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Renewal models of seismic recurrence applied to paleoseismological and historical observations

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Because paleoseismology can extend the record of earthquakes back in time up to several millennia, it represents a great opportunity to study how earthquakes recur through time and thus to provide innovative contributions to seismic hazard assessment.

A worldwide compilation of a database of recurrence from paleoseismology was developed in the frame of the ILP project "Earthquake Recurrence Through Time". From this database, integrated with historical information, we were able to extract 19 sequences with 5 up to 14 dated events on a single fault. By using the age of the paleoearthquakes and the historical earthquakes, with their associated uncertainty, we tested the null hypothesis that the observed inter-event times come from a uniform random distribution (Poisson model). We used the concept of likelihood for a specific sequence of observed events under a given occurrence model. The difference dlnL of the likelihoods estimated under two hypotheses gives an indication of which between the two hypotheses fits better the observations. To take into account the uncertainties associated with paleoseismological data, we used a Monte Carlo procedure. We computed the average and the standard deviation of dlnL for 1000 inter-event sets by choosing the occurrence time of each event within the limits of uncertainty provided by the observations. Still applying a Monte Carlo procedure, we estimated the probability that a value equal to or larger than an observed dlnL comes by chance from a Poisson distribution of inter-event times. These tests were carried out for a set of the most popular statistical models applied in seismic hazard assessment, i.e. the Log-normal, Gamma, Weibull, Double-exponential and Brownian Passage Time (BPT) distributions. In the particular case of the BPT distribution, we also show that the limited number of dated events determines a trend to reducing both the observed mean recurrence time and the coefficient of variation for the studied sequence which can possibly bias the results.

Our results show that a renewal model, associated with a time dependent hazard, and some kind of predictability of the next large earthquake on a fault is significantly better than a plain time-independent Poisson model only for four, out of the 19 sites examined in this study. The complete lack of regularity in the earthquake occurrence for more than 30% of the examined faults can be explained either by the large uncertainties in the estimate of paleoseismological occurrence times or by physical interaction between neighbouring faults.