Supplementary Material of

Comparative Numerical study of $PM_{2.5}$ in Exit-and-Entrance Areas Associated with Transboundary Transport over China, Japan, and Korea

Cheol-Hee Kim [1,*], Fan Meng [2,*], Mizuo Kajino [3], Jaehyun Lim [4,*], Wei Tang [2], Jong-Jae Lee [6], Yusuke Kiriyama [7], Jung-Hun Woo [8], Keiichi Sato [7], Toshihiro Kitada [9], Hiroaki Minoura[7], Jiyoung Kim [4], Kyoung Bin Lee [5], Soona Roh [4], Hyun-Young Jo [10] and Yu-Jin Jo [1]

[1] Department of Atmospheric Sciences, Pusan National University, Busan 46241, South Korea
[2] Chinese Research Academy of Environmental Sciences (CRAES), Beijing 100012, China
[3] Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA), Tsukuba 305-0052, Japan
[4] Climate & Air Quality Research Department, National Institute of Environmental Research (NIER), Incheon 404-170, South Korea
[5] Emission Inventory Management Team, National Air Emission Inventory and Research Center, Osong 28166, South Korea
[6] Ulsan National Institute of Science and Technology, School of Urban and Environmental Engineering, Ulsan 44919, South Korea
[7] Asia Center for Air Pollution Research (ACAP), Niigata 950-2144, Japan
[8] Department of Civil and Environmental Engineering, Konkuk University, Seoul 05029, South Korea
[9] Department of Applied Chemistry and Life Science, Toyohashi University of Technology, Toyohashi 441-8580, Japan
[10] Institute of Environmental Studies, Pusan National University, Busan 46241, South Korea

*Correspondence: chkim2@pusan.ac.kr (C.-H.K.); mengfan@craes.org.cn (F.M.); dr4earth@korea.kr (J.L.)

Table S1. Characteristics of seven monitoring sites located in China, Japan, and Korea.

Country	Sites	Latitude (N)	Longitude (E)
China	Dalian	38°51'50.8"	121°37'31.6"
	Xiamen	24°28'36.1"	118°09'05.0"
Japan	Oki	36°16'44.1"	133°11'51.8"
	Rishiri	45°07'14.4"	141°11'53.4"
Korea	Ganghwa	37°45'52.1"	126°27'47.2"
	Gosan	33°17'33.0"	126°09'43.8"
	Taean	36°44'11.1"	126°07'55.8"

Table S2. Total anthropogenic emissions (Tg/yr) from CREATE-2013 for China, Japan, and Korea over the model domain.

		SO_2	NO_x	NH_3	VOCs	$PM_{2.5}$	CO
LTP emission	CHN	29.9	24.7	14.0	21.6	13.5	166.4
	JPN	0.6	1.2	0.3	0.5	0.1	3.8
	KOR	0.3	0.9	0.2	0.6	0.2	5.4
Emission used in WRF-CAMx*	CHN	28.5	27.3	10.4	22.5	11.6	169.9
	JPN	0.7	2.2	0.5	1.3	0.1	5.0
	KOR	0.4	1.0	0.2	0.8	0.06	0.7

* WRF-CAMx (employed by China) used MEIC (main China) and REAS (outside of China)

Table S3. Statistical summary for SO_2 at seven monitoring sites in three countries.

Sites	Model	RMSE	NMB	NME	FB	FE
Dalian (Fujiazhuang)	CAMx	18.22	-0.09	1.11	-0.08	0.01
	RAQM2	24.18	0.93	1.54	0.06	0.08
	CMAQ	11.69	0.22	0.80	0.05	0.09
Xiamen (Hongwen)	CAMx	12.27	1.98	1.98	0.08	0.00
	RAQM2	1.64	0.09	0.23	0.02	0.01
	CMAQ	1.79	0.02	0.25	0.00	0.08
Oki	CAMx	0.37	0.03	0.56	0.00	-0.02
	RAQM2	1.54	2.13	2.39	0.02	0.09
	CMAQ	0.24	-0.22	0.27	0.08	0.04
Rishiri	CAMx	0.09	-0.20	0.37	-0.01	-0.06
	RAQM2	0.25	0.57	1.12	0.06	0.07
	CMAQ	0.13	-0.55	0.55	0.03	0.03
Ganghwa	CAMx	0.91	0.45	0.58	0.03	-0.01
	RAQM2	1.47	0.34	0.69	0.02	0.04
	CMAQ	0.59	-0.16	0.27	0.02	0.04
Gosan	CAMx	0.91	1.38	1.38	0.06	0.05
	RAQM2	1.47	2.15	2.39	0.05	0.09
	CMAQ	0.59	0.86	0.86	0.08	0.06
Taean	CAMx	0.77	-0.02	0.31	-0.00	-0.02
	RAQM2	1.71	0.49	0.75	0.02	0.05
	CMAQ	0.57	-0.21	0.26	0.03	0.02

Table S4. Statistical summary for NO_2 at seven monitoring sites in three countries.

