



Supplement of

Quantitative impacts of vertical transport on the long-term trend of nocturnal ozone increase over the Pearl River Delta region during 2006–2019

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Supplement

Table S1. Information of air quality monitoring stations

City	Site (Abbreviation)	Latitude	Longitude
Dongguan	Nanchengyuanling (NCYL)	23.0	113.7
	Jinjuju (JJJ)	22.8	113.3
	Huijingcheng (HJC)	23.0	113.1
Foshan	Luhu (LH)	23.2	113.3
	Wanqingsha (WQS)	22.7	113.5
	Tianhu (TH)	23.6	113.6
Guangzhou	Tap Mun (TM)	22.5	114.4
	Tsuen Wan (TW)	22.4	114.1
	Tung Chung (TC)	22.3	113.9
Hong Kong	Xiapu (XP)	23.1	114.4
	Jinguowan (JGW)	22.9	114.4
Huizhou	Donghu (DH)	22.6	113.1
	Liyuan (LY)	22.5	114.1
Zhuhai	Tangjia (TJ)	22.4	113.6
Zhaoqing	Chengzhong (CZ)	23.1	112.5
Zhongshan	Zimaling (ZML)	22.5	113.4

Table S2. Information of meteorological stations

City	Station (Abbreviation)	Latitude	Longitude
Dongguan	Dongguan (DG)	23.0	113.8
Foshan	Shunde (SD)	22.8	113.2
Guangzhou	Guangzhou (GZ)	23.1	113.3
Huizhou	Huiyang (HY)	23.0	114.2
Jiangmen	Taishan (TS)	22.2	112.5
Shenzhen	Shenzhen (SZ)	22.6	114.1
Zhuhai	Zhuhai (ZH)	22.2	113.3
Zhaoqing	Gaoyao (GY)	23.0	112.5
Zhongshan	Zhongshan (ZS)	22.6	113.4

Table S3. Site-specific values of KI and CTT for the randomly selected cases with KI > 30 °C

Time (LT)	Site	KI (°C)	CTT (°C)	Figure
2019/04/11 22:00	WQS	33	-49	Figure S1 (a)
2019/04/16 00:00	XP	33	-45	Figure S1 (b)
2019/05/26 00:00	JJJ	32	-62	Figure S1 (c)
2019/06/25 23:00	DH	34	-51	Figure S1 (d)
2019/07/02 22:00	NCYL	35	-54	Figure S1 (e)
2019/07/21 21:00	NCYL	32	-47	Figure S1 (f)
2019/08/08 22:00	LY	39	-70	Figure S1 (g)
2019/08/24 23:00	LY	31	-68	Figure S1 (h)
2019/09/14 23:00	HJC	31	-48	Figure S1 (i)
2019/10/07 00:00	TJ	37	-68	Figure S1 (j)

Table S4. Site-specific values of KI and CTT for the randomly selected cases with KI < 30 °C

Time (LT)	Site	KI (°C)	CTT (°C)	Figure
2019/04/12 22:00	WQS	29	12	Figure S2 (a)
2019/04/17 00:00	XP	11	Cloudless	Figure S2 (b)
2019/05/03 00:00	JJJ	29	2	Figure S2 (c)
2019/06/27 23:00	DH	25	Cloudless	Figure S2 (d)
2019/07/04 22:00	NCYL	26	-3	Figure S2 (e)
2019/07/25 21:00	NCYL	27	Cloudless	Figure S2 (f)
2019/08/04 22:00	LY	26	-20	Figure S2 (g)
2019/08/20 23:00	DH	29	-6	Figure S2 (h)
2019/09/15 23:00	HJC	28	Cloudless	Figure S2 (i)
2019/10/08 00:00	TJ	26	19	Figure S2 (j)

