Supplement of

Insights into Soil NO Emissions and the Contribution to Surface Ozone Formation in China

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Content

Temperature dependence factor

$$f(T) = e^{k[°C^{-1}]T} \qquad k = 0.103±0.04 \qquad \text{Eq. S1}$$

Table S1 Division of regions

Region	Provinces
Northeast China	Liaoning, Heilongjiang, Jilin
North China	Hebei, Inner Mongolia, Tianjin, Beijing, Shanxi
Central China	Henan, Hubei, Hunan
East China	Fujian, Jiangsu, Shandong, Zhejiang, Shanghai, Anhui, Jiangxi
South China	Hainan, Guangdong, Guangxi
Southwest China	Tibet, Sichuan, Yunnan, Chongqing, Guizhou
Northwest China	Xinjiang, Qinghai, Gansu, Ningxia and Shaanxi

Table S2 Statistical index formula

No.	Index	Formula	Note
1	Pearson correlation coefficient (R)	$\frac{\sum[(P_j-\overline{P})\times(O_j-\overline{O})]}{\sqrt{\sum(P_j-\overline{P})^2\times\sum(O_j-\overline{O})^2}}$	Unitless, -1≤R≤1
2	mean bias (MB)	$\frac{\sum(P_j-O_j)}{N}$	concentration unit
3	root-mean-square error (RMSE)	$\sqrt{\frac{\sum(P_j-O_j)^2}{N}}$	concentration unit
4	normalized mean bias (NMB)	$\frac{\sum(P_j-O_j)}{\sum O_j}\times 100$	-100%≤NMB≤+∞
5	normalized mean error (NME)	$\frac{\sum\lvert P_j-O_j\rvert}{\sum O_j}\times 100$	0%≤NME≤+∞

Table S3 Soil NO emissions* and ratio of soil NO to anthropogenic NO*x* by different regions in China for 2018

Region	Annual Soil NO emissions (Gg)	Soil NO emissions during June-August (Ratio of annual totals)	Ratio of soil NO/anthropogenic NO*x*	Ratio soil NO/anthropogenic NO*x* (June-August)
Northeast China	94.2	63.7 (67.6%)	12.0%	36.0%
North China	200.5	118.1 (58.9%)	14.9%	36.5%
Central China	281.4	146.7 (52.1%)	35.3%	74.0%
East China	264.3	138.4 (52.4%)	12.8%	26.8%
South China	71.4	20.1 (28.2%)	14.3%	15.8%
Southwest China	87.6	34.8 (39.7%)	14.5%	23.9%
Northwest China	158.4	95.8 (60.5%)	26.8%	67.5%
Total	1157.9	63.7 (53.3%)	12.0%	36.0%

*Soil NO emissions given in this table are based on the default temperature dependence factor.

Table S4 Comparison of soil NO emissions and flux in China reported by previous studies

Reference	Region	Reference year	Above canopy (Gg N a^{-1})	Soil NO*x* flux (ng N m^{-2} s^{-1})	Notes
Wang et al. (2005)	China	1999	657	generally more than 40 ng N m^{-2} s^{-1} (in the North China Plain in July) and 20 ng N m^{-2} s^{-1} (in the northeast China in July)	An empirical modeling approach of Yienger and Levy (YL95)

Tie et al. (2006)	China	2004	1375		Dynamical and biogenic emissions models, soil emissions parameterized with an exponential dependence on soil temperature.
Yan et al. (2005)	China		480		Statistical model based on field measurements of NO*x* fluxes combined with land cover, soil pH, soil organic carbon, climate, and nitrogen fertilizers
Huang and Li (2014)	China		1226 (ranging from 588.24 to 2132.05)		Synthesis of 130 NO emissions sampling points at 14 locations to estimate soil NO emissions inventory in China.
Lu et al. (2019)	China	2016 (Mar-Oct)	1140		BDSNP scheme in GEOS-Chem
		2017 (Mar-Oct)	1360		
Lu et al. (2021)	China	2017	770±40		BDSNP scheme in GEOS-Chem
Wang et al. (2007)	East China	1997-1999	850		Application of YL95 scheme in GEOS-Chem
Lin (2012)	East China	2006	380		Top-down estimates using satellite NO_2 retrievals
Wang et al. (2022)	The North	2020		10-40 (crop growing season)	Application of MEGAN scheme in WRF-Chem

