Generalized Deconvolution for GPR image enhancement

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Abstract

In this paper we describe the application of Generalised Deconvolution (also known as Local Wavefield Decomposition) to GPR images with intention to enhance certain features such as reflectors of a particular dip in the data. Because GPR data acquired at the highly fractured summit of Turtle Mountain, Crownest Pass, Alberta, show an enormous amount of details it is rather difficult to detect and follow major reflectors in the migrated images. The application of generalised deconvolution, so far only applied to seismic data in common shot or common midpoint gathers, allows us to extract coherent signals from reflectors of particular dips in the time-distance domain. Using only events with high correlation energy allows us to reconstruct data sets that enhance major reflectors.

Introduction

Ground penetrating radar (GPR) has become a frequently applied survey tool for near surface geophysical studies. Its high vertical and lateral resolution capabilities is often employed in hydrological and environmental (e.g., *Zeng and McMechan*, 1997, *Moldoveanu-Constantinescu and Stewart*, 2004), forensic (e.g., *Hammon et al.*, 2000), and archaeological studies (e.g., *Goodman et al.*, 1995). However, the high-resolution capability of ground penetrating radar can cause problems when the near surface geology contains numerous features such as diffractors and reflectors dipping in many directions. The resulting GPR image can then be difficult to analyse. The GPR data acquired at Turtle Mountain (*Theune et al.*, 2004, *Theune et al.*, 2005) are such an example. The data were collected at the highly fractured summit of the mountain with the intention of determining dips and penetration depths of fractures and fissures, which may pose as potential slide surfaces for future rock avalanches.

The presence of numerous fractures with various dips is reflected in the GPR image shown in Figure 1a. Besides strong reflectors dipping downwards along the profile, which are most likely related to bedding planes at this location of Turtle Mountain, many small events are present in the data that complicate the interpretation of the data. This difficulty is carried on to the analysis of the migrated section, which we show in Figure 2c.

Methodology

In order to enhance coherent reflections in the data we apply Generalised Deconvolution, a concept recently introduced by *Sacchi et al.*, 2004, 2005. We refer to these publications for technical details. This technique, which is based on the Radon transform, has been suggested to selectively remove unwanted events such as ground roll or multiples in seismic data. Here, we adopt the idea of wavefield separation to GPR image enhancement. The data set is first decomposed into several components that are determined by locally summing energy along integration paths of different dip p in the t-x-domain. By locally summing along linear paths px of a given length a, the Generalised Deconvolution can be used to separate coherent reflectors from small features such as scattered energy. The formers are indicated by coherent reflection energy along a larger distance in the t-x-domain, thus resulting in a strong energy in the decomposed wavefield. On the other hand, noise on a length scale shorter than the local operator (a) will appear as low energy in the decomposed wavefield. A data set containing only strong correlated events can be obtained by means of reconstruction using only those wavefield components that contain high correlated energy.

We acquired two different GPR data sets along an approximately 100 m long profile at the West slope of Turtle Mountain (for more details of the survey we refer to *Theune et al.*, 2005). The data were subsequently processed using a standard processing flow consisting of simple trace editing to correct for topographic effects, automated amplitude gain (AGC), and band pass filtering. A processed data set recorded using 50 MHz antennae system is shown in Figure 2a. We then applied Kirchhoff migration assuming a constant velocity of 0.08 m/ns (Figure 2c). The migrated data show strong reflectors dipping approximately 30° with respect to the slope surface, which correspond well with the dip of bedding plans at the part of Turtle Mountain. However, the presence of numerous other small-scaled reflections makes the interpretation of the data rather difficult.

To enhance coherent reflectors we decompose the GPR data set into 25 components. Each component is obtained by summing energy with in the data set along different paths of a fixed length. In the examples shown in Figures 1 and 2, the dip p varies between $p=\pm 56.4$ ns/m (equivalent to ± 9 time samples / distance samples), and the operator length was set to a = 5 spatial samples (corresponding to a length of 1 m). After decomposition, we reconstruct the data set by using only those components that contain the highest coherent energy. For example, to analyse only the reflectors that are dipping downward along the profile (indicated by arrows in Figure 1a) we use only four components with dips 4.7 ns/m, 9.4 ns/m, 14.1 ns/m, and 18.8 ns/m, respectively. These four components are shown in Figures 1b, 1c, 1e, and 1f. If all 25 components are included in the reconstruction (Figure 1d) the original data set is obtained (Figure 1a). We show the reconstructed data using only these four components in Figure 2b. Comparing the reconstructed data set with the original data in Figure 2a it is apparent that it is much easier to follow the major reflections in the data. In Figures 2c and d, we compare the migrated GPR data using a Kirchhoff algorithm with v_{mig}=0.08 m/ns. Figure 2c shows the original data after migration, and the migration results of the partly reconstructed are shown in Figure 2d. The reflectors of these particular dips are more continuous and thus easier to interpret.

