

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



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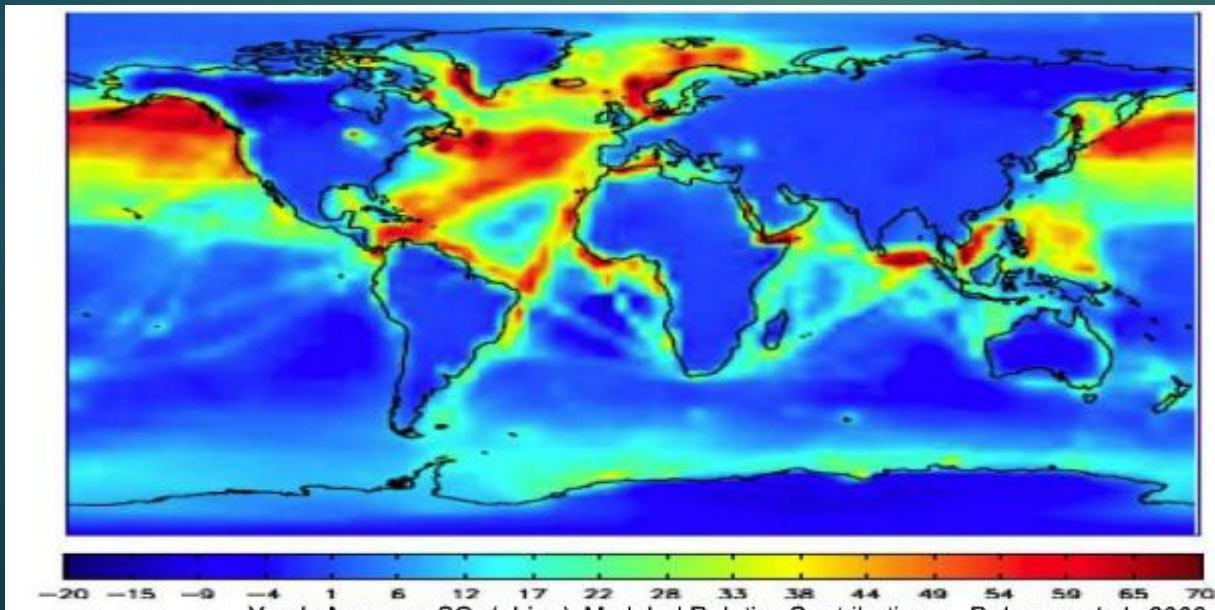
EPA AIR SENSORS 2018



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



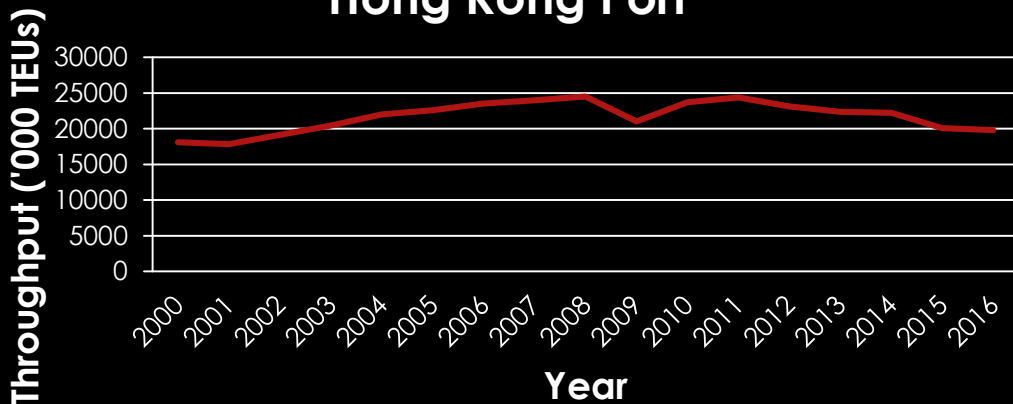
Source: Dalssonren et al., 2008

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.



Container Throughput of Hong Kong Port



Background of port and ship emissions

- ▶ Major contributors to local and regional air pollution problems

Eyjafjallajokull SO₂ emission: 30,000 T/day



Photo: Jon Vidar

One medium size container ship PM_{2.5} emission



Global SO₂ ship emission: ~35,000 T/day



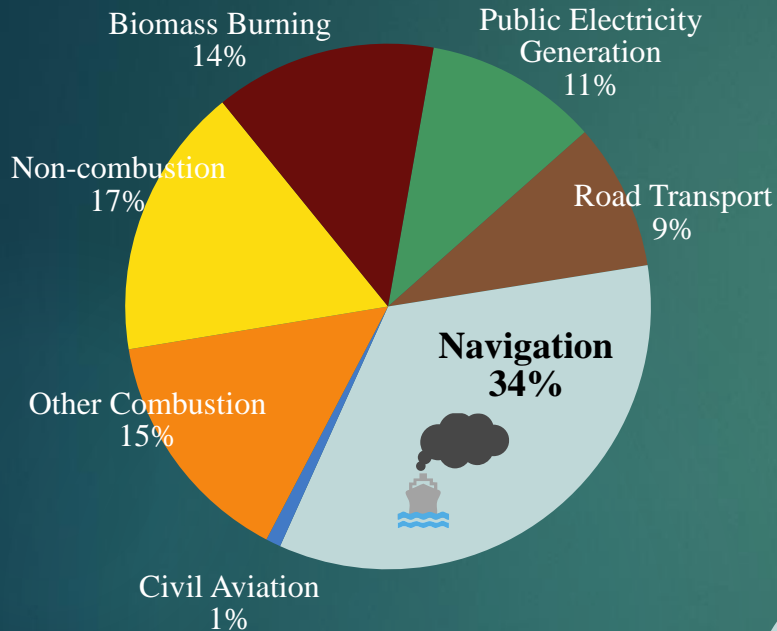
500,000 Euro IV trucks PM_{2.5} emission



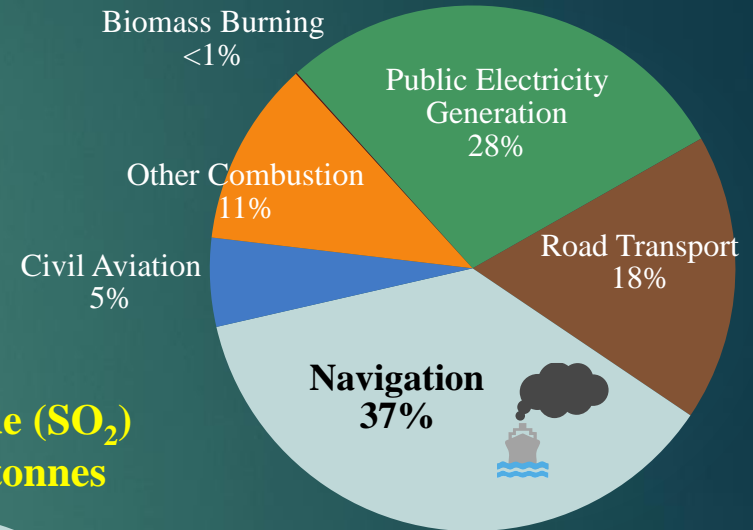
Based on 3.5% sulfur content and 70% of power

Source of Hong Kong Emissions

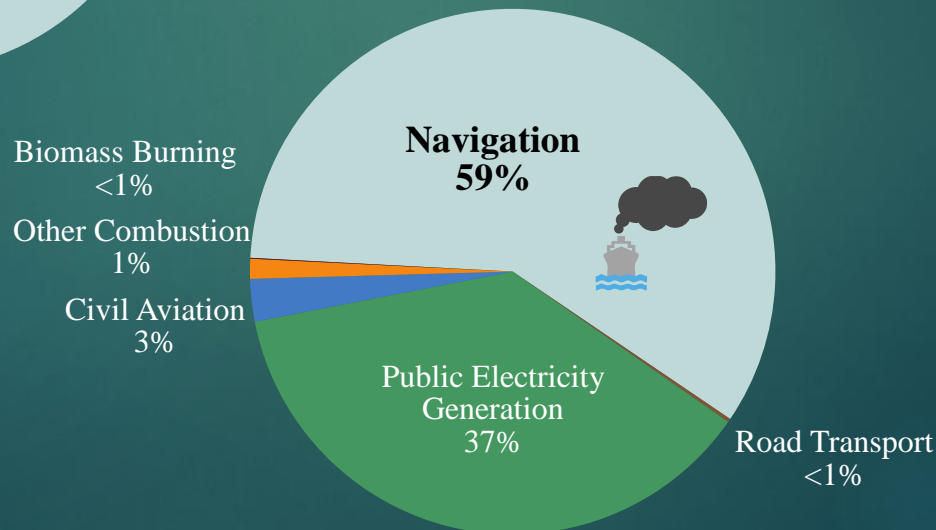
Respirable suspended particulates (RSP)
Total 5,430 tonnes



