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多重地震サイクルとそのすべり・時間依存構成則による解釈
Interpretation of multiple earthquake cycles based on the slip- and time-dependent fault constitutive law

松浦 充宏 [1*]
MATSU'URA, Mitsuhiro[1*]

[1] 統計数理研究所
[1]Institute of Statistical Mathematics

The occurrence of the Mw9.0 Tohoku-oki earthquake in 2011 brought two essential problems in subduction-zone dynamics to light. The first problem is why did such an extraordinarily large earthquake occur in the same place where ordinarily large earthquakes have repeated every 40 years over the past two centuries? In other words, is the multiple earthquake cycles physically explainable? The second problem is when will the surface deformation pattern in northeast Japan be back? In other words, how will the frictional strength of ruptured areas be recovered? To address these problems, first, we need to change the conventional concept of asperity. Since Lay & Kanamori (1981) proposed an asperity model of earthquakes, the asperity has been thought to be an actual entity that means a strongly coupled portion of faults or a fundamental unit of seismic rupture areas. If it is so, plural asperities cannot occupy the same place. Then, no multiple earthquake cycle exists, though the chain rupture of adjacent asperities is possible. Recently, following the idea of spectral analysis, Matsu'ura (2012) redefined the asperity as a notional entity to represent the spatial irregularity in frictional properties (peak strength and critical slip-weakening displacement) of faults. For example, a specific mode in spectral analysis of peak strength corresponds to the asperities of a specific size. Then, plural asperities with different sizes can be in the same place, but it is only a necessary condition for multiple earthquake cycles. Another necessary condition is the scale dependence of critical slip-weakening displacement, which results from the upper fractal limit of fault surface geometry (Matsu'ura et al., 1992). Otherwise the dynamic rupture of a small asperity would easily trigger the dynamic rupture of the largest basement asperity. From the laboratory rock experiments (e.g., Ohnaka & Shen, 1999) and the numerical simulations based on the slip- and time-dependent fault constitutive law (Aochi & Matsu'ura, 2002), we can derive the following quantitative relations on the scale-dependence of frictional properties; 1) the critical slip-weakening displacement is proportional to the upper fractal limit of fault surface geometry and inversely proportional to the abrasion rate of fault surface, and 2) the recovery time of peak strength is proportional to the square of the upper fractal limit and inversely proportional to the adhesion rate. The scale-dependence of fault healing time (the second relation) means that the strength recovery of larger asperities is slower than that of smaller asperities. So, the time needed for the complete recovery of the surface deformation pattern in northeast Japan depends on the fault healing time of the largest basement asperity, which would be very long.

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