Dual streamer vessel simultaneous 3D acquisition in Greenland

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Summary

A dual vessel 3D towed streamer survey was acquired for a JV operated by Shell Greenland in Baffin Bay, West of Greenland. The survey area was infested by ice and water depths ranged between 280 and 820 meters. A number of seismic data acquisition techniques, including the use of two streamer vessels, were combined during this survey in order to ensure that full fold coverage was achieved in a short acquisition window over the primary pre-plot area with minimum impact of seismic interference between the vessels on overall data quality.

These techniques proved very effective and may be applied in other geographical locations with short time windows available for seismic data acquisition, especially where free movements of streamer vessels are limited due to floating ice.

Introduction

One of the main challenges during this project was to complete an ambitious scope of work, about 8,650 km^2, in a remote location within a limited time frame of 2.5 months mandated by whale migrations, in waters contaminated by icebergs, “bergy bits”, “growlers” and drift ice without any safety incidents and damage to in-sea equipment. From the very early stage it was understood that the planning of operations would be crucial to success and very close collaboration was required between operational, technical, geophysical and HSE personnel involved from client, contractor and third party companies such as ice observers.

It was immediately recognized that a single streamer vessel would not be able to acquire the entire nominal area in one season and a second vessel working in tandem with the first could be a way to achieve this. Therefore, two ICE-1A class seismic vessels were mobilized for this survey each towing a wide seismic spread with dual sources and six 8,100m streamers separated by 200m. In addition, there were five support vessels with four of them exclusively dedicated to ice management.

Steering on pre-plotted source positions was employed in order to allow more flexibility for acquisition in case of ice avoidance and to achieve uniform coverage for the near offsets where the smallest estimated radius for the first Fresnel zone was around 50m. Fan spread geometry (125% tail separation) was implemented on both vessels in order to minimize the gaps in coverage at further offsets due to feather effect and steering over pre-plot sail line locations.

The impact of seismic interference (SI) was mitigated by the combination of control of relative vessel positions, ensuring optimal direction of SI arrivals, and source fire time dithering.

In addition, it was decided to tow streamers with a linear increase of tow depths from 10m at the nearest channel down to 15m at the streamer tail, which was meant to help in recovery of broadband signal through application of modern data processing techniques.

Shooting Plan

The principle 3D seismic data acquisition program consisted of 118 prime sail lines. Figure 1 depicts the survey location in Baffin Bay and the primary survey area pre-plot map with a potential extension included (in green).

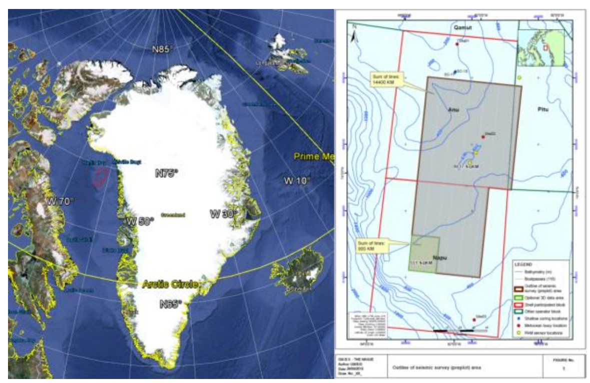

Figure 1: Location of survey area

Because of uncertainty in the estimated progress of seismic data recording operations due to drifting ice it was decided to split the whole full fold polygon into three areas (West, Center and East), with the center area given the highest priority (Figure 2). It was very important for the client’s asset team to receive one continuous 3D dataset without any coverage gaps between acquisition areas for effective data interpretation. In order to satisfy this requirement our initial proposal was simply to define a boundary in the central area, which would split the full fold area into two more or less equal parts requiring the same time to finish all prime lines for each vessel, and then progress from this boundary in opposing directions (one vessel to west and second one to east) keeping the longest inline and cross-line separations between the streamer spreads.

