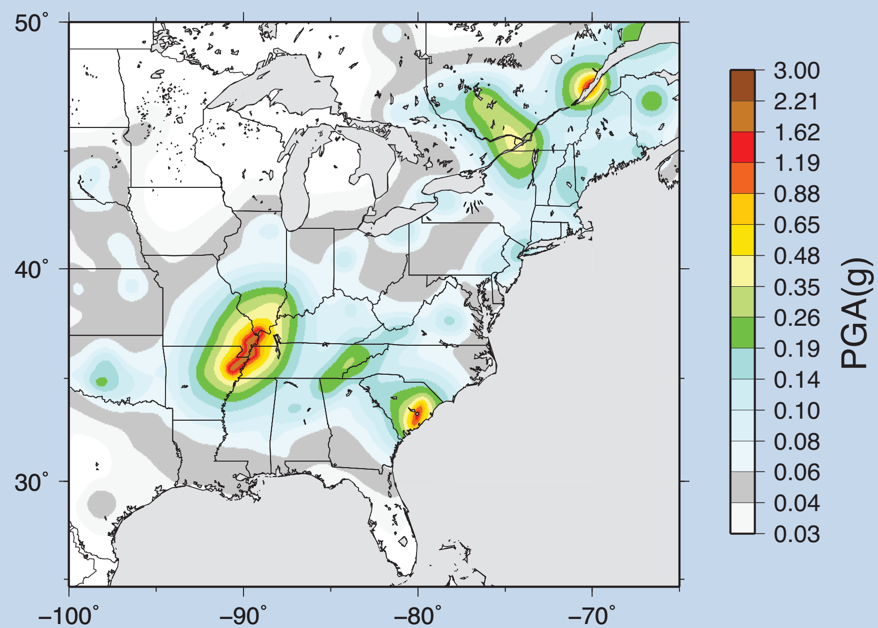
Smoothing methods for background seismicity, CEUS



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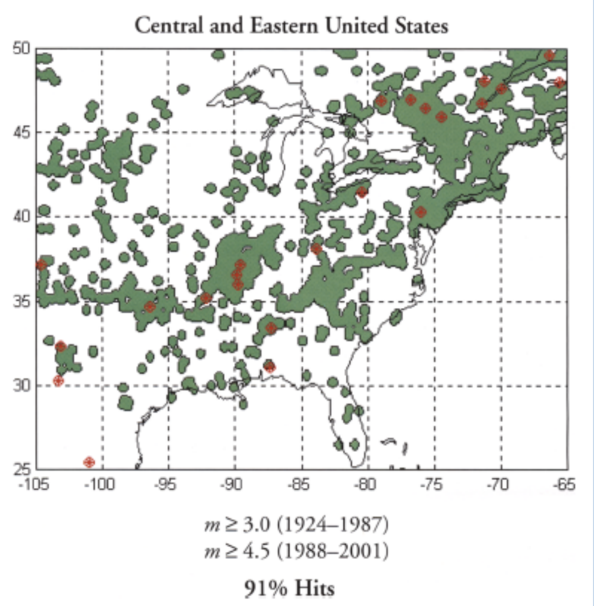
Smoothing methods for CEUS background seismicity

- What is background seismicity? what is smoothed seismicity?
- Contributions of background seismicity contributions to seismic hazard in the CEUS
- Current smoothing methods (fixed-radius) for background seismicity
- Alternative smoothing methods – adaptive-radius
- Comparison of seismicity rates and seismic hazard from fixed-and adaptive-radius smoothing methods
- Comparison of adaptive and fixed-radius smoothing methods for CEUS earthquake catalog – likelihood calculations

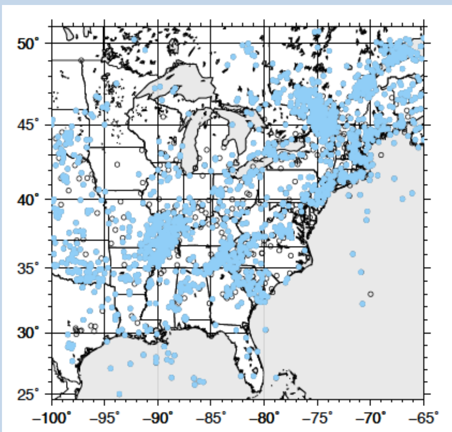
Background seismicity

- Background seismicity comprises: (1) smoothed seismicity rates (observed earthquakes) and (2) a floor value for seismicity rate.
- Interested in locations and rates of large earthquakes, but few observations of these earthquakes
- Evidence that locations of smaller earthquakes forecast locations of large earthquakes (e.g., Kafka, 2002)
- Use smaller earthquakes to estimate seismicity rate assuming G-R relation

