Evaluating the trends and spatial patterns of NOx emissions in urban areas using TROPOMI

By: Dan Goldberg, PhD
PI: Dr. Susan Anenberg
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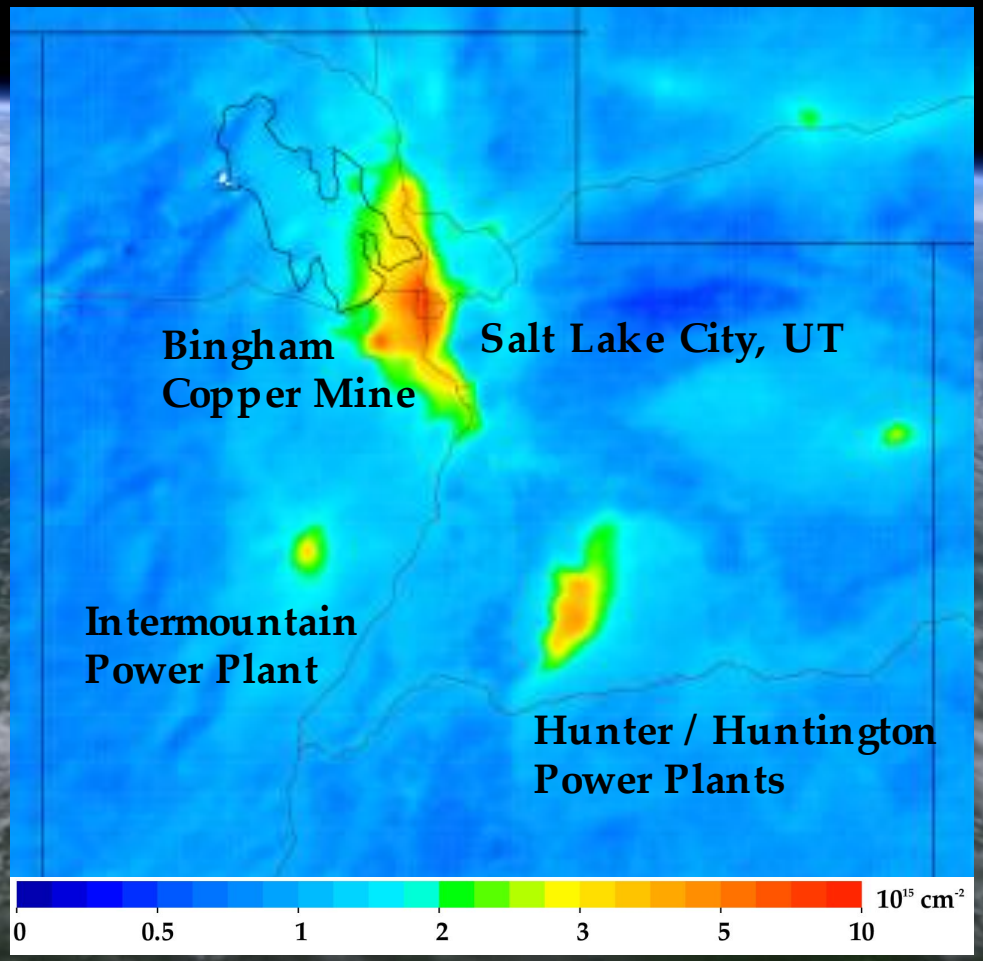
Thursday October 19, 2023



ESA: TROPOMI on the Sentinel 5 Precursor Satellite

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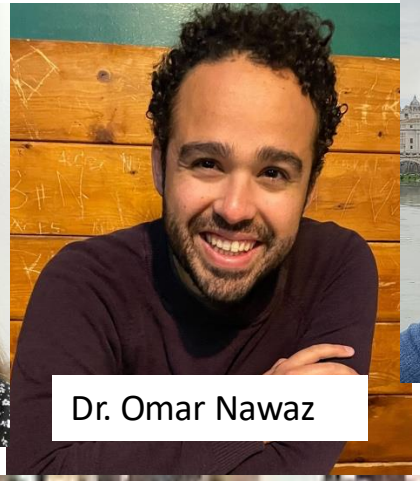
Emily Richardt


Dr. Omar Nawaz


Dr. Laura Judd

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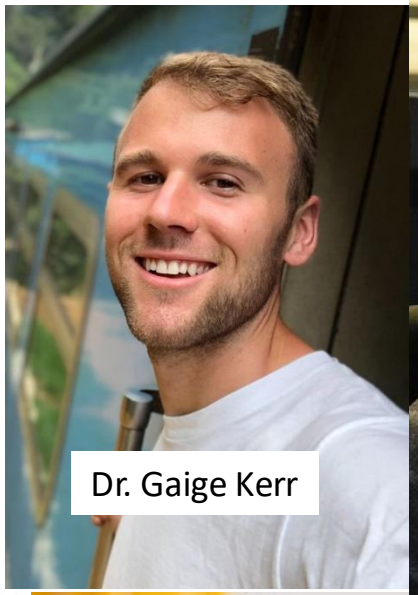
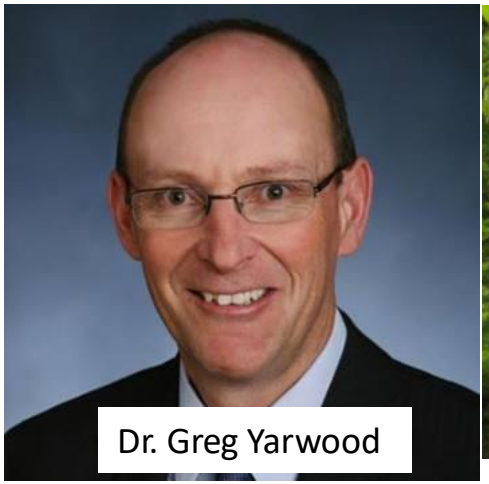
Sara Runkel