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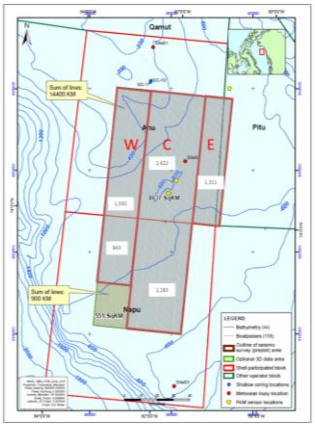

Area's in full fold km^2

	Block 5	Block 8	Total
West	1,592	843	2,434
Central	2,622	2,283	4,905
East	1,311	0	1,311
Total	5,525	3,126	8,650

Area's dimensions in km

	Length	Width	No of Lines
West	119	20.4	34
Central	146.5	33.6	56
East	78.5	16.8	28
Total			118

Figure 2: Survey sub-areas and its dimensions

This initial shooting plan was later revised due to the following operational contingencies; uncertainty about density of floating ice in the area of operations, additional ice management vessels would be required in order to monitor two areas simultaneously, and difference in sail line lengths between western and eastern areas did not allow for good synchronization of two vessels and avoidance of high level seismic interference from different directions and close distances.

After thorough consideration and consultation with the client it was decided to implement a dual vessel "tandem" shooting scenario. This plan consisted of both vessels acquiring data on the same survey pre-plot steering along two adjacent lines but with inline separation of 24-31km (distance between source arrays of one vessel and nearest receivers of another one).

The race tracks of individual vessels were interleaved and turn radii were increased in order to maximize cross-line separation between vessels at SOL and EOL as well as to control the direction of SI, preferably from ahead and from astern. If one of the vessels had to abort a line for any reason both would resynchronize at the next line-change and continue interleaved race tracking. In case of ice avoidance both vessels in tandem would move in synch to another set of prime lines or line segments. This method of coordinating the two vessels aided in minimizing the number of guard vessels with ice observers and maintaining direction of SI relative to receiver spread of each individual vessel. Figure 3 below shows the relative positions of the two streamer vessels during line shooting and turns.

Given the level of ice infestation within the entire area it was paramount to have a detailed "Ice Management Plan" in place. The overall ice management strategy for the project was avoidance. Early detection and continued monitoring and tracking of the glacial icebergs and sea ice was critical for safe seismic operations.

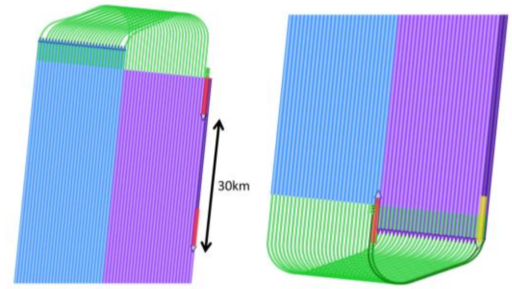

Figure 3: Illustration of "tandem" shooting scenario

For the project there were four dedicated, ICE-1A rated, vessels deployed for ice management in the area of operations. These vessels were all outfitted with Sea Hawk polarmetric radar systems and two dedicated ice observers to detect, monitor and report ice movements to the two ice coordinators, each stationed on one of the seismic vessels. Both seismic vessels were also fitted with Sea Hawk systems and each carried an ice observer as well as an ice coordinator. The latter provided lead advisory and support to the vessel master and seismic party manager. Satellite reconnaissance data was utilized to supplement the in-situ observations and to provide a wider areal view of the area of operations. Figure 4 below shows the relative vessel positions that provided optimal ice management for this project.

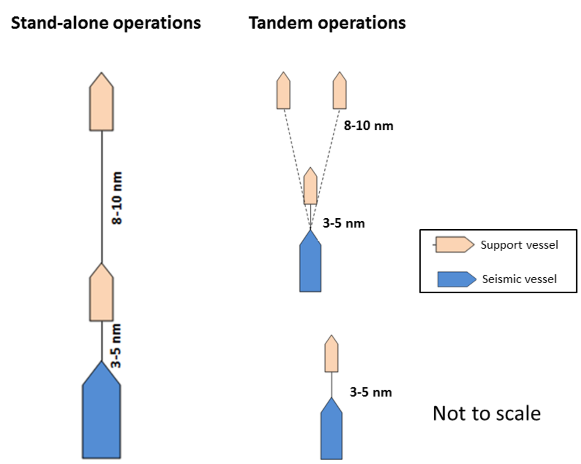

Figure 4: Optimal ice management vessel positions

There was a total of 529 icebergs detected and tracked between the two seismic vessels (302 and 227 icebergs respectively). Both seismic vessels observed the highest abundance of icebergs in August and the lowest abundance in October (Figure 5).

