Differential OBC processing techniques

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Summary

Compared to surface seismic, the increased complexity associated with seafloor seismic data (OBC) requires considerable attention to details if a noise-free and well imaged dataset is to be produced. Best quality control practices and the application of differential processing techniques both contribute to the generation of optimal imaging results. Well designed analyses are used to quickly identify inaccuracies in the coordinates and water depths assigned to the receivers and to derive accurate scalars for summing hydrophone and vertical motion phone data.

OBC data exhibits many of the noises seen on land data ranging from random spikes to coherent ground roll. These noises are most prevalent on the vertical motion phones and must be effectively removed in order to realize the full benefits of pz summation. In water depths greater than approximately 75 meters a 1D datuming of receivers to sea level is invalid. Pre-migration stacking velocities have to be calculated from a mean zero static floating datum and corrected to sea level to be used for pre-stack time migration. OBC compatible time and depth migration algorithms are used to image the data. These allow the OBC data to be input at acquisition datum and output at sea level, taking into account the water depths of the receivers.

Introduction

The 3D OBC data described in this study was recorded in the Main Pass area of the Gulf of Mexico, just off the coast of Louisiana. This is in the vicinity of the low velocity mud sheets located at the mouth of the Mississippi river. This survey was recorded in water depths varying from 10 to over 500 meters and was delivered with the coordinates and water depths in the seismic trace headers.

The acquisition contractor derived the location of the receivers through acoustics and first break analysis. The inline swath acquisition geometry makes it particularly imperative to ensure the coordinates and water depths are accurate because errors will be expressed as vertical seams in the crossline direction either in the middle of or between swath boundaries.

This survey employed accelerometers instead of the conventional geophone to record vertical motion. The quality of the accelerometer data was very good but much of the data recorded along the shoreline contains very slow velocity, high amplitude ground roll. Because many of the shots were recorded with large perpendicular offsets to the receiver lines this resulted in irregular offset spacing negating the use of an FK filter which assumes regular offset spacing.

The derivation of the pz summation scalars is influenced by noise present in the data particularly if it's inconsistent between the hydrophone and vertical motion phone, which is usually the case. It is important to remove as much of the noise differences as possible before calculating the scalars. Removing the high amplitude ground roll from the accelerometer data is important but other noise differences typically still exist between the two that need to be addressed before calculating the scalars.

Water depths varied greatly in this survey, eliminating simple approaches to datuming. Pre-stack data can not be time shifted more than approximately 50 ms before the shape of the reflections no longer fit a hyperbolic curve nor do they equate to a reasonable stacking velocity at their new position in time. Since the pre-stack time migration process is dependent on accurate and reasonable velocities, this invalidates a migration velocity field derived from data datumed to sea level.

Receiver coordinates and water depth verification

Seismic crews use acoustics and fathometers to determine the position of the receivers. These data need to be closely checked for accuracy and consistency by comparing the predicted arrival times with the direct arrivals that have traveled through the water column. When the water depths are very shallow, the first arrivals will likely be refraction energy that has been influenced by variable refractor velocities.

Direct arrivals having only traveled through the water column are preferable because the calculated arrival time will be a function of water velocity and can be easily predicted. When evaluating the accuracy of the receiver water depth versus the coordinates for any given receiver, the optimal traces to be used for direct arrival analysis are different. To evaluate receiver water depth, near offset traces should to be selected from shots with a horizontal distance from the receiver that is less than the water depth of the receiver. The opposite is true to evaluate a receiver coordinate problem. The horizontal distance should be greater than the receiver water depth. Shots from opposite sides of each receiver need to be selected to confirm the discrepancy is not due to an error in the water depth.

Figure 1 illustrates direct arrival analyses for receiver line 1193. This line was laid at a 92 degree azimuth in a water depth of 360 meters. Twelve gun lines parallel receiver line 1193. Gun lines 1182 to 1192 are on the south side of the receiver line and 1194 to 1204 on the north with 80 meter spacing between them. In figure 1(a) the near trace direct arrivals from shots on the two nearest gun lines are displayed with each trace shifted by it's predicted direct arrival time and placed on either the 100 or 200 ms. reference timing lines. In this example an intentional -25 meter error was added to the water depths in the receiver seismic trace headers. Using a 1500 m/s water velocity, this resulted in a predicted time of 17 ms too early between the calculated versus the actual direct arrival times.