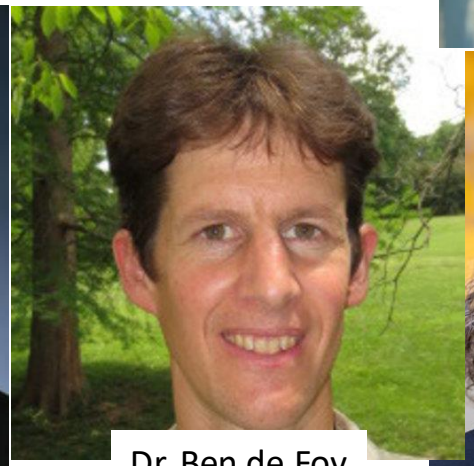

Madankui Tao

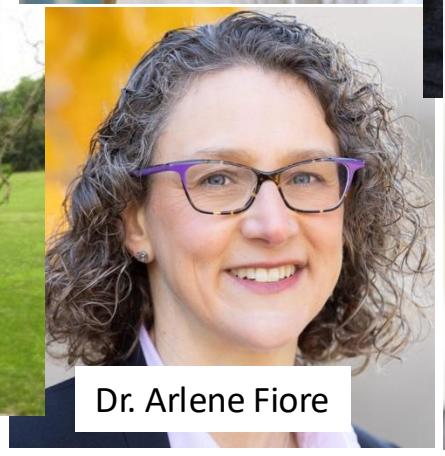

Dr. Gaige Kerr

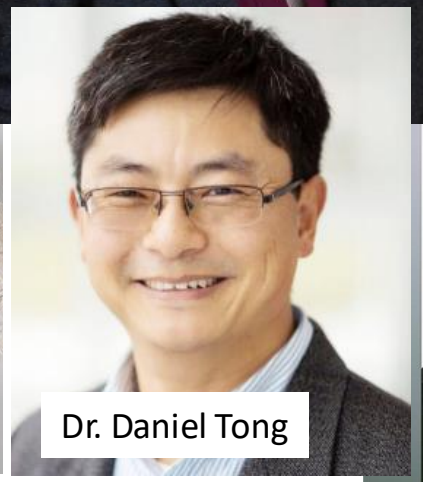

Dr. Susan Anenberg


Dr. Tracey Holloway


Dr. Greg Yarwood


Dr. Ben de Foy


Dr. Arlene Fiore


Dr. Daniel Tong


Nigel Martis


Perrin Krisko

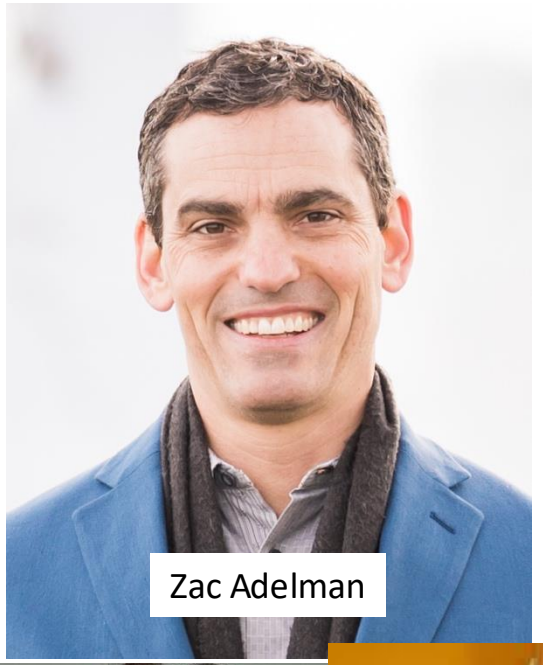

Angie Dickens

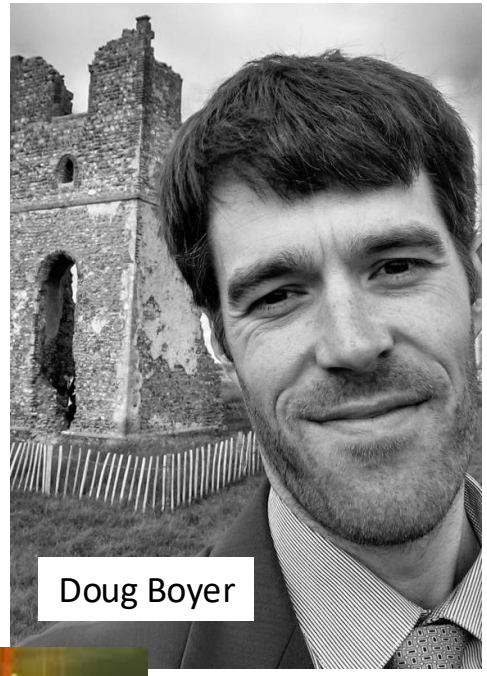

Joel Dreessen


Byeong-Uk Kim

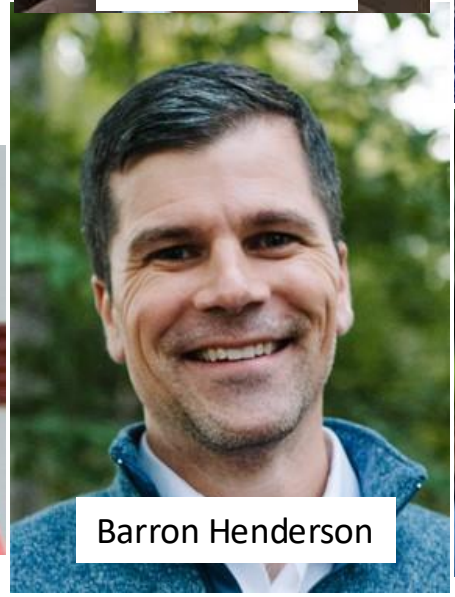

Raed Mansour


Michael Geigert


Zac Adelman


Doug Boyer


Mary Uhl


Barron Henderson


Alex Karambelas


Paul Miller


Masha Pitiranggon


Jay Baker

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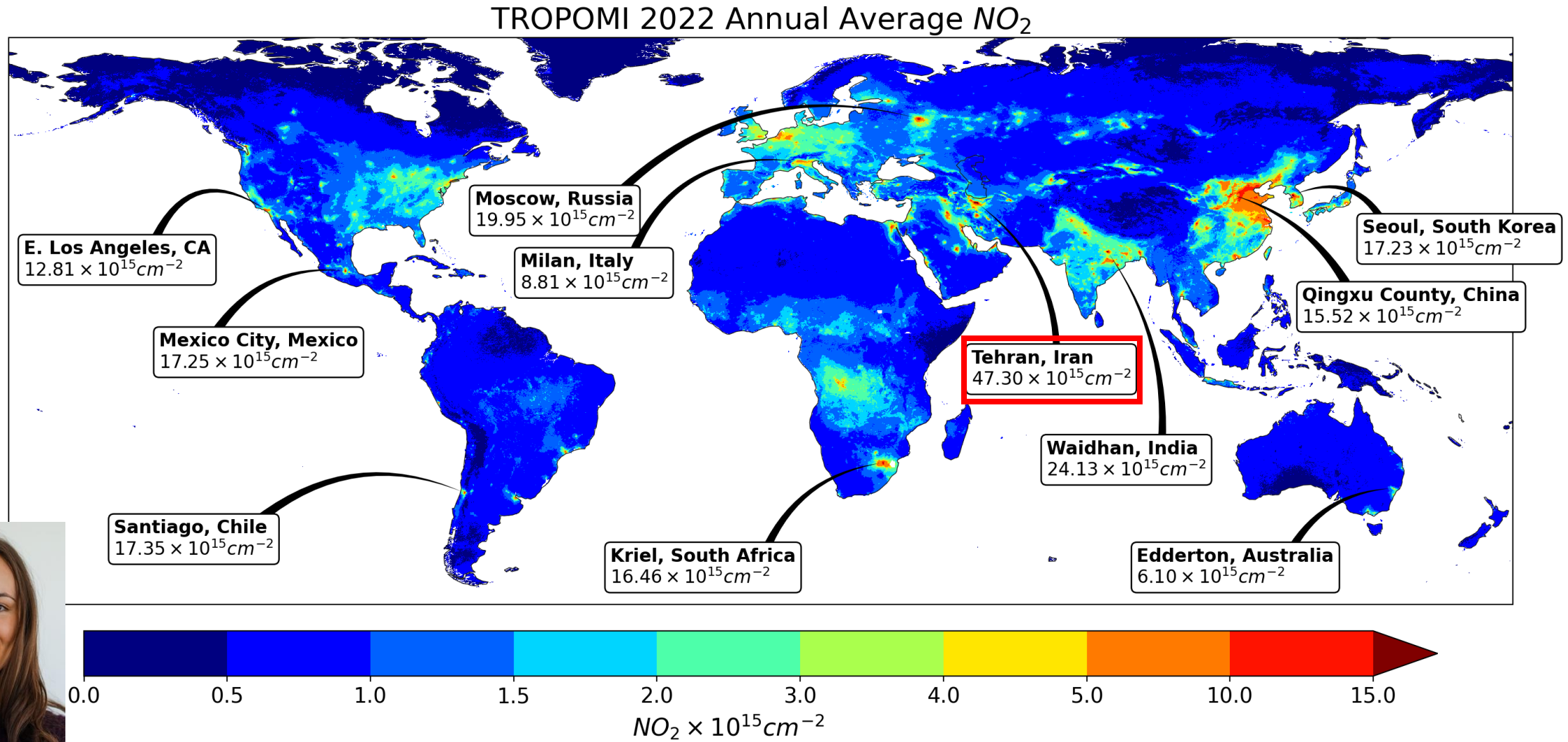
A picture of my family for the HAQAST family

Recent trends in NO_2 pollution (2022)

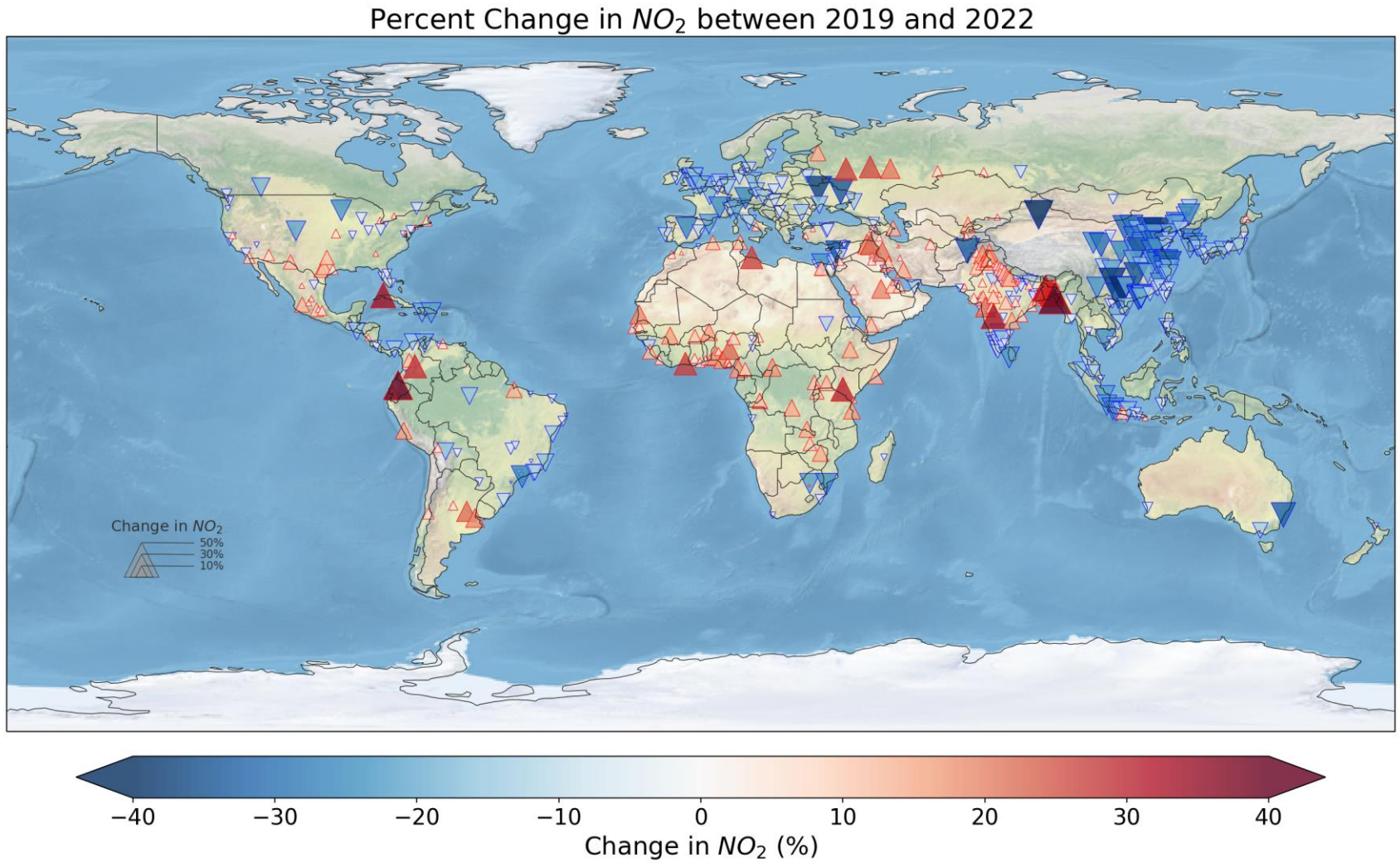
Where is the worst* NO_2 pollution the world?

