Contrasting the TEMPO and TROPOMI Views of Tropospheric NO_2

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Asst Research Professor

and MANY colleagues & co-authors

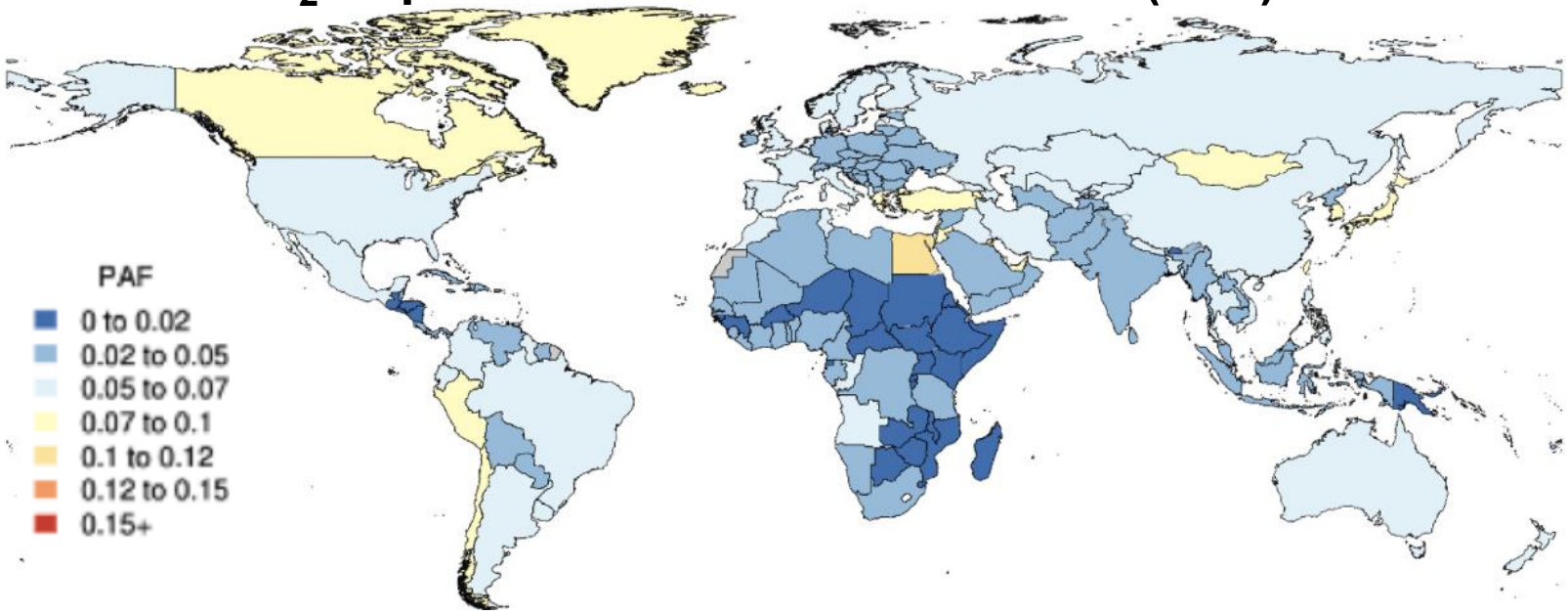
European Space Agency: TROPOMI on the Sentinel 5 Precursor Satellite

The NO_2 Direct Health Effects

- Causes and exacerbates asthma
- Co-emitted with other harmful pollutants (diesel $PM_{2.5}$, CO_2, VOC air toxics, etc.)
- Inequitably distributed across the urban landscape; certain communities can experience much higher levels of this pollutant than a city average

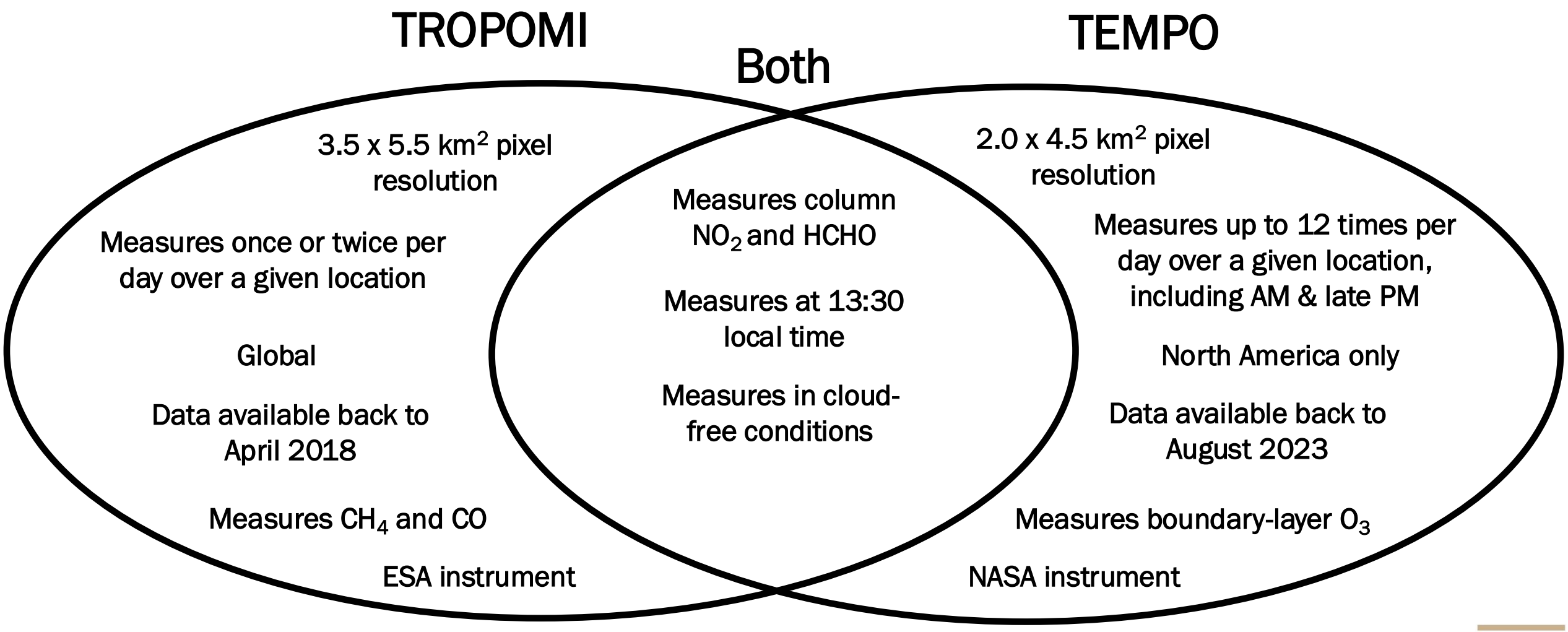
In 2023, 5% of global childhood asthma cases are attributable to NO_2
Equates to 233,000 years lived with a disability

