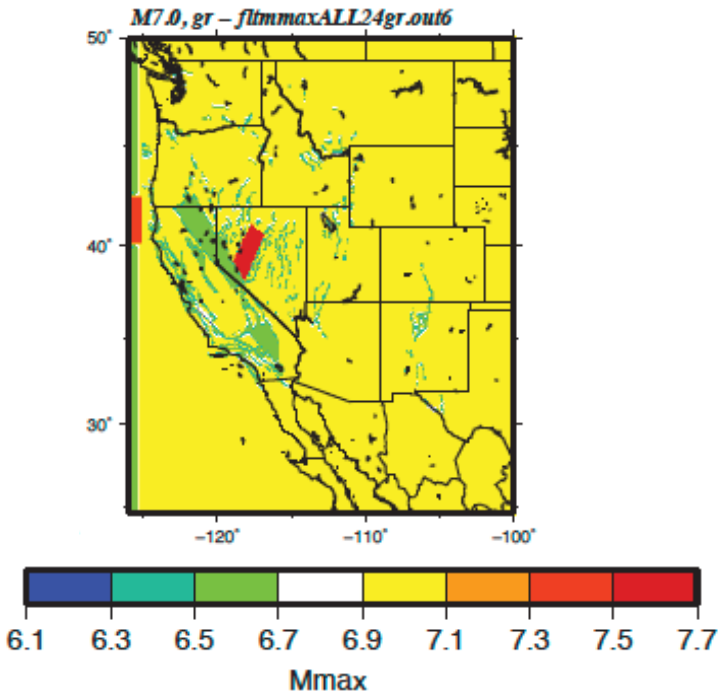
MMAX

Mmax – NSHM-2008



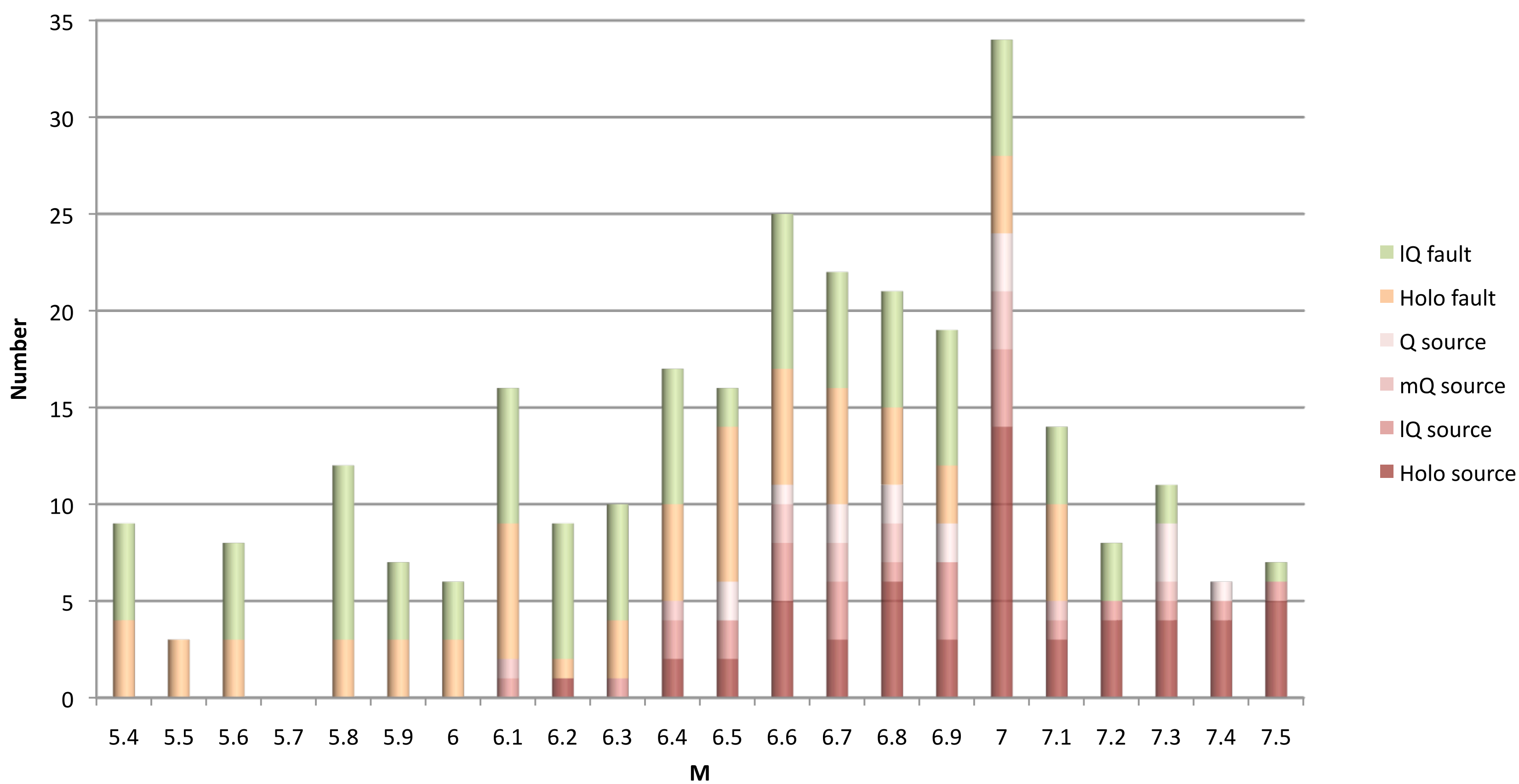
2008 NSHMs

- Mmax for gridded seismicity generally 7 for WUS
- Mmax=7.5, Central Nevada Seismic Zone
- Decrease Mmax (near faults or shear/C zones) to 6.5 (G-R branch)
- Where Mchar<6.5, use Mchar for Mmax (near faults)

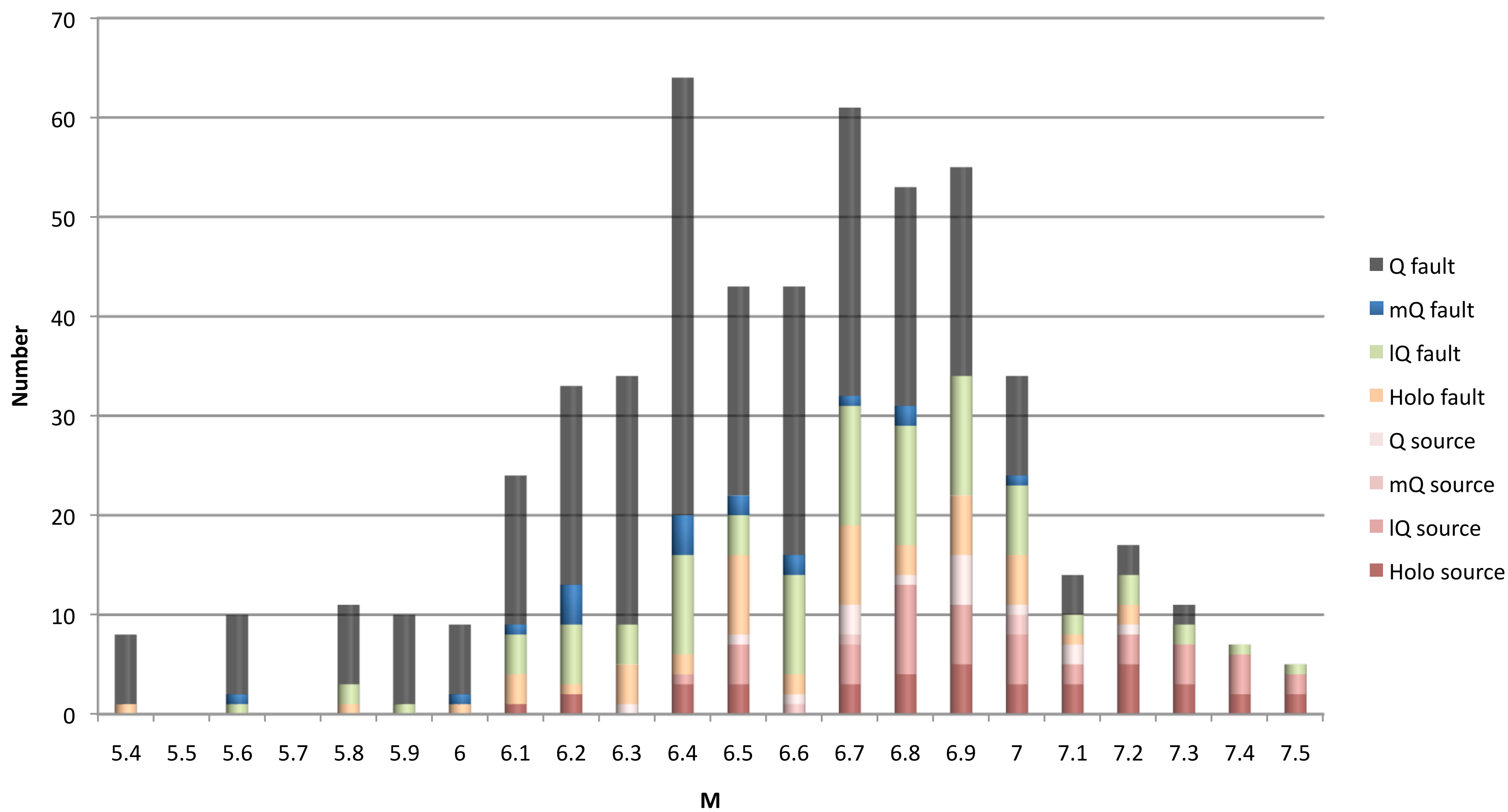
Mmax for IMW background seismicity

- Mmax represents earthquakes off the modeled faults
  - Un-modeled faults (faults in Quaternary fault database, but not included as NSHM sources)
  - Unknown faults
  - Multi-segment ruptures?
- Currently constrained by M7.5 Sonora earthquake
- After an earthquake occurs, people want to know if that earthquake was in the model (e.g., Darfield, NZ EQ)

Potential young sources in the IMW (excluding Nevada)

