



Asia Center for Air Pollution Research
Japan Environmental Sanitation Center

Transient RDE NO_x Emissions from Diesel city bus in Xiamen, China

H. Minoura¹, T. Tange², P.W. Wang³, and J. Ou³

¹Asia Center for Air Pollution Research

²NGK Spark Plug Co. LTD

³Environ Monitoring Center of Xiamen





What is Xiamen city like?



◆ Population : 4 milion

◆ Air Quality :

The air excellent rate is 98.6%, ranking 2nd among 169 key cities in the country.

◆ Motor vehicle emissions NOX have a greater impact on air

◆ Number of registered cars : 1.57 million

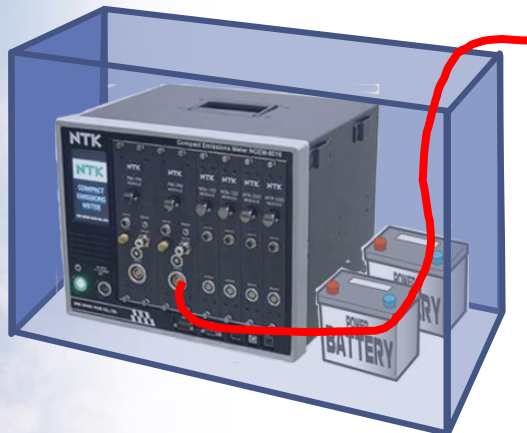
◆ Number of registered diesel city bus : 4459



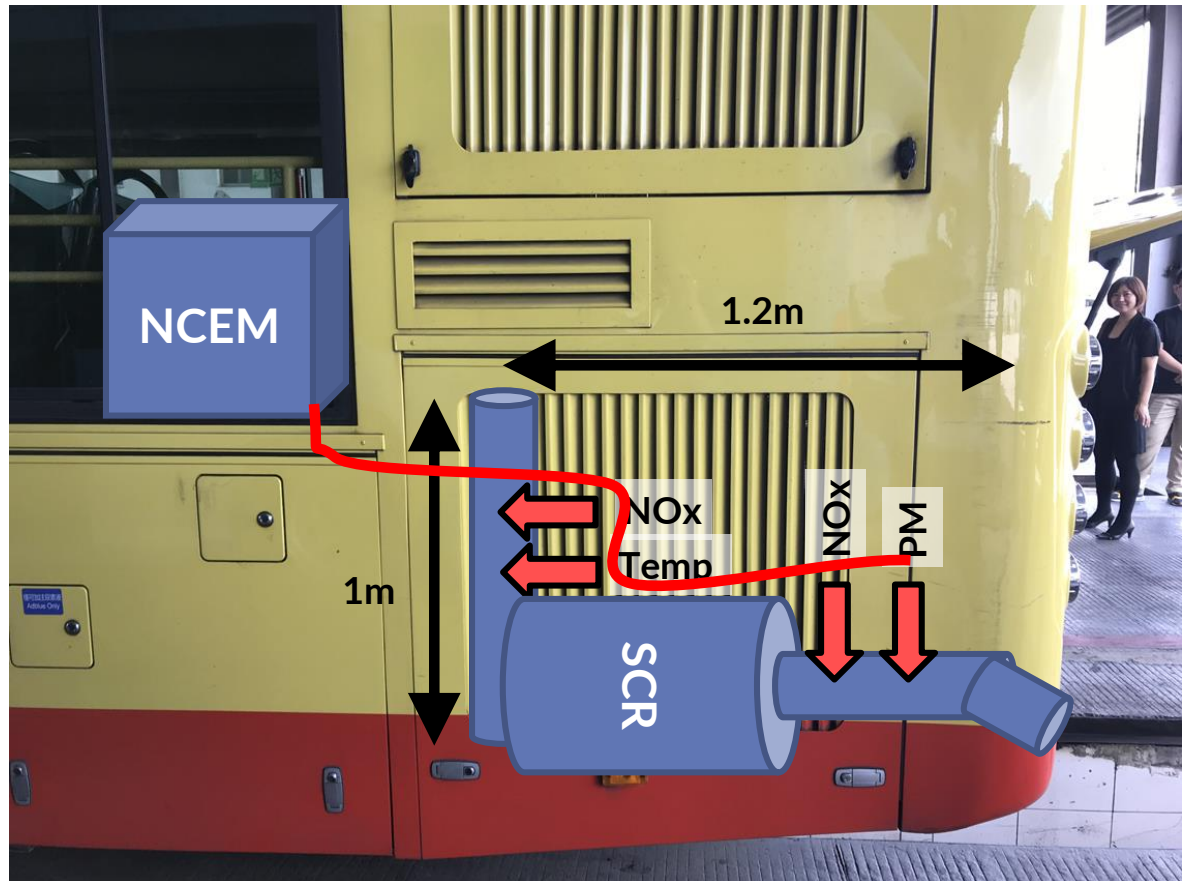
Sensors set-up



Battery drive
Monitor (NCEM)

