Application of UAV based sensor technology for ship emission monitoring and high sulfur fuel screening in Hong Kong

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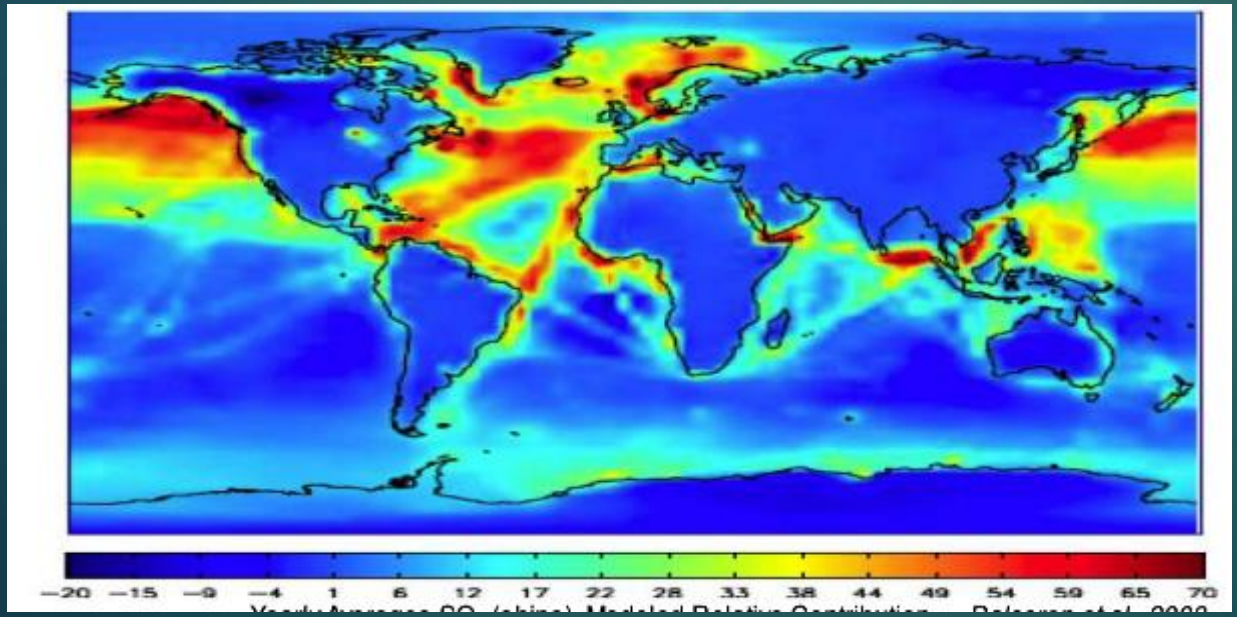
EPA AIR SENSORS 2018

Background of port and ship emissions

- Emission characteristics
  - High contribution to the air quality in remote areas (e.g. the Arctic) and fragile ecosystems (e.g. The Baltic)
  - 70% of ship emissions occur within 400 km of land

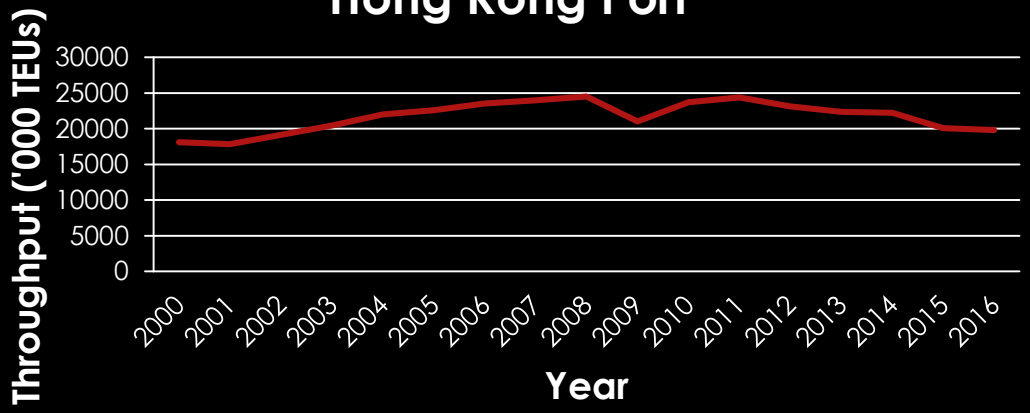


Yearly Average SO_2 (ships) Modeled Relative contribution

Source: Dalsonren et al., 2008

Characteristics of Hong Kong Port

- Top 5 container port in the world in 2016 (in TEUs throughput);
- Terminals close to population;
- Major water fairways nearby.



Background of port and ship emissions

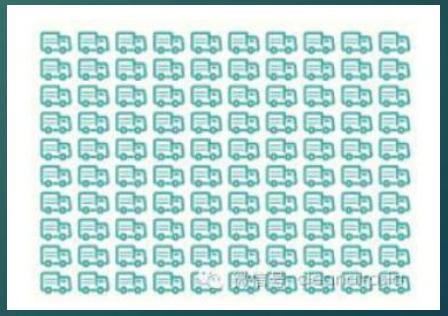
- Major contributors to local and regional air pollution problems

Eyjafjallajokull SO_2 emission: 30,000 T/day

Global SO_2 ship emission: ~35,000 T/day

One medium size container ship $PM_{2.5}$ emission

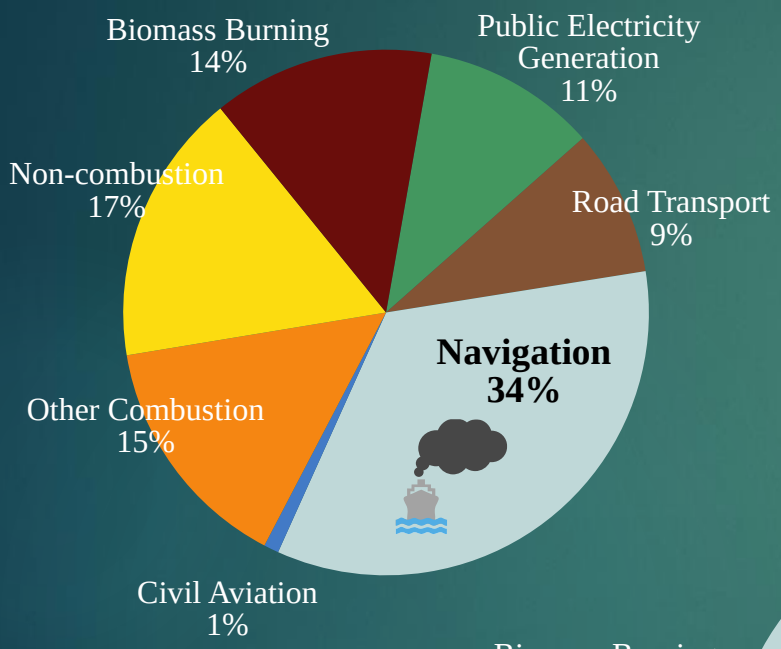
500,000 Euro IV trucks $PM_{2.5}$ emission



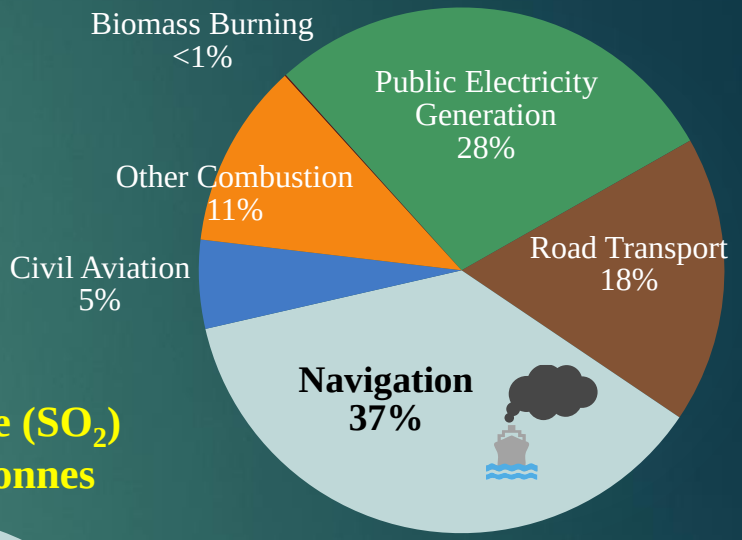
Based on 3.5% sulfur content and 70% of power

