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Supplement of

Deriving regional and point source nitrogen oxides emissions in China from TROPOMI using the directional derivative approach with nonlinear chemical lifetime fitting

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Table S1. Comparison of three DDA-based chemical lifetime (τ) fitting parameters for EN.

Test1: fixed_f and single_τ;

Test2: variable_f and single_τ;

Control: variable_f and nonlinear_τ, i.e., this study.

All values are monthly means: for test1 and test2, the monthly mean is calculated from a single fit over the subregion; for the control setup, the monthly mean is calculated by averaging the piecewise bin results for the subregion. The bottom row shows the mean over the entire study period.

parameters	R^2			RMSE (μmol m^{-2} s^{-1})			τ (h)		
month	Test1	Test2	Control	Test1	Test2	Control	Test1	Test2	Control
1	0.71	0.77	0.66	0.97	1.19	0.83	14.51	11.86	6.19
2	0.68	0.65	0.57	0.72	0.86	0.53	12.13	11.90	5.10
3	0.59	0.57	0.29	0.72	0.81	0.61	15.93	15.87	8.38
4	0.53	0.56	0.45	0.70	0.73	0.44	12.48	11.88	5.94
5	0.53	0.53	0.42	0.57	0.57	0.37	12.70	12.15	6.41
6	0.50	0.49	0.45	0.52	0.51	0.25	20.71	21.45	6.52
7	0.66	0.74	0.42	0.46	0.42	0.26	9.88	7.99	6.41
8	0.33	0.36	0.39	0.51	0.48	0.25	32.60	31.14	6.60
9	0.28	0.30	0.45	0.62	0.61	0.31	25.74	22.84	5.25
10	0.57	0.60	0.52	0.70	0.76	0.40	19.60	18.31	7.13
11	0.32	0.43	0.49	1.14	1.29	0.80	27.48	21.40	6.36
12	0.89	0.93	0.68	0.69	0.85	0.75	11.91	9.96	7.73
mean	0.55	0.58	0.49	0.69	0.76	0.51	17.97	16.40	6.49

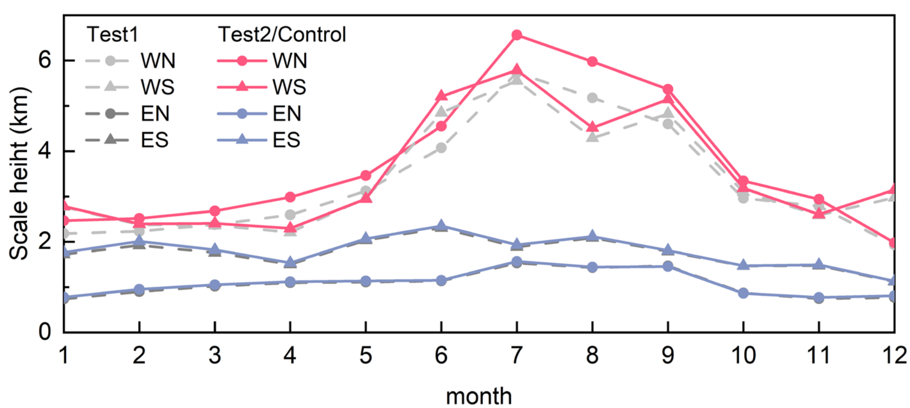

Figure S1. Comparison of monthly scale height (1/X) among three DDA-based setups for each subregion. Test1, Test2, and Control setups are the same as defined in Table S1. The X values are identical for Test2 and the Control setup because both share the same components in the modified DDA framework with variable NO_x/NO_2 ratio.

