Inconsistent effects of COVID-19 social distancing on air quality in global cities: Lessons for protecting near-term public health and designing longer-term urban transportation policies

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THE GEORGE WASHINGTON UNIVERSITY

Objectives

1. How are *NO_2 concentrations changing* in cities due Covid-19 precautions, and how does this affect environmental justice issues?
2. What is the role of *weather versus emissions* in the observed NO_2 declines in different cities following social distancing?
3. What is the role of changes in *different emissions sources*, in the inconsistent trends in NO_2 concentrations in different cities during social distancing?

Technical approach

- Utilize oversampled images (averages over many days) from TROPOMI to identify NO_2 changes in North American cities
- Couple the TROPOMI NO_2 data to ERA-5 re-analysis to disentangle the effects of meteorology on urban NO_2, in order to isolate the anthropogenic signal
- Use granular traffic data for individual cities to tease out the effects of changing transportation patterns on urban NO_2
- Discuss with stakeholders (C40 and International Council on Clean Transportation) along the way, getting feedback on a monthly basis.

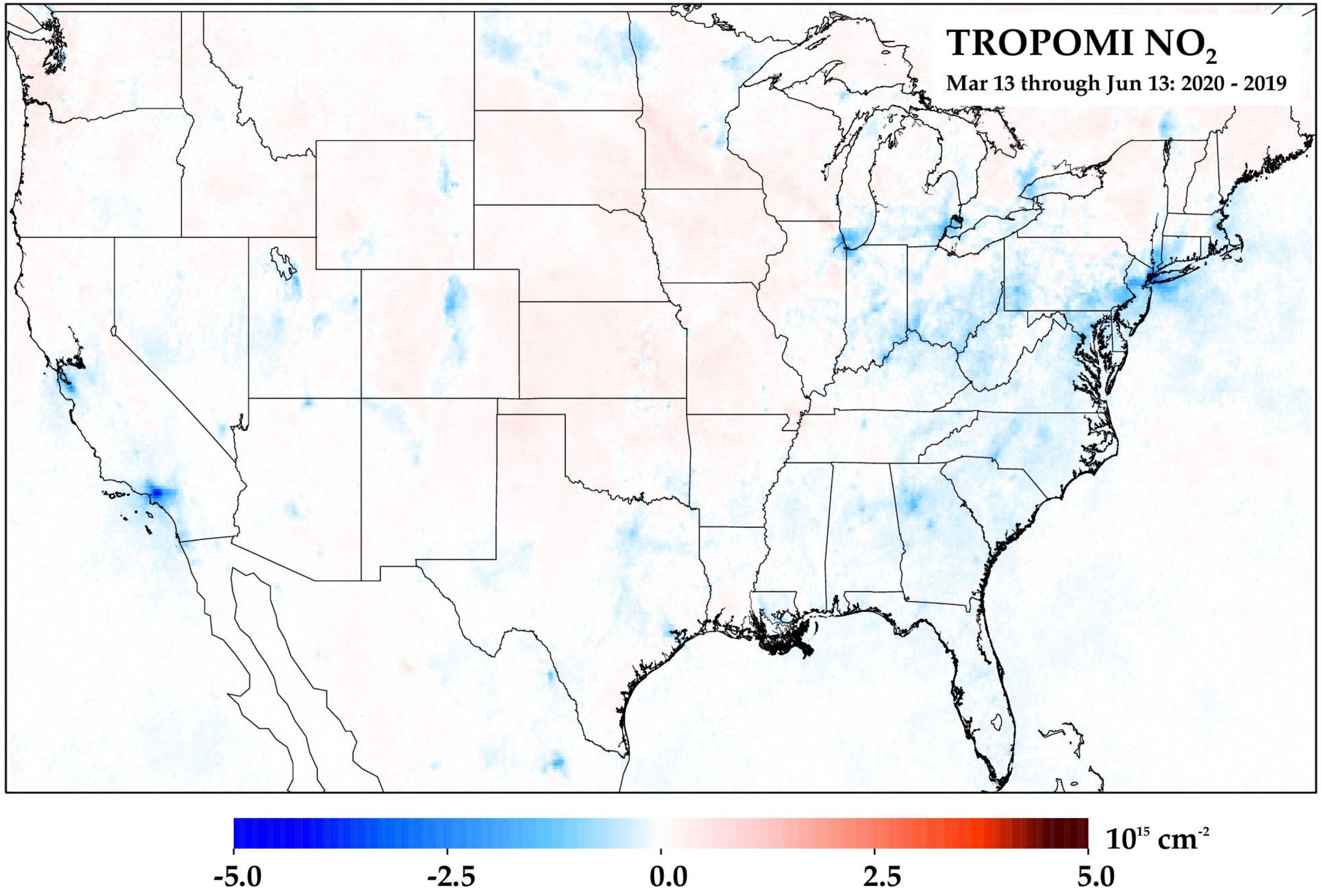
Project team and organization

- Co-PI’s: Dr. Susan Anenberg & Dr. Daniel Goldberg
- Postdoctoral scientist: Dr. Gaige Kerr
- Collaborators:
    - Dr. Zifeng Lu, Argonne National Laboratory
    - Dr. Debora Griffin, Environment & Climate Change Canada
    - Dr. Chris McLinden, Environment & Climate Change Canada
    - Dr. Bryan Duncan, NASA Goddard Space Flight Center
    - Ray Minarjes, International Council of Clean Transportation
    - Josh Miller, International Council of Clean Transportation
    - Joel Dreessen, Maryland Department of the Environment
- Stakeholder organizations:
    - C40 cities
    - International Council of Clean Transportation
    - State environmental agencies (e.g., Maryland)

TROPOMI NO_2: Difference between 2019 vs. 2020

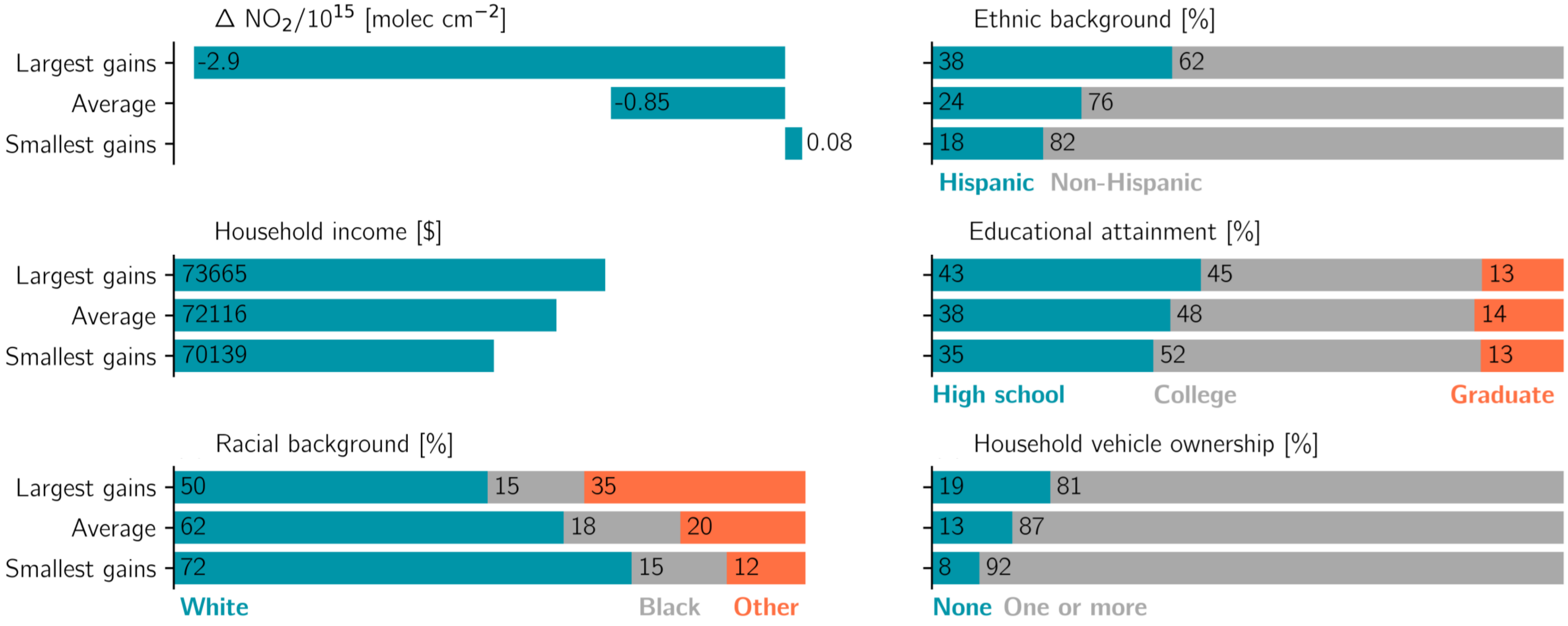
- As compared to 2019, *the first three months* of the 2020 COVID-19 lockdowns caused NO_2 to decrease in North American cities, but to varying degrees.