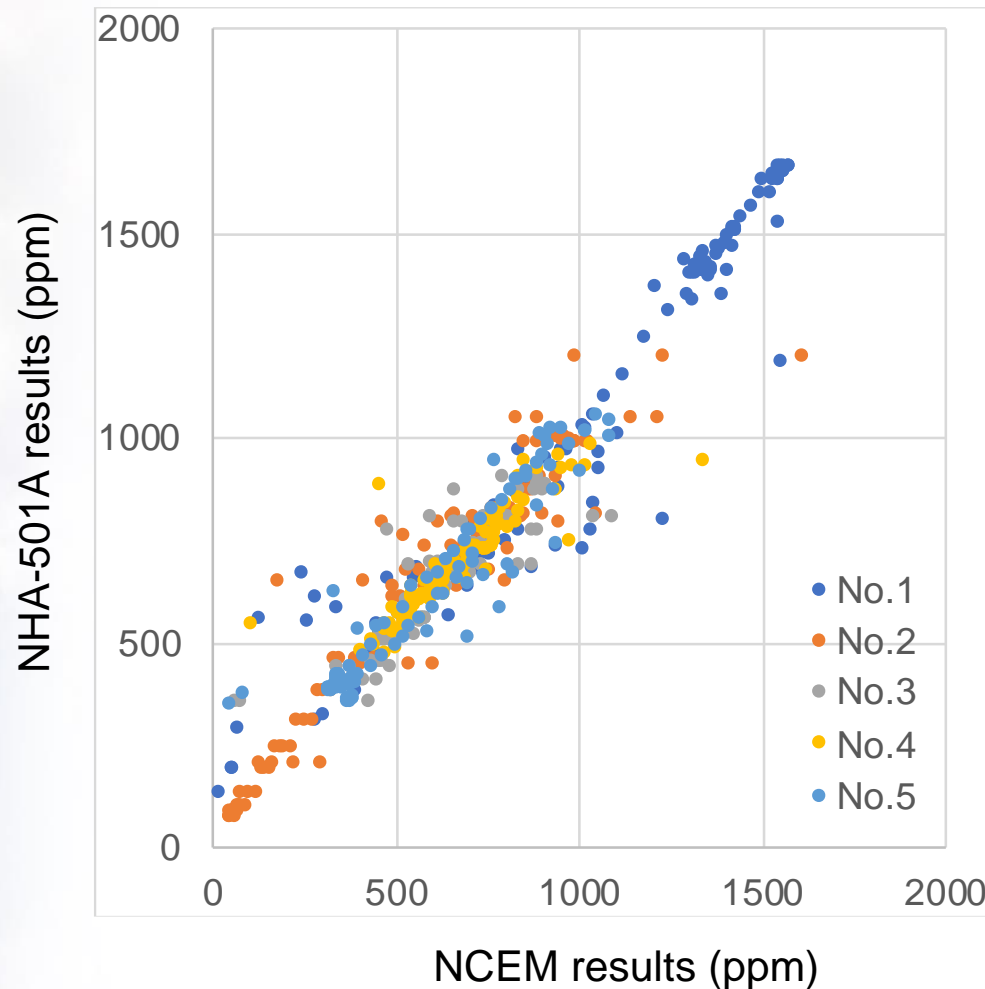


2017 model year 8.5 litter diesel with SCR system





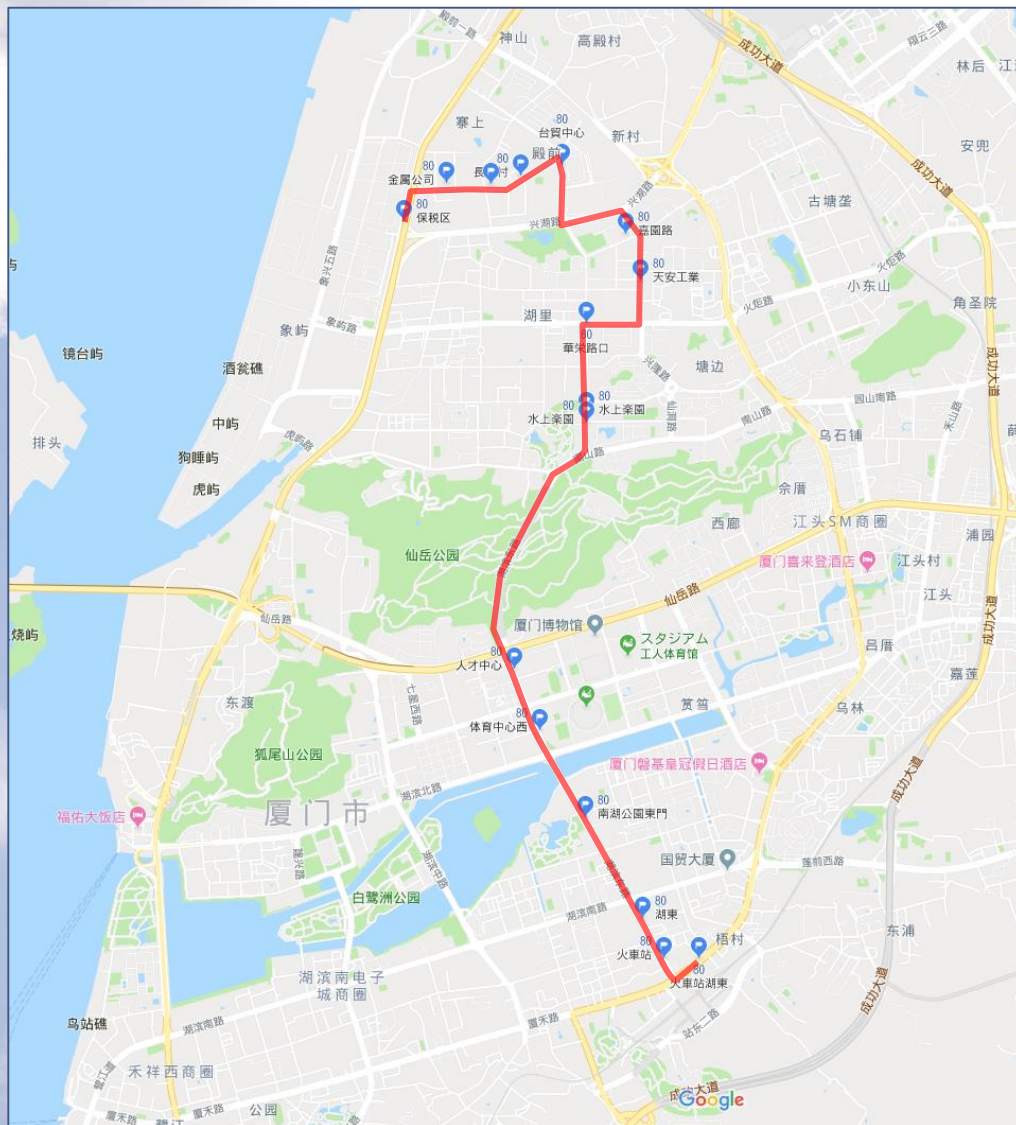
Chassis dynamometer comparison test



Good correlation of NOx concentration was obtained with NDIR analyzer NHA-501A made by Nanhua



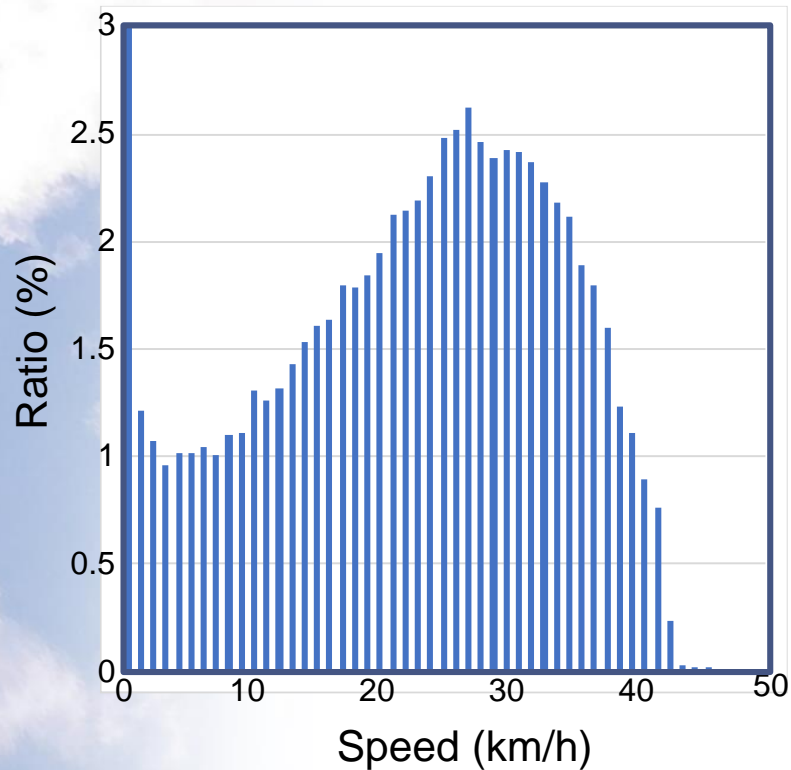
Bus No.80 route map



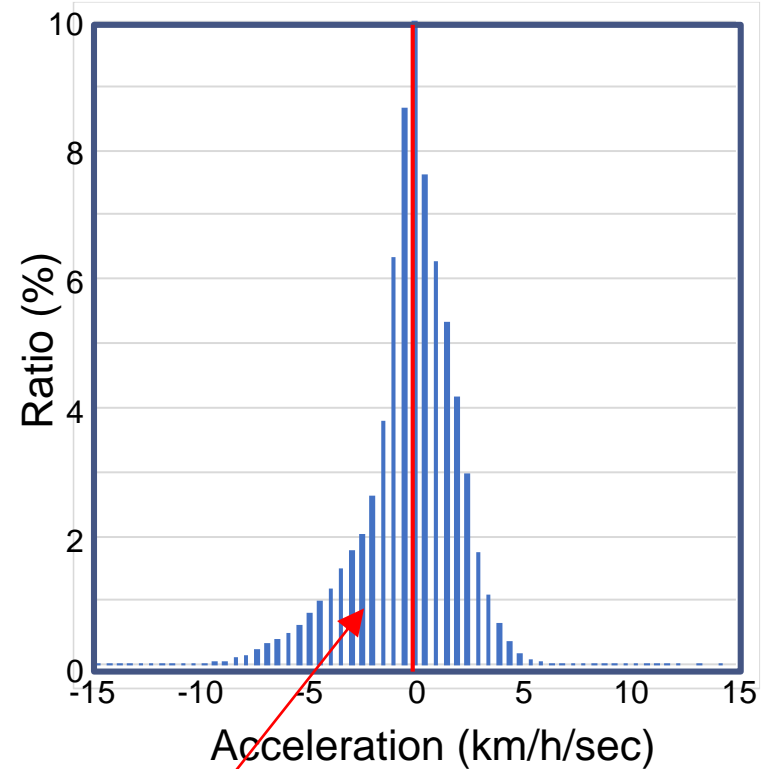
- ◆ Continuous NO_x, PM, exhaust temperature, and OBD measurement were conducted about 8 hours a day for 8 days including morning rush.
- ◆ The bus to be measured carried out a commercial operation that goes back and forth in Route 80 in approximately one hour.
- ◆ Passengers get on and off at 15 stops. The maximum passenger number was about 60.



Diesel bus operation status



average vehicle speed = 16.98 km/h
(including the stop time for passengers)