Sites	Model	RMSE	NMB	NME	FB	FE
Dalian (Fujiazhuang)	CAMx	13.70	0.63	1.05	0.04	0.02
	RAQM2	12.62	0.80	1.03	0.03	0.06
	CMAQ	7.53	0.39	0.46	0.04	0.06
Xiamen (Hongwen)	CAMx	8.75	0.03	0.42	0.00	0.03
	RAQM2	11.71	-0.61	0.61	-0.07	0.07
	CMAQ	12.61	-0.67	0.67	-0.08	0.08
Oki	CAMx	1.87	1.10	1.25	0.05	0.06
	RAQM2	0.61	-0.28	0.44	-0.02	0.04
	CMAQ	0.67	-0.55	0.55	-0.06	0.06
Rishiri	CAMx	0.47	0.22	0.61	0.01	0.04
	RAQM2	0.41	-0.63	0.62	-0.07	0.07
	CMAQ	0.41	-0.67	0.67	-0.08	0.08
Ganghwa	CAMx	12.02	2.04	2.04	0.08	0.08
	RAQM2	7.89	0.66	0.87	0.04	0.05
	CMAQ	2.72	0.36	0.38	0.02	0.02
Gosan	CAMx	1.87	-0.27	0.47	-0.02	0.04
	RAQM2	1.48	-0.35	0.36	-0.03	0.03
	CMAQ	2.15	-0.55	0.55	-0.06	0.06
Taean	CAMx	2.74	0.04	0.37	0.00	0.03
	RAQM2	3.56	-0.35	0.63	-0.07	0.04
	CMAQ	4.11	-0.62	0.48	-0.03	0.07

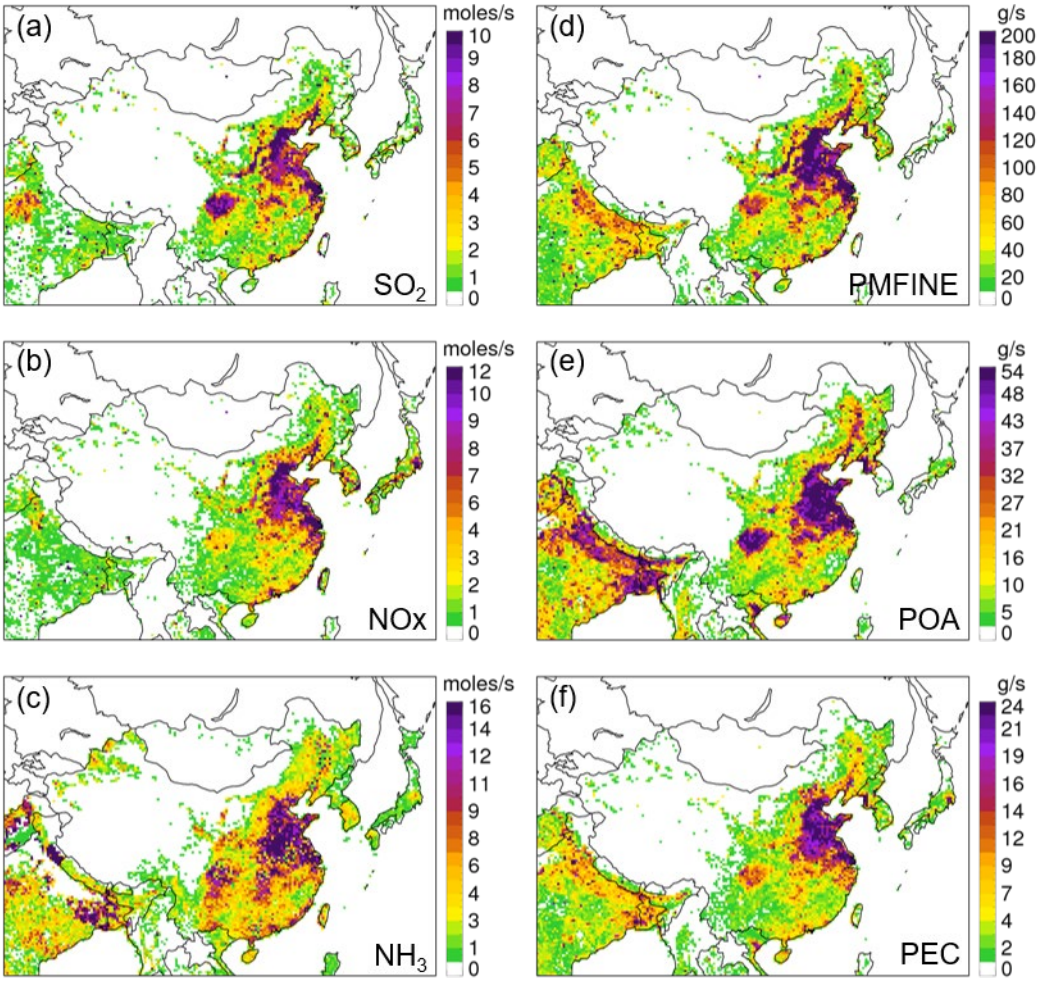

Figure S1. Spatial distributions of CREATE-2013 emissions of selected species in the base year of 2013 (ton/yr/grid).

