

Air quality, health, and equity in the Washington, DC region

Susan Anenberg, PhD

Metropolitan Washington Air Quality Committee

October 27, 2021

Milken Institute School
of Public Health

THE GEORGE WASHINGTON UNIVERSITY

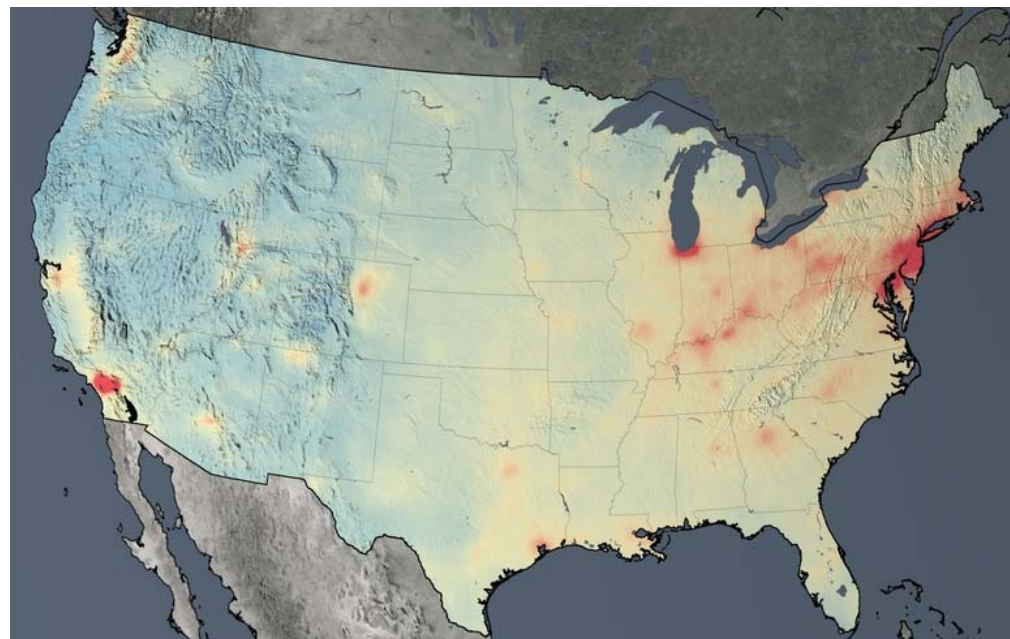
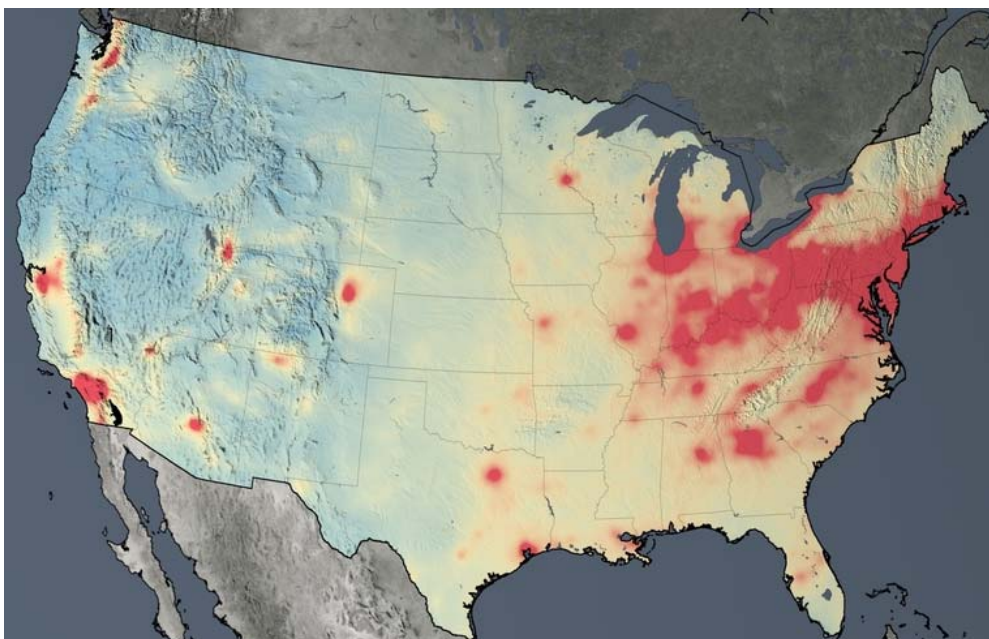


Key points



- Air pollution continues to place a large burden on public health globally and in the U.S.
- Air pollution-related health risks vary within cities, driven by concentrations and disease rates, contributing to health inequity
- Air pollution may worsen in the future under climate change
- Future air quality management requires a shift from engineering controls to reducing burning, with many LOCAL and IMMEDIATE benefits for public health

Efficacy of the Clean Air Act is observable from space

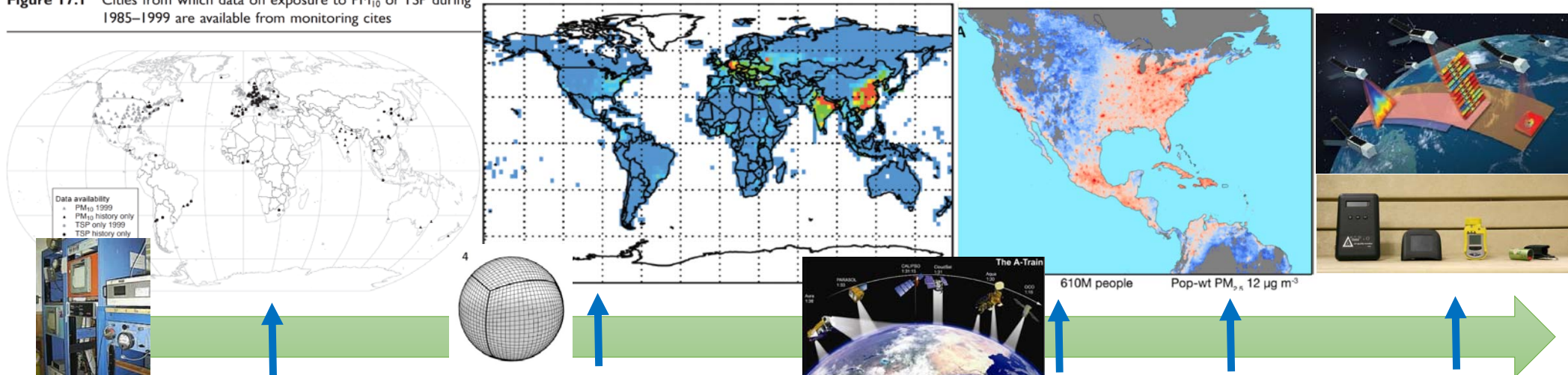


Nitrogen dioxide observed by the Ozone Monitoring Instrument:
20-60% decrease from 2005 to 2016

Courtesy Bryan Duncan, NASA

Evolution of air pollution exposure assessment

Figure 17.1 Cities from which data on exposure to PM₁₀ or TSP during 1985–1999 are available from monitoring cites



2004: **Surface air quality monitors** used to estimate 800,000 premature deaths associated with urban PM_{2.5} (Cohen et al. 2004)

2010: **Global chemical transport model** used to estimate 3.7 million PM_{2.5} deaths and 700,000 ozone deaths globally (Anenberg et al. 2010)

2012: **Satellite observations, global chemical transport model, and ground observations combined** to estimate 3.2 million PM_{2.5} deaths and 152,000 ozone deaths (Lim et al. 2012)

2016-2019: **methods refined** to estimate ~4 million PM_{2.5} deaths and 200,000 ozone deaths (Forouzanfar et al. 2016, etc.)

Future: geostationary satellites, low-cost sensors, mobile monitoring, ???

PM_{2.5} mortality in cities worldwide

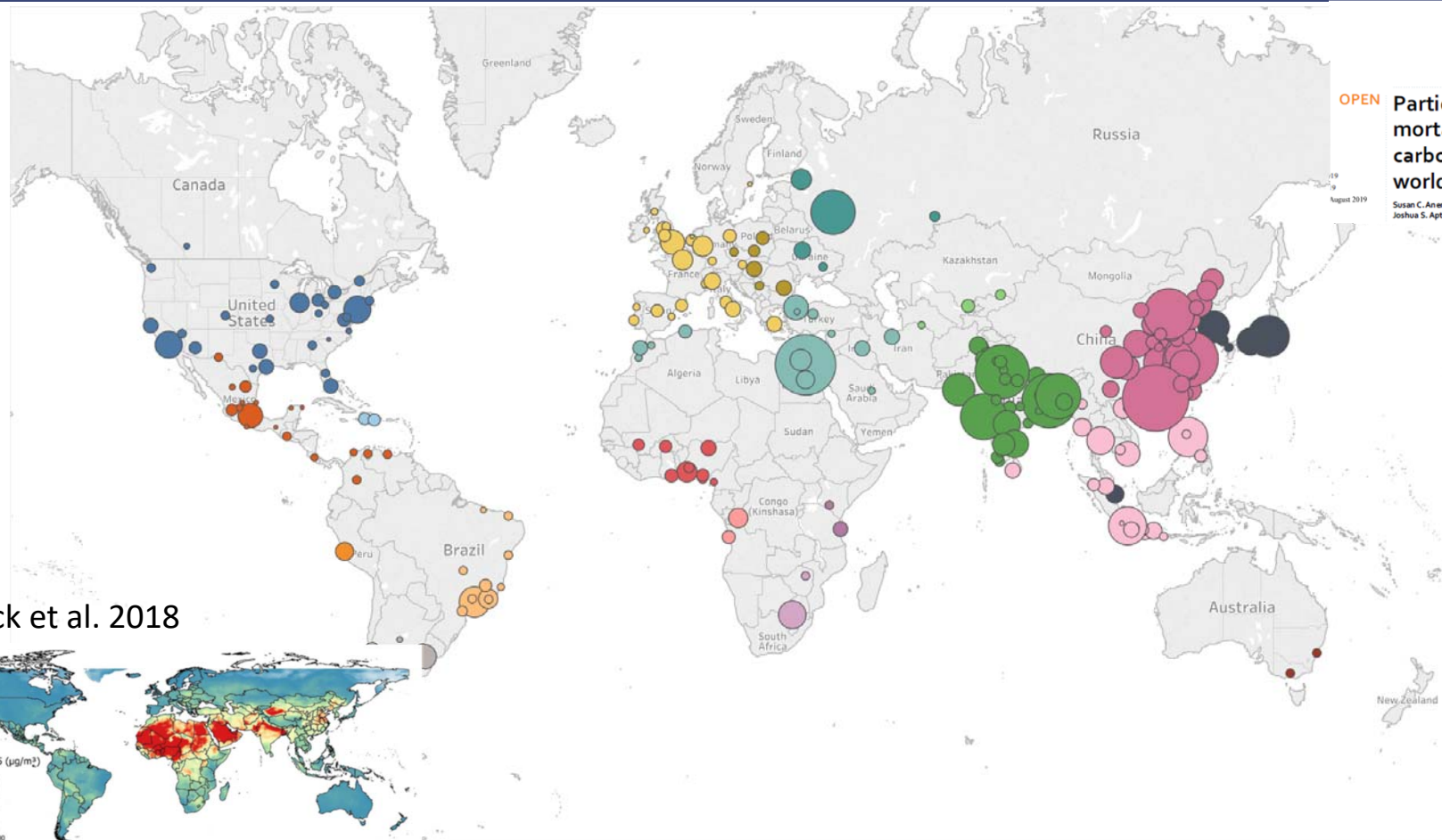


SCIENTIFIC
REPORTS
nature research

OPEN Particulate matter-attributable mortality and relationships with carbon dioxide in 250 urban areas worldwide

