Enhanced onboard 4DQC and in-field Ultra Fast Track PreSDM 4D Volumes, case study 2022 Mariner monitor2

Mark Schons, Dawn Fear, Jerzy Mazur, Ratnesh Pandy, Jonathon Pollatos and Mark Skinner (Shearwater GeoServices)

Introduction

Since the early days of 4D (time-lapse) monitoring (Greaves and Fulp, 1987), seismic data acquisitions often come with some uncertainty regarding whether they will successfully achieve their objectives. The period between first shot and first image can be a nervous one for all involved in the project as they await confirmation that a useable 4D signal can be identified in the data. Improving 4DQC (Quality Control) in field and providing early visibility into data quality would be of great benefit for all with regards to informing line acceptance and building confidence in the final product. Up to now, infield quality control performed on the vessel during the acquisition of 4D monitor seismic has been limited to statistical analysis of geometric repeatability and 3DQC of the acquired seismic data. The innovative approach described here demonstrates the benefits of "real-time" 4D seismic data quality analysis and produces ultra-fast track 4D products in an unprecedented time frame for streamer 4D.

Mariner field 4D QC

This case study reviews the enhanced 4DQC performed onboard during the acquisition of a second monitor over the North Sea Mariner field, in the summer of 2022. This includes the important preparation work undertaken by Equinor and Shearwater prior to the commencement of acquisition in order to establish the extended 4DQC workflow to be used in the field. Starting with the existing baseline and monitor 1 data, a simplified sequence was established, analogous to that which had been applied in the original base to monitor 1 processing project.

The existent base vs monitor-1 full processing deployed an expanded binning methodology (Smith, Scott and Traylen 2012) in an offset-varying manner, with higher offset classes having the search range extended significantly in the crossline direction (figure 1).

Expanded binning allows a trace to find a partner trace from the other vintage but loosens the restriction that this trace must be in the same bin, allowing the search for monitor traces to extend beyond the static bin bounds. This can allow for significant improvements in geometric repeatability metrics by removing a barrier to optimal pair selection. However, care needs to be taken to ensure that improvements in repeatability are not offset by degradation of image quality especially in areas of complex shallow overburden geology. Here, shadowing the preset processing flow, the objective of the expanded binning is to better fill holes around the platform and at swath bounds with more repeatable data. The client's intent for their repeat monitor full processing was to bin against this already pre-selected dataset.

For QC to be meaningful, this expanded binning methodology needed to be replicated to enable equivalent trace selection in the new field data acquisition (monitor 2) as would be used in full processing.

Bin Size	Off Bin Size	Central Offset (Off Bin 1)	Central Offset (Off Bin 59)
6.25x6.25m	50m	250m	3150m

Off Bin Range	Offset Range	Inline Expansion	Xline Expansion
1 to 5	225-475m	+/- 1	+/- 1
6 to 29	475-1675m	+/- 3	+/- 1
30 to 59	1675-3175m	+/- 5	+/- 1

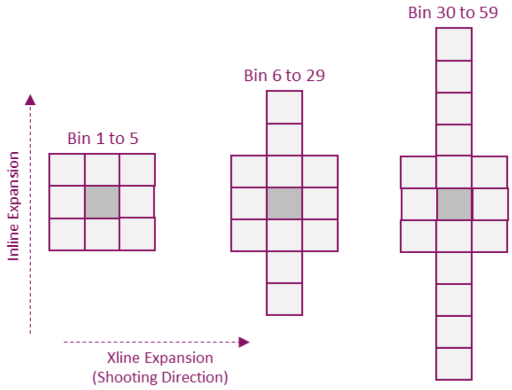

***Figure 1** Offset Dependent 4D Expanded Binning applied to Mariner Data*

In processing, maps for individual offset classes spanning the whole survey area are used for assessing repeatability metrics. This is clearly not practical for the acquisition of a single sail line (figure 2). To be able to perform a similar assessment of the repeatability metrics during acquisition on a sail line by sail line basis, we developed a new infield qc methodology for demonstrating the effect of trace selection on the geometric 4D repeatability attributes. These QC displays, colloquially known as the Northern Lights plot due to their resemblance to the aurora borealis atmospheric phenomena (figure 3), were found to be particularly valuable in understanding the pairing of traces selected for 4D analysis.

