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Signal Enhancement in OBC data- A Case Study Western Offshore Basin, India

Mithai Lal, B N Bhatta, Brajesh Das, D.Chaterjee*

Summary

The Dual sensor technology or popularly known as OBC technology of data acquisition has gained importance in recent times in order to have an improved signal to noise ratio due to increased foldage, its ability to cover the area in congested producing fields clustered with platforms, pipelines, and drilling rigs, where towed source vessel operations are difficult or impossible and its suitability for shallow water, bays, lakes and rivers. It has been confirmed that OBC dataset can be used for better imaging of the overburden as well as within the carbonate zones by efficiently attenuating the water layer reverberations through dual sensor summation. The PS wave data can also be used for shallow gas pockets confirmation. The main disadvantage is however is its high cost and a considerable attention in processing to bringout a noise free and well imaged dataset.

The main challenges in processing an OBC dataset are (a) the ghost generated due to destructive interference of upgoing and downgoing wavefields (b) the derivation of PZ summation scalars which are greatly influenced by the presence of inconsistent noise in the data. (c) Identification of various type of noise and attenuation and (d) careful Velocity analysis because there are various offsets coming from different azimuths.

The present study essentially deals with the preconditioning of OBC data separately for hydrophone and geophone to derive the scalars to be applied to data before summation to bringout data with high resolution so that it could add an interpretational advantage.

Keywords: *OBC, PZ summation, Western Offshore Basin*

Introduction

In the shallow marine environment, ocean bottom cable (OBC) surveying, in which the seismic cable is laid on the bottom, dual sensor recording provide the best method to acquire the seismic data. The dual sensor recording uses co-located hydrophone and geophone. The advantages of OBC over towed streamer surveys are the flexibility of acquisition geometry, greater surface consistency (i.e., more combinations of source and detector at different azimuths for a given midpoint, useful for resolving static delays and for amplitude compensation), more flexibility in working around obstructed zones, the use of dual sensors to remove ghosts and layer reverberations, reduced noise by eliminating cable vibration and strumming caused by towing and surface weather conditions, and better coverage due to the elimination of cable feather caused by currents.

From seismic processing view point, ocean bottom cable seismic data produce better quality images of the subsurface when compared to streamer data, because the hydrophone and vertical geophone data in an ocean bottom cable seismic data can be combined in the processing to effectively attenuate water column reverberations and ghosts, which would not be achieved with a streamer data. Although dual sensor summation is very effective in multiple suppression in an ocean bottom cable data (Loewenthal et. al., 1985, Barr and Sanders, 1989; Draggoset and Barr, 1994; Paffenholz and Barr, 1995; Ball and Corrigan, 1996; Soubaras, 1996), the summation process would be effective if one is able to adequately

ONGC, Mumbai, India
**Email: lal1863@yahoo.com*

suppress coherent noise in the individual hydrophone and vertical geophone dataset prior to the summation, since the magnitude and type of noise recorded by the hydrophone and geophone sensors vary greatly. The challenge to the geophysicist is to be able to process the individual hydrophone and vertical geophone data up to the level where they can conveniently be combined for effective multiple suppression.

Theory:

Generally, the geophone data show more noise than the hydrophone data, although spectral analyses of the raw data showed that the hydrophone data have higher amplitude and lower frequency than the geophone data, which have much lower amplitude and higher frequency (Hoffe et al., 2000). Both the hydrophone and geophone data were heavily contaminated with low frequency noise spanning the whole length of the recording. Common type of noises generally encountered with the hydrophone and geophone data in OBC survey are: Scholte waves generated by an interface between solid and fluid, swell noise characterized by high amplitude and low frequency prevalent on small groups of channels, source-generated noise (for instance direct and scattered waves or multiples), and instrument noise as coherent or incoherent energy in seismic gathers.. Spikes & noise bursts, trapped guided waves and bubble energy in Hydrophone & Geophone and Shear Leakage only in Geophone.

The combination of the hydrophone and vertical geophone data to attenuate multiples and water-column reverberations is an important step in the processing of ocean bottom cable seismic data. Dual sensor recording uses co-located hydrophones and geophones consequently, when traces from these are suitably combined, the receiver ghost trends to cancel, and the reverberation problem is attenuated. It can be seen that the two spectra are complementary – where there are notches in one there are peaks in the other. Hence frequencies missing from the notch in the hydrophone spectrum are supplied by a peak in the geophone spectrum. Summing the two signals removes the spectral notches yielding a much more desirable spectrum (Figure 1).