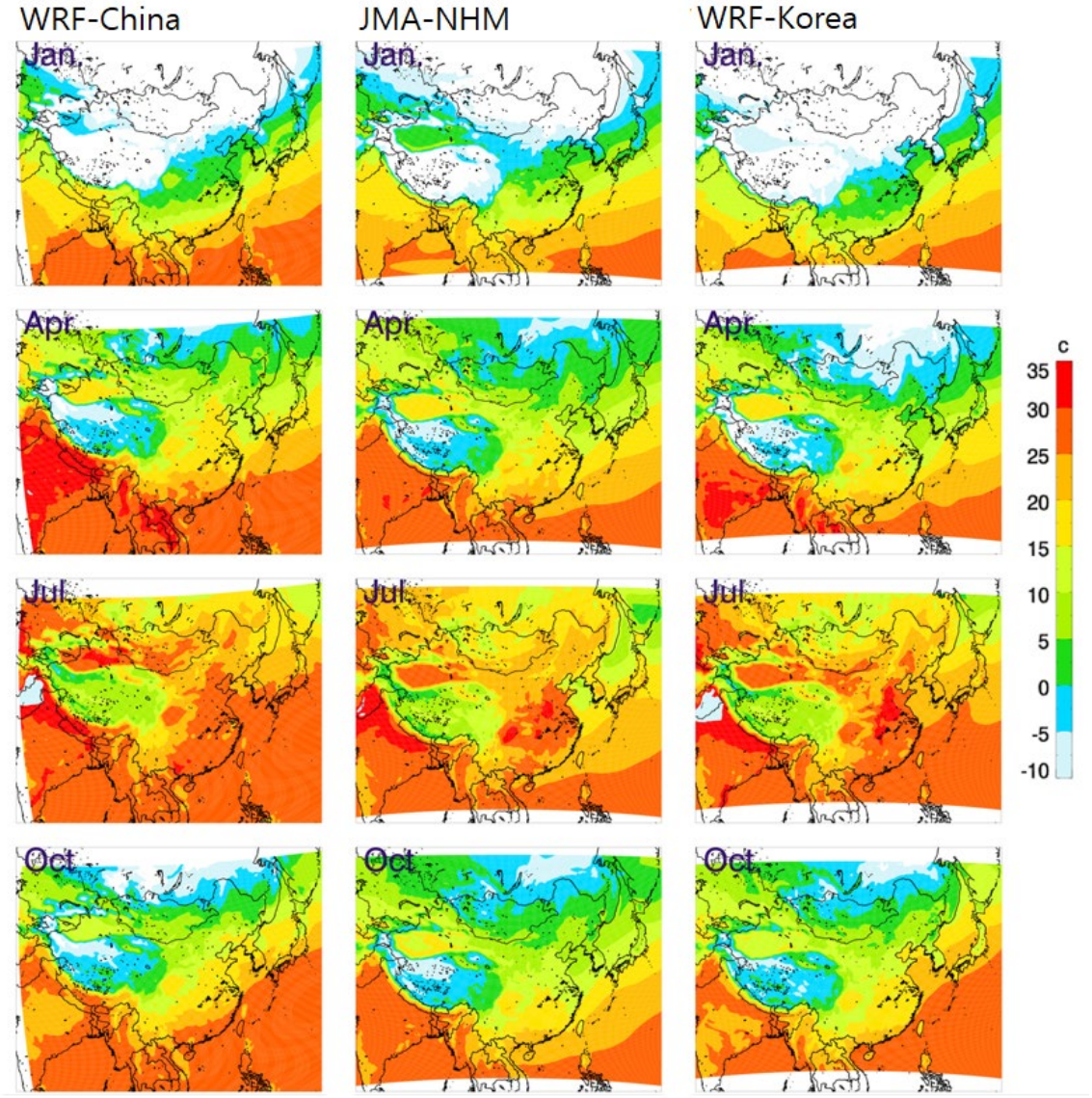

Figure S2. Spatial distributions of monthly average temperature (℃) for January, April, July, and October 2013. The three air quality models are WRF-CAMx, NHM-RAQM2, and WRF-CMAQ, employed by China, Japan, and Korea, respectively.

