Large-Scale Migration Patterns of Wastewater-Induced Earthquakes in the Central U.S.

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It is understood that the recent acceleration of seismic event occurrences in Kansas and Oklahoma, U.S., can be connected to the large-volume disposal of wastewater. These highly saline fluids are co-produced with oil and gas and are re-injected under gravity into the highly porous Arbuckle aquifer. Since 2015, injection rates have been decreasing. However, the seismic hazard in that region remains elevated. Furthermore, it has been noticed that some events in Kansas occur far from disposal wells.

To analyse spatio-temporal patterns between the fluid injection and earthquake locations, we applied a time-dependent 2D cross-correlation technique. This reveals a vectorial migration pattern of the seismic events. Whereas early events occur towards the east-southeast, later events are located preferably in northeastern direction of large volume injectors. With time, event locations migrate further in that direction. We explain this observation as well as measured Arbuckle pore pressures by a directional pore-fluid pressure diffusion and poroelastic stress propagation. This also follows from our principal two-dimension poroelastic finite element model which is of predictive power and identifies controlling parameters of the observations. These are mainly the permeability of the target injection formation and the seismogenic basement as well as the anisotropic permeability and the critical fault strength distribution. Our results lead to the conclusion that remote locations are destabilised also when injection rates are declining.

Thus, volume reductions may only provide a direct effect to lower earthquake rates locally. However, a state-wide decrease of the seismicity may require longer times such that the seismic hazard due to wastewater disposal induced seismicity may remain for decades.