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Probabilistic Seismic Hazard Assessment from Incomplete and Uncertain Data

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A question that frequently arises with seismic hazard assessment is why are our assessments so poor? Often the answer is that in many cases the standard applied methodologies do not take into account the nature of seismic event catalogs. In reality these catalogues are incomplete with uncertain magnitude estimates and a significant discrepancy between the empirical data and applied occurrence model. Most probabilistic seismic hazard analysis procedures require knowledge of at least three seismic source parameters: the mean seismic activity rate λ, the Gutenberg-Richter b-value, and the area-characteristic (seismogenic source) maximum possible earthquake magnitude Mmax. In almost all currently used seismic hazard assessment procedures utilizing these three parameters, it's explicitly assumed that all three remain constant over a specified time and space. However, closer examination of most earthquake catalogues indicates that there are significant spatial and temporal variations in the seismic activity rate λ as well as the Gutenberg-Richter b-value. In the proposed methodology the maximum likelihood estimation of these earthquake hazard parameters takes into account the incompleteness of catalogues, uncertainty in the earthquake magnitude determination as well as the uncertainty associated with the applied earthquake occurrence models. The uncertainty in the earthquake occurrence models are introduced by assuming that both, the mean, seismic activity rate λ and the b-value of Gutenberg-Richter are random variables, each described by the Gamma distribution. The approach results in the extension of the classic frequency-magnitude Gutenberg-Richter relation and the Poisson distribution of number of earthquakes, with their compounded counterparts. The proposed procedure is applied in the estimation of the seismic parameters for the area of Ceres-Tulbagh, South Africa, which experienced the strongest earthquake in the country's recorded history. In this example it is shown that the introduction of uncertainty in the earthquake occurrence model reduces the mean return periods, leading to an increase in the estimated seismic hazard. Accounting for magnitude uncertainties have the opposite effect, leading to increases in the return periods or equivalently to a reduction of the estimated hazard.