Session Code: I-2

INDUCED SEISMICITY & US EARTHQUAKE CATASTROPHE MODELING

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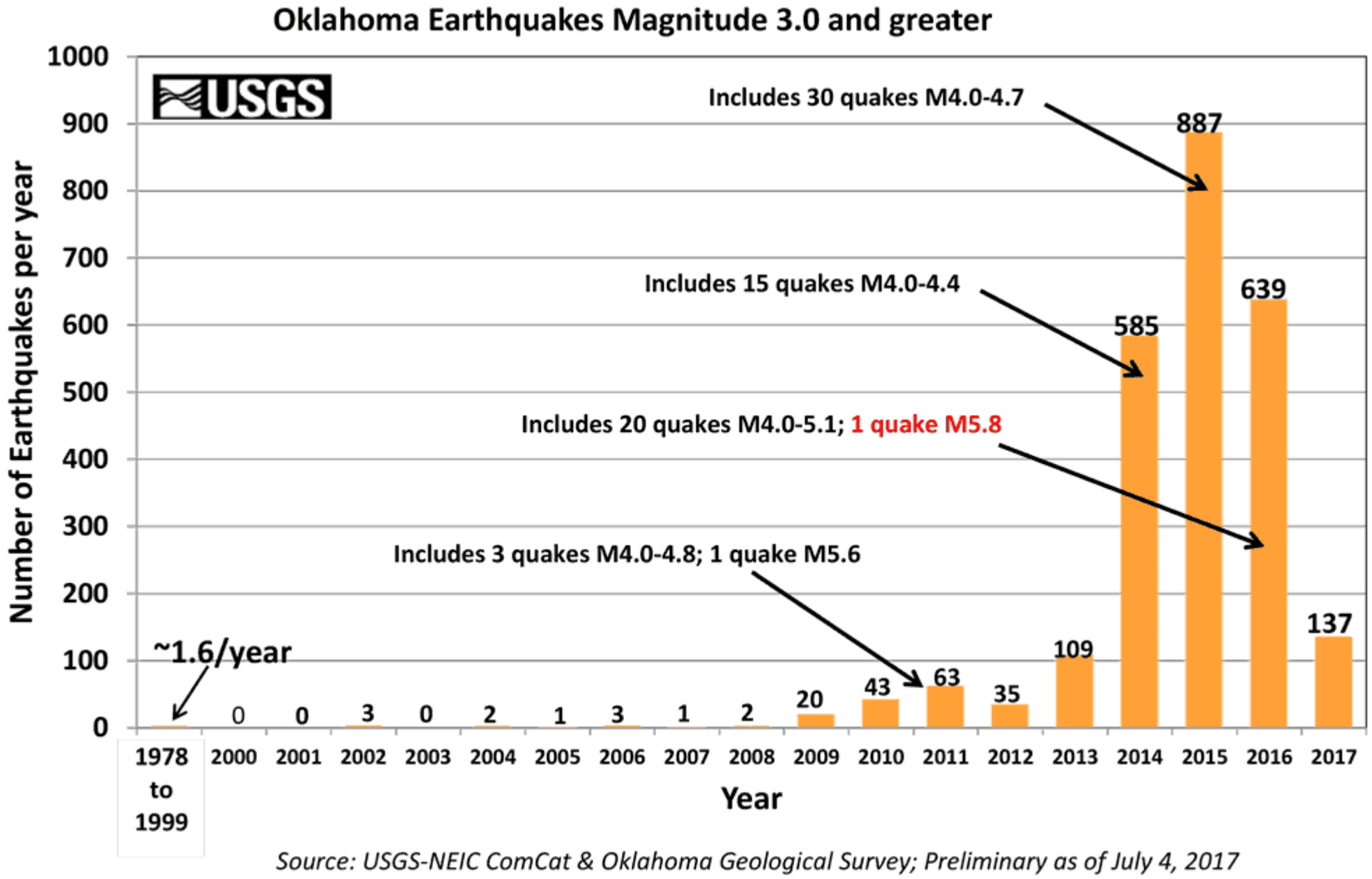
BACKGROUND

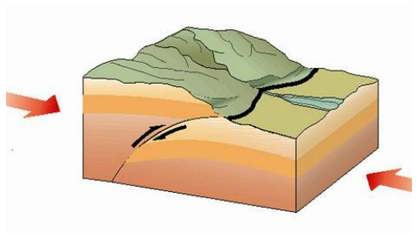


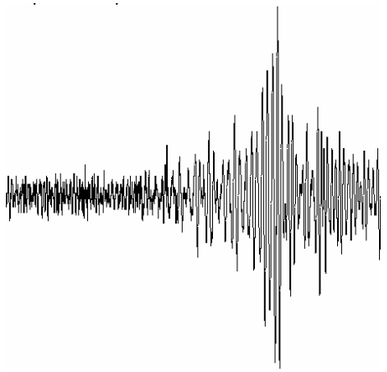
Source: USGS-NEIC ComCat & Oklahoma Geological Survey; Preliminary as of July 4, 2017

