# Using remote sensing and Earth system models to improve air quality and public health in megacities

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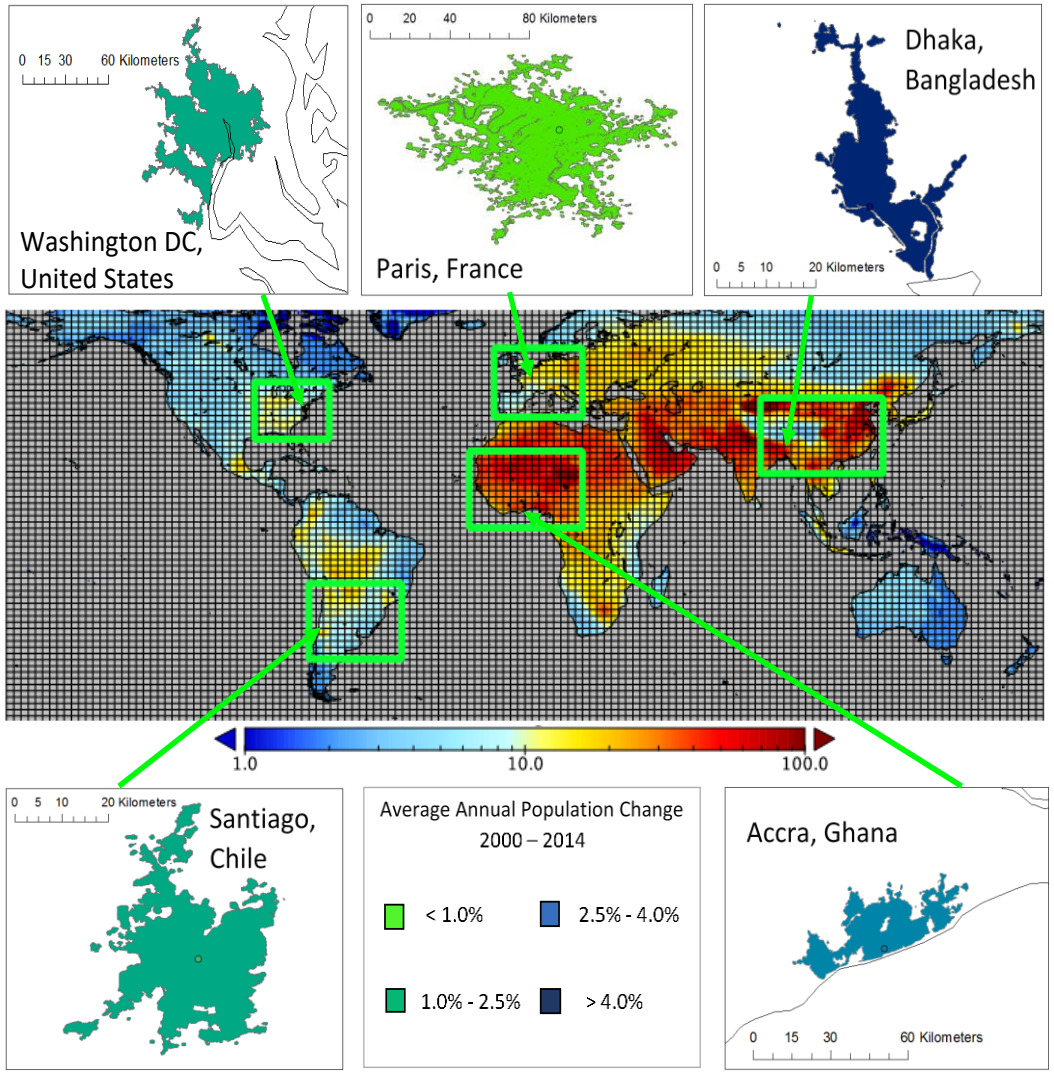
THE GEORGE WASHINGTON UNIVERSITY

