Testing ~~Ground-motion Models and~~ Seismic Hazard Maps

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working together to assess risk

GEM

GLOBAL EARTHQUAKE MODEL

In the Literature ...

Study	Region	Data	Grouping	Counting
McGuire, 1979; McGuire and Barnhard, 1981	China	Macroseismic intensity	Aggregated	Binary
Ward, 1995	California	Synthetic	Aggregated	Binary
Ordaz and Reyes, 1999	Mexico City	Instrumental	Site-specific	Total
Stirling and Petersen, 2006	New Zealand and US	Macroseismic intensity	Site-specific	Total
Albarello and D'Amico, 2008	Italy	Instrumental	Aggregated	Binary
Fujiwara et al., 2009	Japan	Instrumental	Aggregated	Binary
Stirling and Gerstenberger, 2010	New Zealand	Instrumental	Site-specific & aggregated	Total
Mezcua et al., 2013	Spain	Macroseismic intensity	Site-specific	Total

Data

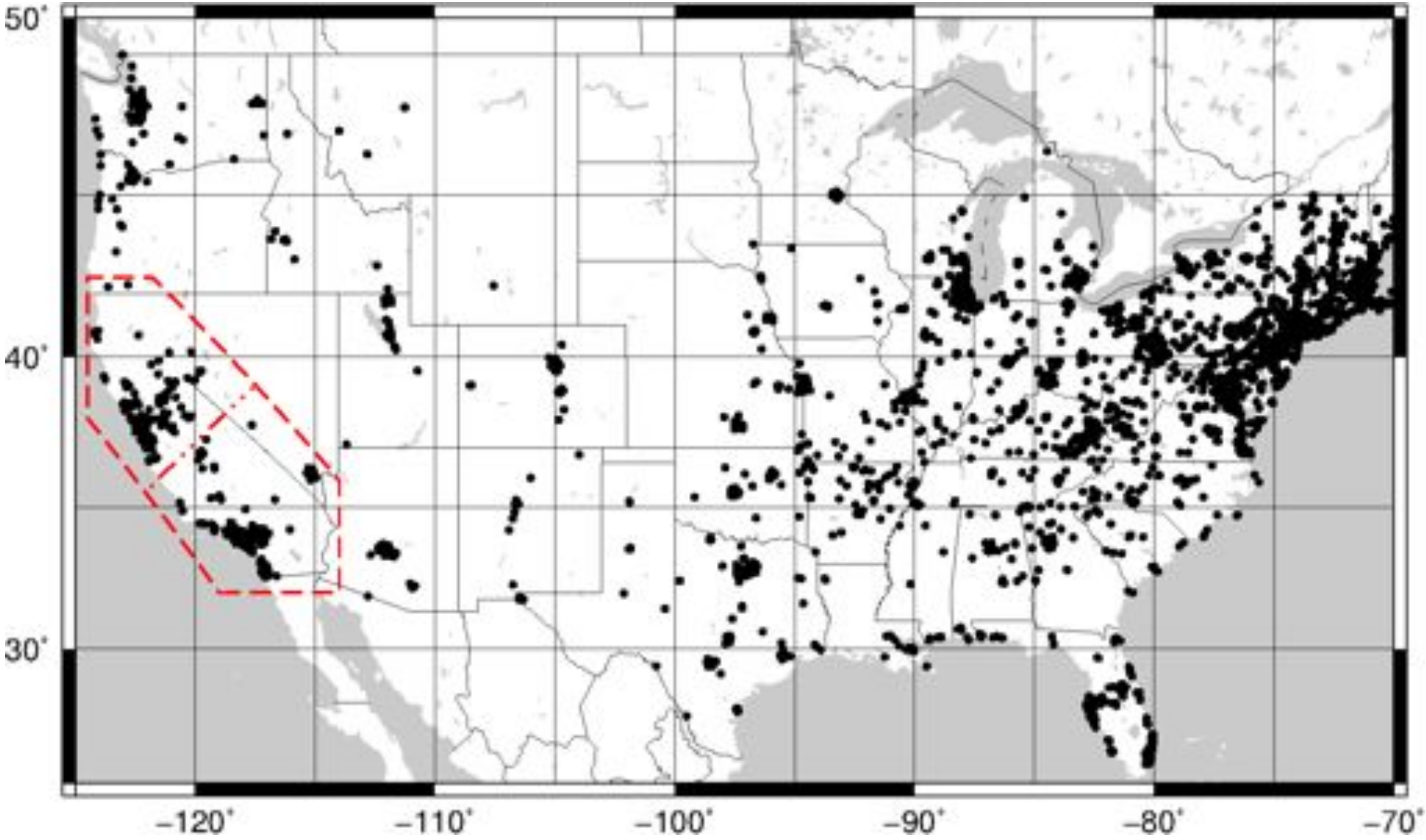
- Macroseismic intensity vs instrumental
  - Data quantity vs conversion
- Modern vs historical
  - Consistency
  - Prospective data

Data (this study)

- DYFI (intensity)
- ShakeMap (synthetic)
- ShakeMap stations (instrumental)

- 2000-2013

Data	What	Quantity	Observational
DYFI (Did You Feel It?)	Macroseismic intensity	A lot	Yes, but conversion
ShakeMap	Modelled ground-motion	Quite many	Somewhat
ShakeMap stations	Instrumental ground-motion	Note quite many (CA only)	Yes



DYFI 2000-2013 ZIP30

	Number of			
Region*	**Data†**	**Eqs**	**ZIPs‡**	**Stat–Yr§**
DYFI				
CA	51472	6456	755	9152
SCA	34586	3811	482	5806
NCA	16886	3170	273	3345
EUS	8850	791	2044	12046
ShakeMap				
CA	9859	1423	755	8840
SCA	7899	1012	482	6225
NCA	1960	459	273	2615
EUS	2926	136	2044	8221
Instrumental				
CA	4375	2720	345	4231
SCA	3418	2533	217	2740
NCA	957	1289	128	1491

Framework

Study	Region	Data	Grouping	Counting
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Site-specific vs aggregated

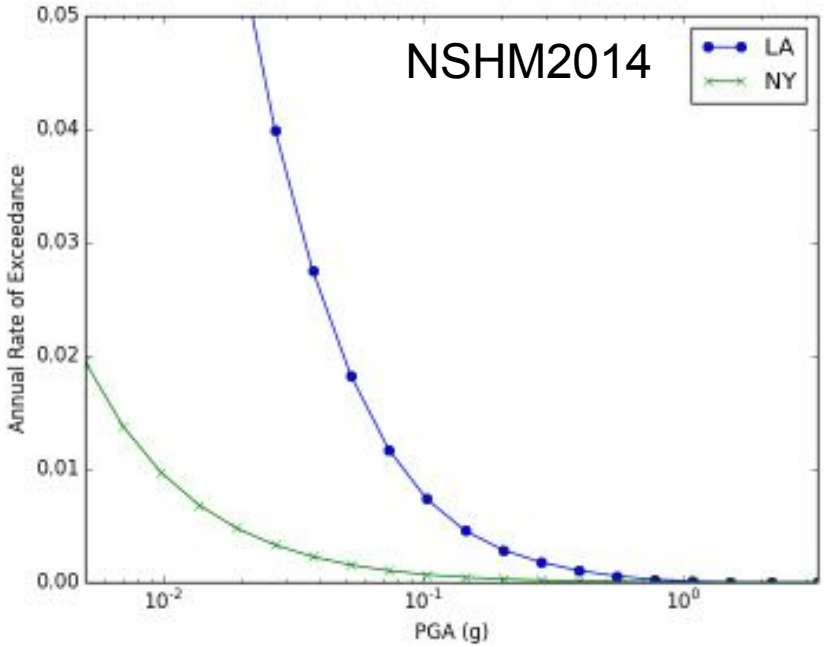
- Idea: site-specific
  - Rule of thumb (Mak *et al.*, 2014, SRL): power >90% if:
    - Data collection period = Return period
    - Actual occurrence rate > 7x modelled rate
- Practical: aggregated

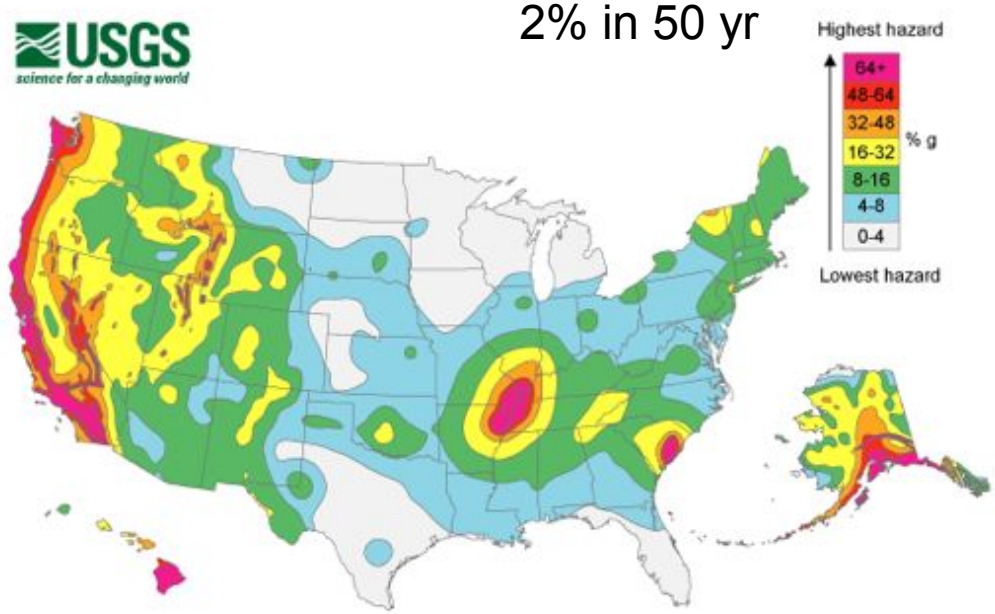
Site	Historical $T^{\S}$ (yr)	Historical $N^{\S}$ (T yr)	Model[F] (N/yr)	Model $N^{\#}$ (T yr)	P_upper[**]	Rejected at >0.975	P_lower[††]	Rejected at <0.025
Christchurch	15	0	1.93E−02	0.28950	0	N	0.7486	N
Dunedin	36	1	0.0036	0.1296	0.8781	N	0.9922	N
Gisborne	44	5	0.0581	2.5564	0.883	N	0.9539	N
Greymouth	42	1	0.0512	2.1504	0.1165	N	0.3669	N
Hamilton	25	2	0.0179	0.4475	0.9246	N	0.9891	N
Hanmer	20	3	0.0710	1.42	0.8286	N	0.944	N
Invercargill	15	0	5.40E−03	0.08100	0	N	0.9222	N
Kaikoura	10	0	3.50E−02	0.35000	0	N	0.7047	N
Masterton	20	0	4.90E−02	0.98000	0	N	0.3753	N
Napier	37	5	0.0720	2.664	0.8688	N	0.9464	N
Nelson	15	1	0.0720	1.08	0.3396	N	0.7064	N
Oamaru	18	0	4.80E−03	0.08640	0	N	0.9172	N
Omarama	44	1	0.0225	0.99	0.3716	N	0.7394	N
Palmerston Nth	36	1	5.80E−02	2.08800	0.1239	N	0.3827	N
New Plymouth	27	2	0.0166	0.4482	0.9246	N	0.9891	N
Queenstown	22	4	0.0380	0.836	0.9893	Y	0.9983	N
Taihape	41	2	0.0590	2.419	0.3041	N	0.5645	N
Taumarunui	7	0	1.70E−02	0.11900	0	N	0.8878	N
Taupo	44	1	0.0250	1.1	0.3329	N	0.699	N
Timaru	6	0	2.60E−03	0.01560	0	N	0.9845	N
Wanganui	33	2	0.0440	1.452	0.5747	N	0.8213	N
Wellington	37	4	0.0450	1.665	0.9112	N	0.9723	N
Westport	42	9	0.0790	3.318	0.9928	Y	0.9977	N
Whakatane	15	0	7.90E−02	1.18500	0	N	0.3057	N
Total[‡‡]		44		27.87	0.5	Y	0.67	N

