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Surface Related Multiple Elimination: A Case study from East Coast India

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Summary

Multiples suppression is an eternal topic in marine seismic data processing. Multiples are main noise in marine data, usually includes strong regular multiples related to surface and diffracted multiples which are generated by serious variation of water bottom. Over the decades several demultiple techniques have come up in the industry. Each technique has its own strengths and limitations. No single technique can ultimately attenuate all multiples. In the recent years, Surface Related Multiple Elimination (SRME) technique has gained importance in the industry because it is fully data driven, which means no auxiliary prior information needs to be supplied, such as, velocity and geometry of the causative horizon. This case study an overview of surface Related Elimination Technique (SRME) is presented along with a case study for deepwater data.

Keywords: SRME

Introduction

De-multiple methods can be classified into data-driven method and model-driven method based on the domain of separating primaries and multiples. Model-driven methods transform seismic data into another domain in which primaries and multiples are easier to be separated from each other. For example after Radon transform, multiples are usually focused around higher moveout parameters in tau-p domain compared with primaries at the same time level. A successful separation of multiples with Radon transform is dependent on the velocity difference between primaries and multiples. If the difference is too small, Radon-based methods will have difficulty in separating primaries and multiples. On the other hand, a data-driven method like SRME (Berkhout and Verschuur, 1997) does not need subsurface information to remove multiples. SRME is totally data-driven, and it can predict all surface-related multiples. Once multiples are predicted, matching filters are applied to match multiples in the original data, and then the filtered multiples are subtracted from the input. Therefore SRME has an advantage that there is no need to separate primaries and multiples in another domain.

SRME: Basic theory

Figure.1 shows the basic idea behind SRME. A surface-related multiple is recorded at receiver Xr due to a shot at location Xs. The event is a surface-related multiple because it undergoes at least one downward reflection at the sur- face, in this case at A, during its propagation. One readily sees that this surface-related multiple event can be considered as the composition of two events: one recorded at A due to a shot at Xs and a second recorded at Xr due to a shot at A. Both these events XsA and AXr are recorded independently when the ship was moving from left to right. Now, if the position A where downward reflection of the surface multiple has taken place is known, the multiple can be predicted by convolving the individual events which were recorded already. But here the challenge before the algorithm is to find the position A. For that the algorithm performs convolutions of individual events for all possible locations between Xs and Xr. As shown in the figure.2, for a given source receiver pair, all possible combinations of ray paths are made and the total travel time of every event is calculated. According to Fermat's principle, the multiple for that source receiver pair is the event which has the least travel time. Thus the basic operation in SRME is a spatio-temporal convolution of the data with itself. This gives the correct kinematics of the surface related multiples. Estimated multiple model is adaptively subtracted from the input data.

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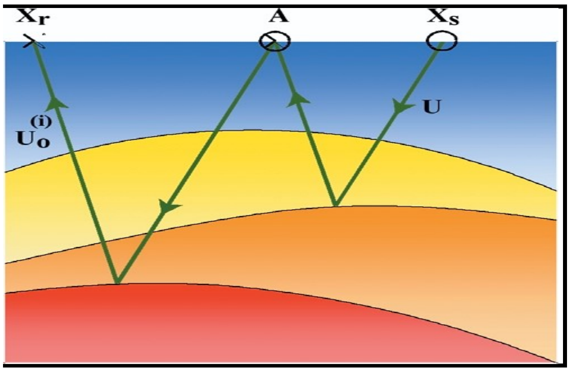

Figure 1: Theory of surface-related multiples (following Berkhout and Verschuur, 1997).

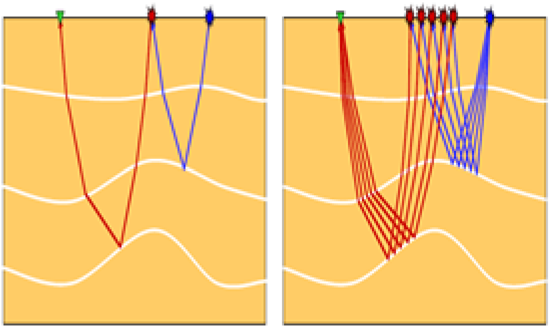

Fig.2 Make all possible primary combinations to model a first order surface multiple for a given source receiver pair.
(From D.J. Verschuur, 2002).

Strengths of SRME

SRME is fully data driven, which means no auxiliary prior information needs to be supplied, such as, velocity and horizon. SRME does not require any subsurface information, nor does it make any assumptions about seismic events such as hyperbolicity or moveout separation between primaries and multiples. As a result, SRME can handle arbitrarily complex multiples (including, in particular, diffracted multiples). In fact, SRME appears to be the only effective approach for attenuating diffracted multiples. SRME performs well at near offsets where the moveout difference is very little.

