The Surface Particulate Matter Network (SPARTAN) for Health and Air Quality Application

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with contributions from

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HAQAST Meeting
MIT
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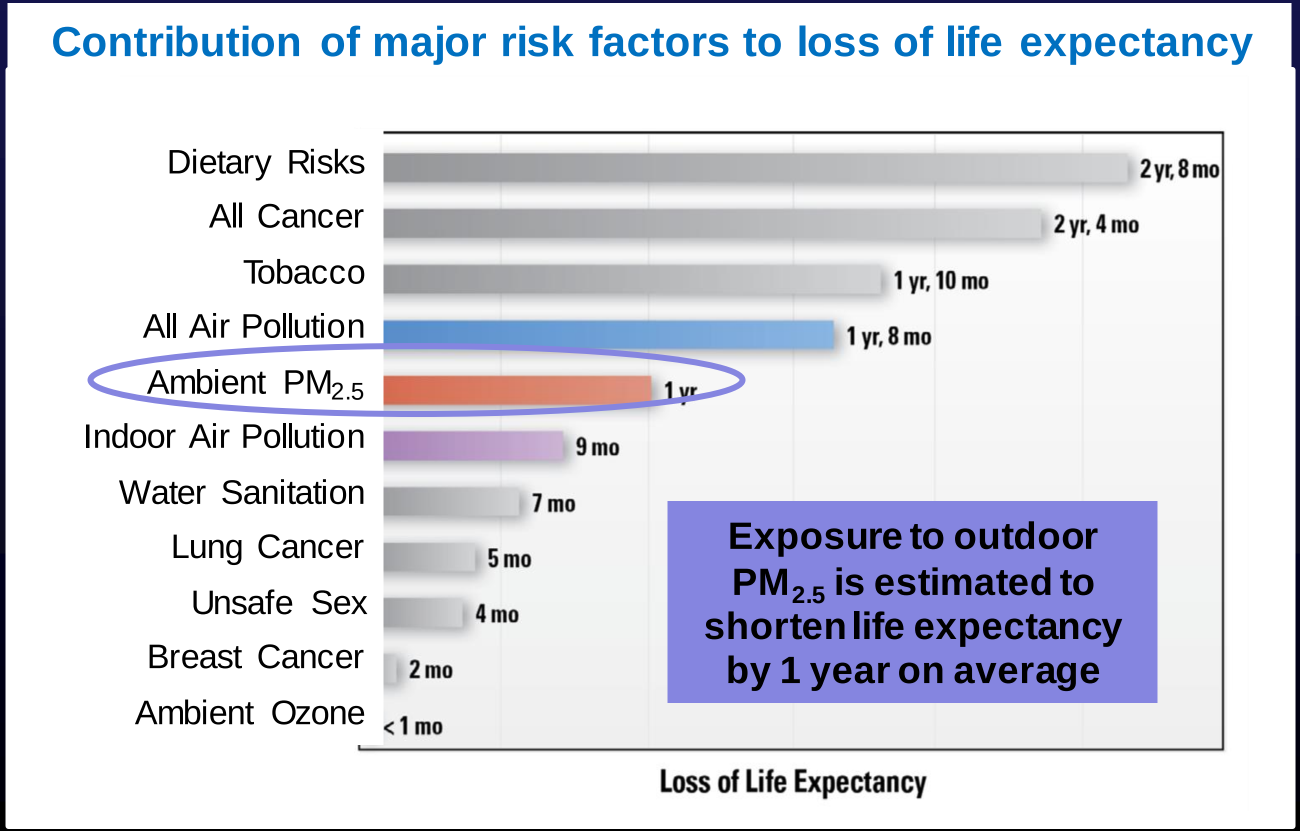
Fine Particulate Matter ($PM_{2.5}$) Affects Longevity

