

Supplementary Materials

**Physics-based simulation of sequences with foreshocks,
aftershocks and multiple main shocks in Italy**

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Table S1: Geometric and kinematics parameters of the 198 quadrilateral fault segments derived from the 43 Composite Seismogenic Sources (CSS) of DISS v. 3.3.0 (DISS Working Group, 2021; <http://diss.ingv.it>) of the northern and central Apennines. Geometric coordinates refer to the upper left edge of the fault. **Name**: Identifier of the CSS of DISS; **#segs**: number of fault segments within the CSS; **Depth**: depth of the upper edge of the fault from the sea level; **Lenx1**: length of the top of the fault segment measured along its strike; **Offsx2**: the horizontal offset of the left bottom corner with respect to the left top corner, in the direction of the strike; **Lenx2**: length of the bottom of the fault segment; **Width**: width of the fault segment measured along its dip; **Sliprate**: maximum slip-rate of the fault. See the sketch of a quadrilateral fault segment in Figure S4.

Name	#segs	Lon (°)	Lat (°)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Lenx1 (km)	Offsx2 (km)	Lenx2 (km)	width (km)	Sliprate (mm/y)
ITCS001	4	11.5818	44.3814	2	120.23	35	90	7.64	0	8.44	10.46	0.63
		11.6649	44.347		109.58			17.84	-0.8	17.98		
		11.8757	44.2934		118.38			7.06	0.66	5.17		
		11.9536	44.2633		134.79			19.17	1.24	17.93		
ITCS008	6	13.2804	43.7508	3	107.74	37.5	90	3.4	0	3.13	5.75	1.35
		13.3206	43.7416		114.4			5.51	0.27	4.96		
		13.383	43.7213		121.55			9.72	0.28	8.85		
		13.4859	43.6757		136.19			17.42	0.59	16.09		
		13.6356	43.5627		154.72			23.86	0.74	22.61		
		13.7613	43.3684		167.34			6.18	0.5	5.67		
ITCS009	1	10.043	44.9953	2	126.85	30	105	51.81	0	51.81	12	0.53
ITCS011	9	11.8679	44.4532	2	103.3	35	90	4.44	0	3.81	13.95	0.33
		11.9222	44.4442		109.57			3.77	0.63	1.97		
		11.9668	44.4329		121.29			2.32	1.17	-0.32		
		11.9917	44.4221		135.87			6.6	1.46	6.64		
		12.0496	44.3795		120.88			6.92	-1.5	9.4		
		12.1241	44.3477		111.1			2.26	-0.98	1.04		
		12.1506	44.3403		132.85			2.07	2.19	-0.66		
		12.1696	44.3277		138.22			2.35	0.54	0.81		
		12.1892	44.3119		148.23			8.55	1	7.55		
ITCS012	7	11.5226	44.7448	2	84.2	30	100	9.25	0	8.07	12	0.55
		11.6388	44.7535		97.11			12.86	1.18	11.19		
		11.8	44.7395		102.55			6.65	0.49	5.25		
		11.882	44.7266		112.47			17.39	0.9	15.29		
		12.0848	44.6669		125.68			4	1.2	1.94		
		12.1257	44.646		135.01			4.1	0.85	2.31		
		12.1622	44.6198		145.43			21.86	0.95	20.91		
ITCS018	3	8.9859	44.9209	2	43.67	32.5	75	10.17	0	10.97	11.17	0.54
		9.0749	44.987		33.99			13.15	-0.8	12.93		
		9.1684	45.085		46.33			7.89	1.02	6.88		
ITCS020	9	13.4298	43.4292	3.5	143.97	30	90	11.93	0	10.27	15	0.4
		13.5168	43.3427		158.52			24.7	1.66	21.46		
		13.629	43.136		172.41			10.32	1.58	10.33		
		13.6459	43.044		158.37			5.1	-1.6	9.06		
		13.6691	43.0013		137.78			5.74	-2.36	6.74		
		13.7165	42.9631		149.69			7.3	1.36	4.57		
		13.7617	42.9065		161.74			27.57	1.37	26.4		
		13.8672	42.6707		159.97			8.57	-0.2	6.89		

