



CDZ Workshop Beijing

Pollutants and aging from agricultural straws burning in China: a chamber simulation

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Agricultural Crop Residue Burning in China





Nanjing, 11 June 2012

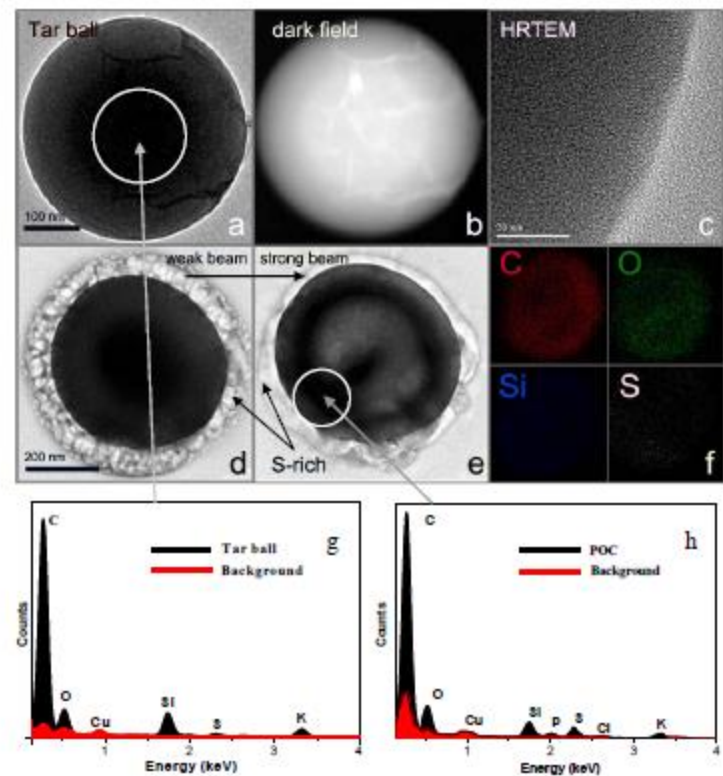
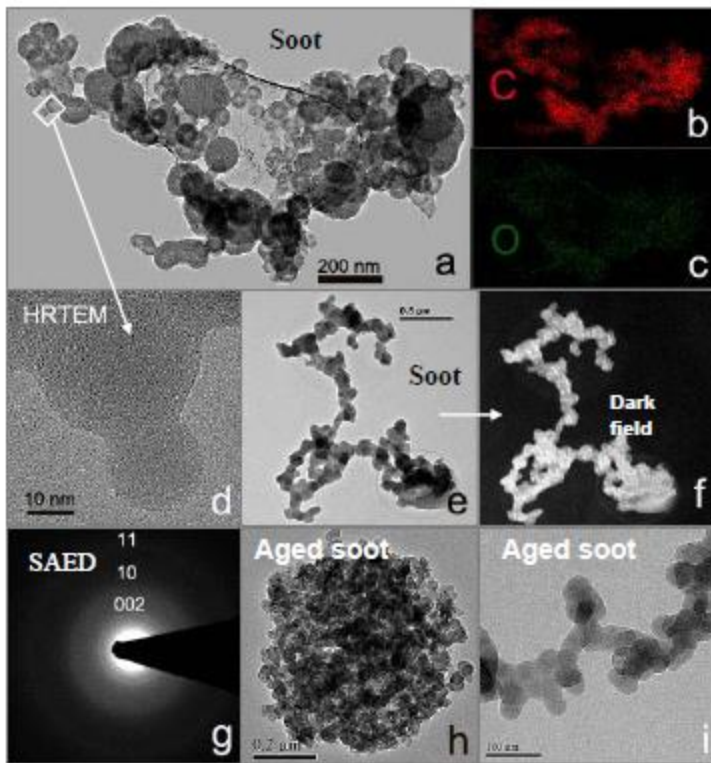




Photo taken in a high speed train by me on 19 June 2013

TEM images of soot, tar ball

C, O, Si, S on ambient particle



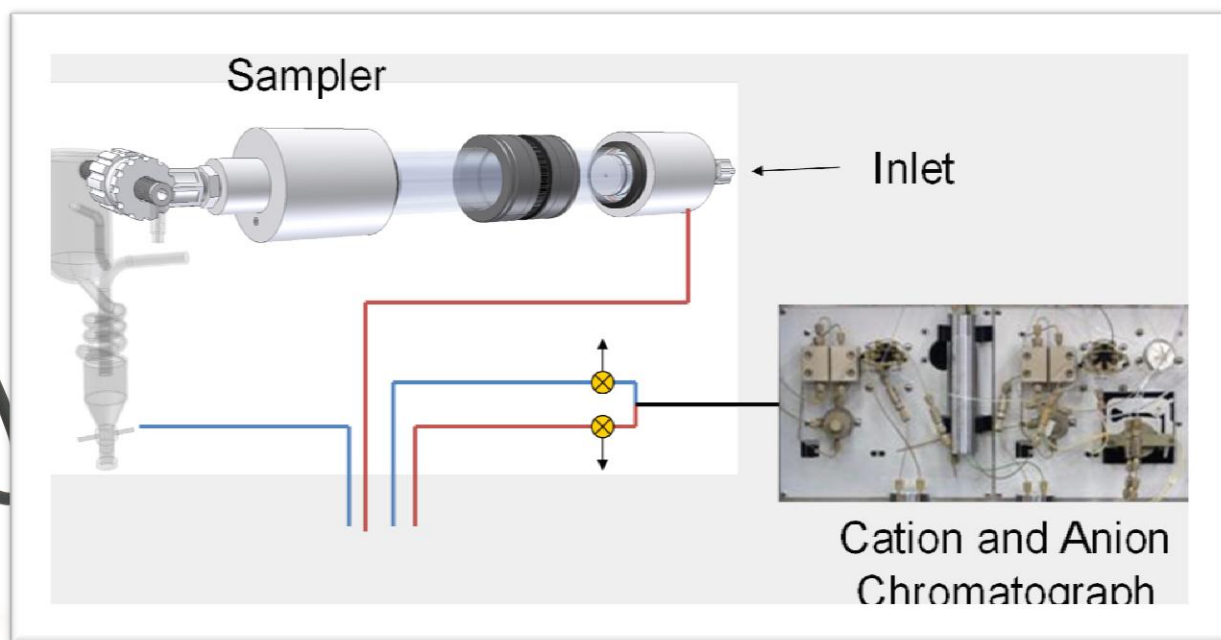
TEM images of soot particles collected from the atmosphere in Shanghai

Fu et al., ACP 2012

On-line Analysis of Water Soluble Ions in PM_{2.5}



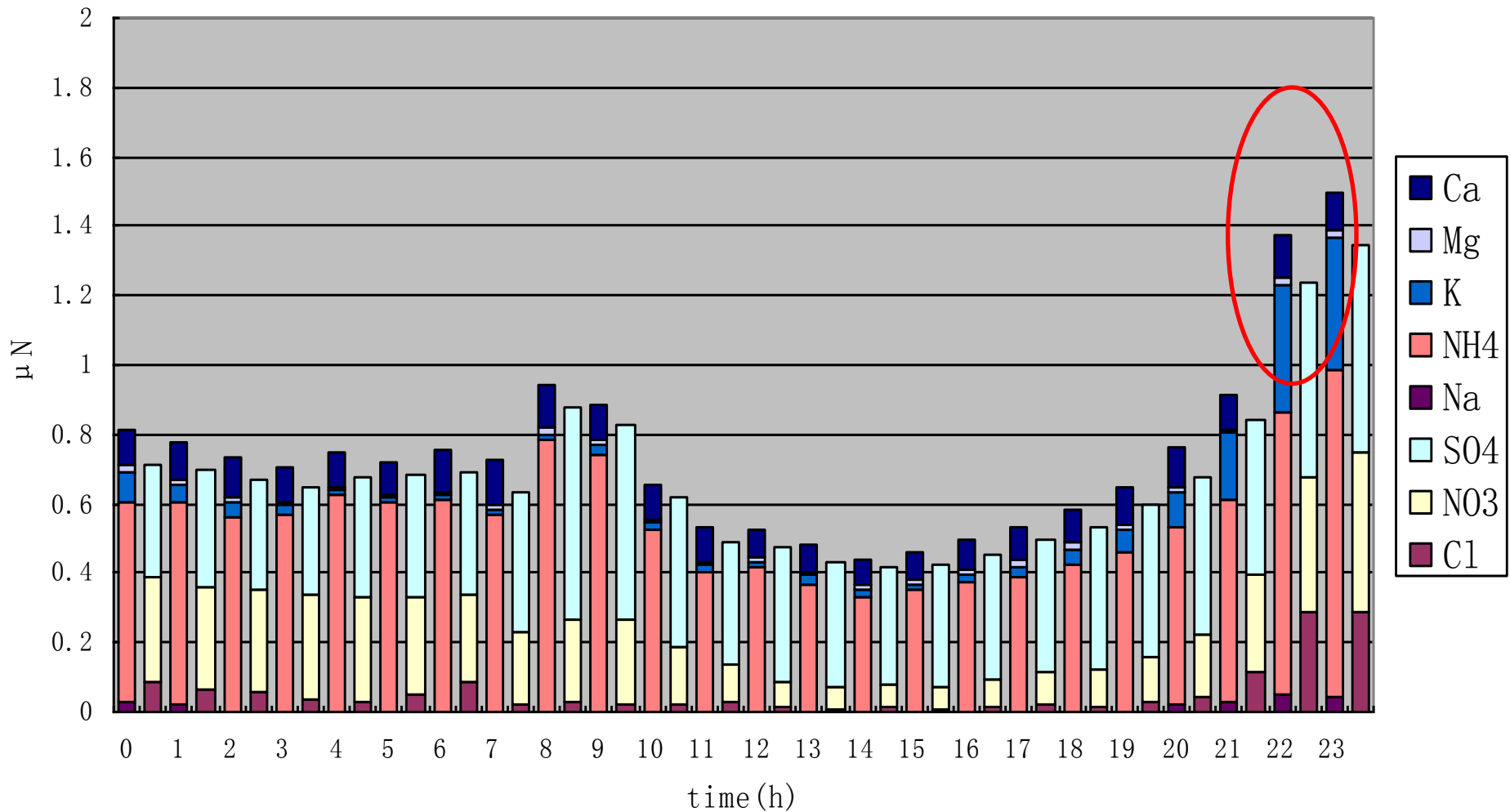
MARGA



$$\text{TWSI} = [\text{SO}_4^{2-}] + [\text{NO}_3^-] + [\text{Cl}^-] + [\text{NH}_4^+] + [\text{Na}^+] + [\text{K}^+] + [\text{Ca}^{2+}] + [\text{Mg}^{2+}]$$

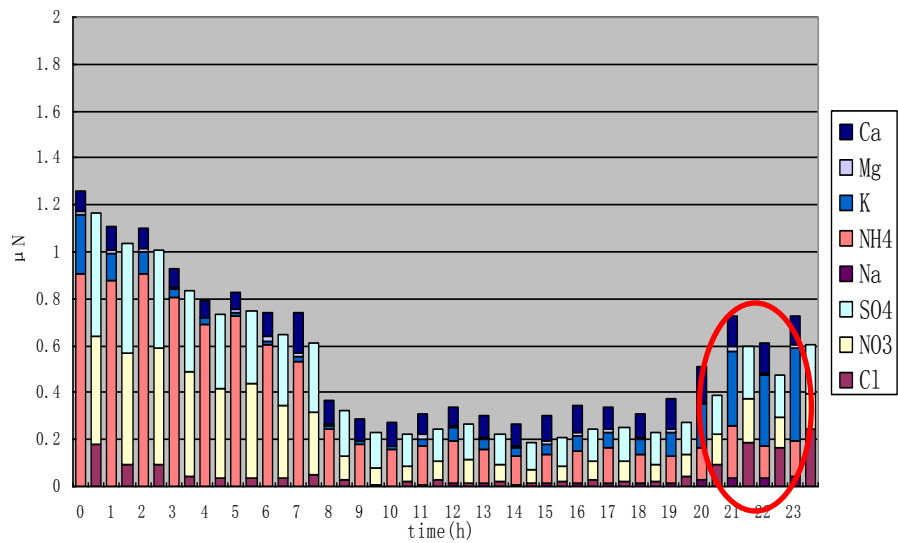
Sulfate, Nitrate, ammonium and Potassium on PM2.5

