Behavior of particulate matters measured in vehicle cabin during real driving conditions

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1. **Measurement method and set up**

2. **Test results**

3. **Conclusion**

1. Measurement Method and Set up

» Test conditions (1)

➢ **Test vehicle age/mileage**

Medium size vehicle

- K5 (KIA motors)
- Fuel: gasoline
- Manufacturing year : 2022
- Vehicle mileage: 1,046 km

SUV

- Sorento (KIA Motors)
- Fuel : diesel
- Manufacturing year : 2022
- Vehicle mileage : 13,755 km

➢ **Cabin air filter age**

- Buy new filters for both vehicles
- Replace with a new genuine product filter purchased
- Filter Information: Hyundai Mobis Aircon Filter

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1. Measurement Method and Set up

» Test conditions (2)

➢ **Meteorological conditions & Background air pollution level**

22. Sep.	23. Sep.	28. Sep.	29. Sep.
K5 (gasoline) **Urban + motorway route**	**K5 (gasoline)** **Urban route**	**Sorento (diesel)** **Urban + motorway route**	**Sorento (diesel)** **Urban route**
Temp. : 21.6 ℃ **Humi. : 55 %** **PM-10 : 22 ㎍/㎥** **PM-2.5 : 2 ㎍/㎥**	**Temp. : 20.8 ℃** **Humi. : 46 %** **PM-10 : 24 ㎍/㎥** **PM-2.5 : 9 ㎍/㎥**	**Temp. : 22.0 ℃** **Humi. : 63 %** **PM-10 : 33 ㎍/㎥** **PM-2.5 : 9 ㎍/㎥**	**Temp. : 26.3 ℃** **Humi. : 47 %** **PM-10 : 57 ㎍/㎥** **PM-2.5 : 32 ㎍/㎥**

- **Meteorological data :** Korea Meteorological Administration

- **Air pollution data :** Airkorea (Urban Atmosphere Measurement Network), Korea Environmental Corporation

- **Weather information of test location and time**

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1. Measurement Method and Set up

❯❯ Measured component and measurement method

➢ **Particulate and gas components to be measured**

Particulate components	Gaseous components
PM 2.5	NOx
PM 10	CO
PM 0.3 ~ 10 (#)	CO_2
Nano Particles (#)	
BC (Black Carbon)	

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1. Measurement Method and Set up

» Measured component and measurement method

➢ **Measurement method and test equipment requirements**

GRIMM 11-A	PM-0.25 ~ PM-32

90° light scattering and filter-sampling (Dual-Technology)

TSI OPS 3330	PM-0.3 ~ PM-10

120° light scattering and filter-sampling (Dual-Technology)

TSI WCPC 3789	2.2 ~ 7 nm particles

Water-Based Condensation Particle Counter

TSI SMPS 3910	10 ~ 420 nm particles

size distribution to amplified particle using alcohol

MAGEE AE43	Black Carbon (BC)

Aethalometer
Continuous collection of aerosol on filter with simultaneous measurement of attenuation of transmitted light at wavelengths of 880 nm

TESTO 350k	NOx

Electro Chemical Sensor
0 ~ 4000 ppm NO
0 ~ 500 ppm NO2

envea MVS 2M heated	CO, CO_2

Gas filter correlation (GFC)
0 - 75 ~ 10 ppm CO
0 - 10 ~ 250,000 ppm CO2

1. Measurement Method and Set up

» Sampling points

➢ **Interior sample point**

Arrangement of measuring instruments

- The measuring instrument is placed in the rear seat of the vehicle
- Install perforated plate for horizontal measurement of measuring instrument in the rear seat
- Install the measuring instrument on the perforated plate and fix it with a Velcro tie

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1. Measurement Method and Set up

» Sampling points

➢ **Interior sample point**

Installing sampling points

- Install the sampling point tube on each measuring instrument
- Install the sampling tube at the height of the respiratory system in the center of the front seat
- The sampling tube is fixed through a Velcro tie

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1. Measurement Method and Set up

» Test modes

➢ **Real driving conditions (Urban route)**

Urban route

Start & end point

Route information

Driving route
Jamsil Sports Complex Parking Lot
→ Jamsil 3-way Intersection
→ Tancheon 1-gyo
→ Yangjae Station
→ Dogok 1-dong Community Center Intersection
→ Yeoksam Station
→ Jamsil Sports Complex Parking Lot

Driving distance
16 km (60 minutes)

Average / Maximum vehicle speeds
K5 : 16.0 kph / 65.3 kph
SUV : 18.1 kph / 58.3 kph

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1. Measurement Method and Set up

» Test modes

➢ **Real driving conditions (Urban & Urban motorway route)**

Urban + motorway route

Start & end point

Route information

Driving route
 Ansan Banwol Park
 → Maesong TG
 → Seosan TG
 → Ansan terminal Intersection
 → Gamgol Stadium
 → Ansan Design Culture High School
 → Ansan Banwol Park

