

Fine scale street-level AQ informatics system for exposure

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Other collaborators:

CERC: Christina M. Hood*, Jenny R. Stocker, David J. Carruthers, William Grayson and Jonathan Handley

HKUST: Alexis Lau, NingZhi, David Yeung, Jimmy Chan

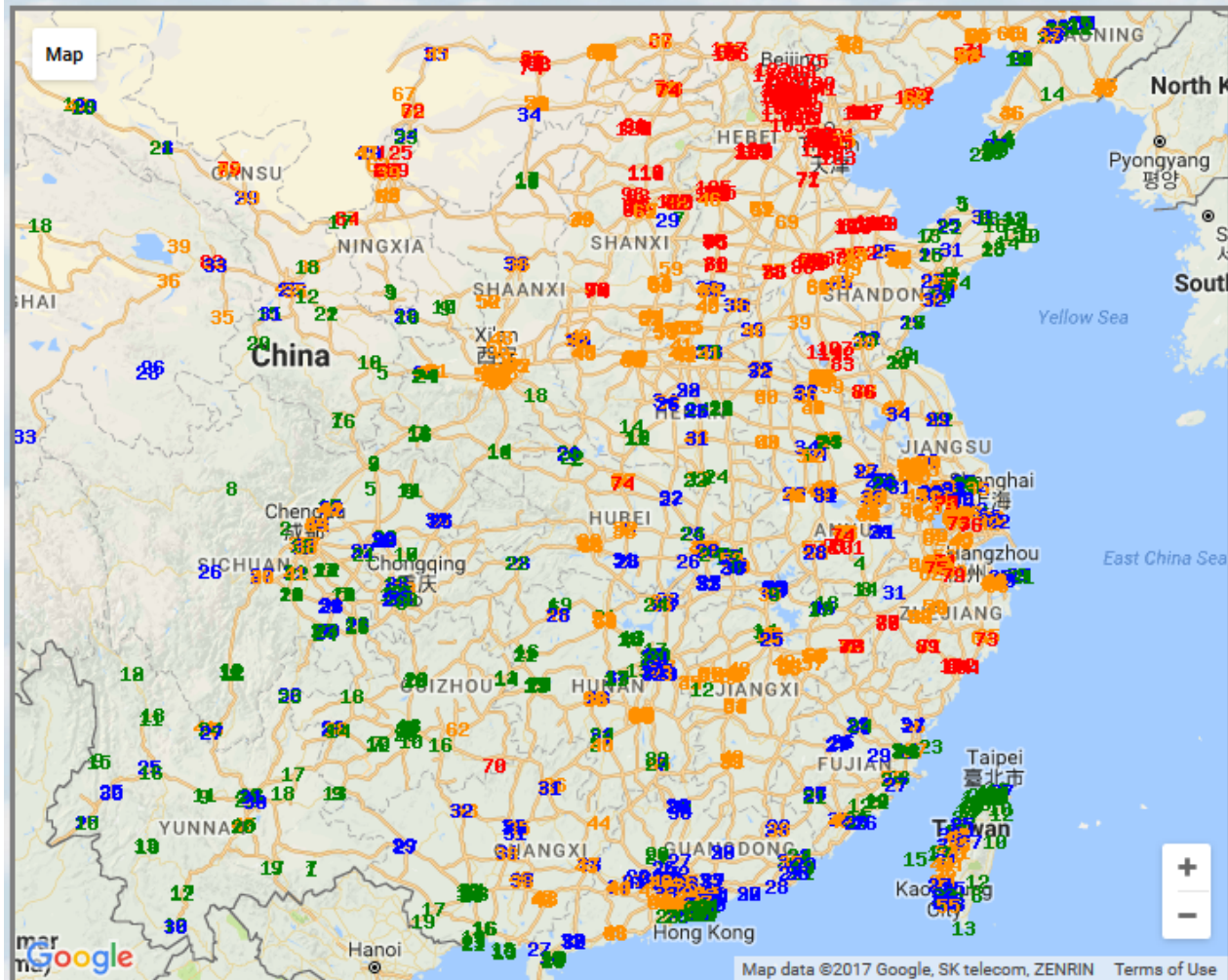


Measured PM2.5 concentration over China

Real-time Data Display from [ENVF Atmospheric & Environmental Database](#)

Spatial 2D Plot for Fine Suspended Particulates (FSPMC) ($\mu\text{g}/\text{m}^3$)

Time: 2017/10/07 03:00(UTC+0). No. of data points: 1552



25.0

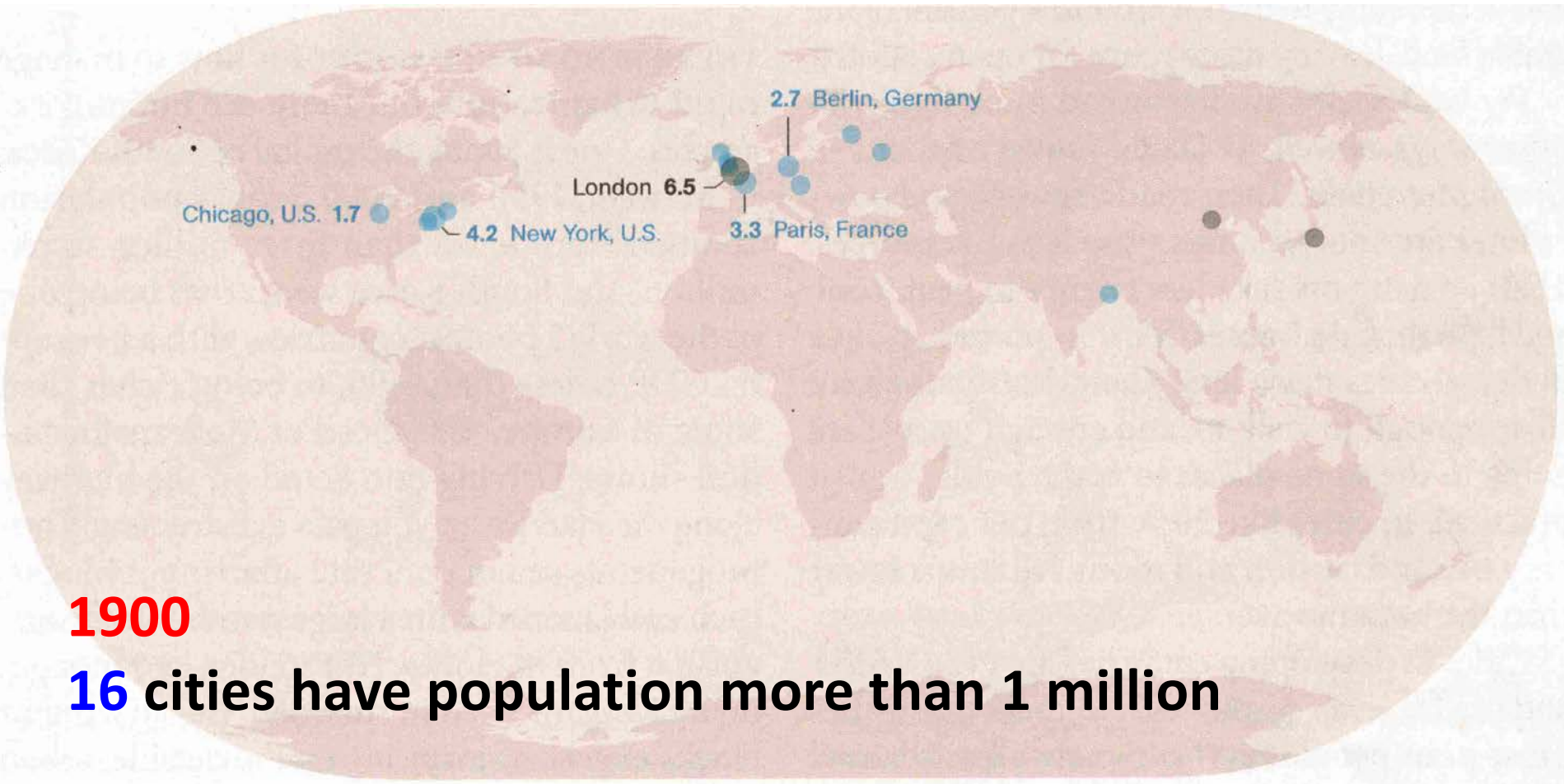
35.0

70.0

Overlay Wind: ☐

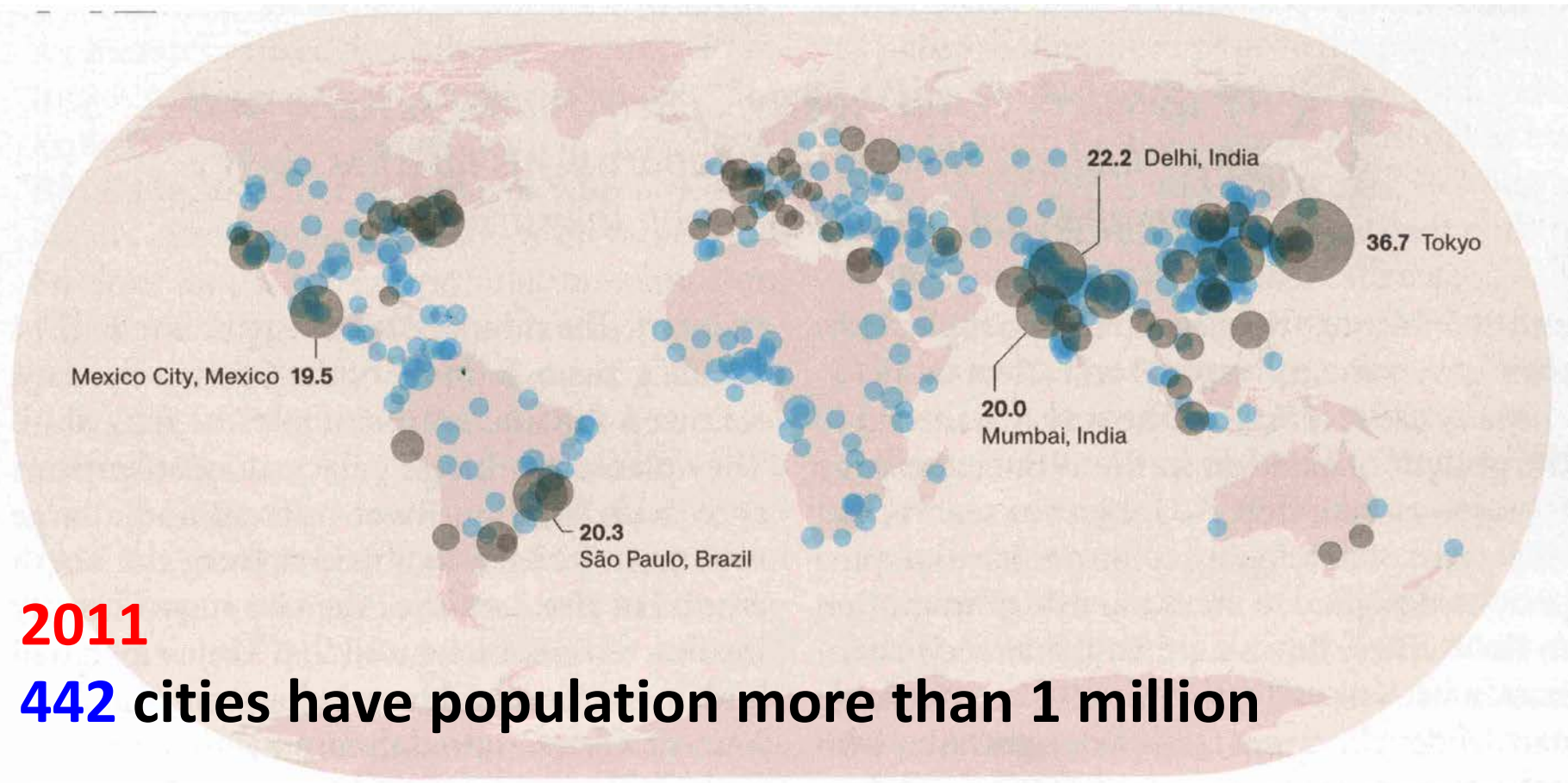
[Change Values](#)

Rise of the Cities



● Cities newly added to each map are in blue.

Rise of the Cities

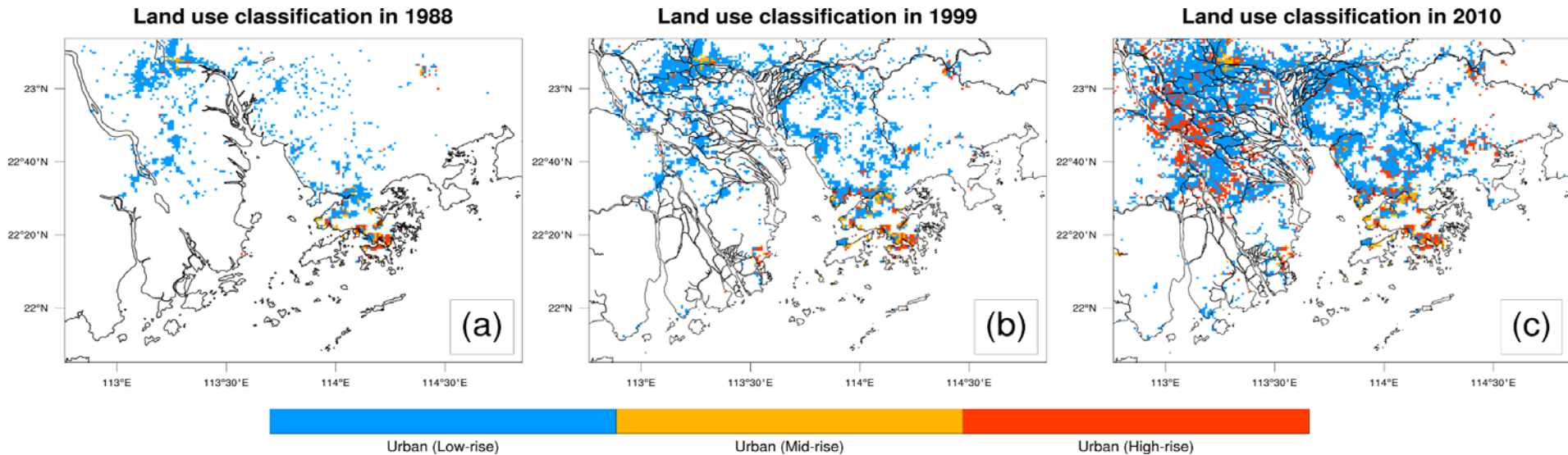


2011

442 cities have population more than 1 million

THE **FIVE** NATIONS WITH THE MOST CITIES OF ONE MILLION OR MORE:
CHINA **89** , India **46** , U.S. **42** , Brazil **21** , Mexico **12**.

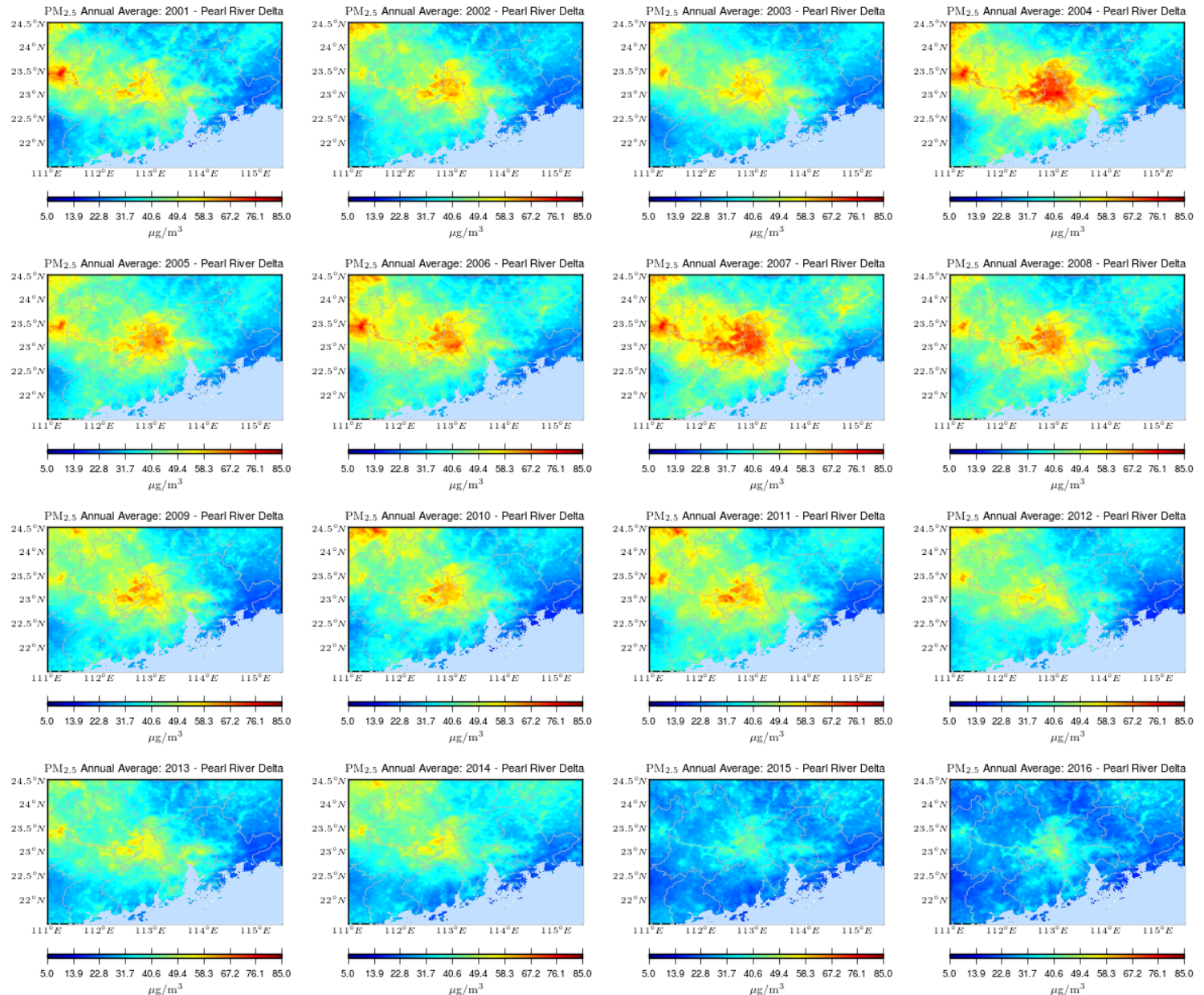
Rapid development over PRD during the past 20 years



The classification of land use in PRD region in year (a) 1988, (b) 1999 and (c) 2010.

