Space-borne and airborne characterization of speciated particulate matter (science of MAIA)

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California Institute of Technology

MISR and MODIS based $PM_{2.5}$

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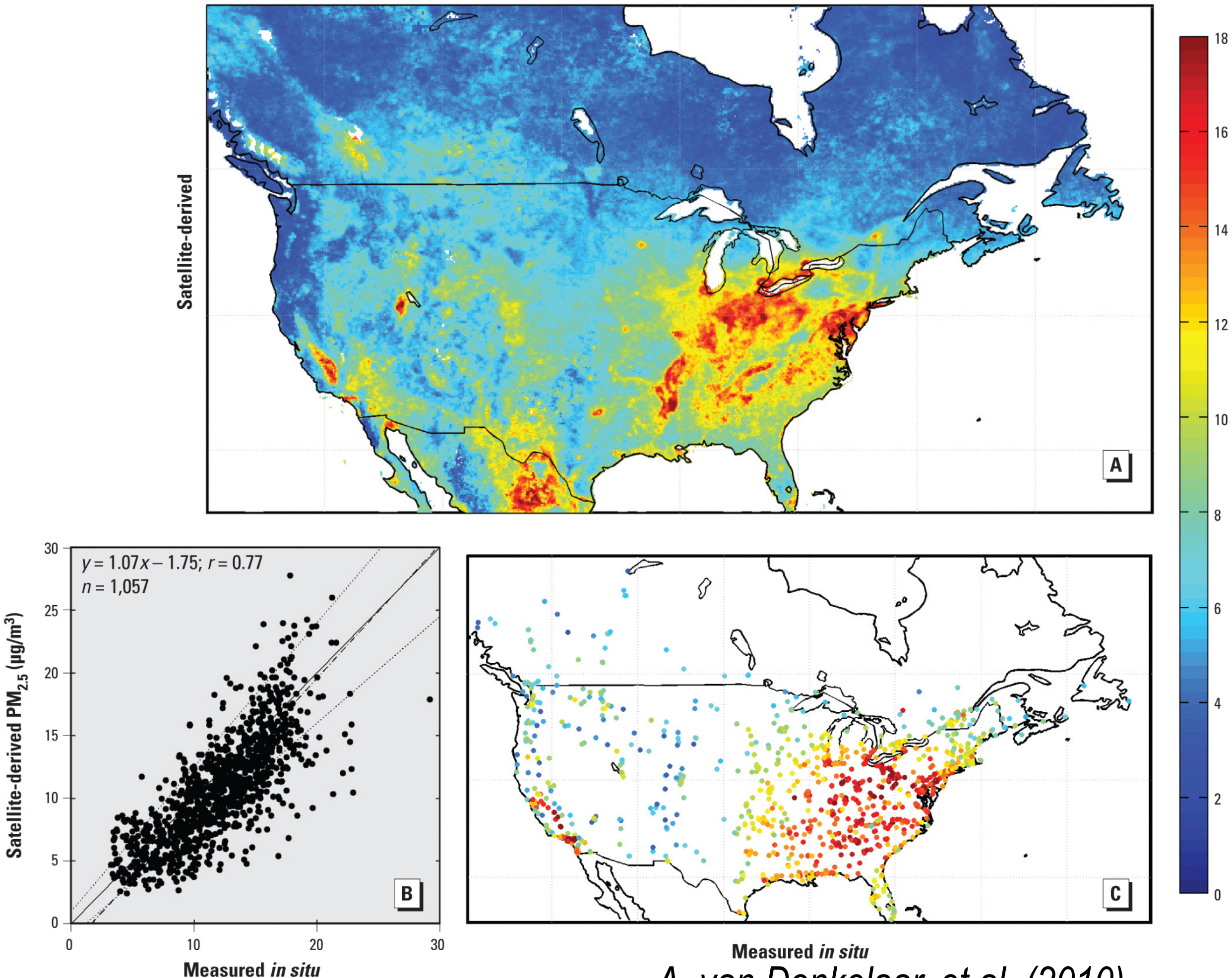
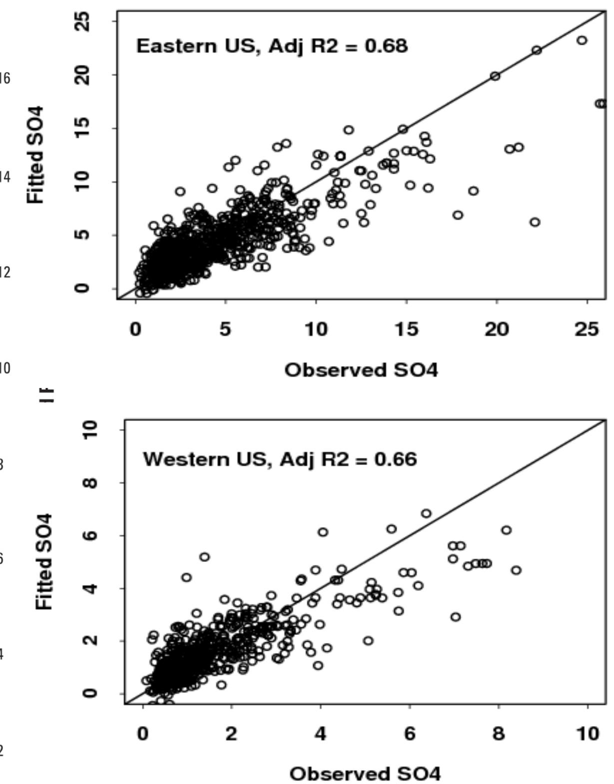


A. van Donkelaar, et al. (2010).



Liu et al. (2009)

Inclusion of MISR data improved $PM_{2.5}$ and sulfate PM predictions in the Western US

MISR-derived 4km resolution speciated PM in the greater Los Angeles area

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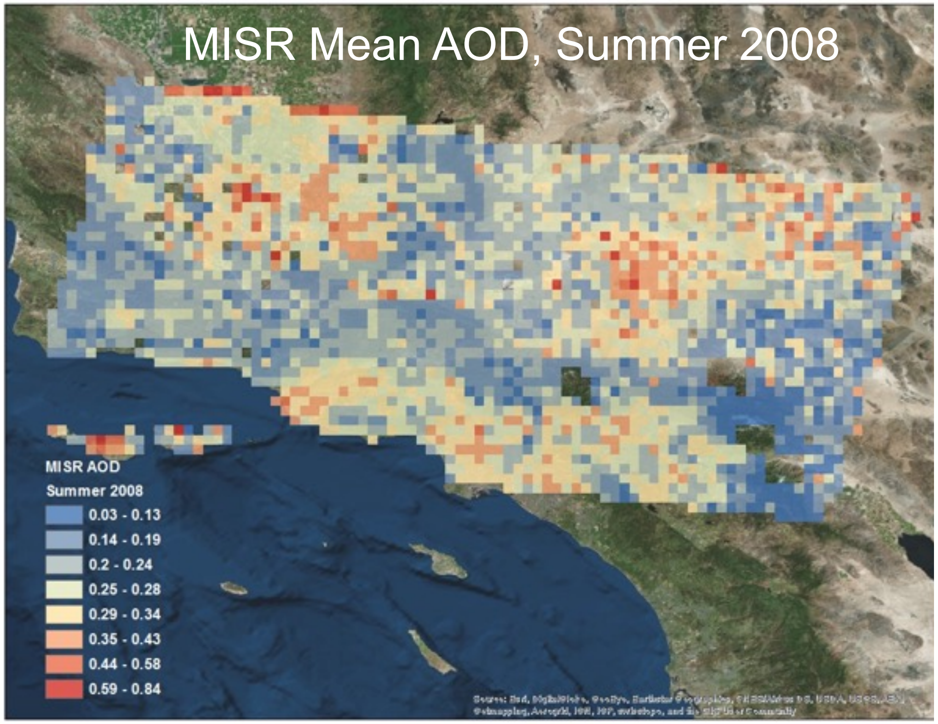

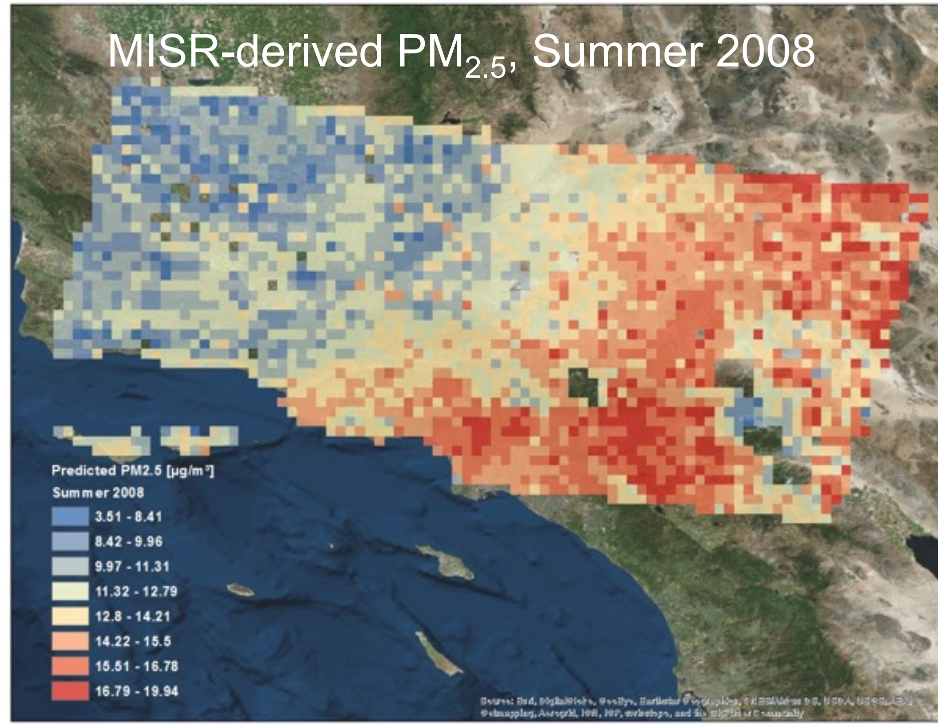

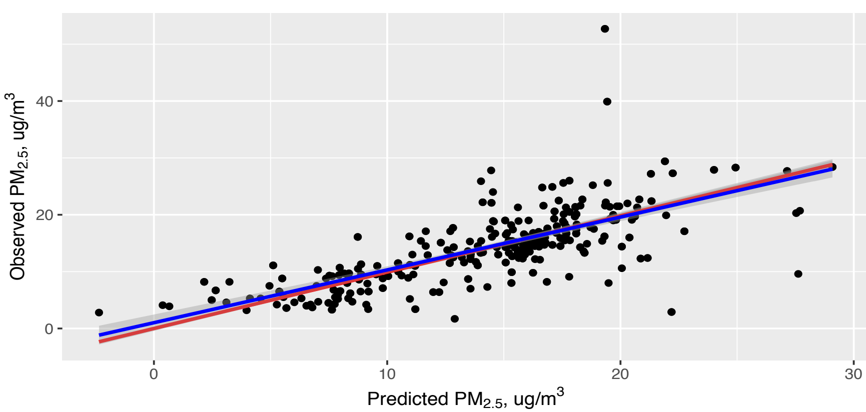

MISR AOD 4.4 km product combined with surface air pollution and meteorological measurements over Southern California were used to build spatio-temporal statistical models to reliably ‘convert’ AOD to PM concentrations of various sizes and types in LA area.

