

Air quality and health in U.S. cities: Lessons from COVID-19 restrictions

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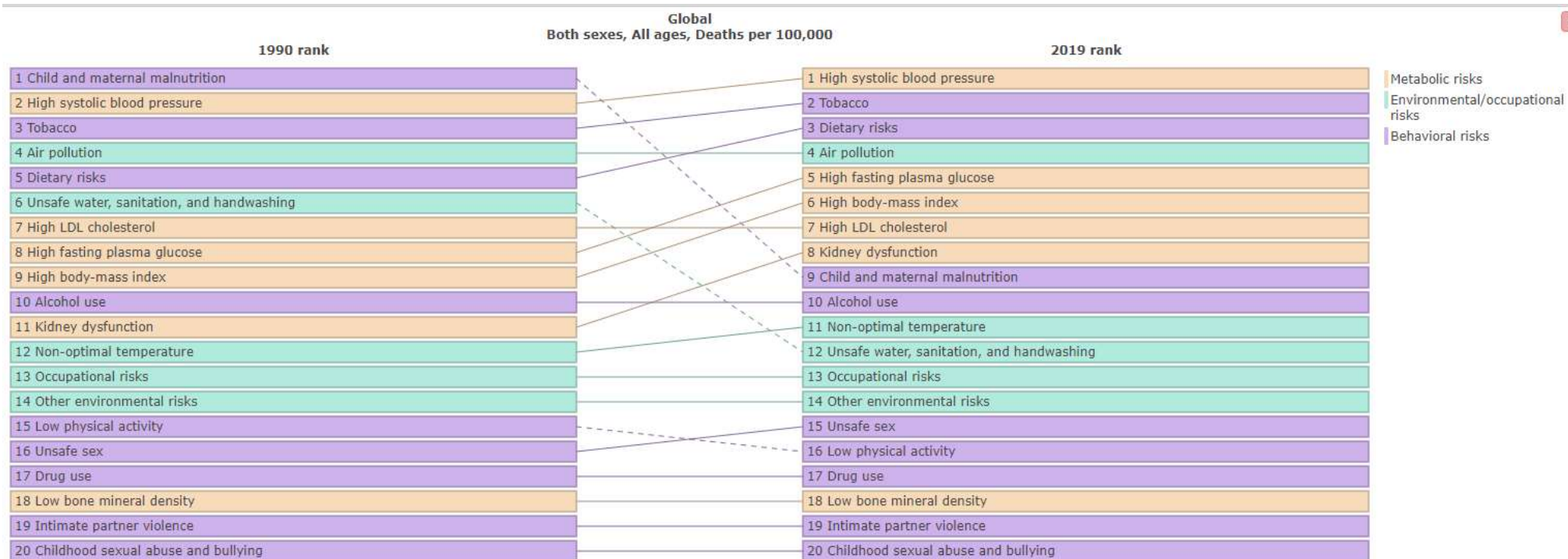
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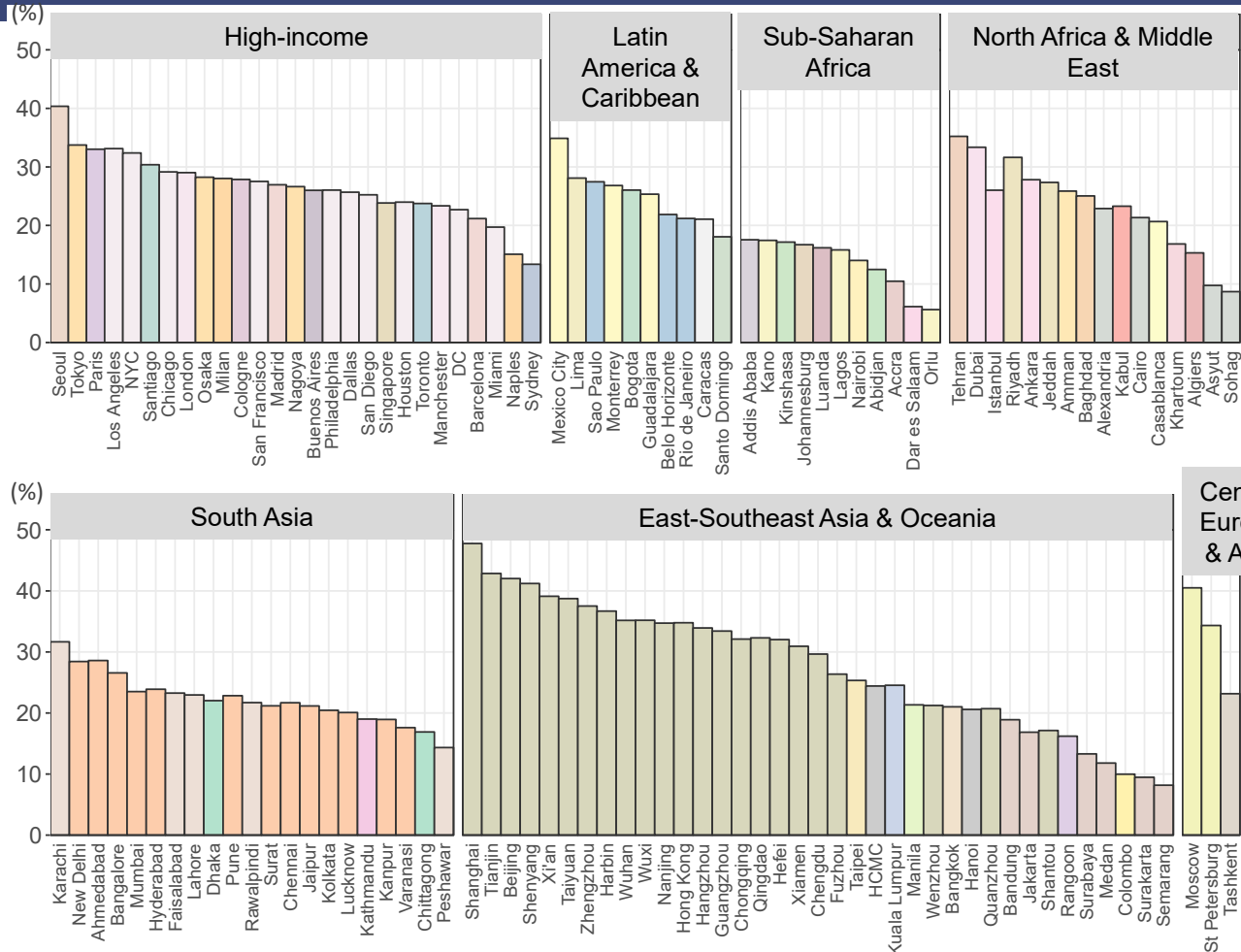


