The NGA-East Ground Motion Characterization (GMC) Model

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Technical Integration Lead

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And contributions from many more...

http://peer.berkeley.edu/ngaeast/

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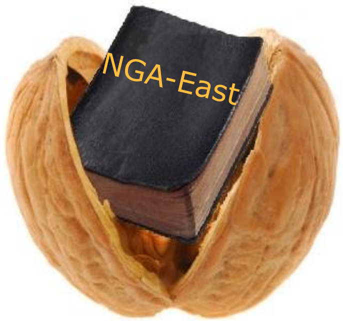
The NGA-East Project



A science/development phase

AND a SSHAC Level 3 project

Objective – to develop GMC model:

- GMMs/GMPEs
  - Median
  - Standard Deviation (aleatory variability)
- Logic trees (epistemic uncertainty)

SSHAC Goals:

Evaluation: The consideration of the complete set of data, models, and methods proposed by the larger technical community that are relevant to the hazard analysis.

Integration: Representing the center, body, and range of technically defensible interpretations in light of the evaluation process (**CBR of the TDIs**).

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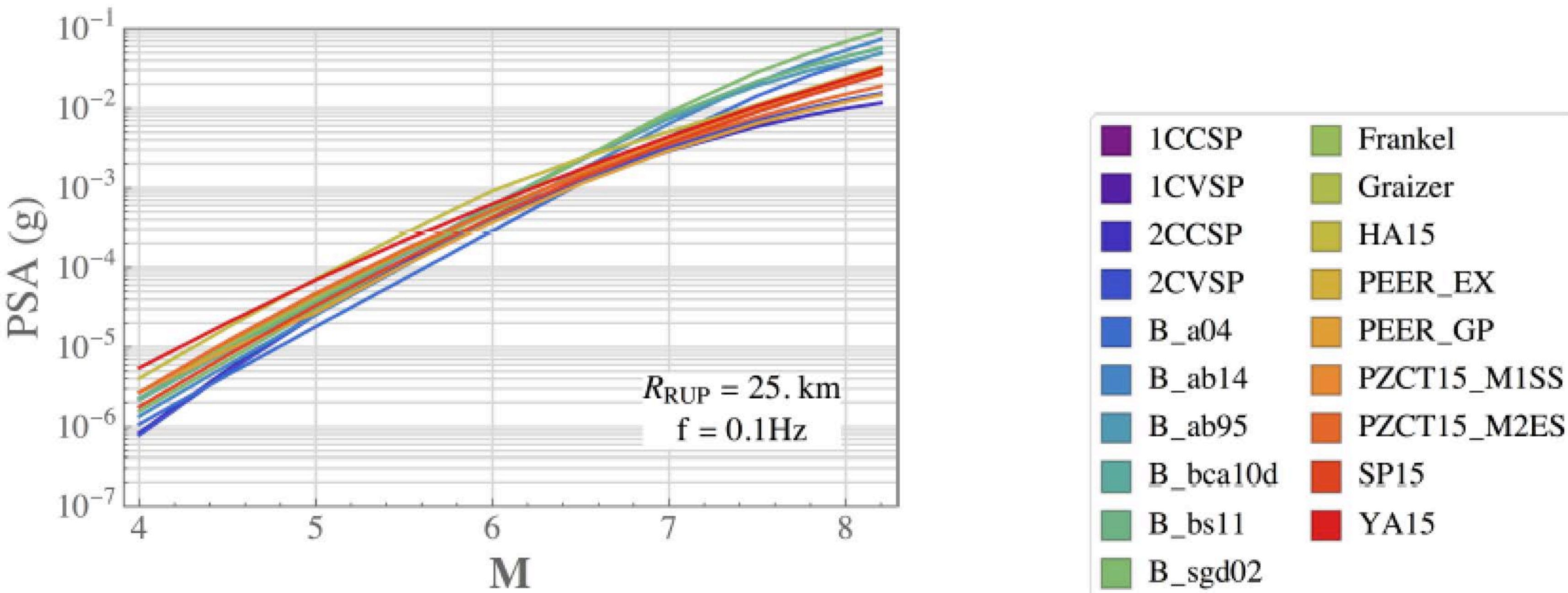
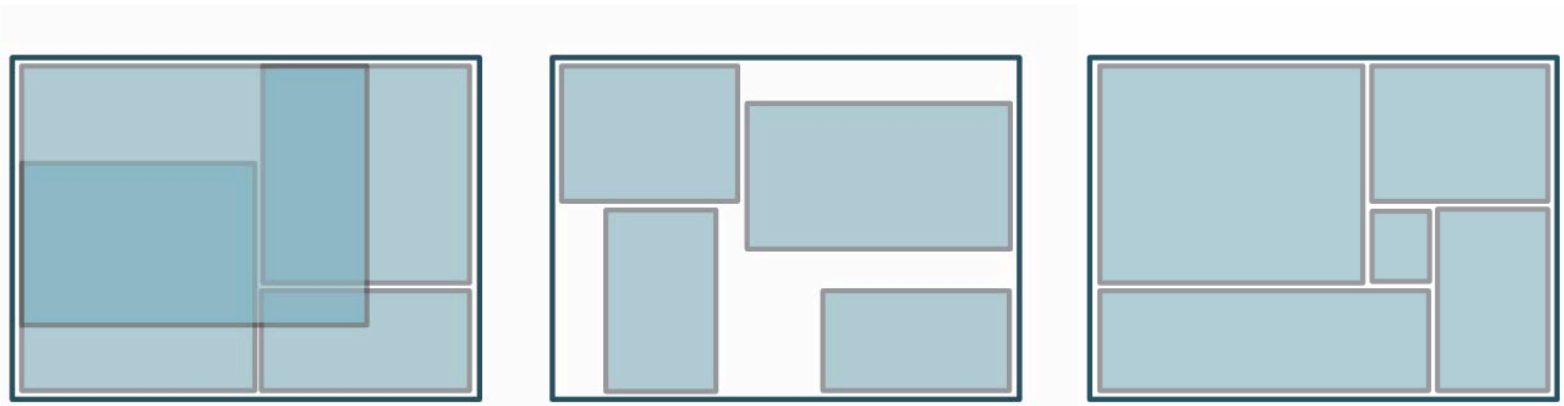
Capturing the CBR of the TDI in median ground motions

- Issue: many GMMs exist, but they may not sample the ground-motion space adequately
  - Redundant models? Confirmatory models?
  - Missing models?



Capturing the CBR of the TDI in median ground motions

- Issue: many GMMs exist, but they may not sample the ground-motion space adequately
  - Redundant models? Confirmatory models?
  - Missing models?
- NGA-East approach: treat epistemic uncertainty as a continuous distribution in GM space
  - Goal is to *try to* select discrete mutually exclusive and completely exhaustive (MECE) GMMs representing the range in ground motions



NOT
mutually exclusive

NOT
completely exhaustive

MECE

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Capturing the CBR of the TDI in median ground motions

- Issue: many GMMs exist, but they may not sample the ground-motion space adequately
  - Redundant models?
  - Missing models?
- NGA-East approach: treat epistemic uncertainty as a continuous distribution in GM space
  - Goal is to *try to* select discrete mutually exclusive and completely exhaustive (MECE) GMMs representing the range in ground motions
- Need to further populate the ground-motion space before re-discretizing into a manageable number of GMMs

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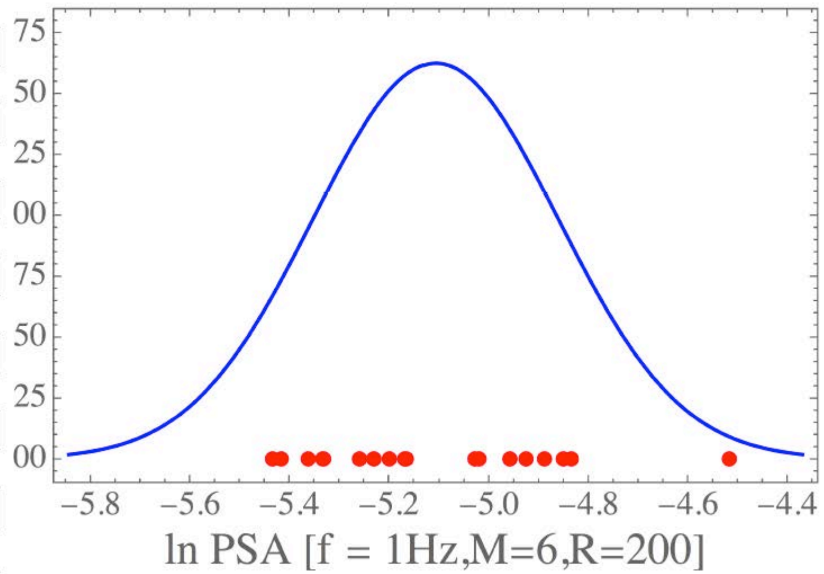
1D example (M6, R200)

1. Seed models evaluated and selected, left with 18 values (table)
2. Develop model based on distribution (mean, std dev)

Model Number	ln PSA(1Hz,M=6,R=200)
1	-4.517
2	-4.834
3	-5.258
4	-5.433
5	-4.926
6	-5.164
7	-4.850
8	-5.362
9	-5.020
10	-5.230
11	-5.332
12	-5.331
13	-5.028
14	-5.416
15	-4.888
16	-4.958
17	-5.167
18	-5.198



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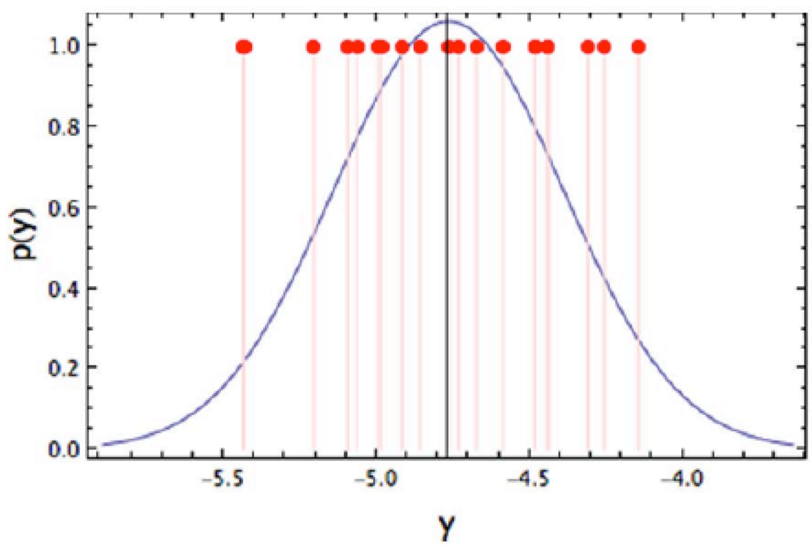
1D illustration of process

- 1. Develop a suite of seed ground-motion models (GMMs)
- 2. Develop parameters for continuous distributions of GMMs (mean and standard deviation)
- 3. Visualize the ground-motion space (trivial in 1D)



