Real World Emissions Analysis Using Sensor-based Emissions Measurement System for Light-duty Direct-Injection Gasoline Vehicle

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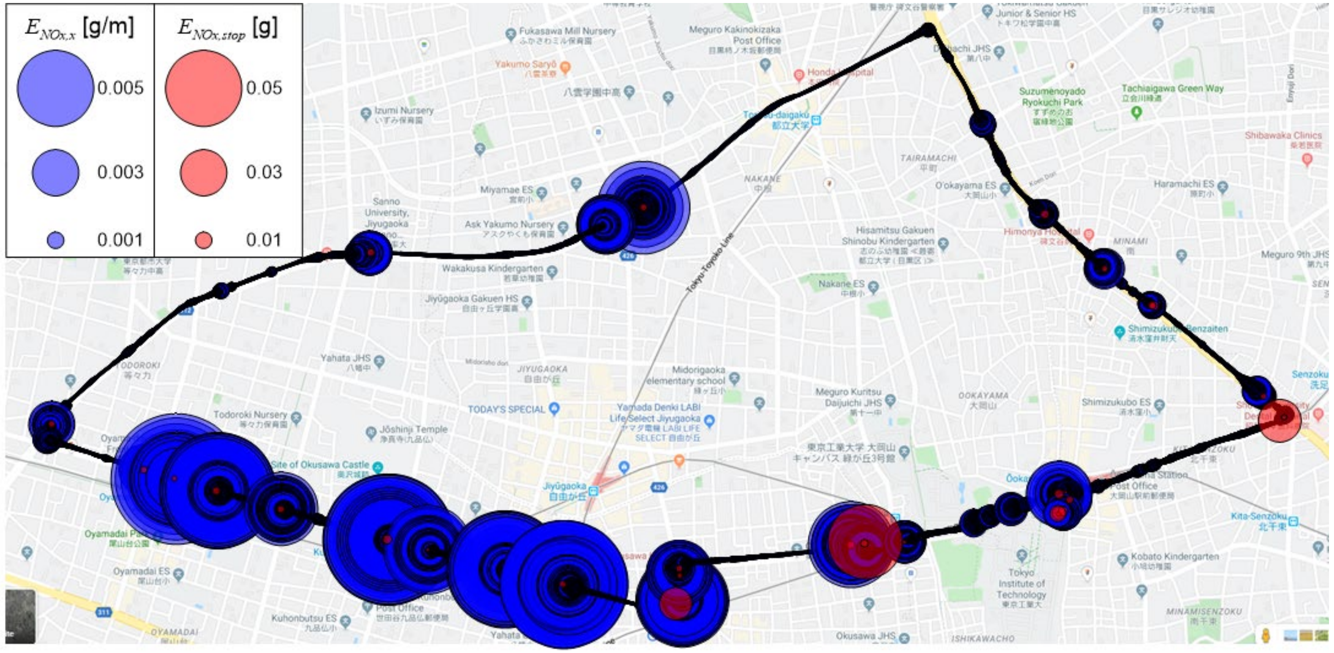
11th Annual International PEMS Conference

Research Background

- ✓ Local roadside emission → "Hot spot"
- ✓ RDE regulations using PEMS



Distance-based NO_x mass emissions for diesel passenger vehicle

PEMS measurement

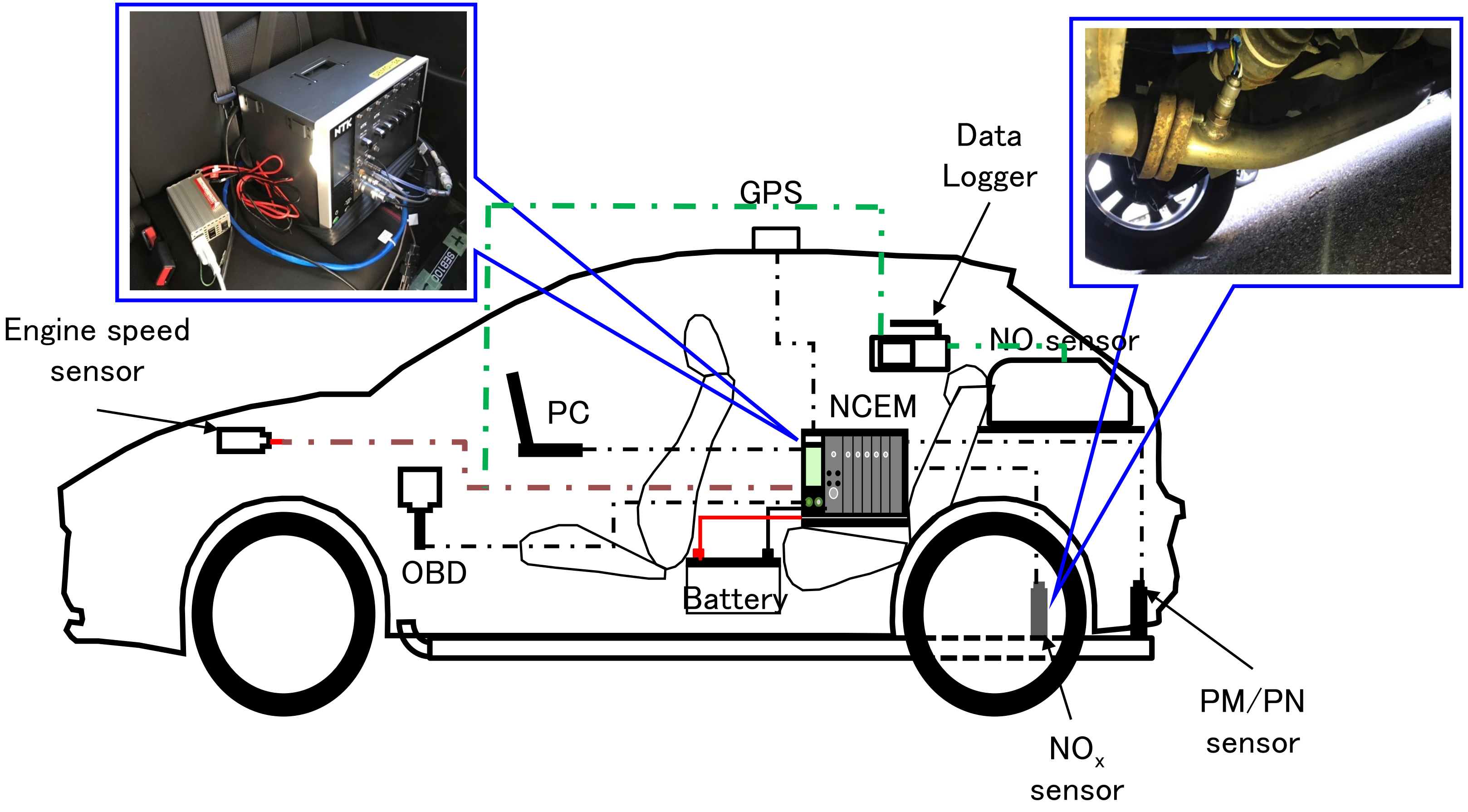
On-road measurement data; NOx mass ≥ 0.08 g/km