Kafka, 2002

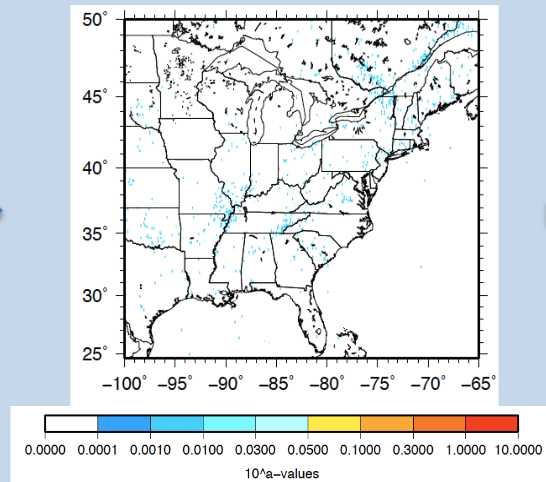


Smoothed seismicity: steps for smoothing seismicity



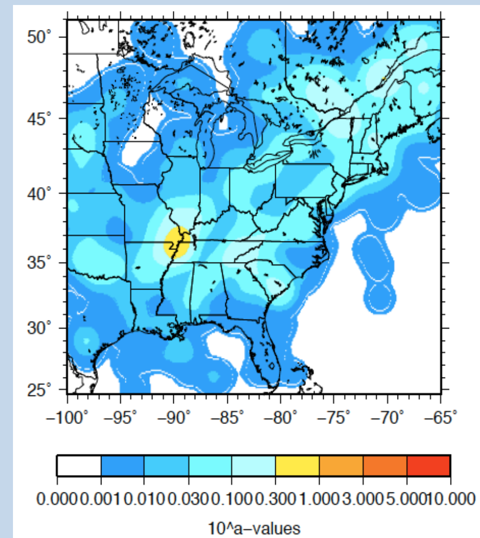
-Select earthquakes for smoothed seismicity (magnitude threshold, completeness levels)

- ~2500 earthquakes (~80, M5+; ~550, M4+)
- Determine *b*-values



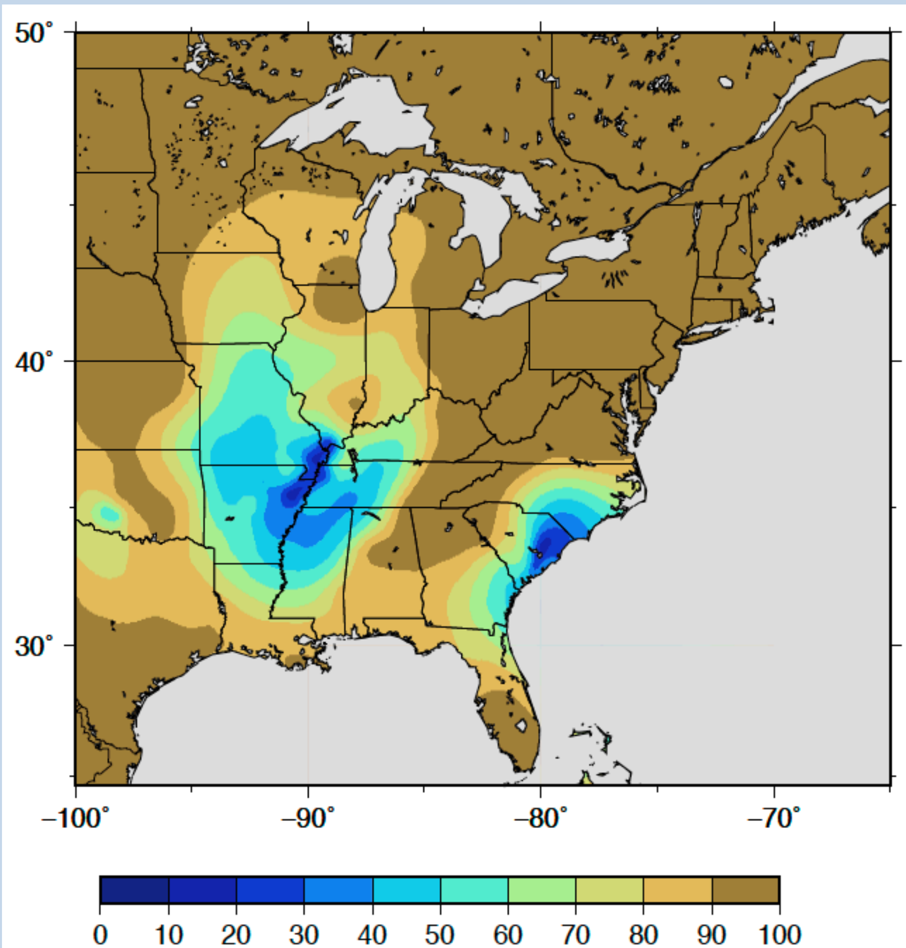
-Count all earthquakes within 0.1^{o}x0.1^o spatial bins