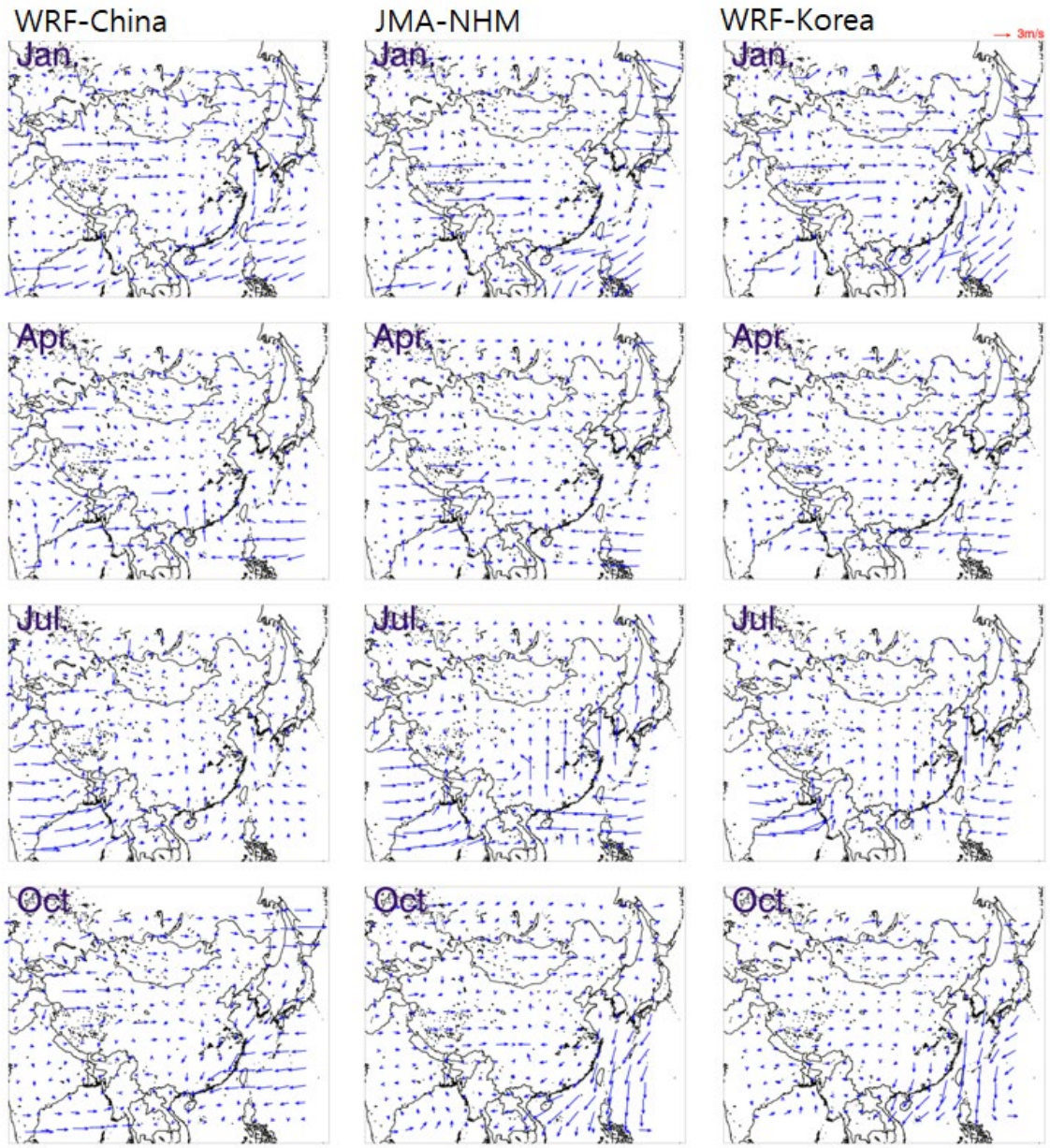

Figure S3. As in Fig. S2, but for wind field (m/s).

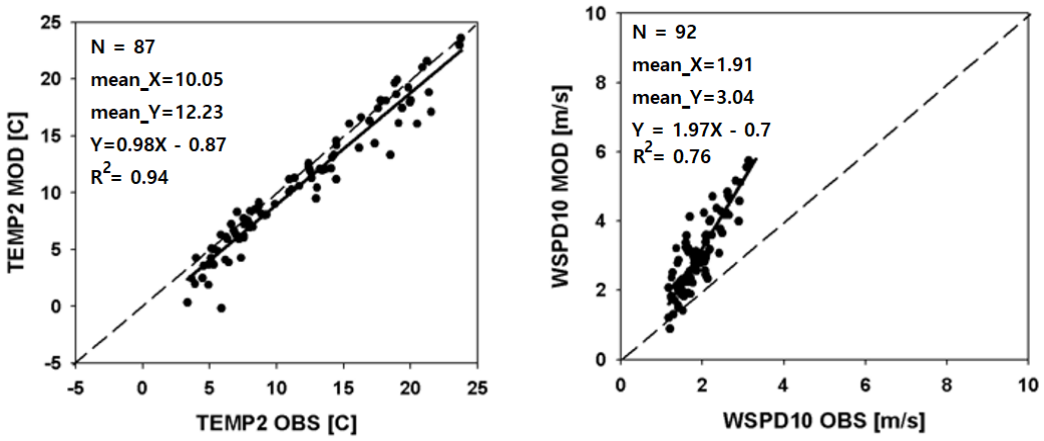

Figure S4. Scatter diagrams of modeled and observed temperatures at 2 m and wind speed at 10 m for the base year of 2013.