Nitrogen oxides (NO_x)
Total 91,700 tonnes



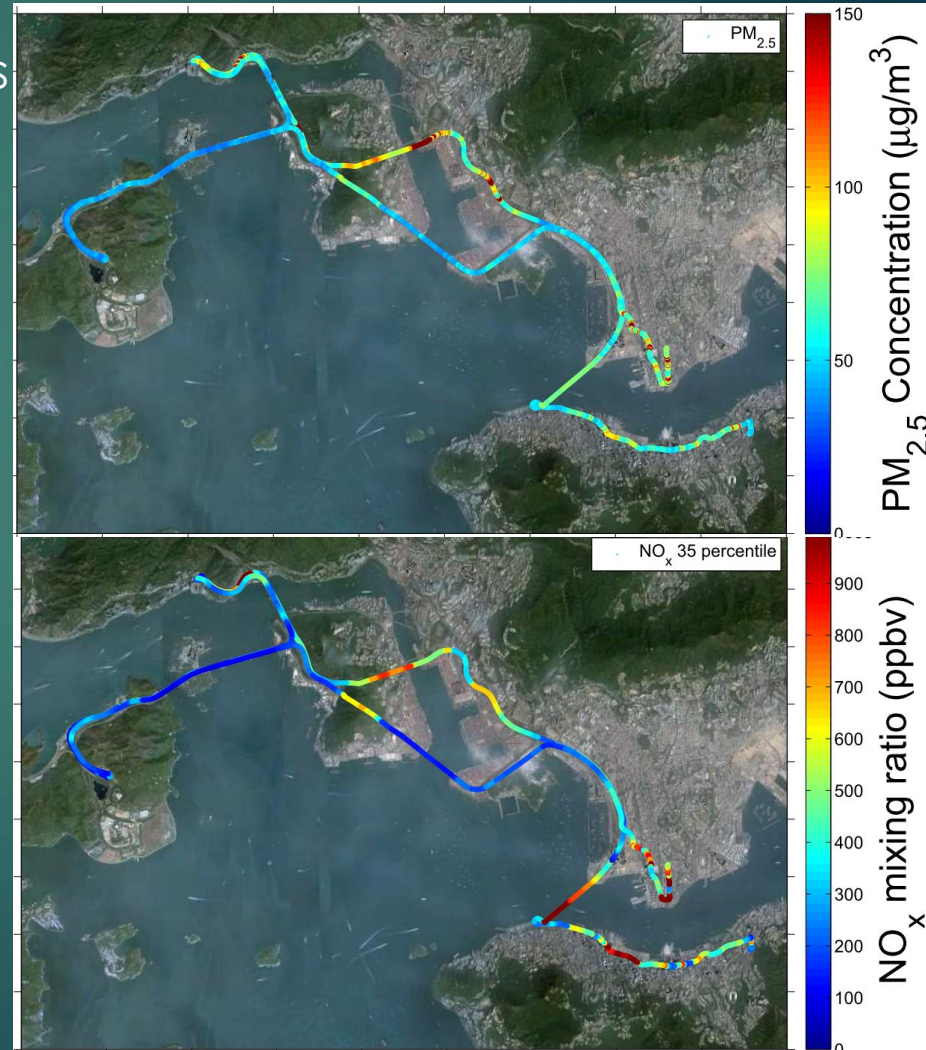
Sulphur dioxide (SO₂)
Total 19,540 tonnes



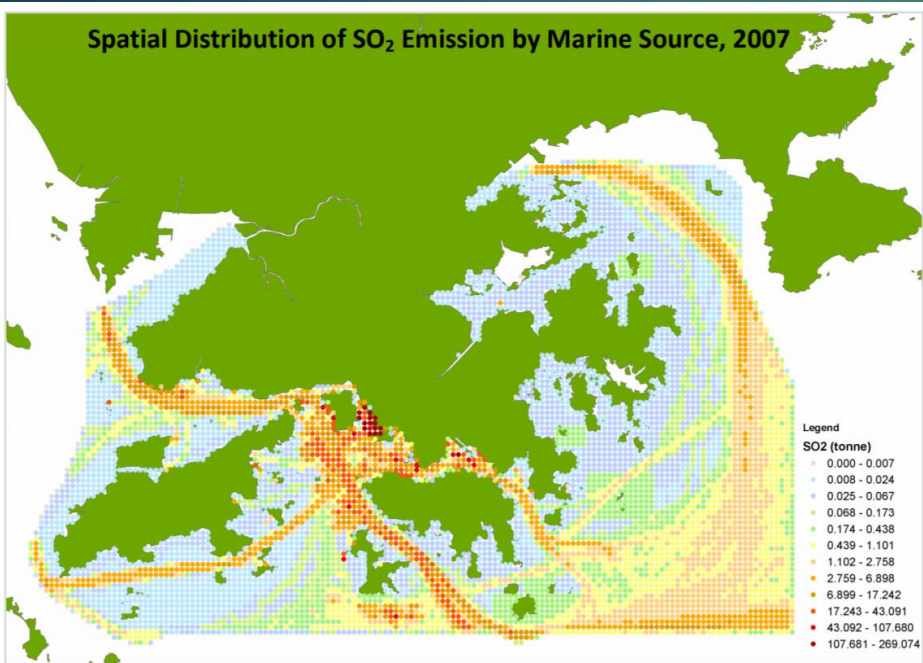
Background of port and ship emissions

Hong Kong case

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



Spatial Distribution of SO₂ Emission by Marine Source, 2007



Needs and constraints

- ▶ 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.

China handles 70% of global container volume



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Experts urge China to detail port emissions

Updated: 2014-07-04 08:38
By Wu Wencong (China Daily)

China should establish emissions inventories for all major port cities as soon as possible to detail pollutants from ships and ports, experts have suggested.

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Report on shipping and port air emissions released

chinagate.cn, July 3, 2014

The Natural Resources Defense Council (NRDC) has released a report on the Prevention and Control of Shipping and Port Air Emissions, which summarizes the latest research in the field, including the impact of port and shipping emissions on the environment and public health, and international experiences from the International Maritime Organization as well as other nations in setting related policies and

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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 ($S \leq 0.5\%$) , 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%
SO₂, 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 supplied 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

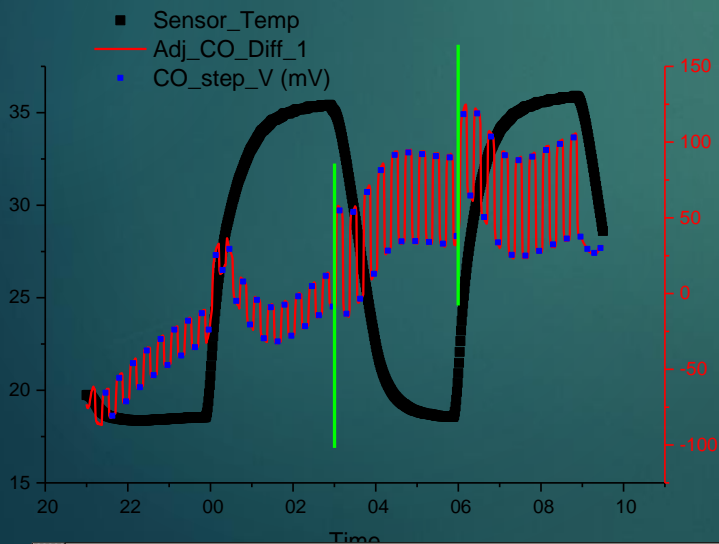
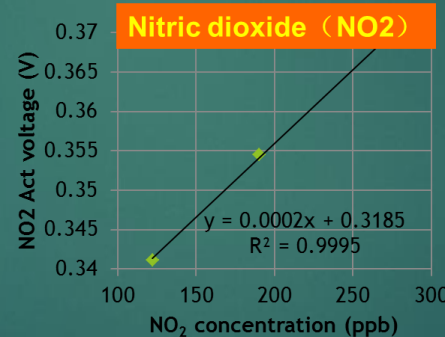
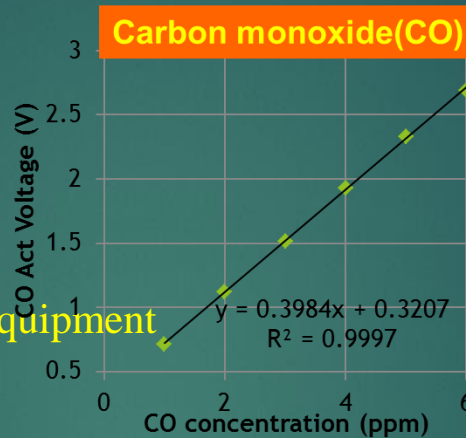