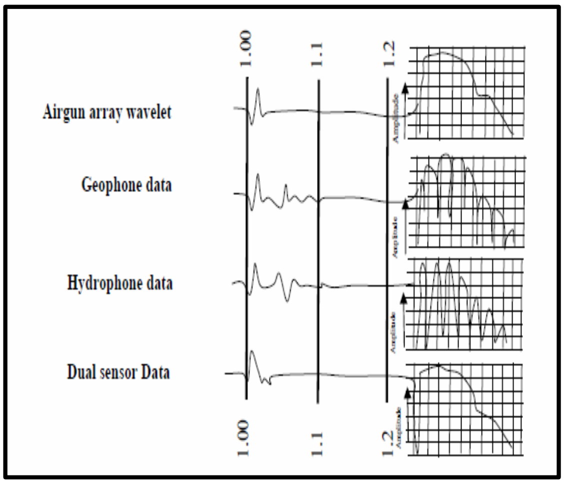

Figure 1: The combination of both ocean bottom cable geophone and hydrophone signals (dual sensor summation) to eliminate water column reverberation (Ugbor C C 2007).

An additional benefit is wavelet stability. After removing the harmful effects of the receiver ghost, a stable wavelet remains, which is independent of water depth and provides for much more detailed stratigraphic analysis. A chief dual-sensor benefit is the improved frequency range, or bandwidth, achieved over other methods. Increasing bandwidth allows resolution of thinner beds. Marine streamers record a receiver ghost, which affects the higher frequency parts of the spectrum, reducing bandwidth. Since the receivers are located on the water bottom, potentially all the water layer reverberations may be eliminated with the ancillary benefit of extracting the relative water bottom reflectivity. Having eliminated the ghost, the dual-sensor data can be richer in higher frequencies. The geophone contribution usually improves low-frequency content as well. But to achieve this, the data (both hydrophone and geophone) should be free from different types of noises. This diversity of noise types with different characteristics makes separation of signal and noise a challenging process. However, efficient noise attenuation and/or removal is important for high-quality imaging.

An attempt was made to process an OBC dataset of Western Offshore Basin, India (Fig.2) to bring out a higher resolution better interpretable data. To achieve this, apart from other regular processing routines, noises were analysed and various noise eliminating processed were applied to data separately for hydrophone and geophone and the results so obtained was encouraging (Basu,2012).

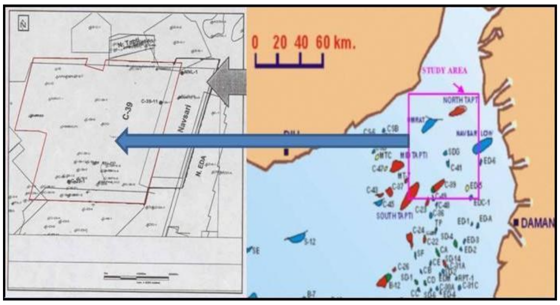

Figure 2: Study Area

Procedure:

The efficient attenuation of coherent noise in seismic data is of high importance for high quality seismic images. Coherent noise suppression is particularly challenging in an ocean bottom cable seismic data since the level of noise recorded by the hydrophone and geophone sensors vary considerably. The basic approach to remove the unwanted noise is that the transfer the data to a domain where the signal and the noise component can be separated. The presumed noise is subsequently removed, before the data component is transformed back to normal physical x-t domain. Below we will briefly describe some noise elimination procedures were adopted in different domain for this dataset of a prospect from west coast, India.

Receiver domain de-noising:

The Fig 3a show the data is contaminated with scholte waves, noise burst, and guided waves as it is clearly visible in shot gather of both hydrophone and geophone. This data is showing full of shear wave leakage due to poor coupling at sea-floor in the OBC survey. De-noising through the use of a time-frequency algorithm, f-x dip filter and median filter in receiver domain was then applied to suppress the noise. The result was a dataset with all visible hyperbolic events with a very good quality is seen (Fig. 3b), which allowed to get the major success in this project.