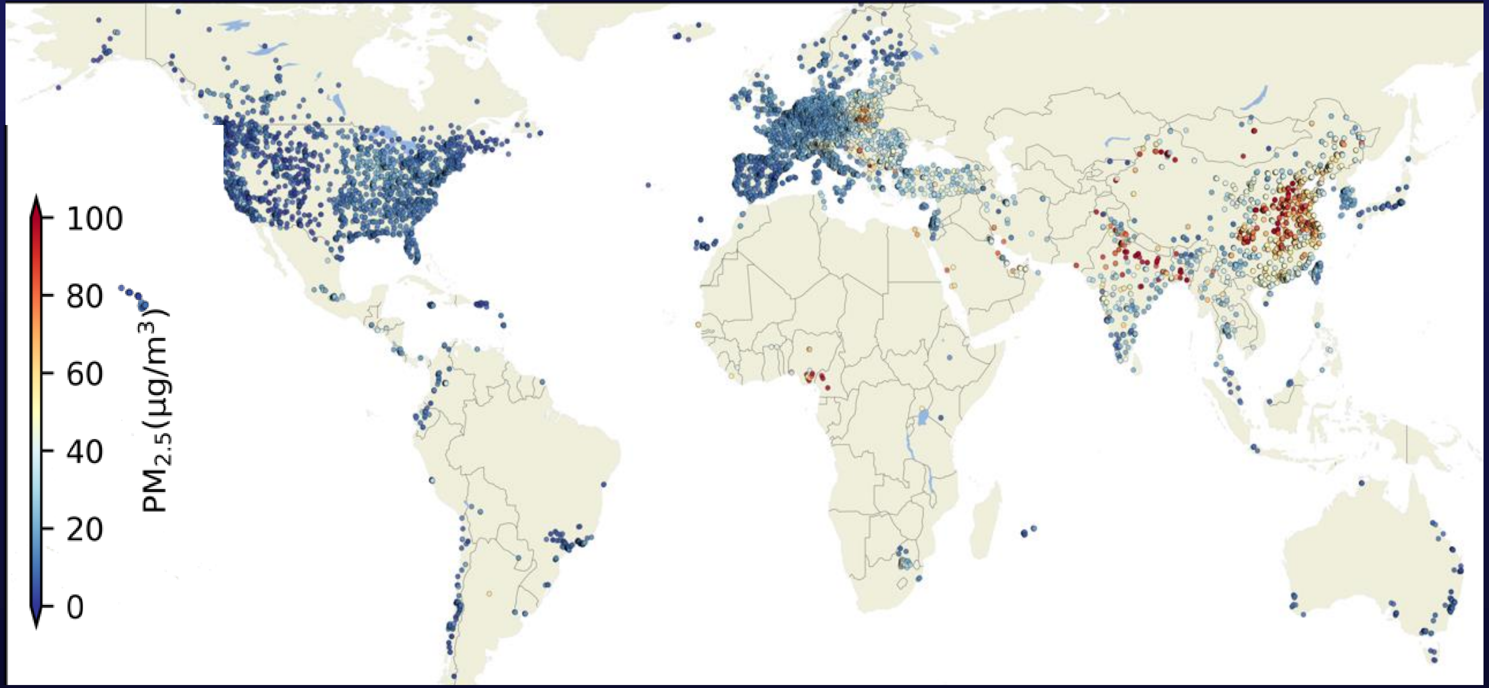
- Outdoor $PM_{2.5}$ leading environmental health risk factor for global burden of disease with 4 million attributable deaths each year (Murray et al., 2020)
- Annual global welfare costs projected to rise from US$3 trillion in 2015 to US$18-25 trillion in 2060 (OECD, 2016)
- Recent lowering of EPA standard (9 µg/m³) and WHO guideline (5 µg/m³) reinforces importance



Health Effects Institute, State of Global Air, 2019

A Broad Health and Air Quality Community Relies Upon Satellite Observations of Aerosol Optical Depth (AOD) for Exposure Assessment