	China plain				
Li and Wang (2007)	the Pearl River Delta	2005		The average is 47.5 (typical vegetable plot)	NO flux measured by static chamber technique in the suburbs of Guangzhou
Li et al. (2007)	South China	2005		The average fluxes of broadleaved forest and pine-leaved forest in the rainy season were 14.9 and 17.1	Sample plots circled in the forest and NO fluxes measured by dynamic flow chamber technique
Liu et al. (2011)	Northern China	2007-2009		Average annual flux of 7.6 (wheat-maize rural)	Experiments NO fluxes were obtained based on automatic measurement systems and intermittent manual measurements
Liu et al. (2017)				The average soil NO flux was 12.9 Vegetable farmland flux is 30.9	Synthesized 520 field observations from 114 publications
This study	China	2018	805.2	6.6 (June average, same below)	BDSNP scheme (default fertilizer data)
			1157.9 (715.7-1902.6)	9.9	BDSNP scheme (N + compound fertilizer data)
	NCP	2018	296.1	38.5	BDSNP scheme (default fertilizer data)
			455.9 (276.5-762.1)	60.1	BDSNP scheme (N + compound fertilizer data)
				35.4	BDSNP scheme (N + compound fertilizer data and adjusted β value)

Table S5 Comparison of observed and simulated values in China and five key regions

	China	**NCP**	**YRD**	**PRD**	**Sichuan Basin**	**Northeast**
OBS (μg/m^3)	129.6	172.4	146.5	97.5	108.3	126.1
MOD (μg/m^3)	146.7	185.7	171.5	108.4	146.7	128.4
MB (μg/m^3)	17.1	13.3	25.0	10.9	38.5	2.4
NMB (%)	13.2	7.7	17.1	11.2	35.5	1.9
R	0.89	0.77	0.80	0.58	0.62	0.83

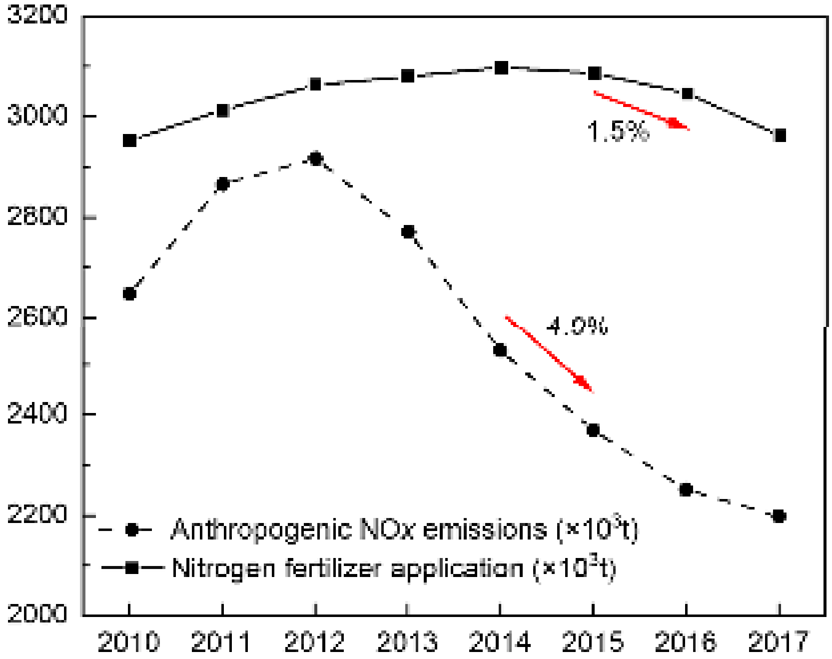

Figure S1 Anthropogenic NO*x* emissions and nitrogen fertilizer application during 2010-2017 (Note: anthropogenic NO*x* emissions are based on MEIC emission inventory; nitrogen fertilizer data from provincial statistical yearbook)

