KING'S College LONDON

SIMON FRASER UNIVERSITY

The University of Hong Kong

THE UNIVERSITY OF BRITISH COLUMBIA

Sensing in three dimensions – Field experience from the Hong Kong D3D Study

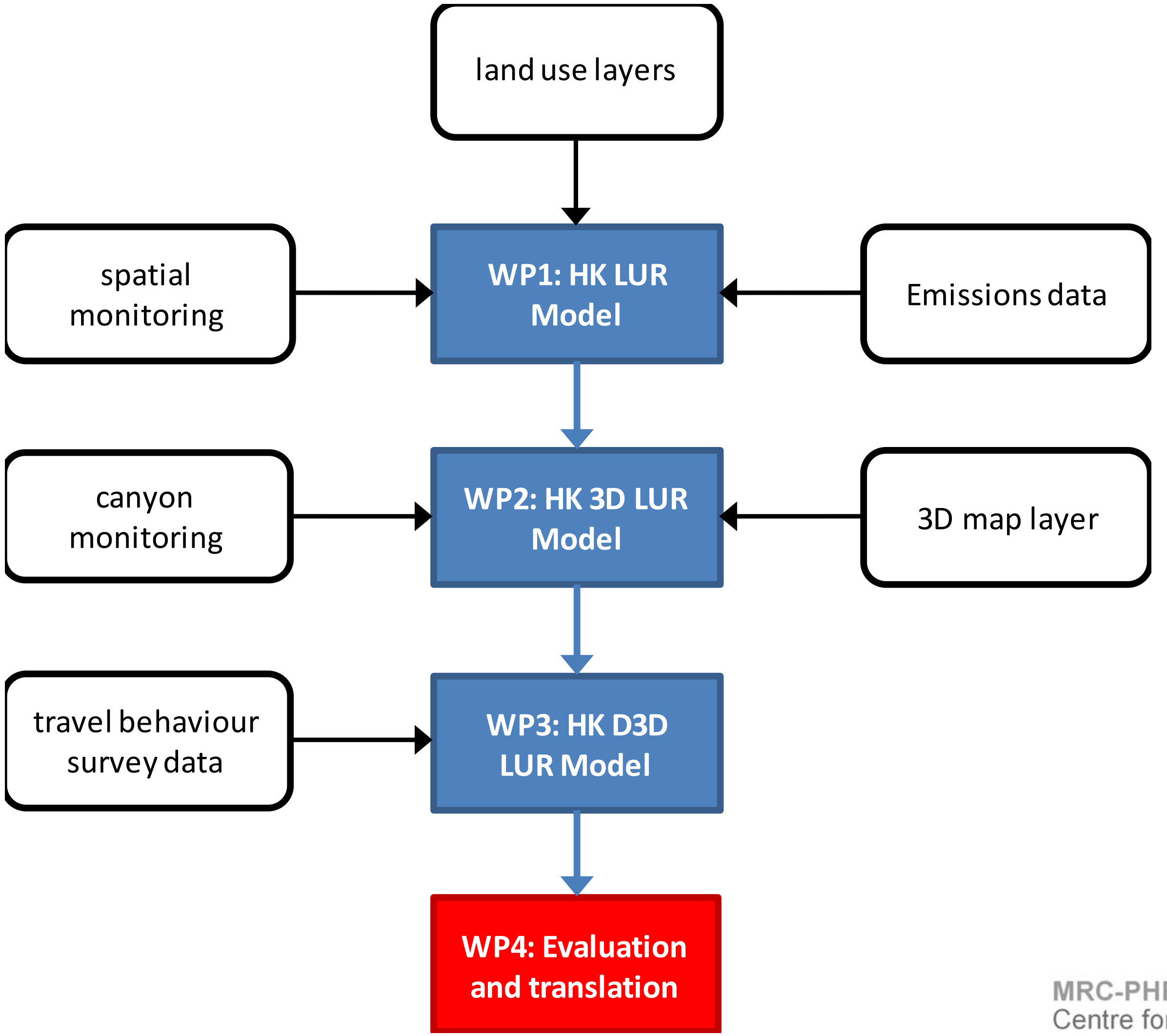
Dr Benjamin Barratt

King's College London, UK

The HKD3D Study

- **Aim:**
  - To improve our understanding of the relationship between the urban environment, population behaviour and public health, facilitating stronger health impact evidence, improved urban design and targeted policy interventions.
- Objectives:
  - To investigate the behavior and distribution of air quality in a 3D urban landscape using air quality sensor networks and population mobility datasets;
  - to develop, evaluate and demonstrate a dynamic 3D air pollution exposure model for Hong Kong and;
  - to create an incremental methodology that can be applied in megacities across Asia and the developing world.

