Deblending 3D NAZ data in high sea surface current environments

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Summary

Virtually all modern seismic surveys are acquired with some level of source blending be it in the form of self blending or from additional source vessels. The level of blending that is observed in the data is due to many factors some that can be controlled during survey design and acquisition; for example shot point interval, number of sources, spacing of additional source vessels. There are additional factors that are outside the control of the acquisition team; other seismic crews in the area, or surface currents. During a recent seismic survey significant sea surface currents significantly influenced the speed of the acquisition vessel. Sailing into the current the vessel could maintain on average about 1.0 knot speed down the line, with the current the speed could exceed 6.5 knot. When sailing with the current the time between shots is nearly identical to the water bottom reflection two way time, which results in the energy from water bottom multiple from the previous shot, water bottom reflection from the current shot, and direct arrival of the next shot arriving at nearly the same time into the streamers. Inversion deblending is necessary as typical denoise deblending methods will not be able to sufficiently separate the events into their appropriate shots, potentially causing significant signal reduction or leaving in a large amount of blended energy reducing the signal to noise ratio in the data. In this paper we show an inversion based deblending technique to separate the energy into the appropriate shots utilizing a FISTA based inversion. The deblending will also be performed on both the raw hydrophone and geosensor components ensuring ideal data being used for Full Waveform Inversion and separation into the upgoing wavefield.

Introduction

Modern marine streamer survey planning entails specifications of shot density, time between shots, and sailing direction, among other parameters. Acquiring data using a triple source configuration can increase the source density and data resolution but does reduce the time between shots (Langhammer et al., 2018). For surveys using multiple sources, there is a preference to shoot the next shot after the main imaging target energy is recorded by the streamers. However, the time between source points is affected by several factors beyond just the distance travelled. An ongoing 3D Narrow Azimuth (NAZ) PAMA 3D Phase I survey in the Pará Maranhão basin of Brazil's Equatorial Margin experienced significant sea surface currents, at times exceeding 2.5 knots. The direction of surface currents, and intensity, is shown in Figure 1 with the survey area indicated by the yellow polygon. Due to very strong surface currents and needing to maintain an in-water vessel speed of approximately 4.0 knots, vessel speeds differ based on acquisition direction. When sailing lines with the current the shot point interval is as small as 4.0 seconds between source points, whereas sailing against the current, the time between shots is typically 13.0 seconds.

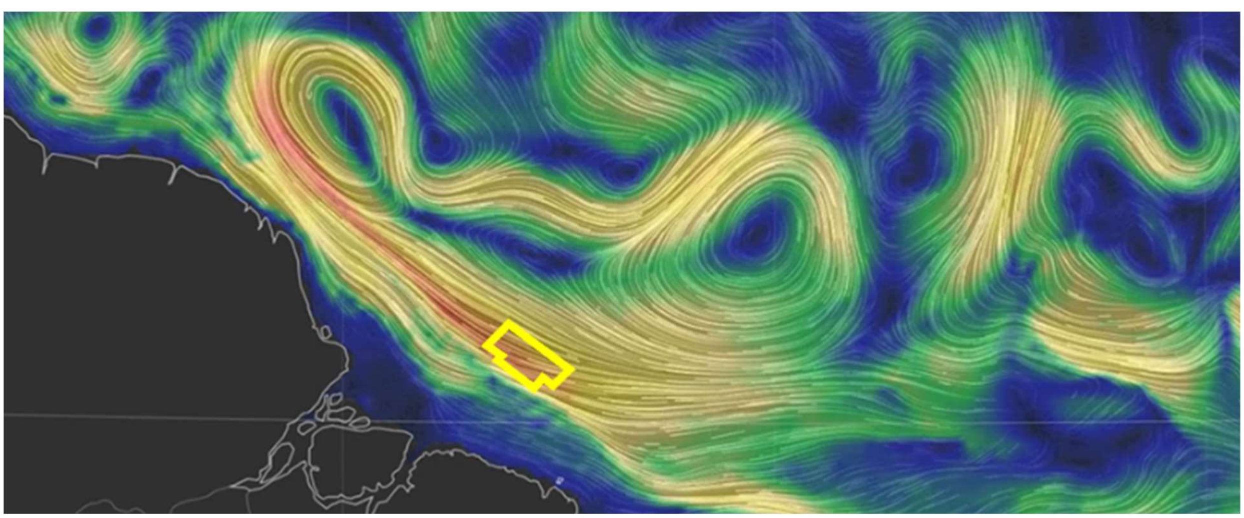

Figure 1 *Map showing surface currents in the Pará Maranhão basin of Brazil's Equatorial Margin area, with PAMA 3D Phase I survey area highlighted by the yellow polygon. Currents in the survey area consistently greater than 2.0 knots from southeast to northwest.*

Deblending high surface current 3D NAZ data

Significant variability in the time between source points led the team on the acquisition vessel to contact shore support for guidance. Complicating matters, the acquisition began within a week after the merger of the acquisition and processing companies.

