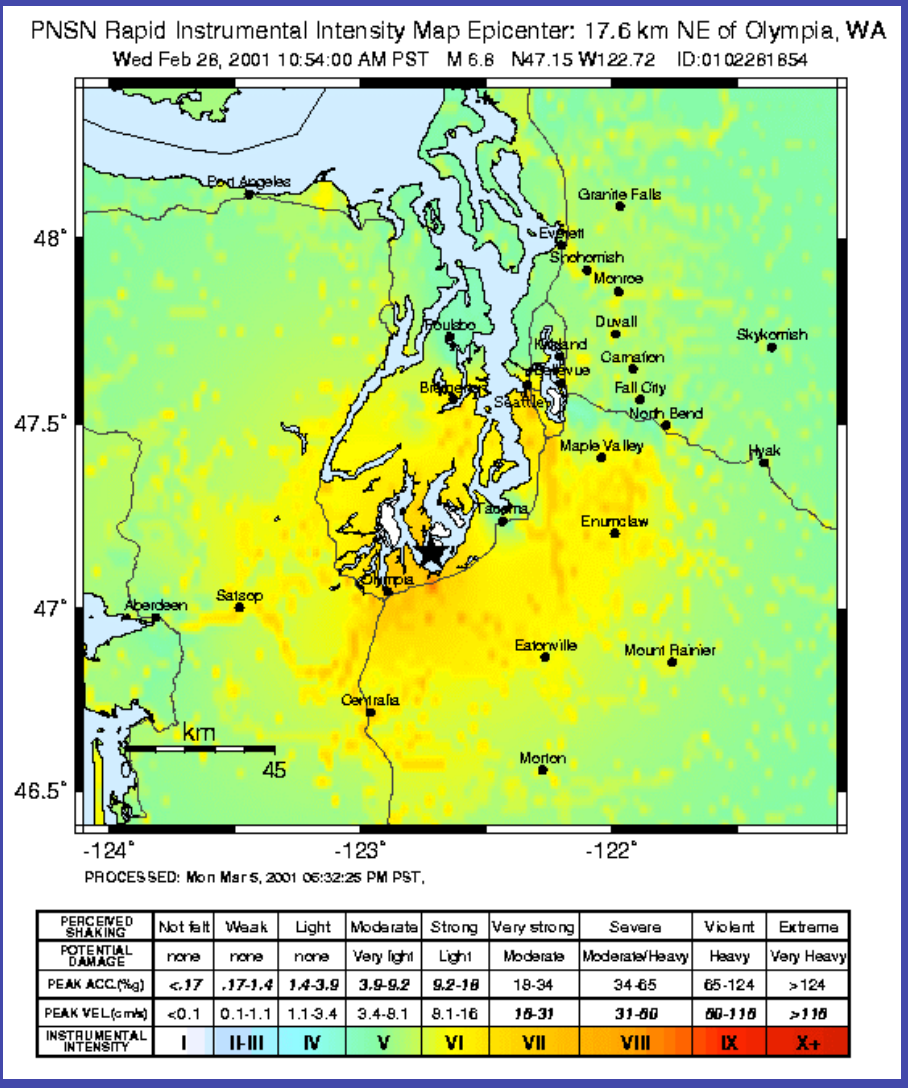
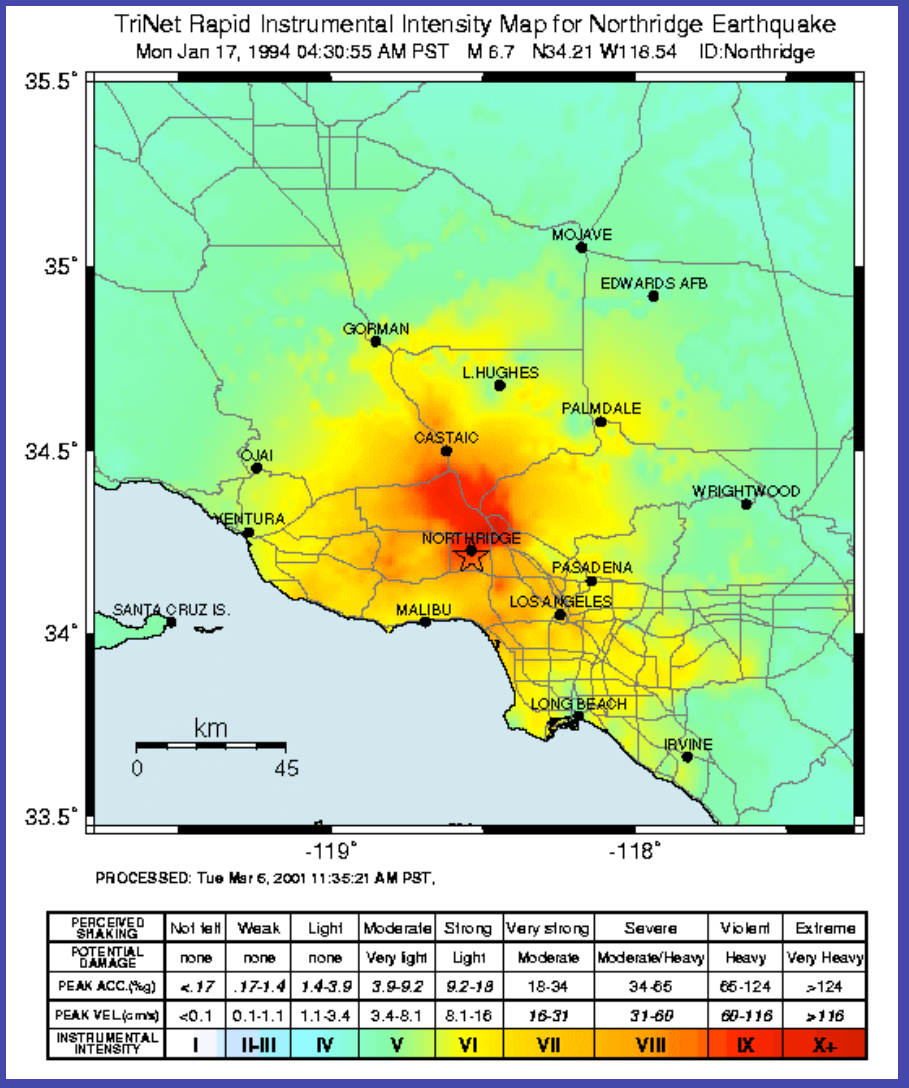


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



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INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

CONSEQUENCES OF SHAKING DIFFERENCES

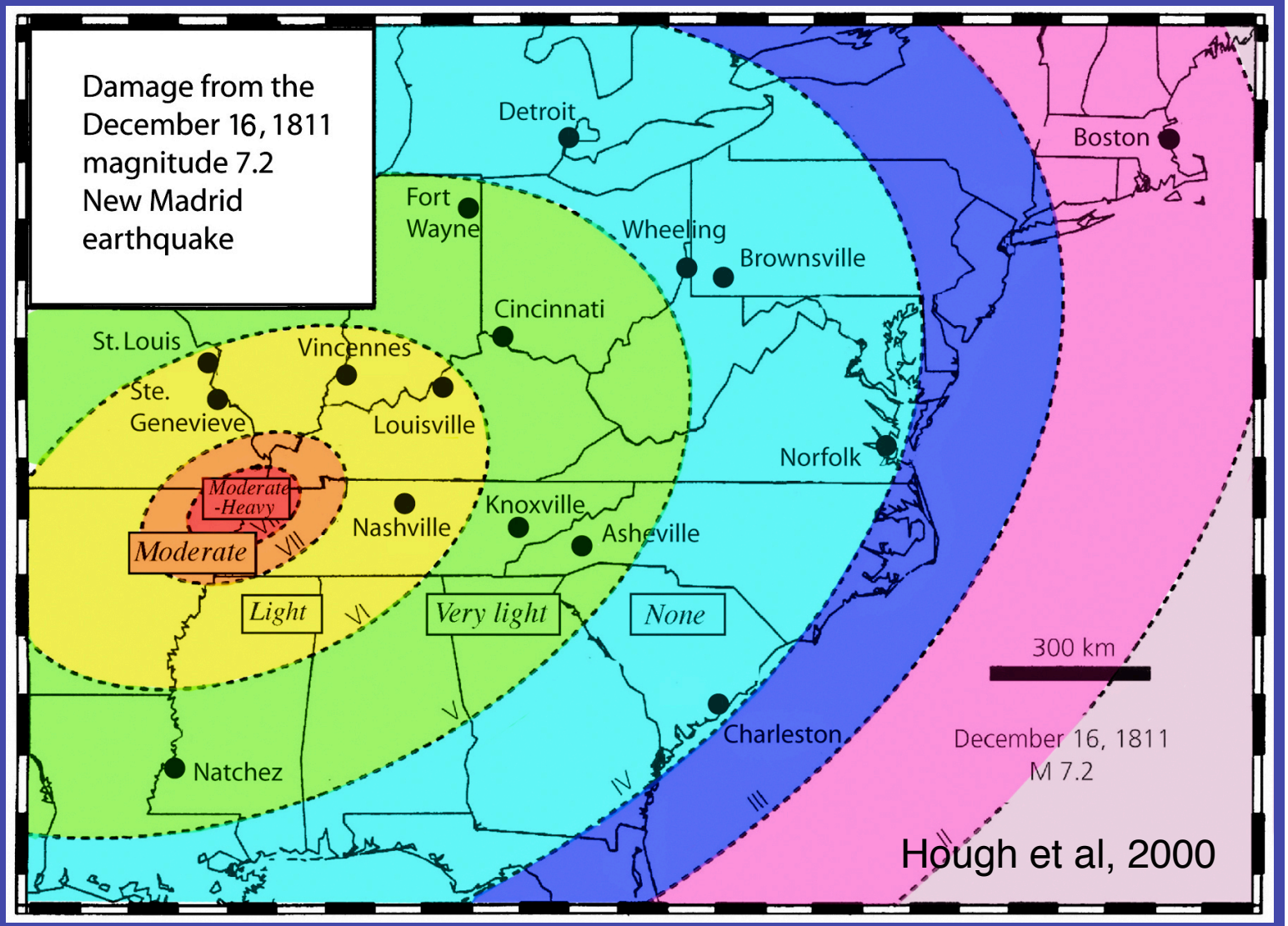
Northridge, M 6.7, was the.costliest earthquake in U.S. history with economic loss of $40 billion. In contrast, loss in Nisqually earthquake is ~$2 billion. One death, a heart attack victim, reported in Seattle area, while 57 people died in the Northridge earthquake.

Shaking intensity used to infer magnitude of earthquakes before seismometer invented

Log cabin damage at New Madrid

Minor damage in St Louis, Nashville, Louisville, etc.

Not felt in Boston, no church bells ring



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News

Quake analysis rewrites history books

Magnitude keeps shrinking

New Madrid quakes were smaller than originally thought.

Richard A. Lovett

A series of earthquakes that hit the North American heartland nearly 200 years ago were considerably smaller than reported in the history books, according to research presented at a meeting this week.

