atmosphere

Supplementary Material

Table S1. Ozone alert days over the southern part of the Korean peninsula for August 2007.

Exceedance Date	Region	Alert Concentration (ppm)	Dismiss Concentrations (ppm)	Peak Concentrations (ppm)	Alert Time (Duration)
2007-08-17	South Busan	0.122	0.108	0.122	15:00 (1 hour)
2007-08-17	Yeosu	0.134	0.096	0.134	14:00 (2 hours)
2007-08-17	Gwangyang	0.150	0.089	0.150	16:00 (1 hour)
2007-08-18	Yeosu	0.132	0.072	0.132	13:00 (1 hour)
2007-08-24	Daegu	0.133	0.106	0.133	14:00 (1 hour)
2007-08-25	Sooncheon	0.128	0.067	0.130	13:00 (2 hours)
2007-08-25	Yeosu	0.126	0.107	0.126	13:00 (1 hour)
2007-08-25	Gwangyang	0.132	0.083	0.149	14:00 (2 hours)

Table S2. WRF configurations.

Physical options	Scheme
Boundary layer	YSU
Cumulus	Kain-Fritsch
Land-surface	Unified NOAH land-surface model
Long-wave radiation	RRTM
Short-wave radiation	Goddard shortwave radiation
Microphysics	WSM3-class simple ice

Table S3. Model performance statistics of WRF for key meteorological variables spatially averaged in the 3-km domain.

	2-m Temperature (°C)	10-m Wind Speed (m/s)	Cloud Fraction
Mean Observed	27.44	1.37	0.34
Mean Modeled	27.30	1.81	0.26
MB	–0.13	0.44	–0.07
MAE	0.59	0.62	0.13
NMB (%)	–0.48	32.21	–21.11
NME (%)	2.17	45.55	38.59
FB (%)	–0.47	36.63	–33.68
FE (%)	2.18	45.76	59.37
R	0.97	0.73	0.61
Slope	0.97	0.89	1.01
Y_0	0.58	0.59	–0.07

$$\text{Mean Bias (MB)} = \frac{\sum(M-O)}{N}$$

$$\text{Mean Absolute Error (MAE)} = \frac{\sum|M-O|}{N}$$

$$\text{Normalized Mean Bias (NMB)} = 100\% \times \frac{\sum(M-O)}{\sum O}$$

$$\text{Normalized Mean Error (NME)} = 100\% \times \frac{\sum|M-O|}{\sum O}$$

$$\text{Fractional Bias (FB)} = 100\% \times \frac{2}{N} \times \sum \frac{(M-O)}{(M+O)}$$

$$\text{Fractional Error (FE)} = 100\% \times \frac{2}{N} \times \sum \frac{|M-O|}{(M+O)}$$

R is the correlation coefficient. Slope and Y_0 are the first order coefficient and the *y*-axis intercept of the linear regression equation. M and O represent modeled and observed values. N is the number of modeled–observed value pairs.

Table S4. Model performance statistics for spatially averaged O_3 and NO_X concentrations modeled with MEGAN and BEIS3 for the 3-km domain.

	MEGAN	**BEIS3**	**MEGAN**	**BEIS3**
Species	O3		NO_X	
MB (ppb)	13.17	9.63	1.67	1.85
MGE (ppb)	13.29	10.15	9.98	9.94
NMB (%)	59.57	43.56	6.18	6.86
NME (%)	60.11	45.90	37.00	36.86
FB (%)	48.65	40.25	-3.93	-3.15
FE (%)	49.40	42.50	35.63	35.13
R^2	0.80	0.79	0.23	0.23
Slope	1.26	1.09	1.07	1.08
Y_0	7.53	7.55	-0.31	-0.22

Table S5. Model performance at five PAMS locations for isoprene during the study period.

SITE	Case	MEAN OBS (ppb)	MEAN MOD (ppb)	MB (ppb)	MAE (ppb)	NMB (%)	NME (%)	FB (%)	FE (%)
Jangjun	MEGAN	0.23	1.10	0.87	0.88	385.34	389.30	13.11	129.19
	BEIS3		0.65	0.42	0.44	186.05	193.25	74.03	98.24
	Revised MEGAN		0.42	0.19	0.24	84.81	105.54	42.47	78.03
Jeongkwan	MEGAN	0.60	1.26	0.65	0.87	108.13	144.41	16.90	110.43
	BEIS3		0.73	0.13	0.45	20.77	74.92	–27.20	91.14
	Revised MEGAN		0.43	–0.17	0.32	–28.16	52.66	–60.52	86.59
Taejong	MEGAN	0.46	0.66	0.21	0.65	45.29	142.65	–4.62	115.00
	BEIS3		0.31	–0.15	0.32	–32.19	70.59	–24.94	76.48
	Revised MEGAN		0.66	0.20	0.65	44.83	142.19	–5.29	114.32
Daeyeon	MEGAN	0.14	1.10	0.96	0.96	678.89	678.89	146.41	146.41
	BEIS3		0.23	0.09	0.16	62.45	109.97	14.68	74.11
	Revised MEGAN		0.43	0.28	0.29	200.98	207.46	87.43	96.76
Danggam	MEGAN	0.15	1.07	0.92	0.92	625.35	625.35	147.22	147.22
	BEIS3		0.48	0.34	0.34	227.83	229.06	98.49	100.72
	Revised MEGAN		0.42	0.27	0.27	181.28	183.69	89.66	95.33

