Top-down Quantification of NO_x Emissions in Wuhan From 2018 to 2023 Using satellite NO_2 observations from TROPOMI

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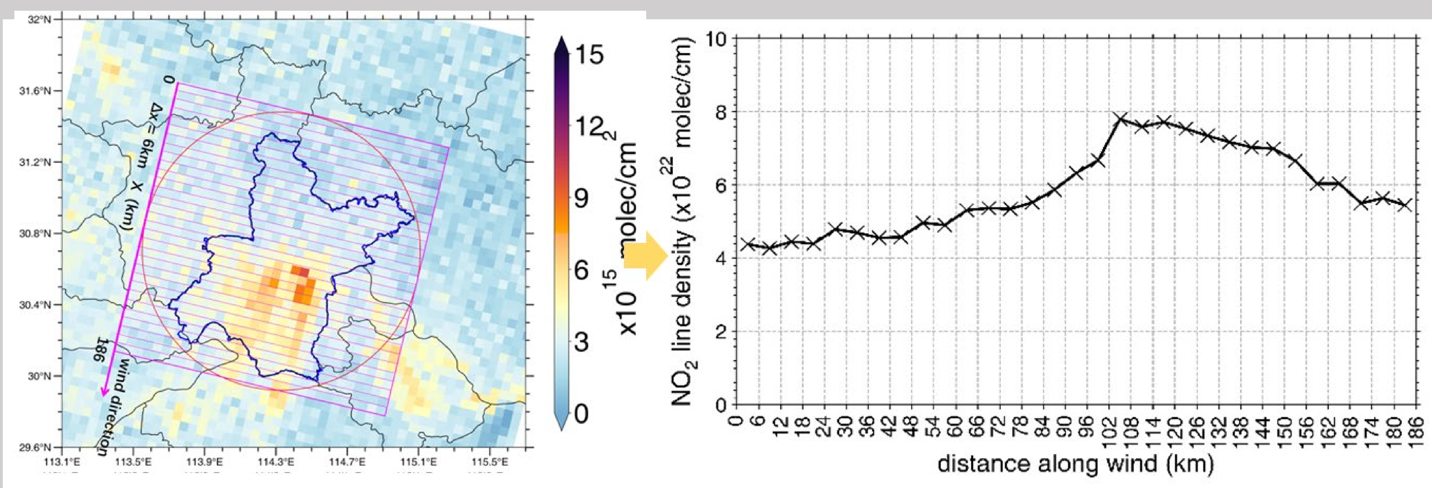
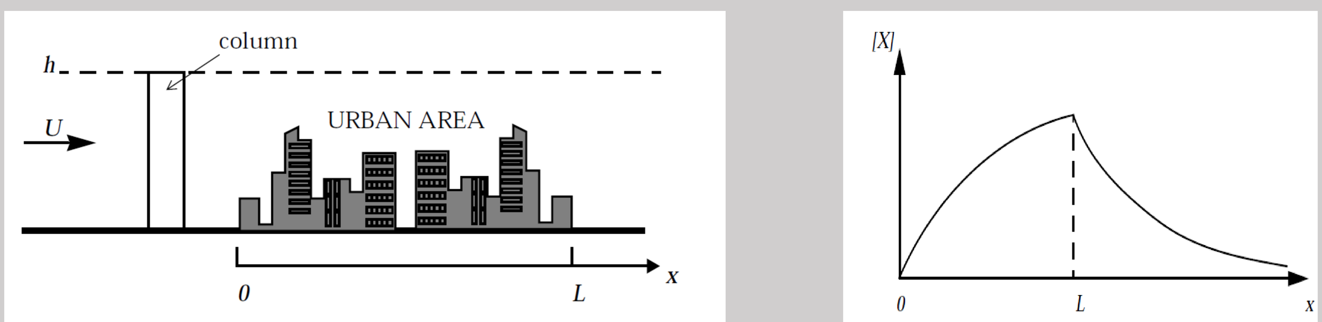
1. Introduction

Quantification and control of NO_x emissions over cities are essential across the world to improve air quality. We use a superposition column model to estimate NOx emissions and lifetimes on the daily basis over a large city of Wuhan, China. We use the TROPOMI v2.4.0—v2.6.0 tropospheric NO2 columns from May 2018 to December 2023. We compared our results with other inventories, investigated the annual and seasonal variability of NOx emissions, the weekend effect, holiday effect and COVID lockdown effect on NOx emissions.