Ground-level concentration of PM_{2.5} using satellite remote sensing (2001-2016)

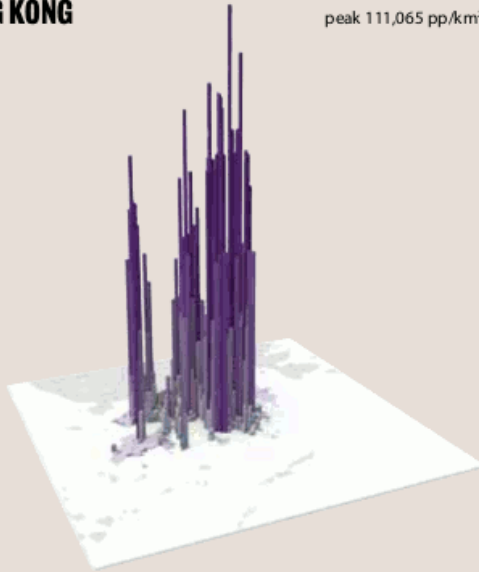
PRD



Urban is only small fraction of Earth's surface (**0.5%**), but with **> 50%** of the world population (3.42b)
Cities have a different **population/morphology** in their built environment

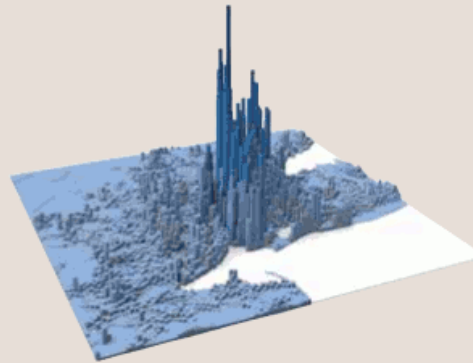
HONG KONG

peak 111,065 pp/km²



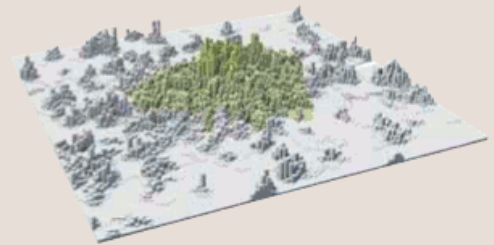
NEW YORK CITY

peak 58,530 pp/km²



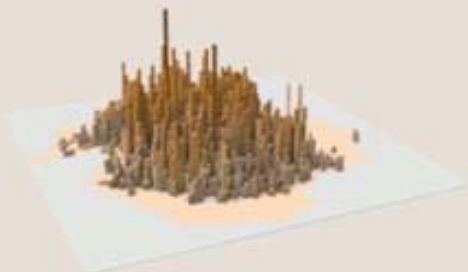
LONDON

peak 17,324 pp/km²



MEXICO CITY

peak 49,088 pp/km²



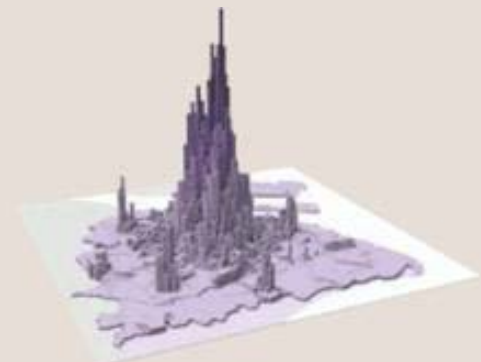
SÃO PAULO

peak 29,704 pp/km²



SHANGHAI

peak 74,370 pp/km²



Challenge: Urban Air Pollution

Heavy traffic activities



Trapped by complex morphology



- High Population Density
- High Rise Buildings
- High Pollution
- Highly Heterogeneous Environment

Rapidly changing exposure patterns



Key questions

Where are they exposed to the highest dose of air pollutants?

Targeted Exposure Management !!

Current AQ information available to the public in Hong Kong

<http://www.aqhi.gov.hk/en.html>

Current AQHI: General Stations: 6 to 8 Roadside Stations: 6 to 7



Causeway Bay AQHI 7

Past 24 hrs Concentration / AQHI

Hourly concentration ($\mu\text{g}/\text{m}^3$)

NO ₂	206.2	PM _{2.5}	45.8
SO ₂	13.8	PM ₁₀	64.3
O ₃	13.3		

FORECAST of Health Risk

22-10-2017	Tomorrow A.M.	Tomorrow P.M.
General Stations	Low	Low to Moderate
Roadside Stations	Low	Low to Moderate



Air Quality Health Index

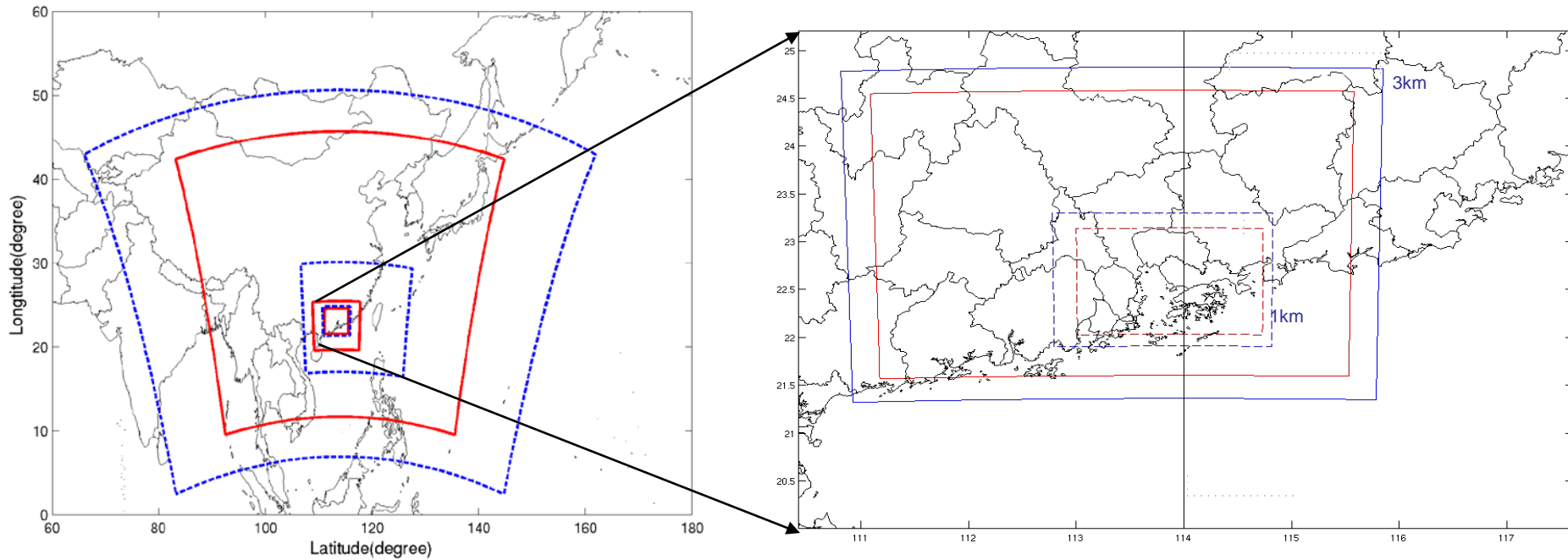
16:00 22-10-2017		AQHI	Health Risk
General Stations	Central/Western	6	Moderate
	Eastern	6	Moderate
	Kwun Tong	6	Moderate
	Sham Shui Po	6	Moderate
	Kwai Chung	6	Moderate
	Tsuen Wan	6	Moderate
	Tseung Kwan O	6	Moderate
	Yuen Long	7	High
	Tuen Mun	8	Very High
	Tung Chung	7	High
	Tai Po	6	Moderate
	Sha Tin	6	Moderate
	Tap Mun	6	Moderate
	Causeway Bay	7	High
Roadside Stations	Central	6	Moderate
	Mong Kok	6	Moderate

What it does not have?

- **Location specific** air quality forecasts
- How much **pollutant** an individual is getting (personalized exposure information) from its daily activity?
- **Personalized air quality health impact alert** for sensitive persons

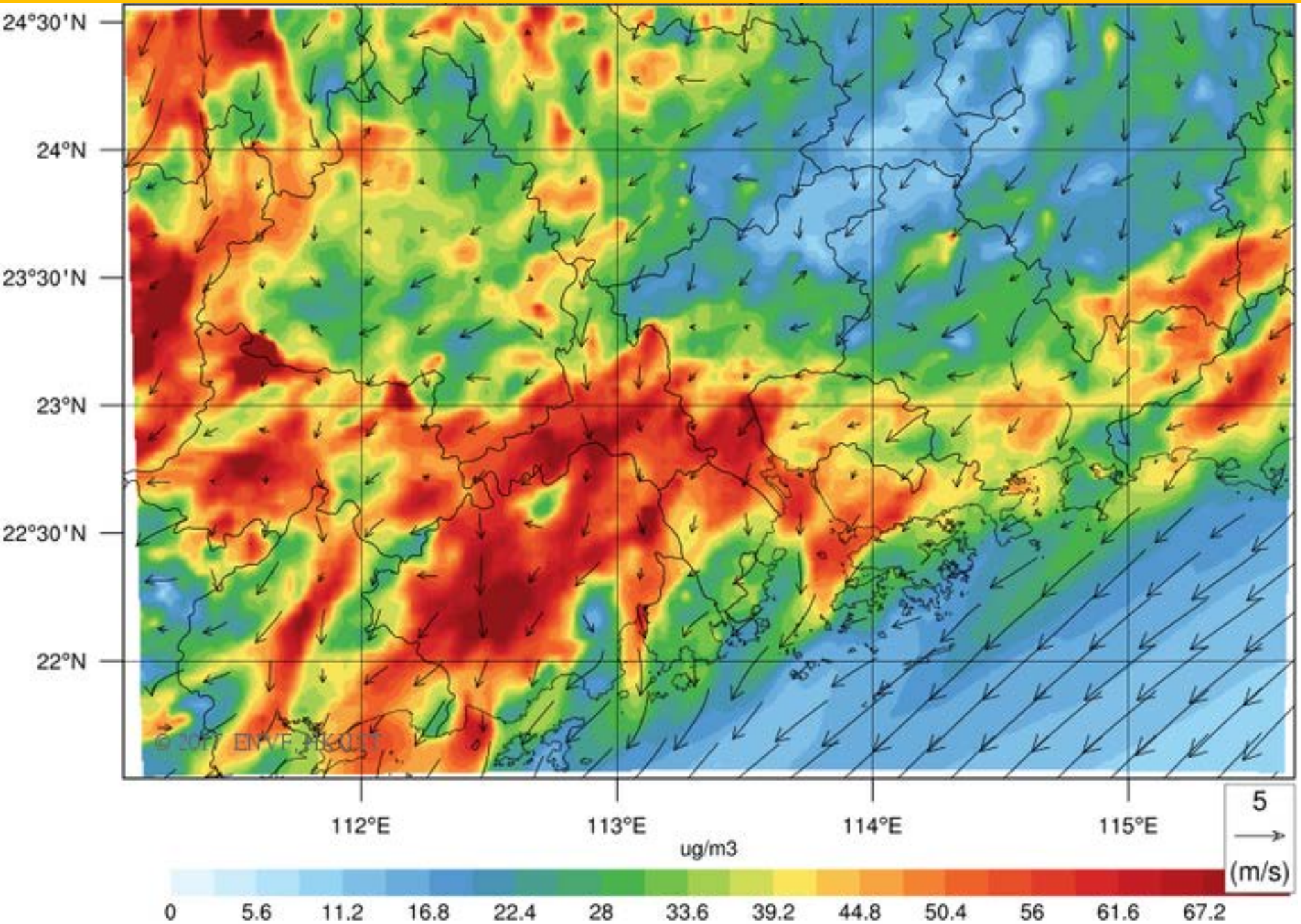
**Regional Air Quality Forecasts
with
resolution down to 1km**

Domain configuration



27km → 9km → 3km → 1km

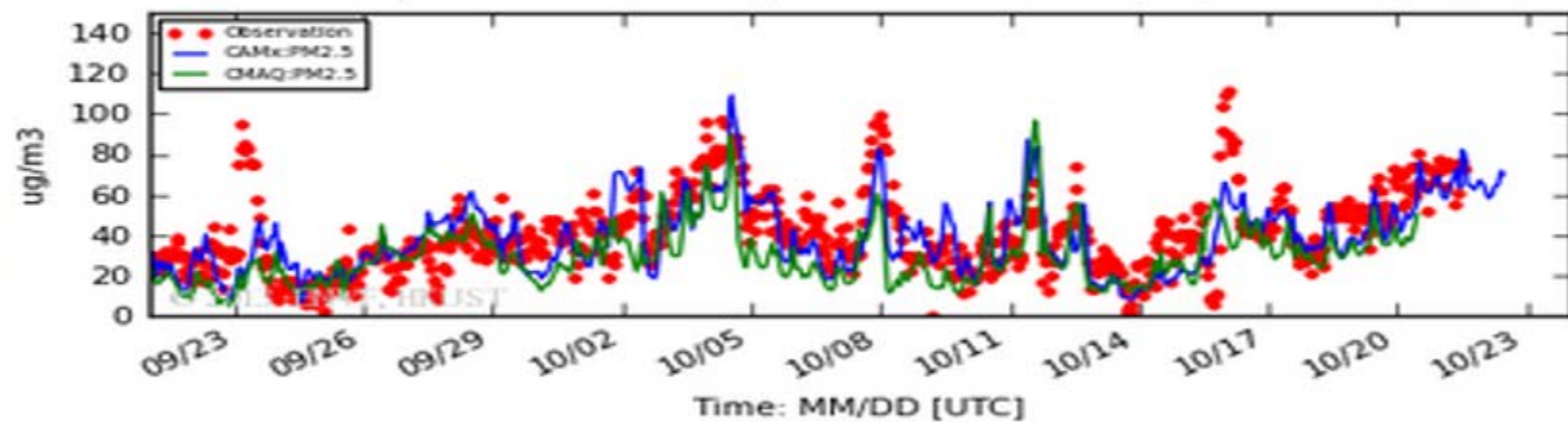
PM2.5 concentration of CMAQ simulation



Monthly comparison between observed and forecasted PM2.5

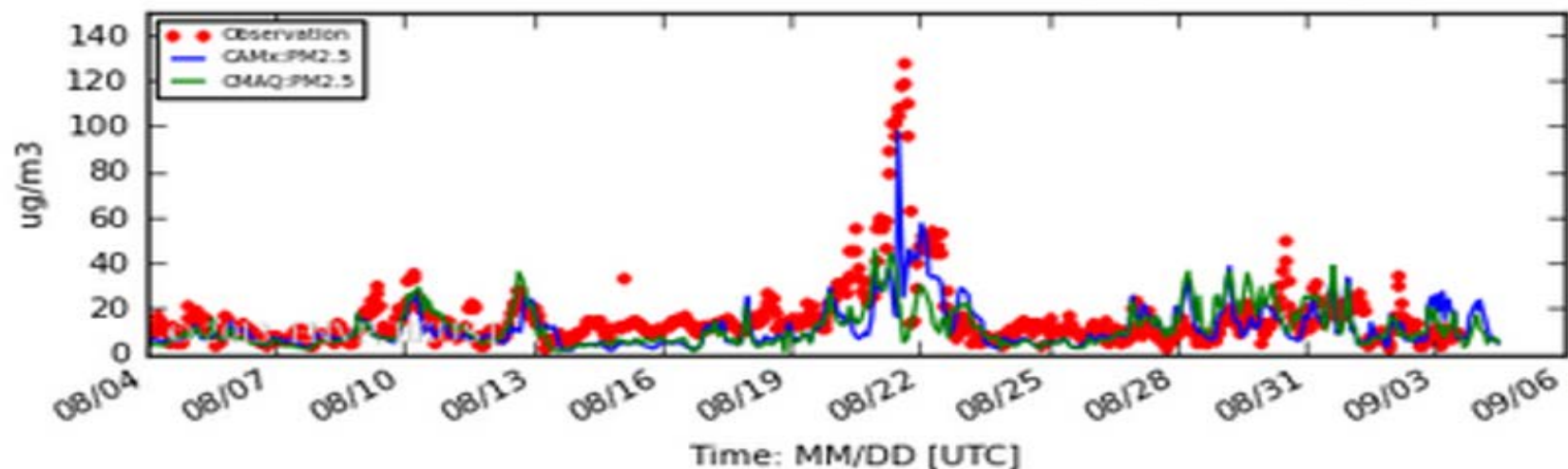
Kwai Chung

Kwai Chung - Time Series [Day2] for PM2.5 (2013/09/21 - 2013/10/23)