A drone made by Austrian firm Schiebel. Agencies are still assessing the kind of aircraft to use. *PHOTO: SCHIEBEL*

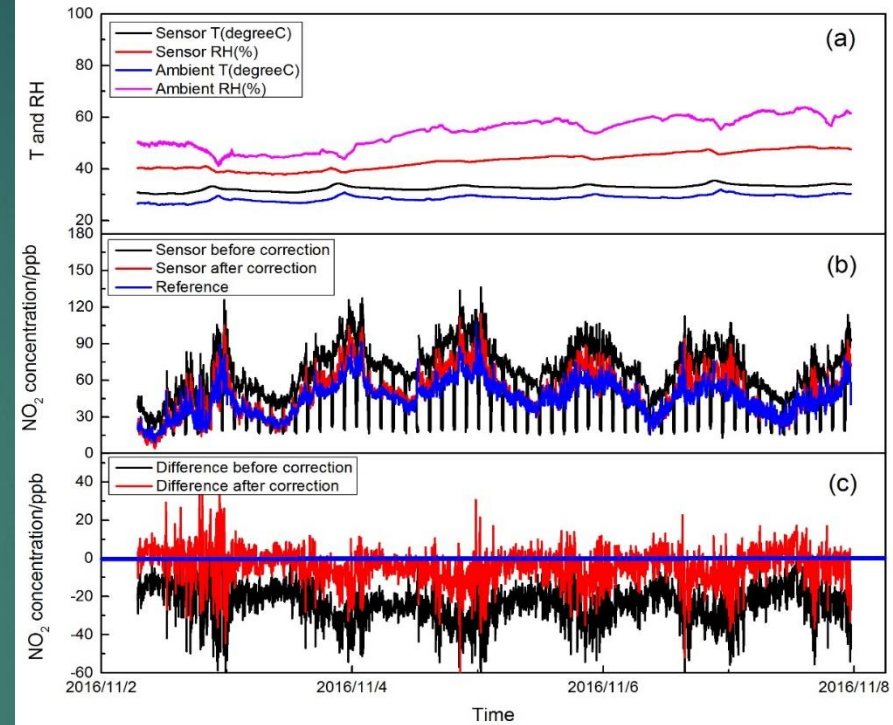
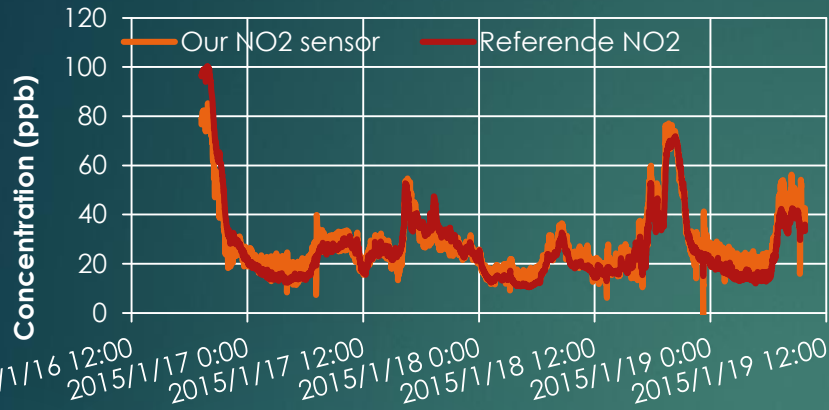
- Technical requirements
 - Flying time: at least 4 hours
 - Flying distance: 20 kilometers
 - It would be equipped with sulfur and CO₂ sniffers

Next generation sensor development: Test in lab

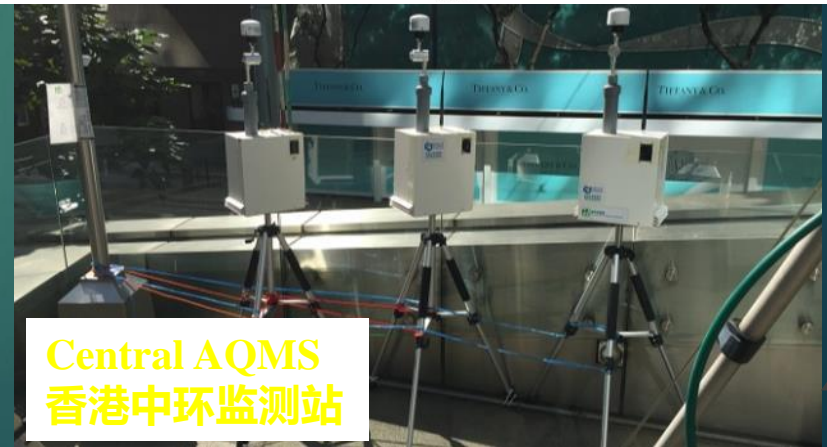
- ▶ Precision & linearity
- ▶ Test limits
- ▶ Long term drift
- ▶ Temperature and RH
- ▶ Comparisons with standard equipment



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



UAV-based airborne monitoring

- **UAV based sensor system**
 - **Sensor array (SO₂, NO_x, CO₂, VOC, CO, PM)**
 - **Visible and infrared camera for plume detection/tracking**
 - **Auto-data transmission and real time processing**



SPSS (Ship Plume Sniffer System)

Ship Plume Sniffer System For Emission Screening
船舶排放快速筛查系统

中/Eng 列表 比较 数据 地图 注销

设备号: dev9706d170700002

状态: 在线

最后更新时间: 2017-08-03 08:24:21.0

污染物在线浓度:

CO ₂	810 ppm
PM ₁₀	null $\mu\text{g}/\text{m}^3$
SO ₂	22.6 ppb
NO	19.9 ppb
NO ₂	22.6 ppb

