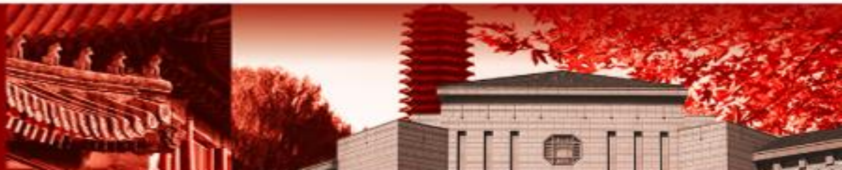
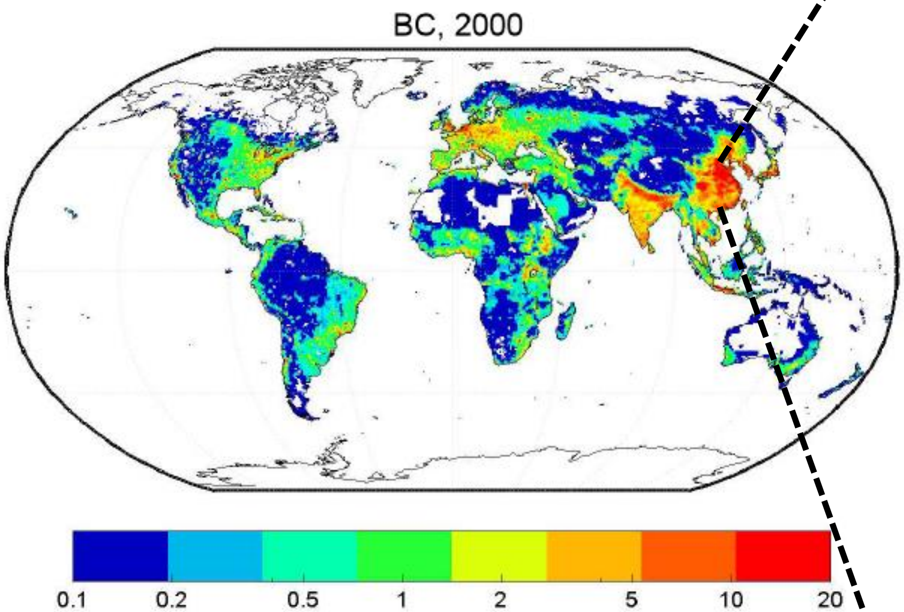
Emission, source identification and evolution of black carbon in China

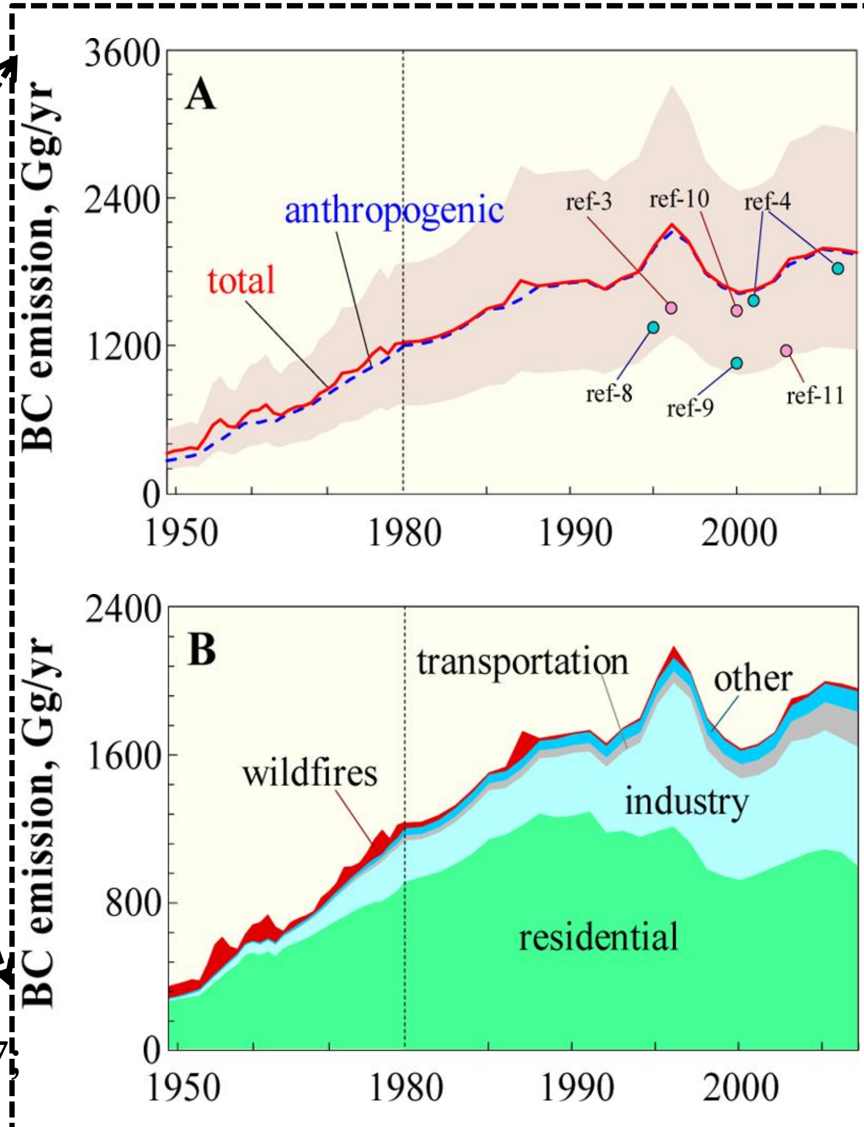
Min Hu, Jianfei Peng, Zhijun Wu, Song Guo, Xiaofeng Huang, Lingyan He, Yujue wang, Weiwei Hu, Wei Hu, Hongya Niu, Renyi Zhang*

State Key Joint Laboratory of Environmental Simulation and Pollution Control
College of Environmental Sciences and Engineering, Peking University, Beijing, China
**Department of Atmospheric Science, Texas A&M University, College Station, TX, USA*



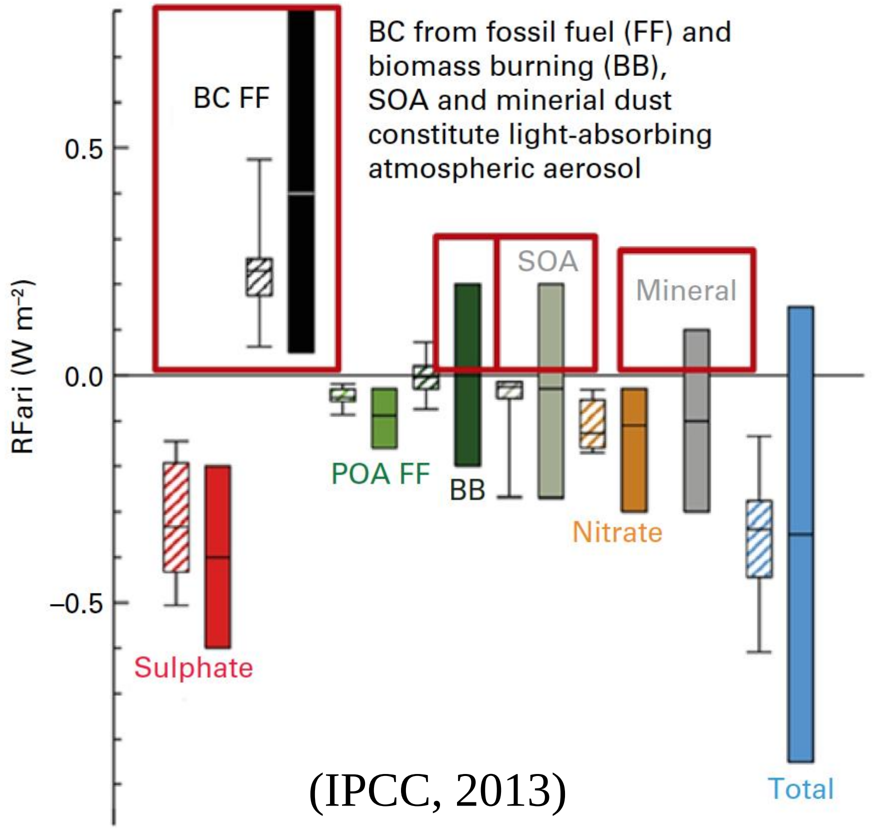
Emission inventory of BC in China





Bond et al., *Global biogeochemical cycles* 2007;
Wang et al., *EST* 2012

Why focusing on BC particle ?

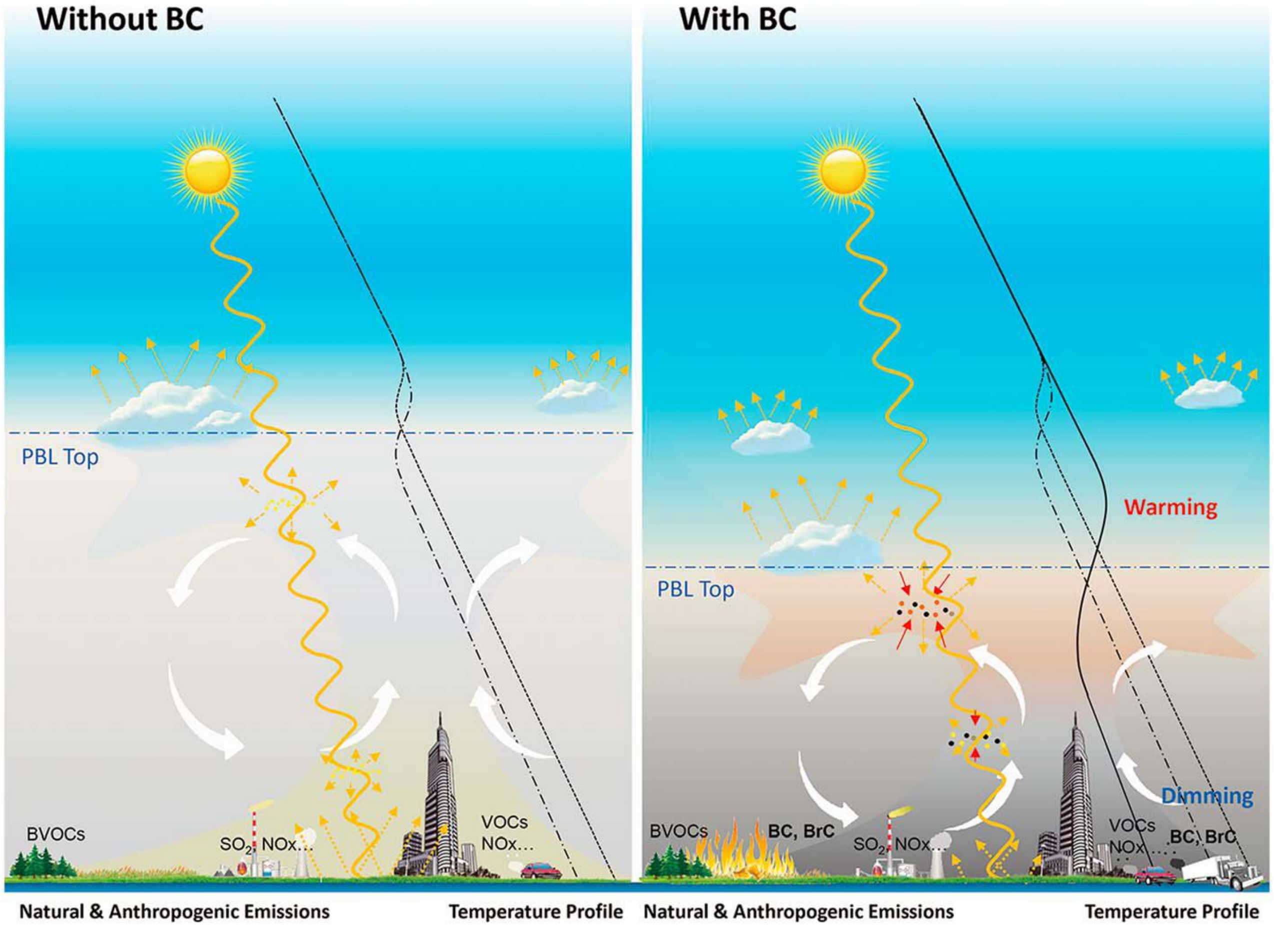


(IPCC, 2013)

BC is the light-absorbing aerosol particle, identified as the second-most important climate forcing agent after CO_2, and as one of the most important so-called short-lived climate forcers.

- BC radiative forcing: +0.64 W/m^2 (IPCC, 2013)
- Uncertainty source: Emission, life time, mass absorption cross-section (MAC), absorption forcing efficiency (Bond et al., 2013)

Why focusing on BC particle ?