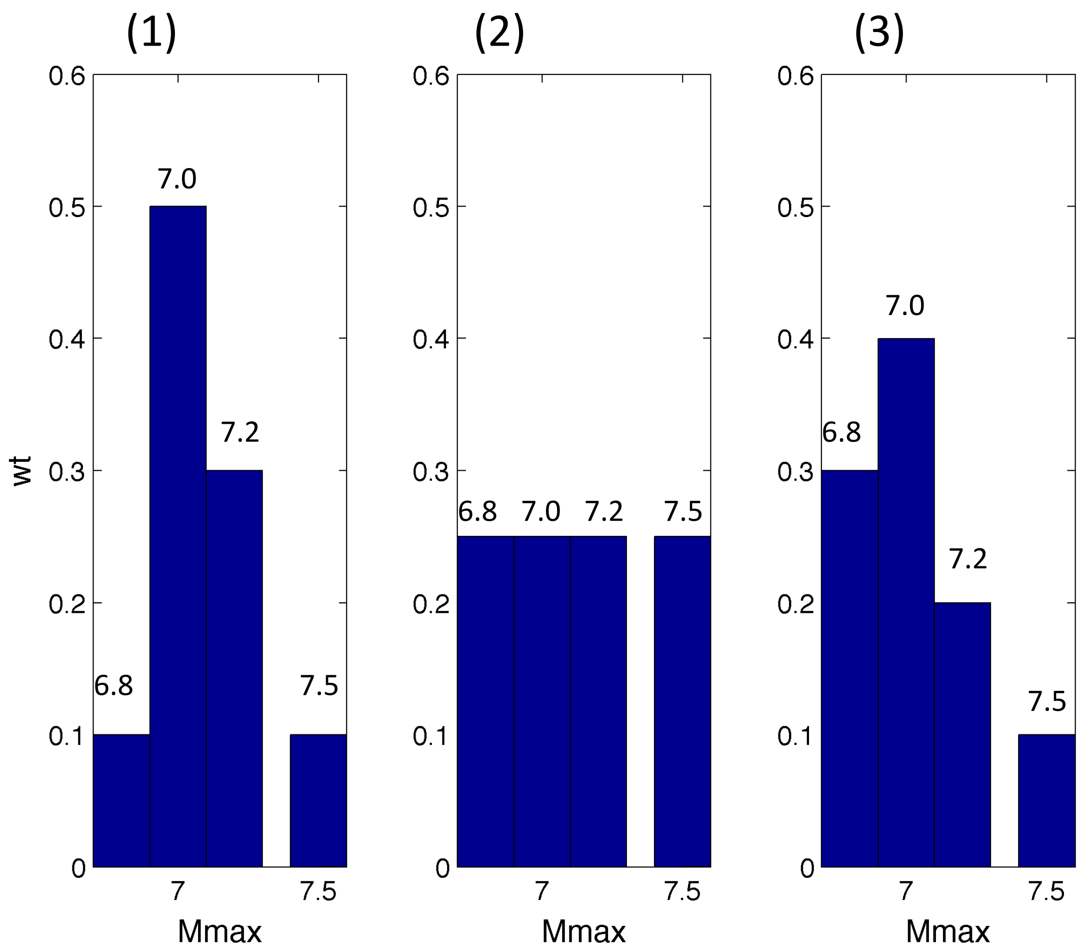


Potential additional sources in Nevada



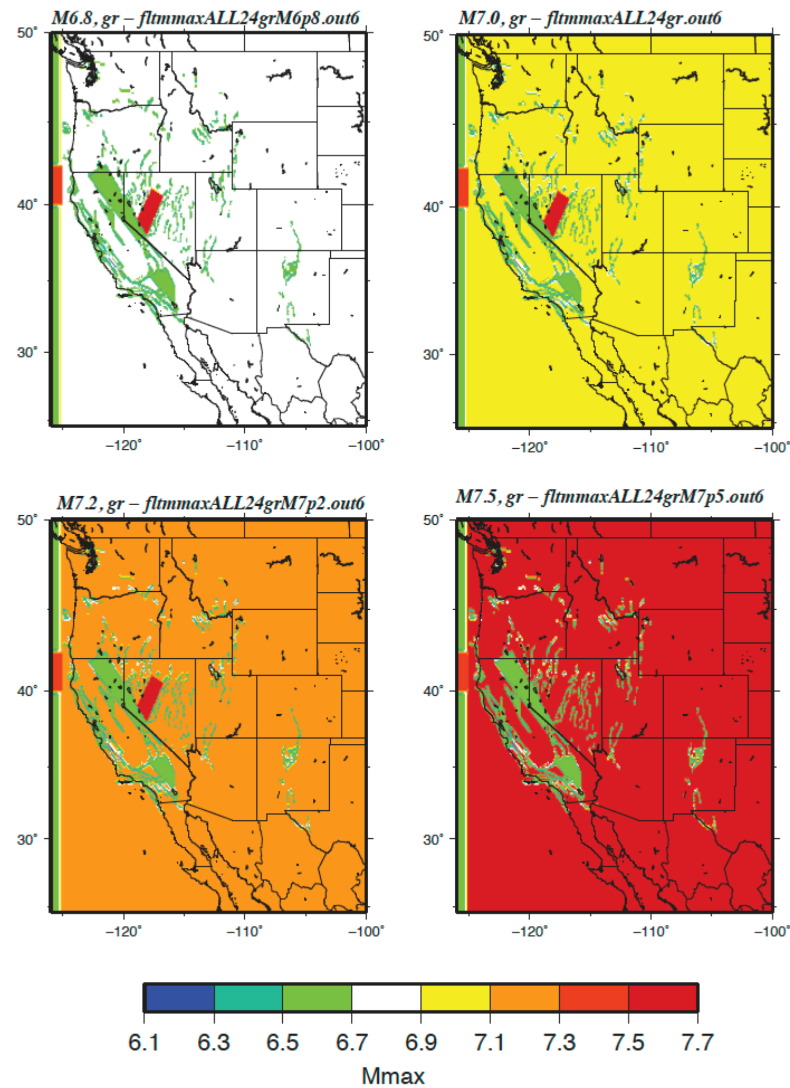
Mmax distributions

Mmax distributions for testing.
Weightings to M6.8/7.0/7.2/7.5
(1) 0.1 – 0.5 – 0.3 – 0.1
(2) 0.25 – 0.25 – 0.25 – 0.25
(3) 0.3 – 0.4 – 0.2 – 0.1



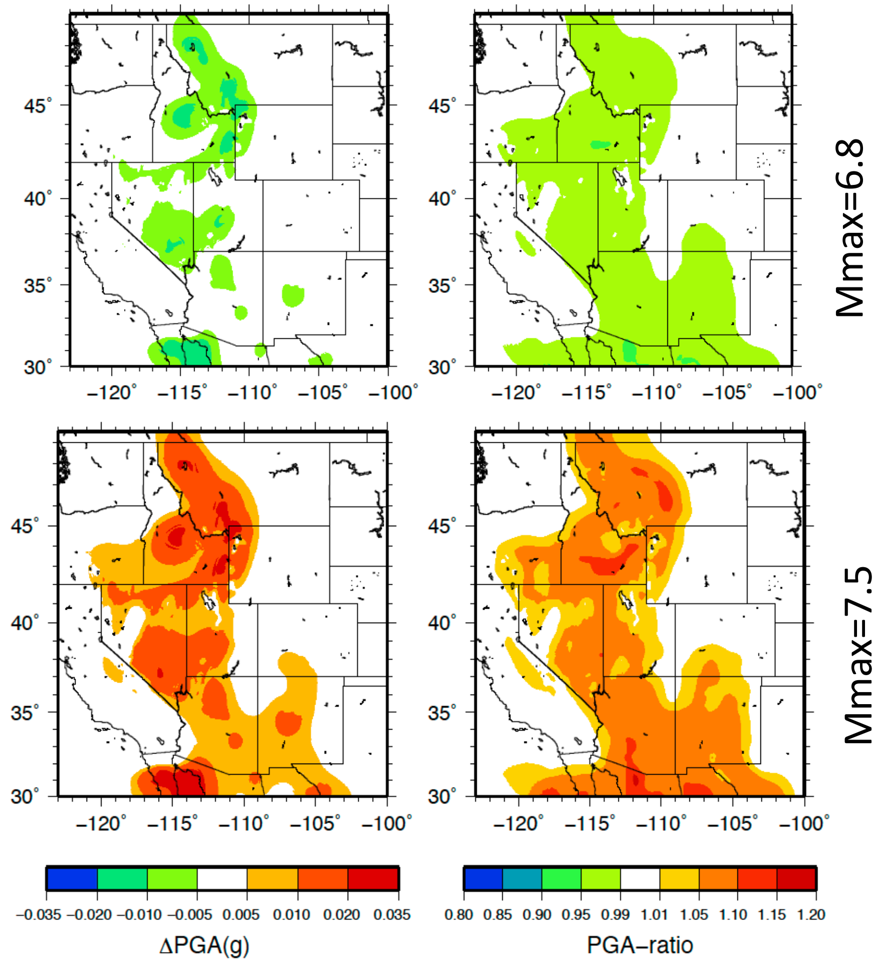
Mmax distributions

- Special zones (CNSZ, shear, faults, Mchar) untouched
- Modify background Mmax from M7.

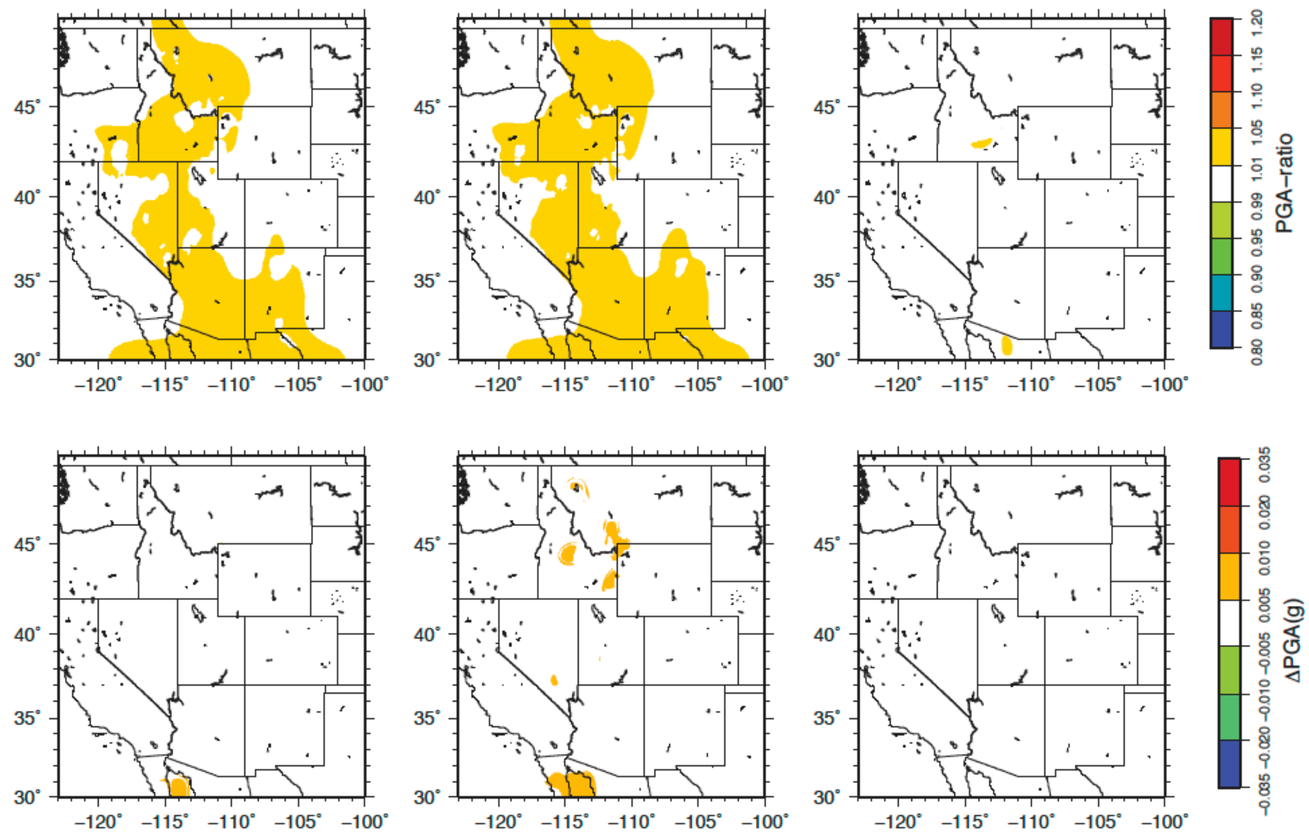


Mmax sensitivity tests – end-members

- End-members: Mmax=6.8, 7.5
- Perturbations of about +/-10%



Mmax sensitivity tests –distributions



- Perturbations of +/- 5% for all Mmax distributions
- Weighted Mmax averages: 7.09, 7.125, 7.03

Mmax distributions: recommendations

- Should we use an Mmax distribution for the IMW?
  - Pros: If a larger earthquake occurs, it will be in the model (e.g., Tohoku)
  - Cons: More complicated computations with little change in hazard (unless weighted average is significantly different from M7).

Seismicity rate discrepancy between NSHM08 and observed seismicity

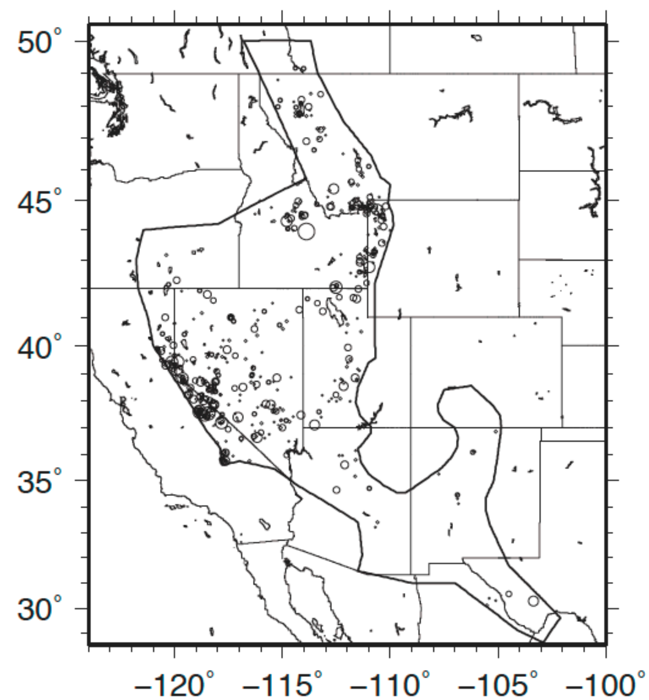
Morgan Moschetti and Stephen Harmsen

2014 NSHM update, IMW workshop

6/14/2012

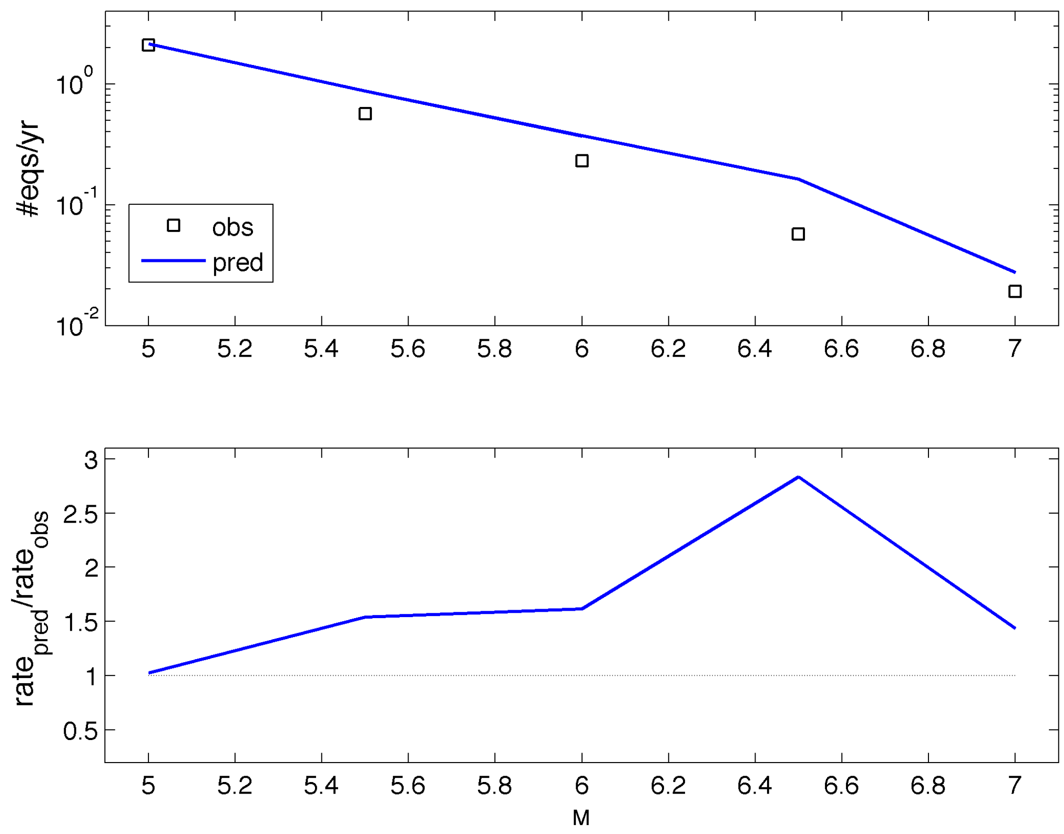
- Compare NSHM08 rates with observed rates
- Source models contributing to NSHM08 rates
- Approaches for reducing rate discrepancy

