

Supplementary information

DEVELOPMENT OF THE MONTHLY AVERAGE DAILY SOLAR RADIATION MAP USING A-CBR, FEM, AND KRIGING METHOD

Choongwan KOO, Taehoon HONG, Kwangbok JEONG, Jimin KIM

Technological and Economic Development of Economy

DOI: doi.org/10.3846/20294913.2016.1213198

Table S1. Geographic information at the 78 locations (i.e., the 24 locations measured from the weather station and the 54 locations estimated using the A-CBR model (Lee *et al.* 2014a))

No.	Region	Longitude (m)	Latitude (m)	No.	Region	Longitude (E°)	Latitude (N°)
1	Gangneung	478,713	572,501	40	Boryeong	270,677	415,054
2	Gosan	229,085	79,110	41	Boeun	376,374	431,917
3	Gochang	272,854	306,452	42	Bongwhoa	481,655	482,860
4	Gwangju	299,231	286,591	43	Buan	284,090	348,528
5	Daegwallyoung	463,561	564,154	44	Buyeo	303,235	408,544
6	Daegu	456,086	365,220	45	Sancheong	389,217	312,657
7	Daejeon	343,855	419,232	46	Sangju	414,315	423,097
8	Mokpo	252,100	247,727	47	Seogwipo	266,506	73,232
9	Busan	494,284	278,946	48	Seongsan	296,012	88,473
10	Bukgangneung	475,517	578,364	49	Sokcho	449,559	628,396
11	Seosan	265,753	465,003	50	Yangpyeong	355,491	543,080
12	Seoul	308,839	552,648	51	Yeosu	376,448	237,944
13	Suwon	310,209	519,433	52	Yeongdeok	526,401	437,872
14	Andong	463,502	441,577	53	Yeongwol	440,813	508,946
15	Wonju	395,465	526,193	54	Yeongju	446,285	474,641
16	Incheon	278,526	542,621	55	Yeongcheon	485,998	375,690
17	Jeonju	323,838	358,310	56	Wando	280,831	200,598
18	Jeju	263,599	103,003	57	Ulleungdo	656,582	546,092
19	Jinju	403,842	285,013	58	Ulsan	519,886	329,785
20	Cheongju	350,180	448,846	59	Uljin	525,958	488,753
21	Chupungnyeong	399,710	402,209	60	Uiseong	462,001	417,507
22	Chuncheon	376,956	588,956	61	Icheon	354,446	518,161
23	Pohang	524,530	382,271	62	Inje	414,860	606,378
24	Heuksando	166,617	235,103	63	Imsil	335,471	334,993

No.	Region	Longitude (m)	Latitude (m)	No.	Region	Longitude (E°)	Latitude (N°)
25	Ganghwa	263,202	568,379	64	Jangsu	356,762	339,821
26	Geoje	455,453	254,598	65	Jangheung	301,194	232,840
27	Geochang	391,958	340,879	66	Jeongeup	297,407	329,902
28	Goheung	333,777	224,726	67	Jecheon	417,452	506,433
29	Gumi	429,048	392,307	68	Juam	330,805	275,420
30	Gunsan	283,495	377,768	69	Jindo	246,207	209,563
31	Geumsan	353,536	389,618	70	Changwon	452,377	285,873
32	Namwon	339,617	312,008	71	Cheonan	321,764	464,649
33	Namhae	393,465	246,497	72	Cheorwon	339,210	616,382
34	Dongducheon	317,590	589,268	73	Chungju	395,983	485,447
35	Donghae	499,600	545,599	74	Taebaek	488,049	508,103
36	Mungyeong	413,502	447,384	75	Tongyeong	440,032	249,789
37	Munsan	291,688	587,793	76	Hapcheon	415,594	329,531
38	Miryang	467,710	321,612	77	Haenam	268,862	218,247
39	Baengnyeongdo	104,095	601,460	78	Hongcheon	389,649	564,611

Note: where: Nos. 1 to 24 refers to the 24 weather stations where the MADSR data are measured and Nos. 25 to 78 refers to the 54 nodes that were used as the independent variable in developing the A-CBR model.

Table S2. Geographic information in the 89 locations estimated using the FEM model

No.	Region	Longitude (m)	Latitude (m)	No.	Region	Longitude (E°)	Latitude (N°)
1	Gapyeong-gun	356,561	578,960	46	Anseong-si	336,175	489,660
2	Gangjin-gun	287,164	227,808	47	Anyang-si	307,846	532,972
3	Gyeongsan-si	467,153	358,610	48	Yanggu-gun	399,337	611,923
4	Gyeongju-si	510,838	362,487	49	Yangju-si	316,103	576,280
5	Gyeryong-si	332,723	408,502	50	Yeongdong-gun	380,673	397,167
6	Goryeong-gun	423,977	347,370	51	Yeongam-gun	280,970	245,445
7	Goseong-gun	429,619	263,881	52	Yeongyang-gun	499,642	452,313
8	Goyang-si	297,156	562,400	53	Yesan-gun	297,310	454,123
9	Gokseong-gun	335,787	298,319	54	Yecheon-gun	440,696	450,829
10	Gongju-si	321,247	427,711	55	Osan-si	318,267	505,748
11	Gwacheon-si	310,585	536,854	56	Okcheon-gun	361,694	411,834
12	Gwangmyeong-si	299,757	542,332	57	Ongjin-gun	279,572	539,152

No.	Region	Longitude (m)	Latitude (m)	No.	Region	Longitude (E°)	Latitude (N°)
13	Gwangyang-si	372,427	260,258	58	Wanju-gun	324,607	367,495
14	Gwangju-si	334,263	536,628	59	Yongin-si	327,228	515,767
15	Goesan-gun	381,173	468,241	60	Eumseong-gun	372,624	482,110
16	Gurye-gun	351,324	289,396	61	Uiryeong-gun	423,992	302,581
17	Guri-si	323,333	555,032	62	Uiwang-si	308,858	527,490
18	Gunwi-gun	451,697	404,825	63	Uijeongbu-si	315,046	571,066
19	Gunpo-si	305,845	529,375	64	Iksan-si	306,166	372,505
20	Gimje-si	299,020	356,572	65	Jangseong-gun	289,664	300,973
21	Gimcheon-si	410,442	393,288	66	Jeongseon-gun	458,717	531,163
22	Gimpo-si	286,807	557,792	67	Jeungpyeong-gun	362,837	464,976
23	Gimhae-si	481,135	292,521	68	Jinan-gun	348,205	354,798
24	Naju-si	282,566	269,364	69	Jincheon-gun	349,863	472,810
25	Namyangju-si	331,033	559,562	70	Changnyeong-gun	444,820	327,355
26	Nonsan-si	319,143	398,872	71	Cheongdo-gun	466,691	338,902
27	Danyang-gun	432,763	487,090	72	Cheongsong-gun	494,981	426,681
28	Dalseong-gun	439,174	352,888	73	Cheongyang-gun	292,822	429,358
29	Damyang-gun	308,208	302,890	74	Chilgok-gun	436,429	377,306
30	Dangjin-si	279,489	477,311	75	Taeon-gun	248,234	461,828
31	Muan-gun	261,559	266,830	76	Paju-si	292,405	573,999
32	Muju-gun	369,614	378,587	77	Pyeongchang-gun	434,774	529,939
33	Boseong-gun	315,981	241,850	78	Pyeongtaek-si	321,222	488,166
34	Bucheon-si	291,082	545,248	79	Pocheon-si	329,875	588,332
35	Sacheon-si	406,092	267,208	80	Hanam-si	330,792	548,838
36	Samcheok-si	503,304	539,276	81	Hadong-gun	377,560	274,317
37	Seocheon-gun	282,343	387,461	82	Haman-gun	437,197	297,122
38	Seongnam-si	322,889	535,697	83	Hamyang-gun	375,272	324,611
39	Seongju-gun	425,757	368,844	84	Hampyeong-gun	264,885	275,112
40	Sunchang-gun	321,847	308,692	85	Hongseong-gun	280,363	445,295
41	Suncheon-si	353,379	261,455	86	Hwaseong-si	296,461	511,459
42	Siheung-si	294,212	531,565	87	Hwasun-gun	307,758	274,430
43	Sinan-gun	249,382	249,583	88	Hwacheon-gun	374,600	611,508
44	Asan-si	311,170	465,837	89	Hoengseong-gun	398,863	543,304
45	Ansan-si	296,644	525,121	-	-	-	-

