Impact of hazard-consistent ground motion duration in structural collapse risk assessment

Digital Appendix

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Version 2.1

Contents

1 Overview

This document provides additional data and plots describing the structural collapse risk calculations presented in Chandramohan et al. [1].

Section 2 tabulates the source-specific conditional median target Ds_{5-75} (5-75% significant duration) values, and the corresponding percentage contributions to the total seismic hazard from each type of seismic source, conditional on the exceedance of $S_a(1.8\,\mathrm{s})$, at the eight different intensity levels, and the three considered sites in Seattle (Washington), Eugene (Oregon), and San Francisco (California).

Section 3 contains plots of the Ds_{5-75} and response spectra of the ground motions selected in all three ground motion groups: the *CS and duration* group, the *CS only* control group, and the *CS and causal parameters* group, at the eight different ground motion intensity levels, and the three considered sites. These groups of ground motions were used to estimate the collapse risk of an eight-story reinforced concrete moment frame building using the multiple stripe analyses technique [2]. Plots of the Ds_{5-75} and response spectra of the selected ground motions are overlaid against their corresponding source-specific target distributions.

The ground motions in the *CS and duration* group were selected to match the source-specific target distributions of Ds_{5-75} and response spectra at each intensity level. Ground motions to match targets corresponding to interface earthquakes were selected from a pool of 3955 ground motions recorded from the following large magnitude interface earthquakes: 1974 Lima (Peru), 1985 Valparaiso (Chile), 1985 Michoacan (Mexico), 2003 Hokkaido (Japan), 2010 Maule (Chile), and 2011 Tohoku (Japan). The process by which these ground motions were baseline corrected and filtered is described in the digital appendix to Chandramohan et al. [3]. Ground motions to match targets corresponding to both crustal and in-slab earthquakes were selected from the PEER NGA-West2 database [4].

The ground motions in the *CS only* control group, on the other hand, were selected to match the source-specific target distributions of response spectra only, without imposing any constraints on the Ds_{5-75} of the selected ground motions. For this group, ground motions corresponding to all types of seismic sources were chosen from the PEER NGA-West2 database.

The ground motions in the *CS and causal parameters* group were also selected to match the source-specific target distributions of response spectra only, but in addition, only those ground motions recorded from earthquakes whose magnitudes and source-to-site distances lie within an allowable range around the mean magnitude and source-to-site distance of earthquakes from each type of contributing source, obtained from seismic hazard deaggregation results [5], were considered for selection. Constraints were also placed on the site Vs_{30} of the ground motions selected from the PEER NGA-West2 database, assuming the structure is located on a rock site with $Vs_{30} = 760\,\mathrm{m/s}$. Since this information was not available for the ground motions recorded from the large magnitude interface earthquakes, the Vs_{30} constraint was not imposed on the ground motions selected to match targets corresponding to interface earthquakes. The constraints imposed on the magnitude, source-to-site distance, and site Vs_{30} of the selected ground motions are summarized in tables.

Section 4 contains plots of the collapse fragility curves of the eight-story reinforced concrete moment frame building, estimated using the three different groups of ground motions, selected for each of the three considered sites. The plots also contain the seismic hazard curves and the $\mathrm{MCE_R}$ ground motion intensity levels at each site.

2 Source-specific targets

2.1 Seattle

Table 1: Source-specific conditional median target Ds_{5-75} values, and the corresponding percentage contributions to the total seismic hazard from each type of seismic source (indicated in parentheses), conditional on different exceedance probabilities of $S_a(1.8\,\mathrm{s})$ at Seattle.

Intensity level $S_a(1.8\,\mathrm{s})(\mathrm{g})$	**Hazard level % in 50 years**	**Interface earthquakes**	**In-slab earthquakes**	**Crustal earthquakes**
0.17	4.70	36 s (42 %)	9 s (30 %)	5 s (28 %)
0.20	3.31	36 s (44 %)	9 s (27 %)	5 s (29 %)
0.24	2.00	36 s (47 %)	9 s (22 %)	5 s (31 %)
0.28	1.34	37 s (49 %)	9 s (19 %)	6 s (32 %)
0.32	1.00	37 s (50 %)	9 s (17 %)	6 s (33 %)
0.36	0.67	37 s (52 %)	9 s (14 %)	6 s (34 %)
0.40	0.50	37 s (52 %)	9 s (12 %)	6 s (35 %)
0.49	0.25	37 s (54 %)	9 s (8 %)	6 s (38 %)

2.2 Eugene

Table 2: Source-specific conditional median target Ds_{5-75} values, and the corresponding percentage contributions to the total seismic hazard from each type of seismic source (indicated in parentheses), conditional on different exceedance probabilities of $S_a(1.8\,\mathrm{s})$ at Eugene.

Intensity level $S_a(1.8\,\mathrm{s})(\mathrm{g})$	**Hazard level % in 50 years**	**Interface earthquakes**	**In-slab earthquakes**	**Crustal earthquakes**
0.14	4.70	33 s (91 %)	9 s (9 %)	–
0.17	3.31	33 s (93 %)	9 s (7 %)	–
0.23	2.00	33 s (95 %)	9 s (5 %)	–
0.28	1.34	34 s (96 %)	9 s (4 %)	–
0.32	1.00	34 s (97 %)	9 s (3 %)	–
0.38	0.67	34 s (98 %)	9 s (2 %)	–
0.42	0.50	34 s (98 %)	9 s (2 %)	–
0.55	0.25	34 s (99 %)	9 s (1 %)	–

2.3 San Francisco

Table 3: Source-specific conditional median target Ds_{5-75} values, and the corresponding percentage contributions to the total seismic hazard from each type of seismic source (indicated in parentheses), conditional on different exceedance probabilities of $S_a(1.8\,\mathrm{s})$ at San Francisco.

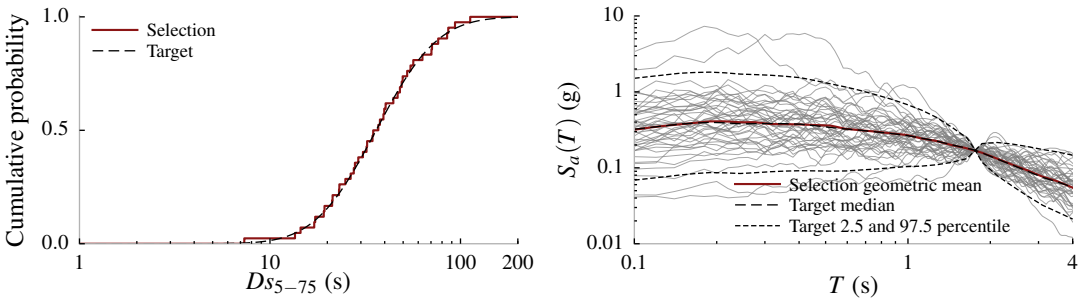
Intensity level $S_a(1.8\,\mathrm{s})(\mathrm{g})$	**Hazard level % in 50 years**	**Interface earthquakes**	**In-slab earthquakes**	**Crustal earthquakes**
0.27	4.70	–	–	11 s (100 %)
0.31	3.31	–	–	11 s (100 %)
0.37	2.00	–	–	11 s (100 %)
0.42	1.34	–	–	12 s (100 %)
0.46	1.00	–	–	12 s (100 %)
0.51	0.67	–	–	12 s (100 %)
0.55	0.50	–	–	12 s (100 %)
0.65	0.25	–	–	12 s (100 %)

3 Selected ground motions

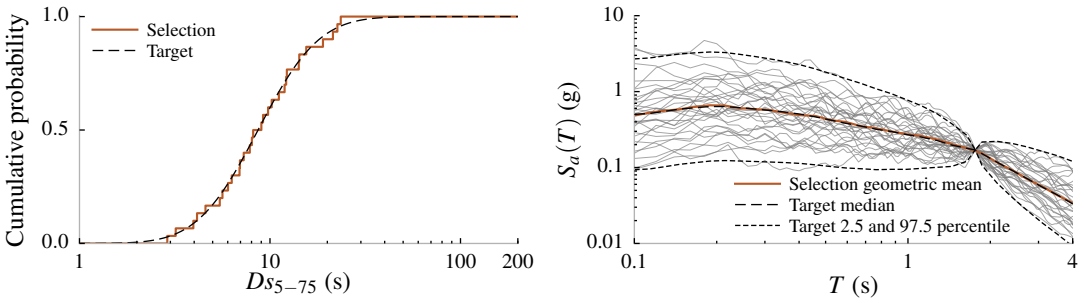
3.1 Seattle

3.1.1 $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level)

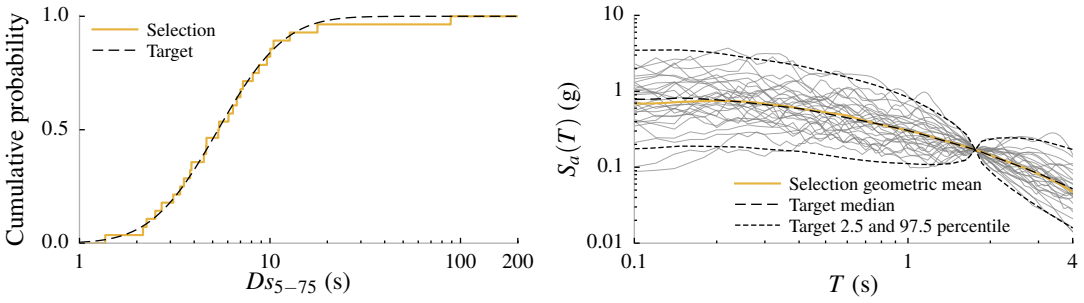
3.1.1.1 *CS and duration* group



(a) Interface earthquakes: 42 / 100 ground motions



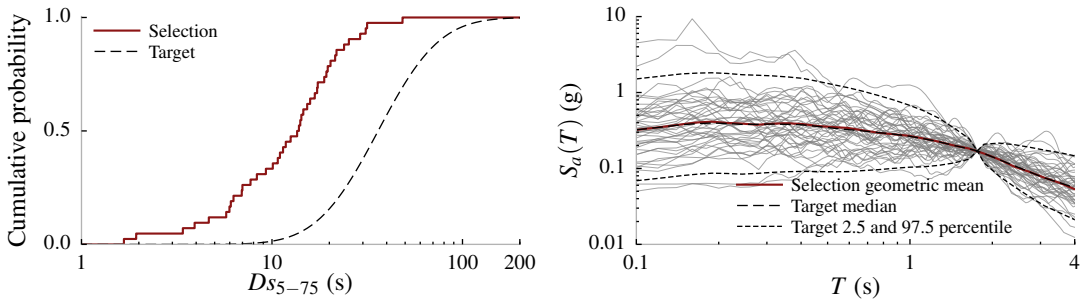
(b) In-slab earthquakes: 30 / 100 ground motions



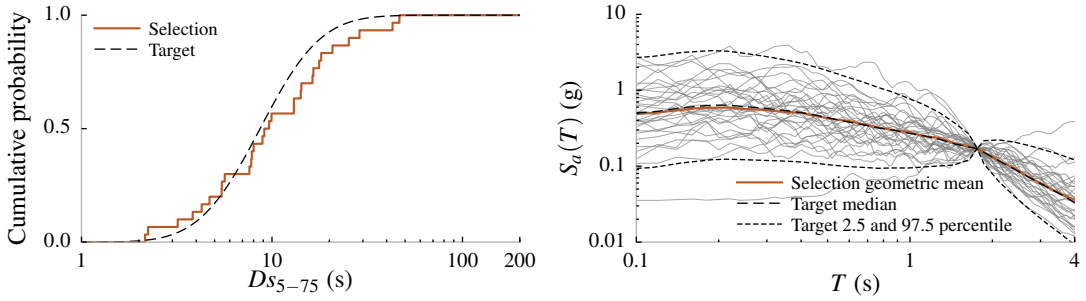
(c) Crustal earthquakes: 28 / 100 ground motions

Figure 1: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Seattle.

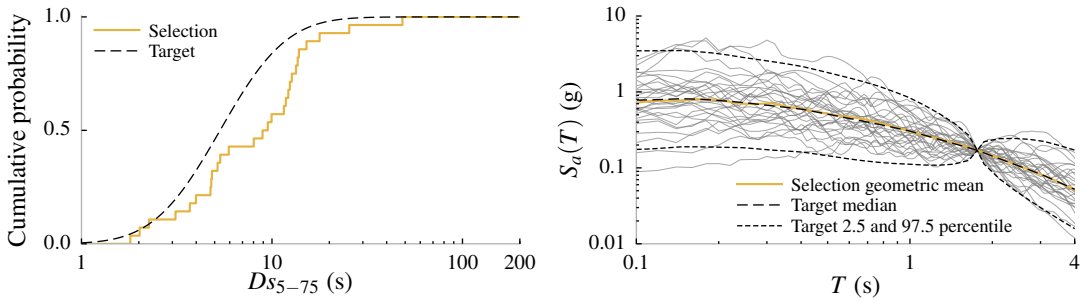
3.1.1.2 *CS only* group



(a) Interface earthquakes: 42 / 100 ground motions



(b) In-slab earthquakes: 30 / 100 ground motions



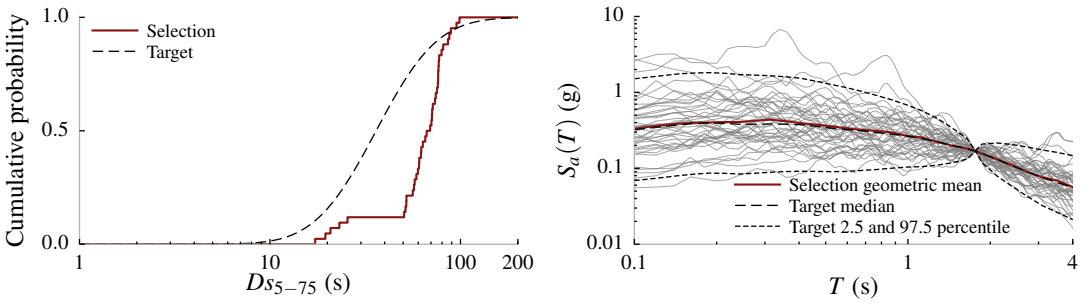
(c) Crustal earthquakes: 28 / 100 ground motions

Figure 2: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Seattle.

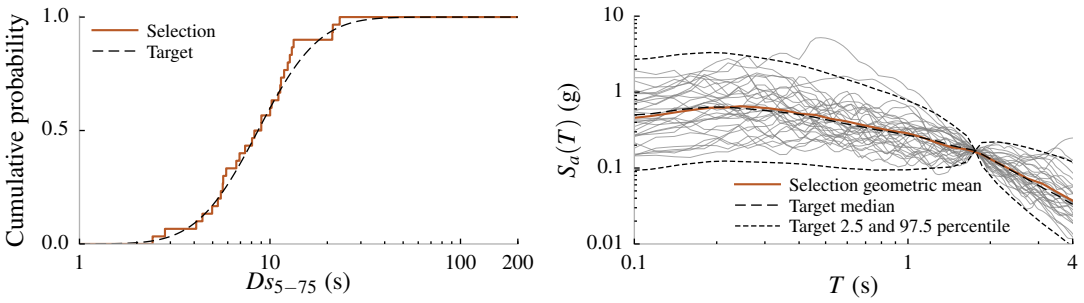
3.1.1.3 *CS and causal parameters* group

Table 4: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Seattle.

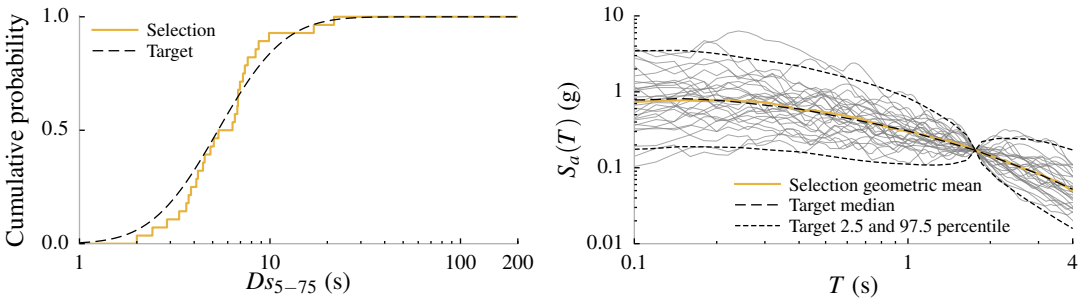
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	117	760	8.6	9.2	77	157	–	–	204	42
In-slab	6.9	65	760	6.4	7.4	45	85	360	1160	98	30
Crustal	6.9	9	760	6.4	7.4	4	14	360	1160	97	28



(a) Interface earthquakes: 42 / 100 ground motions



(b) In-slab earthquakes: 30 / 100 ground motions

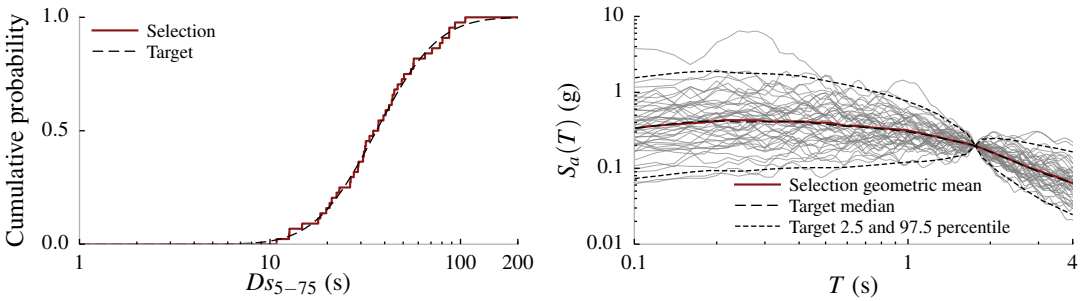


(c) Crustal earthquakes: 28 / 100 ground motions

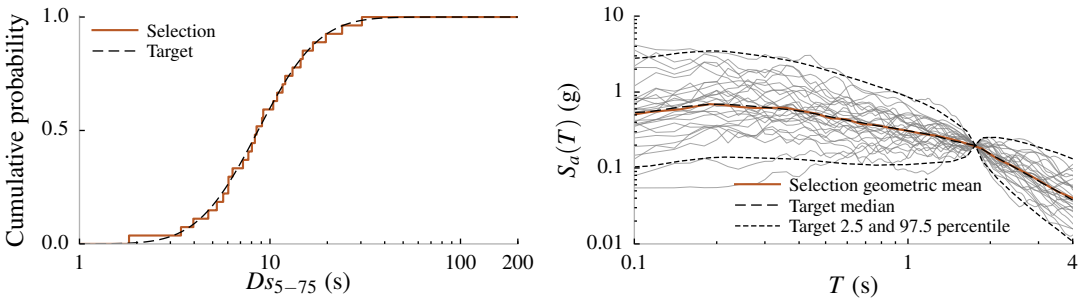
Figure 3: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Seattle.

3.1.2 $S_a(1.8\,\mathrm{s}) = 0.20\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level)

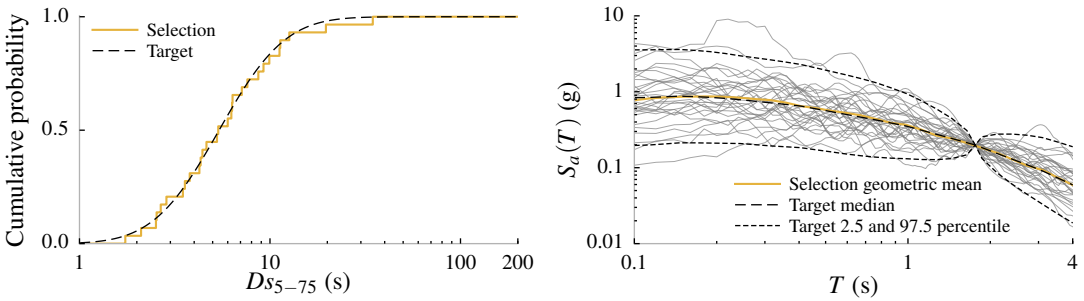
3.1.2.1 *CS and duration* group



(a) Interface earthquakes: 44 / 100 ground motions



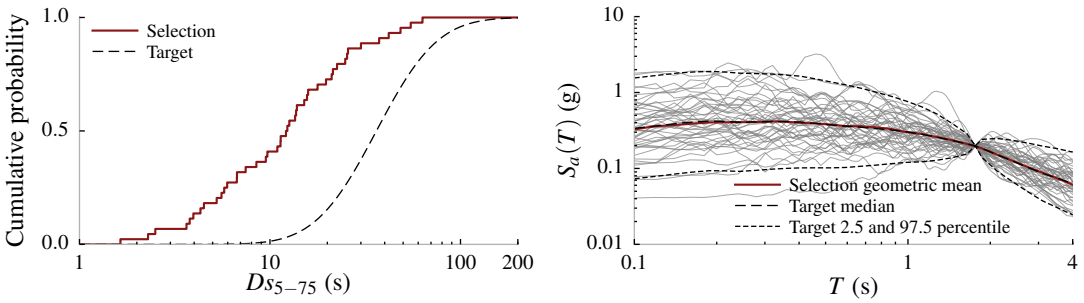
(b) In-slab earthquakes: 27 / 100 ground motions



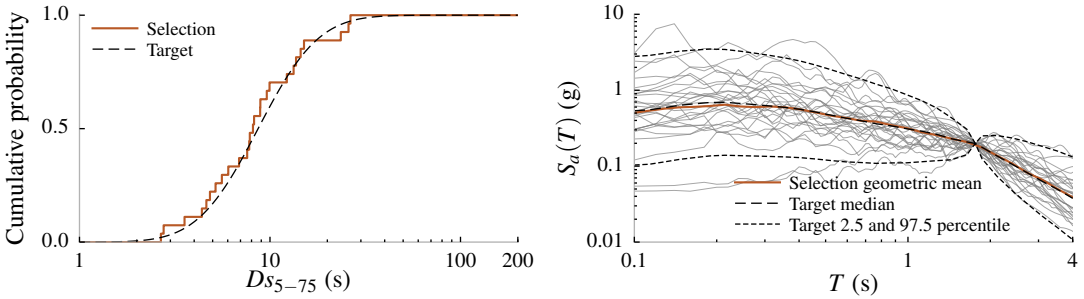
(c) Crustal earthquakes: 29 / 100 ground motions

Figure 4: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.20\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Seattle.

