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Supplement of

Multi-axis differential optical absorption spectroscopy (MAX-DOAS) observations of formaldehyde and nitrogen dioxide at three sites in Asia and comparison with the global chemistry transport model CHASER

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Supplement

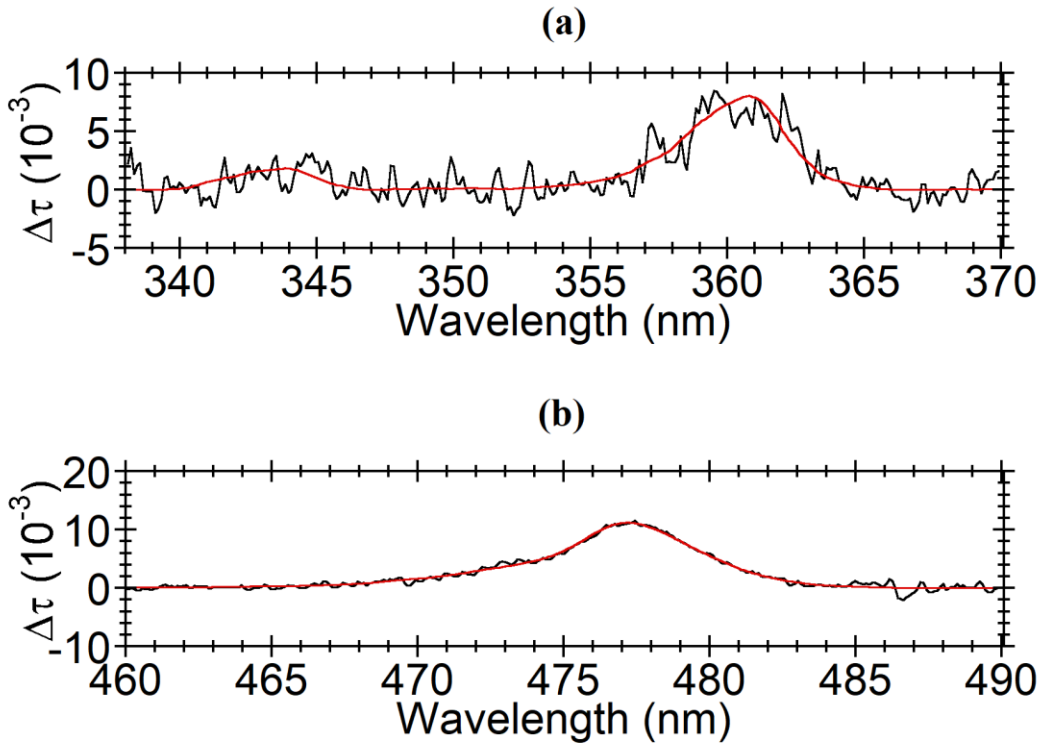

Figure S1. Examples of spectral fitting of O_4 fittings in the (a) 340–370 and (b) 460–490 nm retrieval window, where the red and black lines show the scaled cross-section and the summation of scaled cross-sections and fitting residuals, respectively. The example is shown for the measurements on 10 April 2017, in Phimai at 10:00 LT at an EL of 2°.

