Model-based Water-layer Demultiple (MWD) for shallow water: from streamer to OBS
Hongzheng Jin and Ping Wang, CGGVeritas

Summary

3D Model-based Water-layer Demultiple (MWD) is a recently-developed technique for attenuating water-layer-related multiples for marine streamer data. In particular, MWD targets the challenge of multiple attenuation in shallow water where Surface-Related Multiple Elimination (SRME) struggles. MWD works well in shallow water data by avoiding the crosstalk influence and preserving the spectrum of the input data. In this paper, we demonstrate that the application of MWD is not limited to streamer data, but can also be extended to Ocean Bottom Seismic (OBS) data. For OBS data, MWD can remove water-layer-related multiples and receiver ghost in one step. Therefore it removes the necessity of PZ summation for receiver ghost attenuation.

Introduction

Model-based Water-layer Demultiple (MWD) was recently developed to address the challenge of multiple attenuation in shallow water (Wang et al., 2011). Jin et al. (2012) demonstrated that MWD effectively attenuates water-layer-related multiples on streamer data and outperforms SRME or gapped deconvolution in shallow water.

In places where the presence of obstacles or a shallow water layer prevents the seismic acquisition by towed streamers, Ocean Bottom Seismic (Cable/Nodes) (OBS, or OBC/OBN) is an alternative acquisition method. OBS is also used to provide better illumination due to its full-azimuth coverage, which is especially important for better imaging of complex subsurface structures.

In multi-component OBS surveys, the pressure and the particle velocities are measured by hydrophones and geophones, respectively. A general OBS processing flow usually includes: 1) geophone calibration; 2) PZ summation; and 3) multiple removal (Soubaras, 1996). While PZ summation removes the receiver-side ghost, multiples are attenuated by methods such as predictive deconvolution or up-down deconvolution (Wang et al., 2010). The calibration process is known to be difficult in general and very challenging for shallow water in particular (Wang and Grion, 2008). Also, both predictive deconvolution and up-down deconvolution methods are based on 1D geology assumptions.

SRME (Verschuur et al., 1992; Lin et al., 2005) has been widely used for surface-related multiple attenuation for marine towed streamer data. However, its extension to OBS data is not straightforward. While SRME, being a surface-consistent technique, requires that the source and receivers be located near the surface, OBS data clearly violates this assumption. An alternative solution is to combine OBS data with surface streamer data (Verschuur and Neumann, 1999). Unfortunately, surface data is not always available. In addition, SRME has difficulties in shallow water (Jin et al., 2012), which further limits its usage. Pica et al. (2006) used a wavefield modeling SRME approach for OBS multiple attenuation, but this method requires a high-quality migration section to generate a reflectivity model.

In this paper, we show that the MWD algorithm can be applied to both streamer and OBS data to attenuate water-layer-related multiples. We first explain the MWD methodology and then apply the MWD algorithm on synthetic and real data examples.

Methodology

Wang et al. (2011) developed 3D MWD for streamer data in 2011. MWD first models the Green’s function of the water layer, G, based on a user-supplied water-layer model. A model for the water-layer-related multiples, M, can then be obtained by convolving the recorded data, D, with the modeled Green’s function, G:

\[ M = D \otimes G \]  

The water-layer-related multiples are then attenuated by adaptive subtraction of the model from the input data.

MWD can readily be extended to OBS multiple...
MWD: from streamer to OBS

attenuation, as illustrated in Figure 1. In Figure 1, black solid lines connecting the source (S) and receiver (R) represent the recorded data (SR). Blue dashed-lines (SS' or RR') represent the modeled Green’s function of the water layer. Figure 1 illustrates that the water-layer-related multiples, both source-side (a, c) and receiver-side (b, d), can be predicted by a cross-convolution of the recorded data (SR) with the Green’s function (SS', RR') of the water layer for either streamer data (a, b) or OBS data (c, d). Note that from streamer to OBS, the only difference of MWD methodology lies in the modeling of the water layer Green’s function for the receiver side (RR'). Thus, extension of the MWD method from streamer to OBS is straightforward, and unlike SRME, does not require streamer data. An additional benefit of the MWD workflow is that it also serves to remove the receiver-side ghost. This is because the receiver-side ghost has the same kinematics as the receiver-side multiple for OBS data and is subtracted simultaneously.

Examples

In order to better explain the methodology of MWD multiple attenuation from streamer to OBS, we use a simple 2-reflector model to generate 2D synthetic datasets. For simplicity, we use a constant velocity of 1500 m/s. Figure 2 is the density model with a flat water bottom and one dipping reflector. The deep reflector has a large dipping angle of about 18 degrees in order to introduce significant separation between source-side and receiver-side multiples.

First, three synthetic datasets are generated, each with the same acquisition geometry except for different receiver depths to mimic streamer, OBS survey and a transition case in between.