data-528

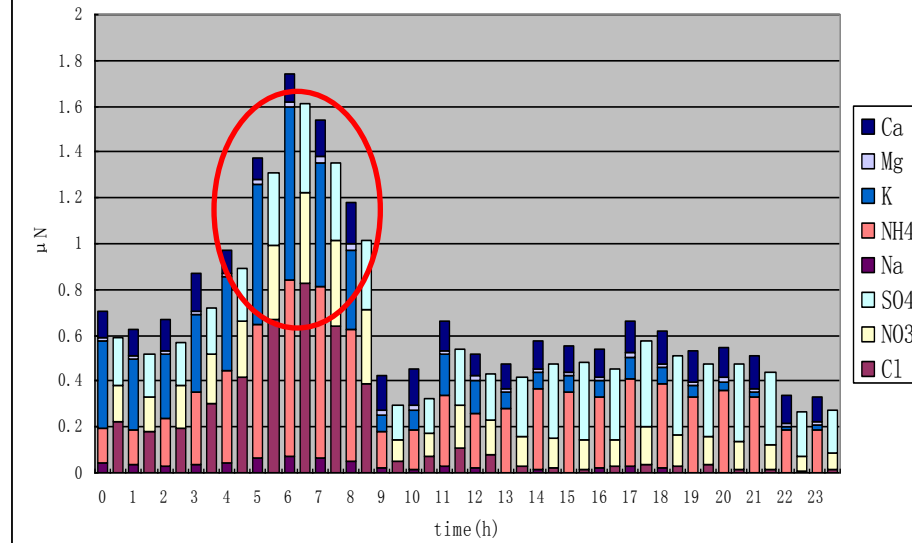


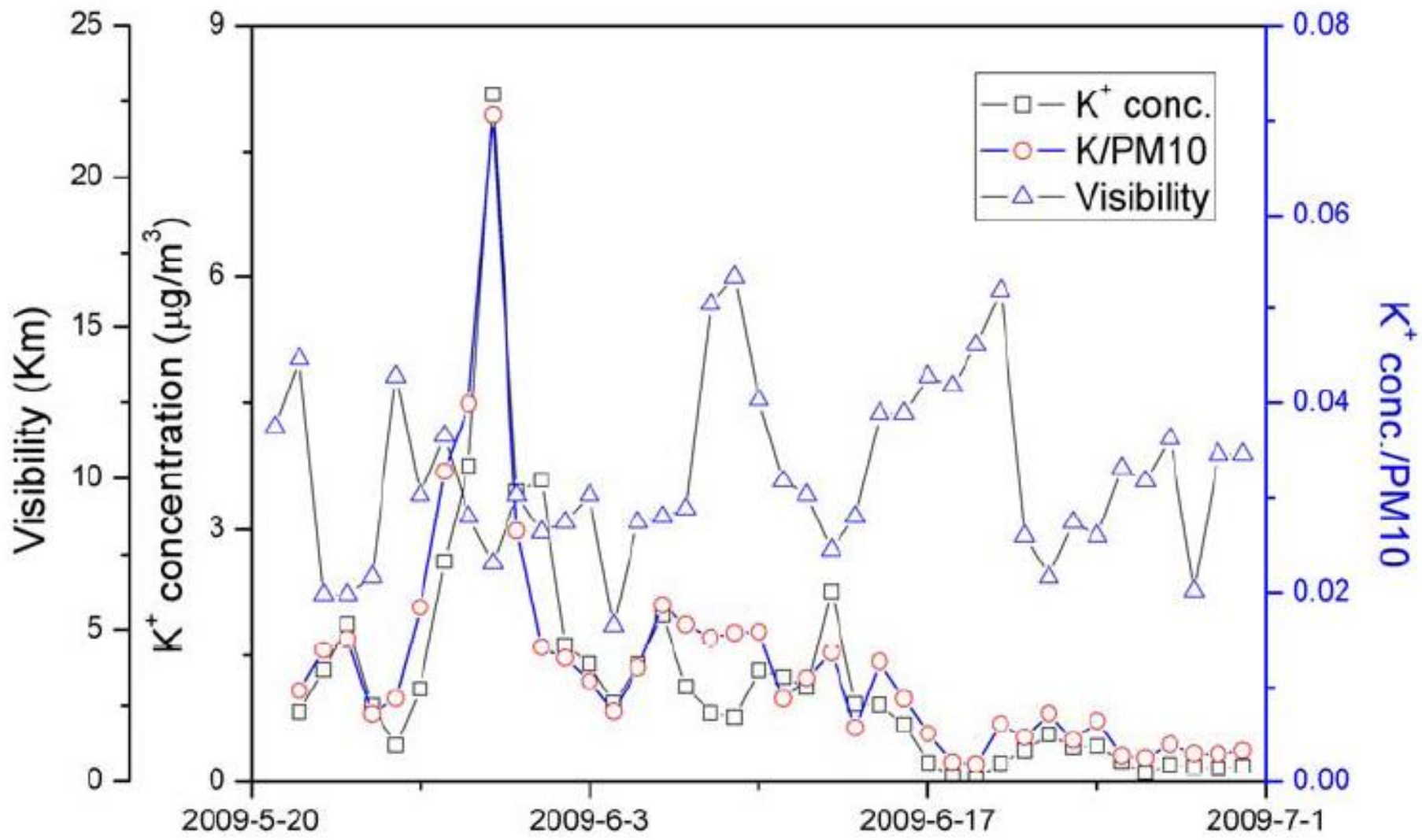
Biomass burning impacted to Shanghai air quality at 23:00, 28 Jun 2009

data-529

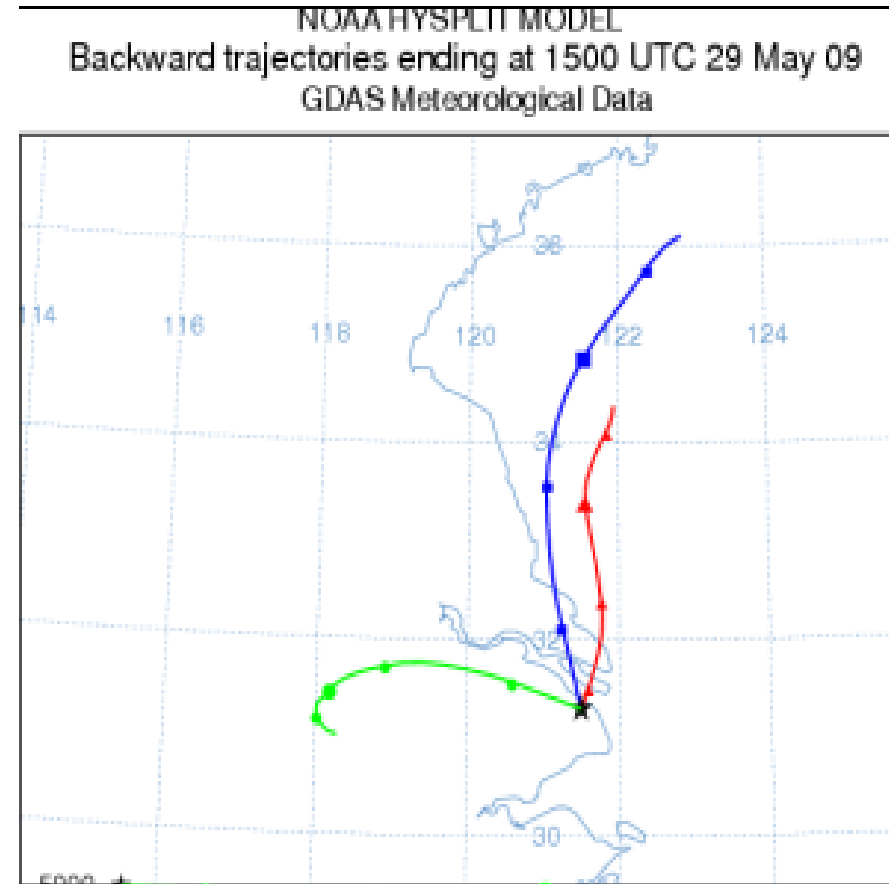
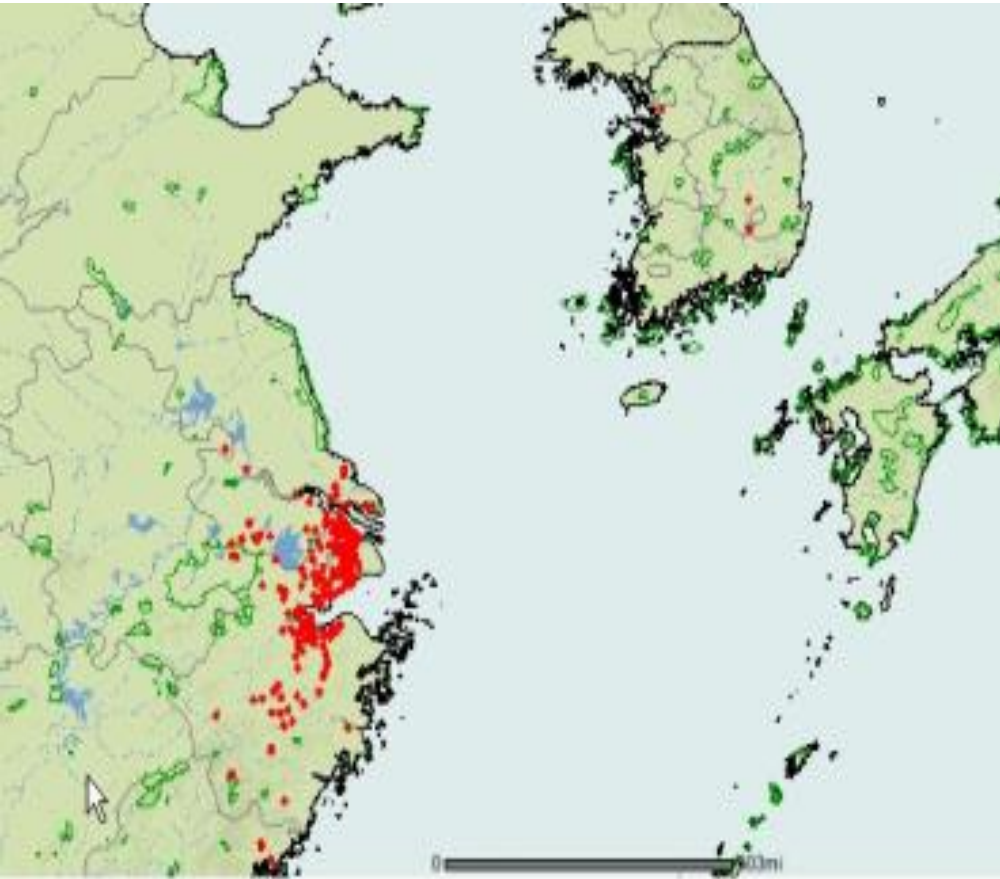


data-530





Fire map & back trajectory on 29 May 2009, Shanghai



上海世博会期间 长三角地区秸秆焚烧遥感信息日报

第 29 期

环境保护部

2010年5月24日

卫星遥感监测秸秆焚烧火点情况

2010年5月24日卫星遥感监测秸秆焚烧火点统计表:

省份	上海市	江苏省	浙江省
火点数	0	21	24

2010年5月24日卫星遥感监测秸秆焚烧火点空间分布图:



图1 长三角地区秸秆焚烧火点分布图

附件 2:

各省(直辖市)卫星遥感 监测秸秆焚烧火点分布详细情况

一、江苏

1. 2010年5月24日火点空间分布

江苏秸秆焚烧卫星遥感监测图
(2010年5月24日)

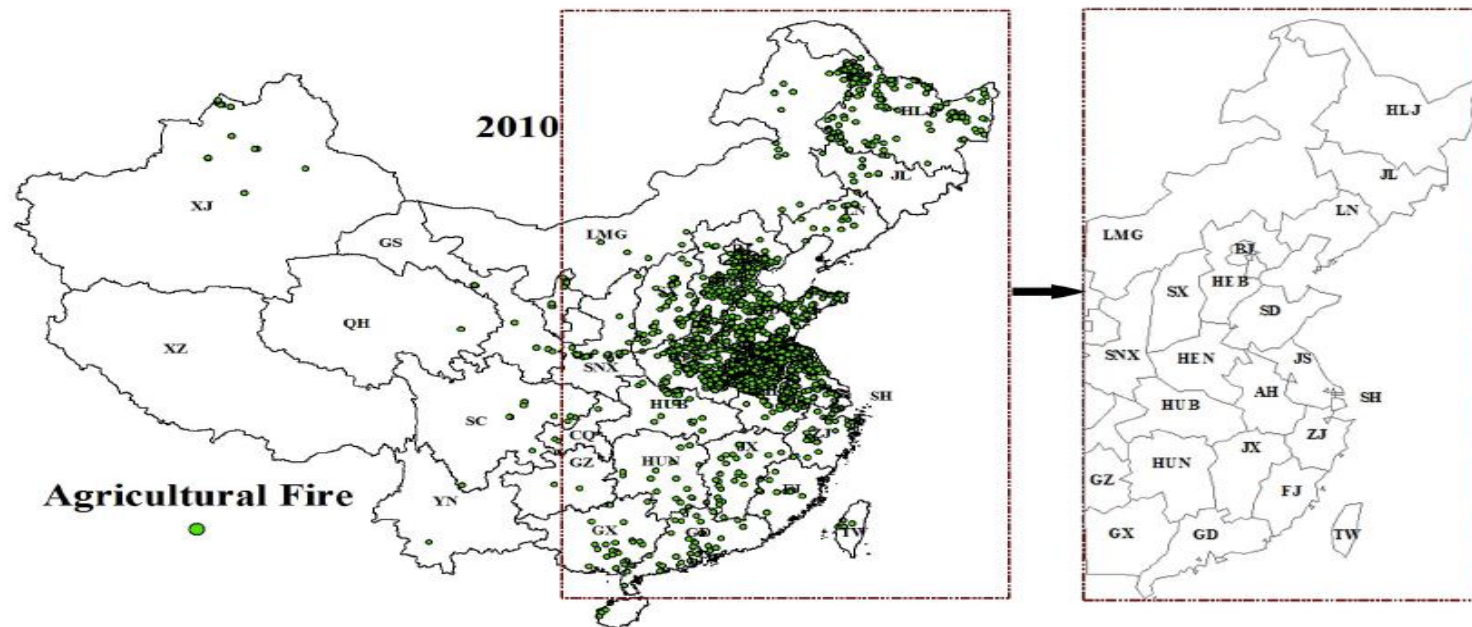
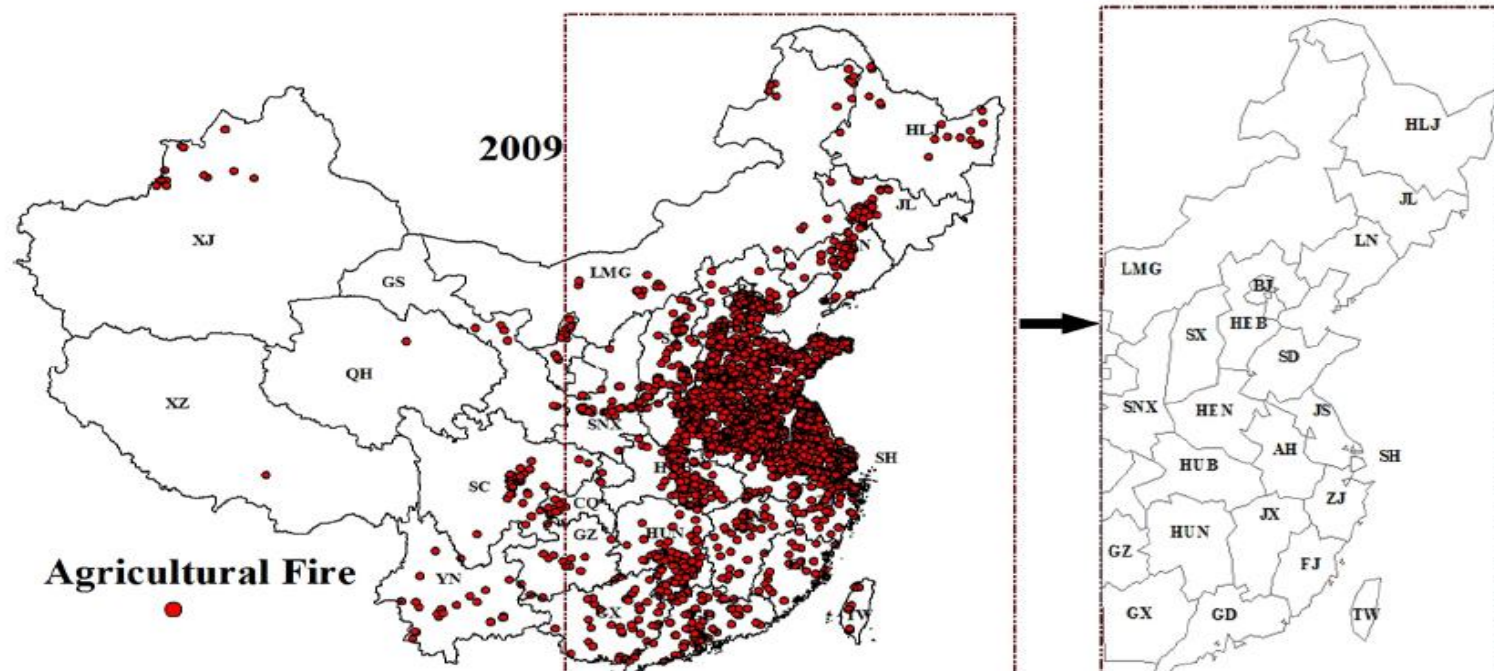