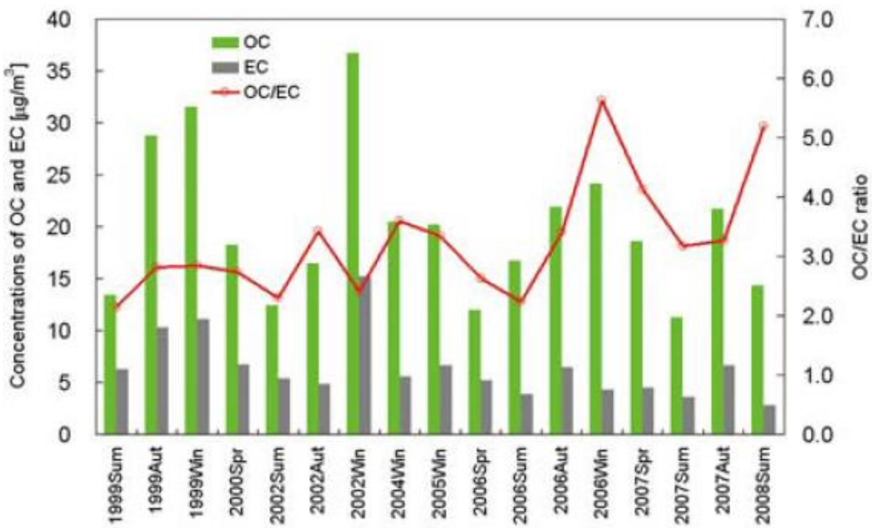


BC plays the key role in modifying the PBL meteorology and hence enhancing the haze pollution

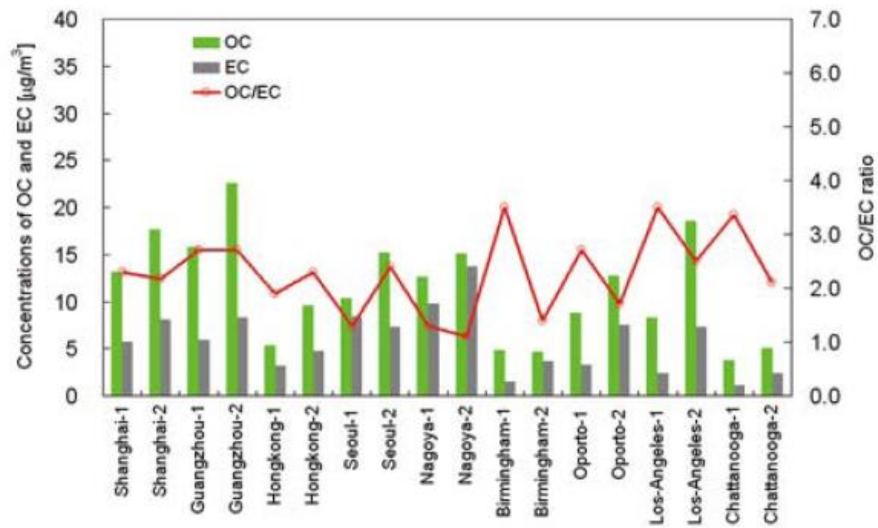
Ding et al., *GRL* 2016

High carbonaceous aerosols in $PM_{2.5}$

Beijing 1999-2008



Comparison with other cities



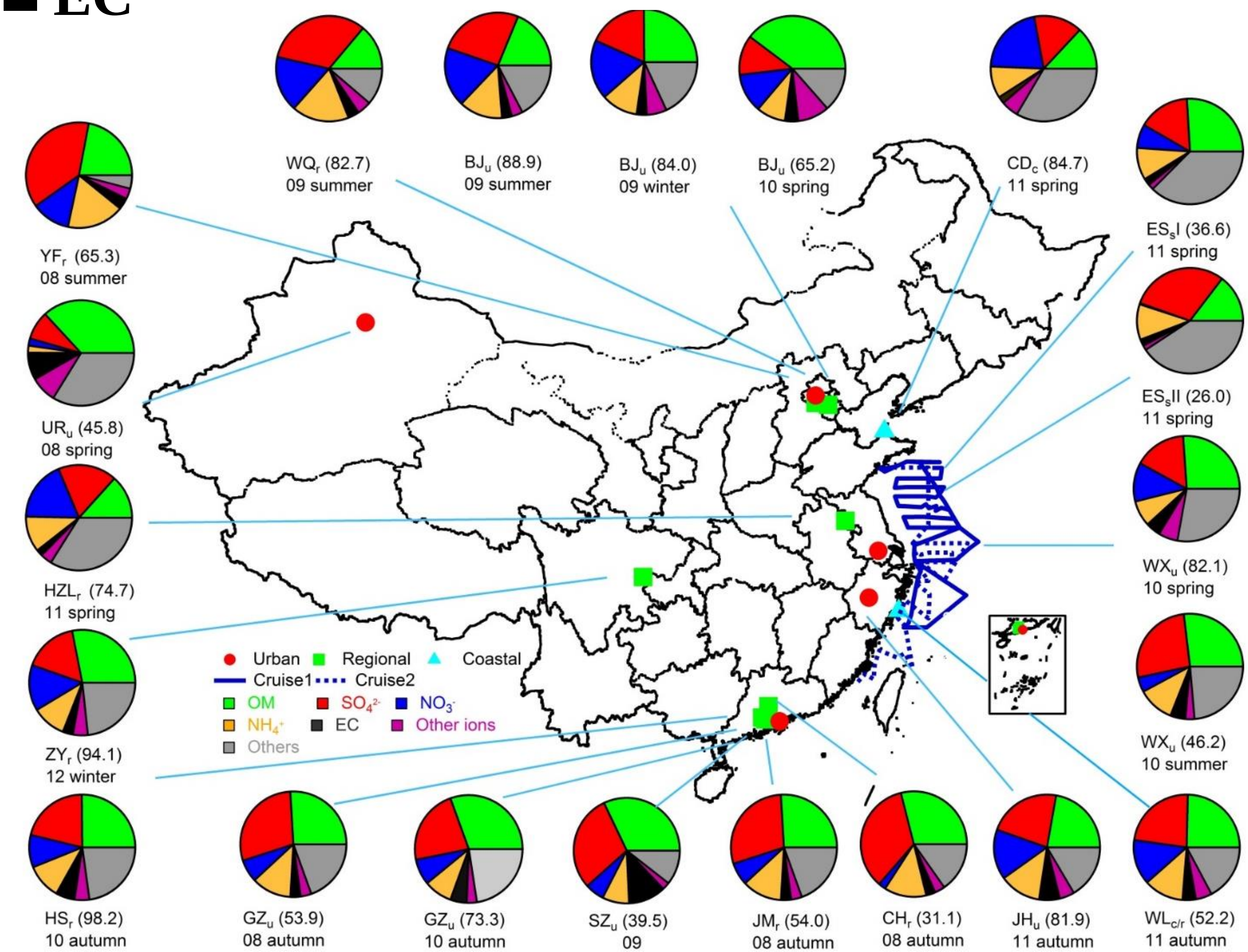
- High OC and EC concentrations in Beijing compared with other cities
- High OC/EC ratio indicates the large fraction of SOC

It is necessary to investigate the sources and formation of organic aerosols

Min Hu and Song Guo, *IGAC Newsletter*, 2010

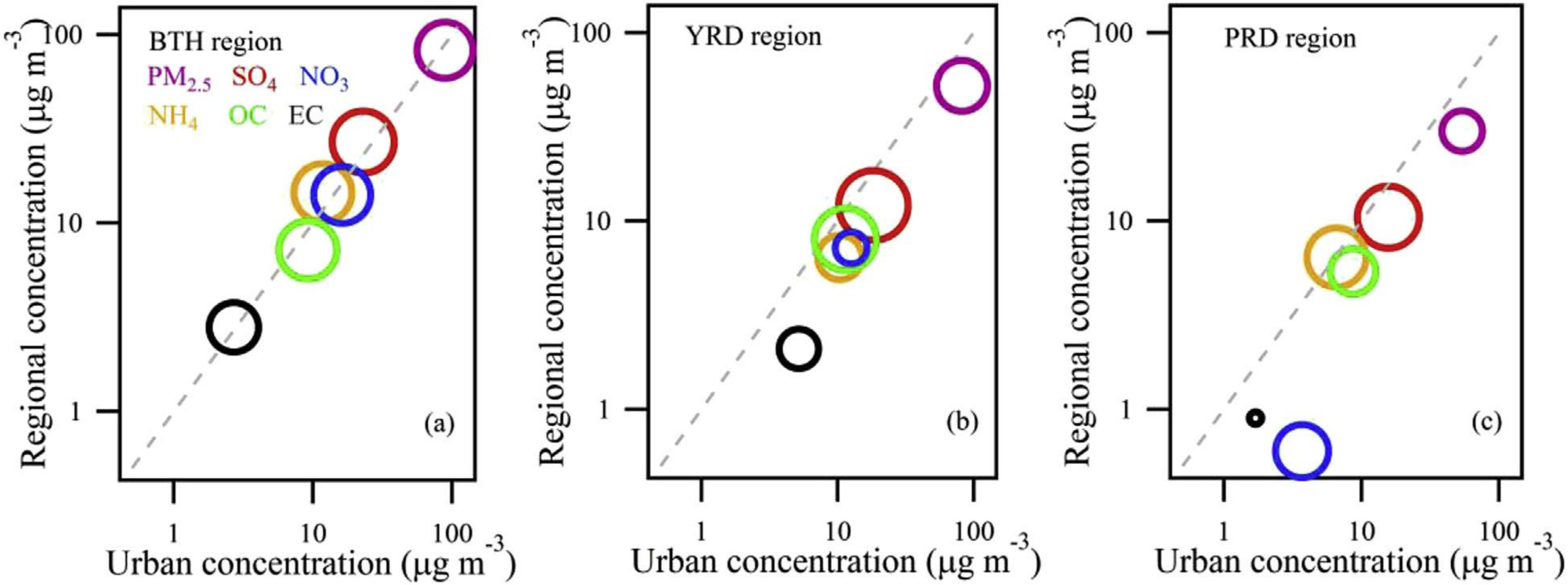
$PM_{2.5}$ and its major chemical speciation at different locations in China

■ **EC**



Jing Zheng, Min Hu* et al, *Chemosphere*, 2016, 159, 480-487

Comparison of $PM_{2.5}$ and major chemical species for urban and regional sites



The size of each cycle is proportional to correlation values between the temporal trends of each species

0.2	0.4	0.6	0.8

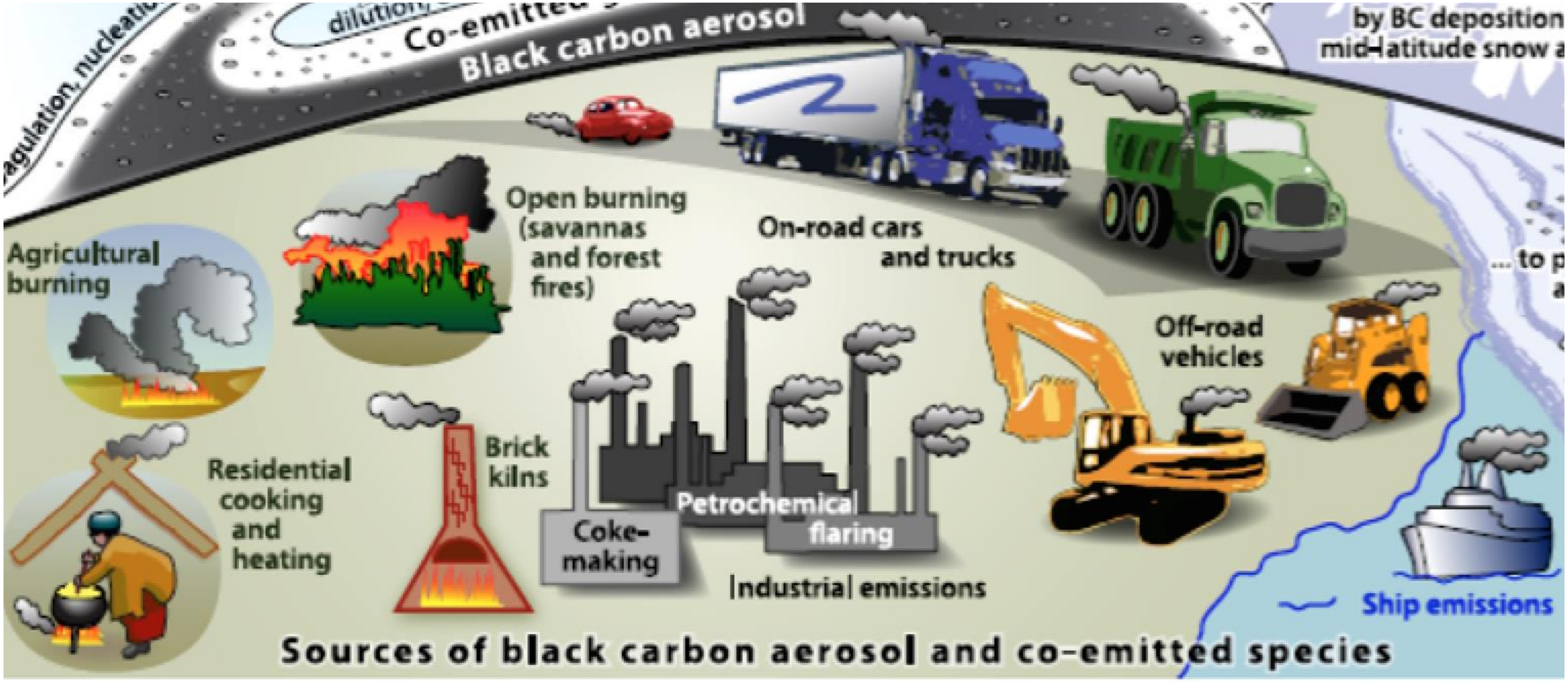
EC, stronger local contribution urban reached 222% higher than regional sites

For most chemical species, urban similar to regional sites, uniform regional pollution

Jing Zheng, Min Hu* et al, *Chemosphere*, 2016, 159, 480-487

Work done by PKU group

- **Emission factor and characteristics of BC**



Fine Particle Emissions from On-Road Vehicles in the Zhujiang Tunnel, China

TABLE 1. Average Speciated $PM_{2.5}$ Emission Factors (mg vehicle^{-1} km^{-1}) in Zhujiang Tunnel and Comparisons with Other Tunnel Studies

species	Zhujiang Tunnel[a]	Sepulveda Tunnel[b]	Kilborn Tunnel[c]	Howell Tunnel[c]
mass	110 (4)	52	24.1	39.3
EC	49.6 (1.9)	25.50	6.87	10.8
OC	24.3 (0.93)	19.27	6.41	12.9
SO_4^{2-}	3.87 (0.61)	1.77		
NO_3^-	1.37 (0.59)	3.27		
Cl^-	0.98 (0.16)	0.67		
NH_4^+	0.80 (0.25)	1.61		
Na (23)	0.37 (0.07)	0.30	0.98	0.038
Mg (24)	0.22 (0.02)	0.26	0.077	0.044
K (39)	0.14 (0.04)	0.08	0.13	0.065
Ca (44)	0.64 (0.09)	0.30	0.31	0.43
Ti (47)	0.027 (0.004)	0.09	0.010	0.19
V (51)	0.0015 (0.0008)	0.05	0.00068	0.00040
Cr (52)	0.0054 (0.0004)	0.02	0.012	0.0018
Mn (55)	0.019 (0.001)	0.02	0.0058	0.0060
Fe (57)	1.12 (0.09)	2.79	0.51	0.55
Co (59)	0.00013 (0.00004)	0.00	0.00	0.0004
Ni (60)	0.0034 (0.0014)	0.01	0.00	0.009
Cu (63)	0.034 (0.002)	0.17	0.014	0.012
Zn (66)	0.078 (0.010)	0.14	0.023	0.028
As (75)	0.0020 (0.0006)	0.00	0.0021	0.00045
Mo (98)	0.0014 (0.0001)	0.01	0.0020	0.0013
Cd (114)	0.00049 (0.00022)	0.02	0.00004	0.00005
Tl (205)	0.00004 (0.00002)	0.00	0.00002	0.00001
Pb (208)	0.014 (0.003)	0.03	0.0031	0.0010
U (238)	0.00004 (0.00001)	0.00	0.00001	0.00

[a] Values in parentheses indicate associated uncertainties (SD/$\sqrt{(n)}$). [b] Data from ref *21*. [c] Data for summer weekday tests in the Supporting Information of ref *22*.

