

Regularization of Simultaneous Long Offset Data Acquired Offshore Gabon - A Case Study

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SUMMARY

The case study investigates the applicability of certain processing steps to a simultaneous long offset acquisition configuration using a data set acquired offshore Gabon. This acquisition configuration is a two vessels operation using relatively short streamers and a simultaneous shooting scheme. One of the main operational advantages is that tangling risks and feathering are reduced compared to towing (12km) long streamers. The simultaneously acquired shots can be deblended with an inversion approach to obtain separate near and far offset data sets. The data are then regularized using an anti-leakage Fourier transform method with an additional anti-aliasing algorithm. Regularization is done in 4-D tackling irregularities in midpoint position and offset. It is demonstrated that processing steps (such as Radon demultiple) that benefit from continuous CMPs can then be applied directly afterwards without any limitations. The combination of simultaneous long offset acquisition and regularization in processing can help to reveal structural and stratigraphic challenging deep targets of complex geology such as the salt morphology offshore Gabon.

Introduction

Acquired data is generally irregularly sampled in space. Hence, regularization and interpolation procedures have become a standard pre-processing step for further processing and imaging. There are several methods that are based on different assumptions and have different characteristics as discussed for example by Schonewille et al., 2009. The regularization method used in this study is based on an anti-leakage Fourier transform with an additional anti-aliasing algorithm.

A 3-D simultaneous long offset seismic survey was acquired offshore Gabon (in the Ntsina and Mbeli blocks) in the beginning of 2012. Whilst this acquisition geometry provides several operational benefits, it also comes with some challenges to the regularization. The question is how to handle overfold and variations in amplitude and signal to noise ratio over the entire offset range. Using three consecutive saillines from the survey, this case study will show that processing procedures (such as Radon demultiple) that require or benefit from continuous CMPs will not need to be excluded from further processing but can be applied directly after regularization without any difficulty.

Acquisition configuration

Simultaneous long offset (SLO) acquisition is a modification of a proposed 3-D marine acquisition configuration using continuous long offset (CLO) as described by van Mastriigt et al., 2002. CLO is a two vessel operation. The first vessel tows relatively short streamers and two sources; the second one is purely utilized as a source vessel and is positioned approximately one streamer length in front of the first vessel. The effective recorded streamer length is thus twice the physical streamer length. Such a configuration has several operational advantages. Due to shorter streamers, feathering and cross-line position errors are reduced and the technique is less prone to tangling risks (Koenitz et al., 2008).

The same set-up is used in simultaneous long offset acquisition, but now the sources from the two vessels are fired simultaneously and data are recorded into the same shot gather. Due to this simultaneous shooting scheme, the shot spacing is no longer doubled as in CLO acquisition, but the same as in a conventional vessel configuration with long streamers. To separate (or deblend) the interfering energy of two sources, an inversion approach with a multi-dimensional median filter is used (van Borselen et al., 2012). The separation result gives two data sets (near and far offsets) as if the two sources were fired in a conventional manner without any time overlap between them.

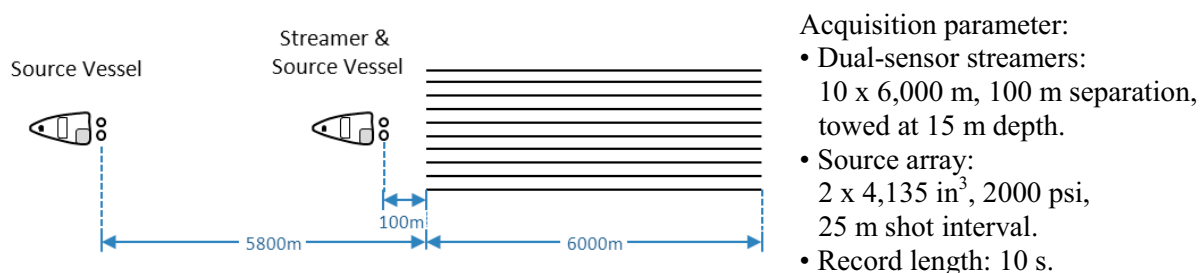


Figure 1 Schematic illustration of the SLO vessel configuration.

The acquisition set-up for the offshore Gabon SLO data set is illustrated in Figure 1. The total offset acquired is 11,800 m. The 200 m overlap (between near and far offset data) allows filling in holes in the mid offset range due to feathering at the end of the streamers. The data were acquired using dual-sensor streamers. Wavefield separation was expected to give an uplift in imaging the complex subsurface geology of salt bodies and sub-salt structures offshore Gabon, as demonstrated previously on 2-D dual-sensor of the area (as discussed by Long et al., 2013).