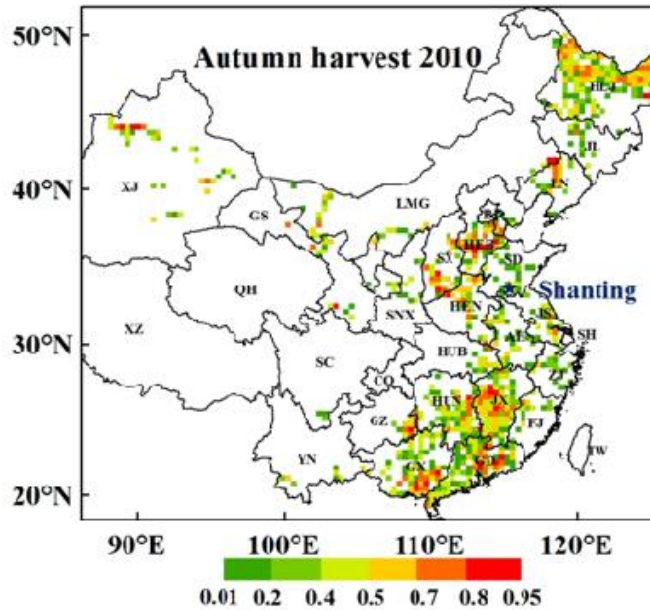
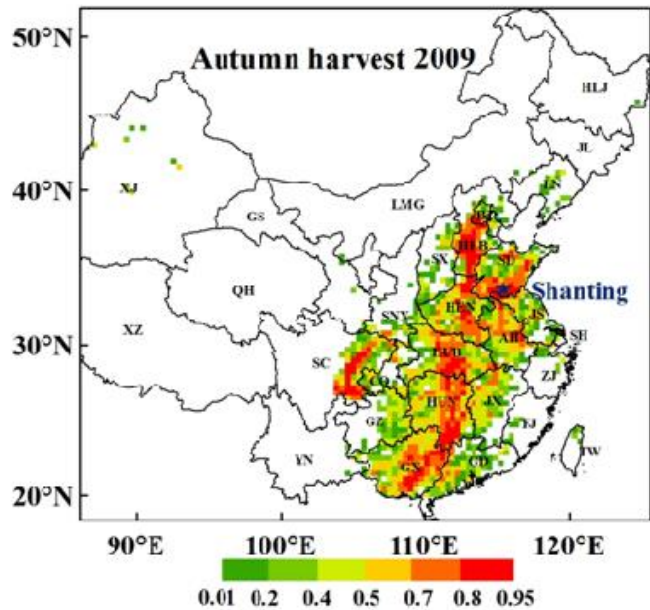
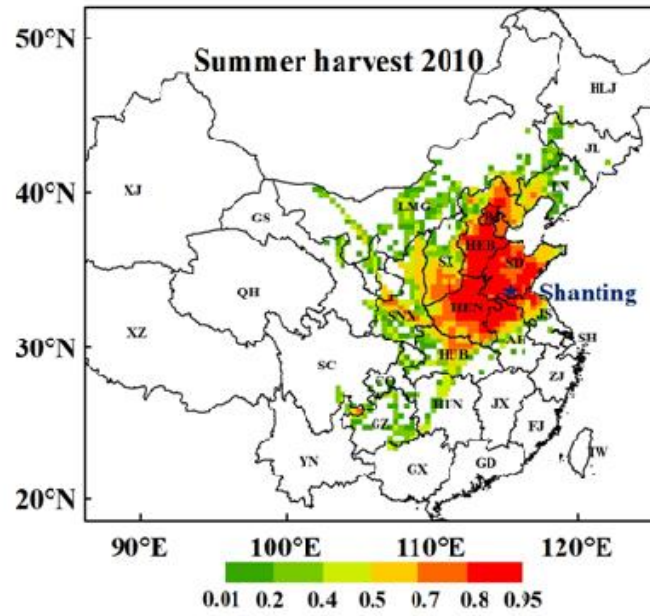
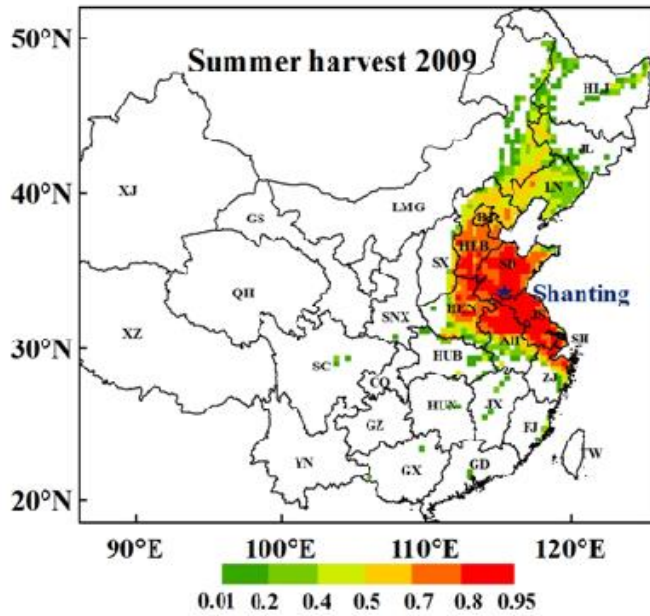
图1 江苏秸秆焚烧火点分布图

2. 2010年5月24日火点统计

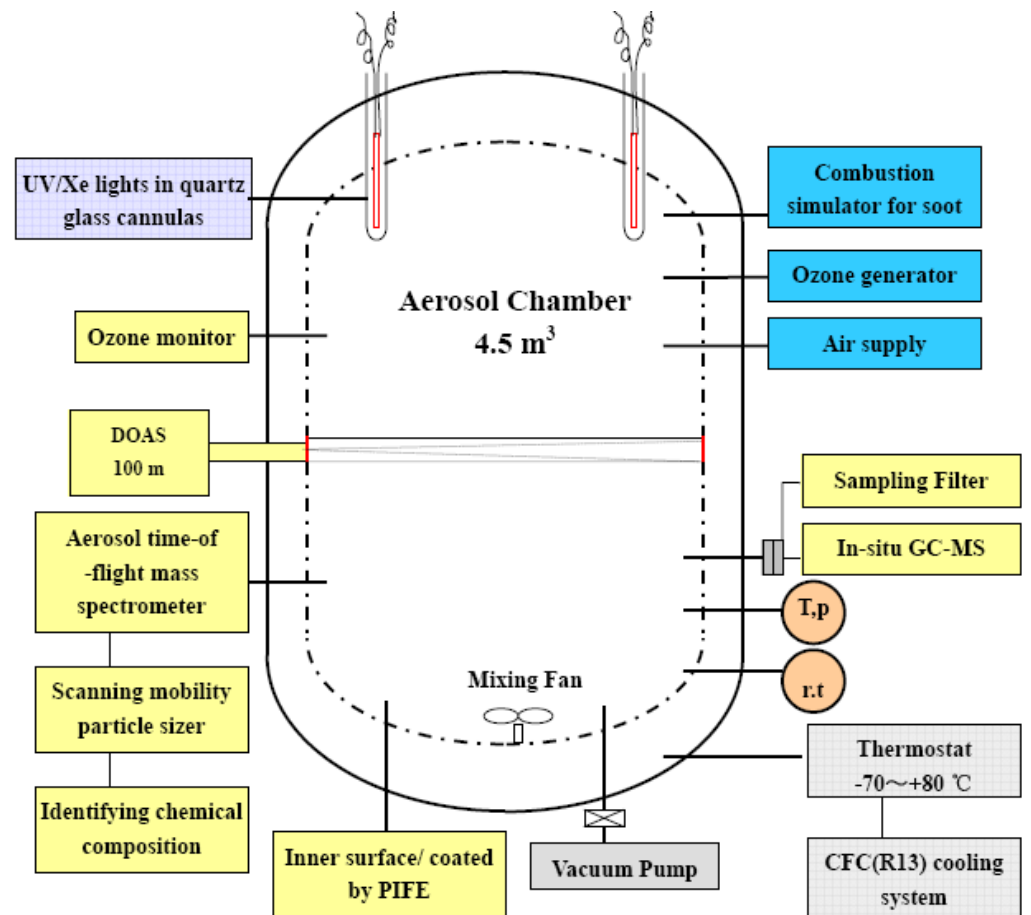
省	市	县	县火点个数	市火点个数	省火点个数
江苏	南京市	江宁区	6	11	21
		溧水县	3		

Shanghai World Expos 2010, to control Biomass Burning

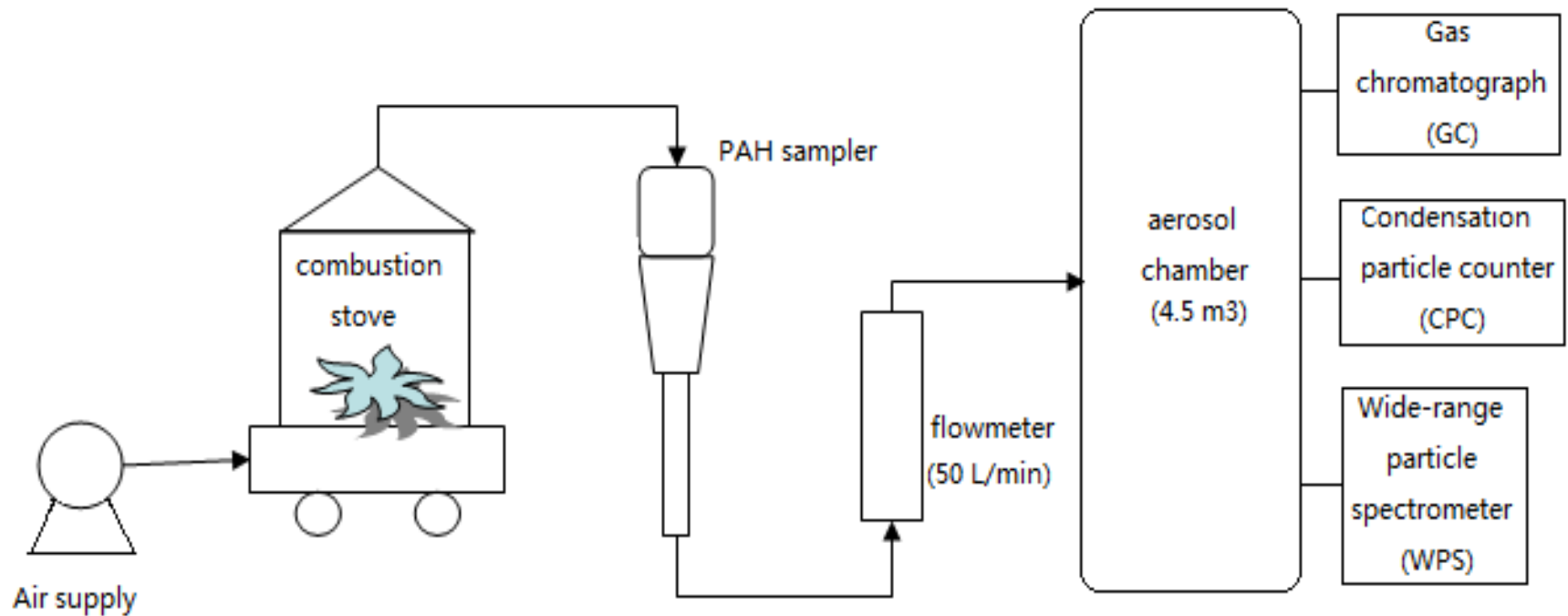




Chamber Facility



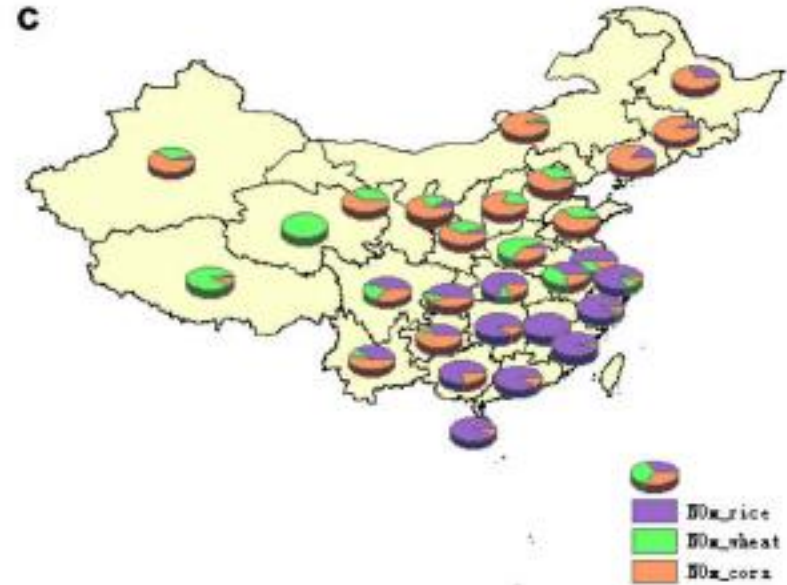
Aerosol chamber and a self-designed combustion stove



NOx Emissions



Distributions of gaseous pollutant emissions for the year 2004 at province -level in China :(c) NOx. (units: kg /km²)