Large Gaps in Ground-Based Monitoring

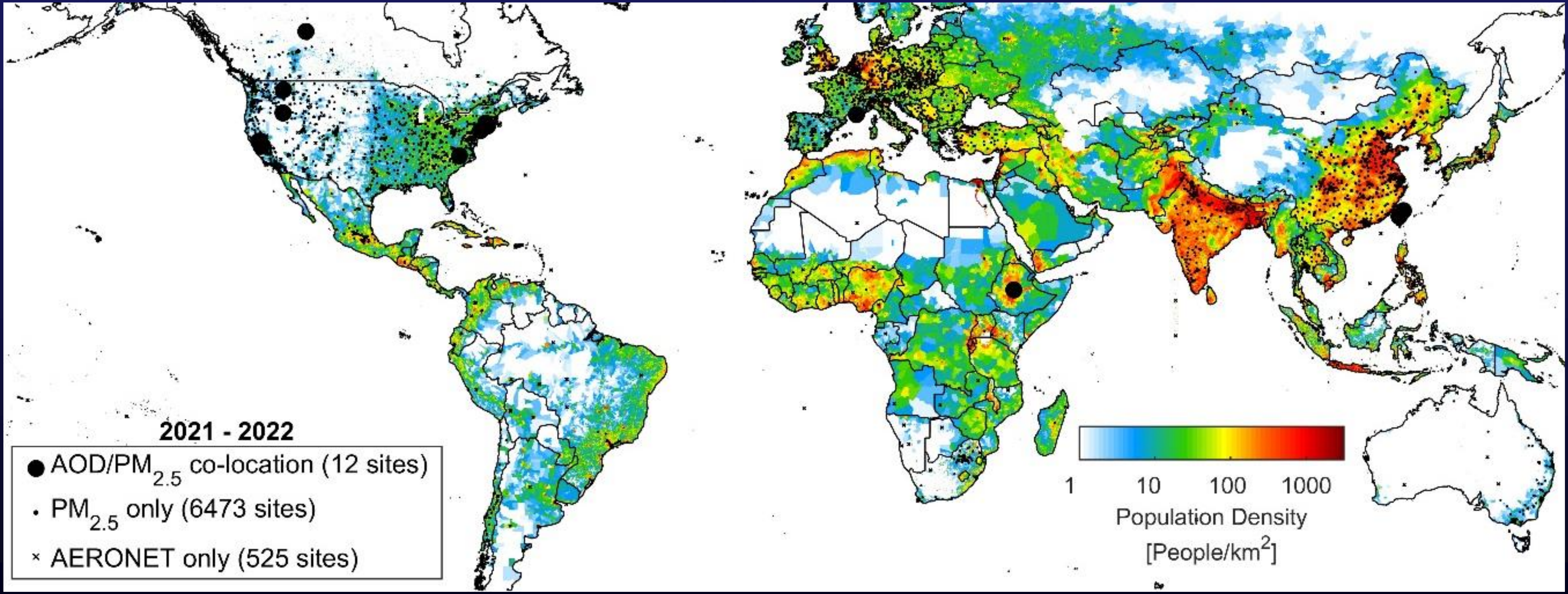


Shen et al., ES&T Air, 2024

VIIRS, MAIA, PACE, ABI, TEMPO, ACX, GXI

The Committee on Earth Observation Satellites (CEOS) recommends co-locating ground-based measurements of $PM_{2.5}$ and of AOD to enhance understanding of their relationship (Kondragunta et al., 2022)

Few Collocated Measurements of $PM_{2.5}$ & AOD
Co-located Chemical Composition Measurements Even Sparser

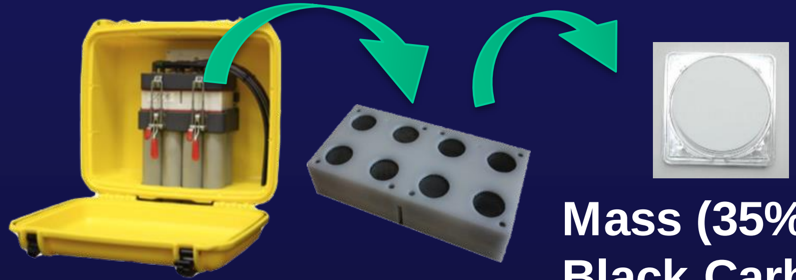


Excluding the Surface Particulate Matter Network

Aaron van Donkelaar

Surface Particulate Matter Network (SPARTAN): Long Term Network to Evaluate and Enhance Satellite-Based Estimates of $PM_{2.5}$

Semi-autonomous $PM_{2.5}$ & PM_{10} Impaction Sampling Station (AirPhoton)



Mass (35% RH)
Black Carbon
Ions (IC)
Metals (XRF)
Organics (FTIR, AMS)

3-λ nephelometer (AirPhoton) Scatter

AOD from Sunphotometer (e.g. AERONET)

SPARTAN
Global Particulate Matter Network

Measured: Surface/Column, Diel, Mass Scattering Efficiency (Depends on size, composition, hygroscopicity)

$$\frac{\mathrm{PM}_{2.5}}{\mathrm{AOD}} = \left(\frac{b_{sp,overpass}}{\mathrm{AOD}_{overpass}}\right)\left(\frac{b_{sp,24h}}{b_{sp,overpass}}\right)\left(\frac{\mathrm{PM}_{2.5,24\mathrm{h}}}{b_{sp,24h}}\right)$$

