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Simultaneous sources in marine acquisition: experiences to date

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SUMMARY

A modified inversion approach is presented for the effective separation of sources in marine simultaneous shooting acquisition. The method aims to distribute all energy in the simultaneous shot records by reconstructing the individual shot records at their respective locations. The method is applied to a simulated simultaneous long offset data set, where two sources are used to acquire long offsets with conventional cables. In the second example, the performance is investigated on a data set from Western Australia, where two sources where located within close proximity, with only a small cross line distance between them. Results demonstrate that the individual sources can be separated satisfactory for both simultaneous source configurations.

Key words: Simultaneous Source Acquisition, Processing, Inversion

INTRODUCTION

In seismic exploration, there is continuous drive towards more dense data sampling to better image complex geological structures. Recent advances in acquisition such as Wide-Azimuth, Multi-Azimuth or Rich-Azimuth acquisition can deliver a more diverse range of source, azimuth and offset sampling. To collect such data, multiple source and receiver vessels are deployed, thereby increasing the costs of the survey significantly.

In simultaneous acquisition, data can be recorded continuously, and temporal overlap between shots is allowed. Consequently, more sources are fired during the same period of acquisition, which greatly enhances the flexibility in survey geometries. As a result, a more densely sampled data set in terms of source spacing, but also azimuth and offset distributions can be obtained. In terms of efficiency, simultaneous acquisition can contribute by reducing survey times, which is of particular value in critical situations where small acquisition time-windows dominate due to severe safety, environmental or economic restrictions.

In this abstract, an inversion-driven method is utilized that aims to distribute all energy in the blended shot records by reconstructing the individual unblended shot records at their respective locations. The method is explained further in the next section, after which two field data examples are presented.

METHOD AND RESULTS

Inversion-driven methods aim to construct the separated sources through the minimization of a cost function that describes the "data misfit" (see, for example, Akerberg *et al*. 2008 and Moore *et al.* 2008).

Using the well-known matrix notation (Berkhout 1982), seismic data in the temporal frequency domain can be represented by data matrix **P**, where each element corresponds to a complex-valued frequency component of a recorded trace, the columns representing shot records and the rows receiver gathers. In general, source blending can be formulated as follows:

$$\mathbf{D}\,(z_d, z_s) = \mathbf{P}\,(z_d, z_s)\,\boldsymbol{\Gamma} \tag{1}$$

where **D** is the blended data matrix, z_d and z_s are the detector and source depth level respectively. Blending matrix $\boldsymbol{\Gamma}$ (Berkhout 2008) contains the blending parameters. In the case of a marine survey with random firing times but equal source strengths, only phase encoding is utilized.

To retrieve individual 'deblended' shot records from blended data, a matrix inversion has to be performed. In general, the blending problem is underdetermined meaning that there is no unique solution to the inverse problem. Hence, the blending matrix is not invertible.

In this paper, a method is used that constrains the inversion by imposing that nearby sources produce records that are similar to each other in the sense that the unblended records contain data that are, at least locally, predictable and contain coherent events (Abma *et al.* 2010).

A key advantage of the proposed separation method is that it iteratively builds up the deblended records using overlapping time windows: strong reflection events from the shallow data are addressed first, such that extracting coherent energy is easier when the process is repeated for larger arrival times, i.e. for deeper events.

Data Example 1

In this example, the proposed method is deployed to a data set that was shot in simultaneous source mode, where two sources were deployed that were separated only by a small cross line distance. The two sources were fired with randomized time delays between -50 and +250 milliseconds to benefit the separation processing.

Figure 1 shows an arbitrary shot gather before and after source separation. Note the very good signal preservation of the events after separation, retaining all events optimally. Figure 2 shows the stacked results before and after source separation.