*In 2022, as seen by satellite, averaged annually to a 10 km grid box



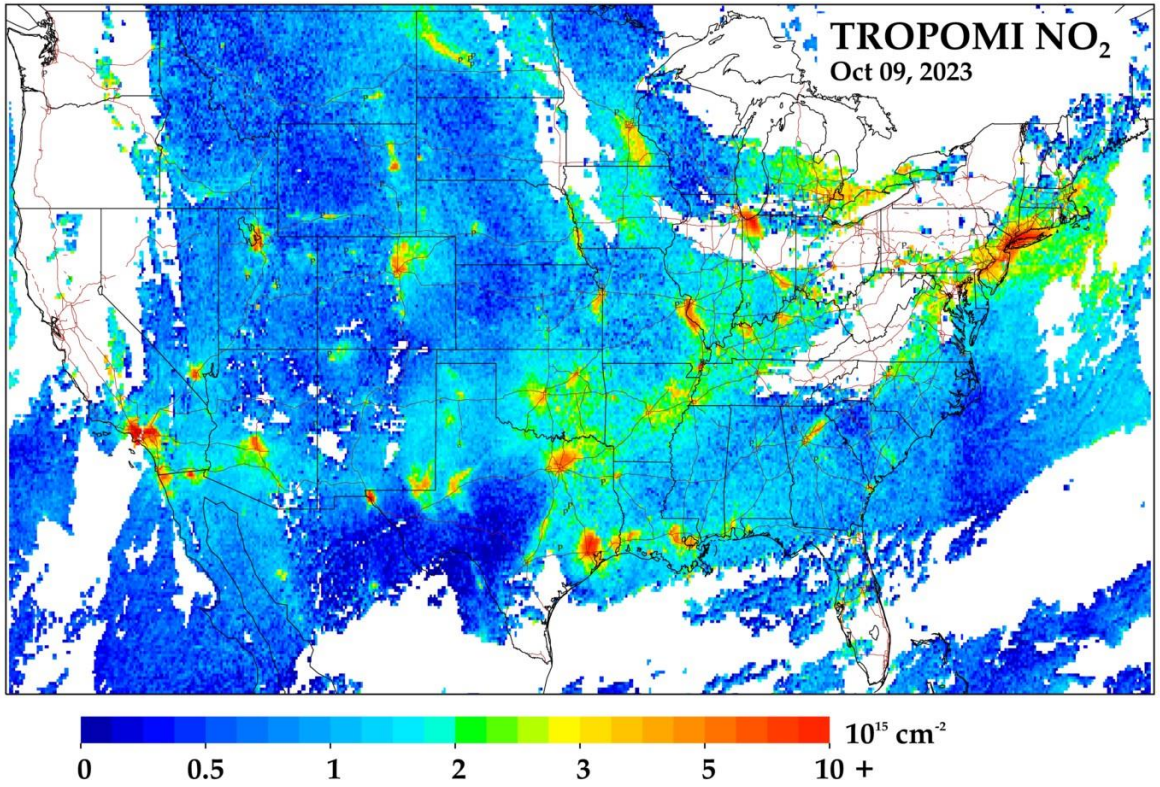
Recent trends in NO_2 pollution (2019 vs. 2022)

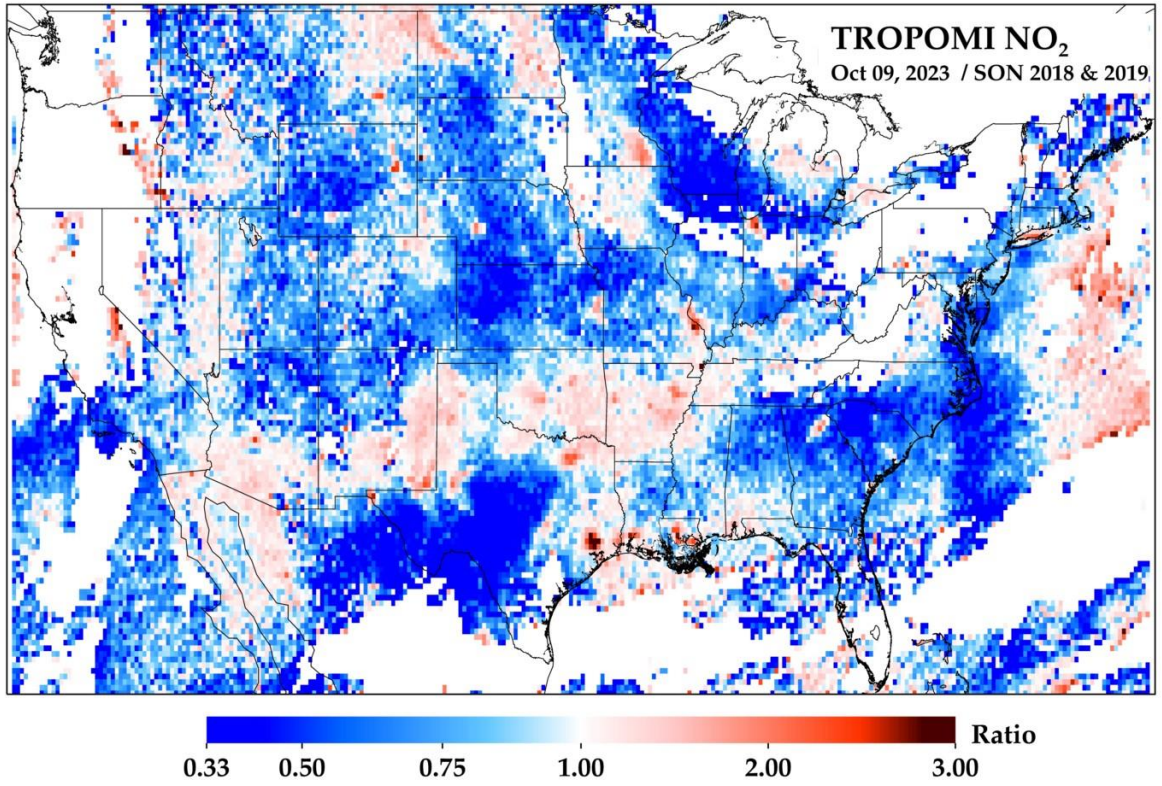
Large NO_2 reduction in China, NO_2 reductions in Europe, NO_2 increases in tropics, mixed but mostly down in the U.S.



