UNIVERSITY OF BIRMINGHAM

Atmospheric Pollution and Human Health in a Chinese Megacity (APHH-China): an overview

Zongbo Shi

On behalf of APHH-China team

5 research projects
30 Institutions
150 scientists
£11 m funding

NSFC
National Natural Science Foundation of China

NERC
SCIENCE OF THE ENVIRONMENT

MRC Medical Research Council

Newton Fund

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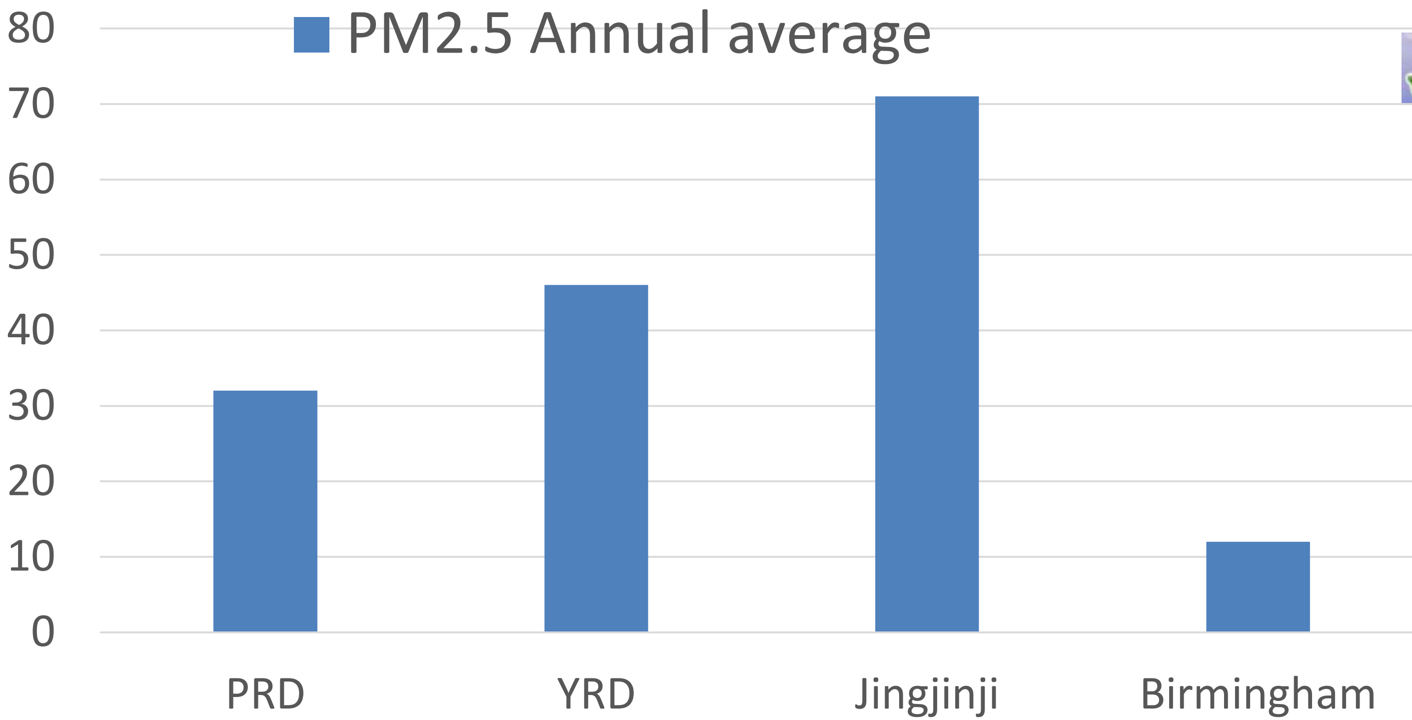
Outline

- Introduction to APHH-China programme
- Aim of APHH-China programme
- APHH-China intensive field observations
- APHH-China highlights
- Summary

Reuters

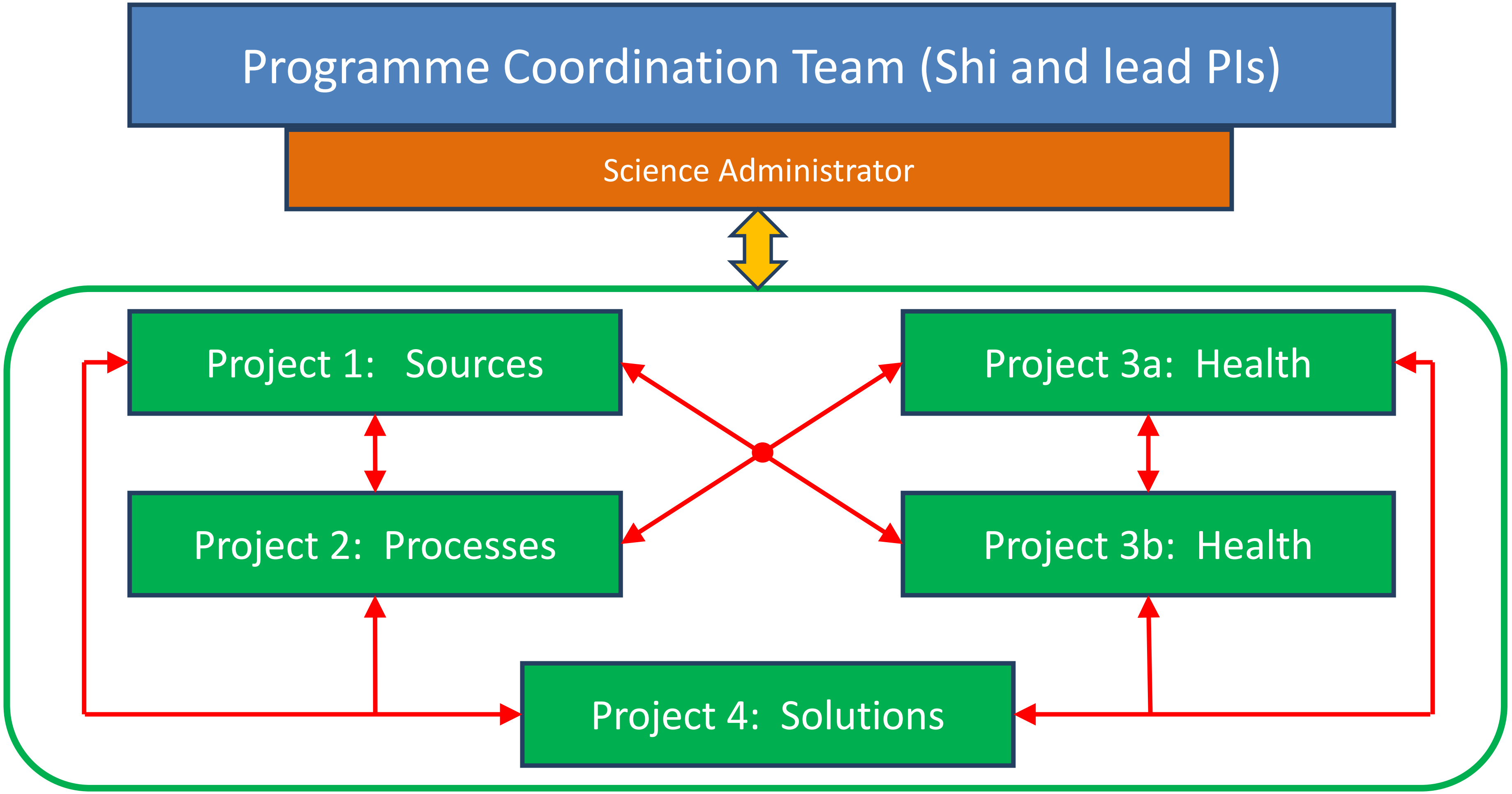
Air pollution in China



- Premature death: 1 - 1.35 m per year
- Jingjinji economic loss: 4.68% GDP - (~ £180b)
- 2% of China’s GDP by 2030 if no action taken

