# The Surface Particulate Matter Network (SPARTAN): An Emerging Grassroots Global Monitoring Activity

**The SPARTAN community:**

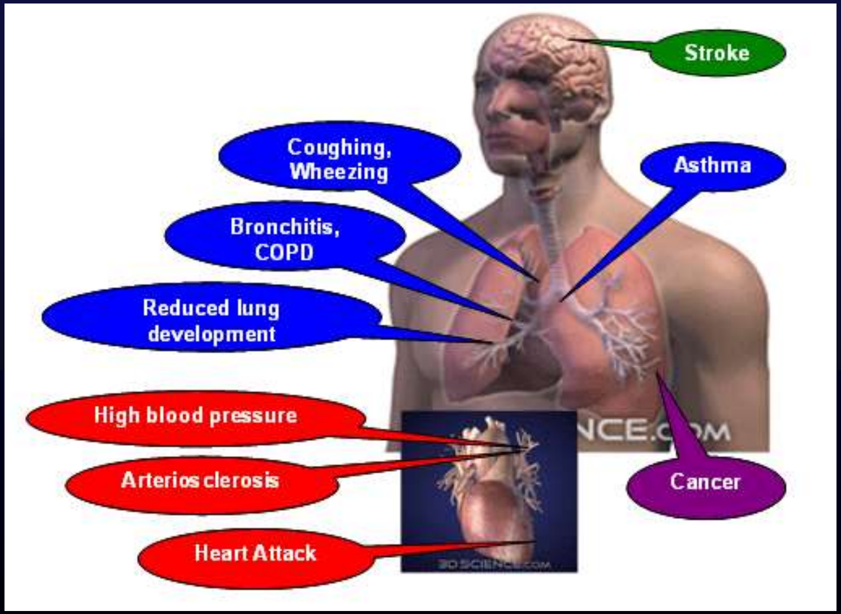
**>100 colleagues, >25 institutions, >15 countries**

**AGU**
**10 December 2018**

**www.spartan-network.org**

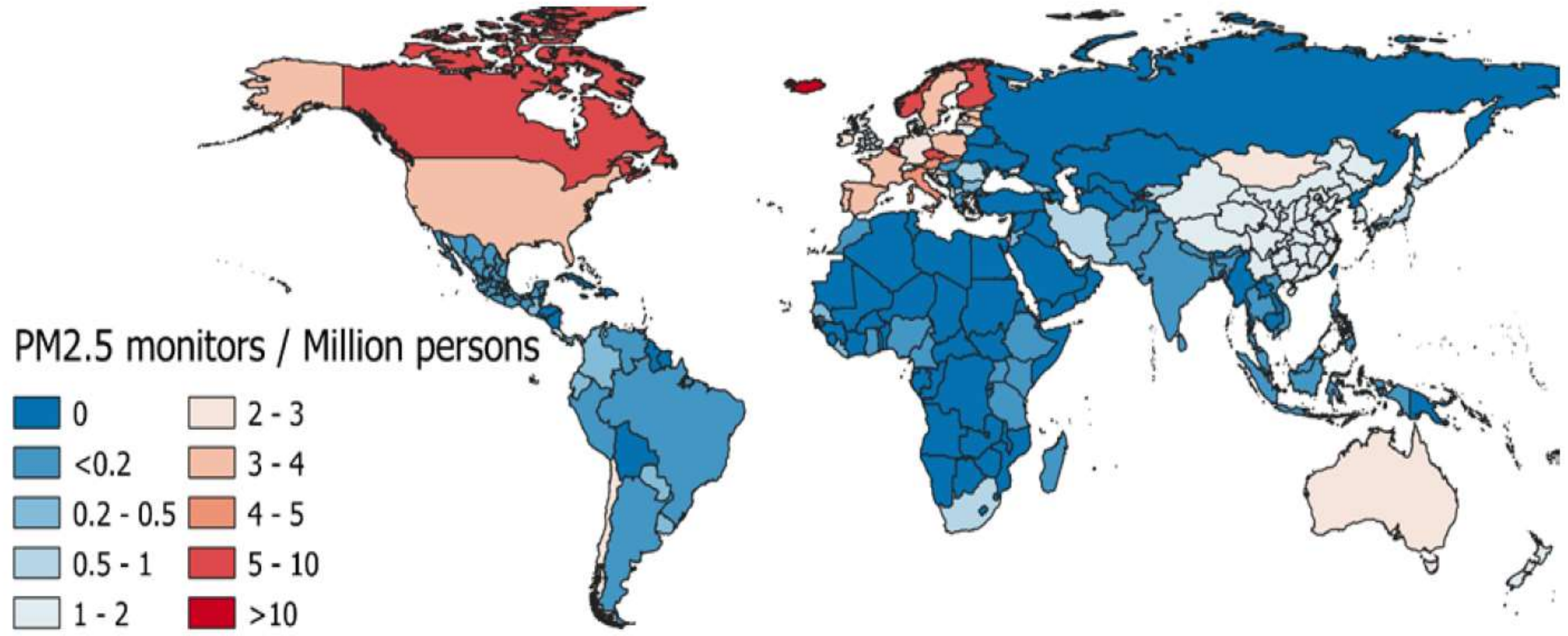
# Fine Particulate Matter ($PM_{2.5}$): Atmospheric Aerosols That Affect Longevity

- Ambient $PM_{2.5}$ leading environmental risk factor for global burden of disease with 4 million attributable deaths (Lim et al., Lancet, 2016)
- Annual global welfare costs projected to rise from US$3 trillion in 2015 to US$18-25 trillion in 2060 (OECD, 2016)
- Regulation of $PM_{2.5}$ achieved the largest estimated benefits of all U.S. Federal Regulations, US Office of Management and Budget
- $PM_{2.5}$ included in UN Sustainable Development Goals (2016)



# Vast Regions Have Insufficient $PM_{2.5}$ Measurements for Exposure Assessment

Density of Long-Term $PM_{2.5}$ Monitoring Sites



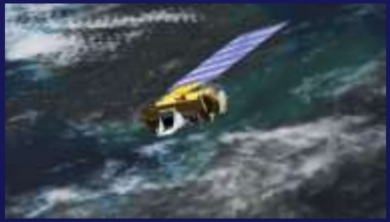

Number of $PM_{2.5}$ monitors per million inhabitants by country for any of the years 2010-2016.