Research Background & Objective

- Studying the cause of the emission.
- Where, how much and why pollutants are emitted?
- Conduct real-driving experiments on light-duty direct injection gasoline vehicle
- Measure PM/PN, NO and NH_3 emissions by using SEMS (Sensor-based Emission Measurement System)

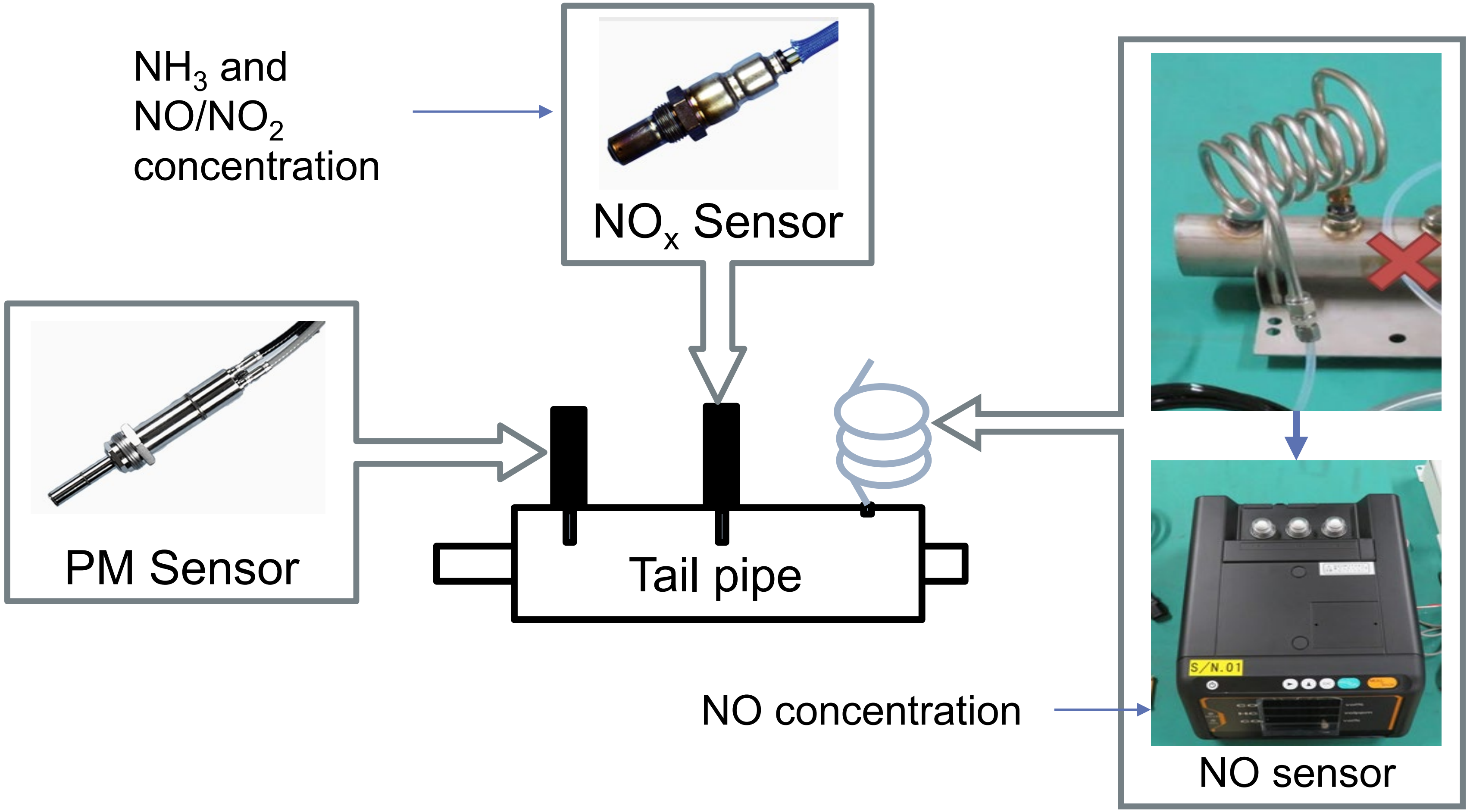
Test Vehicle and Sensor-based Emission Measurement System