deceleration is lager

Diesel bus driving condition

Relative Positive Acceleration

$$(RPA) = \frac{1}{x} \int_0^T v a dt = 0.200 \text{ (m/s}^2\text{)}$$

x : total distance

387km

v : vehicle speed

16.98km/h

a : positive acceleration

t : total (cycle) time

10 mode (Japan) = 0.198

at 17.57km/h

JC08 mode (Japan) = 0.184

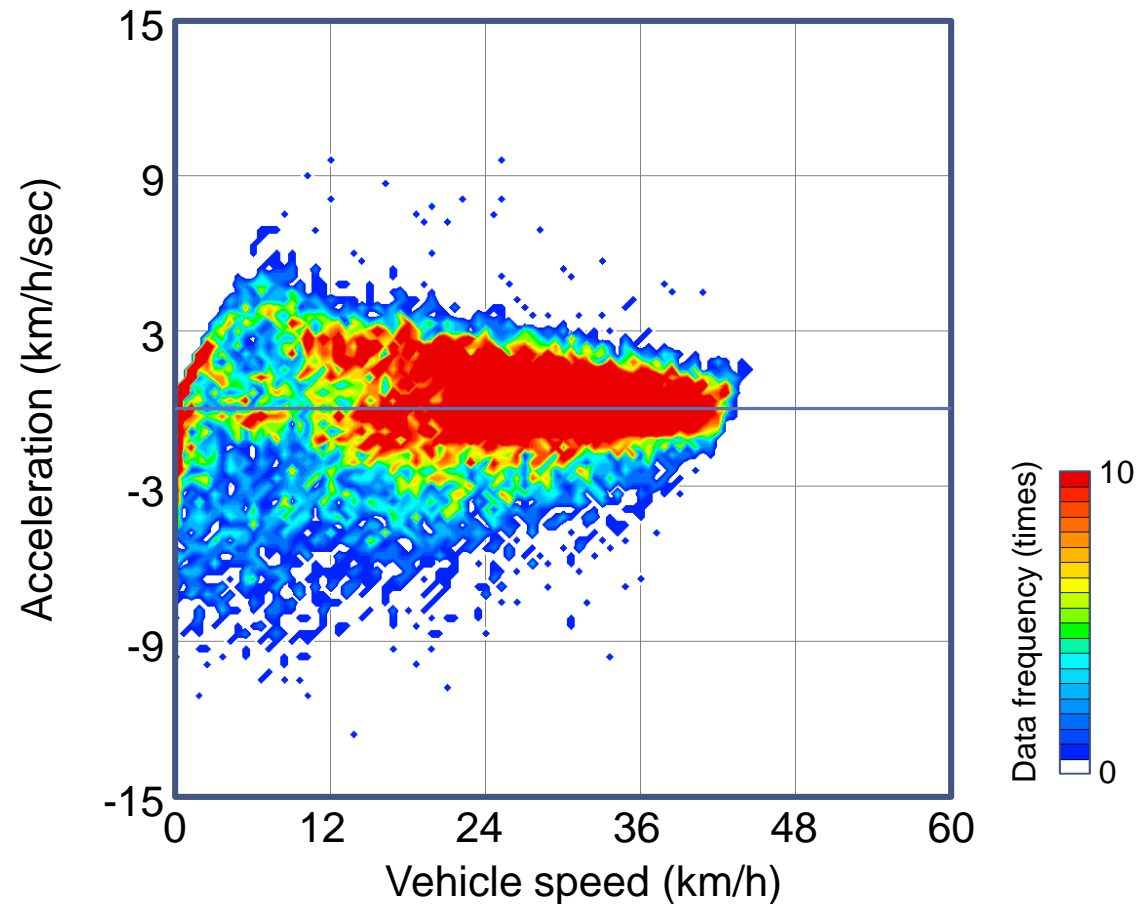
at 24.41km/h

CD34 mode (Japan) = 0.186

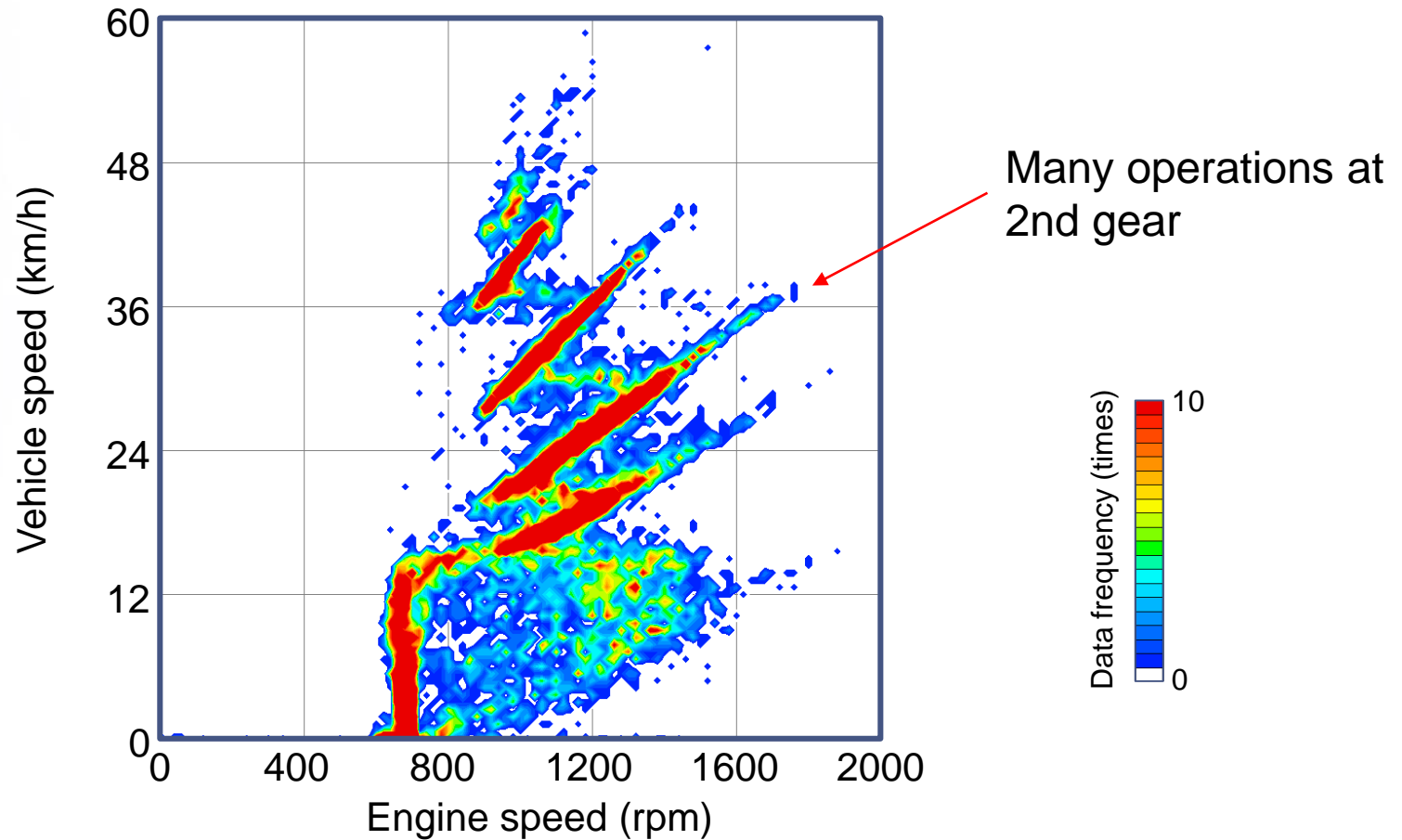
at 24.37 km/h

FTP mode (USA) = 0.376

at 34.12 km/h

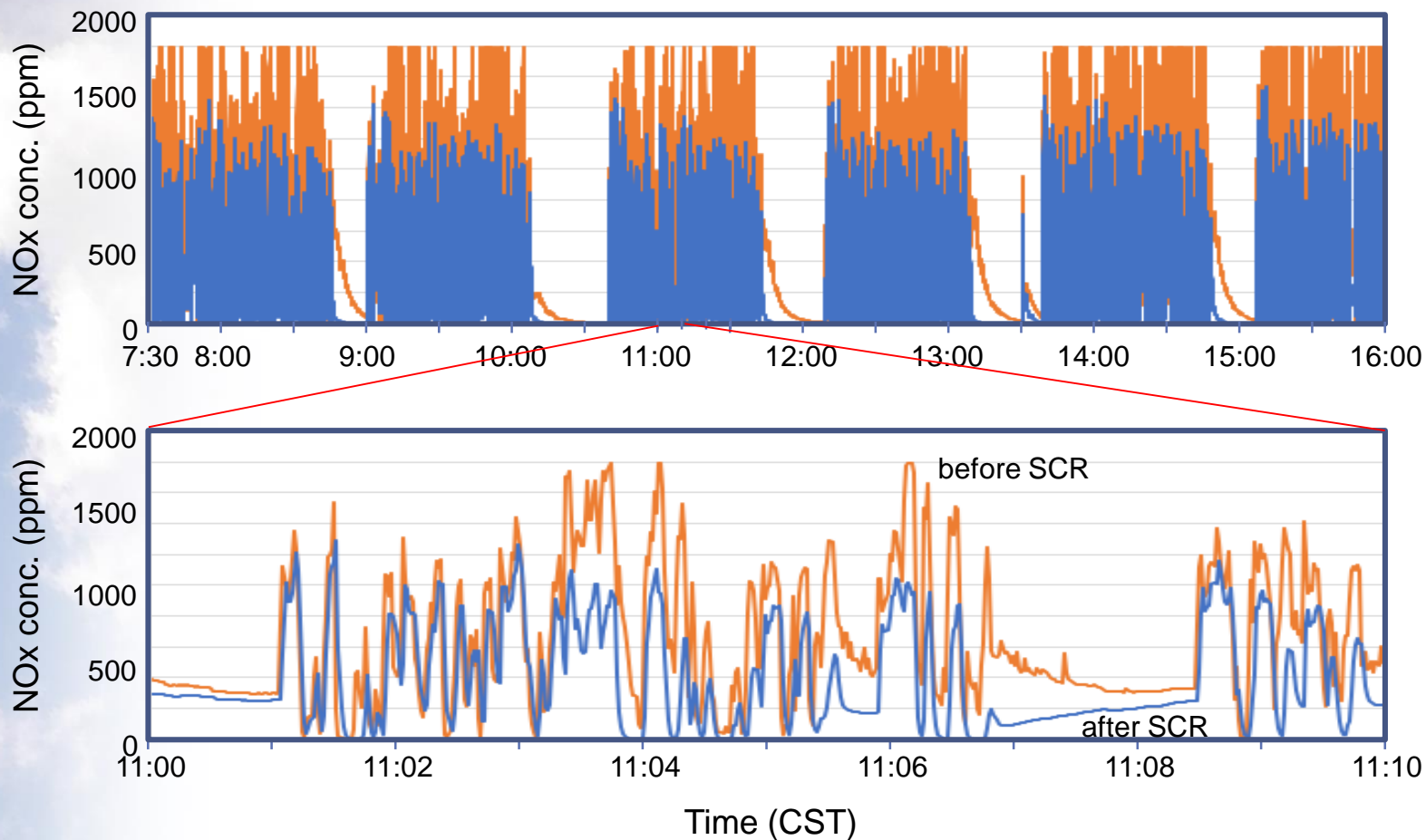


Diesel bus driving condition





Diesel bus NOx exhaust