-Using a given value for *b*, solve for spatially-varying values of *a* – G-R relation, N=10^{a-bM} (spatial distribution of 10^a values referred to as *a*-values, *a*-grids)



- Smooth the 10^a values (*a*-grids) (different smoothing kernels, bandwidths, etc.)
- Uncertainty in predicted locations of future earthquakes

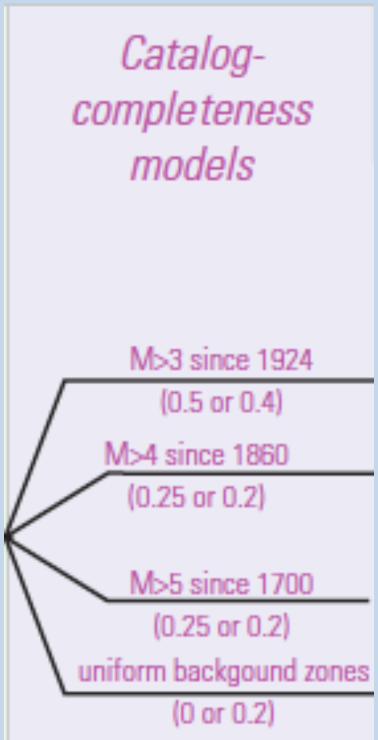
Contribution of background seismicity to hazard, PGA 2%50y



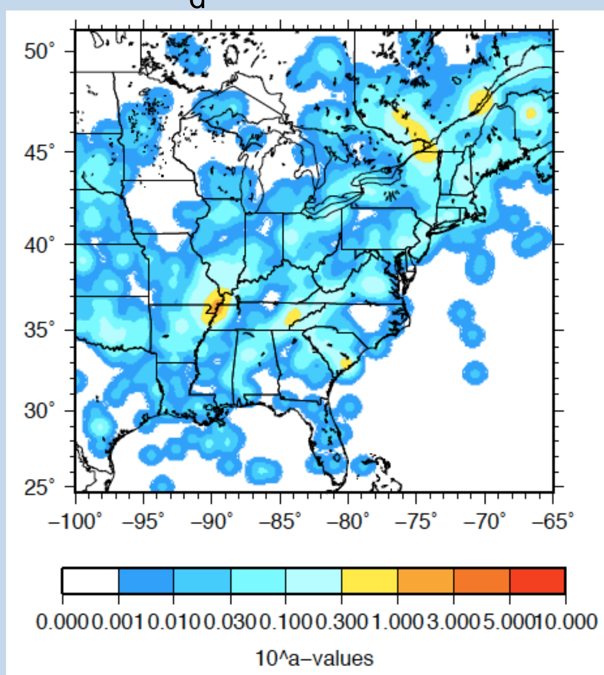
- NSHMs have fault and background source models
- New Madrid, Charleston, Cheraw, Meers faults dominate seismic hazard in those regions
- Up to 100% of hazard from background seismicity in large areas of CEUS