Recent NO_2 pollution

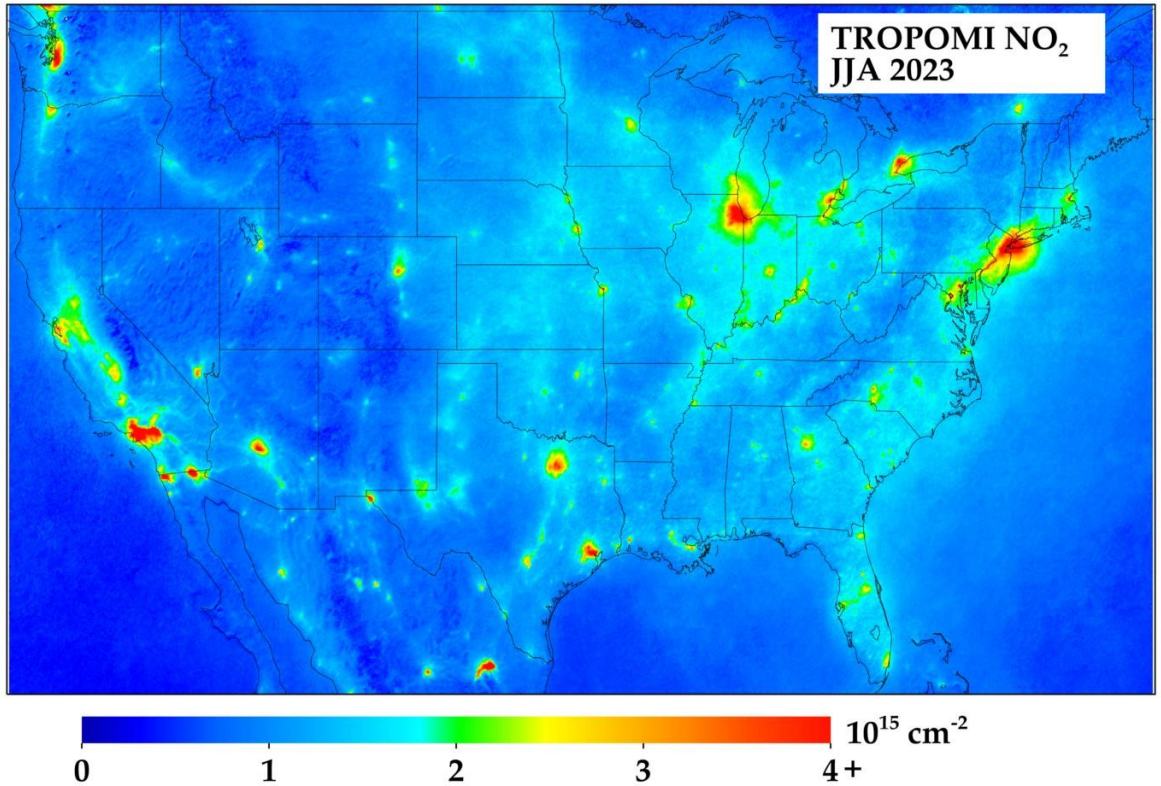
tropomino2.us

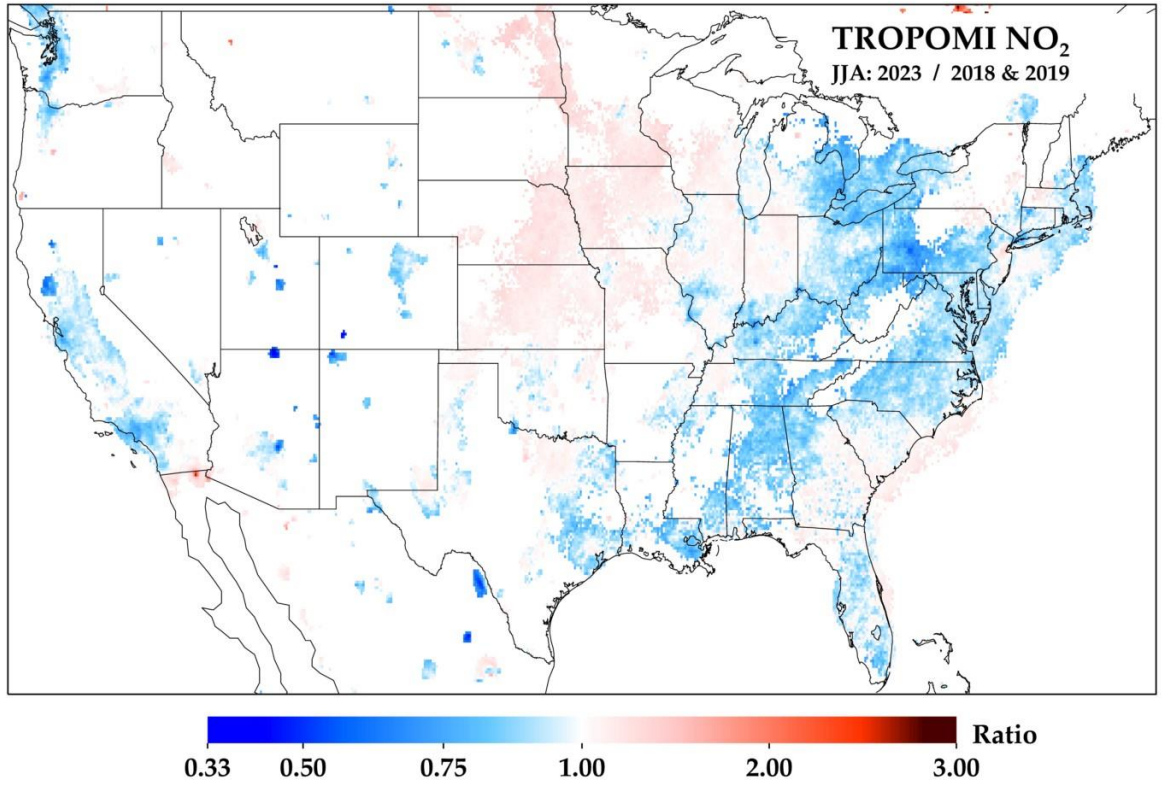




Recent summer trends in NO_2 pollution

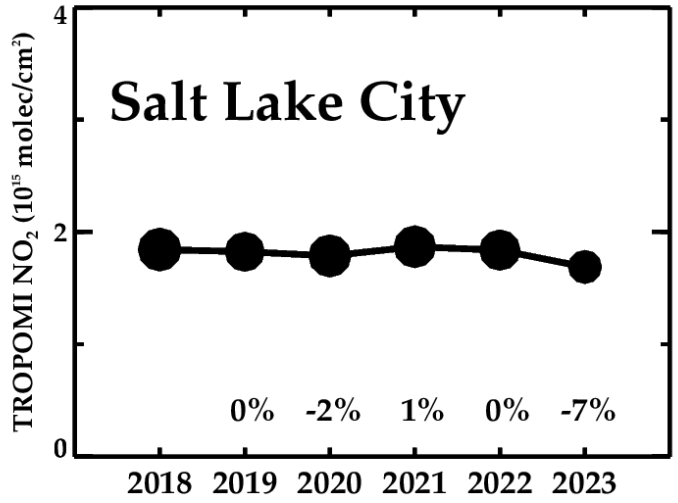
tropomino2.us

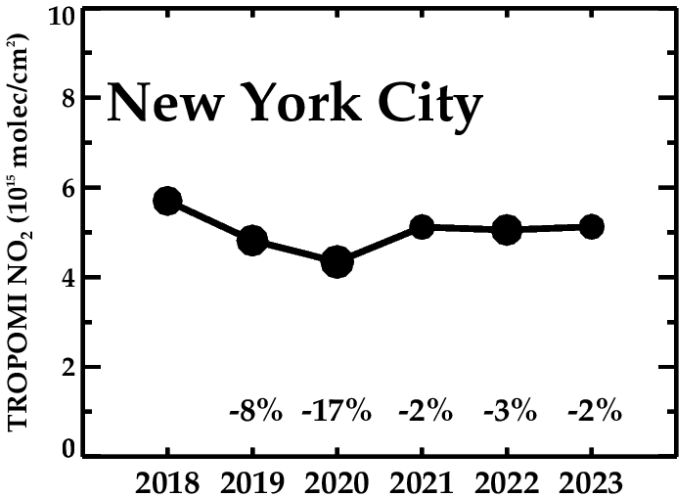


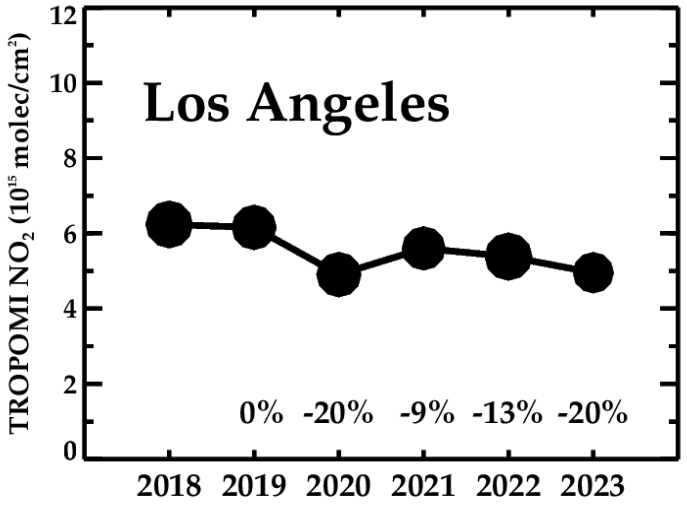


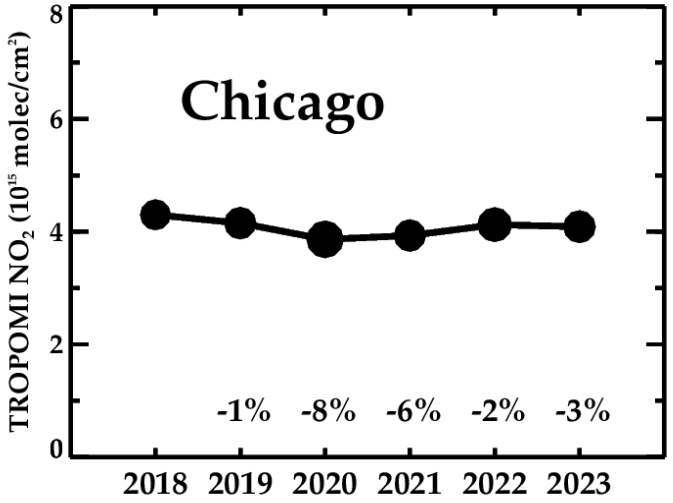
- Broad NO_2 reductions in the Eastern US (driven by coal PP retirements?)
- Largest urban NO_2 reductions in California, less so in other urban areas
- Unclear the causes of NO_2 increases in the central US

Recent summer trends in NO_2 pollution







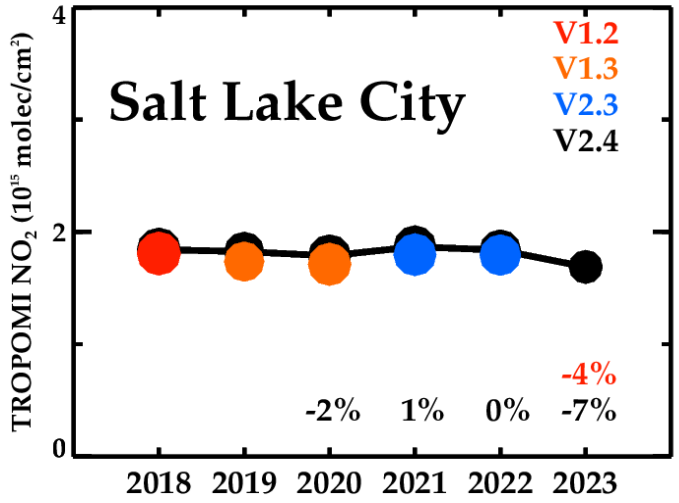


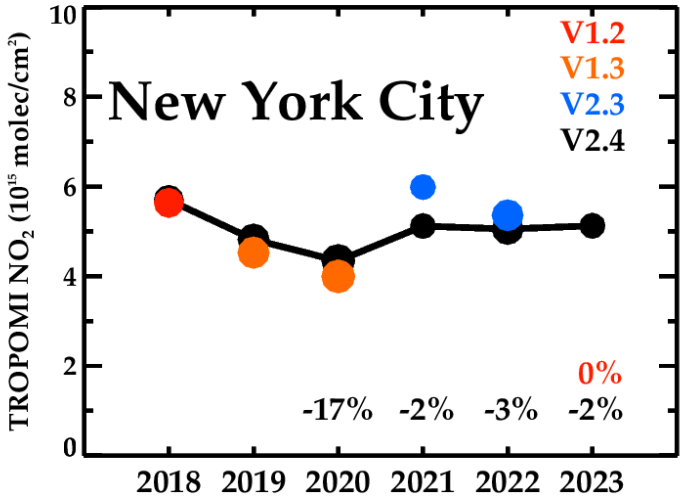
- Most U.S. cities saw a NO_2 recovery after 2020, but not a super-recovery
- Largest NO_2 decrease by percentage and by absolute magnitude has been in Los Angeles
- Too early to tell if urban NO_2 changes are in line with the U.S. EPA National Emissions Inventory (NEI)

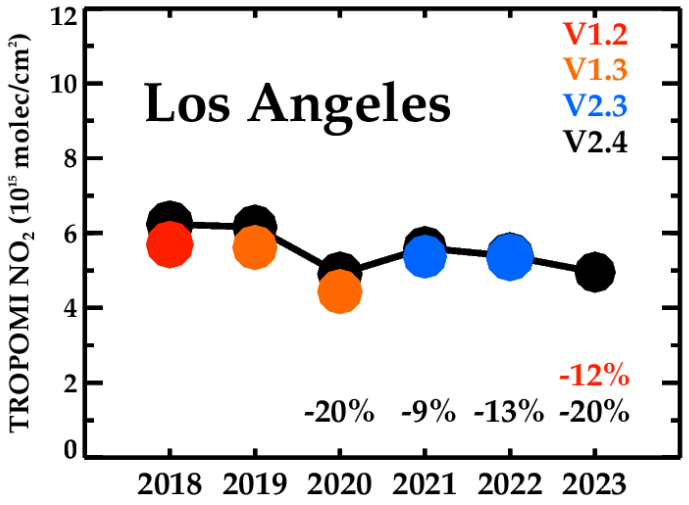
2023 NEI Data and Documentation

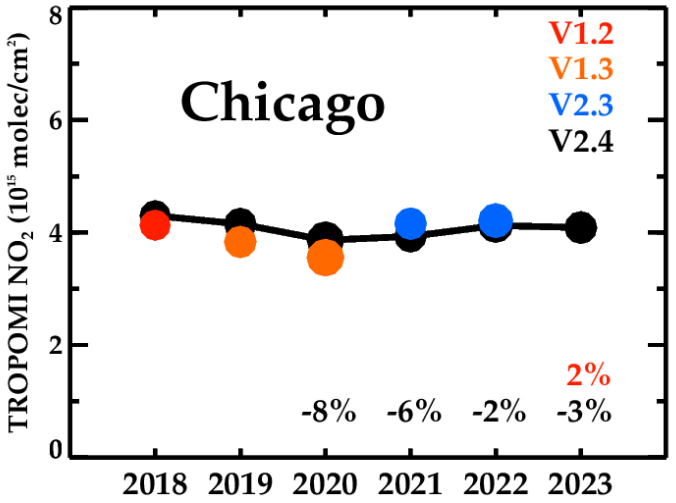
The 2023 NEI inventory year is in progress and will not be published until March of 2026.