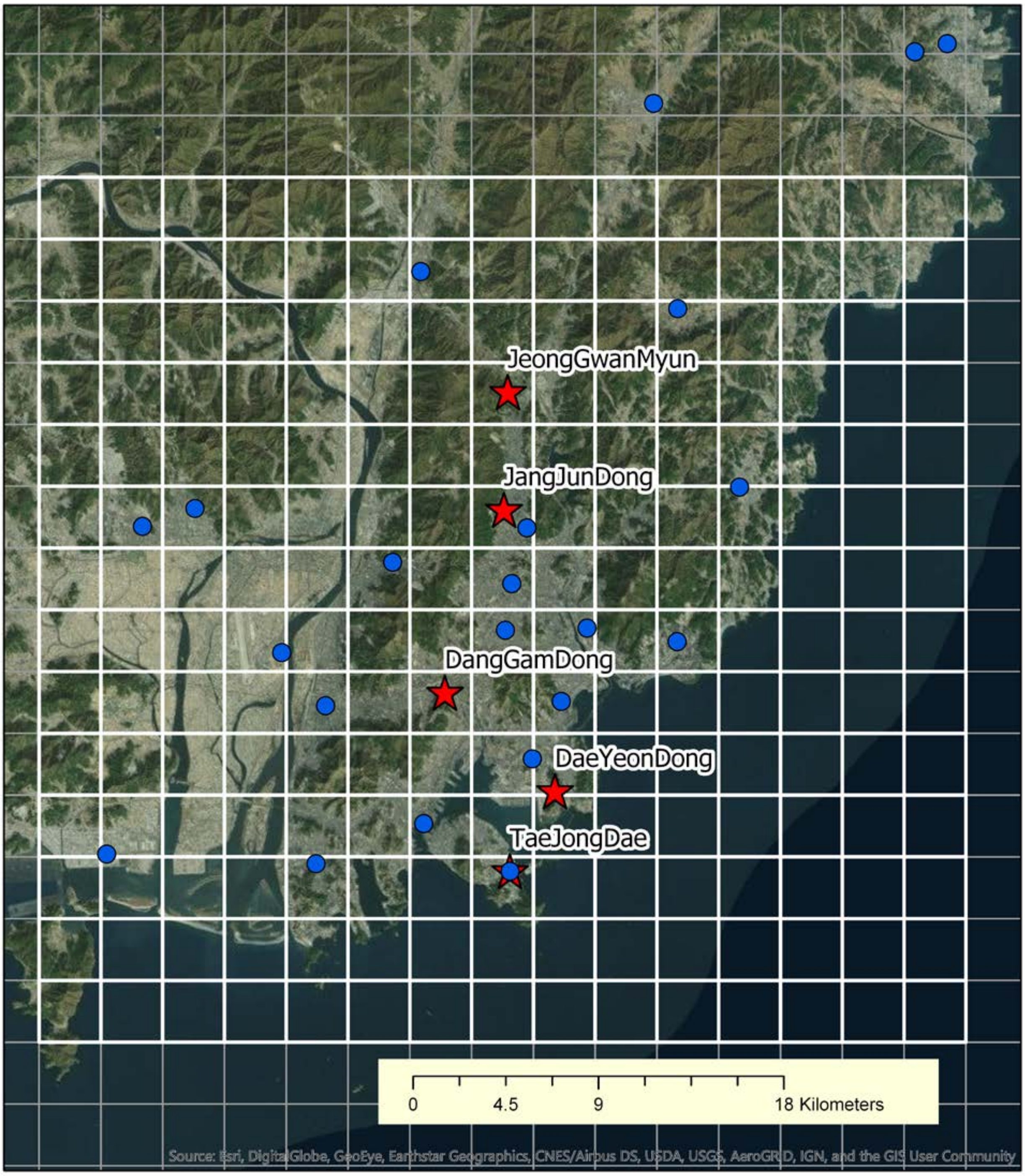


Figure S1. AMS (blue circles) and PAMS (red stars) monitors in the 3-km modeling domain of the area near Busan on an aerial image to highlight forest areas (dark green).

