


Integration of satellite observations with surface monitor measurements for retrieval of speciated particulate matter concentrations

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Making Sense of Sensors
Diamond Bar, CA
September 27-28, 2017



Particulate matter impacts on human health

Airborne PM is a well-known cause of cardiovascular and respiratory diseases.

Coarse particles (PM_{10}-$PM_{2.5}$) irritate our respiratory systems.

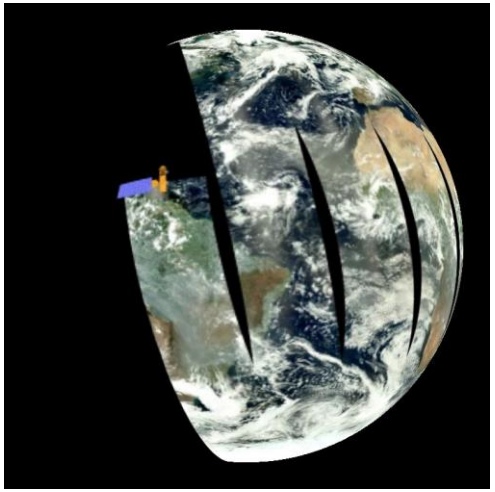
Fine particles ($PM_{2.5}$) penetrate deep into our lungs. Toxins can migrate to other organs.

- Heart attacks
- Stroke
- Lung disease, lung cancer
- Aggravated asthma
- Low birth weight and preterm delivery

PM exposure assessments

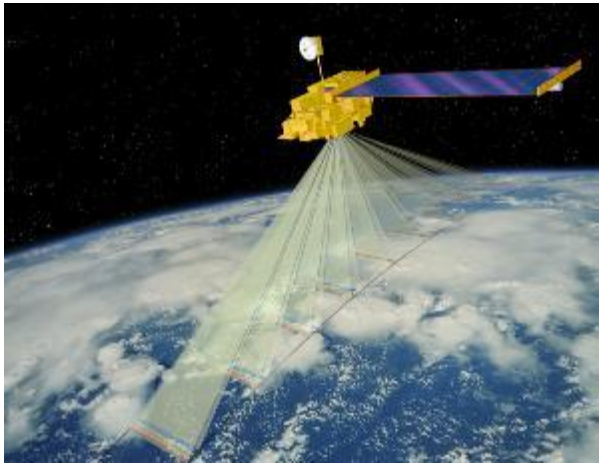
- Calibrated surface monitors provide accurate point measurements
  - These “classical” errors correspond to random variations around the true value
- Even in well-instrumented areas, the sparse distribution of monitors requires the assumption that everyone living within a 20–50 km radius experiences identical PM exposure
  - Results in “Berkson” errors (neglect of personal exposure histories), which can be several times larger than classical errors
- Motivates the use of satellite remote sensing to fill in the gaps

Moderate resolution Imaging Spectroradiometer (MODIS)



- Wide field of view → global coverage in 2 days
- 250 m – 1 km sampling
- Uses six bands for aerosol retrievals: 469, 555, 645, 860, 1240, 1640, 2130 nm
- Single angle of view per observation
- Aerosol types are prescribed

Multi-angle Imaging SpectroRadiometer (MISR)



- 9 day global coverage
- 275 m sampling
- Four spectral bands: 446, 558, 672, 866 nm
- 9 view angles per observation between $\pm 70^{o}$
- Aerosol types retrieved

