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Estimation of the occurrence rate of strong earthquakes based on hidden semi-Markov models

I Votsi (1,2), N Limnios (1), G Tsaklidis (2), and E Papadimitriou (3)

(1) Laboratoire de Mathématiques Appliquées de Compiègne, Université de Technologie de Compiègne, France , (2) Department of Mathematics, Aristotle University of Thessaloniki, Greece, (3) Department of Geophysics, Aristotle University of Thessaloniki, Greece

The present paper aims at the application of hidden semi-Markov models (HSMMs) in an attempt to reveal key features for the earthquake generation, associated with the actual stress field, which is not accessible to direct observation. The models generalize the hidden Markov models by considering the hidden process to form actually a semi-Markov chain. Considering that the states of the models correspond to levels of actual stress fields, the stress field level at the occurrence time of each strong event is revealed. The dataset concerns a well catalogued seismically active region incorporating a variety of tectonic styles. More specifically, the models are applied in Greece and its surrounding lands, concerning a complete data sample with strong $(M \geq 6.5)$ earthquakes that occurred in the study area since 1845 up to present. The earthquakes that occurred are grouped according to their magnitudes and the cases of two and three magnitude ranges for a corresponding number of states are examined. The parameters of the HSMMs are estimated and their confidence intervals are calculated based on their asymptotic behavior. The rate of the earthquake occurrence is introduced through the proposed HSMMs and its maximum likelihood estimator is calculated. The asymptotic properties of the estimator are studied, including the uniformly strongly consistency and the asymptotical normality. The confidence interval for the proposed estimator is given. We assume the state space of both the observable and the hidden process to be finite, the hidden Markov chain to be homogeneous and stationary and the observations to be conditionally independent. The hidden states at the occurrence time of each strong event are revealed and the rate of occurrence of an anticipated earthquake is estimated on the basis of the proposed HSMMs. Moreover, the mean time for the first occurrence of a strong anticipated earthquake is estimated and its confidence interval is calculated.