Table S3. Measured MADSR data in the 24 weather stations

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	Gangneung	2.90	2.92	4.50	4.61	4.23	5.32	3.14	4.08	3.56	3.41	2.06	2.32
2	Gosan	1.70	3.26	4.89	5.96	5.54	3.81	6.10	4.67	5.72	4.23	2.64	1.70
3	Gochang	2.30	2.77	4.18	4.55	4.70	5.24	4.42	3.75	4.61	3.75	2.20	2.07
4	Gwangju	2.94	3.30	5.02	5.44	5.10	4.88	4.27	3.53	4.62	3.64	1.89	1.81
5	Daegwallyoung	3.20	3.40	4.89	4.96	5.00	5.53	3.55	4.11	3.83	3.54	1.92	2.28
6	Daegue	2.98	2.97	4.78	4.90	4.79	5.06	4.09	3.60	3.83	3.30	2.03	2.02
7	Daejeon	2.91	3.18	4.89	5.06	5.00	5.23	3.78	3.74	4.25	3.63	2.28	2.22
8	Mokpo	2.63	3.32	4.97	5.50	5.18	4.86	4.77	3.53	4.81	3.95	2.22	2.03
9	Busan	3.15	3.18	5.03	5.40	4.76	4.66	5.11	4.00	4.29	3.60	2.29	2.54
10	Bukgangneung	2.97	2.98	4.56	4.78	4.27	5.42	3.22	4.20	3.62	3.36	1.87	2.14
11	Seosan	2.77	3.22	4.67	4.81	4.99	4.74	3.36	3.40	4.39	3.55	2.21	2.07
12	Seoul	2.76	3.01	4.54	4.68	4.75	4.56	3.07	3.40	4.16	3.26	1.76	1.93
13	Suwon	2.72	3.04	4.61	4.71	4.86	4.70	3.30	3.65	4.30	3.23	2.05	2.11
14	Andong	3.04	3.18	4.98	5.00	5.01	5.44	4.31	4.00	4.04	3.51	2.19	2.50
15	Wonju	2.83	2.99	4.47	4.55	4.86	5.15	3.47	3.97	4.24	3.51	2.08	2.23
16	Incheon	2.75	2.96	4.70	4.57	4.80	4.72	3.39	3.65	4.20	3.37	2.03	2.24
17	Jeonju	2.73	3.04	4.83	5.12	4.92	5.14	3.88	3.49	4.26	3.65	2.27	2.08
18	Jeju	1.32	2.81	4.48	5.73	5.32	4.62	5.71	4.55	4.63	3.70	1.99	1.24
19	Jinju	3.02	3.41	5.12	5.70	5.11	5.14	4.63	3.80	4.56	3.80	2.29	2.66
20	Cheongju	2.62	2.86	4.54	4.66	4.81	4.92	3.56	3.68	4.04	3.37	2.15	2.12
21	Chupungnyeong	3.03	3.31	5.08	5.13	5.10	5.49	3.97	3.51	4.13	3.63	2.10	2.26
22	Chuncheon	2.72	3.15	4.54	4.57	4.99	5.31	3.31	3.92	4.21	3.46	2.05	2.20
23	Pohang	3.18	2.89	5.07	5.28	4.91	5.51	4.88	3.95	3.92	3.69	2.26	2.58
24	Heuksando	1.81	3.09	5.01	5.73	5.08	4.13	4.10	3.57	4.82	3.91	2.10	1.53

Table S4. Statistics of the MRA models by month

Model	R-squared	Adjusted R-squared	S.E. of regression	F-statistic	Prob. (F-statistic)	Estimation accuracy
Jan.	0.764	0.759	0.19354	4.511	0.035	93.66%
Feb.	0.767	0.762	0.21049	4.960	0.027	95.00%
Mar.	0.827	0.824	0.23152	9.306	0.003	95.75%
Apr.	0.653	0.649	0.26722	18.750	0.000	95.96%
May	0.683	0.678	0.29865	4.694	0.032	95.77%
Jun.	0.632	0.628	0.29802	5.813	0.017	95.28%
Jul.	0.810	0.807	0.31350	5.321	0.022	93.60%
Aug.	0.796	0.792	0.27454	9.954	0.002	95.06%

Model	R-squared	Adjusted R-squared	S.E. of regression	F-statistic	Prob. (F-statistic)	Estimation accuracy
Sep.	0.838	0.835	0.22523	6.640	0.011	95.39%
Oct.	0.628	0.624	0.21675	70.837	0.000	95.47%
Nov.	0.696	0.691	0.20546	7.812	0.006	93.84%
Dec.	0.715	0.710	0.18239	3.939	0.049	92.99%

Table S5. Regression coefficient of the MRA models by month

Model	Variables	Coefficient	Std. error	t-statistic	Prob.	VIF
Jan.	-	4.121	0.631	6.530	0.000	-
	X ₆	0.008	0.000	18.609	0.000	1.855
	X ₂	-0.085	0.018	-4.647	0.000	2.610
	X ₄	-0.019	0.006	-2.942	0.004	2.312
Feb.	-	4.242	0.478	8.883	0.000	-
	X ₆	.011	0.000	21.523	0.000	1.264
	X ₂	-0.079	0.014	-5.804	0.000	1.241
	X ₃	0.000	0.000	3.220	0.002	1.094
Mar.	X ₈	-0.001	0.001	-2.227	0.027	1.207
	-	5.940	0.663	8.963	0.000	-
	X ₆	0.012	0.000	28.316	0.000	1.022
	X ₂	-0.113	0.017	-6.618	0.000	1.634
Apr.	X ₄	-0.031	0.010	-3.051	0.003	1.654
	-	4.839	0.607	7.966	0.000	-
	X ₇	0.048	0.003	16.846	0.000	1.03
May	X ₂	-0.068	0.016	-4.330	0.000	1.03
	-	4.839	0.665	7.278	0.000	-
	X ₇	0.059	0.003	19.153	0.000	1.003
	X ₂	-0.067	0.018	-3.683	0.000	1.091
Jun.	X ₃	0.000	0.000	2.167	0.032	1.092
	-	3.058	0.142	21.559	0.000	-
	X ₇	0.052	0.003	16.245	0.000	1.061
	X ₈	-0.001	0.000	-2.411	0.017	1.061
Jul.	-	9.215	2.841	3.244	0.001	-
	X ₇	0.061	0.003	18.664	0.000	1.586
	X ₈	-0.001	0.000	-4.711	0.000	1.586
	X ₁	-0.052	0.022	-2.307	0.022	1.001
Aug.	-	4.654	0.679	6.850	0.000	-
	X ₇	0.049	0.002	19.528	0.000	1.419
	X ₂	-0.056	0.017	-3.196	0.002	1.215
	X ₈	-0.001	0.000	-3.155	0.002	1.187

