A simple and robust method for combining dual-sensor OBC data?

Brian H. Hoffe, Peter W. Cary and Laurence R. Lines

ABSTRACT

In this paper, we propose a simple and robust method for combining dual-sensor ocean-bottom cable (OBC) seismic recordings for multiple attenuation. This method does not require an estimate of the ocean-bottom reflection coefficient but rather computes a time-variant scalar trace for each common hydrophone-vertical geophone trace pair. When this scalar trace is applied, it essentially equalises the amplitudes of the hydrophone-geophone trace pair such that multiple cancellation is achieved upon their summation.

We then tested this method on both a synthetic and real dual-sensor OBC data set to evaluate its effectiveness. These tests showed that the multiple energy is greatly attenuated on both synthetic and real dual-sensor summed records, producing promising results.

INTRODUCTION

One of the greatest shortfalls of acquiring seismic data in the marine environment is the presence of water-column reverberations which produce undesirable multiples. As a single upgoing reflection wavelet arrives at the ocean-bottom from below, it continues to travel upwards until it impinges upon the ocean's surface where it is completely reflected. Upon arrival at the ocean-bottom, this downgoing wavelet is again partially reflected back towards the water's surface. This cycle repeats producing second and subsequent multiple arrivals of the original reflection at time lags equal to the two-way travel time through the water column. This arrival of primary reflection energy at the ocean-bottom and its subsequent water-column multiples is illustrated schematically in Figure 1.

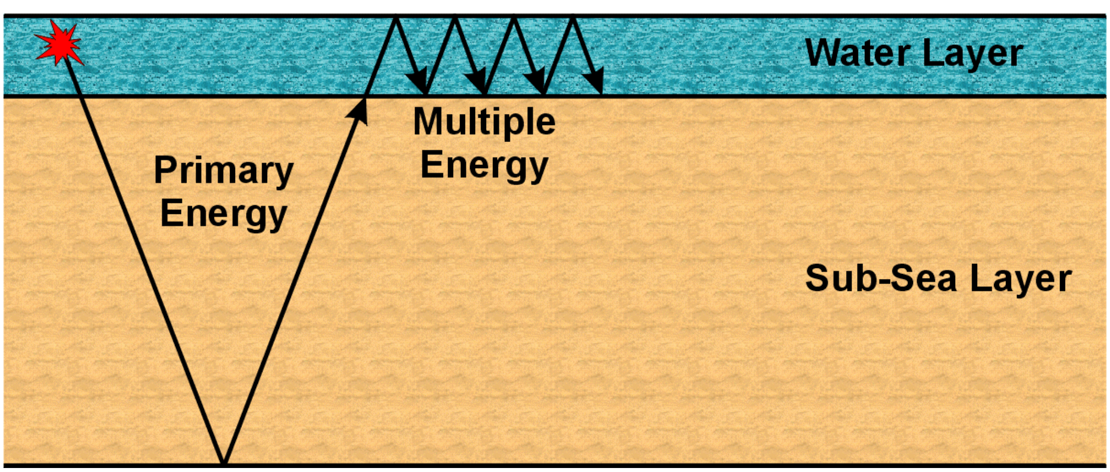

Figure 1. Schematic diagram depicting the ray path geometry for the receiver-side multiples. Note how the primary energy consists of an upgoing wavefield whereas all receiver-side multiples consist of downgoing wavefields.

Thus it is apparent, from the above explanation, that all primary reflections would consist of an upgoing wavefield whereas all the subsequent water-column reverberations or receiver-side multiples would consist of downgoing wavefields. Thus if a composite detector could be designed to perform this wavefield separation, a better method of multiple removal might be achieved. It is this concept of wavefield separation that eventually led to the development of combining both hydrophone and vertical geophone recordings for multiple removal (Loewenthal et al., 1985; Barr and Sanders, 1989; Dragoset and Barr, 1994). This approach is commonly referred to as the dual-sensor method.

It is important to note that the dual-sensor method can only **directly** remove receiver-side multiples (i.e. downgoing multiples) and **not** other types of water-layer multiples as illustrated in Figure 2. Although it can be demonstrated mathematically (Paffenholz and Barr, 1995) that the summation leaves the upgoing reflectivity intact, this reflectivity is usually contaminated by both source-side and interbed multiples (i.e. upgoing multiples).