船舶代号:
基准/峰值 船舶排放因子

CO₂基准:
CO₂峰值:
ppm

PM基准:
PM峰值:
 $\mu\text{g}/\text{m}^3$ 克/千克燃油

NO_x基准:
NO_x峰值:
ppb 克/千克燃油

SO₂基准:
SO₂峰值:
ppb 2.13 克/千克燃油

燃油含硫量: 2130 ppm

计算非排放因子

开始时间

2017-08-01 11:10

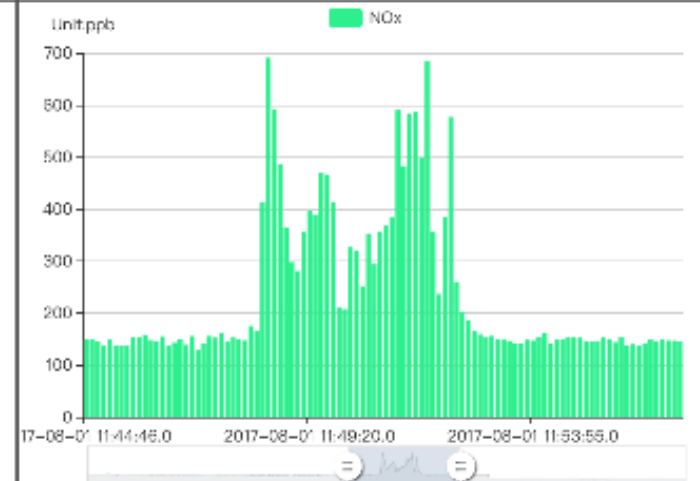
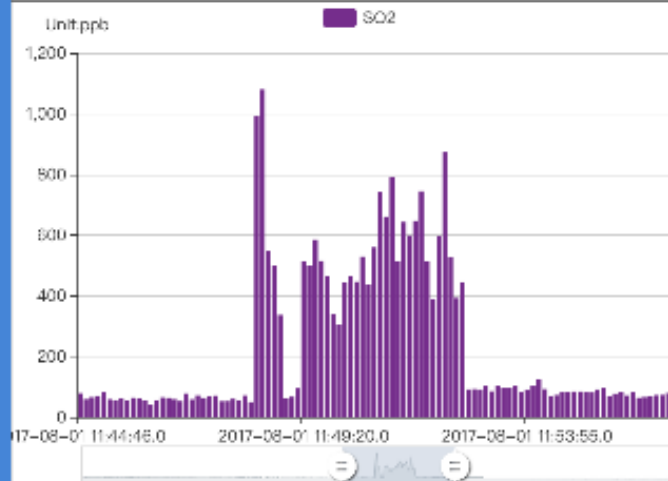
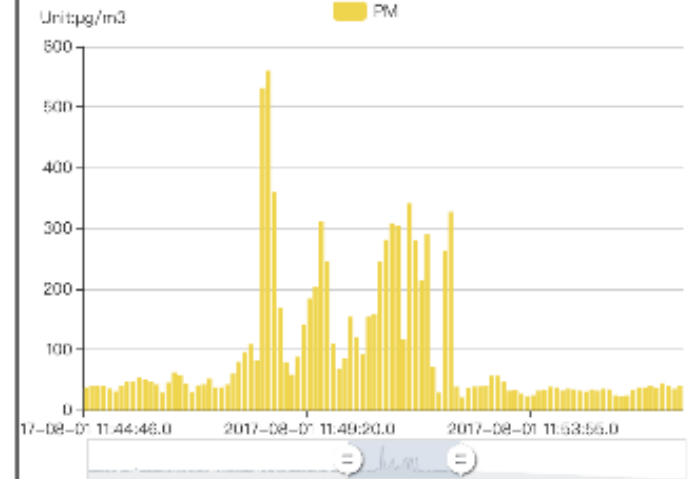
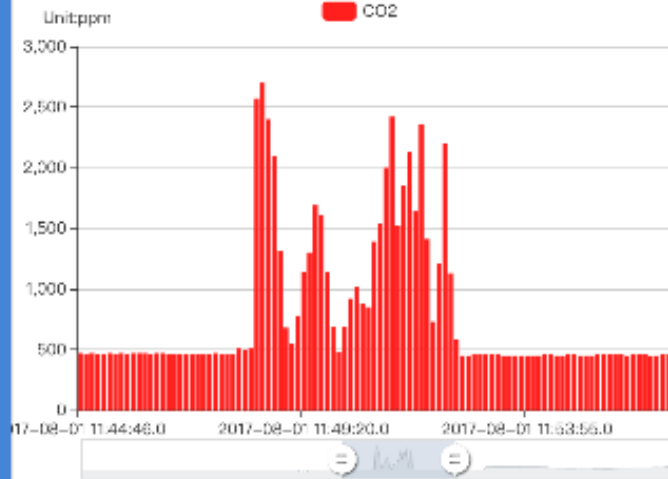
结束时间

2017-08-01 12:00

时间段

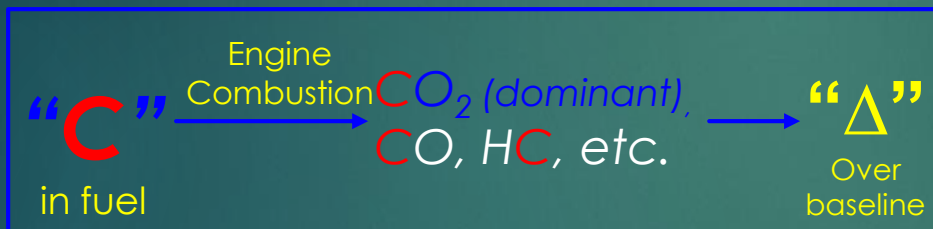
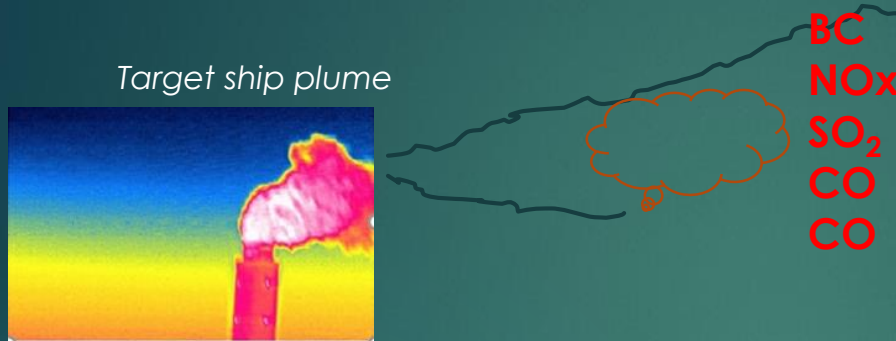
5分钟前

提交

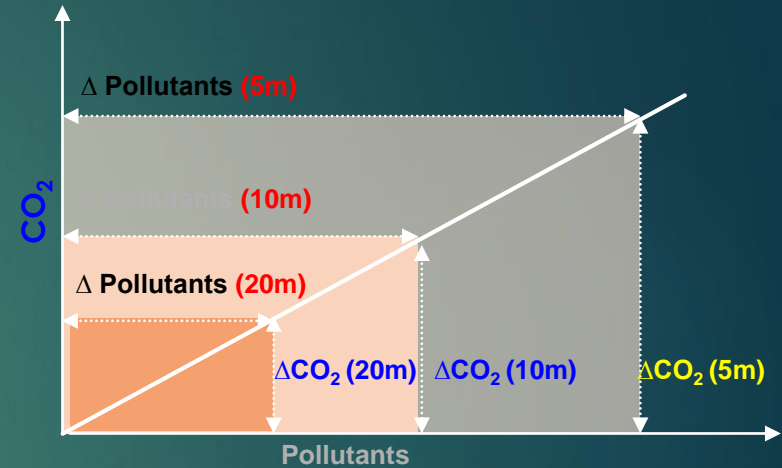


UAV-based airborne monitoring

UAV-Sniff mode: Principles



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



Distance doesn't matter in theory!

$$EF_p = \frac{\Delta[\text{Pollutants}]}{\Delta[\text{CO}_2] * \frac{MW_c}{MW_{\text{CO}_2}} + \Delta[\text{CO}] * \frac{MW_c}{MW_{\text{CO}}}} * w_c$$

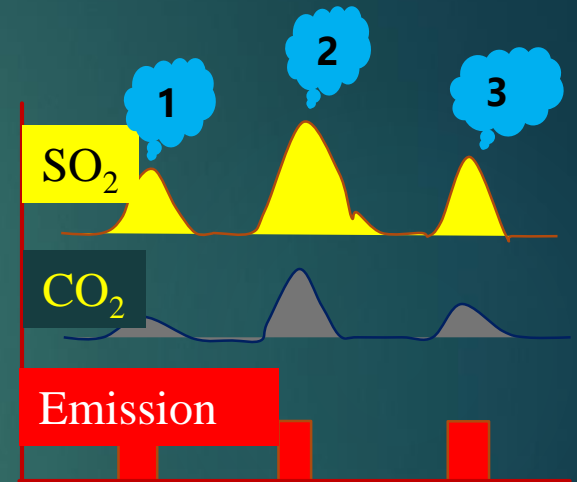
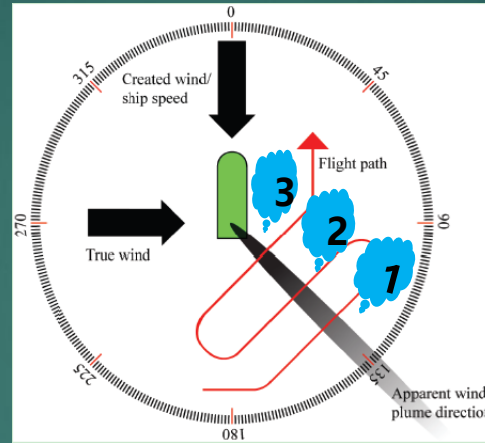
w_c : carbon in fuel; MW: molecular weight;