Model	Variables	Coefficient	Std. error	t-statistic	Prob.	VIF
Sep.	-	4.165	0.479	8.690	0.000	-
	X ₇	0.051	0.002	21.035	0.000	1.692
	X ₂	-0.066	0.013	-4.998	0.000	1.019
	X ₈	0.000	0.000	-2.577	0.011	1.716
Oct.	-	5.675	0.484	11.725	0.000	-
	X ₆	0.009	0.001	14.074	0.000	1.016
	X ₂	-0.106	0.013	-8.416	0.000	1.016
Nov.	-	4.238	0.431	9.829	0.000	-
	X ₆	0.008	0.001	14.621	0.000	1.499
	X ₂	-0.082	0.012	-6.836	0.000	1.018
	X ₈	-0.001	0.000	-2.795	0.006	1.479
Dec.	-	3.753	0.593	6.326	0.000	-
	X ₆	0.008	0.000	19.572	0.000	1.427
	X ₂	-0.079	0.017	-4.709	0.000	2.556
	X ₄	-0.012	0.006	-1.985	0.049	2.272

Note: where: X₁(Longitude); X₂(Latitude); X₃(Altitude); X₄(Monthly average temperature); X₅(Monthly average relative humidity); X₆(Monthly total sunshine duration); X₇(Monthly average percentage of sunshine); X₈(Precipitation); and X₉(Monthly average wind speed) (refer to Table 1 in the main body of this study).

Table S6. Statistics of the ANN models by month

Classification	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Number of layers	Input layers	9	9	9	9	9	9	9	9	9	9	9
	Hidden layers	6	6	5	7	5	3	6	6	5	5	7
	Output layers	1	1	1	1	1	1	1	1	1	1	1
Importance of independent variables	X ₁	0.051	0.080	0.019	0.034	0.045	0.047	0.063	0.046	0.059	0.022	0.038
	X ₂	0.111	0.094	0.092	0.101	0.104	0.057	0.039	0.069	0.039	0.199	0.143
	X ₃	0.067	0.039	0.090	0.071	0.070	0.082	0.086	0.099	0.107	0.059	0.025
	X ₄	0.140	0.158	0.125	0.074	0.079	0.047	0.118	0.175	0.168	0.055	0.073
	X ₅	0.069	0.033	0.026	0.029	0.137	0.082	0.063	0.089	0.038	0.046	0.033
	X ₆	0.342	0.311	0.397	0.241	0.222	0.343	0.336	0.168	0.352	0.092	0.355
	X ₇	0.090	0.186	0.056	0.257	0.231	0.276	0.110	0.238	0.044	0.380	0.094
	X ₈	0.083	0.062	0.090	0.067	0.056	0.036	0.100	0.048	0.125	0.038	0.142
	X ₉	0.047	0.037	0.105	0.125	0.056	0.031	0.085	0.069	0.067	0.109	0.096
Mean square error	Training phase	10.690	17.8	7.812	16.376	22.792	19.832	9.564	16.435	7.909	22.311	16.642
	Test phase	5.426	7.616	5.968	11.39	5.162	14.368	5.465	6.676	4.232	11.319	11.377

Note: where: X₁(Longitude); X₂(Latitude); X₃(Altitude); X₄(Monthly average temperature); X₅(Monthly average relative humidity); X₆(Monthly total sunshine duration); X₇(Monthly average percentage of sunshine); X₈(Precipitation); and X₉(Monthly average wind speed) (refer to Table 1 in the main body of this study).

Table S7. Estimation of the MADSR data in the 54 unmeasured locations using the A-CBR model

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1(25)	Ganghwa	2.71	3.02	4.59	4.66	4.81	4.83	3.25	3.90	4.18	3.55	2.05	2.28
2(26)	Geoje	2.80	3.15	4.75	5.40	4.69	4.40	4.43	3.51	4.24	3.54	2.10	2.25
3(27)	Geochang	2.99	3.27	4.85	5.27	5.30	5.06	3.96	3.72	4.06	3.59	2.13	2.48
4(28)	Goheung	2.74	3.39	4.69	5.37	4.89	4.62	4.20	3.69	4.40	3.77	2.24	2.19
5(29)	Gumi	2.69	3.12	4.79	5.02	4.93	5.29	4.05	3.68	3.81	3.40	2.10	2.28
6(30)	Gunsan	2.76	3.13	4.66	5.14	4.95	4.82	3.61	3.69	4.59	3.61	2.27	1.84
7(31)	Geumsan	2.91	3.15	4.63	5.04	4.86	5.20	3.85	3.51	3.79	3.33	2.11	2.10
8(32)	Namwon	2.97	3.13	4.87	5.24	5.00	5.05	4.09	3.72	4.32	3.68	2.36	2.21
9(33)	Namhae	2.96	3.33	4.70	5.39	5.01	4.66	4.46	3.70	4.35	3.65	2.15	2.54
10(34)	Dongducheon	2.75	3.11	4.47	4.54	4.96	5.11	3.22	3.58	4.24	3.58	2.13	2.25
11(35)	Donghae	2.94	2.92	4.41	4.58	4.40	5.25	3.72	4.07	3.82	3.38	2.03	2.32
12(36)	Mungyeong	2.55	3.20	4.92	4.95	5.02	5.17	3.64	3.43	4.08	3.49	2.03	2.24
13(37)	Munsan	2.81	3.08	4.48	4.63	4.93	4.83	3.20	3.65	4.21	3.53	2.17	2.34
14(38)	Miryang	2.91	3.20	4.92	5.16	4.79	4.86	4.23	3.69	4.12	3.63	2.12	2.48
15(39)	Baengnyeongdo	2.19	3.02	4.82	4.84	5.20	4.97	3.77	4.00	4.40	3.70	2.05	1.74
16(40)	Boryeong	2.48	3.10	4.54	4.79	4.94	4.83	3.36	3.53	4.44	3.62	2.30	2.00
17(41)	Boeun	2.82	3.21	4.56	4.87	5.00	5.16	3.44	3.78	4.22	3.46	2.06	2.21
18(42)	Bongwhoa	2.90	3.17	4.49	4.70	4.93	5.08	3.56	3.75	3.54	3.24	2.11	2.38
19(43)	Buan	2.54	3.06	4.59	5.18	4.98	4.95	4.15	3.67	4.53	3.62	2.13	1.80
20(44)	Buyeo	2.75	2.98	4.56	4.81	4.84	4.93	3.49	3.42	4.19	3.50	2.14	1.94
21(45)	Sancheong	2.75	3.24	4.93	5.24	5.16	5.06	3.92	3.57	4.05	3.54	2.07	2.09
22(46)	Sangju	2.87	3.16	4.84	4.91	4.89	5.04	3.71	3.50	3.86	3.33	2.13	2.41
23(47)	Seogwipo	2.69	3.27	4.62	5.32	4.73	3.89	4.35	3.98	4.81	3.89	2.32	2.06
24(48)	Seongsan	2.21	3.09	4.65	5.39	4.69	3.84	4.65	3.84	4.80	3.74	2.17	1.79
25(49)	Sokcho	2.95	2.81	4.30	4.75	4.23	5.31	3.24	4.05	4.06	3.36	1.88	2.27
26(50)	Yangpyeong	2.71	2.93	4.43	4.44	4.69	4.89	3.00	3.77	4.03	3.32	2.09	2.21
27(51)	Yeosu	2.97	3.39	4.93	5.44	4.80	4.61	4.71	3.92	4.81	3.84	2.45	2.38
28(52)	Yeongdeok	2.89	2.87	4.72	4.97	4.49	5.42	4.52	4.07	3.82	3.56	2.15	2.26
29(53)	Yeongwol	2.82	3.00	4.44	4.69	4.87	5.17	3.60	3.70	3.83	3.26	2.09	2.33
30(54)	Yeongju	2.83	3.19	4.85	4.90	5.07	5.17	3.67	3.58	4.02	3.33	2.06	2.31
31(55)	Yeongcheon	2.88	3.01	4.89	5.02	4.87	5.05	4.16	3.77	3.64	3.41	2.14	2.25
32(56)	Wando	2.61	3.46	4.79	5.39	4.82	4.55	4.62	3.75	4.57	3.90	2.11	2.03
33(57)	Ulleungdo	1.97	2.68	3.91	4.81	4.27	5.33	4.32	4.25	3.60	3.14	2.00	1.85
34(58)	Ulsan	2.96	2.95	4.90	5.23	4.84	4.88	4.66	4.03	4.24	3.59	2.21	2.58
35(59)	Uljin	3.01	2.98	4.64	4.86	4.47	5.29	4.36	4.38	3.94	3.56	2.26	2.32

