

# Plans for integrating satellite aerosol data and surface measurements to map speciated PM<sub>2.5</sub> in Africa as part of NASA's Multi-Angle Imager for Aerosols (MAIA) investigation



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Workshop on a Pilot Design for  
Air Quality in Africa

# Motivation for MAIA

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Ambient airborne particulate matter (PM) is the top environmental health risk worldwide, but the relative toxicity of different **PM types**—mixtures of particles with different sizes, shapes, and compositions—is not well understood.



“A better understanding of [the] characteristics of particles that modulate toxicity could result in targeted control strategies that would specifically address [the] sources having the most significant effects on public health.”  
*(National Research Council, 2004)*

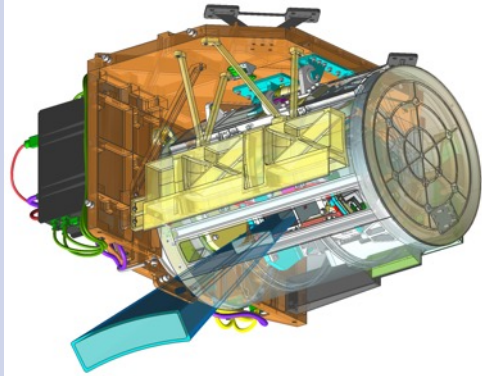
“Researchers must find the particles that are most dangerous to health...PM2.5 is a cocktail of chemicals...The mix – and its toxicity – varies...in ways that are not tracked, understood or managed.”  
*(Li et al., 2019)*



People perch on a high building to breathe the haze using their improvised Zhongguo, China, in January 2013.  
Air pollution: a global problem needs local fixes

# Key elements of the MAIA investigation

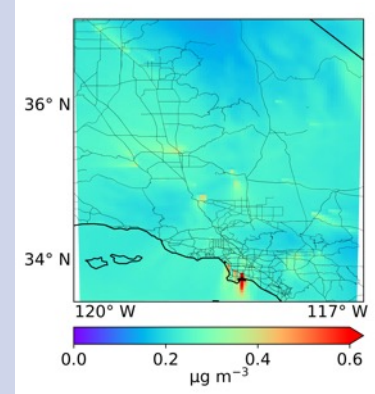
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Satellite instrument



Surface monitors



Chemical transport model



Health records

Public  
products



Privacy  
protected

24-hr averaged concentrations of  
 $\text{PM}_{10}$ ,  $\text{PM}_{2.5}$ , speciated  $\text{PM}_{2.5}$

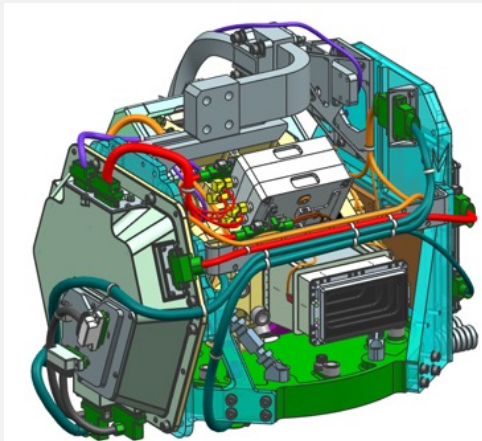
Epidemiological  
studies

Birth, death, and  
hospitalization data

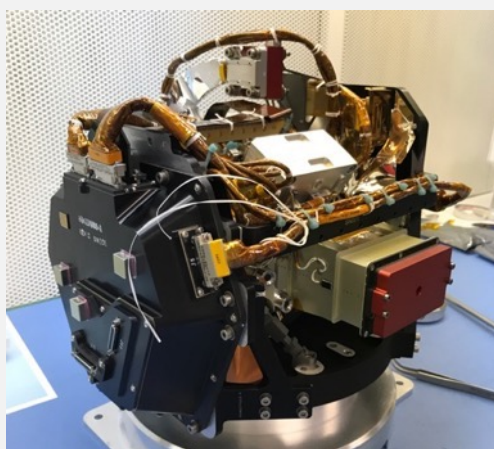
# MAIA instrumentation

The **satellite instrument** contains a 2-axis pointable multispectral polarimetric camera for retrieval of aerosol particle characteristics.

