A robust dual summation method: Application to OBC data from the Arabian Gulf

Saleh M. Al-Saleh, Saudi Aramco and Daniel A. Nietupski, Al-Khaleej*

2005 CSEG National Convention

Summary

One of the advantages of recording OBC surveys is that the summed vertical geophone and hydrophone data suppress unwanted receiver-side (i.e. down-going) water-column multiples. We present in this paper an application of a robust summation technique that successfully suppressed such multiples in an OBC dataset from the Arabian Gulf. This technique does not require an estimate of the sea-floor reflection coefficient; rather it calculates a time variant scalar trace for every hydrophone and vertical geophone trace pair. The scaled vertical geophone traces are summed with their corresponding hydrophone traces. Multiples are cancelled by summation due to their opposite polarities. In this paper, we provide a value-added feature to the technique. We map the average of each scale trace to detect vertical geophone receivers that were not well coupled with the seafloor.

Introduction

Several dual summation methods are described in the literature, e.g. (Ball and Corrigan, 1996; Soubaras, 1996). Most of them require an accurate estimate of the reflection coefficient of the sea floor. Inaccurate estimates lead to inaccurate summation and thus to sub-optimal multiple suppression.

Hoffe et al. (2000) proposed a simple and robust method for dual-sensor summation that can suppress receiver-side water-column multiples. This method does not require an estimation of the sea floor reflection coefficient. The authors explain, "… *summation of the hydrophone recording which measures pressure with a scaled version of the vertical geophone recording which measures velocity of displacement removes one type of multiple. The dual sensor combination of the hydrophone and vertical geophone recordings will cancel out all receiver-side multiples, while preserving reflections from below the ocean-bottom interface*". Such receiver-side multiples are clearly present in OBC datasets and they are effectively removed using this technique.

The technique calculates a scalar trace for each vertical geophone – hydrophone trace pair. The scaled traces are calculated as the absolute values of the hydrophone samples divided by the geophone samples followed by application of a median filter. The vertical geophone samples are multiplied by the scalar samples and the results are added to the hydrophone samples. Summation cancels receiver-side water-column multiples due to opposite polarities in the vertical geophone and hydrophone traces. We present a value-added feature to this technique. We create maps of the average of each scalar trace at each receiver station. These maps provide a QC tool to show how well the geophones are coupled to the sea floor.

Even with the inclusion of the median filters into this technique, it is computationally simple and therefore fast. The technique is robust in that it does not require the sea floor reflectivity to be estimated. Moreover, the application of the median filters reduces the effects of noise. Our tests showed not only that the summation technique worked well, but that the random noise attenuation was a valuable feature and that the mapping of scalars was a valuable QC tool that clearly showed badly coupled geophones (as well as other electronic-type noise).

Theory

The technique derived by Hoffe et al. (2000) is summarized here. Figure 1 shows a simple case where a hydrophone and a vertical geophone are sitting on the seafloor. The raypaths are assumed vertical through the water column. We use the notation from Paffenholz and Barr (1995): P = wavefield pressure, D = down-going wavefield, V = velocity of displacement, ρ = density of water, U = up-going wavefield, and c = P-wave velocity in water. Using the one-dimensional wave equation, Loewenthal et al. (1985) show that the pressure wavefield is given by:

$$P = U + D, \tag{1}$$

and the velocity of the displacement wavefield is given by:

$$V = \frac{1}{\rho c}(U - D). \tag{2}$$

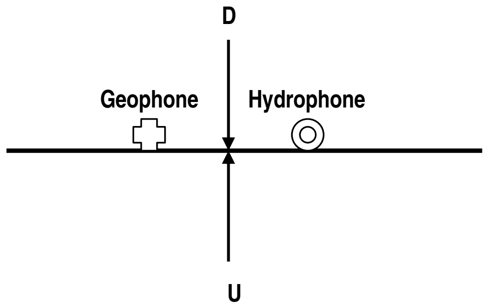

Figure1. The upgoing and downgoing waves are recorded by the hydrophone and vertical geophone on the seafloor.

