Assessing HTAP NO_x Emissions in Cities in South and Southeast Asia using TROPOMI

Gongda Lu, Eloise A. Marais,
Karn Vohra, Sarath Guttikunda

GCE2

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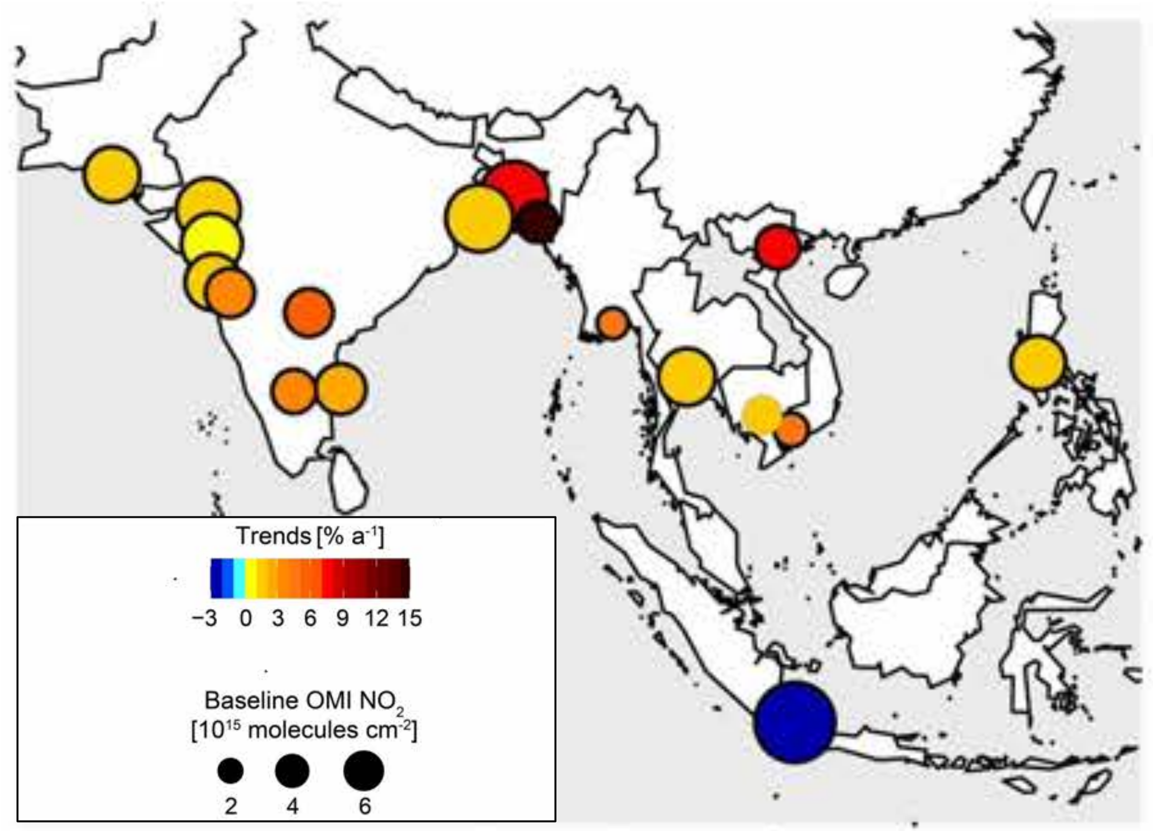
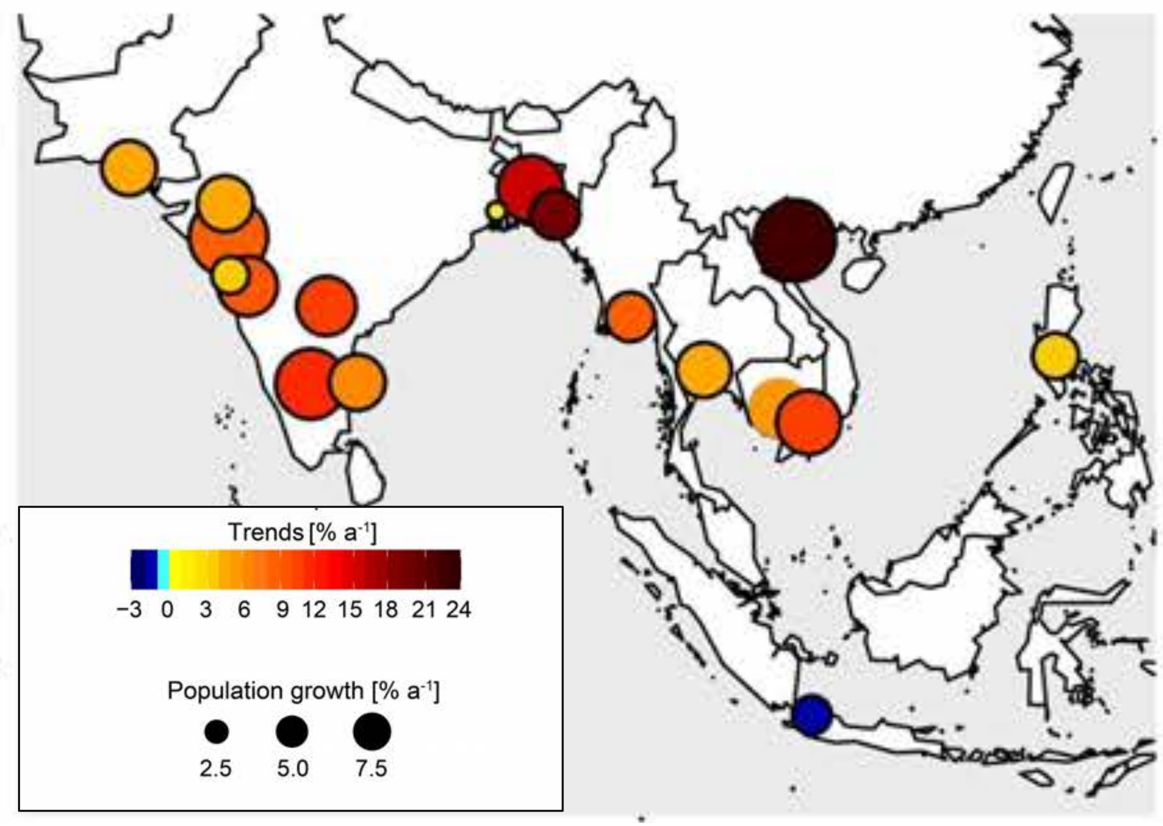
Rapid Rise in NO_2 Concentrations and Exposure in South and Southeast Asia (2005-2018)

