Intra-community air quality monitoring in various urban microenvironments in South Korea: based on observations from highly dense cost-effective sensor network

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1. Introduction

・ Distributions of air pollutants emitted directly from traffic sources are known to vary significantly in both time and space.

・ The major factors that control this spatiotemporal heterogeneity in air pollutant distributions include variations in traffic emissions (e.g., traffic volume, speeds, composition, maintenance, and others), surrounding micro-built environments, and meteorological conditions.

→ Thus, It is very important to understand the spatial variability of air pollutants in urban areas to reduce human exposure to locally concentrated air pollutants.

But limits of AOMS (Air Quality Monitoring Station, Korea)

→ Low-cost sensors can be used to observe spatially dense air quality monitoring networks, and detailed emissions can be obtained (Park et al., 2020).

→ In this paper, concentration changes in various microenvironments, including various built environments within a narrow range, were monitored.

2. Methods - Monitoring site and spatially dense air quality monitoring network

- Sensors were installed on the road for observation.
- A sensor network installed in the sidewalks of traffic roads in four to six distinct micro-built environments within the domain.
- Investigated intra-community variations in air pollutants within the observation domain(800m x 800m) in megacities in Korea

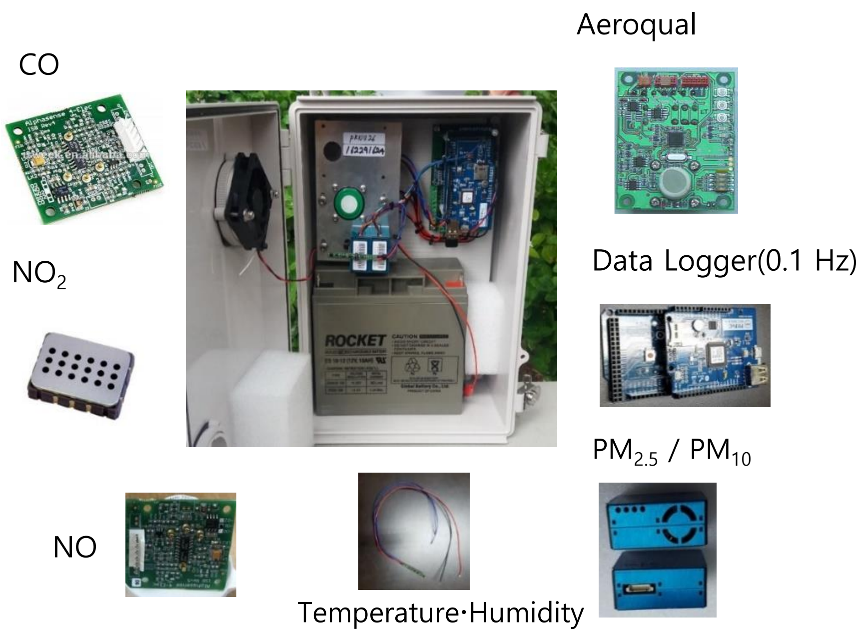
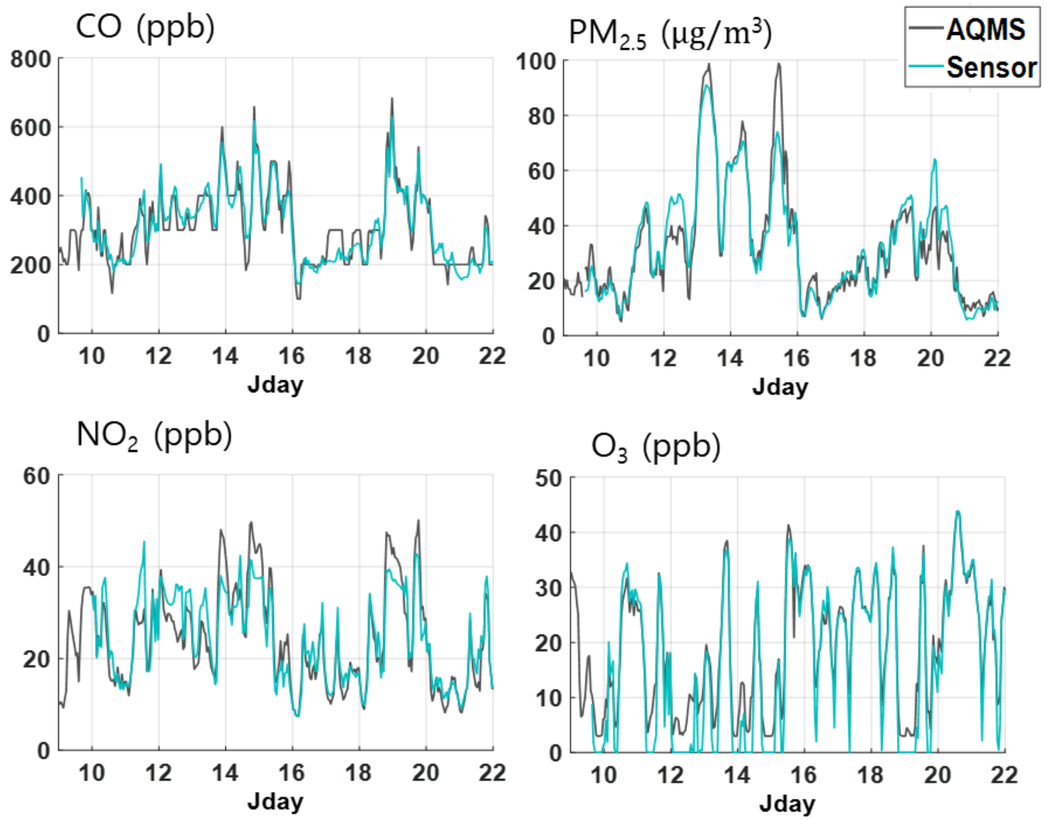


