Inconsistent Effects of Covid-19 Lockdowns on NO_2 Pollution in Cities:

Evidence from Satellite Remote Sensing and Chemical Transport Modeling

Dr. Susan Anenberg

COSEG webinar July 14, 2020

Thanks to: Dan Goldberg, Zifeng Lu, Chris McLinden, Debora Griffin

Support from: NASA HAQ, RRNES

Milken Institute School of Public Health

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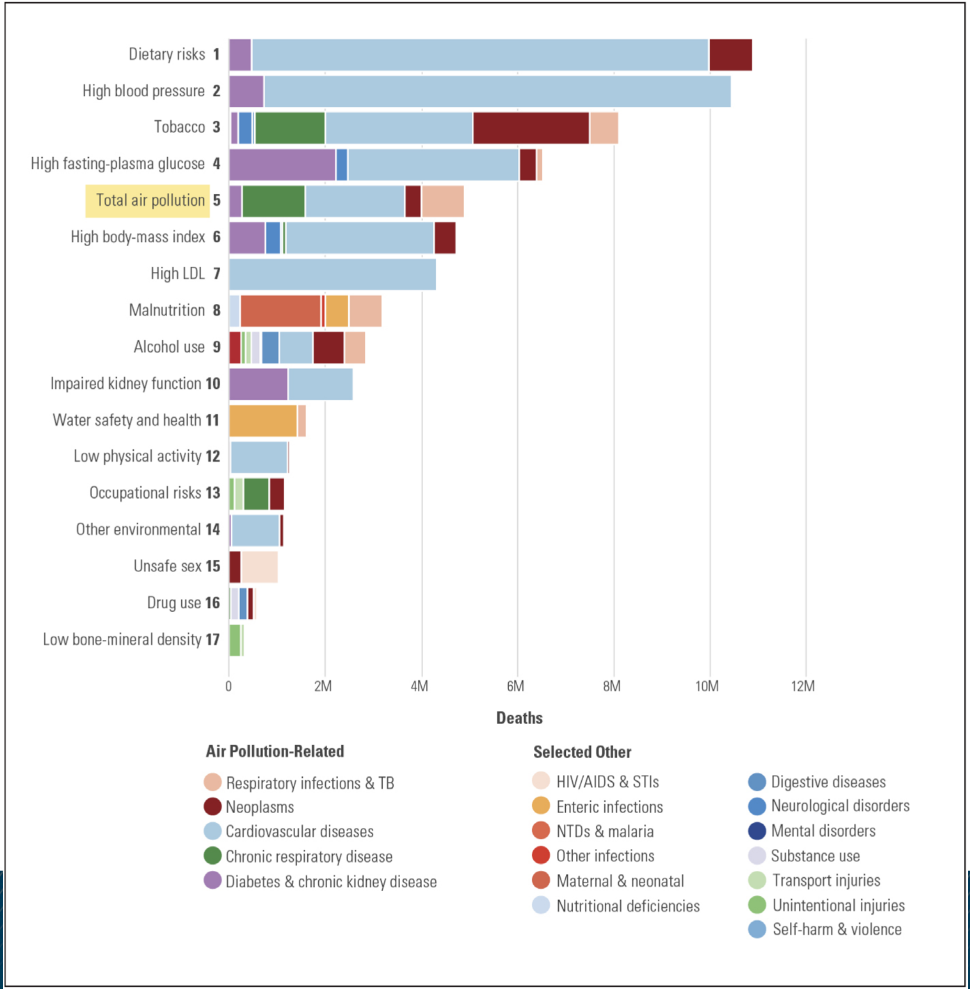
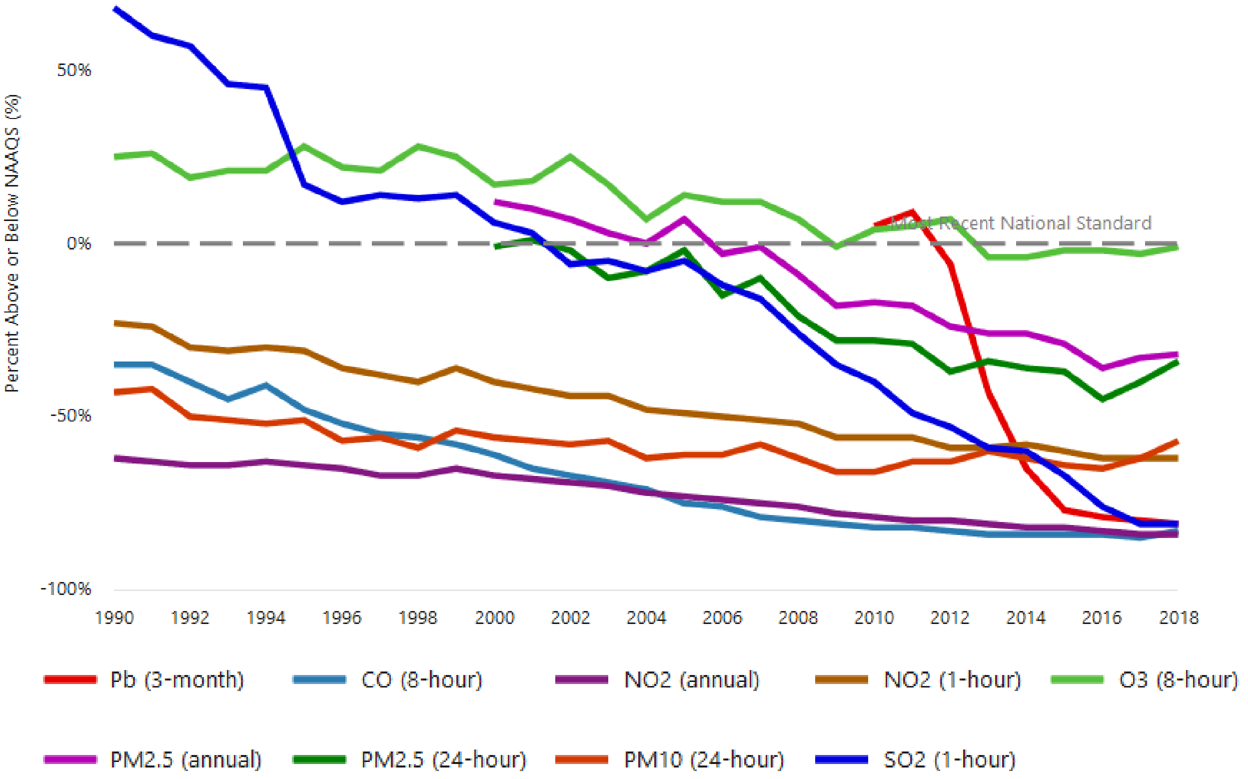
Global ranking of risk factors by total number of deaths (2017)

