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Inferring the time evolution of moment rate and moment magnitude of large earthquakes

W. Friederich and T. Meier

Institute of Geology, Mineralogy and Geophysics, Ruhr-University Bochum
(wolle@geophysik.rub.de)

The rupture process of large earthquakes can last for several minutes. For this reason, it is difficult to obtain a reliable magnitude estimate within a short time as required for early warning purposes. Magnitudes derived from body wave amplitudes usually underestimate the true magnitude. The cumulative body wave magnitude proposed by Bormann and Wylegalla has provided good estimates of magnitude by summing over all discernible subevents in the P-wave coda. But for stations close to the epicentral region the length of the P-wave coda window is limited by the arrival of the S-wave. For example, at an epicentral distance of 2000 km, the S-wave arrives about 4 minutes after the P-wave, a time window much shorter than the duration of the 2004 Sumatra earthquake of more than 10 minutes.

But it is obvious that seismic stations close to the epicentral region would greatly help to quickly estimate the size of an earthquake. However, the different phases in the seismogram are not well separated and partially overlap each other. This is particularly true for large earthquakes where most of the energy is contained in the longer periods. For this reason we apply a waveform fitting approach which is independent of phase identification. The recorded seismograms are considered as the convolution of the Green functions with the moment rate function of the earthquake. To stabilize the result we use a non-negative least-square fit which ensures a monotonic increase of seismic moment with time. Once the moment rate function is determined it can be integrated to obtain the seismic moment as a function of time which can also be expressed as moment magnitude versus time. We present two examples, the 2004 M=9.3 Sumatra and the 2006, M=6.7 Kythira earthquake, for which the time evolution of moment

magnitude could be determined. Final moment and form of the moment rate function agree very well with previous findings.

We consider the method useful for real-time applications where the waveform fitting is done in regular intervals with the available data. In this way, the evolution of seismic moment can be followed as it is growing with time. When a predefined threshold is crossed an alert can be issued. Prerequisite is of course a rapid location and focal mechanism determination of the event.