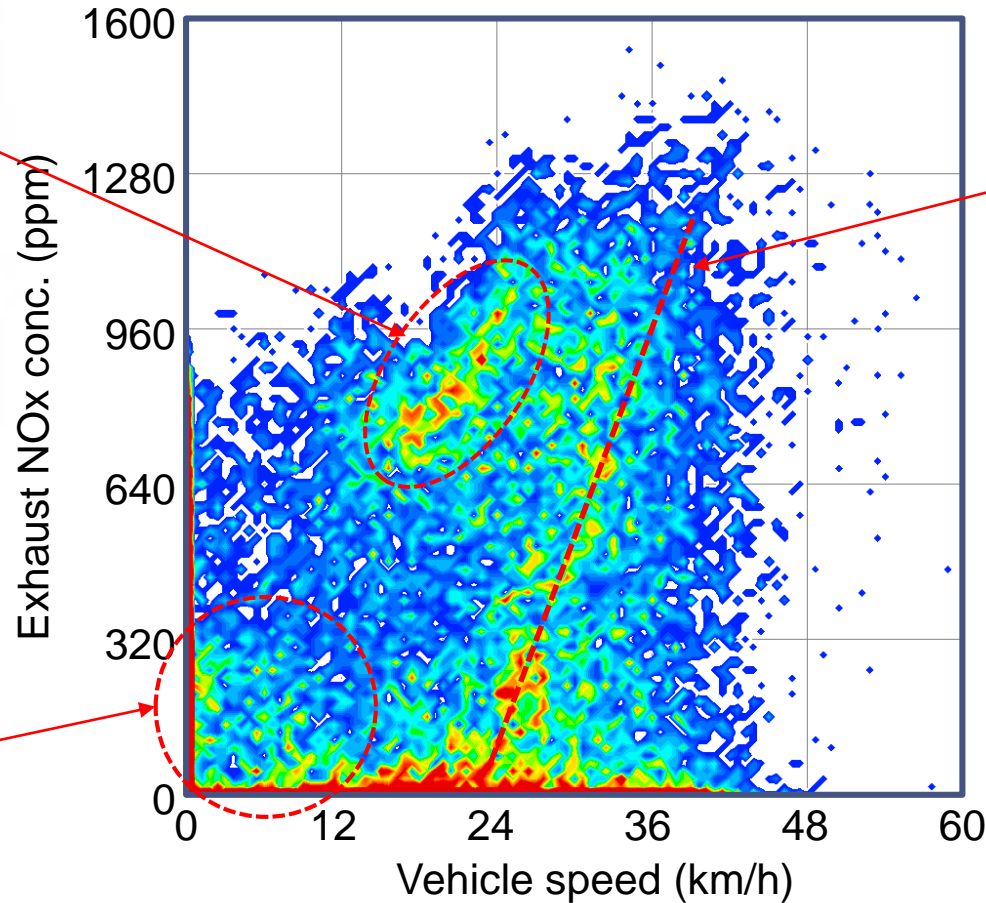
- ◆ SCR NOx reduction control seems to be conducted only when NOx concentration increases over 1000 ppm.
- ◆ High concentrations of NOx are being exhausted during bus service.



Diesel bus exhausted NOx

SCR is not working?
cause unknown

A relatively high NOx
concentration
exhausted at low
speed area



Increase of NOx
concentration with
vehicle speed

Data frequency (times)
0 10

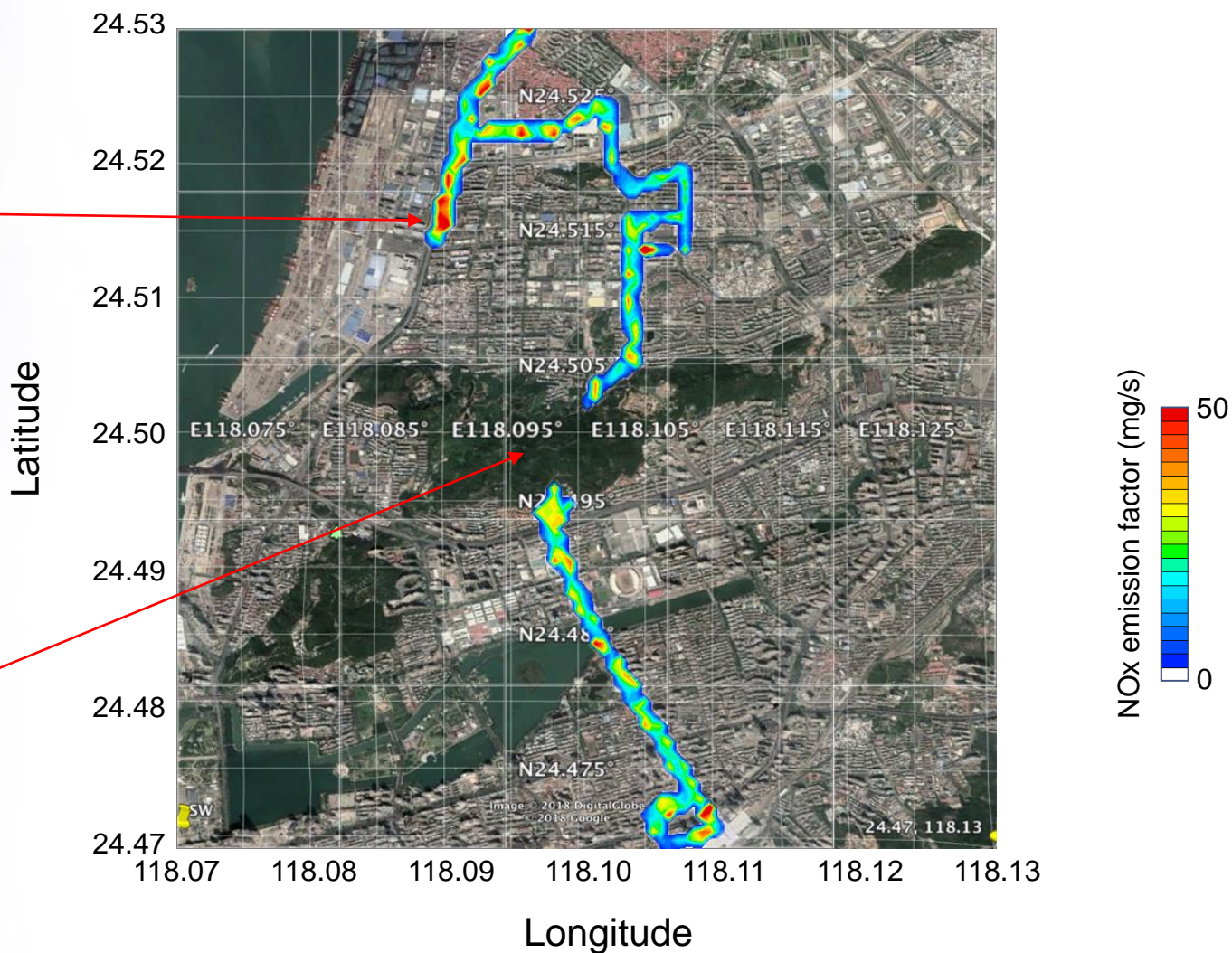
- ◆ NOx concentration in the exhaust gas is slightly high at low speed, but, it is roughly proportional to the vehicle speed.