The quakes struck the New Madrid fault zone 200 kilometres south of St Louis, Missouri, in 1811 and 1812, long before modern seismometers allowed accurate measurements of their intensity. In the 1980s, however, some scientists estimated that the magnitudes of these quakes were over 8.0, says Susan Hough, a seismologist at the US Geological Survey's Pasadena office in California.

The New Madrid earthquakes may have been considerably smaller than scientists had estimated.

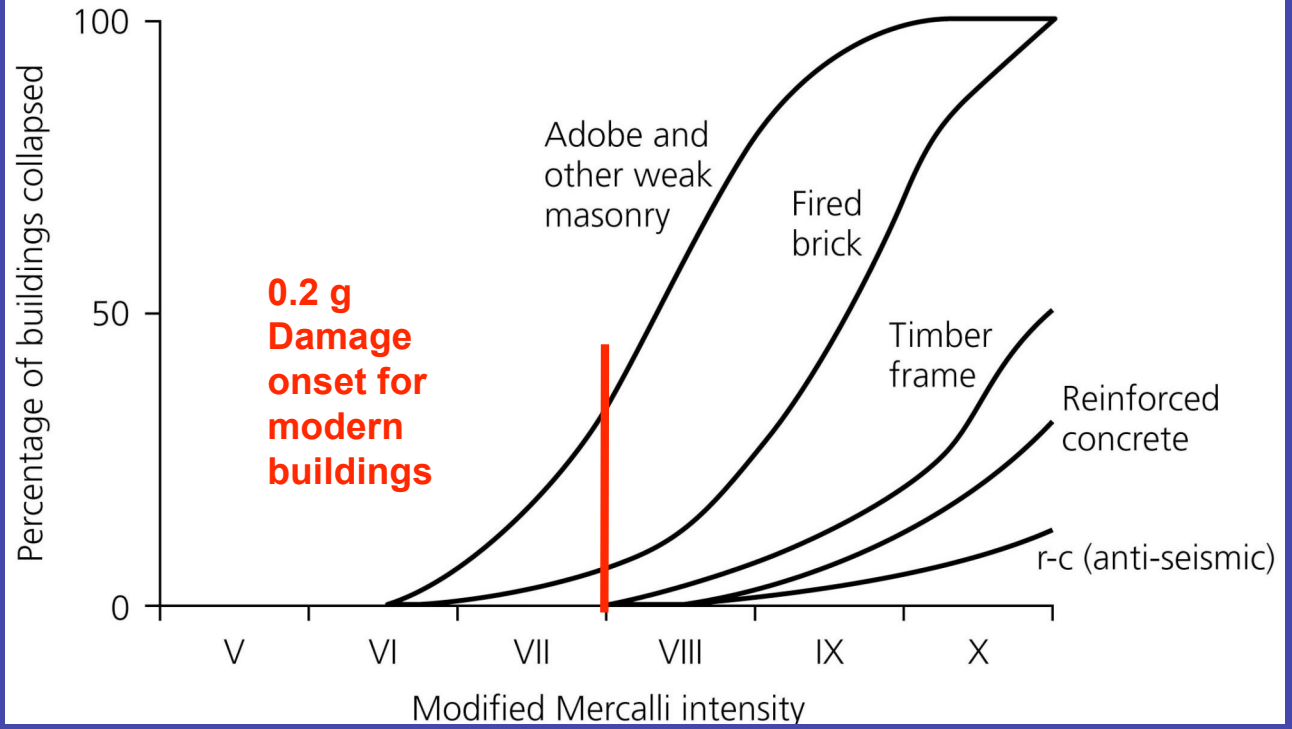
"You'll still find claims that these were the largest earthquakes ever in the contiguous United States," says Hough, who presented her findings on 23 April at a meeting of the Seismological Society of America, in Portland, Oregon.

Previously, Hough had stated[1] that the earthquake magnitudes were only about 7.5. Now, she has reduced her estimates by another half point, to "right around magnitude 7.

DAMAGE DEPENDS ON BUILDING TYPE
RESISTANT CONSTRUCTION REDUCES EARTHQUAKE RISKS

Pigs had it wrong

Figure 1.2-6: Collapse of buildings as a function of intensity of shaking.



ADOBE

12/03 Bam, Iran
M 6.6 27,000 deaths

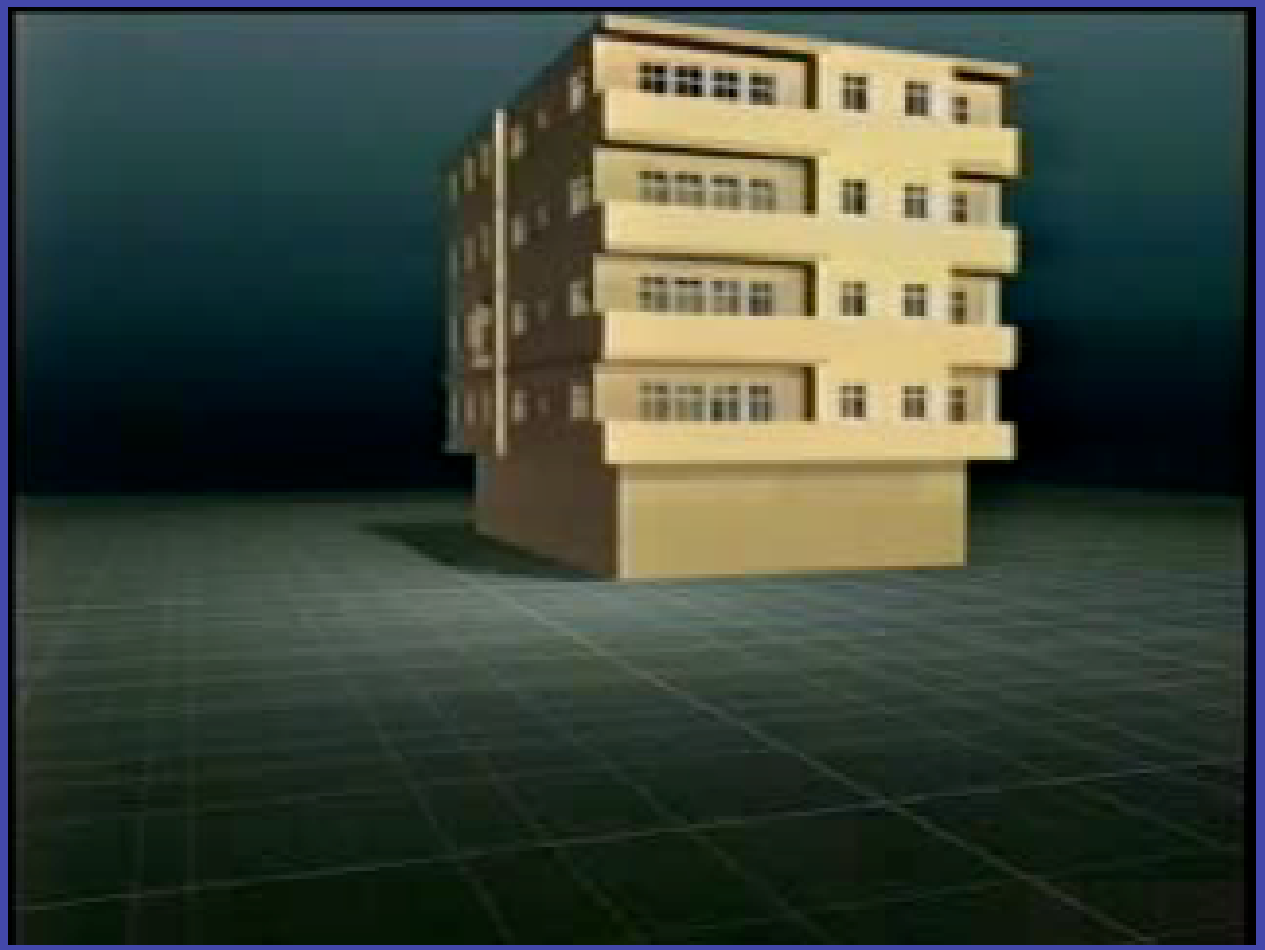
BRICK

10/05 Pakistan M 7.6
80,000 deaths

CONCRETE

2/71 San Fernando,
California M 6.6 65 deaths

MODERN CONSTRUCTION WITHOUT SEISMIC STRENGTHENING: Concrete buildings



USGS

40,000 in California. 8,000 schools, including 239 in Los Angeles. Downtown Los Angeles has about 500.

RETROFIT FOR SEISMIC STRENGTHENING

USGS

Problem: retrofit cost close to that of razing building & starting over. $24 B needed for California hospital retrofits!

PROBLEM: UNFUNDED MANDATE

Property owners don't benefit (can't charge higher rent) & so resist

Maybe society should fund: Would public pay higher taxes for safety?

October 11, 2005 latimes.com : California E-mail s

How Risky Are Older Concrete Buildings?

- State officials say many should be retrofitted for quakes. Others say cost would outweigh benefit.

By Sharon Bernstein, Times Staff Writer

Tens of thousands of older concrete buildings across California represent the state's largest remaining risk of serious damage in a major earthquake, seismic safety officials say.

Constructed as department stores, schools, parking structures and office buildings from the 1930s through the early 1970s, these buildings typically consist of large, open lower stories held up by unreinforced or poorly reinforced concrete pillars.

After several collapsed in the 1971 San Fernando earthquake, seismic safety codes were upgraded to require that any new concrete buildings be better constructed. Many seismic experts say preexisting structures — known as non-ductile concrete buildings — need to be retrofitted to bring them up to current standards.

"It's well recognized within the earthquake professional community that many California non-ductile concrete buildings are at unacceptable risk of collapse in moderately strong shaking," said Thomas Heaton, professor of engineering seismology at Caltech.