Driving distance
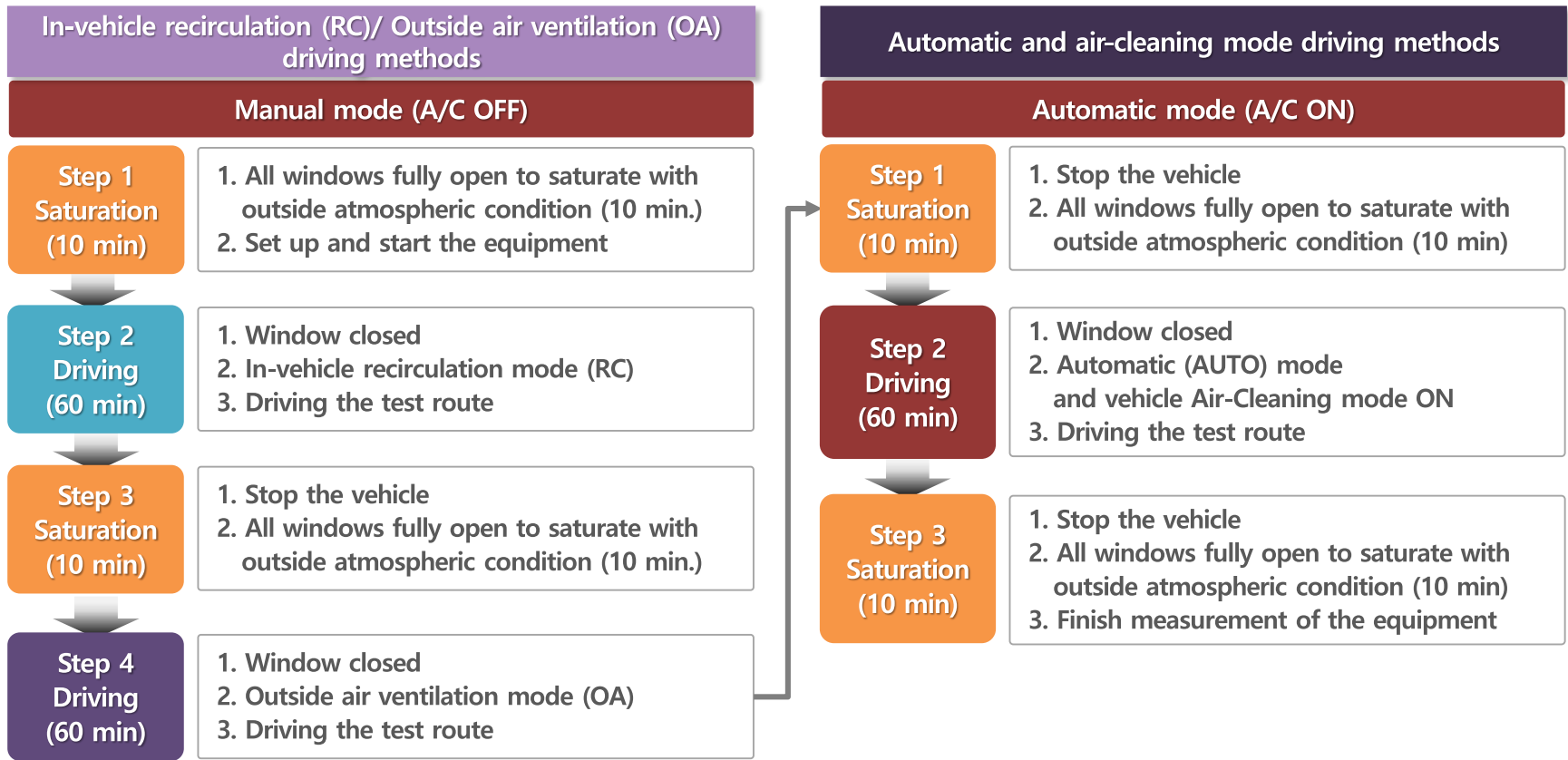 Urban 3.5 km → Motorway 17 km → Urban 16.2 km
 (60 minutes)

Average / Maximun vehicle speeds
 K5 : 41.3 kph / 104.9 kph
 SUV : 39.4 kph / 104.7 kph

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1. Measurement Method and Set up

» HVAC modes

➤ HVAC system settings

In-vehicle recirculation (RC)/ Outside air ventilation (OA) driving methods	
Manual mode (A/C OFF)	
Step 1 Saturation (10 min)	1. All windows fully open to saturate with outside atmospheric condition (10 min.) 2. Set up and start the equipment
Step 2 Driving (60 min)	1. Window closed 2. In-vehicle recirculation mode (RC) 3. Driving the test route
Step 3 Saturation (10 min)	1. Stop the vehicle 2. All windows fully open to saturate with outside atmospheric condition (10 min.)
Step 4 Driving (60 min)	1. Window closed 2. Outside air ventilation mode (OA) 3. Driving the test route

| Automatic and air-cleaning mode driving methods	
Automatic mode (A/C ON)	
Step 1 Saturation (10 min)	1. Stop the vehicle 2. All windows fully open to saturate with outside atmospheric condition (10 min)
Step 2 Driving (60 min)	1. Window closed 2. Automatic (AUTO) mode and vehicle Air-Cleaning mode ON 3. Driving the test route
Step 3 Saturation (10 min)	1. Stop the vehicle 2. All windows fully open to saturate with outside atmospheric condition (10 min) 3. Finish measurement of the equipment

