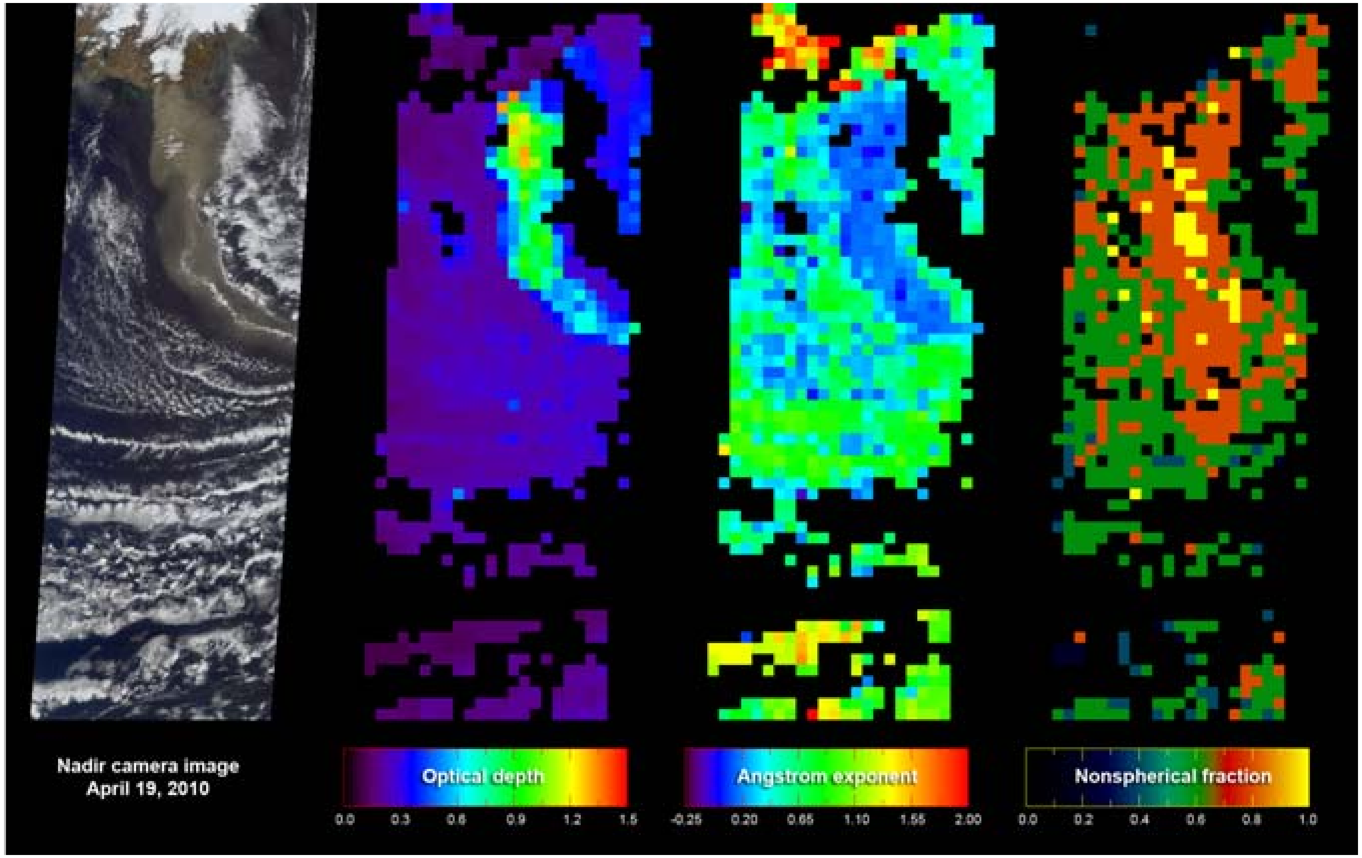
Aerosol Constraints from Multi-angle Imaging That Modelers Can Use