Recent summer trends in NO_2 pollution









- If using the “near-real-time” or “offline” products from ESA (RSIG, Google Earth Engine, etc.) your NO_2 trends will be underestimated!
- Version 1.2 & 1.3 algorithms have smaller NO_2 values than the Version 2 algorithms
- Version 2.4 is mixed compared to Version 2.3 (much lower in E US, a bit higher in W US)

Motivation of recent work

Improved spatial resolution of TROPOMI now allows us to assemble information at the local scale (~1 km).

Questions:

- Can we use TROPOMI data to differentiate NO_X emissions from highways, ports, airports, and large points sources within a metropolitan area?

- Can we use TROPOMI data to diagnose environmental justice issues within urban areas (e.g., NO_2 in poorer neighborhoods) without the use of an additional model?

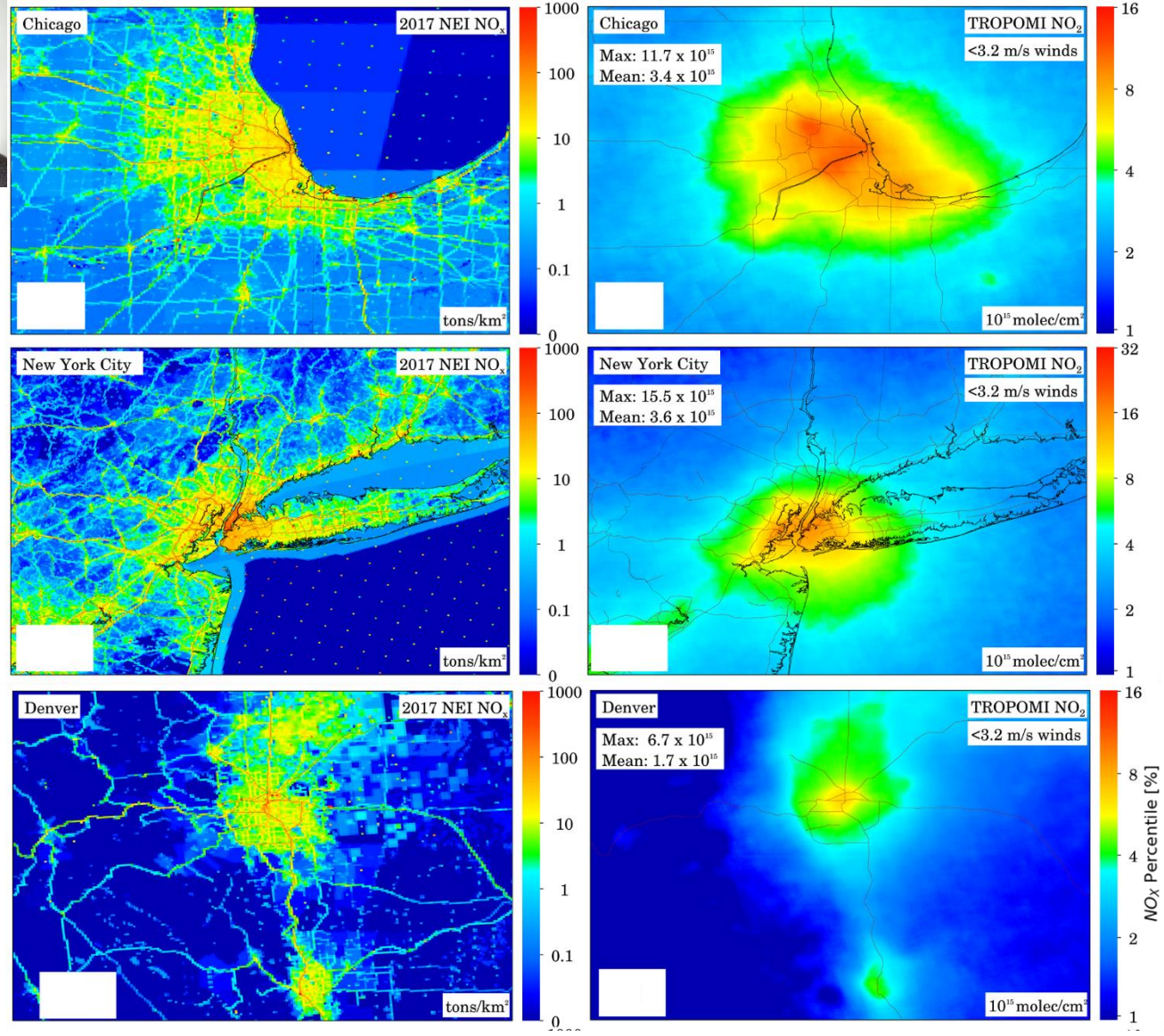
Inventory NO_x vs. Urban NO_2

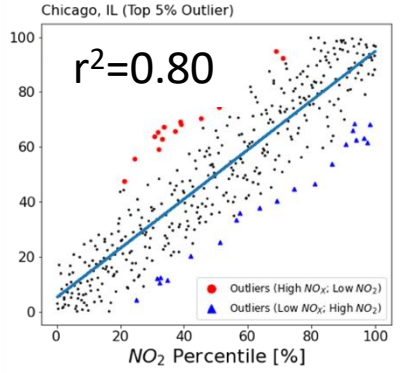
Inventory

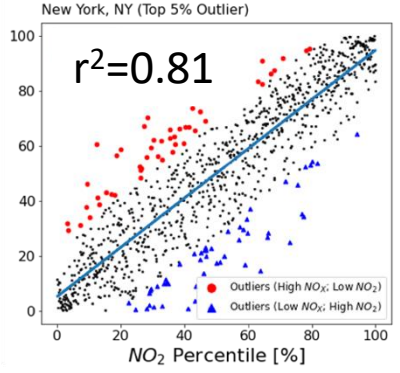
Satellite

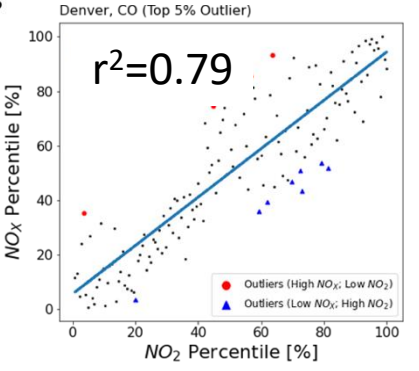
Scatterplot:
x: satellite
y: inventory

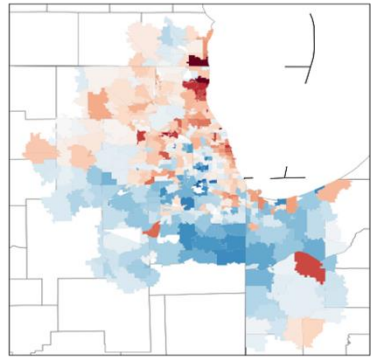
Outliers:
Red: Inventory overestimate
Blue: Inventory underestimate