NO_2 Population Attributable Fraction (PAF)



Burkhardt et al., 2025

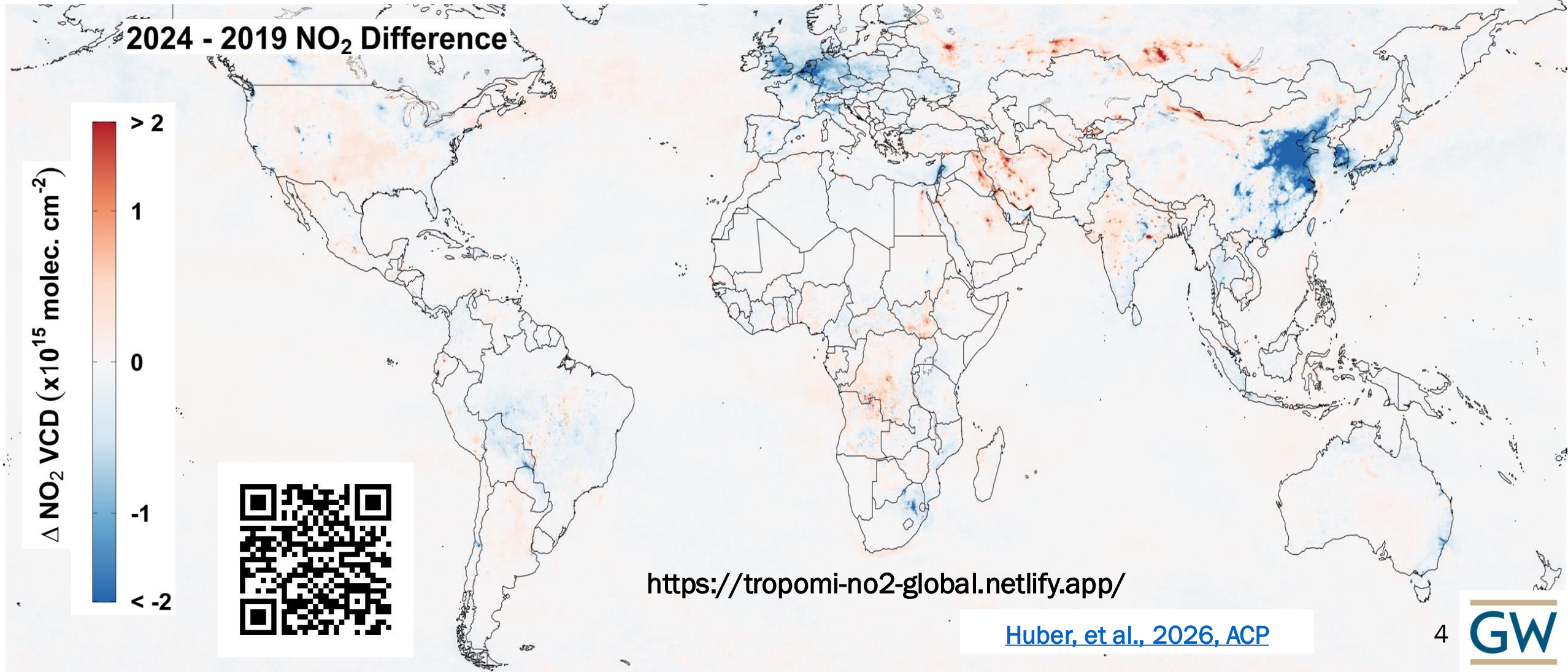
Satellite instruments measuring NO_2
(not a comprehensive list*)



*By my count there are at least 13 active satellites measuring NO_2: TEMPO, TROPOMI, GEMS, Sentinel 4, Sentinel 5, OMI, PACE, 3 x OMPS, 3 x GOME-2

TROPOMI NO_2 data can track global patterns
Recent trends in NO_2 pollution (2019 vs. 2024)

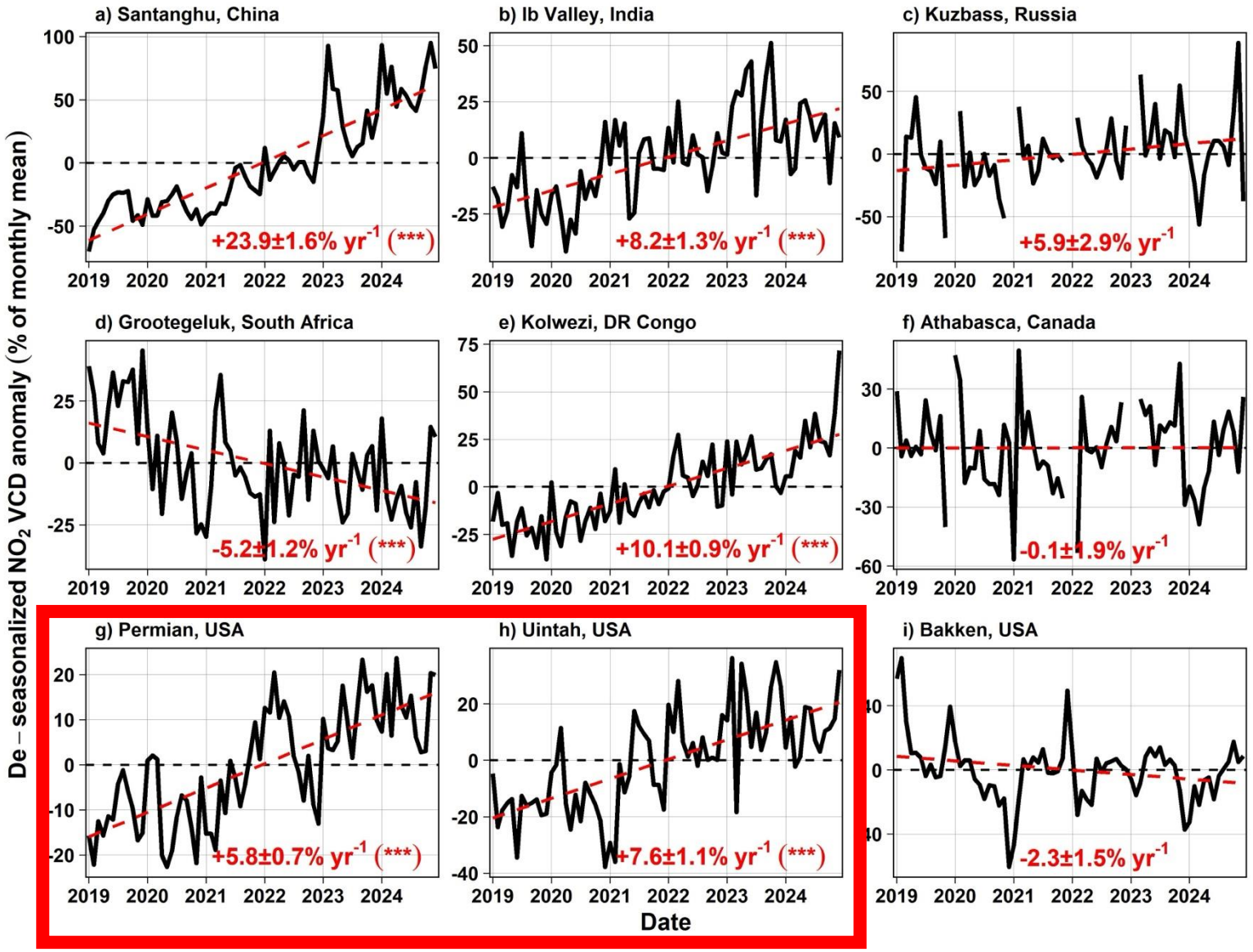
Large NO_2 reductions in China, reductions in Europe, increases in tropics, mixed but mostly down in the U.S.