Ralph Kahn *NASA Goddard Space Flight Center*

and ***The MISR Team****, JPL & GSFC*

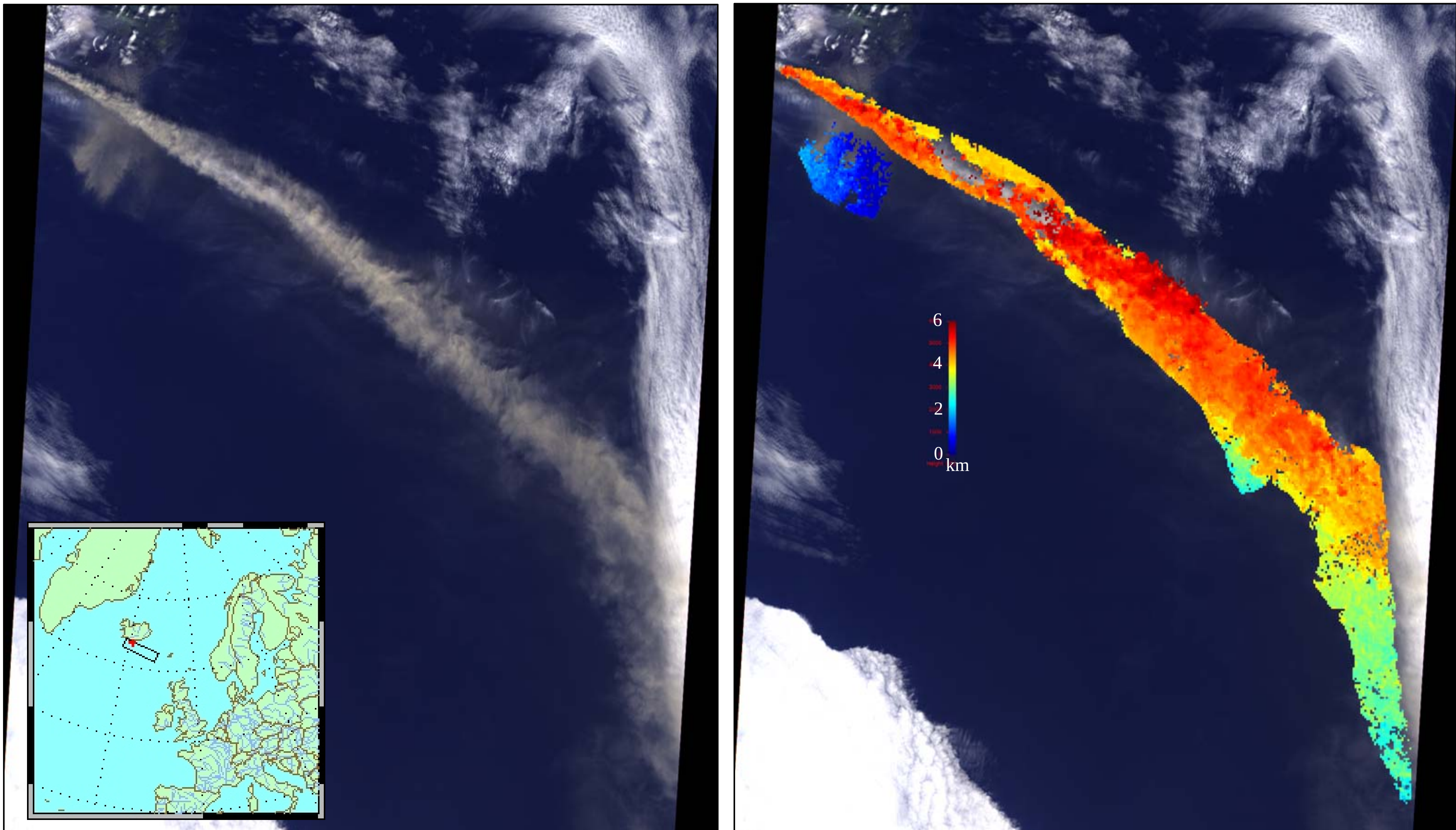


Eyjafjalljökull Volcano Ash Plume – MISR Aerosol Retrieval – April 19, 2010

MISR Team, JPL and GSFC

MISR Stereo-Derived Plume Heights

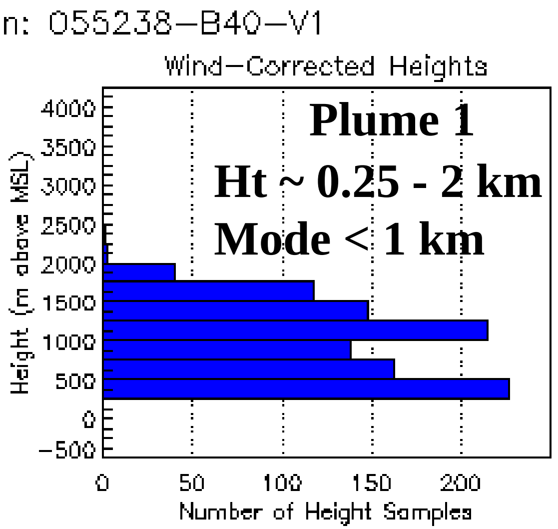
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



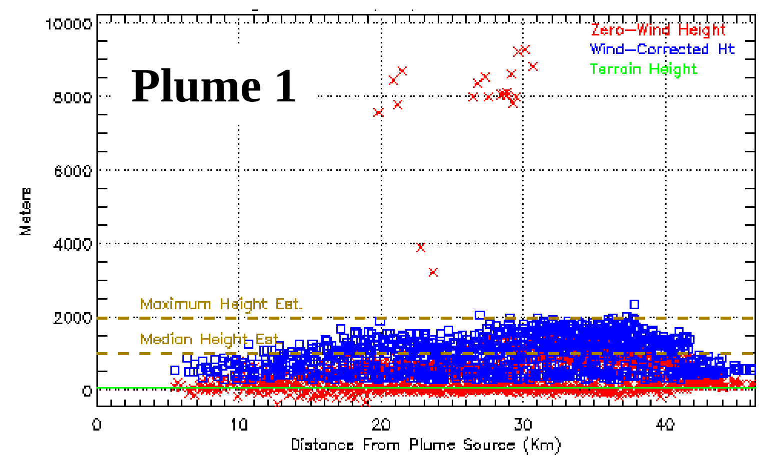
D. Nelson and the MISR Team, JPL and GSFC

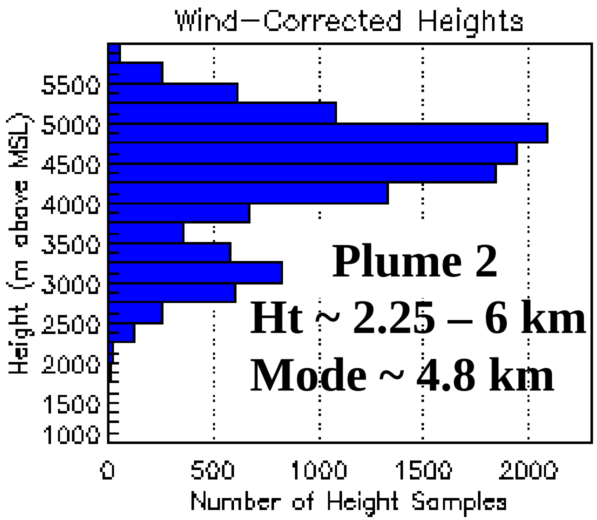
MISR Stereo-Derived Plume Heights

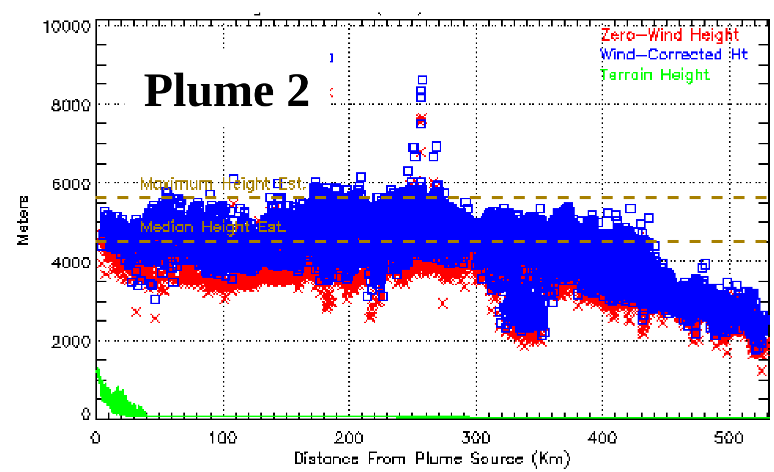
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



