

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

Tuan Vu, Zongbo Shi, Di Liu & Roy Harrison
The University of Birmingham



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- **Trends of Air Pollutants in Beijing**
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- **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: $\text{PM}_{2.5} \leq 60 \mu\text{g}/\text{m}^3$ by the end of 2017 reduction of 32% of its $\text{PM}_{2.5}$ level in 5 years

Objectives of this study:

- The observed concentration of $\text{PM}_{2.5}$ was **58 $\mu\text{g}/\text{m}^3$** 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)

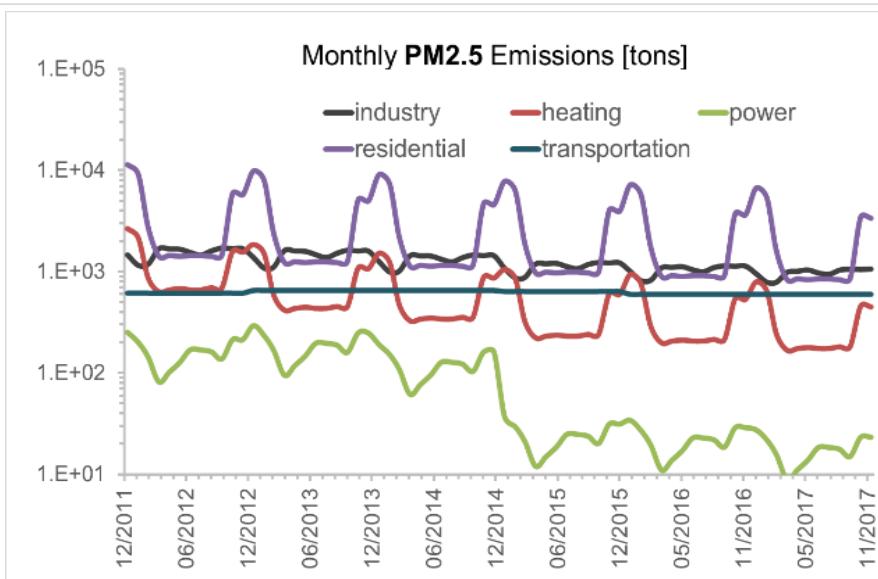
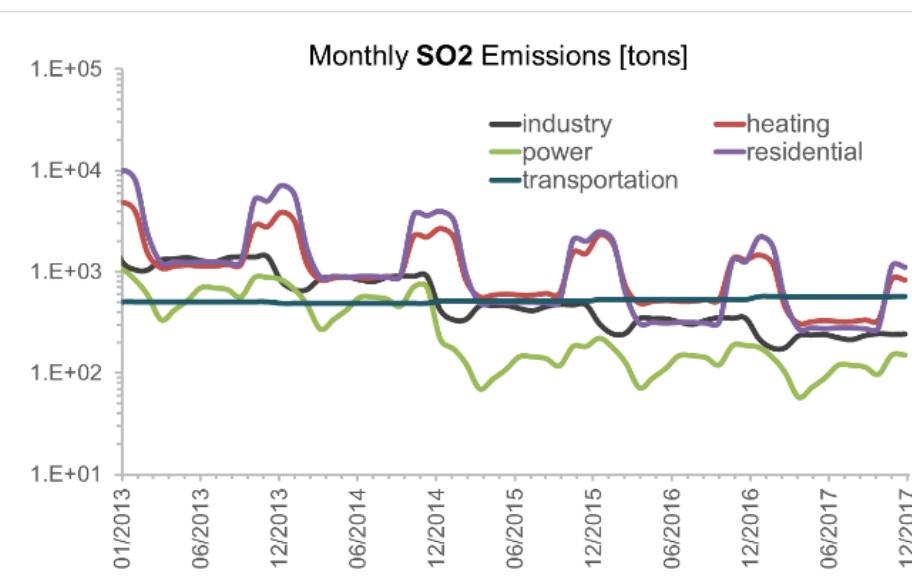
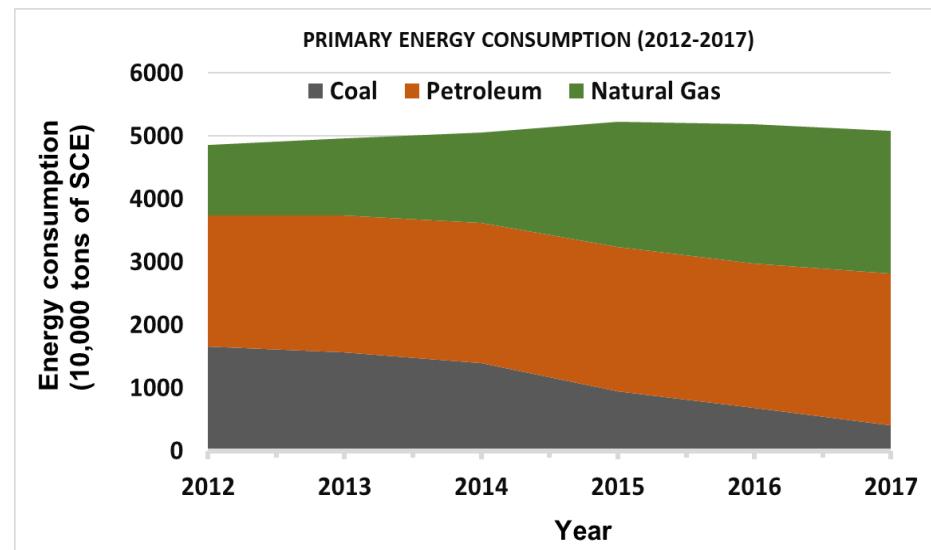
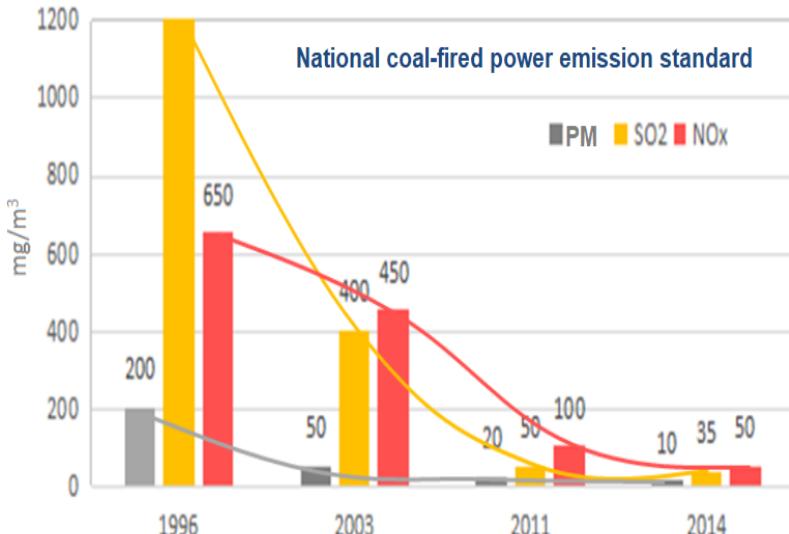
- 1. Restructuring energy** (coal vs clean energy)
- 2. Restructuring vehicles** (new vehicle & fuel standards, public transportation)
3. Controlling the **city development** (population, vehicle ownership)
4. Optimizing **industrial structure**
5. Tightening **environmental protection standards**
6.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

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

Energy consumption in Beijing

> 70% reduction in coal use



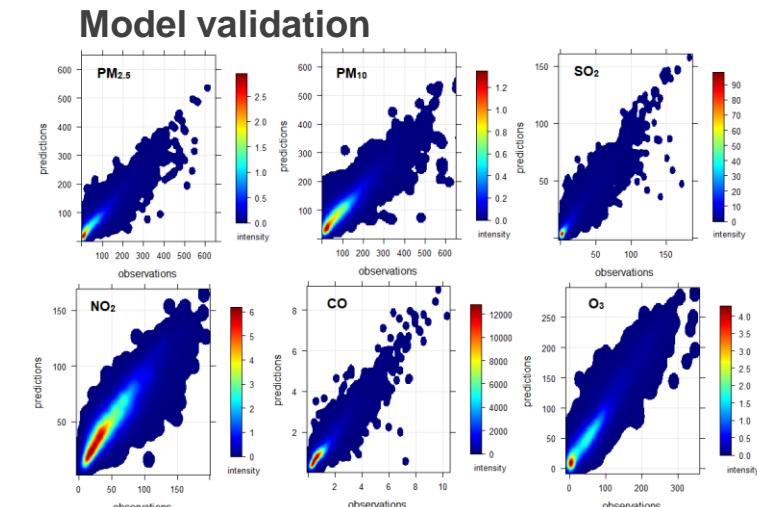
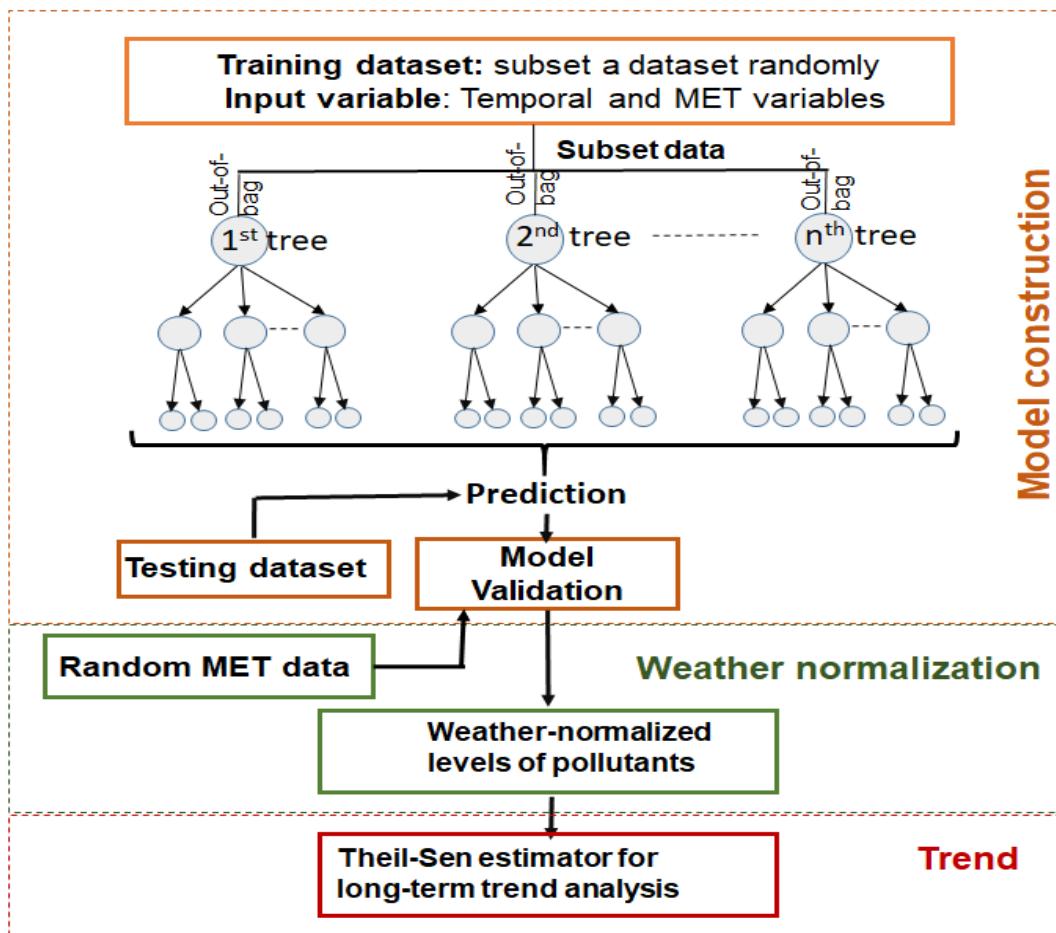
Long-term trend analysis method

