Yale 耶鲁大学-南京信息工程大学大气环境中心
Yale-NUIST Center on Atmospheric Environment

Research on a Continuous Air Pollution Event in January of 2015 in Downtown of Nanjing, China

Liu Xiaoyan
2016/6/24

Outline

- Background
- Material and method
- Results and discussion
- Conclusion
- Next work

Background

- Long duration air pollution in winter is always related with unfavorable weather, such as uniform pressure pattern, low PBL height; And contaminent dominated by biomass burning is reckoned that more frequently occurs in summer/autumn days and secondary pollution prevails in summer.
- This study focuses on characteristics of the pollutant's chemical composition during the pollution event in January of 2015 which last half months; at the meanwhile, it investigates source of fine particle ($PM_{2.5}$) which is the primary pollutant.
- All above will help understand mechanisms of haze’s formation and development during winter in Nanjing.

Material and method

- Sampling site

- $PM_{2.5}$ Sampling instrument
  - Sampler: KC 1000
  - Sample collector: quartz filter（8×10 inch）
- Sampling frequency and time :

Time	Frequency	Notes
14th Jan 16:30-26th Jan 18:00	Every 3 hrs	Afternoon of 14th : after light rain Morning of 25th : light rain 9 a.m. to 1 p.m. of 25th :power failure
26th Jan 18:00-29th Jan 00:00	Every 6 hrs	27th to 29th : rain and snow

Material and method

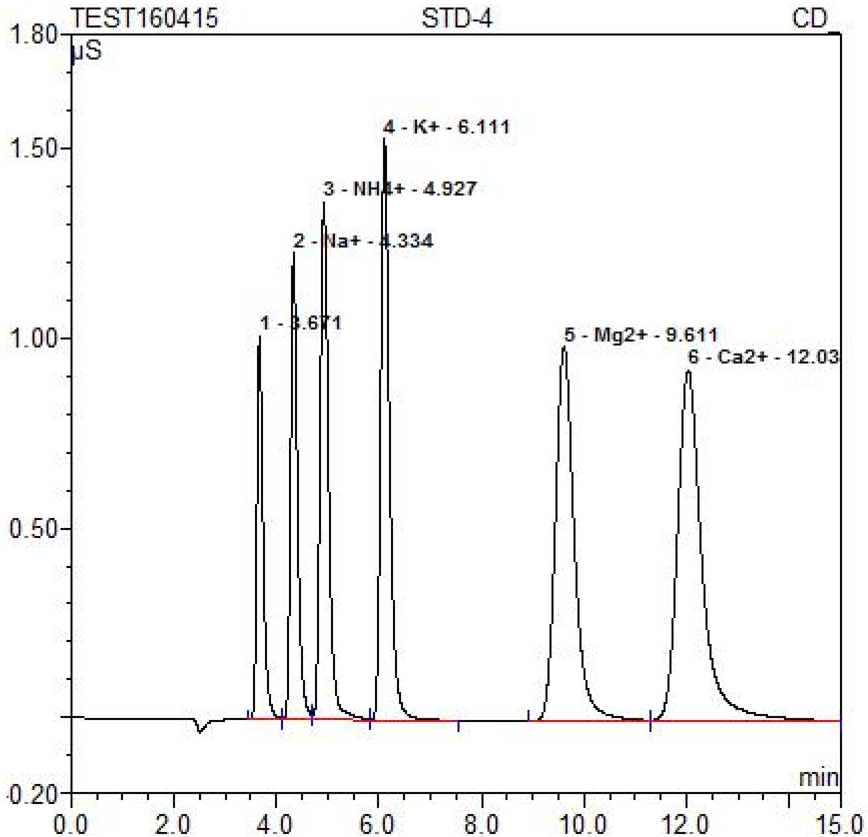
- Laborotary analysis of chemical species

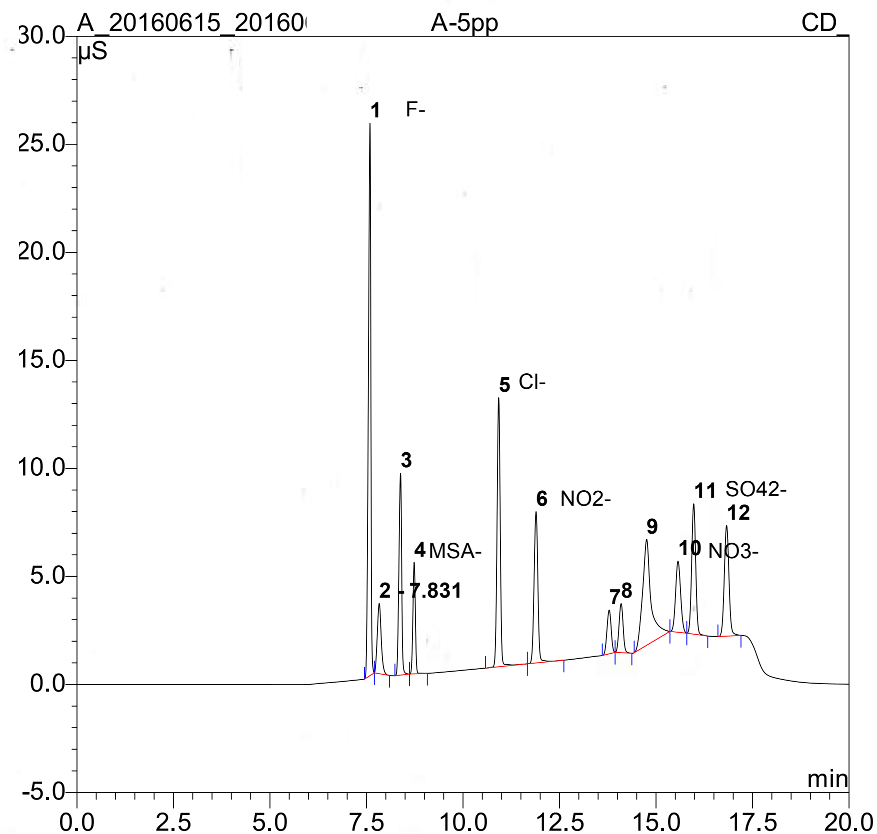
Chemical species	Instrument	Principle
$PM_{2.5}$ mass concentration	Analytical balance	particle mass/sampling volume
Carbonaceous component	Sunset EC/OC analyzer	TOR
Water-soluble ion component	ICS 5000+	Ion Chromatography + Electrical Detector

	Cation	Anion
Column	IonPac CS12A IonPac CG 12A	IonPac AS11-HC IonPac AG11-HC
Loop	25 μ L	25 μ L
Elution Method	Flow:1mL min^{-1} MSA:0-20min 30mM L^{-1}	Flow:1.5mL min^{-1} NaOH:0-3min 0.5mM L^{-1} ,3-5min 0.5-5mM L^{-1} , 5-15min 5-30mM L^{-1},15.1-20min 0.5mM L^{-1}

