Multi-Angle Imager for Aerosols

Project update

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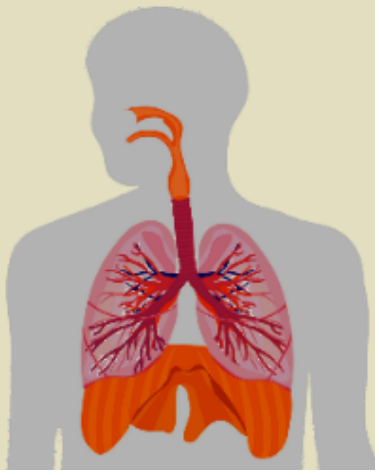
Background and motivation for MAIA

MAIA is part of NASA's Earth Venture Instrument Program.



Airborne particulate matter (PM) has been associated with

- premature deaths (> 4 million globally per year)
- cardiovascular and respiratory disease
- pregnancy complications and low birth weight
- lung cancer
- many other adverse health outcomes

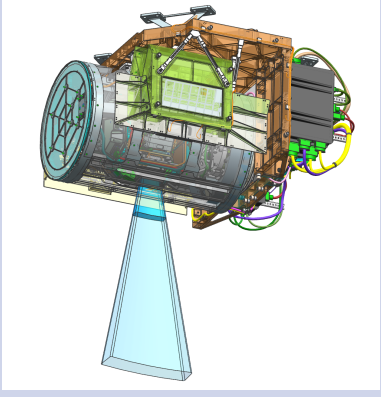


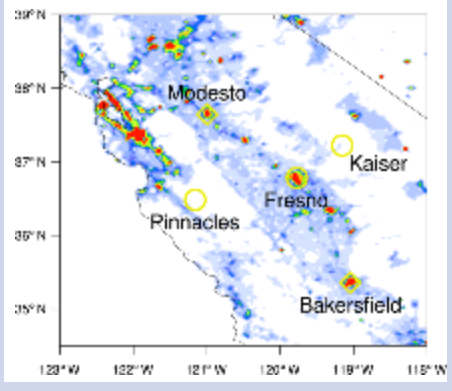



While PM is a known health risk, the relative toxicity of different **PM types**—mixtures of particles with different sizes, shapes, and compositions—is not well understood.

Elements of the MAIA investigation

MAIA's primary objective is to link exposure to different types of PM (mixtures of sulfate, nitrate, organic carbon, elemental carbon, dust) with human health.





Satellite instrument

- Provides image data used in retrieval of column-integrated aerosol properties.

Surface PM monitors

- Calibrate the column aerosol-to-near surface PM relationships.

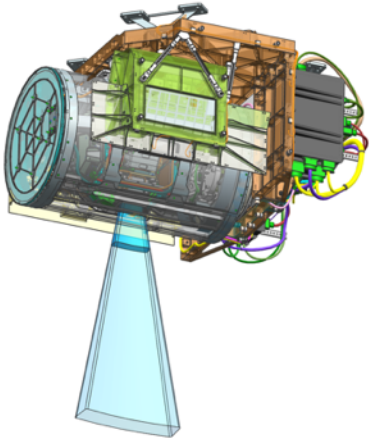
Chemical transport model (CTM)

- Provides meteorological data and spatial/temporal gap-filling.

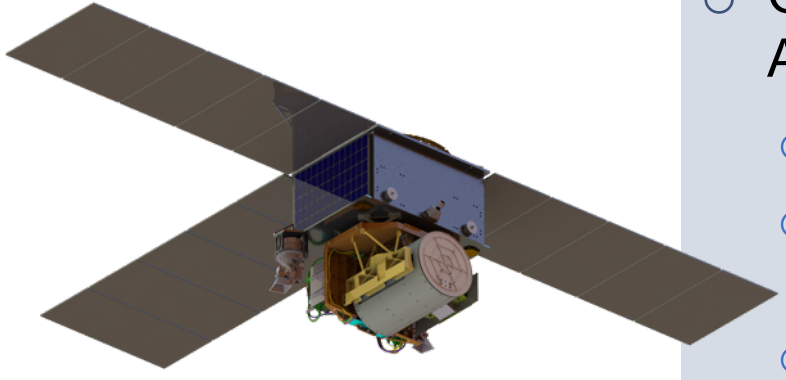
Health records

- Used to associate PM exposure with health effects.

