


Multi-Angle Imager for Aerosols (MAIA):

Observations, measurements, and science



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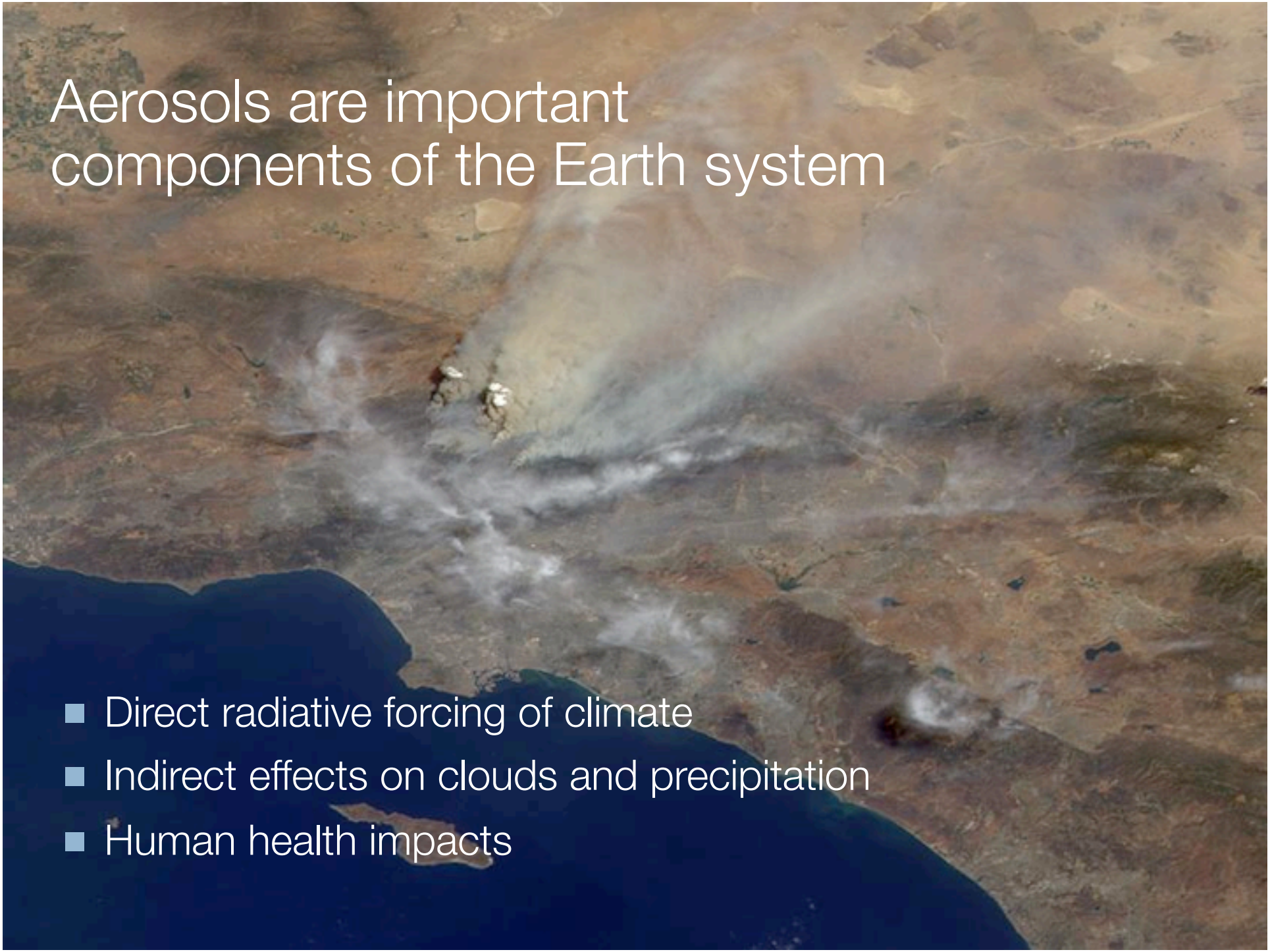
The decision to implement the MAIA mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

The Multi-Angle Imager for Aerosols (MAIA) satellite investigation was selected in March 2016 as part of NASA's Earth Venture Instrument program.