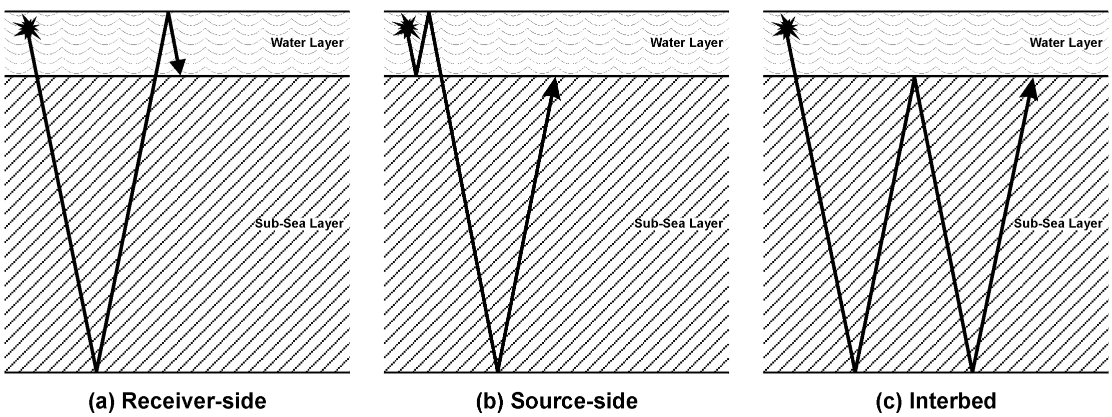

Figure 2. (a) receiver-side multiples, (b) source-side multiples and (c) interbed multiples. Dual-sensor summation can only directly remove receiver-side multiples (i.e. downgoing energy) and not source-side and interbed multiples (i.e. upgoing energy).

Numerous methods have been published on the combination of dual-sensor OBC data for multiple removal (Paffenholz and Barr, 1995; Ball and Corrigan, 1996; Soubaras, 1996; Bale, 1998). All of these methods require the computation of an accurate estimate of the ocean-bottom reflection coefficient in order for them to be effective. Unlike these other methods, our proposed method does not require the computation of the ocean-bottom reflection coefficient.

In this paper, we approach the problem in a much more simplistic manner and propose a very simple and robust method for dual-sensor combination. We simply compute a time-variant scalar trace for every hydrophone-geophone trace pair. Application of these time-variant scalar traces essentially *forces* the amplitudes of the geophone traces near equal to that of the hydrophone traces. Thus, when summed, receiver-side multiple cancellation is achieved due to their opposing polarity on each of the hydrophone-geophone trace pairs.

METHODOLOGY

These time-variant scalar traces are computed as follows:

1. The data is first sorted so that the hydrophone-geophone trace pairs are properly matched for each common receiver location. This is easily done in the common receiver domain.

2. Since the hydrophone amplitudes are commonly an order of magnitude greater that that of the geophone amplitudes, the hydrophone trace is divided by the geophone trace on a sample-by-sample basis which produces a quotient trace.

3. A *median* smoothing filter is then applied to the *absolute value* of this quotient trace over a small time window, typically 80 - 100 ms, and this scalar trace is then output.

4. These scalar traces are then applied to the appropriate geophones traces via trace multiplication and the scaled geophone traces are then simply added to the corresponding hydrophone traces to produce the dual-sensor summation result.

An important and critical assumption required for this method to work is that both the hydrophone and vertical geophone elements of the OBC receiver element be phase matched. One could imagine that if this assumption were severely violated, the summation of hydrophone and scaled geophone traces may produce undesirable results depending on the magnitude of the phase difference between these two recording elements. However, it appears that most equipment manufactures tend to phase match their dual-sensors in the production of their respective OBC receiver elements (W. Dragoset, personal communication).

RESULTS

1) Synthetic Example

To test the validity of this method, we first tested it on dual-sensor synthetic seismic data computed from a general elastic wave model of the Jeanne d'Arc Basin, offshore Newfoundland. As is evident from Figure 3, both the hydrophone and scaled vertical geophone data show a large number of various water layer multiples between 600 and 1600 ms but are severely attenuated on the dual-sensor summed result.

Of particular note is the noticeable enhancement of the first sub-sea primary at ~ 690 ms and the significant reduction of the subsequent receiver-side multiples which have a period of ~ 167 ms (model water depth = 125 m) on the summed result of Figure 3(c).

2) Real Data Example

We next tested this method on some real dual-sensor data from a 4C OBC survey acquired by Geco-Prakla over the Mahogany field, Gulf of Mexico (Caldwell et al., 1998). Figure 4 shows the results for a portion of a receiver gather from this survey.

