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Practical implementation of SRME for land multiple attenuation

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Summary

We present a practical implementation of Surface Related Multiple Elimination (SRME) algorithm for land processing. The processing flow can be generalized as four steps: preprocessing, data preconditioning, multiple prediction and least-squares subtraction. The preprocessing step follows conventional land processing flow except that data is corrected to surface instead of flat datum. Based on the characteristics of land data, the data is preconditioned by applying aggressive noise reduction and then regularized to stabilize multiple prediction. In the final step, least-squares subtraction in higher dimensions is applied to remove multiples and preserve primaries. Synthetic data example demonstrates that SRME algorithm can be used to process land data as well when noticeable surface related multiples are present.

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 compressed and 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 (Hampson, 1987; Sacchi and Ulrych, 1995). 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 and only 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. Another advantage of SRME is that it can handle structured data, which is often difficult to fit with parabolic or hyperbolic curvature as needed in Radon based methods.

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 model. The method has been mainly effective in marine processing in the past due to the reason that marine data is usually better sampled and having 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 are often contaminated with large amount of noise including 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. In this paper, we show that SRME can be effectively applied to 3D land data with proper data preconditioning and robust least-squares subtraction methods, similar to the strategies adopted by Kelamis and Verschuur (Kelmamis and Verschuur, 2000).

Method

SRME is derived based on Huygens principle that every point to which wave reaches becomes a new source of spherical wave, and the sum of new waves determines the waveform at later times. In geophysical background for multiple simulation, the theory can be understood as convolving seismic traces corresponding to two relaying ray paths followed by summing the contributions from all possible relaying ray paths. Figure 1 illustrates the ray path of one contribution related to one seismic trace.

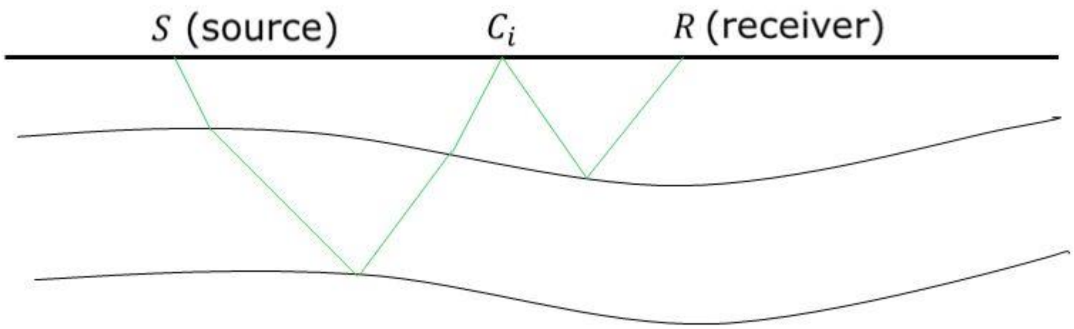

Figure 1: Theory of surface-related multiples (following Berkhout and Verschuur, 1997). The multiples for one pair of source and receiver can be calculated by summing contributions related to all possible relaying ray paths, and each contribution is equal to the convolution of two traces corresponding to two ray paths. The figure shows that one multiple contribution between S and R can be calculated by convolving the trace from S to C and the trace from C to R.

Mathematically the multiple model for the trace from source to receiver as shown in Figure 1 can be expressed as:

$$m = \sum_{i=1}^{n} d(SC_i) * d(C_i R) \qquad (1)$$

where n is the number of contribution points.

The input for SRME is pre-stack and un-migrated data pre-processed by conventional land processing methods. Coherent noise like ground rolls and refractions should be removed. Random noise should be reduced as much as possible. Aggressive noise-reduction may be used since we desire SRME to predict a clean multiple model, which helps to stabilize the matching filtering as described later. Furthermore, elevation statics should not be applied otherwise the multiples will not be surface-consistent. Based on our real data tests, data corrected to floating datum is often suitable for the SRME algorithm.

Contribution points in Figure 1 should be dense enough to avoid spatial aliasing in contribution traces, otherwise the predicted model may lose valuable details (Lin et al, 2005). In the real world, it is not feasible to shoot all required data for multiple prediction. Our strategy is to interpolate the desired trace using data within local aperture. In the next section, we show that this approach has advantage over on-the-fly interpolation using the nearest trace as often used in marine processing.