Most countries have no $PM_{2.5}$ monitoring

Michael Brauer

Martin et al. submitted

# Development of Satellite-Based Estimates of $PM_{2.5}$

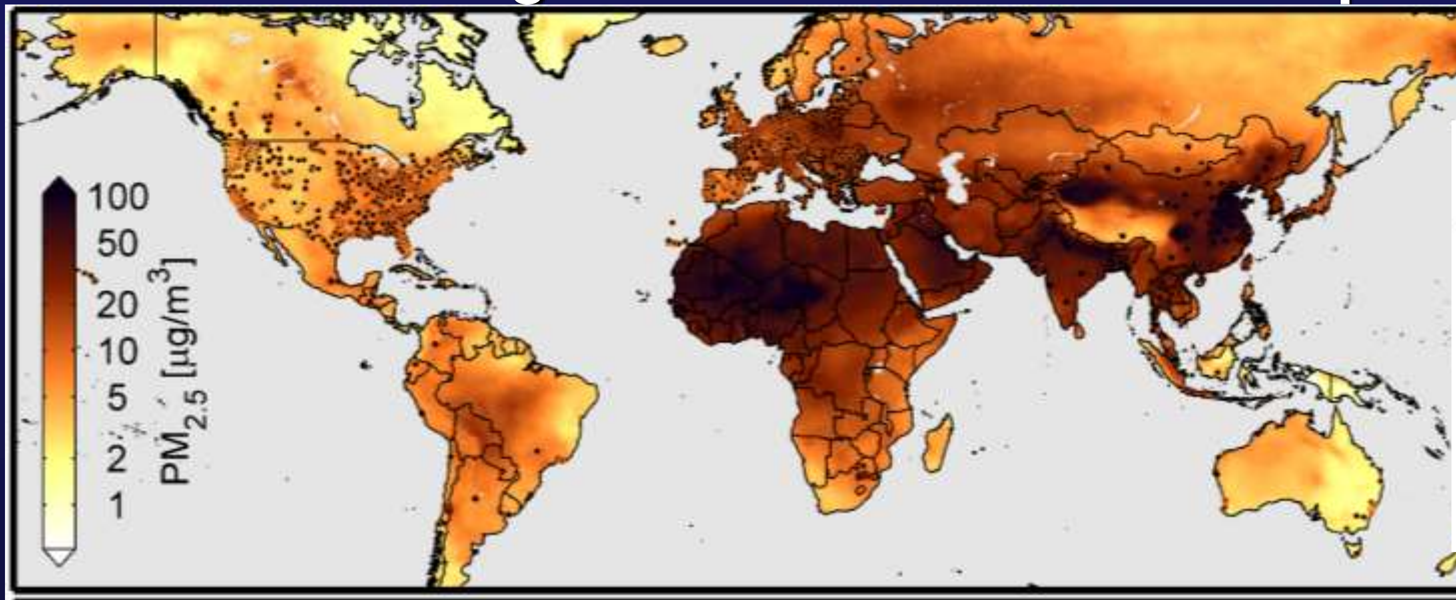


Aerosol Optical Depth (AOD) from multiple satellite instruments and algorithms constrained with AERONET

Satellite-Based $PM_{2.5}$

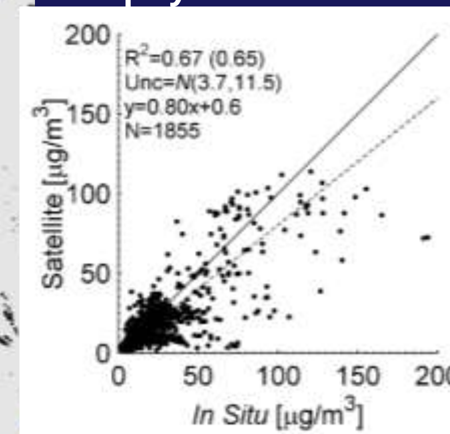
Calculate coincident local solution to $PM_{2.5} = f(x,y,t,AOD)$

# Evaluate and Enhance Satellite-Based Estimates of $PM_{2.5}$
# Promising Results with Room for Improvement




van Donkelaar et al., ES&T, 2016

**Performance of Geophysical Estimates**




**Error likely driven by modeled relation between AOD and $PM_{2.5}$**

**Satellite-derived $PM_{2.5}$ information source for:**

- Global Burden of Disease Assessments (IHME, WHO)
- OECD Regional Well Being Index
- UNICEF
- World Bank
- World Development Indicators
- Yale-Columbia Environmental Performance Index
- Range of epidemiologic studies (low $PM_{2.5}$, PURE-Air, diabetes, birth outcomes)
- Contributed to Canadian annual $PM_{2.5}$ guideline (Crouse et al., 2012)

# Complex Relation of "Dry" $PM_{2.5}$ with AOD

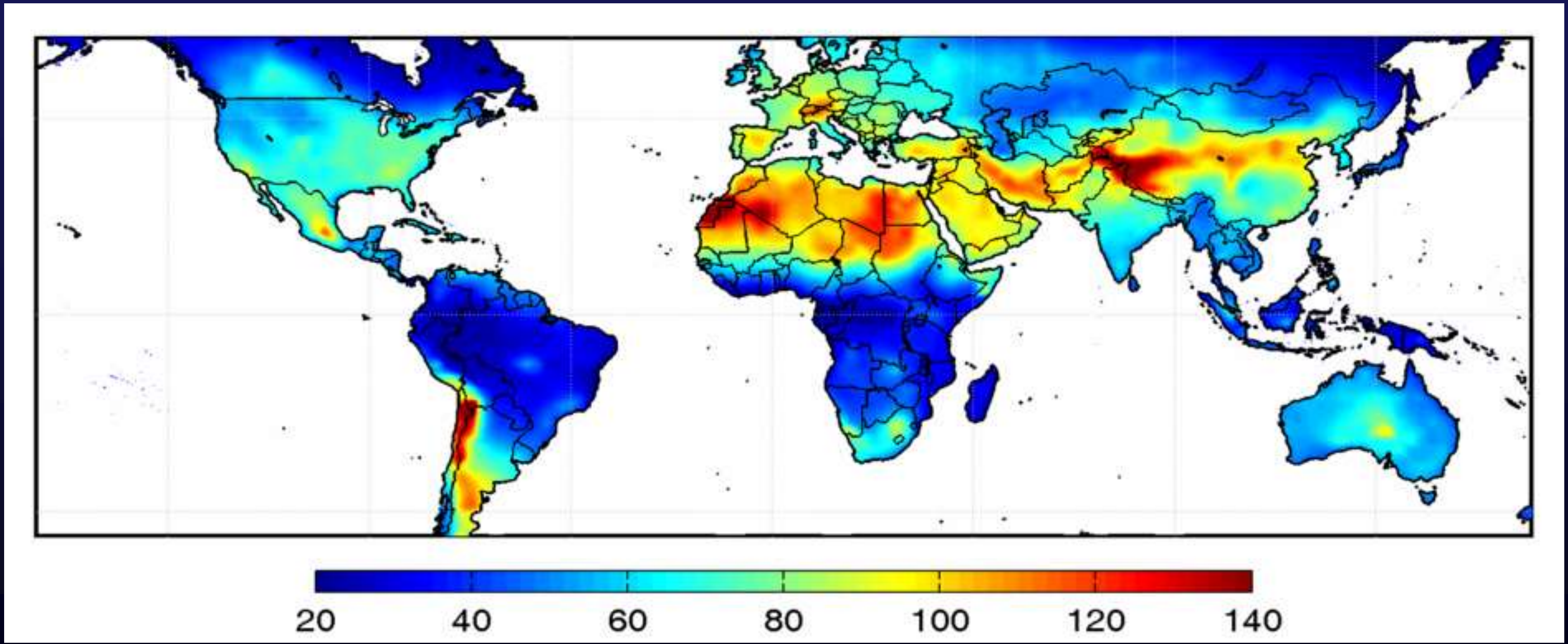
**Affected by vertical structure, aerosol properties, aerosol water**