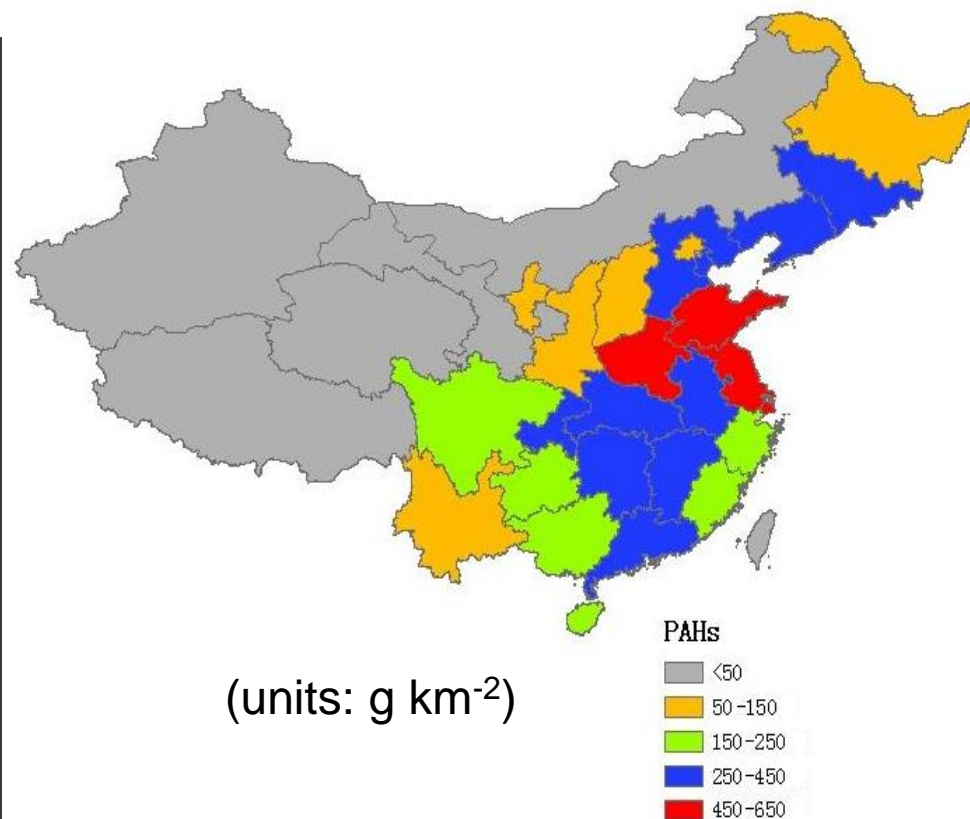
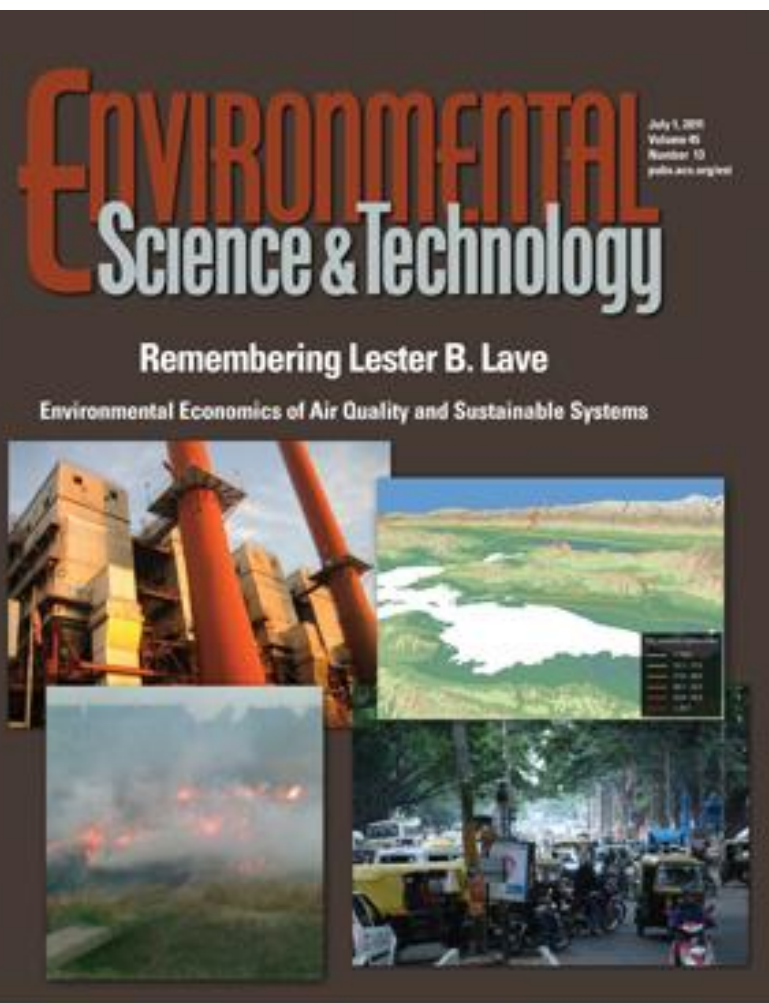
Relative proportion of gaseous pollutant emissions from burning of straws for the year 2004 at province-level in China

Emission Factors of PAHs

TABLE 1. Emission Factors of PAHs from Agricultural Crop Residue Burning (units: mg kg⁻¹)

PAHs	Rice straw (n=5)		Corn straw (n=5)		Wheat straw (n=5)	
	Particle	Gas	Particle	Gas	Particle	Gas
Naphthalene	0.01	1.88	/	0.41	/	0.28
Acenaphthylene	0.02	0.67	0.03	0.2	0.03	/
Acenaphthene	0.02	0.08	0.11	0.03	0.14	0.19
Fluorene	0.01	0.06	0.04	0.04	0.02	0.02
Anthracene	0.33	0.40	0.17	0.06	0.09	/
Phenanthrene	0.04	0.11	0.07	0.01	0.06	0.01
Fluoranthene	0.27	0.09	0.17	0.01	0.14	0.02
Pyrene	0.23	0.07	0.11	0.01	0.11	0.01
Benz [a] anthracene	0.06	0.02	0.01	0.01	/	0.01
Chrysene	0.17	0.08	0.13	0.02	0.07	0.02
Benzo [a] pyrene	0.10	0.04	/	/	/	/
Benzo [b] fluoranthene	0.04	/	0.04	/	0.02	/
Benzo [k] fluorathene	0.08	0.03	0.05	0.01	0.04	0.01
Benzo [g,h,i] perylene	0.12	0.04	/	/	/	0.03
Indeno [1,2,3-cd] pyrene	0.14	/	/	/	/	0.05
Dibenz [a,h] anthracene	0.13	0.05	/	/	/	/
∑PAHs	1.64	3.62	0.93	0.81	0.72	0.65

Geographical distribution of PAHs emission density in China

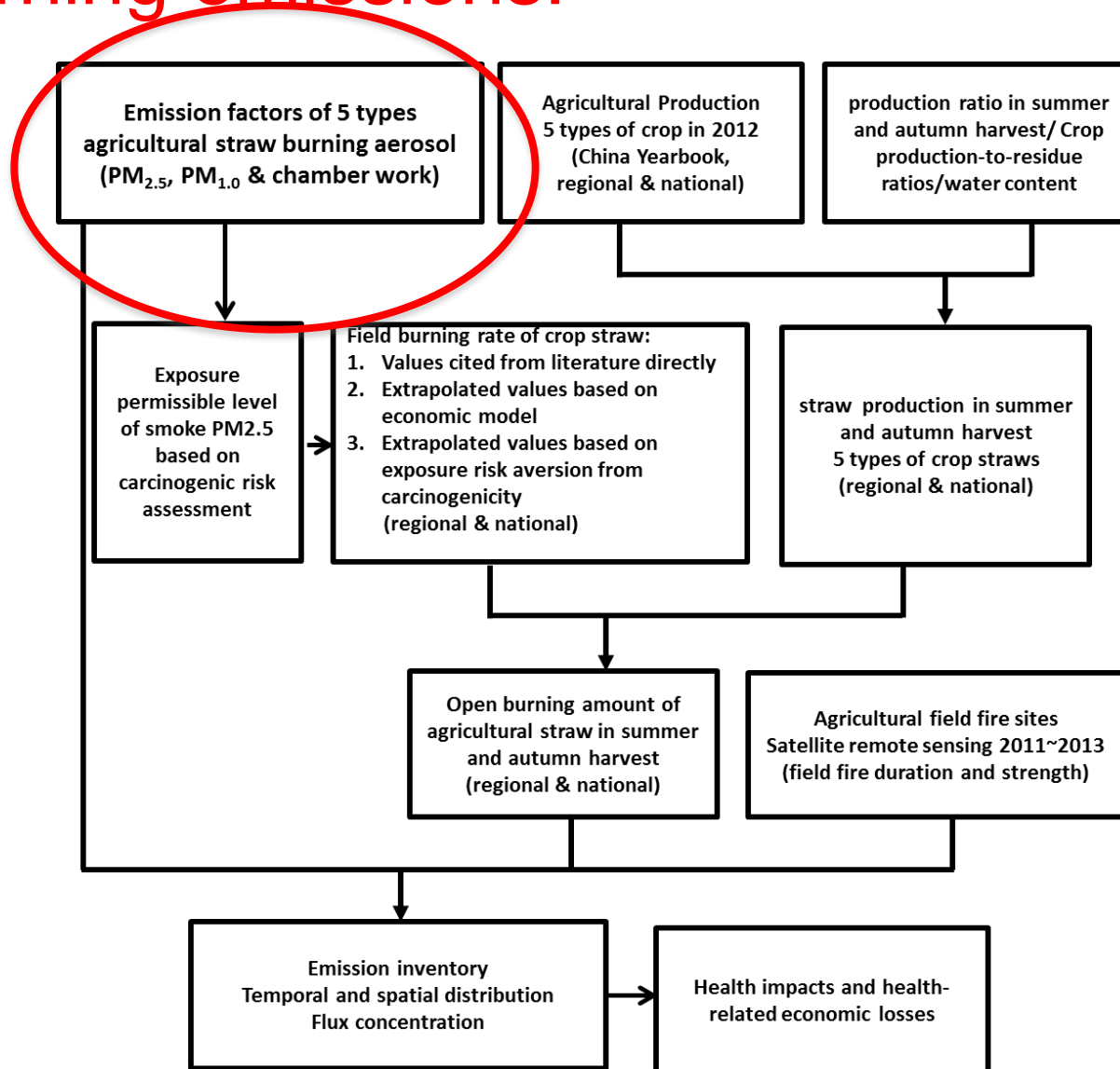


Zhang et al., Environ. Sci. Technol., 2011

Sources contributing to PAHS

- **Polluted soil** 100~200 $\mu\text{g}/\text{kg}$; **cooking barbecue** 144 $\mu\text{g}/\text{kg}$
- **Burning Rice Straw** 5260 $\mu\text{g}/\text{kg}$ (Zhang et al., ES&T, 2011)
- **Traffic Jam in Shanghai:** 43 $\mu\text{g}/\text{m}^3$ (Ren et al, AE, 2006)
- **Hotel and Home Kitchens** in Hangzhou, average conc. of PAHs 17.23 $\mu\text{g}/\text{m}^3$, a cooker breaths in 7-8 $\mu\text{g}/\text{day}$ (Zhu et al., Chin Environ Sci, 2002);
- **Smoke** Main stream-Total PAHs 180~780 ng/cig, by-stream 4.0~6.8 $\mu\text{g}/\text{cig}$; 3.6~15.6 $\mu\text{g}/20$ cigs!

Overall strategy to estimate effects of field burning emissions:



Combustion Stove and Chamber

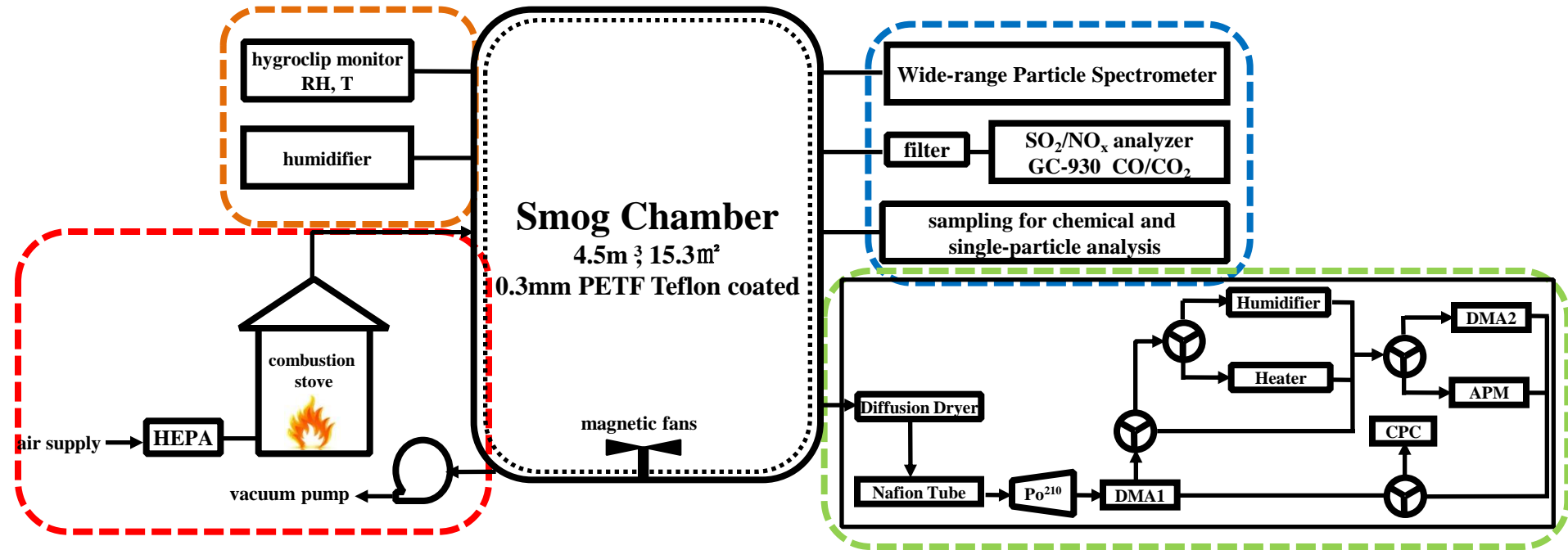


Figure 1. Schematic graph of biomass burning system

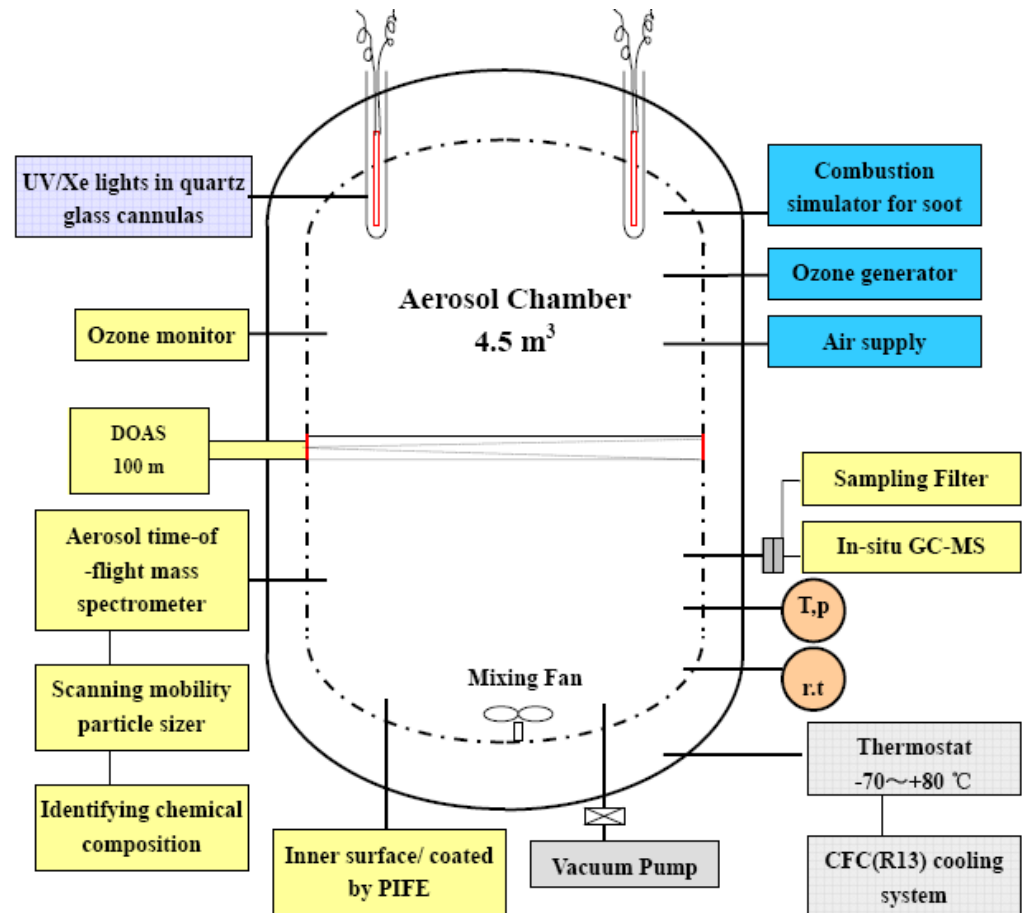
Smog chamber: capsule like, stainless, 4.5m³ in volume, 15.3m² inner surface area, 0.3 mm PETF Teflon inner coating, -70~100°C, 14Pa~0.22MPa

Combustion stove: cylinder like, stainless, ~0.226m³ in volume, portfire equipped inside

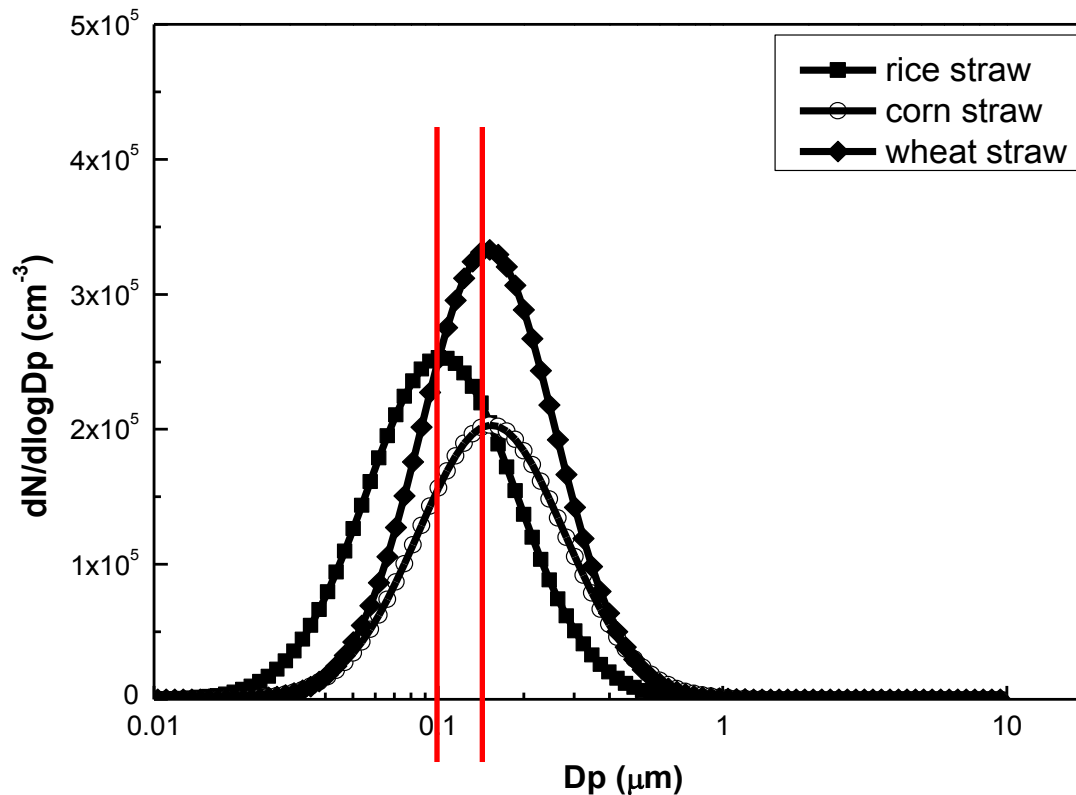
*Straws cleaned & dehydrated before burning

*10.0 g straw burned for 1 min and smoke injected into chamber; residual straw weighed to deduce efficiencies

Chamber Facility

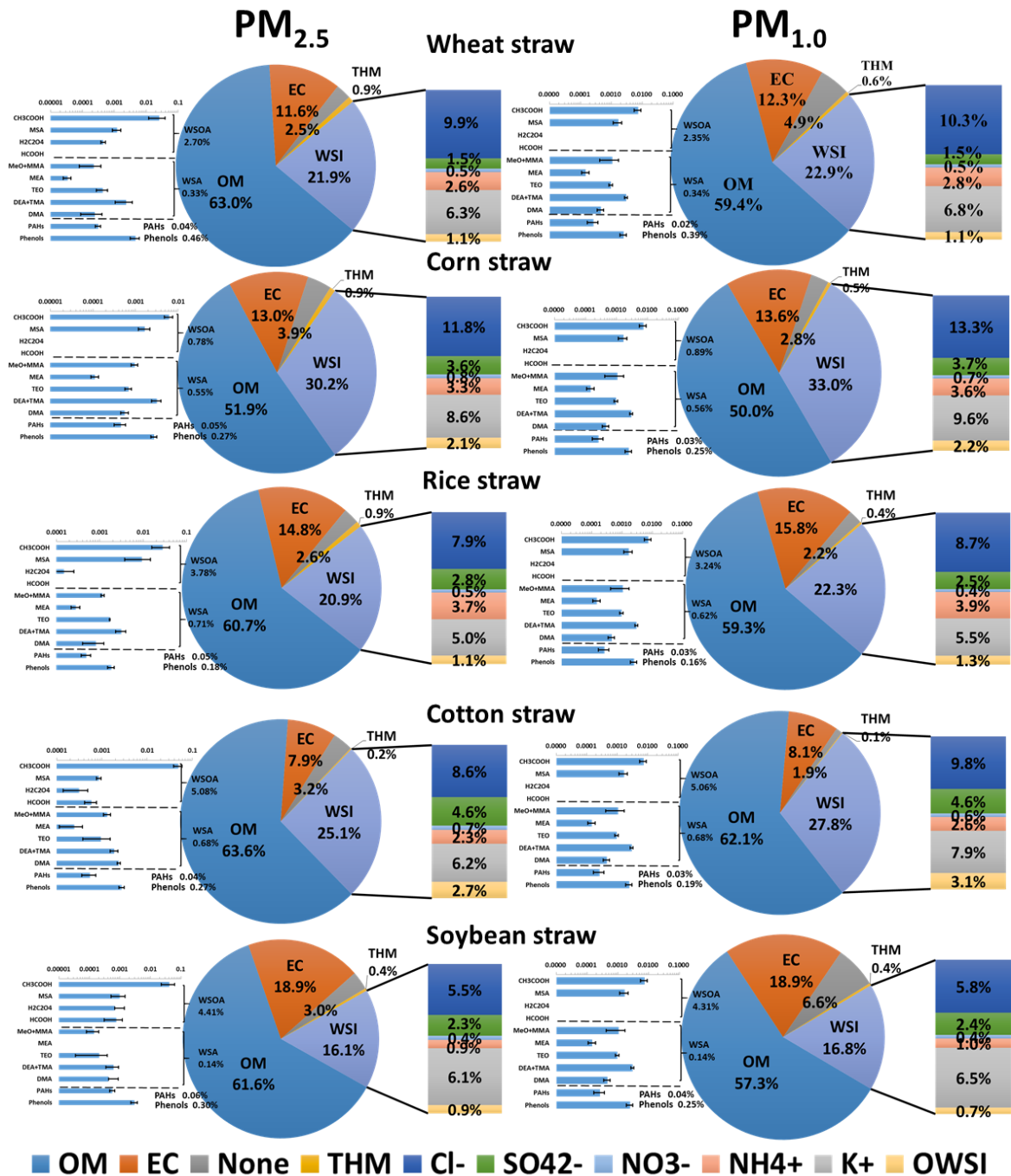


Particle Size Distribution

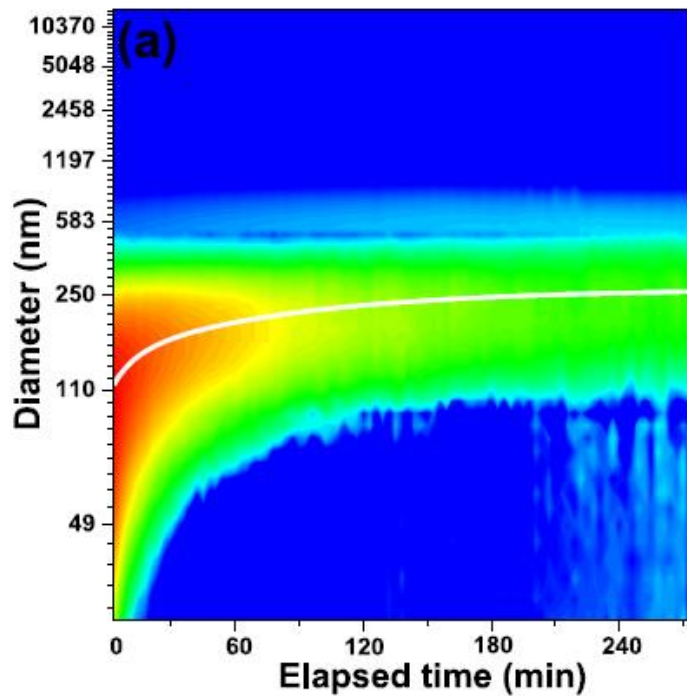


The distributions showed a unimodal mode with peaks at 0.10, 0.15 and 0.15 μm for rice, wheat, and corn straws, respectively

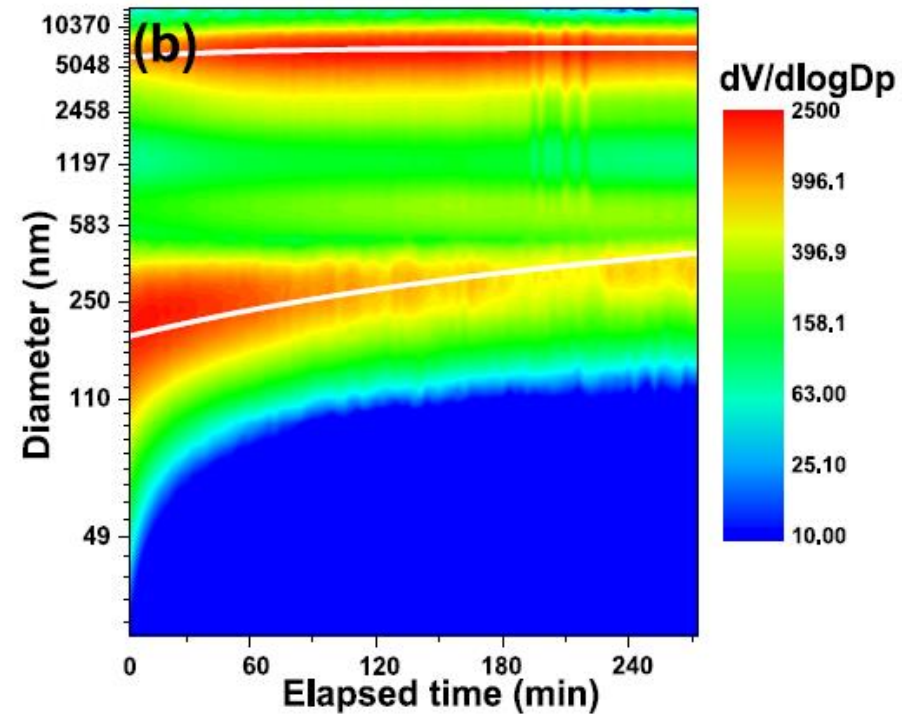
Emissions from the burning of agricultural crop residues were dominated by fine particles (less than 2.5 μm)