Stirling and Gerstenberger (2010)

Counting

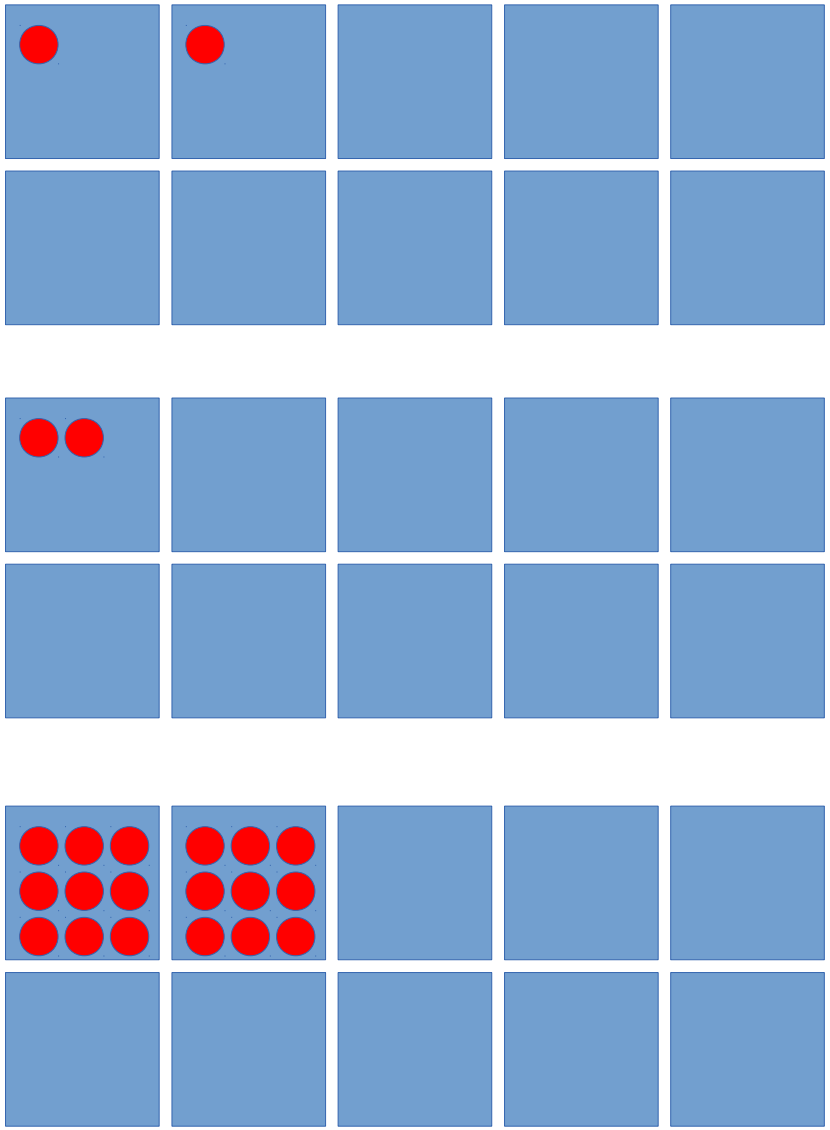
- Total: how many ground-motions that has exceeded a certain level.
- Binary: how many locations that has experienced at least one ground-motion of a certain level.





Counting (example)

- 10 locations, each has an annual rate of 0.2
- Total count: expected total ground-motions: 2
- Binary count: expected total locations with exceedance: 2 (~1.81)



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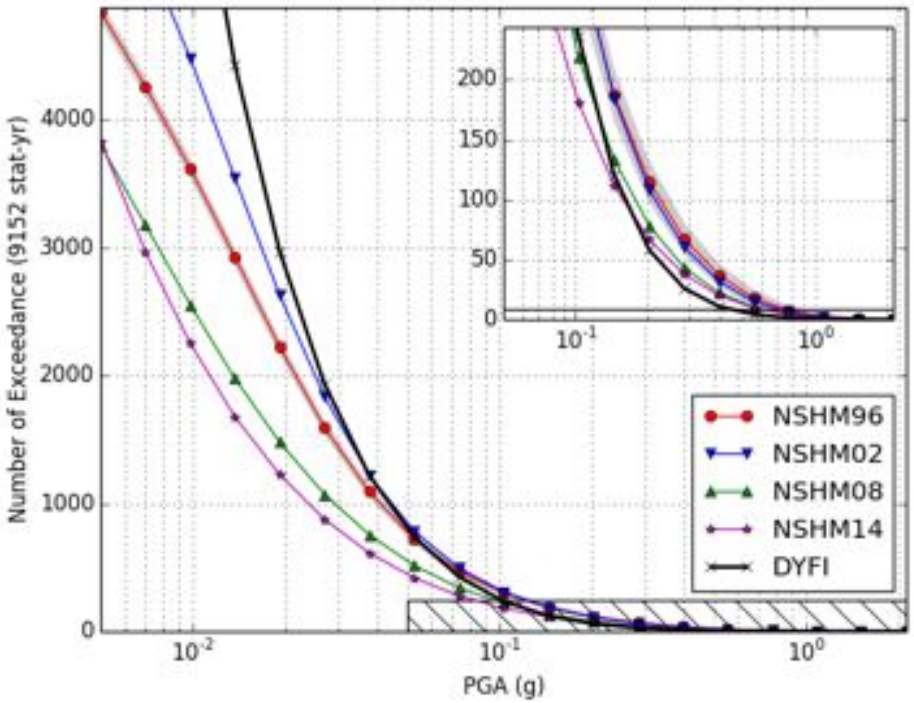
This study	CA & EUS	DYFI, ShakeMap, instrumental	Aggregated	Total & Binary

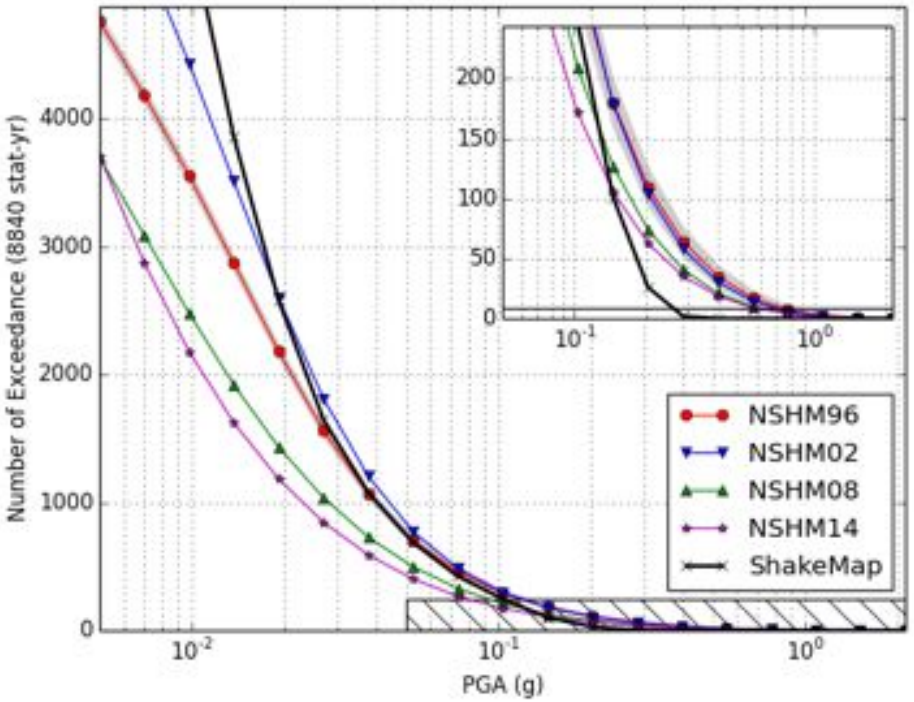
Outline of Results

- Result for CA
  - Dependent observations
  - Divide into spatial subregions
  - Divide by hazard level
- Result CUS