1. Measurement Method and Set up

» HVAC modes

➤ **Automatic mode setting**

- The Air-Cleaning mode automatically shuts off outside air and operates the air conditioner if the fine dust level in the vehicle is poor(36 μg/㎥ or higher)
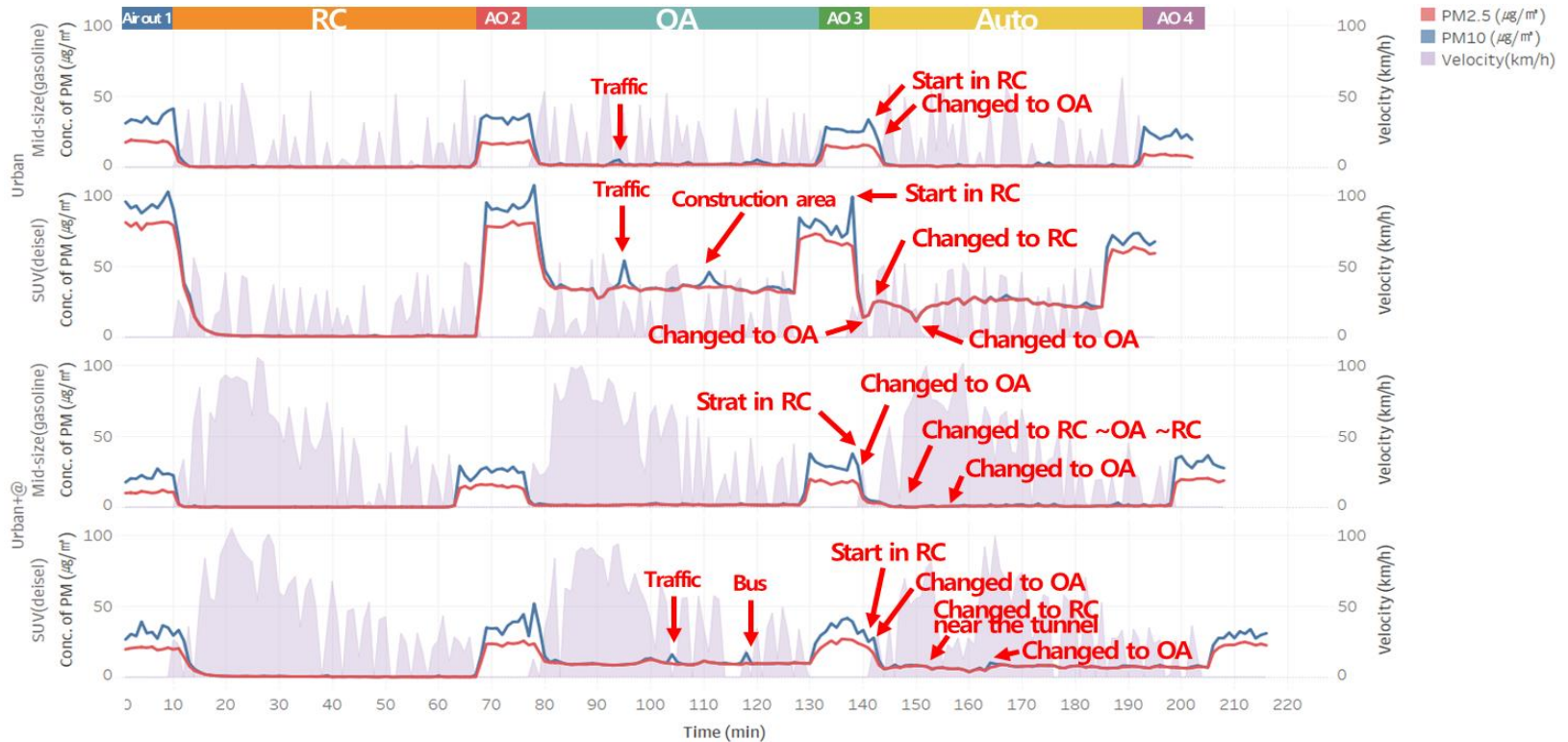- AUTO and Air-Cleaning modes were tested to verify the performance of the Air-Cleaning mode
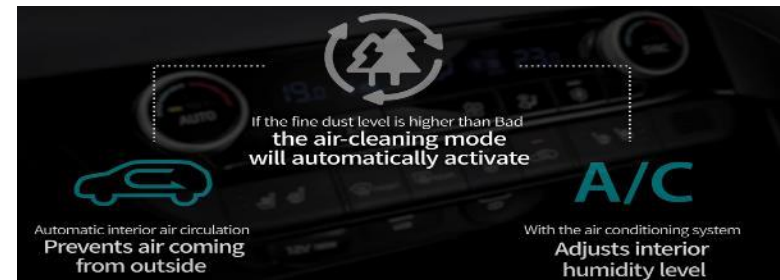
- During driving test, HVAC system changed from OA to RC before tunnel entry
- On the screen of the vehicle, the phrase 'Cut off the outside air for the indoor environment' appears