Aim of APHH-China Programme

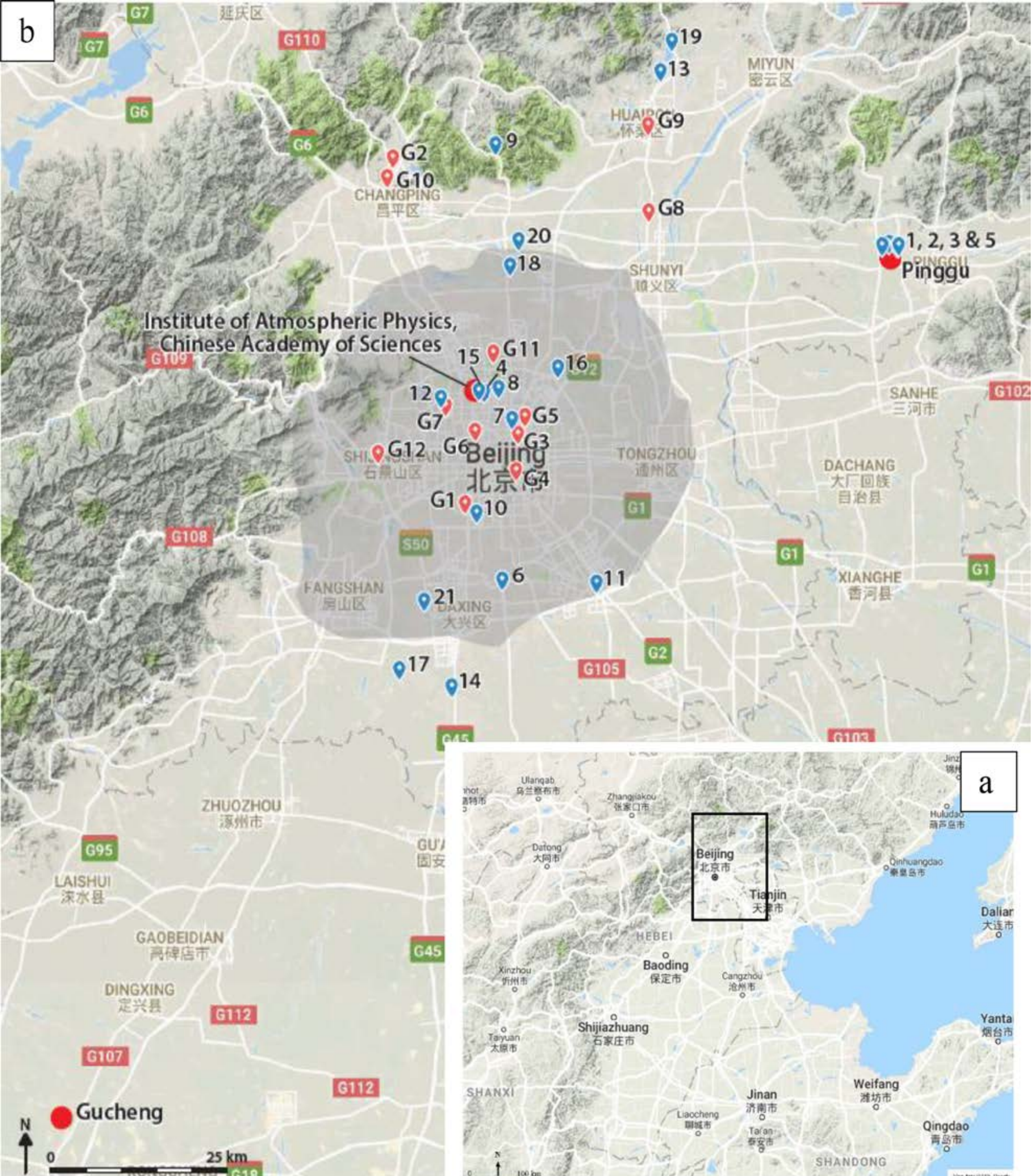
The overall aim of the UK-China APHH programme is to better understand the sources, atmospheric transformations and health impacts of air pollutants in the Beijing megacity and to improve the capability of forecasting air quality and developing cost-effective mitigation measures.



1	Roy Harrison, Kebin He
2	Ally Lewis, Pingqing Fu
3a	Frank Kelly, Tong Zhu
3b	Miranda Loh, Zhiwei Sun
4	Dabo Guan, Shu Tao

Integration activities

- Coordinated joint field campaigns
- Multi-scale modelling of airborne concentrations of pollutants
- APHH-Beijing programme science and stakeholder engagement meetings
- Data depository and sharing



Observation sites

Winter:
10/11 – 10/12 2016

Summer:
15/05 -22/06 2017

- **Over 150 online and offline instrument**
- **20 tons of instruments shipped from the UK**

Table 1. Overview of measurements in APHH-Beijing at the urban site.

Instrument	Measurements	Institute	References
Container 1			
FAGE	OH (chem and wave)[c], HO_2, RO_2	Leeds	Whalley et al. (2010)
OH reactivity	OH reactivity	Leeds	Stone et al. (2016)
Spectral radiometer	Photolysis rates	Leeds	Bohn et al. (2016)
Filter radiometer	$J(O^1D)$	Leeds	Bohn et al. (2016)
Dew point hygrometer	Water vapour	Leeds	Whalley et al. (2010)
Davis met station	Wind speed, direction, temp, RH, pressure	Leeds	
Vaisala CL31 ALC ceilometer[a]	Cloud-base height, mixing height, attenuated backscatter profiles	Reading	Kotthaus and Grimmond (2018a)
Personal air monitors (PAMS)	CO, NO, NO_2, PM_1, PM_{10}, $PM_{2.5}$	Cambridge	Moore et al. (2016)
MicroPEMs	Personal PM exposure	IOM	Sloan et al. (2016)
Container 2			
DC-GC-FID	C_2–C_7 VOCs and oVOCs	York	Hopkins et al. (2011)
GCxGC FID	C_6–C_{13} VOCs and oVOCs	York	Dunmore et al. (2015)
TEI 42i	NO	Birmingham	
Teledyne CAPS	NO_2	York	
TEI 42c	Total NOy	York	
TEI 49i	O_3	York	
TEI 43i	SO_2	York	
Sensor box	CO	York	Smith et al. (2017)
BBCEAS	HONO, NO_3, N_2O_5	Cambridge	Le Breton et al. (2014)
Container 3			
LOPAP	HONO	Birmingham	Crilley et al. (2016)
LIF HCHO	HCHO	Leeds	Cryer et al. (2016)
LOPAP	HONO	IC-CAS	Zhang et al. (2019)
GC-MS	Organic nitrates	East Anglia	Mills et al. (2016)
ROS online analyser	Reactive oxygen species	Cambridge	Wragg et al. (2016)
Container 4[b]			
FAGE	OH (wave)[c], HO_2	Peking	Lu et al. (2012)
FAGE	OH (chem)[c]	Peking	Tan et al. (2017)
TEI 42i	NO	Peking	Tan et al. (2017)
Teledyne CAPS	NO_2	Peking	
TEI 42c with Moly converter	NO_2	Peking	
TEI 49i	O_3	Peking	
TEI	CO	Peking	
Spectral radiometer	Photolysis rates	Peking	
GC-ECD	PAN	Peking	Zhang et al. (2011)
GC-MS	VOCs	Peking	M. Wang et al. (2015)
Container 5[b]			
H-TDMA/V-TDMA	Hygroscopicity/volatility	Peking	Wu et al. (2013)
SMPS+APS	Particle number size distribution	Peking	Wu et al. (2016)
Particle size magnifier	Size distribution of <3 nm particles	Peking	Vanhanen et al. (2011)
IGAC-IC	Water-soluble ions	Peking	Yu et al. (2018)
Xact	Metal	Peking	Yu et al. (2018)
Sunset OC/EC	EC/OC	Peking	Y. Zhang et al. (2017)
Container 6			
IBBCEAS	HONO, NO_2	AIOFM	Duan et al. (2018)
CRDS	NO_3 and N_2O_5	AIOFM	Li et al. (2018)
Nitrate Api-ToF-CIMS	Organics, clusters (HOMs)	Birmingham	Jokinen et al. (2010)
SMPS	Particle size distribution	Birmingham	Shi et al. (1999)
Particle size magnifier	Size distribution of <3 nm particles	Birmingham	Vanhanen et al. (2011)

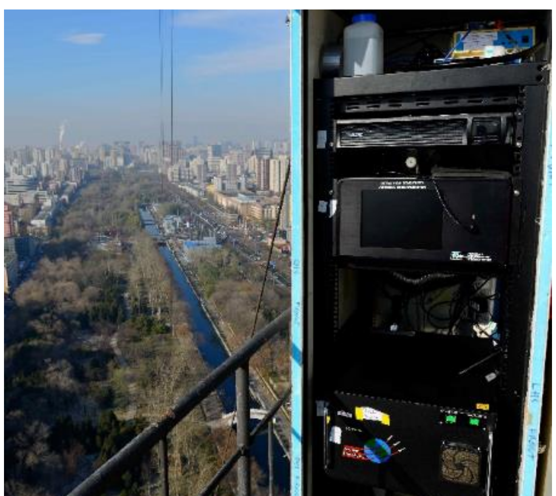
Table 1. Continued.