Δ : Concentration increase
 = $\text{Conc}_{\text{plume}} - \text{Conc}_{\text{baseline}}$

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

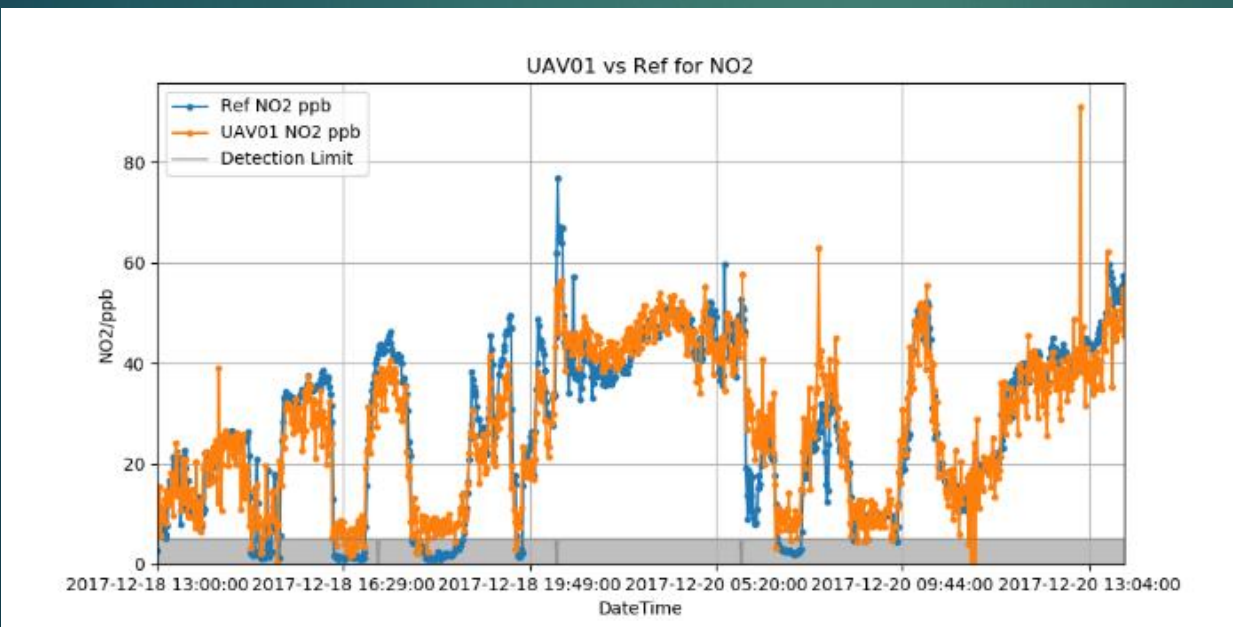
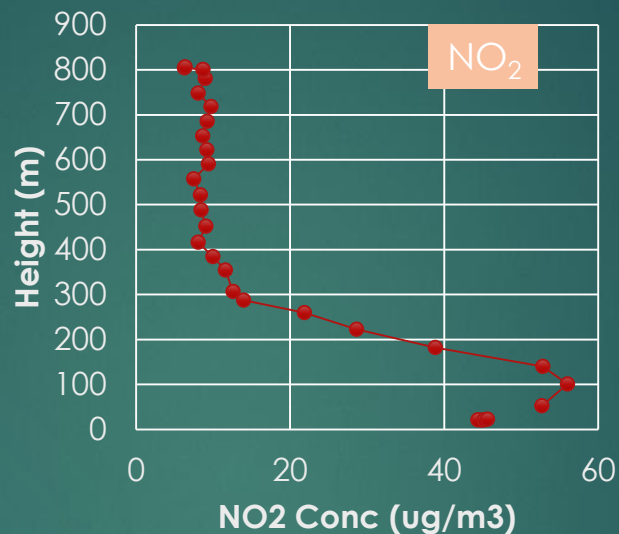
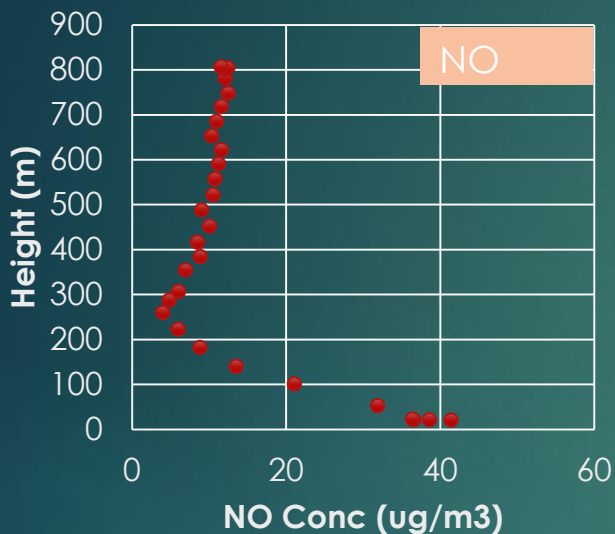
– UAV-Sniff mode: Methodology



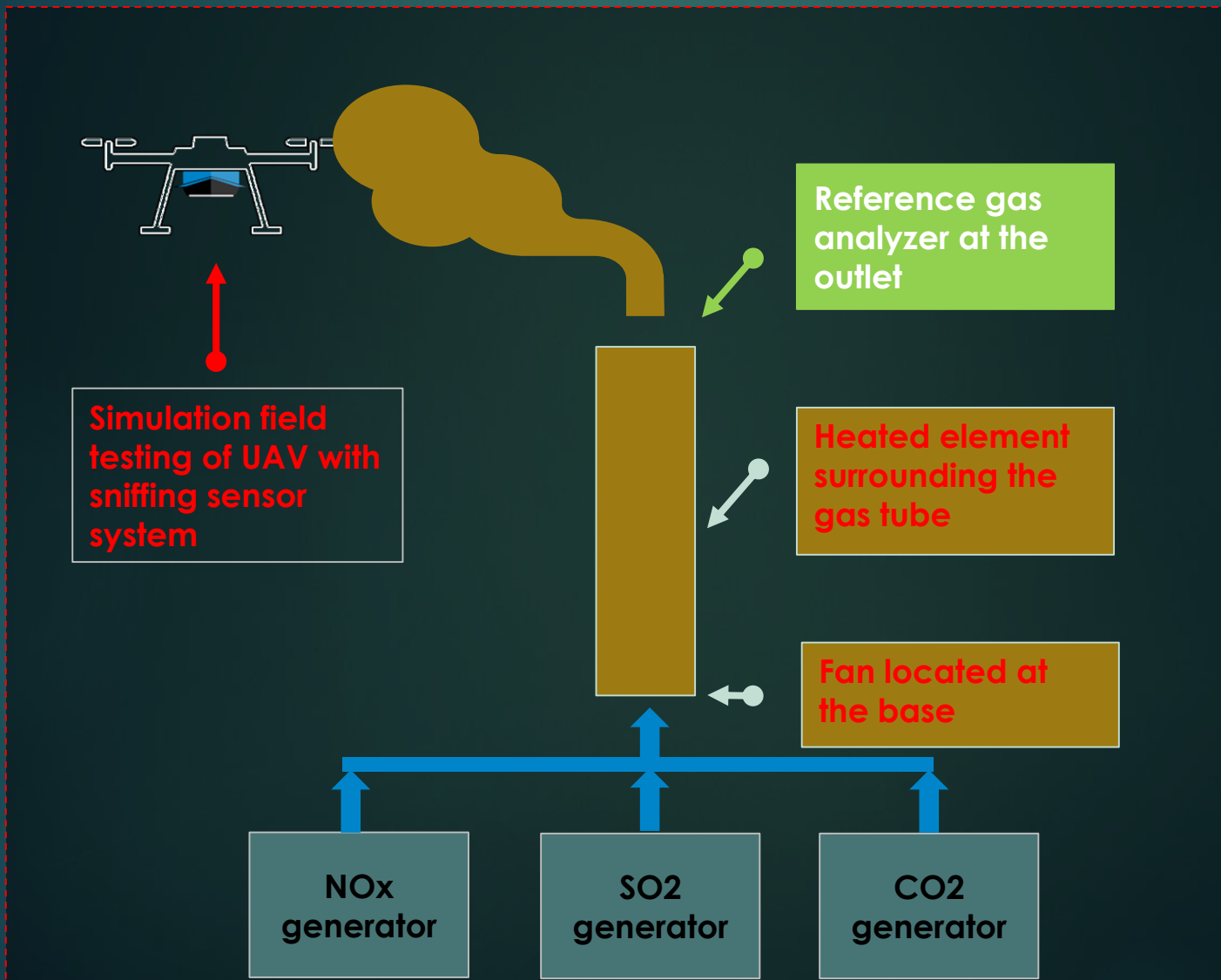
1. Identify and track individual ship plume
2. Cross-sectional scanning of plume
3. Sniff using advanced sensors for pollutants/CO₂
4. Fuel carbon balance method for sulphur content and other pollutant emission factor