Smoke particle number and volume size distribution during aging *in the dark*

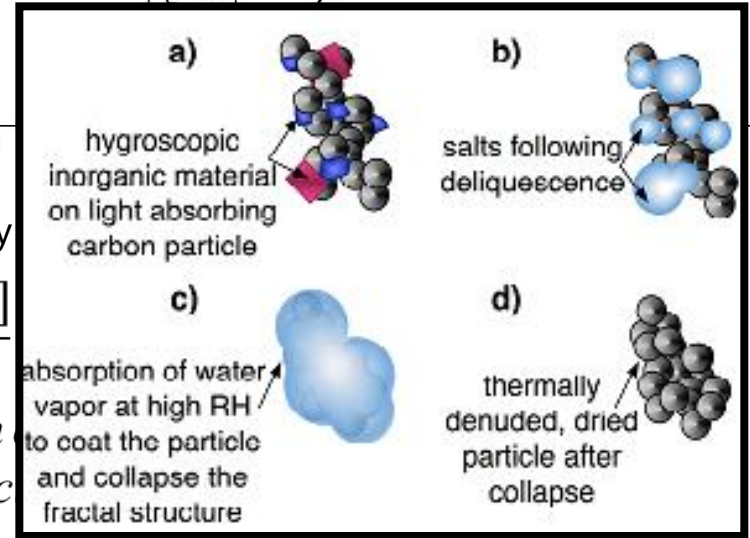
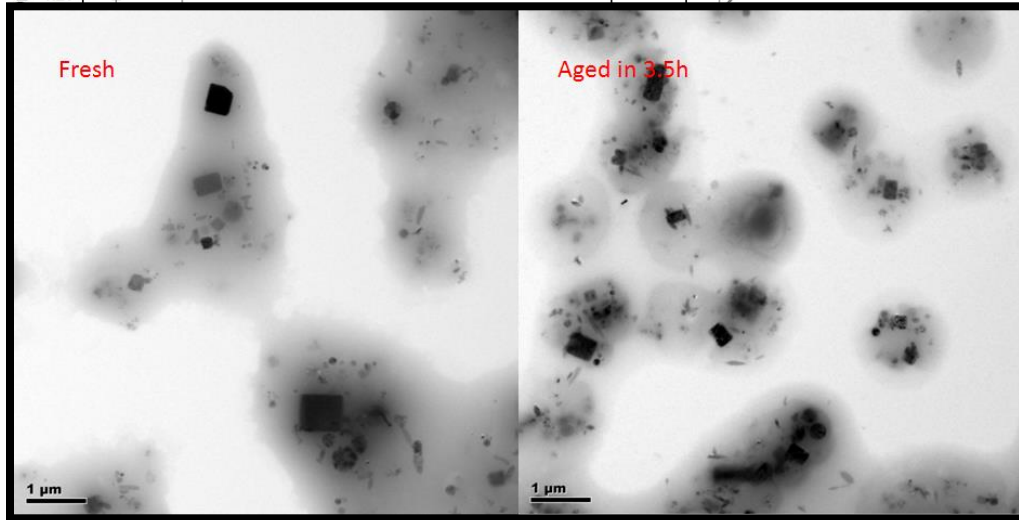
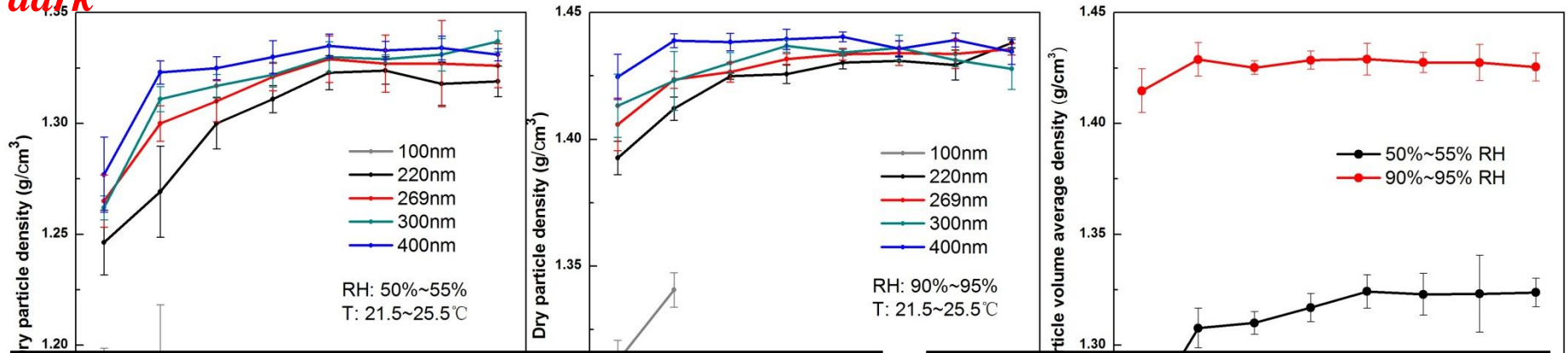


number



volume

Water effect on particles evolution in the chamber : attenuation & *density in the dark*



1. Particle size difference in dry density, with aging process, dry density increase to be uniform and stable at last, dry particle density is about 1.27 ~ 1.43g/cm³
2. Water vapor increase dry particle density, and accelerate the increase process
3. Particle density increase due to morphology, internal mixing, structure and chemical composition changes

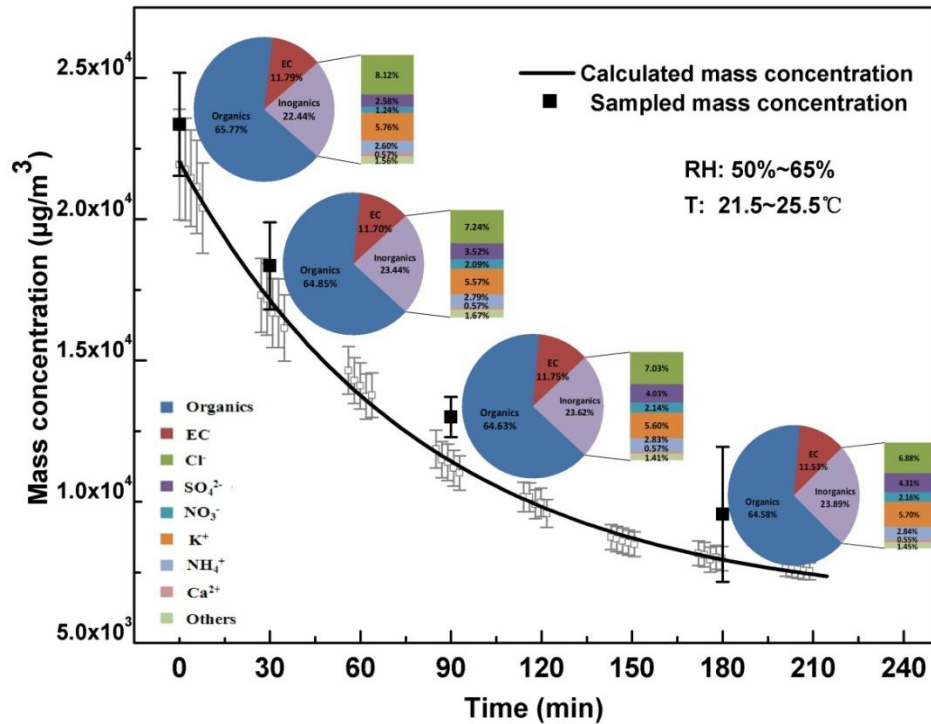
Quentin et al., AST, 2009; Lewis et al., ACP, 2009; Zhang et al., EST, 2005

Dry particle density selected as 1.31 g/cm^3

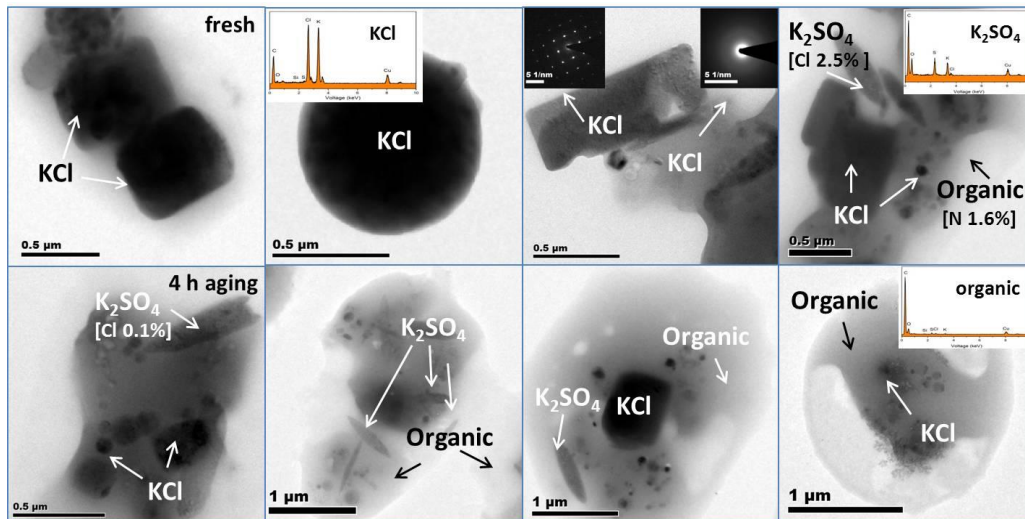
1. Mass concentration change under 50% ~ 65%RH deduced from filter sampling agrees well with calculated

2. Water soluble inorganic salts increase, mainly due to sulfate and nitrate formation, which track and perhaps even offset the decrease of chloride

