Evaluation of GMSM Methods Results

Jennie Watson-Lamprey

November 17, 2006

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Objective

- To determine a basis for evaluation of ground motion selection and modification methods which will depend on the intended use of the time series.

Basis of Comparison

- Goal:
  - Develop a deterministic scenario that
    - Pushes the gmsm methods to extremes
    - Has time series available for selection
  - Develop different points of comparison for different intended uses
  - Develop a robust estimate of response to serve as the point of comparison

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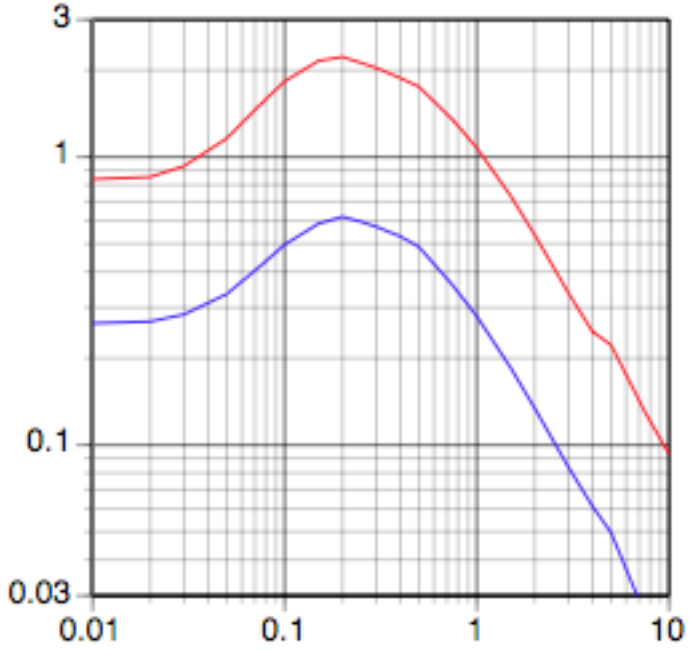
Deterministic Scenarios

- Campbell & Bozorgnia 2006
  - Mw 7
  - Rrup = 10km
  - Vs30 = 400 m/s
  - SS
  - Median random horizontal
  - 96-percentile random horizontal



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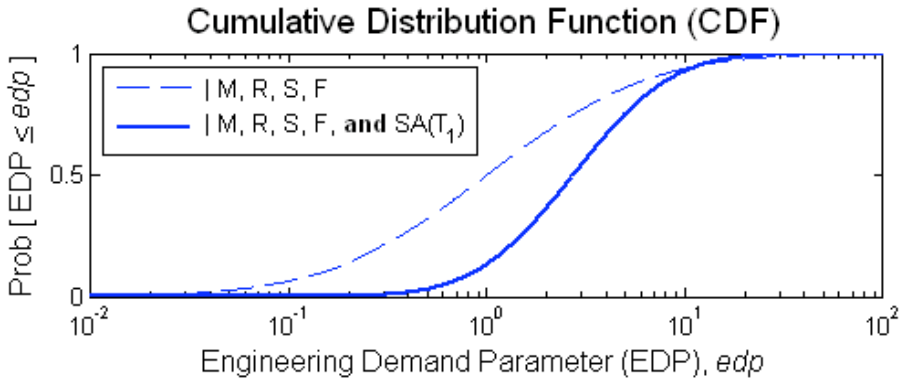
Response Measures -- Points of Comparison

- Presented by Nico Luco
  - Option 1 CDF | M, R, S, F
  - Option 2 Median | M, R, S, F
  - Option 3 CDF | M, R, S, F, Sa(T1)
  - Option 4 Median | M, R, S, F, Sa(T1)



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Calculating the Point of Comparison

- Time series from a bin of M, R
  - Should work for a median
  - Too much variability!
- Time series from a bin of M, R corrected for the difference between the recorded event and the design event
  - Not enough records to push the structure into the nonlinear range -> not a good estimator of rare response values

Calculating the Point of Comparison

- Current Method:
  - Run scaled and unscaled time series through a structural model
  - Perform a regression on a response parameter using time series properties (spectral acceleration)
  - Use predictive equations to define the joint distribution of the time series properties
  - Integrate the regression over the joint distribution
  - This gives a distribution of a response parameter

Method for Estimating Point of Comparison

1. A suite of records from Mw6.75-7.25, Rrup 0-20km events was developed. A total of 98 records were distributed to the group June 26th.
2. The suite is run through each model using scale factors of 1, 2, 4 and 8.
3. A model of the desired structural response parameter using properties of the input time series (e.g. $Sa(T_1)$, $Sa(2T_1)$, duration, etc.) is developed.

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Method for Estimating Point of Comparison

4. The EDP model is checked to ensure that there is no bias with scale factor.
   - This is only a test for the limited M,R range represented by the 98 selected recordings
5. Models for the record properties that affect response are developed using the full PEER database and correlations between properties.
6. Combining the models in step 5 gives the joint pdf of record properties
7. Using the joint pdf of record properties and the model for building response based on those record properties, the pdf of structural response for a M7, R_{rup}=10km earthquake is calculated.

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Initial Analysis Goals

- Simple test case
- Validate methodology
- Feedback from the community on our methodology
- Present initial comparisons so that improvements can be made

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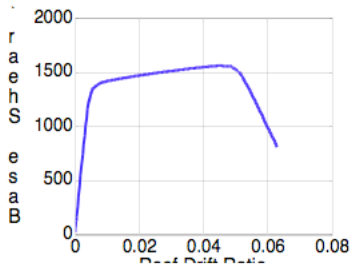
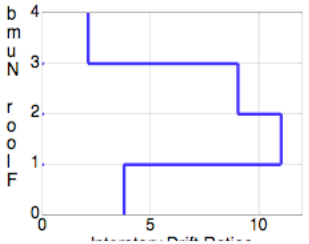
Initial Analysis Structural Model