Air pollution continues to be a leading health risk factor in nearly all countries



GBD 2019 Study
<https://vizhub.healthdata.org/gbd-compare/>

In both developed and developing cities, NO₂ pollution is an important risk factor for pediatric asthma incidence



In 125 major cities, the percent of new pediatric asthma cases attributable to NO₂:

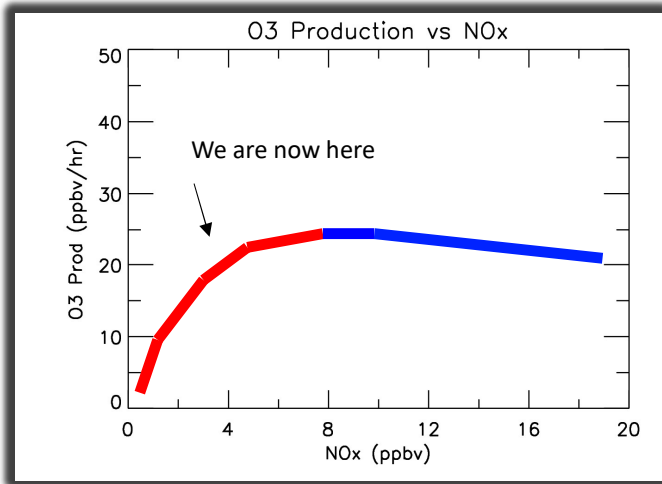
- Ranged from 6% (Orlu, Nigeria) to 48% (Shanghai, China).
- Exceeded 20% in 92 cities, located in both developed and developing countries.

Vast majority of these impacts occurring below the U.S. NAAQS and WHO Air Quality guidelines

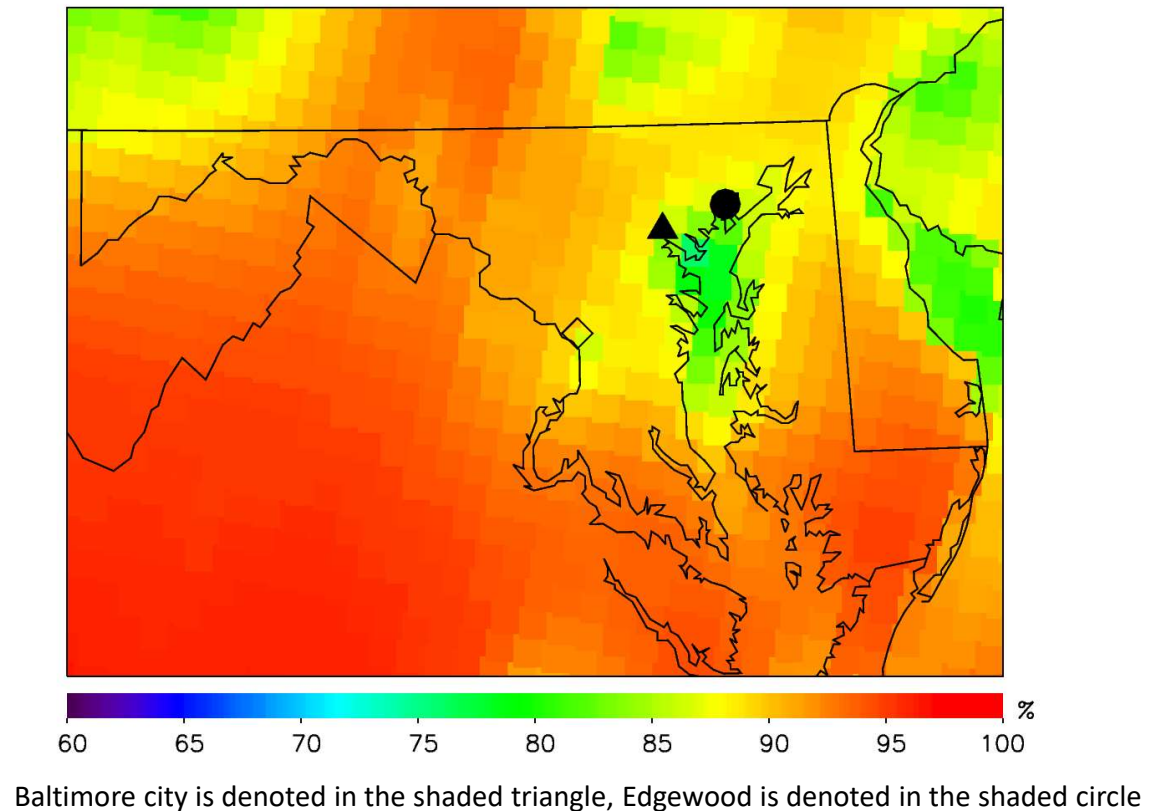
Why does NO_2 matter in Ozone (O_3) formation?



- During the worst smog days, the formation rate of ozone is limited by the amount of NO_2 in the atmosphere.
- Image shows that >80% of ozone is limited by NO_x ; the other <20% is limited by VOCs
- More NO_2 = Faster O_3 production



From a July 2011 CAMx model simulation



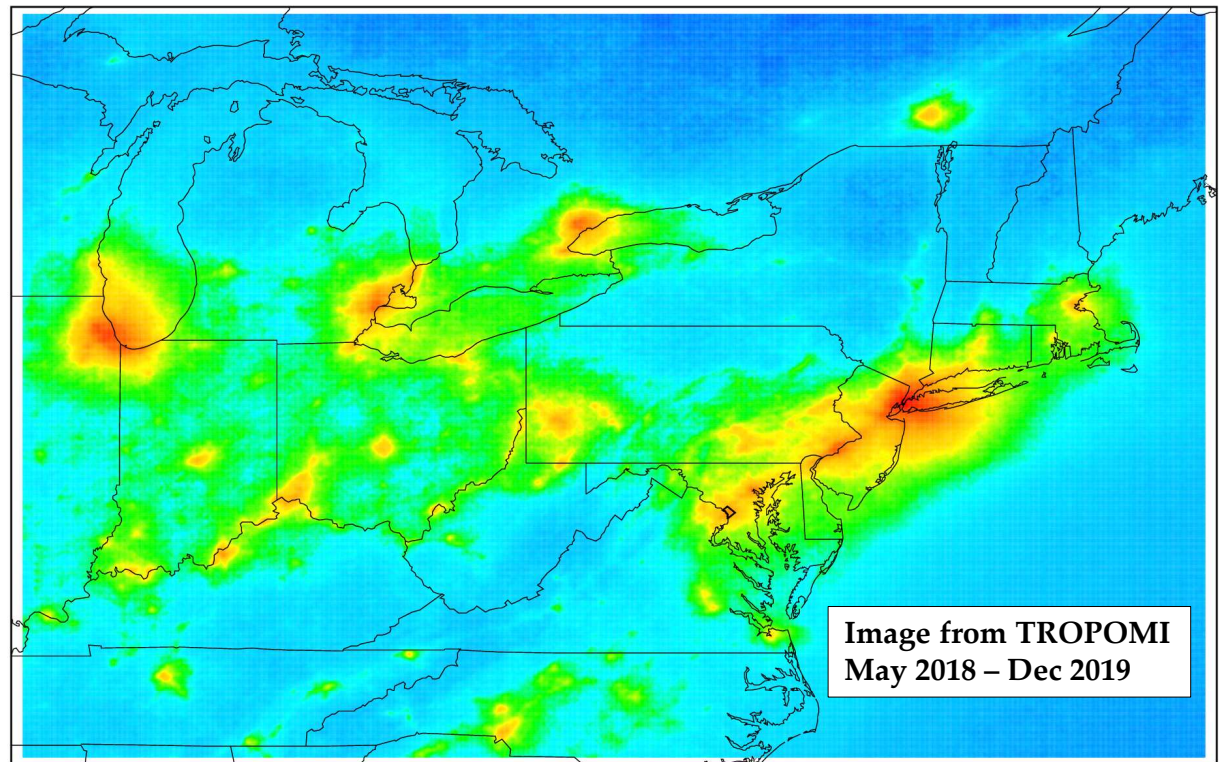
NO₂ as observed by satellite *pre-pandemic*