HKD3D Study Design

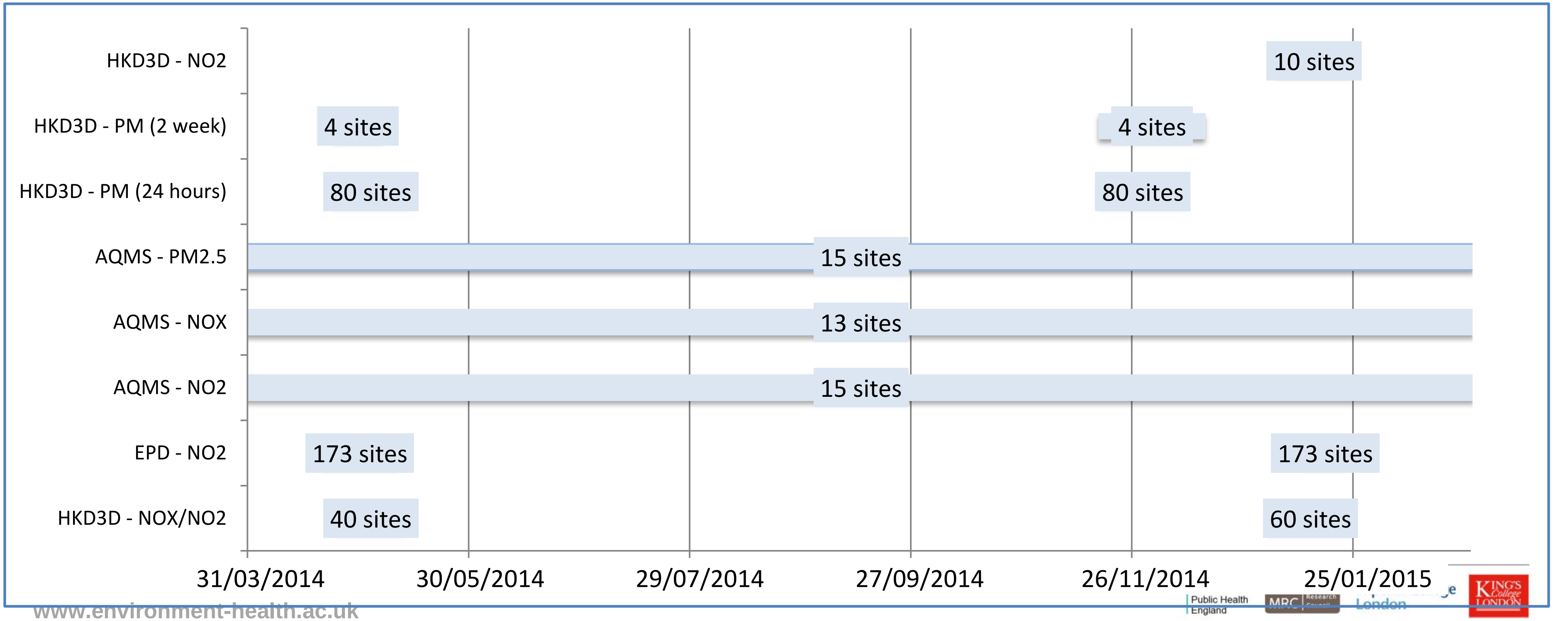


MRC-PHE
Centre for Environment & Health

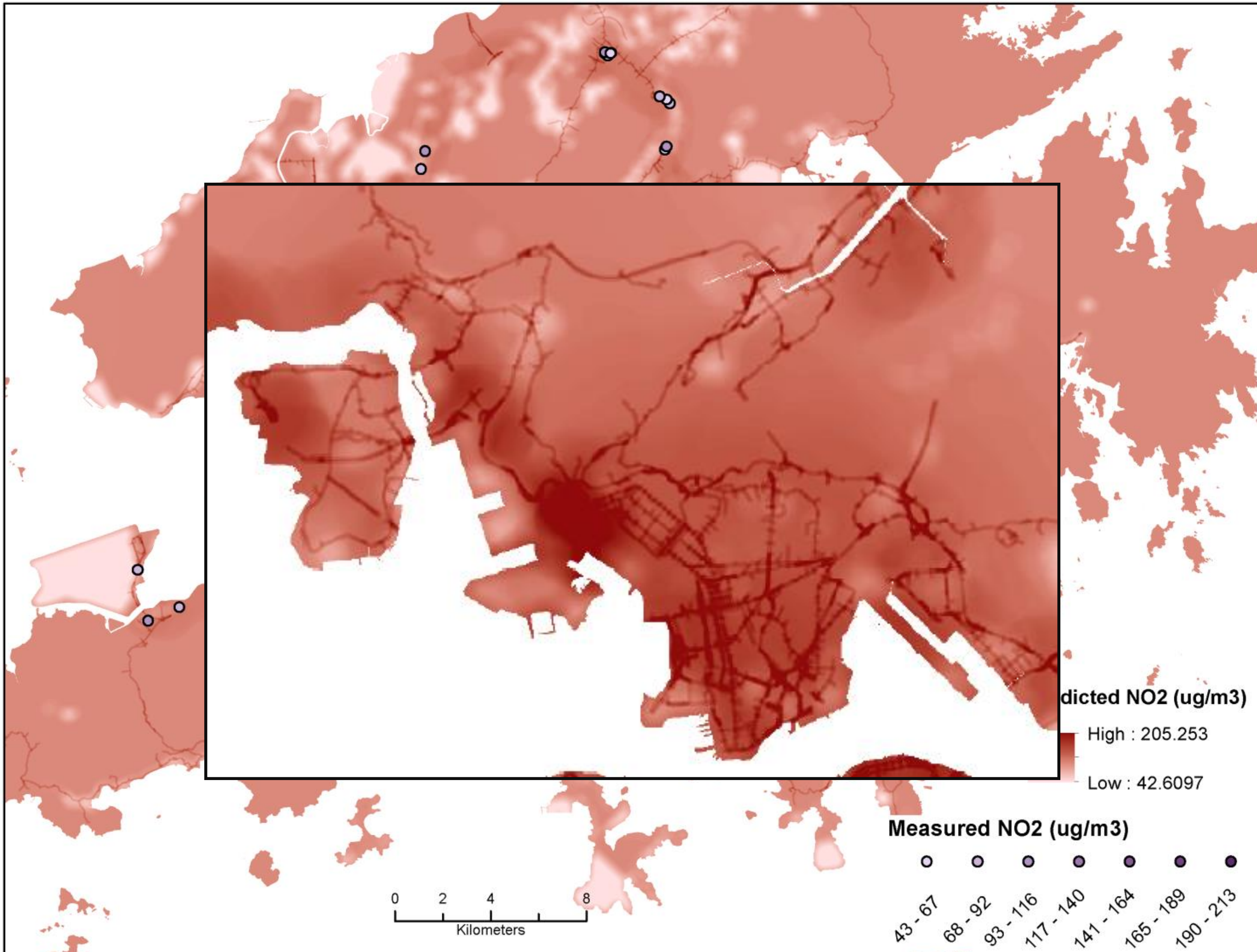
Public Health England MRC Medical Research Council Imperial College London King's College London