- 4-story RC SMF
- Presented by Haselton

Summary of 4-story RC SMF Building

- Design base shear of 640 kips (9.2% of weight)
- Static overstrength of 2.3
- $T_1 - T_4$ (sec) = 0.97, 0.35, 0.18, 0.12
- Pushover roof drifts:
  - Yield: 0.5%
  - 20% strength loss: 5.2%





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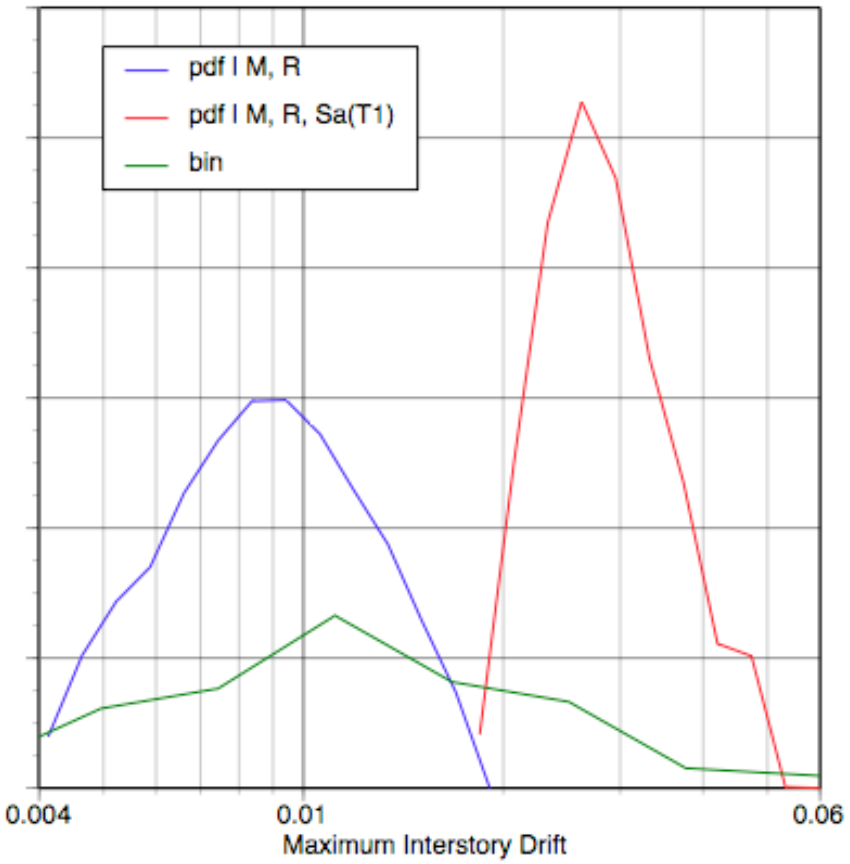
Initial Analysis
Point of Comparison

- Using maximum interstory drift ratio over all floors as the example response parameter
- Performed a regression analysis on response values to calculate the point of comparison

Point of Comparison



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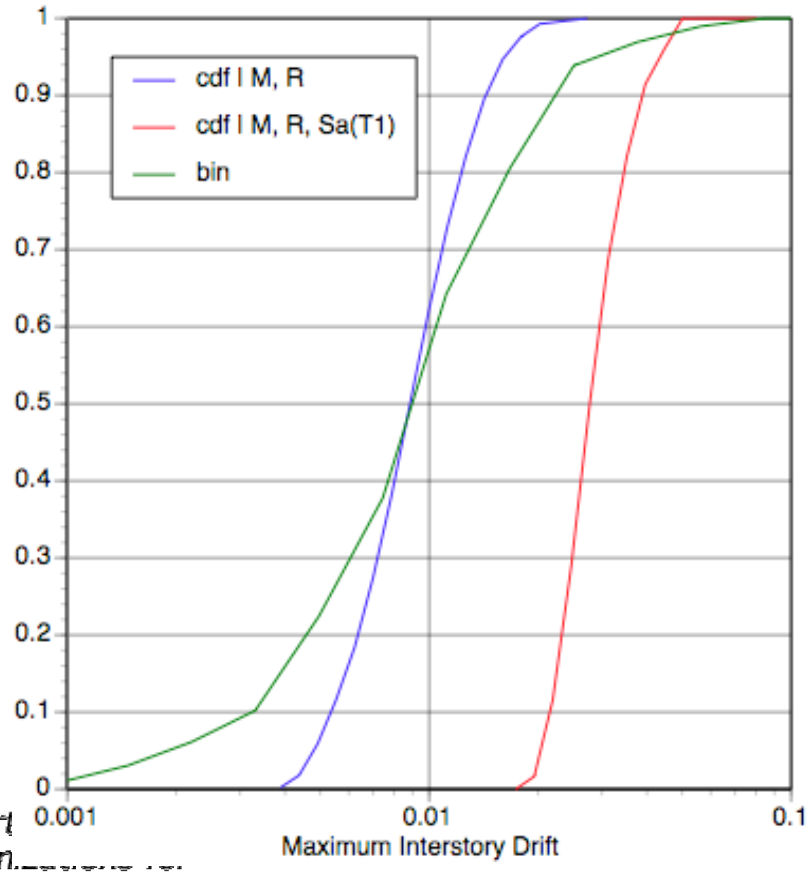
Point of Comparison