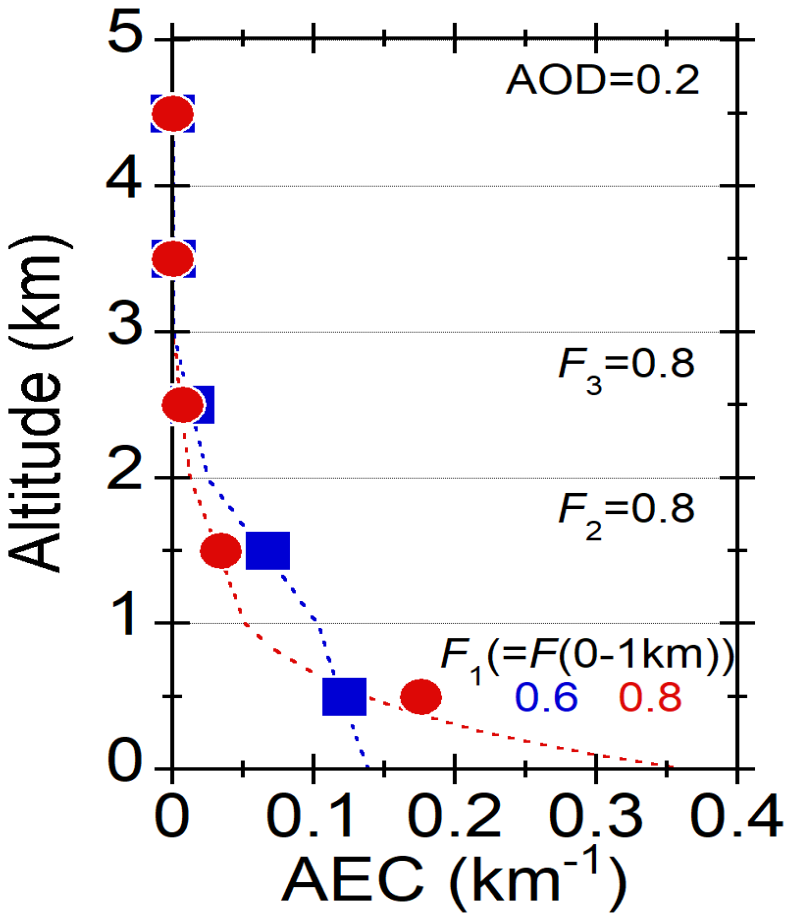

Figure S2: Aerosol extinction profiles corresponding to different profile shape determining factors (F).

