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

Susan Anenberg, PhD

**Metropolitan Washington Air Quality Committee**

**Air and Climate Public Advisory Committee**

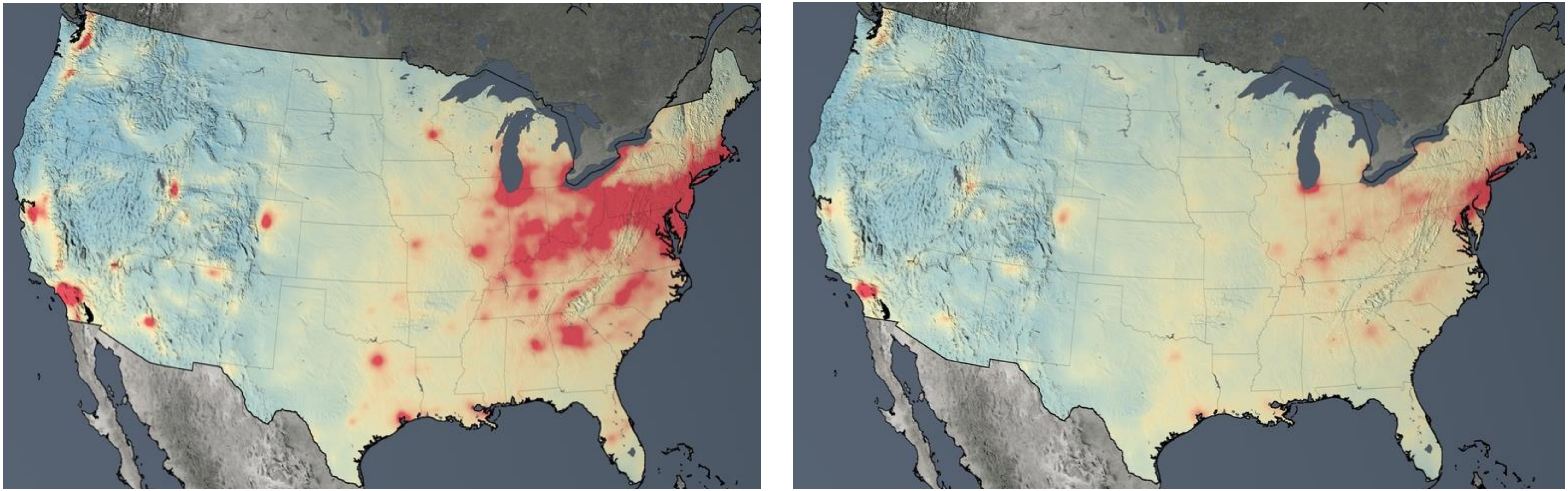
November 15, 2021

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



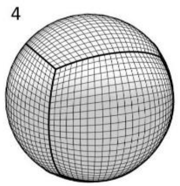
**Nitrogen dioxide observed by the Ozone Monitoring Instrument:**

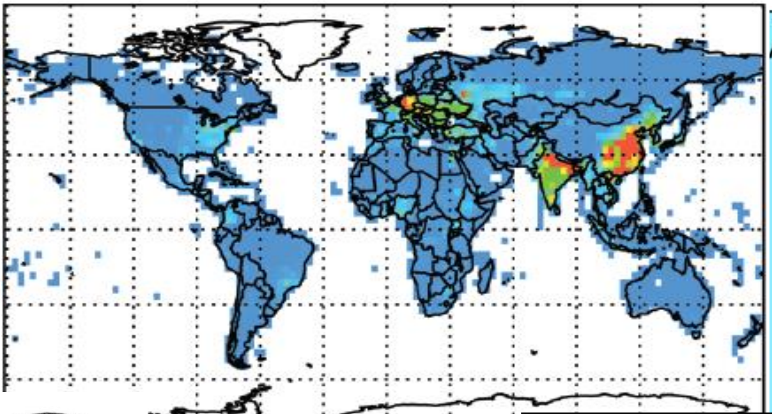
20-60% decrease from 2005 to 2016

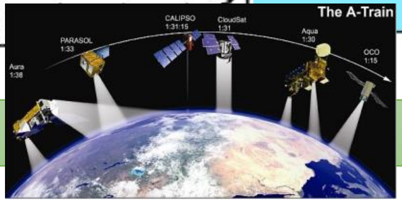
Courtesy Bryan Duncan, NASA

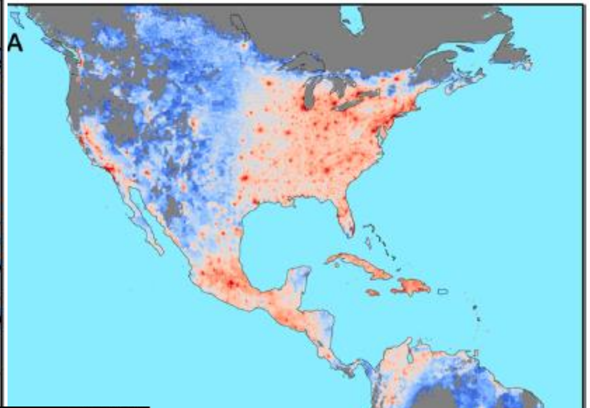
# Evolution of air pollution exposure assessment

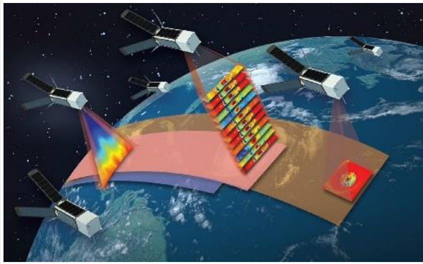
**Figure 17.1** Cities from which data on exposure to $PM_{10}$ or TSP during 1985–1999 are available from monitoring cites











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

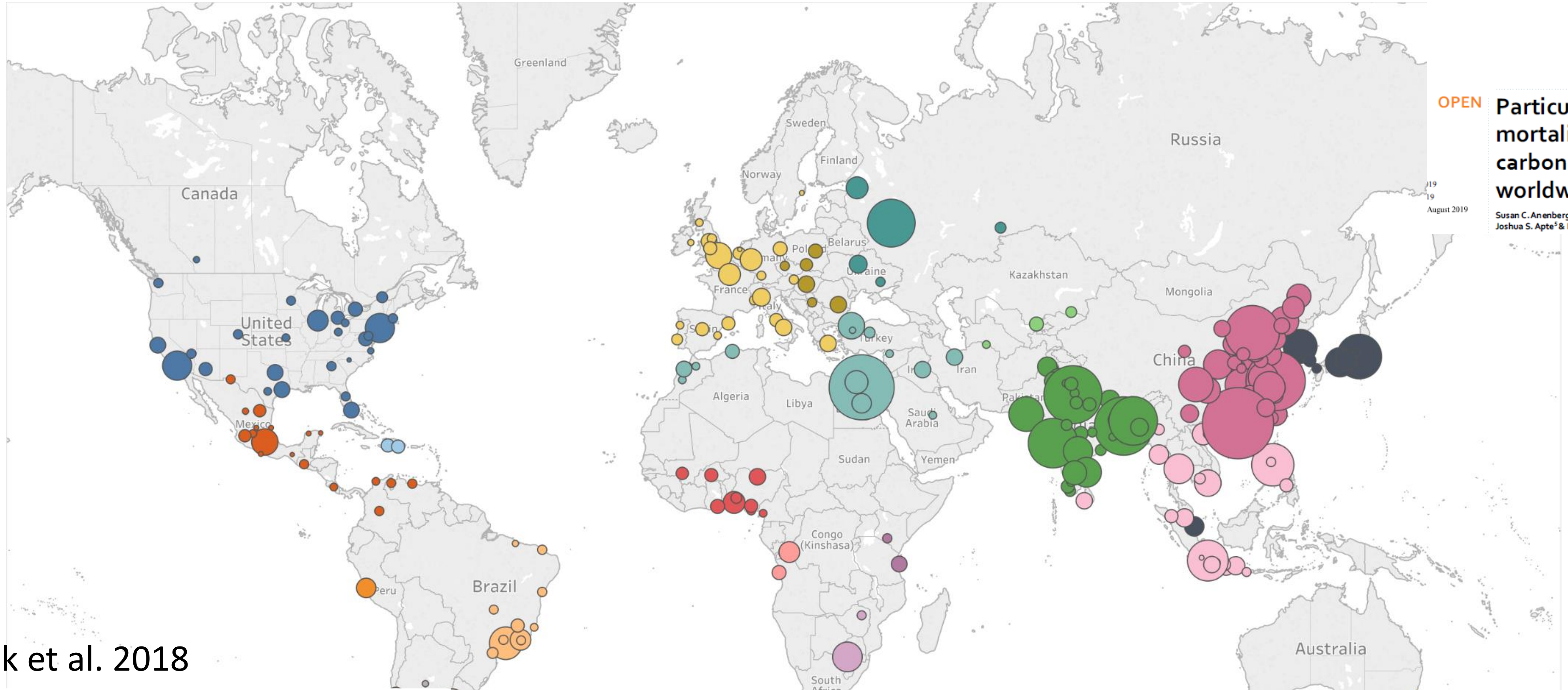
2010: **Global chemical transport model** used to estimate 3.7 million $PM_{2.5}$ deaths and 700,000 ozone deaths globally (Anenberg et al. 2010)

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**
natureresearch

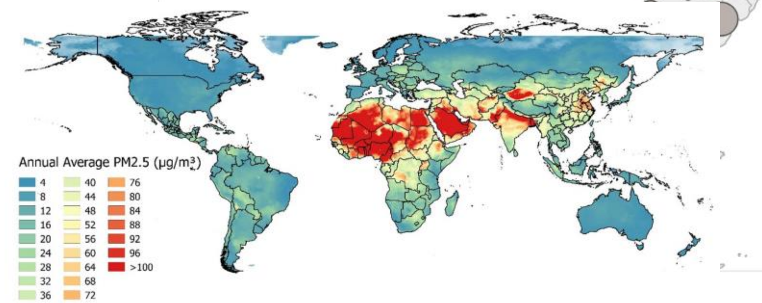
OPEN

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

Susan C. Anenberg[1], Pattanun Achakulwisut[1,7], Michael Brauer[2,3], Daniel Moran[4], Joshua S. Apte[5] & Daven K. Henze[6]

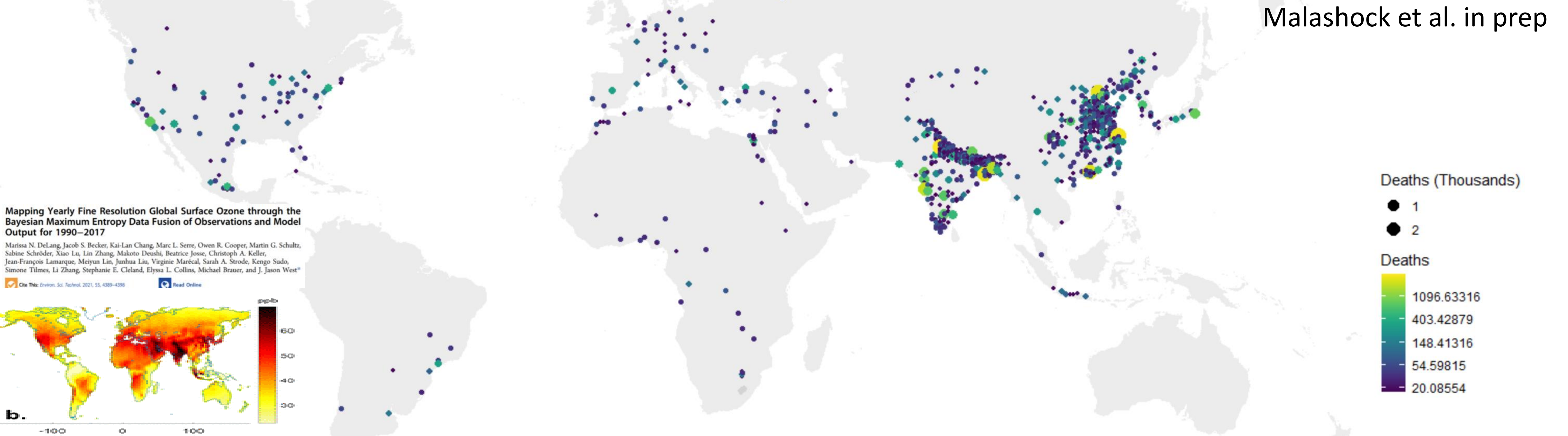
August 2019

Shaddick et al. 2018



# Ozone mortality in cities worldwide

Malashock et al. in prep



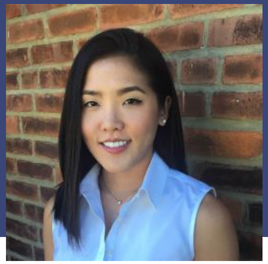
**Mapping Yearly Fine Resolution Global Surface Ozone through the Bayesian Maximum Entropy Data Fusion of Observations and Model Output for 1990–2017**

