Towards smaller source volumes – an example from the Gulf of Mexico

Jan Langhammer, Duncan Bate, Henrik Roende and Roy Ha, TGS*

Summary

In this paper we present results and benefits of using smaller volumes triple source configurations in connection with a large marine streamer exploration campaign in the US Gulf of Mexico. The utilization of more sources behind a streamer vessel will increase efficiency and improve sampling in between the streamers leading to cost savings and improved quality of data. In addition, using a source setup of two sub-arrays instead of three sub-arrays, will reduce the sound pressure level from each source, hence reducing the environmental impact from each shot. However, despite the reduction in sound pressure levels, sufficient acoustic energy is still available for maintaining a good signal-to-noise ratio, and hence, producing excellent data volumes. The use of triple source has become a viable source setup in the deep water of Gulf of Mexico in connection with marine seismic exploration campaigns. The use of smaller source volumes also accommodates to the fact that the seismic business experiences an increased pressure from regulators to reduce the environmental footprint in a survey area.

Introduction

Marine seismic exploration in deep water environment has usually called for large three to four sub-array sources of more than 4000 cu.in. and up to around 8000 cu.in. to image deep complicated structures. The desire to use these larger sources has in some areas been in conflict with more strict limitations from regulators and environmental authorities. Exploration campaigns are now popping up more often in deeper waters and in more challenging geological areas. Environmental issues are also coming higher up on the agenda, and as a result of this more time efficient surveys are requested by oil companies.
The use of triple source in marine seismic towed streamer data acquisition has been tested and reported as a success when it comes to increasing the spatial resolution in between the streamers for exploration purposes (Langhammer and Bennion, 2015). The increase in resolution does not come at the expense of reduced efficiency and thereby increase in cost, in fact, by utilizing a triple source configuration, both resolution and efficiency can be increased. In addition, by going from two to three sources, a conventional streamer vessel can support a larger total receiver spread, or reduce the number of streamers towed in the water, and still maintain the same crossline subsurface bin size. This win-win situation has gained more and more recognition in the industry during the last couple of years. The increased sampling and efficiency achieved by the use of the triple source concept suggest that this way of operating available onboard source inventory has become the best practice and has finally made a breakthrough since it was first tested in the 1980's (Langhammer et al., 2018). The application of two sub-array triple sources then comes in handy with the trend towards using smaller source volumes than used previously, and we have experiences from using smaller sources in connection with explorations surveys in the Norwegian Sea, West of Ireland and West coast of Africa. When operating sources from one single streamer, or source vessel, an additional benefit of using smaller sources can open for more advanced techniques and firing schemes in order to increase sampling and still maintain high signal-to-noise ratios. (Langhammer and Bennion, 2015; Hager et al., 2015; Robertsson et al., 2016; Sjøen Pedersen et al., 2016).
In this abstract we draw the attention to deep water areas in US Gulf of Mexico. Location of the survey area, which was covered by streamer seismic in 2018, is shown in Figure 1. The 6280 sq.km. survey area is situated around 200 Nautical Miles from New Orleans where water depth is varying between 2000 m to 3000 m.

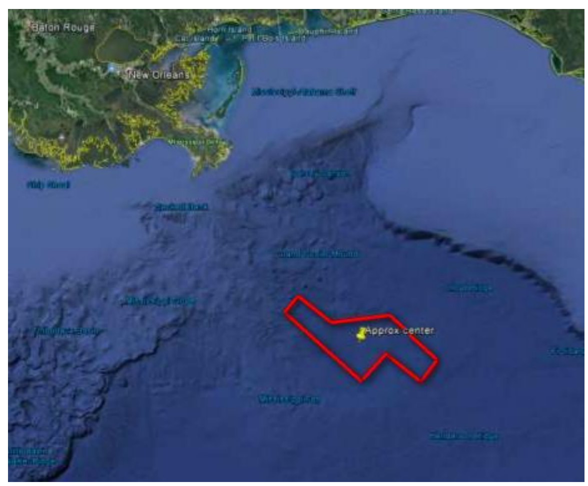

Figure 1: Location of the 2018 survey area in GOM South of New Orleans in deep water.

A survey adjacent and partly overlapping the new survey area was conducted in 2012, where a different streamer configuration was used, in addition to a significantly larger source. Data from the 2018 and 2012 surveys are compared and subject to analysis. The main aim of this paper is to show that based on new and previous data, we can with confidence propose smaller source volumes to be applied in connection with deep water Gulf of Mexico exploration campaigns.

