Supporting Information for

Observational Insights into Atmospheric CO_2 and CO at the Urban Canopy Layer Top in Metropolitan Shanghai, China

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Submitted to: *Atmospheric Chemistry and Physics*

Number of pages: 11

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Tables:

Table S1: Measured CO_2 mixing ratio (ppm) at different sites during nearly concurrent periods.

Observation Site	Category	Geography	Period	CO_2 (±SD or 95% CI*)	Reference
Sutro Tower (STR), California, USA	Urban	122.45°W, 37.76°N; 254 m a.s.l	2021	420.47 ± 11.23	NOAA [a]
Yongsan Building (YSB), Seoul, South Korea	Urban	126.96°E, 37.52°N; 113 m a.s.l	2019/7–2020/9	442.99 ± 18.67	Park et al. (2021)
Lulin (LLN), Taibei, China	Regional background	120.87°E, 23.47°N; 2862 m a.s.l	2021	417.21 ± 3.43	NOAA [a]
King's Park (HKO), Hong Kong, China	Regional background	114.17°E, 22.31°N; 65 m a.s.l	2021	439.11 ± 6.87	NOAA [a]
Waliguan (WLG), China	Global background	100.54°E, 36.17°N; 3810 m a.s.l	2021/4–2023/3	418.95 ± 3.65	NOAA [a]
Mauna Loa (MLO), Hawaii, USA	Global background	155.58°W, 19.54°N; 3397 (+5; +40) m a.s.l	2021/4–2023/3	418.12 ± 2.54; 417.80 ± 2.48	NOAA [a]
Cape Grim, Tasmania, Australia	Global background	144.70°E, 40.68°S; 94 m a.s.l	2021/4–2023/3	413.66 ± 1.34	NOAA [a]
Longfengshan (LFS), Harbin, Heilongjiang, China	Regional background	127.60°E, 44.73°N; 331 m a.s.l.	2021–2022	422.8 ± 0.5–424.9 ± 0.6	China GHG Bulletin[c]
Shangdianzi (SDZ), Beijing, China	Regional background	117.12°E, 40.65°N; 293.3 m a.s.l.	2021–2022	427.7 ± 0.4–428.7 ± 0.4	China GHG Bulletin [c]
Akedala station, Altay region, Xinjiang, China	Regional background	87.93°E, 47.10°N; 563.3 m a.s.l.	2019/11; 2021–2022	~ 410.43; 419.1 ± 0.6–421.4 ± 1.3	Zhao et al. (2022); China GHG Bulletin [c]
Lin'an (LAN), Zhejiang, China	Regional background	119.44°E, 30.18°N; 138.6 m a.s.l	2020/11–2021/10	441.56 ± 15.42	Chen et al. (2024)
Hangzhou (HZ), Zhejiang, China	Urban	120.17°E, 30.22°N; 41.7 m a.s.l	2020/11–2021/10	446.52 ± 17.01	Chen et al. (2024)
Jungfraujoch (JFJ), Switzerland	High-altitude mountain	7.99°E, 46.55°N; 3580 m a.s.l	2021/4–2023/3	418.30 ± 5.39	WDCGG [d]
ABLECAS site, Zhejiang, China	High-altitude mountain	119.51°E, 28.58°N; 1128 m a.s.l	2022/7/10–2021/6/20	426.3 ± 10.0	Ye et al. (2024)
Damingshan (DMS), Zhejiang, China	High-altitude mountain	119.00°E, 30.01°N; 1489.9 m a.s.l	2020/11–2021/10; 2021/4–2022/12	422.02 ± 10.67; 419.38 ± 2.30*	Chen et al. (2024); This study
Shanghai Tower (SHT), Shanghai, China	Urban	121.51°E, 31.23°N; 637.0 m a.s.l.	2021/4/17–2023/3/6	433.50 ± 0.33*	This study
			Spring Summer Autumn Winter	428.16 ± 0.45* 426.98 ± 0.49* 437.55 ± 0.65* 440.73 ± 0.86*	
Global Annual Mean			2021–2022	415.7 ± 0.20–417.9 ± 0.20	WMO (2022, 2023) [b]

[a] Derived from NOAA (available at: https://gml. noaa.gov/dv/iadv/, last access: August 2025); [b] Retrieved from WMO Greenhouse Gas Bulletin, No. 18–26 &19–15 (available at: https://library.wmo.int/records/, last access: 9 September 2025); [c] Retrieved from China Greenhouse Gas Bulletin (available at: https://www.cma.gov.cn/zfxxgk/gknr/qxbg/, last access: 10 September 2025); [d] Derived from WDCGG (available at: https://gaw.kishou.go.jp/, last access: November 2025).

Table S2: Observed CO_2 (ppm) and CO (ppb) mole fractions at the SHT site and their relative excesses above background levels.

