Supplementary Materials to

"Addressing climate internal variability on future intensity-duration-frequency curves at fine scales across South Korea"

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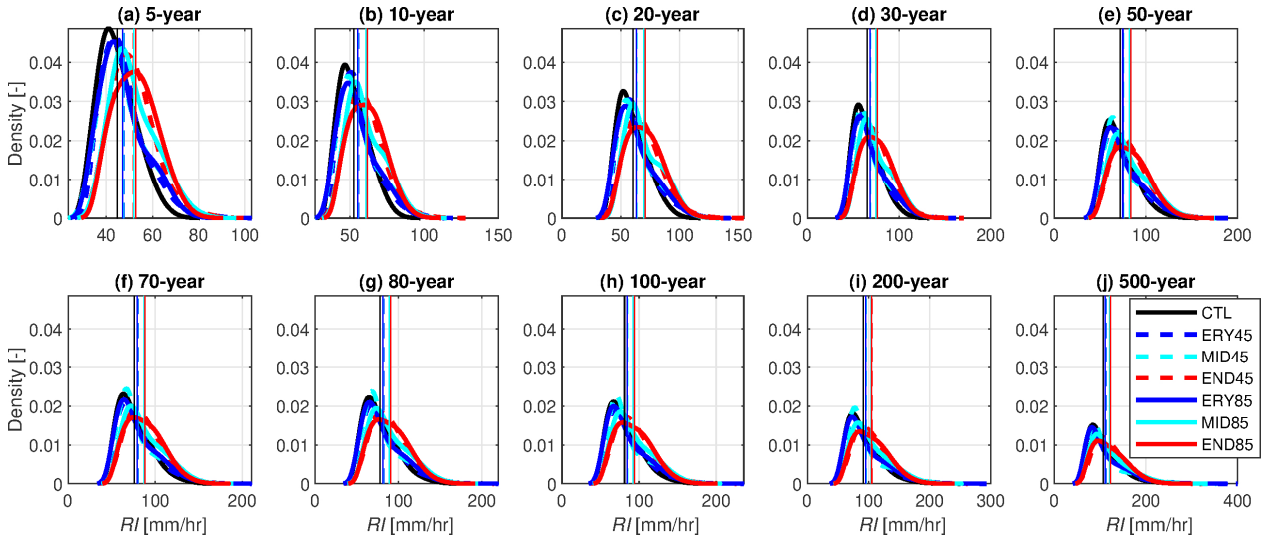

Figure S1. Kernel distribution of precipitation frequency estimates for 40 locations for control and future periods with two emission scenarios (RCP 4.5 and RCP 8.5) for 1-hour duration. The vertical lines represent mean of the distributions.

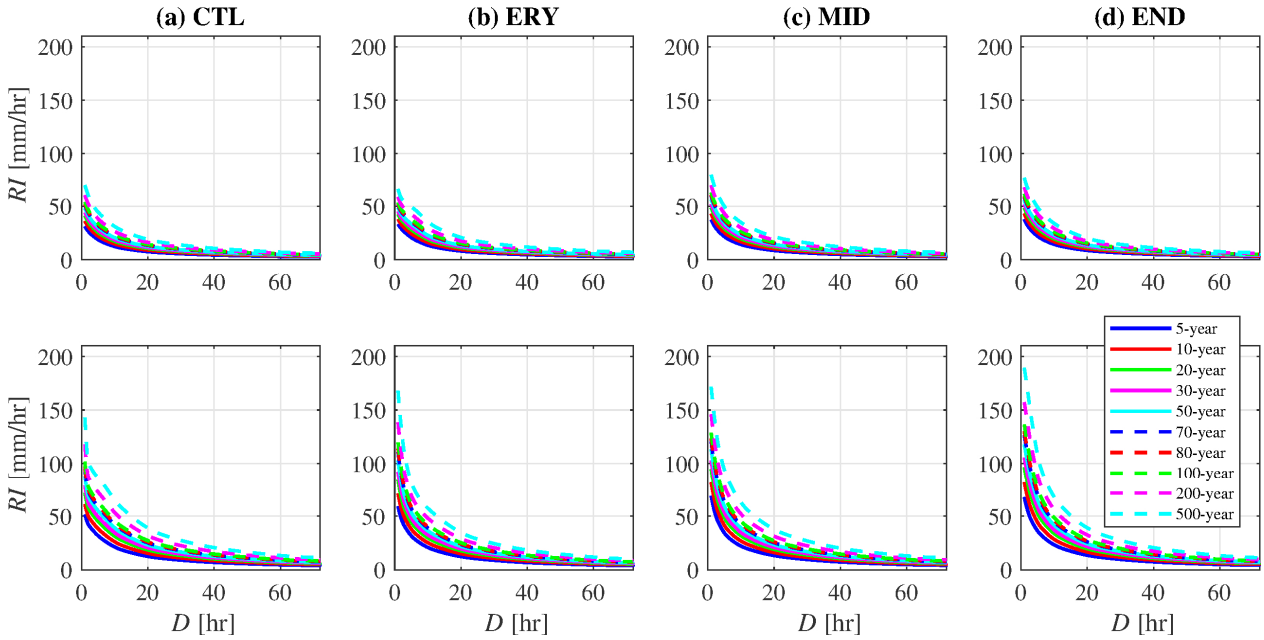

Figure S2. The IDF curves for (a) control and (b-d) future periods under RCP 8.5 scenario for two locations: Chupungnyeong (No. 9) – the subplots in the first row and Gangneung (No. 16) – the subplots in the second row.