In this paper we will demonstrate that quick communication between the acquisition team and the onshore processing team removed the concerns about data quality due to the surface currents. Utilizing an inversion deblending process allowed us to produce high quality results without an imprint of the vessel speed, avoiding the need to reshoot lines acquired in the same direction as the surface currents. The processing solution kept the survey on schedule and minimized the environmental impact of the project.

Method

Upon initial observations of the variability of the time between source points depending on the sailing direction and being concerned with the clean record length being only 4.0 seconds, the field acquisition team contacted the onshore processing team for this project. Initial images and onboard QC plots were quickly shared, identifying a minimum data volume to be sent from the acquisition vessel to the processing team. The team utilized satellite communications to upload several hundred shots from two sail lines, one fast and one slow, for initial deblend testing. Adding to the complexity of the communication, the acquisition and processing companies had merged just prior to the commencement of the project and the systems were not yet in direct communication. Shown in Figure 2 is an example shot gather, from a fast sequence, into four inner cables. Here we can clearly see the previous shot's multiple, the current shot primary reflections, and next shot's direct arrival all arrive into the cable at nearly the same time. Upon initial investigation of the sequences acquired with the current, resulting in vessel speeds in excess of 6.5 knots, an inversion deblending routine was identified as the ideal tool to separate the source energy into deblended shot gathers. The inversion deblending routine used is based on the Fast Iterative Shrinkage-Thresholding Algorithm (FISTA) deblending presented by Sun et al., 2022.

Examples

Figure 3 shows shot gathers before and after deblending from a fast and slow sequence. After inversion deblending the data quality and signal to noise ratio of the fast sequence (Figure 3b) and slow sequence (Figure 3e) are very similar. The deblending performs very well, even in areas where energy from three separate shots arrive nearly coincidentally. Common channel displays, shown in Figure 4, also show that after application of deblending the data quality is consistent regardless of sailing with or against the strong currents.

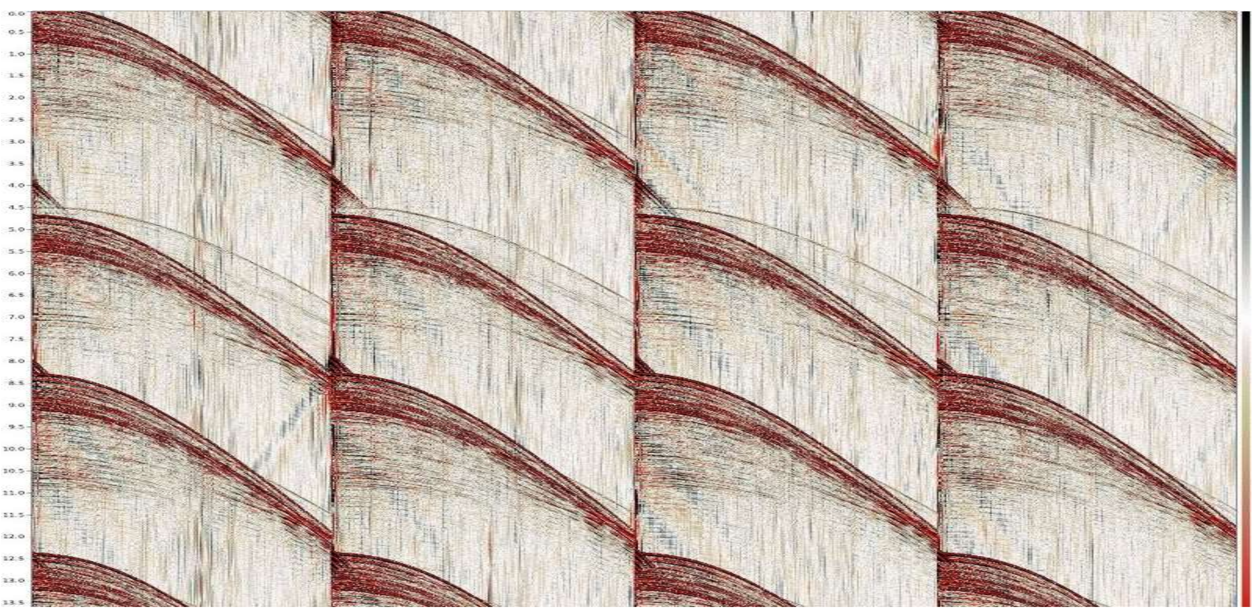

Figure 2 *Example shot gather, into four central cables, showing the overlapping direct arrival, primary, and multiple energy from a sequence with vessel speed in excess of 6.5 knots.*