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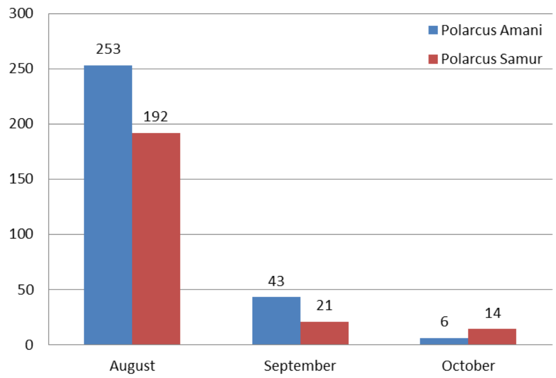

Figure 5: Number of icebergs tracked during survey by month

Figure 6 below shows all prime and infill line segments acquired by individual vessels during this survey and the final combined post-plot map with a total achieved coverage of 7,175 km^2.

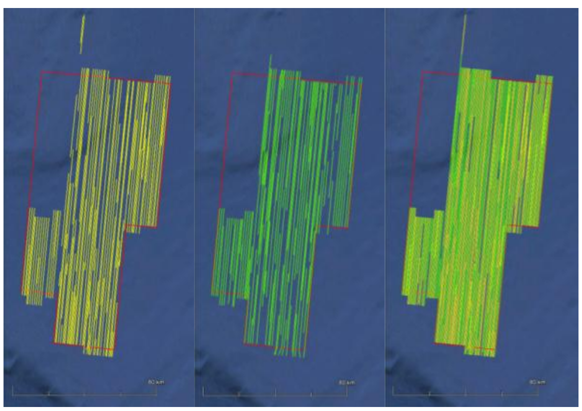

Figure 6: Final post-plot maps showing prime and infill lines acquired by individual vessels on the left and combined survey on the right

All infill decisions were made based on the analysis of coverage gaps relative to the size of Fresnel zones for given targets and offsets. Acceptable effective coverage holes were defined prior to survey start using geological information provided by the client such as target depths, expected frequency range, and average velocities above these targets. Using this approach combined with a fanned streamer spread the total infill ratio achieved during the project was only 7.5% versus 15% estimated during planning stage.

Source Dithering

Due to the relatively narrow width of the survey polygon it would not have been possible to avoid pollution of recorded data by seismic interference from a second vessel working on the same survey. Furthermore, there was a third 3D vessel operating to the south-east of this survey area, thus generating additional seismic interference generally coming in from abeam. This was quite evident during data acquisition on the eastern swath. Therefore, dithering of source firing times was implemented on both vessels in order to randomize SI arrivals, which in theory would help to remove unwanted energy from seismic records during data processing once seismic data is resorted in CDP or other domains where SI would appear as random noise. It was decided to introduce ±0.5s random delays to source fire triggers in the navigation systems on both vessels, which would scatter actual source positions by only ±1.15m relative to pre-plotted locations assuming 4.5knots vessel speed. Figure 7 shows source fire time intervals between the two vessels with and without application of dither.

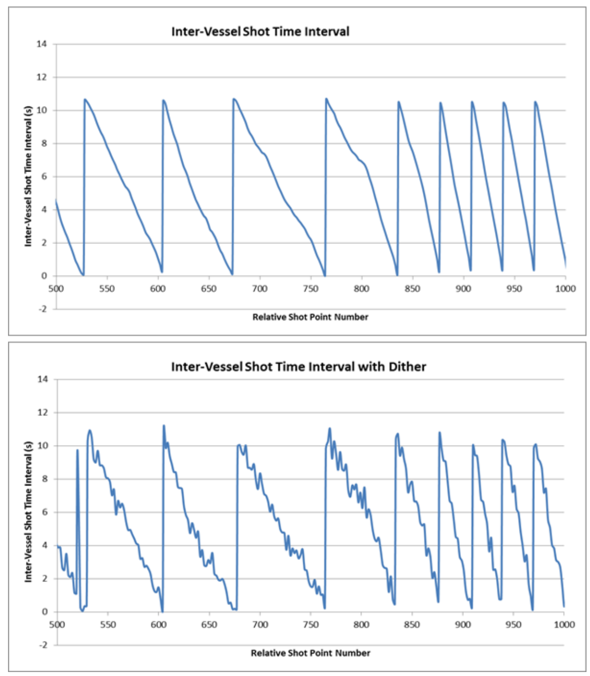

Figure 7: Inter-vessel shot time interval without (top) and with (bottom) application of source dither

It can be seen on the above charts that there was a change (drift) in inter-vessel shot time intervals due to natural differences in relative vessel speeds. The rate of change depends on the difference between vessel speeds and, in theory, it would be equal to zero if both vessels move with the same speed at all times. In practice, we observed that preset randomization of source firing times for most of the survey had only a secondary order effect if compared to the effect introduced by the natural variations in the vessels' ground speed.