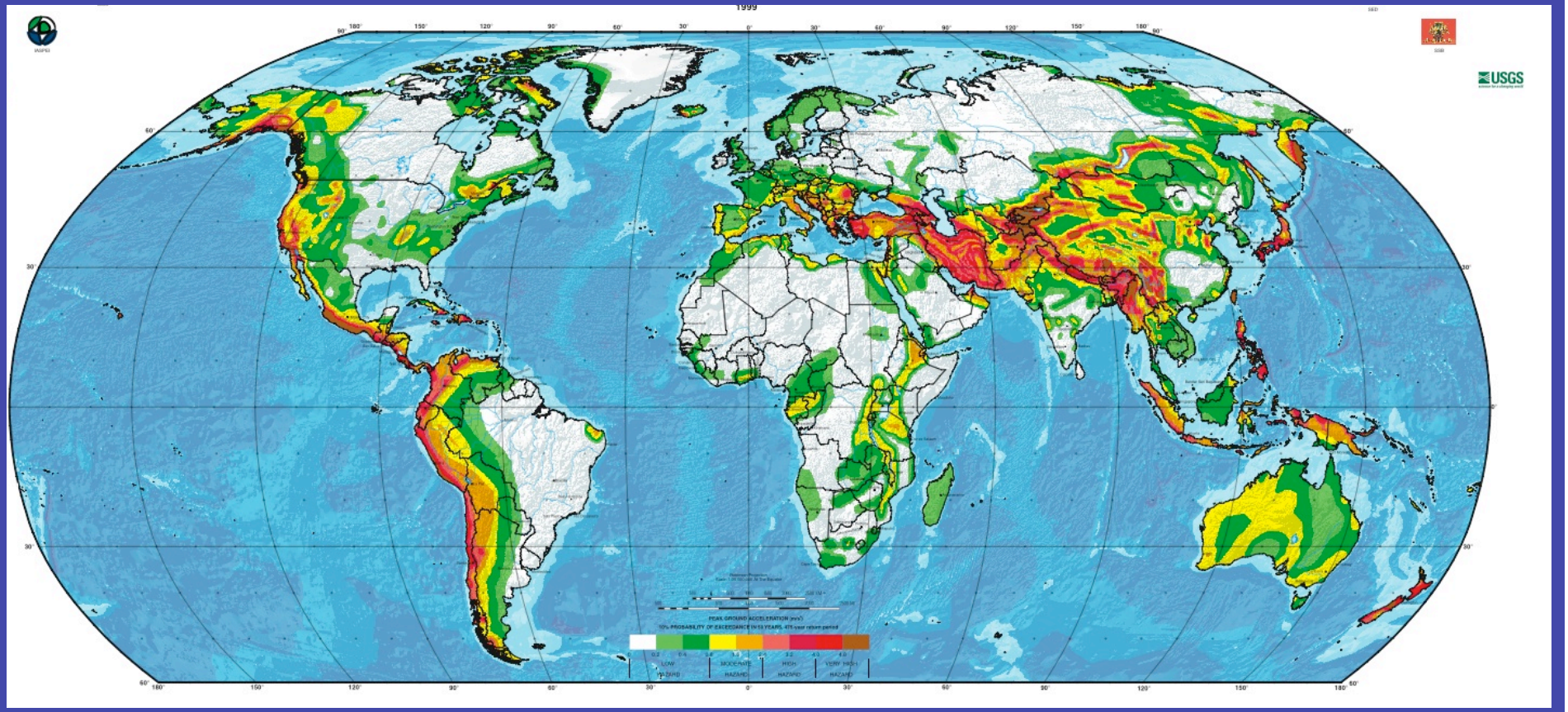
Because many of the older concrete buildings tend to be filled during the day with office workers, schoolchildren or people parking their cars, the death and injury toll from an earthquake that caused several of the structures to collapse could be staggering, said Heaton.

But building owners and business organizations have long fought efforts to require retrofits, arguing that the risk is overstated. And they say that in some cases, the cost of retrofits comes close to that of razing a building and starting over. Neither the state nor local governments have required that the structures be reinforced.

"If you're going to use a 'sky is falling' scenario, then maybe you can justify" a retrofit requirement, said Carol Schatz, president of the Central City Assn. "But if you're going to put a bunch of commercial property owners out of business in the process, what have you accomplished?"

Property owners and business associations opposed a proposal last year by City Councilmen Greig Smith and Alex Padilla to count the number of unreinforced concrete buildings in Los Angeles. The measure didn't make it out of a council committee.

To design buildings, we try to predict the hazard defined as maximum shaking (acceleration) they'll face in some time period



"A game of chance against nature of which we still don't know all the rules" (Lomnitz, 1989)

Earthquake hazard isn't a physical thing we measure. It's something we *define* and use computer programs to predict. Different assumptions produce very different maps.

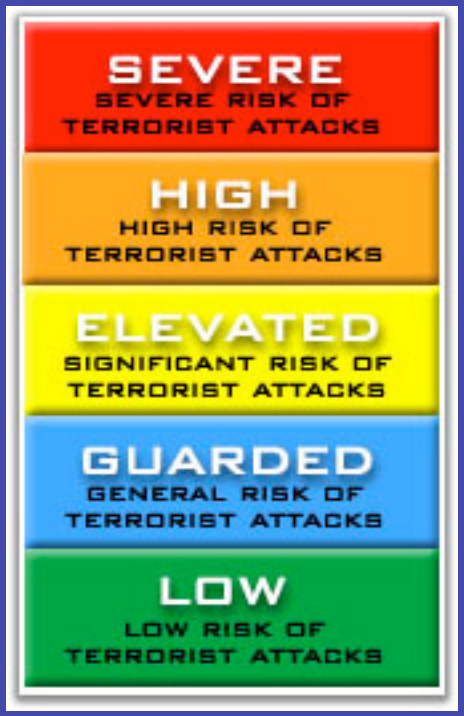
- ***What's the definition*** **of hazard (political, not scientific)**

- ***Where*** **and** ***when*** **will earthquakes occur?**

- **If they occur, then**

- ***How large*****?**

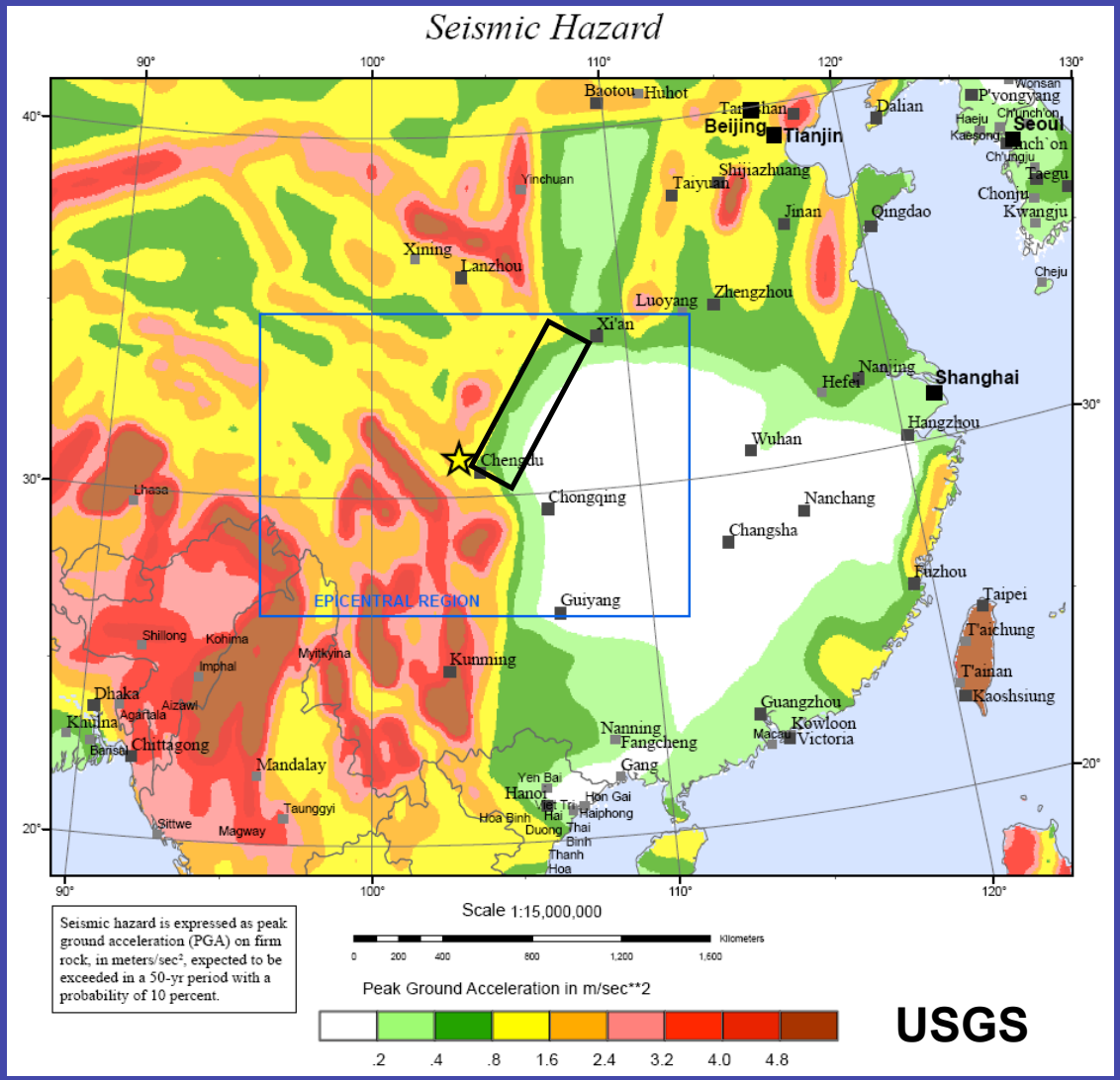
- ***How strong*** **will ground motion be?**



These aren't well understood, especially where large earthquakes are rare, so hazard estimates have considerable uncertainties

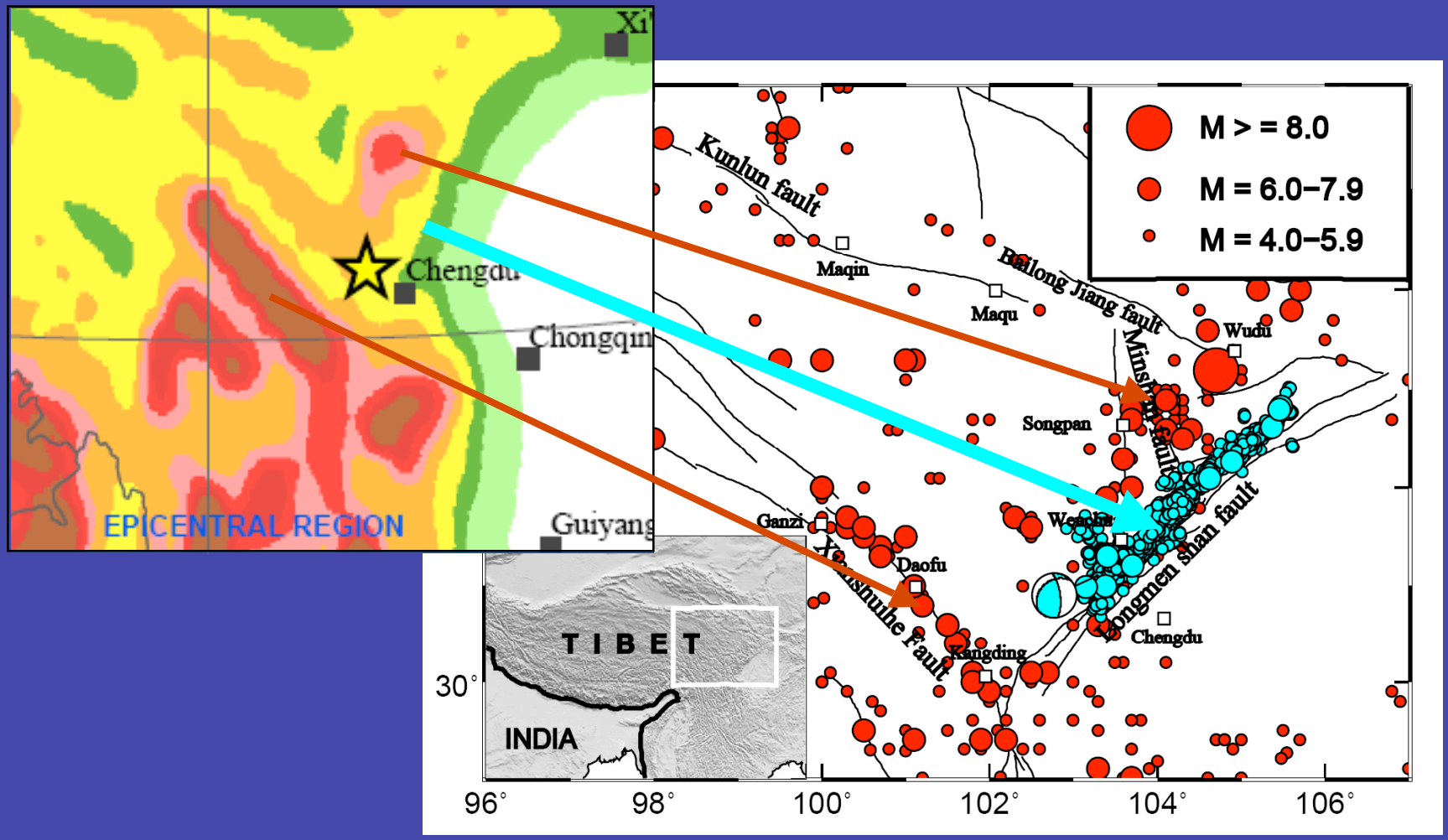
How can we assess these uncertainties?

