We_R11_15

Continuous Wavefields Method – a New Marine Seismic Acquisition and Processing Approach

S. Hegna[1]*, T. Klüver[1], J. Lima[1]

[1] PGS

Summary

There are several challenges with the conventional 3D marine seismic method that are addressed with a novel seismic methodology based on the emission and recording of continuous source and receiver wavefields. The challenges that are discussed in this paper are coarse spatial sampling of source positions, environmental impact of marine seismic sources, and efficiency of the acquisition. The coarse spatial sampling of source positions is addressed by emitting continuous source wavefields. The environmental impact of marine seismic sources is reduced by spreading the emitted energy out in time. The efficiency of marine seismic acquisition can be improved with the continuous wavefields method because there are no vessel speed limitations caused by the method as such, and because source elements can be distributed crossline in multiple positions improving the coverage in each sail line and hence reducing the number of sail lines needed to cover a certain area.

Introduction

A novel seismic methodology based on the emission and recording of continuous source and receiver wavefields has been introduced in Hegna et al. (2018a) and Klüver et al. (2018). With modern continuous recording systems, seismic data recorded continuously can be processed in one operation over the full time-length; typically the length of a sail line. The emitted source wavefield is also treated as a continuous wavefield. The desired continuous source wavefield to be used with this method would be white noise. In order to generate a continuous source wavefield that is approaching the properties of white noise using existing equipment onboard marine seismic vessels, individual air guns can be triggered with very short randomized time intervals in a near-continuous fashion, generating a continuous wavefield. Figure 1 illustrates typical recorded seismic data acquired using the continuous wavefields method.

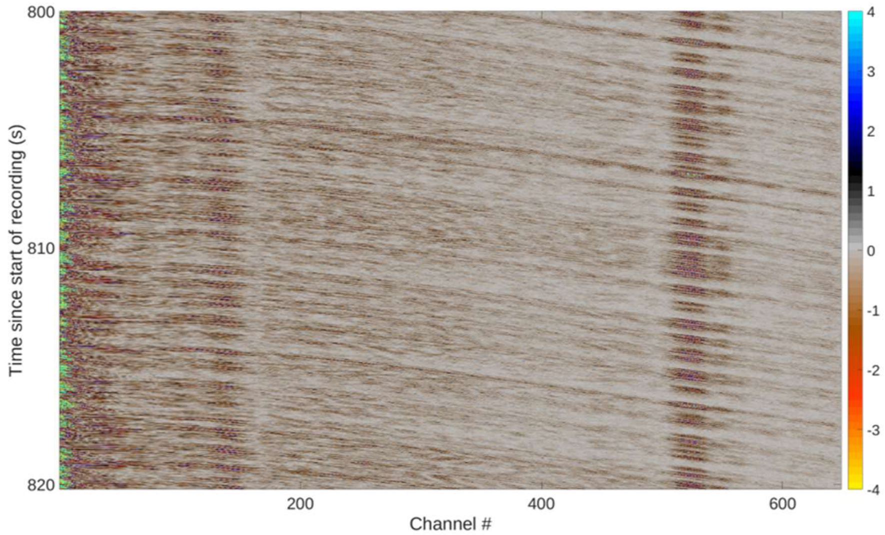

Figure 1 *Twenty second portion of a continuous record of raw seismic data acquired by triggering individual air guns with short randomized time intervals and continuous recording.*

The continuous seismic data illustrated in Figure 1 can be transformed into final seismic images as illustrated in Figure 2 (from Hegna et al., 2018b).