**Dry (35% RH) vs ambient relative humidity (RH)**

**Ground-level vs column aerosol**

**Elevated topography**

## GEOS-Chem Simulation of $PM_{2.5}$ / AOD for 2001-2006



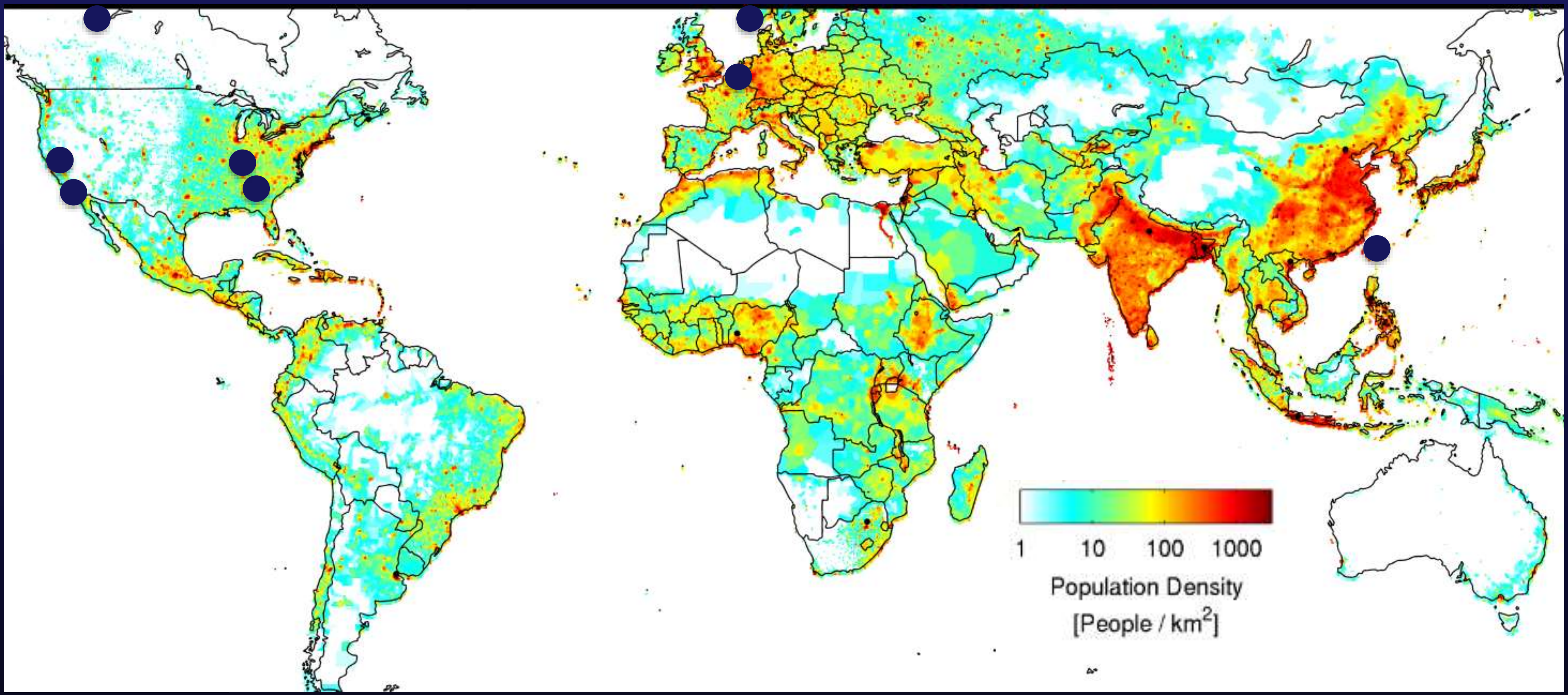

$PM_{2.5}$ / AOD ($\mu g\ m^{-3}$)

Model sampled coincidently with satellite observations

$PM_{2.5}$ calculated at 35% RH

van Donkelaar et al., EHP, 2010

# Few Collocated Measurements of $PM_{2.5}$ & AOD




Data for 2012

# Surface Particulate Matter Network (SPARTAN): Measures $PM_{2.5}$ Mass & Composition at Sites Measuring AOD

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

Mass (35% RH)
Black Carbon
Ions (IC)
Metals (ICP-MS, XRF)
Organics (AMS, FTIR) in progress

3-λ nephelometer (AirPhoton) Scatter

AOD from Sunphotometer (e.g. AERONET)

SPARTAN
Global Particulate Matter Network

Surface/Column — Diurnal — Mass Scattering Efficiency (Depends on size, composition, hygroscopicity)

$$\frac{PM_{2.5}}{AOD} = \left(\frac{b_{sp,overpass}}{AOD_{overpass}}\right)\left(\frac{b_{sp,24h}}{b_{sp,overpass}}\right)\left(\frac{PM_{2.5,24h}}{b_{sp,24h}}\right)$$

