I Simpósio Regional da Sociedade Brasileira de Geofisica

São Paulo 2004

Multi-gate predictive deconvolution for the restoration of primary reflections

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Abstract

In this paper, the effectiveness and successful application of multi-gate predictive deconvolution filters is demonstrated on both a synthetic and a field dataset. Some illustrations are shown on the identification and estimation of multiples and their effective removal from seismic marine data over very shallow water environments. The application of multi-gate predictive deconvolution filters appears to be very effective in areas where other methodologies of multiple suppression, (which are mainly based on long multiple periods) will be difficult to apply and have less success of multiple attenuation.

Introduction

In shallow water environments, multiples tend to create a complex interference pattern with the primaries. Multiples may become very dominant and strong in amplitude in comparison with primary reflections. Of course this situation may also depend on the type of acquisition used in recording marine seismic data and the geology of the earth subsurface. In situations where the multiples become very high in amplitude and dominant over primaries, they may obscure the identification and interpretation of primary reflections. Since the primary reflections are necessary for an accurate interpretation of the earth's subsurface, it becomes very crucial to aim at methodologies that can suppress multiples in an effective and optimal way. Some methodologies for multiple suppression have proven to be very effective and successful, of which one is the surface-related multiple removal method (Verschuur et al., 1992). However many of those methodologies are based on the determination of long multiple periods and first primary reflections. In very shallow marine environments and marine data recordings, it may be very difficult to identify the first primary reflection. Especially because of its interference with the direct source wavefield and near offsets recordings that may be missing. The surface-related multiple removal method (Verschuur et al., 1992), can handle any subsurface geology (provided a 2D limitation in practice) and is capable of removing various types of surface-related multiples at the same time, because each event in the seismic data act as a predictor of a certain type of surface multiples. However, the latter is known to have difficulties with the short period multiples that for example occur in shallow water environments. Predictive deconvolution methods have proven to be very effective and useful in seismic data processing. The process and estimation of the multiples that are illustrated in this paper are based on the principles of predictive deconvolution, as described by Robinson and Treitel (1980) and Taner et al., (1993). In order to validate the effectiveness of numerous multiple suppression methodologies, other techniques have been investigated and considered in very shallow marine environments and the application of multi-gate predictive deconvolution filters appeared to be very effective in the attenuation of surface-related multiples.

Multi-gate predictive deconvolution

As outlined in the introduction, in some very shallow marine environments, it may become difficult to identify the primary seabottom reflections and use standard surface-related multiple removal methods. These standard methodologies use during the process of multiple estimation, the seabottom reflection as the main predictor of multiples. In order to cope with these shallow water problems, a solution is to mimic the effect of surface-related multiple removal with a multi-gate deconvolution. In this way, more than one type of surface multiples is addressed, but with the robustness of the deconvolution for short period multiples. By determining autocorrelations of the seismic traces of prestack and poststack data, several multiple gates are identified and used to predict various types of multiples. Therefore the autocorrelation panels of prestack and postack data play an important role in the identification of different types and orders of surface-related multiples. Once the various types and orders of multiples have been identified, a simultaneous multi-gather subtraction method is used to match the multiple predictions to the input. In the application of simultaneous multi-gate predictive deconvolution filters, followed by a multi-gather, multi-trace adaptive subtraction process in the pre-stack domain, the amplitude and phase discrepancies are being corrected. This procedure can be iterated, each time identifying the next type of surface multiple on the autocorrelation panel, followed by a simultaneous subtraction of these multiples and all previous predictions from the original input, until the autocorrelation does not show clear multiple residuals and primary reflections have been restored optimally.

