TOWARDS EXPOSURE-BASED HEALTH IMPACT INDICATORS: APPLICATION TO HONG KONG

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Impacts of Air Pollution

1. Pollutants such as particulate matter (**PM**) are linked to negative health effects.
    - Worldwide it is estimated that **2 million** people die every year from air pollution[2].
    - A significantly increased hazard ratio (HR) for $PM_{2.5}$ of 1.07 per 5 $\mu g/m^3$ was recorded[3]. For every 10 $\mu g/m^3$ of $PM_{2.5}$ long-term exposure, there was an estimated 8–18% CVD mortality risk[1].
    - By reducing particulate matter pollution from 70 to 20 $\mu g/m^3$ as set out in the new WHO Guidelines[2], the quality related deaths could be cut by around 15%.

[1] Khallaf, Mohamed (2011).
[2] WHO Guidelines (2005).
[3] Beelen, R. et al. (2014).

World Health Organization

Impacts of Air Pollution

2. Air pollution is a serious problem in megacities (e.g. Hong Kong and Beijing).

Figure is from https://en.wikipedia.org/wiki/East_Asia
http://www.citylab.com/tech/2013/01/nasa-satellite-image-shows-beijing-drowning-lake-smog/4397/

Impacts of Air Pollution

3. Air pollution has become an important policy issue.
   - Land-use planning[1].
   - Road-side air quality (e.g. set low emission zones “LEZs” in Causeway Bay, Central and Mong Kok[2]).

http://www.legco.gov.hk/research-publications/english/essentials-1415ise09-low-emission-zone.htm

Effective policy for air pollution requires appropriate indicators for the potential health impact of pollutants.

[1] Guidelines from the Hong Kong Planning Department (2011).
[2] Hong Kong Government (2015).

Limitations of conventional health-impact indicators

The potential health impact of poor air quality may be represented using an index or indicator.

1. Mean concentration as an indicator.
   - 24-hour averaged $PM_{2.5}$, PM_{10} and 1-hour averaged NO_2, SO_2, O_3, CO (AQI, China).
   - 3-hour average of PM, O_3, NO_2, SO_2 (AQHI, Hong Kong).

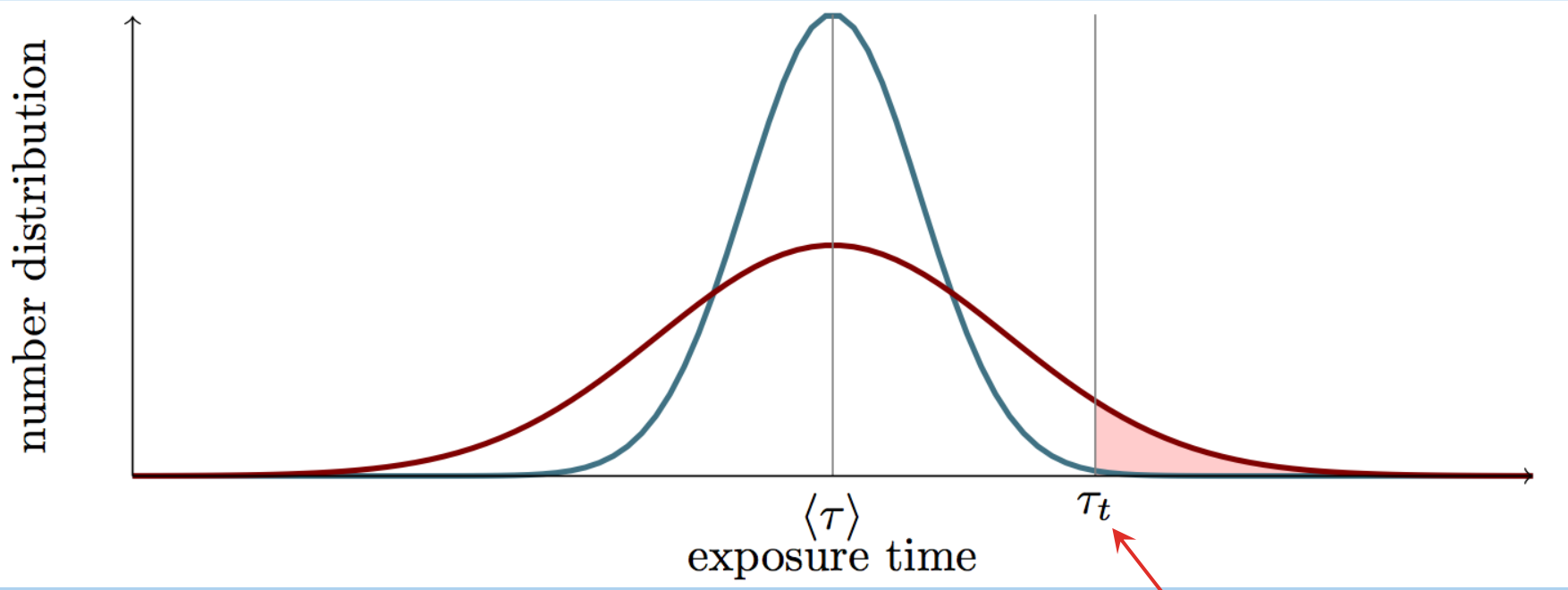
❖ Does not reflect the time spent by pollutants at the pedestrian level.