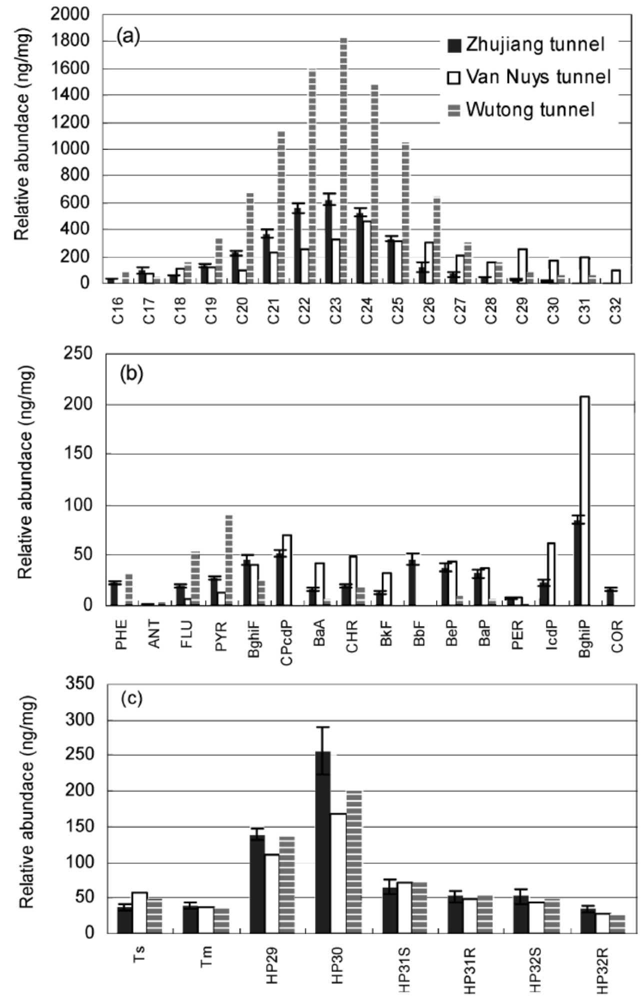
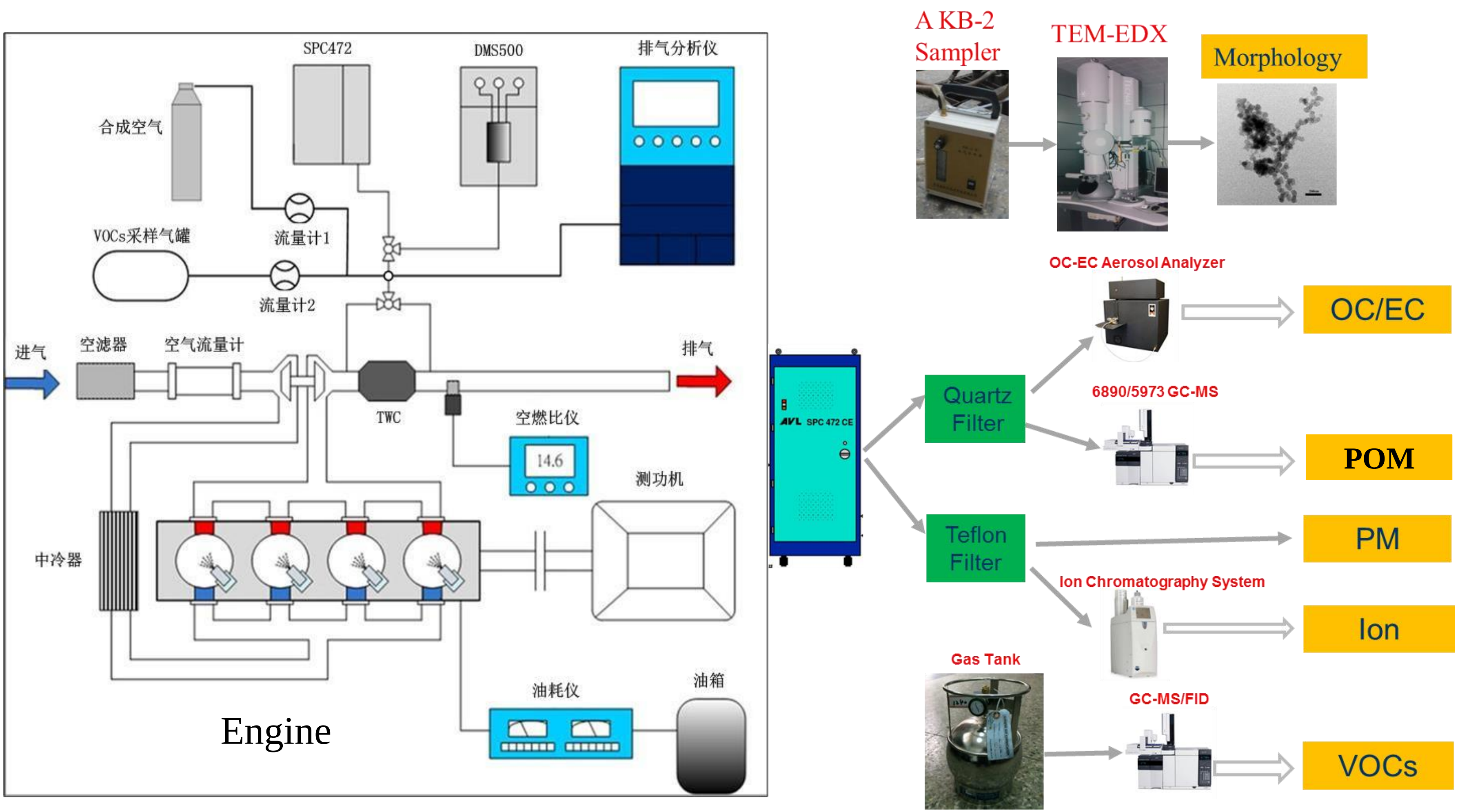


FIGURE 1. Comparison of distributions of *n*-alkanes (a), PAHs (b), and hopanes (c) in $PM_{2.5}$ emissions in the Zhujiang Tunnel, the Van Nuys Tunnel, and the Wutong Tunnel.

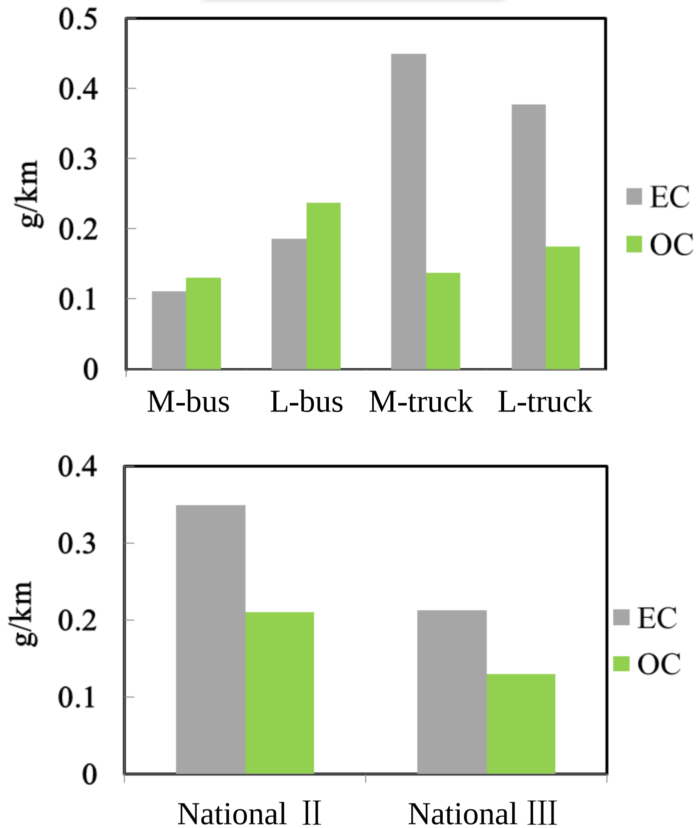
Lingyan He, Min Hu* et al, *Environ. Sci. Technol.* 2008, 42, 4461–4466

