APHH-China Programme

Air quality trends & chemical composition and sources of $PM_{2.5}$ in Beijing Megacity

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The University of Birmingham

School seminar, Oct 2019

Contents

- Beijing Clean Air Action 2013-2017
- Trends of Air Pollutants in Beijing
- APHH sampling campaigns
- Chemical composition & mass closure of $PM_{2.5}$
- Source apportionment of OC

Part I: Clean Air Action & Air Quality Trends in Beijing Megacity, 2013-2017

Beijing 2013-2017 Clean Air Action Plan

Target: **$PM_{2.5} \leq 60$ μg/m^3** by the end of 2017 reduction of 32% of its $PM_{2.5}$ level in 5 years

Objectives of this study:

- The observed concentration of $PM_{2.5}$ was **58** μg/m^3 in 2017. **Is the Clean Air Action Plan successful**?
- **Real trends of air pollutants** during 2013-2017
- **The effectiveness of major control policies**

Mitigations Measures
in the Clean Air Action, 2013-2017

Eight key projects **(Beijing Municipal Government)**

1. **Restructuring energy** (coal *vs* clean energy)
2. **Restructuring vehicles** (new vehicle & fuel standards, public transportation)
3. Controlling the **city development** (population, vehicle ownership)
4. Optimizing **industrial structure**
5. Tightening **environmental protection standards**
6. Strengthening **urban management and regulation enforcement**
7. Constructing an **ecological environment**
8. Strengthening **emergency response to heavy air pollution.**

http://www.ebeijing.gov.cn/feature_2/CleanAirAction/

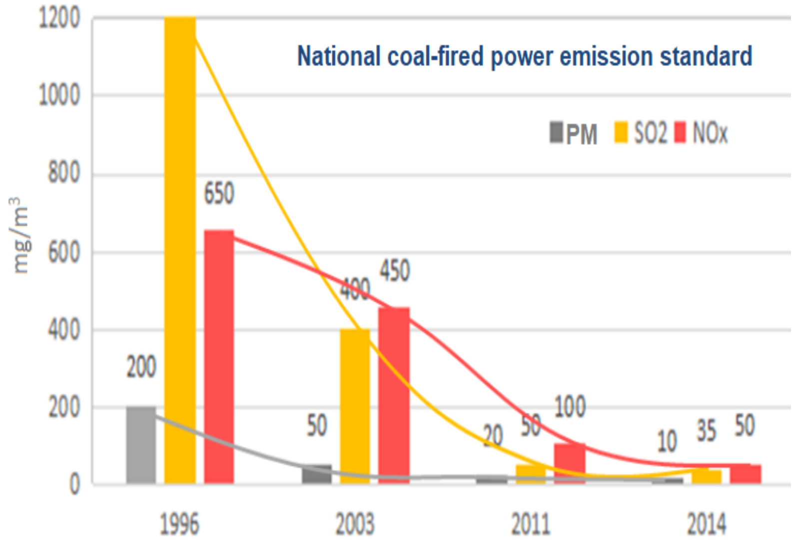
Vehicle emissions controls

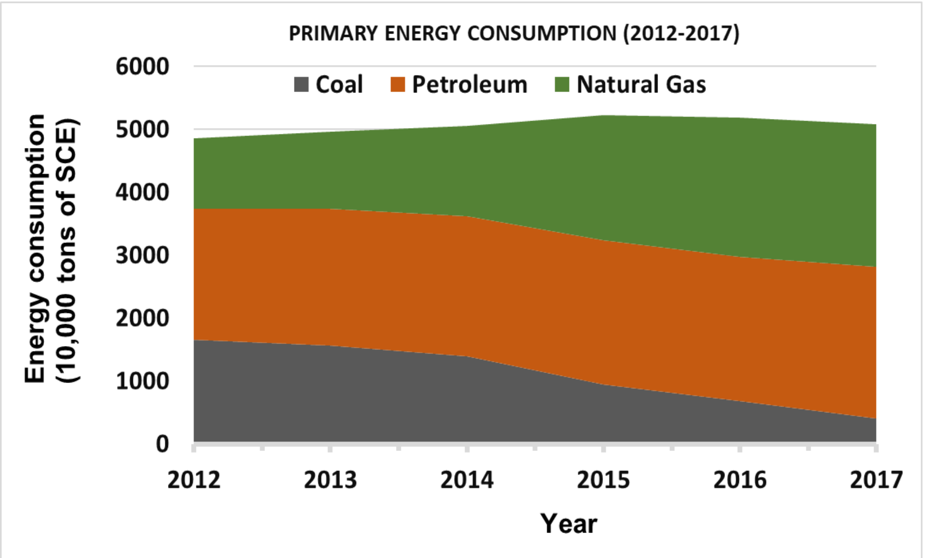
- In 2013: **China V standard** for new light-duty gasoline vehicles (LDVs) and heavy-duty diesel vehicles (HDVs) for public transport.
- Jan 2015: **China V standard** for all LDVs
- **Phased out > 800,000 old vehicles** (age > 6 years) during 2013-2014
- **Prohibit yellow-label gasoline vehicles/ diesel vehicles** entering certain roads

