Windowed GSP (Generalized Screen Propagators) Migration Applied to SEG-EAEG Salt Model Data

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Summary

A windowed GSP (Generalized Screen Propagators) migration method is applied to the Amoco synthetic data for the 2D slice A-A' from the SEG-EAEG salt model to test the accuracy, stability and wide-angle capacity of the method. The migrated image is compared with the popular f-x and Kirchhoff methods and shown better quality than both the latter methods. Not only most of the subsalt structure is reconstructed clearly, but also the nearly vertical reflectors, including the steeply dipping interfaces and the reflecting faults which are missing in the f-x migrated image, are correctly imaged. This demonstrates the potential applicability of the GSP migration method to subsalt structure mappings. However, some migration noises still exist, indicating the necessity of further improvement of the wide-angle capacity of the method.

Introduction

The difficulty in seismic migration of data from the Gulf of Mexico is well known. The high-velocity (as high as 3-4 times of the surrounding media) and irregular salt bodies are the obvious culprit for the bad images of the subsalt structures. The recently developed SEG-EAEG Salt Model and the related synthetic data can be used to test and improve various migration methods. Since Michael J. O'Brien and Samuel G. Gray has done some rather comprehensive study on a 2D slice, profile A-A' of the 3D SEG-EAEG model (O'Brien and Gray, 1996), we will use the same 2D slice and the same synthetic zero-offset data to test our GSP migration method and compare with the popular Kirchhoff and f-x methods.

Brief Description of the Method

The generalized screen propagators (GSP) are one-way wave extrapolators. It can be derived from the phase space path-integral formulation which provides a general and convenient background for accuracy estimation and improvement. Solutions of one-way wave equation can be represented by Hamiltonian path-integrals (phase space or "dual-domain" path-integrals). The GSP is an approximate realization of the phase space path integral, which involves a perturbation approach to the vertical slowness left sym-

bol and a high-frequency asymptotic matching of the approximated path integrals. For detailed derivation and discussion see Wu (1994, 1996), Wu and De Hoop (1996), De Hoop and Wu (1997). The method has been applied to poststack and prestack depth migration (Wu and Xie, 1994; Huang and Wu, 1996). The algorithm is a dual domain technique which shuttles between the wavenumber domain and the space domain. In the traditional phase-screen method (Stoffa et al., 1990), the wave propagates in the wavenumber domain and interacts with the heterogeneities in the space domain. For the newly developed wide-angle pseudo screen method (Wu and De Hoop, 1996; Huang and Wu, 1996), the interaction takes place in the space domain, but with an angular correction in the wavenumber domain. The method works well for weak contrast media. However, in the case of strong contrast media, such as the salt dome related structures where the velocity of salt can be 3-4 times higher than the surrounding media, the global nature of the background velocity selection makes the method less accurate and even unstable in some cases.

In this work we propose and develop a windowed GSP method to overcome the shortcomings of the global Fourier method. We combine the windowed Fourier transform (e.g. Kaiser, 1994) and the interpolation technique (Gazdag and Sguazzero, 1984), aiming at improving both the accuracy and computational efficiency.

The dual domain implementation of the windowed GSP can be expressed by following equation for each step in the propagation direction (here, along the z - axis):

$$P(x_T, z) = \int d\bar{x}_T W^*(x_T - \bar{x}_T) \frac{1}{2\pi} \int dK_T e^{iK_T \bar{x}_T} e^{ik_z^0(K_T, \bar{x}_T) \Delta z} \int dx'_T e^{-iK_T x'_T} W(\bar{x}_T - x'_T) e^{i\Delta k_z(K_T, x'_T) \Delta z} P_0(x'_T, z') \quad (1)$$

where $W(x_T)$ is the window (or weighting) function with its norm $\|W\| = 1$, W^* is the complex conjugate of W , $k_z^0(K_T, x_T)$ is the background wavenumber using the average velocity within the window centered at x_T . P_0 is the incident field at the beginning of the step, $e^{i\Delta k_z \Delta z}$ is the phase correction and $\Delta k_z(K_T, x'_T)$ is the wavenumber perturbation corresponding to the interaction of the wavefield with the heterogeneities and

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can be approximated with different schemes. For the phase-screen approximation, it is simply the slowness perturbation multiplied by the frequency.