- Median MIDR | M, R
  - 0.89 %
- Median MIDR | M, R, Sa (T1)
  - 2.78 %

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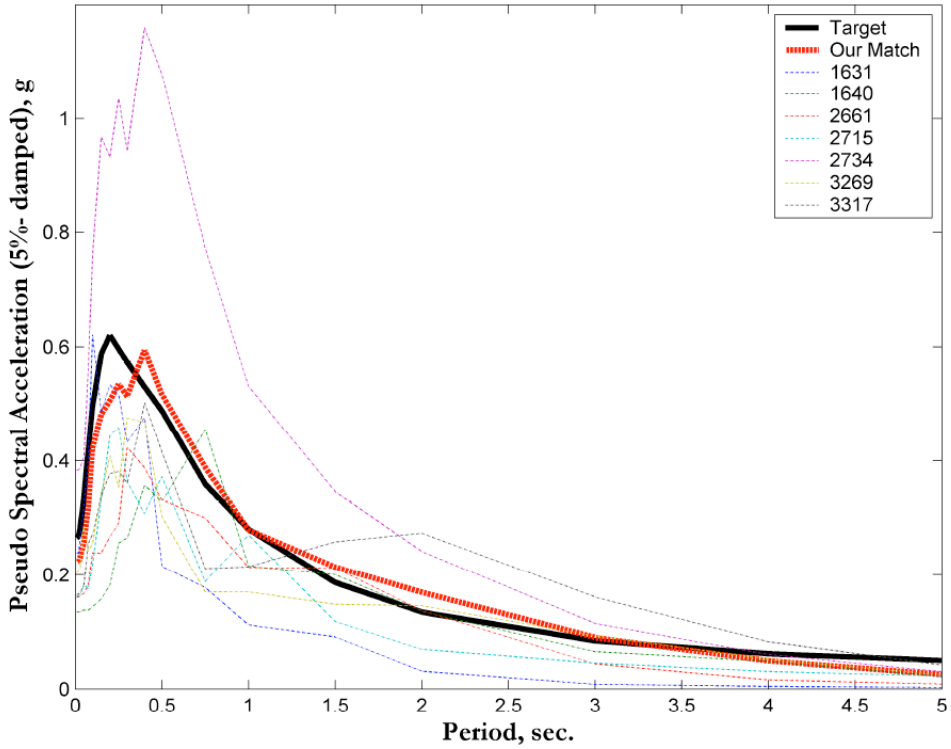
Initial Analysis
GMSM Methods

- Over 300 time series representing 15 GMSM methods



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Thank you to everyone who submitted suites of time series

- Arzhang Alimoradi
- Jack Baker
- Paolo Bazzurro
- Yousef Bozorgnia
- Allin Cornell
- Curt Haselton
- Charlie Kircher
- Albert Kottke
- Nico Luco
- Farzad Naiem
- Ellen Rathje
- Nilesh Shome
- Polsak Tothong
- Bob Youngs

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Initial Comparison Results

- Thanks to Christine Goulet for running the analyses

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Initial Comparison Results - Median

- Following figures:
  - Median estimates
  - Geometric mean of seven time series
  - The point of comparison is represented by a red line
  - Each method is shown with a different shape/color combination which is consistent across all the figures
  - No names are being shown

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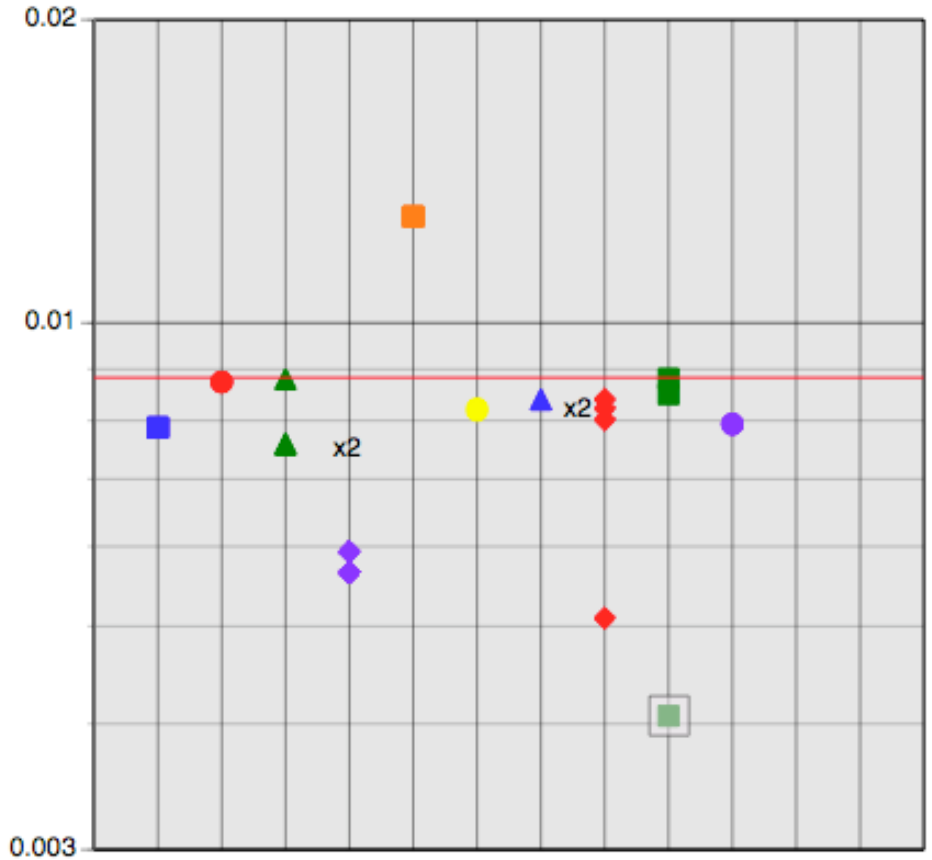
Median MIDR | M, R