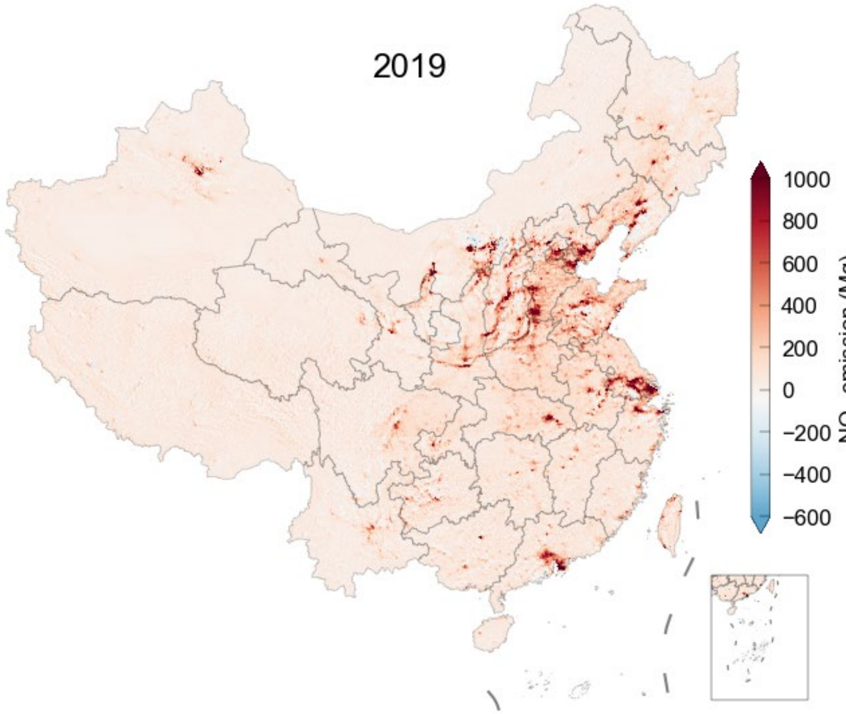

Figure S2. Spatial distribution of total NO_x emissions in China for 2019.

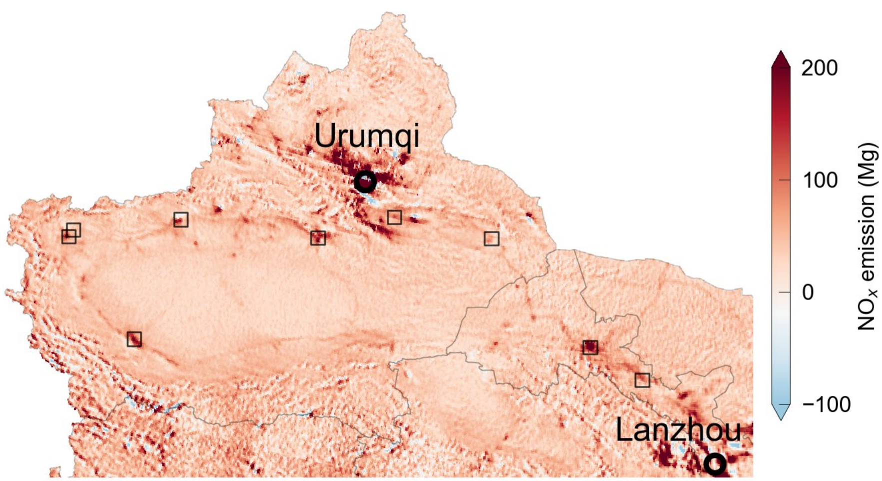

Figure S3. As Fig. S2 but for Northwest China. Urumqi and Lanzhou are major cities in Northwest China, with other cities mark by hollow square symbols. The linear trajectories reflect the transportation routes that connect them.

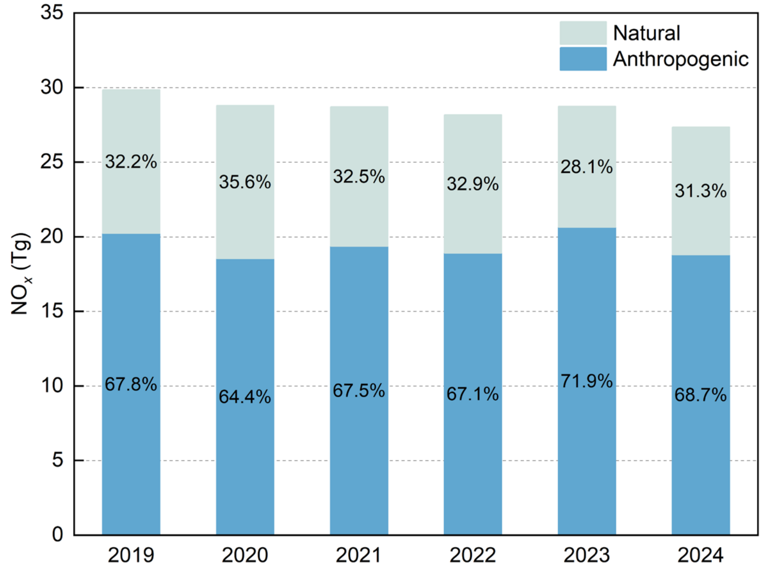

Figure S4. The proportion of anthropogenic and natural NO_x relative to total NO_x emissions in China for 2019–2024.