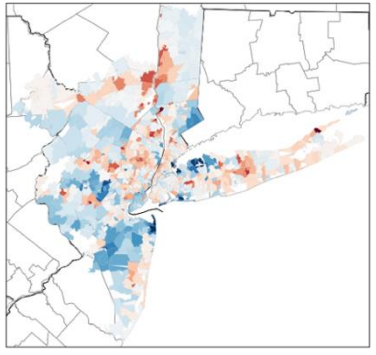


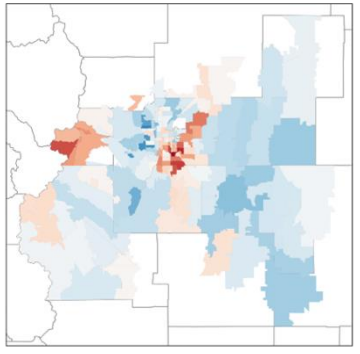




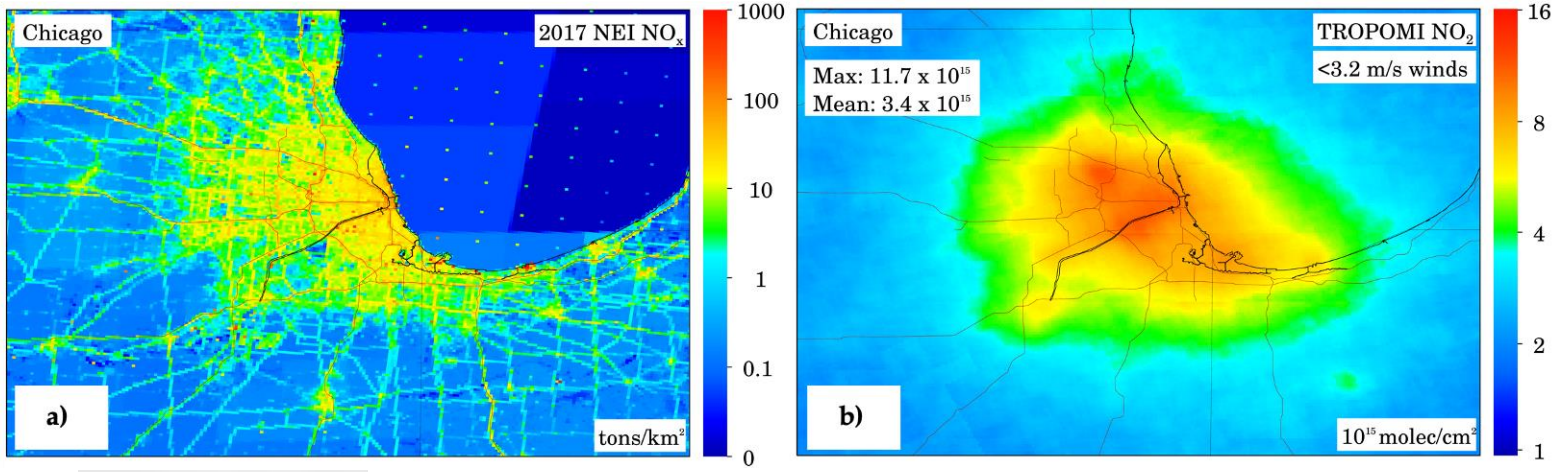


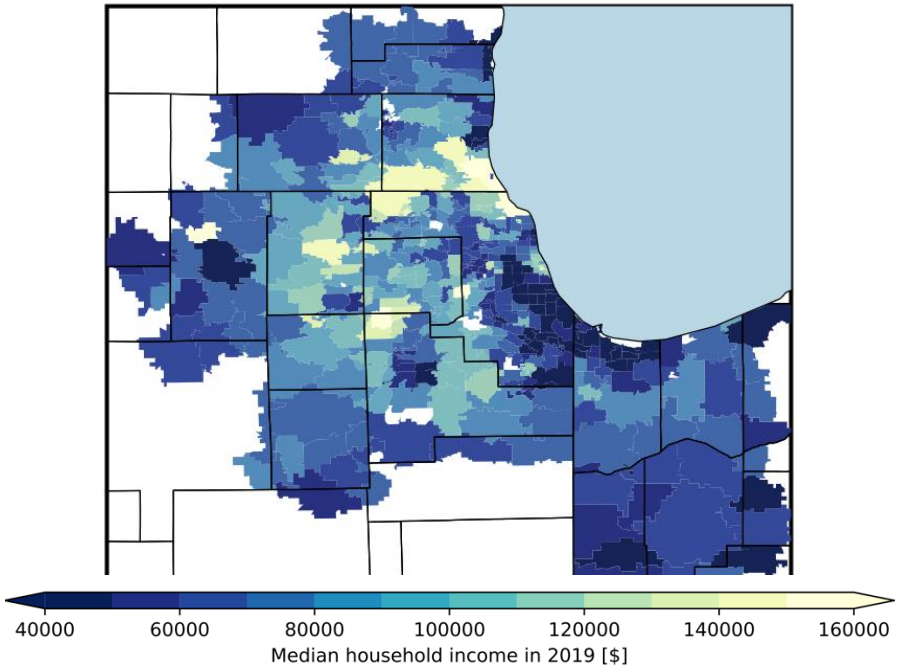


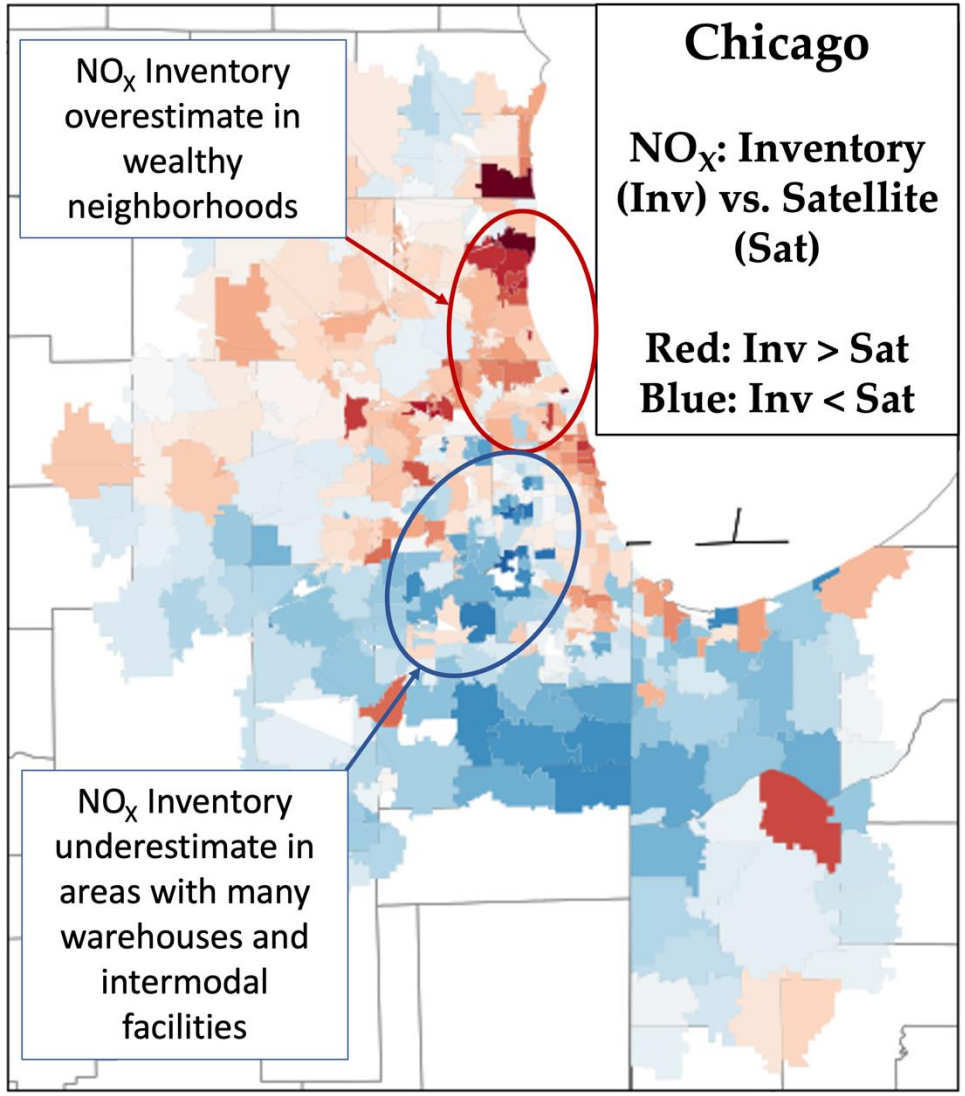




Inventory NO_x vs. Urban NO_2

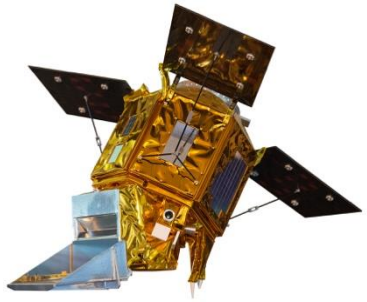




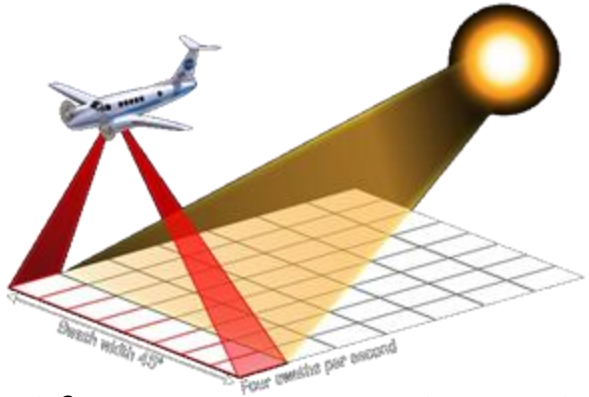


What are biases of TROPOMI, GCAS, and models?

Comparison with Pandora column NO_2 in Houston, TX



(r^2=0.62, and a small but important low bias: –11.2%)

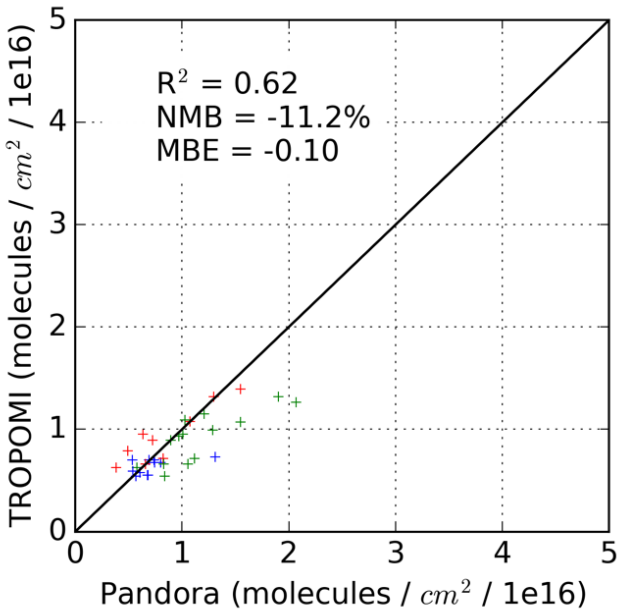


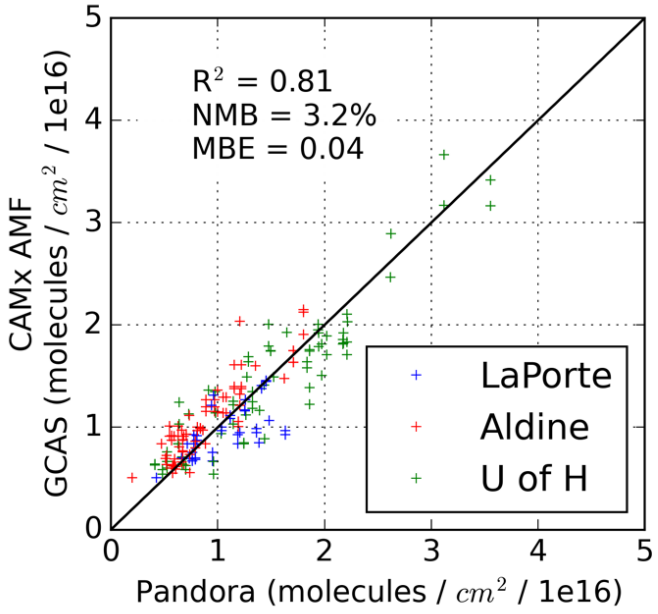
(r^2=0.81 and NMB of +3.2%)

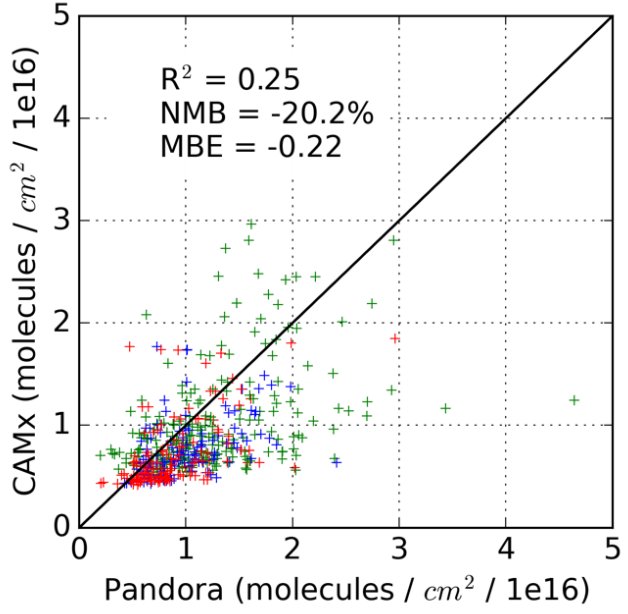
CAMx

444 x 444 m^2 Sept 2021

(r^2=0.25, and a low bias: –20.2%)