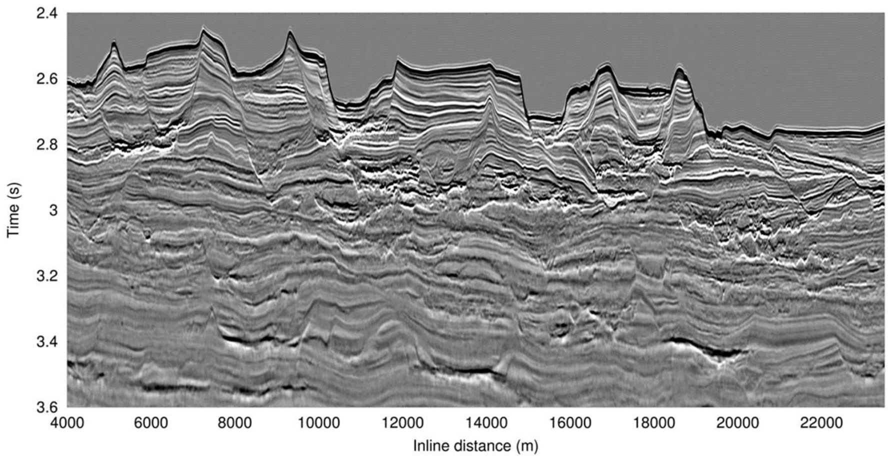

Figure 2 *Seismic image produced using the continuous wavefields method based on input data shown in Figure 1.*

In this paper we discuss several challenges with the conventional 3D marine seismic method and how these are addressed with the continuous wavefields method.

Challenges addressed with continuous wavefields

One of the main challenges with the marine seismic method is the coarse spatial sampling of source positions. Along the acquired lines, the sampling of shot locations has been limited by the required listening time and the vessel speed. The continuous source wavefield allows the trace spacing in the common receiver gathers output to be chosen during the source deconvolution step in processing. The locations of the output traces can be anywhere along the trajectories where source elements have been located during the acquisition. If six strings with air guns are towed behind a seismic vessel, each emitting a continuous or near-continuous wavefield, it is possible to output six common receiver gathers in each respective crossline position of the strings. Therefore, not only can the spatial sampling along the line direction be improved, but also the crossline sampling as illustrated in Figure 3. The improved spatial sampling on the source side can be achieved without loss of acquisition efficiency.

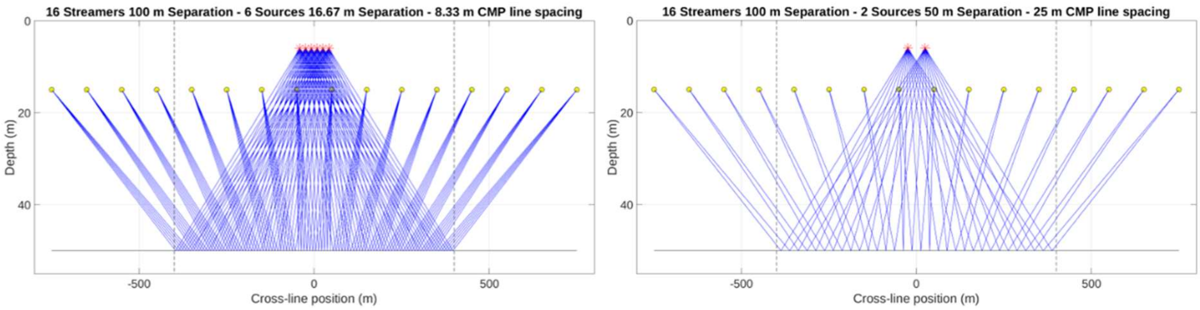

Figure 3 *Continuous wavefields method (left) and conventional dual-source (right) source and streamer setup. Yellow dots represent streamer locations, red stars represent air gun strings, and blue lines are ray paths connecting sources and receivers through a subsurface reflection point.*

In recent years, the focus on the potential environmental impact of marine seismic acquisition has increased. A particular focus has been placed on the peak sound pressure level (SPL) emitted from seismic sources and their potential impact on marine mammals and fish with swim bladders. Consequently, authorities across the world have started to introduce stronger regulations concerning the use of seismic sources. This challenge is addressed by spreading the emitted energy out in time. With the continuous wavefields method, a source can emit signals continuously while moving.