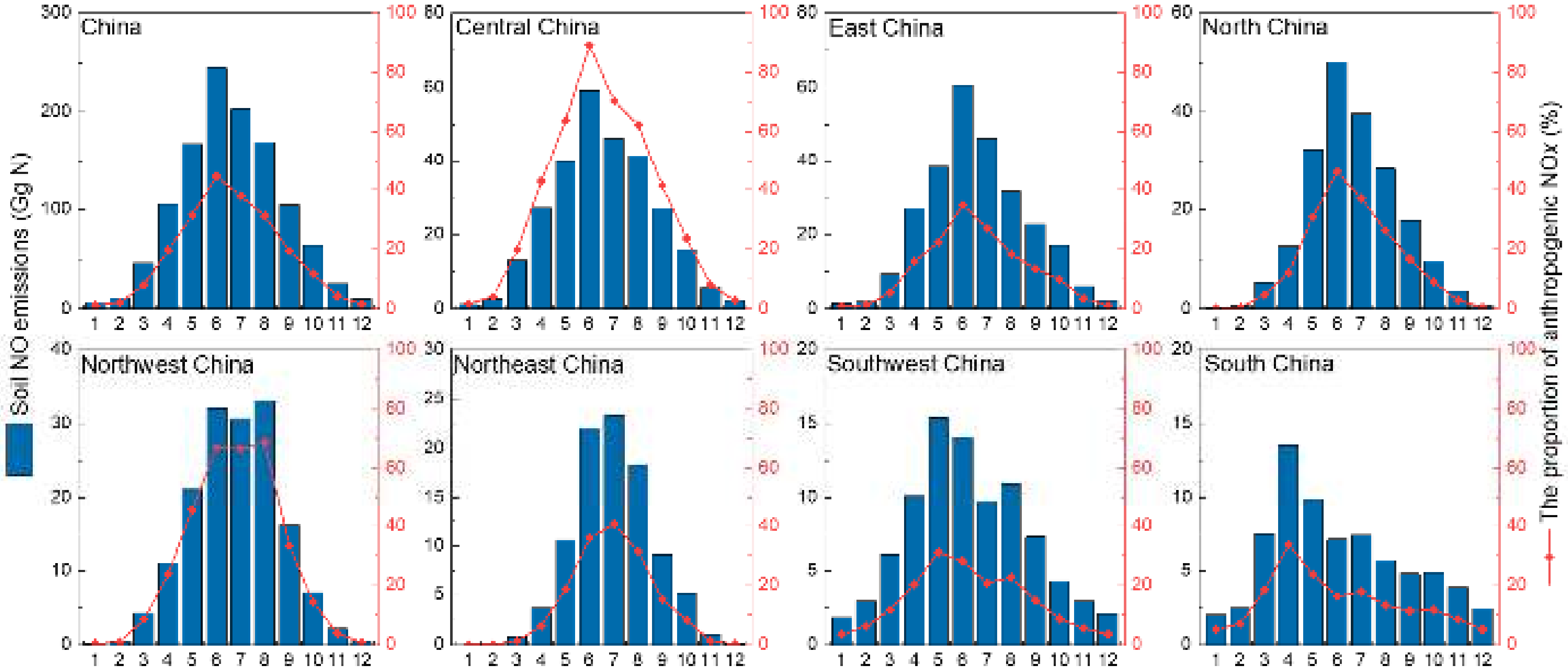

Figure S2 Monthly soil NO emissions (estimated with default temperature dependence factor of 0.103) by region

