Shallow water surface related multiple elimination: a case study from North Sea

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Summary

We present a simple method for eliminating surface-related multiples in shallow water environments. After a brief technical discussion, the procedure is demonstrated on an OBC survey imaging a producing field in the central North Sea. The North Sea's shallow bathymetry and well-known strong water bottom reflectivity make for both a challenging and ideal survey for testing removal of shallow-water layer borne multiples. We demonstrate with CDP stacks and autocorrelations that surface-related multiples are accurately estimated and effectively removed from the dataset.

Introduction

The shortcomings of the industry standard data-driven surface related multiple elimination (SRME) in shallow water environments are well documented. However the method is not straightforward to extend to the OBC case because SRME requires the shot and receiver to be near the surface as a surface-consistent technique. As an alternative approach, tau-*p* decon has been widely used in shallow water OBC data to remove water-bottom related multiple reflections based on the multiples' periodicity in the tau-*p* space. This is however potentially harmful as primaries with similar periodicity are likely to be attenuated as well.

In this paper we discuss a workflow for successful attenuation of shallow-water multiples for a time lapse OBC-4C dataset using a wavefield extrapolation method. Our study shows that application of this wavefield demultiple methodology can act as a complementary tool, which when applied after a regular tau-*p* deconvolution can successfully attenuate the strong remnant water-bottom related multiples. In the following sections, we first briefly review the methodology of multiple model estimation using a wavefield extrapolation approach and then present the results of our study on a shallow water OBC dataset.

Method

The shallow water demultiple method we propose is model driven and uses the bathymetry of the water bottom to estimate a model of the water-layer multiples. After the multiples are estimated, successful multiple elimination relies on subsequent adaptive subtraction of the model from the input. The engine behind the method is a one-way wavefield propagation and extrapolation in the water column.

Starting with the input upgoing wavefield represented in Figure 1, the wavefield is propagated from the surface downwards to the water bottom. Upon reaching the water bottom, the wavefield is convolved with the sea-floor reflectivity represented by a high peak frequency wavelet. Then an empty wavefield is extrapolated upwards to the surface, collecting the downward-propagated wavefield. The resulting application to the input data is the round-trip traversal through the water column. Therefore, primaries become first order multiples, first order multiples become second order multiples and so forth.

The main strengths and highlights of the method are listed below. The approach is

- Well balanced multiple amplitudes due to lack of convolution used.
- Spectrum-preservation from the use of a high peak frequency wavelet as a reflectivity model.
- Compatible with standard SRME workflows that require adaptive subtraction.

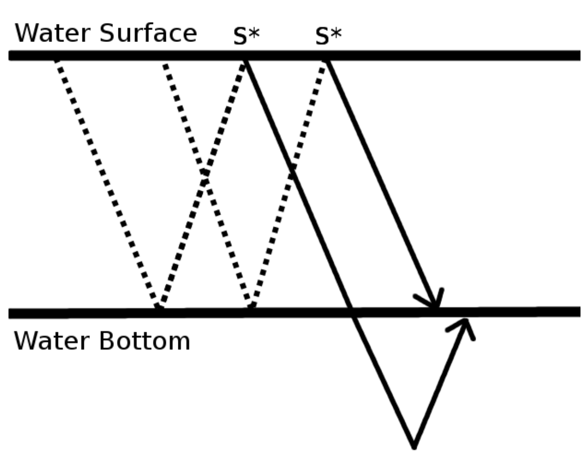

Figure 1: Shot to receiver ray paths shown by solid lines. The propagated wavefield is shown by dotted lines and models the water layer multiple paths.

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Real Data Example

We apply the shallow-water demultiple method to a time-lapse OBC 4C survey over a producing field in central North Sea. The CDP stacks shown in Figure 2 are after PZ summation showing the shallow (above) and deeper section (below). Even with receiver side multiple attenuation achieved by PZ summation there are still strong multiples left in the data.

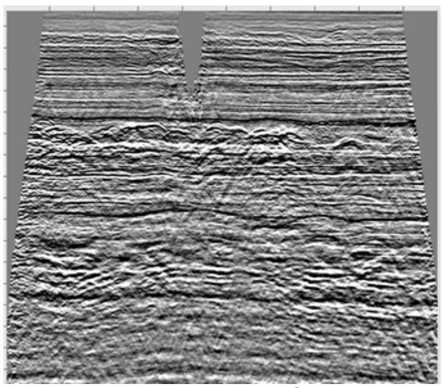

Figure 2a. PZ Sum CDP Stack of shallow section.

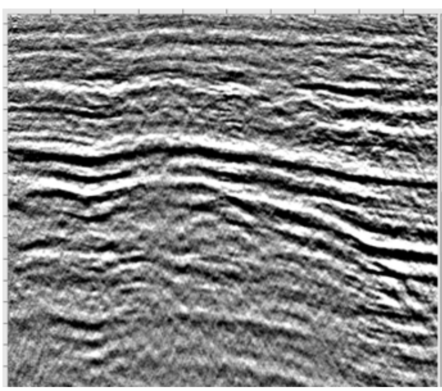

Figure 2b. PZ Sum CDP Stack of deeper section.