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

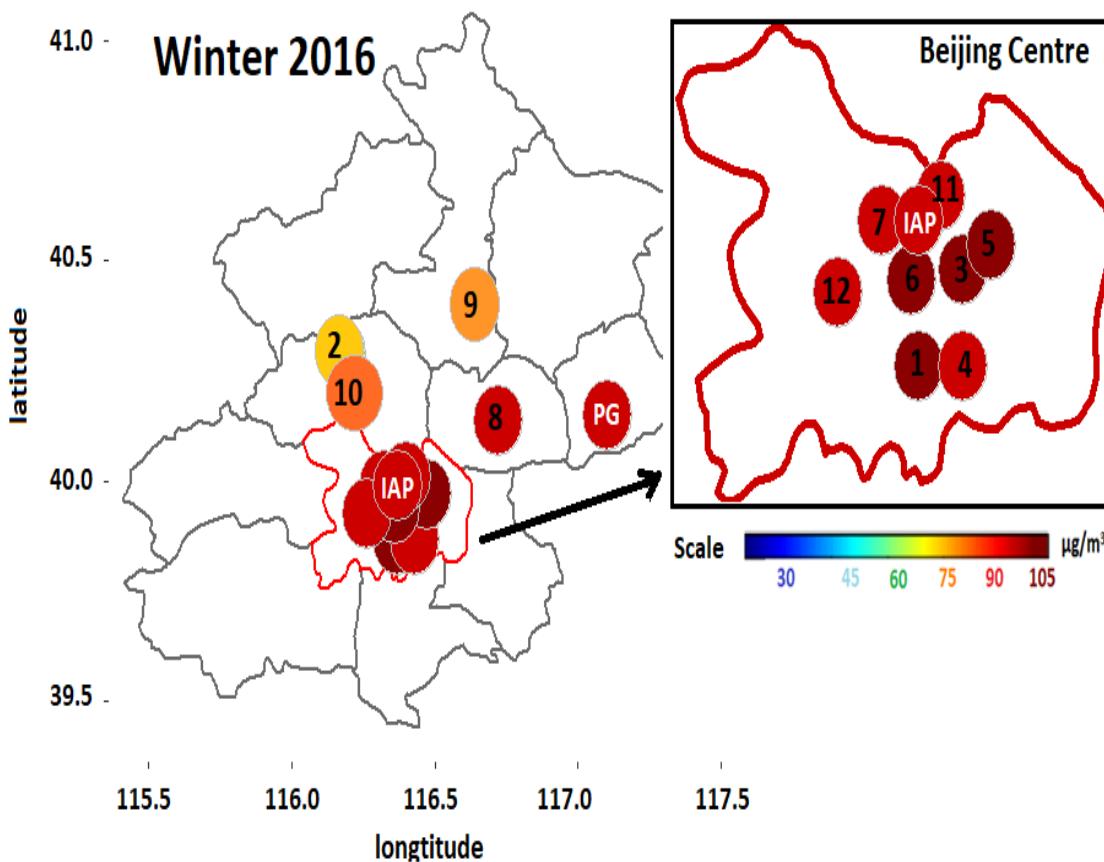


Model construction

1. List of policies
2. MEIC-emission inventory

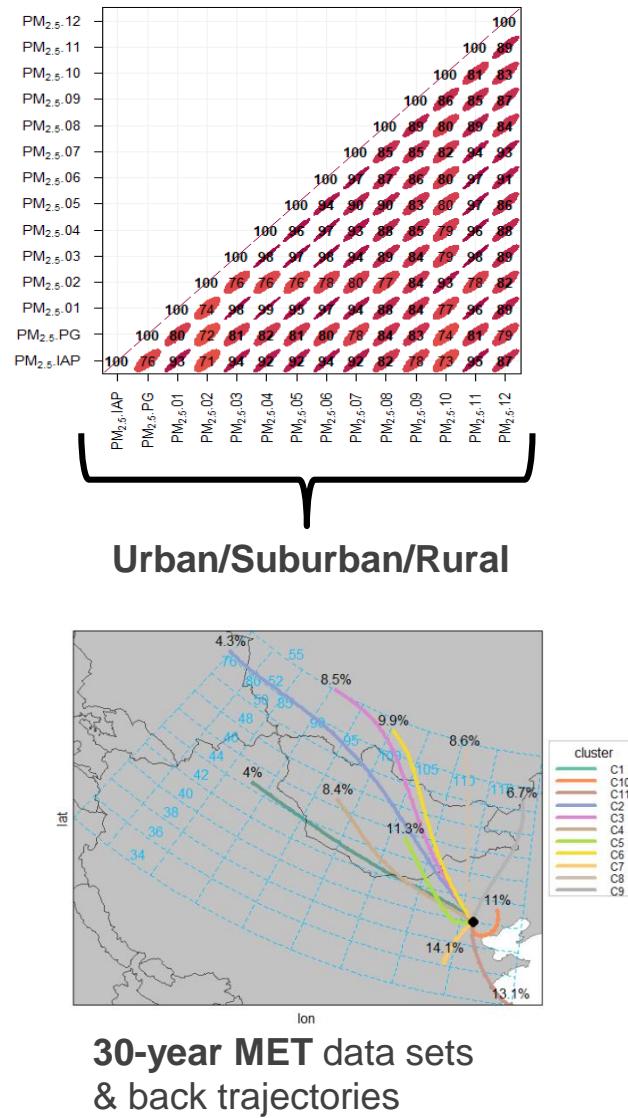
Input datasets of Air Pollutants in Beijing

Six key pollutants: **PM_{2.5}, PM₁₀, SO₂, NO₂, CO, O₃**
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

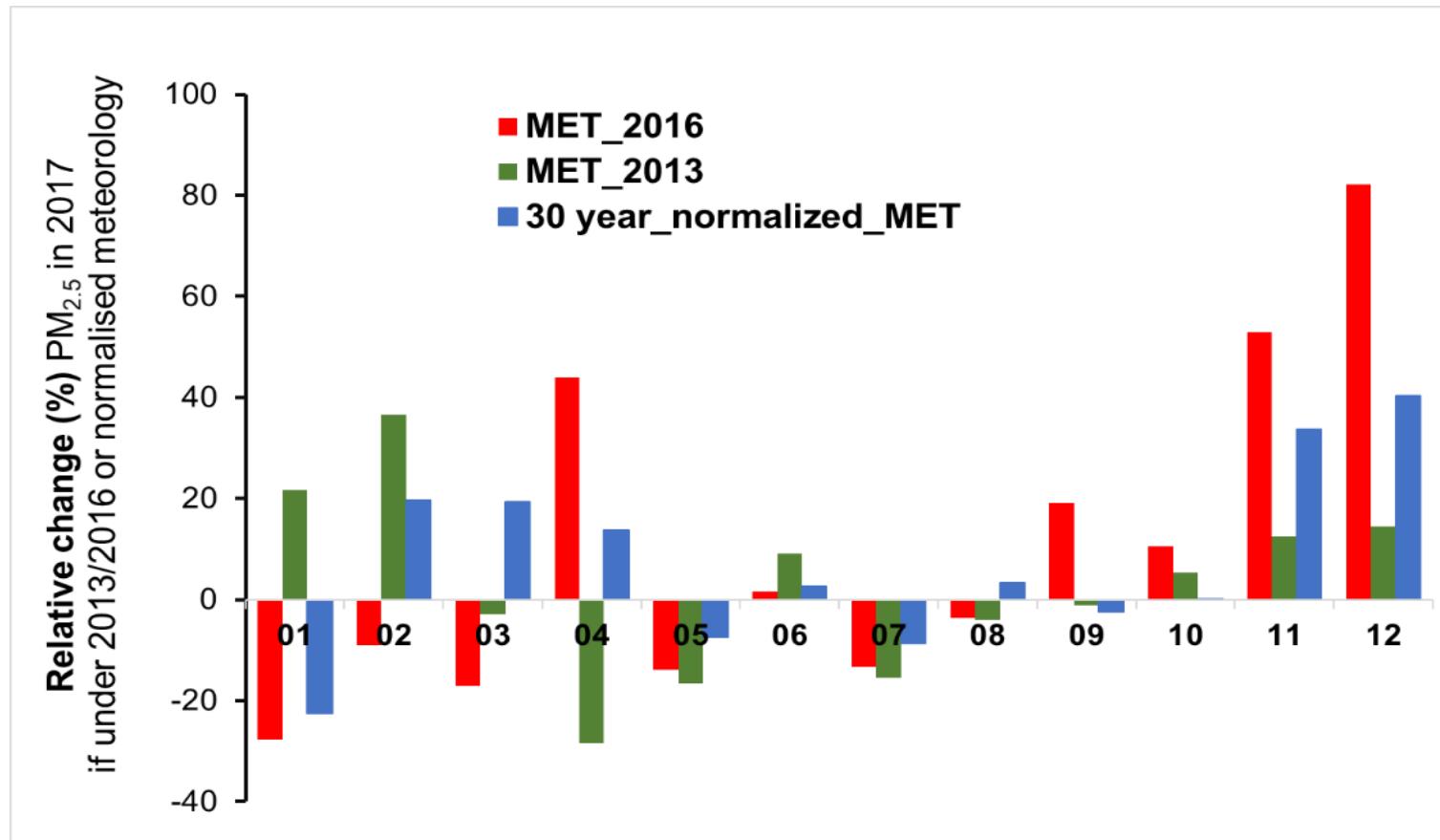
Refs: Shi et al 2019 ACP



Weather Impacts on PM_{2.5} levels:

A comparison with WRF-CMAQ Models results

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



Air Quality Before & After Weather Normalization

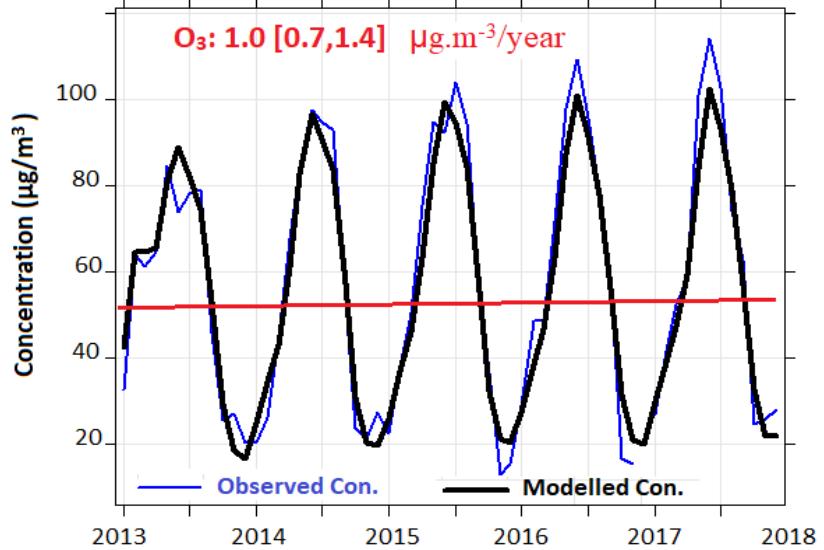
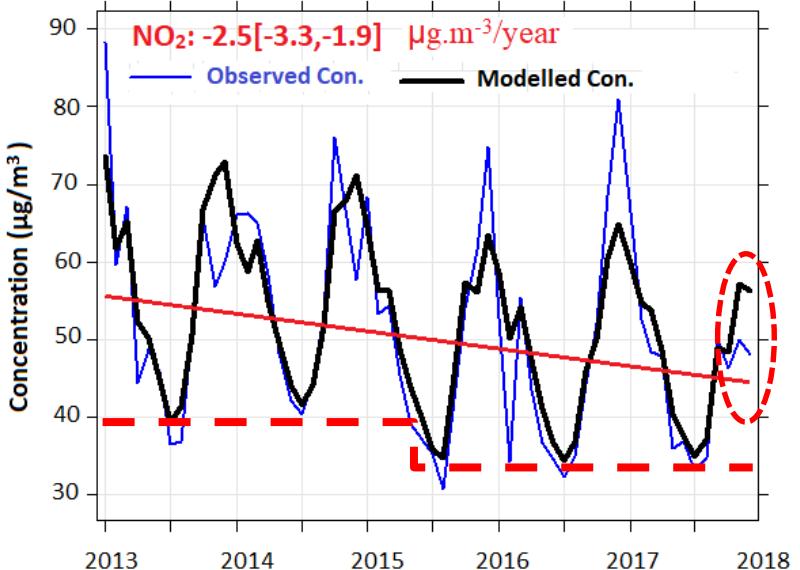
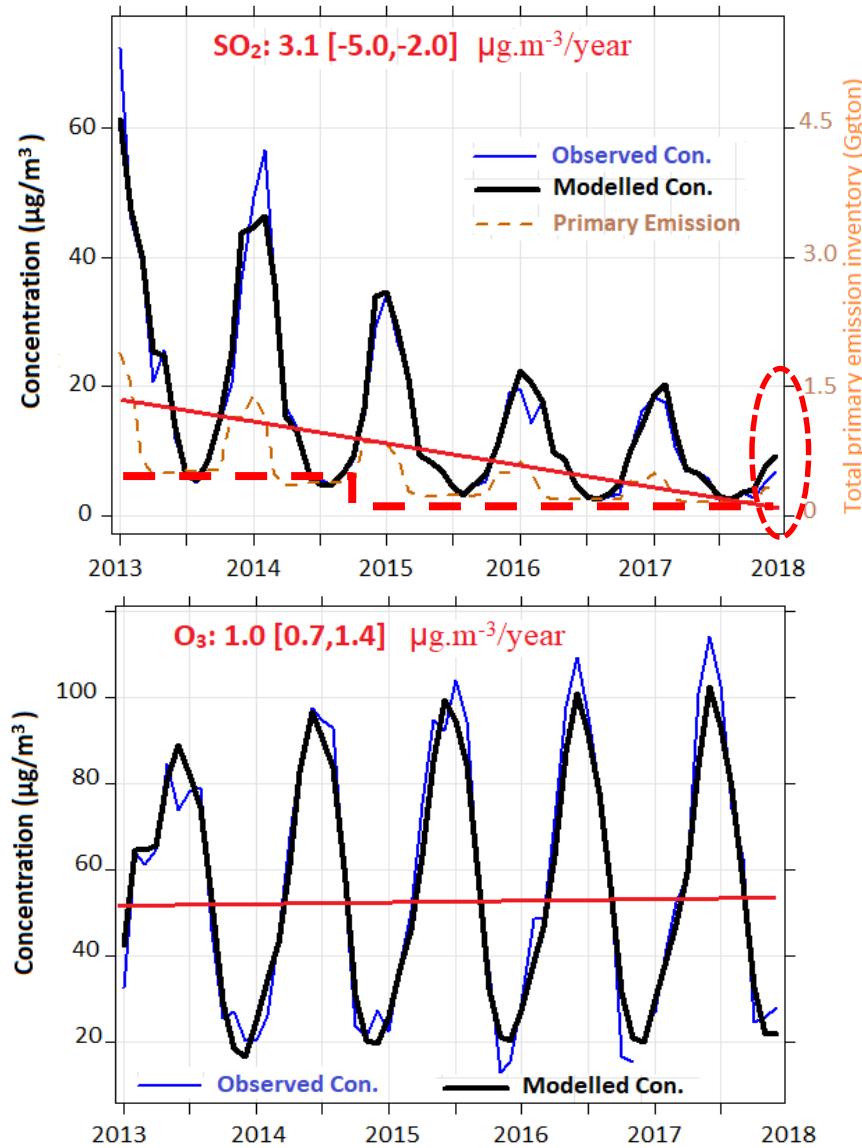
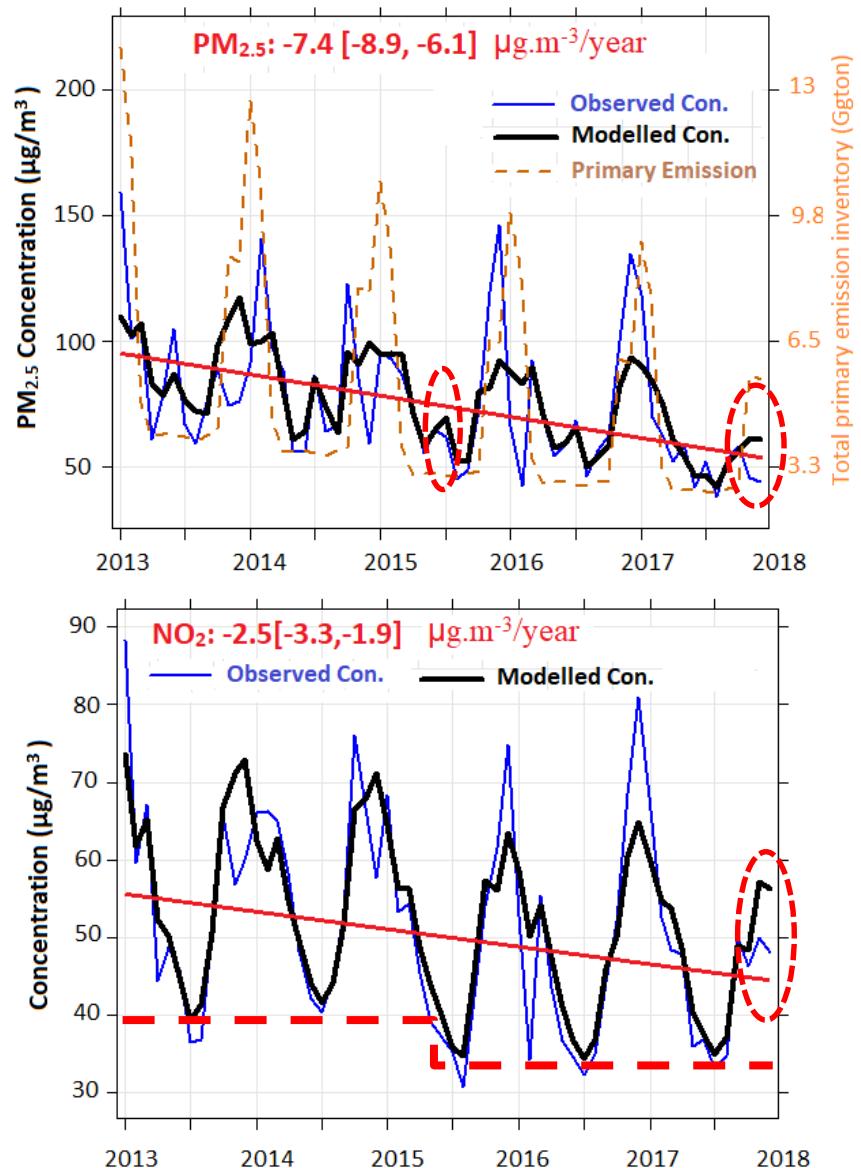
The emission reduction contributed to 10 out of the $13 \mu\text{g m}^{-3}$ (77%) $\text{PM}_{2.5}$ reduction (71 to $58 \mu\text{g m}^{-3}$) from 2016 to 2017