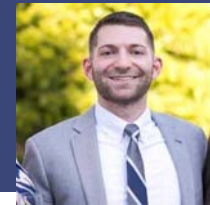
Susan C. Anenberg¹, Pattanun Achakulwisut^{1,2}, Michael Brauer^{3,4}, Daniel Moran⁵, Joshua S. Apte⁶ & Daven K. Henze⁷

August 2019



Shaddick et al. 2018

Ozone mortality in cities worldwide



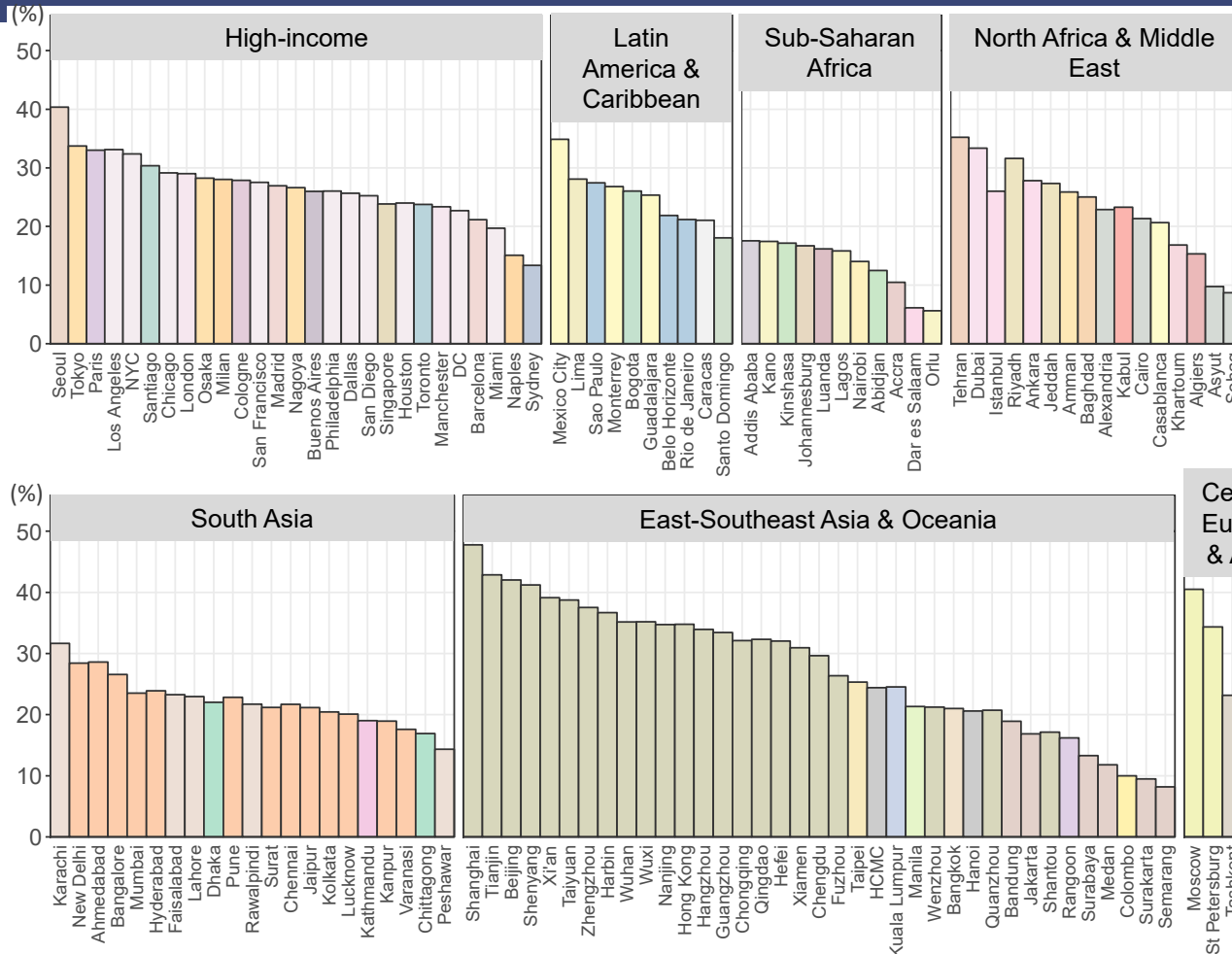
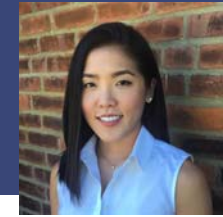
Malashock et al. in prep



Top 5 Cities with the Greatest Ozone-attributable Deaths by Region in 2017

No.	Oceania (n=30)	Latin America & Caribbean (n=428)	Africa (n=653)	Europe (n=763)	N. America (n=302)	Asia (n=2941)
1	Sydney, Australia (9.2)	Mexico City, Mexico (497.3)	Cairo, Egypt (498.6)	Madrid, Spain (306.2)	Los Angeles, CA, USA (829.5)	New Delhi, India (2840)
2	Melbourne, Australia (8.6)	São Paulo, Brazil (314.9)	Johannesburg, South Africa (167.2)	Milan, Italy (165.9)	New York, NY, USA (389.5)	Shanghai, China (2619.6)
3	Brisbane, Australia (3.3)	Buenos Aires, Argentina (128.2)	Kinshasa, DRC (109.7)	Naples, Italy (150.7)	Phoenix, AZ, USA (326)	Kolkata, India (2422.1)
4	Perth, Australia (2.9)	Curitiba, Brazil (83.5)	Algiers, Algeria (66)	Athens, Greece (138.9)	Chicago, IL, USA (234.5)	Beijing, China (2364.7)
5	Adelaide, Australia (2.5)	Ciudad Juárez, Mexico (61.6)	Mbuji-Mayi, DRC (65.7)	Guadalajara, Spain (128.5)	San Diego, CA, USA (186.7)	Guangzhou, China (2179.5)

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.

Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO₂ pollution: estimates from global datasets

Pattaranun Achakulwisut, Michael Brauer, Perry Hyatt, Susan C. Anenberg

Summary

Background Paediatric asthma incidence is associated with exposure to traffic-related air pollution (TRAP), but the Lancet Planet Health 2019



Ambient air quality guidelines and standards



Pollutant	Averaging time	WHO Air Quality Guideline 2021	WHO Air Quality Guideline 2005	U.S. EPA	EU	China Class 1 (2012)	China Class 2 (2012)
PM2.5 (ug/m3)	Annual	5	10	12	25	15	35
	24-hour	15	25	35	-	35	75
PM10 (ug/m3)	Annual	15	20	-	40	40	70
	24-hour	45	50	150	50	50	150
O3 (ug/m3)	Peak season	60	-	-	-	-	-
	8-hour	100	100	140	120	100	160
	1-hour	-	-	-	-	160	200
NO2 (ug/m3)	Annual	10	40	100	40	40	40
	24-hour	25	-	-	-	80	80
	1-hour	200	200	200	200	200	200

Ratio: U.S. EPA
NAAQS: WHO
AQG 2021

2.4

2.4

No NAAQS

3.3

No NAAQS

1.4

No NAAQS

10

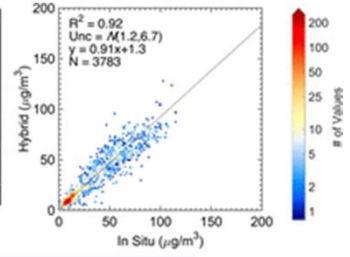
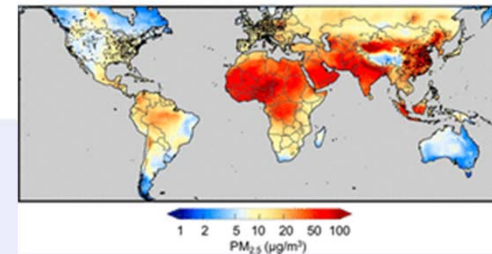
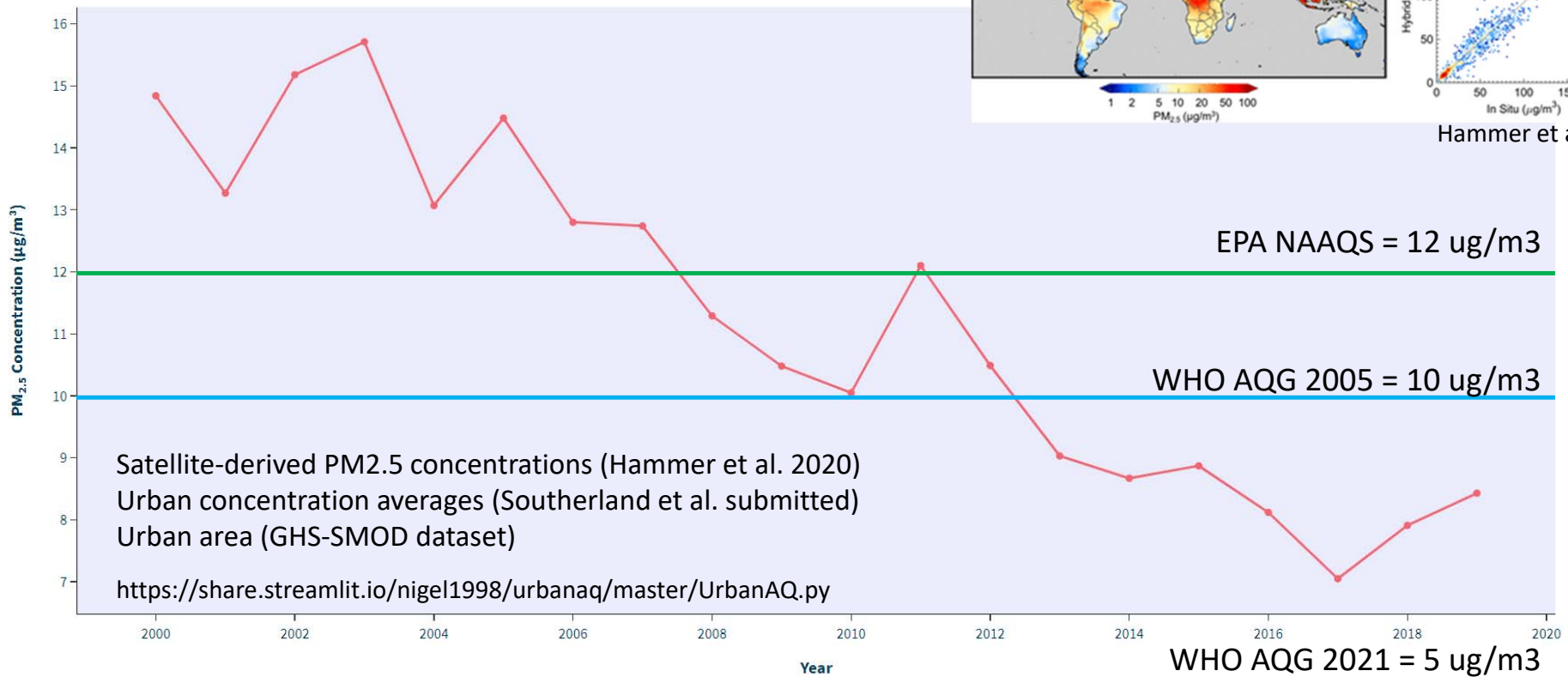
No NAAQS