Data Preconditioning for SRME

For a successful application of SRME, Signal to noise ratio of the input data (S/N ratio) needs to be enhanced. Pre-processing may include direct arrival attenuation, field and residual statics, de-spiking, F-X coherent noise suppression and random noise attenuation. Near offset gap should be filled with traces according to the nominal geometry and any missing traces in the cable length should also be filled prior to the application of SRME. This will enable the algorithm to predict the multiple trace containing all free surface multiples that belong to a source receiver pair. Nominal Geometry should be well defined in the trace header of the seismic data. During denoising stage, one should take sufficient care to preserve the amplitudes and phase of recorded primaries and multiples. Applicability of SRME for land data

The performance of SRME depends on spatial sampling and signal-to-noise ratio of the input data and robust matching filtering of the predicted multiple models. Unlike in marine case, application of SRME for land data is not a straight away procedure The method has been mainly effective in marine processing in the past due to the reason that marine data is usually better sampled and has higher signal-to-noise ratio than land data. In addition, the water layer provides consistent surface condition to generate multiples. In contrast land data is often poorly sampled in space. In particular neighboring shot lines and receiver lines can be a few hundred meters away from each other. Moreover land data is often contaminated with large amount of random noise and coherent noise (ground roll etc), which can pose a challenge to multiple model prediction. Finally statics caused by uneven surface and non-uniform shallow layers can make it difficult to predict the travel times of multiples. Since SRME predicts the travel time of the multiple using the input data, in the presence of strong velocity variations in the near surface, multiple model predictions might be inaccurate. In addition to this, poor signal to noise ratio and irregular source receiver sampling in the data may limit the effectiveness of the methodology. For optimal results in land data one should address these issues adequately during the preprocessing stage.

Limitations of SRME

Like any other demultiple technique, SRME has got its own limitations. However majority of the limitations discussed here are applicable to 2D SRME. In the near offset range SRME works better compared to the far offset range.

Finite aperture: Modeling the multiples on the farthest may require non-recorded data beyond the cable, particularly in the case of data with complex structures.

Directivity effects: Both source and receivers (even if de-ghosted) have anisotropic pattern. This results in incidence angle dependent wavelets, which can significantly reduce the efficiency of the adaptive subtraction process on the far offset range (where events with different incidence angles are superposed).

Spatial aliasing: In deep water, the tails of the hyperbolae are often aliased on the far offset range, especially in modern acquisition geometries (e.g. flip-flop shooting), which lead to under-sampled CMP gathers. The spatial aliasing alter the modeling step.

Cable feathering: In the far offset range, the receivers may deviate significantly from the acquisition plane, hence violating one of the basic assumptions of the method.

Case Study

The present case study deals with the data from the East coast of India. In this area, water depth is ranging from 3065 m to 3180 m. Objective of the processing is to bring out the strati-structural features in Cretaceous and Tertiary sequences and map the same in order to identify leads and prospects. Two way time zone of Interest is 4.5 s - 10 s.

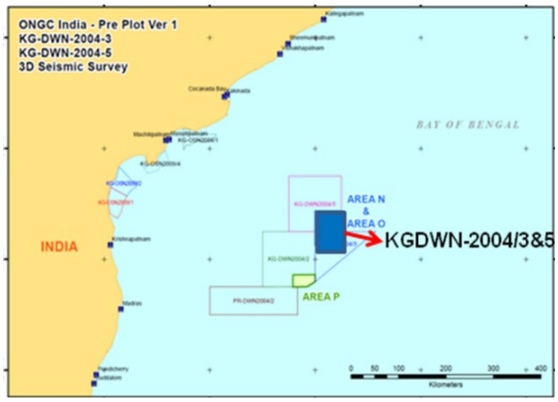

Fig.3 Location map

Ten streamers were deployed during the acquisition of the data. Each streamer is having 648 active channels. Record length and sampling interval are 12 s and 2 ms respectively. 2D SRME has been applied on individual sub-surface lines successfully on this deep water survey with satisfactory results. The results shown here are from the data of fifth streamer. However, application of 2D SRME on the data from farthest streamers may not be as good as these results because cable feathering limits the applicability of SRME.

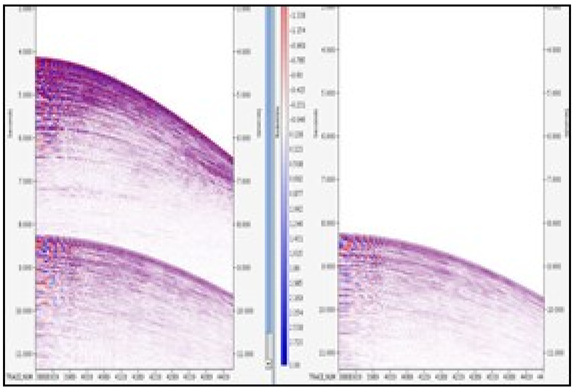
Fig.4 Input shot gather and estimated multiple model

