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Searching for Hidden Microearthquakes using Data-based, Physics-based, and Hybrid Models: Implications for Salt Dome Monitoring

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Earthquakes in stable salt domes are few, with a notable increase in the rate of seismicity prior to catastrophic events, such as the collapse of salt caverns used to store hydrocarbons. Cavern collapse, subsequent gas leakage, and the formation of sinkholes pose a significant hazard for local communities, given that they can disrupt normal societal functions, have various socio-economic impacts, and may result in the evacuation of residents. In Louisiana, one such event was the Bayou Corne collapse in 2012. Following reports of unusual ground tremors, we began monitoring seismicity at the Sorrento salt dome in February 2020. The goal of this study is to improve our understanding of the subsurface processes and their impact on the mechanical integrity of salt domes; we do this by examining the spatio-temporal evolution of the seismicity. We deployed an ~5 km x 4 km nodal array of 12-17 stations, with interstation distances of 0.2 km to 1.9 km, across the dome and recorded eight months of data that were sampled at 500 Hz.

Sorrento dome events are usually low in magnitude, often with emergent P-wave onsets, as well as P-waves shrouded in the coda of preceding events, during swarms. Such characteristics make the events difficult to identify using standard automatic detection and location procedures. We first evaluate current methods using an STA/LTA algorithm, coincidence event detectors, and pre-trained, deep-learning detectors and pickers. We find that detection of consistent P-wave phases across several stations for the same event is challenging and poses a major problem for event association and location. To address this problem, we initiate a manual review of all initial event associations to eliminate false positives that could incorrectly inflate the number of events in the catalog. We, therefore, developed a custom-trained detector and picker that outperformed other methods, and it identified multiple events that were recorded by >70% of the stations in the array. Our approach is well-suited for identifying events with emergent P-wave onsets and short durations (~2-10 s), and our method correctly identified a spike in seismicity in the days leading up to a well failure at the dome. Our methodology can be easily adapted for similar types of studies, such as volcano, mine and dam monitoring, and geothermal exploration.