Trends in NO_2 tropospheric columns



Trends in exposure to NO_2

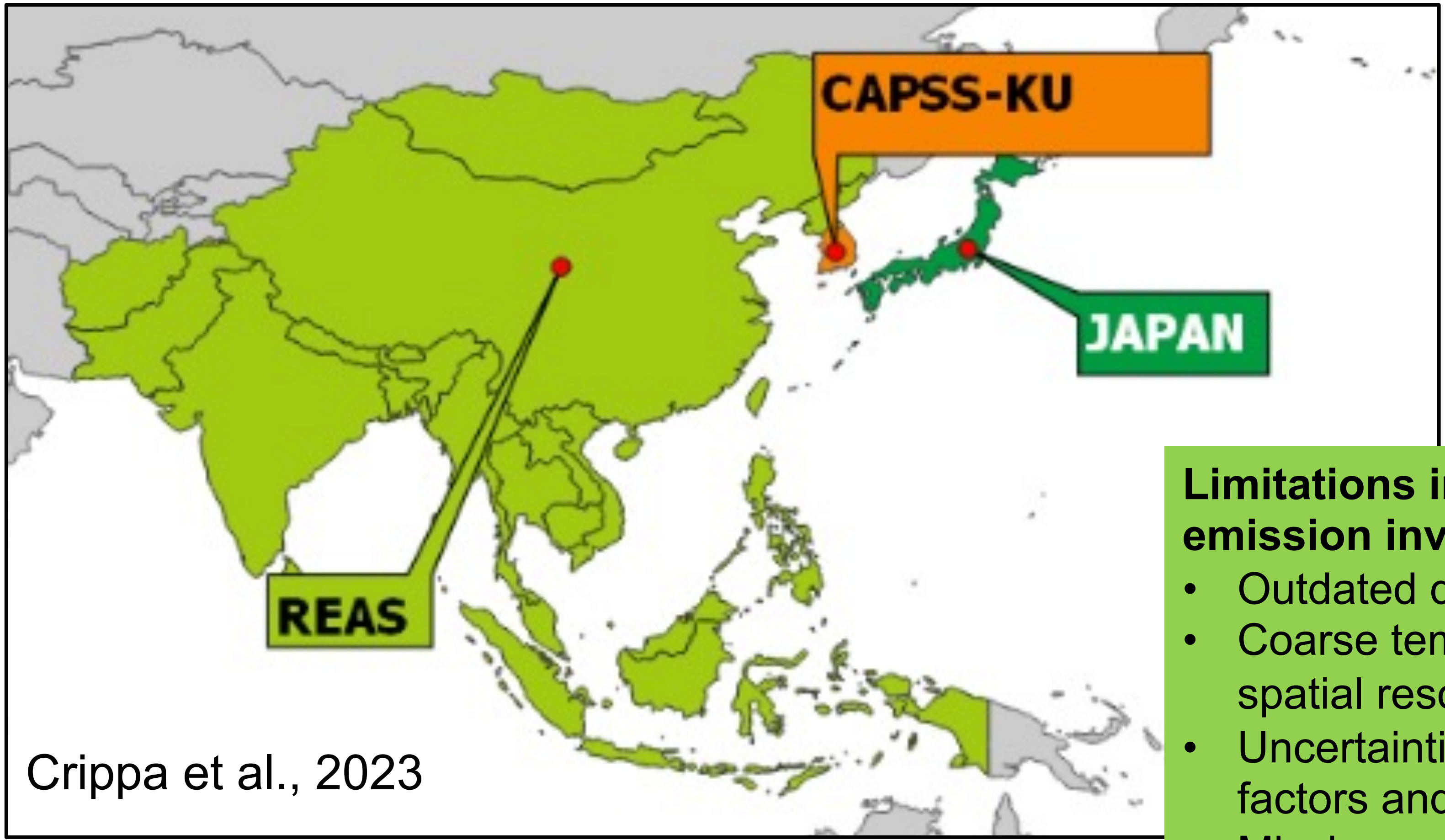


NO_2 increases by ~1-8 % a^{-1} in many large cities in South and Southeast Asia in 2005-2018.
Significant declines are only in Jakarta.

Vohra et al., 2022

Limited Knowledge of NO_x Emissions from Bottom-Up Inventories

The Regional Emission inventory in ASia (REAS) for 1950-2015 is used in the most recent global emission inventories, including Hemispheric Transport of Air Pollution (HTAP)



Crippa et al., 2023

Limitations in bottom-up emission inventories:

- Outdated data
- Coarse temporal and spatial resolutions
- Uncertainties in emission factors and activity data
- Missing sources