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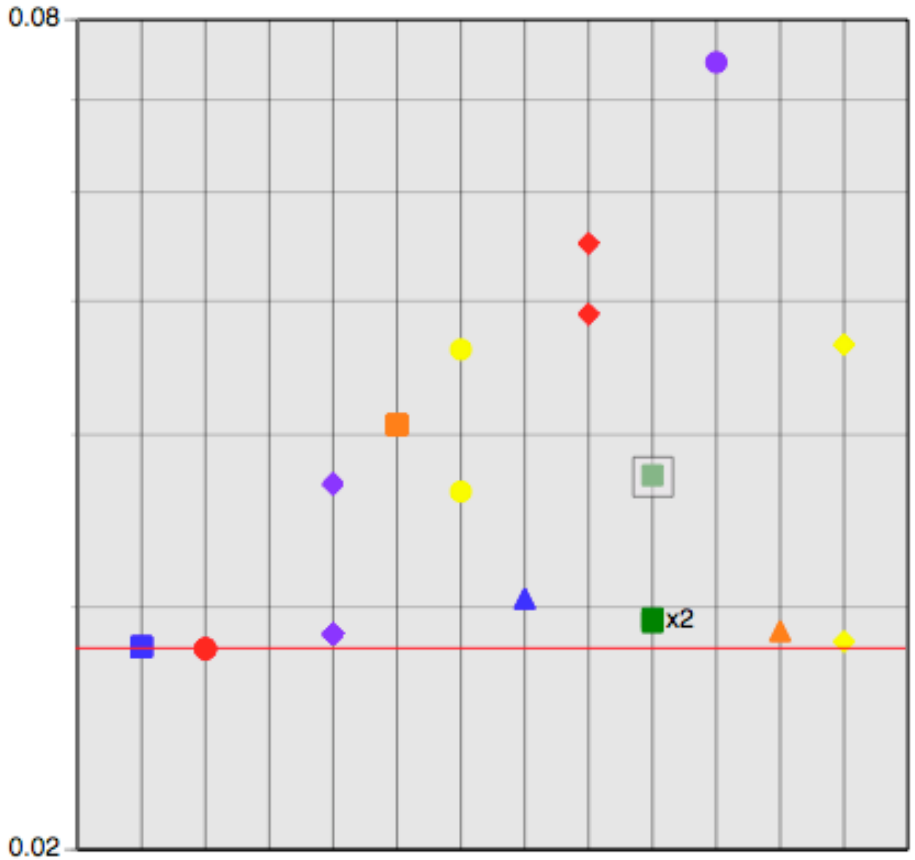
Median MIDR | M, R, Sa (2σ)



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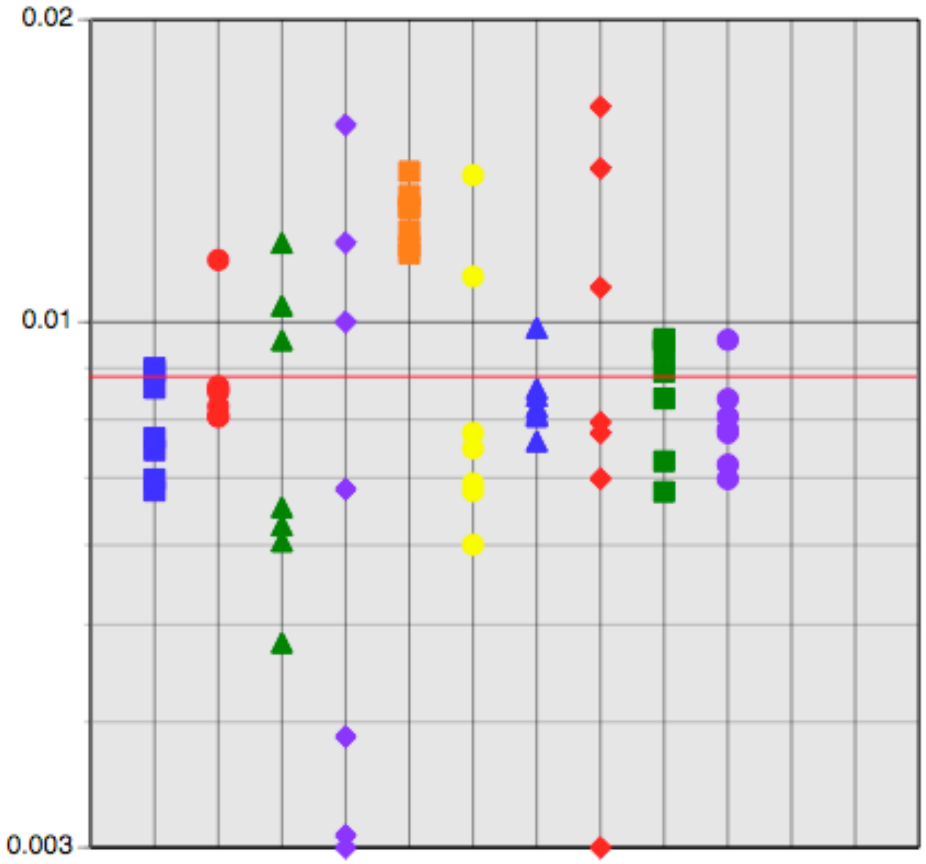
Initial Comparison Results - Median

- Following figures:
  - Median estimates
  - Response values for each of seven time series
  - The point of comparison is represented by a red line
  - Each method is shown with a different shape/color combination which is consistent across all the figures
  - No names are being shown

Median MIDR | M, R



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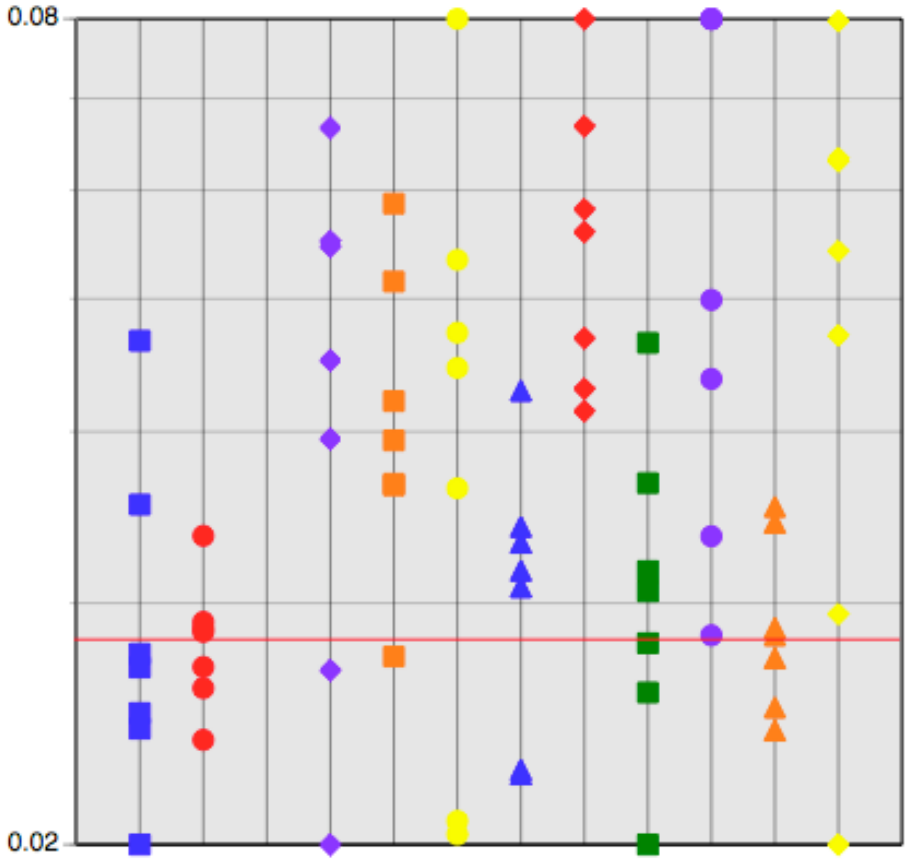
Median MIDR | M, R, Sa (2σ)



