How can we design reliable decon operators for noisy 3-D land data

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Summary

3-D land data is historically very noisy causing various signal enhancement problems. Single trace deconvolution, in particular, fails to obtain a reliable estimate of the multiples on such noisy traces causing ineffectively deconvolved results. Here we introduce a method of reducing noise from input traces before deconvolution operators are designed. As post- NMO stacking is used for this procedure we call this process a poststack driven prestack deconvolution method (abbreviated as PPDEC from here on). In this paper we describe the method and give examples of successful deconvolution applications. We also show that the Radial mixing operation (inherent in the PPDEC method) used before deconvolution design can also be used as a powerful noise attenuation algorithm, which we call Radial Mix.

Introduction

Noisy land data has traditionally been difficult to interpret due to loss of resolution as well as the presence of ineffectively deconvolved multiples. It has recently been reported (Schjolberg et al, 2008) that reprocessing by using the PPDEC method has allowed successful interpretation of data from Oman leading to the discovery of oil. Gulunay & Benjamin explains (2008) the PPDEC method in detail. Here we summarize the idea behind the PPDEC method and show a few applications to field data. We also illustrate the use of radial mix alone as a noise reduction tool.

Field data and shot array forming via radial mix

The data we use to illustrate the method has been recorded as part of a wide azimuth land survey leading to high fold common receiver gathers. The common receiver domain provides a dense areal distribution of shots and this domain is therefore suitable for various noise reduction schemes before deconvolution. X-Y coordinates of shots for part of such a common receiver gather are shown in Figure 1. In this domain, and for each input trace, (post NMO), one can find all of the traces within the neighbourhood of the trace (say within a circle of radius R, typically being less than one hundred meters) and stack them to reduce noise on them (and hence obtain a much better estimate of the primary and multiple amplitude relationship). The result of this process is cleaned up traces from random as well as steeply dipping coherent noise. As can be expected from Figure 1 this is a shot array forming process and is complimentary to short areal shot arrays that are used in current land acquisition systems. Deconvolution operators can now be designed from these improved S/N ratio traces instead of the noisy input data. During this process it is important to allow offset varying deconvolution parameters such as gap, effective operator length and white noise since NMO stretch is present on the traces before deconvolution. To summarise, the noisy traces are deconvolved with more correct and hence more effective operators to produce the deconvolved traces.

The effect of this process on stacked sections are shown in Figures 2, 3, and 4 where stacks with no deconvolution (figure 2) are compared to stacks with single trace decon (Figure 3) and with PPDEC (Figure 4). The corresponding autocorrelations for these stacks are shown underneath each stack. It is clear that ringing present in the stack with no decon (Figure 2) is somewhat suppressed by single trace decon (Figure 3) but is much more effectively suppressed by PPDEC (Figure 4). Comparison of stacks after PPDEC with the stacks after other deconvolution methods than single trace decon (e.g. as tau-p decon) also illustrated us (not shown here) the power of PPDEC in suppressing difficult multiples. Additionally it has been observed in many areas that the use of PPDEC provides greatly improved seismic to well matches as illustrated in Figure 5. There, we observe that a strong multiple that is present on the single trace decon output has been suppressed well by the PPDEC process.

We show in Figures 6 the effect of the radial mix on steeply dipping noise. This example (Figure 6a) shows an inline of a common receiver gather of some OBC data. On this record some ground roll and strong direct arrivals from the source exist. In Figure 6b we show that the direct arrival is attenuated to a large degree by applying linear moveout with water velocity and following it with a 2D inline F-K filter to suppress flat events. This was followed by 3D F-K filter for ground roll attenuation resulting with Figure 6b. We observe that some direct arrival still survived these processes. Figure 6c shows the result of applying radial mix to this data which clearly suppressed the remnant direct arrival. The difference between input and output of radial mix process is given in Figure 6d showing again that the process is signal preserving to a large degree. The effect of the shot array forming process in common receiver domain on continuity of events is clearly illustrated by comparing a stack of the land data with just ground roll attenuation (Figure 7) and with ground roll attenuation followed by radial mix (Figure 8) in a structurally complex area.

Conclusions

Multiples on noisy wide azimuth land data can be more accurately modelled and suppressed when deconvolution operators are designed from noise reduced versions of the original input traces but then applied to the original traces. Application of such a method has been proven on many occasions to effectively suppress multiples and provide greatly improved seismic to well matches. The radial mixing operation that produces these noise reduced traces also seems to be a powerful method for attenuating steeply dipping noise which otherwise leaks into stack volumes. With further refinement to the method it will become standard practice on modern wide azimuth surveys which have an excellent areal coverage of source locations. As the method is both offset and azimuth preserving it is particularly suited for this purpose.