Fuel injection	DI
Engine type	In-line 4 cylinder gasoline turbo
Displacement	1,618 cc
Max. power output	140 / 5600 kW / rpm
Aftertreatment devise	TWC
Vehicle mas	1,565 kg
Emission standard	2005
Model year	2014



Emissions Measurement Sensors

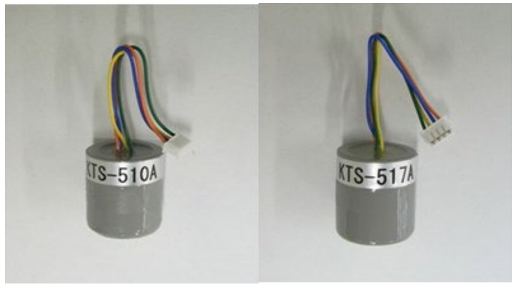
NO_x sensor detected NH_3 as well as NO_x



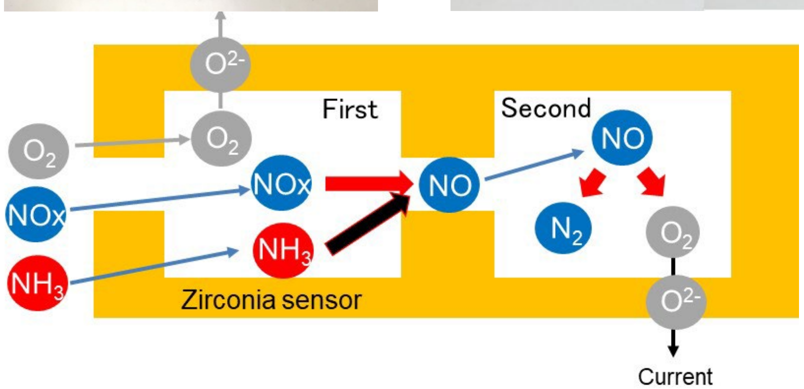
NH_3 Concentration Calculation

NOx sensor (NCEM)

Potential sensor for NO,NH_3



NH3 sensor for diesel



- Signals obtained from NOx sensor include those derived from NO and NH_3.
- Potential sensor for NO can measure the NO concentration.

[NOx sensor] – [Potential sensor for NOx] ≈ NH_3

When NOx sensor and potential sensor for NO are used, ammonia emitted from gasoline vehicles will be measured.

➡ Sensor signals were compared with those obtained by FT-IR and laser-based measurement system.

$$C_{NH3} = \frac{C_{NOx} - C_{NO}}{0.9}$$

Division by 0.9 is used to calibrate the sensor sensitivity.

Ref: K. Tanaka et al., the 10th Annual International PEMS Conference (2021)

Ref: K. Tanaka et al., Society of Automotive Engineers of Japan, 2020 Annual Autumn Conference Proceedings, No. 232 (in Japanese)

On-road Driving Test Routes

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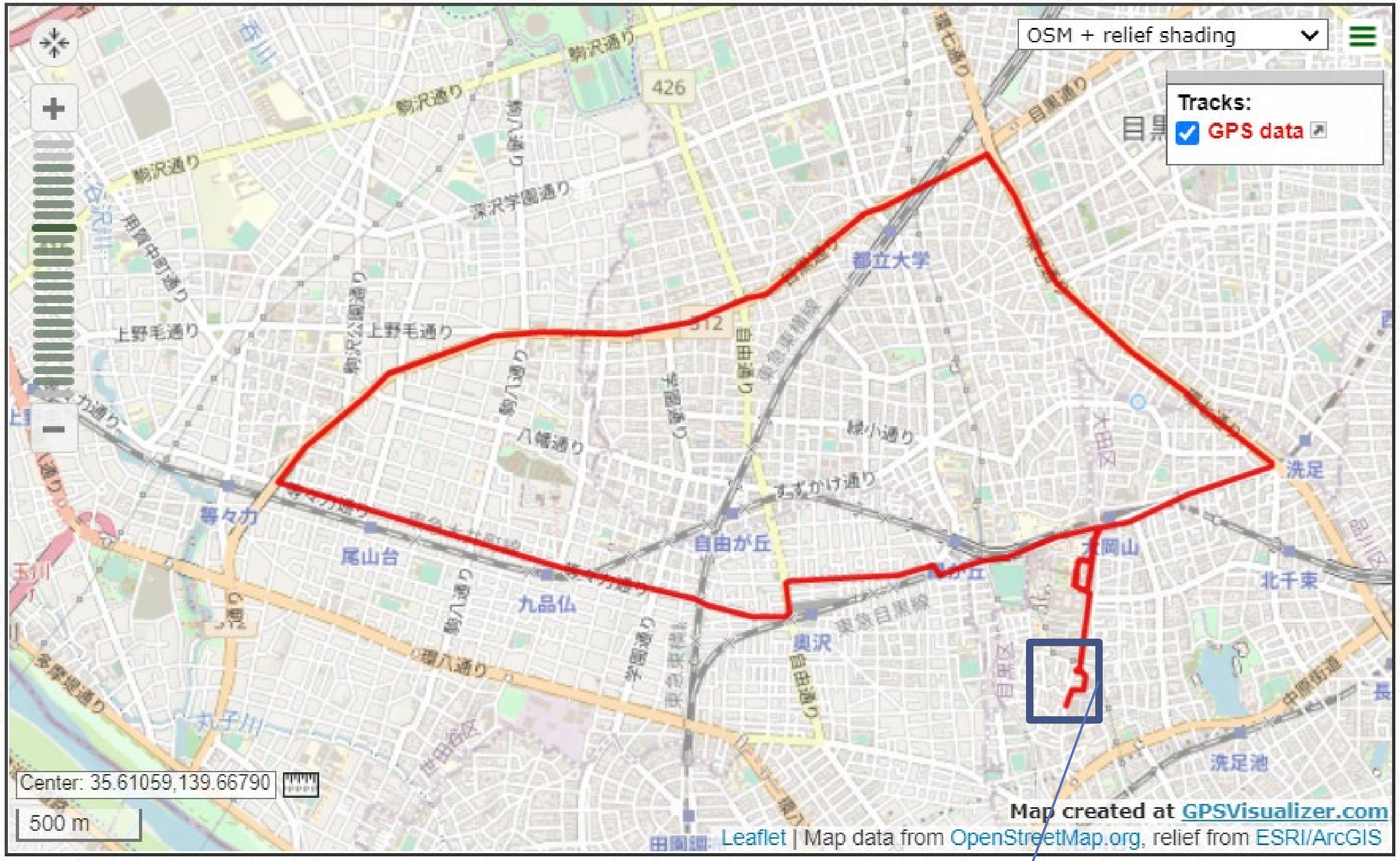