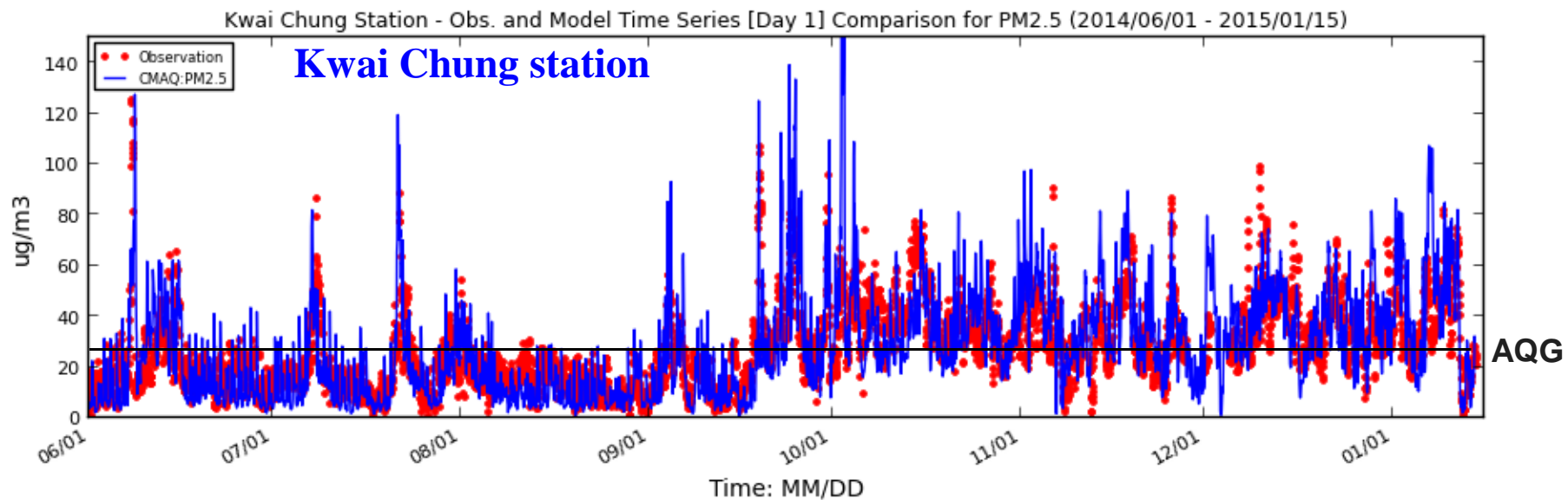
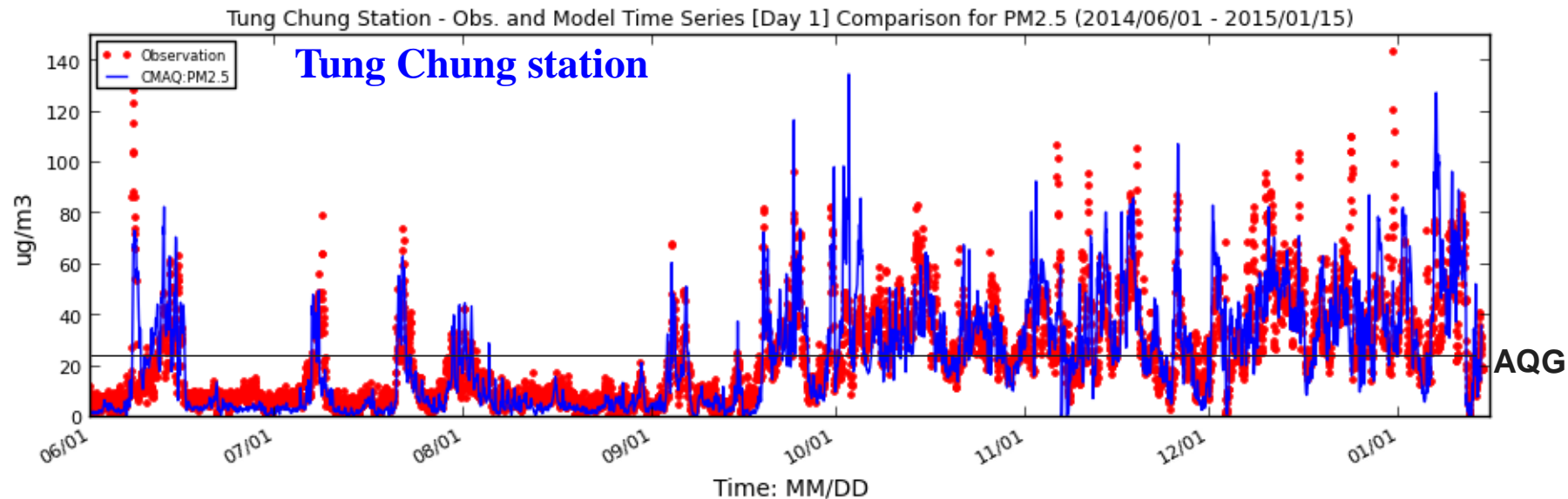


Eastern

Eastern - Time Series [Day2] for PM2.5 (2013/08/04 - 2013/09/05)

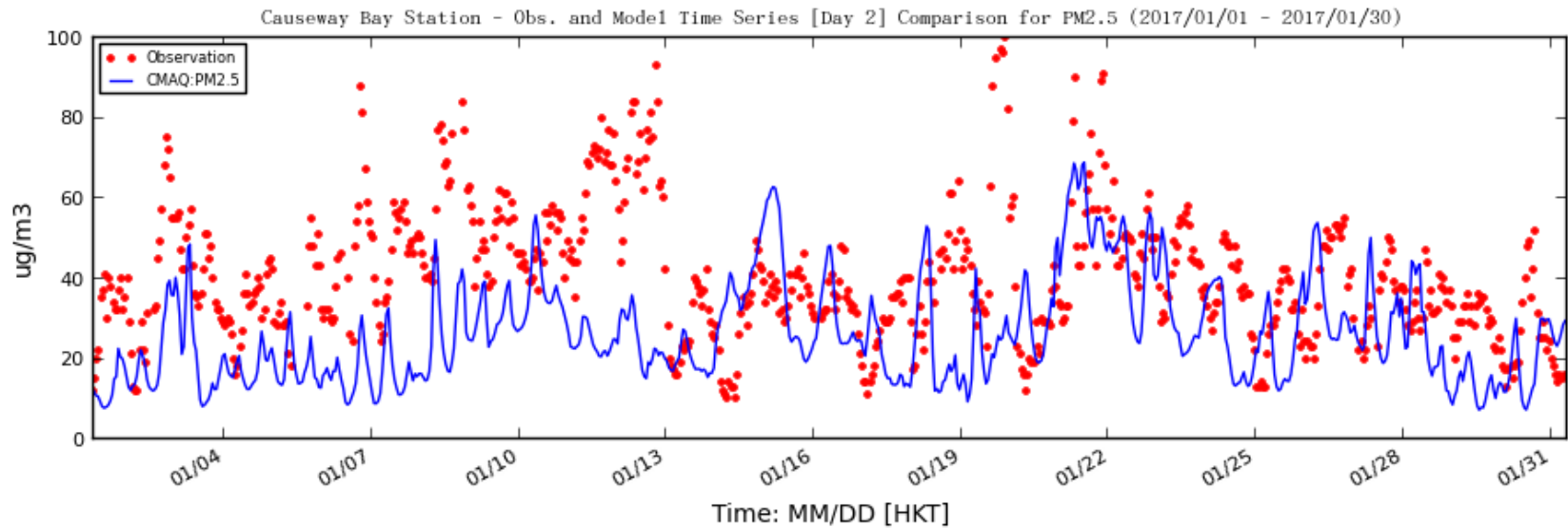


Six months of forecast results of PM2.5

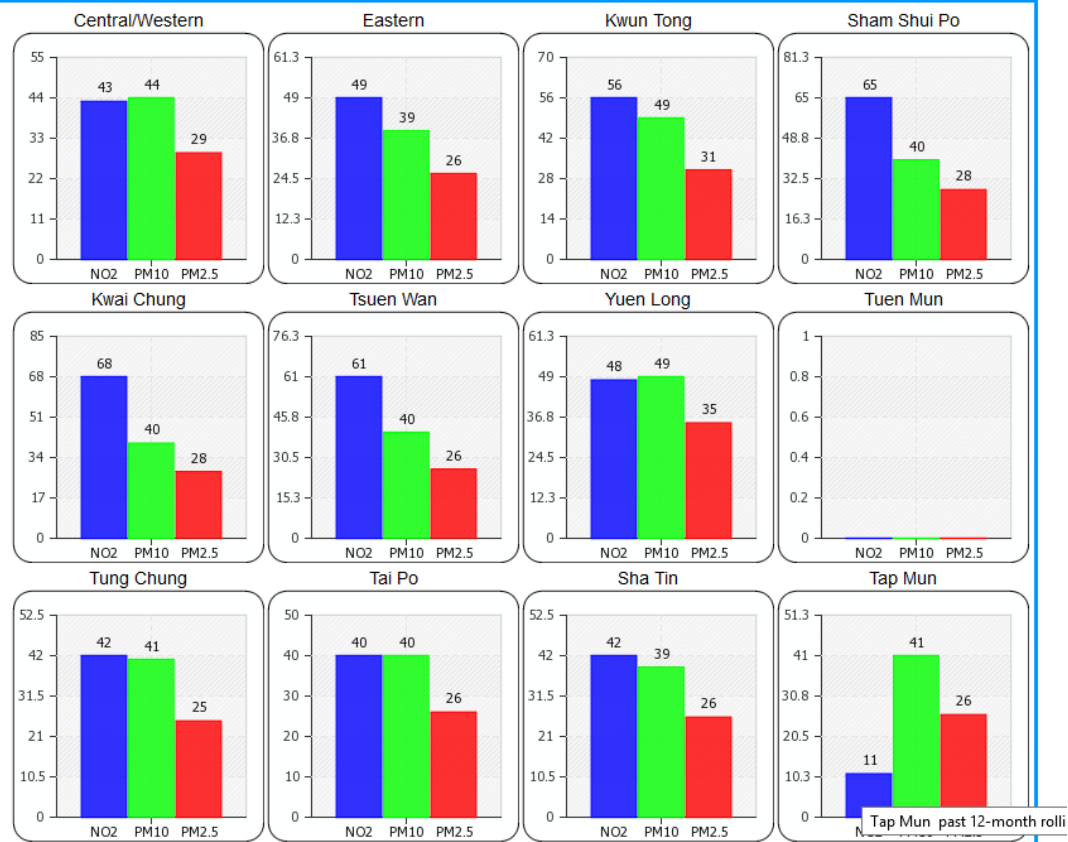


Roadside forecast results from Jan 1 – Jan 31

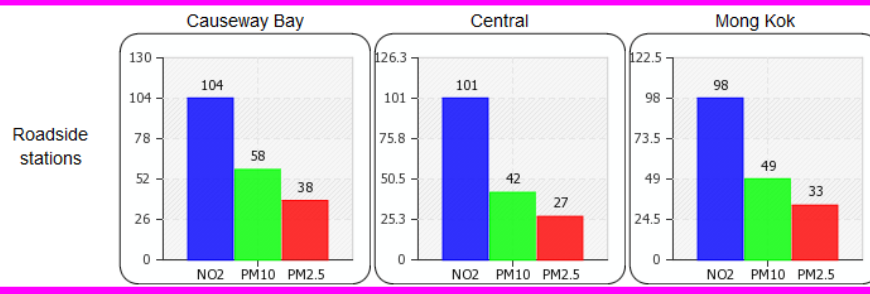
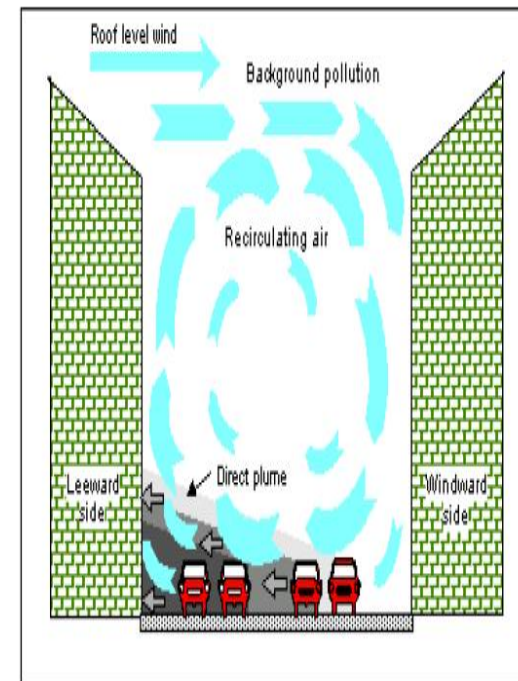
Roadside Causeway Bay monitoring station



General Stations



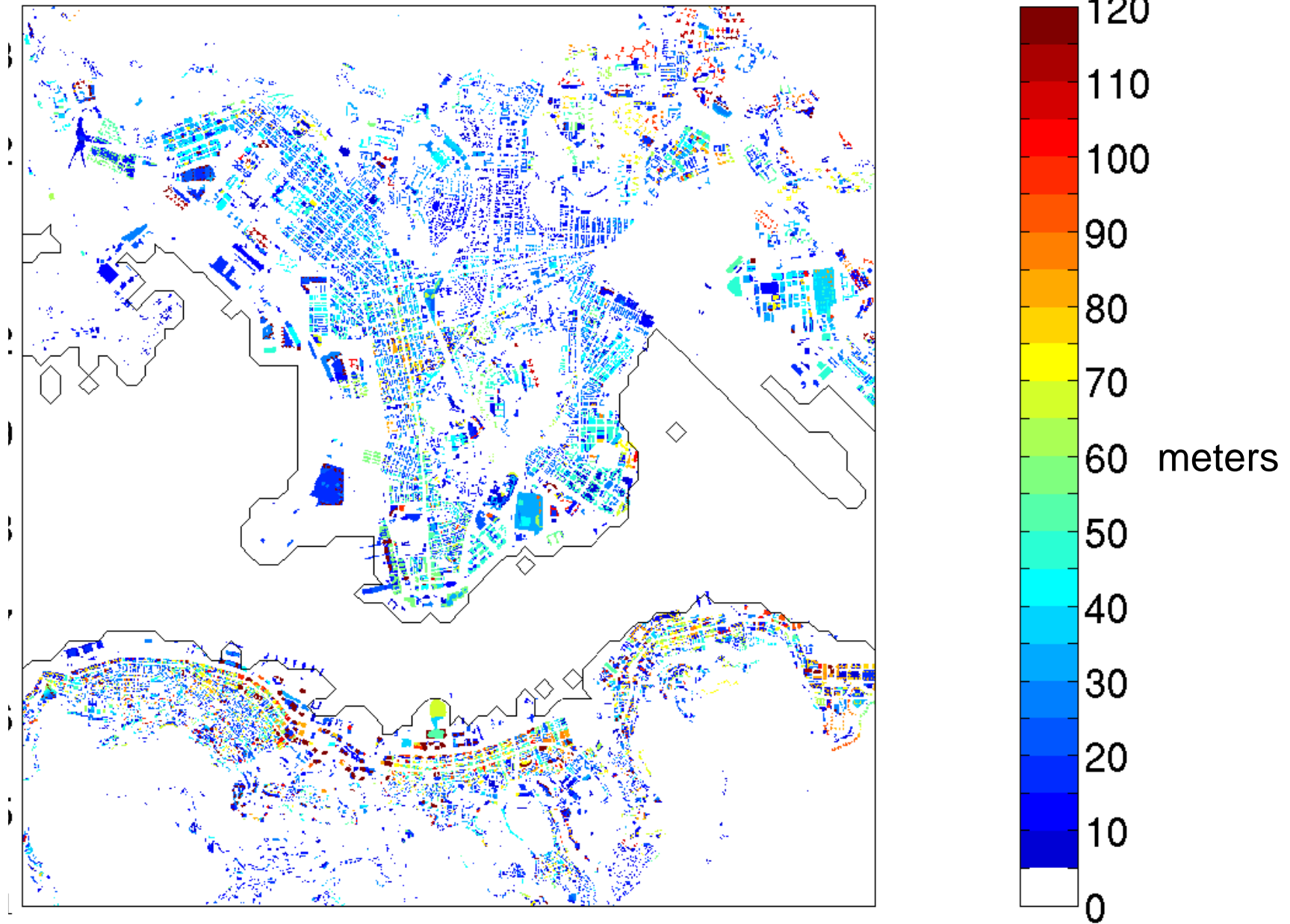
Deep street canyon



Roadside Stations

	Annual WHO AQG ($\mu\text{g}/\text{m}^3$)
Nitrogen Dioxide(NO_2)	40
PM_{10}	20
$\text{PM}_{2.5}$	10