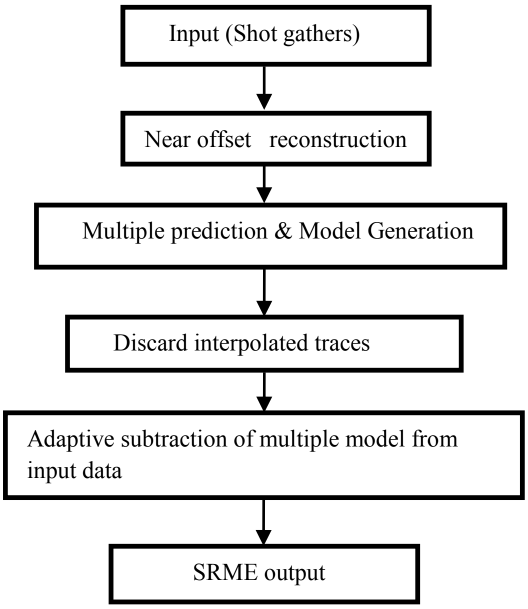

Fig.5 Workflow of SRME

In Fig.3, input shot gather and the predicted multiple model are shown. In Fig.4, Shot gather before and after SRME application is shown. The stacks before and after SRME are displayed in Fig.5 and Fig.6. It was observed that the long period water bottom multiple has been attenuated successfully.Fig.7 and Fig.8 are the zoomed views of the stack before and after application of SRME. In Fig.8, after application of SRME, the water bottom multiple was removed and the genuine dipping primary events have been preserved.

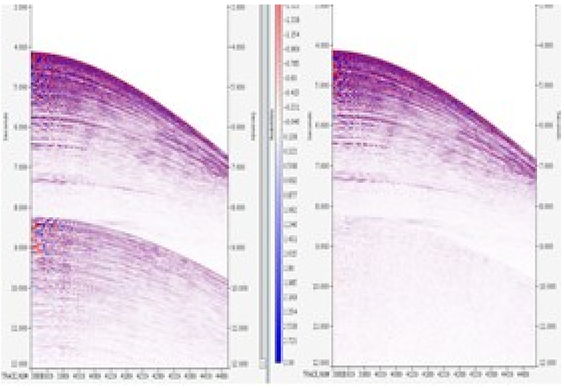

Fig.6 shot gather before and after 2D SRME

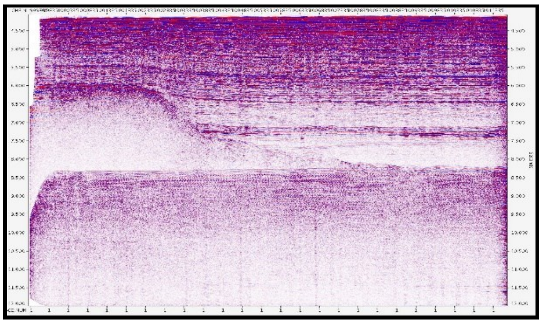

Fig.7 Stack before 2D SRME

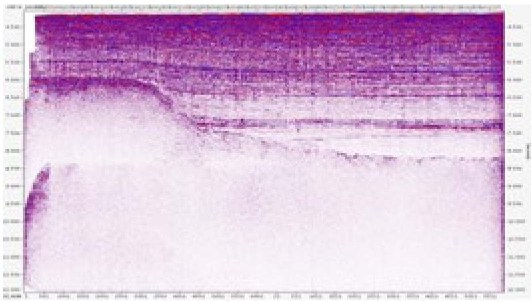

Fig.8 Stack after 2D SRME

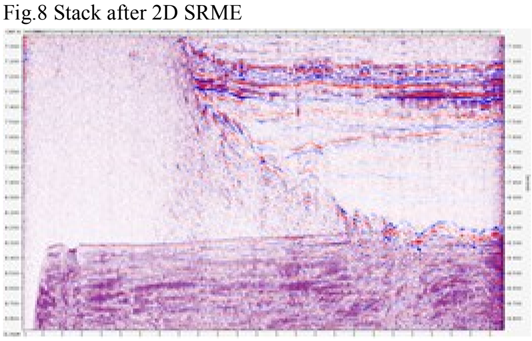

Fig.9 Stack before SRME (zoomed view)

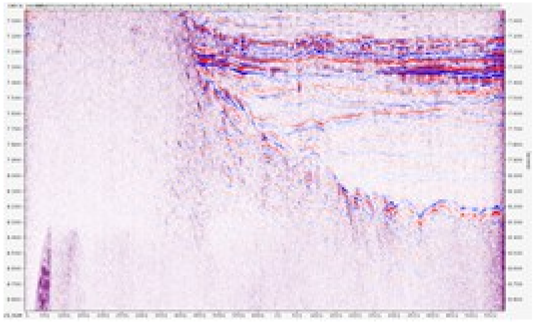

Fig.10 Stack after SRME (zoomed view)

Conclusions

In this work, apart from the theoretical over view of SRME, a deep water data example was discussed in which 2D SRME application has given satisfactory results. Long period water bottom multiples were removed successfully.

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