New Madrid Seismic Zone

Lecture Objectives

- -basics of USGS seismic hazard modeling
- -understand New Madrid earthquake hazard debate
- -implications of hazard predictions

Probabalistic Seismic Hazard Analysis (PSHA)

-USGS uses PSHA to develop national seismic hazard maps. This forms the basis for national seismic safety regulations and design standards.

-Why use this? Easy to develop risk assessments.

-Physical models so poor that the main goal of hazard mapping would never get done.

-Knowledge of seismicity comes from understanding past event types, magnitudes and frequencies, which can be measured through field studies.

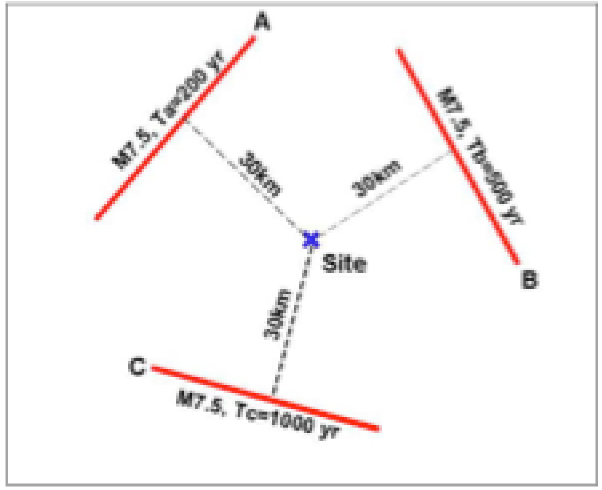


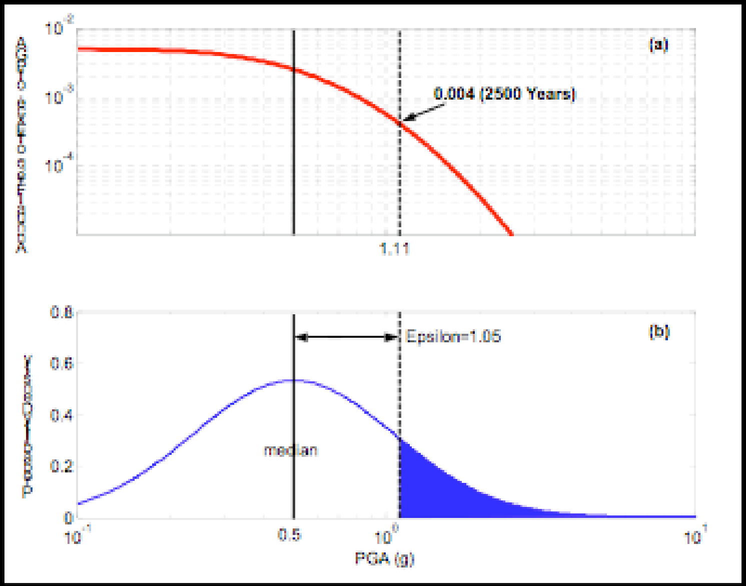
Figure 1. Hypothetical region with three seismic sources (A, B, and C faults) and a site of interest within 30 km of the faults.

Annual frequency of exceedance at site:

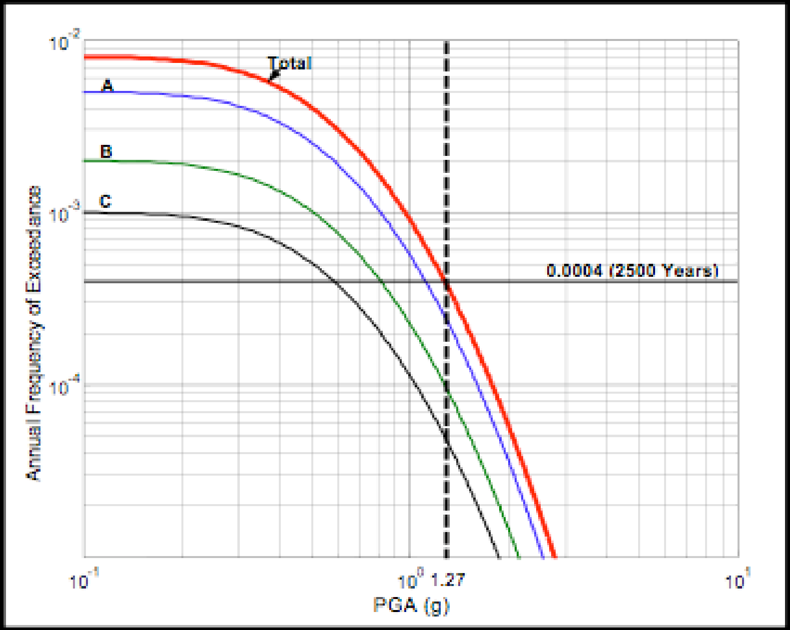
(recurrence rate, 1/T) * (probability of ground motion exceedance)