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Name	#segs	Lon (°)	Lat (°)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Lenx1 (km)	Offsx2 (km)	Lenx2 (km)	Width (km)	Sliprate (mm/y)
		13.9029	42.5982		176.46			7.91	1.88	6.03		
ITCS026	1	10.031	44.1496	1	320.48	37.5	270	53.61	0	53.61	14.78	1
ITCS028	2	12.7361 13.0944	43.2752 42.8586	2.5	147.92 158.89	45	270	54.71 28.87	0 1.1	53.61 27.77	16.26	1
ITCS030	2	12.634 12.7739	44.1619 44.0739	3	131.24 135.64	30	90	14.86 6.32	0 0.27	14.6 6.05	8	0.52
ITCS031	6	13.5808 13.6517 13.693 13.7243 13.7639 13.7809	43.714 43.678 43.6504 43.624 43.5814 43.5477	1.5	125.11 132.7 139.36 146.11 159.85 154.72	32.5	90	6.97 4.53 3.87 5.71 3.99 7.52	0 0.57 0.5 0.51 1.04 -0.39	6.4 3.46 2.86 4.17 3.33 7.91	10.24	0.91
ITCS032	5	12.766 12.8831 13.0342 13.1861 13.3542	43.9793 43.936 43.8311 43.7664 43.6342	3	117.36 134.06 120.54 137.28 129.3	30	90	10.55 16.83 14.18 19.98 7.41	0 1.14 -0.92 1.15 -0.54	9.41 16.61 13.96 19.38 7.95	9	0.52
ITCS037	7	13.0453 12.9347 12.8464 12.1815 11.9933 11.792 11.5196	42.4781 42.5465 42.6148 43.4138 43.5575 43.6167 43.8804	0.5	309.45 315.91 328.46 316.53 292.29 323.64 298.67	32.5	270	11.85 10.49 104 22.06 17.54 36.61 33.24	0 0.66 1.29 -1.23 -2.53 3.3 -2.61	11.19 8.53 103.94 25.81 16.76 35.91 35.85	13.96	1
ITCS039	1	12.3941	44.1917	2	133.11	30	90	34.19	0	34.19	16	1.07
ITCS041	1	12.0957	43.6231	1	132.6	45	270	20.54	0	20.54	5.66	1
ITCS043	6	12.8768 12.9517 13.0068 13.0646 13.112 13.2457	44.0281 44.0188 44.0075 43.9847 43.9596 43.8107	2.5	99.96 105.94 118.74 126.4 147 141.9	37.5	90	6.1 4.6 5.28 4.71 19.73 5	0 0.27 0.58 0.35 0.95 -0.23	5.82 3.74 4.35 3.42 19.01 5.23	6.57	0.52
ITCS044	4	9.2491 9.33 9.3903 9.7034	45.1349 45.1993 45.2192 45.1993	2	41.72 65.03 95.13 114.47	30	90	9.57 5.23 24.7 28.88	0 1.79 2.33 1.48	7.79 1.11 20.89 27.41	10	0.54
ITCS045	3	9.728 9.9101 10.0519	44.9788 44.9144 44.7967	2	116.67 139.46 148.73	30	90	16.05 17.23 15.02	0 2.79 1.12	13.26 13.31 13.9	16	0.63
ITCS046	3	10.1901 10.3558 10.6953	44.6859 44.6748 44.5802	2	95.56 111.38 115.16	30	90	13.2 28.92 16.5	0 1.44 0.34	11.75 27.13 16.16	12	0.63
ITCS047	3	10.9145 11.3483	44.5152 44.5041	2	92.2 115.01	30	90	34.52 9.64	0 2.1	32.42 6.38	12	0.63

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Table S1 – continued from previous page