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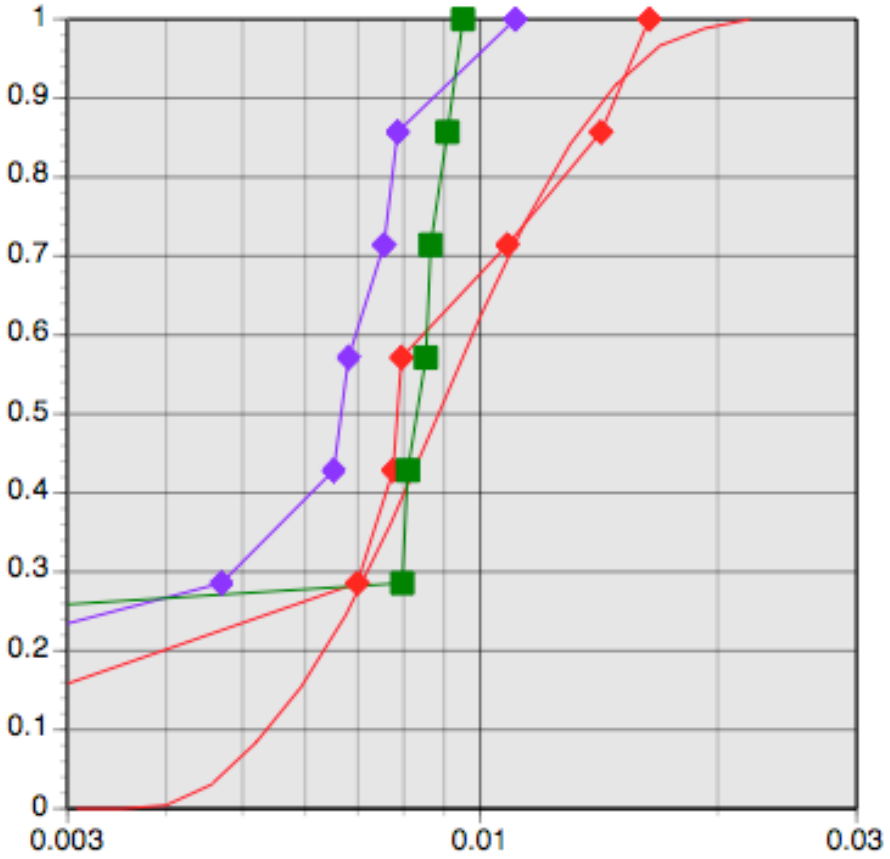
Initial Comparison Results - Distribution

- Following figures:
  - Cumulative distribution functions
  - Only those methods that are to estimate distribution
  - The point of comparison is represented by a red line
  - Each method is shown with a different shape/color combination which is consistent across all the figures
  - No names are being shown

cdf MIDR | M, R



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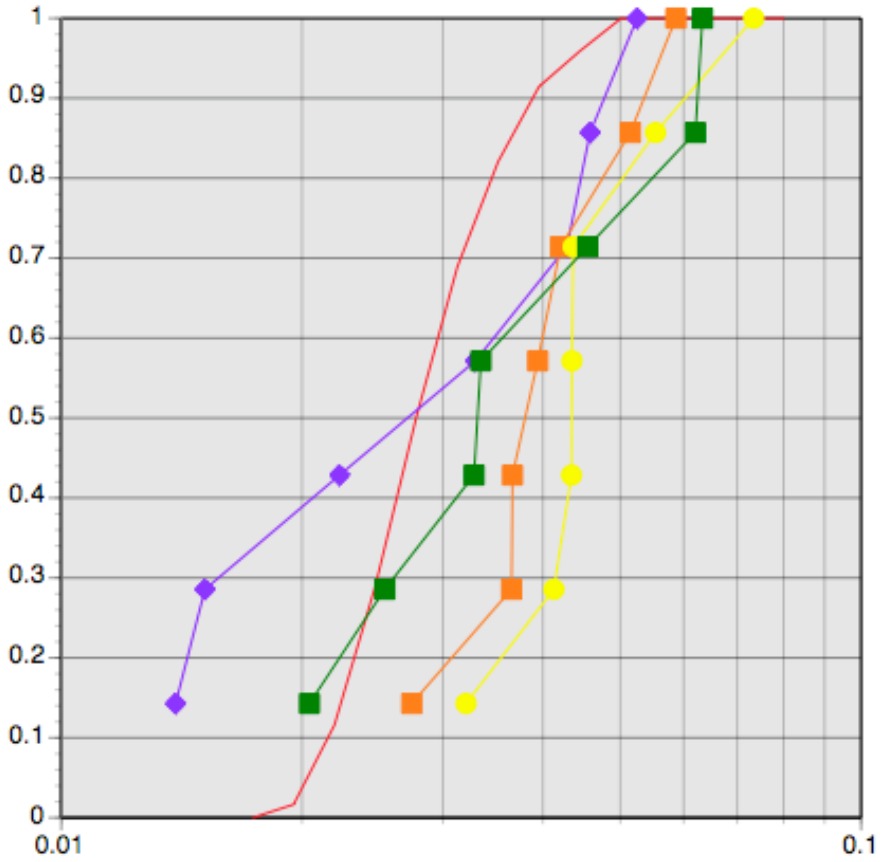
cdf MIDR | M, R, Sa (2σ)



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Evaluation of GMSM Methods

- There is a wide range in estimates of structural response even when the same parameter is estimated for the same structure using the same elastic response spectrum.
- We can divide the GMSM methods into broad categories to help us understand the results.