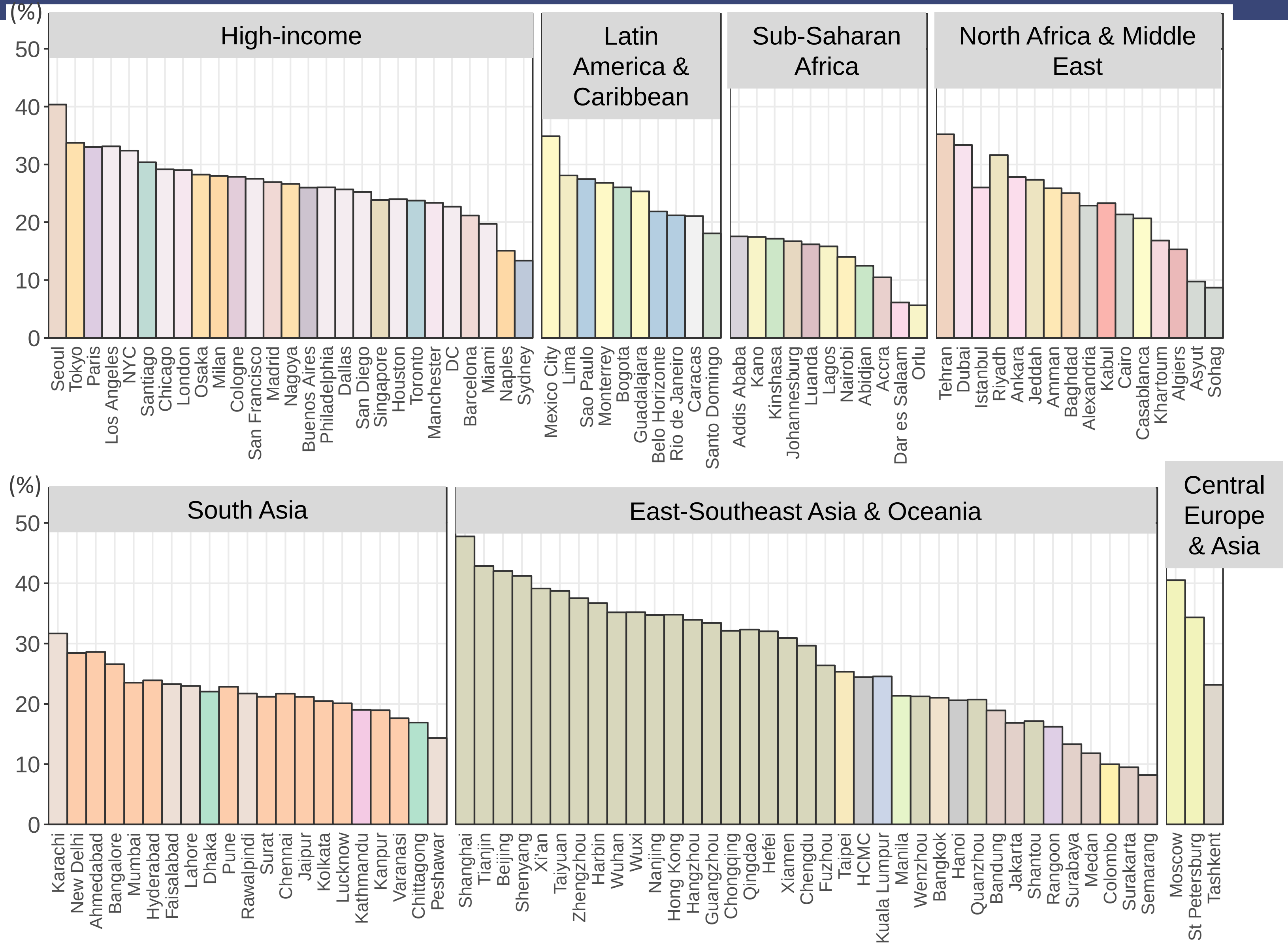
Marissa N. DeLang, Jacob S. Becker, Kai-Lan Chang, Marc L. Serre, Owen R. Cooper, Martin G. Schultz, Sabine Schröder, Xiao Lu, Lin Zhang, Makoto Deushi, Beatrice Josse, Christoph A. Keller, Jean-François Lamarque, Meiyun Lin, Junhua Liu, Virginie Marécal, Sarah A. Strode, Kengo Sudo, Simone Tilmes, Li Zhang, Stephanie E. Cleland, Elyssa L. Collins, Michael Brauer, and J. Jason West*

Cite This: Environ. Sci. Technol. 2021, 55, 4389–4398 Read Online

| | 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) | SÃ£o 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 JuÃ¡rez, Mexico (61.6) | Mbuji-Mayi, DRC (65.7) | Guadalajara, Spain (128.5) | San Diego, CA, USA (186.7) | Guangzhou, China (2179.5) |

# $NO_2$ pollution is an important risk factor for pediatric asthma incidence





In 125 major cities, the percent of new pediatric asthma cases attributable to $NO_2$:

- 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 $NO_2$ pollution: estimates from global datasets**

Pattanun Achakulwisut, Michael Brauer, Perry Hystad, 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**

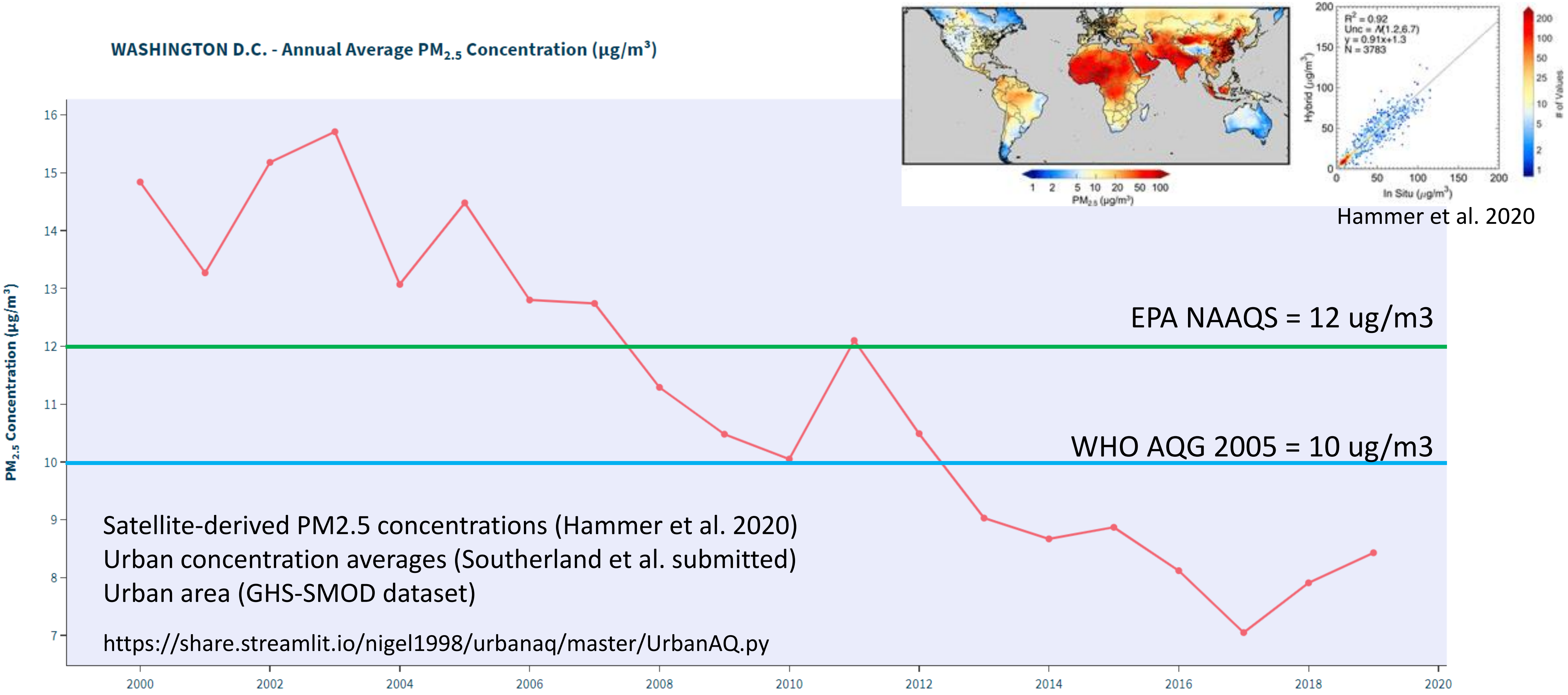
**2.4**
**2.4**

**No NAAQS**
**3.3**

**No NAAQS**
**1.4**
**No NAAQS**

**10**
**No NAAQS**
**1**

# PM$_{2.5}$ trends – Washington, DC metro



Hammer et al. 2020

EPA NAAQS = 12 ug/m3

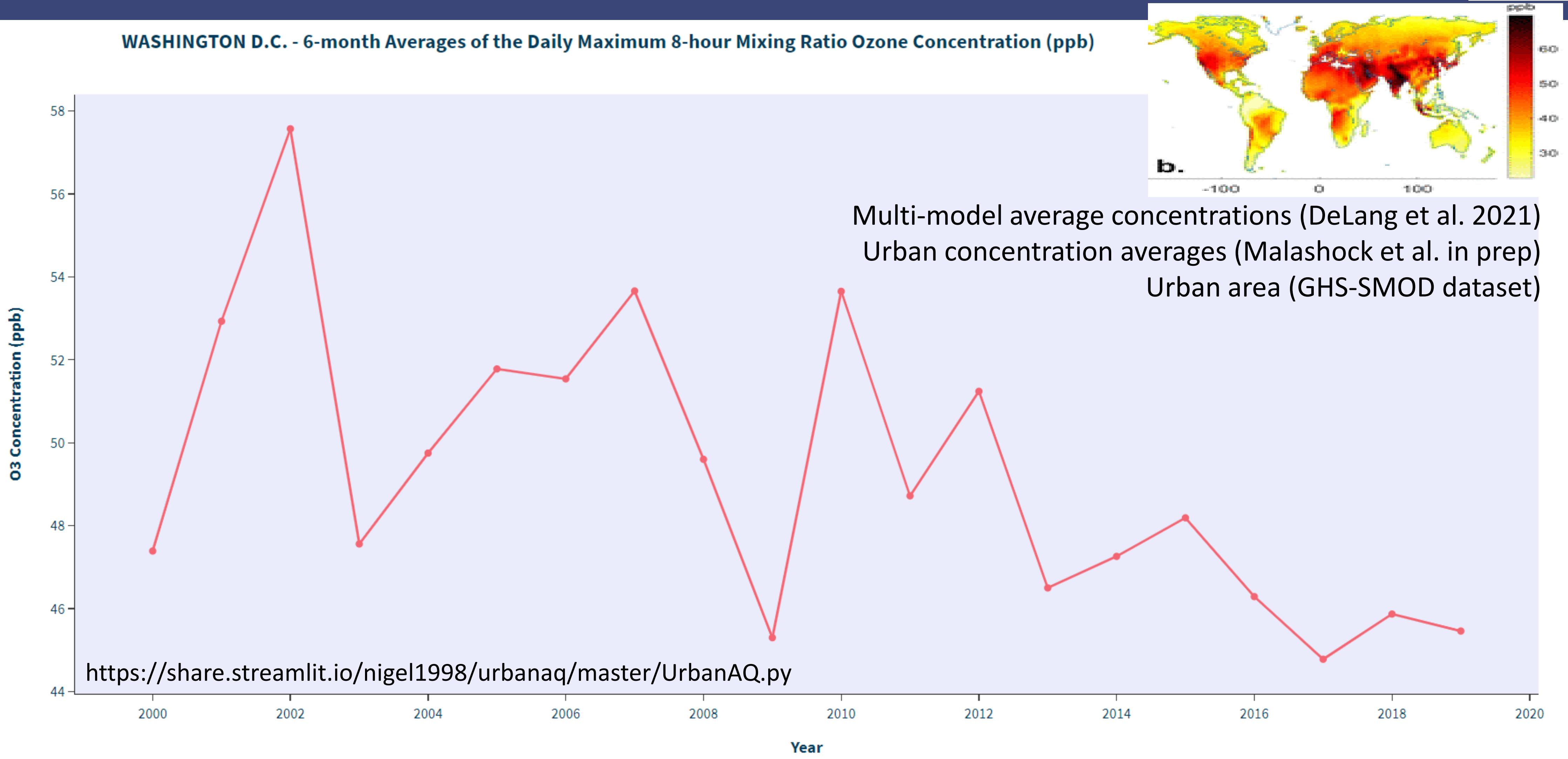
WHO AQG 2005 = 10 ug/m3

Satellite-derived PM2.5 concentrations (Hammer et al. 2020)
Urban concentration averages (Southerland et al. submitted)
Urban area (GHS-SMOD dataset)

