Aerosol Type Mapping from Space: Capabilities and Constraints on Regional Air Quality

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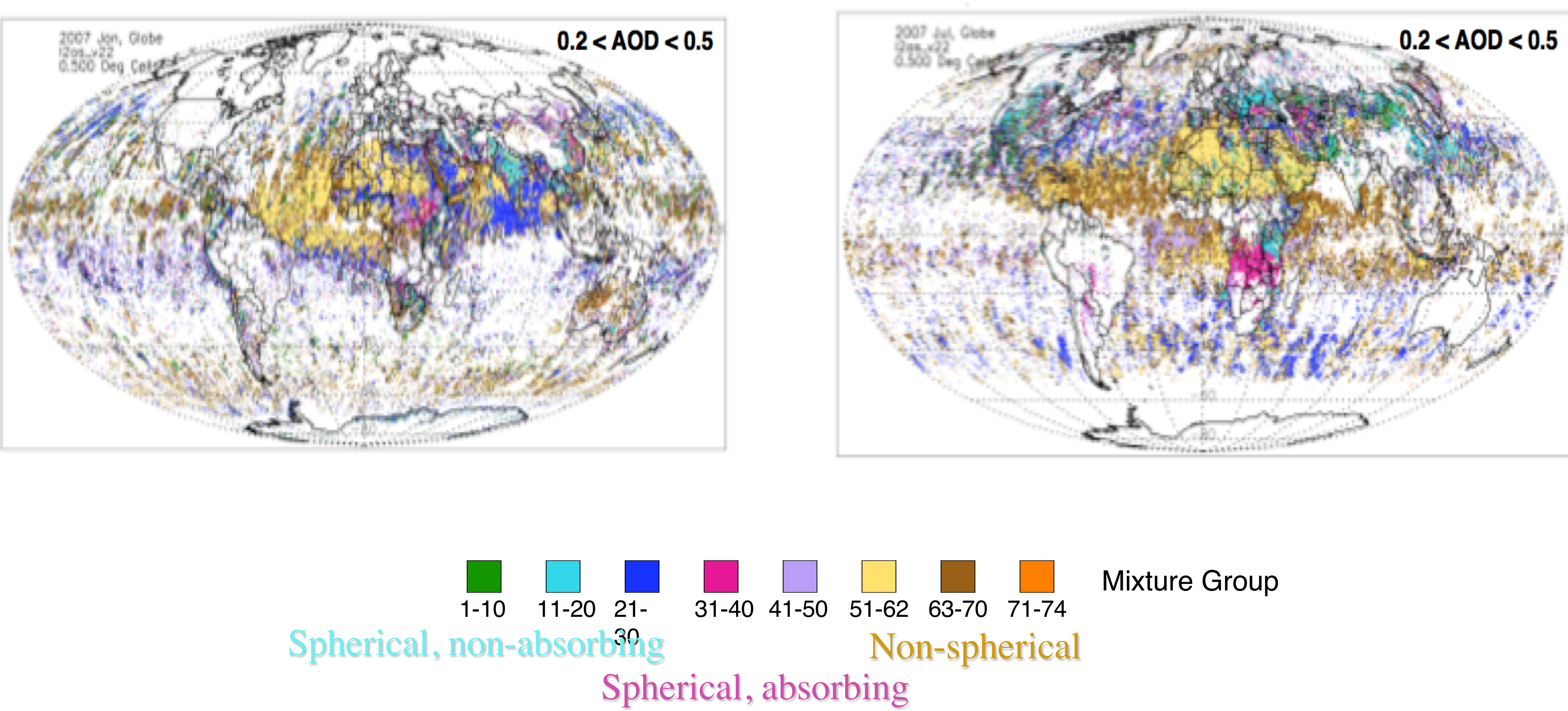
January 2007 **July 2007**



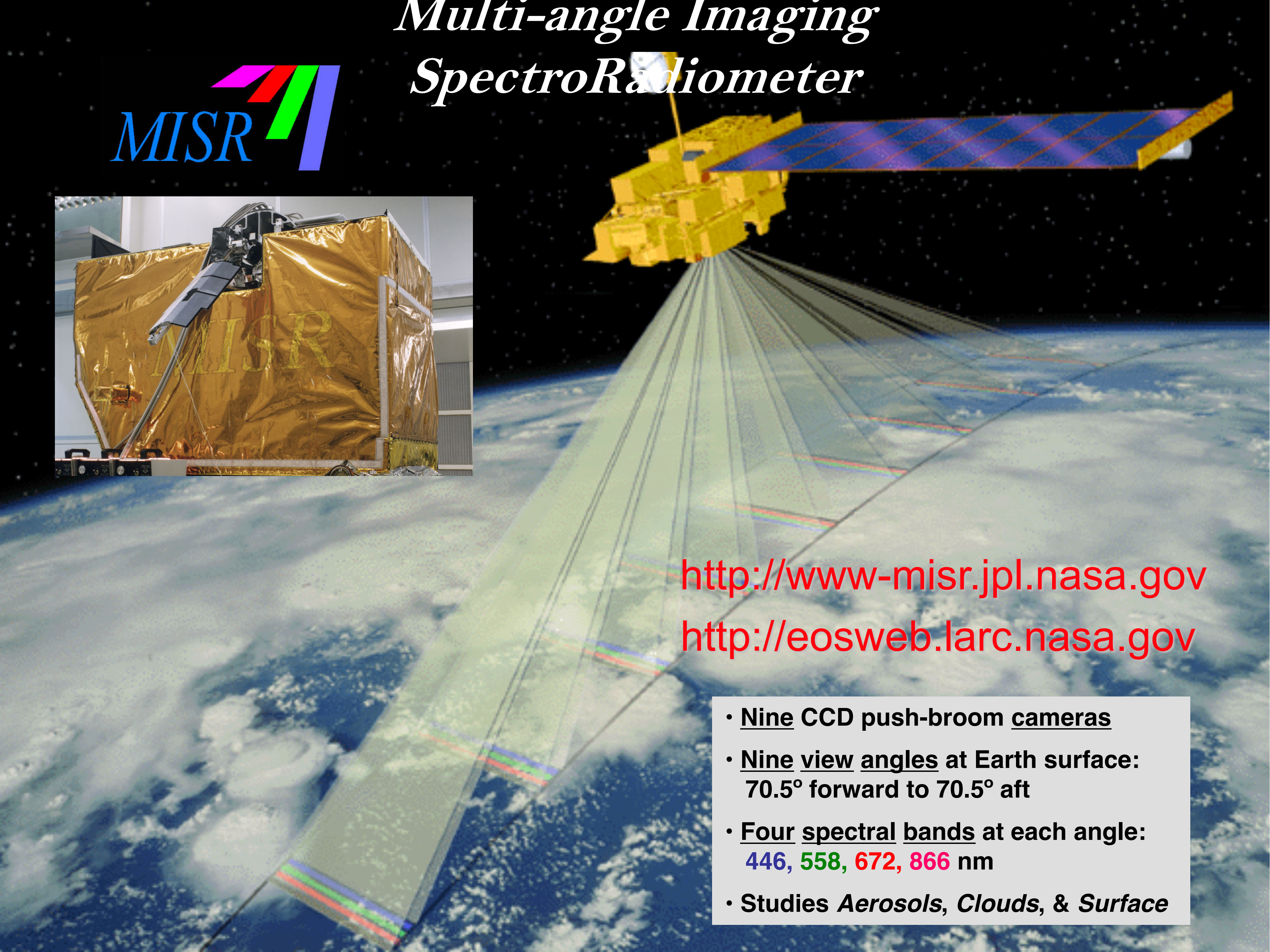
Kahn & Gaitley, JGR 2015

Why We Care About *Aerosol Air Mass Type*

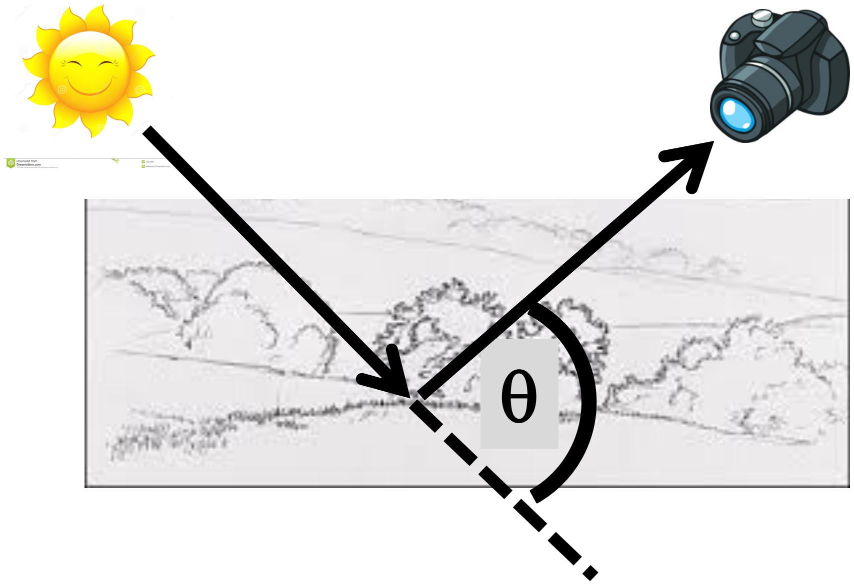
Some applications of satellite-mapped aerosol type, especially when ***combined with*** otherwise-constrained, detailed particle properties:

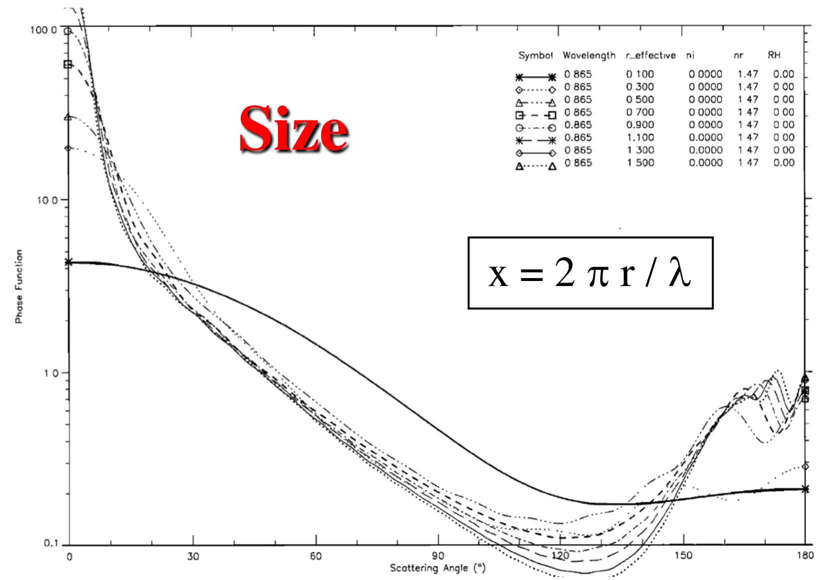
- ***Source Attribution*** and ***Attributes of the Source*** (fires, volcanoes, etc.)
- Mapping 3-D ***Aerosol Absorption*** that mediates impacts on ***atmospheric stability structure*** and can affect ***convection***, ***cloud evolution***, and ***larger-scale atmospheric circulation***
- Mapping ***Particle Hygroscopicity*** required to account for humidity-dependent ***particle optical property changes*** as well as ***particle activation conditions*** that initiate cloud formation
- Deducing ***Mass Extinction Efficiency*** (MEE) distributions, required to ***constrain & validate air quality***, ***aerosol-transport***, and ***climate model*** aerosol mass with remote-sensing-derived particle ***optical*** properties.

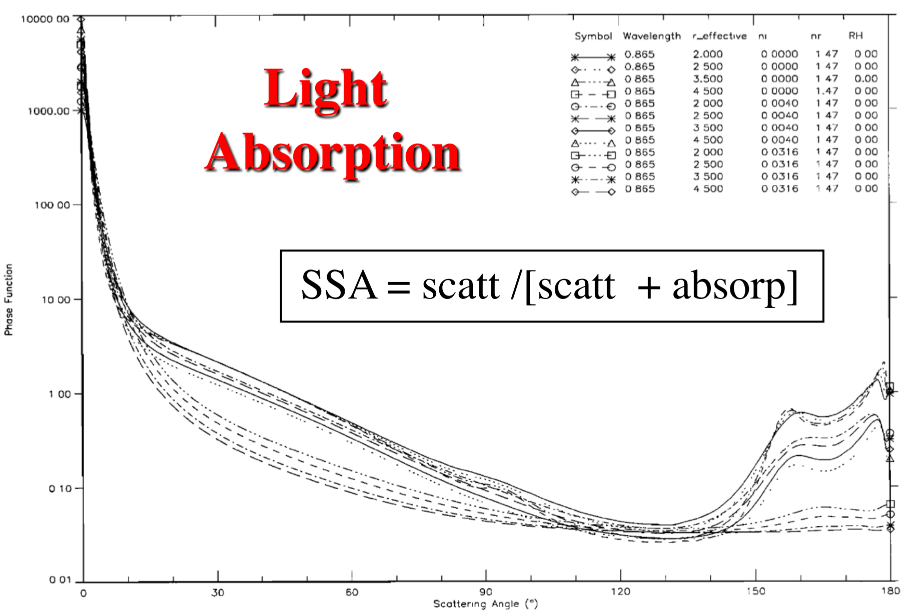
Aerosol Air Mass Type derived from remote sensing can provide ***2-D and 3-D mapping required*** for many of these applications.


Multi-angle Imaging
SpectroRadiometer
MISR
MISR
http://www-misr.jpl.nasa.gov
http://eosweb.larc.nasa.gov
• Nine CCD push-broom cameras
• Nine view angles at Earth surface: 70.5° forward to 70.5° aft
• Four spectral bands at each angle: 446, 558, 672, 866 nm
• Studies Aerosols, Clouds, & Surface

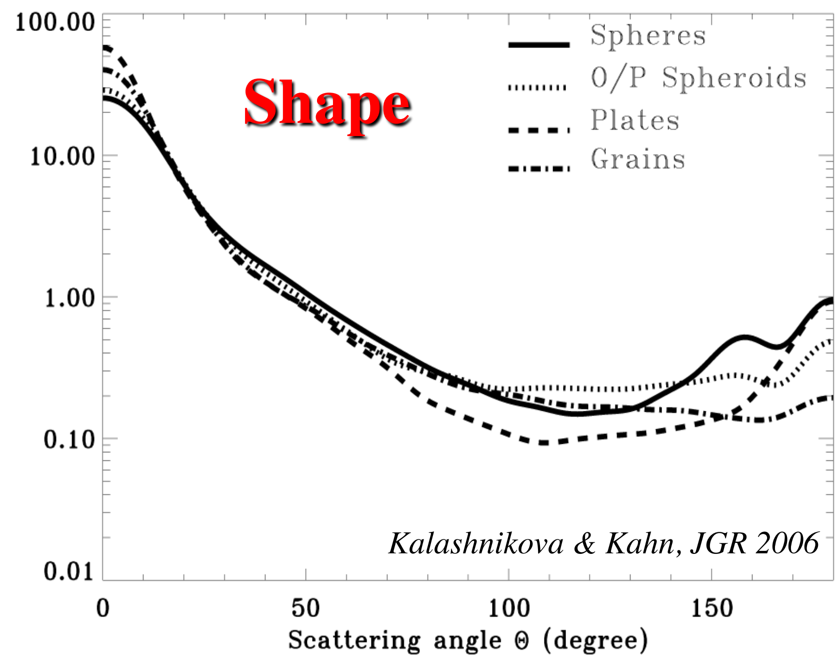
Single-scattering Phase Functions for **Different Particle Properties**