https://tropomi-no2-global.netlify.app/

Huber, et al., 2026, ACP

TROPOMI NO_2 data can track Global Emerging Hotspots: Oil & gas & mining



Huber, et al., 2026, ACP

TROPOMI NO_2 data can track EV adoption

EVs promised cleaner air. Satellites say it's finally happening.

Michelle Lewis | Jan 26 2026 - 4:01 pm PT | 41 Comments

EVs are already making your air cleaner

A study in California finds that even small increases in EV adoption lead to measurable drops in neighborhood-level air pollution.

EVs Are Quietly Cleaning Up The Air. This New Study Proves It

California's EV boom led to cleaner air in its neighborhoods, with satellite data linking this growth to lower NO_2 pollution.

EV Growth Is Already Cutting Neighborhood Air Pollution Across California

Researchers found that adding 200 ZEVs in a neighborhood was associated with about a 1.1% drop in annual average NO2 in California from 2019 to 2023.

Eckel et al., *Lancet Planetary Health*, 2026

Linked EV car registrations & Satellite NO_2 data

↓

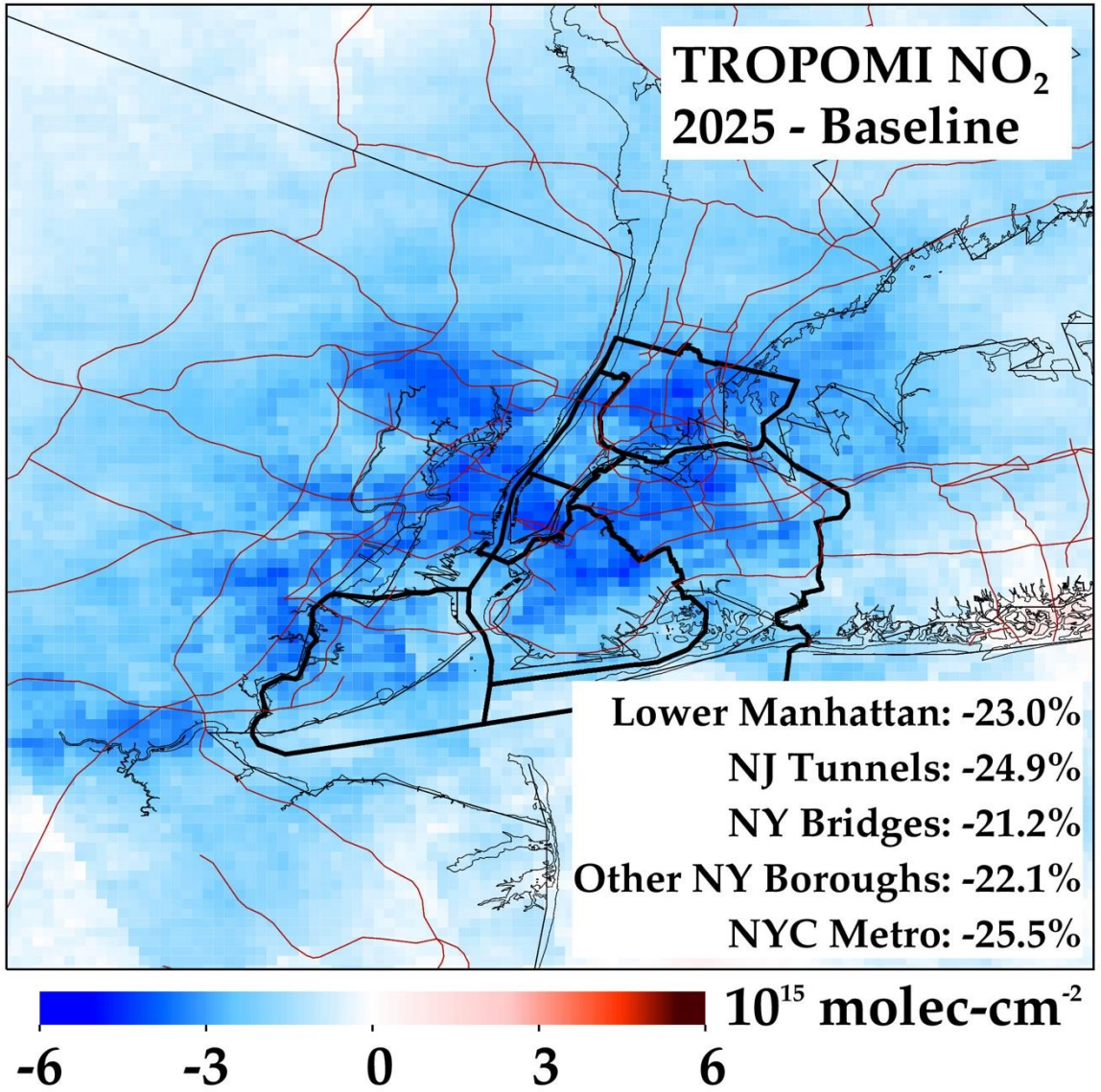
Zip codes with more EV registrations had greater NO_2 reductions over time

GW

TROPOMI NO_2 data can track air quality responses to Congestion Pricing in New York City

Regionwide policies & favorable weather likely led to air quality (NO_2) improvements in 2025