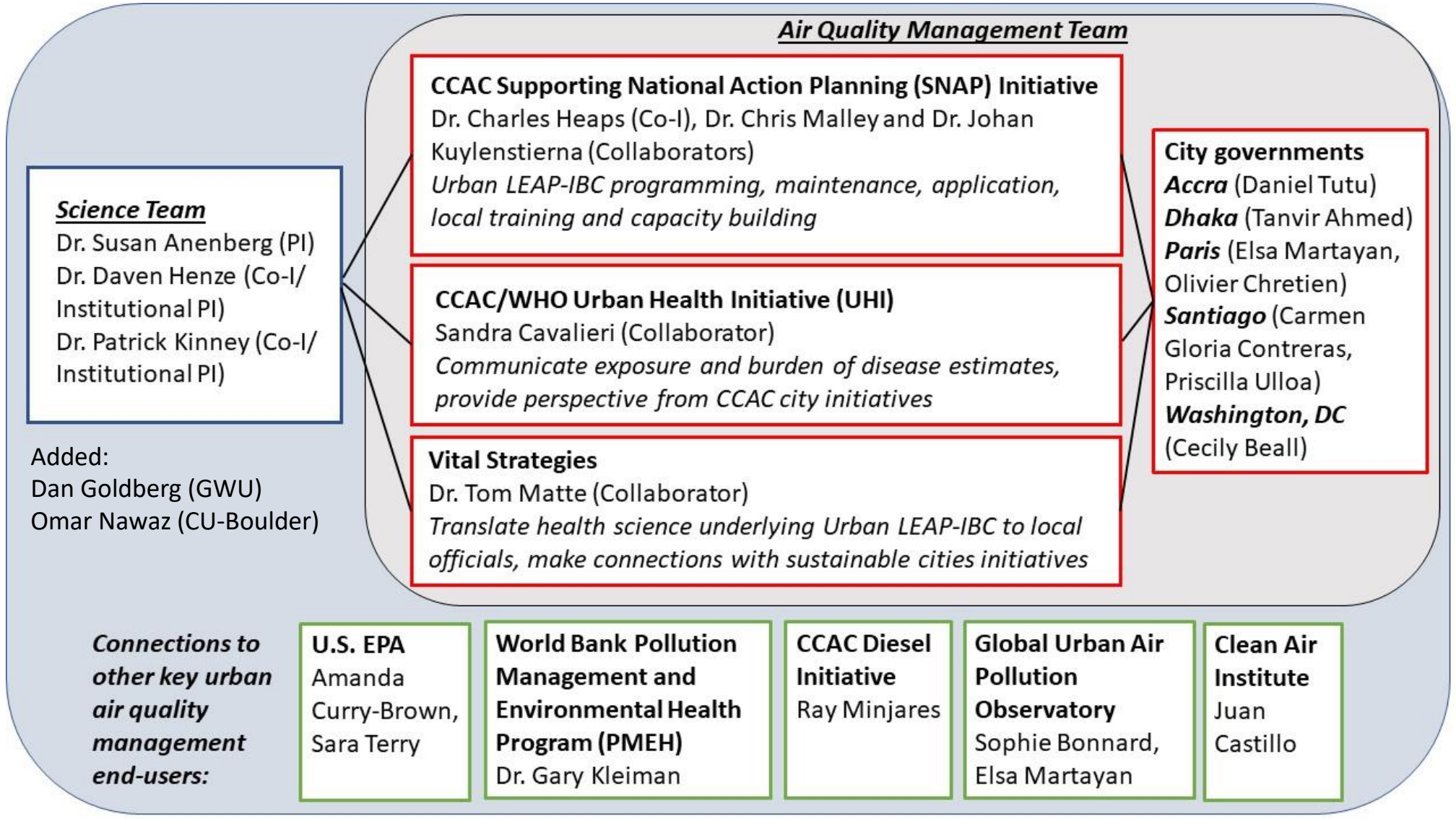
# Objectives

- Meet the needs of U.S. and international organizations to quantitatively assess air pollution health impacts and mitigation benefits in cities
- Leverage the global coverage and fine spatial resolution from remote sensing, combined with Earth system models and *in situ* measurements
- Specific objectives

1. Improve and verify estimates of **urban $PM_{2.5}$, ozone, and $NO_2$ concentrations** and **NOx and SOx emissions** for 5 pilot cities using NASA satellite data from MODIS, MISR, CALIPSO, OMI, as well as TROPOMI and GEOS-Chem
2. Estimate **15-year trends** in $PM_{2.5}$, ozone, and $NO_2$ exposures and associated mortality and morbidity burdens in cities
3. Expand the national-scale **tool used by the Climate and Clean Air Coalition** to estimate health benefits of mitigation policies to the urban scale in 3 pilot cities
4. In partnership with stakeholders, apply the new Urban LEAP-IBC tool to **assess health benefits of air quality policy** options in these three pilot cities