https://share.streamlit.io/nigel1998/urbanaq/master/UrbanAQ.py

WHO AQG 2021 = 5 ug/m3

# Ozone trends – Washington, DC metro



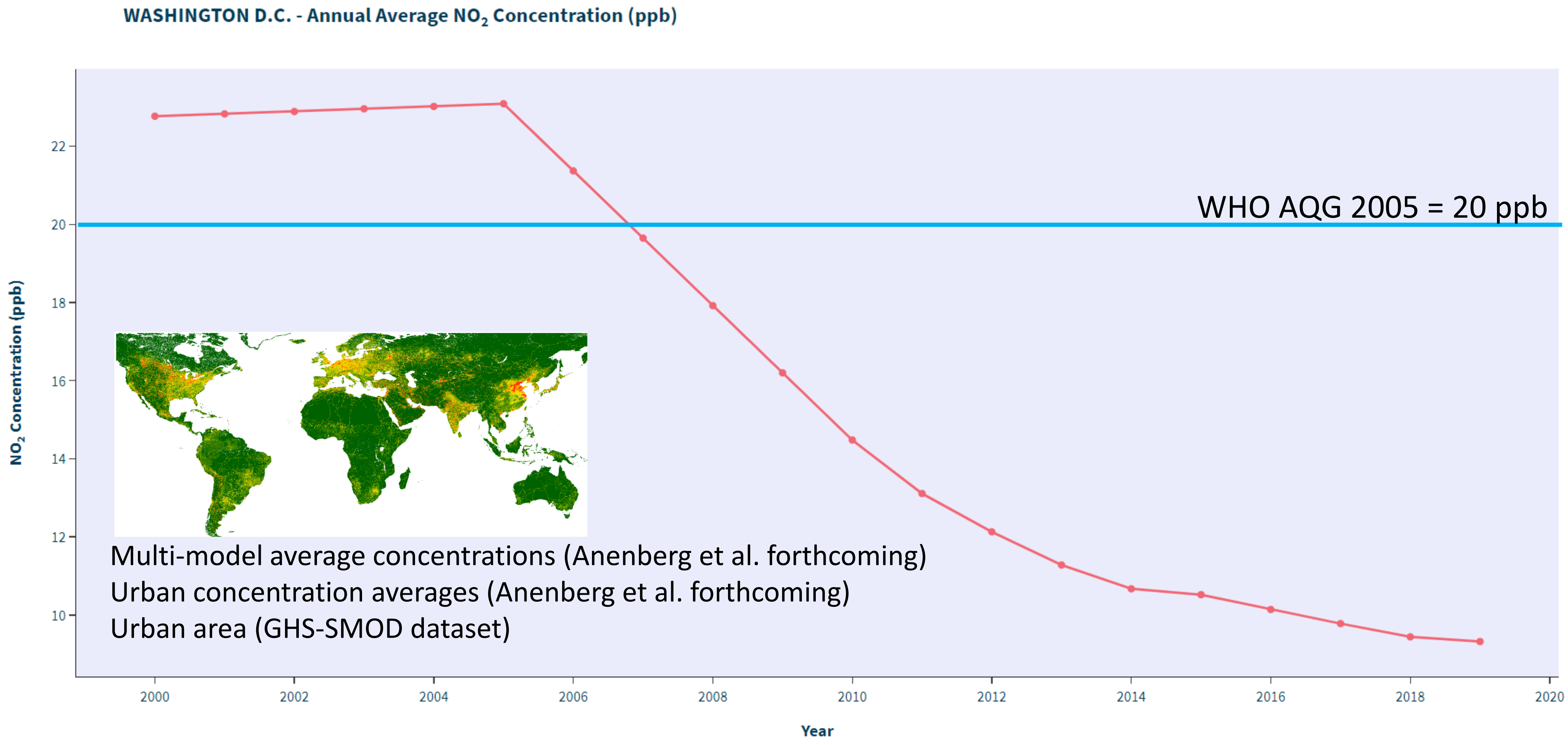
Multi-model average concentrations (DeLang et al. 2021)
Urban concentration averages (Malashock et al. in prep)
Urban area (GHS-SMOD dataset)

https://share.streamlit.io/nigel1998/urbanaq/master/UrbanAQ.py

WHO AQG 2021 = 30 ppb

EPA NAAQS = 53 ppb

# $NO_2$ trends – Washington, DC metro

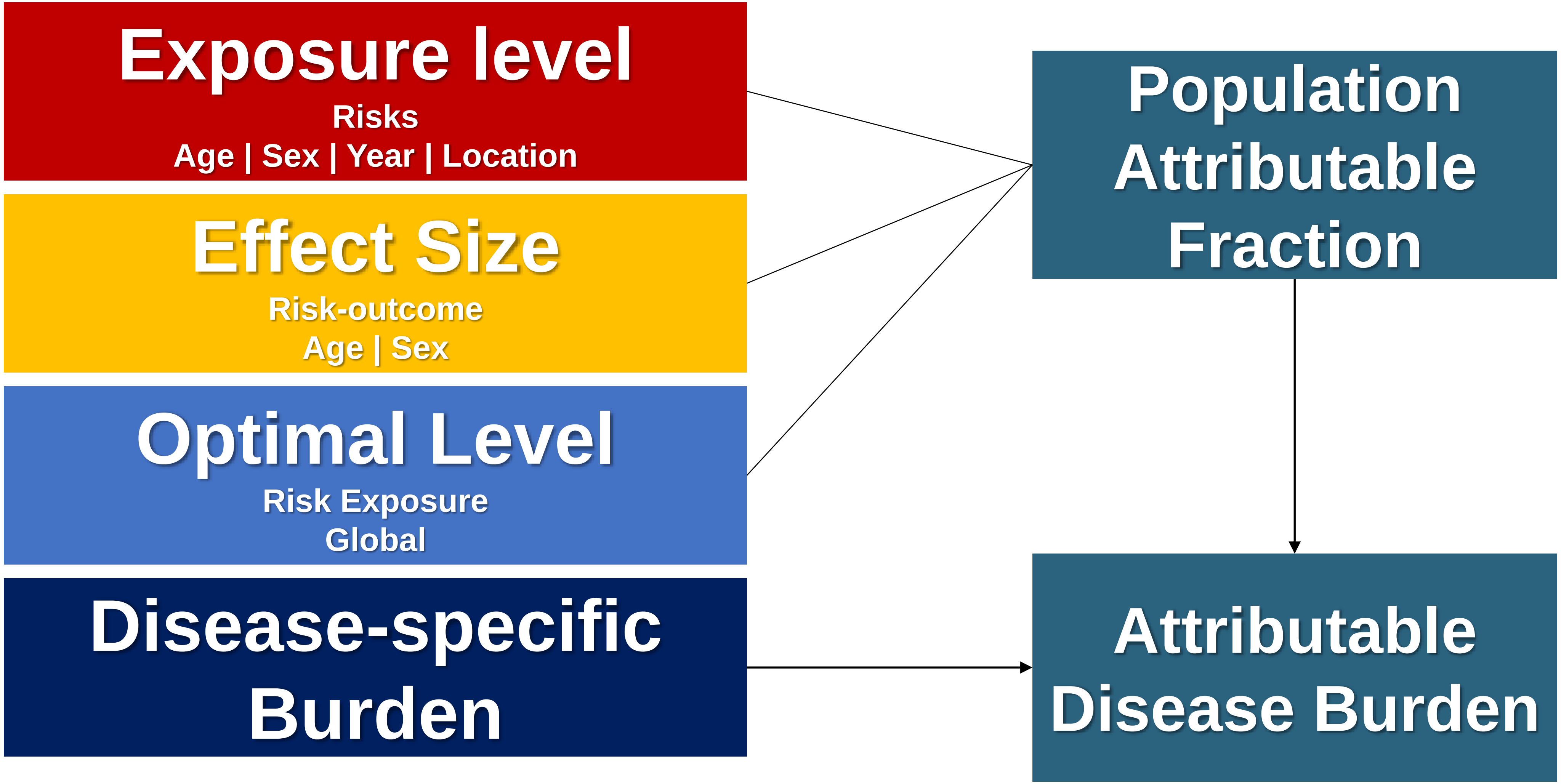

WASHINGTON D.C. - Annual Average $NO_2$ Concentration (ppb)

WHO AQG 2005 = 20 ppb

Multi-model average concentrations (Anenberg et al. forthcoming)
Urban concentration averages (Anenberg et al. forthcoming)
Urban area (GHS-SMOD dataset)