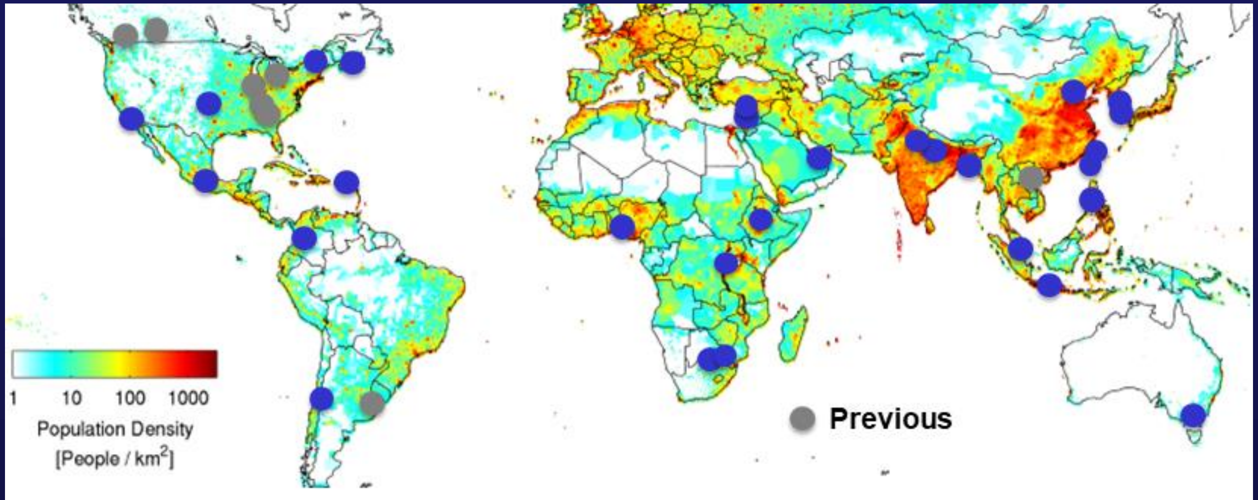
b_{sp} = nephelometer measurements of aerosol scatter

overpass = satellite overpass time

Operating since 2013

www.spartan-network.org

SPARTAN: A Long-Term Growing Harmonized Air Quality Network

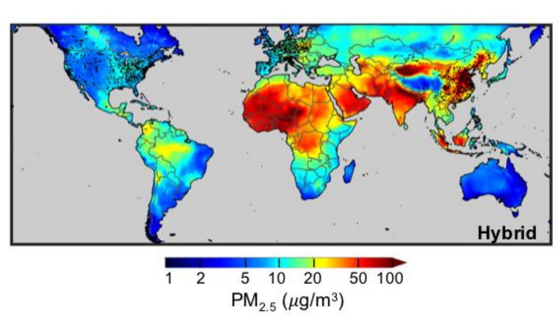


The only global $PM_{2.5}$ composition network: offers information about sources





Supporting satellite-based $PM_{2.5}$ estimates



Liu et al. 2022, 2024
McDuffie et al. 2021
McNeil et al. 2020
Weagle et al. 2018
Philip et al. 2017
Snider et al. 2015, 2016

www.spartan-network.org

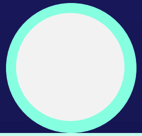
Recent and Ongoing Developments

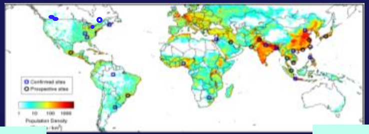
- Major upgrade to analytical instrumentation (robotic weighing facility, XRF, IC Integrion)
- Organics via FTIR (Ann Dillner, UC Davis); AMS & UV-Vis in progress
- Ten new sites over the last couple years
- Global mineral dust equation (Liu et al., 2022) and characterization (Liu et al., 2024)
- Added denuder and nylon filters for more accurate nitrate measurements
- Exploring oxidative potential

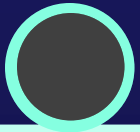



SPARTAN: Maximizing Information from Each Filter

Analyses at State-of-Science Laboratories







Pre-weigh filters → **Ship & sample** → **Post-weigh filters**

Black carbon and organics (HIPS and FTIR)

