A decade of Oklahoma earthquakes: past, present and future

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In the last decade, Oklahoma has experienced significant changes in earthquake activities: earthquake rate dramatically increased since 2009, with a peak rate exceeding California, which has gradually decreased in recent years. This “accidental” large scale earthquake experiment provides us with rich datasets to further understand earthquake physics. Here, focusing on analyses of seismicity and accounting for the physics of earthquake nucleation, we link several studies to give a brief overview of Oklahoma earthquakes, and their implications for future studies in induced seismicity. First, the analysis of spatiotemporal patterns of seismicity rate can help us infer the subsurface hydraulic parameters at both regional and local scales. At the regional level, the hydraulic diffusivities differ between Eastern and Western Oklahoma, separated by the Nemaha Fault, reflecting hydraulic properties of the Arbuckle Group (injection layer). At local scales within individual faults, the analysis suggested similar hydraulic diffusivities to crustal earthquake bursts from other tectonic regions, implying common properties of the crystalline basement. Second, coupled poroelastic responses to injection on individual faults are essential, and produce seismicity rate forecast that more closely resemble observations. However, local stress tensor variations can significantly influence fault “criticality” and should be taken into account for modeling stress interactions. Third, in addition to injection-related stress changes, earthquake interactions and aseismic slip need to be considered in induced earthquake sequences, and detailed source modeling and statistical analysis are required to understand their roles in the evolutions of individual sequences further. Finally, Oklahoma seismicity offers opportunities to test short- to intermediate-term forecasting based on different physical models, and new windows into earthquake rupture initiations.