Shot domain de-noising:

When the data is sorted in shot domain, the geophone data was full of random noise (Fig 4a). The data were de-noised by means of the time-frequency algorithm and f-x dip filter along with the median filter. Note that the abnormal amplitudes, scholte waves and trapped energy found in the data have almost completely been attenuated by this approach (Fig.4b). After removing the random noises and coherent noises from hydrophone and geophone, the data is summed to attenuate ghosts. Fig 5 shows the hydrophone, geophone and summed data in shot domain

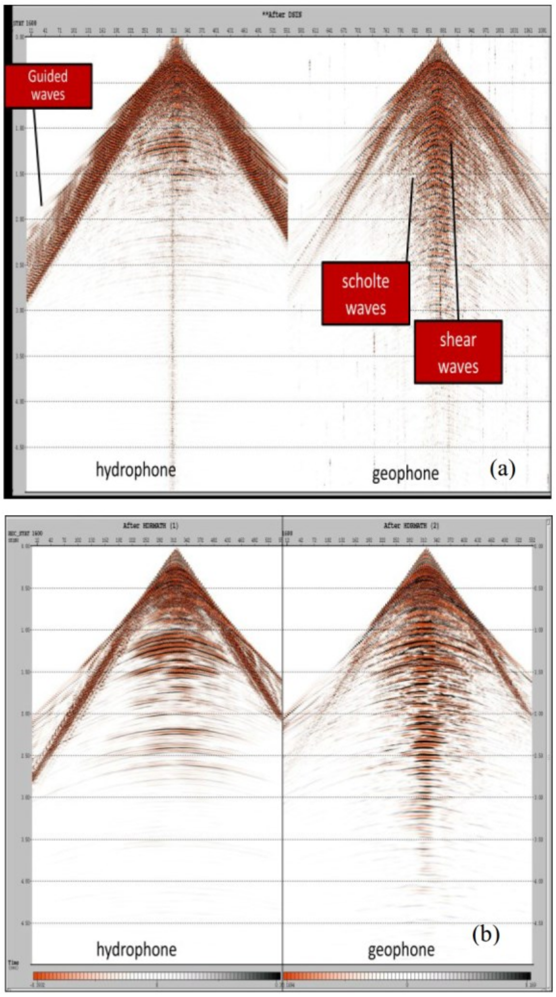

Figure 3a: Geophone and hydrophone gather in receiver domain: Raw(a) and de-noise (b)

CMP domain de-noising:

After denoising in shot and receiver domain, the data was sorted into CMP domain for further improvement of signal to noise ratio. For further elimination of noises and boosting signal level, tau-p decovolution is carried out. It increases the resolution and attenuates the multiples in CMP domain.

Offset domain de-noising:

The data is transformed to offset domain to fill the missing offset and foldage regularization. Random noise attenuation algorithm is also applied to remove the residual random noise.

The data is then finally brought to t-x domain for time domain Pre-Stack Migration. Isotropic Kirchhoff migration is carried out with the migration aperture 6 kms.