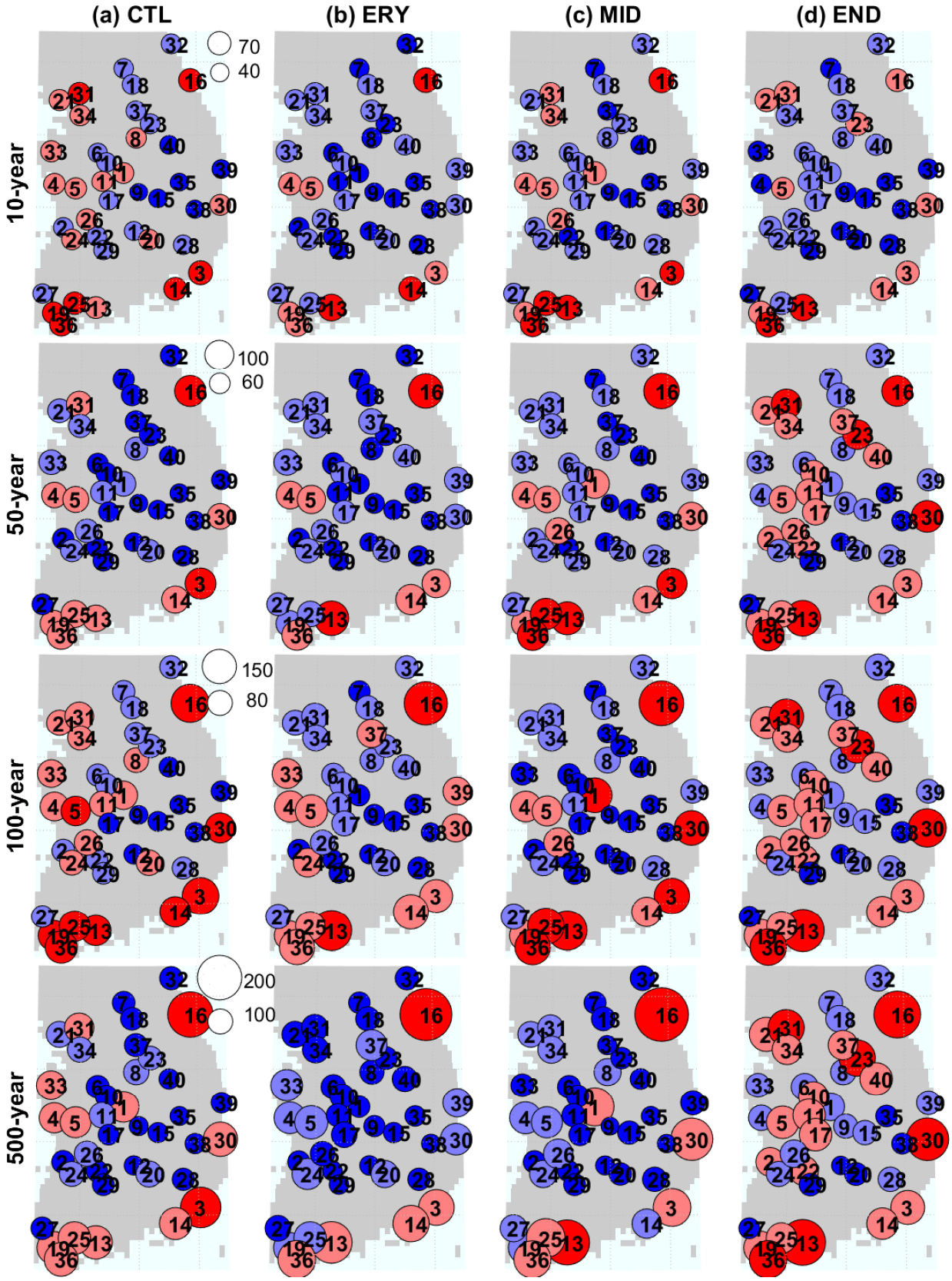

Figure S3. Similar to Figure 4, but for RCP 4.5.