1

PM_{2.5} trends – Washington, DC metro



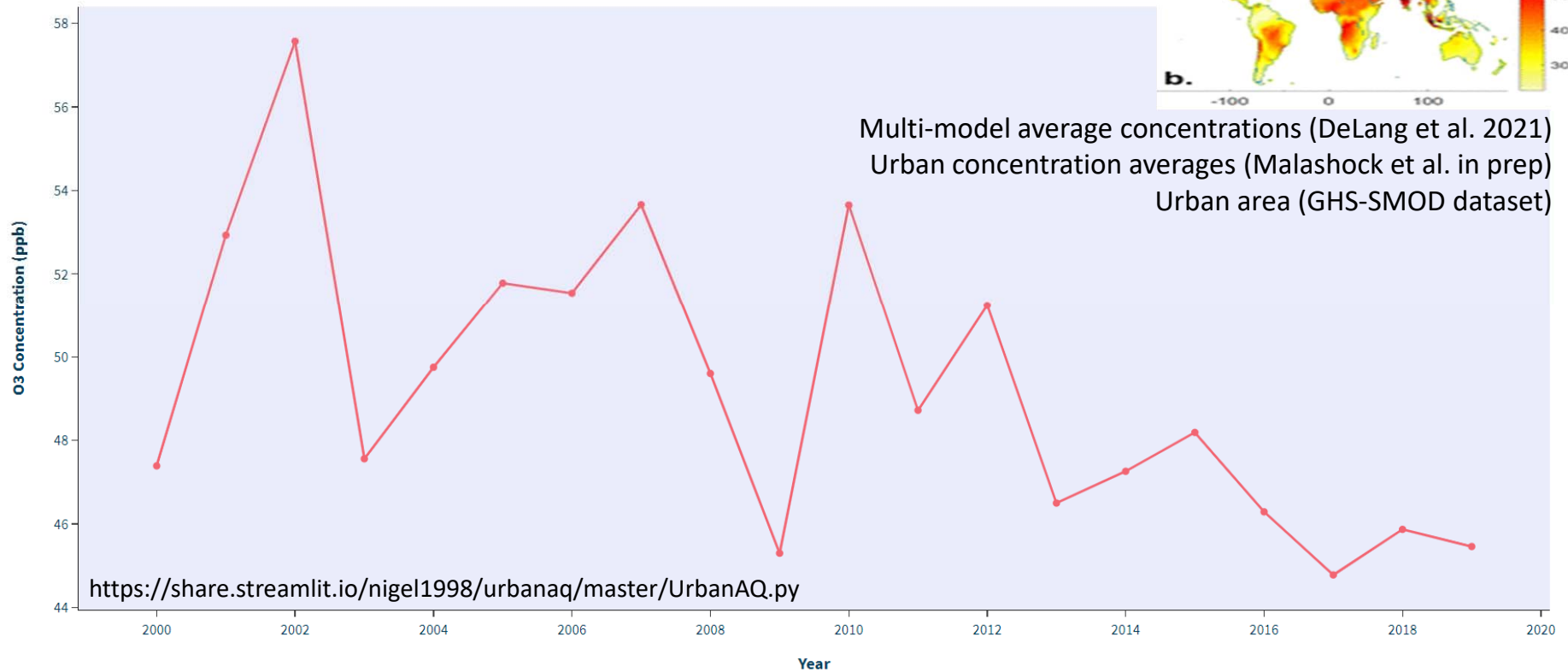
WASHINGTON D.C. - Annual Average PM_{2.5} Concentration (µg/m³)



Hammer et al. 2020

Ozone trends – Washington, DC metro

WASHINGTON D.C. - 6-month Averages of the Daily Maximum 8-hour Mixing Ratio Ozone Concentration (ppb)