Name	#segs	Lon (°)	Lat (°)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Lenx1 (km)	Offsx2 (km)	Lenx2 (km)	Width (km)	Sliprate (mm/y)
		11.4581	44.4674		127.73			11.7	1.16	10.54		
ITCS049	5	10.54	44.8033	3	72.69	40	90	7.19	0	6.58	10.89	0.16
		10.6267	44.8226		80.95			2.14	0.6	1.03		
		10.6534	44.8256		87.93			2.23	0.51	0.99		
		10.6816	44.8263		97.97			2.5	0.73	0.94		
		10.7129	44.8232		109.29			9.91	0.83	9.09		
ITCS050	3	11.0866	45.0116	1	107.04	40	90	25.08	0	26.67	10.89	0.45
		11.391	44.9463		85.52			12.23	-1.59	11.69		
		11.5454	44.9549		114.11			36.65	2.13	34.52		
ITCS051	11	10.7525	44.8637	2	43.89	35	90	1.46	0	0.3	13.95	1.04
		10.7653	44.8731		55.5			4.89	1.16	2.65		
		10.8163	44.8981		66.3			1.75	1.08	-0.2		
		10.8366	44.9044		75.04			4.67	0.87	3.25		
		10.8937	44.9153		80.53			2.45	0.55	0.96		
		10.9243	44.9153		89.96			5.3	0.94	3.11		
		10.9913	44.919		102.42			1.94	1.25	-0.35		
		11.0153	44.9153		112.77			3.23	1.04	1.1		
		11.0531	44.904		123.77			2.13	1.1	1.99		
		11.0755	44.8934		114.18			20.82	-0.96	22.4		
		11.3156	44.8165		107.92			17.88	-0.62	18.5		
ITCS052	8	14.8846	42.9591	3.3	109.19	37.5	90	2.55	0	1.72	5.26	0.5
		14.9142	42.9516		131.66			2.76	0.83	1.27		
		14.9395	42.9351		149.88			14.1	0.67	13.82		
		15.0265	42.8255		139.31			5.84	-0.39	5.99		
		15.0731	42.7856		145.94			5.78	0.24	5.22		
		15.1127	42.7426		154.65			5.21	0.32	3.87		
		15.14	42.7002		182.23			9.36	1.02	8.04		
		15.1354	42.616		190.36			7.35	0.3	7.06		
ITCS056	1	12.4401	43.4159	2	131.47	20	270	27.16	0	27.16	14.62	1
ITCS083	1	10.5825	43.9916	1	304.51	37.5	270	40.15	0	40.15	14.78	1
ITCS103	6	11.0464	44.9476	3.5	100.63	45	90	3.83	0	3.03	9.19	0.5
		11.0941	44.9413		114.76			5.59	0.81	4.99		
		11.1585	44.9204		111.01			19.73	-0.21	20.03		
		11.3917	44.857		109.41			1.72	-0.09	0.86		
		11.4122	44.8518		126			2.92	0.95	2.51		
		11.4421	44.8364		116.47			2.59	-0.54	3.14		
ITCS106	13	12.9839	44.1153	2	99.58	32.5	90	4.04	0	3.42	9.31	0.52
		13.0337	44.1094		108.6			4.09	0.62	2.73		
		13.0822	44.0978		119.43			6.12	0.74	4.87		
		13.1489	44.071		126.79			4.81	0.5	5.11		
		13.1971	44.0452		115.18			5.31	-0.8	4.84		
		13.2572	44.0249		133.62			4.16	1.27	2.32		
		13.2949	43.9991		142.01			3.37	0.58	4.73		
		13.3208	43.9753		114.2			15.25	-1.94	16.71		
		13.4941	43.9191		121.19			4.76	0.48	2.73		
		13.5448	43.8969		143.48			3.83	1.55	0.34		