Comparison of modeled and observed seismicity rates



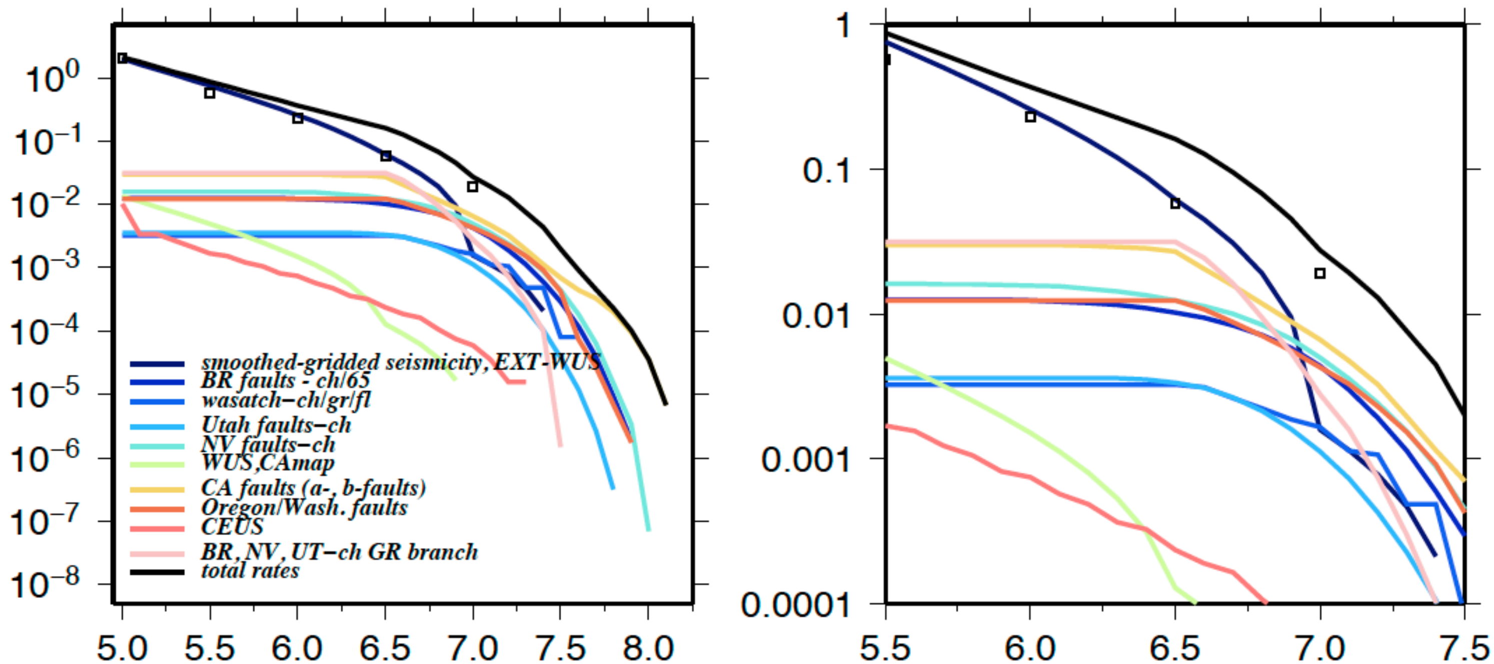
- Sum rates from 2008 NSHMs and compare with observed (cumulative) seismicity rates within IMW polygon

Modeled and observed seismicity rates



- Better agreement below M6, above M7
- Rate discrepancy peaks near M6.5 – factor of greater than 2.5

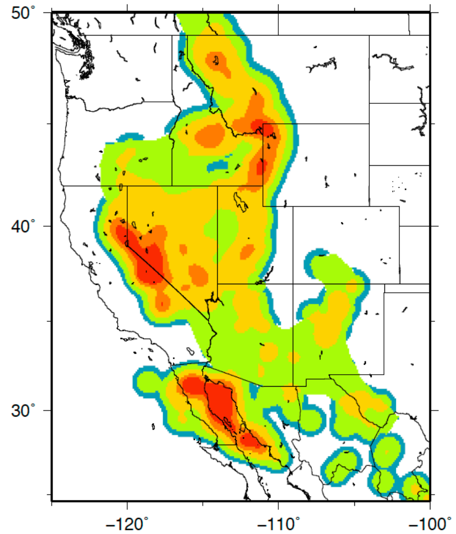
Sources contributing to IMW seismicity rates



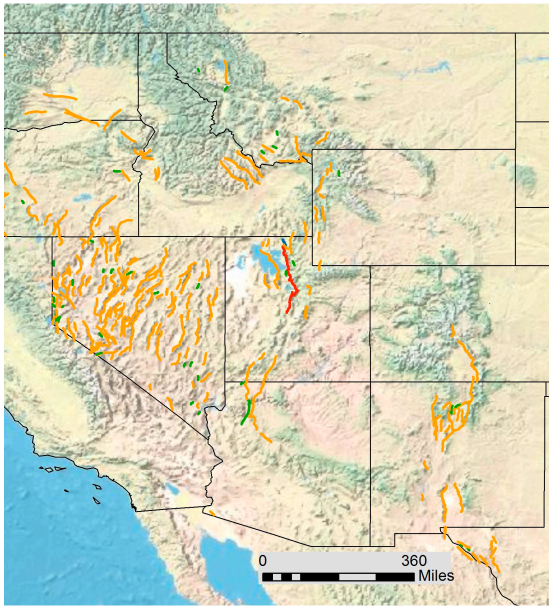
- Below M6.5: smoothed-gridded seismicity, EXT-WUS
- Near M6.5: EXT-WUS, BR/NV/UT partial/floating ruptures, CA faults,
- Above M6.5: CA faults, NV faults, OR/WA faults, BR faults
- Small contribution from Wasatch fault, UT faults

Sources contributing to IMW seismicity rates, I

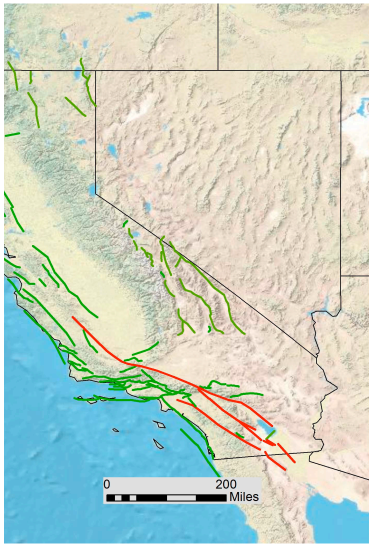
sm-gridded seism., EXT-WUS



B&R, NV and UT faults



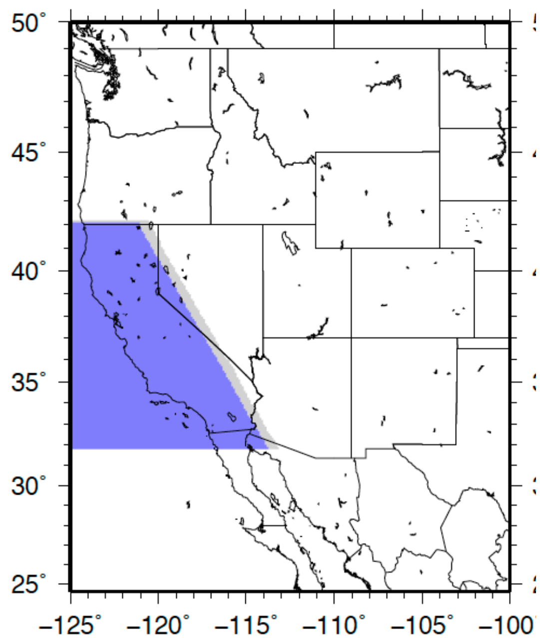
CA a- (red) and b-faults (green)

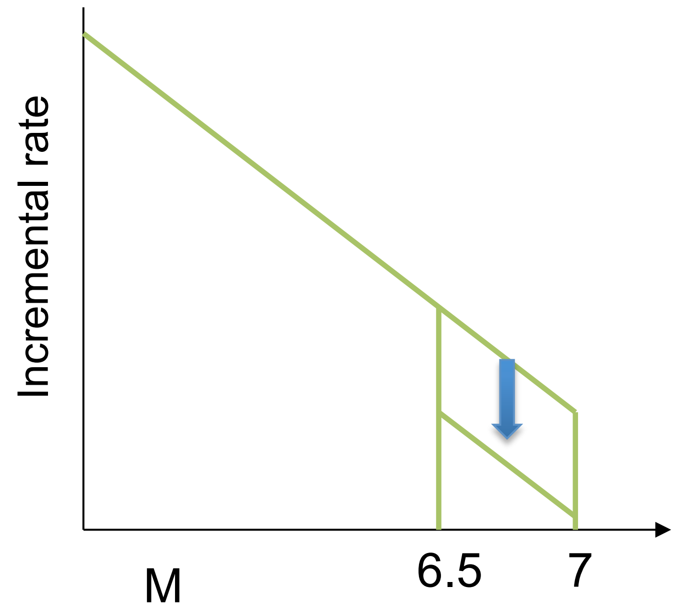


Approaches for reducing rate discrepancy

- Need to decrease rates of lower-magnitude events (M6.5) (often by increasing rates of M>6.5 events)
- Approaches for modifying seismicity rates:
  - BRPEWGII, C. Mueller presented effect of relative weighting on full- and partial-ruptures for fault sources; increasing weight on partial ruptures increases rate discrepancy
  - 0.33 weight on a-grid for M6.5+ events (used in CA)

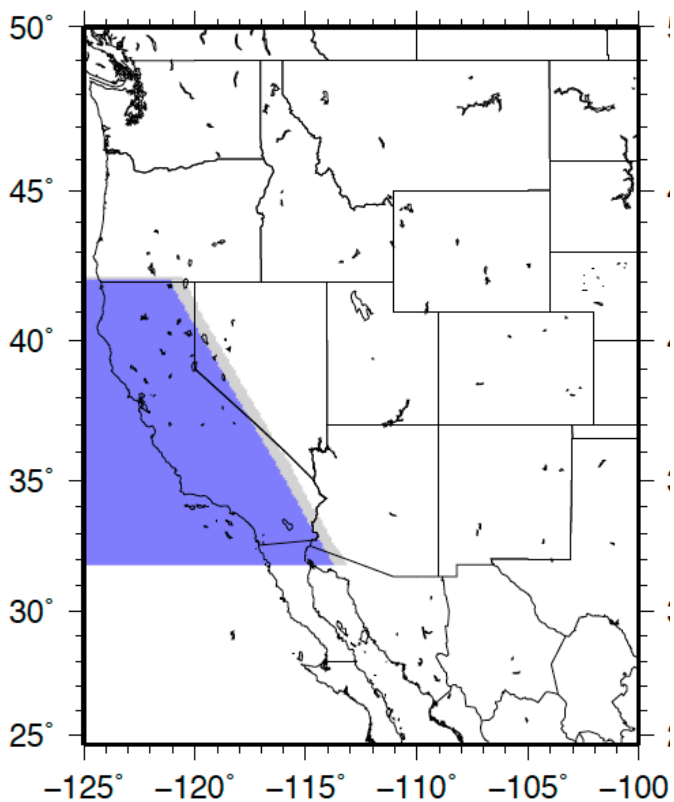
Approaches for reducing rate discrepancy: 33% wt a-grid; an example from California





- 33% weight on a-grid for M6.5+ events – applied to CA smoothed-gridded seismicity calculation

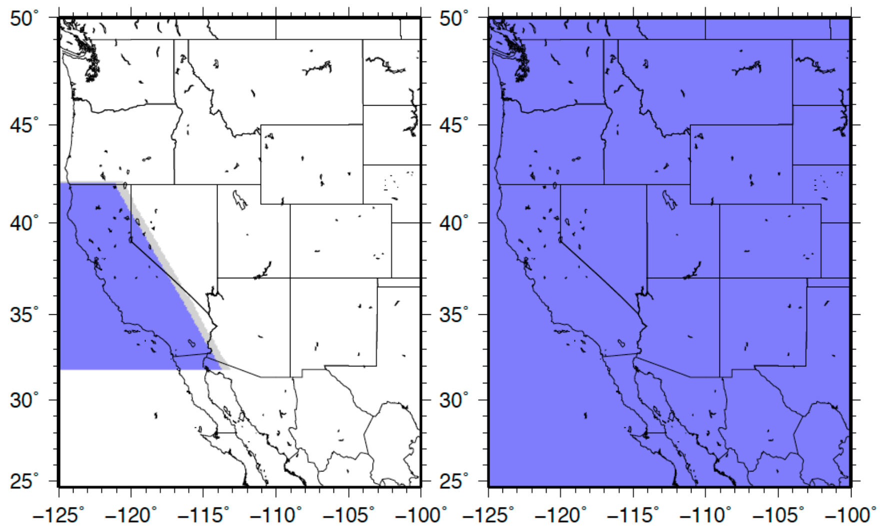
Approaches for reducing rate discrepancy: 33% wt a-grid; rationale

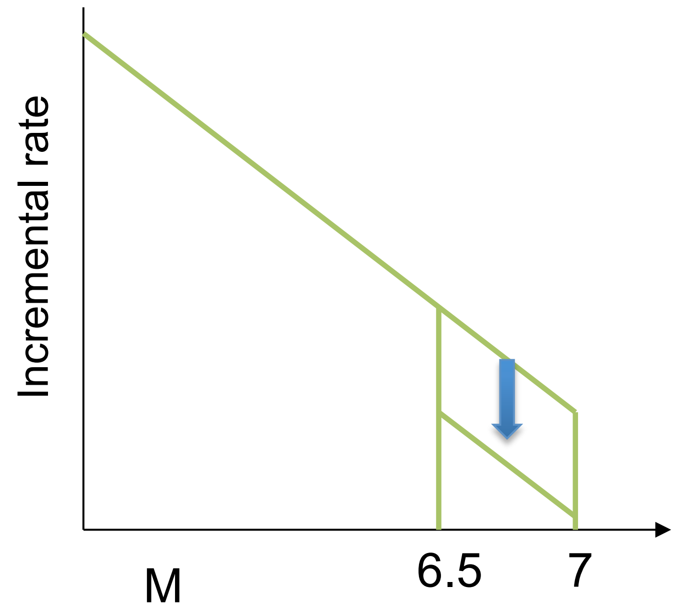


Rationale for 33% weighting to M6.5+ earthquakes in smoothed-gridded seismicity, for CA:
- 2/3 of M6.5+ earthquake occur on faults
- 1/3 occur off of known faults
- 33% weight applied to a-grids for M6.5+ events

This approach was used to reduce the seismicity rate mismatch in CA for NSHM08 model.