Source of Hong Kong Emissions

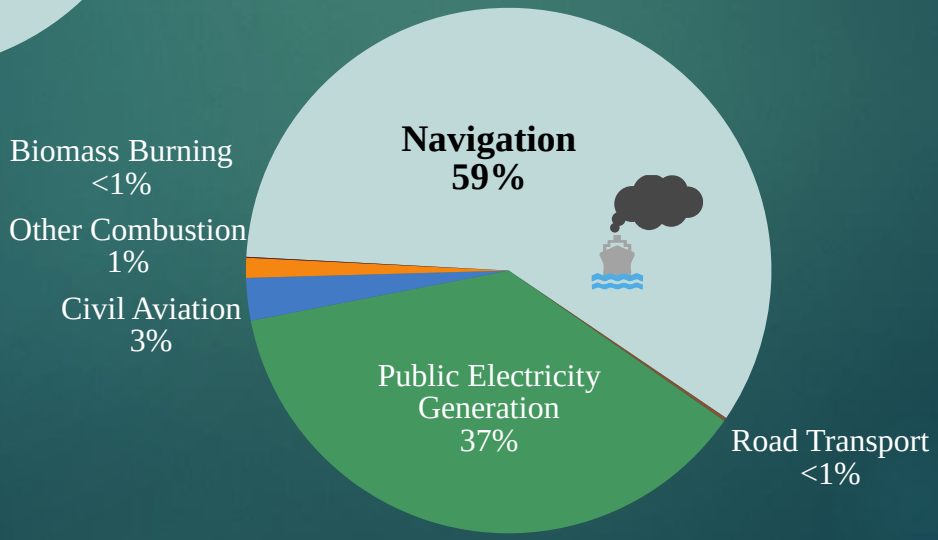
Respirable suspended particulates (RSP)
Total 5,430 tonnes



Nitrogen oxides (NO_x)
Total 91,700 tonnes

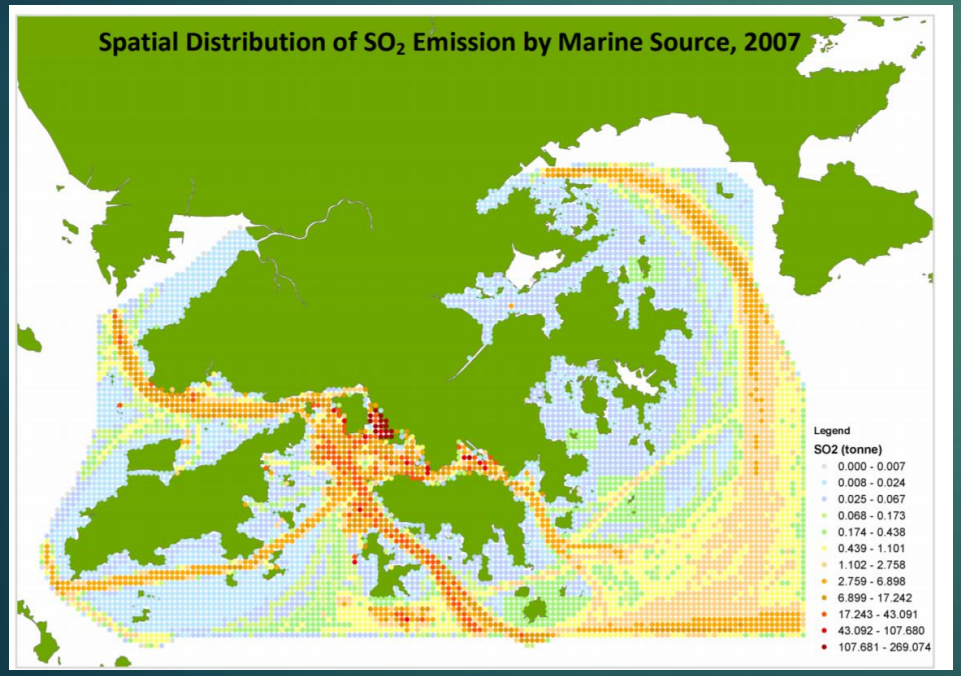


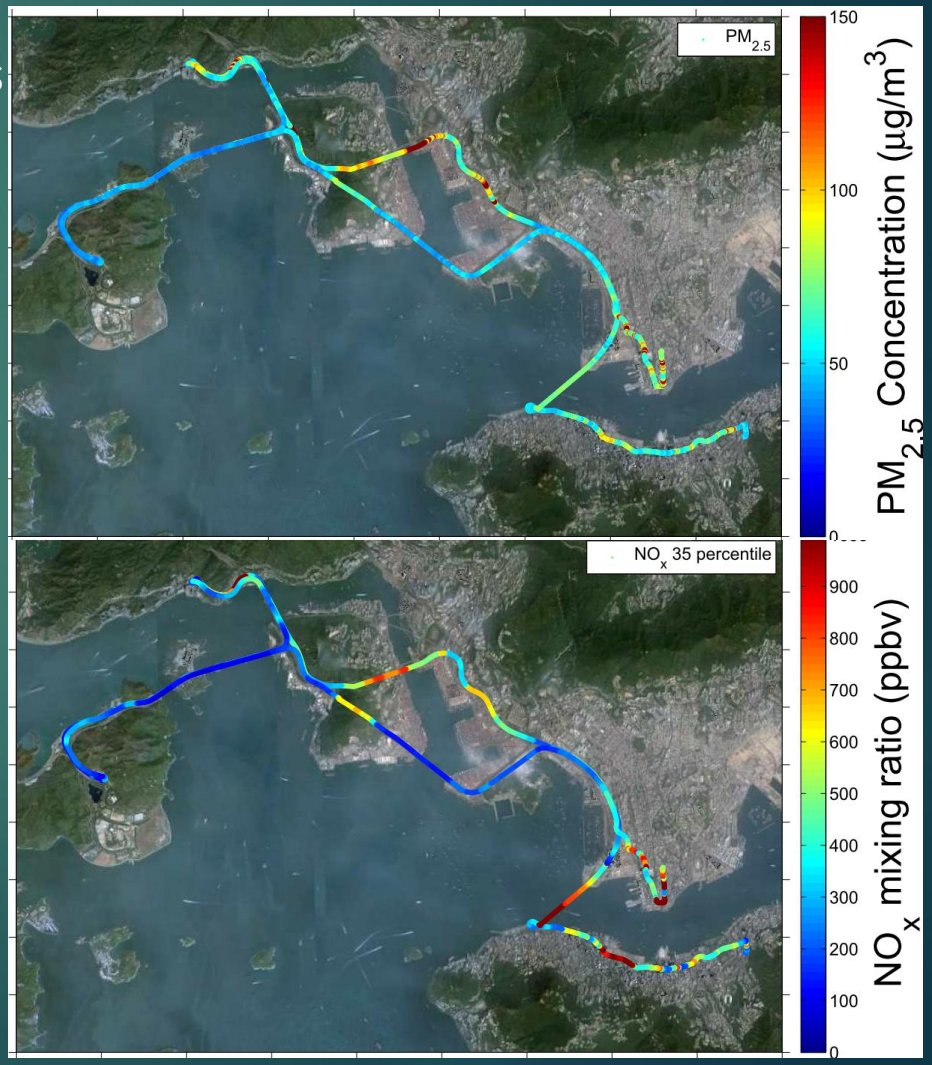
Sulphur dioxide (SO_2)
Total 19,540 tonnes



Background of port and ship emissions

- Hong Kong case
  - Ship emissions near waters
  - Port activity related traffic activities also contribute a lot to local air quality.