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Name	#segs	Lon (°)	Lat (°)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Lenx1 (km)	Offsx2 (km)	Lenx2 (km)	Width (km)	Sliprate (mm/y)
		13.5731 13.5887 13.6142	43.8692 43.7943 43.7572		171.25 153.5 147.27			8.42 4.61 5.54	1.94 -1.23 -0.43	7.7 6.26 5.97		
ITCS107	8	13.9503 13.9121 13.8926 13.8754 13.868 13.8632 13.8559 13.8502	43.421 43.4412 43.4545 43.4703 43.4788 43.4892 43.5268 43.539	1.5	305.99 313.17 321.56 328.05 341.42 351.95 341.27 346.06	47.5	90	3.82 2.16 2.24 1.12 1.22 4.22 1.43 6.42	0 0.37 0.44 0.34 0.7 0.55 -0.56 0.25	3.44 1.35 1.47 0.09 -0.03 4.23 1.74 6.17	8.82	0.54
ITCS108	4	13.7876 13.9597 14.0138 14.0576	43.888 43.8716 43.8572 43.8383	2	97.63 110.3 120.84 125.97	35	90	13.96 4.63 4.1 4.09	0 0.95 0.79 0.38	13 2.89 2.93 3.71	10.46	0.38
ITCS112	7	10.2684 10.3005 10.33 10.4073 10.4304 10.4715 10.4882	45.1523 45.1448 45.1357 45.0967 45.0814 45.0425 45.021	2.5	108.44 113.73 125.59 133.16 143.23 151.05 159.38	35	90	2.66 2.53 7.47 2.49 5.39 2.73 2.59	0 0.23 0.52 0.33 0.44 0.34 0.36	2.43 1.78 6.62 1.72 4.61 2.02 2.23	6.1	0.91
ITCS127	5	13.069 13.1214 13.2296 13.234 13.2246	43.108 43.0434 42.8289 42.8038 42.7776	1.5	149.37 159.75 172.54 194.8 205.68	38.5	270	8.35 25.42 2.81 3.01 7.21	0 0.97 1.2 2.1 1.02	7.38 23.25 -0.49 -0.11 6.19	13.65	0.5
ITCS128	2	13.25 13.2675	42.8252 42.7318	2	172.16 156.41	47.5	270	10.47 13.17	0 -0.89	11.36 14.06	9.49	0.5
ITCS129	5	12.3664 12.412 12.7654 12.9292 12.9475	43.7636 43.7252 43.4761 43.2542 43.2113	1	139.57 134.32 151.7 162.54 177.08	32.5	270	5.63 39.76 28 4.99 13.54	0 -0.65 2.16 1.34 1.8	6.27 38.24 24.5 1.85 11.74	16.75	0.5
ITCS130	2	13.3092 13.3358	42.6086 42.5507	3.9	161.35 140.3	50	270	6.79 15.02	0 -1.11	7.9 16.13	9.27	1
ITCS134	4	13.889 14.0346 14.2348 14.3091	42.6393 42.6716 42.7239 42.7331	4.5	73.36 70.47 80.3 92.46	60	135	12.47 17.4 6.17 8.01	0 -0.15 0.52 0.65	12.62 17.03 5 7.36	12.12	0.74
ITCS135	1	13.3987	42.5078	12	76.31	65	135	41.59	0	41.59	8.83	0.74
ITCS136	4	12.4095 12.8564 13.0786	43.8095 43.5638 43.3188	2.8	127.47 146.62 155.86	35	270	45.21 32.62 21.78	0 1.54 0.74	43.67 30.34 20.02	11.16	0.5

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Name	#segs	Lon (°)	Lat (°)	Depth (km)	Strike (°)	Dip (°)	Rake (°)	Lenx1 (km)	Offsx2 (km)	Lenx2 (km)	Width (km)	Sliprate (mm/y)
		13.188	43.1399		168.62			14.79	1.02	13.77		
ITCS154	5	14.505	43.0982	2.6	127.52	40	90	3.98	0	3.46	9.96	0.5
		14.5439	43.0764		135.39			6.3	0.52	4.46		
		14.5984	43.0362		154.9			13.66	1.31	11.07		
		14.6696	42.9249		173.94			17.19	1.28	17.75		
		14.6918	42.771		146.82			8.33	-1.84	10.17		
ITCS155	5	14.4095	43.242	3.2	300.01	53.5	90	4.43	0	3.78	8.46	0.08
		14.3623	43.2619		314.62			6.48	0.64	5.42		
		14.3054	43.3029		323.94			6.28	0.41	5.21		
		14.2597	43.3485		338.97			8.08	0.66	6.78		
		14.2237	43.4164		353.42			11.83	0.64	11.19		
ITCS156	7	13.9387	43.4238	2.1	163.42	44.5	90	0.95	0	0.66	6.28	0.2
		13.9421	43.4155		170.87			6.22	0.29	5.71		
		13.9543	43.3603		176.46			7.86	0.22	8.21		
		13.9604	43.2896		162.09			6.17	-0.56	6.98		
		13.9838	43.2368		155.81			7.85	-0.25	7.82		
		14.0235	43.1724		162.86			7.37	0.28	6.56		
		14.0503	43.109		176.52			9.78	0.54	9.24		
ITCS158	4	14.4468	43.2007	4.3	292.3	36	90	12.2	0	10.85	9.7	0.08
		14.3079	43.2424		311.86			9.44	1.35	6.15		
		14.2211	43.299		339.72			21.12	1.95	18.33		
		14.1303	43.4772		352.09			11.07	0.85	10.22		
ITCS159	4	14.1171	43.0081	4.8	162.91	48.5	90	5.47	0	5.24	4.27	0.2
		14.1369	42.9611		171.96			5.93	0.22	5.44		
		14.147	42.9083		182.69			5.39	0.27	4.75		
		14.1439	42.8599		197.35			8.93	0.36	8.56		