INTRODUCTION

- RMS models and software help insurers, financial markets, corporations, and public agencies evaluate and manage catastrophe risks throughout the world.
- The RMS Earthquake Model for the U.S. released in April 2017 incorporates:
  - 2014 U.S. Geological Survey (USGS) National Seismic Hazard Mapping Project
  - 2016 USGS update: 1-year forecast for CEUS incorporating induced seismic events (with logic tree specific for induced seismicity)
- RMS continues to evaluate scientific and regulatory developments regarding induced seismicity for consideration in future updates.
  - 2017 USGS update: 1-year forecast for CEUS (same methodology with change to rates only)

CATASTROPHE MODELING FRAMEWORK





Stochastic Event Module

Create a set of earthquake events and associated probabilities

Hazard Module

Calculate the ground motion for all sites due to each stochastic event

Exposure Module

Apply exposure characteristics

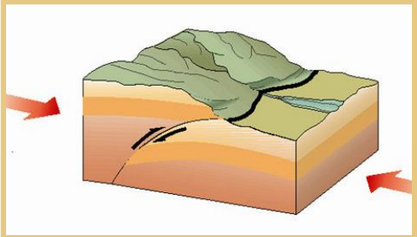
Vulnerability Module

Calculate the average damage and associated variability

Financial Analysis Module

Calculate the financial impact for all perspectives

HOW DOES INDUCED SEISMICITY AFFECT THESE?



Stochastic Event Module

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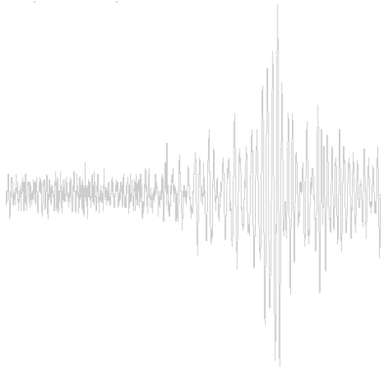


Hazard Module

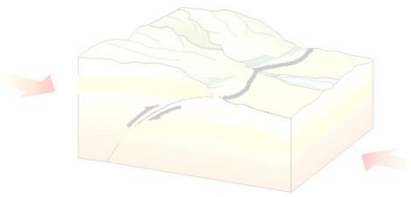
Exposure Module

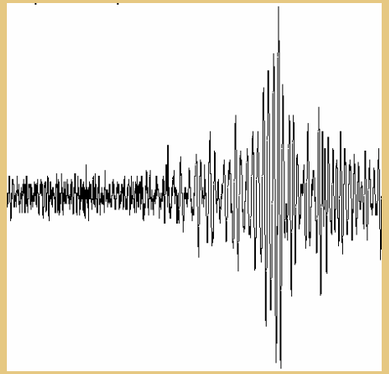
Vulnerability Module

Financial Analysis Module

Earthquake catalog
Earthquake rate model
Earthquake location model
Maximum magnitude model

HOW DOES INDUCED SEISMICITY AFFECT THESE?



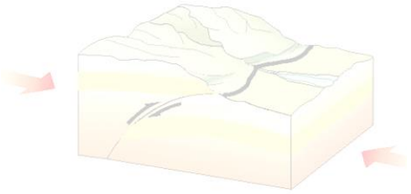


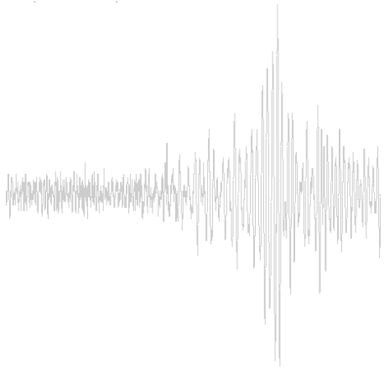
Stochastic Event Module → **Hazard Module** → **Exposure Module** → **Vulnerability Module** → **Financial Analysis Module**

Calculate the ground motion for all sites due to each stochastic event

New Ground motion model (Atkinson 2015 along with CEUS standard model) used in 2016 forecast.
Active area of research.

HOW DOES INDUCED SEISMICITY AFFECT THESE?