Needs and constraints

China handles 70% of global container volume

- Ship and port related emissions are difficult to measure
  - Different activities
  - Fuel quality
- Many ships emission control regulations are in place, but hard to enforce
  - Ship Emission Control Area：Yangtze River Delta, Pearl River Delta and the Bohai Sea.

Fuel Switch at Berth

- Ocean-going vessels to switch to low sulphur fuel in Hong Kong waters

2011:
Fair Winds Charter-voluntary switch

自願轉油計畫
《乘風約章》

September 2012:
3-year incentive scheme – port dues concession

3年港口設施及燈標費寬減計劃

2015:
mandatory switch

強制轉油

Mandatory Fuel Switching – Ocean going vessels

- Ocean going vessels (OGVs) to use low sulphur fuel (S ≤0.5%) , LNG, alternative fuel or equivalent emission abatement technology while berthing

- Air Pollution Control (Ocean Going Vessels)(Fuel at Berth) Regulation became effective on 1 July 2015

- Pioneer in Asia

- Emission reduction at berth:

At least 60% SO_2 , RSP

Regulate Local Marine Fuel Quality

- Introduced Air Pollution Control (Marine Light Diesel) Regulation on 1 April 2014
- Imposed 0.05% sulphur limit on locally supplied marine light diesel

Marine Light Diesel Regulation

- Capped sulphur content of locally suppled marine light diesel at 0.05% since 1 April 2014

Review of existing methods

- **Applications** of drones for **Policing Ship Emissions** in Europe
  - In order to tracking the pollution from ships sailing in some of **Europe's busiest waters**: the English Channel, the Baltic Sea and the Gulf of Bothnia, etc.

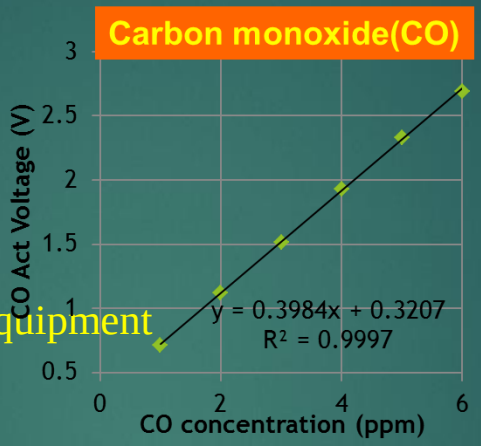
Source: International Maritime Organization

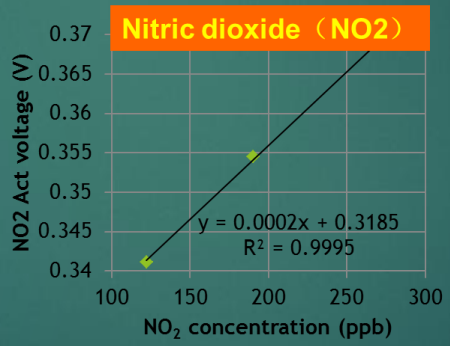
A drone made by Austrian firm Schiebel. Agencies are still assessing the kind of aircraft to use. *PHOTO: SCHIEBEL*

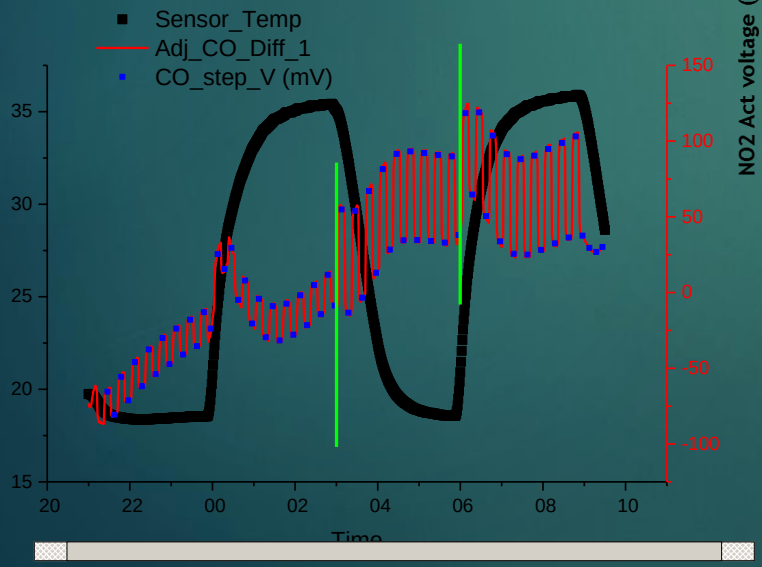
- Technical requirements
  - Flying time: at least 4 hours
  - Flying distance: 20 kilometers
  - It would be equipped with sulfur and CO_2 sniffers

Next generation sensor development: Test in lab

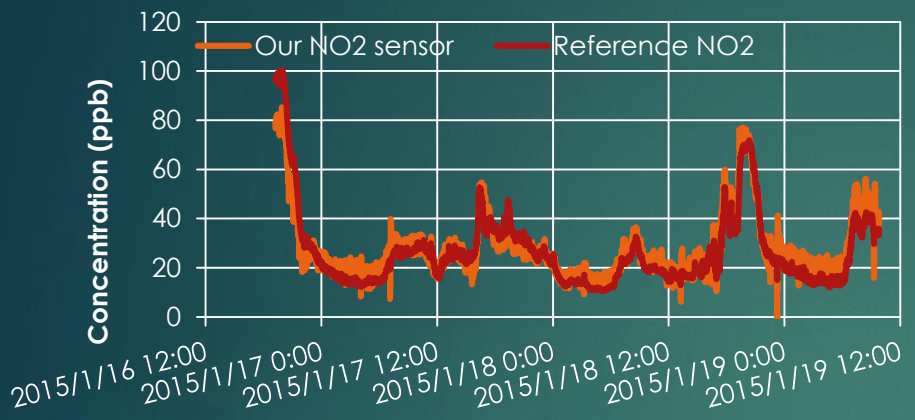
- Precision & linearity
- Test limits
- Long term drift
- Temperature and RH
- Comparisons with standard equipment