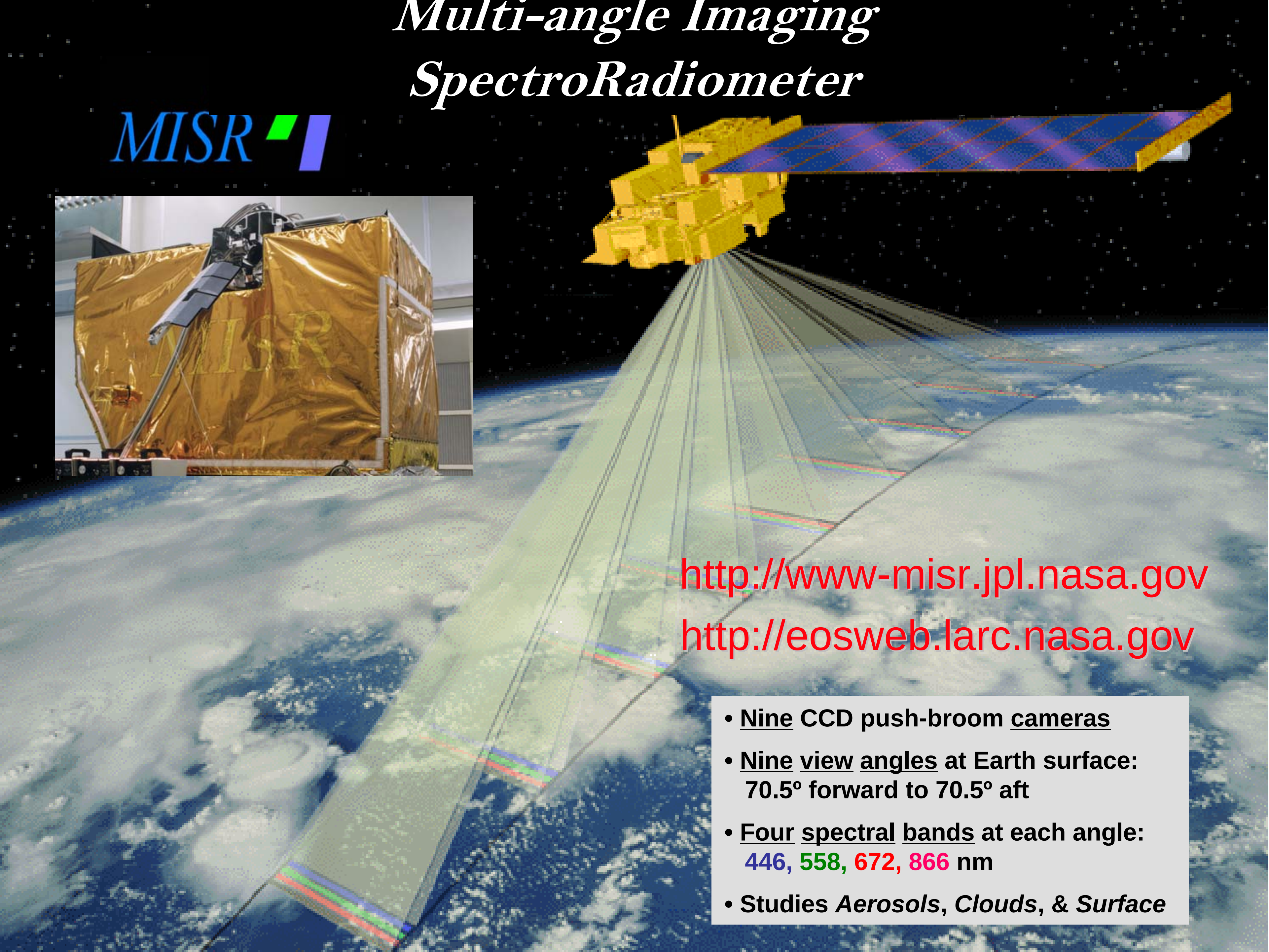
Height: Blue = Wind-corrected



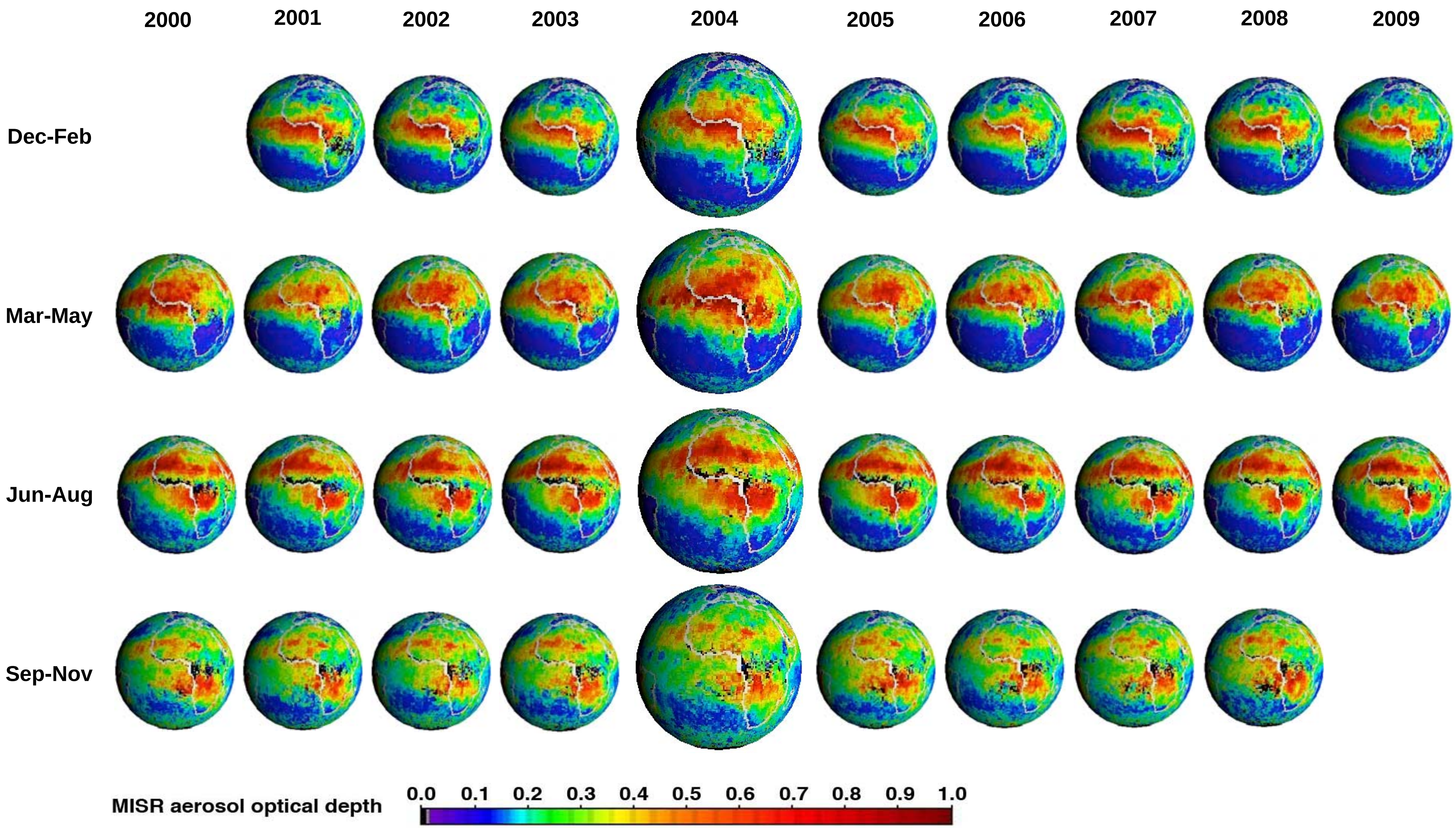




D. Nelson and the MISR Team


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

Ten Years of Seasonally Averaged Mid-visible Aerosol Optical Depth from **MISR**