Relating AOD to PM concentration

- AOD is a column-integrated quantity (dimensionless)
- PM is a near-surface measure of mass concentration ($\mu g\ m^{-3}$)

$$[PM] \approx \left[\frac{4\rho r_{eff}}{3Q_{ext}H}\right] AOD$$

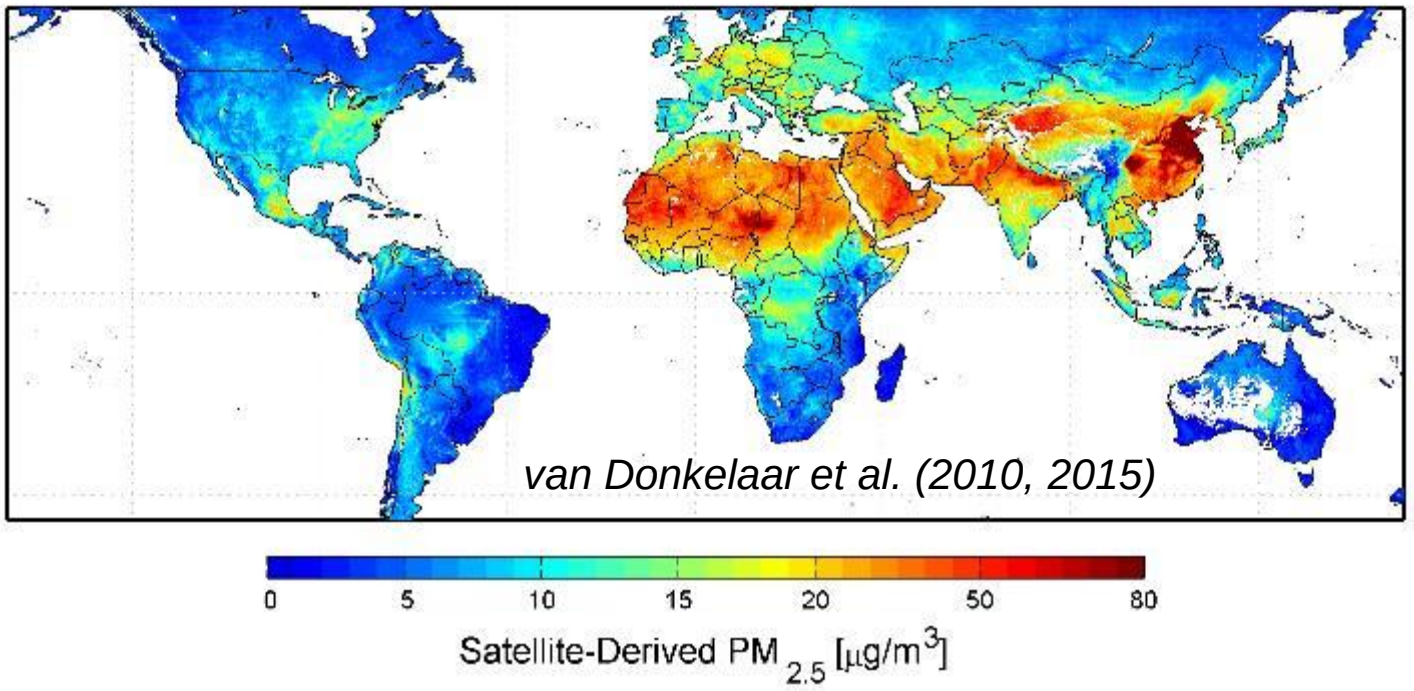
- These factors are highly variable
- Difficult to obtain reliable accuracies from first principles

Gupta and Christopher (2009)

- ρ = particle density
- r_{eff} = effective particle radius
- Q_{ext} = extinction efficiency under ambient conditions
- H = height of the aerosol layer