Examples on restoration of primary reflections

In the following, the application of multi-gate predictive deconvolution filters is illustrated on a synthetic dataset followed by a field dataset. The synthetic dataset is generated from a horizontally layered earth-model with two shallow strong reflectors. Figure 1 shows the input data and the result after multiple suppression. Figure 1a illustrates the input gather with all multiples modeled. The gather displayed in Figure 1a has been FK filtered and some top mute has been applied to remove the effect of the direct wave. The result of applying a series of multi-gate predictive deconvolutions is illustrated in Figure 1b. To observe and identify the amount of multiples in the input gather (Figure 1a), autocorrelations of each seismic trace have been determined from the gathers (Figure 1a and Figure 1b) and are shown respectively in Figure 1c and Figure 1d. Comparing both autocorrelations, one can observe the successful suppression of multiples, (horizontal events in autocorrelation Figure 1c, indicated with the yellow arrows). Figure 1d shows clearly an improvement in applying multi-gate predictive deconvolution filters, followed by a multi-gather, multi-trace simultaneous adaptive subtraction process in the pre-stack domain. This procedure has also been applied and illustrated on shallow water marine dataset. Figure 2a shows a part of the stack of the input data. Some FK filtering has been applied to the prestack data. The stack shows a lot of ringing of short period multiples, especially on the left side of the stack. The multi-gate predictive deconvolution method has been applied prestack to NMO-corrected CDP gathers. Note that the prediction itself is single trace, but during the subtraction stage adaptive filters are designed in half-overlapping, time and space varying windows. Thus, in the subtraction stage, advantage is taken from the different spatial behavior of the multiples and primaries for optimal and effective results. Figure 2b shows the resulting stack after the prediction and subtraction stage. Note the clear reconstruction of primary reflections (indicated with the yellow arrows). Figure 2c shows the difference stack and represents the estimated and removed multiples. The autocorrelation panels for these stacks (before and after the multiple suppression procedure) are displayed in Figure 3.

Figure 3a shows the autocorrelation of Figure 2a, and Figure 3b represents the autocorrelation of Figure 2b (after multiple suppression). Note the clear reduction of the ringing effects and the reconstruction of the primary reflection events (indicated with the yellow arrows in Figure 3b).

Discussion and Conclusions

In shallow water environments, strong multiples may distort the identification of primary reflections. A multi-gate predictive deconvolution procedure, followed by a multi-gather, multi-trace adaptive subtraction process in the pre-stack domain, appears to be robust solution in these situations. The effectiveness of this methos is illustrated on both a synthetic and a field dataset.

Acknowledgments

The authors would like to thank Anadarko Petroleum Corporation for permission to present the data and results.

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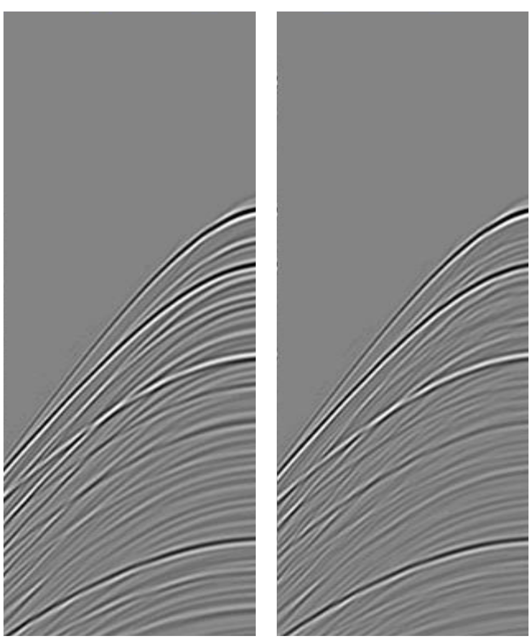
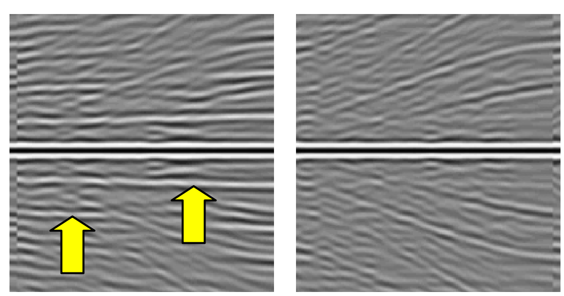




c) *d)*

a) *b)*

Figure 1 – a)Gather with multiples after FK filtering and top mute, b)the result of multi-gate predictive deconvolution. c)Autocorrelation of a). d)Autocorrelation of b).