Hong Kong building heights



大氣監測走航平台 (MAP)

Mobile Air-monitoring Platform



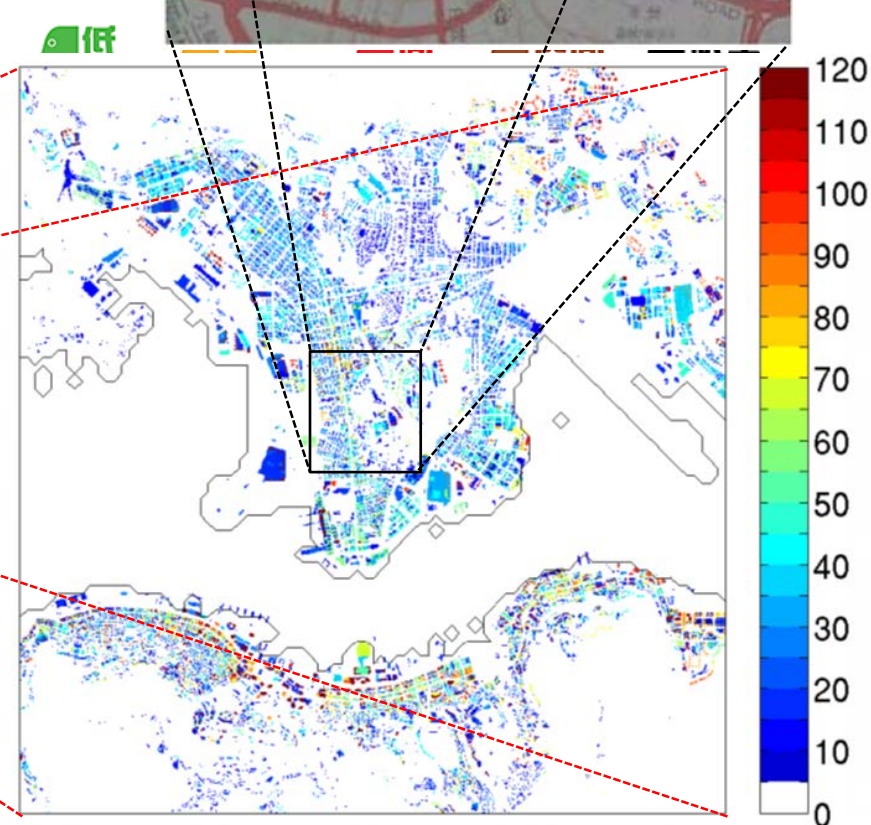
Current AQ information the public in Hong

**There are large variabilities
in Air Quality that the current
AQMS network cannot show**



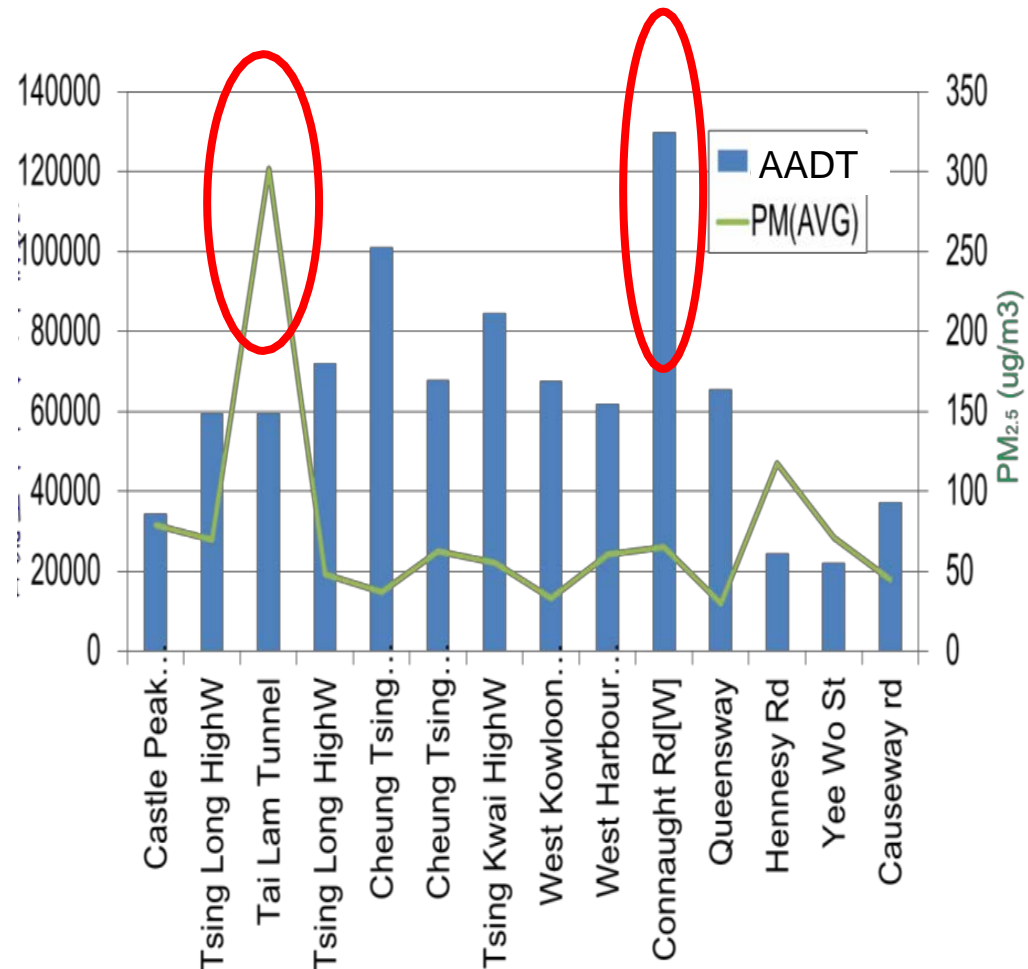
Remark:

- (1) The AQHI information is based on raw data taken directly from EPD's Air Quality Monitoring Network.
- (2) The hourly reported AQHI is for short term health risk communication; for health risks of long-term exposure of the air quality, please refer to [Annual Air Quality Index \(Annual AQI\)](#).
- (3) In case of station or equipment suspension due to maintenance, the data collection for calculation of AQHI at station will be affected, the data of a most similar station will then be



Roadway traffic density versus air quality

- Mostly "**linear**" relation between traffic and pollution levels, but sometimes it is not.
- The **dispersion capacity** of the mobile emission is different across roadway network or urban morphology.



Measure PM_{2.5} on a Tram (2013/8 – 2017/9)



Mesurement tram route along HK island



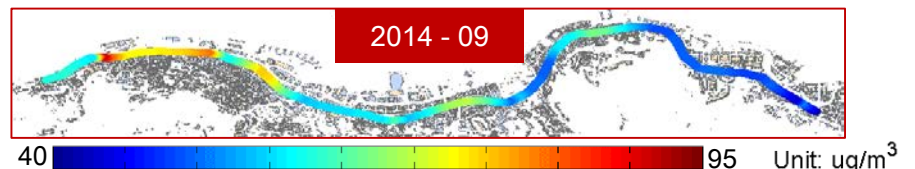
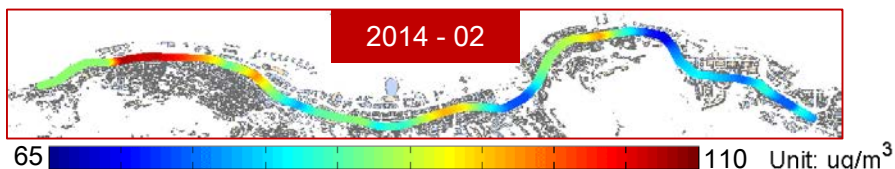
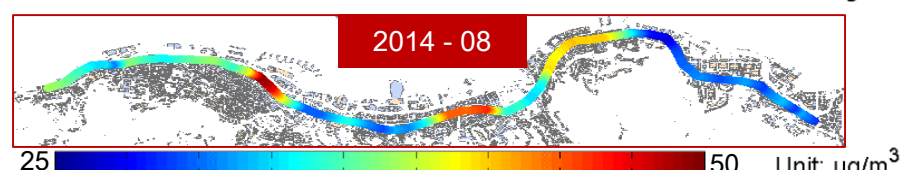
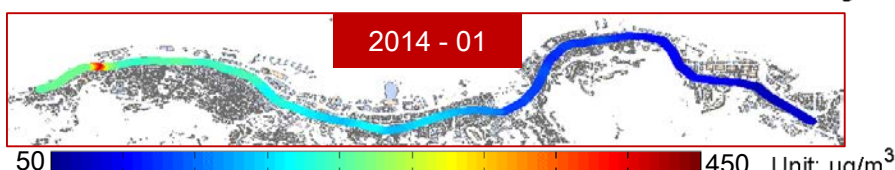
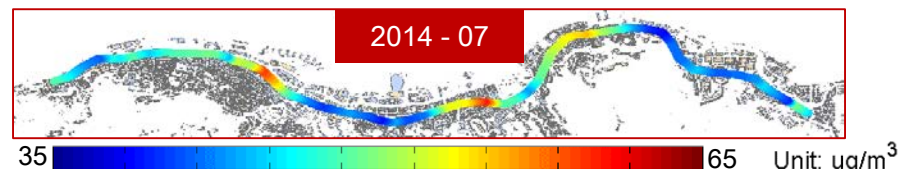
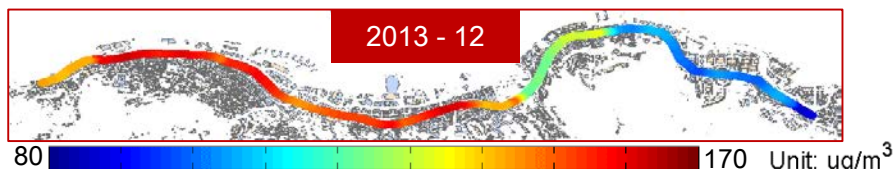
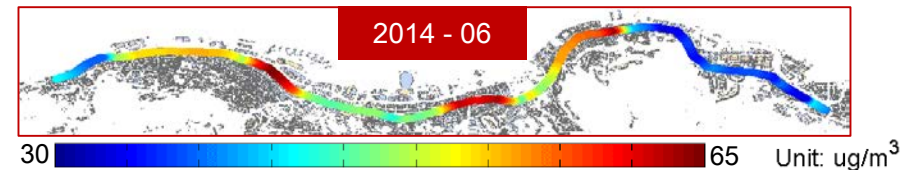
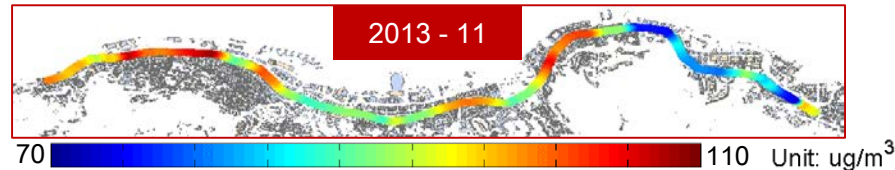
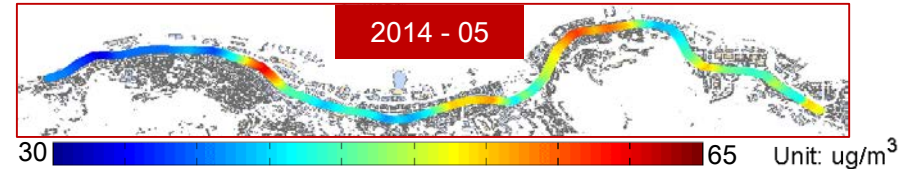
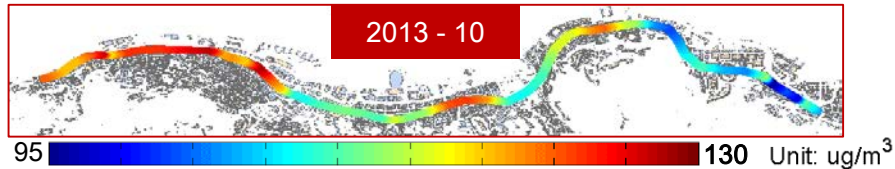
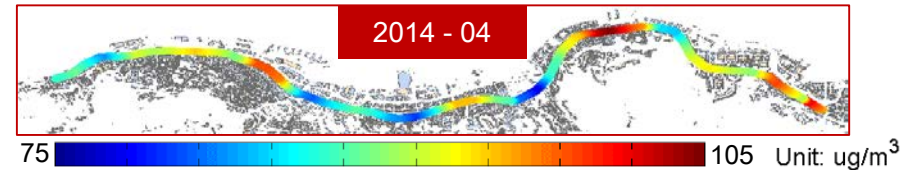
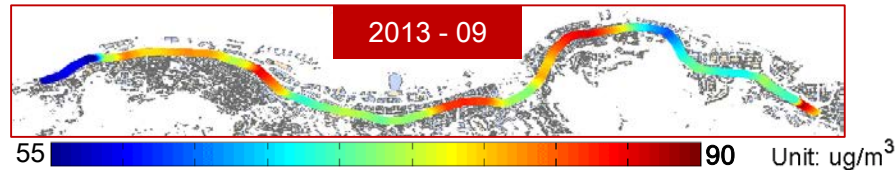
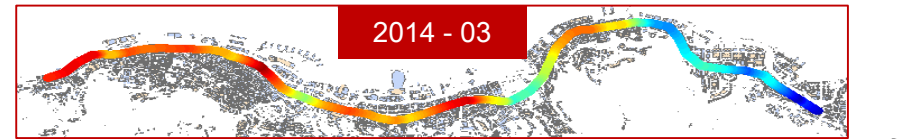
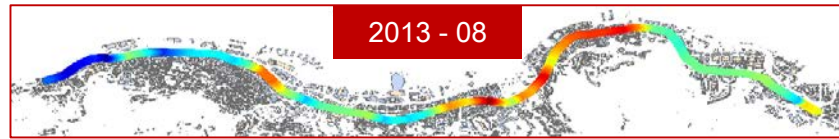
HK Tram PM_{2.5} Fixed by Time Sync Data Display (10m Average: 2013/08/12 14:30 - 2014/03/12 00:00)

No. of Grid Points = 1845

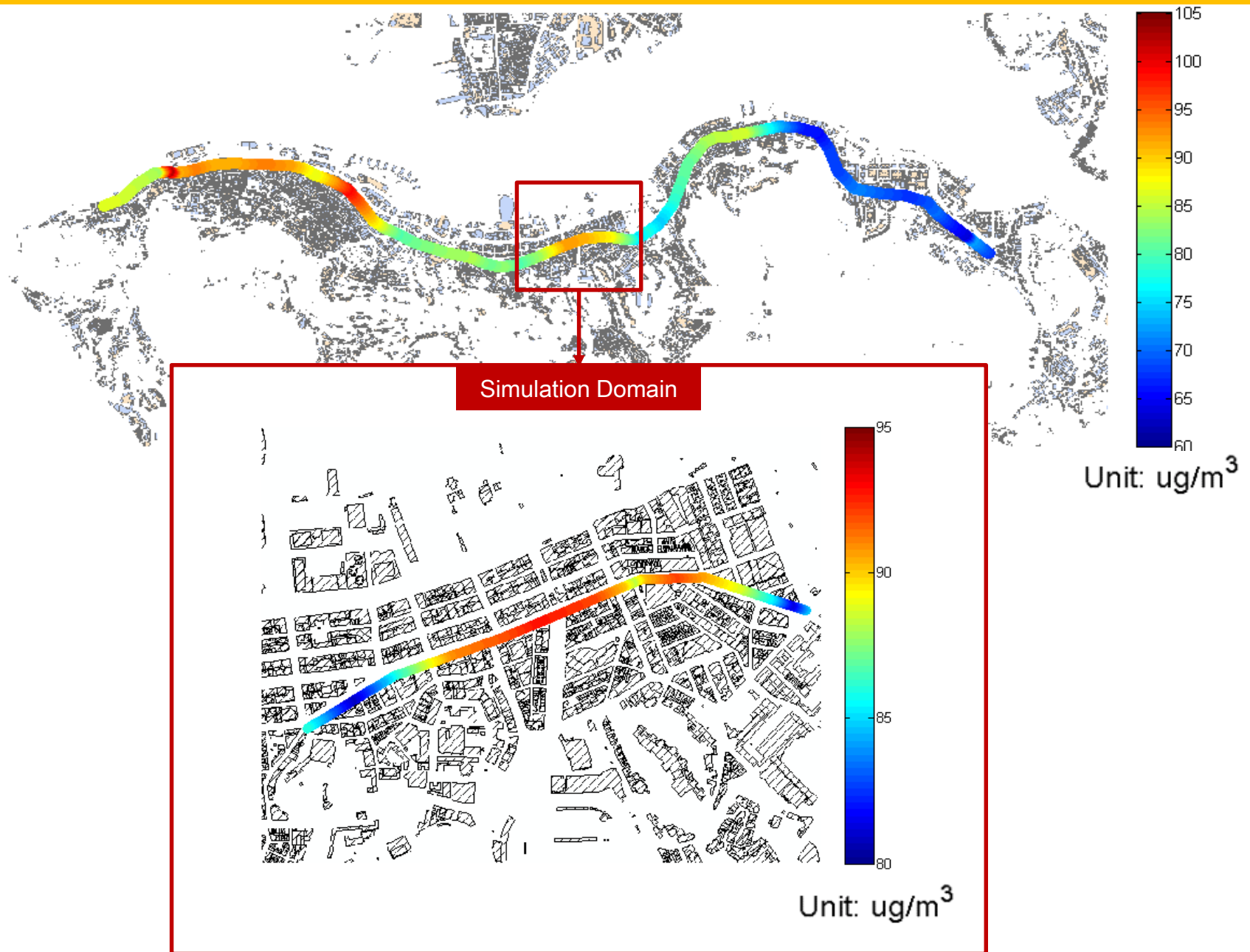


Spatial distribution of monthly mean PM_{2.5} with different color bar

Spatial Pattern is Different in Different Months.



