Supplement of

Surface and tropospheric ozone over East Asia and Southeast Asia from observations: distributions, trends, and variability

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Table S1. The observed ozone trends in 11 long-term measurements over China. The * denotes *p*-value less than 0.1, and ** denotes *p*-value less than 0.01. The *p*-value is also given in the bracket.

Site	Metric	Spring	Summer	Autumn	Winter
Mt. Waliguan	MDA8	0.56* (0.06)	0.37 (0.14)	0.33 (0.26)	0.15 (0.27)
	24h mean	0.51* (0.07)	0.32 (0.19)	0.32 (0.20)	0.15 (0.23)
Shangdianzi	MDA8	0.85* (0.09)	0.73 (0.12)	0.26 (0.58)	0.32* (0.07)
	24h mean	0.55 (0.11)	0.64* (0.09)	0.05 (0.88)	0.23 (0.17)
Lin'an	MDA8	-0.16 (0.82)	0.06 (0.88)	-0.55 (0.40)	0.52 (0.18)
	24h mean	-0.27 (0.60)	0.02 (0.94)	-0.31 (0.50)	0.44 (0.19)
Longfengshan	MDA8	-1.67** (0.00)	-0.25 (0.67)	0.35 (0.44)	-1.24** (0.00)
	24h mean	-1.41** (0.00)	-0.24 (0.57)	0.24 (0.43)	-0.95** (0.00)
Xianggelila	MDA8	0.00 (0.99)	0.26 (0.59)	1.23** (0.03)	0.17 (0.55)
	24h mean	-0.20 (0.54)	0.06 (0.89)	0.53 (0.23)	0.00 (0.99)
Akedala	MDA8	-1.46** (0.01)	-3.65** (0.00)	-1.73 (0.1)	-0.88 (0.27)
	24h mean	-1.84** (0.00)	-2.90** (0.00)	-1.68** (0.01)	-0.44 (0.59)
Mt. Tai	MDA8	N.A.	0.83 (0.35)	N.A.	N.A.
	24h mean	N.A.	0.76 (0.35)	N.A.	N.A.
Gucheng	MDA8	0.89 (0.38)	0.89 (0.20)	-0.23 (0.82)	-0.12 (0.75)
	24h mean	0.26 (0.68)	0.46 (0.35)	-0.31 (0.52)	-0.20 (0.32)
Xunjuahui	MDA8	1.61** (0.00)	1.02** (0.02)	1.26** (0.00)	1.48** (0.00)
	24h mean	1.47** (0.00)	1.04** (0.00)	1.30** (0.00)	1.20** (0.00)
Guangzhou	24h mean	0.48 (0.24)	0.59** (0.01)	-0.37 (0.29)	0.29 (0.23)
Hong Kong	24h mean	0.41* (0.05)	0.45** (0.01)	-0.19 (0.52)	0.04 (0.82)

Table S2. The national air quality standard for MDA8 and MDA1 ozone.

Country	MDA1 ozone ($\mu g\ m^{-3}$)	MDA8 ozone ($\mu g\ m^{-3}$)	Reference
China	160	100	https://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/dqhjbh/dqhjzlbz/201203/t20120302_224165.shtml
Japan	120		https://www.env.go.jp/air/kijun/index.html
South Korea	200	120	https://www.airkorea.or.kr/eng/contents/contentView/?pMENU_NO=160&cntnts_no=16
Singapore	N.A.	120	https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-quality
Myanmar	N.A.	100	https://www.myanmar-responsiblebusiness.org/pdf/2015-12-29-National-Environmental-Quality_Emission_Guidelines_en.pdf
Indonesia	235	N.A.	http://www.brigc.net/zcyj/bgxz/2021/202112/P020211217480996607271.pdf
Vietnam	200	120	
Thailand	200	140	
Laos	200	100	
Malaysia	180	N.A.	
Cambodia	200	N.A.	http://www.epiac.org/uploadfile/2021/0820/20210820032403319.pdf
Philippine	N.A.	60	He et al., 2024

Table S3. Summary of ozonesonde sites used in this study.