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Evaluation of GMSM Methods

- Category 1:
  - GMSM methods that use record properties that influence nonlinear response to select and modify
- Category 2:
  - GMSM methods that attempt to match an elastic response spectrum over a range

Evaluation of GMSM Methods

- Category 1:
  - Conditional Mean Spectrum - Baker
    - Spectral Shape - Shome
    - RASCAL - Bazzurro
  - Inelastic Proxy Response - Watson-Lamprey & Abrahamson
  - NIDD - Shantz

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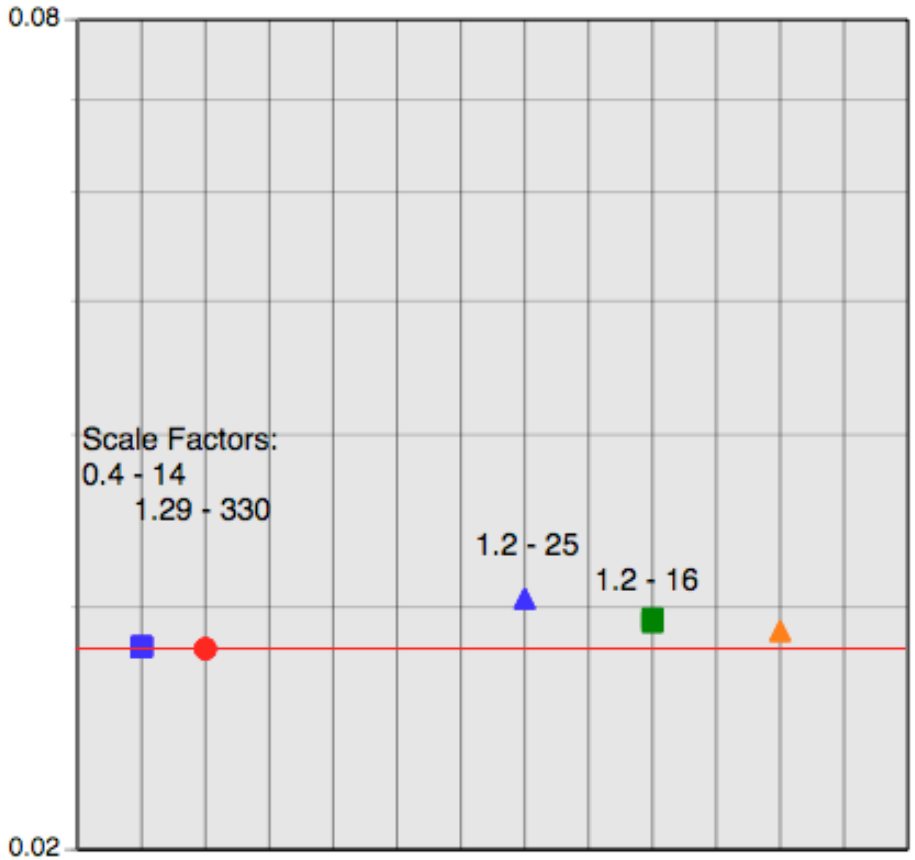
Median MIDR | M, R, Sa (2σ)



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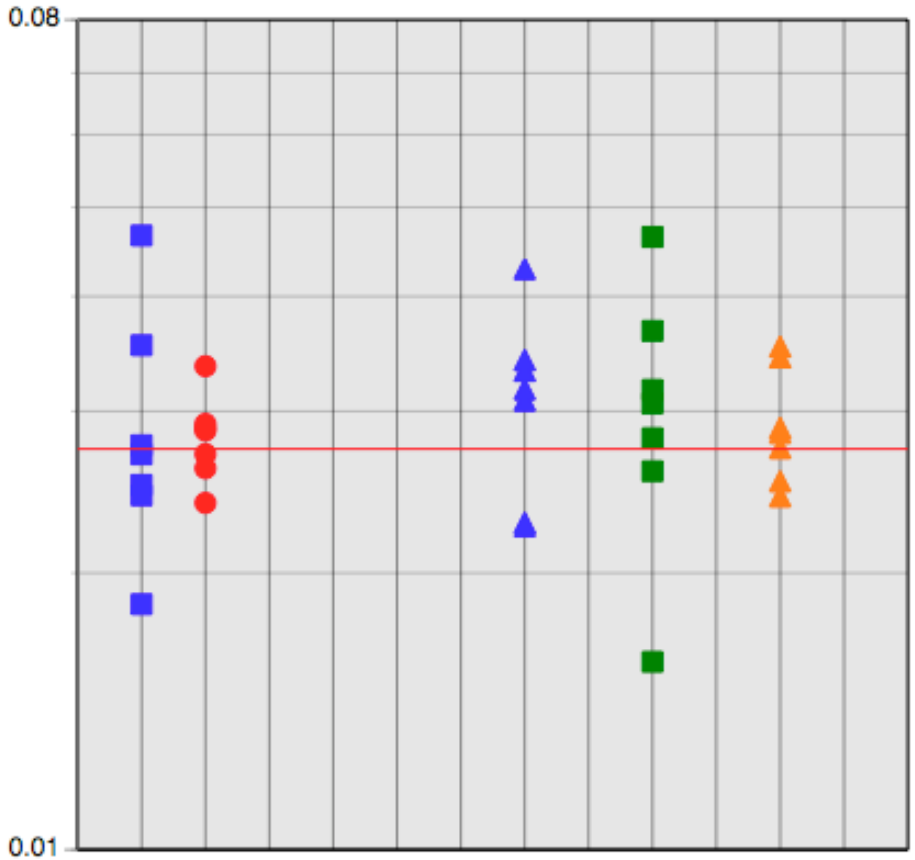
Median MIDR | M, R, Sa (2σ)



