Generic Shapes for Probabilistic MPRS (Multi-Period Response Spectrum)

Building Seismic Safety Council (BSSC) Provisions Update Committee (PUC) Meeting

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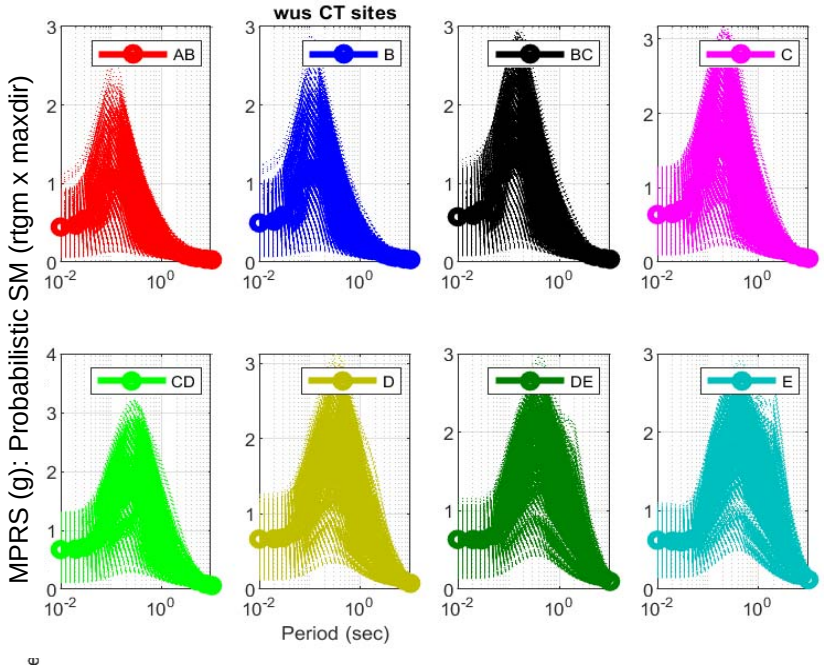
P hwkrgrorj |

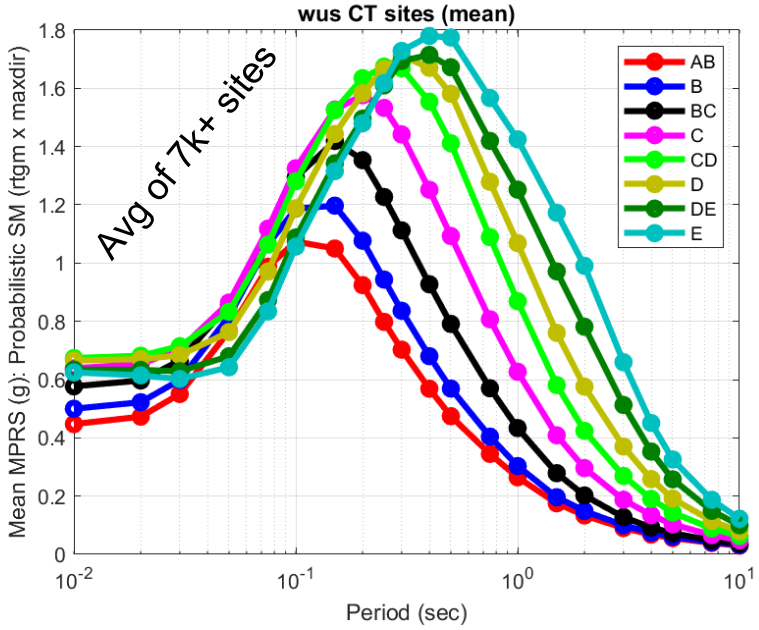
Develop generic response spectrum shapes based on WUS data to use in other regions (AK, HI, GU&AS, PRVI) where only Ss & S1 values are available, until USGS develops multi-period models for each region.

WUS data: more than 7k Census Track sites in CA, OR, WA, ID, NV (Ss & S1 both controlled probabilistically)

Example figure for demonstration only:

Key: develop proper bins for sites with similar hazard





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- TL = 16s, 12s, 8s, 6s(ID,NV), 6s(Puget Sound WA)
- Four Ss groups:
- Four Rs groups:

3.5 < Rs
2.5 < Rs < 3.5
Rs = 2.5
Rs < 2.5

	Ss<=0.5		0.5<Ss<1.5			1.5<=Ss<=2.0			2.0<Ss	
Rs=Ss/S1	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
S1	0.25	0.5	0.75	1	1.25	**1.5**	1.75	2	2.25	2.5
0.1	2.5	5.0	7.5	0.0	0.0	0.0	0.0	[illegible]	0.0	0.0
0.2	1.3	2.5	3.8	5.0	0.0	0.0	0.0	[illegible]	0.0	0.0
0.3	0.0	1.7	2.5	3.3	4.2	0.0	0.0	0.0	[illegible]	0.0
0.4	0.0	0.0	1.9	2.5	3.1	3.8	0.0	0.0	0.0	[illegible]
0.5	0.0	0.0	0.0	2.0	2.5	3.0	3.5	0.0	0.0	[illegible]
0.6	0.0	0.0	0.0	0.0	2.1	**2.5**	2.9	3.3	0.0	0.0
0.7	0.0	[illegible]	0.0	0.0	0.0	2.1	2.5	2.9	3.2	0.0
0.8	0.0	0.0	[illegible]	0.0	0.0	0.0	2.2	2.5	2.8	3.1
0.9	0.0	0.0	[illegible]	0.0	0.0	0.0	0.0	2.2	2.5	2.8
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.5

Impractical Combinations

Impractical Combinations

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- Number of sample sites in each cell for TL=16s (weight by number of sites in each cell):