Periods	CO_2	$CO_{2,\,bk}$	$CO_{2,\,ex}$ (ff; bio-dominated)	CO	CO_{bk}	CO_{ex}
Spring	427.7 ± 12.7	423.2 ± 7.9	4.4 (3.7; 0.7)	199.7 ± 138.0	162.5 ± 92.1	37.2
Summer	424.9 ± 12.0	420.5 ± 5.8	4.4 (6.4; –2.0)	252.3 ± 187.3	152.3 ± 65.6	100.0
Autumn	437.2 ± 19.4	428.9 ± 10.0	8.3 (7.1; 1.2)	428.5 ± 346.3	281.1 ± 162.9	147.4
Winter	443.8 ± 24.5	432.4 ± 15.5	11.4 (8.3; 3.1)	387.1 ± 304.5	278.3 ± 170.9	108.7
No-rain periods	434.4 ± 19.9	426.9 ± 11.7	7.5 (6.4; 1.1)	325.7 ± 283.4	226.8 ± 149.3	98.9

Figures:

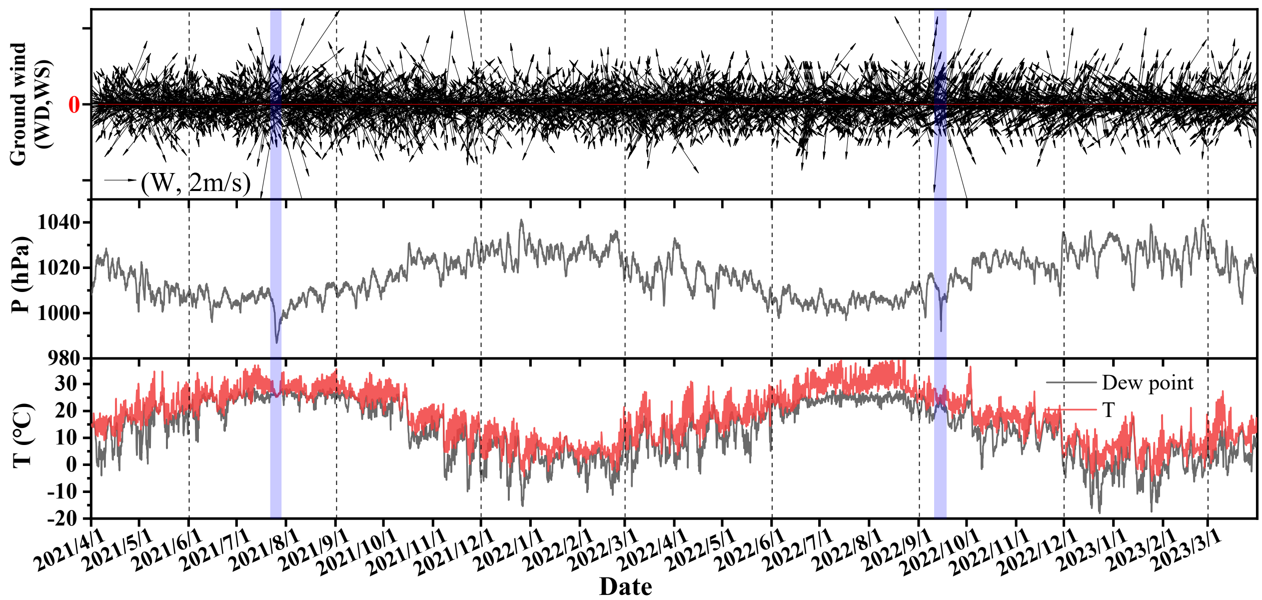

Figure S1: The time series of the ground wind, air pressure and temperature during this campaign with a 3-h time resolution from Baoshan Meteorological Station (BS; 31.23°N, 121.29°E; 20.9 km from SHT). Blue shaded areas mark typhoon events (July 25–26, 2021, and September 14–15, 2022).