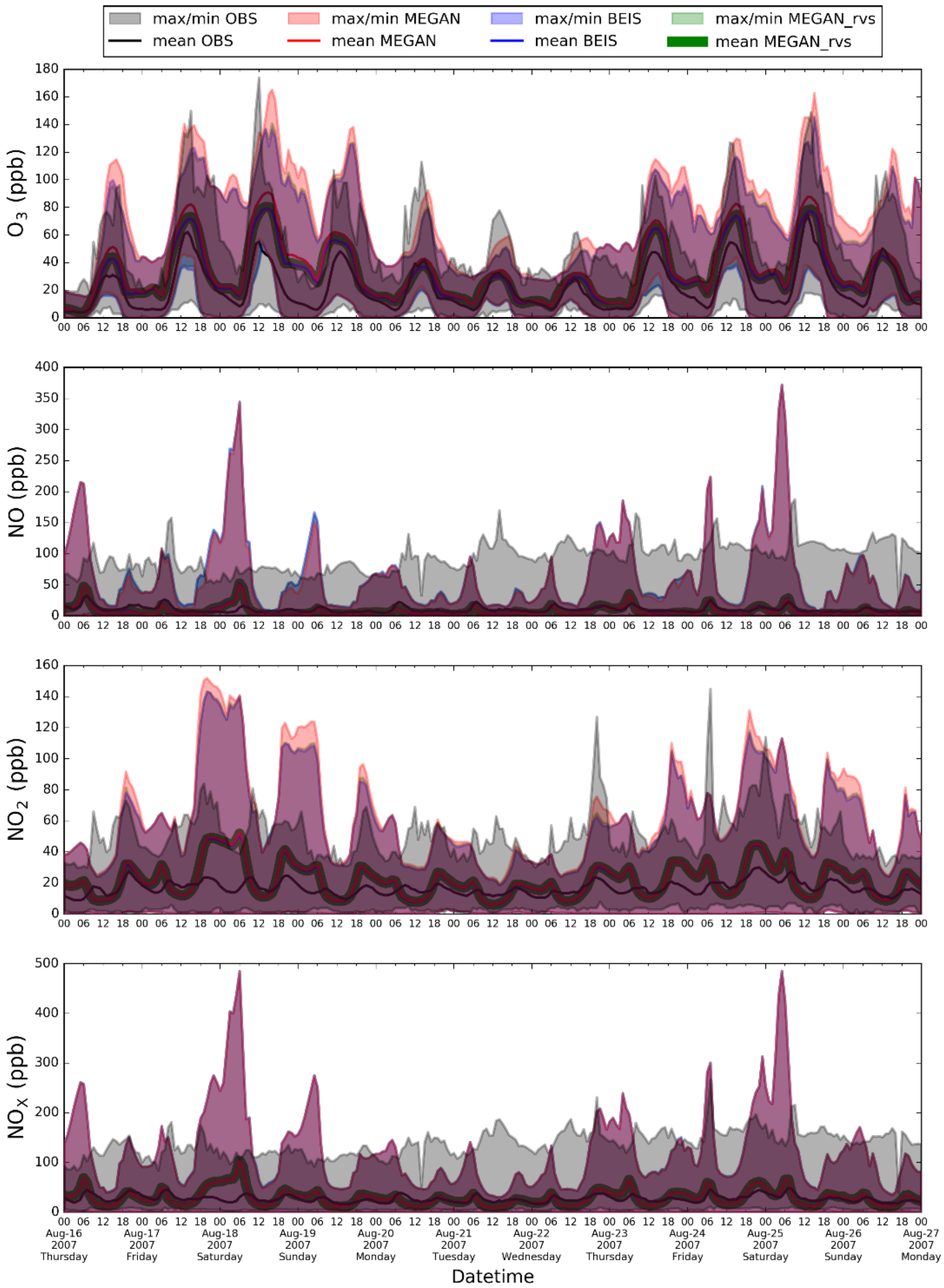


Figure S2. Modeled (including MEGAN with adjusted light correction factors) and observed O3, NO, NO_2, and NO_X concentrations. Area plots show the range of modeled and observed concentrations. Lines represent the spatial average concentrations across all monitors in the 3-km modeling domain.

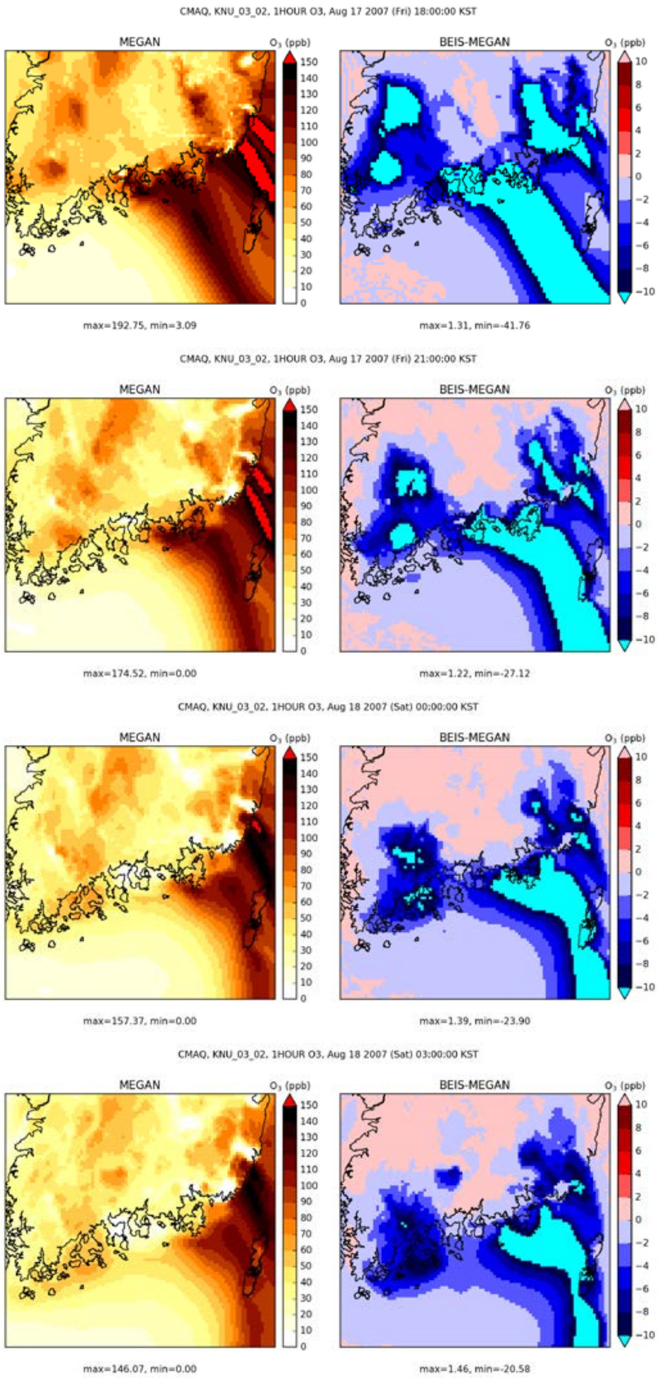


Figure S3. Spatial distribution of one-hour ozone concentrations: 6:00 p.m., 17 August 2007; 9:00 p.m., 17 August 2007; 12:00 a.m., 18 August 2007; 3 a.m., 18 August 2007 (from the top).