Figure 1. Sensor nodes (Park et al., 2020, Aerosol and Air Quality Research (in prints)).

- A comparative evaluation of the reference sensor and Air Quality Monitoring Station(AQMS)



→ It is considered appropriate to observe the distribution characteristics of air pollutants in micro-environments using the sensor network during the monitoring.

2. Methods - Monitoring site and spatially dense air quality monitoring network

(1) urban street canyon (Site 1; Eulji-ro)

(2) a dense mixture of medium-sized and low buildings in the both side of relatively narrow road with some open spaces (parking lots) (Site 2; Sogon-ro)

(3) medium-sized buildings in one side and open space in the other side with limited traffic (Site 3; Deogsugung-gil)

(4) a mixture of tall and medium-sized buildings in the both side of wide road with large traffic.

Figure 3. Observation site. Satellite image for the monitoring domain including spatial scales of the domain.

Table 1. Each road characteristic and observation period.

Qualitative characteristic	Site1	Site2	Site3	Site4
Surroundings Building Composition	Typical urban canyon surrounded by tall buildings on both sides of the road	Large open lot and low buildings between several large buildings	Pedestrian-oriented one lane road. Medium sized building on one side and empty lot on the other	It is composed of large buildings on both sides of the road, but the space between the buildings is large and low buildings and vacant lands exist.
Road width	~21 m	~13 m	~3.5 m	~28 m
Traffic	Medium traffic with traffic predominantly in the direction of the city hall. Many public transportation vehicles such as buses and taxis.	Due to the narrow roads, the traffic volume is not much higher than that of Site1, but it is particularly heavy during the day.	Vehicle control from 11:00 to 13:00. At other times, traffic is minimal compared to the surroundings through pedestrian-oriented one-lane roads.	There is a lot of traffic in both directions, but due to wide roads, traffic jams are not so severe.
Average building height around road	64 m	45 m	22.5 m	31 m
Setback distance from boundary line	both sides wide	both sides narrow	narrow	one sides wide
Sensor installation height	3.5 m	~2.5 m	~2.5 m	~2.5 m
Higher stories Sensor Installation	14 m / 132 m	N/A	N/A	N/A
Observation period	Summer : 2017.8.25 00:00 -9.1 00:00 Winter : 2018.1.9 00:00 -23 00:00			Winter : 2018.1.9 00:00 -23 00:00

3. Results - Temporal variations

• CO : distribution is similar to the traffic volume and traffic congestion on each road.