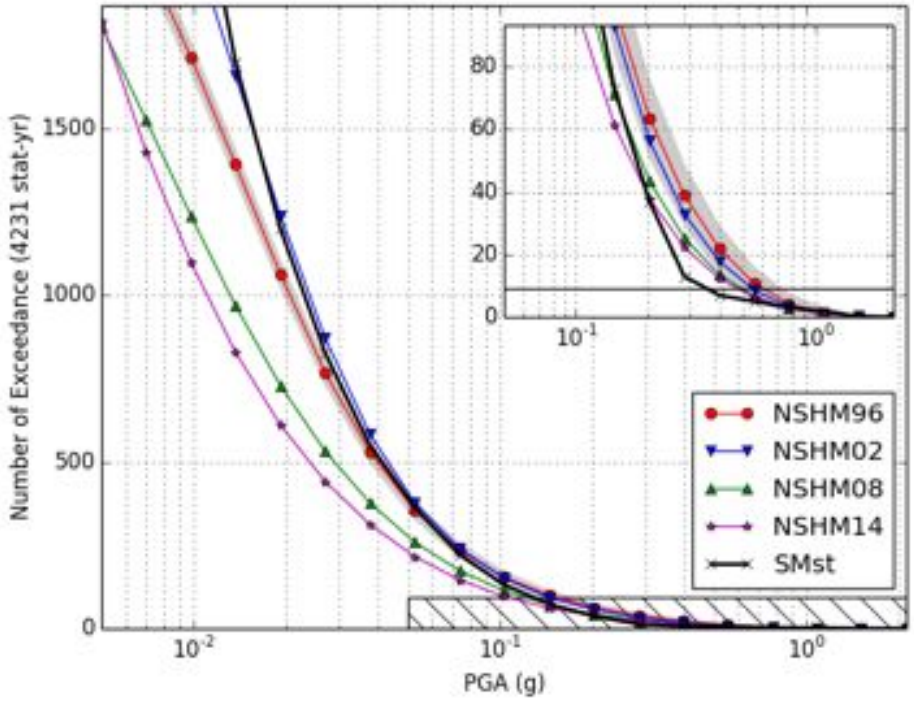
DYFI



ShakeMap

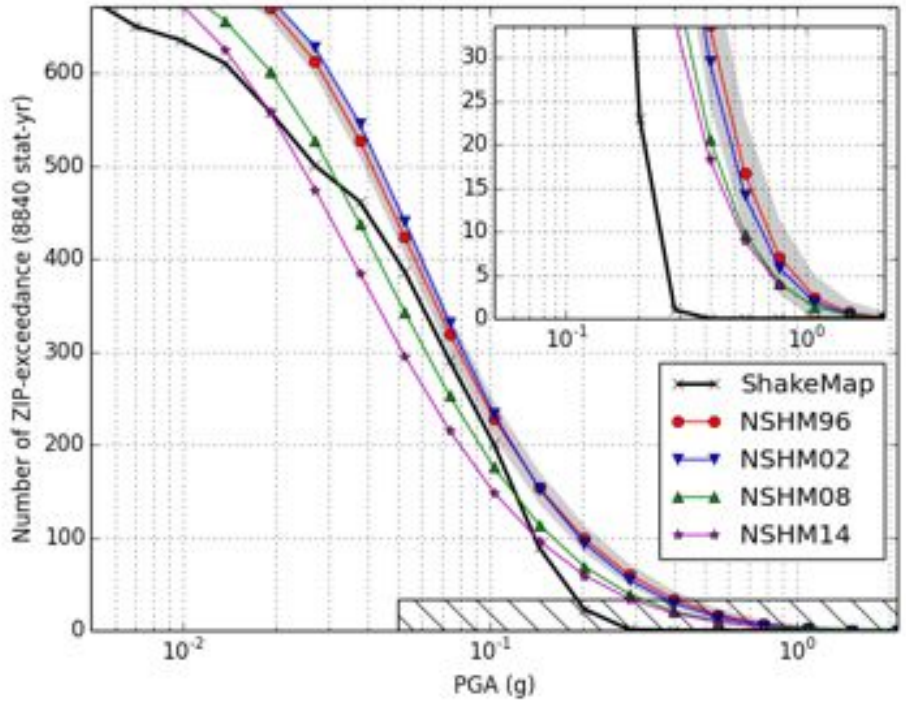


Instrumental

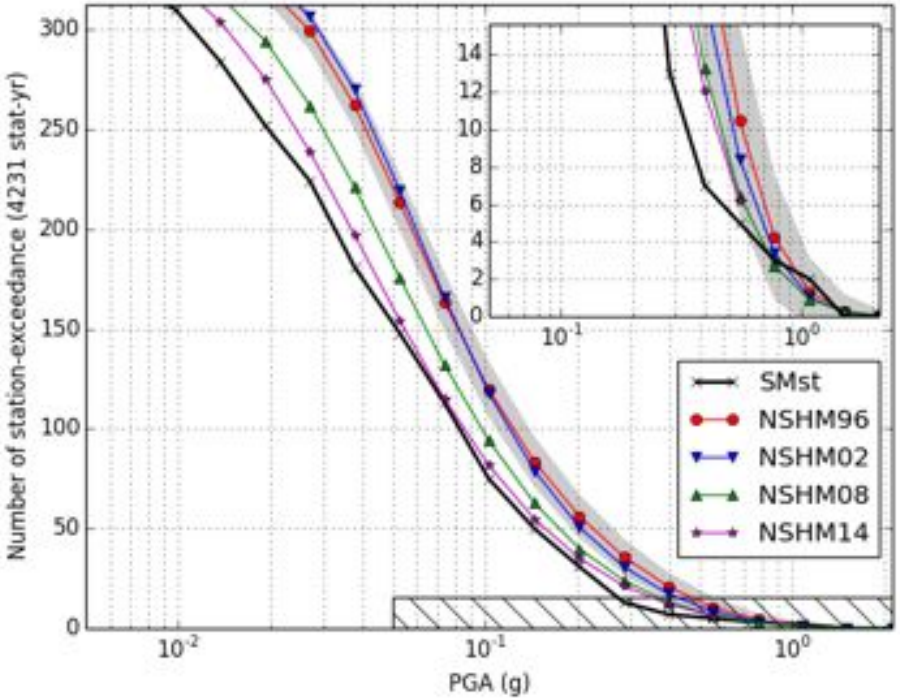


Region: California
Counting: Total
755 ZIPs
345 SMsts

ShakeMap



Instrumental



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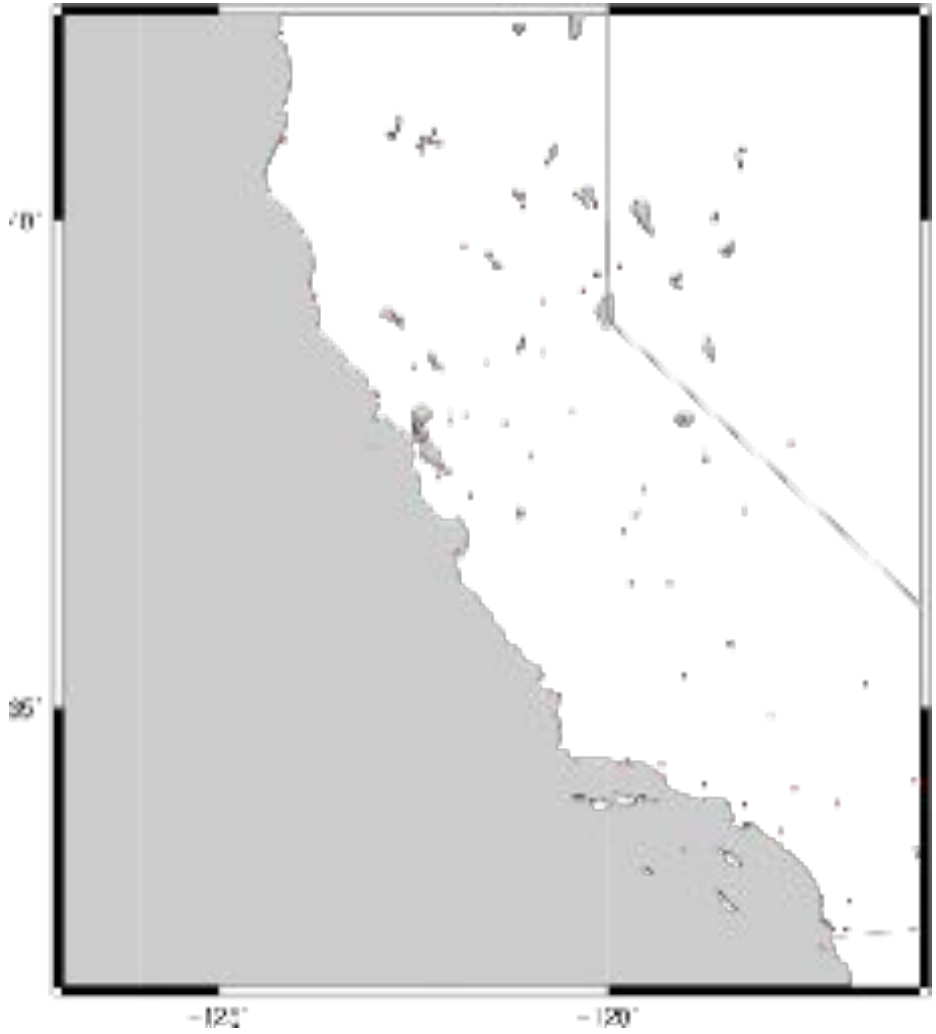
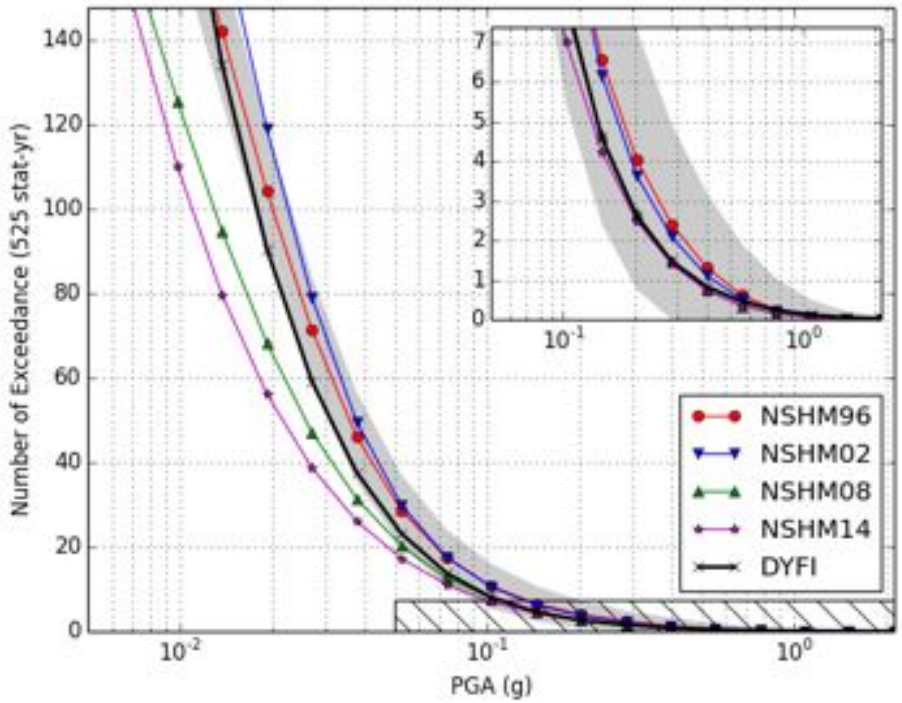
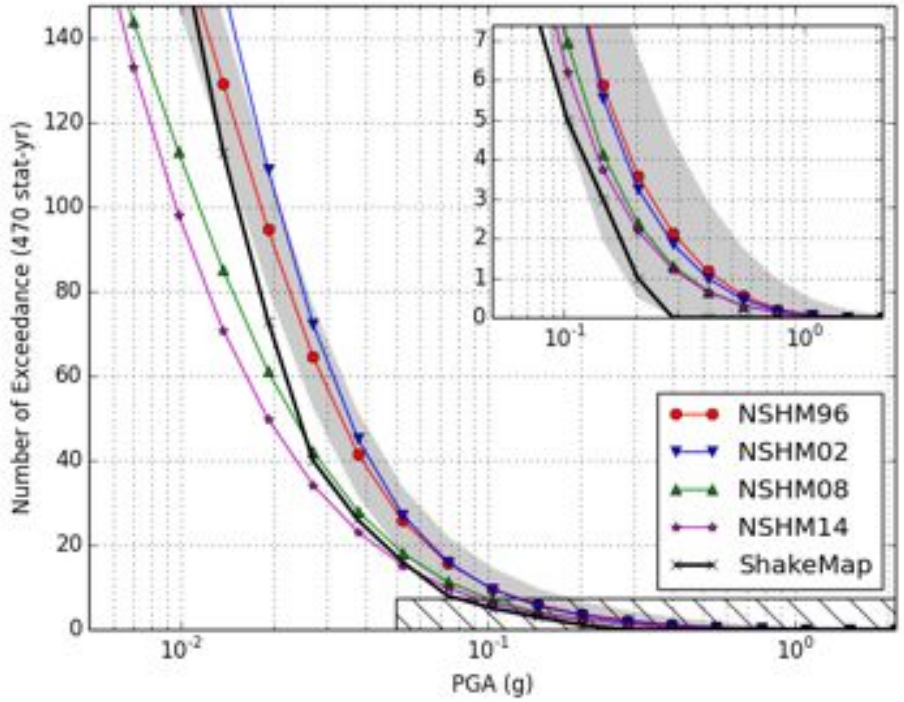
Dependent Observations