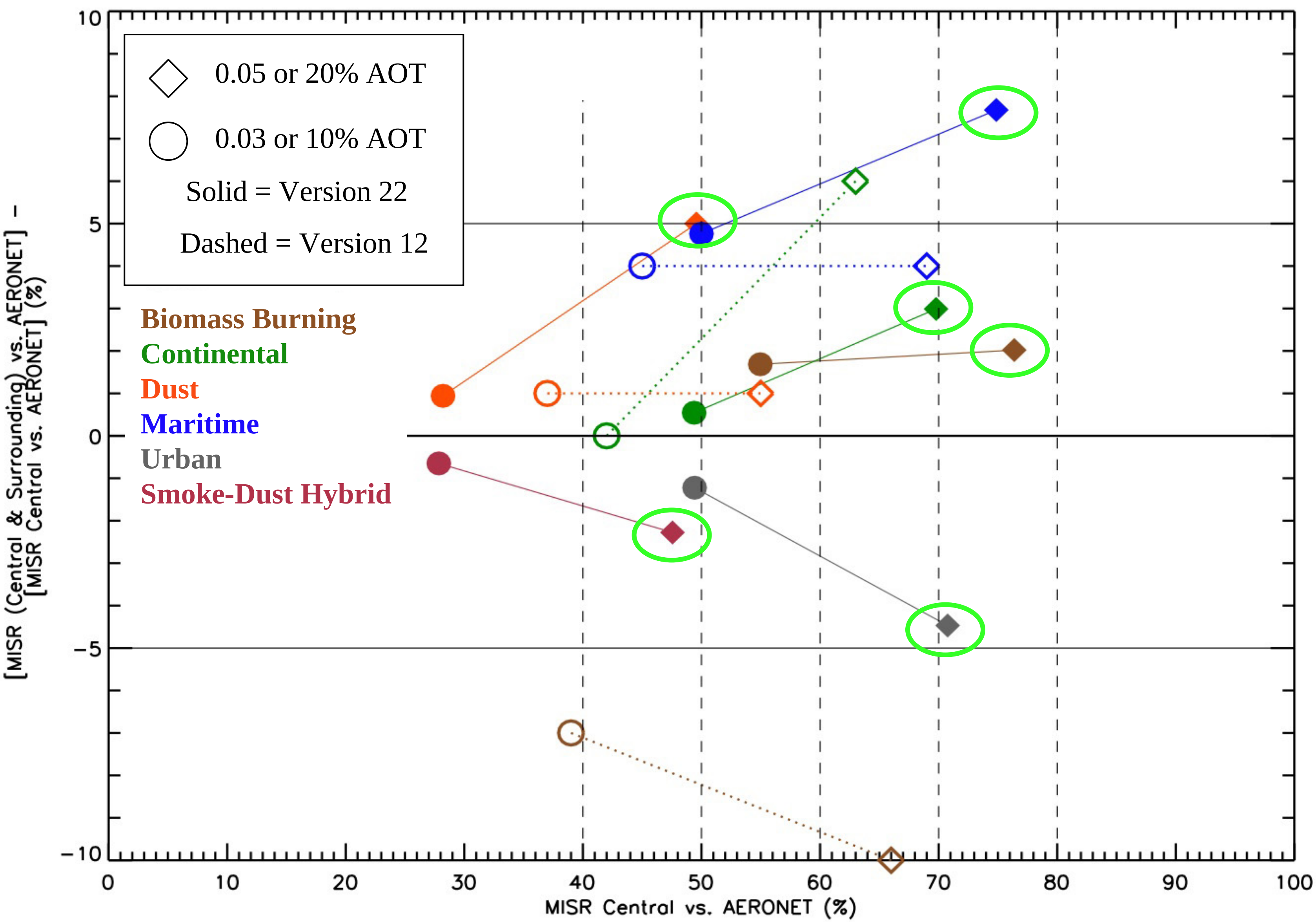


…includes bright desert dust source regions

MISR Team, JPL and GSFC

MISR-AERONET AOD Comparison for 5,156 Coincidences

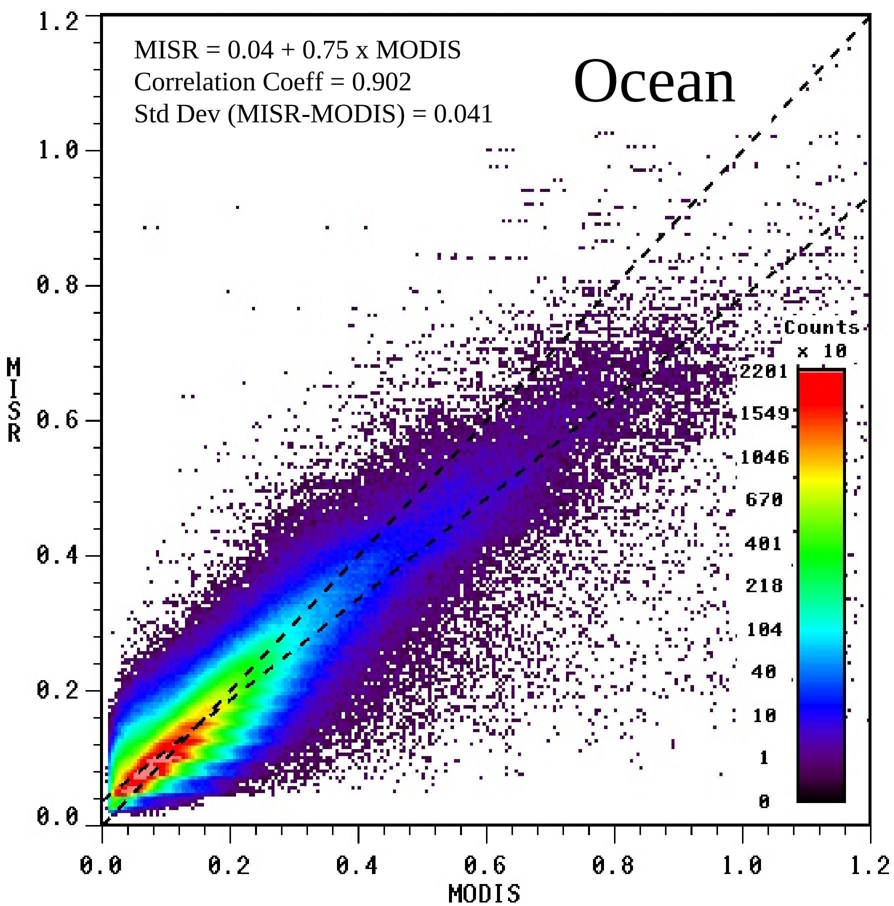
MISR Version 22 – Stratified by expected aerosol air mass type