3. Inorganics mass increase partly explains density changes

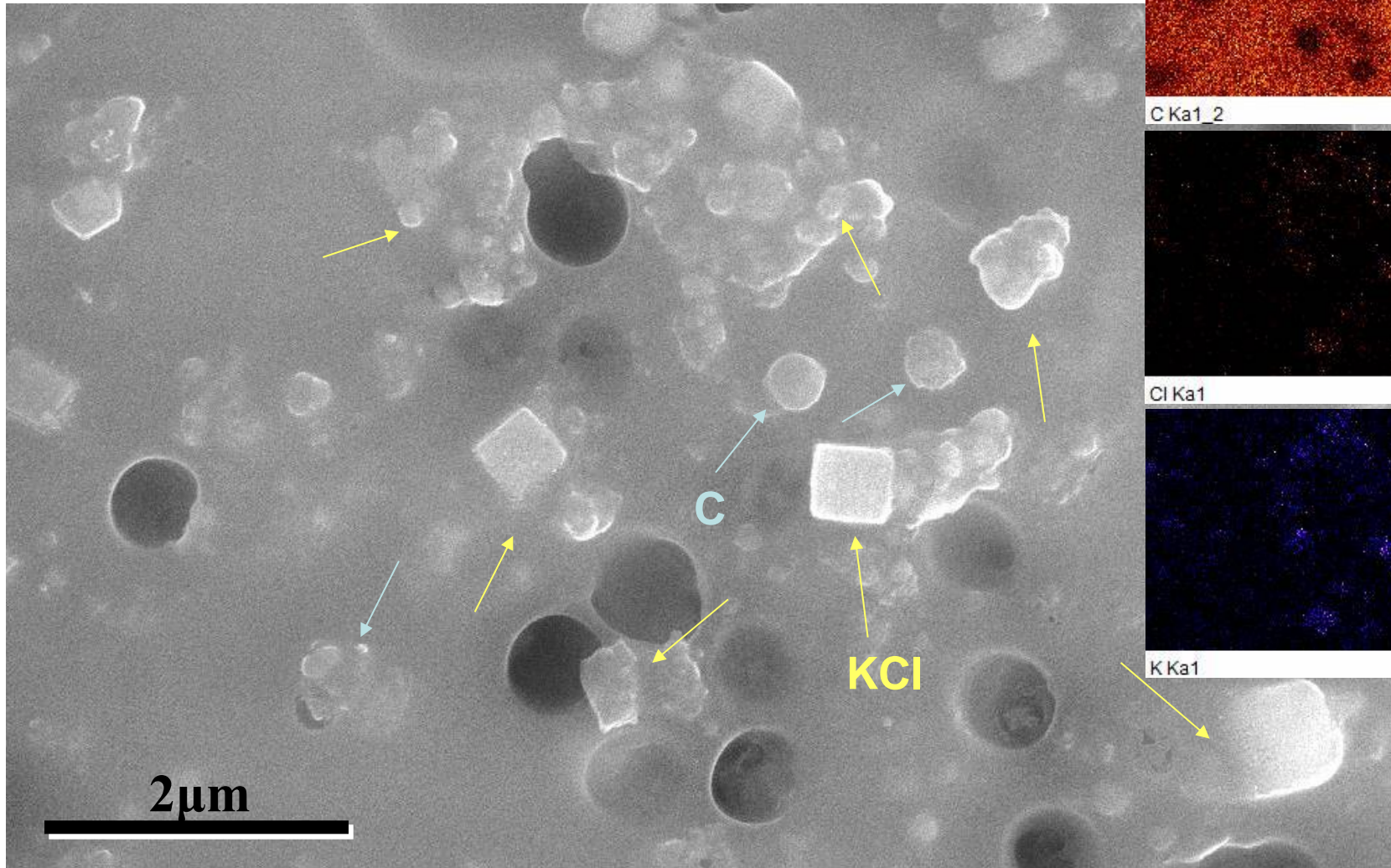


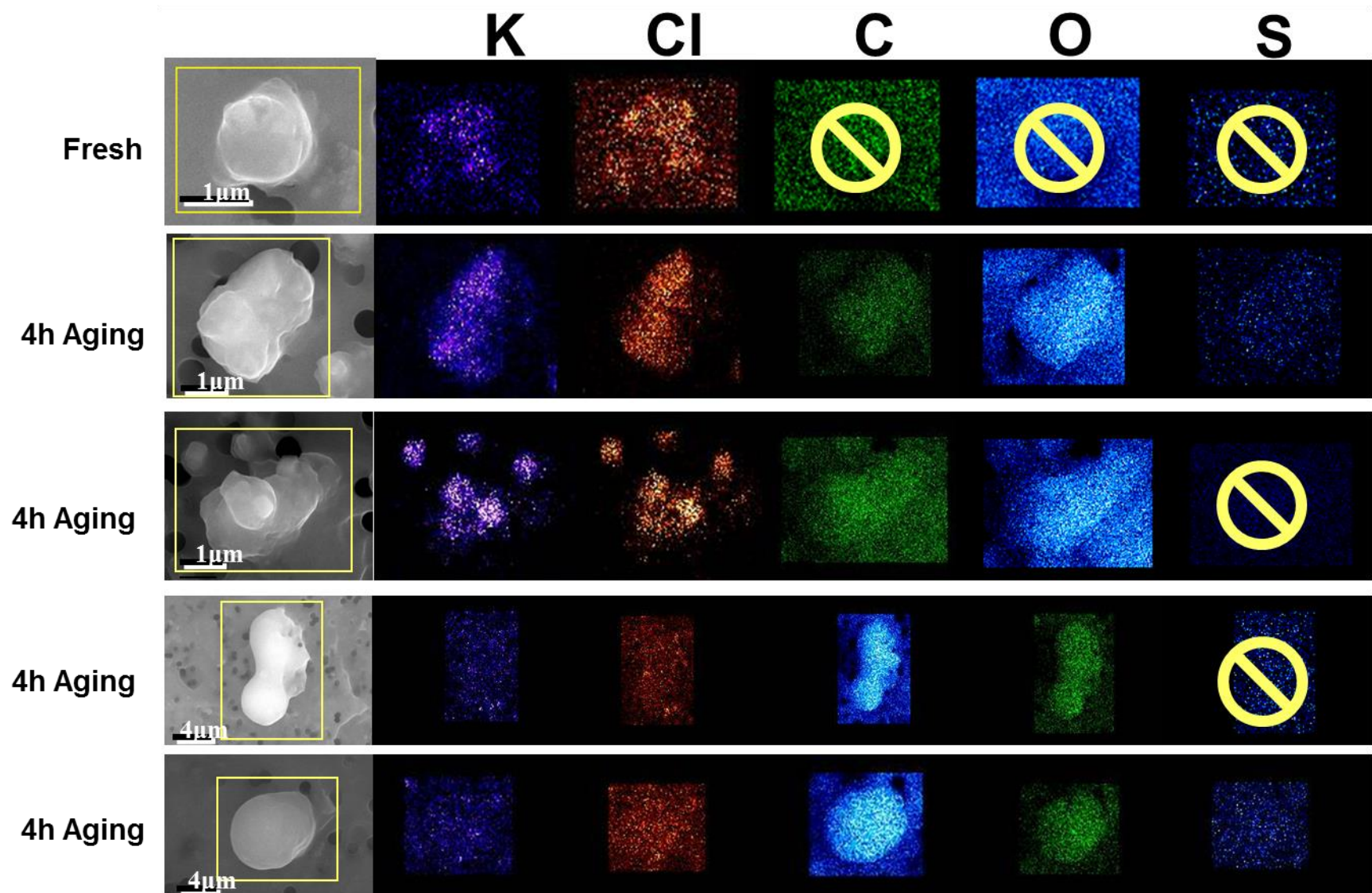
chemical changes of particle during aging in the chamber

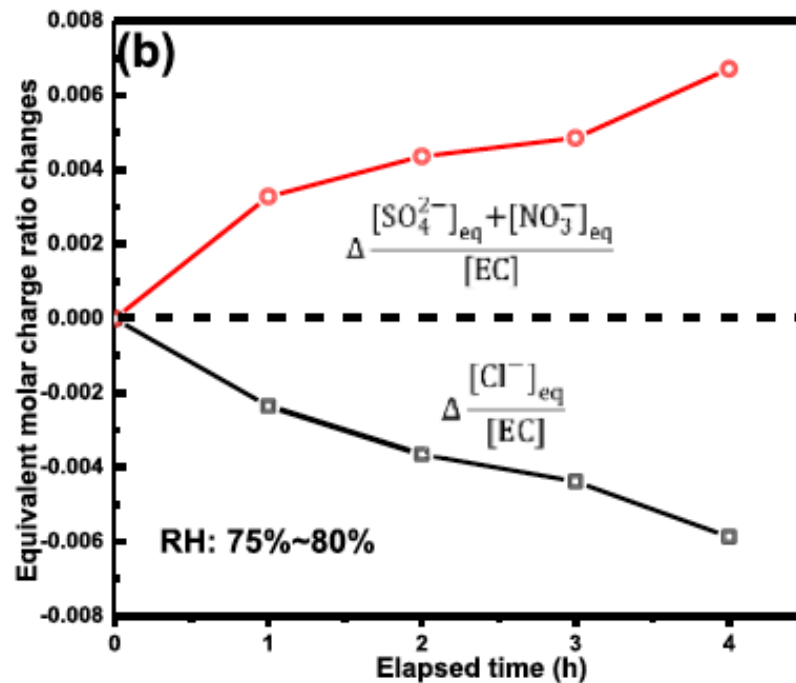
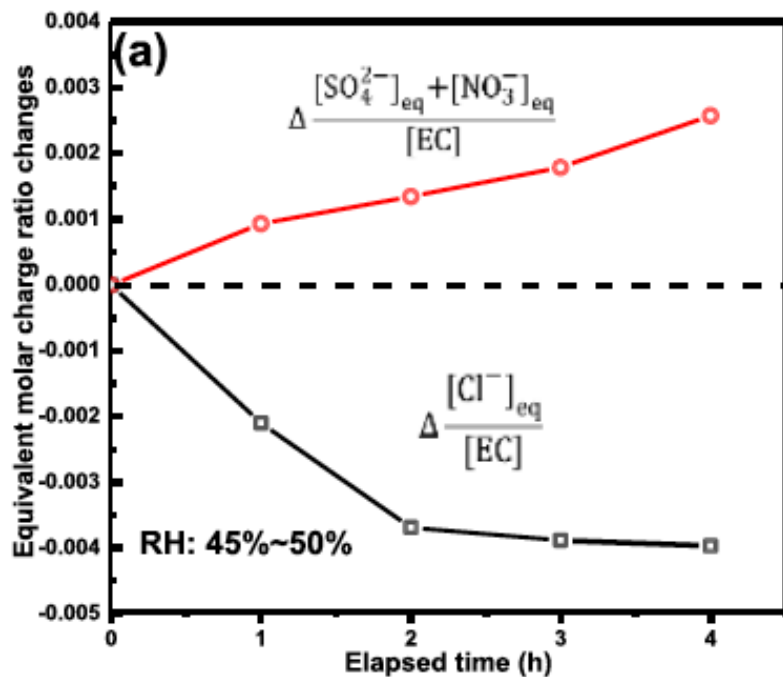


Chunlin Li ..., Jianmin Chen, ...
D.J. Donaldson...AE, 2015

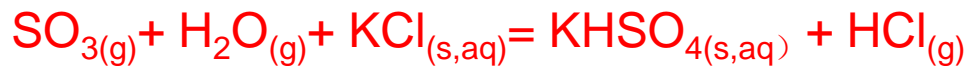
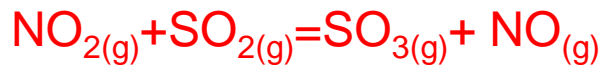
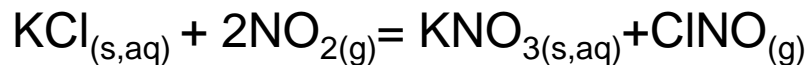
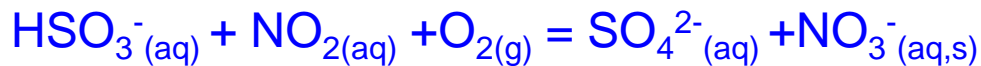
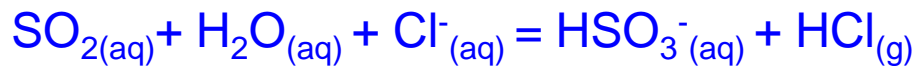
Fresh sample



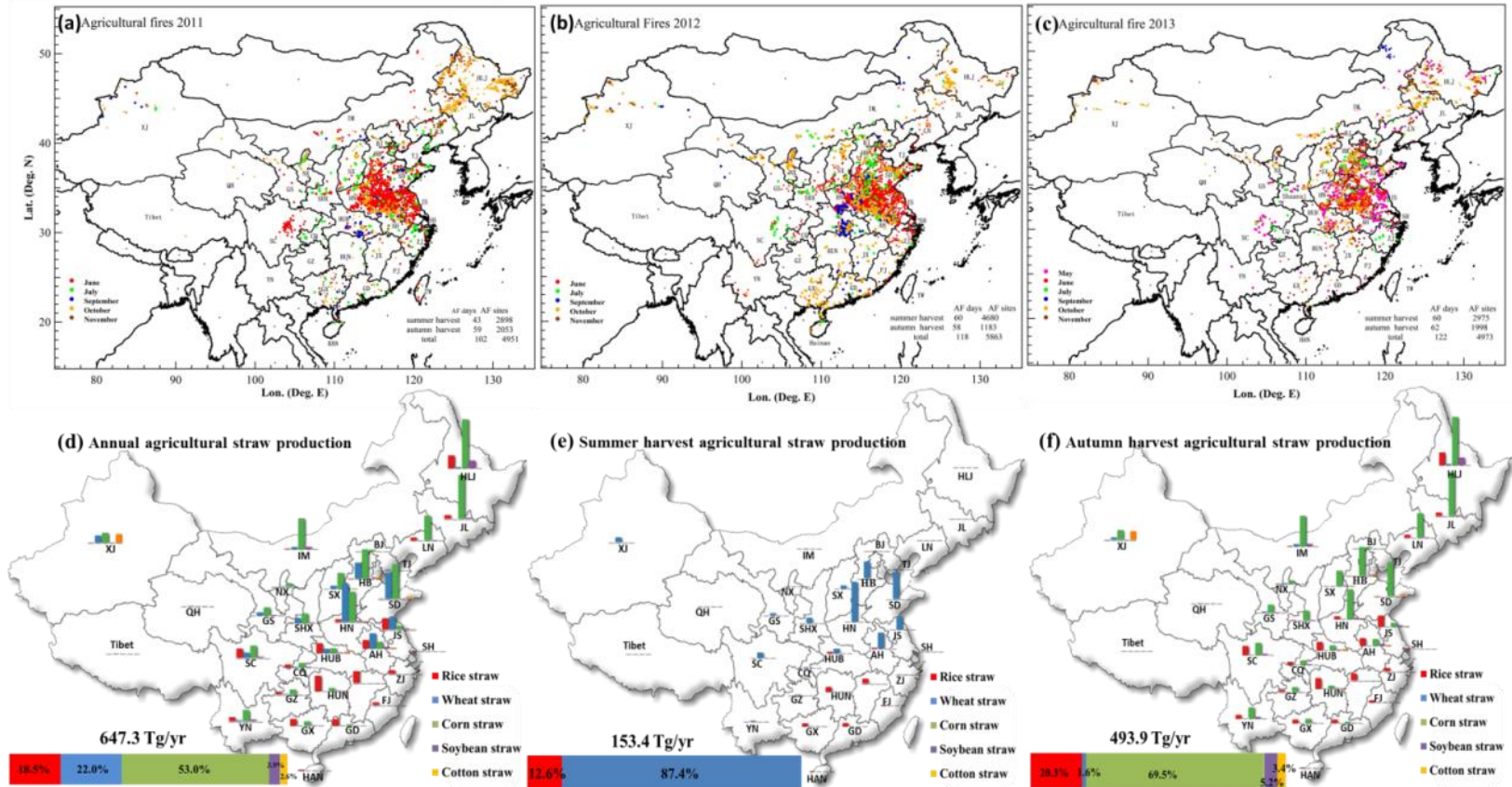




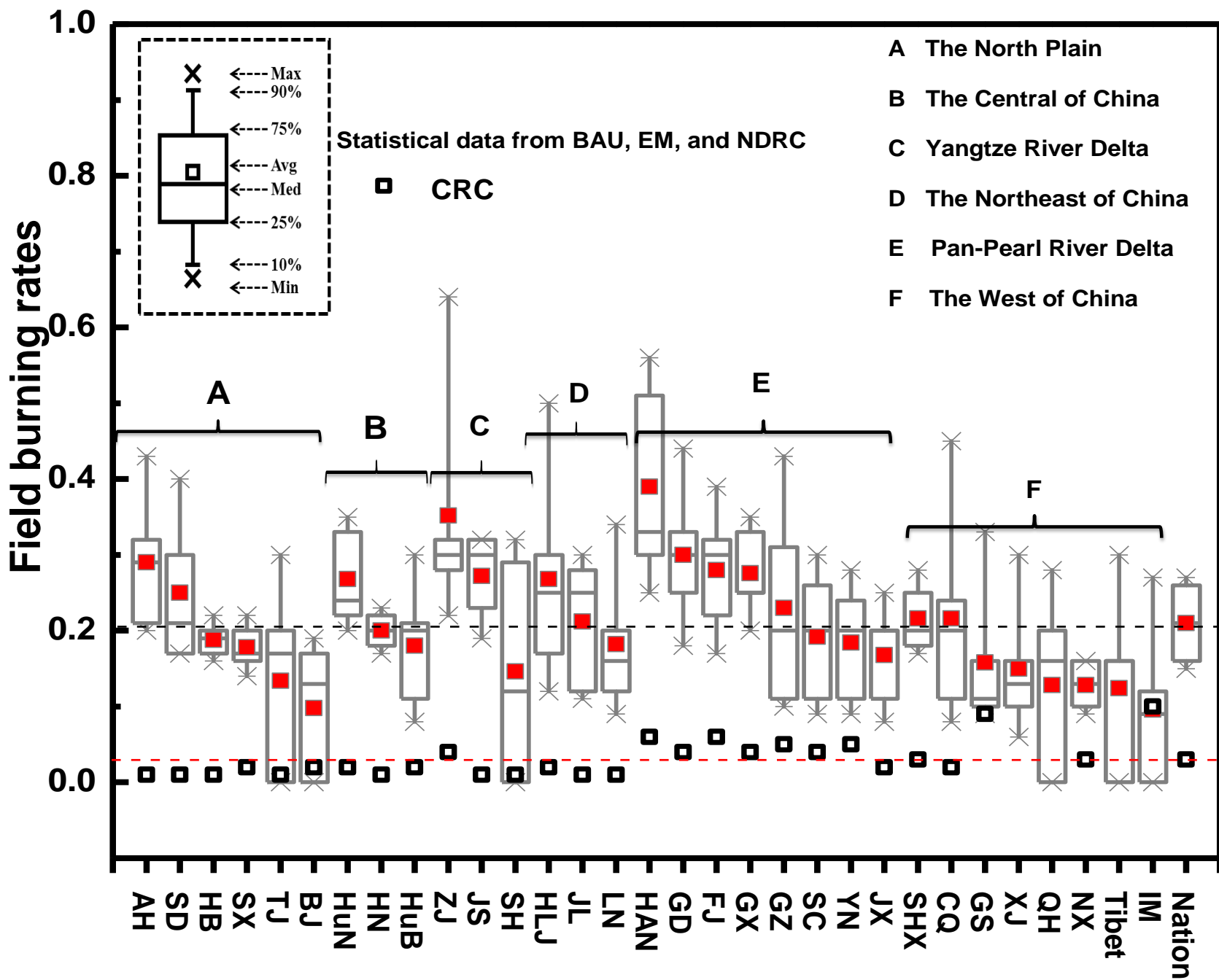
Some hypothetical mechanism of Cl loss :