Pros:

- Satellites give full spatial coverage
- Can capture trends over time, using a single instrument
- Can validate or constrain model simulations

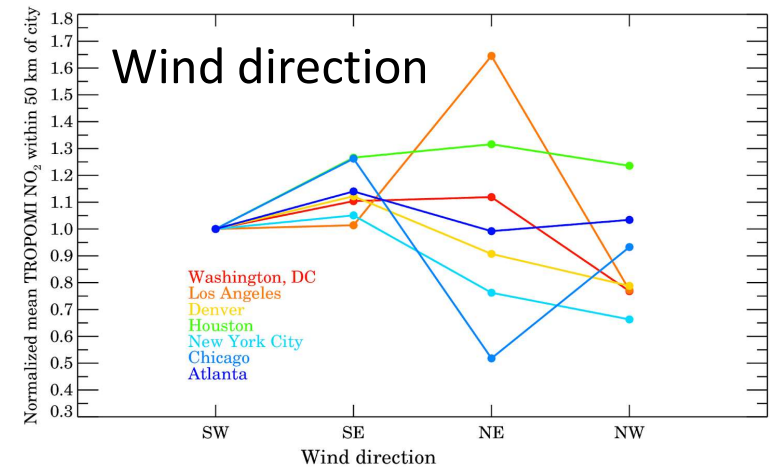
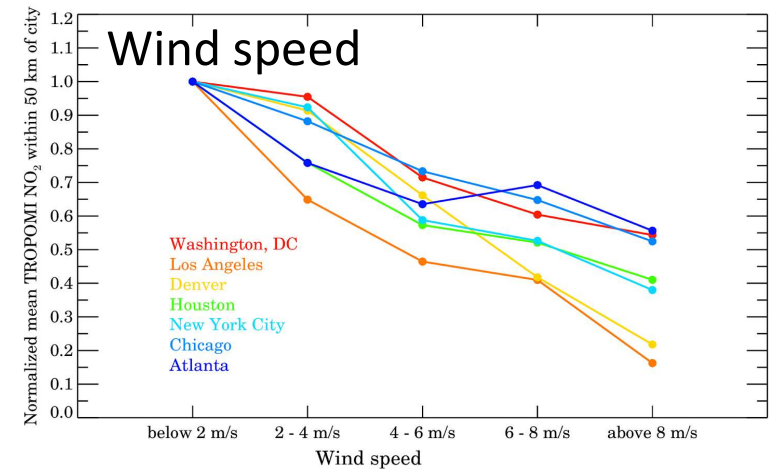
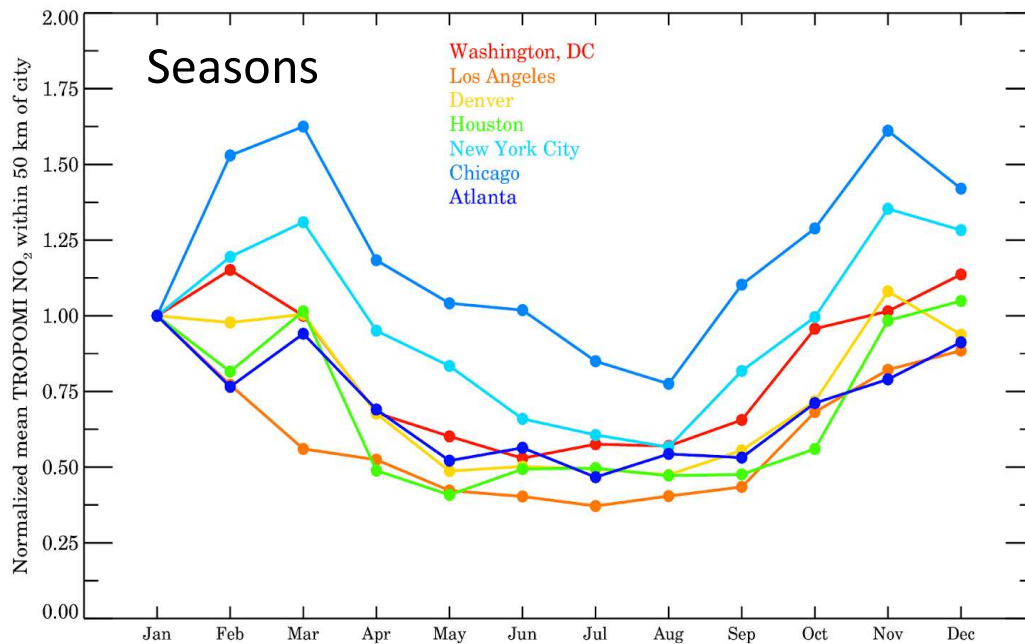
Cons:

- Measurement is once per day in the early afternoon
- Measurement is the amount in the vertical column of the atmosphere, but NO₂ mostly lives near surface