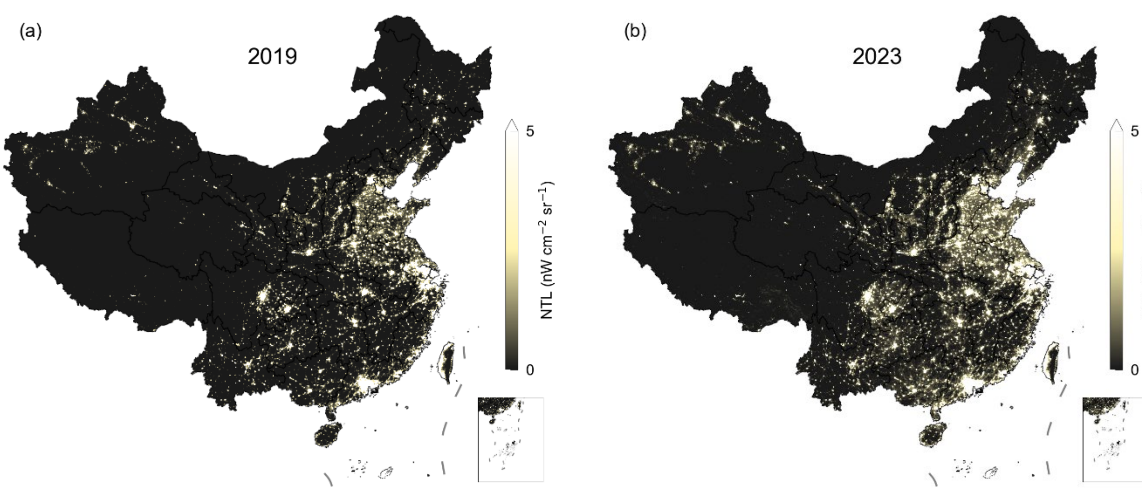

Figure S5. Nighttime Light (NTL) from SNPP/VIIRS in China for (a) 2019 and (b) 2023.

Table S2. NO_x emissions from sensitivity tests of the anthropogenic NO_x filter threshold.

This work (NTL_0.01): Grid cells with either the highest averaged NO_2 TVCDs in summer or the lowest values in winter comparing to other seasons, and with NTL < 0.01 nW cm^{-2} sr^{-1}, are subtracted as natural NO_x (NO_x_nat), and for the remaining grid cells, soil and biomass burning emissions (from CAMS data) are further subtracted to obtain anthropogenic NO_x (NO_x_anthro);

NTL_none: Same as this work, but without applying the NTL filter;

NTL_0.00: Same as this work, but with NTL = 0.00 nW cm^{-2} sr^{-1};

NTL_0.05: Same as this work, but with NTL < 0.05 nW cm^{-2} sr^{-1};

CAMS_none: Same as this work, but soil and biomass burning emissions from CAMS data are not subtracted;

NTL_anthro: Fraction of NTL grids that are also classified as anthropogenic NO_x grids.

Year	Variable	Test				
		This work (NTL_0.01)	NTL_none	NTL_0.00	NTL_0.05	CAMS_none
2019	NO_x_anthro (Tg)	20.2	18.9	20.7	19.7	21.3
	NO_x_nat (Tg)	9.6	11.0	9.2	10.1	9.6
	NTL_anthro (%)	93.0	77.4	100.0	85.5	93.0
2020	NO_x_anthro (Tg)	18.5	17.3	18.9	18.1	19.6
	NO_x_nat (Tg)	10.3	11.5	9.9	10.7	10.3
	NTL_anthro (%)	93.5	78.1	100.0	86.7	93.5
2021	NO_x_anthro (Tg)	19.4	18.3	19.7	19.0	20.5
	NO_x_nat (Tg)	9.3	10.4	9.0	9.7	9.3
	NTL_anthro (%)	94.1	81.6	100.0	88.1	94.1
2022	NO_x_nat (Tg)	18.9	17.2	19.4	18.3	20.0
	NO_x_nat (Tg)	9.3	11.0	8.8	9.9	9.3
	NTL_anthro (%)	93.2	74.7	100.0	85.0	93.2
2023	NO_x_anthro (Tg)	20.7	17.7	21.3	19.8	21.8
	NO_x_nat (Tg)	8.1	11.0	7.4	9.0	8.1
	NTL_anthro (%)	92.6	66.9	100.0	83.0	92.6
2024	NO_x_anthro (Tg)	18.8	16.0	19.5	17.9	19.9
	NO_x_nat (Tg)	8.5	11.4	7.9	9.5	8.5
	NTL_anthro (%)	92.0	67.4	100.0	82.0	92.0