for A, 1/200 years * 0.08 = 0.0004 per year

So, the return period is 1/0.0004 = 2,500 years



Probability of ground-motion exceedance; 0.08 (8%) = the probability that the peak ground acceleration (PGA) of 1.11g will be exceeded - the shaded area under the <u>lognormal</u> curve.



The total hazard (total annual frequency of exceedance, of 0.0004) at the site is the sum of the individual hazards from faults A, B, and C.

Problems with PSHA analyses

-no consensus on how to select parameters, assign weights (e.g., probabilities of occurrence; distance, subsurface factors)

-predicted ground motion is a statistical relationship, and is unlikely to represent the actual motion of any single event. Because they use the total from all possible earthquakes (the site in the middle of 3 faults), the implication is that this is an overestimate. Further, the magnitude of future events is based upon accurate knowledge of past events (e.g., Parkfield).

-because of the log-normal distribution, the high end ground motion is infinitely large, which allows for the possibility of overestimating event magnitudes.

-any choice of frequency and ground-motion probability is biased, because there is essentially an infinite range. Presumably you would choose a representative rate and size, but even this is not generally agreed upon.

Stein: "Should Memphis Build for California's Earthquakes?"

-main issue? New Madrid Seismic Zone (NMSZ) considering adopting building codes to match those of southern California.

-mitigation goals: use seismology, engineering, plus economics and public policy to assess the seismic hazard and choose a level of safety that makes economic sense.

-provide information on the model assumptions and uncertainties, so that model-based decisions can be made fairly.

Stein, continued

-Weak building codes: unsafe construction, higher risks

-Overly stringent building codes: unneeded costs, promoting evasion, and diverting resources from other more pressing areas.

-Stein estimates a 10% additional cost to Memphis building would cost over $200 million per year, 10 times higher than FEMA's estimated annualized earthquake loss in Memphis ($17 million; this is likely too high, because the estimate uses the USGS hazard predictions). FEMA estimates NMHZ buildings 5-10 times less likely to be damaged by earthquakes than in California.