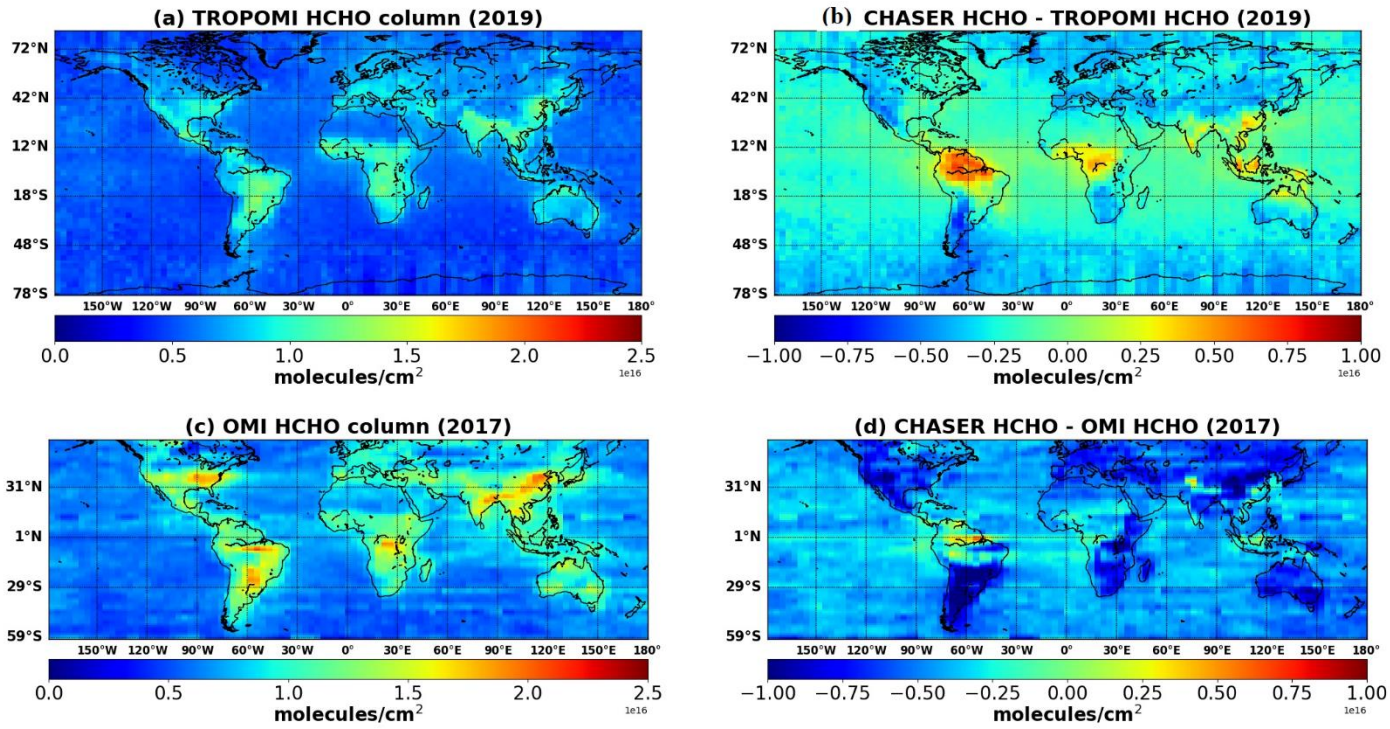

Figure S3: (first column) Annual mean HCHO ($\times 10^{16}$ molecules cm^{-2}) columns retrieved from (a) TROPOMI and (c) OMI observations in 2019 and 2017, respectively. (second column) The differences between the simulated and (b) TROPOMI and (d) OMI HCHO columns. All the datasets are mapped onto a 2.8˚ bin grid.

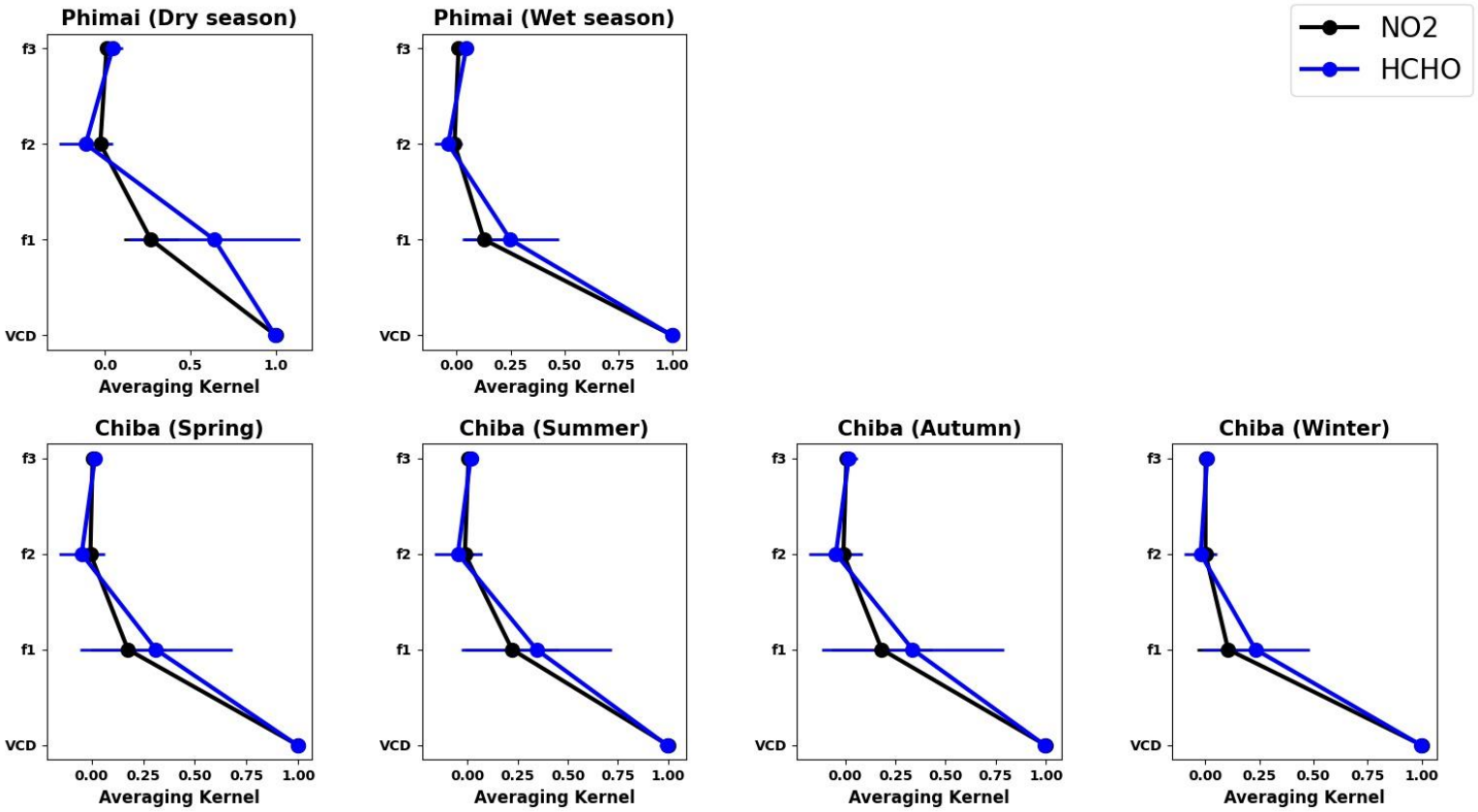

Figure S4. Seasonal mean averaging kernels of the NO_2 (black) and HCHO (blue) retrievals in Phimai and Chiba. The error bars represent the one-sigma standard deviation of the mean values.