Units: Molecules per cm² – Red is larger, blue is smaller; Exponential colorbar

Effects of seasonality and weather on NO₂



Goldberg et al. 2020

<https://www.essoar.org/doi/10.1002/essoar.10503422.1>

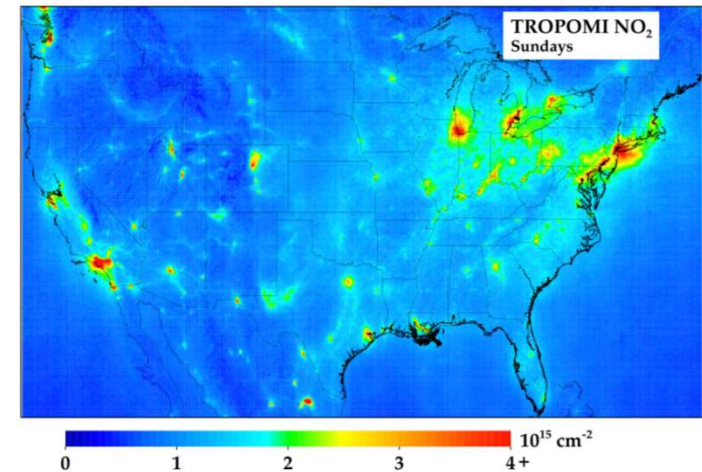
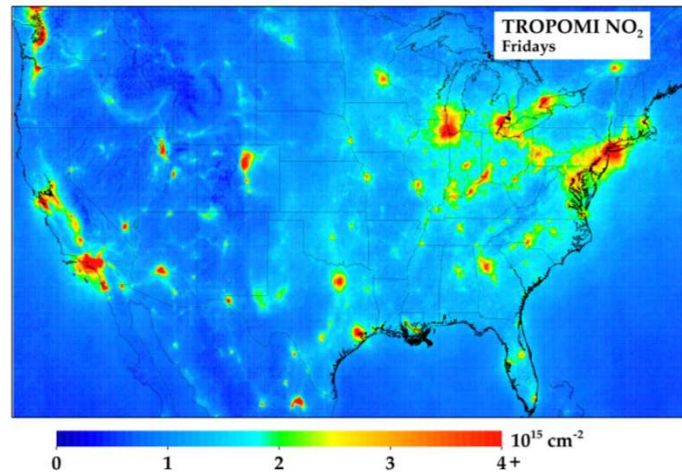
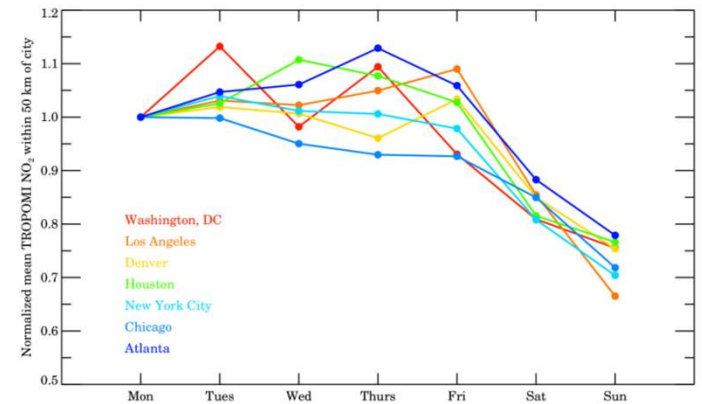
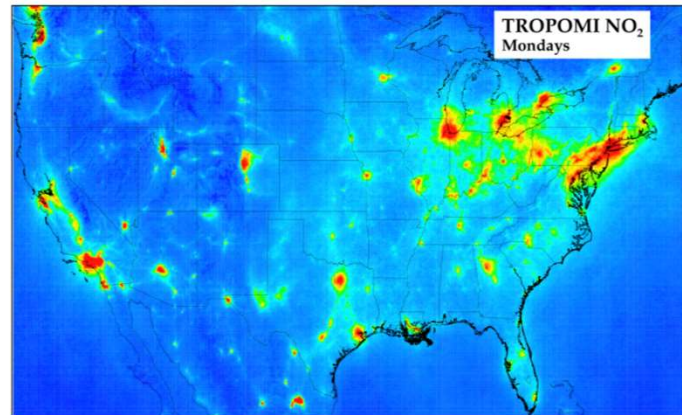
Anthropogenic effects: Weekday vs. weekend



On Saturdays: 16% lower
On Sundays: 24% lower

Some variability on weekdays, but no statistical difference between weekdays themselves

Weekday vs. weekend cycle of NO₂ pollution is “flatter” than 10-20 years ago

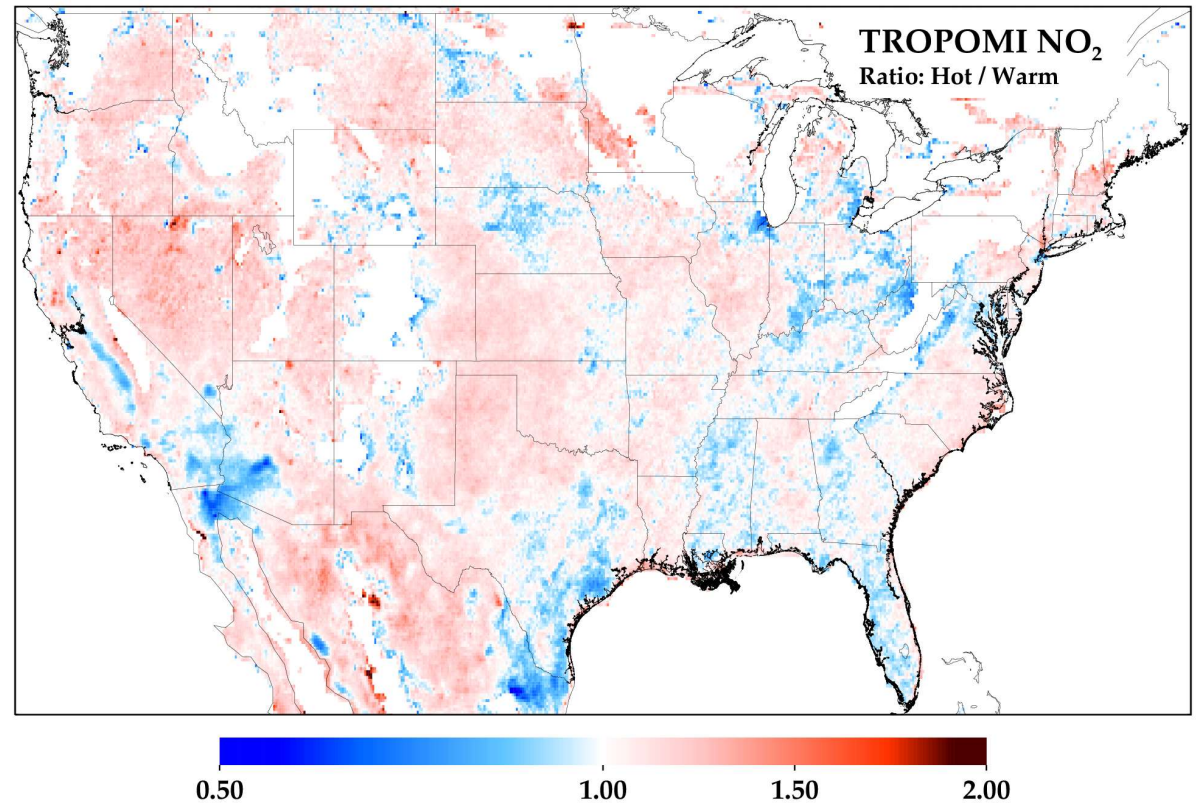


Anthropogenic + Natural effects: Hot vs. warm days



In most areas, NO_2 is larger on the hottest days as compared to seasonably warm days

