Geophysical Research Abstracts,
Vol. 10, EGU2008-A-06467, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-06467
EGU General Assembly 2008

Scaling relations of M_w vs. M_L for families of similar earthquakes in Switzerland

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Theoretical considerations predict a 1:1 scaling relation between M_L and M_w. Observed deviations from this scaling are sometimes interpreted as evidence for a systematic dependence of stress drop (or other rupture properties) on seismic moment. Alternatively, such deviations could also occur due to path effects. Since numerous variables enter in practice into the determination of M_L and M_w, resolving the M_L-M_w discrepancy requires very high data quality and redundant observations to eliminate unknown path effects, Sequences of earthquakes with similar hypocenters and focal mechanisms are therefore ideally suited to address these questions.

Several earthquake sequences have occurred in Switzerland in the recent past, with events in the magnitude range of M = 1 - 4 often exhibiting similar waveforms. We use the dense Swiss broadband network to locate seismicity and determine source properties of selected events. In particular we use data acquired during an injection experiment for geothermal exploration, where more than 13800 events were recorded from which we use 188 for a detailed source study. We perform detailed error analyses and sensitivity tests for each parameter in the determination of M_w and find that the value of M_w is particularly sensitive to uncertainties in seismic velocities at the recording site and to errors of the assumed radiation coefficients.

Our results show that moment magnitude and local magnitude are not identical and that a correction with a constant offset is not appropriate either. Instead, we observe that values of M_L vs. M_w plot along a line with slopes of 1.3 -1.4. To reduce uncertainties due to velocity-density models and radiation characteristics we also compare

Wood-Anderson amplitudes to the low frequency level of the displacement spectra for sequences of similar earthquakes recorded at the same station. These direct comparisons confirm the observed M_L vs. M_w scaling relations.

The observed scaling relations imply that for small earthquakes M_L is systematically much lower than M_w, while the M_L-M_w-differences for large earthquakes are small. This artifact is likely introduced in routine determinations of M_L using Wood-Anderson-transformed seismograms that do not account for frequency- and thus magnitude-dependent effects of inelastic attenuation. The resulting systematic underestimation of M_L for small earthquakes is likely to introduce a significant bias to the corresponding magnitude recurrence relations, hence correcting seismic catalogs for the M_L-M_w-discrepancy is important for earthquake statistics.