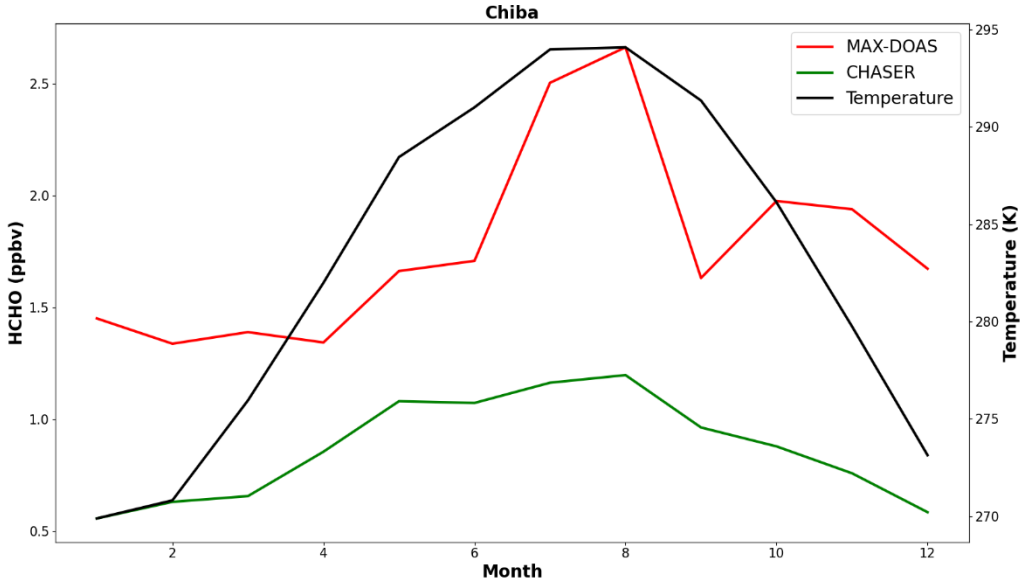

Figure S5. The seasonal variations in the observed (red) and simulated (green) HCHO concentrations in the 0-2 km layer in Chiba. Simulated seasonal changes in the temperature in Chiba are plotted in black.

