NO_2 changes during COVID-19 lockdowns in North America

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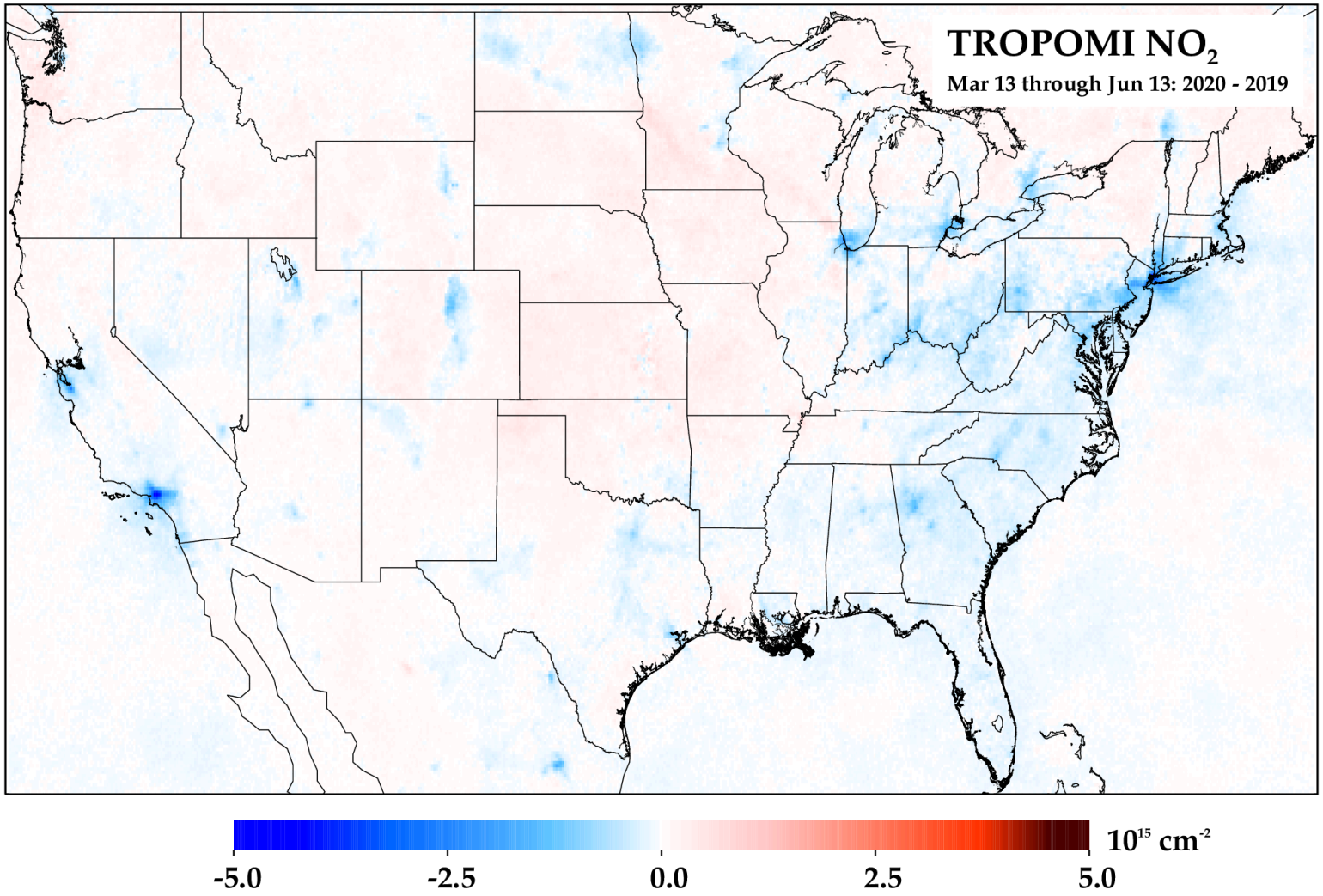
TROPOMI NO_2: Difference between 2019 vs. 2020