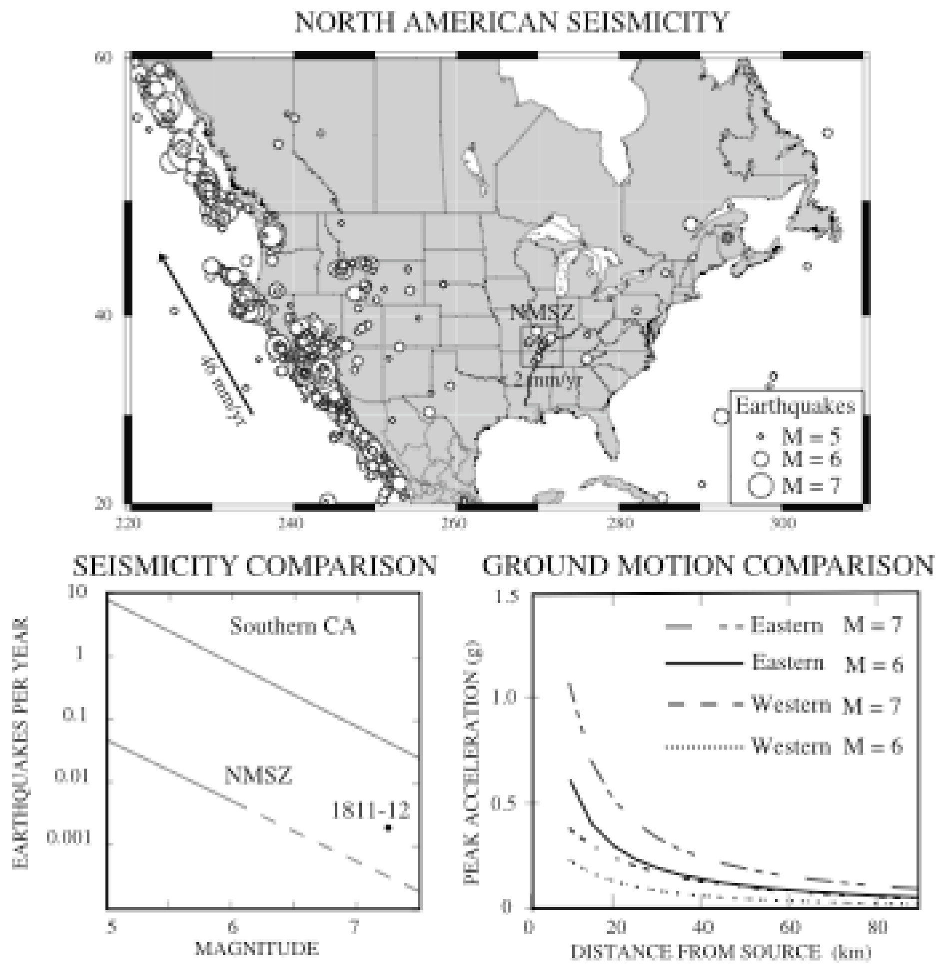


Fig. 1. Top: Seismicity (M 5 or greater since 1900) of the continental portion of the North American plate and adjacent areas. Seismicity and deformation are concentrated along the Pacific-North America plate boundary zone, reflecting the relative plate motion. The stable eastern portion of the continent, approximately east of 260°, is much less active, with seismicity concentrated in several areas, notably the New Madrid seismic zone. Bottom left: Comparison of the annual rates of earthquakes greater than a given magnitude for southern California and the NMSZ. Solid lines are computed from recorded seismicity, whereas dashed are extrapolated. Dot indicates paleoseismically inferred recurrence for the largest NMSZ earthquakes, assuming M 7.2. Bottom right: Predicted strong ground motion from earthquakes in the eastern and western U.S. For the models shown [Atkinson and Boore, 1995; Sadigh et al., 1997], *shaking from an M 6 earthquake in the east is comparable to that for an M 7 earthquake in the west.*

Plots M5 and above since 1900. Tectonics drives the western U.S. activity.

Bottom left: Southern California experiences roughly 100 times greater the number of earthquakes, at any magnitude. Solid lines are from recorded data; dashed are extrapolated. How often should a M7 occur in southern California?

Bottom right: modeling studies of predicted shaking – suggests that western activity is about 10 times less energetic, because the rocks in the NMSZ transmit seismic energy more efficiently.

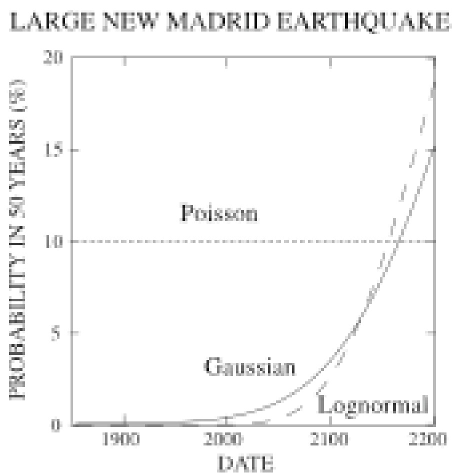


Fig. 2. Probabilities of a large New Madrid earthquake in the next 50 years as a function of time since 1812, for different models assuming a recurrence interval of 500 ± 100 yr.

-paleoseismic studies determine past events at 1450 +/- 100 and 900 +/- AD, suggesting recurrence interval of 500 years.

Poisson model: ignore the timing of any event. Assume 100% that 1 will occur in 500 years. In 50 years, have 50/500 = 10% chance of occurring. Problems? (data, physical basis of strain and release) This is the model used by the USGS for New Madrid.

Time-dependent models: assume earthquake strain release reduces the chances of another event in the near future, increasing as strain rebuilds over time. The recurrence time distributions are assumed to be Gaussian (bell curve centered over recurrence interval) or log-normal (skewed – not sure what the mechanism would be to produce such a distribution).