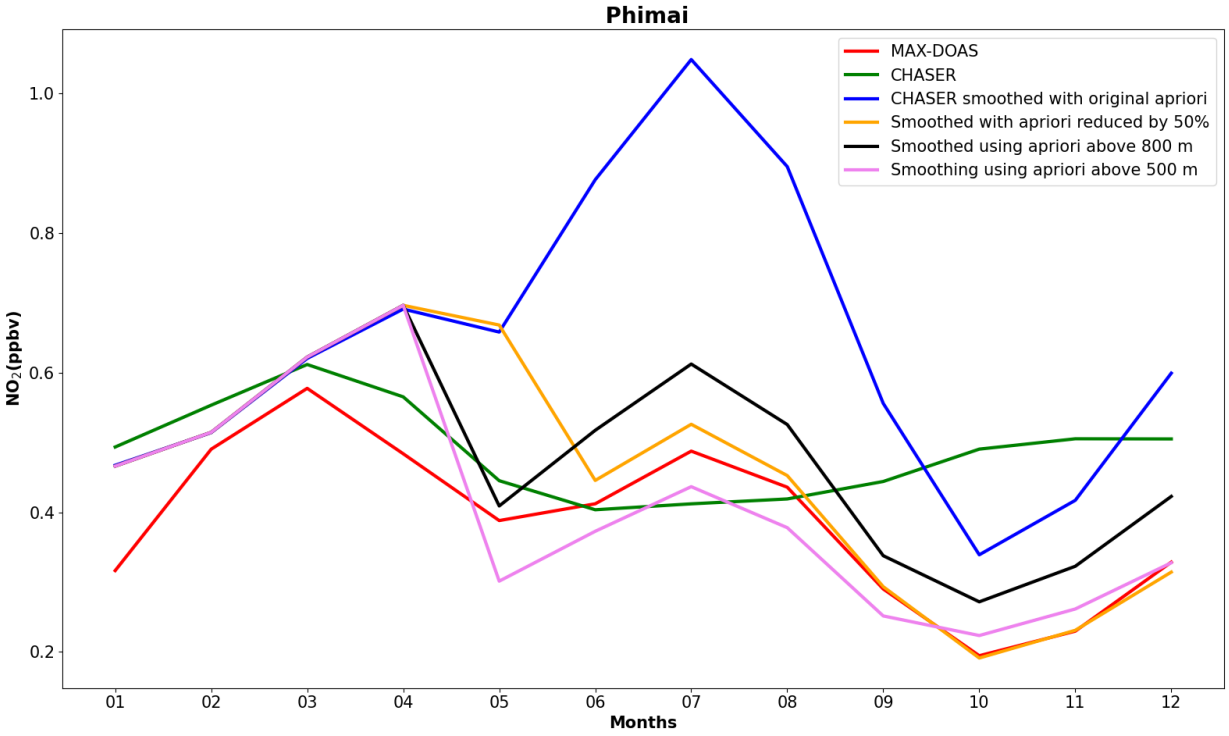

Figure S6. The seasonal variations in the observed (red) and modelled (green) NO_2 concentrations (0-2 km) in Phimai. The CHASER NO_2 concentrations are smoothed with different apriori values to demonstrate the sensitivity of the smoothed profiles. The various cases are- (i)profile smoothed with the original apriori values of the retrievals (blue), (ii) profile smoothed reducing the apriori values by 50% (orange), (iii) profiles smoothed utilizing the apriori values above 800 m (black), and (iv) profiles smoothed using the apriori values above 500 m (pink). The selected CHASER simulated time and date corresponds to the available MAX-DOAS observations at Phimai.