2. Health impacts depend on the exposure.
   - Effects depend on the time interval over which a pollutant is inhaled.
   - Secondary pollutants may be generated.

❖ Long-term exposure to low-level pollutants will have non-negligible effects.

Limitations of conventional health-impact indicators

Hazard ratios (HRs) for $PM_{2.5}$ remained significantly raised even only considering participants exposed to pollutant concentrations lower than the European annual mean limit value of 25 μg/m^3. [1]



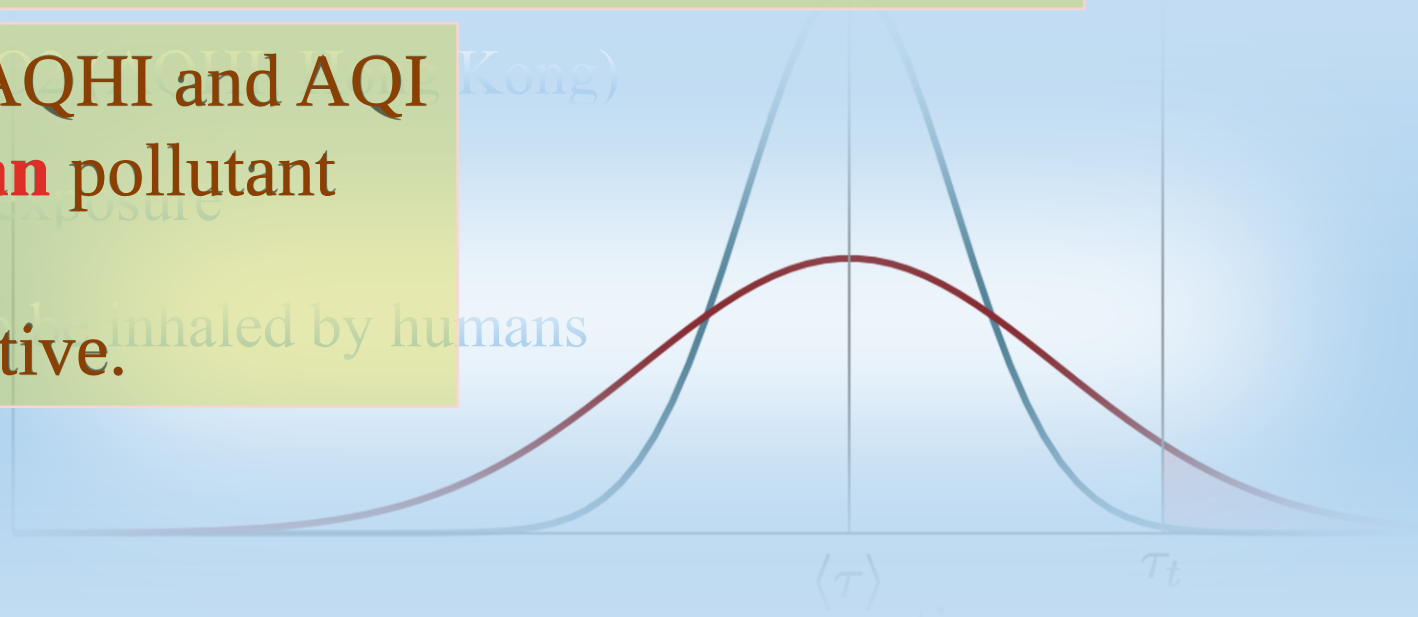
Threshold (corresponds to the limit set by the health/emission regulations).

