Summary
The generalized screen propagator (GSP) is a one-way wave equation based wide-angle wave propagator. It can be used for high quality imaging in complex geological structures. Algorithms for both shot-domain and offset-domain data set have been developed. In this paper, the advantages of the GSP are briefly reviewed. 3D prestack depth migration examples using synthetic land and marine data sets are presented.

Introduction
The phase screen method (split-step Fourier method), is based on the one way wave propagation theory. It can be used as a fast propagator for seismic migration (Stoffa et al., 1990; Wu and Xie, 1994). The derivation of screen method is based on the smallness of velocity perturbation and propagation angle. However, real models used in imaging practice may contain very large velocity contrasts. Under these situations, the conventional phase screen method can give correct phase only for small angles, and cannot generate satisfactory results.

Several attempts have been made to improve the wide-angle capability of the screen method. The Fourier finite-difference method (Ristow and Ruhl, 1994), the generalized screen propagator (Xie and Wu, 1998, 1999; Jin et al., 1998, 1999) and the globally optimized FFD method (Huang and Fehler, 2000) all use finite-difference method to compensate the wide-angle error from the phase screen solutions. Generally speaking, these methods can propagate wide-angle waves quite accurately in strong contrast models and generate high quality image in complex geological structures. Other methods are also proposed to improve the wide-angle accuracies. For example, De Hoop, et al. (2000) gave a general formulation for screen method. Based on their formulation, the accurate solution can be obtained by summing higher order terms in a series. Huang et al. (1999) suggested an extended local Rytov method to improve the screen solution.

The generalized screen propagator (GSP), includes the hybrid pseudo screen method (Jin, et al., 1998, 1999) and wide-angle version based on Pade approximation (Xie and Wu, 1998, 1999). Both of them are wide-angle one-way propagator with implementation in dual domains. The waves propagate with a background velocity in wavenumber domain and interact with the lateral heterogeneities in the space domain. A finite-difference method is used to do the wide-angle correction. The method neglects reverberations between heterogeneities but correctly handles multiple forward scatterings, focusing-defocusing and multi-pathing, etc. The GSP can be used for migration imaging in complex geological structures with large lateral velocity perturbations.

There are two types of observation configurations used in the exploration practice, land survey and marine survey. For land type surveys, the number of shots is usually considerably less than that used in marine type surveys. To efficiently process these data sets, the GSP has been adapted for these purposes. A conventional shot gather algorithm has been developed to process land type data set (Xie, et al. 2000). An offset domain GSP method is also developed for processing the marine type data set (Jin and Wu, 1999; Jin et al., 2000). The double square root equation for laterally varying media in midpoint-offset coordinates provides a convenient framework for developing efficient 3D prestack wave equation depth migration with screen propagators. Both shot-domain and offset-domain methods give better results than the Kirchhoff migration or the first order phase screen method.

In the following section we will test a 3D land type synthetic data, and a 3D marine type synthetic
data with the GSP to show its excellent performance in migration/imaging.

![Accurate phase screen](image1)

![Two-way splitting](image2)

**Figure 1.** Impulse responses using different methods.

**Depth migration of 3D data set**

**Impulse response tests.** To test the wide-angle accuracy of a generalized screen propagator, we calculated impulse responses using different propagators. A constant velocity of 3000 m/sec is used in the test. We choose \( V_o = 1500 \) m/sec as a reference velocity. That means the velocity perturbation is 100%. Figure 1 shows the impulse responses from accurate solution, phase screen solution, as well as wide-angle solutions using two-way and four-way splitting GSP. The depth slices presented here are wave fields at about 55 degree incident angle. It can be clearly seen that phase screen method generates very large error at this angle with such a velocity perturbation. Compared with the phase screen method, GSP solutions give much better wide-angle accuracies. The wave fields are very close to the accurate solution. Compared with the two-way splitting, the four-way splitting method used in the finite-difference compensation considerably eliminates the numerical anisotropy caused by the rectangular grid.

**Figure 2.** Comparison of 3D migration images using different methods. The profile is located at \( X = 7700 \) m. From top to bottom are velocity model, migration image using phase screen method, and image using GSP method, respectively.

**Prestack migration for shot gather data.** Figures 2 and 3 show results of applying shot-gather migration to the 3D SEG/EAGE Salt Model. The data were generated by Sandia National Laboratory as part of the ACTI project (Ober et al., 1997). The data is a typical land type data set, with a total of 45 shots (5 lines with 9 shots per line). Each shot is recorded by an array of 201 x 201 receivers. The receiver space is 20 m. Shots are spaced 1000 m in X and Y, and selected to cover approximately the same region as the SEG/EAGE Salt Model C3 subset (Aminzadeh et al., 1997). The input data are sampled at 8 ms with record length 4 sec, and usable frequency bandwidth is in the range 1 to 30 Hz.
Shown in Figure 2 are results for in-line 386 (X=7700 m). From top to bottom are velocity model, images from phase screen propagator and the GSP propagator. The image generated with GSP method gives much better lower boundary for the salt body. The base reflector and sub salt noise are also improved. These improvements result from that after passing through the irregular high-speed salt body, the GSP recovered the wave front better than the phase screen method. Images shown in Figure 3 are depth slices at Z=2100 m. From top to bottom are velocity model, images from phase screen propagator and the GSP propagator. Compared with the velocity model, the GSP gives much better image than the phase screen method. The salt bodies can be clearly seen in the bottom panel, but they are hardly seen in the phase screen image.

Migration for marine type data set. The second example shows results from the 3D SEG/EAGE Salt Model C3 Narrow Azimuth subset. This is a typical marine data set. The result of AMO processing is a series of regularly sampled 3D common-offset, common-azimuth volumes. The offset domain GSP takes common offset volumes as input, and produces a 3D zero-time, zero-offset image volume as output. Sample results are shown in Figure 4. Figure 4a shows a profile from the 3D velocity model (In-line 289 at X=5760 m). Figure 4b shows the same slice from the offset-domain phase-screen image, and Figure 4c shows the same slice for the GSP image. The GSP image shows significant improvements in both the base salt reflector and in structures below the salt body.

Figure 3. Comparison of 3D migration images using different methods. The profile is located at Z = 2100 m. From top to bottom are velocity model, migration image using phase screen method, and image using GSP method, respectively.

Figure 4. 3D prestack depth migration of SEG/EAGE C3 salt model. The top panel is the velocity model for In-Line 289, X=5760 m. The middle panel shows the migration result of phase screen method (split-step Fourier method). The bottom panel is the migration result obtained using GSP method.
Depth ranges from 0 to 4000 m, and X-Line (model Y-coordinate) ranges from 700 m to 8700 m.

Conclusions
The generalized screen propagator (GSP) is a one-way wave equation based wide-angle wave propagator. It can be used for high quality imaging (migration) in complex geological structures. Algorithms for both shot-domain and offset-domain have been formulated. Synthetic land and marine data sets are tested with these methods. Results from 3D prestack depth migrations show that this is a high resolution and high quality method. When applied to marine data set based on the offset-domain formula, it is also a very fast method with its efficiency compatible with the Krichhoff method. The future work will be focused on reducing the noise level and improving the image of sub-salt structures.

Acknowledgements
The supports from the Basic Energy Science Branch of the Department of Energy and from the WTOPRI Research Consortium at UCSC are acknowledged. The facility support from the W.M. Keck Foundation is also acknowledged.

References