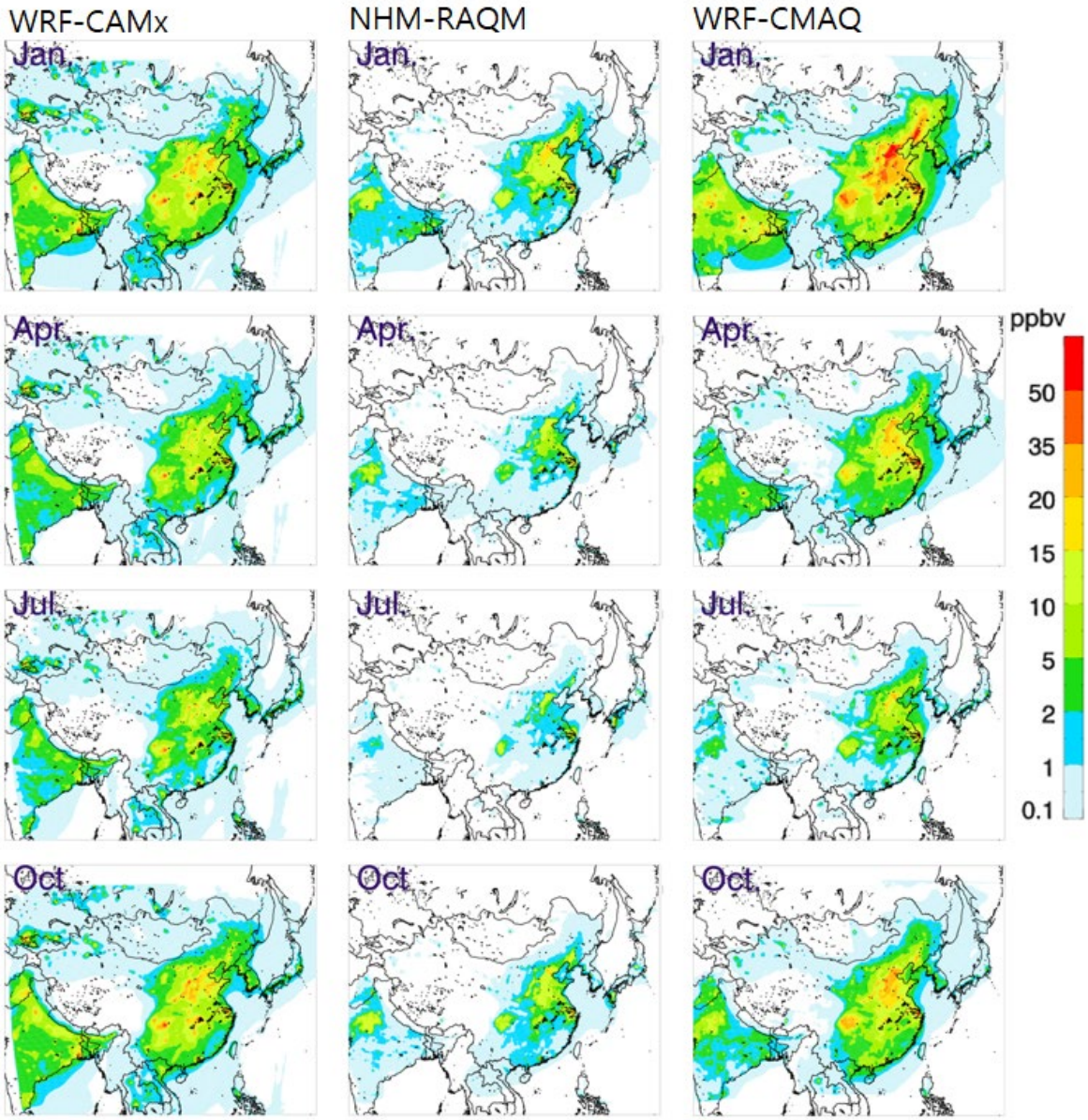

Figure S5. Spatial distributions of monthly average SO_2 concentration (ppb) in January, April, July, and October 2013. Three air quality models—WRF-CAMx, NHM-RAQM2, and WRF-CMAQ, were employed by China, Japan, and Korea, respectively.

.