- Outdoor fine particulate matter ($PM_{2.5}$)
- Household air pollution
- Ambient ozone

Health Effects Institute
State of Global Air 2019 Report

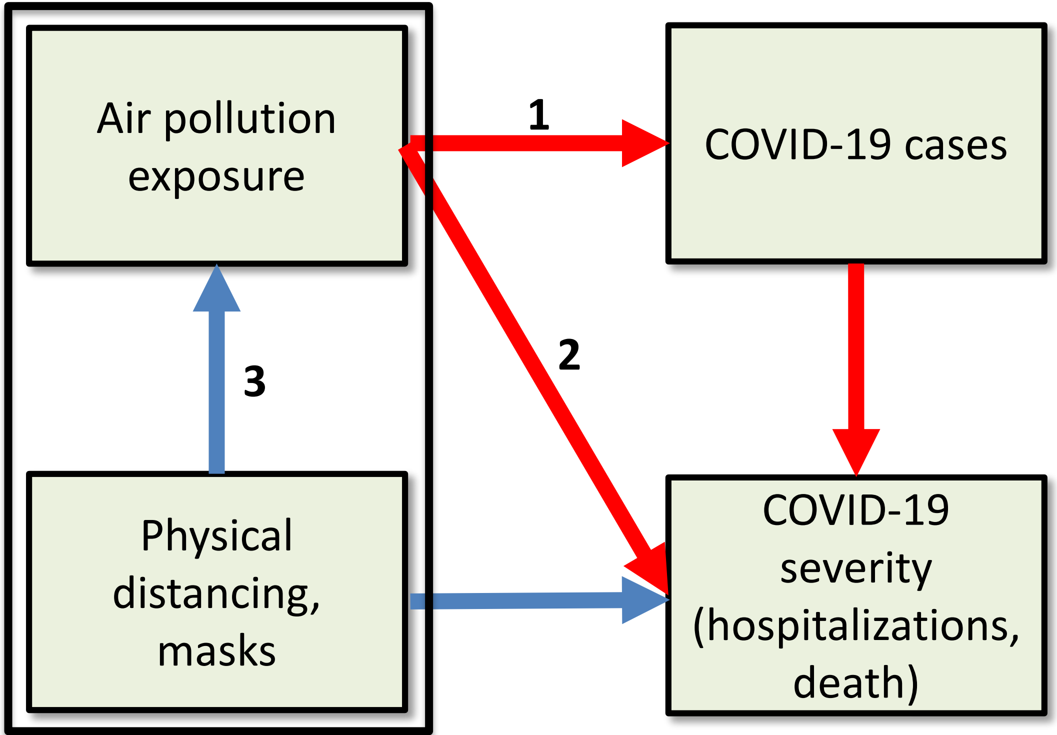


Air pollutants decline due to 1990 Clean Air Act



EPA 2019 Trends Report

Air pollution, COVID-19, and public health



Arrows show effect is hypothesized to improve or worsen outcome

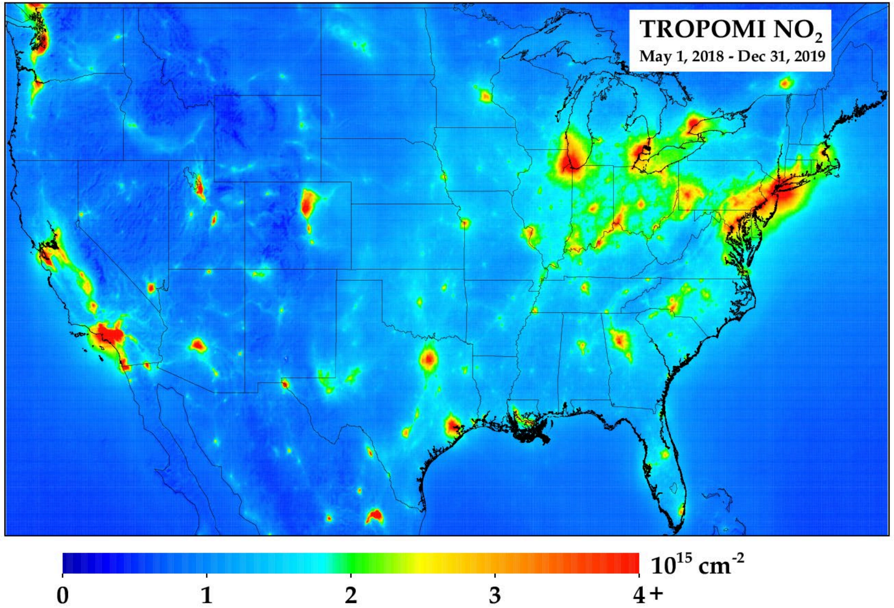
- Interactions
  1. Air pollution may contribute to COVID-19 <u>spread</u>
  2. Air pollution exposure may contribute to COVID-19 severity