Platform of vehicle emission experiments

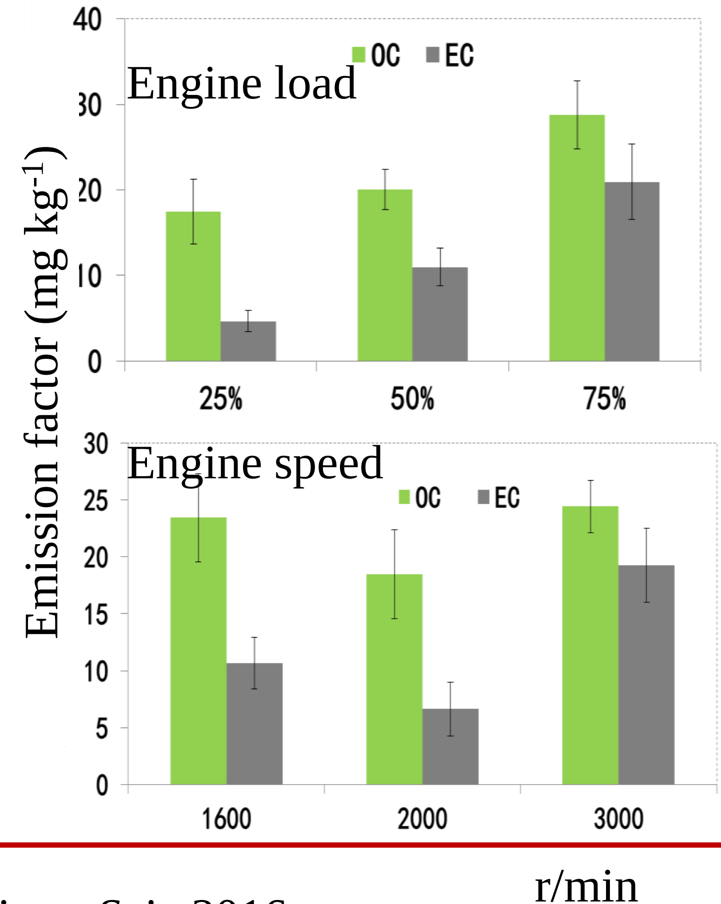


Vehicle Emission Factor of BC

Diesel

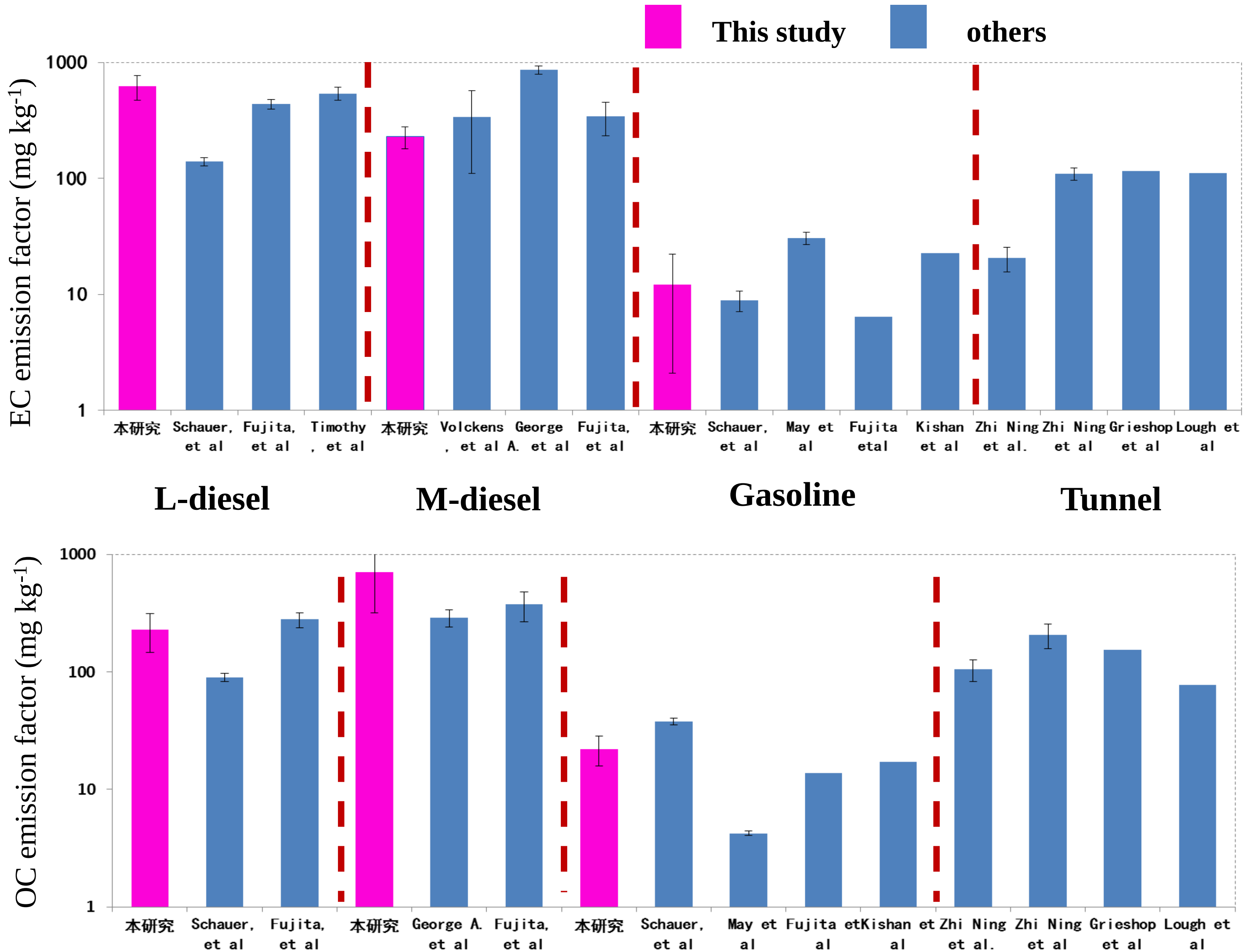


GDI gasoline

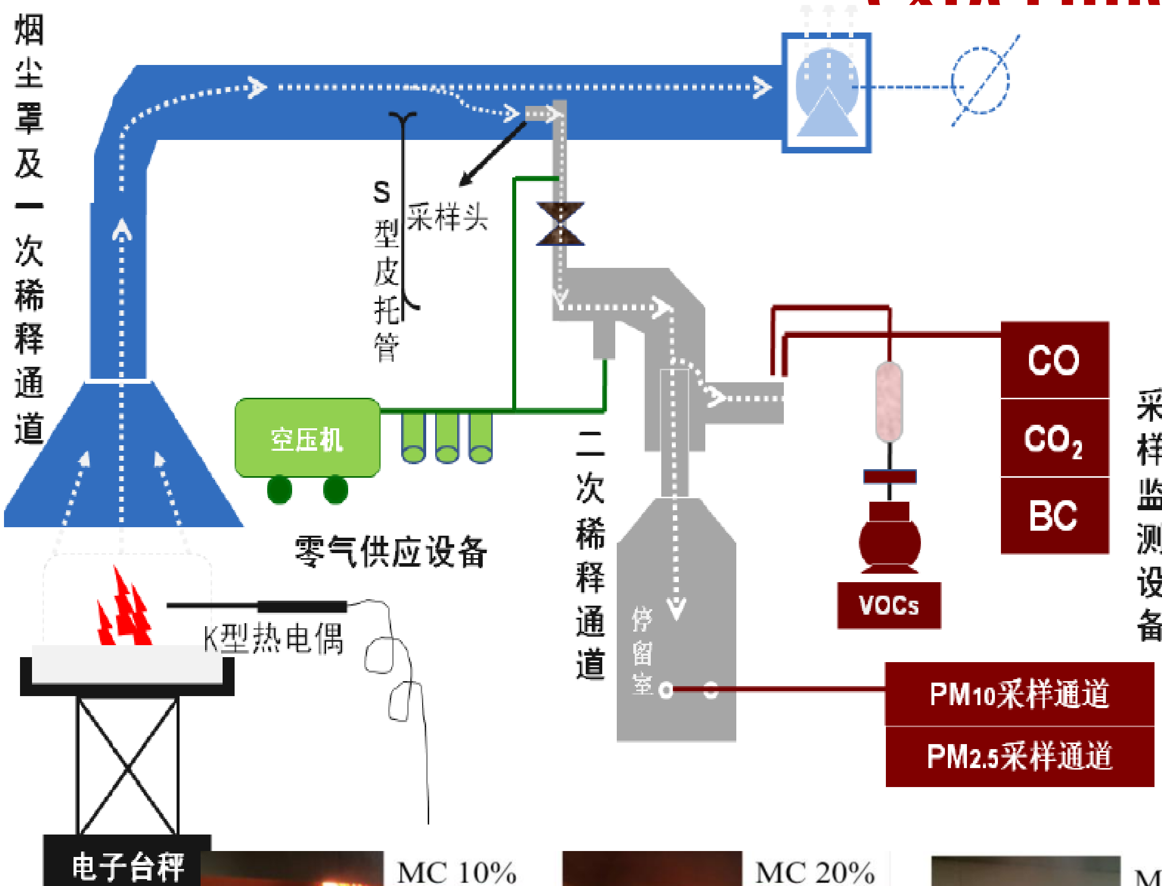


Yanhong Qin, Min Hu* et al. *China Environ. Sci.*, 2016

Vehicle Emission Factor of BC



Platform of biomass burning experiments



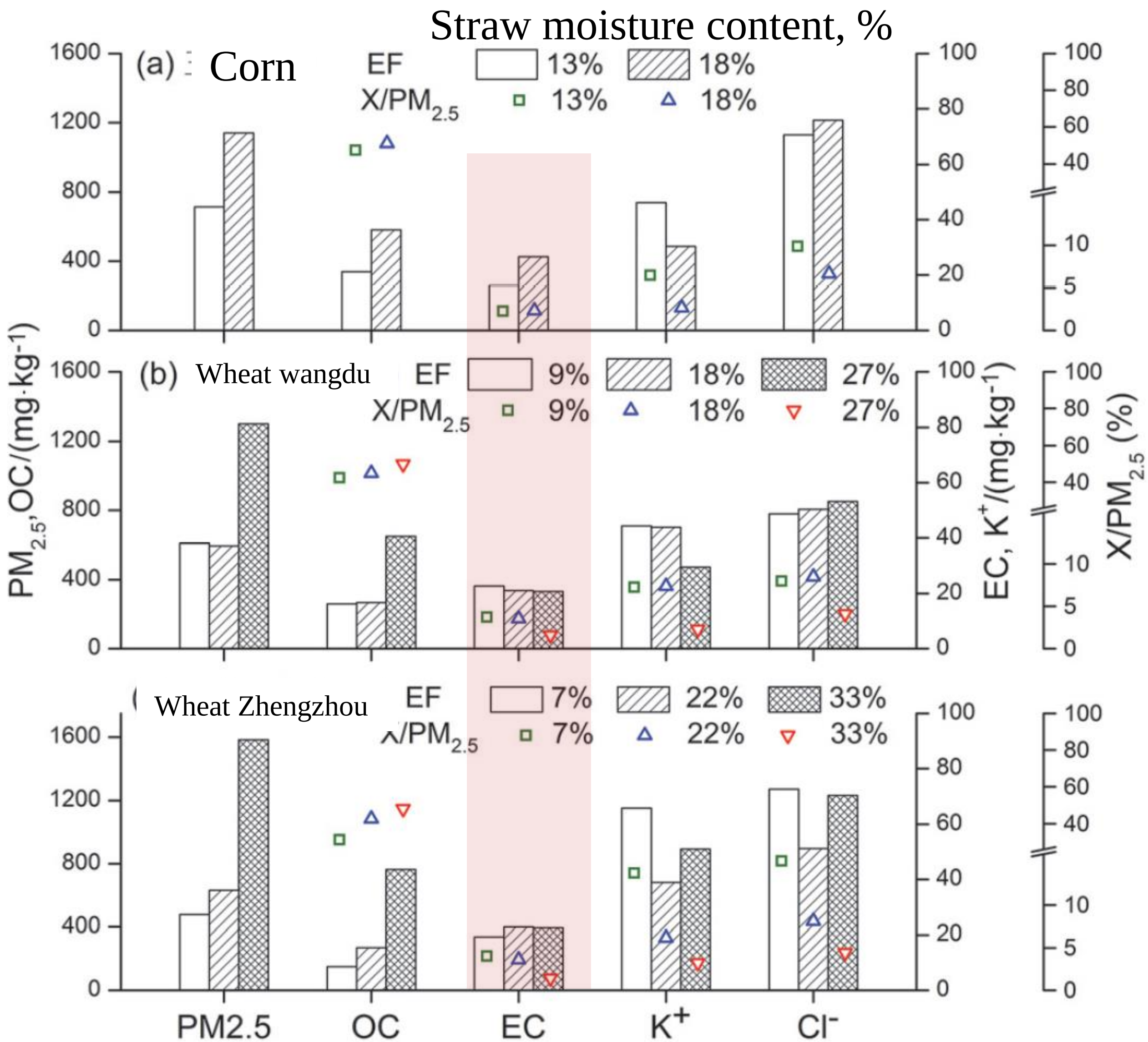
Lower moisture content

Higher moisture content

Corn straw burning↑

←Wheat straw burning

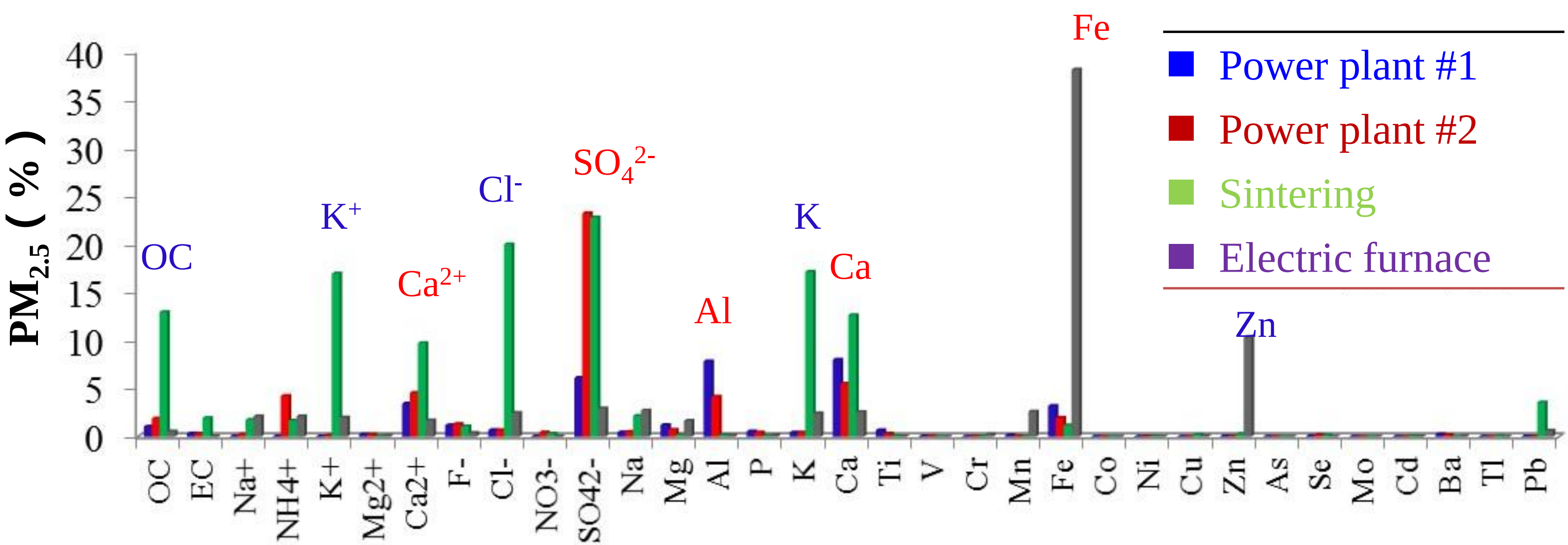
Biomass Burning Emission Factor of BC



Yujue Wang, Min Hu* et al, *Acta Chim. Sinica* 2016, 74, 356-362

Emission factor of BC for power plane and steel plant

	$PM_{2.5}$ conc. (mg/m^3)	OC (%)	EC (%)
Power plant #1	4.35	1.05±0.44	0.34±0.39
Power plant #2	0.94	1.88±0.87	0.33±0.15
Sintering	0.68	12.96±11.49	1.95±1.96
Electric furnace	5.33	0.54 ±0.12	0.02± 0.03

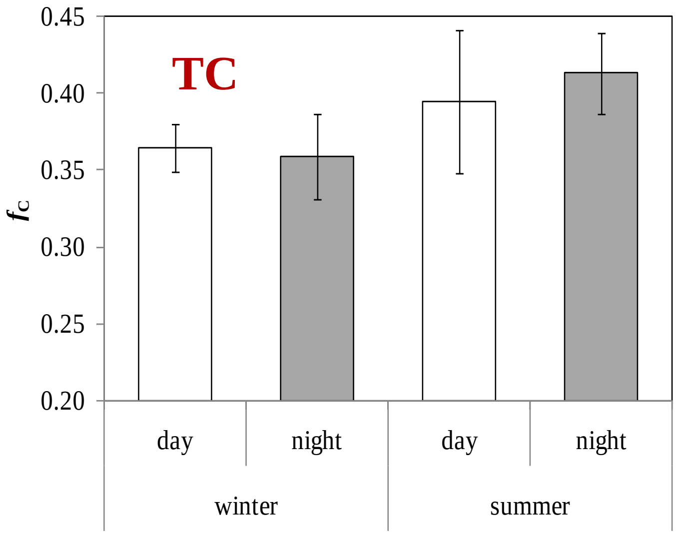


Peking University 北京大學

Work done by PKU group

- Emission factor and characteristics of BC
- Source identification of BC particles
- Evolution of BC particles during aging process in the atmosphere

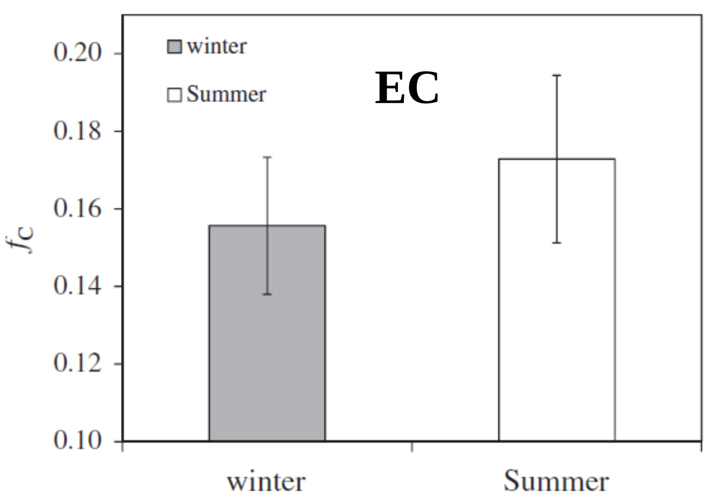
^{14}C-Based source assessment of carbonaceous aerosols at a rural site



$$f_M = \frac{(^{14}C/^{12}C)_{sample}}{0.95(^{14}C/^{12}C)_{OXI}}$$

where $(^{14}C/^{12}C)_{sample}$ is the ^{14}C to ^{12}C ratio observed in the sample, and $(^{14}C/^{12}C)_{OXI}$ is a ratio from the NIST Oxalic Acid Standard I (NBS OXI). The values of blanks ranged from 4×10^{-3} to 5×10^{-3}.