MAIA's primary objective is to assess the impacts of different size and compositional mixtures of airborne particulate matter (PM) on human health.



Aerosols are important components of the Earth system

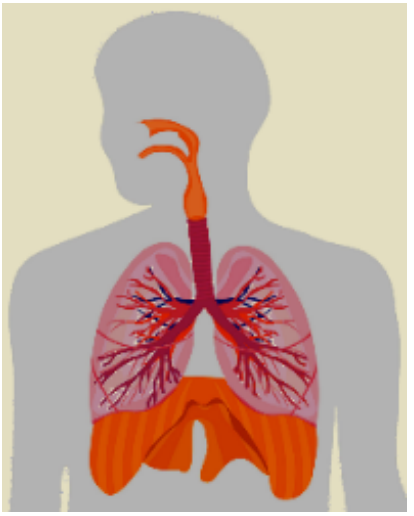
- Direct radiative forcing of climate
- Indirect effects on clouds and precipitation
- Human health impacts

Aerosol impacts on human health

Airborne particulate matter (PM) is a well-known cause of cardiovascular disease and mortality.

> 4 million premature deaths per year

PM has also been associated with respiratory disease, lung cancer, low birth weight, and other adverse health outcomes.

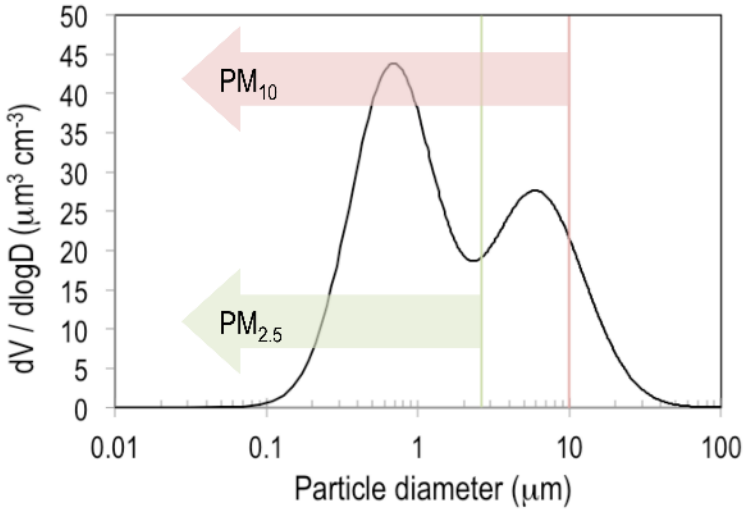


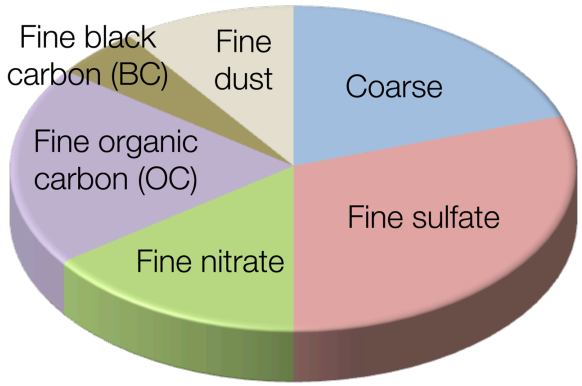
The relative toxicity of specific **PM types** is not well understood.

PM "type" refers to the fractional proportions of coarse particles, fine particles, and fine particle physical and chemical components.

Coarse particles originate from grinding processes, windblown soil.

Fine particles originate from combustion in motor vehicles, power plants, wildfires and agricultural burning, and industrial processes.