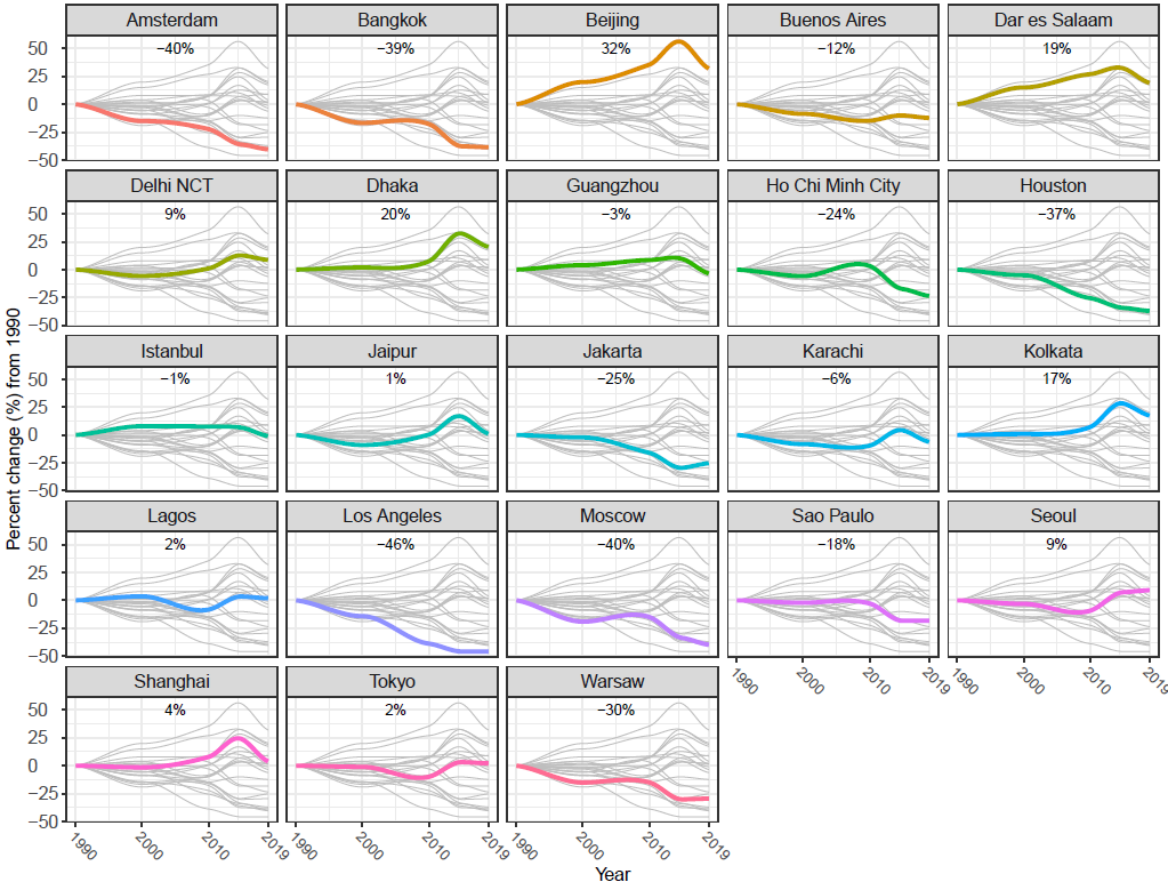
# Project team and organization



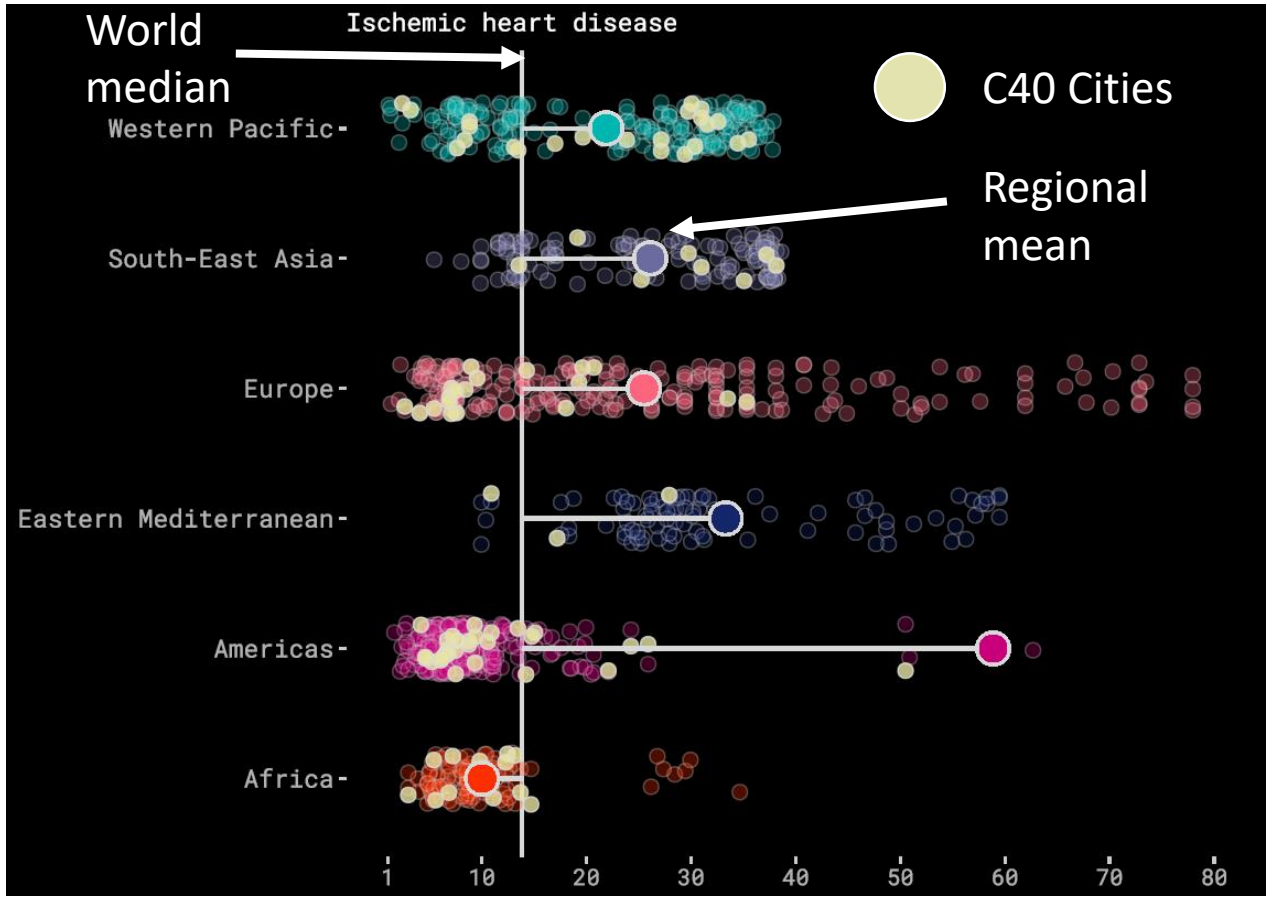
# Scientific accomplishments

# $PM_{2.5}$ mortality trends – C40 Cities

$PM_{2.5}$ concentrations

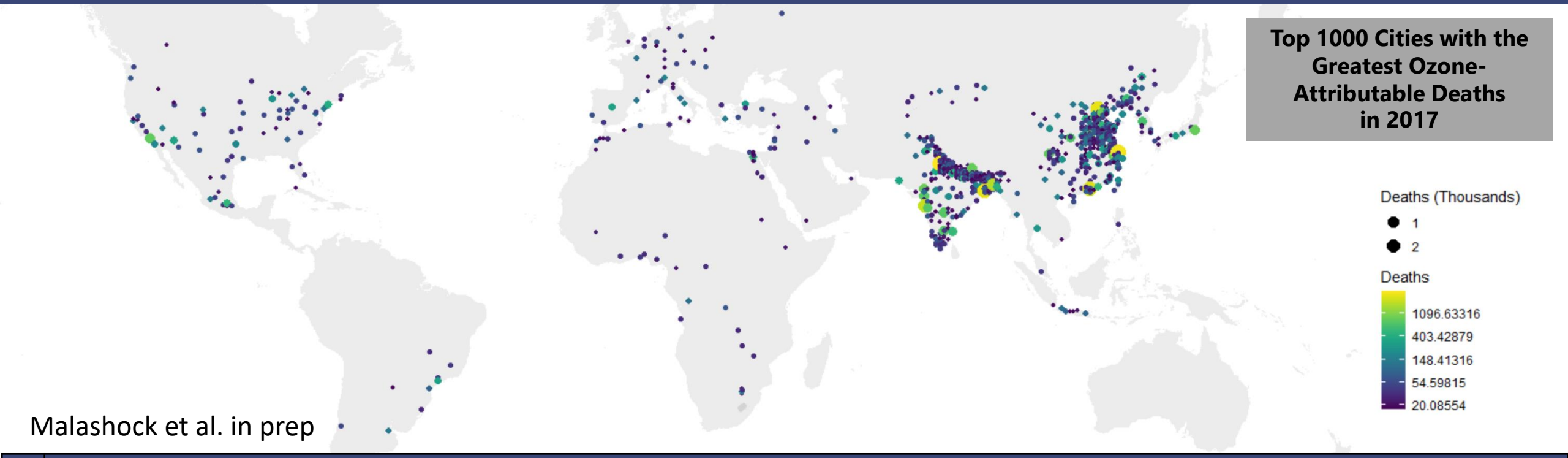



$PM_{2.5}$ attributable mortality per 100,000




