Near Real-Time Broadband Body-Wave Magnitudes mB and mBc: Automatic Procedure for Reliable Magnitude Estimates of Strong Earthquakes

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Abstract

First arriving P-waves allow the fastest magnitude estimates. However, common procedures to calculate mb from short-period records grossly underestimate the size of great earthquakes. For the great Sumatra earthquake of Dec. 26, 2004, for instance, the NEIC QED reported mb = 6.3 (later final value mb = 7.0), while the PTWC assumed an mb > *7* about 8 min after the origin time (OT). Also the currently fastest moment magnitude estimate based on broadband P-wave records, available after about 15 min., still was much too low (Mwp = 8). More than one hour after OT the first good Ms estimates yielded values around 8.5, while the Harvard Mw = 9.0 estimate was available only after several hours, and the now widely accepted Mw = 9.3 (at least) by Stein and Okal, was published months later.

Already 30 years ago, Bormann and Khalturin (1975) urged that broadband P-wave magnitude determinations should be given preference for large earthquakes. They also suggested that magnitude estimates for particularly strong multiple rupture earthquakes should not be based on single amplitude and period measurements ($\log(A/T)_{max}$) but rather on $\log \Sigma_n (A_i/T_i)$ by summing the amplitude/period ratios of n successive P-wave onsets and using the Gutenberg-Richter (1957) Q-function for vertical component P. We followed these recommendations and for 54 EQs in the magnitude range $6 \leq Mw < 9.5$ we interactively calculated the P-wave magnitudes mB and cumulative mBc from unfiltered STS2 velocity broadband records. The interactively derived results for mB, mBc = f(t), mBc at Pmax and mBc(tot) over the total rupture duration then served as training set for the development of a fully automatic procedure, which calculates all these parameters in near real time. Depending on the teleseismic source distance (between $15° < \Delta < 105°$) and total rupture duration (up to about 8 min) the automatic procedure would produce reliable, non-saturating magnitude estimates within 4 to 18 min., provided that a first epicentre estimate is available within this time window. When comparing our results with Mw(HRV) we got the following average deviations and rms errors:

$\Delta mB = mB - Mw(HRV) = 0.00 \pm 0.27$ for $6 \leq Mw < 8$ and $\Delta mB = -0.48 \pm 0.23$ for $Mw \geq 8$;
$\Delta mB(Pmax) = +0.18 \pm 0.23$ for $6 \leq Mw < 9.5$ but $\Delta mB(Pmax) = +0.10 \pm 0.24$ for $Mw \geq 8$.

Both mB and mB(Pmax) are available at the same time and allow in combination to issue in **near real-time realistic non-saturating magnitude estimates** up to the largest EQs possible, with mB being closer to Mw for Mw < 8 and mBc for Mw ≥ 8. For Mw > 8.5, however, it is preferable to give also the values mB(tot). For the Sumatra EQ of 28 March 2005 we got mB(tot) = 8.7 = Mw(HRV) and for the larger 26 Dec. 2004 we got mBc(tot) = 9.4 ≈ Mw9.3 of Stein & Okal (2005).

The relatively large scatter of mB and mBc with respect to Mw is due to the fact, that both magnitudes are derived from peak ground velocities and are thus more directly than Mw related to seismic energy release. Accordingly, they are even more relevant than Mw for quick assessment of potential damage hazard due to strong ground shaking. However, for average stress-drop conditions, they agree well with Mw. A prototype version of the mB-mBc algorithm in C language is available on request from saul@gfz-potsdam.de.