TL	Number of Census Tract Sample Sites as a Function of SS and S1 for TL Region (and Number of Sample Sets)										
16	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
S1	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	All
0.1	111	34	0	0	0	0	0	0	0	0	145
0.2	0	112	0	0	0	0	0	0	0	0	112
0.3	0	0	105	62	0	0	0	0	0	0	167
0.4	0	0	107	469	51	0	0	0	0	0	627
0.5	0	0	0	25	10	54	7	0	0	0	96
0.6	0	0	0	0	0	5	15	0	0	0	20
0.7	0	0	0	0	0	15	12	0	0	0	27
0.8	0	0	0	0	0	0	6	0	0	0	6
0.9	0	0	0	0	0	0	0	0	2	0	2
1	0	0	0	0	0	0	0	0	0	0	0

Note: for the PNW, not many data for very strong shaking cells

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- Number of sample sites in each cell for TL=12s (weight by number of sites in each cell):

TL	Number of Census Tract Sample Sites as a Function of SS and S1 for TL Region (and Number of Sample Sets)										
12	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
S1	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	All
0.1	0	0	0	0	0	0	0	0	0	0	0
0.2	0	437	234	0	0	0	0	0	0	0	671
0.3	0	0	189	92	0	0	0	0	0	0	281
0.4	0	0	0	0	34	0	0	0	0	0	34
0.5	0	0	0	0	7	43	4	0	0	0	54
0.6	0	0	0	0	0	4	28	19	0	0	51
0.7	0	0	0	0	0	0	0	14	14	0	28
0.8	0	0	0	0	0	0	0	0	2	2	4
0.9	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0

San Mateo example (deterministic)

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- Number of sample sites in each cell for TL=8s (weight by number of sites in each cell):

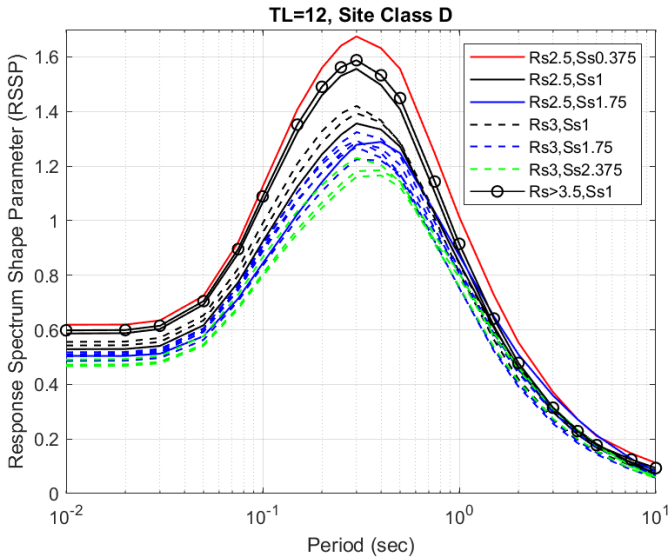
TL	Number of Census Tract Sample Sites as a Function of SS and S1 for TL Region (and Number of Sample Sets)										
8	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
S1	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	All
0.1	4	0	0	0	0	0	0	0	0	0	4
0.2	0	0	0	0	0	0	0	0	0	0	0
0.3	0	0	96	301	14	0	0	0	0	0	411
0.4	0	0	0	23	283	142	0	0	0	0	448
0.5	0	0	0	0	0	393	222	0	0	0	615
0.6	0	0	0	0	0	0	399	731	0	0	1130
0.7	0	0	0	0	0	0	0	197	551	0	748
0.8	0	0	0	0	0	0	0	0	14	57	71
0.9	0	0	0	0	0	0	0	0	0	12	12
1	0	0	0	0	0	0	0	0	0	0	0

Los Angeles example (probabilistic)

Iqixhqfh#ri#Vv dqg#Uv

Response Spectrum Shape Parameters (RSSP) = Normalized MPRS by Ss

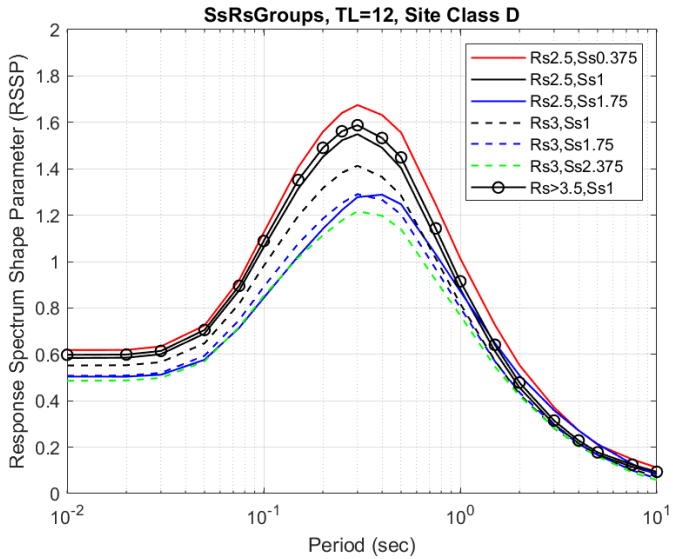
Example RSSP for each cell:



same color = same Ss
same line type = same Rs

Weighted average based on the number of sites in each cell:

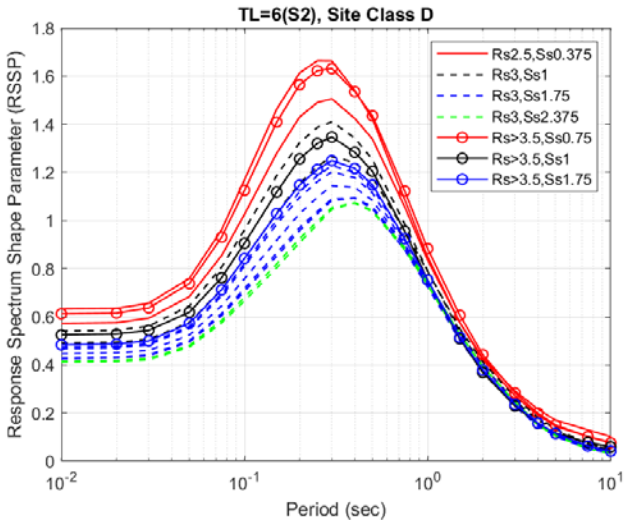
Example RSSP (given TL, Ss, Rs):



Iqixhqfh#ri#Vv dqg#Uv

Response Spectrum Shape Parameters (RSSP) = Normalized MPRS by Ss

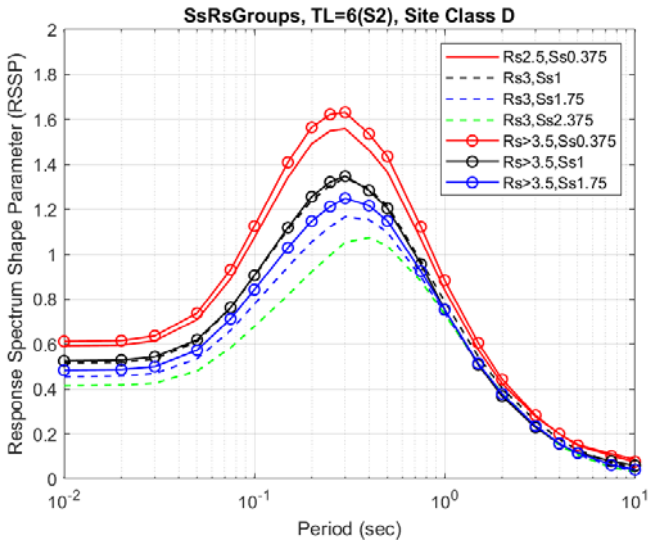
Example RSSP for each cell:



same color = same Ss
same line type = same Rs

Weighted average based on the number of sites in each cell:

Example RSSP (given TL, Ss, Rs):



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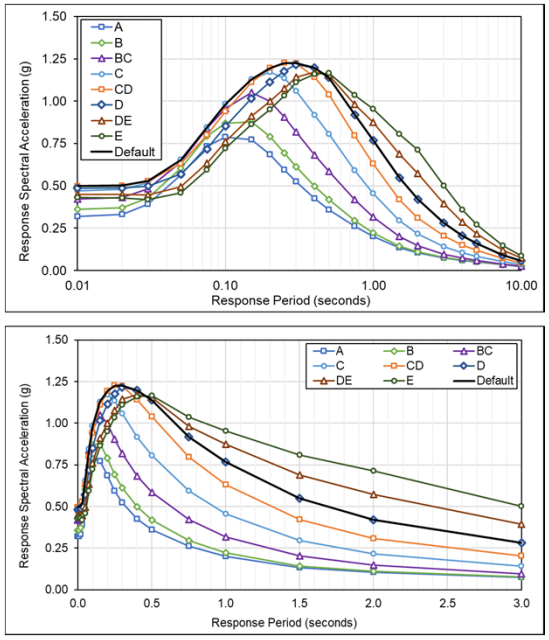
- Example application to a site for which we have the “true” MPRS.

TL=12s, Ss=2.36g, Rs=2.69 (S1=0.88g)

- Selected RSSP (i.e., generic shape):

load('RSSP-G12Rs2535Ss4.mat') size: 18

Ss>2.0 & Rs=[2.5,3.5]								
T, sec	**AB**	**B**	**BC**	**C**	**CD**	**D**	**DE**	**E**
0	0.319	0.358	0.419	0.469	0.496	0.483	0.447	0.428
0.01	0.321	0.360	0.421	0.472	0.499	0.486	0.450	0.432
0.02	0.332	0.372	0.431	0.479	0.502	0.488	0.450	0.427
0.03	0.392	0.430	0.484	0.518	0.528	0.498	0.446	0.418
0.05	0.565	0.604	0.641	0.654	0.631	0.570	0.496	0.460
0.075	0.734	0.793	0.841	0.846	0.801	0.718	0.632	0.595
0.1	0.787	0.870	0.958	0.984	0.940	0.852	0.760	0.722
0.15	0.773	0.878	1.050	1.129	1.110	1.018	0.911	0.865
0.2	0.685	0.791	**1.000**	1.171	1.194	1.113	1.000	0.951
0.25	0.595	0.693	0.905	1.136	1.226	1.177	1.076	1.032
0.3	0.524	0.613	0.818	1.059	1.224	1.217	1.143	1.111
0.4	0.426	0.498	0.681	0.917	1.141	1.197	1.173	1.161
0.5	0.359	0.419	0.585	0.805	1.038	1.139	1.153	1.165
0.75	0.261	0.296	0.420	0.593	0.797	0.919	0.982	1.036
1	0.201	0.221	**0.317**	0.457	0.631	0.768	0.874	0.955
1.5	0.134	0.143	0.203	0.296	0.420	0.548	0.689	0.807
2	0.104	0.110	0.148	0.215	0.309	0.421	0.572	0.712
3	0.074	0.078	0.097	0.141	0.204	0.283	0.395	0.501
4	0.059	0.062	0.074	0.106	0.151	0.207	0.285	0.359
5	0.050	0.053	0.060	0.085	0.119	0.160	0.217	0.270
7.5	0.035	0.036	0.039	0.052	0.070	0.092	0.120	0.147
10	0.025	0.025	0.027	0.035	0.046	0.058	0.073	0.087



Note: This site is deterministically controlled (unusually large gms).