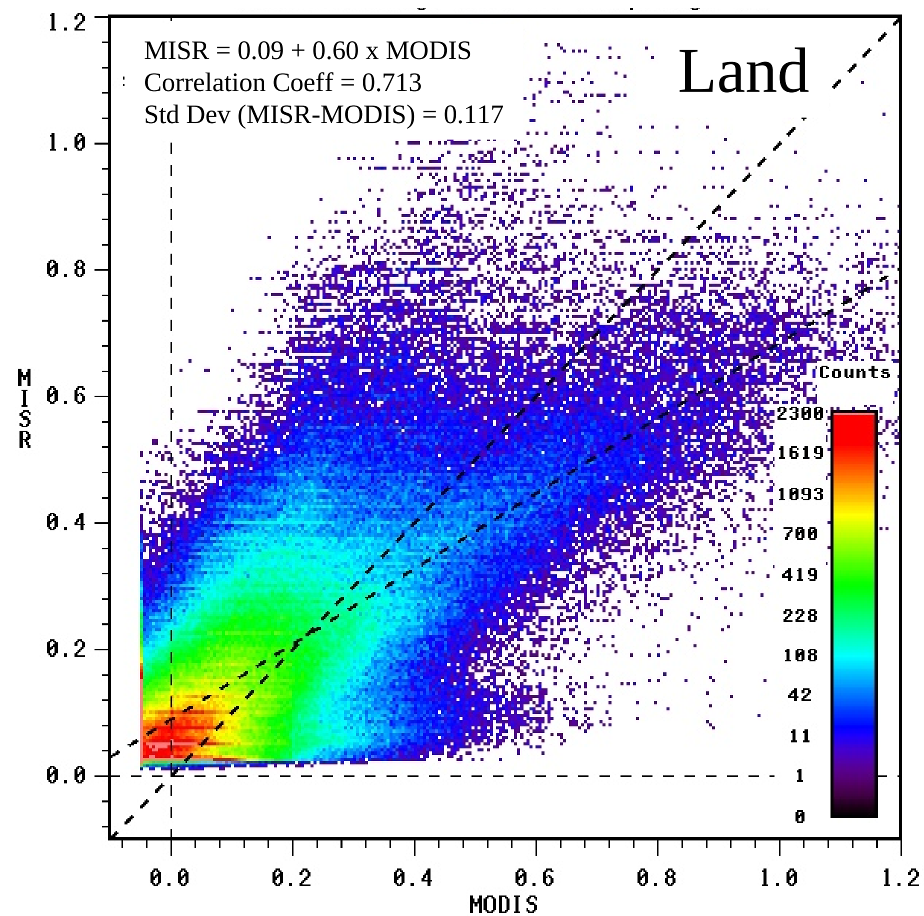


Kahn, Gaitley et al., JGR 2010

MISR-MODIS *Aerosol Optical Depth* Comparison

[MISR V22 vs. MODIS/Terra Collection 5; January 2006 Coincident Data]



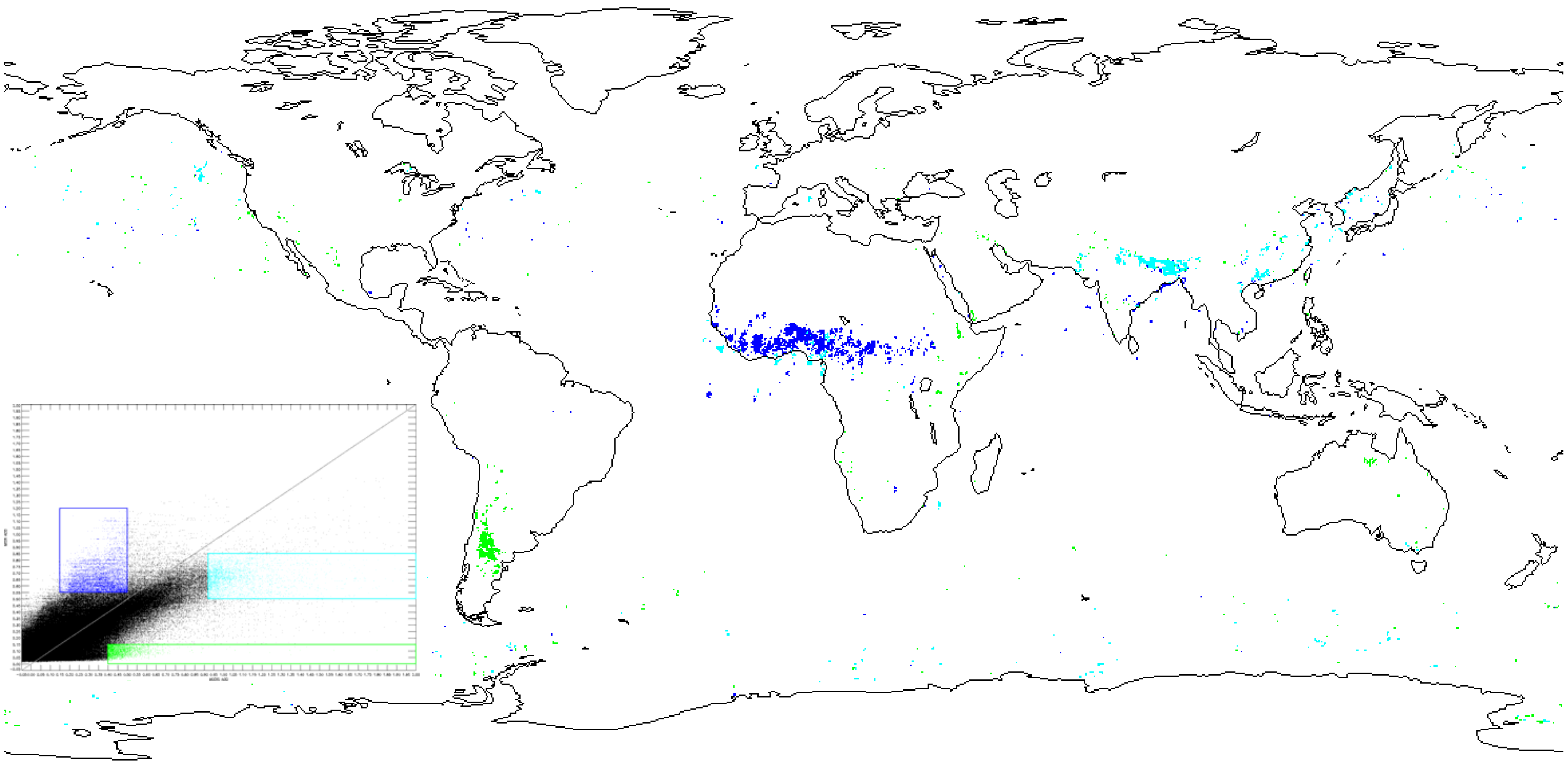


Over-ocean regression coefficient **0.90**
Regression line slope 0.75
MODIS QC ≥ 1

Over-land regression coefficient **0.71**
Regression line slope 0.60
MODIS QC = 3