→ the spatial distribution of CO concentration can be determined by the difference in CO emissions from the road and the distribution of the wind field at the same time.

• $PM_{2.5}$: was less concentration differences in each site.

→ This supports that PM2.5 is a major production source that secondary generation in the atmosphere rather than primary emissions.

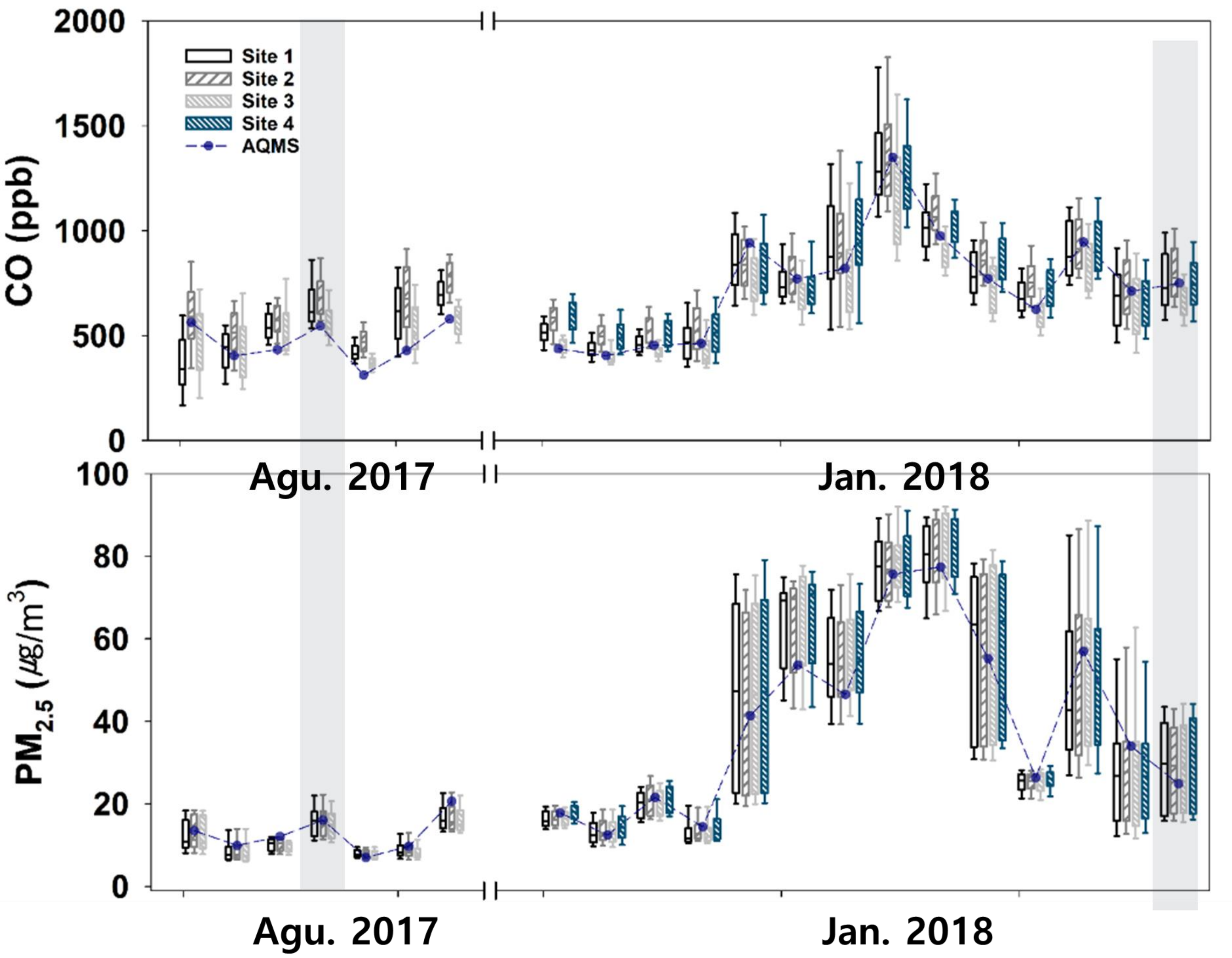


Figure 4. Box plot of daily changes by measured pollutants by observation area. Each box is the lower 25%, 50%, 75% of the concentration observed during each day in each Site. The gray shaded part represents the day of precipitation. The blue dotted line indicates the average concentration value of AQMS. The red shaded part represents the day of high $PM_{2.5}$ concentration event.