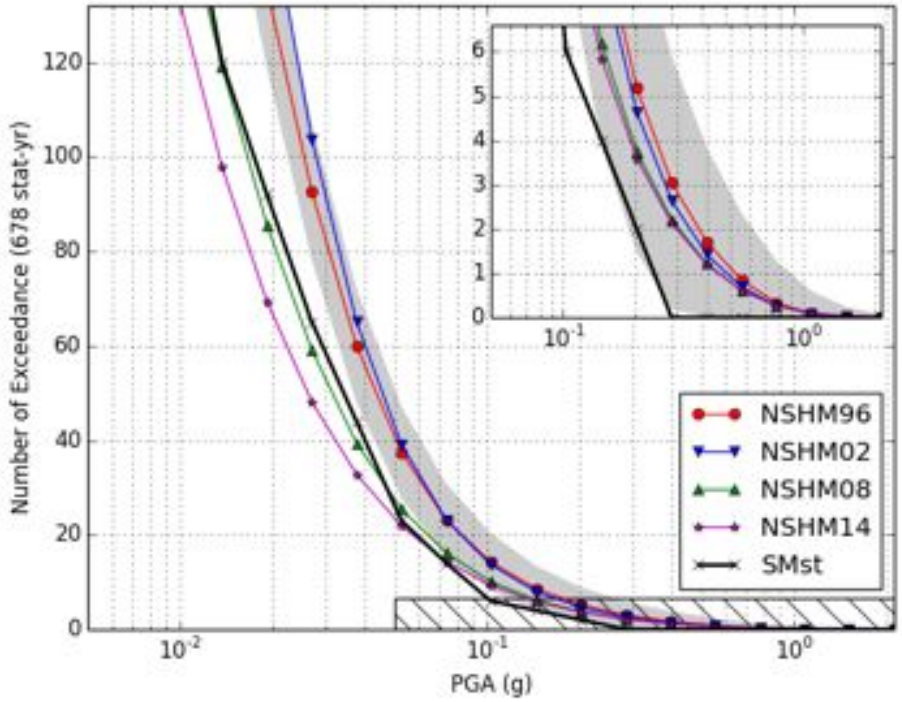
DYFI



ShakeMap



Instrumental



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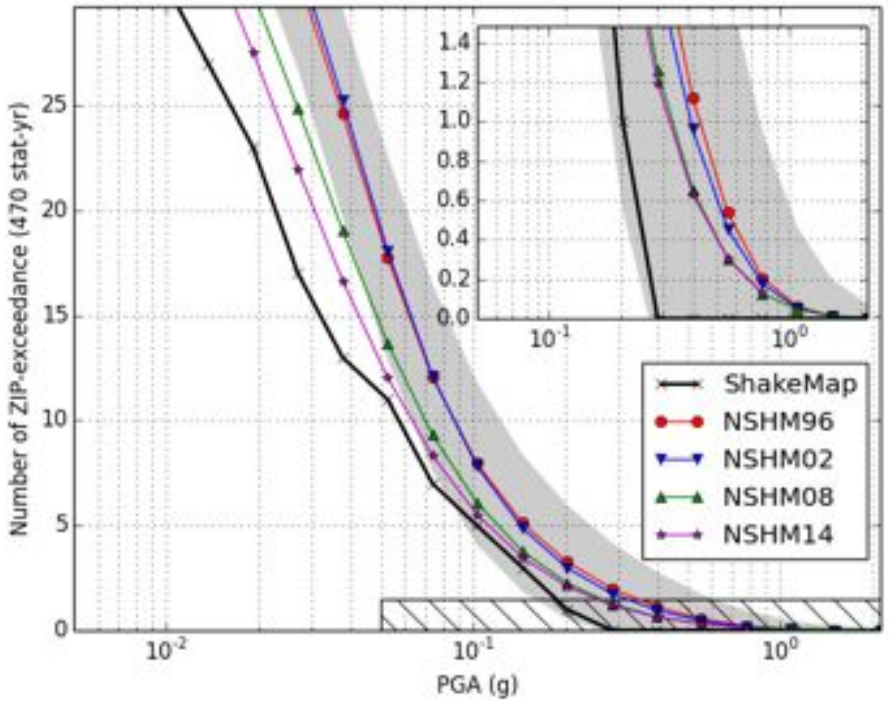
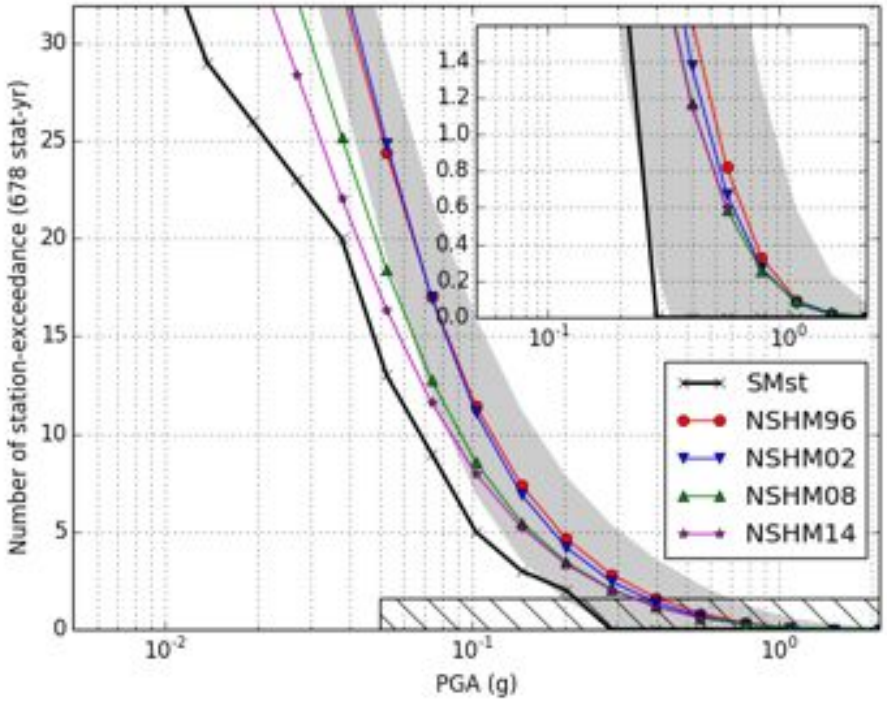
Counting: Total
44 ZIPs
52 Smsts
50km-separation