Southerland et al. in prep

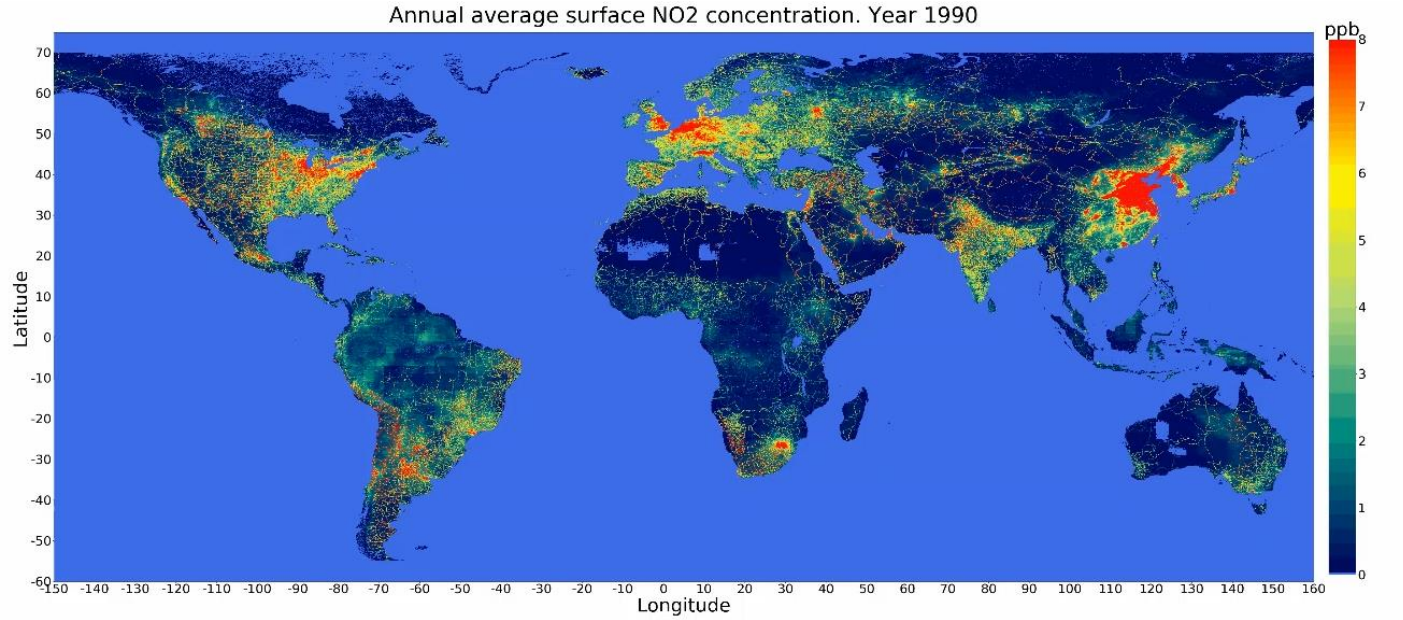
# Ozone mortality in >3,000 cities

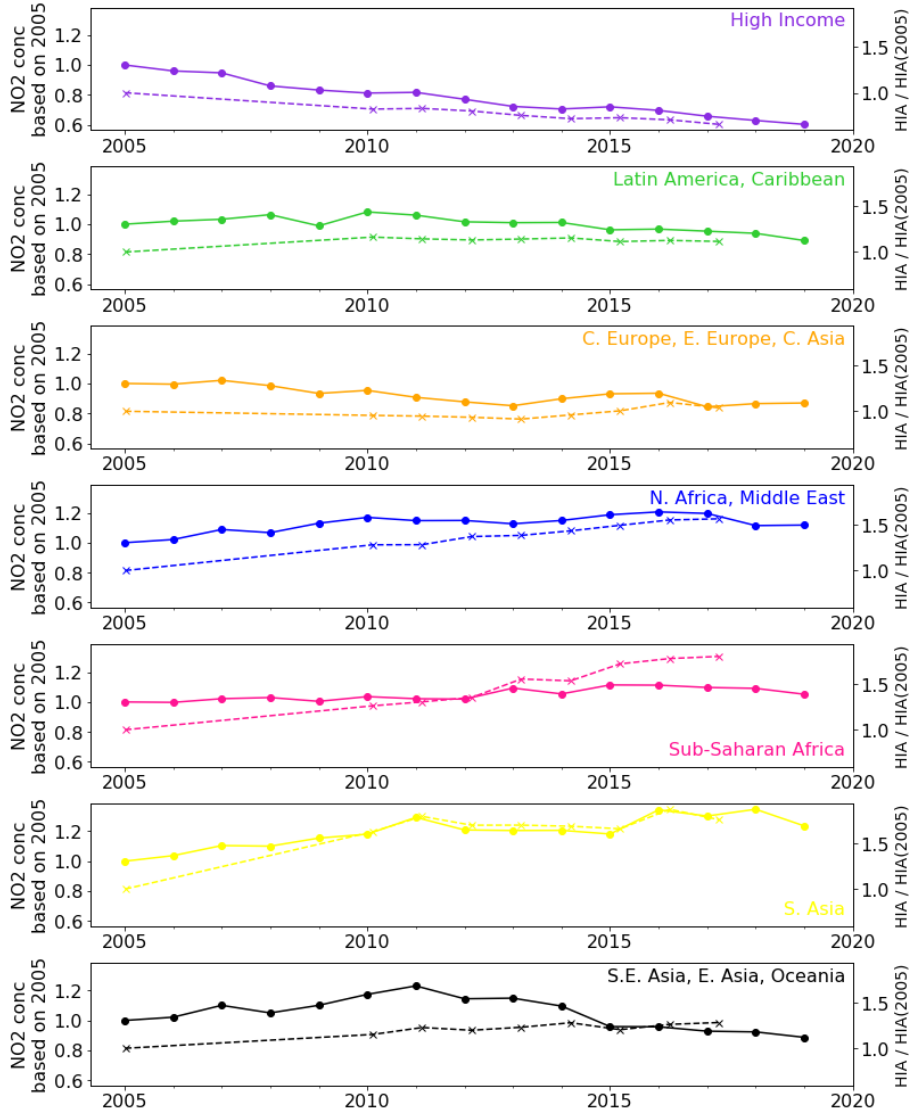



Malashock et al. in prep

| | 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) | 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) |

