Seismic heterogeneity changes before and during slow earthquakes

*Takashi Tonegawa[1], Shunsuke Takemura[2], Suguru Yabe[3], Kiyoshi Yomogida[4]

1. Research and Development center for Earthquake and Tsunami, Japan Agency for Marine-Earth Science and Technology, 2. Earthquake Research Institute, The University of Tokyo, 3. National Institute of Advanced Industrial Science and Technology, 4. Hokkaido University

Slow earthquakes at the shallow plate interface in the Nankai subduction zone, Japan, have been detected by seafloor seismic observations. The activations of the slow earthquakes are potentially related to fluids around the plate boundary, but whether fluids are linked to the activations is still under debate. If fluid migration occurs, it is expected to observe seismic velocity changes associated with slow earthquakes. In the Nankai subduction zone, a cabled-network, named DONET (Dense Oceanfloor Network system for Earthquakes and Tsunamis) have been constructed since 2011. We applied an ambient noise analysis to the continuous records obtained by DONET, in order to investigate whether seismic velocity changes associated with slow earthquakes occur or not.

We calculated cross-correlation functions (CCFs) of ambient noise records in the vertical component with a time window of 400 s and a frequency band of 0.5–2.0 Hz, and stacked the CCFs over 30 days. At this frequency band, ocean acoustic coupled Rayleigh (ACR) waves are dominant in the CCFs. We prepared the reference CCFs by stacking CCFs for the first 1-year in the observation period. Using the reference CCFs and individual 30-day averaged CCFs, the stretching method was applied to a time window of 10–90 s of the CCFs, which contains direct and coda waves, to measure seismic velocity change (dv/v) around pairs of stations. After stretching the individual CCFs using the estimated dv/v, we calculated the cross correlation coefficients (CC) between the reference CCFs and individual corrected CCFs. This processing allows us to estimate temporal variation of seismic heterogeneities.

Our results show (1) gradual seismic velocity increase in the accretionary prism toe and (2) rapid reduction of CC prior to slow earthquakes. On (1), seismic velocities in the southern part of DONET1 was increased 0.1–0.15 % (Fig. 1), while such phenomena were not observed in the northern part of DONET1 and DONET2. The observation in DONET1 is consistent with the result of Ikeda and Tsuji (2018). It is considered that fluids are gradually expelled by sediment compaction in this region. On (2), we observed CC reductions in the southern part of DONET1 before slow slip events that were detected by borehole pore pressures (Araki et al. 2017) (Fig. 1). Although we observed CC reduction in DONET2, this reduction started at the activity timing of very low frequency earthquakes (Takemura et al. 2019). The CC reductions are presumably caused by fluid supply. We consider that if structure near the plate boundary is not saturated with fluids, slow earthquakes occur after fluid saturation and thereby increasing pore fluid pressure. If it is already saturated with fluids and has a pore fluid pressure, slow earthquakes occur after fluid supply.

Acknowledgement: We thank NIED for providing us DONET records. This study is supported by MEXT Grant-in-Aid for Scientific Research on Innovative Areas "Science of Slow Earthquakes" (19H04632).

Keywords: Seismic heterogeneity, Temporal variation, Slow earthquake

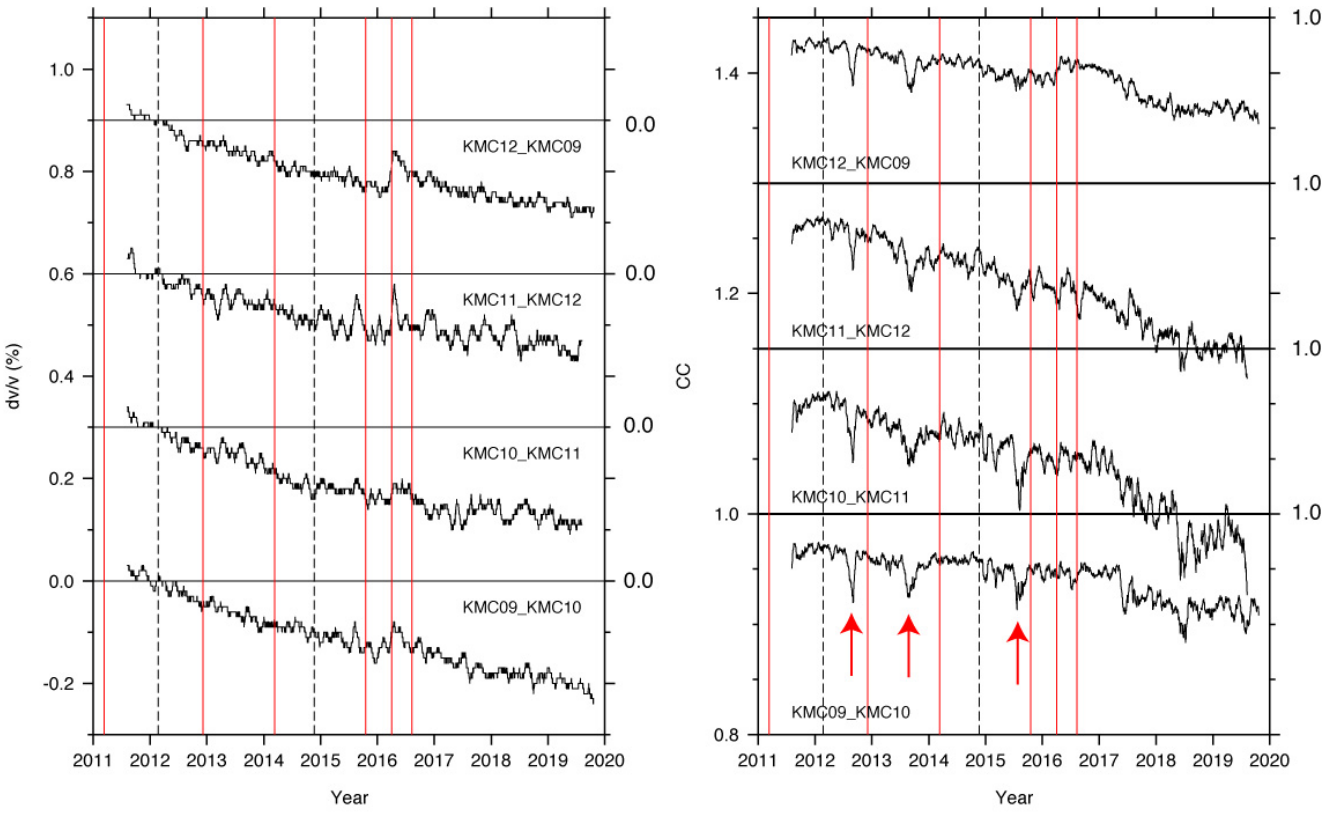

Fig. 1 (left) Seismic velocity changes at the node KMC in DONET1. Red and dashed lines represent slow slip events (SSEs) in which pore pressure variation greater than 0.5 kPa and smaller than 0.5 kPa were observed, respectively (Araki et al. 2017). (right) CC changes at the node KMC in DONET1. Red arrows indicate CC reductions before SSEs.