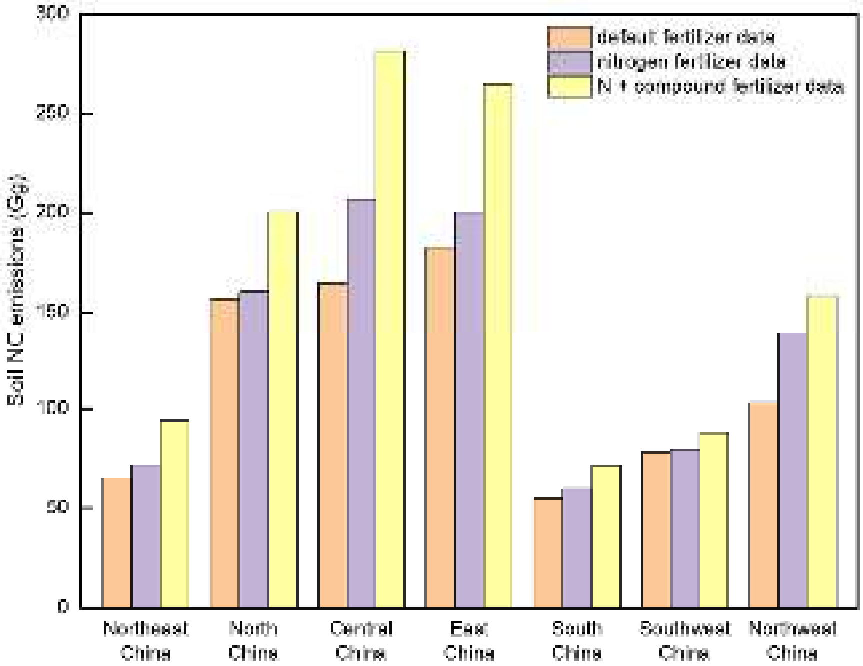

Figure S3 Soil NO emissions estimated using different fertilizer data (default fertilizer data: International Fertilizer Industry Association from Potter et al. (2010) for year 2010; nitrogen fertilizer and compound fertilizer are from statistical yearbooks at the provincial level for year 2018)

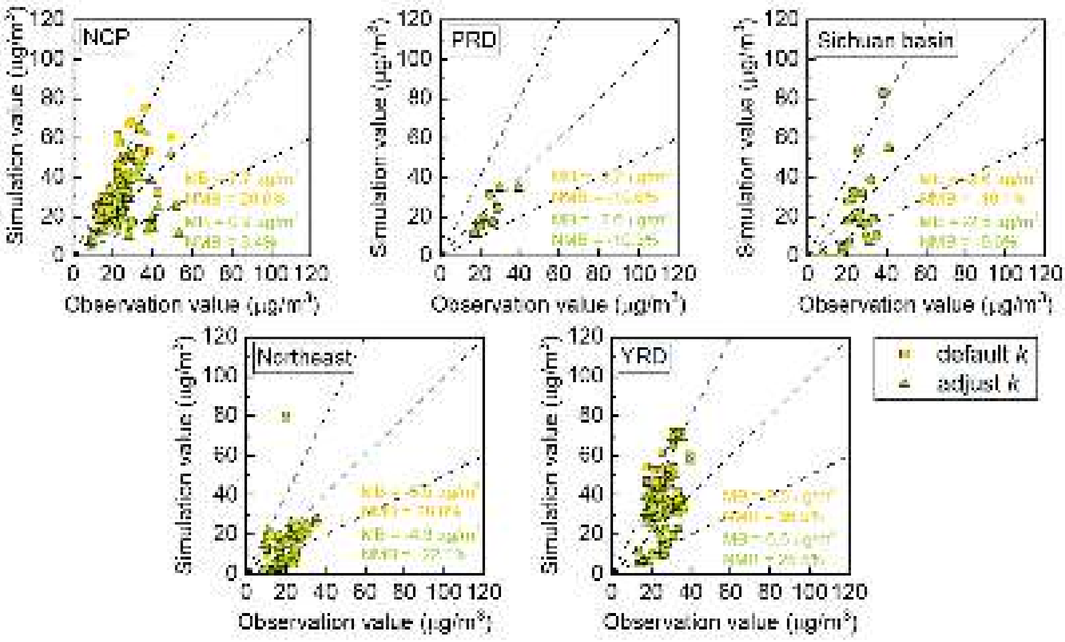

Figure S4 Scatter plot of monthly mean NO_2 concentration (before and after adjusting *k*)