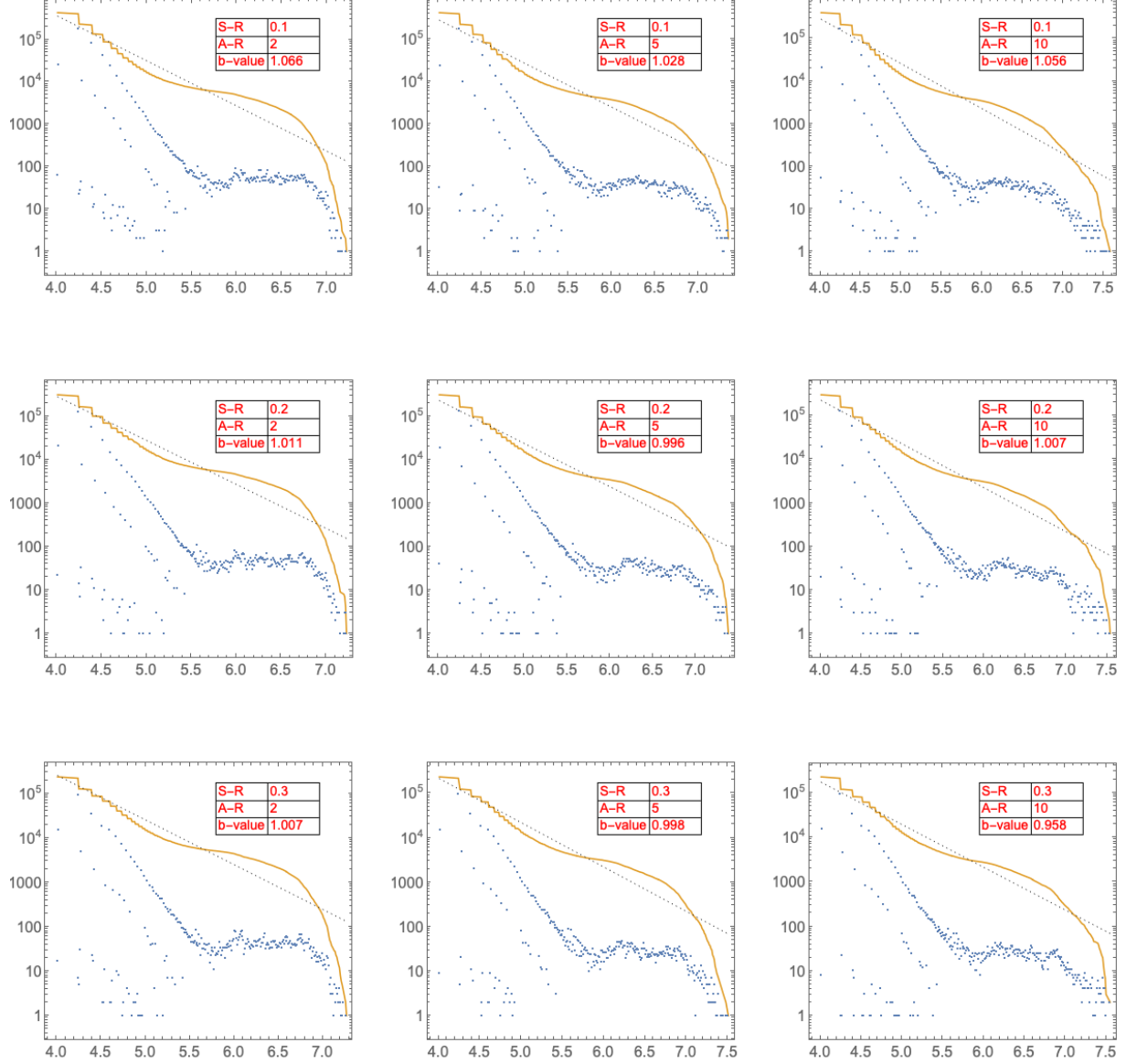


Figure S1: Cumulative (yellow line) and density (blue dots) Magnitude-Frequency distributions of $M_w \geq 4.2$ earthquake simulated catalogues, for the 9 combinations of free parameters of Table 3 considered in this study. The straight dotted lines show the best-fit Gutenberg-Richter distributions.

