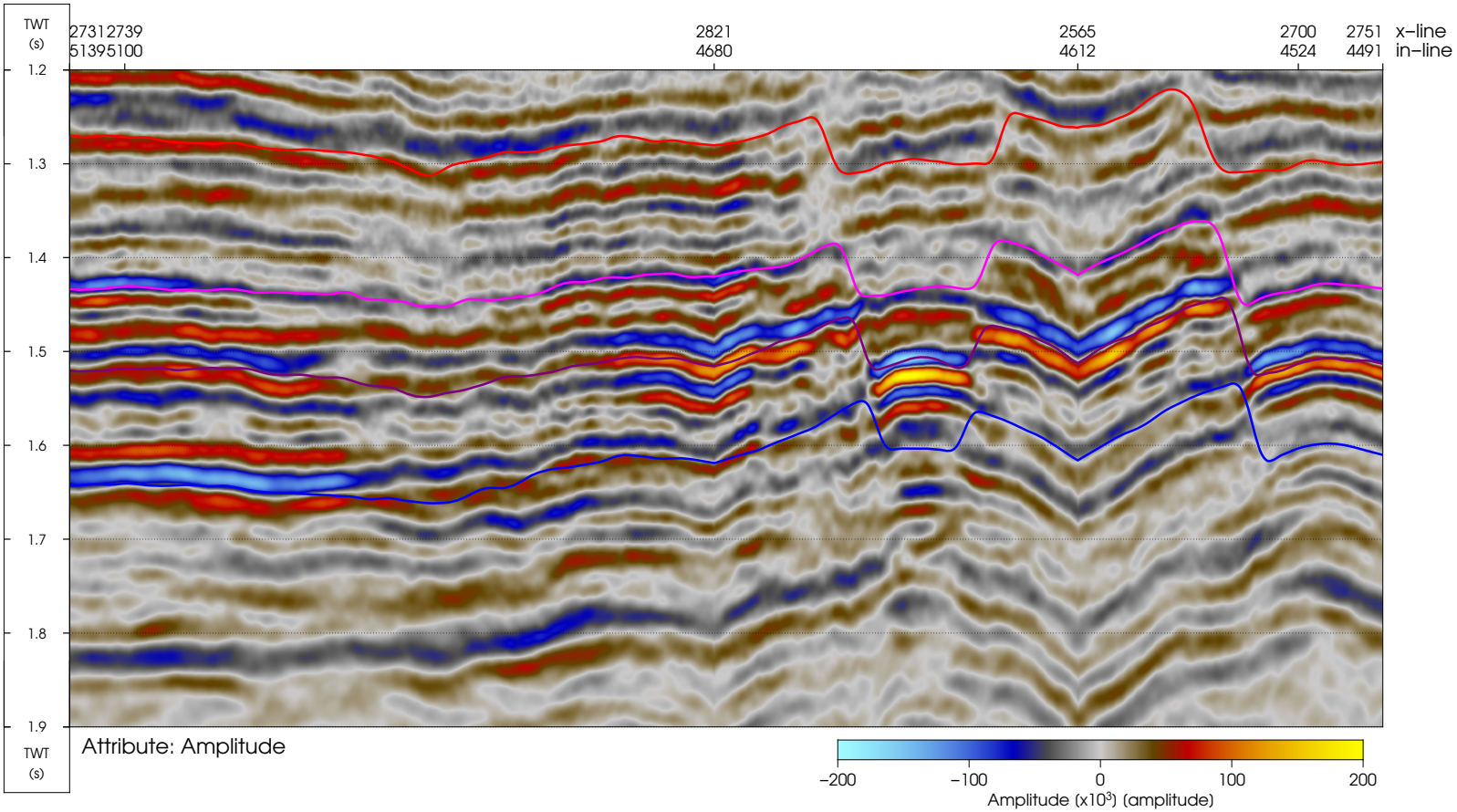
PS seismic (in PP time from supplied gamma)

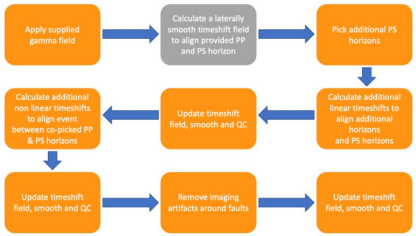




Case study – preconditioning

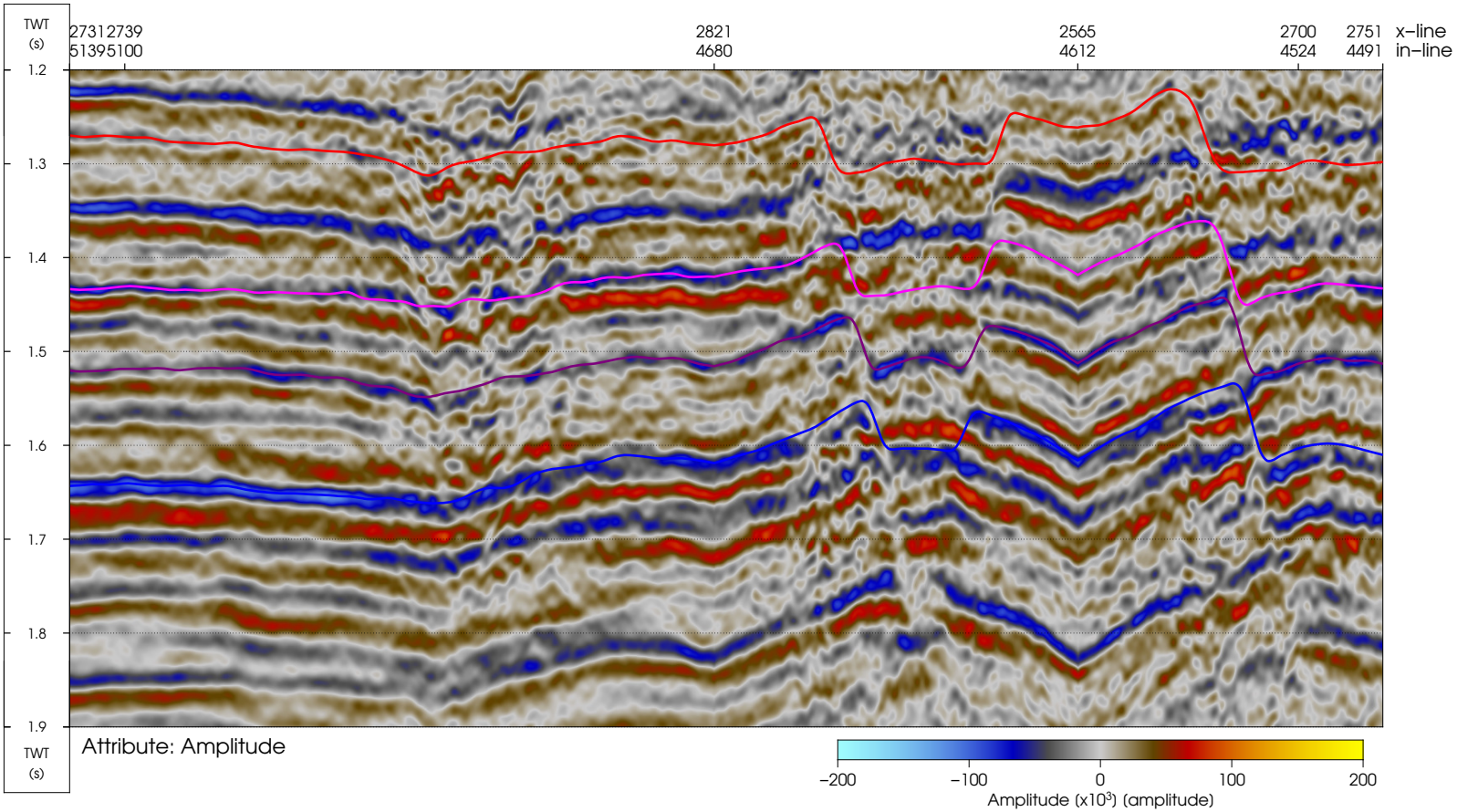
PS seismic (gamma plus residual alignment using supplied PS horizon)





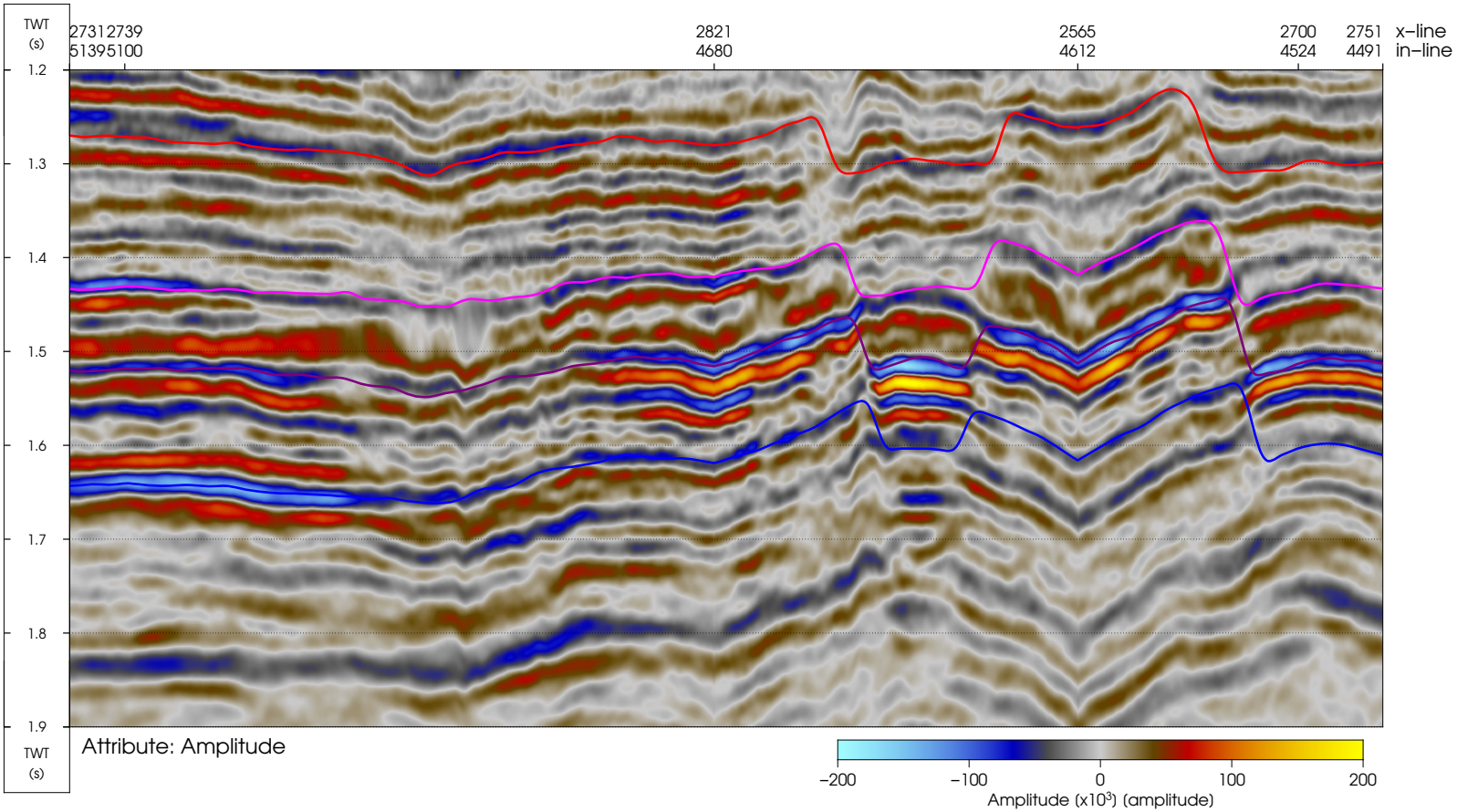
Case study – preconditioning

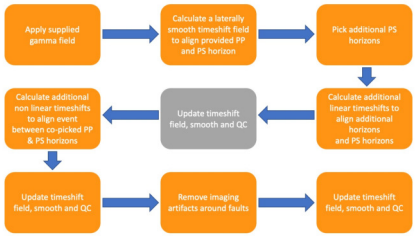
PP seismic section (reference)



