

An Energy-Duration Procedure for Rapid, Robust and Accurate Determination of Earthquake Magnitude and Tsunamigenic Potential: Application to the 26 December 2004, Sumatra-Andaman, 17 July 2006, Java and other large earthquakes

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Abstract

Rapid, robust and accurate determination of the size of large earthquakes is critical for tsunami warning and emergency response. At teleseismic distances, the earthquake hypocenter can be determined from the first seismic P waves within about 15 minutes after the event origin time (OT). However, current methods for determining accurately the size of very large earthquakes, including the important, Harvard Centroid-Moment Tensor (CMT) moment-magnitude, M_w , rely on long period S and surface wave recordings, typically not available until an hour or more after OT.

Here we introduce a robust, energy-duration procedure, based on the Haskell, extended-source model, to obtain an earthquake moment and a moment magnitude, M_{ED} . Using seismograms at teleseismic distances (30° - 90°), this procedure combines radiated seismic energy measures on the P to S interval of broadband signals and source duration measures on high-frequency, P -wave signals. The M_{ED} energy-duration magnitude is scaled to correspond to CMT M_w , and can be calculated within about 20 minutes or less after OT. The measured energy and duration values also provide the energy-to-moment ratio, Θ , used for identification of tsunami earthquakes.

The M_{ED} magnitudes for a set of recent, large earthquakes match closely CMT M_w , even for the largest, great earthquakes; thus the M_{ED} measure is accurate and does not saturate. After the 26 December 2004, Sumatra-Andaman mega-thrust earthquake, magnitude estimates available within 1 hour of OT ranged from $M=8.0$ to $M=8.5$, the CMT magnitude, available about 3 hours after OT, was $M_w=9.0$, and, several months after the event, $M_w=9.1-9.3$ was obtained from analyses of the Earth's normal modes. The energy-duration magnitude for this event is $M_{ED}=9.1$, a measure that is potentially available within 20 minutes after OT. After the 17 July 2006, Java earthquake, the magnitude was evaluated at $M=7.2$ at 17 minutes after OT, the CMT magnitude, available about 1 hour after OT, was $M_w=7.7$; the energy-duration results for this event give $M_{ED}=7.9$, with a very long source duration, about 160 sec, and a very low Θ value, indicating a possible tsunami earthquake.