The predicted multiple model using Equation 1 usually does not have the same wavelet and amplitude level as that of the input data. Matching filtering should be applied to the model to match the multiples in the input, and then the matching model is subtracted from the input. A two-step approach is used to achieve optimal subtraction result. First a CMP-scope global matching filtering is applied to the model to correct phase mismatch and travel-time errors of the model. Second, adaptive matching filters are designed for data within smaller windows gradually changing in four dimensions (inline, crossline, offset and time). The first step is more stable since all input within local aperture are used to compute one filter, which avoids over-fitting the input. It also naturally removes a CMP static so that in the second step a shorter filter can be applied to the output of the first step to effectively match the multiples. The second step mainly matches the amplitude of the input, but it also adaptively removes residual phase errors in the model.

Figure 2 generalizes the processing flow of land SRME.

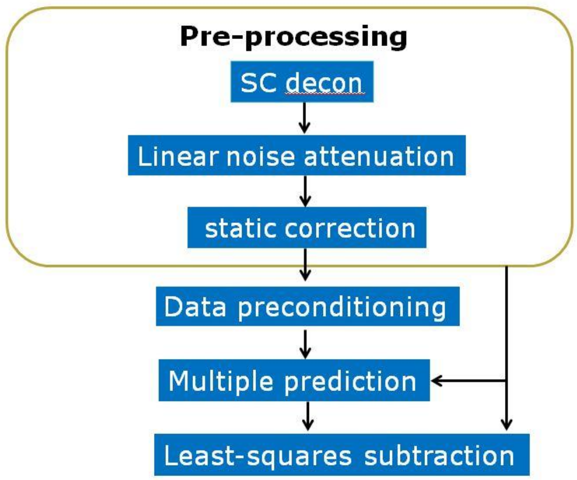

Figure 2 Processing flow of land SRME. The data is first pre-processed following the conventional process flow except that data is not corrected to the final datum. Then the data is preconditioned with aggressive noise attenuation and regularized into regular azimuth and offset bins. Next, multiple model is predicted by equation 1 using the regularized data. Finally the model is filtered to match the input and then subtracted.

Synthetic Example

To show the benefits of the land SRME, we generated some synthetic data for a flat earth model with close velocities in the shallow zone, based on an orthogonal geometry of a real land data survey. It is expected that parabolic Radon transform will have difficulty in separating primary and multiple events since they only have small moveout difference at far offsets.

Figure 3 shows a gather after NMO correction and the result of parabolic Radon transform. It can be seen that it is difficult to separate multiples from primaries based on moveout difference as shown in Figure 3b. The subtraction result (Figure 3c) is not satisfactory: primaries are damaged, and a lot of multiples are still present. On the other hand, SRME method preserves primaries while successfully removing most of the multiples (see Figure 4).