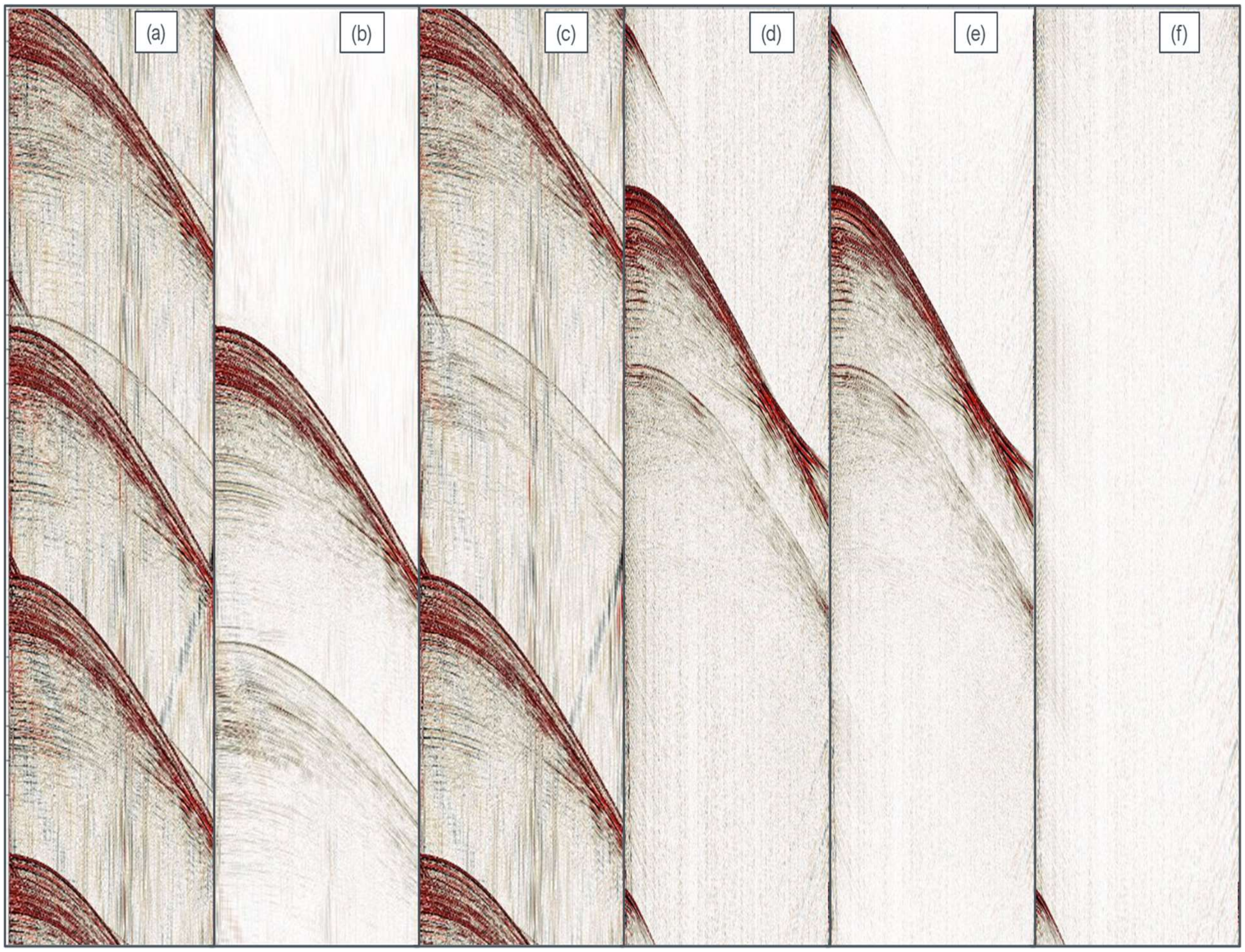

Figure 3 *Example shot gathers from a fast sequence (a, b, c) and slow sequence (d, e, f). The raw hydrophone data is shown in (a) and (d), deblended shot gather in (b) and (e), and differences (c) and (f). After deblending the fast and slow sequences have very similar data quality.*

Conclusions

Timely communication between the offshore seismic acquisition and onshore data processing teams allowed for analysis of the blended data, enabling informed decisions that impact data quality and project timing. Utilizing an inversion deblending we demonstrated the variability in the surface currents would not affect the final data quality of the survey. By ensuring data quality is not compromised, the survey was allowed to continue without additional constraints on the acquisition or the need to reshoot sail lines due to surface currents.