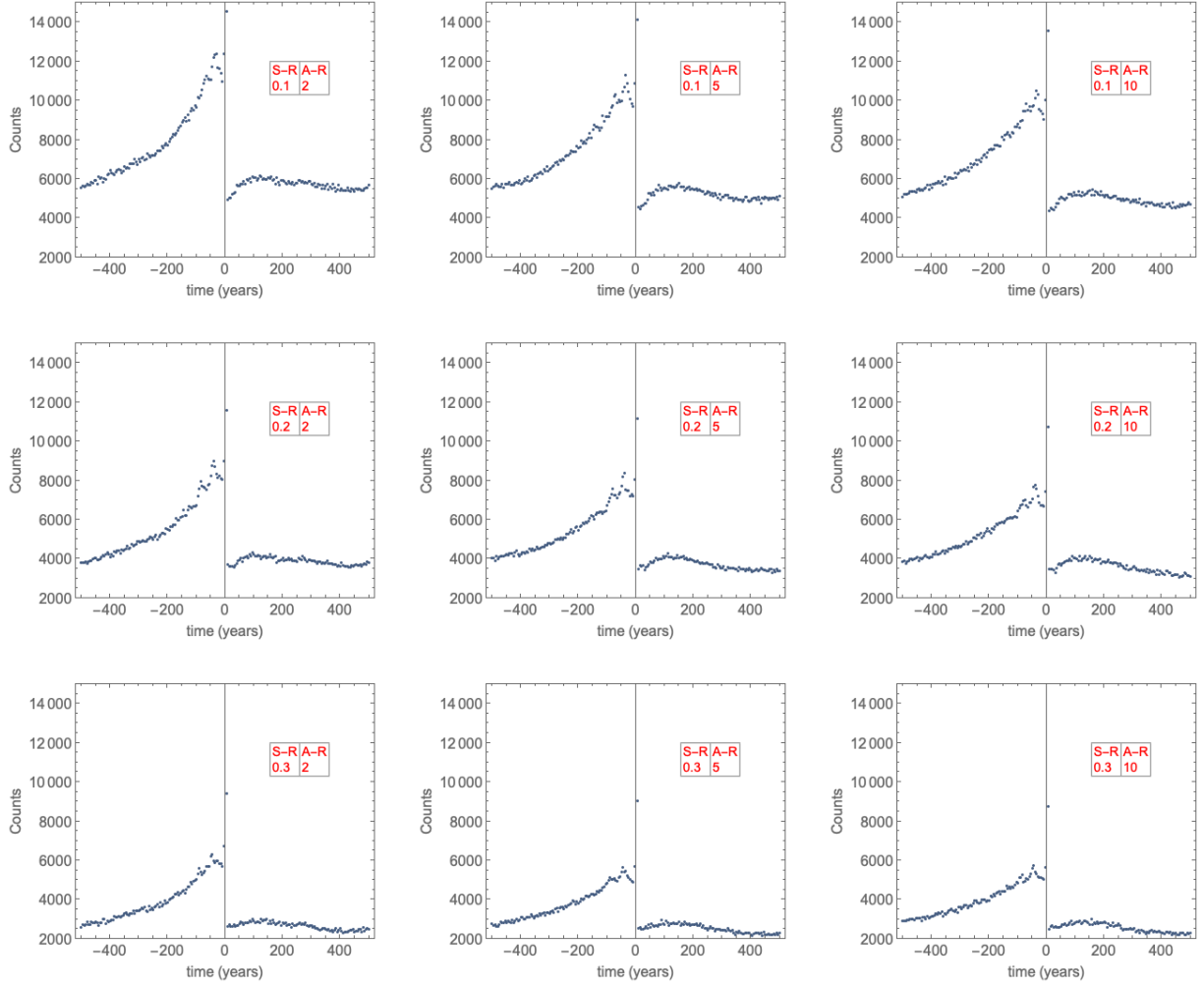


Figure S2: Stacked number of $M_w \geq 4.2$ earthquakes that preceded and followed an $M_w \geq 5.2$ earthquake within an epicentral distance of 20 km in the 100 Kyr simulated catalogue, for the 9 combinations of free parameters of Table 3 considered in this study.