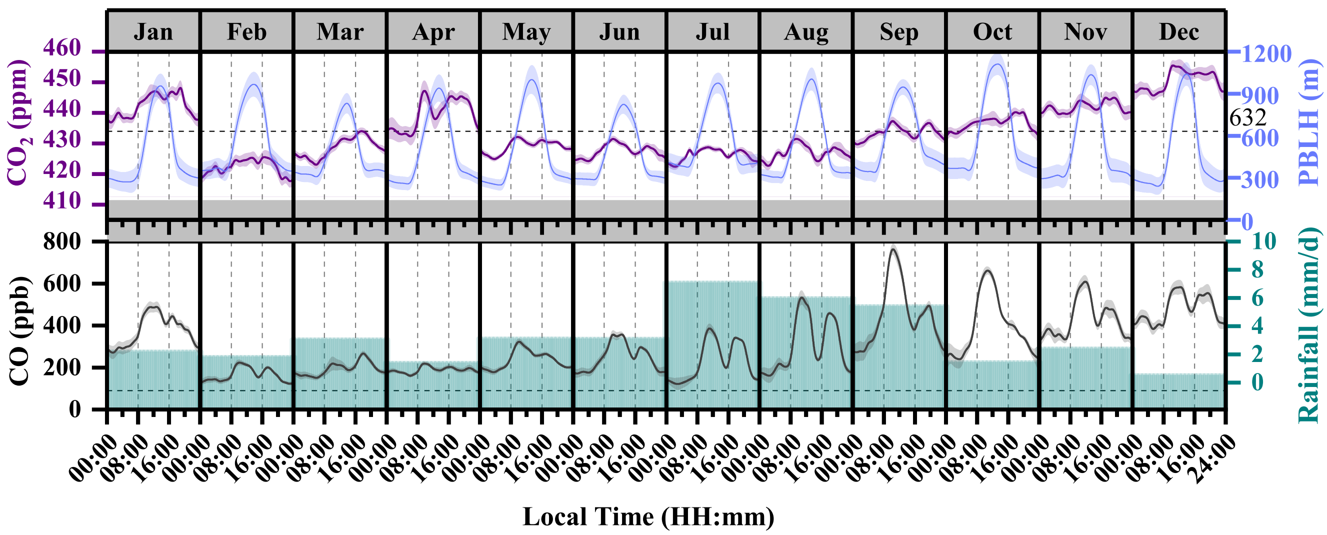

Figure S2: Diurnal cycles for various species and parameters for different months during the campaign at SHT site. Rainfall data were processed from the BS station at 6-h intervals.

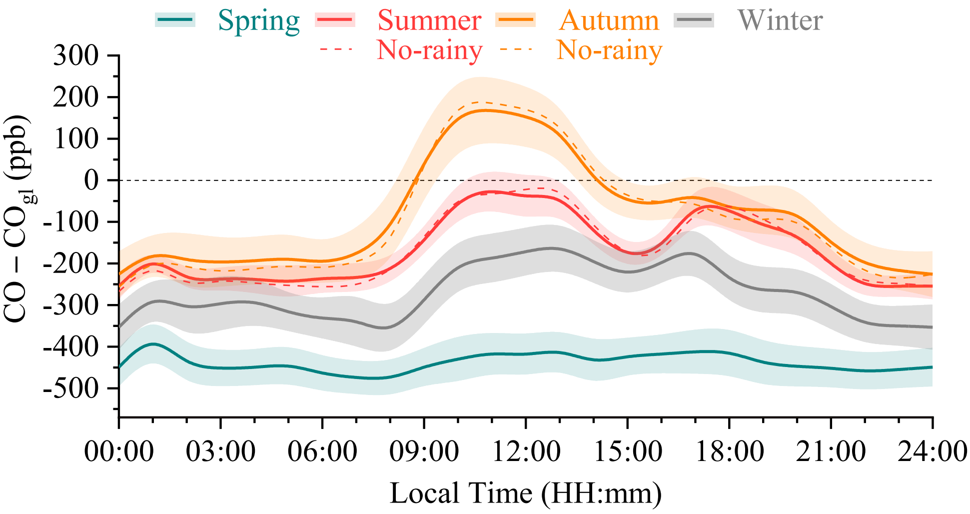

Figure S3: The variations on concentration differences of CO between the tower top (expressed as CO_{st} here) and the ground (CO_{gl}).