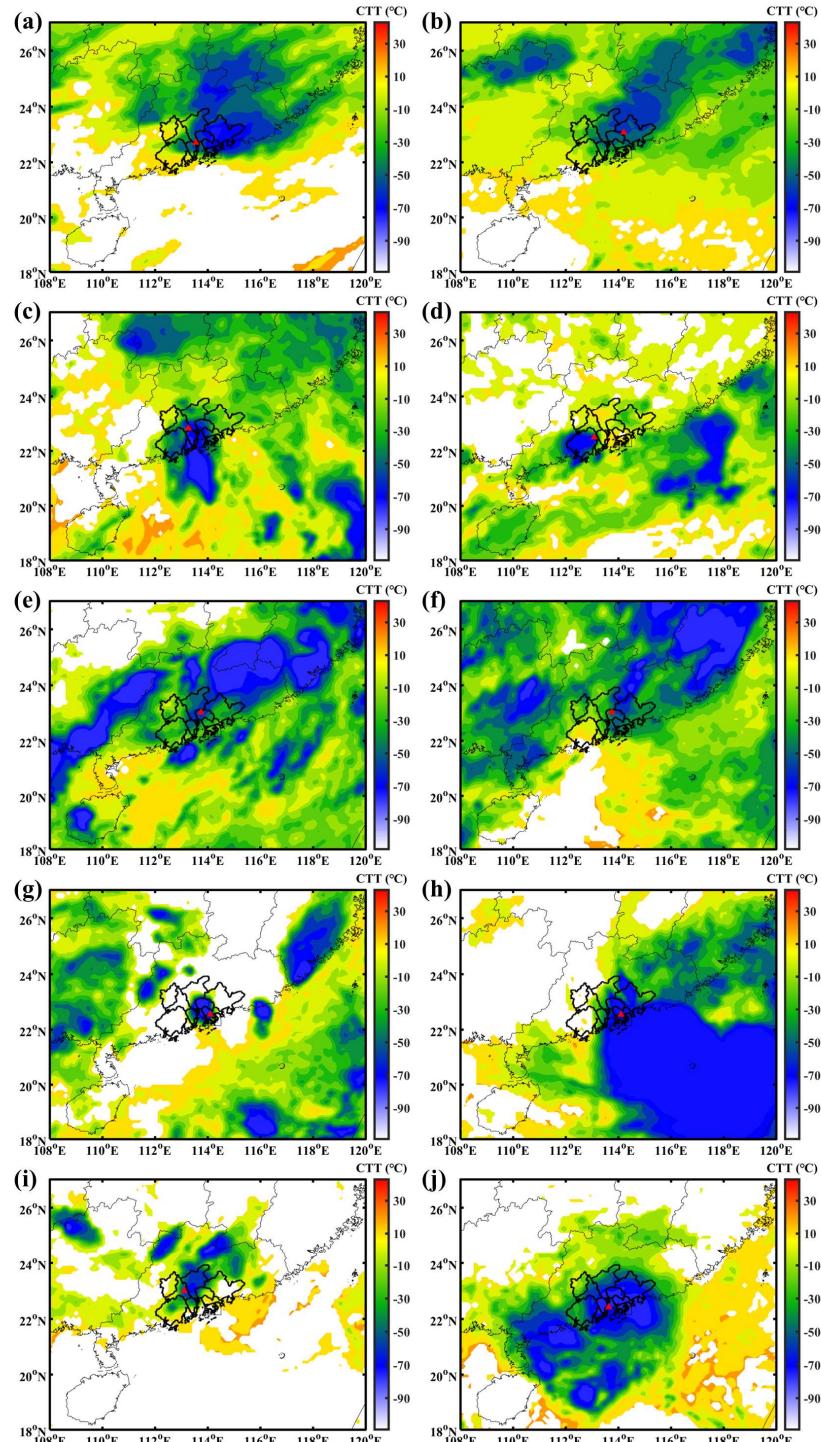


Figure S1. Spatial distribution of CTT for the randomly selected cases with $KI > 30$ °C. (a) to (j) refer to Table S3.