Why observe from space

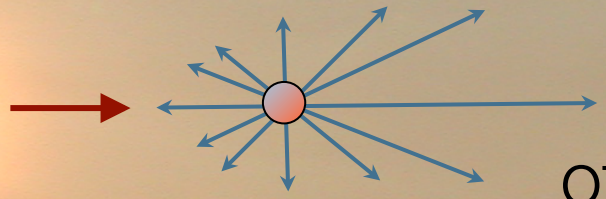
"The use of central fixed-site monitors to represent population exposure is a key factor limiting our knowledge as to which PM types pose the greatest health risks."
— *US EPA (2013)*

Satellite observations enable PM mapping over large areas, including locations where surface monitors are especially sparse.

SUNLIGHT

is the fundamental energy source for the Earth system.

The *color*
angular distribution
polarization



aerosol particle

of scattered sunlight is diagnostic of aerosol properties.

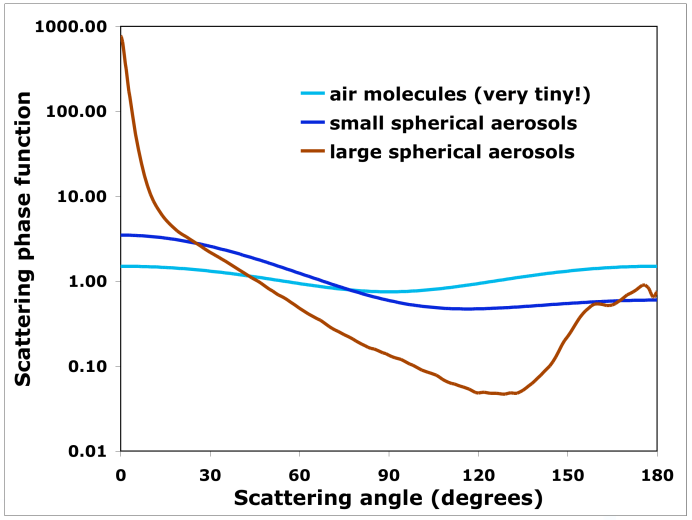
Remote sensing modalities

Spectral coverage

Aerosol absorption Fine mode aerosol Coarse mode aerosol

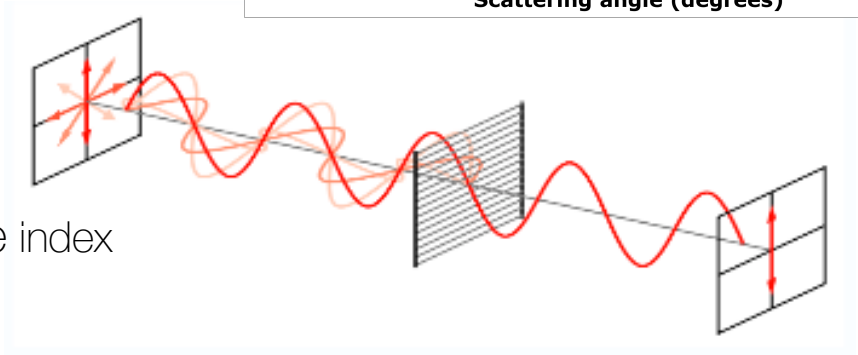
Multiangle imaging radiometry

Particle size and shape