- QAQC

Cation	Cal.Type	Points	Offset	Slope	Coeff.Det. %	RSD %	recovery %	LOD ppb
Na+	LOff	10	0.0108	0.2783	99.998	1.45	98.25	0.06
NH4+	Quad	9	0．0000	0.1975	99.935	1.06	129.51	0.03
K+	LOff	9	0.0025	0.1787	99.9985	0.72	95.72	0.12
Mg2+	LOff	8	0.0037	0.5311	99.9984	1.75	97.25	0.08
Ca2+	LOff	10	0.0113	0.3375	99.9985	1.09	111.95	0.13
F-	LOff	5	-0.0037	0.3836	99.921	0.03	89.59	0.22
MSA-	LOff	6	-0.002	0.0691	99.9321	0.01	107.29	1.62
Cl-	LOff	8	-0.0003	0.2241	99.9494	0.72	95.75	0.64
NO2-	LOff	5	0	0.13	99.9298	0.06	104.48	1.11
NO3-	LOff	5	-0.0254	0.1061	99.9254	0.08	111.85	2.67
SO42-	LOff	9	-0.009	0.1481	99.8518	0.08	116.15	1.41


TEST160415
STD-4
CD
µS
1 - 3.671
2 - Na+ - 4.334
3 - NH4+ - 4.927
4 - K+ - 6.111
5 - Mg2+ - 9.611
6 - Ca2+ - 12.03
min


A_20160615_20160
A-5pp
CD
µS
1 F-
2 - 7.831
3
4 MSA-
5 Cl-
6 NO2-
7
8
9
10 NO3-
11 SO42-
12
min

- SOC
- $SOC=OC-EC*OC/EC_{pri}$

处理	数据	数据总量	数据量	OC/EC_{pri}（斜率）	$R^2_{OC\text{-}EC}$	SOC（μg m⁻³）			$R^2_{SOC\text{-}EC}$
						最大值	最小值	平均值	
未剔除降水、O_3高值时刻，对OC、EC回归分析	$5\%_{min}$	103	5	2.68	0.9316	58.09	4.22	15.98±8.06	0.2142
	$10\%_{min}$		10	3.13	0.9703	56.18	3.96	14.90±7.74	0.1487
剔除降水、O_3高值时刻OC、EC回归分析	$5\%_{min}$	69	4	3.86	0.9138	53.08	1.96	13.15±7.36	0.0584
	$10\%_{min}$		7	3.41	0.973	54.98	3.80	14.23±7.58	0.1106

- NOR SOR
- $NOR=NO_3^-/(NO_3^-+NO_2)$
- $SOR=SO_4^{2-}/(SO_4^{2-}+SO_2)$

NO_3^-,NO_2,SO_4^{2-},SO_2 in Mole number

Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Results and discussion

AQI

Air Quality Index(AQI) implicates quantity of PM_{10}, $PM_{2.5}$, CO, NO_2, SO_2, O_3

Figure 1. AQI per hour on Shanxi Road station from 14th to 29th in January in 2015

Yale 耶鲁大学-南京信息工程大学大气环境中心
Yale-NUIST Center on Atmospheric Environment

Results and discussion

pollutants concentration

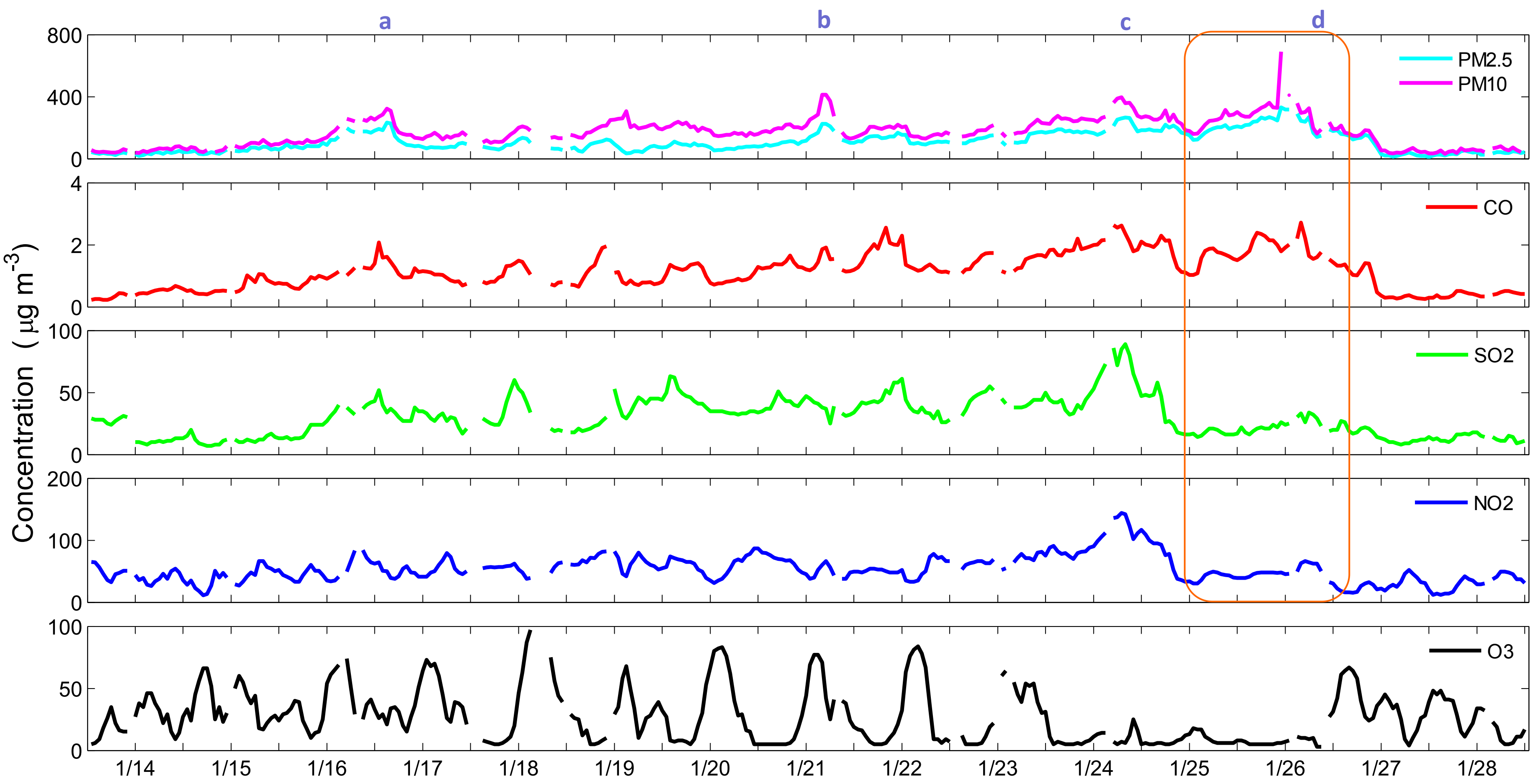


Figure 2. Temporal variation of per hour concentration of $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, O_3 on Shanxi Road station from 14th to 29th in January of 2015

