Western Science

Department of Earth Sciences

Ph.D. Geophysics Public Lecture

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Modeling and Analysis of Mining Induced Seismicity:
Statistical Approaches and Case Studies

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Via ZOOM

Abstract

Earthquakes pose significant risks to populations and infrastructure. Natural earthquakes often occur suddenly and can be catastrophic, whereas induced earthquakes, generated by anthropogenic activities, are typically less severe but are increasingly attracting public attention due to their rising frequency and localized impacts. Despite extensive research, the complex physical processes underlying seismicity remain not fully understood, making it challenging to improve short-term forecasting and manage induced seismic events. Current forecasting models are often hampered by data limitations and inherent uncertainties, complicating efforts to mitigate seismic hazards effectively. This thesis aims to address these challenges through the development and application of advanced statistical models and methodologies. First, it introduces frameworks for analyzing and forecasting seismicity using approaches such as the Gutenberg–Richter (GR) scaling, nearest-neighbour distance (NND) method, and the Epidemic Type Aftershock Sequence (ETAS) model. These models are adapted and extended to better account for the unique characteristics of induced seismicity, including deviations from traditional frequency-magnitude relationships and the clustering behaviours often observed in mining environments. Secondly, the thesis presents novel applications of Bayesian predictive frameworks to quantify the probabilities of large seismic events, incorporating uncertainties to improve short-term risk assessments and decision-making. One major contribution of this research is the application of enhanced clustering analysis using the NND method and mixed frequency-magnitude distributions to investigate clustering characteristics in potash mining environments. This approach provides detailed insights into the temporal and spatial dynamics of seismic clusters, highlighting deviations from standard scaling laws and their implications for hazard mitigation strategies. Another key contribution is the application of advanced predictive models to evaluate the risks associated with mining-induced and natural aftershock sequences. The ETAS model and the temporal Hawkes process are employed to forecast seismicity rates and assess dynamic changes in triggering mechanisms. Additionally, Bayesian inference is utilized to compute the probabilities of extreme seismic events during prescribed intervals, providing actionable insights for hazard mitigation and operational safety. This thesis integrates these methodologies into a comprehensive framework for understanding and managing seismicity, contributing to seismic hazard assessment and the development of safer practices in mining and other industrial operations. By bridging gaps in current models and applying refined seismicity modeling techniques, it offers new tools for assessing and mitigating risks in both natural and induced seismic contexts. Ultimately, the findings of this research may inform future studies, support decision-makers, and enhance public awareness of seismic hazards, contributing to a safer and more resilient society

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