NSHM08 background seismicity

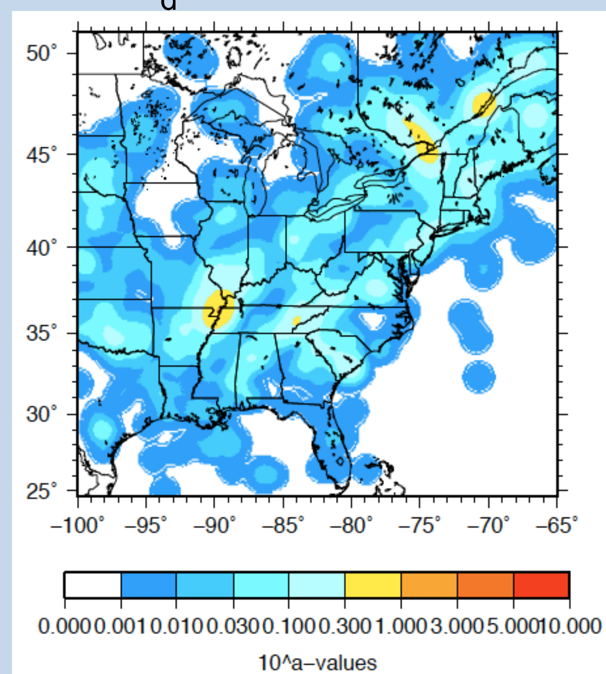
- 2-D isotropic Gaussian smoothing kernel
- Fixed correlation distances: 50 km for M3+, 75 km M4+ and M5+ earthquakes



C_d=50 km



C_d=75 km



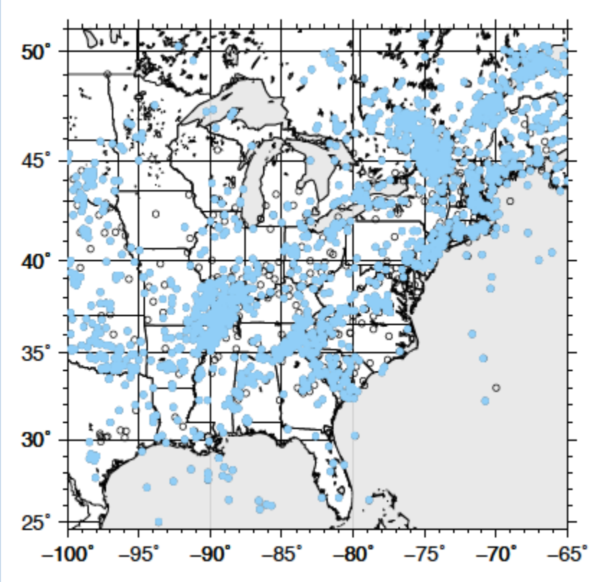
Testing adaptive-radius smoothing kernel

