A COHERENCY GUIDED METHOD FOR PRE-STACK MULTIPLE ATTENUATION

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keywords: *coherency section, stacking, pre-stack multiple attenuation*

ABSTRACT

The main objective of seismic data processing is to obtain information about the subsurface structure and properties from the recorded data. Almost all imaging methods assume that the recorded seismograms contain only primary reflections. Consequently, identification and suppression of multiples is of high importance in data processing. In this paper, we present a coherency guided method for multiple prediction and attenuation, which is applicable to any type of multiple reflection including internal multiples. It includes picking of zero-offset traveltimes in a stacked section using coherence, which are then used to predict the pre-stack multiples with the help of the stacking velocities. The advantage of the proposed approach is that it performs stable for far offsets. Furthermore, it does not require a high computational effort. Both synthetic and field data examples illustrate the potential of the method.

INTRODUCTION

Multiple attenuation is a challenging step in a seismic data processing workflow. Many methods are available for multiple identification and suppression, but every method uses different assumptions and thus has its advantages and drawbacks. In this paper, we present a rapid and robust multiple attenuation approach derived from a previously published Common Reflection Surface (CRS) workflow by Dümmong and Gajewski (2008). Their method is an entirely data driven approach and includes two steps of prediction: first, zero-offset multiples in a CRS stacked section are predicted, and in the second step, the obtained CRS attributes are used for pre-stack multiple prediction. Dümmong and Gajewski (2008) proposed multiple prediction in the CRS stacked section using a series of convolutions. This concept of multiple prediction by convolution of stacked traces (i.e. poststack SRME) originates from the work of Verschuur et al. (1992) and Kelamis and Verschuur (1996). The workflow is restricted to 1D media; therefore, errors for dipping events are inevitable and it is necessary to correct the predicted data. This correction is not easy to determine. To resolve these issues, Vefagh and Gajewski (2015) introduced a method which includes picking multiple events manually in the stacked section instead of predicting them by a convolution approach. Picking multiples in some cases is very challenging and residuals may remain after multiple attenuation. If we tune the stacking operator in a way to preserve multiples in the coherency section multiples will have a higher coherence value in comparison to the primaries. Based on this, we propose picking multiple events using the coherency as a weight in the stacked section instead of picking them manually. This approach can be applied to surface related multiples as well as internal multiples. The disadvantage of the proposed workflow is that it relies on interpretation.

Since hyperbolic stacking operators are affected by spread length bias, we apply the method separately to near and far offsets. The method can be applied to CRS or Common Mid Point (CMP) processed data. Here we consider the workflow in a CMP based workflow, i.e., no CRS processing is required. First we, introduce the methodology and workflow, which is then applied to synthetic and field data.

METHOD

Several multiple attenuation methods are based on periodicity of multiples or moveout discrimination between multiples and primaries. Our method is based on the fact that multiples, like primaries, are hyperbolic events. Thus, it is possible to estimate traveltimes of multiples in the pre-stack domain, if zero-offset traveltimes of multiples and stacking velocities are available.
As an initial step of the coherency guided approach, we apply a stacking operator to obtain a stacked section, a stacking velocity profile, and a coherency section. The stacking velocity and the coherency section are estimated by an automatic semblance optimization (Neidell and Taner, 1971) i.e., the standard data processing sequence. Since the stacking process should be steered such that multiple events are imaged, the velocity search interval is adjusted accordingly. For example, if we are aiming to predict surface related multiples, the velocity search interval should be set to a lower range. The velocity analysis step also provides a coherency section. This section is then used to differentiate between multiples and primaries. For this purpose, a threshold factor is used to cutoff the events with low coherency.
After stacking, pre-stack traveltimes of the multiples are predicted using the following procedure. The stacking velocity section, the picked traveltimes, the coherency section, and the selected threshold factor contribute to the prediction using the following well-known equation:

$$t(h) = \sqrt{t_0^2 + \frac{4h^2}{v^2}} \tag{1}$$

where h is the half-offset, t_0 is the ZO traveltime and v is stacking velocity.
After multiple prediction, we employ an adaptive filtering method to match the predicted multiples with the input data. A Wiener optimum filter (Wiener, 1964) is used to fit the input seismograms to the original data. After matching the predicted events with the input data, the multiples are subtracted from the observations. This process is controlled by a window size and an operator length. The window size is the amount of traces that is used to determine the filter. A single trace, as well as several traces, are valid window sizes. The operator length is the length of the deconvolution operator applied to the data. The operator length is a critical parameter: If it is adjusted too large, the operator matches any predicted trace with the input data. Therefore, primaries in the vicinity of the multiples will be also subtracted. However, with a very short operator length, predicted data will not be matched to the input data properly. Consequently, multiples will not be successfully subtracted from the data. The best result is obtained empirically. A window length matching the prevailing period of the data is a good choice in many cases.
The hyperbolic formula (Equation 1) is limited to near offsets and is affected by spread length bias. To avoid this limitations, we apply the method twice, once to the near offsets and secondly to larger offsets. In the next section the method is applied to synthetic data.

SYNTHETIC DATA EXAMPLE

To illustrate the method, we first applied it to the synthetic BP 2004 dataset. The minimum offset is 125 m and the maximum offset is 8000 m. For the processing, only CMPs in the range between 3550 and 4000 were chosen. As mentioned before, stacking operators are affected by spread length bias. To resolve this limitation, we applied the method to short and large offsets (larger than 3500 m) separately.
First we stacked the near offset data (125 m to 3500 m) tuned to image the multiples. Since our target are surface related multiples we set the velocity search interval between 1450 m/s to 1550 m/s. To avoid attenuating primaries, we mute the upper part of first order multiples. Figure 1(a) shows the stacked section of the data and Figure 1(b) shows the corresponding coherency section. The coherency section shows that the multiples have a higher value in comparison to the value of the primaries. This allows us to differentiate between primaries and multiples in the stacked section. After that, prestack traveltimes of the multiples are estimated and adaptively subtracted from the data.

The far offset data are treated separately. Since our first step is to image the multiples, we adjusted the velocity search interval range and the apertures in a way that we could achieve the best possible result for imaging multiples, primaries in this section may not be optimally imaged. Figure 2 shows the stacked section using only far offsets (3500-8000 m). After treating the data for far offsets the data are summed up.

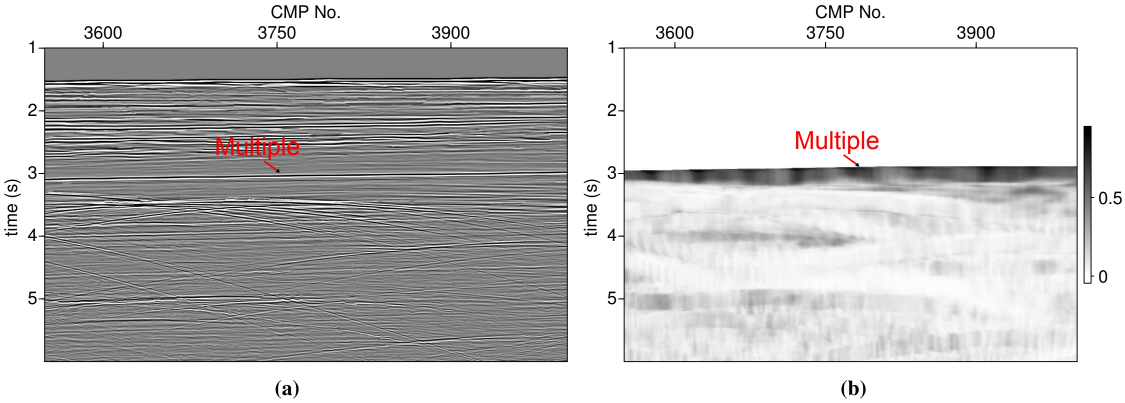

Figure 1: (a) shows the stacked section of the near offset data (from 125 m to 3500 m) CMPs between 3550 and 4000 of the BP 2004 data, (b) shows the corresponding coherency section. The multiple have higher values in comparison to the primaries.

To visualize the result we stack the data again using velocities to optimally image primaries. In Figure 3(a), the stacked section including multiples is displayed and in Figure 3(b) the corresponding stacked section after multiple attenuation is shown. The energy of the first order multiple, which is indicated by an arrow in Figure 3(a), is removed and it is not recognizable in the stacked section in Figure 3(b). Generally, the result is encouraging to further investigate the method. Next, we apply the approach to field data.