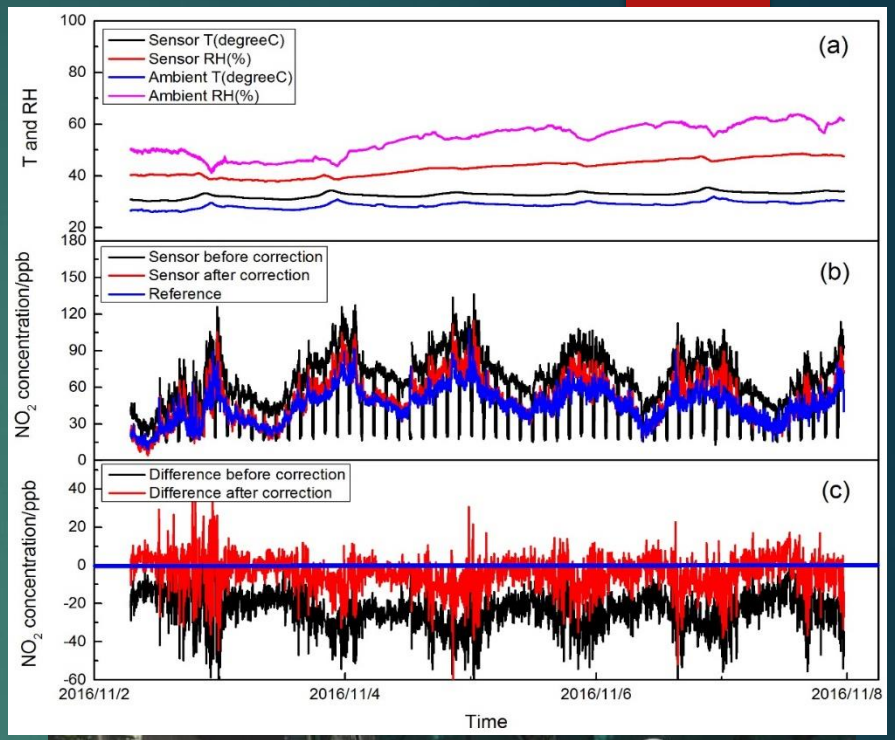






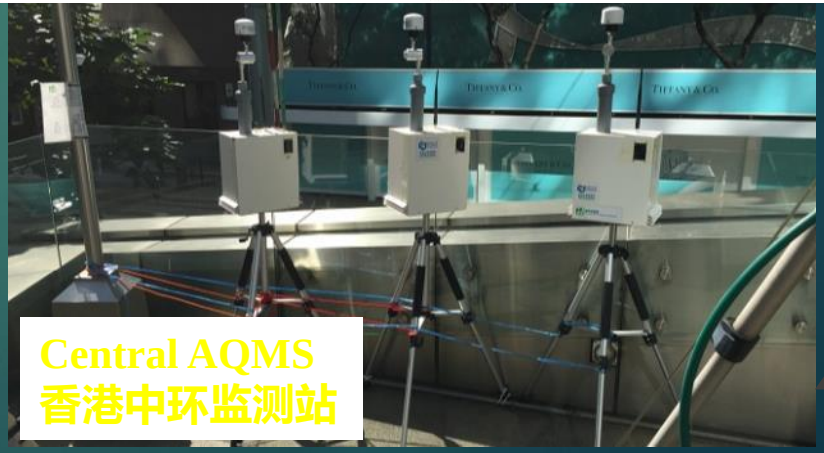
Next generation sensor development: Test in field





- Good reliability in continuous operation
- precision in certain temperature and humidity range
- Ability to show the features of fast changing pollutants
- Drift correction

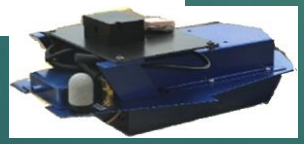
Central AQMS
香港中环监测站



Central AQMS
香港中环监测站

UAV-based airborne monitoring

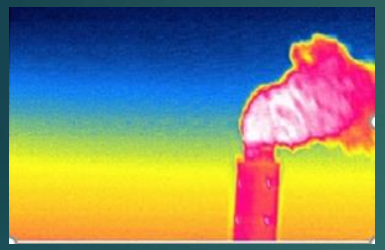
- **UAV based sensor system**
  - **Sensor array (SO_2, NOx, CO2, VOC, CO, PM)**
  - **Visible and infrared camera for plume detection/tracking**
  - **Auto-data transmission and real time processing**

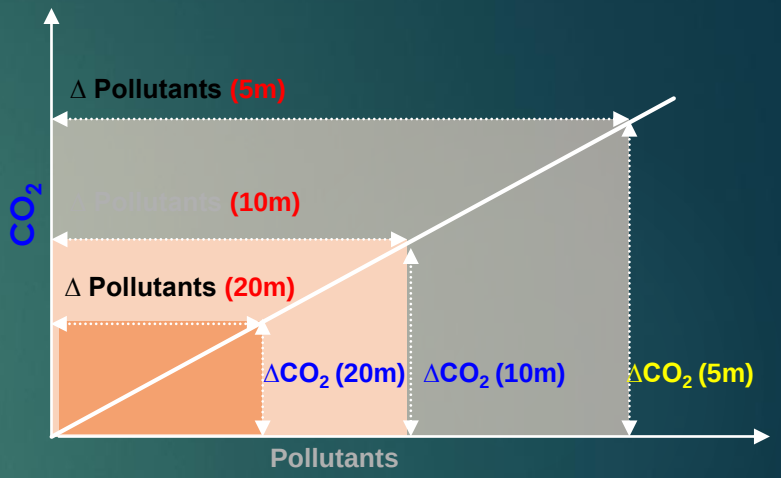


SPSS (Ship Plume Sniffer System)

UAV-based airborne monitoring

- **UAV-Sniff mode**: Principles





"C" in fuel → Engine Combustion → CO_2 (dominant), CO, HC, etc. → "Δ" Over baseline

Distance doesn't matter in theory!

$$EFp = \frac{\Delta[Pollutants]}{\Delta[CO_2] * \frac{MW_C}{MW_{CO2}} + \Delta[CO] * \frac{MW_C}{MW_{CO}}} * w_c$$

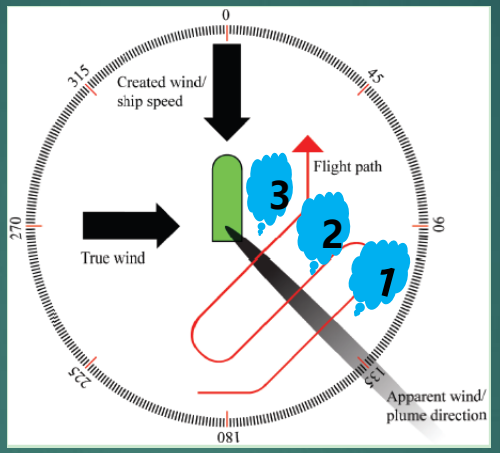
Fuel carbon balance method
Widely used in Remote Sensing, Chasing, Emission estimation for mobile sources

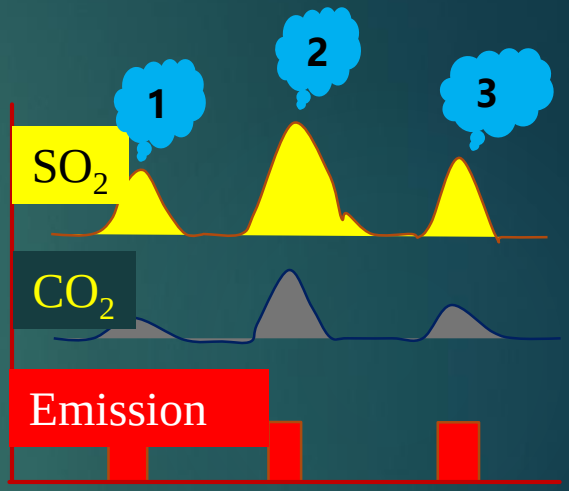
w_c: carbon in fuel; MW: molecular weight;
Δ: Concentration increase
$=Conc_{plume} - Conc_{baseline}$

Chan and Ning 2004, AE, 38, p.2055-2066
Chan and Ning, 2005, AE 39,p. 6843-6856
Ning and Chan, 2007, AE, 41, p. 9099–9110
Ning et al. 2012 AE
Brimblecombe and Ning et al. 2015