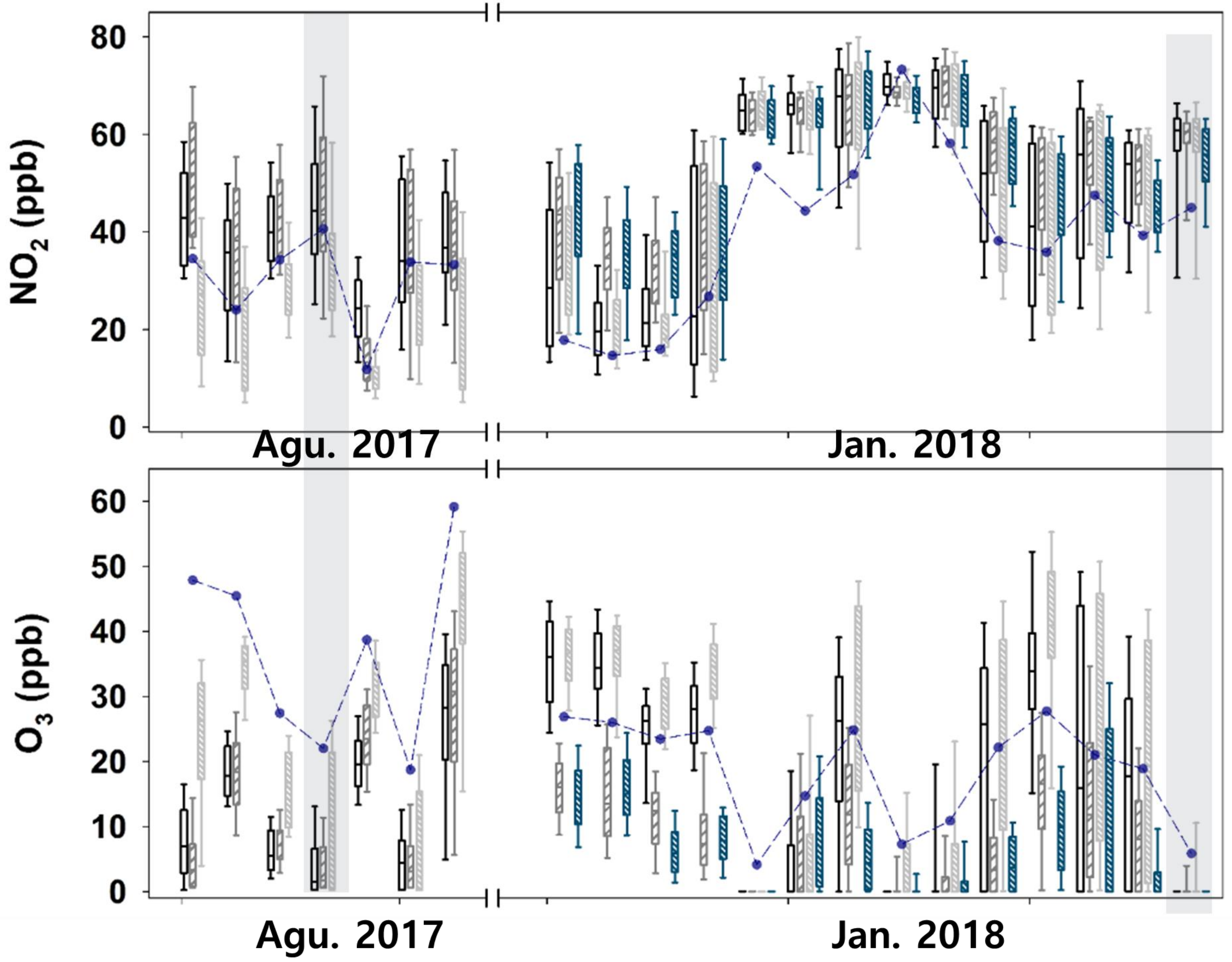
3. Results - Temporal variations

- NO_2 : NO_2 and O_3 were inversely related to the difference in each site.

