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Detectability of crustal change accompanied with shallower slow earthquakes

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Owing to developing dense network of inland seismic observations, deeper slow earthquakes have been observed at the depth of about 30 km in southwestern Japan [e.g., Obara, 2002, Science]. More recently, shallower slow earthquakes have been also confirmed by ocean-seafloor seismograms [Sugioka et al., 2012, Nature Geosci.]. Since the shallower slow earthquakes have been also observed around the source region of the 2011 Tohoku earthquake [Matsuzawa et al., 2012, SSJ-FM], it is important for us to robustly detect shallower slow earthquake from seismic and geodetic observations in order to estimate the spatial distribution of seismic coupling for megathrust earthquake [Ariyoshi et al. 2012, SSJ-FM].

From August 2011, Dense Ocean-floor Network system for Earthquake and Tsunamis (DONET) has been operating steadily until now. The DONET has observation cable extending from land-based Owase city to the trench off Kumano-nada, which covers shallower part of source region of the Tonankai earthquake. Since shor-term slow slip events accompanied with tremor episodes have been observed by tiltmeters in deeper part of subduction zones [e.g., Hirose and Obara, 2006, GRL], crustal deformation driven by shallower slow earthquake is expected to be detected by ocean-floor hydraulic gauges. In the Japan subduction zone, episodic slow slip events had been observed by hydraulic gauge before the 2011 Tohoku-Oki earthquake [Ito et al., 2013, Tectonophys., in press]. In this study, we try to investigate the detectability from an earthquake cycle simulation based on rate- and state-dependent friction law.

As a study of modeling shallower slow earthquakes, Ariyoshi et al. [2012, SSJ-FM] reproduced shallower slow earthquake by assuming frictional property similar to deeper one, which occurs along-strike migration only for deeper slow earthquake with shallower slow earthquake inactive in inter-seismic stage of megathrust earthquake. In this study, we estimate crustal deformation at DONET observation points by applying the reproduced model to the Tonankai area.

In the pre-seismic stage, numerical simulation shows that the rate of vertical displacement is increased and enough to be detectable by hydraulic gauges because of higher rate of moment release for the shallower slow earthquakes. In addition, since the shallower slow earthquake becomes more active in pre-seismic stage, these results indicate that slip events detectable by DONET is expected to be more frequent toward the occurrence of megathrust earthquakes. On the other hand, DONET could not detect the shallower slow earthquakes because of lower rate of moment release.

These results suggest that monitoring slow earthquake by ocean-floor hydraulic gauges in addition to seismometers is expected to play an important role in detecting the generation process of megathrust earthquakes.

Keywords: slow earthquake, ocean-floor network observation, hydraulic pressure, megathrust earthquake cycle simulation, role of geofluid in subduction plate, friction law