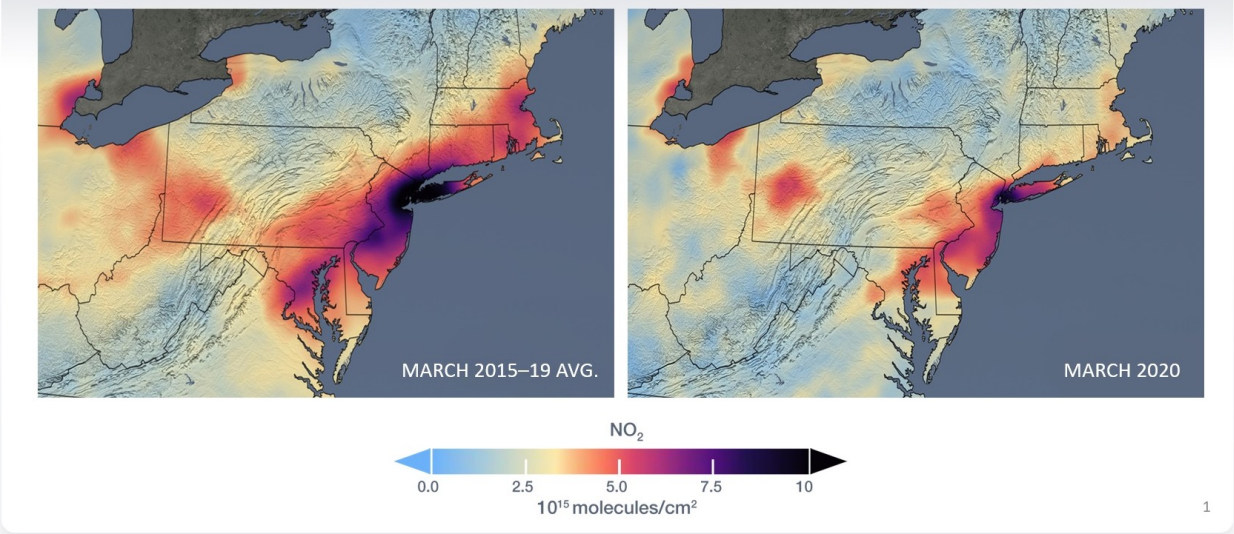
- As compared to 2019, *the first three months* of the 2020 COVID-19 lockdowns caused NO_2 to decrease in North American cities, but to varying degrees.

- Three questions arose to us:
  1. What would this 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?

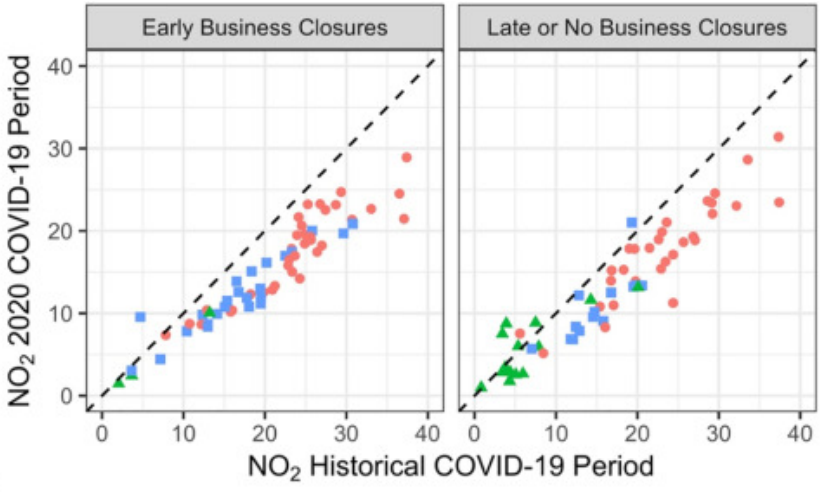


Multiple methods point to major NO_2 drops in U.S.