Kahn, Nelson, Garay et al., TGARS 2009

MISR-MODIS Coincident AOT ***Outlier Clusters***



Dark Blue [MISR > MODIS] – N. Africa ***Mixed Dust & Smoke***

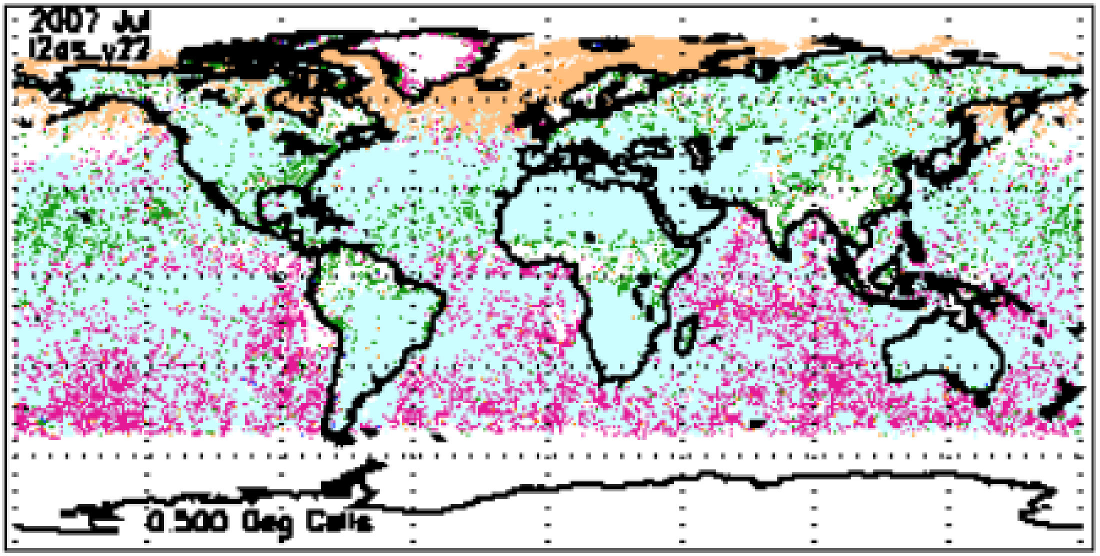
Cyan [MODIS > MISR, AOD large] – Indo-Gangetic Plain ***Dark Pollution Aerosol***

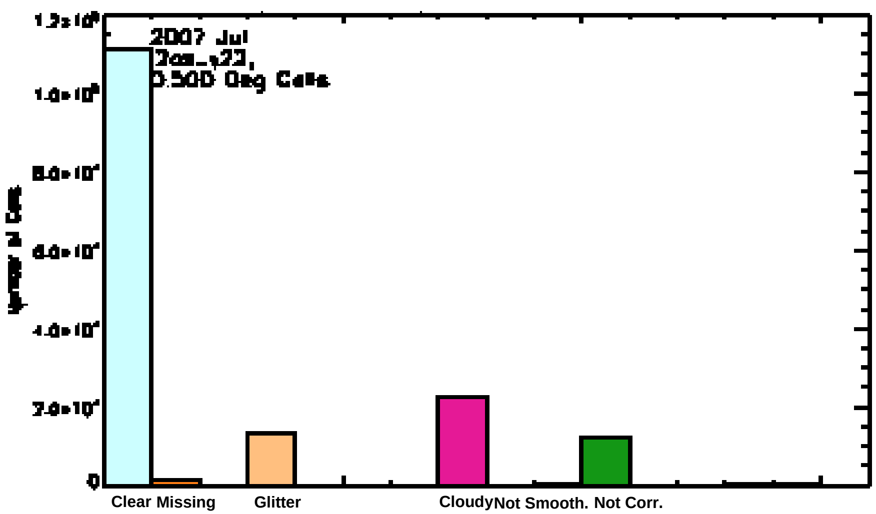
Green [MODIS >> MISR] – Patagonia and N. Australia ***MODIS Unscreened Bright Surface***

Kahn et al., TGARS 2009

Most Frequent Mask – Cf (60˚ forward) Camera

*MISR Version 22 – **July 2007*** [*1.1 km pixels, aggregated to 0.5 x 0.5 ˚cells*]





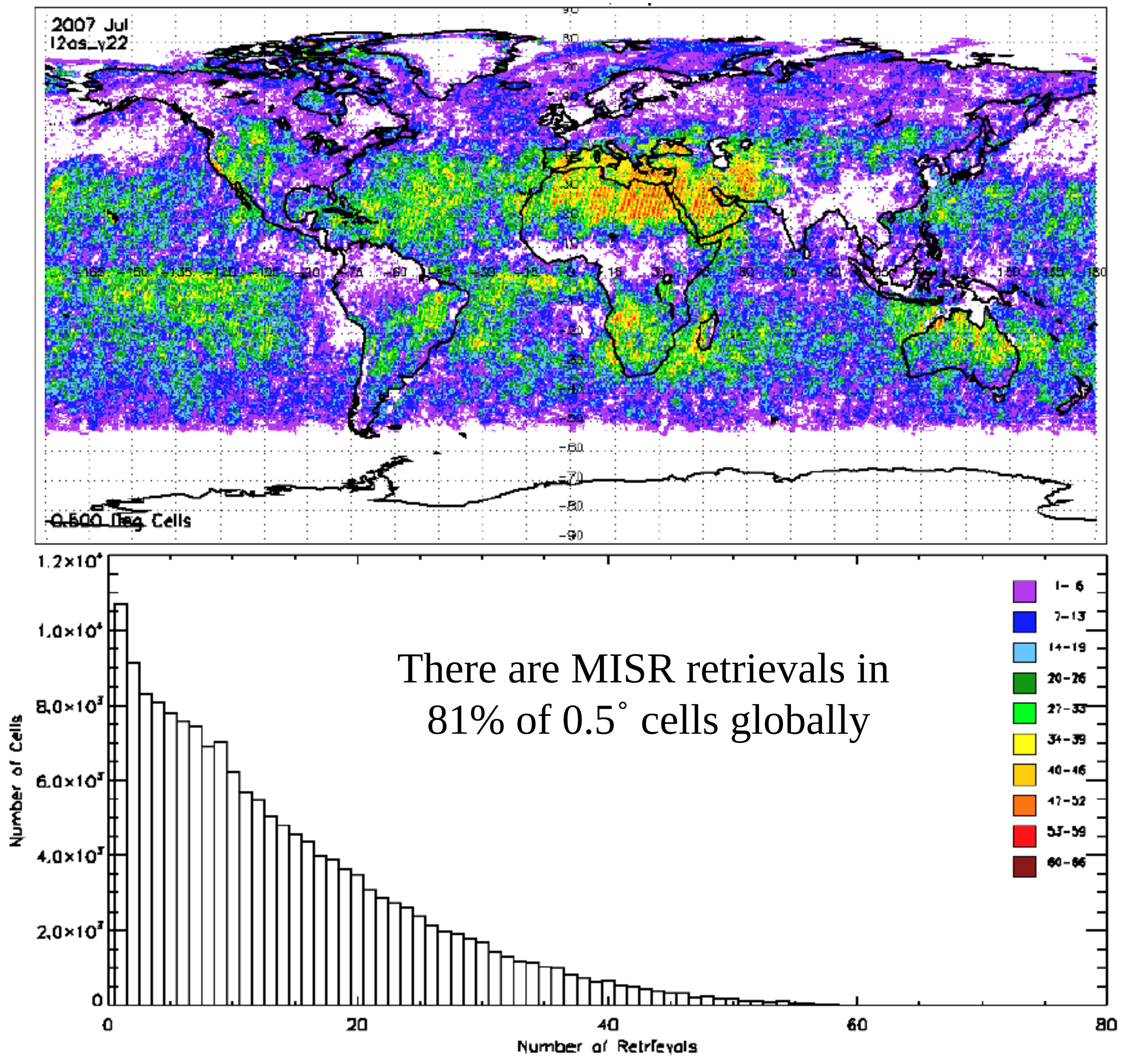
Angular Smoothness Test – Polynomial fit to 4 camera radiances at a time, 1.1 km data

Angular Correlation Test – Each camera vs. 9-cam average of 16 (4 × 4) 275 m pixel arrays

Kahn, Gaitley et al., in prep.