FIELD DATA EXAMPLE

For further investigation, the method was applied to a marine dataset. The data, which originate from the Levantine basin in the Eastern Mediterranean Sea, is provided by TGS-NOPEC. This data features a large offset of 7300 m with a maximum fold of 288.

At first, a stacked section, the corresponding coherency section, and stacking velocity profile were generated for near offsets (from 150 m to 3638 m). Since in this case our target was to image surface related multiples in marine data, we set the velocity search interval from 1450 m/s to 1550 m/s which includes the velocity of water. Then, the upper part of the first order multiple was muted. Figure 4(a) shows the stacked section of the data and Figure 4(b) is the corresponding coherency section showing that the multiples have a higher value in comparison to the other events. After picking post-stack traveltimes of the multiple the results were used to predict pre-stack traveltimes of these events. In order to predict multiples for far offsets, the method was applied once again to far offsets (from 3638 m to 7338 m). Figure 5 shows the stacked section of the far offset data. In Figure 6(a), the stacked section before multiple attenuation is presented, and in Figure 6(b) the corresponding stacked section after multiple attenuation is shown. Overall, we can see that most of the multiple energy, which are marked by arrows in Figure 6(a), is removed from the stacked section in Figure 6(b) and the result is quite promising for future development of this approach.

CONCLUSIONS AND OUTLOOK

We have presented an approach for multiple attenuation within a stacking workflow. Any kind of stacking operator can be used including the CRS operator. In the latter case, it is possible to use CRS pre-stack data enhancement (Baykulov and Gajewski, 2009) to obtain a stacked section with enhanced S/N ratio compared to a CMP stacking workflow. Initial results of a synthetic and marine field dataset show the prospect of the presented multiple attenuation method. The main advantage of the approach is its speed and robustness. The methodology can be applied to any hyperbolic event, including internal multiples and surface related multiples. The drawback of the method is that it is an interpretational approach. Multiple attenuation in areas with triplications and diffractions is a very challenging task because of the conflicting

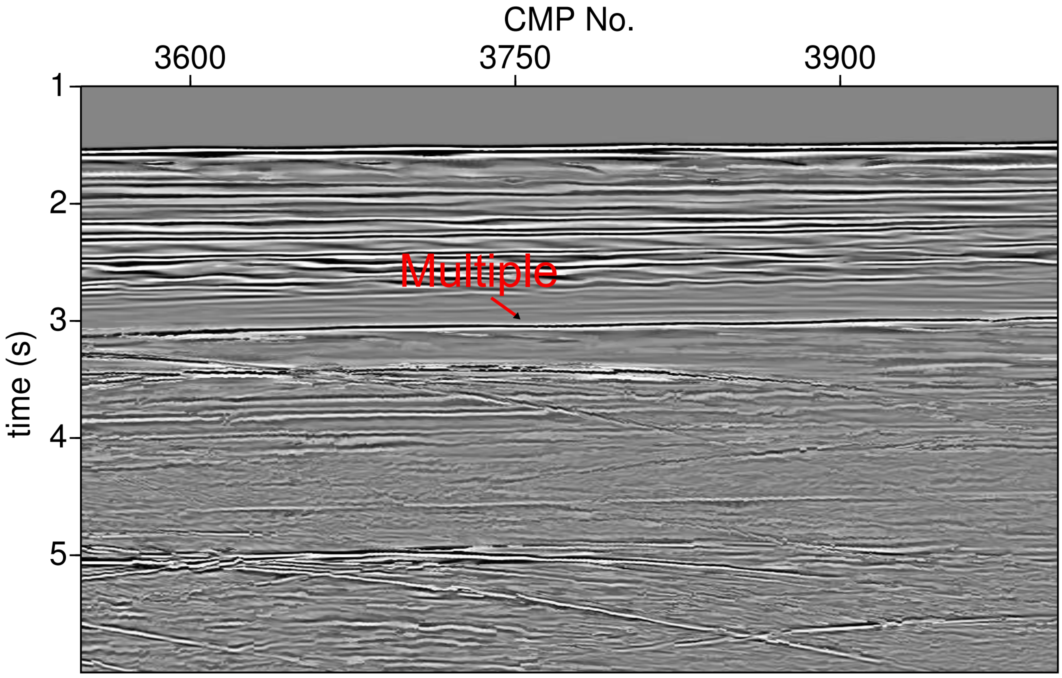

Figure 2: The stacked section of far offsets (3500-8000 m) for the BP 2004 dataset. The stacking process is performed, such that multiples are optimally imaged.

