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Two faces of the Great Tohoku Earthquake: Shallow Dynamic Overshoot and Energetic Deep Rupture

Satoshi Ide[1*], Annemarie Baltay[2], Shintaro Tamura[1], Gregory C. Beroza[2]

[1]Dept. EPS, Univ. Tokyo, [2]Stanford University

We use empirical Green's function-based finite-source imaging and energy estimates to study rupture evolution of the Mw 9.0 Great Tohoku earthquake. We find that the earthquake consists of: a small initial phase, deep rupture up to 40 s, shallow large rupture at 60-70 s, and deep rupture lasting over 100 s. The ratio of seismic energy to seismic moment is within the normal range for earthquakes, but we find that deeper parts of the rupture radiated strongly at high frequencies; whereas, shallower parts of the rupture radiated only weakly at high frequencies despite prodigious total slip. Extremely large values of shallow slip near the trench would have been responsible for the extremely large tsunami and may have been facilitated by a combination of a shallow dipping fault and a compliant hanging wall. Reversed-mechanism (normal faulting) aftershocks suggest complete dynamic overshoot to the point of failure in the opposite direction.

Keywords: Tohoku-Oki earthquake, slip model, dynamic overshoot, seismic energy