Text 1. Model Validation.

The difference between the modeled O_3 concentrations and observed concentrations can be used to judge the rationality of the model results, and the methods were named the index of agreement (IOA), which were calculated by the equation (Liu et al., 2022):

$$IOA = 1 - \frac{\sum_{i=1}^{n}(O_i - S_i)^2}{\sum_{i=1}^{n}(|O_i - \bar{O}| - |S_i - \bar{O}|)^2} \quad (4)$$

where *Si* is modeled O_3 value, *Oi* represents observed O_3 concentration, $\bar{O}$ is the average observed O_3 value, and n is the sample number. The IOA range is 0-1, and the higher the IOA value is, the better agreement between modeled and observed values is. In many studies, IOA ranges from 0.68 to 0.89 (Wang et al., 2018), and the modeled results are reasonable. The IOA in our research is 0.78. Hence, the performance of the OBM-MCM model was reasonably acceptable.

Table S1 The detailed compounds of 106 VOCs and the detectors.

Compounds	Detector	Compounds	Detector
ethene	FID	p-ethyltoluene	MS
ethane	FID	1,2,4-trimethylbenzene	MS
propane	FID	1,2,3-trimethylbenzene	MS
iso-butane	FID	m-diethylbenzene	MS
n-butane	FID	p-diethylbenzene	MS
iso-pentane	FID	naphthalene	MS
n-pentane	FID	dichlorodifluoromethane	MS
cyclopentane	FID	chloromethane	MS
propene	FID	1,1,2,2-tetrachloro-Ethane	MS
1-butene	FID	vinylchloride	MS
cis-2-butene	FID	bromomethane	MS
trans-2-butene	FID	chloroethane	MS
1-pentene	FID	trichlorofluoromethane	MS
trans-2-pentene	FID	1,1,2-trichloro-1,2,2-trifluoroethane	MS
cis-2-pentene	FID	carbondisulfide	MS
acetylene	FID	dichloromethane	MS
isoprene	FID	cis-1,2-dichloroethene	MS
2,2-dimethylbutane	MS	1,1-dichloroethane	MS
2,3-dimethylbutane	MS	trans-1,2-dichloroethene	MS
2-methylpentane	MS	trichloromethane	MS
3-methylpentane	MS	1,1,1-trichloroethane	MS
n-hexane	MS	1,2-dichloroethane	MS
2,4-dimethylpentane	MS	carbon tetrachloride	MS
methylcyclopentane	MS	trichloroethene	MS
cyclohexane	MS	1,2-dichloropropane	MS
2-methylhexane	MS	dichlorobromomethane	MS
2,3-dimethylpentane	MS	cis-1,3-dichloropropene	MS
3-methylhexane	MS	trans-1,3-dichloropropene	MS
2,2,4-trimethylpentane	MS	1,1,2-trichloroethane	MS

n-heptane	MS	dibromochloromethane	MS
methylcyclohexane	MS	tetrachloroethene	MS
2,3,4-trimethylpentane	MS	1,2-ethylenedibromide	MS
2-methylheptane	MS	chlorobenzene	MS
3-methylheptane	MS	tribromomethane	MS
n-octane	MS	Ethane, 1,1,2,2-tetrachloro-	MS
n-nonane	MS	1,3-dichlorobenzene	MS
n-decane	MS	chlorotoluene	MS
n-undecane	MS	1,4-dichlorobenzene	MS
n-dodecane	MS	1,2-dichlorobenzene	MS
1-hexene	MS	1,2,4-trichlorobenzene	MS
1,3-butadiene	MS	1,1,2,3,4,4-hexachloro-1,3-butadiene	MS
1,1-dichloroethene	MS	acrolein	MS
benzene	MS	acetone	MS
toluene	MS	2-butanone	MS
m/p-xylene	MS	2-propanol	MS
ethylbenzene	MS	2-methoxy-2-methylpropane	MS
styrene	MS	vinylacetate	MS
o-xylene	MS	ethylacetate	MS
iso-propylbenzene	MS	tetrahydrofuran	MS
n-propylbenzene	MS	methyl methacrylate	MS
o-ethyltoluene	MS	1,4-dioxane	MS
m-ethyltoluene	MS	4-methyl-2-pentanone	MS
1,2,3-trimethylbenzene	MS	2-hexanone	MS

Table S2. Detailed uncertainty, detection limit, and time resolution of instruments used for trace gas observation at the observation site.