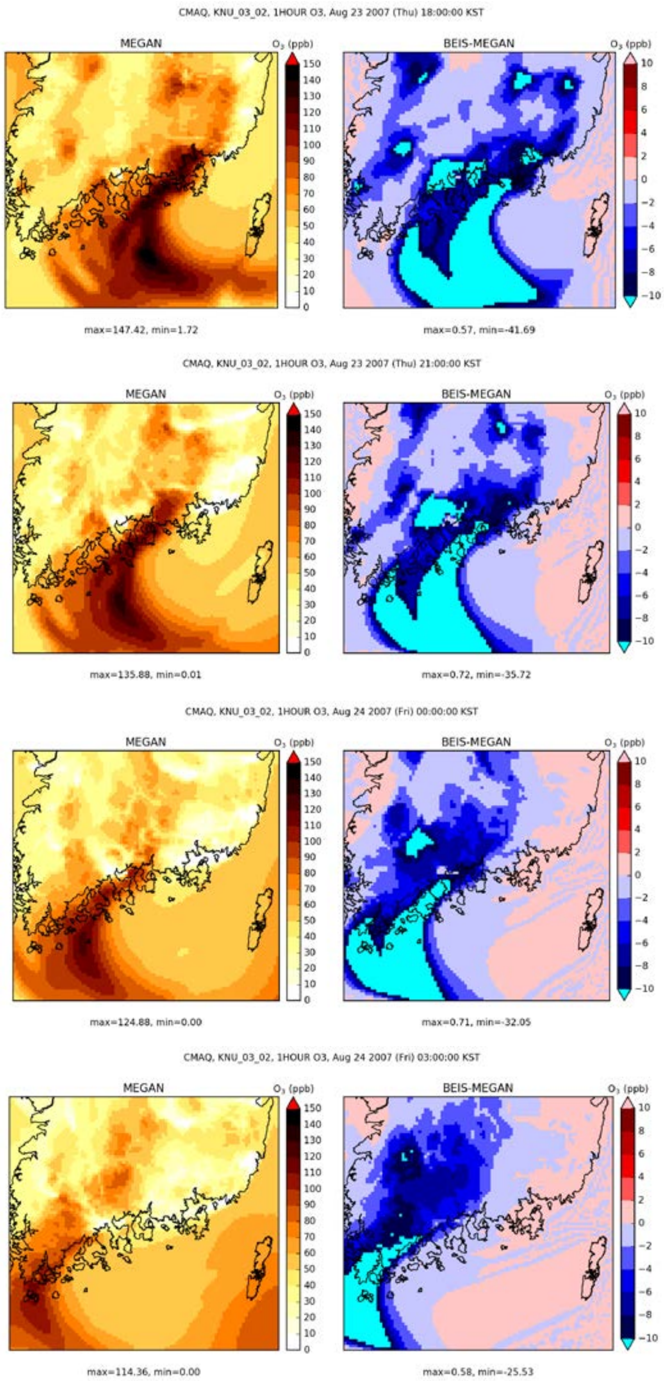
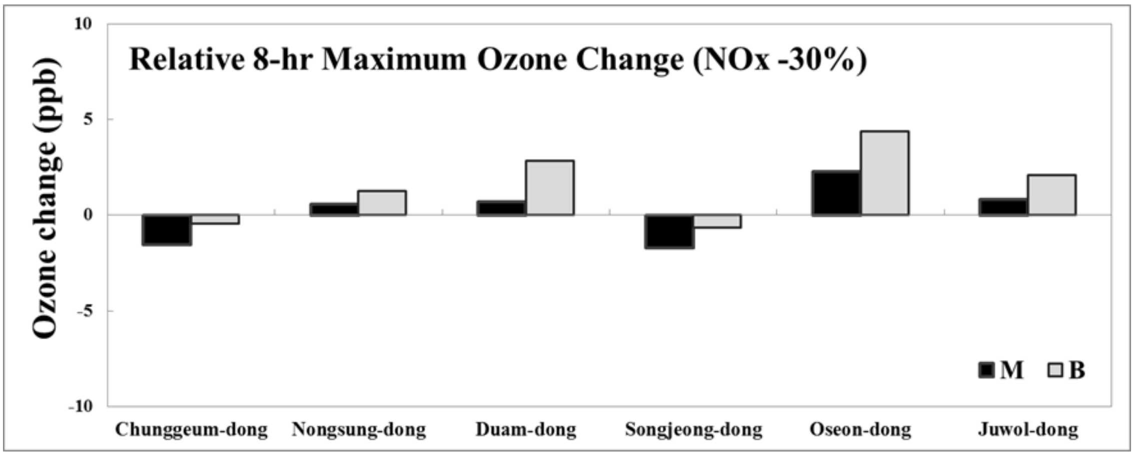
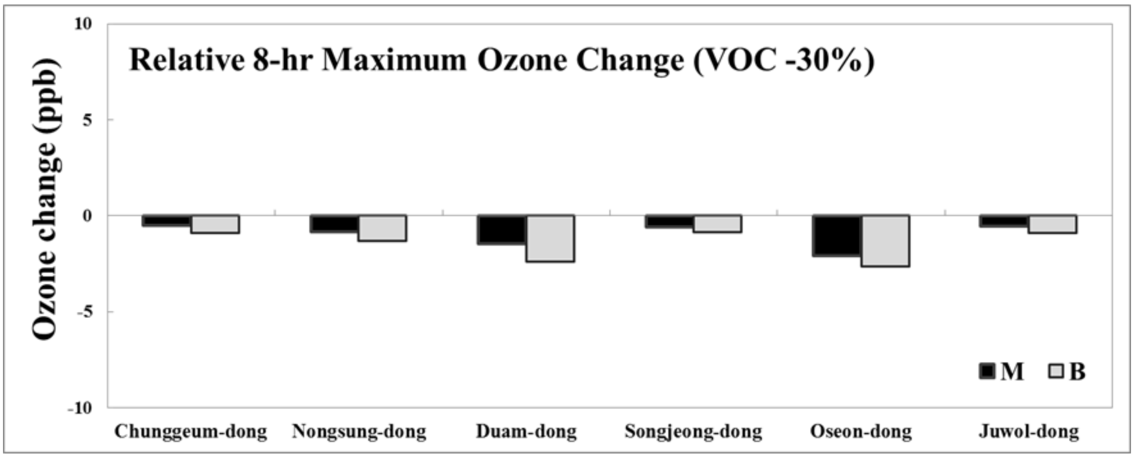


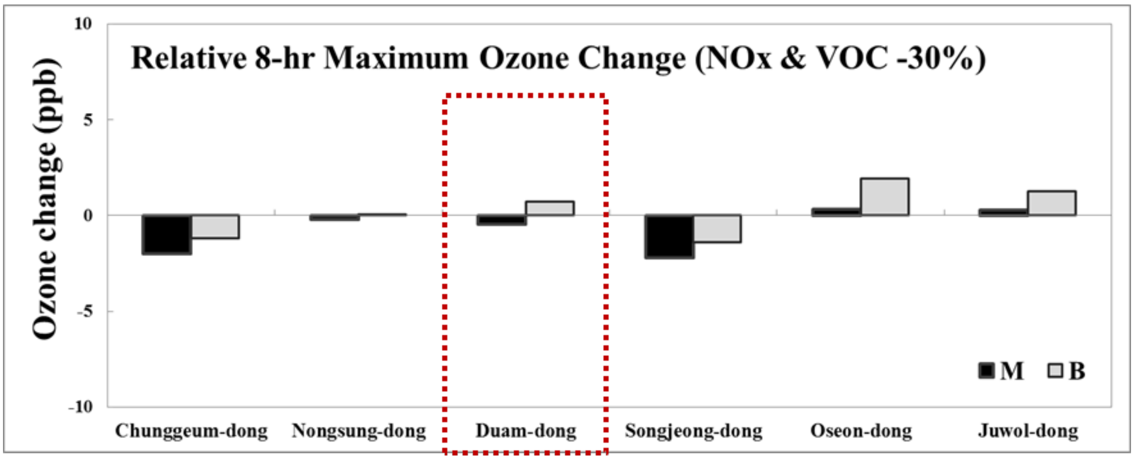
Figure S4. Spatial distribution of one-hour ozone concentrations: 6:00 p.m., 23 August 2007; 9:00 p.m., 23 August 2007; 12:00 a.m., 24 August 2007; 3:00 a.m., 24 August 2007 (from the top).



