Development and applications of 3D ambient noise tomography

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In a microtremor array measurement, receivers are usually placed on a center and the circumference of a circle or a center and the vertexes of a triangle to observe ambient noise from omni-directions for 1D S-wave velocity delineation. We developed 2D/3D ambient noise tomography as an extension of the normal microtremor array method, and we have conducted several field experiments. Cable-less seismographs including GPS clock, AD converter, battery, and SD card memory are used for the survey, and that makes a receiver array deployment flexible. Additionally, the estimated phase velocity is not affected by a specific direction of the ambient noise because several tens of receivers are deployed in X and Y directions on the ground surface. Furthermore, high quality data can be obtained due to a stacking of the multiple receiver pairs even if the observation time is limited.
CMP-SPAC analysis that is a modification of the CMPCC analysis in the 2D surface wave method is used in the 3D ambient noise tomography. SPAC coefficients are calculated for all possible pairs of the receiver arrays, and these are stacked and sorted by receiver separations at each CMP bin to make CMP-SPAC gathers. The frequency versus phase velocity image is obtained by comparing the CMP-SPAC gather with Bessel function. Dispersion curve is obtained from the frequency versus phase velocity image at all CMPs. By the same procedure to the 2D surface wave method, 1D S-wave velocity structure can be estimated by an inversion based on the non-linear least square method. And then 3D S-wave velocity is created by interpolating the 1D velocity structure at all CMPs. The computation time for this analysis is comparable to the 2D surface wave method, so we can easily obtain the 3D S-wave velocity.
Several field experiments have been conducted and the results almost agree with the existing geological information and other geophysical survey results. We found that the accuracy of the estimated S-wave velocity structure is lower around the edge of the survey area, and the estimated phase velocity around the edge might be affected by the direction of the ambient noise due to the limited receiver pairs. Nevertheless, we can eliminate this issue by extending the survey area, which is a usual countermeasure in most of geophysical surveys. Another finding is that even if the ambient noise does not include high frequency or short-wave length, we can investigate the shallow subsurface by adding a manmade vibration around the receiver array easily.

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