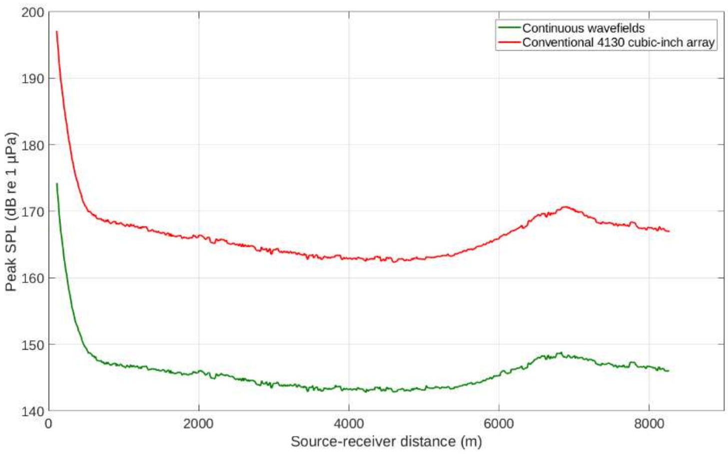

Figure 4 *Peak sound pressure level (SPL) as a function of source-receiver distance for a conventional air gun array (red curve) and when triggering individual air guns with short randomized time intervals (green curve).*

It has been shown during a field trial conducted during the summer of 2018 that the SPL is approximately 20-22 dB lower when triggering individual air guns with short randomized time intervals (see Figure 4), whereas the sound exposure level (SEL) is 8-9 dB lower when compared to the conventional acquisition method (Hegna et al., 2018b).

Another challenge with the marine seismic method has been acquisition efficiency, a key focus during periods with low oil prices when oil companies are reducing their budgets allocated for seismic acquisition. The efficiency of 3D marine seismic acquisition has been improved significantly over the last decades by deploying wider streamer spreads, but further increases have become operationally challenging. With the method utilizing continuous source and receiver wavefields, there are several other aspects that may improve acquisition efficiency. Since the source can emit signals continuously while moving and the recording of the seismic data is continuous, the vessel speed is not limited by a shot spacing or minimum listening time. In contrast, for conventional acquisition the vessel speed may be limited by shot point interval and minimum listening time in areas with strong currents. Figure 5 shows the speed over ground for the field trial acquired last summer in an area with strong currents (Hegna et al., 2018b). When sailing with the currents the bottom speed was up to 6.5 knots. For the conventional acquisition method the maximum bottom speed is typically limited to ~5 knots.