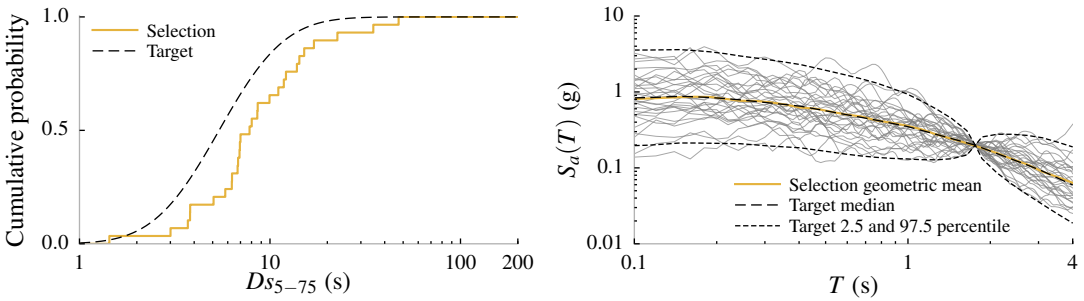
3.1.2.2 *CS only* group



(a) Interface earthquakes: 44 / 100 ground motions



(b) In-slab earthquakes: 27 / 100 ground motions



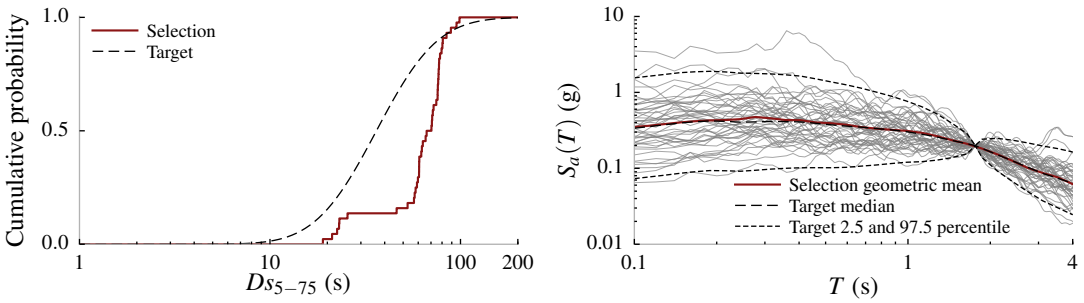
(c) Crustal earthquakes: 29 / 100 ground motions

Figure 5: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.20\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Seattle.

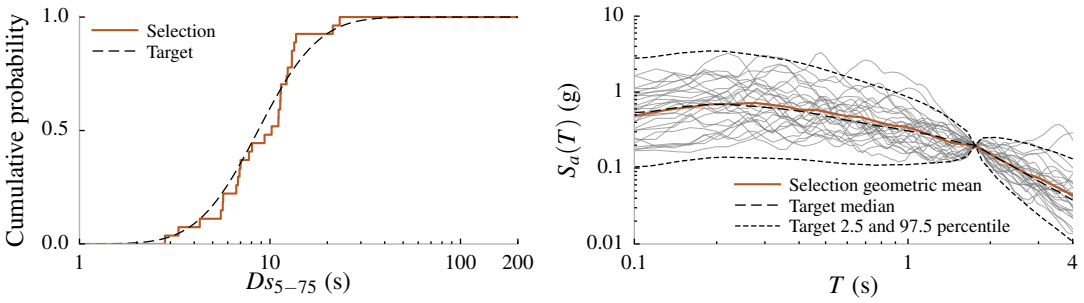
3.1.2.3 *CS and causal parameters* group

Table 5: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.20\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Seattle.

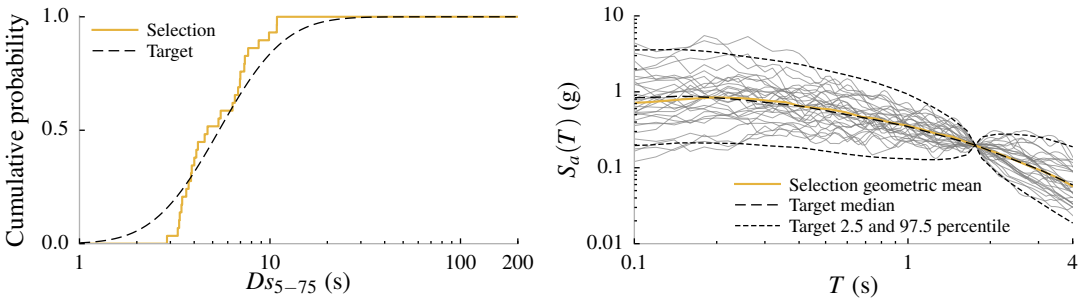
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	116	760	8.6	9.2	76	156	–	–	187	44
In-slab	6.9	64	760	6.4	7.4	44	84	360	1160	74	27
Crustal	6.9	8	760	6.4	7.4	3	13	360	1160	90	29



(a) Interface earthquakes: 44 / 100 ground motions



(b) In-slab earthquakes: 27 / 100 ground motions

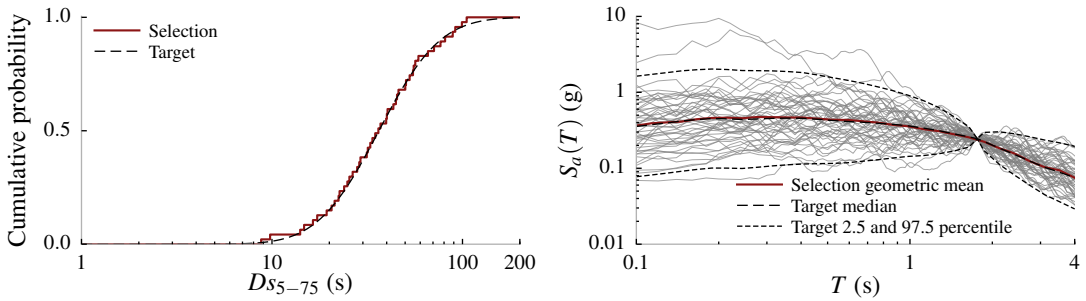


(c) Crustal earthquakes: 29 / 100 ground motions

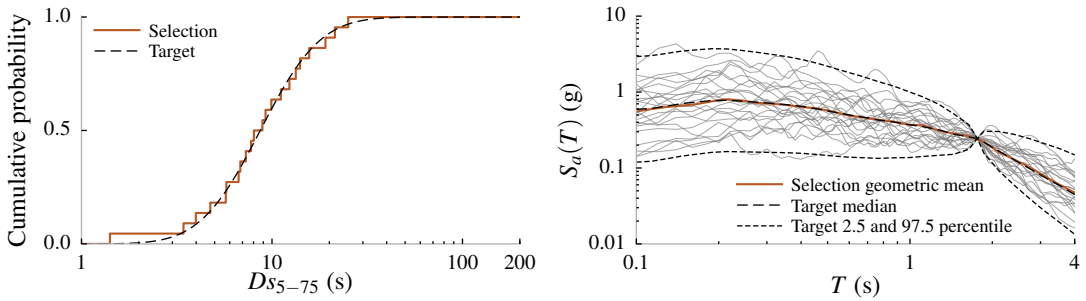
Figure 6: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.20\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Seattle.

3.1.3 $S_a(1.8\,\mathrm{s}) = 0.24\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level)

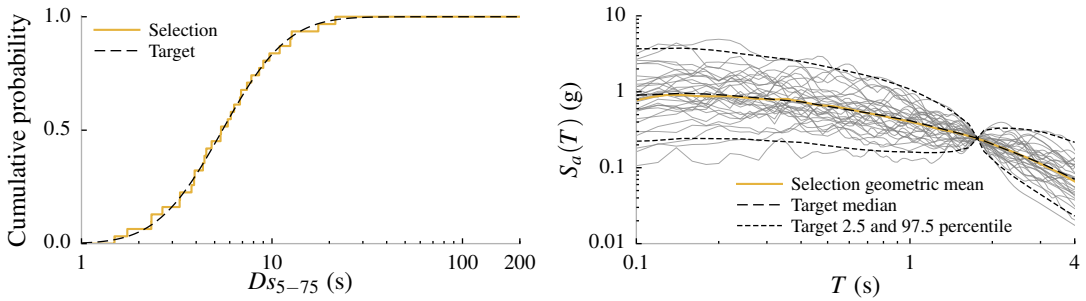
3.1.3.1 *CS and duration* group



(a) Interface earthquakes: 47 / 100 ground motions



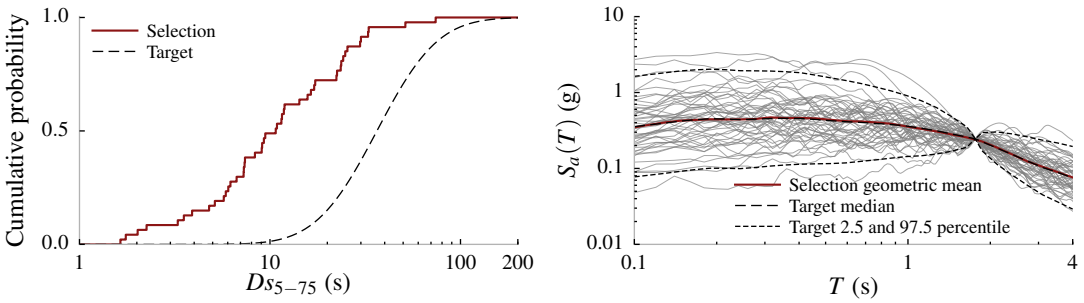
(b) In-slab earthquakes: 22 / 100 ground motions



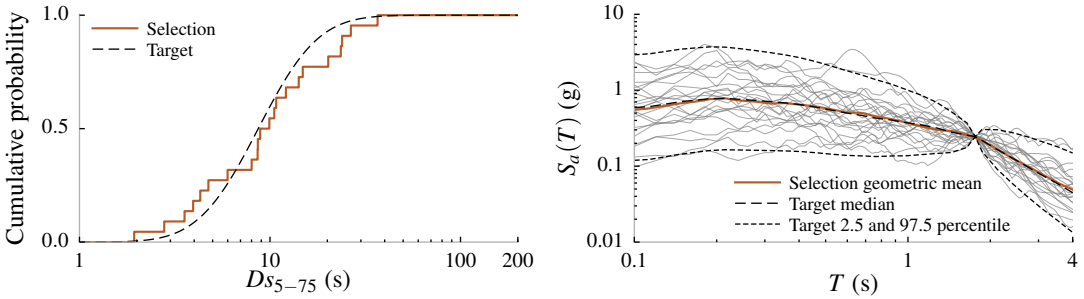
(c) Crustal earthquakes: 31 / 100 ground motions

Figure 7: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.24\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Seattle.

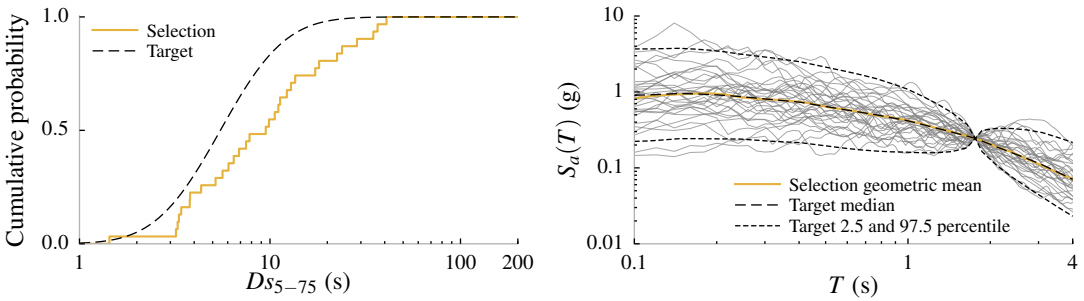
3.1.3.2 *CS only* group



(a) Interface earthquakes: 47 / 100 ground motions



(b) In-slab earthquakes: 22 / 100 ground motions



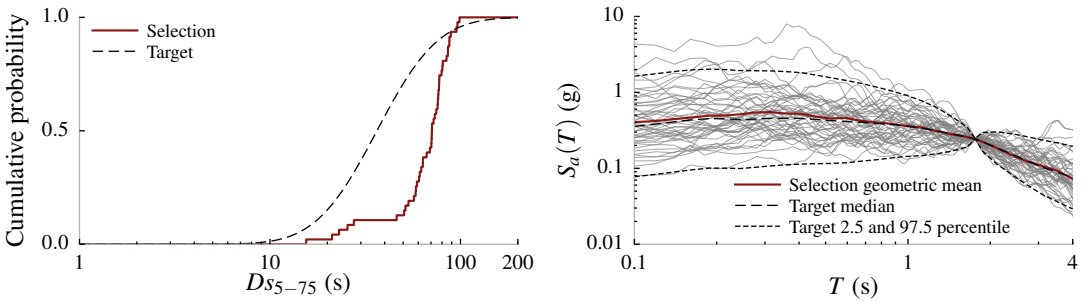
(c) Crustal earthquakes: 31 / 100 ground motions

Figure 8: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.24\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Seattle.

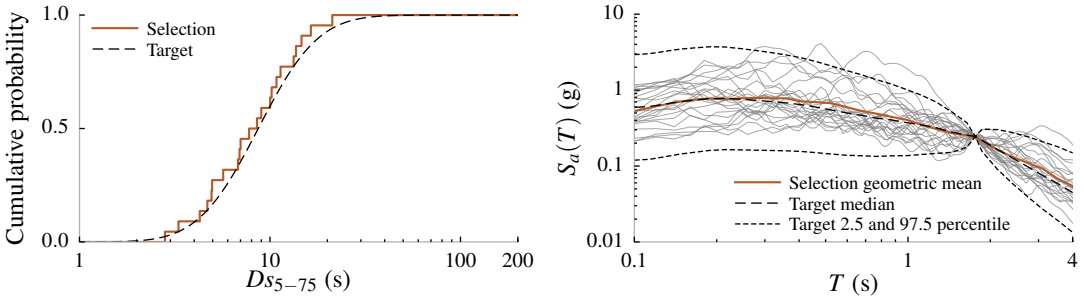
3.1.3.3 *CS and causal parameters* group

Table 6: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.24\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Seattle.

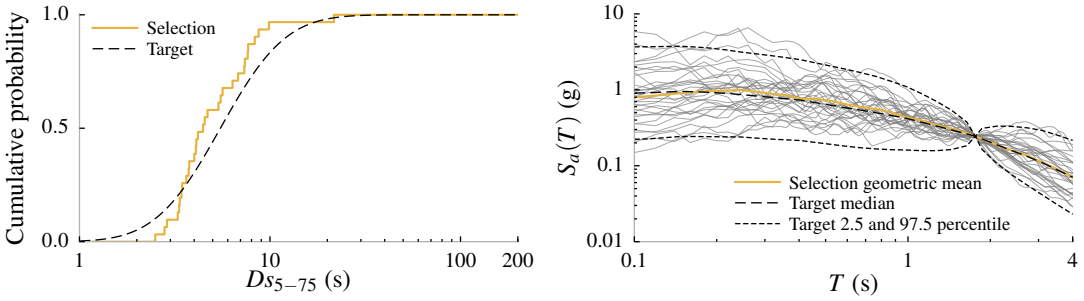
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	114	760	8.6	9.2	74	154	–	–	168	47
In-slab	6.9	62	760	6.4	7.4	42	82	360	1160	48	22
Crustal	6.9	7	760	6.4	7.4	2	12	360	1160	82	31



(a) Interface earthquakes: 47 / 100 ground motions



(b) In-slab earthquakes: 22 / 100 ground motions

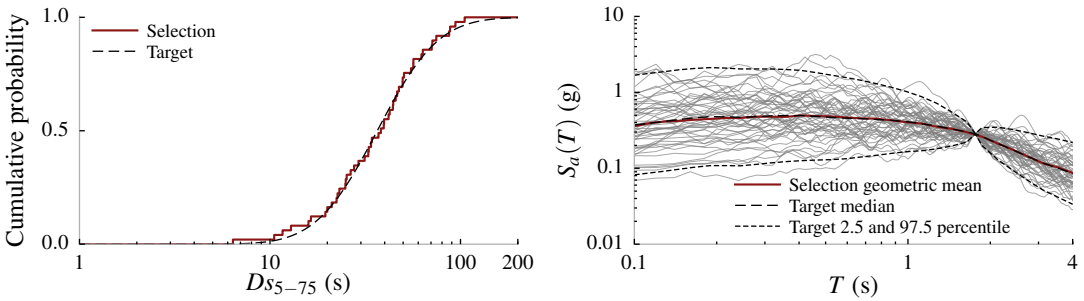


(c) Crustal earthquakes: 31 / 100 ground motions

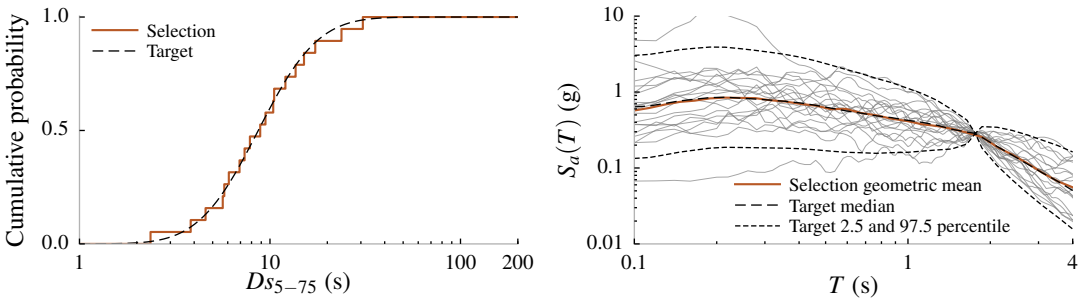
Figure 9: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.24\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Seattle.

3.1.4 $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level)

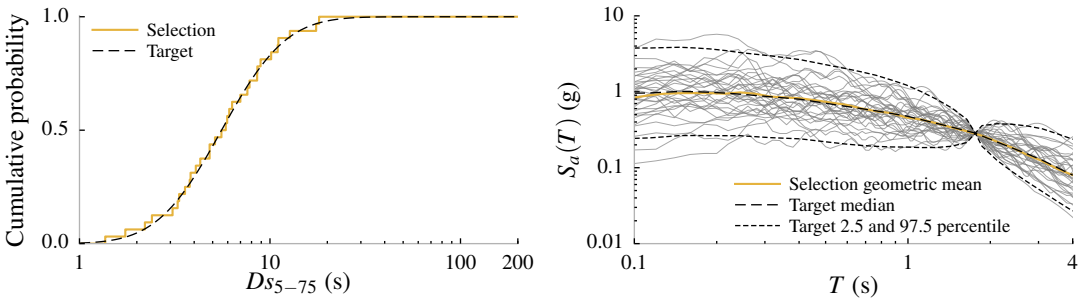
3.1.4.1 *CS and duration* group



(a) Interface earthquakes: 49 / 100 ground motions



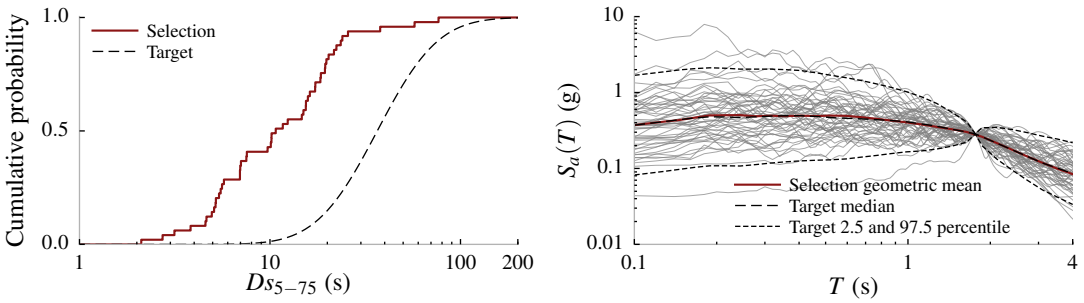
(b) In-slab earthquakes: 19 / 100 ground motions



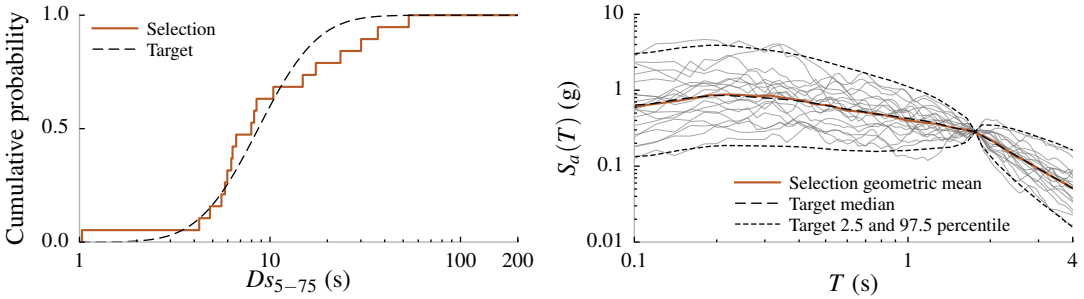
(c) Crustal earthquakes: 32 / 100 ground motions

Figure 10: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Seattle.

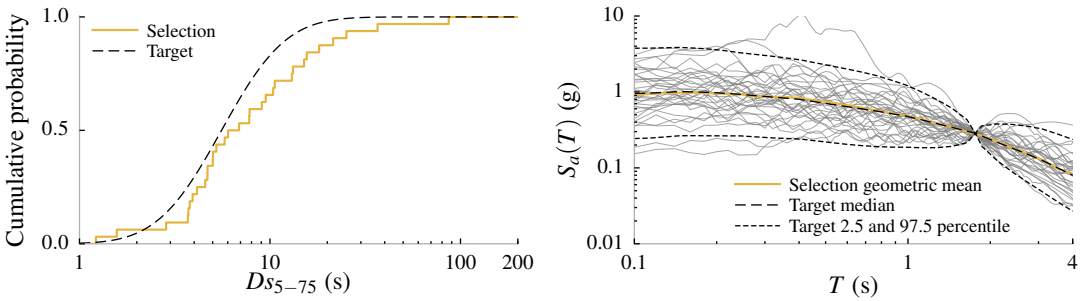
3.1.4.2 *CS only* group



(a) Interface earthquakes: 49 / 100 ground motions



(b) In-slab earthquakes: 19 / 100 ground motions



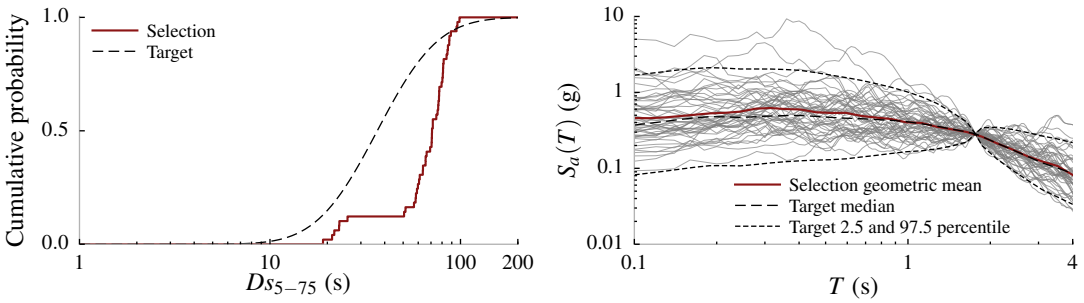
(c) Crustal earthquakes: 32 / 100 ground motions

Figure 11: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Seattle.