Summer and winter spatial campaigns

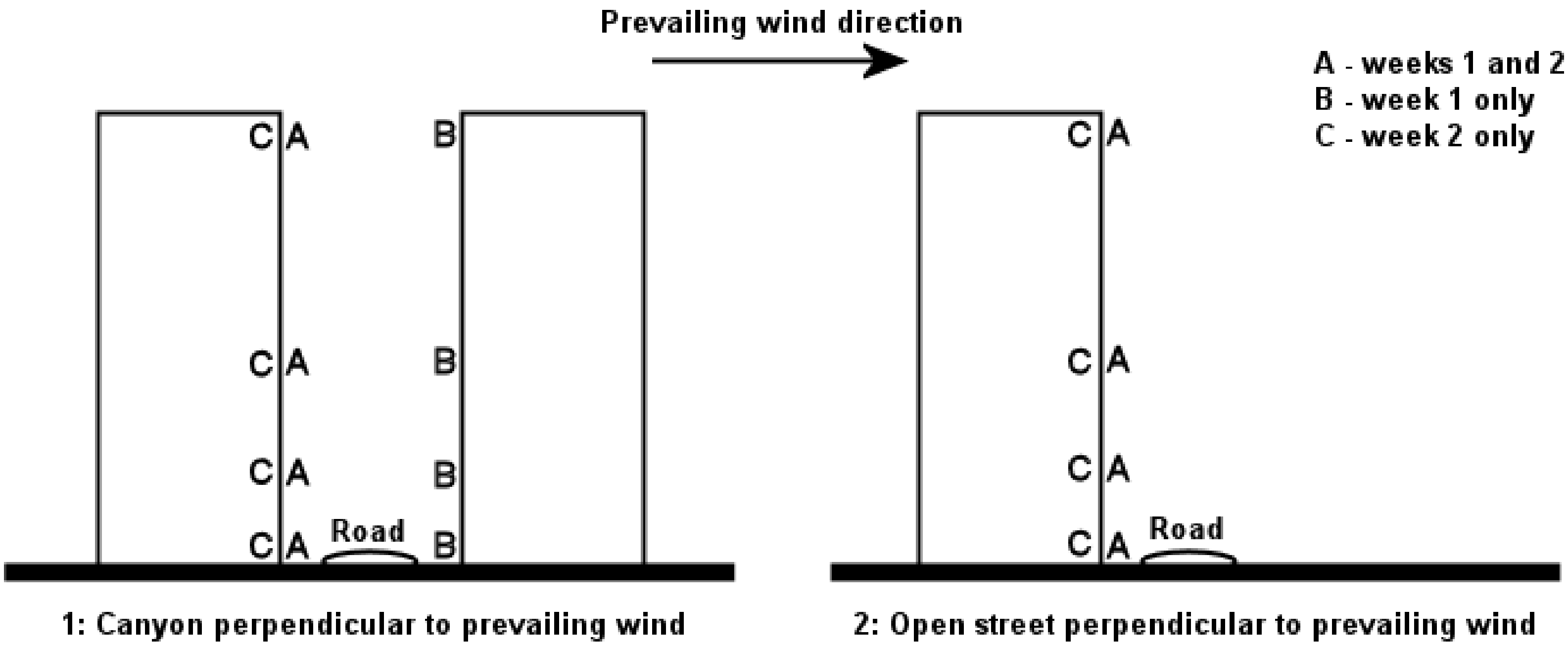
- NO_2 and NO at 40 sites by Ogawa
- NO_2 at 173 sites by diffusion tube (HK EPD)
- $PM_{2.5}$ and BC at 80 sites for 24 hours
- $PM_{2.5}$ and BC at 4 sites for 2 weeks
- NO_2, NO_X and $PM_{2.5}$ continuous at 15 reference sites (HK EPD)



MRC-PHE
Centre for Environment & Health


dicted NO2 (ug/m3)
High : 205.253
Low : 42.6097
Measured NO2 (ug/m3)
43 - 67
68 - 92
93 - 116
117 - 140
141 - 164
165 - 189
190 - 213
0
2
4
8
Kilometers