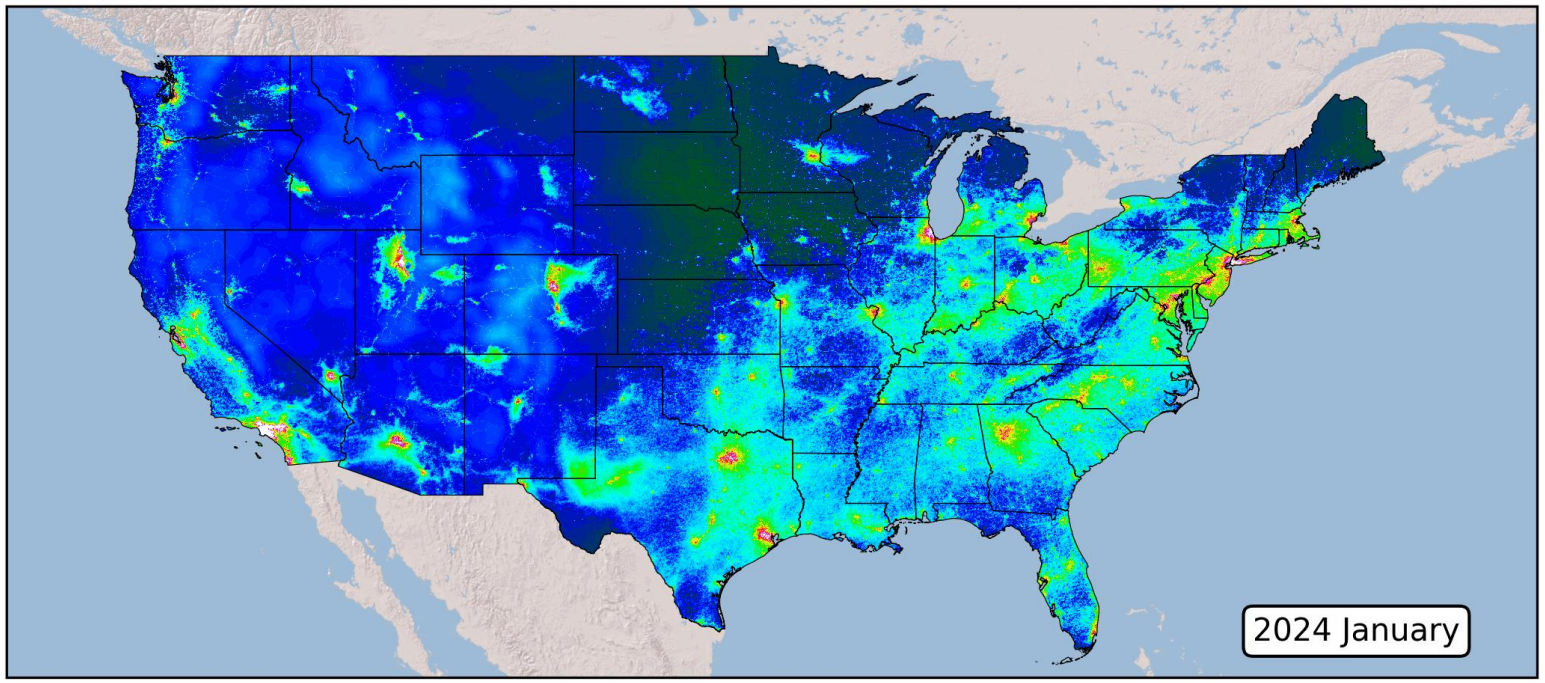
Congestion pricing probably had a small but meaningful improvement (2-5% cleaner), especially at the NJ-NY points of entry



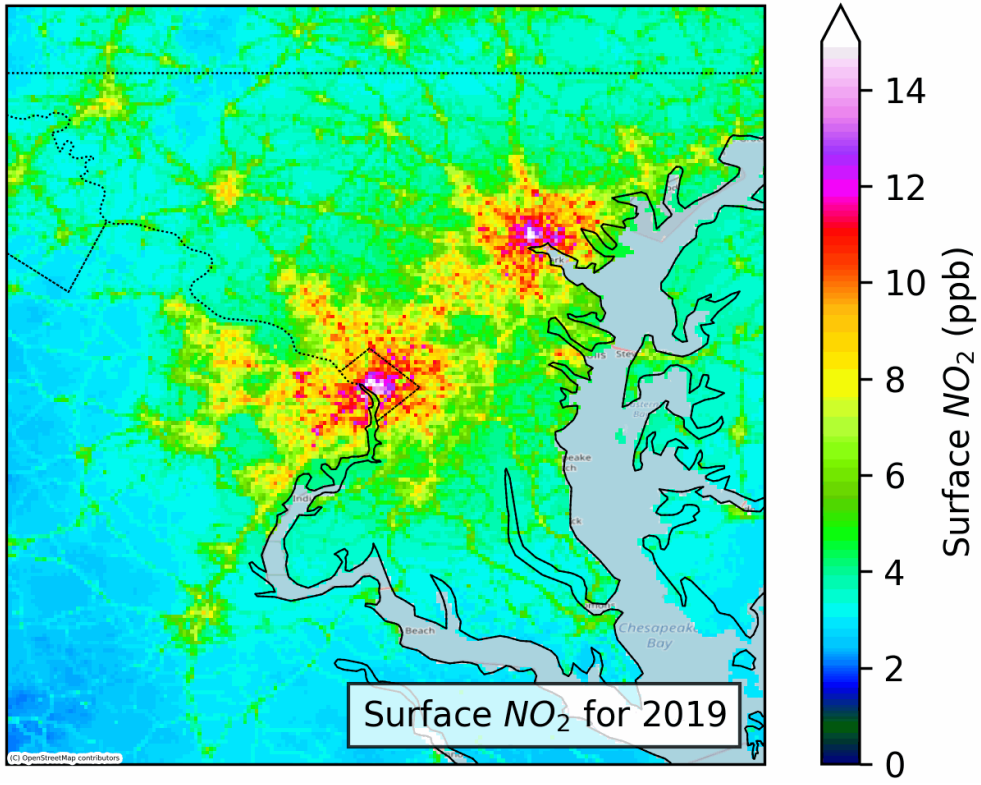
Goldberg, Goldberg, Westervelt et al., submitted
(Not a typo, two unrelated Dan's and Goldberg's are involved ☺)

TROPOMI NO_2 surface estimates (R^2 = 0.75)

