A new M_L-M_D Relationship for Mt. Etna Earthquakes (Italy)

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Studies on seismicity at Mt. Etna are of extreme importance for the high seismic and volcanic risk which characterizes the area. In this region, seismic events are mainly located at less than 5 km b.s.l. depth, producing arrivals with medium-to low-frequency content and/or complicated signatures at stations just a few kilometers distant from the epicentral area [Patanè and Giampiccolo, 2004]; on the other hand, earthquakes which present high frequency content and sharp arrivals, similar to those of typical earthquakes of tectonic areas, are mainly located between 5 and 20 km.

Seismicity mainly occurs in the form of swarms, whereas foreshock-mainshock-aftershock sequences are rarely recorded, and seldom exceed magnitude 4.0 [Ferrucci and Patanè, 1993].

In volcanic areas the calculation of the local magnitude M_L is more objective than that of M_D because the measurement of the signal amplitude is less ambiguous with respect to the decay of the earthquake coda, which may be masked by the presence of noise, volcanic tremor, or other shocks [Del Pezzo and Petrosino, 2001; D'Amico and Maiolino, 2005]. Therefore, since magnitude estimation in M_D and M_L, although mutually related, do not produce the same results, it is mandatory to adopt an empirical conversion to produce a homogeneous catalogue for Mt. Etna region.

The Standard Linear Regression (SLR) is the simplest and most commonly used regression procedure applied in literature [Gasperini, 2002; Bindi et al., 2005]. However its application without checking whether its basic requirements are satisfied may lead to wrong results [Castellaro et al., 2006]. As an alternative it is better to use the Orthogonal Regression (OR) relation [Carrol and Ruppert, 1996], which assumes a different uncertainty for each of the two variables [Lolli and Gasperini, 2012].

Investigating the performance of different regression procedures commonly used to convert magnitudes from one type into another one, is also an operation which has strong influence on the slope of the frequency-magnitude distribution (the b-value of the Gutenberg-Richter). In particular, the frequency-magnitude distribution can be heavily biased when calculated on magnitudes converted from various scales. By contrast, it is possible to obtain unbiased estimates of a and b values by converting magnitudes through OR. The application of OR requires the estimate of the ratio between the dependent and the independent variable variances, and when only the ratio variance is known, the OR represents the simplest and mostly used approach.

A database of magnitude observations recorded at Mt. Etna during the period 2005 – 2012 is used for this study [Gruppo Analisi Dati Sismici, 2013]. The new M_L-M_D relationship obtained by applying the OR is:

$$M_L=1.237(\pm 0.009)M_D - 0.483(\pm 0.016)$$

with a correlation coefficient R=0.90 and rms between observed and calculated M_L of 0.27. The superiority of the OR relation over the SLR has been demonstrated on the basis of the best fitting between regression line and data distribution.

The M_L-M_D relationship obtained significantly reduces the previous bias between M_L and M_D estimated for earthquakes recorded at Mt. Etna and will be used for the purpose of catalogue homogenization.

We conclude that the commonly used SLR may induce systematic errors in magnitude conversion; this can introduce apparent catalogue incompleteness, as well as a heavy bias in estimates of the slope of the frequency–magnitude distributions.

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