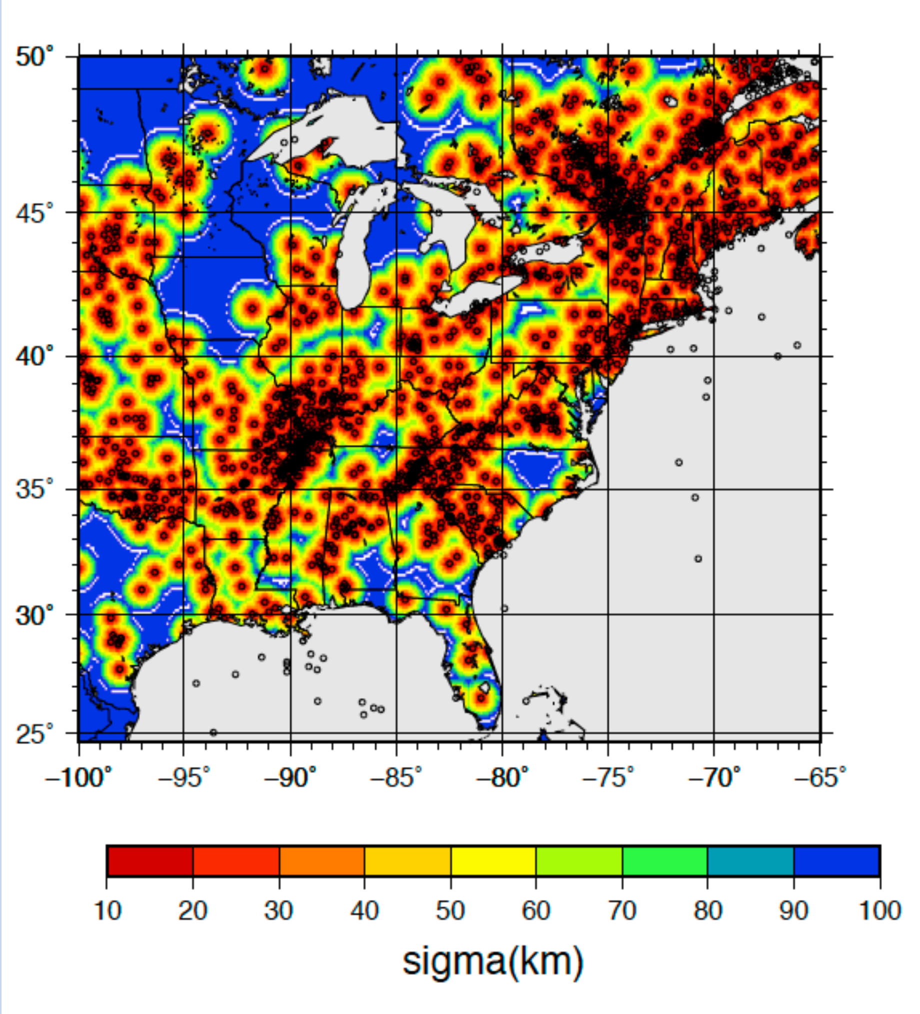
- Here, kernel restricted to 2-D Gaussian:

$$K_d(\vec{r}) = C'(d)\exp\left[-\frac{|\vec{r}|^2}{2d^2}\right]$$

- *d*, smoothing distance, chosen using Helmstetter et al. (2006) criterion (d/σ/sigma/correlation distance)
- Kernel bandwidth, d_i, decreases if density of seismicity at location *i* increases.

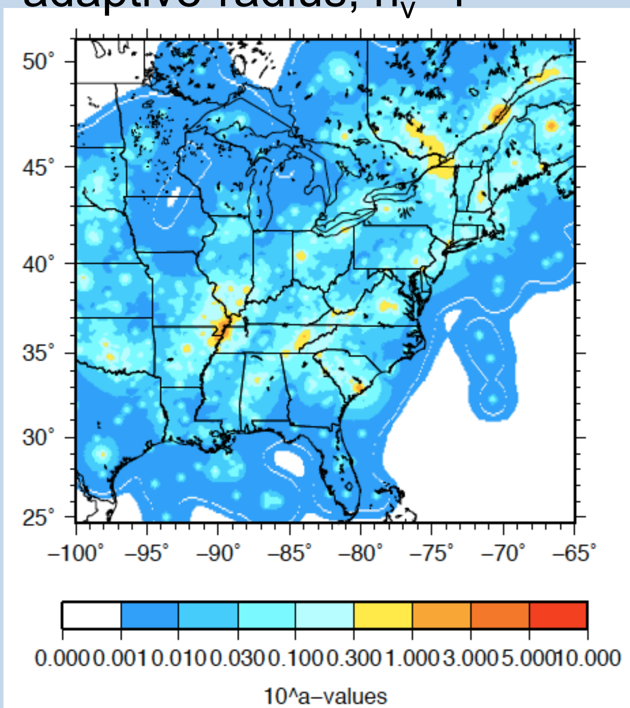
Testing adaptive-radius smoothing kernel (e.g., Helmstetter method, n_v=1)