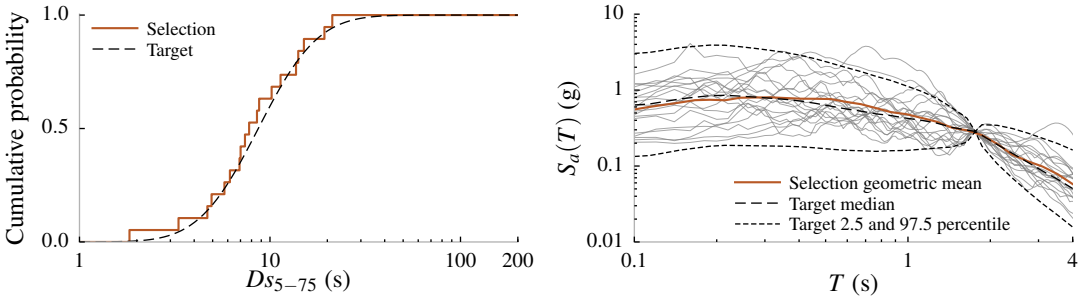
3.1.4.3 *CS and causal parameters* group

Table 7: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Seattle.

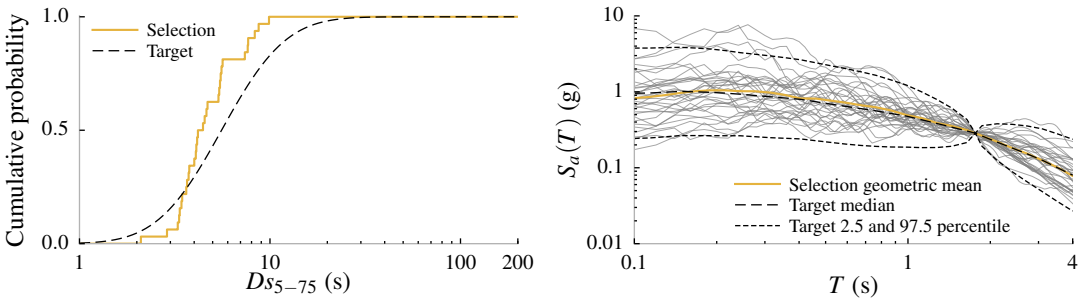
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	113	760	8.6	9.2	73	153	–	–	151	49
In-slab	7.0	61	760	6.5	7.5	41	81	360	1160	47	19
Crustal	6.9	6	760	6.4	7.4	1	11	360	1160	71	32



(a) Interface earthquakes: 49 / 100 ground motions



(b) In-slab earthquakes: 19 / 100 ground motions

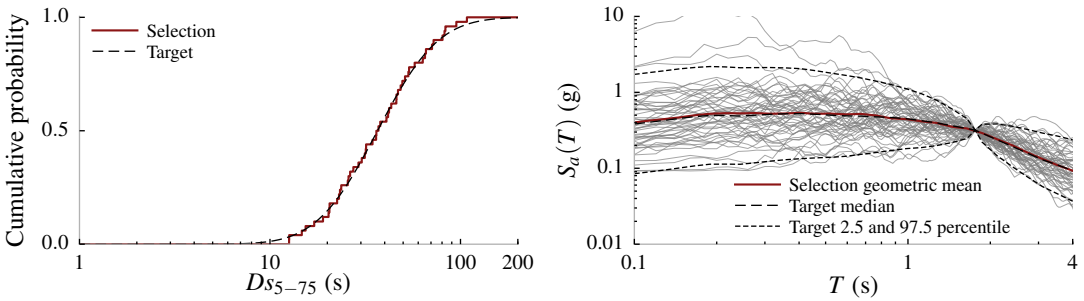


(c) Crustal earthquakes: 32 / 100 ground motions

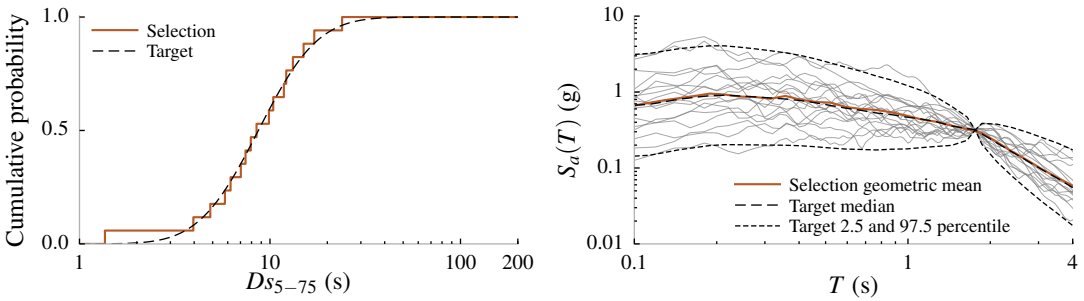
Figure 12: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Seattle.

3.1.5 $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level)

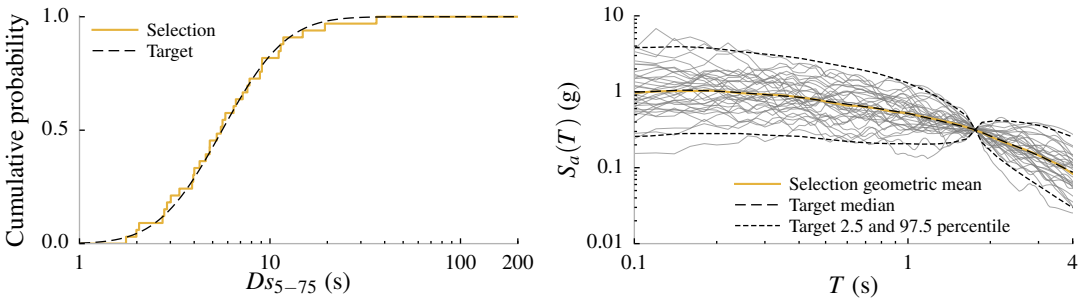
3.1.5.1 *CS and duration* group



(a) Interface earthquakes: 50 / 100 ground motions



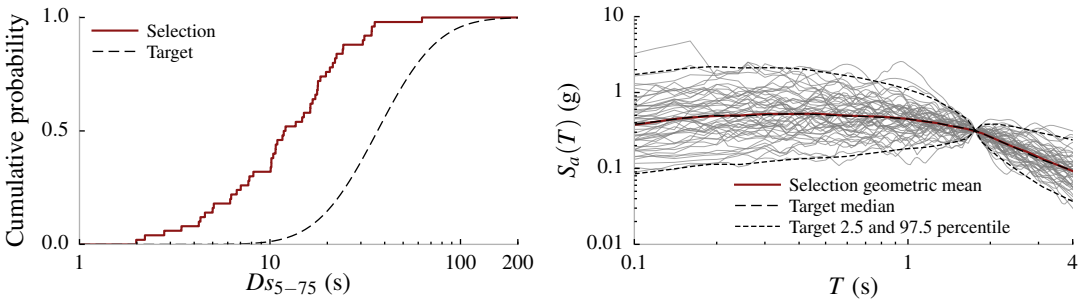
(b) In-slab earthquakes: 17 / 100 ground motions



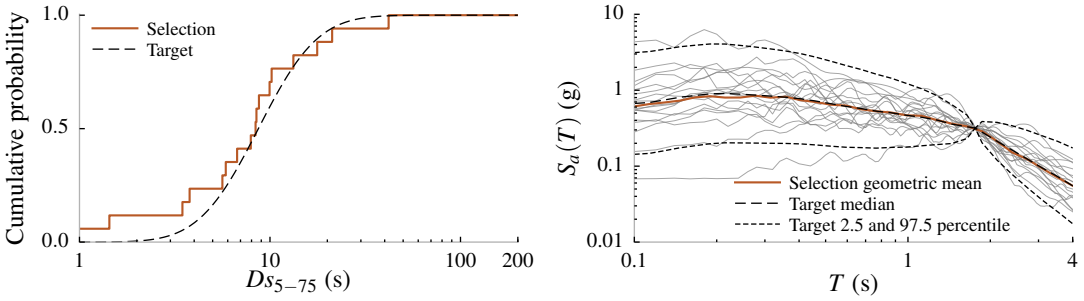
(c) Crustal earthquakes: 33 / 100 ground motions

Figure 13: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Seattle.

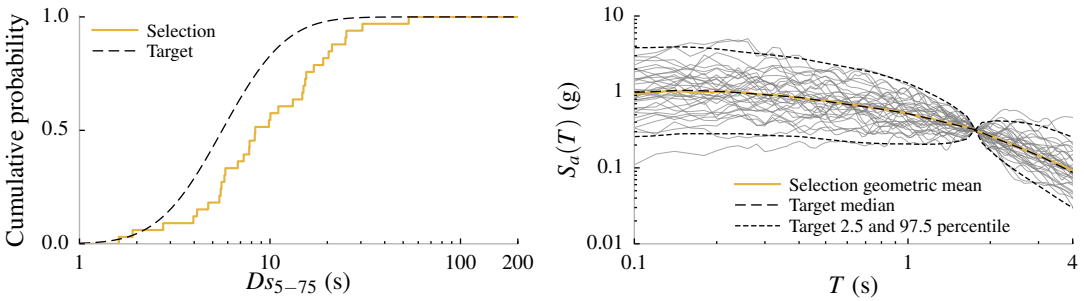
3.1.5.2 *CS only* group



(a) Interface earthquakes: 50 / 100 ground motions



(b) In-slab earthquakes: 17 / 100 ground motions



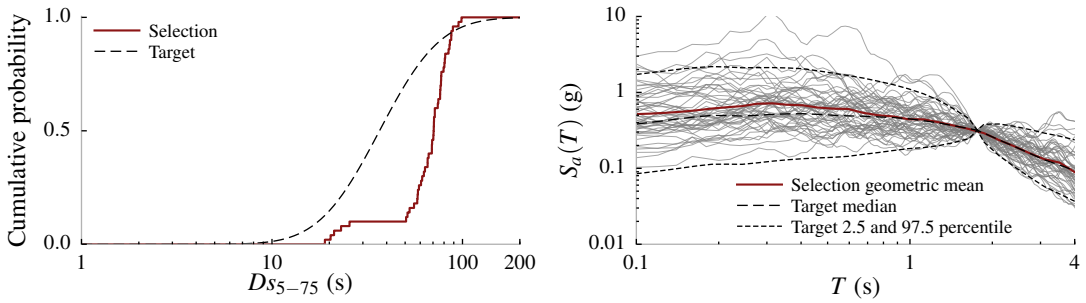
(c) Crustal earthquakes: 33 / 100 ground motions

Figure 14: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Seattle.

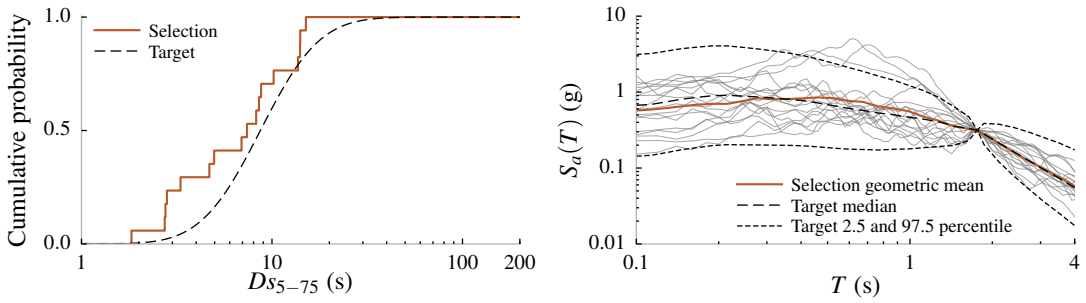
3.1.5.3 *CS and causal parameters* group

Table 8: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Seattle.

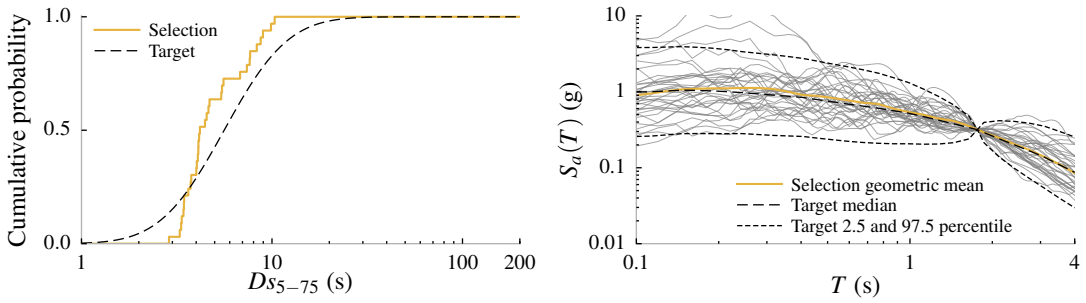
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	112	760	8.6	9.2	72	152	–	–	141	50
In-slab	7.0	60	760	6.5	7.5	40	80	360	1160	33	17
Crustal	6.9	6	760	6.4	7.4	1	11	360	1160	67	33



(a) Interface earthquakes: 50 / 100 ground motions



(b) In-slab earthquakes: 17 / 100 ground motions

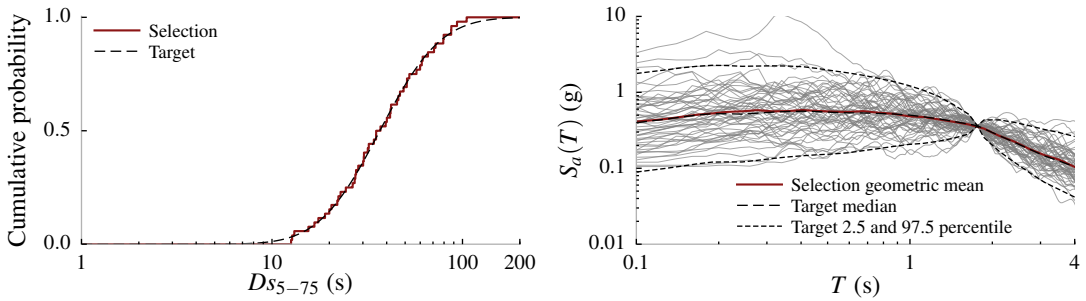


(c) Crustal earthquakes: 33 / 100 ground motions

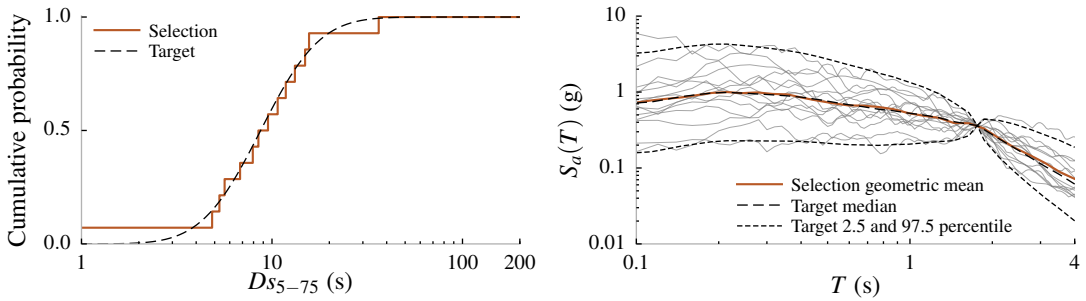
Figure 15: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Seattle.

3.1.6 $S_a(1.8\,\mathrm{s}) = 0.36\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level)

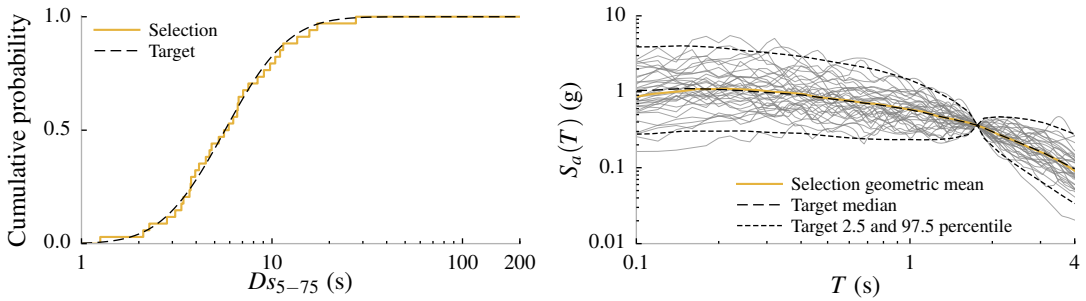
3.1.6.1 *CS and duration* group



(a) Interface earthquakes: 52 / 100 ground motions



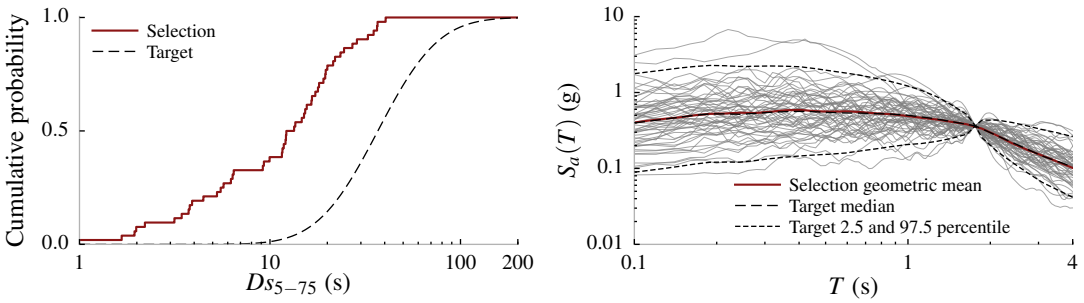
(b) In-slab earthquakes: 14 / 100 ground motions



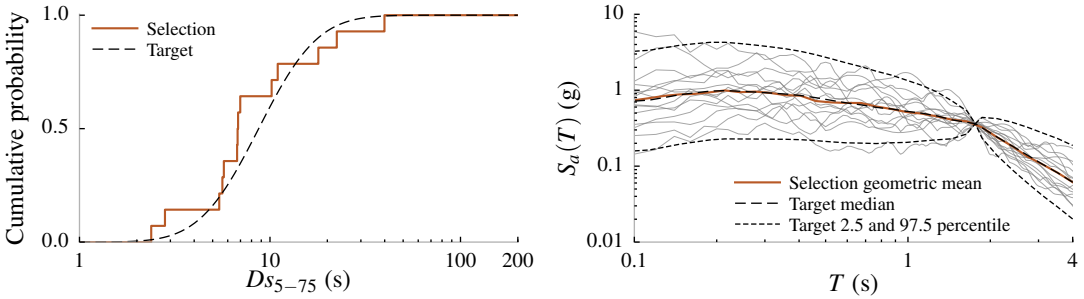
(c) Crustal earthquakes: 34 / 100 ground motions

Figure 16: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.36\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Seattle.

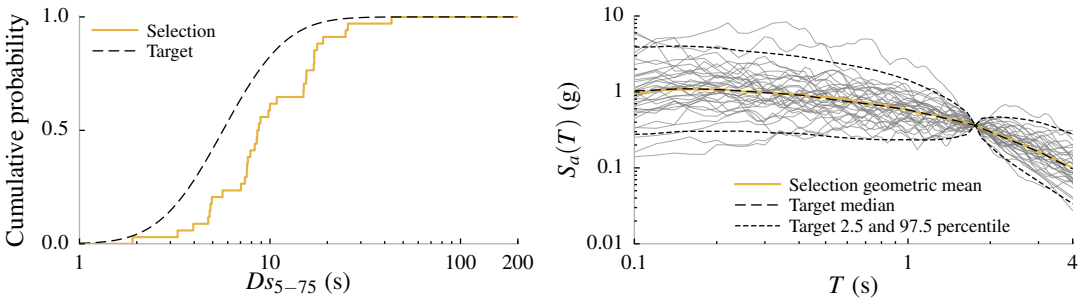
3.1.6.2 *CS only* group



(a) Interface earthquakes: 52 / 100 ground motions



(b) In-slab earthquakes: 14 / 100 ground motions



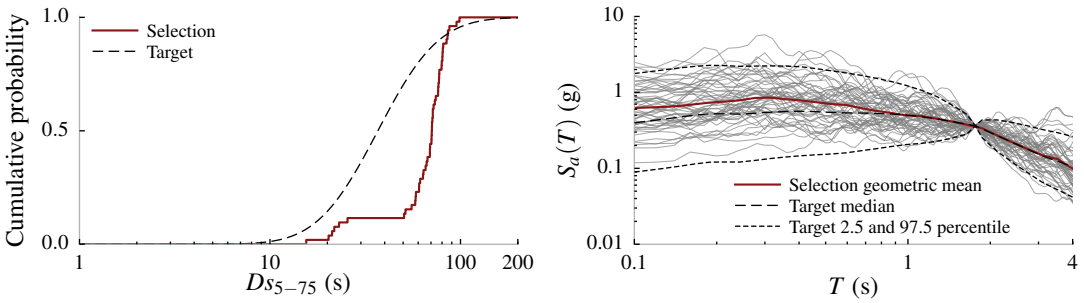
(c) Crustal earthquakes: 34 / 100 ground motions

Figure 17: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.36\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Seattle.

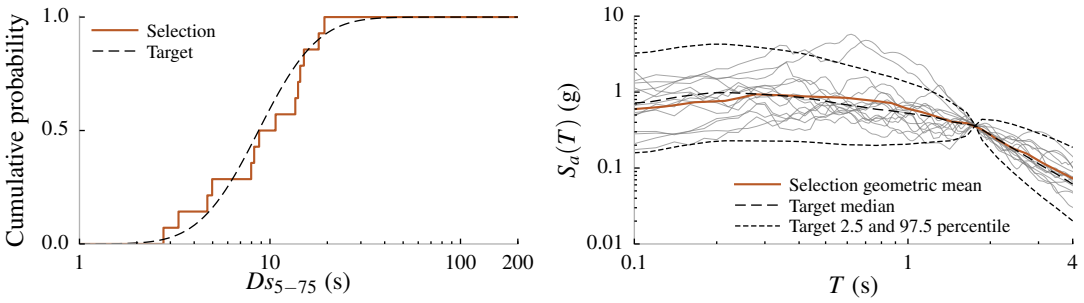
3.1.6.3 *CS and causal parameters* group

Table 9: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.36\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Seattle.