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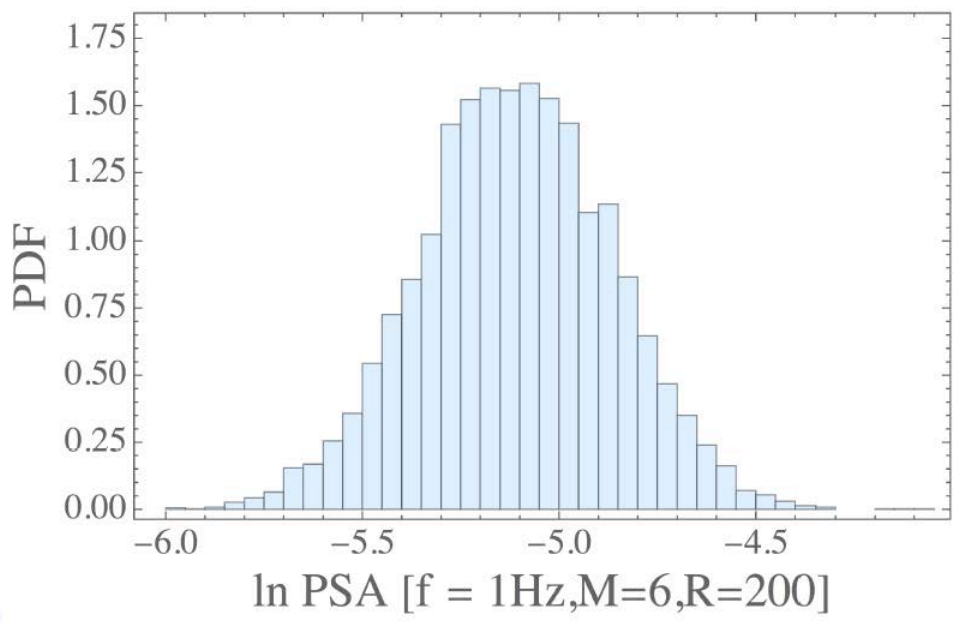
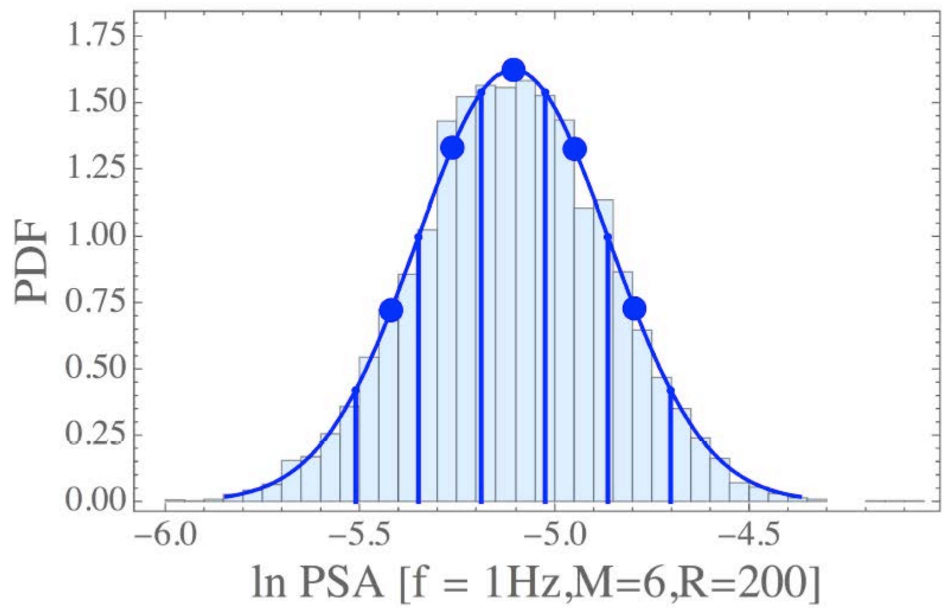
1D illustration of process

- 1. Develop a suite of seed ground-motion models (GMMs)
- 2. Develop parameters for continuous distributions of GMMs
- 3. Visualize the ground-motion space and sample GMMs



1D illustration of process

- 1. Develop a suite of seed ground-motion models (GMMs)
- 2. Develop parameters for continuous distributions of GMMs
- 3. Visualize the ground-motion space and sample GMMs
- 4. Re-discretize the ground-motion space, select representative models



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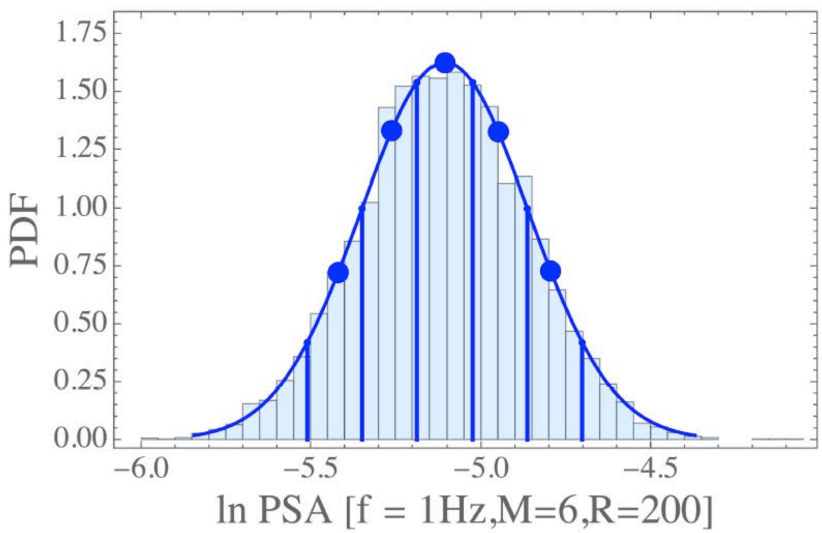
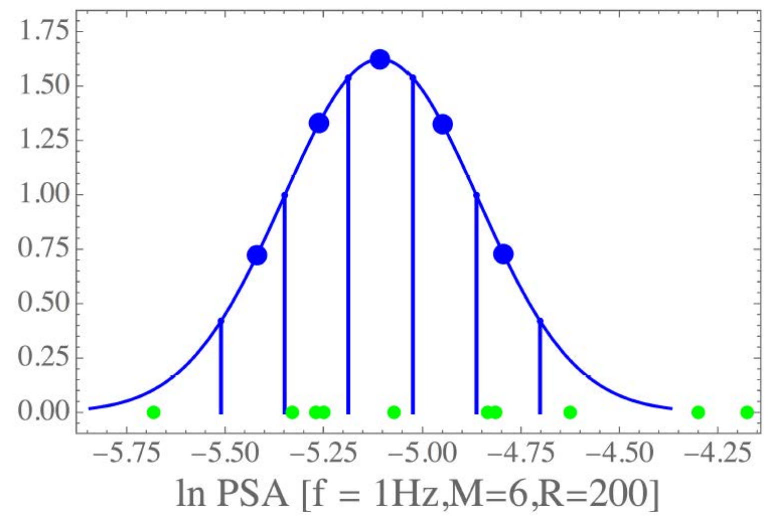
1D illustration of process

- 1. Develop a suite of seed ground-motion models (GMMs)
- 2. Develop parameters for continuous distributions of GMMs
- 3. Visualize the ground-motion space and sample GMMs
- 4. Re-discretize the ground-motion space
- 5. Assign weights

Based on sampled distribution



Based on fit to data



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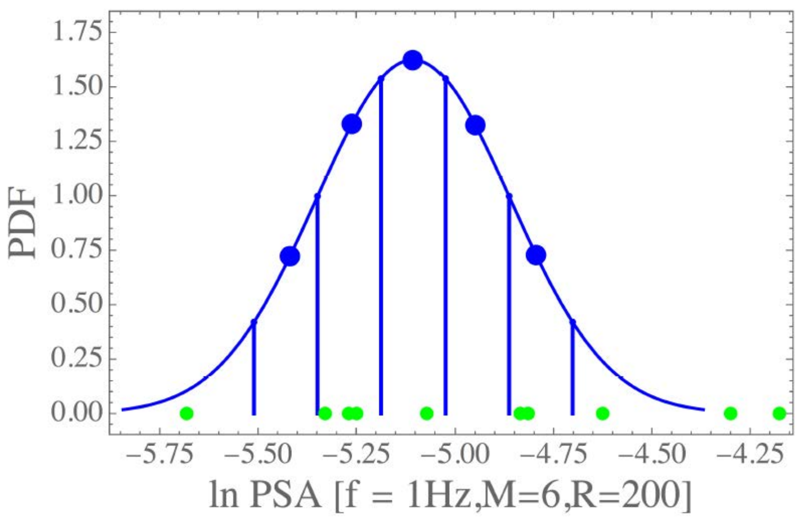
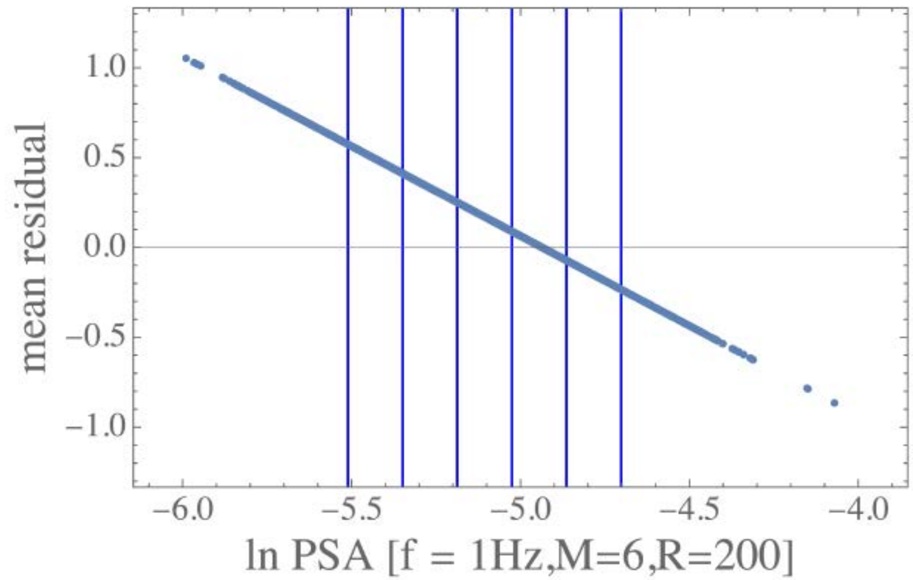
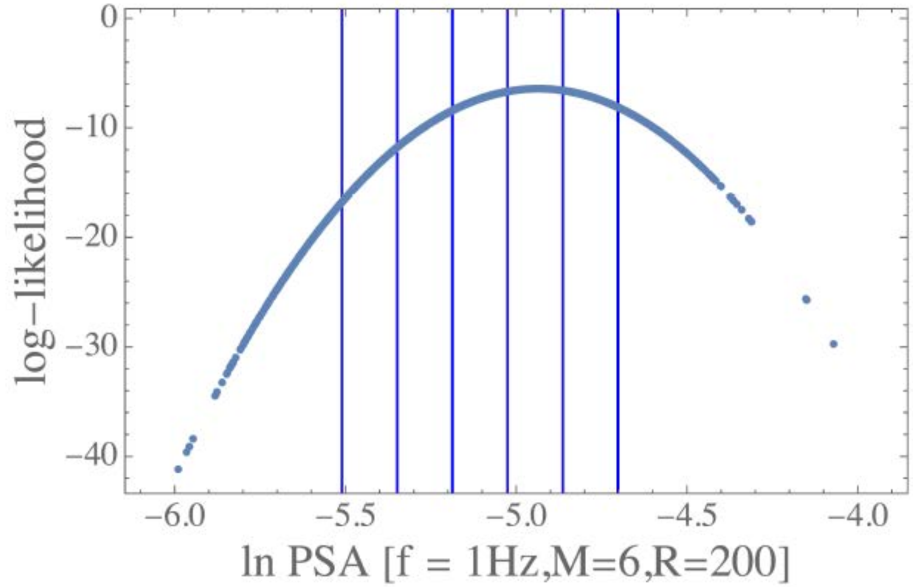
1D illustration of process