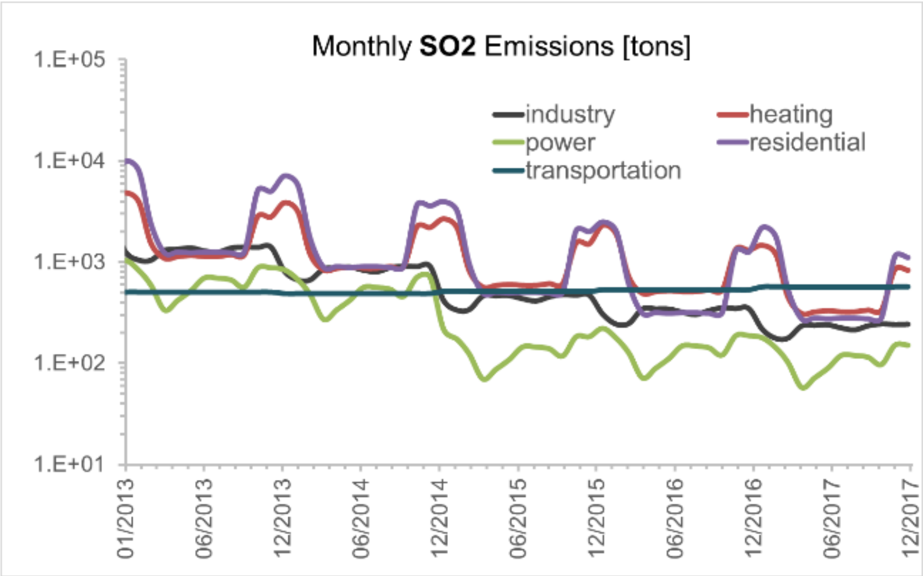
Vu et al . ACP. 2019

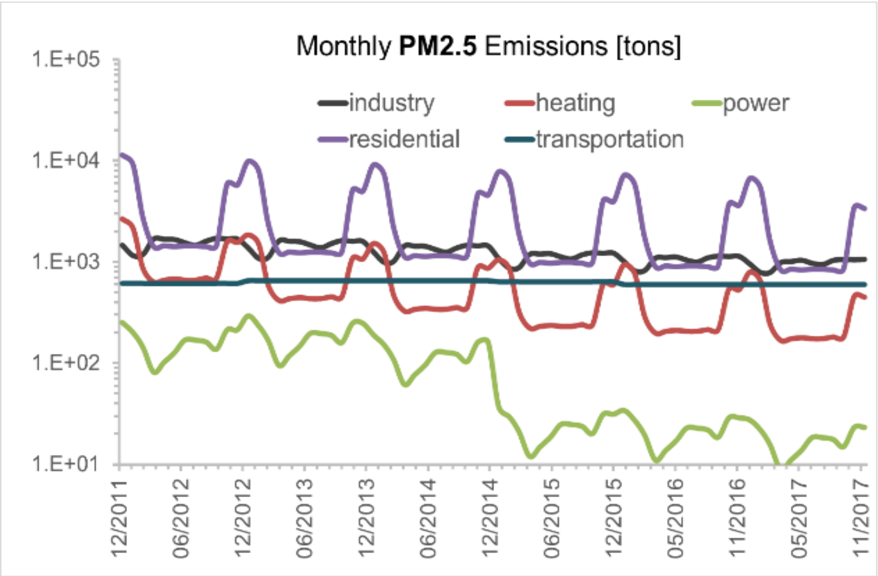
Energy consumption in Beijing

> 70% reduction in coal use









Vu et al . ACP. 2019

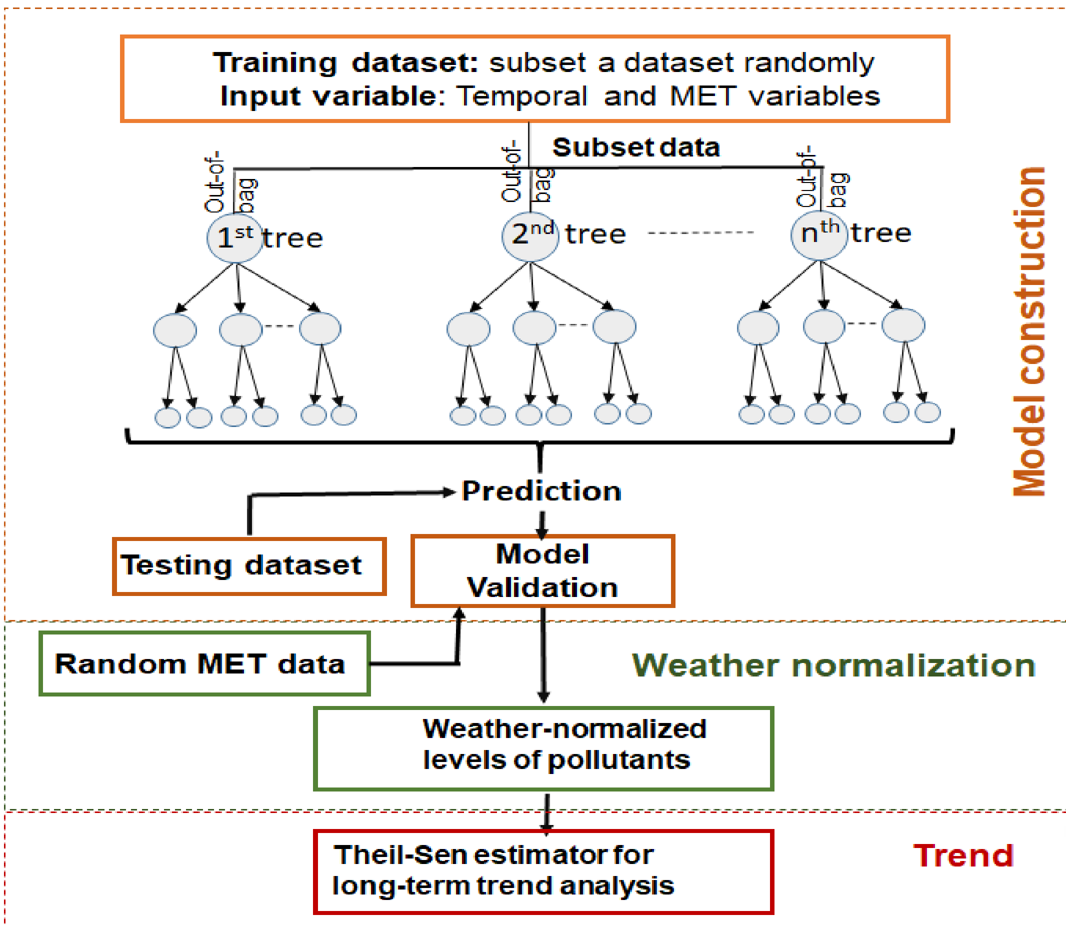
Long-term trend analysis method

The long-term time series of a pollutant can be split into components

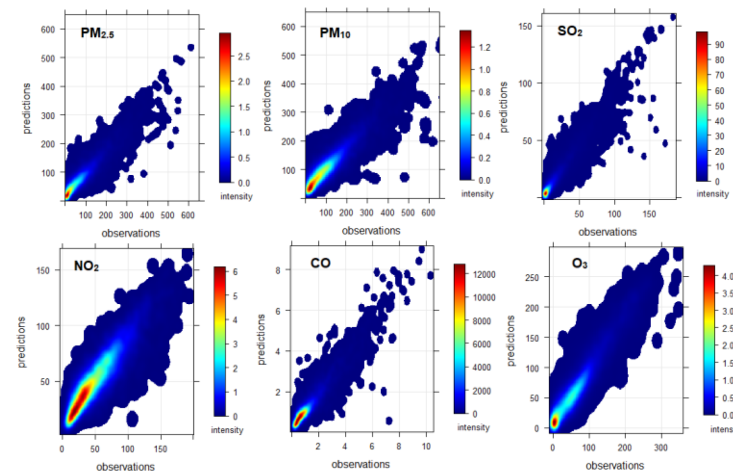
$$\ln[C(t)] = C^{LT}(t) + C^{S}(t) + C^{STM}(t) + C^{WH}(t) + C^{WN}(t)$$

where, LT: long-term component; S: seasonal components; STM: Short-term component; WH: weekend/holiday impact; WN: white-noise is the residual.

A decision tree-based random forest technique



Model validation

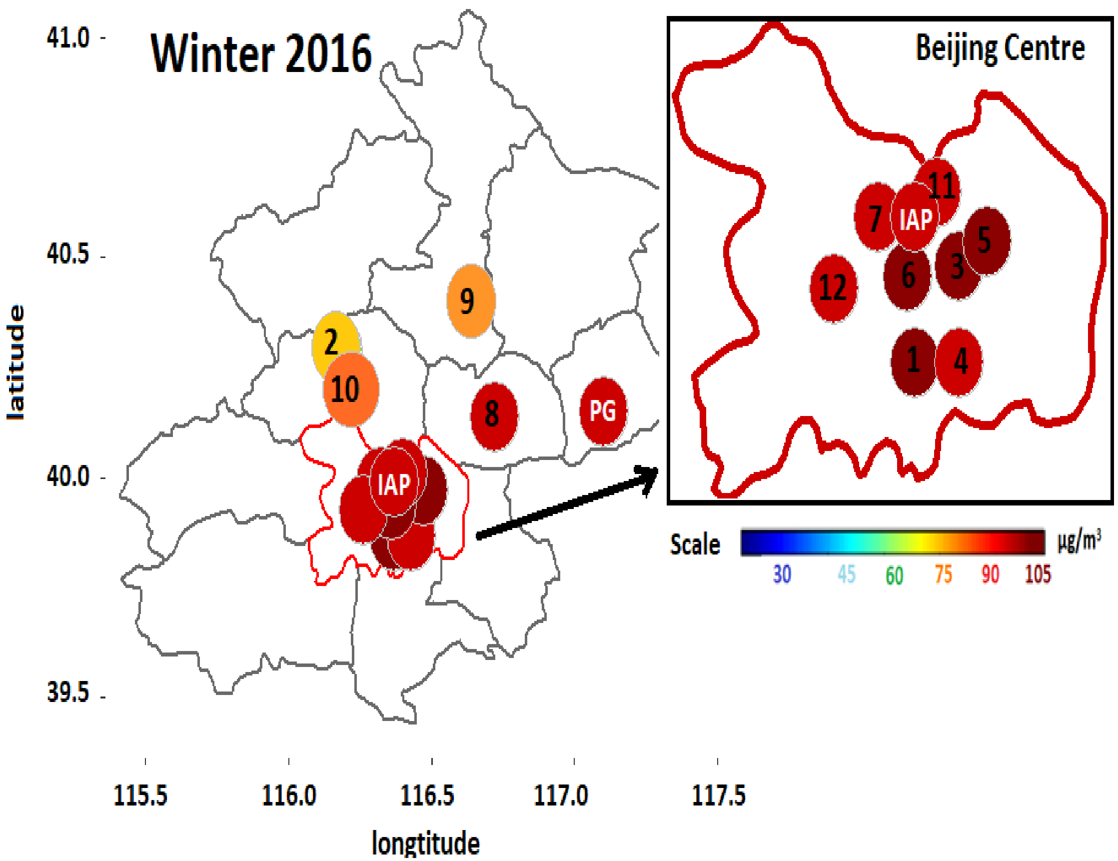


1. List of policies
2. MEIC-emission inventory

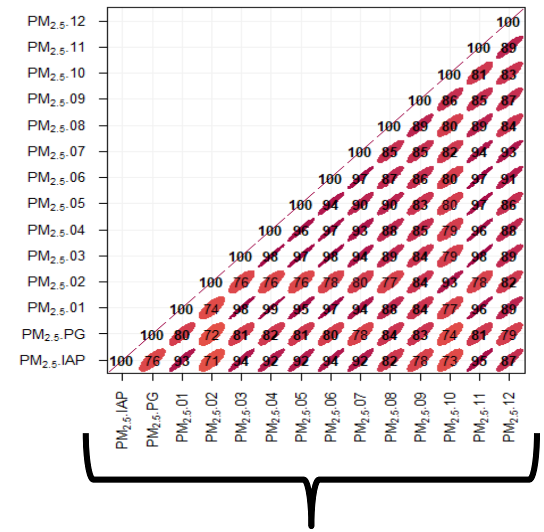
Refs: Carlaws et al. AE. 2009, Vu et al . ACP.2019

Input datasets of Air Pollutants in Beijing

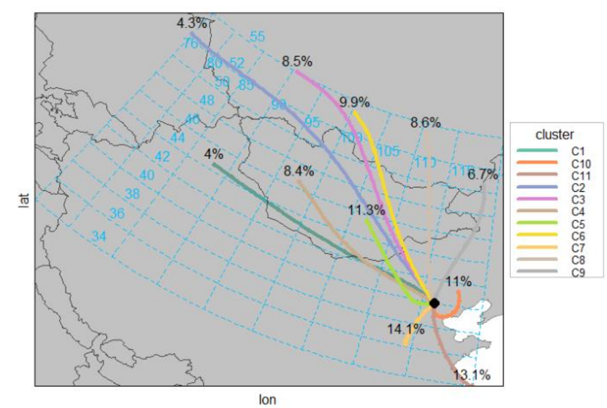
Six key pollutants: **$PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, O_3**
from 12 national monitoring stations during 2013-2017
& **30-year MET** data sets



Spatial variation of $PM_{2.5}$ level during APHH winter campaign 2016



Urban/Suburban/Rural



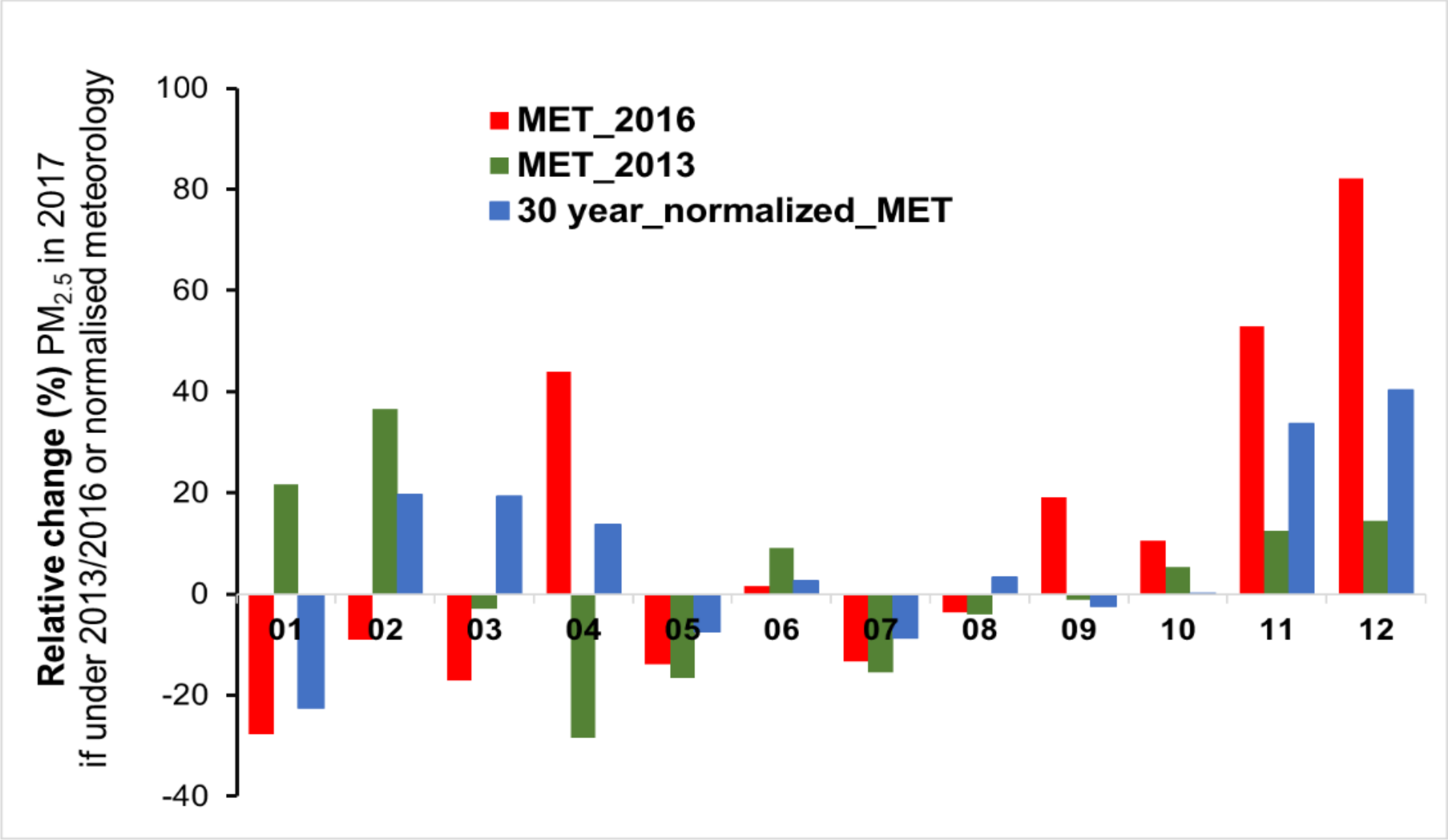
30-year MET data sets
& back trajectories