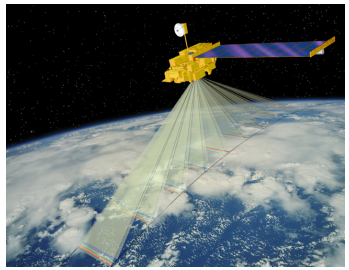


Multiangle polarimetry

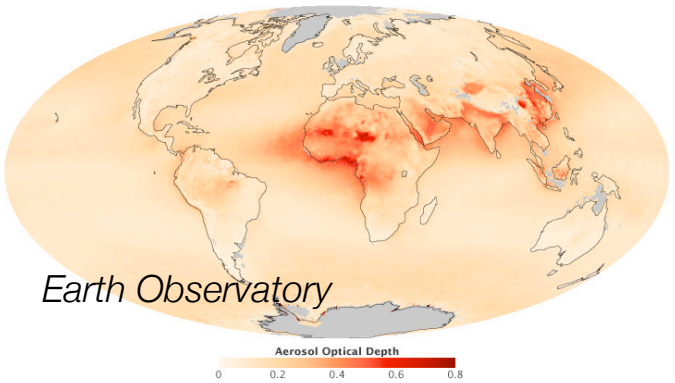
Particle size, shape, and refractive index



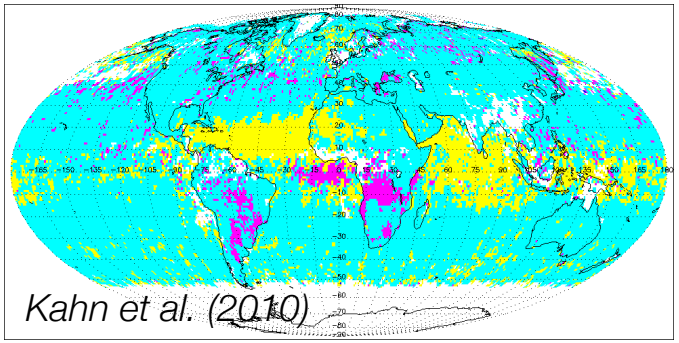
Examples of radiometric and polarimetric sensitivity to aerosol properties



Multi-angle Imaging SpectroRadiometer (MISR)
445, 558, 672, 866 nm



Aerosol optical depth (AOD)

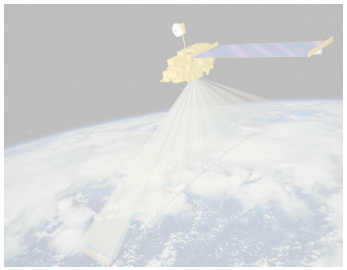


Spherical Nonabsorbing

Spherical Absorbing

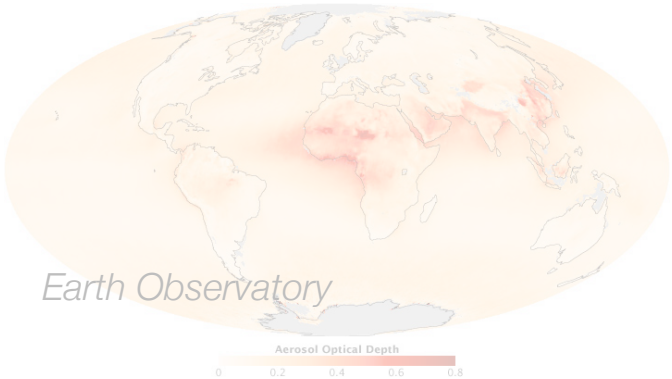
Nonspherical

Examples of radiometric and polarimetric sensitivity to aerosol properties

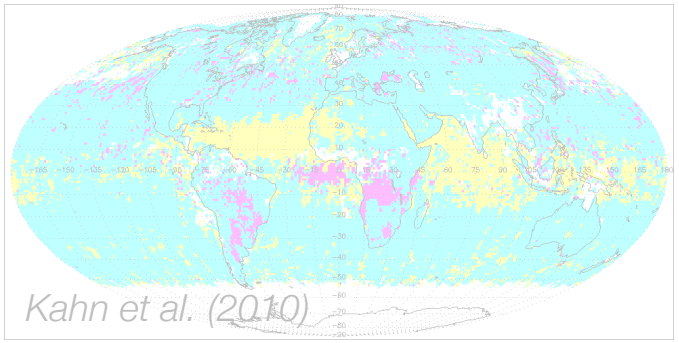


Multi-angle Imaging SpectroRadiometer (MISR)
445, 558, 672, 866 nm

Airborne Multiangle SpectroPolarimetric Imager (AirMSPI)
355, 380, 445, 470*, 555, 660*, 865*, 935 nm (*polarized)