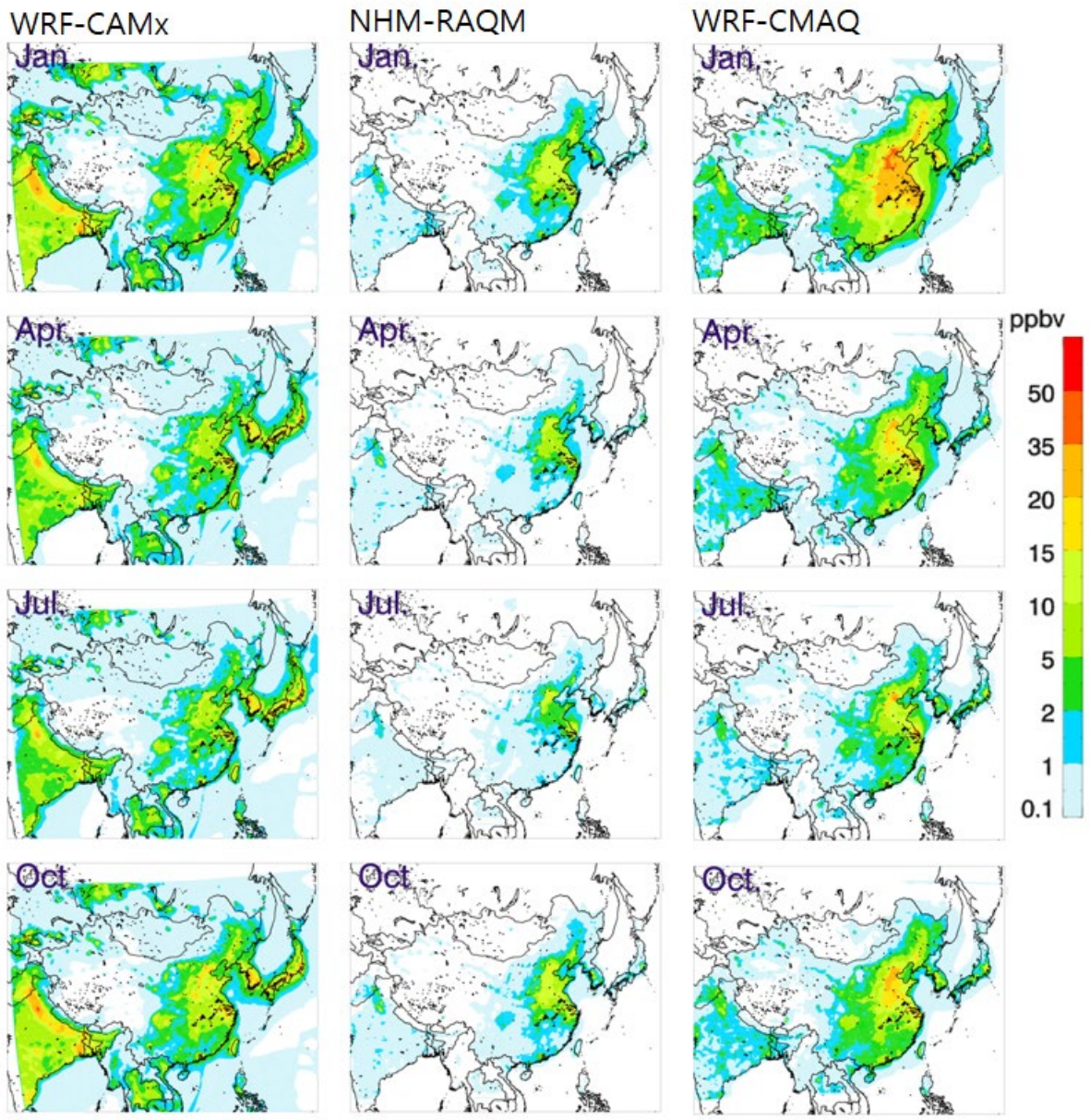

Figure S6. As in Fig. S5, but for NO_2 concentration (ppb).