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Evaluation of GMSM Methods Category 1

- Generally closer to the point of comparison because they condition the record properties on the elastic spectral acceleration value
- Less variability between time series because they are selecting for median record properties
- Some methods are selecting for more properties, so their variability is even smaller
- Large scale factors can be used

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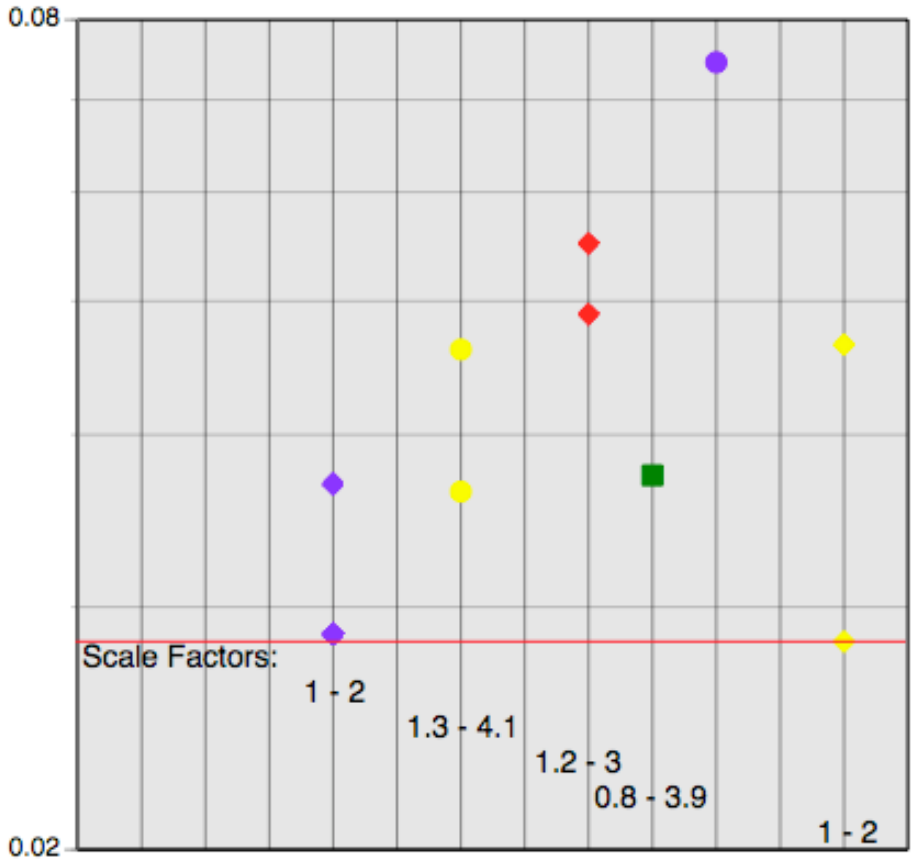
Evaluation of GMSM Methods

- Category 2:
  - Genetic Algorithm - Alimoradi & Naeim
  - Semi-Automatic Selection Procedure - Rathje & Kottke
  - DGML
  - RASCAL
  - Example

Median MIDR | M, R, Sa (2σ)



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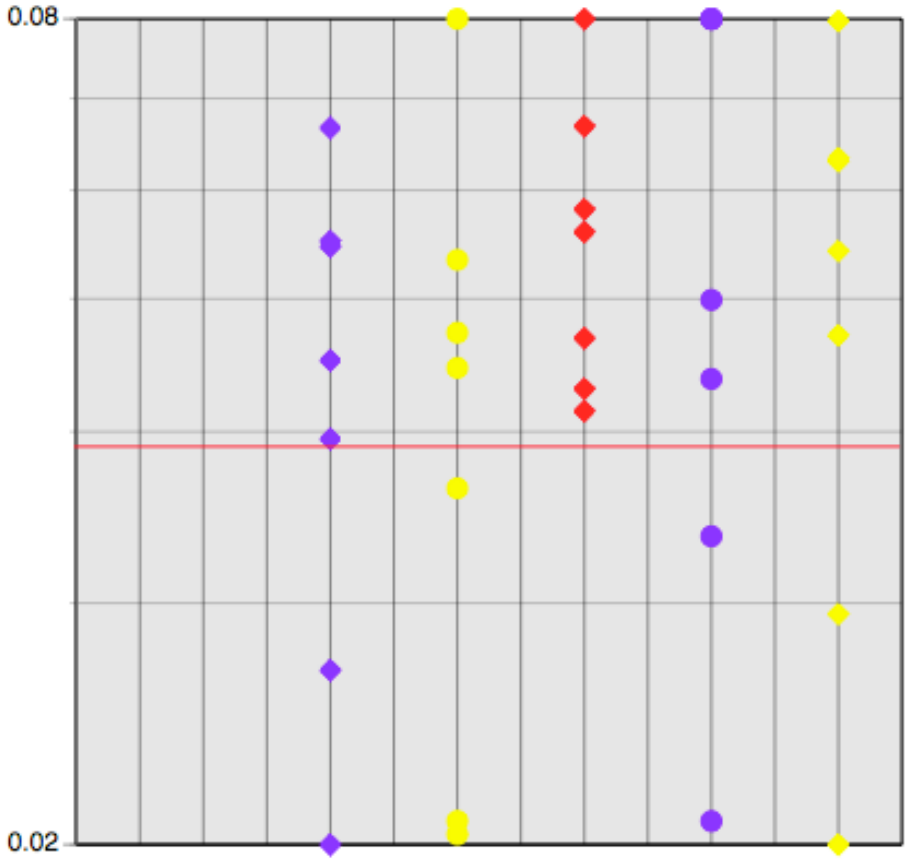
Median MIDR | M, R, Sa (2σ)



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Evaluation of GMSM Method Category 2