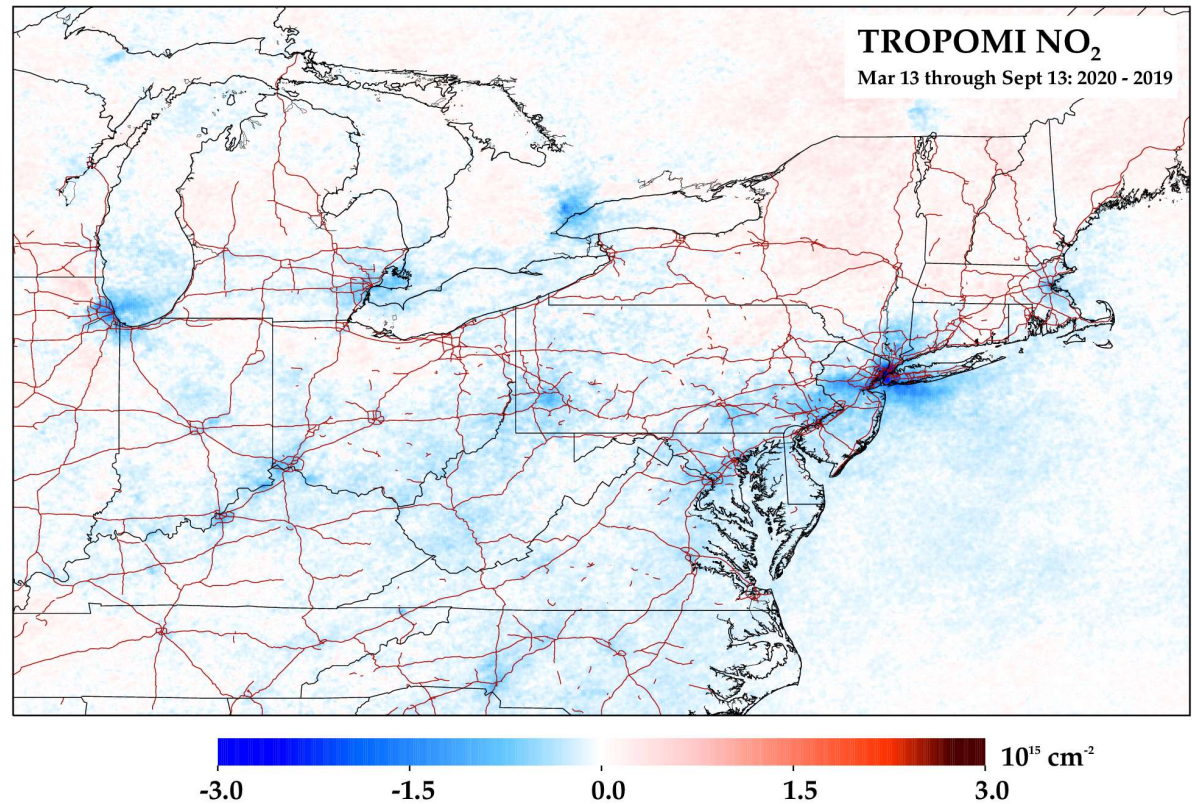
- Often larger NO_x emissions on the hottest days
- Some chemical reactions yield more NO_2 on the hottest days, irrespective of NO_x emissions



What can we learn from COVID-19 lockdowns?



1. What would NO_2 changes look like if meteorology was “normalized” out?
2. What does this reveal about environmental justice issues related to air quality?
3. How did varying degrees of social distancing and urban transportation changes cause these NO_2 decreases?



Disentangling the impact of the COVID-19 lockdowns on urban NO₂ from natural variability



- **Method 0**
TROPOMI NO₂ change 2020 only
(Jan-Feb vs. Mar 15-Apr 30)
- **Method 1 – account for season**
TROPOMI NO₂ 2019 vs. 2020
(Mar 15 – Apr 30)
- **Method 2 – account for season & meteorology**
Normalize TROPOMI NO₂ by meteorology, 2019 v. 2020
(Mar 15 – Apr 30)
- **Method 3 – account for season & meteorology**
TROPOMI NO₂ vs. simulated “normal” times, 2020 only
(Mar 15 – Apr 30)