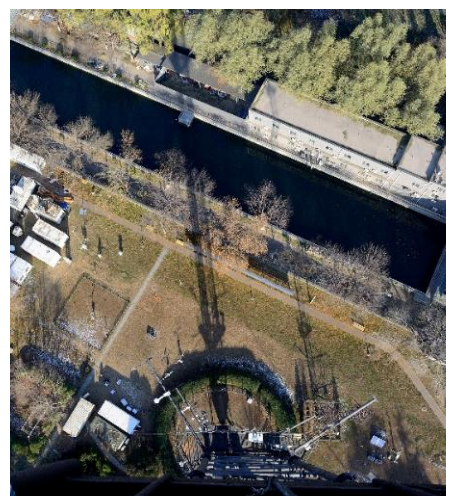
Instrument	Measurements	Institute	References
Container 7			
Fast NO_x	NO_x fluxes	York	Vaughan et al. (2016)
AL5002 CO analyser	CO fluxes	York	Gerbig et al. (1999)
HR-ToF-AMS	Fluxes of PM_1 non-refractory (NR) species	CEH	Nemitz et al. (2008)
SP2	BC fluxes	Manchester	Liu et al. (2017)
PTR-ToF-MS	VOC fluxes	GIG Lancaster	Huang et al. (2016)
SYFT-MS Voice 200 Ultra	VOC fluxes	York	Storer et al. (2014)
Container 8			
SMPS3968-APS3321	Particle number size distribution	BNU	Du et al. (2017)
H/V TDMA	Particle hygroscopicity	BNU	Y. Wang et al. (2017)
CCNC-100	CCN	BNU	Y. Wang et al. (2017)
PAX (870 nm)	Extinction and absorption coefficients	IAP	Xie et al. (2019)
Ammonia analyser	NH_3	IAP	Meng et al. (2018)
Sunset OC/EC analyser	Online OC/EC	IAP	Y. Zhang et al. (2017)
Container 9			
Iodide FIGAERO-ToF-CIMS	Particle- and gas-phase molar molecule	Manchester	Le Breton et al. (2018)
CPMA-SP2	Black carbon mass and mixing state	Manchester	Liu et al. (2017)
Micro-reactor	oVOCs	York	Pang et al. (2014)
Tower ~100 m			
QCL NH_3	Ammonia fluxes	CEH	McManus et al. (2010)
IRGA LICOR-7500	CO_2/H_2O flux	CEH	McDermitt et al. (2011)
DMT UHSAS	Size-resolved particle flux (0.06–1 µm)	CEH	Deventer et al. (2015)
TSI APS3021	Size-resolved particle flux (0.5–25 µm)	CEH	Nemitz et al. (2002)
TSI CPC3785	Total particle number flux	CEH	Petäjä et al. (2006)
ROFI	O_3 flux	CEH	Coyle et al. (2009)
Sonic anemometer R3-50	Turbulence, sensible heat flux	CEH	Högström and Smedman (2004)
WXT530 weather station	T, P, RH, wind speed and direction, precipitation	CEH	
2B O_3 analyser	O_3 concentration	CEH	Johnson et al. (2014)
Tower ~120 m			
High-volume sampler	$PM_{2.5}$ filter samples	IAP	
Anderson sampler	Size-resolved PM samples	IAP	
Tower ~260 m			
High-volume sampler	$PM_{2.5}$ filter samples	IAP	
Anderson sampler	Size-resolved PM samples	IAP	
ACSM	NR PM_1 species	IAP	Sun et al. (2012)
CAPS-PM_{ext} (630 nm)	Extinction	IAP	Q. Wang et al. (2015)
SMPS 3938	Particle number size distribution	IAP	Du et al. (2017)
Gas analyser	CO, O_3 and SO_2	IAP	Zhou et al. (2018)
Aethalometer AE33	Black carbon	IAP	Xie et al. (2019)
Single particle sampler	Individual particles	CUMTB	W. Wang et al. (2018)
Tower and tower basket measurements			
SNAQ boxes (×6 at different heights)	CO, NO, NO_2, SO_2, PM_1, PM_{10}, $PM_{2.5}$	Cambridge	Popoola et al. (2018)
LOPAP	HONO (3 min average)	Birmingham	Crilley et al. (2016)
Spectral radiometer	Photolysis rates	Leeds	Bohn et al. (2016)
SNAQ	CO, NO, NO_2, SO_2, PM_1, PM_{10}, $PM_{2.5}$	Cambridge	Popoola et al. (2018)
WIBS	Fluorescent biological aerosol particles (FBAPs)	IAP	Yue et al. (2016)
AE33	BC	IAP	Xie et al. (2019)
Los Gatos NH_3 analyser	NH_3	IAP	Meng et al. (2018)
PAX	Light scattering/absorption	IAP	Xie et al. (2019)


IAP 325 m tower

Vertical profile observation

Flux observation





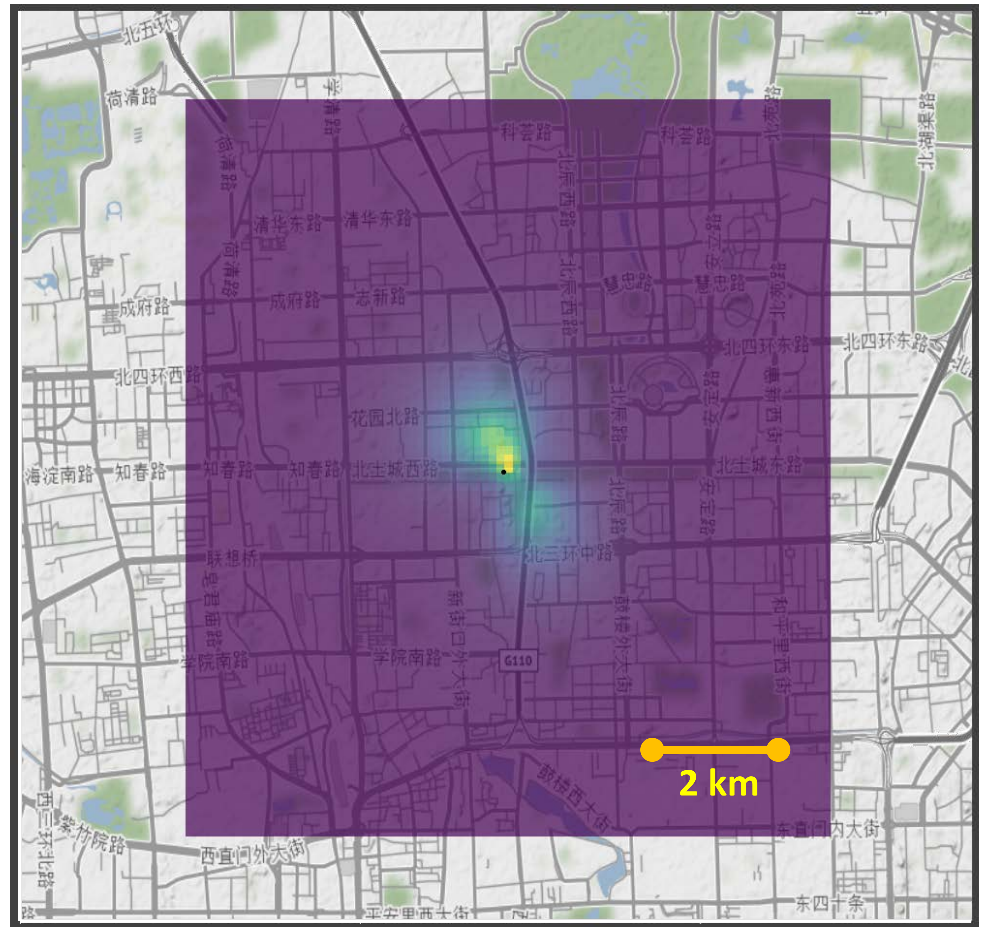
Pollutant Flux Measurements

- Measure fluxes on IAP tower
- Calculate flux per unit area from footprint area
- Compare with emissions inventory
- Improve emissions inventory
- Compare performance of chemistry-transport model before and after inventory change

Where are the emissions coming from?

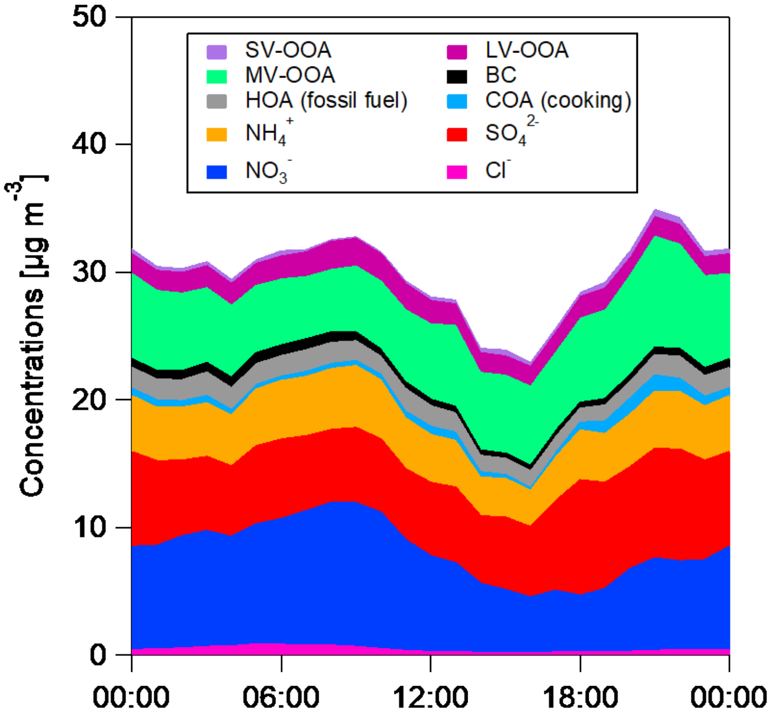
Calculate a **flux footprint** (the area of ground which is contributing to our total measured flux).

We are measuring a small area - the average footprint is shown, with the majority of flux contribution coming within 1 – 2 km from the tower.