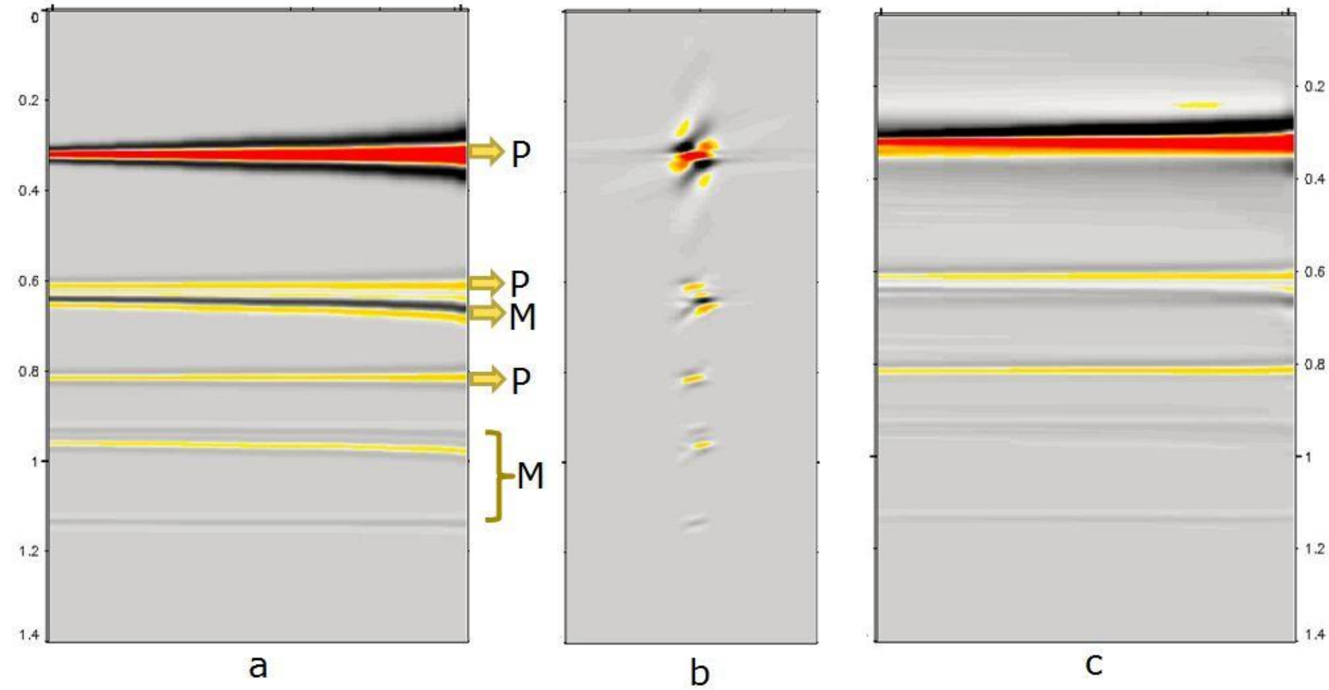

Figure 3 Input gather and the corresponding Radon model. (a) Input gather. P denotes primary, and M denotes multiples. (b) Radon model (computed using high-resolution Radon proposed by Sacchi and Ulrych, 1997). (c) Gather after removing multiples

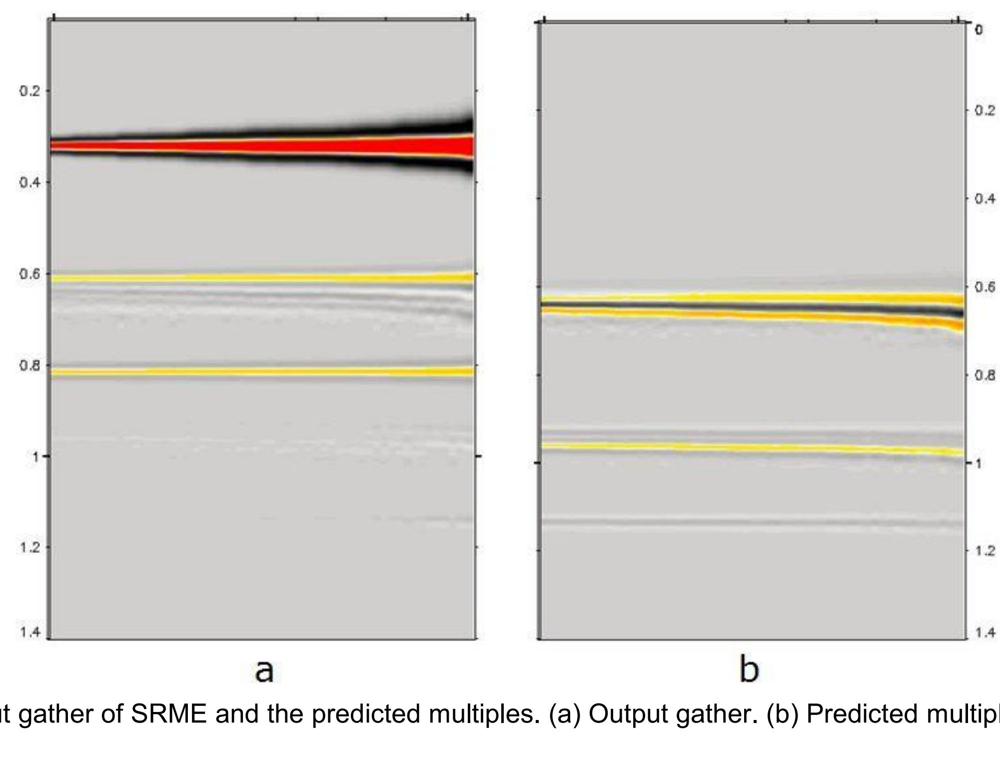

Figure 4 Output gather of SRME and the predicted multiples. (a) Output gather. (b) Predicted multiples.