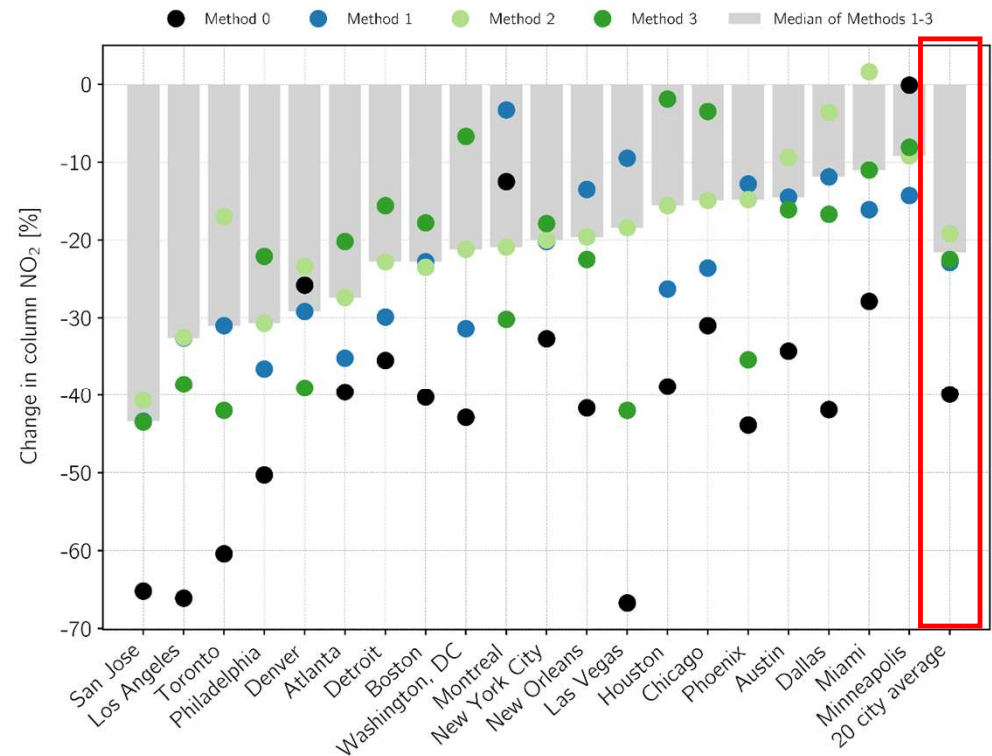
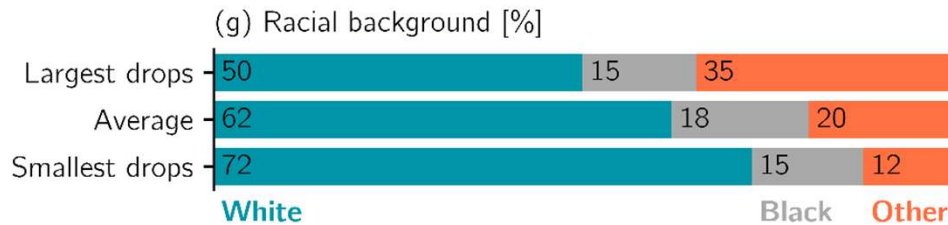
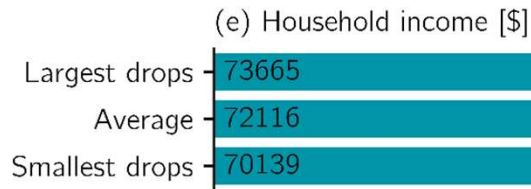
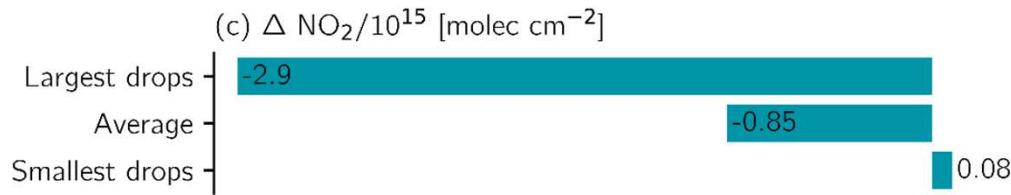


Figure created by Gaige Kerr

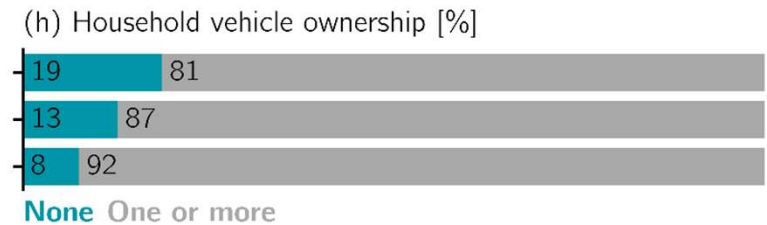
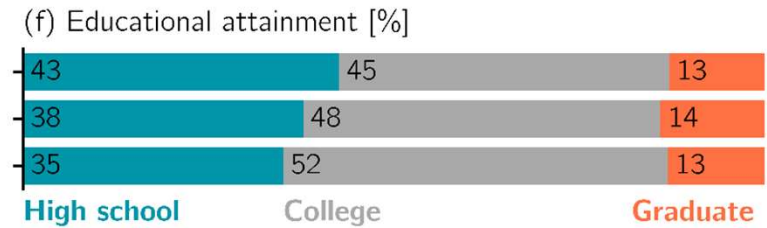
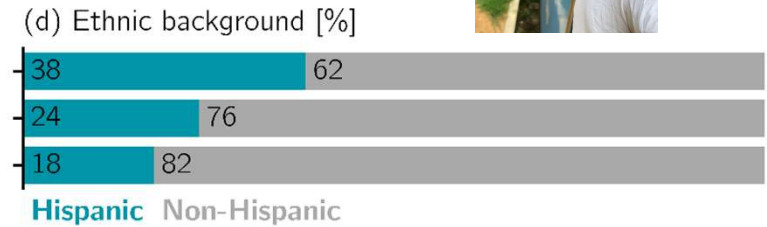
Goldberg et al., GRL 2020

<https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GL089269>

During COVID-19 precautions, less educated, minority communities experience the largest decreases in NO₂



