# What's Shakin'? Geospatial Influence of Fracking on Earthquakes

## INTRODUCTION

Hydraulic Fracturing or "Fracking" has been a topic of debate within the U.S. which as a result of the technology, has become the world's largest exporter of oil in 2016. Fracking has undergone a boom, starting in 2005 when the "Halliburton Loophole" exempted the oil production method from the Clean Water Act. However, it is unclear how safe the process, involving the high pressure injection of fracking fluid (mostly water but also including sand and a mix of undisclosed chemicals) really is in terms of aquifer pollution, land subsidence and among other risks: earthquakes. States such as Oklahoma, Texas, Colorado, Alabama, far from fault lines and traditional geologic activity, are now facing hundredfold increases in these events. This has major implications for urban and natural environments not used to these happenings.

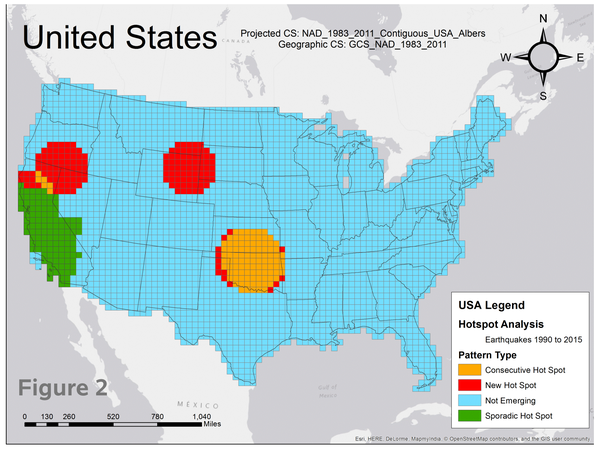


Figure 2

## RESEARCH QUESTIONS

Using scarce fracking well data and widely available earthquake data from USGS, I ask the following…

- How have earthquake trends shifted on the national level since the fracking boom beginning in 2005?
- In those states with high adoption of fracking, how have earthquake trends changed at the state level, both spatially and in overall numbers?
- What is the statistical spatial correlation between well sites and earthquake locations at the state level?

## DATA

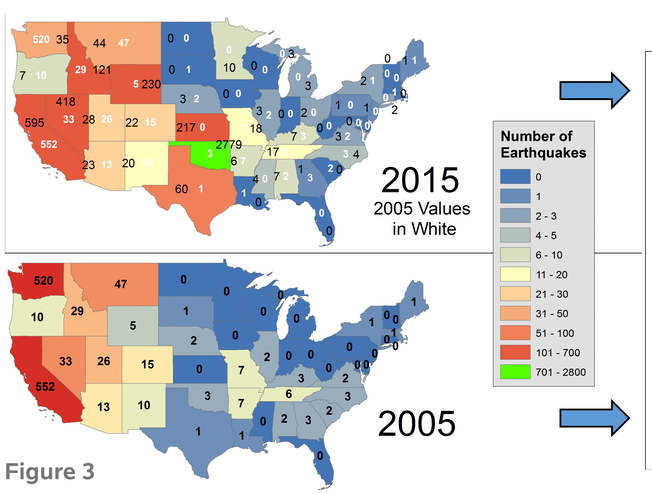
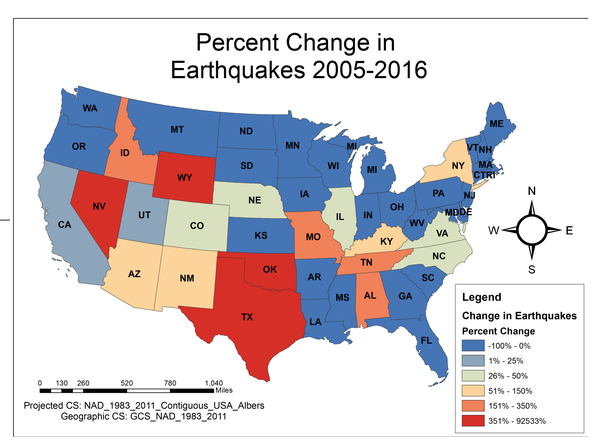


Figure 3




All earthquake data was provided by the United States Geological Survey's Earthquake Hazards Program.
All fracking data is from FrackingData.Org specifically, the Geological Survey of Alabama State Oil and Gas Board, Kansas Geological Survey; University of Kansas, Oklahoma Corporation Commission Oil and Gas Division and the Colorado Oil and Gas Conservation Commission; Department of Natural Resources.