- Three questions arose to us:
    1. How does this affect environmental justice issues related to air quality?
    2. Would would this look like if meteorology was “normalized” out?
    3. How did varying degrees of social distancing and urban transportation changes cause these NO_2 decreases?



During COVID-19 precautions, less educated, minority communities experience the largest decreases in NO_2

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



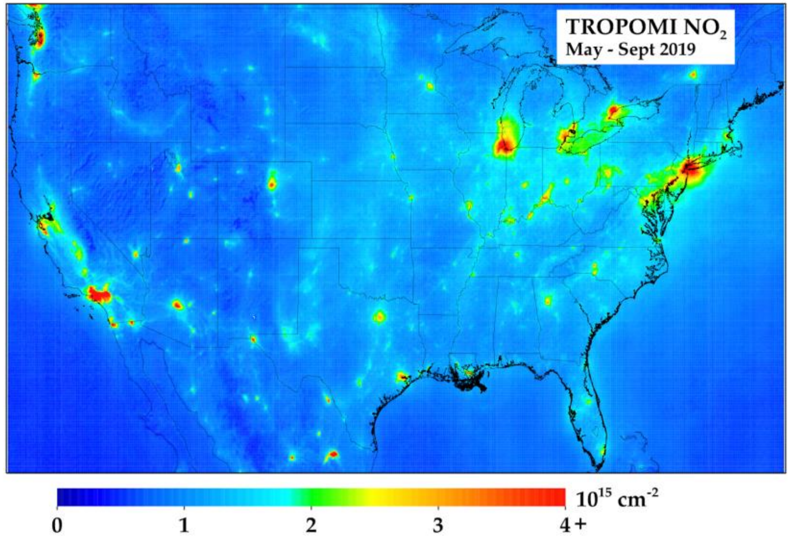
Despite decreases for communities that are less White, lockdowns did not eliminate disparities by race

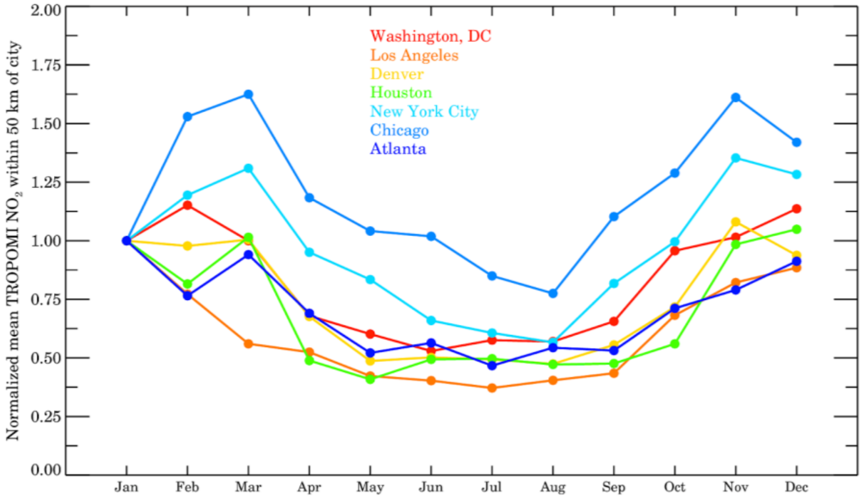
- In many cities, the post-lockdown NO_2 amounts in the Least white communities are still larger than the pre-lockdown NO_2 amounts in U.S. cities (NYC, LA & Chicago are examples)