Due to above-ground nuclear testing during 1950s and 1960s, the ambient ^{14}C excess from nuclear bomb tests needs to be corrected. For biogenic emissions a value of 1.04 was used, taken from measurements performed by Levin in 2007 (Levin et al., 2008). Szidat et al. (2009) recommended that the ratio was 1.16 for 30–50-year-old trees. In this study, a correction factor of 1.08, as suggested by Heal et al. (2011), was chosen. Therefore the fraction of contemporary carbon (f_C) in the samples was estimated using $f_{C(sample)} = f_{M(sample)}/1.08$ and the fraction of fossil carbon (f_f) using $f_f = 1 - f_C$.



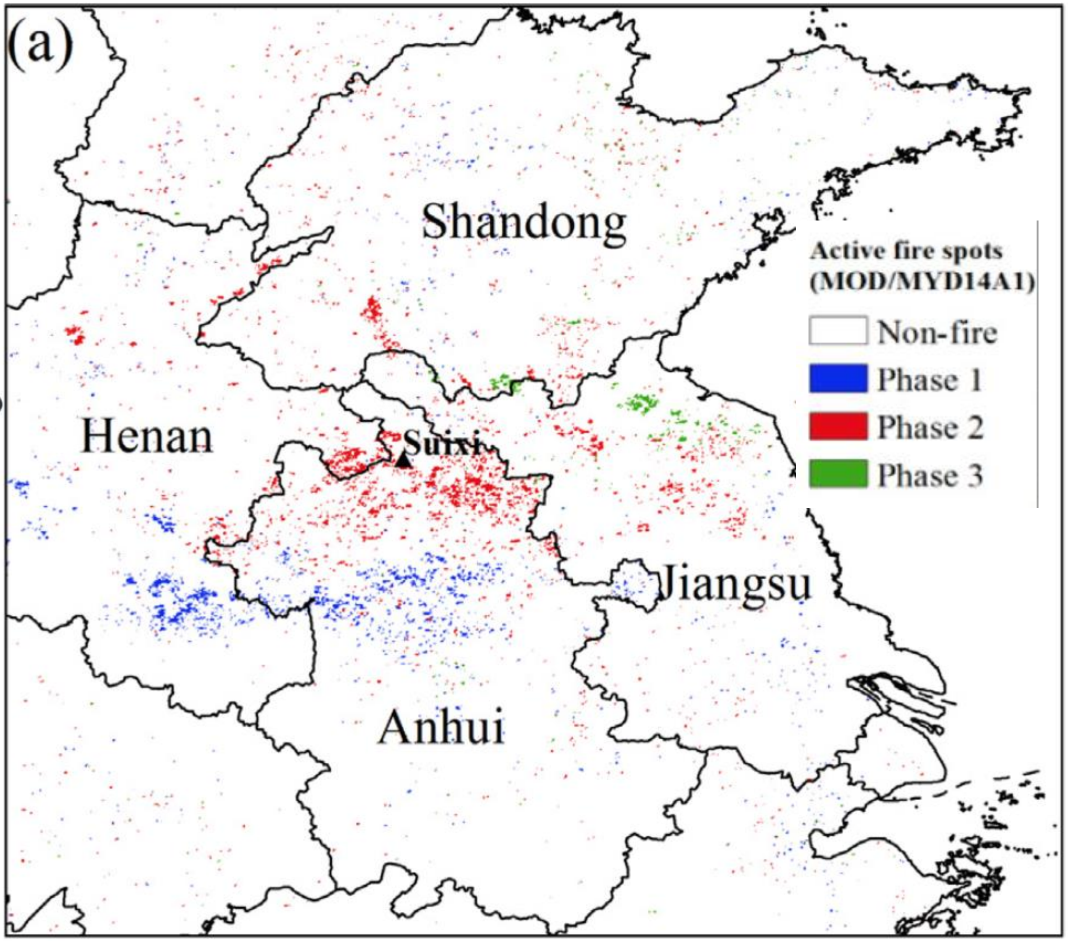
f_c = fraction of contemporary carbon

- Fossil fuel emission contribute about 80-87% EC in both seasons.
- More contemporary carbon in winter due to biomass burning.

Xuesong Sun, Min Hu* et al., *Atmos. Environ*,, 2012

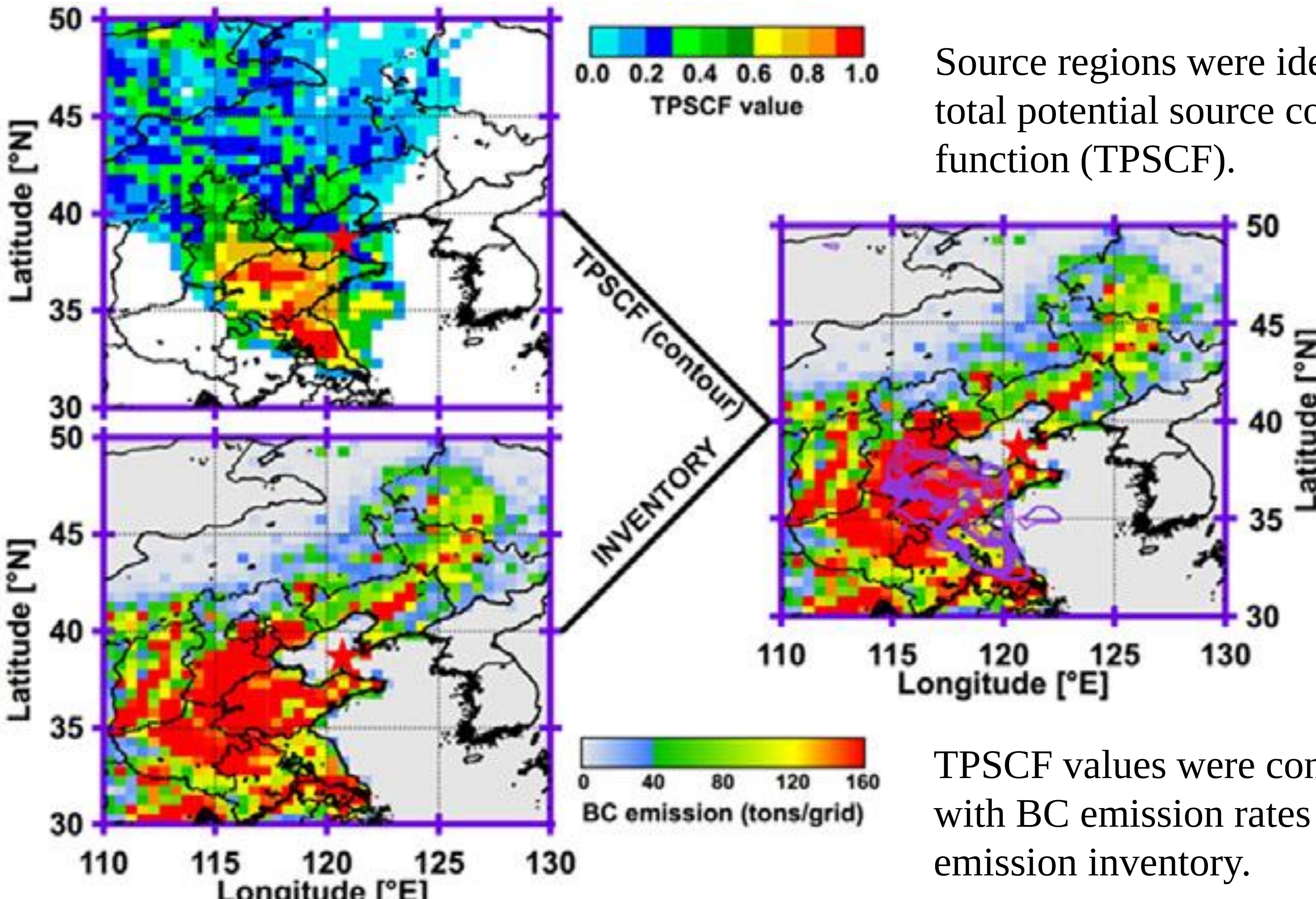
Source apportionment of $PM_{2.5}$ during the harvest season in eastern China's agricultural regions

- High-level $PM_{2.5}$, OC, EC, K and Cl were observed in local wheat burning period.
- Wheat residue burning contributed over 50% of $PM_{2.5}$, OC, EC, K and Cl.
- Relative humidity and aging process of $PM_{2.5}$ might affect the fate of Cl in $PM_{2.5}$.



Jianfeng Li, Yu Song*…Min Hu*, *Atmos. Environ.* 2014

The identification of source regions of BC at a receptor site of the eastern coast of China

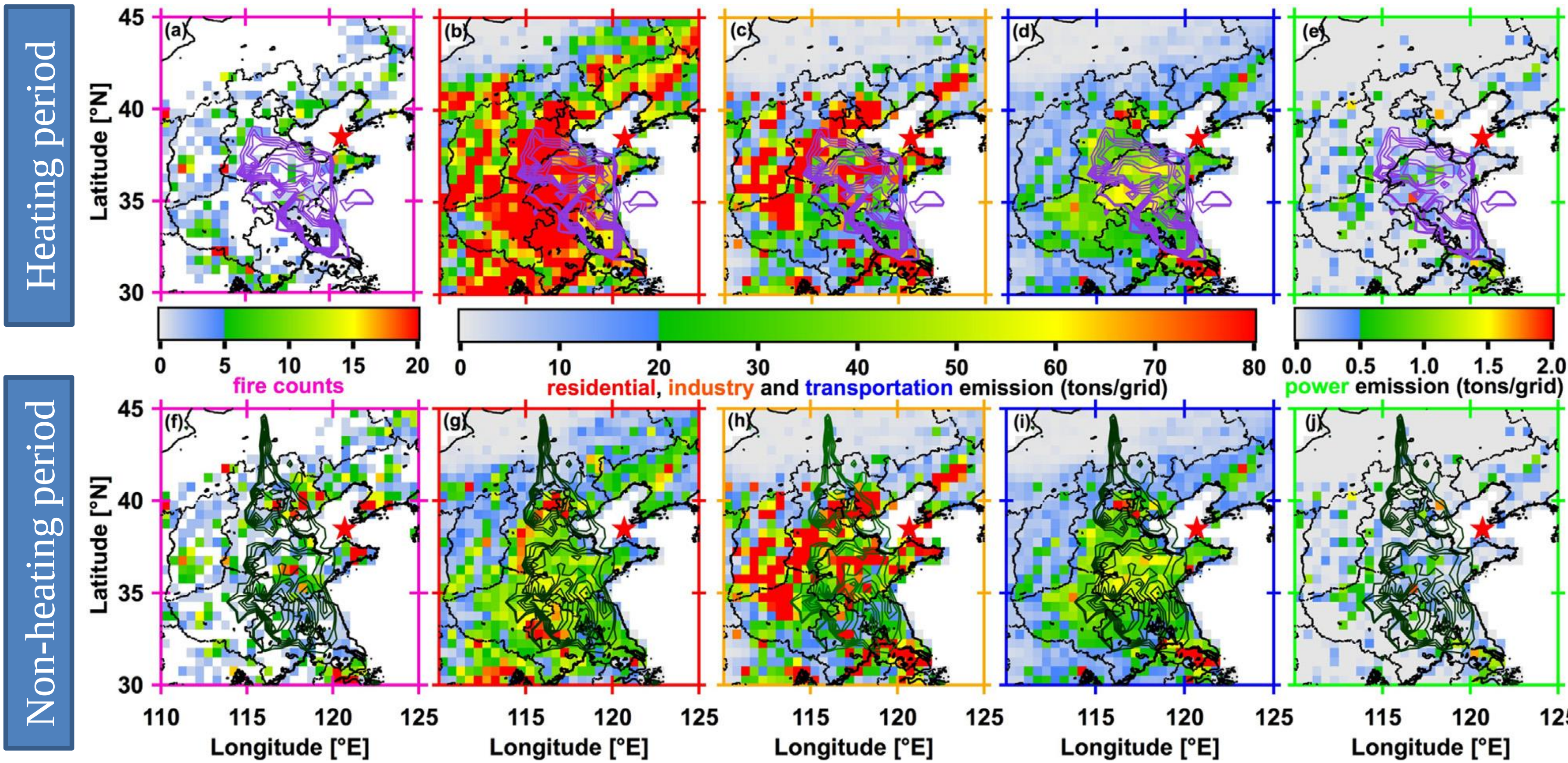


Source regions were identified by total potential source contribution function (TPSCF).

TPSCF values were consistent with BC emission rates in the emission inventory.