Annual mean PM_{2.5} concentration



Parameterizing urban morphology

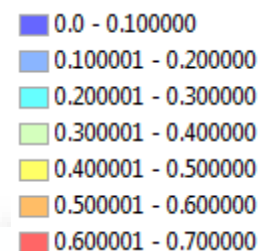
- The area of each grid is around 100x100 m²
- Extract building/ podium plan area inside grid to calculate λ_p .

$$\lambda_p = \frac{\text{Building plan area}}{\text{Total lot area}}$$

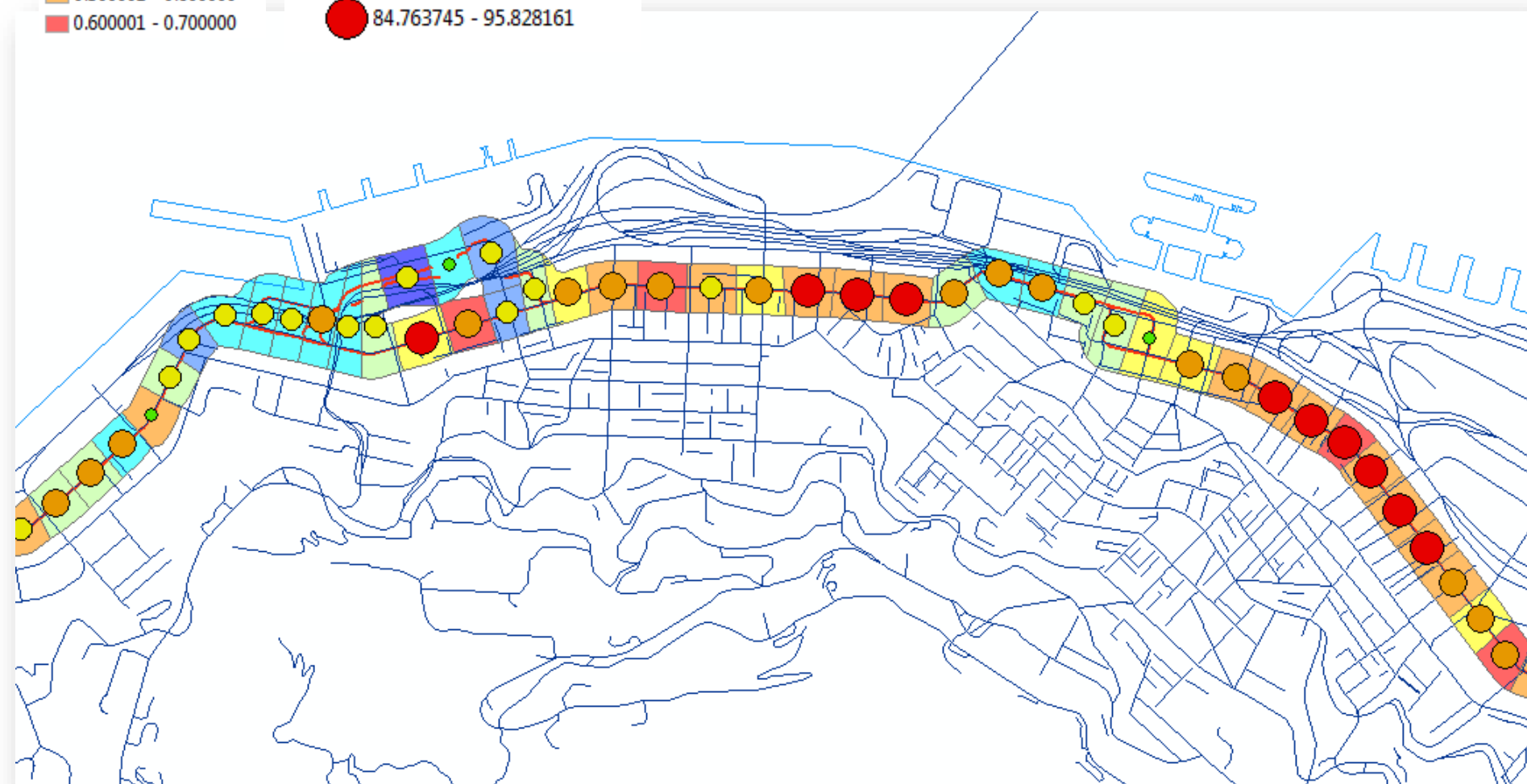
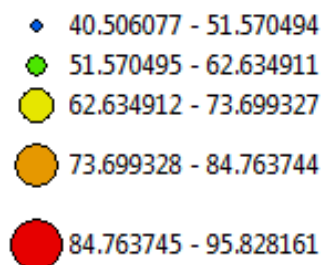


λ_p and average PM_{2.5} in grid

Blockage parameter

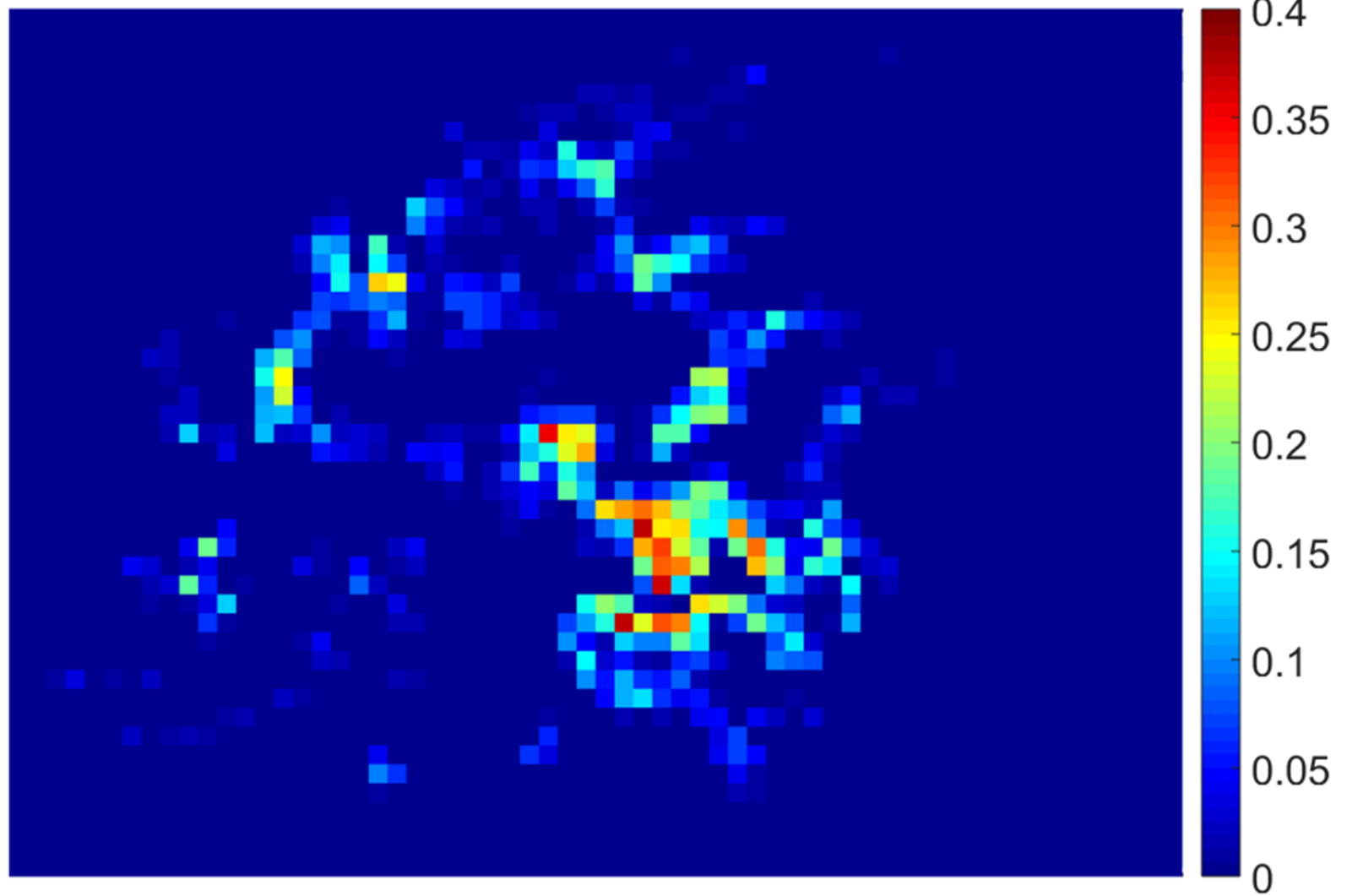


Mean PM_{2.5} concentration

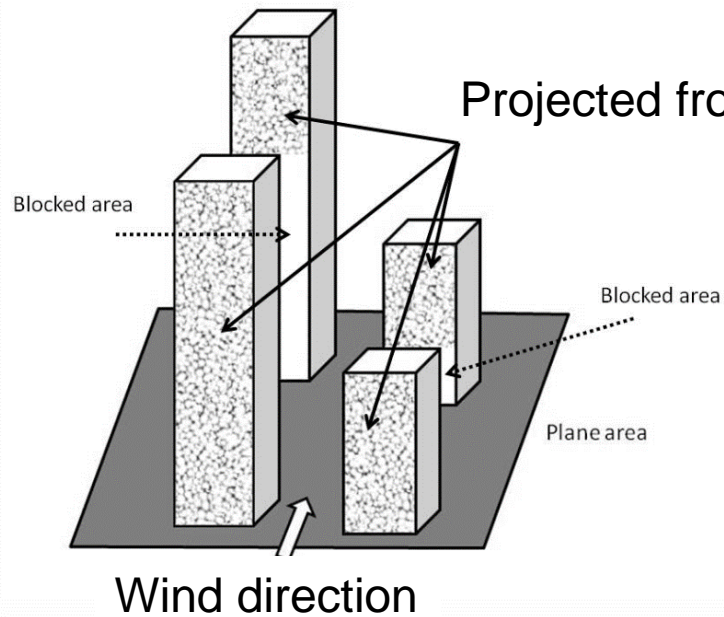


Plan Area Index

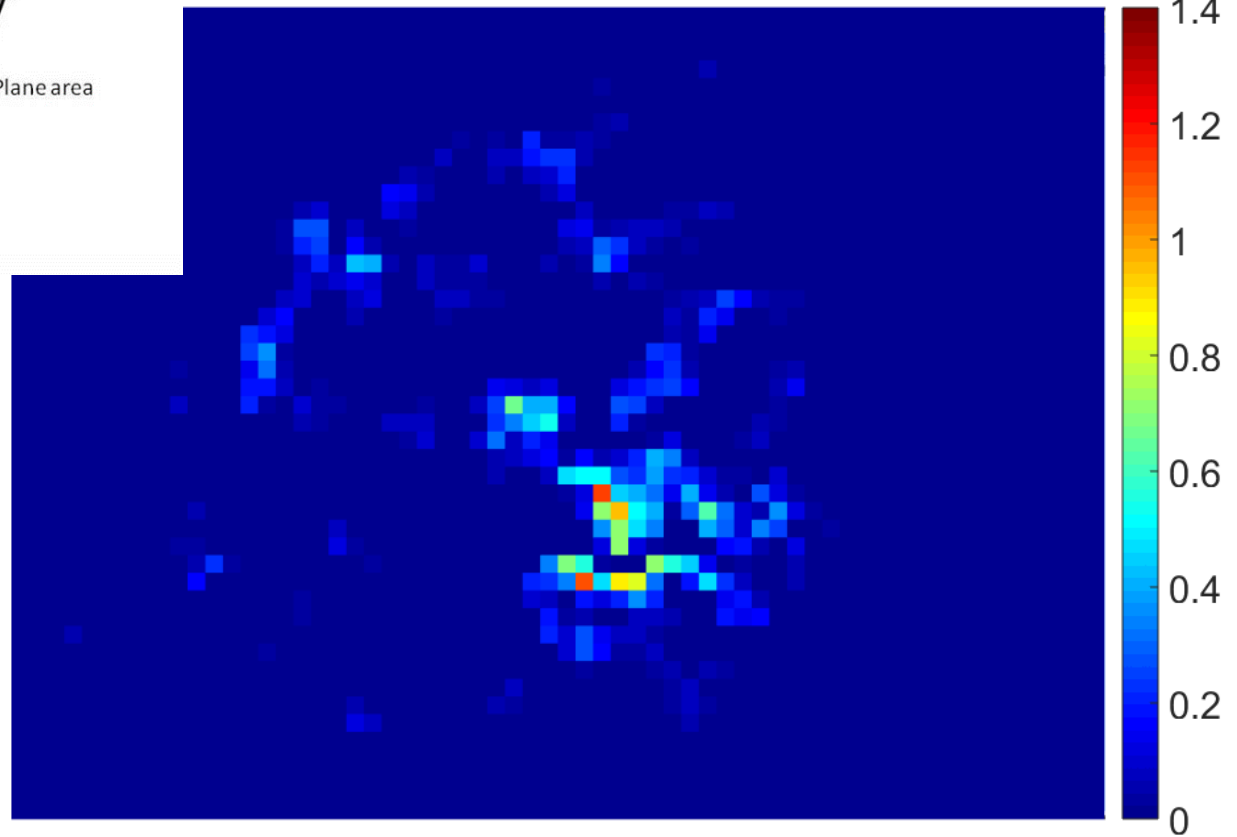
Lambda P



Frontal Area Index with Same Color Bar



$\lambda = \text{Lambda F } 112^\circ\text{-}157^\circ \text{ \& } 292^\circ\text{-}337^\circ$



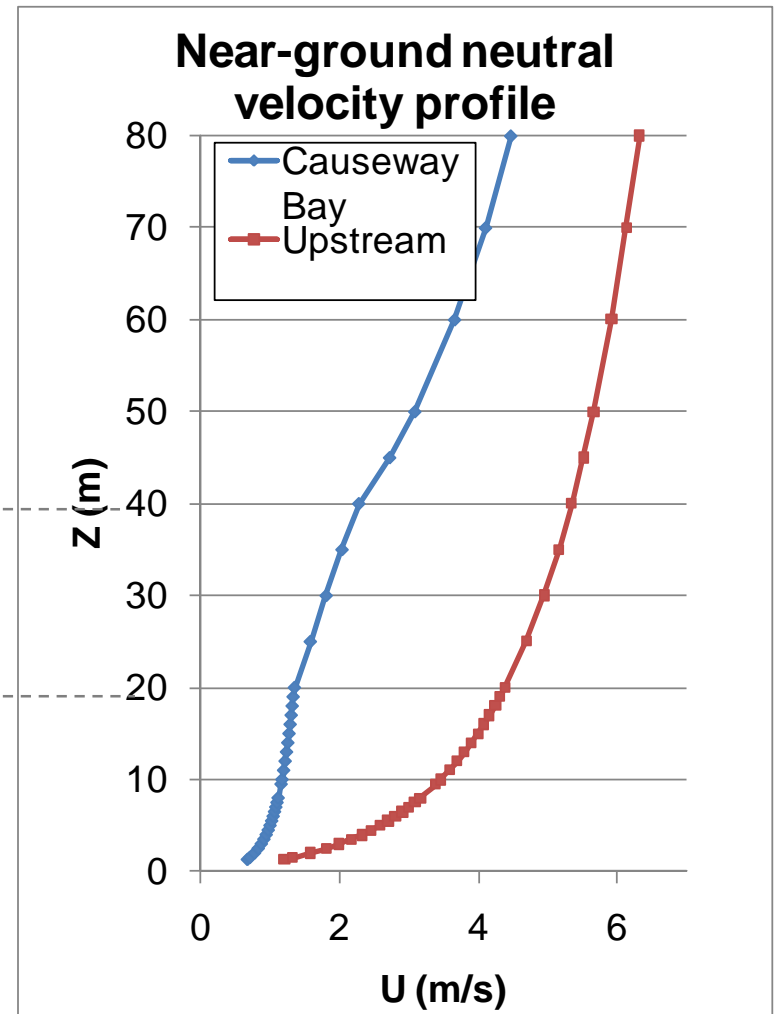
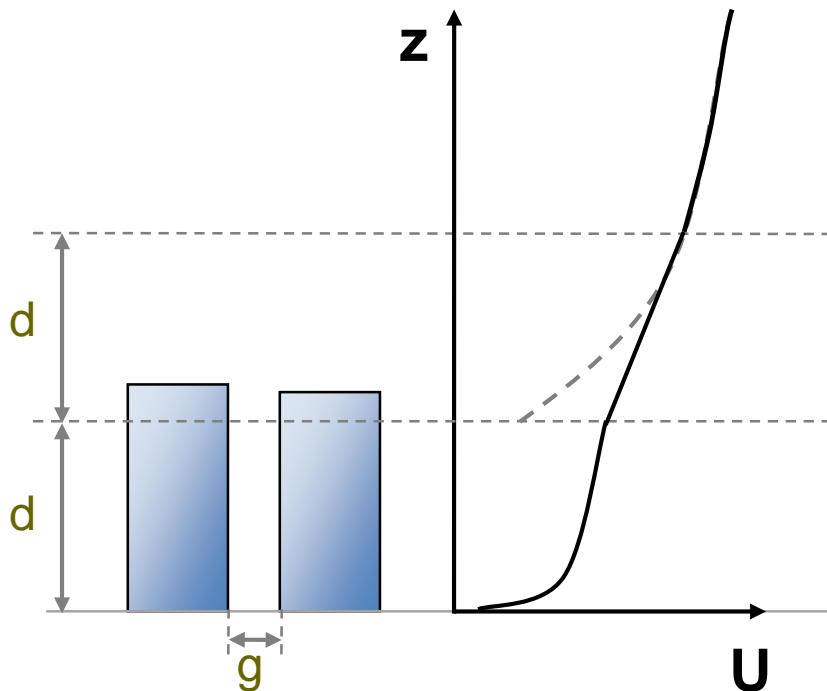
Implementation in ADMS-Urban: Velocity