Partnership with UC Davis (Ann Dillner and Nicole Hyslop)

Trace elements (XRF)

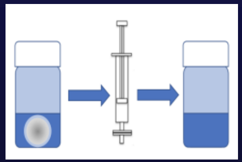
Led by Xuan Liu in partnership with Jay Turner (WashU)

Black & brown carbon (UV-Vis)

Partnership with Joshin Kumar, Sam Black, and Rajan Chakrabarty (WashU)

Black carbon (IBR)

Partnership with Michael Brauer (UBC)



Soluble ions (IC)

Organics (AMS)

Led by Yuxuan Ren in partnership with Jhao-Hong Chen and Lu Xu (WashU)

Oxidative potential

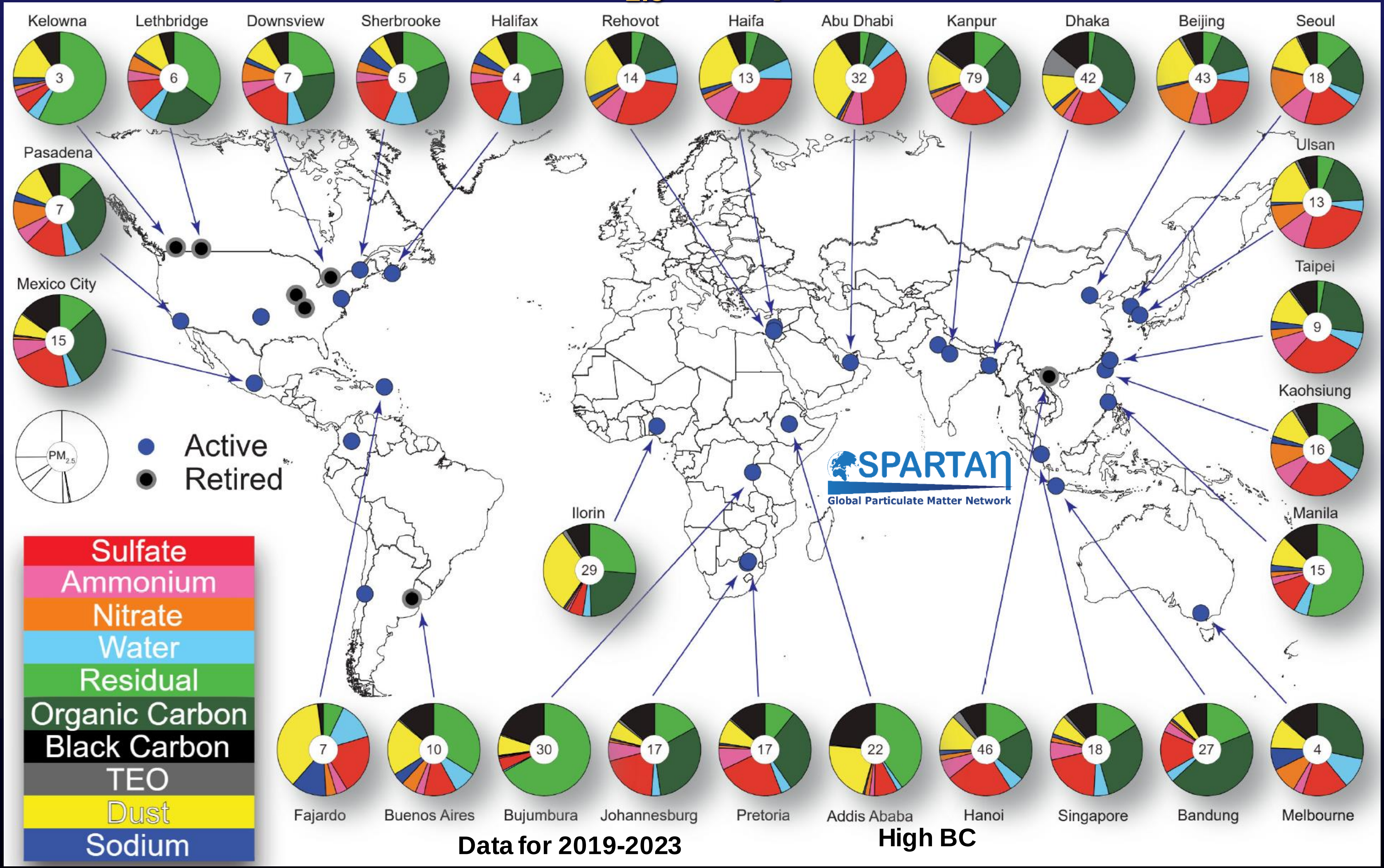
Led by Vishal Verma (UIUC)