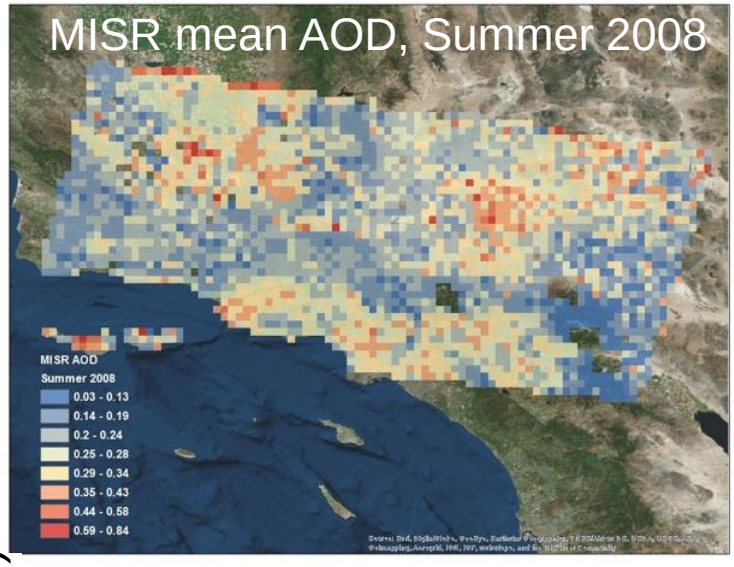
- *Geostatistical regression models* derived from collocated surface and satellite measurements are needed relate AOD to near-surface PM concentrations

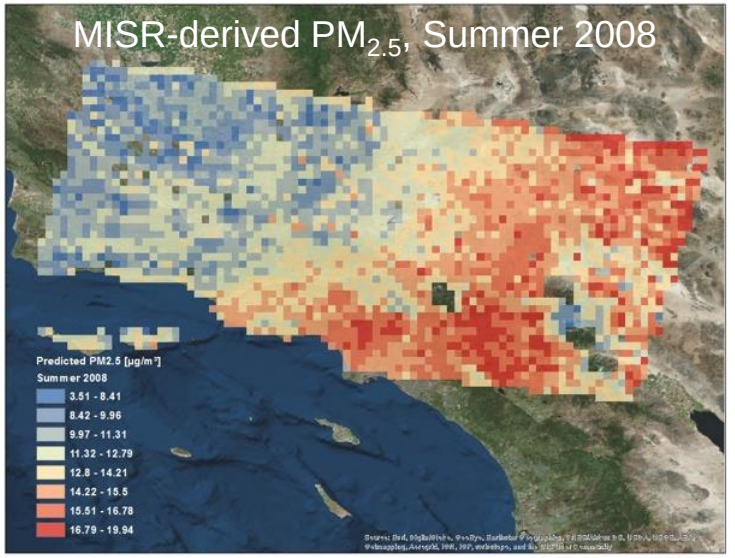
Global and regional $PM_{2.5}$ maps derived from MODIS and MISR