Aerosol optical depth (AOD)

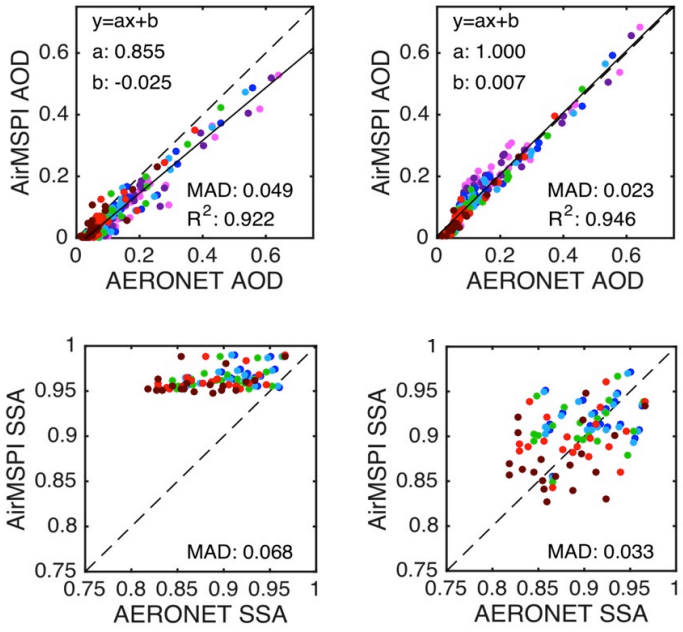


Spherical Nonabsorbing

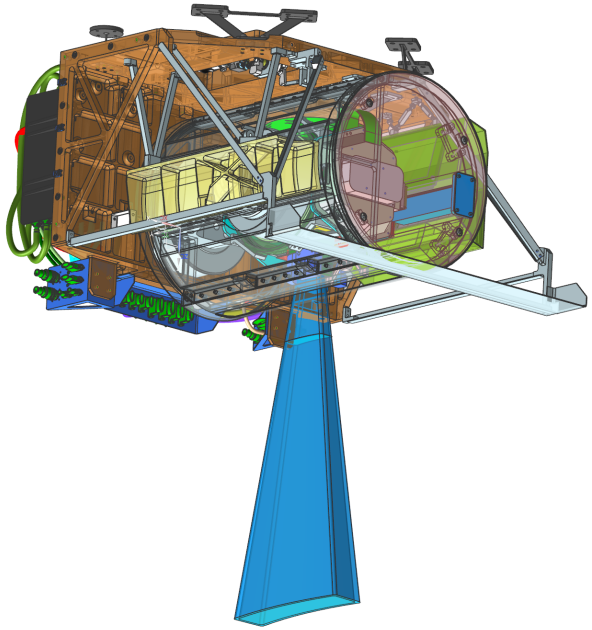
Spherical Absorbing

Nonspherical

Without polarization | With polarization



MAIA combines multiple observing modalities



- The MAIA instrument contains a spectropolarimetric camera on a 2-axis gimbal.
- Along-track (scan) axis provides multiangle imagery (±70° at Earth)
- Cross-track (pan) axis enables observing targets off the sub-satellite track.

