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Estimating b-values and biases in small earthquake catalogues

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The Gutenberg-Richter (GR) b-value represents the relative proportion of small to large earthquakes in a scale-free population. For tectonic seismicity, this is often close to unity, but some studies have shown the b-value to be elevated (>1) in both volcanic and induced seismicity. However, many of these studies have used relatively small datasets – in sample size and magnitude range, easily introducing biases. This leads to incomplete catalogues above the threshold above which all events are assumed to be recorded – the completeness magnitude M_c. At high magnitudes, the scale-free behaviour must break down because natural tectonic and volcano-tectonic processes are incapable of an infinite release of energy, which is difficult to estimate accurately. In particular, it can be challenging to distinguish between regions of unlimited scale-free behaviour and physical roll-off at larger magnitudes. The latter model is often referred to as the modified Gutenberg-Richter (MGR) distribution.

We use the MGR distribution to describe the breakdown of scale-free behaviour at large magnitudes, introducing the roll-off parameter (θ) to the incremental distribution. Applying a maximum likelihood method to estimate the b-value could violate the implicit assumption that the underlying model is GR. If this is the case, the methods used will return a biased b-value rather than indicate that the method used is inappropriate for the underlying model. Using synthetic data and testing it on various earthquake catalogues, we show that when we have little data and low bandwidth, it is statistically challenging to test whether the sample is representative of the scale-free GR behaviour or whether it is controlled primarily by the finite size roll-off seen in MGR.