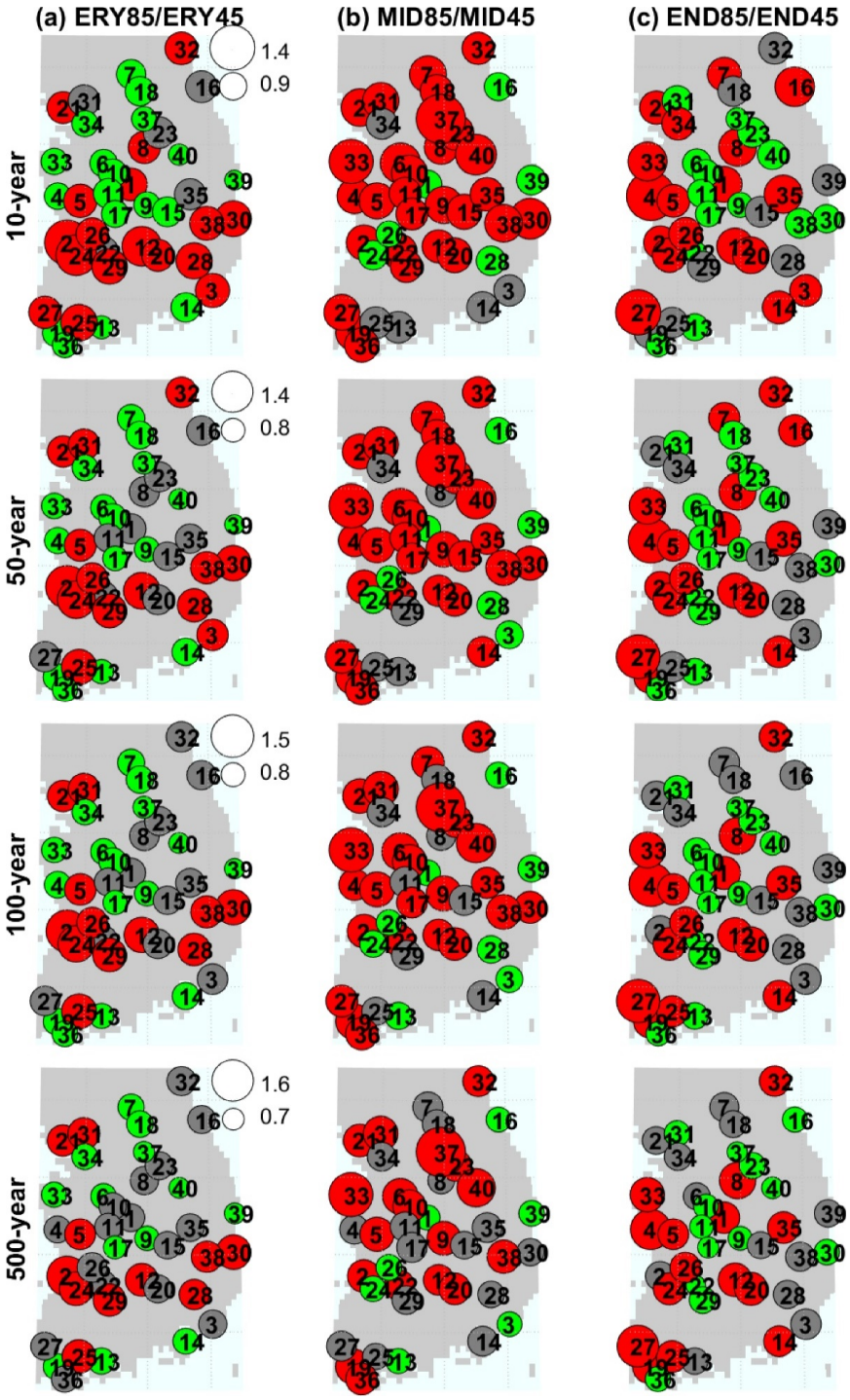

Figure S4. Spatial distributions of the ratio of rainfall frequency estimates between RCP 4.5 and RCP 8.5 for (a) ERY, (b) MID, and (c) END and the return periods of (first row) 10, (second row) 50, (third row) 100 and (last row) 500-year for 1-hour duration. A test of significance, *t*-test is applied to 2 distributions of rainfall frequency estimates of RCP 8.5 and RCP 4.5. The impact of RCP scenarios is greater (red circles) or lower (green circles), or it may be unaffected (grey circles).