Qingfeng Guo, Min Hu* et al., *Atmos. Environ,*, 2015

The identification of source regions of BC at a receptor site of the eastern coast of China



Residential emission is the main BC source during heating period

Qingfeng Guo, Min Hu* et al., *Atmos. Environ,*, 2015

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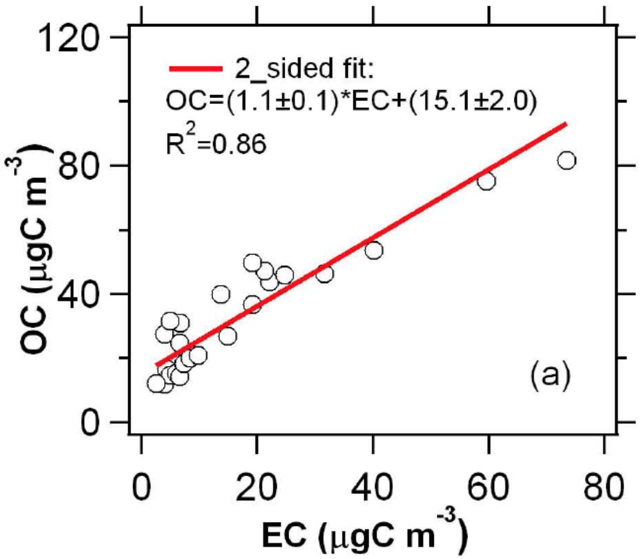
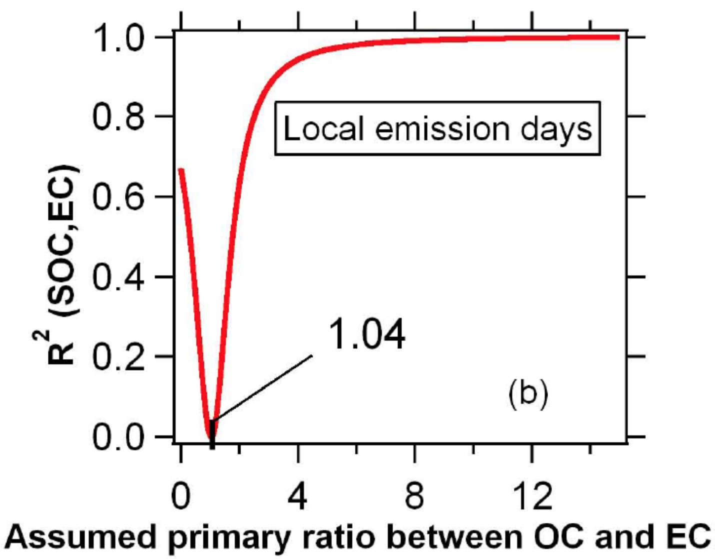
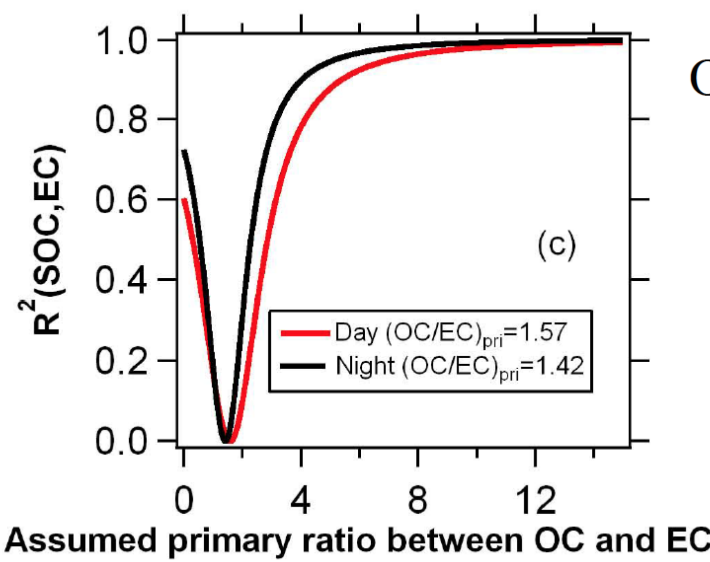
College of Environmental Sciences and Engineering

SOA estimation based on OC/EC method







$$OC_{sec} = OC_{total} - EC_a \times (OC/EC)_{pri} - OC_{non}$$

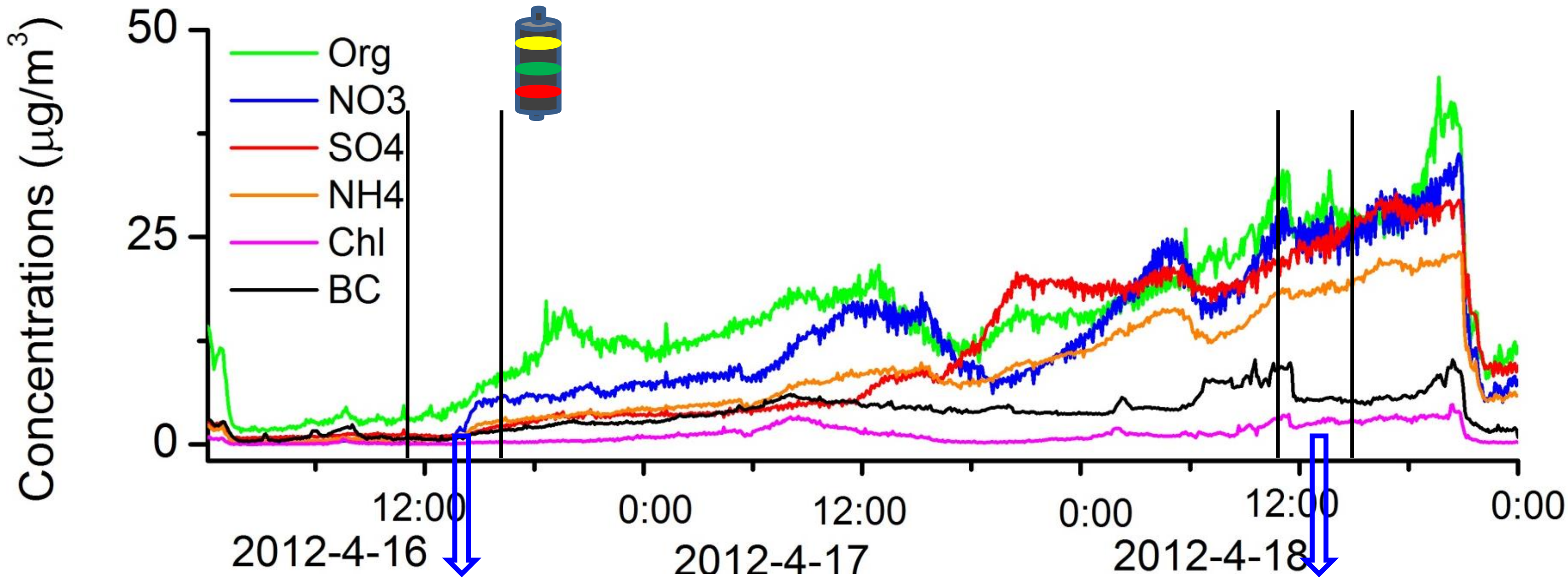
The modified EC tracer method was adopted to estimate SOC. (OC/EC)pri was calculated for the data points in day and night, respectively. At the rural site in the PRD SOA is 47% of OC, up to 80 %. Good correlations between estimated SOC with OOA and WSOC, and estimated POC with HOA, proved the results is reliable

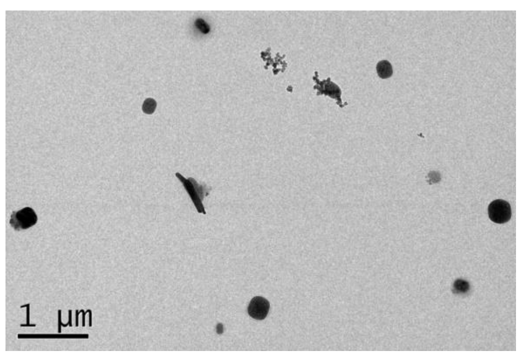
Weiwei Hu, Min Hu* et al., *ACP*, 2012

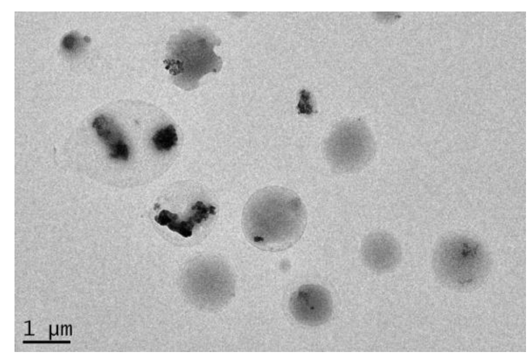
Work done by PKU group

- Emission factor and characteristics of BC
- Source identification of BC particles
- Evolution of BC particles during aging process in the atmosphere