  3. Physical distancing has affected air quality levels
- Research needed to inform:
  - The public health response to COVID-19
  - Longer-term environmental policies
  - Approaches for improving health equity

Why study NO_2

1. Early results that air pollution contributes to **COVID-19 severity**
2. NO_2 is a tracer for urban traffic - **environmental policy planning**
3. NOx emissions are precursors to **$PM_{2.5}$ and ozone**
4. NO_2 associated with **asthma**

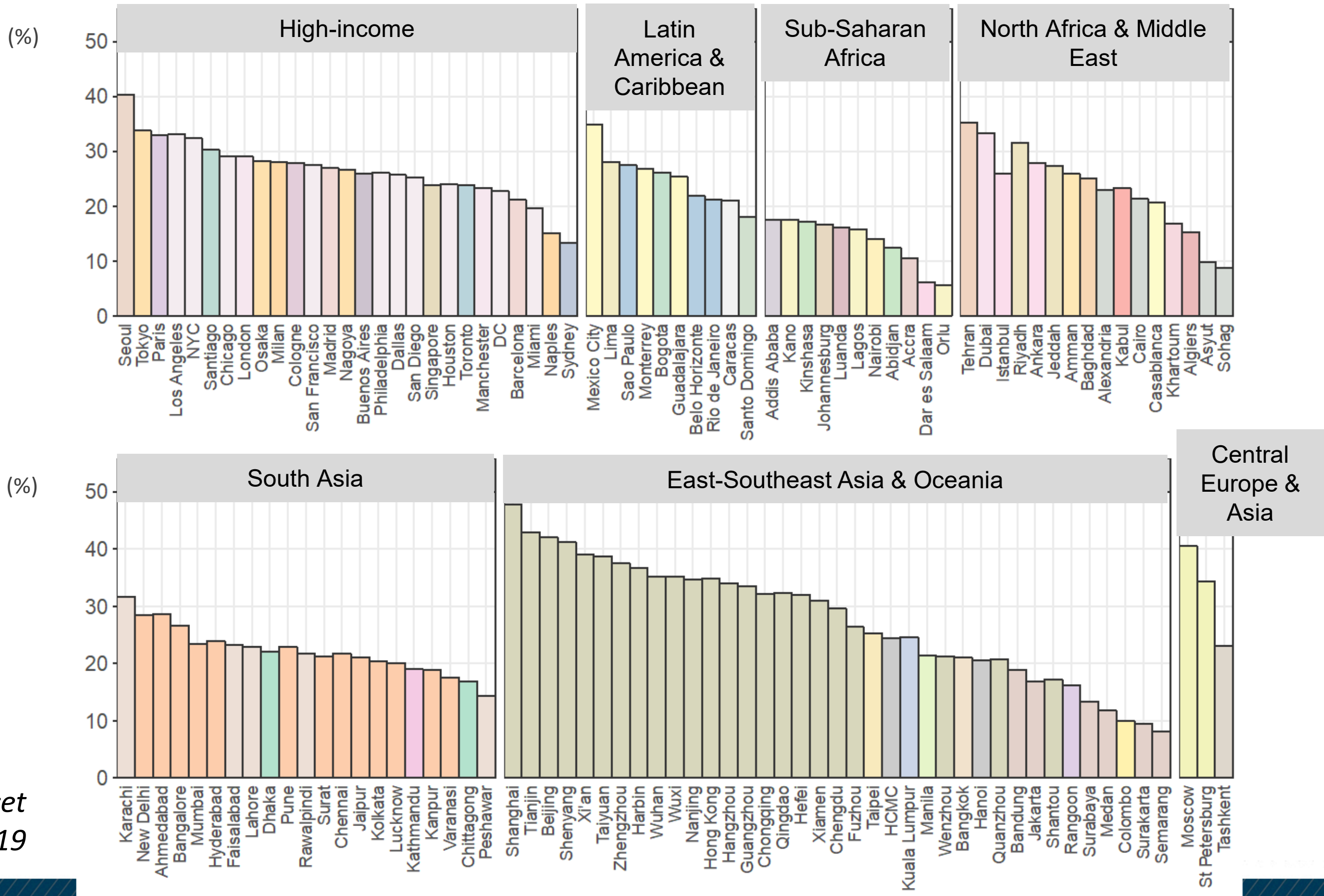
Space-based NO_2 columns are highly correlated with ground-level concentrations