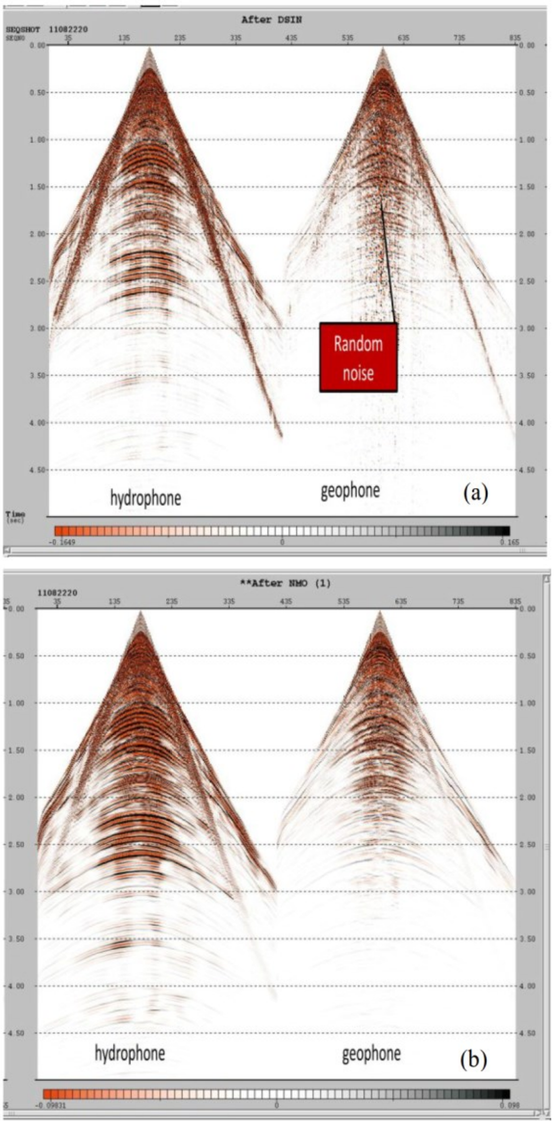

Figure 4a: Geophone and hydrophone gather in shot domain: raw (a) and de-noise (b)

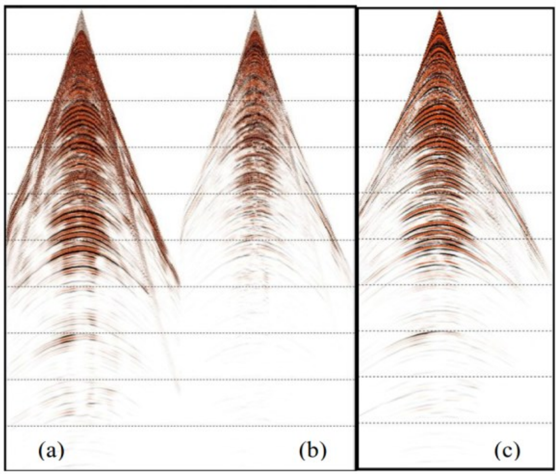

Figure 5: PZ Summation (c) of geophone (b) and hydrophone (a) data

Results

Application of noise attenuation techniques on the hydrophone and geophone data separately before summation has provided fruitful results. Figure 6 shows the PSTM stack with the vintage data where no noise removal process was carried out in receiver domain before summation. The overall improvement in signal to noise ratio and image are clearly visible. The data was handed over to interpreters who carried out pre-stack inversion of the data. Fig. 7 is the PSTM gather with angle response of the data indicating the improvement over the vintage processed data. Fig.8 a & b is the comparison of Angle stacks of vintage data and currently processed data indicating the improvement. As the data quality has improved significantly therefore, quantitative analysis based on seismic inversion has been feasible.

(a) (b)

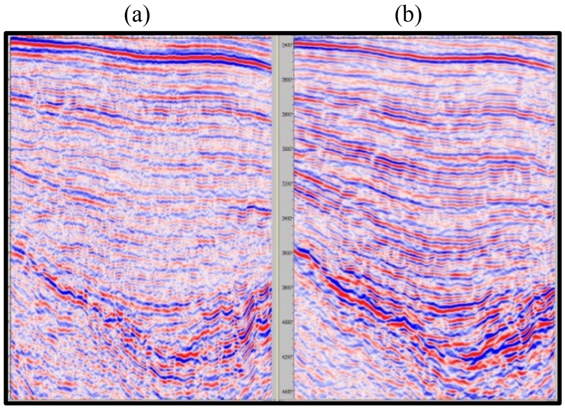

Figure 6: PSTM Stack - a) vintage data, b) re-processed data

(a) (b)

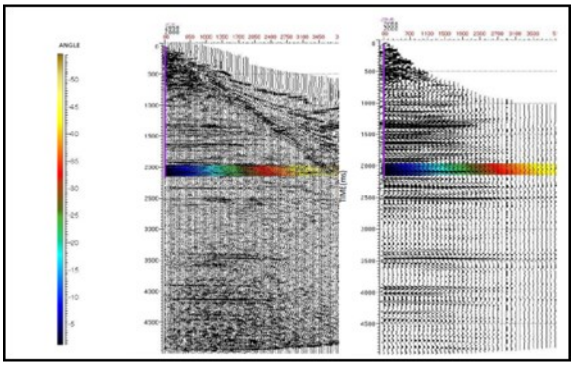

Figure 7: PSTM gather - a) vintage data, b) re-processed data.