Full profile: detail near ground

Causeway Bay example cell

H 36.5 m, g 13.5 m, λ_p 0.30, $\lambda_{F(90)}$ 0.80

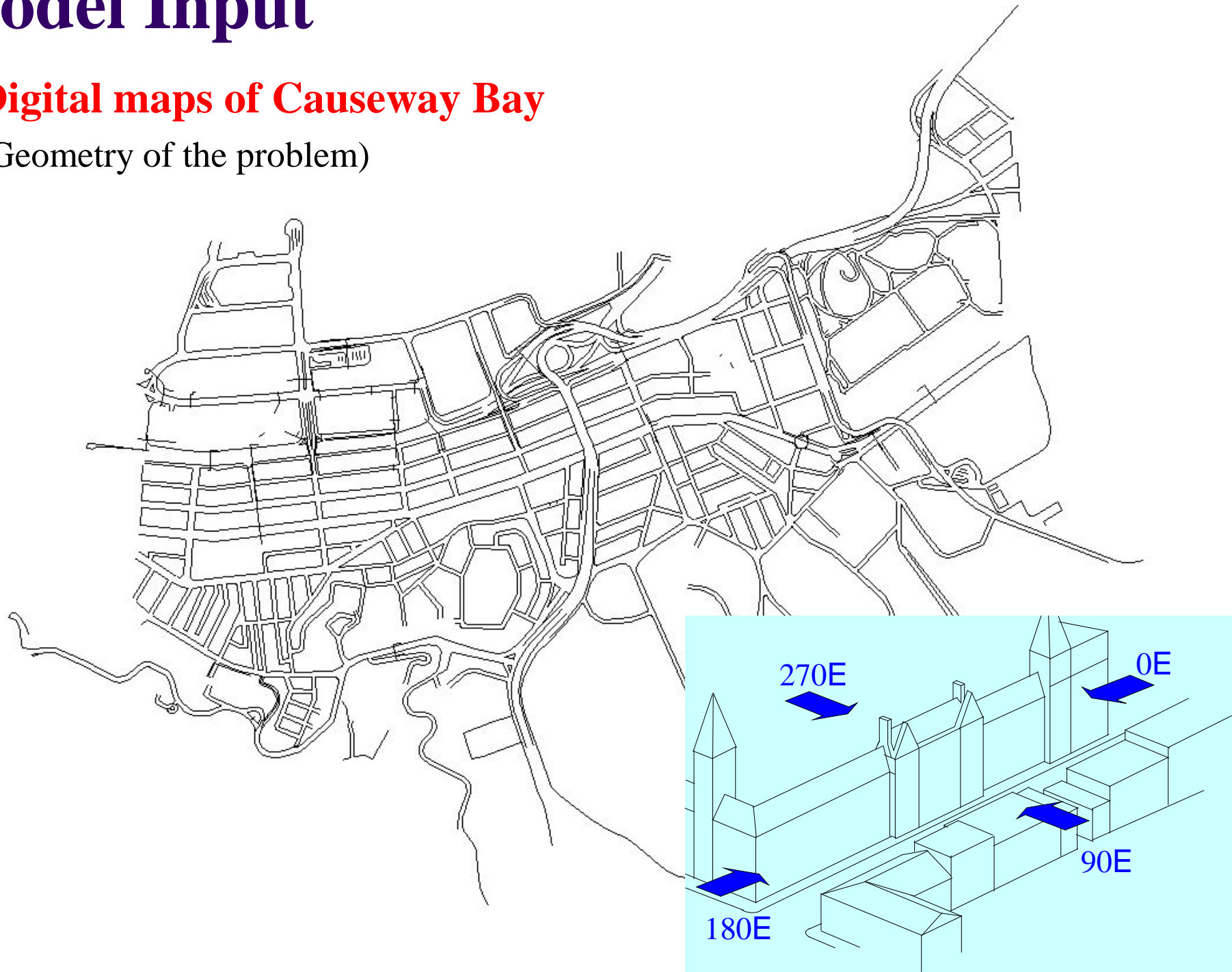
d 19.9 m, z_{0b} 6.5 m



Model Input

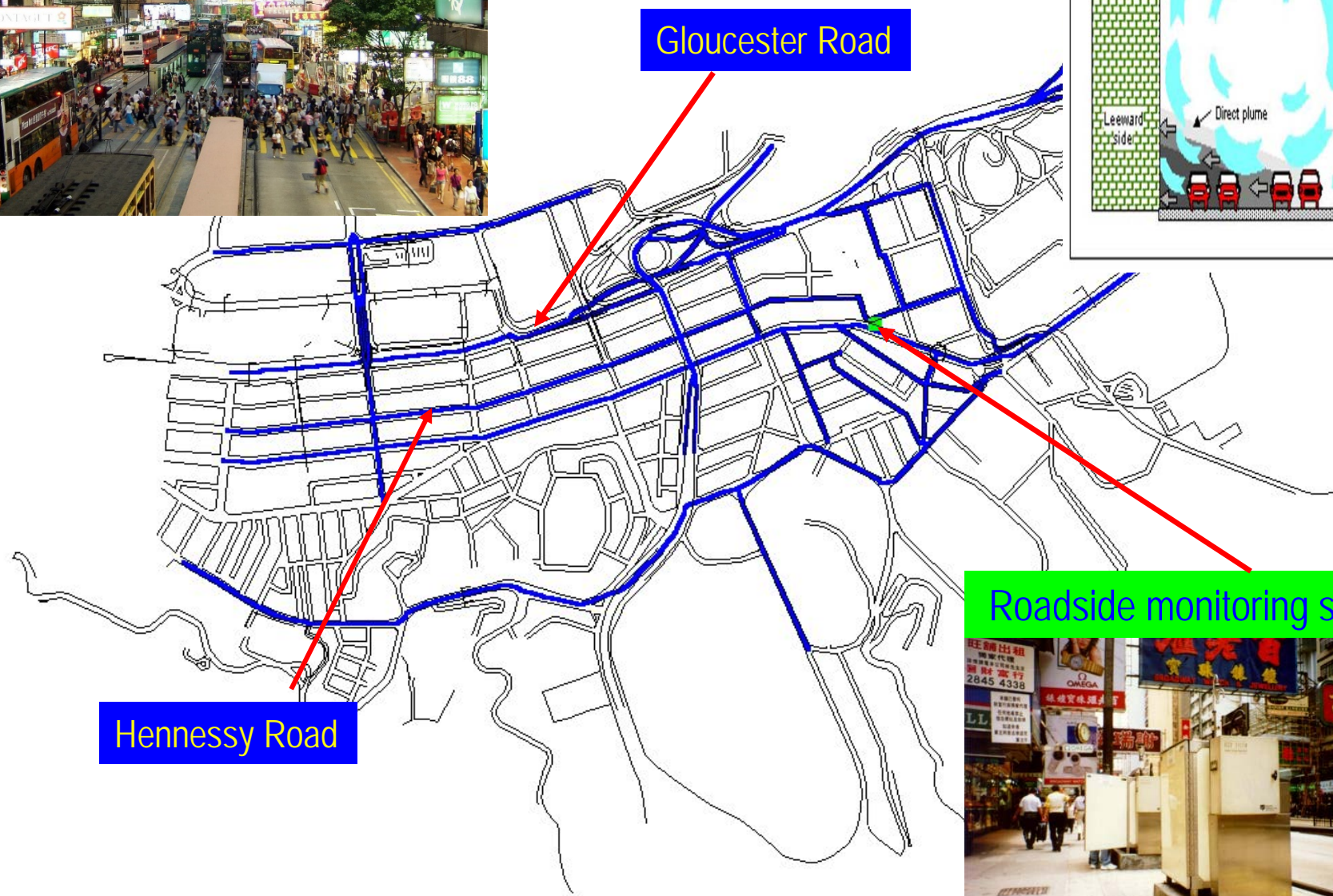
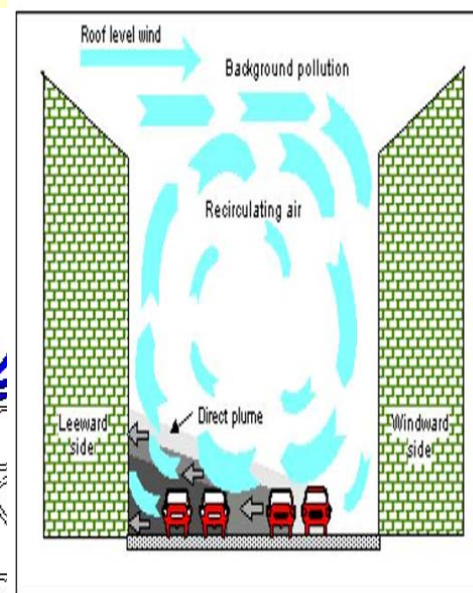
Digital maps of Causeway Bay

(Geometry of the problem)