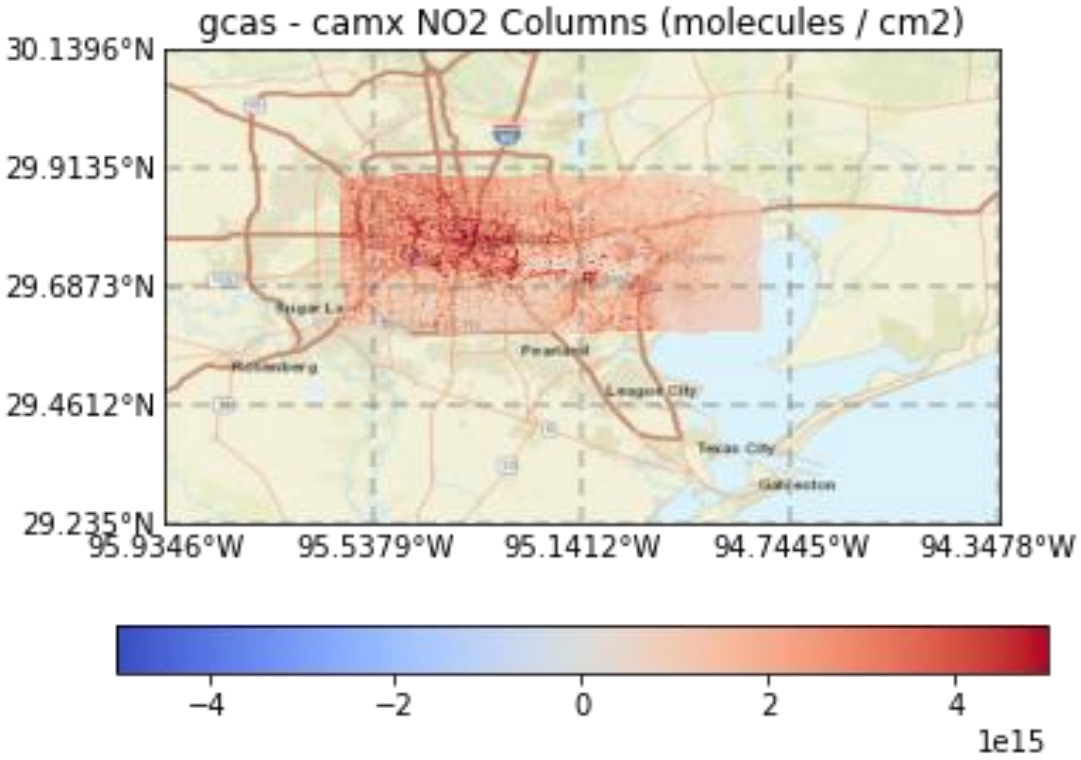




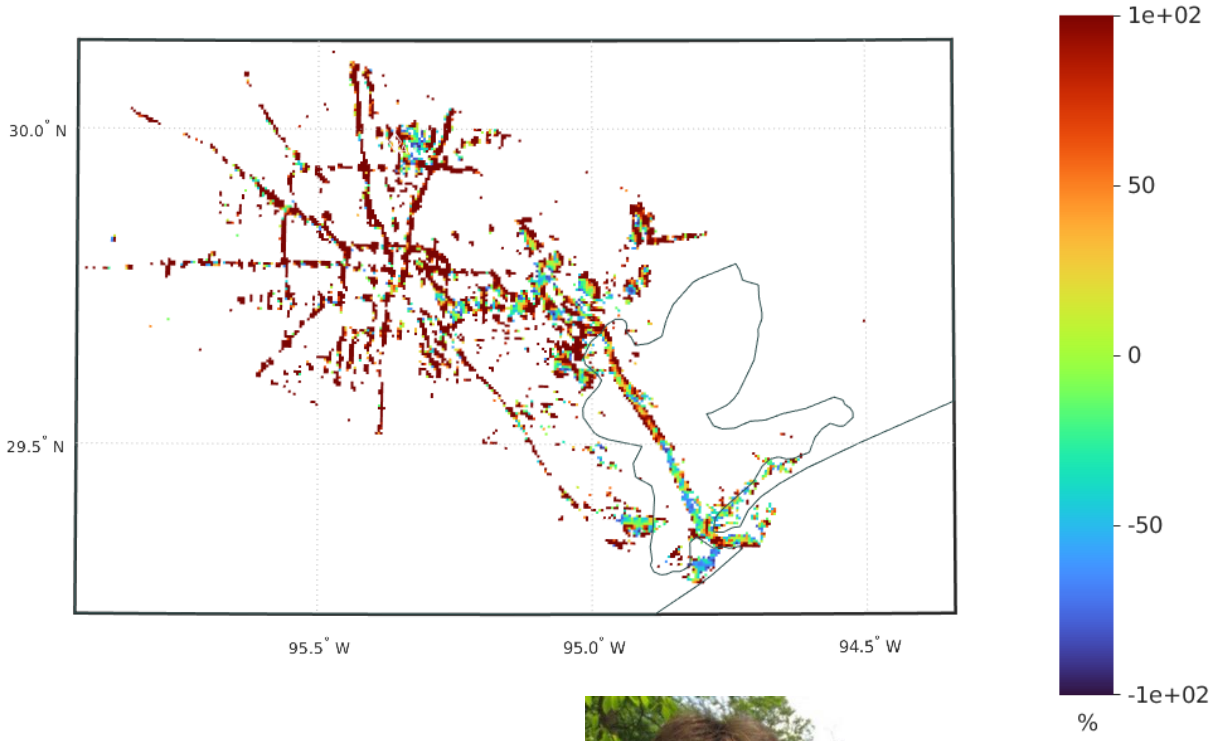


Example of using aircraft + satellite + ground monitors to investigate model biases

CAMx (model) NO_2 low bias worse in downtown



CAMx (model) NO_2 low bias worse near roadways



Ratio of NO_2 flux: GCAS / CAMx

This research was supported by funding from the Texas Commission on Environmental Quality (TCEQ). The findings, opinions, or conclusions expressed do not necessarily represent those of the TCEQ.

Conclusions

- Near-real-time daily, monthly, seasonal, annual TROPOMI NO_2 images are available (tropomino2.us); 2019 – 2022 global annual averages to come soon

- Under the right conditions, satellite NO_2 can be compared directly to NO_X emissions on annual timescales
  - Spatial patterns of NOx emissions in most US cities are comparable to NOx inventory estimates ($r^2 > 0.73$ in most U.S. cities)
  - Some spatial allocation improvement may be needed, especially if high-resolution is requested: EJ communities (near warehouses, ports, industrial areas, etc.)

- GCAS measurements + High-resolution models + TROPOMI/TEMPO provide unprecedented view of urban NO_2 pollution
  - Can begin to diagnose errors in *a priori* emission estimates of individual sectors & neighborhoods