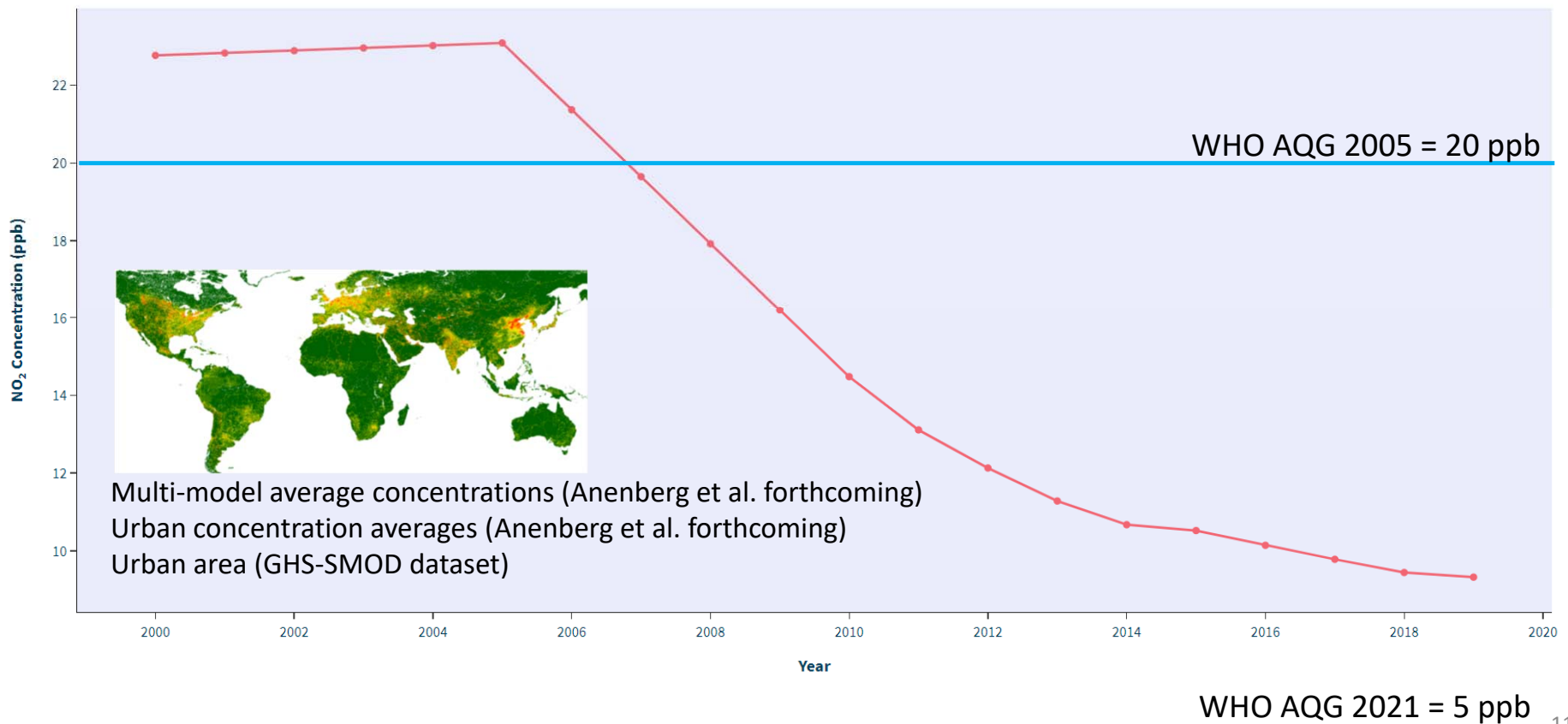


WHO AQG 2021 = 30 ppb

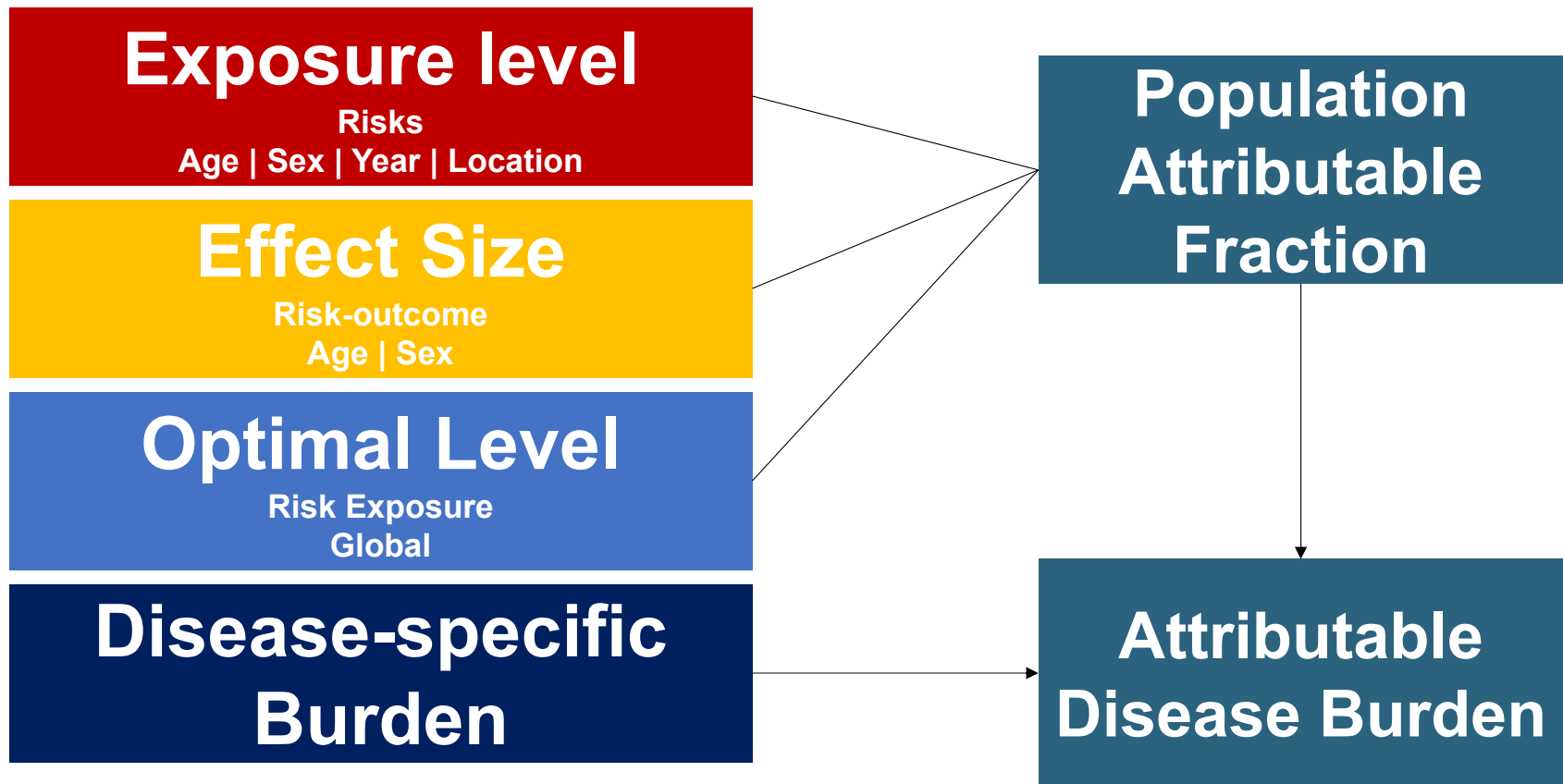


NO₂ trends – Washington, DC metro

WASHINGTON D.C. - Annual Average NO₂ Concentration (ppb)



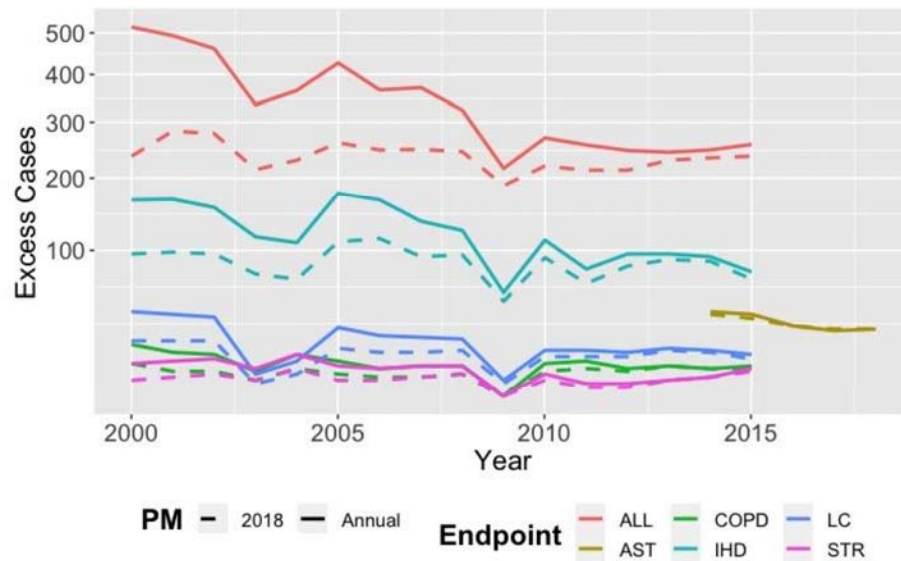
Estimating disease burden from air pollution



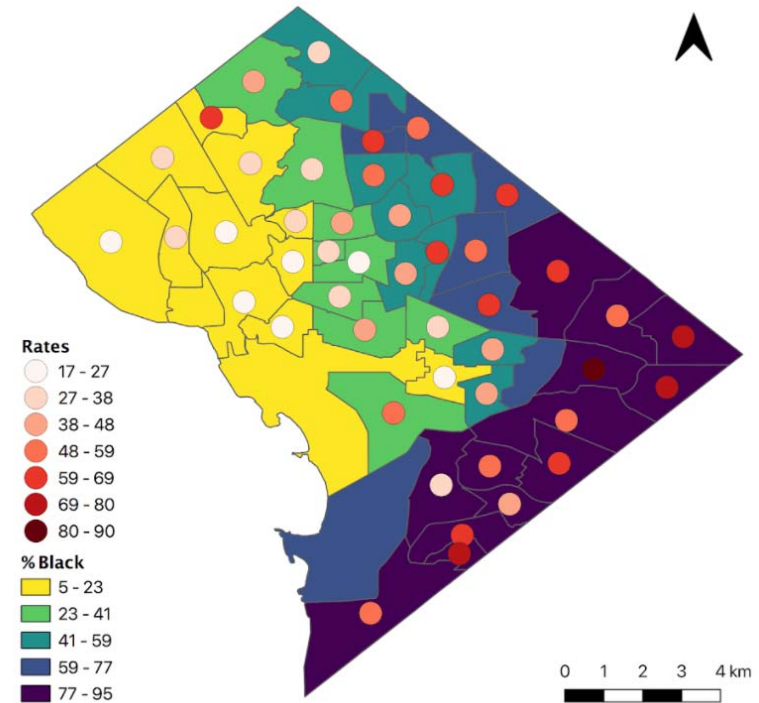
Air pollution inequity in Washington, DC



Temporal trend in PM_{2.5}-attributable mortality

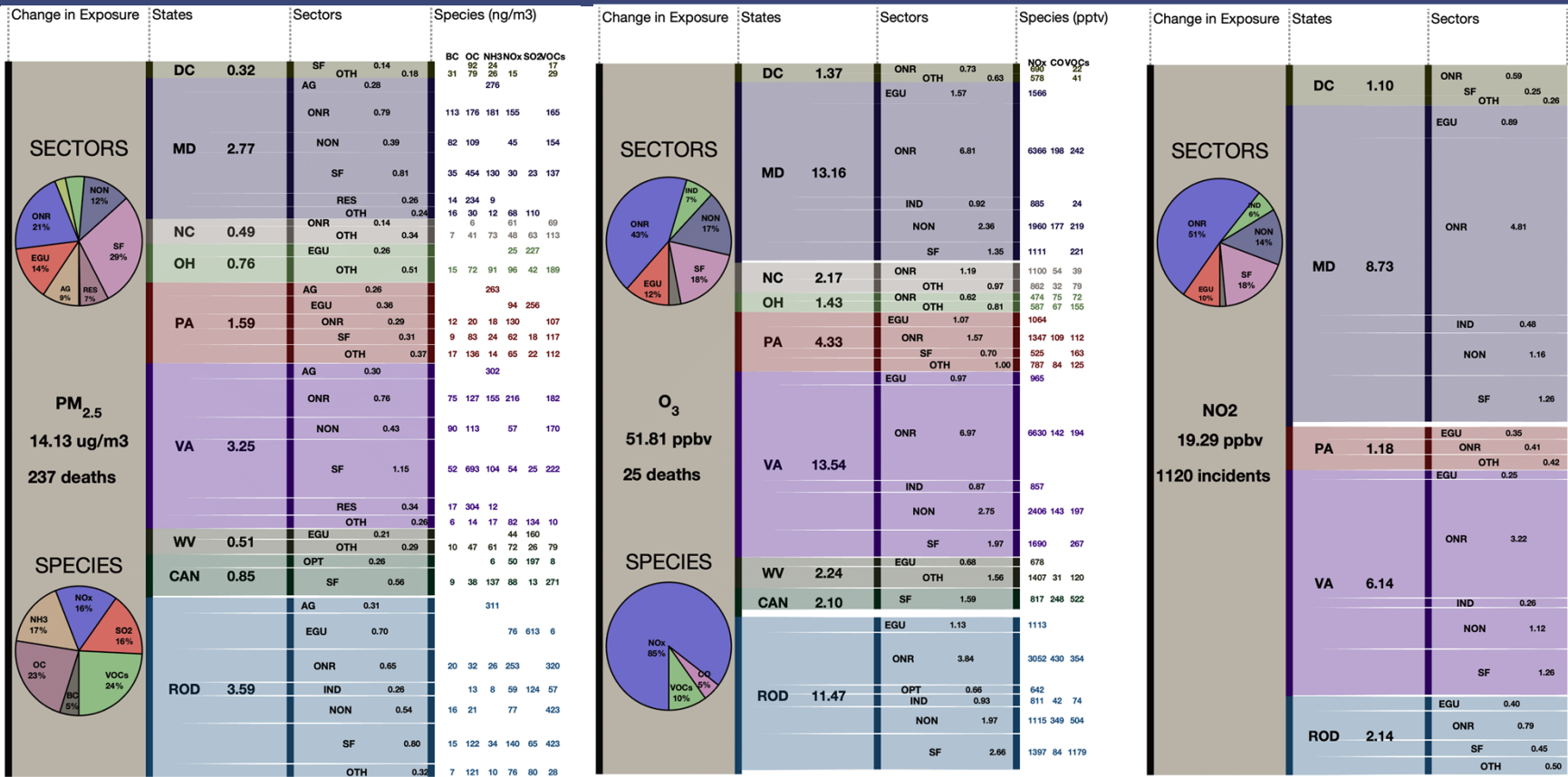


Spatial pattern, links with demographics



Satellite-derived PM_{2.5} concentrations from Hammer et al. (2020)
 Disease rates from DC Health
 Castillo et al., *GeoHealth*, forthcoming

Contributions to air pollution in DC for 2011



Sector Abbreviations
AG – Agriculture
EGU – Electrical Generation Unit
ONR - On-road
IND – Industry
NON – Non-road
SF – Surface Emissions
RES – Residential