Franklin et al., RSE, in review.

MAIA Science Objective

PI: David Diner

MAIA

- **MAIA's primary science objective is to associate *specific types* of airborne particulate matter (PM) with adverse health outcomes**
- Observations of major cities on five continents will provide large sample sizes to conduct statistically robust epidemiological studies
- Secondary targets will also be observed to enable other types of aerosol and cloud investigations

MAIA Science Implementation

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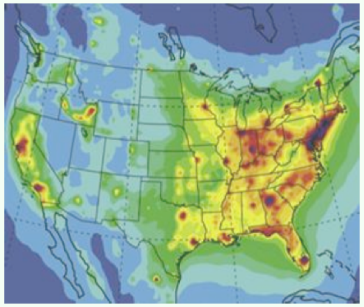
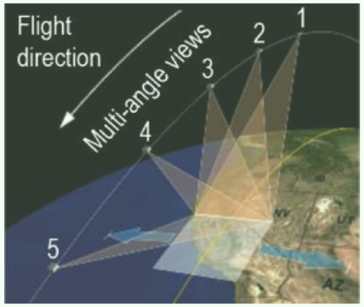
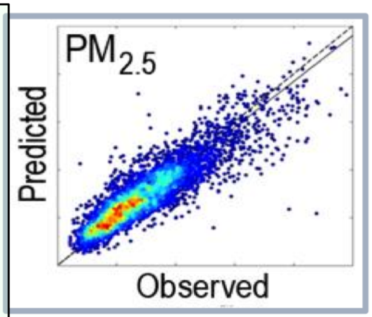
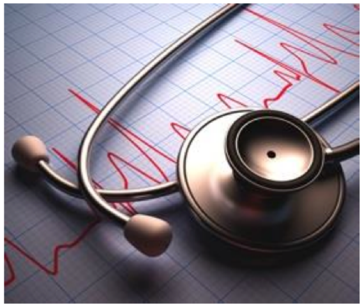
How are we measuring and what will we do with the data?

MAIA's spaceborne observations of PM concentrations in major cities around the globe wield enormous statistical power for associating PM exposure and disease.









A state-of-the-art chemical transport model (CTM) provides initial estimates of the abundances of different aerosol types, along with their vertical distributions.

\+

The MAIA instrument uses the proven power of multi-angle and multispectral radiometry and polarimetry to eliminate CTM biases and retrieve fractional aerosol optical depths of different particle types.

\+

Geostatistical models (GSMs) derived from collocated surface and MAIA measurements relate these fractional aerosol optical depths to near-surface concentrations of major PM constituents.

\+

Geocoded birth, death, and hospital records and established epidemiological methodologies are used to associate PM exposure with adverse health outcomes.

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The MAIA investigation addresses NASA's EVI-3 goal of using observations from space and interdisciplinary Earth science research to benefit society.

Model-constrained retrievals

WRF-Chem AOD biases

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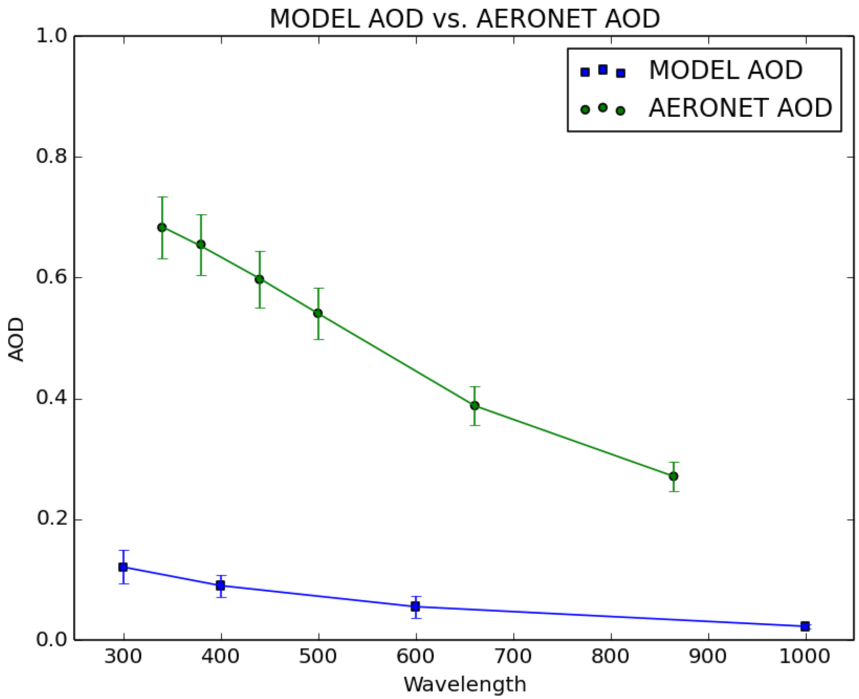

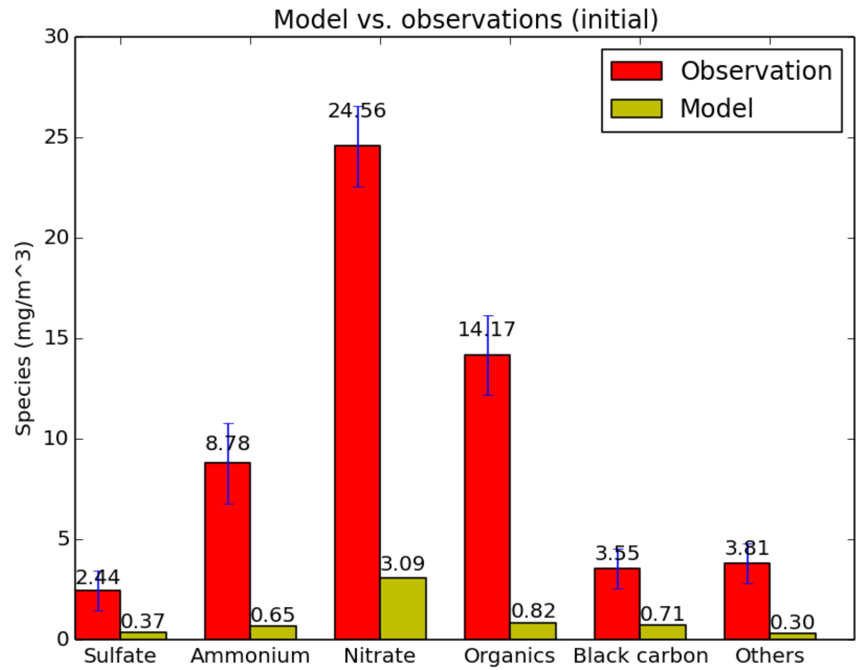

Large uncertainties currently exist in WRF-Chem (and other chemical transport model) estimates of the concentration the various aerosol species (e.g., black carbon, sulfate, dust, etc.).

AOD adjustment approach

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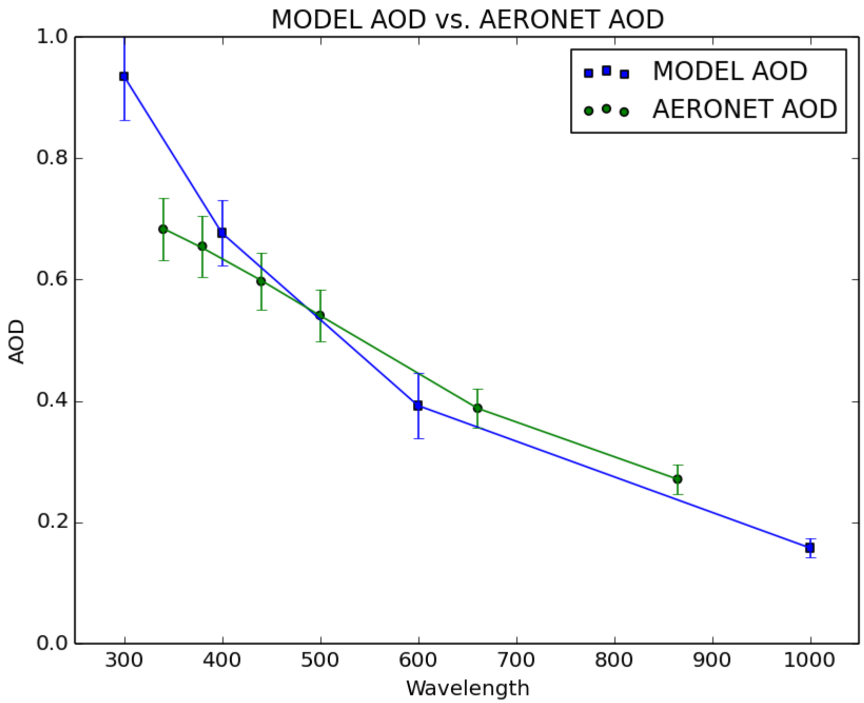
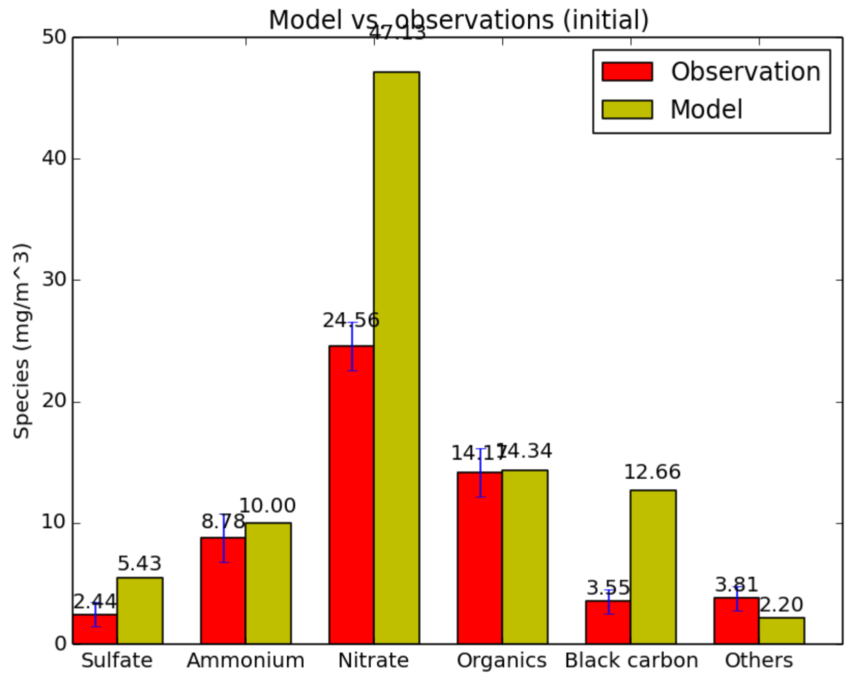
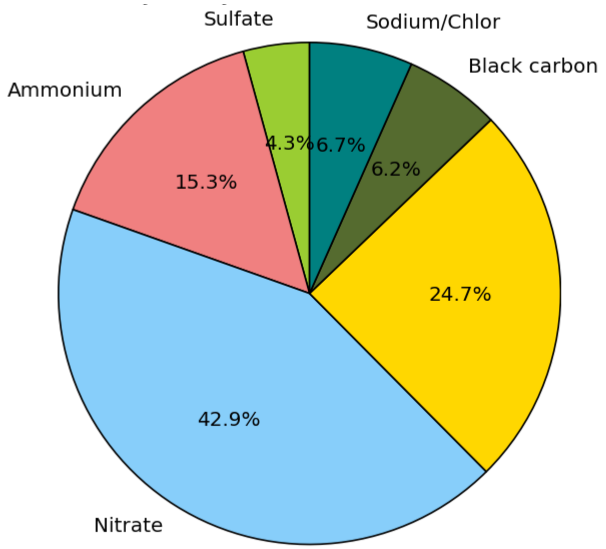




