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Can high seismic *b*-values be explained solely by poorly applied methodology?

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The b-value of the Gutenberg-Richter distribution quantifies the relative proportion of large to small magnitude earthquakes in a catalogue, in turn related to the population of fault rupture areas and the average slip or stress drop. Accordingly the b-value is an important parameter to consider when evaluating seismic catalogues as it has the potential to provide insight into the temporal or spatial evolution of the system, such as fracture development or changes in the local stress regime. The b-value for tectonic seismicity is commonly found to be close to 1, whereas much higher b-values are frequently reported for volcanic and induced seismicity. Understanding these differences is important for understanding the processes controlling earthquake occurrence in different settings. However, it is possible that anomalously high b-values could arise from small sample sizes, under-estimated completeness magnitudes, or other poorly applied methodologies. Therefore, it is important to establish a rigorous workflow for analyzing these datasets.

Here we examine the frequency-magnitude distributions of volcanic earthquake catalogues in order to determine the significance of apparently high b-values. We first derive a workflow for computing the completeness magnitude of a seismic catalogue, using synthetic catalogues of varying shape, size, and known b-value. We find the best approach involves a combination of three methods: ‘Maximum Curvature’, ‘b-value stability’, and the ‘Goodness-of-Fit test’. To calculate a reliable b-value with an error $\leq$0.25, the maximum curvature method is preferred for a “sharp-peaked” discrete distribution. For a catalogue with a broader peak the b-value stability method is the most reliable with the Goodness-of-Fit test being an acceptable backup if the b-value stability method fails.

We apply this workflow to earthquake catalogues from El Hierro (2011-2013) and Mt Etna (1999-2013) volcanoes. In general, we find the $b-$value to be equal to or slightly greater than 1, however, reliably high b-values are reported in both catalogues. We argue that many of the almost axiomatically ‘high’ b-values reported in the literature for volcanic and induced seismicity may be attributable to biases introduced by the methods of inference used and/or the relatively small sample sizes often available. This new methodology, although focused towards volcanic catalogues, is applicabale to all seismic catalogues.