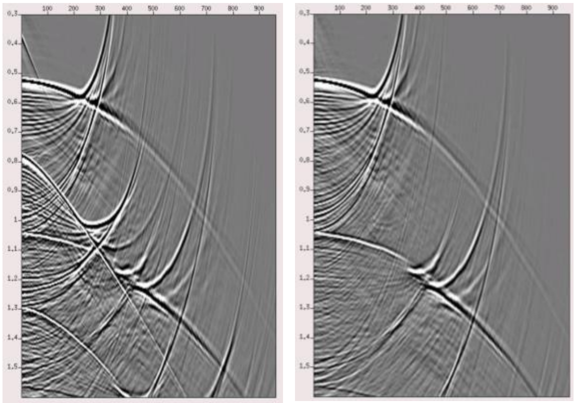

Figure 1. Simultaneous source shot gather before (left), and after source separation (right).

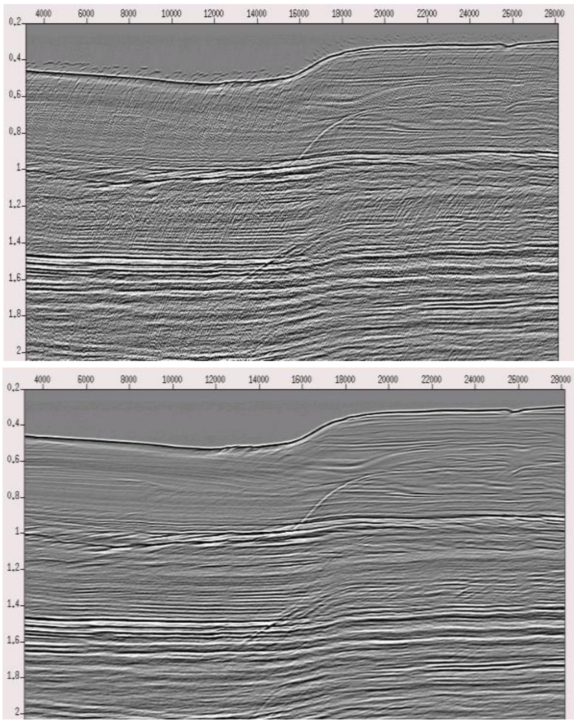

Figure 2. Stacks before (top), and after source separation (bottom).

Data Example 2 - Simultaneous Long Offset (SLO)

In this example, a simulated experiment was conducted, where a conventional single source 12km cable length configuration was used to create a simultaneous source data set where two sources (a long offset source and a near offset source) are fired simultaneously to record near and far offsets up to 12km using a single streamer vessel with 6km cable lengths. The sources are fired with randomized time delays of -500 to +500ms. Figure 3 shows the near-offset source results for an arbitrary shot gather. Figure 3a shows the blended gather, Fig.3b the deblended near-offset shot gather and Fig. 3c the difference with the reference data. Note the good signal preservation of the weaker events at larger arrival times.

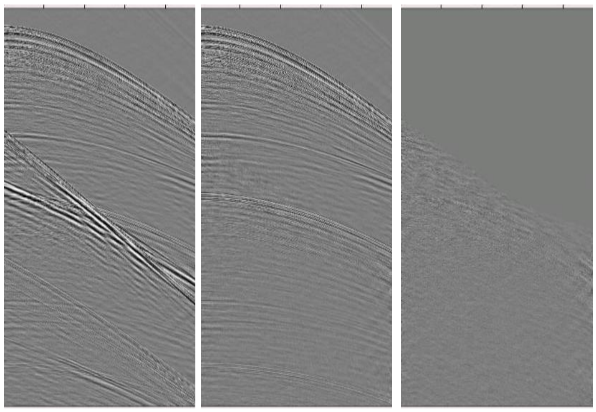

Figure 3. An arbitrary shot gather taken from the simulated SLO data set: the blended shot gather (A), deblended near offset source data (B) and the difference between the reference and the deblended data (C).

CONCLUSIONS

An inversion method for separating sources from simultaneous-source acquired data has been utilized and demonstrated on two data sets with different simultaneous source configurations. Results indicate that sources can be separated very well, and only very low levels of leakage from interfering shots can be detected in the results. As such, the results give confidence that the simultaneous source method has indeed the potential to significantly improve the quality and efficiency of long offset and wide-azimuth acquisition geometries.

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