For the salt model, the velocity distribution can be windowed into a few blocks. We use wide windows with large overlapping areas. In those overlapping areas, we modify the window weighting summation into an interpolation summation

Migration Result and Comparison With Other Methods

Figure 1 shows the synthetic zero-offset data of a 2D profile A-A' of the SEG-EAGE salt model (Figure 2) using a finite difference exploding reflector modeling algorithm, generated at AMOCO. The 2D slice of the salt model, which crosses many of the difficult structural elements in the model, steep, shallow salt flanks, divergence between the top and base of salt, and abrupt dip changes where the faults are located, should all pose challenges to imaging methods. The upper and middle panels of Figure 3 show the results from a space-frequency domain f-x migration and a Kirchhoff migration by AMOCO (courtesy of M. O'Brien and S. Gray), respectively. The f-x algorithm used is an explicit f-x extrapolator using spatial convolutions (Hale, 1991; Nautiyal et al., 1993). We see that it did a fairly good job for this difficult case. Most of the subsalt structure is reconstructed clearly and has less migration noise than the image from the Kirchhoff migration (middle panel). However, there are portions of subsalt structures that did not show up. Reflecting fault planes at points D and E, as well as the dipping reflector at point F are missing. For the Kirchhoff migration (middle panel), almost all new-vertical subsalt structures, including the steeply dipping interfaces and the reflecting fault planes are not well reconstructed or totally missing. Coherent noise from incorrectly migrated fields are strong under the salt body. Furthermore, some false faults appeared due to the interference of coherent noises, such as the false fault on the left of the E-fault which itself is missing.

Our result using the windowed GSP migration is shown in the bottom panel of Figure 3. Not only most of the subsalt structure is reconstructed clearly, but also the nearly vertical reflectors, including the steeply dipping interfaces and the reflecting faults, some of which are missing even in the f-x migrated image, are correctly imaged. D, E and F reflectors all showed up. Especially the E fault appeared clearly and in the correct position. Because of the accurate image of the E fault, the coherent noise around that fault is much reduced and therefore the curved reflecting interface between E and F is also correctly imaged. This demonstrates the potential applicability of the

Figure 1: Zero-offset seismic section of SEG-EAGE salt model generated by exploding reflector simulation (Courtesy of O'Brien and Gray, Amoco)

GSP migration method to subsalt structure imaging. However, some migration noises still exist, such as the false image to right of the E fault and other faint rings, indicating the necessity of further improvement of the wide-angle capacity of the method.

Conclusions

A windowed GSP (Generalized Screen Propagators) migration method is introduced and tested using the Amoco synthetic data for the 2D slice A-A' from the SEG-EAGE salt model. The migrated image has better quality than those from the conventional f-x and Kirchhoff methods. Not only most of the subsalt structure is reconstructed clearly, but also the nearly vertical reflectors, including the steeply dipping interfaces and the reflecting faults which are missing in the f-x migrated image, are correctly imaged. The Kirchhoff method missed almost all the nearly vertical subsalt structures and has distorted images even far flat subsalt interfaces. The windowed GSP image also has much less migration noise than the Kirchhoff image. This demonstrates the potential applicability of the GSP migration method to subsalt structure mappings. However, some migration noises still exist, indicating the necessity of further improvement of the wide-angle capacity of the method. The efficiency of the method will be discussed in future publications.

Figure 2: A-A' Profile of the SEG-EAEG salt model crosses many of the more difficult structural elements in the model (Courtesy of O'Brien and Gray, Amoco)

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Figure 3: Comparison of F-X migration (upper panel), Kirchhoff migration (middle panel) and windowed GSP (generalized screen propagator) migration (bottom panel) on the synthetic data of A-A' profile of SEG-EAEG salt model. (The upper two panels are from O'Brien and Gray, Jan., 1996, "Leading Edge")