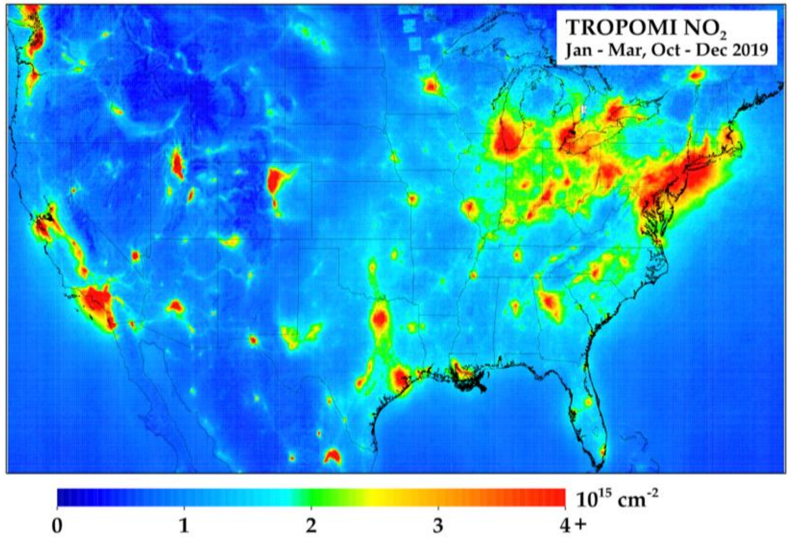
Most (top decile within urban area)
Least (bottom decile within urban area)

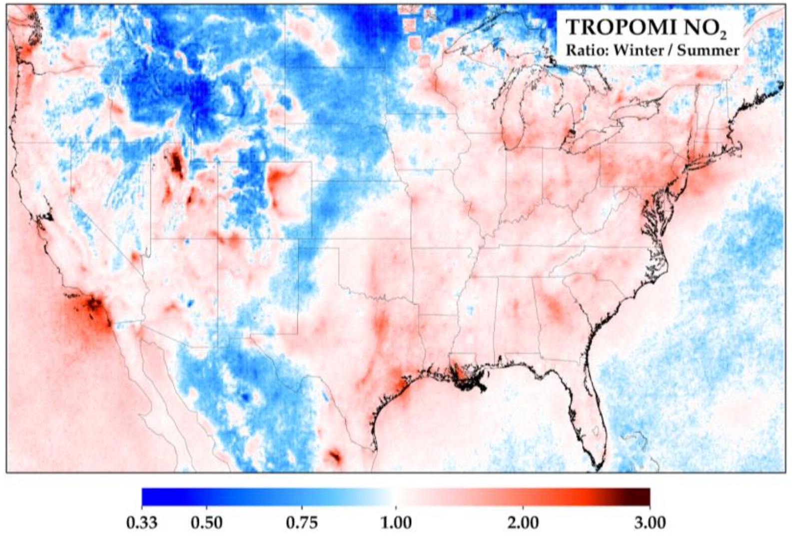
Isolating the anthropogenic signal using TROPOMI NO_2: Warm season vs. cold season