Either time-dependent model suggests a low likelihood of an earthquake in the next 50 years.

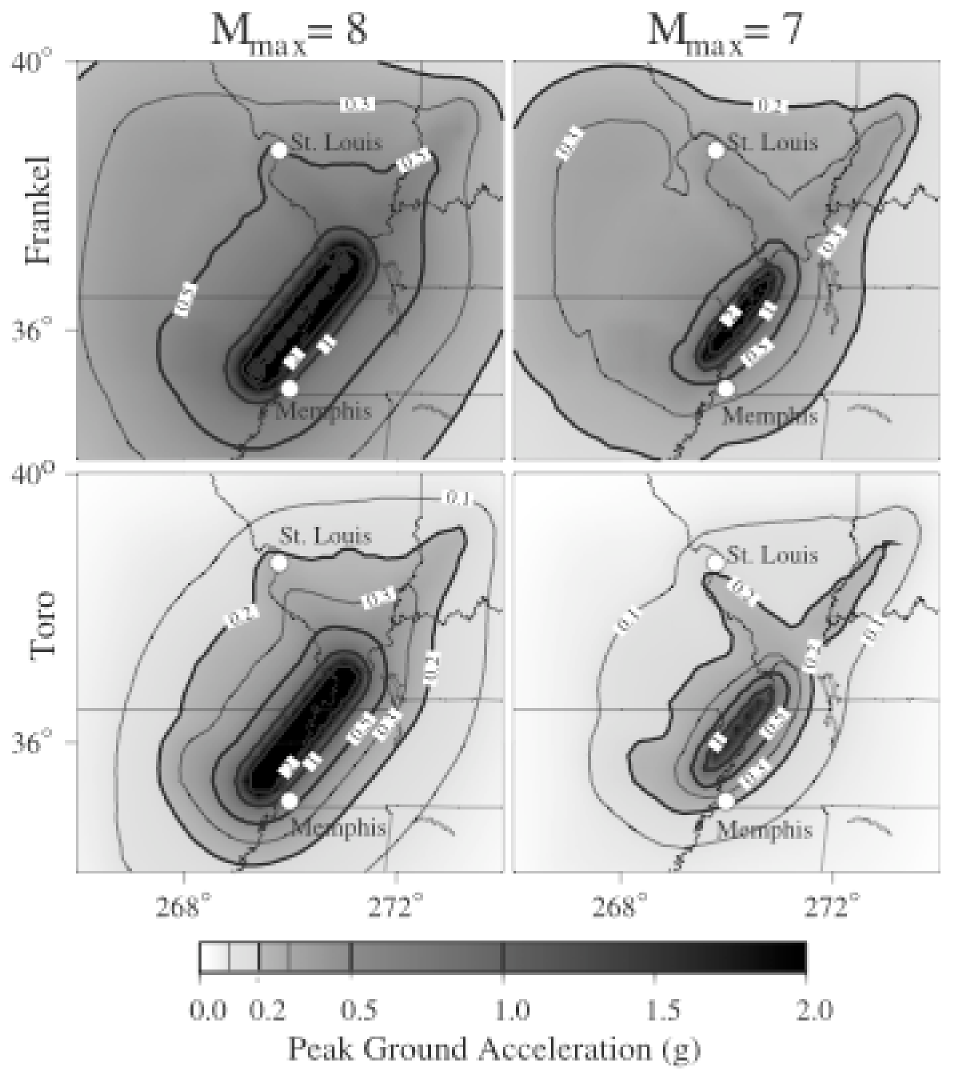


Fig. 3. Comparison of the predicted seismic hazard (peak ground acceleration expected at 2% probability in 50 years) from NMSZ earthquakes for alternative parameter choices. Columns show the effect of varying the magnitude of the largest earthquake every 500 years from 8 to 7, which primarily affects the predicted acceleration near the fault. Rows show how different ground motion models, which were averaged in the USGS maps, affect the predicted acceleration over a larger area. [Newman et al., 2001].

Columns: vary the expected magnitude by one factor (8 and 7). Result is increase in area affected, and increase in shaking in the vicinity of the fault.

Rows: two different ground motion models. Very different in area, less so with maximum shaking, but were averaged in the USGS hazard maps.