Band (nm)	367	389	415	445	551	645	749	762.5	864	943	1039	1607	1880	2124
Polarimetric				✔		✔					✔			

O_2 A-band

TOMS/OMI Heritage
Black carbon

MISR/AirMSPI/POLDER Heritage
Organics, non-organics, dust

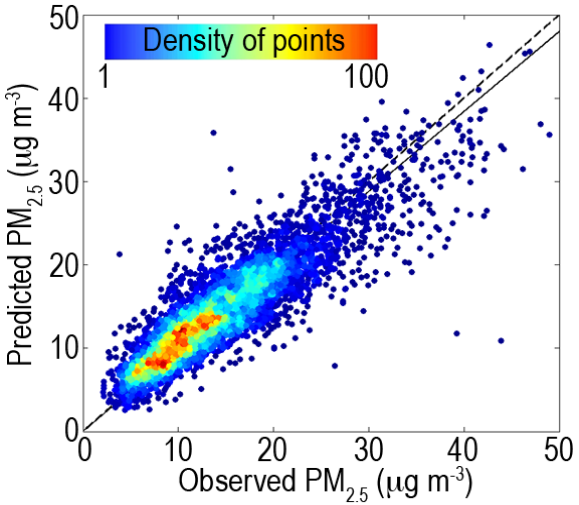
Clouds

MODIS Heritage
Coarse mode, surface

Mapping PM concentrations

- The relationship between column-integrated aerosol properties and near-surface PM concentration is highly variable and difficult to obtain reliably from first principles.
- Collocated satellite and surface monitor data are used to generate empirical regression models relating AOD to PM.
  - Once the regression models are “trained”, they are applied to the satellite image data to create continuous PM maps.

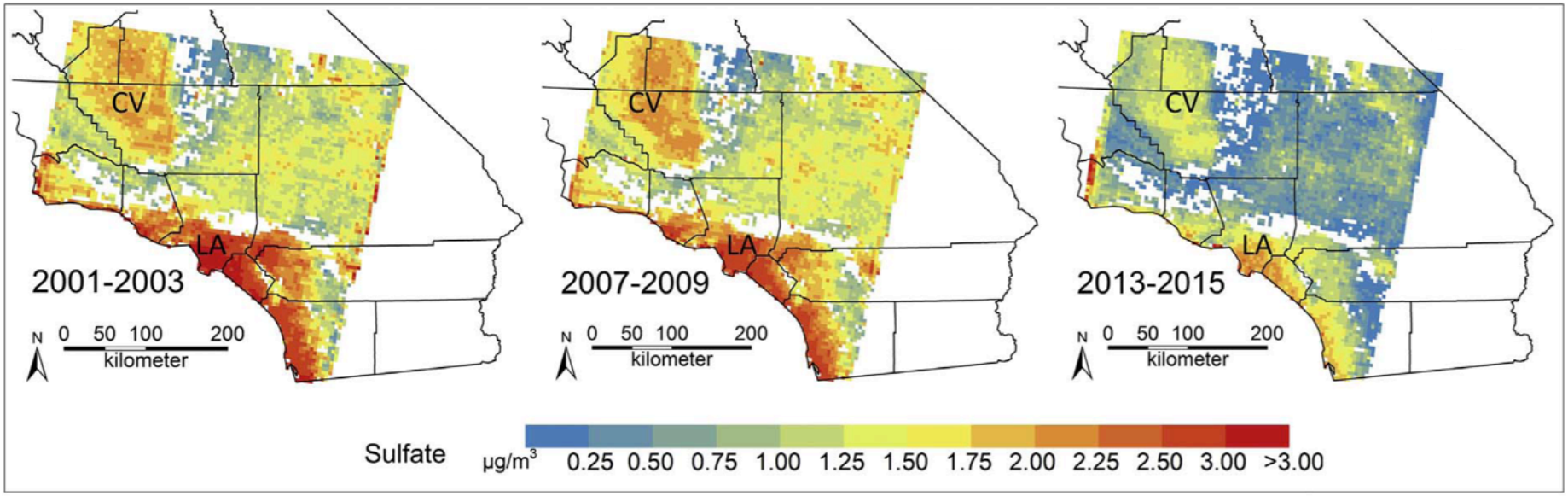
Surface PM monitors
Image credit: L. Tsutsui, KVPR



Regression parameters:

- AOD
- air temperature
- wind speed
- surface elevation
- length of major roads
- forest cover