- 5. Assign weights

Based on fit to data

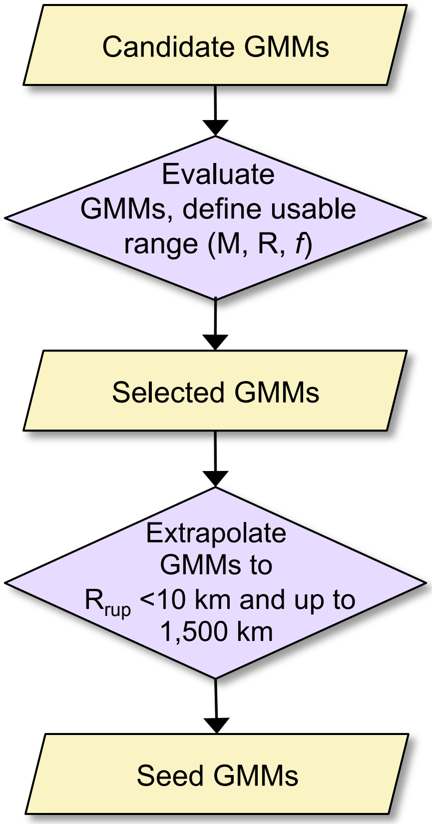


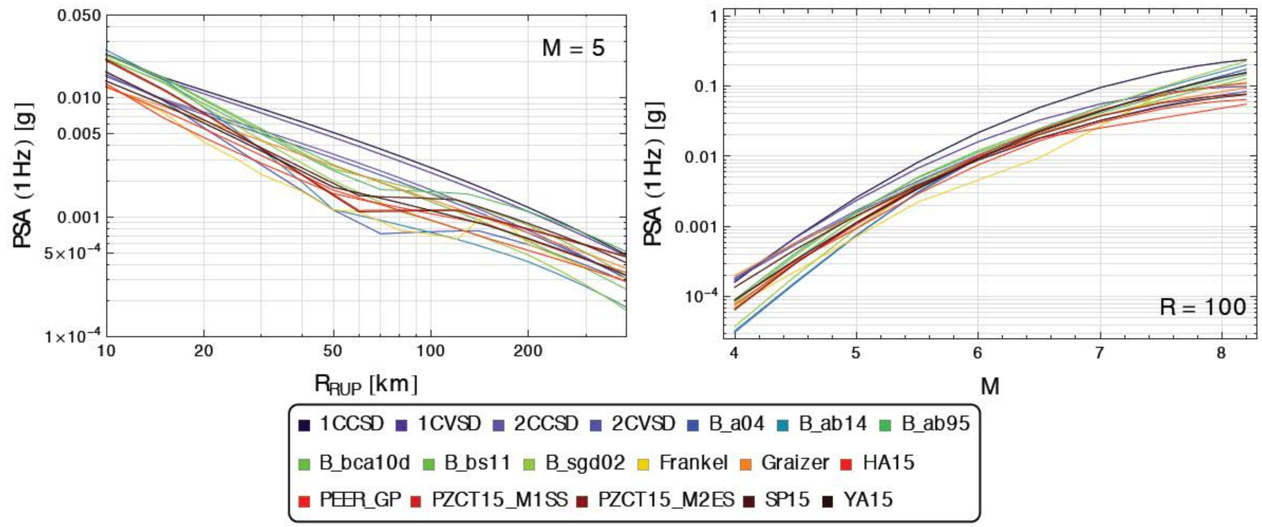


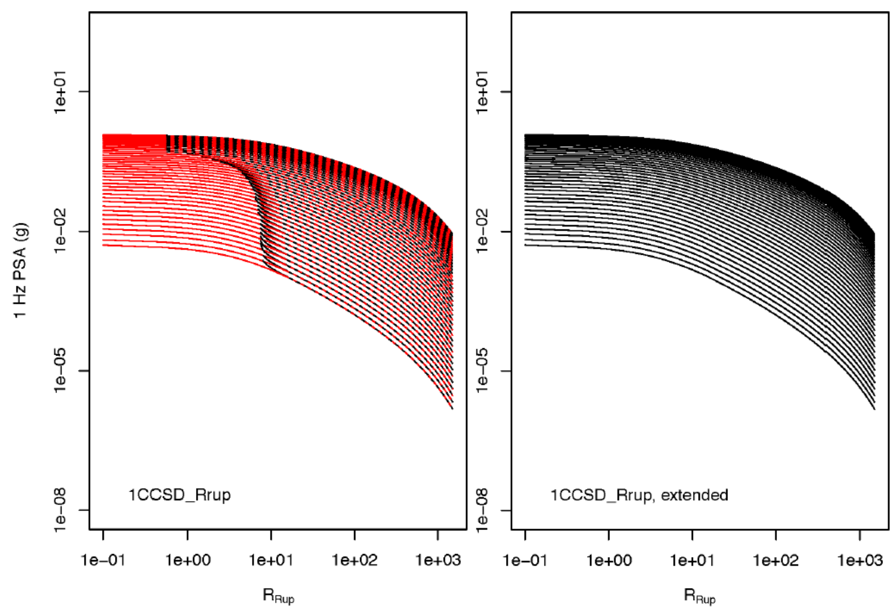


Median ground motions

1. Develop set of seed GMMs







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New Candidate Model Developers (10 groups)

- D.M. Boore
- R.B. Darragh, N.A. Abrahamson, W.J. Silva, and N. Gregor
- E. Yenier and G.M. Atkinson
- S. Pezeshk, A. Zandieh, K.W. Campbell, and B. Tavakoli
- A. Frankel
- A. Shahjouei and S. Pezeshk
- M.N. Al Noman and C.H. Cramer
- V. Graizer
- B. Hassani and G.M. Atkinson
- J. Hollenback, N. Kuehn, C.A. Goulet and N.A. Abrahamson

PEER Reports No. 2015/04 and 2015/08

Legacy Median Candidate GMMs

EPRI 2013 Review Project GMMs

Model	Name and year	Included	Comments
*A08p	Atkinson (2008, 2011)	No	Superseded
*AB06p	Atkinson and Boore (2006, 2011)	No	Superseded
*FEL	Frankel (1996)	No	Superseded
**PZT	Pezeshk, Zandieh and Tavakoli (2011)	No	Superseded
**SDCS	Silva et al. (2003), double corner	No	Superseded
*SEL01NR	Somerville et al (2001), non-rift	No	Expired, poor fit below M5, limited period range
*SEL01R	Somerville et al (2001), rift	No	Expired, poor fit below M5, limited period range
**SSCCSS	Silva et al. (2003), single corner constant stress	No	Superseded
**SSCVS	Silva et al. (2003), single corner variable stress	No	Superseded
*TEL	Toro et al. (1997), middle continent	No	Superseded

* 2014 NSHMP, ** 2014 NSHMP used earlier version

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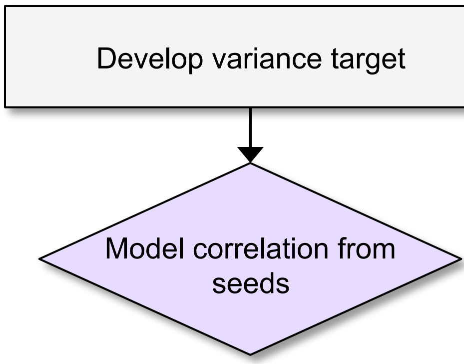
Median ground motions

2. Develop continuous distribution of GMMs

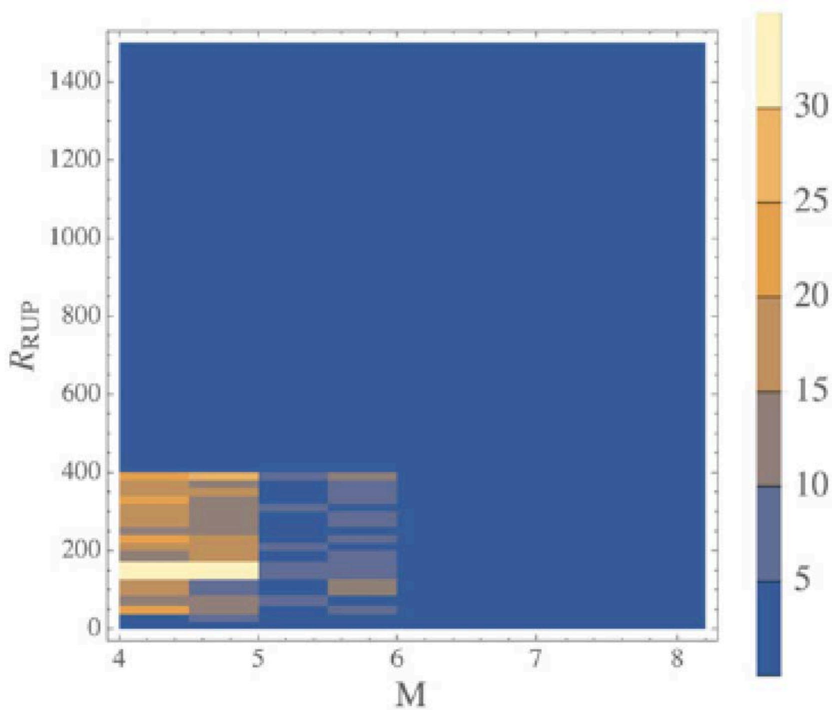


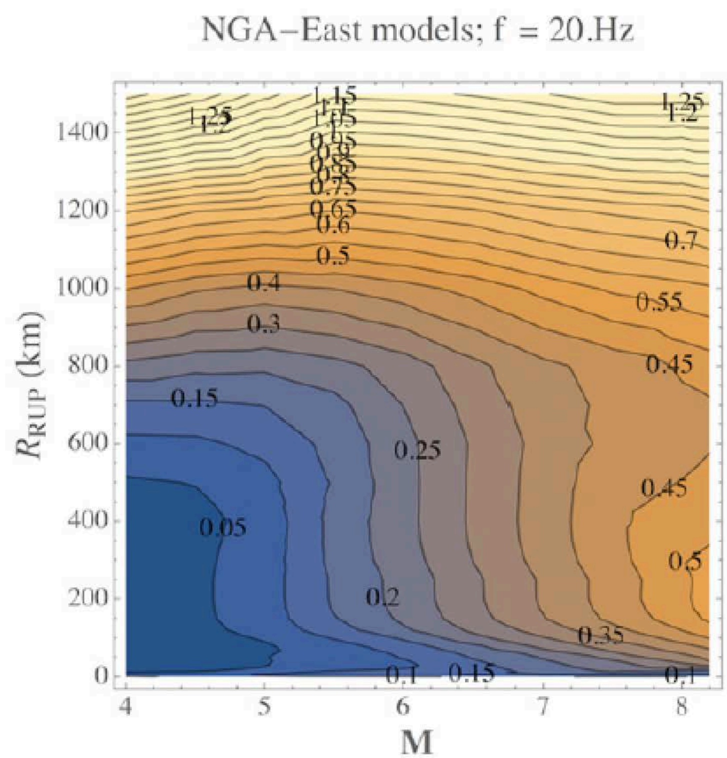
Critical step:

It defines width of distribution in terms of variance = epistemic uncertainty coverage

Considerations:

1. **Should be lowest where there is data and increase beyond data range**
2. **Should be larger that WUS**





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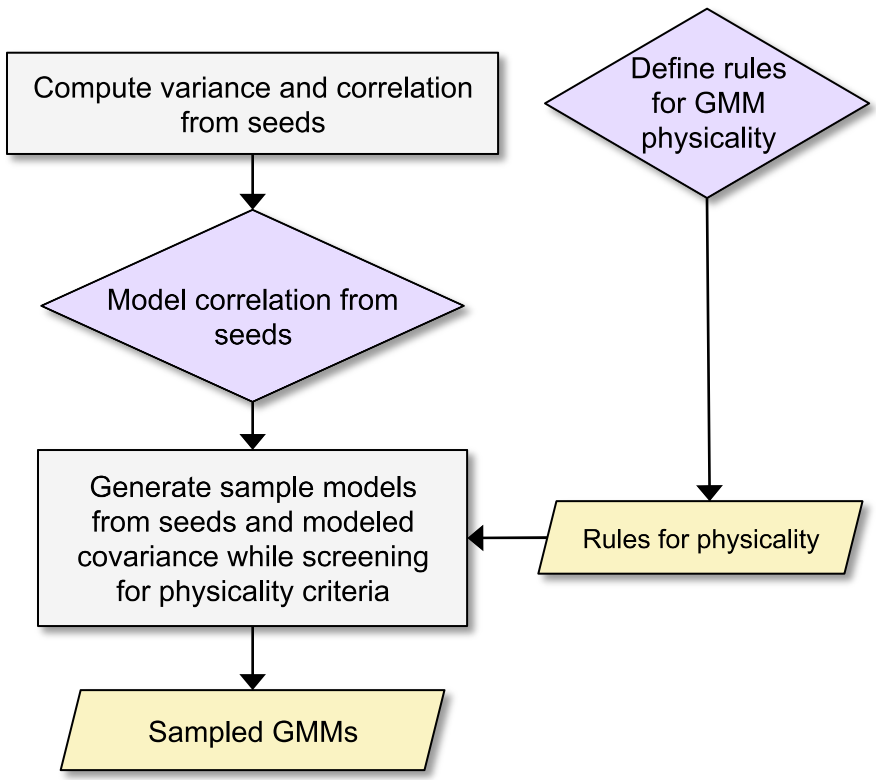
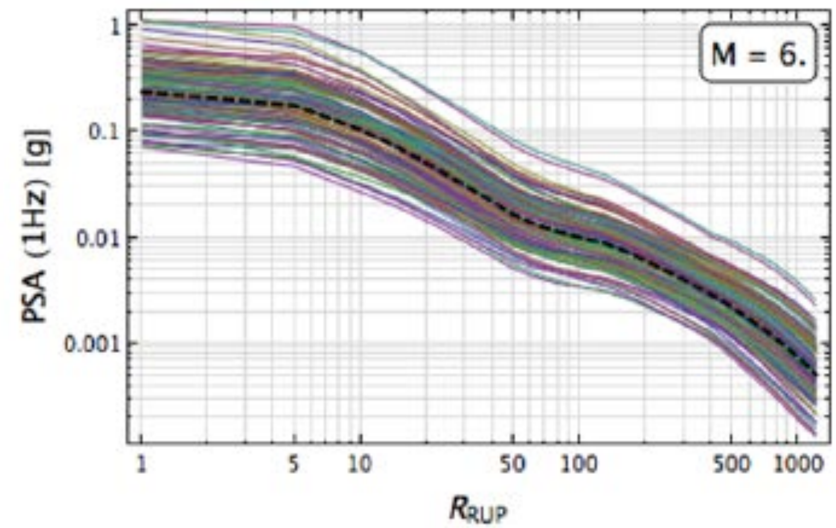
Median ground motions