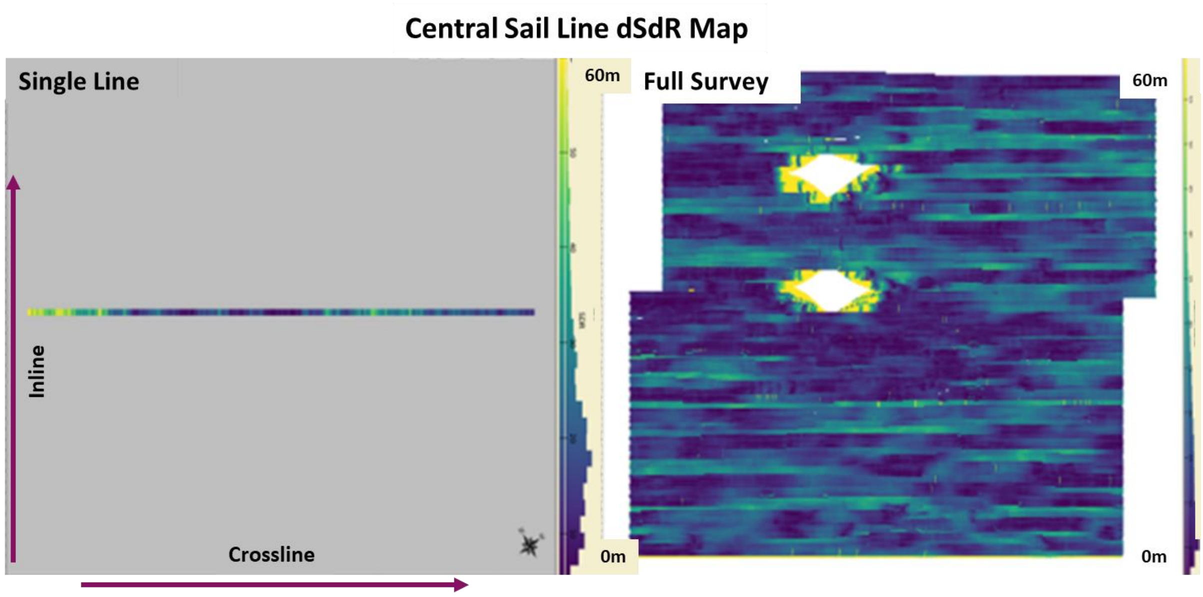

***Figure 2** dSdR plot for a single line vs full survey for a single offset class. Note how impractical this display is for sail line-by-sail line QC*

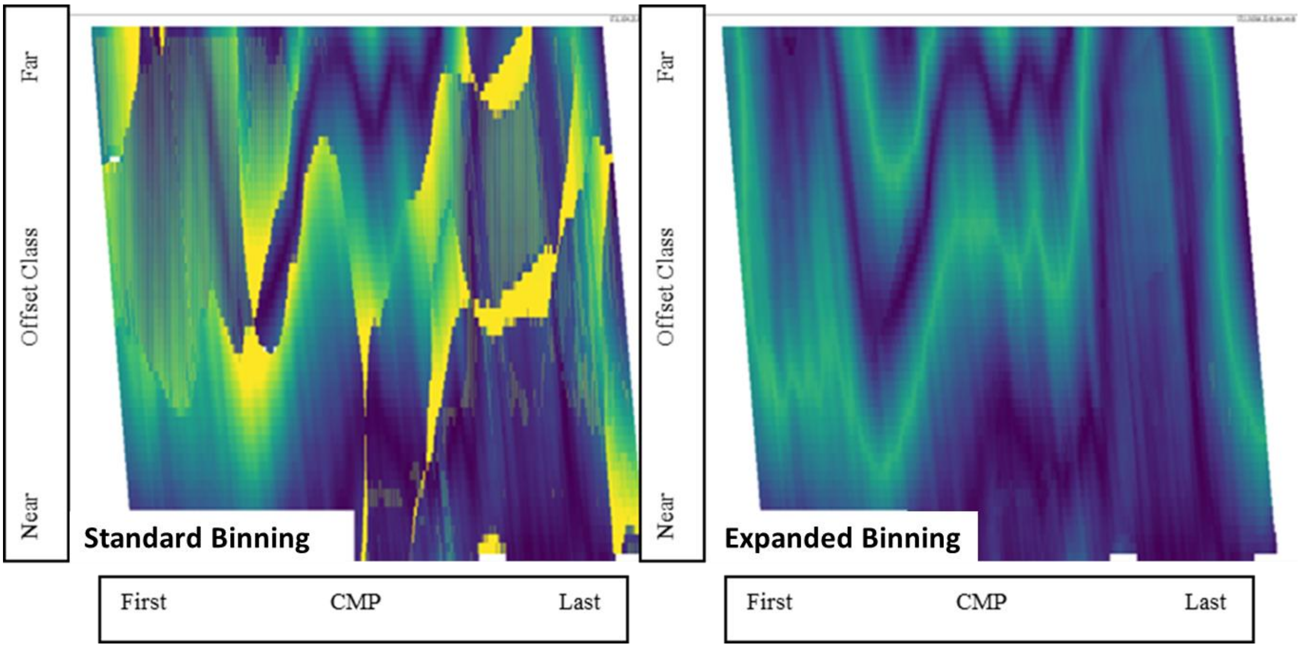

Figure 3 *The Northern Lights dSdR Plots for a single pair of sail lines shows dSdR behaviour along the line for all offset classes and highlights any issues. The colormap goes from blue for small dSdR values to yellow for high values. This example also shows the repeatability benefits of the expanded binning approach, especially in areas of shot and cable skips.*

The in-field, simplified processing sequence needed to be light enough to be achievable offshore in a short timeframe but robust enough to handle important 3D and 4D effects and produce products suitable for meaningful 4D qualitative analysis.