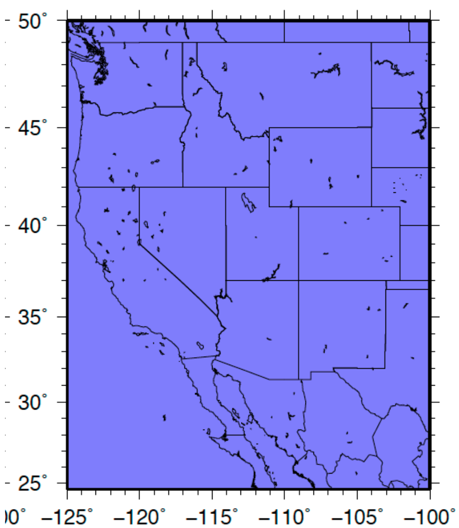
Rate modifications: 33% wt a-grid, sensitivity for IMW-wide application

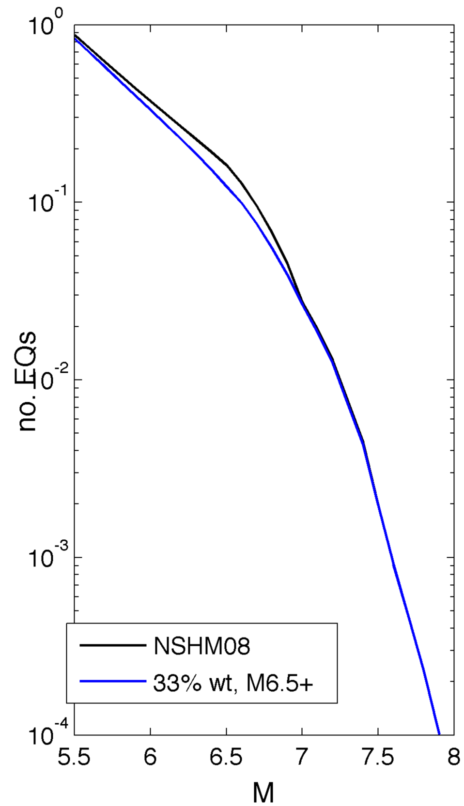


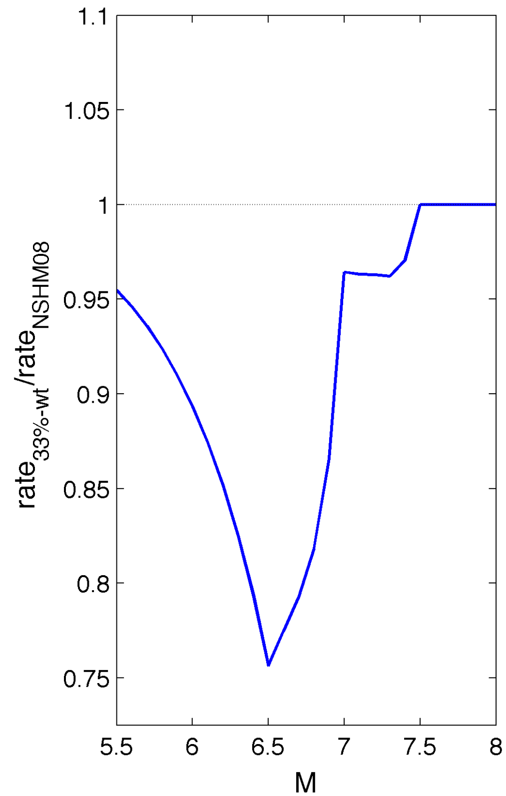


- 33% weight on a-grid for M6.5+ events – applied to IMW smoothed-gridded seismicity calculation

Rate modifications: 33% wt a-grid, sensitivity for IMW-wide application



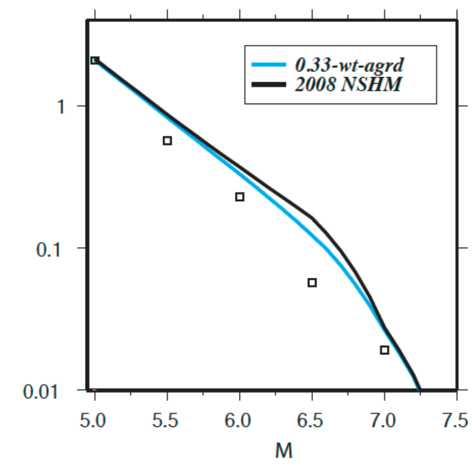




- Rates at M6.5 reduced by about 25%

Rate mismatch: discussion

- Should USGS address IMW seismicity rate mismatch?
- If so, what approaches to reducing mismatch should be implemented?
  - 33% weight to 10^a values for M>6.5 smoothed-gridded seismicity (weight may not be appropriate for IMW
  - b=0 branch on floating/partial ruptures, which results in about 30% decrease in discrepancy
  - Allow for aseismic component of slip rate

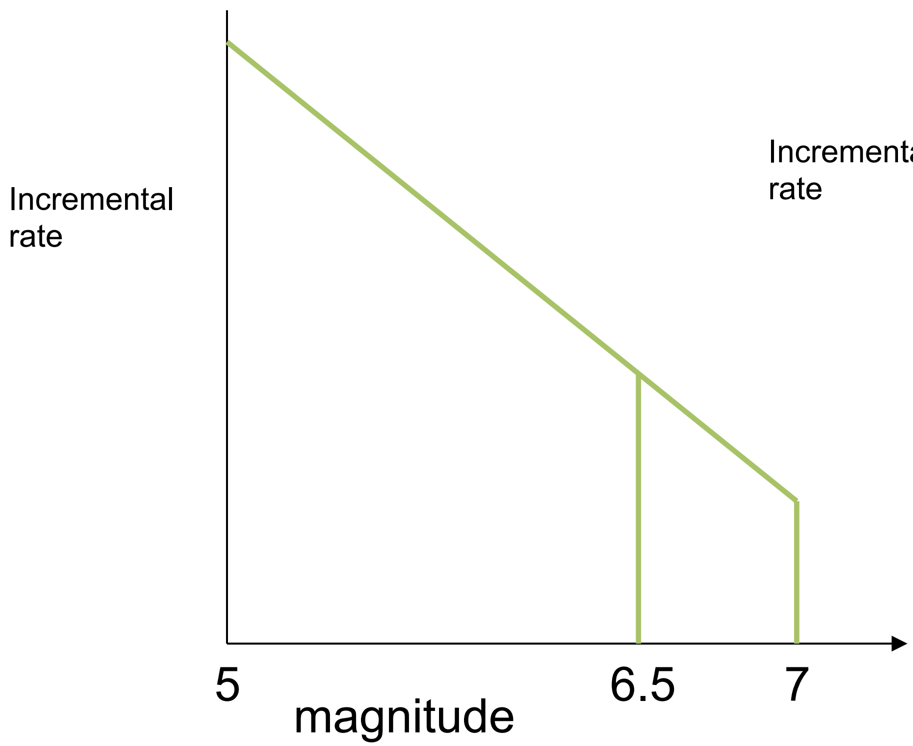


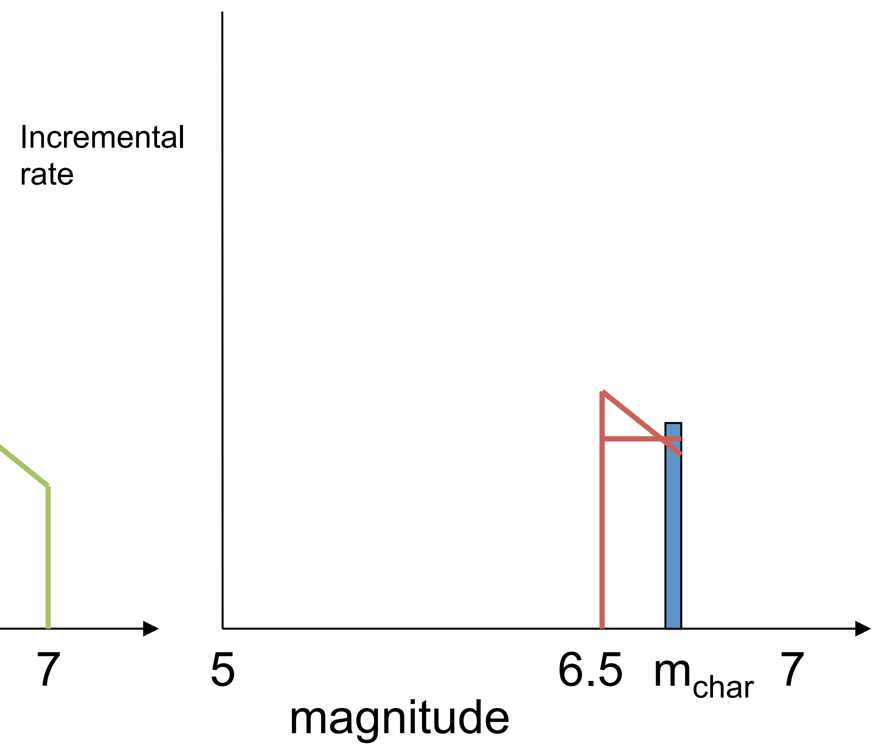
Magnitude-frequency distribution on faults

NSHM – conceptual model (no uncertainty)

•Background model: Use catalog to calculate 10^a for GR distribution.

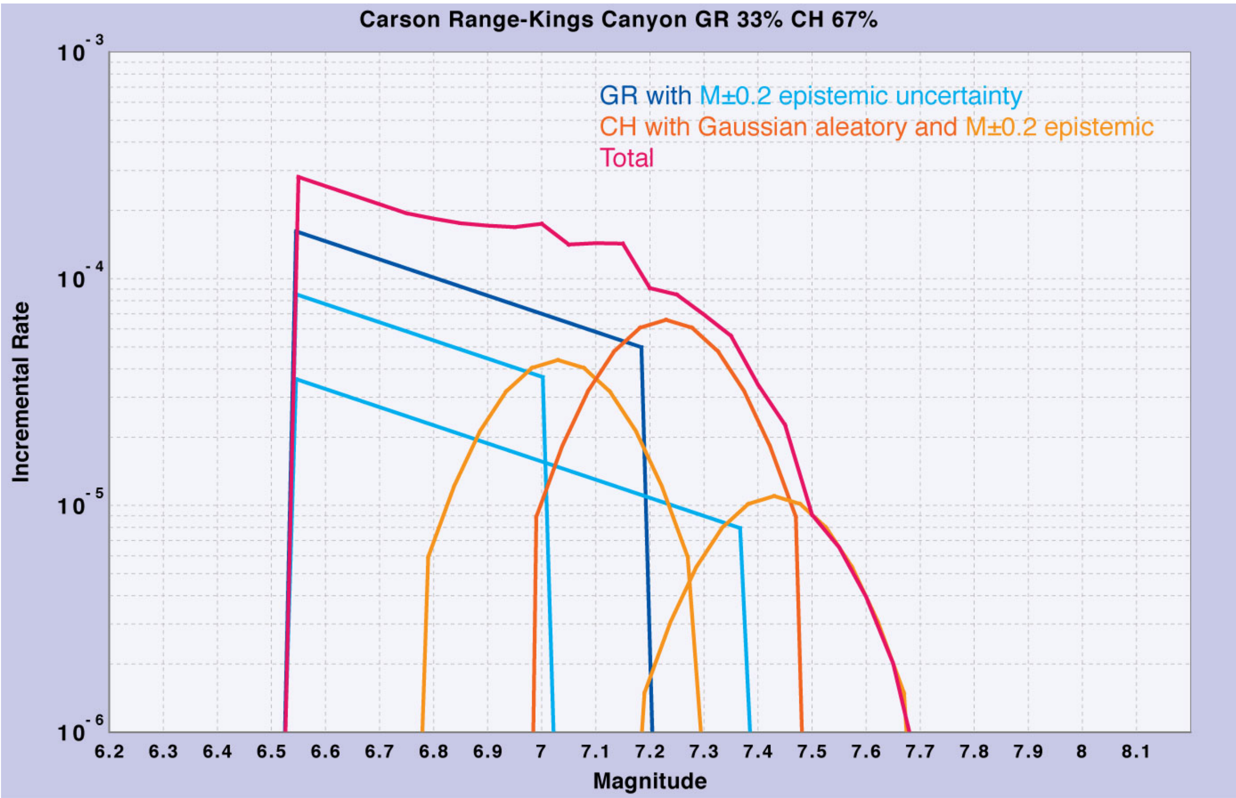
•Fault model: Use slip rates for calculating characteristic or floating partial-segment ruptures - GR