Canyon monitoring campaigns

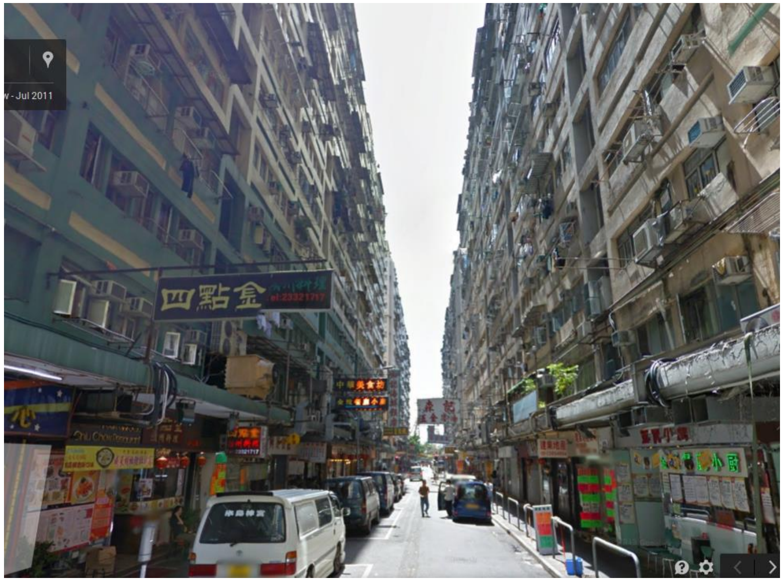


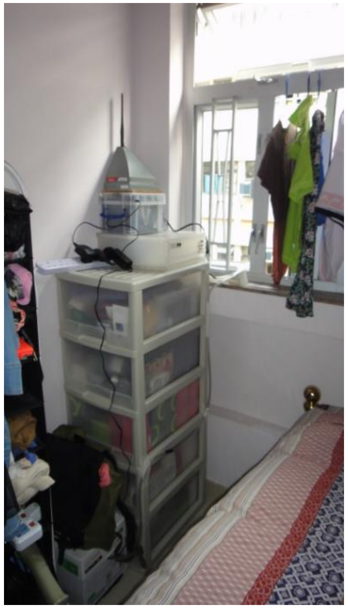
- 2 open sites, 4 canyon sites, 4 street+rooftop canyon sites
- BC (microaeth), $PM_{2.5}$(sidepak), $CO+NO+NO_2$ (electrochem)

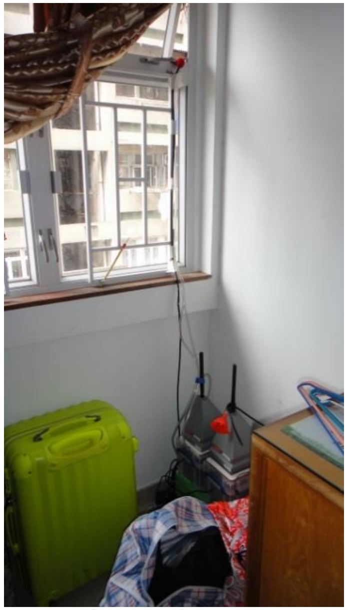
Canyon identification and recruitment

- 3,500 recruitment letters sent to 10 candidate canyon sites.

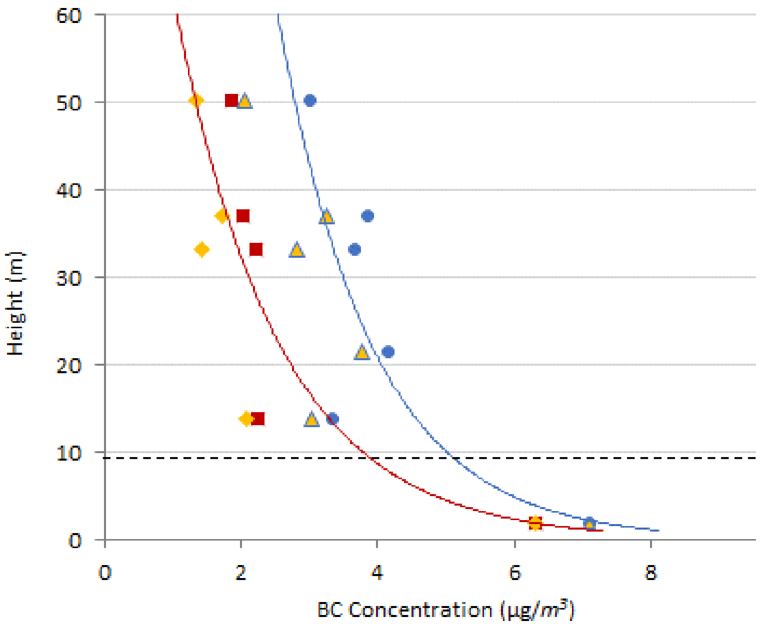
District	H/W Ratio	AADT	Pop^n Den^y	Description	Floors (A)	Floors (B)	Response Rate
Canyon Sites							
Jordan	7.4	1	5	Old residential slab	1, 3, 9, 15	3, 13	7% (24/360)
Mong Kok	3	3	4	Large residential tower blocks (1999)	2, 5, 12, 20	11, 14, 20	5% (17/321)
Hung Hom	2.1	4	5	Large residential tower blocks (1991)	2, 3, 5, 11, 14	2, 6, 13	2% (10/585)
North Point	3.6	4	5	Mixed age residential slab	3, 5, 9, 10, 16	2, 17	2% (12/532)
Open sites							
Sai Wan	-	5	5	Highway + Harborfront residential slab	2, 4, 11, 15	n.a.	3% (7/260)
Choi Hung	-	5	4	Highway residential slab	1, 4, 6, 19	n.a.	2% (6/400)