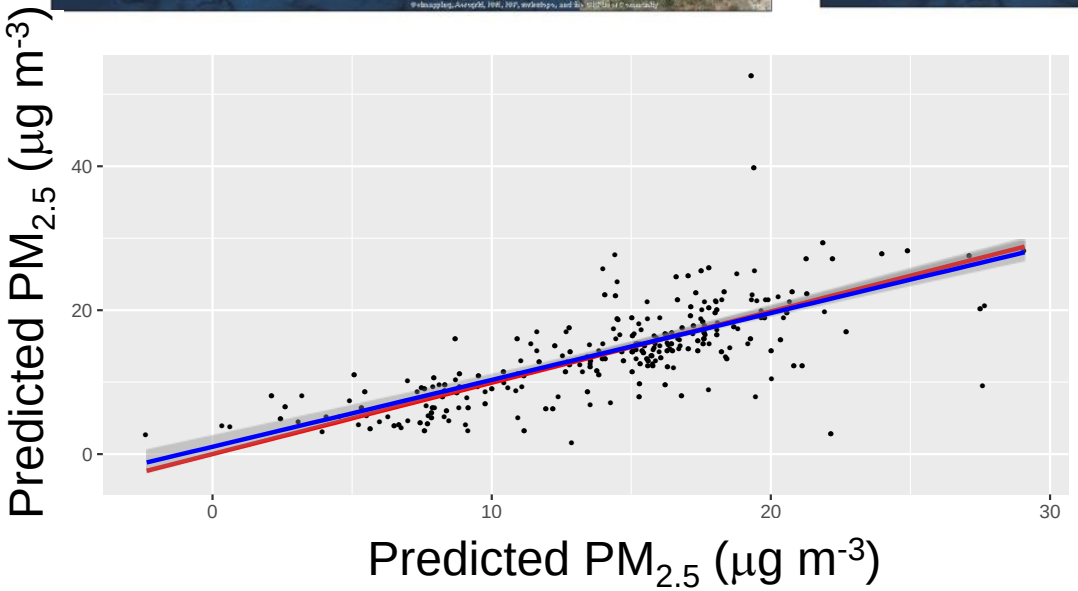


- These data have been used in many health impact studies, e.g.,
  - Global Burden of Disease (*Brauer et al., 2012*)
  - Relative risk of death from circulatory system diseases (*Jerrett et al., 2017*)
  - Associations between $PM_{2.5}$ and low birth weights (*Fleischer et al., 2014*)
  - Increased breast cancer mortality risk from $PM_{2.5}$ exposure (*Tagliabue et al., 2016*)

MISR-derived 4.4 km resolution $PM_{2.5}$ in the greater Los Angeles area



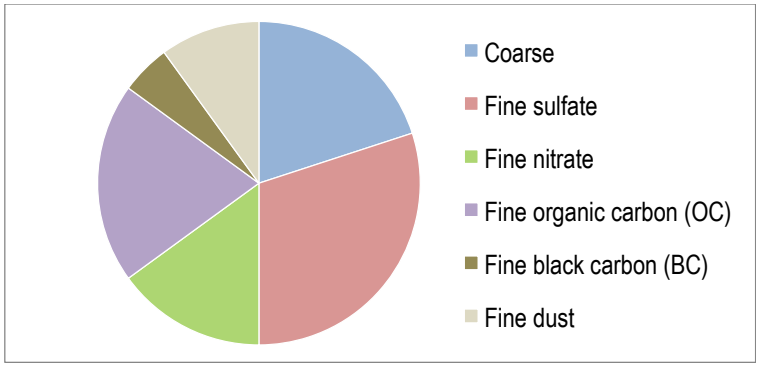




See also
Franklin et al. (2017) Rem. Sens. Environ.