- NO_2 amounts are always less during the summer as compared to winter. This is due to the shorter NO_2 during summer.
- If we were to directly compare February 2020 NO_2 concentrations to July 2020 NO_2 concentrations, some fraction of this change would be due to lifetime changes



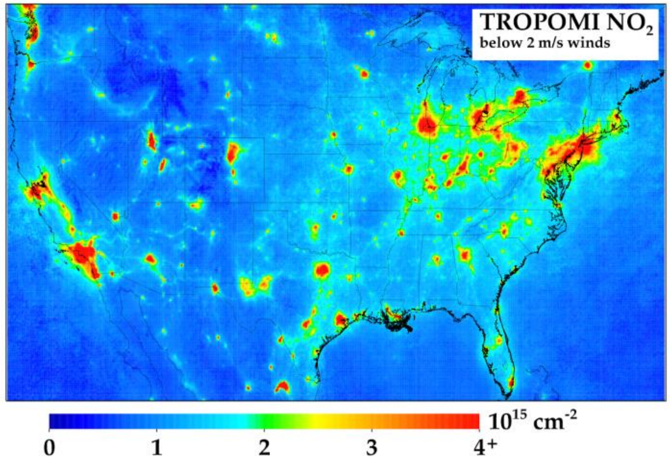


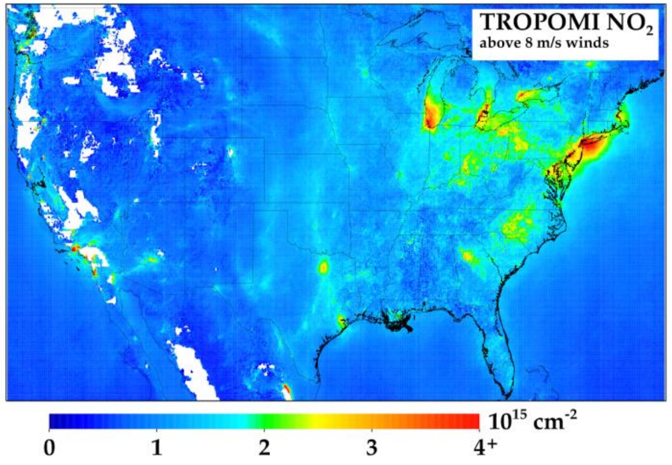


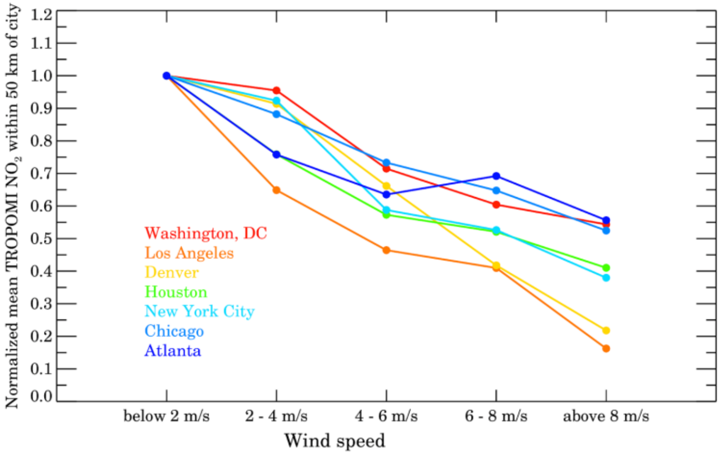


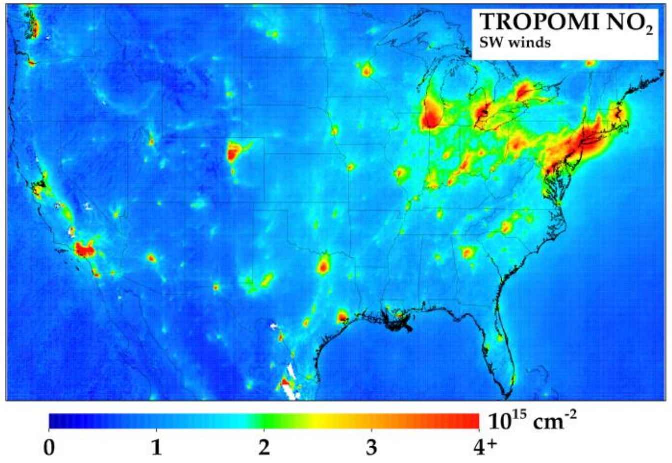
Isolating the anthropogenic signal using TROPOMI NO_2: Effects of wind speed & direction