	$\text{PM}_{2.5}$		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

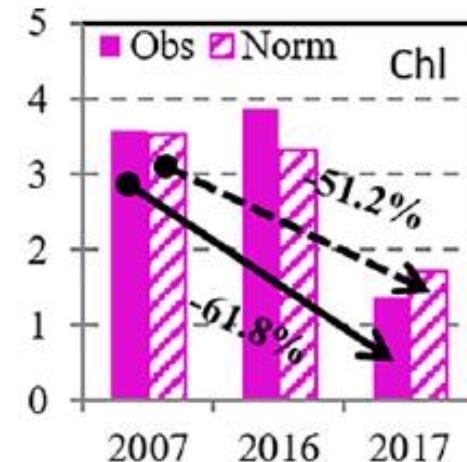
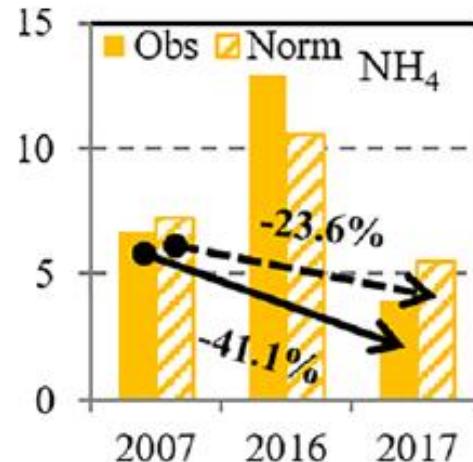
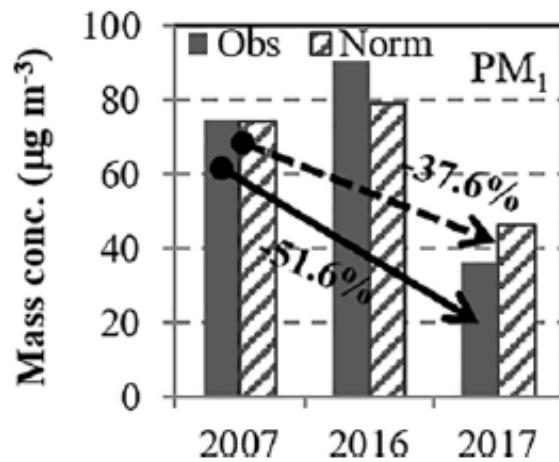
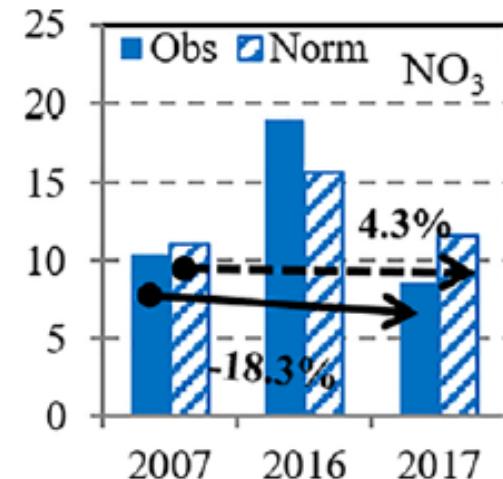
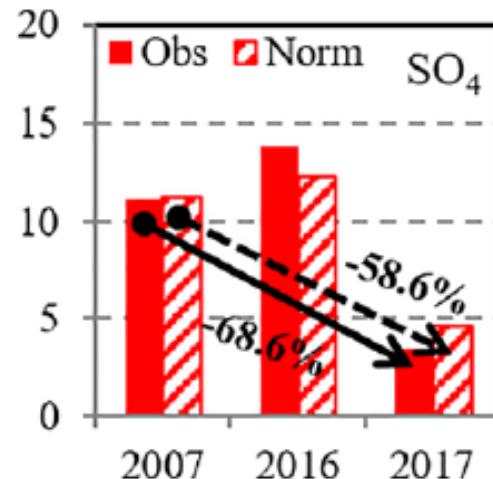
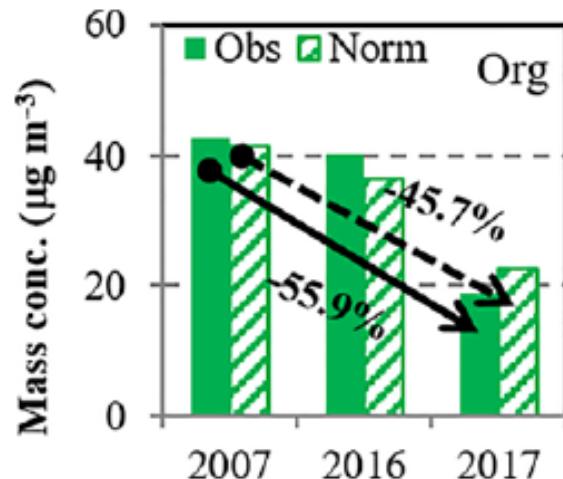
Note: Obs: observed concentration. Nor.: Concentration after weather normalization.

Unit: $\mu\text{g m}^{-3}$ for all pollutants, except CO (mg m^{-3})