Site ID	GAW platform ID	Site name	Country	Latitude	Longitude
SAP	12	Sapporo	Japan	43.06 °N	141.33 °E
TKB	14	Tsukuba	Japan	36.05 °N	140.13 °E
POH	332	Pohang	Korea	36.03 °N	129.38 °E
KAG	7	Kagoshima	Japan	31.55 °N	130.55 °E
NAH	190	Naha	Japan	26.20 °N	127.68 °E
HKO	344	King's park	China	22.31 °N	114.17 °E
AAR	330	Hanoi	Vietnam	21.02 °N	105.80 °E
SEP	443	Sepang Jaya	Malaysia	2.73 °N	101.70 °E
WAT	437	Watukosek	Indonesia	7.5 °S	112.65 °E
Beijing	N.A.	Beijing	China	39.8 °N	116.47◦ E

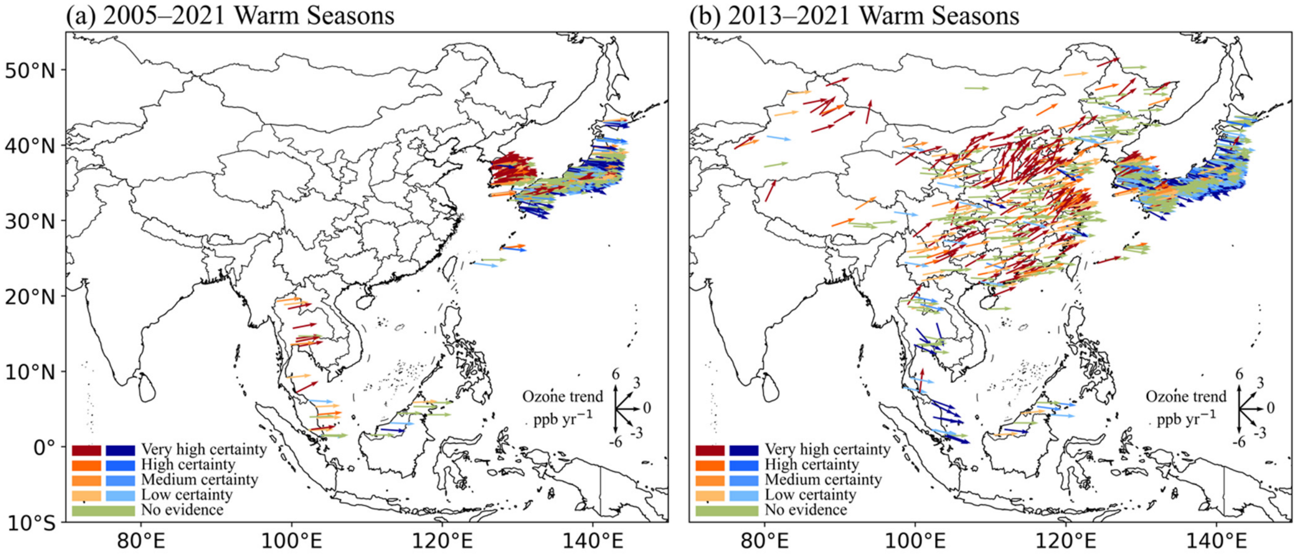

Figure S1. The observed ozone trends during warm seasons (April to September) over 2005-2021 (left) and 2013-2021 (right) over East Asia and Southeast Asia. It is noted that national surface ozone data in China is not available before 2013.

