Title: Premonitory patterns of seismic clustering in natural and induced seismicity

Authors: Ilya Zaliapin[1] and Yehuda Ben-Zion[2]

Affiliations:
[1]Department of Mathematics and Statistics, University of Nevada, Reno, 89557
[2]Department of Earth Sciences, University of Southern California, Los Angeles, 90089

Session: Four paradigms in predicting extremes: Legacy of Vladimir I. Keilis-Borok

Abstract:
Earthquakes and related hazards present a high risk to individuals, infrastructure, and society as a whole. This risk keeps increasing due to urbanization, development of high-risk utility plants (chemical, nuclear, etc.), and expanding hydrocarbon production. Recent earthquakes in the Midwestern US, Basel and St. Gallen in Switzerland, and other areas with hydrocarbon and geothermal production emphasize the increased risk posed by human-induced seismicity, which may be especially acute in California and other tectonically active regions. Reducing the risk associated with natural and induced earthquakes requires improved understanding of spatio-temporal variations of seismicity. Our recent studies established the general existence of several main types of seismic clusters (singles, burst-like, swarm-like) that can be robustly detected in natural earthquake catalogs and are correlated with properties of the crust. This provides a platform for defining the regional *cluster style* (dominant type of cluster statistics) and *cluster anomalies* (deviations from the average style), and studying their relations to various ongoing loadings, including induced events related to exploration activities, and evolution leading to large earthquakes. Here we analyze natural and induced seismicity of California, Turkey, Midwestern US, and the TauTona gold mine in South Africa. We show that the clustering properties of areas with dominant induced seismicity (e.g., Geysers, Salton Trough, TauTona) are different from that of areas with dominant natural earthquakes (e.g., San Jacinto). The results offer robust statistical characteristics that distinguish natural and induced seismic activity. To improve the understanding of conditions leading to large events in different areas, we study the evolution of cluster style and cluster anomalies during the approach of large earthquakes (defined in accordance with seismic activity of examined region). We demonstrate significant statistical changes of earthquake cluster style, as well as existence of prominent cluster anomalies, which are observed in spatio-temporal vicinity of large earthquakes. These results motivate additional studies (in progress) on distinguishing characteristics of natural and induced seismicity and premonitory signals during the approach to large seismic events.