Diesel bus NO_x emission factor

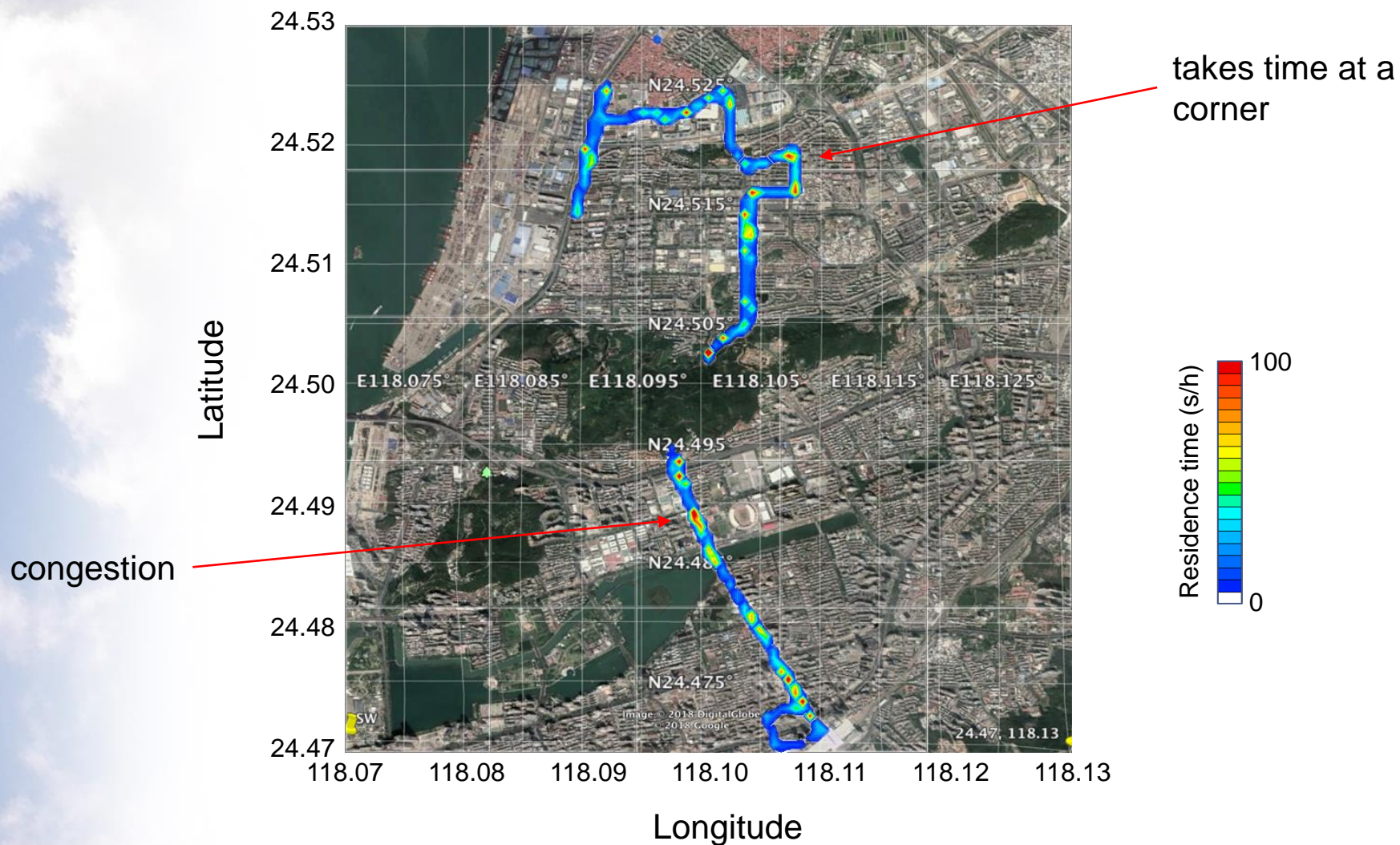
High emission factor around a bus terminal

Tunnel section (no GPS signal)





Diesel bus average residence time





Diesel bus NOx emission

bus terminal

A large amount of NOx is exhausted at corner.

Latitude

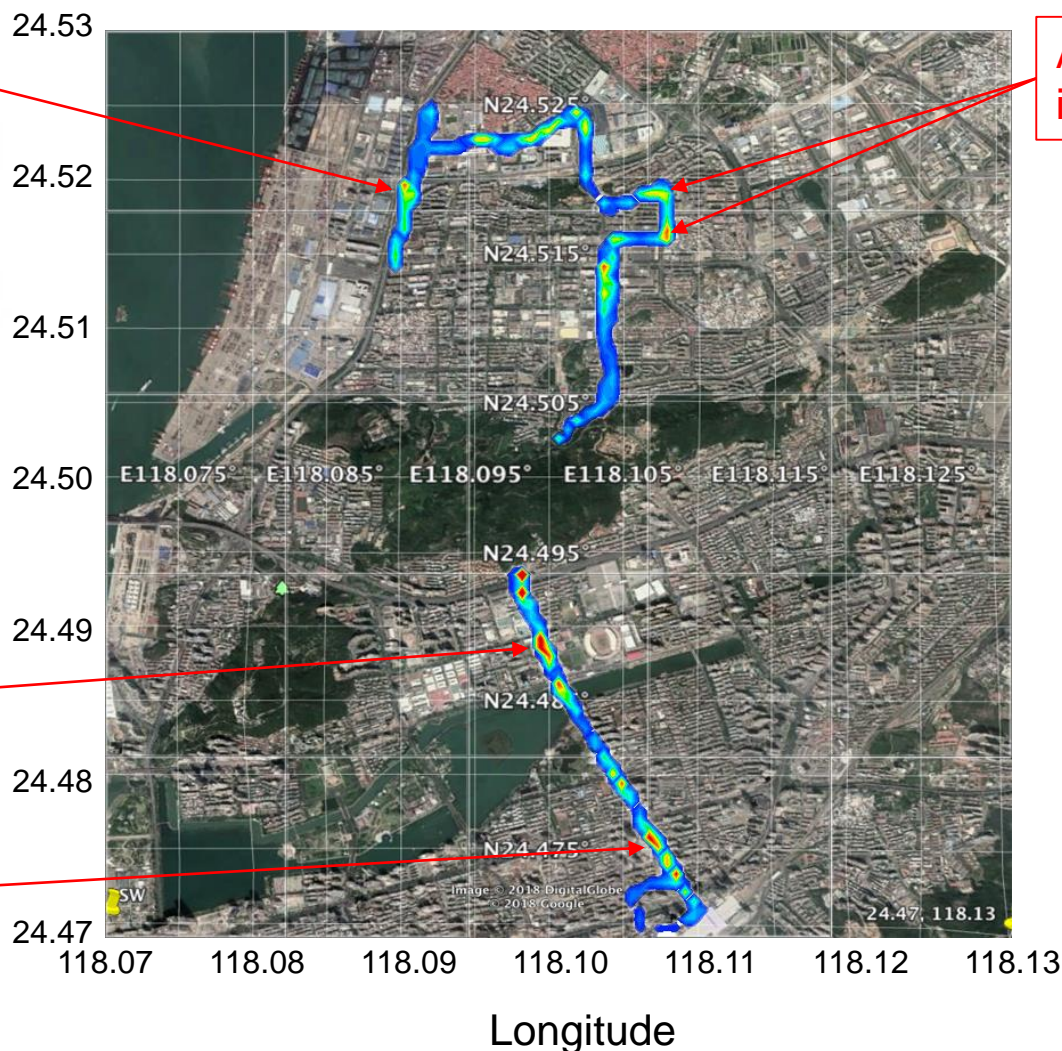
NOx emission (g/h)