Effectiveness of the Mitigations Measures in the Clean Air Action Plan



Significant changes in chemistry of fine particles in winter

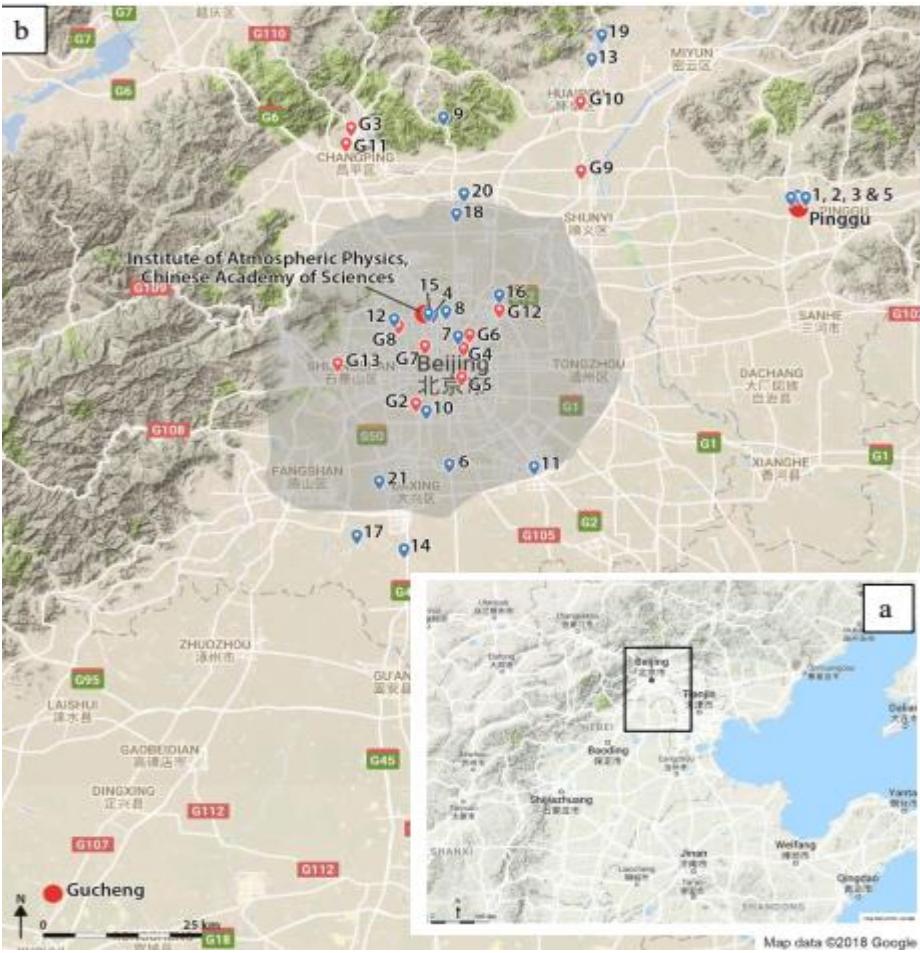


Part II: APHH-China Programme

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

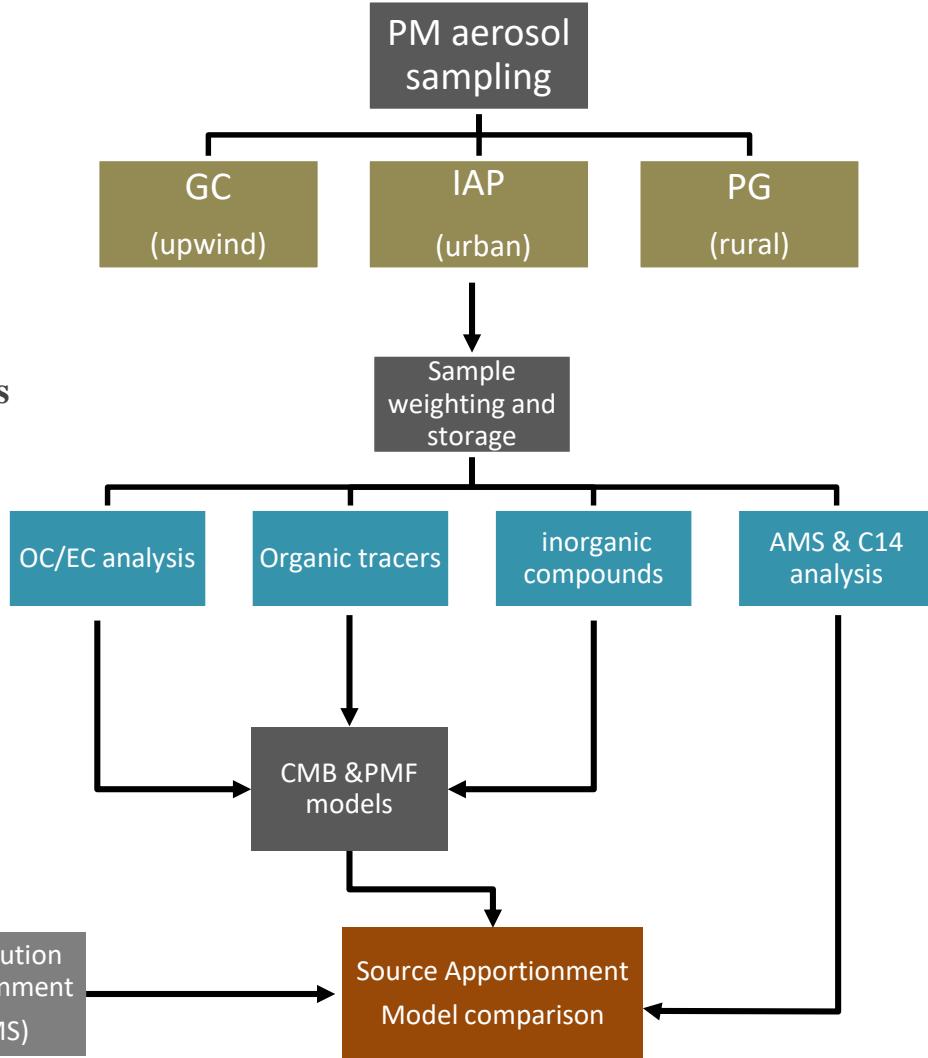
Chemical analysis



PTFE filters

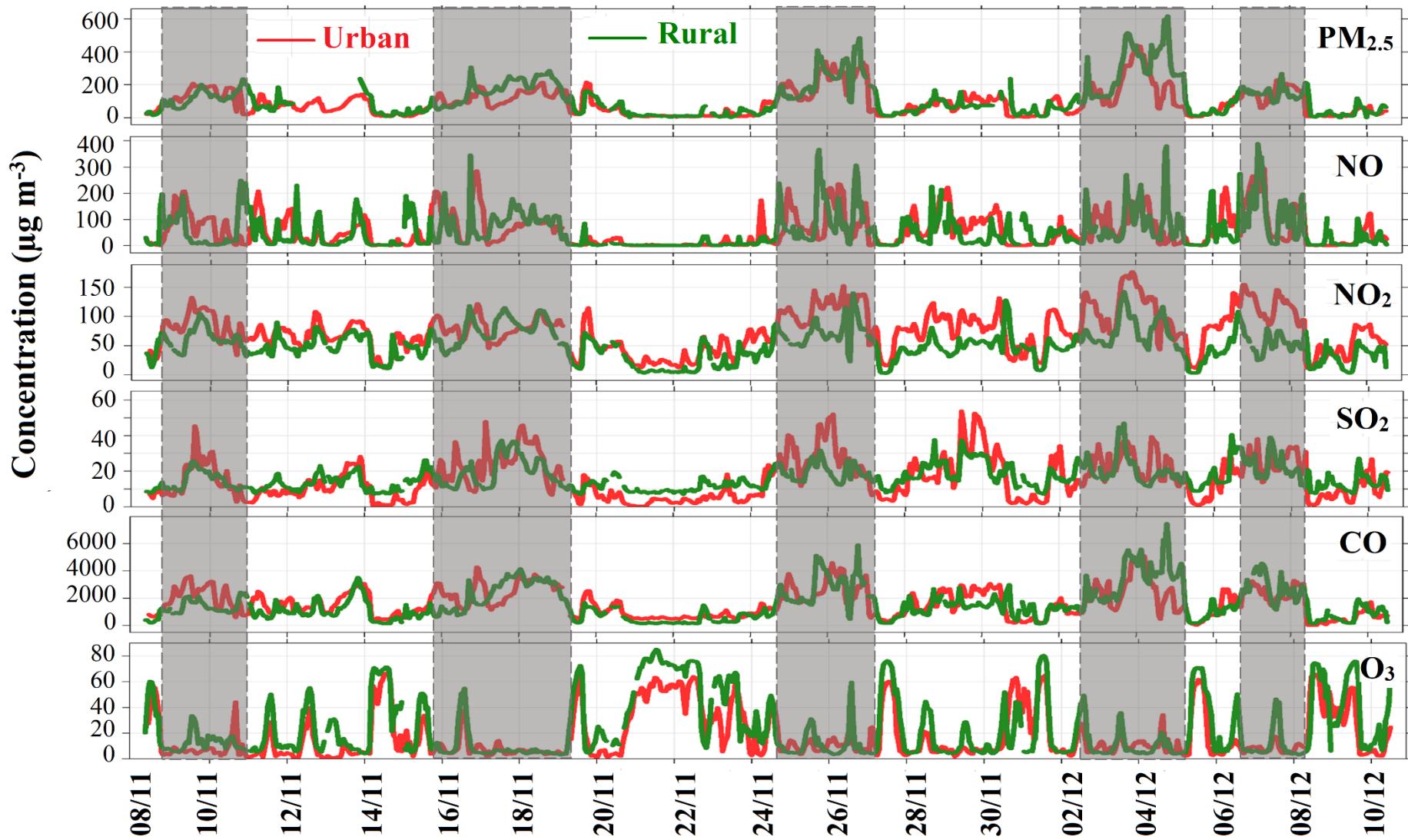


Quartz filters



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

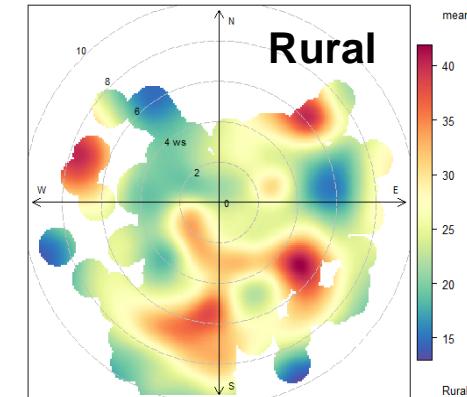
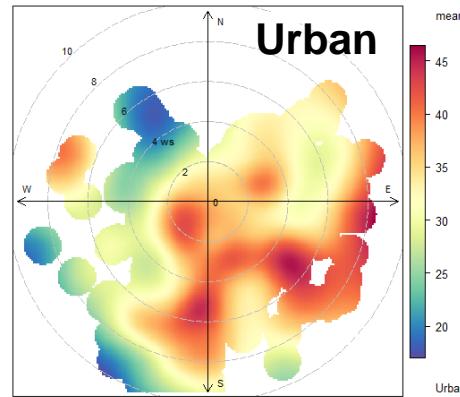
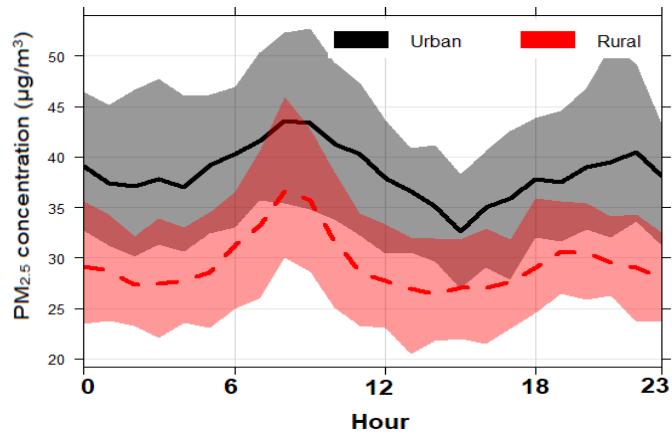


Air Quality during summer 2017 APHH campaign

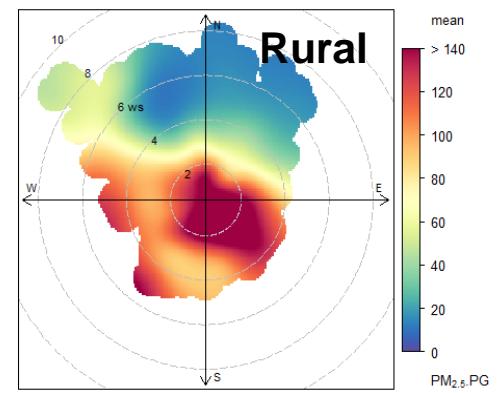
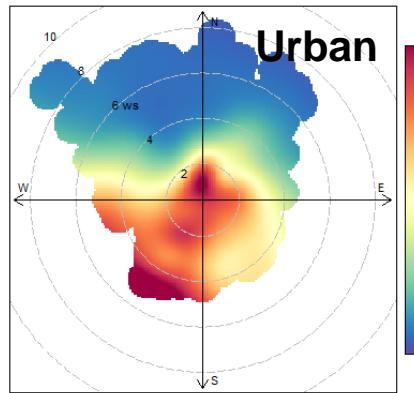
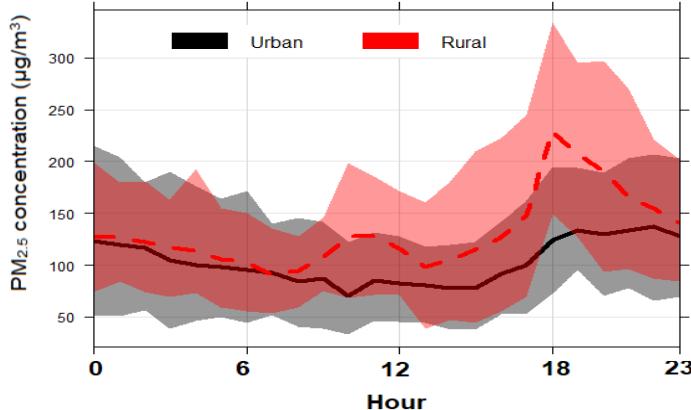


