Study Of Ocean Bottom Interactions With Acoustic Waves By A New Elastic Wave Propagation Algorithm And An Energy Flow Analysis Technique

Ru-Shan Wu
Institute of Tectonics, University of California
Santa Cruz, CA 95064
phone: (831)459-5135 fax: (831)459-2423 email: wrs@es.ucsc.edu

Xiao-Bi Xie
Institute of Tectonics, University of California
Santa Cruz, CA 95064
phone: (831)459-5094 fax: (831)459-2423 email: xie@es.ucsc.edu

Grand Number: N00014-95-1-0093
Category: Shallow-Water Acoustics
http://www.es.ucsc.edu/~acti

LONG-TERM GOALS

Develop a new method and the code to simulate 3D acoustic/elastic wave propagation and interaction with the ocean water and ocean bottom environment. The method will be applied to numerical simulations and imaging to study the wave/sea-bottom interaction, energy partitioning, scattering mechanism and other problems that are crucial for many ocean bottom-surveying techniques. Our understanding of shallow water acoustic wave propagation and its interaction with sediments can be improved.

SCIENTIFIC OBJECTIVES

Improve and develop the ECS (Elastic Complex-Screen), a new one-way elastic wave propagation method, and apply it to the ocean bottom environment to study the elasto-acoustic wave propagation in complex laterally heterogeneous media, including rough interface and random volume heterogeneity.

APPROACH

The basic approach is to connect the acoustic phase screen algorithm and elastic complex screen algorithm with a boundary condition, which may permit certain types of roughness. With this method, the acoustic signal can propagate all the way through seawater and solid bottom. Reflections from both water and sub-bottom structures can also be calculated and propagated upward to the surface. A free surface condition can be added at either the source side or receiver side.

WORK COMPLETED

In the current year, the wide-angle modification for scalar screen propagators has been extended to the elastic case. Compared with the original elastic screen method, the new approach gives much more accurate phase for models with large velocity contrast and for wide propagating angles. The new method offers us an improved one-way propagator for elastic wave modeling and imaging. We derived

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **Study Of Ocean Bottom Interactions With Acoustic Waves By A New Elastic Wave Propagation Algorithm And An Energy Flow Analysis Technique**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of California at Santa Cruz,Institute of Tectonics,Santa Cruz,CA,95064**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

the formulas for the new method. We also generated the code and conducted numerical experiments using the new method in wave propagation modeling.

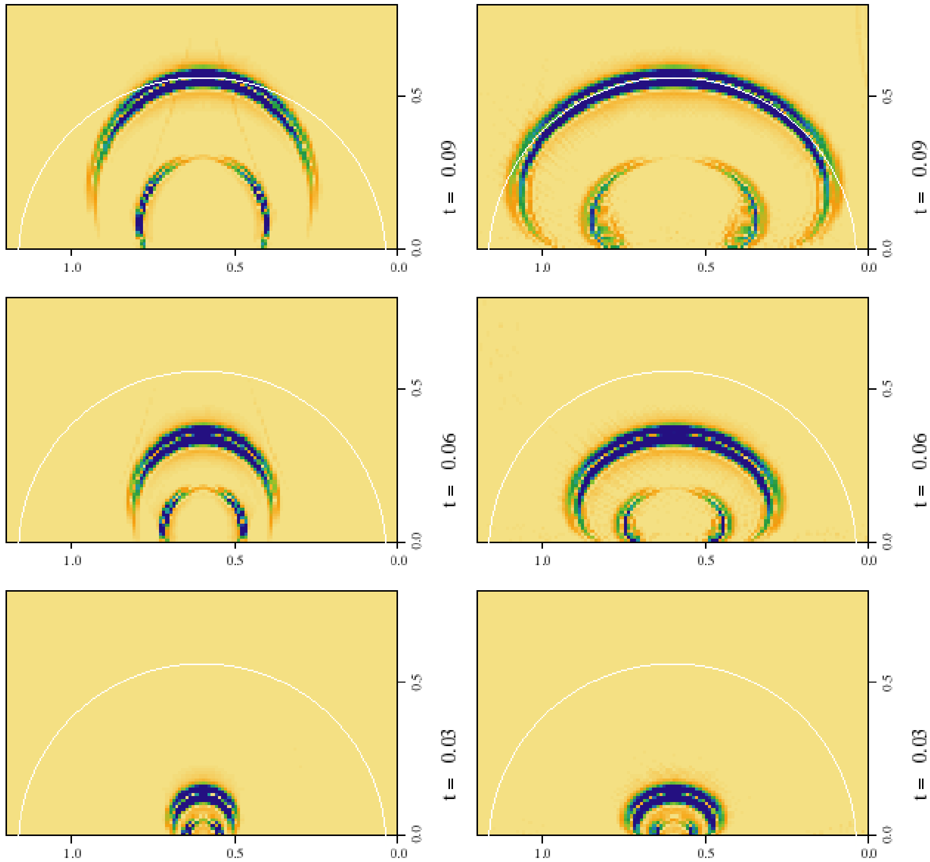

Figure 1. Comparison between wave fields calculated using conventional elastic screen method (left) and its wide-angle version (right). The velocity perturbation is 100%. The wide-angle wave front is considerably improved.