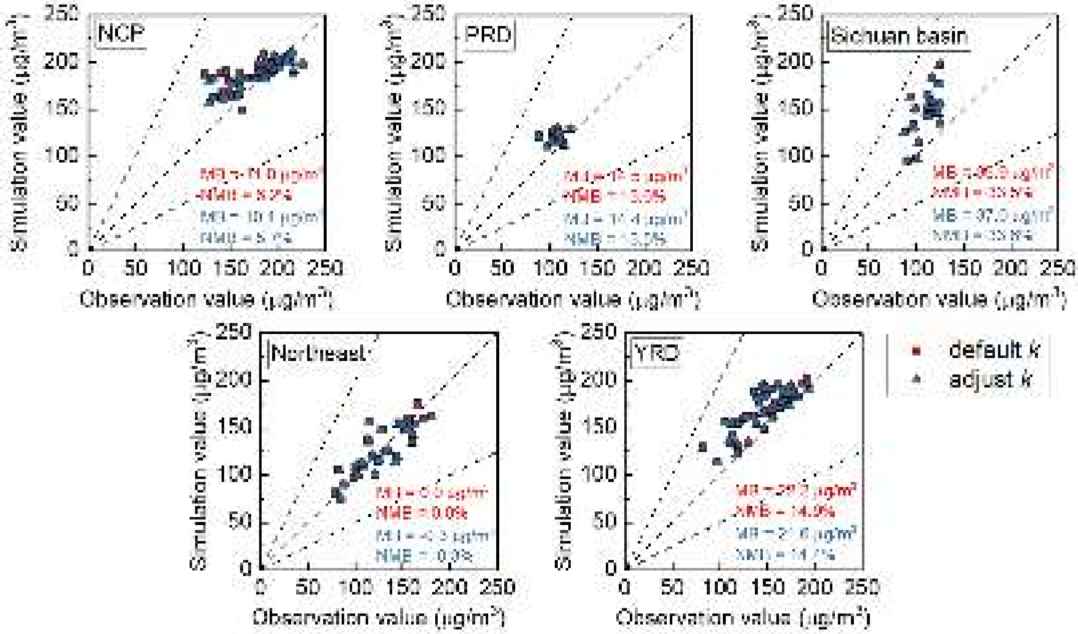

Figure S5 Scatter plot of monthly mean MDA8 ozone concentration (before and after adjusting *k*)

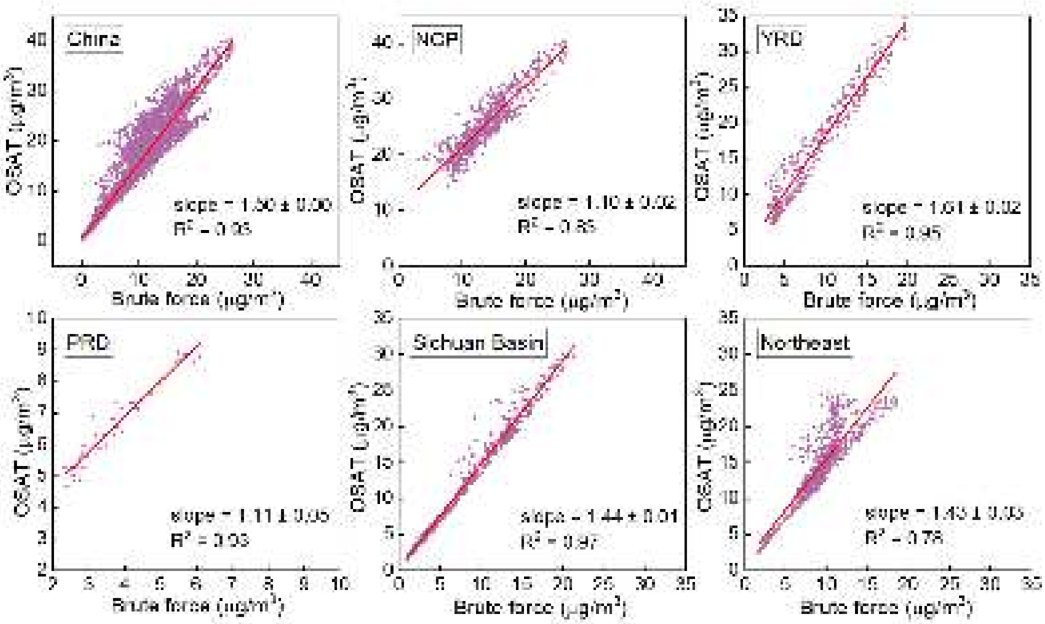

Figure S6 Comparison of OSAT method and Brute force method in China and five key regions