2. Develop continuous distribution of GMMs





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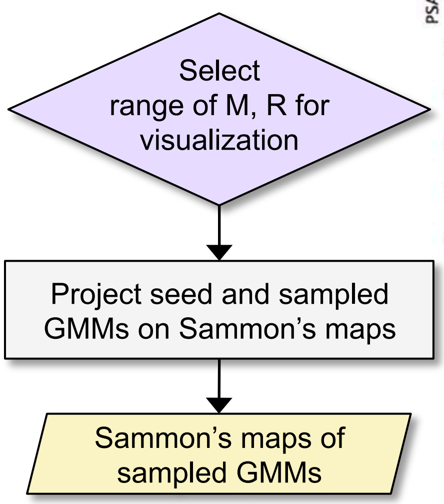
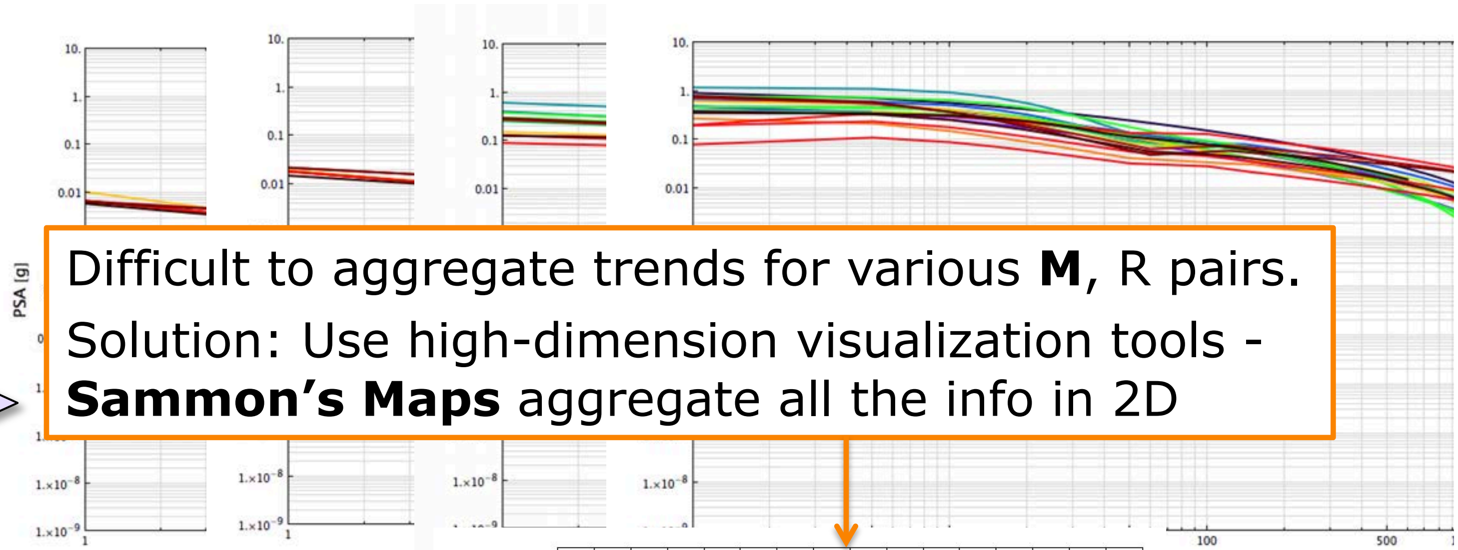
Median ground motions

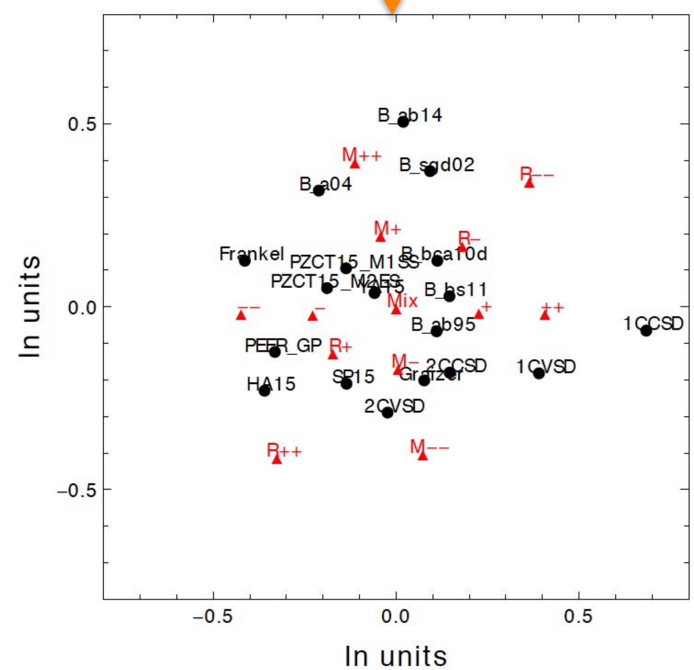
3. Visualize the GM space



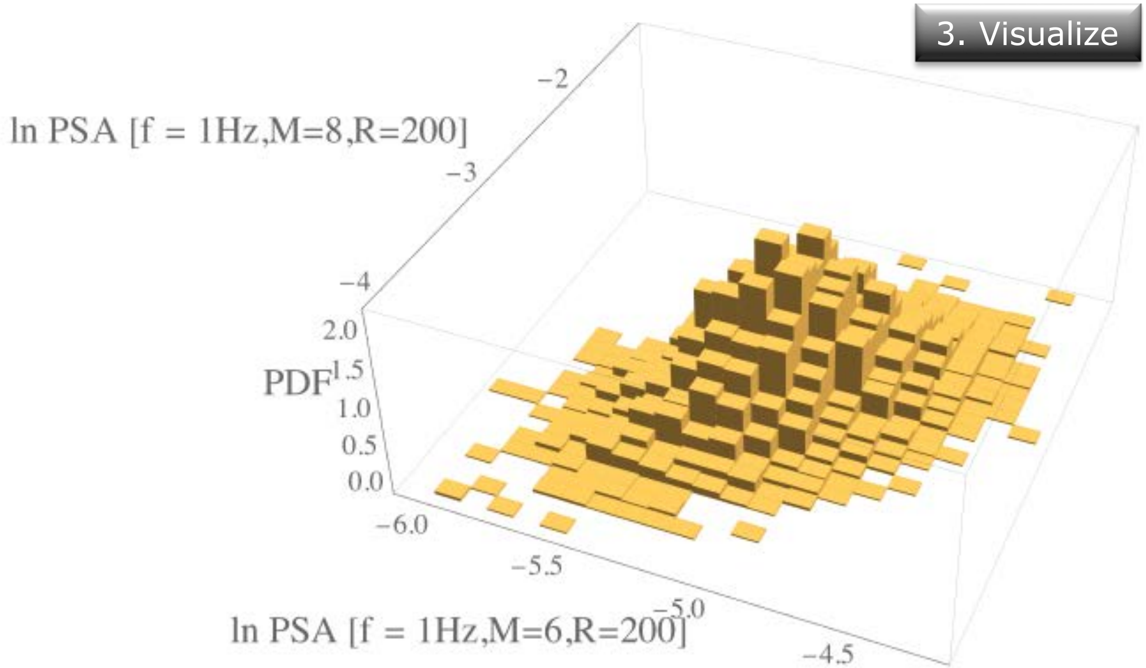


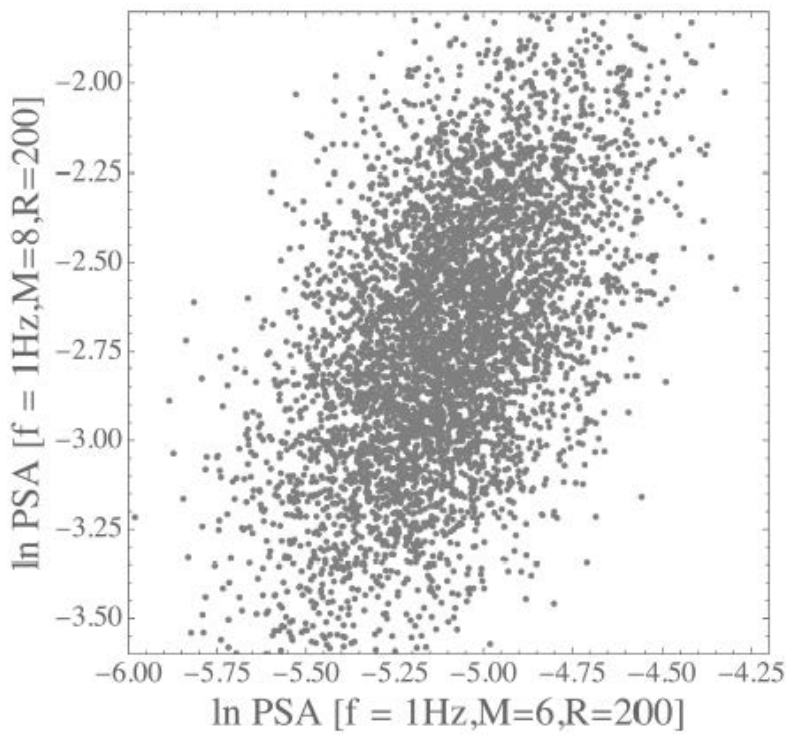
Difficult to aggregate trends for various **M**, R pairs.

Solution: Use high-dimension visualization tools - **Sammon's Maps** aggregate all the info in 2D

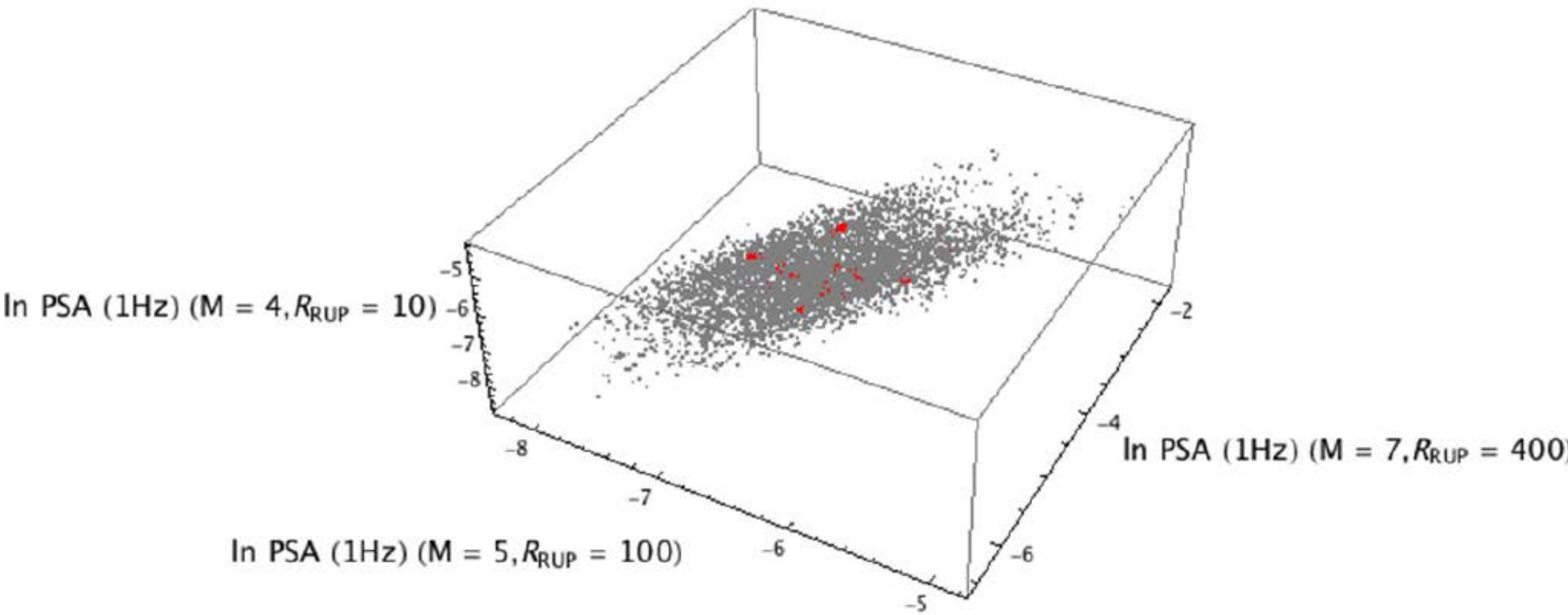


2D case


ln PSA [f = 1Hz,M=8,R=200]
PDF
2.0
1.5
1.0
0.5
0.0
−2
−3
−4
−6.0
−5.5
−5.0
−4.5
ln PSA [f = 1Hz,M=6,R=200]


ln PSA [f = 1Hz,M=8,R=200]
−2.00
−2.25
−2.50
−2.75
−3.00
−3.25
−3.50
−6.00
−5.75
−5.50
−5.25
−5.00
−4.75
−4.50
−4.25
ln PSA [f = 1Hz,M=6,R=200]