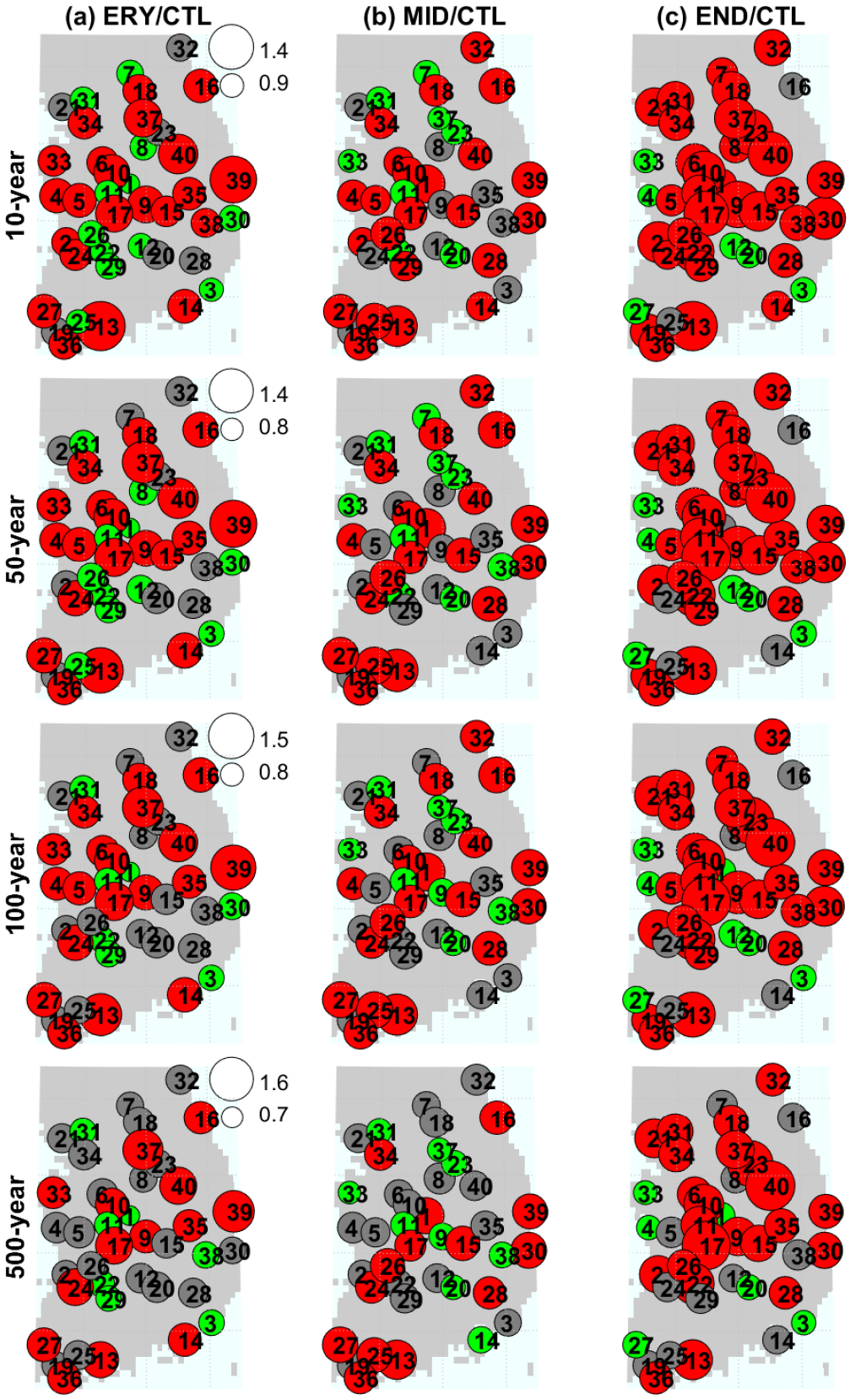

Figure S5. Similar to Figure 5, but for RCP 4.5

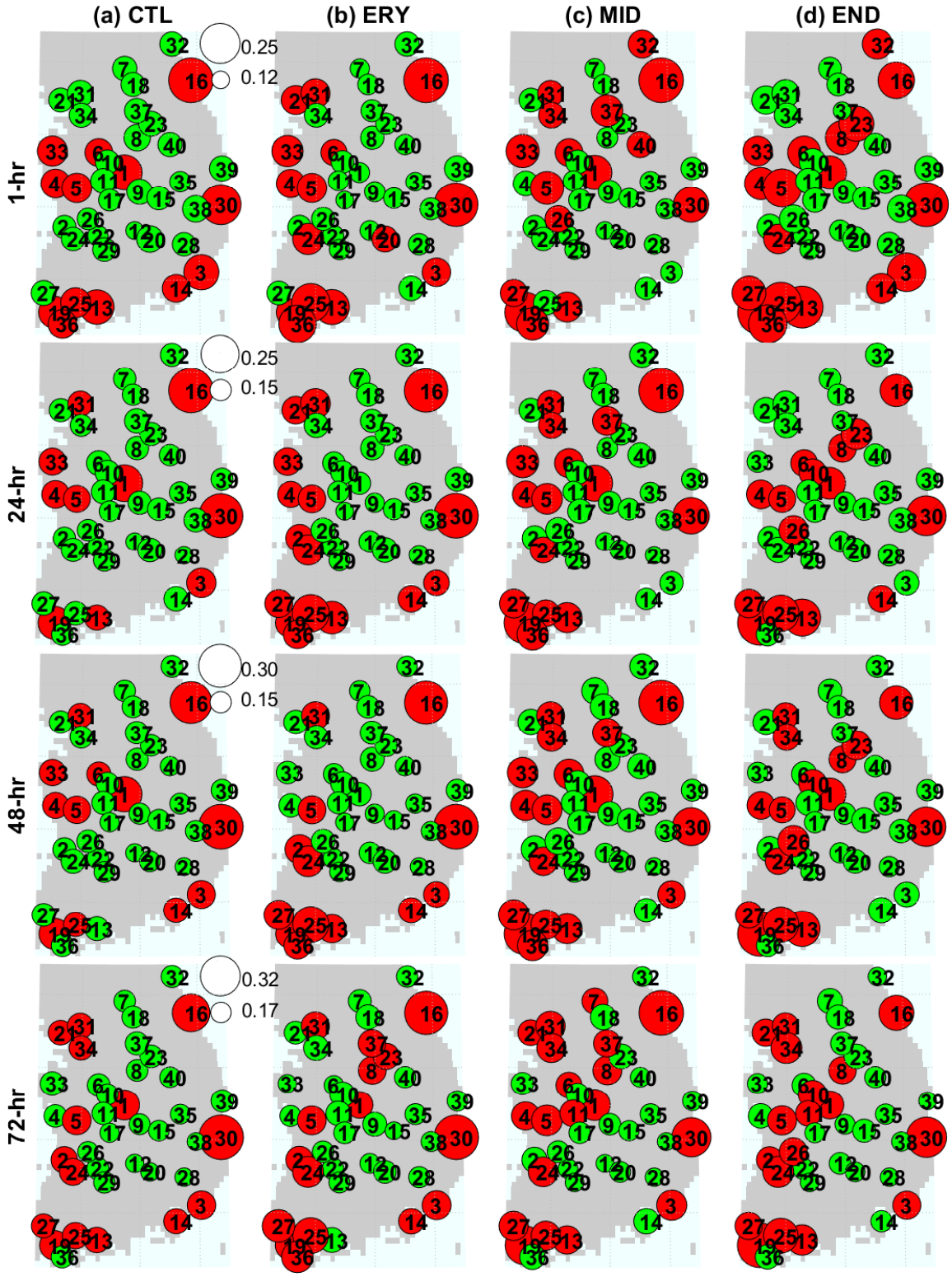

Figure S6. Spatial distribution of slopes which represent the degree of increase of rainfall frequency estimates over return periods, for the control (CTL) and 3 future periods (ERY, MID, END) with the RCP 8.5 for the durations of 1, 24, 48, and 72-hour. The color of circle is determined as in Fig. 6. The number near white circles is the legend to show the relative magnitude of slopes.