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- Example application to a site for which we have the “true” MPRS.

TL=12s, Ss=2.36g, Rs=2.69 (S1=0.88g)

- Short-Period MPRS (Scaled RSSP):

Generic Shape x (Prob Ss=2.358)

T, sec	AB	B	BC	C	CD	D	DE	E
0	0.752	0.845	0.988	1.107	1.170	1.138	1.053	1.010
0.01	0.756	0.850	0.993	1.113	1.177	1.146	1.062	1.020
0.02	0.784	0.877	1.017	1.129	1.183	1.150	1.060	1.008
0.03	0.924	1.013	1.140	1.222	1.245	1.175	1.052	0.986
0.05	1.331	1.425	1.511	1.542	1.487	1.343	1.170	1.084
0.075	1.732	1.870	1.982	1.996	1.888	1.694	1.491	1.403
0.1	1.855	2.052	2.260	2.321	2.217	2.008	1.792	1.703
0.15	1.822	2.069	2.476	2.663	2.617	2.399	2.149	2.039
0.2	1.616	1.866	2.358	2.762	2.817	2.625	2.357	2.242
0.25	1.403	1.635	2.135	2.678	2.891	2.776	2.538	2.434
0.3	1.236	1.445	1.929	2.498	2.887	2.869	2.695	2.619
0.4	1.004	1.174	1.607	2.161	2.691	2.823	2.766	2.737
0.5	0.846	0.988	1.379	1.899	2.448	2.686	2.719	2.748
0.75	0.616	0.699	0.991	1.398	1.878	2.168	2.315	2.443
1	0.474	0.522	0.748	1.077	1.489	1.811	2.061	2.252
1.5	0.315	0.337	0.478	0.697	0.991	1.291	1.626	1.904
2	0.244	0.260	0.349	0.508	0.729	0.993	1.350	1.679
3	0.174	0.184	0.229	0.334	0.481	0.668	0.932	1.181
4	0.139	0.146	0.173	0.250	0.356	0.488	0.673	0.846
5	0.119	0.124	0.141	0.200	0.279	0.377	0.511	0.636
7.5	0.082	0.084	0.091	0.123	0.166	0.217	0.284	0.346
10	0.058	0.059	0.063	0.083	0.108	0.136	0.173	0.205
Tamax	0.2	0.2	0.2	0.2	0.25	0.3	0.4	0.5

- Long-Period MPRS (Scaled RSSP):

Generic Shape / (S1 from RSSP=0.317) x (Prob S1=0.877)

T, sec	AB	B	BC	C	CD	D	DE	E
0	0.882	0.991	1.159	1.299	1.373	1.335	1.236	1.185
0.01	0.887	0.997	1.165	1.306	1.381	1.345	1.246	1.196
0.02	0.919	1.029	1.193	1.324	1.388	1.349	1.244	1.183
0.03	1.084	1.189	1.338	1.434	1.461	1.379	1.234	1.157
0.05	1.562	1.672	1.773	1.809	1.745	1.576	1.372	1.272
0.075	2.032	2.194	2.326	2.341	2.215	1.987	1.749	1.646
0.1	2.177	2.408	2.651	2.723	2.601	2.356	2.102	1.998
0.15	2.137	2.428	2.905	3.124	3.071	2.815	2.521	2.392
0.2	1.896	2.189	2.767	3.241	3.305	3.080	2.766	2.630
0.25	1.646	1.918	2.505	3.142	3.392	3.257	2.978	2.856
0.3	1.451	1.695	2.263	2.930	3.387	3.366	3.162	3.073
0.4	1.177	1.377	1.885	2.536	3.157	3.313	3.245	3.211
0.5	0.992	1.160	1.618	2.228	2.872	3.152	3.190	3.224
0.75	0.723	0.820	1.162	1.640	2.204	2.544	2.717	2.866
1	0.556	0.613	0.878	1.264	1.747	2.124	2.418	2.642
1.5	0.370	0.395	0.561	0.818	1.163	1.515	1.907	2.234
2	0.287	0.305	0.410	0.596	0.855	1.166	1.584	1.970
3	0.204	0.216	0.269	0.391	0.565	0.783	1.093	1.385
4	0.163	0.171	0.203	0.293	0.418	0.573	0.789	0.993
5	0.140	0.146	0.166	0.234	0.328	0.442	0.600	0.747
7.5	0.096	0.099	0.107	0.145	0.195	0.254	0.333	0.406
10	0.068	0.070	0.074	0.097	0.126	0.160	0.203	0.241
Tvmax	2	1	1	1	1	3	3	3

Note: This site is deterministically controlled (unusually large gms).

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- Example application to a site for which we have the “true” MPRS.