The concept of triple source

With a given number of streamers, the sub-surface crossline sampling is doubled by the use of two sources compared to a single source. Dual source in flip-flop mode compared to a single source, will then result in a reduced number of traces in each sub-surface bin. This implies that the fold will be reduced for each sub-surface line when going from a single source, fired at let's say 25m, compared to 25m shot-point interval in flip-flop mode (50m between shot-points within each sub-surface line). Going from dual source to triple source will further increase the number of sub-surface lines, as shown in Figure 2, hence leading to decreased X-line bin spacing. The use of five sources (penta source) has also been tested in the past and was first presented by Hager et al., 2015. Figure 3 shows the dimensions of the natural bin-size as a function of streamer separation for a dual, triple- and penta source configuration.

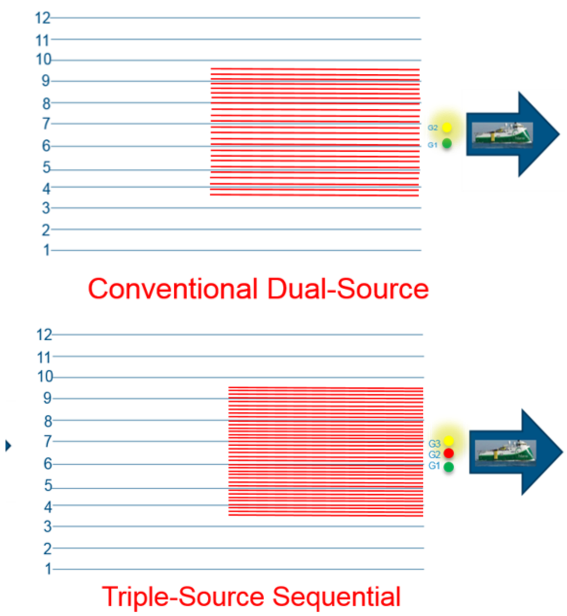

Figure 2: Dual source with corresponding sub-surface coverage lines (upper) and triple-source with the corresponding sub-surface lines (lower) for the same configuration of streamers. Going from dual to triple source will increase the number of sub-surface lines by 50%.

Most modern 3D seismic vessels today are equipped with six subarrays. A dual source usually consists of three subarrays, while a triple source will have to consist of two sub-arrays. However, for a narrow azimuth survey this will not represent any harm to the data because both source power and directivity pattern have from previous testing shown to be more than good enough for the purpose. Going from three to two sub-arrays could result in differences in the pressure signature, but not so large that it could not be handled in the designature process. In addition, reducing the volume of released air in each shot, and using just two sub-arrays instead of three will reduce the emitted sound pressure level (SPL-level) which without doubt has a positive environmental effect. In the recent years, the industry has been focused on using sources with less energy output per shot, without compromising quality and geophysical integrity of the data.

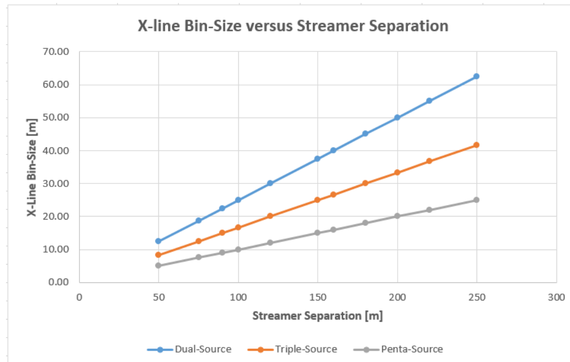

Figure 3: Bin-size as a function of streamer separation for dual source (blue), triple source (red) and penta source (grey). When going from dual- to triple source the X-line bin-sixe is reduced by 33%

The Gulf of Mexico surveys in 2018 and 2012

The 2018 acquisition is summarized in Table 1 and compared with the survey parameters from 2012 acquisition. The survey area covered in 2018 was around 6280 sq.km. The configuration included 10 streamers at depth 15 m, 150 m separation in front and 187.5 m at rear end in a so-called fan-mode of 125% expansion.

Parameter	2018 Acquisition	2012 Acquisition
Streamer Spread	10 x 150 m x 10100 m	8 x 160 m x 12000 m
Streamer Depth	15 m	12 m
Number of Channels	800	960
Fan Mode	25% at tail	No
Source Volume	3090 cu.in.	5130 cu.in.
Source Depth	8 m	8 m
Shot-Point Interval	18.75 m triple-source	37.5 m dual-source
Shot Direction	NW-SE	NW-SE
Record Length	17 s cont. rec.	16.1 s
Fold	90 (10.1 km streamer)	80 (12 km streamer)
Bin-Size	6.25 m x 25 m	6.25 m x 40 m

Table 1: Comparison of main acquisition parameters between the triple source survey in 2018 and the dual source survey in 2012.