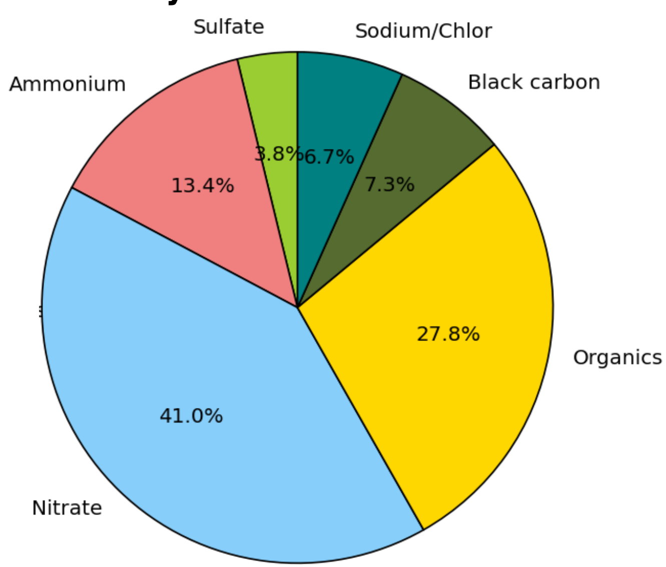
Simple AOD 500nm adjustment while improving $PM_{2.5}$ predictions still bias by ~50% for selected aerosol species

WRF-Chem aerosol species fractions

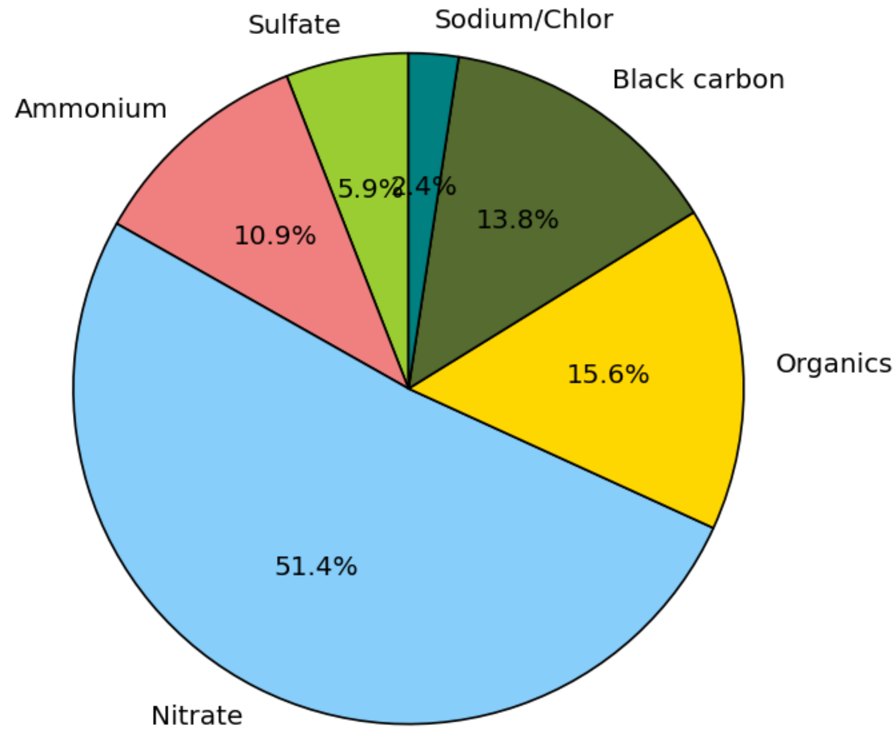
January 1 – surface Network data



January 7 – surface Network data

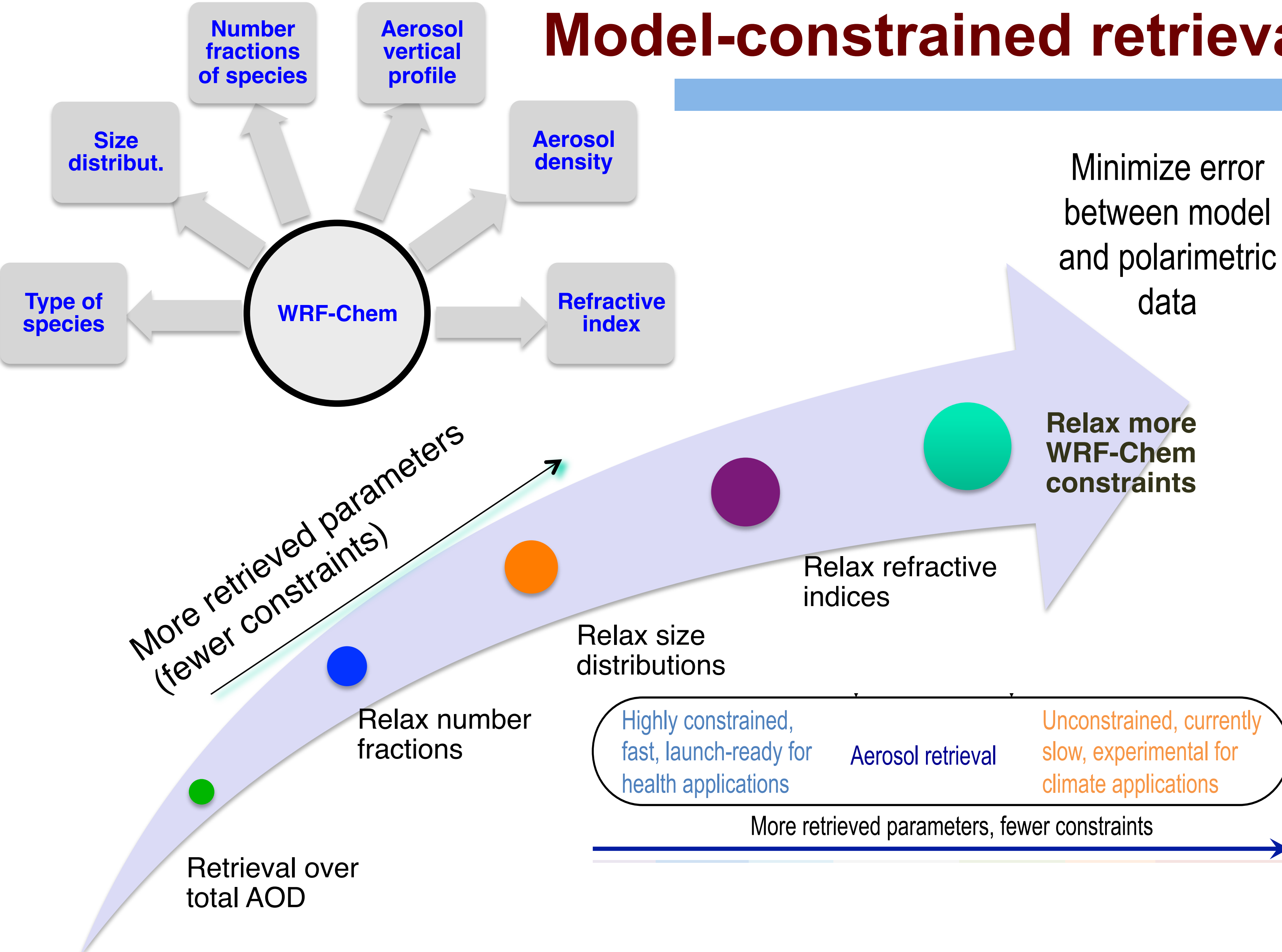


January 6 – WRF-Chem speciation

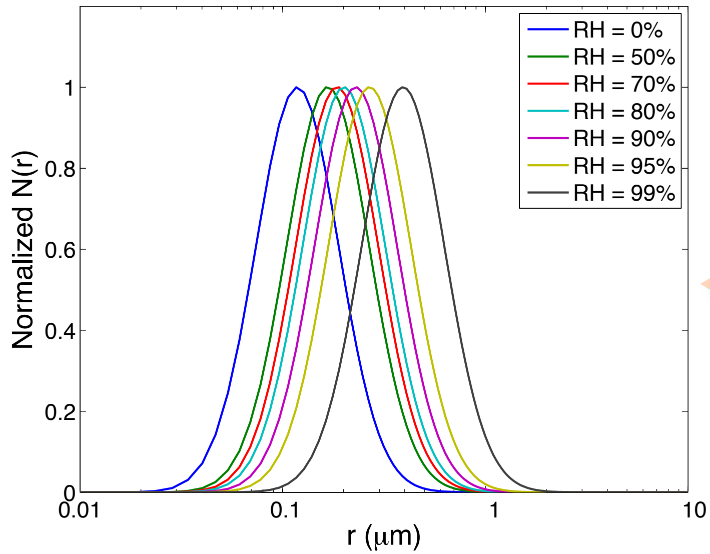


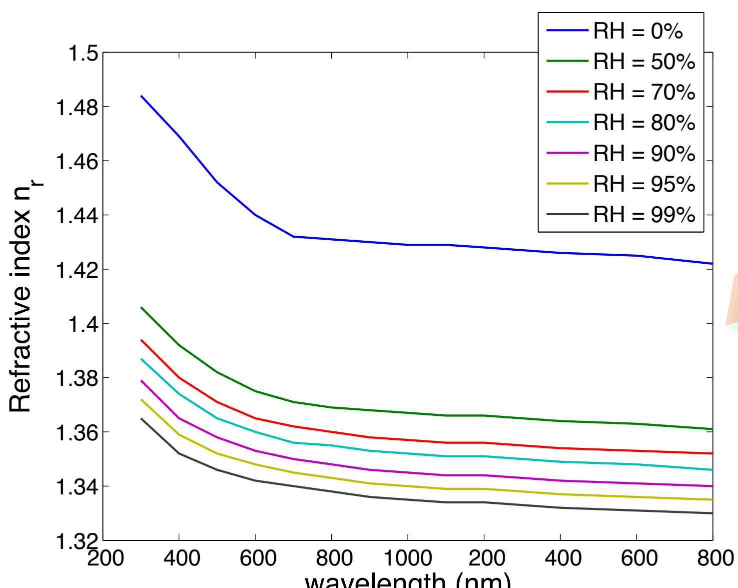
Chemical Transport models (CTM) do well in predicting the types of aerosols present at a given location and time