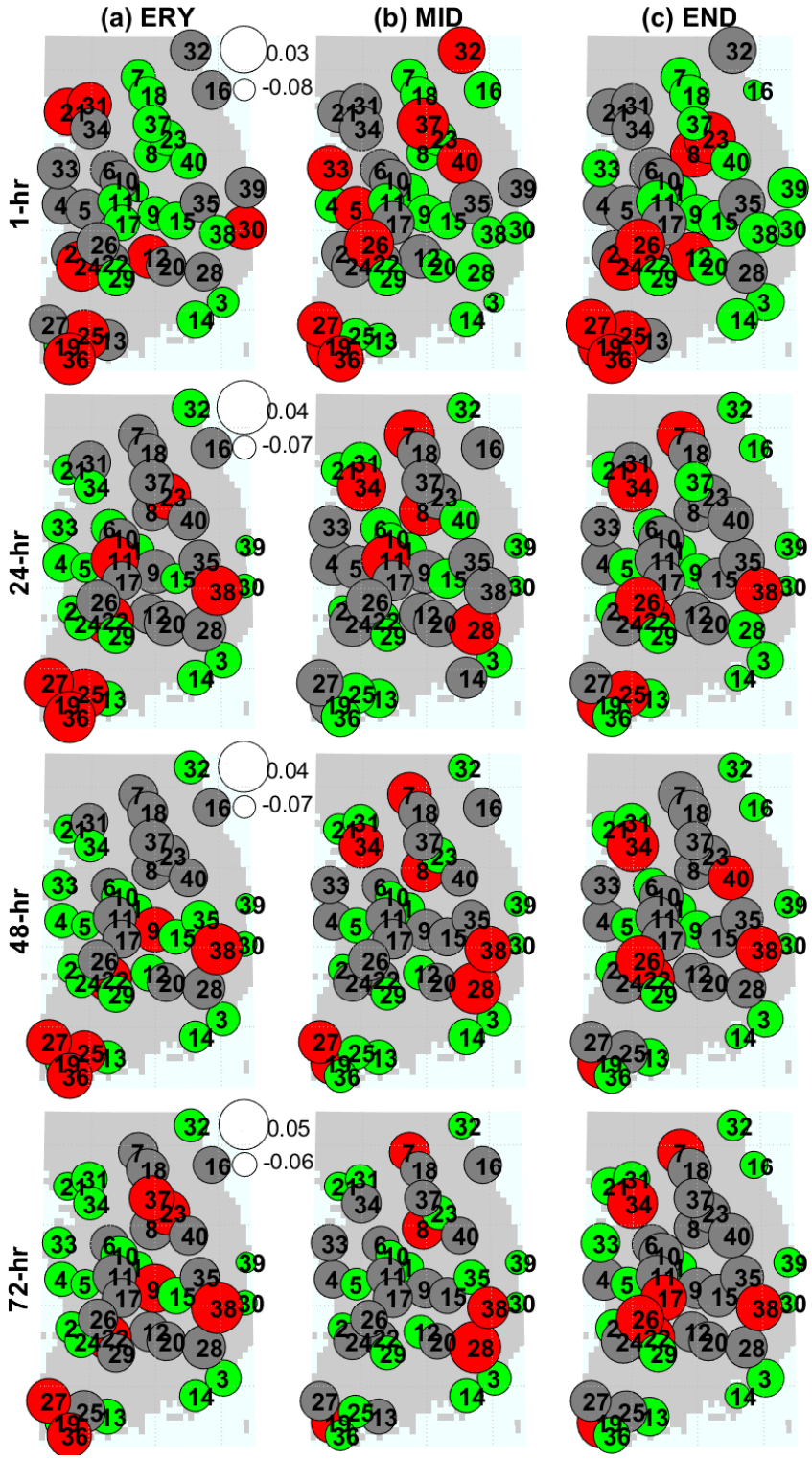

Figure S7. Spatial distribution of slopes which represent the degree of change of the FOC over return periods, for 3 future periods (ERY, MID, END) with the RCP 8.5 for the durations of 1, 24, 48, and 72-hour. The color of circle is determined as in Fig. 7. The number near white circles is the legend to show the relative magnitude of slopes.

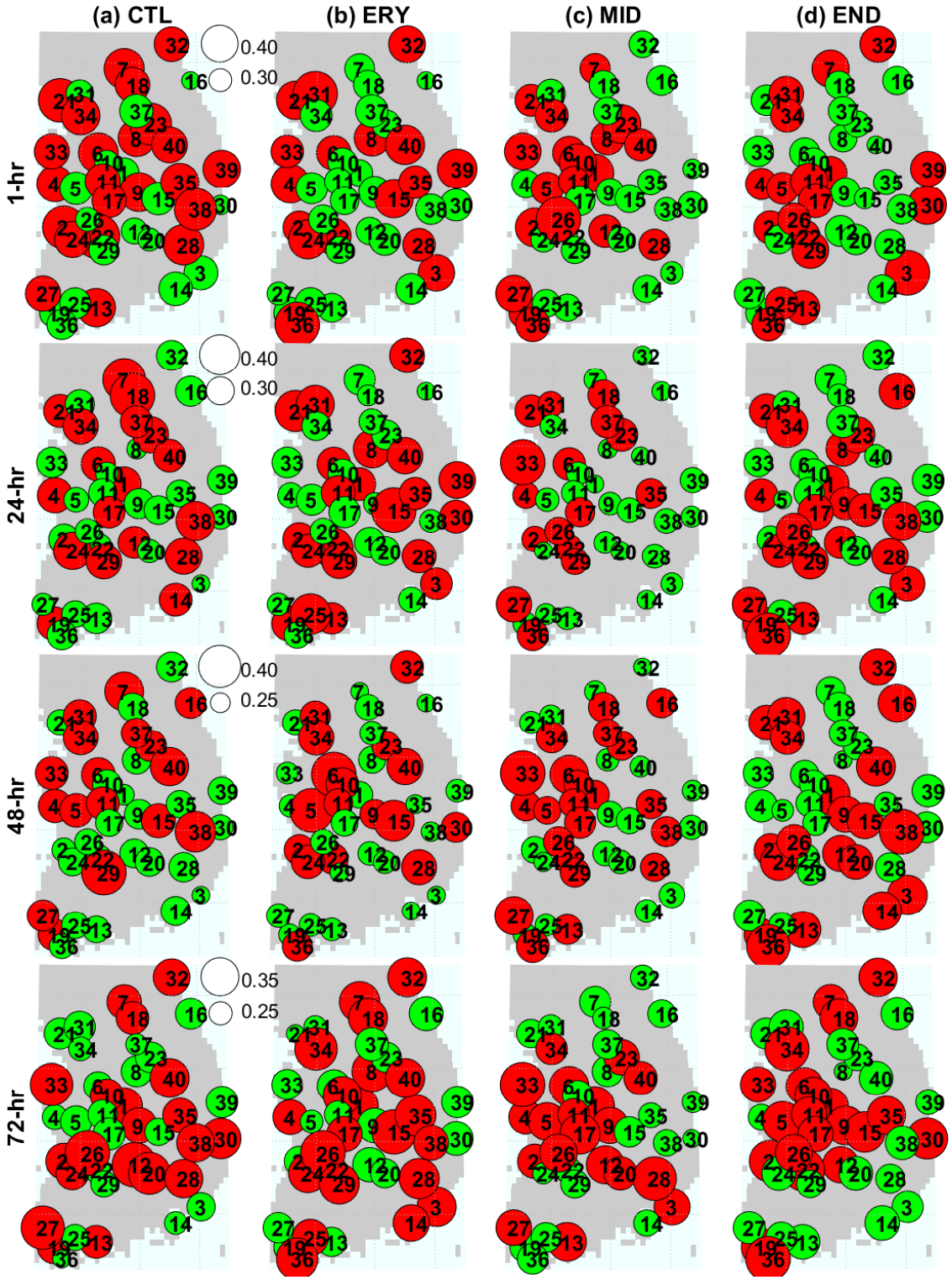

Figure S8. Spatial distribution of slopes (m_{Range}) of the uncertainty range, i.e., the difference between 5th and 95th percentiles of the *normRI* ensemble over (columns) control and 3 future periods and (rows) 4 selected durations of 1, 24, 48, and 72-hour for RCP 8.5. The color of circles is determined as in Fig. 9.

