From earthquake catalogs to hazard: an overview of the seismicity-derived component of the hazard calculation AND questions and discussion about earthquake catalogs for 2014 NSHM update

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USGS - Golden, CO
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USGS hazard model: Western US

**Shallow Seismicity (d < 35 km)**
1) Declustered catalog $M_W \geq 4$
2) Completeness:
   - Coastal CA: 1933, 1900, 1850
   - Other WUS: 1963, 1930, 1850
3) $b = 0.80$
4) $10^a$ grids (spatial distribution seismicity rates):
   - Coastal CA
   - Extensional WUS
   - Non-extensional WUS
   Adjust for mag uncertainty
   Background “floor” (five zones)
5) 50-km smoothing (+ anisotropic in CA)
   $M_{\text{max}} = 7.0$ mostly, < 7.0 near faults

**Ground motion**
- Crustal: NGA (out to 200 km)
- Subduction: various
- Site condition $V_{s30} = 760\text{m/s}$

**Faults**
- IMW: ~ 300 crustal faults
- PNW: crustal + megathrust
- CA: UCERF/WGCEP
Distribution for $M_{\text{char}} \geq 6.5$
Distribution for dip: 40, 50, 60 deg
67% char + 33% GR for CA,IMW

**Deep Seismicity**
- Geodetic Sources
USGS hazard model: Western US

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Deep Seismicity
Geodetic Sources
2008 WUS declustered catalog

Source catalogs in preference order:

Pancha et al (2006): ~200 eqks, $M_w$ 4.8+, 1868-1999 ($M_w$ estimates; recommended @ 2006 wksp)

CGS (Felzer&Cao,2007): ~2100 eqks, $M_w$ & $m_L$ 4+, 1769-2006 (preferred over Pancha in UCERF zone)


Stover, Reagor & Algermissen: ~150 eqks, mag 4+, 1917-1985 (includes many smaller eqks than Stover & Coffman)

PDE: ~550 eqks, mag 4+, 1961-2006 (used for updates)

DNAG: ~150 eqks, mag 4+, 1877-1981

* (we are considering adding the Herrmann Mw catalog)
WUS catalog processing & “agrid”

1) convert magnitude to $M_w$ (as needed; use published rules for active-tectonic regions)
2) concatenate, sort, remove duplicates
3) decluster (G&K) and delete non-tectonic eqks
4) analyze: completeness & $b$
5) Calculate “agrid”
   - adjust for mag uncertainty
   - smooth (gaussian, 50 km correlation length)
   - include background floor
WUS declustered catalog $M \geq 4$, 1850-2011 (exclude eqks in Coastal CA zone, offshore northern CA, Gulf of CA)
For comparison: IMW test zone
WUS declustered catalog M≥4, 1850-2011

$b = 0.801$
Process for calculating a grids \((10^a\) values\):

- Calculate total number of M4+ earthquakes in 0.1-by-0.1 degree grid cells.
- Calculate cumulative seismicity rate \((10^A)\).
Process for calculating agrids (10^a values)

- Calculate total number of M4+ earthquakes in 0.1-by-0.1 degree grid cells
- Calculate cumulative seismicity rate (10^A)
- Modify rates to account for completeness levels (Weichert method)
- Convert from cumulative to incremental seismicity (10^a)
- Spatially smooth 10^a values
Process for calculating agrids (10^a values)

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**10^a values represent annual rate of M0 earthquake for each grid cell **
Laterally-variable seismicity rates (agrids) for the smoothed-gridded seismic hazard calculation

- Background model: Use catalog to calculate \( 10^a \) for GR distribution.
Issues with earthquake catalogs

✓ Catalog mix
  - Should NSHM 2014 update include more local and regional catalogs? (local knowledge vs. loss of regional/national magnitude consistency)
    - Role of ANSS/PDE catalog?
    - $M_W$ for all moderate eqks (Herrmann)?
  - Utah earthquake catalog (Arabasz)
    - Treatment of Pancha et al. catalog

✓ Non-tectonic and anomalous eqks: We currently delete some Utah coal mining events. Are there more we should know about (at the M4 level)? Are there any issues with induced seismicity? How to model?

✓ Regionalize completeness & $b$-value analysis?

✓ Corrections for mag uncertainty?

✓ Implementation of background “floor” – 1/3 weighting on adaptive seismicity rate floor value?
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Identification of non-tectonic earthquakes

- Special studies & published listings. Examples:
  - Mining-related seismicity (e.g., Colorado; Kirkham & Rogers, ColoradoGS Bulletin, 2000)
  - Fluid injection at Paradox Valley, CO (Ake)

- Ad hoc inquiries about specific events

- Explosion flag in PDE listing
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CA: uncertainty for (mostly) $m_L$ (from K Felzer’s work)

<table>
<thead>
<tr>
<th>Time Period</th>
<th>$\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972-present</td>
<td>~ 0.1</td>
</tr>
<tr>
<td>1932-1971</td>
<td>~ 0.2</td>
</tr>
<tr>
<td>1850-1931</td>
<td>~ 0.3</td>
</tr>
</tbody>
</table>

CEUS: uncertainty for “observed” $M_w$

| Time Period     | $\sigma \left[ M | M_{obs} \right]$ |
|-----------------|-------------------------------------|
| 1920–1959       | 0.30                                |
| 1960–1975       | 0.15                                |
| 1975–1984       | 0.125                               |
| 1985–present    | 0.10                                |

From CEUS-SSC (Chapter 3), citing Johnston (1996) and Harvard $M_w$ catalog
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Implementation of background floor for seismicity rates

- Floor seismicity rate calculated from M4 events within tectonic regions
- Adaptive (1/3) weighting to floor value applied where smoothed seismicity rates fall below floor value