Evaluation of Relationships Between Urban CO$_2$ and Air Quality from Ground to Space

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Cities are home to more than half of the global population and are a major source of anthropogenic CO₂ emissions as well as other pollutants which have a great impact on the environment, air quality, and climate change.

With the Paris Agreement and the Global Stocktake in 2023, reducing CO₂ emissions has become one of the biggest concerns of cities.

While cities account for more than 70% of the global CO₂ emissions, they also have great potential to be the drivers of global CO₂ reduction.
In a local/city scale, what relationship do CO₂ and air pollutants have?

Can different city emission policies and air quality management bring different results globally?

Can policies for mitigating urban greenhouse gases also reduce co-emitted air pollutants and improve air quality?

What kind of synergies can we get with different satellite measurements in order to understand emission patterns of cities?
Approach

CO₂ vs. Air Pollutants

Local Scale

**CO₂**

Megacity Seoul CO₂ Project by Seoul National University

Air Pollutants (CO, NO₂, PM₂.₅)

AirKorea by the Korean Ministry of Environment

Global Scale

**CO₂**

Orbiting Carbon Observatory-2 by NASA

Data available: 2014/09 – ongoing

Air Pollutants (CO, NO₂)

Sentinel-5 Precursor TROPOspheric Monitoring Instrument by ESA

Data available: 2018/06 – ongoing
Megacity Seoul CO₂ Project
Understanding CO₂ in Seoul

Climate Convergence Laboratory, Seoul National University (climatelab.snu.ac.kr)
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✓ How much carbon dioxide is in Seoul?

✓ How much of the total carbon dioxide emissions are anthropogenic emissions?

Satellite data + Monitoring network + Modeling
Megacity Seoul CO₂ Project
Understanding CO₂ in Seoul

- Estimate reliable ground carbon flux by constructing an inverse model using ground observations and satellite data.
- Quantify the effect of anthropogenic and biogenic factors on the variation of CO₂ in Seoul.
Ground-based Observations
Seoul CO₂ Monitoring Network

1. Yongsan
   - Location: Seoul
   - Date: (2018/10/18 -)
   - Equipment: LI-COR
   - Coordinates: 37.523/126.963
   - Altitude: 100m

2. Namsan
   - Location: Seoul
   - Date: (2019/02/25 -)
   - Equipment: LI-COR
   - Coordinates: 37.551/126.988
   - Altitude: 716m

3. Gwanak mountain
   - Location: Seoul
   - Date: (2019/05 -)
   - Equipment: Picarro
   - Coordinates: 37.444/126.963
   - Altitude: 626m

Seoul National University
   - Date: (will begin in 2019/08-)
   - Equipment: EM27/SUN Series
   - Coordinates: 37.462/126.954
   - Altitude: 80m

✓ Observations will continue for more than 10 years
Examined relationships of CO\(_2\) & pollutants CO, NO\(_2\), and PM\(_{2.5}\) using ground measurements from Yongsan (LI-COR 850, run by SNU) and AirKorea (run by the Korean MoE) respectively.

S1 and S2 are the two nearest AirKorea stations to the Yongsan measurement site.

The time series of CO\(_2\), CO, NO\(_2\), and PM\(_{2.5}\) show peaks at a similar time.
• At 0 h, NO₂ show highest correlation with CO₂, while CO shows highest correlation at 1 h. PM₂.₅ shows highest correlation at 4h.
• CO and NO₂ are observed to act as precursors for PM₂.₅.
• This could mean that CO₂ and air pollutants could have been transported in the same air or emitted from the same sources.
• The pollutants with the highest correlation between CO₂ is in the order CO > NO₂ > PM₂.₅.
East Asian cities show the highest CO₂ & CO concentrations.

South Asian cities like Dhaka and Kolkata have a higher concentration of CO per CO₂ compared to other cities.

Cities in Europe and North America show high concentrations of CO₂ but a lower concentration of CO per CO₂ compared to East Asian countries.

Cities like Beijing & Guangzhou show a higher CO concentration compared to Paris and London despite similar concentrations of CO₂.
Results
Global Scale

Satellite Observations of Cities in the Northern Hemisphere
CO₂ vs. NO₂

- East Asian cities once again show the highest CO₂ & NO₂ concentrations.
- Cities like Tokyo, LA, and Mexico City show high amounts of NO₂ per CO₂ concentration despite their low CO₂ concentration compared to other cities.
- Aside from Paris, cities in Europe show a lower NO₂ per CO₂ concentration pattern despite their high CO₂ emission rates.
- Seoul and Yeosu both show similar amounts of CO concentration, but Seoul has a higher amount of NO₂ per CO₂ concentration than Yeosu. This shows the characteristics of cities within a country (e.g. Seoul – megacity, Yeosu – industrial area).
• From ground measurements on a local scale in Seoul, we find that there is a high correlation between CO₂, CO, NO₂, and PM₂.₅.

• CO₂ and air pollutants CO, NO₂, and PM₂.₅ show peaks at a similar time.

• At 0 - 1h, CO and NO₂ show highest correlation with CO₂ and act as a precursors for PM₂.₅.

• Using satellite data on a global scale, we could see that cities in the Northern Hemisphere show a linear pattern in the relationship between CO₂ and CO & NO₂ concentrations.

• Regionally, cities show different emission patterns and relationships between CO₂ and pollutants.

• Satellite data and ground-based observations are important in understanding and measuring local emissions in cities.

• Higher spatial and temporal resolution data both from ground and space are still in great need.
Discussion

• Ground measurements at a local scale have limitations as monitoring can be discontinuous and can only measure one point. Thus, a large network of ground measurements are needed.

• Satellite data can cover a larger global scale, yet there are limitations in spatial samples and clear retrievals of greenhouse gases and pollutants especially over urban areas like cities due to cloud cover and aerosols.

• With the launch of OCO-3, GOSAT-2, S5P(TROPOMI), and other GHG monitoring satellites like GK-2B(GEMS) and the Copernicus Sentinels (S4, S5, CO2M), we will be able to understand and measure CO₂ emission patterns of cities and their relationships with air pollutants more clearly.

• With these satellite missions, there will be synergies in observing the relationship between CO₂, CO, and NO₂ in other cities in different regions.
THANK YOU