Example:
Mapping of fine sulfate PM using MISR



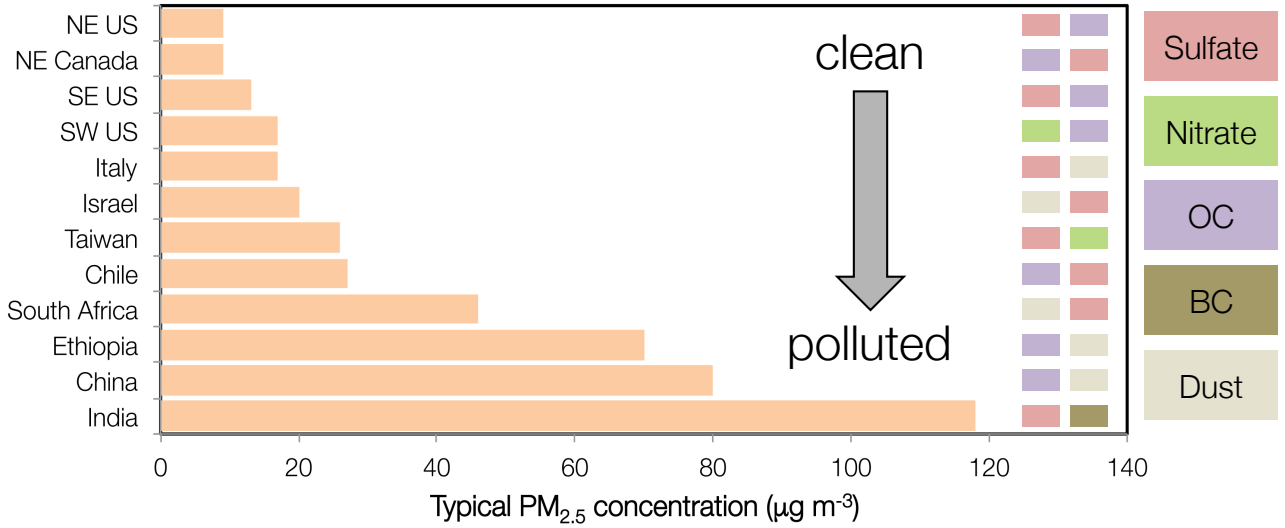
MAIA's extended spectral and polarimetric capabilities will further enhance sensitivity to particle type.

Meng et al. (2018)

MAIA investigation is target-based

- **Primary Target Areas (PTAs)** are regions chosen by the MAIA Science Team for conducting epidemiological studies.
- **Secondary Target Areas (STAs)** are regions designated for other aerosol and cloud science (air quality, climate, environmental impacts...).
- **Calibration/Validation Target Areas (CVTAs)** are areas observed routinely for instrument vicarious calibration and aerosol/PM validation.