2008 Wenchuan earthquake (Mw 7.9) was not expected: map showed low hazard



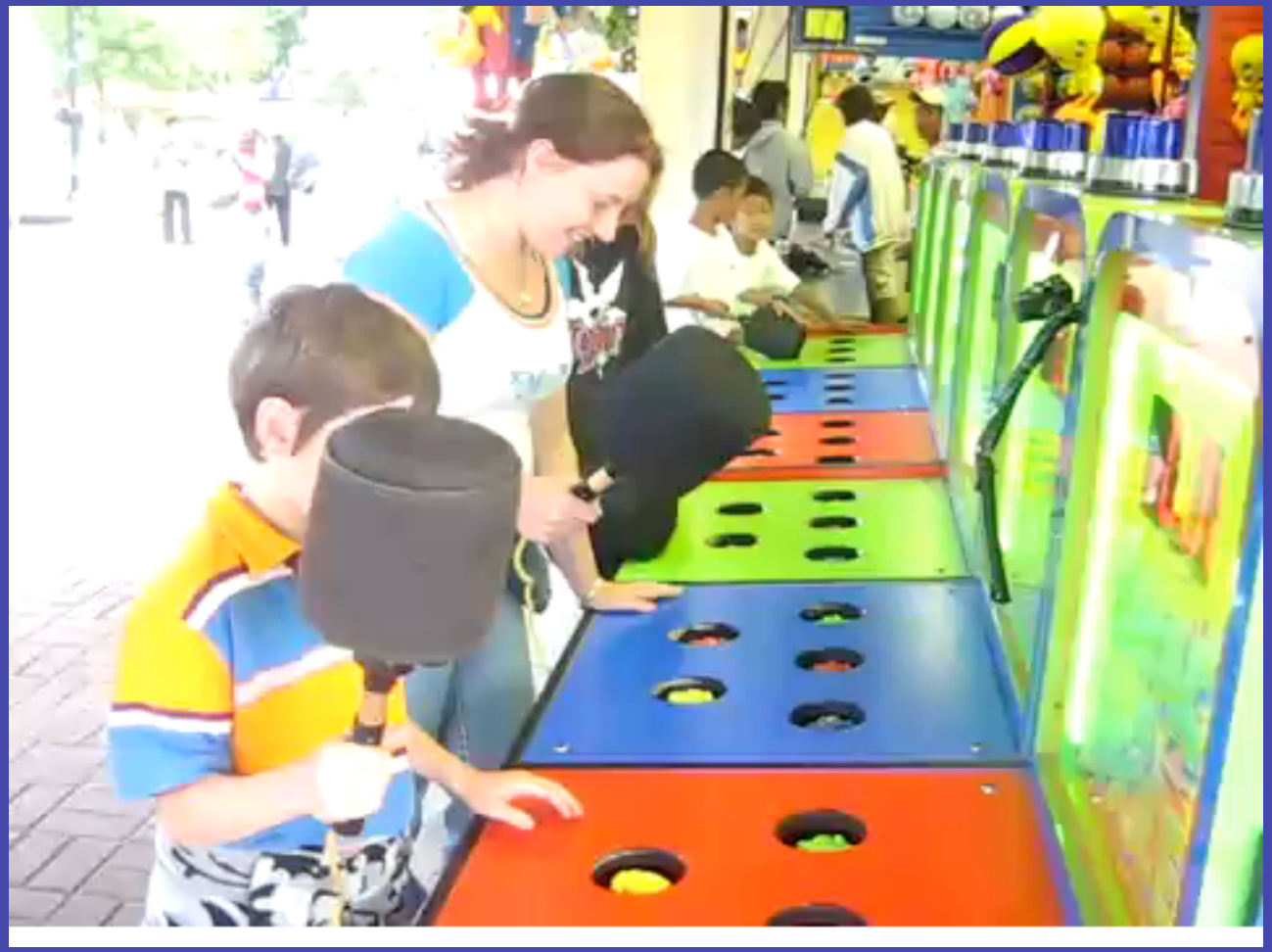
Hazard map ignored variability - assumed steady state - relied on lack of recent seismicity

Didn't use GPS data



- Earthquakes prior to the 2008 Wenchuan event
- Aftershocks of the Wenchuan event delineating the rupture zone

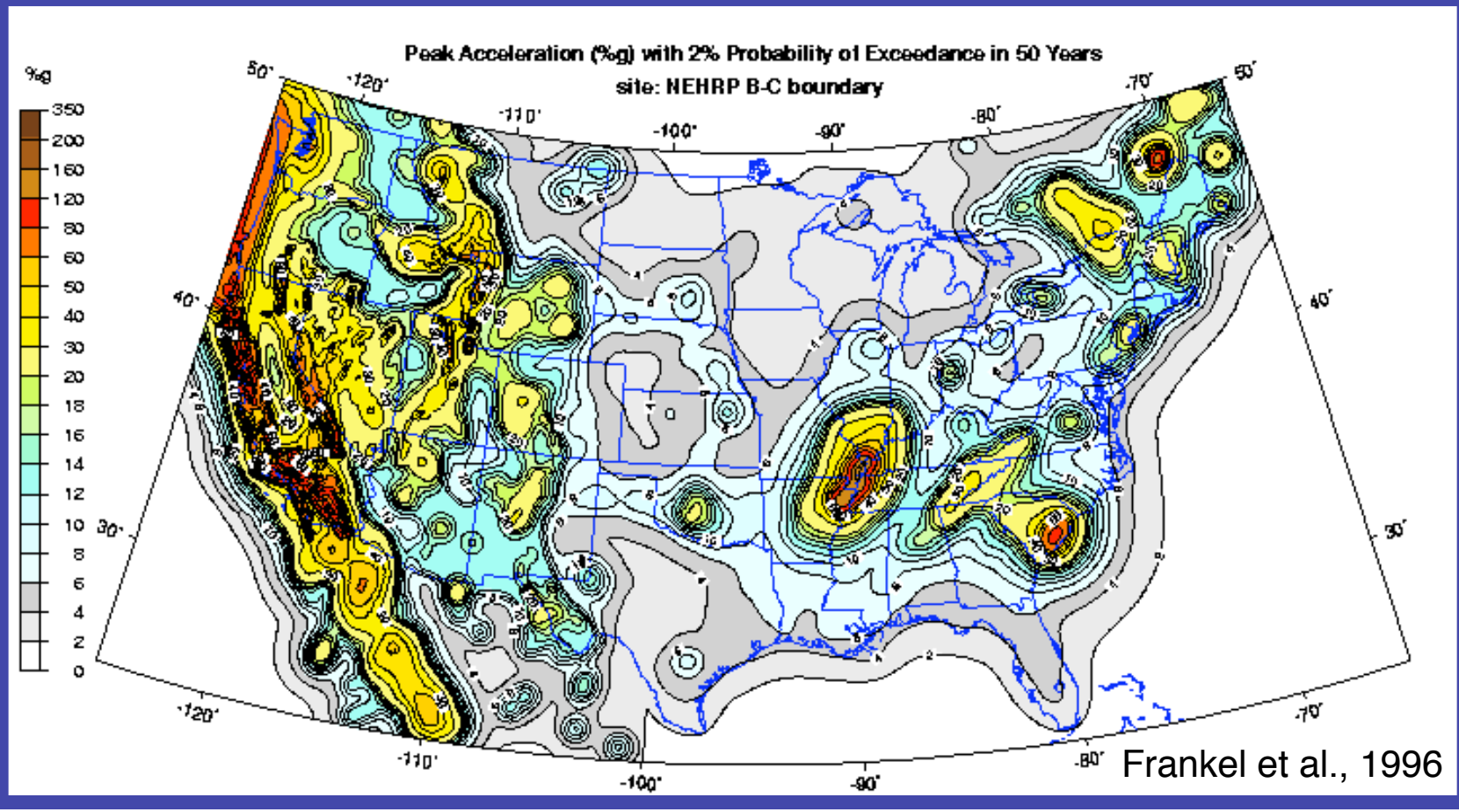
Neglecting variability is like ‘Whack-a-mole’ - you wait for the mole to come up where it went down, but it’s likely to pop up somewhere else.



EXAMPLE: MAP SHOWS NEW MADRID AS HAZARDOUS AS CALIFORNIA

Buildings should be built to same standards

To assess uncertainties, look at other predictions & alternative assumptions



Frankel et al., 1996

P(sinking) = 0

P(loss) = 1/100,000

Predicted Disaster Probabilities

"Apocalyptic claims do not have a good track record. And arguments that statistics support such claims - particularly arguments that simple, easily understood numbers are proof that the future holds complex, civilization-threatening changes - deserve the most careful inspection ."