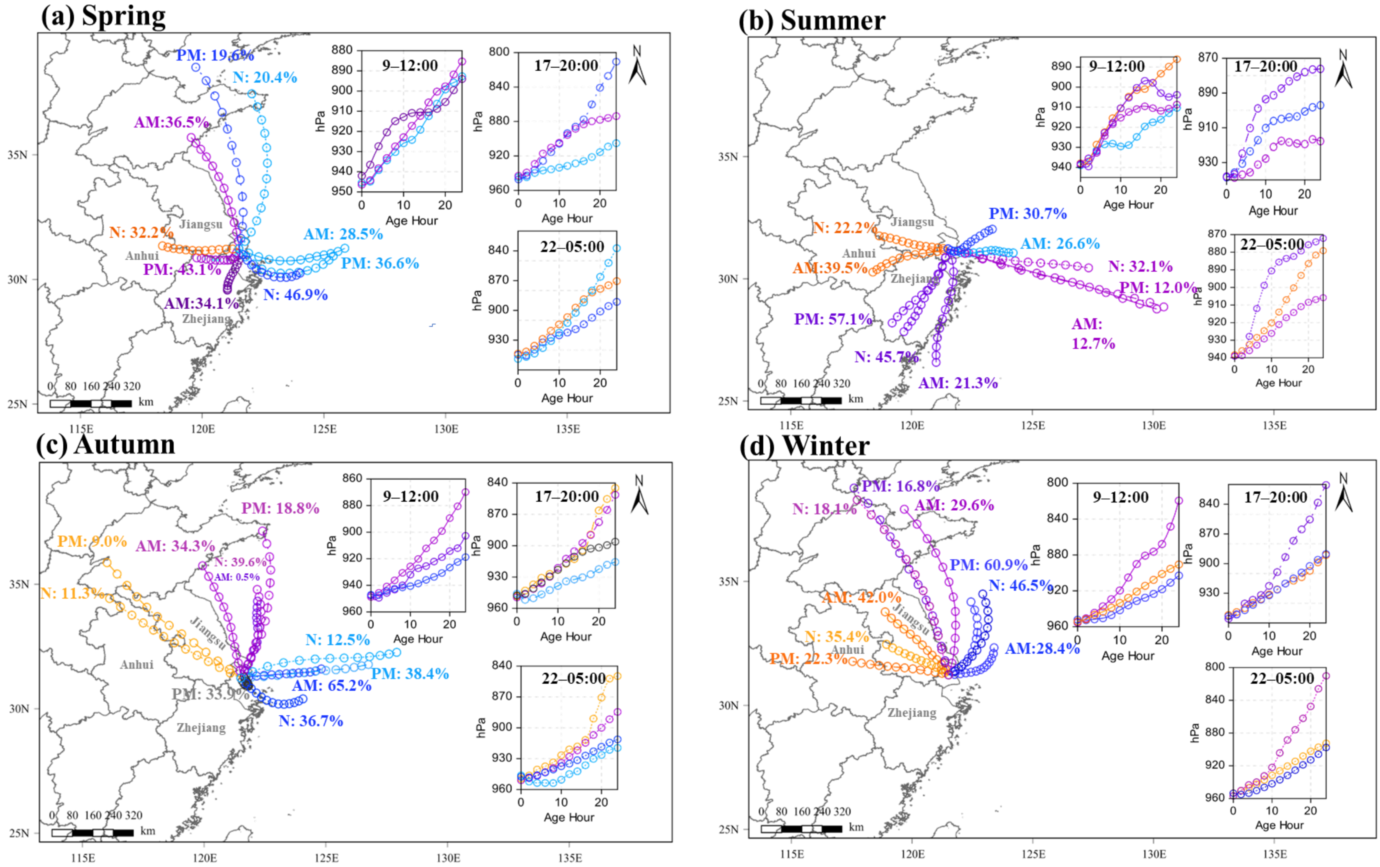

Figure S4: Cluster analysis of the 24-h back trajectories at SHT site for the AM (9:00–12:00), PM (17:00–20:00), and N (22:00–05:00) periods.

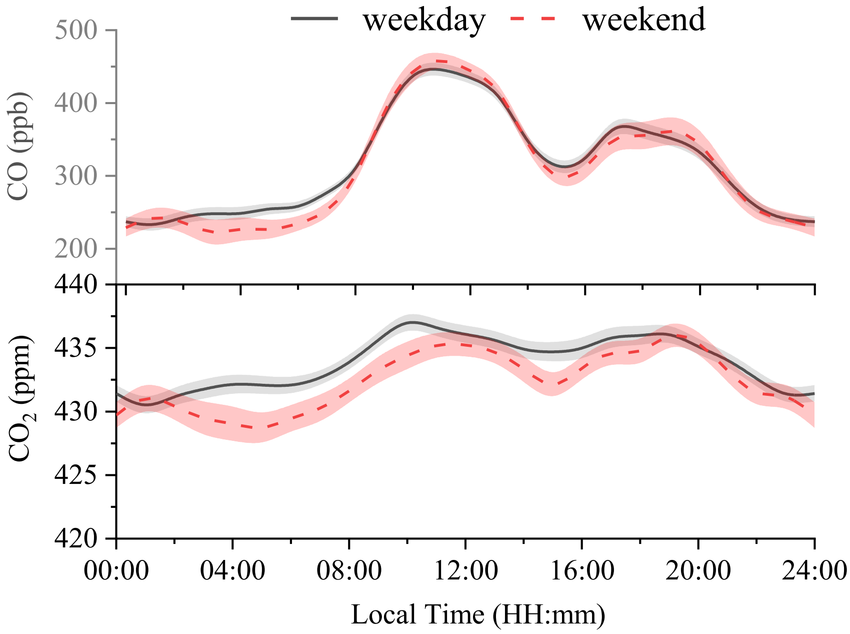

Figure S5: The diurnal variations of atmospheric CO_2 and CO between weekdays and weekends at the SHT site.