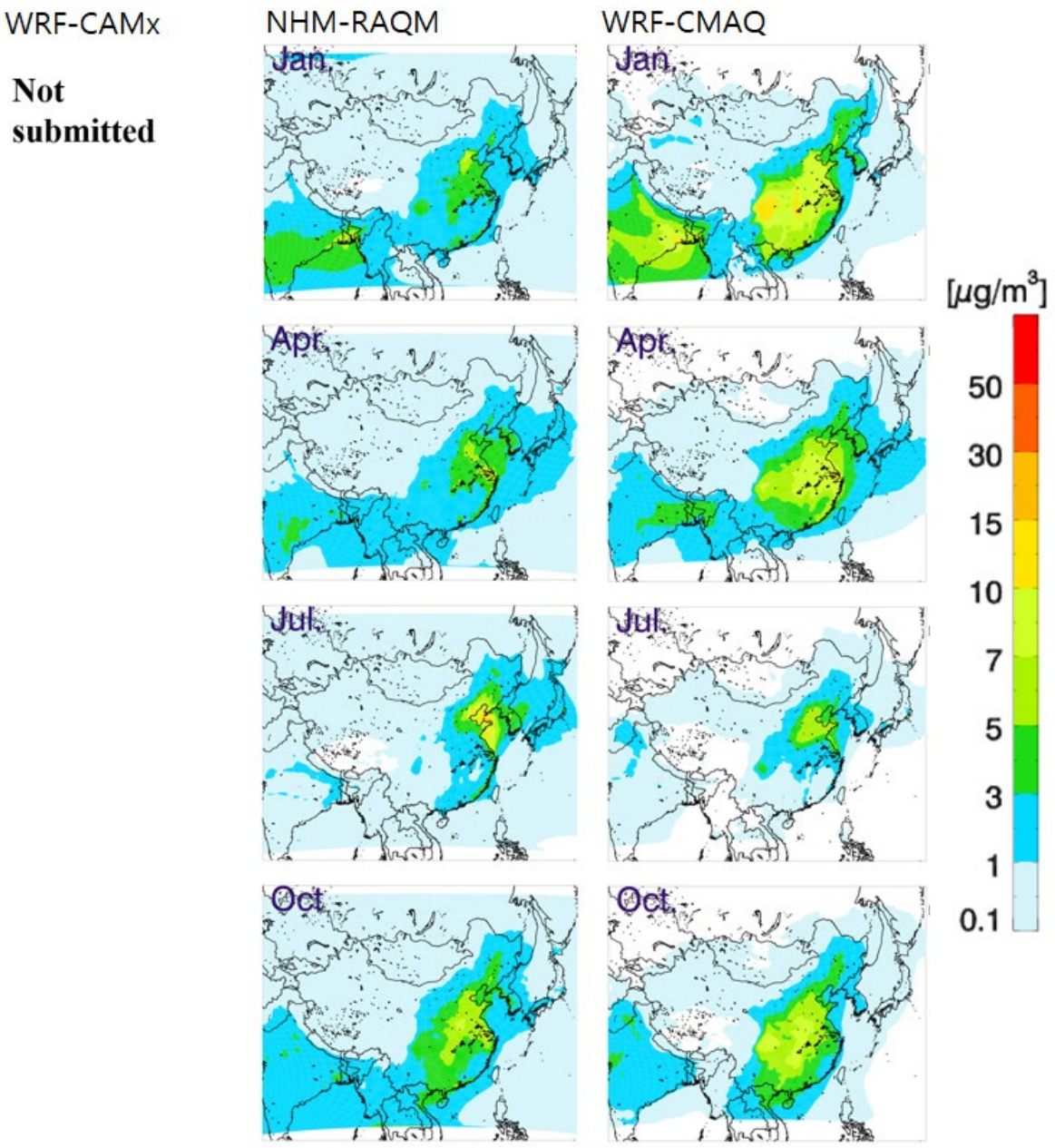

Figure S7. As in Fig. S5, but for NH_4^+ concentration (μg/m^3).