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Streamer length 10,050 m, triple source of size 3090 cu.in. placed at 7 m depth and shot-point interval of 18.75 m, giving 56.25 m shot-point interval per sub-surface sampling line, fold 90, and finally a natural bin-size of 6.25 m x 25 m. A shot-point interval of 18.75 m gives a “clean” record length of a bit more than 8 seconds when accounting for a vessel speed of around 4.5 knots. However, the continuous recording allows us to expand the record length beyond the timing between the individual shots. The survey parameters marked in red emphasize the main differences in parameters between the two surveys.

Comparison of sources 3090 cu.in. and 5130 cu.in.

The modelled source signatures, and the corresponding spectra, from the two data acquisition vintages, are shown in Figure 4. The source of 5130 cu.in. used in 2012, was a three sub-array dual source configuration. The survey in 2018 used a two sub-array triple source of size 3090 cu.in. This survey is the first larger dataset acquired in the Gulf of Mexico using a triple source configuration, and hence, with reduced source volume compared to what has been the recognized standard during the last couple of decades. The main aim with this source design was to reduce crossline bin-size and increasing the spatial resolution and still maintain high efficiency.

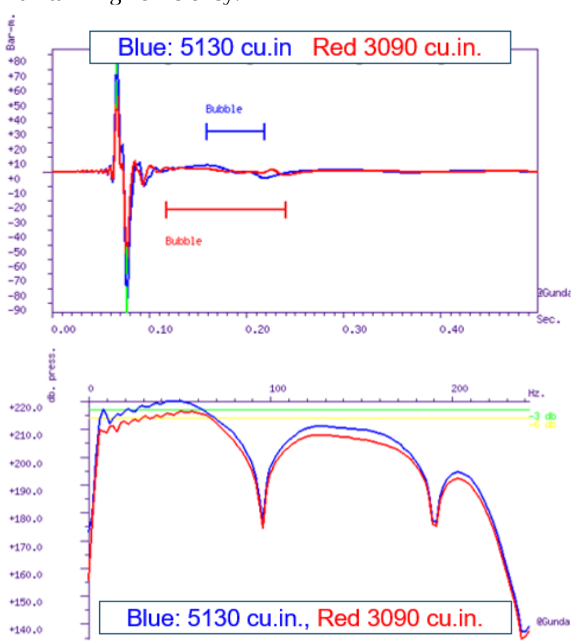

Figure 4: Top: Modelled signature of a three sub-array dual source of size 5130 cu.in. (red) and a two sub-array triple source of size 3090 cu.in. (blue); bottom: Corresponding spectra.

The main modelled output parameters are shown in Table 2. The 3090 cu.in. two sub-array triple source configuration is using only 22 guns opposed to 35 guns of the corresponding three sub-array dual source configuration. A filter with a high-cut of 200 Hz was used when calculating the modelled parameters. We will of course see a lower emitted sound pressure level in peak-to-peak of the 3090 cu.in. compared to the 5130 cu.in.

Parameter	5130 cu.in.	3090 cu.in.
# of guns	35	22
P-P [bar-m]	164.0	113.0
0-P [bar-m]	76.2	52.5
P/B	18.5	21.4

Table 2: Main parameters from modelling of three sub-array 5130 cu.in. and two sub-array 3090 cu.in. sources.

Results and discussion

Data examples of near traces from a chosen cable are shown in Figure 5 for the two sub-array source of volume 3090 cu.in. and Figure 6 shows the corresponding data from the 5130 cu.in. three sub-array source.

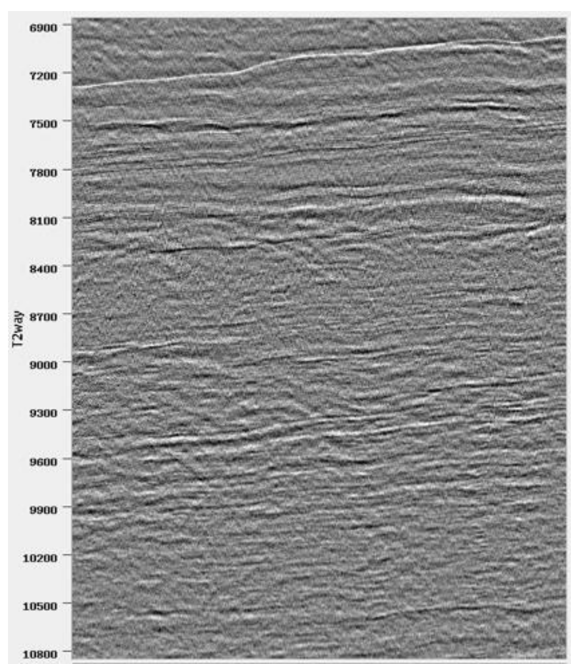

Figure 5: Near channel data from the survey in 2018 when using the 3090 cu.in. two sub-array source.