Species	Experimental Technique	Uncertainty	Detection limit	Time resolution
HCHO	FMS-100, Focused Photonics Inc., Hangzhou, China	≤5%	50 pptv	1 s
PAN	PANs-1000, Focused Photonics Inc., Hangzhou, China	±10%	50 pptv	5 min
O_3	Model 49i, Thermo Fischer Scientific, USA	±5%	1 ppbv	1 h
NOx	Model 42i, Thermo Fischer Scientific, USA	±10%	0.5 ppbv	1 h
CO	Model 48i, Thermo Fischer Scientific, USA	±5%	40 ppbv	1 h
SO_2	Model 43i, Thermo Fischer Scientific, USA	±10%	0.5 ppbv	1 h
VOCs	GC-FID/MS, TH-300B, Wuhan, China	±10%	20-300 pptv	1 h
HONO	MARGA, ADI 2080, Applikon Analytical B.V., the Netherlands	±20%	50 pptv	1 h

Table S3. Summary of PMF and BS-DISP diagnostics

Diagnostic	4 factors	5 factors	6 factors
Qexpected	9120	7950	7355
Qrobust	15689	11113	8124
Qtrue	16011	11276	8208
Qrobust/Qexpected	1.72	1.40	1.10
DISP % dQ	<0.1%	<0.1%	<0.1%
BS mapping <80%	Yes	NO	Yes

Table S4. Dry deposition velocity (cm s^{-1}) for chemical species (Zhang et al., 2003).

Symbol	Name	Dry deposition velocity
O_3	Ozone	0.6
NO_2	Nitrogen dioxide	0.6
HONO	Nitrous acid	1.9
HNO_3	Nitric acid	4.7
HNO_4	Pernitric acid	3.3
NH_3	Ammonia	1.0
SO_2	Sulphur dioxide	0.8
H_2SO_4	Sulphuric acid	1.1
H_2O_2	Hydrogen peroxide	1.2
PAN	Peroxyacetylnitrate	0.4
PPN	Peroxypropylnitrate	0.4
APAN	Aromatic acylnitrate	0.5
MPAN	Peroxymethacrylic nitric anhydride	0.3
HCHO	Formaldehyde	0.9
MCHO	Acetaldehyde	0.2
PALD	C3 Carbonyls	0.2
C4A	C4-C5 Carbonyls	0.2
C7A	C6-C8 Carbonyls	0.2
ACHO	Aromatic carbonyls	0.2
MVK	Methyl-vinyl-ketone	0.2
MACR	Methacrolein	0.2
MGLY	Methylgloxal	0.2
MOH	Methyl alcohol	0.7
ETOH	Ethyl alcohol	0.6
POH	C3 alcohol	0.5
CRES	Cresol	0.2
FORM	Formic acid	1.4
ACAC	Acetic acid	1.1
ROOH	Organic peroxides	0.6
ONIT	Organic nitrates	0.4
INIT	Isoprene nitrate	0.3

Table S5. Statistics of measured concentrations in spring and autumn.

Parameters	Spring			Autumn		
	ave.	st.	range	ave.	st.	range
O_3 (ppbv)	29.52	15.97	5.13-85.40	36.25	22.36	3.73-109.67
HCHO(ppb)	2.94	1.28	0.88-8.70	3.19	1.41	0.55-7.96
PAN (ppbv)	0.53	0.54	0.05-3.28	0.27	0.29	0.05-1.91
NO_2 (ppbv)	9.84	5.33	0.49-33.11	8.63	4.35	2.43-27.76
NO (ppbv)	3.67	4.93	0.75-40.32	2.15	2.10	0.75-20.16
CO (ppbv)	460.05	85.63	270.40-759.20	406.50	57.25	301.60-627.20
T (℃)	27.54	3.35	22.39-37.85	29.76	2.58	24.00-36.25
RH (%)	79.88	10.95	44.05-94.00	70.98	10.73	43.19-93.73
P (hPA)	1003.54	2.14	996.87-1009.22	1005.72	3.51	994.45-1012.60
WS ($m \cdot s^{-1}$)	1.26	0.75	0.30-4.17	1.93	1.05	0.33-6.31
JHCHO ($\times 10^{-5}$ s^{-1})	1.22	1.76	0.00-6.03	1.49	1.98	0.00-5.78
JO^{1}D ($\times 10^{-5}$ s^{-1})	1.18	1.85	0.00-6.95	1.38	2.03	0.00-6.75
JNO$_2$ ($\times 10^{-3}$ s^{-1})	2.60	3.57	0.00-11.38	3.36	4.18	0.00-11.51
TVOCs (ppbv)	23.93	8.16	7.69-48.62	17.42	7.79	7.19-47.86
Isoprene (ppbv)	0.33	0.38	0.04-2.05	0.41	0.54	0.04-2.77