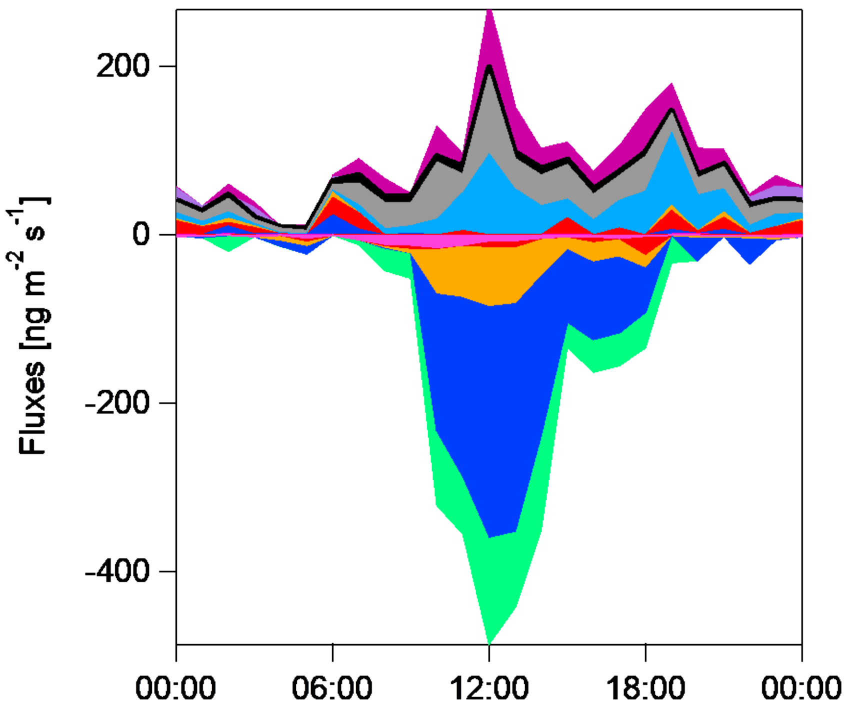


Aerosol composition: concentrations and fluxes
Summer

Concentrations



Fluxes



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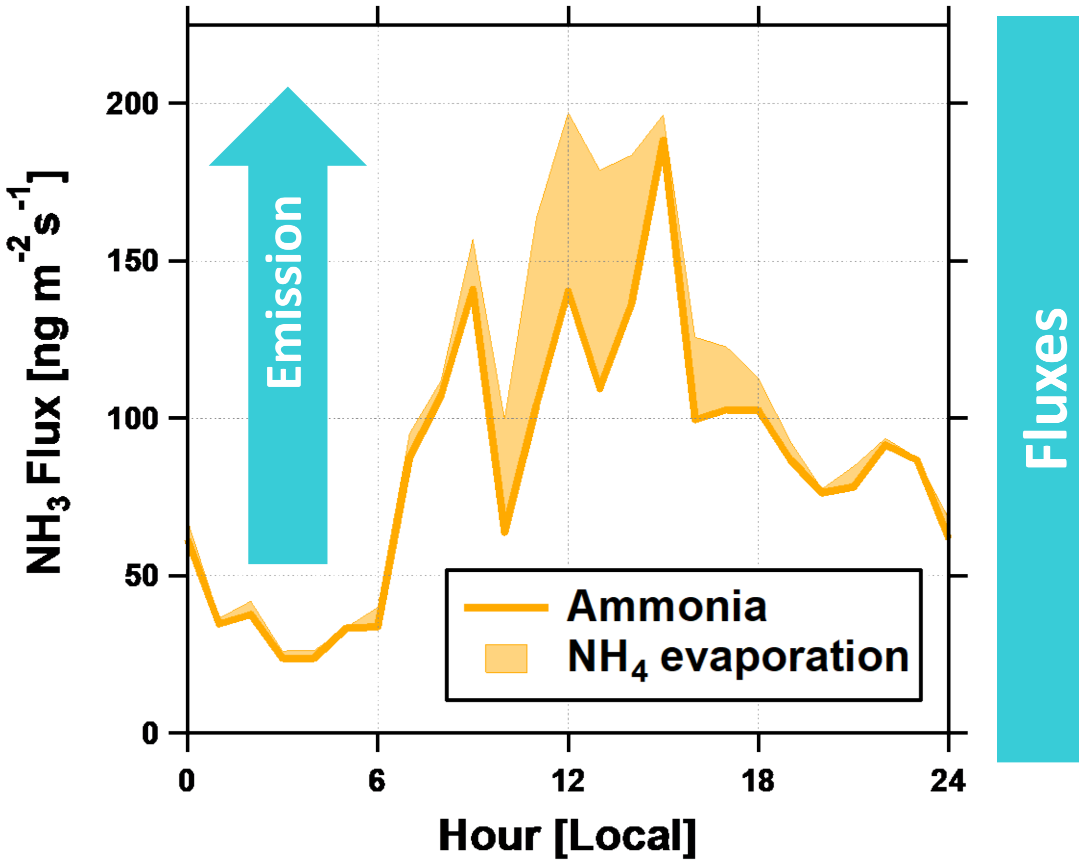
Ammonia flux measurements over Beijing - contribution from NH_4NO_3 evaporation -



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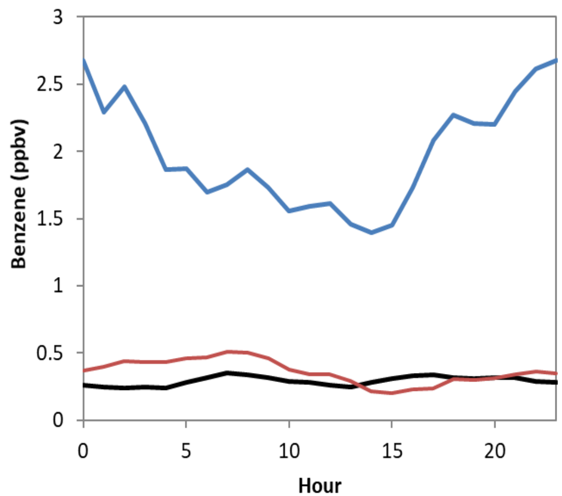
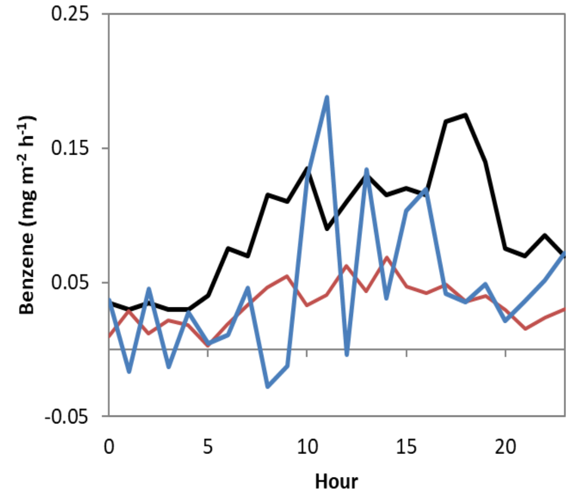
Aromatic fluxes: Beijing vs. London

Black - London Aug-Dec 2012 (Valach et al. 2015)