Regularization method

The regularization/interpolation scheme used is based on Fourier reconstruction. Spatio-temporal windows of irregularly sampled input data are transformed into a regularly sampled Fourier space. The windowing of the data is employed to “sparsify” the spectrum. The combination of irregular sampling and use of a discrete Fourier transform (DFT) will result in spectral leakage. The original

anti-leakage Fourier transform (ALFT) overcomes this limitation by an iterative approach, as described in detail by Xu et al., 2005 and exemplified in Figure 2.

An additional weighting scheme (Schonewille et al., 2009) will improve the handling of aliased energy. Low, non-aliased frequency parts of the spectrum are used to extrapolate weights for higher, aliased frequencies that influence the matching pursuit algorithm. A suitable inverse non-uniform fast Fourier transform (NFFT) will reconstruct the spatio-temporal data at any requested output position. The final regularized output is obtained by merging the data of all windows.

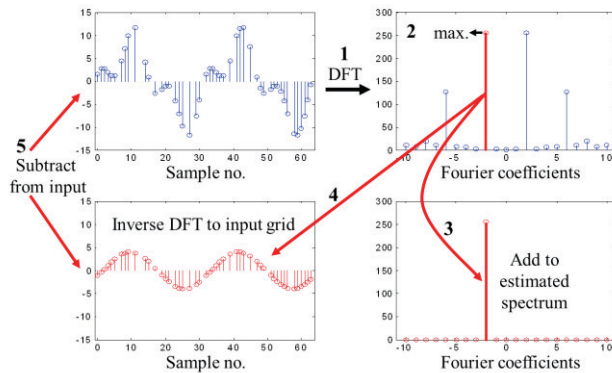


Figure 2 A schematic representation of a single iteration of the ALFT:
 1. Compute the DFT;
 2. Select the Fourier component with the maximum energy;
 3. Add this component to the estimated Fourier spectrum;
 4. Inverse DFT this maximum Fourier component back to the original grid;
 5. Subtract the component from the previous step from the input data.

Field data example: processing and results

Prior to regularization, the near and far offset data were processed separately. Main pre-processing steps included:

- Swell noise attenuation and wavefield separation (processing done on-board)
- Optimized source separation (van Borselen et al., 2012)
- Designature (debubble and zero-phase equivalent)
- Resampling to 4 ms and phase only Q compensation
- Receiver motion and tidal static correction (to improve continuity of events)

The near and far offset data sets for all three saillines were combined allowing overfold. Differences in signal to noise characteristic between near and far offsets can be observed (Figure 3a) which are partly due to the conservative approach of the source separation (van Borselen et al., 2012).

The full offset data were then NMO corrected using manually picked velocities and the regularization method described above was applied in 4-D (midpoint position, offset and time). Figure 3b shows CMP gathers after regularization. The differences between near and far offsets appear less strong. The general noise level is reduced which is a well-known effect of the ALFT when using a finite number of iterations. The regularization algorithm will also reconstruct data at positions (offsets and/or midpoints) where no prior data had been recorded, so that gaps are filled with interpolated data. As a result, events appear more continuous over the full offset range. Improvements are also visible in the stack section in Figure 4. The deep structure looks less scattered after regularization; events appear more continuous.

After regularization, Radon demultiple was applied, an application that benefits from continuous CMPs. Modelling and subtracting the multiples on regularized (merged near and far offsets) CMPs can be done without any difficulties (Figure 5). Hidden flat primaries become visible and continue from near to far offsets. These continuous primaries will contribute significantly to imaging deeper structures as observed in the stack section in Figure 4c and presented by Long et al., 2013.

Conclusions

It has been demonstrated that SLO data can be regularized and processing steps that use continuous CMP gathers can be successfully applied afterwards as shown on Radon demultiple. Regularization suppresses the general noise level and thus differences in signal to noise characteristics observed between near and far offsets are reduced. Events appear more continuous (on CMP gathers and in

stack section). After Radon demultiple hidden continuous flat primaries appear over the full offset range of nearly 12 km.

The SLO acquisition configuration has not only operational advantages (such as less feathering and reduced tangling risks due to shorter streamers), but also no processing limitations. Imaging of deep structures (as the salt morphology offshore Gabon) can benefit significantly from such long offsets.