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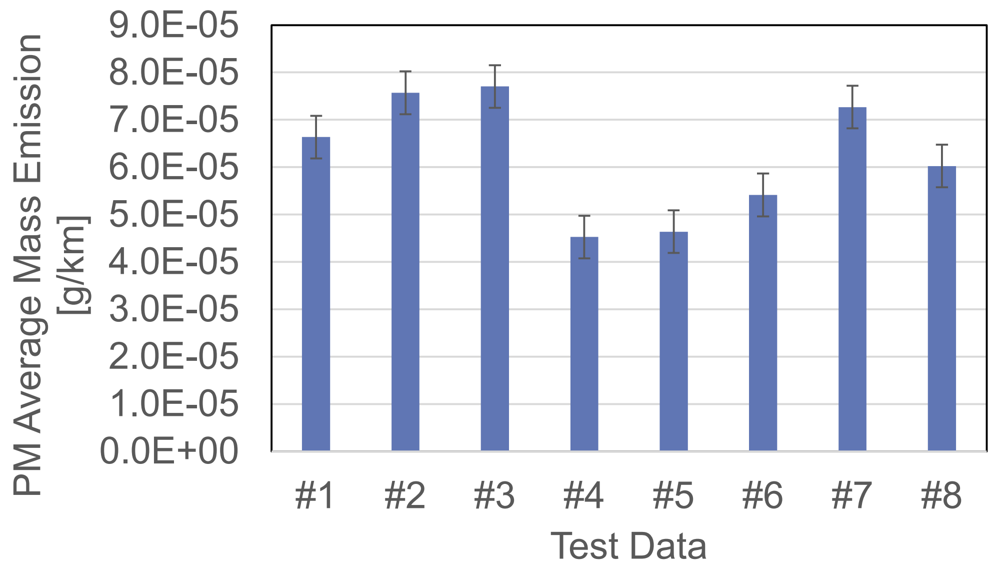
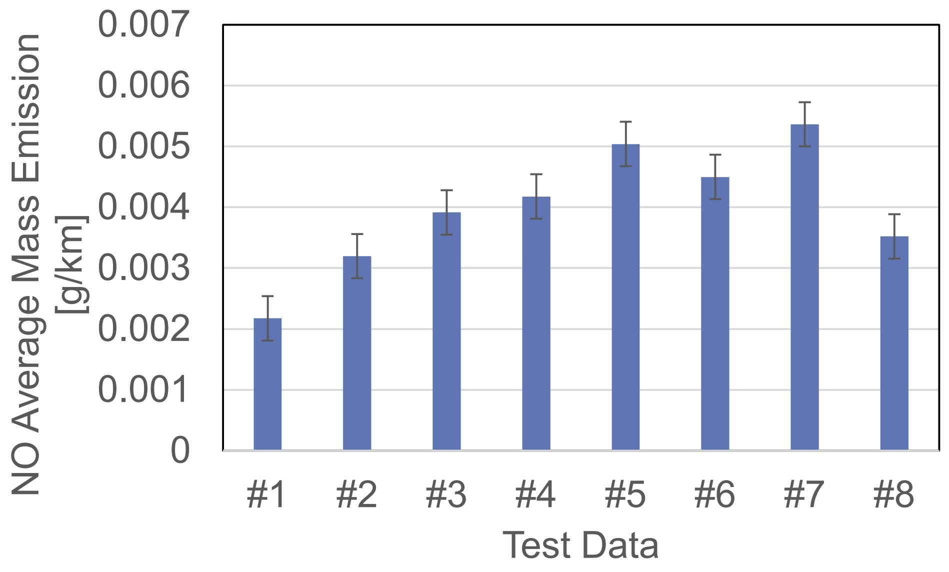
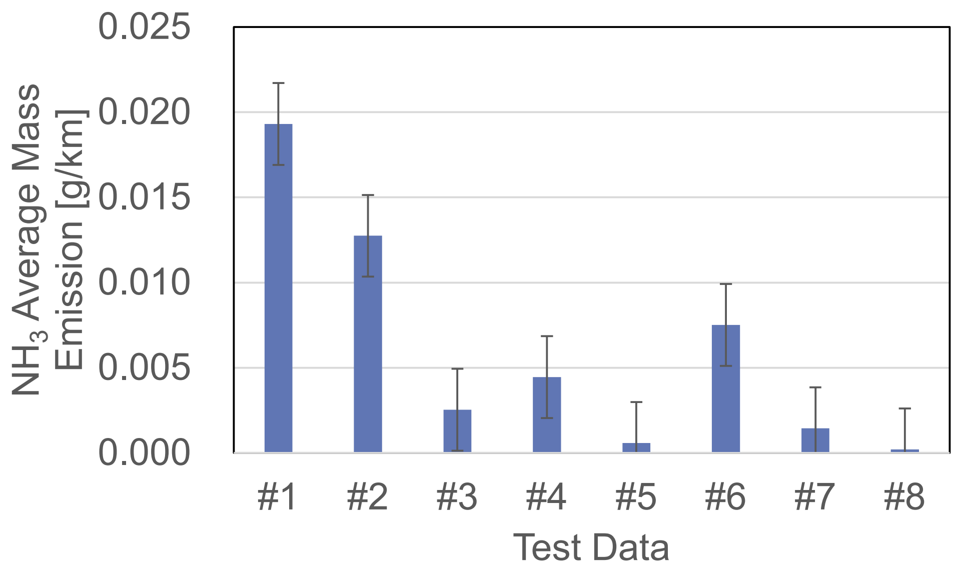
Data sampling rate	10Hz
Number of measurement	8 times
Fuel	Gasoline (HC1.8)