UAV-based airborne monitoring

- **UAV-Sniff mode**: Methodology

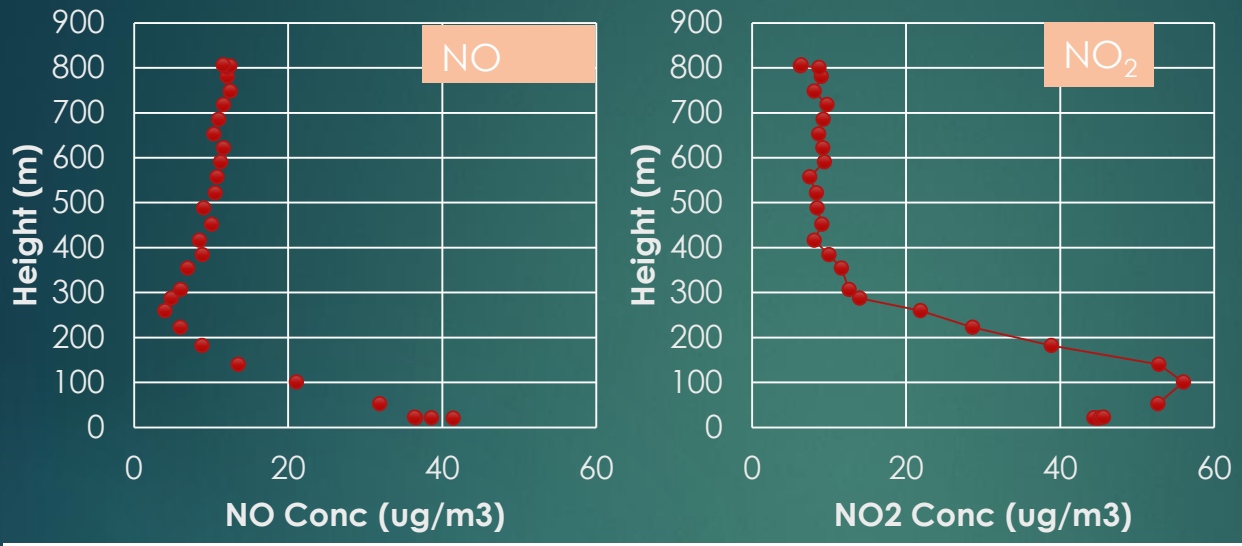


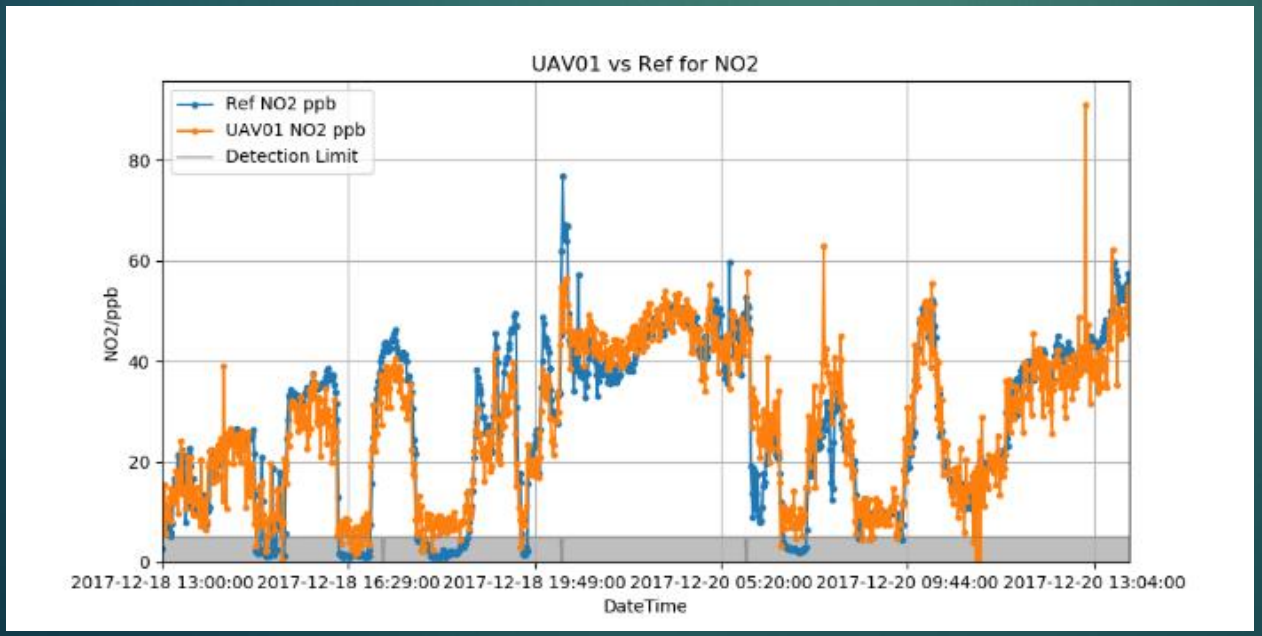


1. Identify and track individual ship plume
2. Cross-sectional scanning of plume
3. Sniff using advanced sensors for pollutants/CO_2
4. Fuel carbon balance method for **sulphur content** and other **pollutant emission factor**

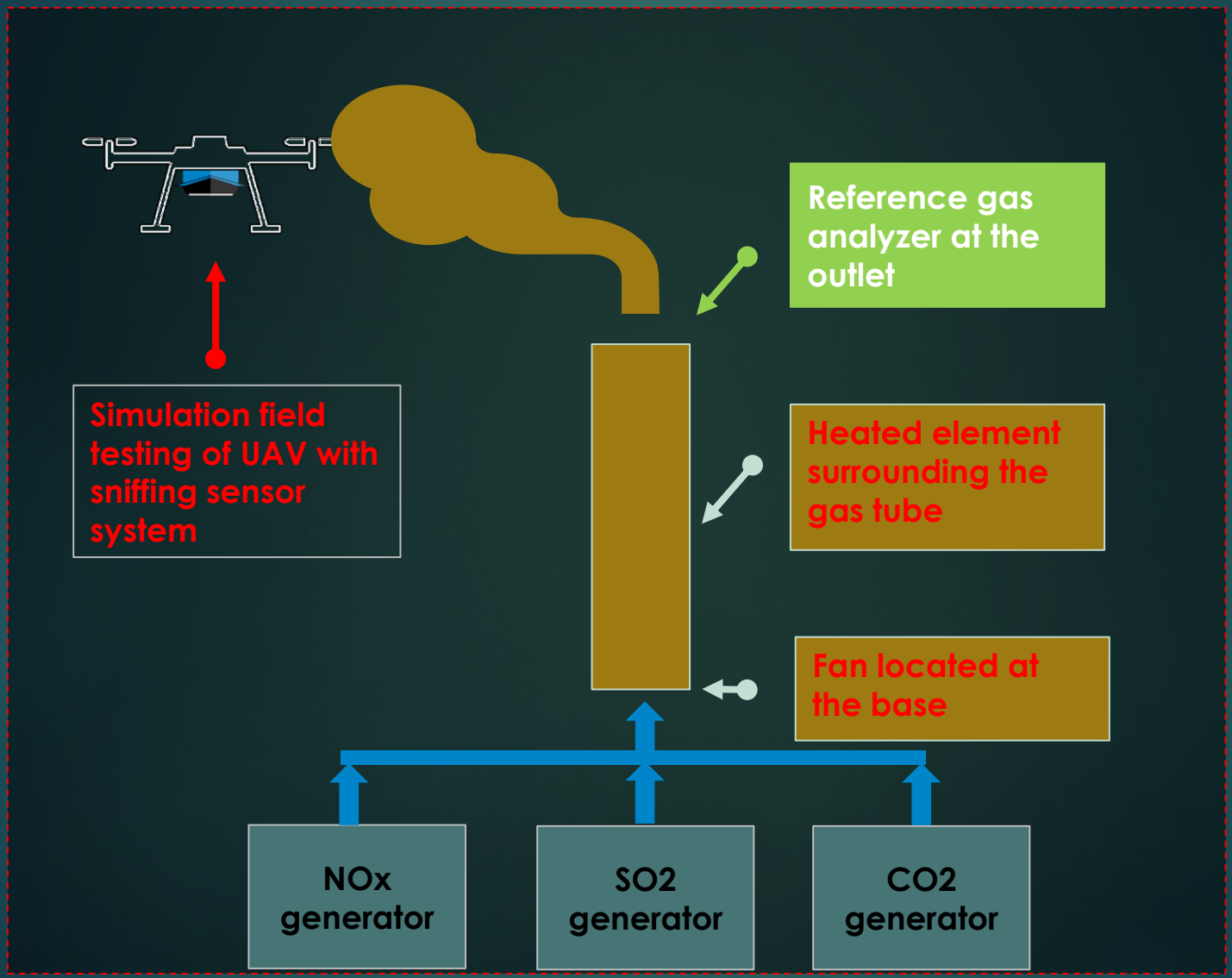
Establish emission factors (SO2, NOx, PM, BC) for Ship emissions
1-2 minutes measurement of individual ship plume
Max 4.5%, Avg 3% to 0.5% Sulfur content will have big difference