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
36(60)	Uiseong	2.91	3.15	4.66	4.74	4.86	5.26	4.19	3.75	3.95	3.42	2.09	2.41
37(61)	Icheon	2.69	2.94	4.43	4.67	5.08	5.13	3.32	3.71	4.06	3.33	2.22	2.25
38(62)	Inje	2.56	2.87	3.93	4.27	4.62	4.94	3.32	3.74	3.52	3.10	2.05	2.20
39(63)	Imsil	2.81	3.15	4.77	5.20	5.00	4.99	3.70	3.49	4.37	3.60	2.10	2.04
40(64)	Jangsu	2.81	3.34	4.83	5.07	5.16	5.09	3.71	3.49	4.24	3.50	2.11	2.07
41(65)	Jangheung	2.94	3.47	4.91	5.28	4.82	4.54	4.23	3.65	4.38	3.91	2.21	2.06
42(66)	Jeongeup	2.48	3.04	4.72	5.20	4.92	5.01	4.15	3.36	4.39	3.64	2.08	1.78
43(67)	Jecheon	2.87	3.13	4.50	4.57	4.92	5.05	3.72	3.70	3.88	3.33	2.09	2.32
44(68)	Juam	2.74	3.25	4.75	4.91	4.84	4.68	4.00	3.68	4.06	3.45	2.05	2.04
45(69)	Jindo	2.36	3.43	4.81	5.44	5.08	4.36	3.77	3.93	4.81	3.86	2.10	1.84
46(70)	Changwon	3.00	3.25	4.78	5.36	4.88	4.62	4.37	3.86	4.35	3.65	2.23	2.54
47(71)	Cheonan	2.76	3.13	4.67	4.92	4.96	5.11	3.53	3.70	4.31	3.51	2.11	2.10
48(72)	Cheorwon	2.79	3.08	4.42	4.52	5.00	5.14	3.35	3.72	4.28	3.40	2.05	2.12
49(73)	Chungju	2.76	2.95	4.54	4.67	5.02	5.08	3.71	3.68	4.18	3.44	2.14	2.25
50(74)	Taebaek	2.83	3.21	4.53	4.61	5.14	5.03	3.56	3.53	3.57	3.47	2.05	2.23
51(75)	Tongyeong	3.02	3.26	4.83	5.41	4.67	4.55	4.85	3.81	4.66	3.68	2.30	2.62
52(76)	Hapcheon	2.98	3.17	4.78	5.31	4.94	5.16	4.26	3.62	4.20	3.63	2.05	2.40
53(77)	Haenam	2.70	3.31	4.63	5.20	4.85	4.55	4.58	3.75	4.57	3.90	2.12	2.04
54(78)	Hongcheon	2.76	2.89	4.35	4.44	4.92	5.03	3.41	3.78	3.94	3.24	2.10	2.19

Table S8. Estimation of the MADSR data in the 89 unmeasured locations using the FEM model

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	Gapyeong-gun	2.73	3.09	4.49	4.53	4.92	5.16	3.22	3.79	4.18	3.46	2.08	2.21
2	Gangjin-gun	2.79	3.38	4.78	5.28	4.88	4.59	4.42	3.68	4.50	3.89	2.18	2.06
3	Gyeongsan-si	2.94	3.03	4.84	4.98	4.81	5.01	4.14	3.66	3.84	3.39	2.08	2.17
4	Gyeongju-si	3.03	2.95	4.96	5.19	4.87	5.17	4.60	3.92	3.95	3.59	2.21	2.49
5	Gyeryong-si	2.85	3.11	4.74	4.98	4.92	5.13	3.71	3.59	4.15	3.53	2.21	2.11
6	Goryeong-gun	2.98	3.15	4.83	5.19	4.93	5.17	4.18	3.60	4.11	3.56	2.05	2.30
7	Goseong-gun	3.01	3.30	4.86	5.46	4.84	4.70	4.66	3.81	4.54	3.70	2.27	2.60
8	Goyang-si	2.78	3.02	4.55	4.63	4.82	4.69	3.18	3.53	4.19	3.38	1.96	2.14
9	Gokseong-gun	2.74	3.24	4.76	5.03	4.90	4.78	3.87	3.58	4.19	3.50	2.02	2.04
10	Gongju-si	2.76	3.03	4.65	4.84	4.89	4.99	3.57	3.57	4.19	3.51	2.19	2.07
11	Gwacheon-si	2.74	3.02	4.57	4.69	4.80	4.64	3.17	3.53	4.23	3.25	1.90	2.02