ShakeMap



Instrumental



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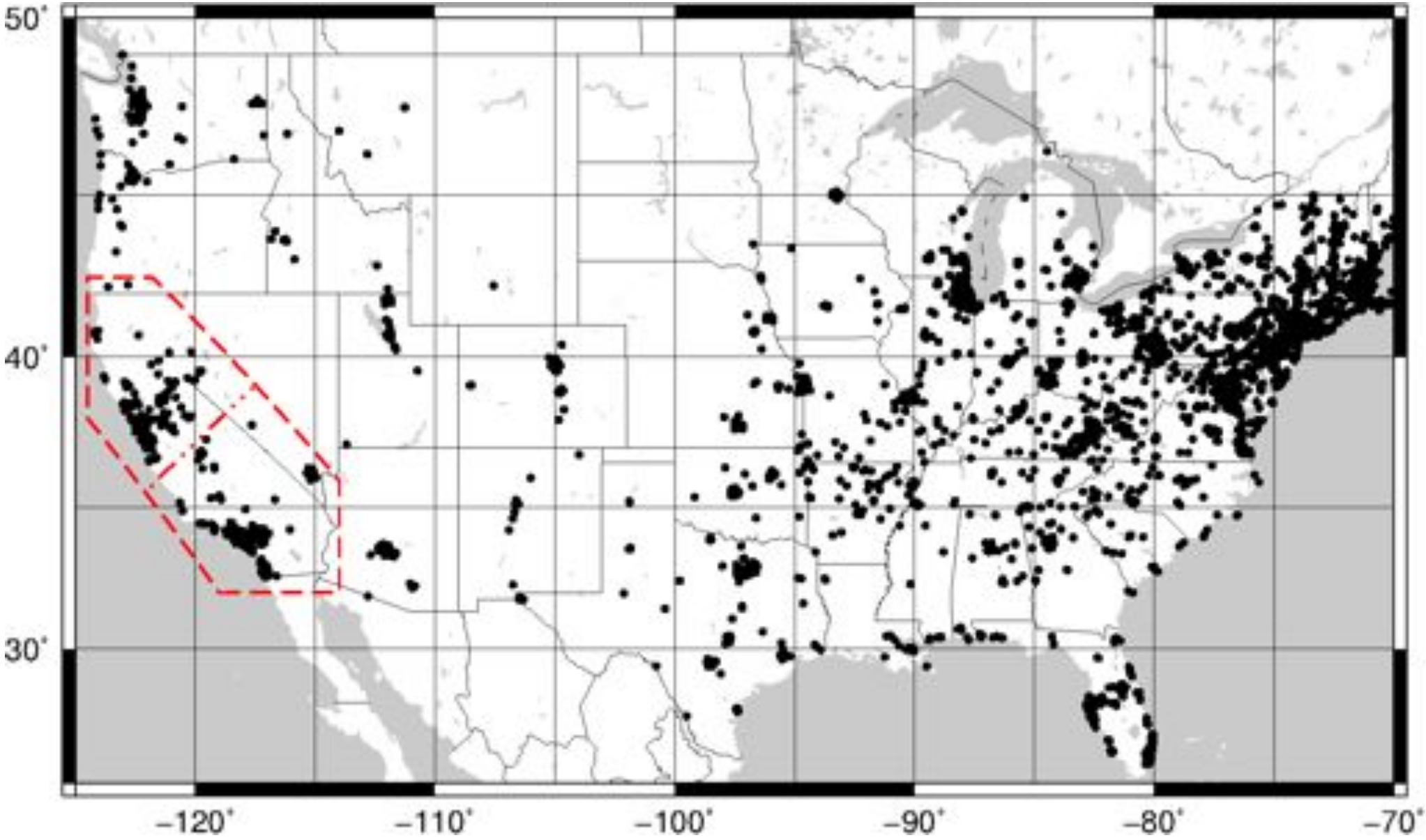
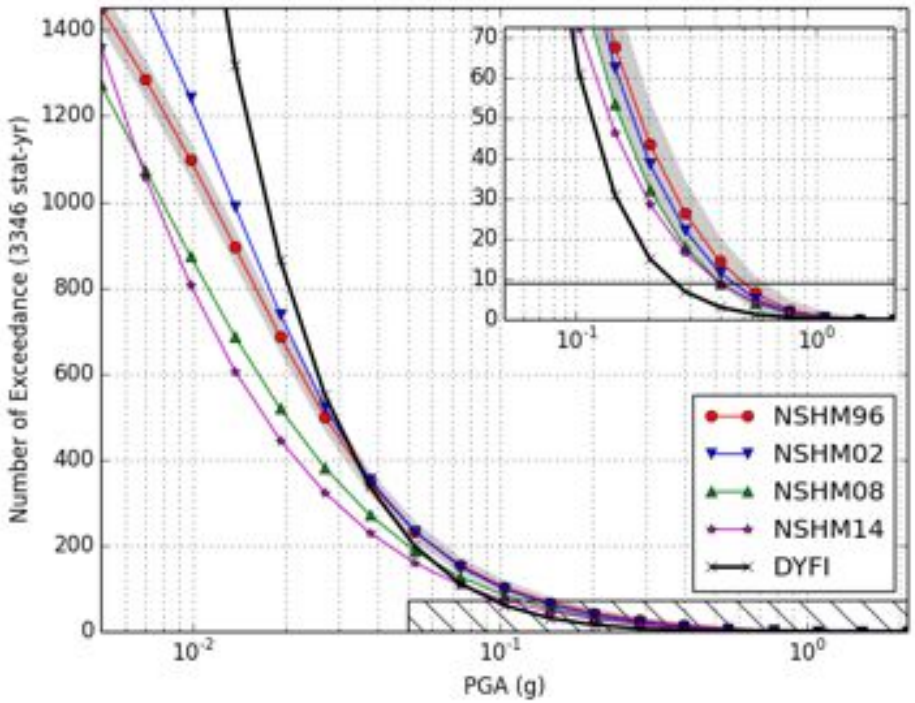
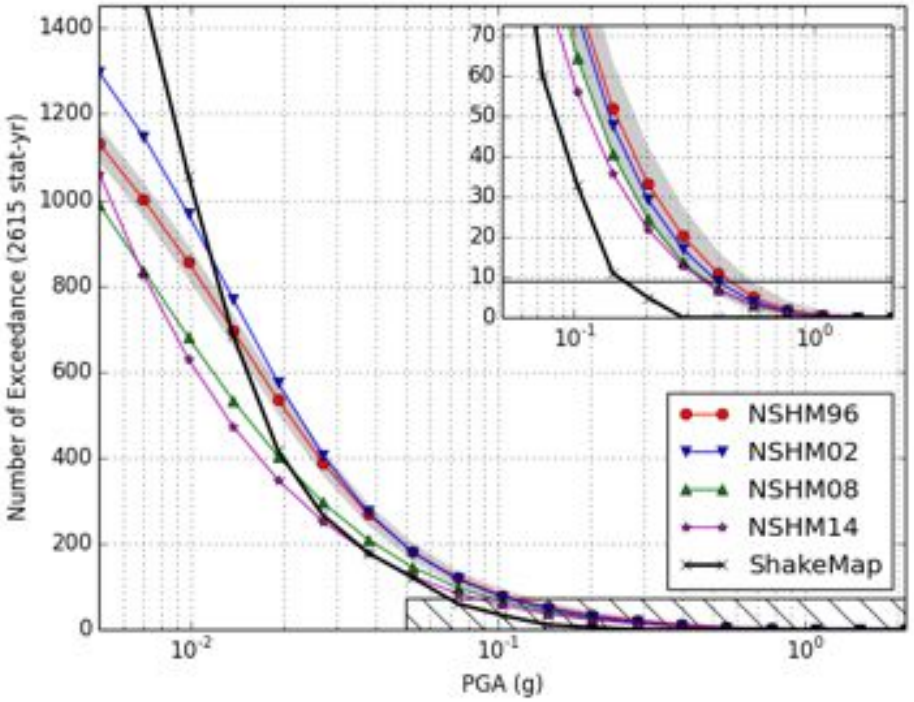