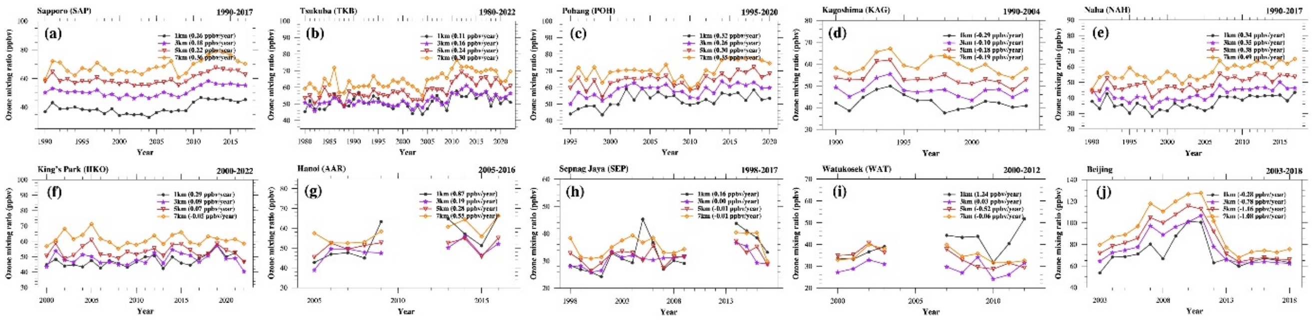

Figure S2. Annual mean ozone variation of 1-km (black), 3-km (purple), 5-km (red), and 7-km (orange) altitudes at (a) Sapporo (SAP), (b) Tsukuba (TKB), (c) Pohang (POH), (d) Kagoshima (KAG), (e) Naha (NAH), (f) King's park (HKO), (g) Hanoi (AAR), (h) Sepang Jaya, (i) Watukosek, and (j) Beijing site: March-April-May (MAM, red), June-July-August (JJA, blue), September-October-November (SON, green), and December-January-February (DJF).

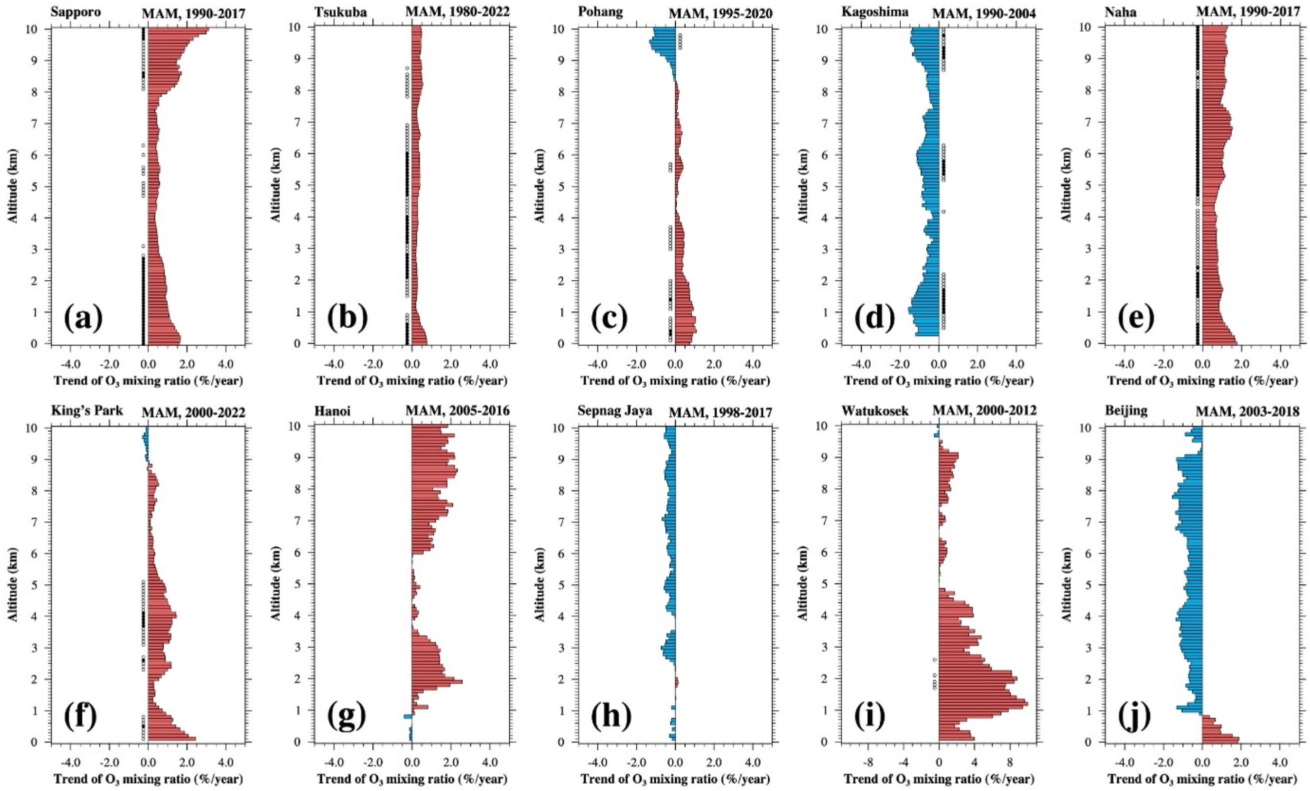

Figure S3. Long-term trends of spring (MAM) mean ozone per 100-m range from 0 to 10 km altitude at (a) Sapporo (SAP), (b) Tsukuba (TKB), (c) Pohang (POH), (d) Kagoshima (KAG), (e) Naha (NAH), (f) King's park (HKO), (g) Hanoi (AAR), (h) Sepang Jaya, (i) Watukosek, and (j) Beijing site. Orange color means increasing, and blue color means decreasing trend. Black dot indicates that the trend is statistically significant having a p-value smaller than 0.01, and white dot does that the trend is statistically significant having a p-value between 0.01 and 0.05.