Baseline: 13 March – 13 June 2019
 Lockdown: 13 March – 13 June 2020

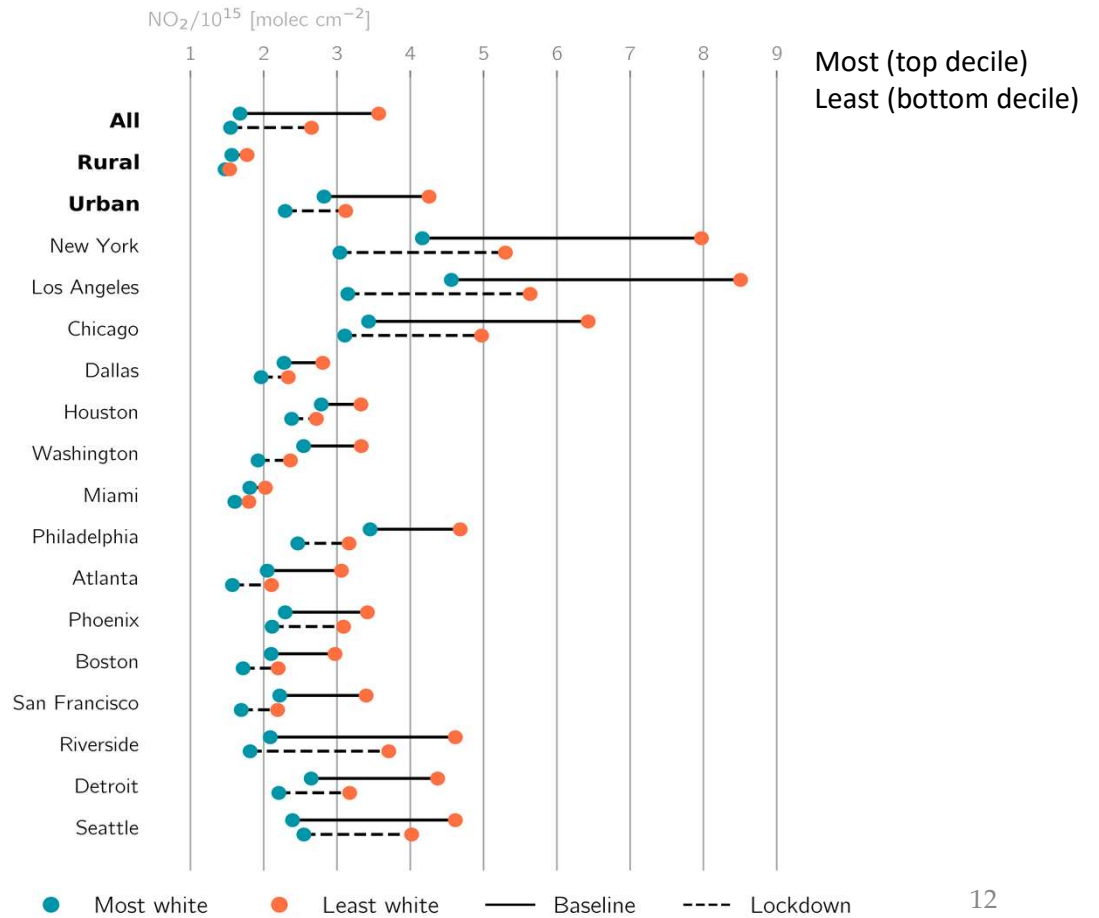


Largest drops (top decile in urban areas)
 Average (middle decile in urban areas)
 Smallest drops (bottom decile in urban areas)

Despite decreases for communities that are less white, lockdowns did not eliminate disparities by race



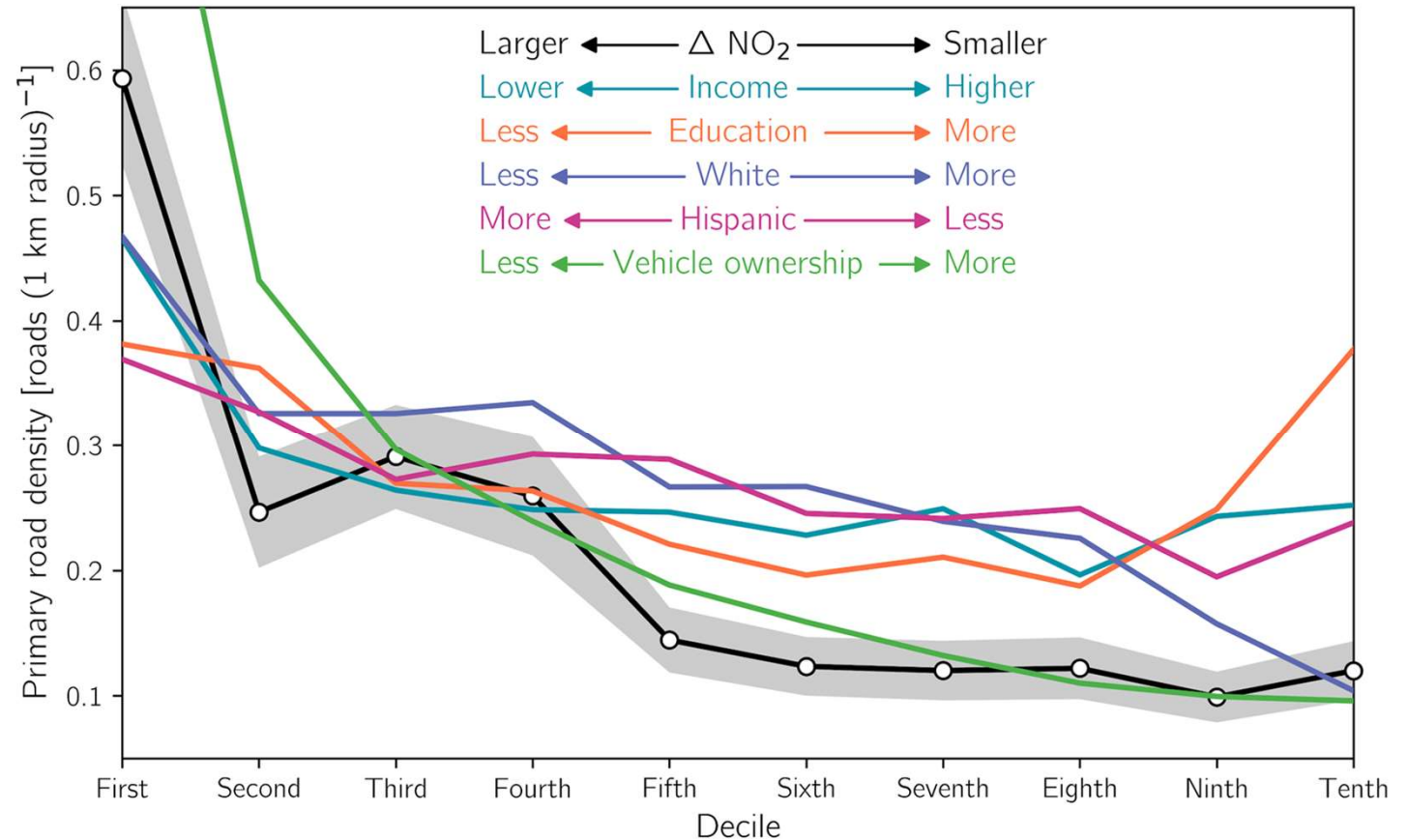
- In many cities, the post-lockdown NO₂ amounts in the least white communities are still ~50% larger than the pre-lockdown NO₂ amounts in the most white communities
- Also holds for income and educational attainment



Density of highways coupled to NO₂ gains and demographics



- Road density highest in tracts with larger NO₂ drops and more racial/ethnic diversity.
- Yet, these tracts also had lower vehicle ownership, suggesting influence from non-local drivers.