Case study – preconditioning

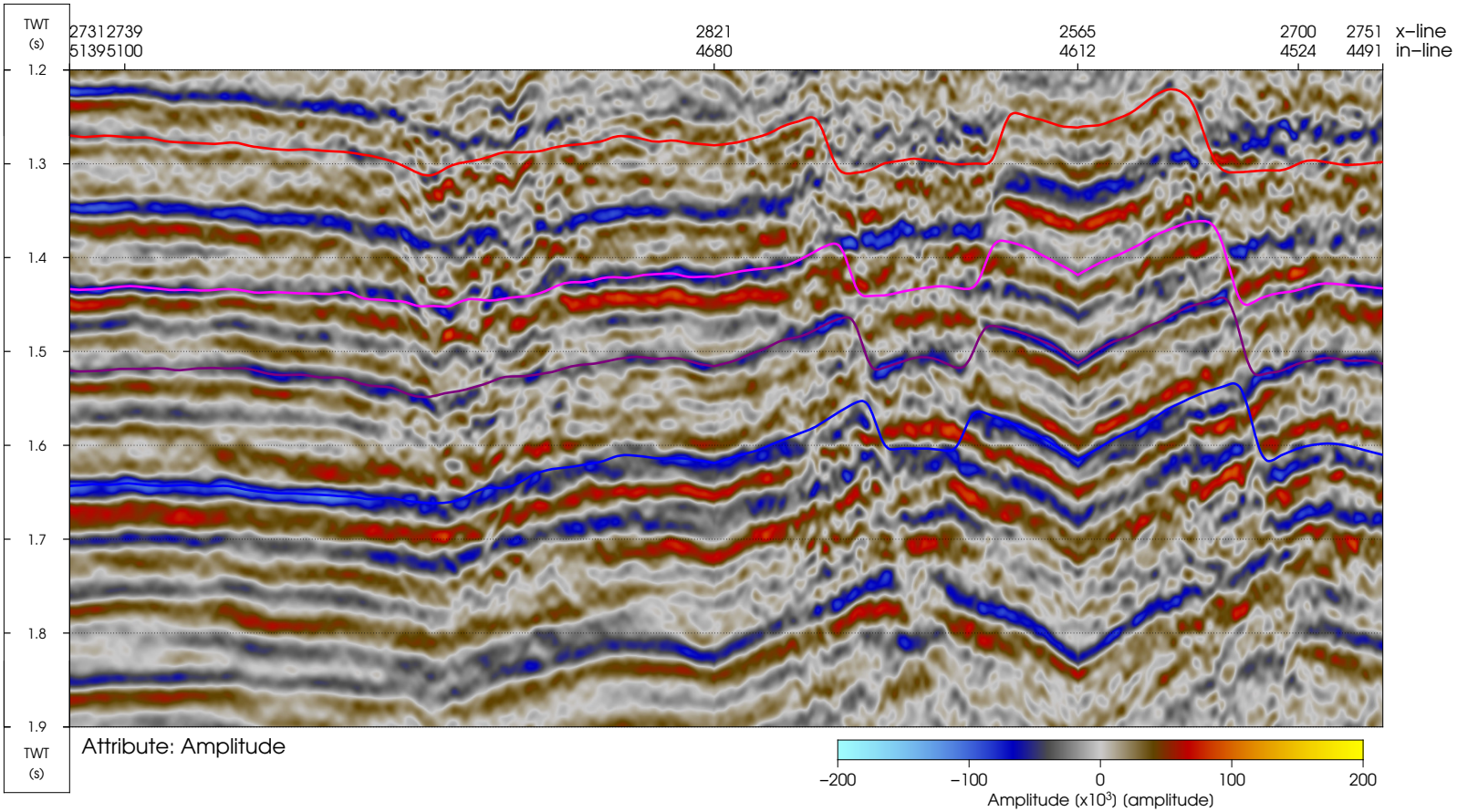
PS seismic (gamma plus residual alignment using picked PS horizons)





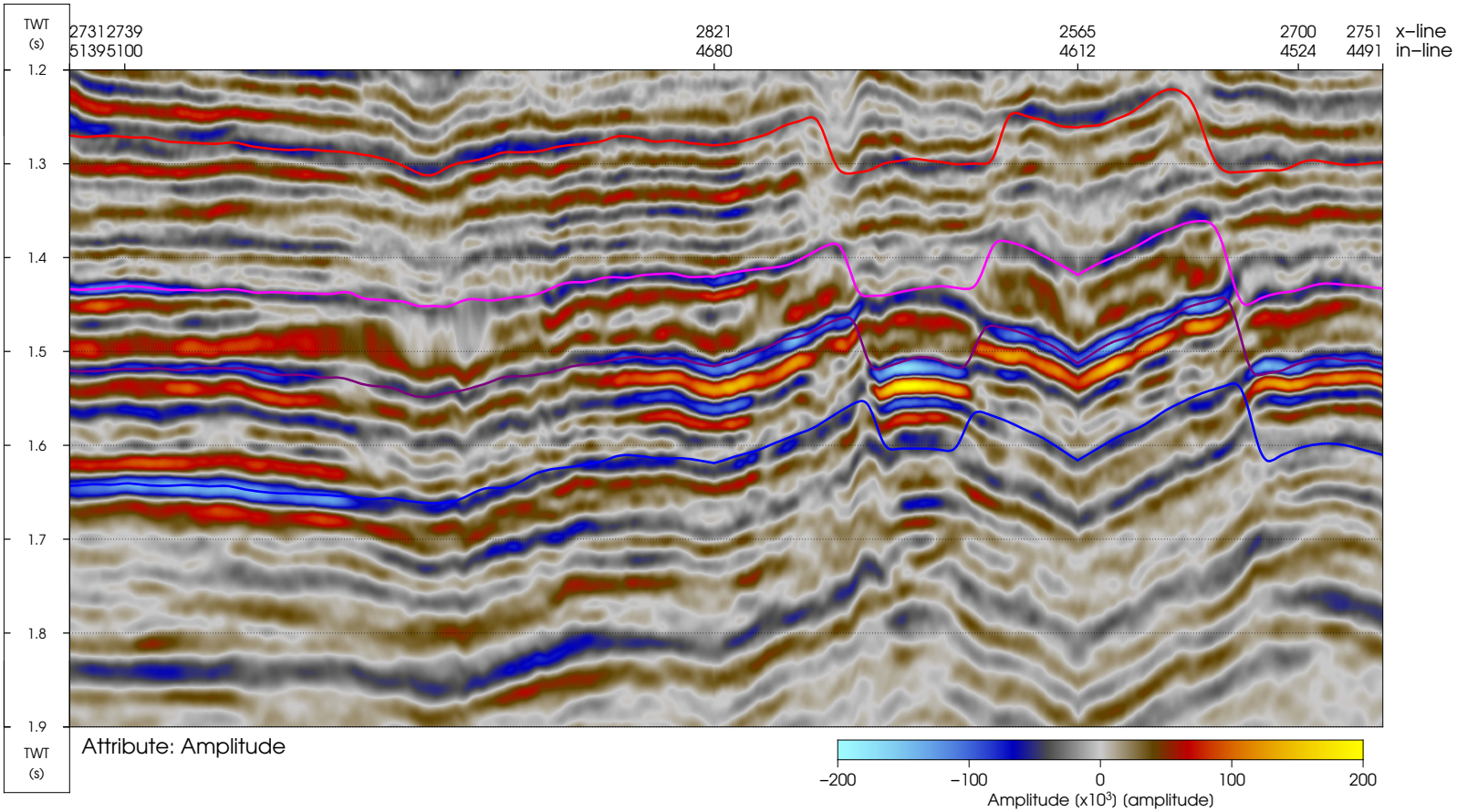
Case study – preconditioning

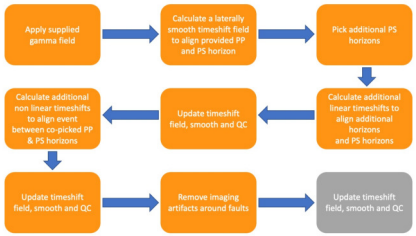
PP seismic section (reference)



Case study – preconditioning

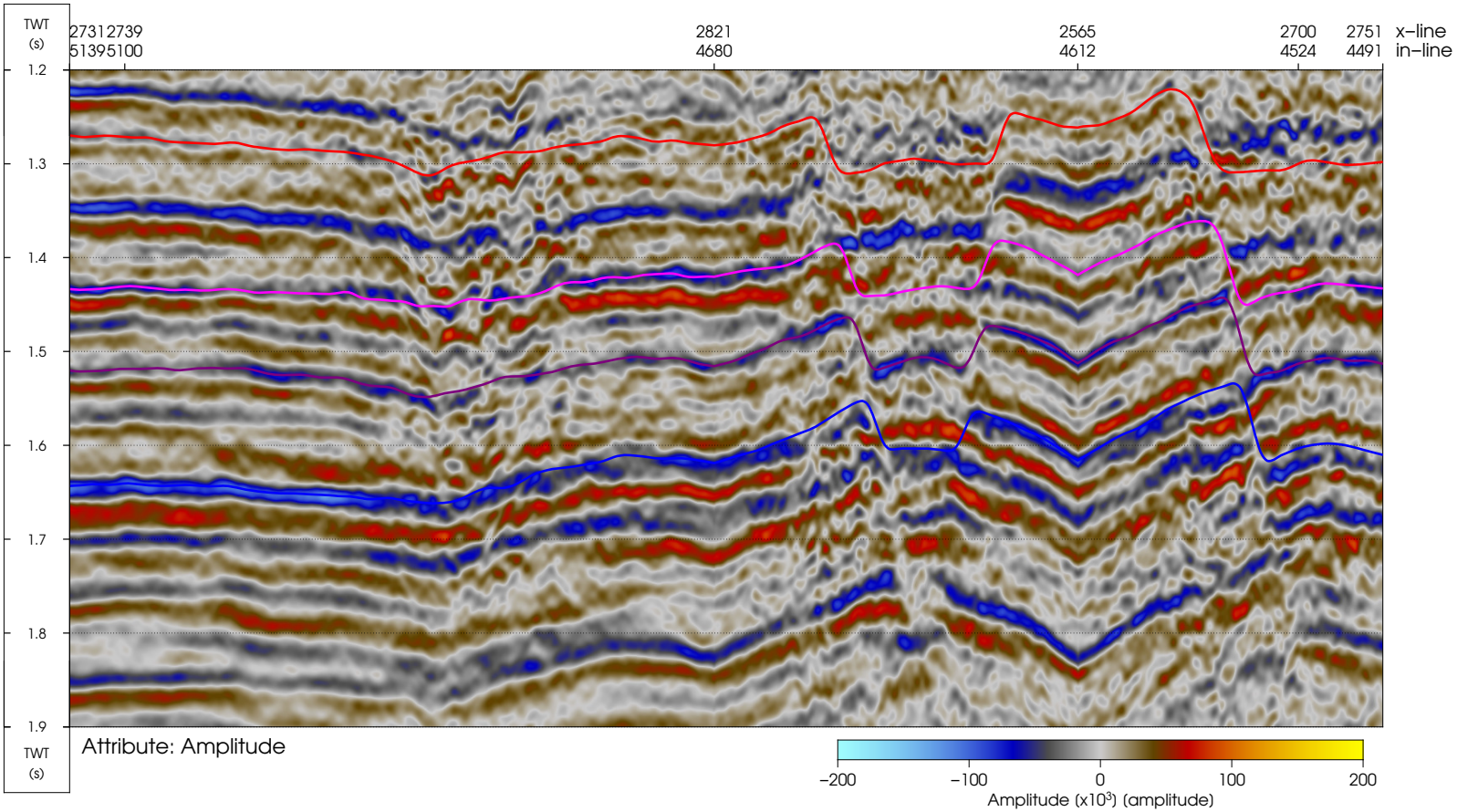
PS seismic (after final event registration)





Case study – preconditioning

PP seismic section (reference)



Case study – preconditioning

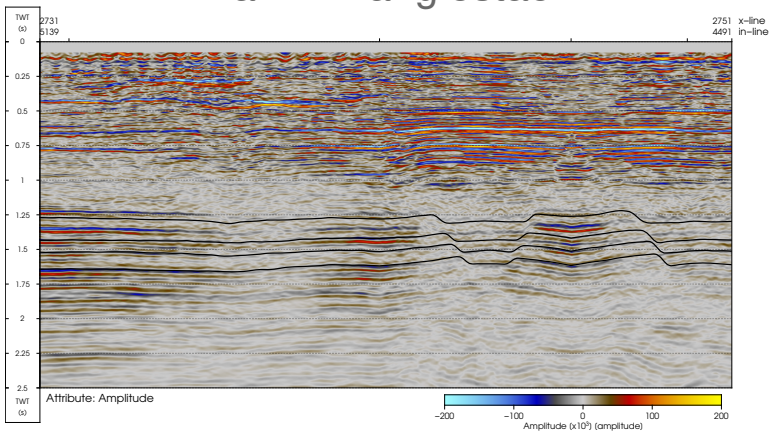
Angle stack conditioning

- Final PP time to PS time correction field now applied to anglestacks
- Anglestacks within each component then aligned to the component full stack
  - All anglestacks in PP time
  - All angelstacks flattened
- Raw PP anglestacks require amplitude calibration
  - Repeat similar workflow to the full stack calibration anglestack by anglestack
  - Amplitude effects are angle specific
  - Only correct amplitudes, spectral variations between stacks and components will be corrected by wavelets