Model-constrained retrieval

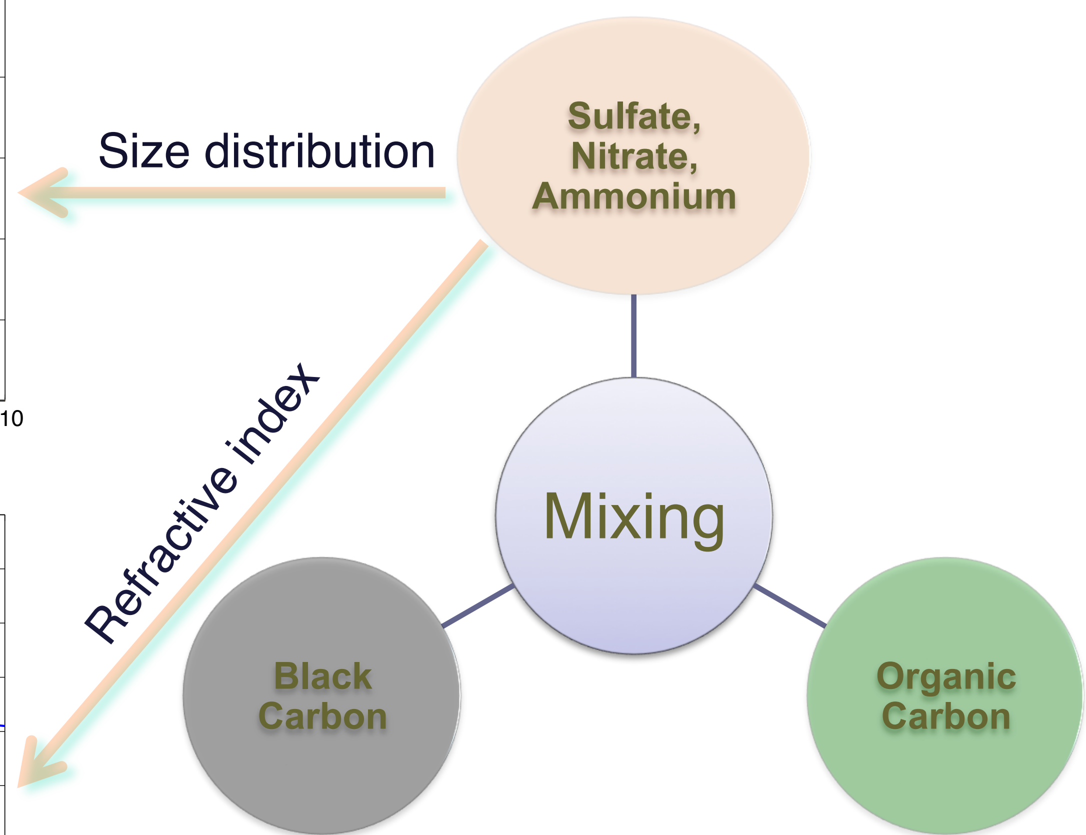


MAIA approach: Optical properties



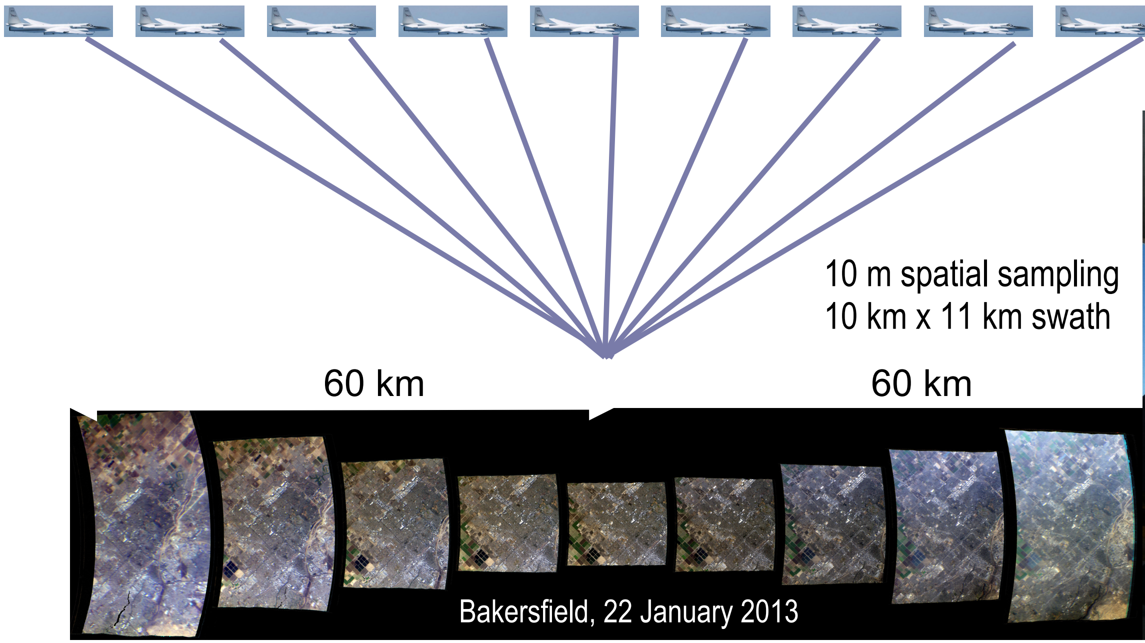


Aerosol species



MAIA Retrieval Implementation

AirMSPI Aerosol Retrieval: from column to species properties

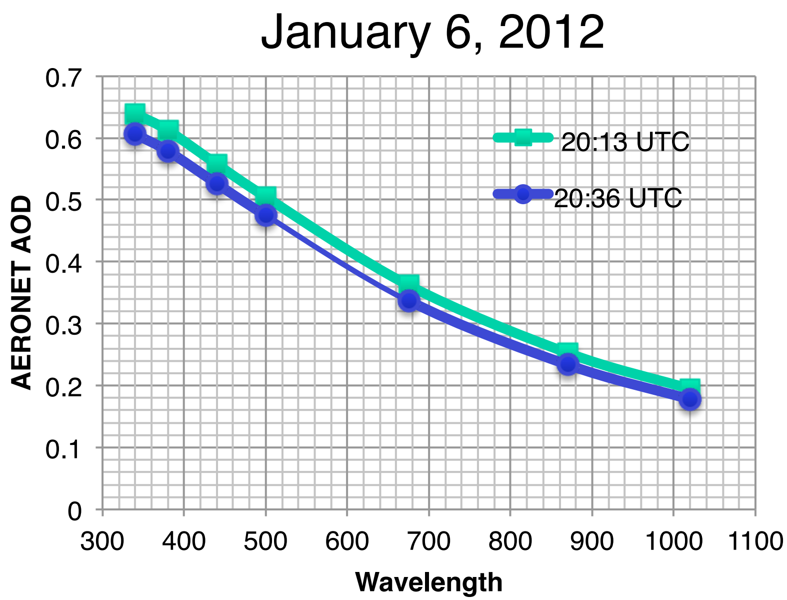


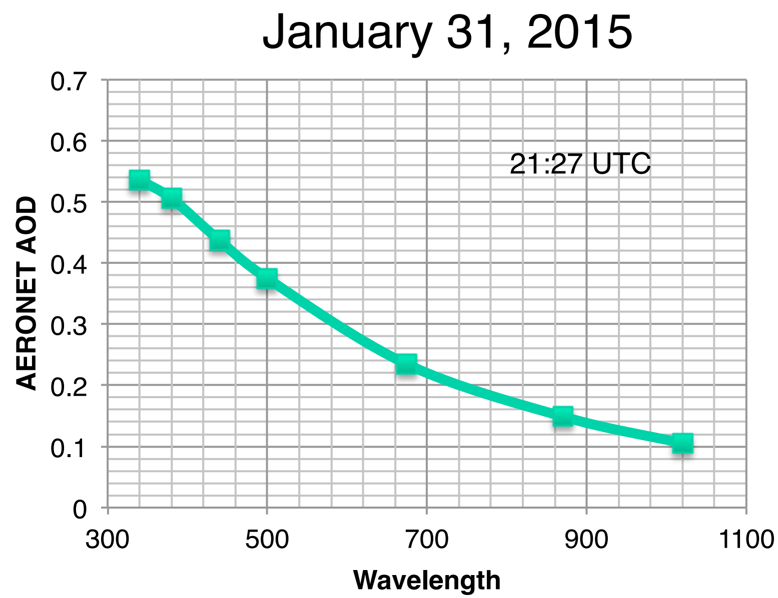
Demonstrate that multiangular polarimetric observations combined with WRF-Chem high-resolution model are a promising tool for retrieving $PM_{2.5}$ by particle type

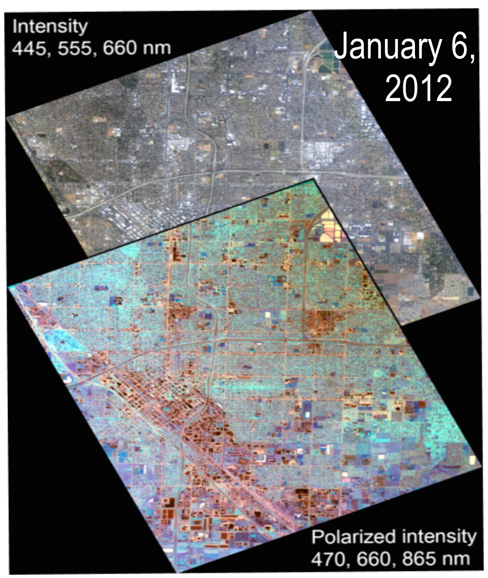
Infusion Path:

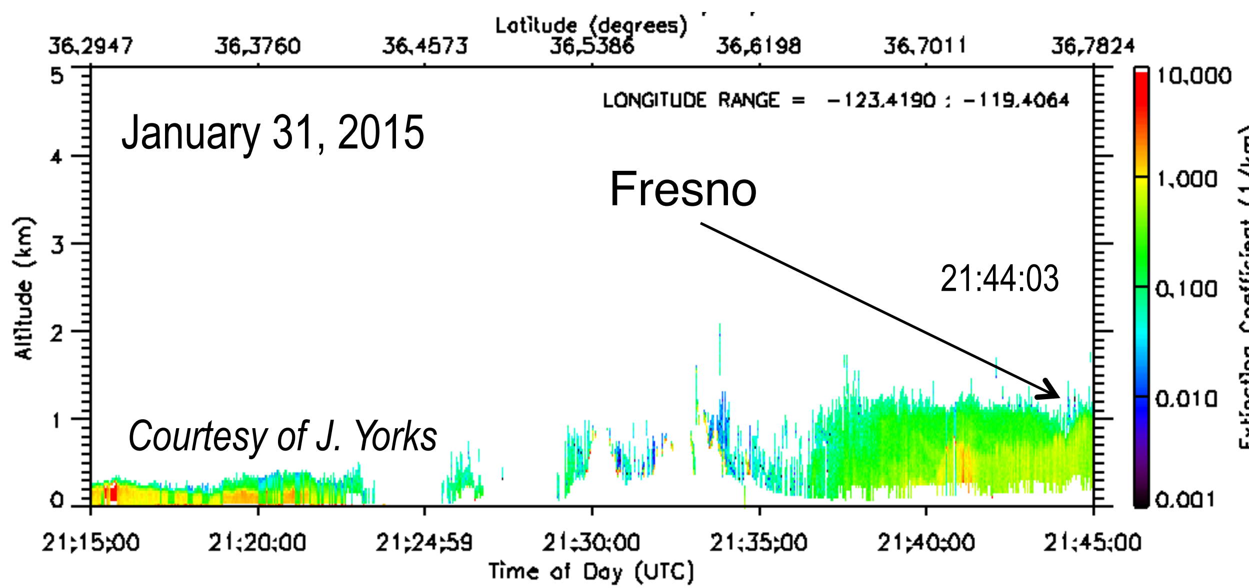
- Collect AirMSPI data over the California Central Valley EPA sites
- Integrate WRF-Chem initial guess on aerosol types and 3D distributions into retrievals
- Evaluate WRF-Chem simulations using ground-based and airborne in-situ data
- Develop and validate model-constrained polarimetric retrievals of PM types

