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Possibility of timelapse survey by seismic interferometry in image domain

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(1) Seismic interferometry in image domain

Seismic interferometry (SI) is generally applied in a data domain by crosscorrelating the different seismic traces without information of media for a redatuming or a signal extraction. Then the synthesized virtual source records are processed for a subsurface imaging. The direct subsurface imaging of passive seismic data by interference of extrapolated wavefields based on an imaging condition can be recognized as a SI in the image domain. Although the image domain SI is based on the velocity model for wavefield extrapolation, the fact that both the passive observation data and the velocity model are required for the depth imaging is common in the data domain SI and the image domain SI.

In the SI in the image domain by combining with the principle of a reverse time migration (RTM), arbitrary time-windowed seismic record is propagated forwards from a receiver point which become a virtual source and the same time-windowed records are propagated backwards from other receiver points. If any multiple reflection waves between the surface and the reflection boundaries satisfy the imaging condition, the reflected energy will be focused on those points. Because the seismic records of all receivers in one passive observation are not independent each other, the wavefield extrapolations can be only once in forward and backward respectively. In the data domain SI, however, the forward and backward extrapolations are repeated over all receiver points in a final RTM, because the virtual source records synthesized by the crosscorrelation should be treated independently. Therefore, total computational cost of the image domain SI could be lower than the data domain SI.

(2) Applicability to a time-lapse study of passive

Passive seismic monitoring or time-lapse survey using permanent observation systems are one of recent research topics. Although high repeatability can be kept in the active seismic survey both on sources and receivers, any repeatability on sources is not guaranteed in the passive seismic survey. In this study, numerical simulation is demonstrated to evaluate the repeatability of the subsurface image and the possibility of extracting a small temporal velocity change by image domain SI with passive seismic data. In this simulation study, simple assumptions with an acoustic wavefield and a same mechanism for all sources are introduced. The passive seismic data for different condition of source distribution or/and velocity perturbation are synthesized, and then the image domain SI is applied for each data set. The repeatability of imaging and the possibility of extraction are measured by some repeatability indexes.

The passive observation records are synthesized using modified overthrust model of SEG/EAGE (15 km x 5 km) with 151 receivers on the surface due to independent 128 sources in the ground (Ricker wavelet with 10 Hz). The sources in the ground are randomly distributed for each model respectively. A velocity change with 10 percent decrease is added in an anticline structure around the center of the model with an elliptical shape (1 km x 0.1 km). A smoothed model from the true velocity model is commonly used for each RTM.

From the simulation study, the global images of the overthrust model are well reproduced in appearance for the different source distributions. However, the repeatability indexes show that the amplitude change due to the source distribution difference is too large to ignore even though the small velocity change can be extracted. Some additional techniques are required to extract only the velocity change without the influence due to the source distribution difference. In addition, there are other difficulties in a real data such as different source mechanism, elastic effects, and some kinds of noises.

Keywords: seismic interferometry, timelapse, reverse time migration