WHO AQG 2021 = 5 ppb

# Estimating disease burden from air pollution



**Exposure level**
Risks
Age | Sex | Year | Location

**Effect Size**
Risk-outcome
Age | Sex

**Optimal Level**
Risk Exposure
Global

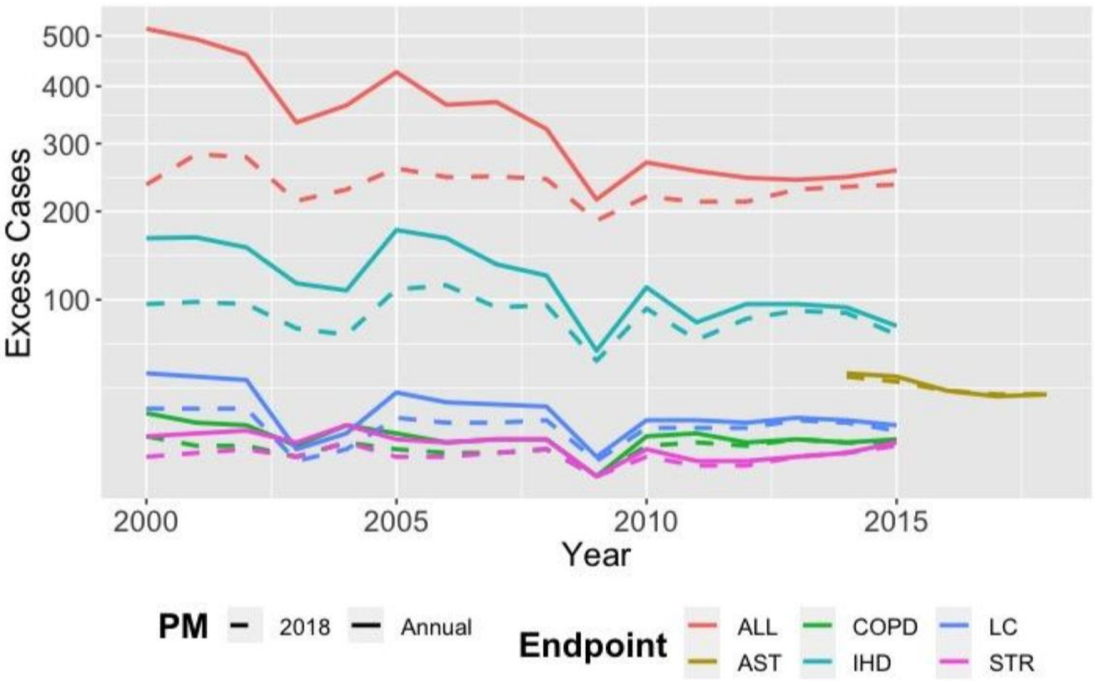
**Disease-specific Burden**

**Population Attributable Fraction**

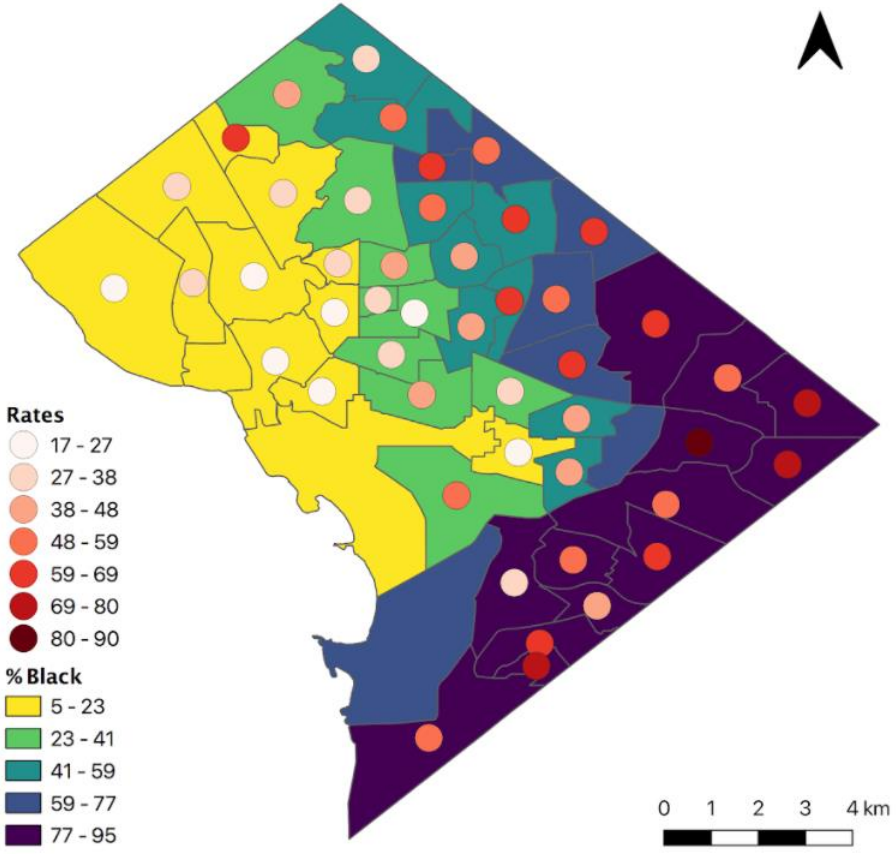
**Attributable Disease Burden**

# Air pollution inequity in Washington, DC

Temporal trend in $PM_{2.5}$-attributable mortality

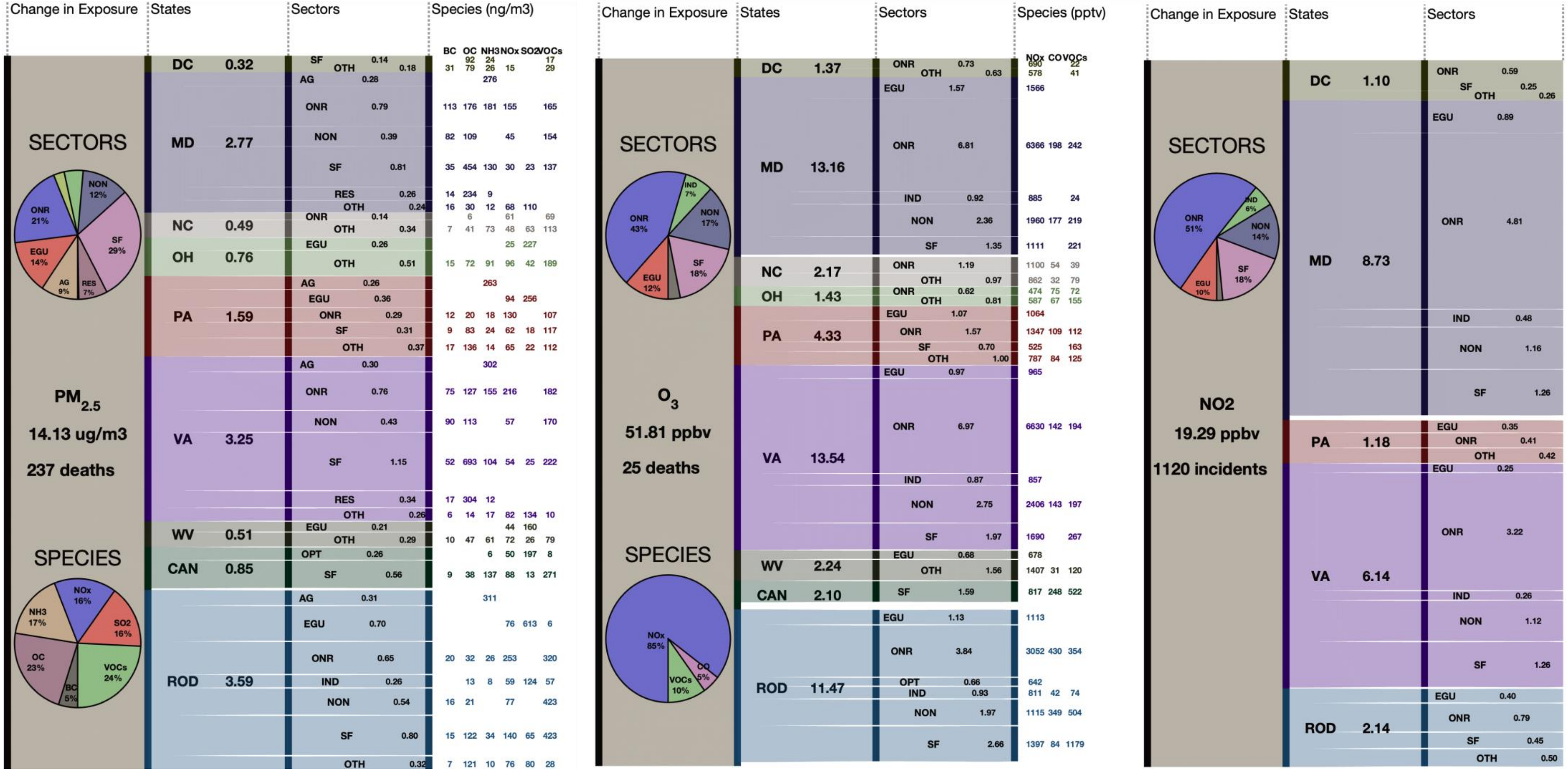


Spatial pattern, links with demographics



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

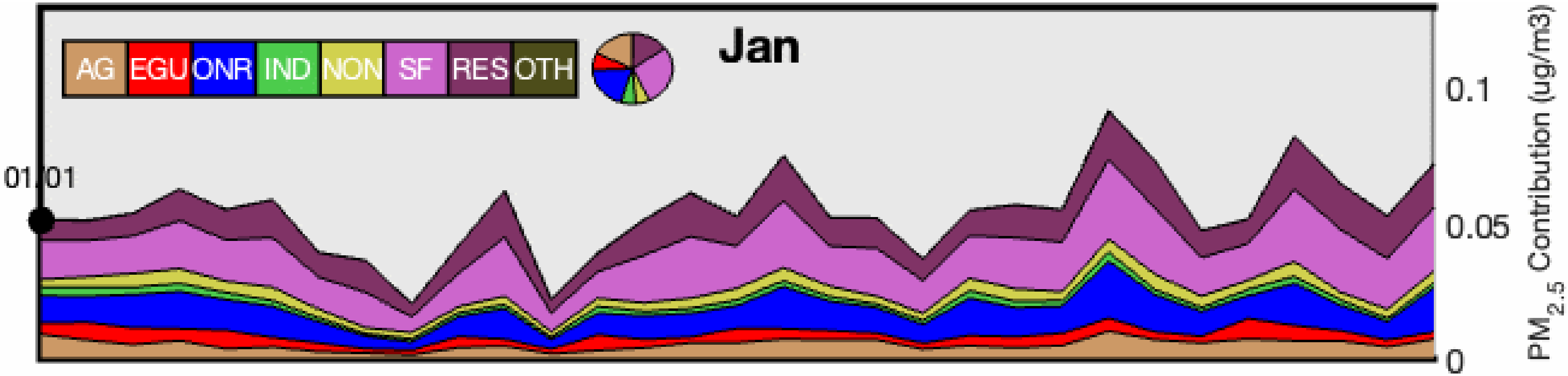
**NON** – Non-road

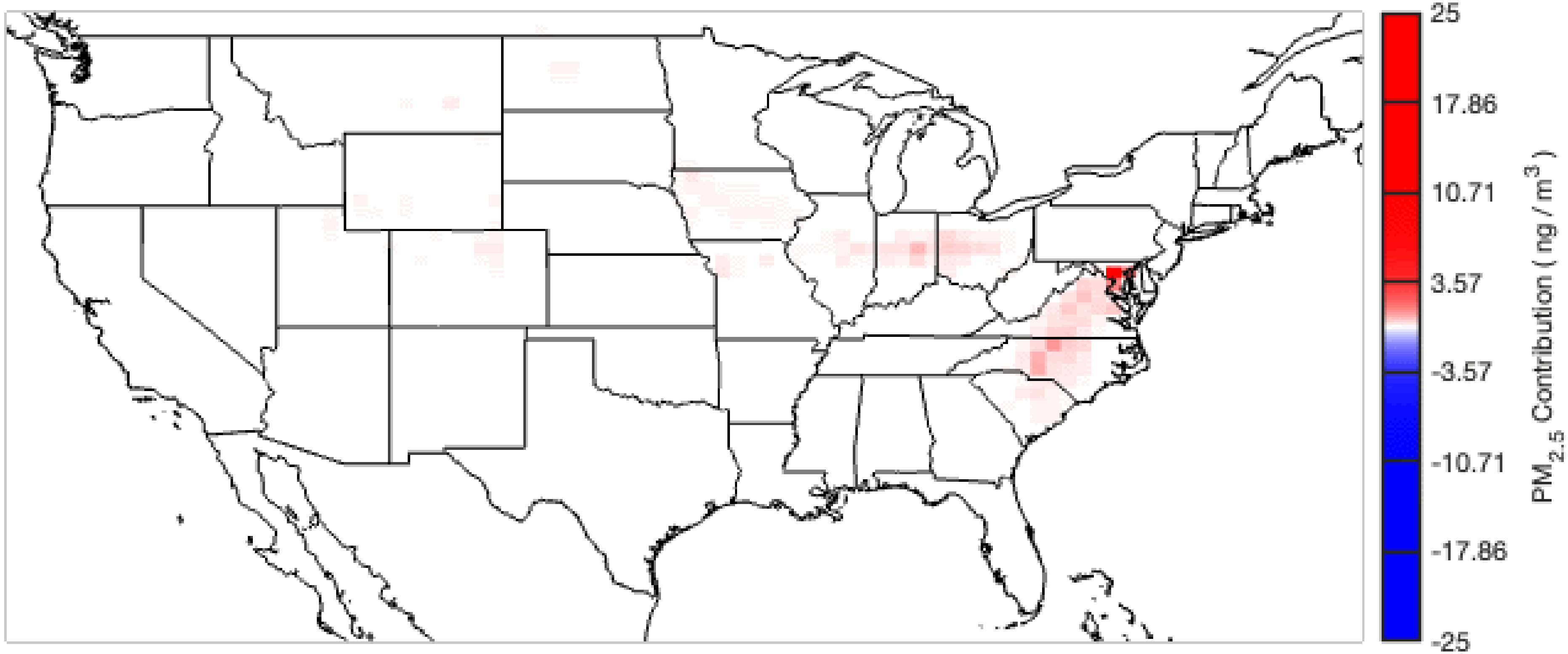