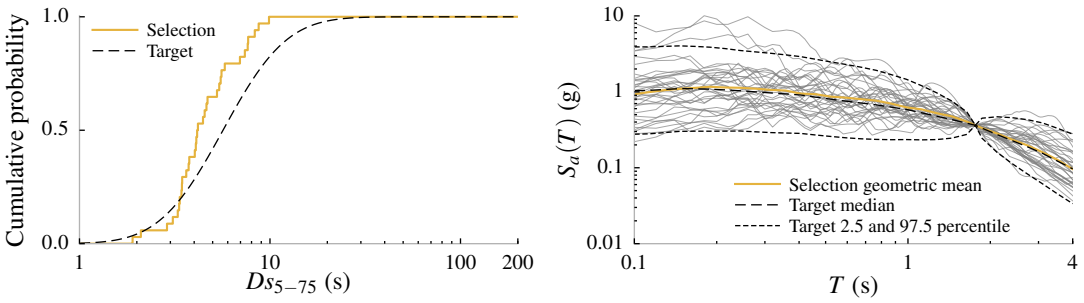
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	111	760	8.6	9.2	71	151	–	–	132	52
In-slab	7.0	58	760	6.5	7.5	38	78	360	1160	28	14
Crustal	7.0	5	760	6.5	7.5	0	10	360	1160	68	34



(a) Interface earthquakes: 52 / 100 ground motions



(b) In-slab earthquakes: 14 / 100 ground motions

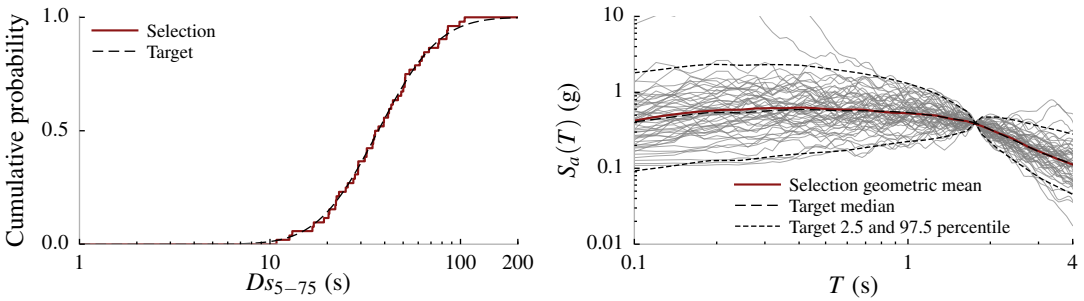


(c) Crustal earthquakes: 34 / 100 ground motions

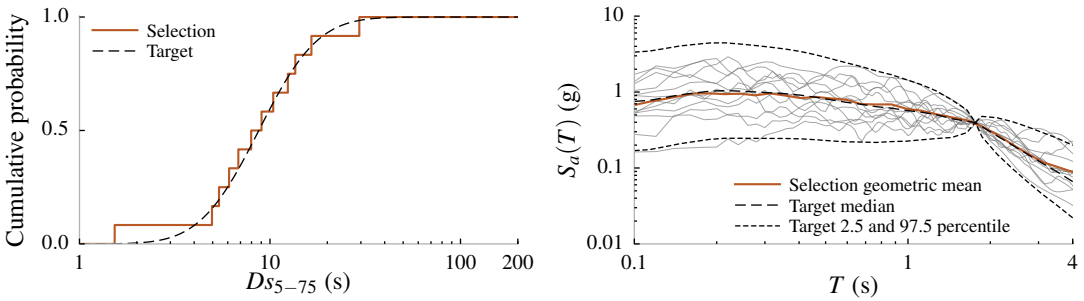
Figure 18: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.36\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Seattle.

3.1.7 $S_a(1.8\,\mathrm{s}) = 0.40\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level)

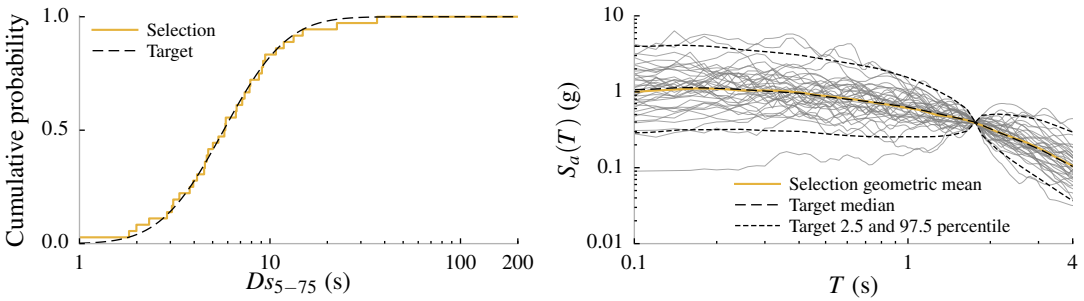
3.1.7.1 *CS and duration* group



(a) Interface earthquakes: 52 / 100 ground motions



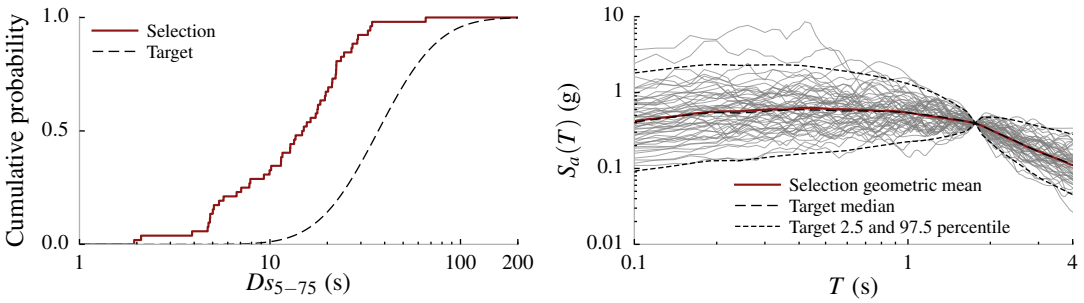
(b) In-slab earthquakes: 12 / 100 ground motions



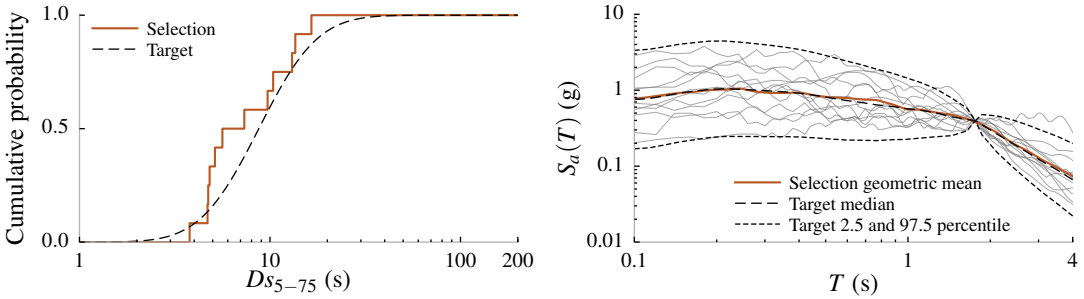
(c) Crustal earthquakes: 36 / 100 ground motions

Figure 19: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.40\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Seattle.

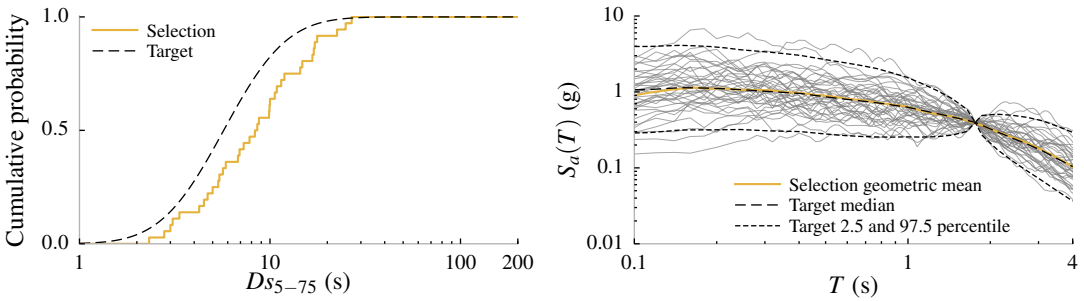
3.1.7.2 *CS only* group



(a) Interface earthquakes: 52 / 100 ground motions



(b) In-slab earthquakes: 12 / 100 ground motions



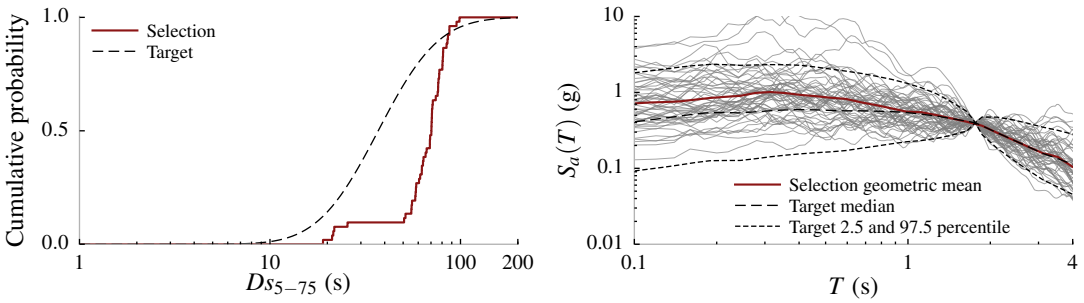
(c) Crustal earthquakes: 36 / 100 ground motions

Figure 20: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.40\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Seattle.

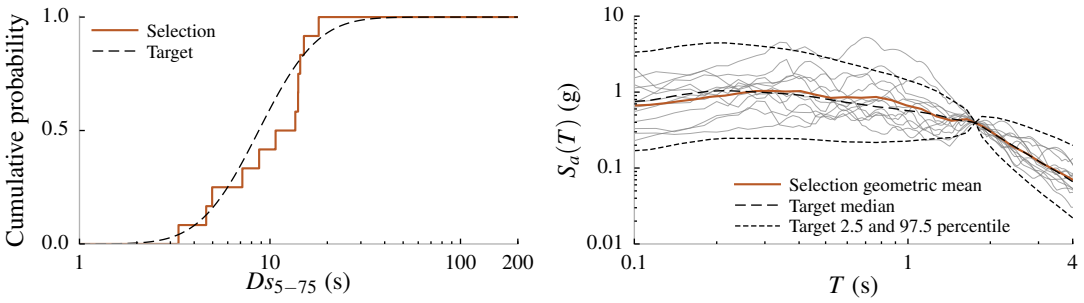
3.1.7.3 *CS and causal parameters* group

Table 10: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.40\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Seattle.

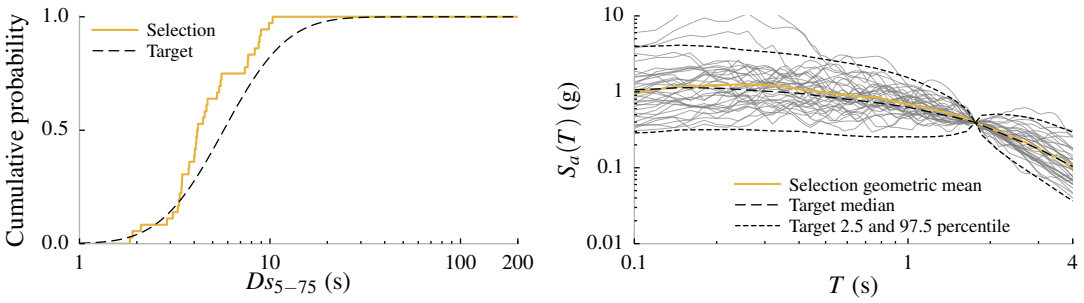
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	110	760	8.6	9.2	70	150	–	–	129	52
In-slab	7.0	58	760	6.5	7.5	38	78	360	1160	26	12
Crustal	7.0	5	760	6.5	7.5	0	10	360	1160	61	36



(a) Interface earthquakes: 52 / 100 ground motions



(b) In-slab earthquakes: 12 / 100 ground motions

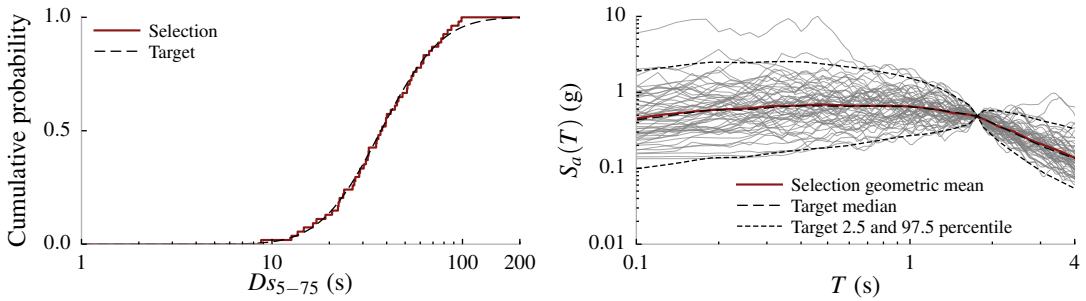


(c) Crustal earthquakes: 36 / 100 ground motions

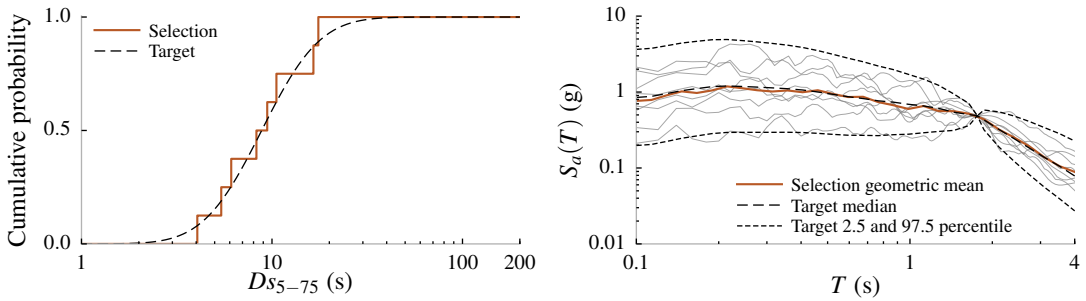
Figure 21: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.40\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Seattle.

3.1.8 $S_a(1.8\,\mathrm{s}) = 0.49\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level)

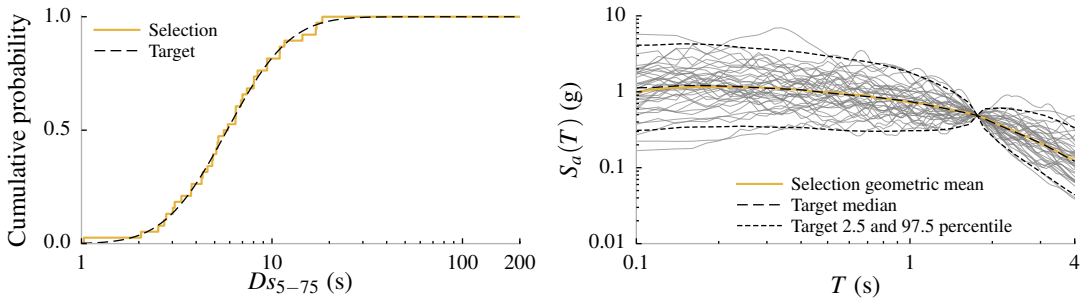
3.1.8.1 *CS and duration* group



(a) Interface earthquakes: 54 / 100 ground motions



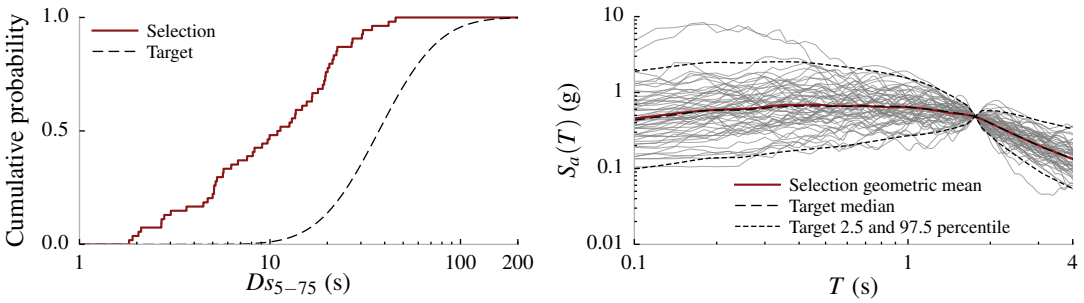
(b) In-slab earthquakes: 8 / 100 ground motions



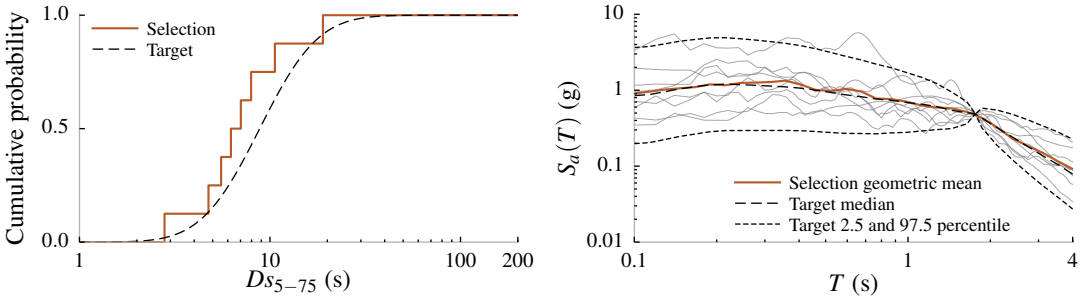
(c) Crustal earthquakes: 38 / 100 ground motions

Figure 22: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.49\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Seattle.

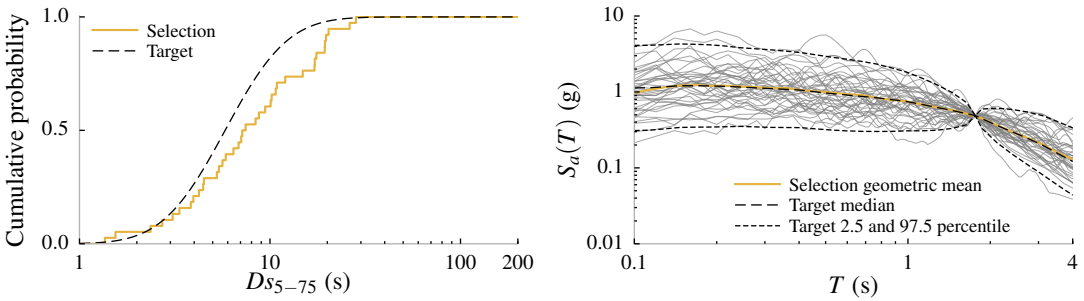
3.1.8.2 *CS only* group



(a) Interface earthquakes: 54 / 100 ground motions



(b) In-slab earthquakes: 8 / 100 ground motions



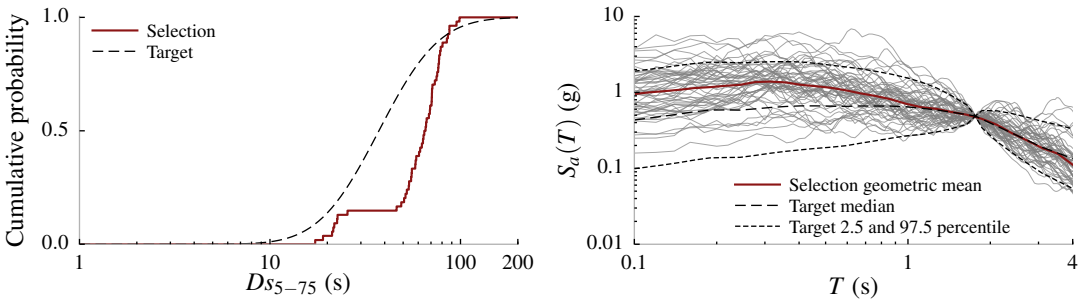
(c) Crustal earthquakes: 38 / 100 ground motions

Figure 23: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.49\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Seattle.

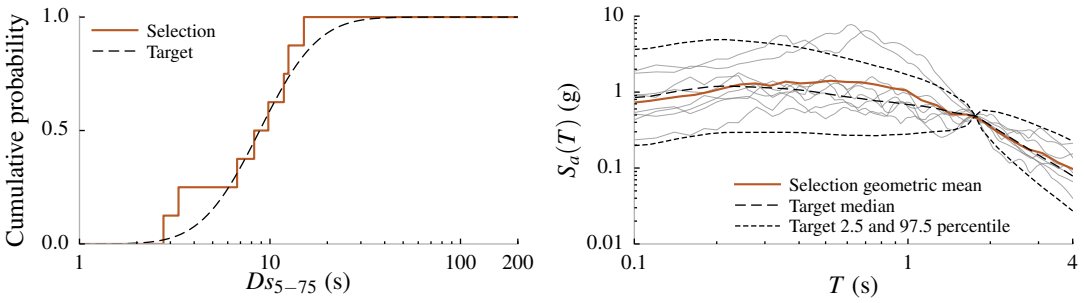
3.1.8.3 *CS and causal parameters* group

Table 11: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.49\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Seattle.

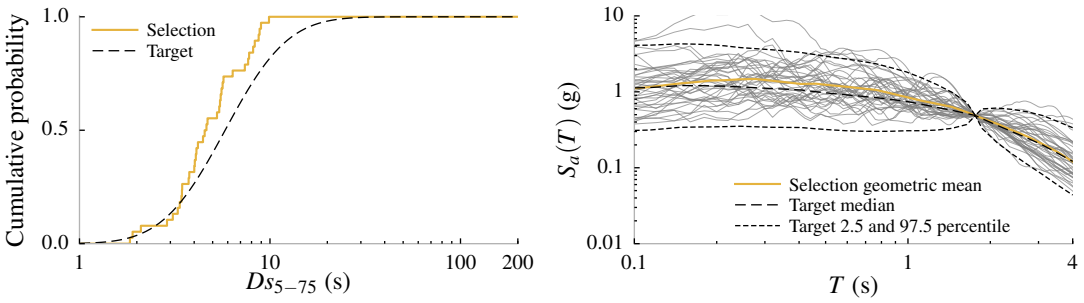
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	9.0	108	760	8.7	9.3	68	148	–	–	99	54
In-slab	7.1	56	760	6.6	7.6	36	76	360	1160	18	8
Crustal	7.0	4	760	6.5	7.5	0	9	360	1160	55	38



(a) Interface earthquakes: 54 / 100 ground motions



(b) In-slab earthquakes: 8 / 100 ground motions



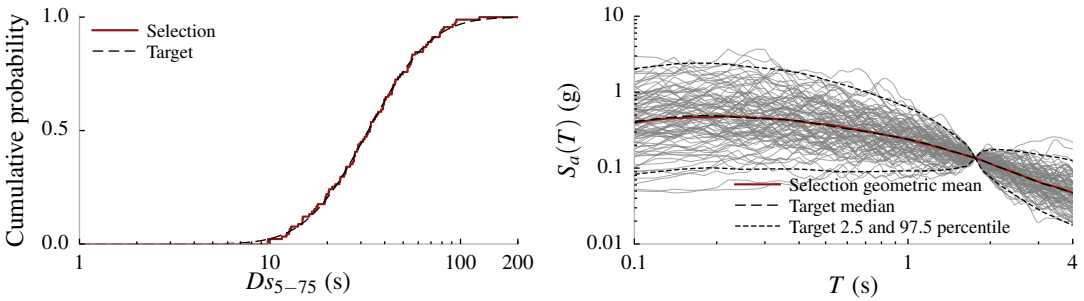
(c) Crustal earthquakes: 38 / 100 ground motions

Figure 24: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.49\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Seattle.