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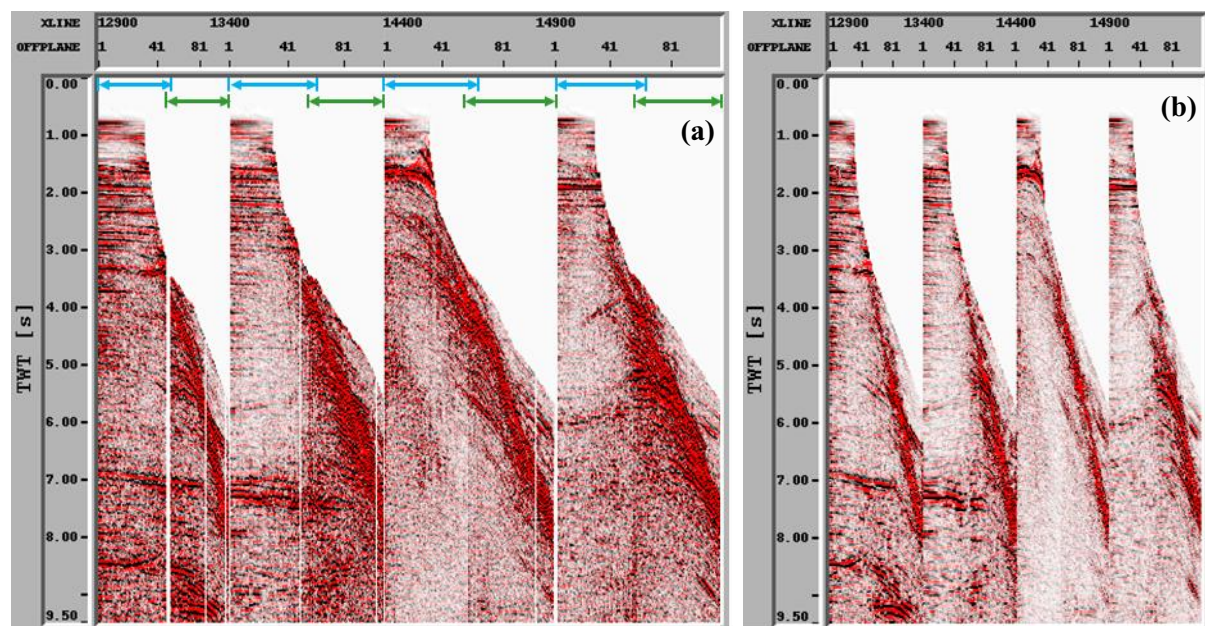


Figure 3 CMP gathers (a) before and (b) after regularization. Note CMPs have different number of traces depending on fold prior to regularization. \longleftrightarrow near offsets \longleftrightarrow far offsets

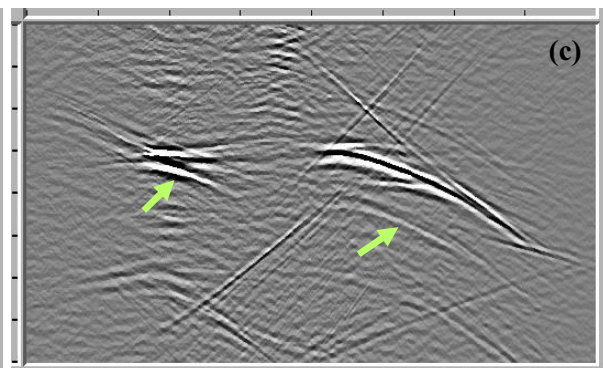
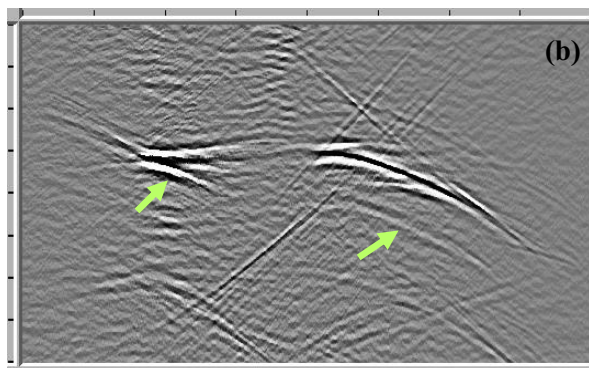
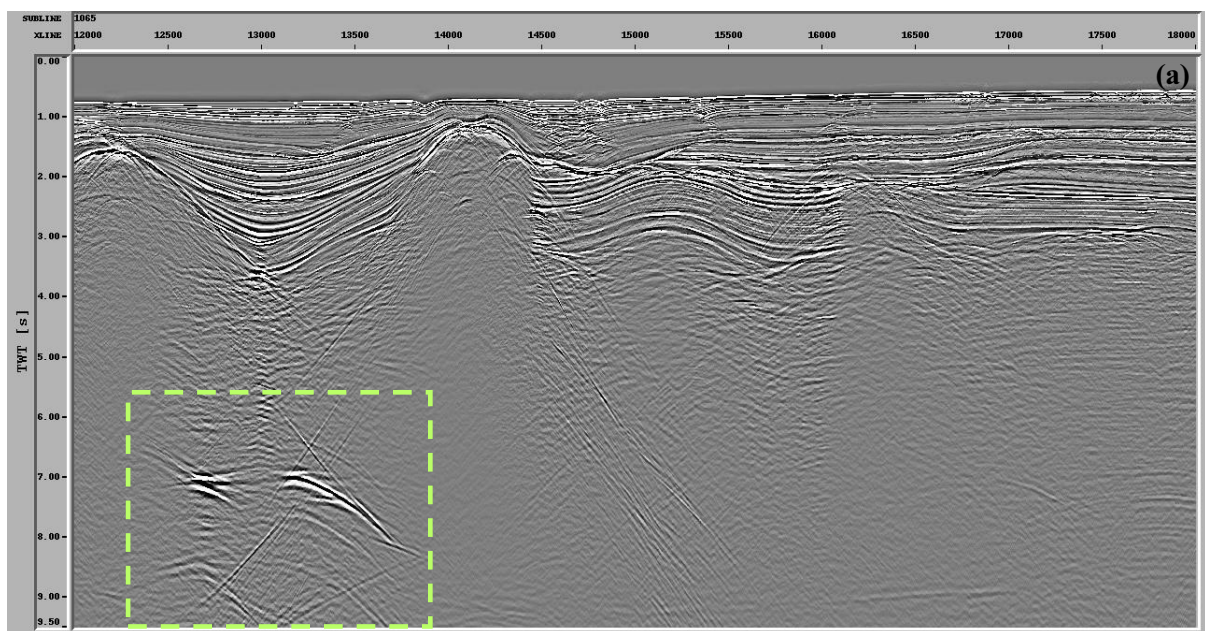