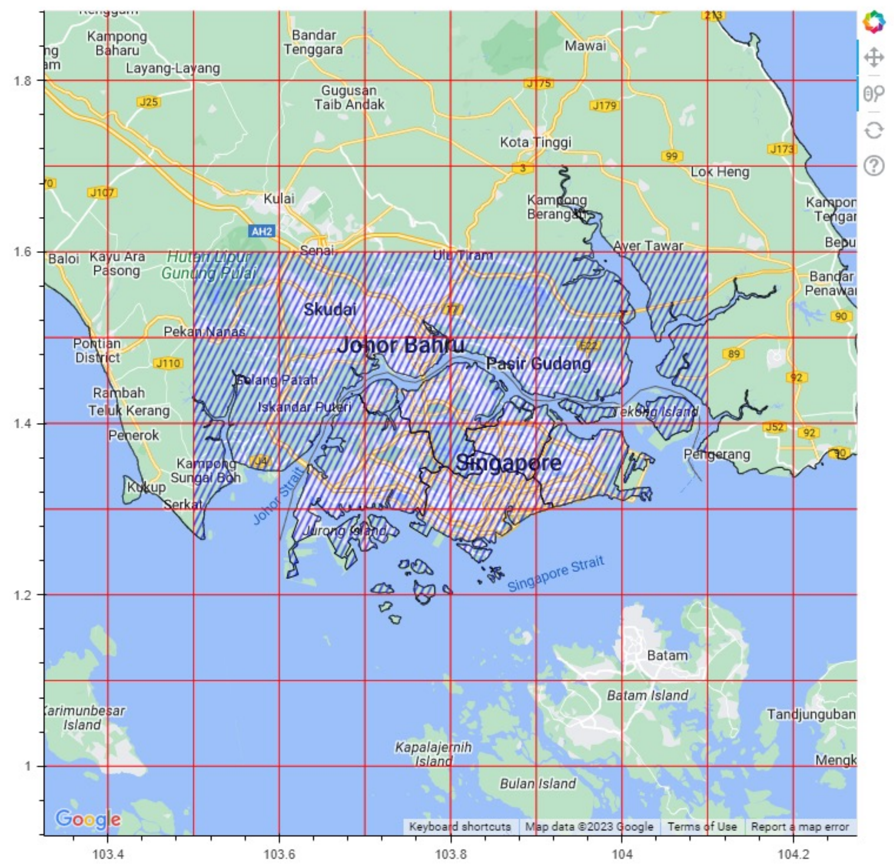
Calculating Anthropogenic NO_x Emissions from HTAP

We use the Harmonized Emissions Component (HEMCO) to determine the role of anthropogenic NO_x emissions.

Then we calculate NO_x emissions using HTAP:

HTAP: Hemispheric Transport of Air Pollution (Version 3)
Year: 2018
Temporal resolution: Monthly
Spatial resolution: 0.1° × 0.1°
Sampling domain: Urban areas for each city