**Surface monitors** calibrate the transformation of satellite-derived aerosol information to near-surface total and speciated PM concentrations.



Camera CAD design



Camera as built

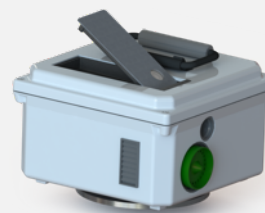
Instrument is undergoing assembly, test, and calibration at JPL



*SPARTAN*

Filter-based samplers

PM2.5 speciation



*AMOD*



*MicroAeth*

Aethalometers

Black carbon



*PurpleAir*

Low-cost sensors

Total PM2.5

aerosol absorption

fine particles

coarse particles/water vapor

Band (nm)	365	387	415	442*	550	645*	749	762.5	866	945	1040*	1610	1885	2125
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\*polarimetric bands

# PM product generation uses Geostatistical Regression Models (GRMs)

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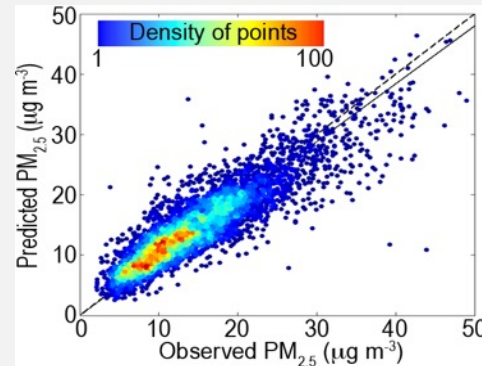
Surface monitor measurements calibrate the transformation from satellite aerosol parameters to total and speciated PM at 1 km resolution.

WRF-Chem model PM concentrations are also regressed against surface monitor data to generate bias-corrected model results.

Satellite and CTM-based maps are combined using Bayesian ensemble averaging.

Separate GRMs will be used for each PTA and PM species.

PM concentrations



$$\begin{aligned} &= \alpha \text{ (Spatiotemporal offsets)} \\ &+ \beta \times \text{Aerosol optical depth (L2) or CTM PM (L4)} \\ &+ \gamma \times \text{Geospatial predictors (elevation, urban density, population, green space)} \\ &+ \delta \times \text{Spatiotemporal predictors (e.g., meteorological variables, aerosol parameters, CTM PM)} \end{aligned}$$

# MAIA focuses on a discrete set of globally distributed target areas

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- Primary Target Areas (PTAs): Epidemiological studies (3-4 satellite observations/week)
- Secondary Target Areas (STAs): Air quality, aerosol and cloud climate studies
- Calibration/Validation Target Areas (CVTAs)



from  
*Li et al.*  
(2017)