Kahn et al., JGR 1998



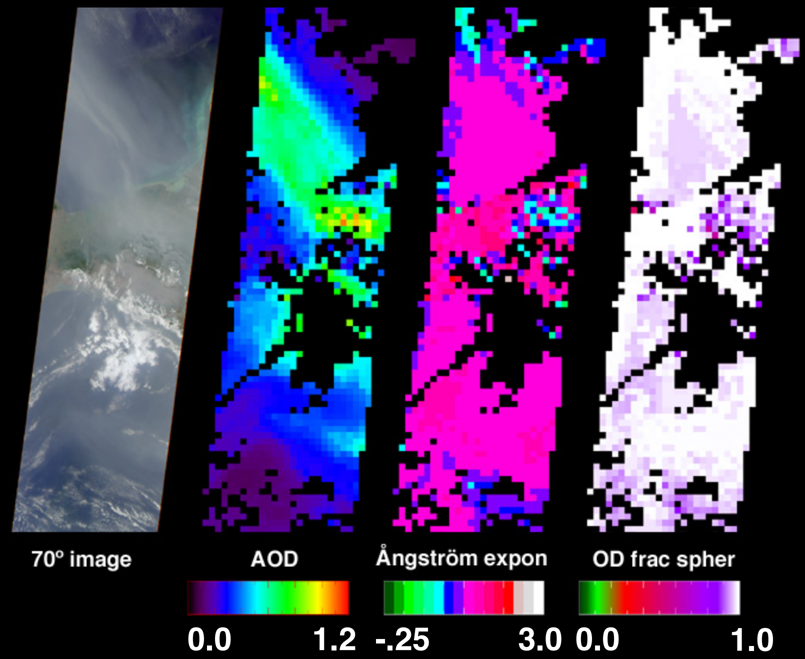
Smoke from Mexico -- 02 May 2002

Aerosol:

Amount

Size

Shape



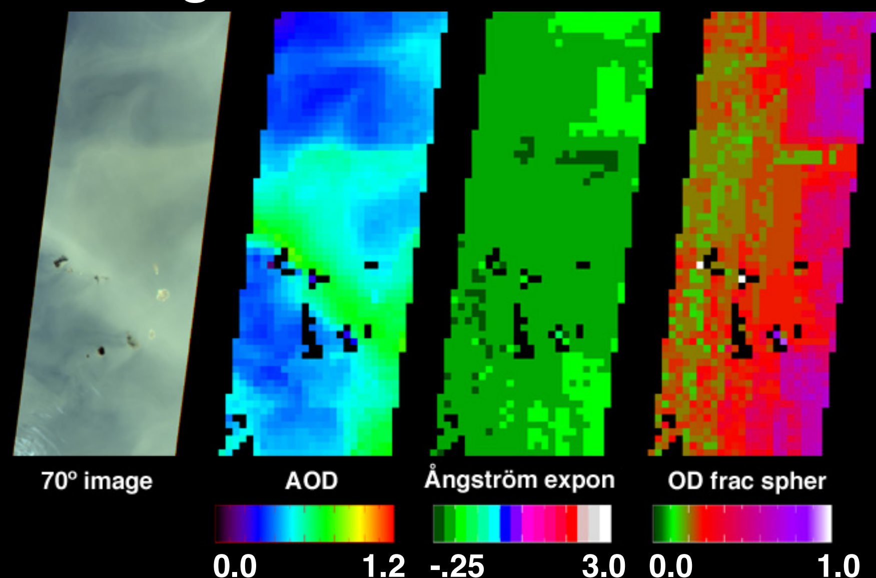
Medium

Spherical

Smoke

Particles

Dust blowing off the Sahara Desert -- 6 February 2004



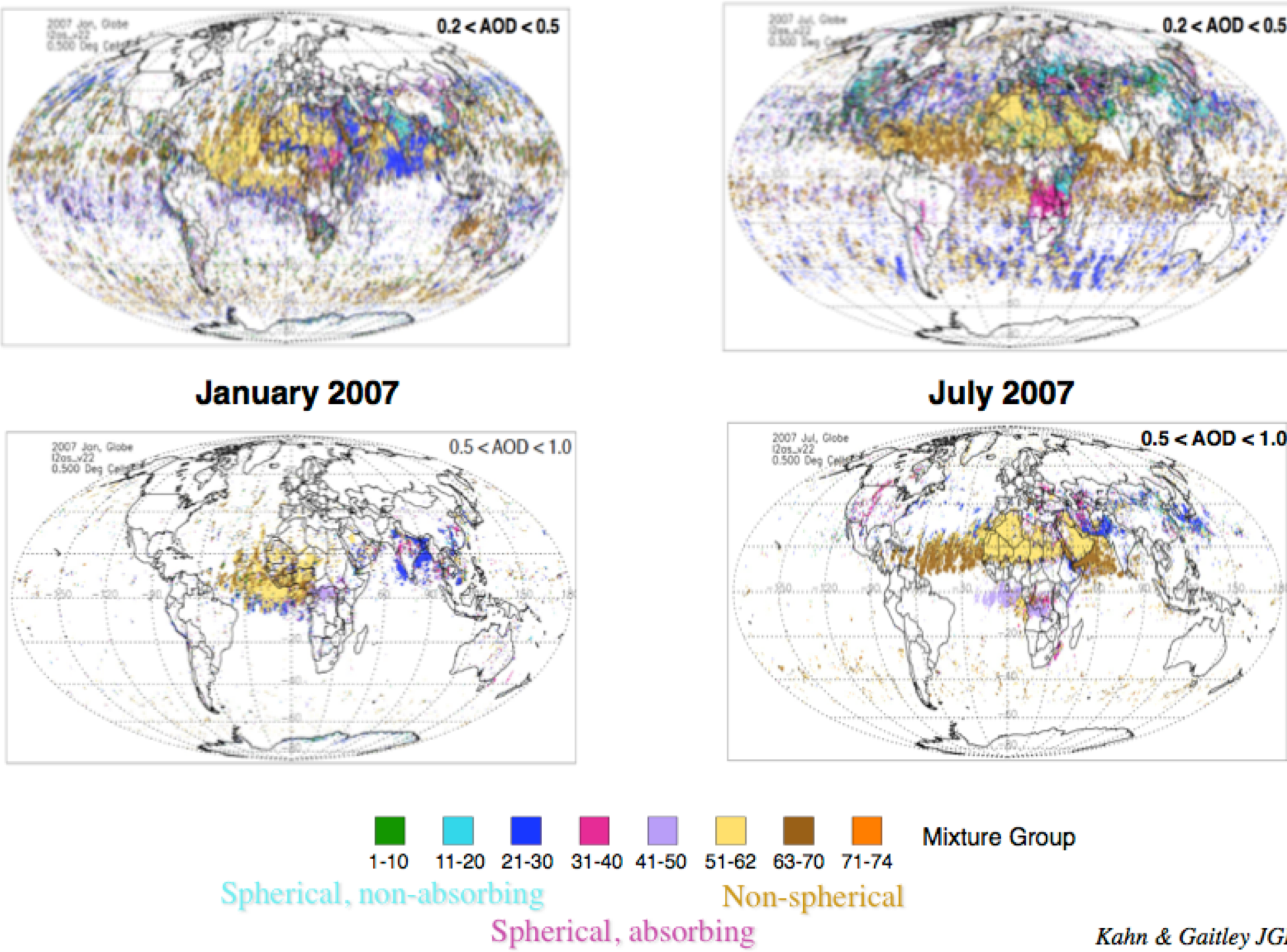
Large

Non-Spherical

Dust

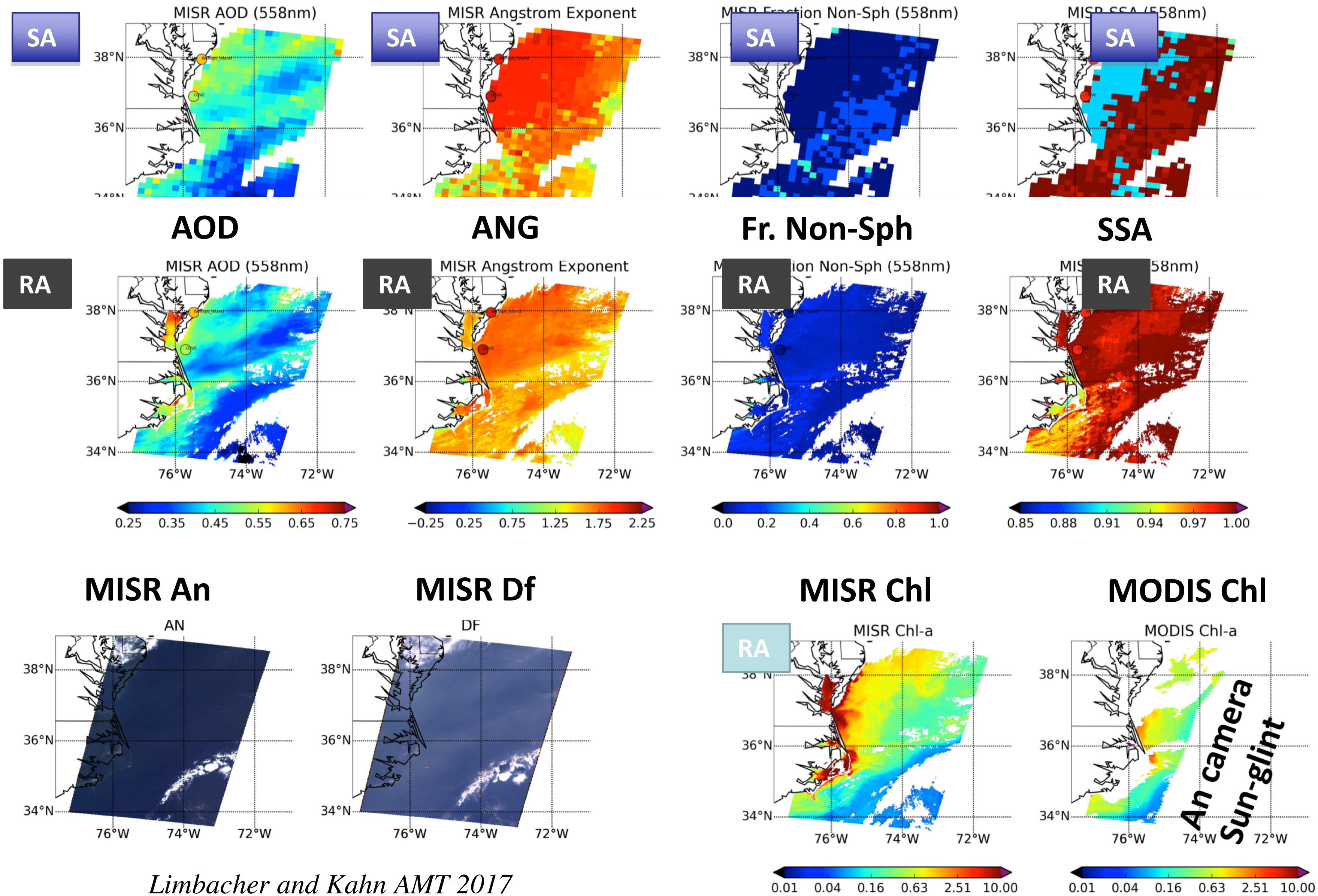
Particles

MISR Aerosol Type Discrimination



Kahn & Gaitley JGR 2015

MISR *Research Algorithm* With Self-consistent Ocean Surface Retrieval

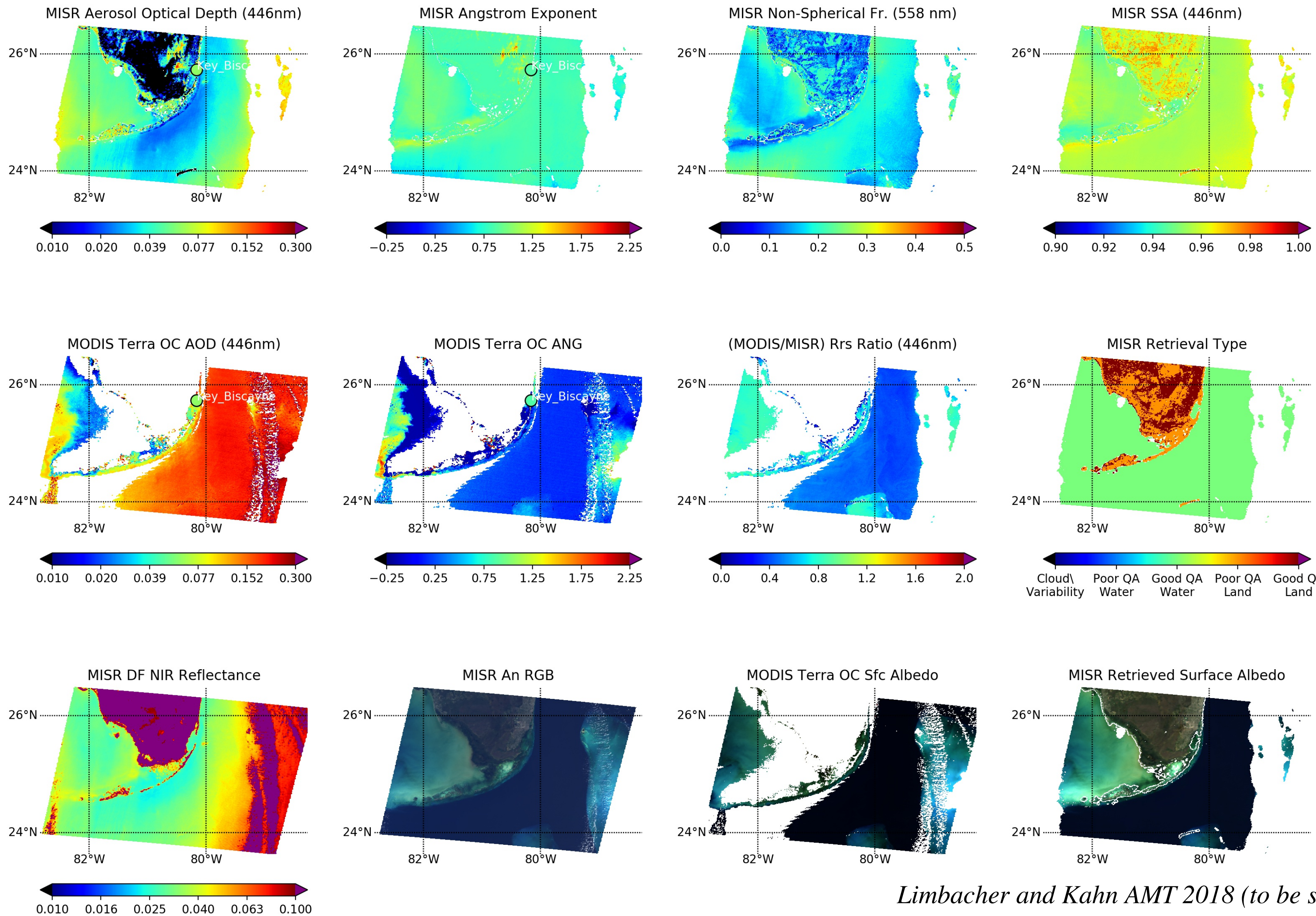


Limbacher and Kahn AMT 2017

MISR *Research Algorithm*

Turbid Water + Over-Land Retrieval

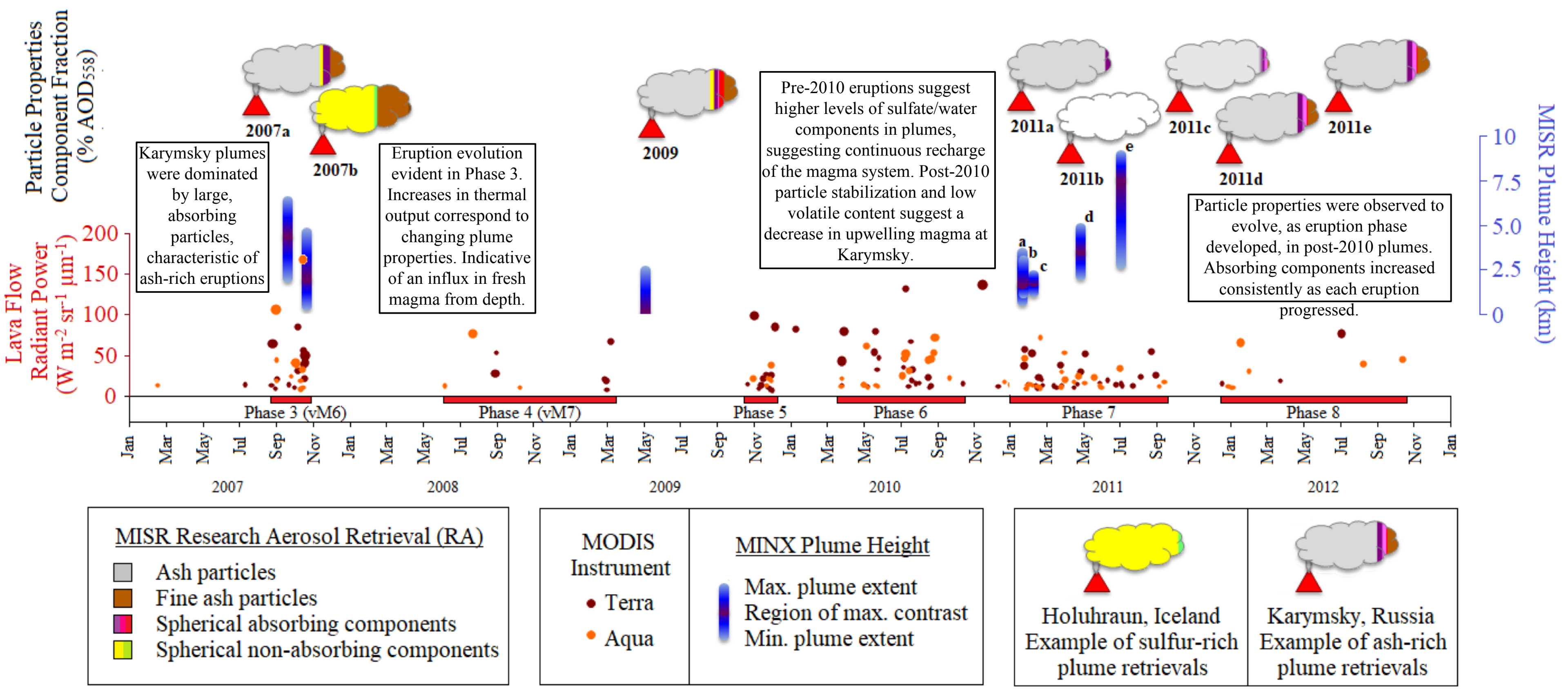
Orbit 69220 Path 15 Blocks 70-71 *22 December 2012*