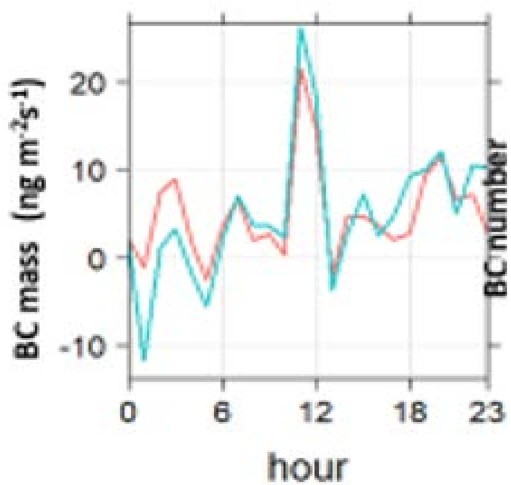
Red- Beijing May-Jun 2017

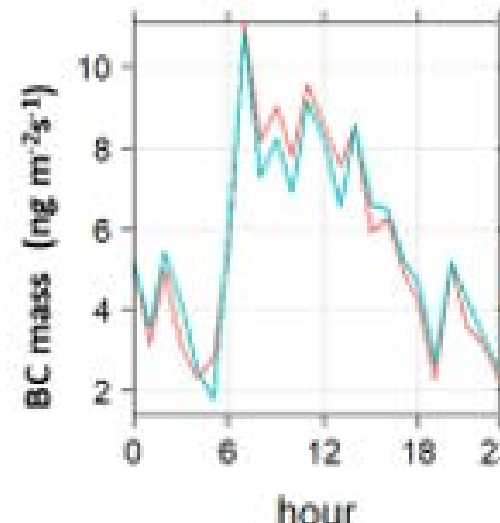
Blue –Beijing Nov- Dec 2016



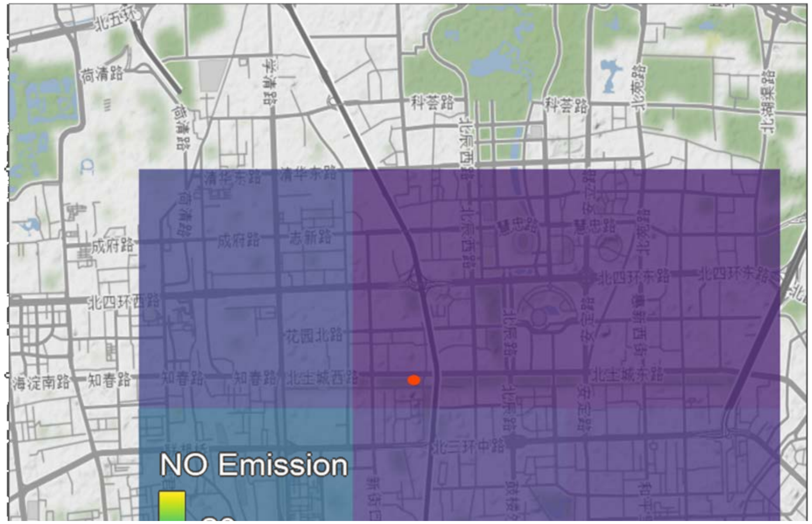


BC flux

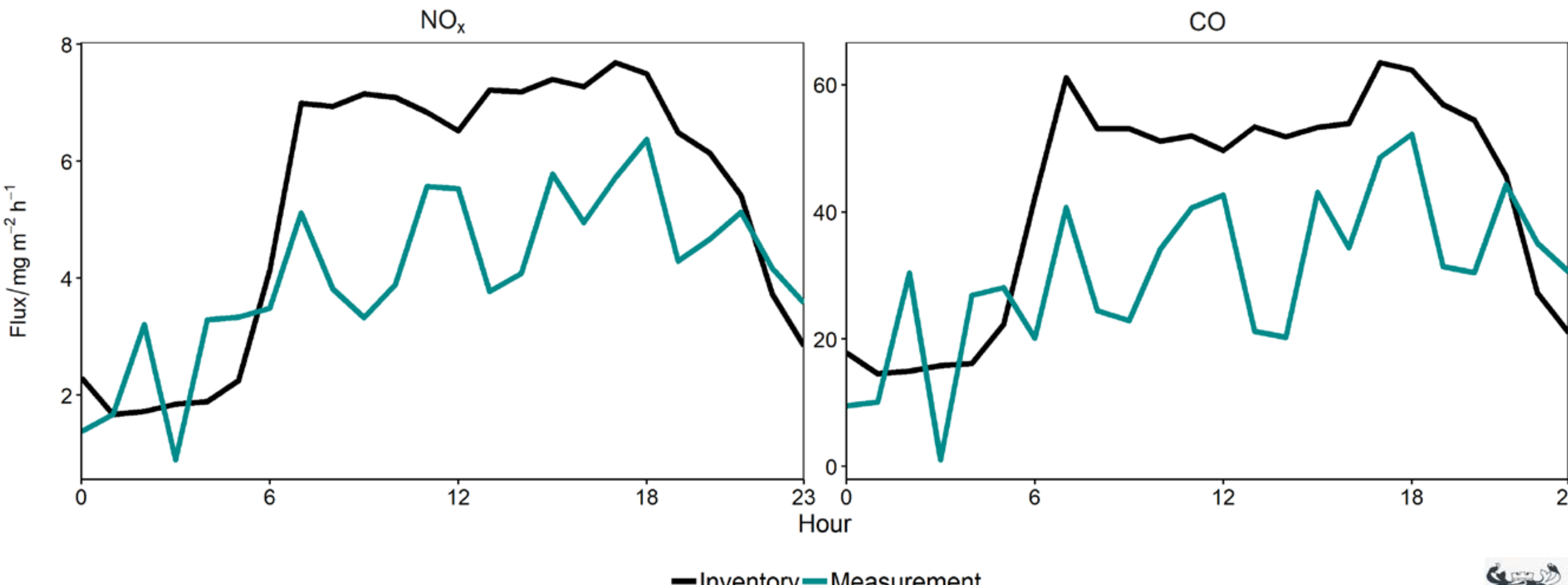




Comparison to emissions inventory

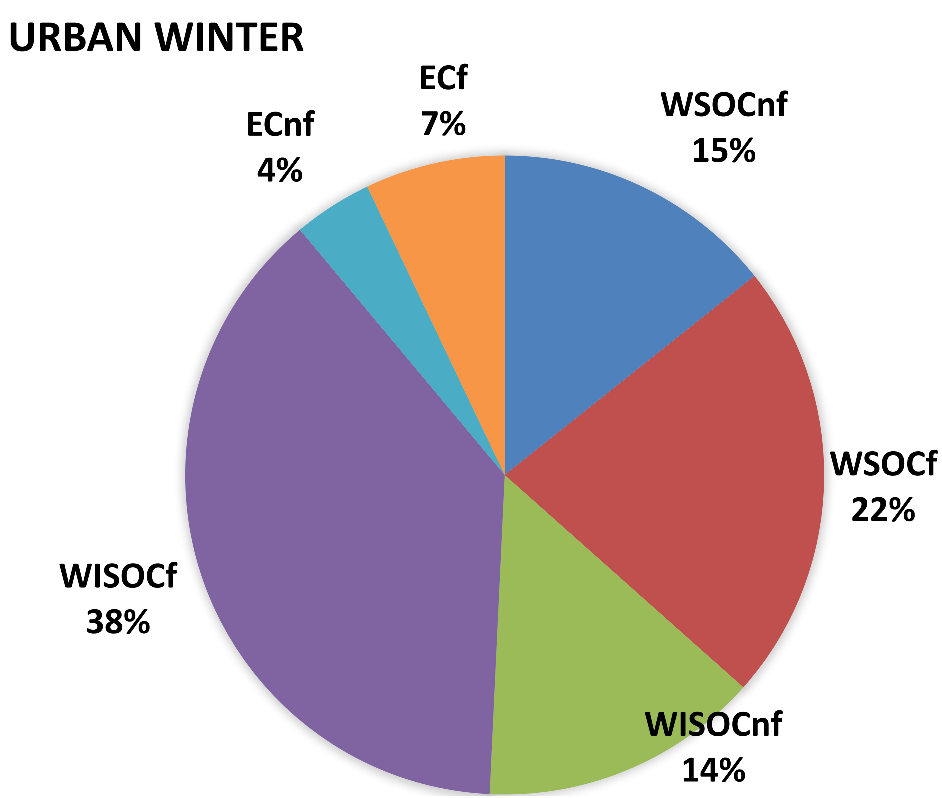


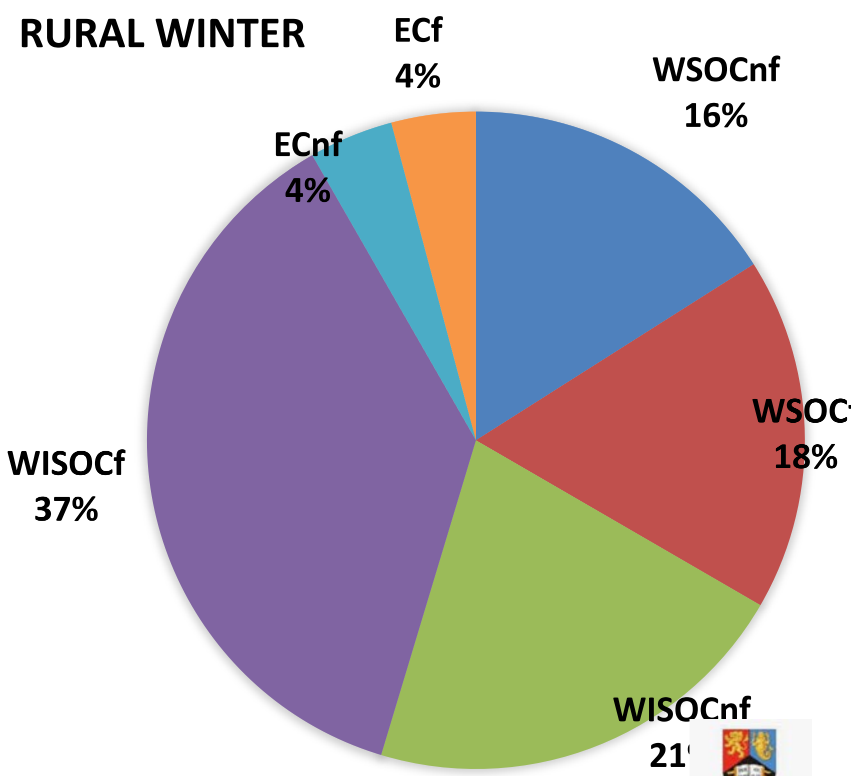
Left is the MEIC Emissions Inventory for October 2010 (scaled down by 25 %)



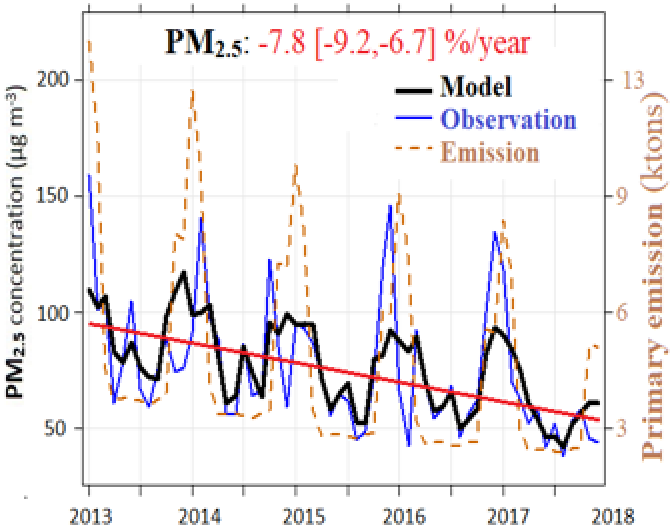
Multiple approaches to source apportionment of carbonaceous aerosol