J. Best: *More Damned Lies and Statistics: How Numbers Confuse Public Issues*

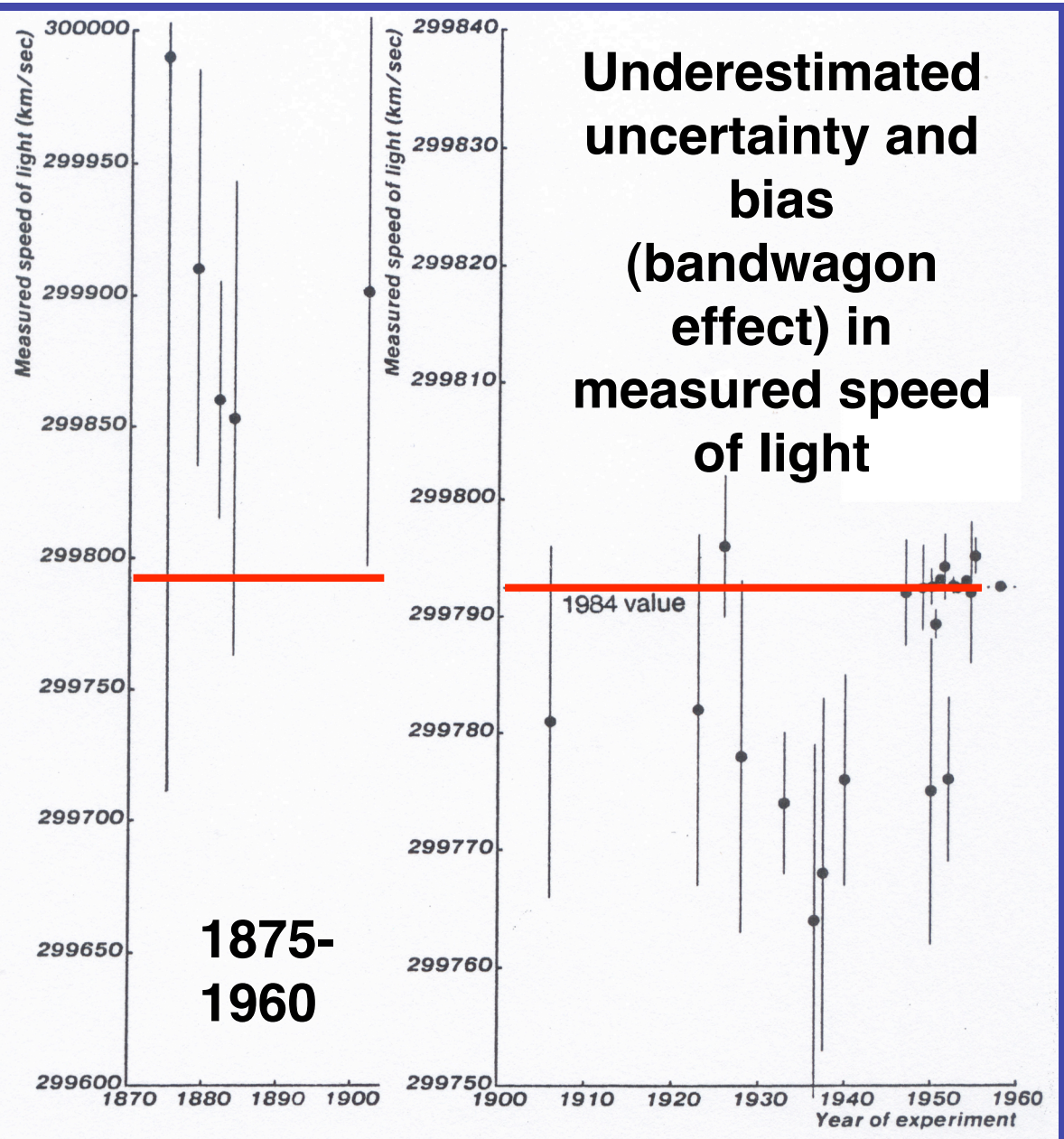
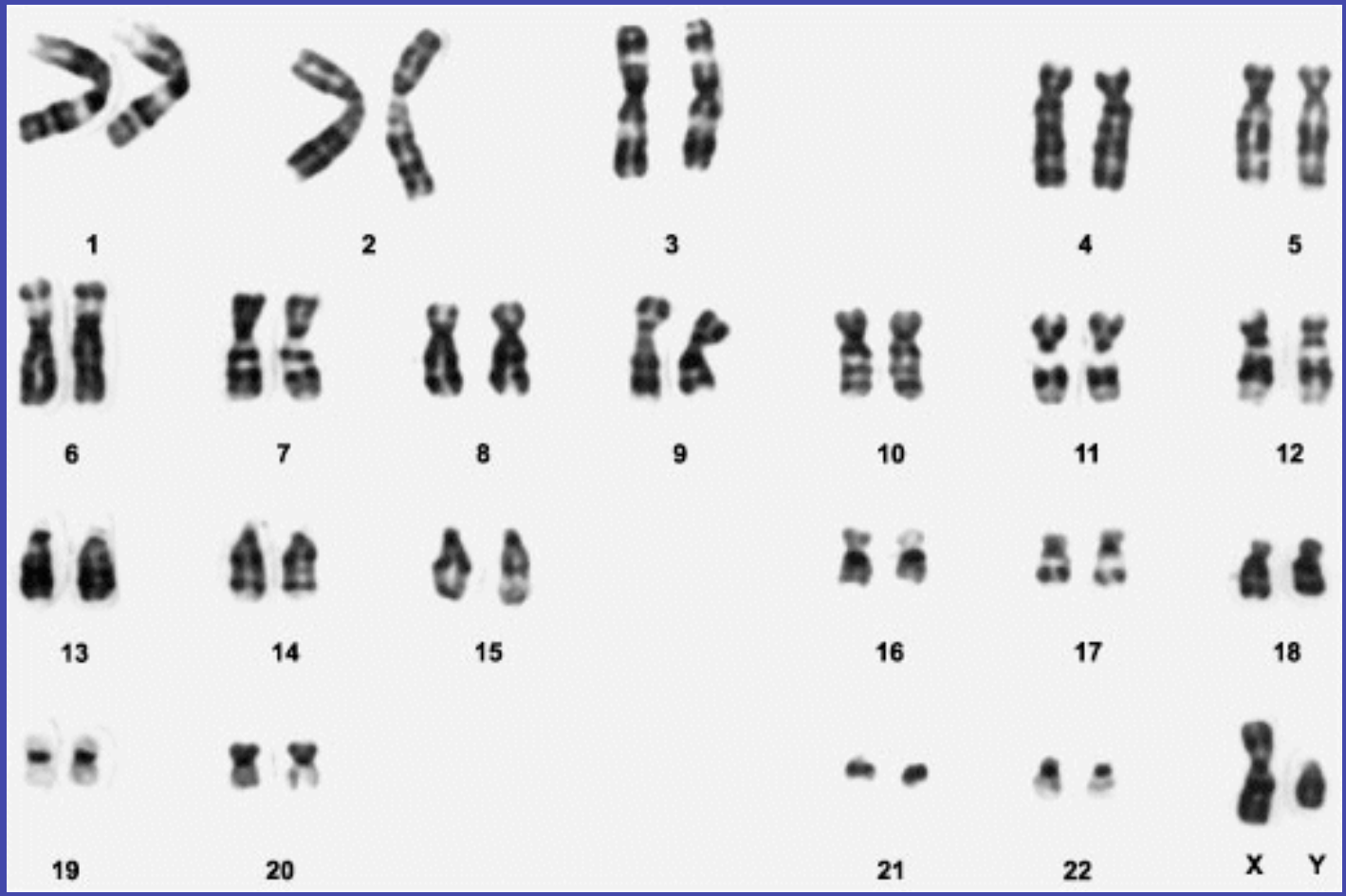


Figure 4.1. Experimental measurements of the speed of light between 1875 and 1960. Vertical bars show reported uncertainty as standard error. Horizontal dashed line represents currently accepted value. Less than 50% of the error bars enclose the accepted value, instead of the expected 70%. From Henrion and Fischoff, 1986.

Uncertainties are hard to assess and generally underestimated

Systematic errors often exceed measurement errors

Number of human chromosome pairs



1921-1955: 24 **Now: 23**

OVERESTIMATED HAZARD

1976 SWINE FLU *"APORKALPSE"*

CDC reported "strong possibility" of epidemic. HEW thought "chances seem to be 1 in 2" and "virus will kill one million Americans in 1976."

President Ford launched program to vaccinate entire population despite critics' reservations

40 million vaccinated at cost of millions of dollars before program suspended due to reactions to vaccine

About 500 people had serious reactions and 25 died, compared to one person who died from swine flu

HAZARD OVERESTIMATED: Y2K

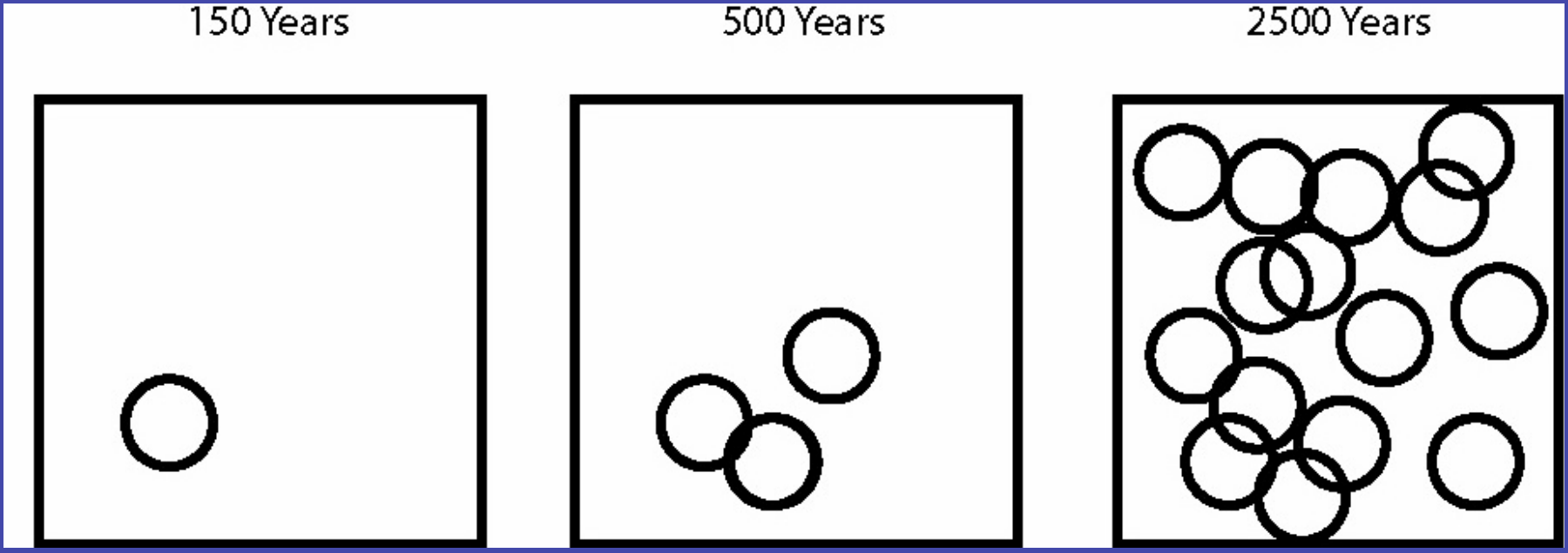
Much ado made that on January 1, 2000 computer systems would fail, because dates used only two digits

U.S. & other governments established major programs

Estimated $300 billion spent on preparations

Few major problems occurred, even among businesses and countries who made little or no preparation

Assumed hazard depends on definition: that an earthquake of a certain size will strike in a certain time and cause shaking within a certain area.