Limbacher and Kahn AMT 2018 (to be submitted)

Volcanology from Space

Six-year Synthesis Timeline for Karymsky Volcano, Kamchatka



<u>Top row</u>: *particle types*; <u>Middle row & left axis</u>: *plume height*;
<u>Bottom row & right axis</u>: *MODIS Thermal Anomaly & Eruption Phases*

Flower & Kahn ACP., 2018

Research Algorithm Upgrades

- Empirical ***Radiometric Calibration*** adjustments
- Better ***Ocean Surface Characterization***
    Under-light included; ***Whitecap Reflectance*** updated
    Ocean surface retrieval over ***turbid, eutrophic, & shallow water***
- Physically based ***Particle Property*** and ***Mixture*** adjustments*
- An ***Adaptive Pixel Selection*** method – median or minimum
- Spectral ***Reflectance Uncertainty*** determined from vicarious cal.
- More stringent ***Cloud Screening***
- ***Modified-Linear-Mixing*** removed
- Better ***Land Surface Characterization****
- Weight aerosol type using ***Transport Model*** at low AOD*

Current, continuing work

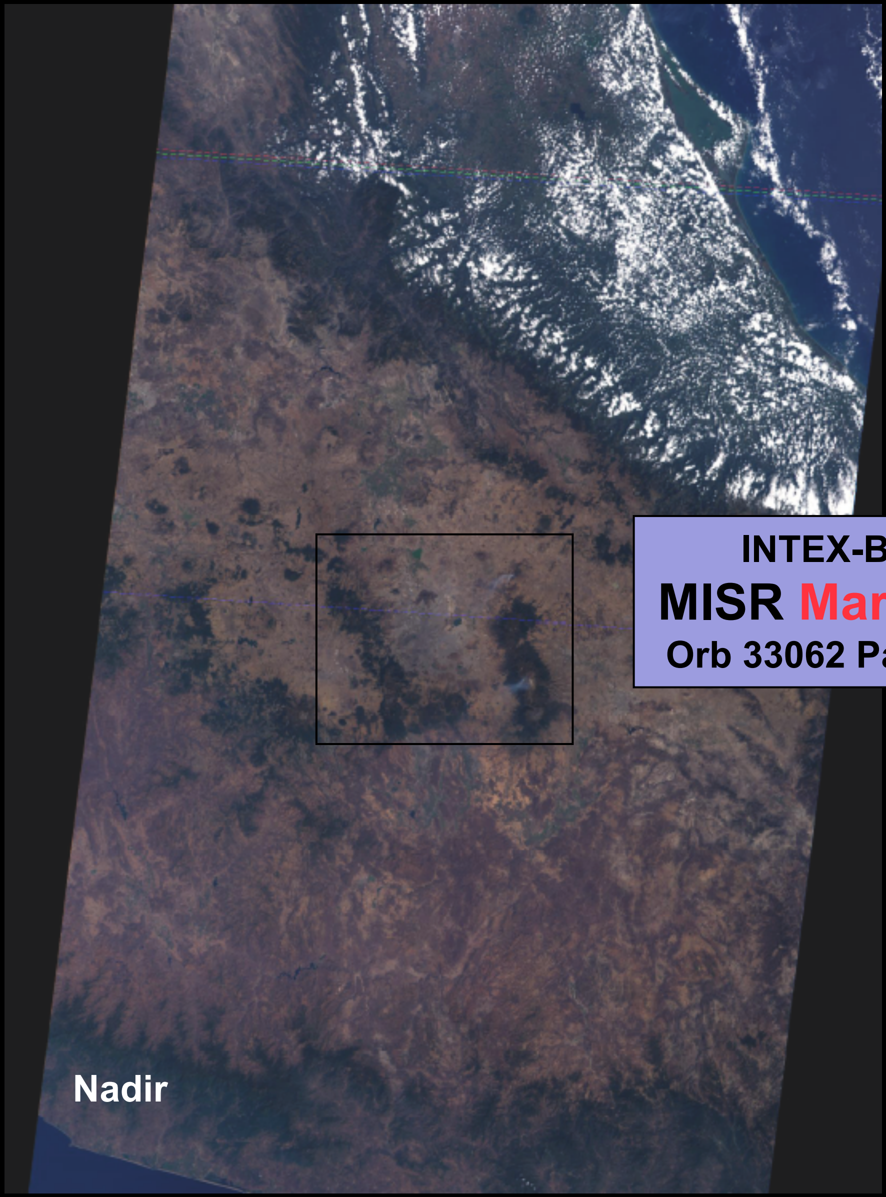
Limbacher & Kahn, AMT 2014, 2015, 2017, 2018

Satellite Aerosol-Type Summary

- Remote-sensing can provide optical constraints interpreted as particle ***Size, Shape, and Indices of Refraction***
- A ***further*** interpretative step, entailing additional assumptions, reports particle ***Chemical Composition***
- Remote-sensing ***sensitivity to particle properties is much more dependent than AOD on retrieval conditions***
- Improvements in ***Calibration, Surface Representation, Particle Microphysical Properties*** needed to make progress
- ***Validation Data*** for aerosol type are very limited

  -- ***Model simulations*** and ***In Situ measurements*** can help
- ***In situ Data*** also needed for particle microphysical properties ***unobtainable from remote-sensing***