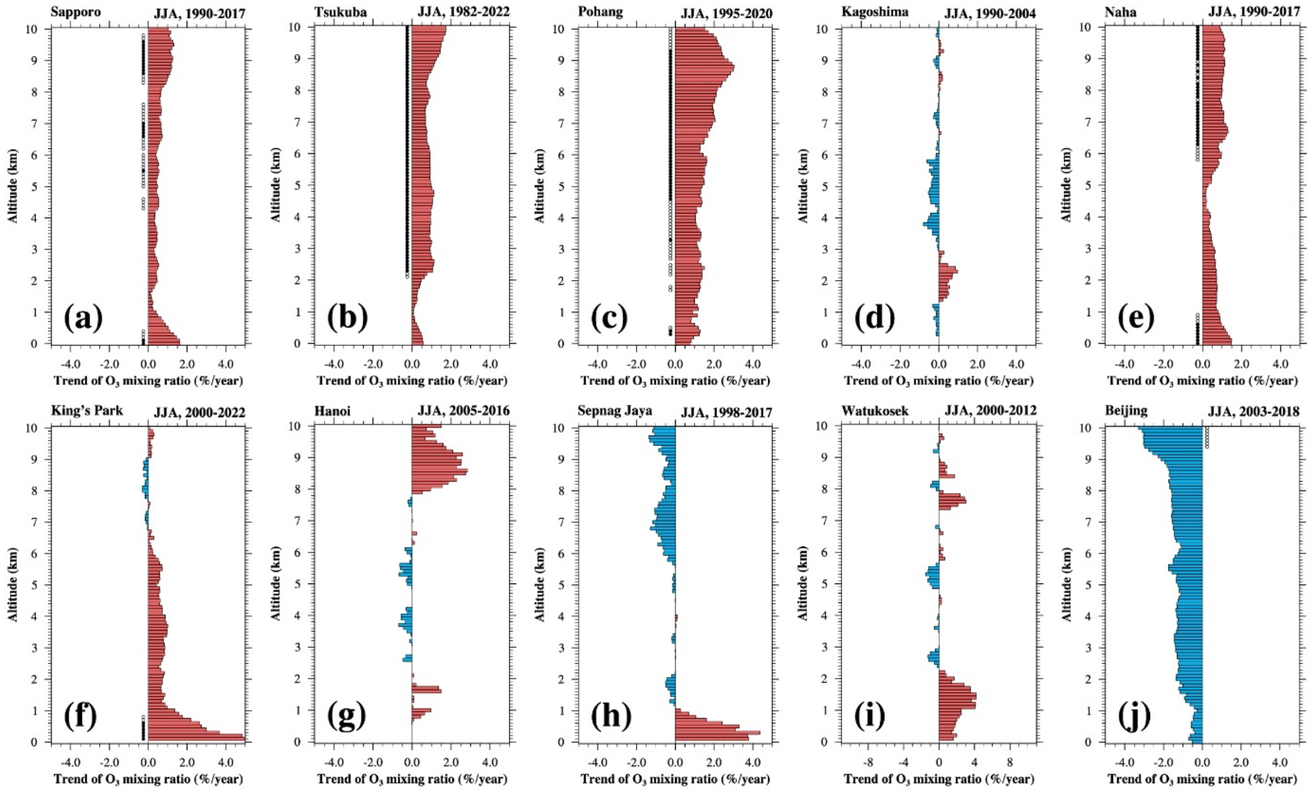

Figure S4. Same as Figure S3 but for long-term trends of summer (JJA) mean ozone.