dip situations. To relax this issue, we can apply the described method in the Common Scatter Point (CSP) domain (Dell et al., 2010) or generally the partially time migrated domain where triplications are unfolded and all events are dip corrected (see papers by GlÃűckner et al., and Yang et al., this volume) . Extending the method to 3D is a straight forward step.

ACKNOWLEDGMENTS

The authors would like to acknowledge Robert Pfau, Stefan Dümmong and the Applied Seismic Working group of the University of Hamburg for their support. The authors would also like to thank TGS-NOPEC for providing the marine dataset and BP for Providing the BP 2004 data. This work was partially supported by the Wave Inversion Technology consortium (WIT).

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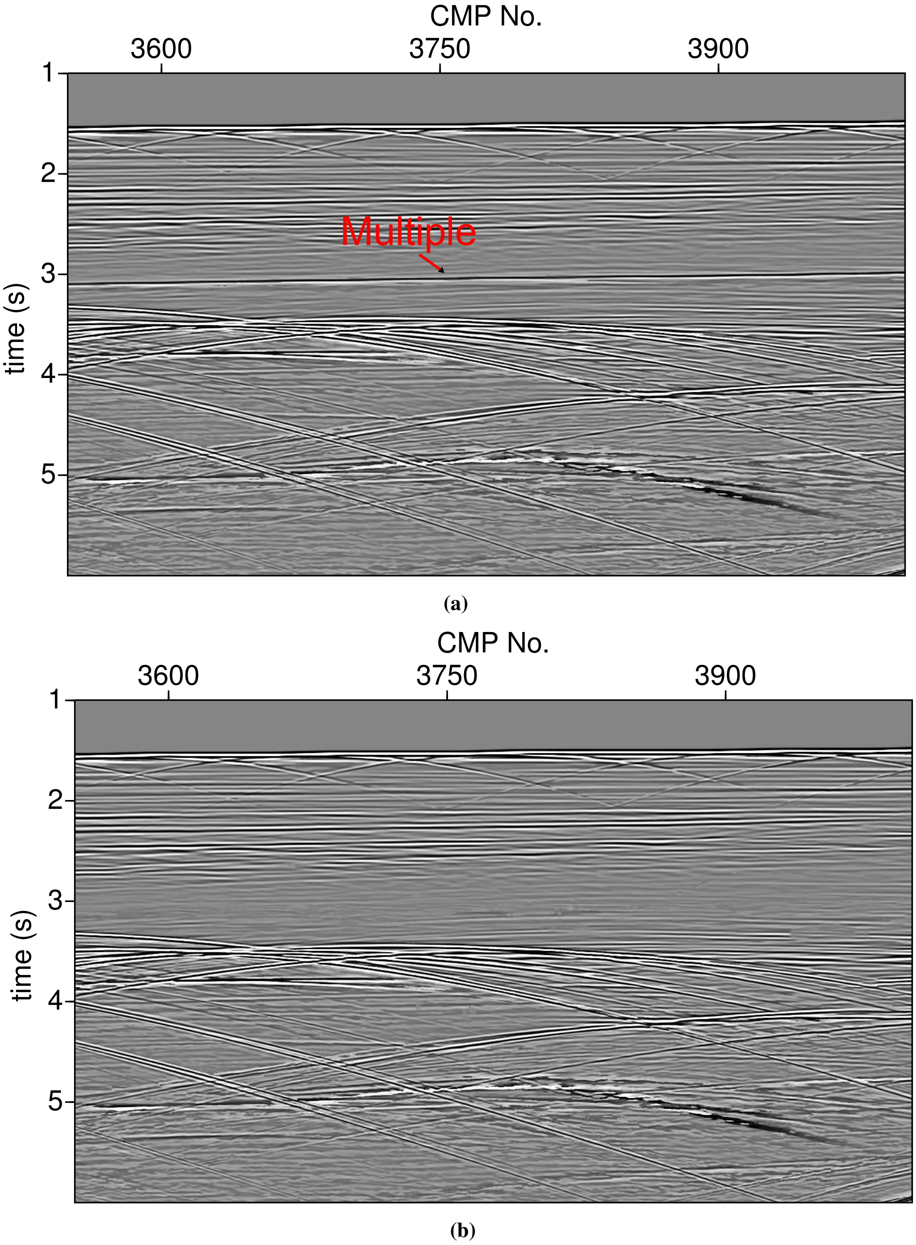