Acknowledgments

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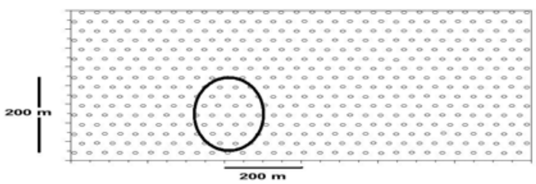

Figure 1. Shot x, y coordinates for a common receiver gather

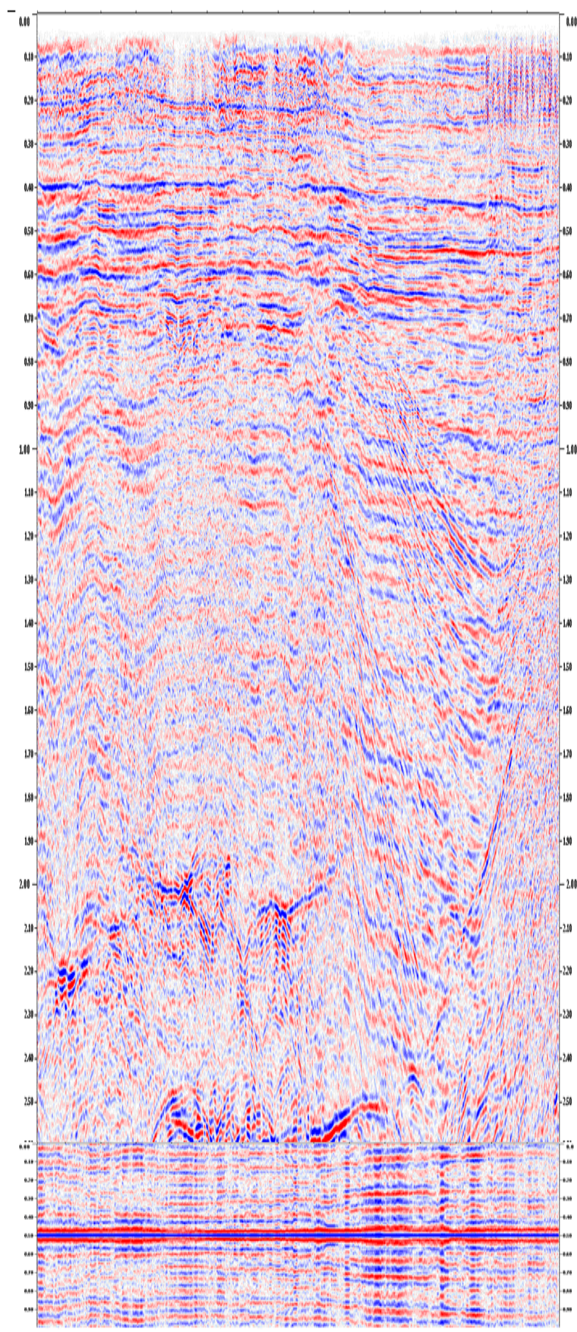

Figure 2. Stack with no deconvolution and its autocorrelations.