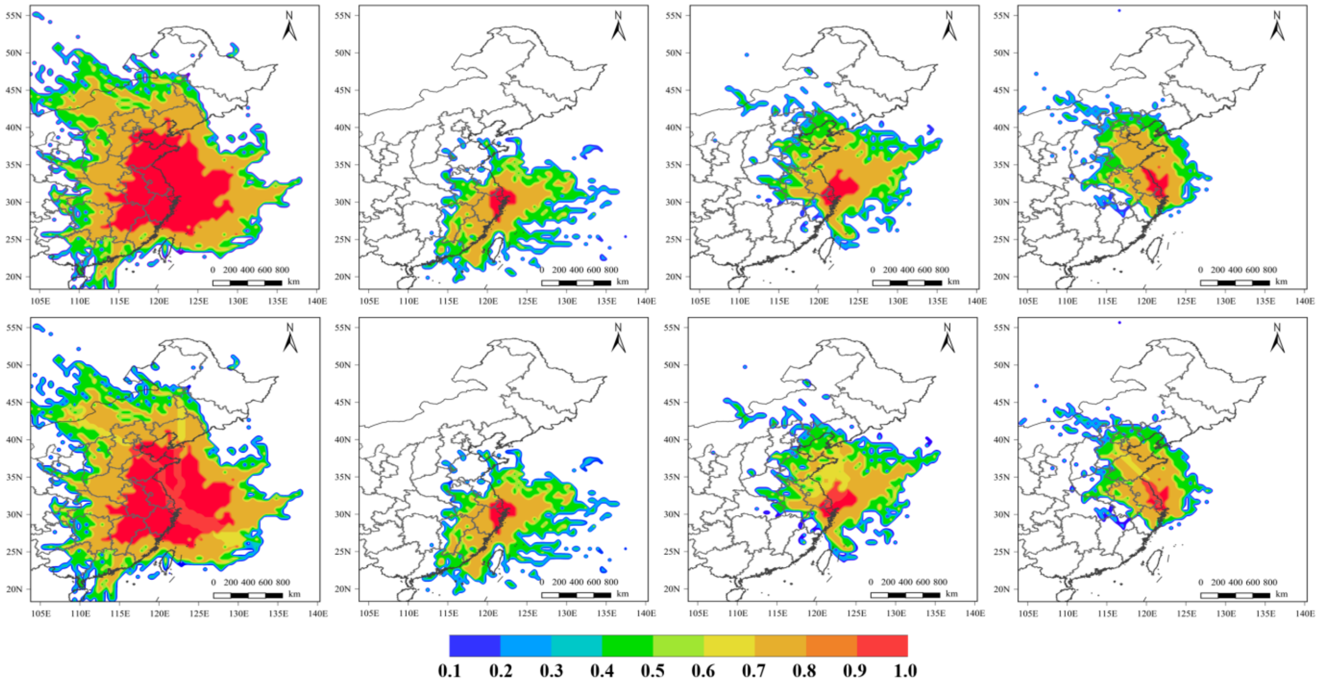

Figure S6: The spatial contribution of potential sources using the Weighted Potential Source Contribution Function (WPSCF; see main text Section 2.2) based on 3-day back trajectories.

