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A networks-based discrete dynamic systems approach to volcanic seismicity

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The detection and relevant description of pattern change concerning earthquake events is an important, but challenging task.

In this paper, earthquake events related to volcanic activity are considered manifestations of a dynamic system evolving over time. The system dynamics is seen as a succession of events with point-like appearance both in time and in space. Each event is characterized by a position in three-dimensional space, a moment of occurrence, and an event size (magnitude).

A weighted directed network is constructed to capture the effects of earthquakes on subsequent events. Each seismic event represents a node. Relations among events represent edges. Edge directions are given by the temporal succession of the events. Edges are also characterized by weights reflecting the strengths of the relation between the nodes. Weights are calculated as a function of (i) the time interval separating the two events, (ii) the spatial distance between the events, (iii) the magnitude of the earliest event among the two. Different ways of addressing weight components are explored, and their implications for the properties of the produced networks are analyzed. The resulting networks are then characterized in terms of degree- and weight distributions.

Subsequently, the distribution of system transitions is determined for all the edges connecting related events in the network. Two- and three-dimensional diagrams are constructed to reflect transition distributions for each set of events.

Networks are thus generated for successive temporal windows of different size, and the evolution of (a) network properties and (b) system transition distributions are followed over time and compared to the timeline of documented geologic processes.

Applications concerning volcanic seismicity on the Big Island of Hawaii show that this approach is capable of revealing novel aspects of change occurring in the volcanic system on different scales in time and in space.