PM_{2.5} diurnal patterns & Polar Plot

Summer 2017



Winter 2016

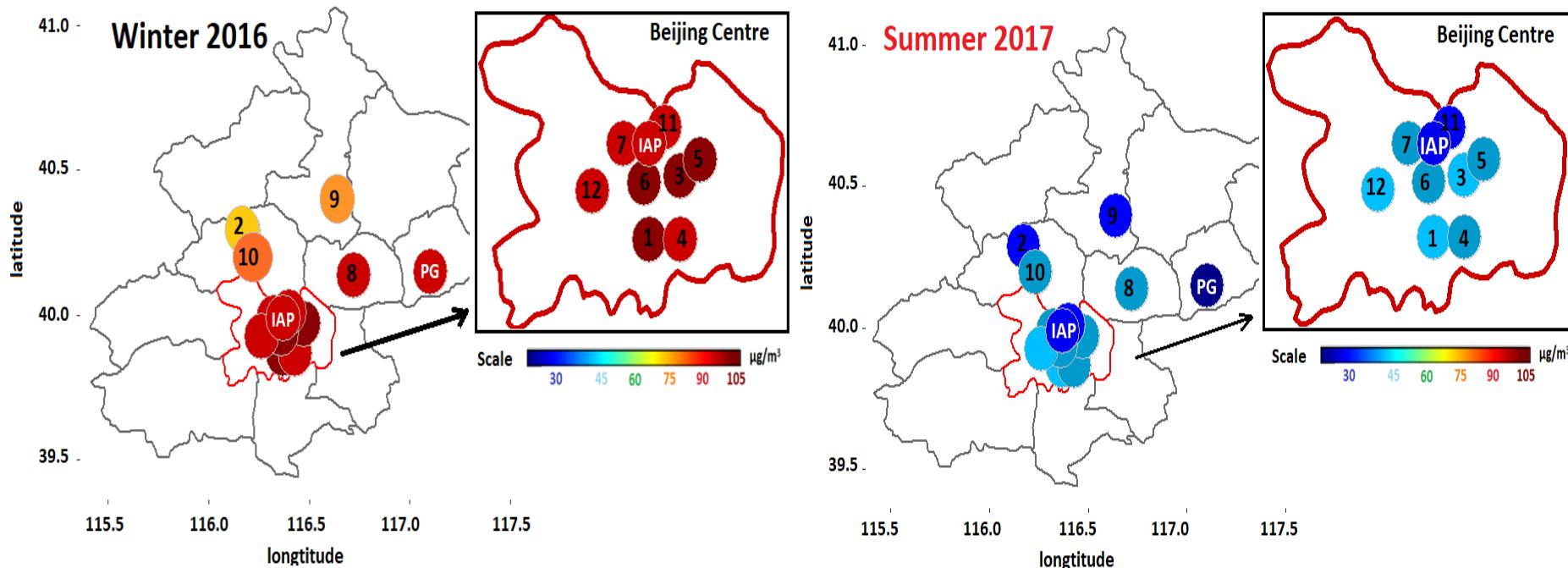


Hourly PM_{2.5} data in Pinggu was provided by PKU

Spatial distribution of PM_{2.5}

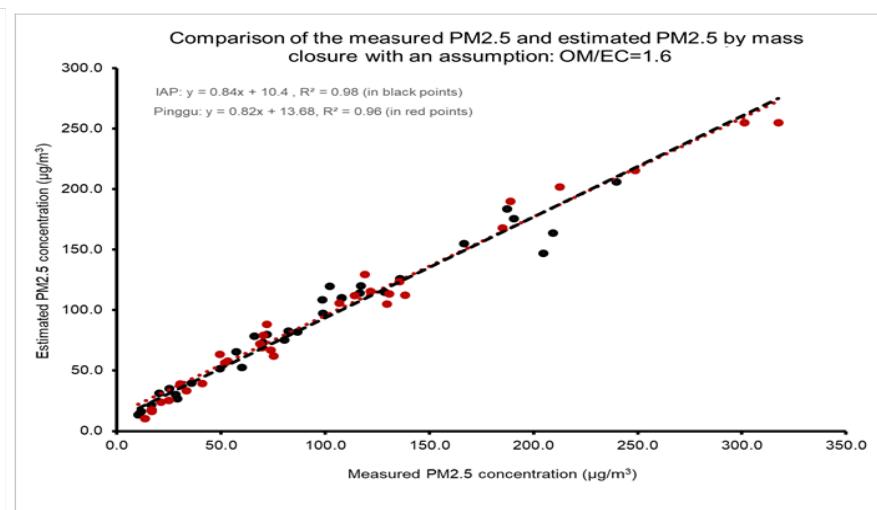
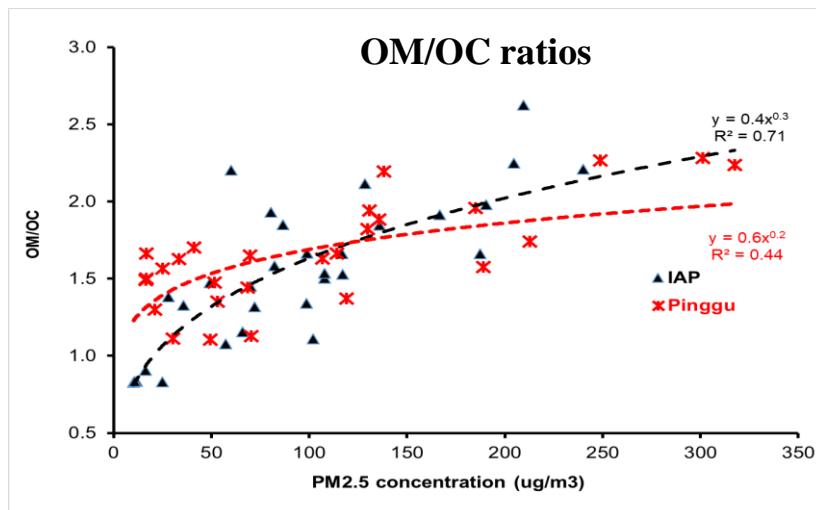
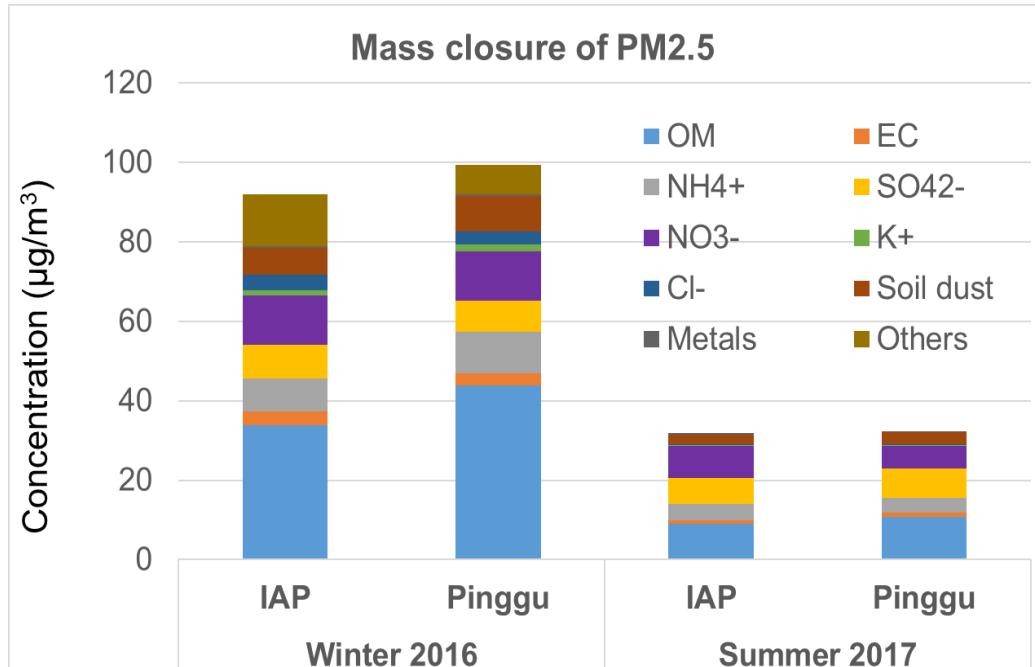
- PM_{2.5} pollution is an urban scale phenomenon.
- The air quality data at the campaign sites are reasonably representative of the Beijing urban area.

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: Shunyixicheng; 09: Huairouzhen; 10:Changpingzhen; 11: Aotizhongxin; 12: Gucheng.

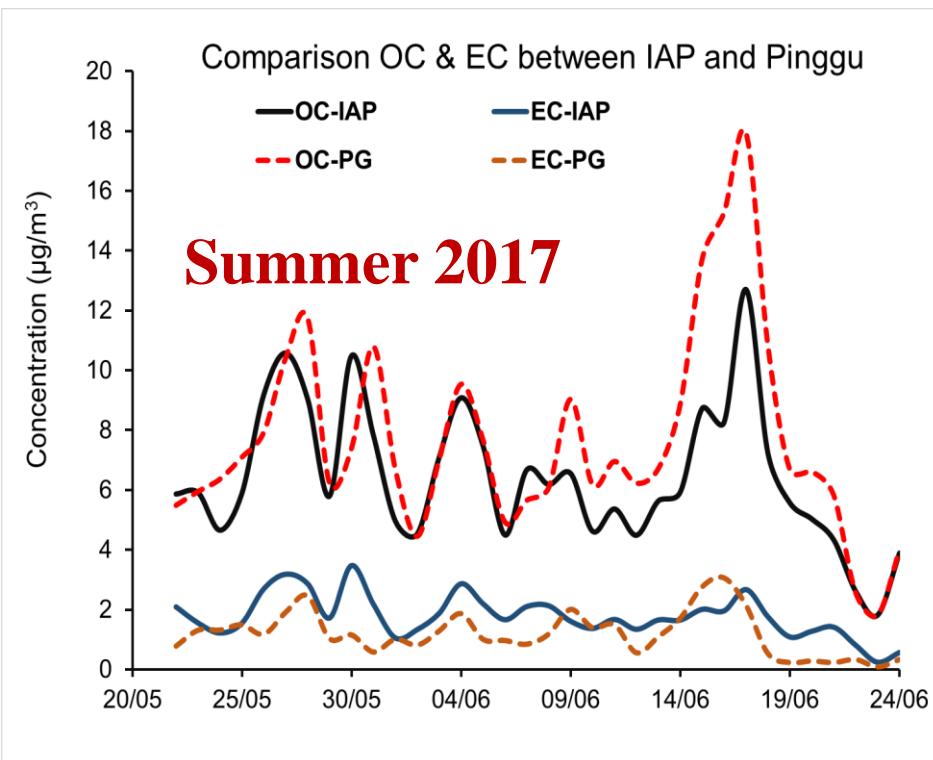
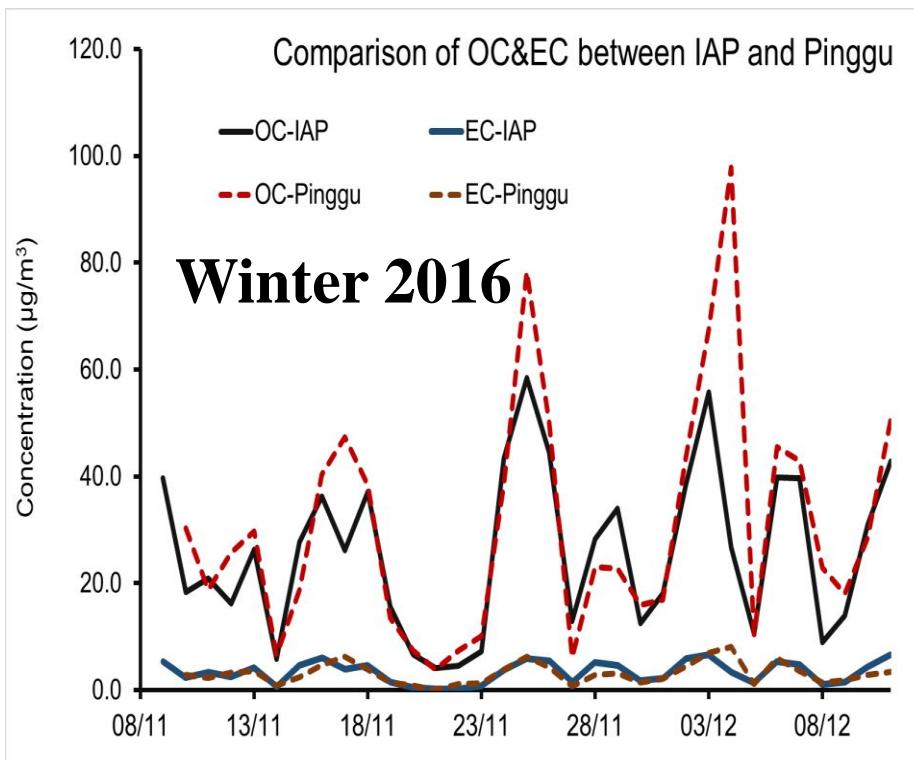
Mass Closure Model