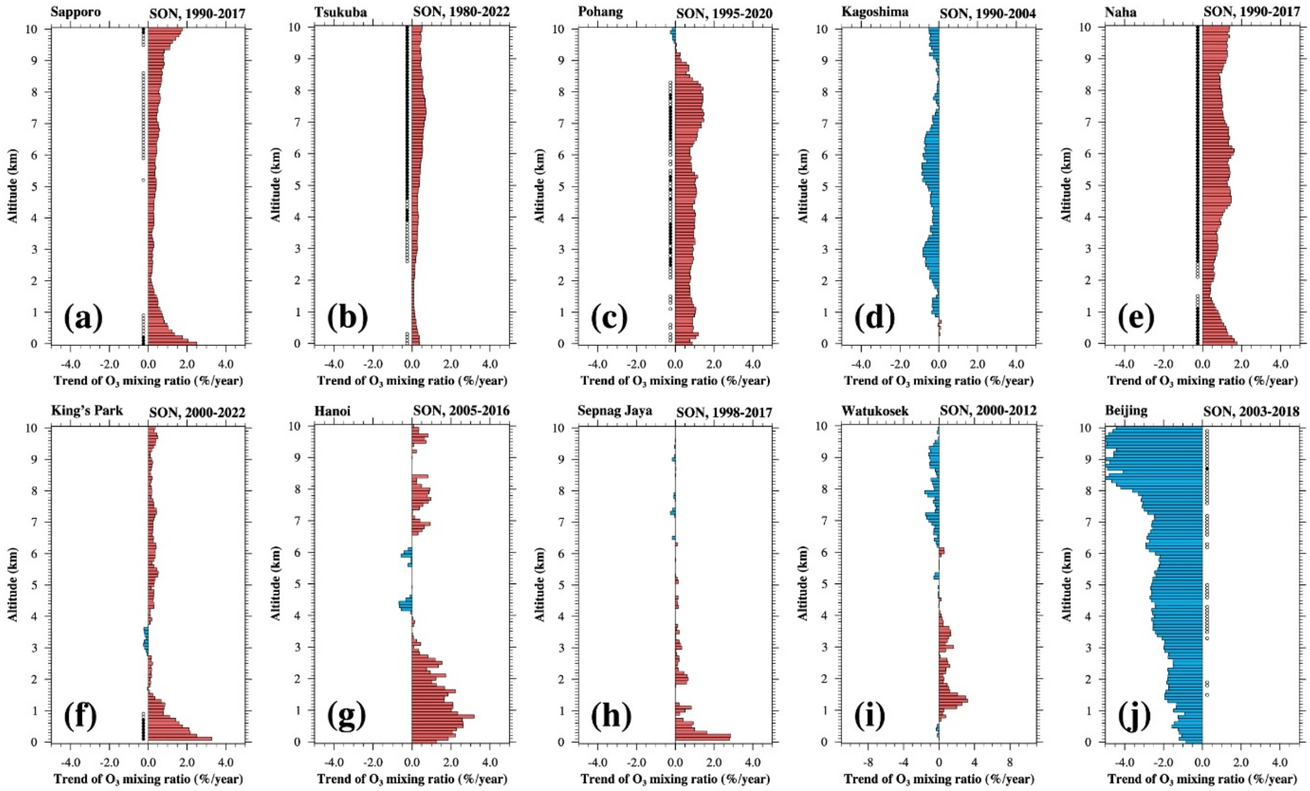

Figure S5. Same as Figure S3 but for long-term trends of autumn (SON) mean ozone.

