Estimating the magnitude of completeness M_c: uncertainties and implications

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A critical parameter for seismicity and hazard related studies is the magnitude of complete reporting M_c. Variations in M_c as a function of space and time form a complex 4-dimensional surface. Causes of these variations are often related to natural phenomena but also various artificial changes - e.g. network reconfigurations, change of magnitude determination - are possible. The objective of our study is to evaluate and refine approaches that map M_c and its uncertainty, ÄM_c. Uncertainties in M_c have largely been neglected in seismicity studies; however, it generally influences the b-value estimation stronger than the formal errors.

A general drawback of methods applying a power-law fit to the frequency-magnitude distribution is that earthquakes below the magnitude of completeness are left out in the determination process, disregarding a major portion of the dataset. We introduce a new method stimulated by an approach of Ogata (1993), which has the additional advantage of giving a stochastic model of the entire magnitude range. In this method, we determine M_c by modeling the entire magnitude range (EMR) of any given earthquake dataset using: 1) a normal cumulative density function to model the frequency-magnitude distribution below M_c and 2) the Gutenberg-Richter law for the higher magnitude part. Varying an assumed magnitude of completeness M_{ca}, the best estimate of M_c is chosen using a maximum likelihood estimate, comparing the modeled frequency-magnitude distribution with the original FMD. We compared the abilities of this method with several other approaches proposed in the literature considering their robustness and their capability of being used in an automatic fashion. This includes one M_c determination approach based on Schuster's method, which does not assume earthquake self-similarity. In order to quantify uncertainties in M_c, expressed as one and two ó ranges, we adapt a bootstrap approach.

The behavior of uncertainties is first studied using synthetic earthquake catalogs, enabling us to define the dependence on earthquake sample size. Using this knowledge, we apply the same procedures to different real earthquake catalogs from California and Japan as well as the global Harvard CMT dataset. The software developed to compute M_c and its uncertainty is integrated into the seismicity analysis toolbox ZMAP as well as in a stand alone version.