TL=12s, Ss=2.36g, Rs=2.69 (S1=0.88g)

- Estimated “blended” MPRS:

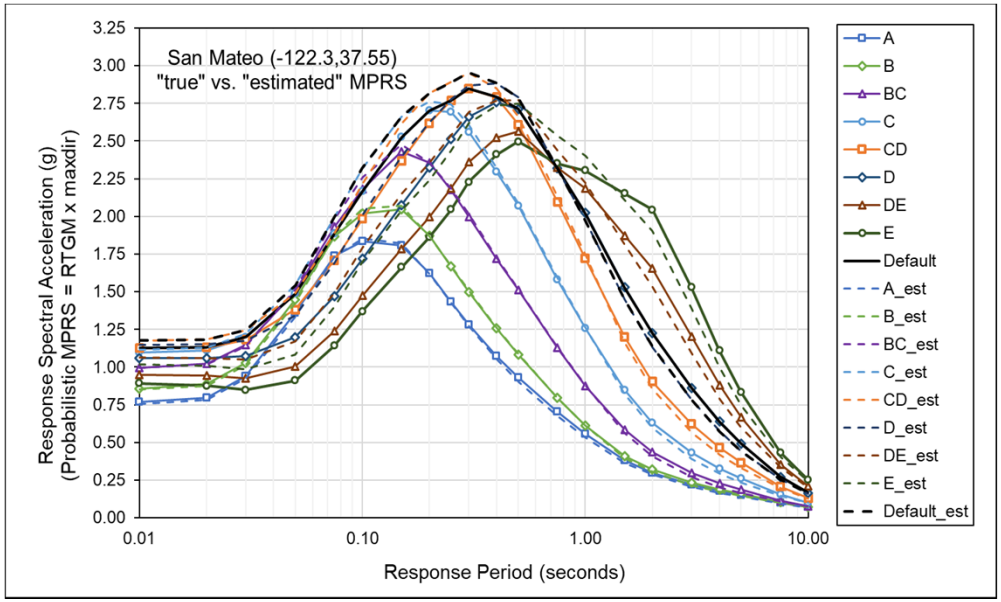
short T MPRS

“blended”

Long T MPRS

Prob MPRS (RTGM x maxdir):

T, sec	AB	B	BC	C	CD	D	DE	E
0	0.752	0.845	0.988	1.107	1.170	1.138	1.053	1.010
0.01	0.756	0.850	0.993	1.113	1.177	1.146	1.062	1.020
0.02	0.784	0.877	1.017	1.129	1.183	1.150	1.060	1.008
0.03	0.924	1.013	1.140	1.222	1.245	1.175	1.052	0.986
0.05	1.331	1.425	1.511	1.542	1.487	1.343	1.170	1.084
0.075	1.732	1.870	1.982	1.996	1.888	1.694	1.491	1.403
0.1	1.855	2.052	2.260	2.321	2.217	2.008	1.792	1.703
0.15	1.822	2.069	2.476	2.663	2.617	2.399	2.149	2.039
0.2	1.616	1.866	**2.358**	2.762	2.817	2.625	2.357	2.242
0.25	1.427	1.674	2.186	2.742	2.891	2.776	2.538	2.434
0.3	1.274	1.508	2.013	2.607	2.953	2.869	2.695	2.619
0.4	1.056	1.261	1.727	2.323	2.849	2.884	2.766	2.737
0.5	0.904	1.086	1.515	2.086	2.660	2.789	2.771	2.748
0.75	0.677	0.798	1.131	1.597	2.136	2.318	2.440	2.539
1	0.531	0.613	**0.878**	1.264	1.747	1.975	2.223	2.403
1.5	0.363	0.395	0.561	0.818	1.163	1.448	1.810	2.106
2	0.287	0.305	0.410	0.596	0.855	1.136	1.537	1.904
3	0.204	0.216	0.269	0.391	0.565	0.783	1.093	1.385
4	0.163	0.171	0.203	0.293	0.418	0.573	0.789	0.993
5	0.140	0.146	0.166	0.234	0.328	0.442	0.600	0.747
7.5	0.096	0.099	0.107	0.145	0.195	0.254	0.333	0.406
10	0.068	0.070	0.074	0.097	0.126	0.160	0.203	0.241



Note: This site is deterministically controlled (unusually large gms).

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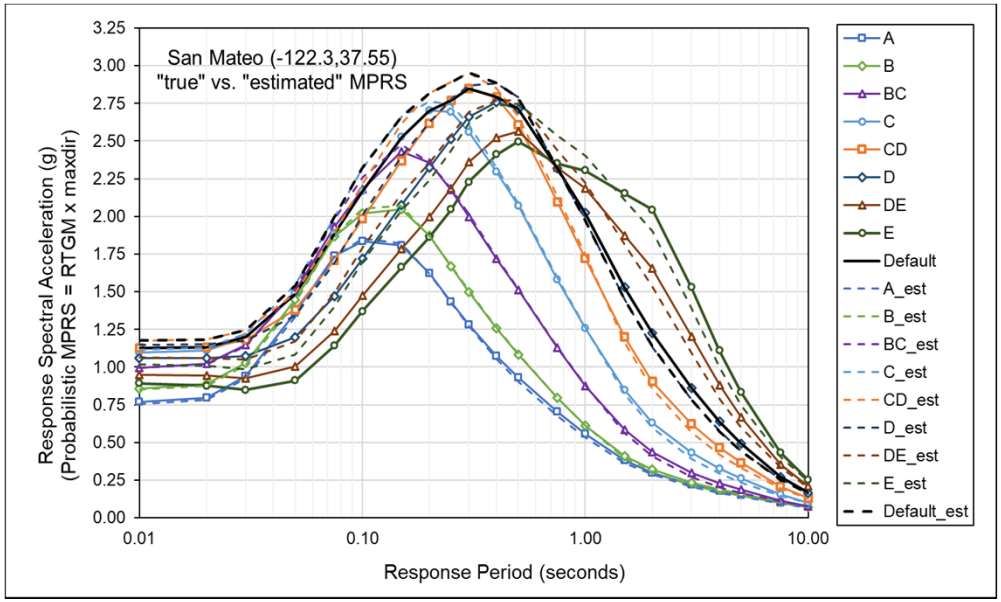
- Example application to a site for which we have the “true” MPRS.