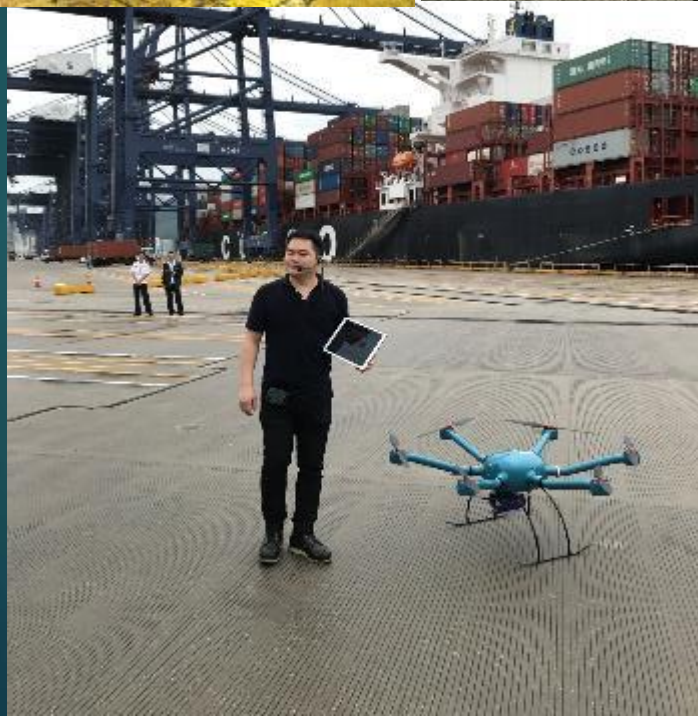
Establish emission factors (SO₂, NO_x, PM, BC) for Ship emissions
1-2 minutes measurement of individual ship plume
Max 4.5%, Avg 3% to 0.5% Sulfur content will have big difference

1000m sensor validation for airborne temperature and humidity impact



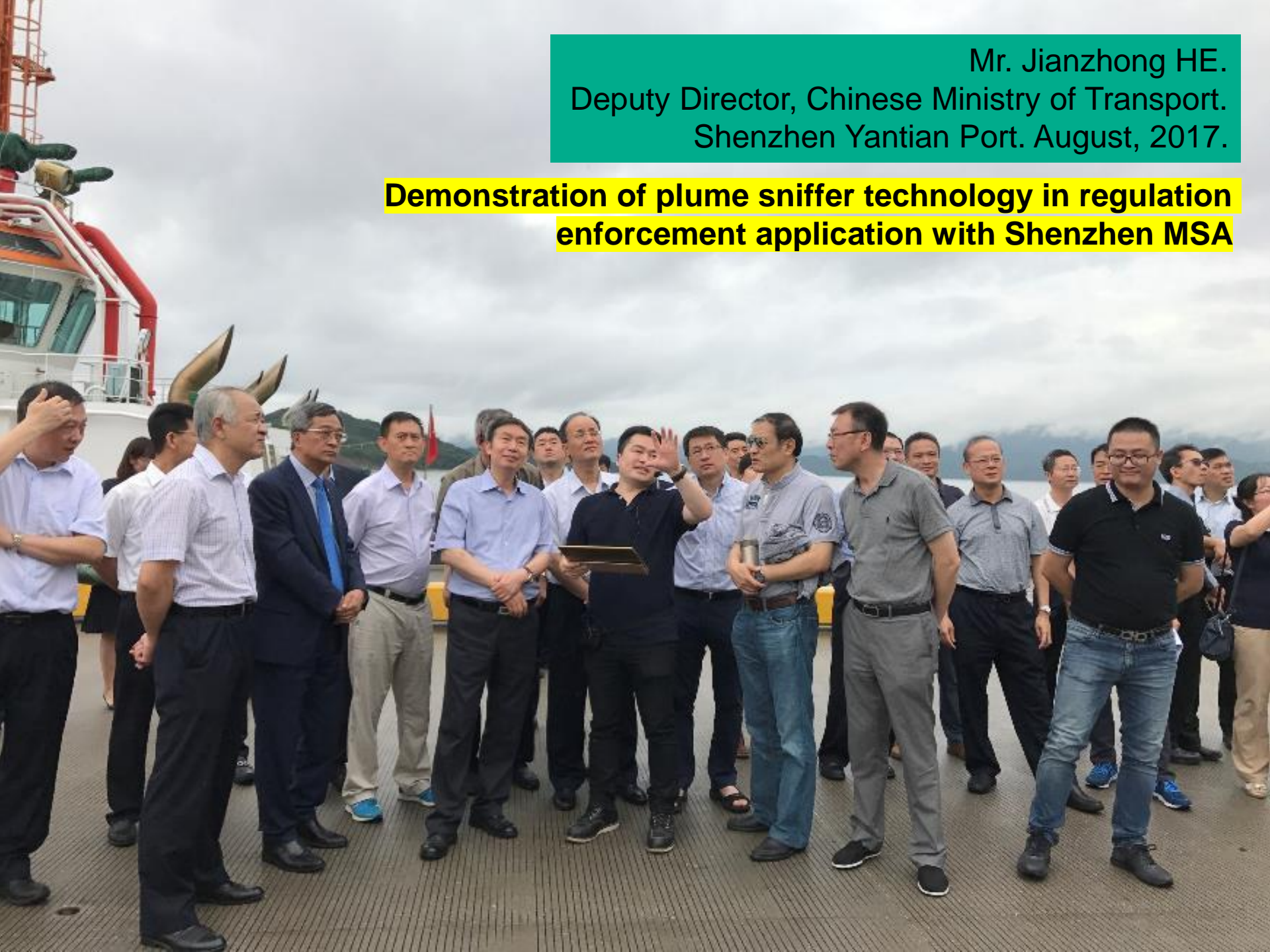
Simulation field testing and protocol development





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

珠三角水域船舶大气污染
排放控制区调研座谈会

2015年9月22日



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

《内地与香港船舶大气污染防治合作协议》签署仪式



内地与香港船舶大气污染防治合作协议
Cooperation Agreement on Prevention and Control of Air Pollution
from Vessels between the Mainland and Hong Kong