In figure 1(b) traces are displayed from the two gun lines furthest away from receiver line 1193 at a distance of 440 meters. In this example an intentional -25 meter error was added to the receiver y coordinates in the seismic trace headers. The far north gun line 1204 resulted in a predicted time of 13 ms too late while the far south gun line 1182 is 13 ms too early.

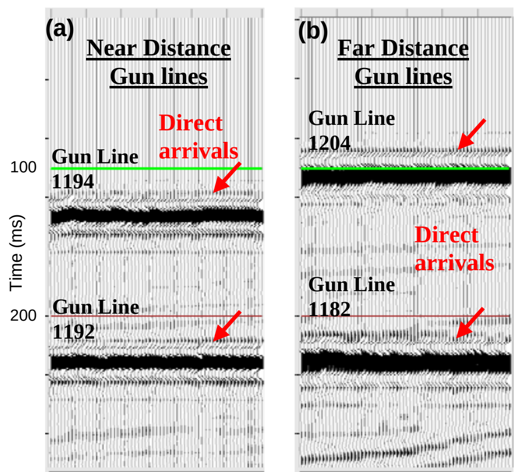

Figure 1. Direct arrivals for receivers on receiver line 1193. Near offset traces from each gun line are time shifted to reference timing lines based on calculated arrival times (a) with a -25 meter receiver water depth error. (b) with a -25 meter receiver y-coordinate error.

Optimal pz summation through effective noise suppression

The accelerometer shot record in figure 2(a) is typical of the data recorded in the very shallow water in this survey. The ground roll present ranges in velocity from 100 to 700 m/s with a dominant frequency well below 10 Hz. While proper attenuation of this noise is desirable for the improvement of the overall signal-to-noise ratio, it is also necessary for an accurate calculation of the pz summation scalars. A 3D f-x-y domain coherent linear noise filter was chosen for this step. It properly accounts for the variation of source-receiver offset from near to far traces that occurs when the source is broadside to the receiver line. The shot in figure 2 is a good example of this. It is located 120 meters away from the receiver line causing the ground roll to have a hyperbolic appearance on the near offsets. Figure 2(b) shows the same accelerometer data after ground roll attenuation with the linear noise filter. Filtering was only applied to the accelerometer data since the hydrophones contained minimal ground roll.

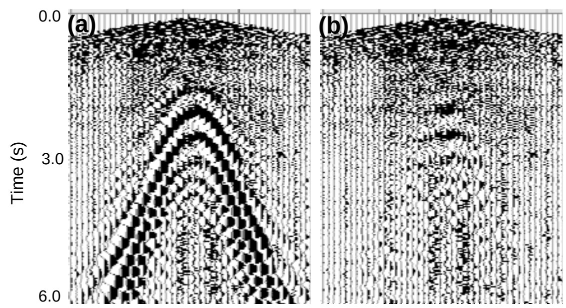

Figure 2. (a) Accelerometer shot record in shallow water. (b) same shot with 3D linear noise attenuation applied.

Figure 3 shows common receiver stacks of the accelerometer, hydrophone and pz summation data respectively. The receiver line that is shown is located near the shore in water depths ranging from 14 to 37 meters. Note pz summation scalars are graphed above the receiver stacked traces and show a range of 1500 to 3500. Receiver stations in the middle of the line are located over the mud sheets resulting in high frequency attenuation and the largest scalars. Figure 3(a) shows the accelerometer receiver stack with the pz summation scalars applied. This stack exhibits a good amplitude match when compared to the corresponding receiver stack of the hydrophone data in figure 3(b).