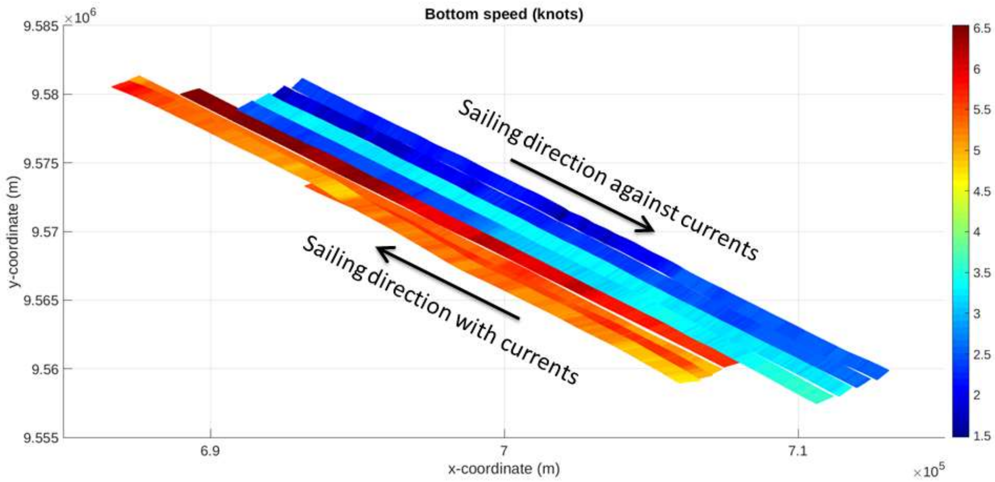

Figure 5 *Bottom speed (knots) when sailing with and against the currents.*

A further efficiency gain can be achieved with the continuous wavefields method if distributing the strings of air guns in a wider spread. Whilst the number of streamers towed and the streamer spread dimensions have increased over the years, the number of sources and the width of the source spread have, however, remained small. There are several disadvantages with wide streamer spreads and narrow source spreads. Adjacent sail lines need to be overlapping in terms of receiver coverage in order to achieve uniform common mid-point (CMP) coverage. The overlap is typically ~50%. Another disadvantage with such spreads is poor near-offset coverage. To improve the acquisition efficiency as well as the near-offset coverage it would be beneficial to increase the source spread width. With the continuous wavefields method it is possible to output one common receiver gather in each crossline position of the air gun strings, as discussed above. There are no limitations in terms of number of crossline positions with source elements. These crossline positions can be anywhere. Figure 6 shows a comparison between a triple-source and 16 streamer configuration, and a wider spread hexa-source configuration and with a similar streamer spread width. The hexa-source configuration is ~22% more efficient compared to the triple-source configuration, and the near-offset coverage is improved due to reduced crossline offsets.

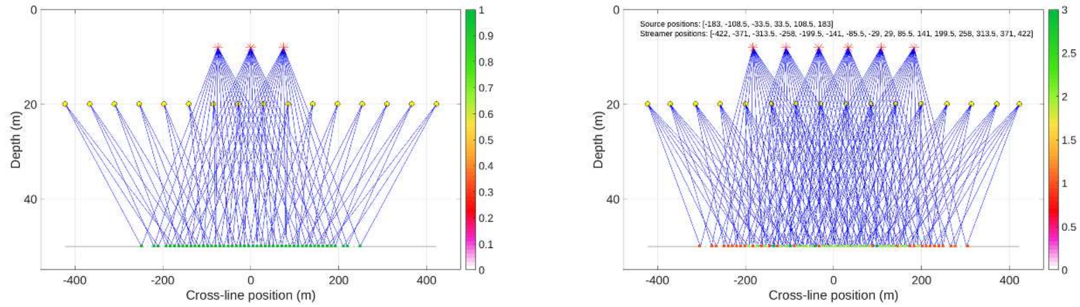

Figure 6 *Triple-source (left) and a wider hexa-source configuration (right) with an equivalent streamer spread in both cases.*

Conclusions

The seismic methodology utilizing continuous source and receiver wavefields introduced by Hegna et al. (2018a) and Klüver et al. (2018) addresses several challenges with the marine seismic method. The spatial sampling of source positions along the line direction is improved because of the ability to acquire and process data based on continuous wavefields on both the source and on the receiver side. The trace spacing in the common receiver gathers output from the source deconvolution step is a processing parameter with this method. The crossline sampling of source positions can also be improved by outputting one receiver gather per crossline position of the air gun strings in the source deconvolution step. Concerns with the environmental impact of marine seismic acquisition, and in particular the received SPL from conventional air gun arrays, is addressed by spreading the emitted energy out in time. By triggering individual air guns with short randomized time intervals, the SPL is reduced by 20-22 dB compared to conventional source arrays, whereas SEL is reduced by 8-9 dB. Finally, the acquisition efficiency and the near-offset coverage can be improved by distributing source elements in a wider crossline spread. There are no limitations with regards to the number of crossline source element positions that the method utilizing continuous source and receiver wavefields can handle.

Acknowledgements

We thank PGS for permission to publish this paper, and Equinor and The Research Council of Norway for funding the project together with PGS.

References

Hegna, S., Klüver, T. and Lima, J. [2018a] Making the transition from discrete shot records to continuous wavefields - Methodology. *80th EAGE Conference and Exhibition,* Extended Abstracts, We A10 03.

Hegna, S., Klüver, T., Lima, J. and Asgedom, E. [2018b] Latest field trial confirms potential of new seismic method based on continuous source and receiver wavefields. *First Break,* **36**(11), 83–88.

Klüver, T., Hegna, S. and Lima, J. [2018] Making the transition from discrete shot records to continuous wavefields – Real data application. *80th EAGE Conference and Exhibition,* Extended Abstracts, We A10 04.