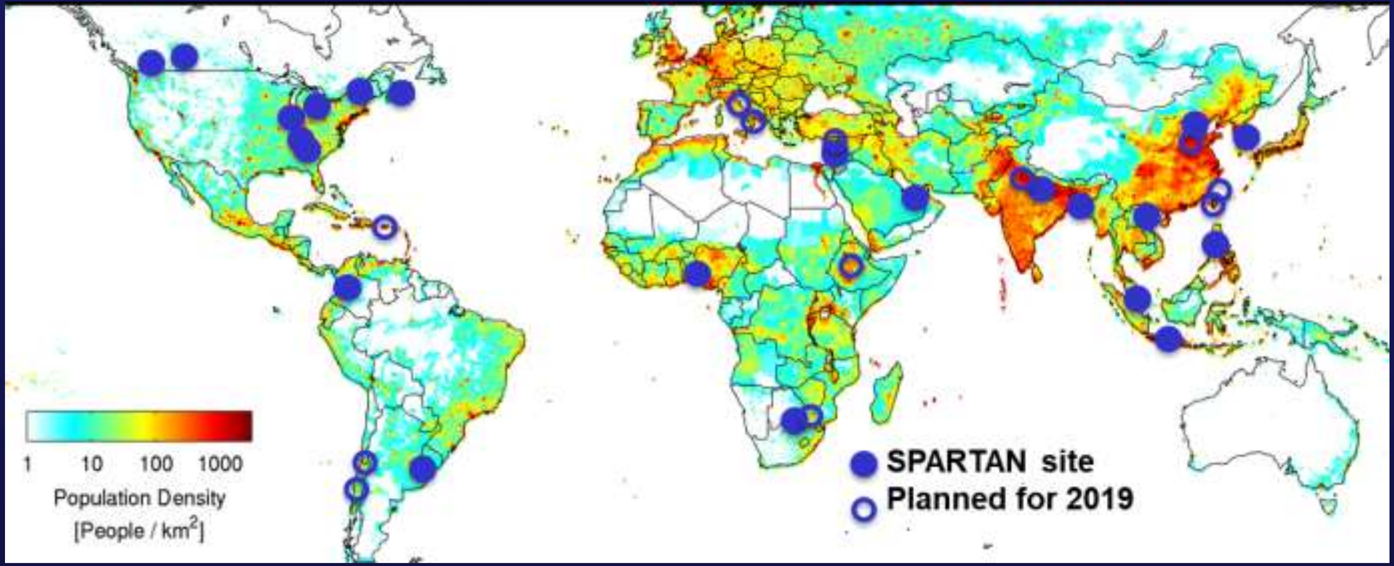
$b_{sp}$ = nephelometer measurements of aerosol scatter

overpass = satellite overpass time

www.spartan-network.org

Snider, Weagle, et al., AMT, 2015

# SPARTAN: A Growing Global Network to Evaluate and Enhance Satellite-Based Estimates of $PM_{2.5}$




Globally consistent $PM_{2.5}$ mass and composition network


Coal, Traffic

Fires

Agriculture

Sea Spray

Mineral Dust

SPARTAN Measurements

| Coal, Traffic | Fires | Agriculture | Sea Spray | Mineral Dust |
|---|---|---|---|---|
| $SO_4^{2-}$, Pb, As, V, Zn, BC | K | $NH_4^+$ | $Na^+$ | Al, Fe, Mg, Ti |

