#Abstract Code: EGU23-4794 | AS3.15

Machine learning based estimation of urban on-road CO_2 concentration in Seoul

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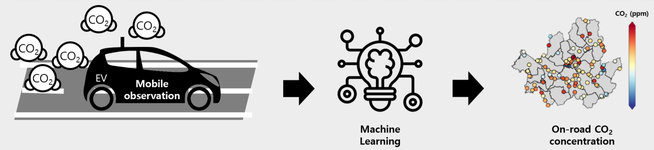
European Geosciences Union (EGU) 2023
23 – 28 April 2023, Vienna, Austria & Online

HIGHLIGHTS OF THIS STUDY



- A machine learning based model predicting on-road CO_2 concentration was developed
- The model estimates hourly on-road CO_2 concentrations with high precision
- On-road CO_2 in Seoul was highly variable (14.3 ppm by time and 345.1 ppm by road)
- The reason for the increase in on-road CO_2 concentration varies by road type
- Speed (arterial roads) and volume (urban highways) explained increased CO_2

INTRODUCTION

- CO_2 emissions from the transportation sector accounted for 23.9% of global total carbon emissions in 2007, with the proportion expected to increase to 41% by 2030. As the growth of traffic-related CO_2 emissions is concentrated in urban areas, managing on-road CO_2 emissions in urban areas is crucial to mitigate climate change.
- Mobile observations have the advantage of being able to observe on-road CO_2 concentrations at a high spatial resolution of less than 1 km. However, owing to the difficulty of continuous mobile observations for all roads in city, most mobile observations were undertaken for specific roads and periods as a campaign.
- Therefore, this study sought to develop a mobile observation-based machine learning model that enables the continuous calculation of on-road CO_2 concentrations on all roads in Seoul, South Korea, the world's largest carbon-producing city.

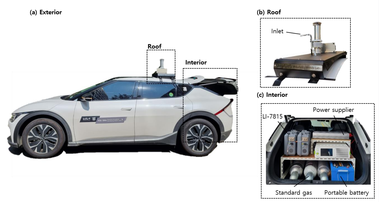
OBJECTIVE

- Develop a mobile observation-based machine learning model that enables the continuous calculation of on-road CO_2 concentration on all road.
- Evaluate spatiotemporal on-road CO_2 concentration variability.
- Find the cause of on-road CO_2 concentration by each road type (Major arterial road, Minor arterial road, Urban highway).

DATA AND METHODOLOGY

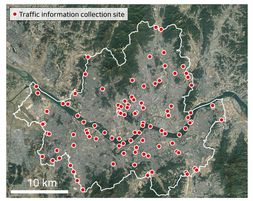
OBSERVATION DATA

Mobile Observation System



- Customized carbon-free electric vehicle.
- Measuring on-road CO_2 concentration every 1s using LI-7815 instrument.
- Measuring location and speed data every 1s using GPS device.

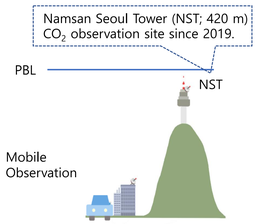
Observation details



- Observation period: 2022/01~2022/02
(limited to winter with minimum vegetation activity)
- Observation time: 10:00~12:00
(highest PBL height with active atmospheric circulation)
- Having 1,260 km drive in total.

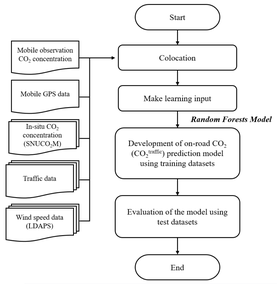
METHODOLOGY

1. On-road CO_2 Concentration ($CO_2^{traffic}$)



- On-road CO_2 concentration ($CO_2^{traffic}$), which reflects the CO_2 emissions discharged from on-road emissions, was quantified by eliminating representative urban CO_2 concentration from the on-road CO_2 concentration.
- Here, CO_2 concentration from NST was used as a regional background of the on-road CO_2 concentration of Seoul.
- $CO_2^{traffic} = CO_2^{measured} - CO_2^{regional\ background}$