TROPOMI NO_2 at 0.01° × 0.01° resolution



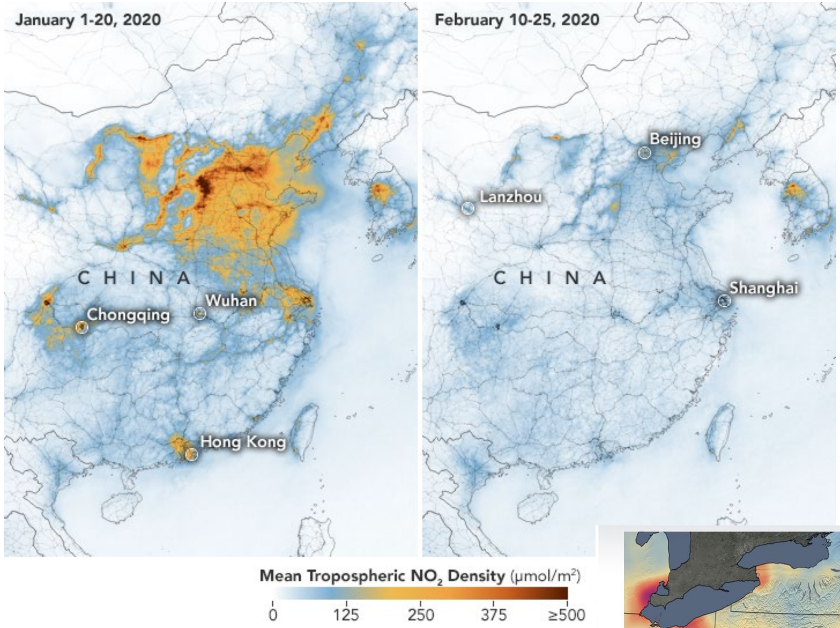
https://doi.org/10.1002/essoar.10503422.1

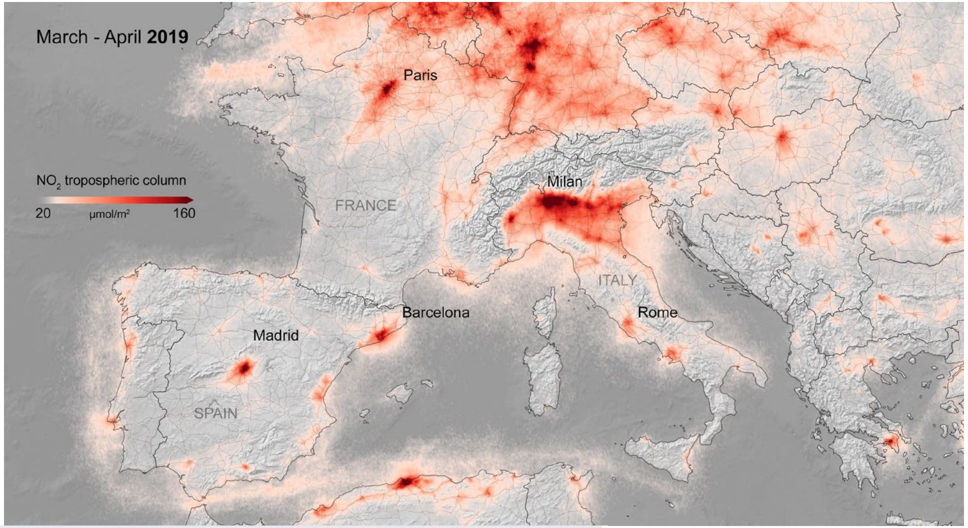
Pediatric asthma incidence attributable to NO_2 pollution

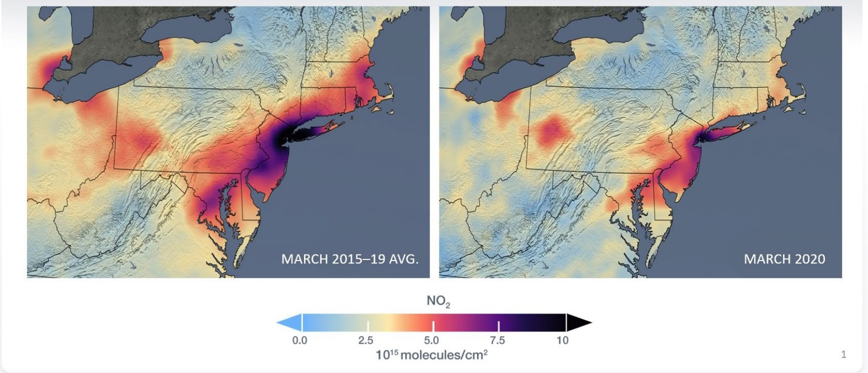


Achakulwisut et al. Lancet Planetary Health, 2019

OMI and TROPOMI capture NO_2 changes







Credits:
NASA 2020
ESA 2020

Observations from individual cities

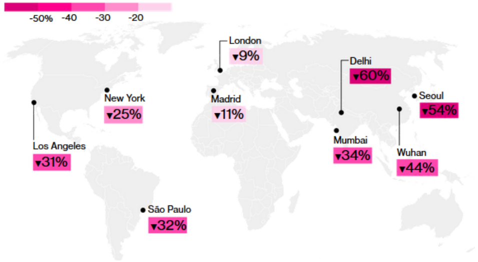
These Cities Now Have Less Air Pollution During Virus Lockdowns

By Hannah Dormido
April 22, 2020, 9:00 AM

Restrictions on travel and non-essential business over the past weeks to control the sprea of Covid-19 have meant dramatically cleaner air for some of the world's most polluted cities.