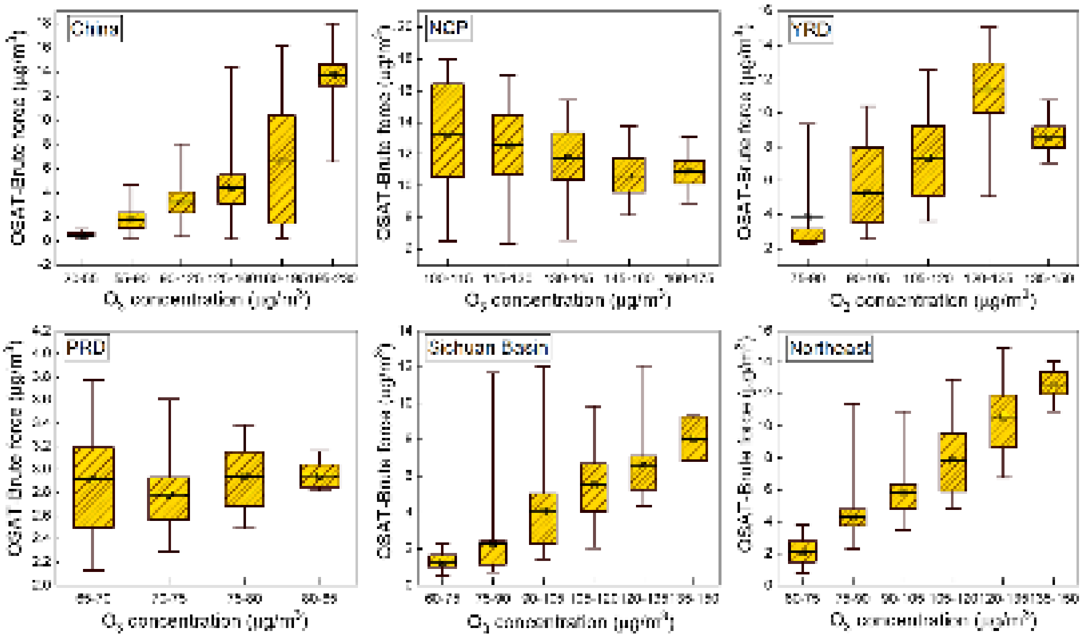

Figure S7 Ozone differences between OSAT method and brute force method under different ozone concentrations in China and five key regions

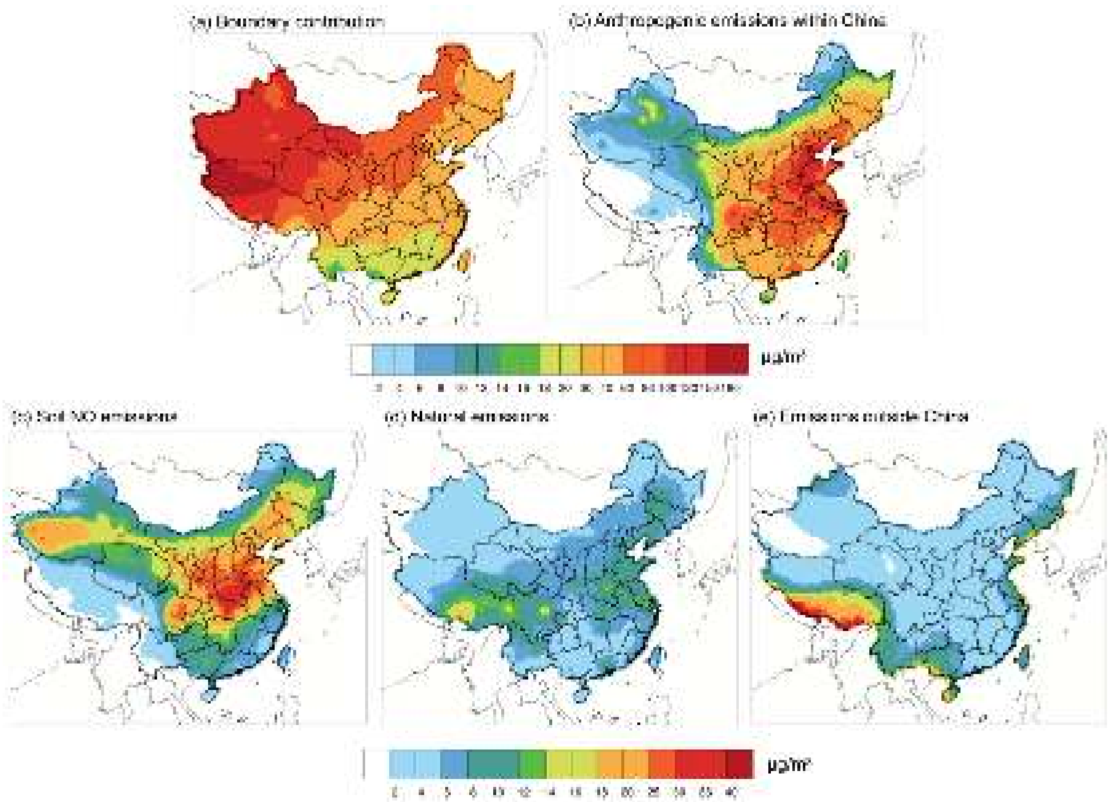

Figure S8 Spatial distribution of ozone contribution from different source groups based on OSAT results