PM<sub>2.5</sub> species to be mapped by MAIA

# Surface monitor deployments in Africa and planned health studies summary

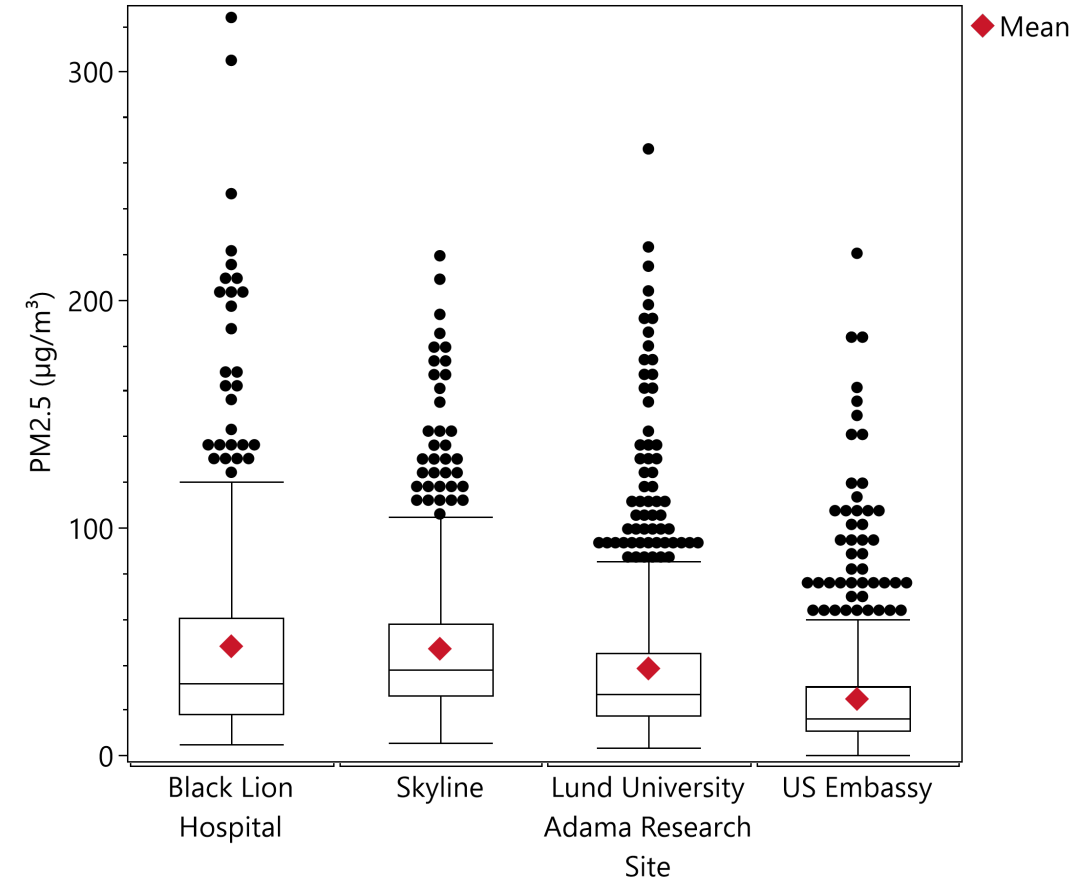
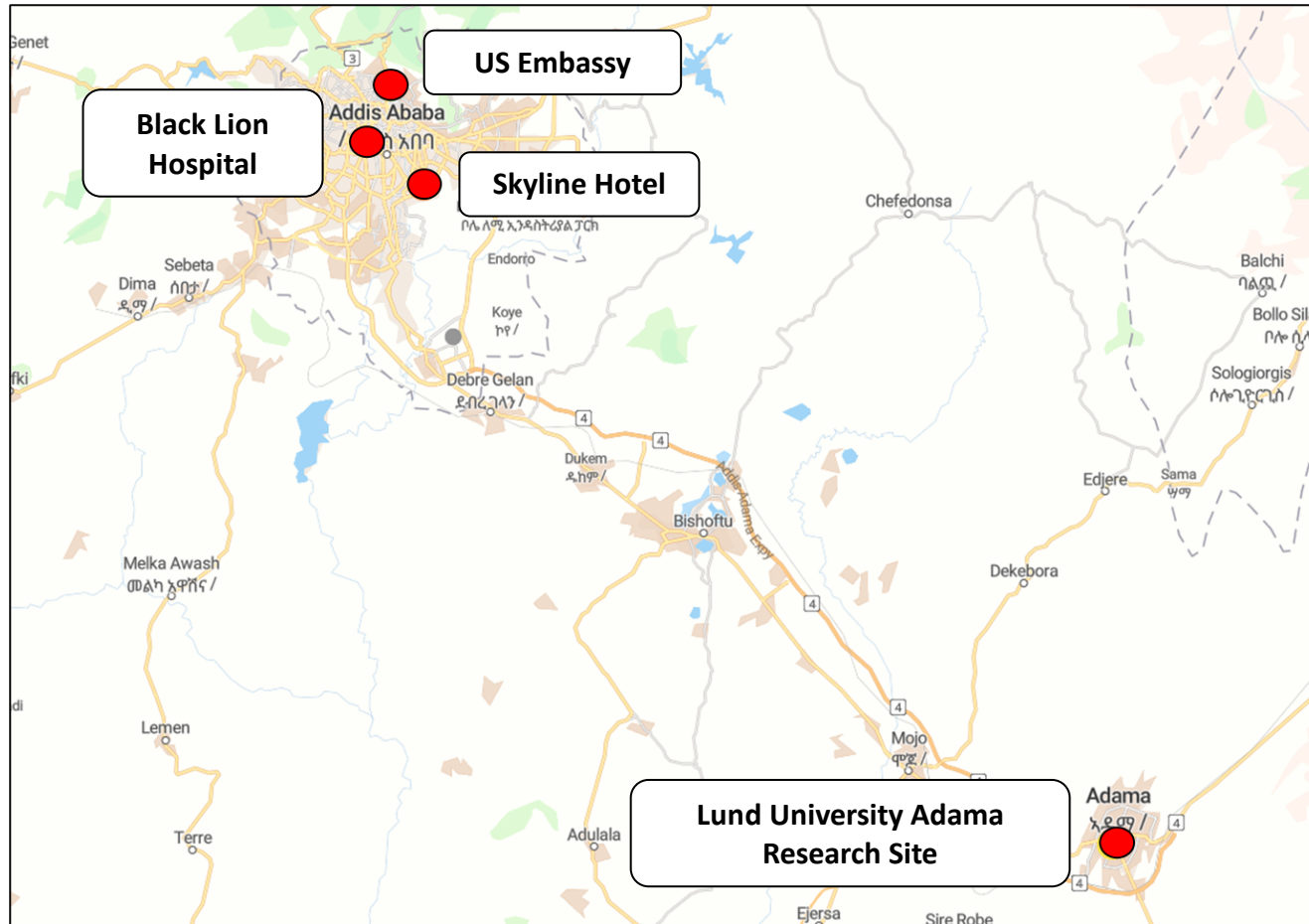
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PTA	Location	SPARTAN	AMOD	Aethalometer	BAM	PurpleAir	AERONET	Health outcomes to be studied
ETH-AddisAbaba	US Embassy, Addis Ababa			Operating	Operating	Operating		Preeclampsia, birth outcomes, childhood mortality/morbidity
	Black Lion Hospital	Overseas delivery in preparation		Temporary siting for calibration	Operating	Operating	Operating	
	Lund University Research Station, Adama		Overseas delivery in preparation			Operating		
	Skyline Hotel					Operating		
	ALERT Hospital/AHRI		Overseas delivery in preparation			Local delivery or installation in process		Respiratory disease, cognition
	Environ. Protection and Green Devel. Comm.			Operating		Local delivery or installation in process		
	International Community School				Operating	Local delivery or installation in process		
	UNICEF/UNECA					Local delivery or installation in process		
Other PurpleAir sites					Local delivery or installation in process			
ZAF-Johannesburg	CSIR, Pretoria	Operating					Operating	Cause-specific mortality
	University of Johannesburg	Overseas delivery in preparation						
	South African Weather Service, Irene		Overseas delivery in preparation					