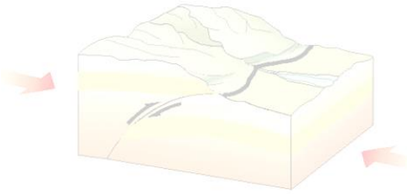


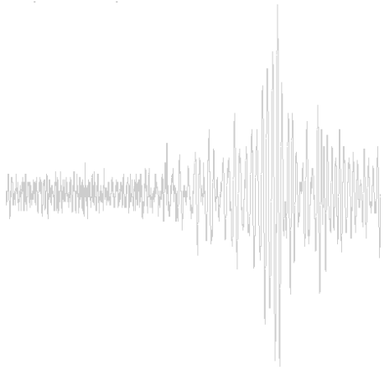
Stochastic Event Module → **Hazard Module** → **Exposure Module** → **Vulnerability Module** → **Financial Analysis Module**

Apply exposure characteristics

Increasing take-up of EQ insurance.

HOW DOES INDUCED SEISMICITY AFFECT THESE?



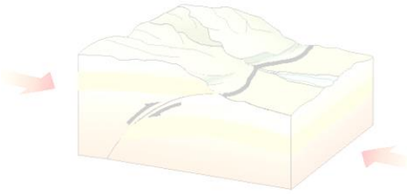


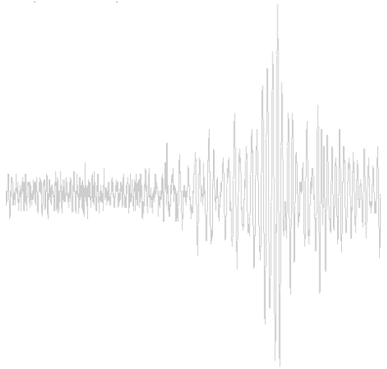
Stochastic Event Module → **Hazard Module** → **Exposure Module** → **Vulnerability Module** → **Financial Analysis Module**

Calculate the average damage and associated variability

Limited.
Potential for progressive damage, but similar enough to treat the same for now.

HOW DOES INDUCED SEISMICITY AFFECT THESE?





Stochastic Event Module → **Hazard Module** → **Exposure Module** → **Vulnerability Module** → **Financial Analysis Module**

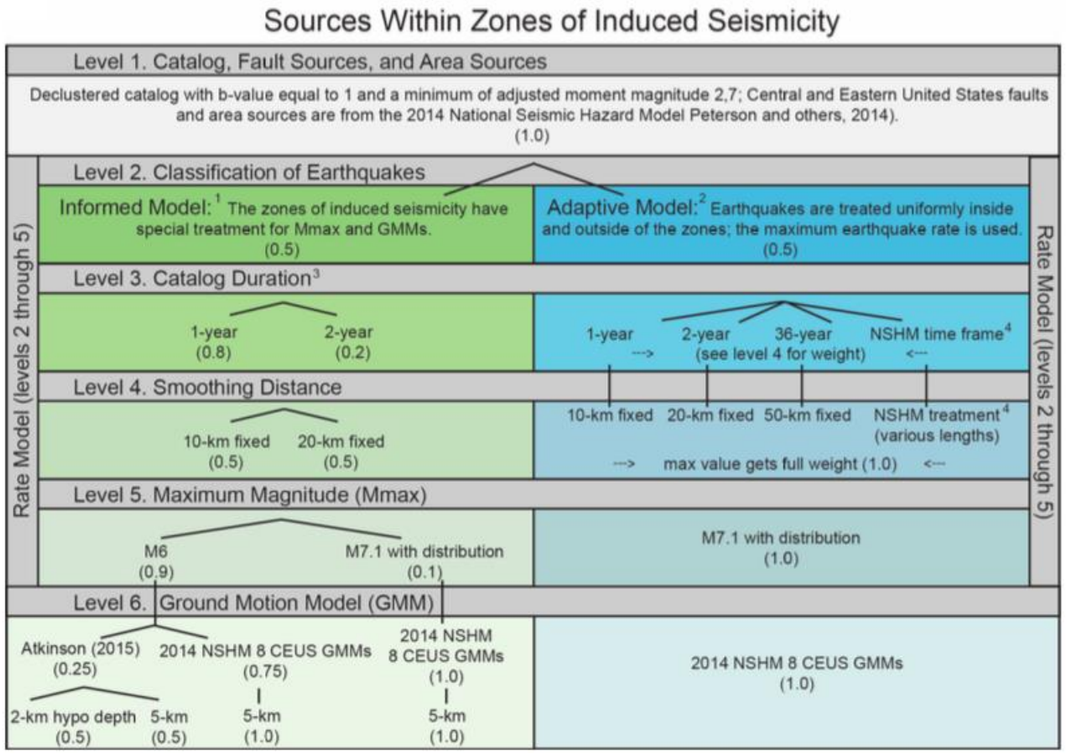
Calculate the financial impact for all perspectives

Who pays?
Model provides a tool for quantification based on user assumptions.