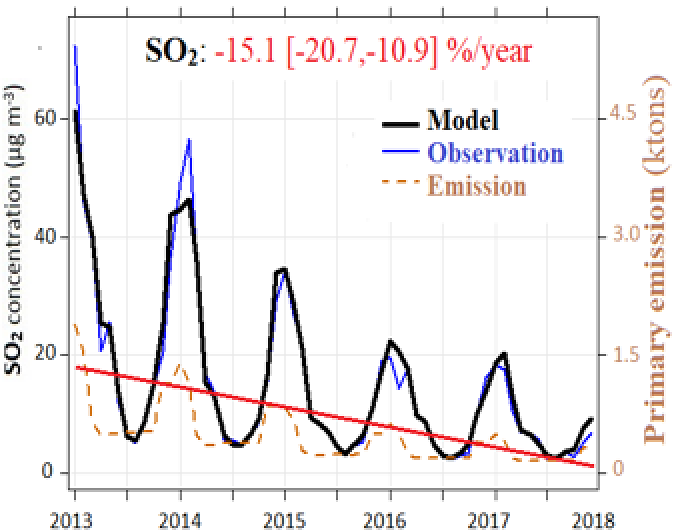
- Urban - OM: 45.2 %; EC 3.7%
- Rural - OM: 49.2%; EC: 3.1 %



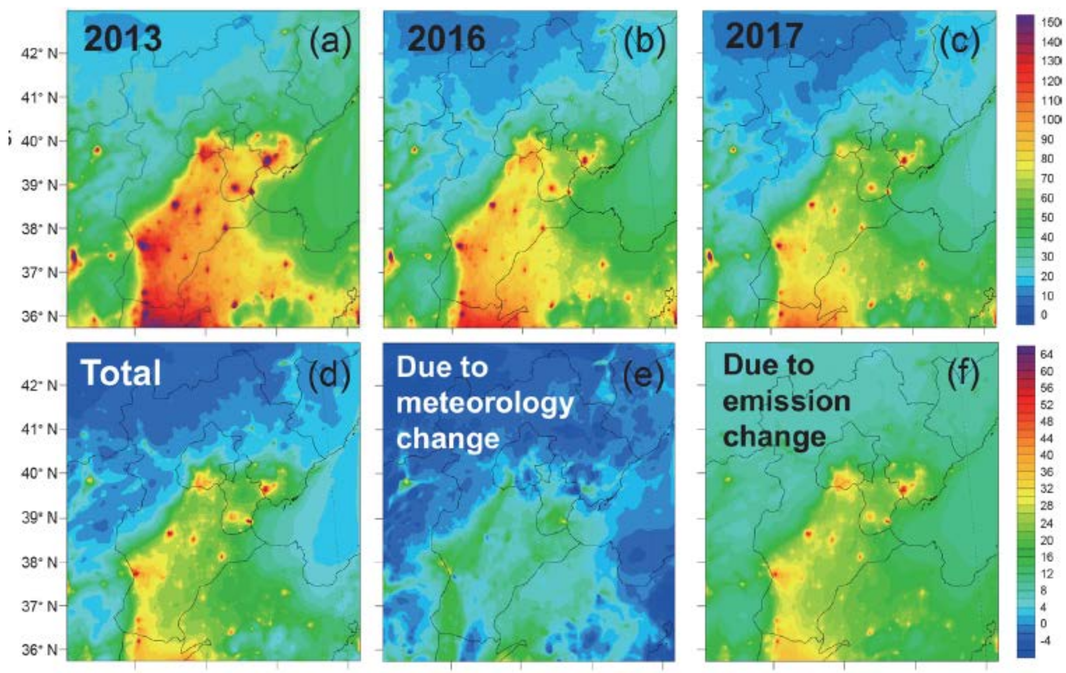


Understanding the effectiveness of Clean Air Actions on air quality





Annual mean $PM_{2.5}$ concentrations ($\mu g\ m^{-3}$)



$PM_{2.5}$ changes from 2013–2017 ($\mu g\ m^{-3}$)

Vu et al. 2019. ACPD; Cheng et al., 2019 ACP

Key scientific values and innovation

- More accurate knowledge on sources and emissions: eddy flux, receptor modelling, satellite retrievals and modelling
- Lessons learned from Clean Air Actions
- Improvement in understanding of air pollution processes: nitrate and ammonia evaporation, ozone and secondary aerosol formation
- Effectiveness of personal intervention: face masks, home air purifiers

Thanks for your attention…

Alastair Lewis
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Chunxiang Ye
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Dantong Liu
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Hana Pearce
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Kai Qiao
Kaja Milczewska
Kaja Milczewska
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Peter Ivatt
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Yangfeng Wu
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Yao Xiao
Yele Sun
Yingjie Fan
Yiqun Han
YUE Siyao
Yuechen Liu
ZHANG Zhimin
ZHAO Jian
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Atmospheric Chemistry and Physics
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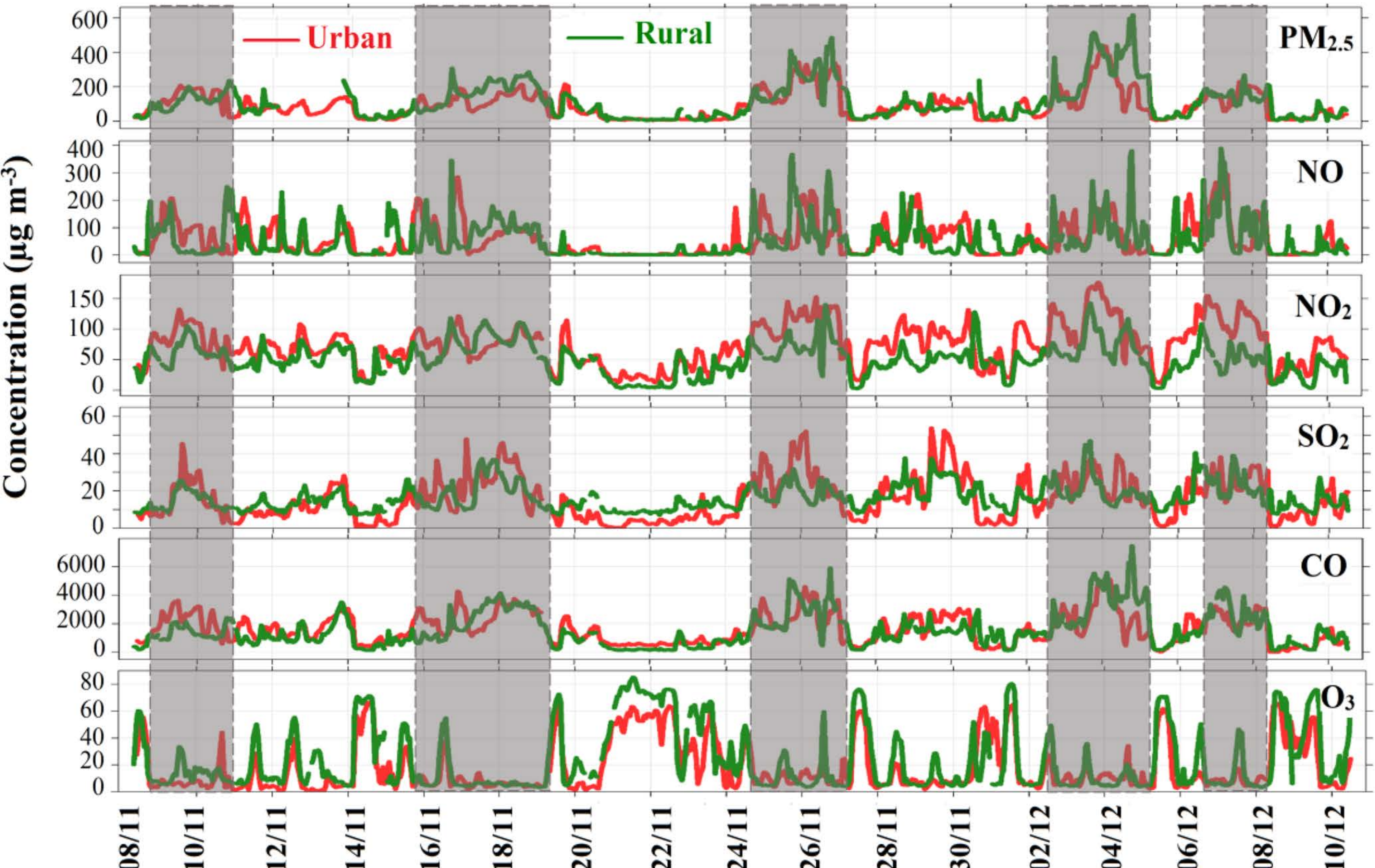
Introduction to the special issue "In-depth study of air pollution sources and processes within Beijing and its surrounding region (APHH-Beijing)"