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2. Test Results

» Particulate components
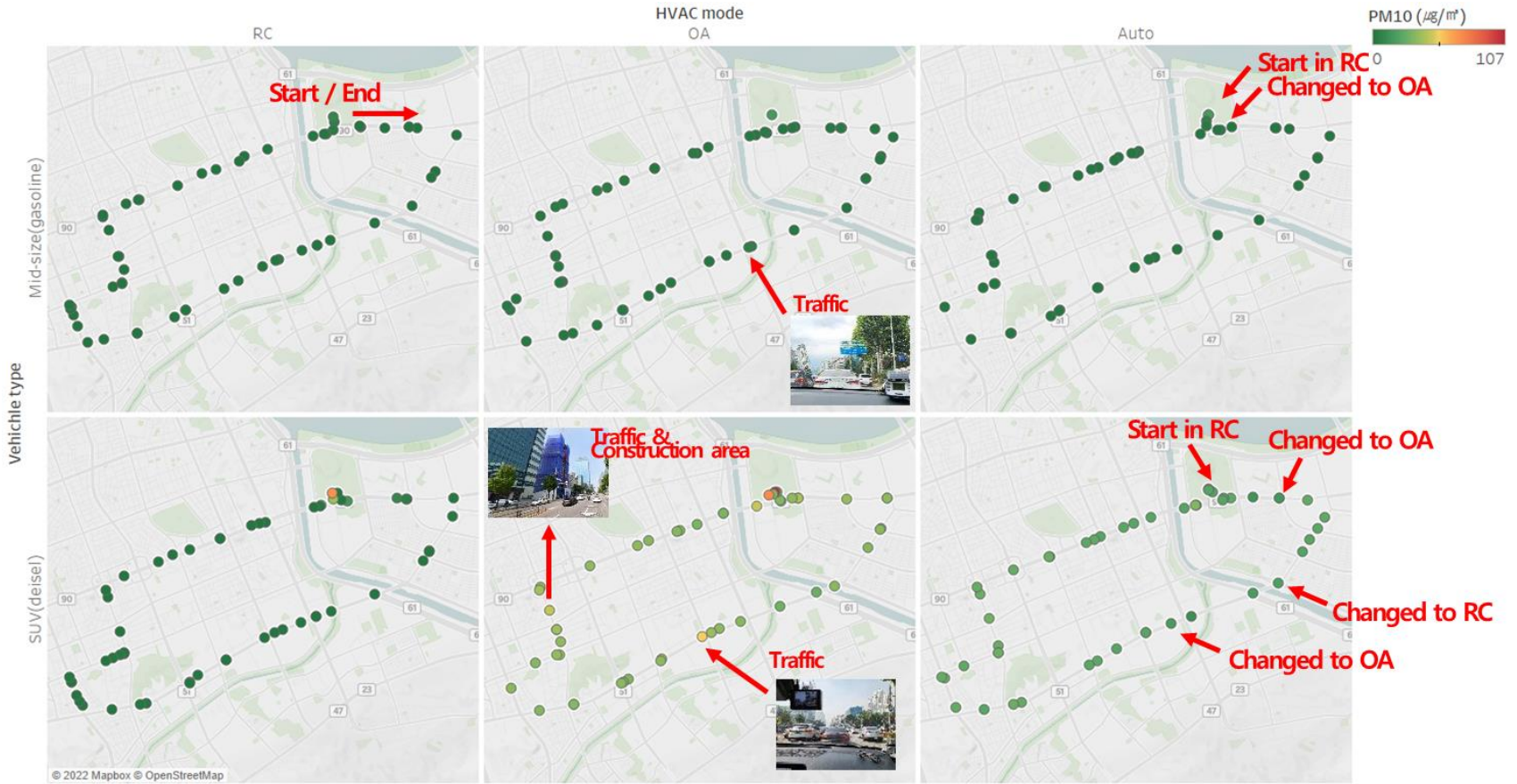
➢ **Particulate matters (PM10, PM2.5, Equipment : GRIMM)**

☑ When outside air ventilation(OA), PM10 conc. increasing in congestion sections, near construction sites

☑ When AUTO mode, air conditioning mode changed to OA or RC depending on air quality in the vehicle
In particular, it changed from OA to RC before entering the tunnel

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2. Test Results

»» Particulate components

➢ **PM10 Urban route**

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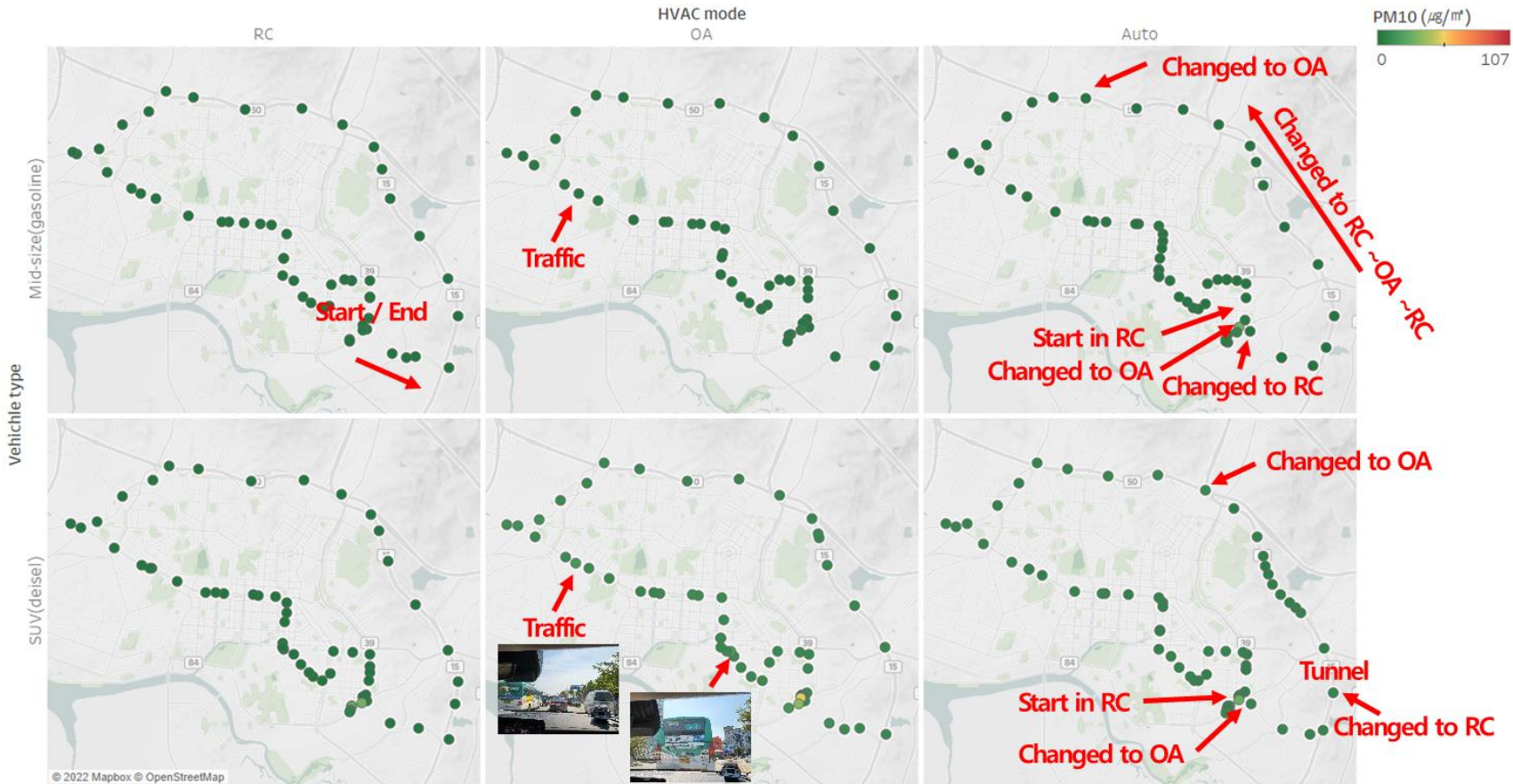Infrastructure and Transport