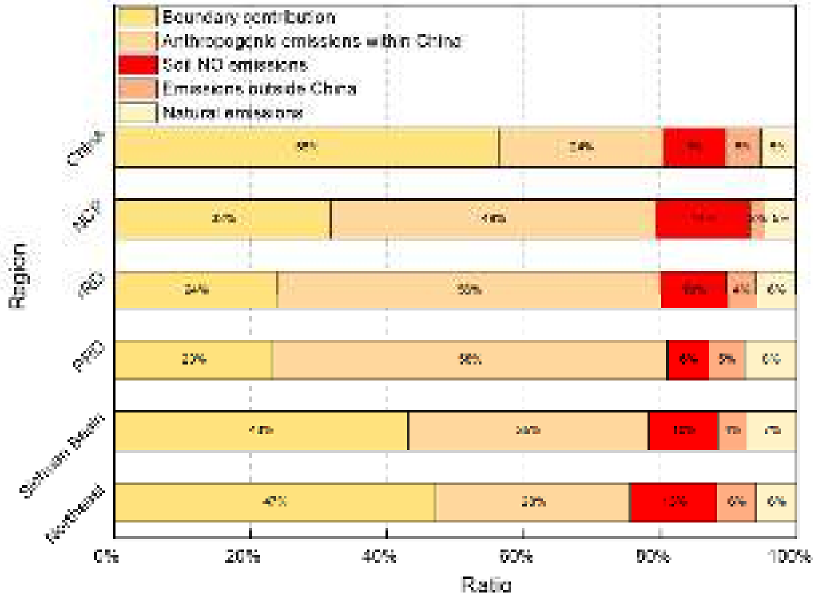

Figure S9 Relative ozone contribution by emission groups and regions

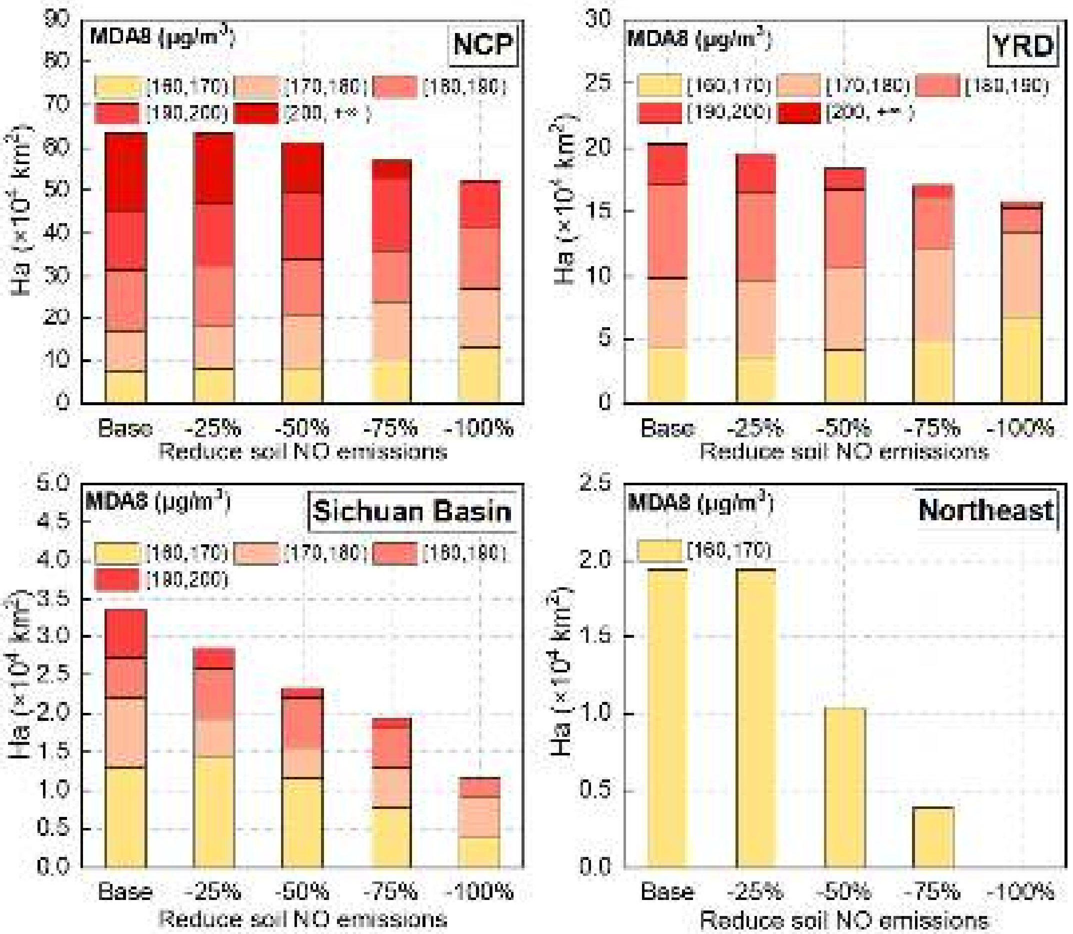

Figure S10 Area exposed to MDA8 > 160 µg/m³ under different soil NO emission reduction scenarios (PRD is not shown because MDA8 ozone concentration is less than 160 µg/m³)

