# Spatio-temporal variation of tidal triggering effect related to the occurrence of large earthquakes

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We examined the spatio-temporal variation of the correlation between the earth tide and earthquake occurrence for reverse-fault type earthquakes occurring in subduction zones. The data we used are the times, places, and mechanisms of earthquakes with moment magnitude (Mw) of 5.0 or larger and with focal depth shallower than 70 km, which were listed in the Harvard CMT catalog for the period from 1977 to 2000. We divided the whole world into 50 regions according to Flinn et al. (1974), and selected 3430 reverse-fault type earthquakes occurring in twelve subduction zones. We calculated the tidal stress at the hypocenter of each earthquake; this calculation included the effect of ocean loading according to the ocean tide model, NAO.99b. For the fault plane, we selected one of the nodal planes whose dip direction was closer to that of the plate subduction. We considered three stress components on the fault plane; shear stress, normal stress and Coulomb failure function varying the frictional coefficient (m) between 0.1 and 1.0. We assigned the tidal phase angle at the occurrence time of each earthquake, and tested the phase selectivity by using Schuster's test. In this test, the result is evaluated by p-value, which represents the significance level to reject the null hypothesis that the earthquakes occur randomly irrespective of the tidal phase angles.

Of twelve subduction zones, relatively small p-values less than 20% were found for seven regions. We precisely investigated the spatial and temporal variation of p-value for these seven regions, focusing on the stress component for which the smallest p-value was obtained for each region. As a result of analysis, we found a clear relation between the p-value change and the occurrence of large earthquakes for Akaska-Aleutian and Tonga-Kermadec regions.

In Alaska-Aleutinan region (N=358, m=0.4, p=11%), two large earthquakes with Mw of 7.9 occurred in 1986 (event A) and 1996 (event B). The spatial distribution of p-values showed a clear low-p region (p=0.72%) covering a 500 km segment including the epicenters of these events. In this region, the p-value dropped before the large earthquakes (p=0.93% for event A, and p=2.9% for event B), and it rose after them (p=20% for event A, and p=61% for event B). This indicates that the phase selectivity concentrated around the focal regions of the large earthquakes before they occurred. By using the information criterion, AIC, we confirmed that the tidal triggering effect disappeared after the large events for both the cases. The frequency distribution of the phase angles before the events had a peak at the phase angle where the tidal stress accelerated the fault slip, which indicates that the observed small p-value was not a stochastic chance.

In Tonga-Kermadec region (N=649, normal stress, p=17%) a large earthquake with Mw of 7.5 occurred in 1982. The spatial distribution of p-values showed a clear low-p region (p=0.18%) covering a 600 km segment including the epicenter of this event. In this region, the p-value for the period before the event and for that after the event was 3.2% and 41%, respectively. This fact indicates that the p-value dropped before the large earthquake. The AIC analysis also showed that the phase selectivity existed before the event and it disappeared after that. After the 1982 event, we observed low p-values that continued since 1995.

Similar pattern of p-value change with respect to space and/or time was also found for Mexico-Guatemala, Solomon, and NE Japan-Kamchatka regions. On the other hand, p-value decrease after a large earthquake was observed for Andean South America and Sunda regions.

We found clear tidal triggering effects spatially and temporally in close relation to the occurrence of large earthquakes.