- Carbonaceous components

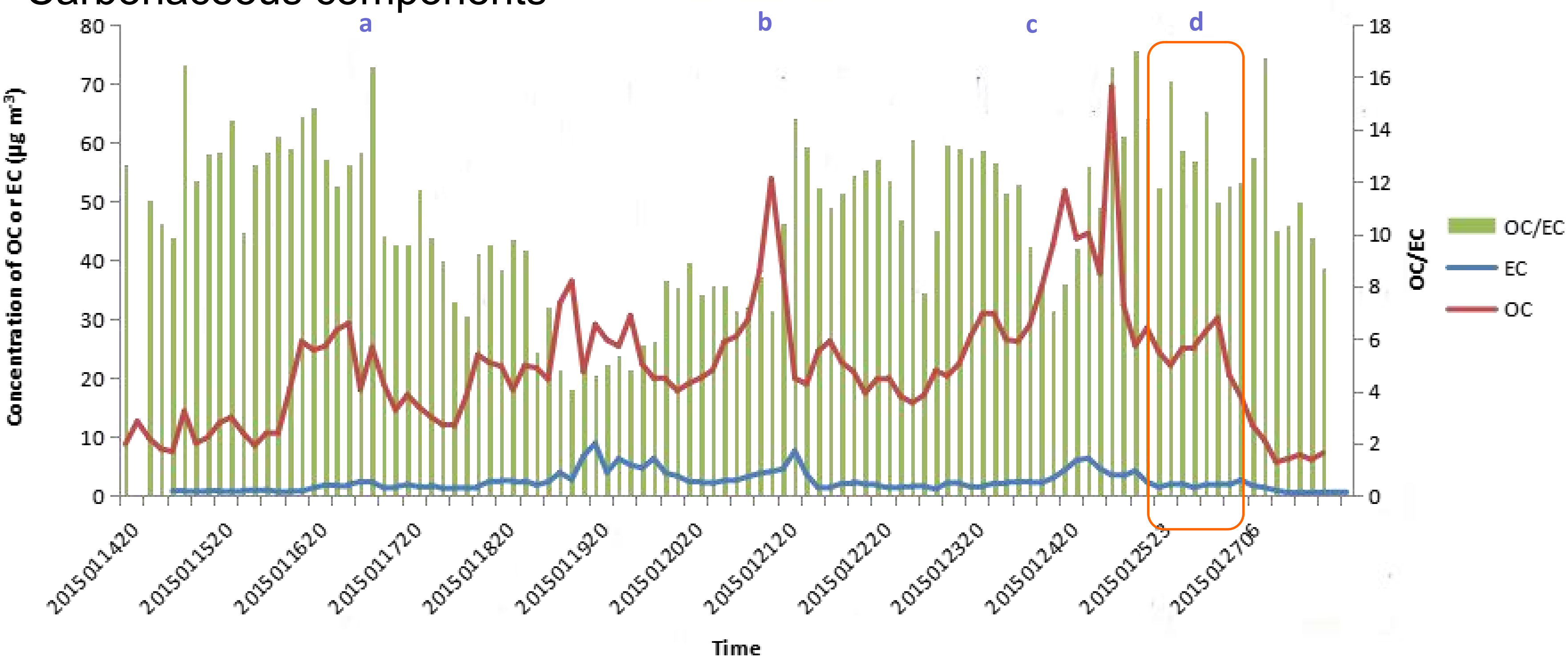


Figure 3. Temporal variation of OC EC OC/EC

Table 1. The max, min and average value of OC, EC, OC/EC, $TC/PM_{2.5}$. OC, EC in μg m^{-3}

	entire period			period a			period b			period c			period d		
	min	max	average	min	max	average	min	max	average	min	max	average	min	max	average
OC	5.75	69.47	22.18	24.79	29.35	26.94	21.12	53.79	37.62	25.51	69.47	37.59	11.97	30.16	23.31
EC	0.00	8.91	2.34	1.67	2.38	2.09	1.73	7.63	4.33	1.50	6.39	3.49	0.92	2.69	1.80
OC/EC	4.09	17.02	10.72	11.84	14.82	13.04	7.05	12.23	9.89	7.05	17.02	11.59	11.22	15.86	13.02
$TC/PM_{2.5}$	5.54%	24.48%	11.11%	8.94%	11.30%	10.55%	11.17%	15.36%	12.87%	8.39%	24.48%	13.94%	8.17%	9.84%	9.14%

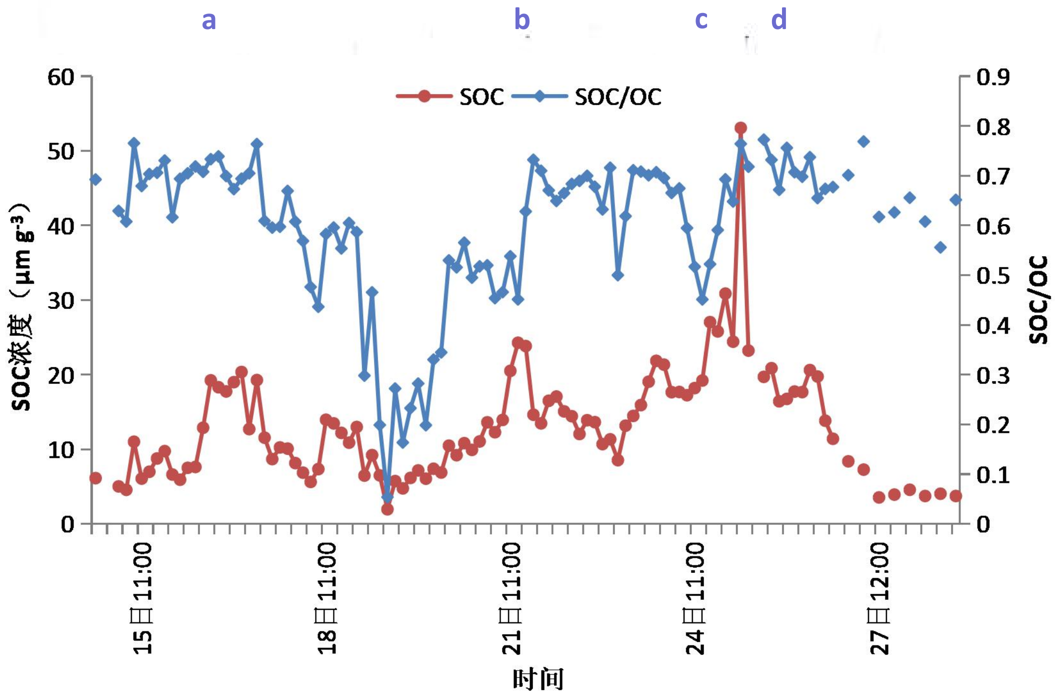


Figure 4. Temporal variation of SOC SOC/OC

Table 2. The max, min and average value of SOC and OC/EC. SOC in μg m^{-3}

	entire period			period a			period b			period c			period d		
	min	max	average	min	max	average	min	max	average	min	max	average	min	max	average
SOC	1.96	53.09	13.16	17.76	20.37	18.86	14.44	24.29	20.86	17.26	53.09	24.10	20.88	8.39	16.35
SOC/OC	0.05	0.77	0.60	0.67	0.74	0.70	0.45	0.68	0.59	0.45	0.77	0.64	0.66	0.76	0.70