# $NO_2$ and pediatric asthma incidence



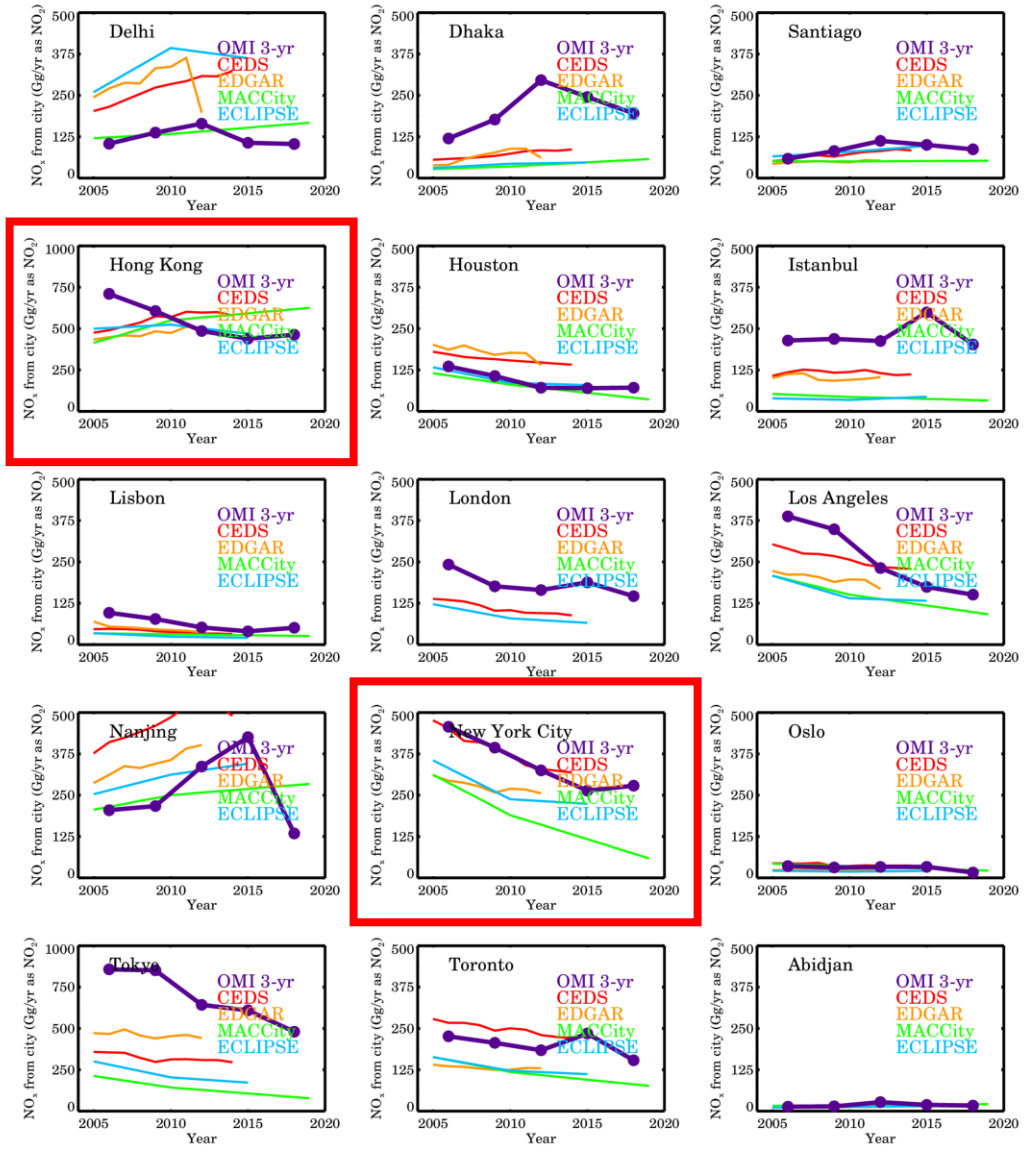




Solid lines = $NO_2$ concentrations
Dashed = $NO_2$ attributable asthma cases

Mohegh et al. in prep

# Top-down NOx emission estimates

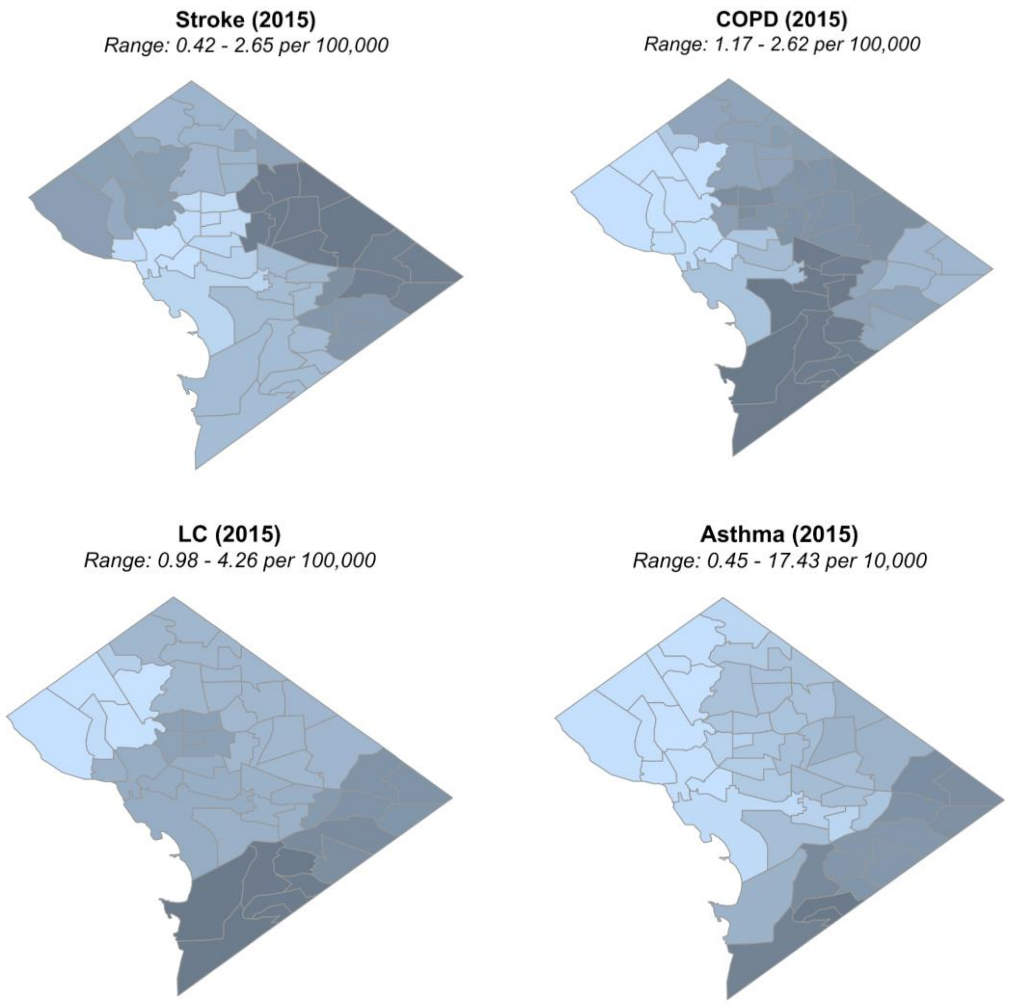
- Showing 15 cities out of 96 C40 Cities
- OMI $NO_2$ values are compared to four widely available global emissions inventories