On-fault, M-f distributions

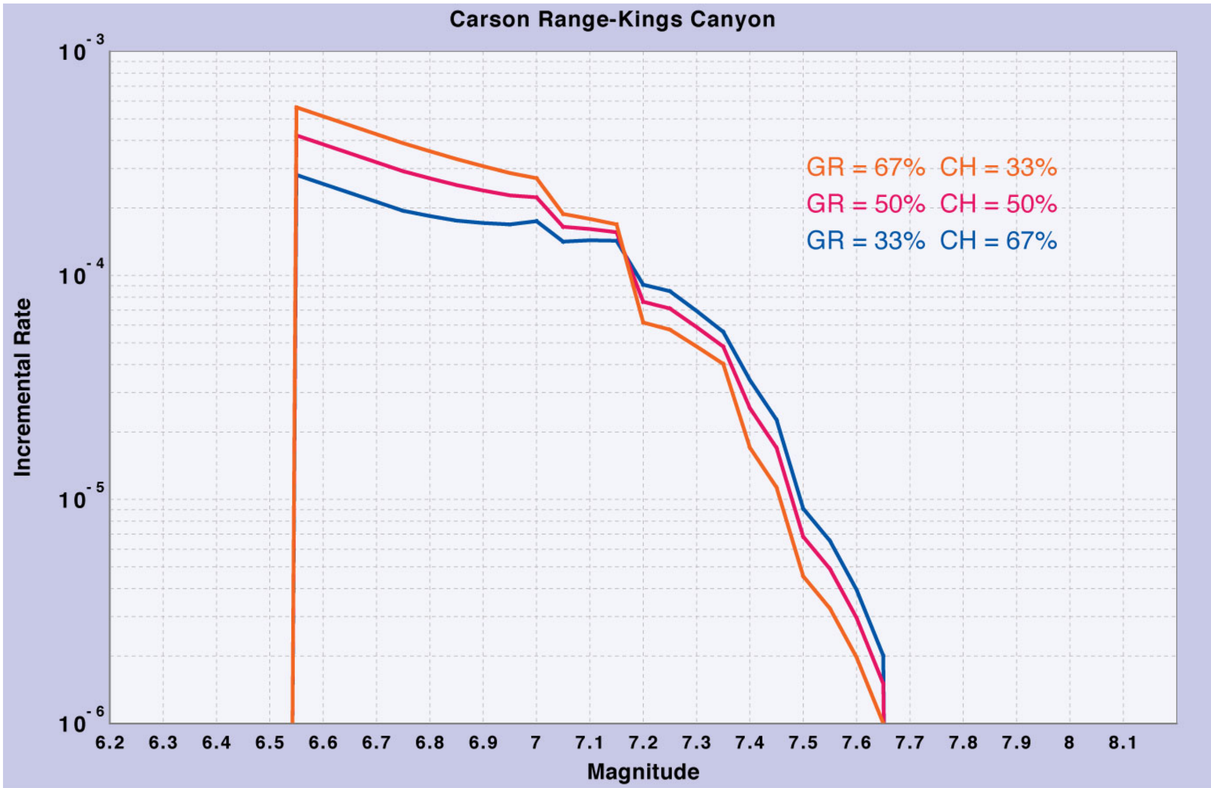
(courtesy P. Powers)



- Perturbations of +/- 20% – greater weight on characteristic branch generally reduces hazard
- Changes in hazard in vicinity of faults

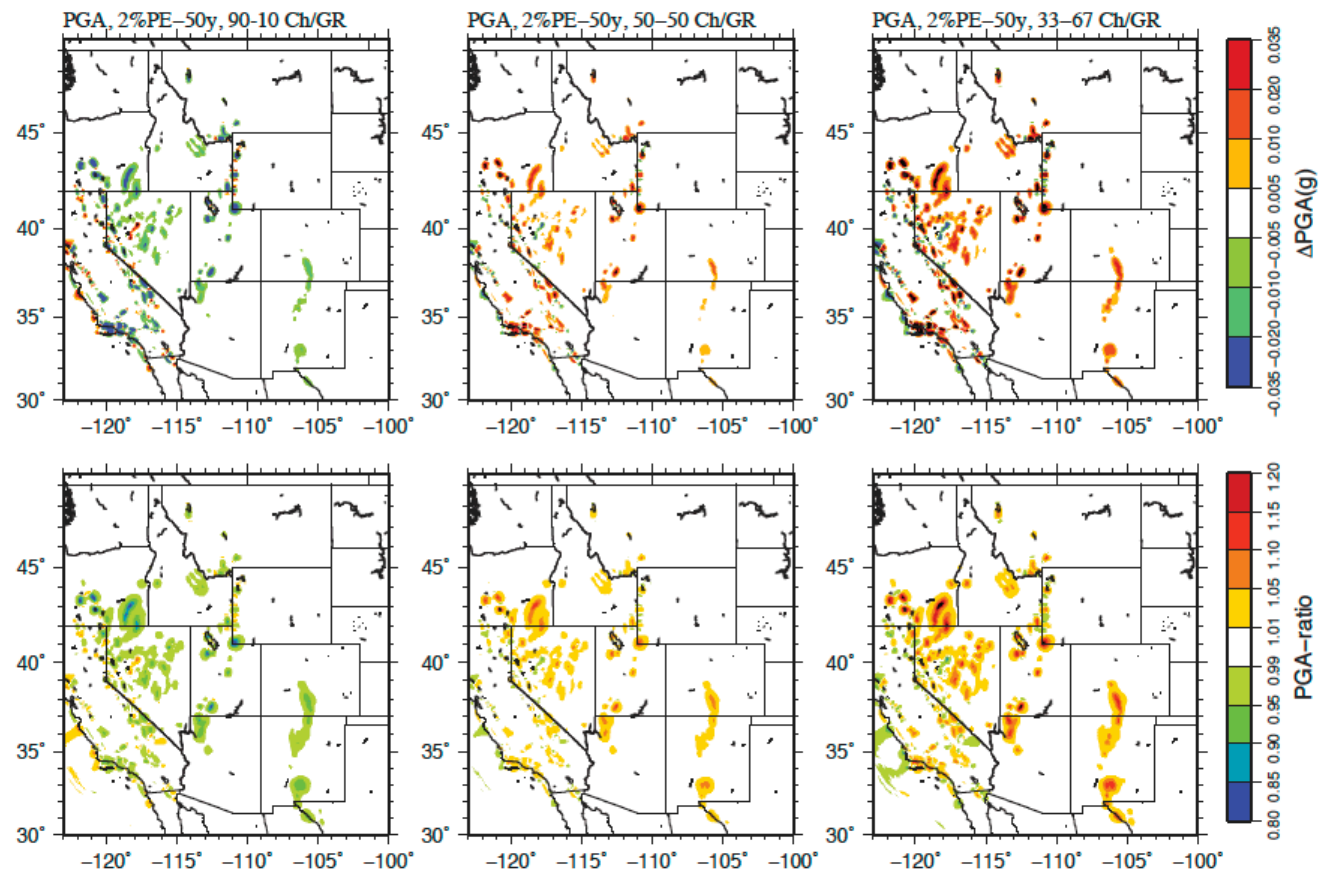
On-fault, M-f distributions

(courtesy P. Powers)



- Perturbations of +/- 20% – greater weight on characteristic branch generally reduces hazard
- Changes in hazard in vicinity of faults

Ch/GR weightings for fault sources



- Perturbations of less than 0.1g (+/- 20%) in vicinity of faults
- Greater weight on characteristic branch generally reduces hazard

Magnitude-frequency issues

- Is the current M-F distribution reasonable or are there compelling reasons to change the model?
- Is the current weighting reasonable? (2/3 full rupture, 1/3 partial source rupture models)

SMOOTHED SEISMICITY

Smoothed-gridded (background) seismicity: testing forecast models generated from fixed- and adaptive-radius smoothing methods

Morgan Moschetti

2014 NSHM update – IMW workshop

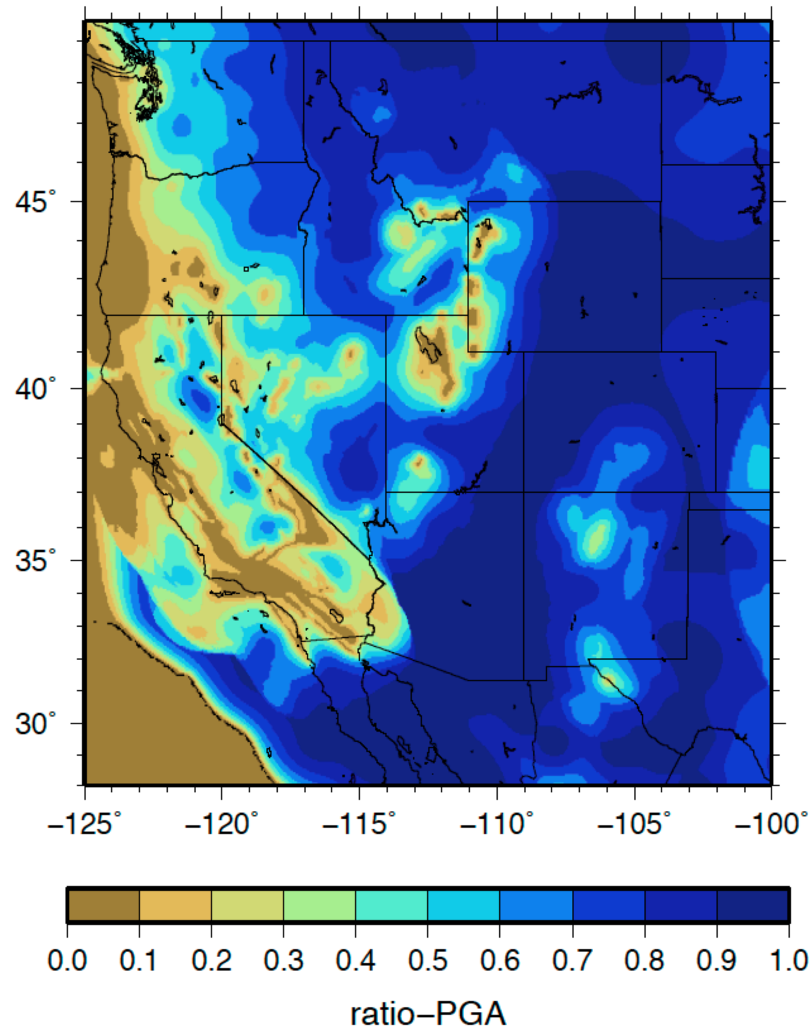
6/14/2012

What to expect

- Where does smoothed-gridded seismicity matter most?
- Smoothing methods – kernels/bandwidths
- Examples of smoothed seismicity rates – fixed- and adaptive-radii
- Compare predictive power of seismicity rates from spatial smoothing
- Recommendations and discussion about spatial smoothing methods

Contribution from smoothed-gridded seismicity to hazard?

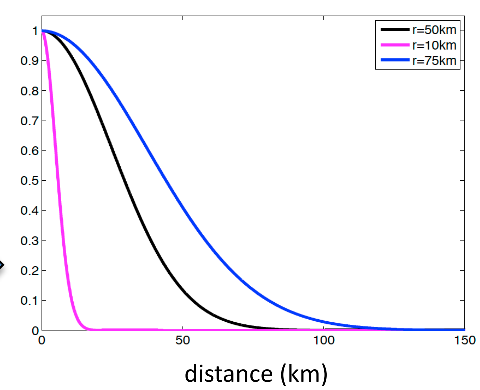
- Fraction of hazard (PGA, 2% PE 50yrs) from gridded seismicity ($(PGA_{NSHM}-PGA_{no\_sm\text{-}gr})/PGA_{NSHM}$)
- Fault sources dominate hazard near in much of CA, western NV, Cascadia, Wasatch.
- Gridded seismicity contributes more than 50% (up to 100%) to hazard across large areas of IMW.