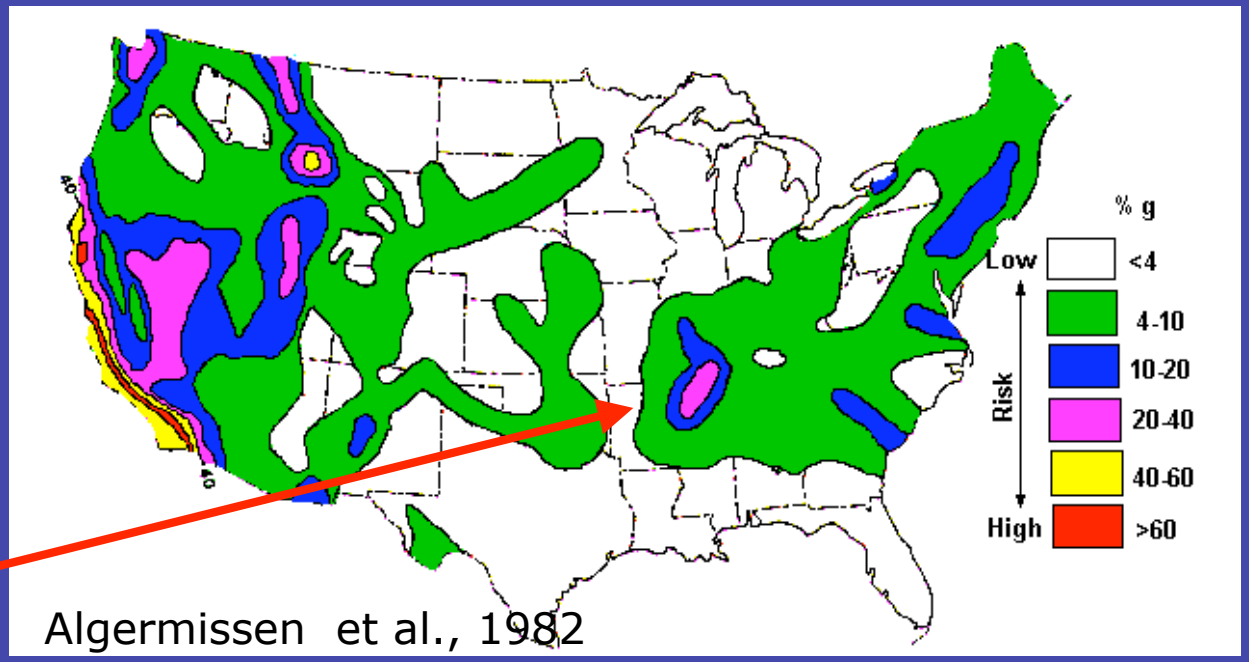
Strongly shaken areas MMI > VII for M 6

Include earthquakes of different magnitudes, assume some areas more likely to have earthquakes, and have stronger shaking close to the epicenter. Hazard at a given location is described by the maximum shaking due to earthquakes that is predicted to happen in a given period of time. Thus it increases for longer time windows / lower probabilities

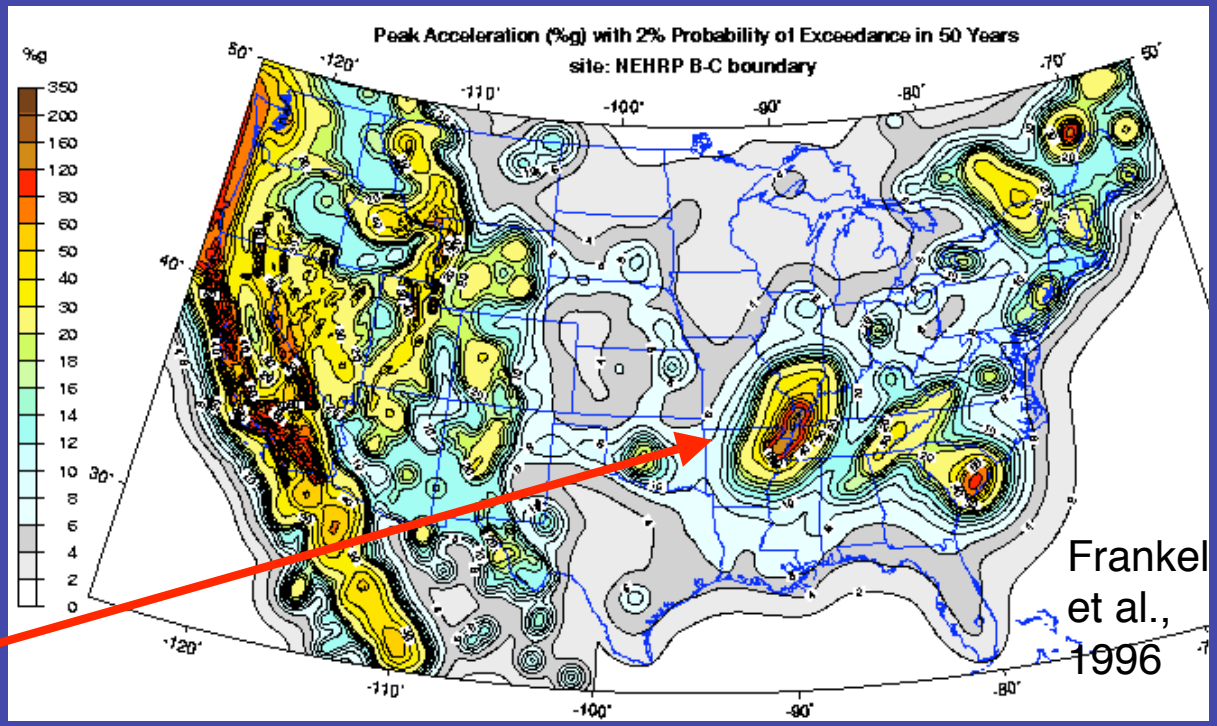
Hazard redefined with longer window

from maximum acceleration predicted at 10% probability in 50 yr (1/ 500 yr)

to much higher 2% in 50 yr (1/2500 yr)

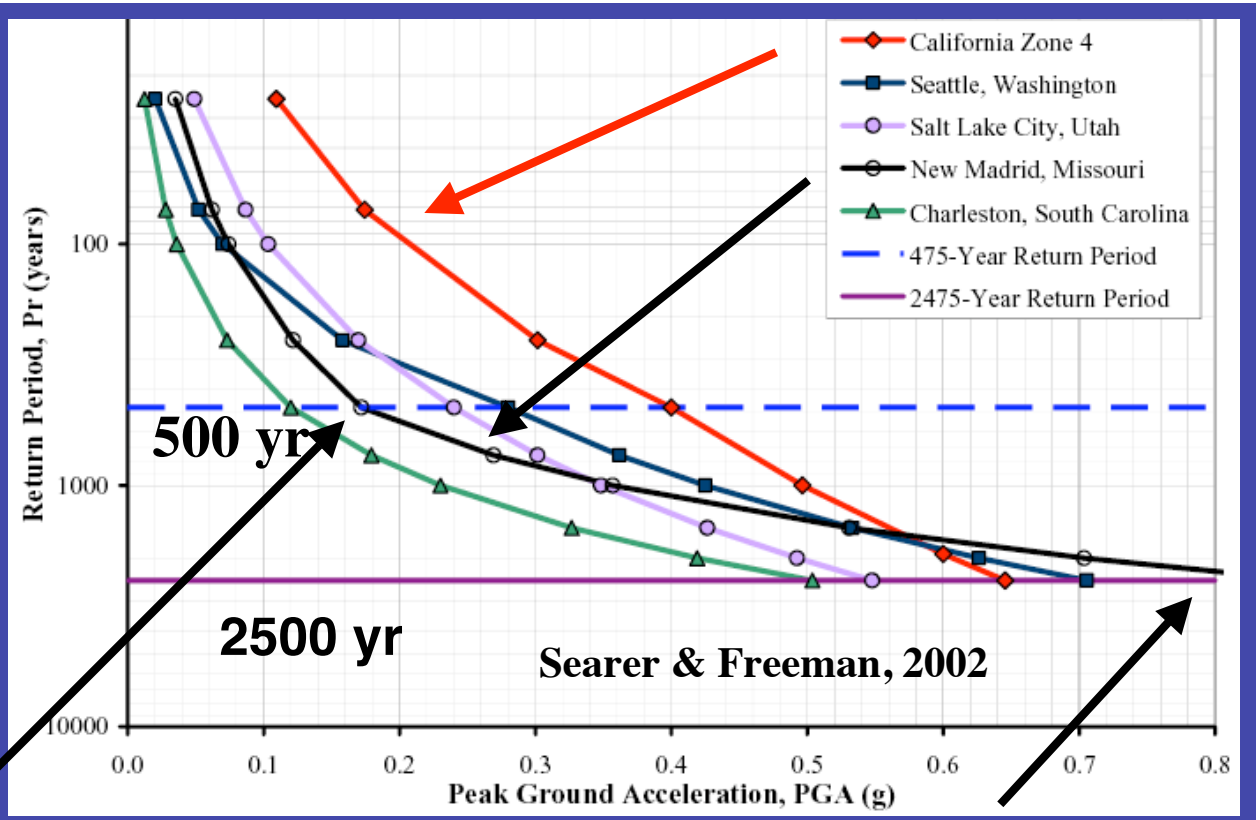


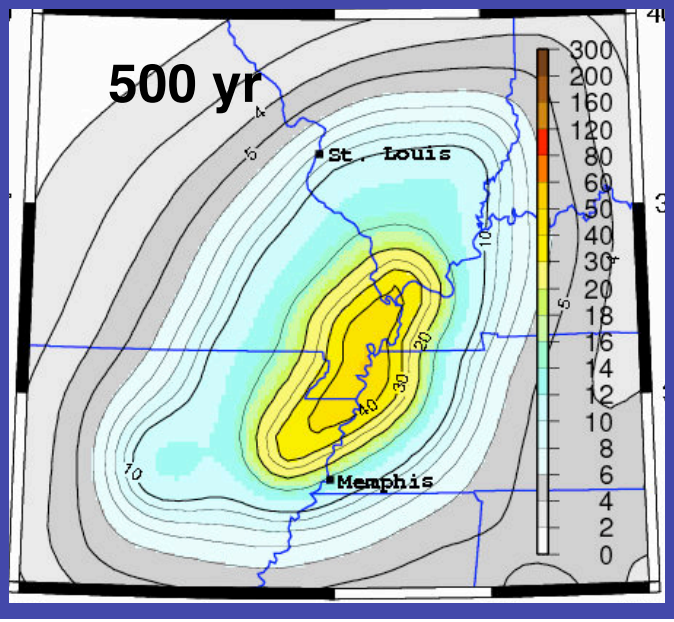
Algermissen et al., 1982



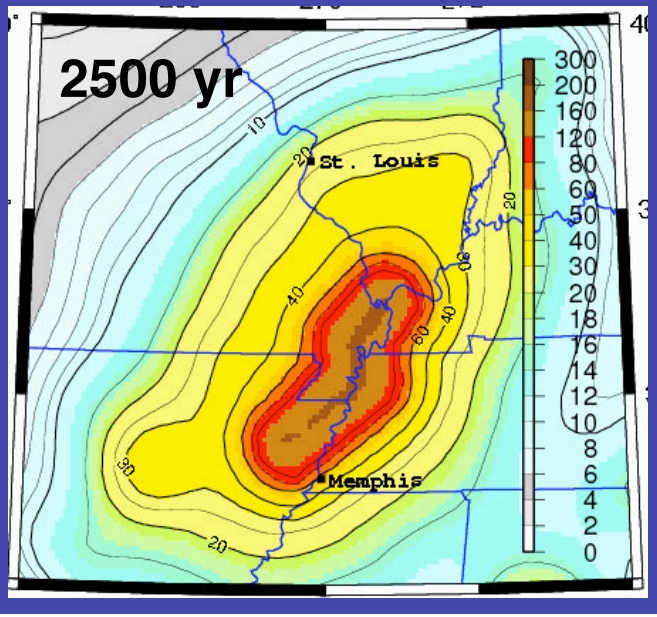
Frankel et al., 1996

New Madrid hazard higher than California results largely from redefining hazard as largest shaking expected every 2500 yr: Not so for 500 yr