**SF** – Surface Emissions

**RES** – Residential

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

# 2011 Daily $PM_{2.5}$ Contributions in DC

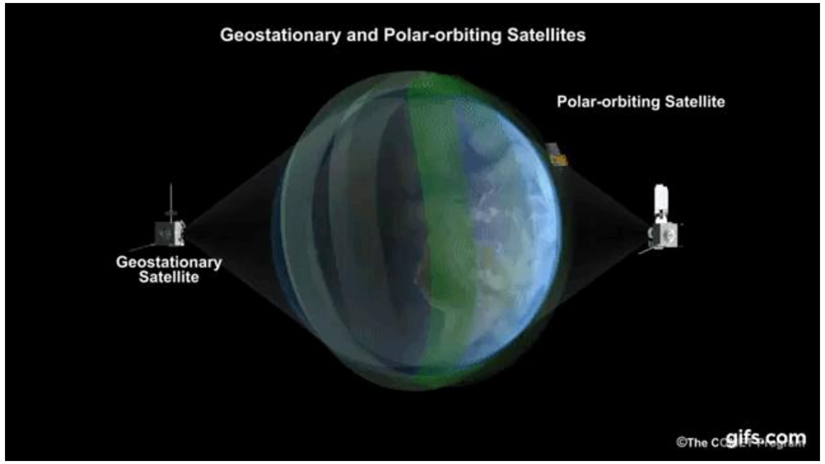


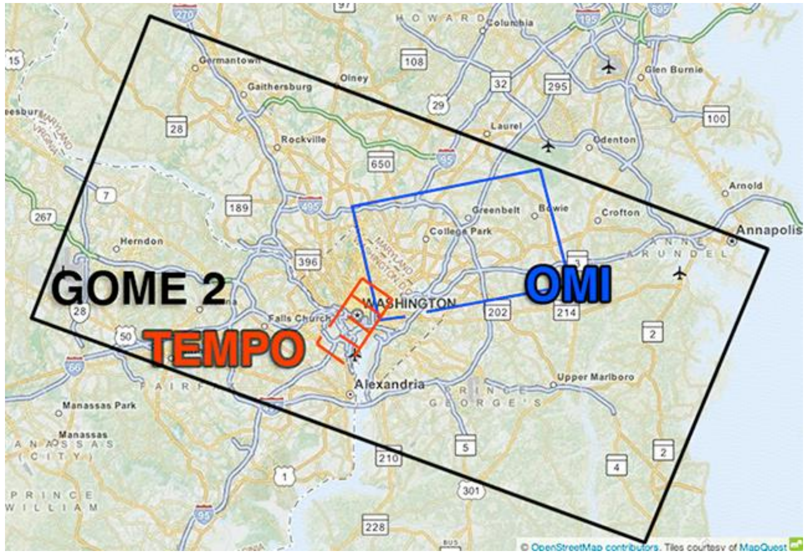


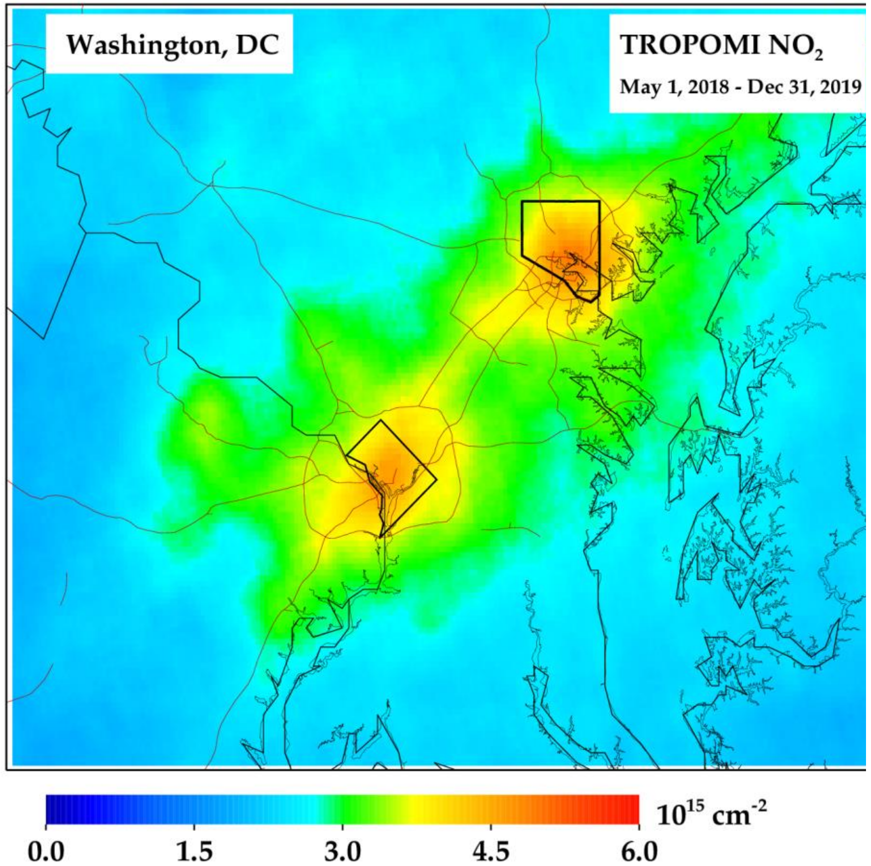
| Sectors | |
|---|---|
| **OTH** | **Other Sectors** |
| **RES** | **Residential** |
| **SF** | **Surface Emissions** |
| **NON** | **Non-road** |
| **IND** | **Industry** |
| **ONR** | **On-road** |
| **EGU** | **Energy Generation** |
| **AG** | **Agriculture** |

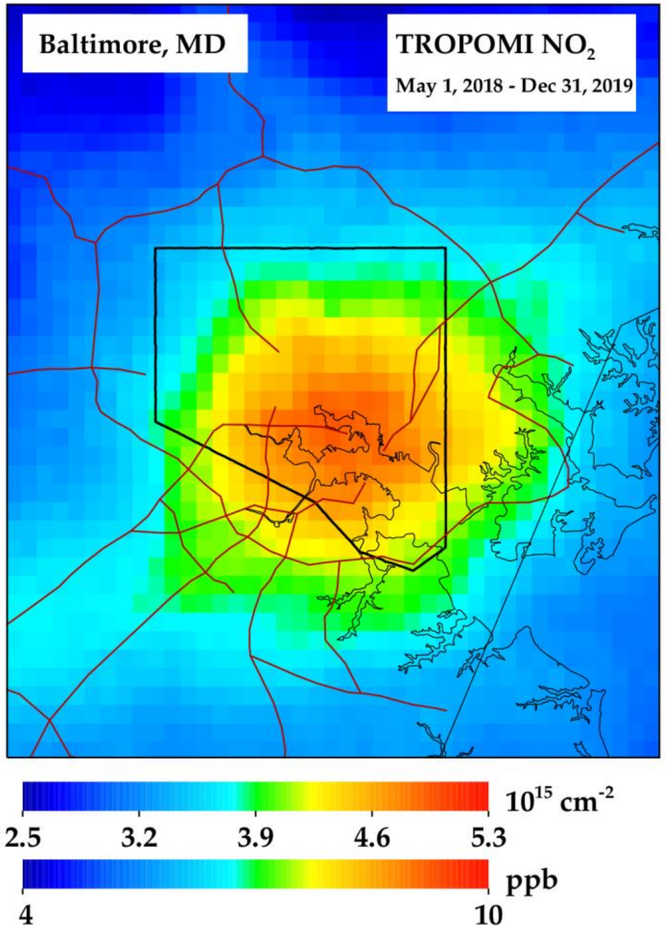
Nawaz et al. submitted. Emission to concentration sensitivities from GEOS-Chem model