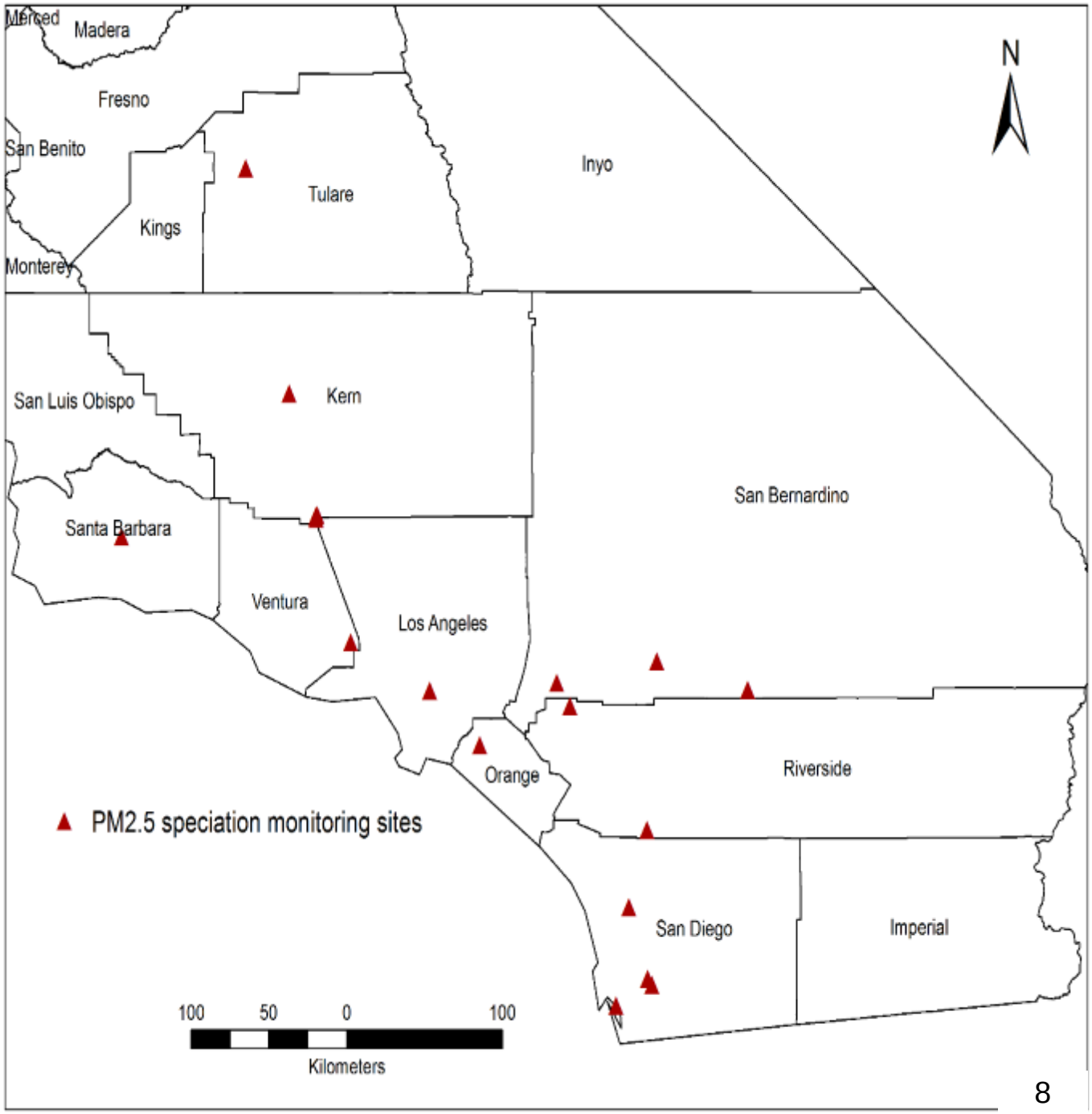
Importance of particle type

- Although PM is a known health risk, the relative toxicity of specific **PM types** (fractional proportions of PM_{10}, $PM_{2.5}$, and PM chemical components) is less well understood



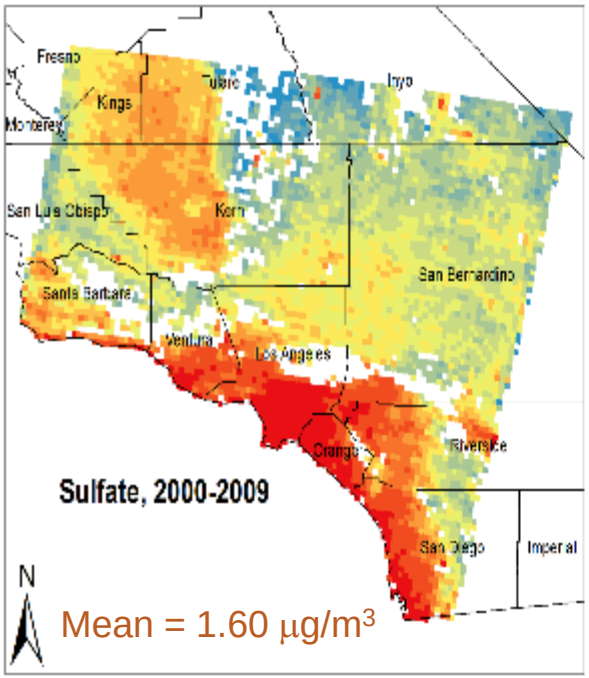
- According to the US EPA (2013)
  - [T]he evidence is not yet sufficient to allow differentiation of those constituents or sources that may be more closely related to specific health outcomes.
  - The use of central fixed-site monitors to represent population exposure limits our understanding of which PM types pose the greatest health risks.