Initial analysis: AirMSPI data over Fresno









From column to species retrievals

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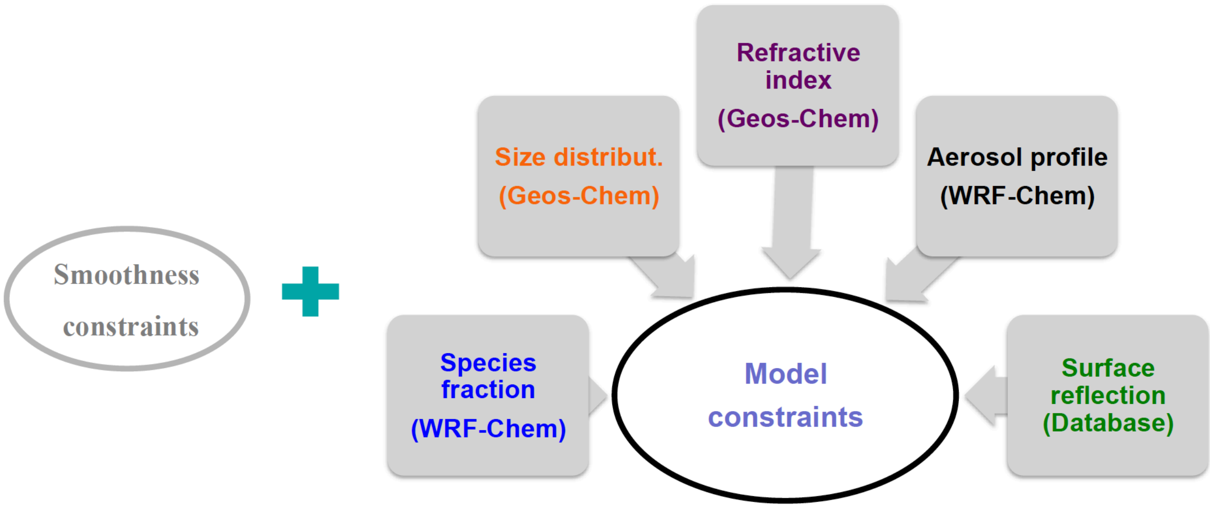
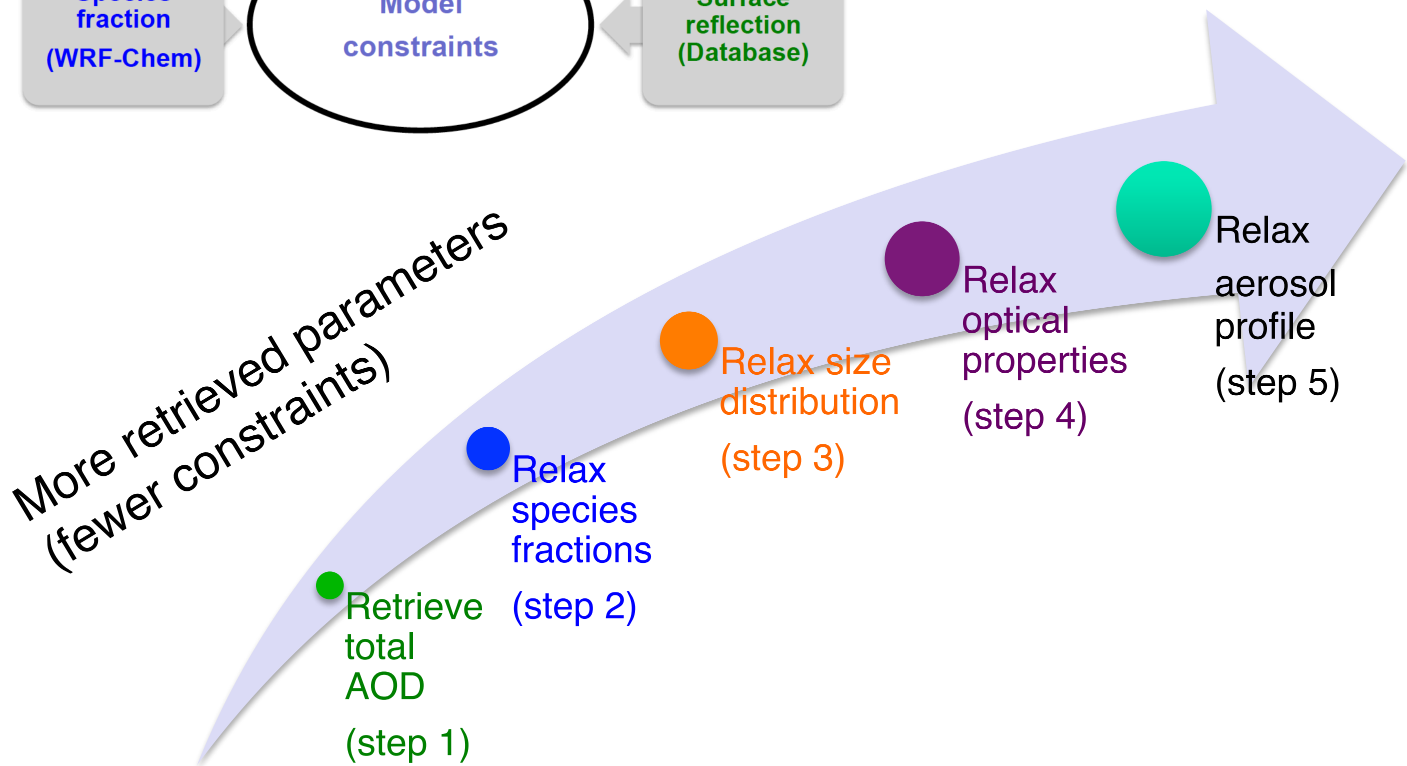


Both aerosol & surface are retrieved for initial test cases – but surface reflection dataset will be generated for MAIA retrieval



Minimize error between model and data

AirMSPI data collocated with EPA sites

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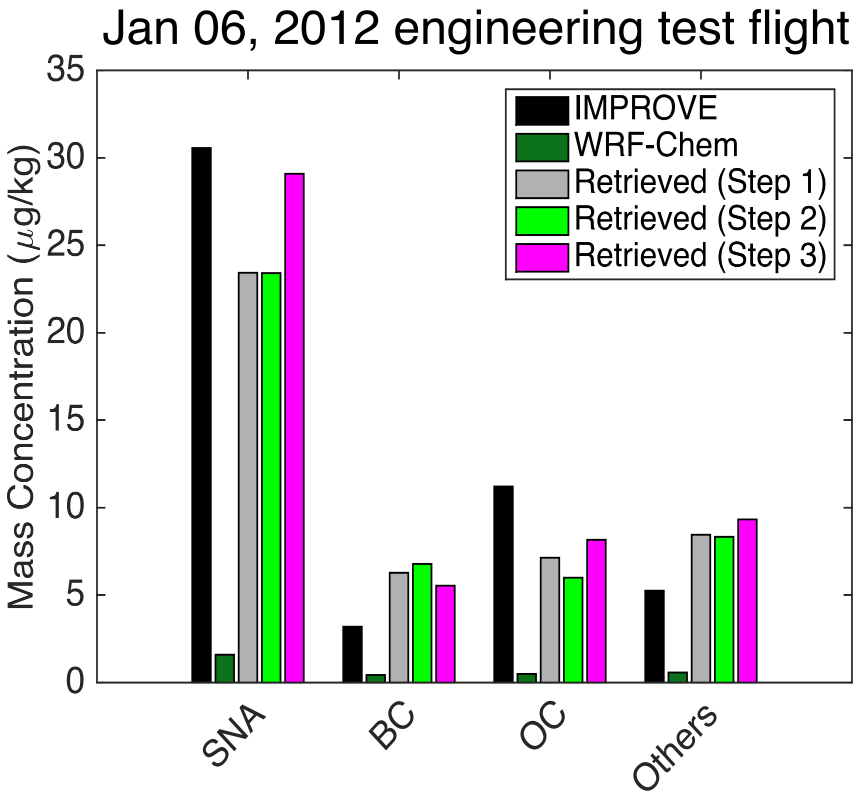
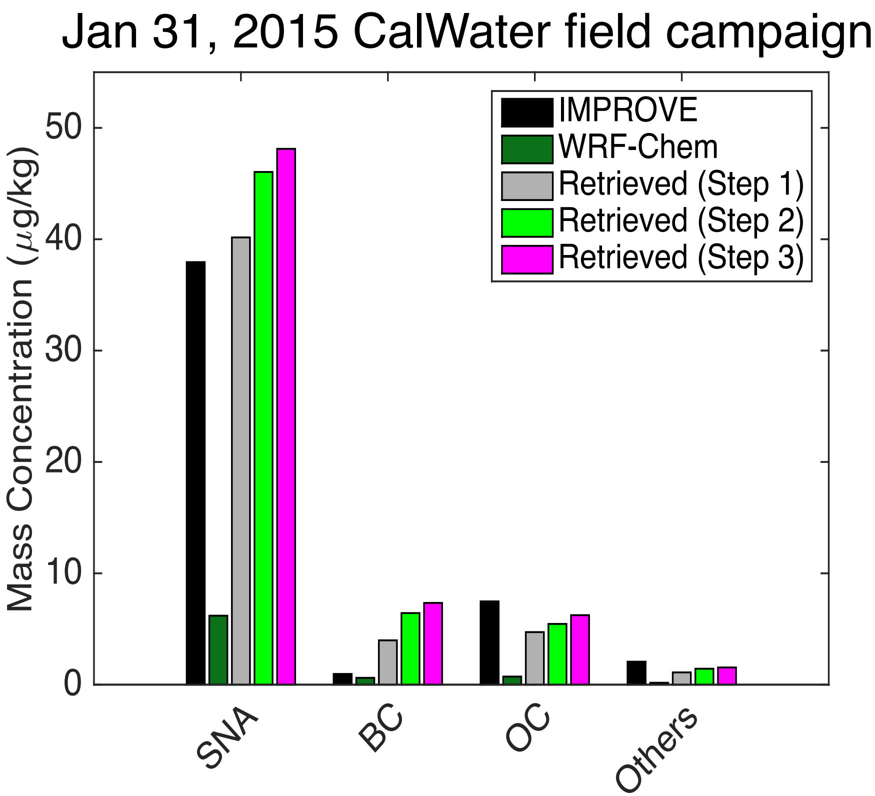
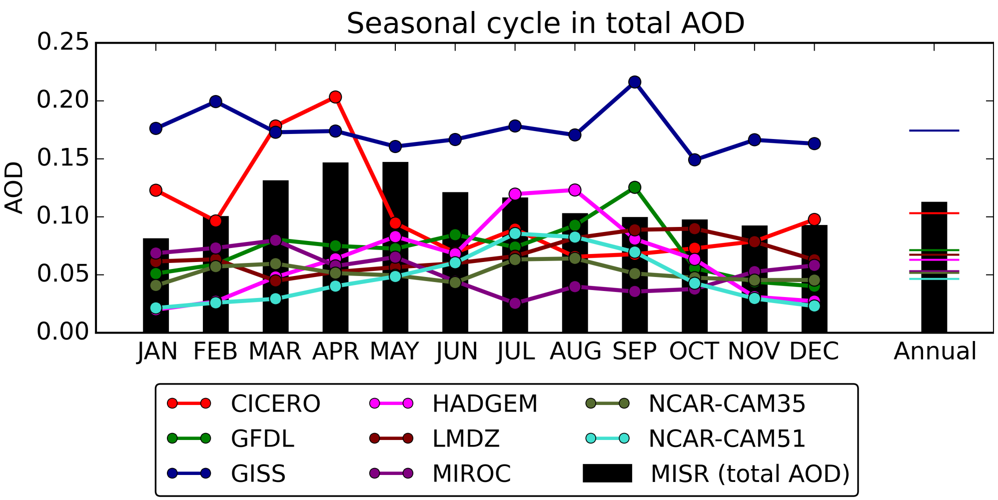
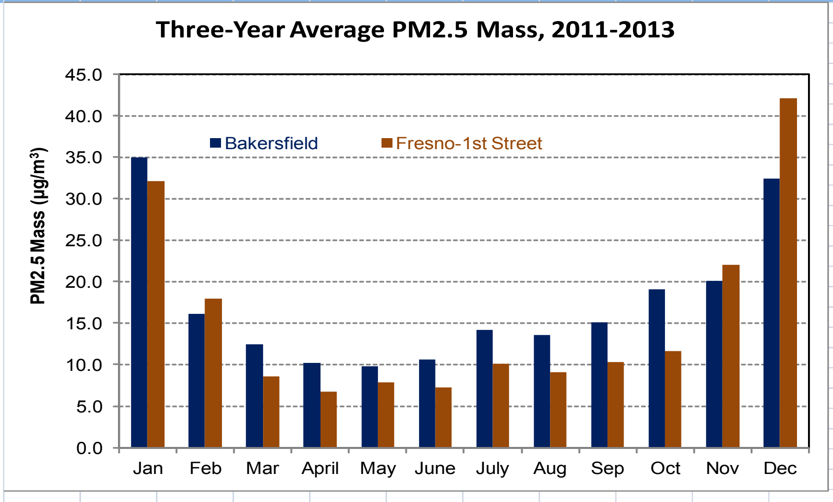