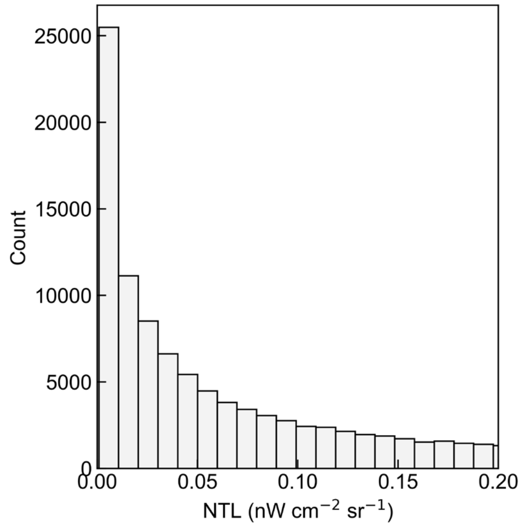

Figure S6. Probability density function (PDF) of SNPP/VIIRS Nighttime Light (NTL) in China in 2023.

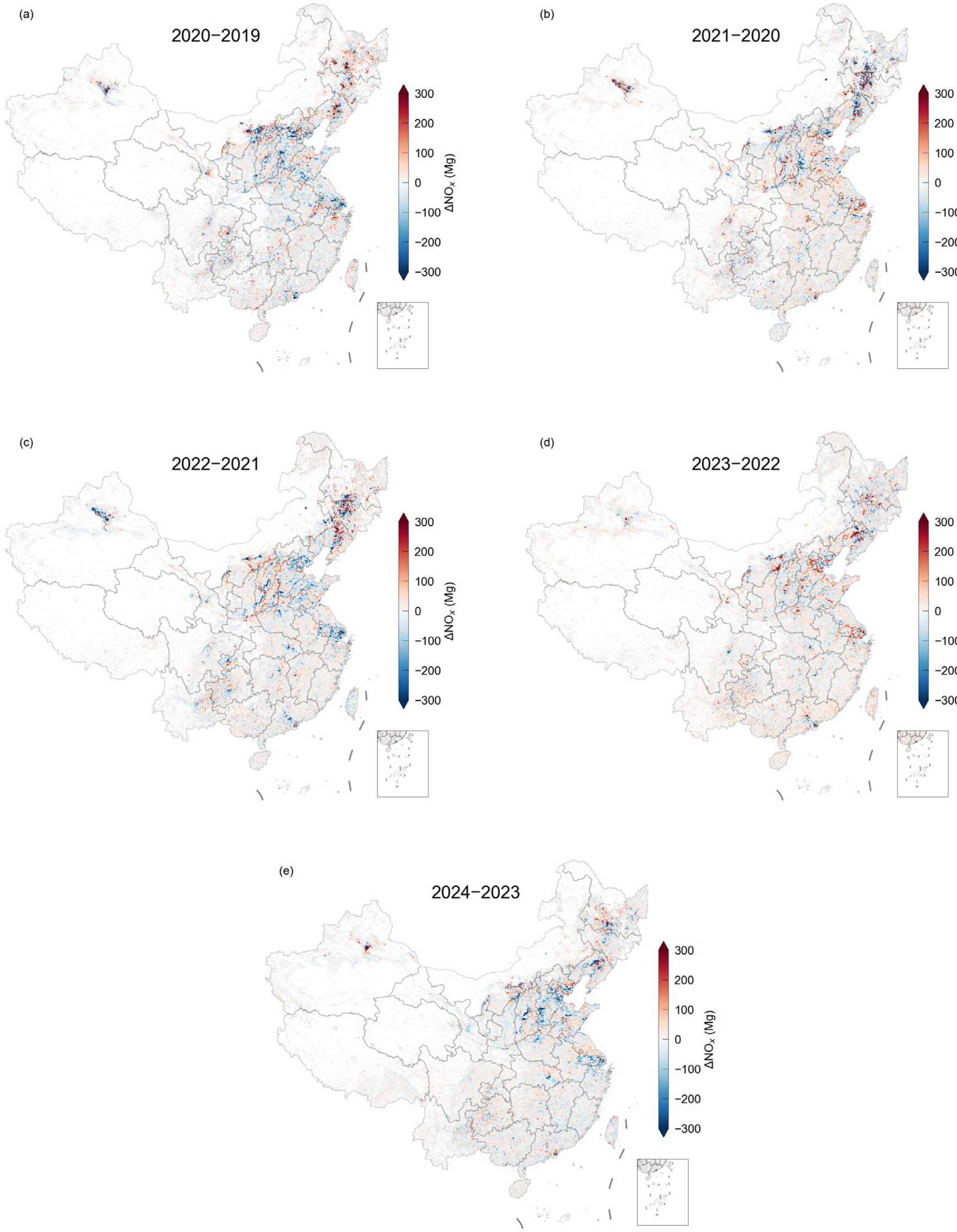

Figure S7. Spatial distribution of year-on-year changes in anthropogenic NO_x emissions in China for (a) 2020−2019, (b) 2021−2020, (c) 2022−2021, (d) 2023−2022, and (e) 2024−2023.

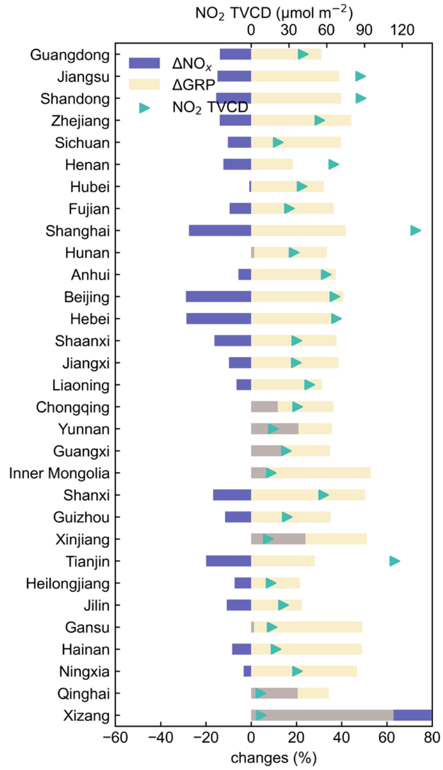

Figure S8. Changes in provincial NO_x emissions, Gross Regional Product (GRP) and NO_2 TVCDs in China from 2019 to 2024.