Seven global cities including Delhi, Seoul, Los Angeles, and New York, experienced 25% t 65% reduction in fine particulate matter or PM2.5 air pollutants during the lockdown, according to a report by IQAir.

Major Cities See Decrease in PM2.5 During Covid-19 Lockdown
Percent change for a three-week period in 2020 compared to same period in 2019



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Despite telework, stay-at-home orders, not much change to air quality in DC area

Brandon Millman | @BrandonMillman
April 1, 2020, 6:15 PM

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A street near the Tidal Basin is shown nearly empty due to the impacts of the pandemic on March 31, 2020 in Washington, D.C. (Anadolu Agency via Getty Images/Anadolu Agency)

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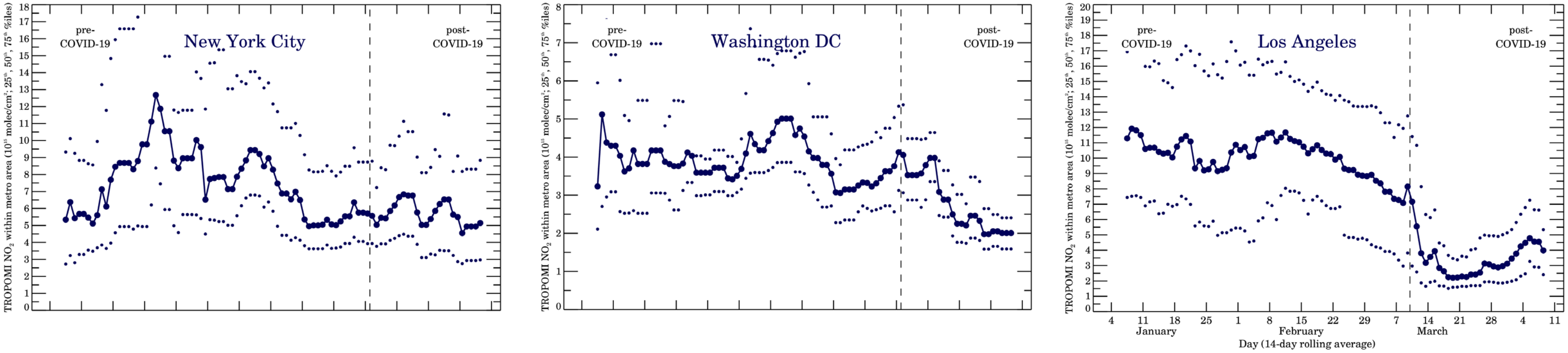
Our initial results confirmed that urban NO_2 changes were inconsistent

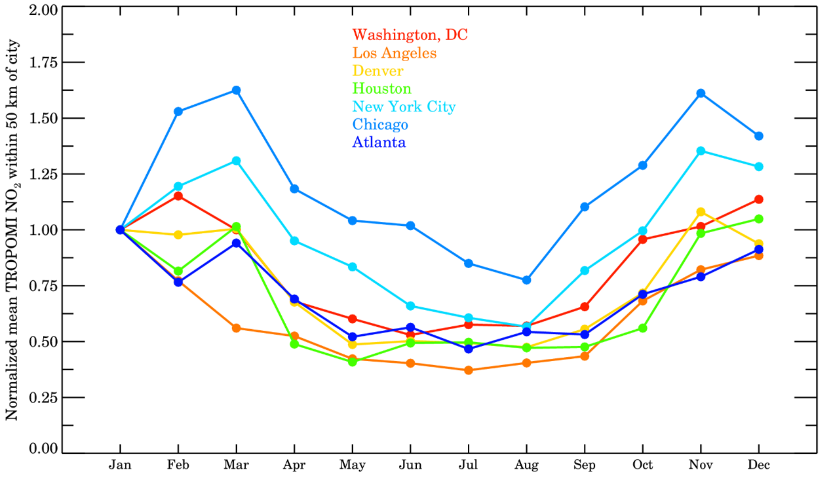
14-day rolling averages from Jan 1 – March 11, 2020



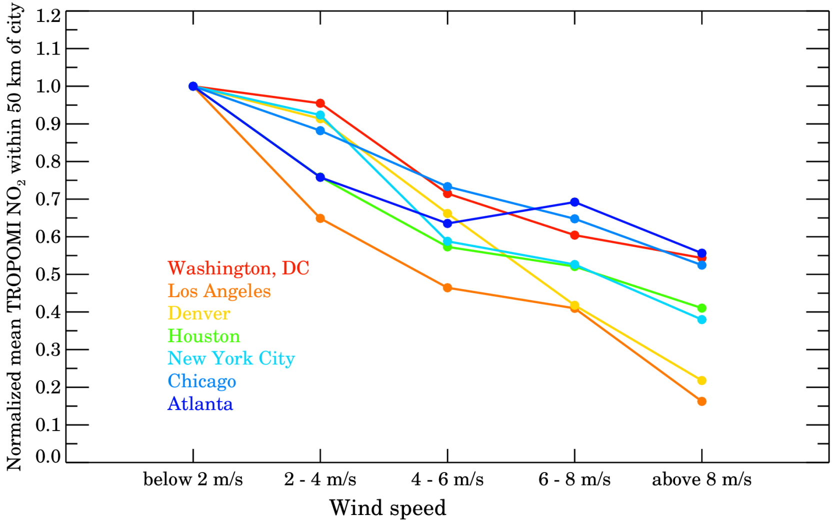
Results and figures generated by Dan Goldberg, GWU