2

0

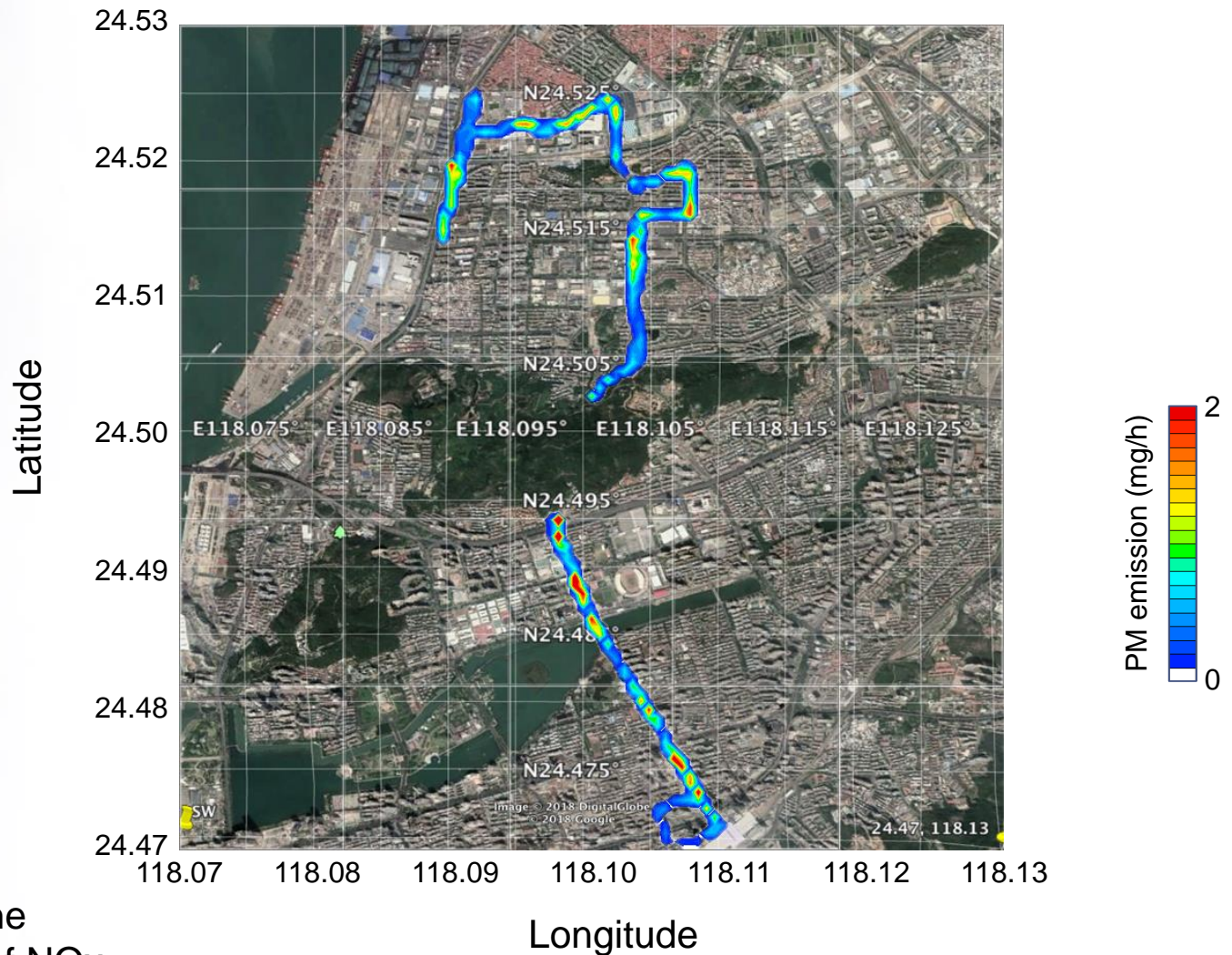
A large amount of NOx is exhausted before bridge.

A large amount of NOx is exhausted at downtown street.





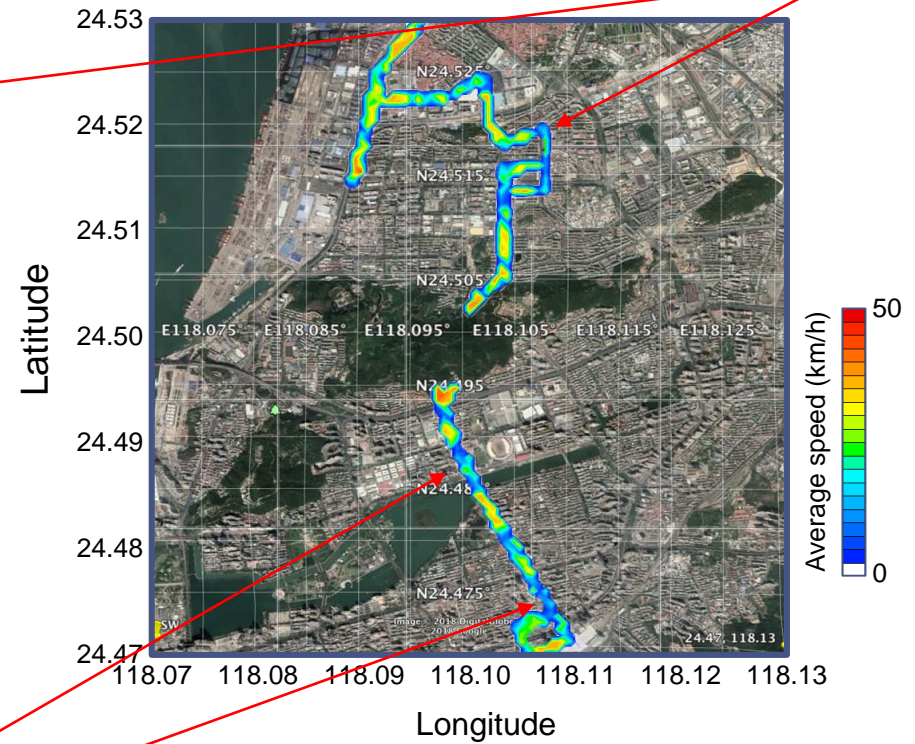
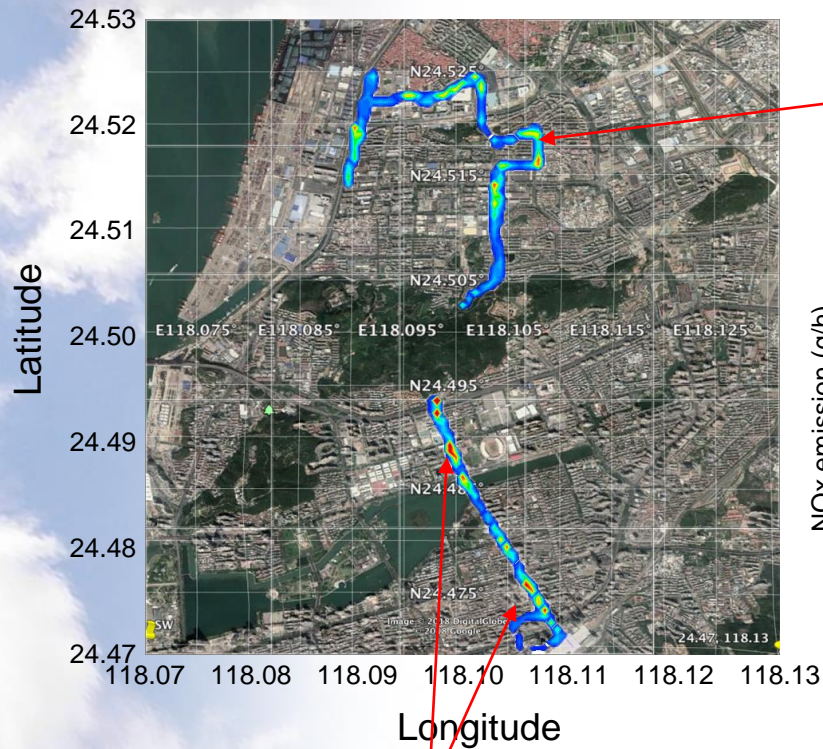
Diesel bus PM emission



Almost the same as the
emission distribution of NO_x



Diesel bus average speed



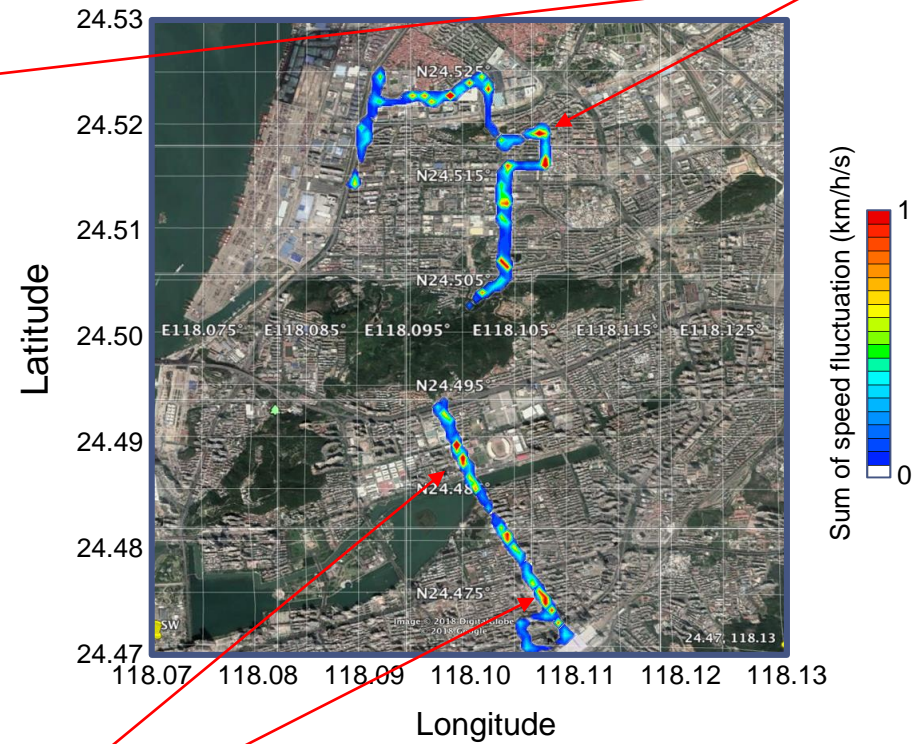
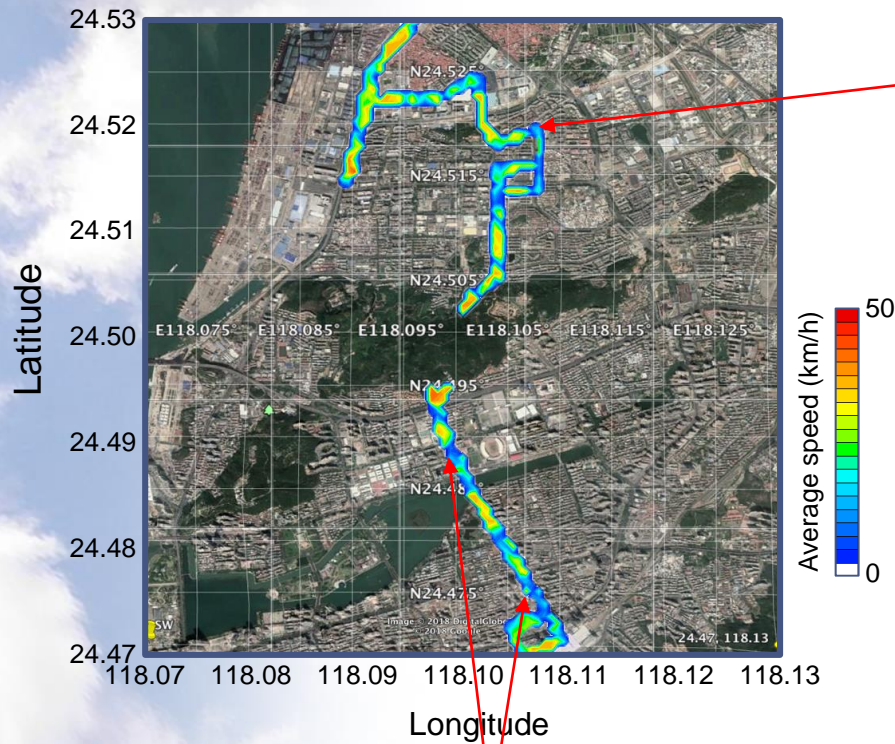
A large amount of NOx is exhausted at low speed driving condition = congestion