Figure 4 (a) CMP stack of regularized data. (b) and (c) Close-up of deeper structure in stack section; (b) before and (c) after regularization. Events appear more continuous and less scattered in (c), see e.g. green arrows.

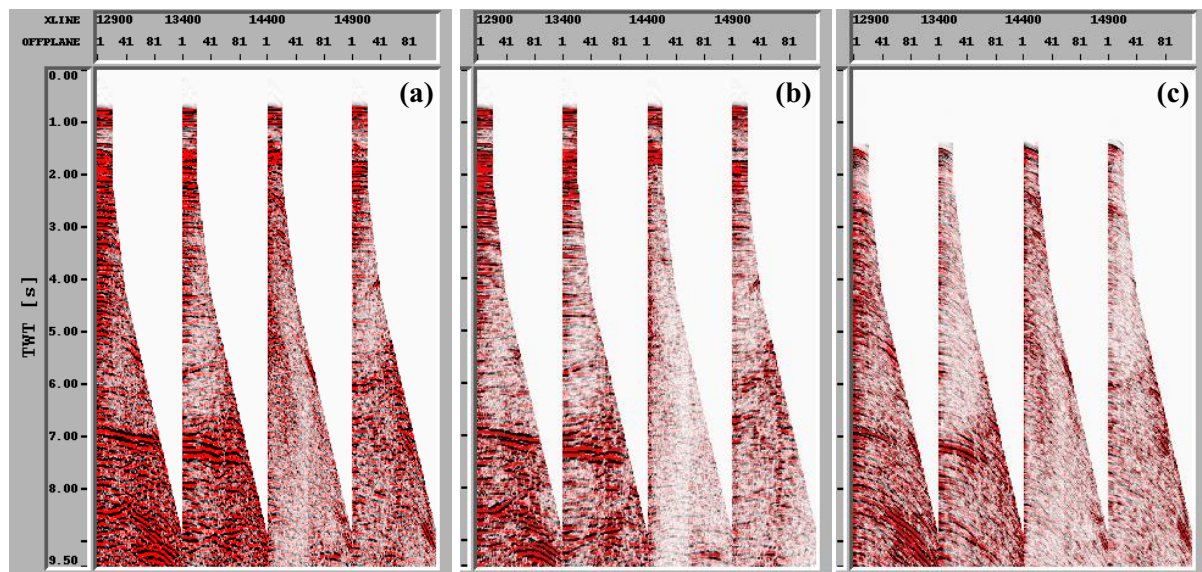


Figure 5 Application after regularization using continuous CMP gathers (a) before and (b) after Radon demultiple; (c) modelled multiples.