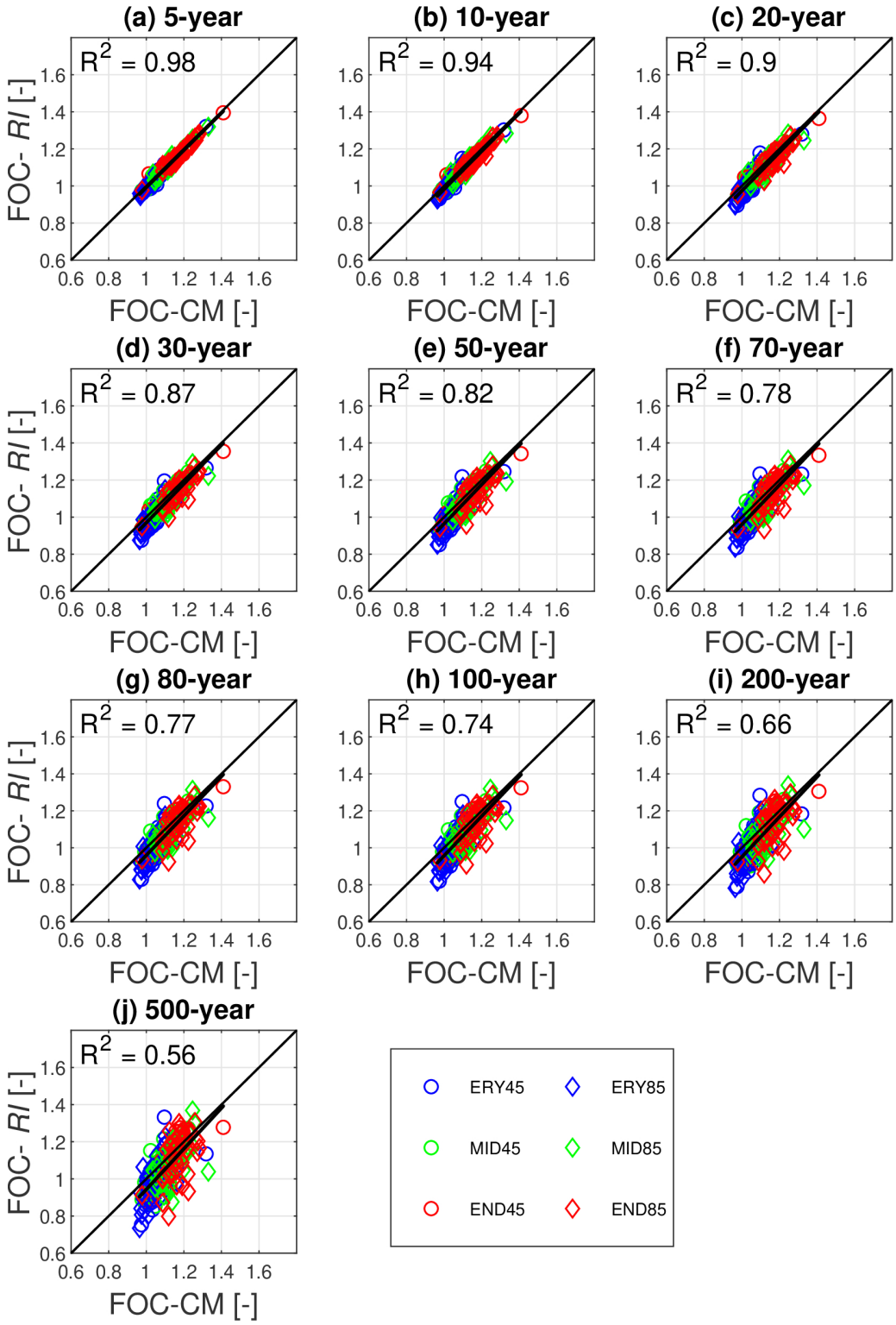

Figure S9. Comparisons between the factor of change of climatological mean (FOC-CM) of daily maximum precipitation with the factor of change of rainfall frequency estimates (FOC-*RI*) for 24 – hour duration for 10 return periods. The number of data points is 240 for the subplot (40 locations × 6 comparing periods). The R^2 values are computed for the 1:1 line.

Table S1. List of global climate models from the fifth phase of the Coupled Model Inter-comparison Project

	Institute	**Model name**	**Lon × Lat**
1	BCC	BCC-CSM1-1	128 × 128
2	CCCMA	CanESM2	128 × 64
3	CMCC	CMCC-CM	480 × 480
4	CNRM	CNRM-CM5	256 × 128
5	CSIRO-BOM	ACCESSS1-0	288 × 192
6	CSIRO-QCCE	CSIRO-Mk3-6-0	192 × 96
7	INM	INM-CM-4	180 × 120
8	IPSL	IPSL-CM5A-LR	96 × 96
9	LASG-CESS	FGOALS-g2	128 × 128
10	MIROC	MIROC5	256 × 256
11	MOHC	HadGEM2-ES	192 × 145
12	MPI-M	MPI-ESM-MR	192 × 192
13	MRI	MRI-CGCM3	320 × 160
14	NCAR	CCSM4	288 × 192
15	NCC	NorESM1-M	144 × 96
16	NOAA-GFDL	GFDL-ESM2G	180 × 180
17	BNU	BNU-ESM	128 × 128
18	NSF-DOE	CESM1-CAM5	382 × 288