Refs: Shi et al 2019 ACP

Weather Impacts on $PM_{2.5}$ levels:

A comparison with WRF-CMAQ Models results

$PM_{2.5}$: 61.8 and 62.4 μg m^{-3} if under the 2013 and 2016 from WRF-CMAQ model



Vu et al. ACP. 2019

Air Quality Before & After Weather Normalization

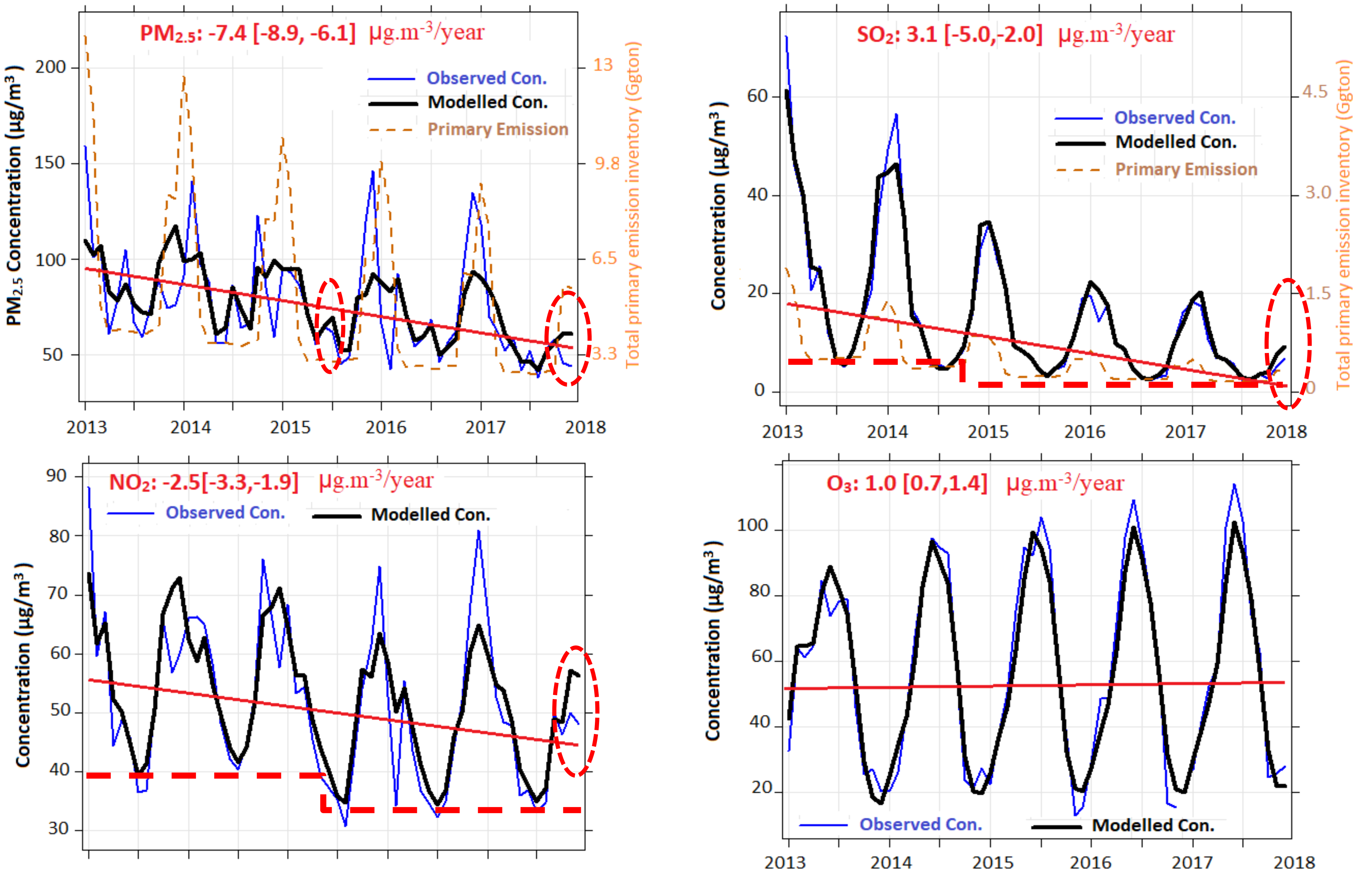
The emission reduction contributed to 10 out of the 13 µg m^{-3} (77%) $PM_{2.5}$ reduction (71 to 58 µg m^{-3}) from 2016 to 2017

	$PM_{2.5}$		PM_{10}		NO_2		SO_2		CO		O_3	
year	Obs.	Nor.	Obs.	Nor.	Obs.	Nor.	Obs.	Nor.	Obs.	Nor.	Obs.	Nor.
2013	88	93	110	123	54	58	23	26.3	1.4	1.5	58	59
2014	84	85	119	121	57	56	20	20	1.2	1.3	55	56
2015	80	75	107	106	50	50	13	13	1.3	1.2	58	59
2016	71	71	98	101	47	48	10	10	1.1	1.1	63	60
2017	**58**	**61**	90	93	45	48	7.5	8.4	0.9	1.0	60	61

Note: Obs: observed concentration. Nor.: Concentration after weather normalization.
Unit: µg m^{-3} for all pollutants, except CO (mg m^{-3})