2. Data and Method



- Use the TROPOMI v2.4.0—v2.6.0 NO_2 product.
- Sample the NO_2 data into 0.05°lat × 0.05°lon grid (~ 6 × 6 km^2) and rotate it toward wind direction.
- Accumulate NO_2 column density perpendicular to wind direction to get the NO_2 line density.
- Fit the NO_2 line density with a superposition column model.



Atmospheric Chemistry, D.J. Jacob, 1999

$$N_i(x) = \frac{E_i}{k}\left(1 - e^{-kL/u}\right) \times e^{-k(x-x_i)/u} \times \frac{[NO_2]}{[NO_x]} \quad for\ x > x_i$$

$$N_i(x) = 0 \quad for\ x \le x_i$$

$$N(x) = \sum_{i=1}^{n} N_i(x) + b + \alpha x$$

- The NO_2 chemical loss rate (OH concentration) and the NO_x/NO_2 ratio is from the GEOS-Chem model simulation.
- The wind field is from the ERA5.

3. Results

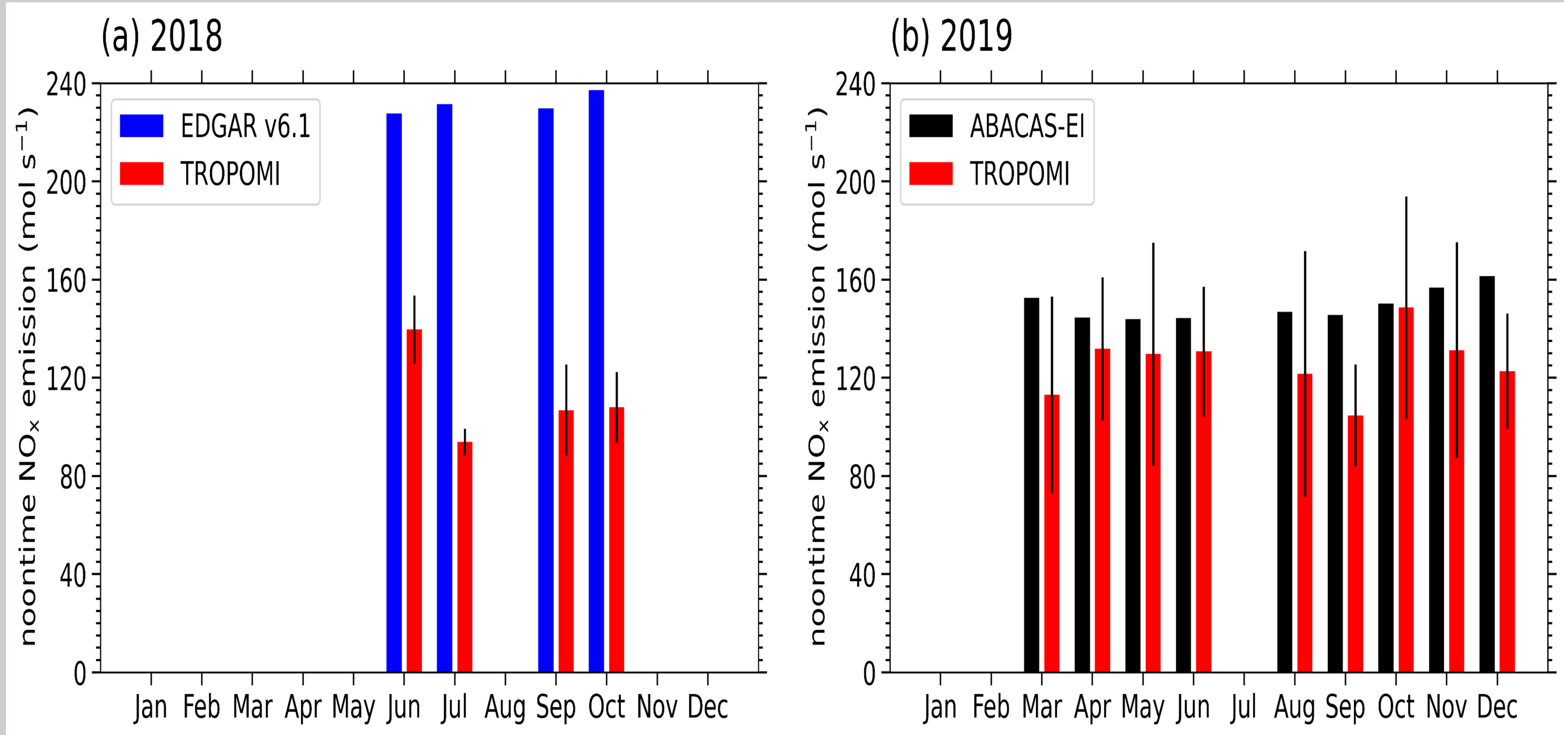
Data availability

By year	2018	2019	2020	2021	2022	2023
	27	58	61	51	68	52

By season[a]	Spring	Summer	Autumn	Winter
	72	66	101	52

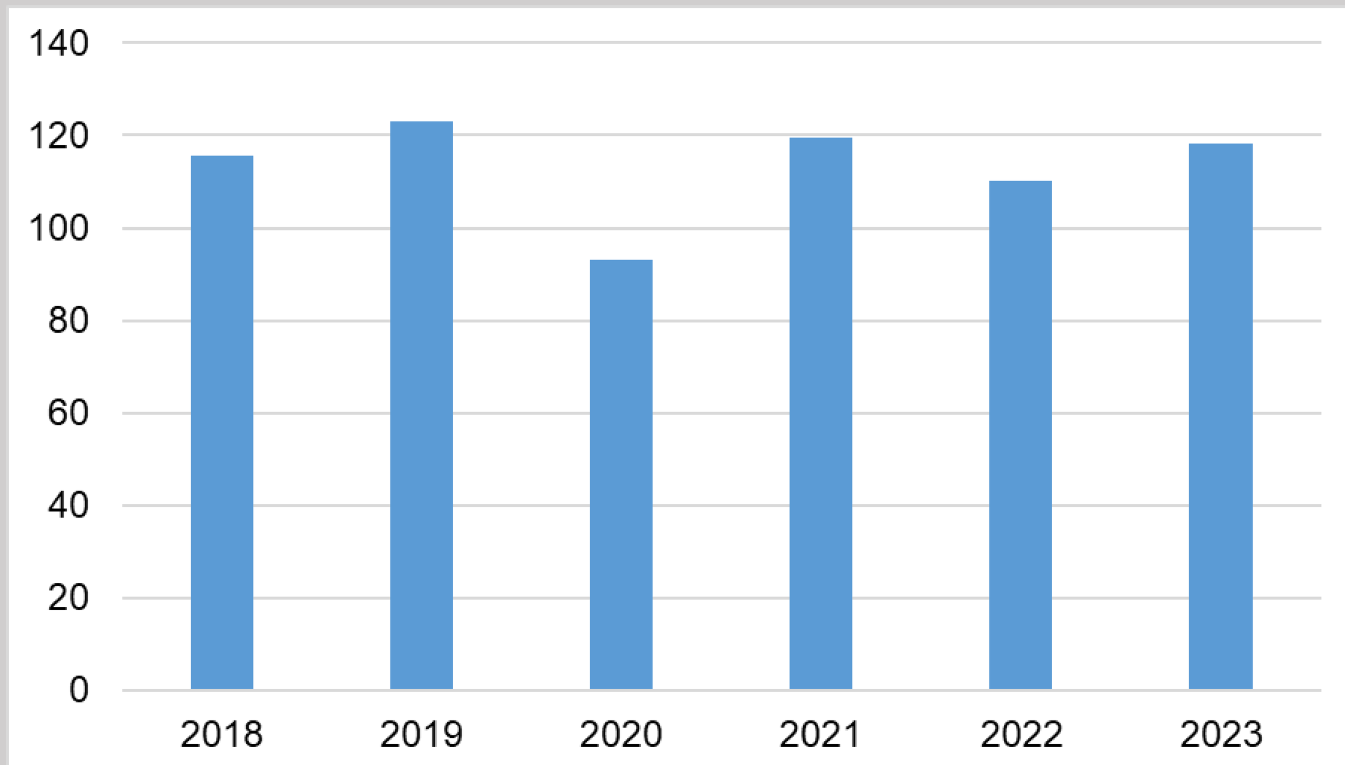
- We obtain a total 317 days from May 2018 through December 2023 with valid NO_x emissions and lifetimes estimations.
- For the 5 years (2019 – 2023) with full-year's measurement, the percentage of valid estimations is 14.5% – 18.6%.
- Seasonally, we obtain most valid days in autumn, and then is spring. The spring days are nearly 30% less than the autumn days because that when we calculate the seasonal emissions, we exclude the COVID-19 lockdown influenced days and there is no satellite measurements in 2018 spring.