3D case produces a thin cloud



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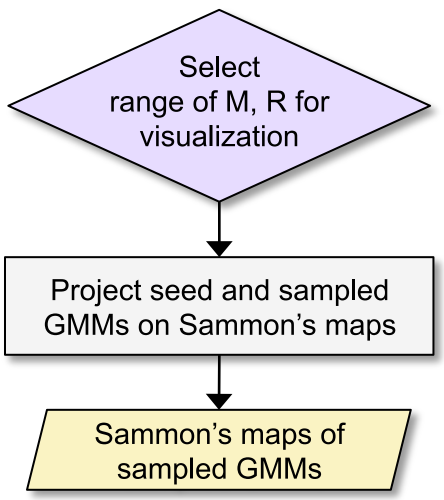
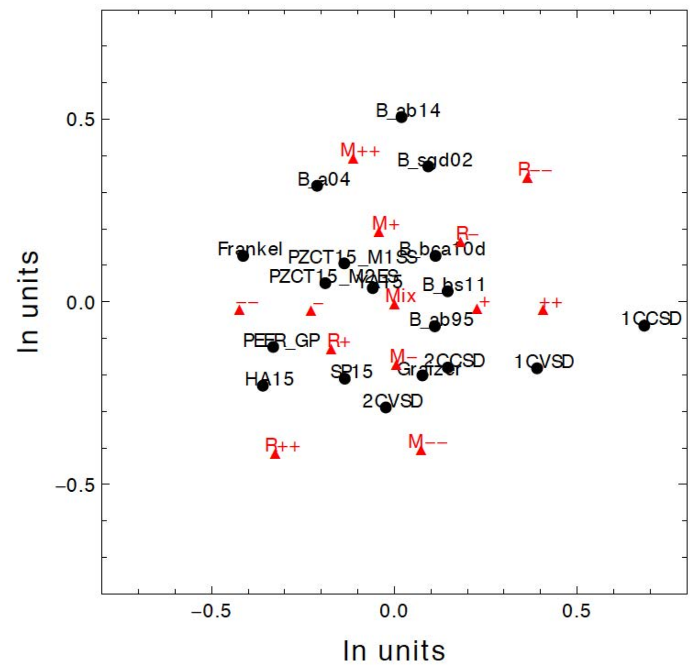
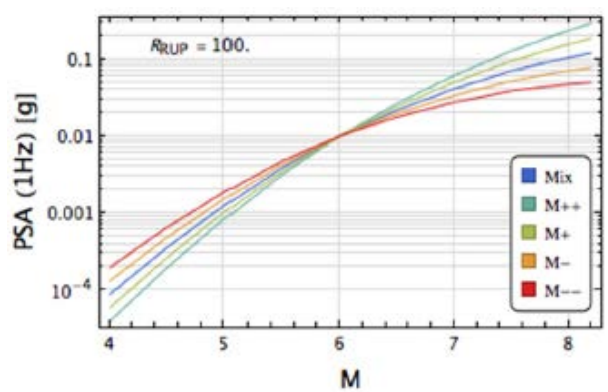
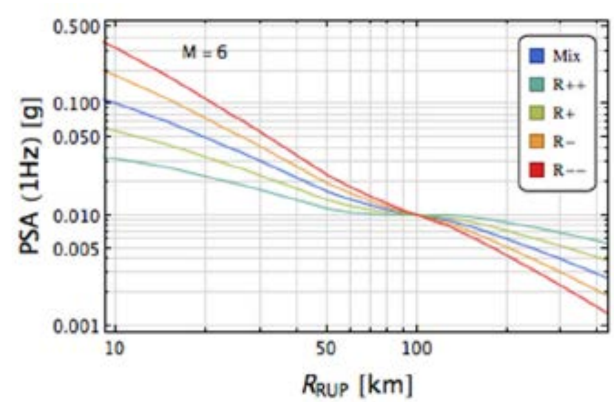
Median ground motions

3. Visualize the GM space









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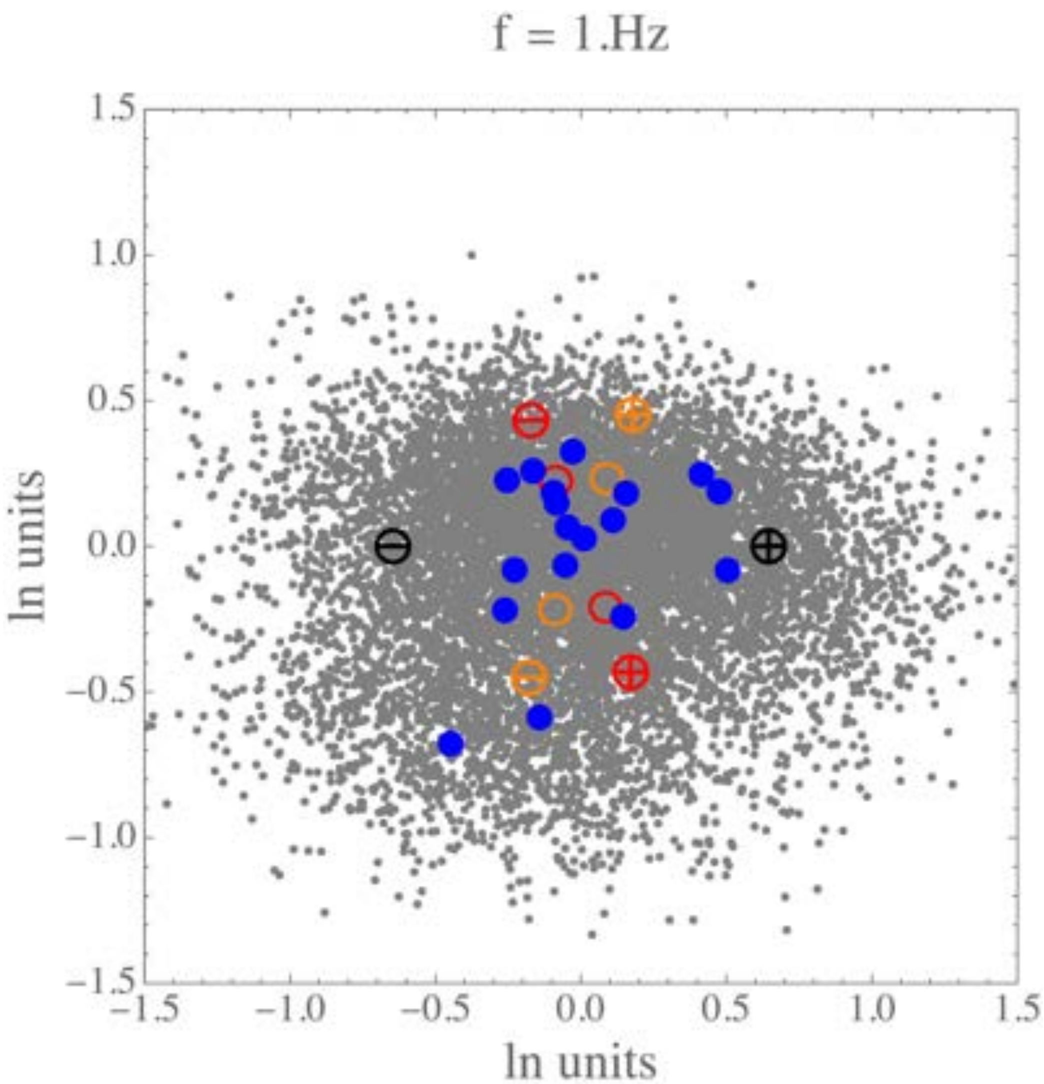
Median Ground Motions

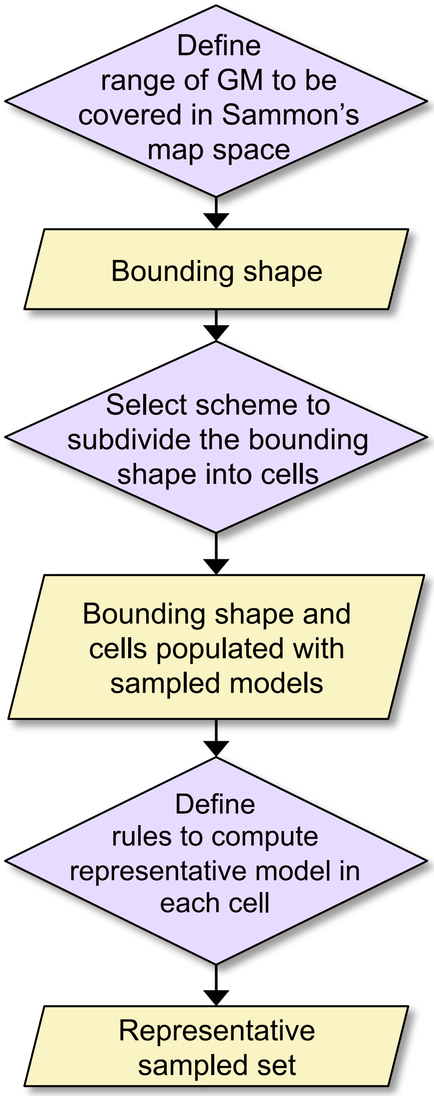
3. Visualize the GM space

- Combine the variance model and correlation models from the seeds.
- Populate GM-space with M,R scenarios: **M**=4-8.2 & R=0-1500 km
- Each resulting GMM is a vector of ground-motion values
- Project seeds and samples on Sammon's map