The following steps were seen as being key to achieving this.

- De-signature (de-bubble, zero phasing and source-side de-ghosting)
- De-multiple.
- 4D expanded binning against a pre-binned dataset.
- 4D de-striping.
- 4D global matching.
- PreSDM (pre-stack depth migration) of selected lines.

This sequence was designed to be performed by the onboard team immediately after the acquisition completion for each sail line, producing a suite of QCs including:

1. Statistical geometric 4D spatial QCs
   - Surface positioning comparisons
   - dSdR (sum of source and receiver dislocations) maps of expanded binned data (Northern Lights plots)

2. 4D PreSDM data quality analysis
   - 4D stack and difference sections
   - 4D Window based attributes (NRMS, RRMS, time shift, phase shift, predictability)

4D seismic images from migrated data were produced from the fast and robust 4D sequence per sail-line and were used to investigate quantitatively lines and areas where there were concerns over factors such as seismic interference, rig noise or where there were concerns on the suitability of the specified geometric repeatability. These QCs demonstrated the quality of each line and allowed real-time evaluation of these questions. It was found that even where these noise types were prominent in the raw data, there was no significant impact on the result, thus demonstrating that expensive and time-consuming re-shoots were not required.

Discussion and Conclusions

This study shows some of the QCs from the inline depth migrations, including migrated 4D sections from a line acquired early in the acquisition programme, that revealed clear and true 4D signal where it was expected (Figure 4). This study also demonstrates how these products were used to aid decision making for line acceptance. Further, the onboard processing qc team were able to extend the flow to full pre stack 3D depth migrations of the data and provide interpretable ultra-fast track 4D PreSDM volumes within 9 days of the survey final shot. This is extremely fast for towed streamer 4D products. These fast-track products enabled the interpretation team to get a first look at the data and identify issues and questions to be investigated and addressed in the full processing project.

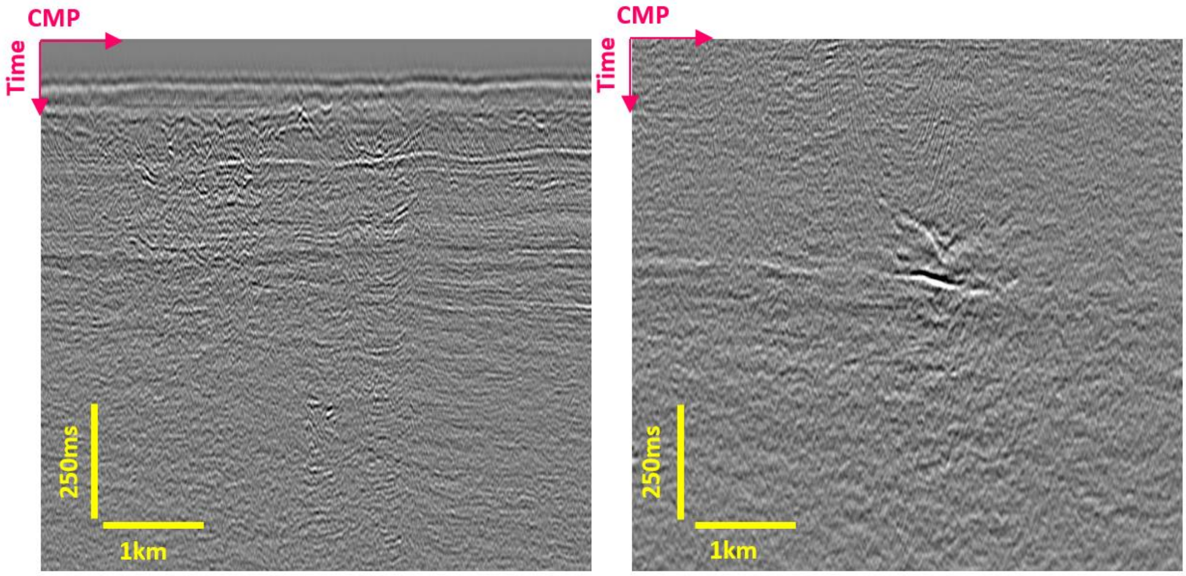

Figure 4. Zoomed 4D Sections, Overburden (left) and reservoir (right) from an in-field QC line

References

Greaves, R. J., and T. J. Fulp, 1987, Three-dimensional seismic monitoring of an enhanced oil recovery process: *Geophysics*, 52, no. 9, 1175–1187.

P.J. Smith, I. Scott & T. Traylen 2012, Simultaneous Time-lapse Binning and Regularization of 4D Data , Copenhagen 2012.