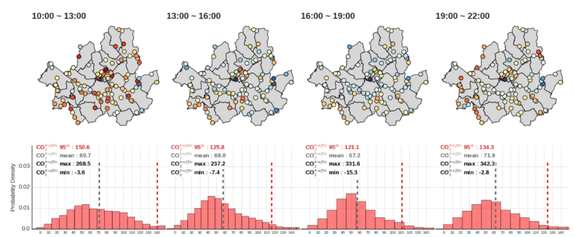
2. Observation-based Machine Learning Model



- Random forests model for continuous prediction on-road CO_2 concentration ($CO_2^{traffic} = CO_2^{measured} - CO_2^{regional\ background}$).
- Input data are collocated based on the traffic information collection site.
- Training and test datasets are divided into a 3:1 ratio.
- This model predicts hourly $CO_2^{traffic}$ with high precision (R^2 = 0.8) by utilizing CO_2 observations, traffic volume, traffic speed, and wind speed as the main factors.

RESULTS

1. Spatiotemporal variations in on-road CO_2 concentration

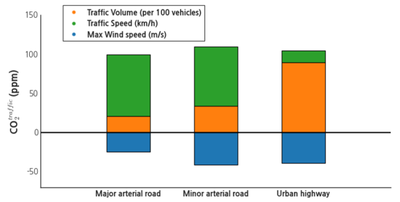


A map of averaged estimated on-road CO_2 concentration ($CO_2^{traffic}$) at three-hour intervals for each site (first row). The probability density function graph for the hourly $CO_2^{traffic}$ used for each three-hour (second row). The gray and red dotted line indicates the mean and 95th percentile value of $CO_2^{traffic}$.

RESULTS

- On-road CO_2 concentration over Seoul is highly different by road (up to 346.9 ppm) and time (up to 13.5 ppm).
- On-road CO_2 concentration exhibiting high spatiotemporal variability over all time zones.

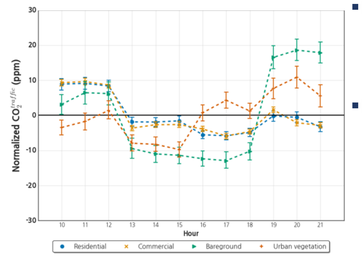
2. On-road CO_2 concentration by road type



- Arterial road
  Traffic speed (57%) contributes more to increasing on-road CO_2 concentration than traffic volume (20%).
- Urban highway
  Traffic volume (63%) contributes more to increasing on-road CO_2 concentration than traffic speed (10%).

➔ The main factor affecting the on-road CO_2 concentration differed across road types

3. On-road CO_2 concentration by land-use type



- Residential and Commercial
  - Has identical diurnal on-road CO_2 cycle with highest concentration between 10:00 to 12:00 and remaining constant for other times.
- Bareground and Urban vegetation
  - On-road CO_2 concentration increased rapidly during afternoon, showing highest concentration between 19:00 and 21:00.
  - Mostly located in the outskirts of Seoul, connecting the urban venter and outer Seoul and traffic volume changes significantly by times.

➔ Land-use type and locations to which each road belongs are likely to have a significant influence on on-road CO_2 concentration.

CONCLUSION

- Observation-based model can be utilized to evaluation urban on-road CO_2 concentration.
- The cause and variation of on-road CO_2 concentration may differ by it road type and land-use type.
- Various information on on-road CO_2 emissions can be obtained through mobile observation and can be utilized to develop effective urban on-road CO_2 reduction policies.

**This work was supported by Korea Environment Industry &Technology Institute(KEITI) through "Climate Change R&D Project for New ClimateRegime.", funded by Korea Ministry of Environment(MOE) (2022003560006).*