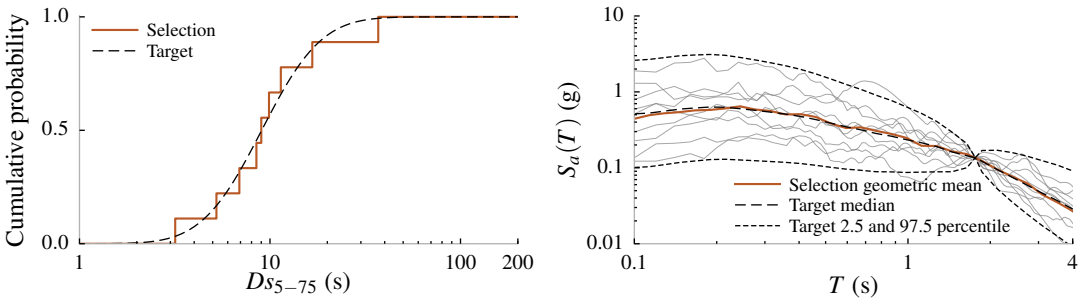
3.2 Eugene

3.2.1 $S_a(1.8\,\mathrm{s}) = 0.14\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level)

3.2.1.1 *CS and duration* group



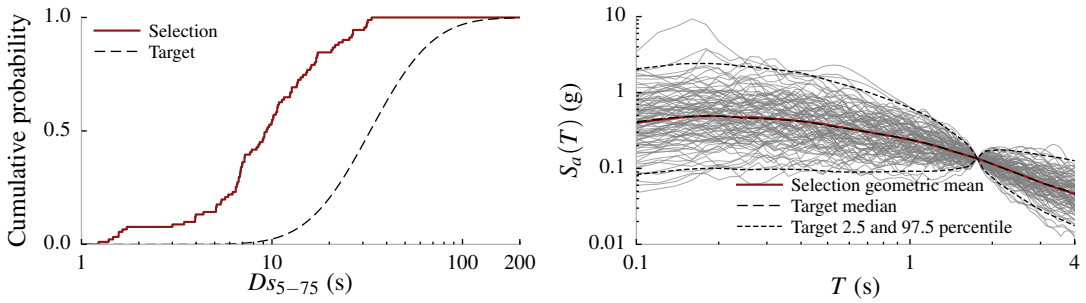
(a) Interface earthquakes: 91 / 100 ground motions



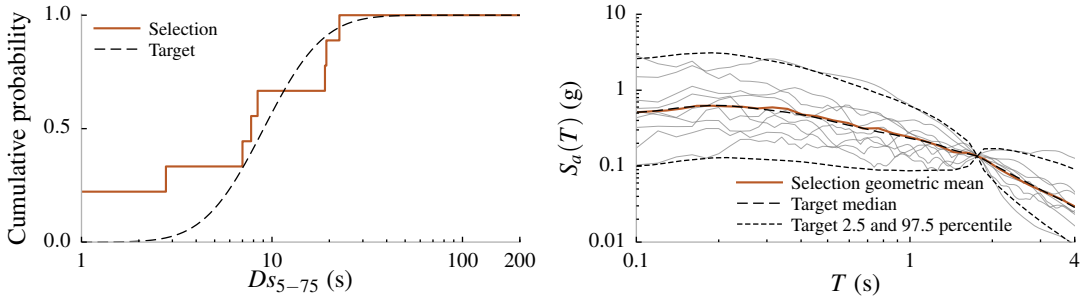
(b) In-slab earthquakes: 9 / 100 ground motions

Figure 25: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.14\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Eugene.

3.2.1.2 *CS only* group



(a) Interface earthquakes: 91 / 100 ground motions



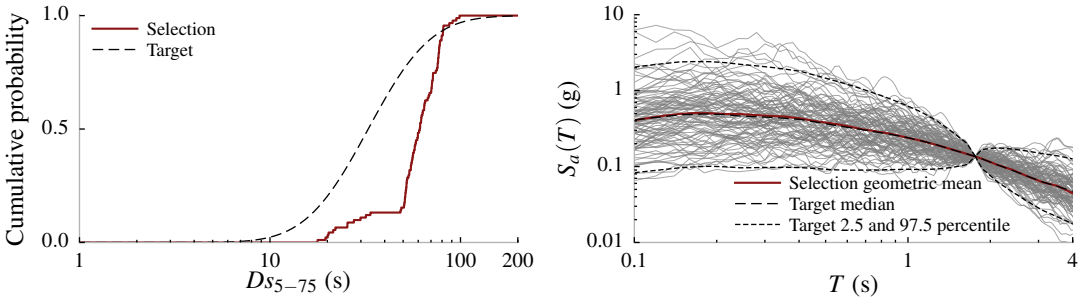
(b) In-slab earthquakes: 9 / 100 ground motions

Figure 26: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.14\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Eugene.

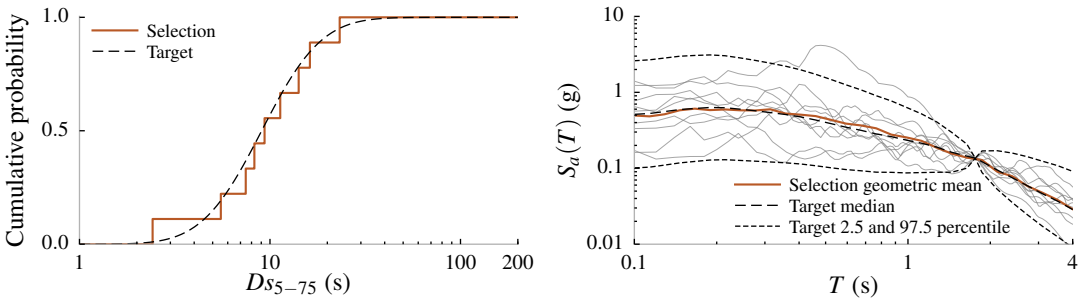
3.2.1.3 *CS and causal parameters* group

Table 12: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.14\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.8	85	760	8.5	9.1	5	165	–	–	323	91
In-slab	7.0	67	760	6.5	7.5	47	87	360	1160	123	9



(a) Interface earthquakes: 91 / 100 ground motions

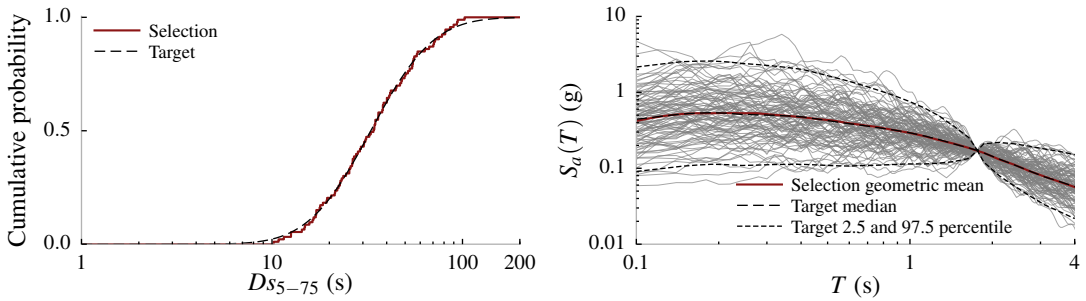


(b) In-slab earthquakes: 9 / 100 ground motions

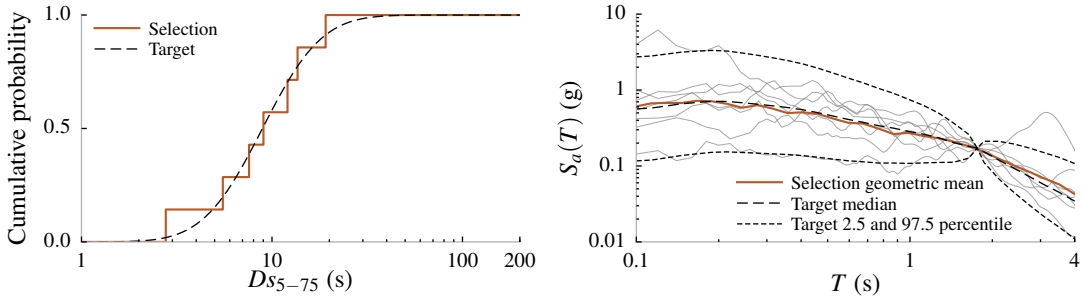
Figure 27: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.14\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in Eugene.

3.2.2 $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level)

3.2.2.1 *CS and duration* group



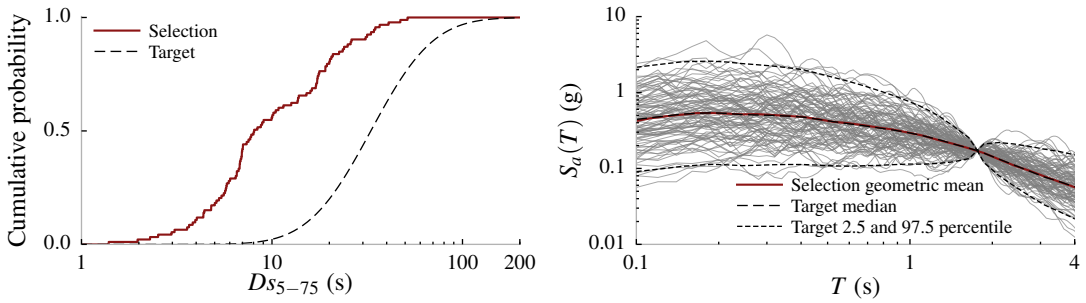
(a) Interface earthquakes: 93 / 100 ground motions



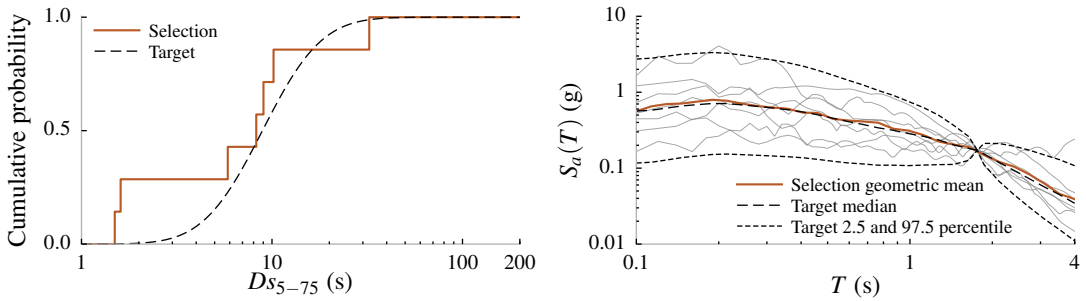
(b) In-slab earthquakes: 7 / 100 ground motions

Figure 28: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Eugene.

3.2.2.2 *CS only* group



(a) Interface earthquakes: 93 / 100 ground motions



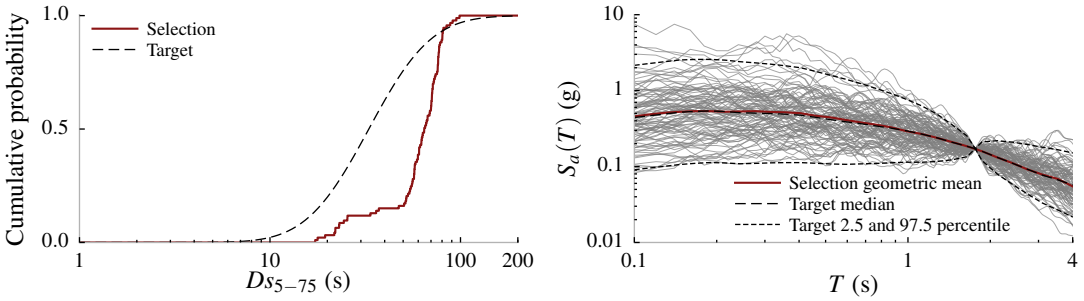
(b) In-slab earthquakes: 7 / 100 ground motions

Figure 29: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Eugene.

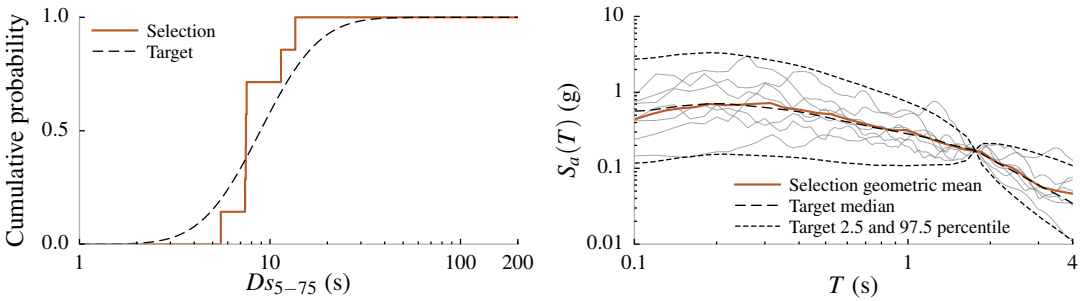
3.2.2.3 *CS and causal parameters* group

Table 13: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.8	82	760	8.5	9.1	2	162	–	–	301	93
In-slab	7.0	65	760	6.5	7.5	45	85	360	1160	95	7



(a) Interface earthquakes: 93 / 100 ground motions

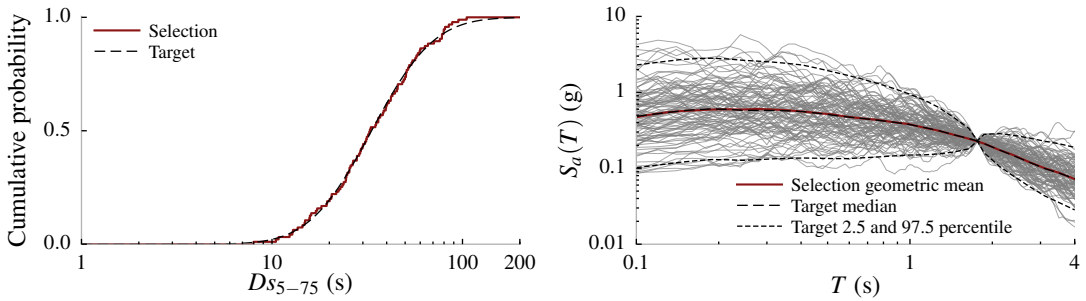


(b) In-slab earthquakes: 7 / 100 ground motions

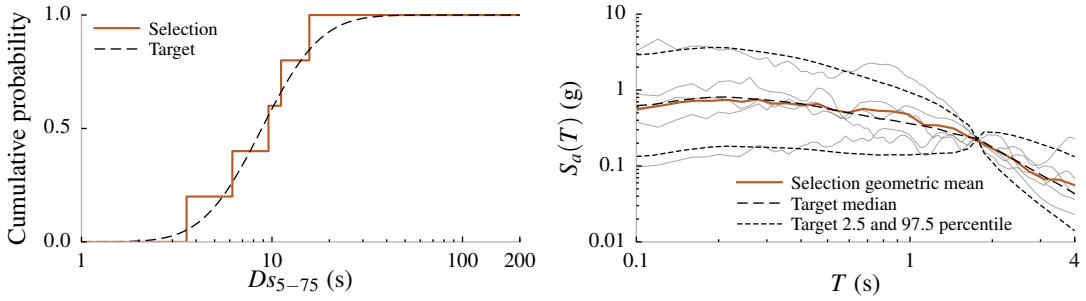
Figure 30: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.17\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in Eugene.

3.2.3 $S_a(1.8\,\mathrm{s}) = 0.23\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level)

3.2.3.1 *CS and duration* group



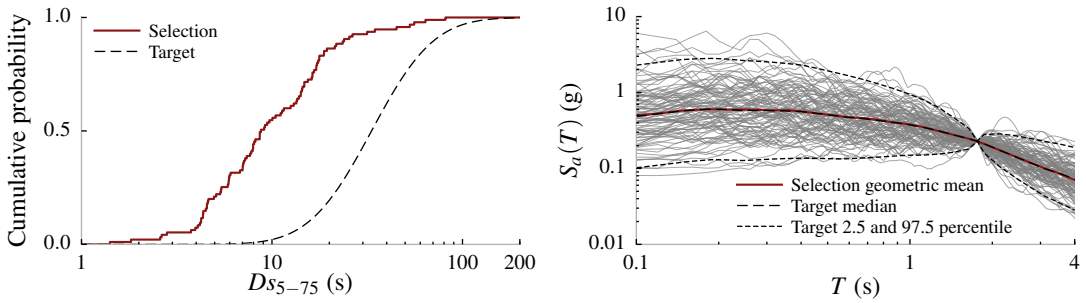
(a) Interface earthquakes: 95 / 100 ground motions



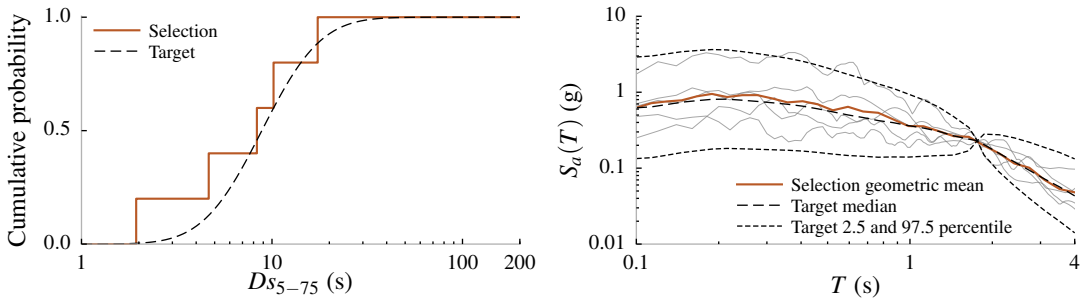
(b) In-slab earthquakes: 5 / 100 ground motions

Figure 31: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.23\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Eugene.

3.2.3.2 *CS only* group



(a) Interface earthquakes: 95 / 100 ground motions



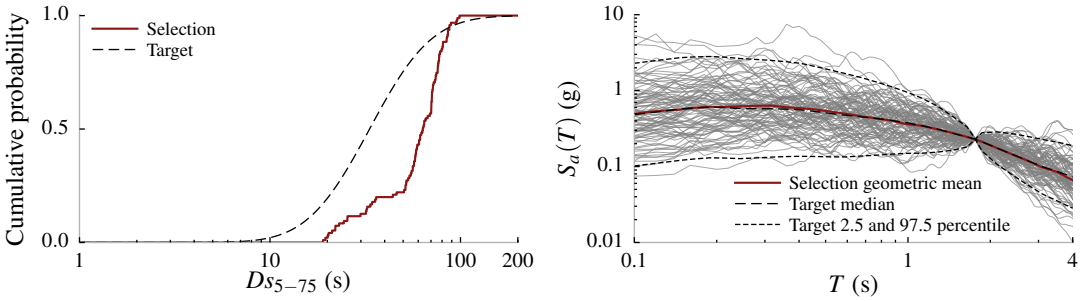
(b) In-slab earthquakes: 5 / 100 ground motions

Figure 32: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.23\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Eugene.

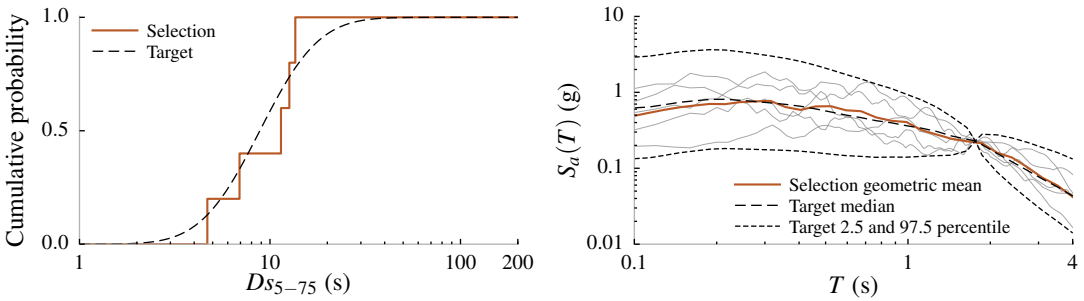
3.2.3.3 *CS and causal parameters* group

Table 14: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.23\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.8	79	760	8.5	9.1	0	159	–	–	247	95
In-slab	7.0	62	760	6.5	7.5	42	82	360	1160	58	5



(a) Interface earthquakes: 95 / 100 ground motions

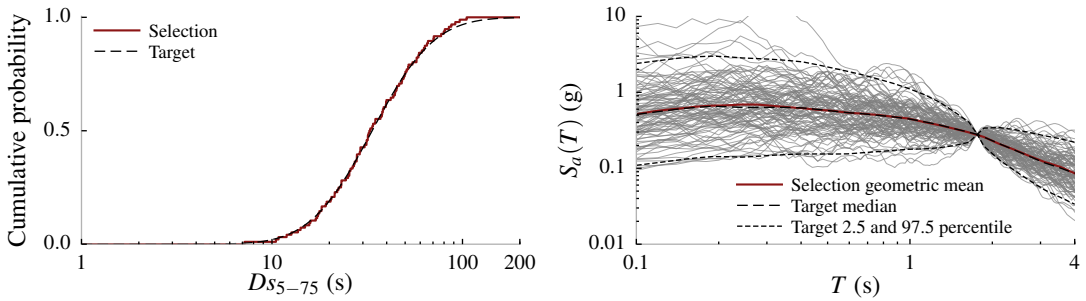


(b) In-slab earthquakes: 5 / 100 ground motions

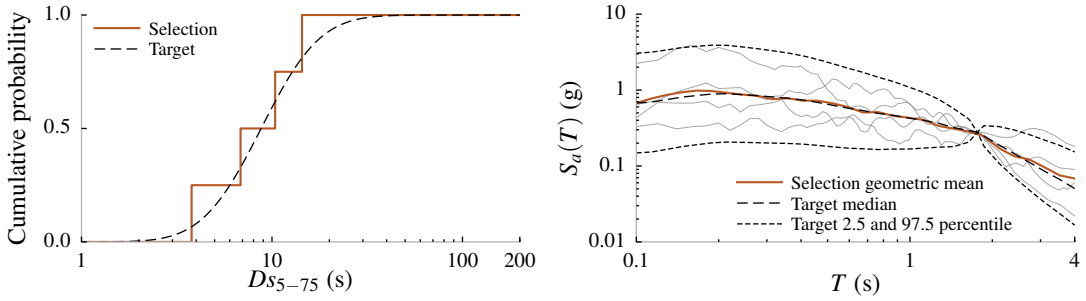
Figure 33: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.23\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in Eugene.