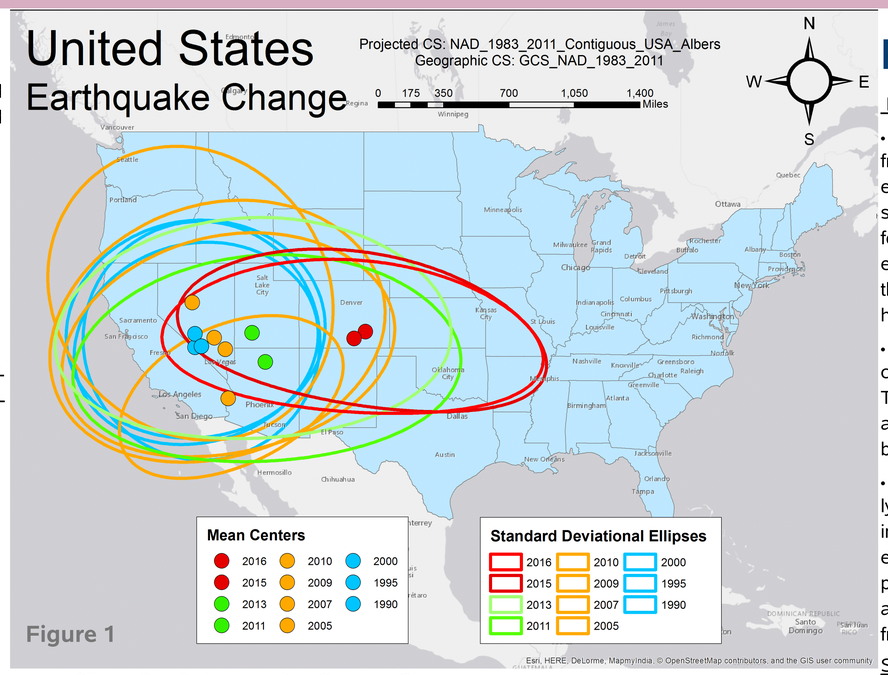


Figure 1

## METHODS

1) Use of two simple statistical tools: Directional Distribution (Standard Deviational Ellipse) and Mean Center. The first, draws an ellipse around the points (wells or earthquakes) at 1.0 standard deviation, encompassing 68% of the data assuming said data has a relatively equal distribution. The second identifies the center of concentration for a set of data features (wells or earthquakes).

2) In the states of Colorado and Oklahoma and then nationally I conducted Emerging Hot Spot Analyses (Space Time Pattern Mining). This tool identifies trends and clusters over time, focusing on new, sporadic and consecutive hotspots of activity, in this case of earthquakes.

3) Finally, over Colorado and Oklahoma, I assigned an artificial coordinate system of blocks, or a fishnet, to spatially divide all the earthquakes and wells that occurred over the period of 2005 to 2016. I then used the program GeoDa to assess the statistical spatial association of the number of fracking wells to number of earthquake occurrences in each block over said period of time.

## RESULTS

National Analysis

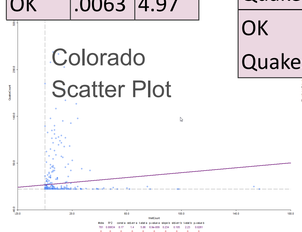
- *Figure 1* shows that from 1990 to 2015, earthquake trends have shifted east, from California to the Mid-West especially starting in the early 2010's and hugely into 2015.
- *Figure 2* supports this claim, with Oklahoma, Texas and Nebraska as a consecutive hotspot between '05 and '15.
- *Figure 3* is particularly interesting highlighting the extreme changes in number of quakes per year in the South and Midwest since the fracking boom in 2005.

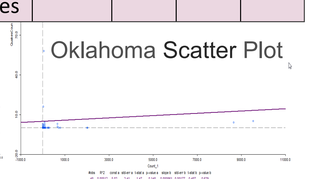
State Analysis

- *Figure 4* shows Colorado, an example of a state where wells (density shown in blue) appear to have relatively low spatial correlation with earthquakes experienced in the state (red triangles). The two mean centers, are very dissimilar.
- *Figure 5* however, is an example where we can see a significant shift in earthquake locations (ellipses) pre-fracking and today. We also see moderate spatial correlation between fracking wells (red triangles), the hotspot squares, and well density . Oklahoma had the most spatial correlation of any state assessed.
- *Figures 6* demonstrate the method used to calculate the spatial statistical correlation between fracking wells and earthquake occurrences in OK and CO. By comparing the counts of these two variables in each artificial 10 square mile blocks, the scatter plots and regression reports below were generated. These "Coefficient" indicates that per 10 mile block square, as number of wells increase by 1, earthquakes increase by .001 in CO and .234 in OK. This matches the data in Figures 4 and 6 with wells and earthquake locations matching up in Oklahoma but appearing random in Colorado. A .234 coefficient in Oklahoma is interesting but the $R^2$, or fit, of the data, along with associated significance tests are all very low.