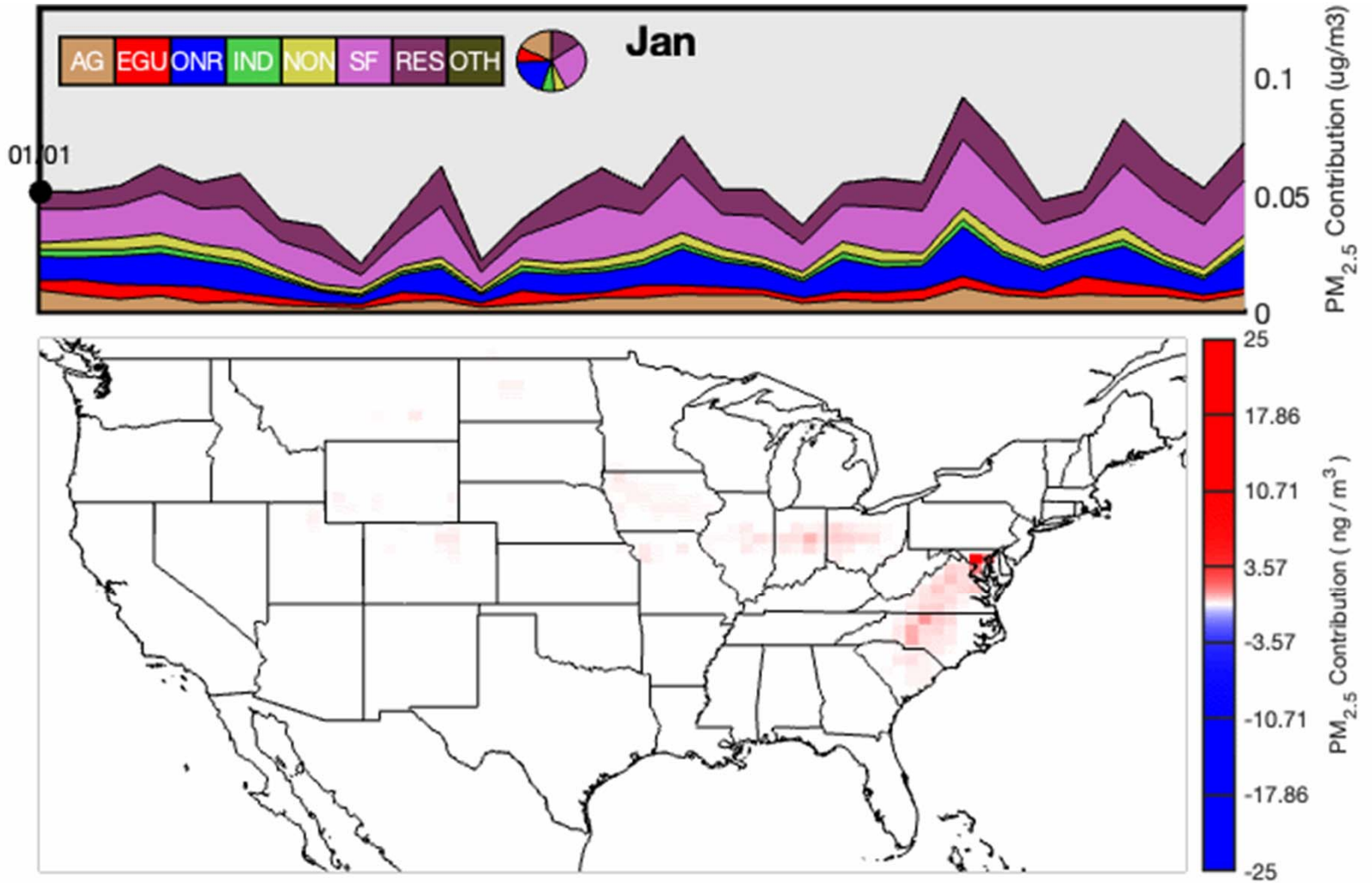
Nawaz et al. submitted. Emission to concentration sensitivities from GEOS-Chem model



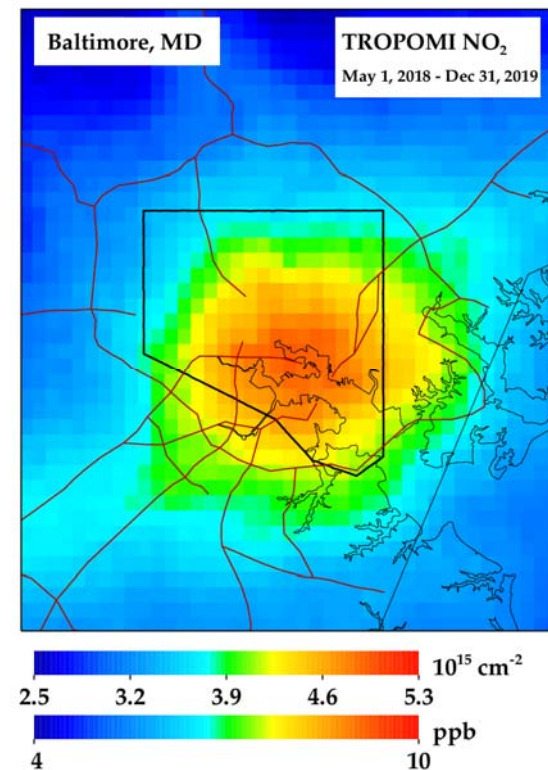
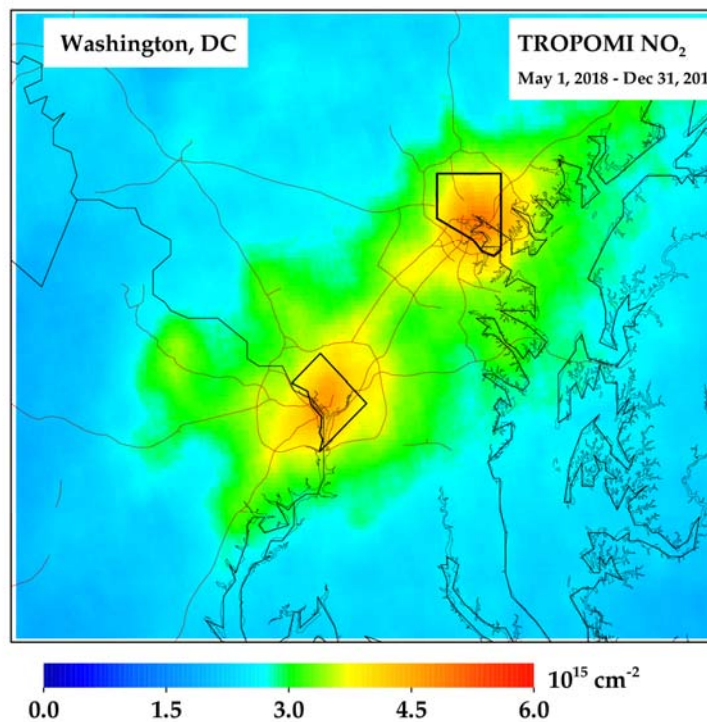
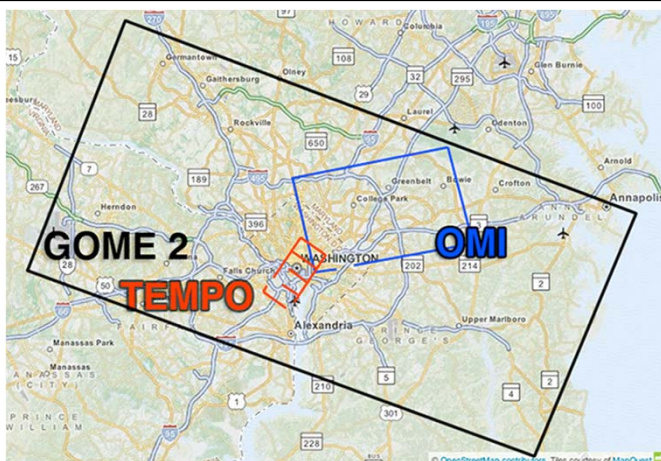
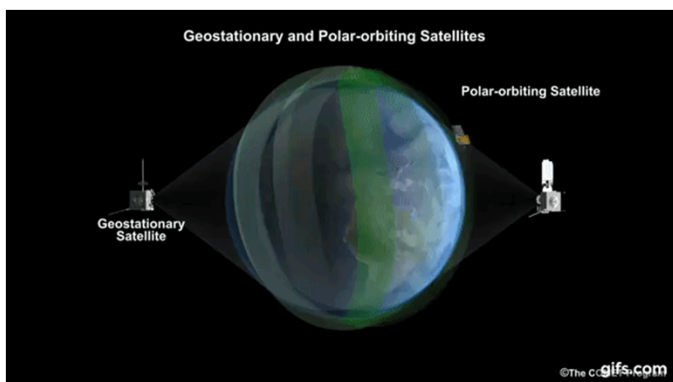
2011 Daily PM_{2.5} Contributions in DC

Sectors

OTH	Other Sectors
RES	Residential
SF	Surface Emissions
NON	Non-road
IND	Industry
ONR	On-road
EGU	Energy Generation
AG	Agriculture