Table S6. Correlation coefficients among HCHO, air pollutants, and meteorological parameters in spring and autumn (colour in green for spring, yellow for autumn)

Parameters	HCHO	TVOCs	O_3	PAN	NO_2	NO	CO	T	RH	*J*HCHO	Isoprene
HCHO	1	0.54*	0.65*	0.65*	-0.07	0.00	0.38*	0.52*	-0.40*	0.61*	0.64*
TVOCs	0.44*	1	0.15*	0.23*	0.27*	0.26*	0.36*	0.03	0.08	0.35*	0.29*
O_3	0.64*	0.23*	1.00	0.86*	-0.44*	-0.39*	0.27*	0.62*	-0.55*	0.39*	0.63*
PAN	0.80*	0.36*	0.76*	1	-0.29*	-0.25*	0.16*	0.70*	-0.56*	0.42*	0.73*
NO_2	-0.07	0.18*	-0.35*	-0.10*	1	0.37*	0.41*	-0.45*	0.53*	-0.31*	-0.36*
NO	-0.11*	0.08*	-0.43*	-0.23*	0.26*	1	0.03	-0.17*	0.21*	0.19*	-0.07
CO	0.20*	0.59*	0.04*	0.17*	0.43*	0.31*	1	-0.16*	0.32*	-0.06	-0.04
T	0.40*	-0.19*	0.22*	0.28*	-0.33*	-0.09*	-0.47*	1	-0.80*	0.48*	0.78*
RH	-0.53*	0.11*	-0.46*	-0.45*	0.37*	0.18*	0.43*	-0.88*	1	-0.53*	-0.65*
*J*HCHO	0.49*	0.13*	0.25*	0.42*	-0.25*	0.11*	-0.10*	0.60*	-0.63*	1	0.65*
Isoprene	0.33*	-0.15*	0.32*	0.24*	-0.29*	-0.14*	-0.42*	0.73*	-0.68*	0.37*	1

*: Correlation is significant at the 0.05 level (2-tailed)

Table S7. A specific reaction scheme about the 'others' category of the HCHO formation

'others' category reactions in MCM (http://mcm.leeds.ac.uk/MCM/)
CH3O2 + HO2 = HCHO
CH3O2 = HCHO
ACO3 + HO2 = HO2 + CO + HCHO + OH
ACO3 + NO = HO2 + CO + HCHO + NO2
ACO3 + NO3 = HO2 + CO + HCHO + NO2
ACO3 = HO2 + CO + HCHO
GLYOOB = HCHO
CH3C2H2O2 = CH3CO3 + HCHO
CH3C2H2O2 = HCHO + CH3O2 + CO
ACROOA = HO2 + CO + HCHO + CO + OH
ACROOA = HO2 + CO + HCHO + HO2
MACROOA = CH3CO3 + HCHO + HO2
MACROOA = OH + CO + CH3CO3 + HCHO
MVKOOA = CH3O2 + HCHO + CO + HO2
HOCH2CO3 + HO2 = HO2 + HCHO + OH
HOCH2CO3 + NO = NO2 + HO2 + HCHO
HOCH2CO3 + NO3 = NO2 + HO2 + HCHO
HOCH2CO3 = HCHO + HO2
CH2OO + NO2 = HCHO + NO3
CH2OO + SO2 = HCHO + SO3
CH2OO + CO = HCHO
CH2OO + NO = HCHO + NO2
CH2OO = HCHO + H2O2
GLYOOA = HCHO
MGLOOA = CH3CO3 + HCHO + HO2
ISOPBO2 = MVK + HCHO + OH
ISOPDO2 = MACR + HCHO + OH
NO3CH2CO3 + HO2 = HCHO + NO2 + OH
NO3CH2CO3 + NO = HCHO + NO2 + NO2
NO3CH2CO3 + NO3 = HCHO + NO2 + NO2
NO3CH2CO3 = HCHO + NO2
NAOOA = HO2 + NO2 + HCHO
NAOOA = OH + NO2 + CO + HCHO
GAOOA = HO2 + HO2 + HCHO
GAOOA = OH + HO2 + CO + HCHO
C524O2 = HMACR + HCHO + OH
HMACO3 + HO2 = HOCH2CO3 + HCHO + OH
HMACO3 + NO3 = HOCH2CO3 + HCHO + NO2
HMACO3 = HOCH2CO3 + HCHO
C522CO3 + HO2 = CHOC2CO3 + HCHO + OH