Average Emission

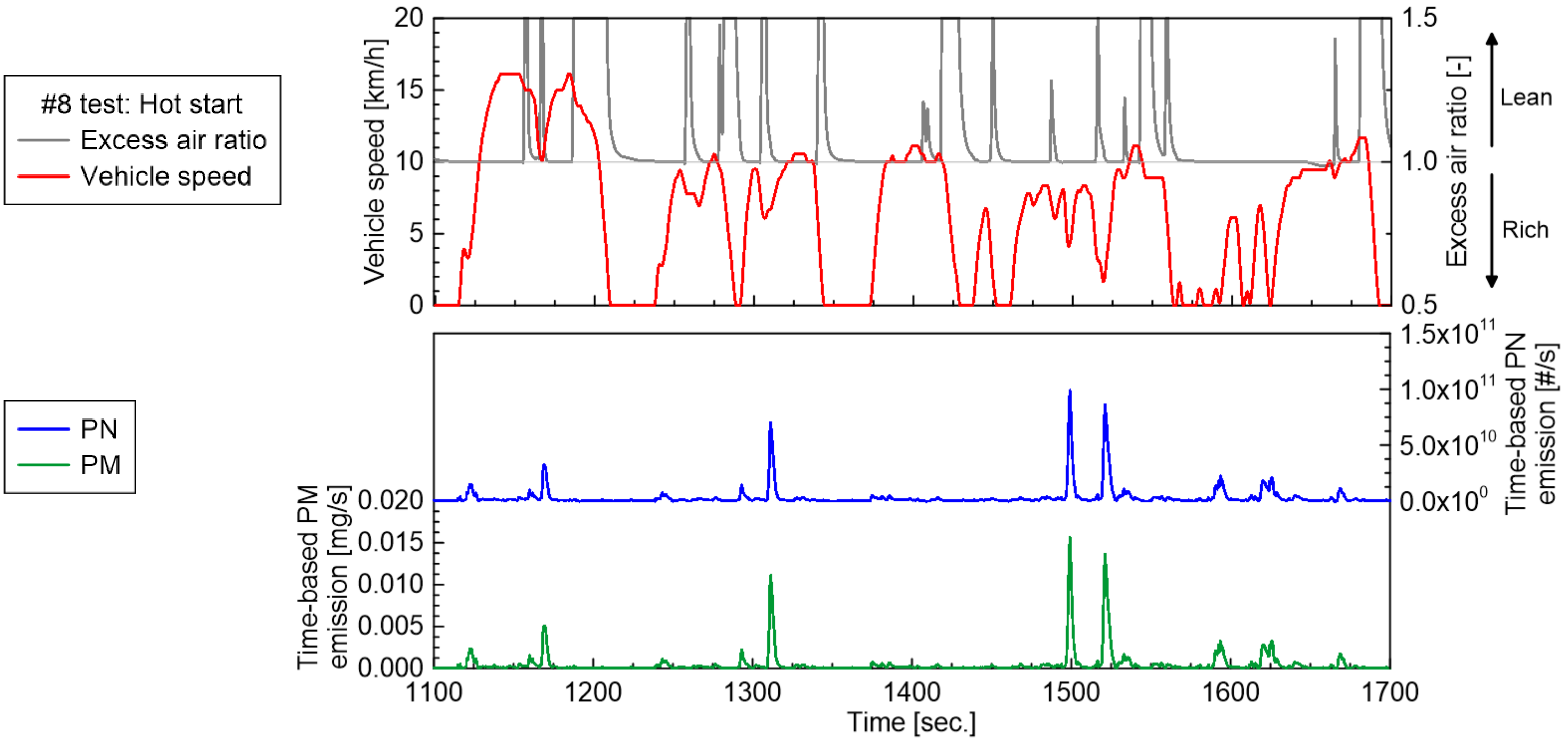


Test Data	Hot/Cold
#1	Cold
#2	Cold
#3	Hot
#4	Cold
#5	Hot
#6	Cold
#7	Hot
#8	Hot

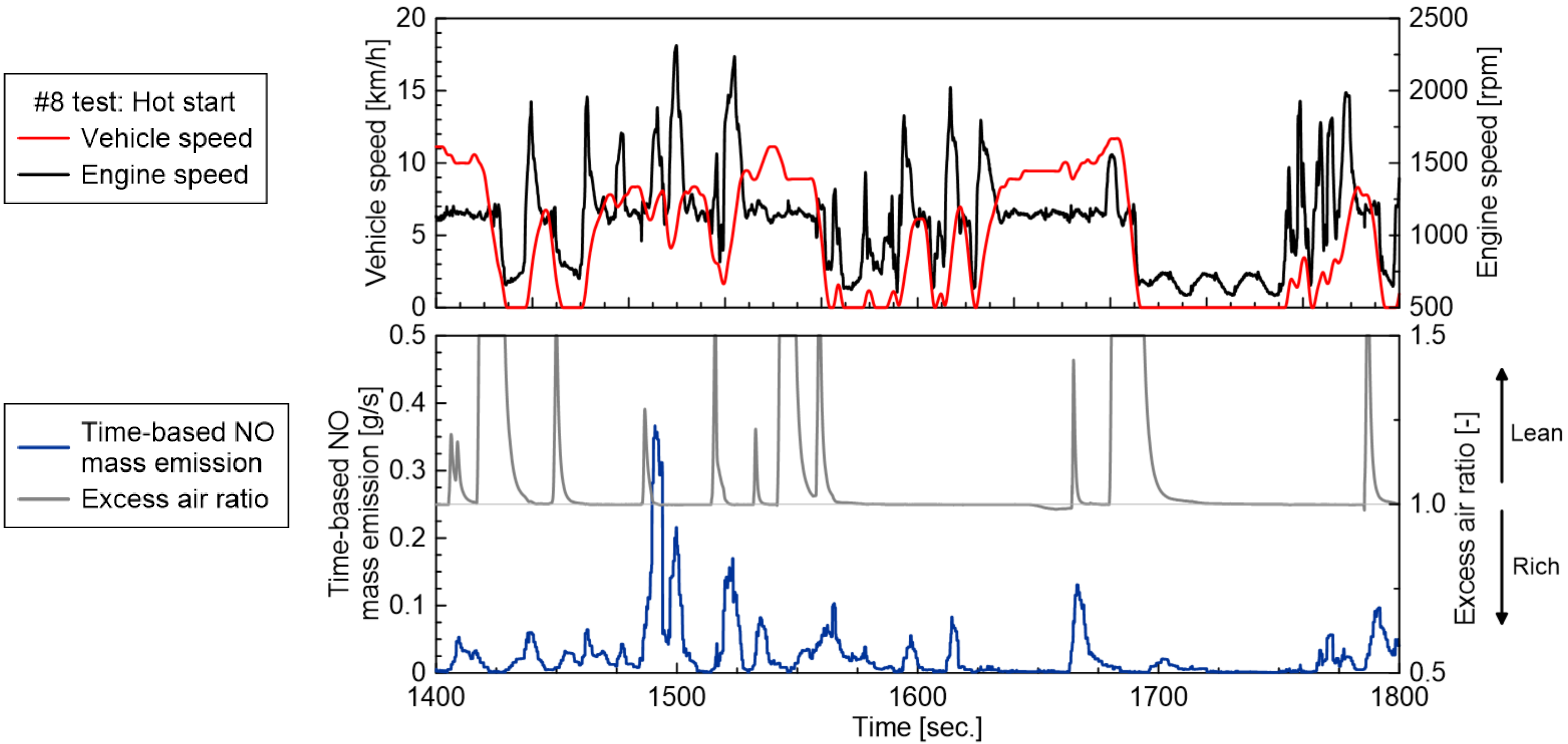




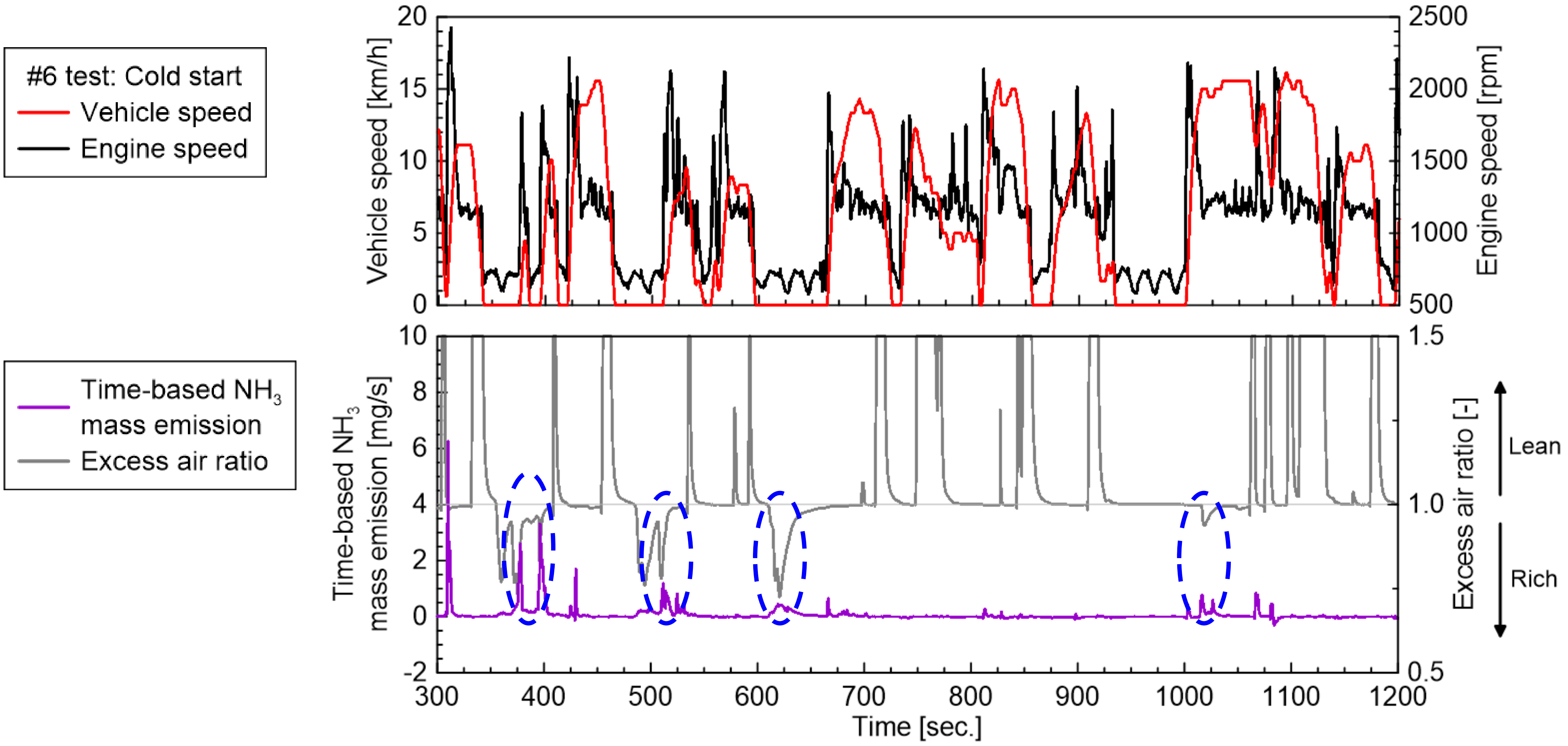