TL=12s, Ss=2.36g, Rs=2.69 (S1=0.88g)

- “True” vs. Estimated MPRS:

Differences for
site classes A-D: 0 to 17%
default site class: 0 to 10%
sites class DE & E: 0 to ~20%



Note: This site is deterministically controlled (unusually large gms).

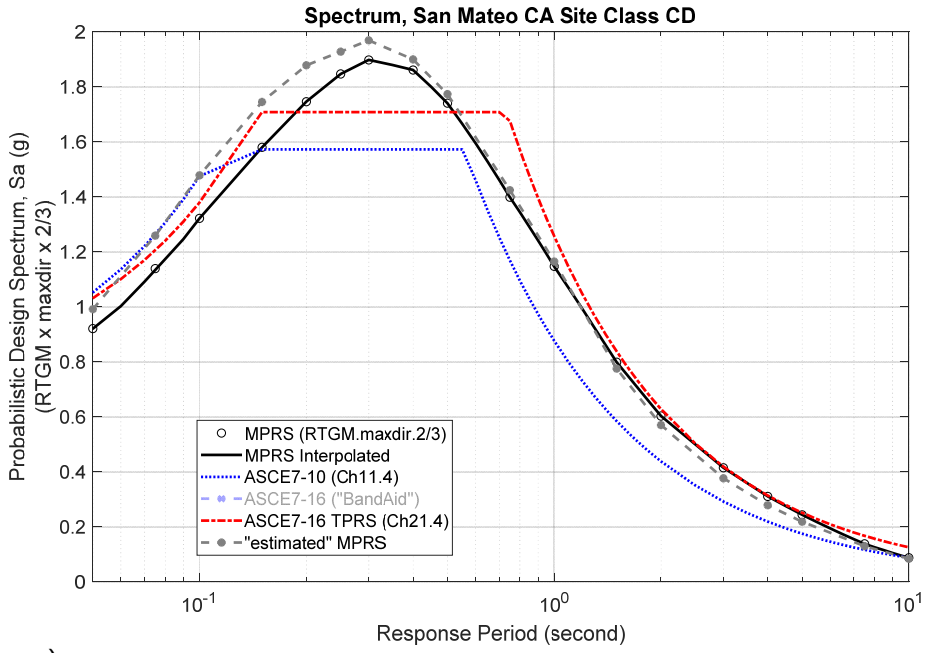
Suredeblvwlf#P SUV#iru#Vdq#P dwhr#045516/#6:188,

- Example application to a site for which we have the “true” MPRS.

TL=12s, Ss=2.36g, Rs=2.69 (S1=0.88g)

- “True” vs. Estimated MPRS:

compare to current code spectrum



Note: This site is deterministically controlled (unusually large gms).

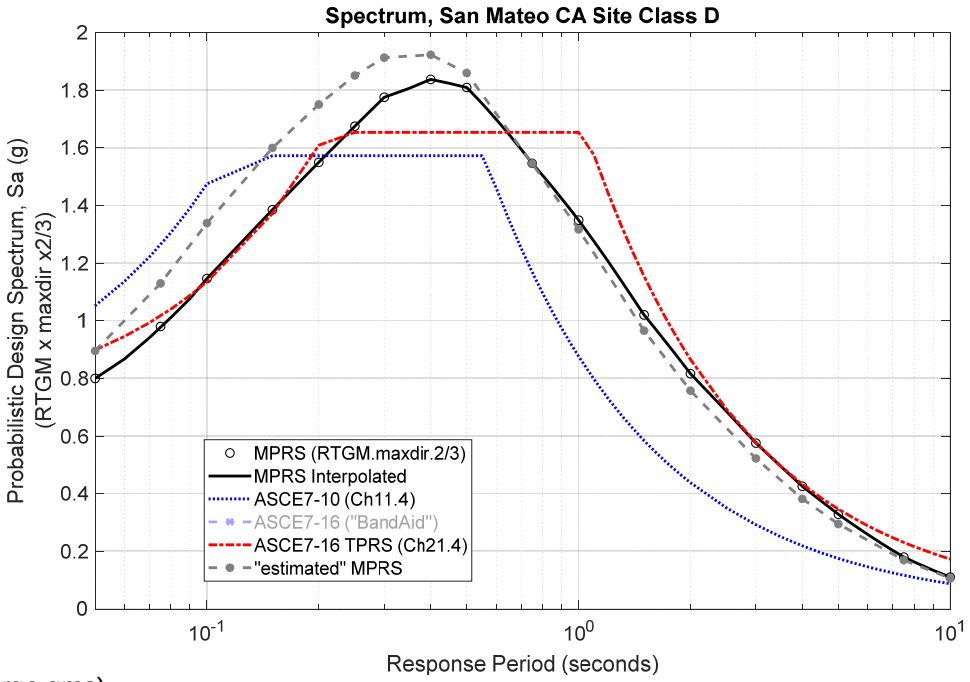
Suredeblvwlf#P SUV#ru#Vdq#P dwhr#045516/#6:188,

- Example application to a site for which we have the “true” MPRS.

TL=12s, Ss=2.36g, Rs=2.69 (S1=0.88g)

- “True” vs. Estimated MPRS:

compare to current code spectrum



Note: This site is deterministically controlled (unusually large gms).