→ due to the chemical removal of ozone by NOx emitted from the vehicle.

- O_3 : the concentration difference of O3 at each site was very large.

→ the effect of NOx that emitted from vehicle emission in the road.



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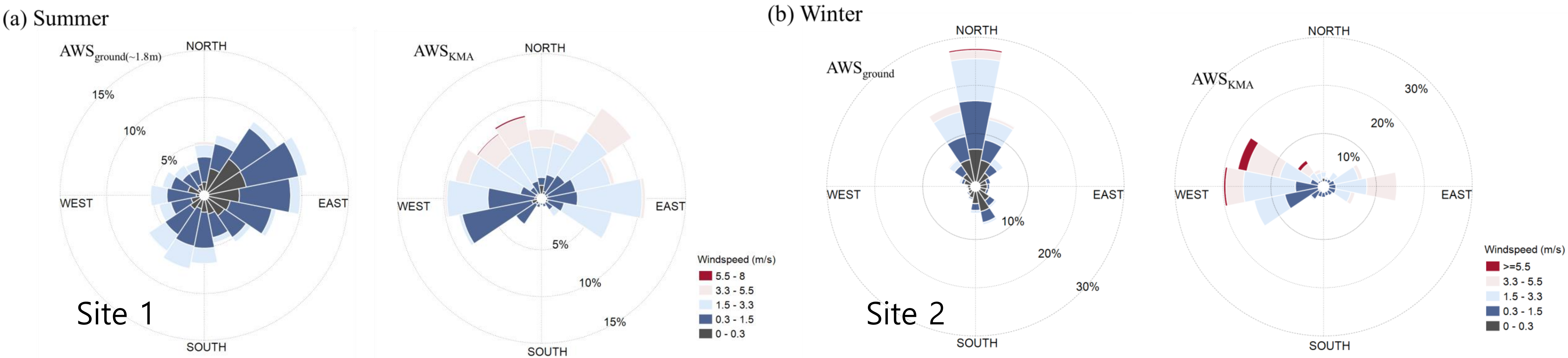
3. Results - Meteorology

- Weather data were obtained from AWS (Automatic Weather System) managed by the Korea Meteorological Administration (KMA) located within 2 km at the monitoring site.



Site 1, $AWS_{ground(\sim1.8m)}$:
Clam(windspeed ≤ 0.3 m/s) : 29%
Temperature : 18.4 ~ 30.5 ℃ (Avg. : 23.4±3.2 ℃)
Humidity : 23.7 ~ 78.7% (Avg. : 49.1±13.7%)

Site 1, AWS_{KMA}:
Clam(windspeed ≤ 0.3 m/s) : 5.7%
Temperature : 15.2 ~ 30.6 ℃ (Avg. : 21.2±3.3 ℃)

Site 2, AWS_{ground}:
Clam(windspeed ≤ 0.3 m/s) : 39%
Temperature : -13.6 ~ 8.6 ℃ (Avg. : -0.9±6.4 ℃)
Humidity : 20.4 ~ 81.6 % (Avg. : 52.9±14.1 %)

Site 2, AWS_{KMA}:
Clam(windspeed ≤ 0.3 m/s) : 3.8%
Temperature : -16.2 ~ 7.4 ℃ (Avg. : -3.2±6.6 ℃)