Natural influences on TROPOMI NO_2

Seasonal variations of column NO_2



Meteorological effects on column NO_2



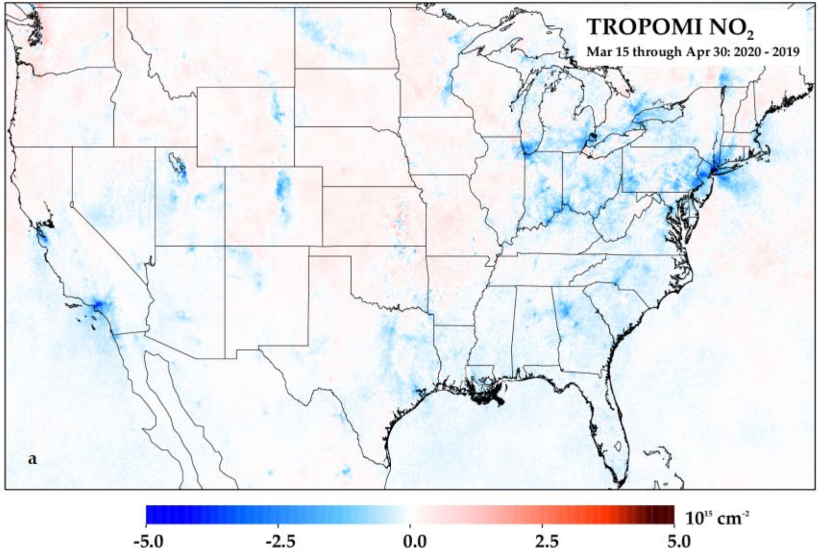
Goldberg et al., submitted
https://doi.org/10.1002/essoar.10503396.1

Disentangle the effects of meteorology and emissions: 3 approaches

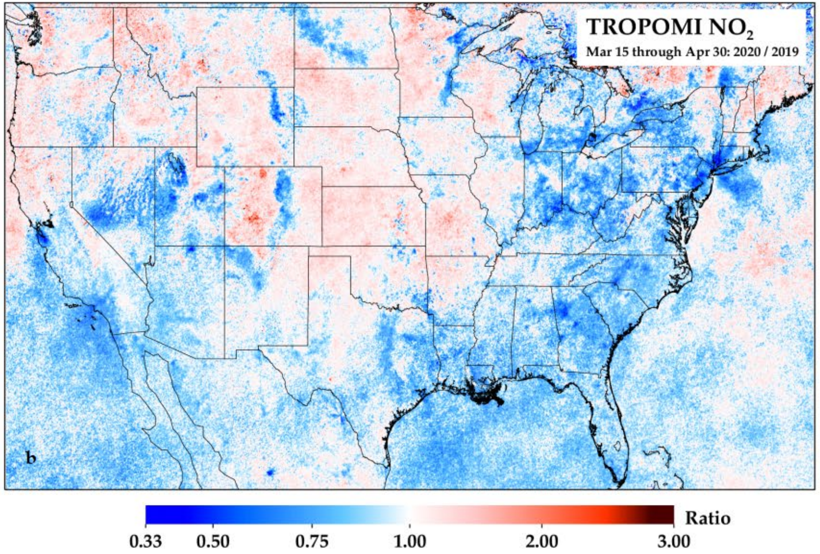
- **Method 0 – reference case**
  TROPOMI NO_2 change from Jan-Feb to Mar-Apr 2020
- **Method 1 – account for season**
  Compare TROPOMI NO_2 in same months in 2019 vs. 2020
- **Method 2 – account for season & meteorology**
  Normalize TROPOMI NO_2 by meteorology, compare results for 2019 v. 2020
- **Method 3 – account for season & meteorology**
  Simulate "normal" times, compare to TROPOMI NO_2 observations for 2020 only

Approach 1: Compare 2020 and 2019 TROPOMI NO_2

Absolute difference (2020-2019)



Ratio (2020:2019)