[1] Beelen, R. et al. (2014).

Need for improved indicators

The **exposure-time distribution** provides valuable insights into the health impact;
The **Value at Risk** captures information about the prolonged exposure events.

Air pollution indexes like AQHI and AQI that based on the **time-mean** pollutant concentrations could be misleading or unrepresentative.



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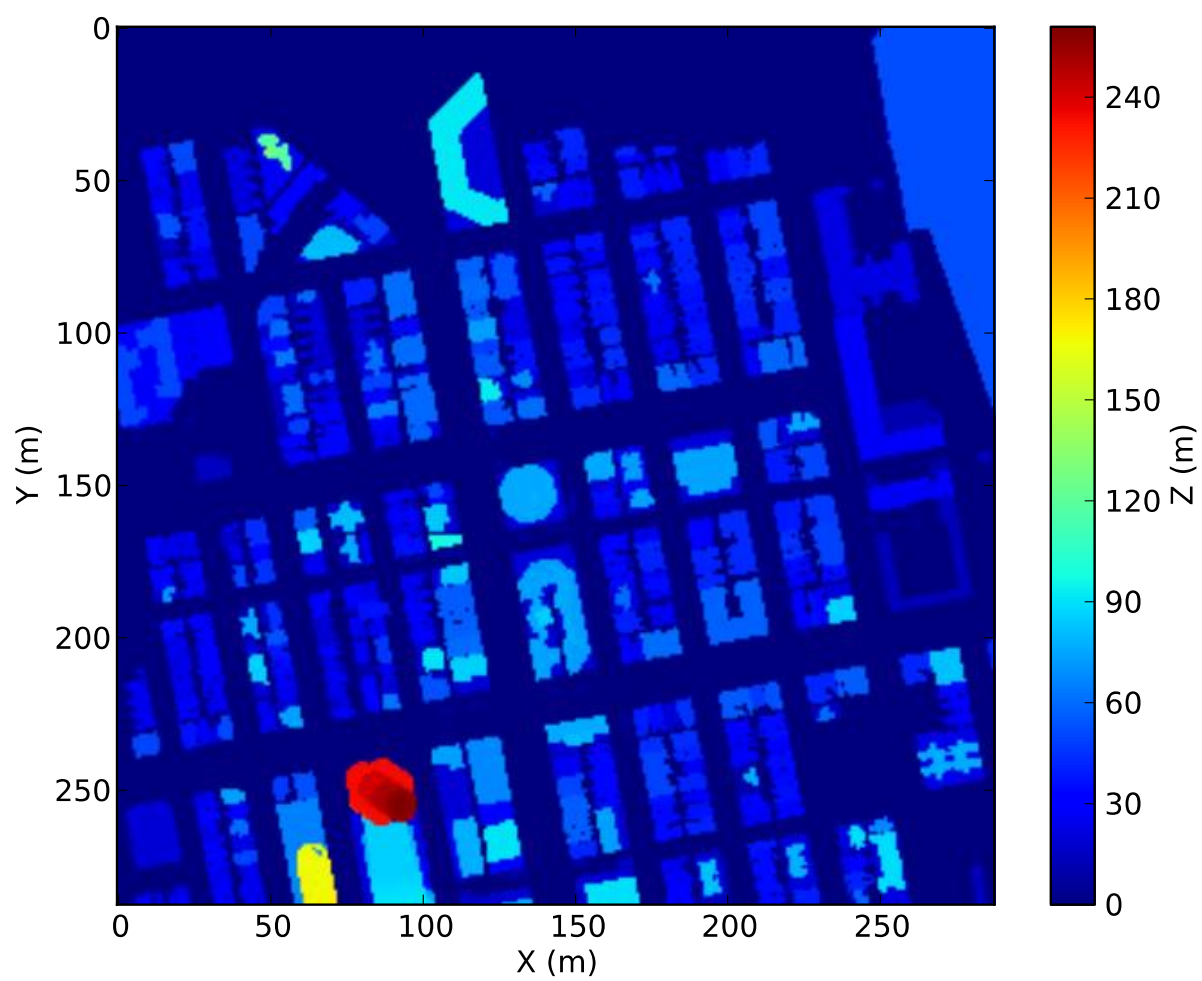
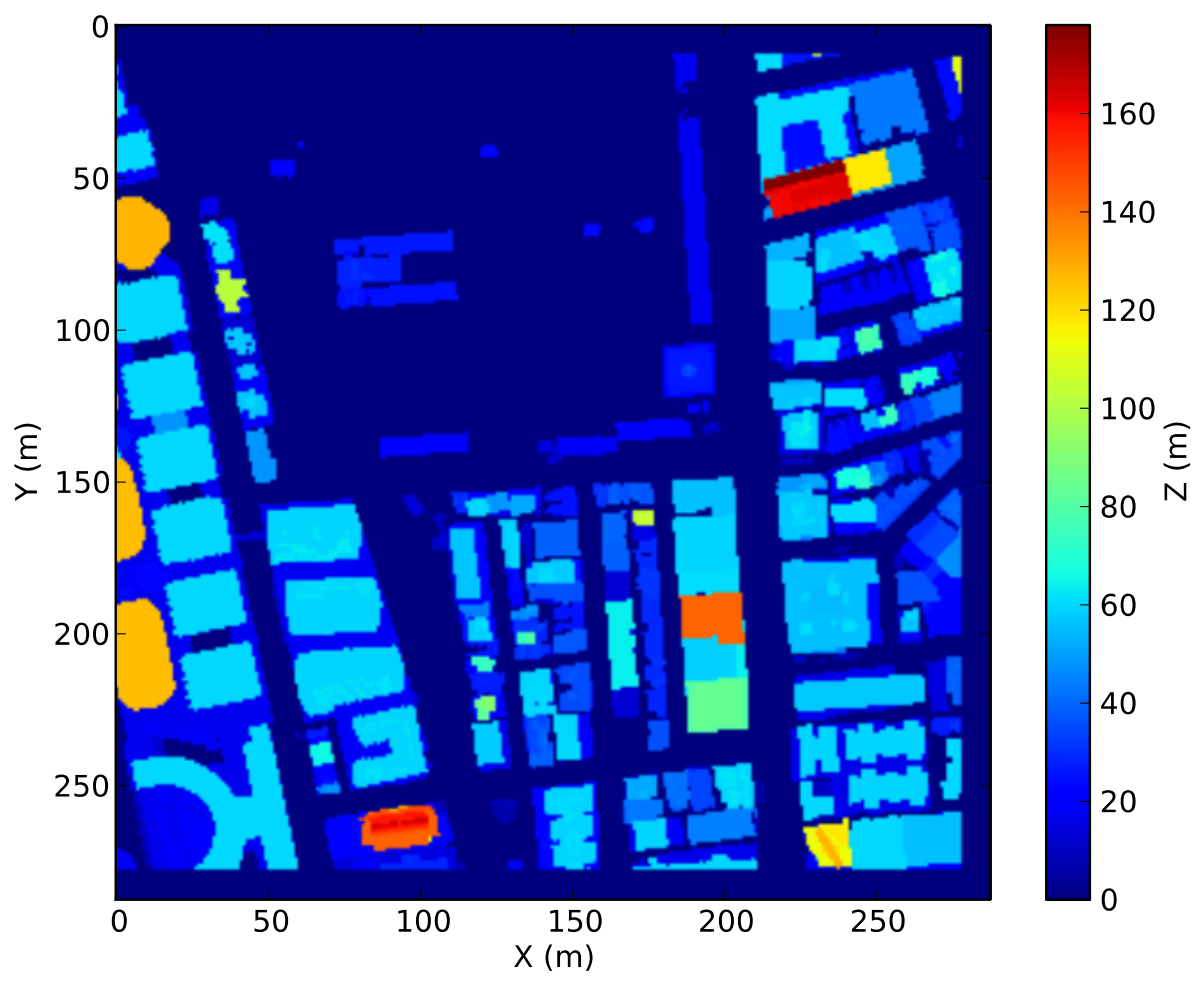
Topography of Mong Kok and Tsim Sha Tsui