# TROPOMI $NO_2$ can identify local pollution relatively well





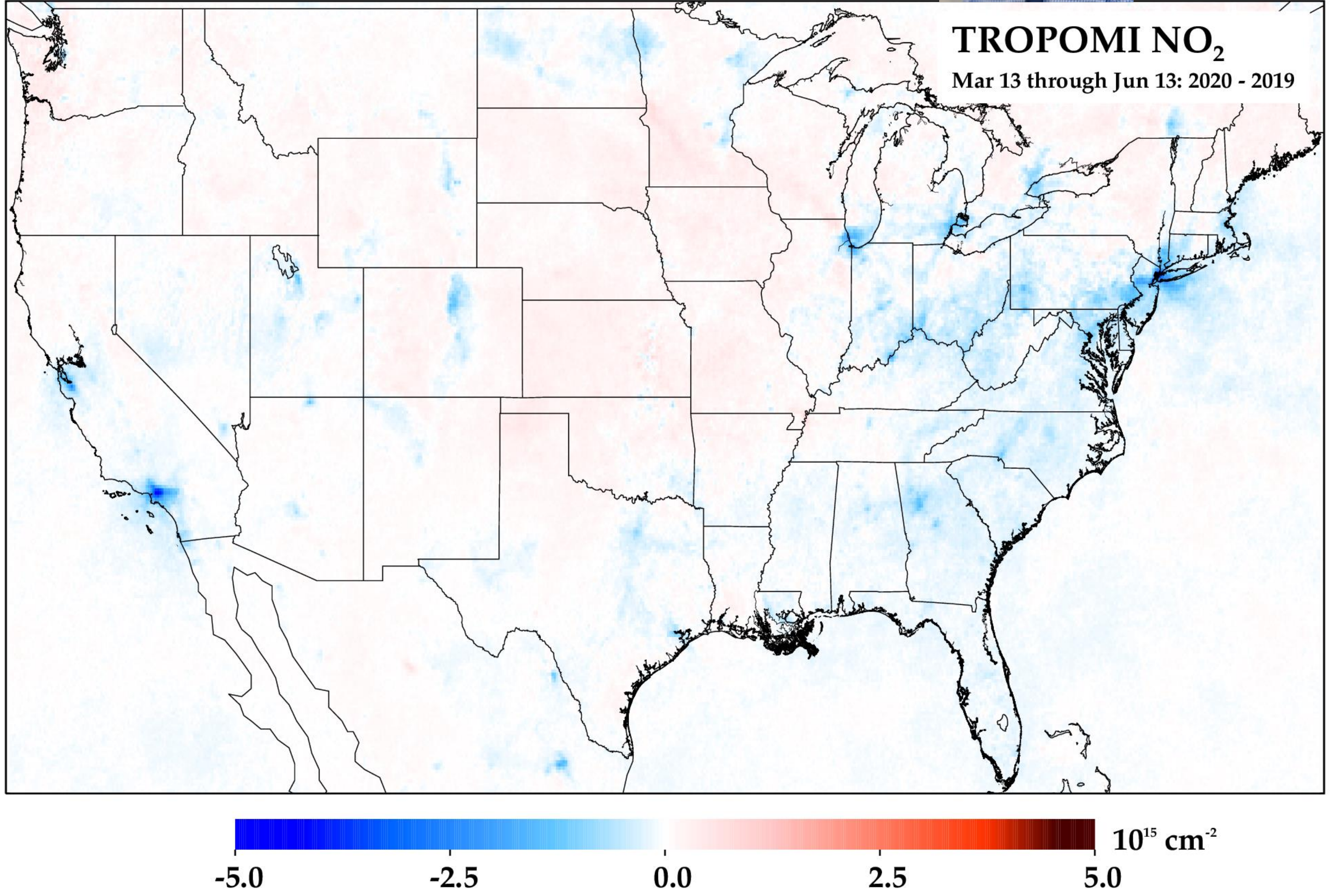


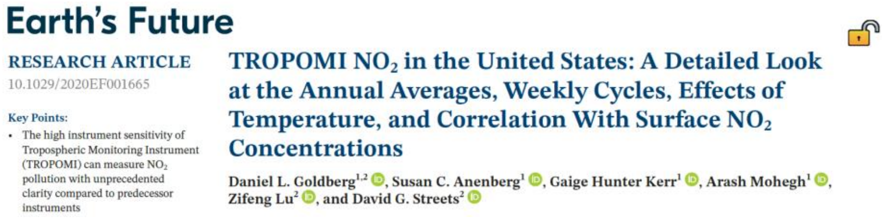


Goldberg et al., 2021,
*Earth's Future*
Open Access

# 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 $NO_2$ decreases?





**Earth’s Future**

**RESEARCH ARTICLE**

10.1029/2020EF001665

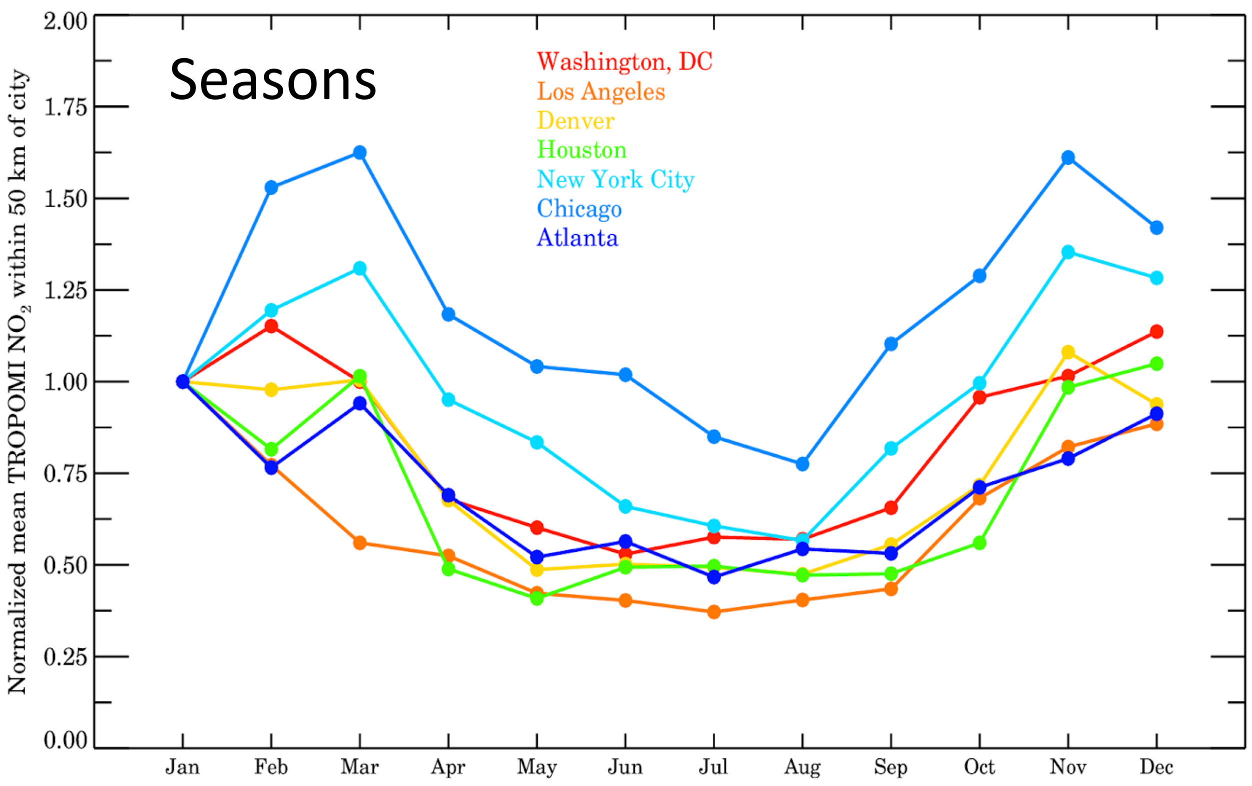
**Key Points:**

- The high instrument sensitivity of Tropospheric Monitoring Instrument (TROPOMI) can measure $NO_2$ pollution with unprecedented clarity compared to predecessor instruments

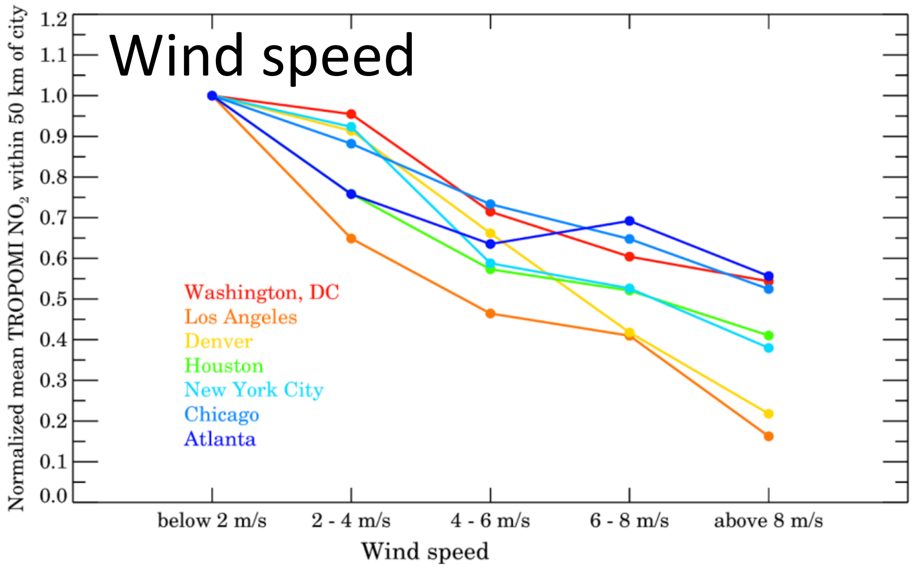
**TROPOMI $NO_2$ in the United States: A Detailed Look at the Annual Averages, Weekly Cycles, Effects of Temperature, and Correlation With Surface $NO_2$ Concentrations**

Daniel L. Goldberg[1,2], Susan C. Anenberg[1], Gaige Hunter Kerr[1], Arash Mohegh[1], Zifeng Lu[2], and David G. Streets[2]

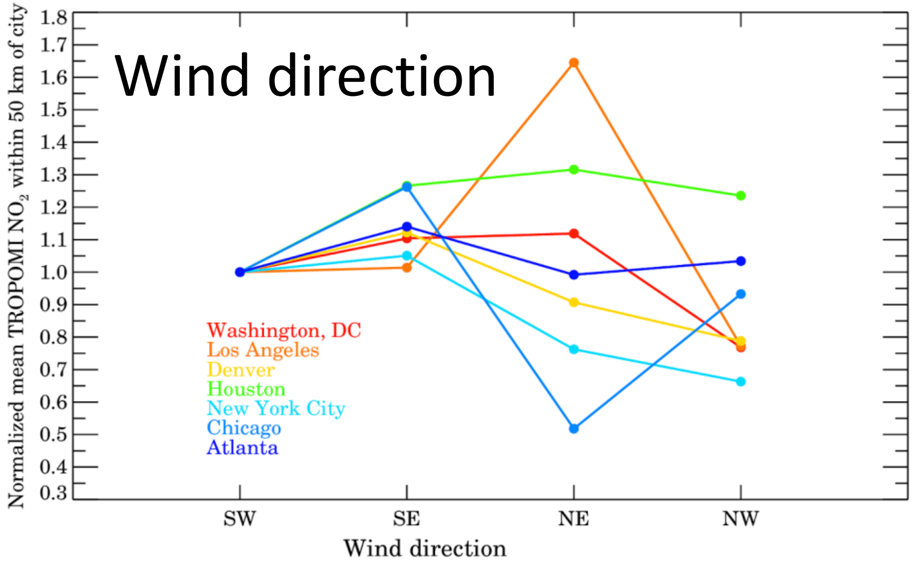
# Natural influences on TROPOMI $NO_2$



Seasons



Wind speed



Wind direction

**Geophysical Research Letters**

**RESEARCH LETTER**

10.1029/2020GL089269

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

**Disentangling the Impact of the COVID-19 Lockdowns on Urban $NO_2$ From Natural Variability**

Daniel L. Goldberg[1,2], Susan C. Anenberg[1], Debora Griffin[3], Chris A. McLinden[3], Zifeng Lu[2], and David G. Streets[2]

# 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)

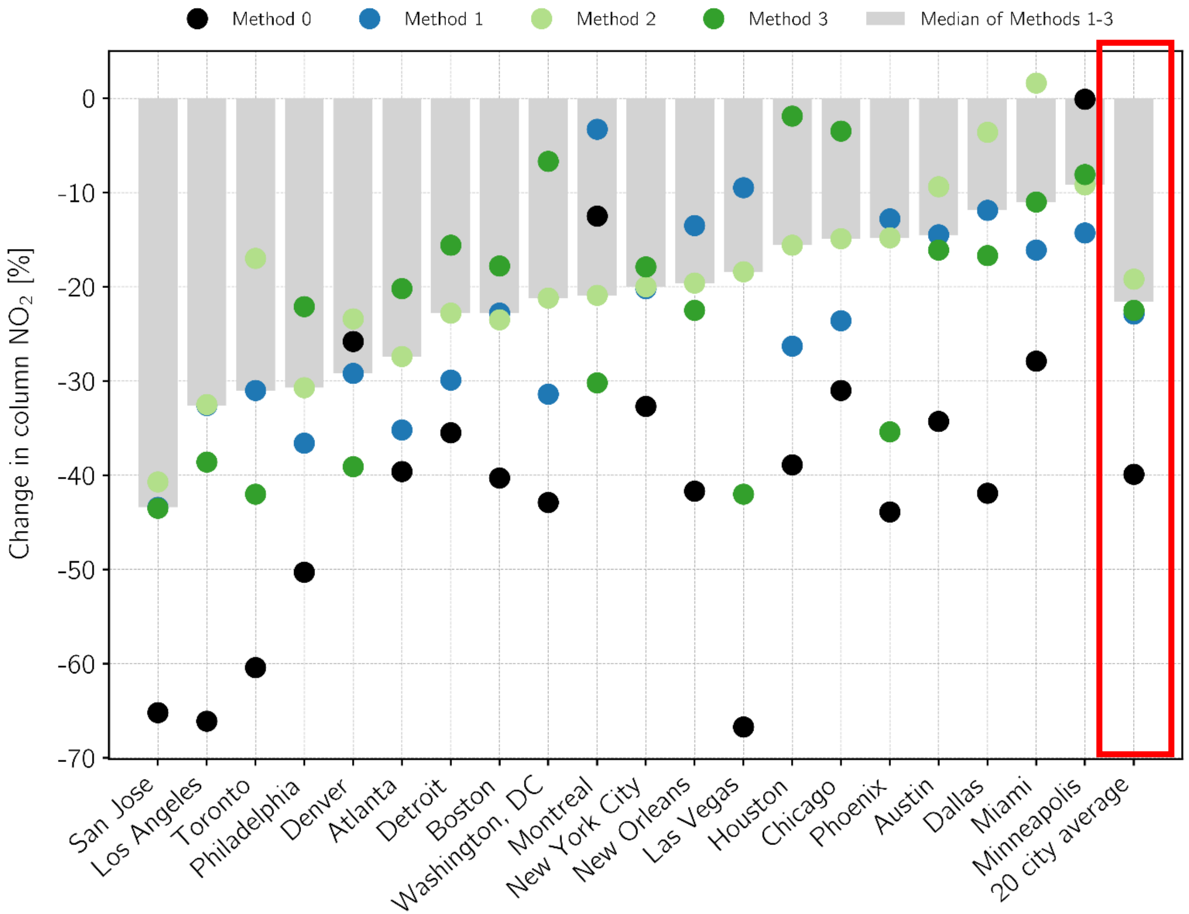


Figure created by Gaige Kerr

**Geophysical Research Letters**

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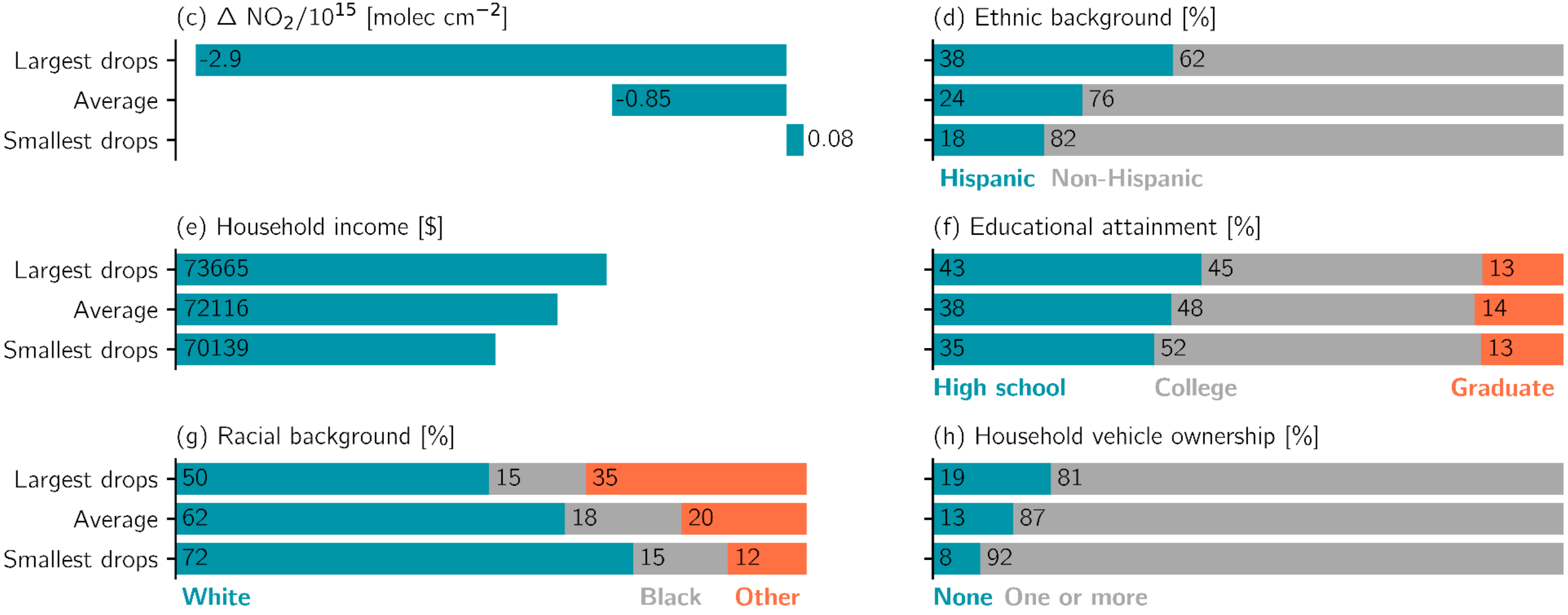
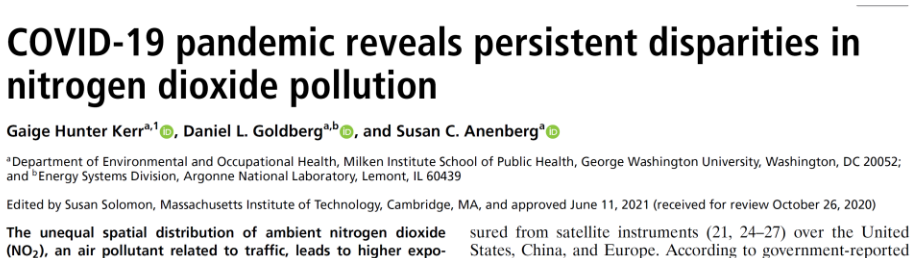
# During COVID-19 precautions, less educated, minority communities experience the largest decreases in $NO_2$