Number of Retrievals Per Grid Cell

MISR Version 22 – July 2007 [*Aggregated to 0.5 x 0.5 °cells*]

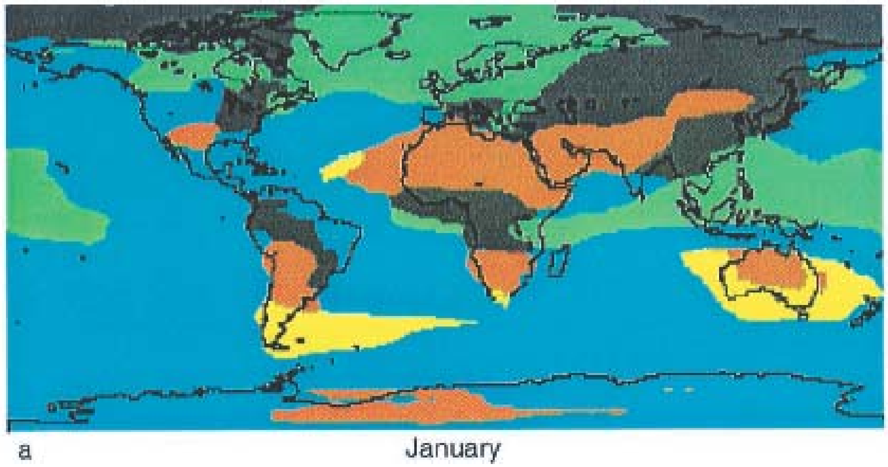


Although ***~85% of 1.1 km pixels*** are rejected overall, ***<u>nearly the entire planet is covered</u>*** at 0.5° resolution, except for perpetually cloudy, ice-covered, or mountainous regions

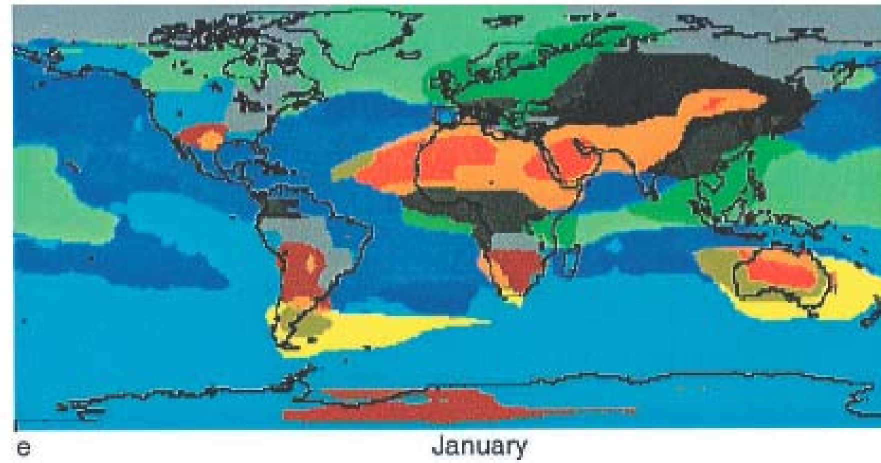
Kahn, Gaitley et al., in preparation

With ***current*** technology, we are aiming for Regional-to-Global

Aerosol Type Discrimination something like this…



5 Groupings Based on Aerosol Properties



13 Groupings Based on Aerosol Properties

Global, **Monthly** Aerosol Maps Based on Expected MISR Sensitivity

The examples shown here are simulated from aerosol transport model calculations…

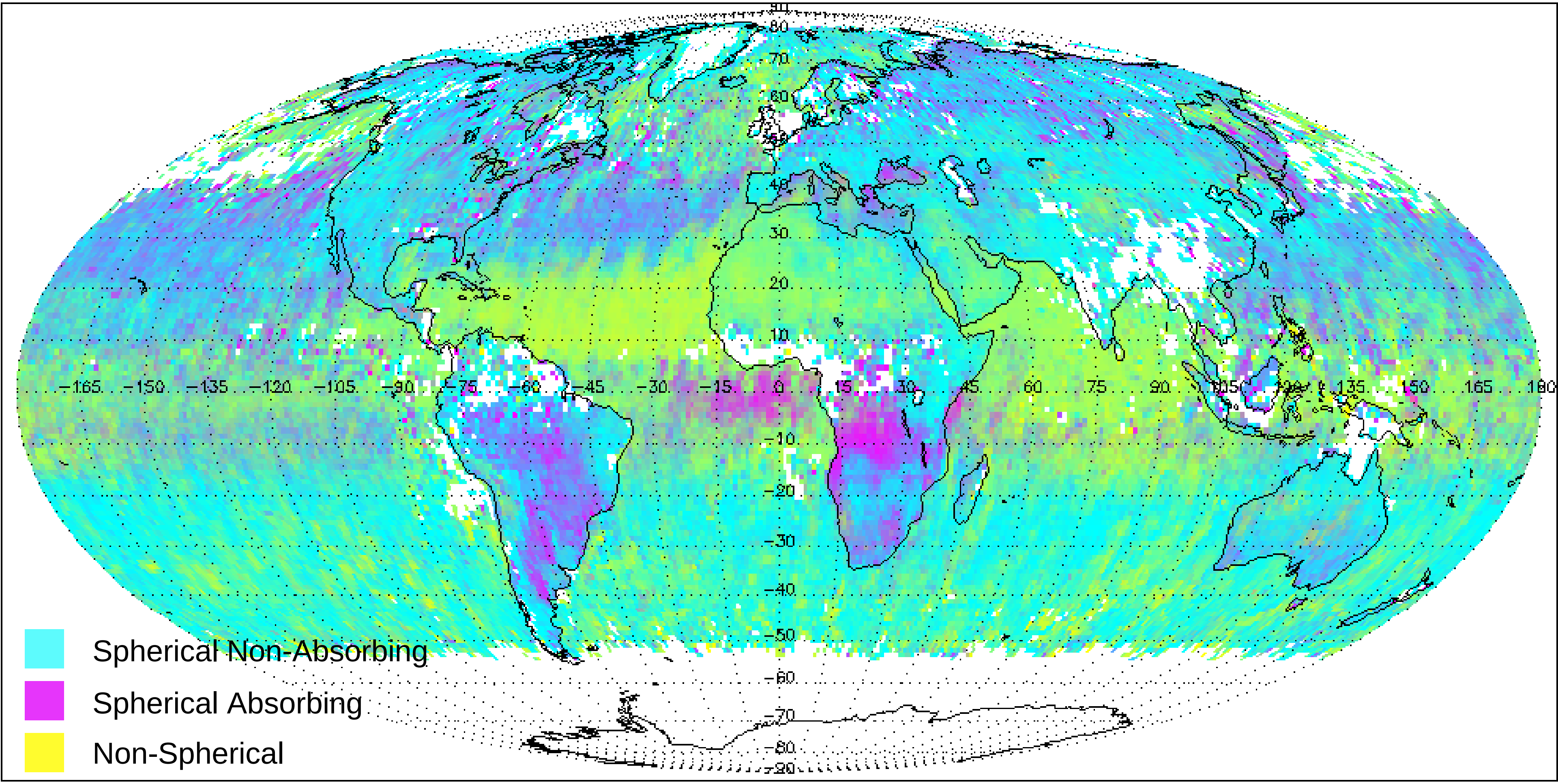
- With MISR – ***About a dozen Aerosol Air Mass type distinctions***, based on 3-5 size bins, 2-4 bins based on SSA, and spherical vs. non
- Sensitivity depends on conditions; ***AOD >~0.15*** needed, etc.