Instrument and spacecraft



- MAIA Instrument (JPL)
  - Flight Instrument Electronics, Detector, and Structure have been delivered
  - Camera and Camera Electronics are in final assembly and preparing for test
  - Flight Bi-axial Gimbal Assembly is in assembly
  - Camera Calibration and Instrument Integration & Test activities are planned



- Orbital Test Bed-2 spacecraft (General Atomics)
  - May - Oct 2022 launch (to be confirmed)
  - 740 km altitude, sun-synchronous orbit with 10:30 am equator crossing time
  - 3 year baseline mission duration

MAIA provides multiangle, multispectral, polarimetric observations

aerosol absorption

Band (nm)	365	387	415	442*

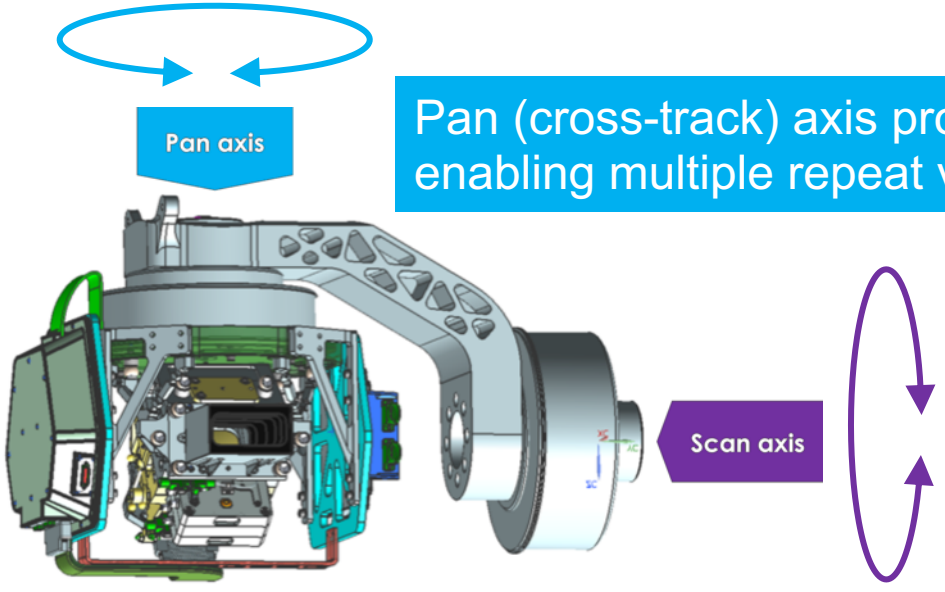
*polarimetric bands

fine particles

Band (nm)	550	645*	749	762.5	866

coarse particles

Band (nm)	945	1040*	1610	1885	2125



Pan (cross-track) axis provides ±45° field of regard enabling multiple repeat visits of each target per week

Scan (along-track) axis enables multiangle imagery (±60° at instrument) in “step and stare” and “sweep” modes

Retrieved aerosol properties

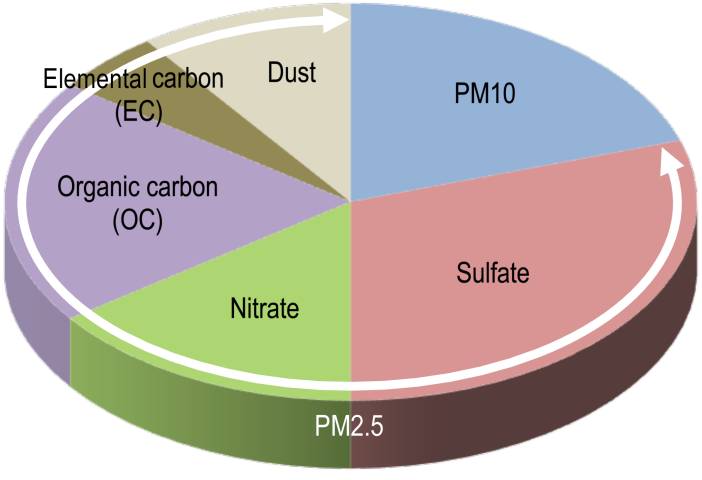
L2 Aerosol parameter	Comment
Total aerosol optical depth (AOD)	At 365, 387, 415, 442, 550, 645, 749, 866, 1040, 1610 nm
Absorbing/nonabsorbing AOD	"
Spherical/nonspherical AOD	"
Phase function asymmetry parameter	"
AOD for each of two lognormal aerosol size modes	"
Real and imaginary refractive indices for two aerosol modes	"
Characteristic radius, logarithmic characteristic width, effective radius, effective variance for two aerosol modes	
Aerosol height parameters	