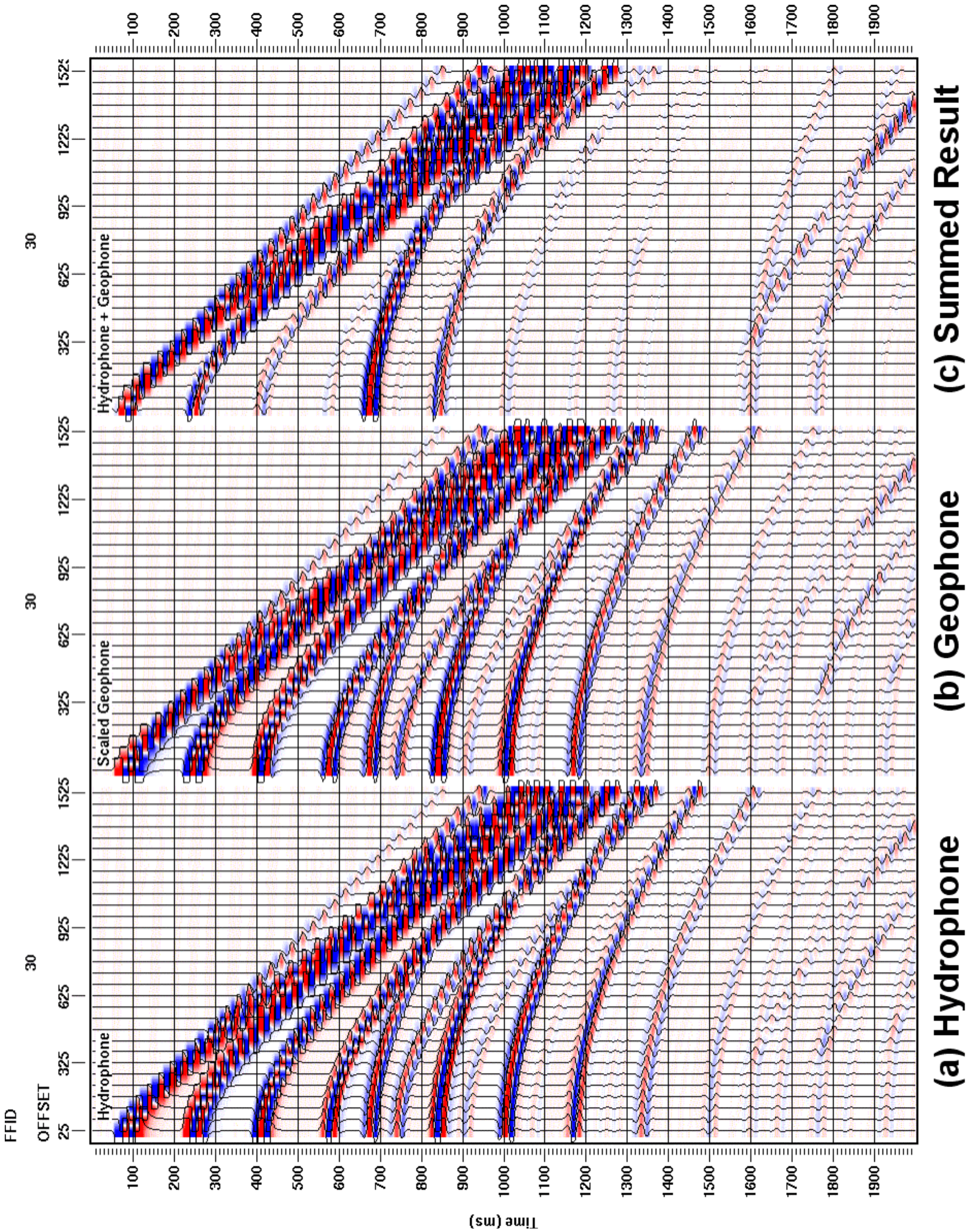

Figure 3. Synthetic dual-sensor seismic data computed from a general elastic wave model of the Jeanne d'Arc Basin for offsets 25-1525 m. (a) hydrophone source gather and (b) the scaled geophone source gather and (c) the dual-sensor summation result. Note on (c) how the receiver-side multiples are greatly reduced in amplitude