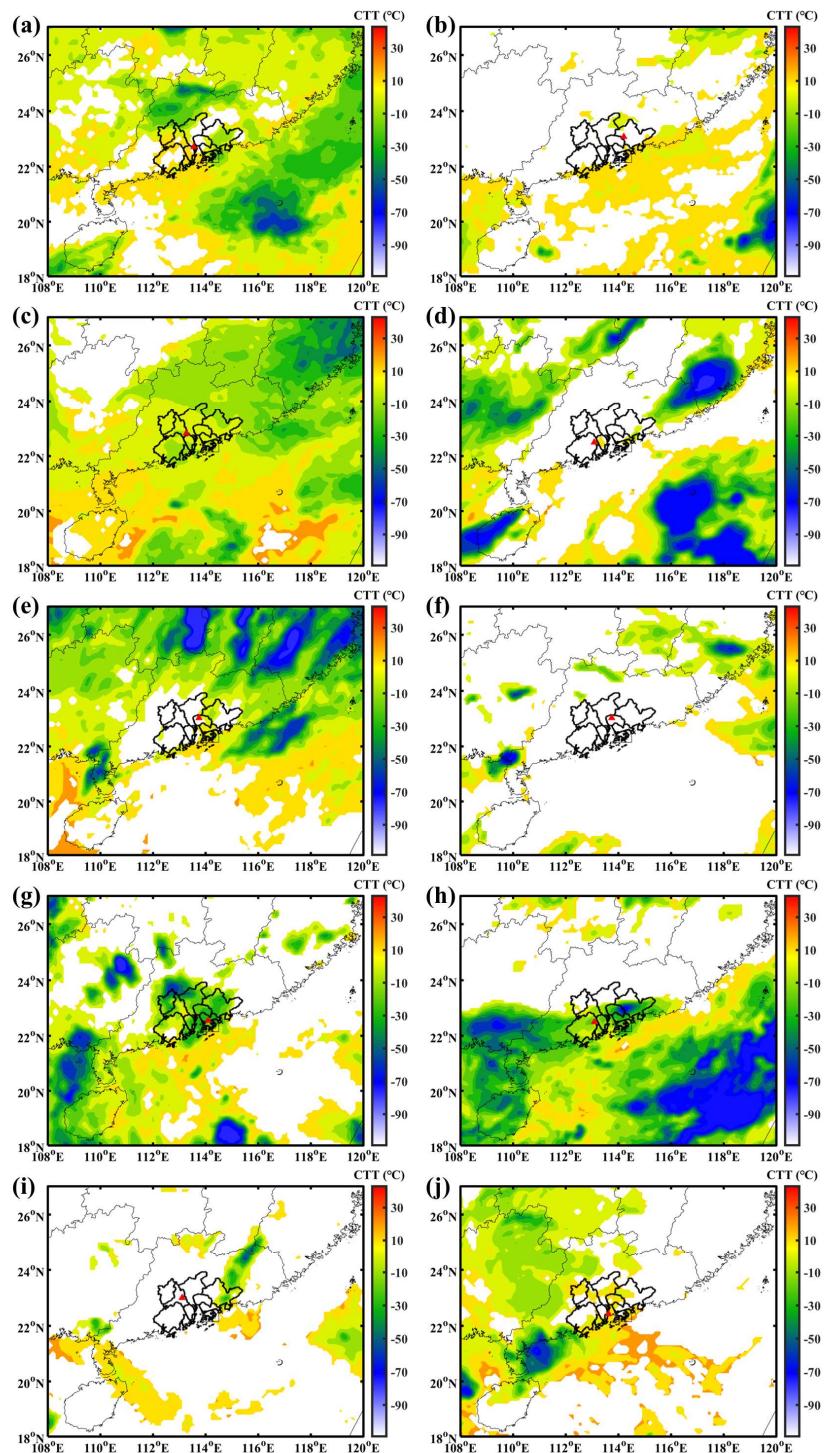


Figure S2. Spatial distribution of CTT for the randomly selected cases with $KI < 30^{\circ}\text{C}$. (a) to (j) refer to Table S4.

Table S5. The annual average NOI frequency (relative contribution) caused by different meteorological processes at the 16 air quality monitoring sites during 2006-2019

Site	LLJs (d y ⁻¹)	Conv (d y ⁻¹)	LLJs+Conv (d y ⁻¹)	Others (d y ⁻¹)
LH	28 (68%)	3 (7%)	6 (15%)	4 (10%)
WQS	24 (56%)	4 (10%)	7 (16%)	7 (17%)
TH	21 (59%)	3 (9%)	7 (19%)	5 (14%)
LY	34 (61%)	6 (11%)	10 (18%)	5 (9%)
JJJ	23 (63%)	3 (7%)	6 (16%)	5 (14%)
HJC	21 (68%)	1 (4%)	5 (17%)	3 (11%)
TJ	37 (51%)	10 (13%)	14 (20%)	12 (16%)
DH	21 (60%)	4 (10%)	6 (18%)	4 (12%)
CZ	26 (67%)	3 (8%)	5 (14%)	4 (11%)
XP	43 (70%)	5 (8%)	7 (11%)	6 (11%)
JGW	31 (66%)	4 (9%)	6 (12%)	6 (12%)
ZML	17 (56%)	4 (12%)	5 (18%)	4 (14%)
NCYL	36 (61%)	5 (9%)	9 (15%)	9 (15%)
TM	29 (58%)	6 (13%)	9 (18%)	5 (10%)
TW	40 (54%)	10 (14%)	13 (18%)	11 (14%)
TC	37 (52%)	9 (13%)	14 (20%)	11 (15%)