(**a**)

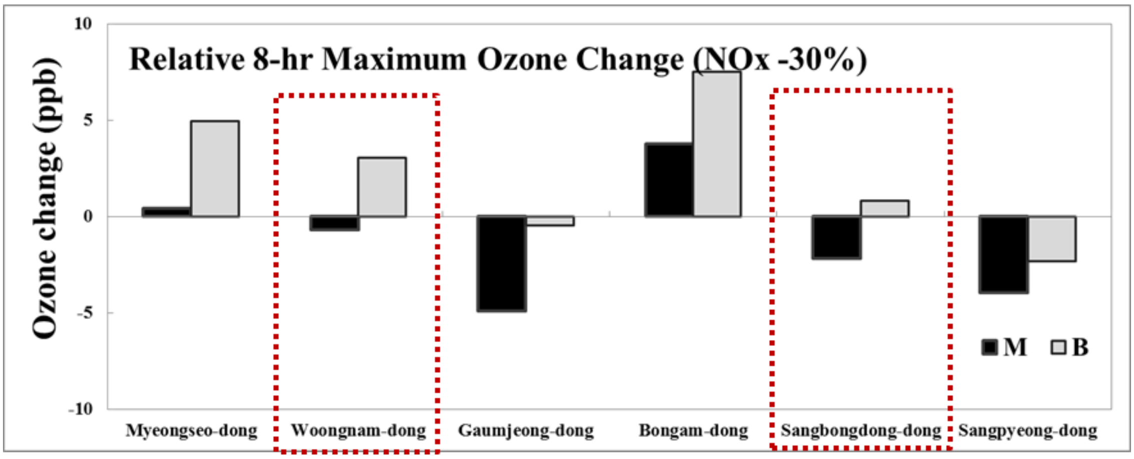


(**b**)

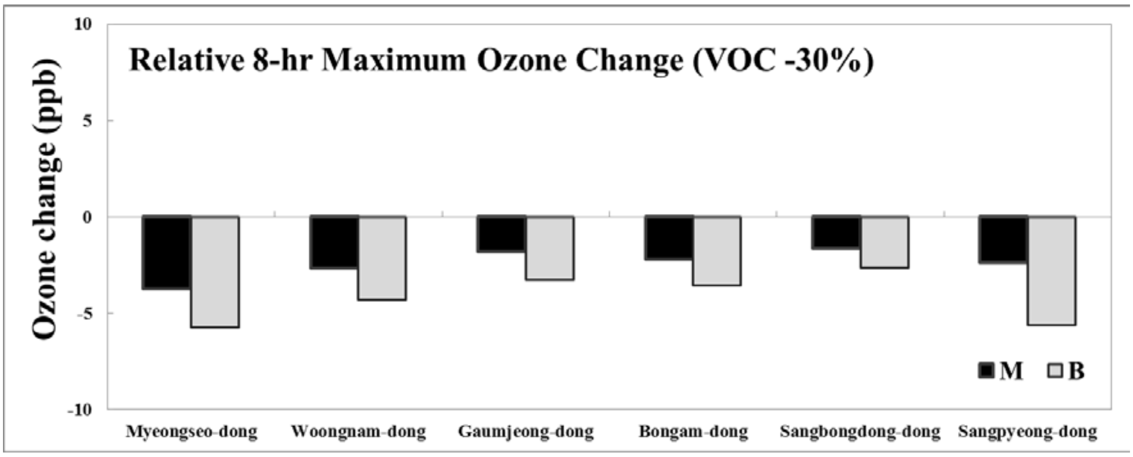


(**c**)

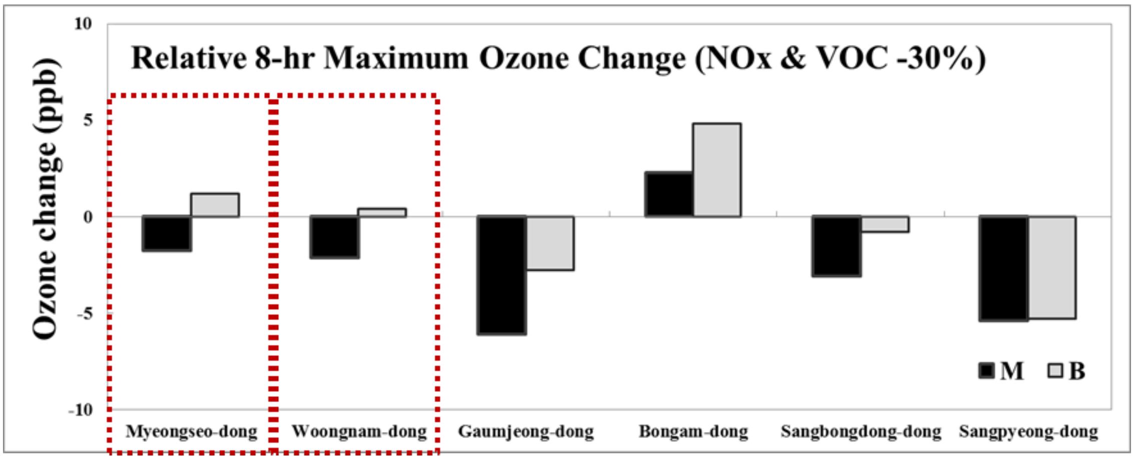
Figure S5. Relative changes of MDA8O3 in Gwangju because of anthropogenic emissions reduction with MEGAN (black) and BEIS (gray) estimated biogenic emissions: (**a**) 30% NO_x reduction, (**b**) 30% VOCs reduction, and (**c**) both 30% NO_x and 30% VOCs reduction. Dotted red boxes indicate cases in which MEGAN and BEIS show an opposite trend of MDA8O3 changes with regard to precursor controls.