CHALLENGES OF MODELING HAZARD FROM INDUCED SEISMICITY

- **Depth** - Induced earthquakes appear to be much shallower.
- **Source assumptions** - Do induced earthquakes behave the same way as natural ones?
- **Catalog** - Which catalog should be used to characterize the events?
- **Location** - How should the temporal migration be modeled?
- **Smoothing** - Distance over which seismicity rate should be spread out.
- **Maximum magnitude** - What is the potential maximum magnitude that should be considered?
- **Ground motion models** - Is the shaking caused by induced earthquakes different enough from natural ones that a different model should be used?

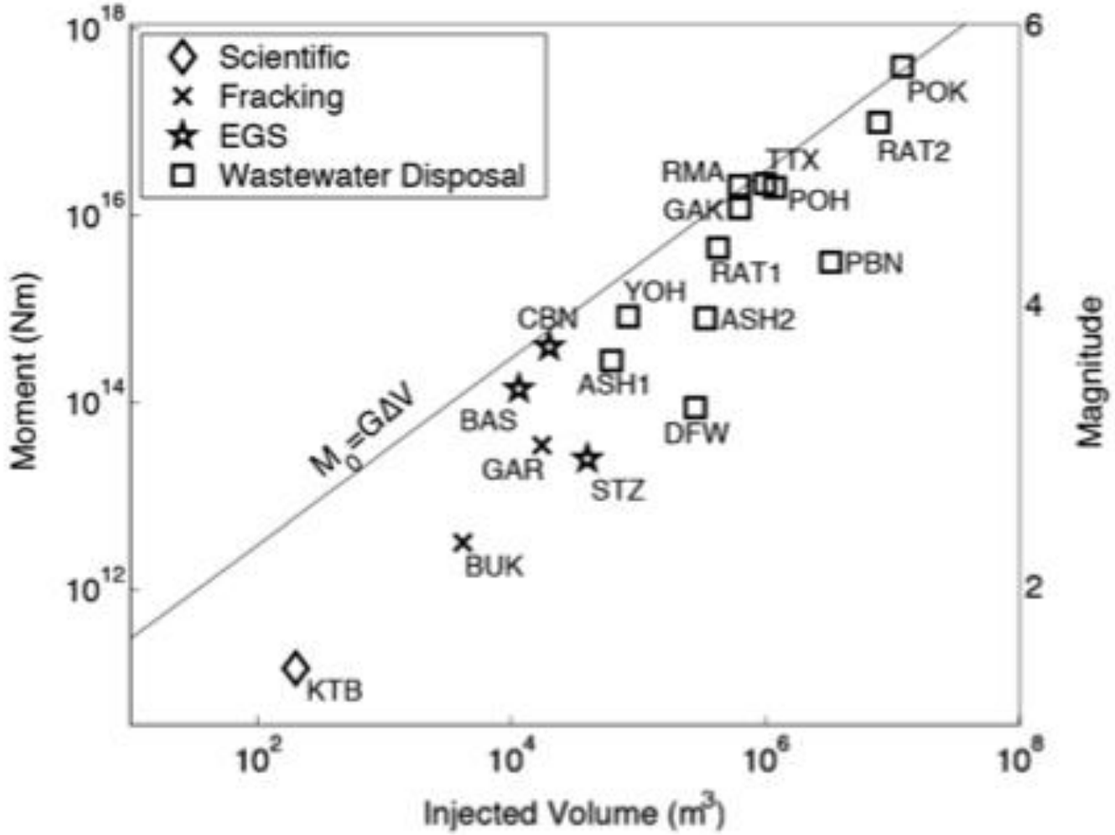
USGS Logic tree



USGS Open-File Report 2016-1035

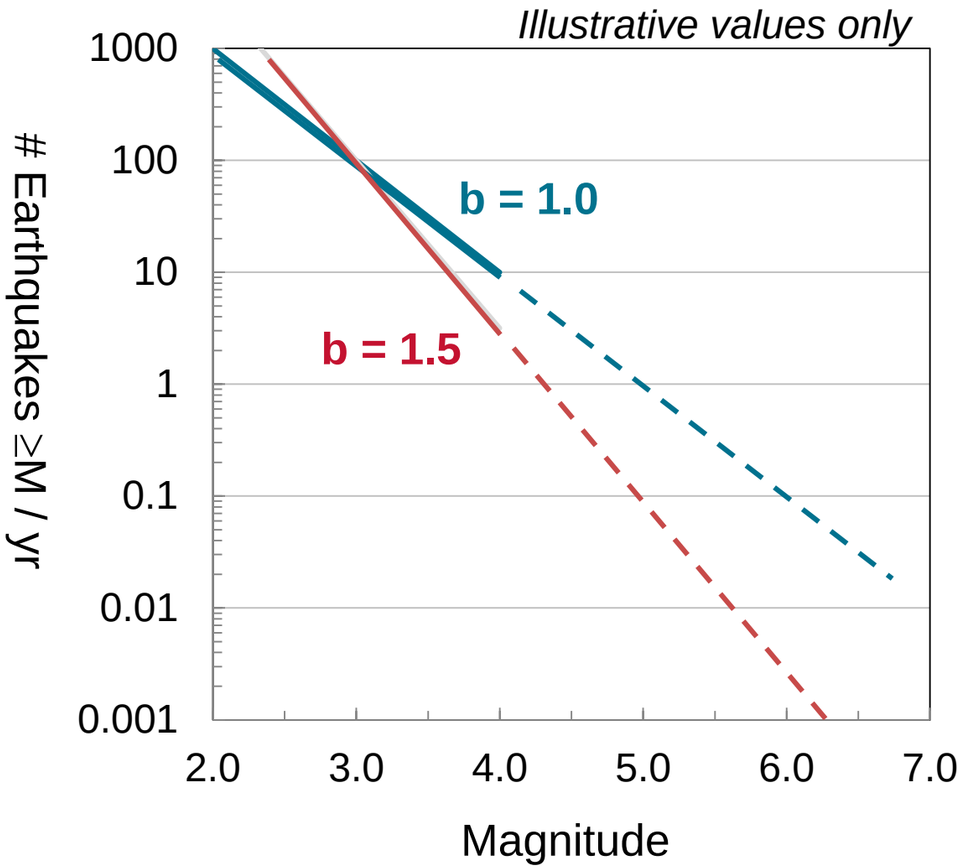
MAXIMUM MAGNITUDES

- Maximum magnitude appears to be limited to total volume of injected fluid – under investigation
- Main source of uncertainty: assumption that slip in response to injection is limited to region experiencing pore pressure increase…



McGarr, 2014 JGR

B-VALUE AND WHY IT'S RELEVANT



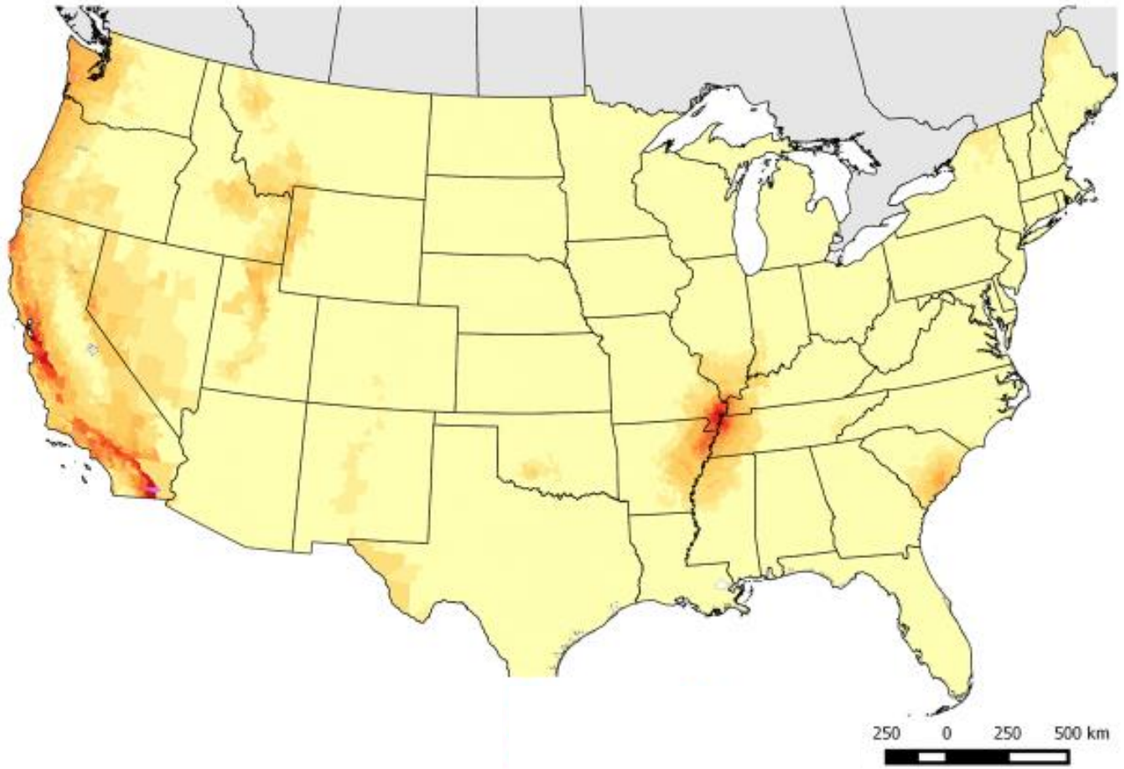
Gutenberg-Richter relationship:

$$\log_{10}(N/yr \geq M) = a - b\,M$$

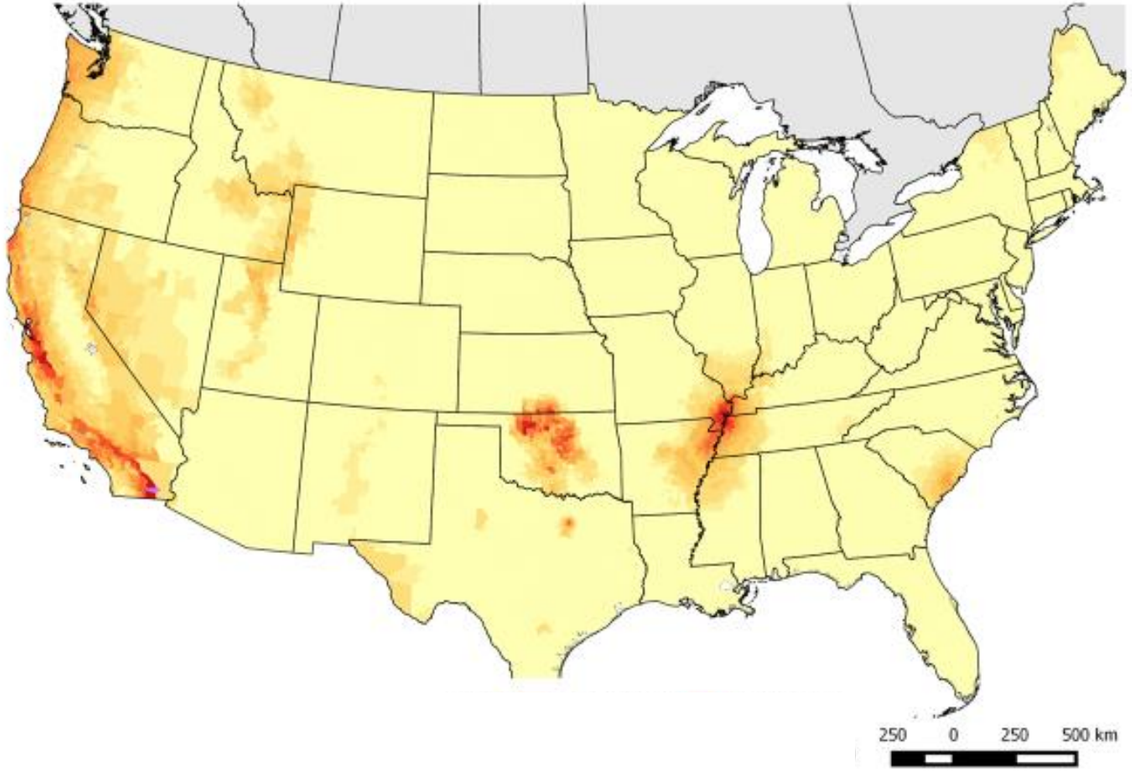
- b-value represents relativity between small and large events
- Value of 1.0 is typical, but some research suggests induced event sequences have a higher slope
- Significant for probabilities of larger magnitude events