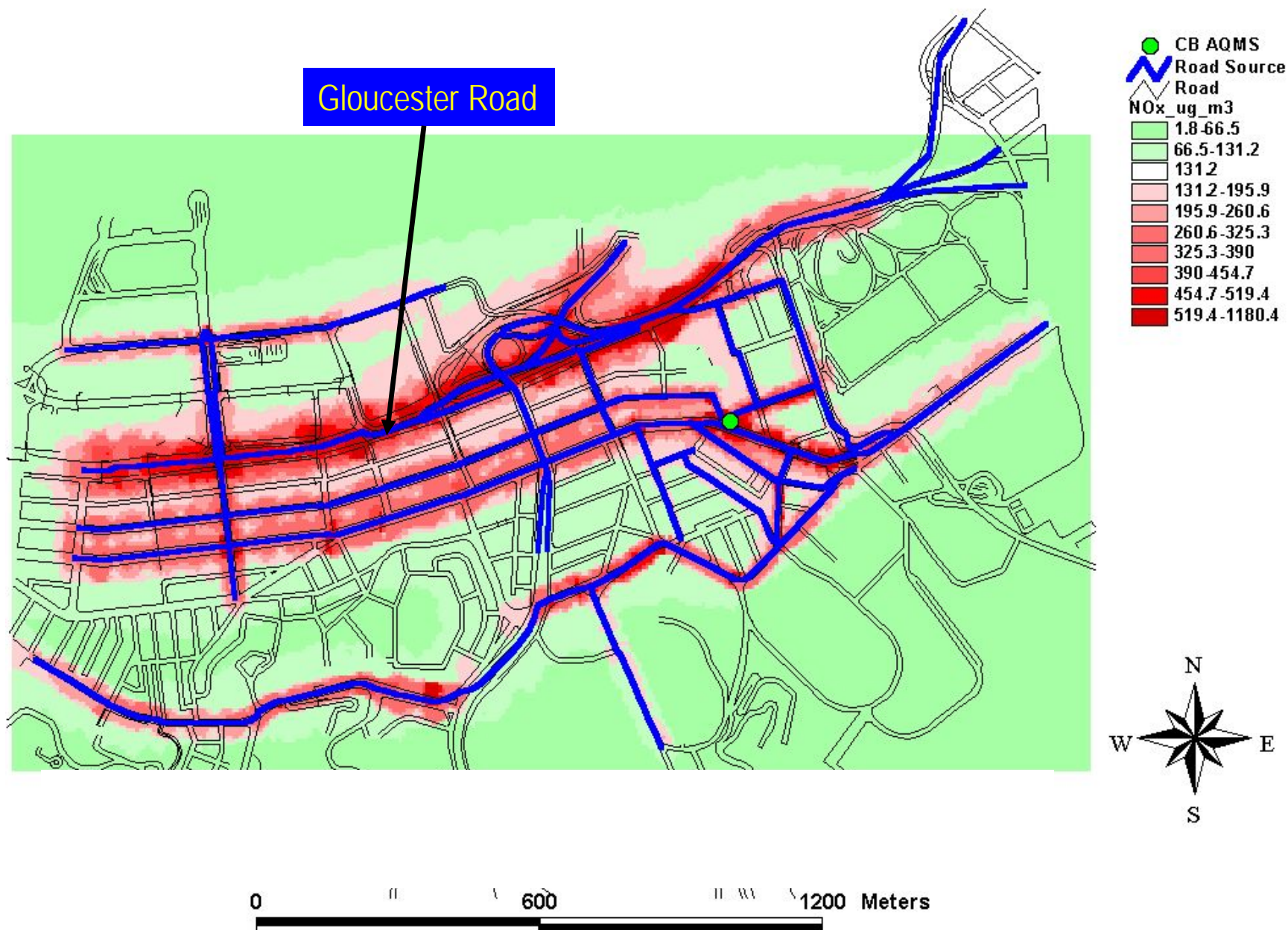
Road network – downtown of HK



Roadside monitoring station

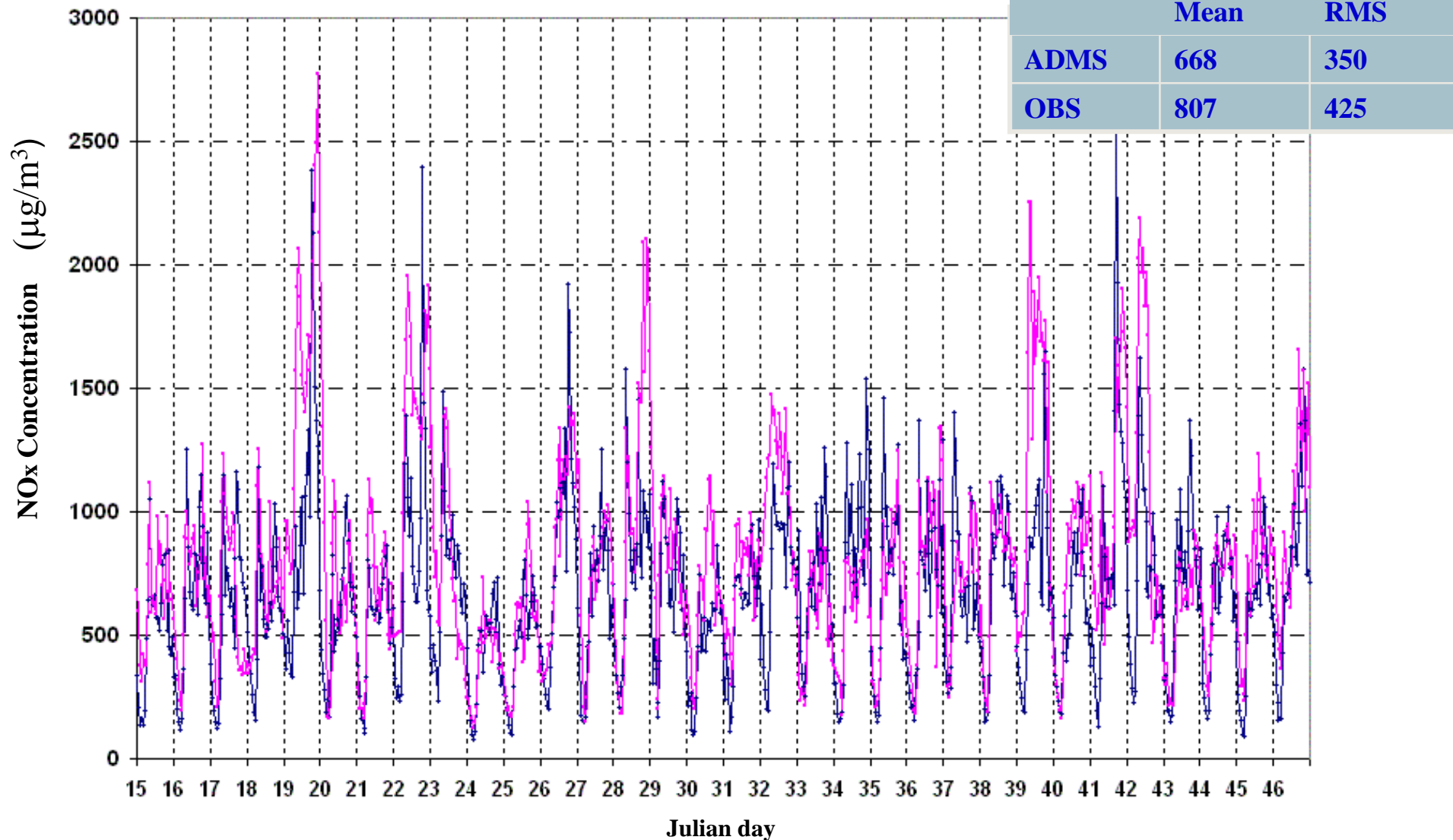


Hourly average contour output of NO_x concentration at Causeway Bay



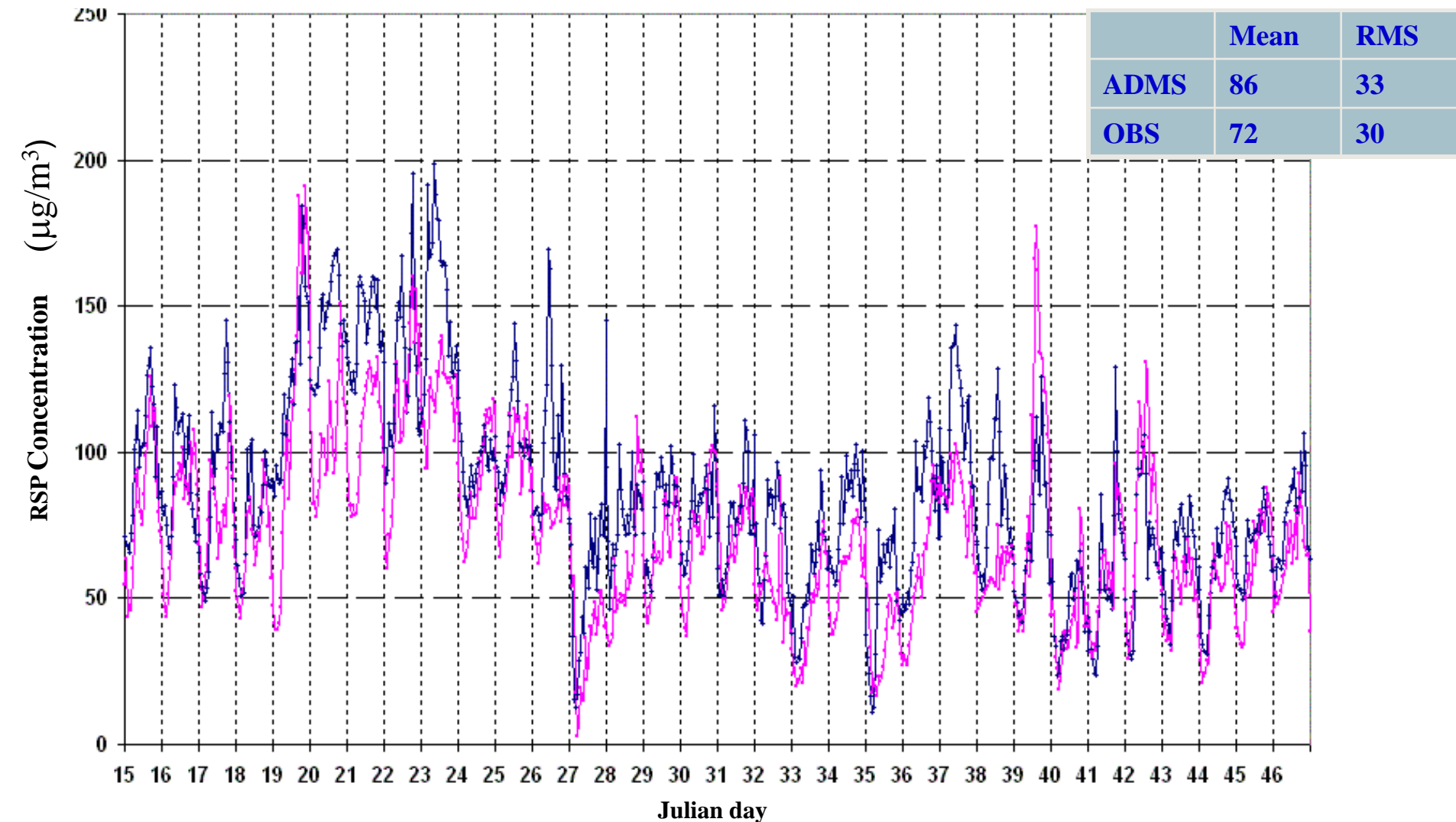
Comparison between simulation and observational concentration of NO_x at the roadside AQMS

Causeway Bay roadside stations (15 Jan – 15 Feb)

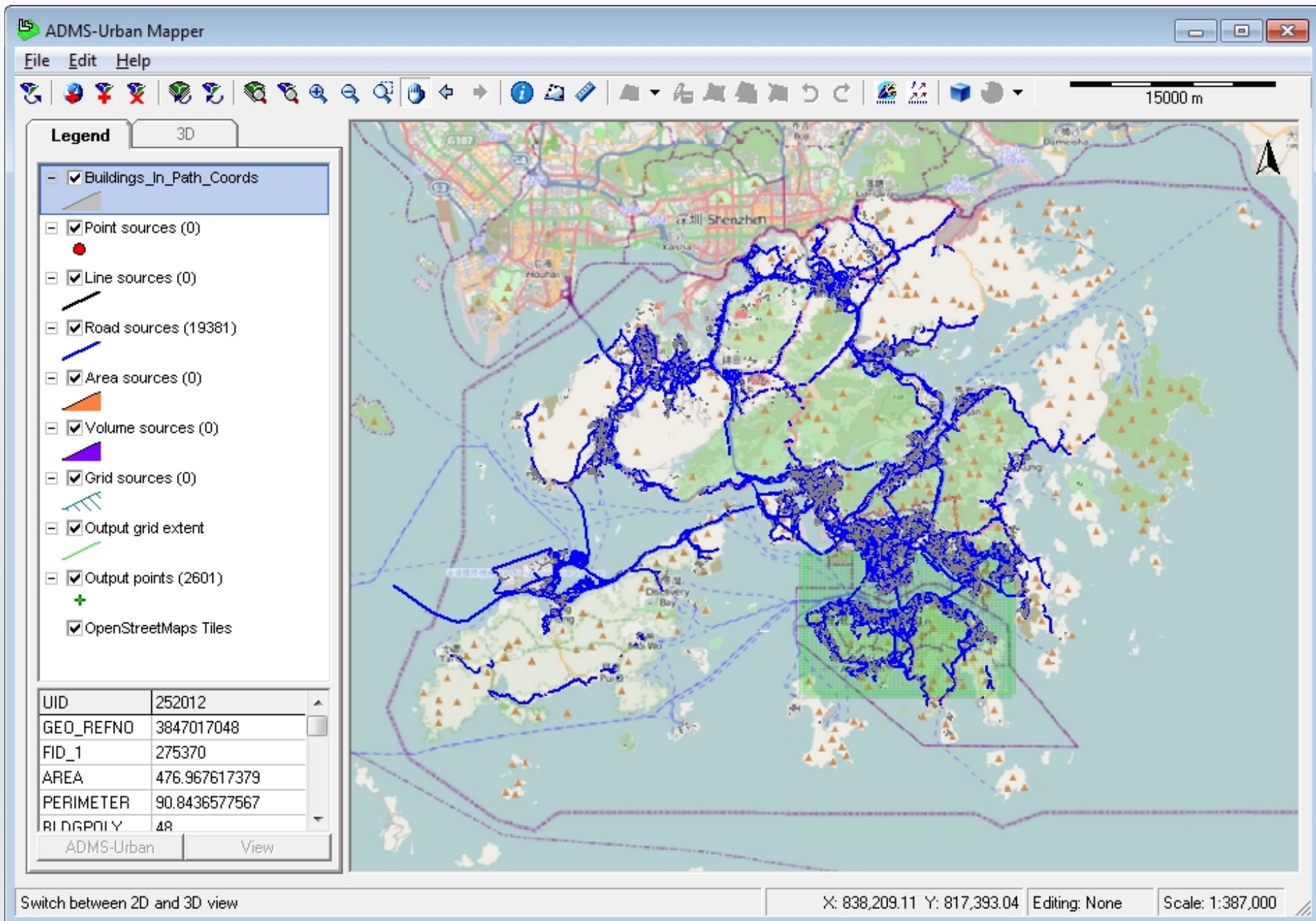


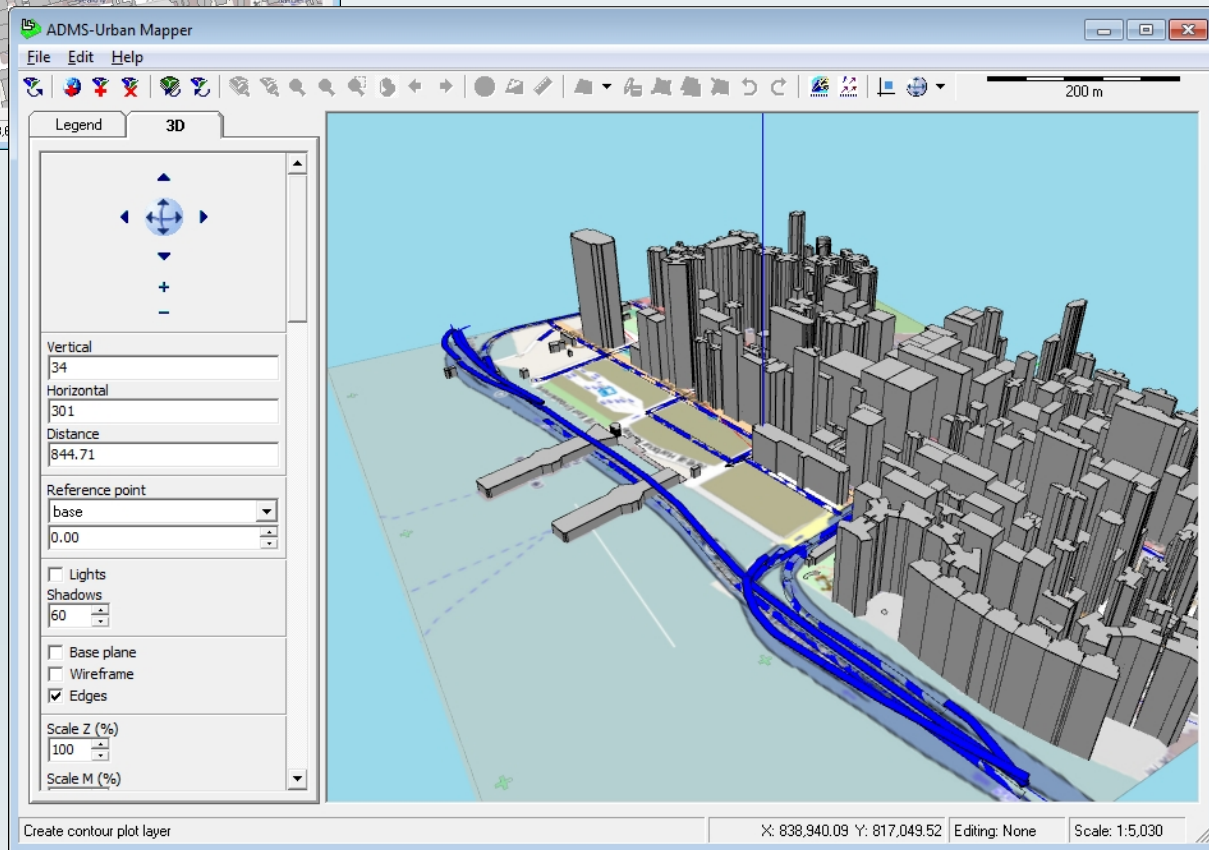
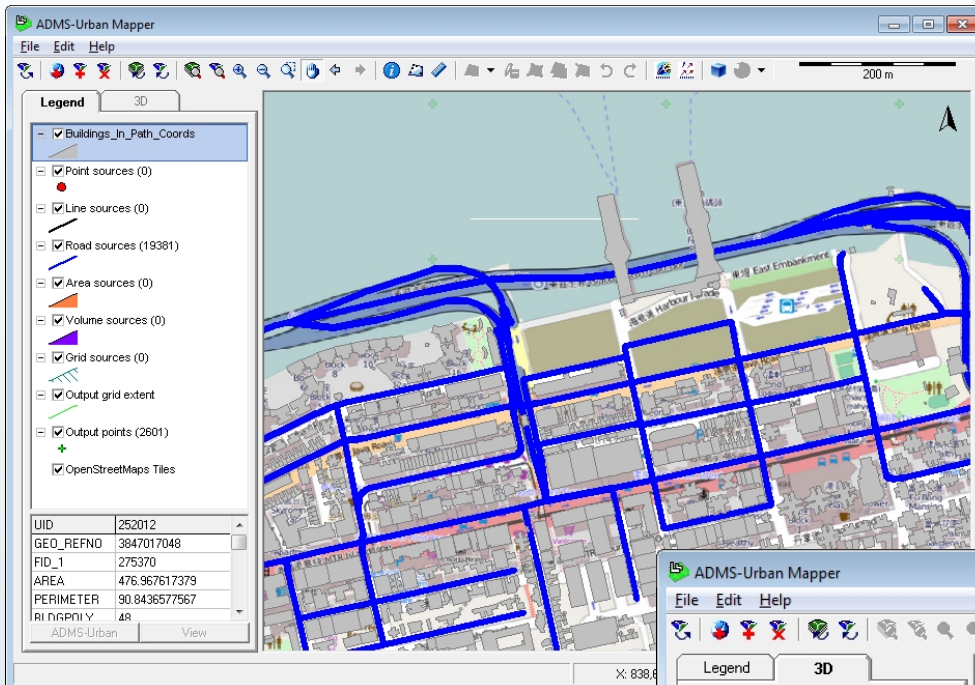
Comparison between **simulation** and **observational** concentration of **PM₁₀** at the roadside AQMS

Causeway Bay roadside stations (15 Jan – 15 Feb)



Road sources are shown as **blue lines**



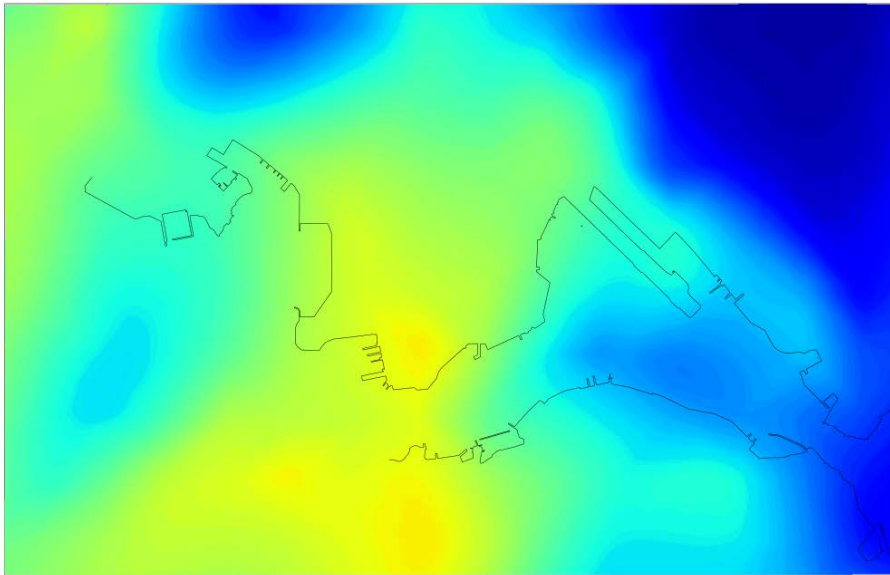


Comparison between CMAQ and ADMS_RML

CMAQ

NO2 Concentration

ug/m3

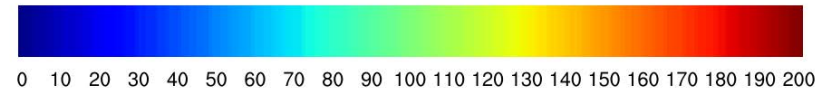
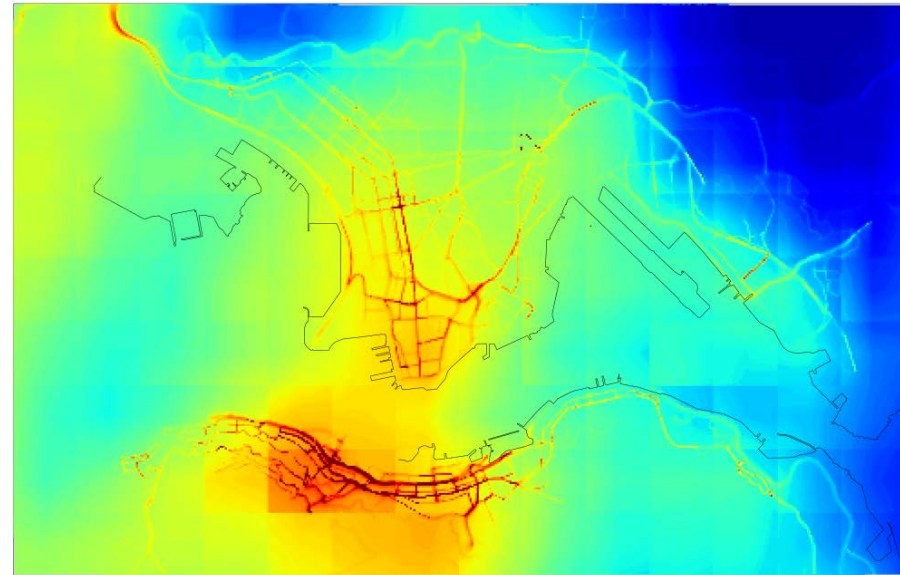


