Migration Deconvolution Applied to Marine Seismic Data from Campeche Bay, Gulf of Mexico
Guoan Luo, University of Utah; Sergio Chavez-Perez, IMP

Abstract
Migration deconvolution has been empirically shown to be an effective approach for decreasing migration imaging artifacts, improving spatial resolution, and alleviating acquisition footprint problems. Because of this, IMP and PEMEX, the Mexican Petroleum Institute and Petroleum Company, respectively, became interested in applying migration deconvolution to a relevant data set from a Gulf of Mexico field. Applying migration deconvolution to their 3D prestack migration image from Campeche Bay, Gulf of Mexico, shows that this method is indeed capable of noticeably improving spatial resolution and structural definition.

Introduction
Migrated sections are blurred images of the geologic reflectivity distribution, where the blurring kernel is the point spread function, also known as the migration Green’s function (Schuster and Hu, 2000). To partially remedy this blurring, the migration deconvolution (MD) approach was proposed and applied to a series of data sets including prestack and poststack seismic data, VSP data, and converted wave data by different authors (e.g., Hu, 1997, 2000a; Hu et al., 2001; Yu et al., 2003, 2006).

In this report we show the results of applying MD to Pemex’s latest prestack time migration cube from their Campeche Bay field, Gulf of Mexico (Mitra et al., 2005). Despite careful, in-house processing by PEMEX, the data may still have some residual multiples and acquisition footprint problems in the shallow part. The deeper part has low-frequency reflectors that are very important for interpreters. Applying the MD filters to their migration image shows a noticeable improvement in both spatial and temporal resolution, especially in the shallow zones of the image. However, some portions of the MD image did not show improved quality.

Migration deconvolution
The migration deconvolution equation can be expressed in matrix vector form by
\[ m = L^T L m_0, \]
where \( L \) denotes the seismic data forward modeling operator that relates the actual reflectivity model \( m_0 \) to the scattered seismic data \( d \), i.e., \( d = L m_0 \). \( m_0 \) denotes the true reflectivity vector, and \( m \) denotes the migration image that can be obtained by applying the adjoint \( L^T \) of the forward modeling operator to the data. Here, the transpose of \( L \) represents the migration operator.

Equation 1 says that the migration image \( m \) is a blurred version of the actual subsurface reflectivity distribution \( m_0 \). To deblur \( m_0 \), we apply \( \Gamma^{-1} = (L^T L)^{-1} \) to both sides of equation (1) to obtain
\[ m_0 = (L^T L)^{-1} m. \]

This deblurring operator \( \Gamma^{-1} \) can be obtained by calculating the migration Green’s function associated with the specified acquisition geometry and velocity model (Schuster and Hu, 2000; Hu et al. 2001).

To improve spatial resolution and illumination of the migration images from complex data, more care is needed to construct the appropriate migration Green’s function or MD filter \( \Gamma^{-1} = (L^T L)^{-1} \). For example, MD parameters (layer width and wavelet period) should be optimized by trial and error for successful results (Hu, 2000b; Yu, 2002; Yu et al., 2006). An important trick is to increase the layer width of the MD filter with increasing depth.

3D Poststack MD Results
MD processing aims to extract more structural information from the 3D Kirchhoff prestack time migrated cube provided to us by PEMEX. The original data size is 1001x801x1250 grid points, bin size is 25 m by 25 m, and time sampling interval is 4 ms. Due to memory problems, it is necessary to halve the size of the migration cube by decimating the inline and crossline sections and by reducing the number of time samples. After decimation, the spatial intervals of the migration images are 100 m, 100 m, and 8 ms in the X, Y, and T directions, respectively. The inline and crossline grid size of the migration cube for MD is 251x201 grid points, the MD filter length \( N \) is 15, and the reference position is in the middle of the model (Yu et al., 2006).

Figure 1 compares the time migrated slices before and after MD processing at 2.4 s. We see spatial resolution improvements in the MD images. Figures 2 and 3 compare migrated sections for the inline and crossline sections, respectively, before and after MD processing. We...
find that, for several regions, MD produces sharper sections with more detailed structural definition and yields better spatial resolution and illumination. This improvement can be seen in some of the portions of the section in the deeper target of interest.

Of course, there are portions in the MD images that show little improvement as compared with the original migration results. This is probably due to (1) the use of a constant velocity model for the design of the MD filter in this case, and (2) too large of a bin size. We believe that resolution improvements are due to the fact that the MD filter accounts for the limited frequency band of the source and the spatial aperture of the data, and tends to transform a sinc function response into a point-like object. Thus, spatial resolution increases and the wavenumber spectra of the time slices is whitened.

Summary

We applied 3D MD to a stacked cube of 3D prestack time migrated images from the Campeche Bay oil field, Gulf of Mexico. Examples demonstrate that MD improves spatial resolution and structural definition. Ongoing and future work include the use of 3D prestack MD for this data set, and the development of a faster approach to design the MD filter. We should also use larger offsets (and larger apertures) or a smaller bin size to design the MD filter. This would help to improve the stability and overall performance of MD for complex 3D velocity models.

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References


Figure 1: Migration time slice result at 2.4 s (top) before and (bottom) after MD processing.
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Figure 2: Prestack time migration results in inline direction (top) before and (bottom) after MD processing.
Figure 3: Prestack time migration results in crossline direction (top) before and (bottom) after MD processing.
REFERENCES