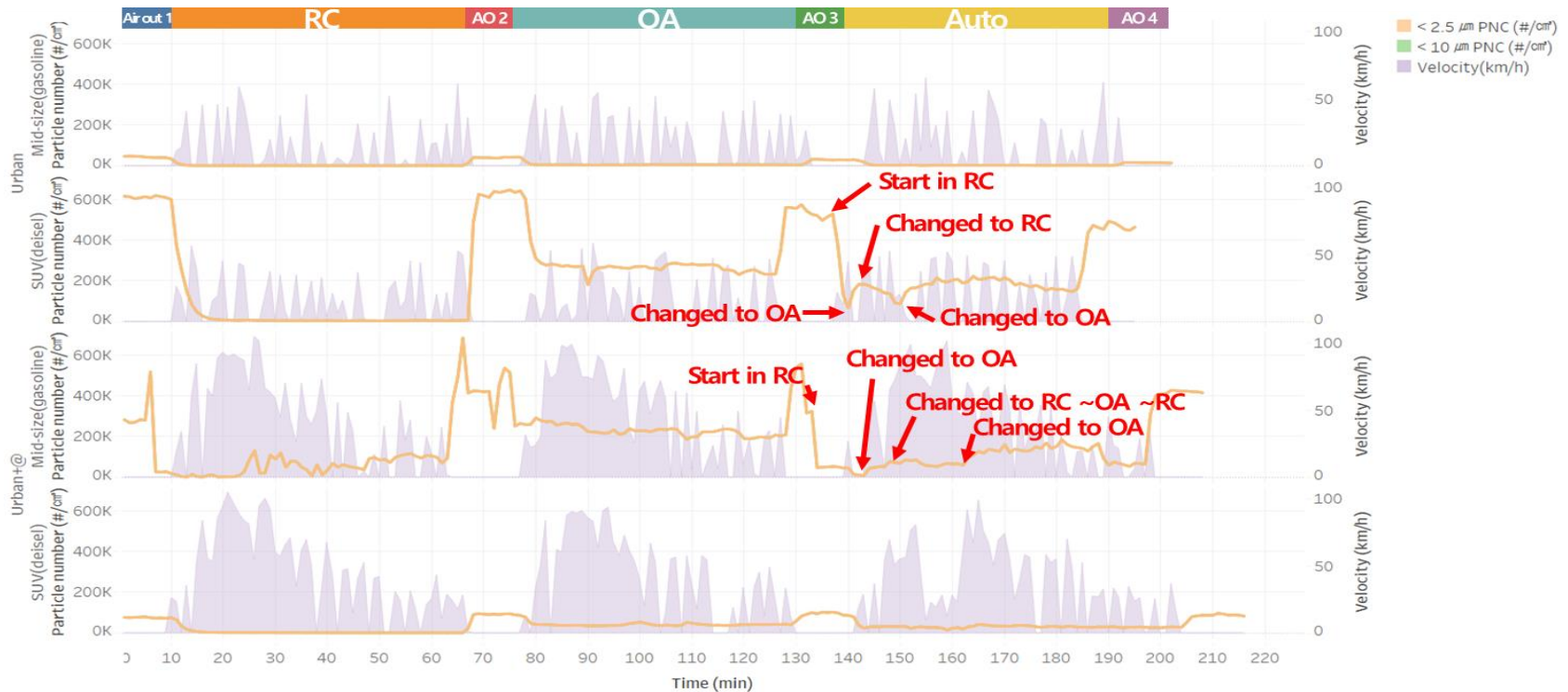# 2. Test Results

» Particulate components

➢ **PM10 Urban + Motorway route**

2. Test Results

» Particulate components

➤ **Particle number concentration (Equipment : OPS)**

☑ In AUTO mode, PNC depends on HVAC mode change (RC or OA)

☑ RC mode < AUTO mode < OA mode in order of concentration intensity

2. Test Results

>> Particulate components

➢ **Particle number concentration (Equipment : WCPC / 2.2 ~ 7 ㎚ PNC)**

☑ PNC changes frequently in OA mode and low in RC mode

☑ In the A/C OFF state, the WCPC equipment generates a measurement error message due to increasing temperature