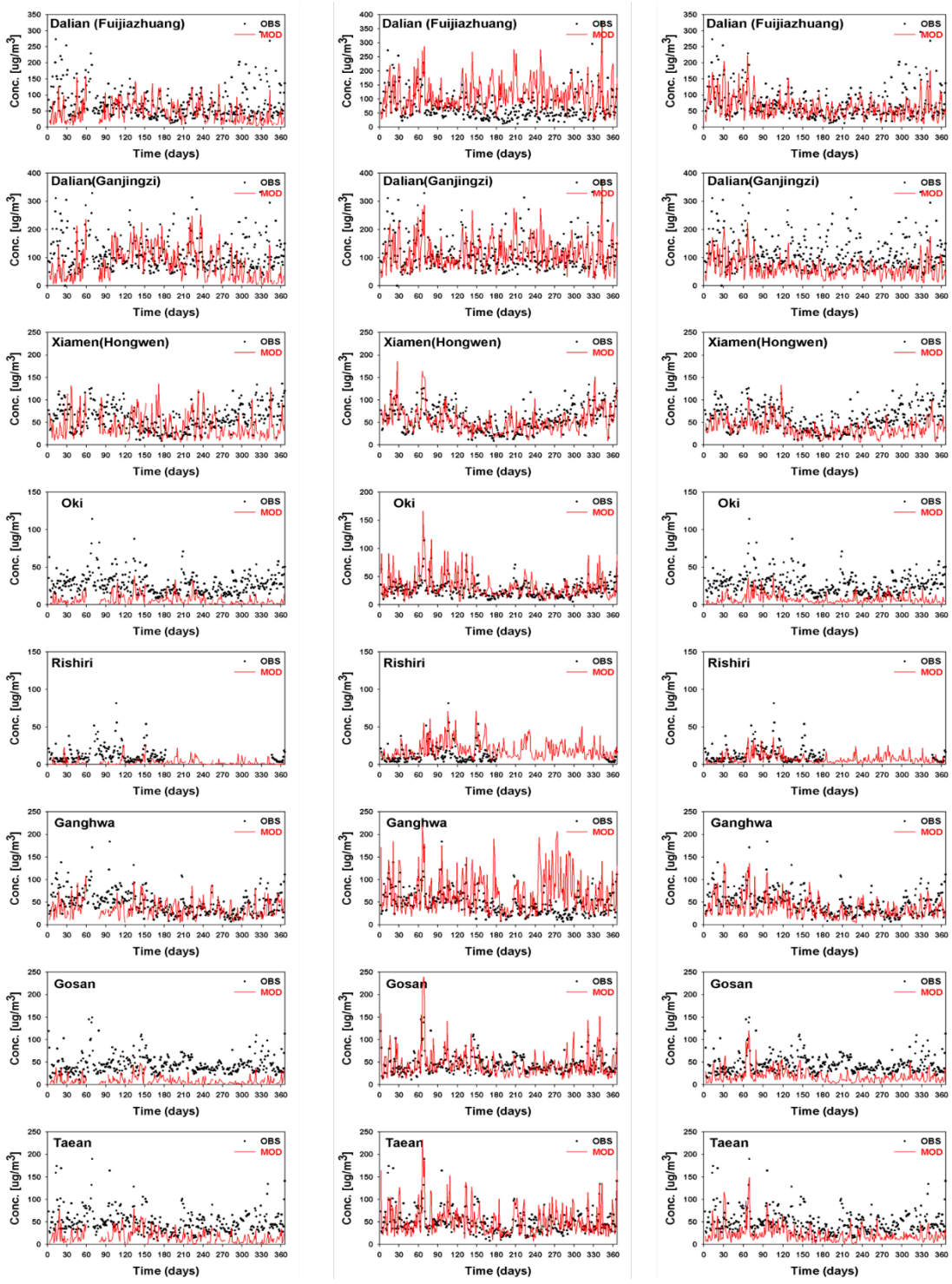

Figure S8. Time series of simulated (red lines) and observed (black dots) daily mean PM_{10} concentrations at seven monitoring sites. Three air quality models—WRF-CAMx, NHM-RAQM2, and WRF-CMAQ, were employed by China, Japan, and Korea, respectively.

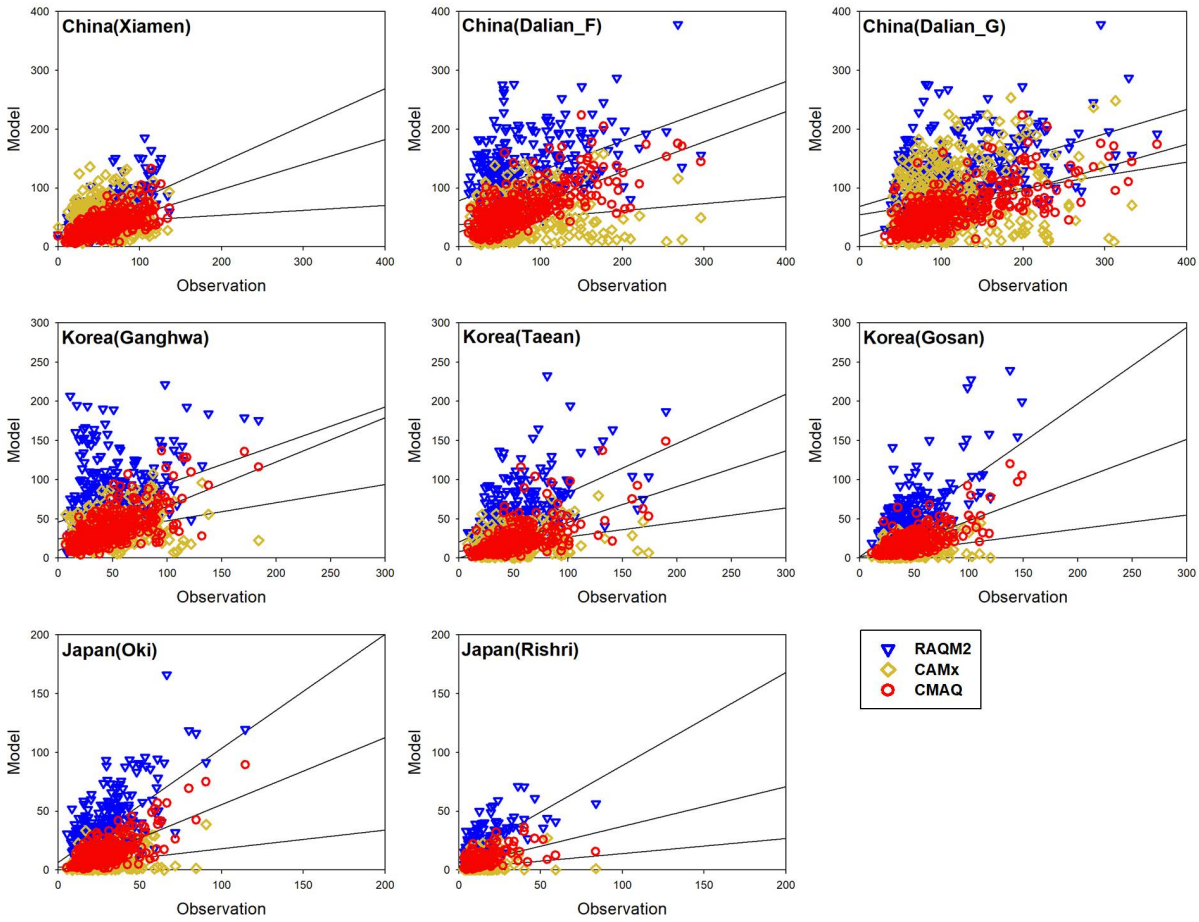

Figure S9. Scatter plots of daily mean modeled versus observed PM_{10} in exit-and-entrance areas associated with transboundary transport over China, Japan, and Korea.