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Fast Photochemistry Discovered in Winter Beijing: Current Haze and Future Ozone Pollutions (?)

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Winter Air Pollutions



"London Smog" ------ "New York Smog" ------ "Eastern China Smog" ²

Winter Air Pollution in NCP

Formation mechanism of the particulate nitrate and POM?



Chinese EPA: NCP particle components monitoring network

Winter Air Pollution in NCP

Formation mechanism of the particulate nitrate and POM?



Measured by AMS @ Peking University Super site

Winter radical measurements

Field campaigns including HO_X or NO_3 radical measurements



Lu et al., NSR, 2018

2015/2016 Winter: BEST-ONE campaign

Beijing winter finE particle Study: Oxidation \rightarrow Nucleation \rightarrow Extinction



Trace gas compounds		Particles		Radicals	
NOx	TE-42i-TL, Ecophyics	PM ₁₀	TEOM1	ОН	LIF
NOy	TE-42c-Y	PM _{2.5}	TEOM2	HO_2	LIF
SO_2	TE-43i-TLE, GAC	Filter	Moudi	RO_2	LIF
со	TE-48i-TL, PICARRO	Filter	H volume	k _{OH}	LIF
CO_2	TE-410i, PICARRO	PM chemical composition	TAG-AMS, PTR- ACM, GAC	NO ³	LP-DOAS
O_3	TE-49i, ESA	Size distribution	PSM, SMPS, APS	N_2O_5	CRDs, CEAS
H ₂ O	PICARRO	PM Hydroscopic	HTDMA	Meteorolo	gical parameters
HONO	FZJ-LOP, GAC, CEAS	PM Volatility	VTDMA	Visibility	Belfort
HNO3	GAC, PKU-LOP	PM abs. coeff.	Maggi	J-values	Spectroradiometer
$ m NH_3$	GAC, CIMS	BC	MAAP	Aerosol vertical	LIDAR
PAN, PPN	GC-ECD	PM scattering	Nephelometer	O3 vertical	LIDAR
H ₂ O ₂ , ROOH	HPLC	OA	PKU-EC/OC	AOD	CIMEL318
CH_4	PICARRO	CCN	CCNs	Temperature	METONE
NMHC (C ₂ -C ₁₂)	GC-MS	Metal	XRF	RH	METONE
OVOCs (C2-C10)	PTR-TOF-MS	Cluster	API-TOF	Pressure	METONE
НСНО	Hanstch			Wind profile	LIDAR
SVOC	PUFF				
ELVOCs	CIMS				
H2SO4	CIMS				



2016/2017 Winter: APHH campaign

PKU contributions on the gas phase chemistry





In parallel: HOx radical also detected by U Leeds (Lisa & Dwayne)

2017/2018 Winter: J³-Haze campaign

PKUERS







	地面气象	风温湿压
	能见度仪	能见度
	全自动太阳光度计	大气气溶胶光学厚度(AOD)
1 Motoorology	光谱光度计	光化辐射通量
1. Meleorology	微波辐射计	水汽总量及温湿廓线
	风廓线雷达	风廓线
	激光雷达	颗粒物消光廓线,臭氧
	Camera Lidar	近地面颗粒物消光廓线
	Thermo系列	NO, NO ₂ , O ₃ , CO, SO ₂ , NOy
	GAC	气体/颗粒物水溶性离子
	Online-GCMS	VOCs, OVOCs
	Piccarro	氨气
	GC-ECD	PAN
2 Oxidation	FAGE-LIF	OH, HO ₂
	TD-CEAS	N ₂ O ₅
	LOPAP	HONO
	Hanstch	НСНО
	HPLC	H ₂ O ₂
	PTR-ToF-MS	VOCs, OVOCs
	Nitrate CIMS	硫酸、有机物、HOMs
	TH、Thermo	PM _{2.5} 、PM ₁₀ 质量浓度
	SMPS	3-500 nm颗粒物数浓度
	APS	500nm-10um颗粒物数浓度
	MAAP	颗粒物吸光系数
	Aethelometer	颗粒物吸光系数
	Nephelometer	颗粒物散射系数
	XRF	重金属
3. Aerosol	在线EC/OC	颗粒物EC/OC浓度
	PM2.5膜采样器	POM:GCMS, Orbitrap
	MOUDI	分粒径化学组成(过程)
	PSM	1-3nm颗粒物数浓度
	HR-ToF-AMS	分粒径非难熔颗粒物化学组成
	f(RH)	含水量、kappa、CCN相函数、SSA
	H/V-TDMA	颗粒物吸湿性/挥发性
	颗粒物粘性和相态仪	颗粒物粘性和相态

Observations



Obs vs Mod for haze



RACM2 updated by LIM

Radical budget



OH turnover rates

OH turnover rates = R (OH+CO) + R (OH+NOx) + R (OH+VOCs)

 $= OH \times k_{OH}$



Gas phase oxidation rates of photochemistry



Fast OH oxidation and gross O₃ production rates were determined, comparable to summer time !

The produced O_3 is quickly titrated to be NO_2 and further converted to NOz and particulate nitrate (NO_3^-) by OH and NO_3 oxidation.

Total oxidants, PAN and fine particles



The observed O_3 is small but the total oxidants ($Ox = O_3$ + NO_2 + NOz) and PAN is quite high, comparable to summer.

The fine particles are mainly secondary, and ammonium nitrate as the largest components.

Indicator of Photochemistry - PAN and PM



Observation and modeled photochemistry



Model: RACM2 updated by LIM and Chlorine chemical module

Experimentally determined



20%

Policy Implications: future ozone pollutions?



Concept of Winter Photochemisty in Beijing

Currently, the O₃ pollution problem is masked by nitrate pollution



Concept of Winter Photochemisty in Beijing

Fast photochemistry in winter may able to explain both the formation of nitrate and SOA.



Nocturnal Transformation

Summary and conclusions

- High concentrations of total oxidants (O₃+NO₂+NOz) and high concentrations secondary aerosols (especially nitrate) were observed indicating intensive photochemistry in winter Beijing.
- Consistently, fast photochemical reaction rates that drive formation of ozone and particulate nitrate are experimentally determined from observed radical concentrations.
- The fast winter ozone production is currently masked by a nitrate pollution phenomena. As the future control is solely planned for NOx, the ozone pollution problem may appear in winter Beijing subsequent to the haze problem.

EGU2019



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AS3.17 Air pollution in Asia

Convener: Hendrik Fuchs Q Co-conveners: Xin Li Q, Keding Lu Q, Lisa Whalley Q, Zhijun Wu Q

Abstract submission

Air pollution is of great concern by the public and government in Asia, specifically in India and China, due to the risk to human health. To elucidate the formation mechanisms of air pollution in Asia, numerous field studies and modelling studies have been conducted in different Asian countries in the recent years, accompanied by mandatory emission restriction strategies that have been put into action.

This session aims for presentations about recent results from field studies, and also air quality monitoring activities in Asia linked to photochemistry, aerosols, emissions of air pollutants and tropospheric chemical composition.

All stages of data analysis are welcome in this session, including presentations of early field data, modelling studies, and results on the global impact of air pollution in Asia.

Thanks! Questions & Comments