PM/PN Emission Analysis



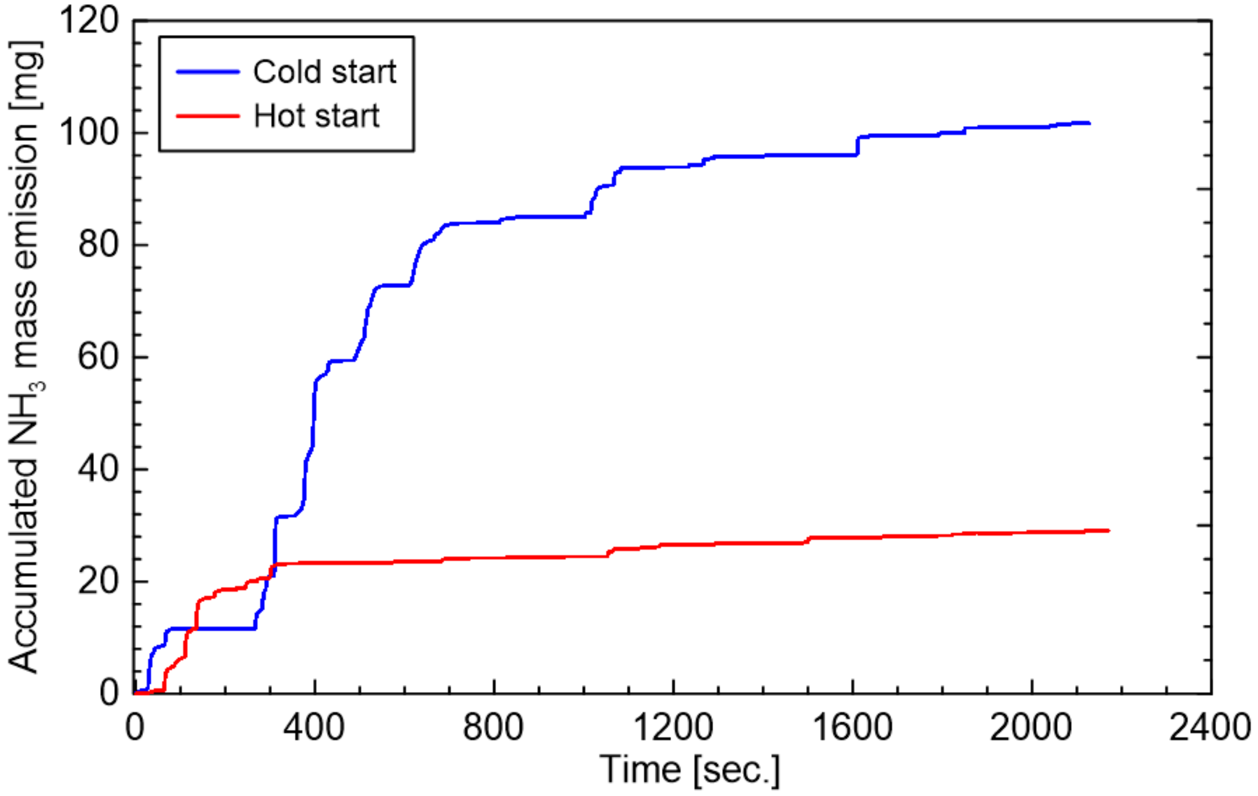
NO Emission Analysis



NH_3 Emission Analysis



Accumulated NH_3 Mass Emission



$CO + H_2O \rightarrow CO_2 + H_2$

$2NO + 2CO + 3H_2 \rightarrow 2NH_3 + 2CO_2$

$2NO + 5H_2 \rightarrow 2NH_3 + H_2O$

Ref: Barbier et al., Applied Catalysis B Environmental, Vol. 4, p. 105-140, 1994

PM Emission Hot-spot

Distance-based
PM mass emission
[mg/km]