3. Results - Meteorology

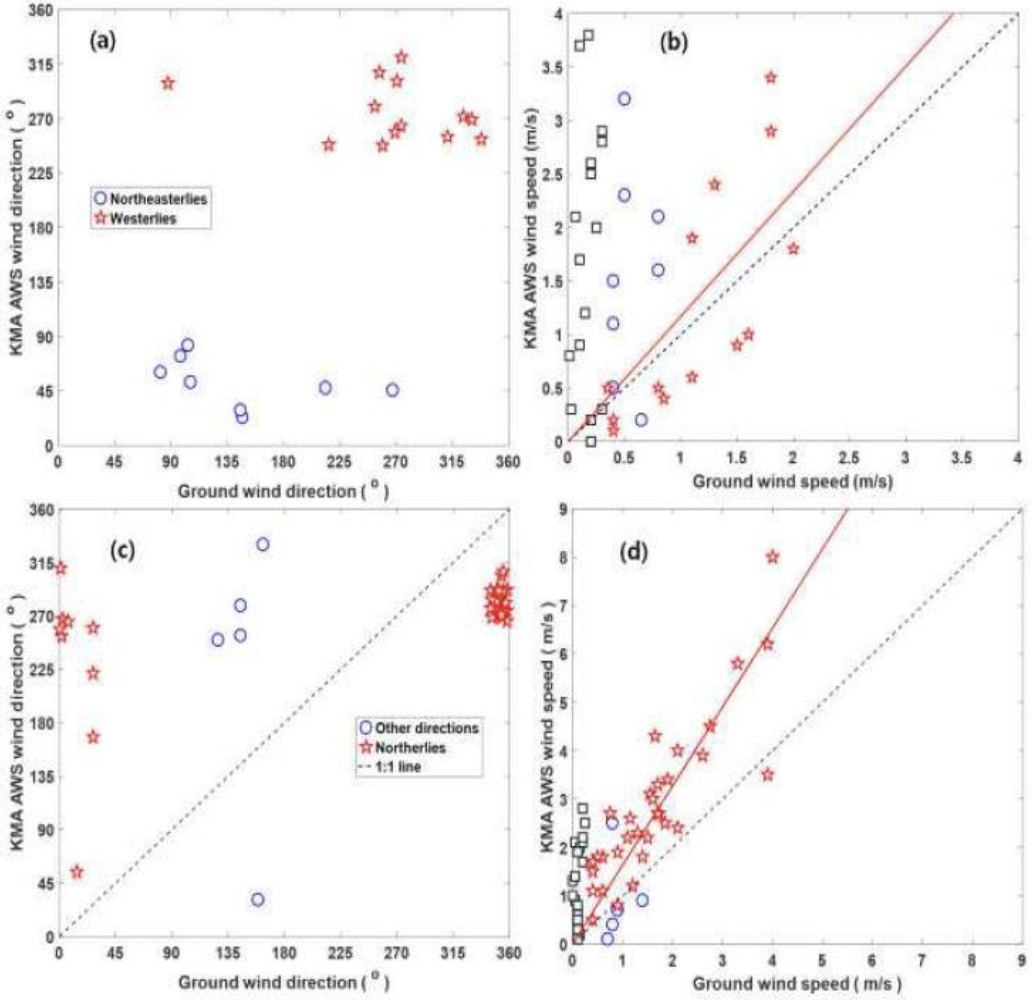


Figure. 5. Summer and Winter observations period, KMA comparison of wind direction / wind speed observed on the ground at the same time as the wind direction / wind speed of AWS in Site 1 (summer) and Site 2 (winter). (a) and (b) summer wind direction and wind speed scatter plots (blue circle indicates the weather direction of the AWS is northeast wind, red star indicates the west wind series), (c) and (d) winter wind direction and wind speed scatter plot (red) Stars are in the north wind system, while blue circles are in the southwest wind system.) The black square shows the case where the wind speed is less than 0.3 m / s and there is no wind direction.

The wind direction of the upper = The direction of the road

→ the wind speed can be <u>relatively strong</u> due to the influence of the upper wind speed.

Ex) Fig. a, b

direction of road (Site 1) : West-East

wind direction : Westerlies

→ KMA AWS wind speed 1.28 m/s vs ground wind speed 1.15 m/s)

The wind direction of the upper ≠ The direction of the road

→ the wind blows in the other direction, the wind speed recorded significantly <u>lower value</u> due to blocking by the building.

Ex) Fig. a, b

direction of road (Site 1) : West-East

wind direction : Northeasterlies

→ KMA AWS wind speed 1.56 m/s vs ground wind speed 0.56 m/s)

• Therefore, the spatial distribution of pollutants concentration can be determined by the difference the distribution of the wind field at the same time.