TROPOMI NO₂ can identify local pollution relatively well

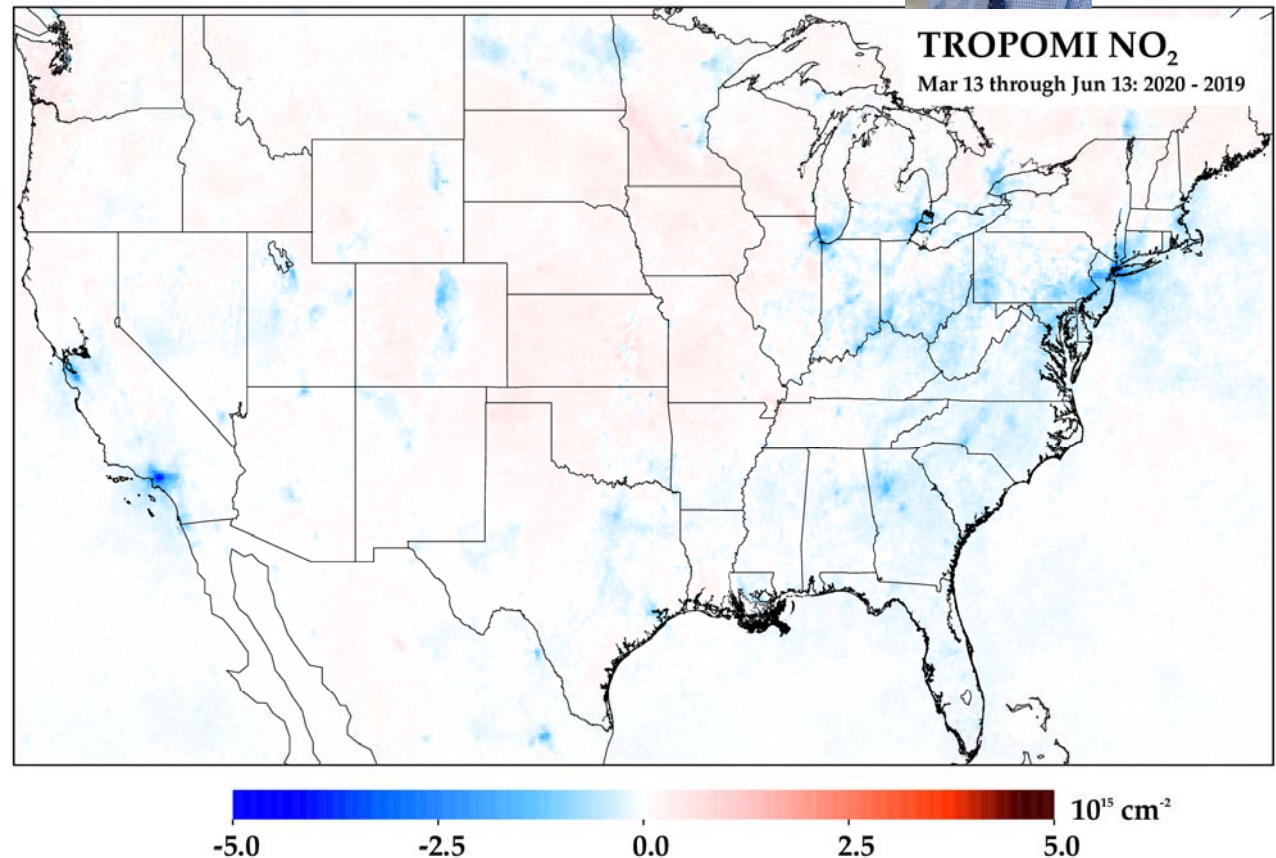


Goldberg et al., 2021,
Earth's Future
Open Access

Learning from COVID-19 lockdowns



- What would this look like if meteorology was “normalized” out?
- What does this reveal about environmental justice issues related to air quality?
- How did varying degrees of social distancing and urban transportation changes cause these NO₂ decreases?



Earth's Future

RESEARCH ARTICLE
10.1029/2020EFO01665

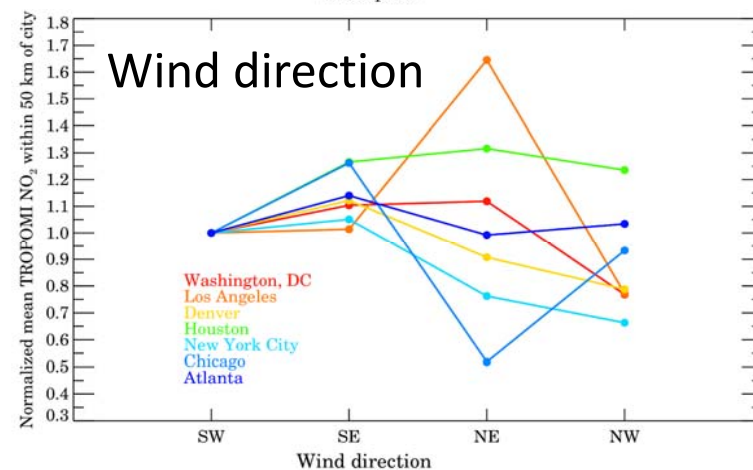
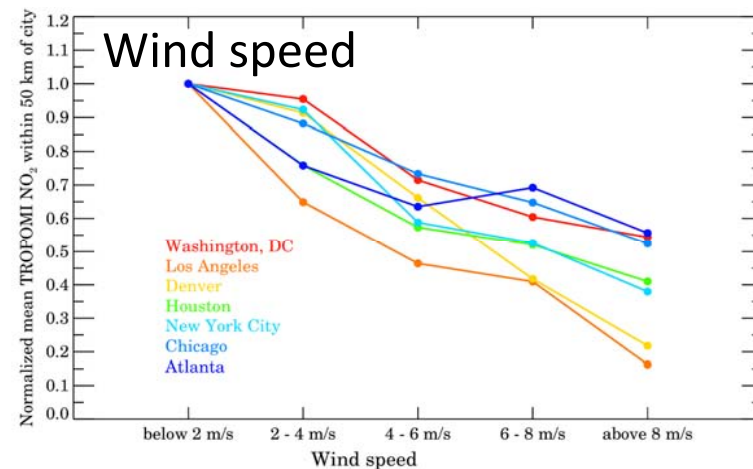
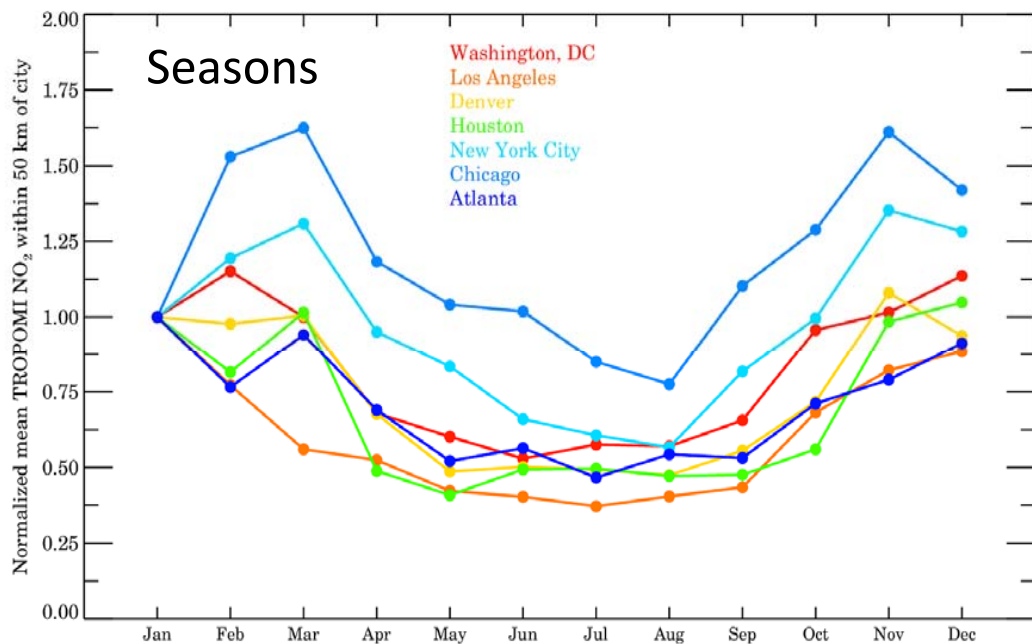
Key Points

- The high instrument sensitivity of Tropospheric Monitoring Instrument (TROPOMI) can measure NO₂ pollution with unprecedented clarity compared to predecessor instruments

TROPOMI NO₂ in the United States: A Detailed Look at the Annual Averages, Weekly Cycles, Effects of Temperature, and Correlation With Surface NO₂ Concentrations

Daniel L. Goldberg^{1,2}, Susan C. Anenberg¹, Gaige Hunter Kerr¹, Arash Moheghi¹, Zifeng Lu¹, and David G. Streets²

Natural influences on TROPOMI NO₂



Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL089269

Disentangling the Impact of the COVID-19 Lockdowns on Urban NO₂ From Natural Variability

Special Section:
The COVID-19 pandemic:
Linking health, society and

Daniel L. Goldberg^{1,2}, Susan C. Anenberg¹, Debora Griffin³, Chris A. McLinden³, Zifeng Lu², and David G. Streets²



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)