3.2.4 $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level)

3.2.4.1 *CS and duration* group



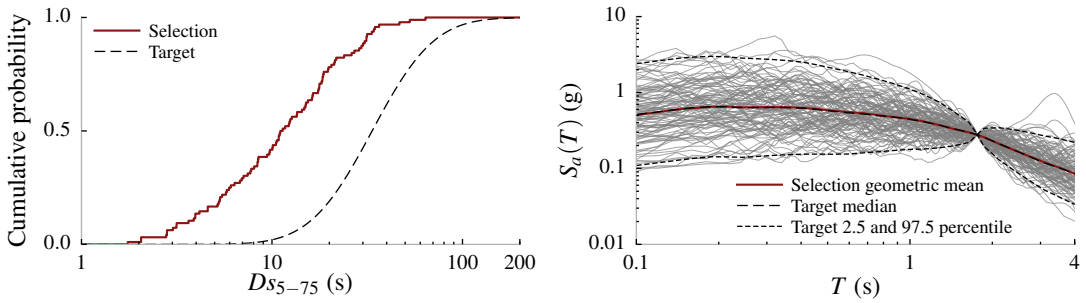
(a) Interface earthquakes: 96 / 100 ground motions



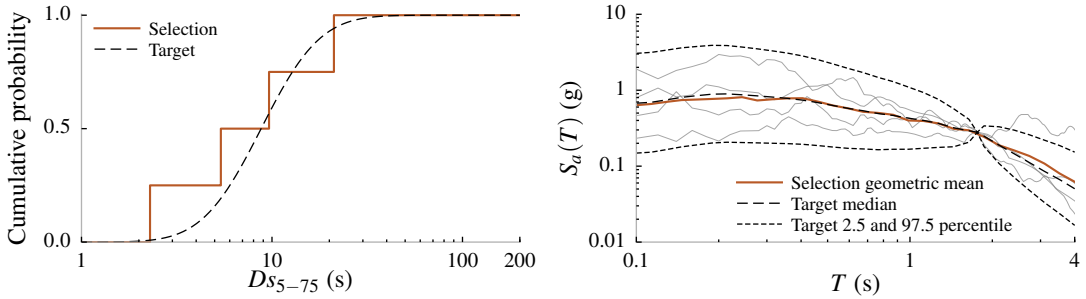
(b) In-slab earthquakes: 4 / 100 ground motions

Figure 34: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Eugene.

3.2.4.2 *CS only* group



(a) Interface earthquakes: 96 / 100 ground motions



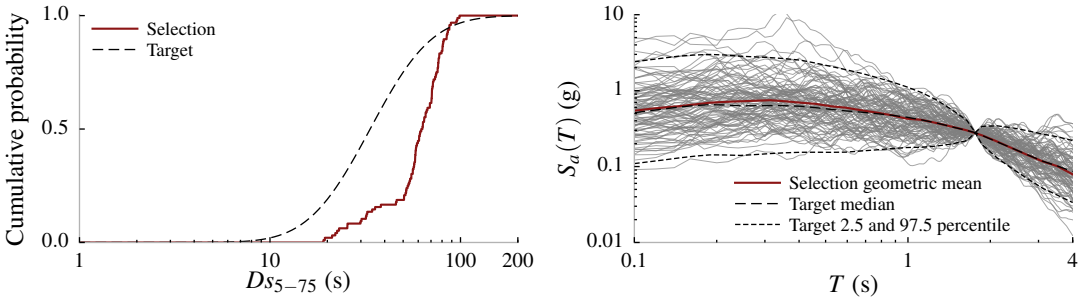
(b) In-slab earthquakes: 4 / 100 ground motions

Figure 35: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Eugene.

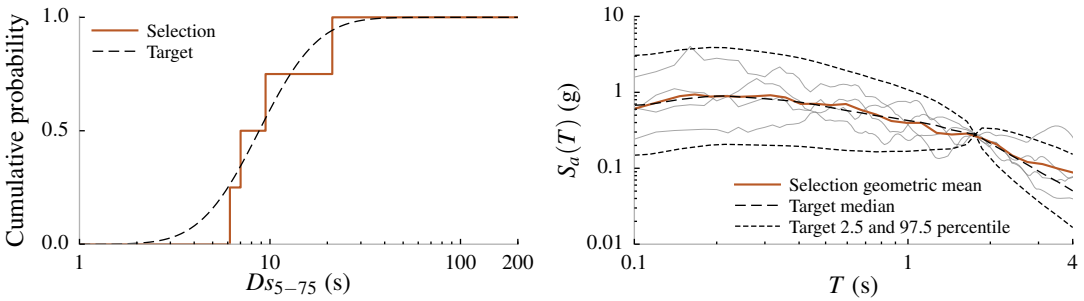
3.2.4.3 *CS and causal parameters* group

Table 15: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	77	760	8.6	9.2	0	157	–	–	221	96
In-slab	7.0	61	760	6.5	7.5	41	81	360	1160	49	4



(a) Interface earthquakes: 96 / 100 ground motions

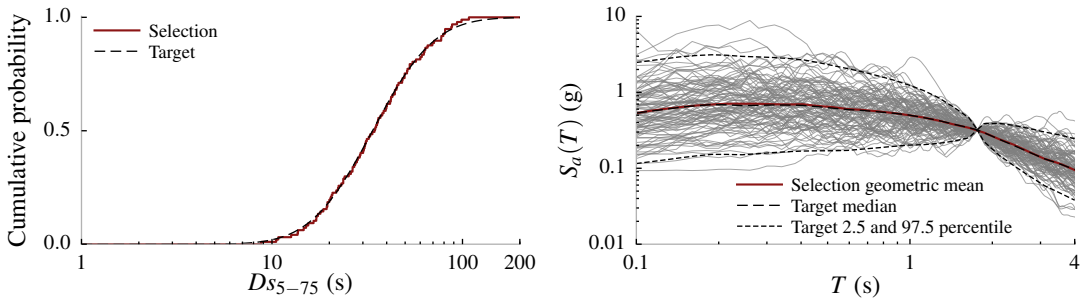


(b) In-slab earthquakes: 4 / 100 ground motions

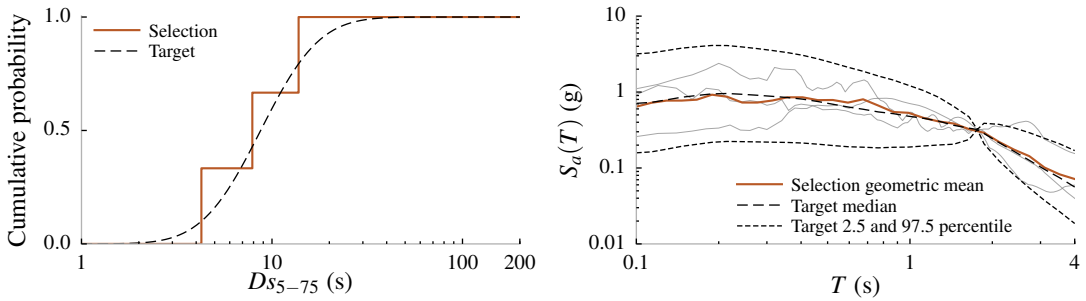
Figure 36: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.28\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in Eugene.

3.2.5 $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level)

3.2.5.1 *CS and duration* group



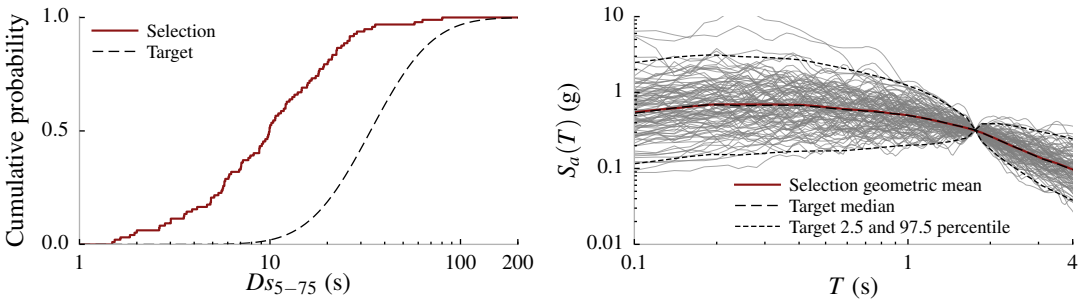
(a) Interface earthquakes: 97 / 100 ground motions



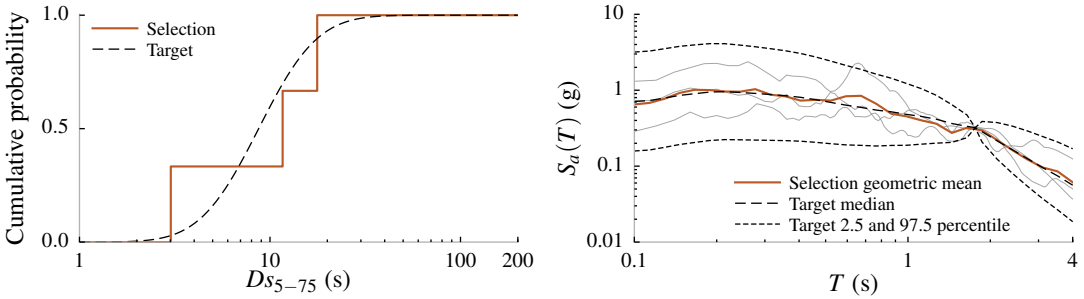
(b) In-slab earthquakes: 3 / 100 ground motions

Figure 37: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Eugene.

3.2.5.2 *CS only* group



(a) Interface earthquakes: 97 / 100 ground motions



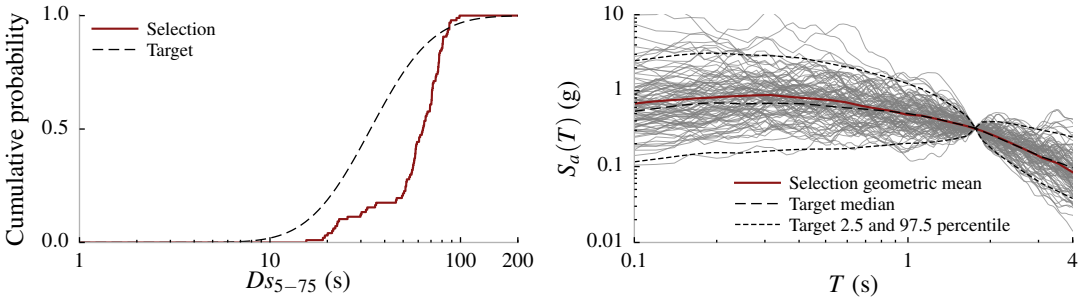
(b) In-slab earthquakes: 3 / 100 ground motions

Figure 38: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Eugene.

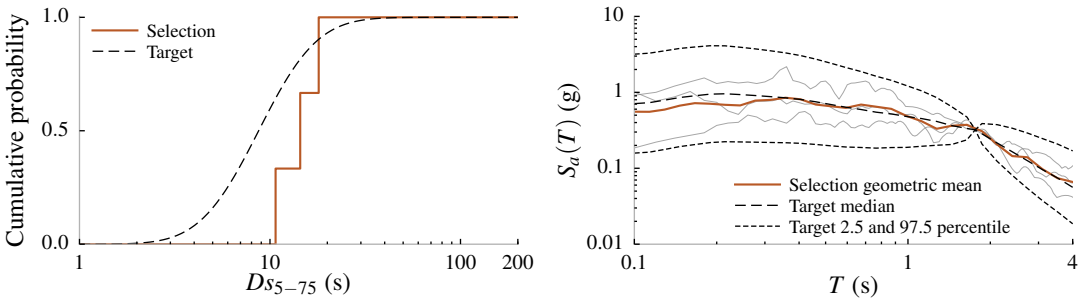
3.2.5.3 *CS and causal parameters* group

Table 16: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	76	760	8.6	9.2	0	156	–	–	199	97
In-slab	7.0	58	760	6.5	7.5	38	78	360	1160	37	3



(a) Interface earthquakes: 97 / 100 ground motions

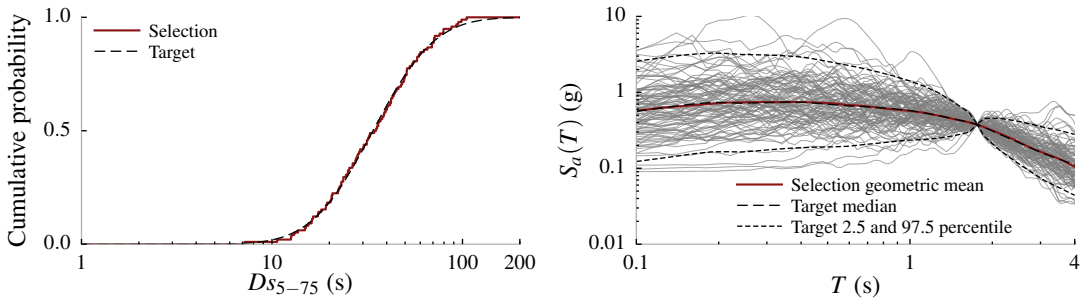


(b) In-slab earthquakes: 3 / 100 ground motions

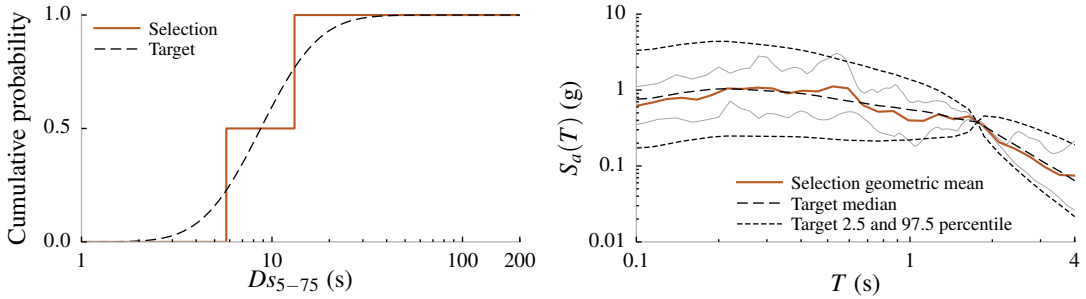
Figure 39: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.32\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in Eugene.

3.2.6 $S_a(1.8\,\mathrm{s}) = 0.38\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level)

3.2.6.1 *CS and duration* group



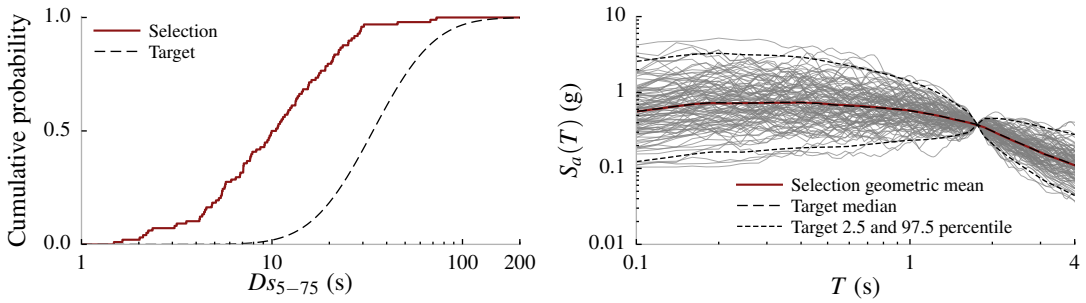
(a) Interface earthquakes: 98 / 100 ground motions



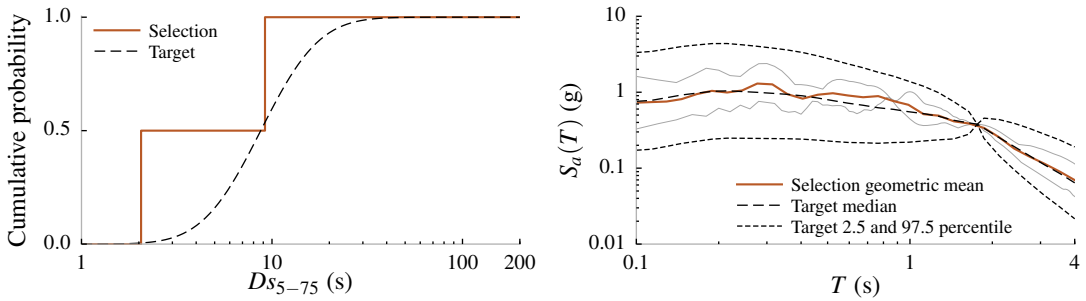
(b) In-slab earthquakes: 2 / 100 ground motions

Figure 40: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.38\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Eugene.

3.2.6.2 *CS only* group



(a) Interface earthquakes: 98 / 100 ground motions



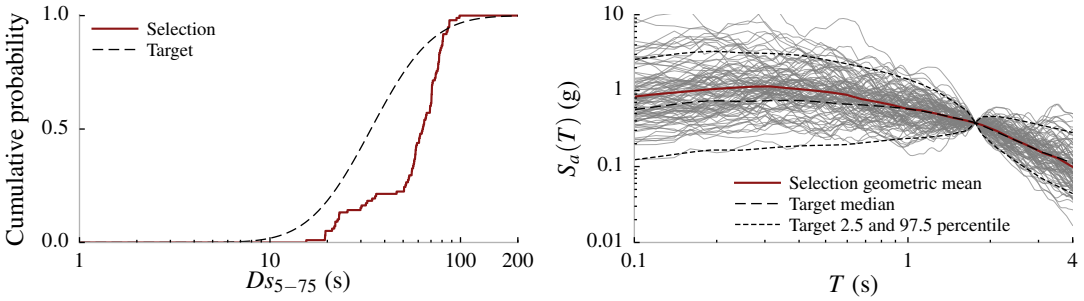
(b) In-slab earthquakes: 2 / 100 ground motions

Figure 41: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.38\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Eugene.

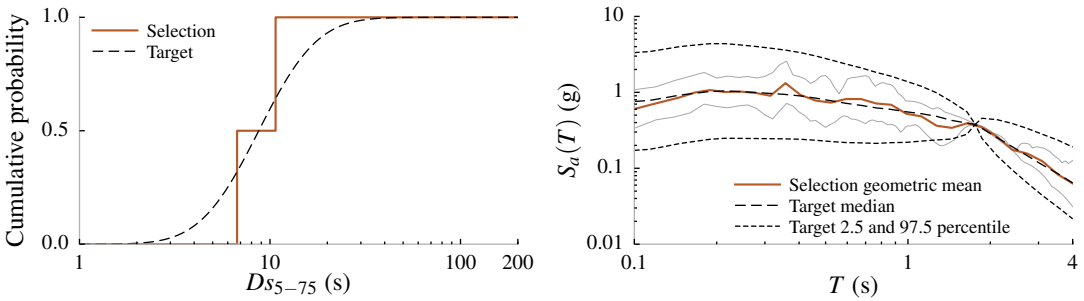
3.2.6.3 *CS and causal parameters* group

Table 17: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.38\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	74	760	8.6	9.2	0	154	–	–	180	98
In-slab	7.0	57	760	6.5	7.5	37	77	360	1160	27	2



(a) Interface earthquakes: 98 / 100 ground motions

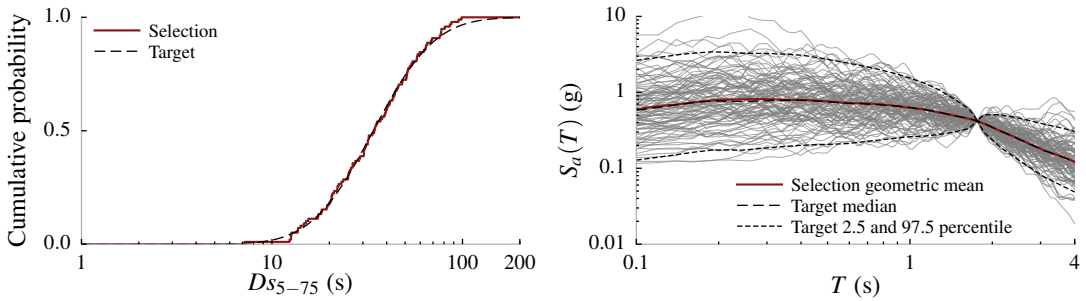


(b) In-slab earthquakes: 2 / 100 ground motions

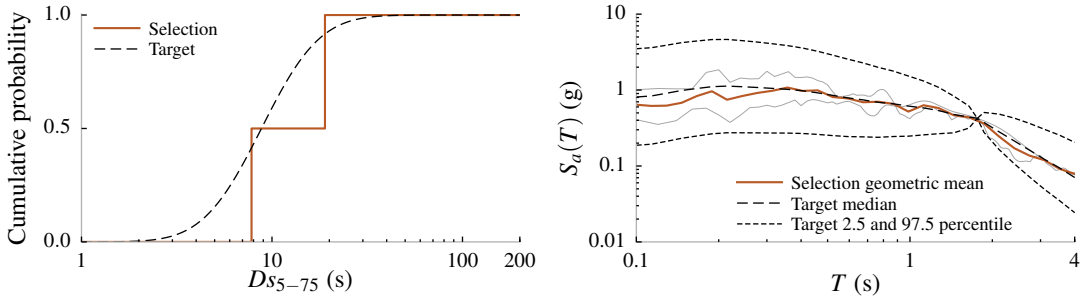
Figure 42: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.38\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in Eugene.

3.2.7 $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level)

3.2.7.1 *CS and duration* group



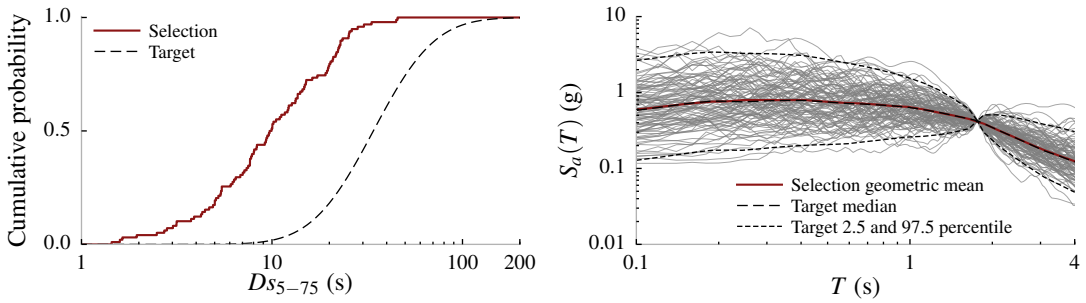
(a) Interface earthquakes: 98 / 100 ground motions



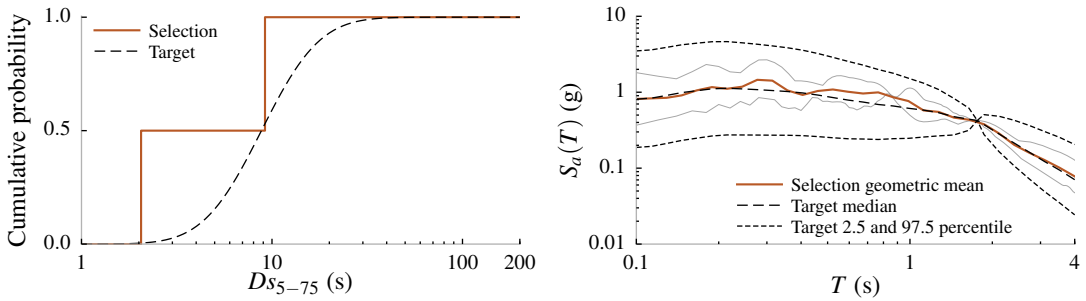
(b) In-slab earthquakes: 2 / 100 ground motions

Figure 43: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Eugene.