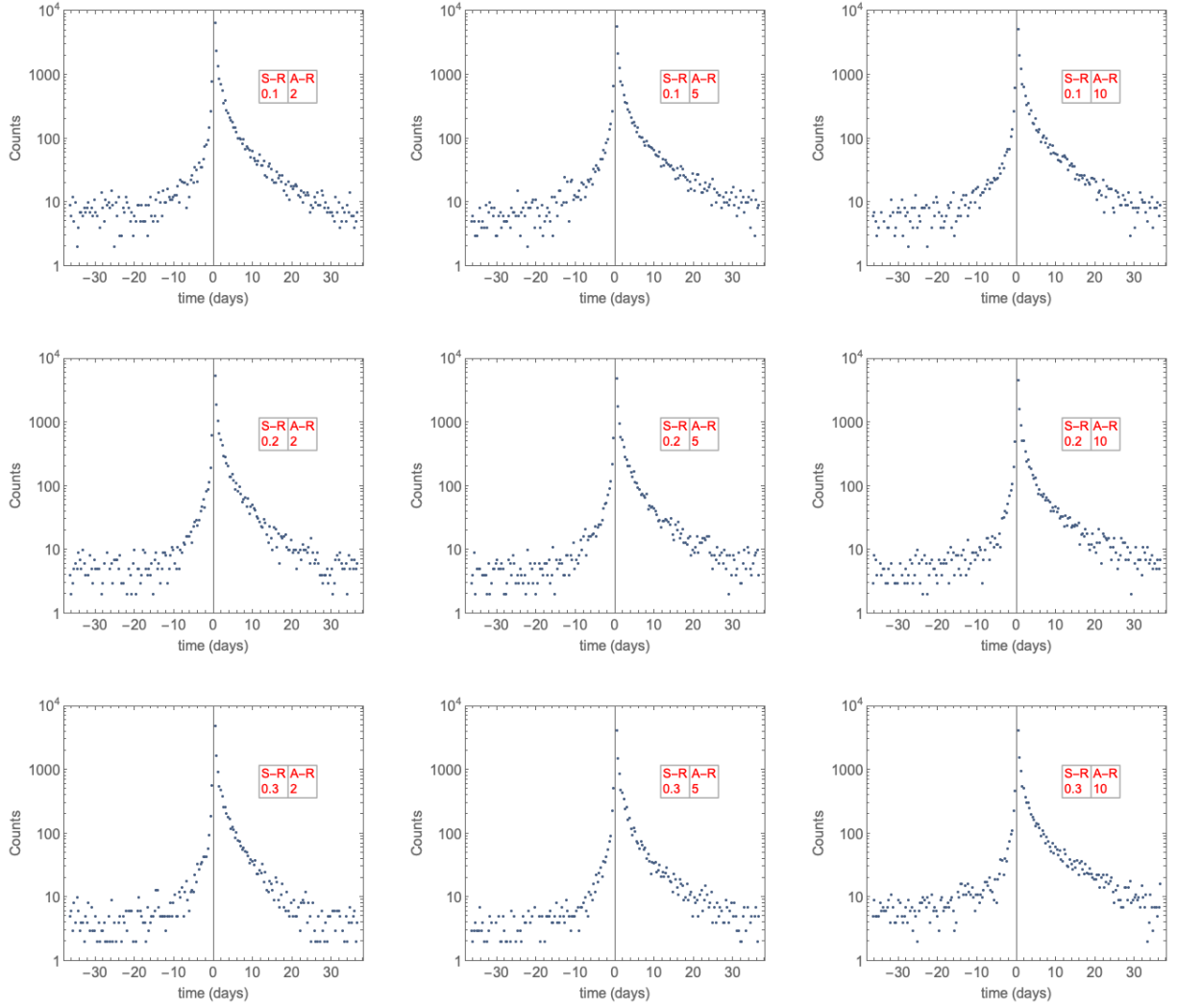


Figure S3: (a) As in figure S2, within an epicentral distance of 50 km, zooming on a time scale spanning only 0.1 years (36.5 days) before and after an earthquake of $M_w \geq 5.2$.