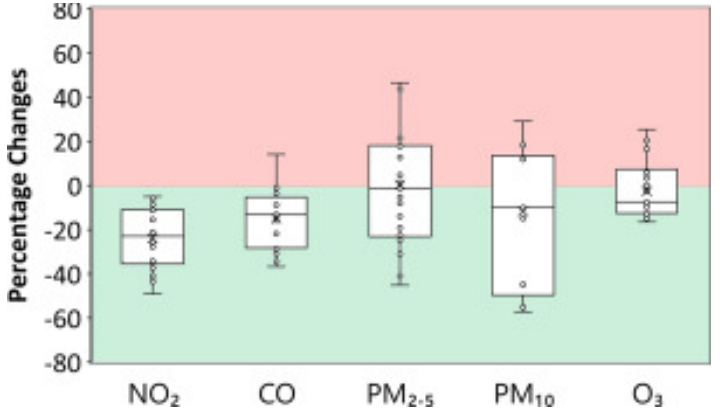
NASA, 2020
OMI (NE U.S.; 5 year avg. vs. 2020)



Berman and Ebisu, STE, 2020
Monitors



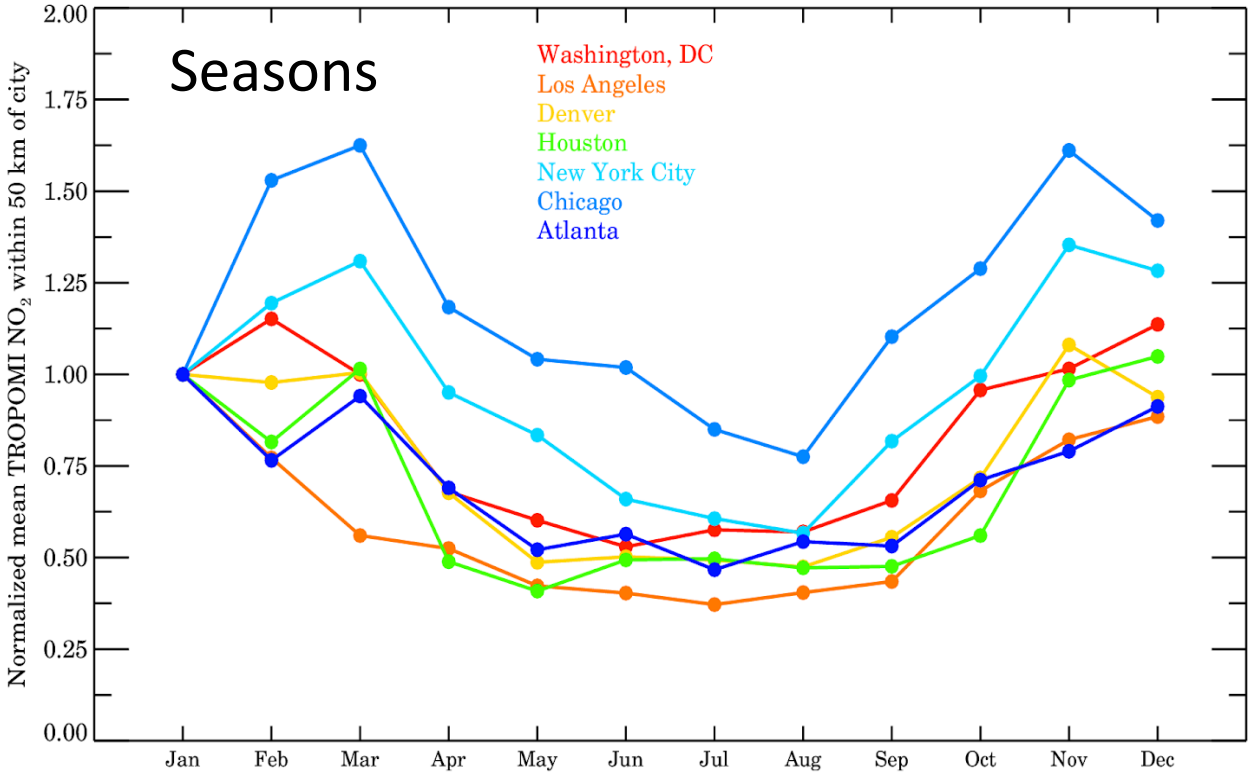