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2. Test Results

≫ Particulate components

➢ **Particle size distribution (Equipment : SMPS / 10 ~ 420 ㎚ PNC)**

☑ SMPS cannot be measured accurately due to tilt error while dynamic driving

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2. Test Results

» Particulate components

➢ **Particle size distribution (Equipment : SMPS / 10 ~ 420 ㎚ PNC)**

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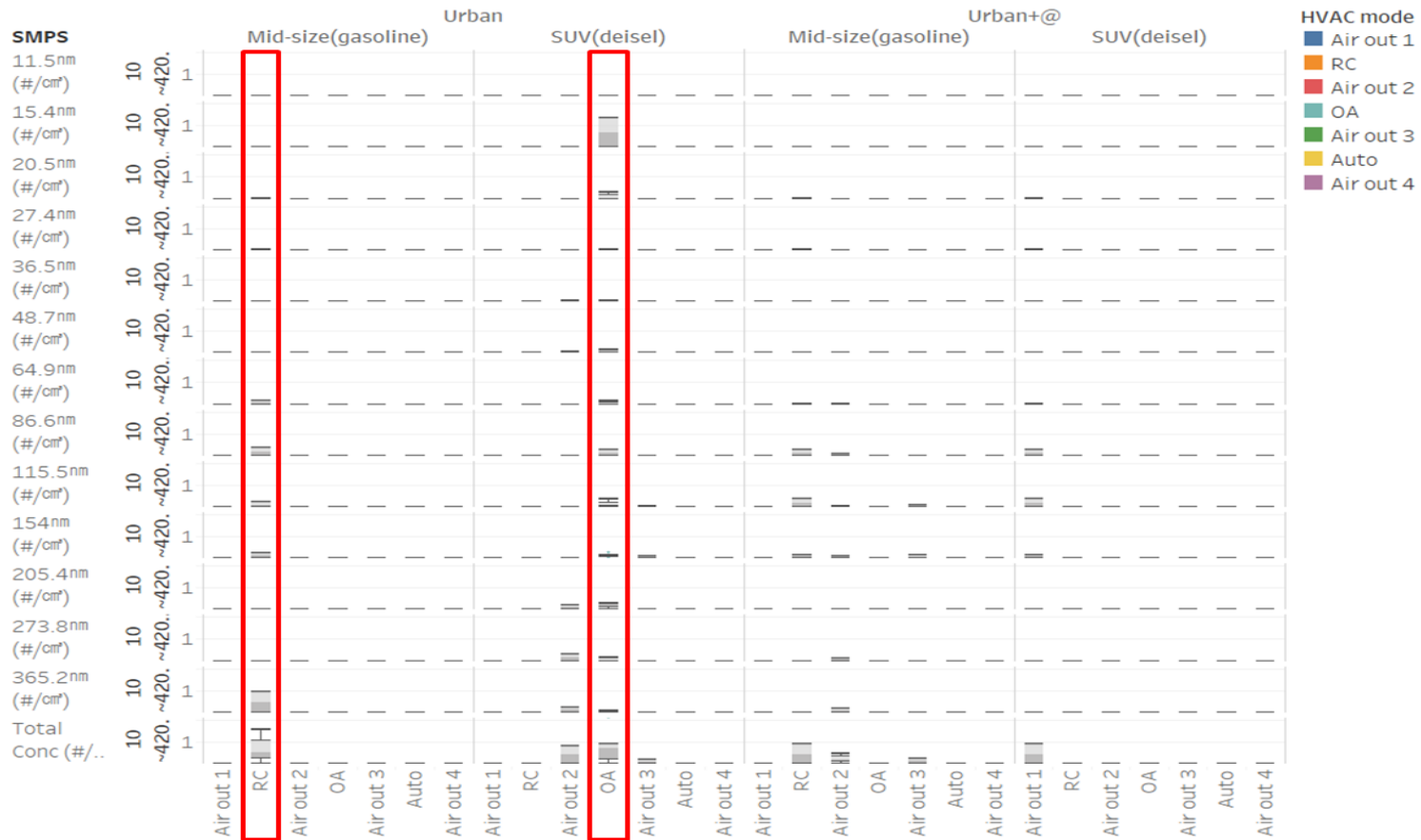
2. Test Results

» Particulate components

➢ Black carbon (Equipment : MAGEE AE43)

☑ BC not showing dependence on HAVC mode

☑ BC conc. increased when diesel vehicles nearby while driving

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2. Test Results

» Gaseous components

➢ **CO_2 concentration**

☑ When RC mode, CO_2 accumulated in vehicle over time

☑ When driving in AUTO mode, CO_2 distribution changed as HVAC mode changed to OA or RC state