- Ion components

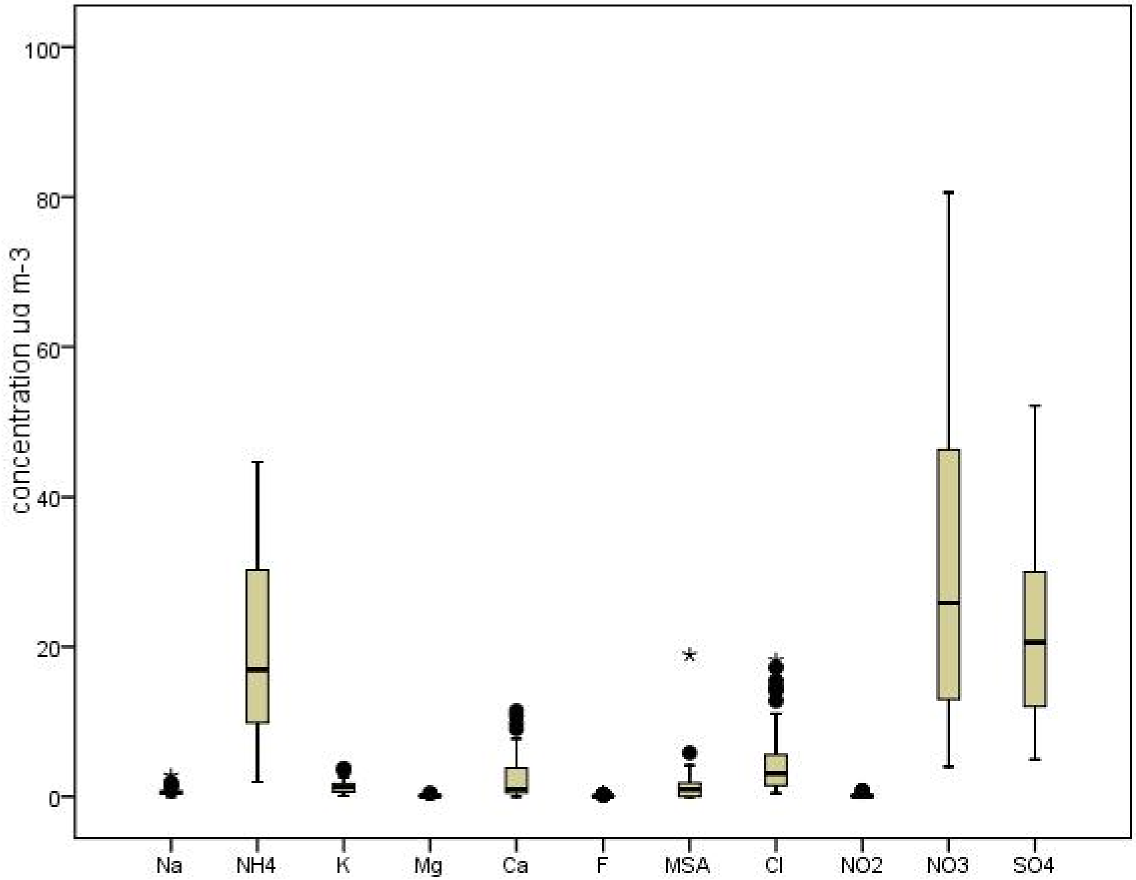
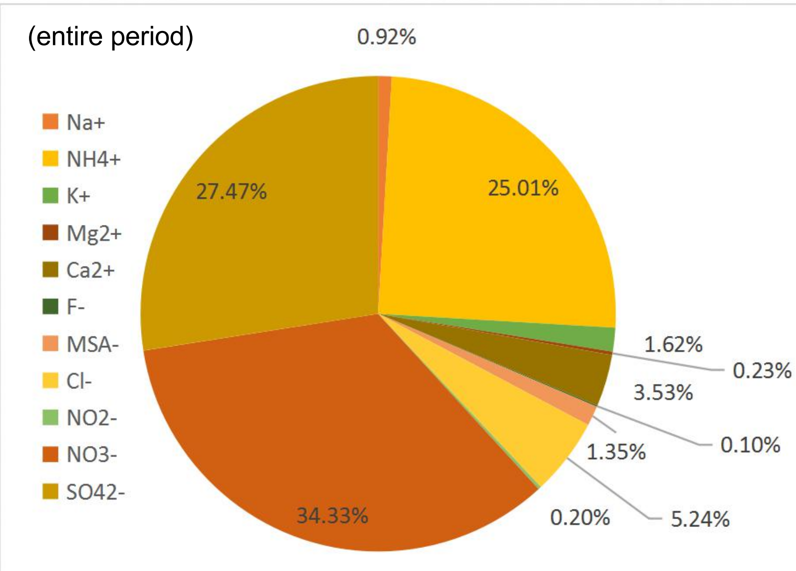
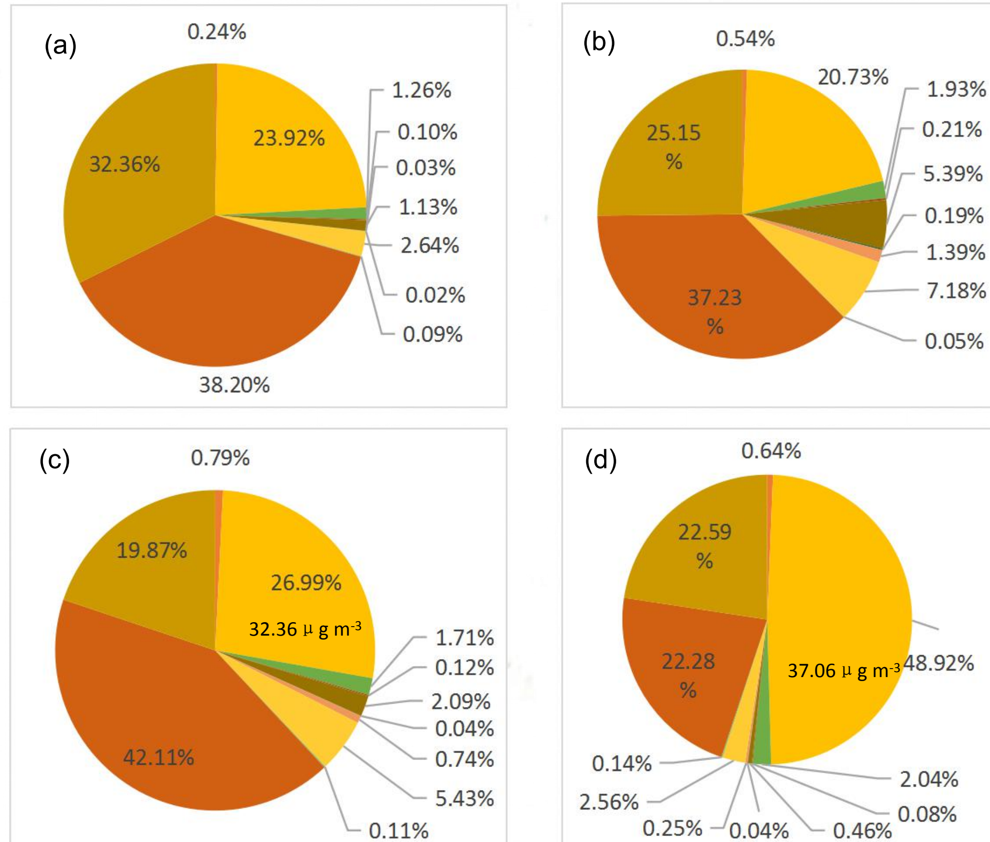


Figure 5. Concentration distribution of inorganic ion. The box represent the 25th (lower line),50th (middle line), 75th (top line) percentiles; the end of the vertical bars represent the 10th (below the box) and 90th (above the box) percentiles.The solid dots and stars represent abnormal value.

