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Modeling earthquake numbers by Negative Binomial Hidden Markov models

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Modeling seismicity data is challenging and it remains a subject of ongoing research. Assumptions about the distribution of earthquake numbers play an important role in seismic hazard and risk analysis. The most common distribution that has been widely used in modeling earthquake numbers is the Poisson distribution because of its simplicity and easy to use. However, the heterogeneity in earthquake data and temporal dependencies that are often present in many real earthquake sequences make the use of the Poisson distribution inadequate. So, we propose the use of a Hidden Markov model (HMM) with state-specific Negative Binomial distributions in which some states are allowed to approach the Poisson distribution. A HMM is a generalization of a mixture model where the different unobservable (hidden) states are related through a Markov process rather than being independent of each other. We parameterize the Negative Binomial distribution in terms of the mean and dispersion (clustering) parameter. Maximum likelihood estimates of the models' parameters are obtained through an Expectation-Maximization algorithm (EM-algorithm).

We apply the model to real earthquake data. We have selected the area of Killini Western Greece to test the proposed hypothesis. The area of Killini has been selected based on the fact that in a time window of 17 years three clusters of seismicity associated with strong mainshocks are included in the catalog. Application of the model to the data resulted in three states, representing different levels of seismicity (low, medium, high). The state that corresponds to the low seismicity level approaches the Poisson distribution while the other two states (medium and high) are following the Negative Binomial distribution. This result complies with the nature of the data. The variation within each state that is introduced to the model by the Negative Binomial distribution is greater in the states of medium and high seismicity.