-> For example, in Site 2, the road lies in the northwest-southeast direction, and when the ground wind blows in a direction similar to the road direction, strong wind speed can increase the diffusion efficiency of pollutants and reduce the concentration in the atmosphere. Particularly, when this is consistent with the wind direction of upper and road direction, the efficiency of diffusion increases further.

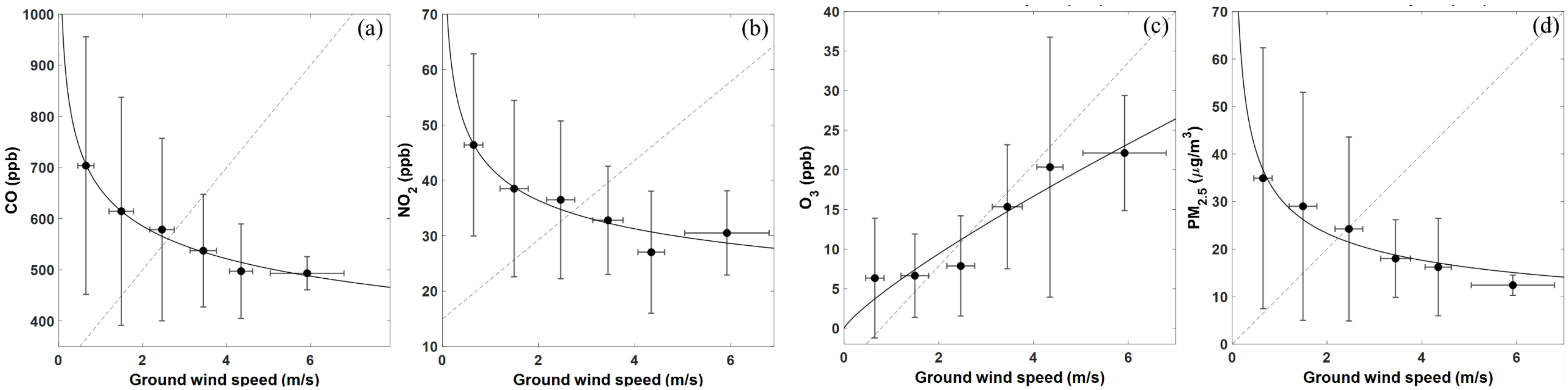


Figure. 6. The wind speed and pollutants concentration comparison when the ground wind direction and the upper wind direction coincide with the road direction (the wind speed comparison plot that when the wind direction coincides with the north wind and the northwest wind in winter (considering monsoon, except high $PM_{2.5}$ con. Day and weekend)). (a) CO ($y=ax^b$, $R^2=0.98$), (b) NO_2 ($y=ax^b$, $R^2=0.91$), (c) O_3 ($y=ax^b$, $R^2=0.97$), (d) $PM_{2.5}$ ($y=ax^b$, $R^2=0.86$).

3. Results - Spatial variations

- To quantify spatial heterogeneity the COD was used between two observation points (Wilson et al., 2005).

$$\mathrm{COD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{x_{if}-x_{ih}}{x_{if}+x_{ih}}\right)^{2}} \quad \text{(Eq 1)}$$

COD >0.2 **heterogeneously distributed**

COD =0 **totally homogeneous**

NO_2 : This is directly affected by road traffic emissions, so the difference differs in the number of traffic sources. → similar to pollutant source but difference in concentration range between Site in winter.

O_3 : showed a heterogeneity distribution because of react chemistry react (ex) NO_2.

CO : showed slight heterogeneity (concentration distribution related to windspeed).

→ similar to pollutant source but difference in concentration range between Site.

$PM_{2.5}$: was spatially homogeneously distributed in both time and space.