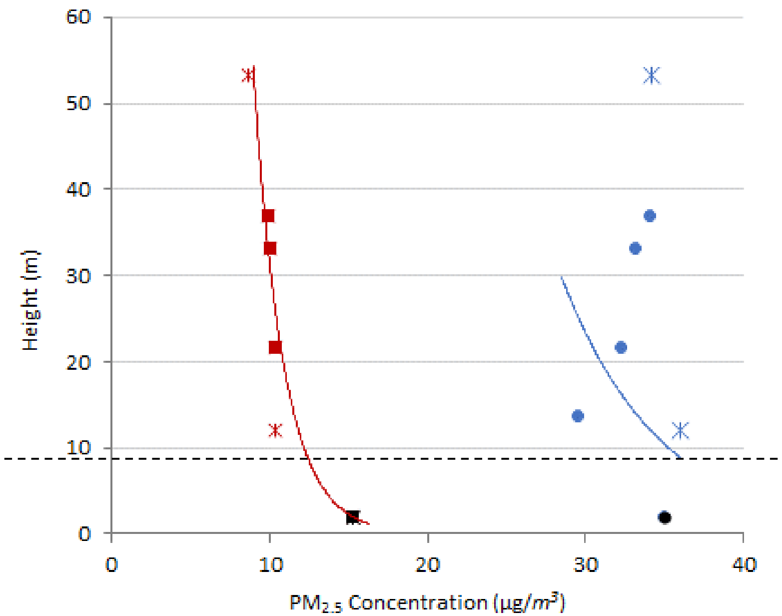

Jul 2011
四點金





Vertical dispersion of traffic emissions



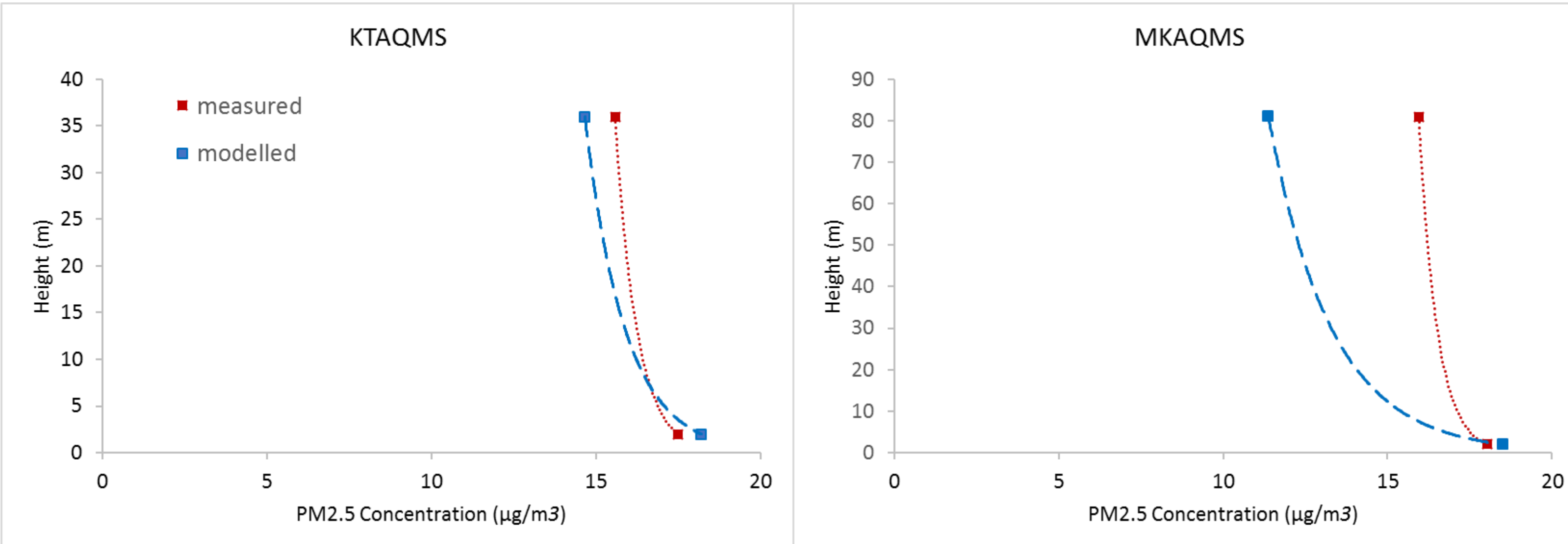


First residential floor

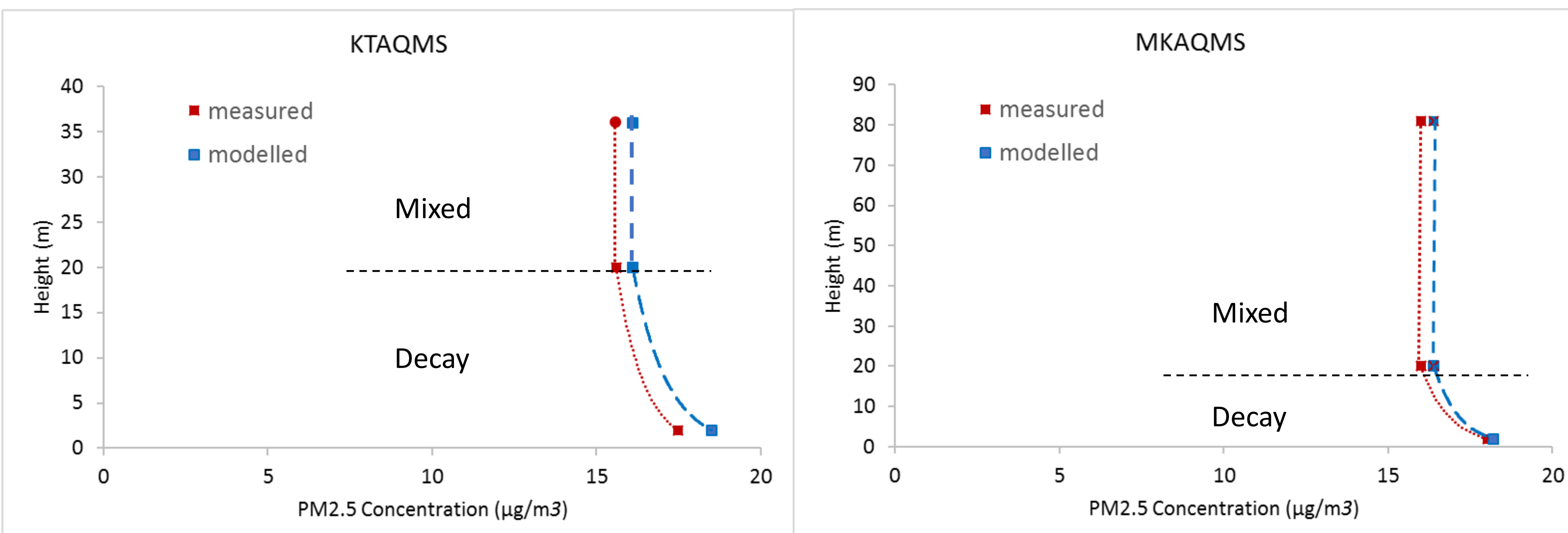
- No evidence of stagnation within canyons
- Vast majority of the population lives within the well mixed zone
- Little protective effect inside homes

Continuous decay or well mixed?

(a)



(b)



Particulate infiltration into homes

	$PM_{2.5}$ warm	$PM_{2.5}$ cool	BC warm	BC cool
Natural ventilation	81%	91%	88%	91%
Mechanical ventilation	40%		45%	
US homes (MESA-Air)	47%-62%		-	

- Implications for SES, energy use, building design, schools
  - All homes and schools have air conditioning, but it is rarely used to save money.

Implications for urban development

From this…

To this

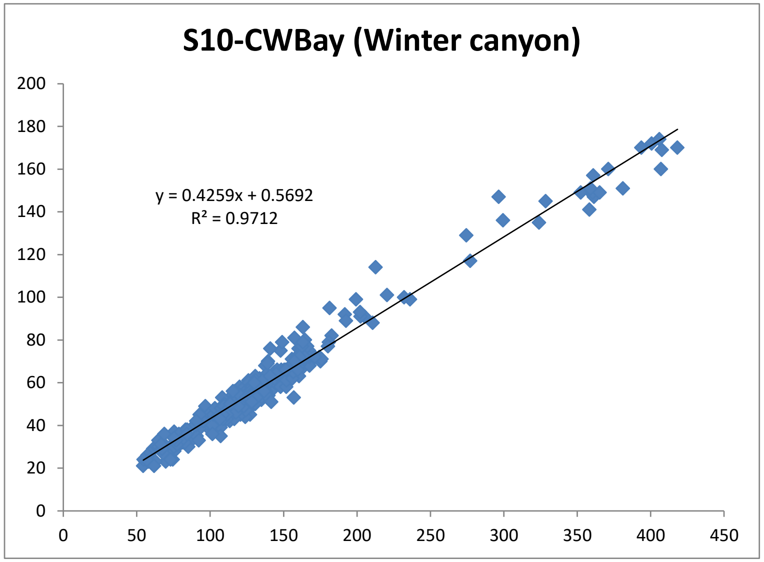
2D vs D3D hazard ratios

Cause of Death	Fine particulates ($PM_{2.5}$)		Nitrogen Dioxide (NO_2)	