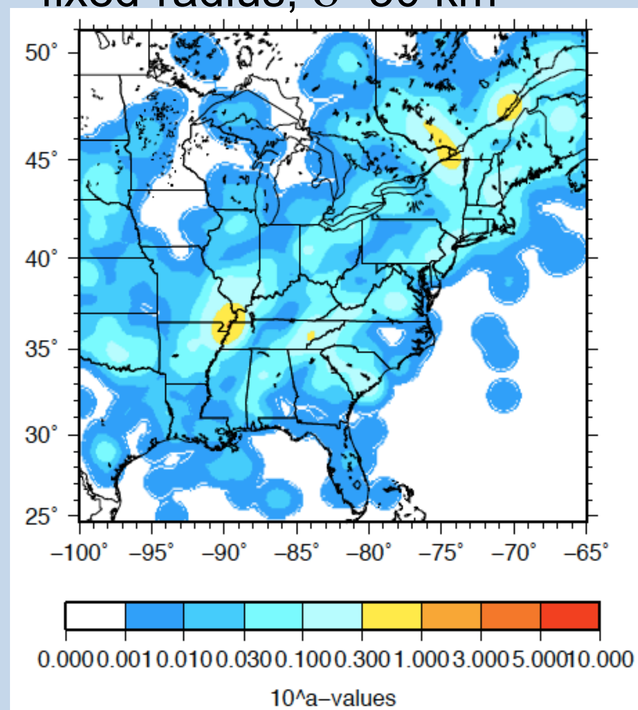


Effect of adaptive-radius smoothing method

adaptive-radius, n_v=1

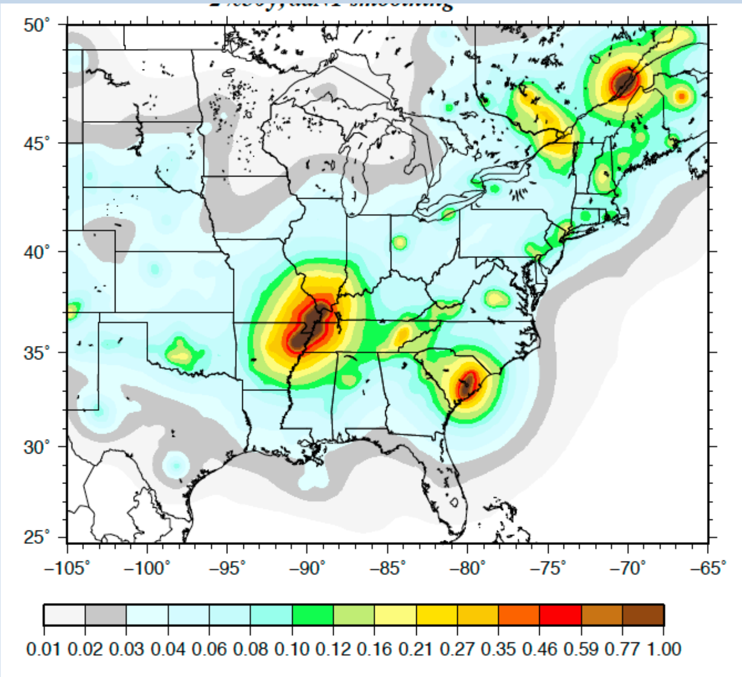


fixed-radius, σ=50 km

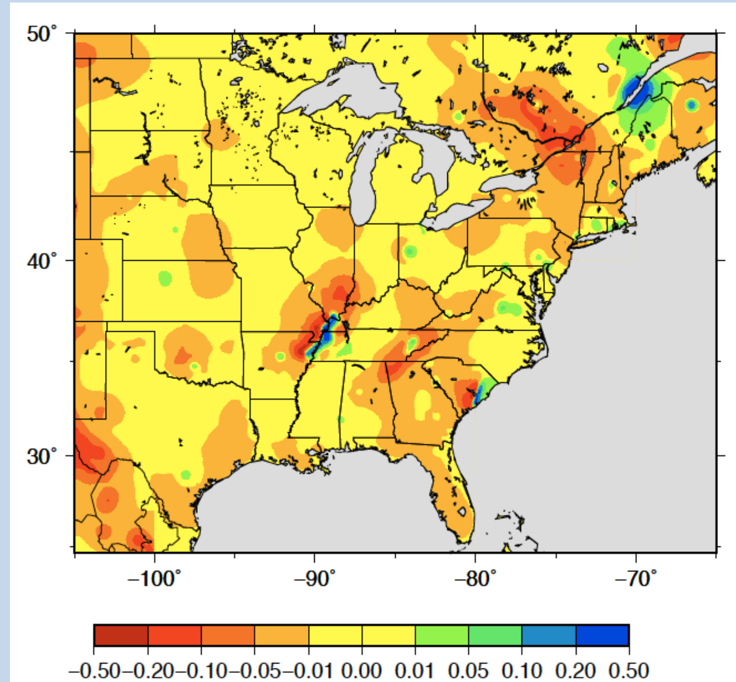


- Little smoothing where density of seismicity is high and large degree of smoothing where density of seismicity is low
- Increased seismicity rates in regions of highest and lowest seismicity densities – how does this affect hazard?