Hydrophones record the pressure wavefield, which is a scalar quantity. The pressure wavefield is the sum of the up-going and down-going wavefields (Equation 1). On the other hand, the vertical geophone records the velocity of particle displacement so it is a vector field and thus sensitive to the wave direction (Equation 2). The Z-transform of down-going wavefield is given by:

$$D(Z) = 1 - RZ + R^2Z^2 + \ldots\ldots = \frac{1}{1+RZ}, \quad (3)$$

and the Z-transform of the up-going wavefield is given by:

$$U(Z) = R - R^2Z + R^3Z^2 + \ldots\ldots = \frac{R}{1+RZ}. \quad (4)$$

By using Equations (3) and (4), the Z-transforms of the pressure and velocity of displacement wavefields are:

$$P(Z) = \frac{R+1}{1+RZ}, \quad (5)$$

and

$$V(Z) = \frac{1}{\rho c}\left(\frac{R-1}{1+RZ}\right) \quad (6)$$

Combining Equations (5) and (6) gives:

$$P(Z) + \rho c\left(\frac{1+R}{1-R}\right)V(Z) = 0. \quad (7)$$

Equation 7 shows that summing the hydrophone and the scaled version of the vertical geophone will cancel the receiver related multiples, but the cancellation will be sub-optimal unless the right scalar is used.

Discussion

Figure 2 shows a hydrophone gather, a vertical geophone gather, and the corresponding summed gather. The hydrophone gather is contaminated with multiples while the summed gather is cleaned considerably. The summed data may still contain source-related and inter-bed multiples, which must be attenuated using other techniques. The autocorrelations of the hydrophone and summed data (Figure 3) show that this technique suppressed some of the multiple energy, but there are still other types of multiples present in the data. Random noise and strong coherent noise with high amplitudes can affect the summation process. Dividing by noisy samples with high amplitudes can make the scalar traces less effective in scaling the vertical geophone traces to match the hydrophone traces. This method applies a median filter to the scalar traces to make them less affected by the presence of noise. This median filter is typically applied over a small window such as 100 ms.

We also found it useful to map the average scalar values for all receivers (Figure 4). Any receiver that is not well coupled with the seafloor will show an anomalous scalar value. Figure 5 shows stacked sections for the hydrophone, vertical geophone, and summed data. The stacked section of the summed data shows that the water-column related multiples have been significantly suppressed after the summation, confirming the effectiveness of this method.

Conclusions

We applied a dual summation method to an OBC dataset from the Arabian Gulf and we successfully suppressed water-column multiples generated at the receiver side. The employed method was fast and robust and did not require an estimate of the sea-floor reflection coefficient; rather, it calculated a time variant scalar trace for every hydrophone-vertical geophone trace pair. The scalar traces were median filtered and applied to the vertical geophone traces to match them to the hydrophone traces. After trace summation, the multiples were cancelled due to their opposite polarities. Applying a median filter to the scalar traces has improved the summation process and eliminated noise. The scalar traces are also used to QC the coupling of the vertical geophones.

Acknowledgments

We would like to thank Panos Kelamis and Steve Kellogg for their comments and suggestions. We would like also to thank the CREWES project.

References

Ball, V., and Corrigan, D., 1996, Dual-sensor summation of noisy ocean-bottom data: 66th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 28-31.

Hoffe, B. H., Lines, L. R., and Cary, P. W., 2000, Applications of OBC Recording. The Leading Edge, April 2000, Vol. 19, No. 4.

Lowenthal, D., Lee, S. S., and Gardner, G. H. F., 1985, Deterministic estimation of a wavelet using impedance type technique: Geophys. Prosp., **33**, 956-969.

Paffenholz, J., and Barr, F. J., 1995. An improved method for determining water bottom reflectivities from dual- sensor ocean bottom cable data: 65th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 987- 989.

Soubaras, R., 1996, Ocean-bottom hydrophone and geophone processing: 66th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 24-27.