Cannot resolve the mobile source
in street canyon

ADMS-RML

NO2 Concentration

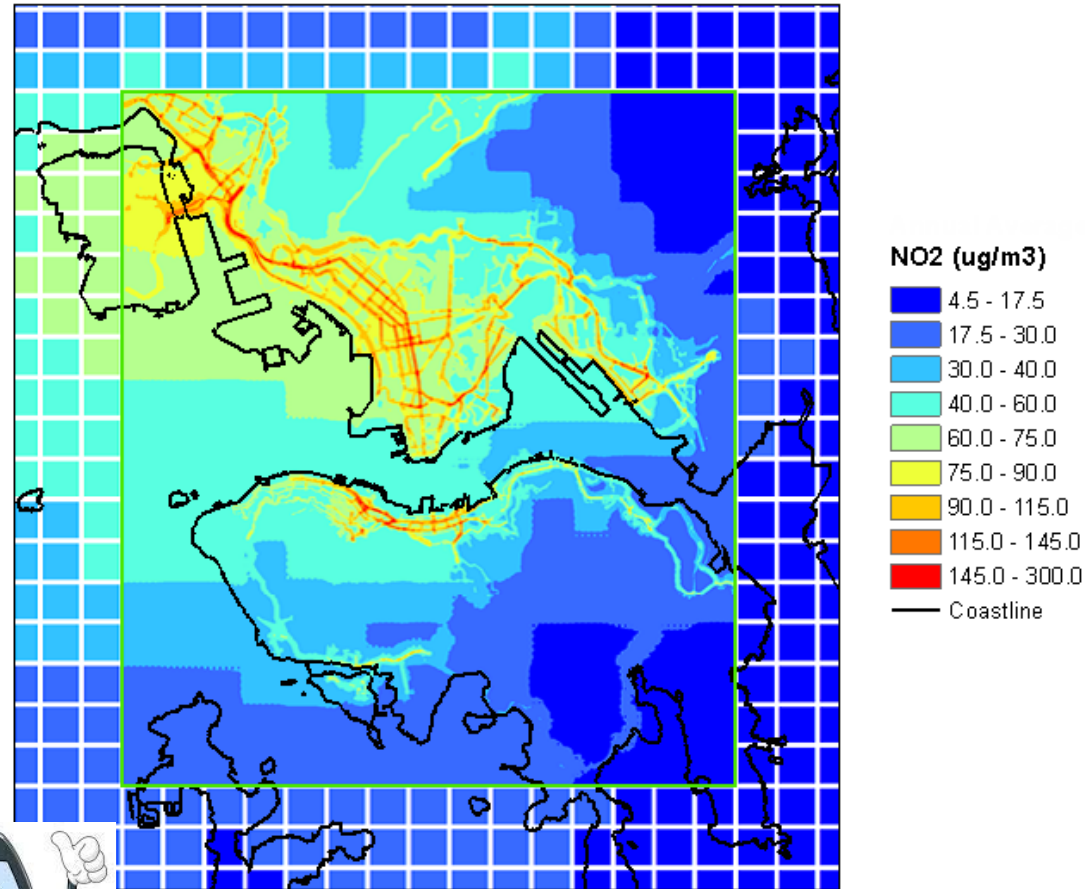
ug/m3



Can resolve the mobile source
in street canyon

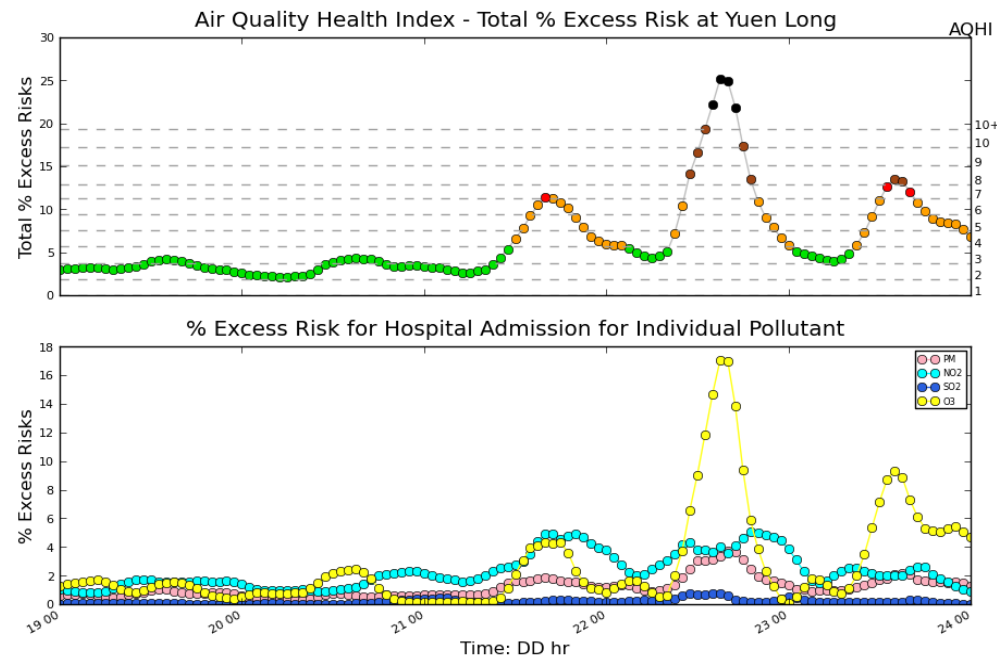
Personalised Real time Air quality Informatics System for Exposure (PRAISE-HK)

- ❖ **Real-time, urban AQ modelling system** that can analyse and forecast (up to 3-day) the AQ in HK down to street levels
- ❖ **Mobile App** to allow the public to query the current and predicted AQ at their specified location(s)



Personalised Real time Air quality Informatics System for Exposure (PRAISE-HK)

- ❖ Personalised short-term AQ exposure and health outcome database

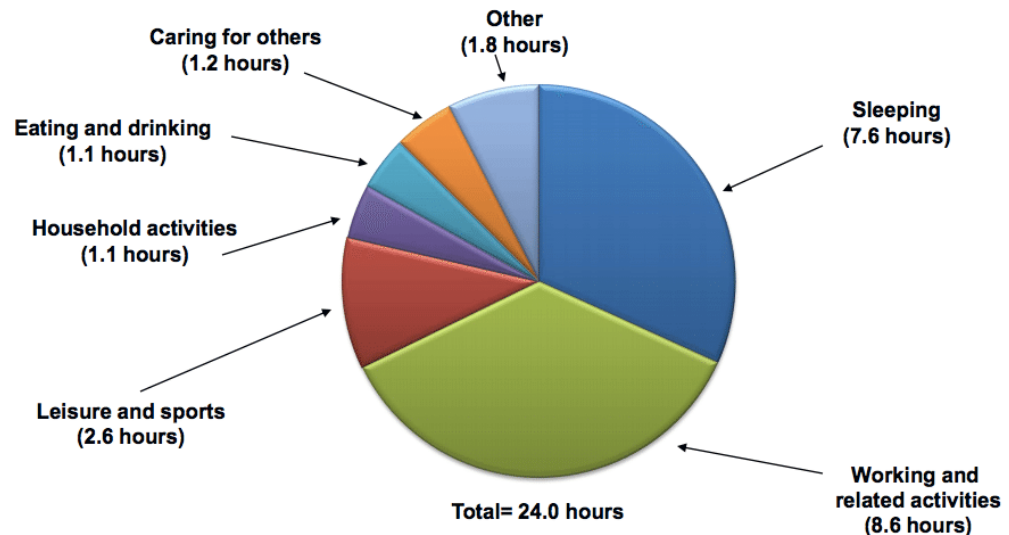


- **Mobile App (PRAISE-HK)** to allow the **users to receive AQ warnings** when the *pollutants they are sensitive to* are predicted to increase, and to **query the pollutant exposure** for their past and planned trips up to next 72 hours.

Exposure into human health

Exposure is the sum of concentration of air pollutants over time in different environments

$$E = \int_{t_1}^{t_2} C(t) dt$$



80% of our time is spent in indoor environments

Sampling Sites in Hong Kong

(High-rise)



Building A
- 21 floors



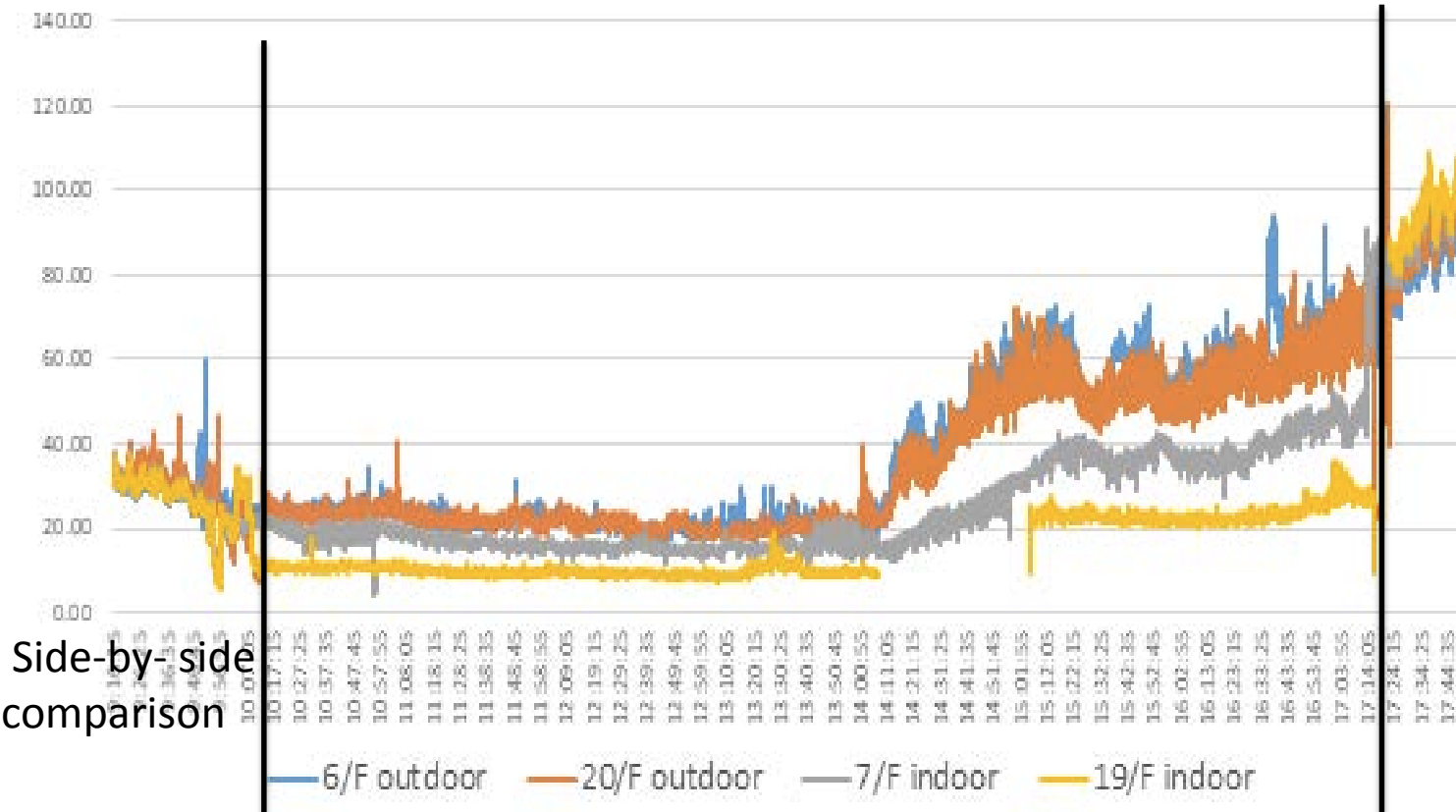
Building B
- 21 floors



Building C
- 32 floors

Indoor – outdoor Relationship

Calibrated PM_{2.5} Levels in different floors of building B
on 2017-01-19 ($\mu\text{g}/\text{m}^3$)

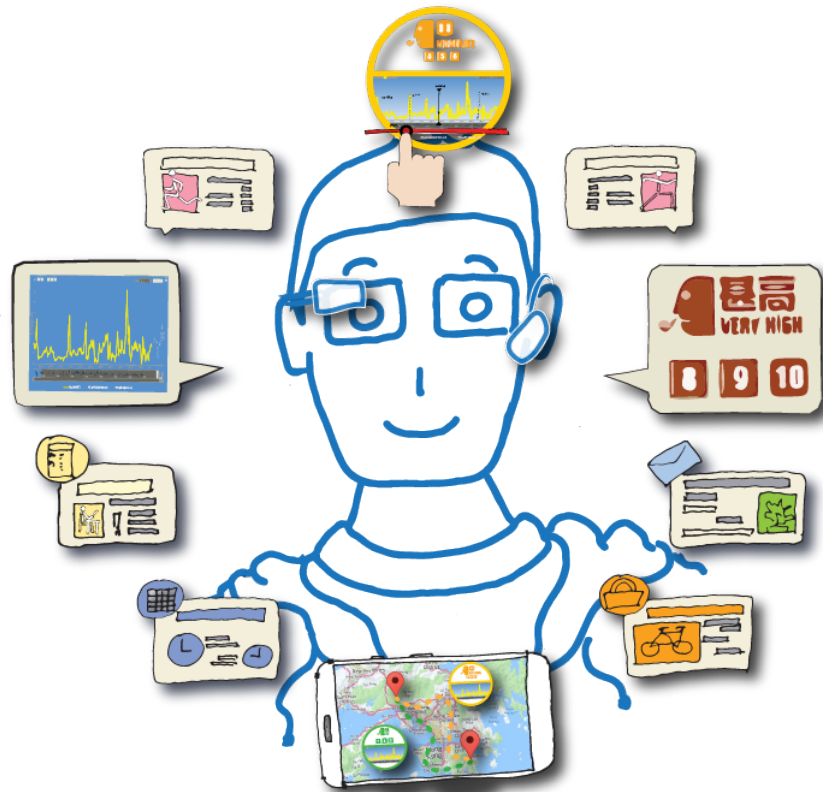


As outdoor PM_{2.5} raised, indoor followed the trend.

Opportunities

To empower the public with personalized air quality information...

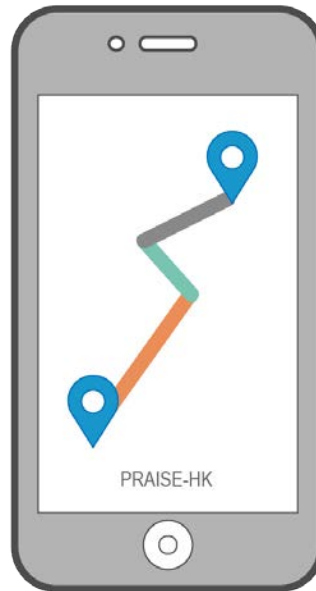
... so that they can plan their daily activities, reduce their pollutant exposure and hence the associated health impacts



Moving Forward: Personalized Real-time Air-quality Information System for Exposure – Hong Kong



**Real time high resolution
AQ spatial map**



**Air pollution exposure
health-risk review**

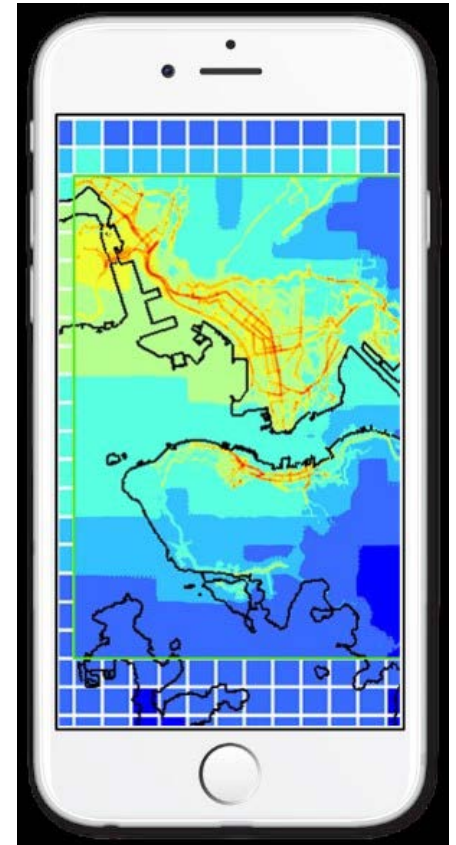


**Personal AQ &
health alert generator**

Empower the Public with Personalized AQ information

PRAISE – HK

Empower the Public with Personalized AQ information



<http://praise.ust.hk>

Other collaborators:

CERC: Christina M. Hood*, Jenny R. Stocker,
David J. Carruthers, William Grayson and
Jonathan Handley

HKUST: Alexis Lau, NingZhi, David Yeung, Jimmy Chan

More detailed talk on the model system:

ADMS-Urban Regional Model Link (RML)

- Oct 25 (Wed), 8:50am-9:10am
- Integrating regional and local modelling to create a high-resolution air quality forecasting system for Hong Kong

By: Christina Hood

Thank You