Smoothed-gridded seismicity – smoothing methods

- Kernels – gaussian and power-law (isotropic) kernels
- Bandwidths (radius/d) – fixed- and adaptive-radius methods
- Magnitude threshold for smoothing (M4/5)

Fixed- and adaptive-radius methods, e.g., standard deviation of gaussian kernel



a power-law

$$K_d(\vec{r}) = \frac{C(d)}{\left(|\vec{r}|^2 + d^2\right)^{1.5}},$$

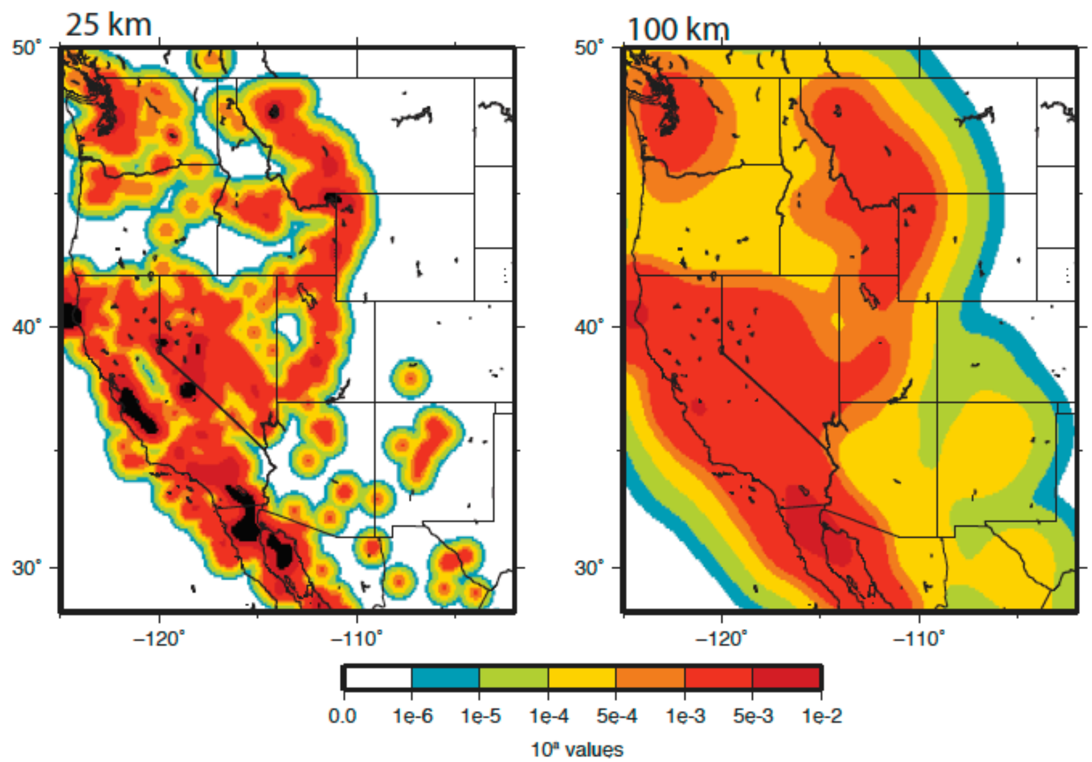
or a Gaussian

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

(Helmstetter et al, 2007)

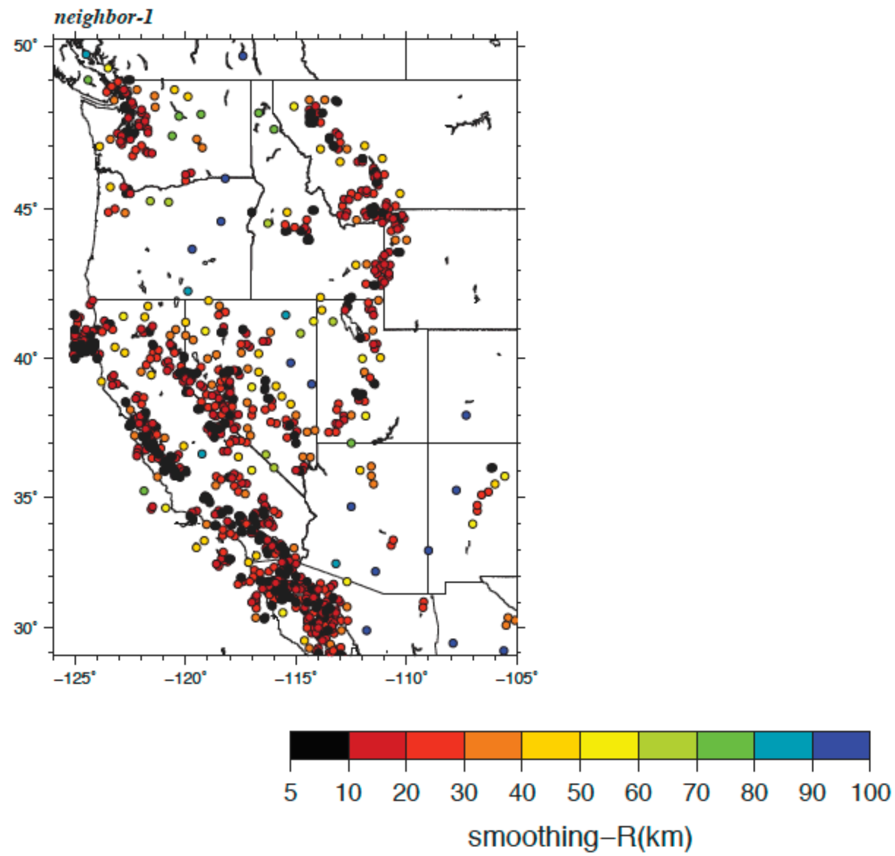
Smoothed-gridded seismicity – fixed-radius examples

- Smooth-gridded seismicity with fixed bandwidth/radius values ranging from 25-200 km
- Two smoothing kernels – gaussian and power-law
- Examples from gaussian kernels, d=25 km and d=100 km
- NSHM2008 smoothed with d~35 km.



Smoothed-gridded seismicity – adaptive-radius examples

- Helmstetter et al (2007) approach – smoothing bandwidth/radius given by distance to Nth nearest neighbor
- Regions of dense seismicity give smaller smoothing distances (standard deviations, correlation lengths)
- Examples for N=1, N=5



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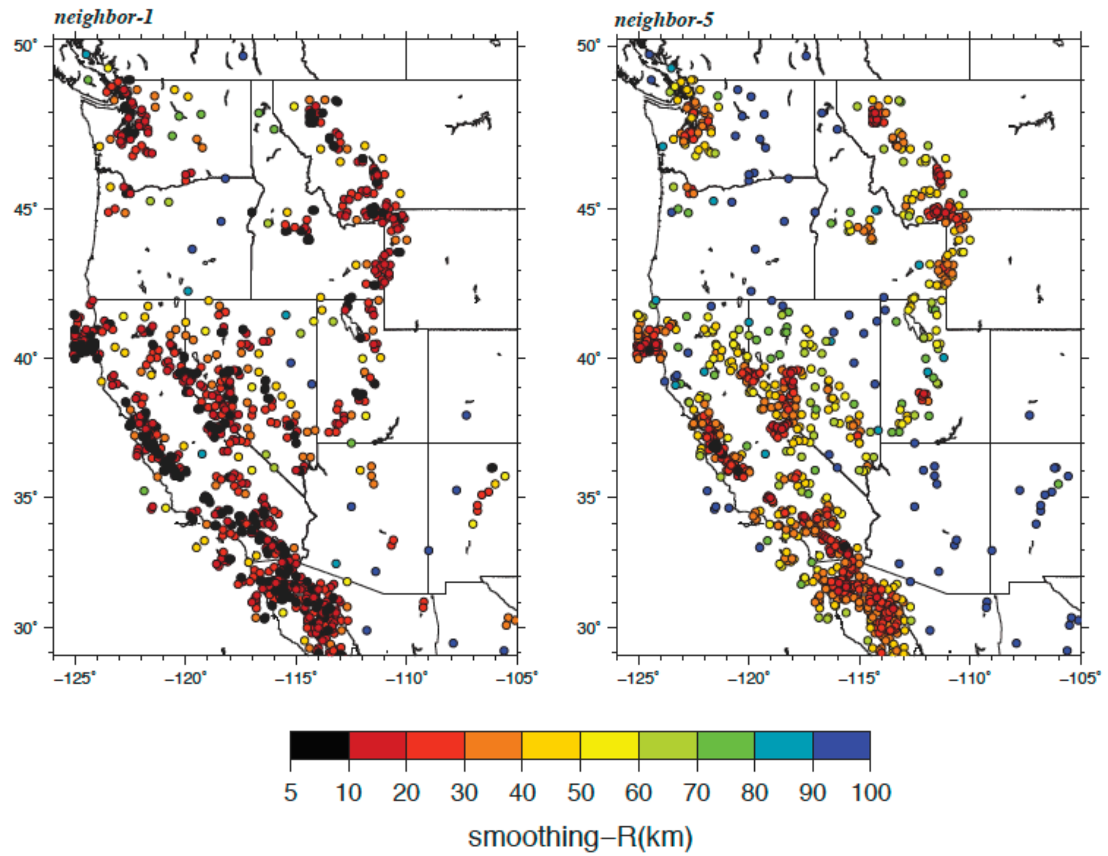

Smoothed-gridded seismicity – adaptive-radius examples, II

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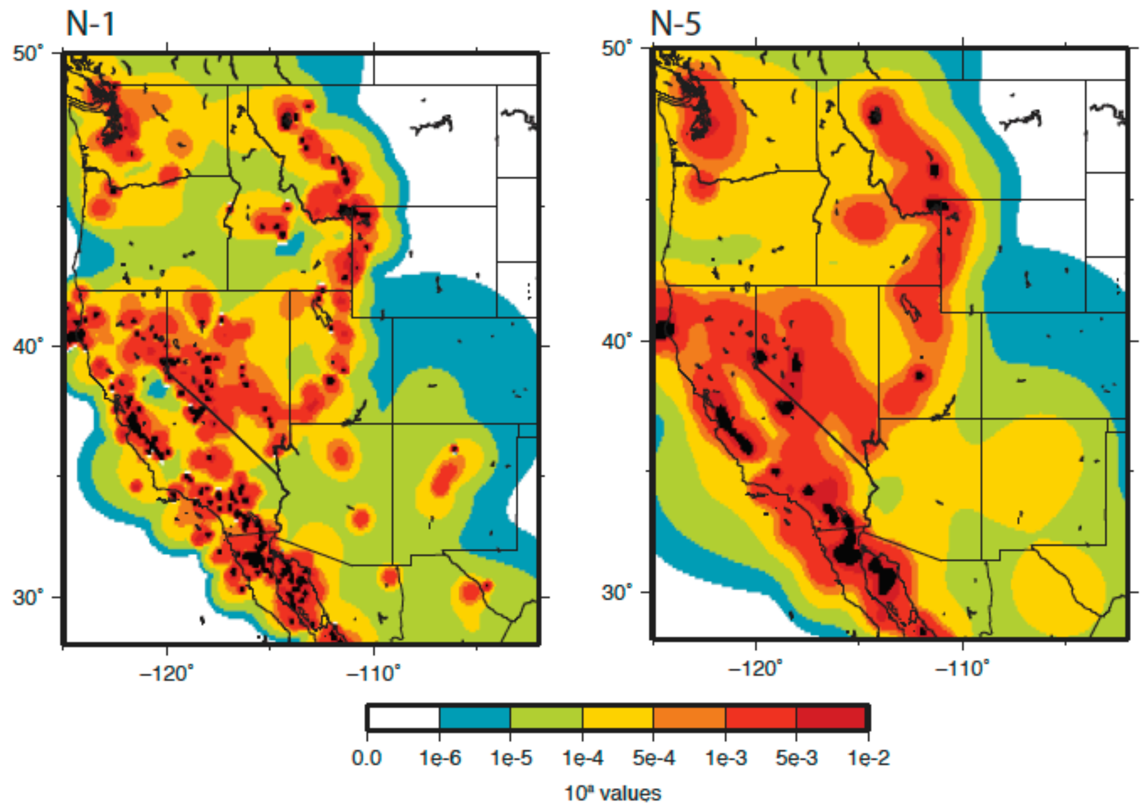
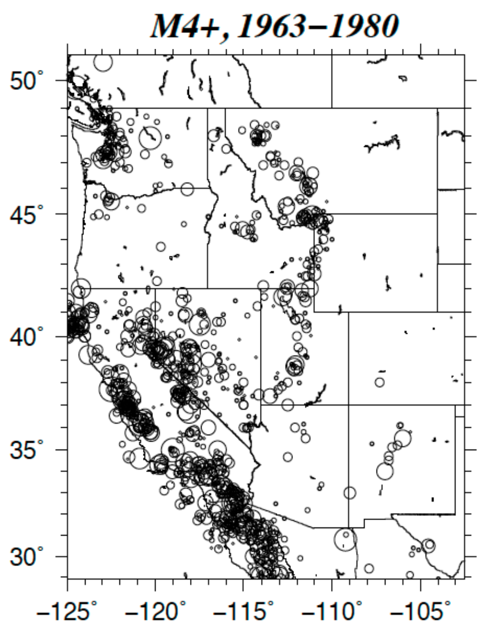
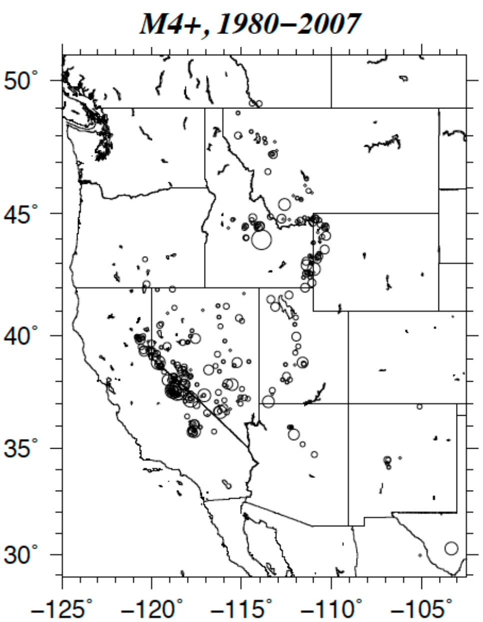


Testing smoothing methods – general approach –

- Calculate (smoothed) rates from early part of catalog.
- Compare these rates with rates observed in later part of catalog by assuming Poisson distribution for earthquake occurrence.
- Select smoothing method that maximizes information gain.
- Comparative method used in RELM/CSEP testing (Helmstetter et al., 2007; Werner et al., 2010; others)