Conclusion

The present case study of the preconditioning of OBC data separately for hydrophone and geophone to derive the scalars to be applied to data before summation has bringout clearer image of the subsurface with high resolution. Identification of various type of noises; their attenuation and the derivation of PZ summation scalars in the absence of noise in the data are the main contributing factors for improved results. Improved signal to noise ratio in the gather resulted in higher angles available for inversion study and added an interpretational advantage. Pre-stack attributes generated with this data will help in reservoir characterization

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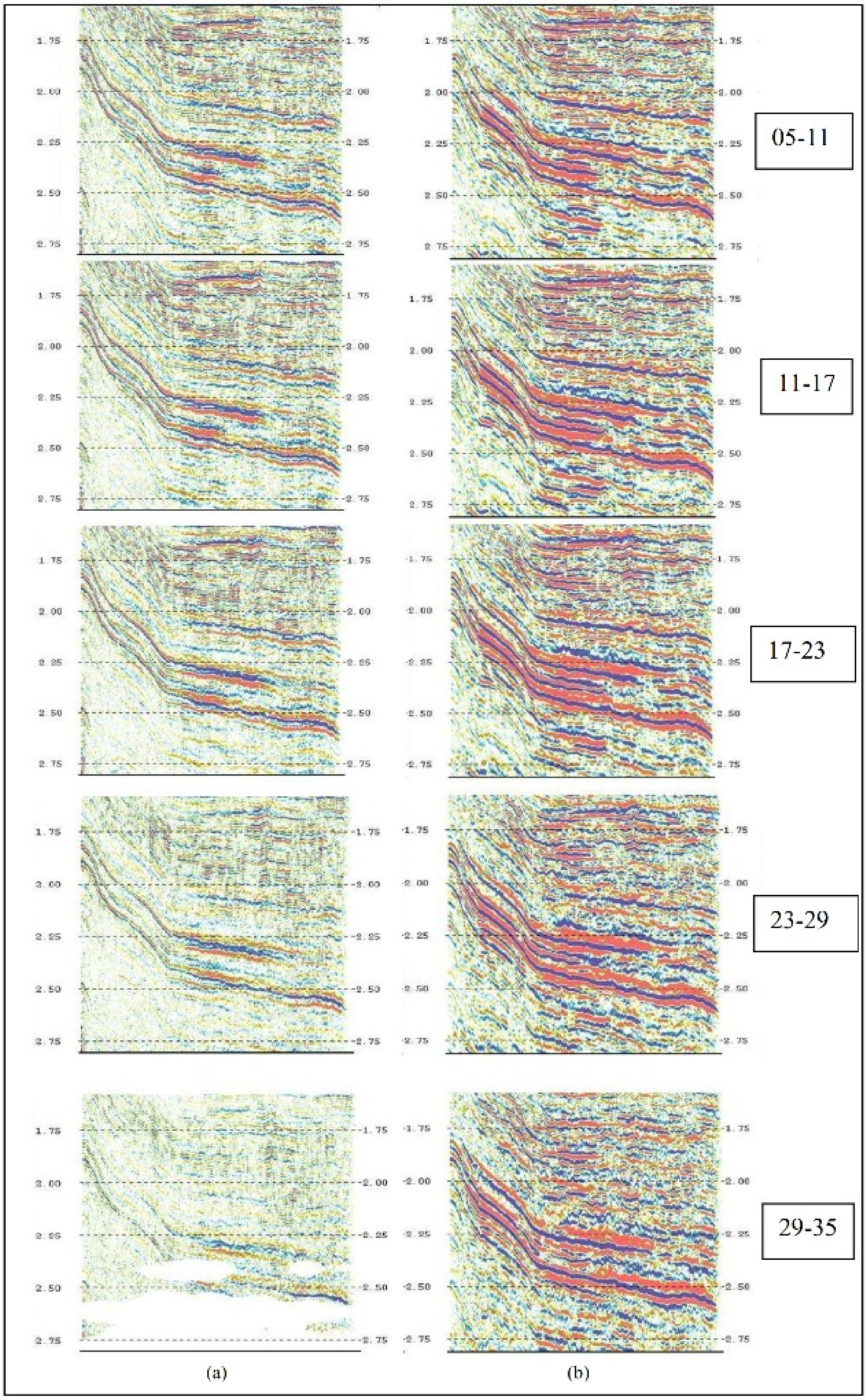

Figure 8a: Angle Stack - a) vintage data and, b) re-processed data.