	2D	D3D	2D	D3D
All natural causes	**1.03 (1.01, 1.06)***	**1.07 (1.04, 1.09)***	1.00 (0.97, 1.03)	**1.06 (1.03, 1.08)***
Cardiovascular	**1.06 (1.02, 1.10)***	**1.10 (1.05, 1.14)***	1.00 (0.95, 1.05)	**1.09 (1.04, 1.14)***
IHD	1.03 (0.97, 1.10)	**1.09 (1.03, 1.17)***	1.09 (1.00, 1.18)	**1.15 (1.06, 1.24)***
Cerebrovascular	1.06 (0.99, 1.13)	**1.08 (1.01, 1.16)***	1.00 (0.91, 1.09)	1.06 (0.98, 1.15)
Respiratory	1.02 (0.97, 1.06)	**1.06 (1.01, 1.11)***	0.99 (0.93, 1.06)	1.06 (1.00, 1.12)
Pneumonia	1.00 (0.94, 1.06)	1.05 (0.99, 1.12)	0.98 (0.90, 1.06)	1.06 (0.99, 1.14)
COPD	1.06 (0.97, 1.15)	1.09 (1.00, 1.19)	1.02 (0.90, 1.15)	1.06 (0.96, 1.18)
External causes	1.02 (0.90, 1.16)	1.04 (0.90, 1.19)	1.10 (0.92, 1.31)	1.08 (0.93, 1.27)

Hazard ratios (95%CI) per IQR increase of pollutants for baseline exposure. *$p<0.05$.

Dynamic component had little impact due to cohort's age-related homogeneity.