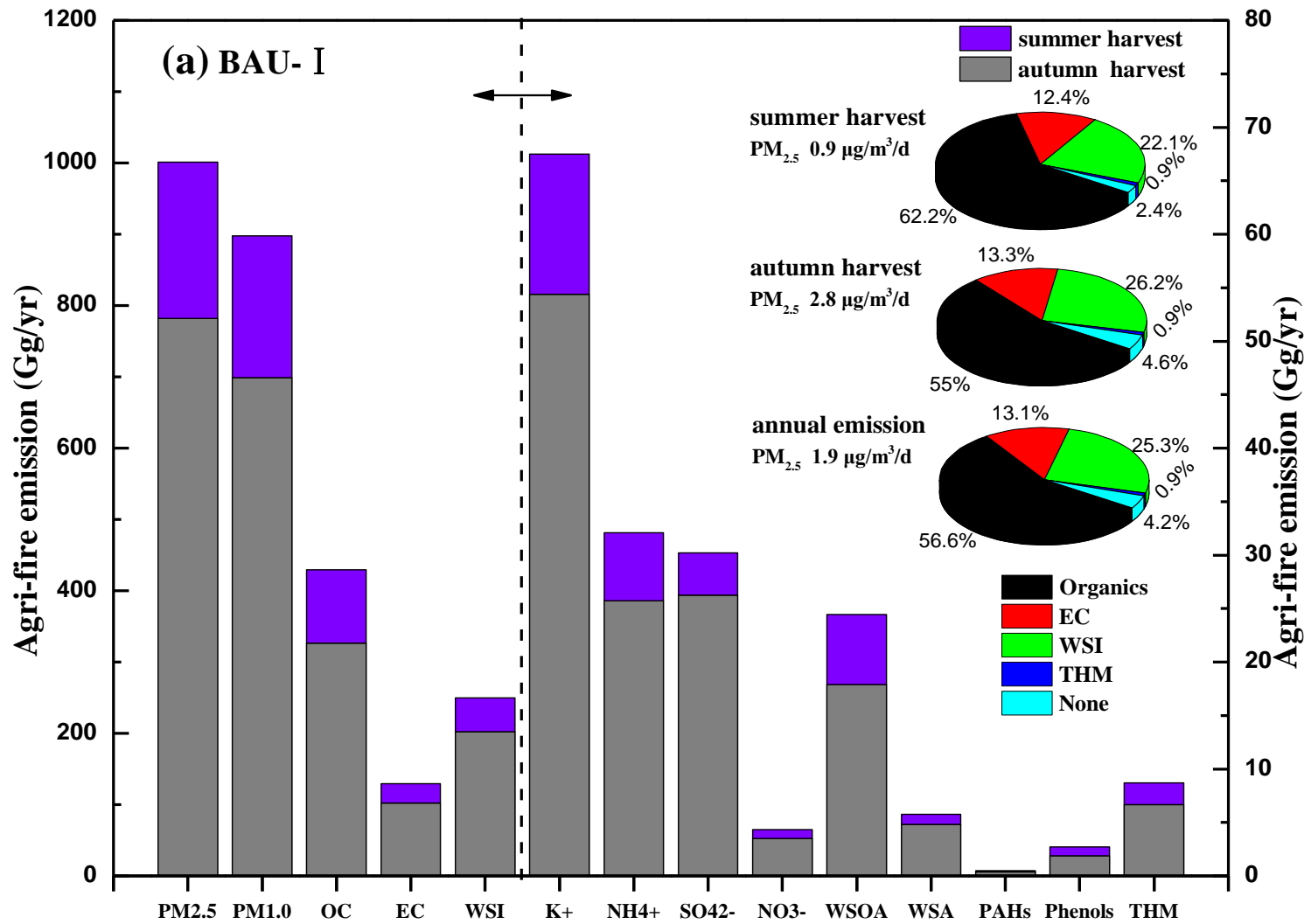
Multi-pollutants emissions from the burning of 5 agricultural straws



Agricultural field burning information over China. (a)-(c) Satellite remote sensing of agricultural fire sites from 2011 to 2013, average nationwide open burning lasts 114 days annually (54 days in summer harvest from May to Aug., 60 days in autumn harvest from Sept. to Nov.). (d)-(f) Annual agricultural residue production of 5 major crops and allocated into two harvest (summer and autumn harvest) based on agricultural yield in China, 2012.



Statistical analysis of field burning rates from BAU, EM, NDRC, and CRC versions



Estimated total particulate components emitted in 2012 (in Tg):

..
PM_{2.5} 0.74-1.24

PM_{1.0} 0.66-1.11

OC 0.32-0.53

EC 0.10-0.16

WSOA 18.77-30.82 x 10⁻³

WSA 4.23-7.19 x 10⁻³

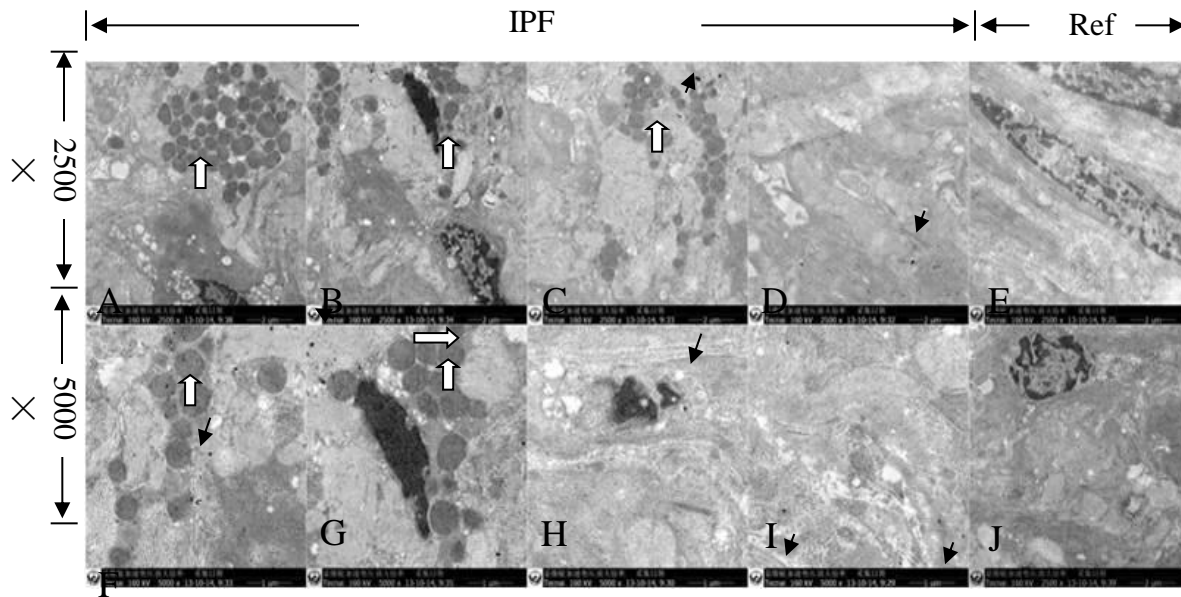
PAHs 0.35-0.59 x 10⁻³

Phenols 2.02-3.40 x 10⁻³

THM 6.36-10.64 x 10⁻³

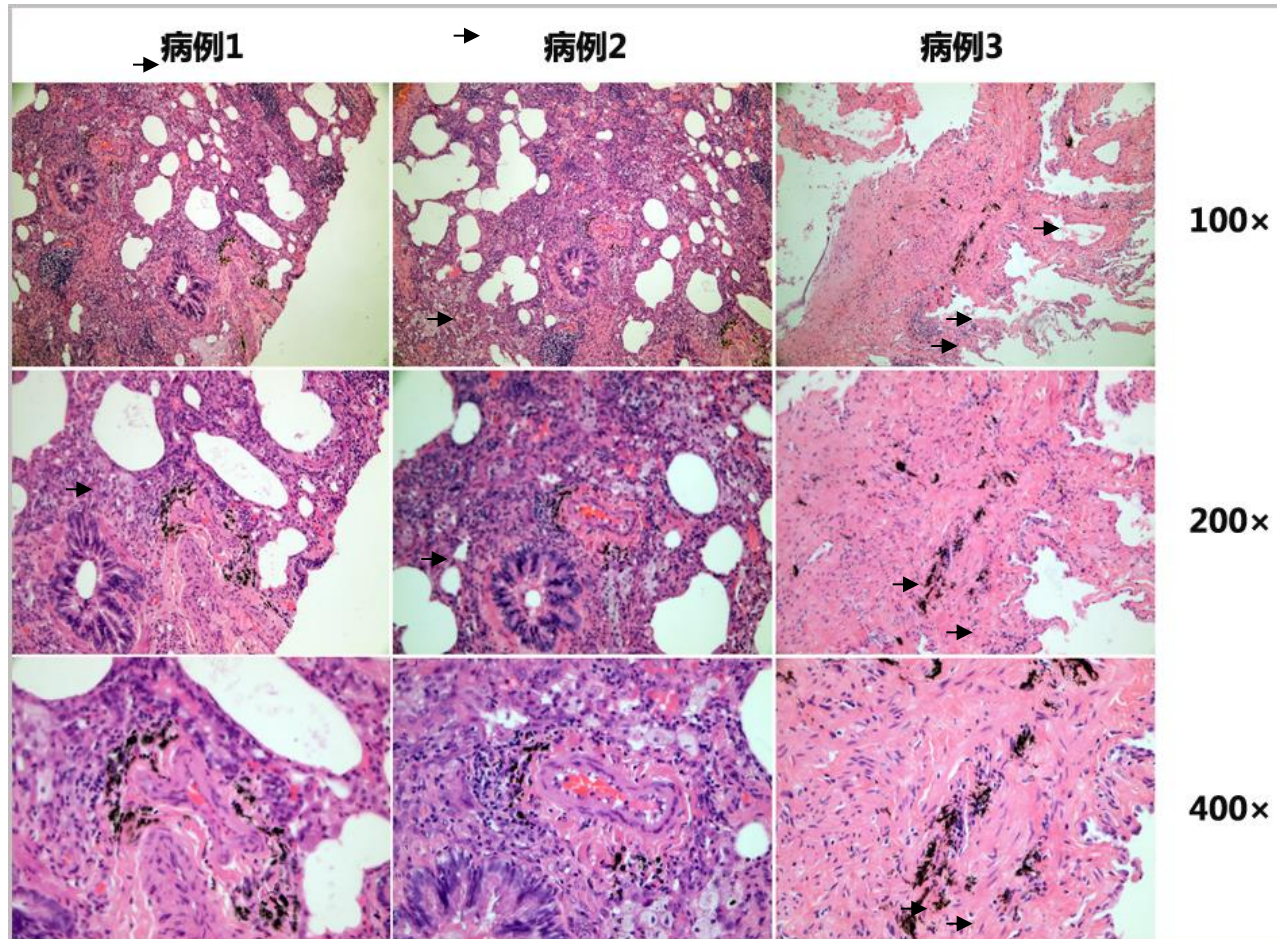
Further Work

Microstructure of Lung cell with particle deposition



TEM IPF Lung cell with PM deposition

IPF Lung Cell with EC deposition



512 patients, IPF 1.1%

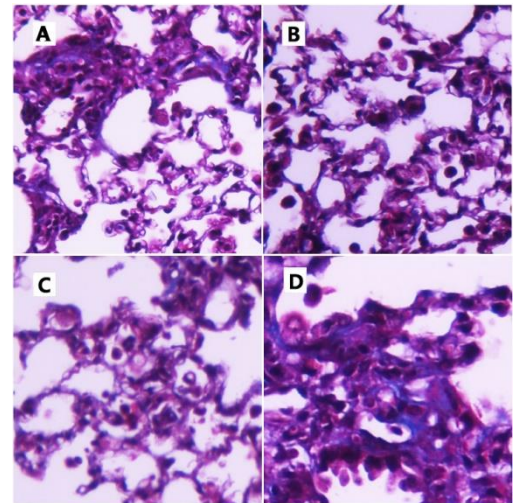
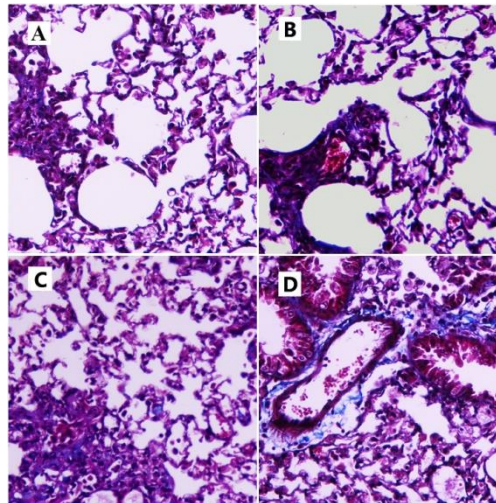
Chen et al., Cell Death Dis. 2013; Li et al., J. Thorac. Dis. 2013

PM2.5 to Mice Lung

- Smoke particles to mice lung



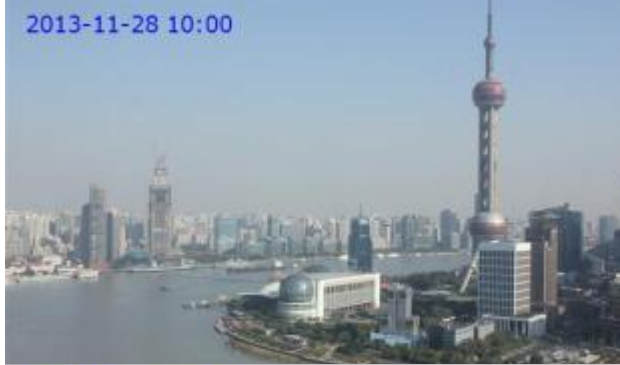
Mice in the Chamber





Pudong Area, Shanghai Night

2013-11-28 10:00



2013-11-29 22:00



2013-12-01 10:00



2013-12-02 07:30



2013-12-03 09:30



2013-12-04 09:00



2013-12-05 14:00



2013-12-06 11:30



2013-12-07 15:30



2013-12-08 14:00



2013-12-09 07:30



2013-12-10 10:30



谢谢！ Thanks!