Eliminate congestion by signal cycle and variable lane number system, and contribute to reducing emissions



Diesel bus average speed vs fluctuation



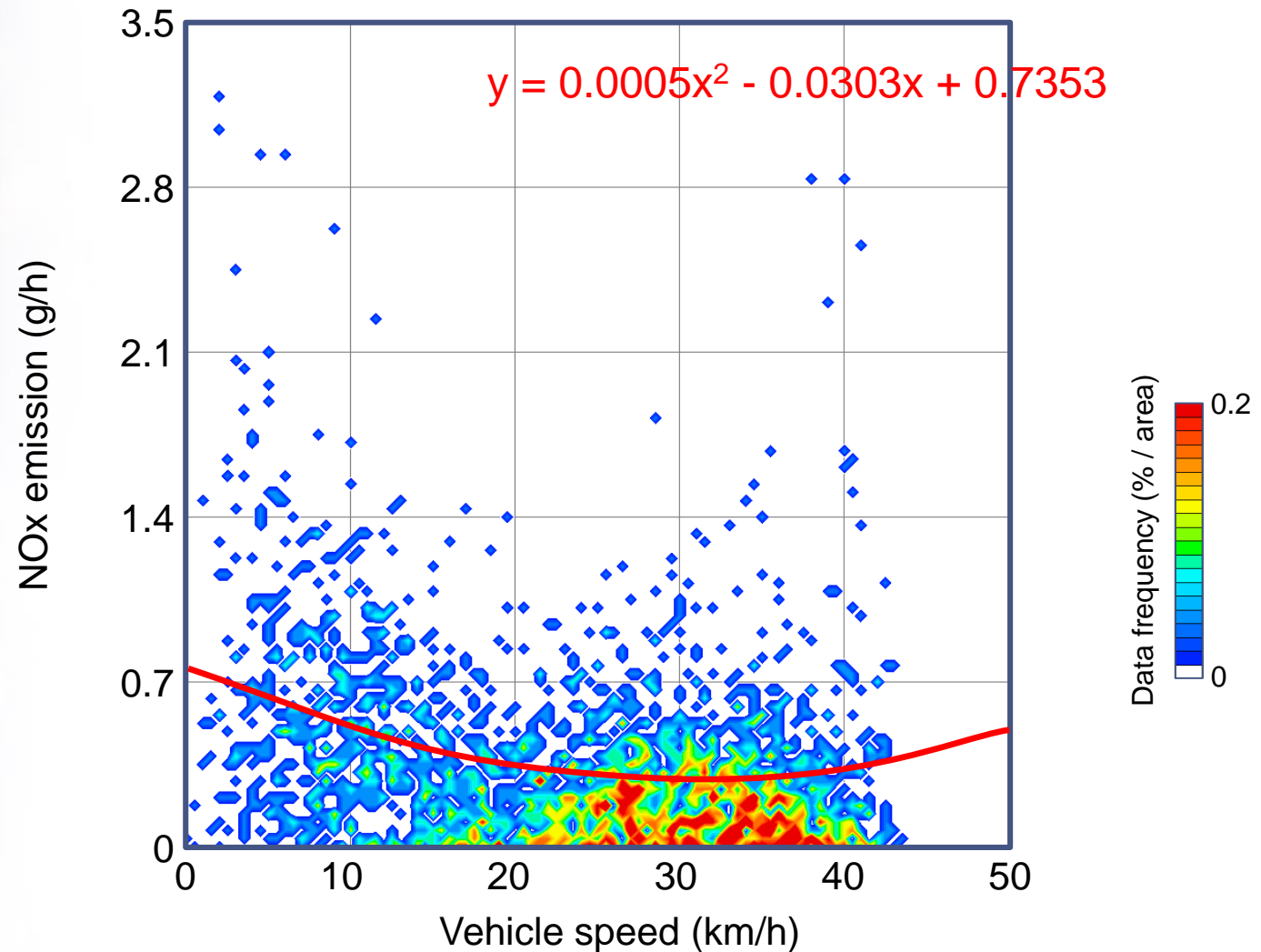
In the slow driving area, it corresponds to a place where there is a lot of speed fluctuation that the acceleration and deceleration occur frequently.

$$z \text{ value} = \left(\sum_0^{3600} \left| \frac{\partial v}{\partial t} \right| \right)_{\text{average}}$$

average value obtained from sum of bus speed fluctuation (acceleration + deceleration) for 1-hour

