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A scaling approach and a phase map of the large deviation function for frequency in a simple model of earthquakes

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Statistical indices for characterizing earthquake are important for understanding the mechanism of earthquakes. The Gutenberg-Richter (GR) law for the earthquake magnitude is well established in seismology and it is well known that the b-value depends on time and space. However in the tail part of the distribution which corresponds to large magnitudes, the functional form is still a subject of concern not only because we want to know how frequent the large earthquakes occur but also because we have insufficient data of large earthquakes. Moreover, the estimation of frequency or probability of rare events like disastrous earthquakes is a big concern from the hazard assessment point of view.

To study further the frequency of large earthquakes, we adopt a large deviation function (LDF). The LDF is related to the probability of rare events which constitute the tail part of the distribution. In addition to the practical usefulness similar to that of log scale, the LDF is universal in the sense that it is an asymptotic form whenever the number of elements is large. In general it is difficult to calculate the exact form of the LDF. Recently, a population Monte Carlo method has been introduced to obtain the LDF of some cellular automaton models. Among those simple models, we adopt an one-dimensional forest-fire model, which can be understood as one of minimalist models for earthquakes. Recently, the configuration of ignition sites (trigger sites) is investigated in the 2D forest-fire model by Tejedor et.al.[1] where they limit and fix the trigger sites to represent various heterogeneous faults. They found that there exist some asperity regions where large earthquakes tend to occur in their models. The power-law line of the frequency distribution (GR law) is adopted as criterion for the definition of phases which are classified as subcritical, critical or supercritical.

In this study we numerically calculate the LDF for frequency in the 1D forest-fire model. The configuration dependence is examined by introducing four models of different numbers of trigger sites. A mean frequency distribution is calculated to make a phase map analogous to the one by Tejedor et.al. Among various earthquakes that occur in the model, for practical reasons, we focus on the characteristic earthquake which is the earthquake that break all the area. Next we numerically calculate the LDF for frequency of the characteristic earthquake. In all cases, the LDF display a peak structure around the mean frequency. Whether the scaled data of the LDF by the mean frequency fall on to a curve or not depends on parameters such as the number of trigger sites and the ratio between loading rate and triggering rate. When the scaling do not collapse, the system size dependence of the symmetric part differs from that of the anti-symmetric part in some region. We draw a phase map by comparing the LDF of the present model to that of the Poisson process. Finally we calculate the LDF from the real seismic catalogs and find that the LDF is different from that of the Poisson process.

[1] A.Tejedor, J.B.Gomez and A.F.Pacheco, Phys.Rev.E. 79 (2009) 0461021

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