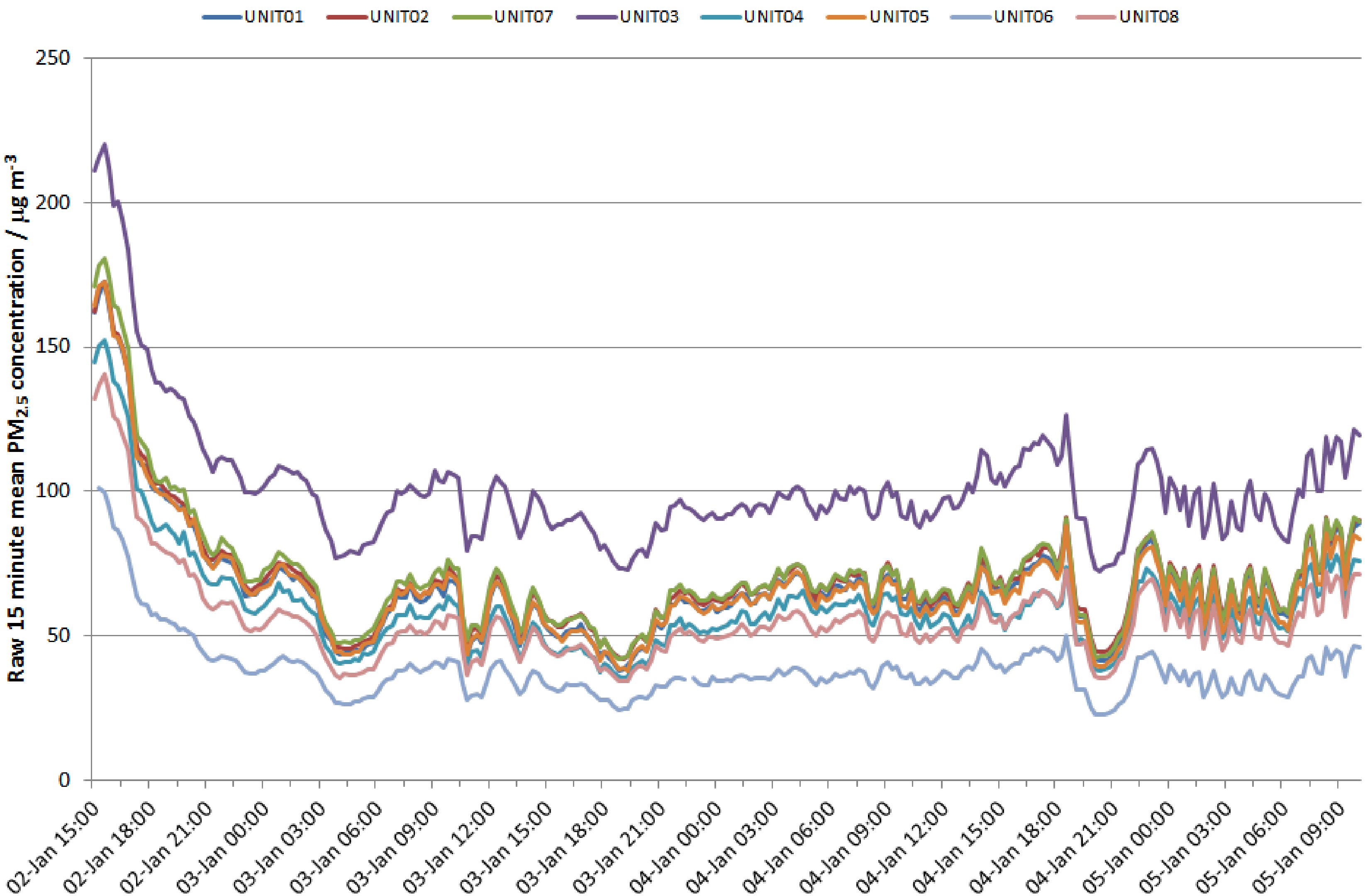
The importance of inter-unit precision



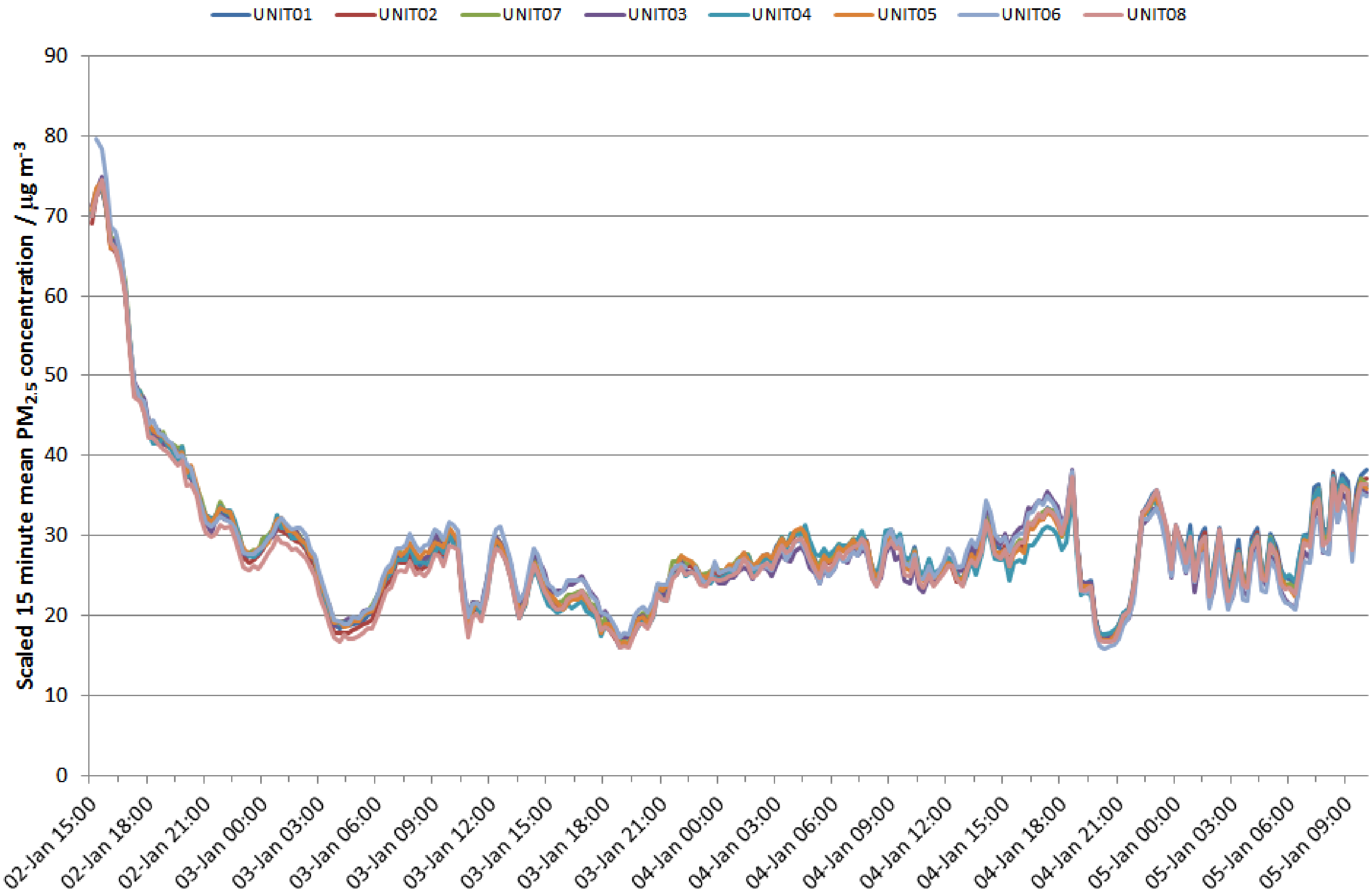
Sidepak accuracy scaling

Sidepak inter-unit precision scaling

Unit \ R^2	S01	S02	S03	S04	S07	S09	S10	S11	S12	CAN06
S01		1.00	0.21	0.97	0.98	0.99	1.00	0.96	1.00	1.00
S02	1.00		0.21	0.97	0.98	0.99	1.00	0.97	1.00	1.00
S03	0.21	0.21		0.12	0.27	0.24	0.25	0.28	0.25	0.19
S04	0.97	0.97	0.12		0.94	0.96	0.95	0.92	0.96	0.98
S07	0.98	0.98	0.27	0.94		0.96	0.98	0.99	0.99	0.98
S09	0.99	0.99	0.24	0.96	0.96		0.99	0.96	0.99	0.99
S10	1.00	1.00	0.25	0.95	0.98	0.99		0.98	1.00	0.99
S11	0.96	0.97	0.28	0.92	0.99	0.96	0.98		0.98	0.97
S12	1.00	1.00	0.25	0.96	0.99	0.99	1.00	0.98		0.99
S13	1.00	1.00	0.19	0.98	0.98	0.99	0.99	0.97	0.99	
Offset	1	5		41	29	2		3	1	5
Gradient	1.01	1.02	-	0.95	0.91	1.14		1.89	0.96	1.28



- Co-location precision and reference testing pre and post campaign ($PM_{2.5}$)



- Co-location precision and reference testing pre and post campaign ($PM_{2.5}$)

Electrochemical stability issues

- Inter-unit precision scaling of electrochemical sensors was not maintained during campaigns
- Issues with stabilisation, temperature, humidity, drift
- High humidity caused frequent sensor failures

NO	R^2			Gradient			Offset (ppb)		
Test period:	1	2	3	1	2	3	1	2	3
UNIT01 (ref)	1.00	1.00	1.00	1.00	1.00	1.00	0	0	0