Mapping AOD & Aerosol Air-Mass-Type in Urban Regions



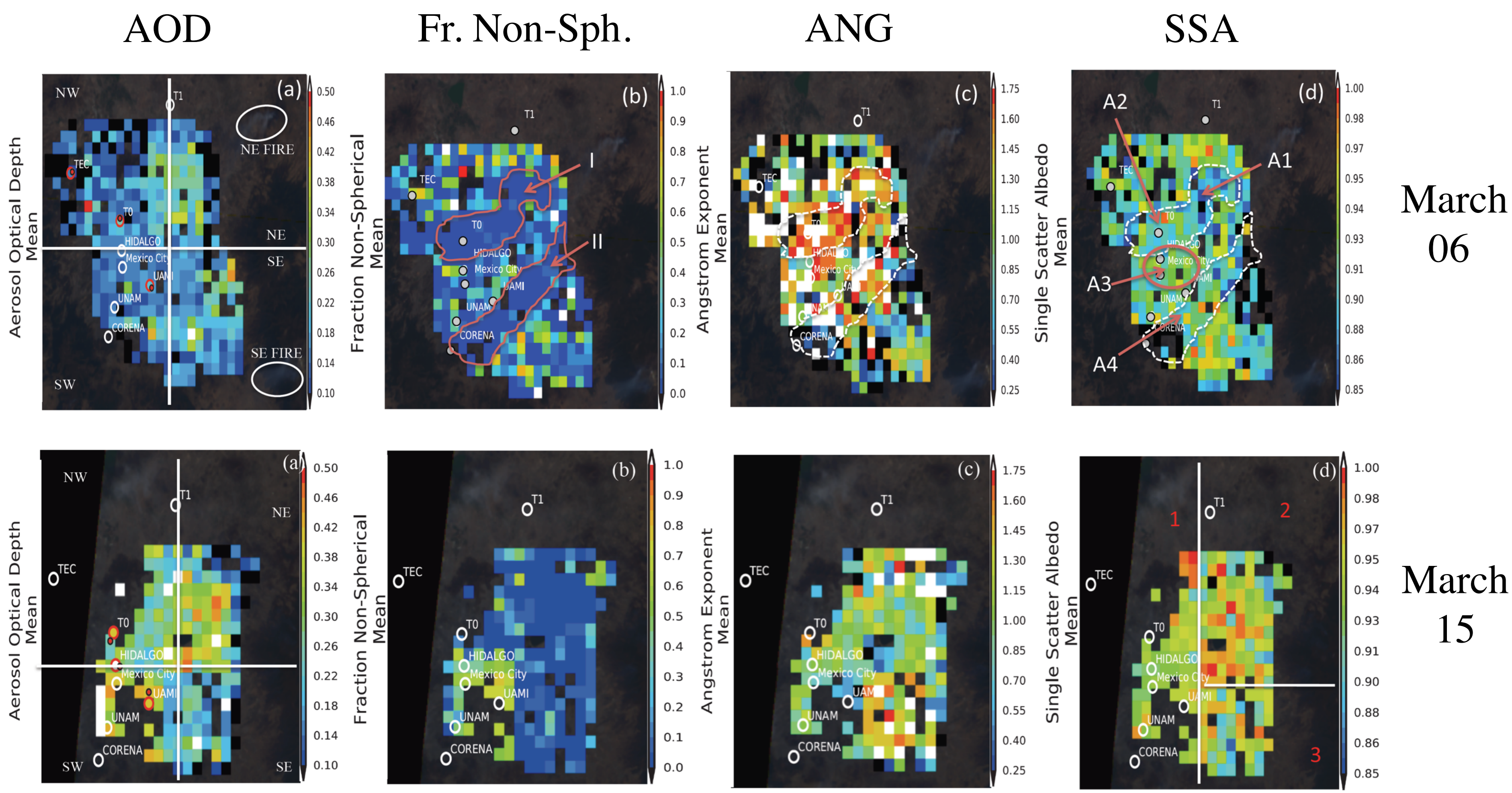
INTEX-B/MILAGRO

MISR March 06, 2006

Orb 33062 Path 26 Block 75

Patadia et al.

Urban Pollution AOD & Aerosol Air Mass Type Mapping
INTEX-B, 06 & 15 March 2006

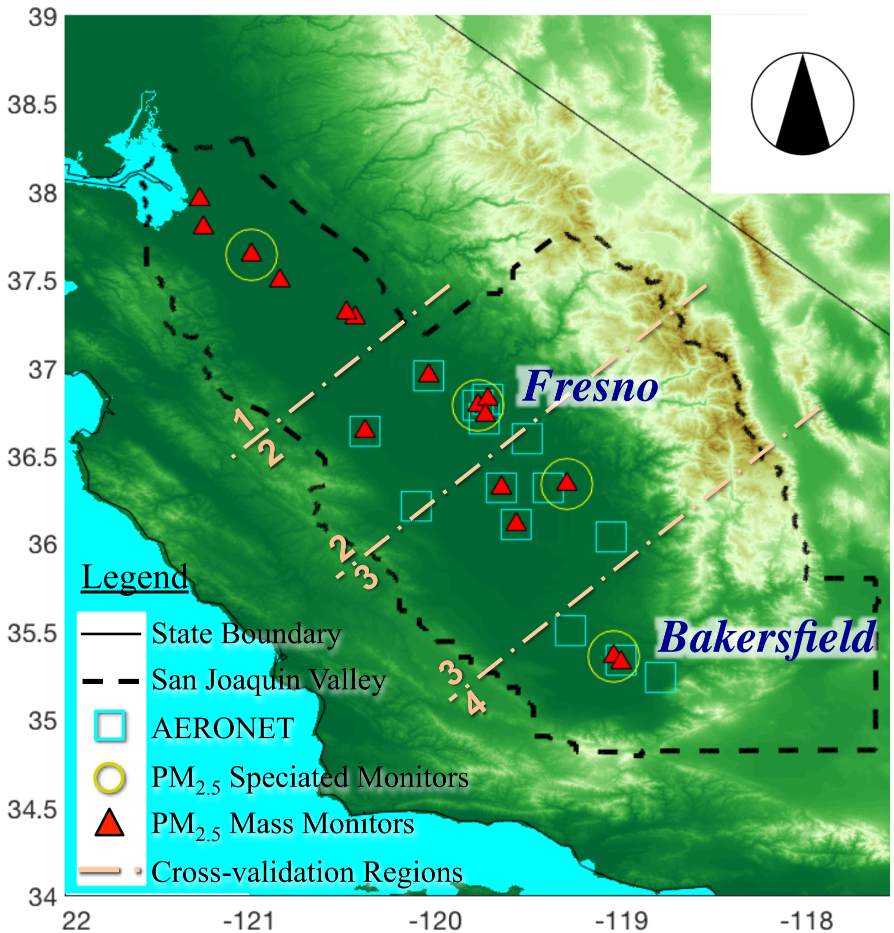


Aerosol Air Masses: ***Dust*** (non-spherical), ***Smoke*** (spherical, spectrally steep absorbing), and ***Pollution*** particles (spherical, spectrally flat absorbing) dominate specific regions

Patadia et al., ACP 2013

Air Quality – Satellite + *In Situ* Constraints on Model

San Joaquin Valley DISCOVER-AQ
January-February 2013



MISR **Research Algorithm** Provides:

- Regional AOD Snapshots
- ***Spherical Abs.***, ***Sph. Non-Abs.***, ***Non-Sph.***

Surface Stations Provide:

- Species-specific Surface Concentrations
- Diurnal Sampling

CMAQ Model Provides:

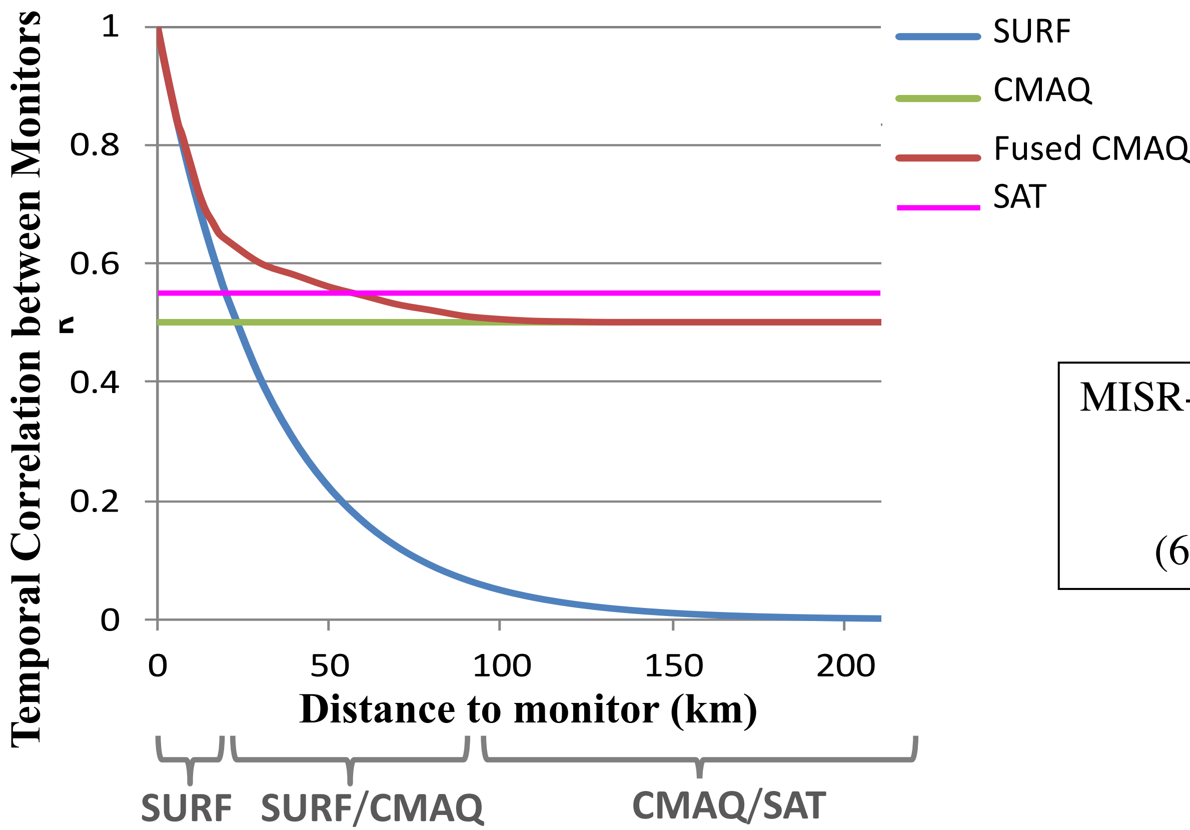
- Vertical Distribution
- Interpolation/Extrapolation in Time & Space

