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Modelling temporal earthquake occurrence from days to decades

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Two empirical relationships are commonly used to model earthquake occurrence in time: The Poisson distribution for the occurrence of large earthquakes and Omori's law for the decay of aftershock activity. The Poisson distribution has no memory and thus the occurrence of the next large earthquake does not depend on the occurrence of the last. However, large earthquakes have been observed to cluster in time and space (e.g. Kagan & Jackson, 1999, Faenza et al., 2003, Corral, 2004, Lombardi & Marzocchi, 2007). The short-term clustering following large earthquakes is well described by Omori's law where the number of aftershocks per day decays with time t as $\frac{1}{(c+t)^p}$, with c a small constant to avoid the singularity at $t = 0$ and p around 1 the decay parameter (e.g. Utsu et al., 1995). Using Omori's law as a probability density function is problematic because of the non-integrable singularity at infinity if $p \geq 1$ and the dependence on the choice of c.

In this study, we introduce exponential modulating functions to remove the singularities. We find $p = 1$ for all studied data sets. Moreover, by combining the modulated Omori's law with the Poisson distribution, we can model the probability density function $f(t)$ of earthquake recurrence times in a region as:

$$f(t) = w_1 f_0 (1 - e^{\frac{-t}{t_s}}) e^{\frac{-t}{t_1}} / t + w_2 e^{\frac{-t}{t_0}} / t_0,$$

where w_1 is the portion of earthquakes that follows Omori's law, f_0 is a normalizing constant, t_s and t_1 are parameters of the exponential modulation, $w_2 = 1 - w_1$ and t_0 the Poisson parameter. This new model allows for the calculation of conditional probabilities. The probability of another large earthquake is significantly larger than Poisson, immediately following a large event. If more than about 100 days pass without a second earthquake as large, the probability of another one is similar to Poisson.