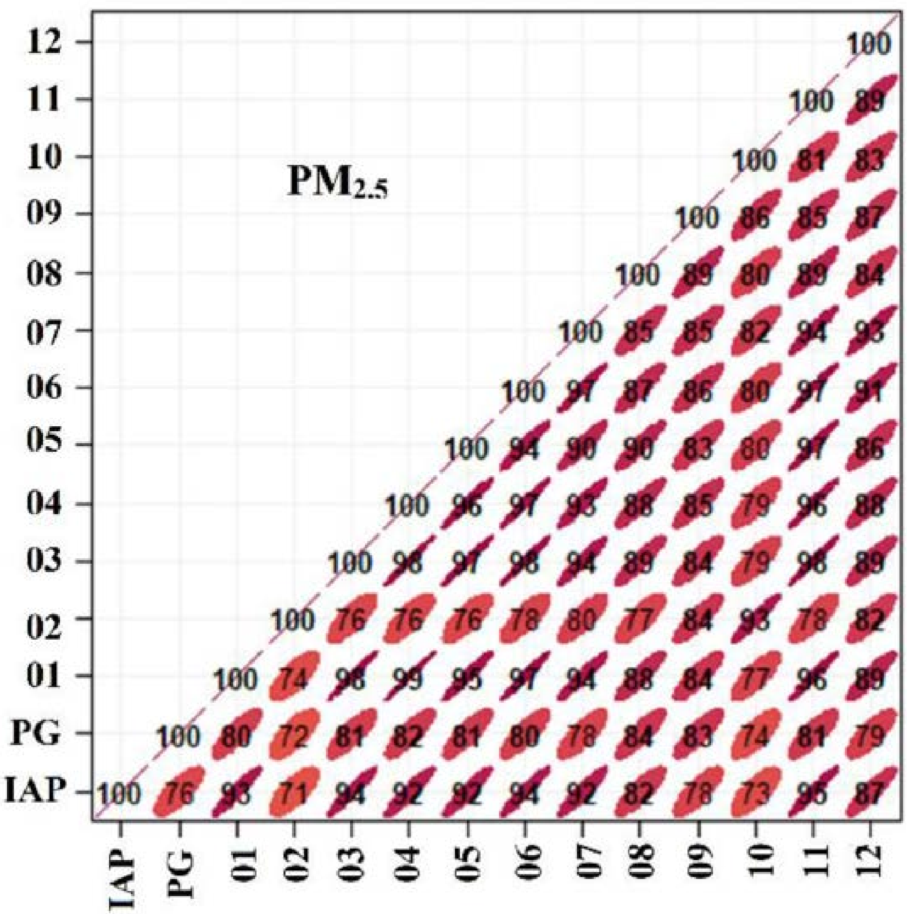
Zongbo Shi[1,2], Tuan Vu[1], Simone Kotthaus[3,4], Roy M. Harrison[1,a], Sue Grimmond[3], Siyao Yue[5], Tong Zhu[6], James Lee[7,8], Yiqun Han[6,9], Matthias Demuzere[10], Rachel E. Dunmore[7], Lujie Ren[2,5], Di Liu[1], Yuanlin Wang[5,11], Oliver Wild[11], James Allan[12,13], W. Joe Acton[11], Janet Barlow[3], Benjamin Barratt[9], David Beddows[1], William J. Bloss[1], Giulia Calzolai[14], David Carruthers[15], David C. Carslaw[7,16], Queenie Chan[9], Lia Chatzidiakou[17], Yang Chen[18], Leigh Crilley[1], Hugh Coe[12], Tie Dai[5], Ruth Doherty[19], Fengkui Duan[20], Pingqing Fu[2,5], Baozhu Ge[5], Maofa Ge[21], Daobo Guan[22], Jacqueline F. Hamilton[7], Kebin He[20], Mathew Heal[19], Dwayne Heard[23], C. Nicholas Hewitt[11], Michael Hollaway[11], Min Hu[6], Dongsheng Ji[5], Xujiang Jiang[20], Rod Jones[17], Markus Kalberer[17,b], Frank J. Kelly[9], Louisa Kramer[1], Ben Langford[24], Chun Lin[19], Alastair C. Lewis[7], Jie Li[5], Weijun Li[25], Huan Liu[20], Junfeng Liu[26], Miranda Loh[27], Keding Lu[6], Franco Lucarelli[14], Graham Mann[28], Gordon McFiggans[12], Mark R. Miller[29], Graham Mills[30], Paul Monk[31], Eiko Nemitz[24], Fionna O'Connor[32], Bin Ouyang[11,17], Paul I. Palmer[19], Carl Percival[12,c], Olalekan Popoola[17], Claire Reeves[30], Andrew R. Rickard[7,8], Longyi Shao[33], Guangyu Shi[5], Dominick Spracklen[28], David Stevenson[19], Yele Sun[5], Zhiwei Sun[34], Shu Tao[26], Shengrui Tong[21], Qingqing Wang[5], Wenhua Wang[33], Xinming Wang[35], Xuejun Wang[26], Zifang Wang[5], Lianfang Wei[5], Lisa Whalley[23], Xuefang Wu[1], Zhijun Wu[6], Pinhua Xie[36], Fumo Yang[37], Qiang Zhang[38], Yanli Zhang[35], Yuanhang Zhang[6], and Mei Zheng[6]

