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Self-correcting models driven by seismic strain, moment or energy. Applications to the Italian seismicity

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The stress release model (*Vere-Jones, 1978*) provides a stochastic version of the Reid's elastic-rebound theory, which is commonly accepted as the most feasible physical description of the long-term evolution of the earthquake process. It assumes that the stress X, which governs the state of the system in a region, increases linearly with time at a constant loading rate ρ imposed by external tectonic forces until it exceeds the strength of the medium and decreases abruptly generating an earthquake. This hypothesis is formalised by a self-correcting point process with conditional intensity function $\lambda(t \mid H_t) = exp\{\alpha+\beta[\rho t - S(t)]\}$, where H_t is the seismic history up to time t, $S(t)$ is the cumulative stress release due to all the earthquakes up to t and α, β and ρ are model parameters. X can be any physical parameter that constitutes a proxy measure of the strength of an earthquake, therefore we propose four possible definitions of X and consequently four versions of the stress release model. Let m_w denote the moment magnitude of an earthquake and A be its rupture area. We consider two classical versions of the model: in the former $X = 10^{0.75(m_w-5.3)}$ is the Benioff strain, in the latter $X = 10^{1.5(m_w-5.3)}$ is the seismic moment. Then we propose two new versions: the third model is based on seismic energy $X = 10^{2.25(m_w-5.3)}/A$, the fourth one on the scaled energy $X = 10^{0.75(m_w-5.3)}/A$, as defined by Senatorski (2005, 2012). The rupture area A is evaluated by the Wells and Coppersmith regression with parameters depending on the faulting type of the earthquake.

We analyse the Italian historical seismicity on a regional basis by subdividing the Italian territory into eight tectonically-coherent large regions. For each model and region, a fully Bayesian analysis is carried out in order to estimate the posterior distributions of the model parameters. We also deal with the forecast problem by evaluating, for each region, the probability distribution $F(t \mid H_s)$ of the time t to the next event conditioned on the past history H_s. The time to the next event turns out to have an extreme value distribution, known as Gompertz distribution, with a shape parameter that depends on time through the value of the conditional intensity. Hence retrospective and prospective forecasts are obtained and validated by comparing them with the earthquakes of the data set and those recorded in the time period from the end of the catalog to the present time (2003-2012). In this last period there have been four earthquakes exceeding the magnitude threshold Mw 5.3, excluding aftershocks (among these, the L'Aquila earthquake in 2009, Mw 6.3, and the Finale Emilia earthquake in 2012, Mw 5.9). The forecast for these events falls between the estimated median and mean of the corresponding time to the next event.

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