(a) Mong Kok



(b) Tsim Sha Tsui

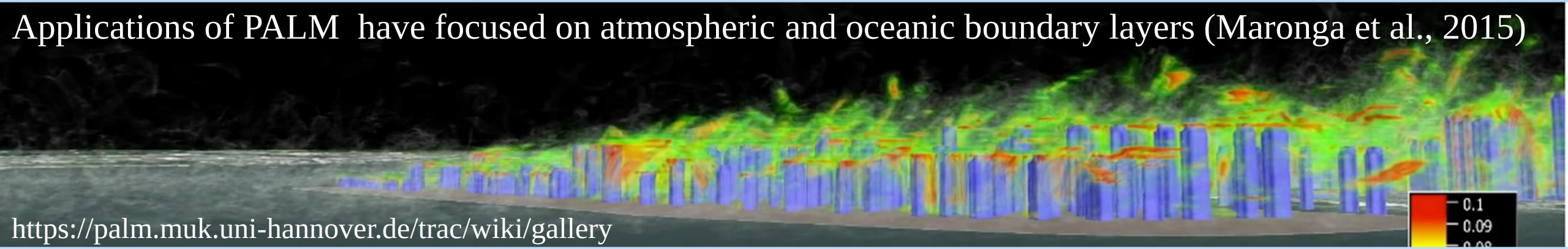
Building data was provided by the Hong Kong Lands Department.

Methodology

- Computational Fluid Dynamics (**CFD**) and the Large-Eddy Simulation (**LES**) technique are used to simulate turbulent flows and pollutant dispersion.