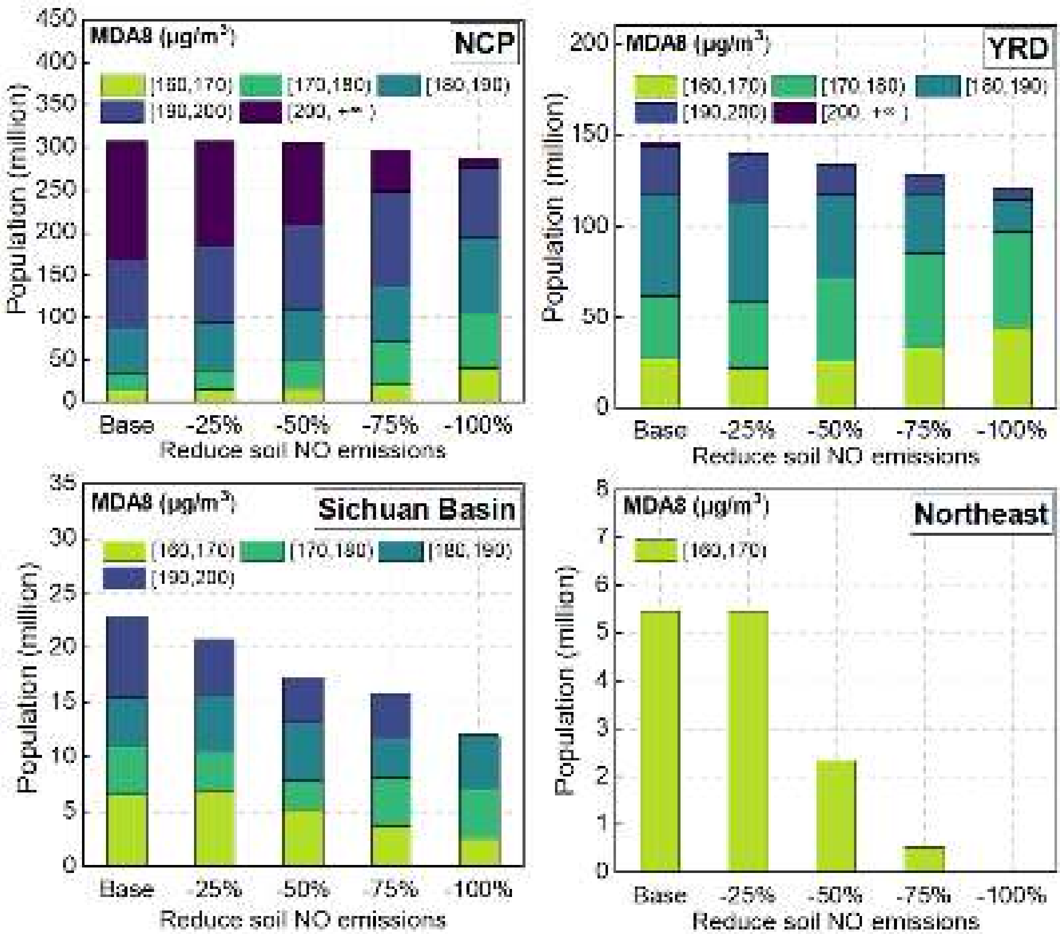

Figure S11 Population exposed to MDA8 > 160 μg/m^3 under different soil NO emission reduction scenarios (PRD is not shown because MDA8 ozone concentration is less than 160 μg/m^3)

Supplementary Information References

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