Example: Sampling HTAP over Singapore

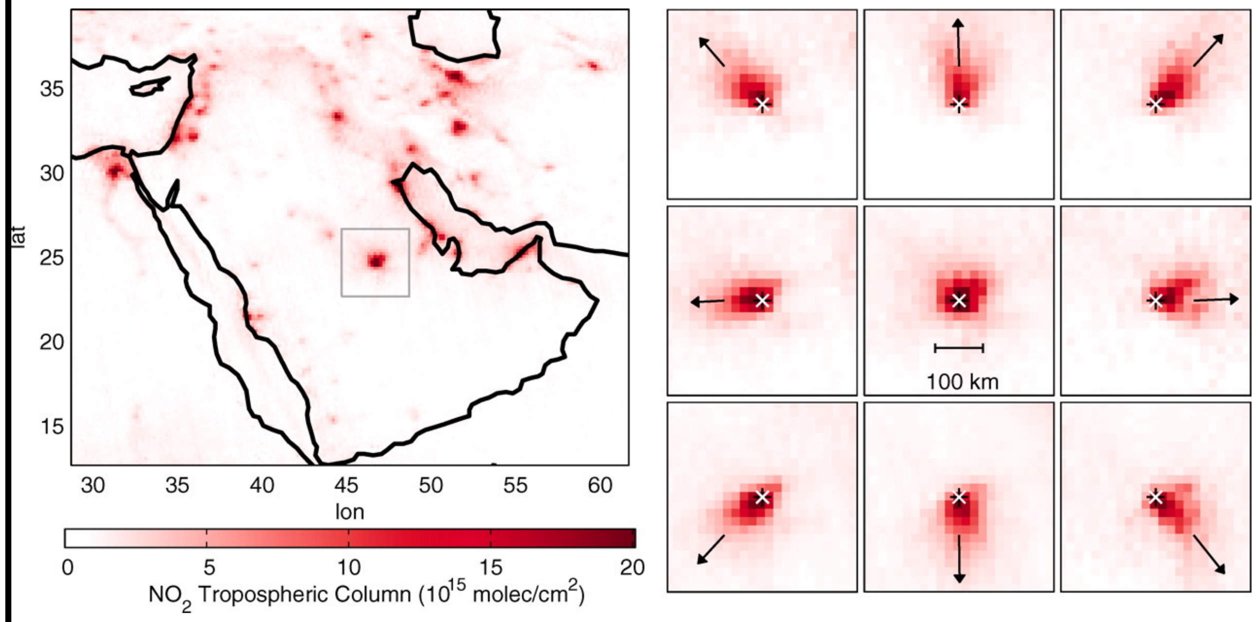


HTAP Grids

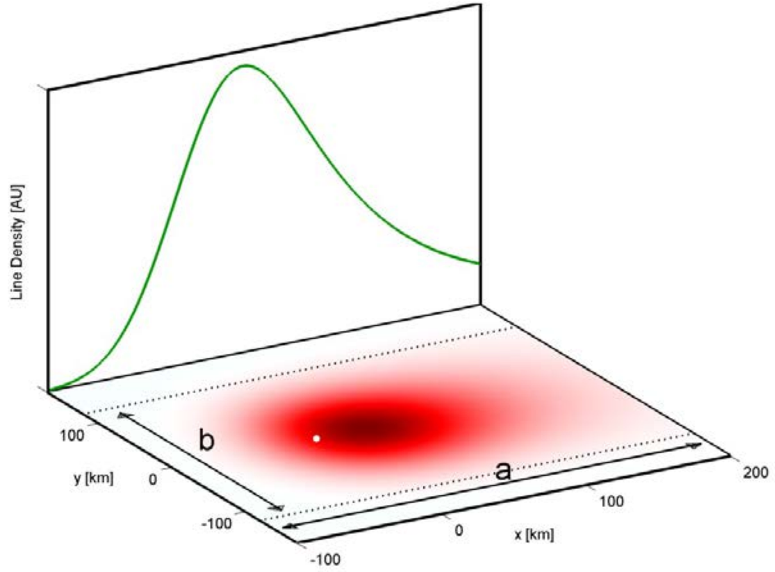
Urban Areas

Top-down Estimates of NO_x Emissions From Isolated Cities

Step 1: Mapping observed satellite NO_2



Step 2: Converting 2D NO_2 maps to 1D NO_2 line densities

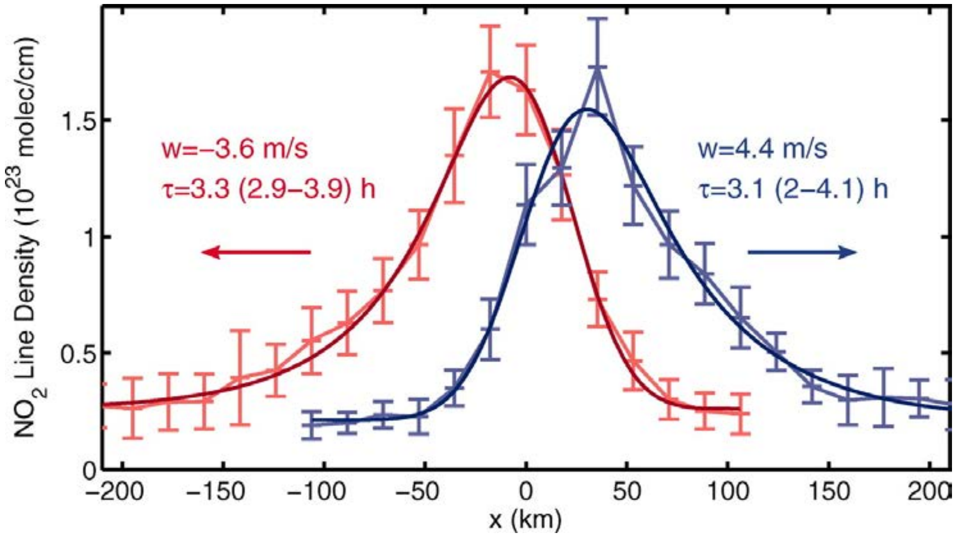


Step 3: Exponentially Modified Gaussian (EMG) fitting

$$F(x|a, x_0, \mu_x, \sigma_x, B) = \frac{a}{2x_0}\exp\left(\frac{\mu_x}{x_0} + \frac{\sigma_x^2}{2x_0^2} - \frac{x}{x_0}\right)\operatorname{erfc}\left(-\frac{1}{\sqrt{2}}\left[\frac{x-\mu_x}{\sigma_x} - \frac{\sigma_x}{x_0}\right]\right) + B$$

$$\tau_{NO2} = \frac{x_0}{\omega}$$

$$E_{NOx} = \gamma \times \frac{a}{\tau_{NO2}}$$



Beirle et al., 2011; Laughner and Cohen (2019)

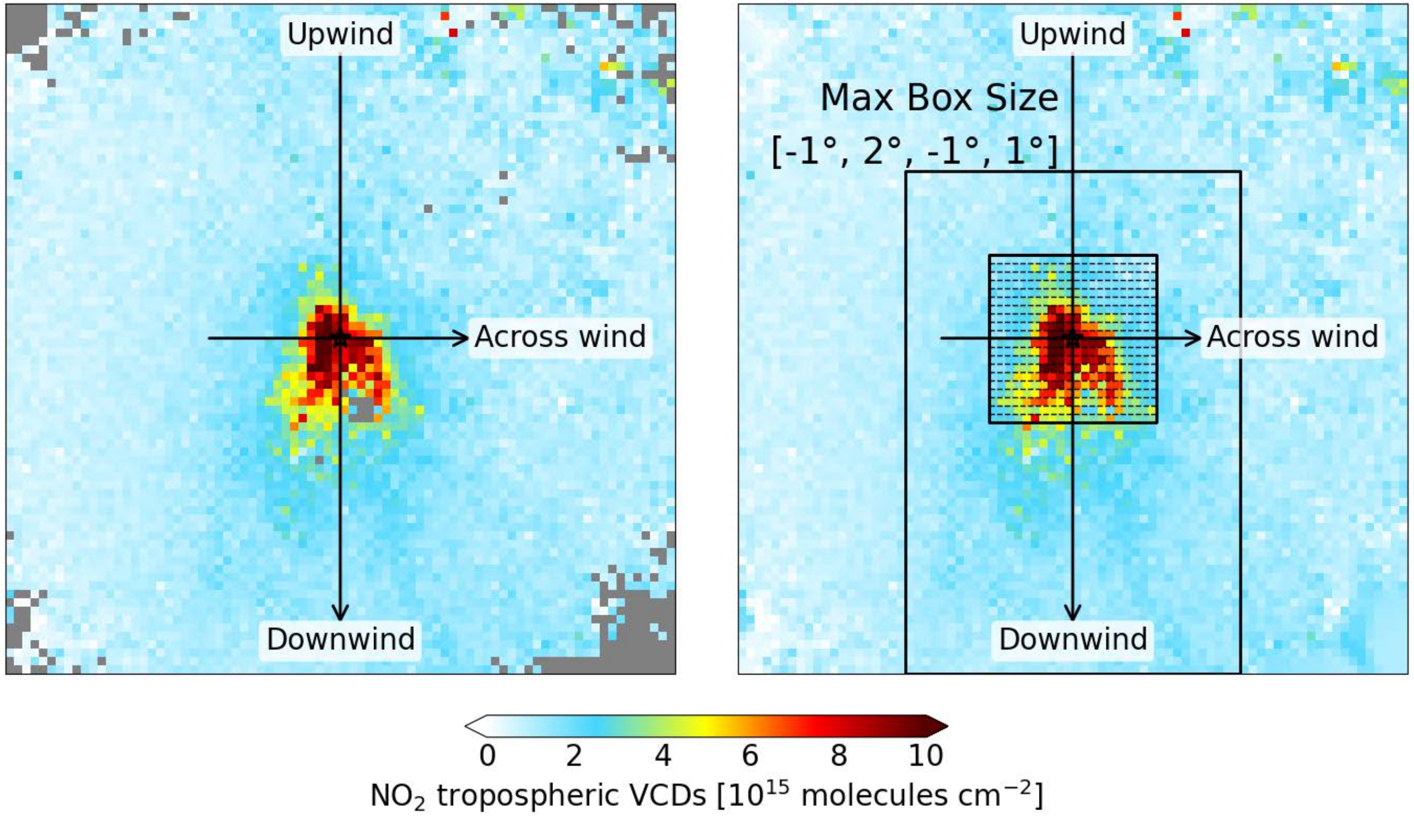
Automated Estimate of NO_x Emissions From Isolated Cities