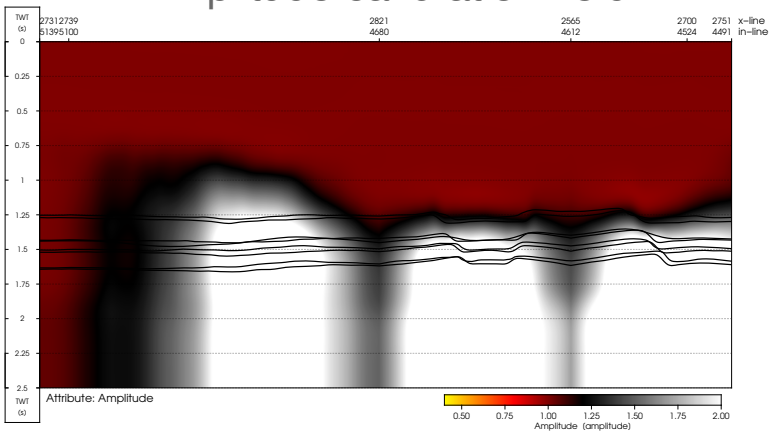
Case study – preconditioning

Angle stack amplitude calibration and intra–component alignment

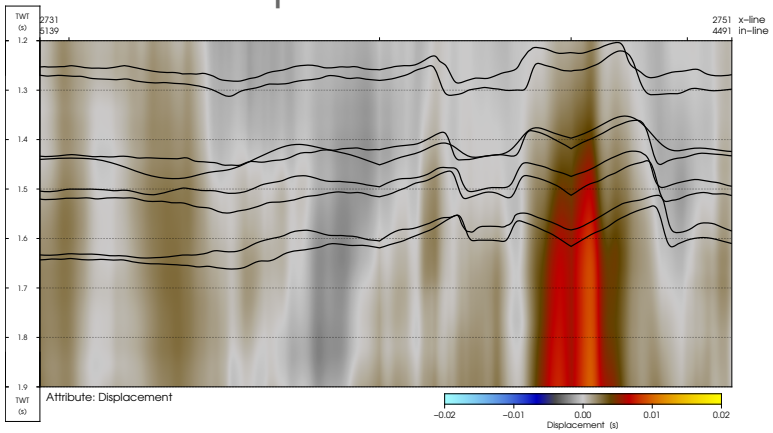
Raw PP anglestack



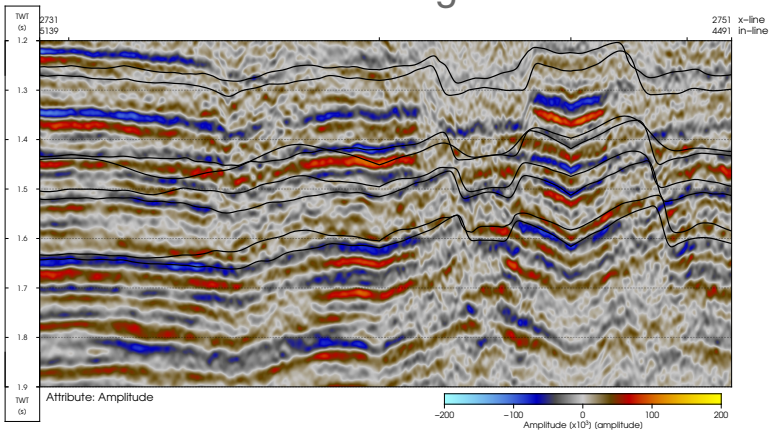
Amplitude calibration field



Displacement field



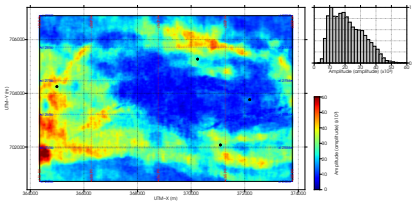
Calibrated anglestack

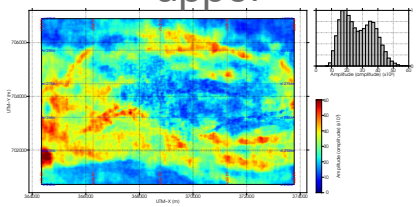


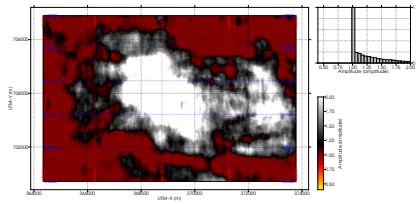
Case study – preconditioning

25° to 35° PP anglestack amplitude calibration

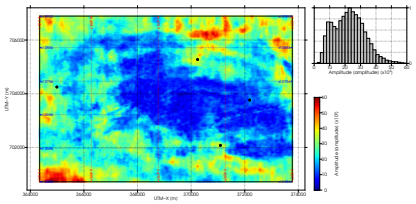
upper

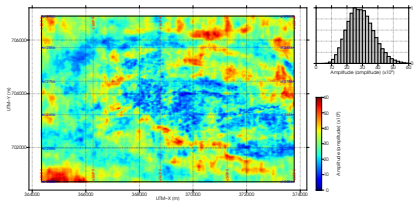


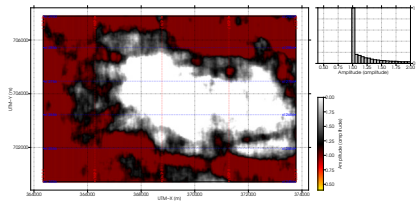




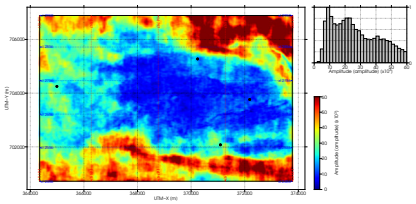
central

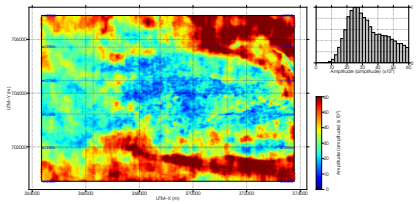


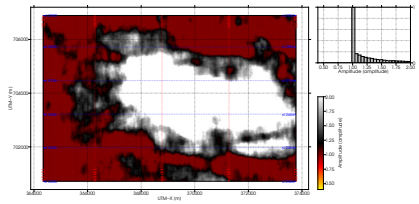




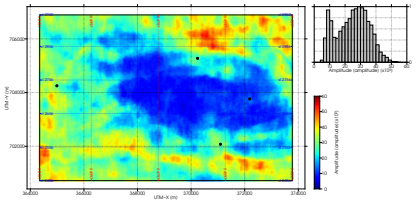