Discussion and Conclusions

The application of generalised deconvolution to GPR processing demonstrates that a significant improvement of the analysis of "noisy" data can be achieved. The division of the data set into several components allows us to separate coherent reflectors from uncorrelated events that we consider as noise. After reconstructing the data only partially, a data set is obtained that enhances coherent linear reflectors. As we were interested in improving the image of long linear reflectors, we employed only the local linear Radon transform. However, diffraction hyperbolas could also be enhanced in a similar way by applying a local hyperbolic Radon transform. Applying generalised deconvolution to GPR images, which are equivalent to a non-migrated low-fold seismic CMP stack, was originally not considered as a possible application by *Sacchi et al.*, 2004. The examples in this paper demonstrate, that such a data decomposition is also a powerful tool when applied to GPR images.

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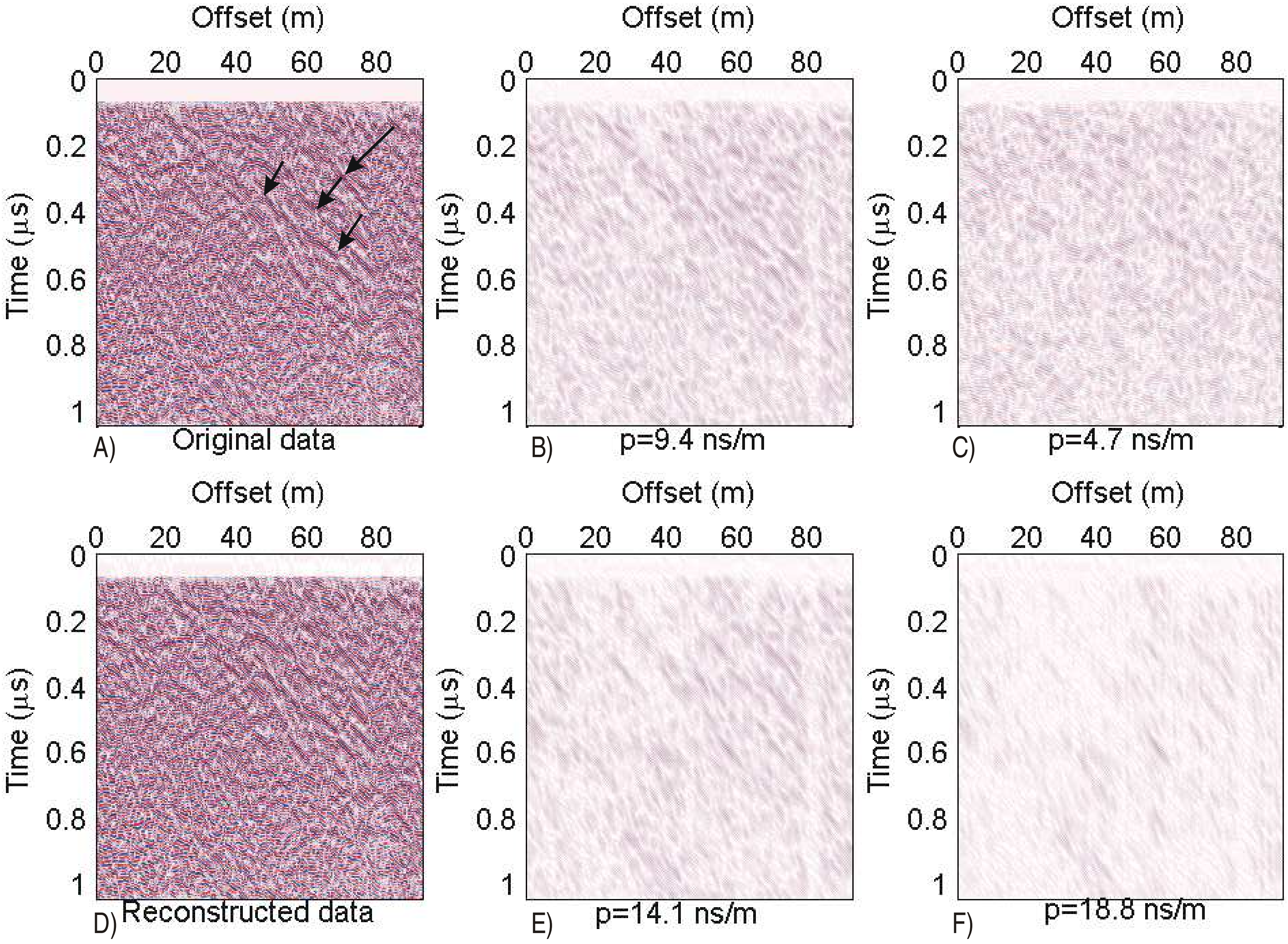

Figure 1 The original GPR data set is shown in panel A). Panel D) shows the reconstructed data using all components of the decomposition. The panels B), C), E), and F) show four components that are used to enhance the strong reflections in the original data indicated by arrows in panel A).