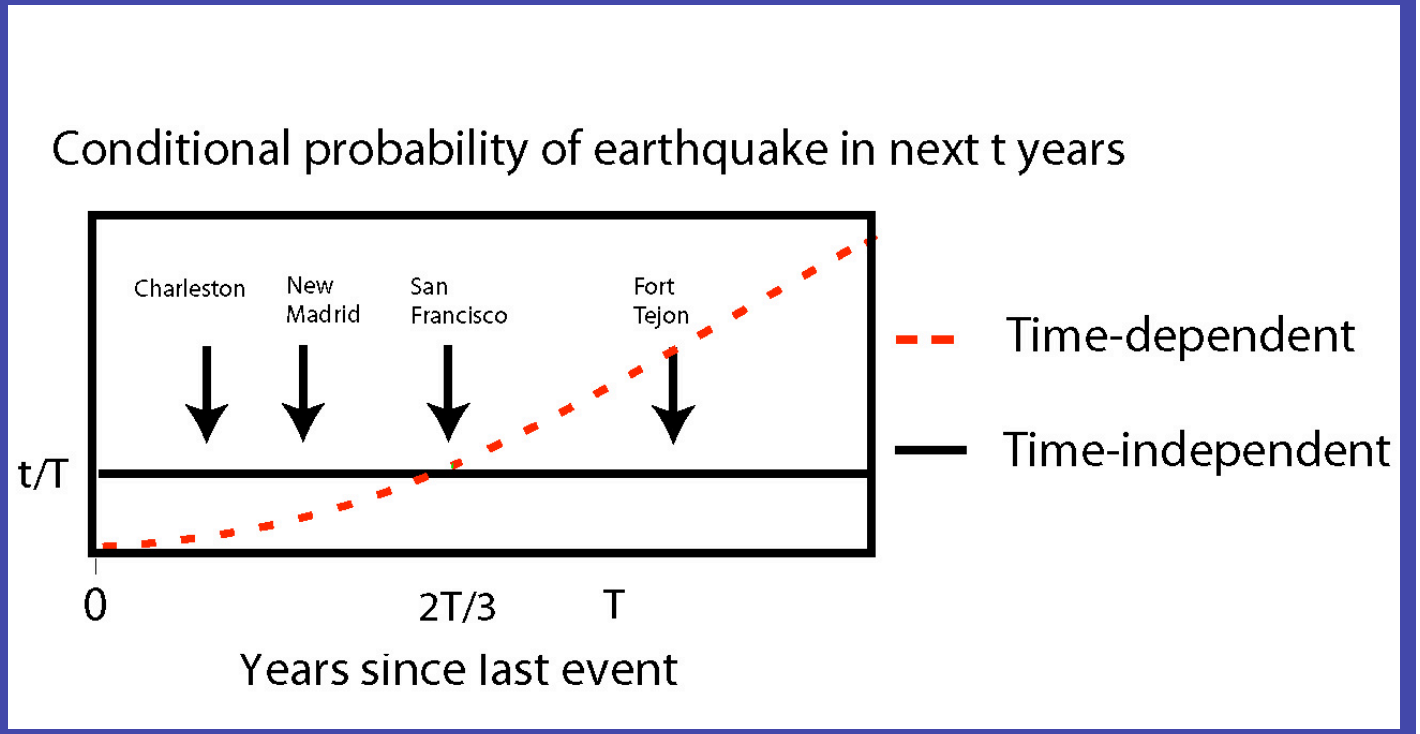
400%



RELATIVE PREDICTED HAZARD DEPENDS ON POSITION IN EARTHQUAKE CYCLE

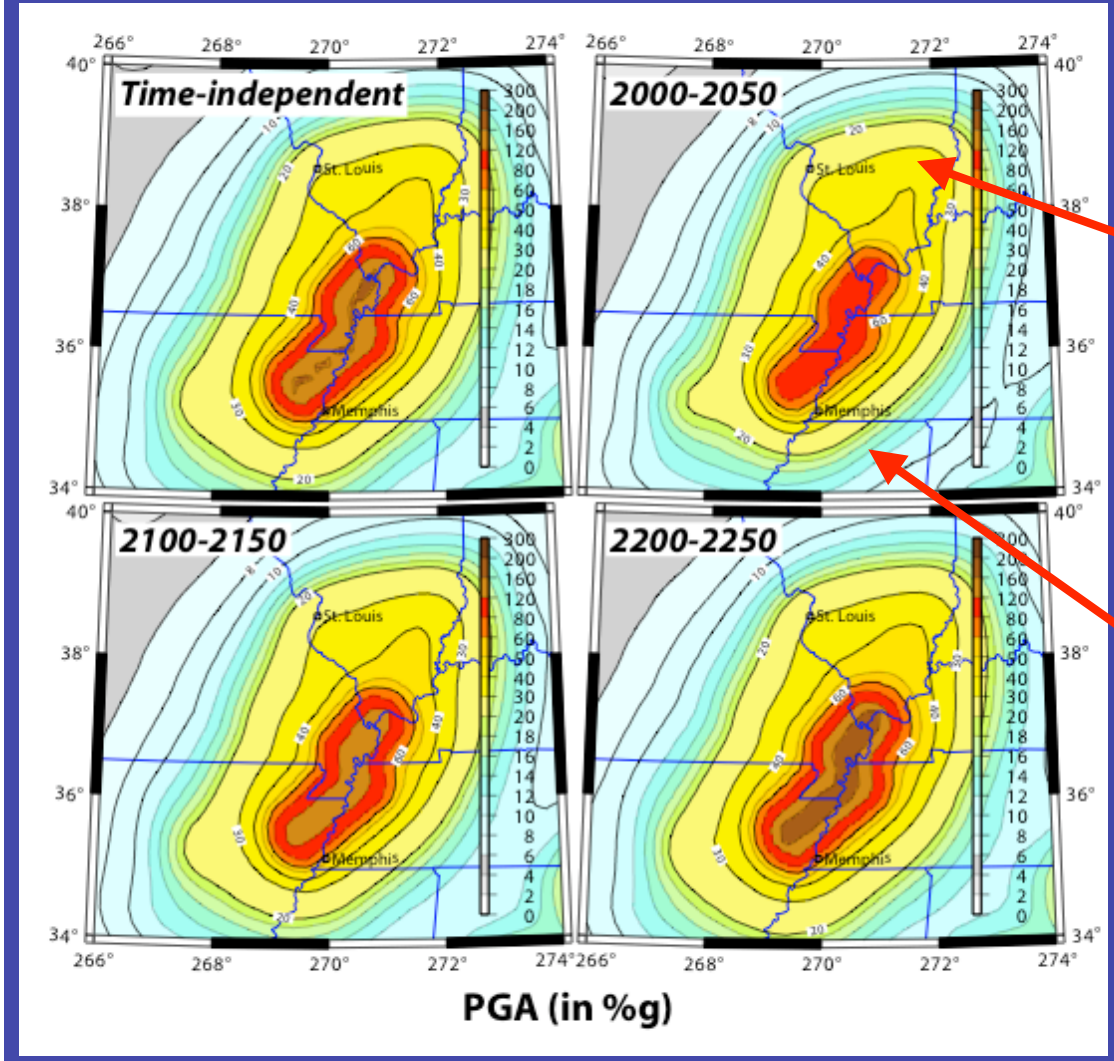
Time dependent lower until ~2/3 mean recurrence

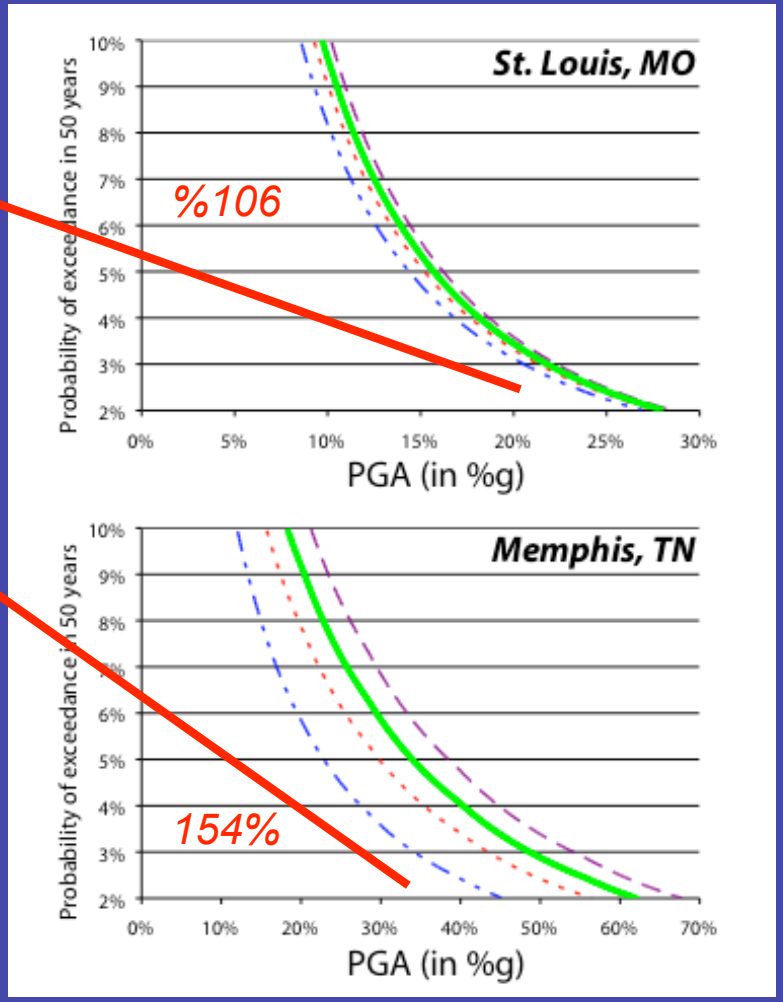
New Madrid in mid-cycle so USGS time independent assumption predicts higher hazard