lower

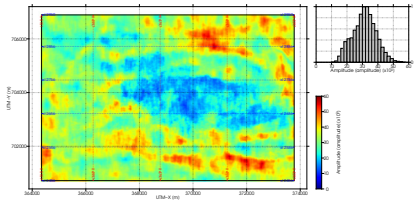


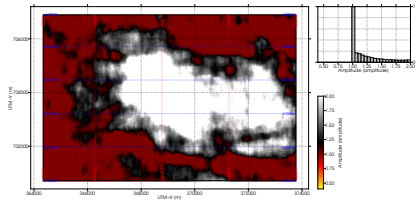




full



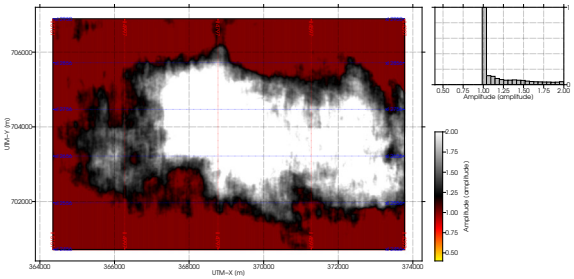




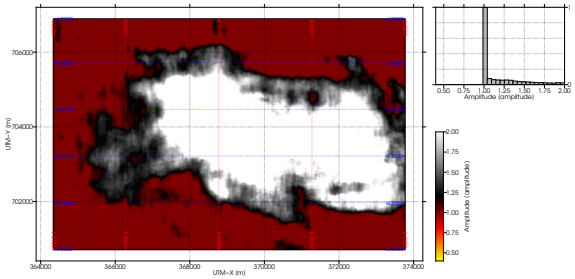
Case study – preconditioning

Scalar fields by PP anglestack for amplitude calibration

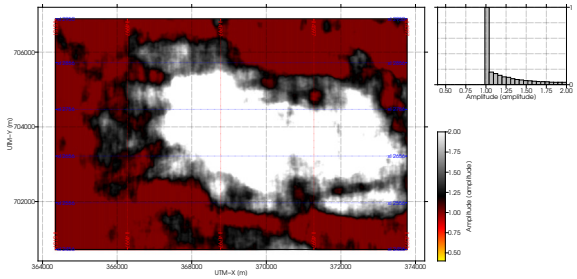
5°–15°



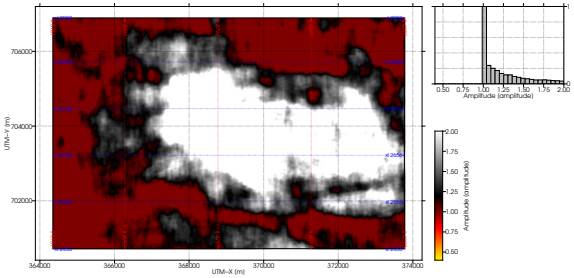
15°–25°



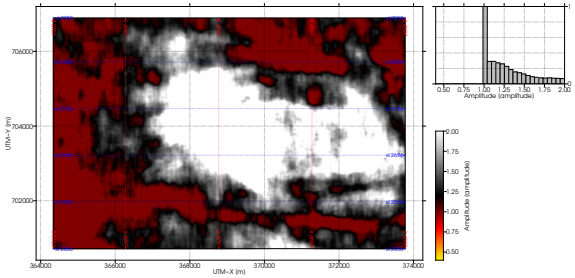
25°–35°



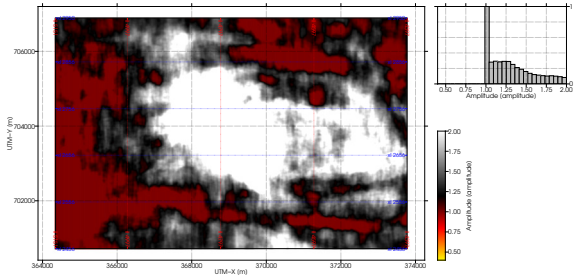
25°–40°



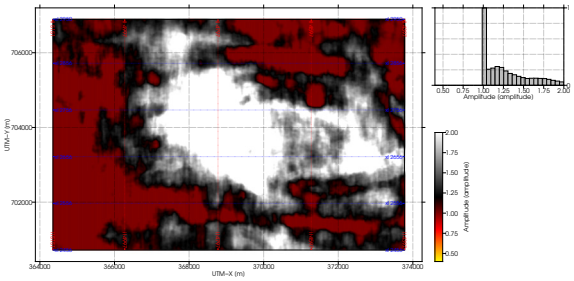
30°–45°



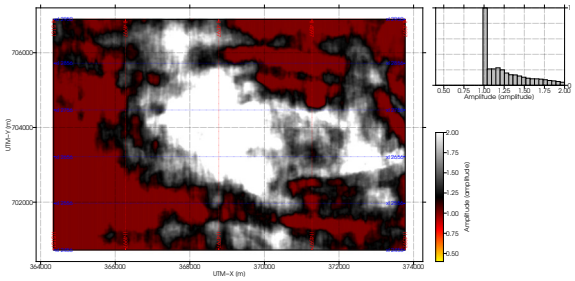
35°–45°



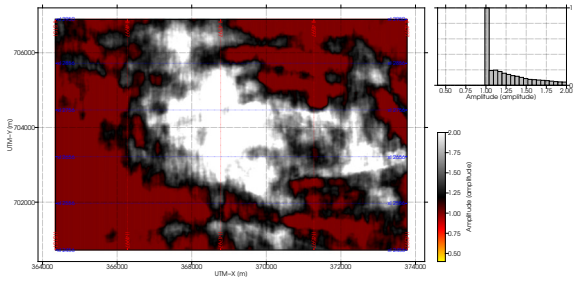
35°–50°



40°–55°

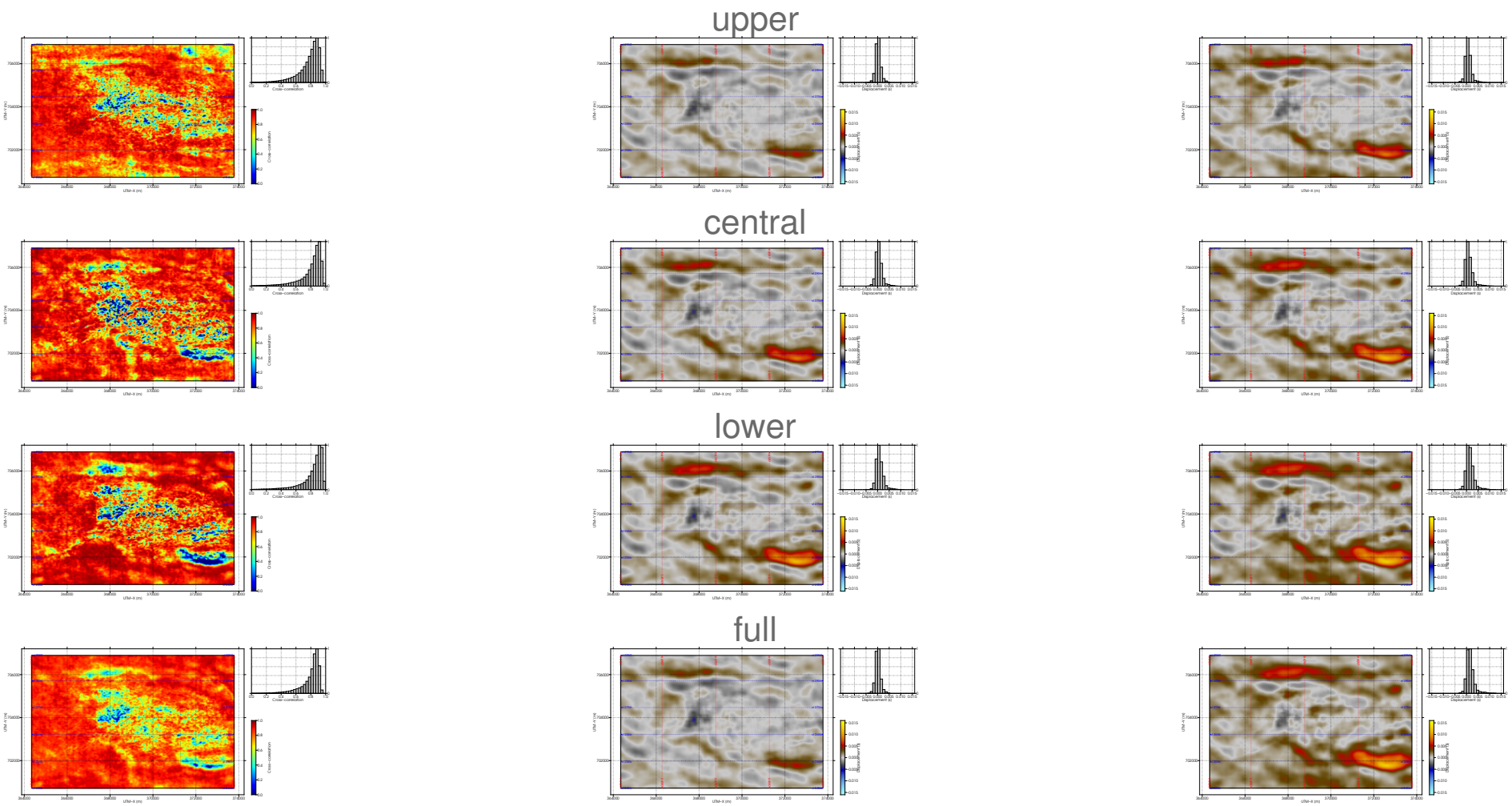


45°–55°



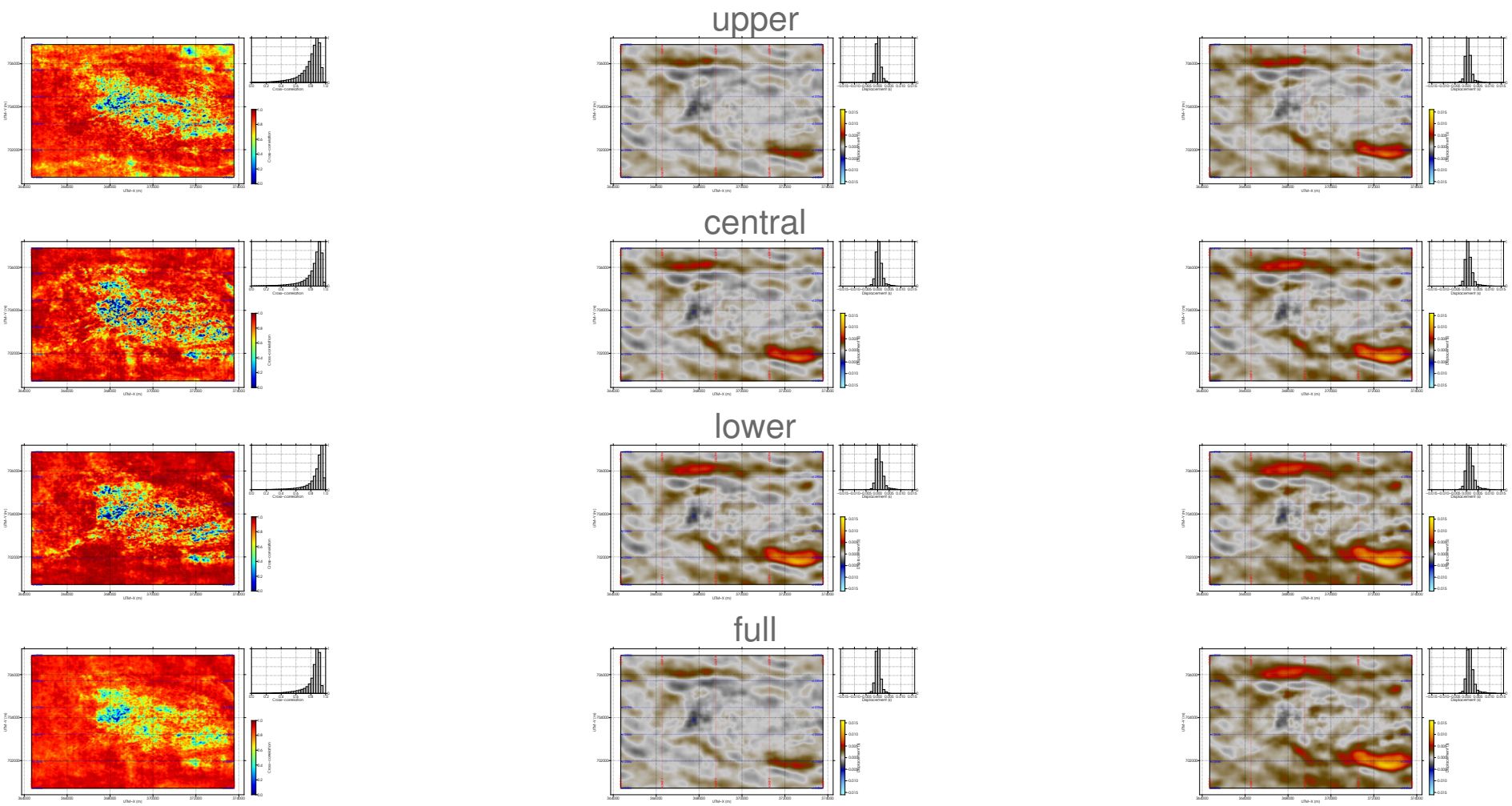
Case study – preconditioning

25° to 35° PP anglestack event alignment