Overall operations led by Chris Oxford

Supported by Summer Liu, Wilson Hou, Ryan Graham, Haihui Zhu

www.spartan-network.org

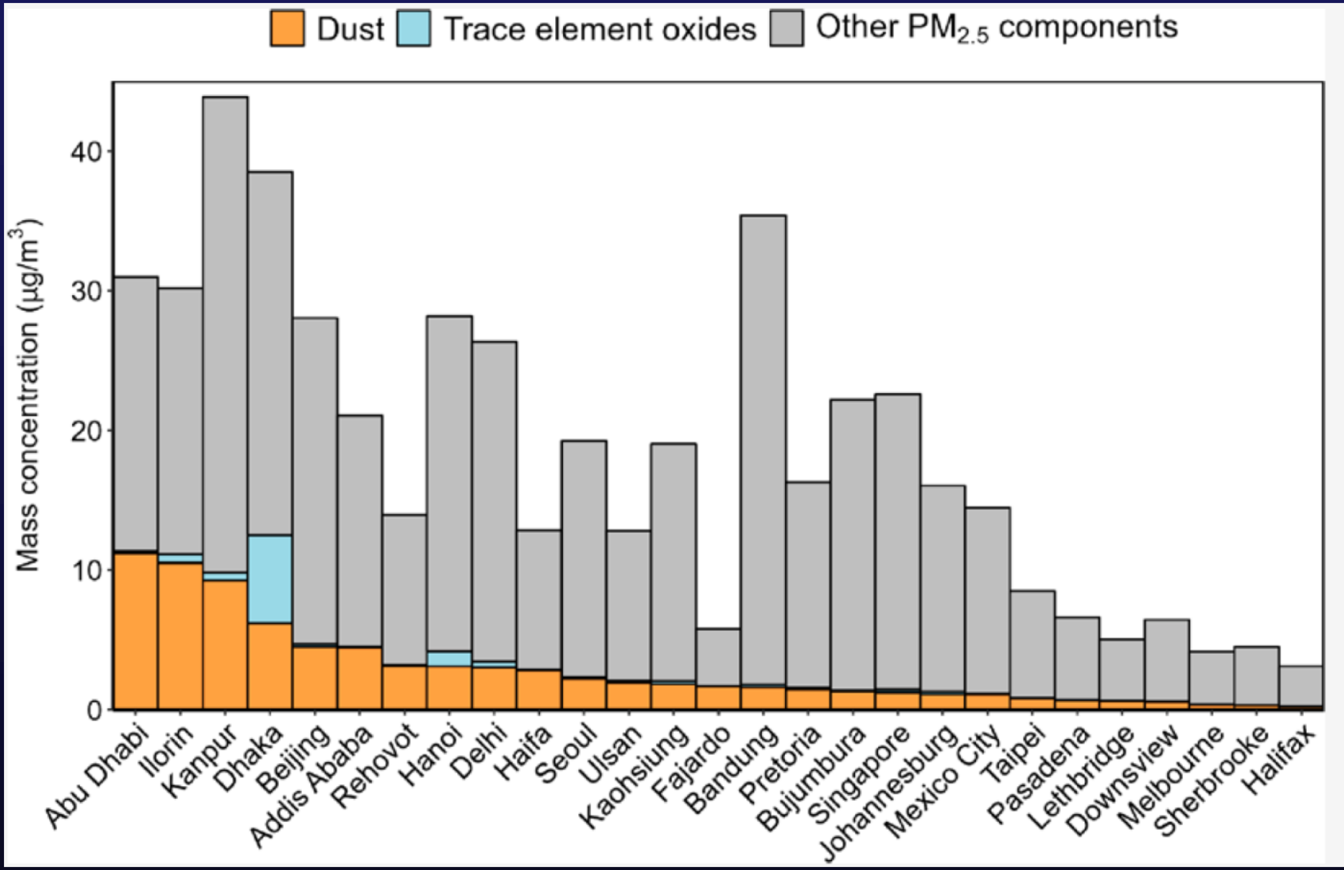
SPARTAN $PM_{2.5}$ Composition

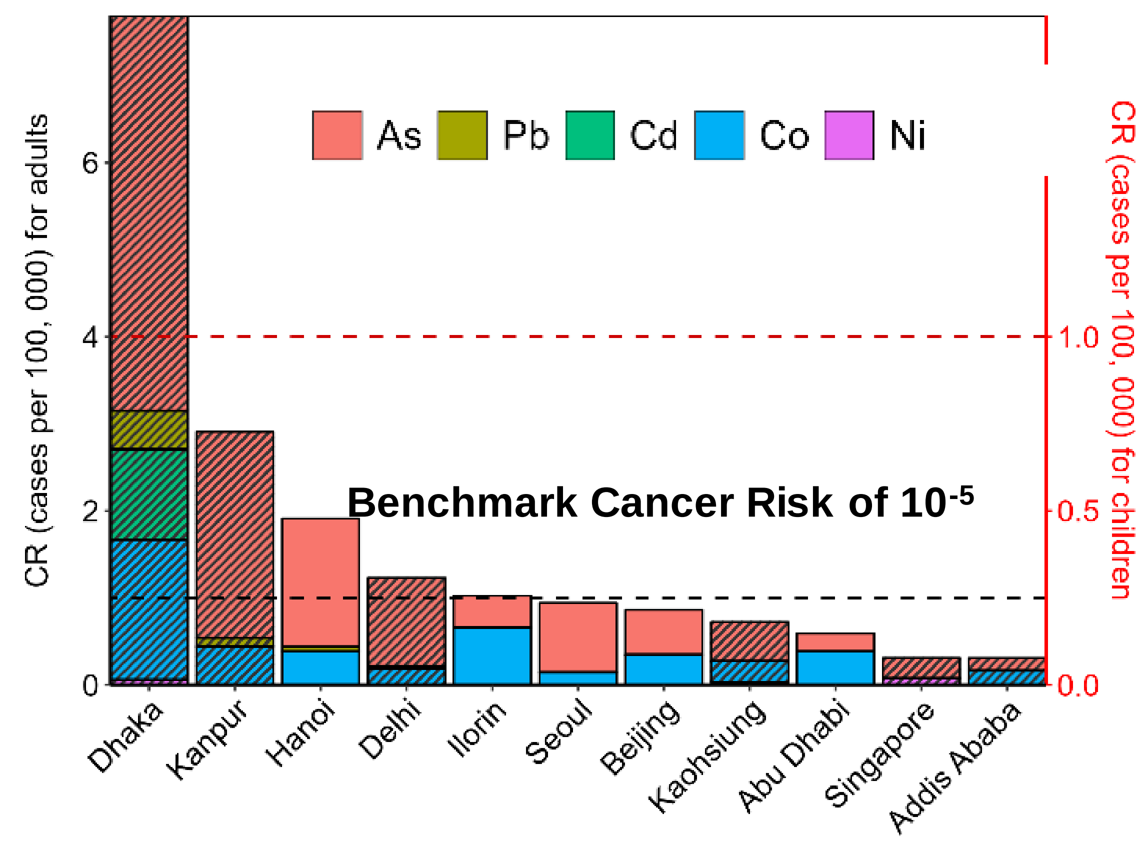


Middle contains $PM_{2.5}$ Mass in ug/m^3

Data publicly available at spartan-network.org

Concerning Levels of Trace Element Oxides and Associated Cancer Risk





Elemental composition measured with XRF

Uses global mineral dust equation (Liu et al., JGR, 2022)