Offline-OC & EC winter & summer

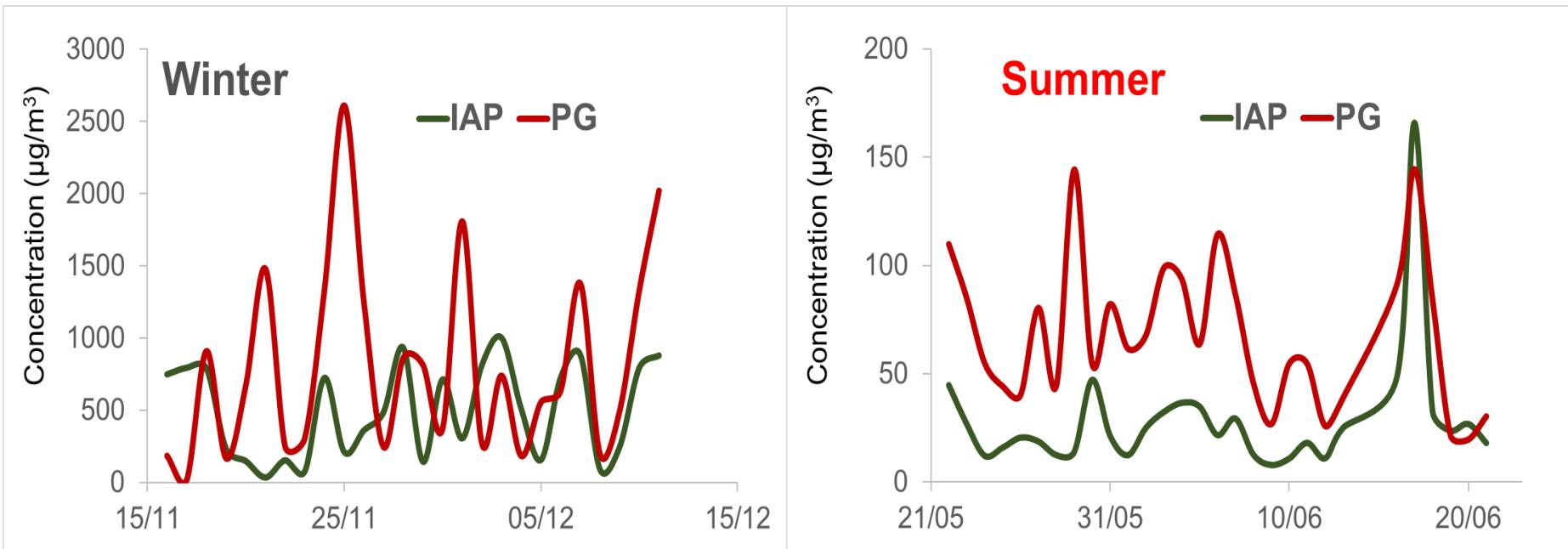
	OC ($\mu\text{g}/\text{m}^3$)	EC ($\mu\text{g}/\text{m}^3$)	OC/EC
IAP	25.8 (6.4)	3.4 (1.8)	8.0 (3.8)
PG	30.6 (7.6)	3.1 (1.2)	11.6 (8.9)

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



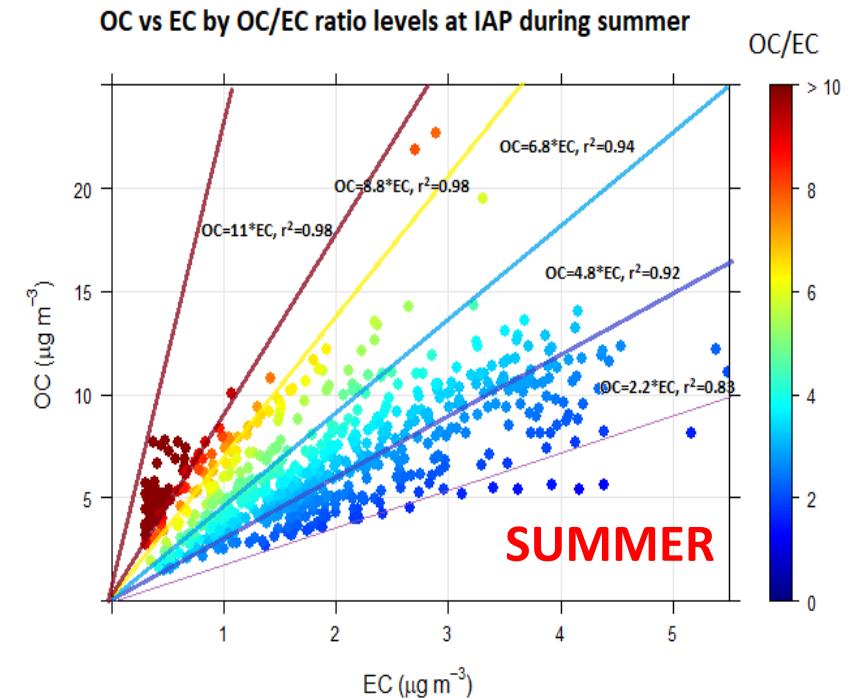
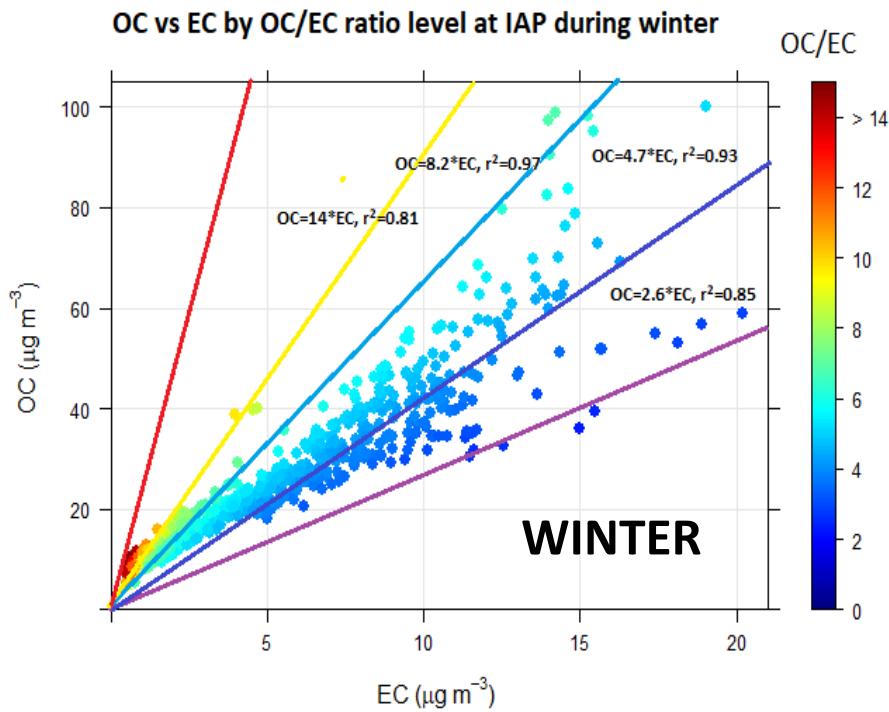
Wood smoke

Comparison concentration of levoglucosan between IAP & PG



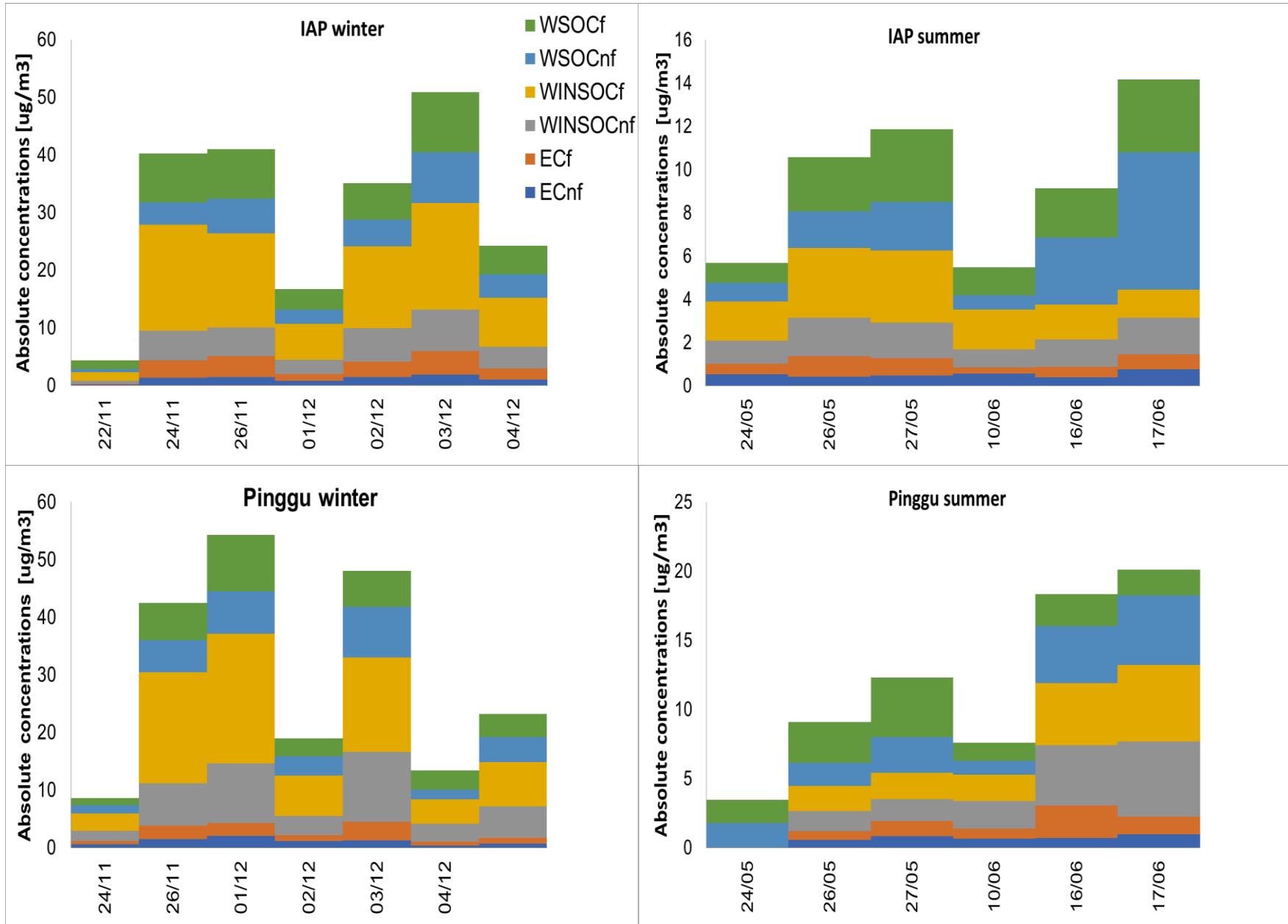
- Higher contribution of biomass burning from the rural site and during the winter
- Biomass burning is from both local and regional sources