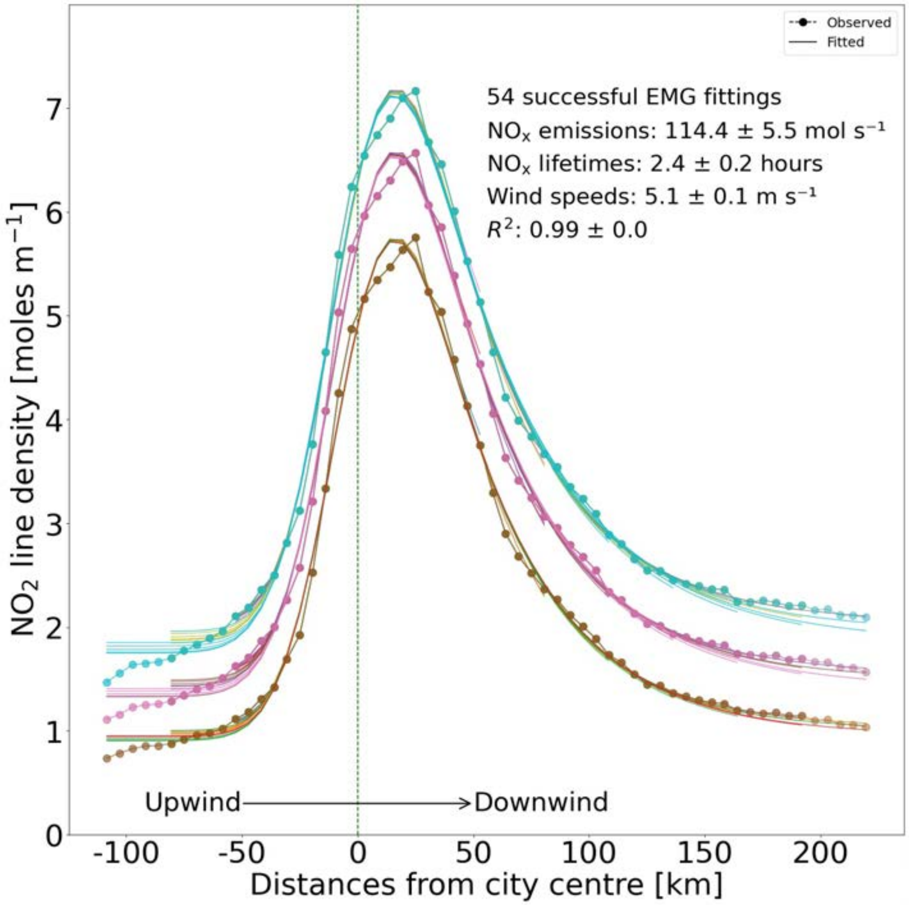
Example: Singapore (May 2019)