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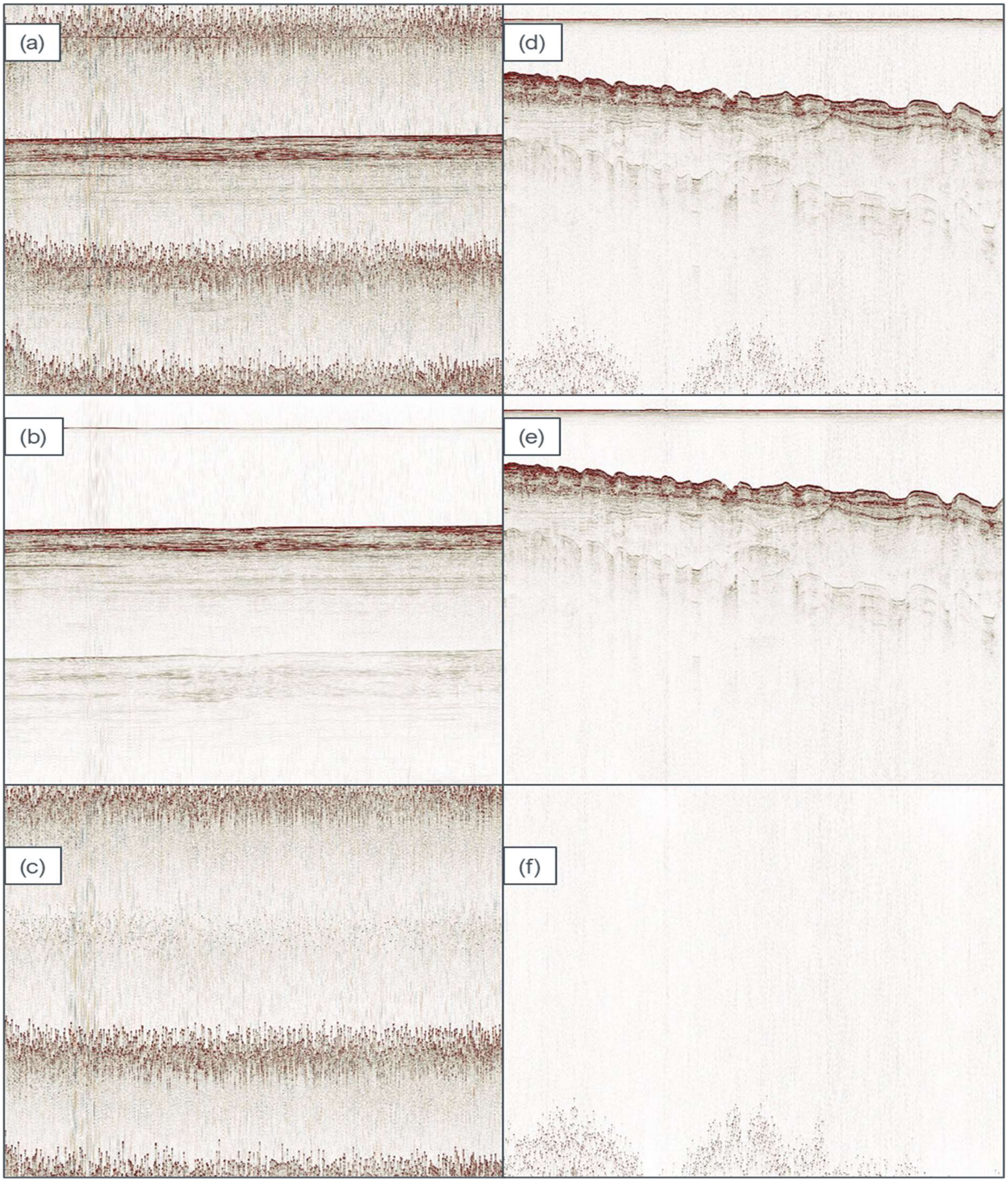

Figure 4 *Channel gather from a fast sequence (a, b, c) and slow sequence (d, e, f). The raw hydrophone data is shown in (a) and (d), deblended shot gather in (b) and (e), and differences (c) and (f). In the slow sequences the time between shots could exceed 18 seconds.*