Monthly patterns of Surface NO_2



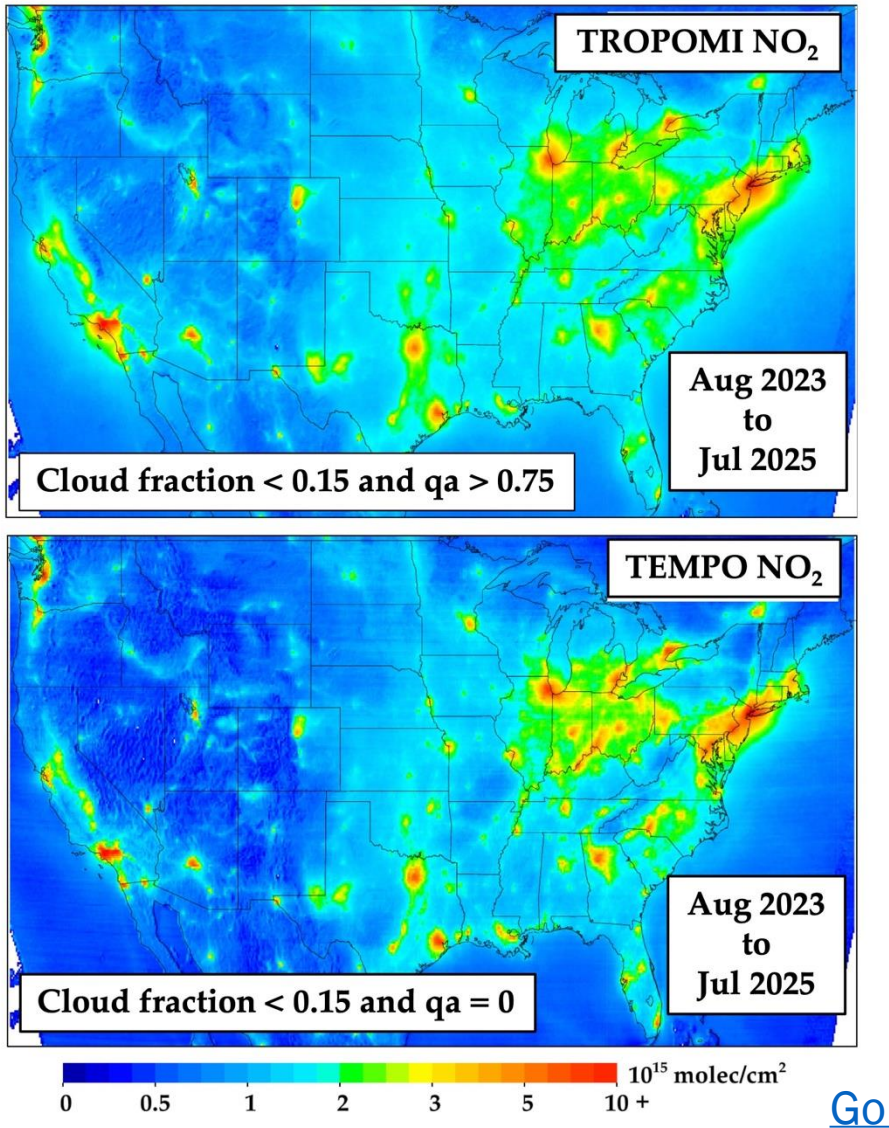
Annual patterns of Urban Surface NO_2



Generate your own maps by downloading data here! https://doi.org/10.5281/zenodo.14646033

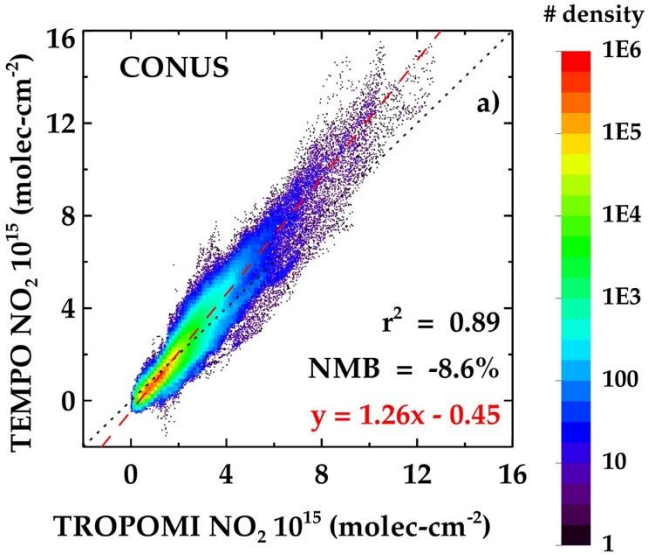
Nawaz, Goldberg, et al., *Environmental Science & Technology – Air*, 2025

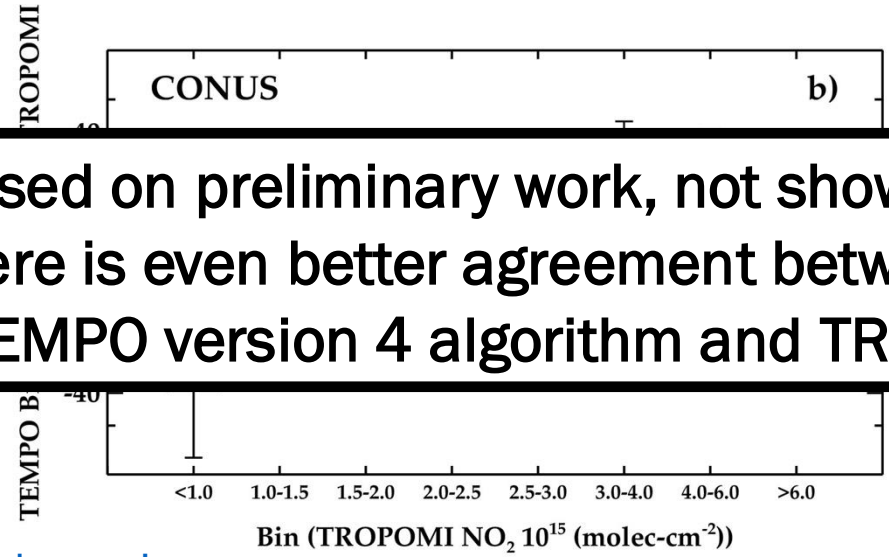
Since 2023, we have TEMPO (version 3), but first how does it compare when overlapping with TROPOMI?