LOSS COST IMPACT OF INDUCED SEISMICITY MODEL

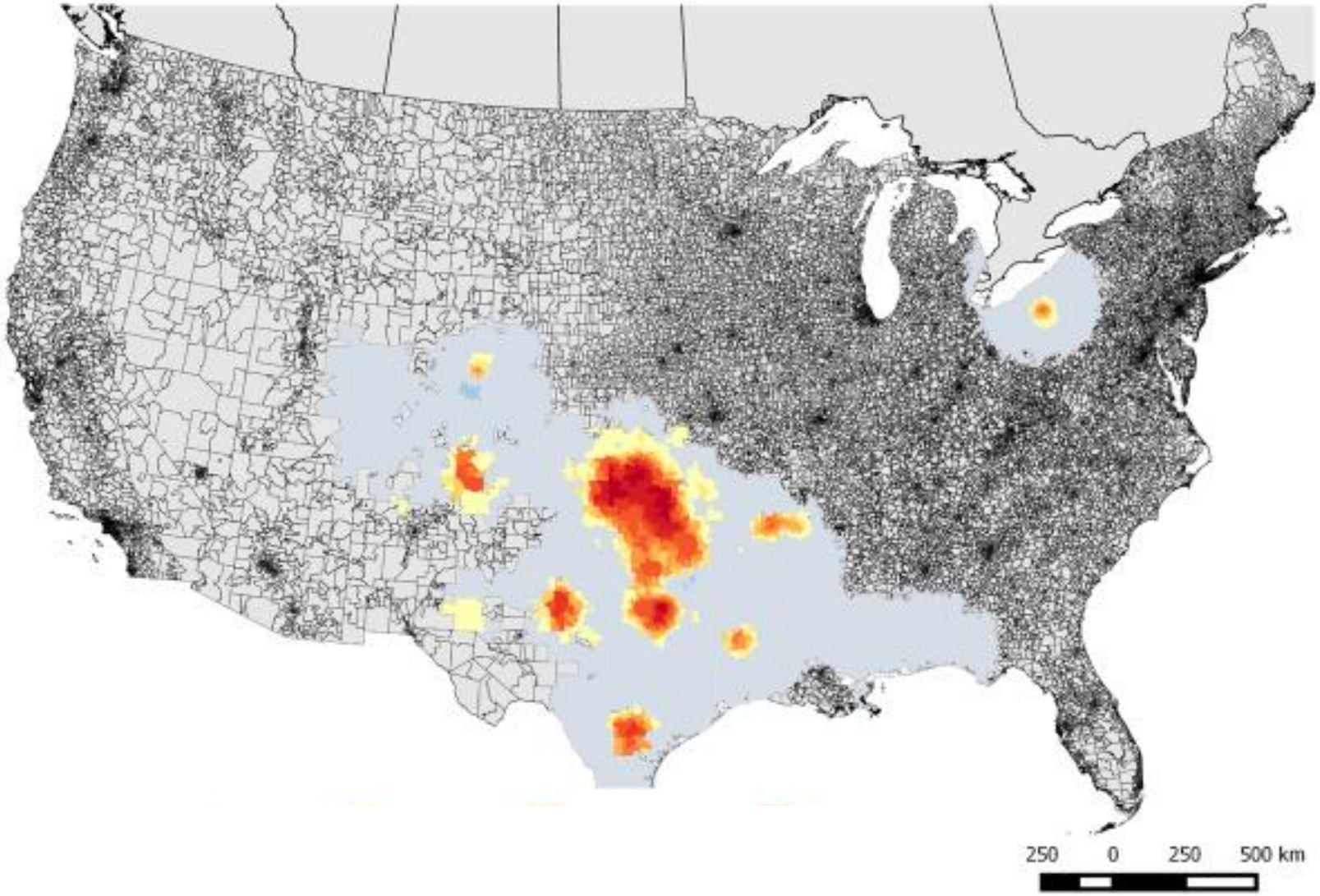
DEFAULT MODEL



WITH INDUCED SEISMICITY

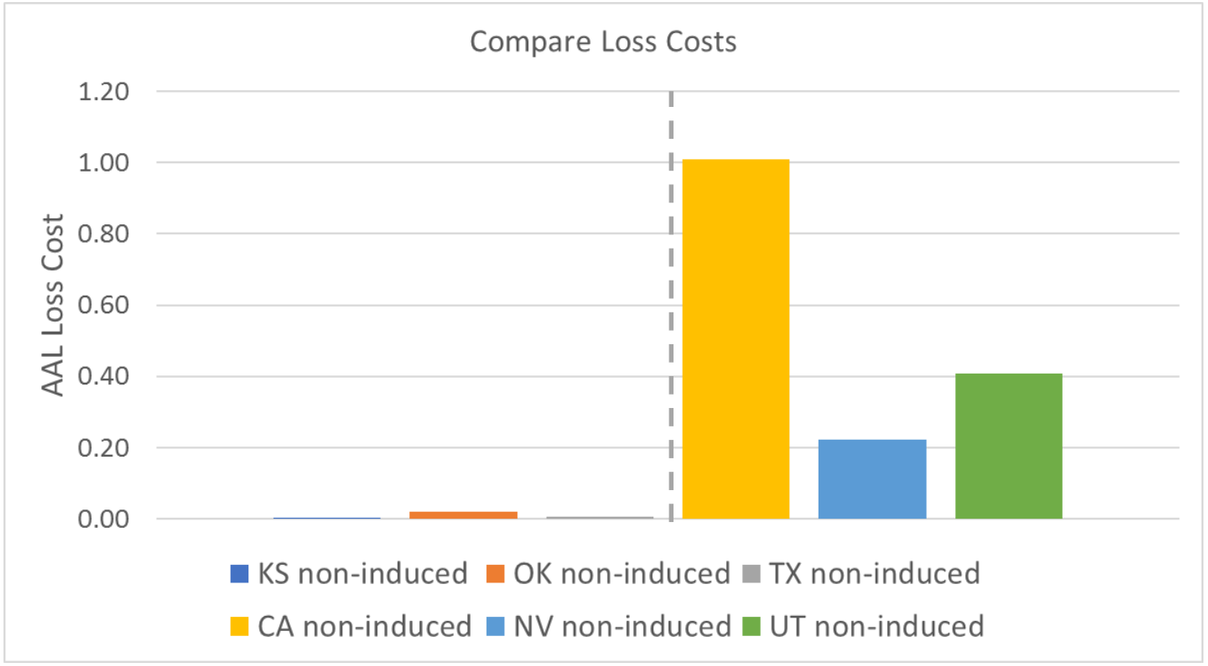


AAL CHANGE (%)

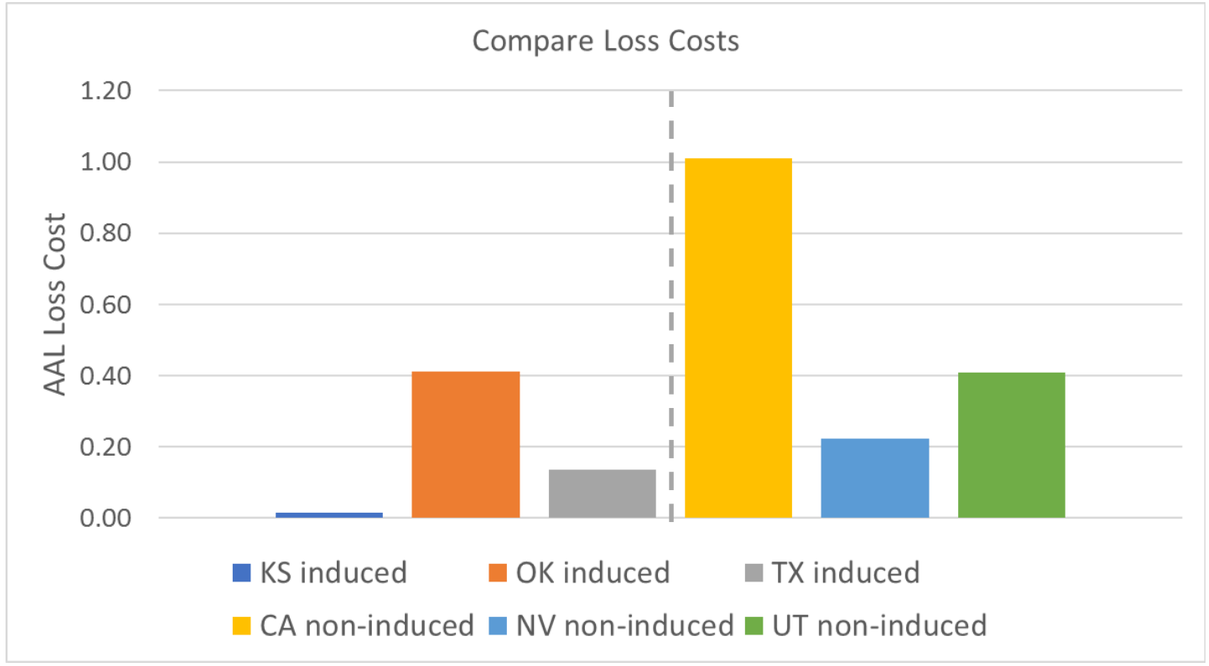


IMPACT OF INDUCED SEISMICITY ON STATE-WIDE IED PORTFOLIO: LOSS COST

DEFAULT MODEL



WITH INDUCED SEISMICITY



CLOSING THOUGHTS…

- Quantifying the risk due to induced earthquakes has numerous challenges
  - Rate of events is non-stationary and is influenced by human decisions
  - Very sensitive to treatment of larger events
- Severity is more straightforward than frequency
  - Scenario modeling of accumulations
- Very active area of research – science continues to evolve

THANK YOU FOR YOUR ATTENTION!