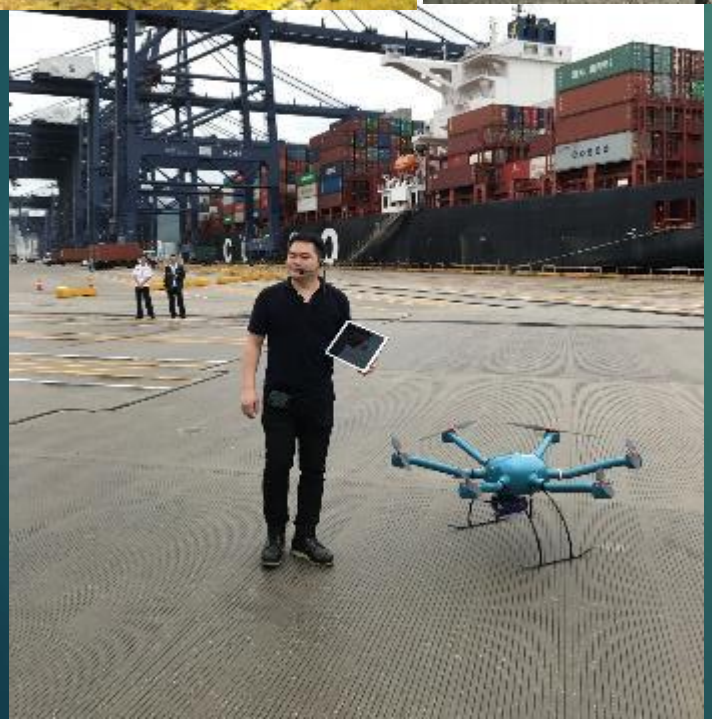
1000m sensor validation for airborne temperature and humidity impact

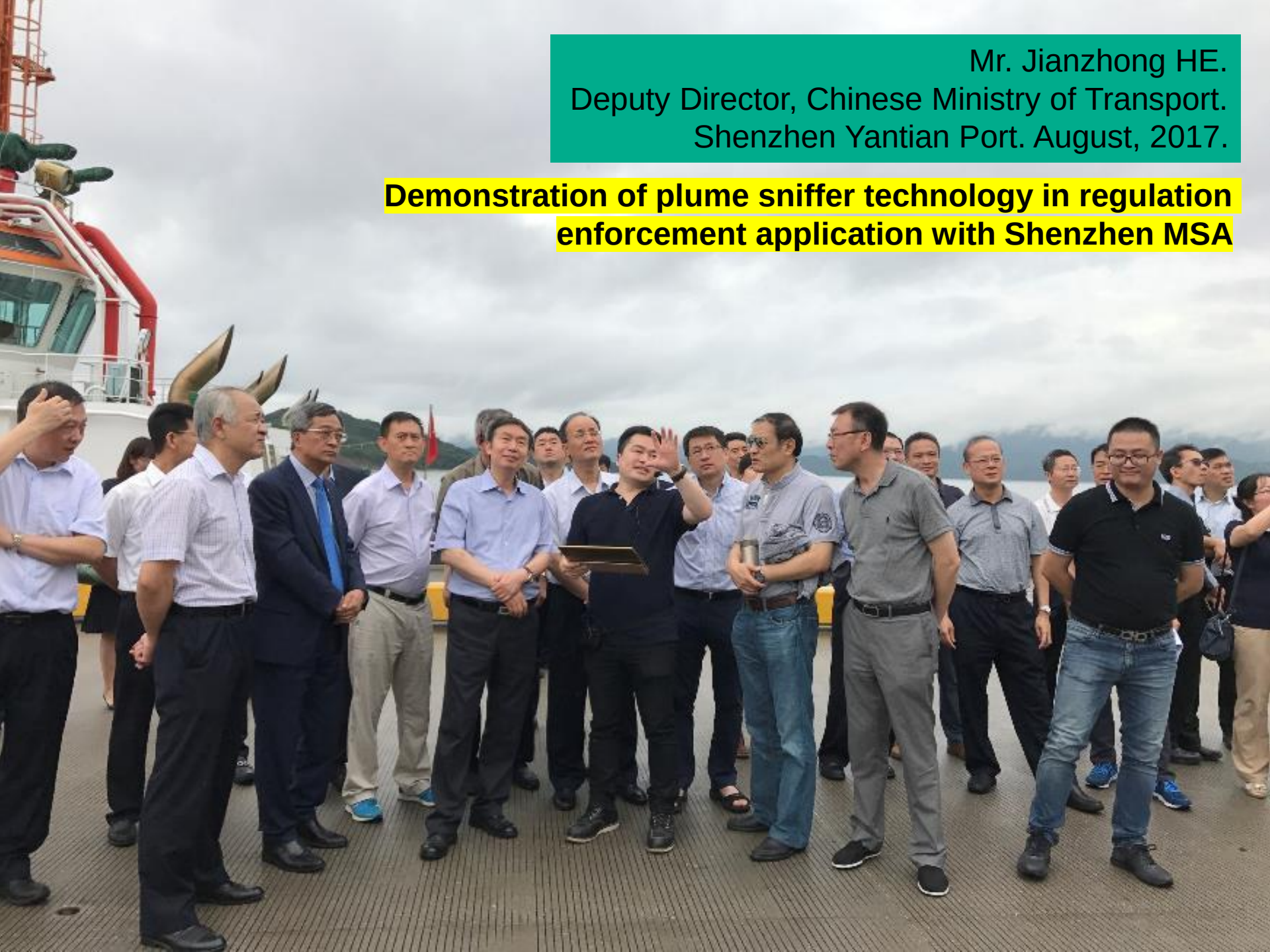




Simulation field testing and protocol development







Mr. Jianzhong HE.
Deputy Director, Chinese Ministry of Transport.
Shenzhen Yantian Port. August, 2017.

Demonstration of plume sniffer technology in regulation enforcement application with Shenzhen MSA

Regional Cooperation

- Maximize environmental and health benefits in the region
- Level-playing field for the shipping industry

Domestic Emission Control Areas in Mainland China

- In December 2015, the Ministry of Transport issued an Implementation Plan of setting up three Domestic Emission Control Areas (DECAs) in the Mainland