UNIT02	0.69	0.11	0.71	1.03		0.44	2		-25
UNIT03	0.98	0.99	0.98	1.17	1.28	1.69	-33	-4	-2
UNIT04	0.99	0.99	0.87	1.25	1.48	1.16	-16	7	-62
UNIT05	0.96	0.97	0.94	1.5	1.27	1.06	8	19	-12

Inter-unit precision test results during summer canyon campaign

Sensor network challenges

- Harsh operating environment – rain falling upwards, tornados, pollution, heat, humidity, continuous relocation etc…
- Installation – identifying locations, resident permissions, space, availability, height, security. Surprisingly few locations met all criteria
- Sensor precision – high precision required to correctly quantify relatively small spatial contrasts
- Sensor drift and dynamic calibration factors – changes with meteorology, atmospheric composition, sensor age.
- Huge data QA/QC overhead to produce data of sufficient quality
- Unforeseen circumstances!

KING'S College LONDON

SIMON FRASER UNIVERSITY

The University of Hong Kong

THE UNIVERSITY OF BRITISH COLUMBIA

Acknowledgements

Study funded by the Health Effects Institute, USA
Report available from www.healtheffects.org

Co-Investigators and research staff:
HKU: Poh-Chin Lai, Robert Tang, Linwei Tian, Thuan-Quoc Thach, Crystal Choi, Paulina Wong, Jenny Cheng, Anthony Tsui
UBC: Martha Lee, Michael Brauer
Simon Fraser: Ryan Allen, Weiran Yuchi
HKSAR: Environmental Protection Department and Department of Transport