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At this level (between 7 to 10 seconds) the signal strength from different layers of geology is observed to be similar, but one main difference stands out and is that the 5130 cu.in. source is producing more shot generated noise
Examples of overlapping data areas from the surveys acquired in 2018 and 2012 are shown in Figure 7. We observe from the gathers and stacks when reducing the source volume, which again leads to a decrease of the source strength (SPL-level), may not decrease the signal-to-noise ratio, and we still maintain good signal strength from sub-surface targets. Similar effects have previously been investigated by Musser and Dunbar (1984), Laws et al. (2008), Langhammer and Bennion (2015), Dhelie et al. (2017) and Rocke et al. (2018).

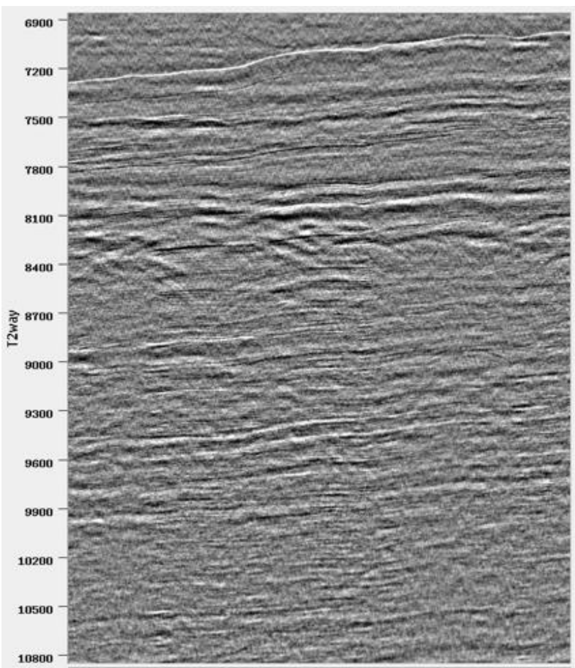

Figure 6: Near channel data from survey in 2012 when using the 5130 cu.in. three sub-array source.

Since a lot of the noise is shot generated, the signal-to-noise ratio may not improve using a larger source with an increased sound pressure level. Therefore, the acoustic levels produced by the 3090 cu.in. two sub-array source prove to be good enough. In addition, going from three to two sub-arrays will also limit the areal extent of the source, hence going towards the ideal situation of more compact sources trending towards a point source (Dhelie et al., 2017).

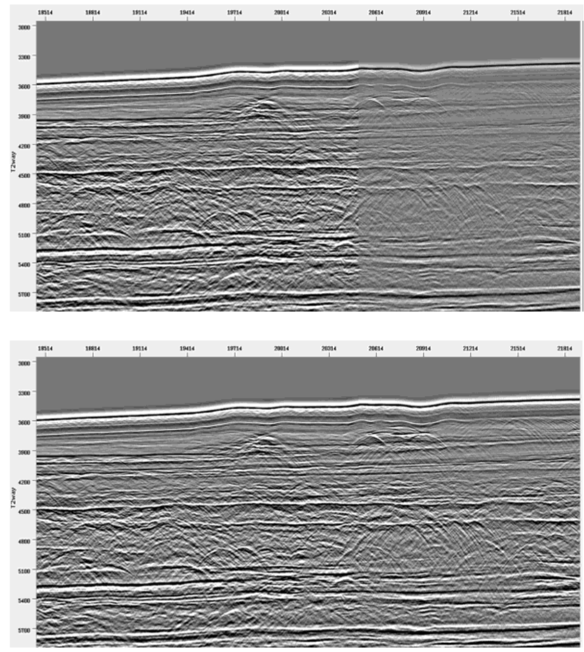

Figure 7: Segment (3 to 6 seconds) of overlapping data area from the 2018 and 2012 acqusition campaigns, with the sources of 3090 cu.in. (right part of line) and 5130 cu.in. (left part of line). Top: without any compensation gain and maching; bottom: with gain and matching.

Conclusions

Using the triple source solution, and thereby smaller source volumes in deep water exploration in the Gulf of Mexico, has through the 2018 marine streamer acquisition campaign proven to be a viable solution when it comes to improving the spatial sampling between the streamers and still maintain efficiency. Previously, the solution with more sources has found acceptance in European exploration campaigns when using larger spreads of streamers to cover large survey polygons, providing an uplift in both efficiency and quality. Smaller source volumes have in this case provided sufficient source strength to maintain signal-to-noise ratio for imaging of deeper targets in deep waters. In addition, smaller source volumes and lower sound pressure levels contribute to reduced environmental impacts.

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