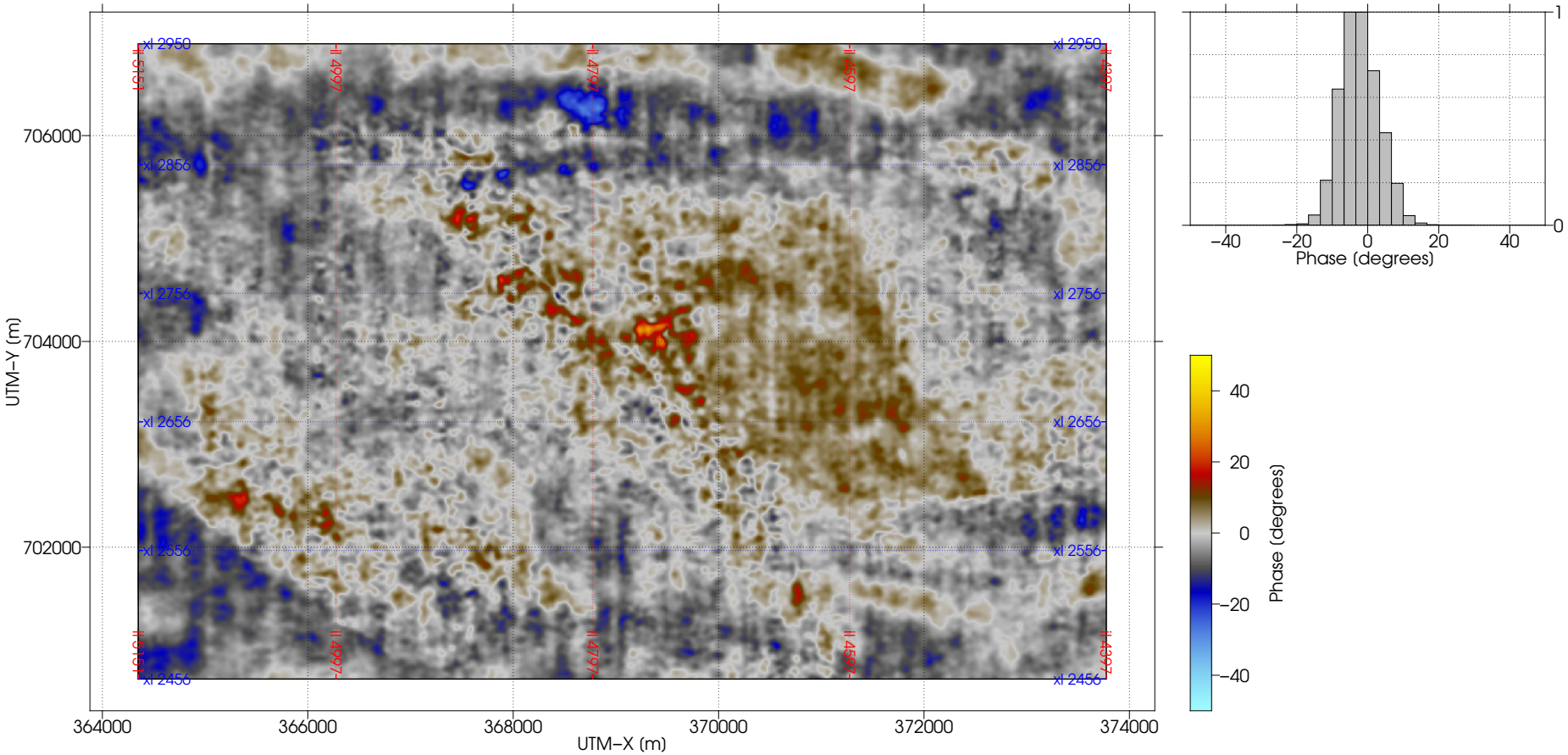
Case study – preconditioning

25° to 35° PP anglestack event alignment



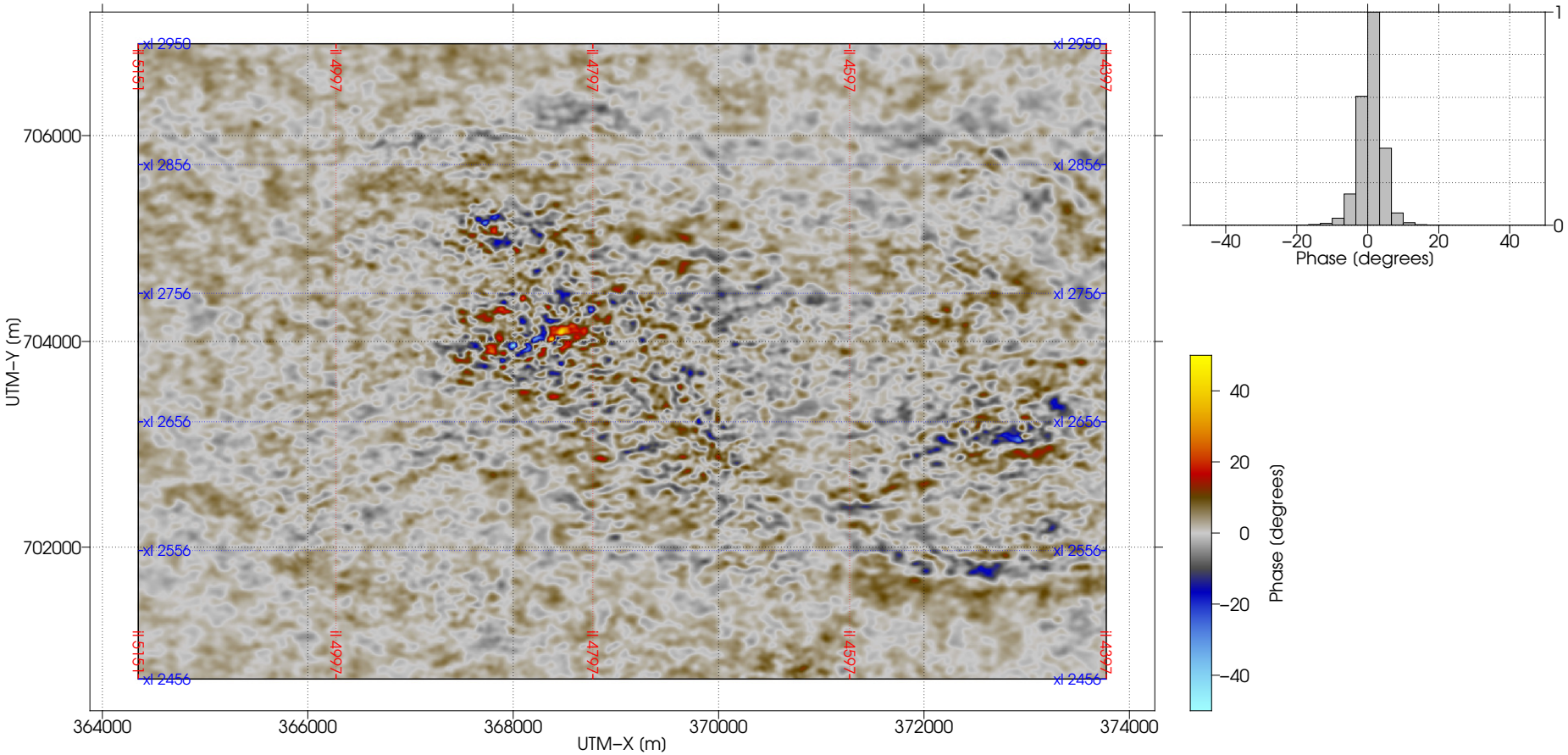
Case study – preconditioning

25° to 35° PP anglestack phase mismatch before event alignment



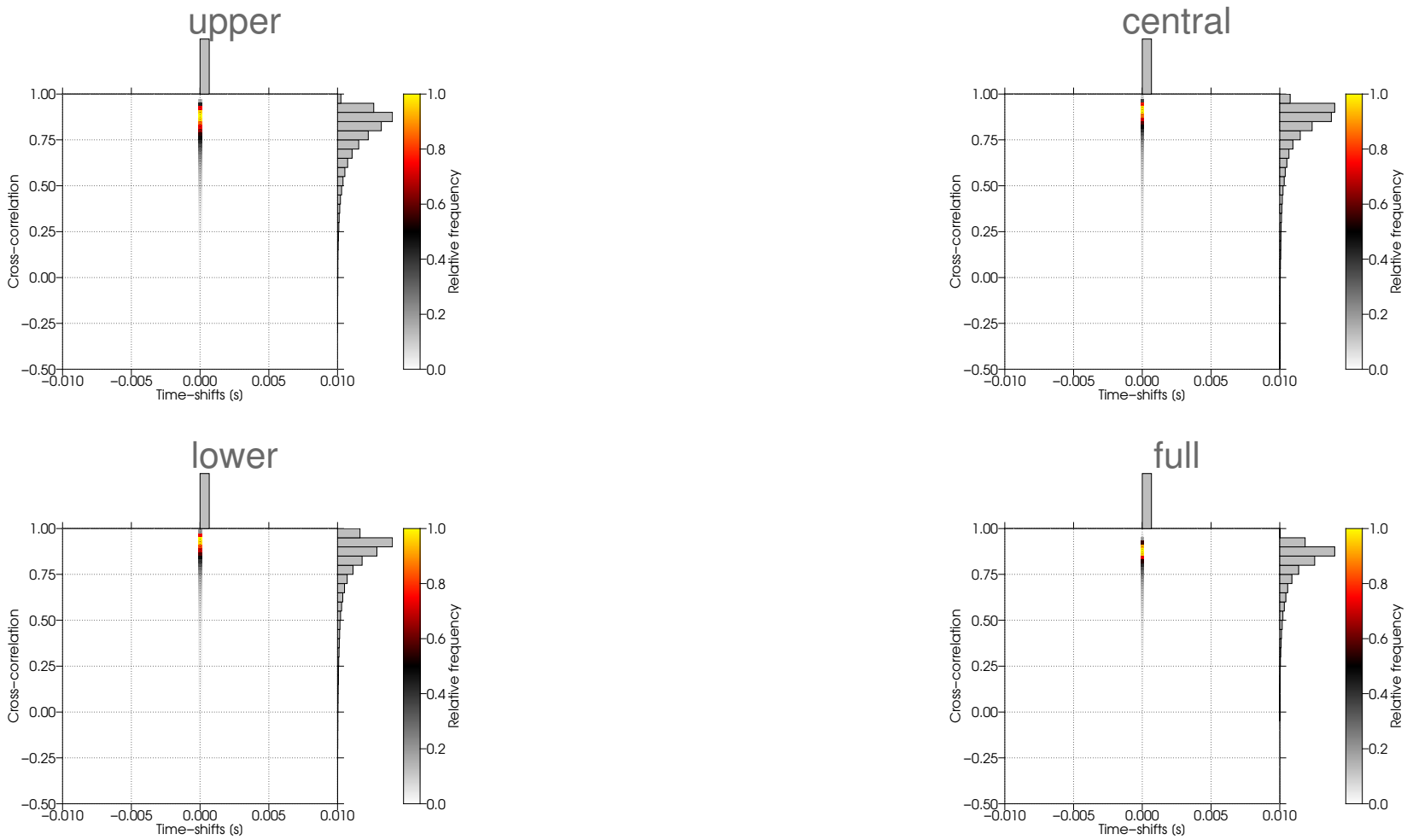
Case study – preconditioning

25° to 35° PP anglestack phase mismatch after event alignment



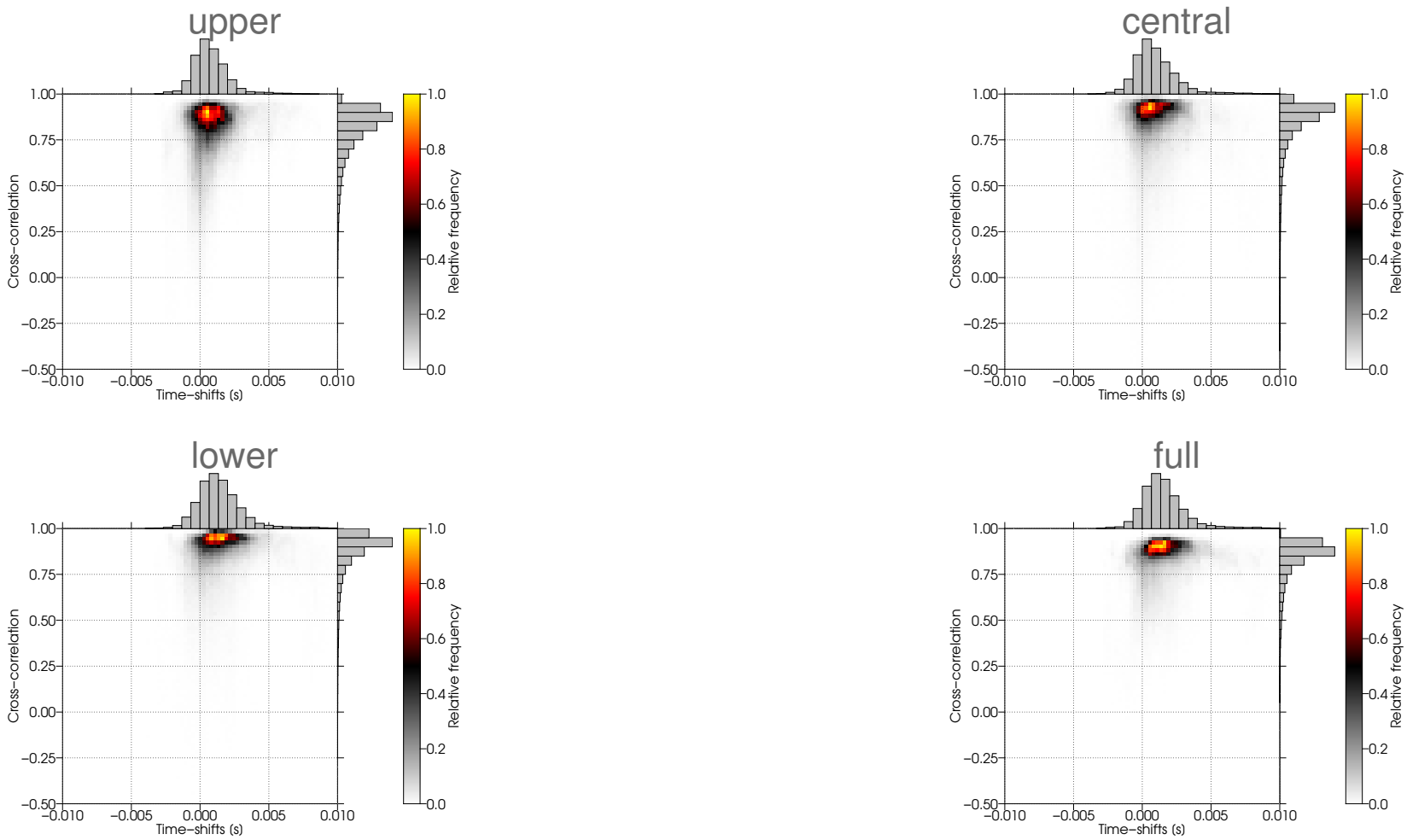
Case study – preconditioning

25° to 35° PP anglestack Xcorrelation vs max displacement before event alignment



Case study – preconditioning

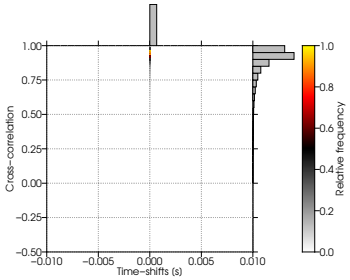
25° to 35° PP anglestack Xcorrelation vs max displacement after event alignment



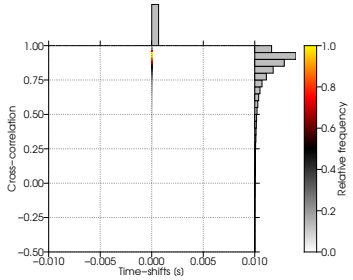
Case study – preconditioning

Lower window PP anglestack Xcorrelation vs max displacement before event alignment