C522CO3 + NO3 = CHOC2CO3 + HCHO + NO2
C522CO3 = CHOC2CO3 + HCHO
C46CO3 + HO2 = HOC2H4CO3 + HCHO + OH
C46CO3 + NO3 = HOC2H4CO3 + HCHO + NO2
C46CO3 = HOC2H4CO3 + HCHO
C522CO3H = CHOC2CO3 + HCHO + OH
CH3OH + Cl= HO2 + HCHO + HCl
CH3OOH + Cl = HCHO + OH + HCl
CH3NO3 + Cl = HCHO + NO2 + HCl

Table S8. The average daytime (06:00-17:00) concentrations, production rates, and differences of OH, HO_2, and RO_2 in model scenarios of AS and DS. AS scenario was run with all MCM mechanism, and DS scenario was run with the HCHO mechanism disabled in MCM mechanism.

	Spring			Autumn		
	AS	DS	Difference	AS	DS	Difference
ROx concentration (molecule·cm^{-3})						
OH	7.30×10^{6}	5.49×10^{6}	25%	1.12×10^{7}	9.33×10^{6}	16%
HO_2	2.41×10^{8}	1.32×10^{8}	45%	4.72×10^{8}	2.83×10^{8}	40%
RO_2	1.26×10^{8}	9.33×10^{7}	26%	2.17×10^{8}	1.77×10^{8}	19%
OH production rate (ppbv h^{-1})						
HO_2+NO	7.78	5.03	35%	8.57	5.96	30%
O_3 photolysis	0.71	0.65	9%	1.06	0.98	8%
HONO photolysis	0.53	0.47	12%	0.45	0.41	9%
HO_2 production rate (ppbv h^{-1})						
OH+CO	2.91	2.17	26%	3.93	3.27	17%
RO_2+NO	1.77	1.57	11%	1.82	1.71	6%
OH+VOCs	1.30	0.20	84%	1.83	0.29	84%
HCHO photolysis	0.79	0.00	100%	0.92	0.00	100%
OVOCs photolysis	0.38	0.37	2%	0.36	0.36	1%
RO_2 production rate (ppbv h^{-1})						
OH+VOCs	2.75	2.22	19%	2.74	2.45	10%
OVOCs photolysis	0.33	0.31	5%	0.34	0.32	5%