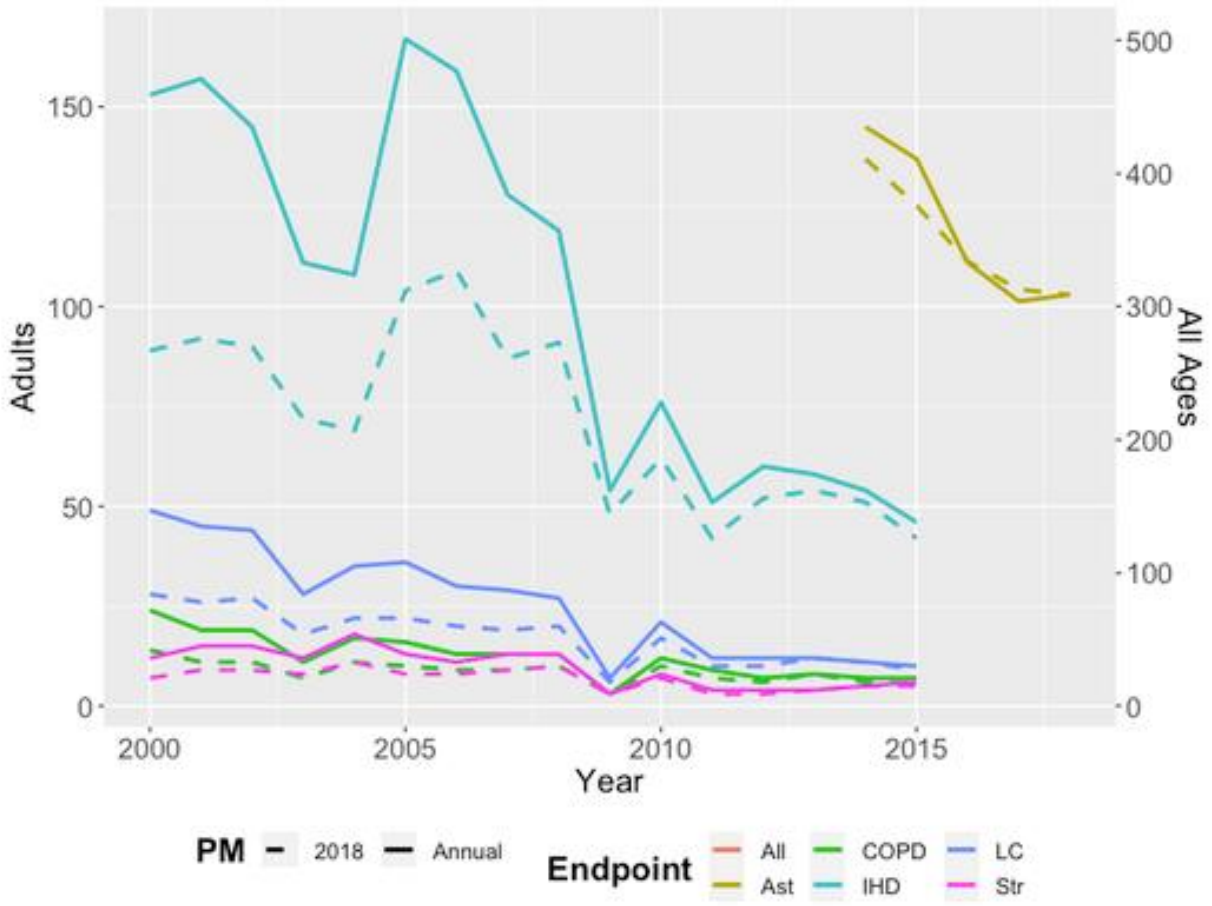

Goldberg et al. in prep

# Deep dive for Washington, DC: Disparities in $PM_{2.5}$ mortality rates

## $PM_{2.5}$ mortality at neighborhood scale



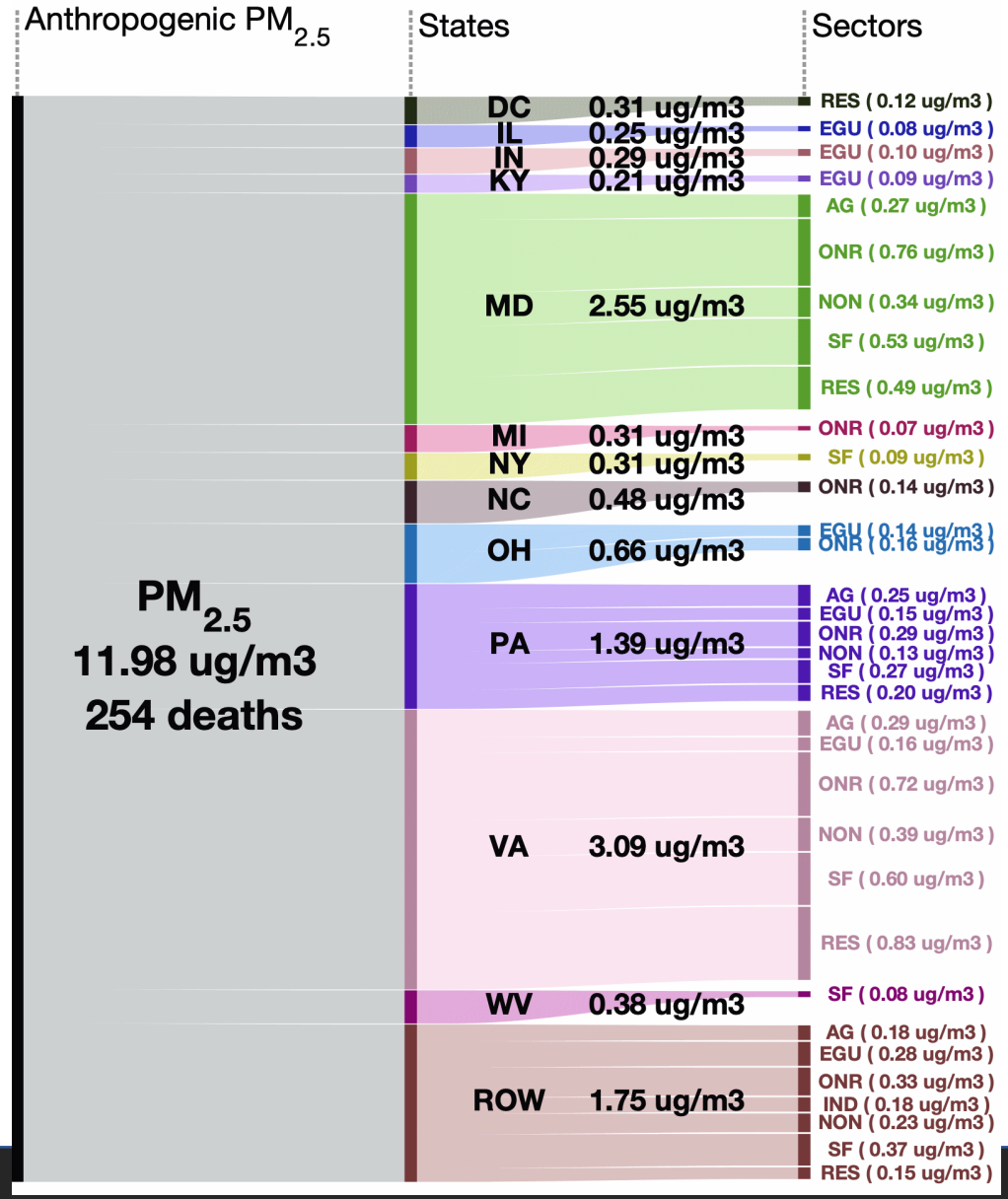

## Trend in $PM_{2.5}$ mortality for DC




Castillo et al. in prep

# Contributions to Annual $PM_{2.5}$ in DC for 2011

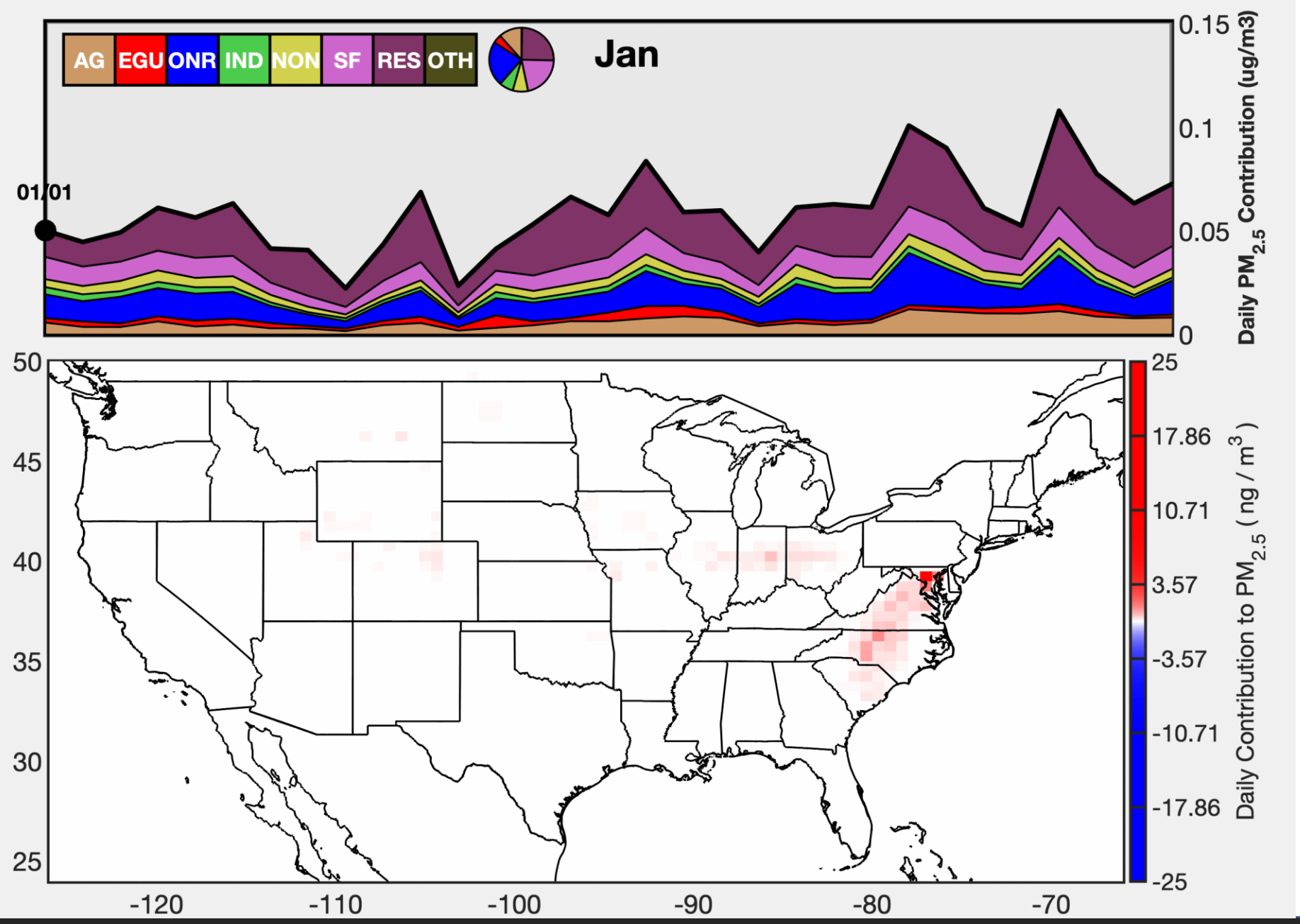
**Sector Abbreviations**
**AG** – Agriculture
**EGU** – Electrical Generation Unit
**ONR** - On-road
**IND** – Industry
**NON** – Non-road
**SF** – Surface Emissions
**RES** – Residential




Nawaz et al. in prep

# 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. in prep

# Stakeholder achievements

# Stockholm Environment Institute (SEI) and Climate and Clean Air Coalition (CCAC)

- Major upgrade to SEI's Low Emissions Analysis Platform (LEAP) in 2020 that includes:
  - Integrated Benefits Calculator (IBC)
  - Urban capability
- LEAP-IBC used for National Action Planning on short-lived climate pollutants by the CCAC
- Methods described by Kuylenstierna et al. under review:
  - GEOS-Chem Adjoint emissions to concentration sensitivities
  - Satellite-derived $PM_{2.5}$ to transition from global model resolution to urban scale
  - Global Burden of Disease methods for health impacts

# C40 Cities – integrating air quality into urban climate action planning

## Clean Air Declaration (Oct. 2019)

C40 CITIES

**Clean Air Cities: Our Commitment to Healthy Air for Every Citizen**

Nine out of 10 people around the world are breathing dirty air.[1] Not only does this lead to early death and increased disease, it impacts our economies and reduces opportunities for our citizens to thrive. It is the poorest and most vulnerable communities in our cities that are most at risk.

Breathing clean air is a human right. As mayors of world-leading cities, we will not wait for others to act to protect our citizens from the devastating consequences of air pollution.

We know that air pollution and the climate crisis go hand-in-hand. Both need swift, unprecedented and collective action to remove the pollution that is harming our health and warming our planet.

The most significant causes of air pollution vary between our cities. We must take action to better understand the problem, find ways to control pollution at the source, protect people from exposure to dirty air, evaluate the health impacts and determine how all these factors are shaped by our local economy, geography, demographics and city powers.