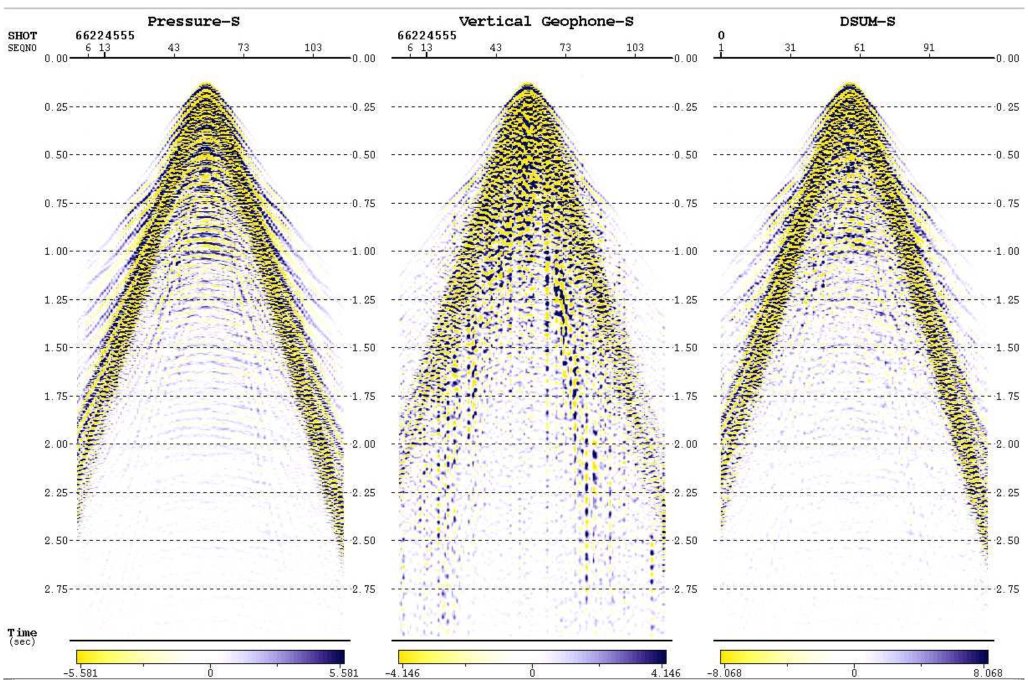

Figure 2. Hydrophone gather (left), vertical geophone gather (in the middle), and the summed gather (right).

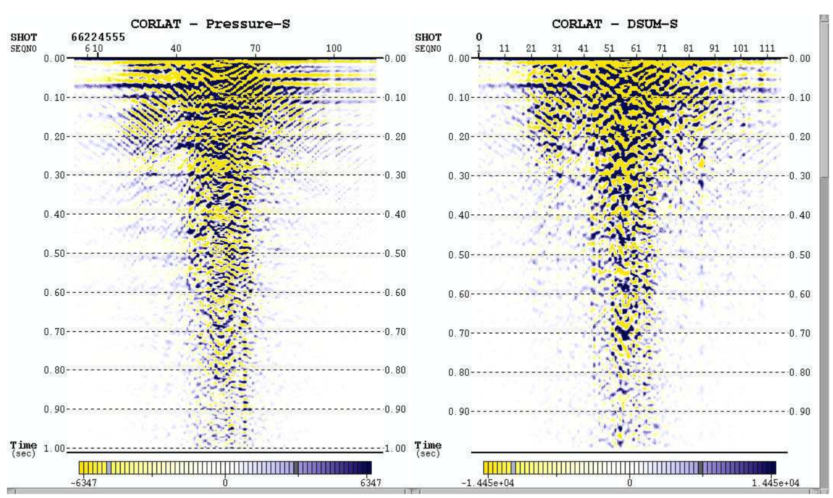

Figure 3. Autocorrelations of the hydrophone data (on the left) and the summed data (on the right).

