Occurrence probability and frequency of large (Mj6.8) earthquakes on active faults in Japan

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The 2016 Kumamoto earthquake (Mj 7.3; Japan Meteorological Agency magnitude) caused devastating damages and more than 180 casualties. It occurred in an active fault zone and surface ruptures appeared mostly along the previously mapped active faults (The Headquarters for Earthquake Research Promotion-HERP, 2016). The source fault was a part of the Futagawa fault zone that has been evaluated for long-term forecast of destructive earthquake occurrence in Japan (HERP, 2002; 2013). The Mj 7.3 earthquake was the first case, after the 1995 Kobe earthquake, that characteristic earthquake with surface rupture occurred on the major active fault zone evaluated by HERP. It coincides with the past estimation of the average occurrence interval of 10-20 years of an earthquake on those active faults in Japan (Secretariat of HERP, 2001). Meanwhile, the occurrence of large (Mj6.8) earthquakes on minor active faults has been more frequent in recent years.

Under these circumstances, we re-examined the frequency and probabilities of large (Mj6.8) earthquakes on active faults in the last 125 years. In order to classify the damaging earthquakes on active faults, we used the catalogue of damaging earthquakes in Japan (Usami et al., 2013) and previously evaluated reports by HERP.
In total, 28 large (Mj6.8) damaging crustal earthquakes occurred in the last 125 years, and 22 of them (80 %) are related with mapped active faults, and 6 (20 %) are not. The 22 earthquakes in 125 years yield the average recurrence interval of 5.7 years. Using the individual recurrence intervals, 4.6+/-3.7 years is obtained for all large (Mj6.8) damaging earthquakes and 6.0+/-5.5 years for those on active faults. These estimates clearly show shorter recurrence intervals than the previous estimation made in 2001.

We also examined the frequency distribution of recurrence intervals of all the large (Mj6.8) damaging earthquakes. The distribution shows a bimodal distribution consisting of two groups: one <6 years and another >8 years. The average recurrence interval of the former group is 2.9+/-1.5 years, which is extremely short in comparison with the average recurrence interval in the last 125 years. The longest interval in the latter group is 17 years between the 1978 Izu-Oshima-Kinkai earthquake and the 1995 Kobe earthquake. It is thus apparent that the occurrence of the Mj6.8 damaging earthquakes exhibits the temporal clustering and long quiescence periods.
Under the assumption of Poisson process, we then calculated the earthquake probability within the next 5, 10 and 30 years for entire Japan. We obtained 72%, 92%, 100% probabilities for all Mj6.8 damaging earthquakes, and 62%, 86%, 99.7% for active fault earthquakes, respectively. Assuming the present day is within a clustering period, the probability increases up to 68-97% within the next 5 years.

We further investigated the temporal clustering and the timing of mega-thrust earthquakes along the subduction zones. In northeastern Japan, 5 active fault earthquakes occurred within 5 years before and after the 2011 Tohoku earthquake. In southwestern Japan, 3 active fault earthquakes occurred within 5 years before and after the 1944 Tonankai and 1946 Nankai earthquakes. These frequencies are comparable with the average recurrence interval of 2.9+-1.5 years for the above-mentioned <6 years

group. This result is in accord with the previously known idea that inland crustal earthquakes increase before and after the occurrence of mega-thrust earthquakes along the subduction zones, although the above probability is computed with the assumption of Poisson process, hence it is time-independent. We can reasonably expect the occurrence of a few active fault earthquakes before the upcoming Nankai earthquake, probably 3 to 5 active fault earthquakes. To forecast them more accurately, the earthquake probability based on the BPT model for individual active faults and time-dependent seismic hazard assessment are necessary.