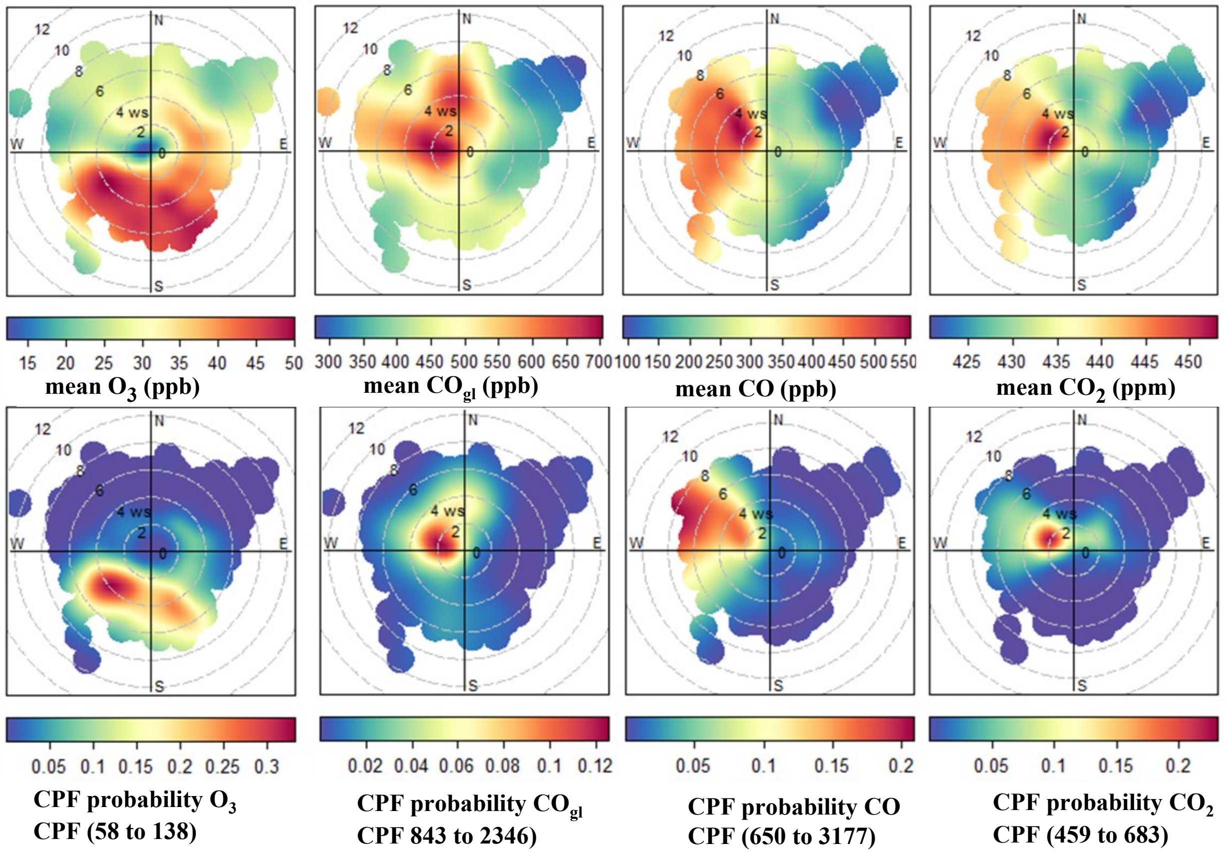

Figure S7: The wind rose plots of ground-level O_3 and CO, and tower-top CO and CO_2 measurements and the corresponding Conditional Probability Function (CPF) statistics for their upper 10% values.