Inorganic ion





Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

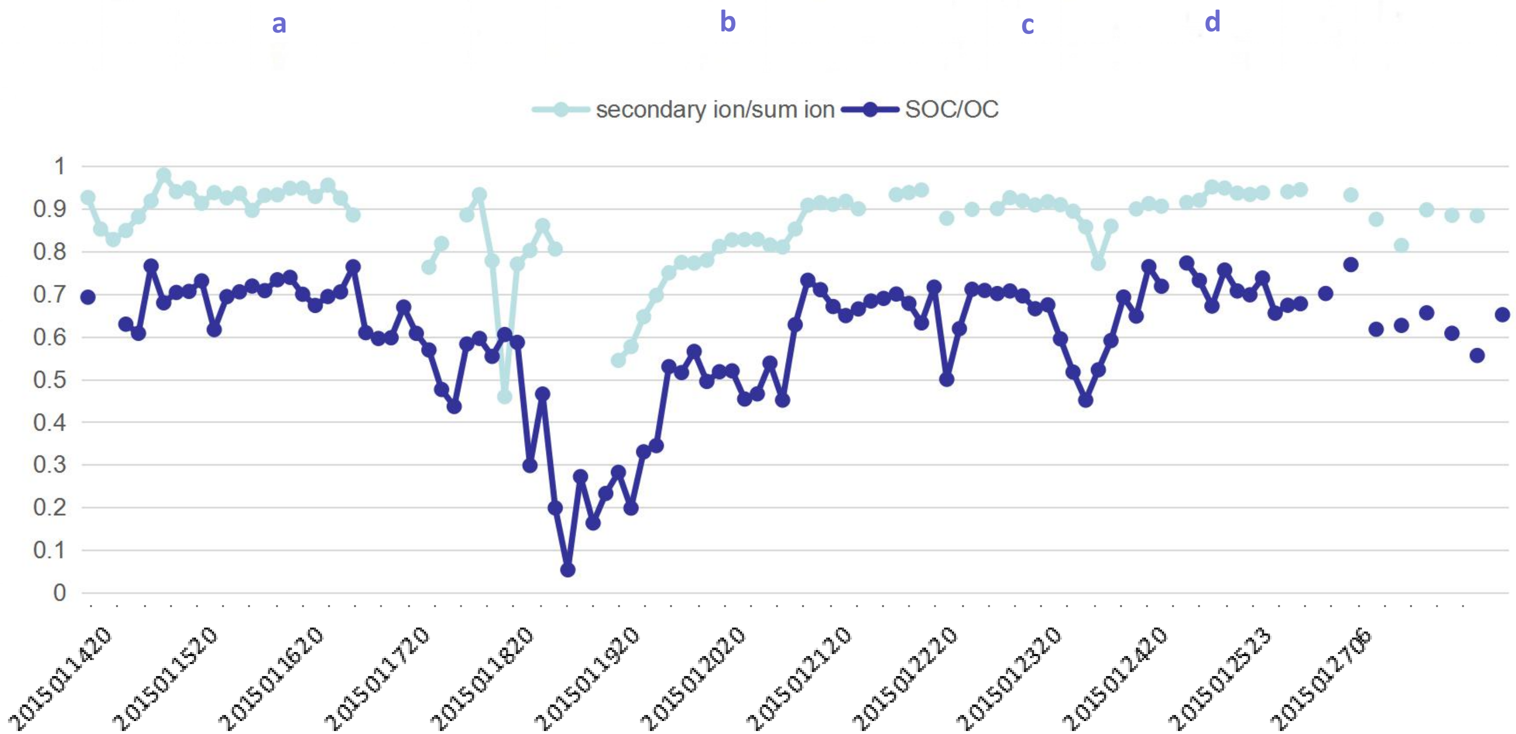
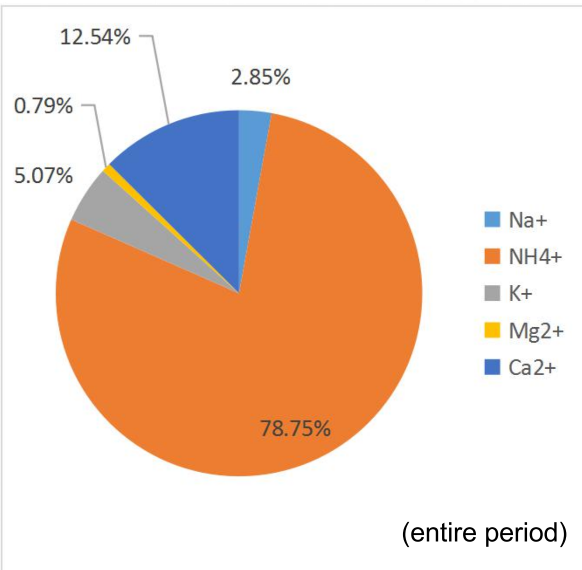
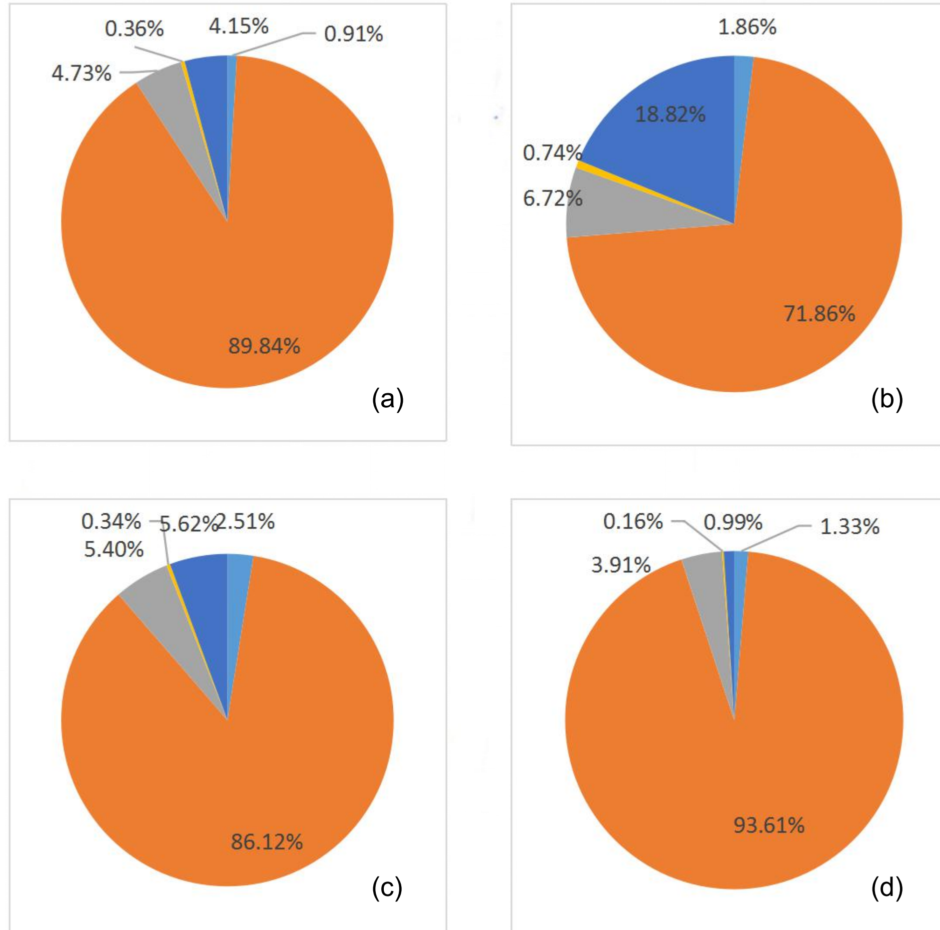