www.spartan-network.org

Snider, Weagle, et al., AMT, 2015

# Thanks to Site Operators

## Manila, Philippines

## Hanoi, Vietnam

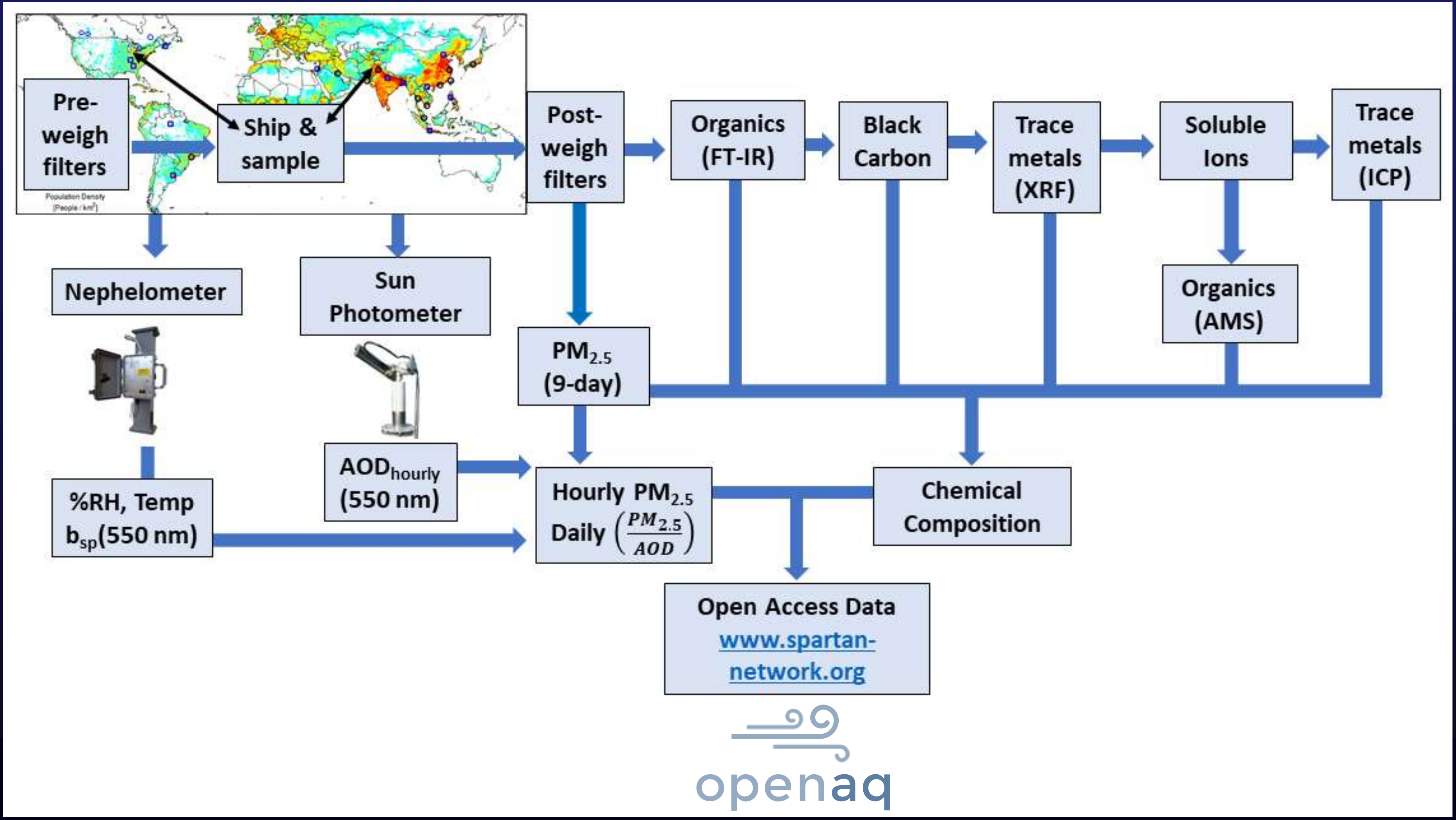
## Dhaka, Bangladesh

## Ilorin, Nigeria

## Bandung, Indonesia

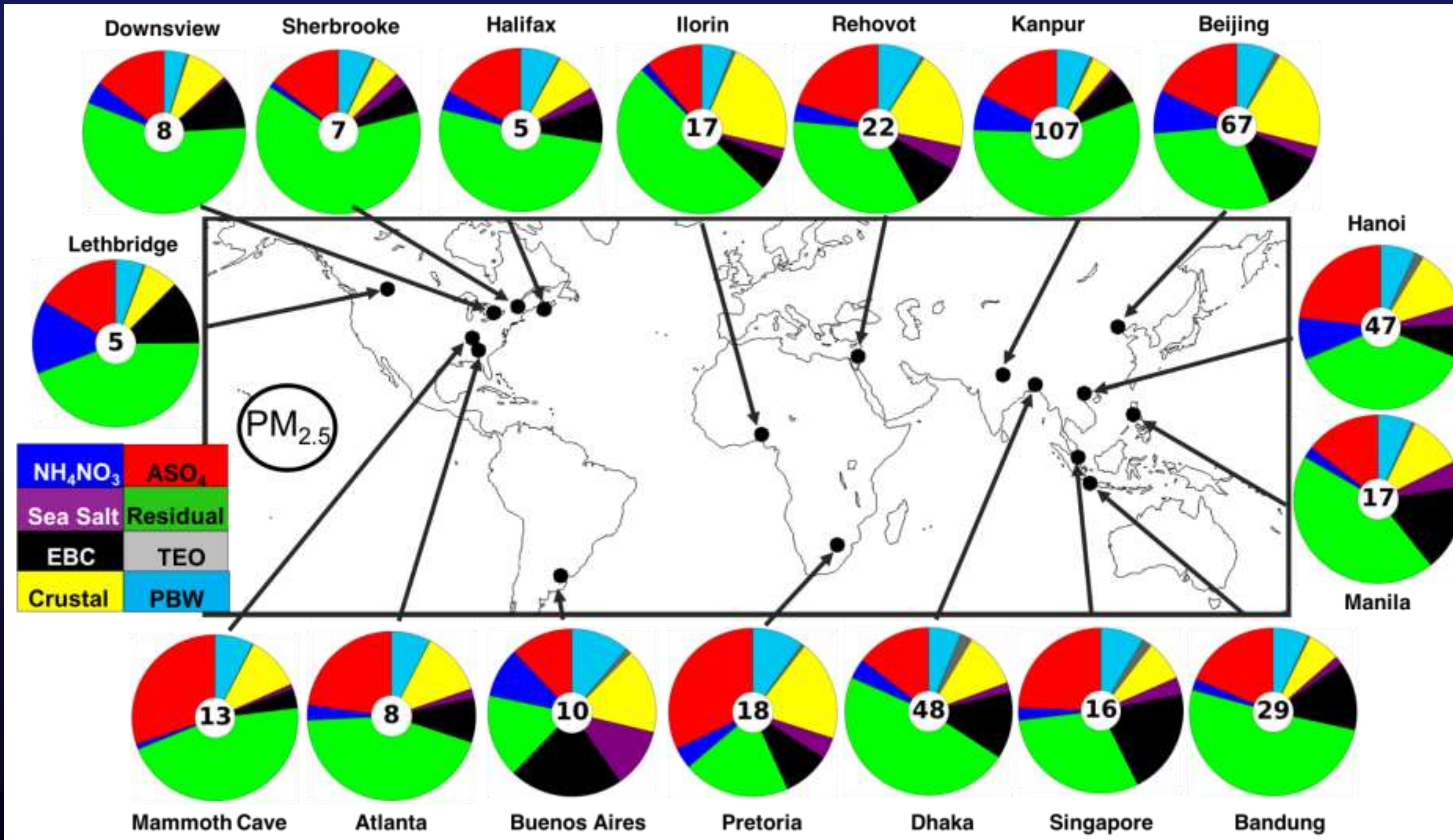
## Buenos Aires, Argentina

# Data Collection and Analysis
## Maximizing Information from Each Filter



# SPARTAN $PM_{2.5}$ Mass and Composition (>2000 filters)

Low $PM_{2.5}$ High Dust Fraction High PM, Nitrate



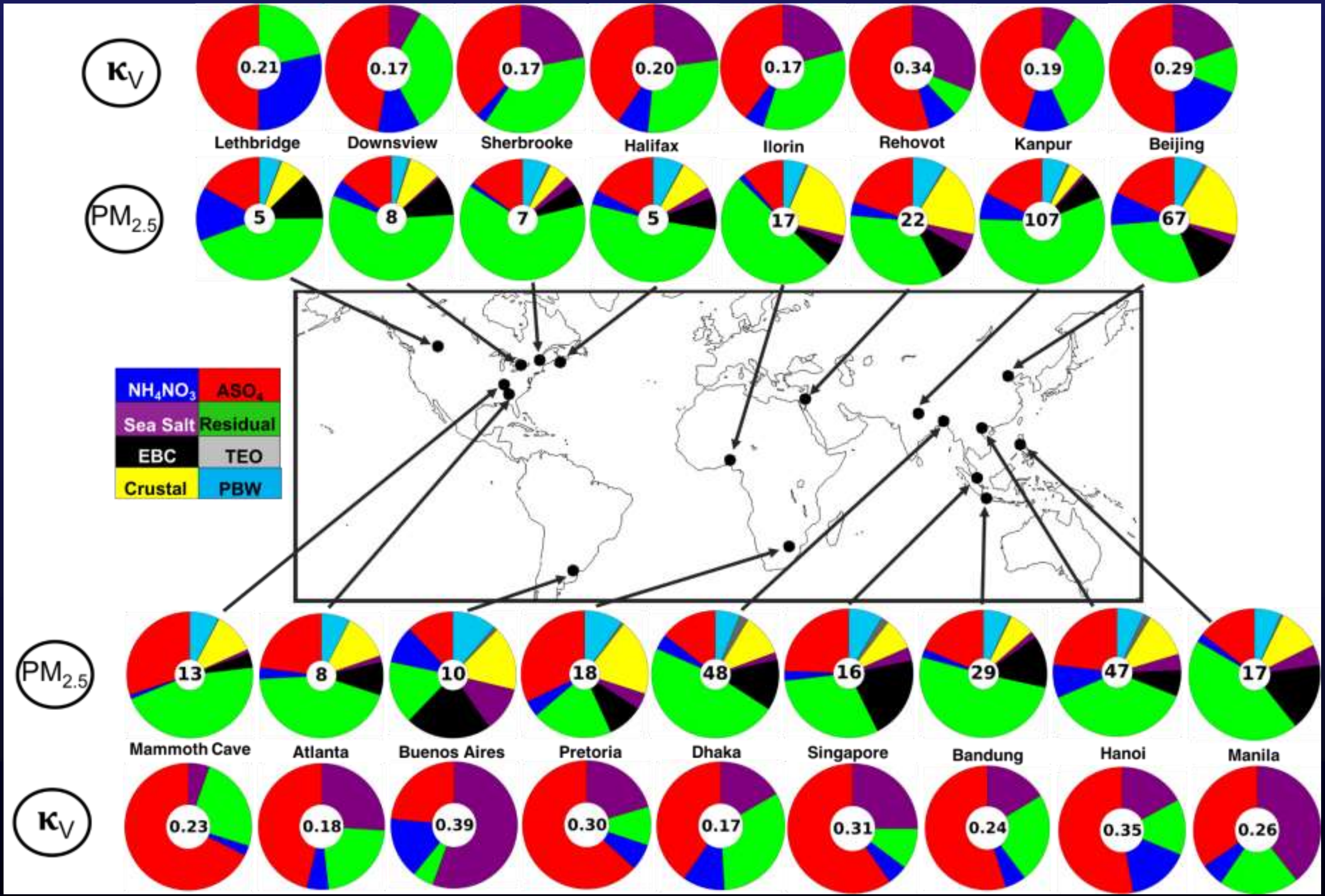

High BC High BC

Data publicly available at spartan-network.org

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

Snider et al., ACP, 2016

# Hygroscopicity ($\kappa_v$) Important to Relate Scatter to Mass




Middle contains $PM_{2.5}$ Mass in ug/m$^3$ and volume hygroscopicity coefficient. Snider, Weagle, et al., ACP, 2016