Table S6. Statistical metrics of meteorological variables at the 9 meteorological sites during 8-14 September 2017

Parameter	Site	SIM _{mean}	OBS _{mean}	MB	NMB (%)	NME (%)	r	RMSE	IoA
WS10 (m s ⁻¹)	GZ	1.3	1.6	0.3	-23.5	42.3	0.5	0.9	0.9
	DG	1.3	2.0	0.7	-33.8	47.9	0.4	1.1	0.9
	HY	1.8	1.7	-0.1	6.5	52.3	0.4	1.1	0.9
	TS	2.7	1.8	-0.9	50.1	65.4	0.5	1.5	0.9
	SD	2.9	1.8	-1.1	60.5	76.3	0.3	1.8	0.9
	ZS	2.7	1.6	-1.1	70.8	84.1	0.5	1.6	0.9
	ZH	2.0	2.5	0.5	-21.4	44.6	0.4	1.4	0.9
	GY	2.2	1.9	-0.3	14.9	59.9	0.3	1.5	0.9
	SZ	2.3	1.5	-0.8	58.2	86.7	0.2	1.7	0.8
	Regional average	2.1	1.8	-0.3	16.1	29.0	0.7	0.7	1.0
RH (%)	GZ	81.8	86.3	4.5	-5.3	9.4	0.8	11.3	1.0
	DG	82.7	81.7	-1.0	1.2	10.8	0.8	10.8	1.0
	HY	87.1	84.2	-2.9	3.4	7.3	0.8	8.4	1.0
	TS	89.8	81.5	-8.3	10.2	11.9	0.7	12.4	1.0
	SD	84.0	77.5	-6.5	8.4	13.6	0.7	12.6	1.0
	ZS	86.7	81.5	-5.2	6.3	10.1	0.7	10.8	1.0
	ZH	86.4	77.7	-8.7	11.3	15.3	0.6	14.0	1.0
	GY	91.0	86.1	-4.9	5.7	10.0	0.6	12.5	1.0
	SZ	91.4	77.7	-13.7	17.6	17.8	0.7	15.8	1.0
	Regional average	83.7	77.6	-6.1	7.9	9.0	0.9	8.2	1.0
T2 (°C)	GZ	27.7	27.9	0.2	-1.0	5.4	0.8	2.0	1.0
	DG	28.5	29.0	0.5	-3.2	5.4	0.8	1.9	1.0
	HY	27.6	28.3	0.7	-2.4	4.7	0.8	1.7	1.0
	TS	27.5	29.1	1.6	-5.7	7.0	0.7	2.5	1.0
	SD	28.7	29.9	1.2	-4.2	5.7	0.8	2.2	1.0
	ZS	28.1	28.9	0.8	-2.7	4.1	0.9	1.5	1.0
	ZH	27.7	29.0	1.3	-4.5	6.2	0.6	2.2	1.0
	GY	26.1	28.6	2.5	-8.8	9.0	0.7	3.1	1.0
	SZ	27.7	27.9	0.2	-5.4	5.8	0.7	2.1	1.0
	Regional average	27.7	29.1	1.4	-4.9	5.1	0.9	1.7	1.0

Table S7. Statistical metrics for O₃ at the 16 air quality monitoring sites during 8-14 September 2017