To predict these remnant multiples, the PZ Sum receiver gathers were fed into the shallow-water demultiple program. Using a nominal constant water velocity, bathymetry information extracted from the known receiver depths, and a 75 Hz peak-frequency wavelet to model the seafloor's reflectivity, we produced the predicted multiple result and adaptive subtraction results shown in Figures 3b and 3c, respectively.

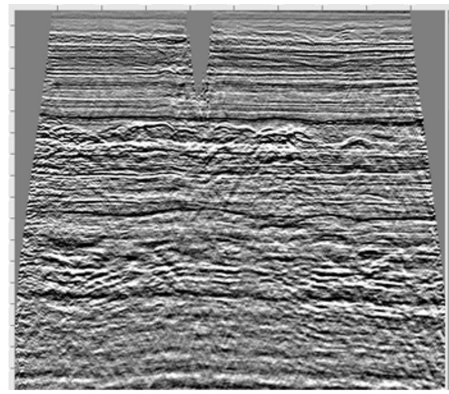

Figure 3a. PZ Sum CDP Stack (Input)

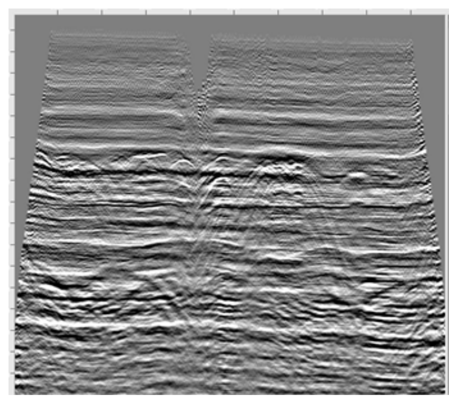

Figure 3b. Predicted Multiple Model from Shallow Water Wavefield Extrapolation Method

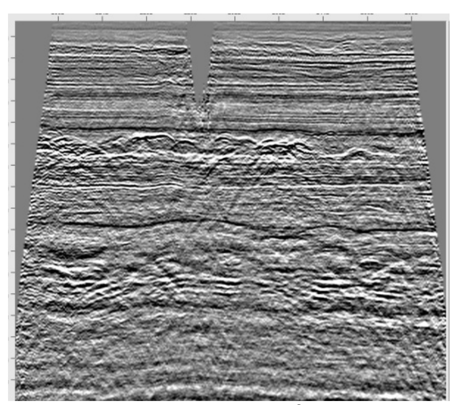

Figure 3c. Adaptive subtraction of predicted multiple model (3b) from the input (3a).

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Figure 4 compares the adaptive subtraction result to the predicted multiple model.

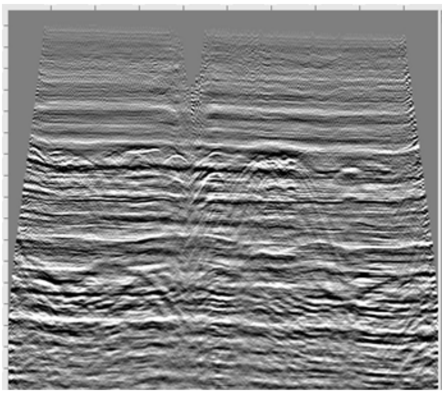

Figure 4a. Predicted Multiple Model

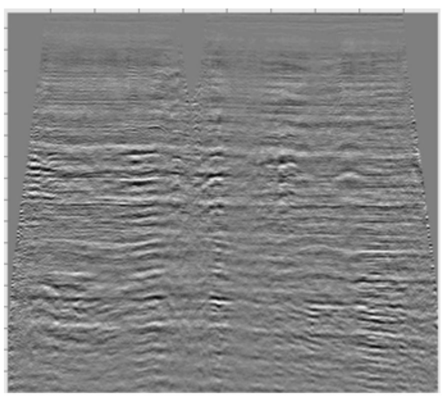

Figure 4b. Difference between input and adaptive subtraction.

The comparison in Figure 4 demonstrates the importance of adaptive subtraction in the overall success of the shallow-water demultiple. In this case we used essentially similar adaptive subtraction parameters as are used in our production-standard SRME workflows. Especially notable are the bands of ringing in the central and right hand side of the section that have been modeled and effectively subtracted from the input, lending to greater ease in interpretability.

Figure 5 now showcases the same set of displays in Figure 3 for the deeper section.