(1) Wind-rotate and grid TROPOMI NO_2 at 0.05° × 0.05°

(2) Fill gaps and set EMG areas

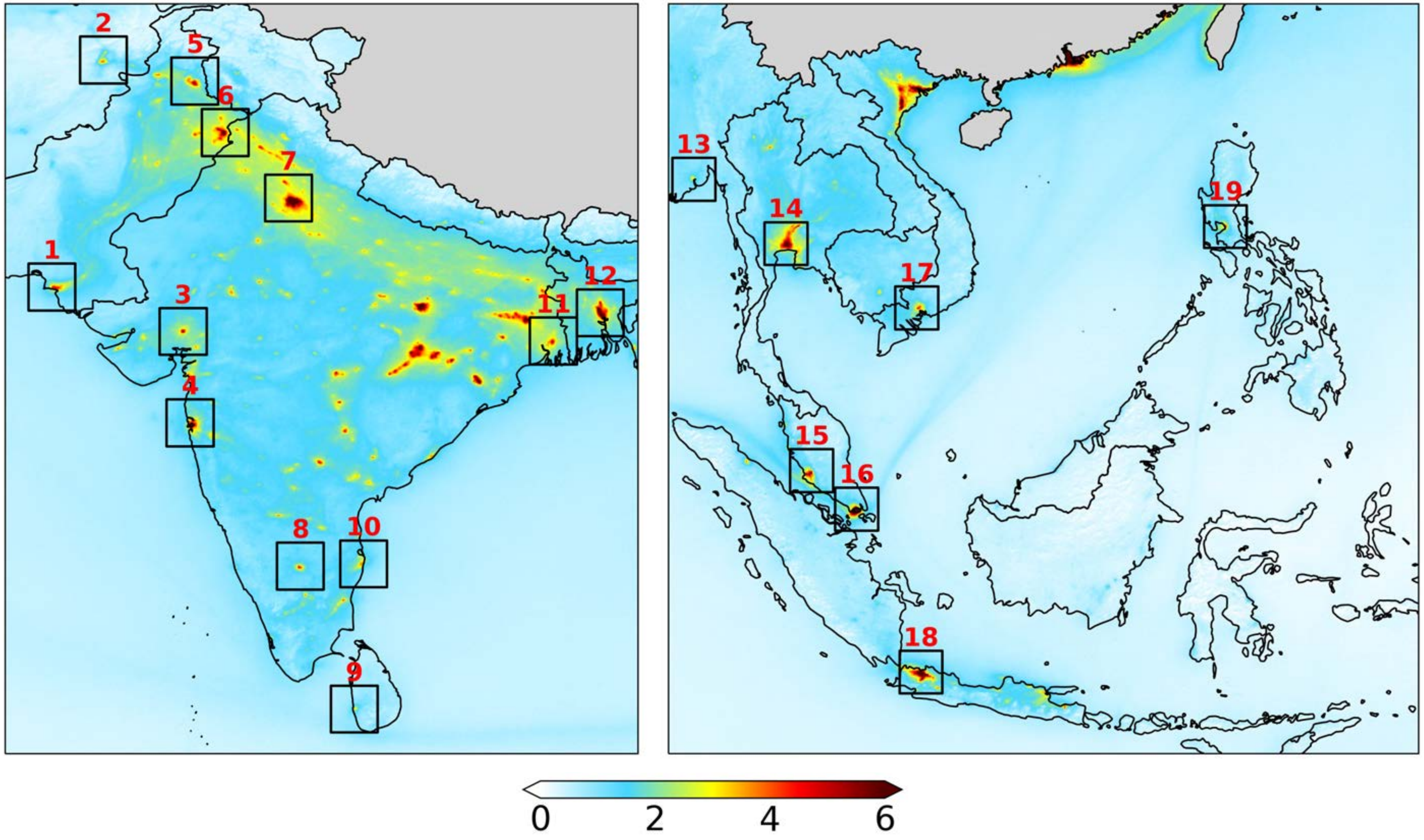
(3) Derive line densities and emissions





The wind rotation technique is from Valin et al., 2013

Isolated NO_2 Hotspots Cities in South and Southeast Asia in 2019

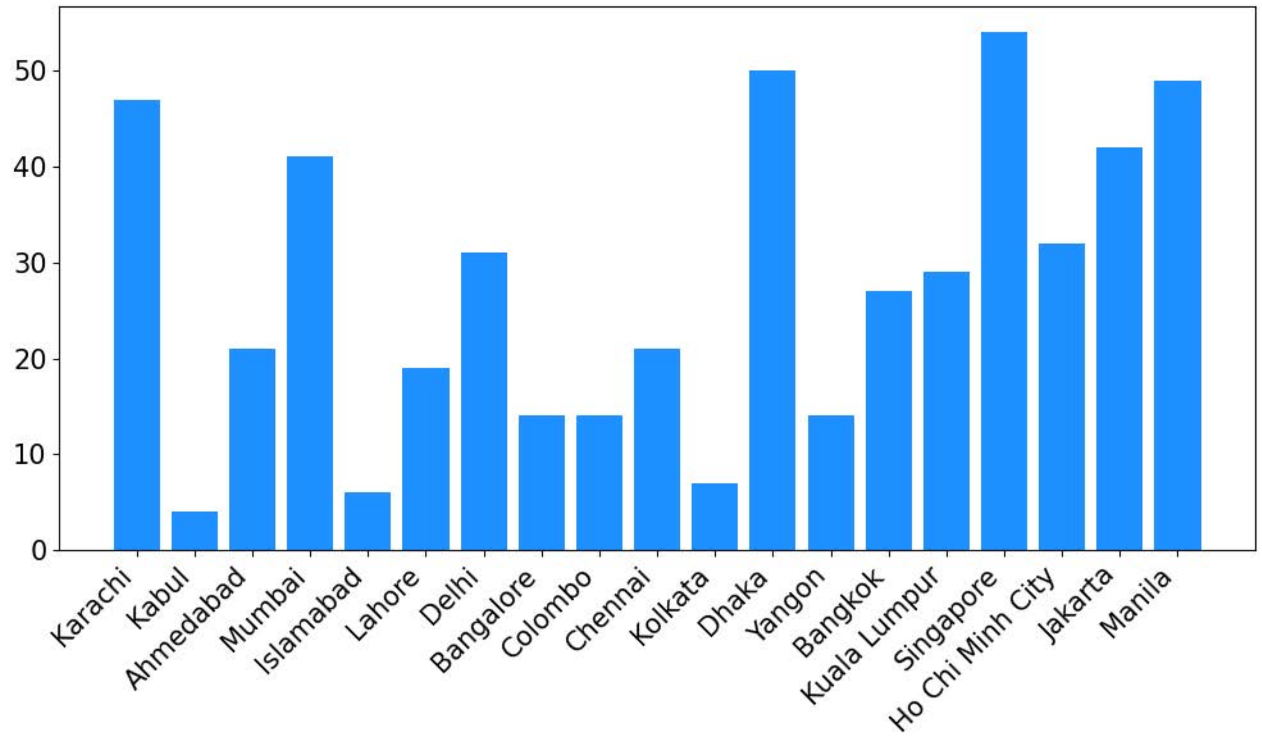


1. Karachi
2. Kabul
3. Ahmedabad
4. Mumbai
5. Islamabad
6. Lahore
7. Delhi
8. Bangalore
9. Colombo
10. Chennai
11. Kolkata
12. Dhaka
13. Yangon
14. Bangkok
15. Kuala Lumpur
16. Singapore
17. Ho Chi Minh City
18. Jakarta
19. Manila