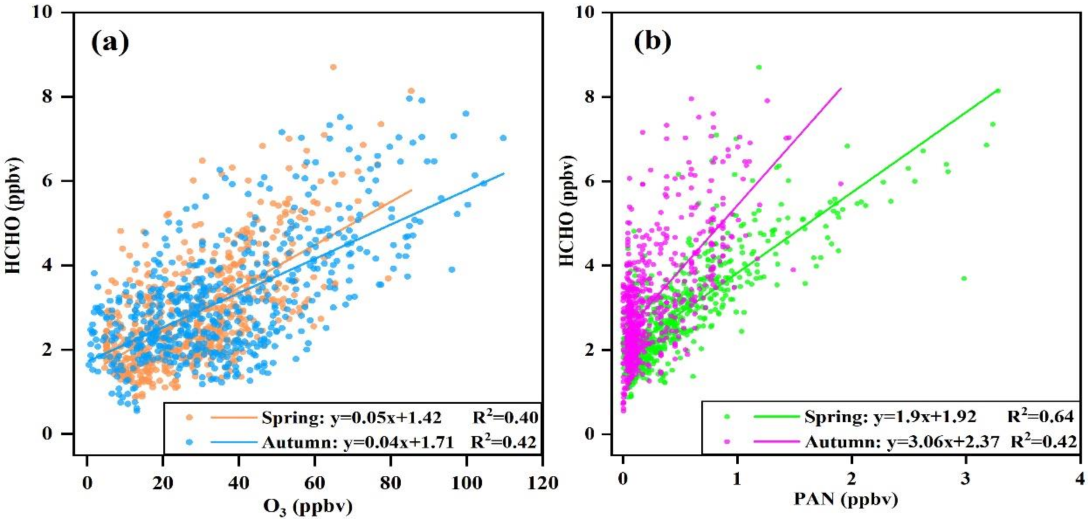

Figure S1. Scatter plots of HCHO versus (a) O_3 and (b) PAN during the observation periods.