Testing smoothing methods – forecast and testing catalogs, M4



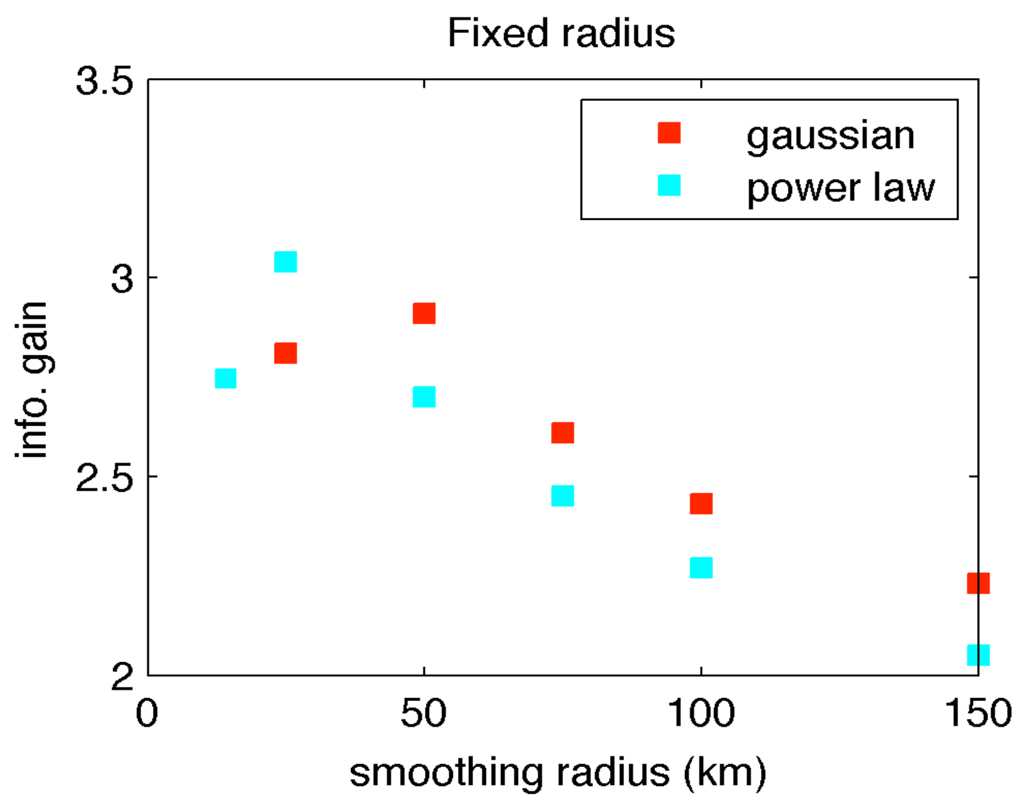


EQ summary (forecast/testing):

	Forecast	Testing
M4-5:	742	269
M5-6:	342	37
M6-7:	168	4

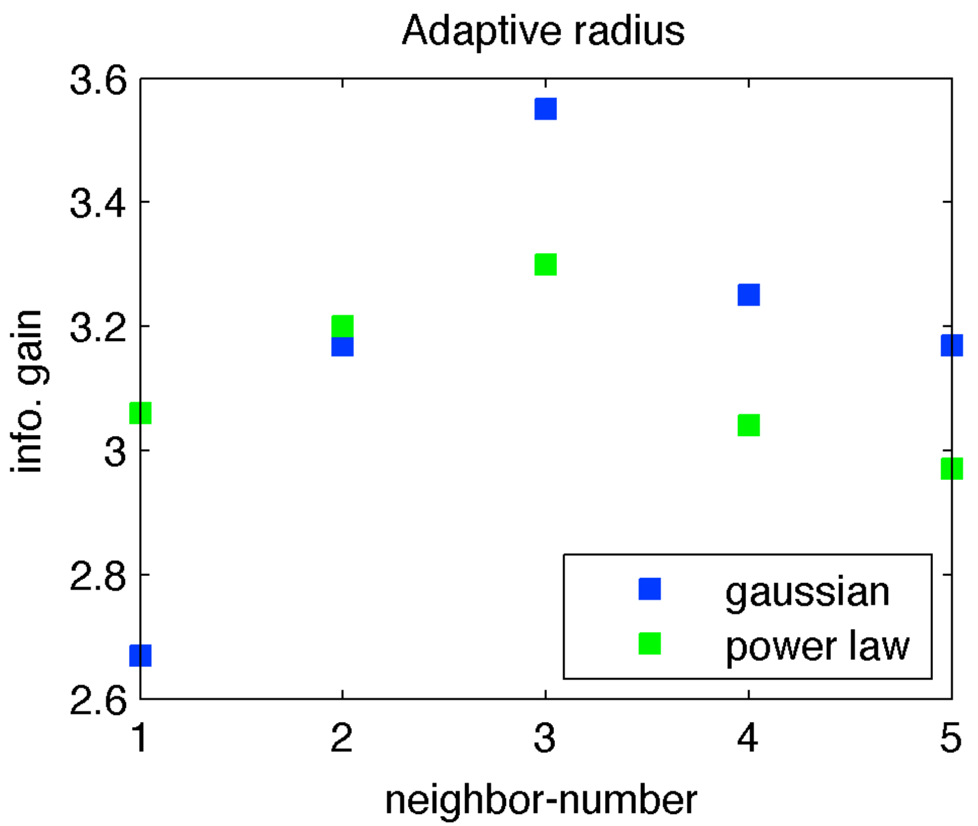
- Use 1980 as year for for separating catalogs because gives about 50% of M4 events in each sub-catalog (IMW).
- Forecast and testing catalogs for M4+/M5+

Information gain results, fixed radius



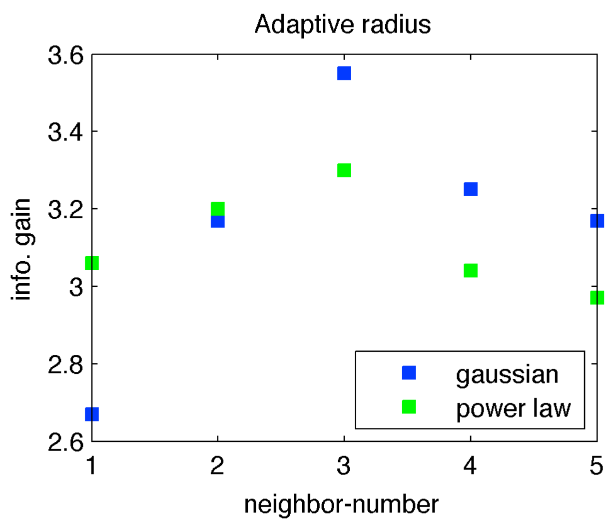
- For fixed-radius, gaussian kernel (NSHM08 smoothing approach), 25-50 km bandwidth gives best information gain.
- Power law kernel gives better information gain with smaller smoothing radius.

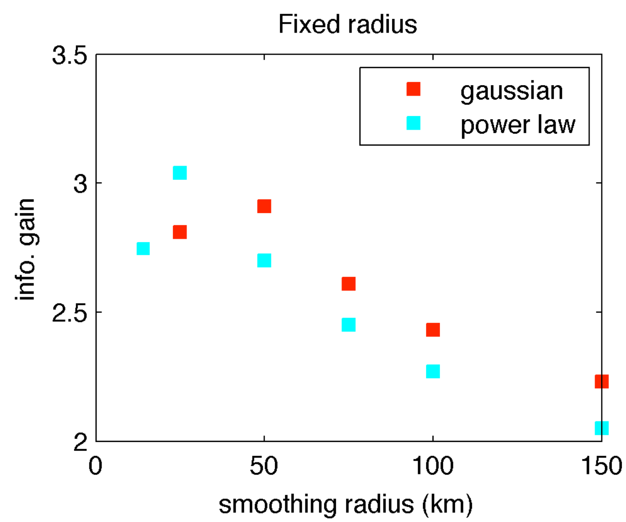
Information gain, adaptive radius



- Adaptive-radius method with gaussian kernel (N=3) gives highest information gain
- M4+ and M5+ earthquakes better predicted using M4+ catalog than M5+ catalog – better information gain from M5+ testing catalog

Information gain, all methods





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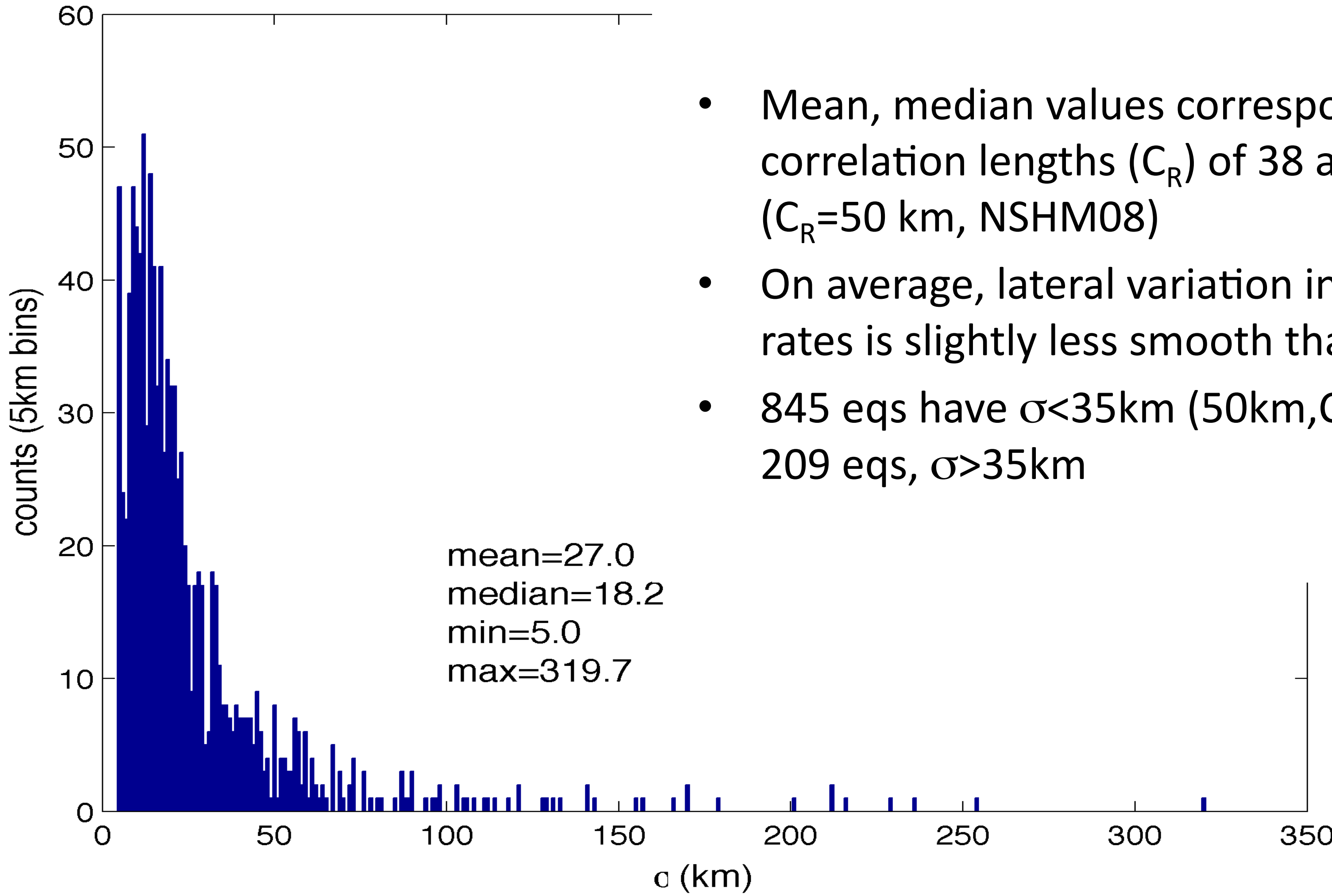
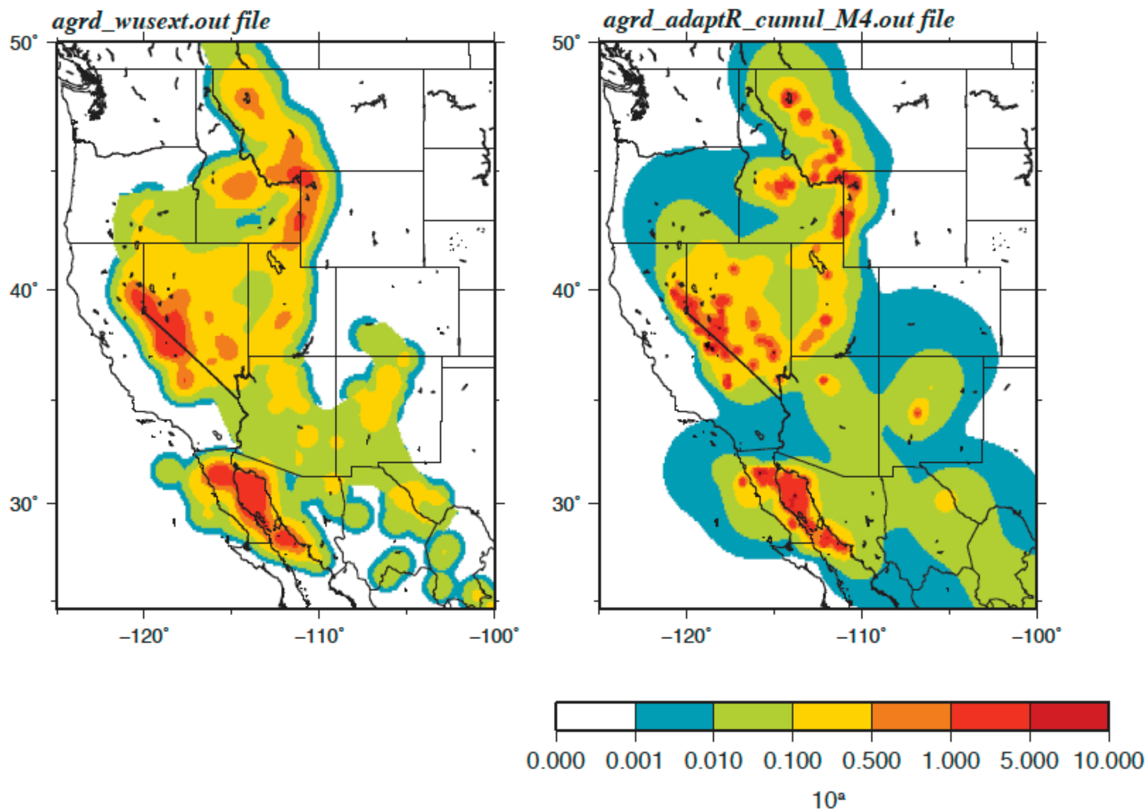
Adaptive smoothing: final smoothing bandwidths