3.2.7.2 *CS only* group



(a) Interface earthquakes: 98 / 100 ground motions



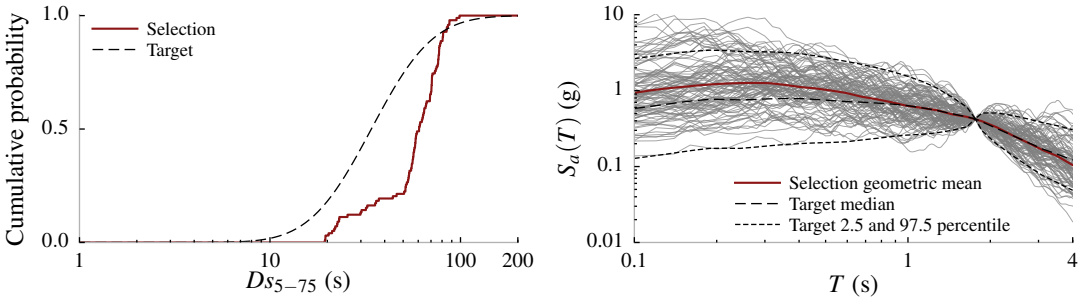
(b) In-slab earthquakes: 2 / 100 ground motions

Figure 44: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Eugene.

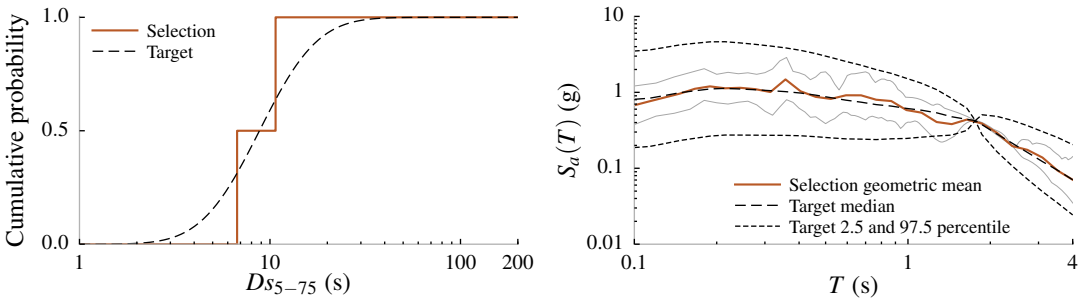
3.2.7.3 *CS and causal parameters* group

Table 18: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	73	760	8.6	9.2	0	153	–	–	164	98
In-slab	7.1	56	760	6.6	7.6	36	76	360	1160	24	2



(a) Interface earthquakes: 98 / 100 ground motions

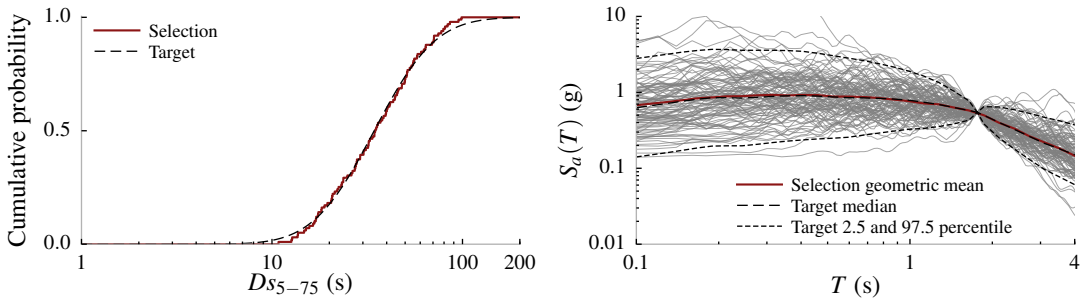


(b) In-slab earthquakes: 2 / 100 ground motions

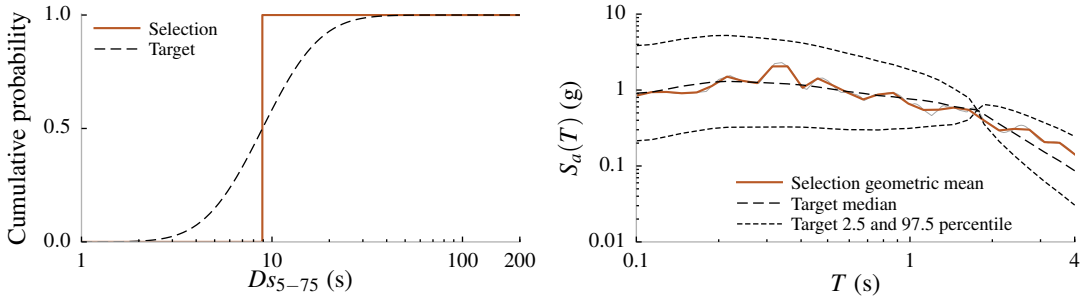
Figure 45: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in Eugene.

3.2.8 $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level)

3.2.8.1 *CS and duration* group



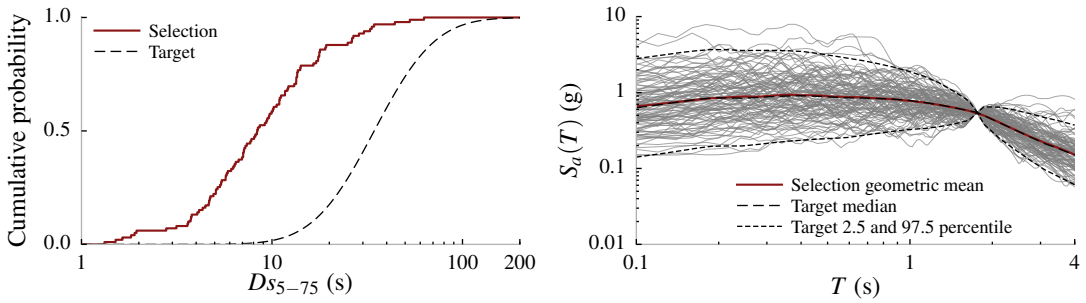
(a) Interface earthquakes: 99 / 100 ground motions



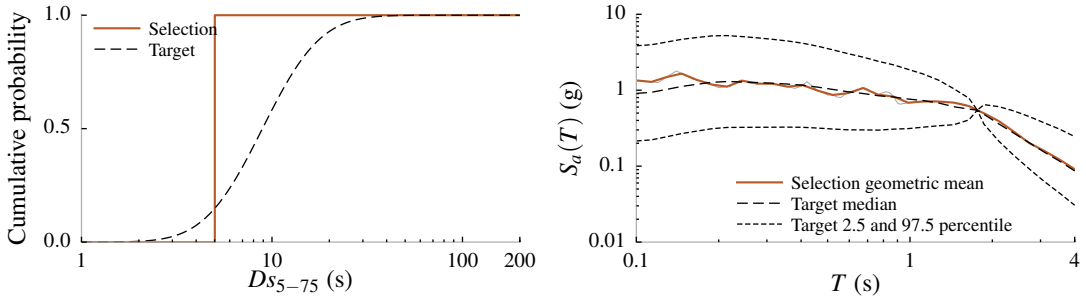
(b) In-slab earthquakes: 1 / 100 ground motions

Figure 46: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Eugene.

3.2.8.2 *CS only* group



(a) Interface earthquakes: 99 / 100 ground motions



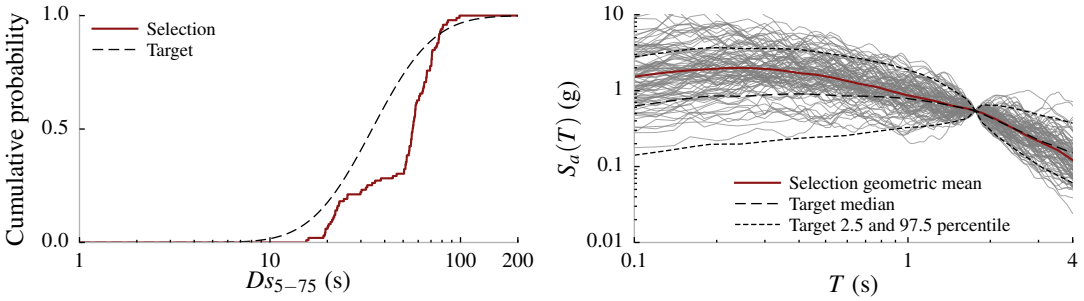
(b) In-slab earthquakes: 1 / 100 ground motions

Figure 47: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Eugene.

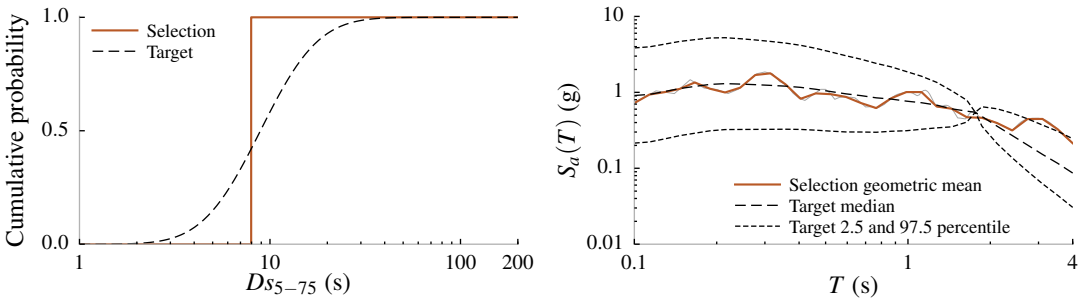
3.2.8.3 *CS and causal parameters* group

Table 19: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Eugene.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs}_{30}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Interface	8.9	70	760	8.6	9.2	0	150	–	–	128	99
In-slab	7.1	55	760	6.6	7.6	35	75	360	1160	15	1



(a) Interface earthquakes: 99 / 100 ground motions



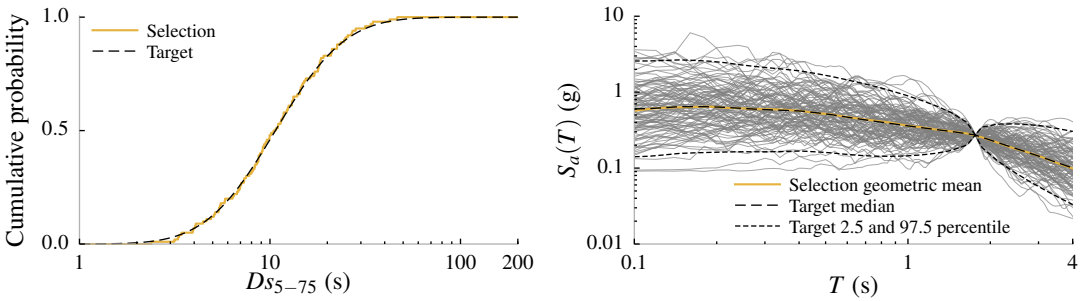
(b) In-slab earthquakes: 1 / 100 ground motions

Figure 48: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in Eugene.

3.3 San Francisco

3.3.1 $S_a(1.8\,\mathrm{s}) = 0.27\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level)

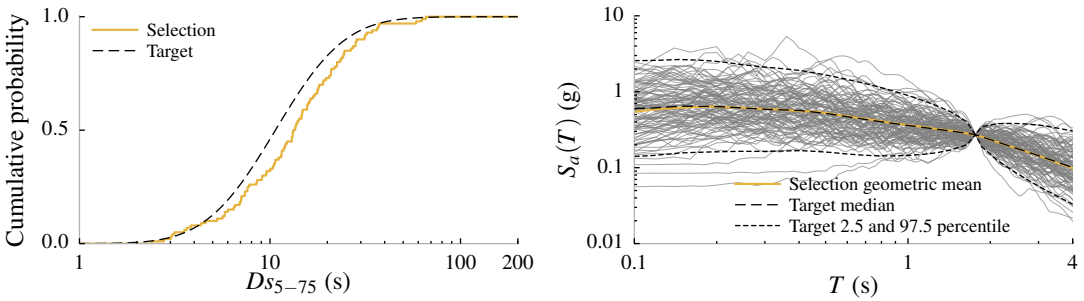
3.3.1.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 49: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.27\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in San Francisco.

3.3.1.2 *CS only* group



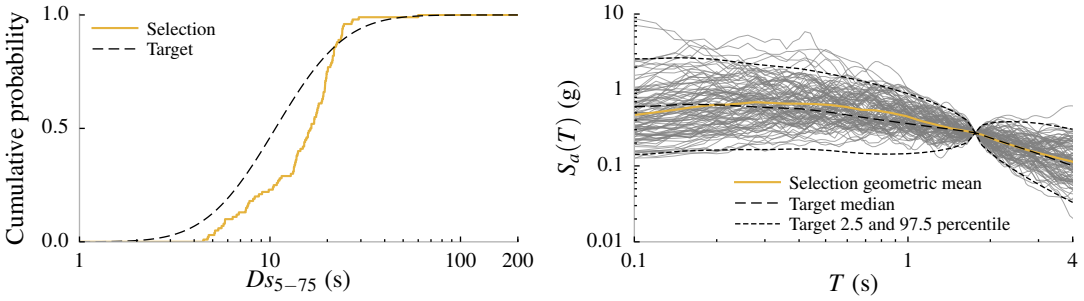
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 50: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.27\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in San Francisco.

3.3.1.3 *CS and causal parameters* group

Table 20: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.27\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in San Francisco.

Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	$\bar{Vs_{30}}$ (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.7	14	760	7.2	8.2	0	29	360	1160	163	100

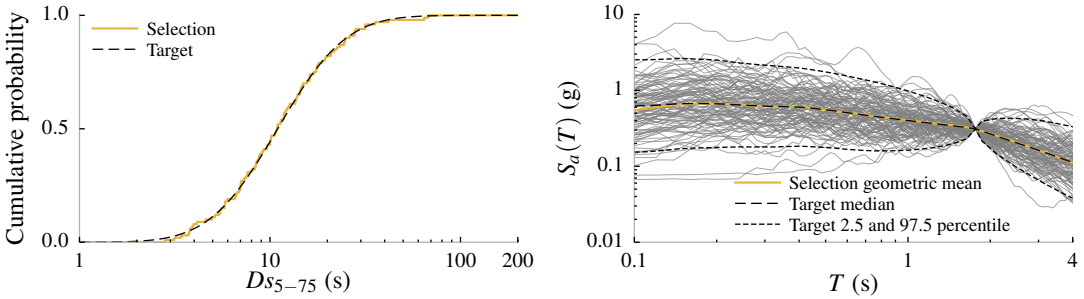


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 51: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.27\,\mathrm{g}$ intensity level (4.70 % in 50 year hazard level) in San Francisco.

3.3.2 $S_a(1.8\,\mathrm{s}) = 0.31\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level)

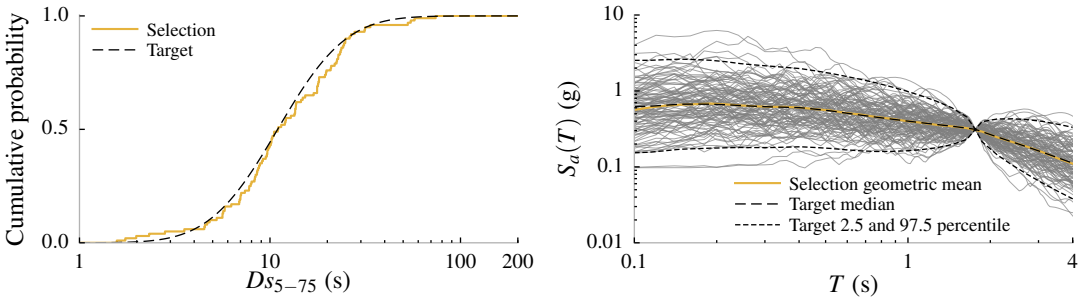
3.3.2.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 52: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.31\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in San Francisco.

3.3.2.2 *CS only* group



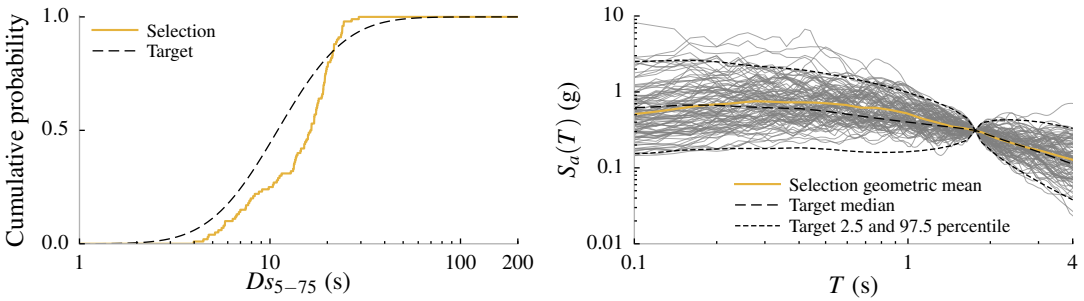
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 53: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.31\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in San Francisco.

3.3.2.3 *CS and causal parameters* group

Table 21: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.31\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in San Francisco.

Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.7	14	760	7.2	8.2	0	29	360	1160	162	100

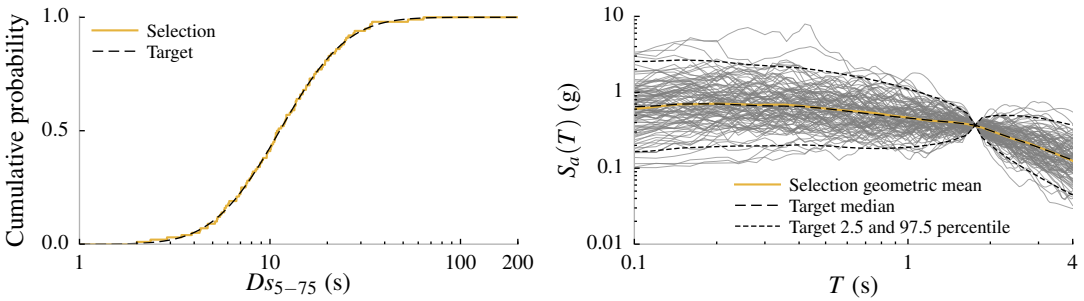


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 54: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.31\,\mathrm{g}$ intensity level (3.31 % in 50 year hazard level) in San Francisco.

3.3.3 $S_a(1.8\,\mathrm{s}) = 0.37\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level)

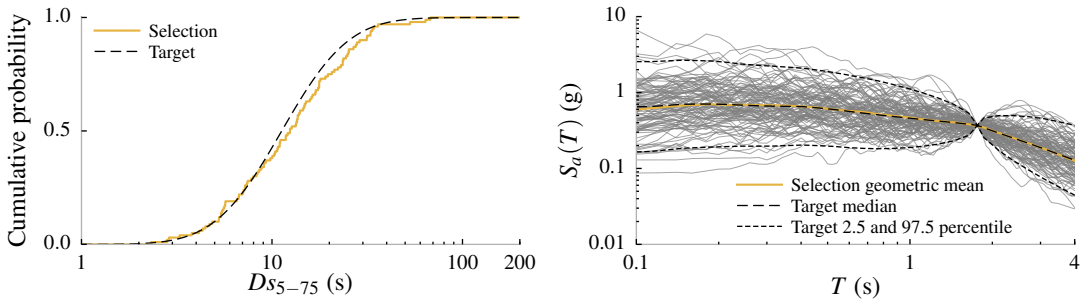
3.3.3.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 55: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.37\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in San Francisco.

3.3.3.2 *CS only* group



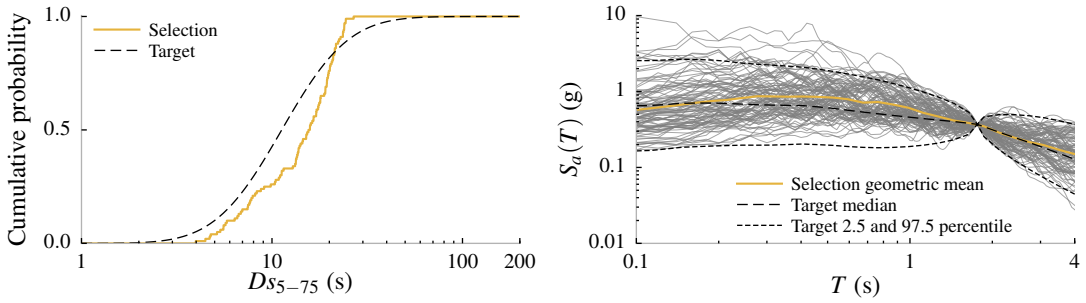
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 56: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.37\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in San Francisco.

3.3.3.3 *CS and causal parameters* group

Table 22: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.37\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in San Francisco.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.7	14	760	7.2	8.2	0	29	360	1160	158	100

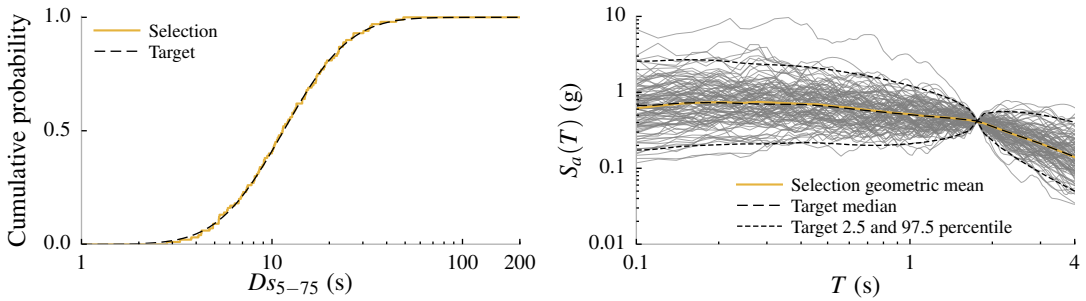


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 57: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.37\,\mathrm{g}$ intensity level (2.00 % in 50 year hazard level) in San Francisco.

3.3.4 $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level)

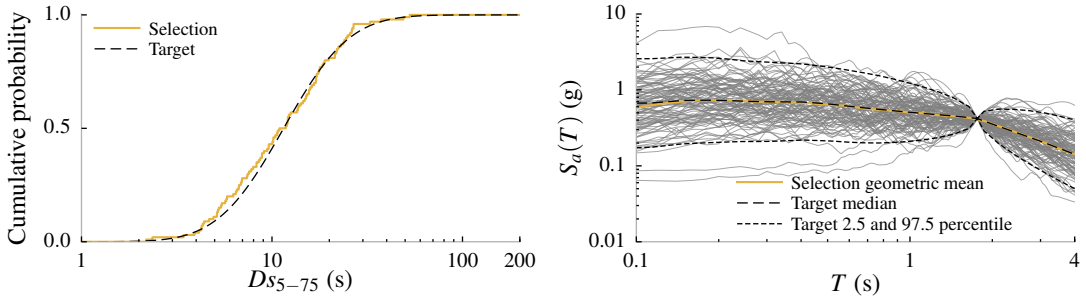
3.3.4.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 58: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in San Francisco.

