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Multi-vintage Coherent Noise Attenuation in Time-lapse Processing

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SUMMARY

We present the application of a 4D simultaneous coherent noise adaptation algorithm and demonstrate its value with a multi-vintage North Sea case study. The 4D simultaneous adaptation workflow significantly helps in reducing coherent noise and multiple leakage into the 4D difference sections, thus improving its quality and interpretability. The QC maps show a reduction in NRMS of about 20%. The methodology is applicable in a multi-vintage context where more recent surveys are processed simultaneously without imposing a reference base, while older surveys are processed using the fixed base method. The fixed base method is also suitable for repeat-processing projects.

Introduction

Time-lapse processing today regularly deals with multiple acquisitions acquired several years apart, occasionally as much as two decades. This leads to dramatic changes in the signal and noise characters of each vintage, due to technological advances or changes in the acquisition equipment, geometry, the prevailing environment and changing facilities.

4D seismic processing is designed to minimise non-repeatable noise whilst preserving real 4D signal. Removing 4D noise is complex, particularly in settings where acquisitions are not well repeated and the overburden (especially the water-layer) changes significantly. Coherent noise, such as surface and interbed multiples, rig-generated diffractions, direct arrivals, etc… generally has different character from one vintage to another. Mitigating these unwanted effects in a vintage-independent manner leads to suboptimal 4D results. Residual noise leaks into the 4D difference sections and attributes, degrading their quality and interpretability.

Zabihi *et al*. (2012) proposed a new method for reducing residual 4D multiple leakage: The idea is to introduce an extra 4D term into the adaptive multiple subtraction, which simultaneously subtracts noise models from all vintages with a coupling term that looks at their 4D differences. Khalil *et al*. (2013) presented a workflow utilising this idea which generalises the concept and enables a practical implementation. We build upon this workflow to demonstrate its applicability in a multi-vintage study including legacy and modern 4D acquisitions with very different 4D noise characteristics. Furthermore, we propose an extension to this method that also improves the quality of the 3D sections.

Method

Adaptive subtraction has been the industry's workhorse for matching modelled noise to recorded seismic data. It plays a key role in surface related multiple elimination (SRME) (Verschuur and Berkhout, 1997; Lin *et al*., 2005) where the multiple model is distorted by the squaring of the wavelet and other modelling-related deficiencies. Adaptive subtraction minimises the energy E between the noise model, and recorded data

$$E = \left\| d_i - f_i * n_i \right\| \tag{1}$$

where d_i is the recorded data, f_i is the matching filter, n_i is the noise model, and i is the vintage index. Different norms and cost functions are available.

Typically, Equation (1) is minimized for each vintage independently. Whilst this is by definition optimal in a 3D sense, in our experience it often leaves residual coherent noise leaking into the 4D difference sections which are the key deliverable of any time-lapse project. Zabihi *et al*. (2012) proposed coupling the adaptive subtractions to make them more 4D friendly:

$$E = \sum_{i=1}^{N} \left\| d_i - f_i * n_i \right\| + \lambda \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left\| \left(d_i - d_j \right) - \left(f_i * n_i - f_j * n_j \right) \right\| \tag{2}$$

where λ is a weighting parameter that controls the ratio between noise model matching and 4D differences. Khalil *et al*. (2013) generalised the concept to all kinds of coherent noise such as interbed multiples, rig-generated diffractions, and direct arrivals. A workflow was presented that allowed for an efficient application of the idea, in particular, the problem of the co-location of the data for 4D subtraction was addressed. A trial on North Sea data proved promising, which encouraged us to pursue this idea further.

In a setting where many vintages are being processed, direct coupling of all surveys may not be suitable. The quality of the output could be damaged by less-repeatable vintages, such as those from older, legacy acquisitions. To address this issue we propose to use Equation (2) to couple only vintages which are of similar character, design, and noise content, while for vintages of lower quality we modify Equation (2), such that one vintage is fixed, thus becoming a reference:

$$E = \|d_i - f_i * n_i\| + \lambda \|(d_o - d_i) - (n_o - f_i * n_i)\| \tag{3}$$

where d_o and n_o are the recorded data and the noise model respectively of the fixed vintage. The matching filter only modifies vintage 'i', so that the reference vintage is not changed, and thus is not influenced by the shortcomings of the other vintages. In a typical processing scenario, the noise model of the fixed vintage 'n_o' has already been processed using Equation (2), along with other vintages of similar character. Only older or less repeatable surveys are processed using Equation (3).