RESULTS

The elastic screen method (Wu 1994, 1996, Xie and Wu, 1995, 1996, Wu and Wu, 1998) is based on the one-way wave equation and small angle, small perturbation approximations. It provides an efficient way for calculating the propagation of elastic waves in a laterally heterogeneous model. However, for models with large velocity perturbations, the elastic screen method often gives large phase error at wide scattering angles. In this study, the wide-angle modification method for scalar wave (Xie and Wu, 1998) has been adopted to elastic waves. For the elastic screen method, the calculation of wave propagation can be separated into two steps, P- and S-wave coupling through their interaction with heterogeneities, and their propagation in the background velocities. Having obtained the coupling terms, the P- and S-waves can propagate through the homogeneous background velocity independently, i.e., their propagations are decoupled. This permits us to modify P- and S-wave propagations separately, and the technique used in the scalar wave propagation can be adopted.

Numerical tests have been conducted for forward modeling. Figure 1. shows the comparison between wave fields calculated using narrow-angle elastic screen method (left) and wide-angle elastic screen propagator (right). The velocity perturbation is 100%. Semicircles indicate where the correct wave front should be. The results show that the new method gives results that are much better than those using the original elastic screen method, and this new method can be a very useful propagator in modeling/imaging where large velocity contrasts exist.

IMPACT/APPLICATION

The elastic screen method is based on the one way wave equation method. It can be used as a high efficiency propagator for forward propagation (Wu, 1994; Xie and Wu, 1995, 1996; Wu 1996; Wu and Wu, 1998) or seismic migration (Wu and Xie 1994). The derivation of elastic screen method usually requires that the velocity perturbation is small or the incident angle is small. However, the real models may contain very large velocity contrasts. Xie and Wu (1998) derived a new phase screen propagator for the acoustic wave, which can handle large velocity contrast and wide propagation angles. The new propagator developed in this study extends the wide angle and large velocity perturbation capabilities from acoustic wave to elastic waves. The new elastic wave propagator can be directly applied to wave propagation and migration under large velocity perturbations and wide propagation angles. This greatly increased the modeling and imaging capabilities of the elastic screen method in models with large velocity contrasts.

TRANSITIONS

None

RELATED PROJECTS

The ONR supported project is part of research conducted in the Modeling and Imaging Project (MIP) at University of California, Santa Cruz. The MIP is co-sponsored by DOE, DOD/DTRA, ONR, GRI, NSF and some industrial companies. The MIP is aiming at developing new theories, methods and algorithms for modeling and imaging in 3D complex environments. This project emphasizes the fast one-way propagation methods, and also searches for the application of newly developed technologies, such as the wavelet transform, in the wave propagation theory.

REFERENCES

Web page for MIP (Modeling and Imaging Project) at UCSC
http://www.es.ucsc.edu/~acti

Wu, R.S., 1994, Wide-angle elastic wave one-way propagation in heterogeneous media and an elastic wave complex-screen method, J. Geophys. Res., 99, 751-766.

Wu, R.S., 1996, Synthetic seismograms in heterogeneous media by one-return approximation, Pure and Applied Geophys., 148, 155-173.

Wu. R.S. and Xie, X.B., 1994, Multi-screen backpropagator for fast 3D elastic prestack migration, Mathematical Methods in Geophysical Imaging II, SPIE, 2301, 181-193.

Xie, X.B. and Wu, R.S., 1995, A complex-screen method for modeling elastic wave reflections, Expanded Abstracts of the Technical Program, SEG 65th Annual Meeting, 1269-1272.

Xie, X.B. and Wu, R.S., 1996, 3D elastic wave modeling using the complex screen method, Expanded Abstracts of the Technical Program, SEG 66th Annual Meeting, 1247-1250.

Wu, X. and Wu, R.S., 1998, An improvement to complex screen method for modeling elastic wave reflections, Expanded abstracts, SEG 68th Annual Meeting, 1941-1944.

PUBLICATIONS

Xie, X.B. and R.S., Wu, 1998, Improve the wide-angle accuracy of screen method under large contrast, SEG 68th annual Meeting, Technical Program, Expanded Abstracts, 1811-1814.

Xie, X.B. and R.S. Wu, 1999, improving the wide angle accuracy of the screen propagator for elastic wave propagation, accepted: SEG 69th Annual Meeting.

Wu, R.S. and X.B. Xie, (editors), Modeling and Imaging Project, Technical Report No 4 Institute of Tectonics, University of California, Santa Cruz, 1998

Wu, R.S. and X.B. Xie, (editors), Modeling and Imaging Project, Technical Report No 5 Institute of Tectonics, University of California, Santa Cruz, 1999

Wu, R.S. and X.B. Xie, (editors), Modeling and Imaging Project, Technical Report No 6 Institute of Tectonics, University of California, Santa Cruz, 1999