Table S2. The values of precipitation frequency estimates for each location corresponding to **Fig. 4.**

Unit: mm/hr

No.	10-year				50-year				100-year				500-year			
1	54.7	46.5	62.5	64.7	80.0	59.8	89.2	88.9	93.2	65.7	103.0	100.6	131.6	80.7	143.2	132.9
2	48.4	69.9	56.0	67.6	63.5	92.9	73.8	89.0	70.5	103.4	82.1	98.7	88.5	130.4	104.0	124.0
3	75.1	74.9	76.4	73.5	109.2	103.6	100.6	102.3	126.9	117.5	111.4	117.1	179.3	155.3	138.5	160.9
4	60.4	60.9	73.2	78.3	83.5	83.4	98.7	107.3	94.9	94.6	110.6	121.2	126.5	125.9	141.6	159.1
5	61.5	75.1	74.2	69.8	85.6	104.6	105.6	98.7	97.5	119.1	121.4	113.3	130.7	159.1	166.5	154.4
6	44.6	43.8	60.0	51.0	60.8	58.4	81.4	69.4	68.7	65.5	91.9	78.5	90.4	85.5	120.8	103.7
7	46.9	43.5	52.6	55.5	62.2	55.5	67.9	71.5	69.4	60.9	74.7	78.8	88.3	74.2	92.0	97.5
8	51.8	51.9	57.6	68.1	69.9	68.3	74.7	93.6	78.6	76.0	82.5	106.1	102.2	96.3	102.4	140.9
9	36.1	37.9	43.0	43.2	48.2	48.6	56.4	55.7	53.9	53.4	62.7	61.5	69.6	66.0	79.3	76.5
10	45.5	50.3	56.2	54.6	60.3	66.0	74.9	72.7	67.2	73.3	83.6	81.0	85.1	92.1	106.0	102.2
11	54.3	49.0	54.7	58.7	72.9	63.1	70.7	77.0	81.5	69.4	77.9	85.5	104.3	85.2	96.5	107.7
12	43.3	50.5	45.7	48.2	54.4	65.0	57.9	61.8	59.1	71.4	63.3	67.8	70.4	87.2	76.6	82.8
13	61.3	71.1	81.6	81.7	87.7	103.0	113.3	117.9	101.6	119.6	128.8	136.4	143.0	168.0	171.7	189.4
14	67.3	73.4	70.7	75.4	91.4	98.2	93.8	102.0	103.1	109.8	104.2	114.5	135.9	140.4	130.4	147.2
15	40.2	41.5	50.3	51.2	52.9	53.5	65.0	66.5	58.8	58.9	71.6	73.3	74.5	72.9	87.8	90.5
16	69.1	80.5	74.4	83.5	109.9	127.8	116.0	117.7	132.7	153.9	138.6	134.4	204.3	234.6	207.7	180.0
17	43.6	47.2	50.2	51.8	56.7	59.5	65.6	67.2	62.6	64.8	72.8	74.4	77.8	78.0	91.5	93.2
18	47.4	49.6	54.9	57.7	62.5	64.1	70.9	74.4	69.6	70.6	78.1	82.0	88.3	87.0	96.2	101.4
19	62.6	58.8	71.9	74.1	88.7	79.7	107.5	107.9	101.8	89.8	126.4	125.6	139.2	117.4	183.3	178.2
20	53.5	56.2	57.1	59.5	72.6	75.7	73.8	78.2	81.7	85.1	81.3	86.7	105.8	110.1	100.0	108.2
21	56.1	57.3	66.6	74.8	74.9	79.2	88.9	100.7	83.4	89.9	99.1	112.6	105.1	119.7	125.4	143.2
22	47.5	42.6	50.6	43.9	61.0	55.0	65.3	55.3	67.1	60.7	71.9	60.5	82.1	75.8	88.8	73.7
23	49.6	49.3	53.0	68.0	66.0	63.9	68.4	94.3	73.7	70.6	75.5	107.2	94.2	87.4	93.5	142.7
24	54.1	74.5	52.5	60.6	71.3	105.5	69.0	81.1	79.3	120.8	76.9	90.9	99.8	163.3	97.5	117.3
25	65.3	68.1	80.5	64.8	90.5	100.5	108.2	92.2	103.1	118.0	121.0	106.2	138.6	171.9	154.6	147.4
26	56.9	56.6	55.5	65.8	74.3	74.7	74.5	87.9	82.0	83.0	83.7	98.1	101.3	104.9	109.3	125.1
27	45.7	54.3	59.6	61.0	61.0	72.3	80.6	84.3	68.1	80.5	90.7	95.5	87.1	101.9	118.7	126.2
28	46.6	52.8	51.3	54.4	61.0	68.4	65.8	70.3	67.7	75.6	72.4	77.7	85.4	94.0	89.2	96.9

29	45.7	49.2	49.1	48.2	59.7	63.3	62.8	61.0	66.4	69.7	69.1	66.7	84.0	85.7	85.1	80.9
30	55.2	60.4	76.2	68.6	83.8	93.9	112.0	100.5	99.4	112.7	129.9	117.1	147.6	172.0	179.8	165.1
31	62.3	60.3	68.8	73.5	84.6	83.1	92.9	98.0	95.1	94.4	104.3	109.3	122.6	126.0	134.8	138.8
32	48.6	50.4	54.7	59.4	64.0	66.7	74.3	79.6	71.4	74.5	84.0	89.4	91.1	95.4	110.6	115.7
33	56.9	52.9	69.0	62.9	79.1	74.0	97.5	84.4	90.2	84.7	112.0	94.6	121.3	115.4	154.1	122.0
34	54.2	51.1	58.5	66.2	71.8	67.6	78.4	87.0	80.0	75.3	87.9	96.4	101.4	95.8	113.8	120.1
35	39.5	44.1	41.9	53.3	50.8	56.2	54.0	69.3	55.9	61.5	59.6	76.6	68.7	74.9	74.2	95.4
36	70.2	62.5	85.3	64.9	96.3	89.9	119.4	89.2	109.1	105.0	136.8	102.0	144.5	153.1	186.6	140.9
37	47.6	48.4	63.5	46.9	63.1	63.2	88.5	59.0	70.5	70.0	101.2	64.2	89.8	87.2	137.5	76.8
38	38.5	42.9	46.3	43.8	51.5	55.5	59.5	57.8	58.0	61.4	65.6	64.4	75.7	76.9	80.9	82.1
39	41.4	40.4	46.9	50.1	55.1	54.0	61.5	65.8	61.7	60.5	68.3	73.0	79.2	78.2	86.1	91.4
40	40.8	37.7	57.7	54.9	53.7	48.3	77.8	71.1	59.8	53.1	87.3	78.3	76.0	65.5	113.1	96.3

