Monitoring seismic velocity changes caused by offshore earthquakes using DONET ambient noise records

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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 includes seafloor broadband seismometers and borehole seismometers 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. Therefore, we need to have some other methods to see the state and time variation of the stress in the subseafloor.

In this study, we applied seismic interferometry technique to ambient noise records observed by DONET seafloor seismometers to obtain time dependent seismic velocity as a proxy of stress state below seafloor. We calculated zero-offset horizontal and vertical pseudo shot records from every 1 hour ambient noise records in two years continuous data since July 2014, which were observed by three components of DONET seismometers. Obtained pseudo shot records are then stacked every 240 hours (10 days). Clear events are visible in both vertical and horizontal components of the pseudo shot records, which could be reflected P- and S-waves from the bottom of the shallow sediment layer, respectively. Then we applied the stretching interpolation method to the obtained pseudo shot records. Results confirmed that time variation of P- and S-wave velocity in the shallow sediment layers are stable with its velocity changes of less than 1 percent without large seismic events.

On 1 April 2016, a large offshore earthquake, the off Mie earthquake (Mw = 6.0), occurred. DONET KME18 seismometer is located in the vicinity of the source region with horizontal distance of less than 10 km, and clearly observed co- and post-seismic events including aftershocks and tremors. In pseudo shot records obtained from the KME18 seismometer, large S-wave velocity change of 5 percent maximum, was observed as co- and post-seismic velocity change with duration of approximately 20 days, although velocity change of P-wave was less than 1 percent in the same duration. Results confirmed that change of pore fluid migration and crack distributions, which could be caused by strong motion of the large earthquake, are observable as a proxy of stress distribution and changes below each seismometer by using ambient noise records.

We plan to perform further analysis and discussion including S-wave anisotropy analysis and more quantitative discussion of the relationship between seismic velocity, its anisotropy, pore-fluid pressure and stress for this approach to be used as simple stress monitoring tool to understand the mega-thrust earthquake preparation and generation cycle.

Keywords: Nankai Trough, Mega-thrust earthquake, DONET, Velocity monitoring, Seismic interferometry