Overseas delivery in preparation
Local delivery or installation in process
Operating
Temporary siting for calibration

Acute effects (days/weeks)
Subchronic effects (months)
Chronic effects (years)

# PurpleAir PM2.5 data in Ethiopia (Feb – May 2021)



Credits: Araya Asfaw, Sina Hasheminassab



# Africa Primary Target Area partnerships

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Country	Principal cities	MAIA Lead Co-Is	Partnerships for surface monitor operations and epidemiology	Partners
Ethiopia	Addis Ababa, Adama	Beate Ritz, Michael Jerrett (UCLA)	<ul style="list-style-type: none"><li>• Addis Ababa University/Ethiopian Wildlife and Natural History Society</li><li>• Lund University</li></ul>	Araya Asfaw Christina Isaxon Ebba Malmqvist
South Africa	Johannesburg, Benoni, Pretoria	Michael Brauer (UBC)	<ul style="list-style-type: none"><li>• Council for Scientific &amp; Industrial Research</li><li>• University of Johannesburg</li><li>• South African Weather Service</li><li>• University of Pretoria</li></ul>	Rebecca Garland Kristy Langerman Lotta Mayana Janine Wichmann



Through interagency agreement with NASA, USAID is supporting MAIA surface monitor deployments, chemical analyses, and capacity building in Ethiopia and South Africa.

# Concluding remarks

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

Baseline flight mission duration = 3 years (2023-2025).

A network of surface monitors is a critical element of the strategy to generate PM maps.

MAIA data processing and product archiving will take place at the NASA Atmospheric Science Data Center. Data products will be publicly available, free of charge.

Epidemiologists on the MAIA team and their collaborators in the PTAs will conduct health investigations.



<https://maia.jpl.nasa.gov>