

Validation of a 3-stage Source Scaling for Crustal Earthquakes

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Source scaling is a fundamental issue to understand earthquakes. A magnitude and log rupture area relation is a key scaling to link modeling of seismic source and ground motion. Currently, scenario seismic hazard maps in Japan adopt a 3-stage source scaling for crustal earthquakes, although many national seismic hazard maps use a linear or bilinear scaling. The 3-stage source scaling is originally proposed by Scholz (2002). Recent development of slip inversions enabled us to improve quantitative estimates of the scaling. Based on the source characterization of slip inversions, the 3-stage source scaling for crustal earthquakes are: The first circular-crack model stage of $S \text{ (km}^2\text{)} = 2.23 \times 10^{-15} (M_0 \text{ (Nm)} \times 10^7)^{2/3}$ by Somerville et al. (1999) for $M_w < 6.5$, the second L-model stage of $S \text{ (km}^2\text{)} = 4.24 \times 10^{-11} (M_0 \text{ (Nm)} \times 10^7)^{1/2}$ by Irikura and Miyake (2001, 2011) for $M_w = 6.5 \sim 7.4$ after fault width saturation, and the third W-model stage of $S \text{ (km}^2\text{)} = 1.0 \times 10^{-17} M_0 \text{ (Nm)}$ by Murotani et al. (2015) for $M_w > 7.4$ after fault displacement saturation. The 3-stage scaling shows the first bending at $L \sim W_{\text{max}}$ without significant gaps that pointed out by past 2-D numerical simulations. The second L-model stage is similar to Hanks and Bakun (2002) that is well constraint by megafault systems. We also confirmed that dynamic rupture simulations for strike-slip faulting using 3-D FDM of Dalguer et al. (2008) naturally reproduce the 3-stage source scaling. To fit the scaling between slip inversions and dynamic rupture simulations, slight increase of stress drop from 2.3 to over 3.0 MPa is required in the second L-model stage. Those are compatible with the static models by Fujii and Matsu'ura (2000) and Shaw and Scholz (2001). Finally, we validate the 3-stage source scaling and other published scaling (e.g., Leonard, 2010) for recent crustal earthquakes with slip inversions, and compare their performance.

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