Figure 6. Temporal variation of SOC/OC and secondary ion/ total inorganic ion

Inorganic Cation





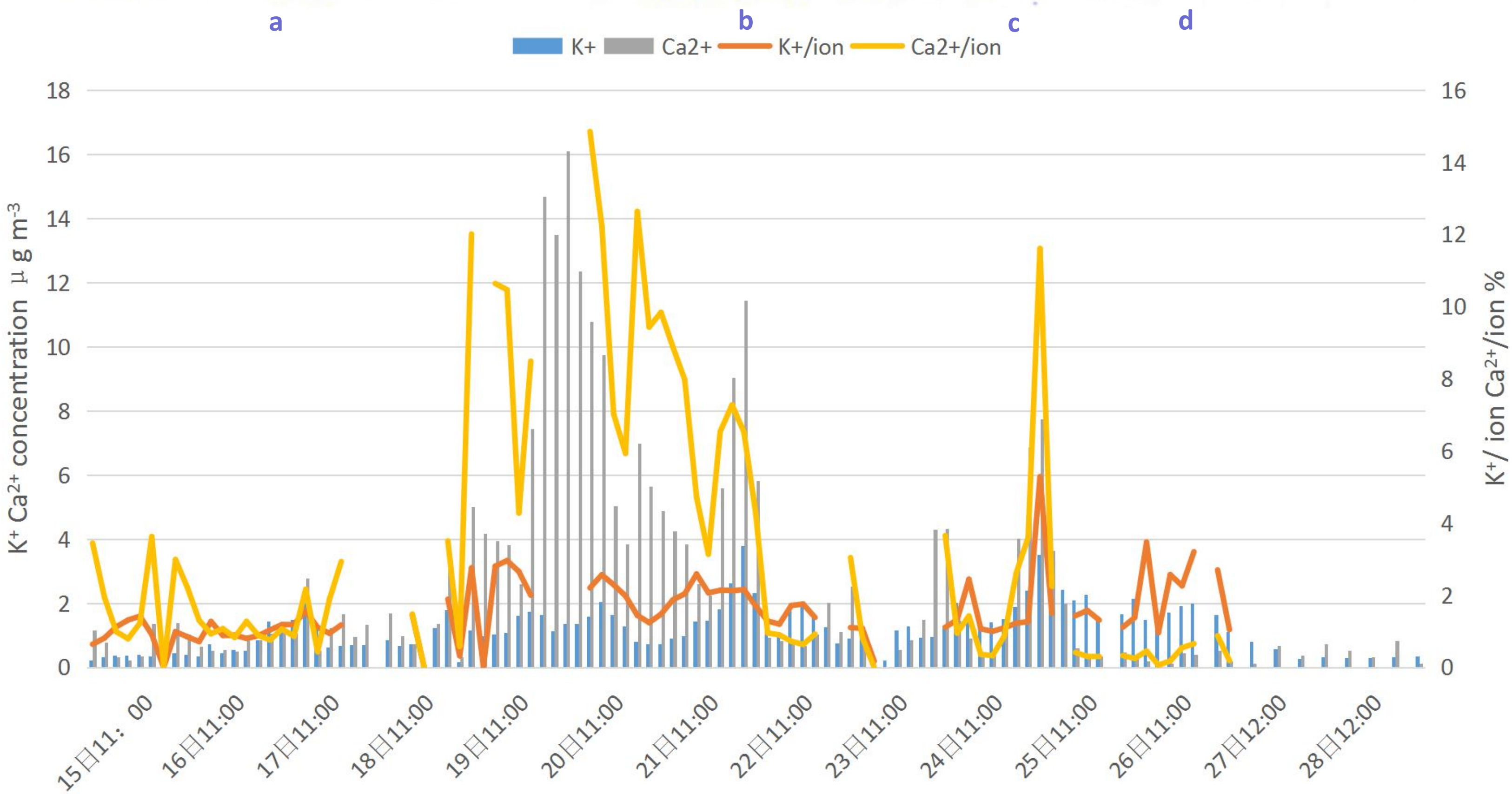
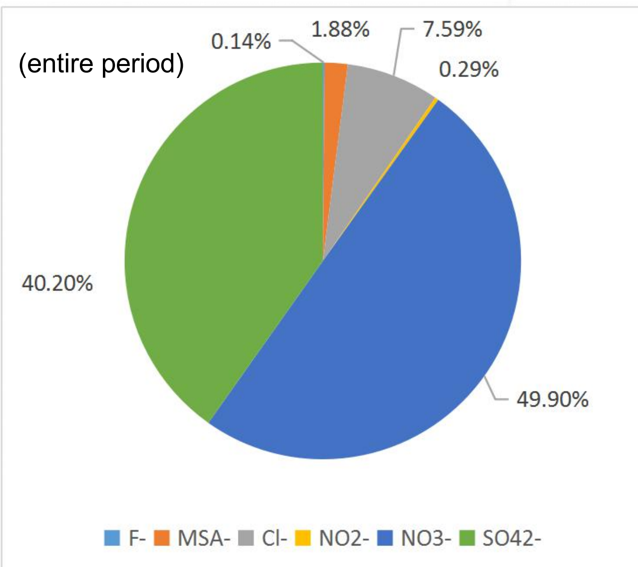


Figure 7. Temporal variation of K+, Ca2+, K+/ total inorganic ion, Ca2+/ total inorganic ion