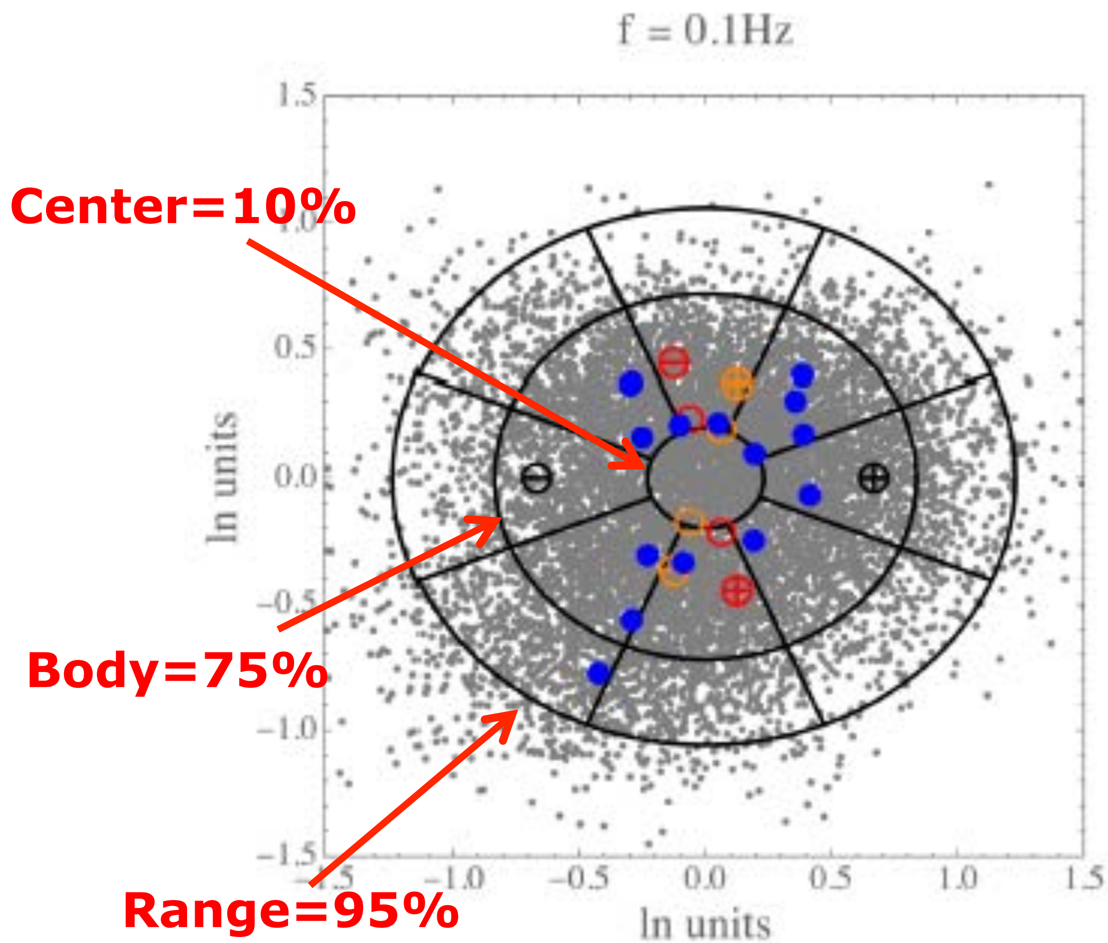


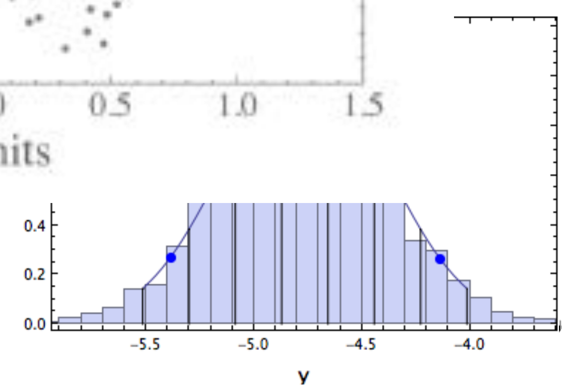
Median Ground Motions

4. Discretize the GM space



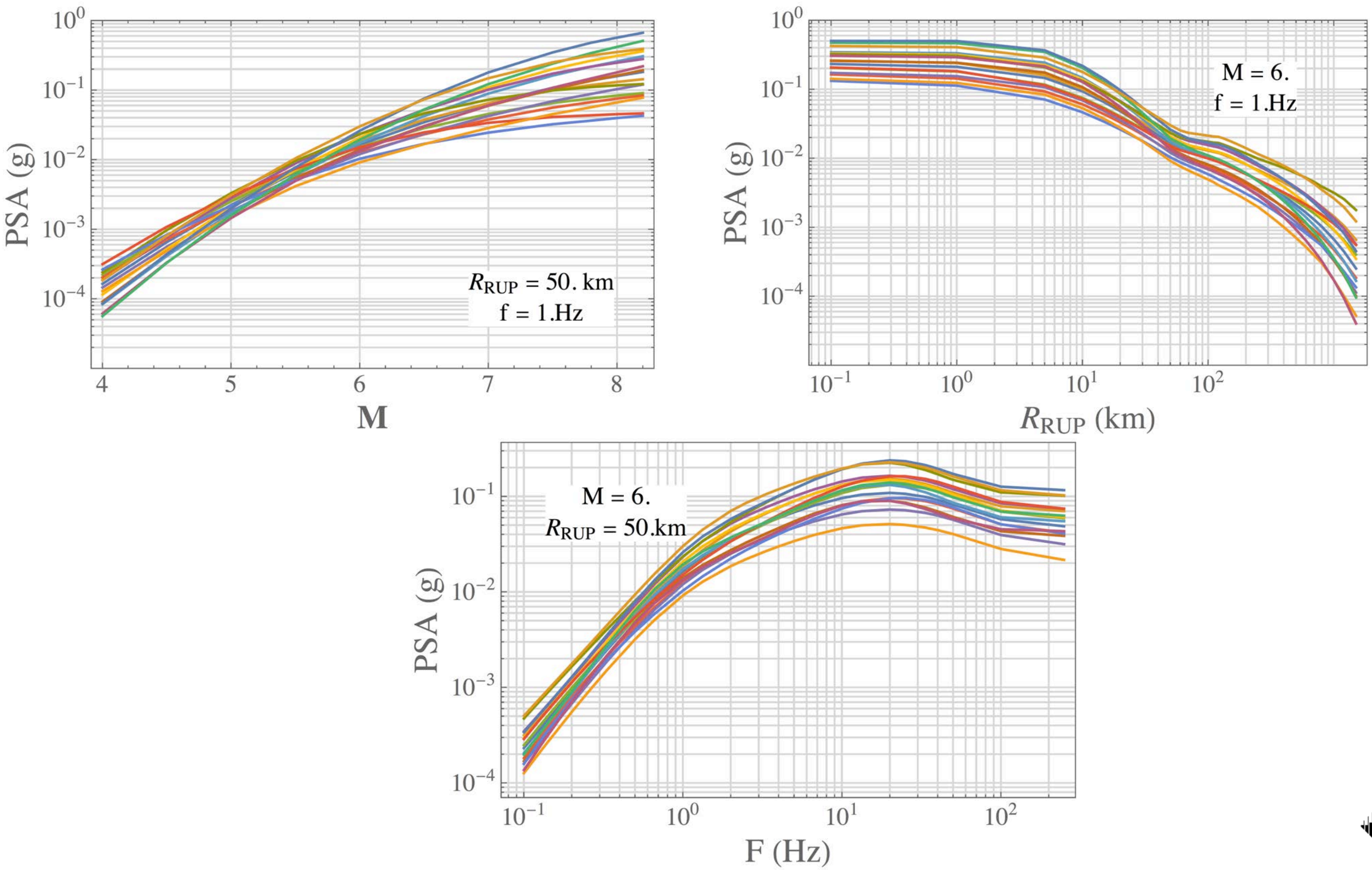
Sample Sammon's map space using ellipse with 17 cells





Sample result

- 17 GMMs, each representing one cell



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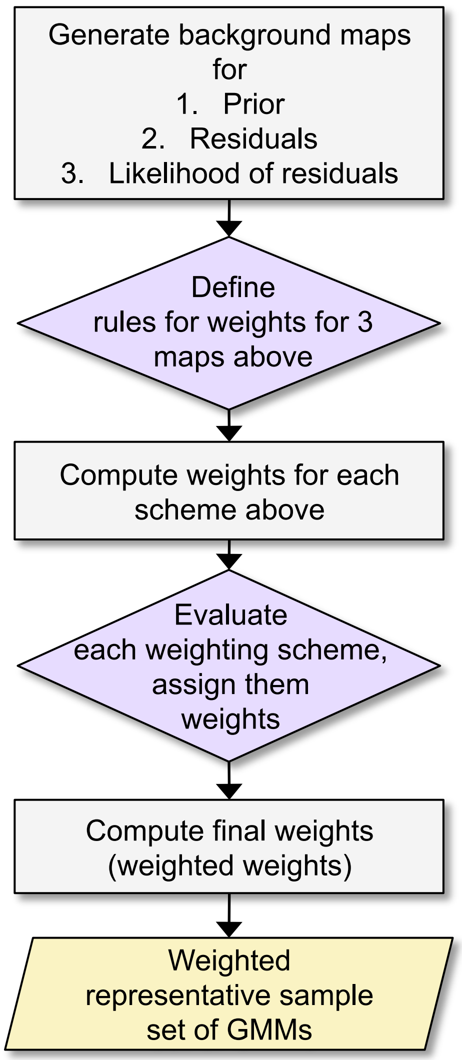
Median Ground Motions

5. Assign weights

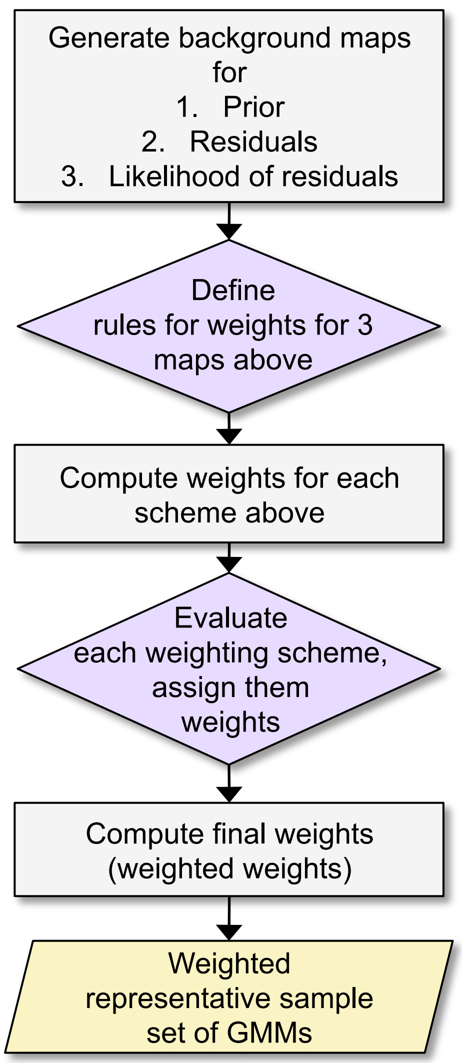


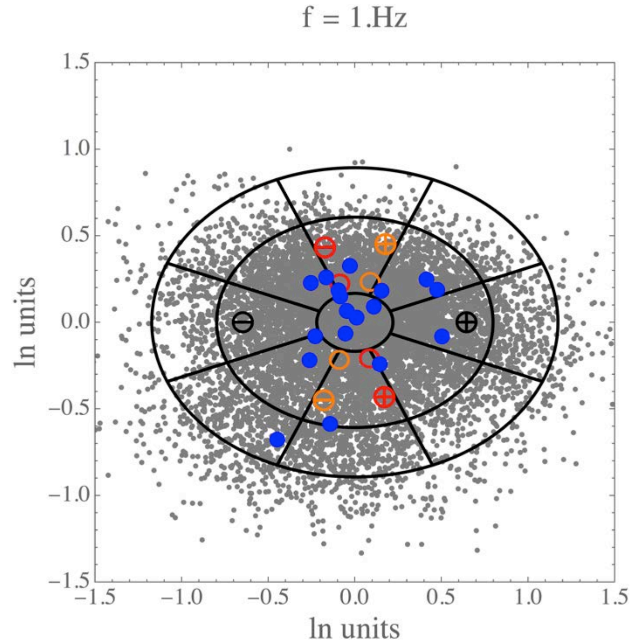
Weights

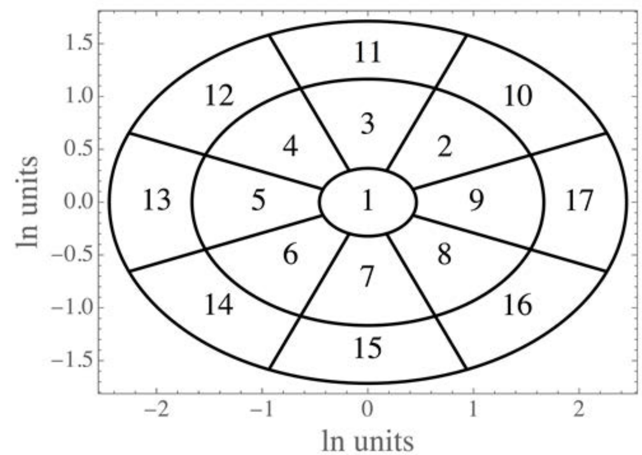
- Number of models in cell (Nsamples)
- Residuals (res)
- Likelihood (like)

