Triggered tremors and stress perturbations due to surface waves

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Surface waves radiated from distant large earthquakes sometimes trigger a series of deep non-volcanic tremors with intervals of 20-30 seconds, which are the same as dominant periods of surface waves [e.g. Miyazawa & Brodsky 2008]. Understanding the triggering mechanism is important because it provides us clues to the slip process occurring along the transition zone of subducting plate interface. Dynamic stress perturbations due to surface waves that triggered tremors were estimated on the order of 1 to 10 kPa [e.g. Chao & Obara 2016]. To study the relationship between triggered tremors and stress perturbations due to surface waves, we computed theoretical dynamic stresses due to surface waves from large earthquakes by using observed and theoretical surface waves.

We focused on the triggered tremors in the western Shikoku region of the Nankai subduction zone. Most of them occurred in two clusters where tectonic tremors actively occur. We computed theoretical dynamic stress perturbations due to surface waves from 106 earthquakes between 2004 and 2016 with moment magnitudes of 7.0 or grater. The receiver points at which the stress components were computed are at the plate boundary below the N.TSAF and N.KWBH stations, which are the nearest stations of the triggered tremors in F-net and Hi-net, respectively. PREM [Dziewonski & Anderson 1981] and Global CMT catalog [Dziewonski et al. 1981; Ekstrom et al. 2012] were used for the Earth model and the seismic sources for computing theoretical surface waves. Source time functions were approximated with triangular functions whose half durations are equal to the centroid time lags.

The stress change at the plate boundary by the surface wave was estimated based on the method of Spudich et al. (1995). This method consists of two stages: (1) Estimate the stress at the surface from the observed ground velocity and (2) Estimate the stress at the plate boundary from the stress at the surface estimated in (1). In these estimations, we used theoretical proportional relations between the ground velocity and the surface stress and those between the surface and the deep stresses in the frequency domain, which were obtained from the theoretical surface waves. We used the N.TSAF and N.KWBH records as the observed ground velocity. The records from the latter were corrected using the method of Maeda et al. (2011).

The stress components in the source coordinates were transformed to the stress normal to the plate interface and the stress along the possible slip direction of tremor source. The normal and slip directions were obtained from the model plate interface [Baba et al. 2002; Nakajima & Hasegawa 2007; Hirose et al. 2008] and plate convergence vectors [Miyazaki & Heki 2001]. We computed waveforms of the Coulomb failure function (ΔCFF) using a frictional coefficient of 0.2 at periods between 20 and 50 seconds.

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Results from the N.TSAF records show that the maximum ΔCFF for the events that triggered tremors are greater than 0.5 kPa. The magnitudes of triggering earthquakes are greater than 7.5. ΔCFFs were generally overestimated when we used the corrected N.KWBH records because the correction did not well work, in particular, for the earthquakes with magnitudes less than 7.5. The important point is that not all of the events that provided the stress perturbations greater than 0.5 kPa triggered tremors. This shows that the stress perturbation due to surface waves cannot be the unique triggering condition: other conditions, for example, stress perturbations due to possible background slow slip events and/or high pore fluid pressure are required.

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