Hebden & Stein, 2008

NEW MADRID





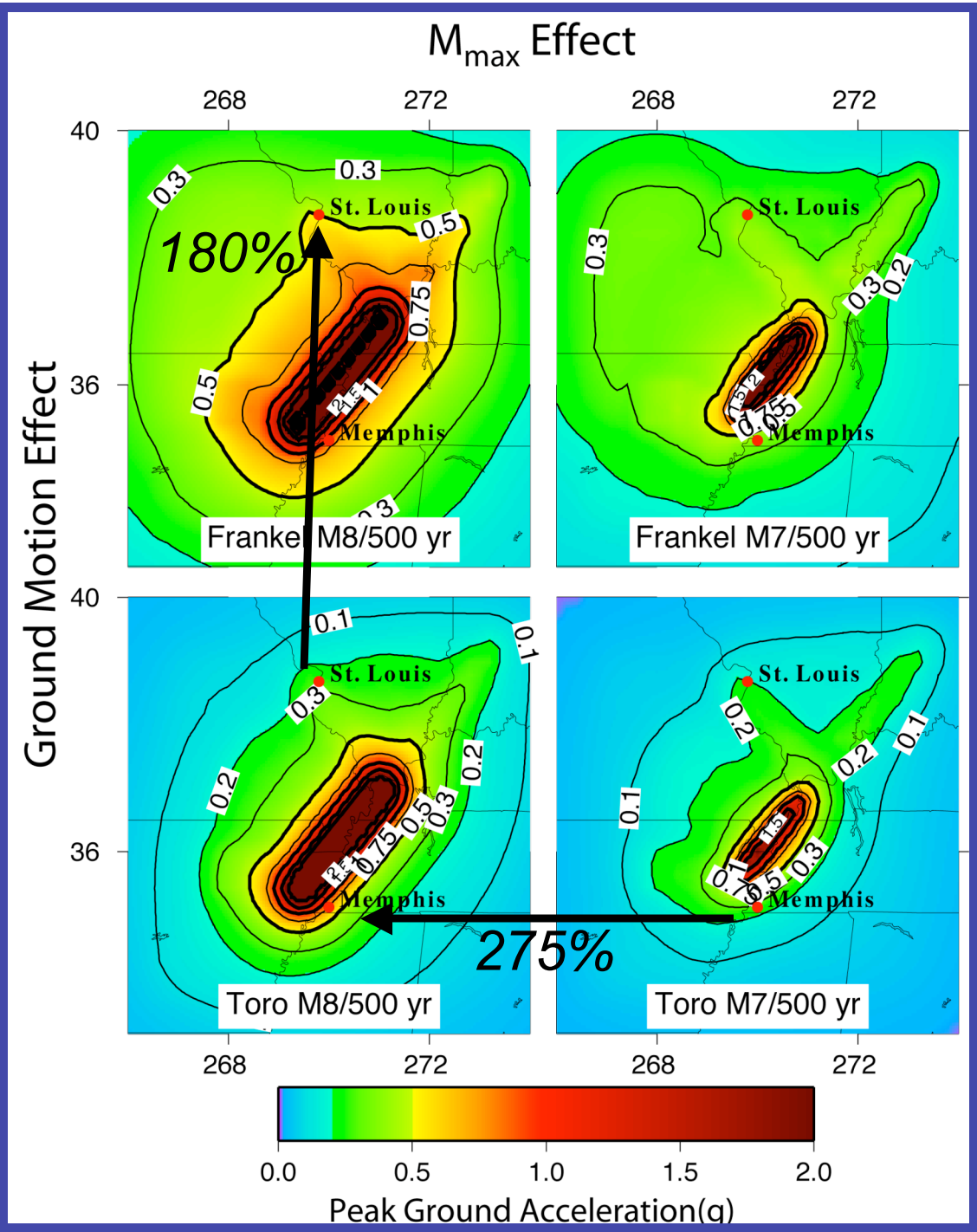
2% in 50 yr (1/2500 yr)

2000-2050 2100-2150 2200-2250 Time-independent

PREDICTED HAZARD DEPENDS ON

- Assumed maximum magnitude of largest events
- Assumed ground motion model

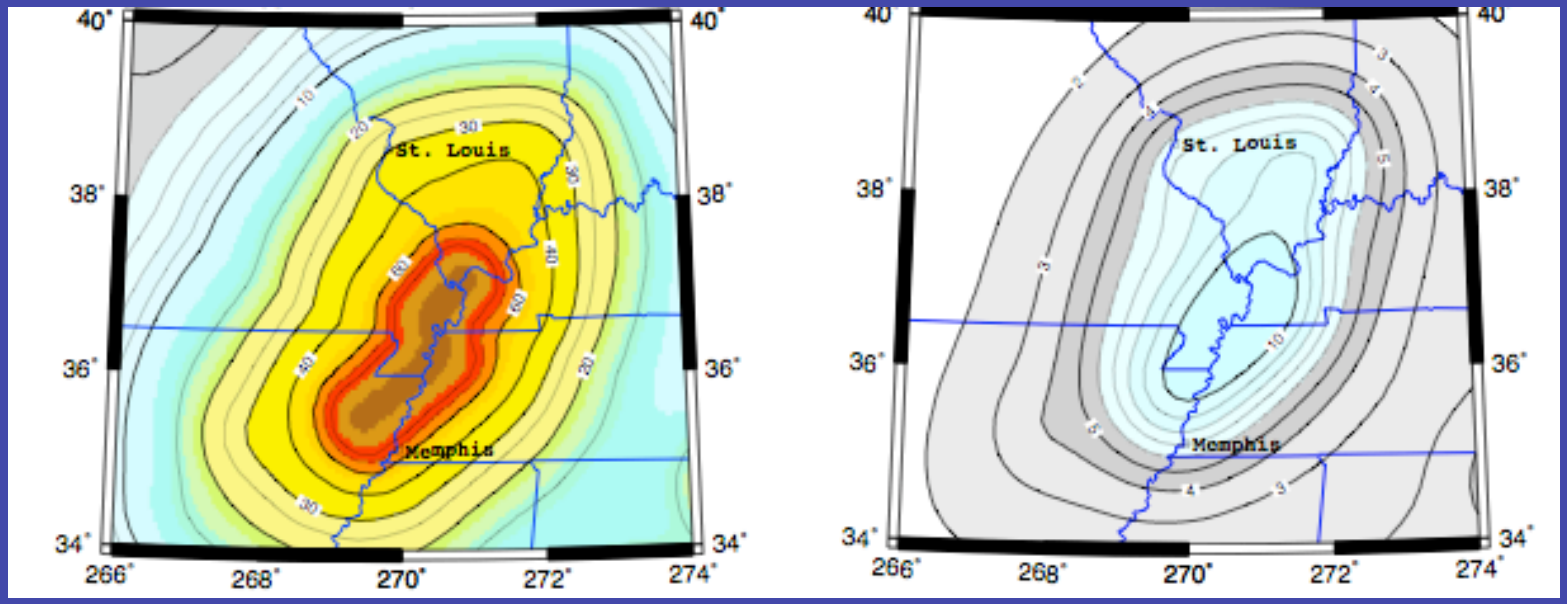
Newman et al., 2001



Assume from GPS no M7 on the way

Hazard from quakes up to M ~ 6.7

~ 1/10 that of USGS prediction



USGS, 2500 yr, assumes M 7 coming

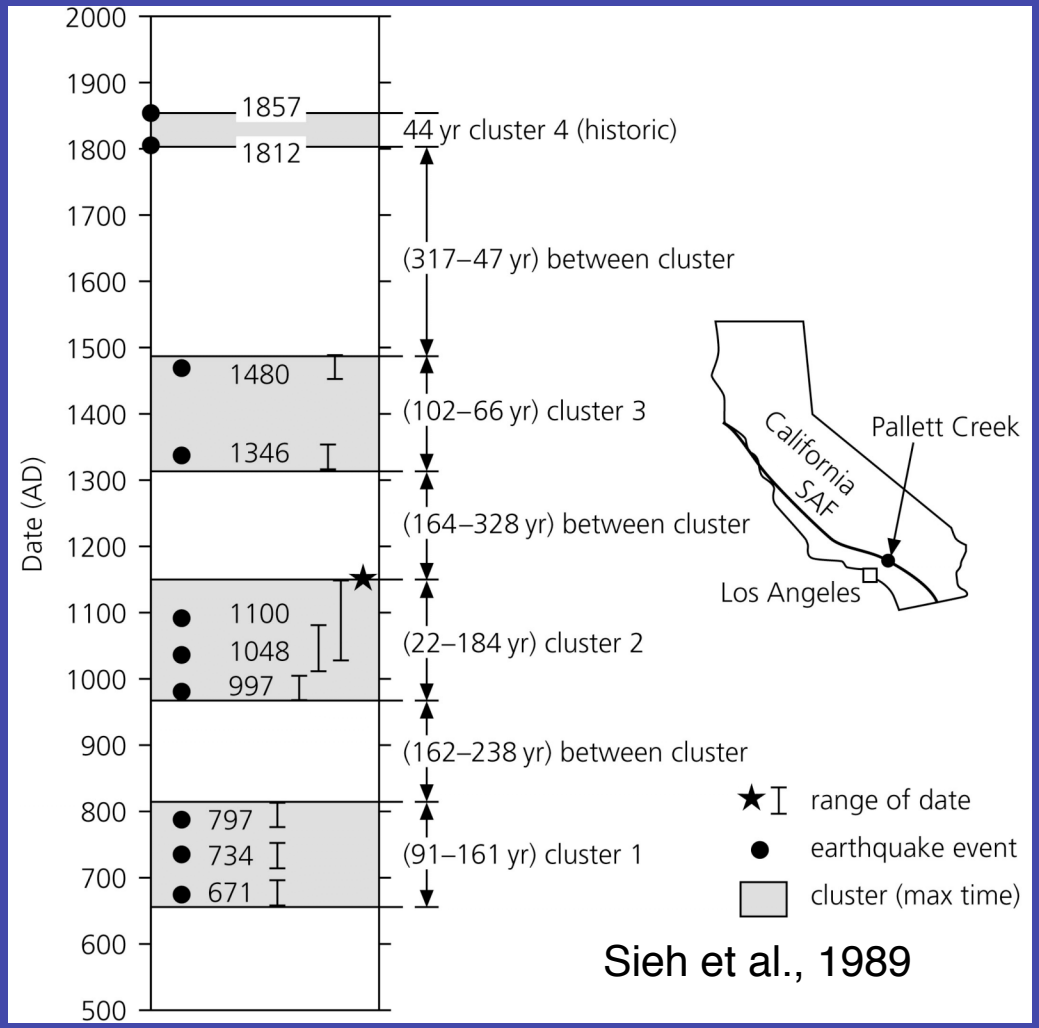
GPS, 500 yr, assumes no M 7 coming

Need continuing GPS to assess possible hazard of M7 here & on other faults

No evidence, but can't exclude until we understand mechanics

"Complexity demands attitudes quite different from those heretofore common in physics. Up till now, physicists looked for fundamental laws true for all times and all places. But each complex system is different; apparently there are no general laws for complexity. Instead one must reach for 'lessons' that might, with insight and understanding, be learned in one system and applied to another. Maybe physics studies will become more like human experience."

Goldenfeld & Kadanoff, 1999



"Half of what we will teach you in the next few years is wrong. The problem is we don't know which half"

Medical school dean to incoming students

"When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong."

Arthur C. Clarke in "Hazards of Prophecy: The Failure of Imagination," 1962