Aging of BC particles from clean to haze in Beijing

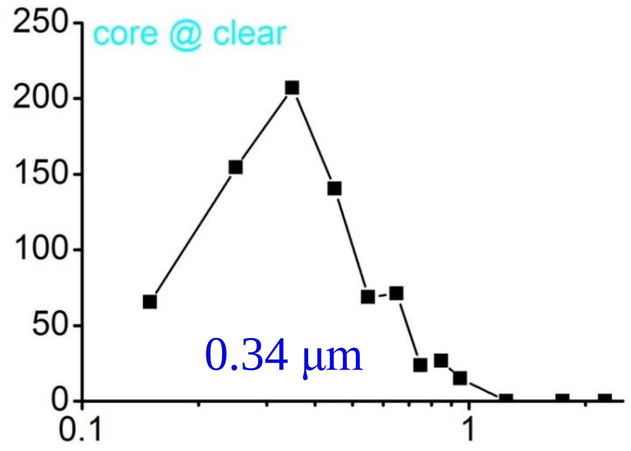


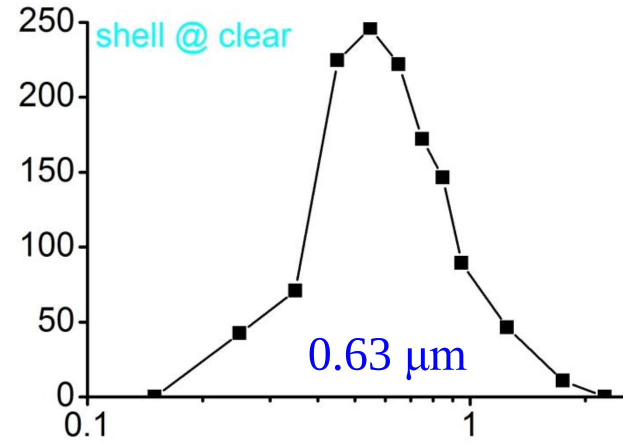


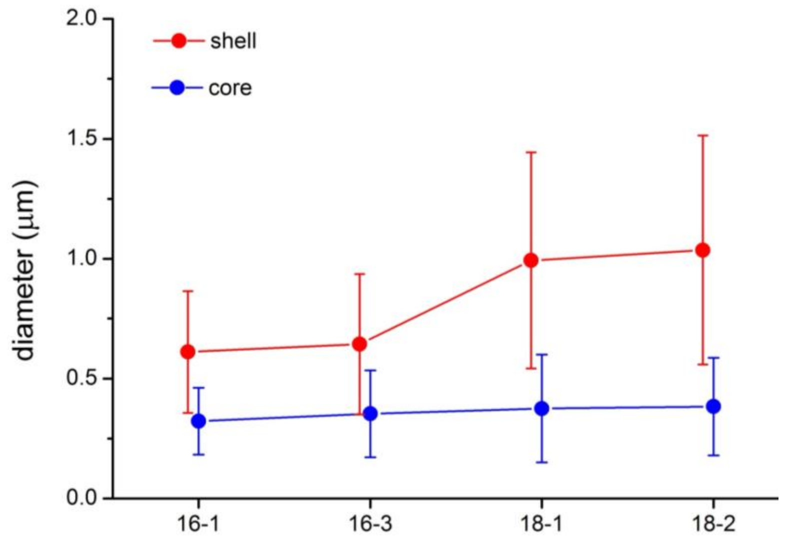


Hongya Niu, Min Hu* et al, STOTEN, revised after review

Growth of BC particles with comparison between clean and haze period







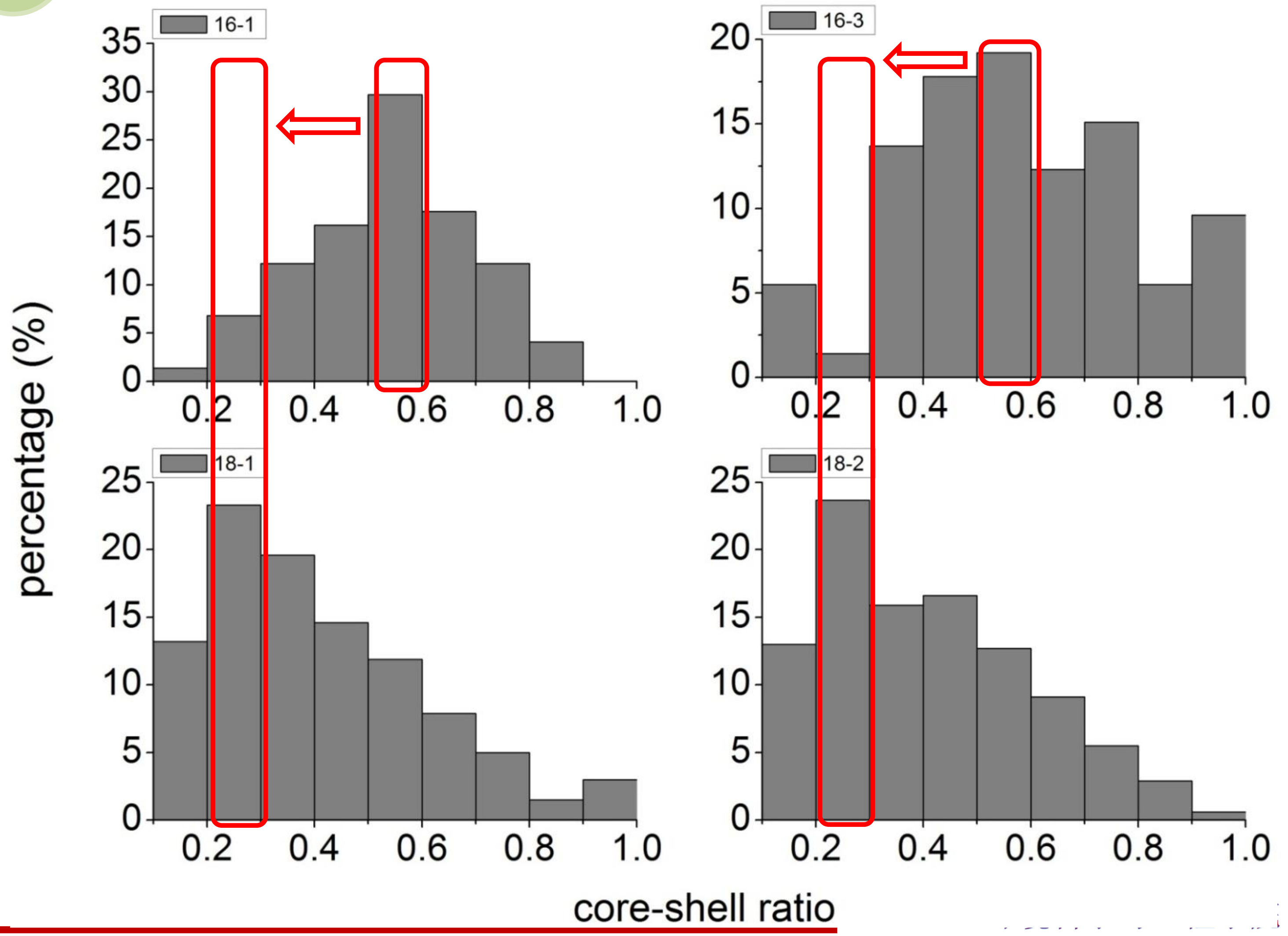
Clean day Haze day

- Higher shell diameter in haze day
- No obvious change in core diameter

Hongya Niu, Min Hu* et al, STOTEN, revised after review

Growth of BC particles with comparison between clean and haze period

- Core-shell ratio = core $_{diameter}$ / shell $_{diameter}$ (0<ratio<1)



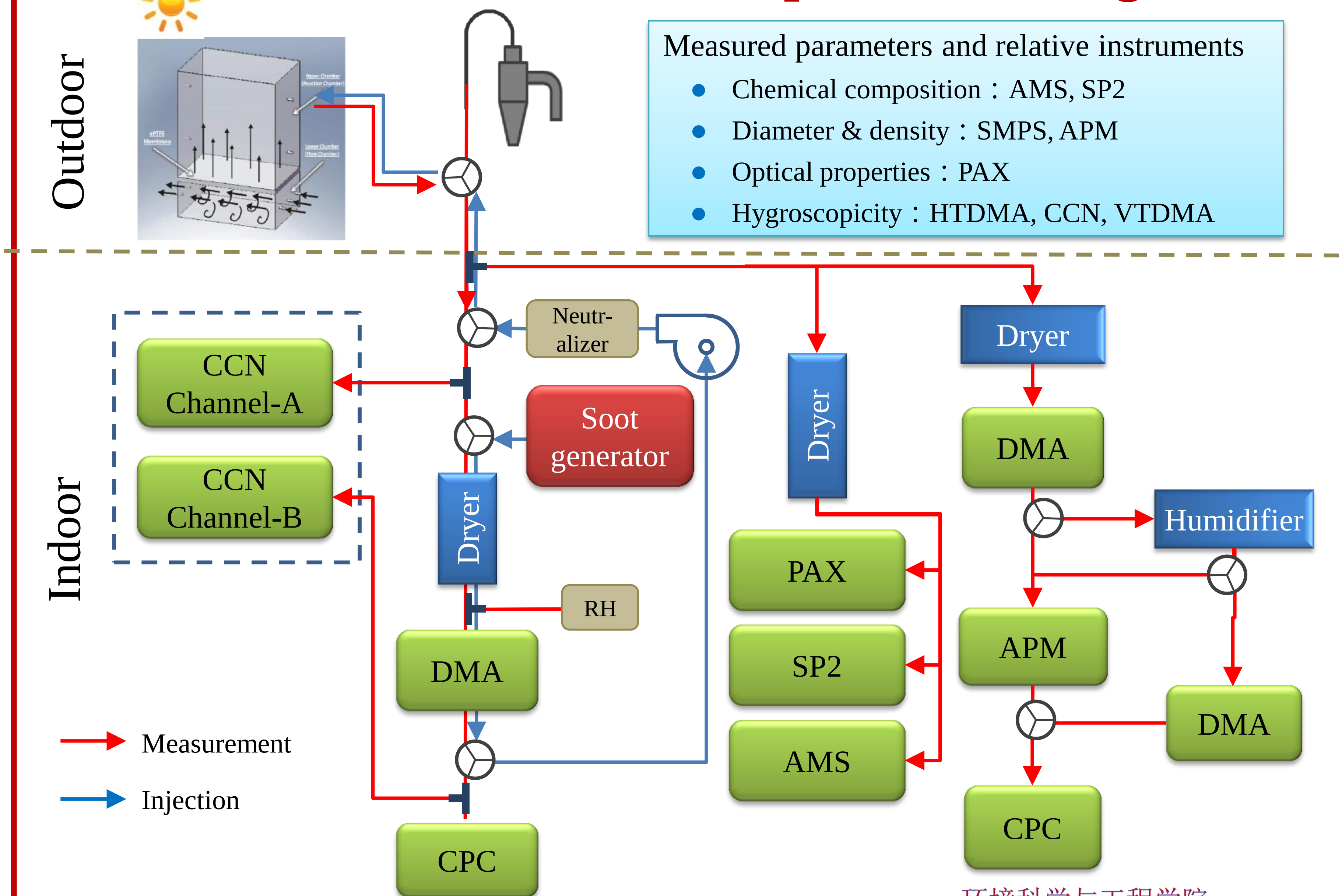
QUasi-real Atmosphere aerosoL evolutIon sTudY Chamber: QUALITY Chamber

Condition	Discripsion
Temp. &RH	Same as in the ambient air, Difference of Temp. <1℃ , Difference of RH<3%
Radiation	Same trends as in the ambient air , but 50% lower
Gaseous species	Same as in the ambient air, Difference < 10%
Particles	Controlled in the chamber, lower than in the ambient air

Chamber Experiment design

Measured parameters and relative instruments

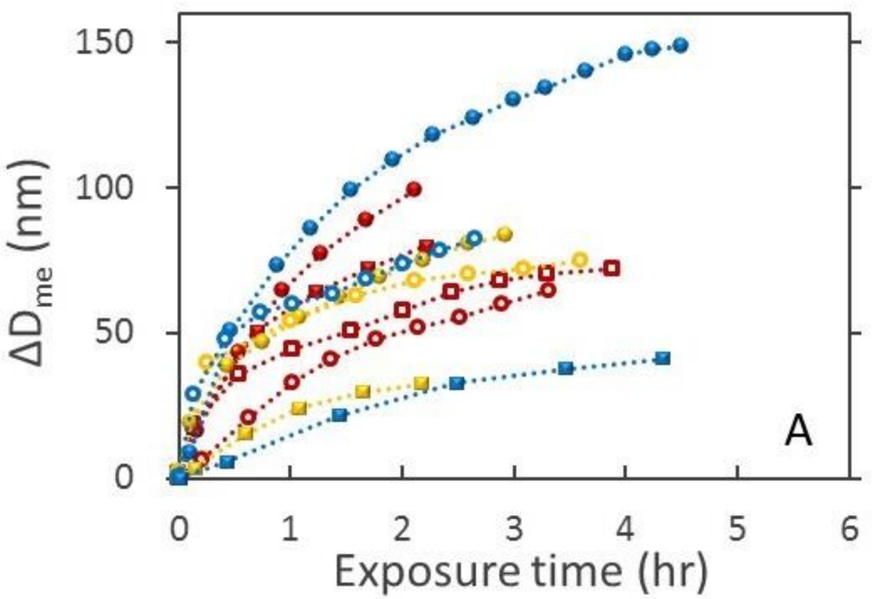
- Chemical composition：AMS, SP2
- Diameter & density：SMPS, APM
- Optical properties：PAX
- Hygroscopicity：HTDMA, CCN, VTDMA

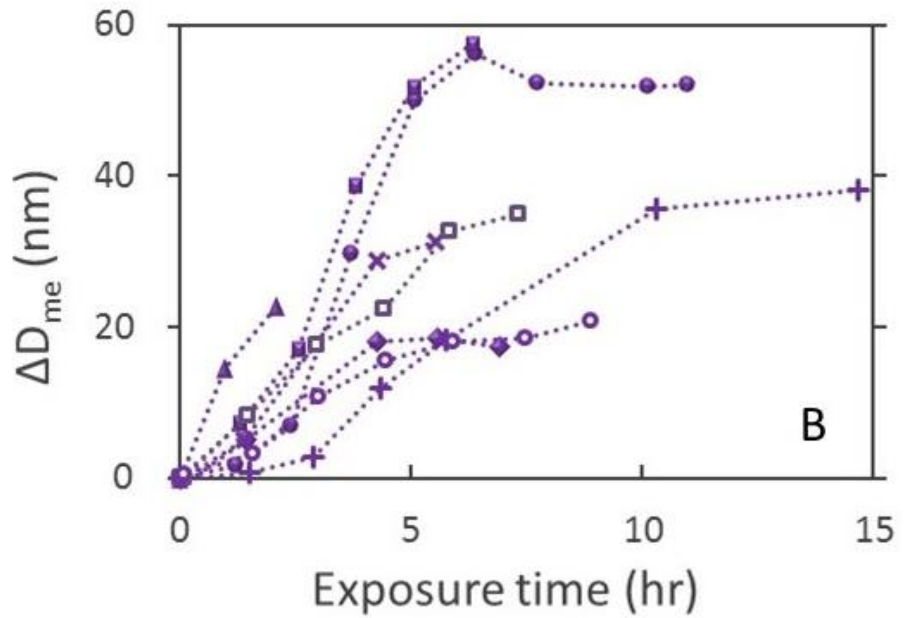


Growth of BC particles in different environment

Beijing

Houston

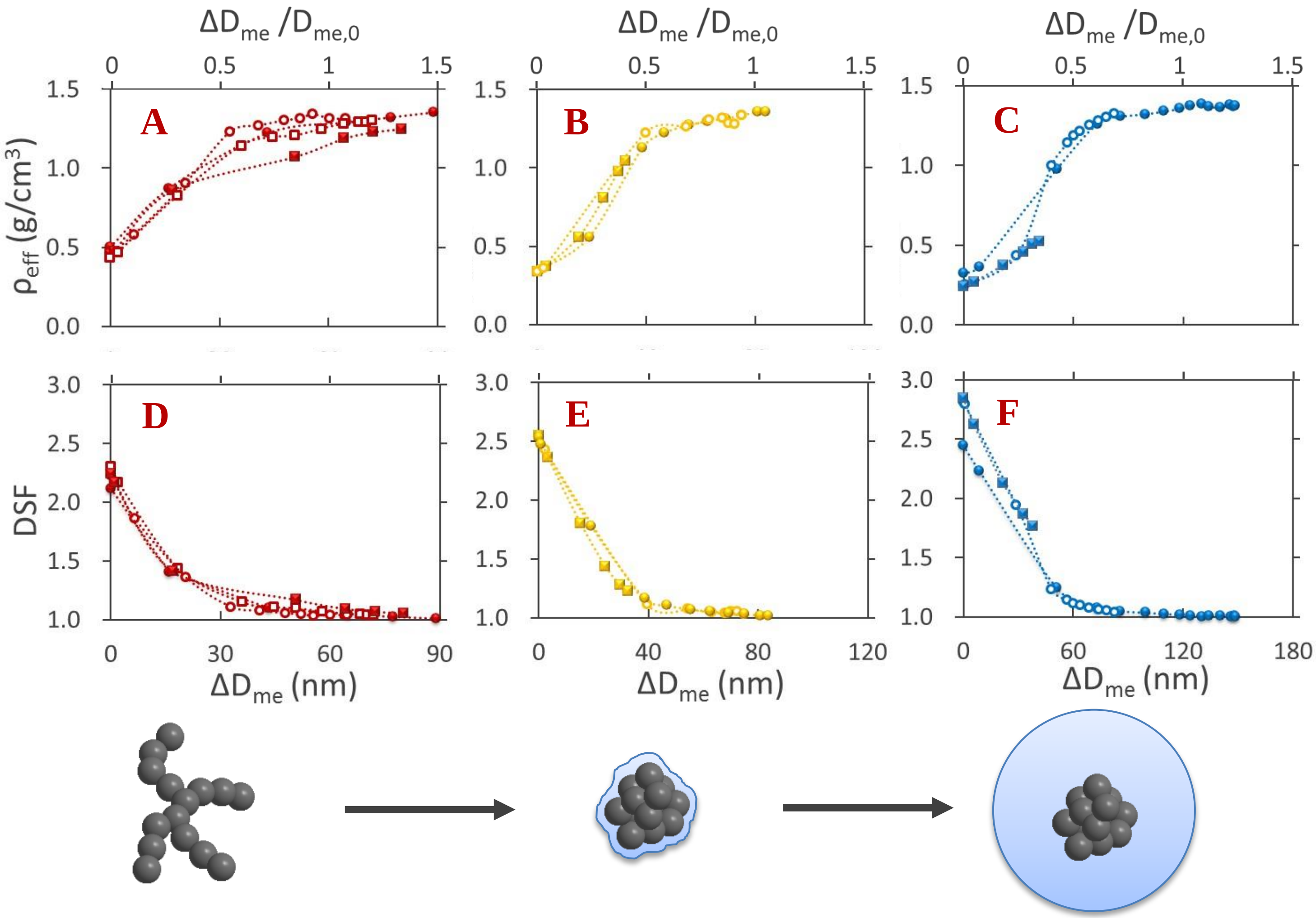




- Fast increase of diameter, density and mass
- Total growth of D_{me} in each experiment: 32-152 nm
- Growth rate: 26 (11-47) nm/h