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

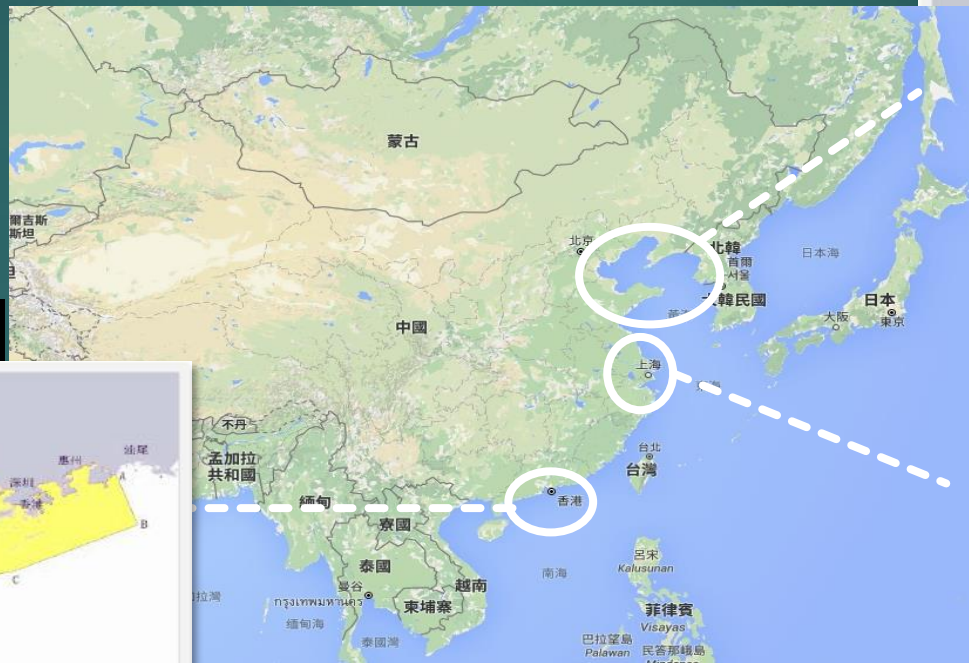
Bohai Rim ECA



YRD ECA



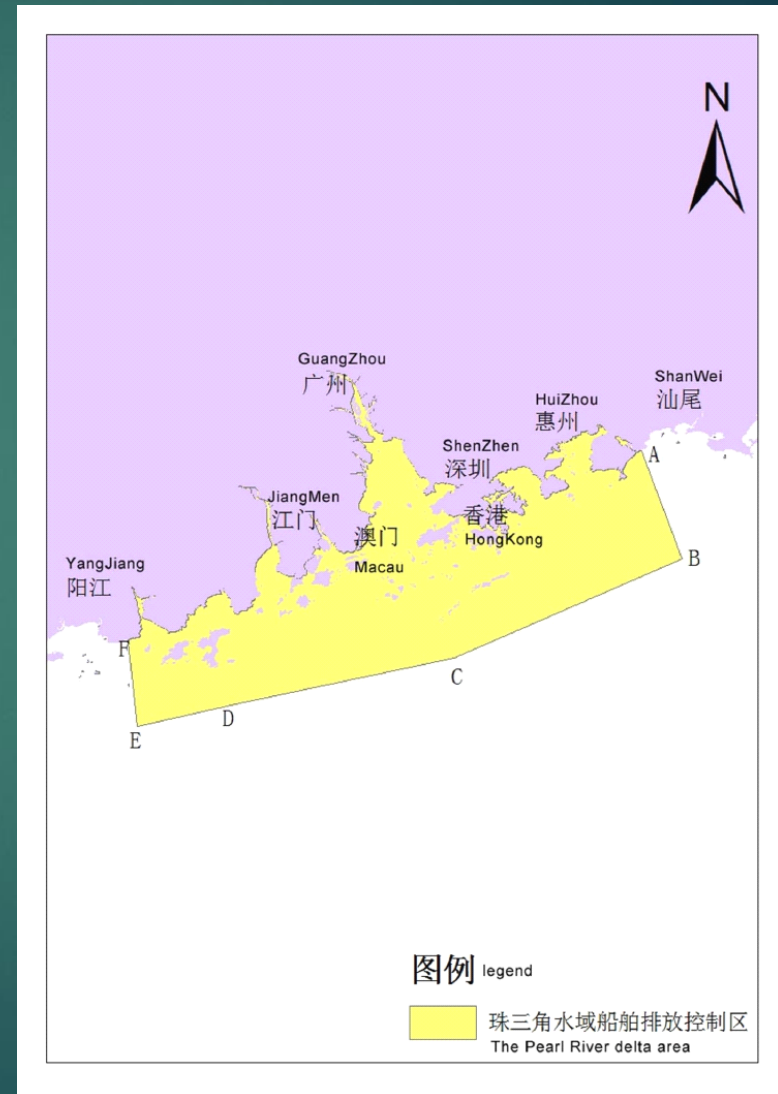
PRD ECA



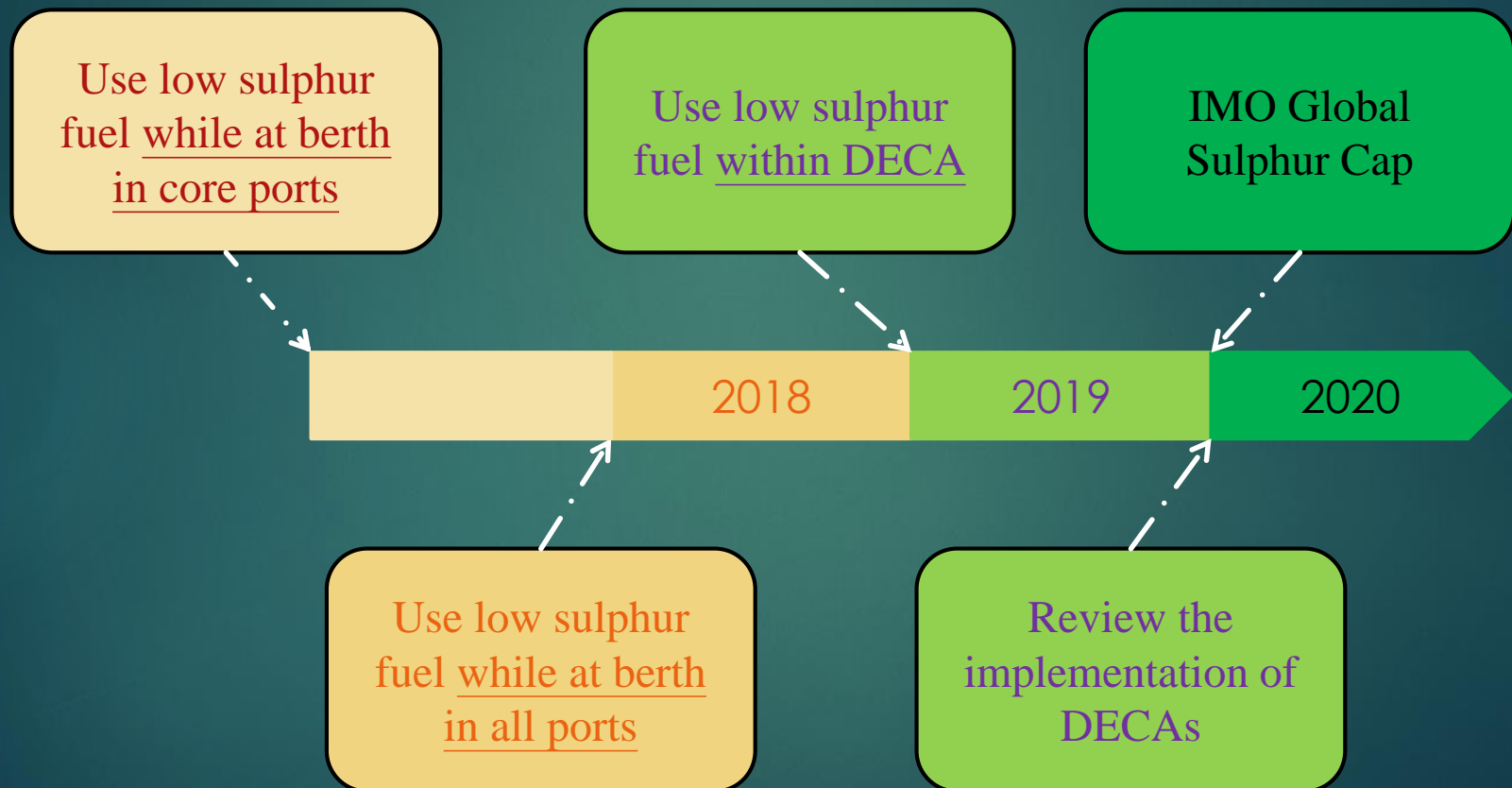
Coverage of PRD DECA

25

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



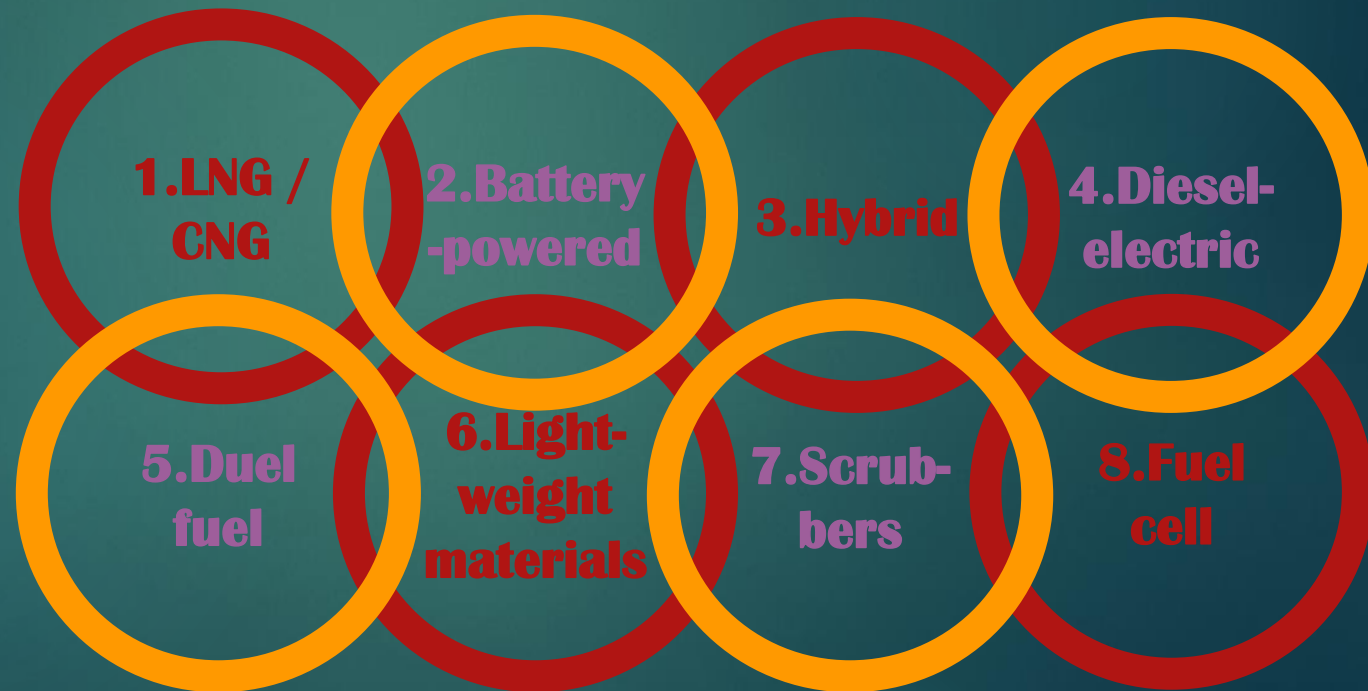
Implementation Plan on Domestic Emission Control Area (DECA)



Future of Green Shipping



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

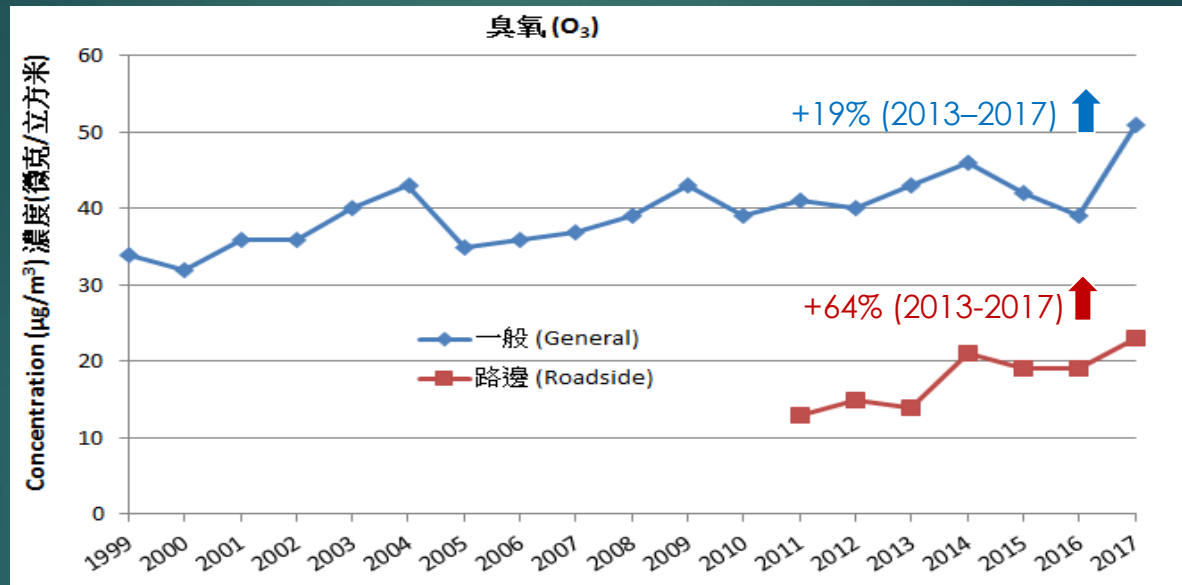


Thank you

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。