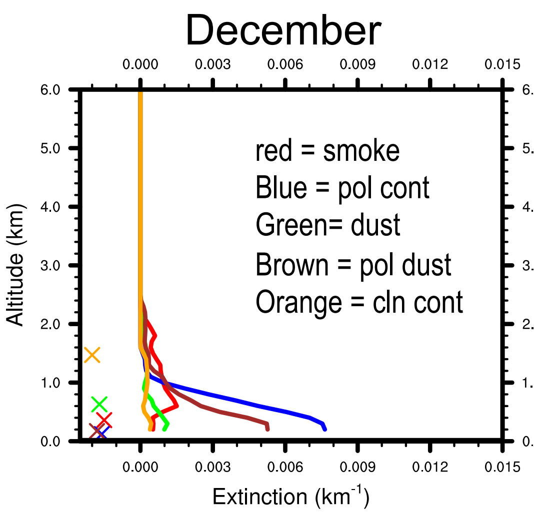


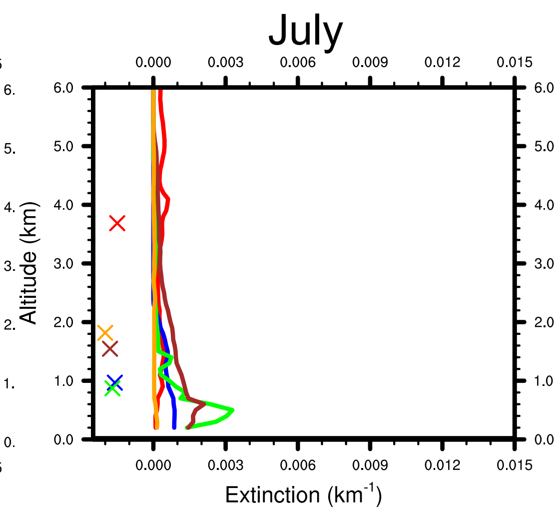
Multiangular polarimetric observations constrained by WRF-Chem model are promising tool for retrieval $PM_{2.5}$ by particle species (sulfate, nitrate, organic carbon, black carbon, dust)

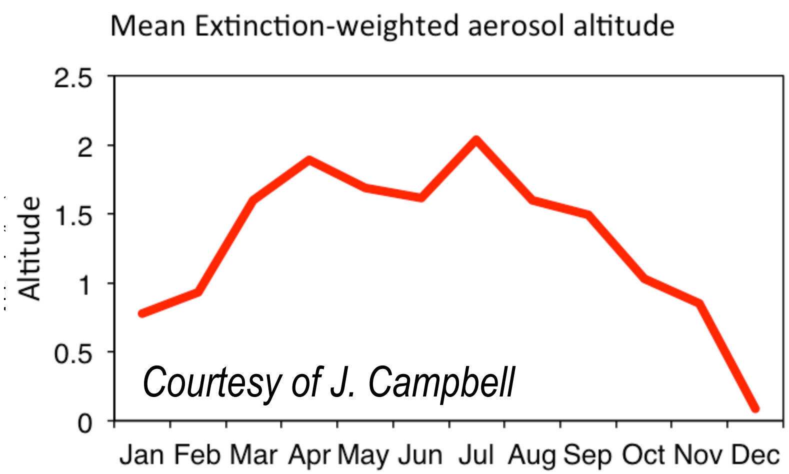
Central Valley aerosol climatology











Quantify the uncertainty of combined AirMSPI/WRF-Chem retrievals of speciated PM in µg/m^3 under elevated aerosol conditions; evaluate WRF-Chem vertical profiles

ImPACT-PM Central Valley

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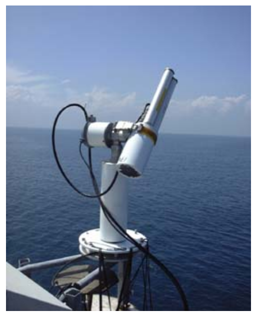
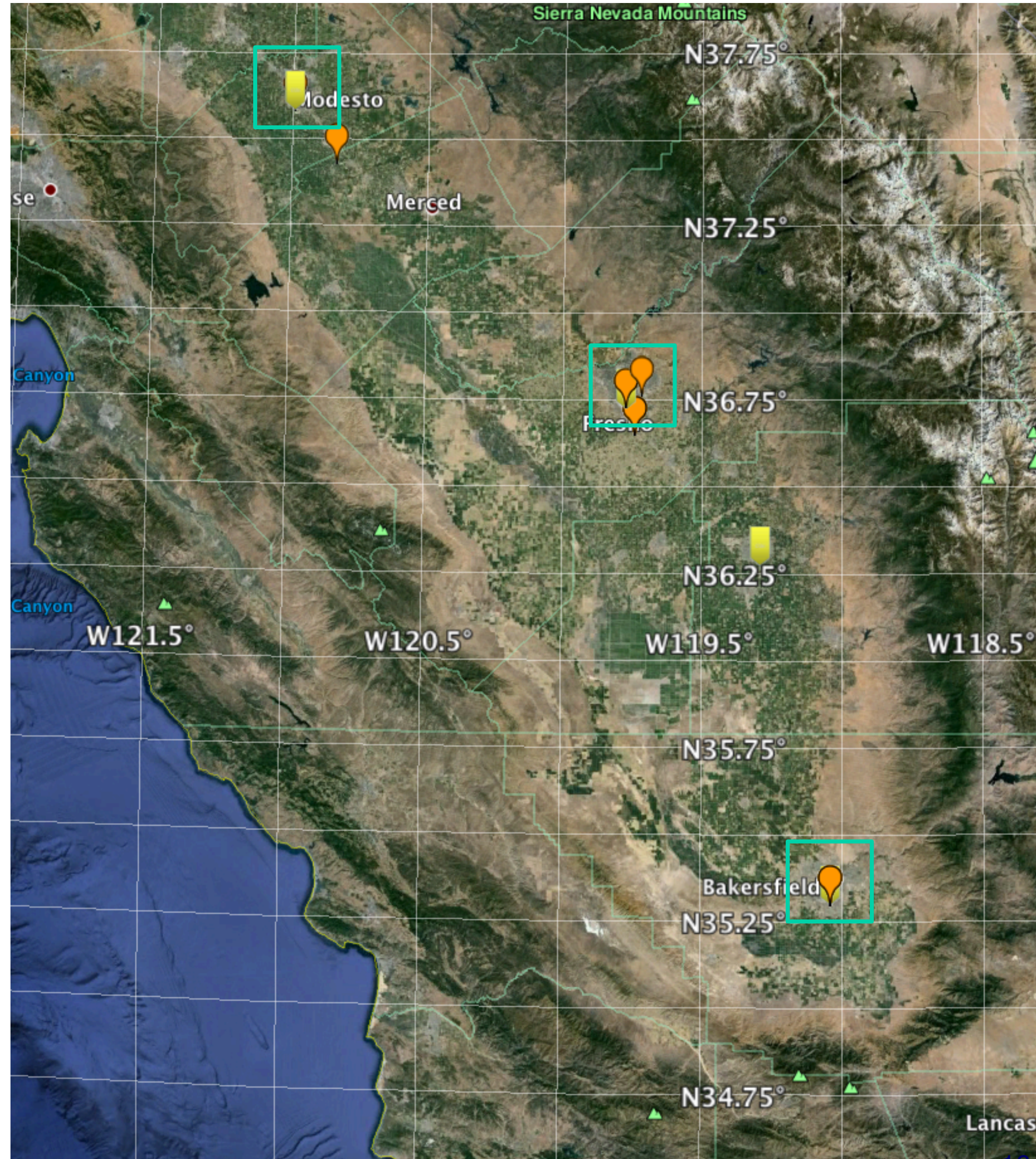
Imaging Polarimetric Assessment and Characterization of Tropospheric Particulate Matter (ImPACT-PM)