ΔPGA (2% PE 50y), adaptive-radius (n_v=1) (wrt NSHM08)



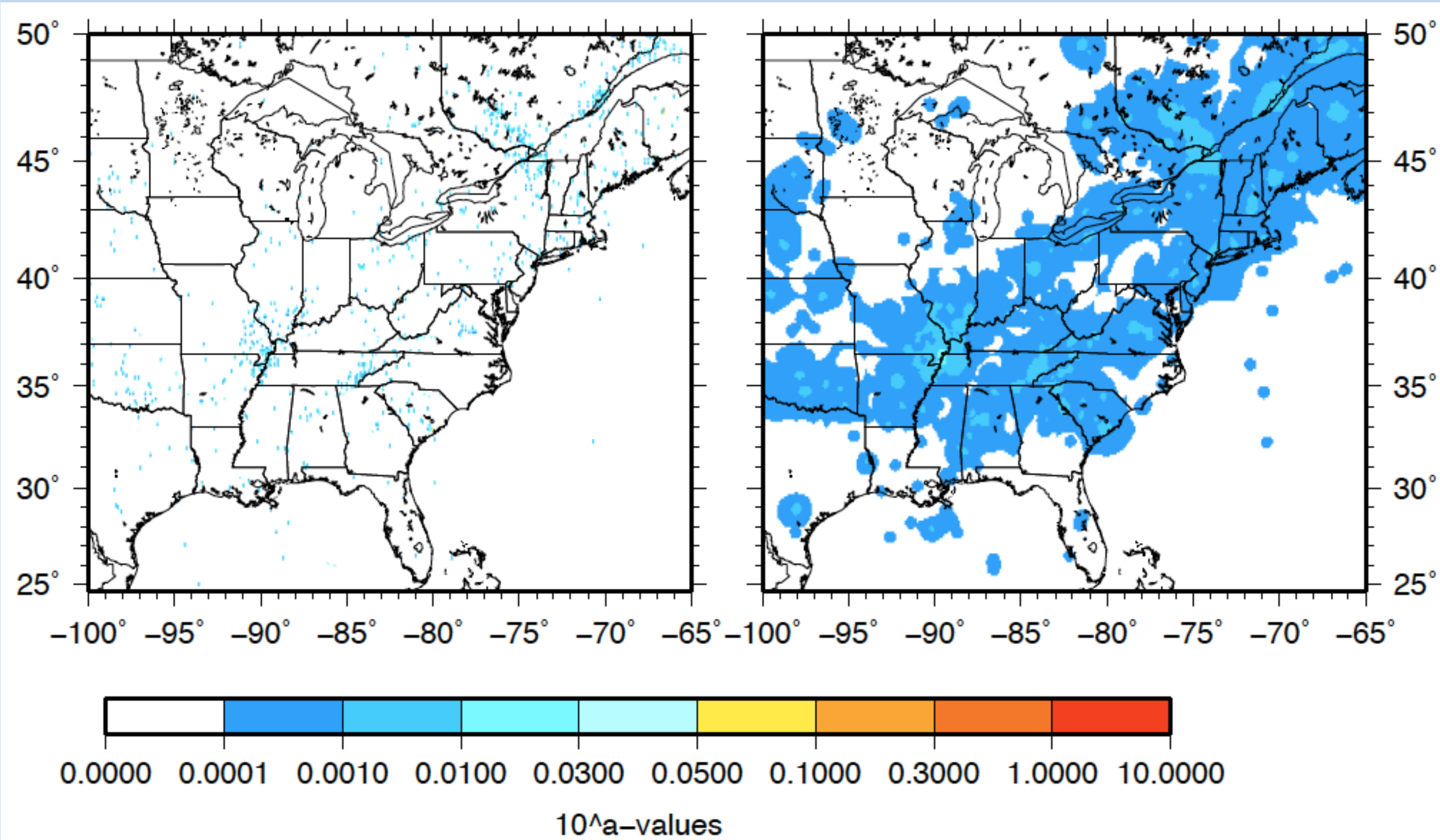
PGA (g)