DYFI 2000-2013 ZIP30

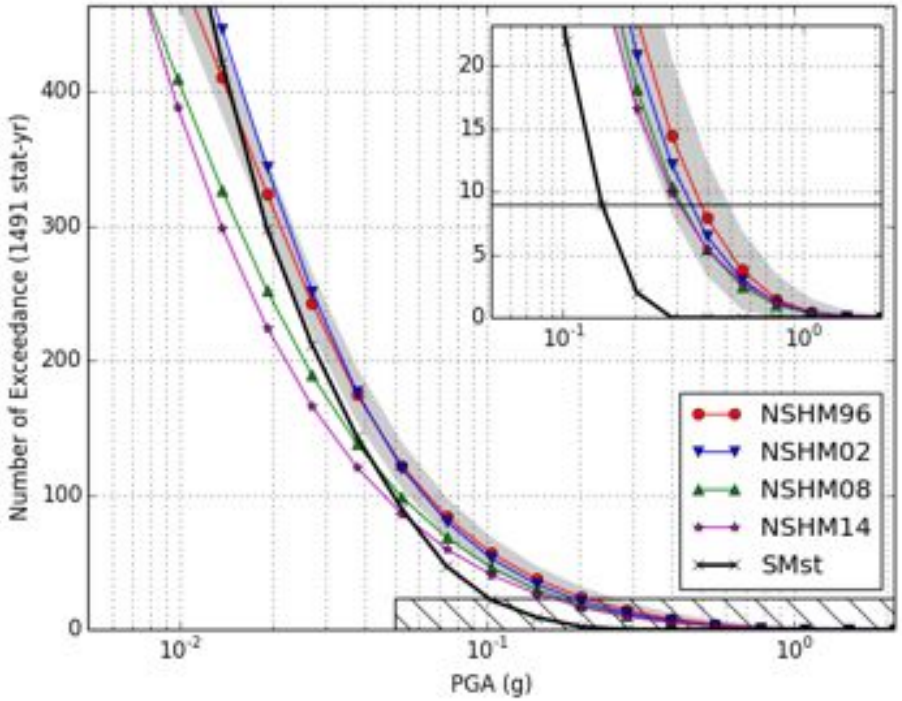
DYFI



ShakeMap

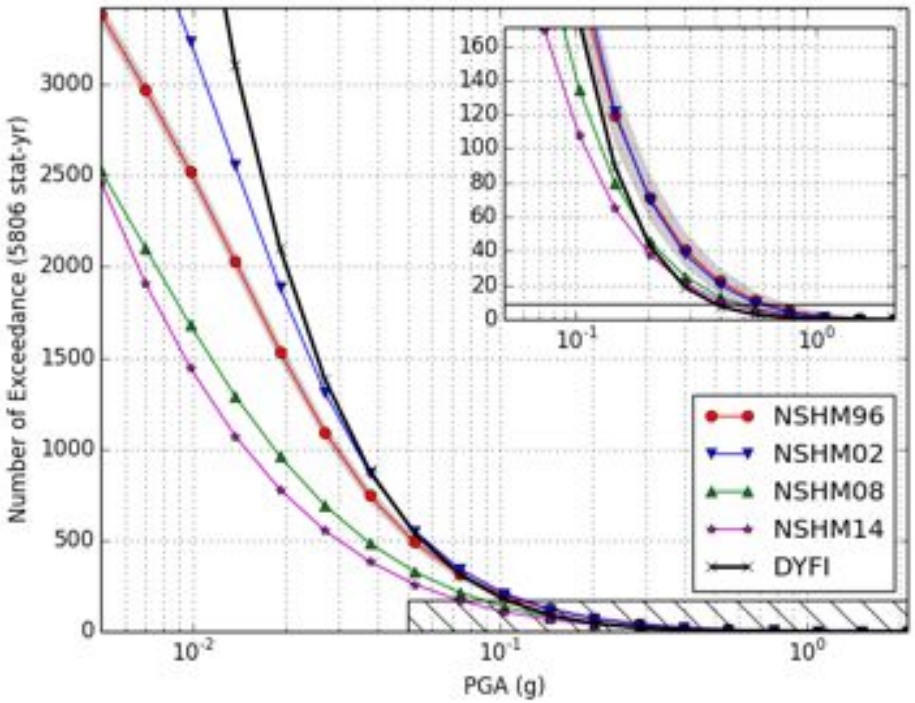


Instrumental

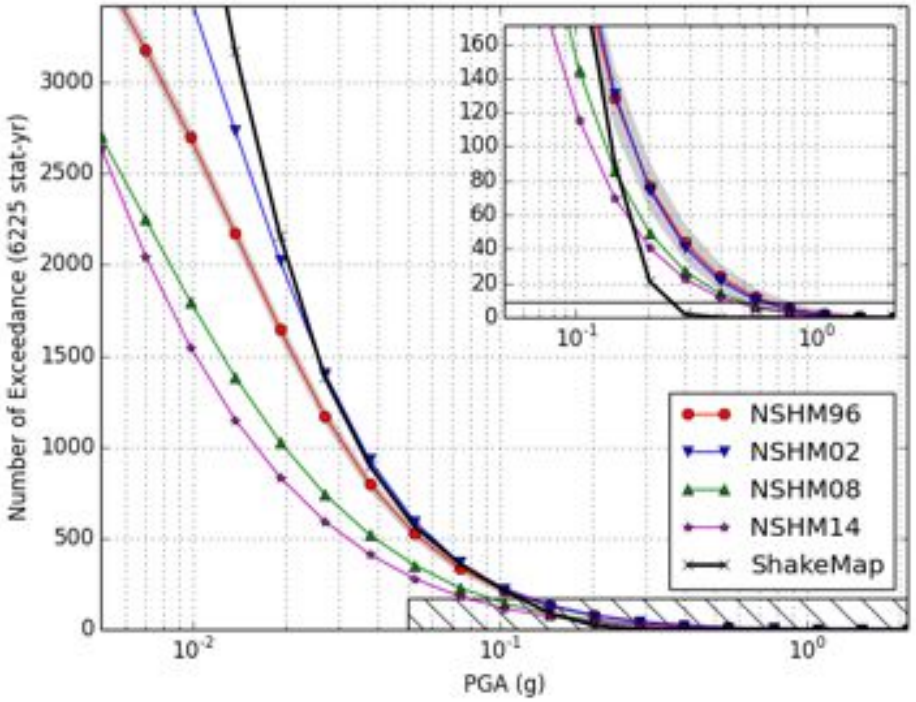


Region: NCA
Counting: Total
273 ZIPs
128 SMsts

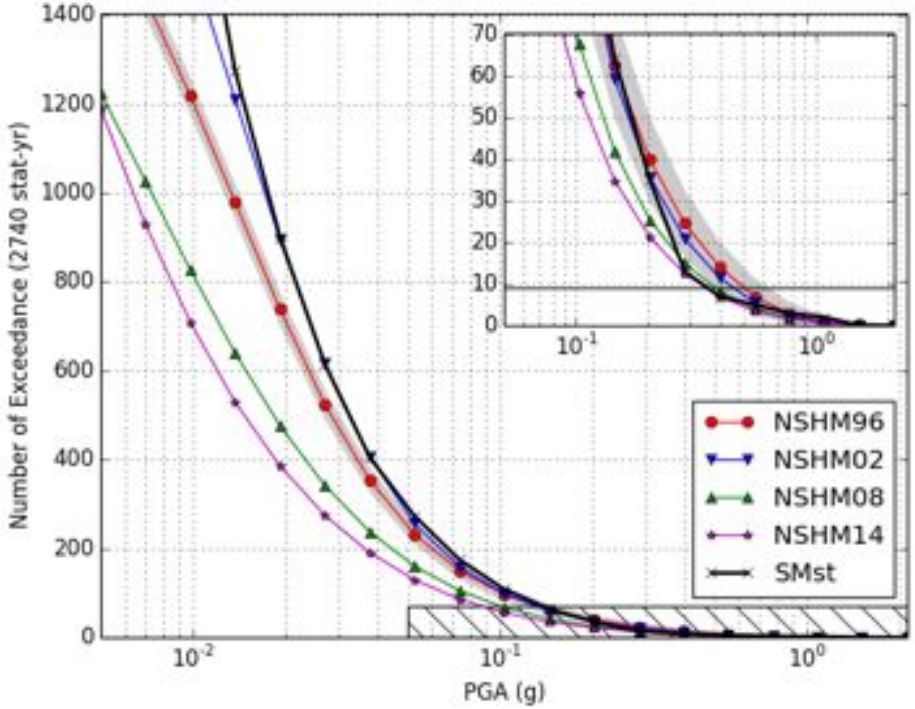
DYFI



ShakeMap



Instrumental

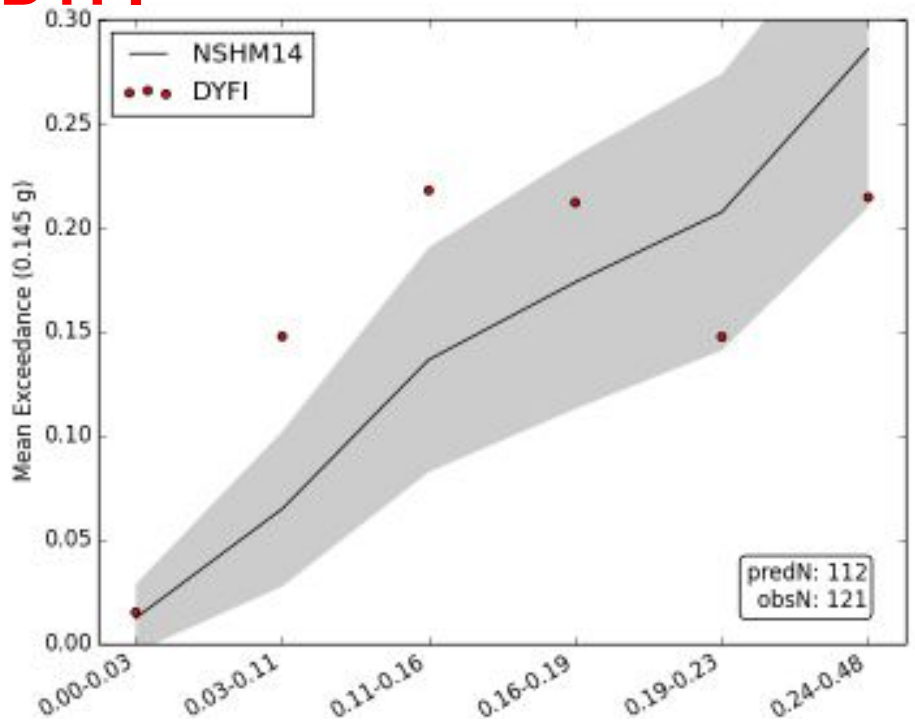


Region: SCA
Counting: Total
482 ZIPs
217 SMsts

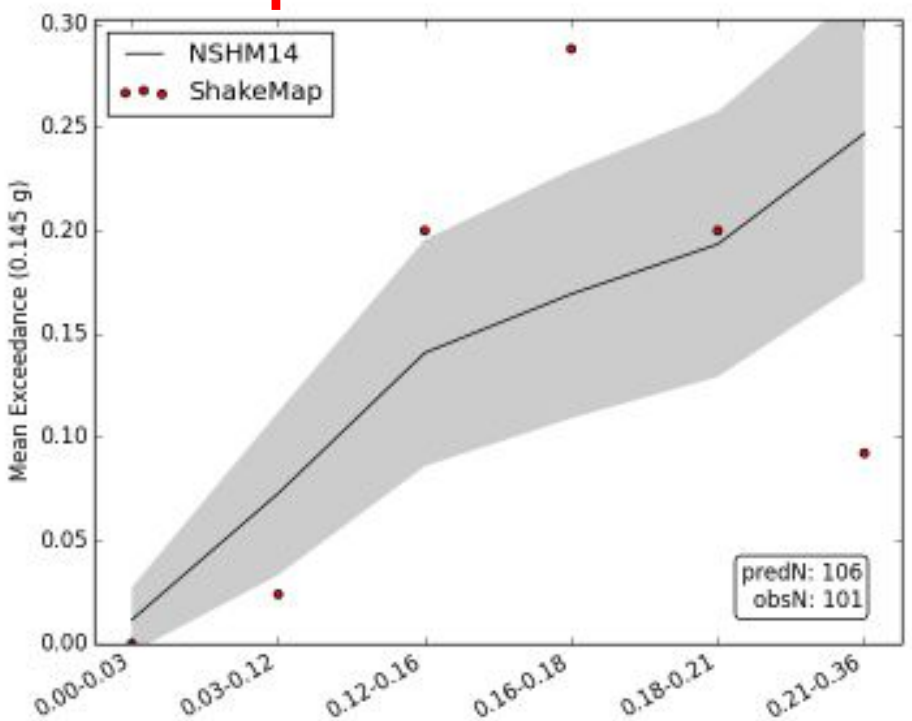
Subregion by Hazard Level

- Used in early studies (McGuire, 1979; McGuire and Barnhard, 1981; Ward, 1995).
  - $E(o|f) = f$
- "Calibration" in weather forecast verifications.