Very good!
R^2 =0.89

Lower in rural
Higher in urban

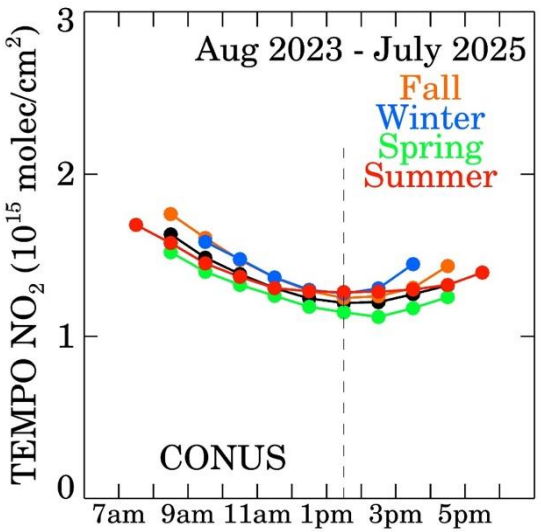


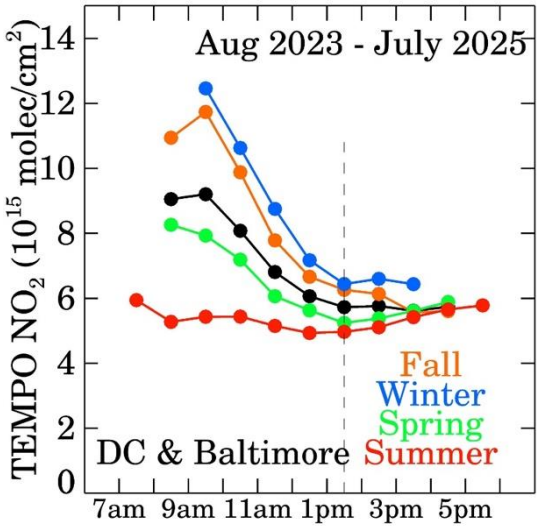


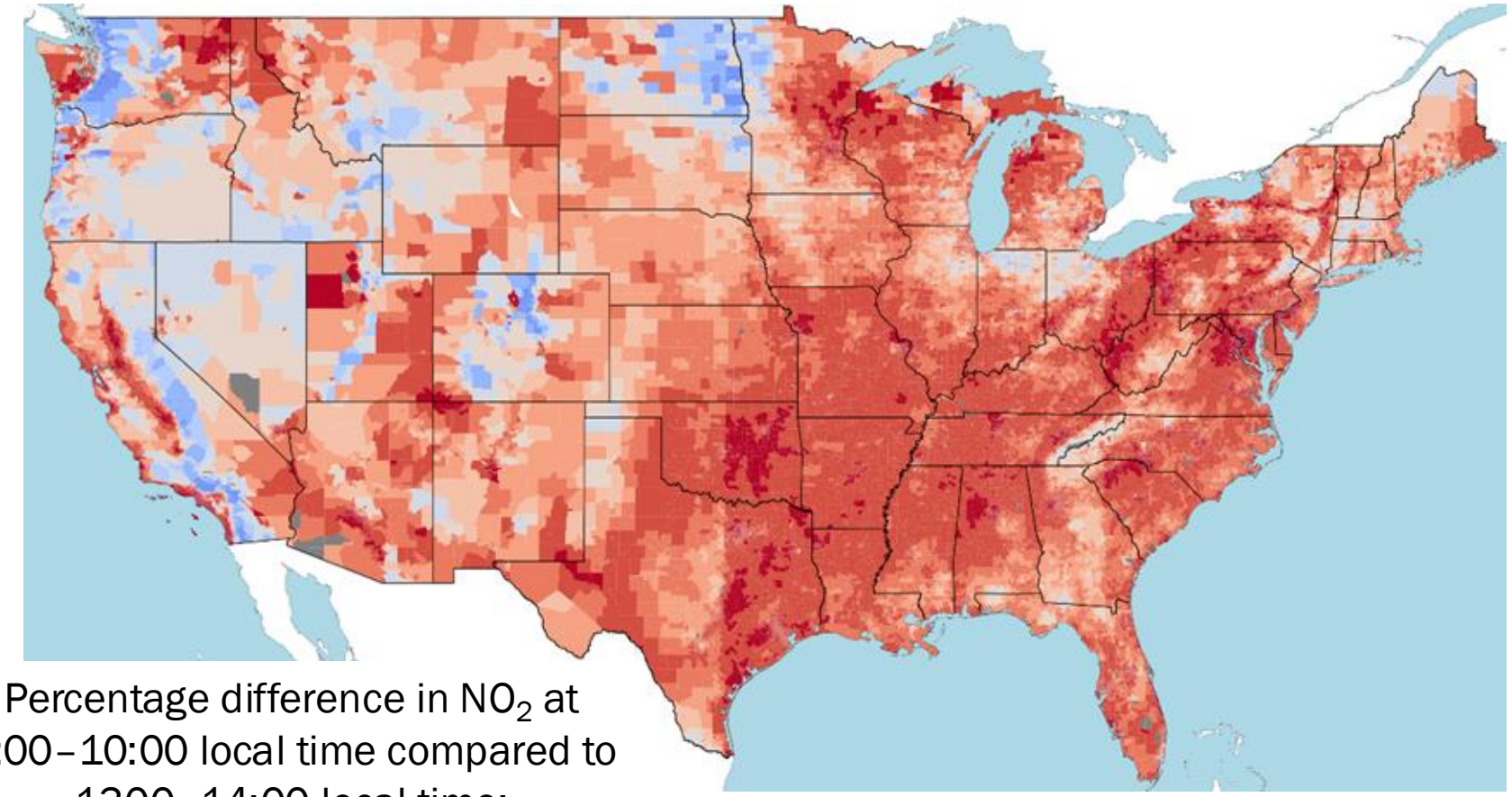
Based on preliminary work, not shown here, there is even better agreement between the TEMPO version 4 algorithm and TROPOMI

Goldberg et al., under review

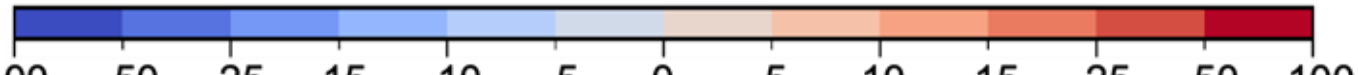
There are larger NO_2 values in the morning that we have been missing with prior satellite instruments