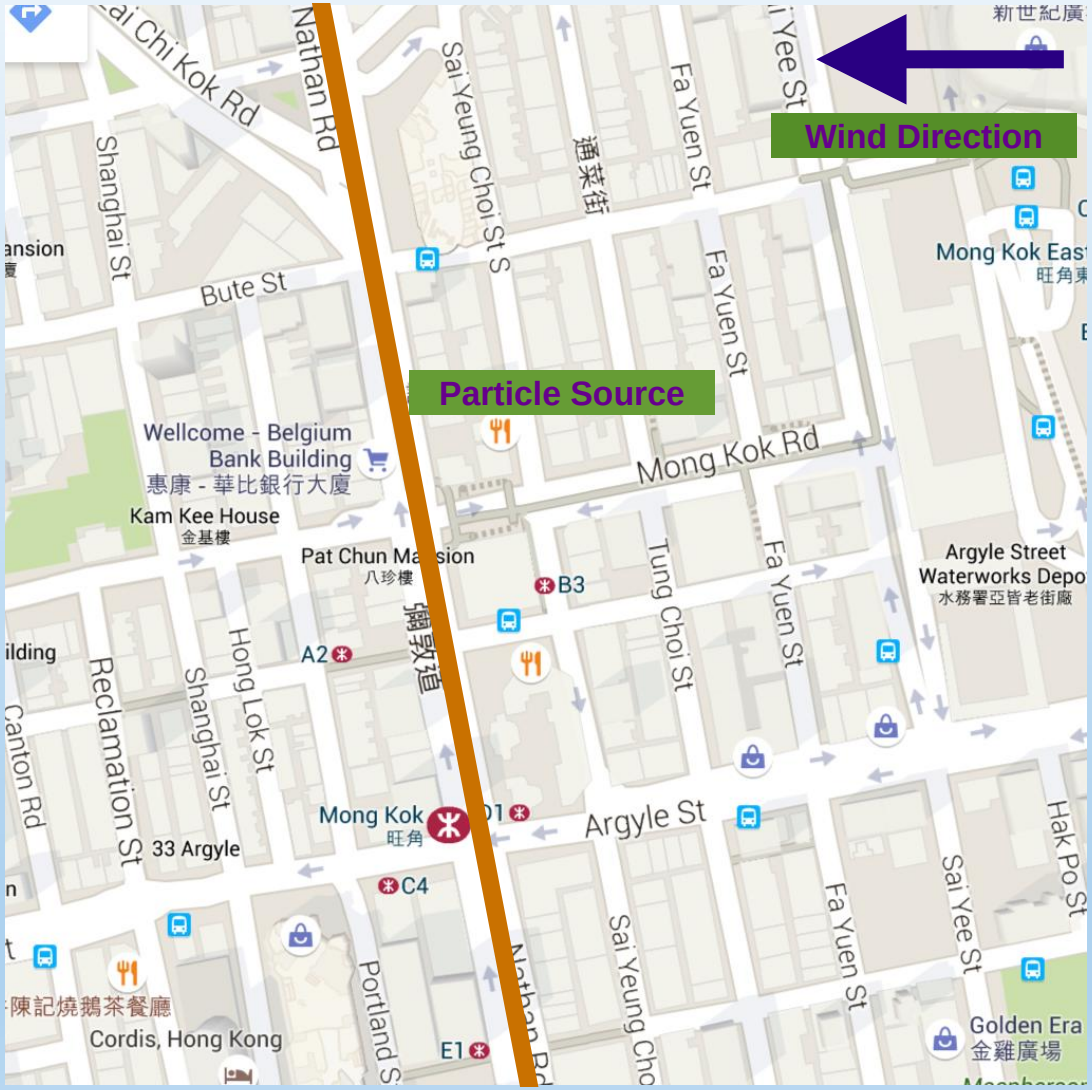
- We used the PArallelised Large-eddy simulation Model (**PALM**).

Applications of PALM have focused on atmospheric and oceanic boundary layers (Maronga et al., 2015)



https://palm.muk.uni-hannover.de/trac/wiki/gallery

Wind Direction and Particle Source



(a) Mong Kok

(b) Tsim Sha Tsui

Exposure Time at The Pedestrian Level

- It is desirable that the indicator use fewer numbers to summarise the health impact of a pollutant.

exposure time	MK	TST
$\leq$200s	72%	61%
200-400s	14%	21%
400-600s	2.1%	9.9%
600-800s	4.0%	2.9%
800-1000s	2.0%	1.4%
$\geq$1000s	6.3%	4.0%

Table 1: Exposure time in Mong Kok (MK) and Tsim Sha Tsui (TST).