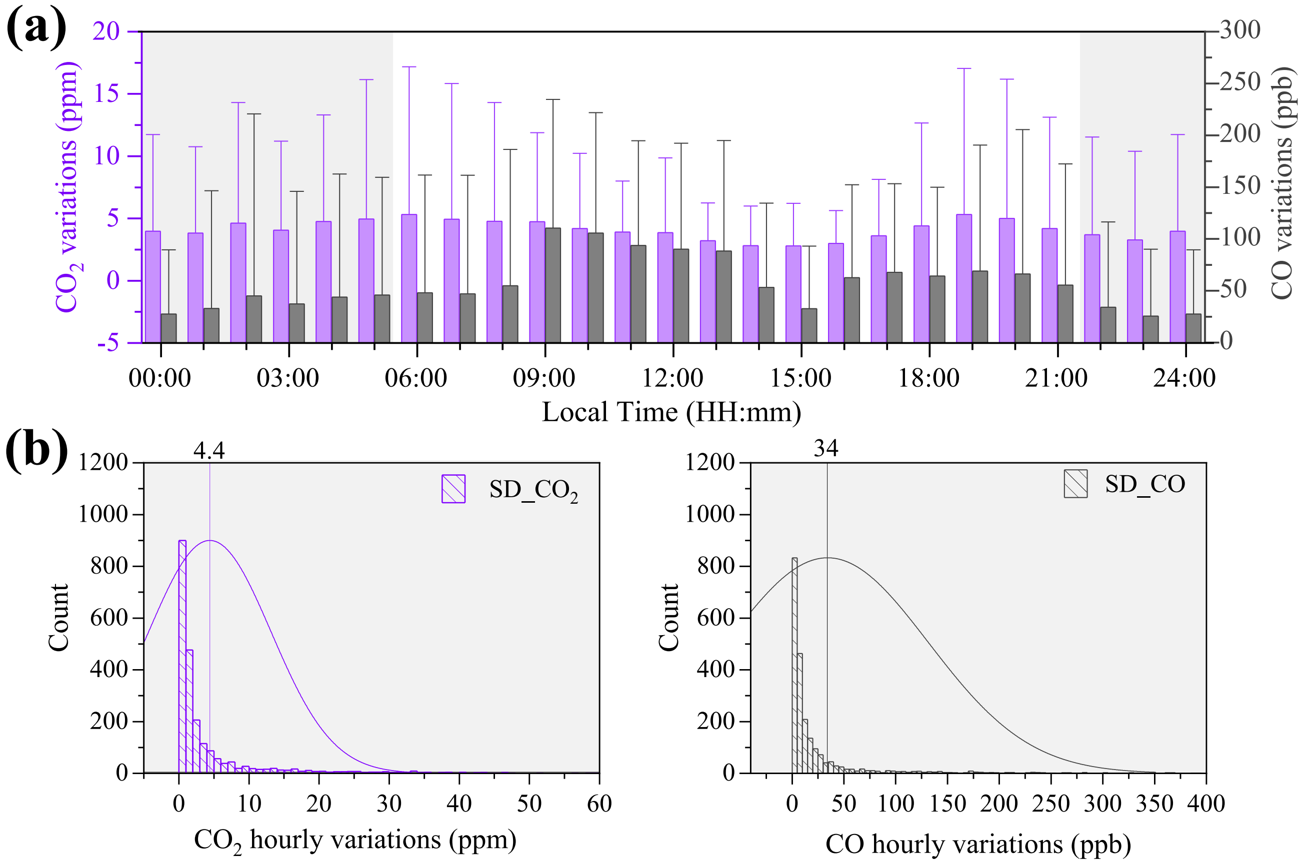

Figure S8: Mean diurnal cycles of CO_2 and CO variations (hourly standard deviation, SD, at SHT) and their distributions based on 1-h resolution data.

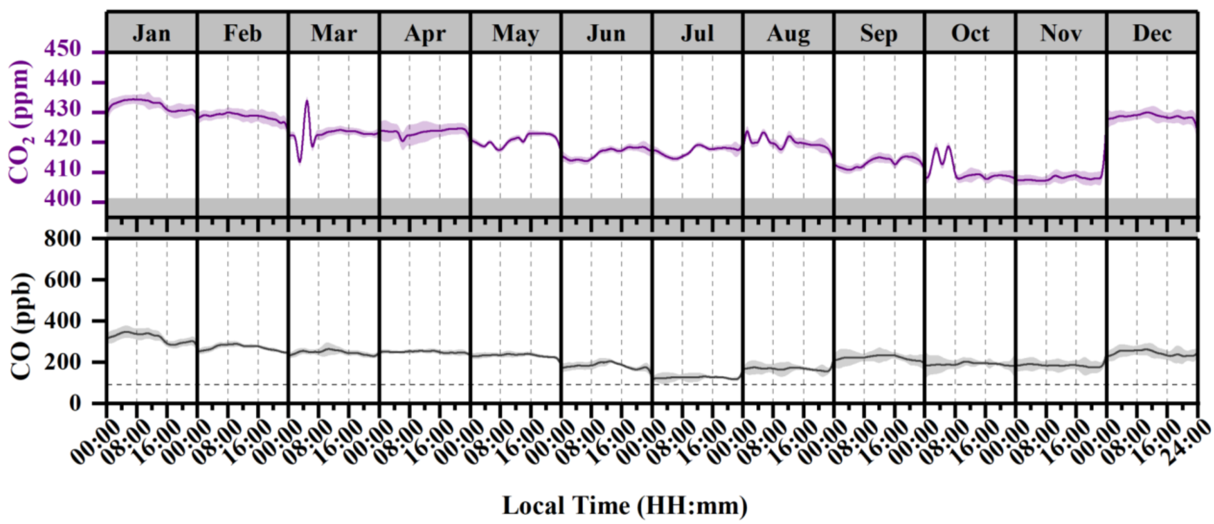

Figure S9: The averaged diurnal cycles of atmospheric CO_2 and CO concentrations over different months measured at the DMS site during April 2021–December 2022.