Aerosol and surface parameters are retrieved using a Markov chain/adding-doubling radiative transfer code and optimal estimation *(Xu et al., 2016, 2017)*

MAIA data products

Level	Description	Spatial/temporal grid
1	Calibrated, Earth-projected radiance and linear polarization imagery	250 m/overpass days
2	Cloud-screened aerosol properties	1 km/overpass days
	24-hr averaged concentrations of PM10, PM2.5, and speciated PM2.5	1 km/overpass days
4	Gap-filled total and speciated PM	1 km/daily

To be archived and distributed at the NASA Atmospheric Science Data Center



Health records are privacy protected, not publicly distributed by NASA

MAIA will observe a discrete set of globally distributed target areas

- Primary Target Areas (PTAs): Locations identified for project epidemiological studies (3 – 4 revisits/week)
- Secondary Target Areas (STAs): Support other air quality, aerosol and cloud climate studies (1 – 3 revisits/week)
- Calibration/Validation Target Areas (CVTAs): Provide vicarious calibration and instrument stability monitoring (3 – 4 revisits/season)

Primary Target Areas

- USA-LosAngeles
- USA-Atlanta
- USA-Boston
- ESP-Barcelona
- ITA-Rome
- ZAF-Johannesburg
- ISR-TelAviv
- ETH-AddisAbaba
- IND-Delhi
- CHN-Beijing
- TWN-Taipei
- KOR-Seoul

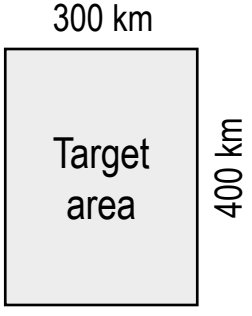
Secondary Target Areas

- USA-Hilo
- PAC-OceanStCu
- USA-SanFrancisco
- USA-Phoenix
- USA-Denver
- MEX-MexicoCity
- CAN-Toronto
- PER-Lima
- CHL-Santiago
- BRA-SãoPaulo
- SEN-Dakar
- GHA-Accra
- ATL-OceanStCu
- NGA-Lagos
- ZAF-CapeTown
- SRB-Belgrade
- KEN-Nairobi
- ETH-Harar
- KWT-KuwaitCity
- IND-Chennai
- BGD-Dhaka
- THA-Bangkok
- VNM-Hanoi
- MNG-Ulaanbaatar
- AUS-Sydney

As of May 2020; subject to updates

Calibration/Validation Target Areas

- USA-RailroadValley
- LBY-Libya4
- NAM-Gobabeb



Primary Target Areas (PTAs)

- Primary Target Areas (PTAs) have been chosen by the MAIA Science Team for conducting and supporting epidemiological studies
  - List includes 12 sites, based on science value to MAIA, surface monitoring, weekly revisit frequency, health data access, cloud cover

Country	Major cities	Long name	Short name
United States	Los Angeles	UnitedStates_SouthernCalifornia	USA-LosAngeles
United States	Atlanta	UnitedStates_CentralGeorgia	USA-Atlanta
United States	Boston	UnitedStates_NewEngland	USA-Boston
Spain	Barcelona	Spain_Catalonia	ESP-Barcelona
Italy	Rome, Bologna	Italy_Central	ITA-Rome
South Africa	Pretoria, Johannesburg	SouthAfrica_Gauteng	ZAF-Johannesburg
Israel	Tel Aviv, Haifa	Israel_CentralNorthern	ISR-TelAviv
Ethiopia	Addis Ababa	Ethiopia_Central	ETH-AddisAbaba
India	Delhi	India_Northern	IND-Delhi
China	Beijing	China_Northern	CHN-Beijing
Taiwan	Taipei, Kaohsiung	Taiwan_Western	TWN-Taipei
South Korea	Seoul	SouthKorea_Central	KOR-Seoul