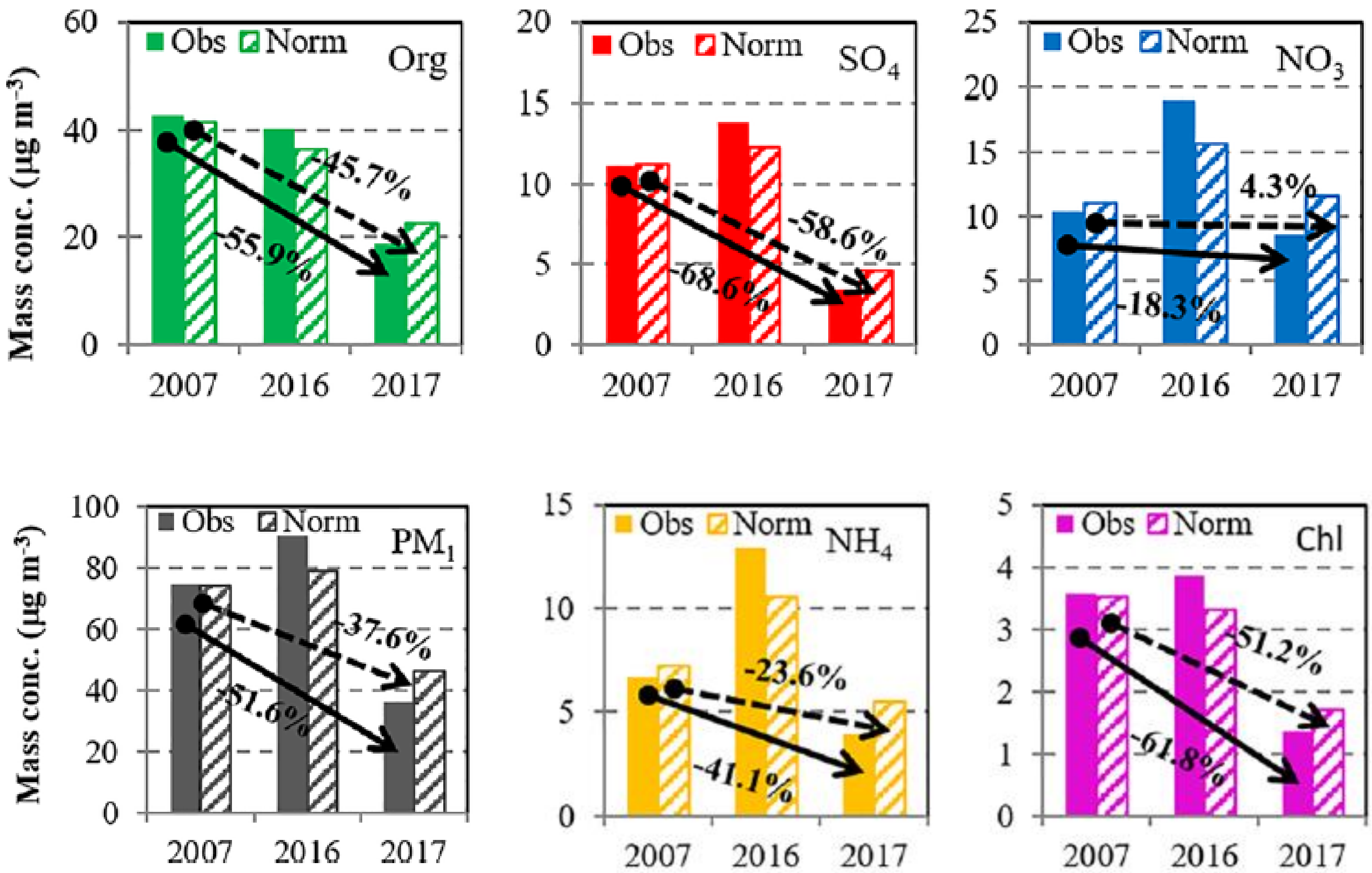
Vu et al . ACP. 2019

Effectiveness of the Mitigations Measures in the Clean Air Action Plan



Vu et al . ACP. 2019

Significant changes in chemistry of fine particles in winter



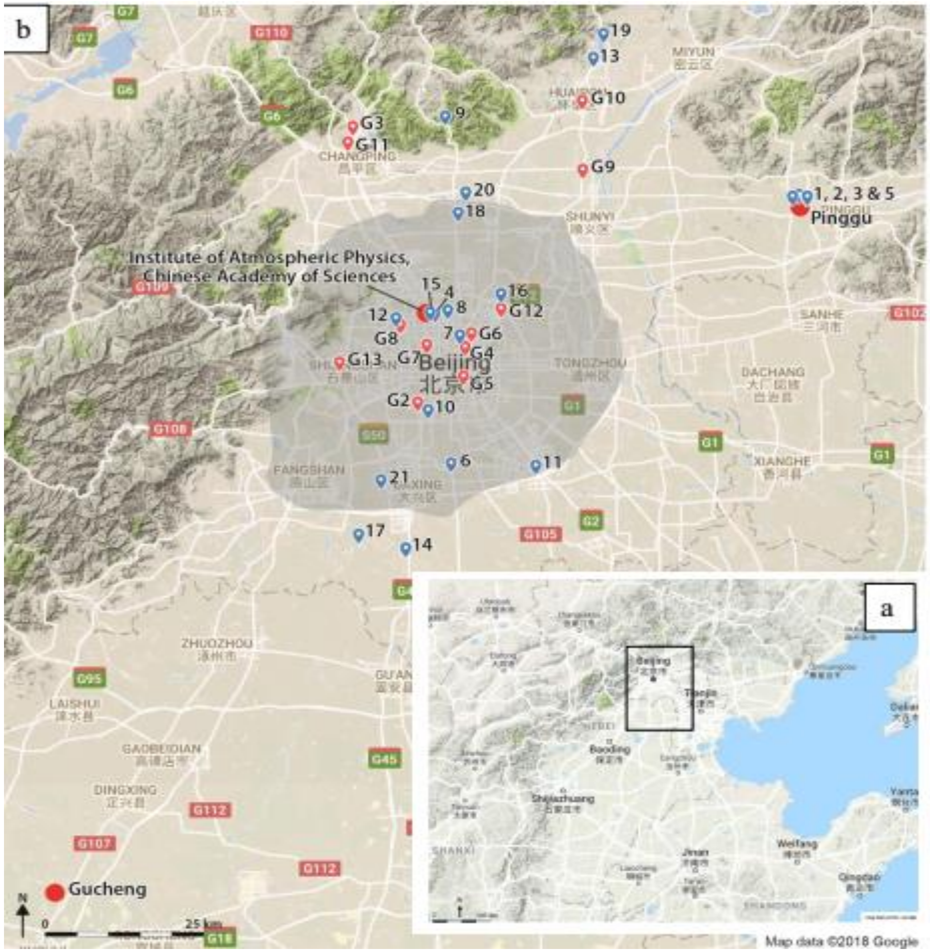
Zhang et al . ES&T. 2019

Part II: APHH-China Programme

Chemical Composition & Source Apportionment studies

APHH Sampling campaigns

Sampling campaigns: Nov-Dec. 2016 & May-Jun. 2017



Sites: Institute of Atmospheric Physics (IAP, urban site), Pinggu (rural site) & Gucheng (upwind site)

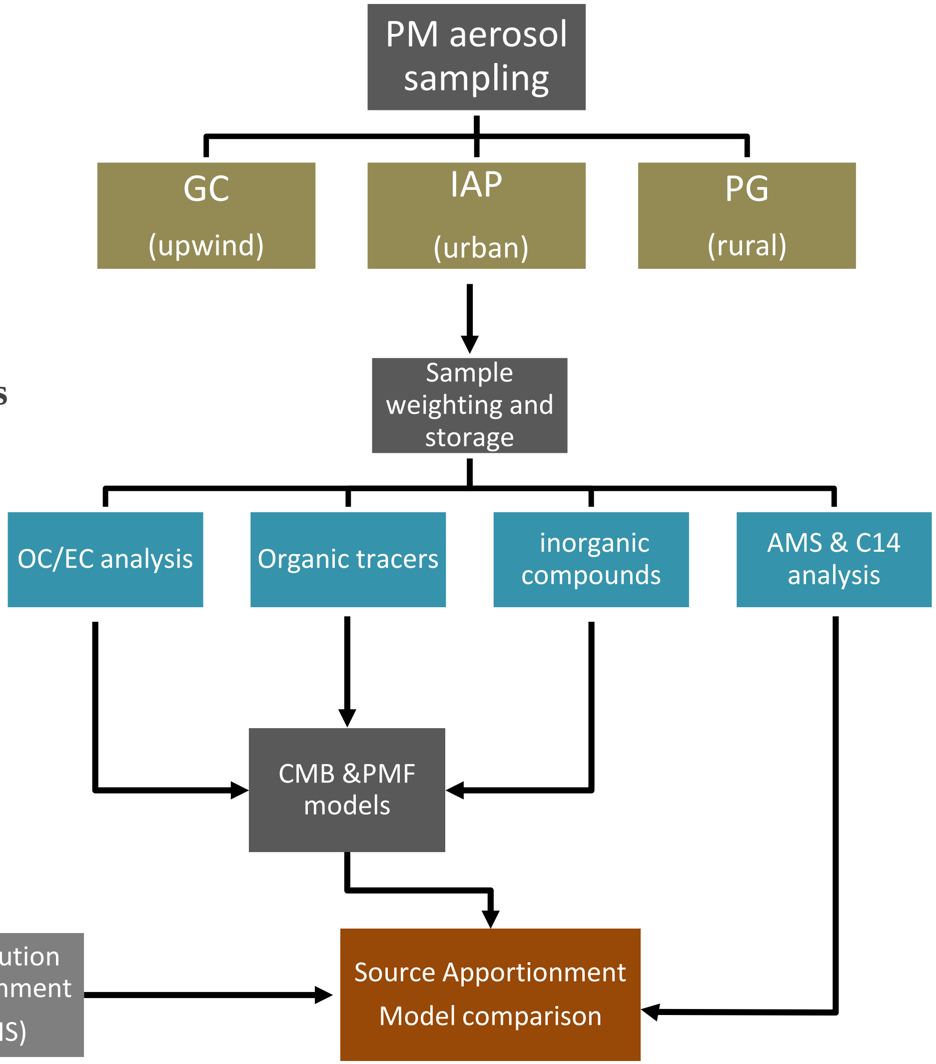
Online instruments: Api-TOF, PSM & SMPS systems, AE-33

Off-line samplers: Streaker, Digitel, Partisol & other high volume samplers

Chemical analysis

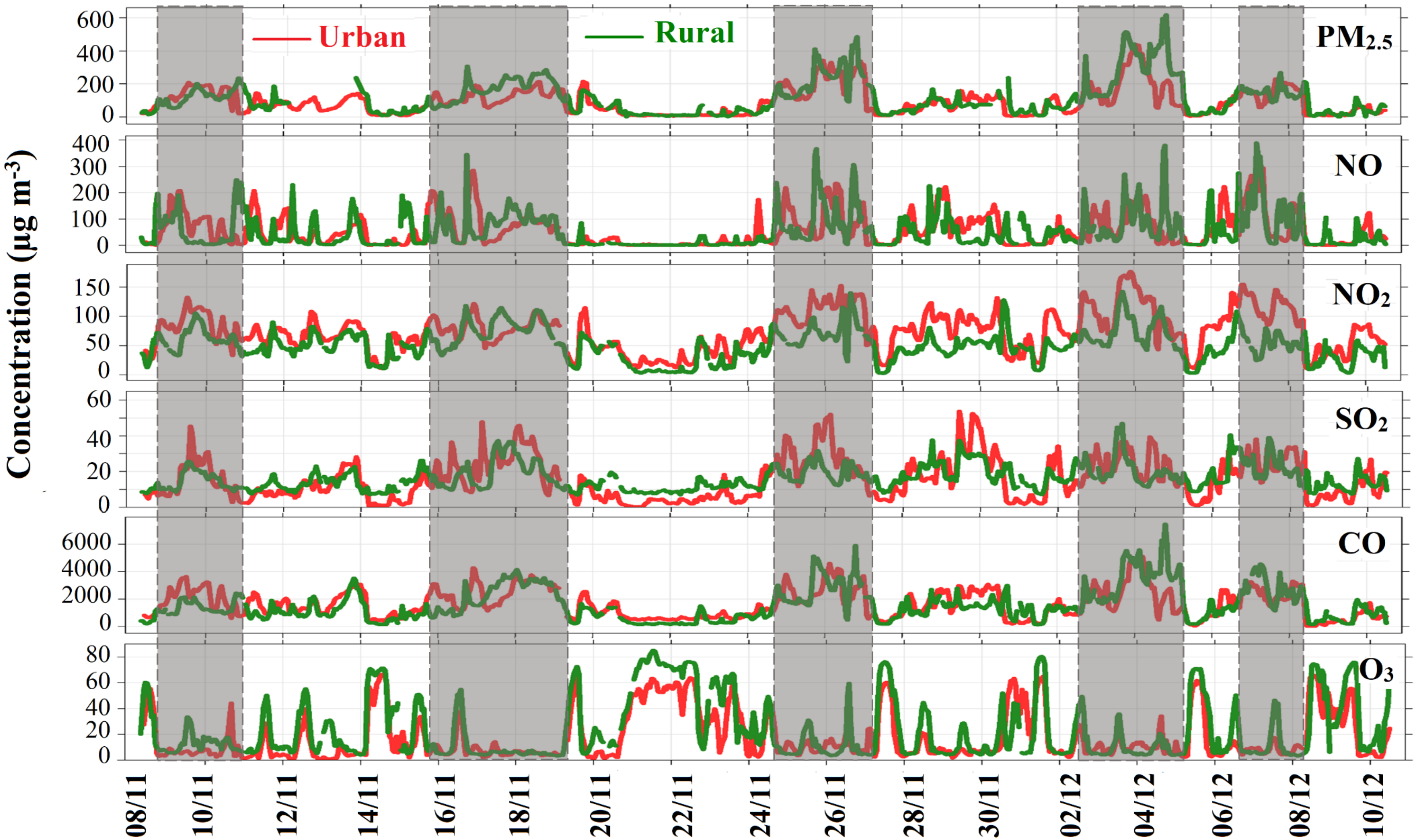
PTFE filters

Quartz filters



Technique	Parameters
High-Vol	PM samples for chemical analysis
Digitel	PM samples for chemical analysis
Partisol	PM samples for chemical analysis
PIXE (Streaker)	Hourly elemental composition
XRF, ICP-MS	metal concentration
IC	soluble ions
Carbon analyser	OC/EC
GC/MS, GCxGC-TOF	Organic tracers (PAHs, alkanes, hopanes, etc.)
AMS & C14	Modern vs fossil: water soluble and insoluble OC & EC