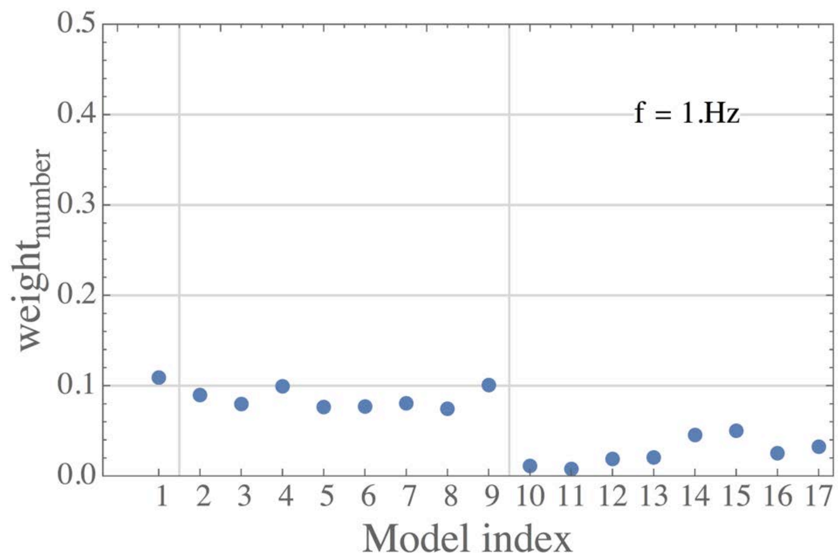
Median Ground Motions

5. Assign weights



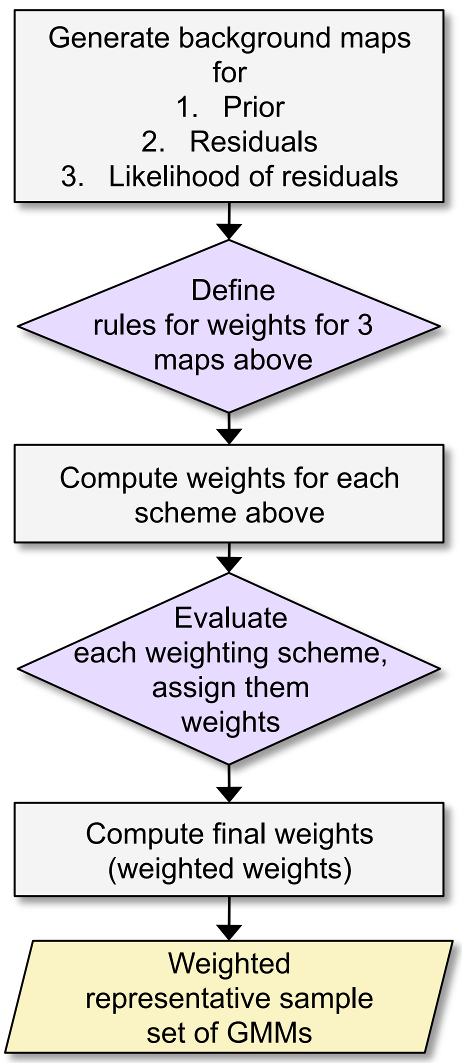


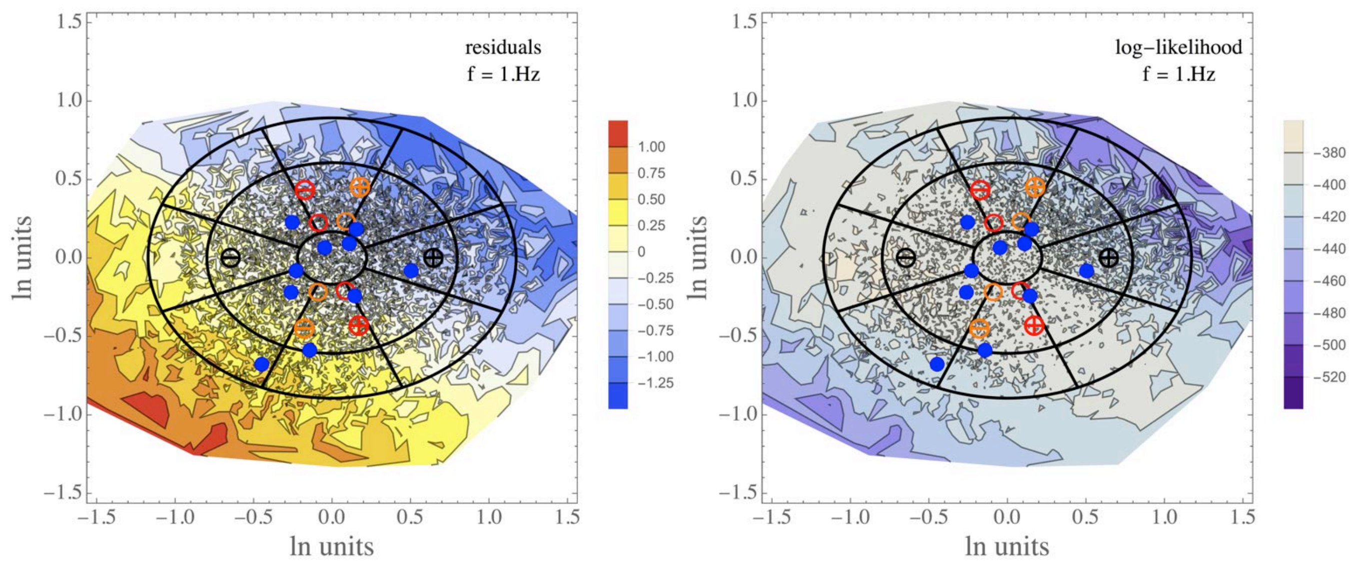


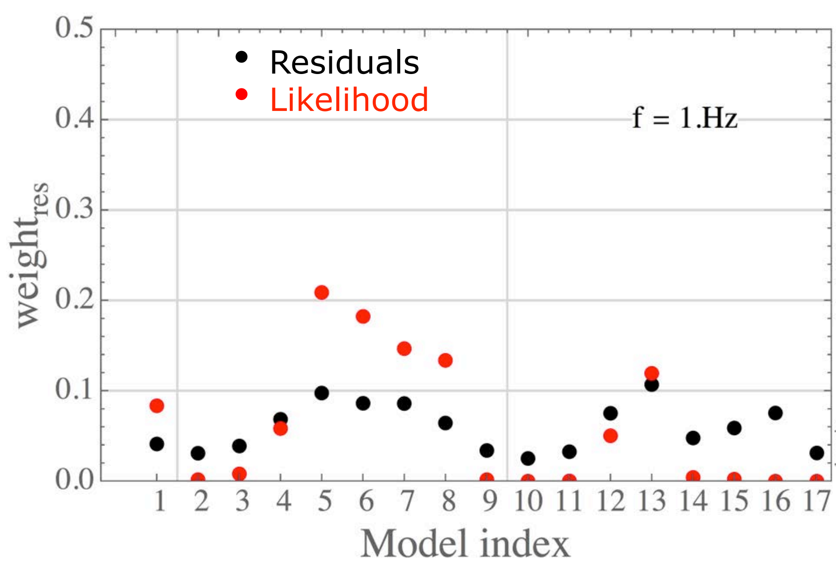


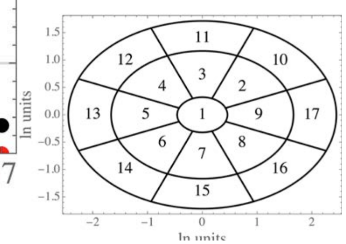
Median Ground Motions

5. Assign weights



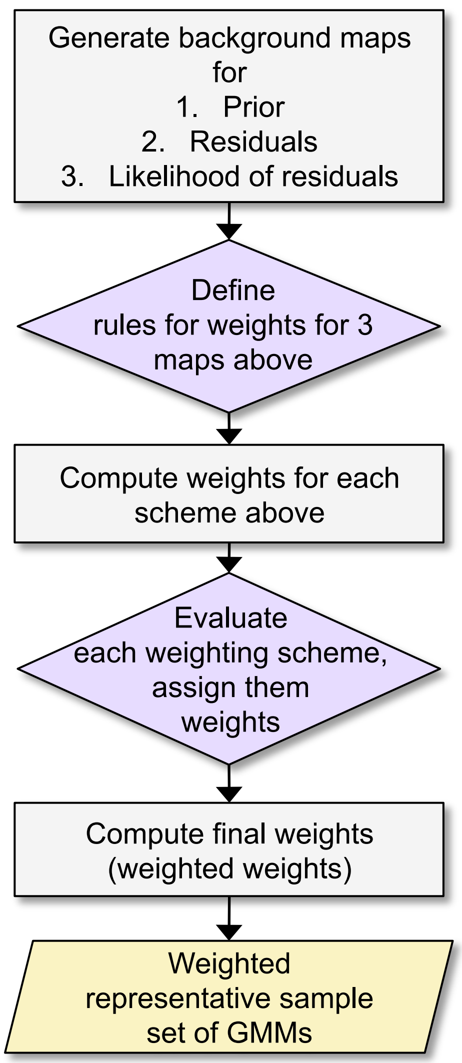






Median Ground Motions

5. Assign weights



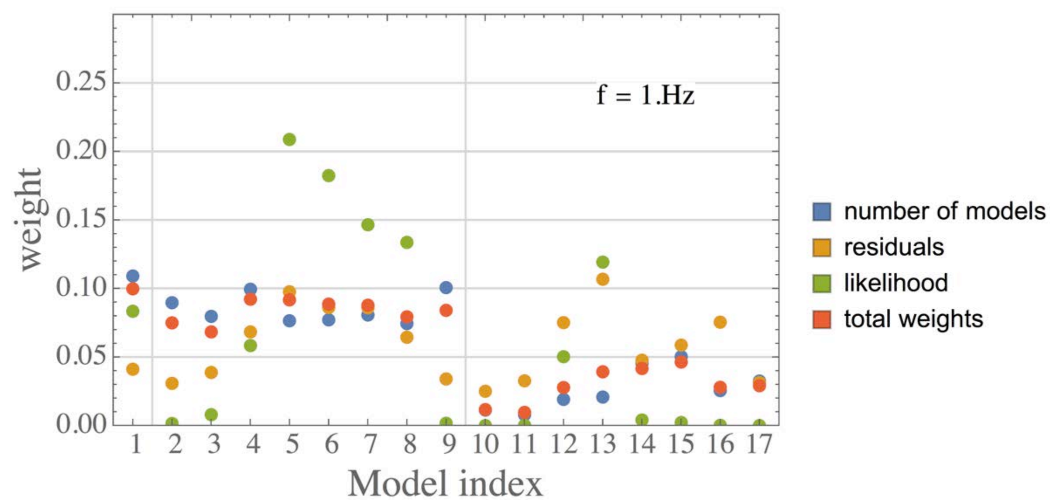
Final (weights on weights)

Within 1-10 Hz bandwidth:

- 80% for w(Nsamples)
- 10% for w(res)
- 10% for w(like)

Everywhere else:

- 100% to w(NSamples)



