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Cellular automaton simulations of the temporal pattern of activity of a volcano with an application to Vesuvius activity between 1631 and 1944

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We simulate the volcanic activity of a basaltic stratovolcano by using a cellular automaton model where magma is allowed to rise through self-organized crack networks. Magma rises toward the surface by filling connected paths of fractures until the magma's density is less than, or equal to that of the surrounding rocks. If magma enters a less dense rock layer, it cools and thus solidifies; as a result, the local density profile is modified, and solid filled dikes are formed. We simulate the temporal evolution of such high density pathway of dikes which magma may eventually utilize to reach the surface with the occurrence of an eruption. Magma degassing is also taken into account by means of the relationship between the pressure-controlled water solubility and the lithostatic pressure. We study the statistical properties of the automaton by varying the model parameters and, in particular, the thickness of the uppermost rock layer, which controls the buoyancy rate of magma rise because of its low value of density. We show that, if the initial rock density profile is restored after each eruption because, for example, piecemeal or chaotic collapses, a characteristic timescale appears in the inter-event repose time distribution, which represents the average time that magma takes to form an high density pathway through the less dense rock layer. An application of the model to the statistics of the eruptive activity of the Somma-Vesuvius volcano for the 1631-1944 period is discussed.