Figure 3: BP 2004 dataset CMPs form 3550 to 4000. In (a), the stacked section including multiples is displayed. In (b) the corresponding stacked section after multiple attenuation is shown. The first order multiple (indicated by an arrow in (a)) is removed and it is not recognizable in the stacked section in (b).

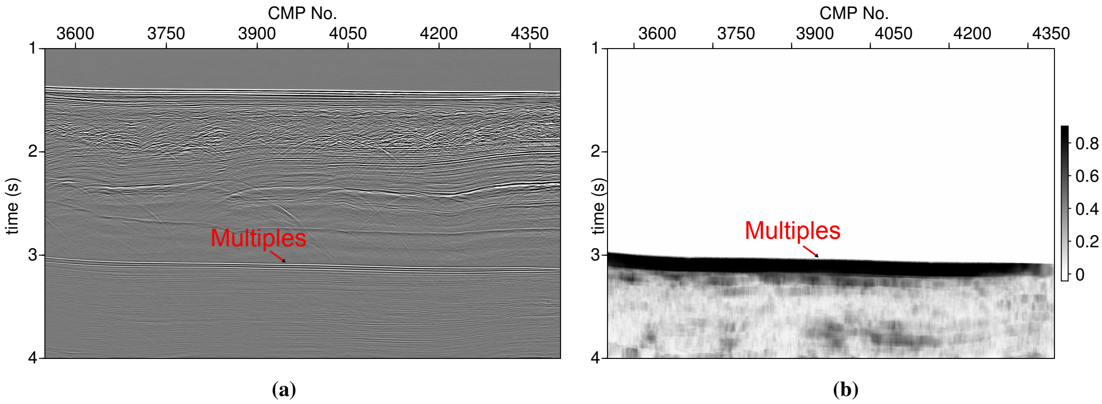


Figure 4: (a) shows the stacked section of the near offset TGS data (from 150 m to 3638 m). CMPs between 3600 and 4450 are considered. (b) shows the corresponding coherency section. In the coherency section multiples have a higher value in comparison to the other events.