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
12	Gwangmyeong-si	2.75	3.00	4.60	4.65	4.79	4.64	3.22	3.53	4.20	3.29	1.90	2.07
13	Gwangyang-si	2.93	3.36	4.94	5.38	4.89	4.77	4.51	3.83	4.55	3.73	2.31	2.37
14	Gwangju-si	2.72	2.97	4.50	4.59	4.80	4.80	3.13	3.65	4.13	3.29	2.02	2.13
15	Goesan-gun	2.66	2.98	4.62	4.73	4.96	5.05	3.61	3.63	4.10	3.42	2.13	2.21
16	Gurye-gun	2.88	3.25	4.88	5.20	4.96	4.91	4.17	3.72	4.26	3.61	2.20	2.24
17	Guri-si	2.75	2.99	4.50	4.60	4.75	4.69	3.07	3.52	4.14	3.29	1.87	2.02
18	Gunwi-gun	2.89	3.11	4.72	4.82	4.86	5.20	4.10	3.69	3.90	3.38	2.08	2.32
19	Gunpo-si	2.74	3.03	4.60	4.69	4.83	4.67	3.25	3.58	4.26	3.26	1.98	2.08
20	Gimje-si	2.65	3.07	4.69	5.15	4.96	5.00	3.96	3.61	4.44	3.63	2.20	1.91
21	Gimcheon-si	2.89	3.24	4.96	5.10	5.06	5.40	4.01	3.59	4.01	3.55	2.10	2.28
22	Gimpo-si	2.76	3.01	4.60	4.62	4.81	4.71	3.24	3.62	4.19	3.40	1.98	2.18
23	Gimhae-si	3.06	3.18	4.94	5.33	4.80	4.70	4.73	3.91	4.27	3.62	2.24	2.53
24	Naju-si	2.72	3.22	4.79	5.21	4.96	4.88	4.41	3.61	4.61	3.80	2.11	1.98
25	Namyangju-si	2.74	3.02	4.49	4.57	4.79	4.83	3.10	3.59	4.14	3.36	1.95	2.10
26	Nonsan-si	2.81	3.07	4.63	4.96	4.88	5.02	3.65	3.52	4.14	3.48	2.16	2.00
27	Danyang-gun	2.81	3.07	4.65	4.79	5.00	5.15	3.66	3.64	4.01	3.34	2.09	2.30
28	Dalseong-gun	2.90	3.10	4.81	5.10	4.87	5.11	4.16	3.64	3.99	3.48	2.07	2.27
29	Damyang-gun	2.80	3.19	4.89	5.30	5.01	4.94	4.19	3.53	4.46	3.64	2.04	1.89
30	Dangjin-si	2.77	3.16	4.68	4.80	4.96	4.81	3.40	3.50	4.34	3.51	2.16	2.10
31	Muan-gun	2.52	3.11	4.63	5.11	4.96	4.96	4.61	3.65	4.70	3.87	2.20	2.04
32	Muju-gun	2.93	3.23	4.78	5.10	5.02	5.23	3.88	3.54	3.96	3.45	2.11	2.19
33	Boseong-gun	2.85	3.39	4.82	5.25	4.87	4.61	4.18	3.66	4.35	3.77	2.17	2.08
34	Bucheon-si	2.75	2.99	4.63	4.62	4.79	4.67	3.27	3.57	4.20	3.33	1.94	2.13
35	Sacheon-si	3.00	3.36	4.94	5.55	5.01	4.89	4.60	3.77	4.50	3.73	2.25	2.61
36	Samcheok-si	2.91	2.95	4.42	4.60	4.47	5.23	3.75	4.03	3.80	3.39	2.04	2.30
37	Seocheon-gun	2.67	3.09	4.60	4.99	4.92	4.85	3.57	3.62	4.51	3.60	2.26	1.90
38	Seongnam-si	2.73	3.00	4.53	4.64	4.80	4.73	3.16	3.59	4.18	3.27	1.97	2.08
39	Seongju-gun	2.89	3.13	4.83	5.10	4.93	5.23	4.11	3.62	3.98	3.49	2.07	2.26
40	Sunchang-gun	2.84	3.15	4.86	5.25	4.99	4.99	4.13	3.60	4.38	3.65	2.19	2.03
41	Suncheon-si	2.84	3.33	4.84	5.22	4.88	4.73	4.29	3.76	4.36	3.64	2.21	2.24
42	Siheung-si	2.75	3.01	4.64	4.65	4.83	4.69	3.31	3.60	4.24	3.31	2.01	2.14
43	Sinan-gun	3.11	3.52	5.60	6.12	5.57	5.17	6.07	2.98	4.93	4.17	2.35	2.21
44	Asan-si	2.76	3.14	4.67	4.90	4.96	5.03	3.49	3.64	4.32	3.51	2.13	2.10