Table S3. The values of factor of change (FOC) for each location corresponding to **Fig. 5**

Unit: [-]

No.	10-year			50-year			100-year			500-year		
1	0.85	1.14	1.18	0.75	1.12	1.11	0.71	1.11	1.08	0.61	1.09	1.01
2	1.45	1.16	1.40	1.46	1.16	1.40	1.47	1.16	1.40	1.47	1.18	1.40
3	1.00	1.02	0.98	0.95	0.92	0.94	0.93	0.88	0.92	0.87	0.77	0.90
4	1.01	1.21	1.29	1.00	1.18	1.28	1.00	1.17	1.28	1.00	1.12	1.26
5	1.22	1.21	1.14	1.22	1.23	1.15	1.22	1.25	1.16	1.22	1.27	1.18
6	0.98	1.34	1.14	0.96	1.34	1.14	0.95	1.34	1.14	0.95	1.34	1.15
7	0.93	1.12	1.18	0.89	1.09	1.15	0.88	1.08	1.14	0.84	1.04	1.10
8	1.00	1.11	1.32	0.98	1.07	1.34	0.97	1.05	1.35	0.94	1.00	1.38
9	1.05	1.19	1.20	1.01	1.17	1.16	0.99	1.16	1.14	0.95	1.14	1.10
10	1.10	1.24	1.20	1.09	1.24	1.21	1.09	1.24	1.20	1.08	1.25	1.20
11	0.90	1.01	1.08	0.87	0.97	1.06	0.85	0.96	1.05	0.82	0.92	1.03
12	1.17	1.06	1.11	1.19	1.06	1.14	1.21	1.07	1.15	1.24	1.09	1.18
13	1.16	1.33	1.33	1.17	1.29	1.34	1.18	1.27	1.34	1.17	1.20	1.32
14	1.09	1.05	1.12	1.07	1.03	1.12	1.06	1.01	1.11	1.03	0.96	1.08
15	1.03	1.25	1.28	1.01	1.23	1.26	1.00	1.22	1.25	0.98	1.18	1.21
16	1.17	1.08	1.21	1.16	1.06	1.07	1.16	1.04	1.01	1.15	1.02	0.88
17	1.08	1.15	1.19	1.05	1.16	1.19	1.04	1.16	1.19	1.00	1.18	1.20
18	1.05	1.16	1.22	1.02	1.13	1.19	1.01	1.12	1.18	0.99	1.09	1.15
19	0.94	1.15	1.18	0.90	1.21	1.22	0.88	1.24	1.23	0.84	1.32	1.28
20	1.05	1.07	1.11	1.04	1.02	1.08	1.04	1.00	1.06	1.04	0.94	1.02
21	1.02	1.19	1.33	1.06	1.19	1.34	1.08	1.19	1.35	1.14	1.19	1.36
22	0.90	1.07	0.92	0.90	1.07	0.91	0.91	1.07	0.90	0.92	1.08	0.90
23	0.99	1.07	1.37	0.97	1.04	1.43	0.96	1.02	1.45	0.93	0.99	1.51
24	1.38	0.97	1.12	1.48	0.97	1.14	1.52	0.97	1.15	1.64	0.98	1.18
25	1.04	1.23	0.99	1.11	1.19	1.02	1.14	1.17	1.03	1.24	1.12	1.06
26	1.00	0.98	1.16	1.01	1.00	1.18	1.01	1.02	1.20	1.04	1.08	1.23
27	1.19	1.30	1.33	1.19	1.32	1.38	1.18	1.33	1.40	1.17	1.36	1.45
28	1.13	1.10	1.17	1.12	1.08	1.15	1.12	1.07	1.15	1.10	1.05	1.14
29	1.08	1.08	1.06	1.06	1.05	1.02	1.05	1.04	1.01	1.02	1.01	0.96
30	1.09	1.38	1.24	1.12	1.34	1.20	1.13	1.31	1.18	1.16	1.22	1.12
31	0.97	1.11	1.18	0.98	1.10	1.16	0.99	1.10	1.15	1.03	1.10	1.13
32	1.04	1.12	1.22	1.04	1.16	1.24	1.04	1.18	1.25	1.05	1.21	1.27
33	0.93	1.21	1.11	0.93	1.23	1.07	0.94	1.24	1.05	0.95	1.27	1.01
34	0.94	1.08	1.22	0.94	1.09	1.21	0.94	1.10	1.21	0.94	1.12	1.18
35	1.12	1.06	1.35	1.11	1.06	1.36	1.10	1.07	1.37	1.09	1.08	1.39
36	0.89	1.21	0.92	0.93	1.24	0.93	0.96	1.25	0.93	1.06	1.29	0.97
37	1.02	1.33	0.99	1.00	1.40	0.93	0.99	1.44	0.91	0.97	1.53	0.86
38	1.11	1.20	1.14	1.08	1.16	1.12	1.06	1.13	1.11	1.02	1.07	1.08
39	0.98	1.13	1.21	0.98	1.12	1.19	0.98	1.11	1.18	0.99	1.09	1.16
40	0.92	1.41	1.34	0.90	1.45	1.32	0.89	1.46	1.31	0.86	1.49	1.27