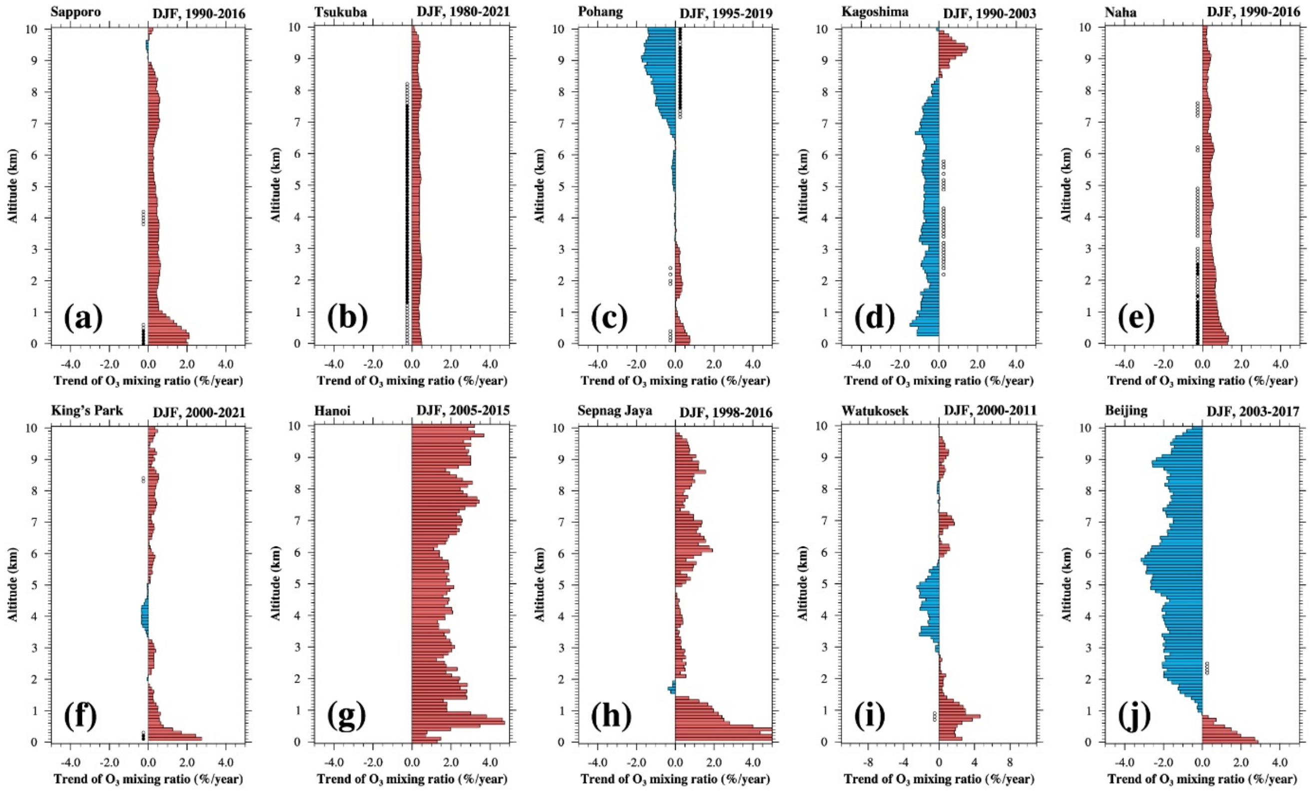

Figure S6. Same as Figure S3 but for long-term trends of winter (DJF) mean ozone.

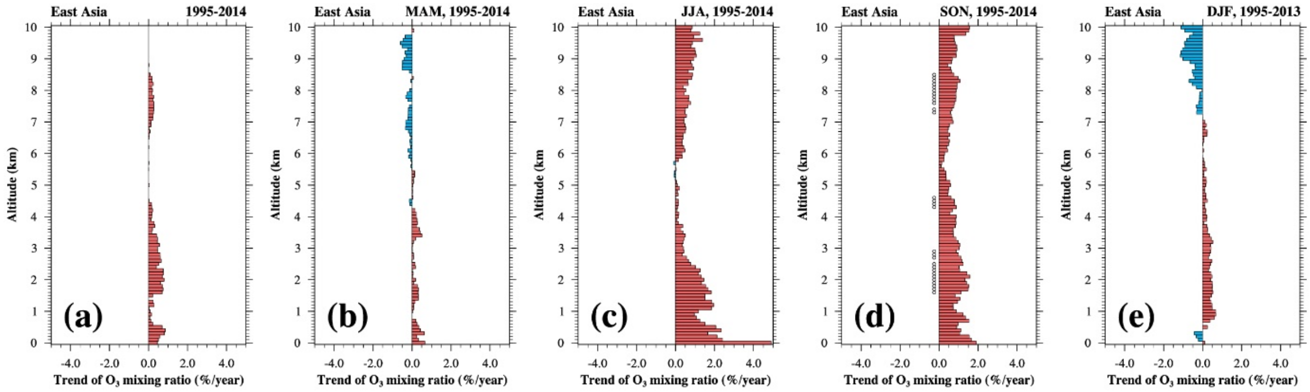

Figure S7. Long-term trends of (a) annual, (b) MAM, (c) JJA, (d) SON, and (e) DJF mean ozone in Northeast Asia obtained from the IAGOS aircraft measurement. The period of used data is from 1995 to 2014.