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
45	Ansan-si	2.74	3.03	4.64	4.67	4.84	4.70	3.32	3.62	4.27	3.30	2.04	2.14
46	Anseong-si	2.70	2.99	4.55	4.74	4.95	5.00	3.42	3.69	4.17	3.37	2.14	2.16
47	Anyang-si	2.74	3.03	4.59	4.69	4.81	4.65	3.21	3.55	4.24	3.25	1.94	2.05
48	Yanggu-gun	2.68	2.92	4.12	4.41	4.67	5.05	3.32	3.78	3.80	3.22	2.03	2.19
49	Yangju-si	2.75	3.07	4.49	4.58	4.88	4.93	3.16	3.53	4.21	3.47	2.02	2.16
50	Yeongdong-gun	2.81	3.14	4.65	5.00	4.89	5.21	3.84	3.61	3.85	3.36	2.10	2.17
51	Yeongam-gun	2.81	3.38	4.93	5.38	5.00	4.71	4.46	3.60	4.59	3.88	2.16	2.01
52	Yeongyang-gun	2.95	3.03	4.76	4.92	4.72	5.36	4.29	4.04	3.86	3.50	2.17	2.36
53	Yesan-gun	2.75	3.14	4.65	4.86	4.95	4.94	3.46	3.55	4.32	3.53	2.16	2.06
54	Yecheon-gun	2.80	3.19	4.93	4.96	5.03	5.28	3.91	3.68	4.05	3.46	2.10	2.36
55	Osan-si	2.73	3.05	4.60	4.76	4.92	4.86	3.36	3.67	4.27	3.31	2.09	2.13
56	Okcheon-gun	2.91	3.20	4.78	5.03	4.98	5.25	3.76	3.66	4.11	3.52	2.16	2.20
57	Ongjin-gun	2.75	2.98	4.70	4.58	4.81	4.72	3.39	3.64	4.21	3.37	2.04	2.23
58	Wanju-gun	2.81	3.12	4.71	5.12	4.93	5.04	3.76	3.55	4.23	3.53	2.18	2.01
59	Yongin-si	2.71	3.01	4.55	4.71	4.95	4.88	3.32	3.68	4.21	3.28	2.12	2.16
60	Eumseong-gun	2.71	2.95	4.51	4.68	4.99	5.07	3.55	3.70	4.12	3.40	2.16	2.22
61	Uiryeong-gun	2.99	3.28	4.91	5.45	4.98	5.00	4.42	3.75	4.36	3.70	2.19	2.53
62	Uiwang-si	2.74	3.03	4.59	4.71	4.83	4.66	3.24	3.58	4.27	3.24	1.97	2.06
63	Uijeongbu-si	2.76	3.06	4.50	4.60	4.85	4.85	3.14	3.51	4.19	3.43	1.97	2.12
64	Iksan-si	2.76	3.10	4.70	5.12	4.93	4.98	3.75	3.60	4.37	3.58	2.24	1.95
65	Jangseong-gun	2.64	3.08	4.70	5.12	4.94	5.02	4.30	3.56	4.58	3.68	2.03	1.89
66	Jeongseon-gun	2.96	3.20	4.63	4.77	4.98	5.27	3.57	3.82	3.77	3.41	2.02	2.29
67	Jeungpyeong-gun	2.70	2.96	4.52	4.71	4.93	5.04	3.50	3.71	4.10	3.39	2.15	2.19
68	Jinan-gun	2.82	3.22	4.77	5.09	5.03	5.11	3.77	3.50	4.15	3.49	2.14	2.08
69	Jincheon-gun	2.65	2.89	4.51	4.67	4.90	4.98	3.47	3.69	4.06	3.36	2.17	2.16
70	Changnyeong-gun	2.93	3.17	4.86	5.19	4.86	4.99	4.21	3.65	4.12	3.60	2.09	2.39
71	Cheongdo-gun	2.92	3.12	4.88	5.08	4.80	4.93	4.19	3.68	3.99	3.52	2.10	2.34
72	Cheongsong-gun	2.96	3.01	4.79	4.94	4.74	5.39	4.42	3.95	3.91	3.52	2.15	2.38
73	Cheongyang-gun	2.69	3.07	4.59	4.83	4.91	4.91	3.45	3.49	4.30	3.54	2.18	2.00
74	Chilgok-gun	2.82	3.08	4.78	5.01	4.89	5.20	4.09	3.65	3.86	3.40	2.07	2.22
75	Tae'an-gun	2.69	3.20	4.71	4.88	5.02	4.71	3.44	3.44	4.41	3.58	2.19	2.02
76	Paju-si	2.76	3.05	4.52	4.64	4.86	4.80	3.18	3.64	4.19	3.47	2.03	2.21
77	Pyeongchang-gun	2.91	3.10	4.54	4.70	4.91	5.21	3.58	3.81	3.85	3.33	2.05	2.30
78	Pyeongtaek-si	2.74	3.08	4.62	4.83	4.94	4.98	3.43	3.68	4.28	3.40	2.10	2.12
79	Pocheon-si	2.70	3.16	4.48	4.48	5.00	5.34	3.23	3.48	4.27	3.68	2.12	2.21
80	Hanam-si	2.74	2.97	4.49	4.58	4.75	4.71	3.08	3.56	4.11	3.28	1.91	2.05
81	Hadong-gun	2.91	3.34	4.90	5.37	5.01	4.89	4.37	3.73	4.33	3.64	2.17	2.43
82	Haman-gun	2.99	3.27	4.88	5.41	4.93	4.86	4.40	3.79	4.35	3.68	2.20	2.54

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
83	Hamyang-gun	2.85	3.25	4.88	5.21	5.17	5.06	3.91	3.61	4.13	3.56	2.14	2.19
84	Hampyeong-gun	2.60	3.20	4.76	5.21	5.00	4.90	4.53	3.62	4.67	3.88	2.20	2.06
85	Hongseong-gun	2.69	3.15	4.62	4.82	4.96	4.85	3.40	3.49	4.37	3.56	2.21	2.04
86	Hwaseong-si	2.74	3.06	4.65	4.71	4.88	4.76	3.36	3.62	4.29	3.34	2.08	2.14
87	Hwasun-gun	2.89	3.32	4.93	5.27	4.98	4.77	4.19	3.59	4.43	3.64	1.99	1.91
88	Hwacheon-gun	2.80	3.05	4.43	4.58	4.86	5.23	3.33	3.86	4.22	3.40	2.01	2.16
89	Hoengseong-gun	2.79	2.97	4.38	4.49	4.86	5.08	3.47	3.86	4.03	3.37	2.09	2.23

Table S9. Estimation of the MADSR data in the 24 weather stations using the proposed MADSR map

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	Gangneung	2.91	2.93	4.50	4.63	4.23	5.34	3.15	4.10	3.57	3.41	2.04	2.30
2	Gosan	1.70	3.26	4.89	5.96	5.54	3.81	6.10	4.67	5.71	4.22	2.64	1.69
3	Gochang	2.31	2.77	4.19	4.56	4.71	5.24	4.42	3.75	4.61	3.75	2.20	2.06
4	Gwangju	2.93	3.30	5.01	5.42	5.09	4.88	4.27	3.54	4.62	3.65	1.90	1.82
5	Daegwallyoung	3.19	3.39	4.88	4.95	4.98	5.52	3.54	4.10	3.82	3.54	1.92	2.28
6	Daegye	2.97	2.97	4.79	4.91	4.79	5.06	4.10	3.61	3.83	3.31	2.03	2.03
7	Daejeon	2.90	4.88	4.88	5.05	5.00	5.23	3.77	3.74	4.24	3.62	2.28	2.22
8	Mokpo	2.63	3.32	4.95	5.48	5.17	4.85	4.75	3.55	4.80	3.95	2.21	2.03
9	Busan	3.15	3.18	5.02	5.40	4.76	4.66	5.10	4.00	4.29	3.60	2.29	2.54
10	Bukgangneung	2.96	2.97	4.55	4.77	4.26	5.41	3.21	4.19	3.62	3.36	1.89	2.16
11	Seosan	2.77	3.22	4.68	4.82	4.99	4.74	3.36	3.40	4.39	3.55	2.21	2.07
12	Seoul	2.76	3.01	4.69	4.89	4.75	4.70	3.08	3.51	4.47	3.58	2.22	2.00
13	Suwon	2.73	3.04	4.60	4.71	4.86	4.70	3.31	3.64	4.30	3.23	2.04	2.10
14	Andong	3.04	3.18	4.98	4.99	5.00	5.44	4.31	4.00	4.03	3.51	2.19	2.50
15	Wonju	2.83	2.99	4.47	4.55	4.86	5.14	3.47	3.96	4.23	3.51	2.09	2.24
16	Incheon	2.75	2.97	4.68	4.91	4.81	4.70	3.38	3.53	4.49	3.59	2.23	1.98
17	Jeonju	2.73	3.04	4.82	5.13	4.92	5.13	3.88	3.50	4.27	3.65	2.27	2.07
18	Jeju	1.33	2.82	4.49	5.73	5.33	4.61	5.71	4.55	4.65	3.71	2.00	1.25
19	Jinju	3.01	3.41	5.12	5.69	5.11	5.13	4.62	3.80	4.55	3.80	2.29	2.65
20	Cheongju	2.63	2.87	4.55	4.67	4.82	4.93	3.56	3.68	4.05	3.38	2.16	2.12
21	Chupungnyeong	3.02	3.31	5.06	5.12	5.10	5.47	3.96	3.52	4.12	3.62	2.10	2.26
22	Chuncheon	2.72	3.14	4.52	4.56	4.98	5.30	3.31	3.91	4.19	3.45	2.05	2.20
23	Pohang	3.17	2.89	5.06	5.28	4.91	5.49	4.86	3.95	3.92	3.69	2.26	2.57
24	Heuksando	1.81	3.09	5.01	5.73	5.08	4.14	4.11	3.57	4.82	3.91	2.10	1.53