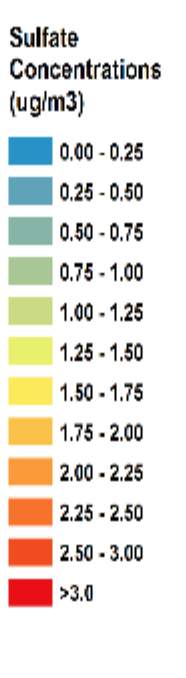
Monitoring sites (CSN, IMPROVE) in CA used to generate speciated $PM_{2.5}$ – fractional AOD regressions

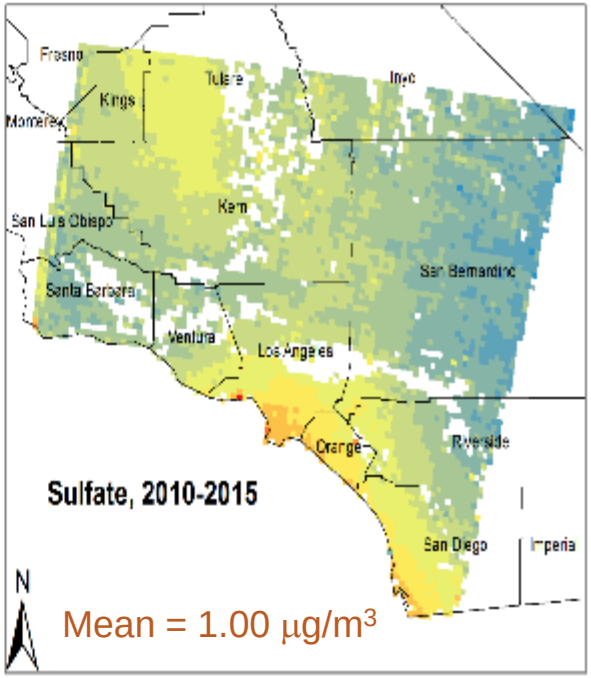


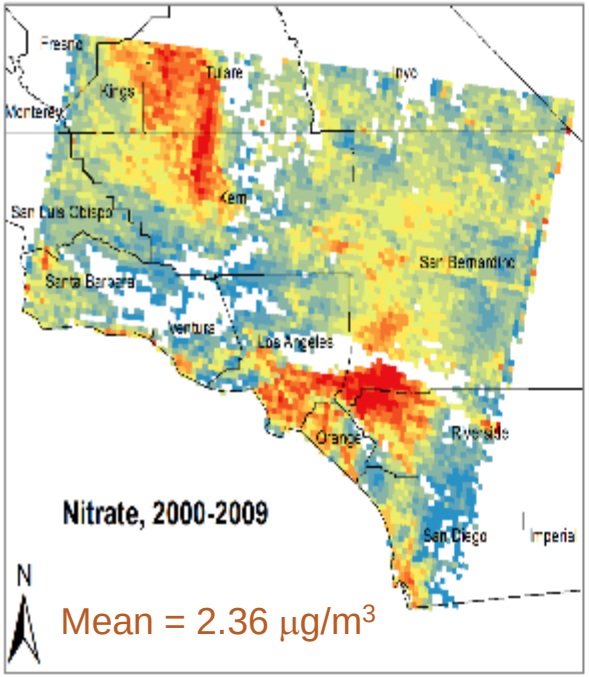
Meng et al. (2017)

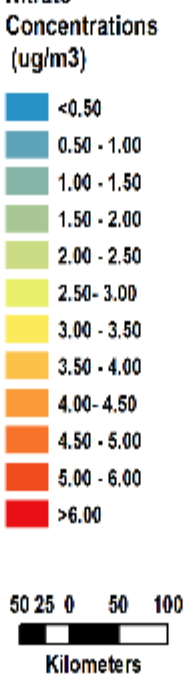
Averaged multi-year means of predicted sulfate and nitrate $PM_{2.5}$ concentrations