Jianfei Peng, Min Hu*…Renyi Zhang*, *PNAS*, 2016

BC morphology change



Jianfei Peng, Min Hu*…Renyi Zhang*, *PNAS*, 2016

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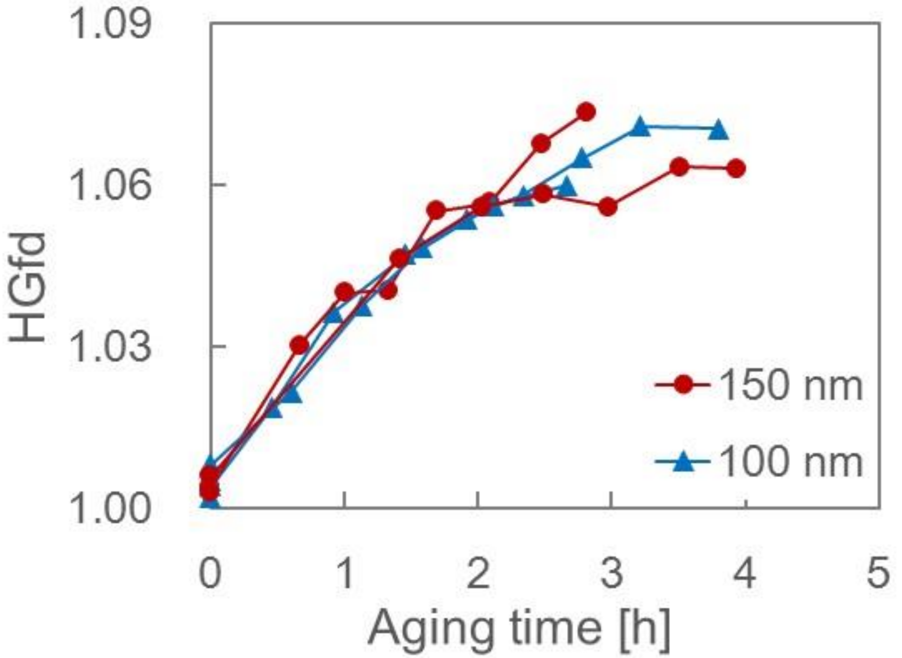
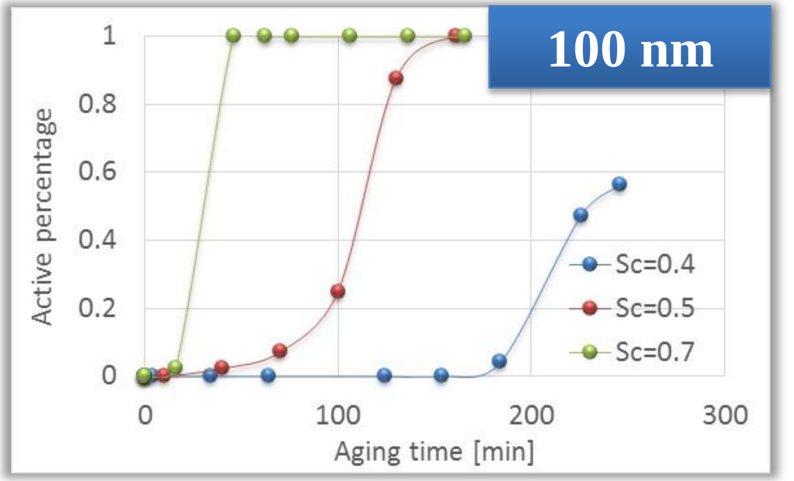
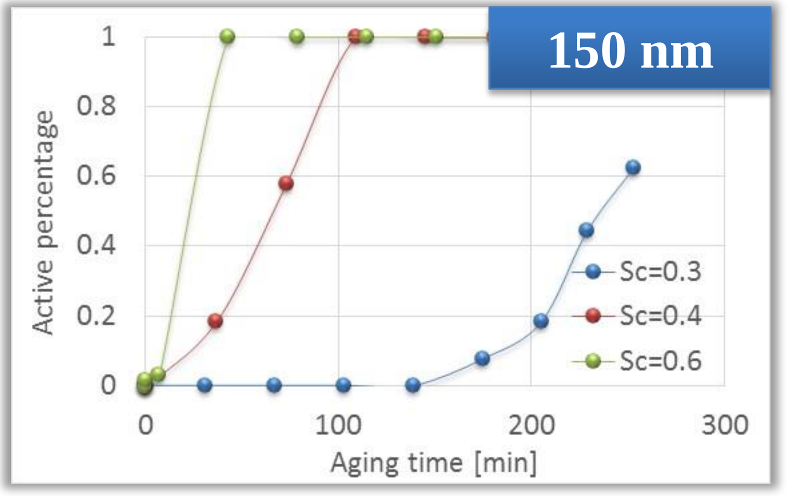
Evolution of hygroscopicity

- HTDMA RH=88%
- CCN 100.2%-100.8%



HGfd: hygroscopicity growth factor in diameter

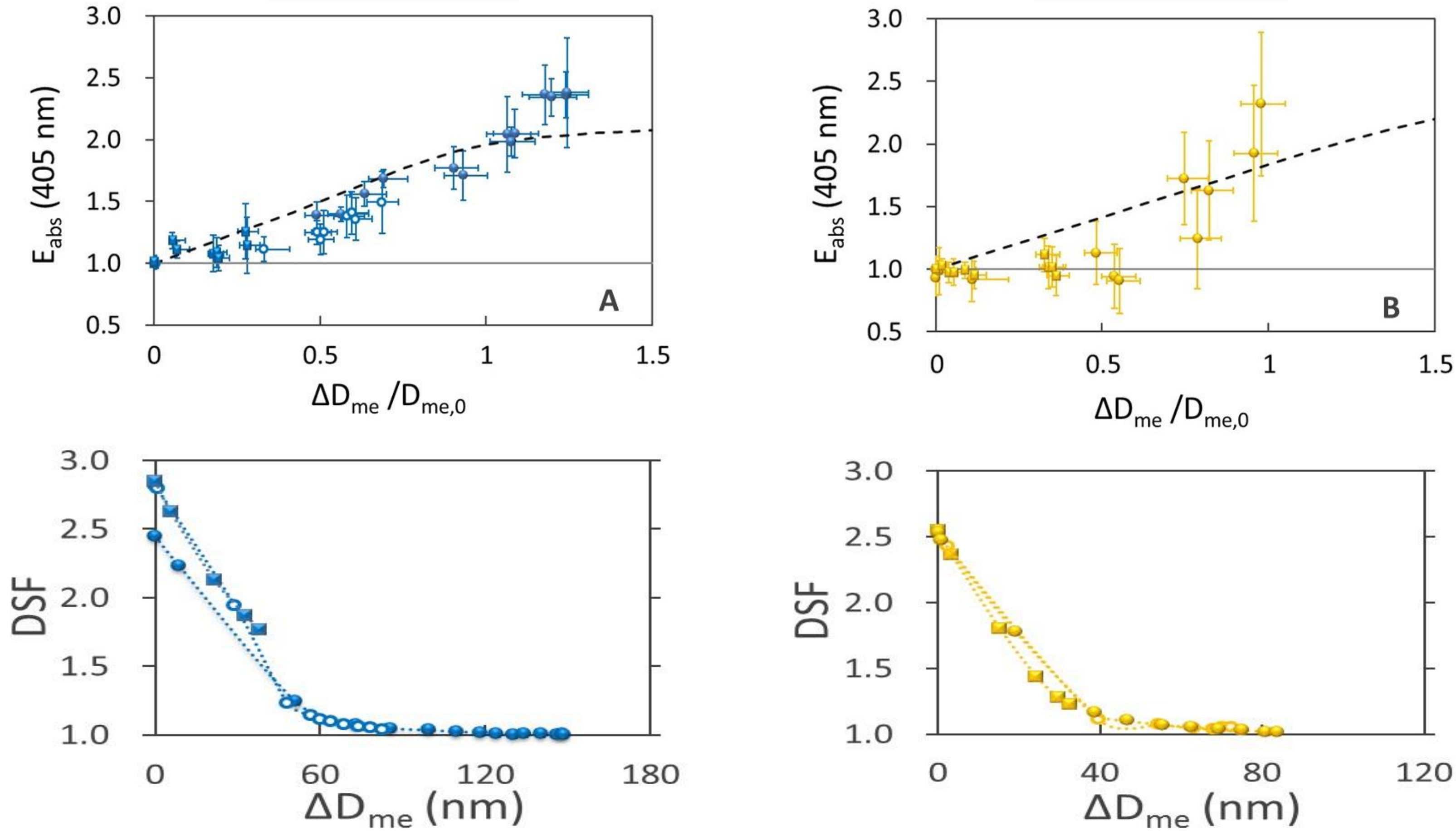




Enhancement of light absorption

220 nm

150 nm



Jianfei Peng, Min Hu*…Renyi Zhang*, *PNAS*, 2016

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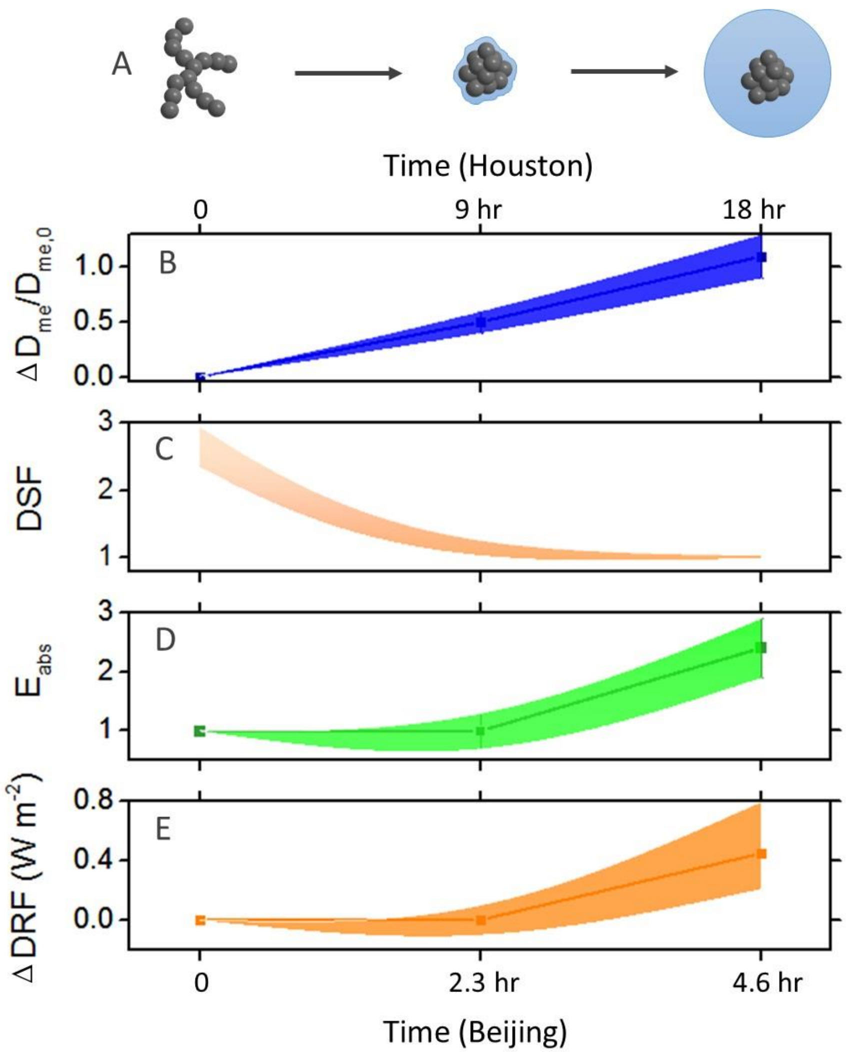
BC aging and direct radiative forcing



- The timescales to achieve complete morphology modification and an absorption amplification factor of 2.4 for BC particles are estimated to be 2.3 h and 4.6 h, respectively, in Beijing, compared with 9 h and 18 h, respectively, in Houston
- BC under polluted urban environments could contribute significantly to both pollution development and large positive radiative forcing, implying that reduction of BC emissions achieves a co-benefit in simultaneously controlling air pollution and protecting climate, especially for developing countries.

Jianfei Peng, Min Hu*…Renyi Zhang*, *PNAS*, 2016

Future work

- Aging of BC particles from vehicles & biomass burning, properties changing and impacts on climate change
- Evaluation of the aging time scale and absorption enhancement of BC particles in the ambient air with DMA-SP2 system

Look forwards to cooperating with you

Acknowledgements

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  - ✓ Prof. Ali Wiedensohler, Birgit Wehner, Leibniz Institute for Tropospheric Research (Tropos), Germany
  - ✓ Prof. Michael Boy, Department of Physics, University of Helsinki, Finland
  - ✓ Prof. Kondo, Univ. of Tokyo, Japan
  - ✓ Prof. James J. Schauer, Univ. of Wisconsin, USA
  - ✓ Prof. Jose Jimenez, Univ. of Colorado, USA
  - ✓ Prof. Douglas Worsnop, John Jayne, Aerodyne Res. Inc., USA….

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Thank you for your attentions

Your comments are welcome!

Min HU 胡 敏
Peking University

Email:
minhu@pku.edu.cn