Chen et al., STE, 2020
Monitors

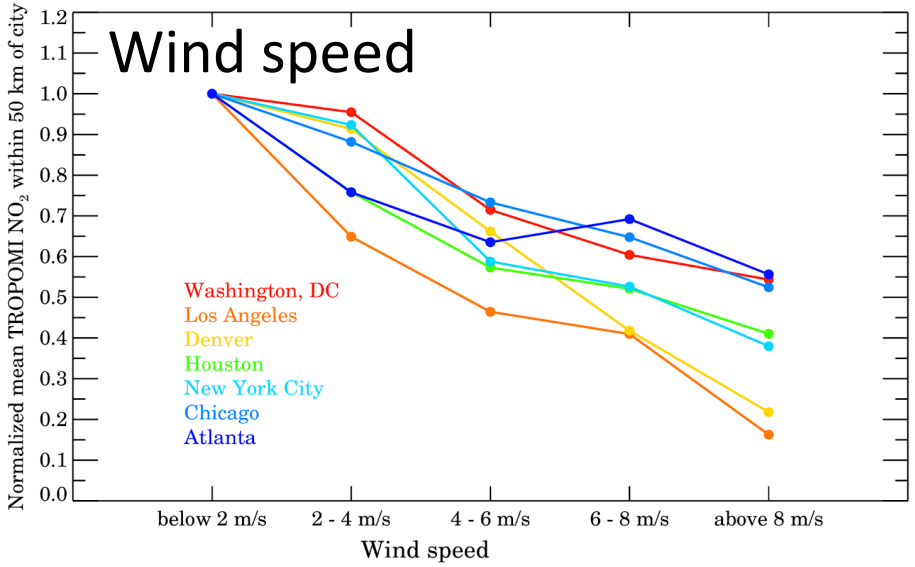


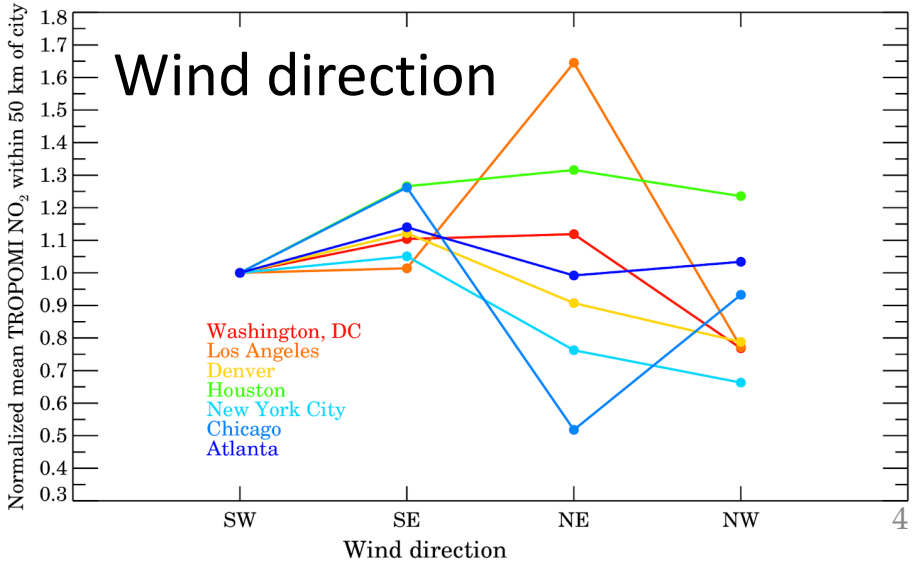
Naeger and Murphy, AAQR, 2020
TROPOMI, monitors (California)