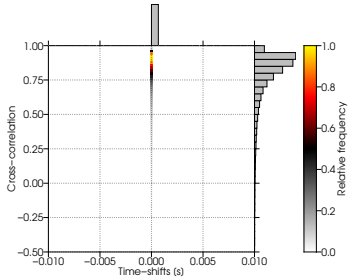
5°–15°



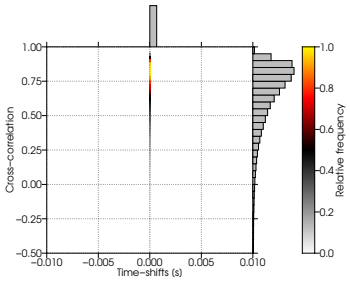
25°–35°



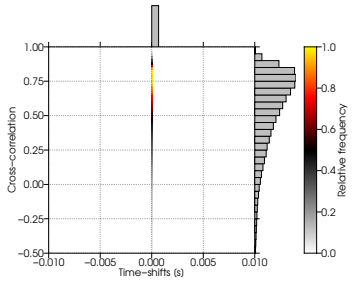
25°–40°



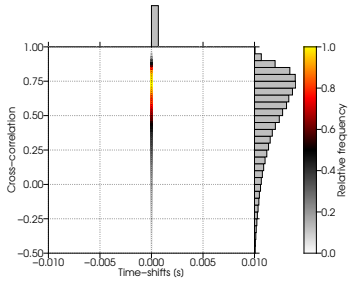
30°–45°



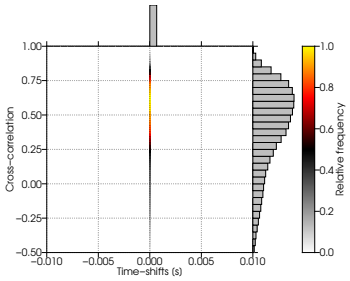
35°–45°



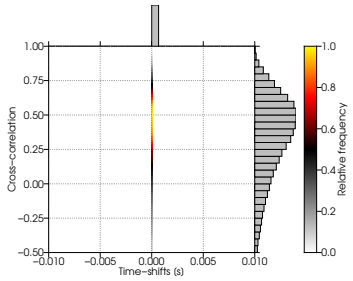
35°–50°



40°–55°

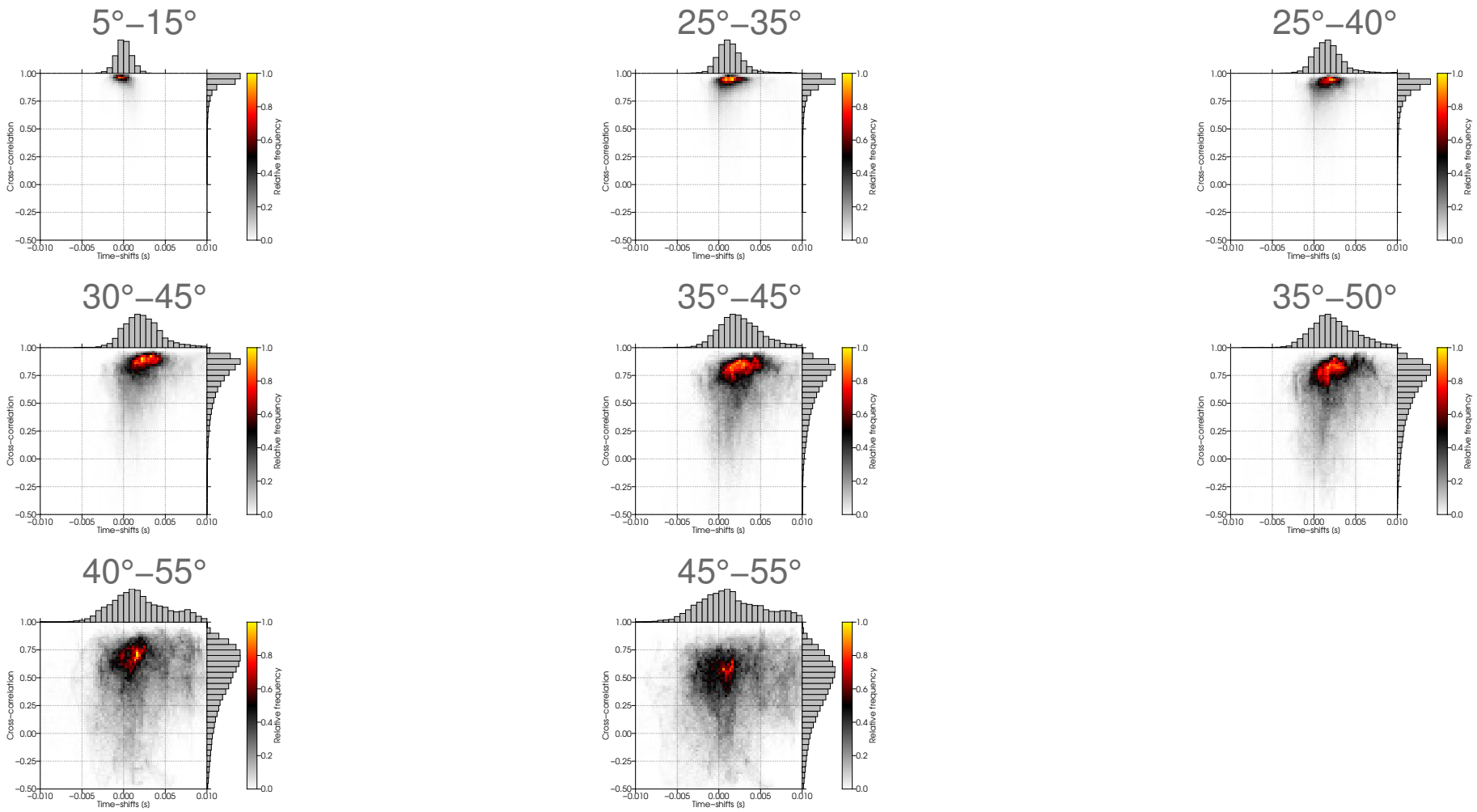


45°–55°



Case study – preconditioning

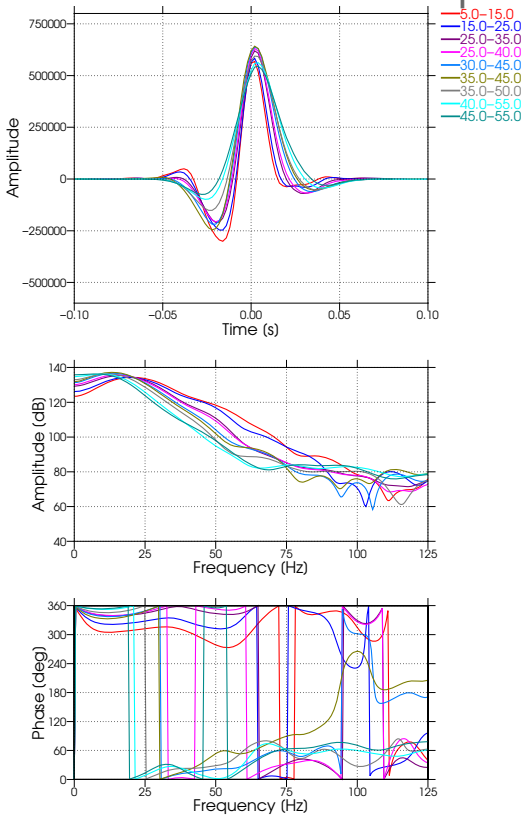
Lower window PP anglestack Xcorrelation vs max displacement after event alignment