Candidate PTAs cover a range of PM concentrations and types

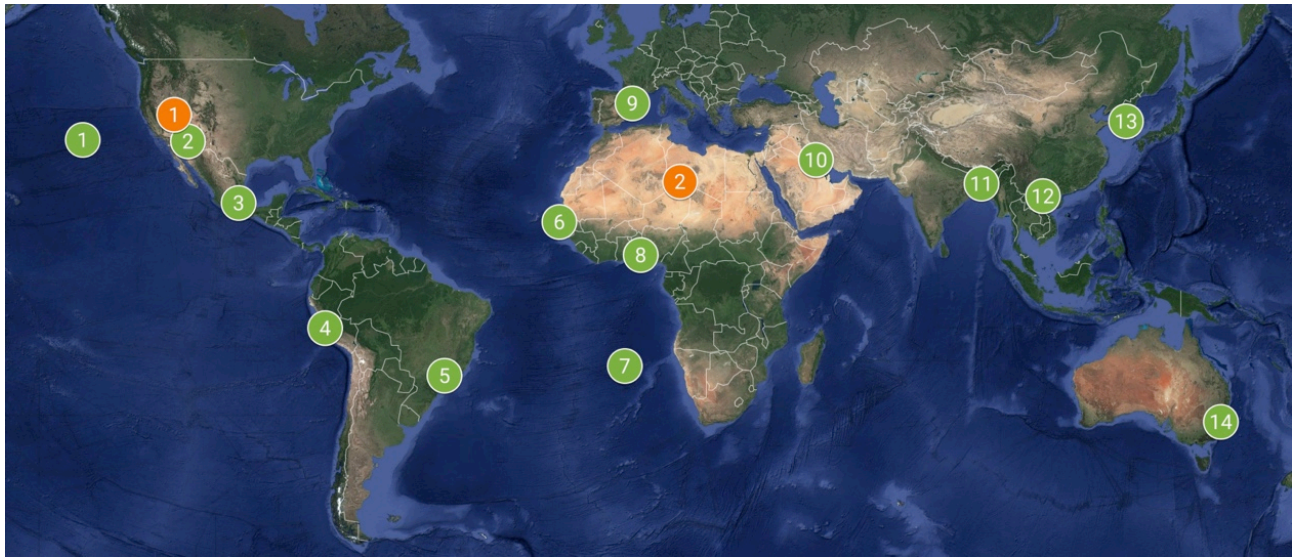


Prospective health investigations

Acute (days to weeks)	Subchronic (months)	Chronic (years)
Hospital visits, heart attacks, strokes, premature deaths	Adverse birth outcomes, pregnancy complications	Cardiovascular and respiratory diseases, cancer

PTA	Representative major cities	Acute	Subchronic	Chronic
NE US	Boston, Providence, Hartford, NYC			
NE Canada	Toronto, Hamilton			
SE US	Atlanta			
SW US	LA, Fresno, Bakersfield, Riverside			
Italy	Rome, Bologna			
Israel	Tel Aviv, Haifa, Jerusalem, Beer Sheba			
Taiwan	Taipei, Taichung, Tainan, Kaohsiung			
Chile	Santiago, Concepción			
South Africa	Johannesburg, Pretoria			
Ethiopia	Addis Ababa, Adama			
China	Beijing			
India	Delhi			

Candidate STAs and CVTAs



Secondary Target Areas

1. Cloud field
2. Arizona (Phoenix)
3. Mexico (Mexico City)
4. Peru (Lima)
5. Brazil (Sao Paulo)
6. Senegal (Dakar)
7. Cloud field
8. Nigeria (Lagos)
9. Spain (Barcelona)
10. Kuwait (Kuwait City)
11. Bangladesh (Dhaka)
12. Vietnam (Hanoi)
13. South Korea (Seoul)
14. Australia (Sydney)

Calibration/Validation Target Areas

1. Nevada (Railroad Valley)
2. Libya (desert site)

STAs include cities with major pollution, aerosol source regions, climatically important cloud regimes, and episodic events such as major wildfires or volcanic eruptions.

CVTAs are sites for radiometric, polarimetric, aerosol, or PM validation, and for instrument stability monitoring.

MAIA Science Team

Principal Investigator	
David Diner	JPL

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Kembra Howdeshell	NIH
John Langstaff	EPA
Pius Lee	NOAA
Fuyuen Yip	CDC

Summary

- MAIA is the first NASA satellite mission with applications/societal benefit as its primary objective.

- MAIA is targeted to fly on a commercial satellite in polar, sun-synchronous orbit (launch ~2021, 3 year mission).

- MAIA adopts capabilities, technologies, and data processing approaches from:
  - Satellite imaging spectroradiometers (MISR, MODIS, TOMS/OMI)
  - Airborne imaging polarimeters (AirMSPI)
  - Previous PM exposure and health assessment studies

- Epidemiologists on the MAIA team will conduct health impact investigations in the Primary Target Areas.

Thank you