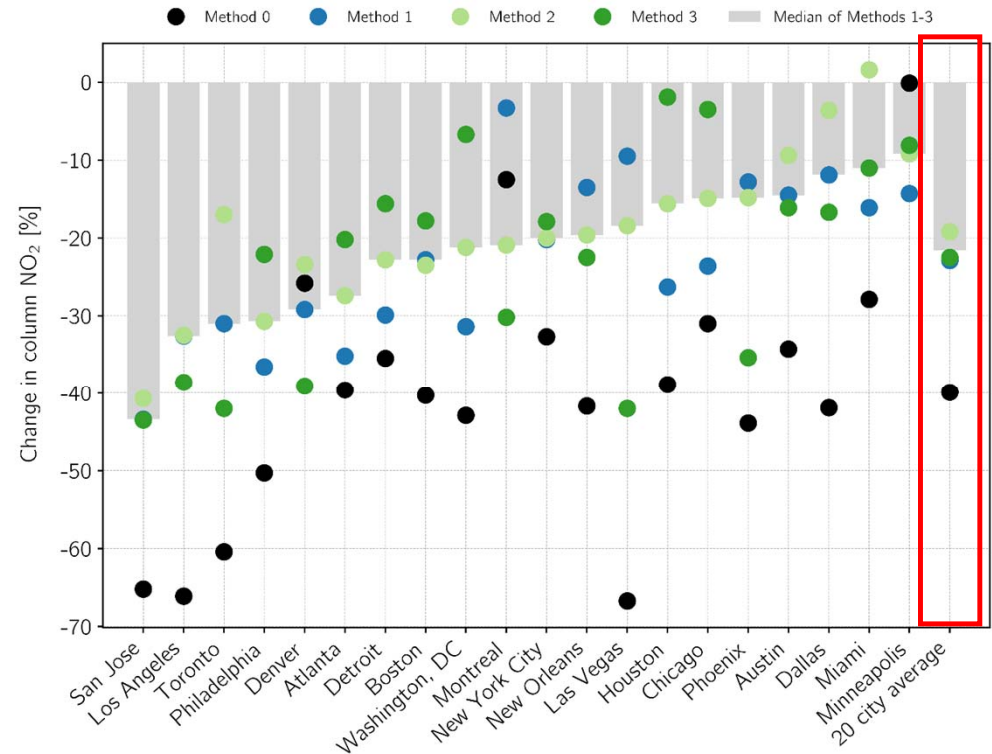


Figure created by Gaige Kerr

Geophysical Research Letters

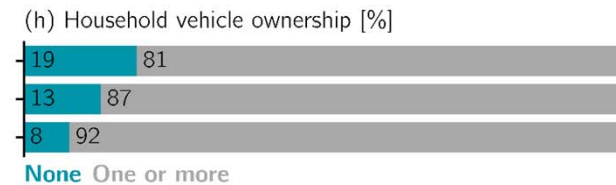
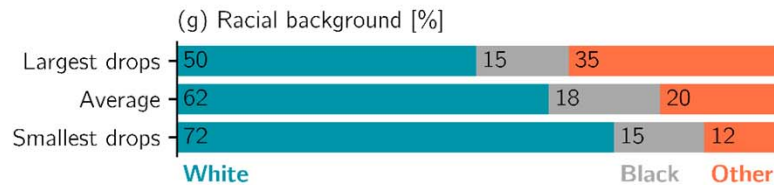
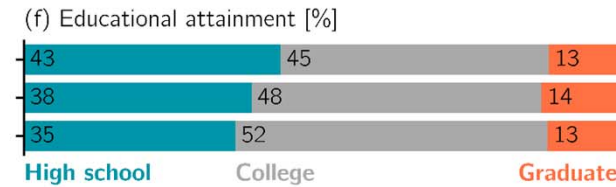
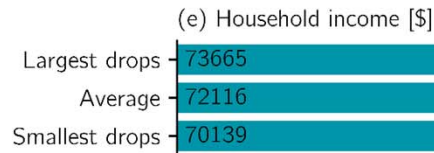
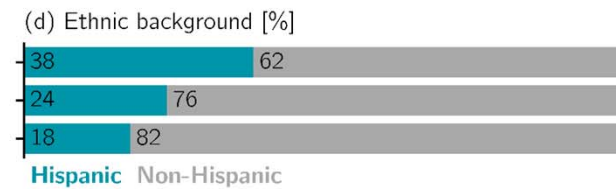
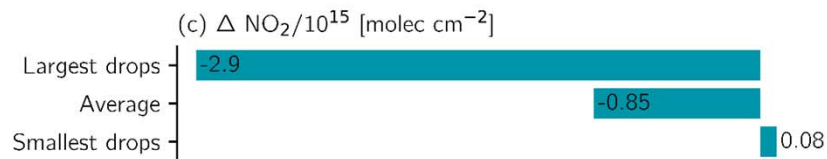
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Disentangling the Impact of the COVID-19 Lockdowns on Urban NO₂ From Natural Variability

Daniel L. Goldberg^{1,2}, Susan C. Anenberg¹, Debora Griffin³, Chris A. McLinden³, Zifeng Lu², and David G. Streets²

Special Section:
The COVID-19 pandemic:
Linking health, society and

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



COVID-19 pandemic reveals persistent disparities in nitrogen dioxide pollution

Gaige Hunter Kerr^{a,1}, Daniel L. Goldberg^{a,b}, and Susan C. Anenberg^a

^aDepartment of Environmental and Occupational Health, Milken Institute School of Public Health, George Washington University, Washington, DC 20052; and ^bEnergy Systems Division, Argonne National Laboratory, Lemont, IL 60439

Edited by Susan Solomon, Massachusetts Institute of Technology, Cambridge, MA, and approved June 11, 2021 (received for review October 26, 2020)

The unequal spatial distribution of ambient nitrogen dioxide (NO₂), an air pollutant related to traffic, leads to higher exposure from satellite instruments (21, 24–27) over the United States, China, and Europe. According to government-reported

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

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

COVID-19 lockdowns did not eliminate NO₂ disparities by race



COVID-19 pandemic reveals persistent disparities in nitrogen dioxide pollution

Gaige Hunter Kerr¹, Daniel L. Goldberg², and Susan C. Anenberg¹

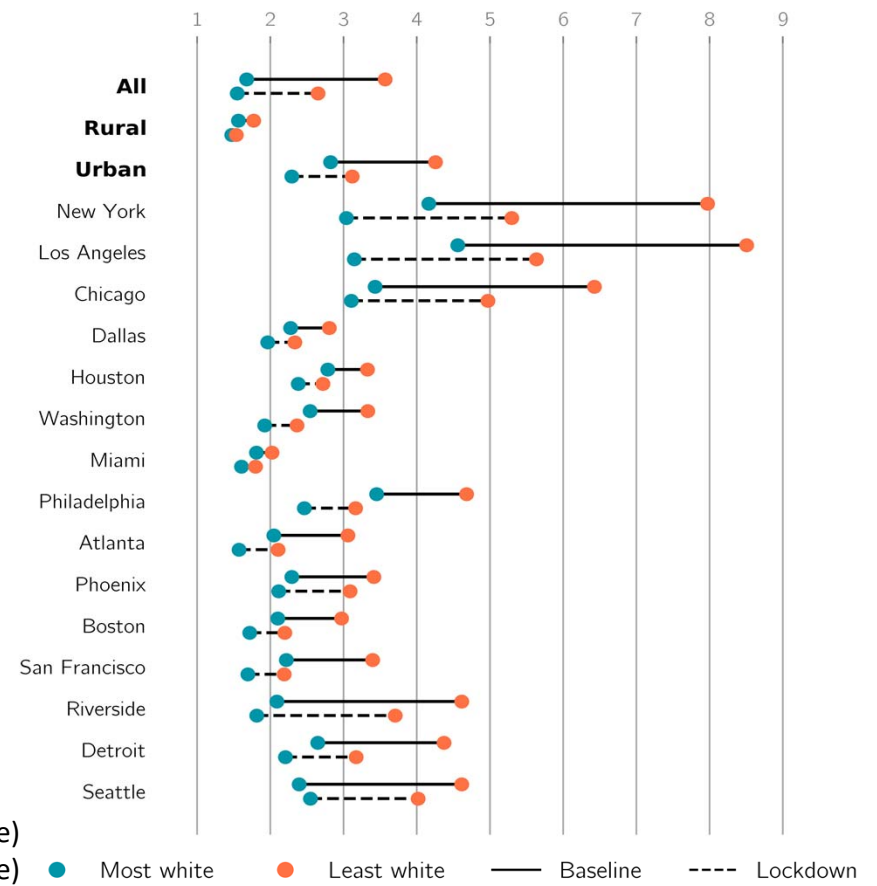
¹Department of Environmental and Occupational Health, Milken Institute School of Public Health, George Washington University, Washington, DC 20052; and ²Energy Systems Division, Argonne National Laboratory, Lemont, IL 60439

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- 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

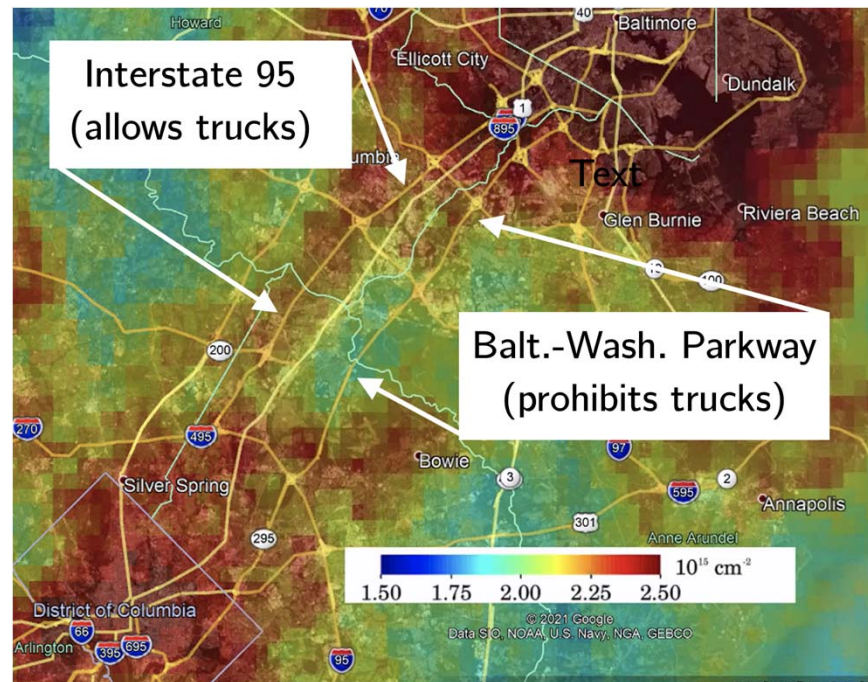
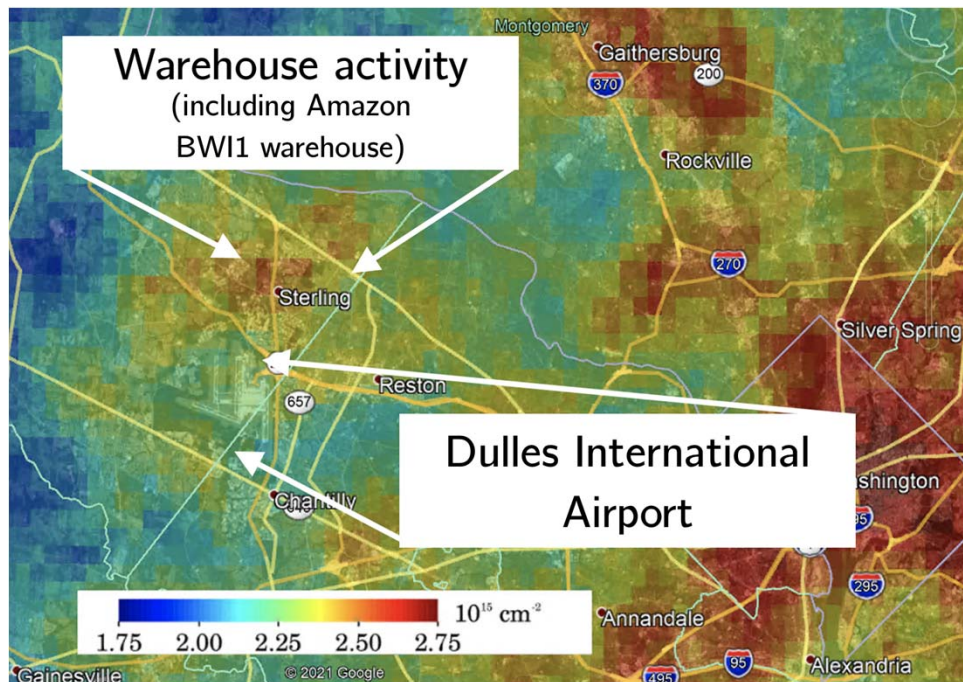
NO₂/10¹⁵ [molec cm⁻²]



