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Seismic clustering and regional physical properties: a statistical analysis

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Discovering genuine spatio-temporal seismicity patterns characterizing local regions beyond the classical large-scale average patterns remains an extremely challenging problem. Of particular importance are patterns that can be related to key physical processes associated with specific properties of faults and the lithosphere. This study addresses two related topics: (i) Non-parametric identification of statistically significant seismic clusters, and (ii) Establishing correlations between seismic cluster patterns and regional physical properties. The first issue is solved using a cluster detection technique of Zaliapin et al. (2008), based on bimodality of the 2-D joint distribution of normalized space and time distances between earthquakes. In the second topic we study two types of patterns. First, we examine the relations between symmetry properties of spatial earthquake patterns along various faults in CA and corresponding local velocity structure images. This is done to test the hypothesis that ruptures on bimaterial faults have statistically preferred propagation directions (e.g., Ben-Zion, 2001). The results indicate strong asymmetric patterns in early-time spatially-close aftershocks along large faults with prominent bimaterial interfaces (e.g., sections of the San Andreas fault), with enhanced activity in the directions predicted for the local velocity contrasts; and absence of significant asymmetry along most other faults. Second, we compare seismic productivity within statistically significant clusters in CA with heat flow and general rock type (crystalline vs. deep sedimentary basins), which serve as proxies for the effective viscosity of the crust (Ben-Zion and Lyakhovsky, 2006). We find that (i) relatively cold regions with crystalline rock in the seismogenic zone have high aftershock productivity and low foreshock productivity, and vice versa (ii) regions with high heat flow and deep sedimentary basins have increased foreshock activity and reduced aftershock productivity. The results demonstrate that seismicity patterns do not follow universal power law statistics in all space-time domains. Assuming the observed asymmetric properties of seismicity reflect asymmetric properties of earthquake ruptures, and earthquake productivity reflects the local seismic potential of the crust, the discussed methodology and results can be used to develop refined estimates of seismic shaking hazard associated with individual fault zones and regions.