(**a**)

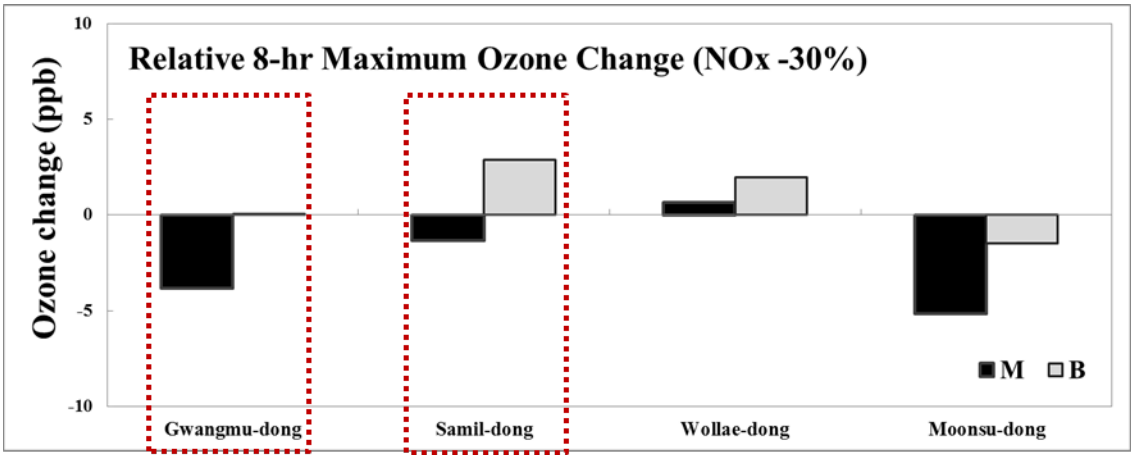


(**b**)

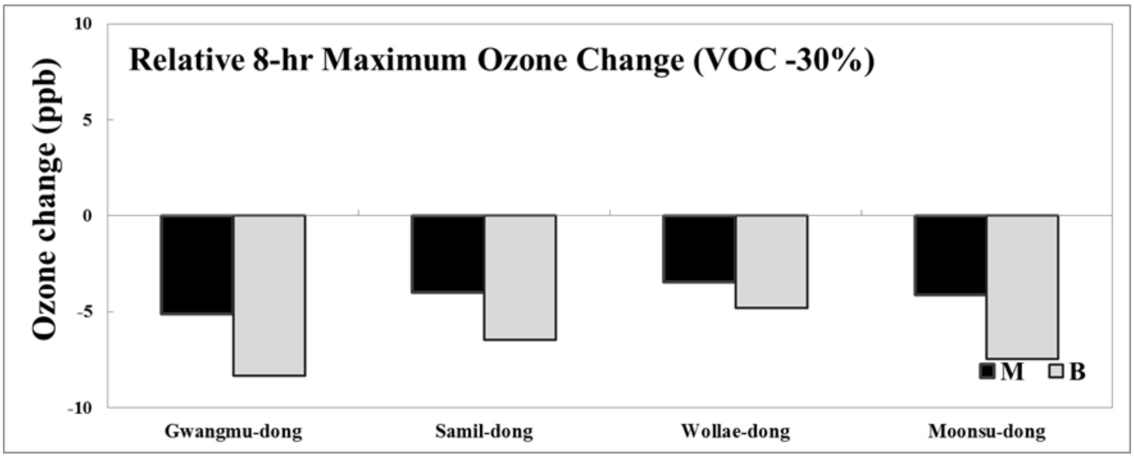


(**c**)

Figure S6. Relative changes of MDA8O3 in Jinju because of anthropogenic emissions reduction with MEGAN (black) and BEIS (gray) estimated biogenic emissions: (**a**) 30% NO_X reduction, (**b**) 30% VOCs reduction, and (**c**) both 30% NO_X and 30% VOCs reduction. Dotted red boxes indicate cases in which MEGAN and BEIS show an opposite trend of MDA8O3 changes with regard to precursor controls.



(**a**)



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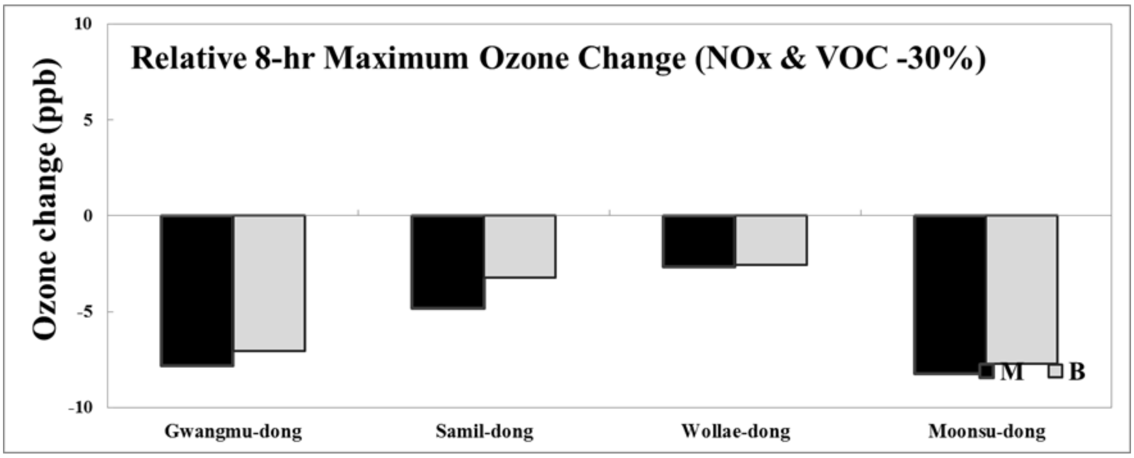
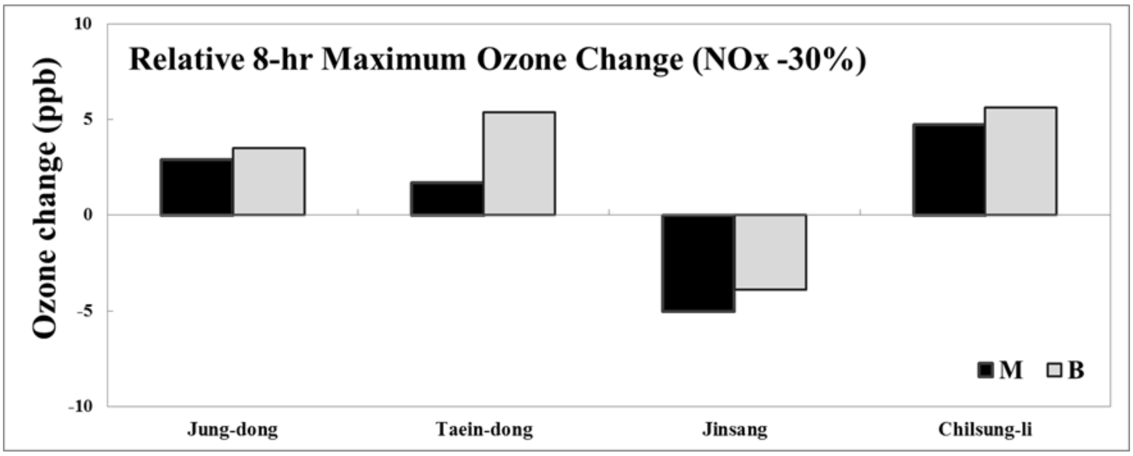


