Rapid, energy-duration estimates of seismic moment and implications for rupture scaling and dynamics

A. Lomax (1), A. Michelini (2) and A. Piatanesi (2)
(1) A Lomax Scientific, Mouans-Sartoux, France, (2) Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Italy (anthony@alomax.net)

We describe a new, rapid and robust, energy-duration procedure (Lomax, Michelini and Piatanesi, 2006) to obtain earthquake moment, $M_{ED}^0$, and a moment magnitude, $M_{ED}$. Using seismograms at teleseismic distances (30º-90º), this procedure combines measures of radiated seismic energy, $E$, on the $P$ to $S$ interval of broadband signals and measures of source duration, $T_0$, on high-frequency, $P$-wave signals to estimate moment through the relation $M_{ED}^0 = kE^{1/2}T_0^{3/2}$. The $M_{ED}^0$ energy-duration moment is scaled to correspond to Harvard Centroid-Moment Tensor (CMT) moment, $M_{CMT}^0$, and can be calculated within about 20 minutes or less after the event origin time. The availability of a reliable size estimation for large earthquakes within this time frame is important for tsunami warning and emergency response. The measured energy and duration values also provide the energy-to-moment ratio used for identification of tsunami earthquakes and for analysis of apparent stress and other source properties.

The energy-duration moments, $M_{ED}^0$, for a set of ~40 major and great earthquakes ($M_w$=6.6-9.2) match closely $M_{CMT}^0$, typically within a factor of 2 (i.e., $M_{ED} = M_{CMT}^0 \pm 0.2$ or less), even for the largest, great earthquakes. This result indicates that the $M_{ED}^0$ measure is accurate and does not saturate, and implies that seismic moment for large earthquakes scales with the square-root of far-field radiated energy, $E$, and with the $3/2$ power of the total source duration, $T_0$.

We examine the implications of these results to the scaling and dynamics of the earthquake rupture process. We show that the energy-duration relation, $M_{ED}^0 = kE^{1/2}T_0^{3/2}$, suggest a scaling relation between $T_0$ and a characteristic duration of initiation or termination of rupture of individual asperities, providing evidence that, in a given tectonic setting, longer duration events involve rupture on larger asperities. The energy-
duration results also suggest a scaling relation between increasing duration, $T_0$, and an increasing deficiency in observed, far-field, radiated wave energy relative to that expected from very long period moment estimates such as $M_{\text{CMT}}^0$, providing evidence that relatively more energy is dissipated on or near the fault for events of longer duration than for shorter duration events.