Site	SIM _{mean} ($\mu\text{g m}^{-3}$)	OBS _{mean} ($\mu\text{g m}^{-3}$)	MB ($\mu\text{g m}^{-3}$)	NMB (%)	NME (%)	r	RMSE	IoA
LH	33.2	39.2	6.1	-14.5	31.8	0.8	30.0	0.9
WQS	62.2	67.7	5.5	-8.1	36.8	0.8	37.7	0.9
TH	82.0	77.7	-4.3	5.5	25.2	0.7	27.6	1.0
LY	42.2	51.6	9.4	-18.3	39.7	0.8	29.9	0.9
JJJ	59.0	59.5	0.5	-0.9	13.6	0.9	14.0	1.0
HJC	65.7	78.7	13.0	-16.6	34.0	0.9	35.8	1.0
TJ	82.9	78.7	-4.2	5.3	26.6	0.9	25.9	1.0
DH	49.7	59.2	9.5	-16.0	32.8	0.9	26.2	1.0
CZ	87.9	79.7	-8.2	10.3	21.1	0.9	30.7	1.0
XP	50.1	55.3	5.2	-9.4	42.7	0.7	32.7	0.9
JGW	85.6	58.0	-27.6	37.6	44.7	0.6	44.5	0.9
ZML	57.8	70.4	12.7	-18.0	31.8	0.9	30.5	1.0
NCYL	56.6	61.0	4.4	-12.7	29.8	0.8	39.7	0.9
TM	88.9	86.4	-2.5	2.9	29.1	0.8	33.2	1.0
TW	92.8	64.0	-28.8	45.0	53.6	0.8	49.0	0.9
TC	93.0	65.4	-27.5	42.1	57.3	0.8	48.4	0.9
Regional average	75.8	79.7	3.9	-4.8	17.7	1.0	18.7	1.0

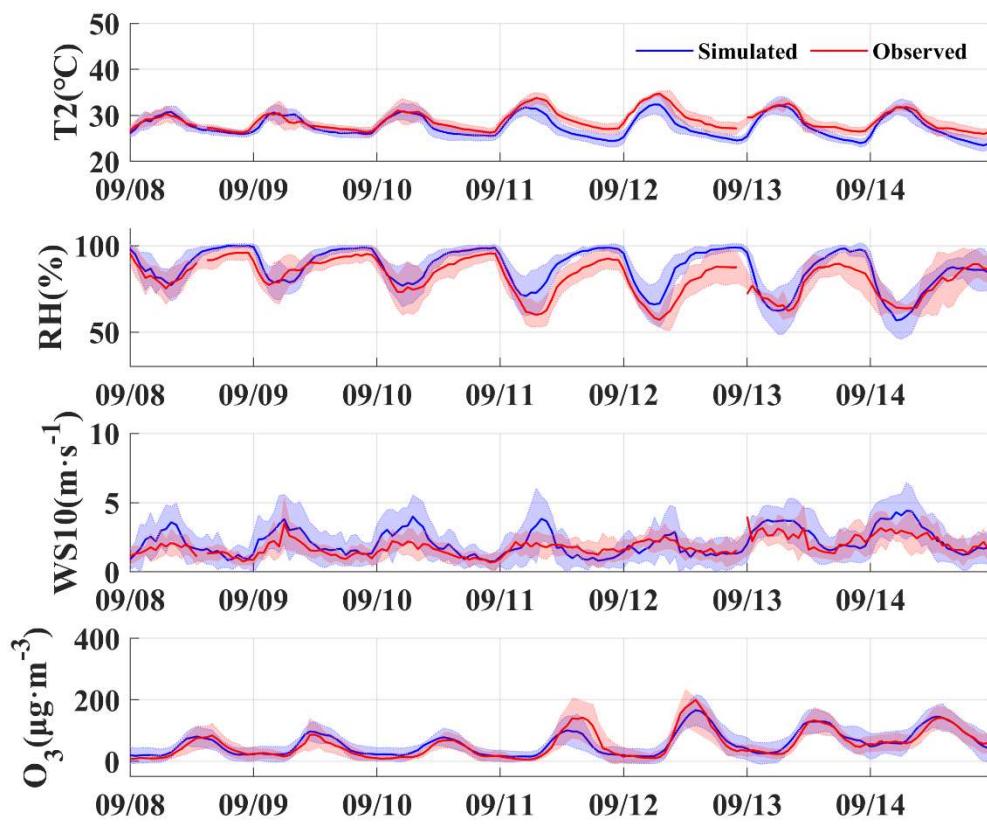


Figure S3. Diurnal variations of observed (red) and simulated (blue) T_2 , RH, WS10 and O_3 during 8-14 September 2017. Shade areas indicate the range of deviations for the monitoring sites.