![Figure 2: 2-reflector density model used in 2D synthetic test. Three datasets are generated using this density model and a constant velocity with the same shot/receiver locations except for different receiver depths to mimic streamer, OBS survey and a transition case in between.](image)

Note that due to the shallow source depth of 5m for all three cases, source-side ghosts do not need to be considered as separate wavelets. In case (b) with a receiver depth of 375m, those previously identified events separate from each other. For the surface streamer case (a), receiver ghosts are very close to their corresponding primary events (e.g., P_1 and P_{1G}, M_1, etc.) due to short ghost delay caused by a shallow receiver depth. For the OBS case (c), receivers are located at the sea floor; thus receiver ghosts overlay with receiver-side multiples (e.g., M_{1R}, M_{1RG}, M_{2RG}). Figure 3d illustrates a few events with ray-path diagrams according to case (b).

We use MWD to predict multiples for streamer and OBS cases on the synthetic datasets shown in Figure 3. Figure 4a and 4c show the same gathers as Figure 3a and 3c. Their corresponding MWD multiple models are shown in Figure 4b and 4d, respectively. The green arrows indicate primary

![Figure 3: Three synthetic shot gathers generated from model in Figure 2 with different receiver depths: (a) 5m (streamer), (b) 375m, (c) 750m (OBS). (d) Ray-path diagram explaining different events.](image)
events. We can see that all previously identified multiples were successfully predicted by MWD. In particular, receiver ghost in OBS data has the same kinematics as receiver-side multiple and can be attenuated simultaneously in the adaptive subtraction step. In other words, a PZ summation step to remove receiver ghost is not a prerequisite in order for MWD to be applied to OBS data.

Next we show the application of MWD for the steamer case with a real data example. The data was acquired in offshore Nova Scotia, Canada. Figures 5a, 5b and 5c show the input data, after 3D SRME and after 3D MWD multiple attenuation, respectively. The water depth is about 100-190 m for the section shown in Figure 5. Peg-leg multiples in the deep section, as indicated by green ovals, are difficult to attenuate with 3D SRME. 3D MWD (Figure 5c), however, effectively removes water-layer-related multiples from top to bottom, which is attributed to MWD avoiding cross-talk issues (Wang et al., 2011; Jin et al., 2012).

The last example is a synthetic dataset for the OBS case. The density and velocity models are shown in Figure 6. This model has a thin water layer ranging from 44-140 m with high dip features in the water bottom, a complex sub-surface structure with anticline folding and a large fault. This results in a very challenging dataset for multiple attenuation. Figure 7 shows the reverse-time migration (RTM) images of (a) the synthetic dataset with multiple, (b) the MWD multiple model and (c) after MWD multiple attenuation. The MWD model (Figure 7b) closely matches the multiples in the input dataset (Figure 7a). The complex sub-surface structures, once plagued by heavy contamination from multiples (Figure 7a), are now clearly imaged after attenuation of water-layer-related multiples and receiver ghost by MWD (Figure 7c).
MWD: from streamer to OBS

Discussions and Conclusions

In shallow water, water-layer-related multiples are often dominant in the data with strong amplitudes. SRME struggles in shallow water, due to strong cross-talk between multiples, lack of near offset data, contamination in water-bottom primary reflection, etc. In addition, applying SRME to OBS data requires surface data. In this paper, with synthetic and real data examples, we have demonstrated that MWD works well in removing water-layer-related multiples for both streamer and OBS data. The effectiveness of MWD on multiple attenuation in shallow water is attributed to the fact that MWD avoids the cross-talk influence and preserves the spectrum of the input data. In particular, the advantages of MWD for OBS include: 1) MWD does not require surface data while SRME does. 2) MWD works on general 3D cases while gapped deconvolution is best suited for 1D geology. 3) MWD attenuates water-layer-related multiples as well as receiver ghost in one step. Therefore, MWD can be applied on the data with or without PZ summation. 4) MWD works well in shallow water situations where both PZ summation and SRME encounter difficulties.

In order for MWD to predict both the source-side and receiver-side multiples, the wavefield needs to be densely recorded or interpolated in both the receiver and shot grids. In the case of sparse receiver distribution, however, MWD may have difficulty in predicting receiver-side multiples. In such cases, MWD can still be applied to predict and remove source-side multiples if the shot grid is reasonably dense, since source-side multiple prediction is carried out in individual common receiver gathers.

While MWD only attacks water-layer-related multiples, which are the dominant multiples in shallow water, it can be followed by SRME to remove other types of surface-related multiples. MWD ensures that subsequent SRME has significantly less cross-talk influence by removing the bulk of water-layer-related multiples beforehand.

Acknowledgements

The authors thank CGGVeritas for permission to publish this work. Special acknowledgements go to Yan Huang and Tony Huang for support and suggestions to this work.
MWD: from streamer to OBS

REFERENCES