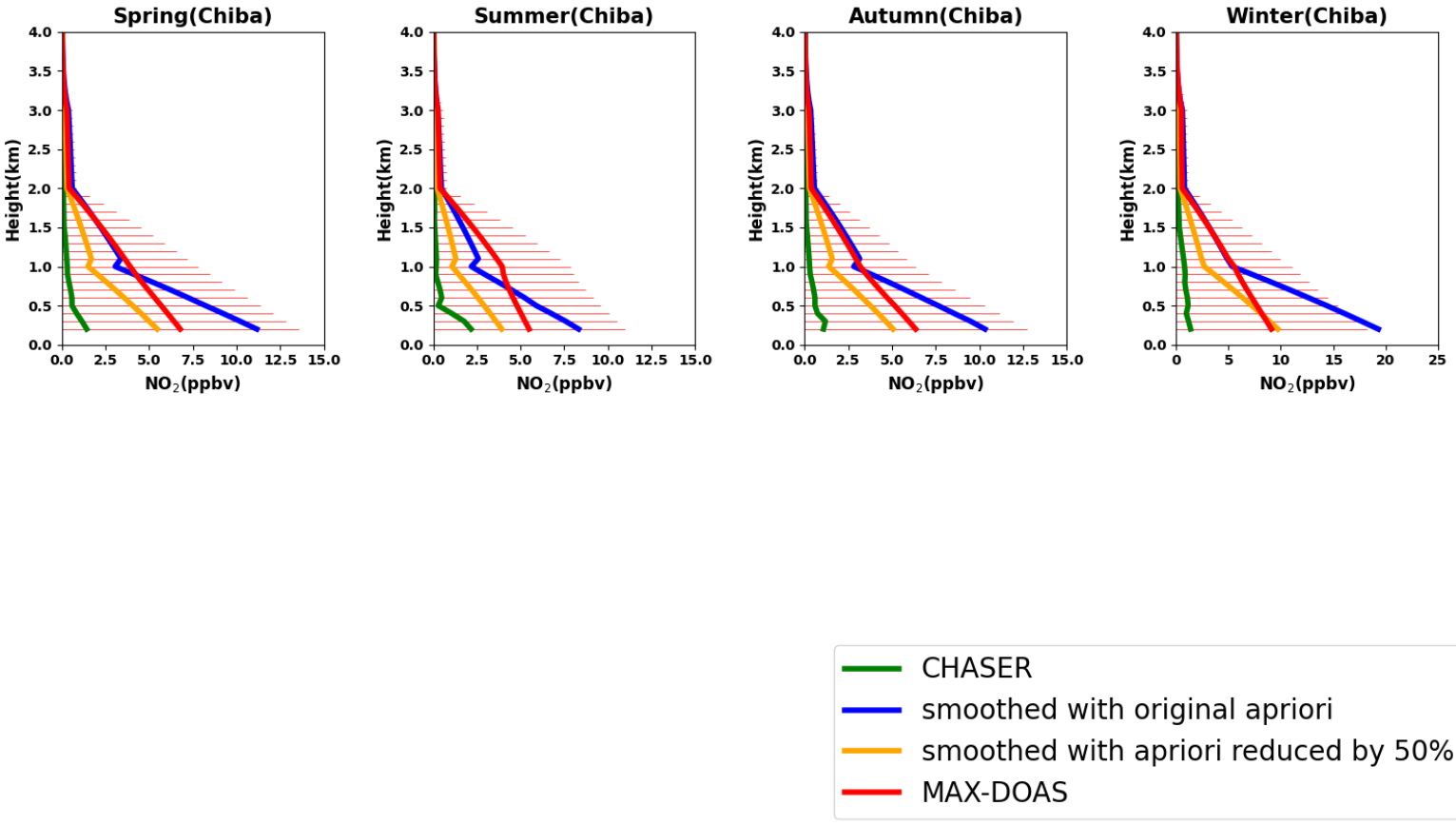

Figure S7. The seasonal variations in the observed (red) and modelled (green) NO_2 concentrations (0-4 km) in Chiba. The CHASER NO_2 concentrations are smoothed with different apriori values to demonstrate the sensitivity of the smoothed profiles. The cases are- (i) profile smoothed with the original apriori values of the retrievals (blue), and (ii) profile smoothed, reducing the apriori values by 50% (orange). The selected CHASER simulated time and date corresponds to the available MAX-DOAS observations at Chiba.