The “other” MAIA instrument: Network of surface PM monitors

“Integration of satellite-based estimates with reliable ground-based measurements is…necessary to…provide an enhanced understanding of local and regional air quality.” — *UNICEF, 2019*

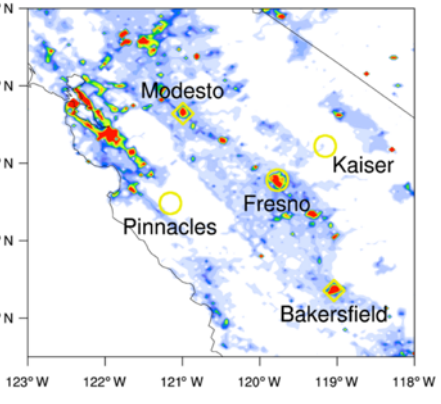
Equipment to be deployed





SPARTAN	AMOD v.2.0	Aethalometer	Low-cost sensor	AERONET
AirPhoton	CSU	AethLabs	PurpleAir	CIMEL
PM2.5 speciation	PM2.5 speciation	Black carbon	PM2.5	Aerosol properties

Integration of satellite, surface monitor, and Chemical Transport Model (CTM) data



WRF-Chem CTM
(4 km x 4 km grid)

- Surface monitors are used to calibrate the Geostatistical Regression Models (GRMs) that transform retrieved aerosol properties to near-surface PM concentrations
  - Geospatial datasets and data from the CTM (GEOS-FP/MERRA-2 + WRF-Chem) are also used in the GRMs
  - The calibrated GRMs are applied to MAIA aerosol parameters to map PM at 1 km spatial resolution
- Where satellite aerosol data are missing (clouds, no-overpass days), separate GRMs correct biases in CTM-based PM concentrations
  - These results are merged with the satellite-based PM to generate daily gap-filled PM maps

Geostatistical Regression Models (GRMs)

Level 2: Regressions of MAIA aerosol properties against surface monitor measurements calibrate the transformation from aerosol parameters to PM

Level 4: Regressions of CTM PM estimates against surface monitor data correct for model biases

PM concentrations

Training: surface measurements
Mapping: estimates from the calibrated data model

Level 2 and Level 4 PM maps are combined using Bayesian ensemble averaging.

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

$=$ α (Spatiotemporal offsets)

$+$ β x Aerosol optical depth (L2) or CTM PM (L4)

$+$ γ x Geospatial predictors (elevation, urban density, population, green space)

$+$ δ x Spatiotemporal predictors (e.g., meteorological variables, aerosol parameters, CTM PM)

Planned health investigations

PTA	Acute effects (days/weeks)	Subchronic effects (months)	Chronic effects (years)
Southern Calif.		Birth outcomes	Cause-specific mortality
Georgia	Respiratory morbidity		
New England	Mortality, heart attack, stroke, pneumonia	Birth outcomes	Mortality, heart attack, stroke, pneumonia
Spain			Mortality, primary care outcomes physical/mental health outcomes
Italy	Cause-specific mortality, hospital admissions		Cause-specific mortality, hospital admissions
South Africa	Cause-specific mortality		
Israel	Mortality, heart attack, stroke, pneumonia	Birth outcomes	Mortality, heart attack, stroke, pneumonia
Ethiopia		Preeclampsia, birth outcomes, childhood mortality/morbidity	Respiratory disease, cognition
India	Mortality, cardiovascular/ respiratory disease		Cardiovascular biomarkers
China	Cardiovascular disease		
Taiwan		Pregnancy complications, birth outcomes	COPD, heart disease
South Korea	Neurological disorders	Birth outcomes	Cardiovascular mortality