Inorganic Anion



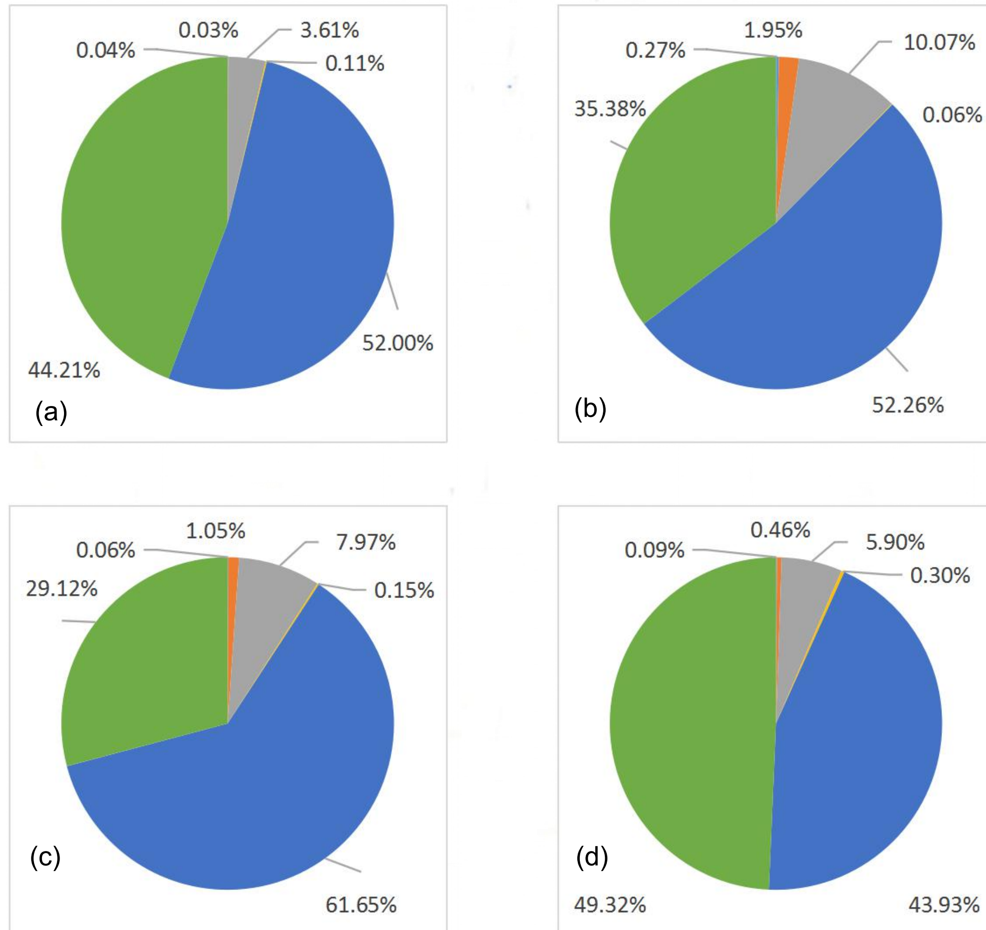


Table 4. The max, min and average value of NO_3^-/SO_4^{2-},SOR and NOR

	entire period			period a			period b			period c			period d		
	min	max	average	min	max	average	min	max	average	min	max	average	min	max	average
NO_3^-/SO_4^{2-}	0.27	2.42	1.37	1.02	1.53	1.19	1.17	1.89	1.53	1.15	2.42	2.05	0.75	1.20	1.00
SOR	0.10	1.70	0.73	0.82	0.90	0.85	0.82	0.91	0.87	0.10	1.28	0.68	0.38	1.25	0.84
NOR	0.12	1.74	0.60	0.65	0.93	0.74	0.79	1.02	0.91	0.12	1.05	0.72	0.17	1.13	0.63

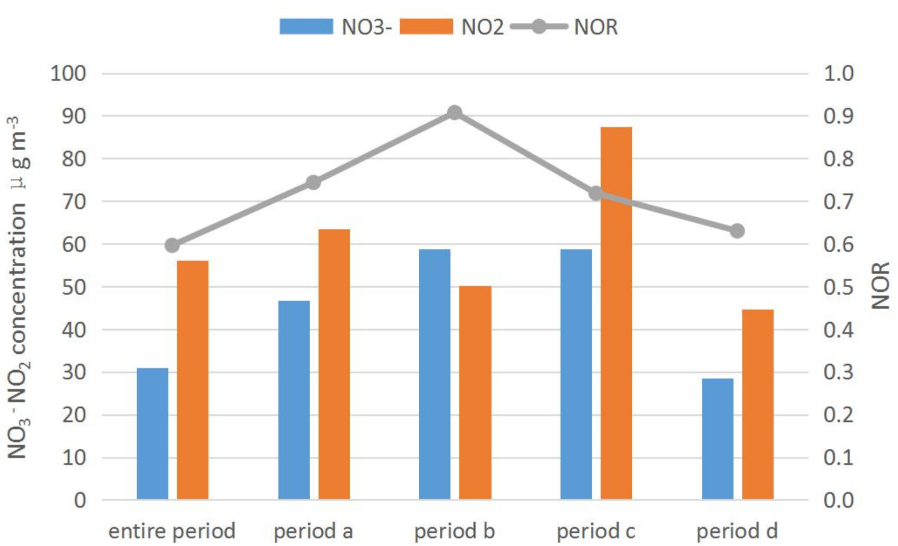


Figure 8 (a). NO_3^-, NO_2, and NOR in entire period and period a, b, c, d

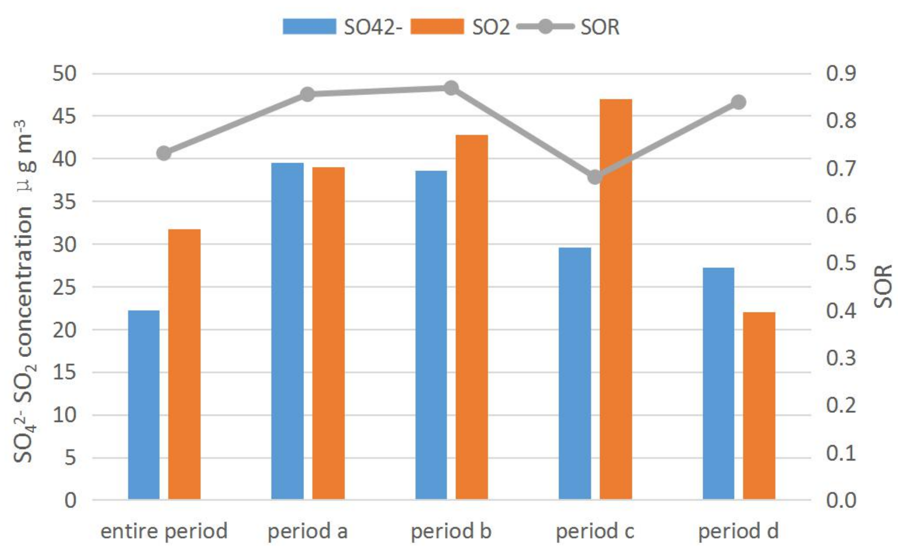


Figure 8 (b). SO_4^{2-}, SO_2, and SOR in entire period and period a, b, c, d

Fossil fuel combustion

Table 5. The correlation between $PM_{2.5}$CO, EC, NO_3^- , SO_4^{2-}

		$PM_{2.5}$	CO	EC	NO_3^-	SO_4^{2-}
$PM_{2.5}$	entire	1	.467**	.777**	.472**	.283**
CO				.387**	.582**	.428**
EC					.445**	.146
NO_3^-						.807**
SO_4^{2-}						
$PM_{2.5}$	c	1	.433	.582*	-.125	-.090
CO			1	.877**	-.123	-.262
EC				1	-.064	-.116
NO_3^-					1	.826**
SO_4^{2-}						1
$PM_{2.5}$	d	1	.542	.908**	-.190	-.145
CO			1	.538	-.685	-.622
EC				1	.314	.431
NO_3^-					1	.986**
SO_4^{2-}						1

Biomass Burning

Table 6. The correlation between $PM_{2.5}$, K^+, POC, POC/OC, OC/EC, CO , EC. K^+, POC, CO , EC in μg m[-3]