**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]

[a]Department of Environmental and Occupational Health, Milken Institute School of Public Health, George Washington University, Washington, DC 20052; and [b]Energy 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)

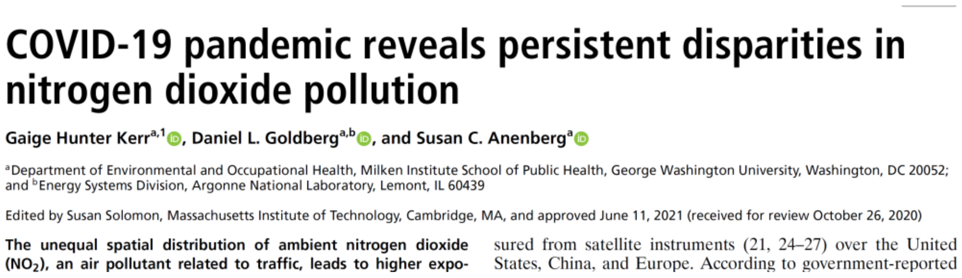
**The unequal spatial distribution of ambient nitrogen dioxide ($NO_2$), an air pollutant related to traffic, leads to higher expo-**

sured 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 $NO_2$ disparities by race



## COVID-19 pandemic reveals persistent disparities in nitrogen dioxide pollution

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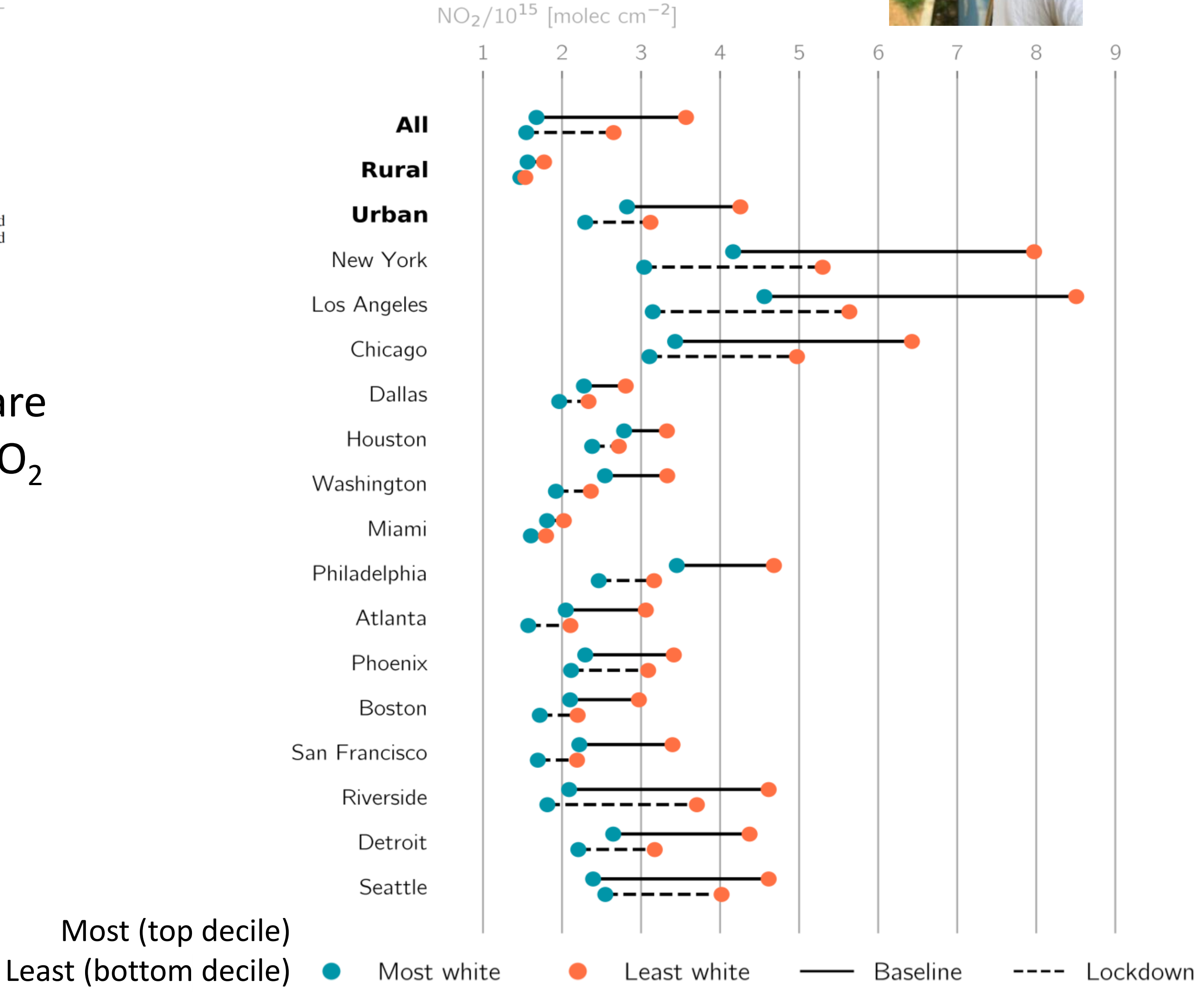
**The unequal spatial distribution of ambient nitrogen dioxide ($NO_2$), an air pollutant related to traffic, leads to higher expo-**

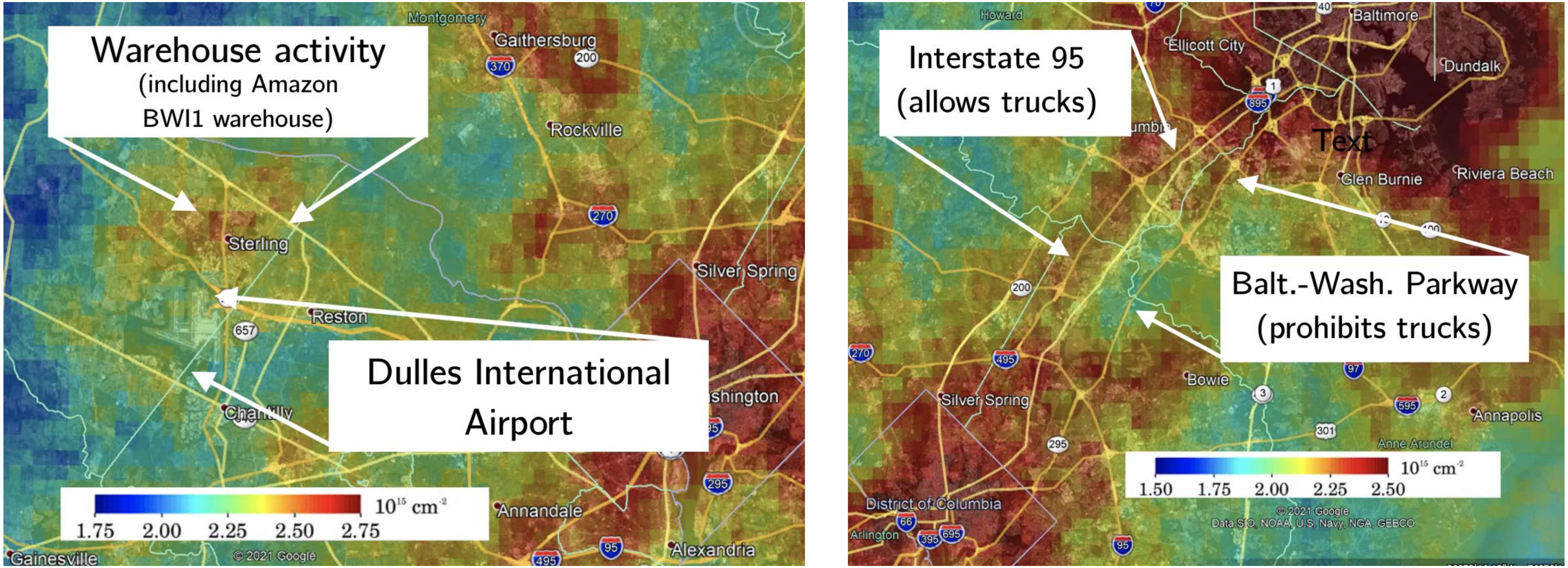
sured from satellite instruments (21, 24–27) over the United States, China, and Europe. According to government-reported

- 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



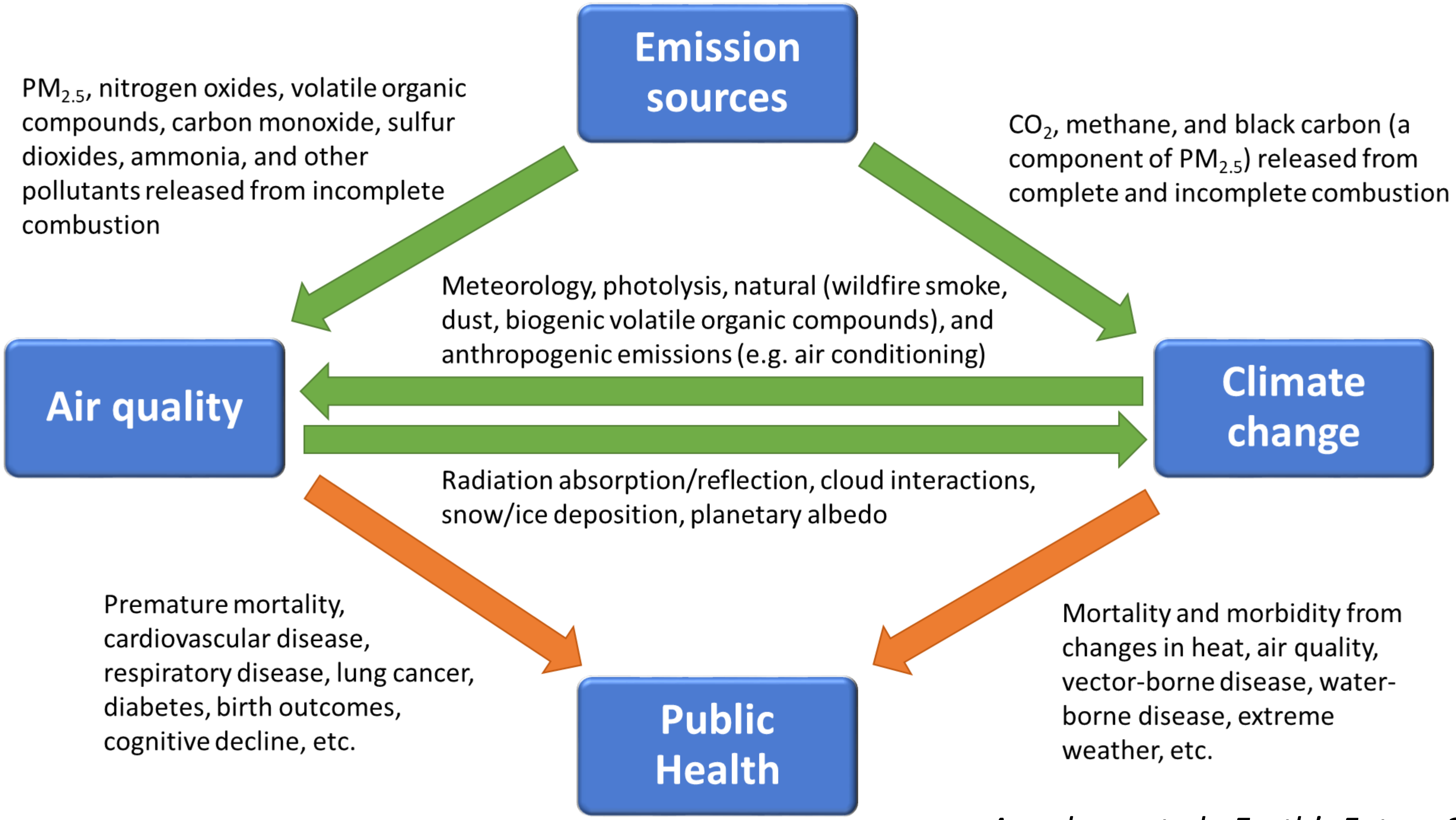
# Using satellites to link $NO_2$ disparities to sources

Figure credit: Dan Goldberg and Gaige Kerr



TROPOMI $NO_2$ oversampled to ~1 × 1 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) $2.75 \times 10^{15}$ and (right) $2.5 \times 10^{15}$ molecules cm$^{-2}$ for greater contrast.