3.3.4.2 *CS only* group



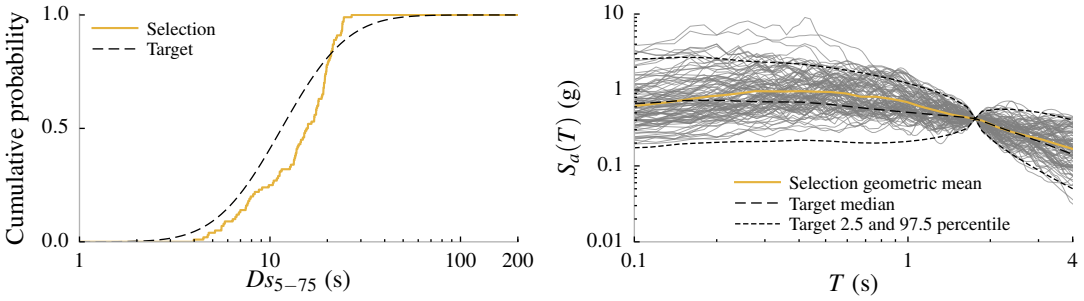
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 59: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in San Francisco.

3.3.4.3 *CS and causal parameters* group

Table 23: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in San Francisco.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.8	14	760	7.3	8.3	0	29	360	1160	154	100

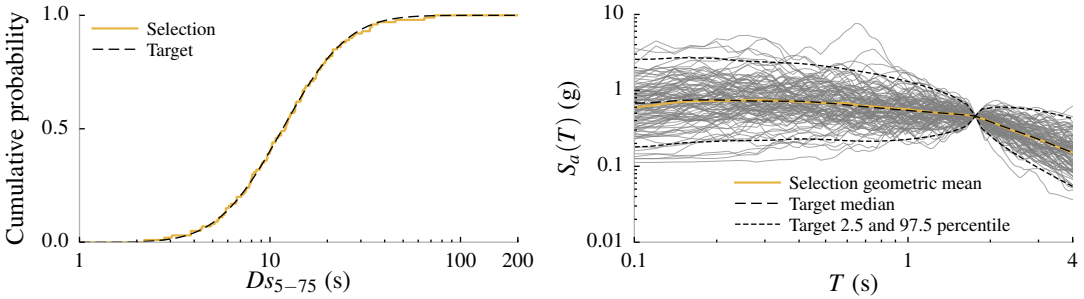


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 60: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.42\,\mathrm{g}$ intensity level (1.34 % in 50 year hazard level) in San Francisco.

3.3.5 $S_a(1.8\,\mathrm{s}) = 0.46\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level)

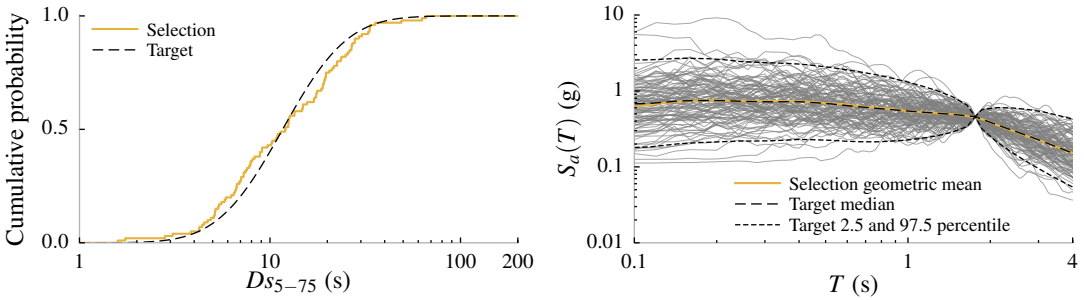
3.3.5.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 61: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.46\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in San Francisco.

3.3.5.2 *CS only* group



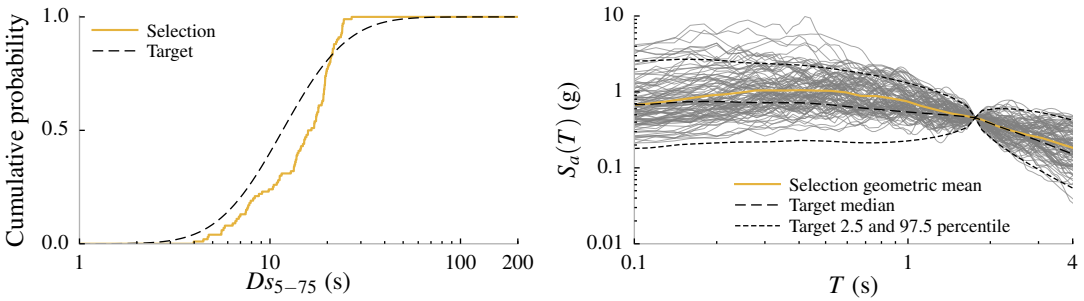
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 62: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.46\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in San Francisco.

3.3.5.3 *CS and causal parameters* group

Table 24: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.46\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in San Francisco.

Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.8	14	760	7.3	8.3	0	29	360	1160	149	100

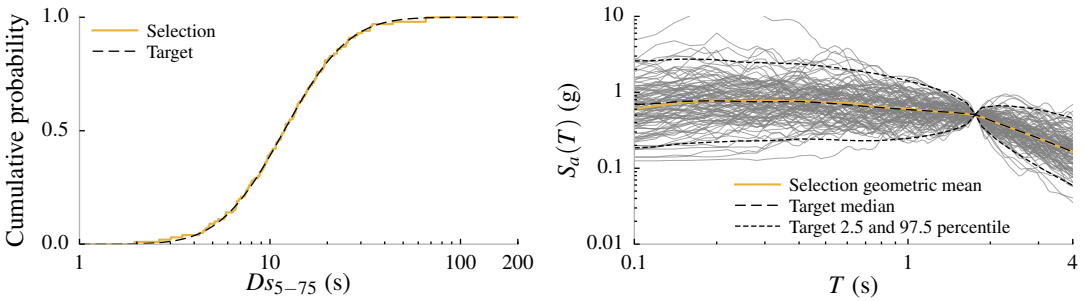


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 63: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.46\,\mathrm{g}$ intensity level (1.00 % in 50 year hazard level) in San Francisco.

3.3.6 $S_a(1.8\,\mathrm{s}) = 0.51\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level)

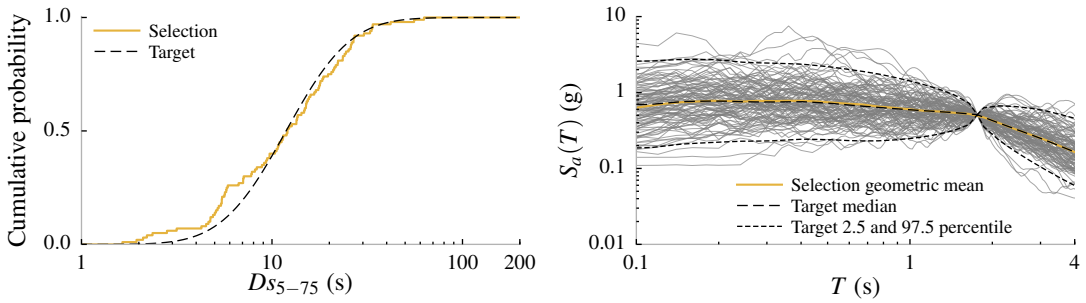
3.3.6.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 64: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.51\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in San Francisco.

3.3.6.2 *CS only* group



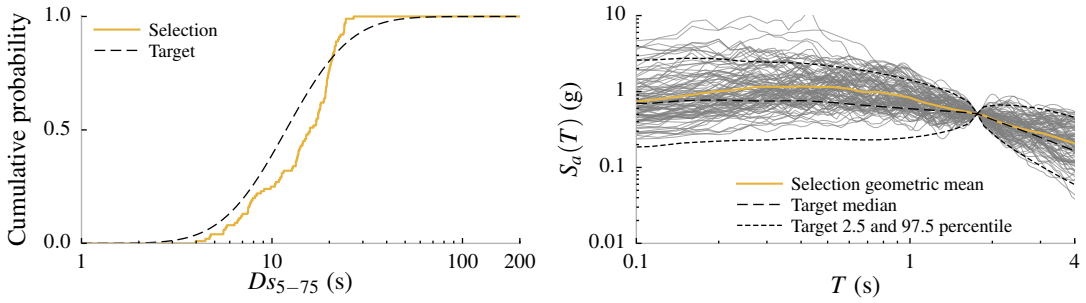
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 65: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.51\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in San Francisco.

3.3.6.3 *CS and causal parameters* group

Table 25: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.51\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in San Francisco.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.8	14	760	7.3	8.3	0	29	360	1160	141	100

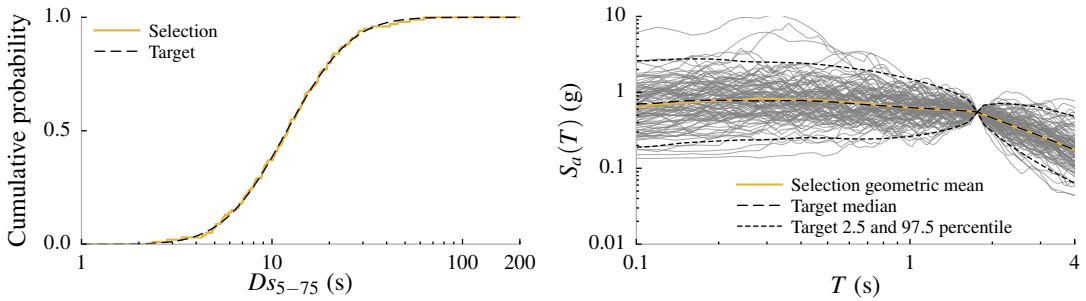


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 66: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.51\,\mathrm{g}$ intensity level (0.67 % in 50 year hazard level) in San Francisco.

3.3.7 $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level)

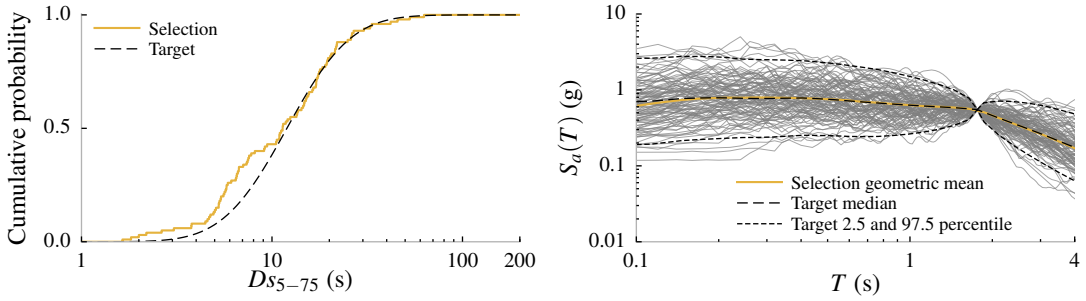
3.3.7.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 67: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in San Francisco.

3.3.7.2 *CS only* group



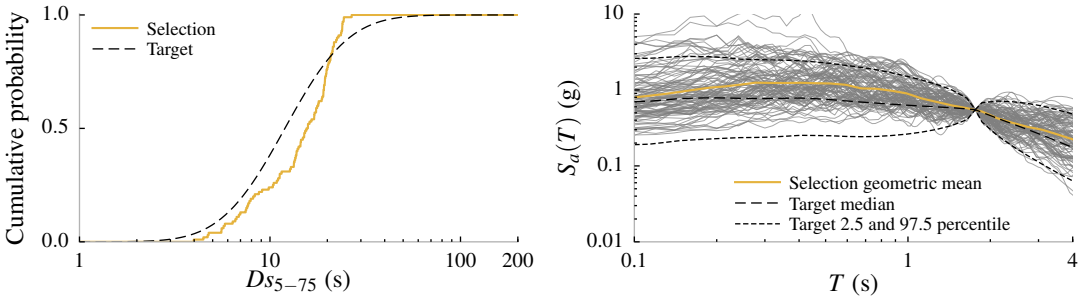
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 68: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in San Francisco.

3.3.7.3 *CS and causal parameters* group

Table 26: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in San Francisco.

Seismic source type	**Target mean**			**Selection constraints**						**No. of suitable records**	**No. of selected records**
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.8	13	760	7.3	8.3	0	28	360	1160	135	100

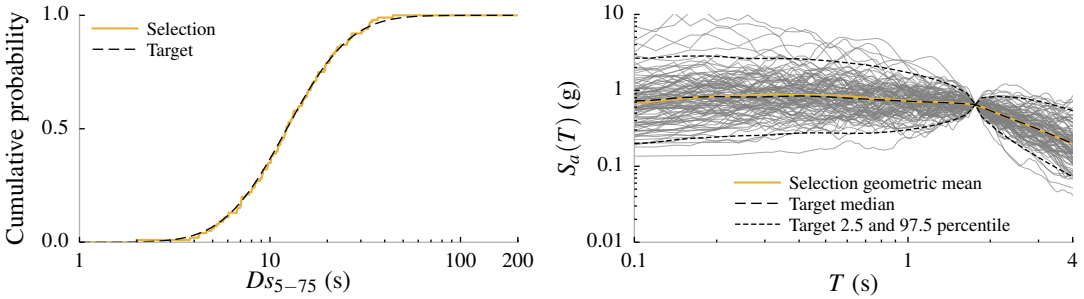


(a) Crustal earthquakes: 100 / 100 ground motions

Figure 69: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.55\,\mathrm{g}$ intensity level (0.50 % in 50 year hazard level) in San Francisco.

3.3.8 $S_a(1.8\,\mathrm{s}) = 0.65\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level)

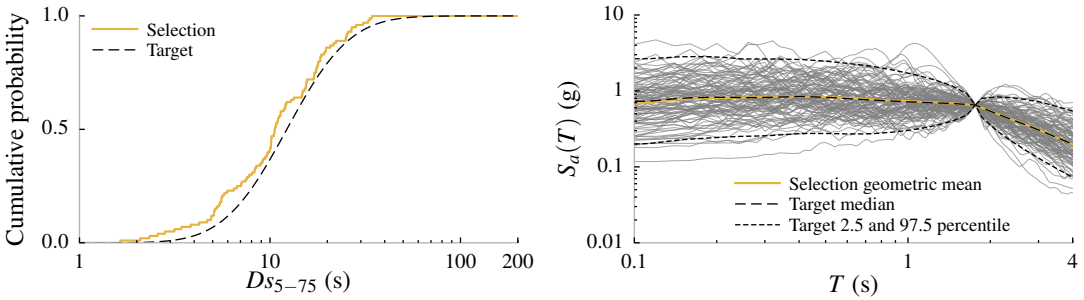
3.3.8.1 *CS and duration* group



(a) Crustal earthquakes: 100 / 100 ground motions

Figure 70: Ds_{5-75} and response spectra of the ground motions selected in the *CS and duration* group at the $S_a(1.8\,\mathrm{s}) = 0.65\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in San Francisco.

3.3.8.2 *CS only* group



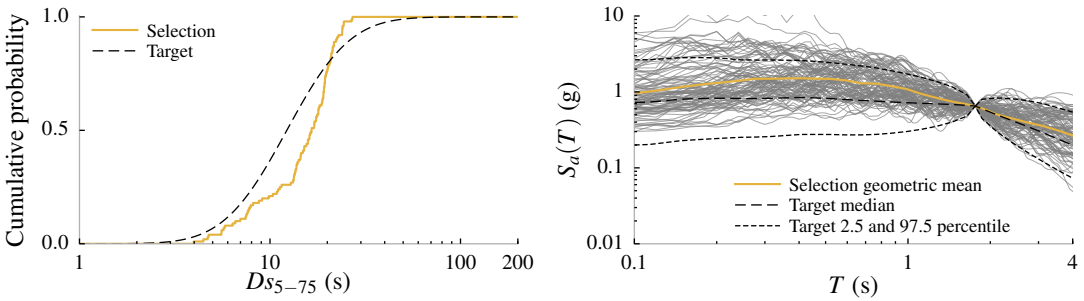
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 71: Ds_{5-75} and response spectra of the ground motions selected in the *CS only* group at the $S_a(1.8\,\mathrm{s}) = 0.65\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in San Francisco.

3.3.8.3 *CS and causal parameters* group

Table 27: Constraints on the magnitude, M, source-to-site distance, R, and site Vs_{30} of the selected ground motions, relative to the target mean causal magnitude and source-to-site distance obtained from deaggregation results, at the $S_a(1.8\,\mathrm{s}) = 0.65\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in San Francisco.

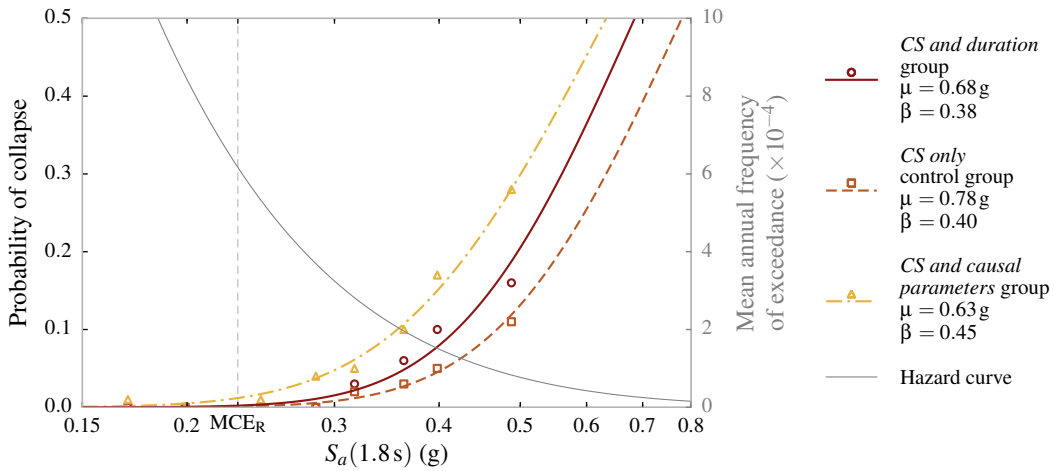
Seismic source type	Target mean			Selection constraints						No. of suitable records	No. of selected records
	$\bar{M}$	$\bar{R}$ (km)	Vs_{30} (m/s)	M_{min}	M_{max}	R_{min} (km)	R_{max} (km)	$Vs_{30,min}$ (m/s)	$Vs_{30,max}$ (m/s)		
Crustal	7.9	13	760	7.4	8.4	0	28	360	1160	123	100



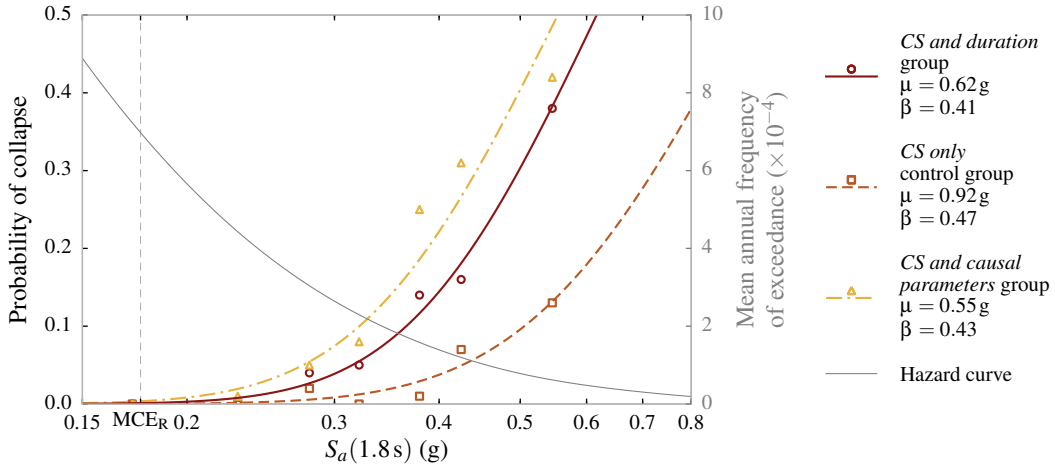
(a) Crustal earthquakes: 100 / 100 ground motions

Figure 72: Ds_{5-75} and response spectra of the ground motions selected in the *CS and causal parameters* group at the $S_a(1.8\,\mathrm{s}) = 0.65\,\mathrm{g}$ intensity level (0.25 % in 50 year hazard level) in San Francisco.

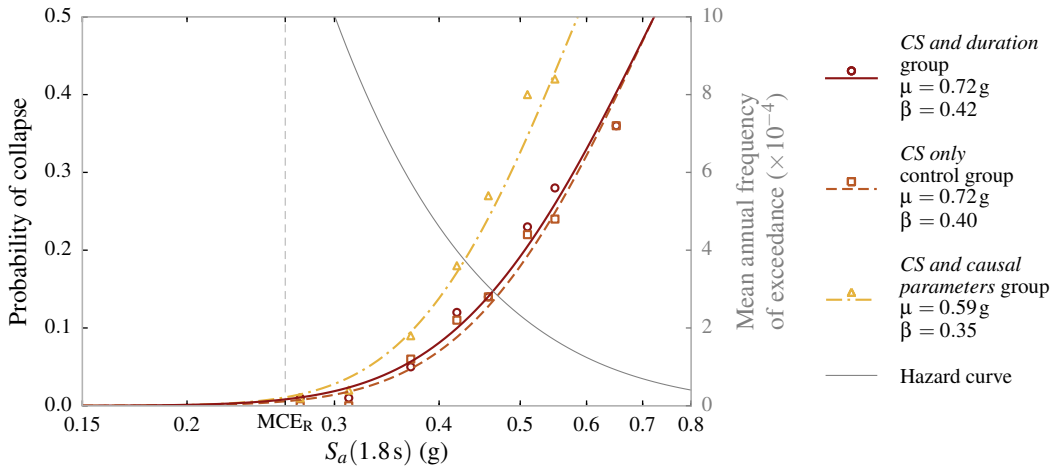
4 Collapse fragility curves



(a) Seattle



(b) Eugene



(c) San Francisco

Figure 73: Collapse fragility curves of the eight-story reinforced concrete moment frame building, estimated using the three groups of ground motions selected for each site (with median, μ, and lognormal standard deviation, β, indicated in the legend), along with the seismic hazard curve and the MCE$_R$ ground motion intensity level at that site.

References

[1] Chandramohan R, Baker JW, Deierlein GG. Impact of hazard-consistent ground motion duration in structural collapse risk assessment. *Earthquake Engineering & Structural Dynamics* 2016; **45**(8):1357–1379, doi:10.1002/eqe.2711.

[2] Jalayer F. Direct probabilistic seismic analysis: Implementing non-linear dynamic assessments. PhD Thesis, Stanford University, Stanford, CA 2003.

[3] Chandramohan R, Baker JW, Deierlein GG. Quantifying the Influence of Ground Motion Duration on Structural Collapse Capacity Using Spectrally Equivalent Records. *Earthquake Spectra* 2016; **32**(2):927–950, doi:10.1193/122813EQS298MR2.

[4] Ancheta TD, Darragh RB, Stewart JP, Seyhan E, Silva WJ, Chiou BSJ, Wooddell KE, Graves RW, Kottke AR, Boore DM, *et al.*. PEER NGA-West2 Database. *Technical Report PEER 2013/03*, Pacific Earthquake Engineering Research Center, Berkeley, CA 2013.

[5] McGuire RK. Probabilistic seismic hazard analysis and design earthquakes: Closing the loop. *Bulletin of the Seismological Society of America* 1995; **85**(5):1275–1284.