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New Frontiers in Passive Seismic Monitoring

Camilla Rodrigues (Nanometrics), Benjamin Witten (Nanometrics), Adam Baig (Nanometrics)

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Introduction

Passive seismic monitoring is a critical component in managing subsurface operations such as wastewater injection, enhanced geothermal systems, hydraulic fracturing, mining, and similar activities. Its importance is often underscored by regulatory requirements like Traffic Light Protocols (TLPs), which use seismicity as a feedback mechanism to guide operational decisions. These frameworks typically focus on locating events, estimating magnitudes, and characterizing ground motion to manage induced seismicity risks.

While this application is essential, it represents only a fraction of the potential value embedded in passive seismic data streams. To fully understand how operational activities drive seismicity, including the triggering mechanisms and subsurface fluid migration, we need to go beyond the limited parameters required by TLPs.

Methods and/or Theory

In this talk, we explore advanced uses of passive seismic data through higher-order waveform analyses. Central to this approach is the consistent, high-accuracy processing of large volumes of seismic events—an area where machine learning plays a pivotal role. By improving detection rates and event location accuracy, we open the door to robust analyses such as moment tensor inversion for larger events and, where fault geometries are known, constraint of regional stress orientations. Further, relationships between seismic moment and radiated energy offer insights into fault slip behavior, including stress buildup, fluid lubrication, and failure dynamics.

Results and Conclusions

Drawing on case studies from geothermal and wastewater disposal projects, we will demonstrate how these advanced techniques can enhance the application of passive seismic monitoring in carbon capture, utilization, and storage (CCUS) settings.