(**c**)

Figure S7. Relative changes of MDA8O3 in Yeosu because of anthropogenic emissions reduction with MEGAN (black) and BEIS (gray) estimated biogenic emissions: (**a**) 30% NOx reduction, (**b**) 30% VOCs reduction, and (**c**) both 30% NOx and 30% VOCs reduction. Dotted red boxes indicate cases in which MEGAN and BEIS show an opposite trend of MDA8O3 changes with regard to precursor controls.



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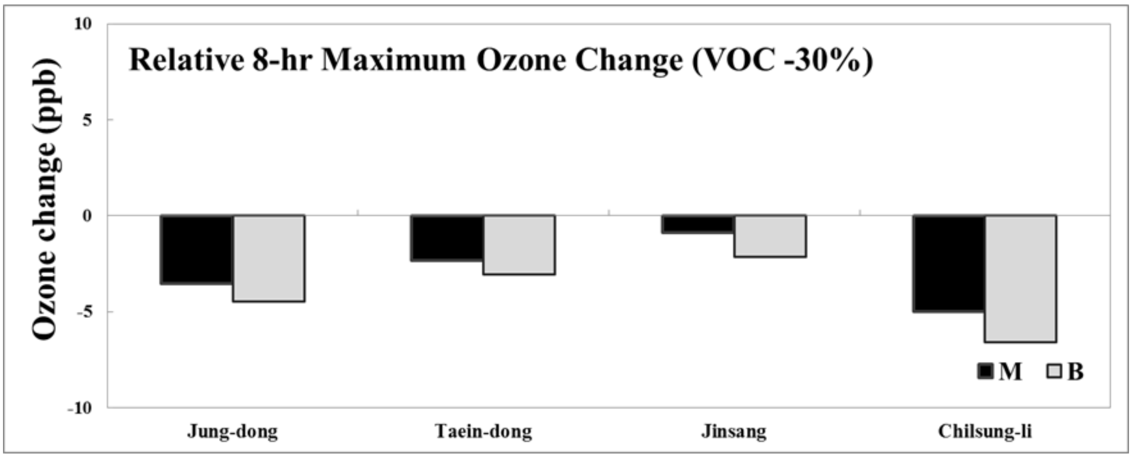
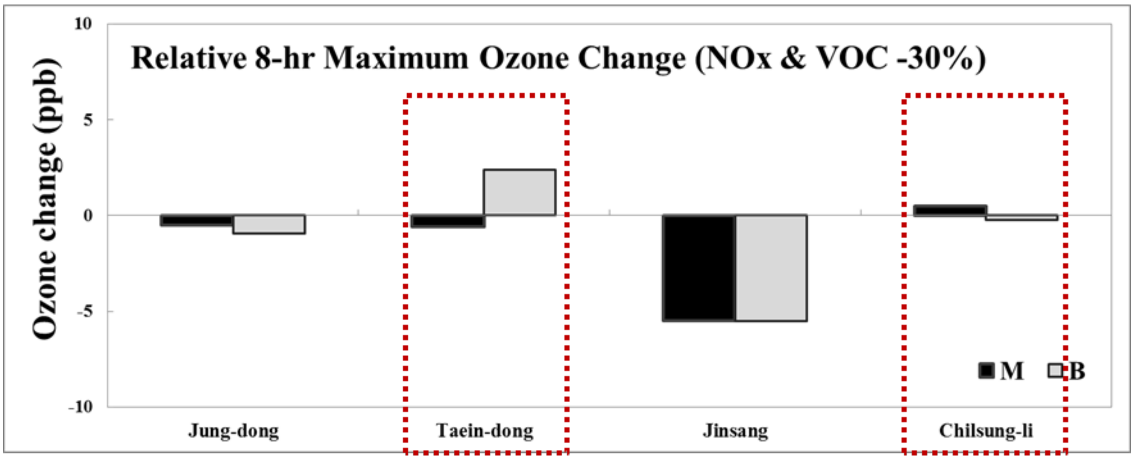


(**b**)



(**c**)

Figure S8. Relative changes of MDA8O3 in Gwangyang because of anthropogenic emissions reduction with MEGAN (black) and BEIS (gray) estimated biogenic emissions: (**a**) 30% NOx reduction, (**b**) 30% VOCs reduction, and (**c**) both 30% NOx and 30% VOCs reduction. Dotted red boxes indicate cases in which MEGAN and BEIS show an opposite trend of MDA8O3 changes with regard to precursor controls.

Appendix S1. Causes and Effects of Discrepancies between MEGAN and BEIS

For MEGAN v2.04, the possibility of isoprene overestimation due to the light correction factor has been reported in previous studies [1,2]. The light correction factor differences between MEGAN and BEIS seem to be due to the way the two models treat light with respect to the scope of the factor. MEGAN utilizes a canopy-/branch-scale factor, while BEIS uses a leaf-scale factor [2]. In addition, for temperature and light adjustments, BEIS uses values at the top of the canopy while MEGAN utilizes values within the canopy [2]. Another potential source of differences is that MEGAN incorporates the effects of leaf age and monthly changes to the leaf area index, whereas BEIS does not.