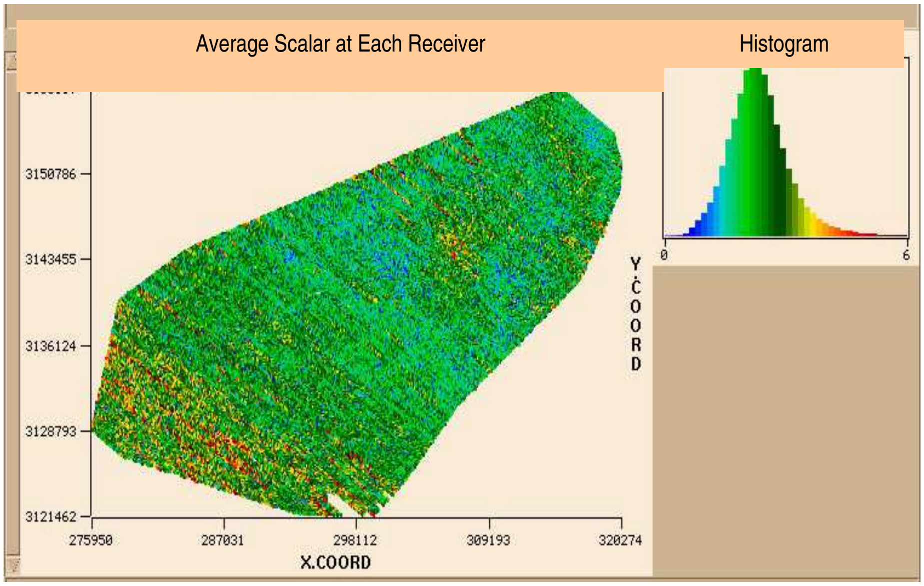

Figure 4. Map and histogram of the QC scalars, which are the average of the scalar traces at each receiver location. Poorly coupled receivers can be seen in the map and in the histogram as anomalously high values.

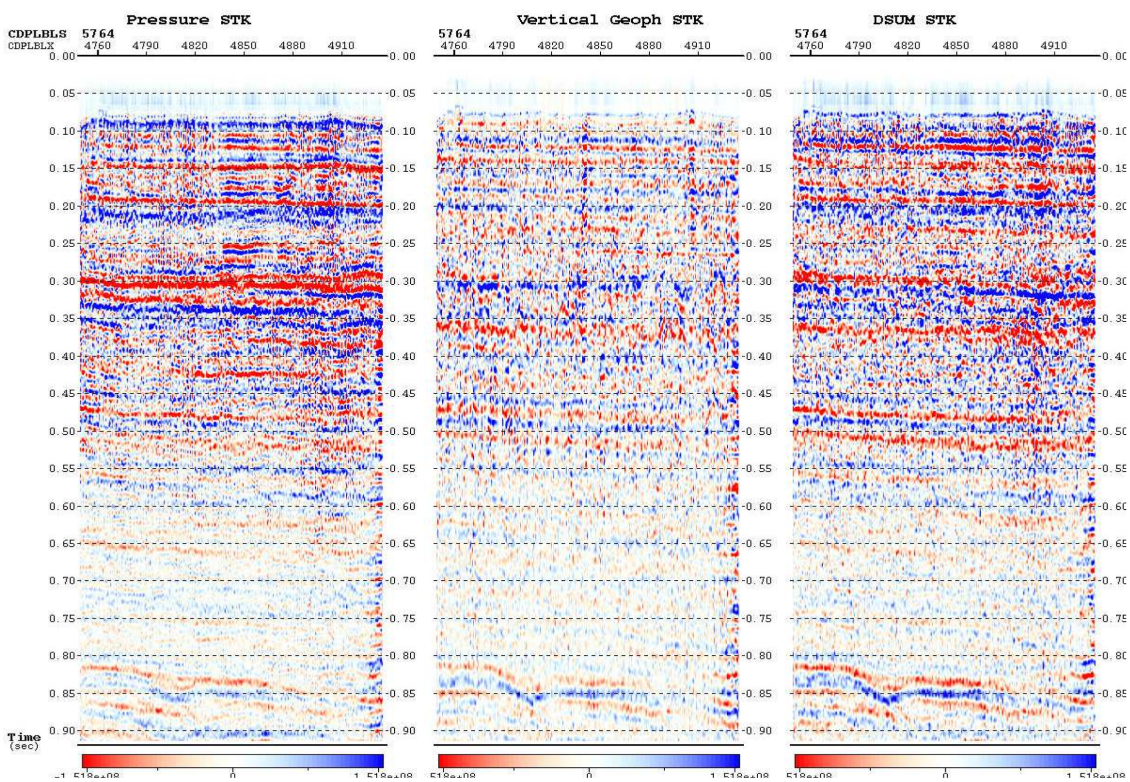

Figure 5. A comparison between the unsummed hydrophone (on the left) and vertical geophone data (in the middle) and the summed data (on the right).