As Equations (2) and (3) have an extra 4D coupling term, they may degrade the quality of the 3D sections. Following the 4D driven subtraction, we can aim to further improve the 3D data quality, so long as we preserve the optimal 4D differences. This can be achieved by evaluating and subtracting the common part of all multiple models from each vintage. This leaves the optimized 4D differences intact.

A Ten-vintage real data example

In this example we demonstrate the method on a ten-vintage project. The datasets have been acquired over a span of 20 years, the earliest in 1993 and the most recent in 2013. Surveys acquired after 2004 have denser, more repeatable acquisition design. If all vintages are processed simultaneously, non-repeatable noise from older surveys leaks into the more recent ones, degrading their quality. To overcome this issue, the sequence was designed such that vintages acquired from 2004 onwards are processed simultaneously using Equation (2). The processed 2013 vintage is then used as a fixed reference for the rest of the older surveys.

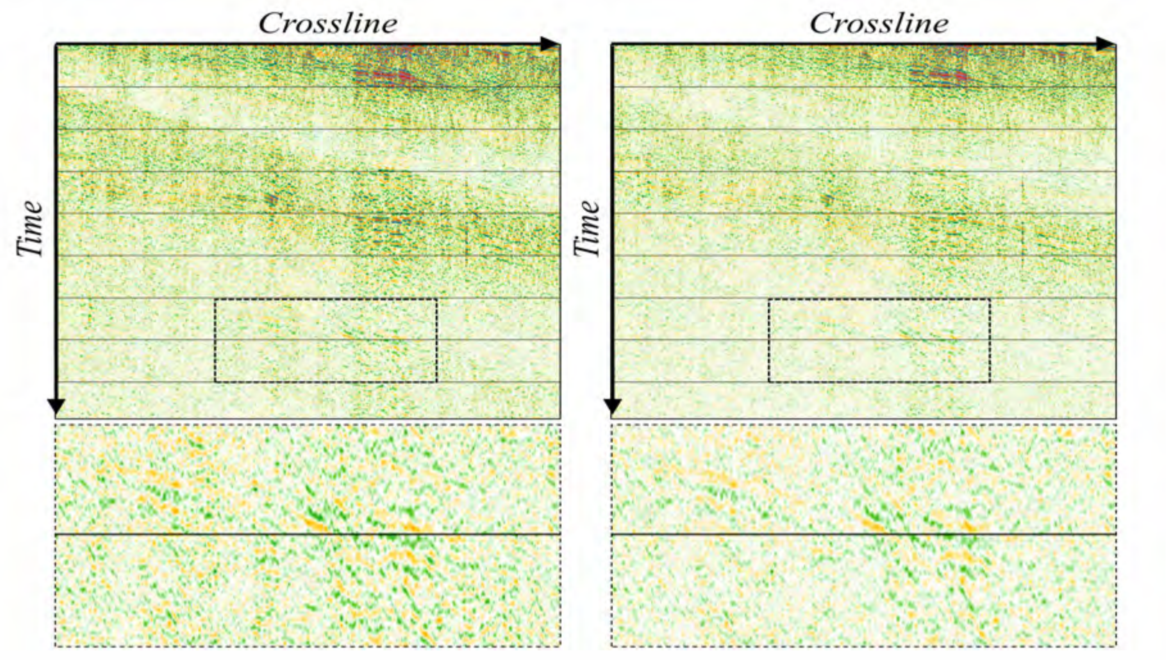

Figure 1 *4D difference section for vintage 2013 vs. 2010 (Left) without applying the 4D adaptation process. (Right) the 4D adaptation process is applied.*

Figure 1 shows the 4D difference sections between vintage 2010, and vintage 2013. Vintage 2013 along with 2004, 2006, 2008, and 2010 are processed simultaneously using Equation (2). On the left side, the 4D difference is shown without applying the 4D adaptation process while on the right side, it is applied. Residual 4D noise leaking into the sections is significantly reduced; this is particularly observable where the energy of the multiple trains is attenuated. The real 4D signal is preserved.