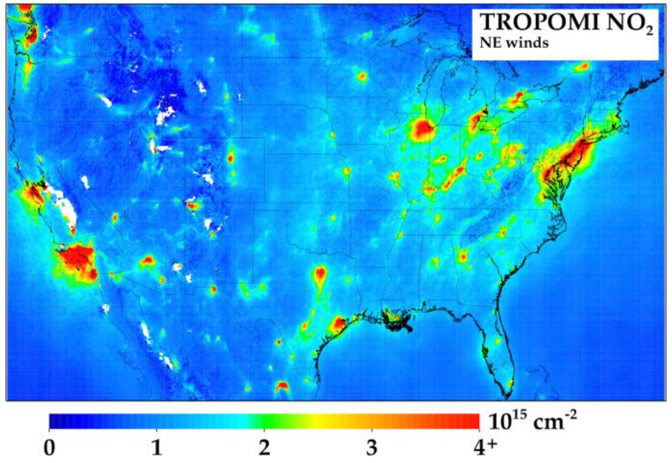
- Similarly, wind speed and direction can have dramatic effects on NO_2 concentrations in urban areas

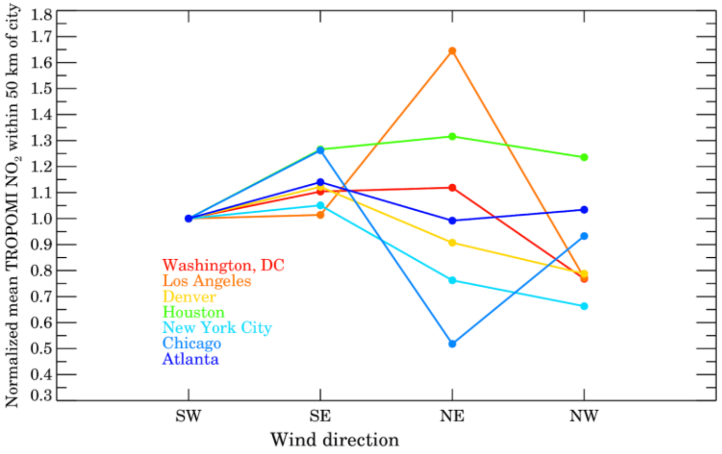












Estimated changes in anthropogenic NO_X due to COVID-19 precautions (*through April 30, 2020 only*)

Largest NO_2 drops in San Jose, Los Angeles, & Toronto

Smallest NO_2 drops in Dallas, Miami & Minneapolis

Weather favorable for lower NO_2 (e.g., winder): Washington DC & Miami

Weather favorable for larger NO_2 (e.g., stagnant): Montreal, New Orleans & Las Vegas

