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Space-time pattern change identification and quantification: applications regarding volcanic seismicity

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Seismicity related to volcanic activity is both relevant to the study of the dynamics of volcanoes, and challenging to characterize in a comprehensive and useful way. Most approaches to seismicity patterns consider sets of earthquakes in a spatial or temporal perspective and aim at describing patterns of points. However, since seismic events typically involve irreversible processes such as rupture, slip on rough surfaces implying heat dissipation, and stress reconfiguration, the succession of earthquakes in time and mutual influences among events are important to consider.

This paper presents recent results we obtained regarding the quantitative evaluation of patterns on a range of scales with the aim of supporting the search for relevant information regarding their temporal change. Our approach is based on events thread analysis (ETA), which is capable of capturing interrelationships among seismic events occurring at successive moments in time. We apply ETA in three-dimensional space to quantitatively characterize orientation-dependent scaling properties of seismicity patterns in Hawaii. With the help of ETA, we construct the "dynamic fingerprint" of the volcanic system, with the aim of identifying its changes over time. First, all the hypocentres corresponding to the studied set of events are connected according to their temporal succession, which leads to an "events thread". Subsequently, the events thread is projected on a line passing through the origin of an orthogonal system and successively taking "all" possible spatial orientations. For each position of the line, the projection of the events thread is subject to multiscale time series analysis (detrended fluctuation analysis); a scaling exponent is thus identified for each spatial orientation. Based on these results, iso-persistence diagrams are constructed for any desired time interval. In view of the identification and assessment of pattern change, difference iso-persistence diagrams are produced for successive time windows. The 3-dimensional graphical representation of difference diagrams supports an effective evaluation of pattern change. Concrete examples refer to different manifestations of the volcanic system on the Big Island of Hawaii.