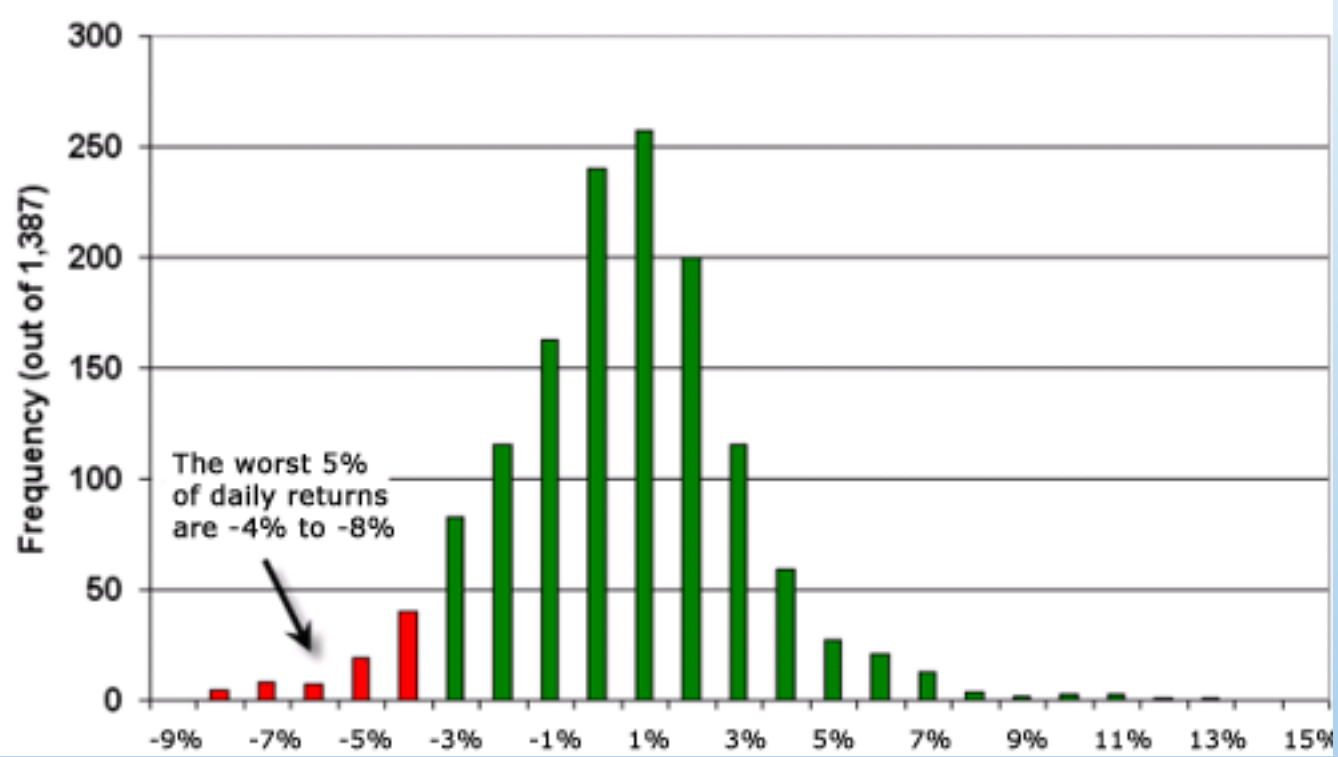
If threshold is 1000s, health impact on MK would be 29% greater than TST

- The particle-averaged exposure times are similar, i.e. 296s and 311s for MK and TST. However, Table 1 shows that the situation is more complicated.

Value at Risk

In finance, the **Value at Risk** (**VaR**) concept has been used to quantify the risk of potential loss (Duffie et al. 1997).

Definition of VaR in finance: 1% VaR of 100 dollars means there would be a 1% chance that the potential loss would be greater than 100 dollars.



95% confidence: If we invest $100, we are 95% confident that our worst daily loss will not exceed $4 (4% VaR of $4).

INVESTOPEDIA by David Harper
(http://www.investopedia.com/articles/04/092904.asp?header_alt=b)

Value at Risk as an Indicator for Air Quality

Value at Risk (**VaR**) can be applied to air quality. Incorporating information about the exposure time and relative concentration more accurately represents the potentially harmful effects of long-term exposure.

- Reinterpreted VaR for air pollution:

  1% VaR of 100 s means that at least 1% of the pollutants have exposure time greater than 100 s.

VaR	MK	TST
1%	3505s	3359s
5%	1366s	981s
10%	755s	570s

Nearly 30% smaller than MK

Table 2: Value at Risk for exposure time in Mong Kok (MK) and Tsim Sha Tsui (TST).

The VaR is a better indicator of the extremes of prolonged exposure than the raw exposure time!