Air Quality during winter 2016 APHH campaign



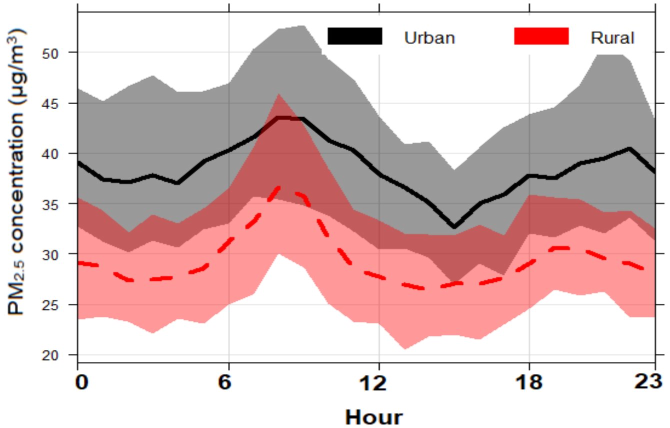
Shi et al . ACP (2019)

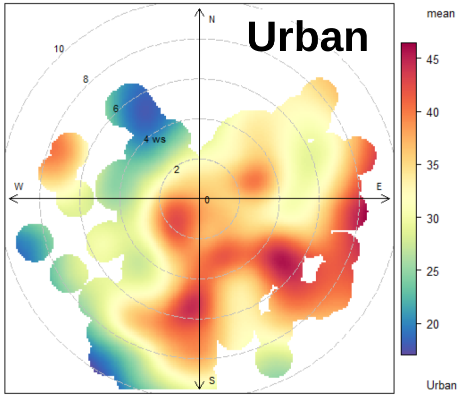
Air Quality during summer 2017 APHH campaign

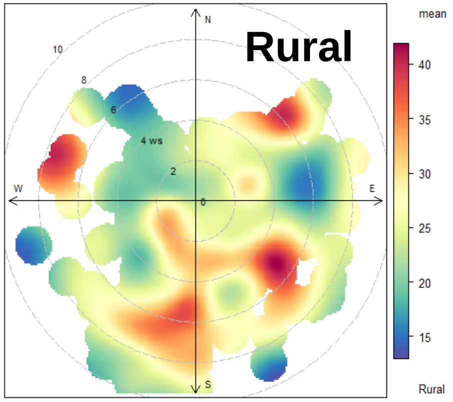
Shi et al . ACP (2019)

$PM_{2.5}$ diurnal patterns & Polar Plot

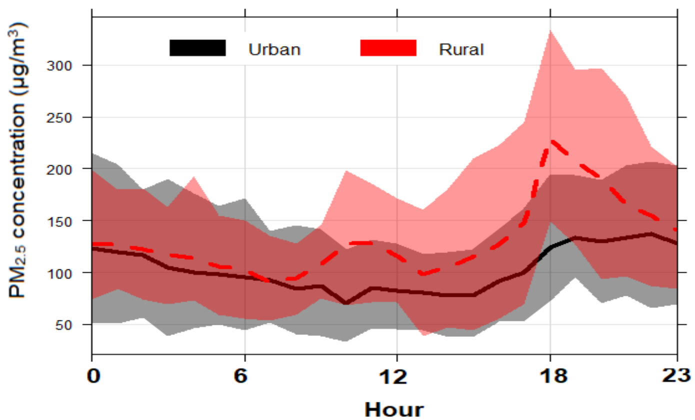
Summer 2017

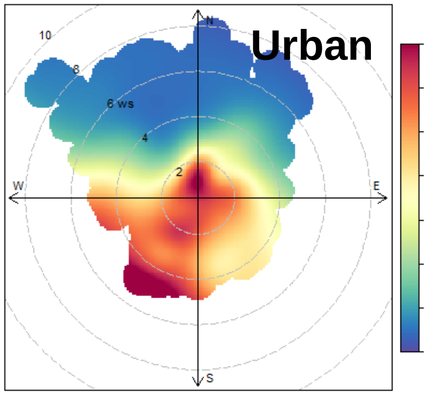


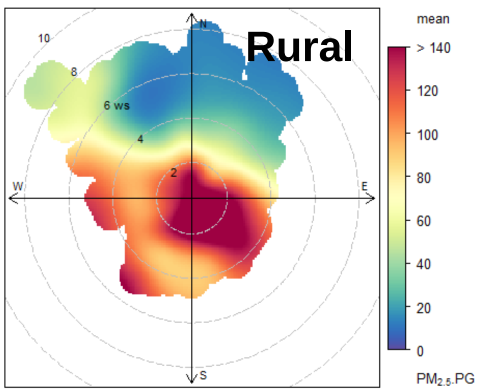




Winter 2016





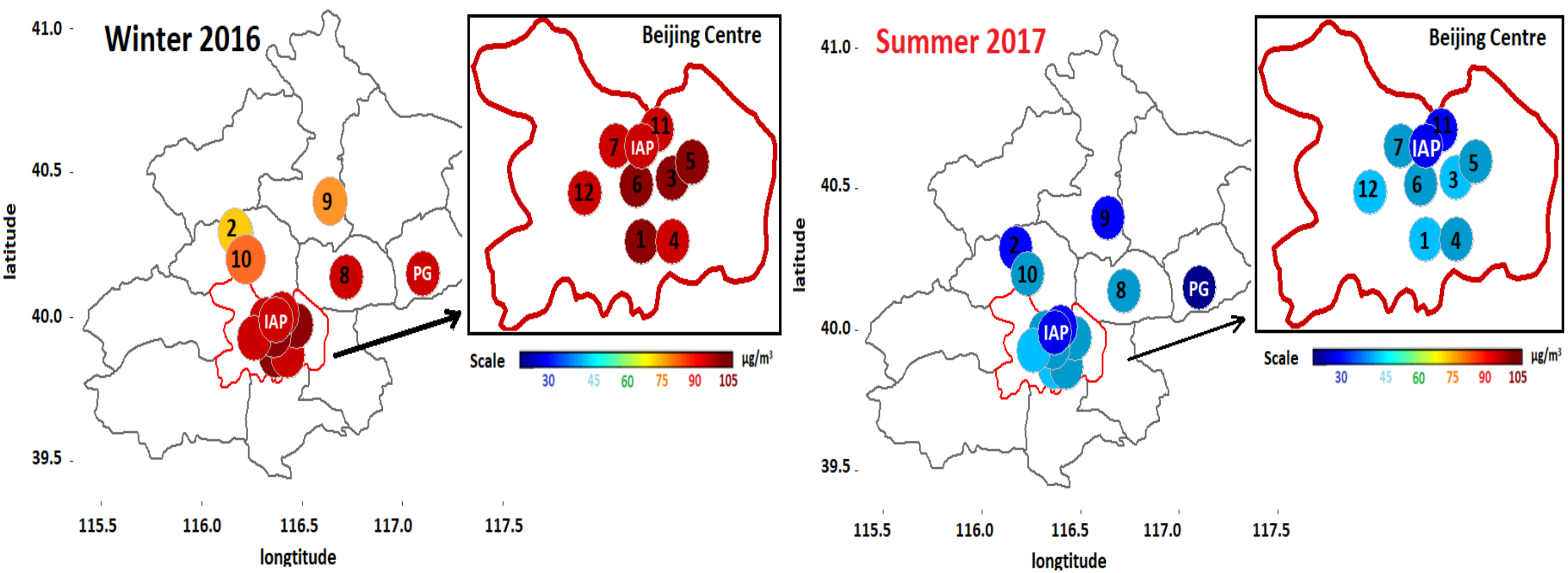


Hourly PM2.5 data in Pinggu was provided by PKU

Spatial distribution of $PM_{2.5}$

- $PM_{2.5}$ pollution is an urban scale phenomenon.
- The air quality data at the campaign sites are reasonably representative of the Beijing urban area.

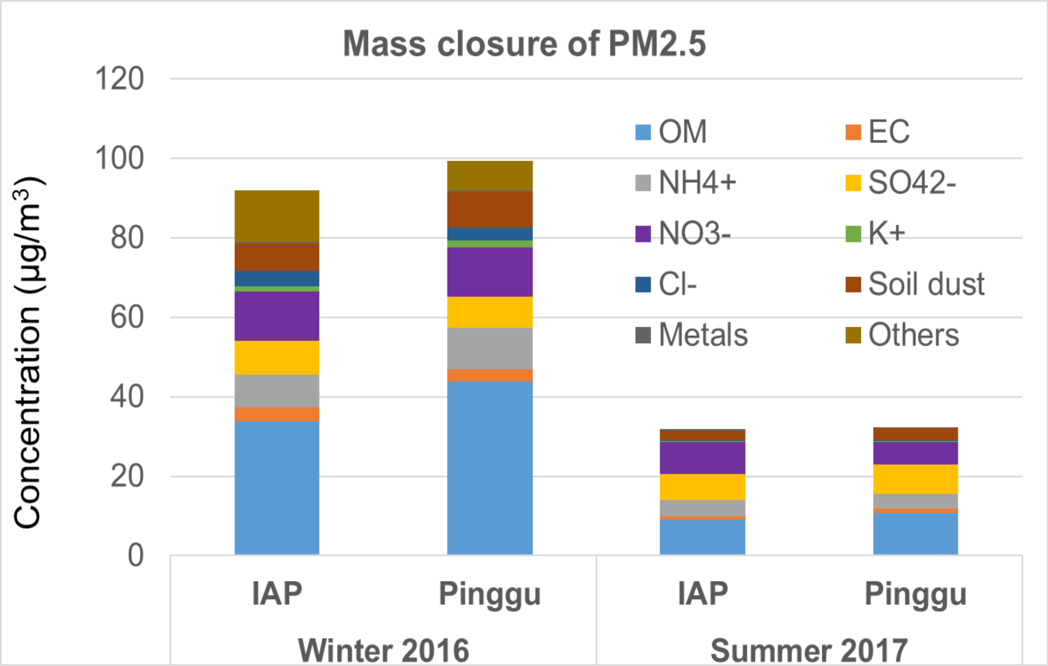
High correlations of air quality between IAP, PG and 12 monitoring site