Cancer risk calculated using EPA health risk assessment model

Liu et al., ES&T Air, 2024

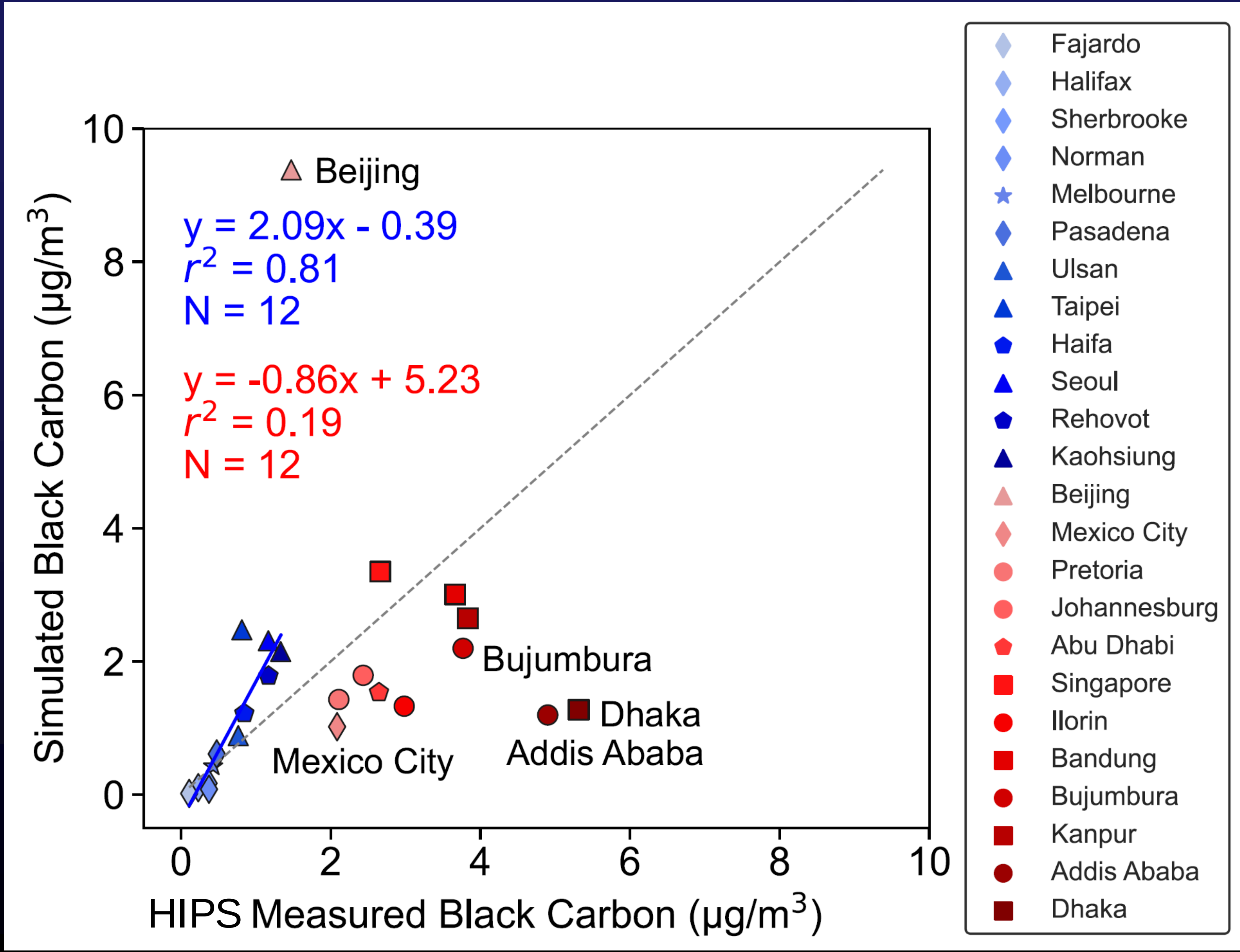
Emission Inventories Underestimate Black Carbon in the Global South

Comparison of SPARTAN with GEOS-Chem Using CEDS Emission Inventory

GEOS-Chem simulation for 2019 using GCHP at C360 (~25 km)

Similar bias using 1-month tests in Jan & Jul at C720 (~12 km)

Similar bias in Global South found using HTAP or EDGAR inventories



Puerto Rico
Canada
Canada
Oklahoma
Australia
California
South Korea
Taiwan
Israel
South Korea
Israel
Taiwan
China
Mexico
South Africa
South Africa
UAE
Singapore
Nigeria
Indonesia
Burundi
India
Ethiopia
Bangladesh

Yuxuan Ren

Conclusions

- Emerging data from SPARTAN offer measurements to interpret satellite observations
- Data on chemical composition of $PM_{2.5}$
- Concerning levels of trace elements
- Black carbon concentrations generally underestimated in urban areas across Global South with implications for health

GEOS Chem

SPARTAN Global Particulate Matter Network

Photo from SPARTAN meeting in 2023