Air pollution does not recognize municipal, regional and national borders. Clean air can only be achieved by forming strong partnerships, including between cities, with regional and national authorities, as well as with the private sector and academic institutions. We must exchange best practices and coordinate action to address the sources of pollution both within and beyond our borders or control.

Together, we will work towards a shared vision of meeting World Health Organization Air Quality Guidelines by 2030.[2] We will use all the powers at our disposal as mayors to tackle air pollution, and call on others responsible for the sources of air pollution that poison the air in our cities to match this commitment.

This declaration sets out our overarching commitments to deliver clean air for every citizen. These goals are supported by other bold actions being taken in the world's great cities, including the transition to zero emission transport under the *C40 Green and Healthy Streets Declaration* and to zero emission buildings under the *C40 Net Zero Carbon Buildings Declaration*, as well as the work of global partners, such as the BreatheLife Action Platform.

We are committed to a future where *all people* can thrive and enjoy healthier, more active lives – where breathing clean air is an undeniable human right upheld by ambitious and innovative policies and laws.

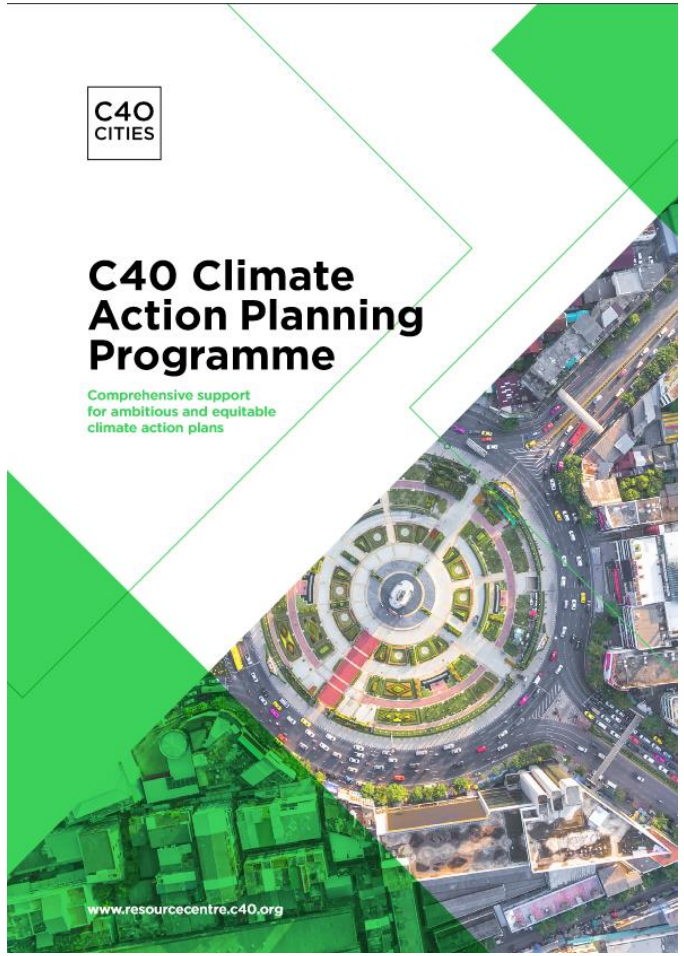
**To clean the air our citizens breathe and help meet the goals of the Paris Agreement, we pledge to:**

- Within two years, establish baseline levels and set ambitious reduction targets for air
- Before 2025, implement new substantive policies and programmes to address the top causes of air pollution emissions within our city and under our control.
- Publicly report annually on our progress in reducing pollution levels relative to targets and achieving the commitments in this declaration.

**To meet this commitment, we will:**

- Implement new policies, enforce strong regulations, prioritise resources, and build necessary capacity and skills to achieve ambitious reductions in air pollution source sectors that are within our control.
- Integrate the relevant top pollution-reducing actions -- that are within our city and under our control -- into our Climate Action Plans, such as: rapidly expanding zero emission public transport, creating low or zero emission areas, supporting walking/cycling, implementing vehicle restrictions or financial incentives/disincentives (e.g. road or parking charging), reducing truck, non-road machinery and city owned vehicle emissions, cleaning up construction sites and equipment, reducing industrial emissions, reducing emissions from wood burning, expanding affordable access to clean energy for cooking and heating, restricting pollution from solid waste burning and expanding greening.
- Establish, maintain, increase, or contribute to reliable city-wide air quality monitoring, making data publicly available in a timely manner or as close to real-time as possible and in an accessible format, in coordination with relevant departments and institutions.
- Conduct, expand, or collaborate with relevant institutions to increase research on the health impacts of air pollution, the benefits of air quality improvements, and associated economic implications, and publish the results.
- Raise awareness of air quality to help vulnerable citizens reduce their exposure, and to reduce the causes of air pollution, such as traffic.
- Create, update, or work with relevant institutions to ensure high quality emissions inventories, models, and analysis are available to describe where and how outdoor air pollution is formed in our city, both today and in the future.
- Work with and advocate for regional, state, supranational, and national government to take action on sources outside our boundaries or our control.

## Climate Action Planning (ongoing)



# Successes and challenges

- Successes:
  - Cross-sectional analyses of $PM_{2.5}$, ozone, $NO_2$ health impacts and NOx emissions in cities worldwide
  - Deep-dive for Washington, DC
  - Stakeholder achievements: SEI/CCAC Urban LEAP-IBC, C40 Clean Air Declaration
- Next priorities: further scientific support for stakeholder policy analysis
- Challenges: obtaining local-scale health data, stakeholders with different geopolitical focus, pandemic-related difficulties with collaborating internationally
- Started at ARL 6 (Nov. 2018), plan to get to ARL 9 (Oct. 2022)
  - Advanced to ARL 7 in May 2020 as Urban LEAP-IBC model was released, urban $PM_{2.5}$ disease burdens have been integrated into C40 Cities' operations

# Manuscript/Publications

- Goldberg, D., Z. Lu, D.G. Streets, A. Mohegh, S. Anenberg (2020) TROPOMI NO2 in the United States: A detailed look at the annual averages, weekly cycle, effects of temperature, and correlation with PM2.5. Under review.
- 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*, in press.
- Nawaz, M. O., and D. K. Henze (2020) Premature deaths in Brazil associated with long-term exposure to $PM_{2.5}$ from Amazon fires between 2016-2019, *GeoHealth, doi: 10.1029/2020GH000268.*

# Thanks!

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