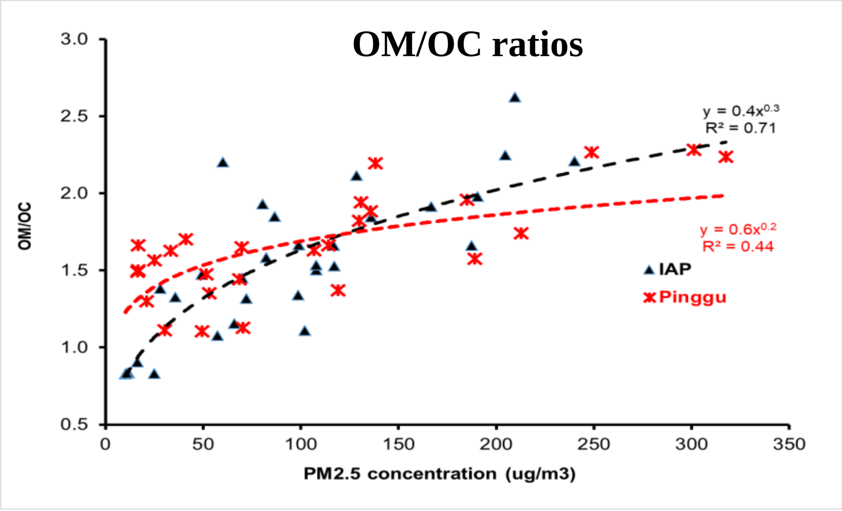


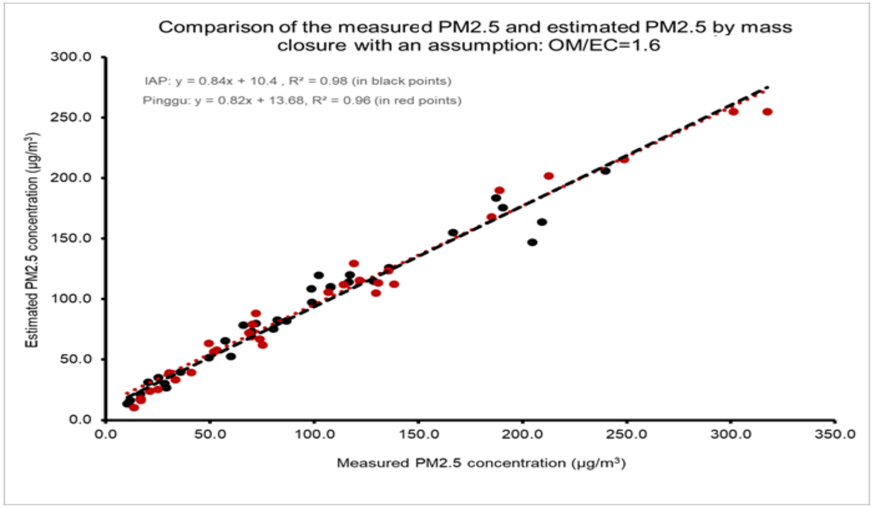
01: Wangshouxigong; 02: Dingling; 03: Dongsi; 04: Tiantan; 05: Nongzhanguan; 06: Guanyuan; 07: Haidianquwanliu; 08: Shunyxicheng; 09: Huairouzhen; 10:Changpingzhen; 11: Aotizhongxin; 12: Gucheng.

Shi et al . ACP (2019)

Mass Closure Model



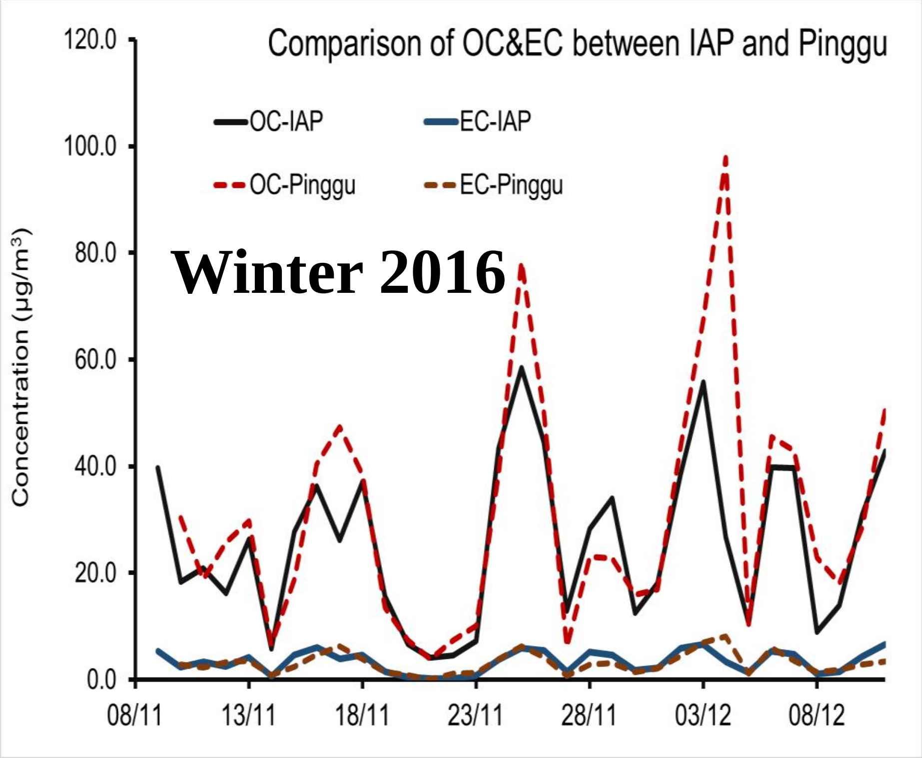


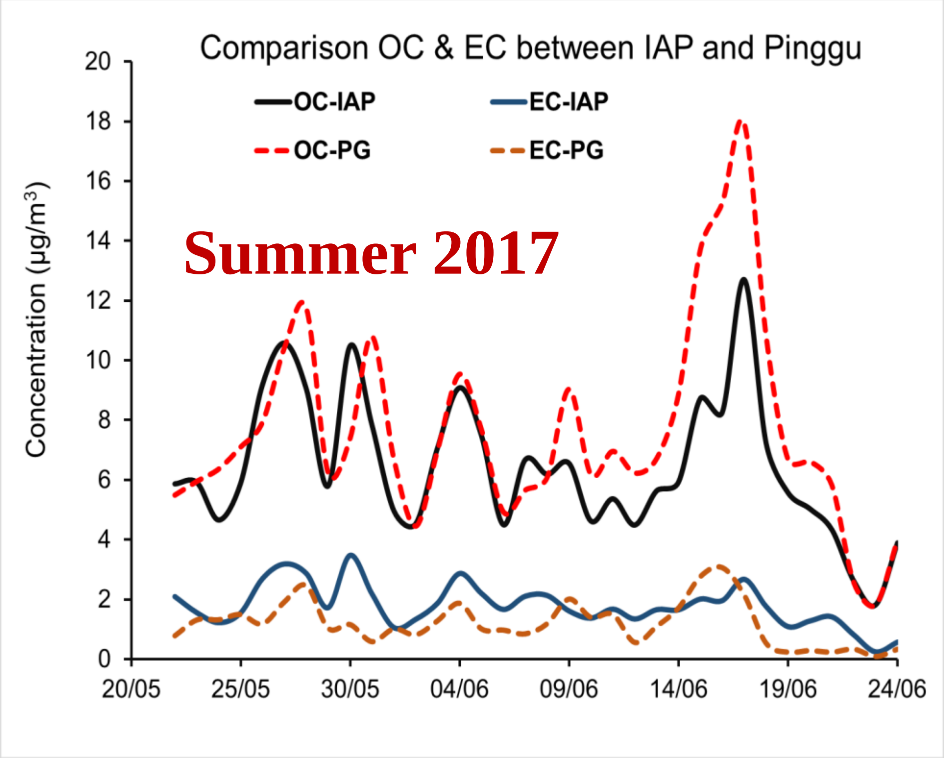


Offline-OC & EC winter & summer

	OC (µg/m3)	EC (µg/m3)	OC/EC
IAP	25.8 (6.4)	3.4 (1.8)	8.0 (3.8)
PG	30.6 (7.6)	3.1 (1.2)	11.6 (8.9)

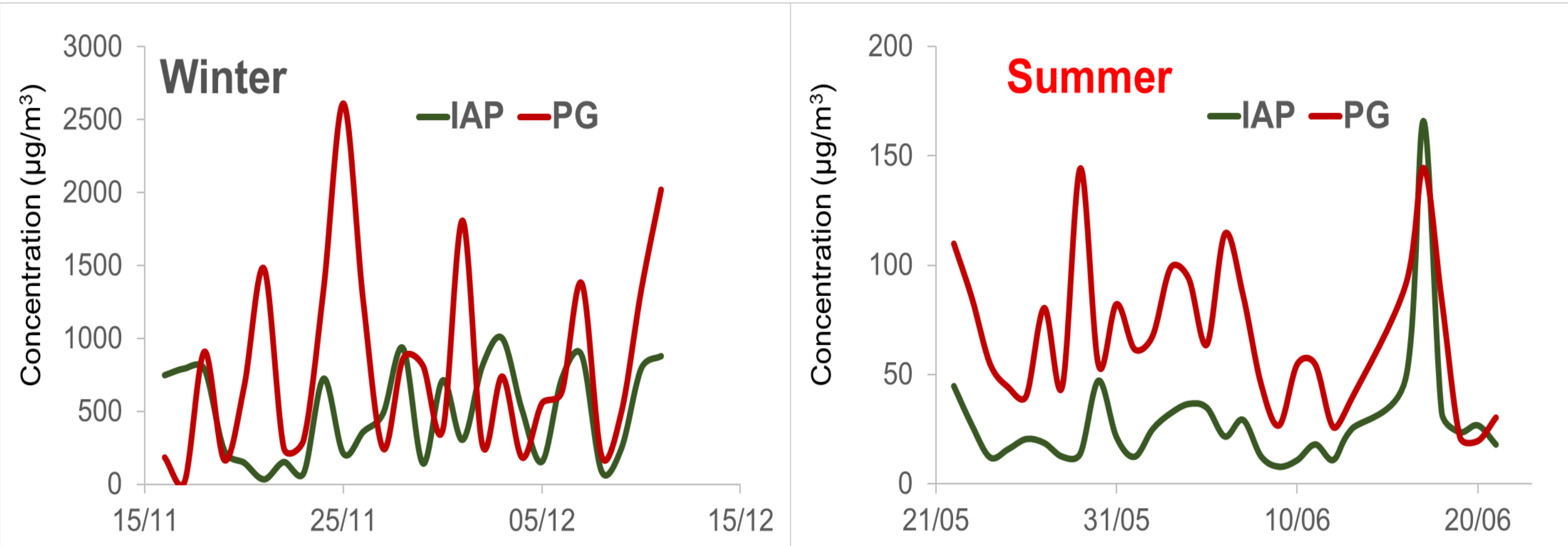
Summer concentration of OC & EC as red number in the bracket