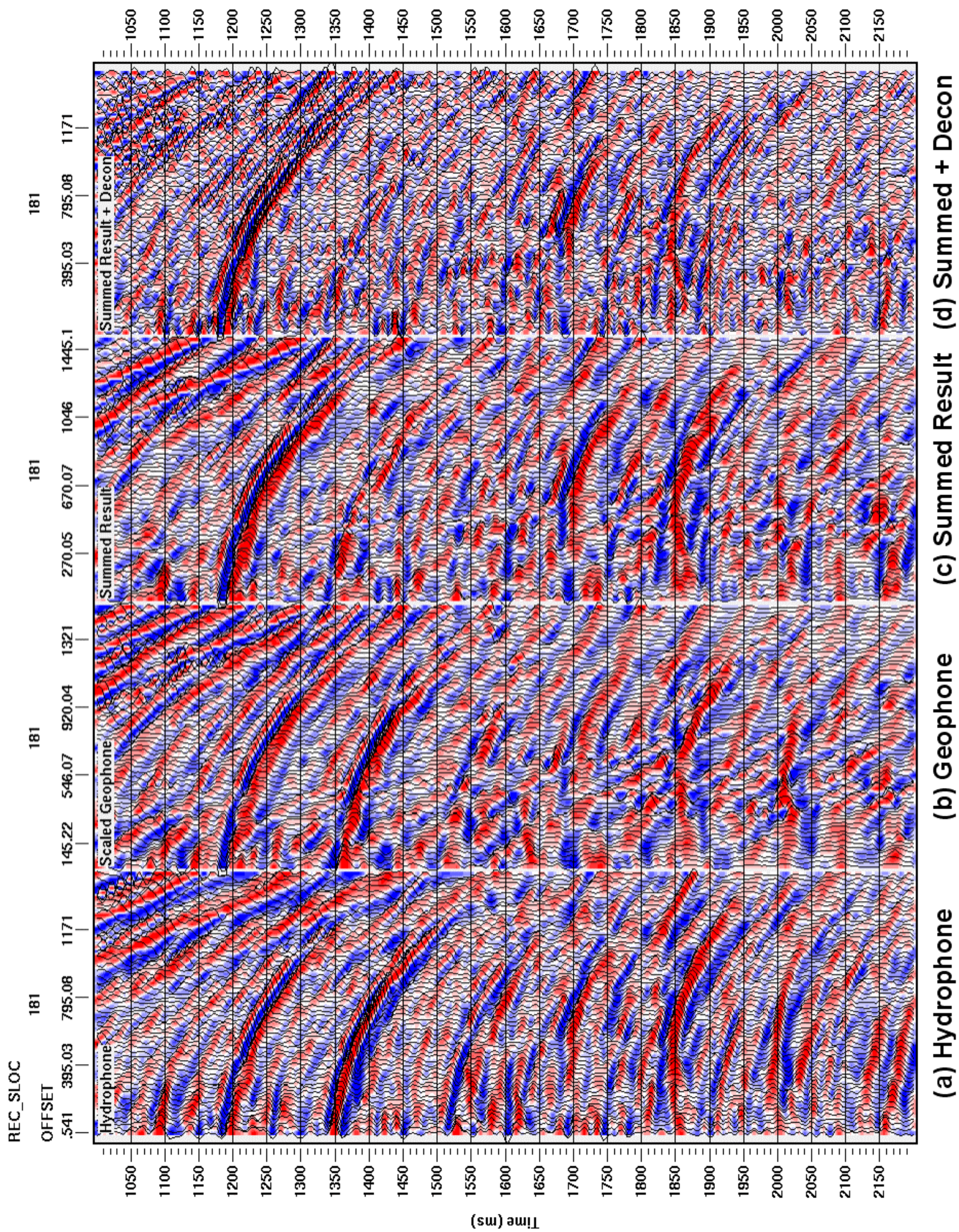

Figure 4. Dual-sensor seismic data from the Mahogany field, Gulf of Mexico. (a) hydrophone data, (b) scaled geophone data, (c) summed result and (d) summed result + deconvolution (spiking + predictive). Note the considerable reduction in the amplitude of the multiples compared to the primaries between 1190 ms and 1690 ms on (c). Also, note removal of residual, source-side multiple energy + sharpening of primary reflectivity on (d).

Prominent primary events are visible on both the hydrophone traces, Figure 4(a), and the scaled geophone traces, Figure 4(b) at near offset arrival times of about 1190 ms and 1690 ms. The water depth at the Mahogany field is about 120 m, so the first receiver-side (and first source-side multiple) arrive at about 160 ms (~ 1350 ms) after each primary event. The second multiple event is also visible about 160 ms later (~ 1510 ms). Notice that the primaries are in phase and the multiples are out of phase on the two components. The summed result in Figure 4(c) shows a considerable reduction in the amplitude of the multiples compared to the primaries.

However, as expected, source-side (and interbed) multiple energy remains on the summed result of Figure 4(c). In order to eliminate this residual multiple energy from the summed result, a spiking deconvolution followed by a predictive deconvolution was applied and this result is shown in Figure 4(d). As is evident from Figure 4(d), the deconvolution has effectively eliminated a majority of the residual multiple energy and significantly sharpened the primary reflectivity.

CONCLUSIONS

We have proposed a simple and robust method of combining dual-sensor OBC data for multiple attenuation. A critical assumption required of this method is that both the hydrophone and vertical geophone elements be phase matched. Application of this method to both synthetic and real data sets as shown here has clearly demonstrated that it can effectively attenuate multiple energy.

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