DYFI



ShakeMap



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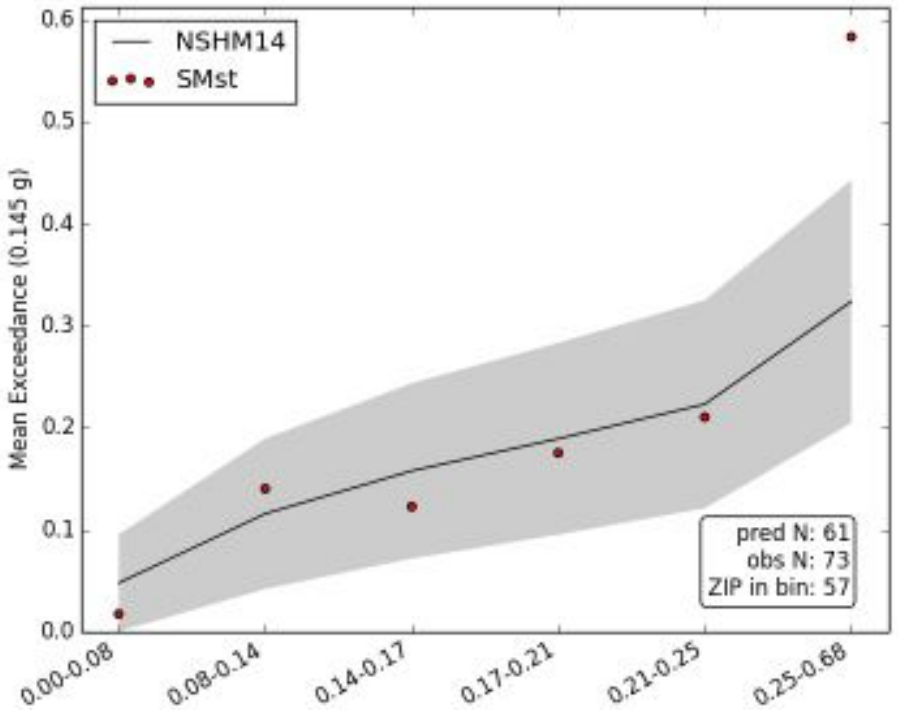
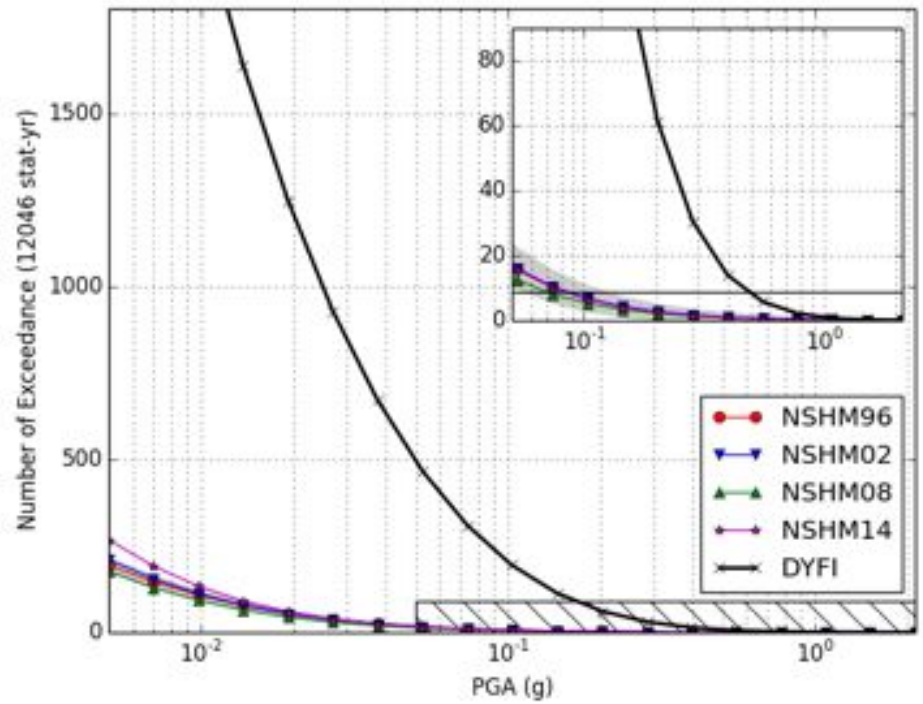


Region: California
Counting: Total
PGA>0.145 g

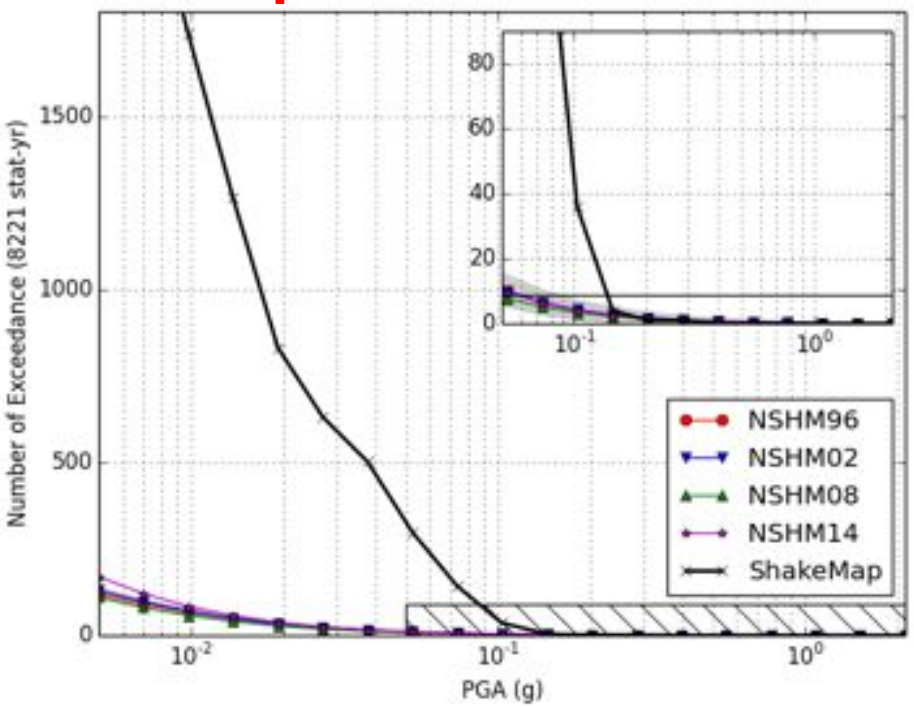
Summary

- Three data sets (DYFI, ShakeMap, instrumentals) give consistent results.
- Robust result: NSHMs lies on the safe side at high PGA (>0.1 g) levels.
  - Site effects are ignored.
- Observed more weak ground-motions than predicted by total counting but not binary counting.
  - Aftershocks, small earthquakes.