Values: 0.2 g corresponds to the onset of major damage to (some) buildings. What type of frequency would correspond to high acceleration? (rapid cycling - high frequency) For long-period ground motion (smaller accelerations), which types of buildings would be most affected?

Frankel Comment

Project chief for USGS national seismic hazard maps. Uses the word “expert” 37 times.

-Stein presents no scientific arguments; claims incorrectly that Stein does not account for ground shaking.

-ignores research used in the USGS methodology

-cost benefit analysis unrealistic (but provides no better analysis, likely because it has not been done)

Stein Reply

-still no justification that new Madrid earthquake hazards are the equal of southern California.

-NOT a consensus, giving examples of some organizations.

-refers to the Parkfield prediction: under some of the best (most predictable) earthquake conditions, the forecast was poor.

-the arguments can go on forever, but they expose the vulnerability of hazard assessments to the range of models, theories and assumptions that go into the maps.

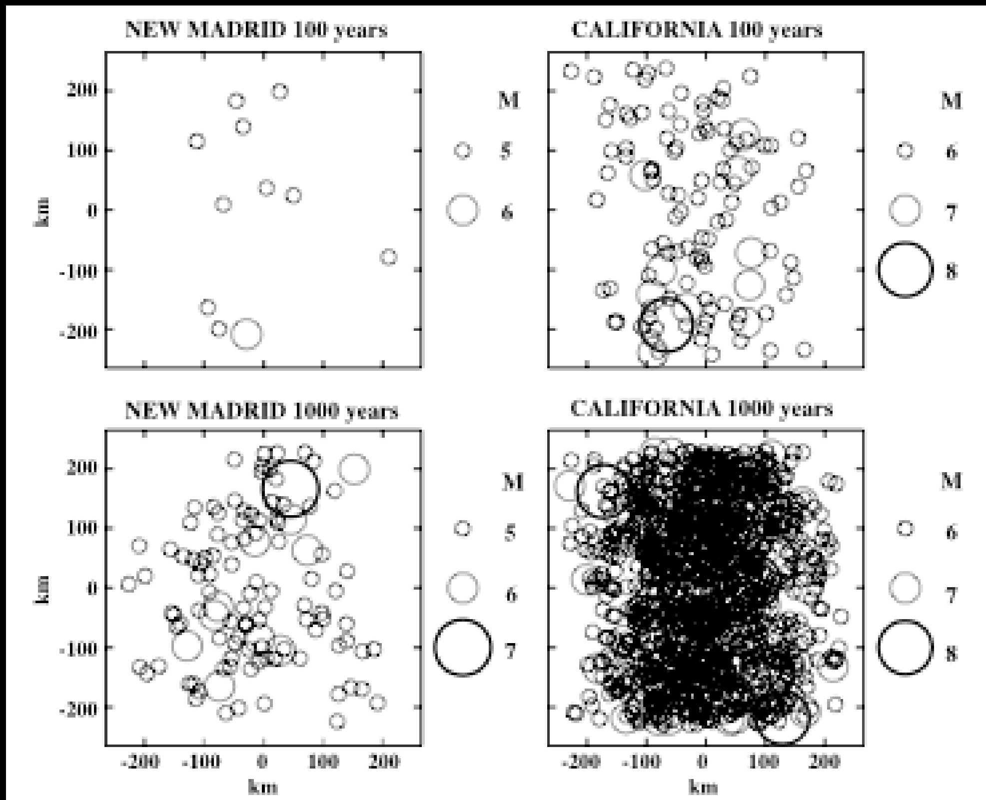


Fig. 1. This schematic compares seismic hazard for the New Madrid Seismic Zone (NMSZ) and southern California on two time scales. Seismicity is assumed to be random, with California 100 times more active but New Madrid earthquakes causing strong shaking over an area equal to that of a California earthquake one magnitude unit larger. Circles mark areas of shaking with acceleration > 0.2 g.

Model: takes a representative area, and known earthquake frequency. Empirically generates the known distribution (size and frequency) of events. At the boundaries, any partial events are filtered out.

In California, over 1000 years virtually certain total area will experience an earthquake.

Summary

-what to do? Adopt, reject? Who should be involved in the decisions?

-Is it wise to base such a major financial investment on this basis?

-leave long-term mitigation up to local communities? Will they be willing to invest in any long-term mitigation?

-best way to create, use seismic hazard maps?