Three cross-validation techniques to evaluate the optimized datasets

- Tenfold 10% withholding applied to all
- Leave-One-Out applied to $PM_{2.5}$ speciated components
- Regional Holdout applied to $PM_{2.5}$

Friberg et al. ACPD 2018

Air Quality – Satellite + *In Situ* Constraints on Model



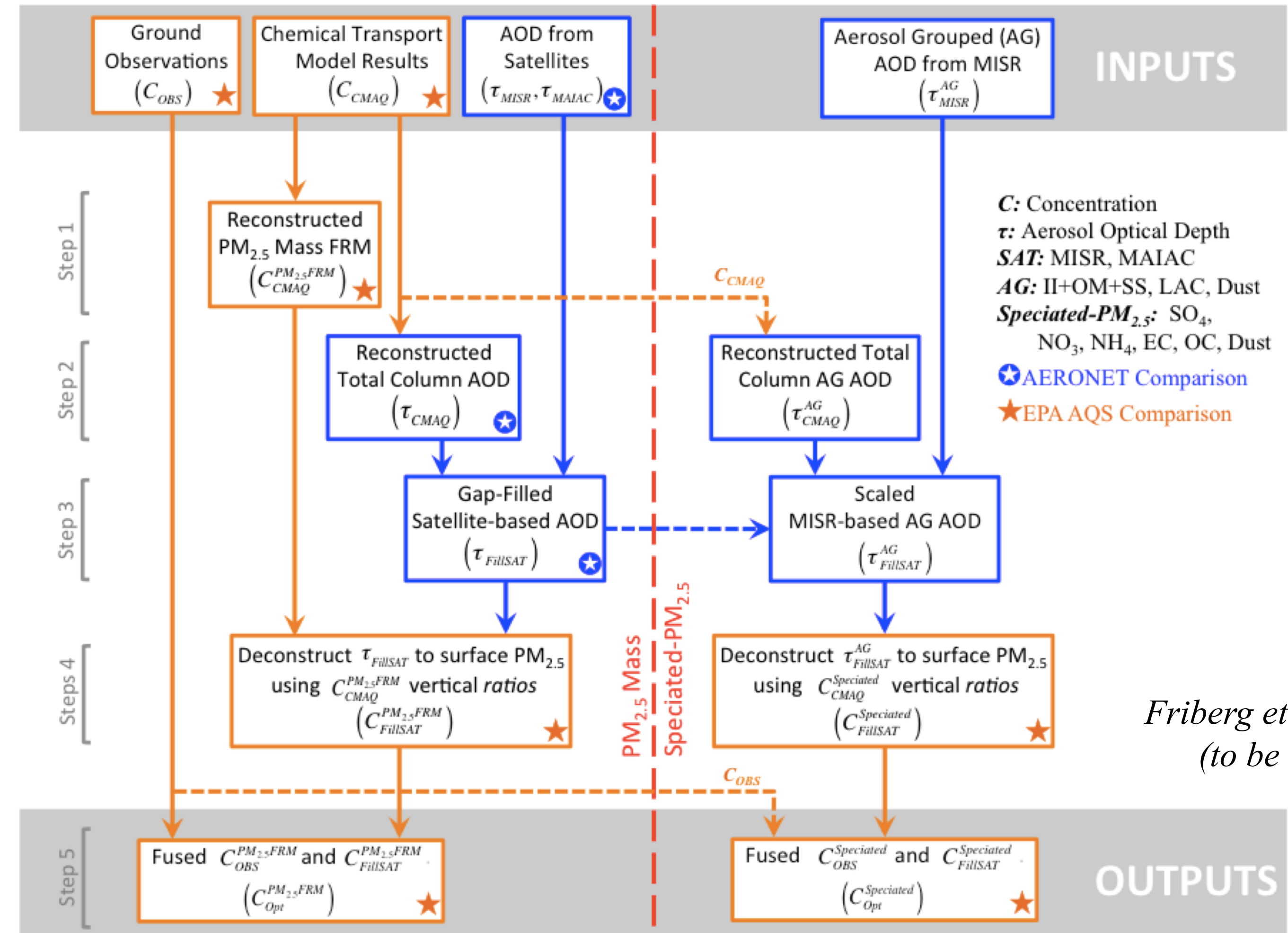
MISR-derived concentrations replace CMAQ when available (6 days in this study)

$$C_{FCMAQ_{s,t}} = \alpha_{t_{trend}} \overline{C_{CMAQ_s}}^{\beta} \left[W_{s,t} \left\{ \frac{C_{OBS_{s_m,t}}}{\overline{C_{OBS_{s_m,t}}}} \right\}_{krig} + (1 - W_{s,t}) \left\{ \frac{C_{CMAQ_{s,t}}}{\overline{C_{CMAQ_s}}} \right\} \right]$$

Daily Optimized Fused Fields — *Estimated Annual Mean Fields* — *Weighting Factor* — *Daily Interpolated OBS Ratio Fields* — *Daily Adjusted CMAQ Results Ratio Fields*

Friberg et al., (2016; 2017; 2018)

Air Quality – Satellite + *In Situ* Constraints on Model



Friberg et al., ACP, 2018 (to be submitted.)

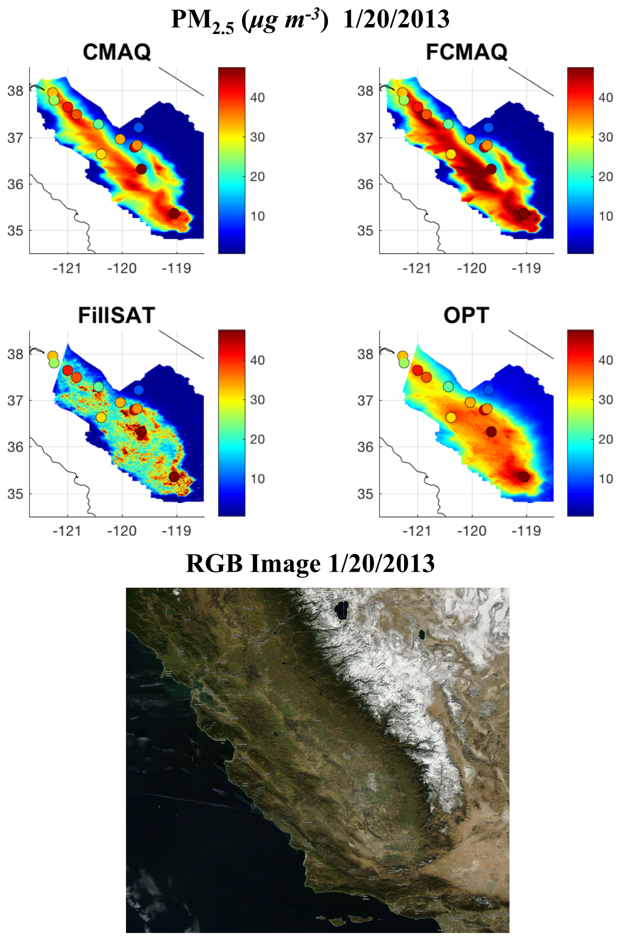
• ***Physically based*** method, integrating ***ground-station + satellite data*** with an air quality model (CMAQ)