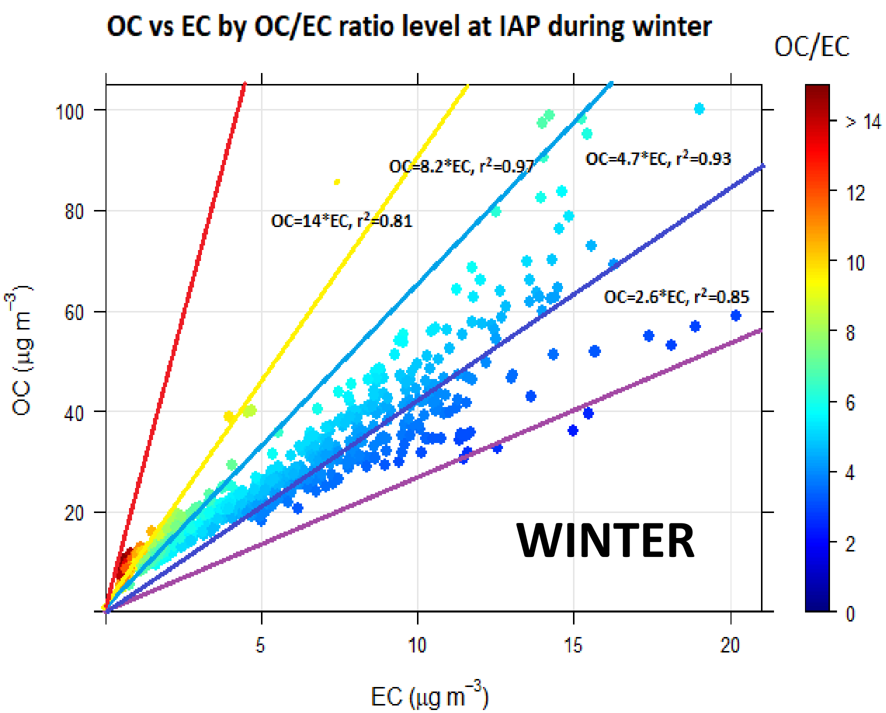
Wood smoke

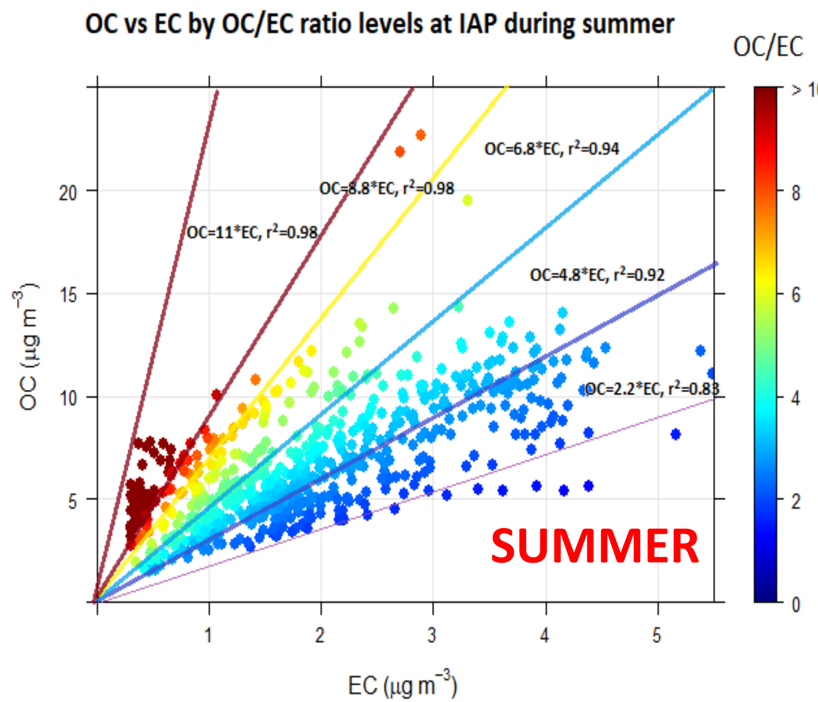
Comparison concentration of levoglucosan between IAP & PG



- **Higher contribution of biomass burning from the rural site and during the winter**
- **Biomass burning is from both local and regional sources**