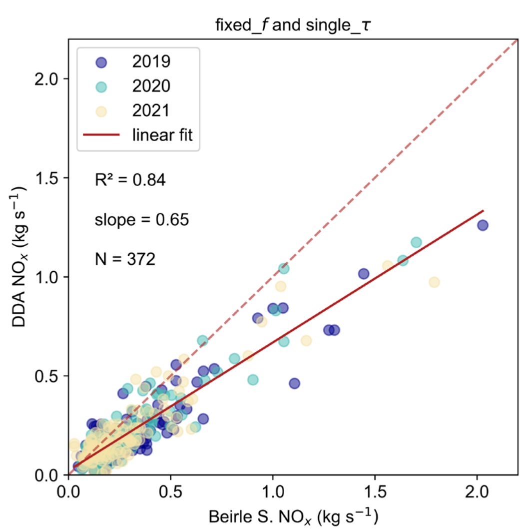

Figure S9. Comparisons of NO_x point source emission rates between the DDA test without ratio correction and fitting scheme improvement (fixed_*f* and single_τ) and Beirle et al. (2023) data.

Table S3. Description of variables in the dataset.

Name	Description	Dimensions	Units	Fill_value
lat	Latitude	lat	degrees_north	NaN
lon	Longitude	lon	degrees_east	NaN
grid_area	Grid-cell area	lat × lon	m^2	NaN
NO_x_emission	Annual anthropogenic NO_x emissions per grid	lat × lon	tonnes (1 tonne =10^3 kg)	NaN