Year	Los Angeles		San Francisco		Fresno		Bakersfiled	
	NO_2	$PM_{2.5}$	NO_2	$PM_{2.5}$	NO_2	$PM_{2.5}$	NO_2	$PM_{2.5}$
2019	16.2	10.2	12.8	5.4	7.3	6.4	10.0	7.2
2020	10.1	6.5	8.9	3.9	4.9	4.2	7.4	5.4
2020–2019	**37.7**	**36.3**	**30.5**	**27.8**	**32.9**	**34.4**	**26.0**	**25.0**

Natural influences on TROPOMI NO_2







Goldberg et al. submitted
https://www.essoar.org/doi/10.1002/essoar.10503422.1

Disentangling the impact of the COVID-19 lockdowns on urban NO_2 from natural variability

- **Method 0**
  TROPOMI NO_2 change 2020 only
  (Jan-Feb vs. Mar 15-Apr 30)
- **Method 1 – account for season**
  TROPOMI NO_2 2019 vs. 2020
  (Mar 15 – Apr 30)
- **Method 2 – account for season & meteorology**
  Normalize TROPOMI NO_2 by meteorology, 2019 v. 2020
  (Mar 15 – Apr 30)
- **Method 3 – account for season & meteorology**
  TROPOMI NO_2 vs. simulated "normal" times, 2020 only
  (Mar 15 – Apr 30)