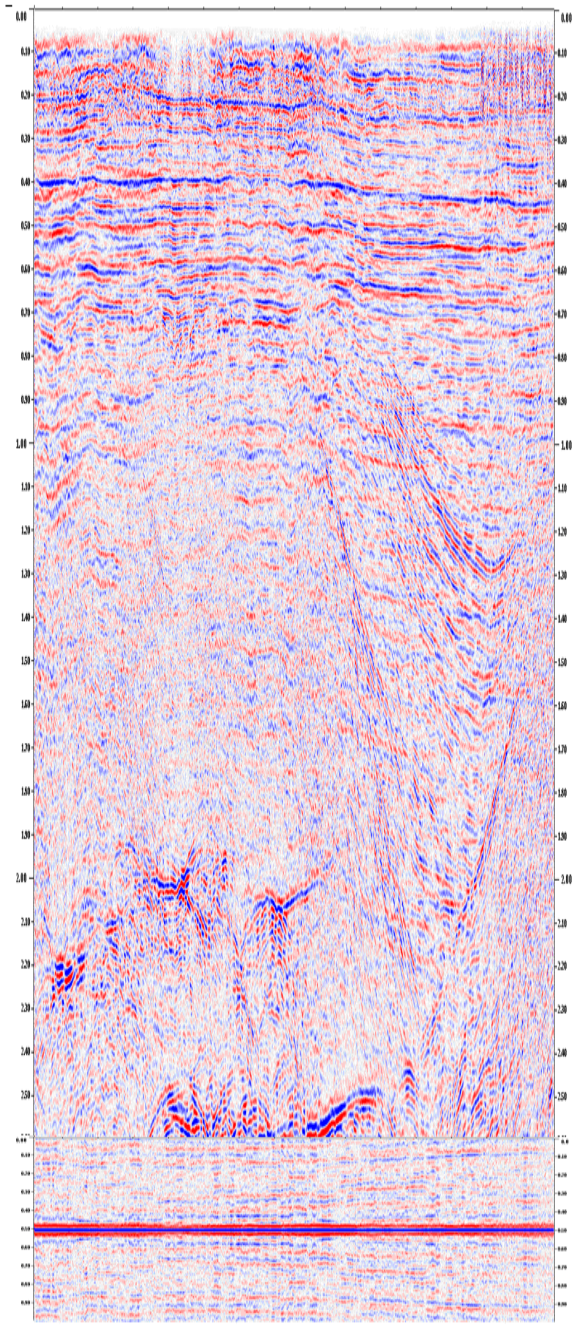

Figure 3. Stack with single trace gapped deconvolution and its autocorrelations.

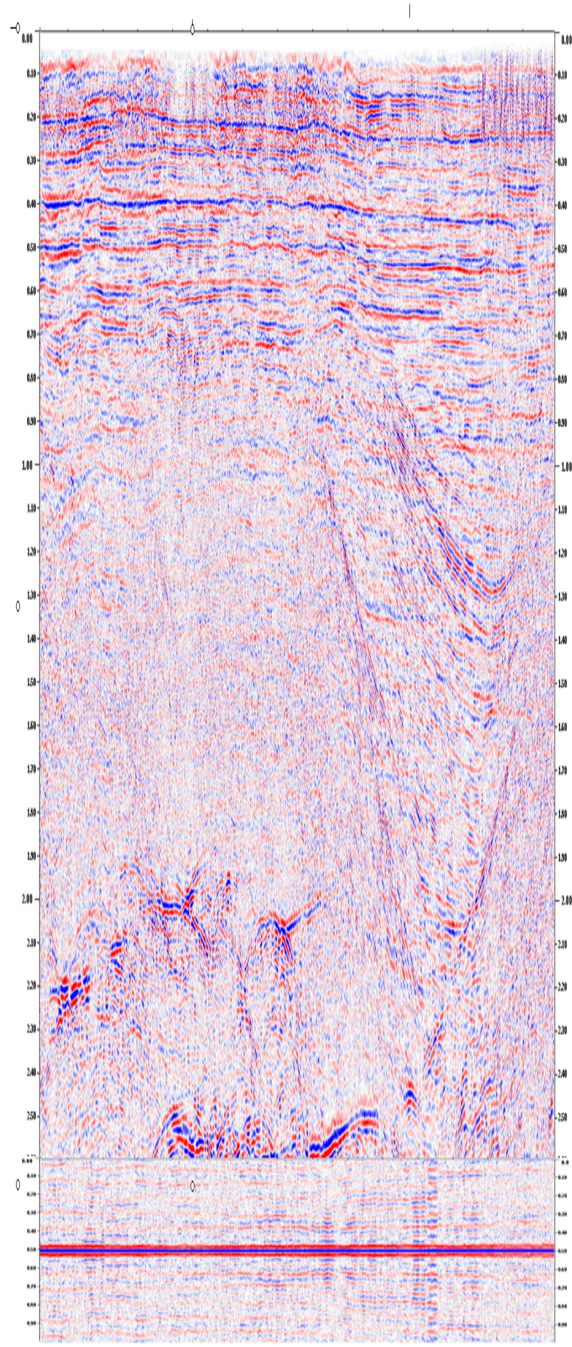

Figure 4. Stack after PPDEC and its autocorrelations.

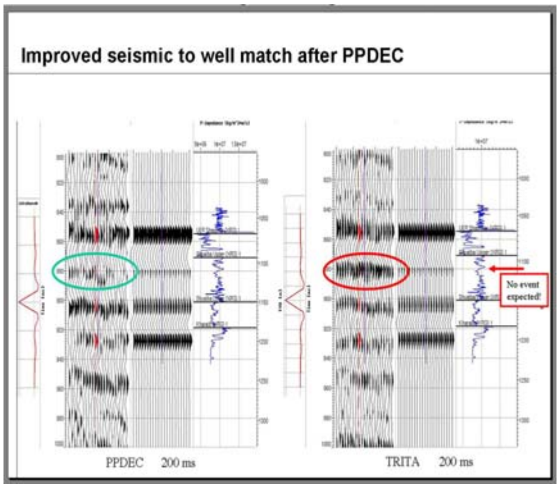

Figure 5. Improved seismic-to-well match that is provided by PPDEC is shown on the left. Single trace deconvolution result is shown on the right.