Relationship between OC&EC at IAP

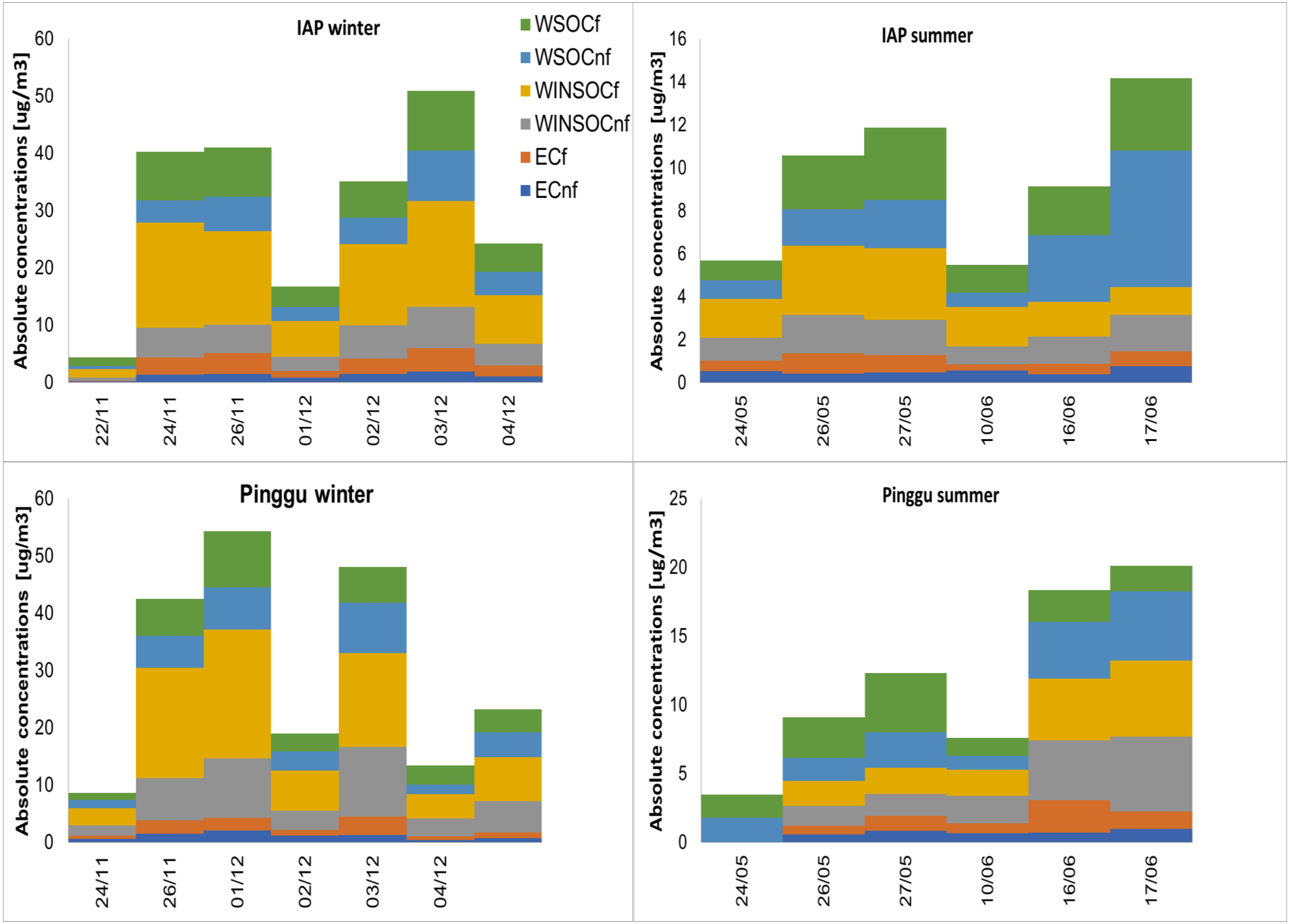




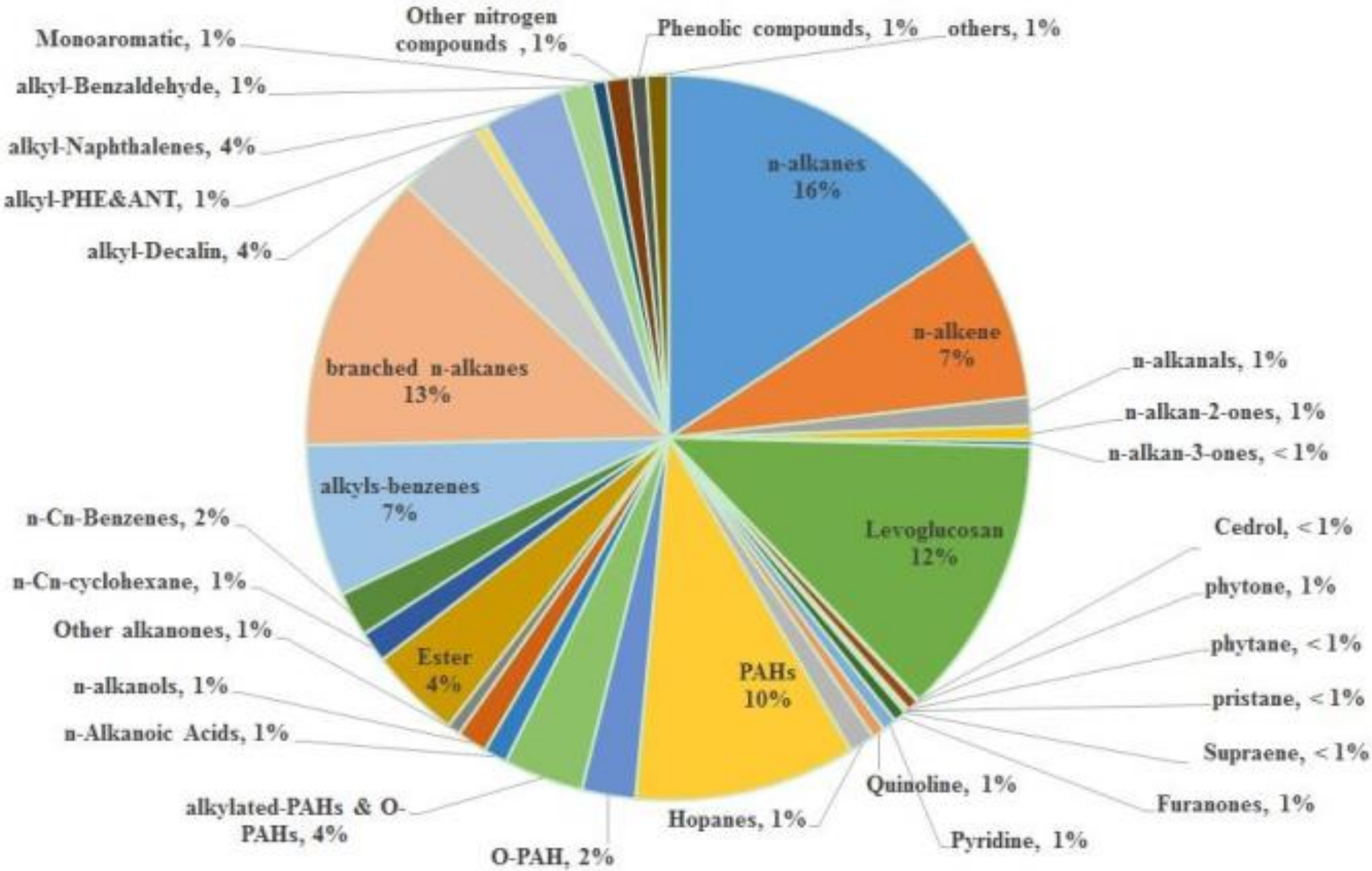
- OC-EC was more scattered in summer

Online OC & EC was provided by IAP team

C14 analysis

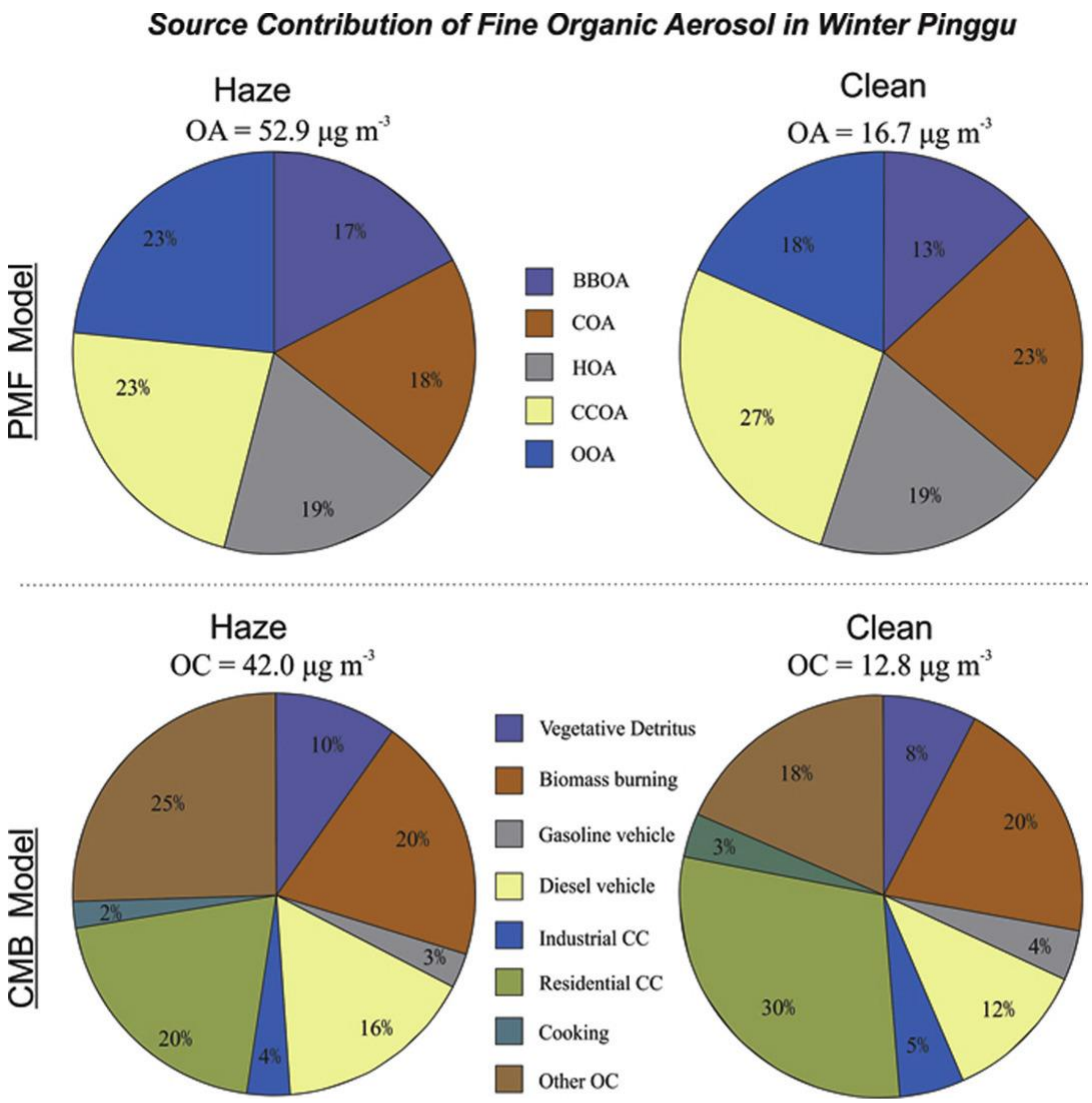


Composition of Organic Compounds (≥ C6) in PM2.5 at IAP in Wintertime



Lyu et al., ACP, 2019

Source apportionment of OC during winter in Rural site using a CMB & PMF model



Wu et al., Environ. Poll. 2020

Conclusion I

- The weather impact should be considered in assess the trend of air pollutants.

- The “Action Plan” has been **highly effective** in improving real (normalized) air quality of Beijing.
  (34 %, 24 %, 17 %, 68 %, and 33 %, for PM2.5, PM10, NO2, SO2, and CO)

- **Major challenges** remain in reducing the $PM_{2.5}$, NO_2, O_3 levels.

Conclusion II

Air Quality during two APHH campaigns

- Extremely **high levels of $PM_{2.5}$** in winter 2016 campaign
- Lower polluted air in summer campaign but still exceed standard for PM and especially ozone
- Air pollution in Beijing is an urban/regional scale phenomenon

Chemical Composition

- **High concentration of Cl^-** in **winter**
- **SIA** was main components of $PM_{2.5}$ in **summer** while **OM** is most dominant of $PM_{2.5}$ in **winter**
- **Coal combustion & biomass burning** are dominant sources of OC.

Future work

- Organic molecular markers: POA and SOA; Offline-AMS
- PMF and CMB-molecular tracers & Model comparison

Acknowledgements

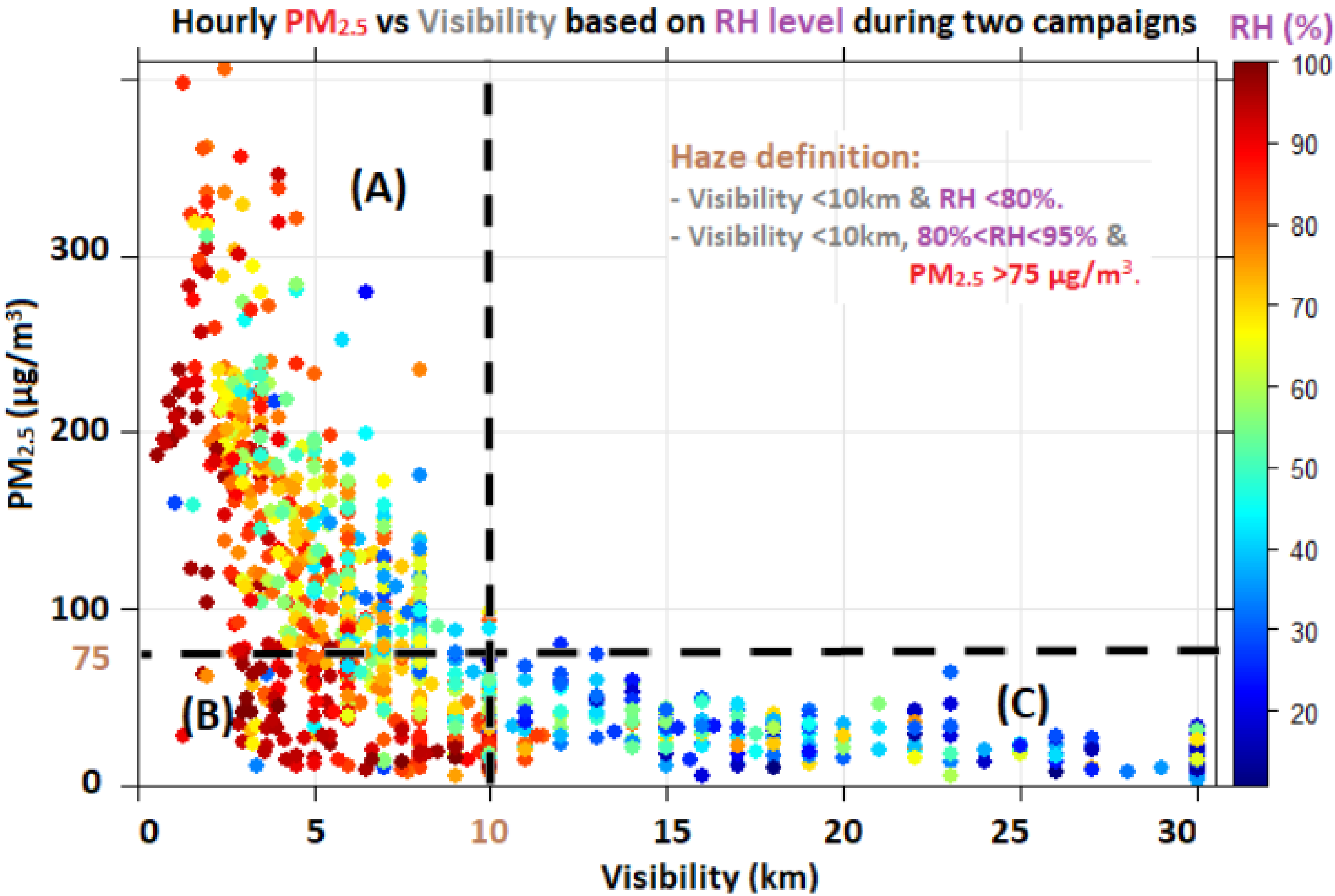
Dr X. Wu, R. Lyu (University of Birmingham)

Prof P. Fu (IAP)

Prof. J. Cheng, Q. Zhang, K. He, S. Wang (Tianjin University)

Other APHH members during two APHH campaigns

Thank you
for your attention!



Hourly PM2.5 vs Visibility based on RH level during two campaigns
RH (%)
100
90
80
70
60
50
40
30
20
Haze definition:
- Visibility <10km & RH <80%.
- Visibility <10km, 80%<RH<95% &
PM2.5 >75 μg/m3.
(A)
(B)
(C)
PM2.5 (μg/m3)
300
200
100
75
0
0
5
10
15
20
25
30
Visibility (km)