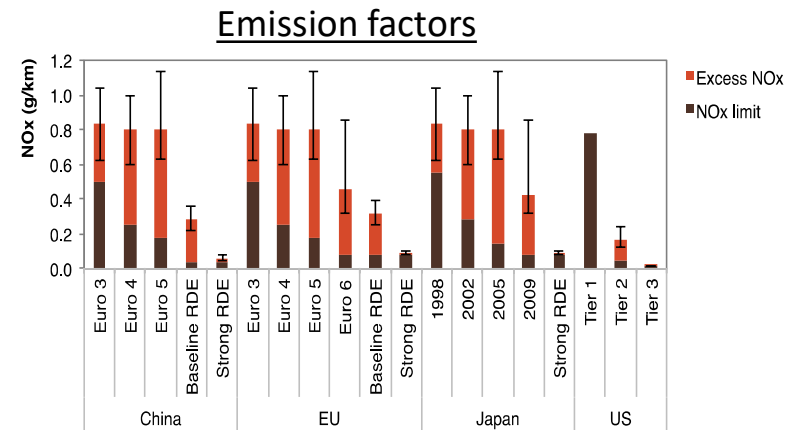
Primary roads = major interstates and highways (generally limited-access)

Next step: Policy implications

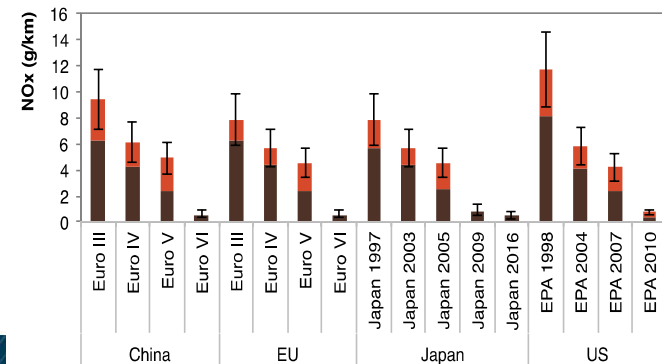


- Future policies aimed at eliminating pollution disparities will need to look beyond reducing emissions from only passenger traffic
- Also consider other collocated sources of emissions such as heavy-duty trucks, power plants, and industrial facilities.

CARS



TRUCKS (scale x10)



Anenberg et al., Nature, 2017

Conclusions



- NO_2 is a substantial contributor to pediatric asthma incidence globally and in the U.S., in addition to its role in O_3 and $\text{PM}_{2.5}$ formation.
- NO_2 drops attributed to COVID-19 lockdowns (anthropogenic forcing) ranged between 9.2% and 43.4% among 20 cities in North America, with a median of 21.6%.
- Meteorological patterns were favorable for low NO_2 in eastern U.S. in spring 2020, complicating comparisons with spring 2019.
 - Weather variations between years can cause NO_2 differences of ~15% over monthly timescales.
- Urban neighborhoods with a high percentage of racial and ethnic minorities and lower educational attainment experienced the largest reductions in NO_2 during lockdowns, but the lockdowns did not eliminate disparities.
 - In some cases, NO_2 in the most-white neighborhoods pre-pandemic was still lower than NO_2 in least-white neighborhoods post-pandemic.

Manuscript/Publications



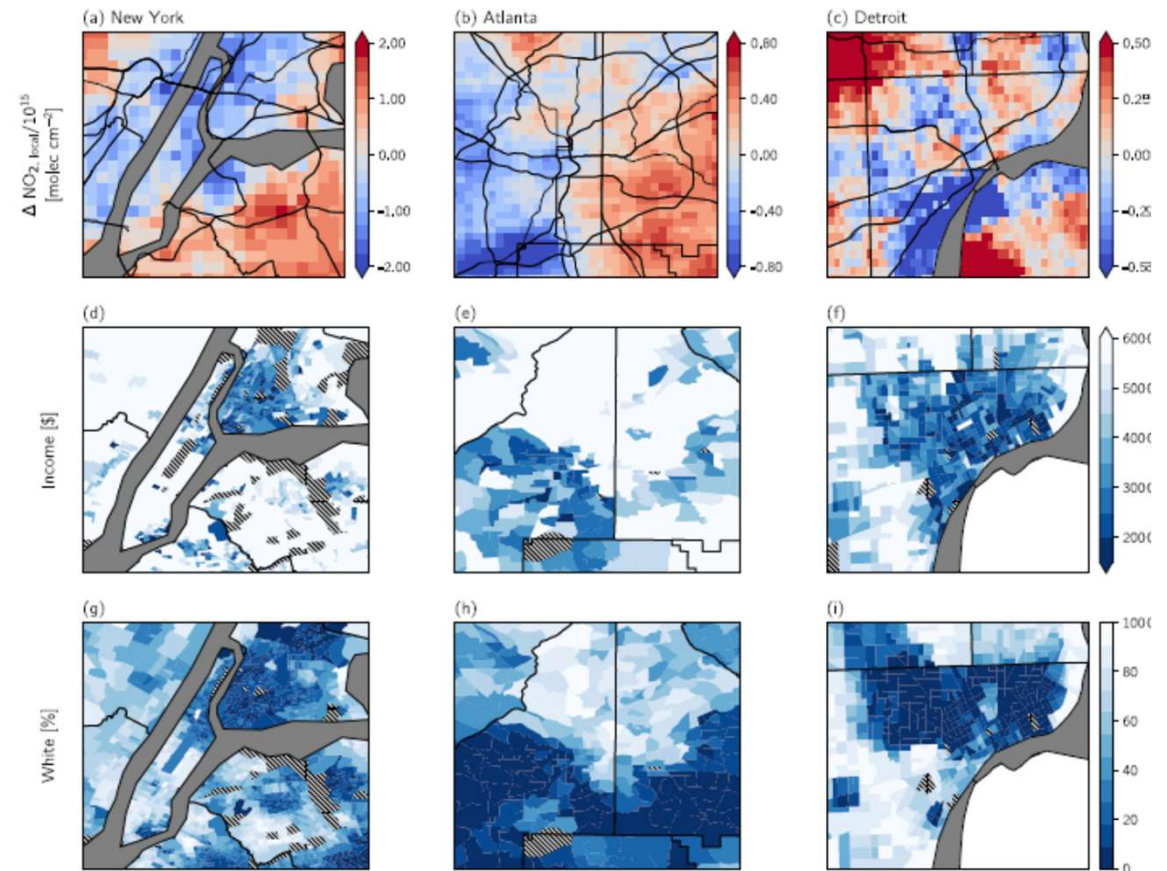
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- Goldberg, D.L., S.C. Anenberg, Z. Lu, D.G. Streets, D. Griffin, C.A. McLinden (2020) Disentangling the impact of the COVID-19 lockdowns on urban NO₂ from natural variability. *Geophysical Research Letters*, <https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GL089269>
- Goldberg D.L., Anenberg S.C., Mohegh A., Lu Z., Streets D.G. TROPOMI NO₂ in the United States: A detailed look at the annual averages, weekly cycles, effects of temperature, and correlation with PM_{2.5}. Pre-print, <https://www.essoar.org/doi/abs/10.1002/essoar.10503422.1>
- Kerr, G., Goldberg, D.L., S.C. Anenberg. Impact of the COVID-19 lockdowns on environmental justice issues related to NO₂ pollution, in prep.

extra

Case studies for individual cities



Intersectionality between race and poverty may be associated with even more pronounced lockdown-related drops in NO₂ pollution.



Primary roads = major interstates and highways (generally limited-access)