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Final Comments

- **Long-term exposure to concentrations below the regulatory limit can have serious health effects. Particles with longer exposure times cause more damage to human health.**

- **The exposure-time distribution and VaR provide valuable information relating to the potential health impact of pollutants.**

- **Improved AQI or pollutant monitoring policy should take the exposure time distribution into account.**

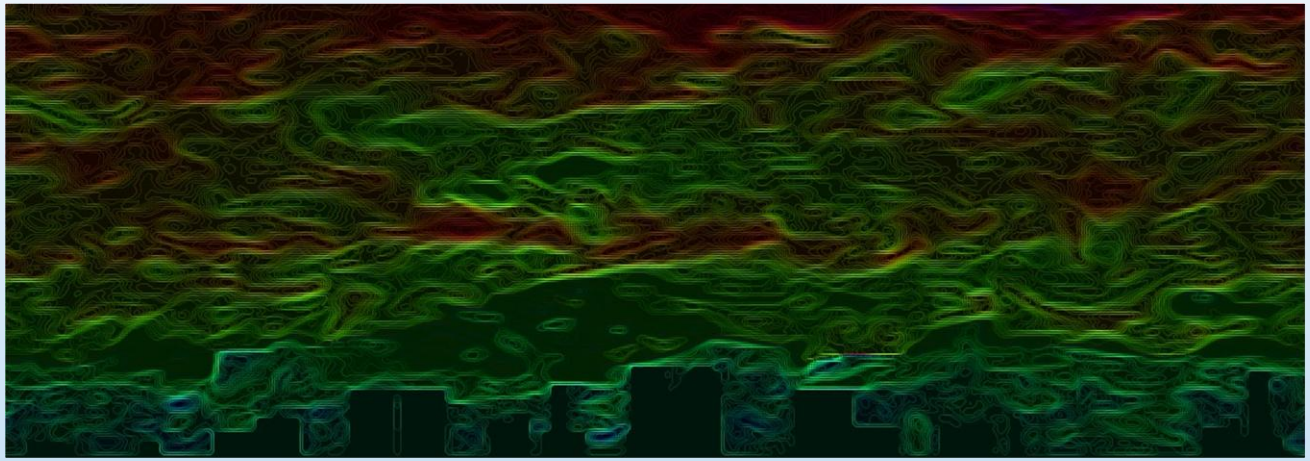

FIG. (a) Flow in MK

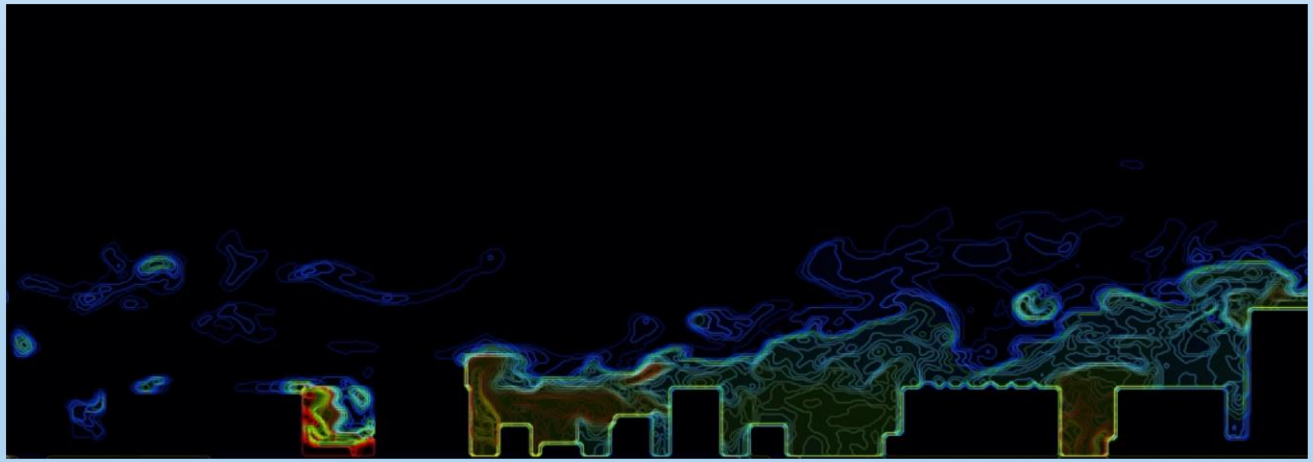

FIG. (b) Pollutant in TST

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Q & A

Thank you !