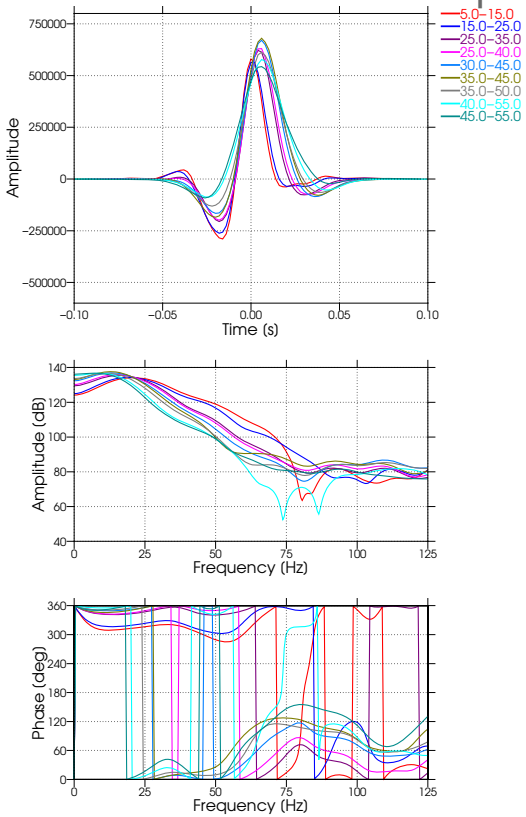
Case study – inversion parameterisation

Final multiwell wavelets – wavelets without preconditioning shown for comparison

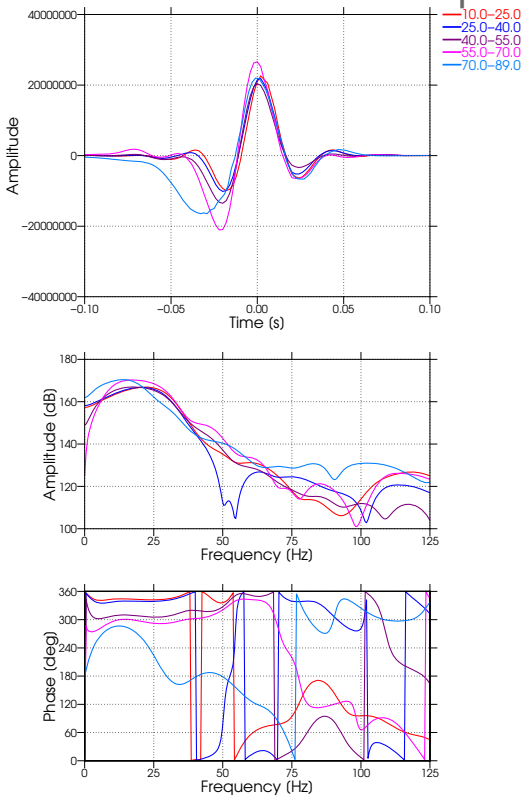
PP wavelets after warp



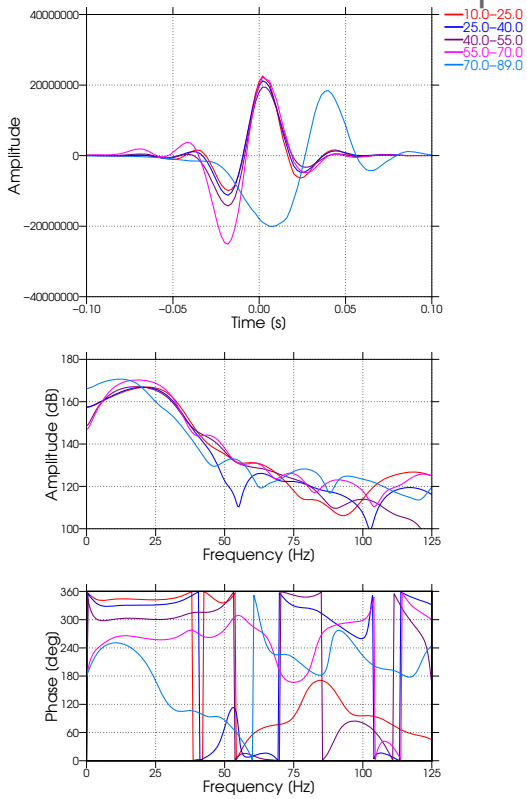
PP wavelets before warp



PS wavelets after warp

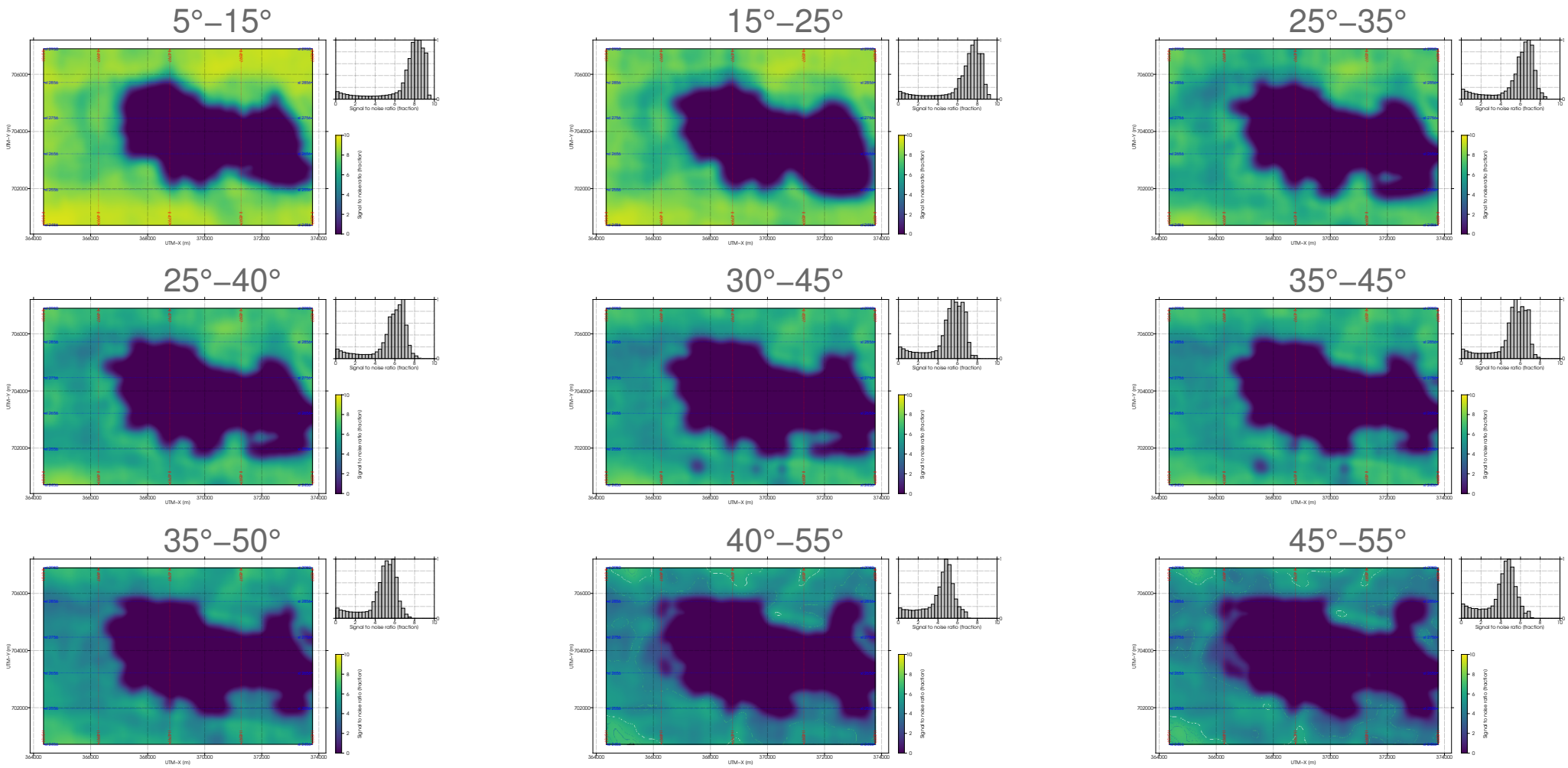


PS wavelets before warp



Case study – inversion parameterisation

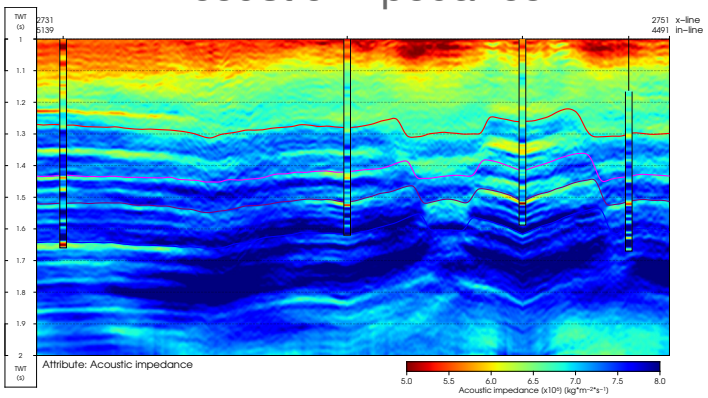
Component weighting



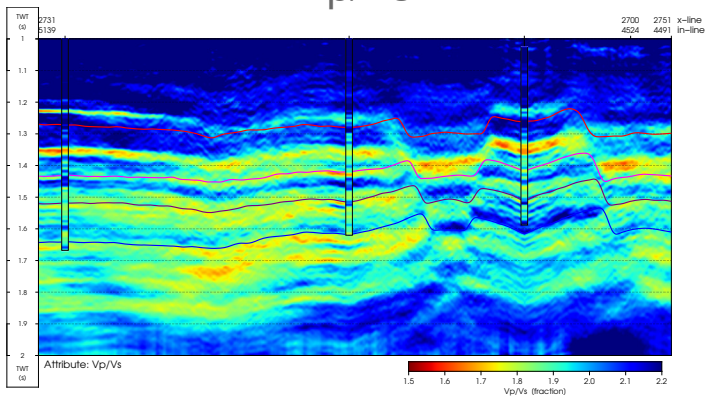
Case study – inversion

Final inversion PP

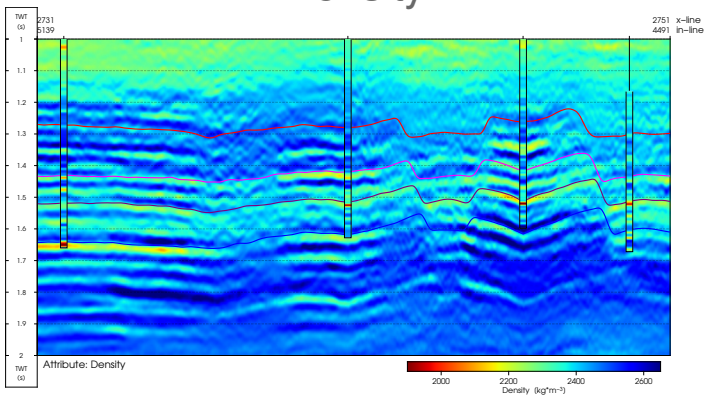
Acoustic impedance

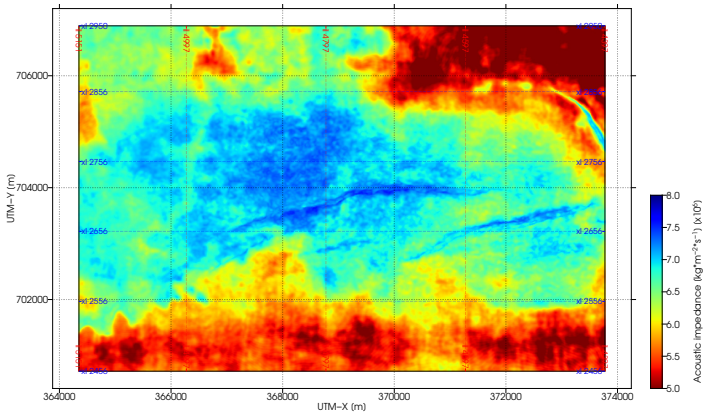


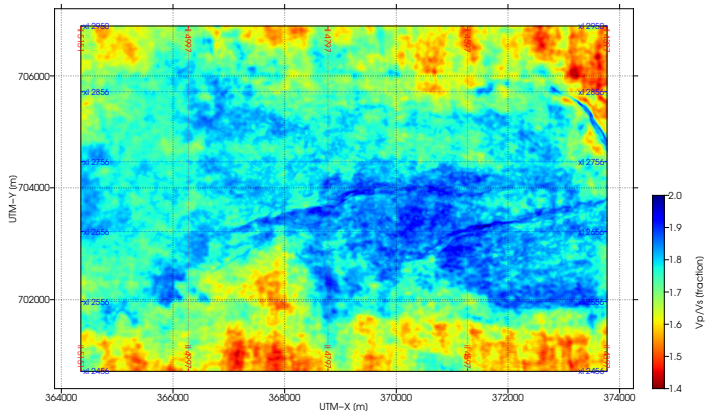
Vp/Vs

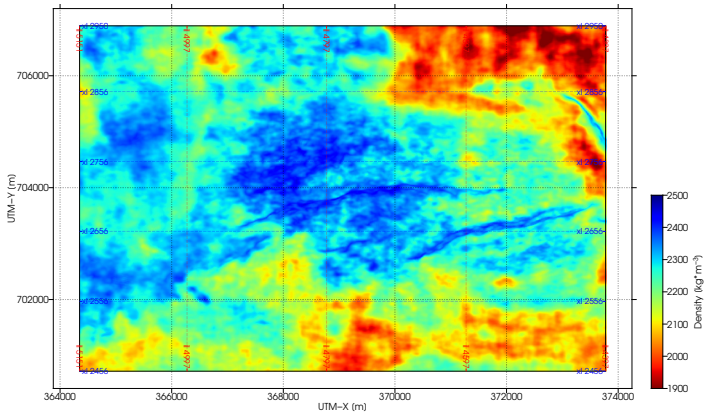


Density





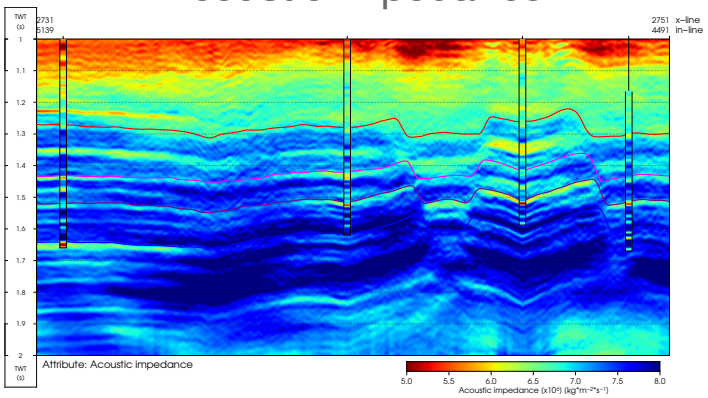




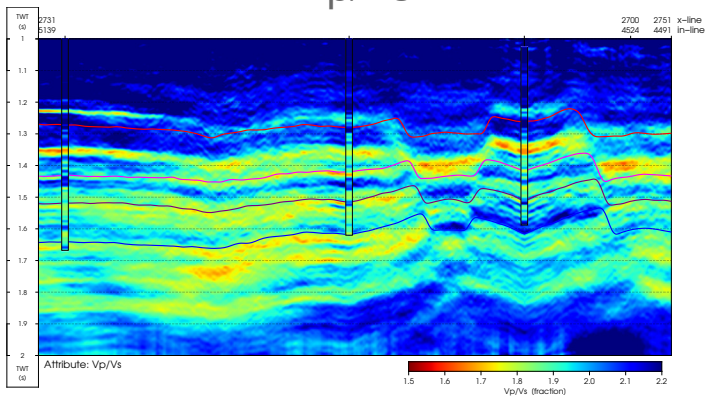
Case study – inversion

Final inversion PPPS

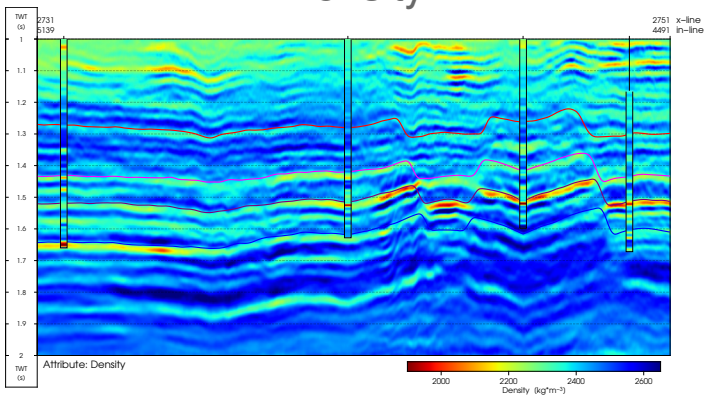
Acoustic impedance

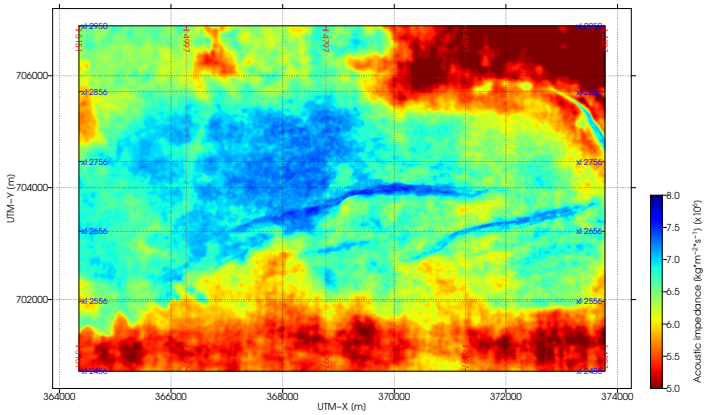


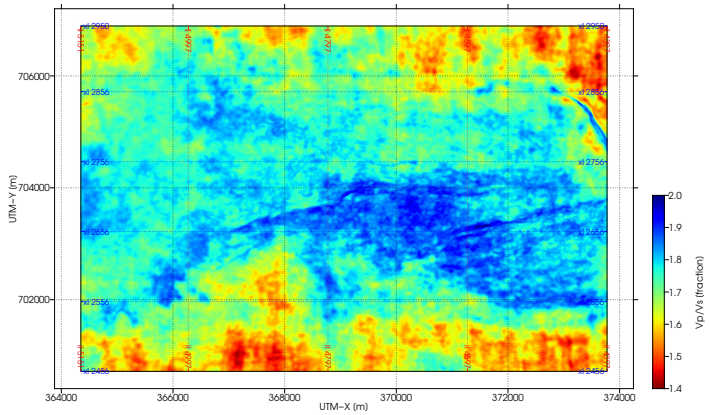
Vp/Vs

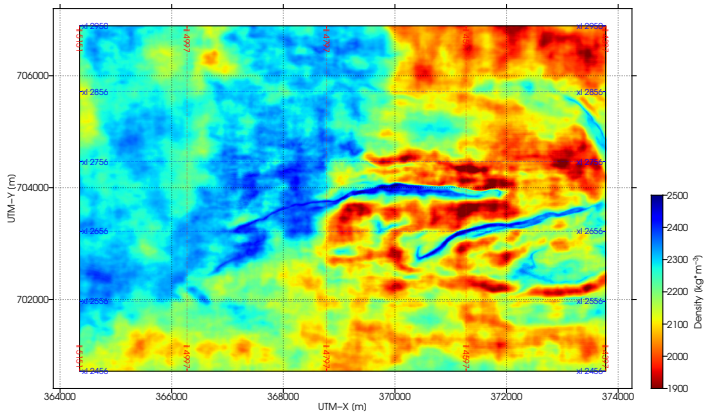


Density





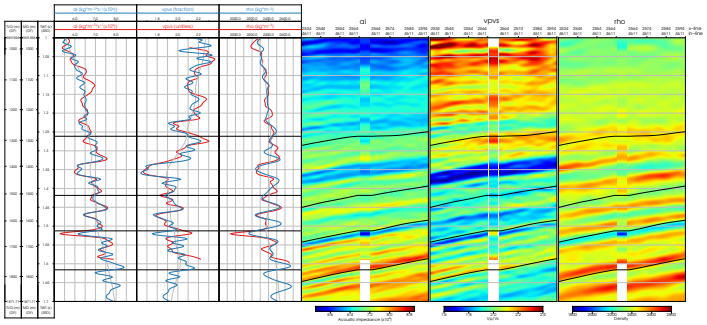


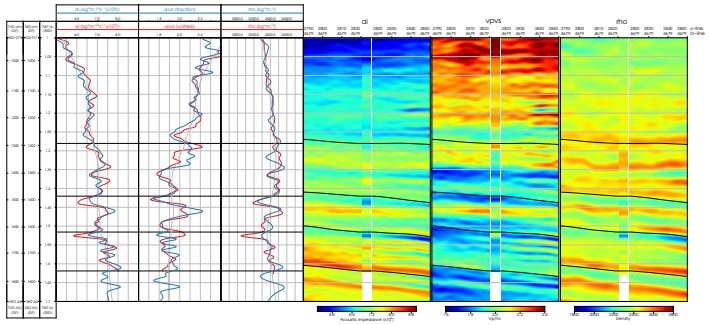


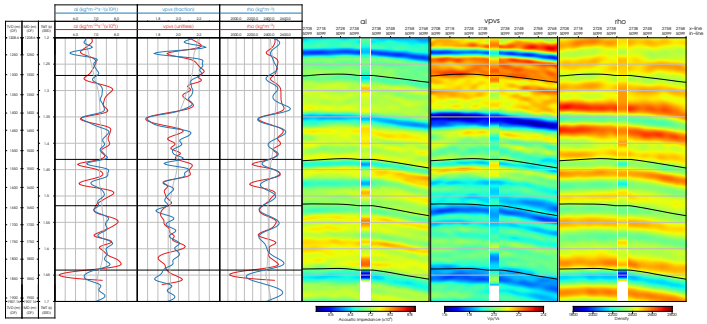
Case study – calibration vs blind wells

Final inversion PP

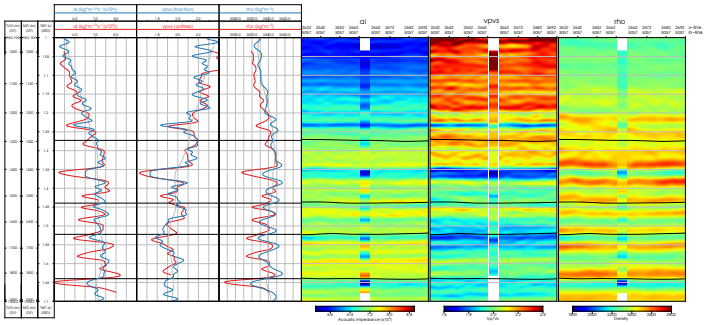
Calibration wells

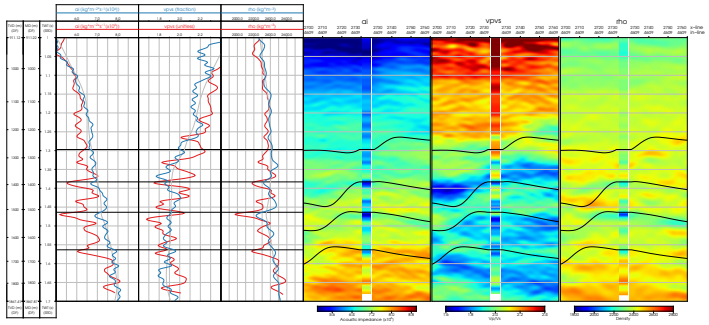


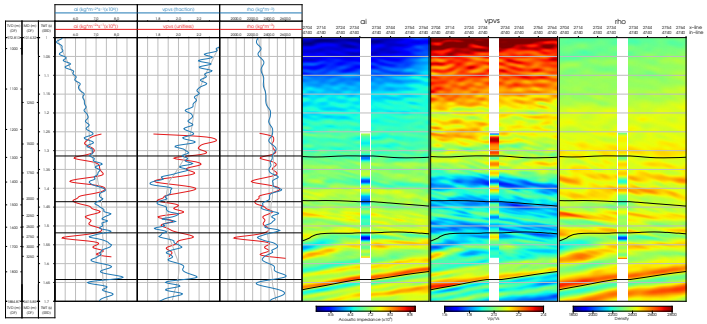




Blind wells



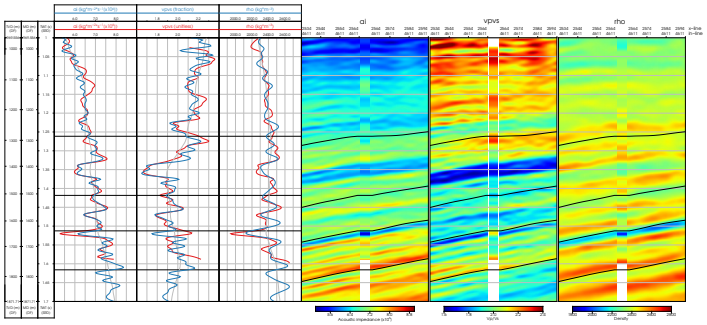


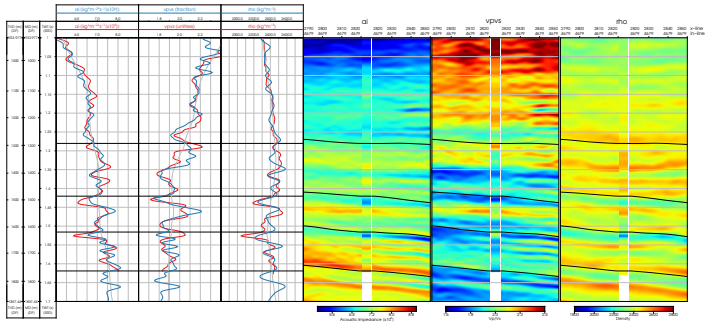


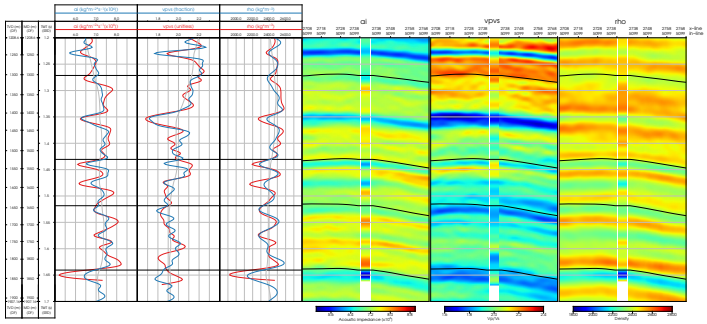
Case study – calibration vs blind wells

Final inversion PPPS

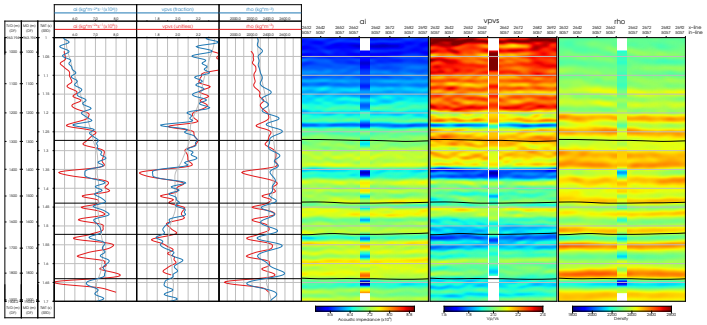
Calibration wells