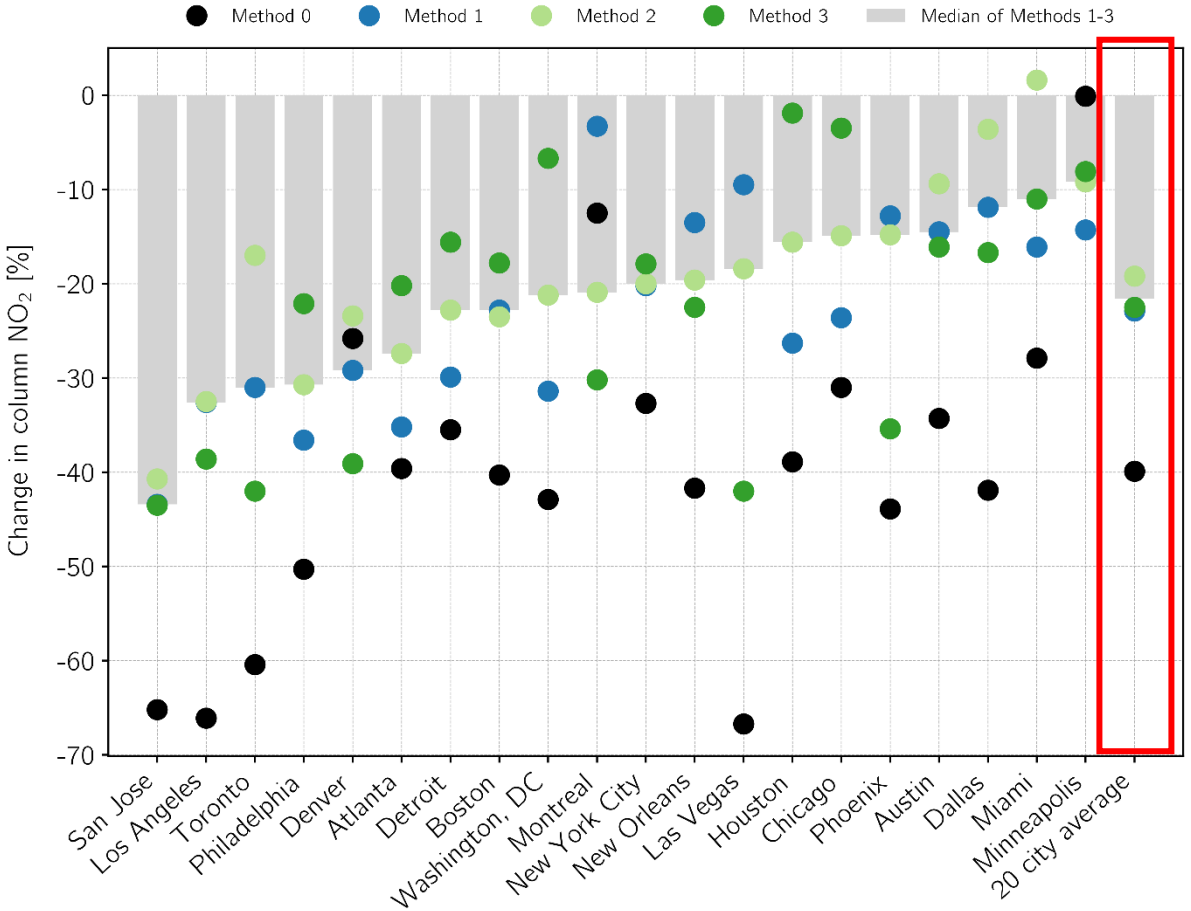
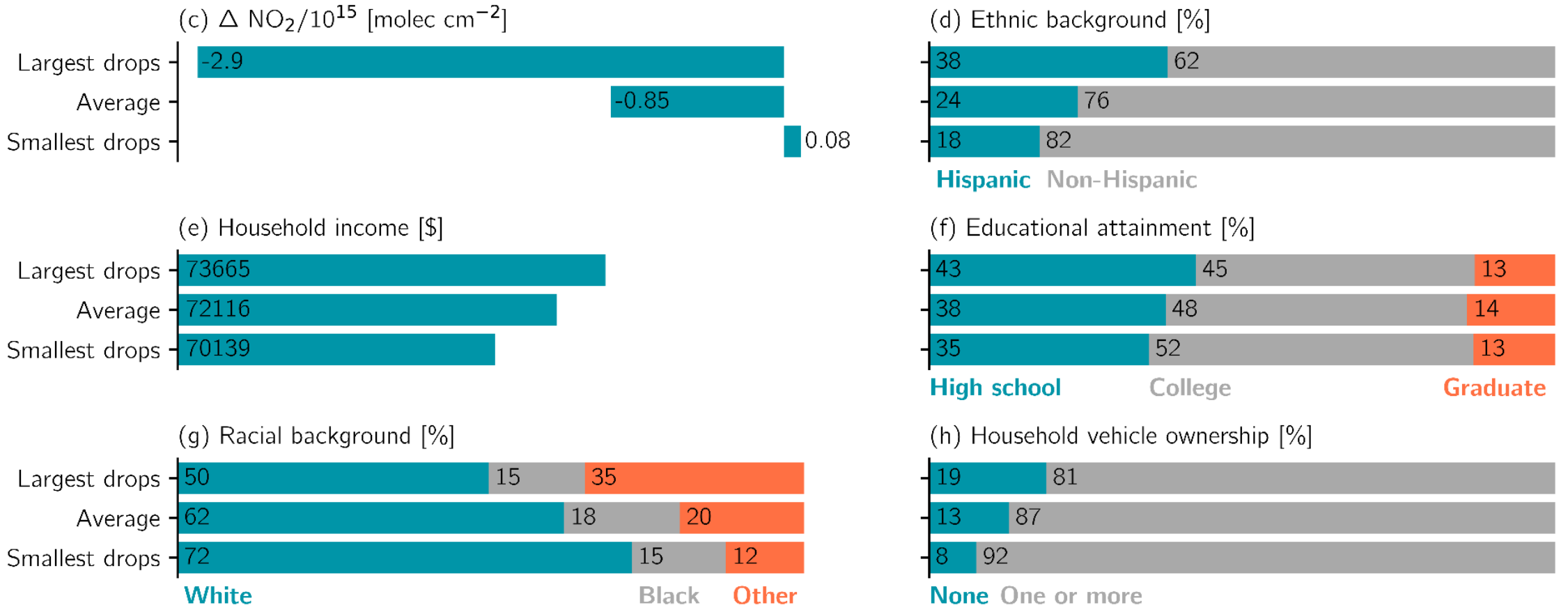