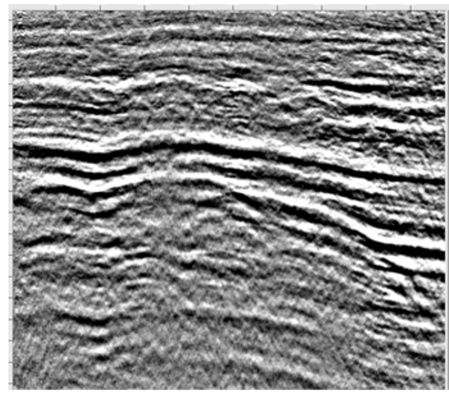

Figure 5a. PZ Sum CDP Stack (Input)

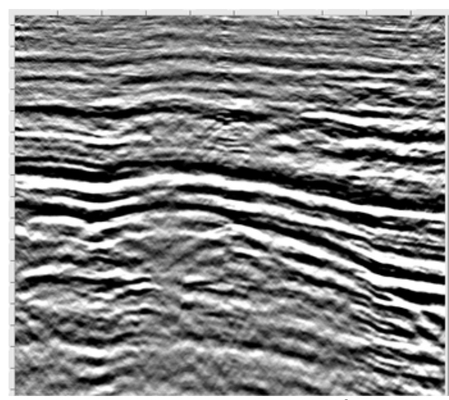

Figure 5b. Predicted Multiple Model from Shallow Water Wavefield Extrapolation Method

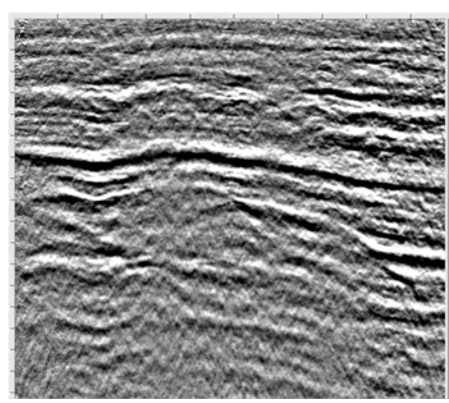

Figure 5c. Adaptive subtraction of predicted multiple model (5b) from the input (5a)

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Figure 6 compares the adaptive subtraction result to the predicted multiple model in the deeper section.

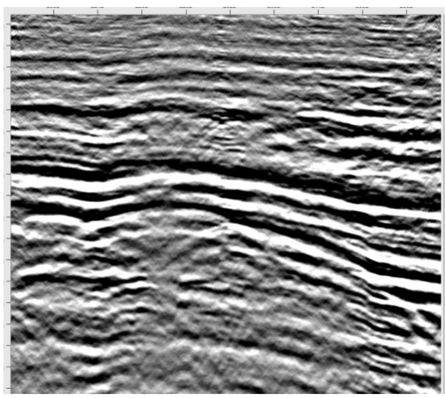

Figure 6a. Predicted Multiple Model

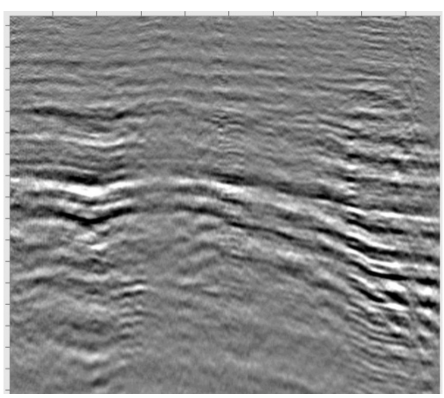

Figure 6b. Difference between input and adaptive subtraction.

As was seen in the shallow section, the prominent short-period bands of multiples on the left and right-hand side have been estimated and removed from the data.

Finally, we analyze autocorrelations on the stack section before and after shallow-water demultiple, which are shown in Figure 7. The analysis window contained data from both the shallow and deep sections. The autocorrelation shows reduced ringing after demultiple.

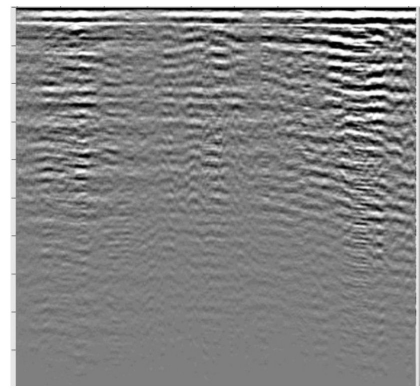

Figure 7a. Autocorrelation before shallow water de-multiple

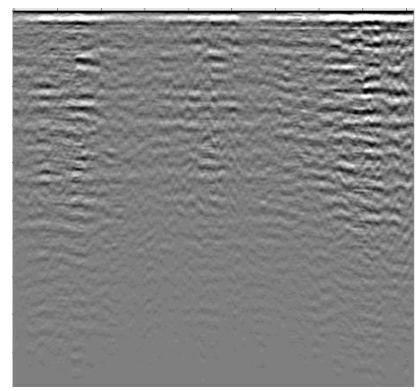

Figure 7b. Autocorrelation after shallow water-demultiple

Conclusion

We have demonstrated a method for eliminating surface-related multiples on a shallow-water OBC survey. Multiples are estimated via wavefield propagation of the input through the water column and are subsequently removed using adaptive subtraction. The CDP stack data and autocorrelations show that the method successfully and effectively removes surface related multiples.

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EDITED REFERENCES

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