Using satellites to link NO₂ disparities to sources

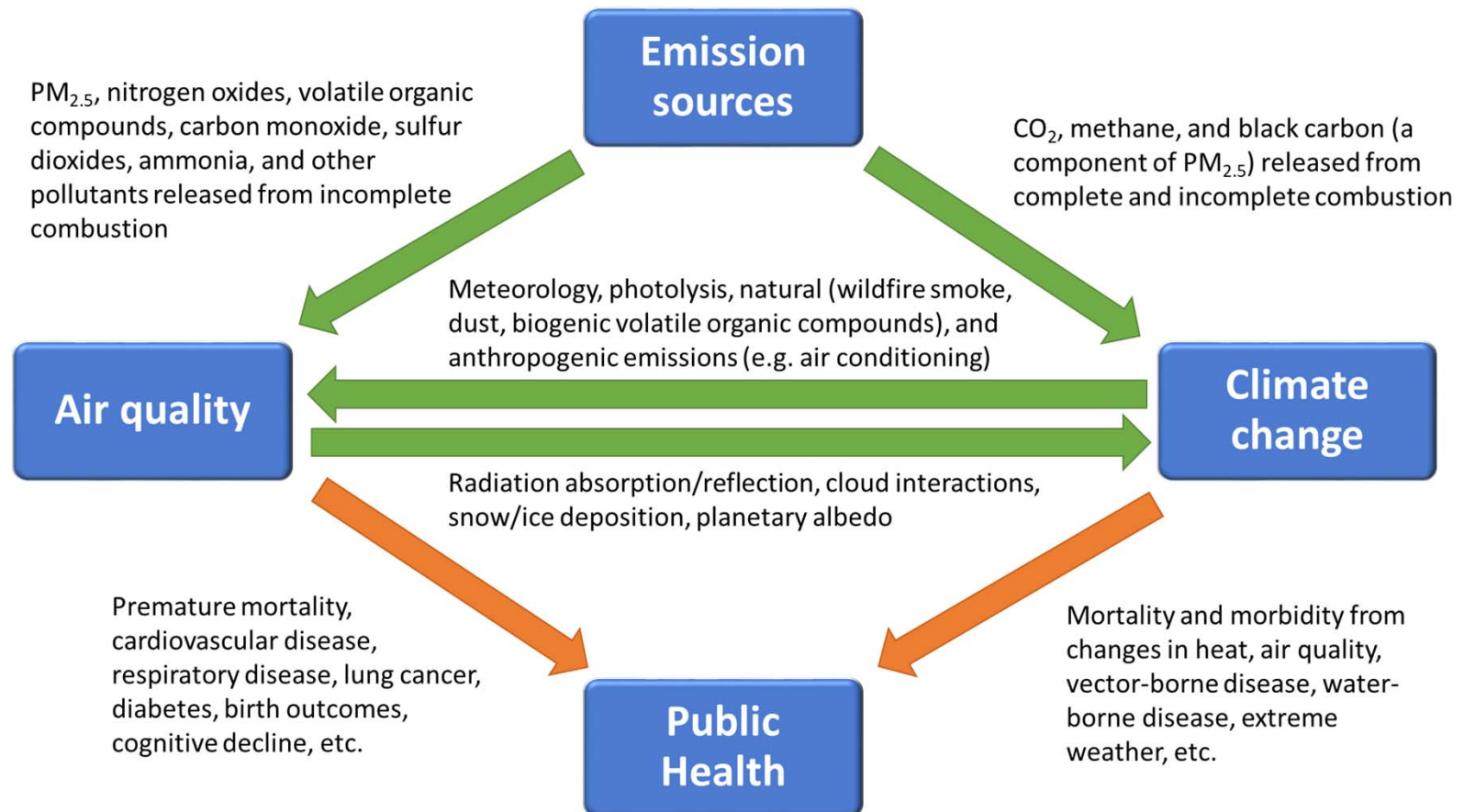


Figure credit: Dan Goldberg and Gaige Kerr



TROPOMI NO₂ oversampled to $\sim 1 \times 1 \text{ km}^2$ over the Baltimore-Washington metropolitan region for March 13-September 13, 2020. Only retrievals exceeding a quality assurance flag > 0.75 are included. Colorbar saturates at (left) 2.75×10^{15} and (right) 2.5×10^{15} molecules cm^{-2} for greater contrast.

Air pollution, climate change, and health are interconnected



Anenberg et al., *Earth's Future* 2019

Time to rethink air quality management



From “end of pipe” engineering controls



Catalytic converters,
Diesel particulate filters



Scrubbers

To burning less stuff in the first place



Active transportation

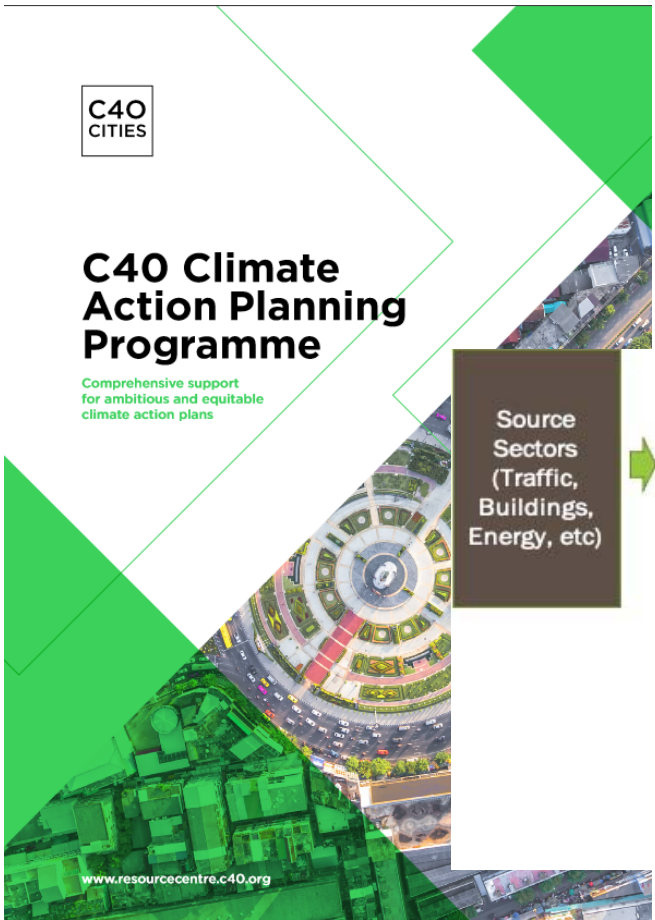


Zero emission energy



Energy efficiency

New decision-support tool: Pathways-AQ



Source Sectors (Traffic, Buildings, Energy, etc)

GHG Emissions Inventory

GHG Goal Setting

Urban planning and policy decision-making through CAP process

Reduced GHG Emissions

Air quality emission inventory

- AQ model
- Public health impact assessment

Air quality benefits
Public health benefits

- Prioritize strategies that maximize public health
- Reveal unintended consequences
- Identify new strategies
- More effective communication of near-term benefits of action
- Assess win/win, improve

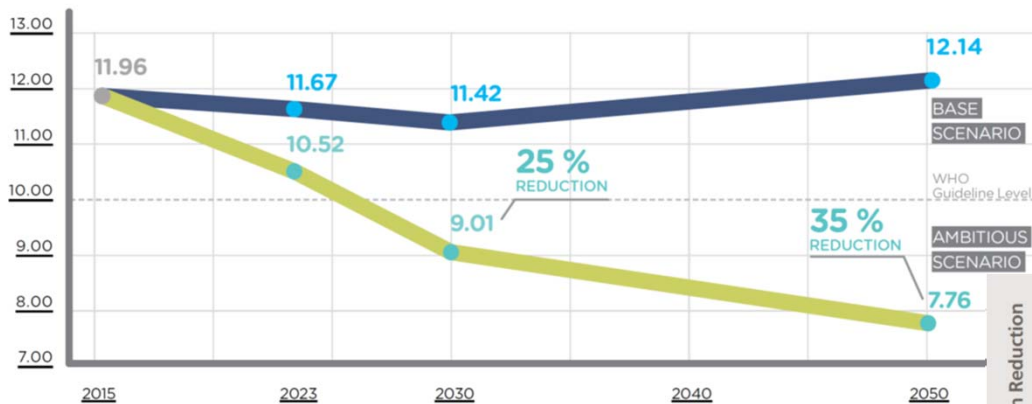
Integrated planning, AQ+GHGs

Integrating AQ into urban CAPs



Buenos Aires

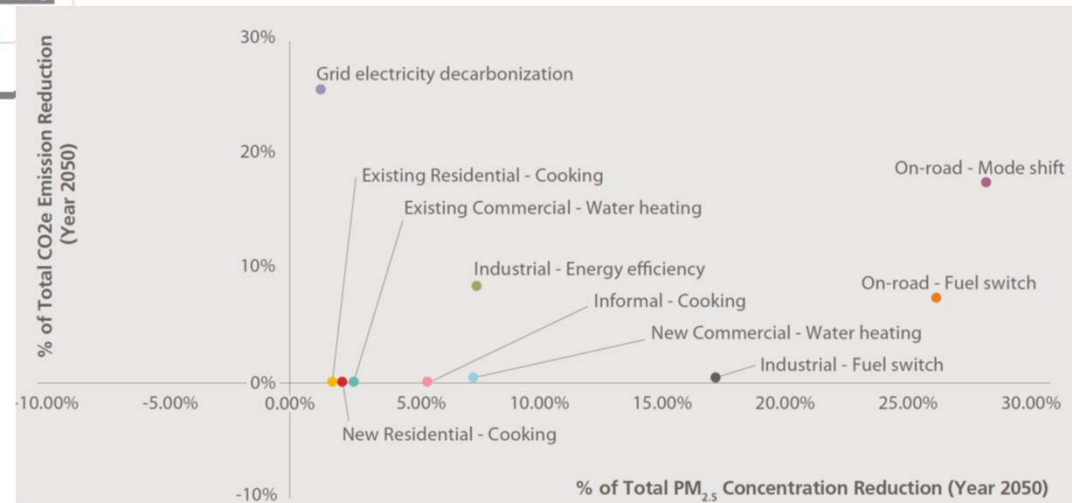
ANNUAL AVERAGE CONCENTRATION PM_{2.5} [µg/m₃]



[https://cdn.locomotive.works/sites/5ab410c8a2f42204838f797e/content_entry5c8ab5851647e1\[...\]4e5a4f200a691392e/files/PAC_2050_-_ENGLISH_.pdf?1623076753](https://cdn.locomotive.works/sites/5ab410c8a2f42204838f797e/content_entry5c8ab5851647e1[...]4e5a4f200a691392e/files/PAC_2050_-_ENGLISH_.pdf?1623076753)

https://www.joburg.org.za/departments/_Documents/EISD/City%20of%20Johannesburg%20-%20Climate%20Action%20Plan%20%28CAP%29.pdf

Johannesburg



Key points



- Air pollution continues to place a large burden on public health globally and in the U.S.
- Air pollution-related health risks vary within cities, driven by concentrations and disease rates, contributing to health inequity
- Air pollution may worsen in the future under climate change
- Future air quality management requires a shift from engineering controls to reducing burning, with many LOCAL and IMMEDIATE benefits for public health
- We look forward to working with partners across the DC region and beyond to reduce air pollution, eliminate environmental and health injustice, and slow climate change.