Figure created by Gaige Kerr

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 NO_2



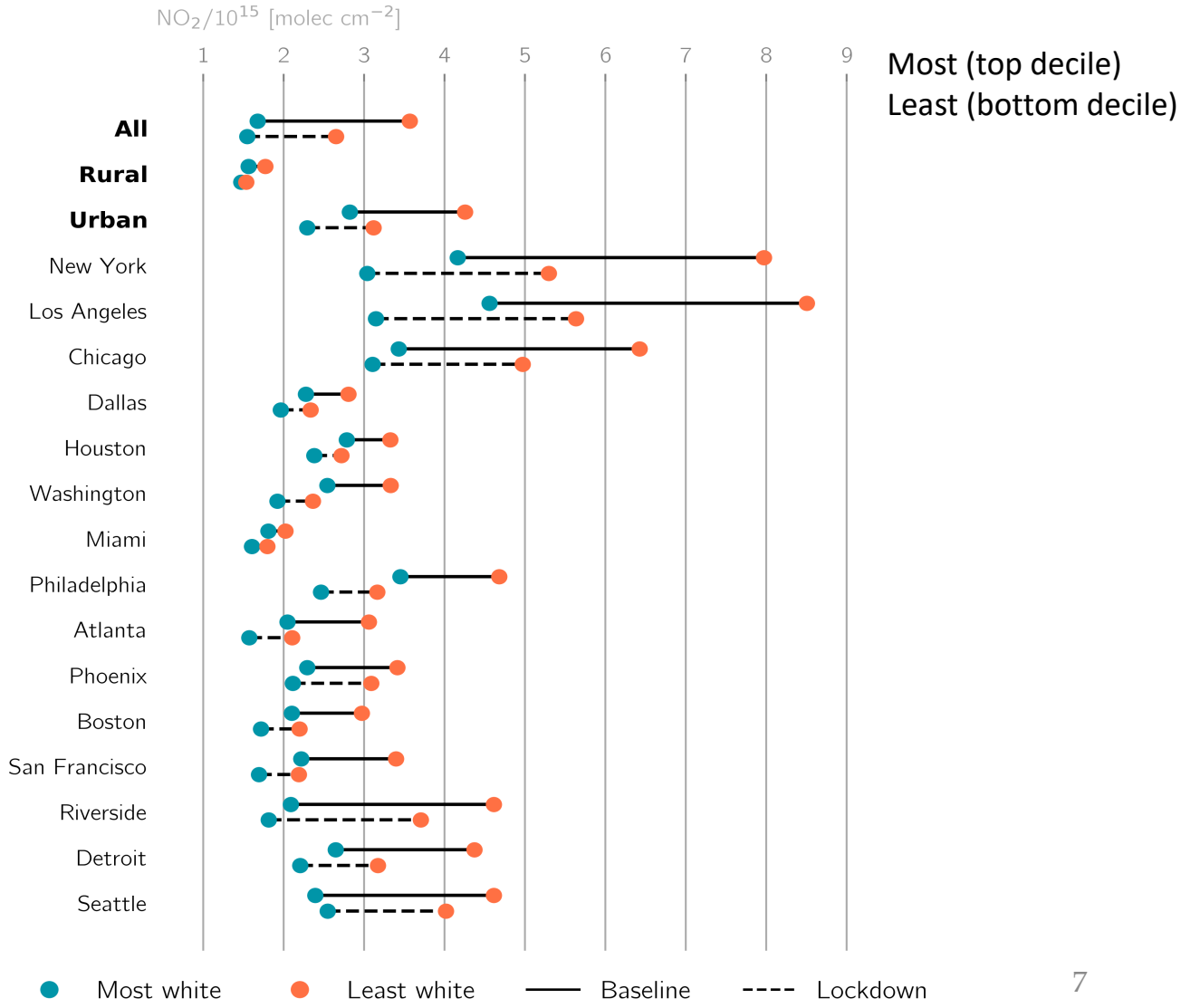
Baseline: 13 March – 13 June 2019
Lockdown: 13 March – 13 June 2020