Secondary Target Areas (STAs)

- Secondary Target Areas (STAs) include cities with major PM pollution, aerosol source regions, climatically important cloud regimes, or other locations of scientific interest
  - Observations and data processing use instrument storage capacity and spacecraft downlink bandwidth on as-available basis
  - List includes 25 sites, based on inputs from the Science Team, domestic and international collaborators, university researchers, and other stakeholders
  - Development of ancillary datasets and access to external inputs to support STA data processing will be addressed after surface monitoring and software infrastructure for the PTAs have been fully implemented and tested
  - Community engagement is important for maximizing the utility of these targets

MAIA Science Team

Principal Investigator	
David Diner	JPL

Co-Investigators: Instrument Characterization	
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Gerard van Harten	JPL
Veljko Jovanovic	JPL

Co-Investigators: Aerosol Remote Sensing, Modeling, Validation	
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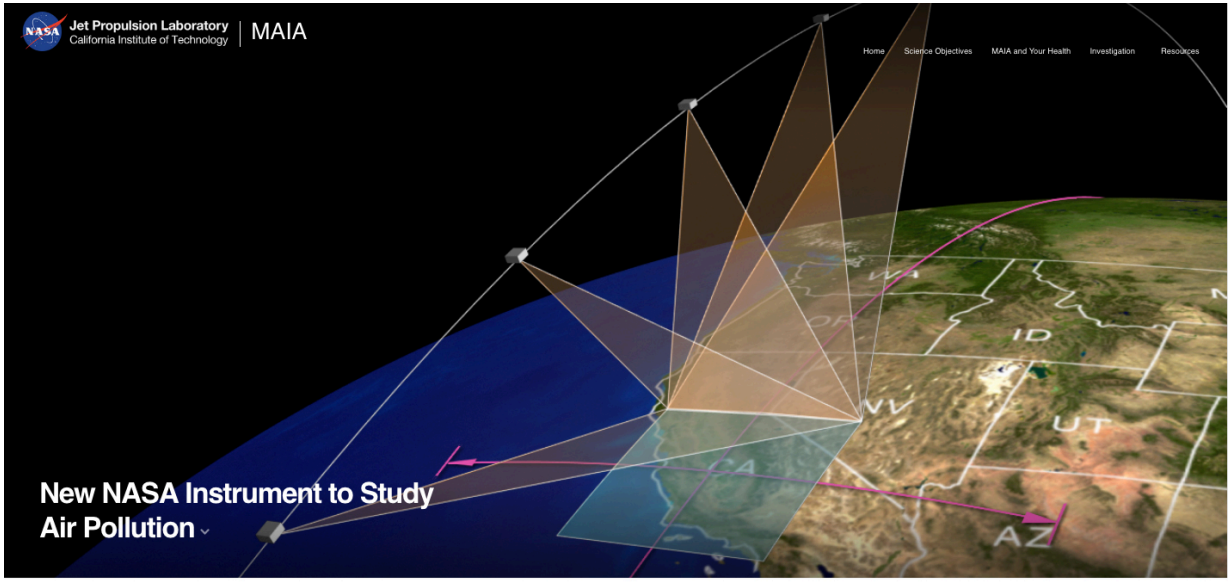
Pius Lee	NOAA
Katherine Swanson	USAID
Fuyuen Yip	CDC

For more information
https://maia.jpl.nasa.gov



The Multi-Angle Imager for Aerosols (MAIA) represents the first time NASA has partnered with epidemiologists and health organizations to use space-based data to study human health and improve lives.

What is MAIA?

The Multi-Angle Imager for Aerosols (MAIA) investigation will seek to understand how different types of air pollution affect human health.

SCIENCE OBJECTIVES

MAIA and Your Health

Air pollution can cause serious health problems such as heart disease, lung disease, and stroke. Find out more about what is known.

AEROSOLS AND HEALTH

The MAIA Investigation

A state-of-the-art satellite instrument producing data that will be used in health studies to examine the health effects of various types of air pollution.

MISSION

News

NASA Awards Contract for Earth Science Mission Hosting Services

New NASA Instrument to Study Air Pollution