To show the importance of data preconditioning, a significant amount of random noise was added to the input. Figure 5 compares the models computed with input from two kinds of interpolation methods. The conventional method constructs each required trace using only one nearest trace. Although the method predicts a multiple model with reasonable travel times, the result is contaminated with a lot of noise, which will hamper the procedure of least-squares subtraction. On the other hand, our new method provides a much cleaner result using data interpolated frommulti-channel input.

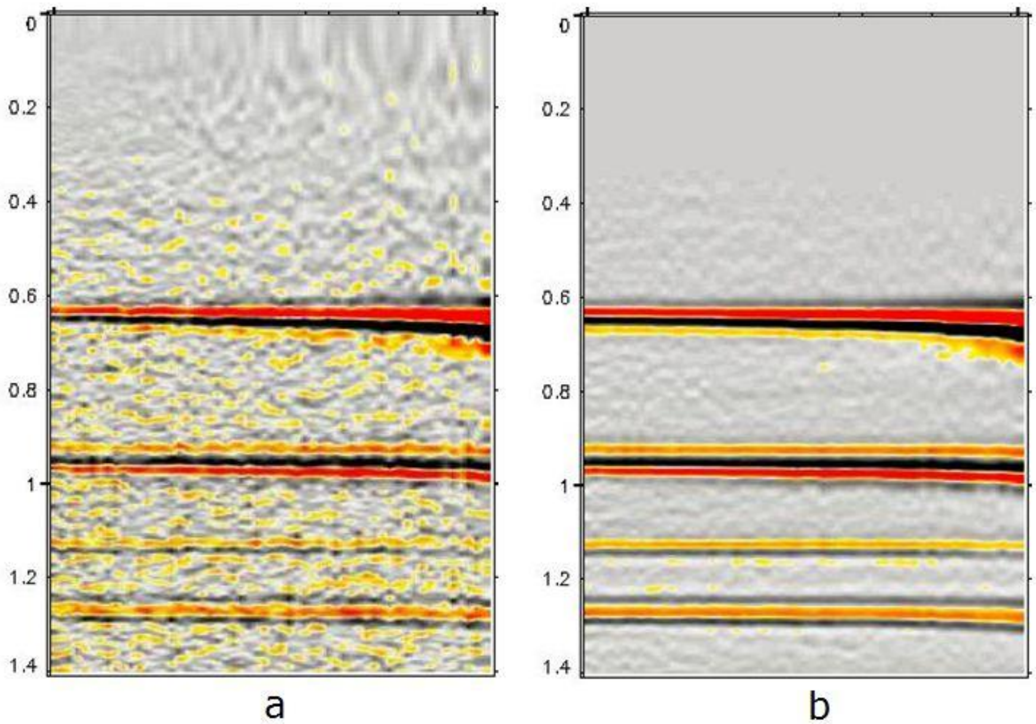

Figure 5 Comparison of models computed using input from different interpolation methods. (a) Model computed using input from the nearest trace to each desired trace. (b) Model computed using interpolated data from multi-channel input. Note: no matching filters are applied to the models.

Conclusions

We have proposed a practical implementation of SRME for land data. A synthetic test demonstrates the robustness of the algorithm in the case where primaries and multiples have close velocities.

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References

Berkhout, A. J. and D. J. Verschuur, 1997, Estimation of multiple scattering by iterative inversion, Part I: theoretical consideration: Geophysics, **62**, 1586-1595.

Hampson, D., 1987, The discrete radon transform: A new tool for image enhancement and noise: 57th Annual International Meeting, SEG, Expanded Abstracts, 141-143.

Kelamis, P.G., and D.J Verschuur, 2000, Surface-related multiple elimination on land seismic data-Strategies via case studies, Geophysics, 65, no 3. P719-734.

Lin, D., J. Young, W. Lin, M. Griffiths and M. Hartmann, 2005, 3DSRME prediction and subtraction practice for better imaging: 75th Annual International Meeting, SEG, Expanded Abstracts, 2088-2091.

Sacchi, M. D. and T. J. Ulrych, 1995, High resolution velocity gathers and offset space reconstruction: Geophysics, **60**, 1169-1177.