Spatiotemporal variation of earthquake-tide correlations after the 2011 Tohoku earthquake

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We examined correlations between tides and earthquakes off the Pacific coast of eastern Japan for about five years after the 2011 Tohoku earthquake (Mw 9.1). A previous study by Tanaka (2015) using the earthquakes with Mw 5.0 or larger in the Global Centroid Moment Tensor (CMT) catalog after the Tohoku earthquake showed significant correlations on the northwest side of the large-slip area of the Tohoku mainshock, where large postseismic afterslip has been identified by geodetic measurements (Ozawa et al., 2012; Sun et al., 2014). In the present study, we extend this work to a larger catalog including smaller earthquakes, to more thoroughly explore the earthquake-tide correlations. In about ten years prior to the Tohoku earthquake, high correlations were observed in the northern part of the Tohoku source area where the mainshock rupture initiated (Tanaka, 2012); however, those correlations could not be seen with smaller earthquakes (Tanaka and Asano, 2012).

The data we used are the CMT solutions of 1068 interplate earthquakes with Mw 4.0 or larger from the Tohoku earthquake to December 2015, which were determined by the waveform inversion of seismograms from the NIED Hi-net and F-net stations (Asano et al., 2011). Based on tidal phase angles at the earthquake origin times derived from theoretically-calculated tidal Coulomb failure stresses with a friction coefficient of 0.2 (Tanaka et al., 2012), we evaluated the Shuster's p-value (Schuster, 1897), which represents the significance level to reject the null hypothesis that the earthquakes occur randomly irrespective of the tidal phase angle.

We examined the spatial distribution of p-value using the 200 km x 200 km moving windows for the period after the Tohoku earthquake. The results indicate significant correlations on the south side of the Tohoku large main-slip area. The smallest p-value of 0.52% was observed in the window located off Ibaraki prefecture. The temporal variation of p-value in this region shows the p-value was larger than 10% just after the Tohoku earthquake and gradually decreased with time. The p-value in the latest 700 days is 0.09%. When using only larger earthquakes, we found no significant correlation in this region; we can see p-values smaller than 5% with the earthquake magnitude cutoff smaller than 4.8.

On the other hand, with increasing the earthquake magnitude cutoff, we observed high correlations on the northwest side of the Tohoku large slip area. The highest correlation was seen when the magnitude cutoff was set to be 4.8, and the smallest p-value of 0.63% was obtained in the window located near the coast off Iwate prefecture. The area of high correlation is well correlated with the large afterslip area (Ozawa et al., 2012; Sun et al., 2014), as documented in the previous work (Tanaka, 2015). The temporal variation of p-value shows that the p-value was smallest (0.12%) just after the Tohoku earthquake and gradually increased with time. No significant correlation was found after 2014 in this region.

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