4

1

0.4

PM mass emission
at stop [mg]

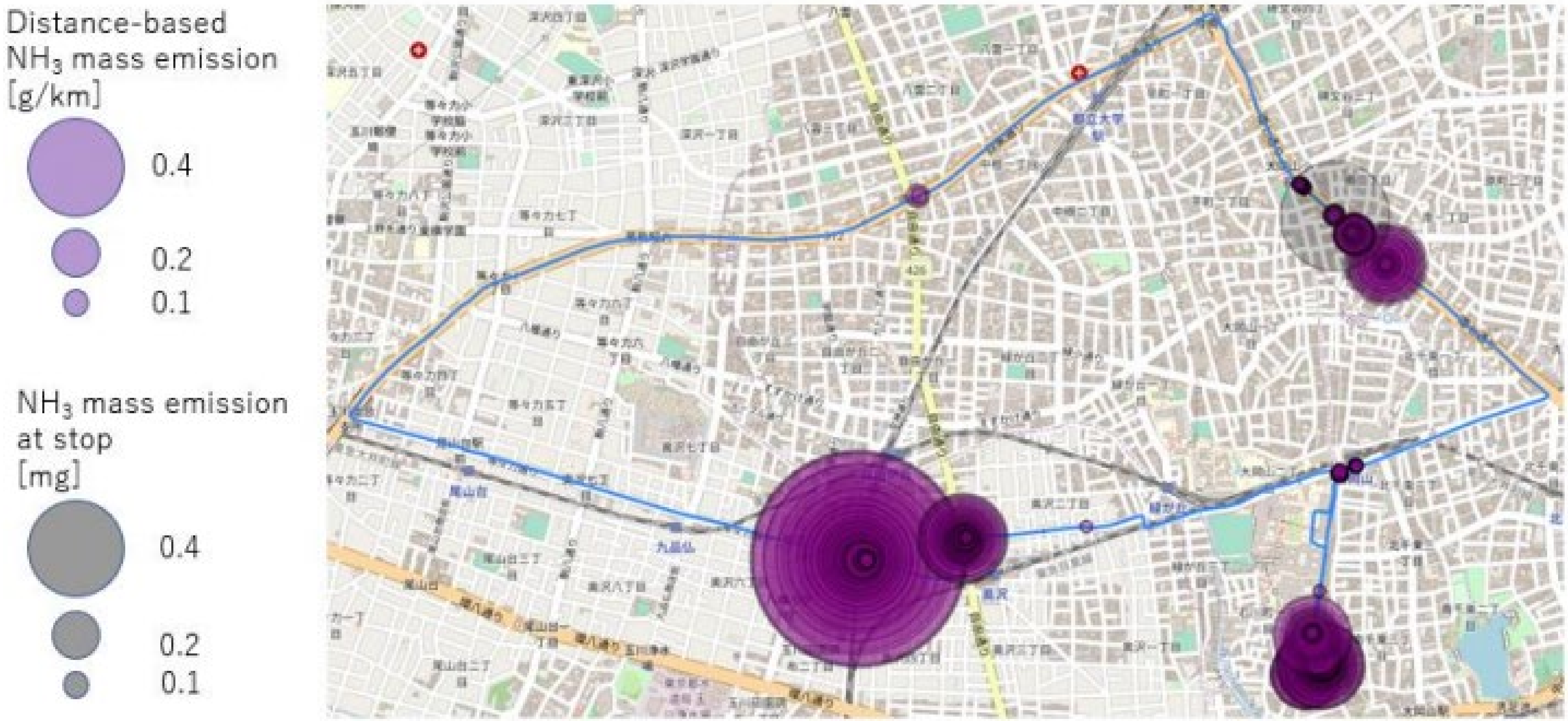
0.008

0.002

0.0002

NO Emission Hot-spot

NH_3 Emission Hot-spot



Summary

1. PM emission increased during rapid acceleration and even more so when vehicle reaccelerates after deceleration.

2. NO emission was found especially in lean condition where the excess air ratio is close to 1.

3. NH_3 emission increased in rich condition. In rich condition, there is not enough oxygen for complete combustion and CO was formed. NH_3 was generated from this CO.

4. NH_3 emission in the first 10 minutes of cold-start was found several times higher than in hot-start and the rest of the data. When the engine is cold, injected fuel is not completely oxidized which leads to the formation of CO and NH_3.

5. PM, NO and NH_3 emission tends to occur before and after traffic lights. However, each component hotspot tends to be at different places.

* For more details, please refer our SAE technical paper, #2022-01-0572

Future Work

Hypothesis of cold start NH_3 emission due to the existence of CO will be verified by the driving test with SEMS and PEMS.

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Thank You for Your Listening

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Statistical Data

On Road Driving Test Data	Driving time [s]	Driving Distance [km]	Average Speed [km/h]	Maximum Speed [km/h]	Hot/Cold Condition
#1	1966.8	10.165	18.61	48.14	Cold
#2	1857.9	10.455	20.26	58.90	Cold
#3	2131.3	10.461	17.67	60.09	Hot
#4	1941.0	10.445	19.37	59.56	Cold
#5	2174.1	10.417	17.25	60.08	Hot
#6	2108.6	10.456	17.85	58.09	Cold
#7	2256.6	10.425	16.63	56.12	Hot
#8	2100.4	10.445	17.90	58.11	Hot