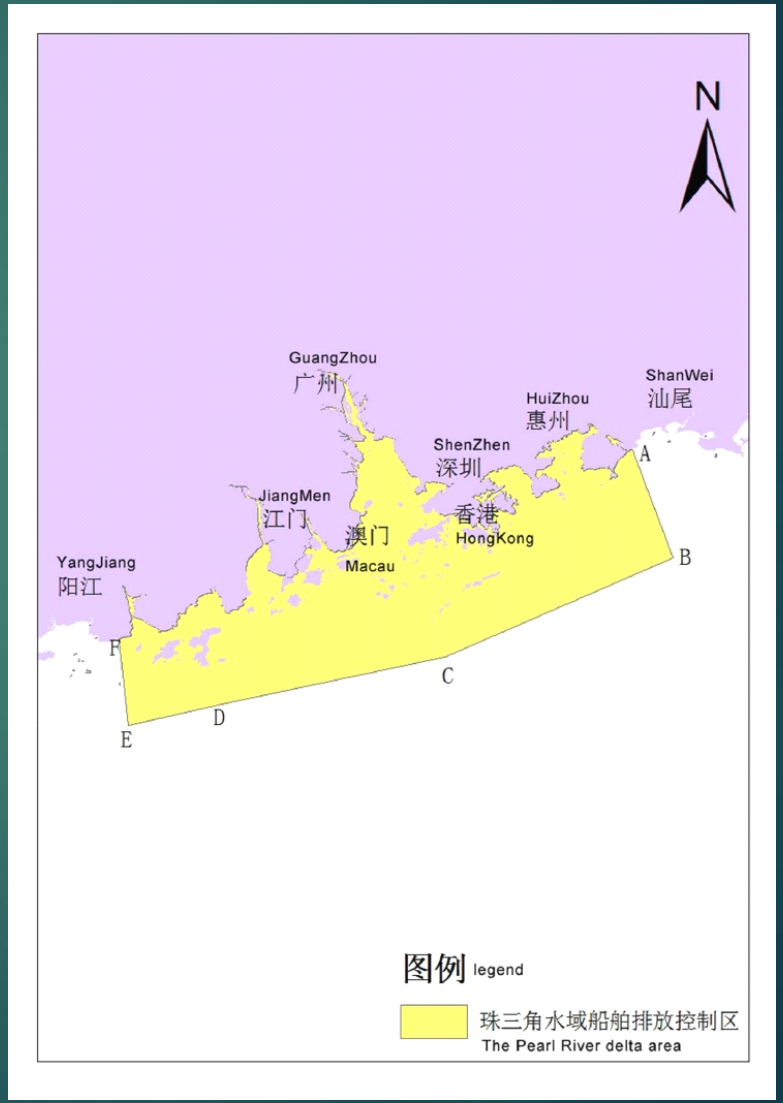
Bohai Rim ECA

PRD ECA

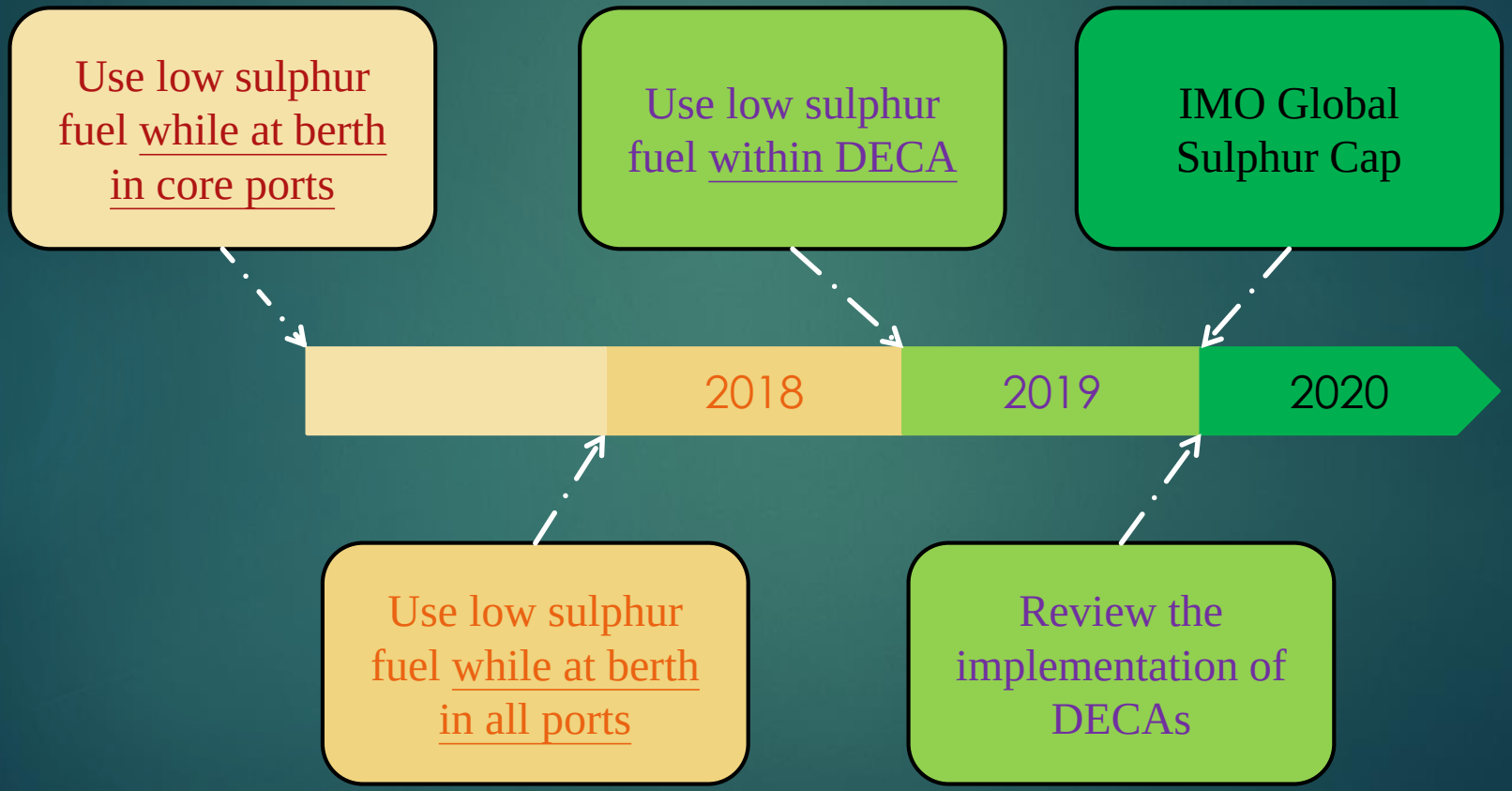
YRD ECA

Coverage of PRD DECA

- About 12 nautical miles of coastal extension
- Hong Kong will collaborate with MoT to implement the same requirements within Hong Kong waters

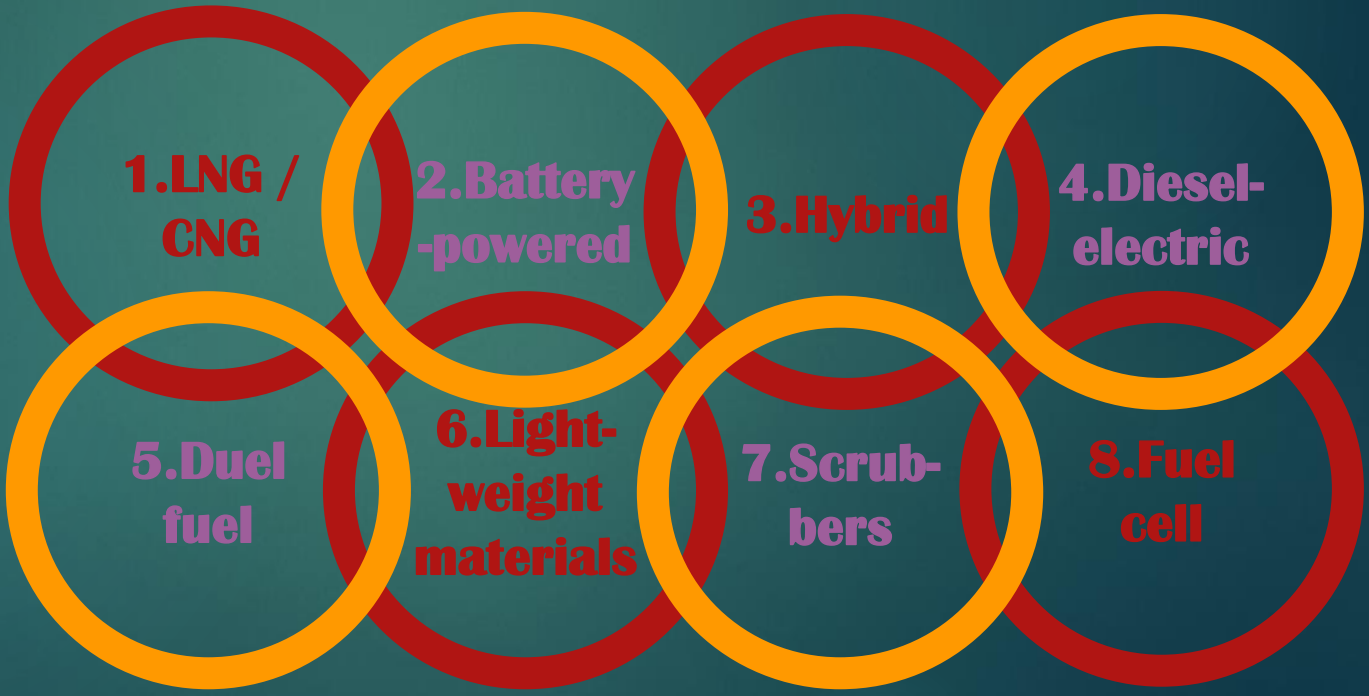


Implementation Plan on Domestic Emission Control Area (DECA)