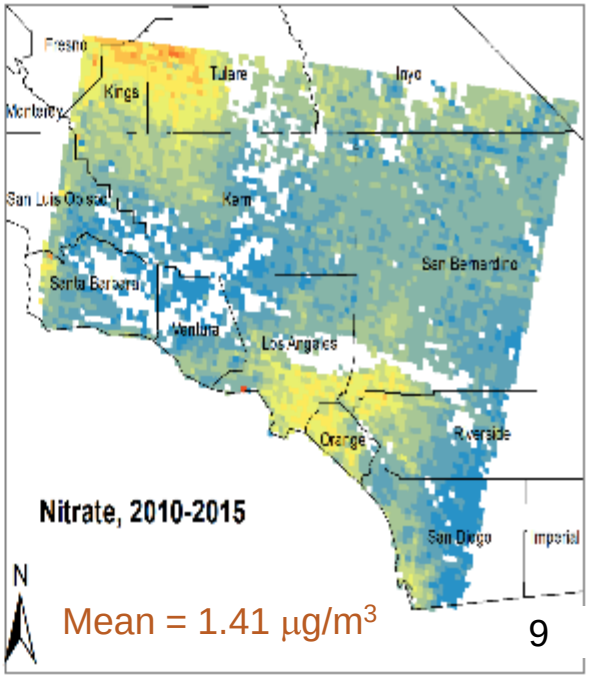










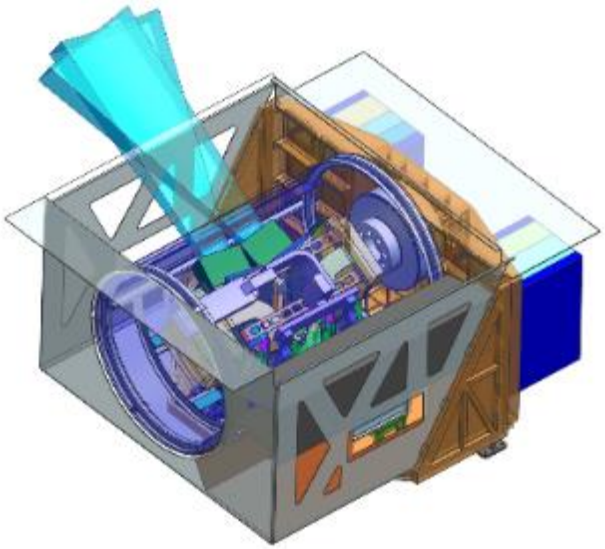


Meng et al. (2017) Atmos. Environ. (submitted)

Looking to the future: Multi-Angle Imager for Aerosols (MAIA)

- MAIA was selected in March 2016 as part of NASA's Earth Venture Instrument program. Objectives:
  - Collect targeted observations over major metropolitan areas
  - Assess the impacts of different size and compositional mixtures of airborne particulate matter on adverse human health outcomes

Liu and Diner (2017)



- MAIA instrument will contain a pair of UV/VNIR/SWIR spectropolarimetric cameras on a 2-axis gimbal to observe selected target areas
  - Along track axis provides multi-angle viewing
  - Cross-track axis provides axis to targets off the sub-S/C track
- To be launched into polar orbit ~2021

Candidate MAIA target areas

- Primary Target Areas (PTAs) are regions to be observed routinely for conducting epidemiological studies
  - Include major population centers
  - Cover a variety of PM concentrations and size/composition mixtures
  - Contain surface-based sunphotometers, PM size discrimination and chemical speciation monitors
  - Enable access to geocoded health datasets
- Secondary Target Areas (STAs) are for additional aerosol/cloud air quality and climate science