Role	Name
JPL PI	Olga Kalashnikova
Caltech Co-I	John Seinfeld



July 5-8, 2016



ImPACT-PM Central Valley - summer

ER-2 instruments

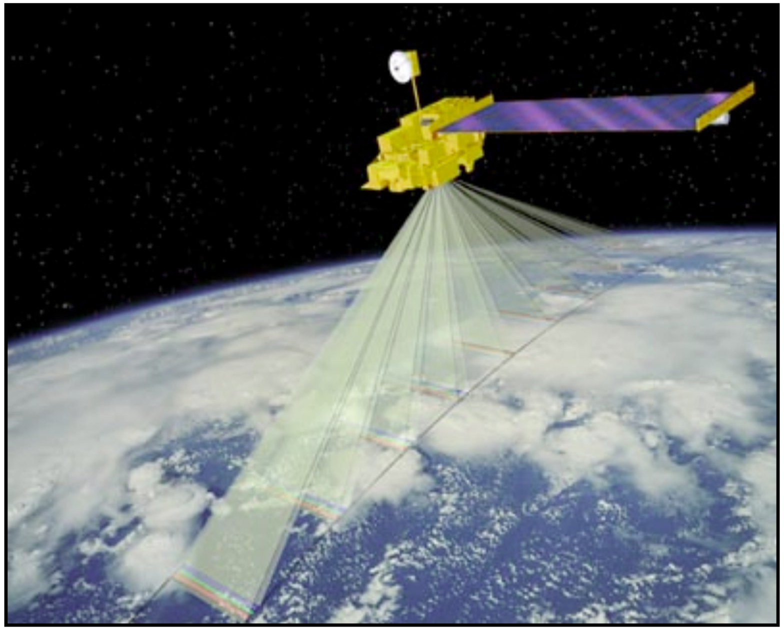
- AirMSPI-1
- CPL (high priority)
- AirHARP
- SPEX

The Caltech instruments:

- Aerodyne Aerosol Mass Spectrometer (AMS)
- Differential Mobility Analyzer (DMA)
- Cloud Condensation Nucleus Spectrometer (CCN)
- SP2 (Black Carbon)

CIRPAS Twin Otter aerosol instruments:

Condensation Nuclei Counters (TSI 2010 and 2025), Aerosol Size distributions for Dp>100 nm (PCASP, CAPS),
Scattering Coefficient (TSI 3l Nephelometer),
Absorption Coefficient (3l PSAP),
BC Mass (DMT SP2).



Ground-based instruments:

- GroundMSPI (Fresno)
- JPL MTHP (Fresno)
- AERONET: Fresno, Bakersfield, Modesto
- EPA CSN instruments and PM monitors

February 5, 2016 (MISR under-flight, Fresno)

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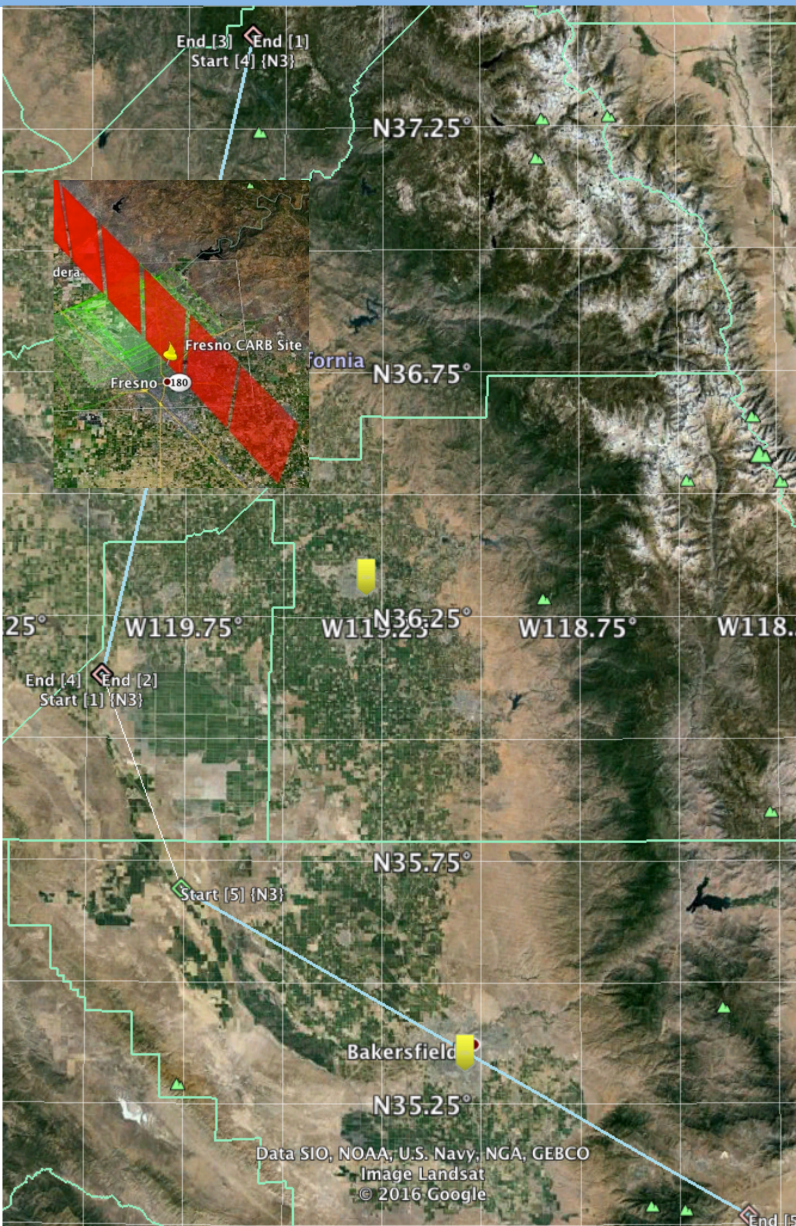
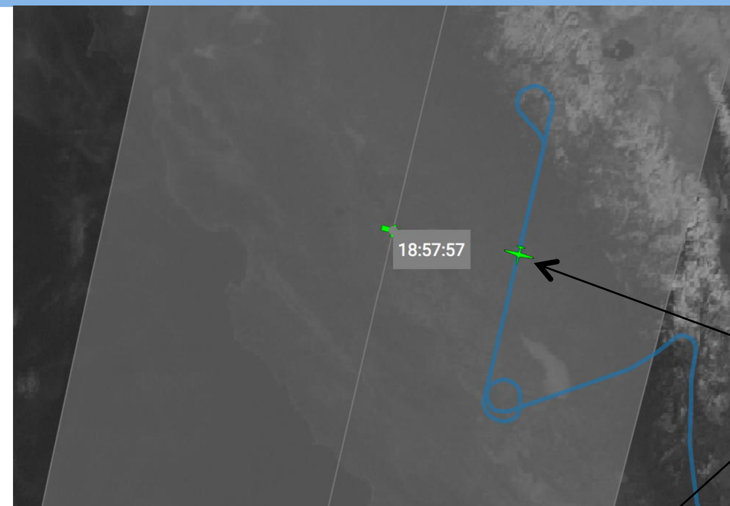
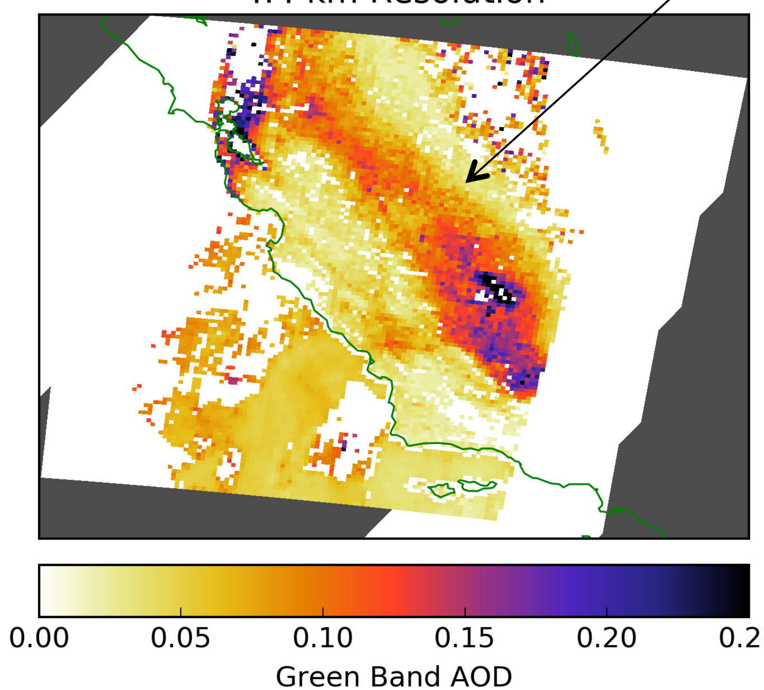




4.4 km Resolution



Fresno

AERONET
AOD =0.09
at 500nm

ImPACT-PM – July flight planning

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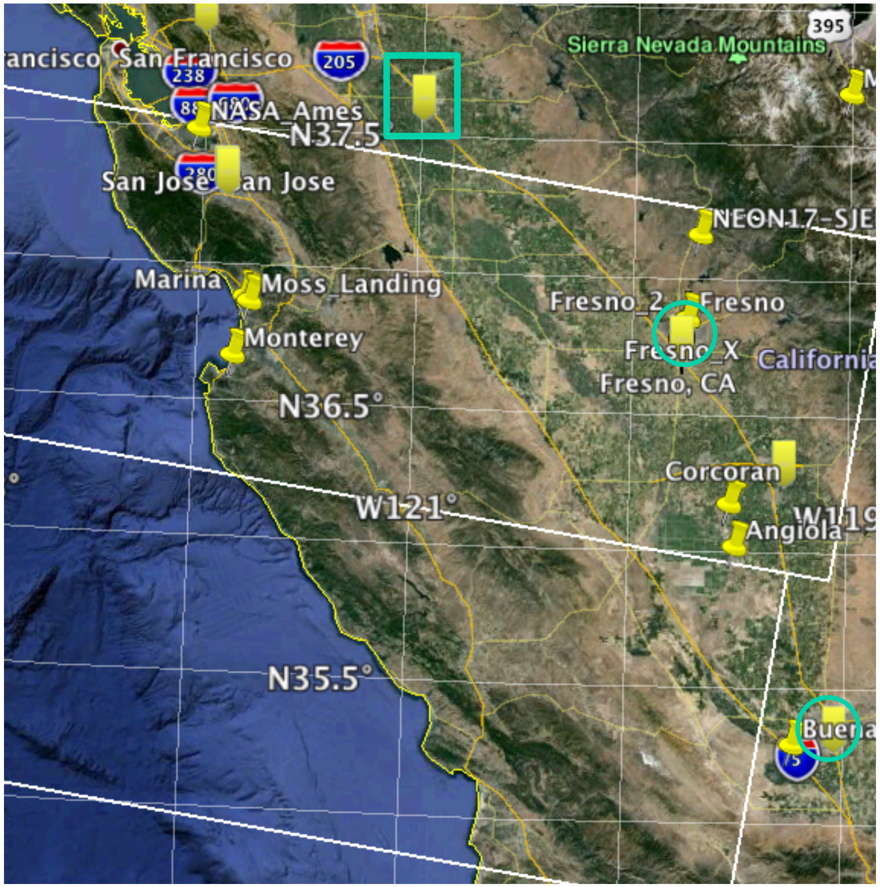
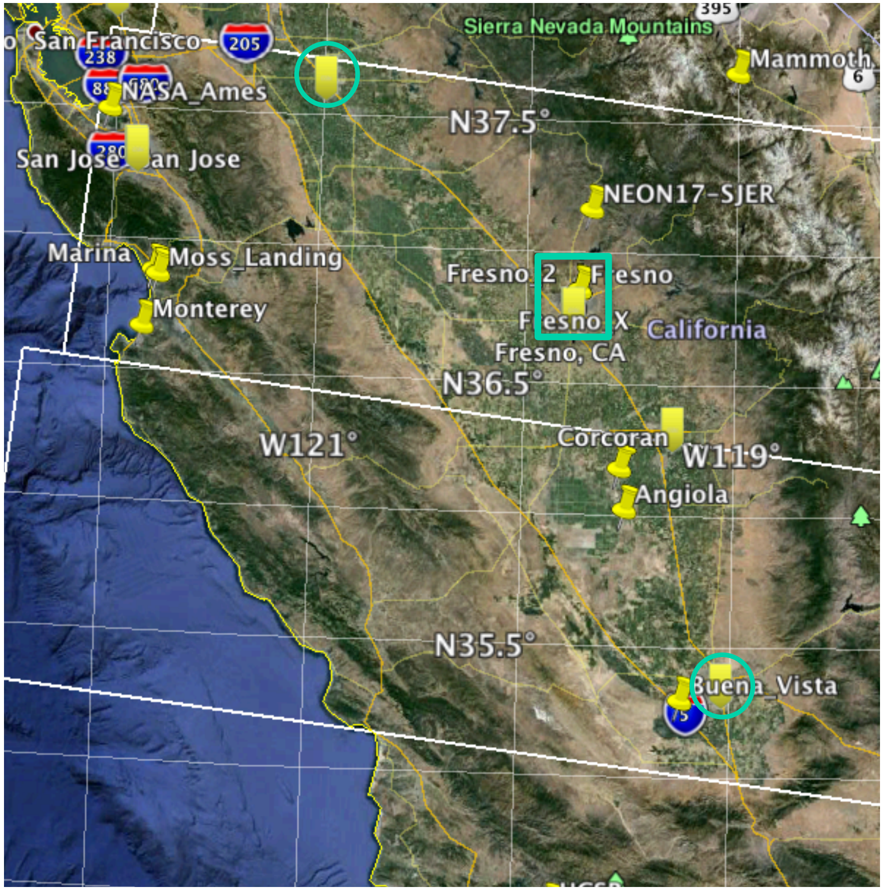
July 5, 2016 (path 44)