Table 1
Percentage Drop in Column NO_2 as Observed by TROPOMI

City name	Reference case Method 0: Δ between months 2020 only (January–February vs. 15 March to 30 April)	Account for solar zenith angle only Method 1: Δ between years 2019 vs. 2020 (15 March to 30 April)	Account for solar zenith angle and meteorology Method 2: Using ERA5 analogs to account for meteorology 2019 versus 2020 (15 March to 30 April)	Account for solar zenith angle and meteorology Method 3: Using GEM-MACH to infer NO_2, 2020 only (15 March to 30 April)	Mean of methods 1–3	Median of methods 1–3
San Jose	65.2%	43.4%	40.7%	43.5%	42.5%	**43.4%**
Los Angeles	66.1%	32.6%	32.5%	38.6%	34.6%	**32.6%**
Toronto	60.4%	31.0%	17.0%	42.0%	30.0%	**31.0%**
Philadelphia	50.3%	36.6%	30.7%	22.1%	29.8%	**30.7%**
Denver	25.8%	29.2%	23.4%	39.1%	30.6%	**29.2%**
Atlanta	39.6%	35.2%	27.4%	20.2%	27.6%	**27.4%**
Detroit	35.5%	29.9%	22.8%	15.6%	22.8%	**22.8%**
Boston	40.3%	22.8%	23.5%	17.8%	21.4%	**22.8%**
Washington DC	42.9%	31.4%	21.2%	6.7%	19.8%	**21.2%**
Montreal	12.5%	3.3%	20.9%	30.2%	18.1%	**20.9%**
New York City	32.7%	20.2%	20.0%	17.9%	19.4%	**20.0%**
New Orleans	41.7%	13.5%	19.6%	22.5%	18.5%	**19.6%**
Las Vegas	66.7%	9.5%	18.4%	42.0%	23.3%	**18.4%**
Houston	38.9%	26.3%	15.6%	1.9%	14.6%	**15.6%**
Chicago	31.0%	23.6%	14.9%	3.5%	14.0%	**14.9%**
Phoenix	43.9%	12.8%	14.8%	35.4%	21.0%	**14.8%**
Austin	34.3%	14.5%	9.4%	16.1%	13.3%	**14.5%**
Dallas	41.9%	11.9%	3.6%	16.7%	10.7%	**11.9%**
Miami	27.9%	16.1%	−1.6%	11.0%	8.5%	**11.0%**
Minneapolis	0.1%	14.3%	9.2%	8.1%	10.5%	**9.2%**
Mean of each method	39.9%	22.9%	19.2%	22.5%	21.6%	**21.6%**

Scientific accomplishments so far

1. Near real-time documentation of NO_2 changes in global cities (https://so2.gsfc.nasa.gov/tropno2/tropno2_index.html)
2. Investigated how NO_2 changes in disadvantaged communities compare to changes in other communities
3. Developed a methodology to isolate meteorological effects on urban NO_2 in order to isolate the anthropogenic change in cities

C40 Cities – on-going discussion on how on knowledge learned from this project will help global cities

- Partners at C40 are in contact with the local governments of 13+ cities worldwide to gauge interest on collaboration and to better understand how our work can be policy-relevant

- **Auckland** - Waiting for update on activity and fuel mix details
- **Barcelona** - Has already accounted for meteorological and emission changes in the city's original COVID-19 assessment thus the GW project won't add value - city was not included in the first round of calls.
- **Berlin** - We have everything we need
- **Bogota** - We have everything we need
- **Durban** - Waiting for update on activity and fuel mix details
- **Lima** - Waiting for update on activity and fuel mix details
- **London** - We have everything we need
- **Los Angeles** - We have everything we need
- **Medellin** - Waiting for update on activity details
- **Mexico City** - They rely on Waze and TomTom for traffic data since August 2019 - otherwise we have everything we need
- **Milan** - Waiting for activity and fuel mix details
- **Paris** - We have everything we need
- **Santiago** - Waiting for activity and fuel mix details

Successes and challenges

- Successes:
  - Quick turn-around of information; critical for stakeholder organizations
  - Somewhat surprising results regarding environment justice work; did not expect NO_2 drops in disadvantaged communities to be so large
  - Implemented a strategy to account for meteorological effects on NO_2 in near-real-time
- Challenges: obtaining traffic & fuel data in cities worldwide; changing stringency of lockdowns sometimes on a weekly basis and can vary dramatically by region & country
- Next priorities: teasing out impacts of social distancing & urban transportation on NO_2 concentrations and NO_X emissions

Manuscript/Publications

- 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.
- Kerr, G., Goldberg, D.L., S.C. Anenberg. Impact of the COVID-19 lockdowns on environmental justice issues related to NO_2 pollution, in prep.