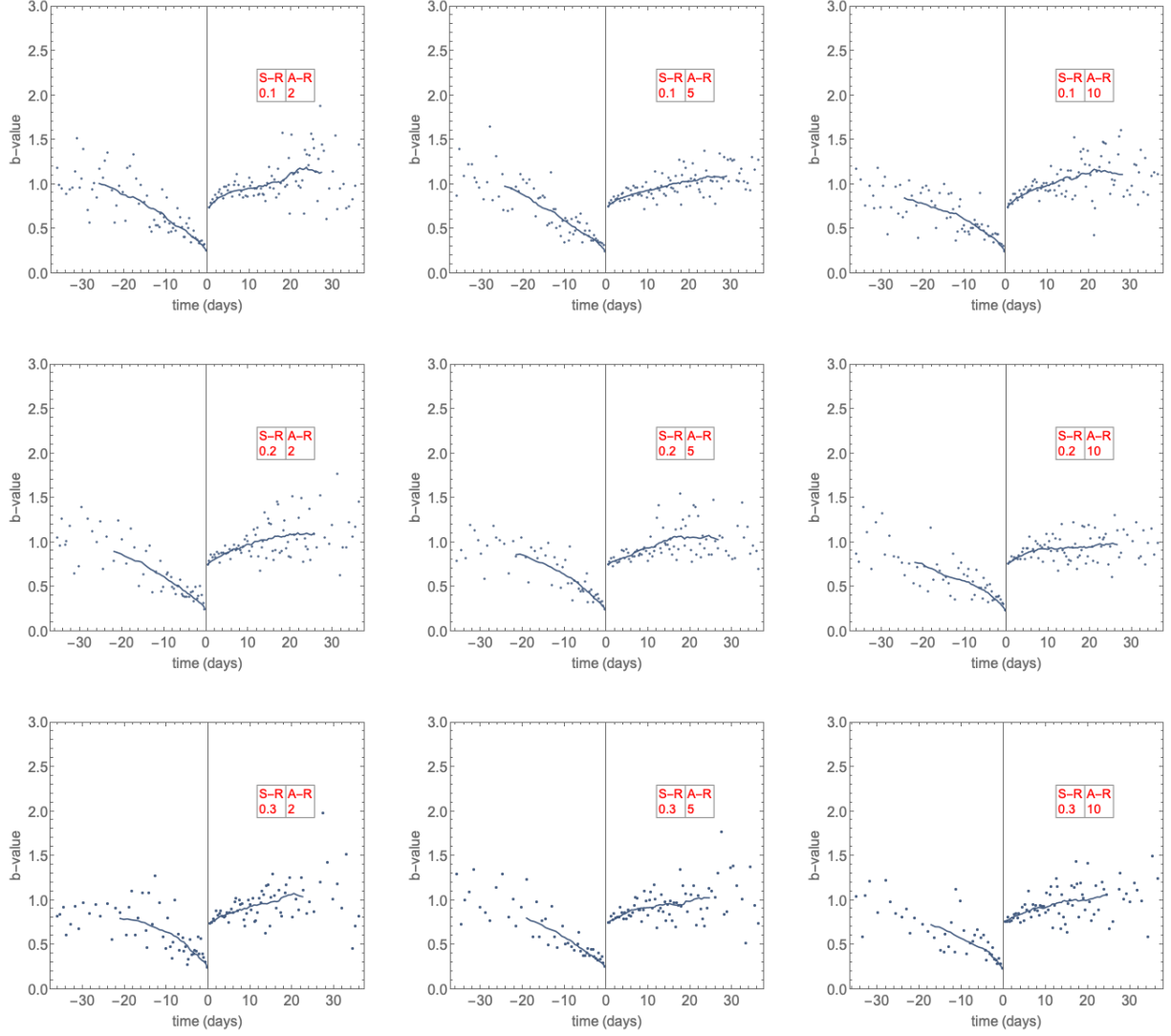


Figure S3: (b) b-value in the time bins of 0.365 days before and after an earthquake of $M_w \geq 5.2$ containing at least 10 events, for the 9 combinations of free parameters of Table 3 considered in this study.

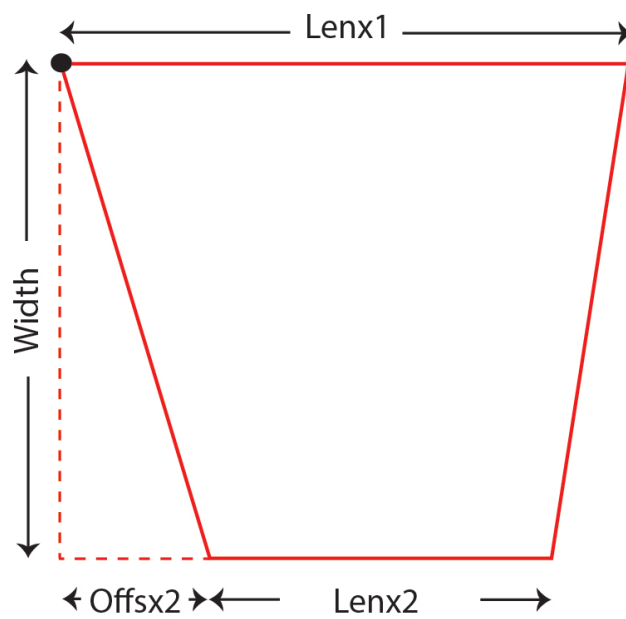


Figure S4: Sketch of a fault segment characterised by a set of geometric parameters (lenx1 , lenx2 , Offsx2 , and width). Geometric coordinates refer to the upper left edge of the fault (shown by the black dot).