A fast non-local transform-domain method for seismic random noise attenuation

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All of the seismic data include different amounts of seismic random noises, even after doing a comprehensive seismic data processing. This results in lower signal to noise ratio (SNR), or in other word, lower quality of seismic data. Because of the time consuming processes of methods for doing seismic random noise attenuation, data processing companies don’t perform additional processing for attenuating of random noises after doing conventional methods like stacking and applying some filters. BUT, what about a very fast method which increases SNR both in pre-stacked and post-stacked data, significantly? Here, in this study we introduce an algorithm which is called ‘Fast 3D Block Matching (F3DBM)’ which combines the advantages of non-local and transform-domain denoising methods. This method has superior capability for preserving discontinuities presented in seismic data both qualitatively and quantitatively. We compare the ability of F3DBM with that of the state-of-the-art curvelet-based seismic denoising method for random noise attenuation both in pre-stacked and post-stacked data.

Keywords: Random noise, Block matching, Curvelet-based denoising method, Pre-stacked and post-stacked seismic data denoising

Seismic scattering for a point scatterer -With a special interest to the application in Exploration Geophysics-

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Seismic scattering is key phenomena to deal with seismic survey data using reflection, diffraction caused by the inhomogeneities in a medium where seismic waves travel through. Scattered seismic waves are in general exploited using the first order Born or Rylov approximation to inhomogeneous Helmholtz equation to weak inhomogeneites or contrasts in elastic parameters, i.e., two Lame's constants and density, that could have distribution to break the assumption of weak contrast in practice. When the order of such inhomogeneities increases, only a spherical inclusion of inhomogeneities has been studied although a point scatterer is preferred to treat seismic scatterers as point scatterers to satisfy the wave equation including virtual seismic sources in our conventional seismic surveys In this study, an elastic scattering theory is presented to express scattered seismic waves generated by a point scatterer to incident both compressional and shear waves. We first obtained a small spherical inclusion of inhomogeneities in a uniform medium and then take the smallest limit of the diameter of the inclusion. Our results show that the scattered waves are similar to what has been obtained for a weak contract case but differs in terms of the combination of elastic parameters. Based on our results, we may use the solution of our scattering equation directly in the inhomogeneous wave equation as a scattering Green's function.

Keywords: Compressional Waves, Point Scatterer, Green's Function

Full waveform inversion with elastic scattering theory

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The waveform analysis is a powerful tool to investigate the physical properties at high resolution in the areas of interest. Since the wave propagation is influenced by all elastic parameters, it is necessary to include these parameters in the inversion. On the other hand, multi-parameter FWI is a challenging problem because plural elastic parameters increase the dimension of the solution space, in other words the desensitization of each parameter occurs. Some authors used a preconditioned gradient method based on approximate Hessian that takes both the radiation pattern that is dependent on each parameter and geometrical spreading into account in order to discriminate the influence of parameters that could relax the desensitization. However, such methods need to solve so many forward calculations that the computational becomes costly. We suggest a new preconditioned gradient method that seeks preconditioning operator derived from a seismic scattering theory instead of applying many forward calculations to reduce the desensitization.
We incorporate a preconditioning operator of each kinematic parameter, i.e., either of two Lame constants or density based on the scattering theory in 2D frequency-domain FWI. We conduct numerical experiments to compare the results using the new method with those from a conventional method. A single anomaly model with one anomalous block and a model with two anomalous blocks with different anomalous values are used to confirm the performance of the new method and the crosstalk among the kinematic parameters. These results show that our new method could estimate the desired parameter values and minimize the cross-talk. Moreover, complex structure models with free a surface are also used to evaluate the capability of the method in more realistic data that includes the surface wave. Results of our method show that the new preconditioning method could estimate the anomaly in the deeper part of the model because of the sensitivity that is increased after the reduction of the influence of the surface waves. All results indicate this method is advantageous in respect to both the reliability in the estimation and the computational efficiency over the conventional techniques.