Table S10. Estimation of the MADSR data in the 24 weather stations using the previous MADSR map

No.	Region	Monthly average daily solar radiation (kWh/m ² /day)											
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	Gangneung	2.90	3.01	4.52	4.61	4.36	5.33	3.14	4.11	3.56	3.41	1.98	2.32
2	Gosan	1.71	3.19	4.78	5.96	5.40	3.81	6.10	4.61	5.71	4.22	2.48	1.70
3	Gochang	2.31	3.01	4.53	4.55	4.82	5.24	4.42	3.71	4.62	3.75	2.14	2.07
4	Gwangju	2.94	3.21	4.81	4.44	5.01	4.88	4.27	3.55	4.62	3.64	2.03	1.81
5	Daegwallyoung	3.20	3.12	4.61	4.96	4.77	5.52	3.55	4.08	3.83	3.54	1.97	2.28
6	Daegye	2.84	3.13	4.88	5.06	4.91	5.10	4.13	3.71	3.84	3.47	2.12	2.33
7	Daejeon	2.91	3.12	4.74	5.06	4.96	5.23	3.78	3.71	4.25	3.62	2.21	2.22
8	Mokpo	2.63	3.28	4.84	5.50	5.10	4.85	4.77	3.56	4.81	3.95	2.17	2.03
9	Busan	3.15	3.16	4.94	5.40	4.76	4.66	5.10	3.97	4.29	3.60	2.25	2.54
10	Bukgangneung	2.97	3.00	4.51	4.78	4.34	5.42	3.22	4.16	3.62	3.36	1.95	2.15
11	Seosan	2.77	3.13	4.65	4.81	4.97	4.74	3.36	3.43	4.39	3.55	2.19	2.07
12	Seoul	2.76	3.02	4.54	4.68	4.80	4.56	3.07	3.45	4.16	3.27	1.93	1.94
13	Suwon	2.72	3.03	4.59	4.72	4.87	4.71	3.30	3.64	4.30	3.23	2.05	2.11
14	Andong	3.04	3.14	4.84	5.00	4.97	5.44	4.31	3.94	4.04	3.51	2.15	2.50
15	Wonju	2.83	3.01	4.47	4.55	4.89	5.15	3.47	3.93	4.24	3.51	2.09	2.23
16	Incheon	2.75	3.06	4.63	4.92	5.02	4.70	3.65	3.65	4.55	3.70	2.16	1.85
17	Jeonju	2.73	3.10	4.76	5.12	4.94	5.14	3.88	3.50	4.26	3.65	2.21	2.08
18	Jeju	1.33	3.06	4.62	5.72	5.19	4.61	5.70	4.46	4.64	3.71	2.14	1.25
19	Jinju	3.02	3.32	4.95	5.70	5.06	5.14	4.63	3.78	4.56	3.80	2.23	2.66
20	Cheongju	2.62	3.02	4.62	4.66	4.88	4.92	3.56	3.69	4.05	3.37	2.15	2.12
21	Chupungnyeong	3.03	3.22	4.89	5.13	5.05	5.49	3.97	3.53	4.13	3.63	2.10	2.26
22	Chuncheon	2.72	3.04	4.41	4.56	4.93	5.31	3.31	3.88	4.21	3.46	2.05	2.20
23	Pohang	3.18	2.94	4.94	5.28	4.85	5.50	4.87	3.96	3.92	3.69	2.22	2.57
24	Heuksando	1.81	3.13	4.93	5.72	5.09	4.13	4.10	3.59	4.82	3.91	2.13	1.53

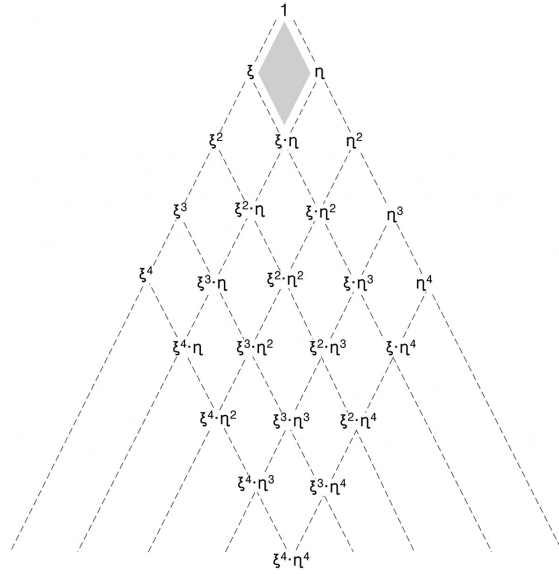


Fig. S1. Pascal's triangle for the *Lagrangian* quadrilateral elements

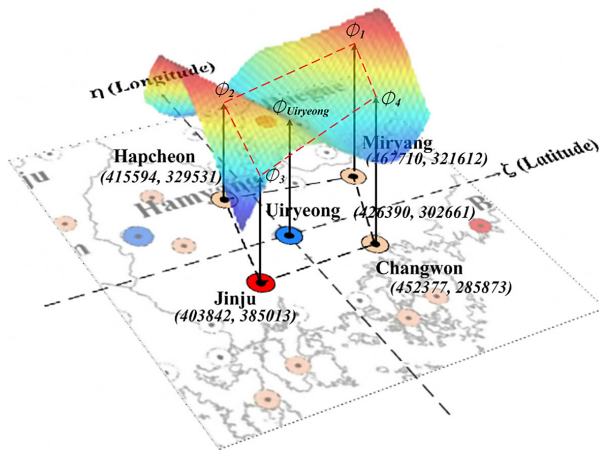
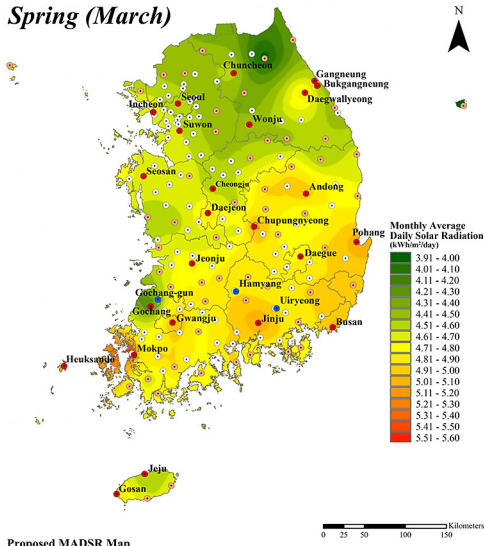