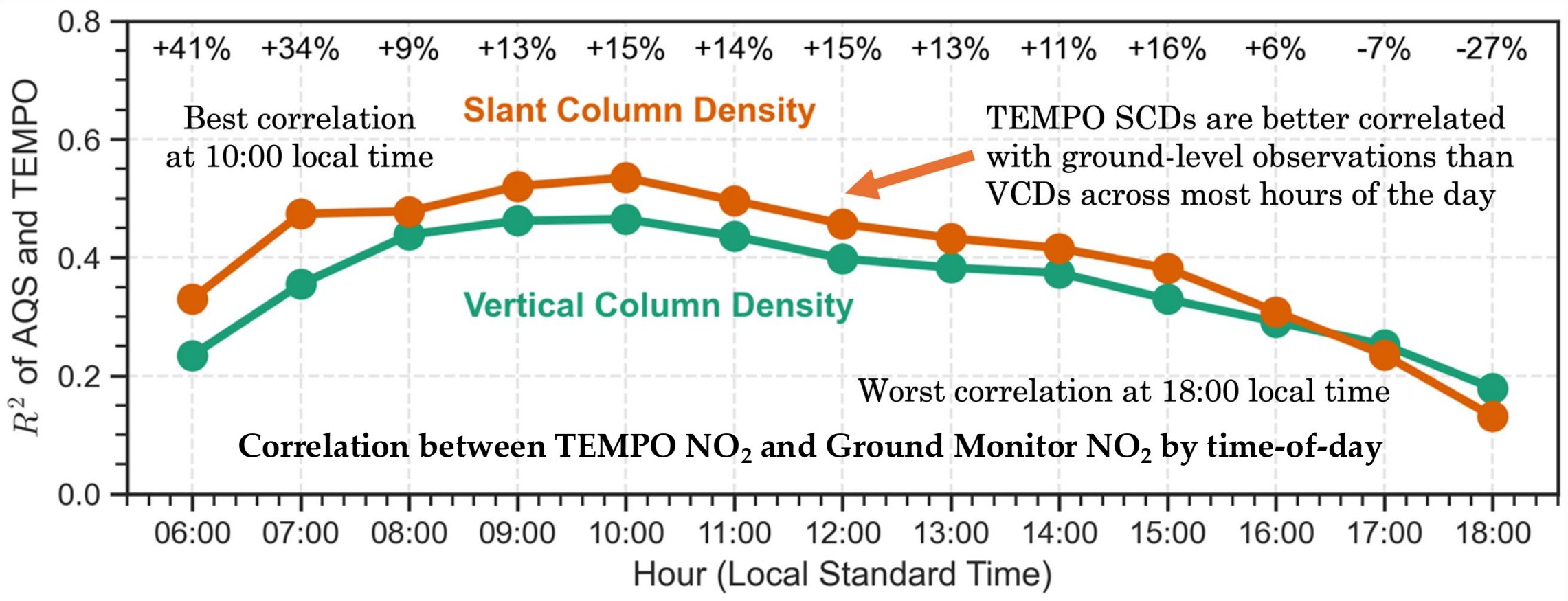


Percentage difference in NO_2 at 9:00–10:00 local time compared to 1300–14:00 local time:
>90% tracts experience higher NO_2



Goldberg et al., under review & Chen et al., under review

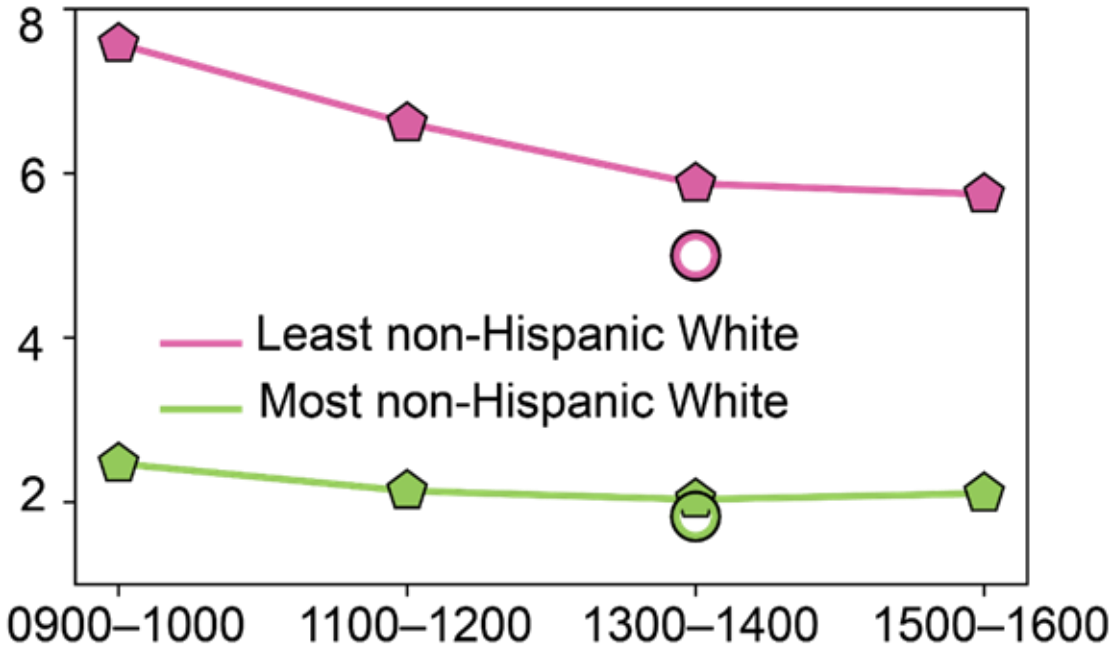
And! Satellite measurements correlate better with surface concentrations in the morning time



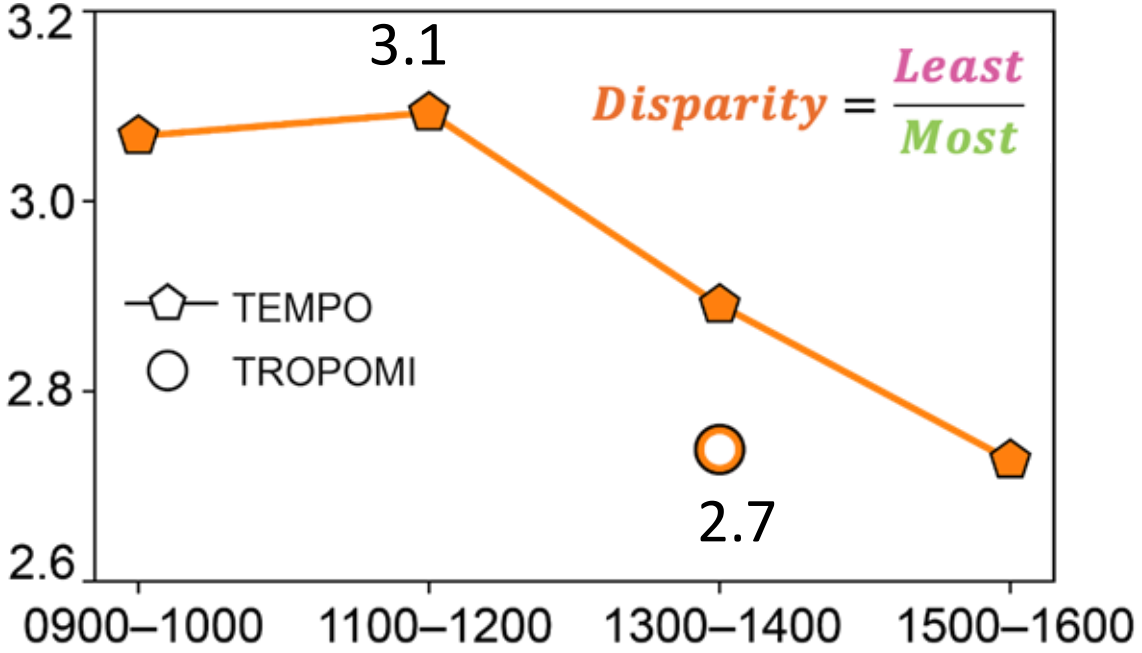
Nawaz, Goldberg, et al., *Journal of Geophysical Research – Atmospheres*, 2025

Let's reinvestigate the NO_2 disparities… Now even larger

Population-weighted NO_2 (10^{15} molec. cm^{-2})



Daytime variation in NO_2 racial-ethnic disparity



Least / Most NHW = bottom / top 10% by non-Hispanic White share

Lulu Chen, et al., under review
Check out her poster on disparities near warehouses!