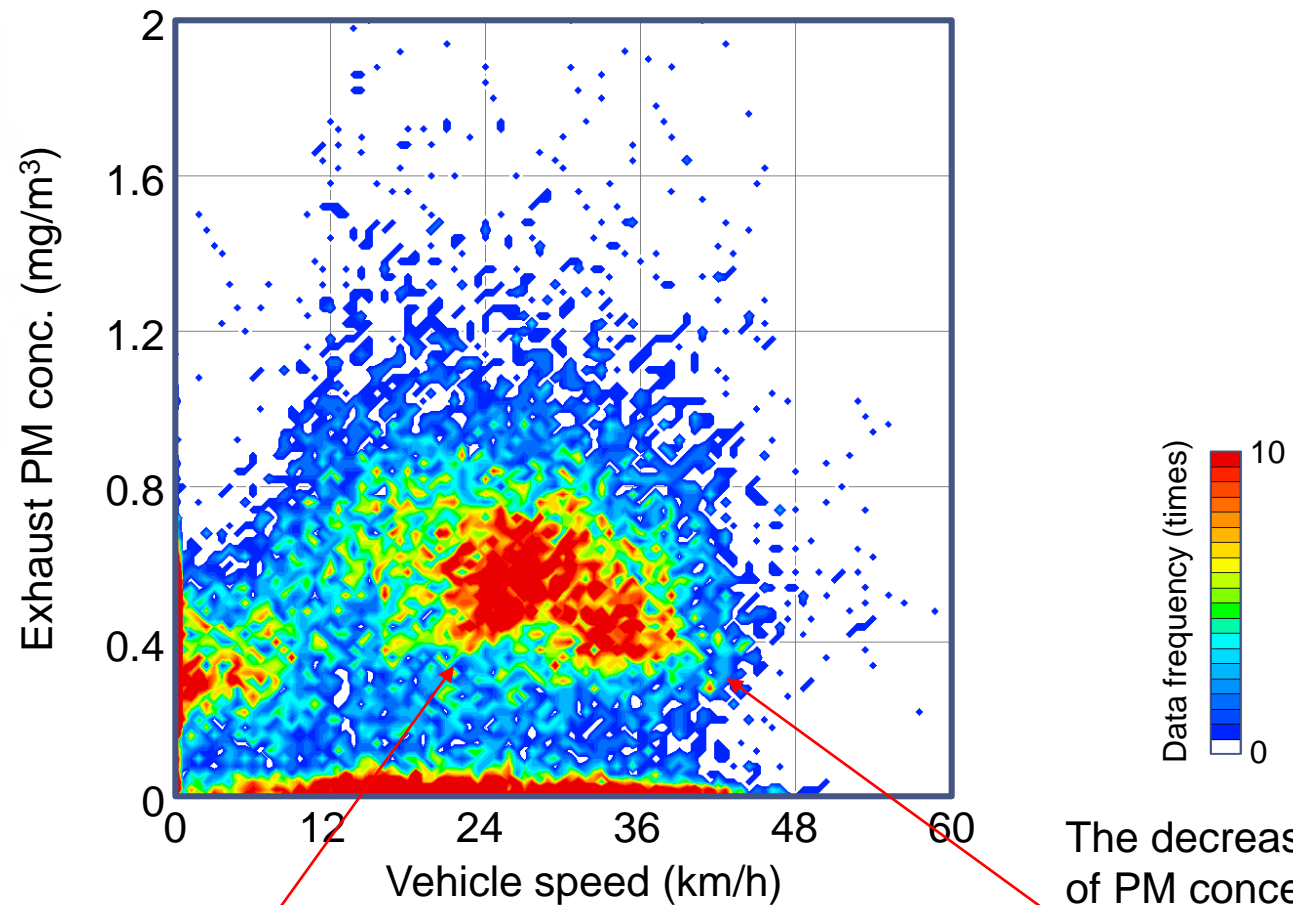


Relationship between bus NOx emissions and vehicle speed seen on the route





Diesel bus exhausted PM

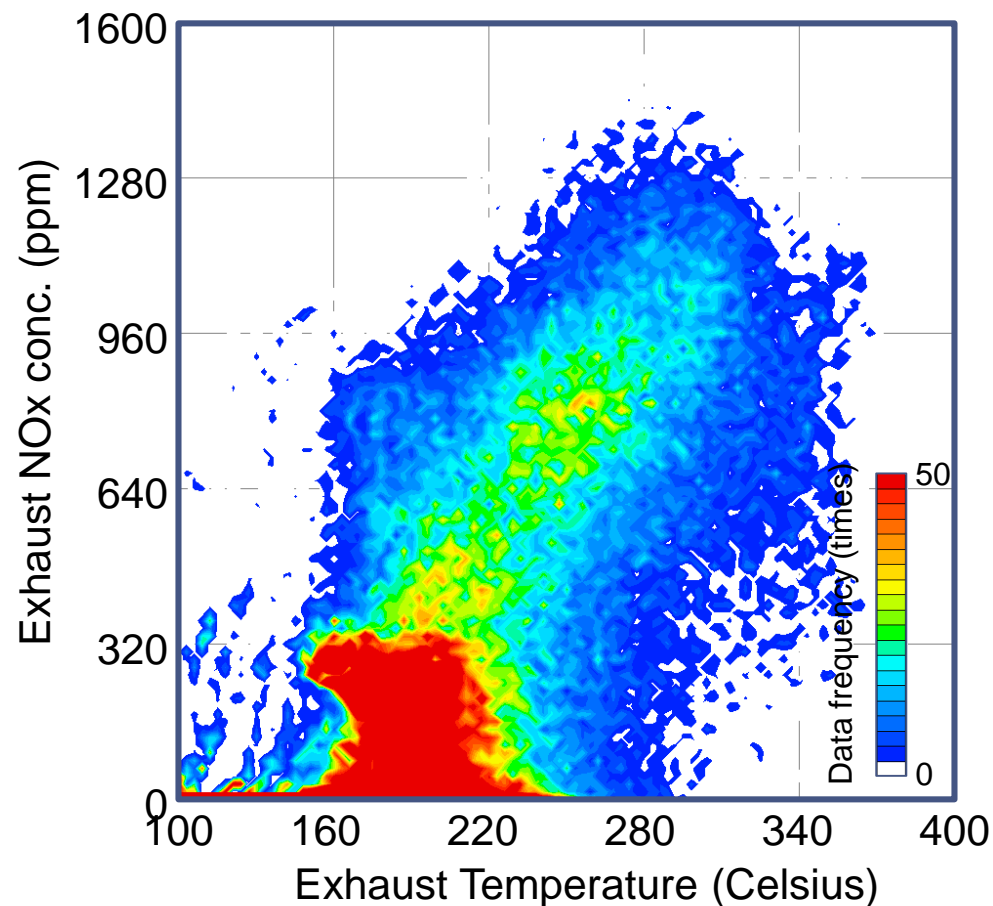
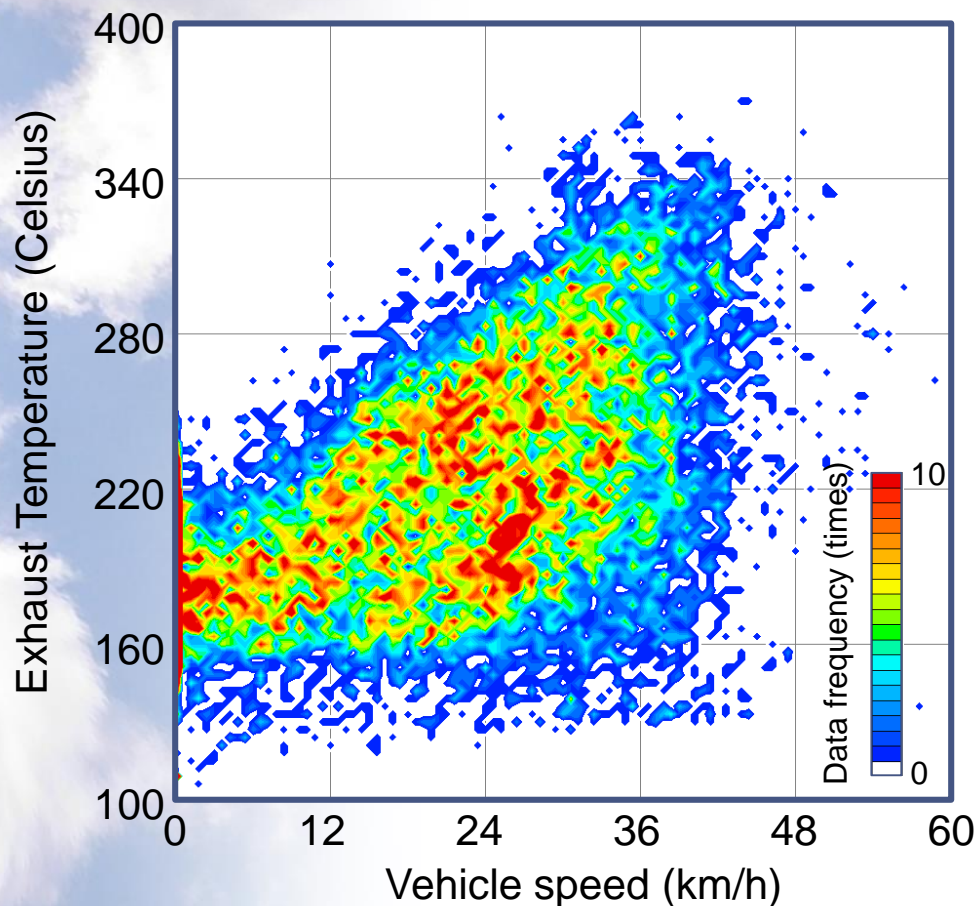


High PM concentration was seen in the middle-speed region

The decrease trend of PM concentration was seen in the high-speed region



Exhaust temperature and NOx purification



- ◆ Although an increase in the exhaust temperature was observed with an increase in the vehicle speed, a clear relationship with the NOx purification rate of the SCR could not be obtained.



Summary

- ◆ The NO_x / PM meter was mounted on the city bus (2017 model year of 8.5 liter diesel with SCR system) actually being operated in Xiamen City and continuous measurement was carried out for about 8 hours a day for 8 days.
- ◆ SCR NO_x reduction control seems to be conducted only when NO_x concentration increases over 1000 ppm. High concentrations of NO_x are being exhausted during bus service.
- ◆ NO_x concentration in the exhaust gas is slightly high at low speed, but, it is roughly proportional to the vehicle speed. However, busy stagnation time is long in traffic jams and places where there are many passengers in the downtown area, so many gas is discharged as a result. The purification effect by SCR system dependent on exhaust temperature was not clear.
- ◆ On the other hand, the exhaust PM concentration showed a peak concentration around 25 km/h, and a declining trend was seen at a speed higher than 25 km/h.



Acknowledgments

- ◆ This research is based on collaborative research with Xiamen City, which was implemented as a part of Japan - China city collaboration project funded by the Japanese Ministry of the Environment.
- ◆ This research were carried out with the following great cooperation; Xiamen City Environmental Science Institute, Xiamen Environmental Protection Bureau, the Sino-Japan Friendship Center for Environmental Protection, and the Institute for Global Environmental Strategies, Japan.
- ◆ In particular, we thank Mr. Xiangdong ZHAI and Xiamen Bus Group Huli Public Transport Co., Ltd who accepted and helped for the measurement.

Thank you for your
attention