4. Compare with other inventories

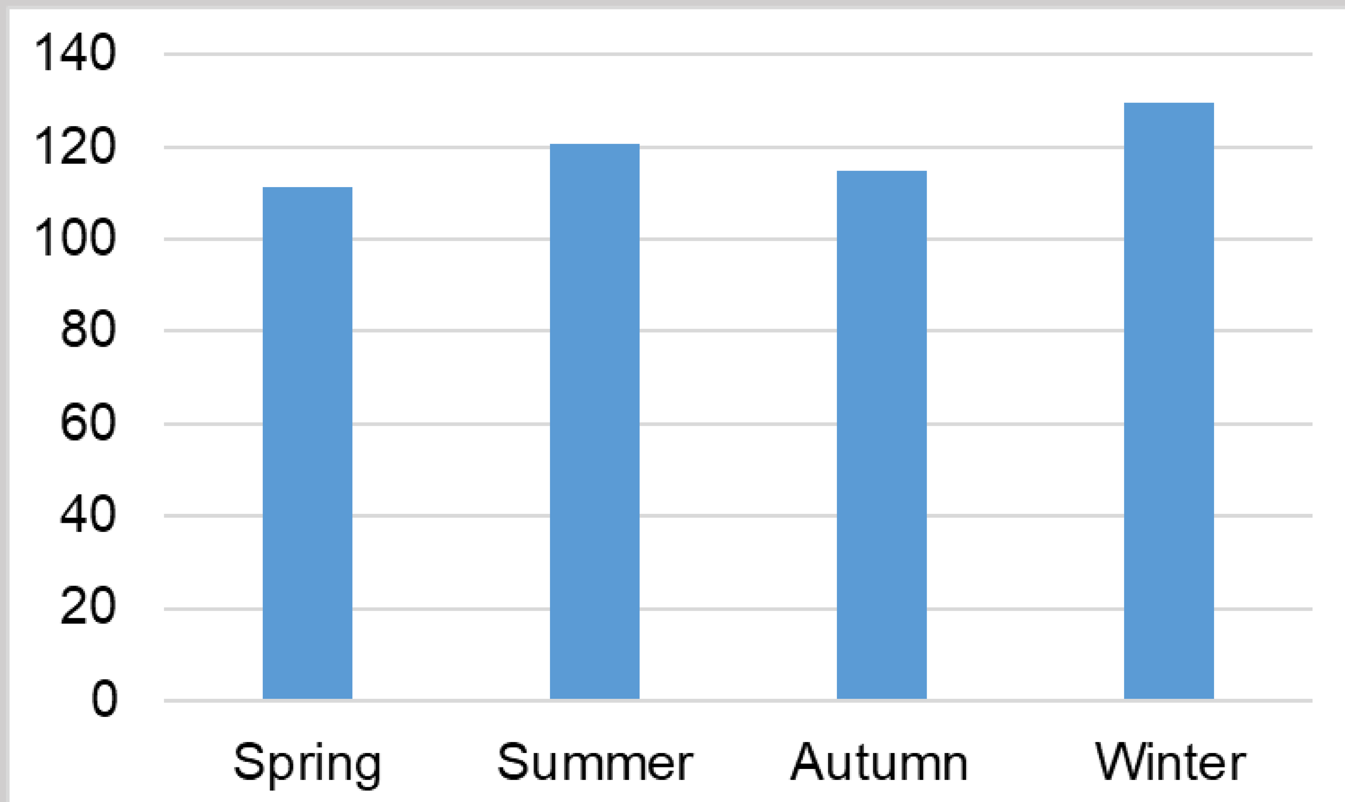


- For the year 2018, we estimate monthly NOx emissions over Wuhan of 93.9 – 139.7 mol s-1, while it is as high as ~230 mol s-1 estimated by EDGAR v6.1. Lange et al. (2022) also found a large discrepancy between EMG calculated and EDGAR estimated NOx emissions over Wuhan and other large cities.
- For 2019, the monthly NO_x emissions over Wuhan calculated by the superposition column model is 1.1% – 28.1% (13.9% on average) lower than that from the ABACAS-EI. Q. Zhang et al. (2023) reported only a less than 5% difference in NO_x emissions between the superposition column model and the ABACAS-EI. This can be explained by the low bias of the TROPOMI v2.4.0 – v2.6.0 data products or the uncertainty in the downscaling of bottom-up emission inventories.

6. Estimate NOx and CO_2 emissions directly with the super position model



- NOx emissions over Wuhan are highest in 2019.
- The emission in 2020 is 24% below the 2019 level due to the lockdown in early 2020.



- We see highest NOx emissions in winter, but the difference between winter and summer is less than 10%