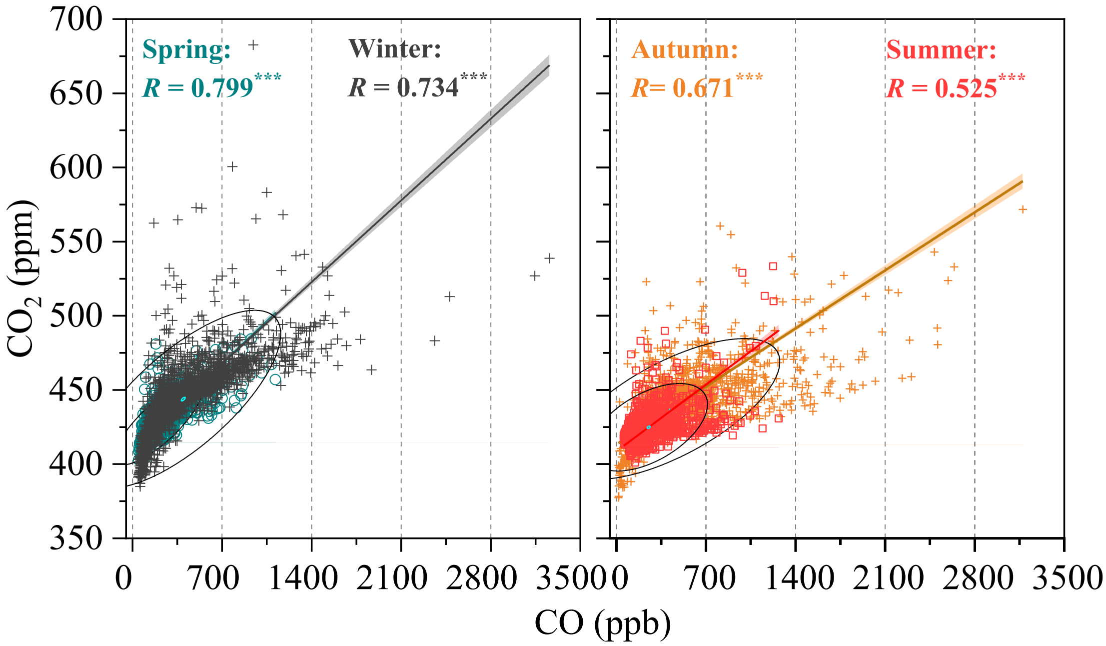

Figure S10: Correlations of concurrent CO_2 and CO measurements of different seasons at the SHT site.

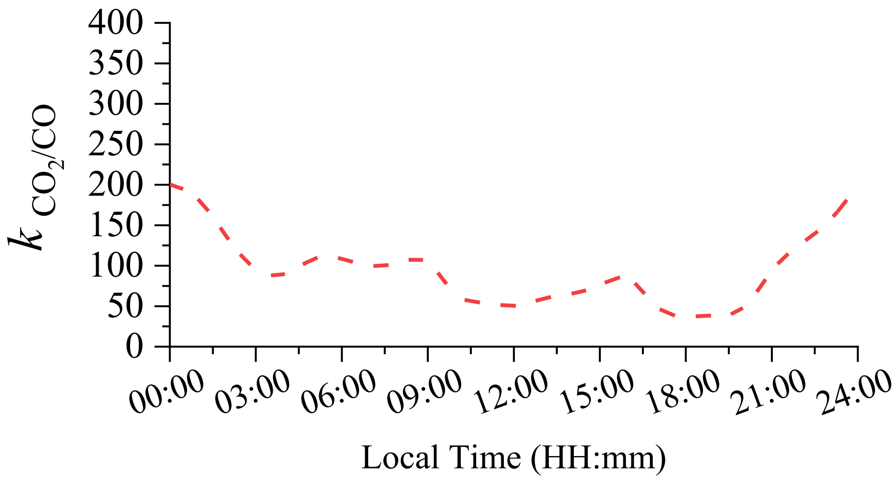

Figure S11: Time-dependent $k_{CO_2/CO}$ as a function of local time in summer for the SHT site.

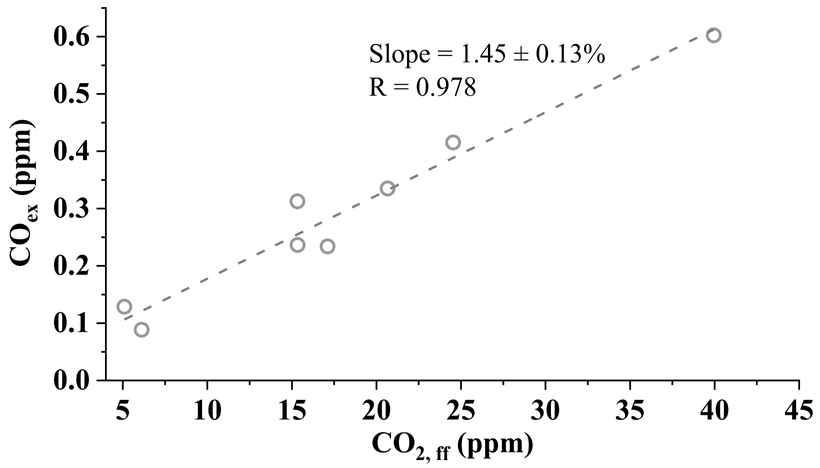

Figure S12: Correlations between the mole fractions of excess CO (CO_{ex}) and fossil fuels-derived CO_2 ($CO_{2,\ ff}$) at the site of Hengxiwu (HXW, 119.48°E, 30.60°N; 200 m a.s.l.) in the Yangtze River Delta (YRD) region. The CO_{ex} was estimated relative to the background station WLG, representative of the Northern Hemisphere mid-latitude interior. The $CO_{2,\ ff}$ was quantified using the CO_2-$\Delta^{14}C$ method, according to Levin et al. (2003) and Vásquez et al. (2022).

References

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