# Recent and Ongoing Developments

- Cyclone inlets on sampling station and nephelometer
  - sharper size cut
  - dynamic $PM_{2.5}/PM_{10}$ on nephelometer

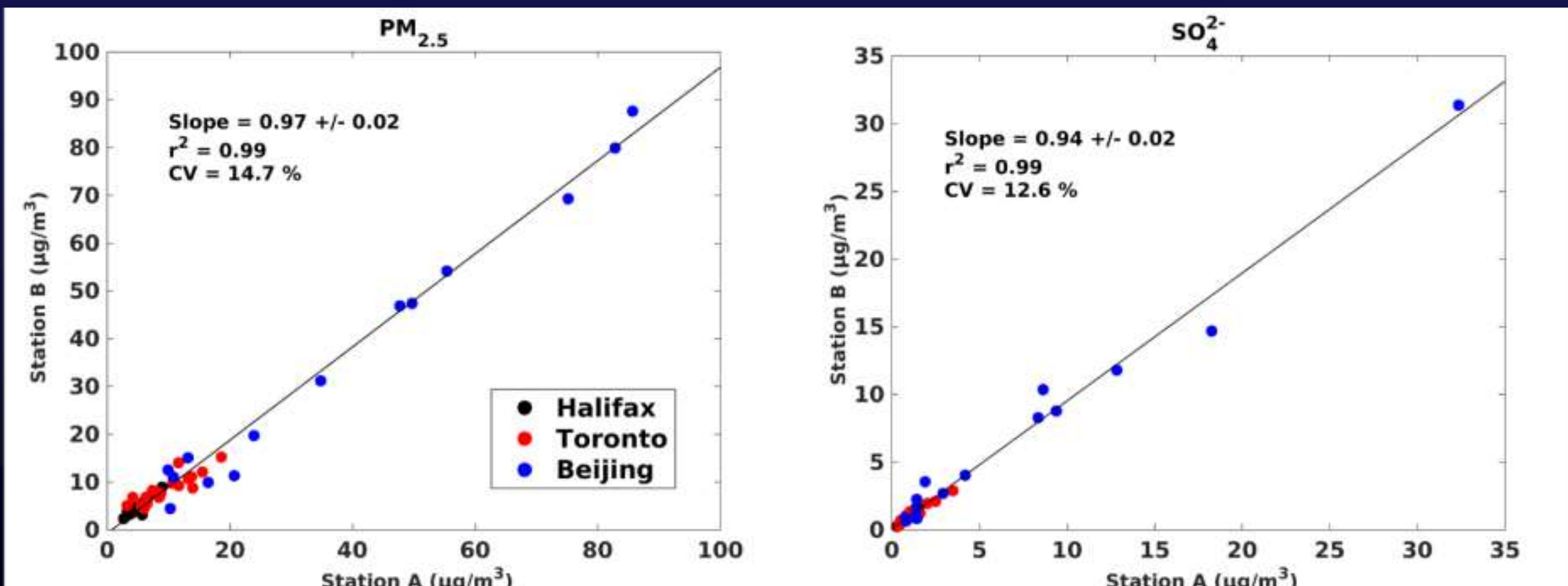
- Consistent Teflon filter media as EPA CSN and IMPROVE
- Organics (AMS, FTIR), Elements via XRF
- Additional sites to better resolve global variation
- Plans to sample MAIA sites on days of MAIA overpass
- Central nodes (e.g. connect with low-cost sensors)
- Connect with vertical profiles (e.g. aircraft campaigns, MPLNET)


# Ongoing Investment in QA/QC

## Facilitated by Traveling Blanks (12.5% of Filters)

## Periodic Collocation with Established Networks (e.g. IMPROVE, EPA, NAPS)

## Collocated Measurements Test Performance



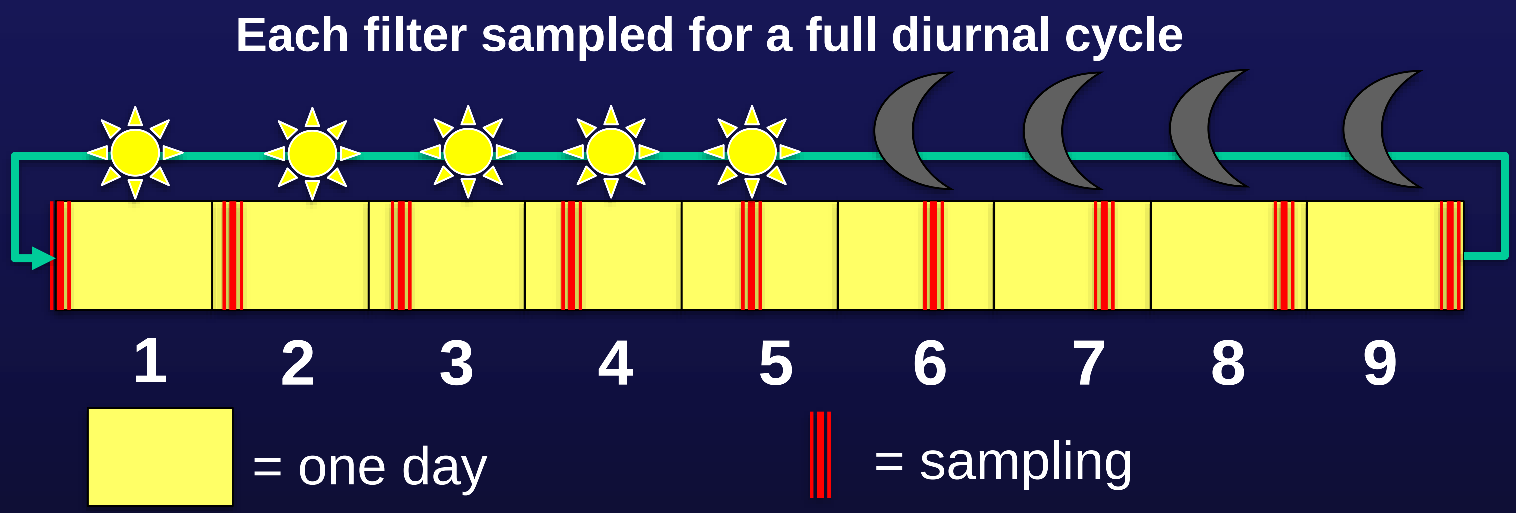

Weagle, et al., ES&T, 2018

# Seek Your Ideas to Develop Collaborations to Enhance the Grass-roots Surface Particulate Matter Network and Connections with Other Networks