Conclusions

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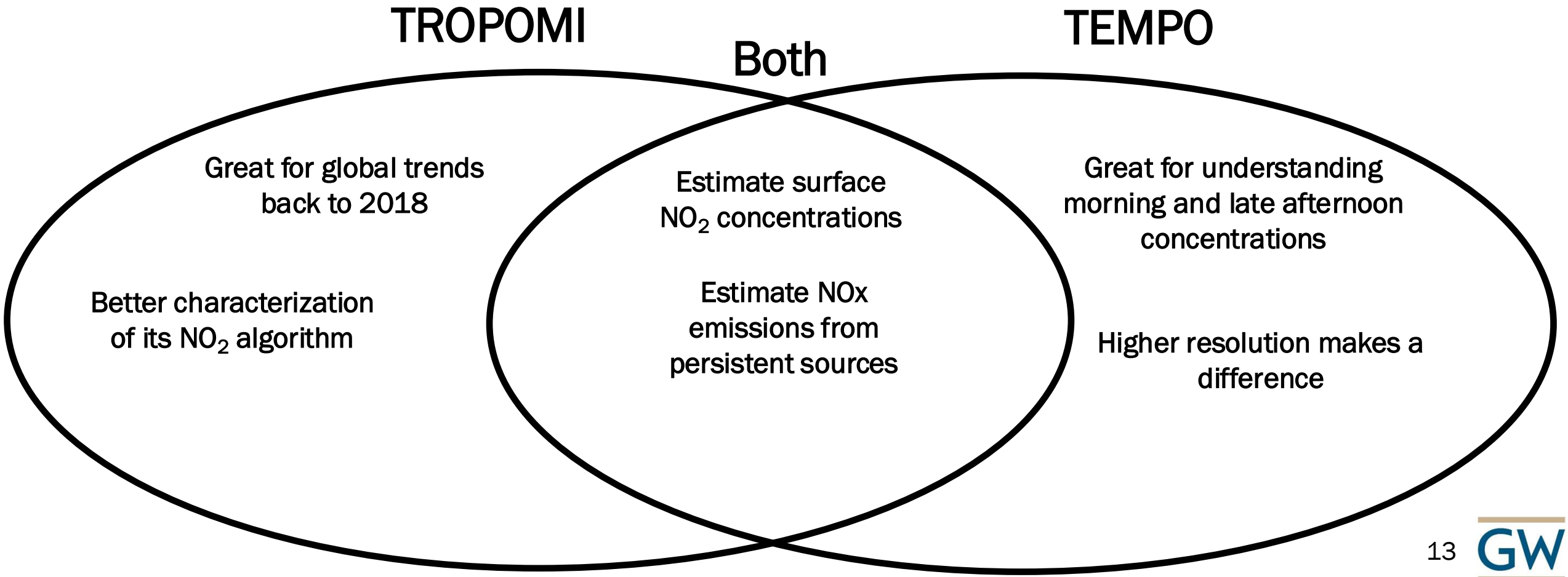
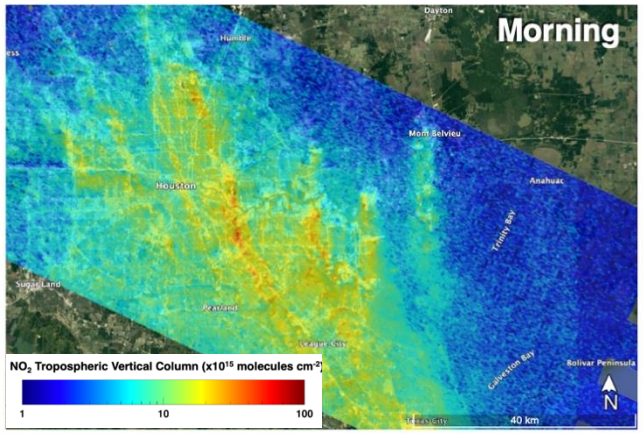
LinkedIn

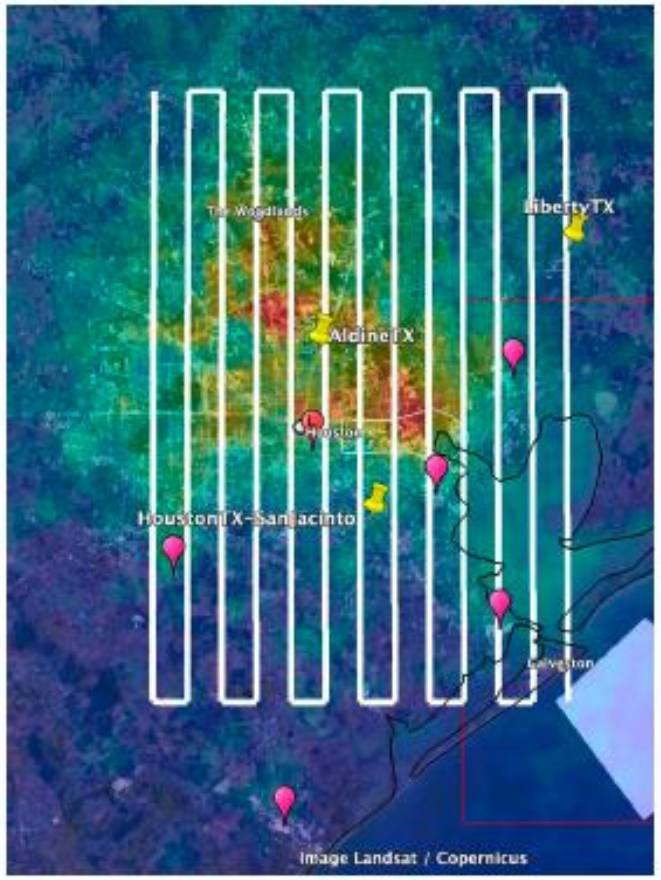
- Both satellite NO_2 measurements offer complementary advantages, despite not measuring nose-level concentrations:



NASA SARP Texas: June 3 – 13, 2026



Houston Raster



Overall science objectives, interests, and questions:

1. Evaluate TEMPO NO_2 PBL O_3, TROPOMI NO_2 CH_4 products
2. Understand urban (Houston) NOx emissions, inclusive of on-road, industrial, power generation
3. Track evolution of urban air pollution plume downwind
4. Better quantify rural sources of NOx, primarily related to soils and secondarily related to lightning
5. Quantify oil&gas extraction emissions in the Permian Basin