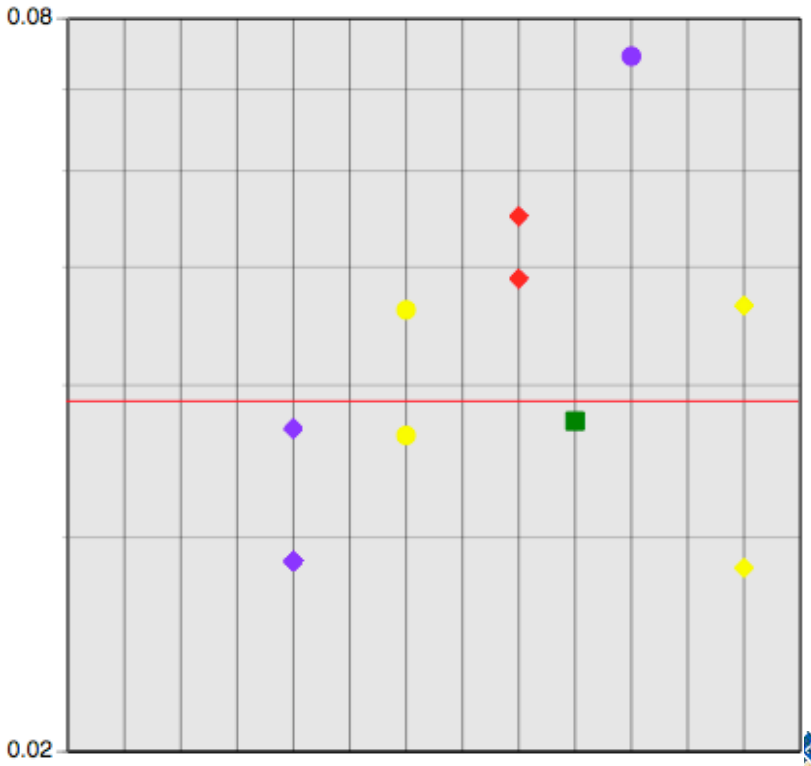
- Generally overestimate the point of comparison because they are not conditioning record properties on the elastic spectral acceleration value
- Greater variability between time series
- Less accurate at estimating median response values
- Small scale factors do not necessarily lead to accurate estimates of response

Conclusions

- There is a disconnect between what the engineer asks for and what the ground motion expert provides.

Conclusions

- Do not blindly use the deterministic elastic response spectrum.



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Conclusions

- Selecting time series based on record properties that affect nonlinear response leads to a decrease in variability and better estimates of response.
- Knowledge of structural characteristics helps ground motion experts select and modify time series.

Conclusions

- We need to be smarter about time series selection, and we are getting smarter.
- GMSM Working Group: Round 2
  - Updated deterministic scenarios
  - Three structural models
  - GMSM Methods ?
  - PEER.Berkeley.edu/GMSM
  - January 2007

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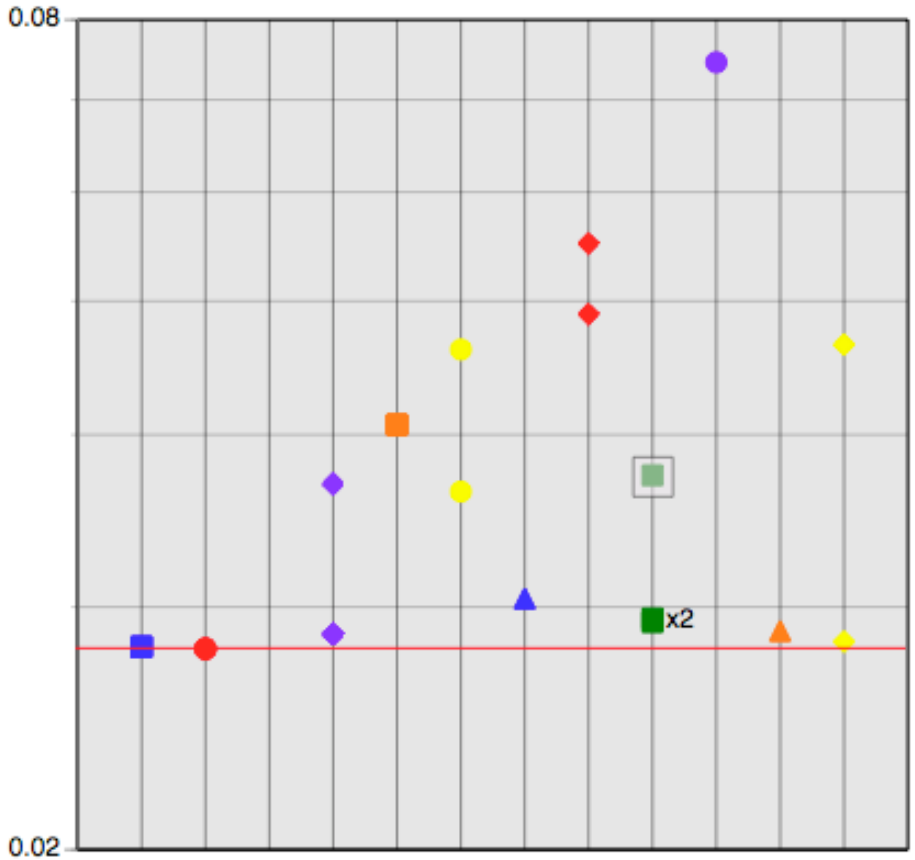
Thank You.



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Model of Maximum Interstory Drift

$$Drift^{0.2} = \begin{Bmatrix} 0.553 + 0.0321\ln(Sa_1) - 0.00476\ln(Sa_1)^2 \\ +0.0835\ln(Sa_2) + 0.01551\ln(Sa_2)^2 \\ +0.0199\ln(Sa_{0.4}) + 0.00041\ln(Sa_{0.4})^2 \end{Bmatrix} \qquad sigma = \begin{Bmatrix} if\ (Sa_1 < 0.4) \quad 0.016 \\ else \quad 0.016 + 0.0070 * \ln\left(\frac{Sa_1}{0.4}\right) \end{Bmatrix}$$

- Sa_1 = 0.6g
- sigma = 0.019
- median Drift = 0.015
- 84th percentile = 0.019, 16th percentile = 0.012
- 84th percentile = 27%, 16th percentile = 80%

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