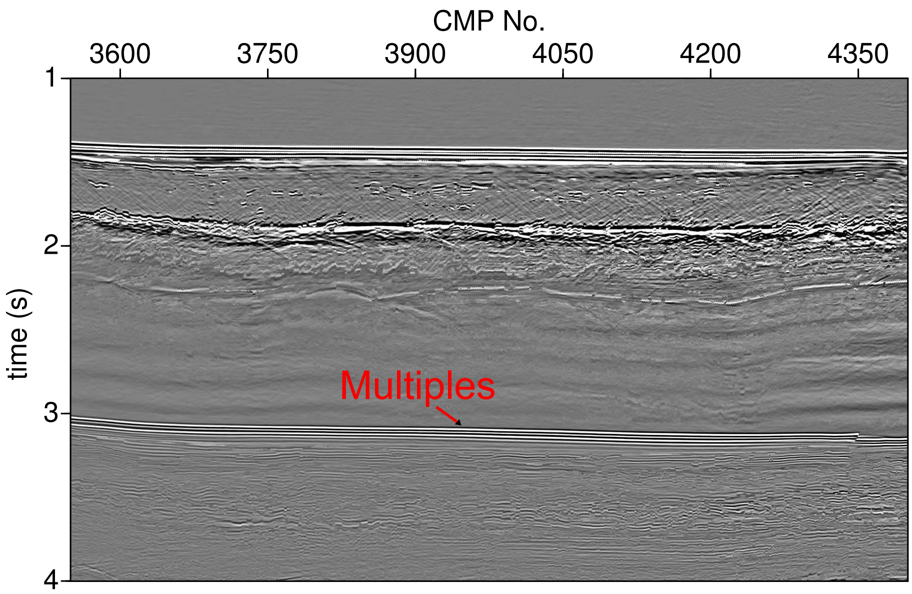
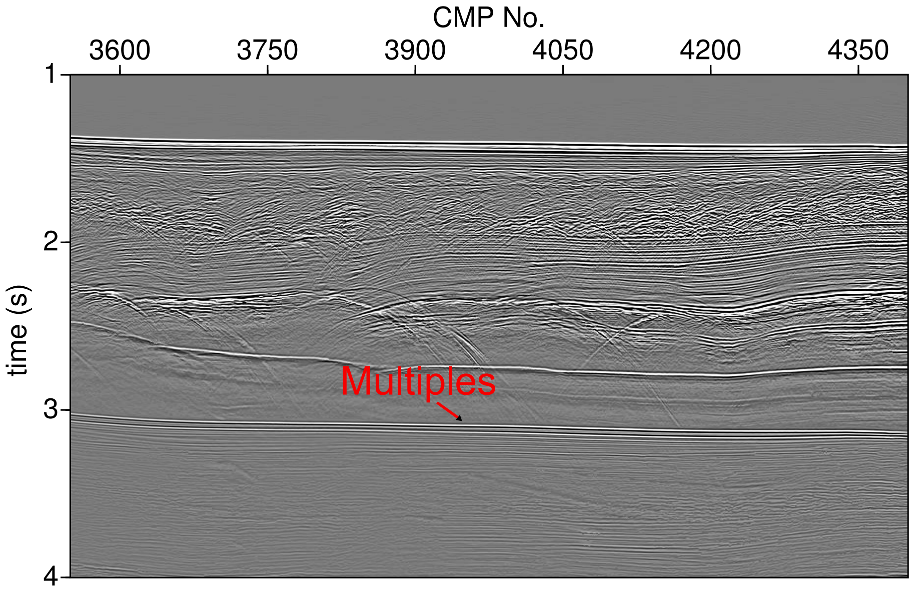
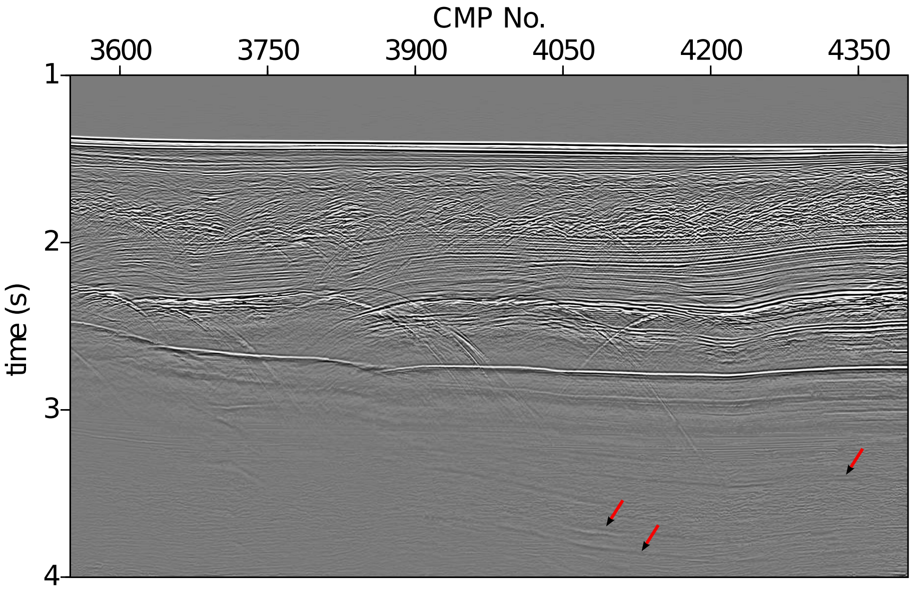


Figure 5: The stacked section of far offsets (3638-7338 m) for the TGS data. The stacking process is done, such that multiples are optimally imaged.



(a)



(b)

Figure 6: TGS data CMPs between 3600 and 4450. In (a) the stacked section including multiples is displayed. In (b) the corresponding stacked section after multiple attenuation is shown. We can see that most of the multiple energy is removed from the stacked section in (b) and some events which are indicated by arrows became visible.

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