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

Kerr et al. submitted
https://www.essoar.org/doi/pdf/10.1002/essoar.10504561.1

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

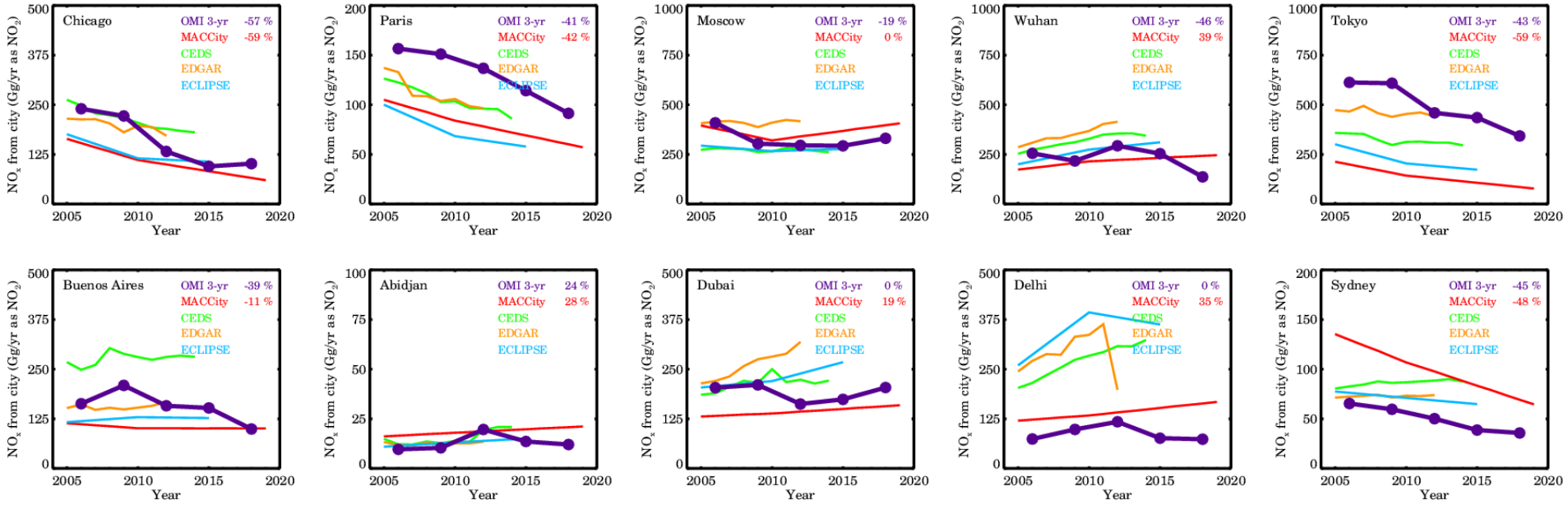
- In many cities, the post-lockdown NO_2 amounts in the least white communities are still ~50% larger than the pre-lockdown NO_2 amounts in the most white communities
- Also holds for income and educational attainment



Kerr et al. submitted
https://www.essoar.org/doi/pdf/10.1002/essoar.10504561.1

Conclusions and next steps

- After accounting for sun angle and meteorological considerations, NO_2 drops ranged between 9.2 – 43.4% among 20 cities in North America, with a median of 21.6%.
- The least white tracts still had ~50% higher NO_2 levels during the lockdowns than the most white tracts had prior to the pandemic
- Next steps
  - Role of light-duty vs. heavy-duty trucks/buses, power plants, industrial facilities
  - Compare top-down OMI-derived NOx emissions versus bottom-up inventories



Goldberg et al., in preparation

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.
- Goldberg, D.L., S. Anenberg, A. Mohegh, Z. Lu, D.G. Streets (2020) TROPOMI NO2 in the United States: A detailed look at the annual averages, weekly cycles, effects of temperature, and correlation with PM2.5, under review. https://www.essoar.org/doi/10.1002/essoar.10503422.1
- Kerr, G., Goldberg, D.L., S.C. Anenberg. COVID-19 lockdowns reveal pronounced disparities in nitrogen dioxide pollution levels, under review. https://www.essoar.org/doi/pdf/10.1002/essoar.10504561.1