Figure 3(c) shows the receiver stack of the pz summation exhibiting crisper reflectors than either the accelerometer or hydrophone receiver stacks. Figure 4 shows an amplitude spectrum of the data in the box outlined in figure 3. The location of the analysis is at a water depth around 37 meters and shows distinct notches in the hydrophone amplitude spectrum at approximately 20 Hz intervals as expected. The accelerometer amplitude spectrum exhibits complementary notches to those of the hydrophone resulting in a well balanced pz summation amplitude spectrum. The pz summation scalars were derived through effective handling of the noise differences between the hydrophone and accelerometer data when deriving the scalars. The receiver gathers were frequency filtered and edited of any traces containing excessive noise but only for the purpose of deriving the scalars. The resultant pz summation scalars were applied to the accelerometer data and summed with the hydrophone data without the filter or editing applied.

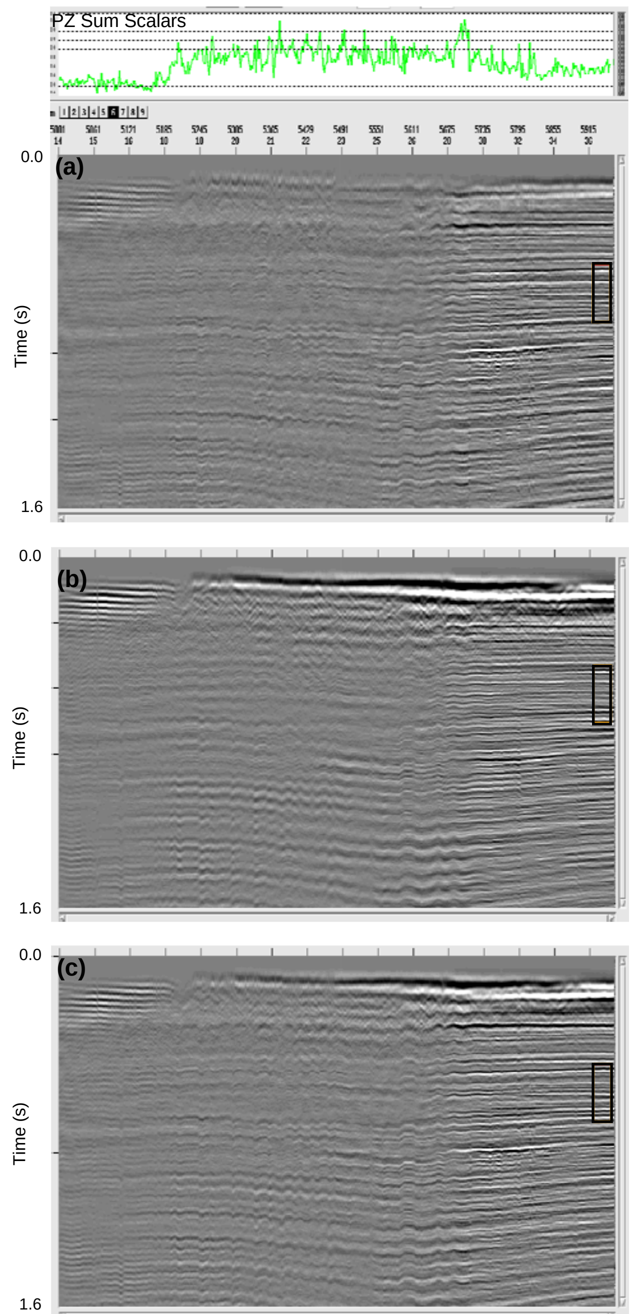

Figure 3. (a) accelerometer common receiver stack with pz summation scalars applied. (b) hydrophone common receiver stack. (c) pz summation common receiver stack.

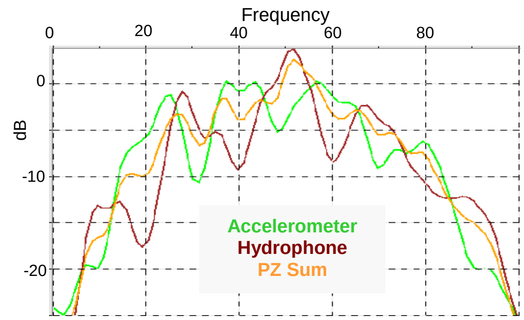

Figure 4. Amplitude spectrums of accelerometer, hydrophone and pz sum receiver stacks in figure 3.