# SPARTAN Filter Sampling Strategy

## Sampling Each Day Better Characterizes Long-term Concentrations

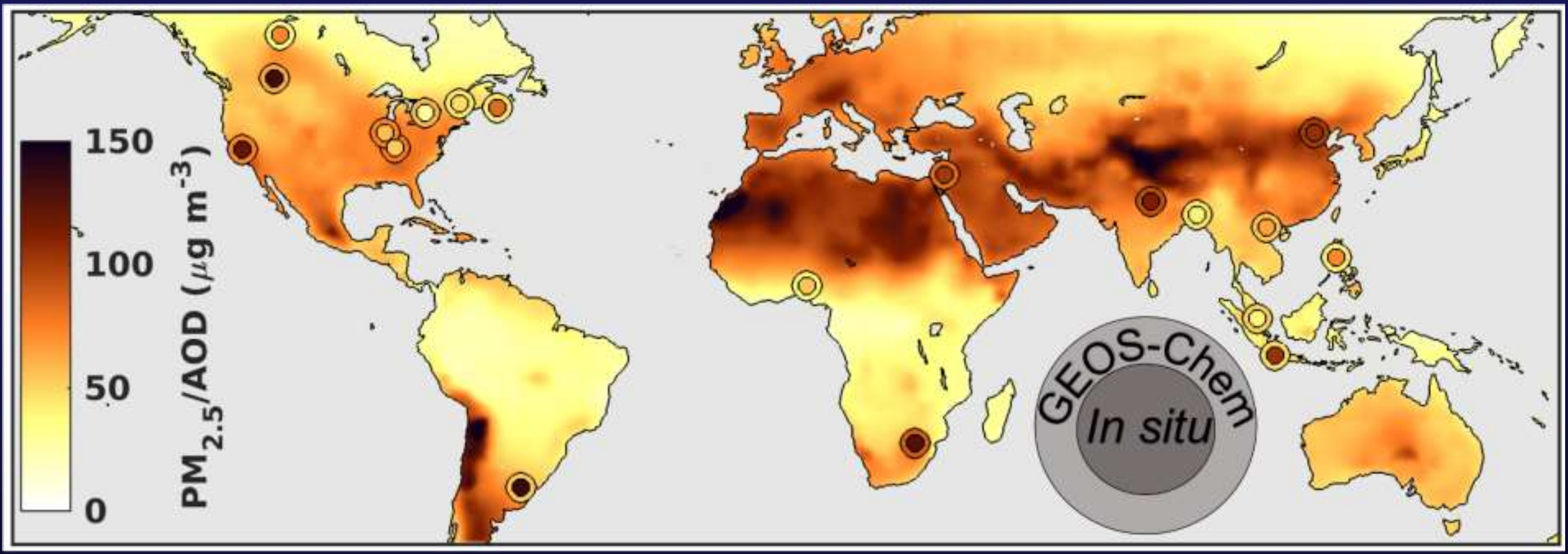
## Integration with Nephelometer Yields Hourly Resolution




- **Sample daily**
- **Cost effective**
- **Integrated sampling with nephelometer yields hourly PM**
- **Cease airflow in morning to retain semivolatiles**
- **More frequent filters possible (higher operating costs)**

# Emerging Evidence that $PM_{2.5}$/AOD May be Larger: Increased Global $PM_{2.5}$ Burden

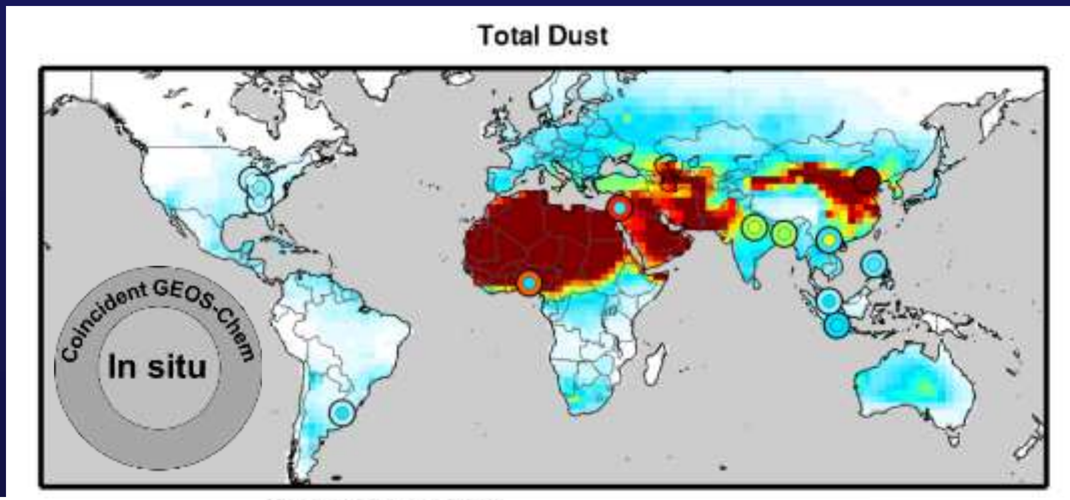
## Initial Evaluation of GEOS-Chem Simulation of $PM_{2.5}$/AOD vs SPARTAN




Consistent with slope < 1 vs monitors outside North America; van Donkelaar et al. (2010, 2015, 2016)