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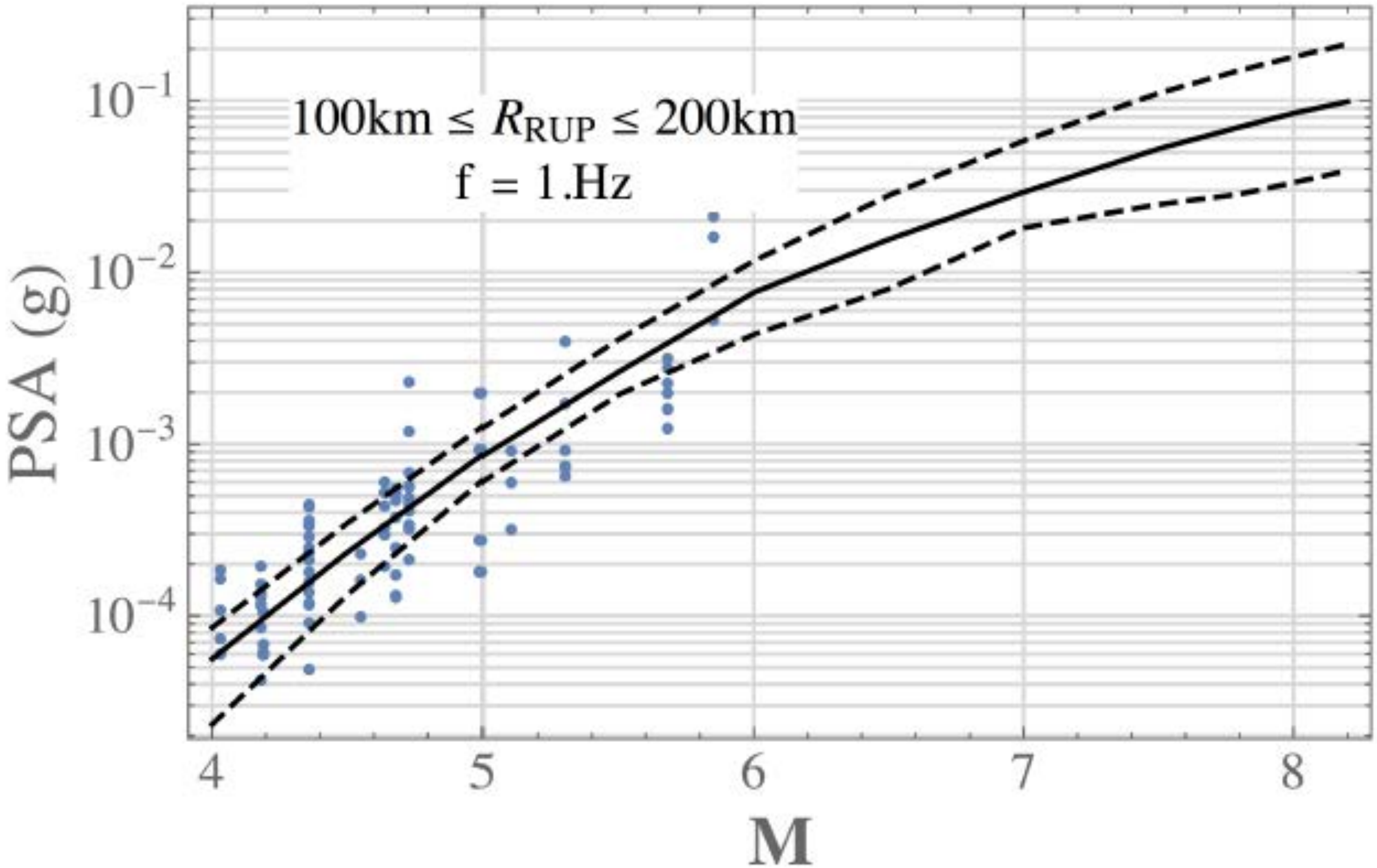
Sample result

- Scaling of 10th, 50th, and 90th fractiles of final GMM distribution compared with observations



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Sample result

- Scaling of 10th, 50th, and 90th fractiles of seeds and NGA-East models

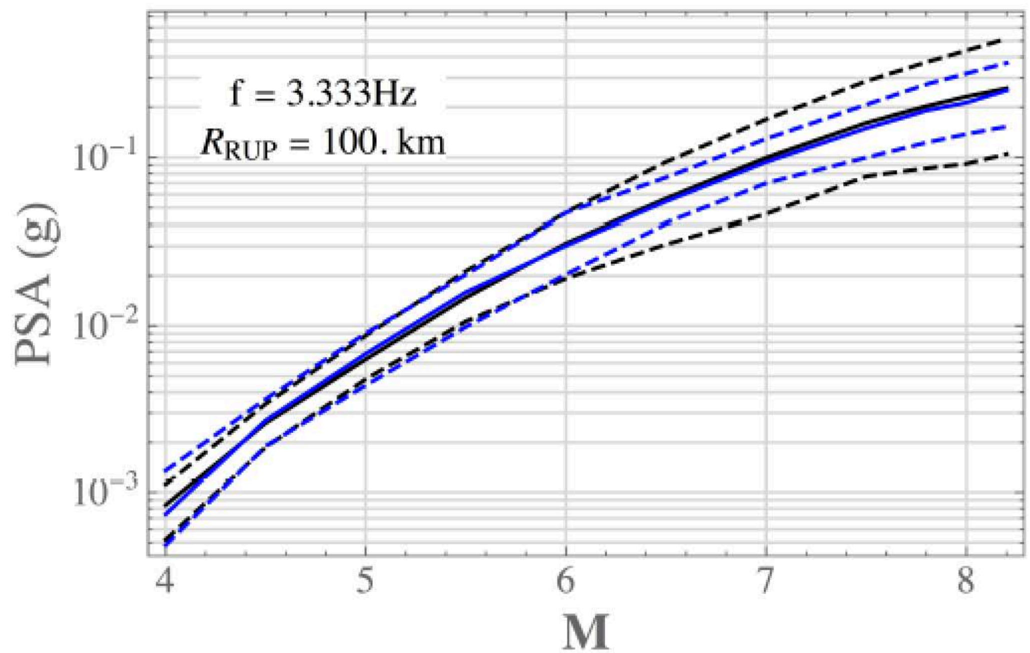

Figure 5182: 10%,50% and 90% fractiles of NGA-East GMMs (black) and seed models (blue), for $R_{RUP} = 100.$, and $f = 3.333\text{Hz}$

Sample result

- CDF of ground motions

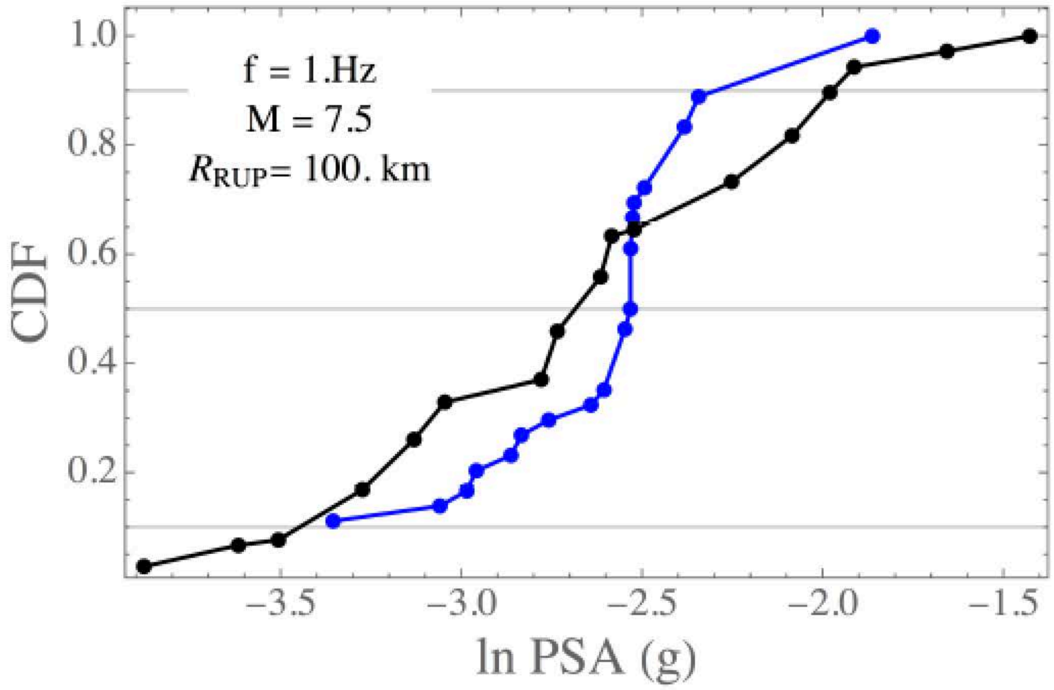

Figure 2355: Cumulative density function of NGA-East GMMs (black) and seed models (blue), for a scenario with $M = 7.5$, $R_{RUP} = 100.$, and $f = 1.$Hz

Standard deviation

$$\sigma = \sqrt{\phi_{SS}^2 + \phi_{S2S}^2 + \tau^2}$$

$$\sigma = \sqrt{\phi^2 + \tau^2}$$

- Model developed for partitioned residuals
  - Phi, Phi_{S2S}, Phi_{SS}, Tau
- Considered models from data-rich regions (NGA-West2, Japan) to extrapolate models to larger magnitude
- Phi_{S2S} also from NGA-East database
- Evaluated the models and assigned weights
- For USGS application, favored NGA-West2 based model (updated EPRI 2013)

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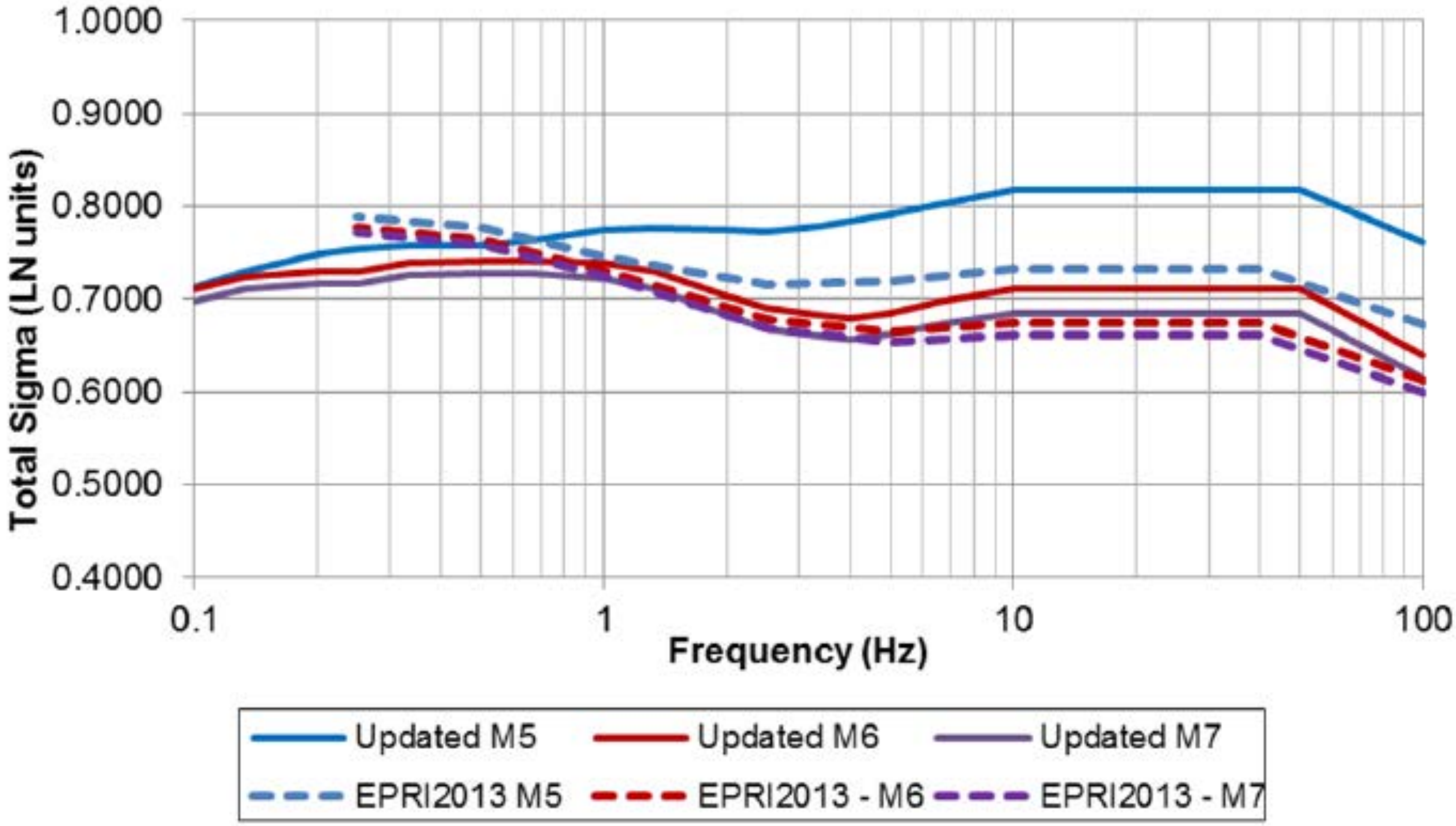
Recommended Sigma model

Based on final NGA-West2 models and updated relative to EPRI 2013.



GMC model summary

Median GMM logic tree applicable to CENA, **M**4-8.2, R_{RUP} up to 1,500 km

- CBR of the TDI in medians: 17 GMMs per frequency, provided in tables of **M**, R (no equations) for each PSA frequency, PGA and PGV
- The following models provided as “adjustments” to the 17 median GMMs
  - Source-depth adjustment factors that interface with CEUS SSC
  - Gulf Coast region adjustments

Use recommended ergodic sigma model for USGS applications

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Thank you…

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