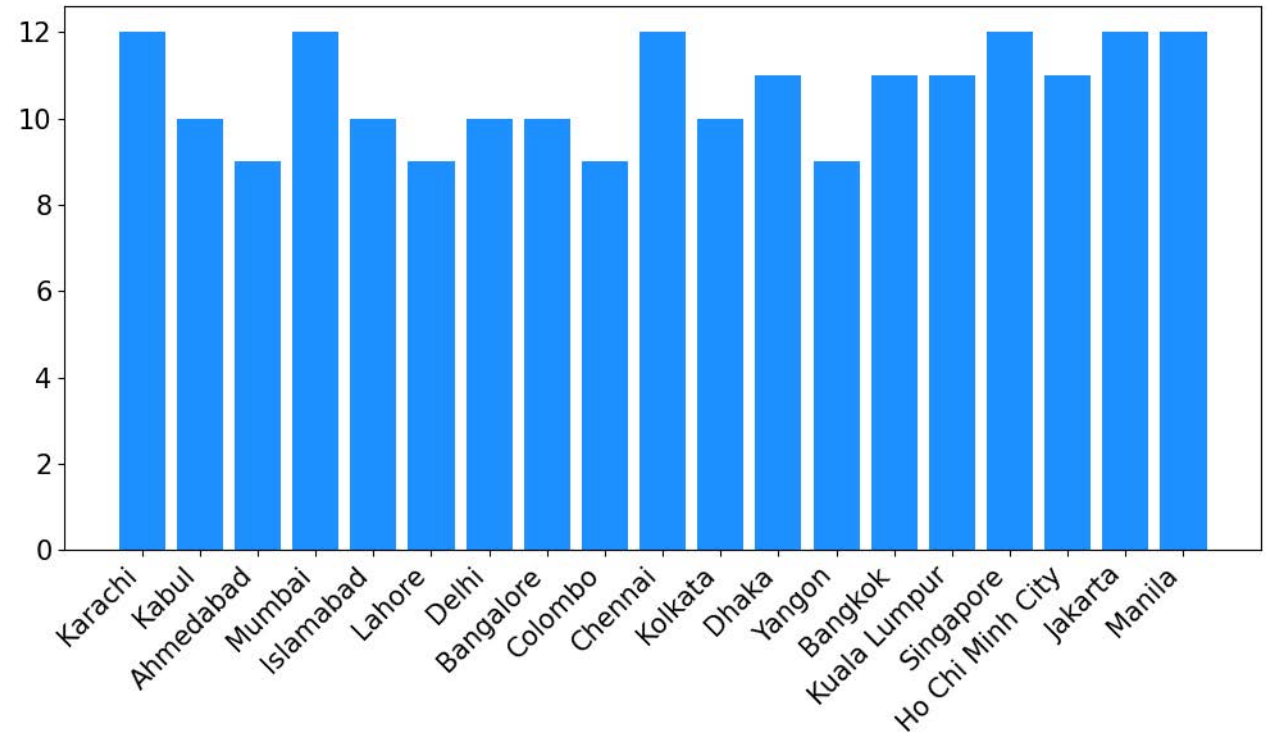
Annual oversampled TROPOMI NO_2 tropospheric vertical column densities in 2019 [1×10^{15} molecules cm^{-2}]

Our Method Improves the Utility of EMG Fittings For Top-down Estimates of NO_x From Isolated Cities

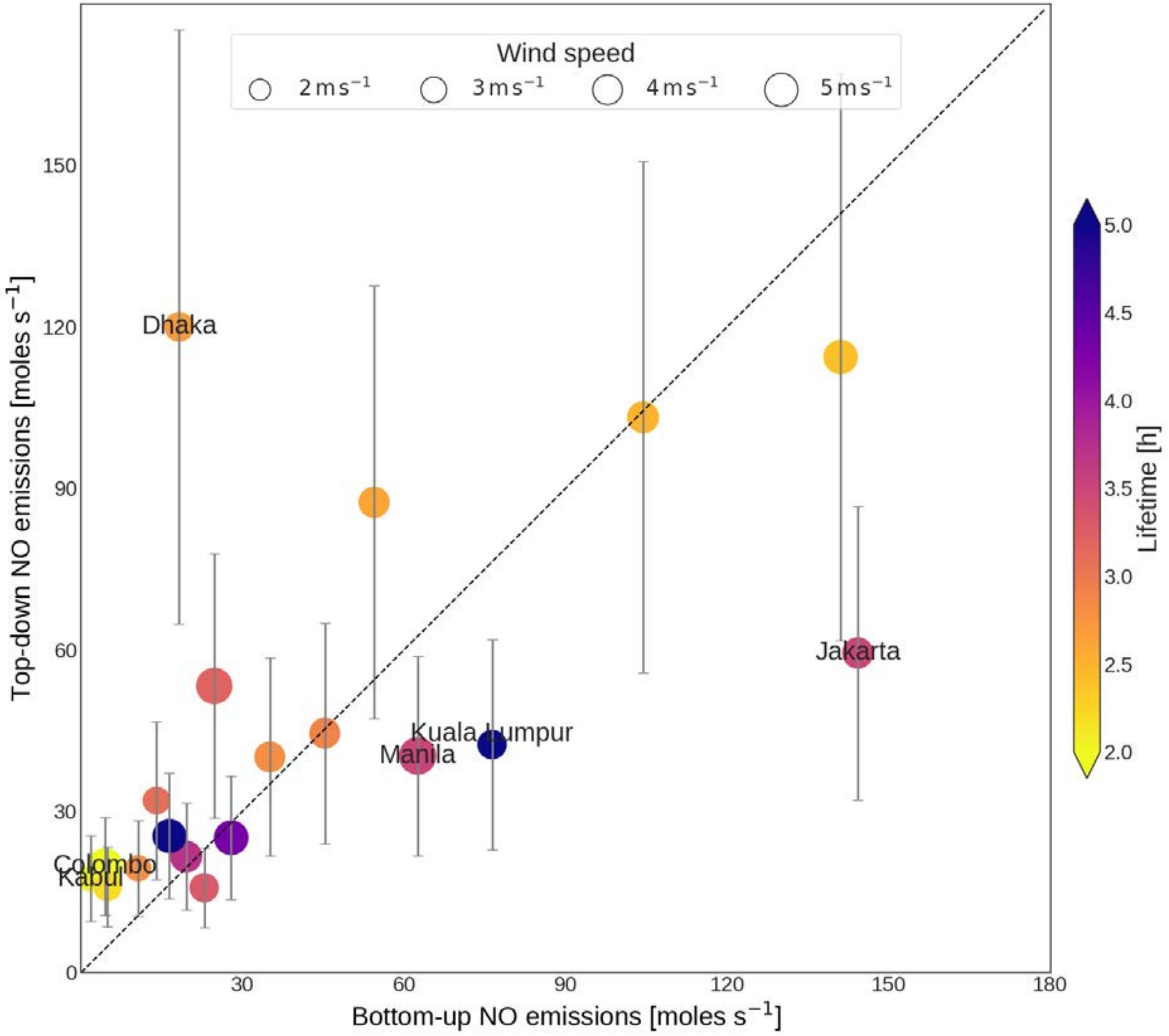
Number of successful EMG fittings for annual data for each city