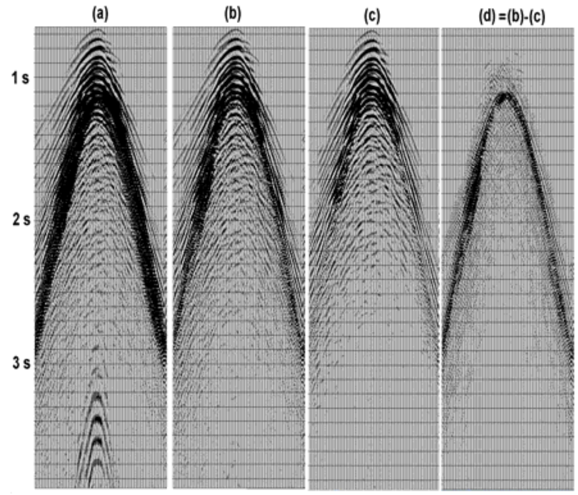

Figure 6. (a)-An inline record from an OBC common receiver gather, (b)- same record after direct arrival and ground roll attenuation, (c)- record in “(b)” after radial mix,(d) the difference between input and output of radial mix process.

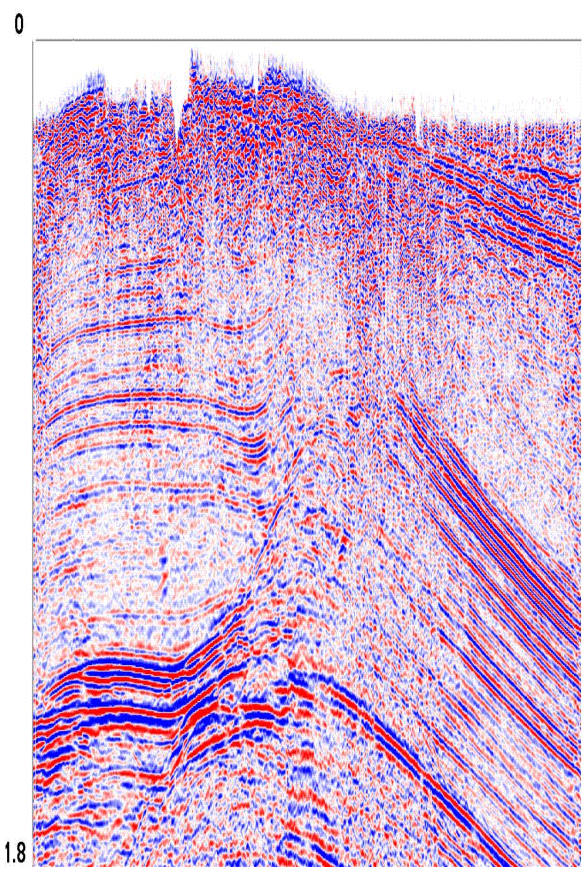

Figure 7. Stack from a structurally complex area (after ground roll attenuation).

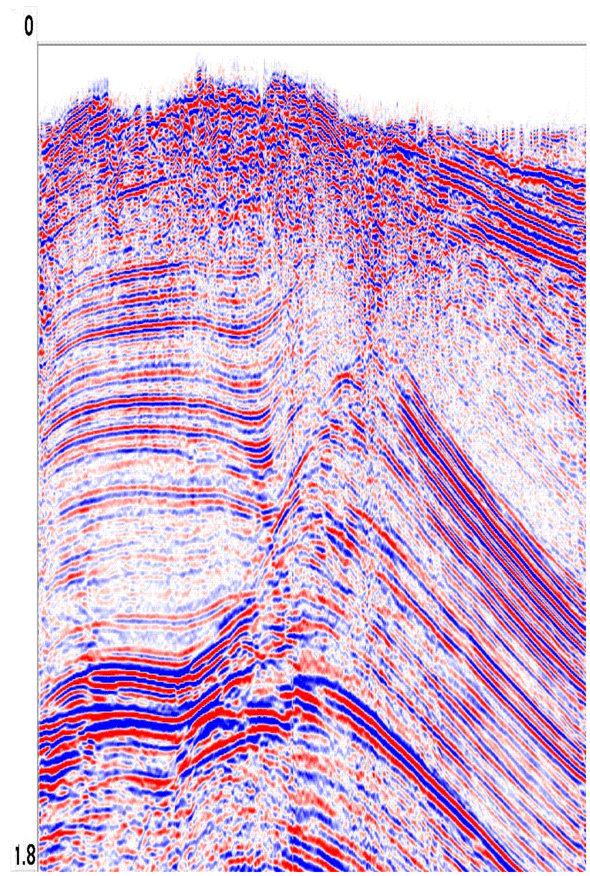

Figure 8. Stack after ground roll attenuation and radial mix.