Relationship between OC&EC at IAP

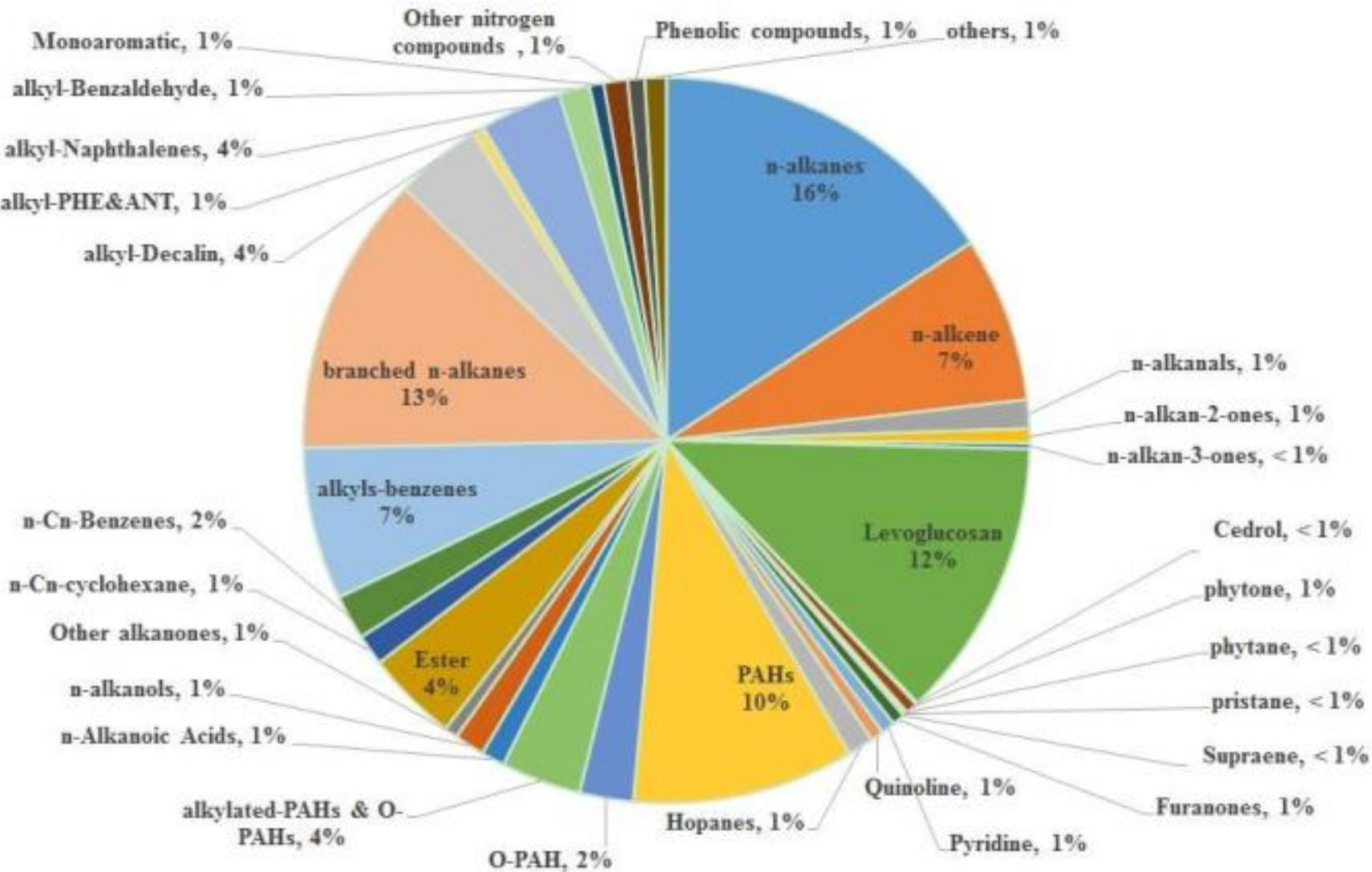


- OC-EC was more scattered in summer

C14 analysis

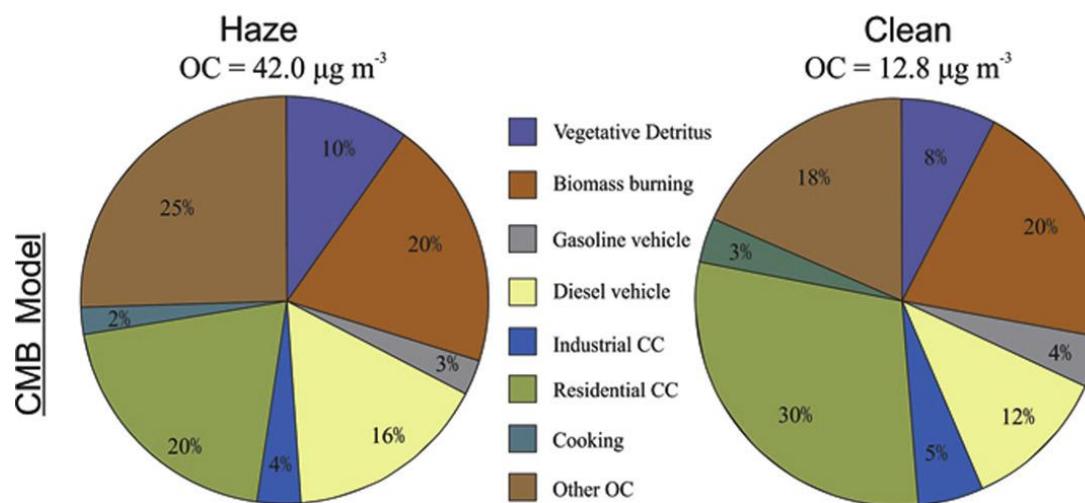
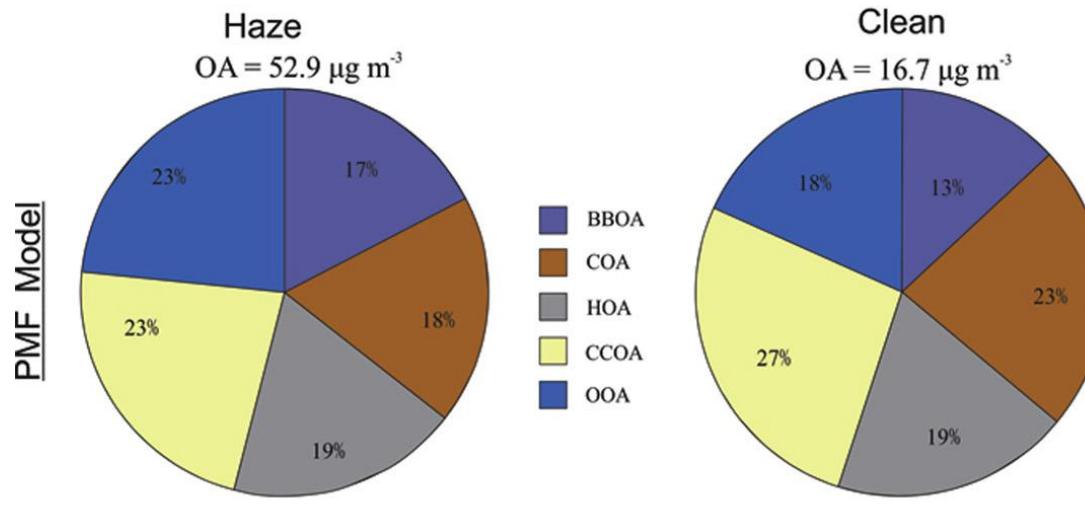


Composition of Organic Compounds (\geq C6) in PM2.5 at IAP in Wintertime



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

Source Contribution of Fine Organic Aerosol in Winter Pinggu



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}, NO₂, O₃ 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

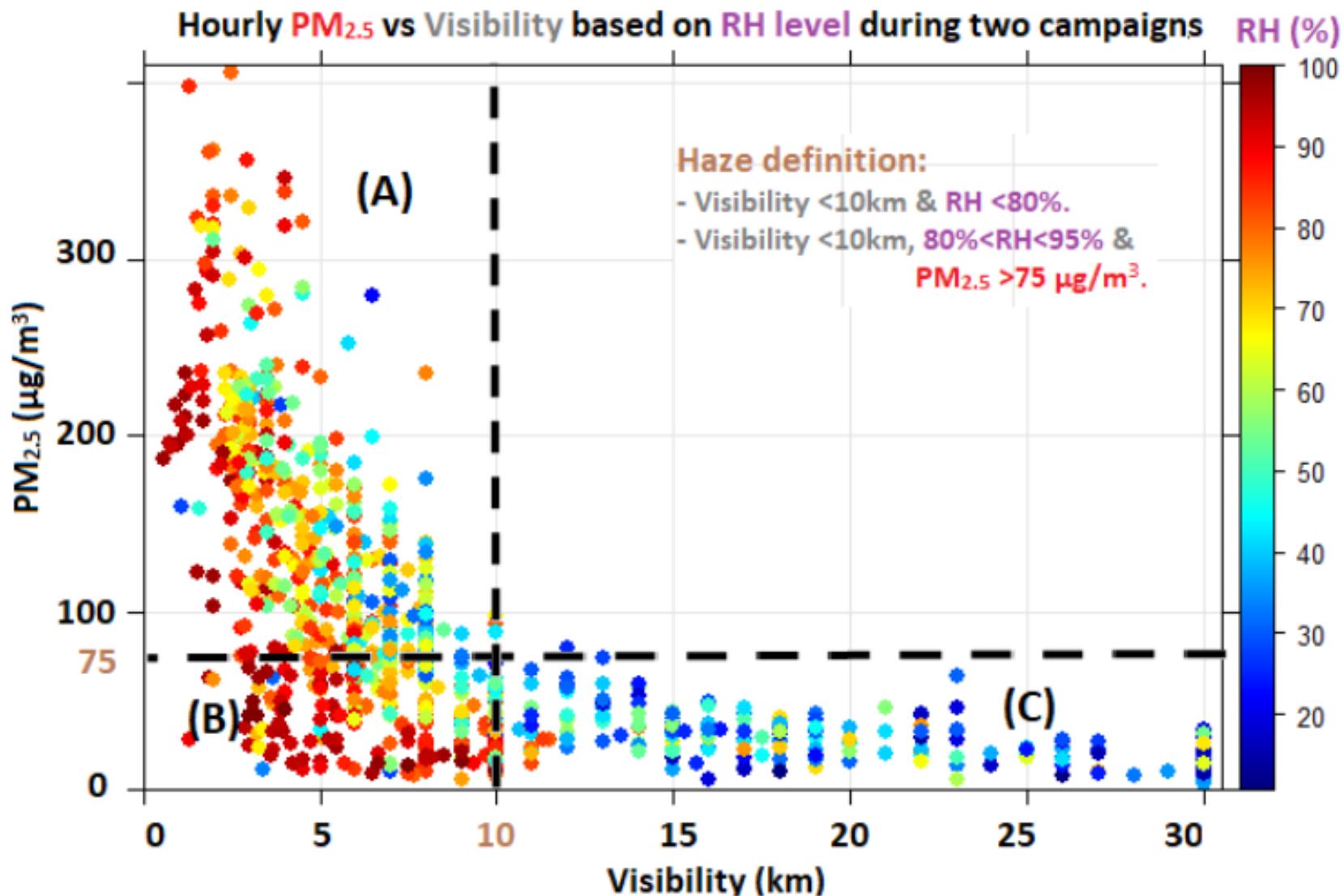
Dr X. Wu, R. Lyu (University of Birmingham)

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!



Mass Closure Model

% Contribution to PM_{2.5} mass at IAP/Pinggu:

- Secondary Inorganic Aerosols: 31.9 % / 30.1%
- K⁺ and Cl⁻ : 5.6 % / 4.9%
- Soil dust: 9.2 % / 6.5%
- OM: 45.2 % / 49.2% & EC: 3.7% / 3.1 %

