Geophysical Research Abstracts, Vol. 8, 06866, 2006
SRef-ID: 1607-7962/gra/EGU06-A-06866

The Magnitude Scale Conversion Problem

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Magnitude scale conversion is a common problem in seismology, encountered each time a homogeneous earthquake catalogue is to be compiled, which has important implications in seismic hazard evaluation. Standard least squares linear regression cannot be used a priori to study it, since its basic requirement of an uncertainty on the independent variable much smaller than the one on the dependent variable and of a normal distribution of magnitude data are not satisfied.

When the ratio between errors (h) on the independent and the dependent variable can be estimated, general orthogonal regression can be applied. We test the performance of orthogonal regression in its general form on synthetic data sets which mimic the true magnitude distributions (exponential distribution with reasonably true data errors) and compare with standard least square regression and the more commonly used orthogonal regression with h=1. General orthogonal regression is found to be superior in all the cases investigated and its general use is recommended. However, since determining the ratio of errors between two magnitude scales is often difficult, we also test the performance of a non-parametric regression based on Kendall tau statistics which does not need any assumption on this ratio. The advantage of the latter method, extended to allow for ties on the dependent variable, is its robustness also in presence of outliers.

Our analysis yields that the still commonly used standard regression may induce systematic errors in magnitude conversion up to 0.3-0.4, which in turn introduce an apparent catalogue incompleteness, as well as a heavy bias in the slope estimate of the frequency-magnitude distributions. All this is avoided by using the general orthogonal regression or the extended non-parametric method in magnitude conversions.