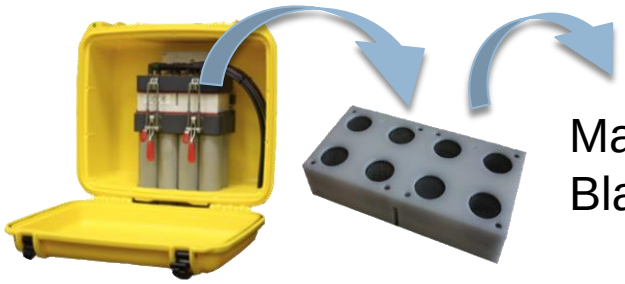
Calibration of satellite retrievals with surface stations is essential

- AERONET sunphotometers are used to correct for systematic total aerosol optical depth (AOD) retrieval biases and for validation

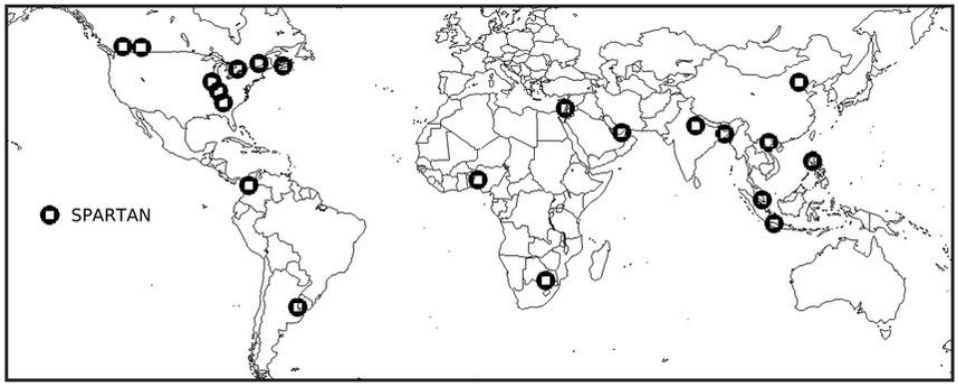
- ✓ Surface monitors are used to generate geostatistical regression models (GRMs) relating column aerosol properties to surface PM
  - EPA Chemical Speciation Network
  - Interagency Monitoring of Protected Visual Environments (IMPROVE)
  - SouthEastern Aerosol Research and Characterization Network (SEARCH)
  - European Monitoring and Evaluation Programme
  - Surface PARTiculate mAtter Network (SPARTAN) (to be supplemented with additional stations by the MAIA Project)
  - Low-cost distributed sampling networks

SPARTAN network enables speciated PM retrievals in other countries

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



Mass (35% RH)
Black Carbon

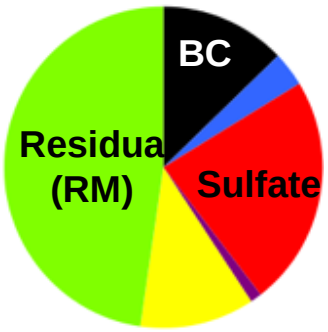


3-λ nephelometer (AirPhoton)
Scatter ($PM_{2.5}$ & PM_{10})

www.spartan-network.org
Snider et al. (2015)

Atlanta, South Dekalb (non coincident)

SPARTAN



EPA Network

Concluding remarks

- Passive remote sensing to determine near-surface PM types and distributions has made significant advances over the last decade.
  - Calibration of AOD with surface PM data is essential.
- The MAIA investigation will apply current strategies used to derive $PM_{2.5}$ from satellites (MISR/MODIS) to map $PM_{10,}$ $PM_{2.5}$, and $PM_{2.5}$ components (sulfate, nitrate, organic carbon, black carbon, dust).
- MAIA will capitalize on the SPARTAN network and the project plans to deploy new SPARTAN stations.
- **The project is also seeking robust low- to medium-cost samplers for ambient $PM_{2.5}$ mass and especially speciation.**


Thank you
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