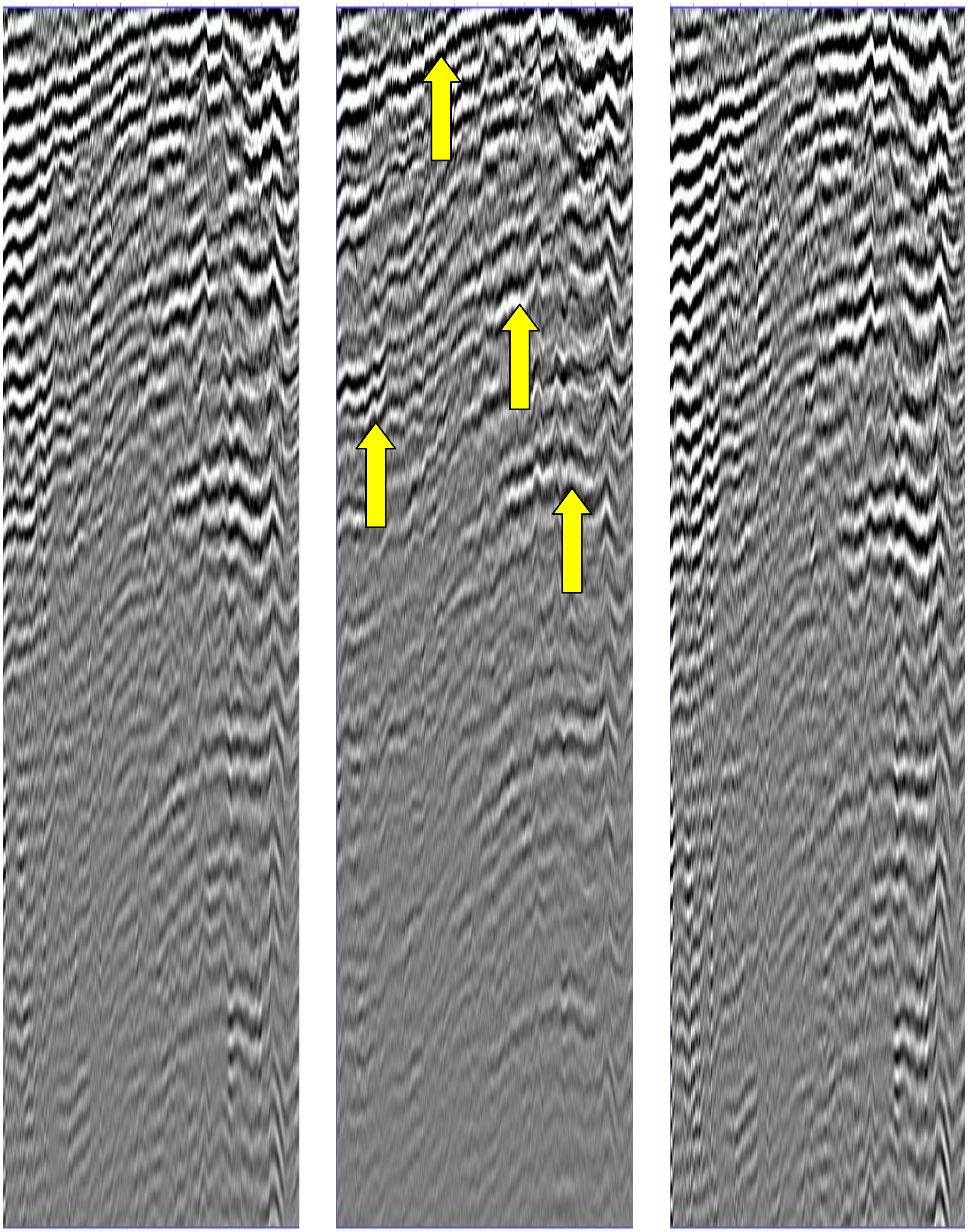
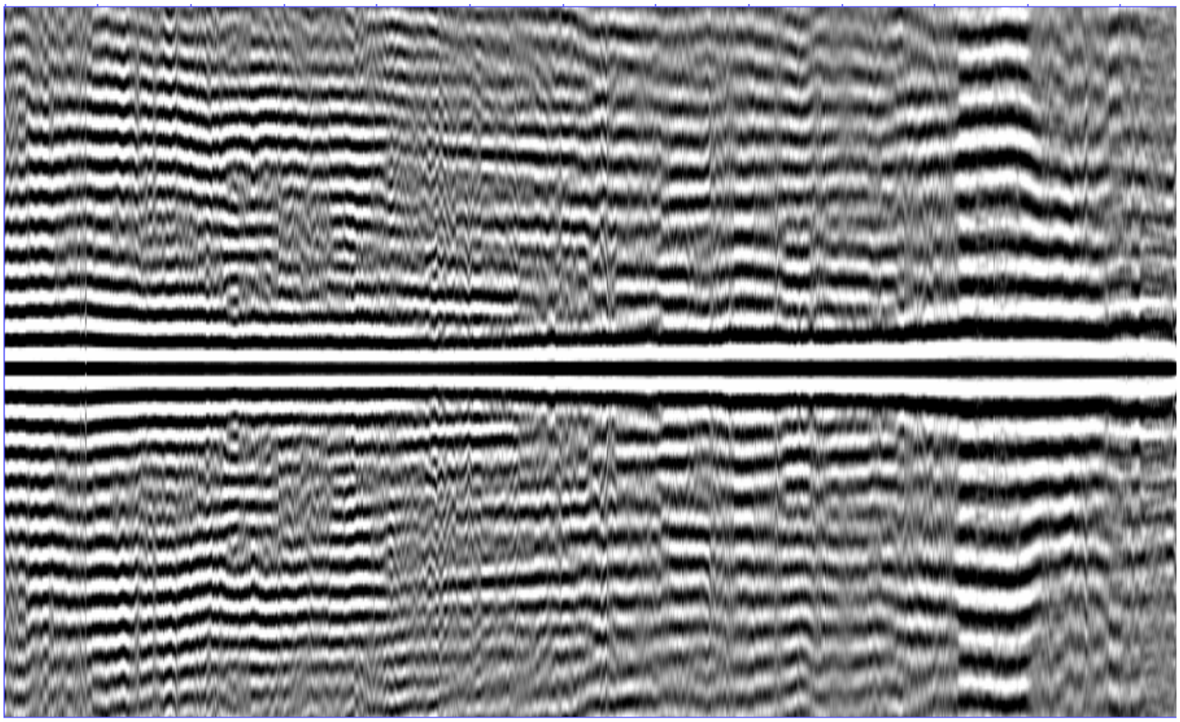
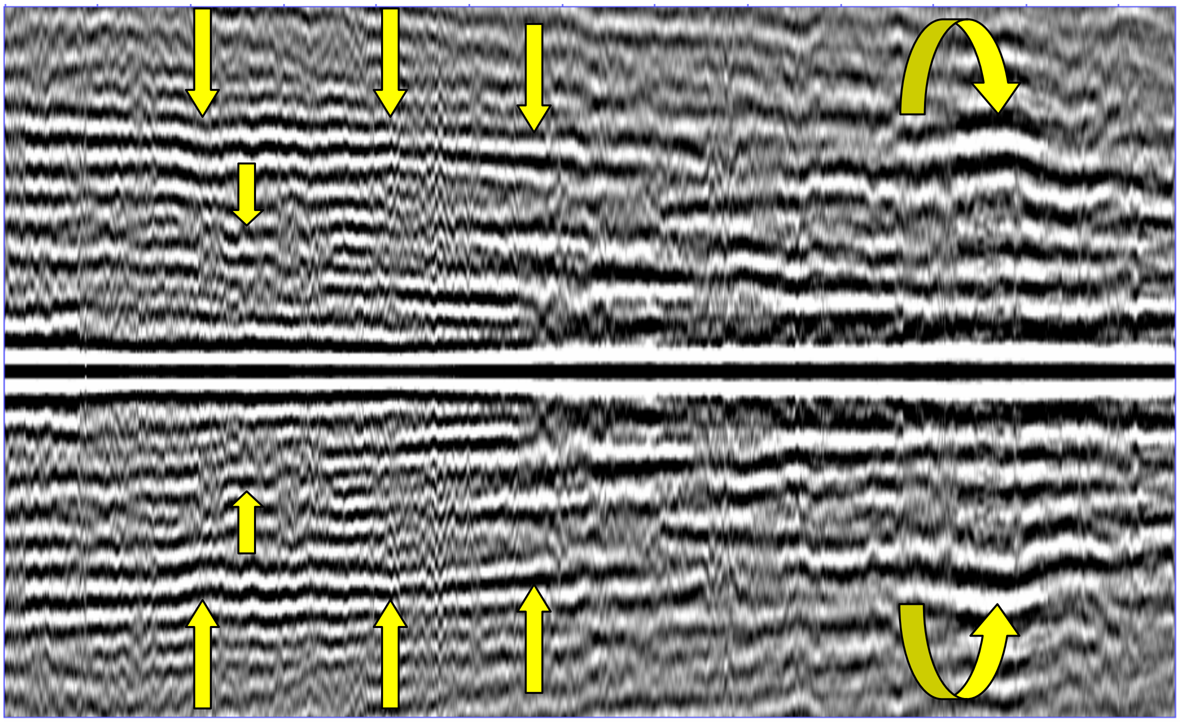


Figure 2 – Stacks of data: a)Raw data after FK noise suppression, b)data after FK noise suppression and multiple attenuation and c)the estimated and removed multiples.



a)



b)

Figure 3 – Autocorrelations of the stacks of Figure 2: a)data after FK noise suppression, b)data after FK noise suppression and multiple attenuation.