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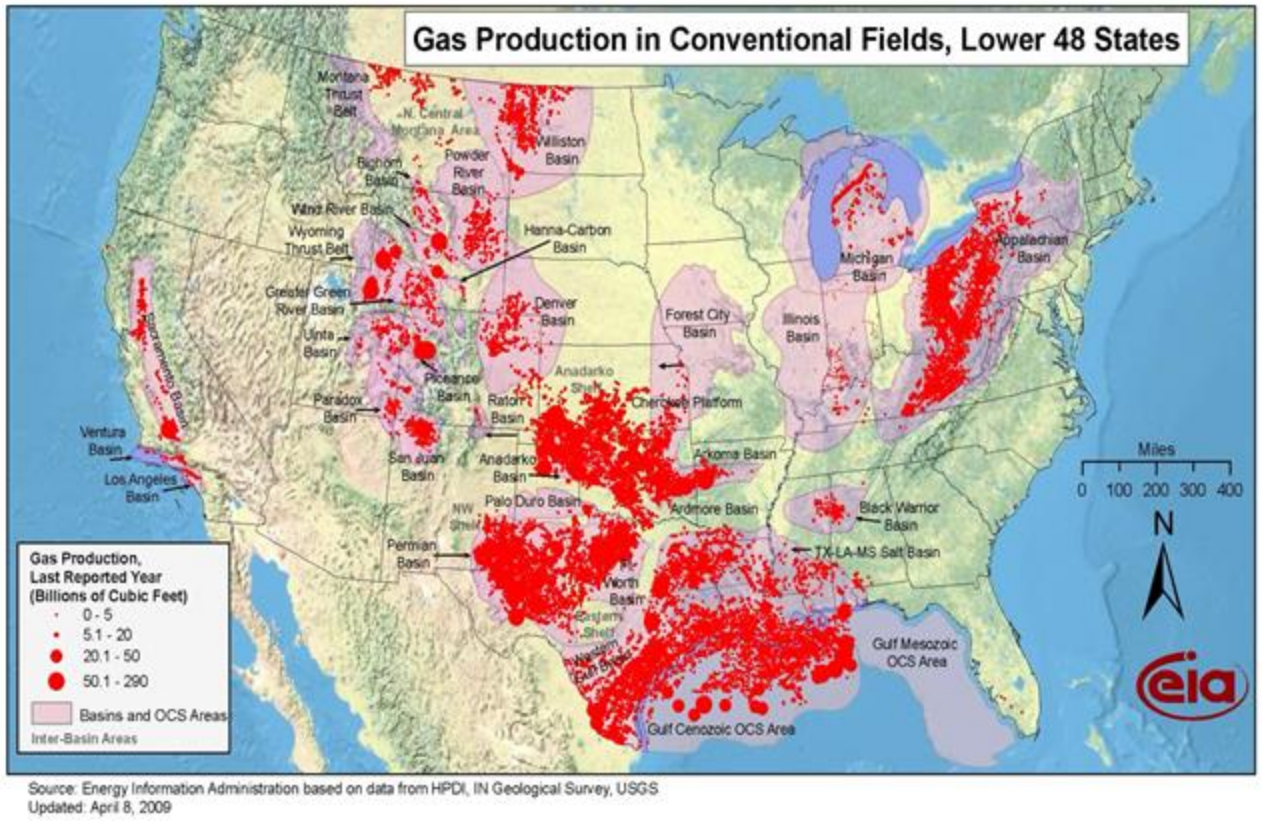
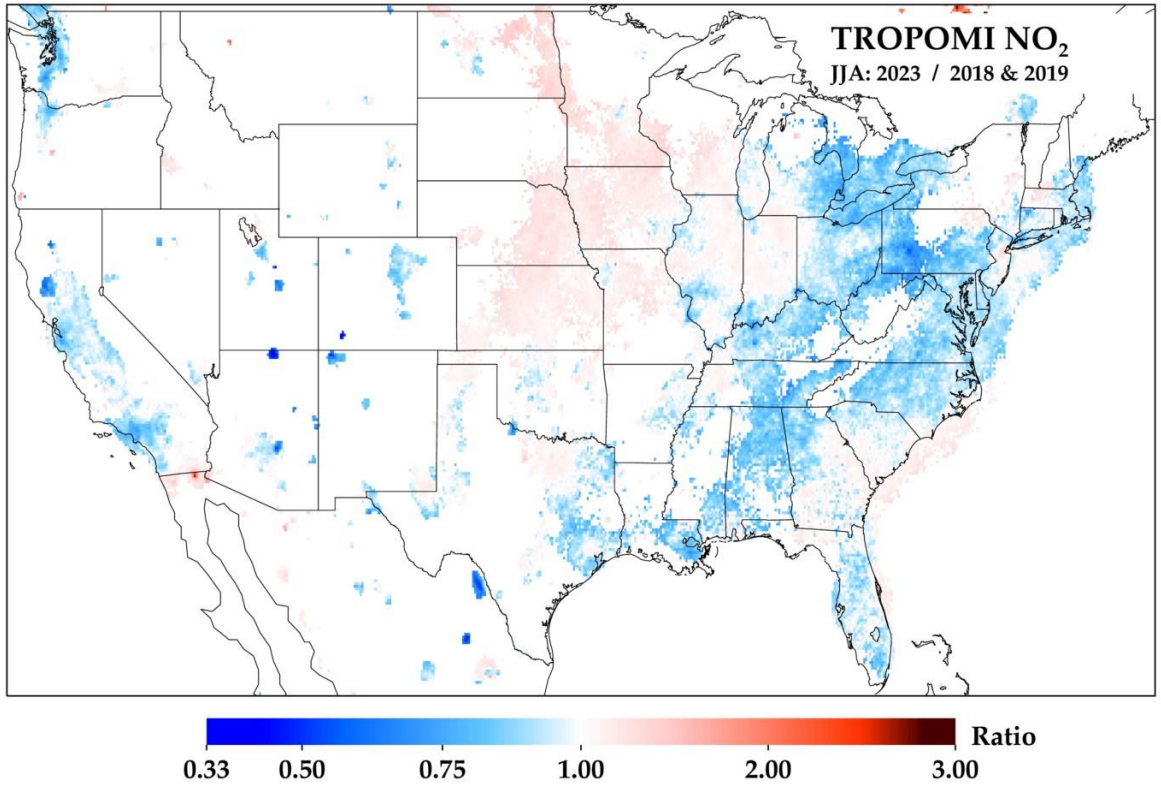
Record Natural gas production in 2023

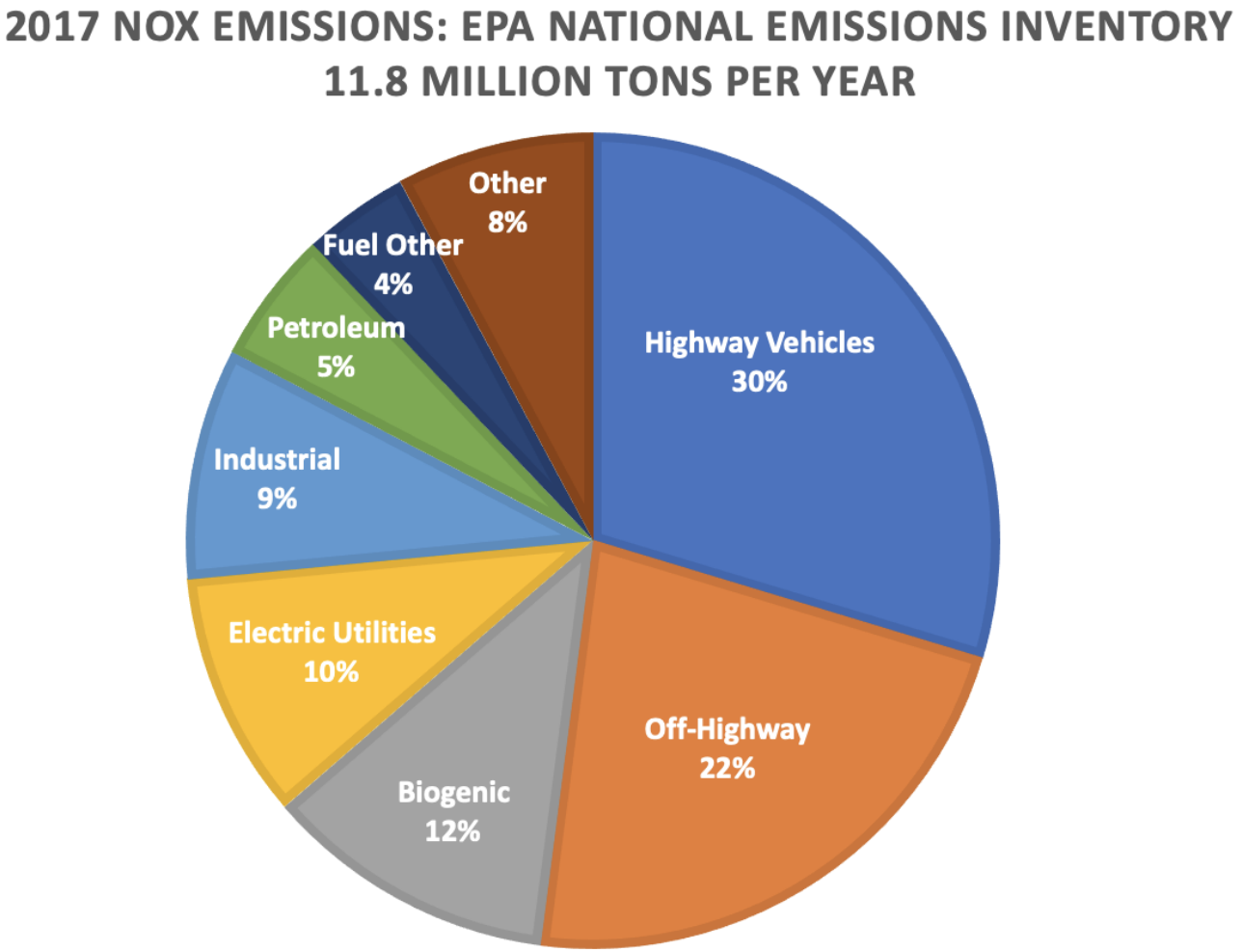


Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009

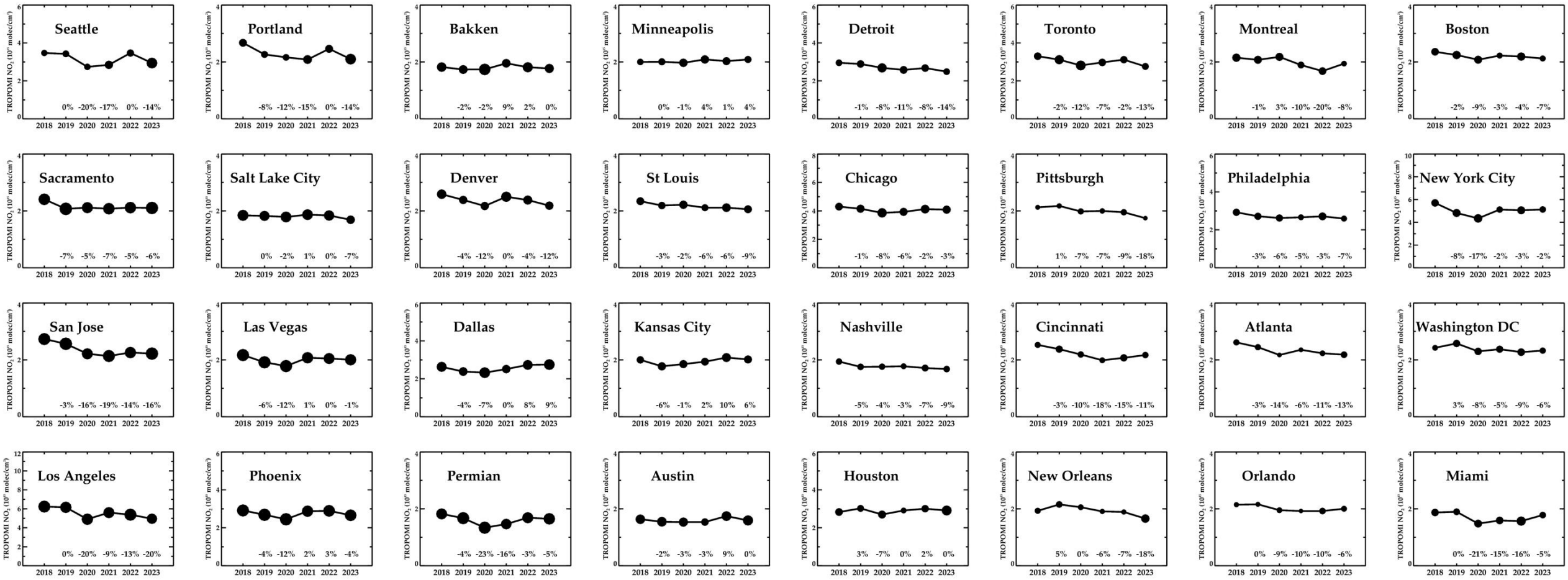


https://www.eia.gov/todayinenergy/detail.php?id=60582

Sector-inventory of NOx emissions



Recent trends in NO_2 pollution



Recent trends in NO_2 pollution