| | $R^2$ | F |
|---|---|---|
| CO | .0038 | 4.38 |
| OK | .0063 | 4.97 |

| Variable | Coefficient | Std. Error | t-Stat | Prob. |
|---|---|---|---|---|
| CO Quakes | .001 | .001 | 2.09 | .037 |
| OK Quakes | .234 | .105 | 2.23 | .026 |



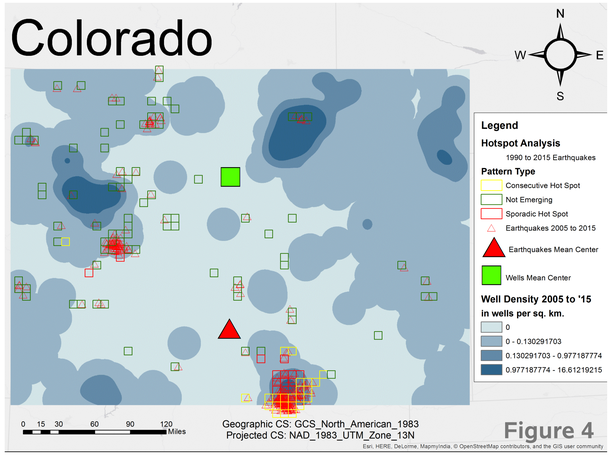



Figure 4

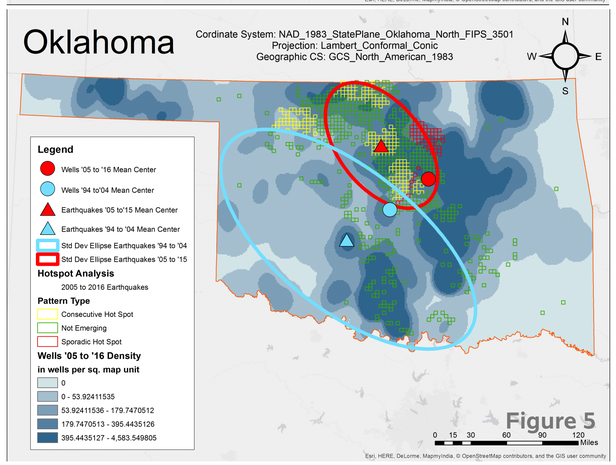


Figure 5

## CONCLUSION

The biggest limitation in this analysis was quality of data. Oklahoma and Colorado were chosen because they had the best data sets including most importantly well types and dates.
It is certainly evident at the national level that earthquake trends are shifting, despite that they show low spatial autocorrelation at the state level. If national fracking well data was available, it would be interesting to run the same fishnet regression based analysis done here on CO and OK on the US as a whole. Though on the state level, CO showed little correlation, OK earthquakes shifted significantly after 2005 and earthquake hotspots fell near areas of high well density.
In numbers alone, earthquakes are having an enormous exponential rise. Hopefully with time, more data will be released on fracking in the US so that further research can be done on topics such the role of fluid disposal sites, well depth/type's roles and a variety of other factors that could be at play.

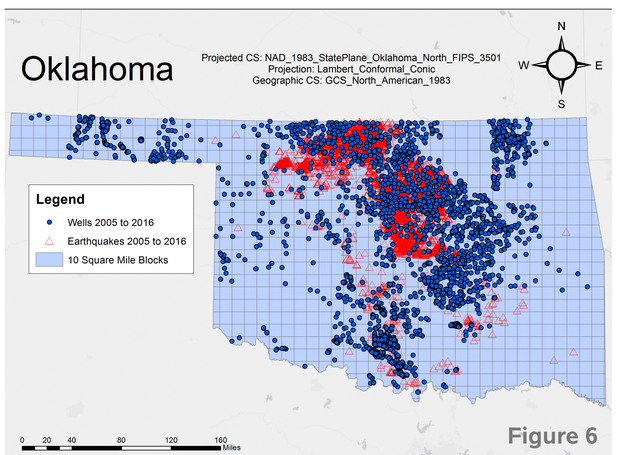


Figure 6


Cartographer: Tyler McCullough, Undergrad A&S 2017

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Data: USGS, Geological Survey of Alabama, Kansas Geological Survey, Oklahoma Corporation Com-

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