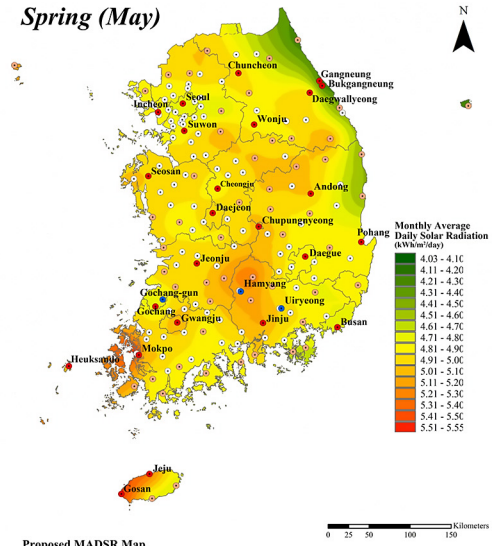
Fig. S2. Application of the *Lagrangian* shape function in quadrilateral coordinates (March in Uiryeong)

Spring (March)



Proposed MADSR Map developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

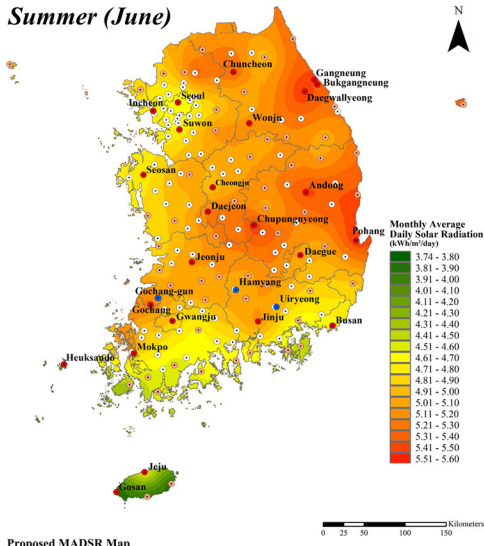
Spring (May)



Proposed MADSR Map developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

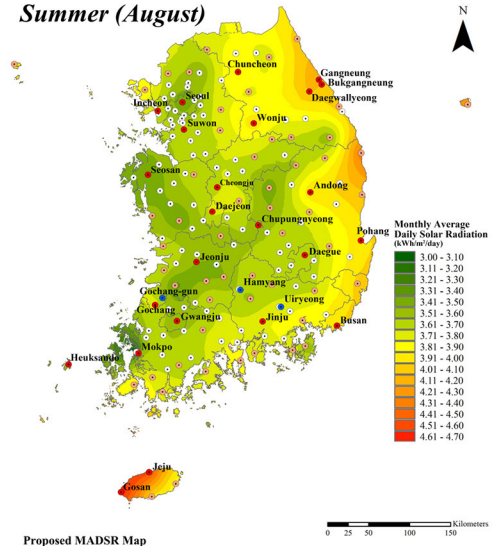
Fig. S3. The proposed MADSR maps of March (left) and May (right) in spring season in South Korea

Summer (June)



Proposed MADSR Map developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

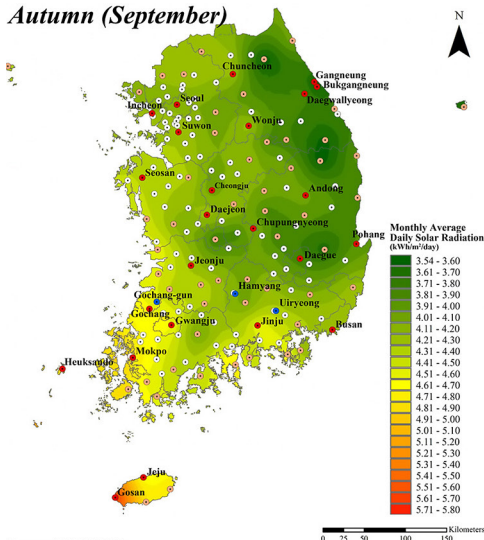
Summer (August)



Proposed MADSR Map developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

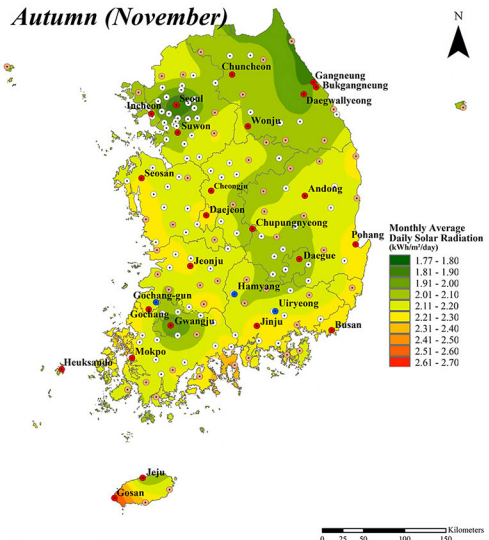
Fig. S4. The proposed MADSR maps of June (left) and August (right) in summer season in South Korea

Autumn (September)



Proposed MADSR Map
developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

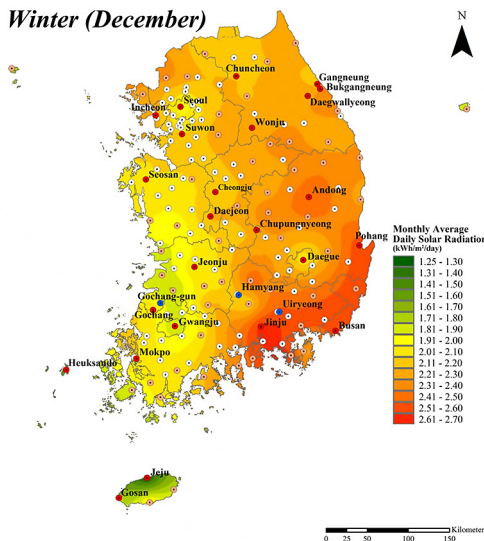
Autumn (November)



Proposed MADSR Map
developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

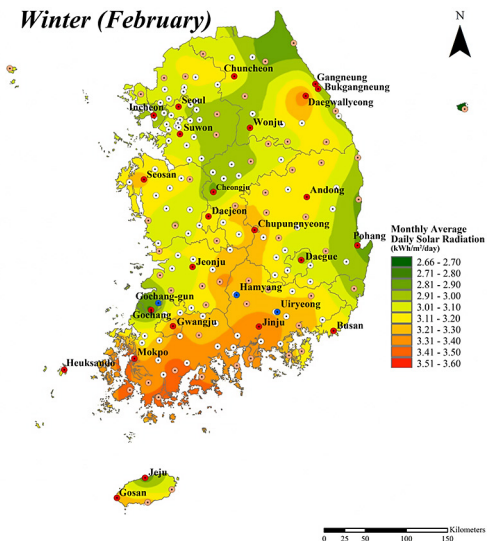
Fig. S5. The proposed MADSR maps of September (left) and November (right) in autumn season in South Korea

Winter (December)



Proposed MADSR Map
developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

Winter (February)



Proposed MADSR Map
developed with 167 MADSR data (measured: 24, A-CBR: 54, and FEM: 89)

Fig. S6. The proposed MADSR maps of December (left) and February (right) in winter season in South Korea