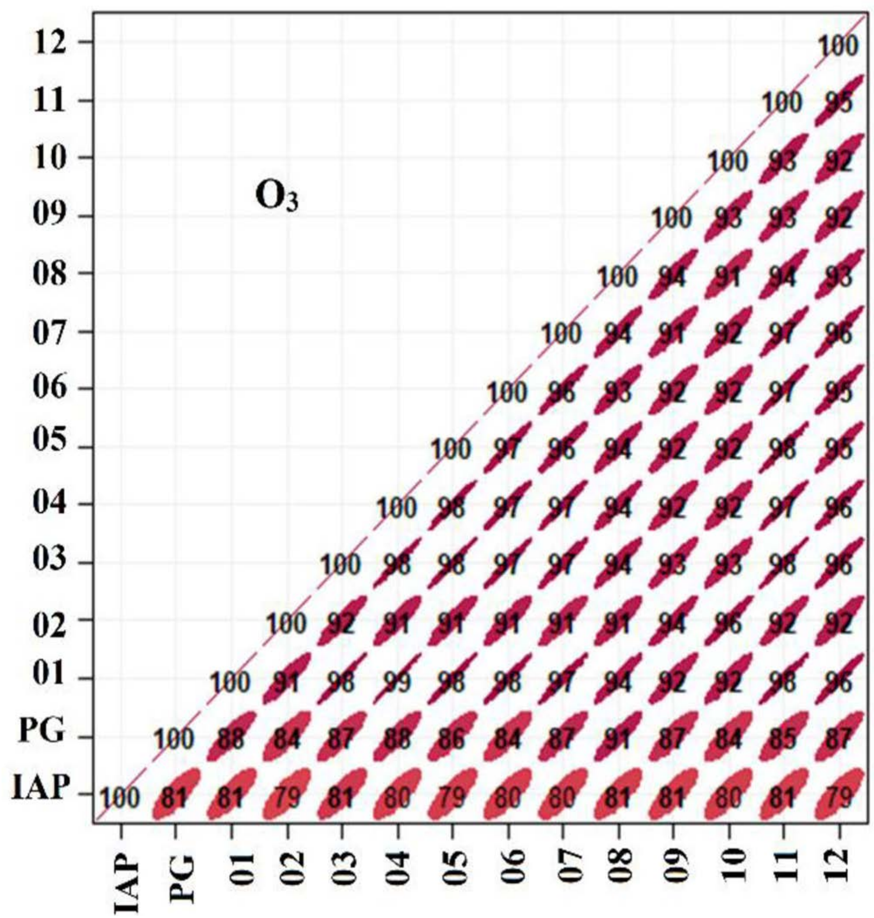
Winter campaign air quality

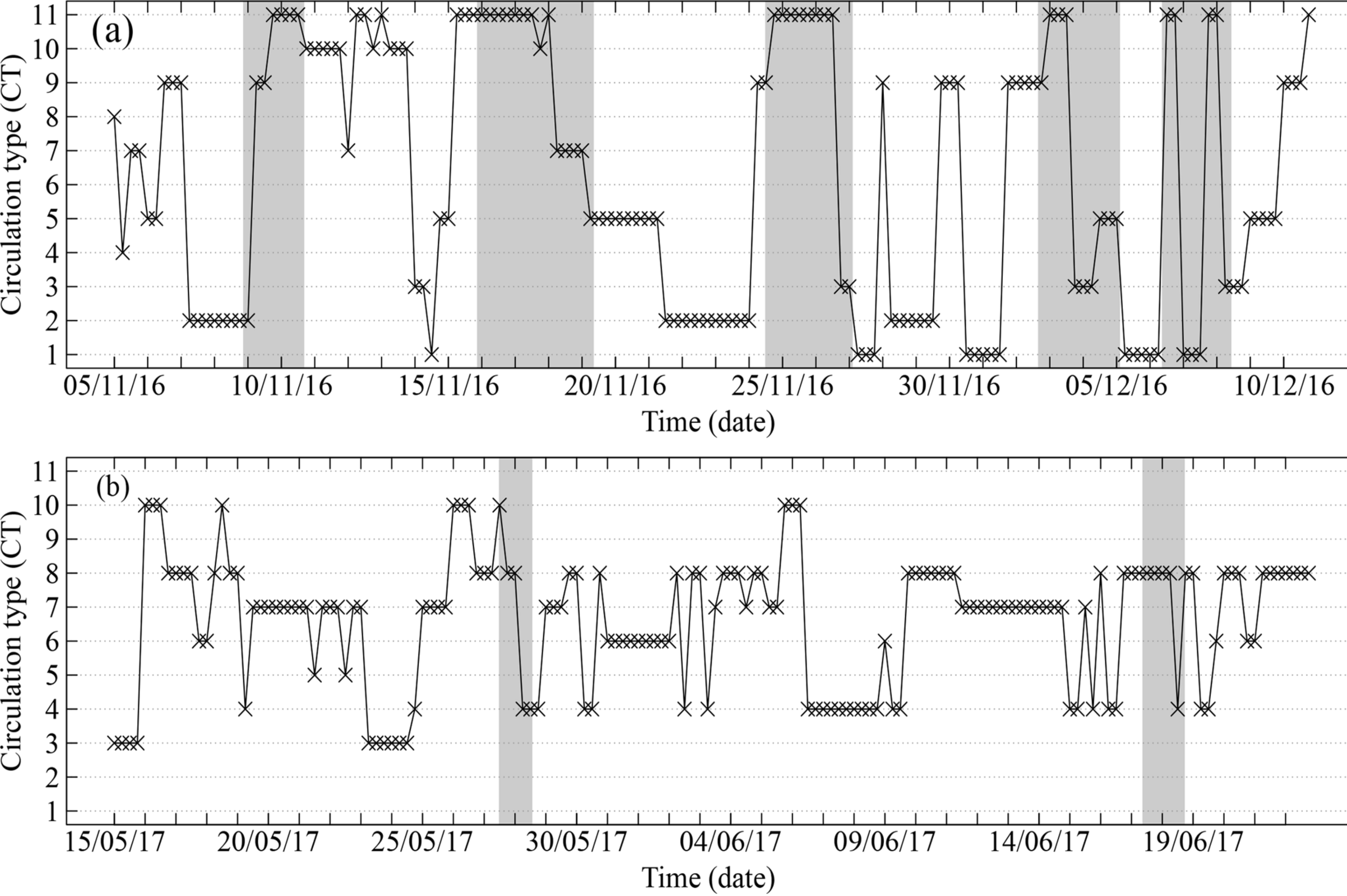


Summer campaign air quality

How representative is IAP site?







Frequency of circulation types

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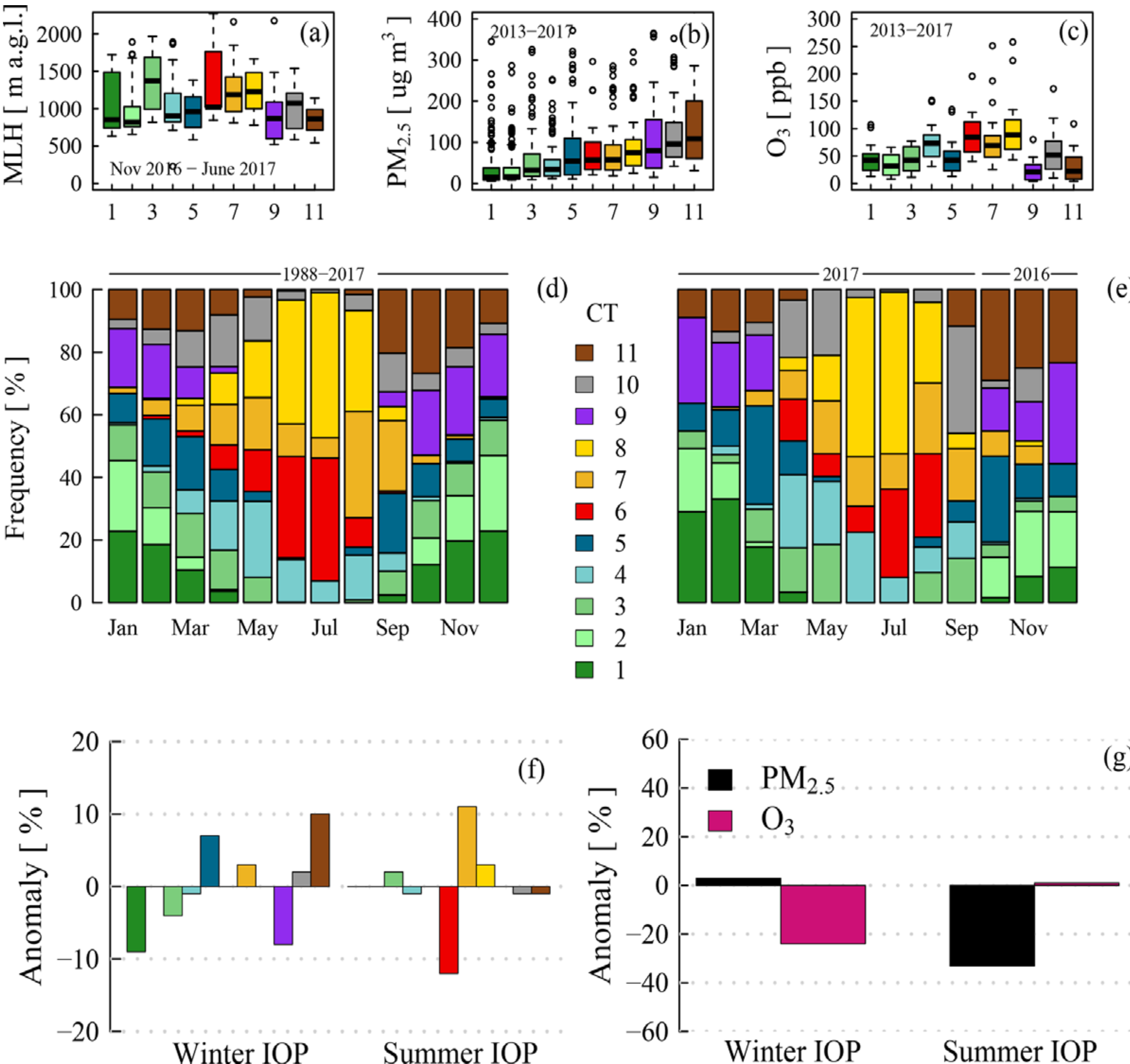

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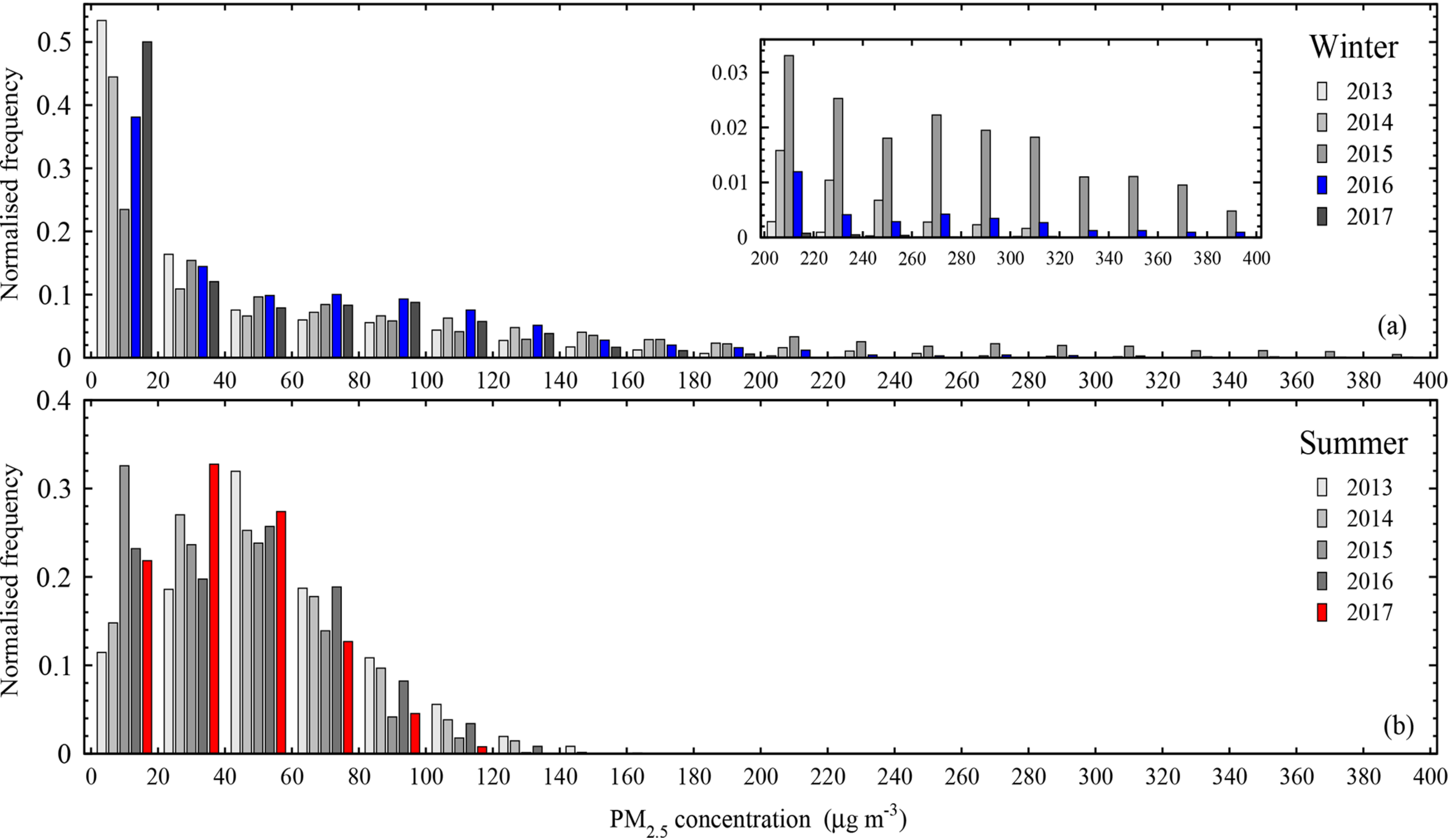

Lancaster University