DYFI

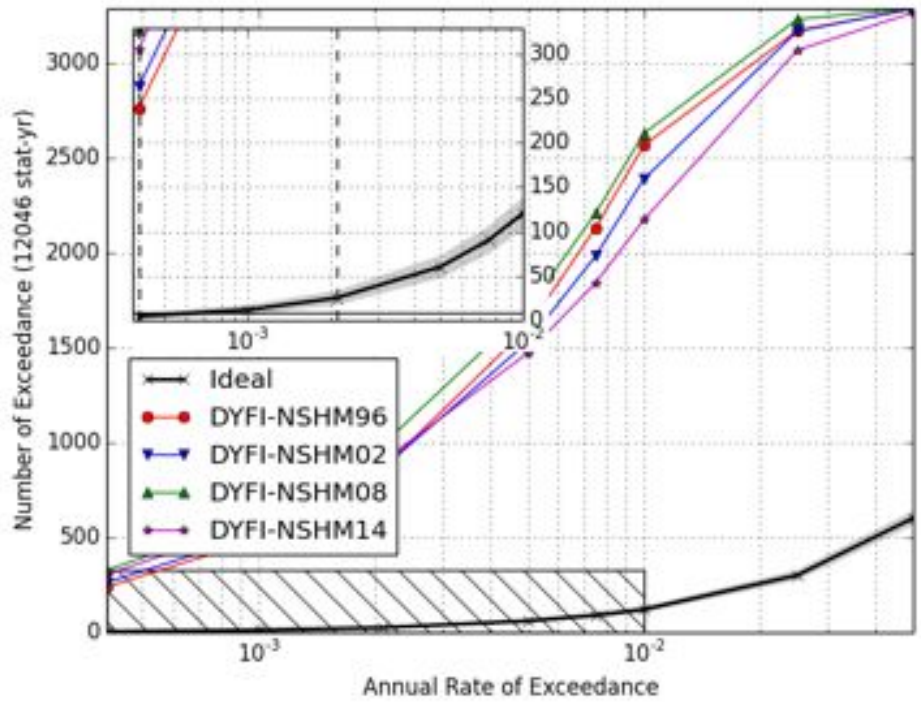


ShakeMap

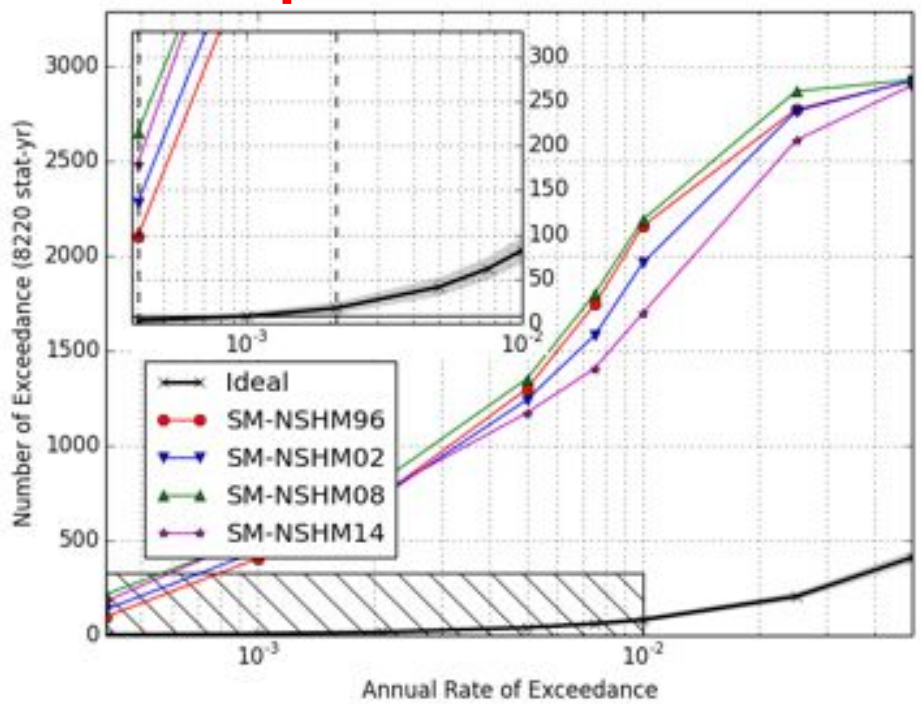


Region: EUS
Counting: Total
ZIPs: 2044

DYFI



ShakeMap



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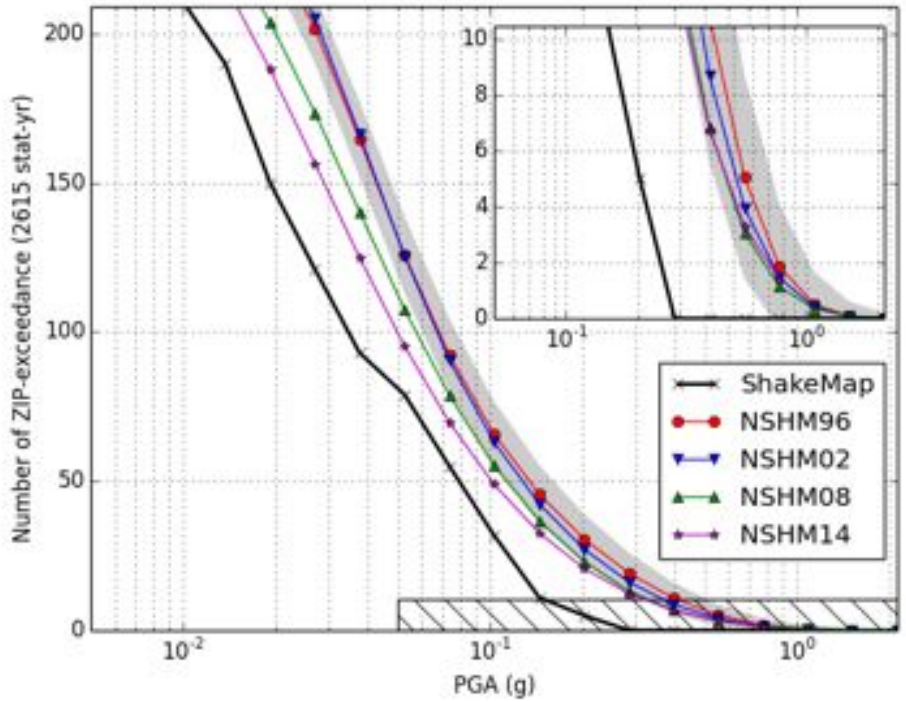
CSEP/GEM testing
GMPE (Japan and NZ)

working together to assess risk

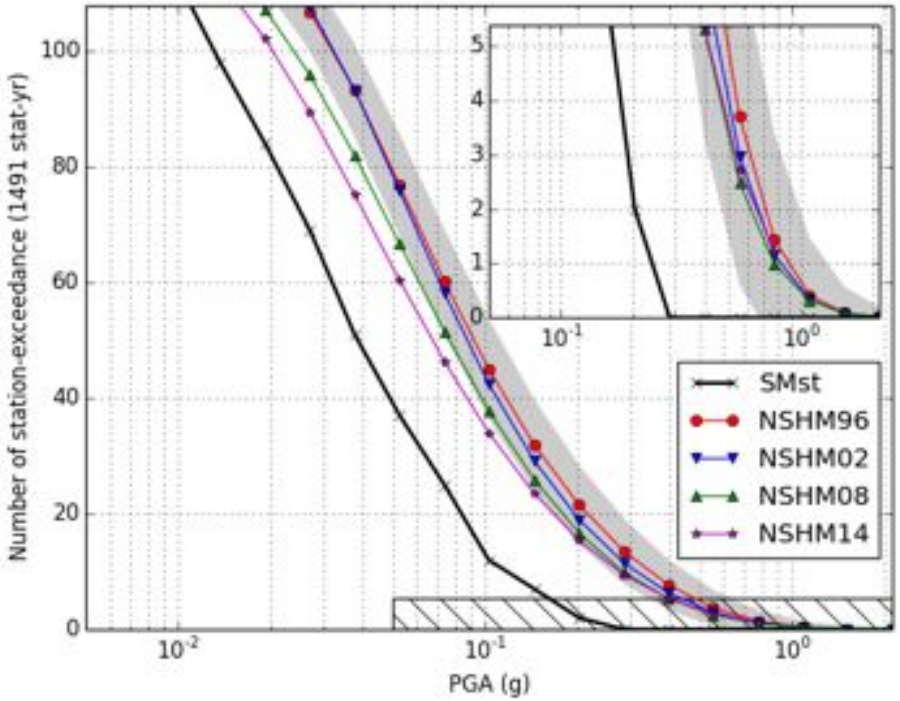
GEM

GLOBAL EARTHQUAKE MODEL

ShakeMap



Instrumental



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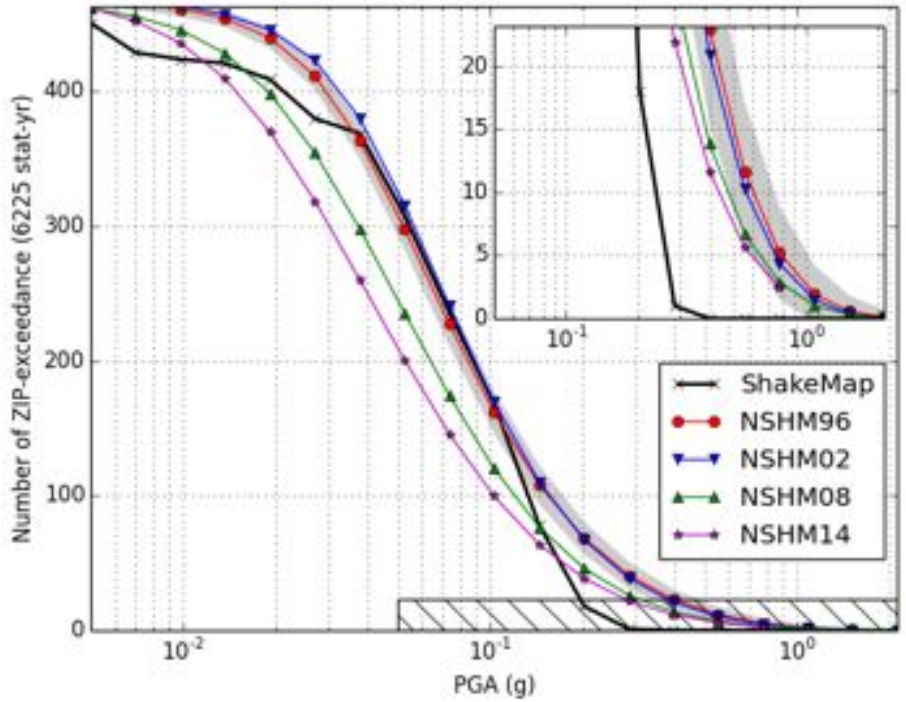
ShakeMap



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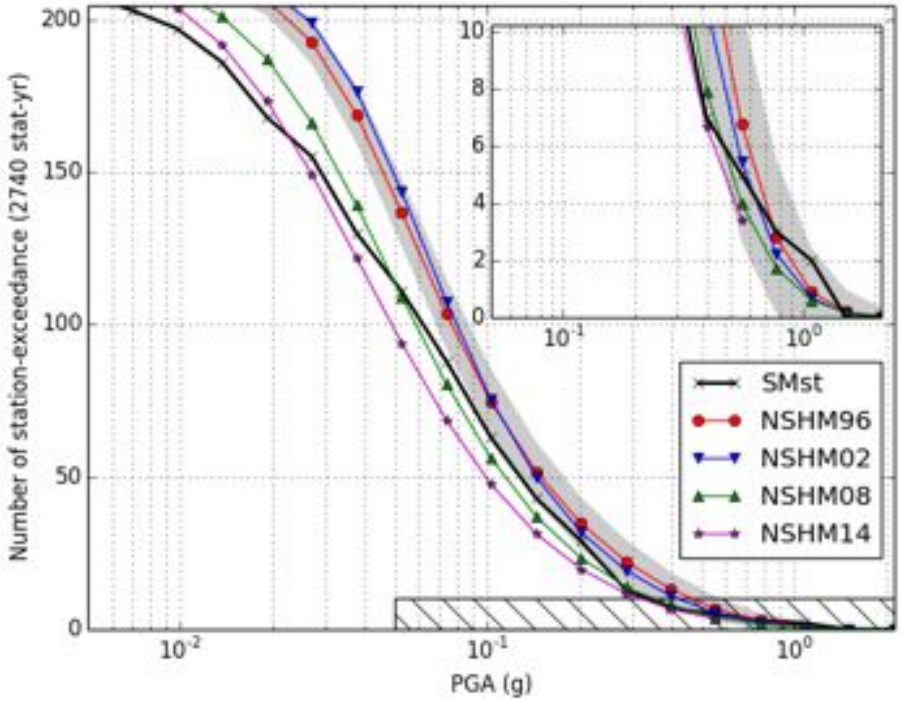

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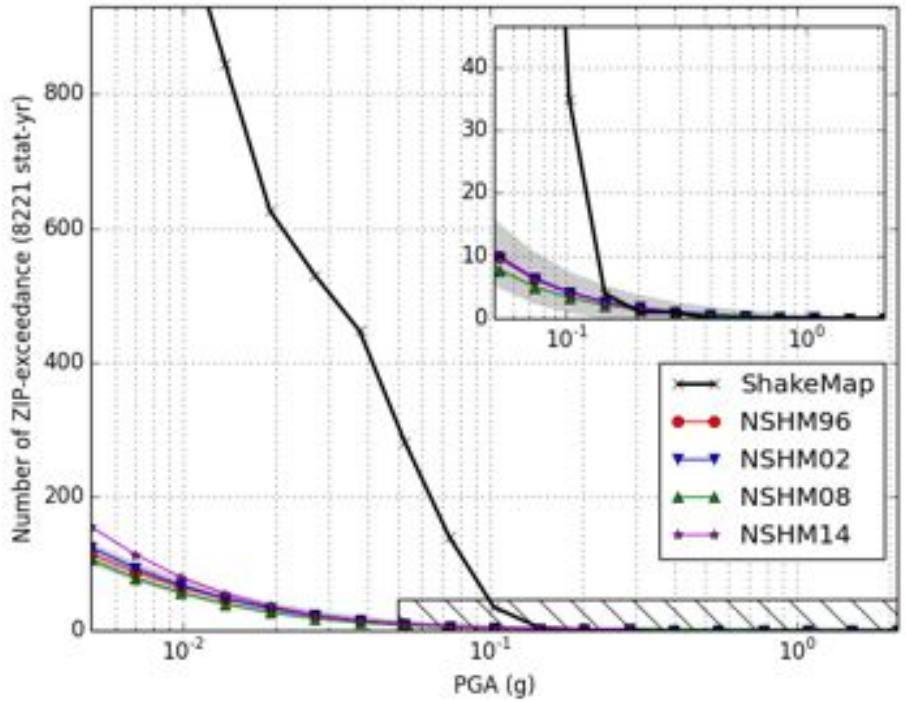

Region: EUS
Counting: Binary
ZIPs: 2044