The focus of this study is how different biogenic VOC loadings from two models affect ozone response to anthropogenic precursor changes in South Korea. Thus, among the potential causes of differences mentioned above, we observed that MEGAN estimated approximately 2.4 times the light correction factors compared with BEIS3 (Figure S9). Thus, we derived the adjustment ratio of light correction factors between the two models, 0.4 = (1/2.4). To further examine the potential effects of light correction factor differences, we tentatively adopted the factor of 0.4 as an "operational" parameter to revise isoprene emissions from MEGAN and performed CMAQ simulations (hereinafter, the adjusted MEGAN is labeled as "MEGAN_rvs"). We noticed that the adjusted MEGAN results similar to BEIS results for O_3 (Figure S2) and isoprene (Table S5). Without any adjustment, we estimated 110 tons/hour and 95 tons/hour of isoprene across the land part of South Korea in the modeling domain as the normalized emission rates with MEGAN and BEIS3.

The maximum MDA1O3 during the study period with MEGAN, BEIS, and the adjusted MEGAN were 165 ppb, 145 ppb, and 146 ppb, respectively. However, we also noticed that NO, NO_2, and NO_x results were changed little (Figure S2). The maximum hourly NO_x concentrations with MEGAN, BEIS, and the adjusted MEGAN were 485.4 ppb, 485.3 ppb, and 485.6 ppb, respectively. The period average hourly NO_x concentrations with MEGAN, BEIS, and the adjusted MEGAN were 28.6 ppb, 28.8 ppb, and 30.0 ppb, respectively. The period average hourly isoprene bias at the Jeongkwan PAMS location with MEGAN, BEIS, and the adjusted MEGAN were 0.65 ppb, 0.13 ppb, and –0.17 ppb, respectively. As shown here, simple light correction factor adjustment may make MEGAN and BEIS produce similar amounts of isoprene emissions and apparent ozone and NO_x concentrations. However, further studies should be conducted before such adjustment is acceptable for policy-making processes, as the bias correction approach in this study needs a more mechanistic explanation.

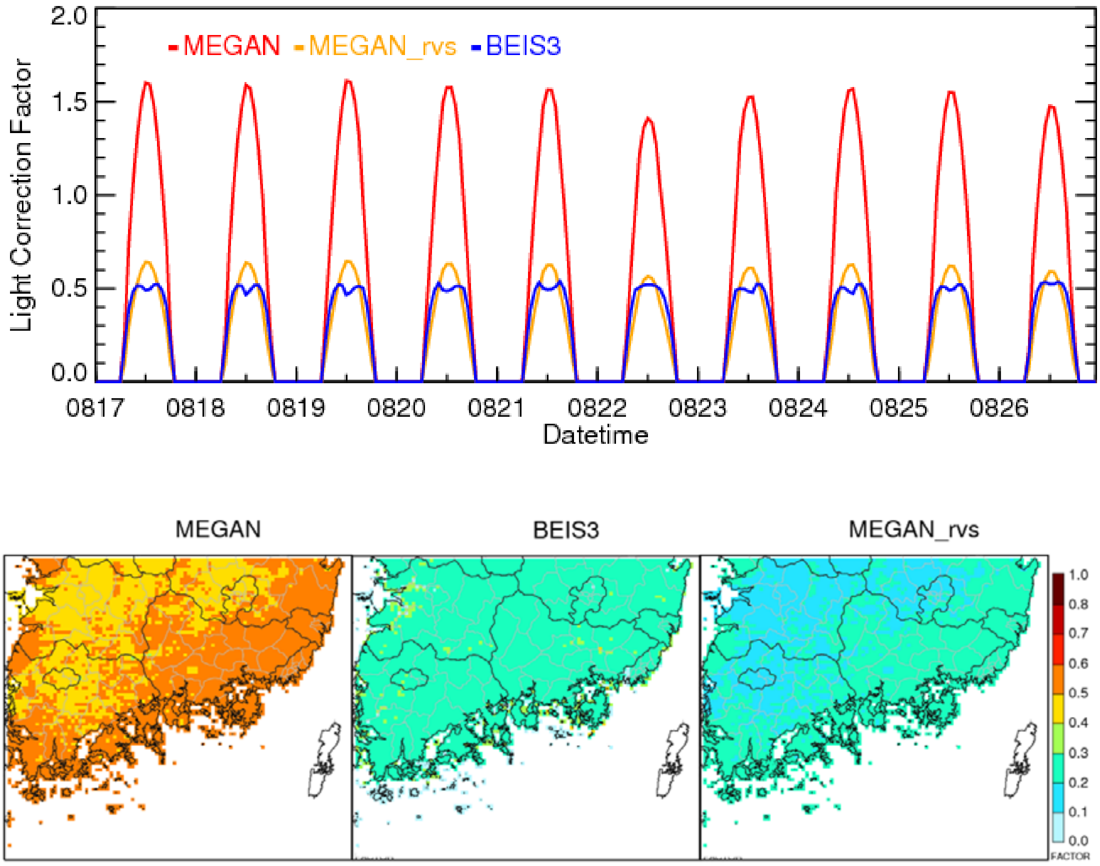


Figure S9. Light correction factors from MEGAN and BEIS. The top panel depicts the hourly modeled (red lines for MEGAN and blue lines for BEIS3) light correction factor. Yellow lines are for the revised light correction factor based on the rough estimation of the light correction factor ratio between the two models. The bottom panel shows the spatial distribution of period mean light correction factor estimated with MEGAN (bottom left), BEIS (bottom middle), and the adjusted MEGAN (bottom right).

References

1. Carlton, A.G.; Baker, K.R. Photochemical Modeling of the Ozark Isoprene Volcano: MEGAN, BEIS, and Their Impacts on Air Quality Predictions. *Environ. Sci. Technol.* **2011**, *45*, 4438–4445, doi:10.1021/es200050x.
2. Pouliot, G.; Pierce, T. Integration of the Model of Emissions of Gases and Aerosols from Nature (MEGAN) into the CMAQ Modeling System. In Proceeding of 18th Annual International Emission Inventory Conference, Baltimore, MD, USA, April 2009.