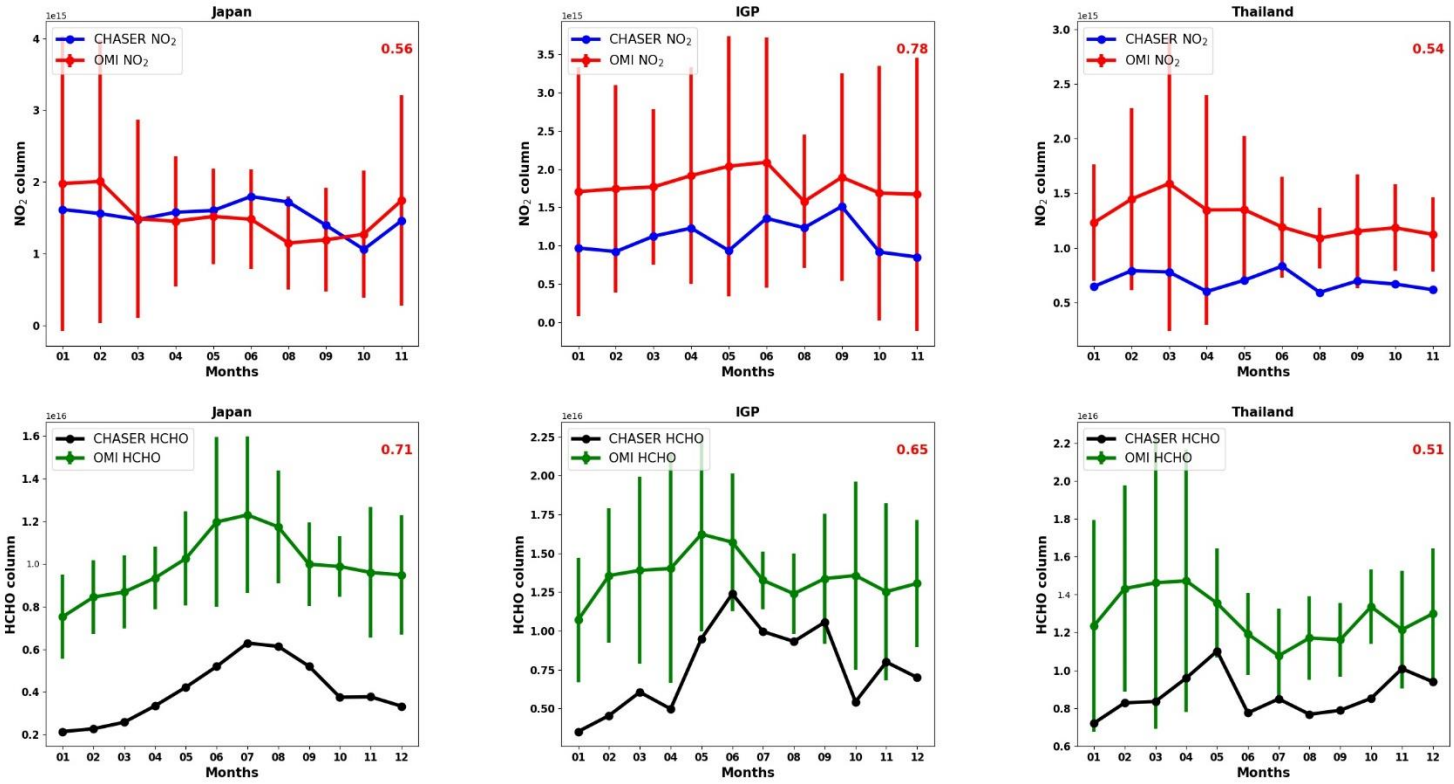

Figure S8: Seasonal variations in HCHO (second row) and NO_2 (first row) columns in Japan, Thailand, and the IGP region, as inferred from OMI observations and CHASER simulations. The error bars represent the 2-sigma variation of the observed mean values. The numbers in the insets signify the regional spatial correlation between the datasets.

Table S1: The global monthly mean bias error (MBE) between CHASER and OMI HCHO columns. The unit of MBE is $\times 10^{16}$ molecules cm^{-2}.

Months	MBE (CHASER HCHO – OMI HCHO)
January	-0.41
February	-0.47
March	-0.48
April	0.49
May	-0.47
June	-0.48
July	-0.47
August	-0.47
September	-0.46
October	-0.49
November	-0.46
December	-0.44

Table S2: Statistical comparison of annual mean HCHO columns between CHASER, TROPOMI, and OMI.MBE1 and MBE2 are the respective mean bias error. RMSE1 and RMSE2 are the respective root mean square errors. r1 and r2 signify the spatial correlation coefficient. The units of the MBEs and RMSEs are $\times 10^{16}$ molecules cm^{-2}.

Region	r1 (CHASER HCHO vs TROPOMI HCHO)	MBE1(CHASER HCHO – TROPOMI HCHO)	RMSE1 (CHASER HCHO – TROPOMI HCHO)	r2 (CHASER HCHO vs OMI HCHO)	MBE2 (CHASER HCHO – OMI HCHO)	RMSE2 (CHASER HCHO – OMI HCHO)
Global	0.78	-0.23	0.28	0.74	-0.45	0.49

Table S3: Statistical comparison of annual mean HCHO and NO_2 columns in Japan, Thailand, and the IGP region between CHASER and OMI. MBE1 and MBE2 are the respective mean bias error. RMSE1 and RMSE2 are the respective root mean square errors. r1 and r2 signify the spatial correlation coefficient. The units of the MBE1 and RMSE1 are $\times 10^{15}$ molecules cm^{-2}, whereas MBE2 and RMSE2 units are $\times 10^{16}$ molecules cm^{-2}.

Region	r1 (CHASER NO_2 vs. OMI NO_2)	MBE1 (CHASER NO_2 – OMI NO_2)	RMSE1 (CHASER NO_2 – OMI NO_2)	r2 (CHASER HCHO vs. OMI HCHO)	MBE2 (CHASER HCHO – OMI HCHO)	RMSE2 (CHASER HCHO – OMI HCHO)
Japan	0.56	0.01	0.55	0.71	-0.58	0.60
IGP	0.78	-0.69	0.80	0.65	-0.57	0.66
Thailand	0.54	-0.57	0.60	0.51	-0.41	0.47