Keywords: Full waveform inversion, scattering theory, Preconditioning

Seismic velocity monitoring using ambient noise observed by DONET seismometers in the Nankai Trough, Japan

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Subduction zones, where a tectonic plate subducting beneath the other plate, megathrust or interplate earthquakes could be generated repeatedly. Because of the nature of interplate earthquakes, the process of plate subduction governs the distribution, mechanics, and style of slip along the interplate fault. At the Nankai Trough subduction zone, located beneath the Pacific Ocean off the southeast coast of Japan, we have installed a seismic observation system, named DONET (Dense Oceanfloor Network system for Earthquake and Tsunamis), which is composed of twenty seafloor broadband seismometers and a borehole vertical seismic array to monitor the seismic activity and the process of earthquake generation including the stress accumulation.
To elucidate earthquake generation and preparation process, it is necessary to investigate how the stress could be accumulated not only in deeper part but also in the shallow sediments, what the role of interstitial fluid could be in the stress accumulation processes, etc. There are some conventional methods to measure these physical properties, such as borehole strainmeter, borehole breakouts or borehole dynamic tests. However, these methods have some difficulties from the viewpoints of technical and/or cost. For example, borehole breakouts and dynamic tests can be conducted only while drilling and/or immediately after that. Therefore we need to have some other methods to see the state and variation of the stress in the subseafloor.
In this study, we applied seismic interferometry technique to ambient noise records observed by horizontal components of DONET seafloor seismometers to obtain time dependent S-wave velocity and its anisotropy as a proxy of stress state below each DONET observatory. We first calculated cross-diploe 4-C pseudo shot records from every 1 hour ambient noise records observed by horizontal components of DONET seismometers. More than 8700 traces for each 4-C component were obtained from 1 year continuous data. Obtained 4-C shot records are then stacked every 48 hours. Clear phases, which should be caused by S-wave anisotropy, are visible in off-diagonal components. We then evaluated time variation of S-wave velocity below each observatory by using phase variation of reflected waves from the bottom of the shallow sediment layer. Alford rotation method was also applied to the 4-C shot records to obtain S-wave anisotropy parameters, directions of fast S-wave and time lag between fast and slow S-wave velocities below each observatory. Although, further analysis and discussion, such as error analysis and more quantitative discussion of the relationship between S-wave anisotropy and stress, we expected that our method can be a simple tool to monitor stress state in the Nankai Trough seismogenic zone.

Keywords: Nankai Trough, velocity monitoring, ambient noise

Developing Initial Model for Seismic Full Waveform Inversion Using Conventional Data Processing Tools

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Full waveform inversion (FWI) of seismic reflection data is a powerful tool for high resolution subsurface modeling. Despite of demanding computational resources, the method has shown successful applications both in industrial and academic fields. Since the high performance machines and sophisticated parallel processing algorithms are now readily available, we believe FWI is capable to be used as a part of seismic data processing routines. In order to check the possibility of using FWI in conventional data processing, we evaluated the effect of different initial models on inversion results. We developed new initial models for full waveform inversion using horizon-guided well interpolation and compared it against initial velocities converted from stacking velocities with and without dip move-out (DMO) correction. Acoustic full waveform inversion results from Marmousi2 model showed that when the subsurface structure has strong dips, interval velocities which are converted from stacking velocity fail to initialize FWI properly. However, applying dip move-out (DMO) correction on the seismic data will relax the dip complexities in the velocity analysis stage and a good initial model for FWI could be developed. On the other hand, horizon-guided well interpolation uses velocities derived from well logs and makes an interpolated velocity model along the picked horizon. This makes a good initial velocity model for full waveform inversion which ensures the convergence to the correct solution. As a result, our new initial model confirmed that full waveform inversion could be included in the data processing sequence to develop high resolution velocity model for depth imaging.

Keywords: Full Waveform Inversion, Initial Model, Horizon Interpolation