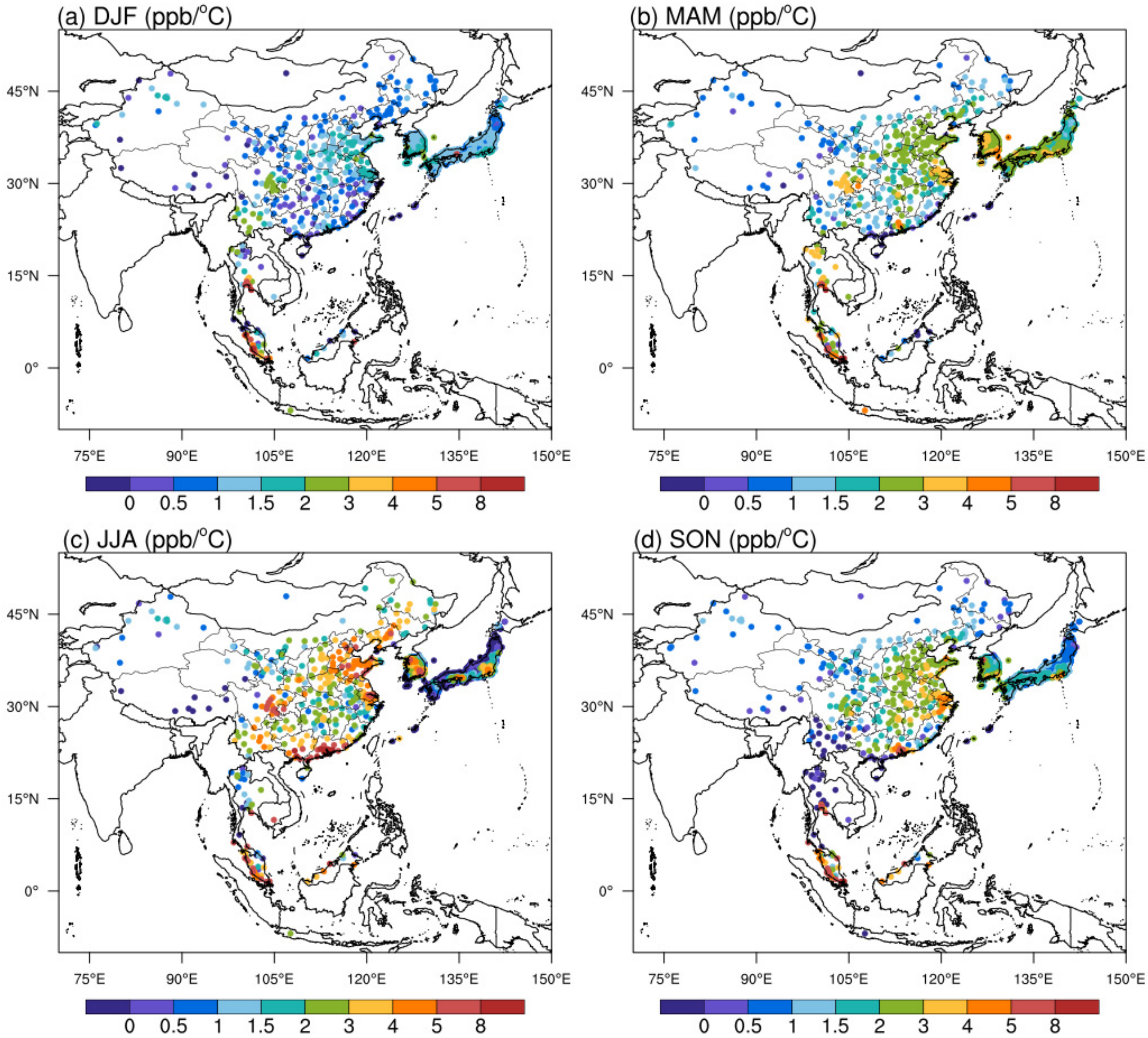

Figure S8. The observed 95th percentile regression slope (ppb °C^{-1}) between daily surface MDA8 ozone and daily maximum 2-m air temperature (Tmax) in (a) DJF, (b) MAM, (c) JJA, and (d) SON averaged over 2017-2021.

Reference

He, J., Wang, Z., Guo, M., Gu, Y., Jiang, M., Hu J., Wu X., and Chai, F.: Research on global ambient air quality standards and future prospects of China's standards[J]. Res. Environ. Sci. (in Chinese), 37(9), 1897-1910, https://doi.org/10.13198/j.issn.1001-6929.2024.07.07, 2024.