July 7, 2016 (path 42)



<u>Quantify the uncertainty of combined AirMSPI/WRF-Chem retrievals</u> of speciated PM in mg/m^3 under elevated aerosol conditions through comparisons with both Caltech *in situ* and EPA ground-based measurements, develop spatial error estimates, and compare these results with EPA PM monitoring requirements.

Concluding remarks

- Quantitative determination of PM distributions, trends, sources, and types is necessary for measuring and predicting exposure and toxicity
- Advanced polarimetric remote sensing technologies improve aerosol retrieval sensitivity to particle type
- MAIA major advance will be to partition $PM_{2.5}$ by particle species (sulfate, nitrate, organic carbon, black carbon, dust) over selected target areas
- We demonstrated that reliable conversion of column AOD and fractional AOD to $PM_{2.5}$ species is achievable trough combined WRF-Chem/AirMSPI retrievals
- ImPACT-PM field campaign will provide additional data to quantify the uncertainty of combined AirMSPI/WRF-Chem retrievals

Global Burden of Disease Study 2010

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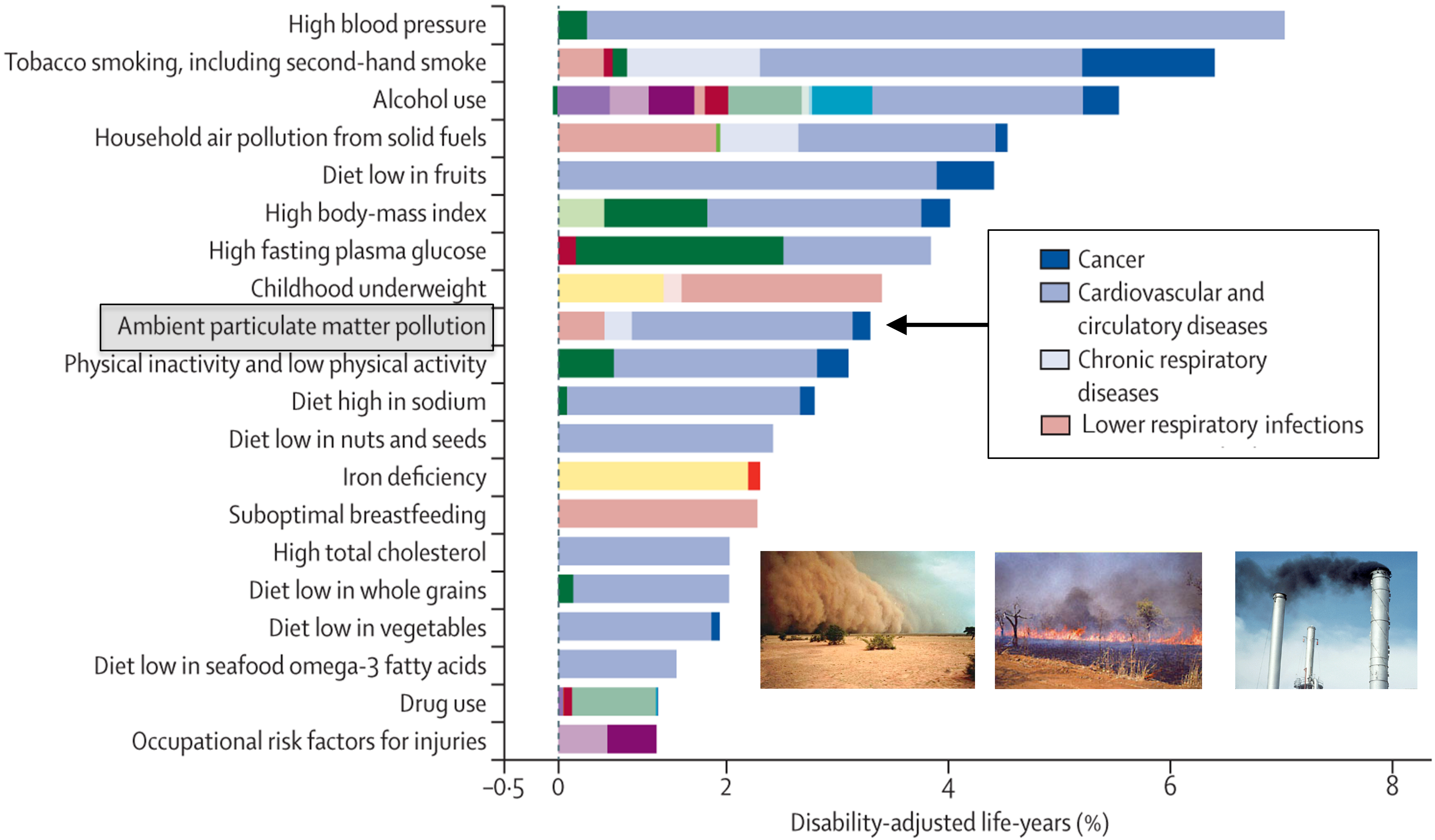


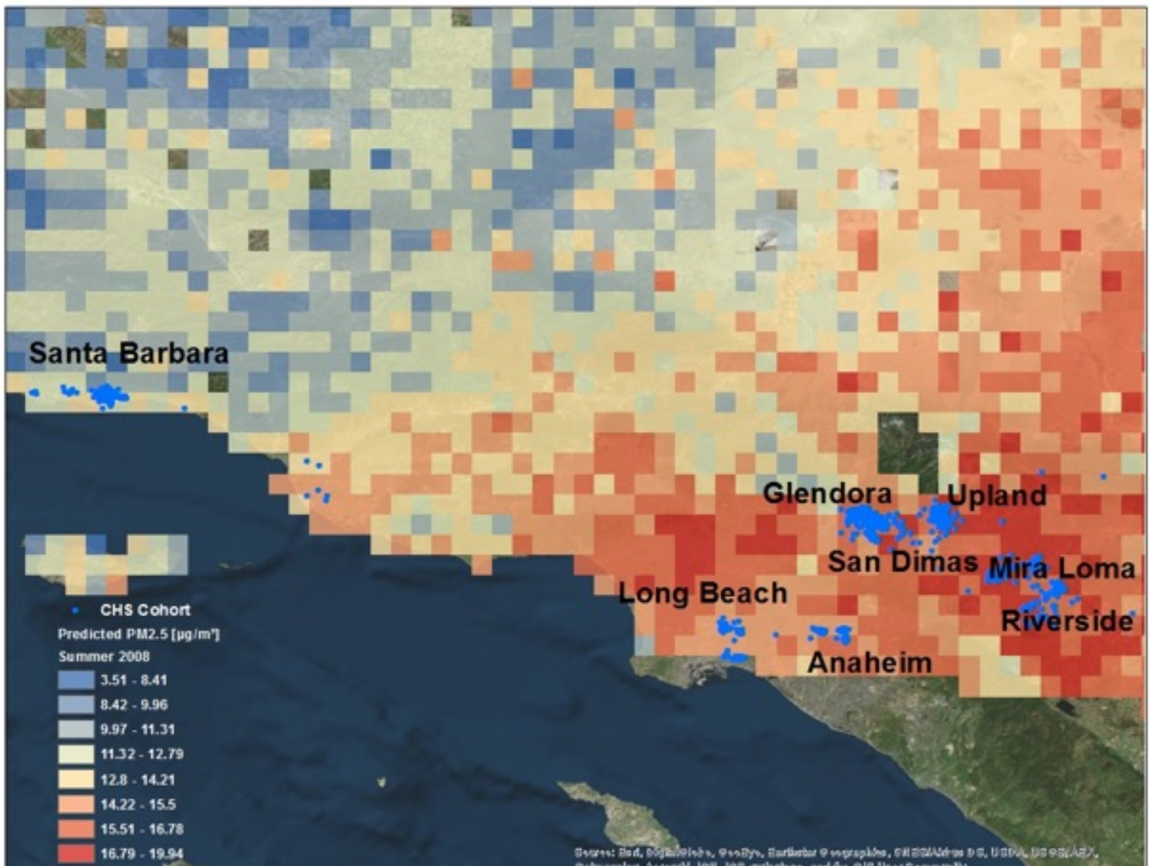
Lim et al. (2012)

Impact of PM on children's respiratory health in the greater Los Angeles area

Jet Propulsion Laboratory

Solution for Fixed Effects						
Effect	Level	Estimate	Standard Error	DF	t Value	Pr > |t|
PM25		-18.773	7.0361	1176	-2.67	0.0077

Children's Health Study subject locations with summer 2008 MISR AOD-derived $PM_{2.5}$ concentrations



18.77 mL decrease in lung's Forced vital capacity (FVC) per 1 $\mu g/m^3$ increase in $PM_{2.5}$

As a proof of concept, the JPL-USC team linked MISR AOD-derived PM concentrations to 1286 children who were participants in the Southern California Children's Health Study. An epidemiological assessment found that there was a statistically significant ($p<0.05$) decrease in lung function with an increase in $PM_{2.5}$ (fine mode PM).

Courtesy of M. Franklin, JPL SURP project