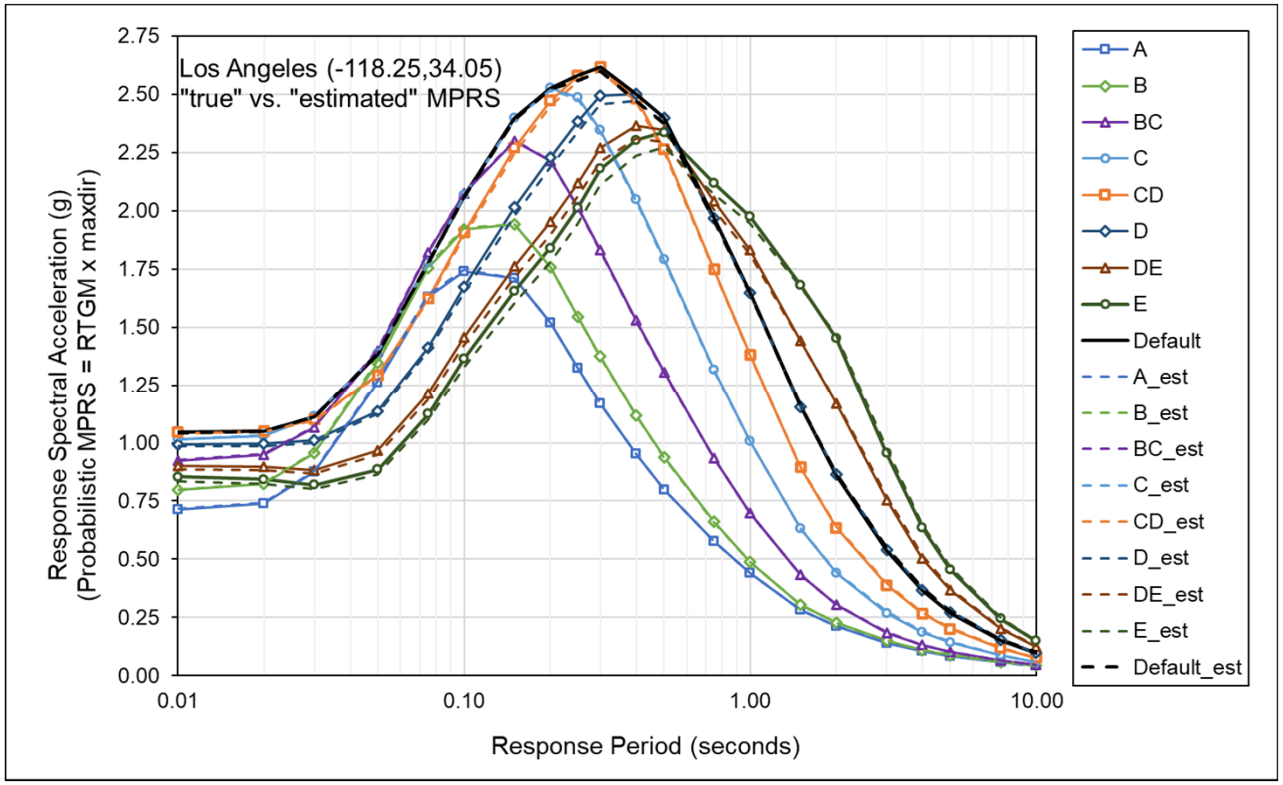
Suredelbvwlf#P SUV#ru#Orv#Dqjhdnv#044;158/#67138,

- Example application to a site for which we have the “true” MPRS.

TL=8s, Ss=2.21g, Rs=3.16 (S1=0.70g)

- “True” vs. Estimated MPRS:

Differences for all sites < 3%



Note: This site is probabilistically controlled.
(634 sites in the bin)

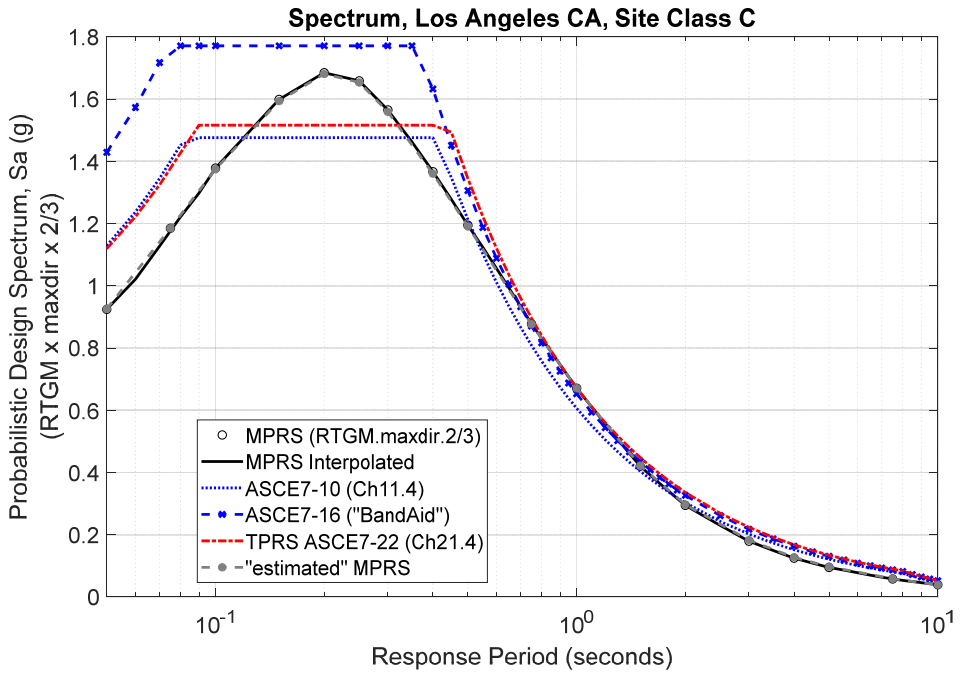
Surededlvwlf#P SUV#ru#Orv#Dqjhdnv#044;158/#67138,

- Example application to a site for which we have the “true” MPRS.