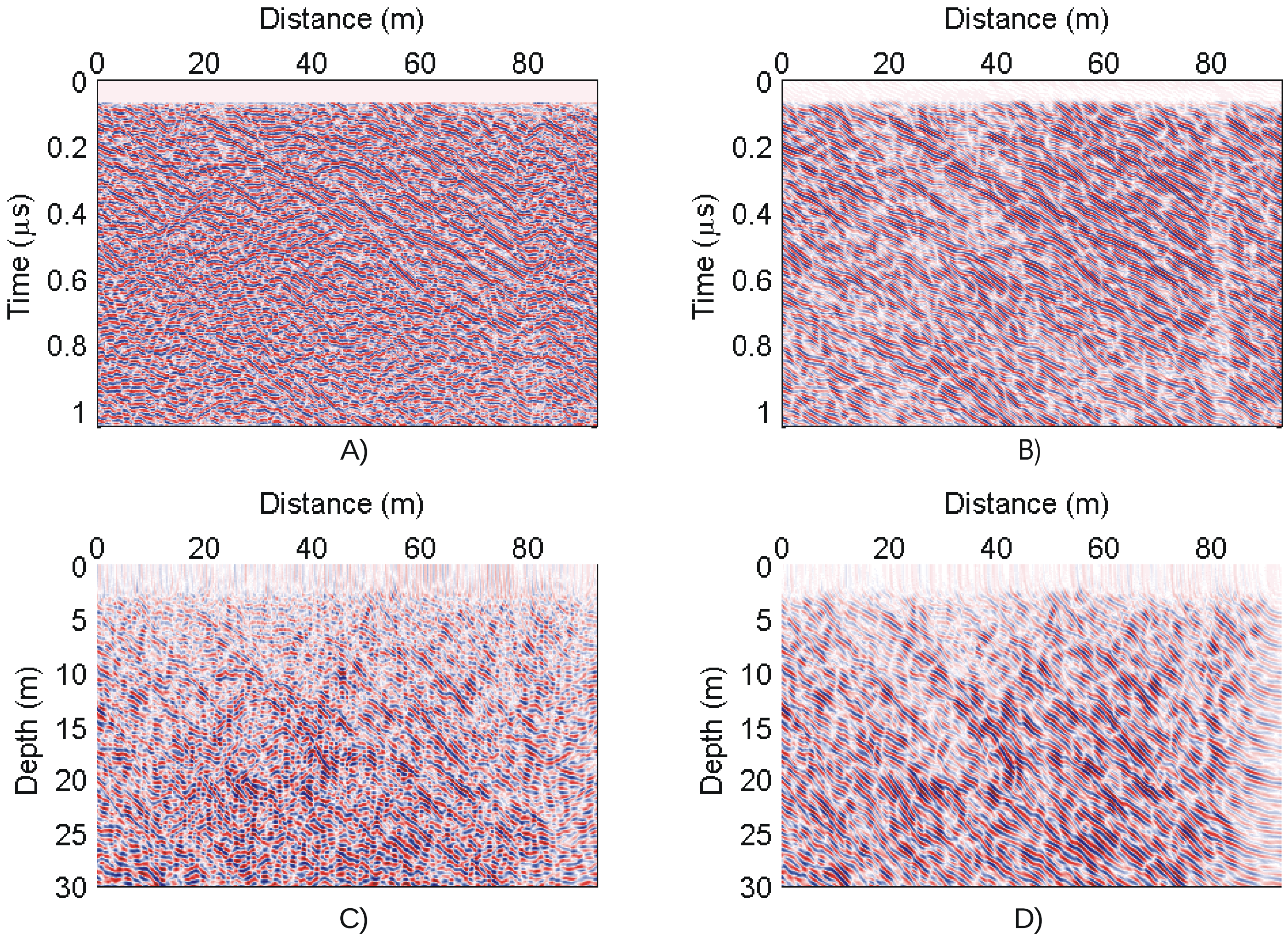

Figure 2 Comparision of the original data in the t-x domain (A) with reconstructed data to highlight the strong reflectors (B). In panels C) and D), we compare the the migrated data using the original data (panel C) and the partially reconstructed data (panel D). The vertical axis of the migrated data is two-times exaggerated.