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Seismic Interference Attenuation

In order to validate that the quality of the recorded seismic data was not compromised due to mutual SI during dual vessel operations we tested the application of two SI attenuation processing methods shortly after commencements of data acquisition. These processing workflows were focused on two main properties of the interfering seismic energy: its randomness in various domains such as CDP or Common Channel and its linearity in Common Shot domain due to control of relative vessels positions (inline offset/separation).

The attenuation of SI based on its randomness in the t-x domain (cdp and/or common channel) was found less effective and required significantly more testing of processing parameters (Figure 8).

Modeling of SI energy in tau-P space using linear Radon transformations and subsequent subtraction in the shot domain removed virtually all seismic interference from the data (Figure 9 and Figure 10).

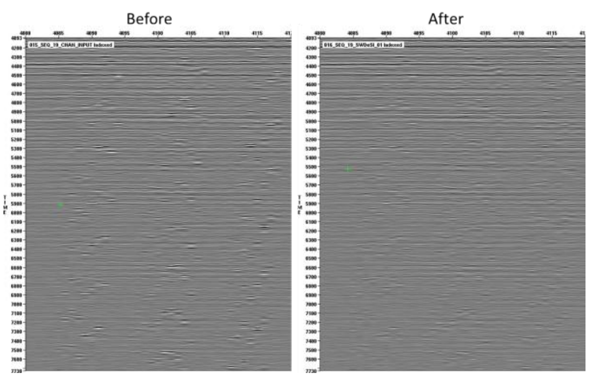

Figure 8: Example of SI attenuation after random-noise attenuation application on common channel gathers

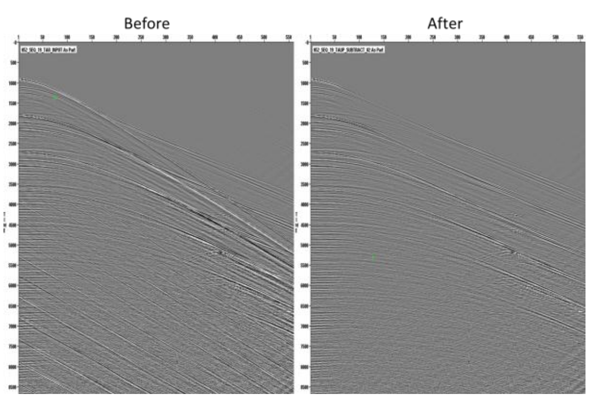

Figure 9: Example of SI attenuation in Tau-P domain on common shot gathers (positive dips/interference from ahead)

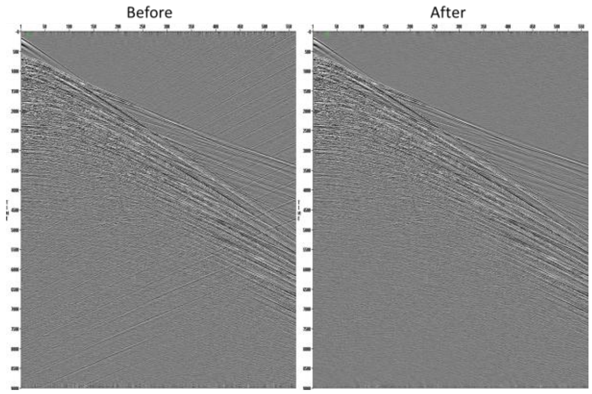

Figure 10: Example of SI attenuation in Tau-P domain on common shot gathers (negative dips/interference from astern)

Conclusions

The application of dual vessel simultaneous “tandem” acquisition while shooting on pre-plotted source locations with fan shaped streamer spreads and controlled inline separations allowed the acquisition of 7,175 km² of high-end 3D data in Arctic ice-infested waters during a short operational season.

In addition to operational benefits such as ice-management and relative flexibility of line choice, the synchronous “tandem” vessel movements on interleaved race-tracks allowed control of the SI direction and thus enabled application of noise attenuation processing techniques exploiting linear noise characteristics as separation criteria rather than its randomness.

Naturally occurring minor differences in relative vessel speeds introduced natural drift in SI arrival times observed on seismic shot records. At times when both boats were moving at the same pace the dither of source firing times would be deemed advantageous but its benefits need further analysis and validation by data processing.

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REFERENCES

None