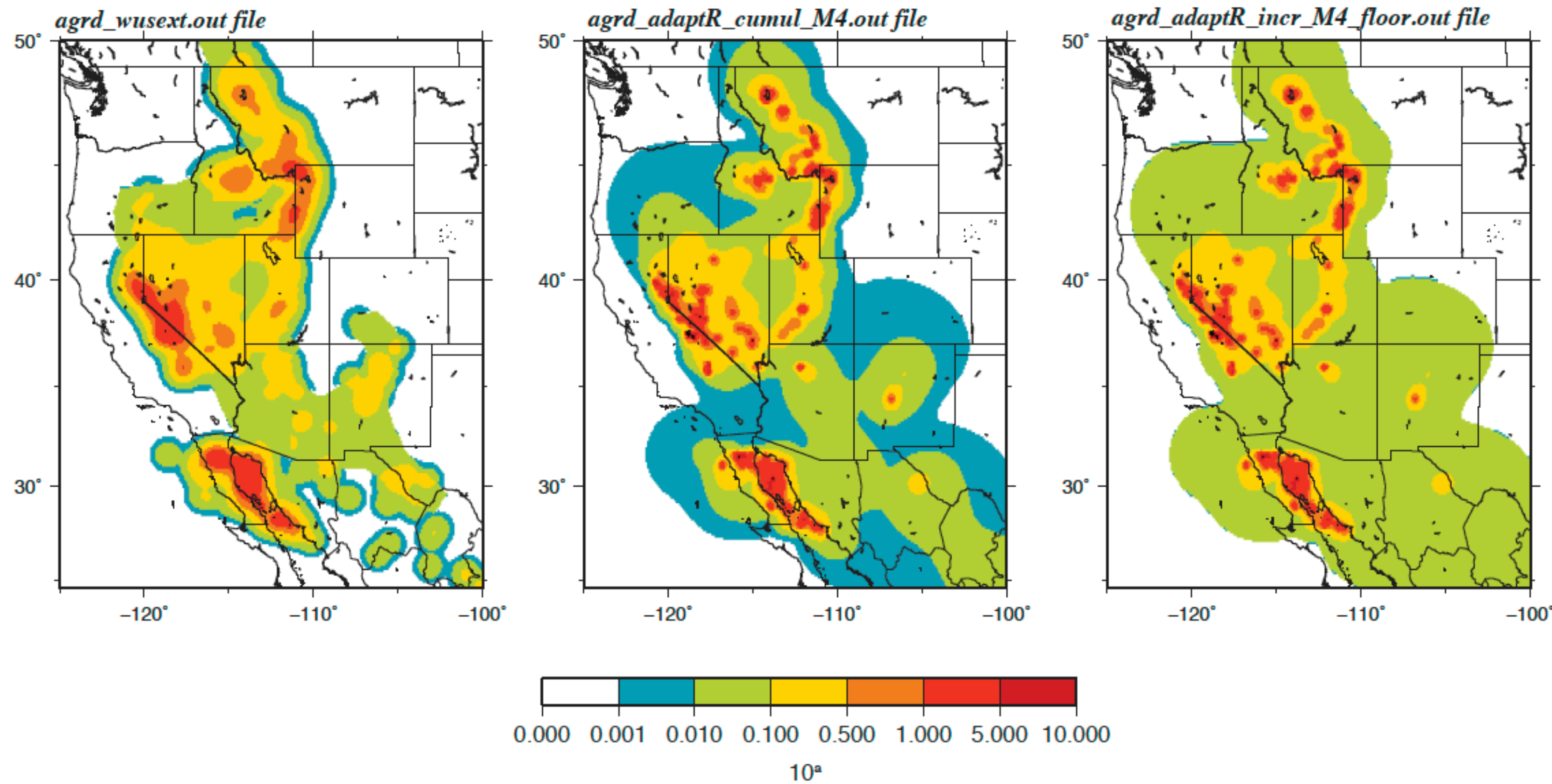
- Mean, median values correspond to correlation lengths (C_R) of 38 and 25 km (C_R=50 km, NSHM08)
- On average, lateral variation in seismicity rates is slightly less smooth than NSHM08
- 845 eqs have σ<35km (50km,C_R=50km); 209 eqs, σ>35km

Adaptive smoothing: hazard sensitivity tests, rates



- Calculate 10^a values from full catalog (IMW, Mexico regions) using adaptive-radius method with gaussian kernel (N=3)
- Run hazard calculations, compare 2% PE 50y PGA

Adaptive smoothing: hazard sensitivity tests, rates



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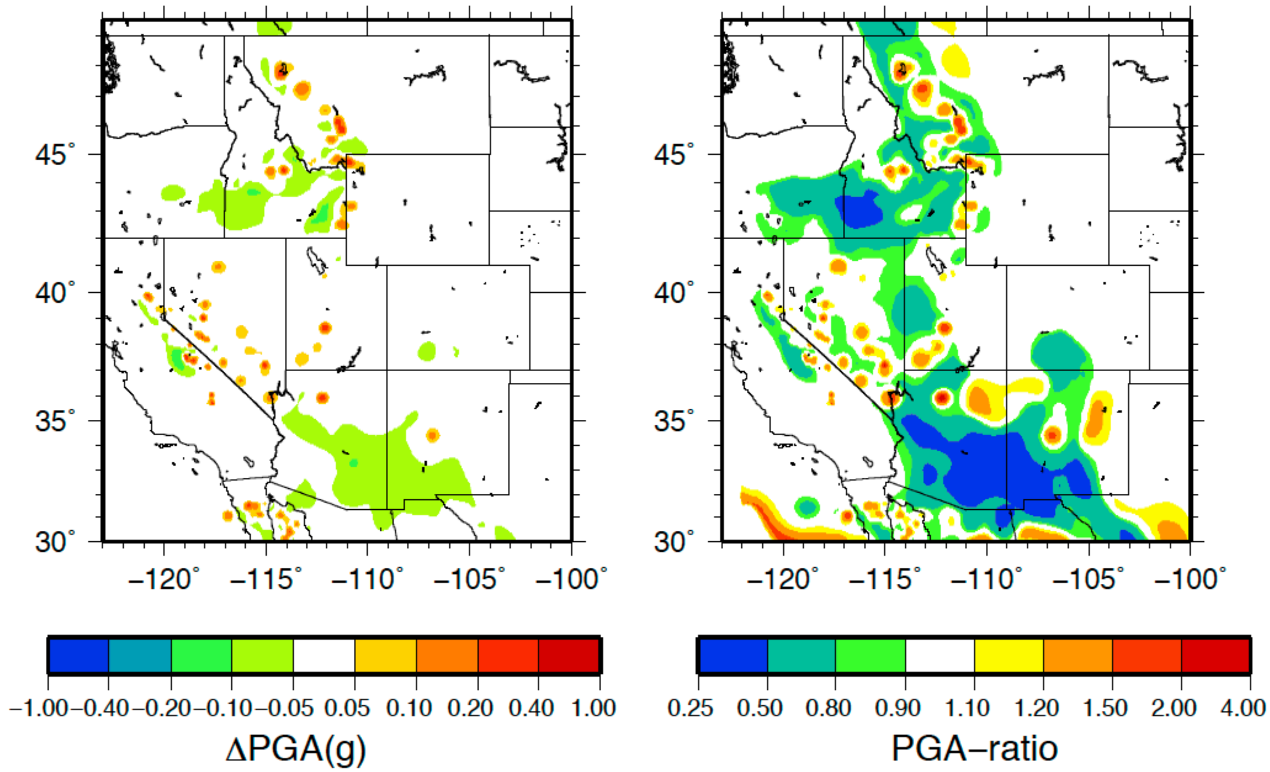
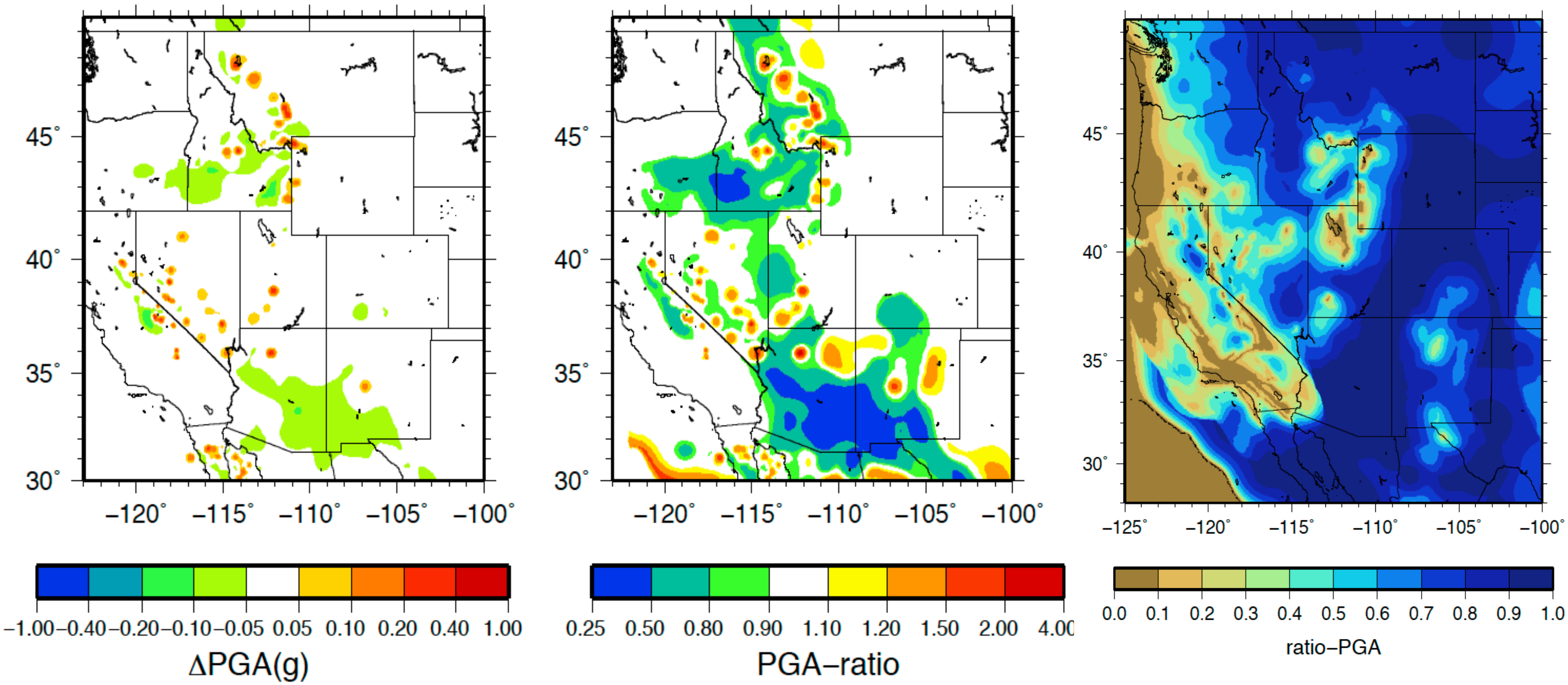
Hazard sensitivity tests



- Calculate 10^a values from full catalog (IMW, Mexico regions) using adaptive-radius method with gaussian kernel (N=3)
- Run hazard calculations, compare 2% PE 50y PGA
- Highly localized increases of 0.4g

Sensitivity tests in context gridded seismicity contributions to hazard



- Focus on changes to hazard where gridded seismicity makes large contribution to seismic hazard
- Increases: W-MT, SE-NV, N-AZ, central-NM
- Decreases: SW-ID, S-AZ

Adaptive smoothing: recommendations and discussion

- Recommend use of alternative, adaptive smoothing methods for calculating a-grids (seismicity rates) in 2014 NSHM update.
- Recommend partial weight on new smoothing methods and smoothing methods used in 2008 NSHMs
- Recommend further investigation of smoothing methods (including anisotropic kernels) with final selection of adaptive smoothing method based on information gain calculations.

ADDITIONAL DETAILS: SPATIAL SMOOTHING

Information gain: eq-number-normalized ratio of probabilities

$$p[\mu^*(i_x, i_y), n] = [\mu^*(i_x, i_y)]^n \frac{\exp[-\mu^*(i_x, i_y)]}{n!}$$

$$\mathrm{LL} = \sum_{i_x} \sum_{i_y} \log p[\mu^*(i_x, i_y), n],$$

$$G = \exp\left(\frac{\mathrm{LL} - \mathrm{LL}_{\mathrm{ref}}}{N_t}\right),$$

(Werner et al., 2010)

- Poisson distribution for earthquake occurrence probability
- Use uniform seismicity rate for reference model.
- Number-normalized rates (μ*) forces comparison of spatial distribution of seismicity.

Smoothed-gridded seismicity – catalogs

- WUS catalog: M4 since 1963; M5 since 1930; M6 since 1850.
- IMW region defined by combining regional zones of WUS from NSHM08
- Earthquakes from WUS catalog used for smoothed-gridded seismicity; IMW sub-catalog used for testing smoothing methods