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

Susan Anenberg, PhD

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Milken Institute School of Public Health
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

**Science Team**
- Dr. Susan Anenberg (PI)
- Dr. Daven Henze (Co-I/Institutional PI)
- Dr. Patrick Kinney (Co-I/Institutional PI)

Added:
- Dan Goldberg (GWU)
- Omar Nawaz (CU-Boulder)

**Air Quality Management Team**

**CCAC Supporting National Action Planning (SNAP) Initiative**
- Dr. Charles Heaps (Co-I), Dr. Chris Malley and Dr. Johan Kuylenstierna (Collaborators)
- *Urban LEAP-IBC programming, maintenance, application, local training and capacity building*

**CCAC/WHO Urban Health Initiative (UHI)**
- Sandra Cavalieri (Collaborator)
- *Communicate exposure and burden of disease estimates, provide perspective from CCAC city initiatives*

**Vital Strategies**
- Dr. Tom Matte (Collaborator)
- *Translate health science underlying Urban LEAP-IBC to local officials, make connections with sustainable cities initiatives*

**Connections to other key urban air quality management end-users:**
- **U.S. EPA**
  - Amanda Curry-Brown, Sara Terry
- **World Bank Pollution Management and Environmental Health Program (PMEH)**
  - Dr. Gary Kleiman
- **CCAC Diesel Initiative**
  - Ray Minjares
- **Global Urban Air Pollution Observatory**
  - Sophie Bonnard, Elsa Martayan
- **Clean Air Institute**
  - Juan Castillo

**City governments**
- Accra (Daniel Tutu)
- Dhaka (Tanvir Ahmed)
- Paris (Elsa Martayan, Olivier Chretien)
- Santiago (Carmen Gloria Contreras, Priscilla Ulloa)
- Washington, DC (Cecily Beall)
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

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

Malashock et al. in prep

Top 1000 Cities with the Greatest Ozone-attributable Deaths in 2017
NO$_2$ and pediatric asthma incidence

Mohegh et al. in prep

Solid lines = NO$_2$ concentrations
Dashed = NO$_2$ attributable asthma cases
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

- **Stroke (2015)**
  - Range: 0.42 - 2.65 per 100,000

- **COPD (2015)**
  - Range: 1.17 - 2.62 per 100,000

- **LC (2015)**
  - Range: 0.98 - 4.26 per 100,000

- **Asthma (2015)**
  - Range: 0.45 - 17.43 per 10,000

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

PM$_{2.5}$
11.98 ug/m$^3$
254 deaths

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)

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

Nine out of 10 people around the world are breathing dirty air. 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. 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 City 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 Bruges Cities Platform.

We are committed to a future where all people can thrive and enjoy health, 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

Climate Action Planning (ongoing)

C40 Climate Action Planning Programme

www.c40.org
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


Thanks!

Susan Anenberg
sanenberg@gwu.edu