Filling in for
“Record Selection Insights from the Study of Epsilon and Inelastic Displacements: Use with Deterministic Code Applications”
(C. Allin Cornell)

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Most appropriate definition of target?

1) Building code design response spectrum (+ M, R, etc.)?
2) Uniform Hazard Response Spectrum (UHRS)?
3) Sa(T1), deaggregated M, R, etc. ?
4) Sa(T1), deaggregated M, R, and $\varepsilon$, etc.?
5) Inelastic Spectral Displacement?

Different targets can lead to different recommendations for selection/scaling, some easier to apply than others.

Last year the focus was bias associated with scaling for Option #3, this year it’s #4, next year #5?

Same experiments need to be repeated for Option #1 (i.e., bias in nonlinear dynamic structural analysis induced by code procedures?)
Intra-Bin Scaling for Nonlinear Oscillator

"Near-Source" Bin, $T = 1s$, $R = 4$

Scaled/Unscaled $S_d (T, \zeta = 5\%, R, \alpha = 2\%)$

$SF = 0.1$
$SF = 2$

$Bias = 1.3$
$Bias = 0.4$

$Bias = a SF^b$
$a = 1.00$
$b = 0.38$
Intra-Bin Scaling for Nonlinear Oscillator

31 "Near-Source" Recordings

\[ S_a(T, \zeta = 5\%) \theta \]

Period, \(T\) [sec]
Intra-bin scaling results in term of $\theta_{\text{max}}$ for a Three-Story Frame Model (from Tothong & Cornell)
Does Using *Only* Higher Epsilon Records Reduce Inter-bin Scaling Bias?
(from Baker & Cornell)

Magnitude 7+/− Random Set  Wide M, R Range Set; Epsilon > 1.5 Only

1 Sec Bilinear Oscillator, R factor = 4
Consideration of Spectral Shape

- Considering not only the target $S_a(T_1)$ but also the “target spectral shape” …

Target $S_a = 2.0g$
Consideration of Spectral Shape

- and distinguishing the scaled earthquake records with spectral shapes “most similar” to the target ...
Consideration of Spectral Shape

- Little bias is induced, even at relatively large scale factors:

"Near-Source" Bin, $T=1s$, $R=4$
Consideration of Spectral Shape

- Little bias is induced, even at relatively large scale factors:
Setting $M_w$, $R_{close}$, $S_a(T_1)$, and Spectral Shape

2) The $M_w$ and $R_{close}$ that contribute most to the occurrence probability of the target $S_a(T_1)$ can then be found via “banded deaggregation” (a new USGS website):

Prob. Seismic Hazard Deaggregation
Monterey 121.90° W, 36.6 N.
0.3-s or 3.3-Hz SA 0.6 to 0.7 g

$M_w=7.9$, $R_{close}=42\text{km}$

Binning: DeltaR 10. km; deltaM=0.2; deltaa=0.25

2005 version USGS PSHA
3) With the “target” $M_w$ and $R_{close}$, the median spectral shape can be estimated via an empirical ground motion prediction equation:

San Andreas Scenario: $M_w = 7.9$, $R_{close} = 42$ km
Setting $M_w$, $R_{close}$, $S_a(T_1)$, and Spectral Shape

2) The $M_w$ and $R_{close}$ that contribute most to the occurrence probability of the target $S_a(T_1)$ can then be found via “banded deaggregation” (a new USGS website):

- $M_w = 7.9$, $R_{close} = 42\text{km}$, $\epsilon = 1.1$

Prob. Seismic Hazard Deaggregation
Monterey 121.90° W, 36.6 N.
0.3-s or 3.3-Hz SA 0.6 to 0.7 g

Binning: DeltaR 10 km; deltaM=0.2; deltae=0.25

2005 version USGS PSHA
4) With $M_w$, $R_{close}$, and $\varepsilon(T_1)$, the expected spectral shape that passes through $S_a(T_1)$ can be calculated:

\[
E[S_a(T) \mid \varepsilon(T_1)] = E[S_a(T)] + \rho[\varepsilon(T_1), \varepsilon(T)] \cdot \sigma[S_a(T)] \cdot \varepsilon(T_1)
\]

From, for example, Baker & Cornell (2005)
In short, it can be important to consider $\varepsilon(T_1)$ in addition to $M_w$ and $R_{\text{close}}$ in quantifying the expected (or target) spectral shape:

![Graph showing Spectral Acceleration, $S_a(T)$ vs. Period, $T$ for San Andreas and San Gregorio Scenarios. The graph includes two lines: one for San Andreas (Median) and one for San Andreas (Expected).]
2) The $M_w$ and $R_{close}$ that contribute most to the occurrence probability of the target $S_a(T_1)$ can then be found via “banded deaggregation” (a new USGS website):

Prob. Seismic Hazard Deaggregation
Monterey 121.90° W, 36.6 N.
0.3-s or 3.3-Hz SA 0.6 to 0.7 g
Mean Return Time of Occurrence O(1540) yrs

Cond. Mode $(R,M,e_g) = 42.1$ km, 7.9 1.08 (from peak R,M bin)

Binning: DeltaR 10. km; deltaM=0.2; deltae=0.25
In short, it can be important to consider $\varepsilon(T_1)$ in addition to $M_w$ and $R_{close}$ in quantifying the expected (or target) spectral shape:
More questions (without answers) …

- What about MDOF structures, and real multi-component ground motions? … vector hazard?
- Can we use “risk deaggregation” to defined target ground motion scenarios, even for building code applications?
Additional Slides …
Intra-Bin Scaling for Nonlinear Oscillator

Example …

- **Ground motion scenario**
  - $M_w = 6.5 - 6.9$, $R_{close} = 0 - 16$ km
  - Forward-directivity conditions
  - Strike-normal component
  - NEHRP C or D site classification
  - Shallow crustal event
  - Target $S_a = 2.0g$

- **Structure**
  - SDOF oscillator (e.g., bridge bent, 1-story building)
  - $T = 1$ sec, $\zeta = 5\%$
  - $R = 4$ (i.e., $F_y = \text{Target } S_a \times m / 4$)
  - Bilinear hysteretic behavior with $\alpha = 2\%$

"Near-Source" Scenario
Intra-Bin Scaling for Nonlinear Oscillator

Target $S_a = 2.0g$
Intra-Bin Scaling for Nonlinear Oscillator

31 "Near-Source" Recordings

\[ S_a(T, \zeta = 5\%) \] vs. Period, \( T \) [sec]
Intra-Bin Scaling for Nonlinear Oscillator

"Near-Source" Bin, $T = 1s$, $R = 4$

Scaled/Unscaled $S_d$ ($T, \zeta = 5\%$, $R, \alpha = 2\%$)
Intra-Bin Scaling for Nonlinear Oscillator

31 "Near-Source" Recordings

$S_a (T, \zeta = 5\%) [g]$ vs $T [sec]$

Target $S_a = 0.07g$
Intra-Bin Scaling for Nonlinear Oscillator

31 "Near-Source" Recordings

\[ S_a (T, \zeta = 5\%) \]

\[ S_a \] vs. Period, \( T \) [sec]
Intra-Bin Scaling for Nonlinear Oscillator

"Near-Source" Bin, $T = 1s$, $R = 4$
Intra-Bin Scaling for Nonlinear Oscillator

"Near-Source" Bin, $T = 1\text{s}$, $R = 4$

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