Number of months when top-down estimates are available



Top-Down vs Bottom-Up Annual Emissions

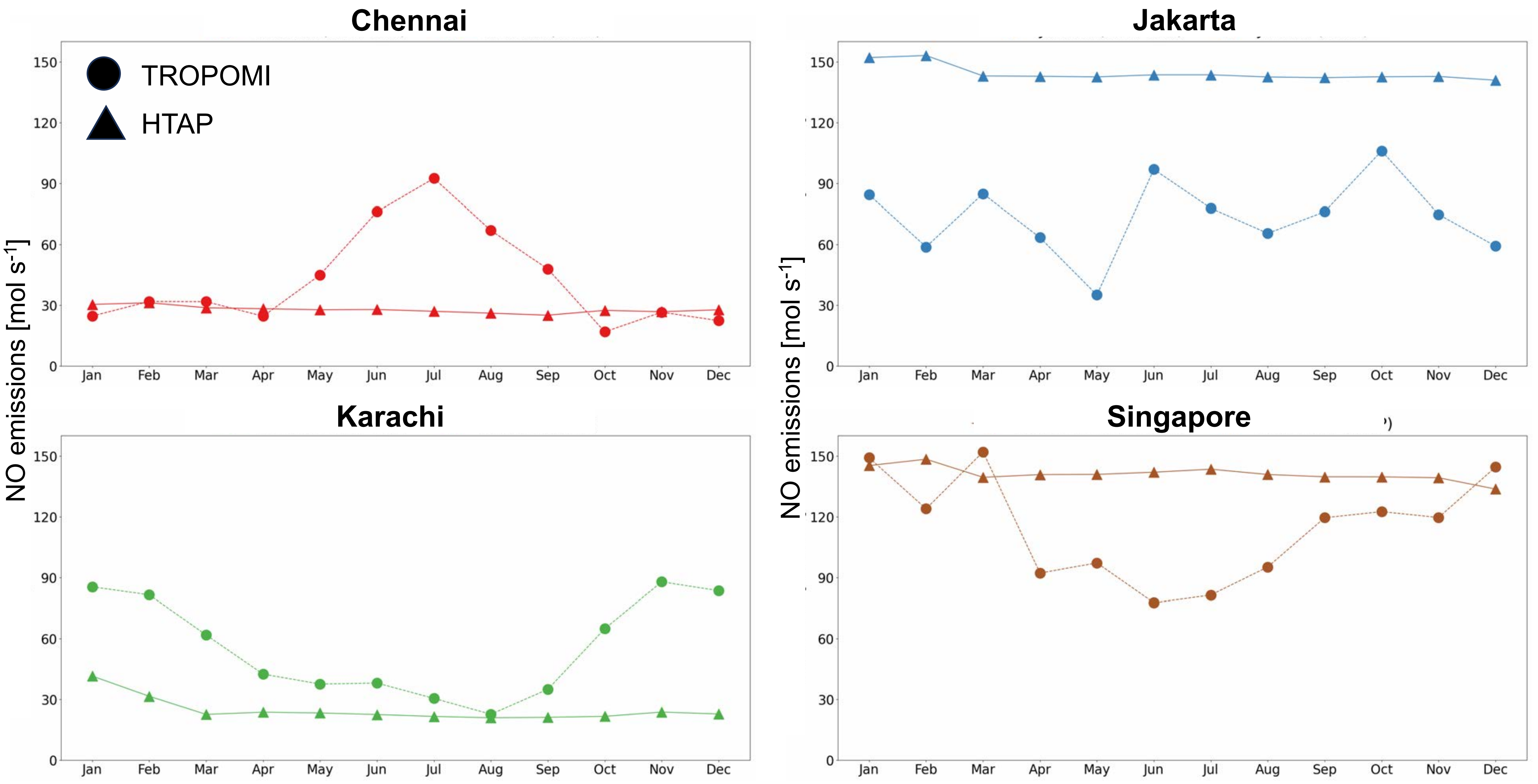


Relative differences between top-down and bottom-up estimates:

Kabul (Afghanistan) +878%, Dhaka (Bangladesh) +558%, Colombo (Sri Lanka) +344%

Jakarta (Indonesia) -59%, Kuala Lumpur (Malaysia) -44%, Manila (the Philippines) -36%

Unveiled Seasonality: Top-Down vs Bottom-Up Monthly Emissions



Conclusions

Annual top-down NO_x emissions are 1%-59% less than or 11-878% more than HTAP estimates.

Large discrepancies (> 100%) exist between monthly TROPOMI-based estimates and HTAP for some months.

Top-down estimates show month-to-month variabilities that are missing in HTAP.

We are developing a Python tool for automating top-down estimates of NO_x emissions from isolated point sources, such as cities.