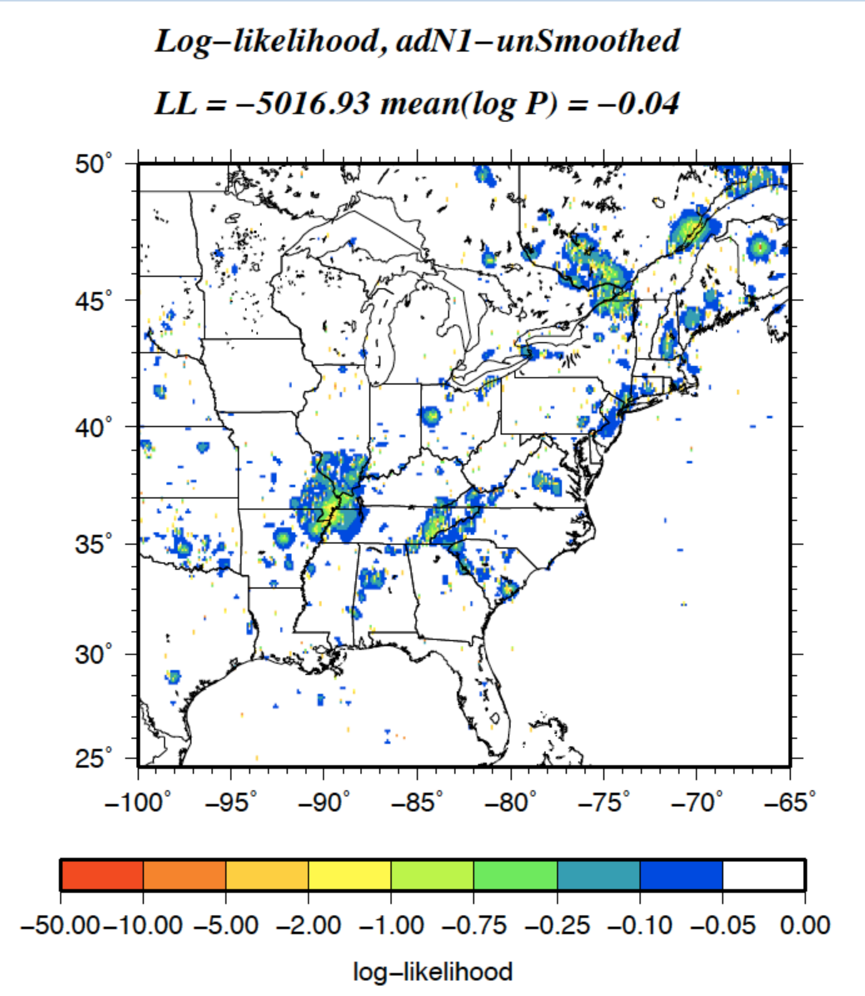
ΔPGA (g)

- General pattern of increased hazard centered on regions of high seismicity density, decreased hazard away from high density
- New Madrid, eastern Tennessee seismic zones and Charlevoix not treated as in NSHM08. (Source zones since 1976 and modified b-values.)
- Changes in seismic hazard of 0.1 g across broad areas - how determine appropriate smoothing?

Comparison of forecast and observed seismicity rates from subsets of the earthquake catalog



Calculate likelihood of observed events, given forecast rate



- Assume earthquake occurrence modeled by Poisson distribution
- Log-likelihood value for each spatial bin.
- Comparison between log-likelihood values from different smoothing methods

Recommendations

- Implement fixed- and adaptive-radius smoothing methods
- Perform likelihood calculations to determine kernel/bandwidth combinations that best predict epicentral locations. Investigate magnitude dependence.
- Full or partial weight on kernel/bandwidth combinations with highest likelihood. (Partial weight would include non-zero weighting on NSHM08 a-grid model.)