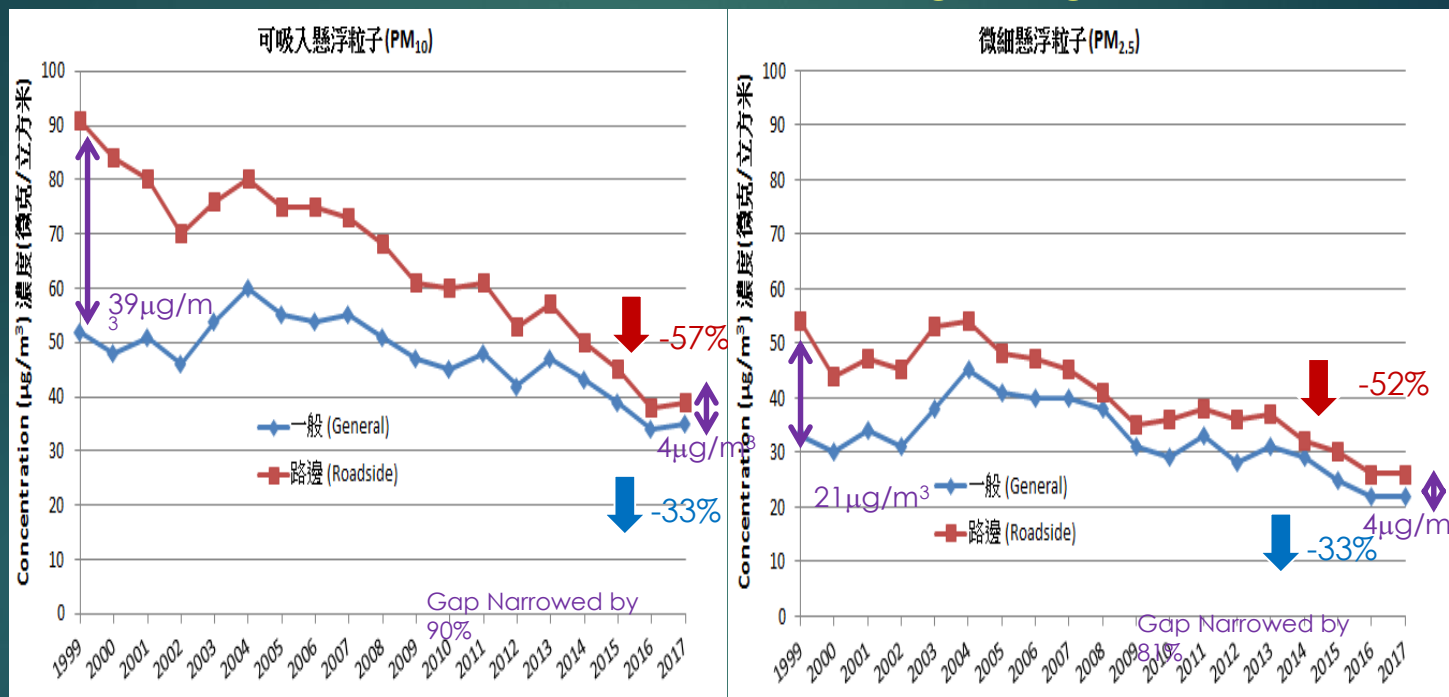
From 1999 to 2017, ambient O₃ level is still on a rise.

- 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 O₃ remained at a low level while on a rise.

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PM₁₀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PM₁₀和PM_{2.5}水平則變化不大。

Source:
HKEPD

From 1999 to 2017, both ambient and roadside PM₁₀ and PM_{2.5} levels were on a declining trend. Compared with 2016, both ambient and roadside PM₁₀ and PM_{2.5} levels in 2017 showed no significant changes.