Goldberg et al., submitted
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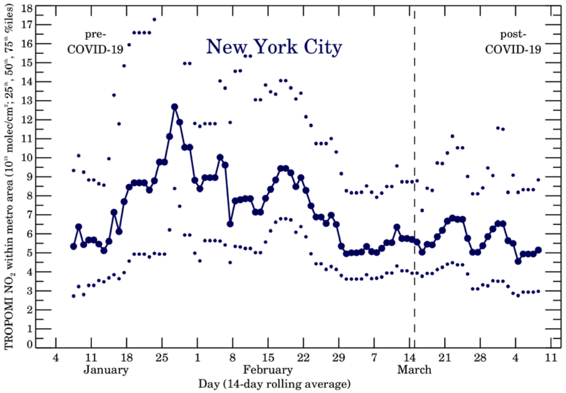
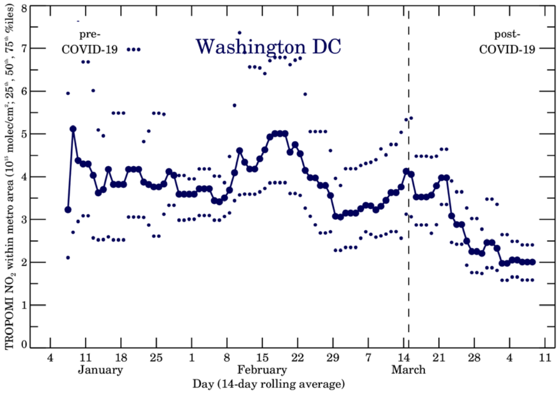
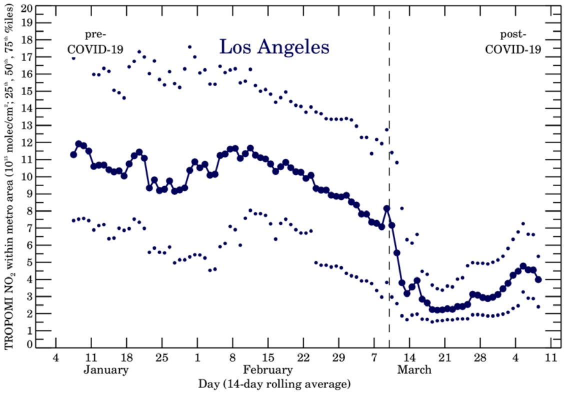
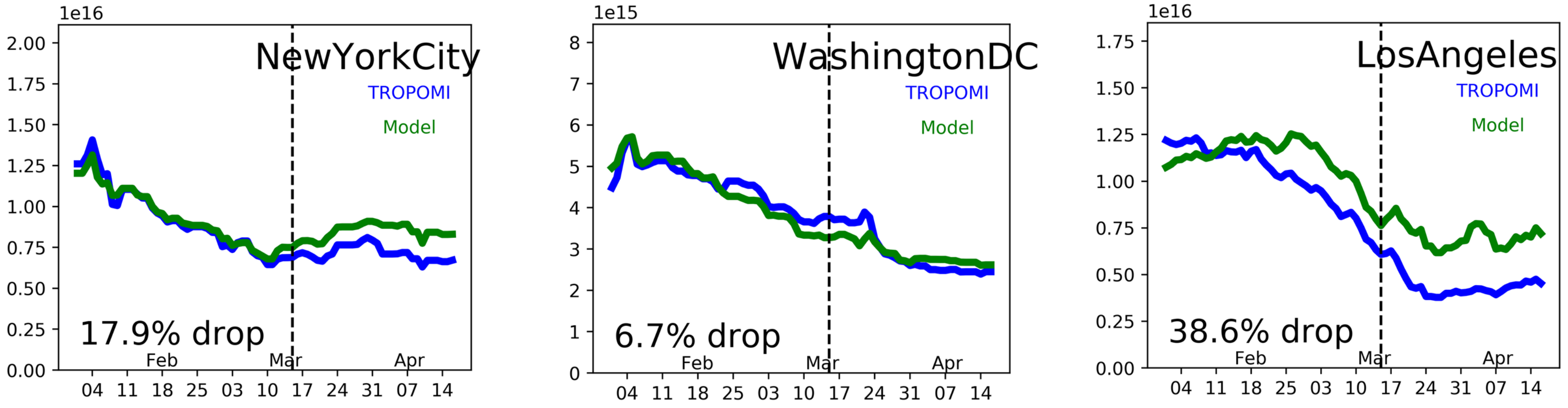
Approach 2: Normalize TROPOMI NO_2 columns by “typical” meteorology







Approach 3: Simulated TROPOMI NO_2 columns under "normal" times



Green = simulated normal
Blue = COVID-19 lockdowns

GEM-MACH regional chemical transport model
(Environment & Climate Change Canada)

Goldberg et al., submitted
https://doi.org/10.1002/essoar.10503396.1

NO_2 drops during COVID-19 lockdowns

- **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)