# Air pollution, climate change, and health are interconnected



**Emission sources**

$PM_{2.5}$, nitrogen oxides, volatile organic compounds, carbon monoxide, sulfur dioxides, ammonia, and other pollutants released from incomplete combustion

$CO_2$, methane, and black carbon (a component of $PM_{2.5}$) released from complete and incomplete combustion

**Air quality**

**Climate change**

Meteorology, photolysis, natural (wildfire smoke, dust, biogenic volatile organic compounds), and anthropogenic emissions (e.g. air conditioning)

Radiation absorption/reflection, cloud interactions, snow/ice deposition, planetary albedo

Premature mortality, cardiovascular disease, respiratory disease, lung cancer, diabetes, birth outcomes, cognitive decline, etc.

Mortality and morbidity from changes in heat, air quality, vector-borne disease, water-borne disease, extreme weather, etc.

**Public Health**

*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

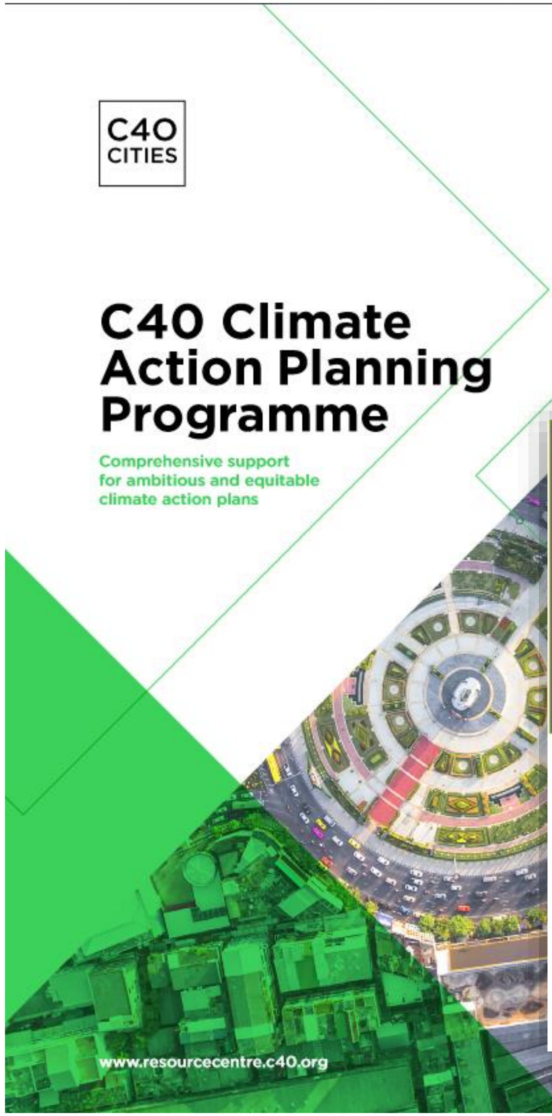
## To burning less stuff in the first place


Active transportation


Zero emission energy


Energy efficiency

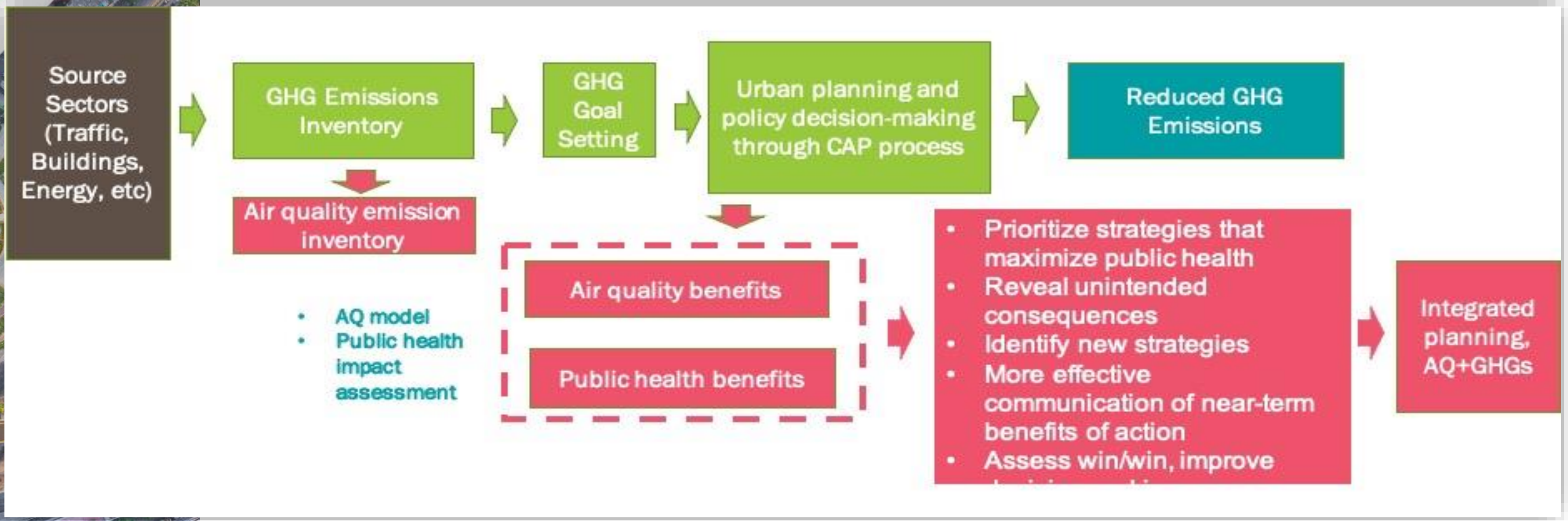
# New decision-support tool: Pathways-AQ


C40 CITIES

## C40 Climate Action Planning Programme

Comprehensive support for ambitious and equitable climate action plans

www.resourcecentre.c40.org


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

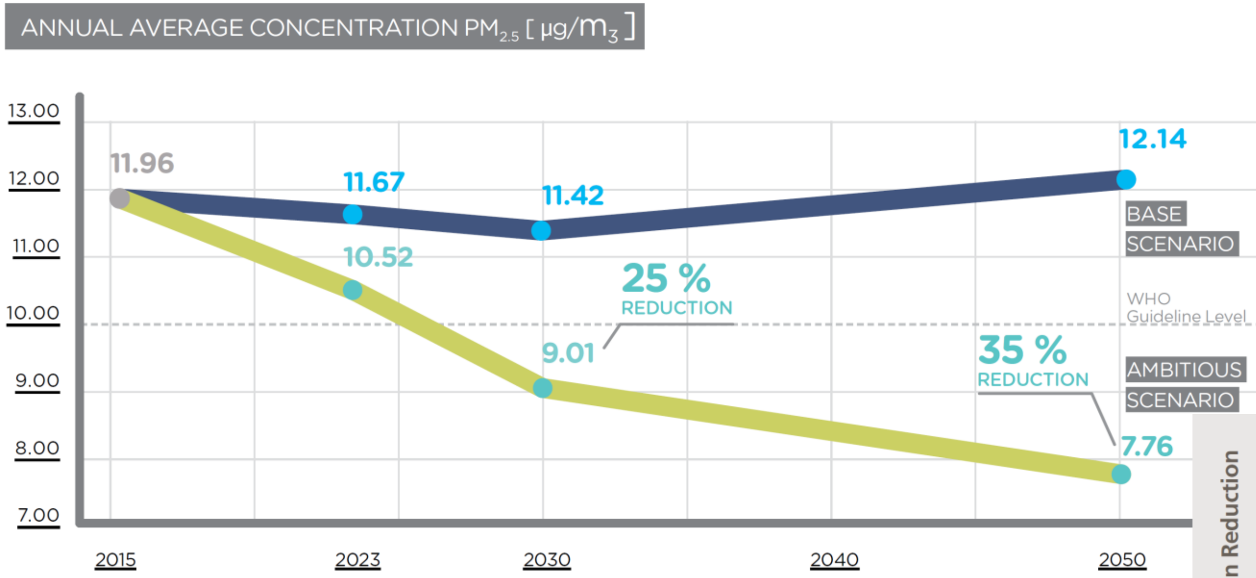
Public health benefits

- 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

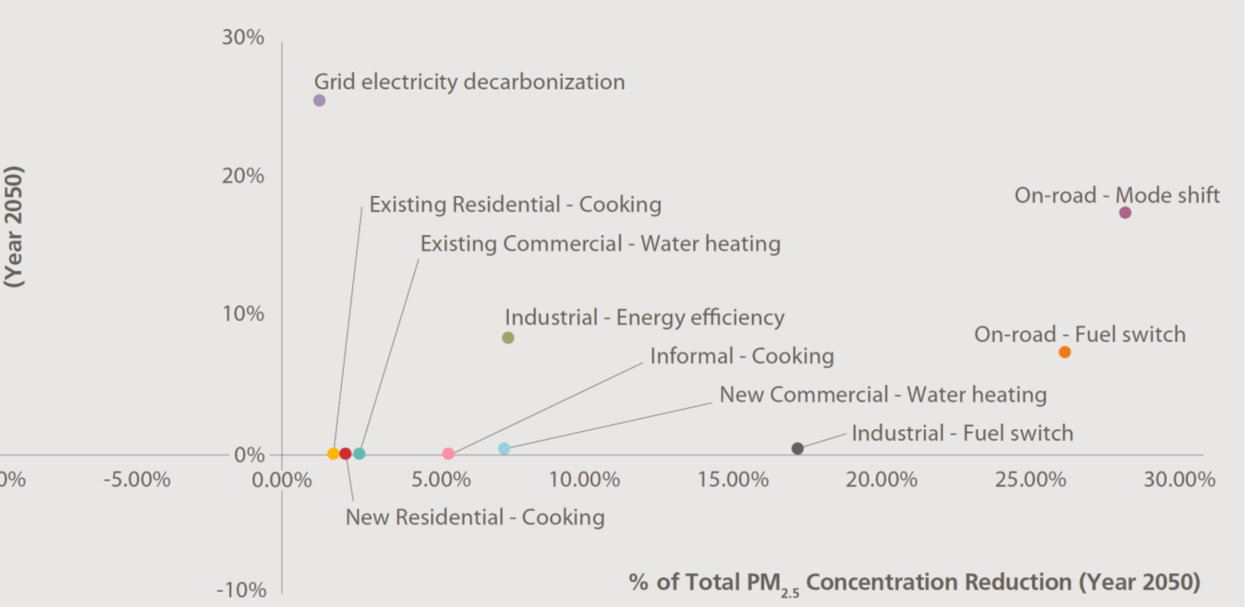
# Integrating AQ into urban CAPs

## Buenos Aires



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

## Johannesburg



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

# 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.