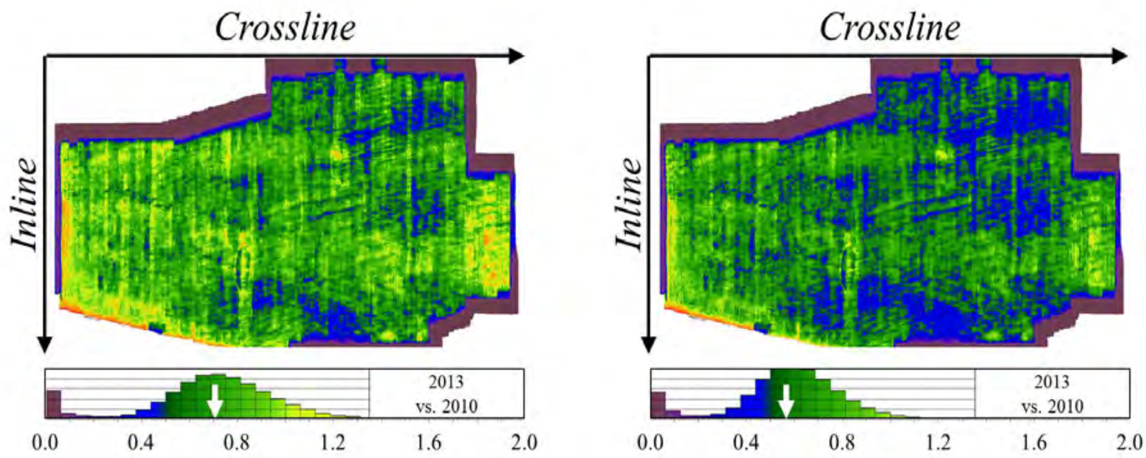

Figure 2 *NRMS map for vintage 2013 vs. 2010 (Left) without applying the 4D adaptation process. (Right) the 4D adaptation process is applied. The arrows point at the median NRMS values.*

Figure 2 shows the NRMS maps for the 2013 survey measured against 2010. The 4D adaptation process significantly reduces the median NRMS by about 20%.

Figure 3 shows the 4D difference section for vintage 1993 vs. 2010. The 1993 dataset is the oldest of all vintages and has been processed with the fixed reference method of Equation (3). Vintage 2013 is the largest, densest and most recent survey acquired; for these reasons it is chosen as the reference. Note that it has already gone through a 4D adaptation process with the other more recent vintages. The section where the 4D adaption is applied (Figure 3, right), is cleaner and residual noise is efficiently attenuated.

Figure 4 shows the NRMS maps for the 1993 survey, measured against 2010. Again we see that the 4D adaptation process significantly reduces the median NRMS by about 20%. Other older surveys (1996, 1999, 2000, and 2002) are also processed with the fixed reference method using Equation (3).

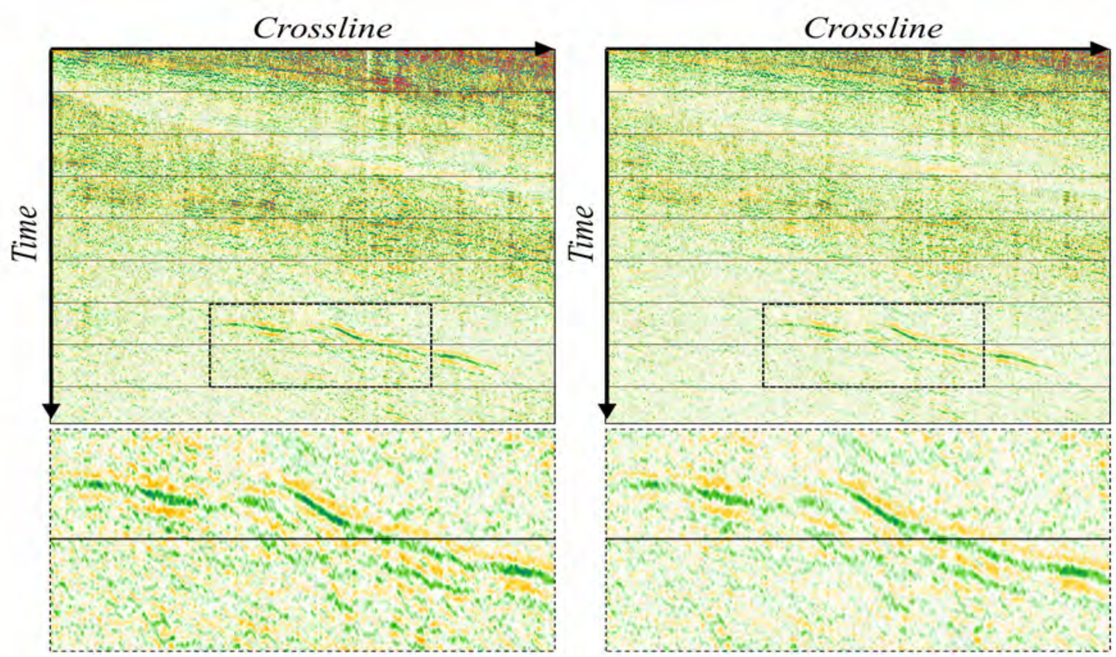

Figure 3 *4D difference section for vintage 1993 vs. 2010 (Left) without applying the 4D adaptation process. (Right) the 4D adaptation process is applied.*