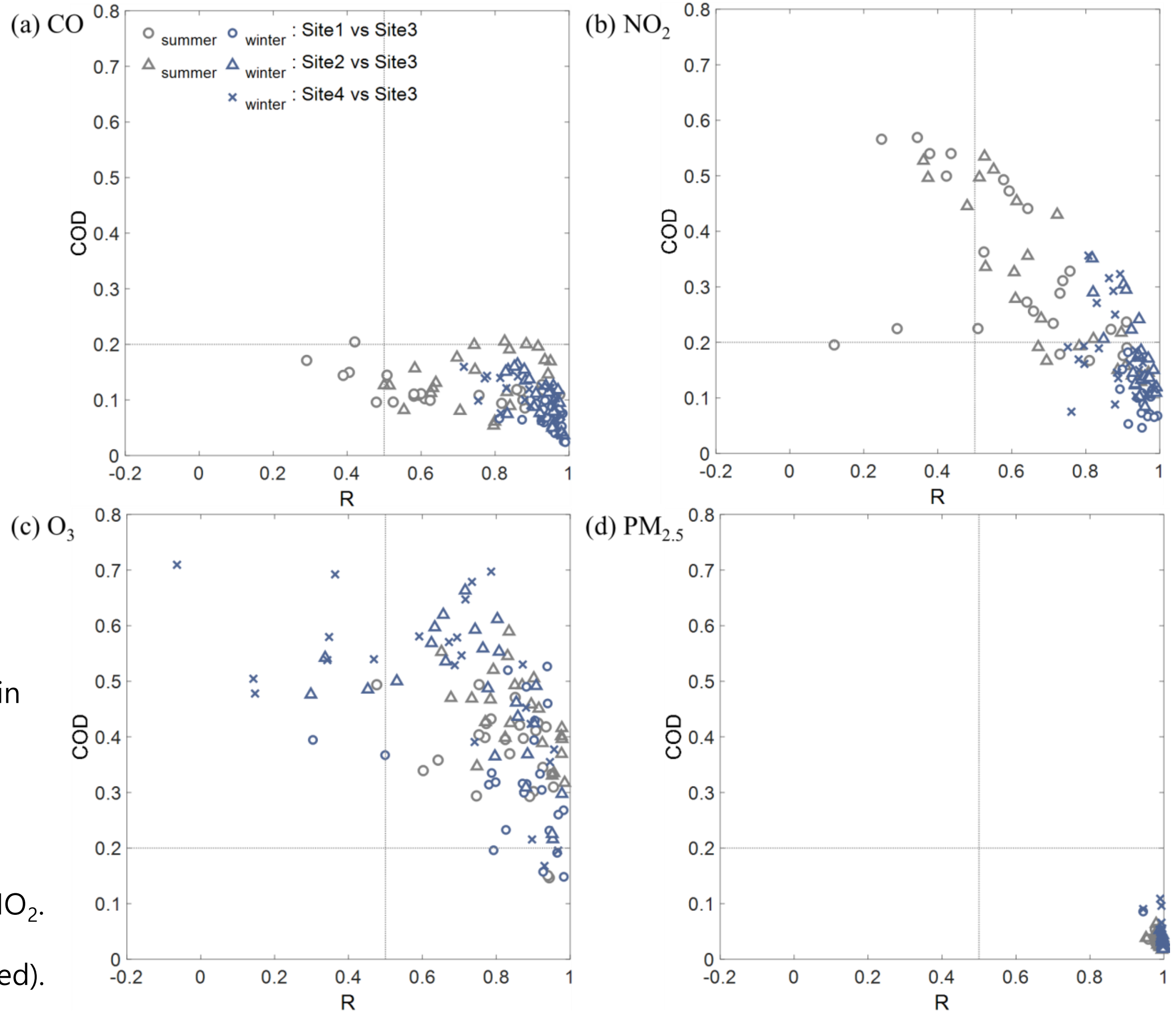


Figure 7. A daily average COD distribution with a concentration of pollutants at 1 h interval (except for the day when precipitation and high concentrations occurred).

4. Summary

• CO showed moderate heterogeneity in small intra-community scale

→ Emissions from traffic sources have been reduced significantly.

→ Thus, the local traffic sources have relatively less significant impact.

• NO_2 distributions in intra-community scale were highly heterogeneous

→ directly affected by various local emission sources.

• Heterogeneous distributions of O_3 was caused by a rapid reaction with NO emitted from local traffic sources.

• $PM_{2.5}$ showed homogeneous spatial distributions in this monitoring domain

→ $PM_{2.5}$ is secondary products formed in the atmosphere by chemical reactions or transported from other regions (Effects of direct emissions from local traffic is limited).

Acknowledgements

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Thank you

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