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2. Test Results

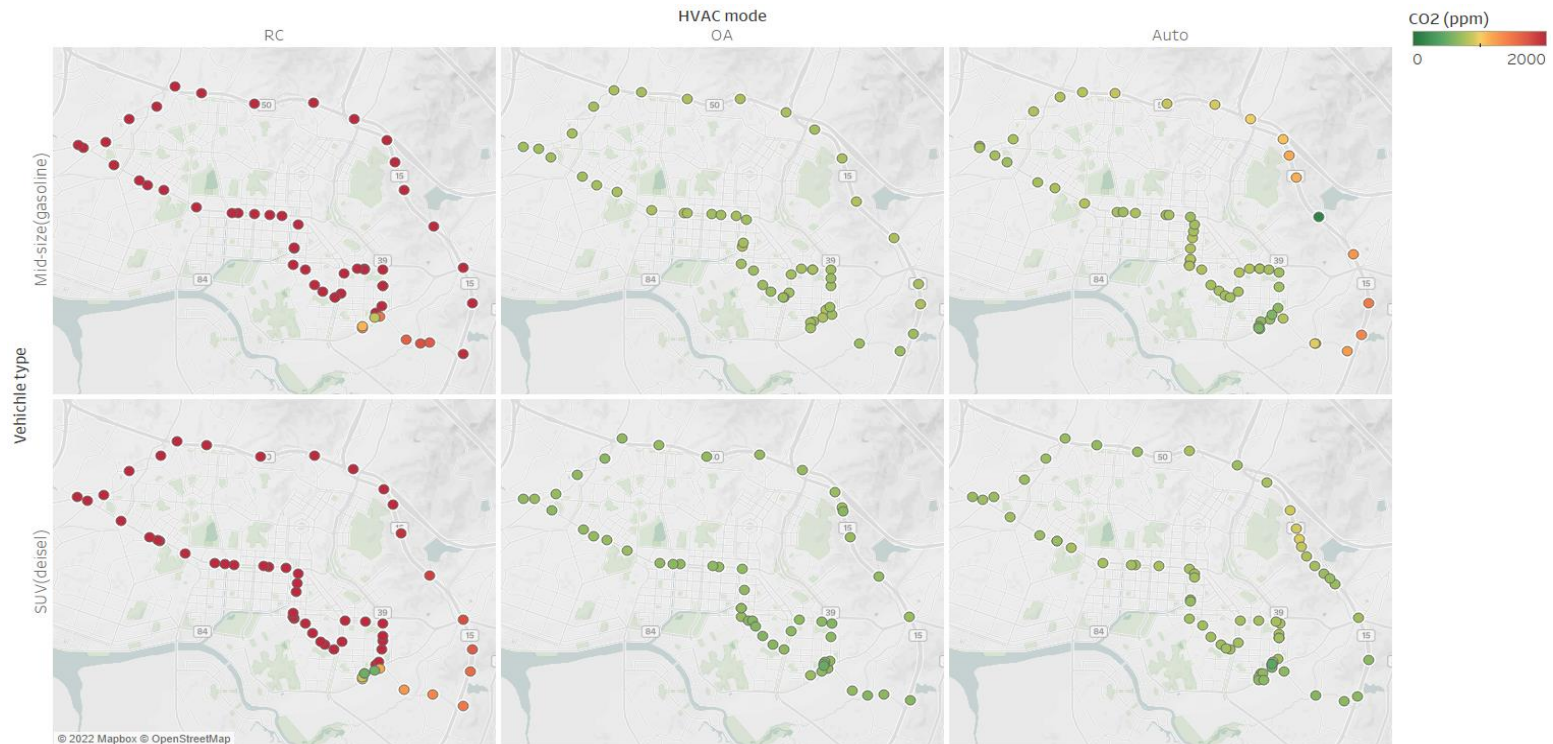## ›› Gaseous components

➤ **CO_2 Urban route**

☑ In RC mode, CO_2 conc. exceeded 2,000 ppm(Criteria for Public Transportation Vehicles in Korea) within 20 minute.

☑ In OA mode and AUTO mode, the CO_2 conc. around 1,000 ppm.

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2. Test Results

›› Gaseous components

➤ **CO_2 Urban + Motorway route**

☑ In the AUTO mode, the RC mode was operated before the tunnel section, and the CO_2 conc. increased

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2. Test Results

» Gaseous components

➢ CO concentration
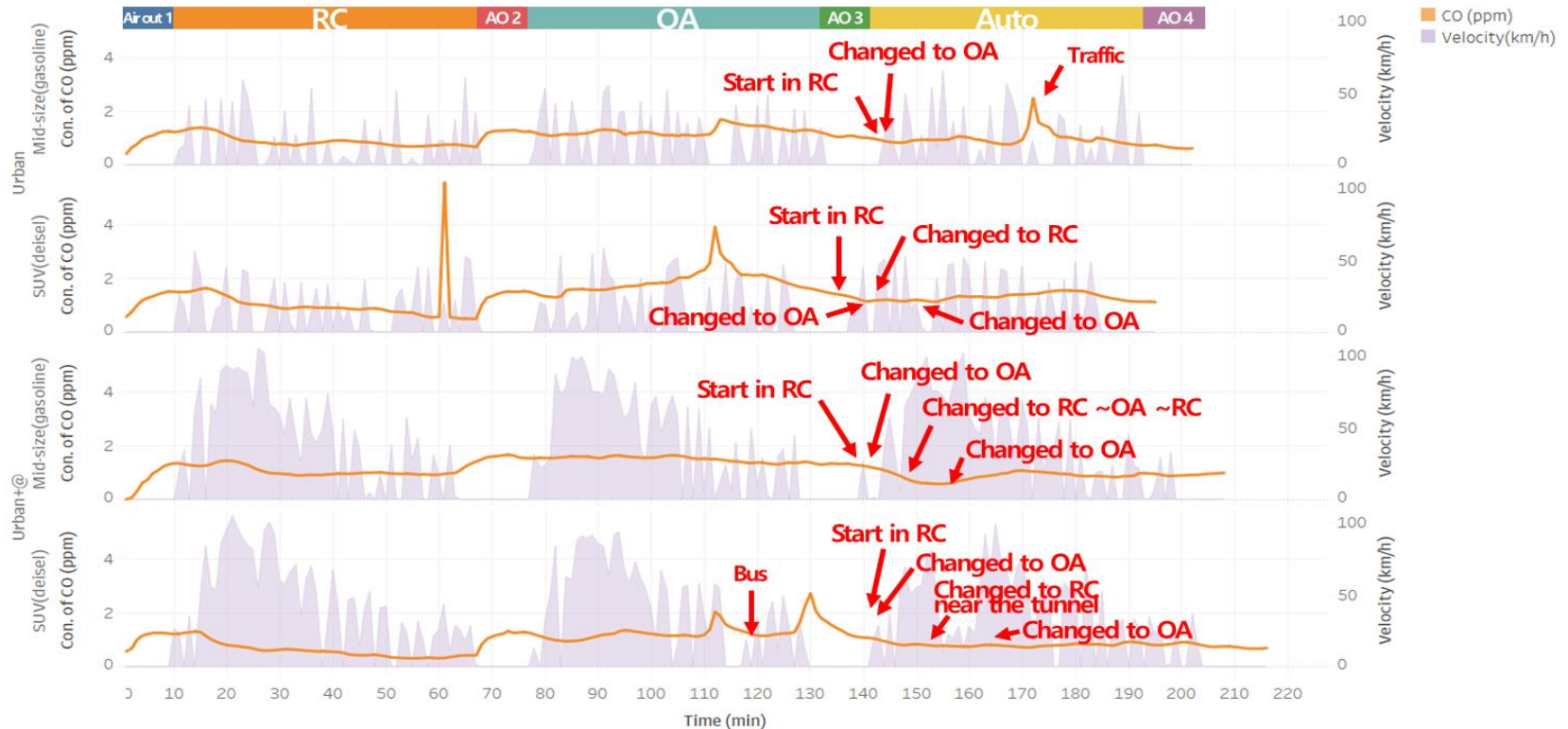
- ☑ The CO conc. higher in the order of RC mode < AUTO mode < OA mode
- ☑ When driving in OA mode, CO conc. increased at the point of heavy traffic

2. Test Results

» Gaseous components

➢ **NOx concentration**

☑ Not depending on HVAC mode, the state of traffic while driving, and the type of vehicle.