TL=8s, Ss=2.21g, Rs=3.16 (S1=0.70g)

- “True” vs. Estimated MPRS:

compare to current code spectrum



Note: This site is probabilistically controlled.
(634 sites in the bin)

Suredelbvwlf#P SUV#ru#Orv#Dqjhdnv#044;158/#67138,

- Example application to a site for which we have the “true” MPRS.

TL=8s, Ss=2.21g, Rs=3.16 (S1=0.70g)

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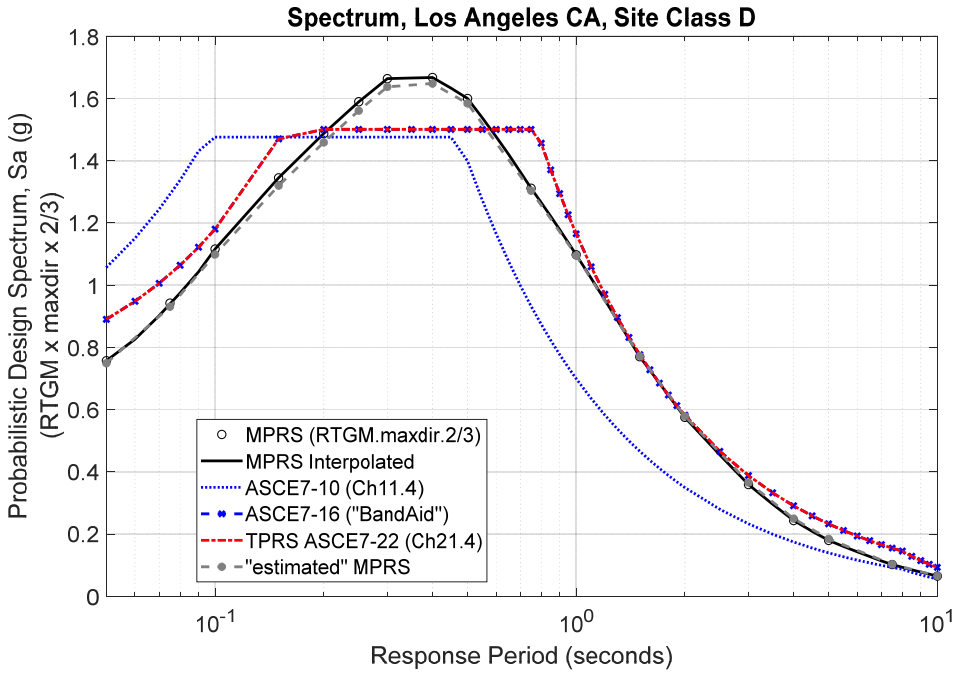
compare to current code spectrum



Note: This site is probabilistically controlled.
(634 sites in the bin)

Surededlvwlf#P SUV#ru#Orv#Dqjhodv#044;158/#67138,

- Example application to a site for which we have the “true” MPRS.

TL=8s, Ss=2.21g, Rs=3.16 (S1=0.70g)

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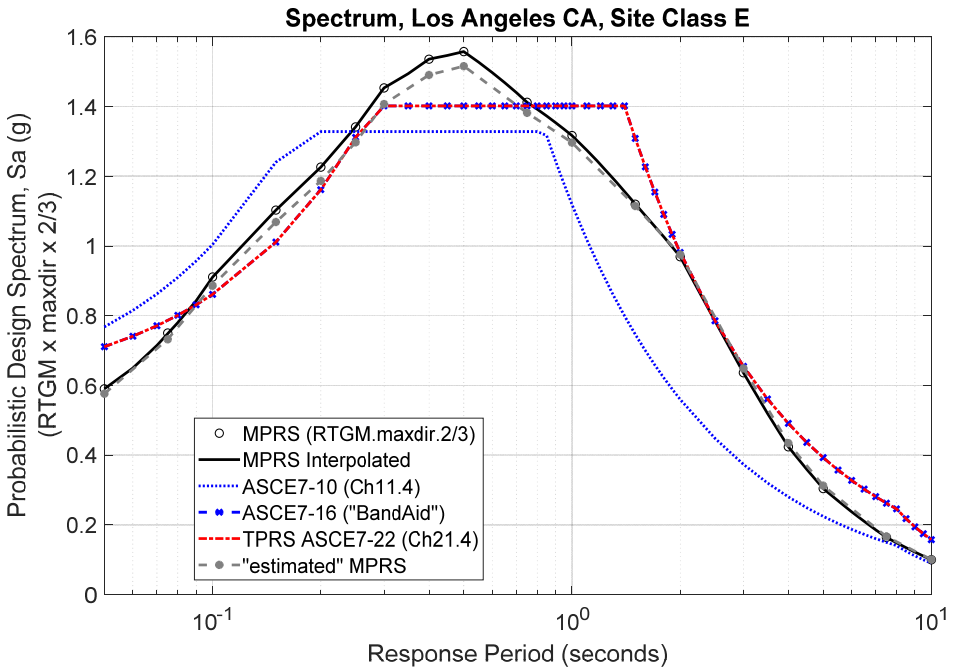
compare to current code spectrum



Note: This site is probabilistically controlled.
(634 sites in the bin)

- For all other US territories where NSHMs are currently limited in terms of periods and site classes (i.e., AK, HI, GU&AS, PRVI), Response Spectrum Shape Parameters (RSSPs) are developed based on WUS data.
- MPRS can be estimated from TL, Ss, and S1
  - Four TL values: 16, 12, 8, 6 (two regions for 6)
  - Four Ss groups
  - Four Rs=Ss/S1 groups
- Estimated MPRS was within 10% of “true” MPRS for San Mateo for default site class
- Estimated MPRS was within 3% of “true” MPRS for L.A. for all sites