		$PM_{2.5}$	K^+	POC	POC/OC	OC/EC	CO	EC
$PM_{2.5}$	entire	1	.747**	.771**	.456**	-.342**	.467*	.777**
K^+			1	.688**	.218*	-.189	.756*	.717**
POC				1	.754**	-.645**	3.52*	.970**
POC/OC					1	-.930**	-.132	.754**
OC/EC						1	.128	-.645**
CO							1	.387**
EC								1
$PM_{2.5}$	c	1	.752*	.582*	.240	-.156	.433	.582*
K^+			1	.838**	.450	-.377	.813**	.838**
POC				1	.776**	.185	.877**	1.00**
POC/OC					1	-.682**	.617*	.776**
OC/EC						1	-.571*	-.682**
CO							1	.877**
EC								1
$PM_{2.5}$	d	1	.966*	.966**	-.484*	.425*	.907**	.966**
K^+			1	.957**	.638**	.573*	.942**	.957**
POC				1	-.346	-.346	.264	1.00**
POC/OC					1	-.980**	-.607**	.754**
OC/EC						1	.527*	-.346
CO							1	.264
EC								1

Secondary pollution

Table 7. The correlation between $PM_{2.5}$, SOC, SOC/OC, Secondary ion (S ion), Secondary ion to total inorganic ion ration (S/t ion), SOR, NOR, O_3. SOC, S ion, O_3 in μg m^{-3}

		$PM_{2.5}$	SOC	SOC/OC	S ion	S/t ion	SOR	NOR	O_3
$PM_{2.5}$	entire	1	.429**	-.456**	.329**	-.317**	-.291**	.189	-.083
SOC			1	.383**	.640**	.226*	-.023	.350**	-.150
SOC/OC				1	.298**	.717**	.522**	.266*	.084
S ion					1	.373**	.328**	.762**	-.168
S/t ion						1	.593**	.302**	-.056
SOR							1	.502**	-.124
NOR								1	.201
O_3									1
$PM_{2.5}$	c	1	.277	-.240	-.138	-.728**	-.208	-.322	.-131
SOC			1	.357	-.175	-.067	.024	-.086	-.164
SOC/OC				1	-.143	.663*	.537	.391	.159
S ion					1	.381	.649*	.791**	.119
S/t ion						1	.636*	.704**	.254
SOR							1	.929**	.001
NOR								1	.061
O_3									1
$PM_{2.5}$	d	1	.930**	-.003	-140	-461	-.364	-.510	-.740*
SOC			1	.292	.071	-.591	-.300	-.415	-.749*
SOC/OC				1	.628	-.287	.266	.159	-.037
S ion					1	-.306	.869**	.805*	.058
S/t ion						1	-.093	.103	.162
SOR							1	.955**	.410
NOR								1	.392
O_3									1

Ocean source

Table 8. The correlation between $PM_{2.5}$, MSA^-, Na^+，Cl^- in μg m^{-3}

		$PM_{2.5}$	MSA^-	Na^+	Cl^-
$PM_{2.5}$	entire	1	.008	.464**	.541*
MSA^-			1	-.098	.071
Na^+				1	.461**
Cl^-					1
$PM_{2.5}$	c	1	.251	.533	.212
MSA^-			1	.327	.182
Na^+				1	.052
Cl^-					1
$PM_{2.5}$	d	1	-.666	707*	.107
MSA^-			1	-.455	-0.80
Na^+				1	.279
Cl^-					1

- PBLH Vs $PM_{2.5}$

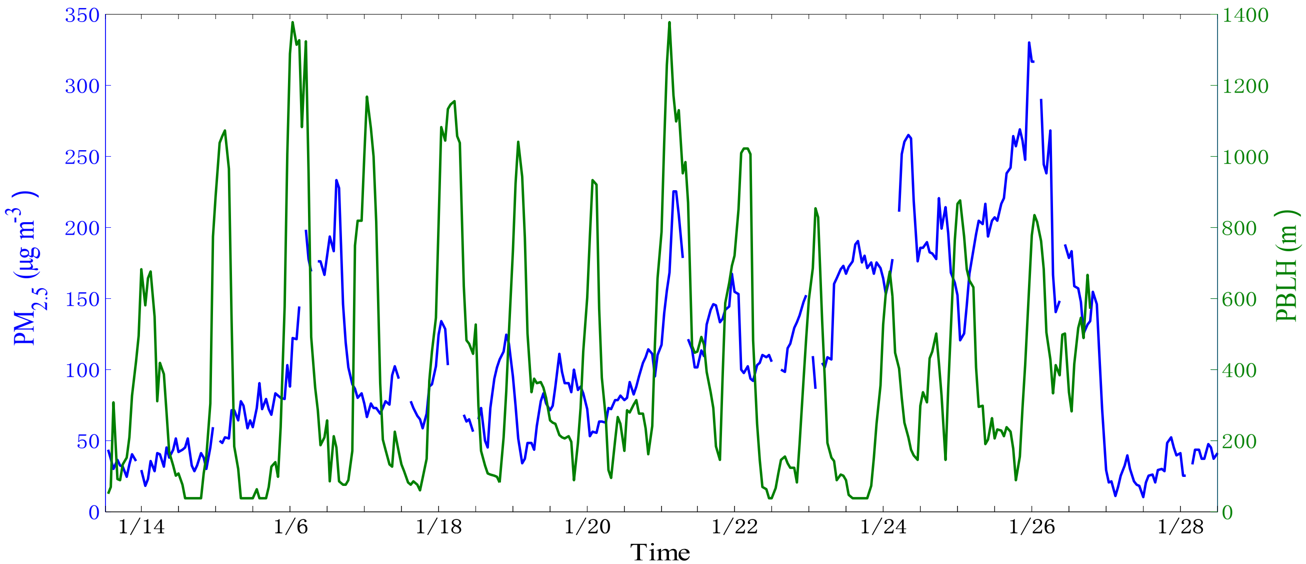


Figure 9. Temporal variation of PBLH and $PM_{2.5}$

Primary conclusion

- Fossil fuel combustion, biomass burning, secondary photochemical pollution, soil dust and ocean were sources of contaminents in this event. Among fossil fuel combustion sources, while industrial emission influenced pollution as usual, vehicle exhaust has made an unusual contribution during whole eposide with the average NO_3^-/SO_4^{2-} 1.37.
- $PM_{2.5}$ peak on 16th Jan is mainly the result of both fossil fuel combustion and secondary contamination.
- Soil dust, marine emission, mobile source and secondary oxidation of NO_2 are both responsible for pollution on 21th Jan.
- In the evening of 24th Jan, $PM_{2.5}$ peak has attributed to biomass burning, ocean emission and its low PBL height .
- The highest $PM_{2.5}$ concentration appear at the noon of 26th . It was mainly because biomass burning and secondary photoxidation reaction exists. And the significant correlation between NO_3^- and SO_4^{2-} indicated indurstial emission has contributed a lot.

Next work

- Detect organic acids and carbohydrates of $PM_{2.5}$ samples to dig out more chemical information.
- Learn to use PMF model. Input carbonaceous information, inorganic ion, organic data and six pollutants concentration data into PMF to quantify the source of pollutants.

Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

Thank you for your time