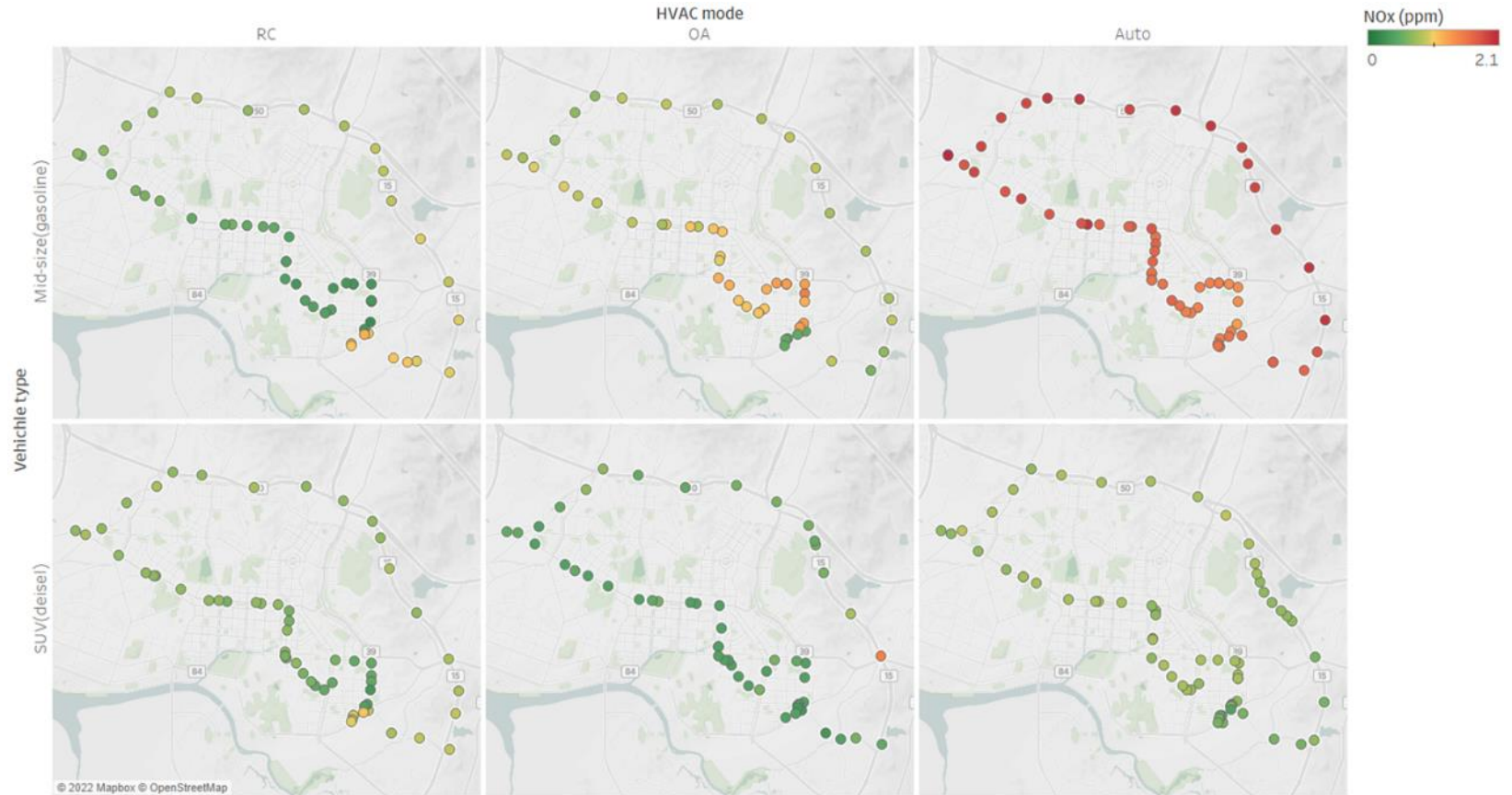☑ Generally showing relatively high conc. in AUTO mode and urban+motorway route than urban route.

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2. Test Results

» Gaseous components

➢ **NOx Urban route**

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2. Test Results

» Gaseous components

➤ **NOx Urban + Motorway route**

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3. Conclusion

>> Particulate components

☑ Particulate components were considerably influenced by HVAC system settings.

☑ AUTO mode showed the effect of improving vehicle cabin air quality of particulate components.

☑ PM conc. in vehicle cabin influenced by the degree of PM introduced from the outside sources. Thus in-cabin and outside air should be measured simultaneously.

☑ Nano size particle components showed a similar characteristics with PM except Black carbon.

☑ WCPC showed sensitivity with operating temperature, SMPS with vibration and BC with humidity and vibration while driving.

☑ Therefore, maintaining the stabilized conditions for operating equipment for nano particles would be critical during dynamic driving test.

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3. Conclusion

» Gaseous Components

☑ CO_2 was affected by the HVAC mode settings especially RC mode.

☑ CO conc. considerably depended on vehicle speed as it increased when the vehicle speed decreased while traffic volume was high.

☑ The CO intensity in vehicle cabin could be determined by outside air quality generated by surrounding traffic conditions while driving.

☑ NOx did not show the effect of HVAC mode settings, traffic conditions while driving, and the types of vehicles. Thus, more precise and accurate NOx equipment needed.

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Thank you!!

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