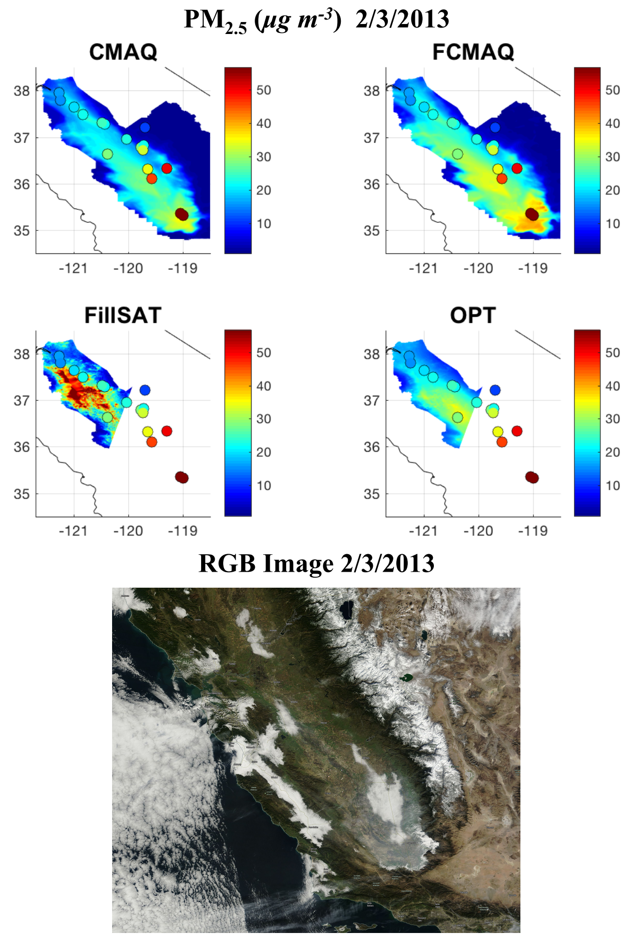
• Satellite snapshots of ***AOD*** & ***qualitatively speciated AOD*** improve results over ***extended areas***

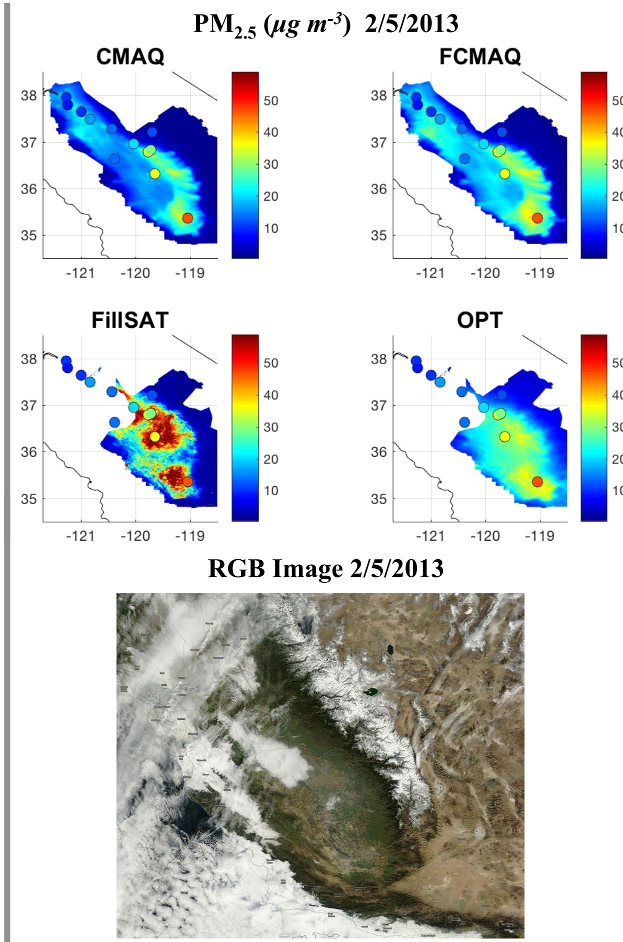
• Complements ***statistically based methods***

Friberg et al. ACPD 2018

PM2.5: (1) Model (2) Model + Surface Data (3) Model + MISR/MODIS (4) All Three

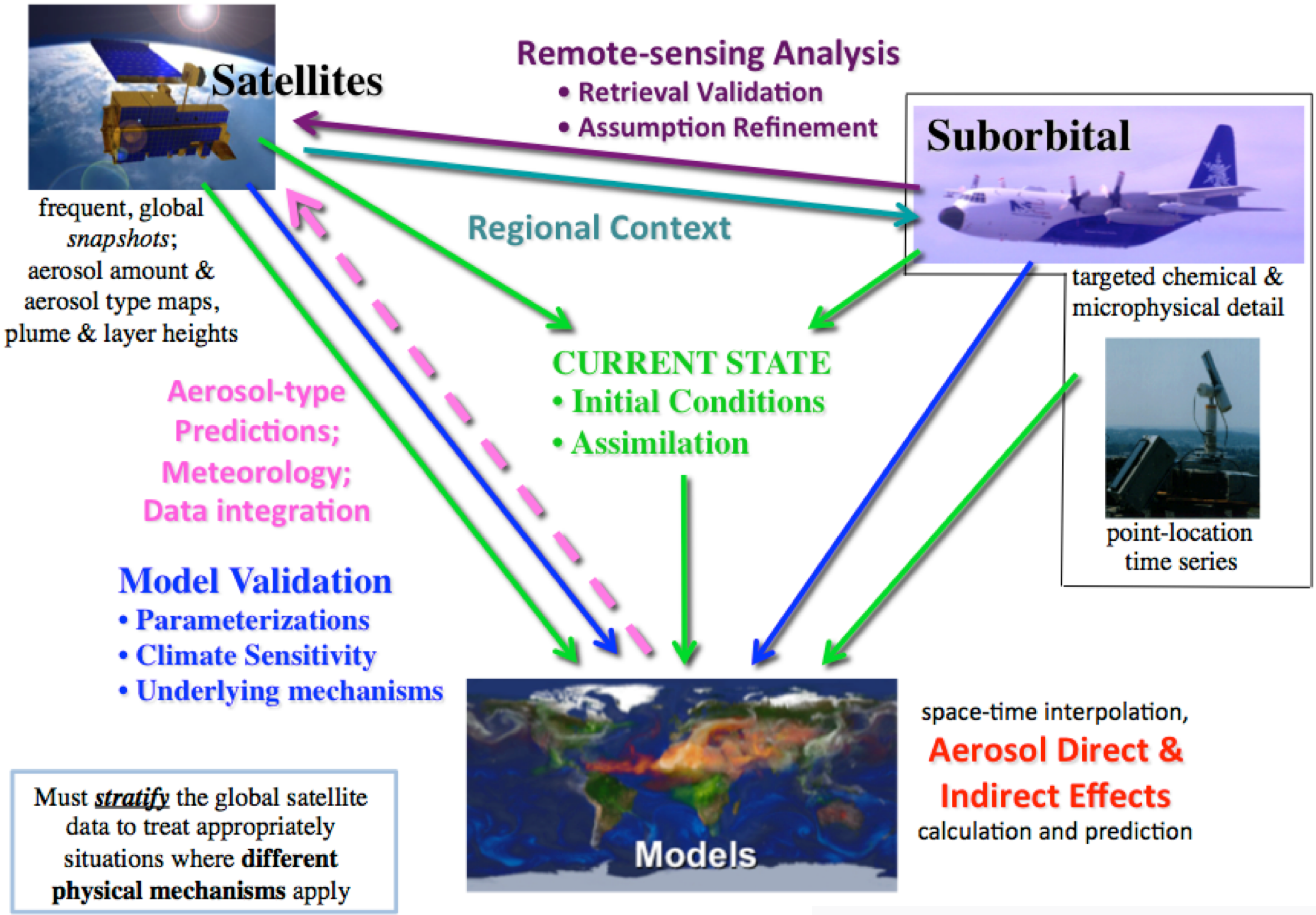






- ***Station data*** anchors species-specific surface concentrations, time series
- ***Satellite data*** captures spatial gradients, urban hot-spots, topographic control of dispersion

Friberg et al. ACPD 2018



Adapted from: Kahn, Survy. Geophys. 2012