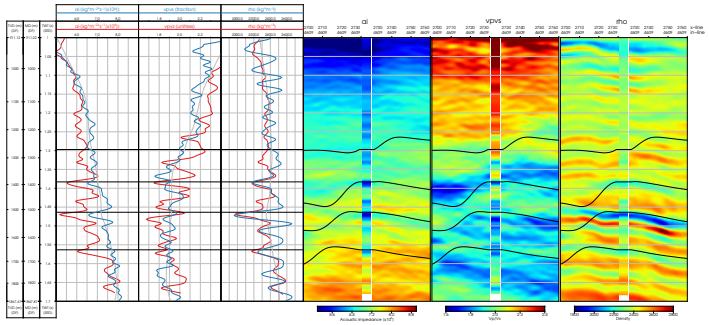


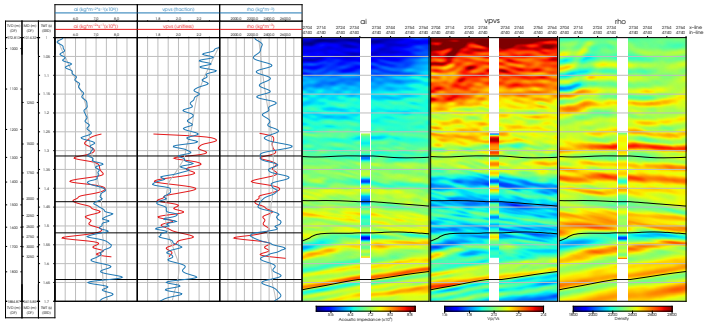




Blind wells







Conclusions

- A focus on preconditioning, and especially event registration, produced a more geologically consistent density volume
- Acoustic impedance is relatively robust and, after amplitude calibration, PP inversions showed limited improvement with the addition of PS data
- Vp/Vs improvements are smaller than you might expect. This is consistent with results seen on other projects

Lessons learned and recommendations

- You can get good density results from simultaneous PPPS AVO inversion
  - It does require care and attention – but it can be done
  - You need to parameterise such that there is no cross talk between the terms

- The PS data does not improve all components equally
  - Where the PP data was already good, the addition of the PS data can downgrade the results

- Frame the question
  - The workflow and the focus depends on the question asked
  - In this case density was important and it required the PS data in the gas obscured areas
  - This workflow combines easily with others – e.g. thin bed resolution, time lapse, etc.

Lessons learned and recommendations

- Process the PS data
  - This workflow leverages the excellent quality PS image
- Depth process the data
  - The PP and the PS data are spatially different in this case despite being depth processed
  - This is particularly apparent around the faults
- Preserve the azimuth information
  - Most modern OBS geometries are naturally full azimuth
  - This information increases inversion resolution
  - This information contains the stress/fracture signature

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- Audience
  - As long as the questions are not too difficult!