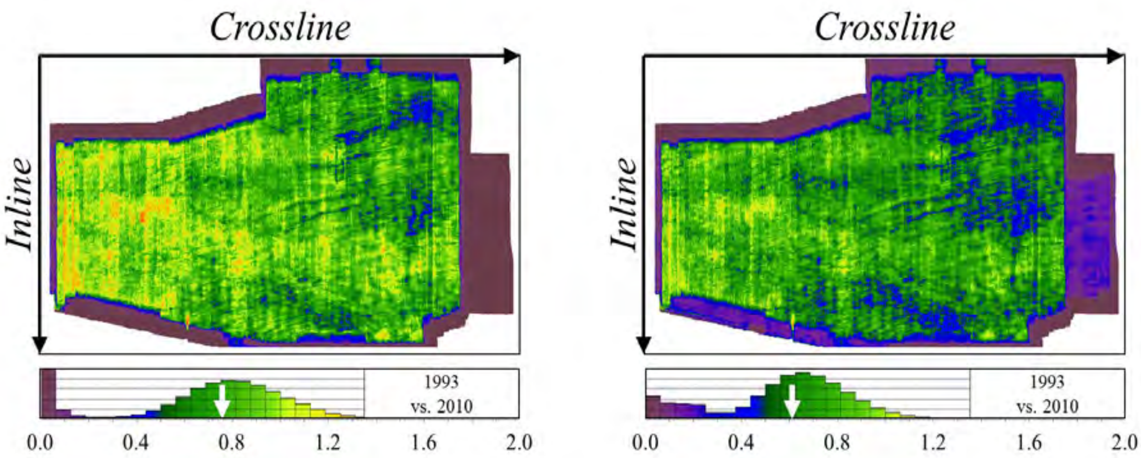

***Figure 4** NRMS map for vintage 1993 vs. 2010 (Left) without applying the 4D adaptation process. (Right) the 4D adaptation process is applied. The arrows point at the median NRMS values.*

Figure 5 shows the progression of NRMS around the reservoir horizon throughout the full processing sequence for all vintages measured against the 2010 dataset. The improvement in NRMS at the stage where the 4D adaption is applied is clear. Repeatability is improved for all vintage pairs, including the older ones that traditionally suffer from more 4D noise even in co-processing.

Conclusions

The 4D simultaneous adaptation process significantly helps in reducing noise leakage into the 4D difference sections, thus improving its quality and interpretability. The QC maps show a reduction in NRMS of about 20%. The methodology is applicable in a multi-vintage context where more recent surveys are processed simultaneously without imposing a reference base, while older surveys are processed using the fixed base method. The fixed base method is also suitable for repeat-processing projects.

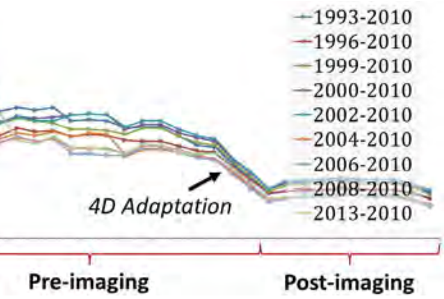

***Figure 5** NRMS progression throughout the processing sequence. The arrow points at the stage where the process applied.*

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References

Khalil, A., Hoeber, H., Campbell, S., Ibram, M. and Davies, D. [2013] An optimized workflow for coherent noise attenuation in time-lapse processing. *75th EAGE Conference & Exhibition*, Expanded Abstracts, Th 11 03.

Lin, D., Young, J., Lin, W.J. and Griffiths M. [2005] 3D SRME prediction and subtraction practice for better imaging. *75th Annual International Meeting, SEG*, Expanded Abstracts, 2088-2091.

Verschuur, D. J., and Berkhout, A.J. [1997] Estimation of multiple scattering by iterative inversion: Part II: Practical aspects and examples. *Geophysics*, **62**, 1596-1611.

Zabihi Naeini, E., Hoeber, H. and Campbell, S. [2012] A new approach to reducing multiple leakage on time lapse datasets. *74th EAGE Conference & Exhibition*, Expanded Abstracts, E010.