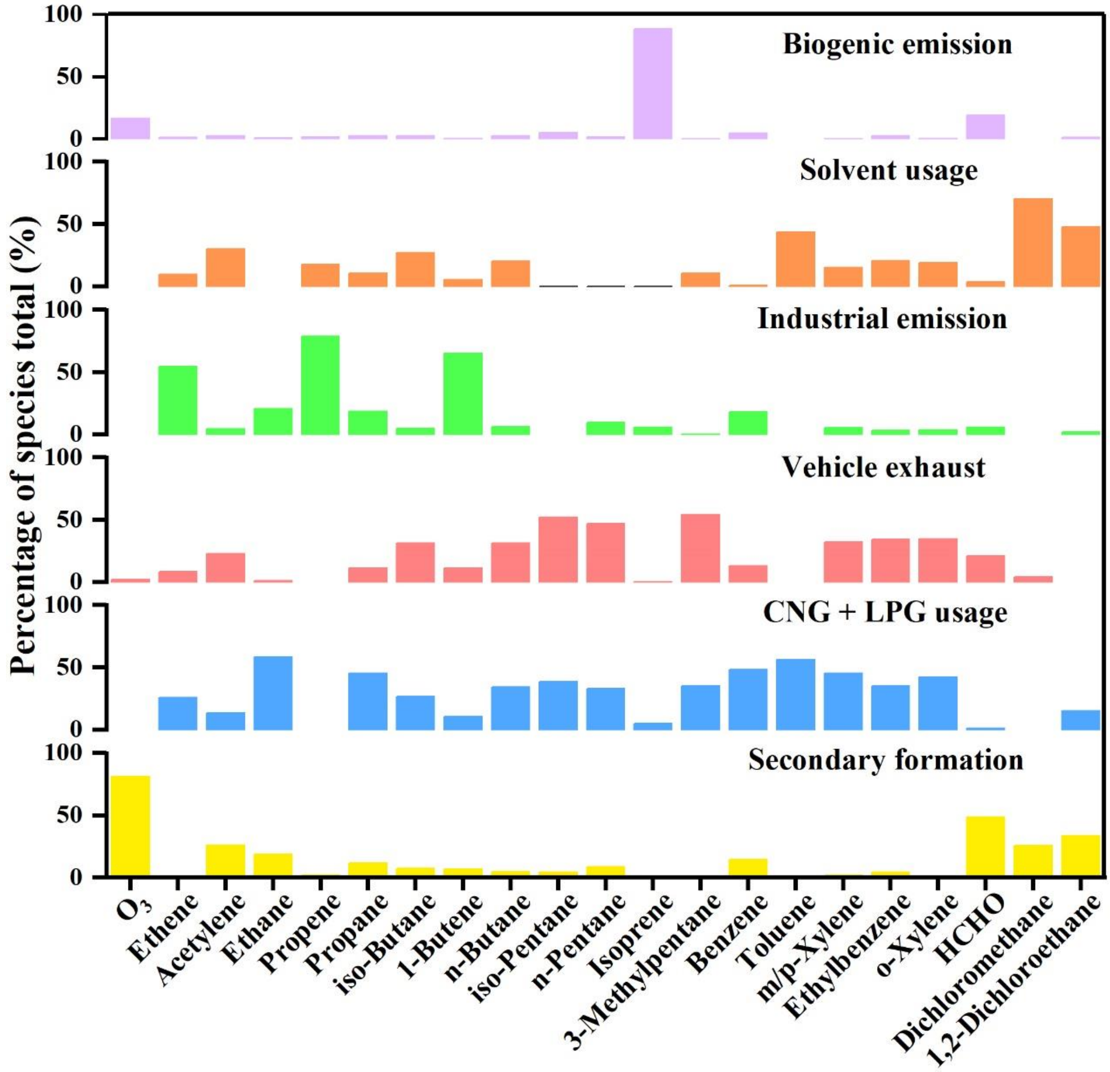

Figure S2. The source profiles of HCHO extracted from the PMF model.

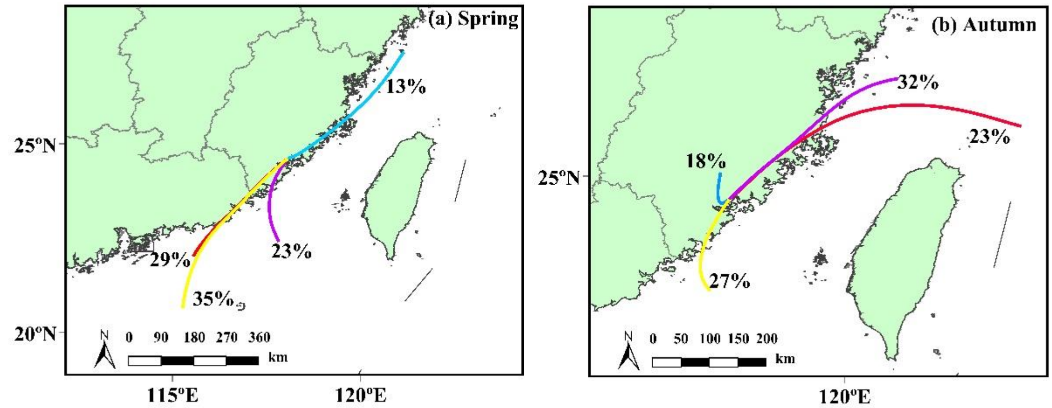

Figure S3. Cluster results of air mass trajectories during the observation periods.

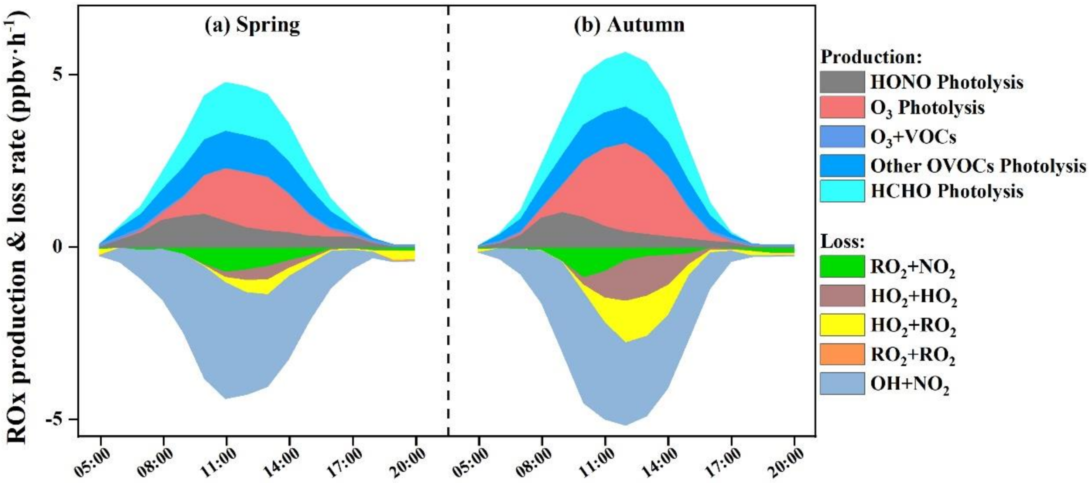

Figure S4. The simulated primary production rates and loss rates of ROx in (a) spring and (b) autumn.

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