Weagle et al. in prep

# Adding Anthropogenic Fugitive, Combustion, and Industrial Dust to GEOS-Chem Improves Agreement with SPARTAN Dust

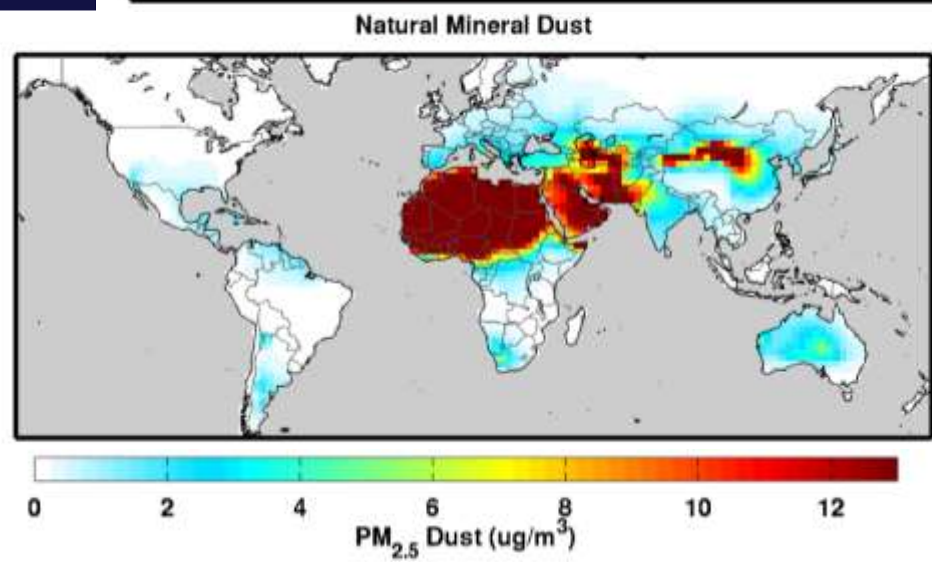


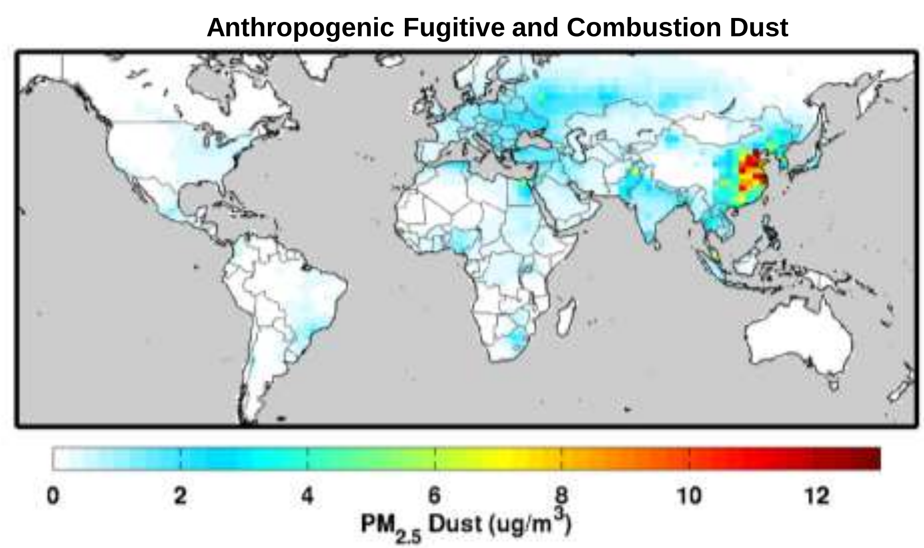

**Correlation vs SPARTAN**

**r = 0.06 with natural dust alone**

**r = 0.66 with natural and anthropogenic dust**

**Explains 10% of global population-weighted $PM_{2.5}$**

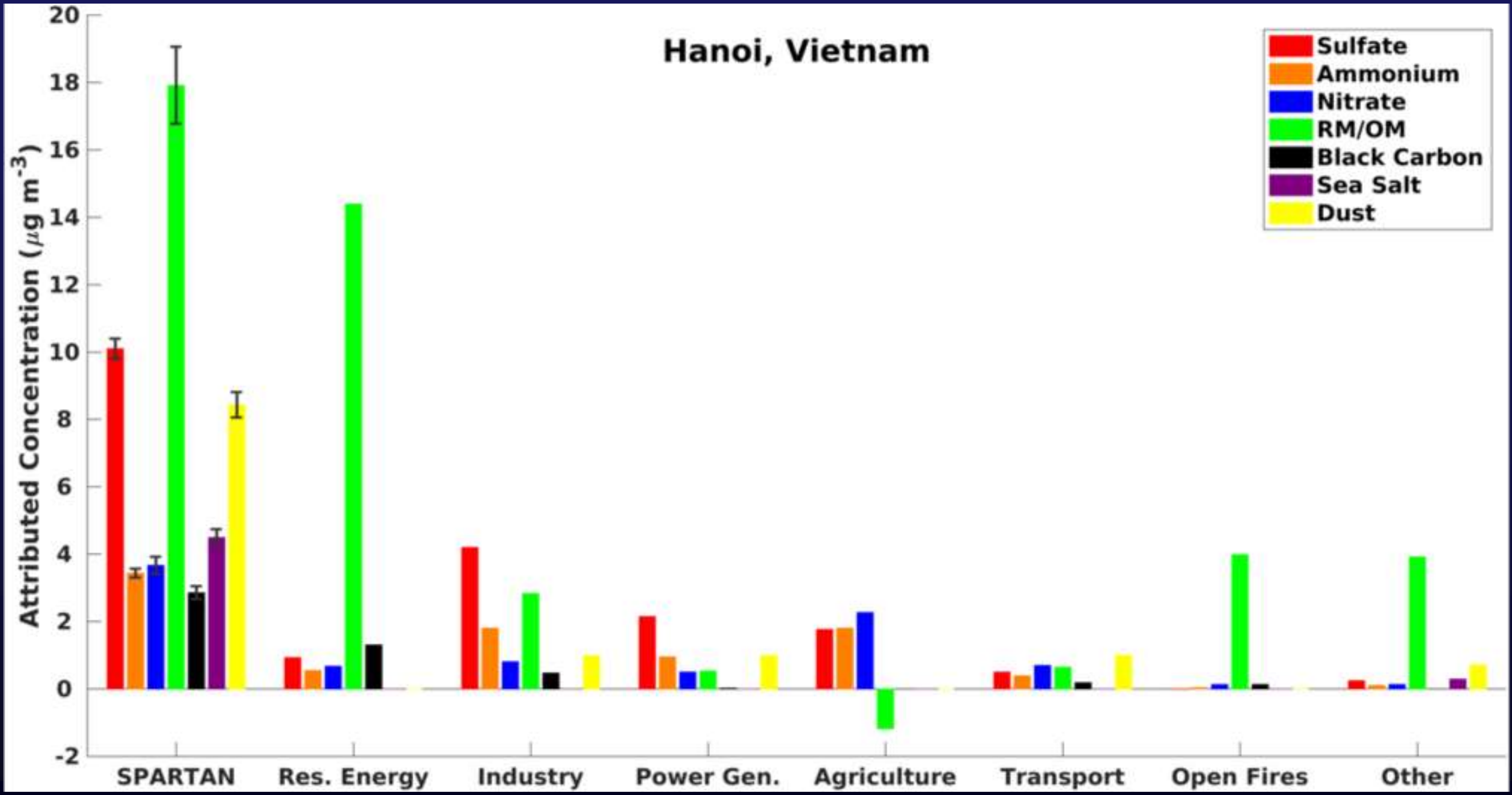



Philip et al., GRL, 2017

# Applicability of SPARTAN for Bottom-up Source Attribution

## Example Source Attribution using SPARTAN and GEOS-Chem




Measured

GEOS-Chem Calculations

Weagle et al., submitted