Pre-stack Kirchhoff time migration

The OBC data in this study was processed before migration on a floating datum defined as half way between the water surface and water bottom. The traces in each cdp gather are time shifted to the same datum which corrects for the differences in receiver water depths. Since the datum is half way between the water surface and water bottom, the shot and receiver statics will have very similar magnitudes but opposite signs resulting in a small net static for each trace. This allows for reasonable cdp stacking velocities to be derived which can then be easily converted to sea level for use in migration.

Many pre-stack time migration algorithms assume the input data is on a flat datum, which is typically sea level for marine surveys. Since this OBC survey has water depths in excess of 500 meters, this equates to over 300 ms. of time shift to datum the receivers to sea level.

Figure 5(a) shows the results of a pre-stack time migration in which the data was time shifted to sea level before migration then migrated with an accurate velocity field referenced to sea level. The deeper time section is reasonably well imaged but the imaging in the shallow section is poor. Inspection of the pre-stack time migrated gathers show they are severely under corrected at the shallow times while the reflections at the deeper times are relatively flat. This happened because the data had not been recorded at sea level. A simple 1D time shift did not adequately correct for the reflection arrival times on the far offset traces had the data actually been recorded at sea level.

Figure 5(b) shows the results of a properly imaged section produced by inputting the data into an OBC pre-stack time migration algorithm without any time shifts applied. As input, the algorithm is provided an accurate migration velocity field referenced to sea level and a water bottom elevation surface. Shot and receiver depths are read from the seismic trace headers. The deep and shallow sections are well imaged and the gathers are flat.

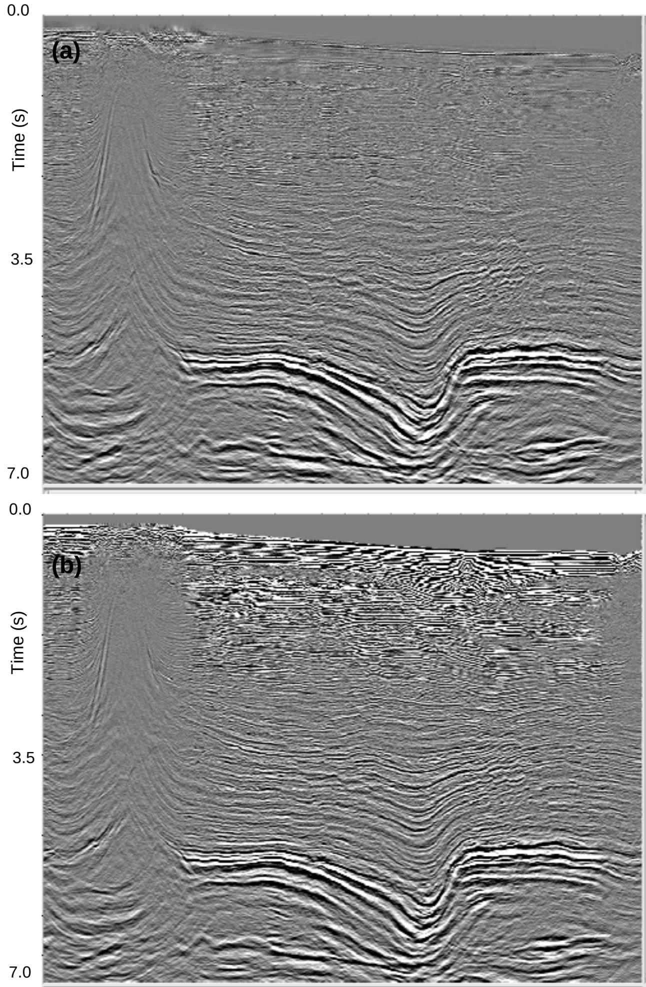

Figure 5. OBC pre-stack time migration (a) with data datumed to sea level before migration (b) with data migrated from acquisition surface.

Conclusions

More OBC surveys are being recorded in deep water to avoid cultural obstructions and reap the benefits of wide azimuth shooting. These surveys have to be accurately and optimally processed to ensure the best imaging results. Methods are available for deriving accurate receiver coordinates and water depths along with optimal pz summation scalars. Migration algorithms have to accommodate deep water OBC surveys by allowing the data to be input on the recorded acquisition surface.

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