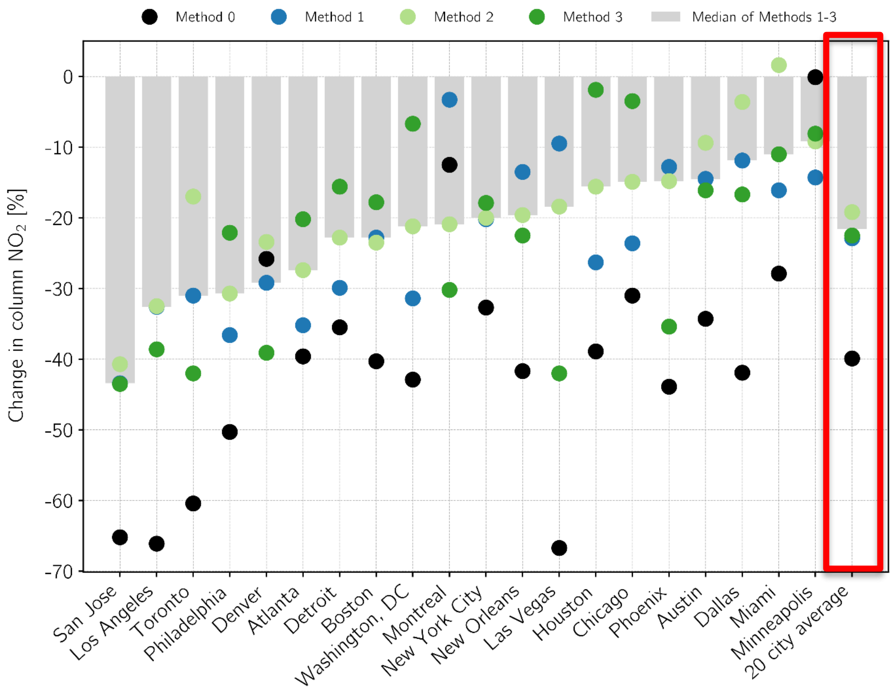


Figure created by Gaige Kerr

Goldberg et al., submitted
https://doi.org/10.1002/essoar.10503396.1

Concluding thoughts

- Physical distancing led to substantial NO_2 drops in urban areas, aided in some locations by favorable meteorology
- Unknowns
  - Factors driving inconsistencies in NO_x emission drops between locations
  - $PM_{2.5}$ and ozone changes -- location-specific, driven by emissions, meteorology, atmospheric chemistry

Science REPORTS

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Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China

Tianhao Le[1]*, Yuan Wang[1]*†, Lang Liu[2,3]*, Jiani Yang[1], Yuk L. Yung[1], Guohui Li[2,3], John H. Seinfeld[4]

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The absence of motor vehicle traffic and suspended manufacturing during the COVID-19 pandemic in China produced a unique experiment to assess the efficiency of air pollution mitigation. Up to 90% reduction of certain emissions during the city-lockdown period can be identified from satellite and ground-based observations. Unexpectedly, extreme particulate matter levels simultaneously occurred in northern China. Our synergistic observation analyses and model simulations show that anomalously high humidity promoted aerosol heterogeneous chemistry, along with stagnant airflow and uninterrupted emissions from power plants and petrochemical facilities, contributing to severe haze formation. Also, because of non-linear production chemistry and titration of ozone in winter, reduced nitrogen oxides resulted in ozone enhancement in urban areas, further increasing the atmospheric oxidizing capacity and facilitating secondary aerosol formation.

Two preprints available

TROPOMI NO_2 in the United States: A detailed look at the annual averages, weekly cycles, effects of temperature, and correlation with $PM_{2.5}$

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https://doi.org/10.1002/essoar.10503422.1

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

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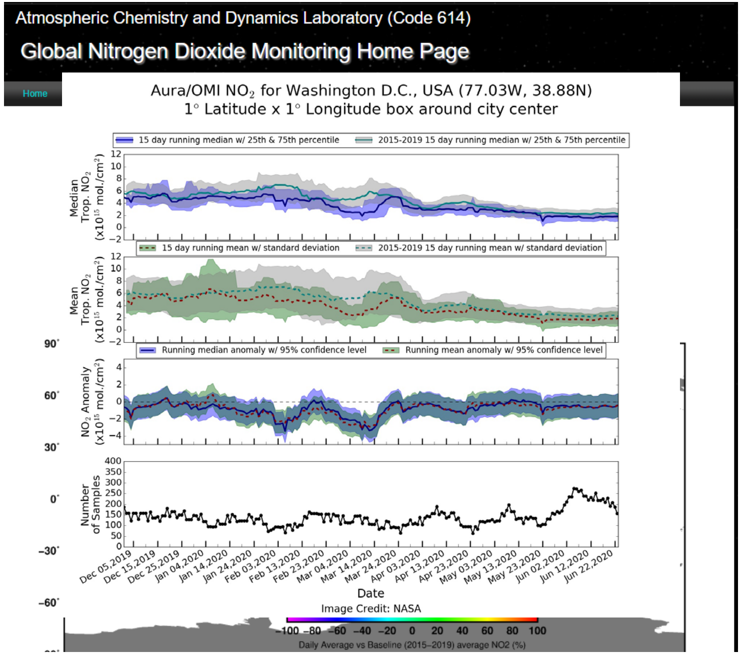
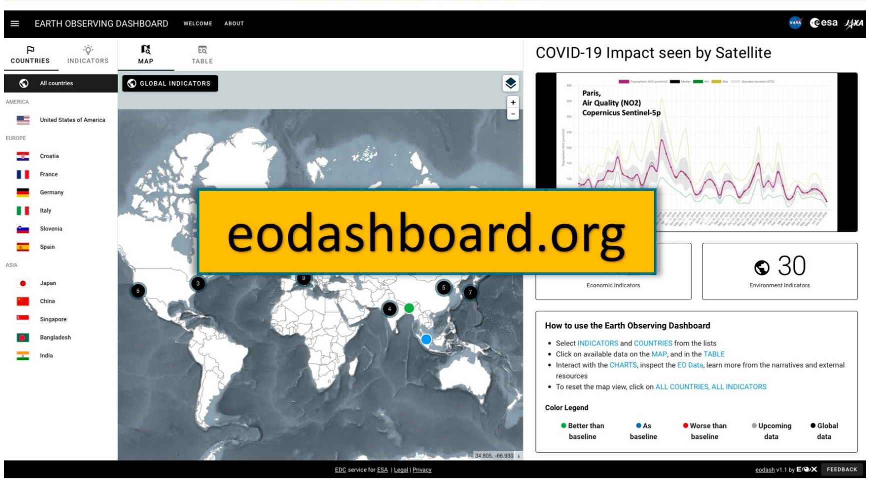
https://doi.org/10.1002/essoar.10503396.1

More resources for satellite NO_2 observations



https://so2.gsfc.nasa.gov/no2/no2_index.html



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