Future of Green Shipping

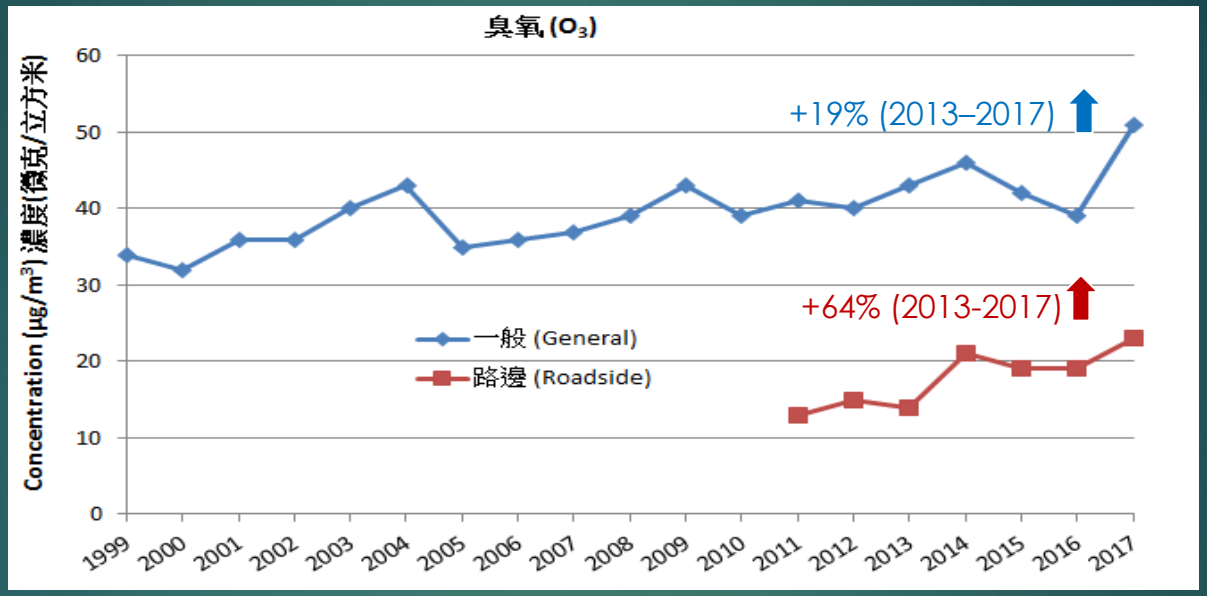
- To explore green marine technologies that could be technically feasible for local applications
- Consideration of operational profile



Thank you

多謝

香港空氣質素趨勢
Air Quality Trends in Hong Kong



- **由1999 至 2017年，一般空氣中的臭氧水平仍然上升。**

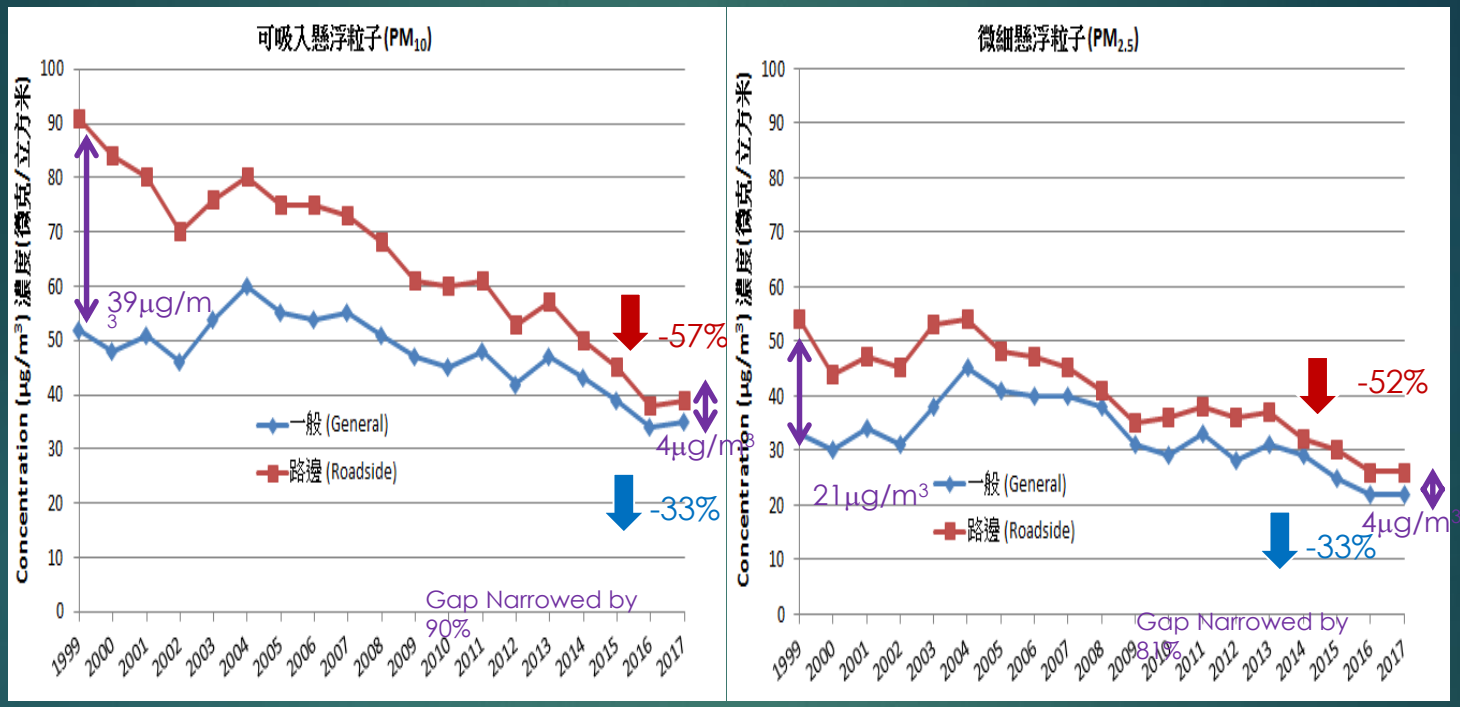
  From 1999 to 2017, ambient O_3 level is still on a rise.

- **由2011 至 2017年，路邊臭氧一直處於低水平，但呈上升趨勢。**

  From 2011 to 2017, roadside O_3 remained at a low level while on a rise.

Source:
HKEPD

香港空氣質素趨勢
Air Quality Trends in Hong Kong



- **由1999 至 2017年，一般空氣及路邊PM_{10}和$PM_{2.5}$水平均呈下降趨勢。與2016年比較，2017年一般空氣及路邊PM_{10}和$PM_{2.5}$水平則變化不大。**

Source: HKEPD

From 1999 to 2017, both ambient and roadside PM_{10} and $PM_{2.5}$ levels were on a declining trend. Compared with 2016, both ambient and roadside PM_{10} and $PM_{2.5}$ levels in 2017 showed no significant changes.