→Adding ***NIR & UV*** wavelengths, ***Polarization*** should increase this capability

Kahn et al., JGR 2001

MISR ***Aerosol Type*** Distribution

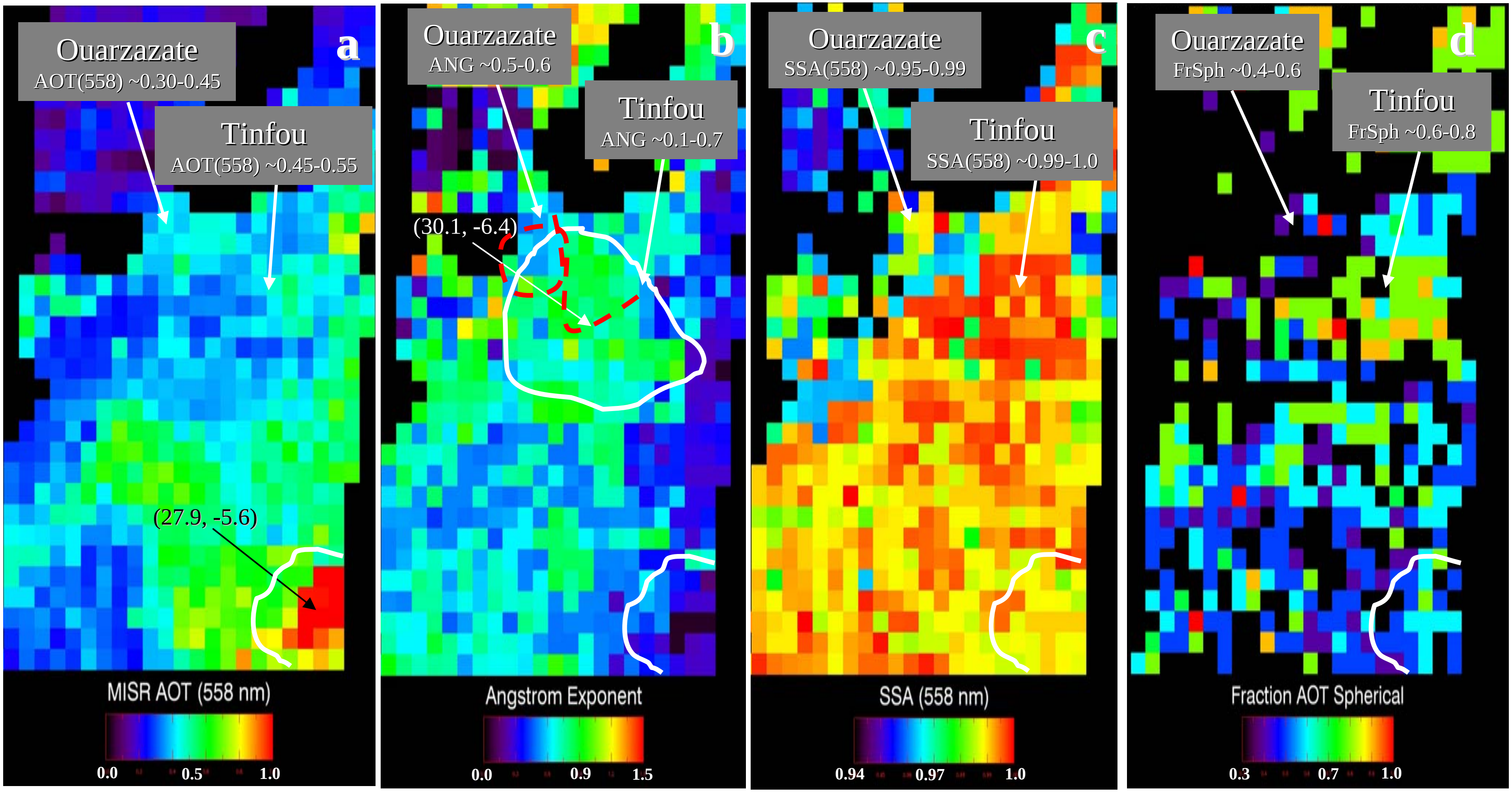
MISR Version 22, July 2007



Kahn, Gaitley, Garay, et al., JGR 2010

MISR SAMUM Aerosol Air Masses (V19) - June 04, 2006

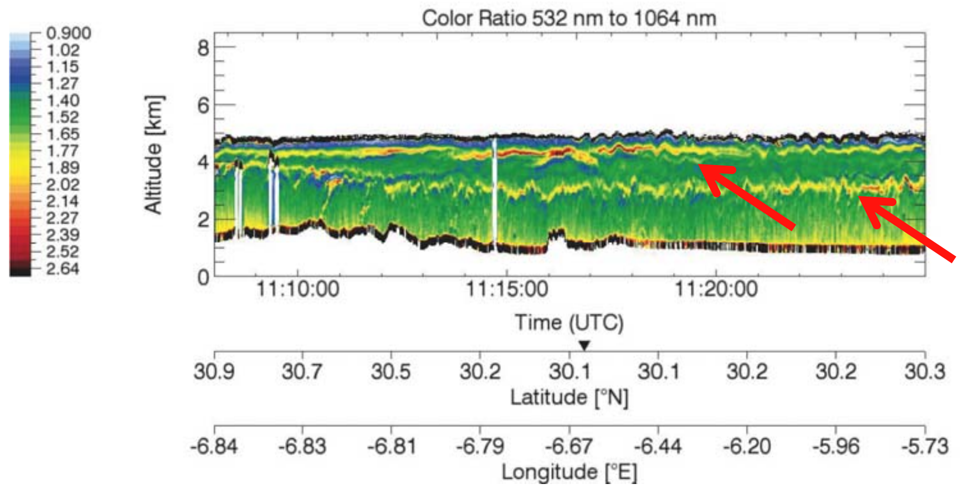
Orbit 34369, Path 201, Blocks 65-68, 11:11 UTC



- A **dust-laden density flow in the SE** corner of the MISR swath
- **High SSA, ANG** & **Fraction Spherical** region SE of Ouarzazate, includes Zagora

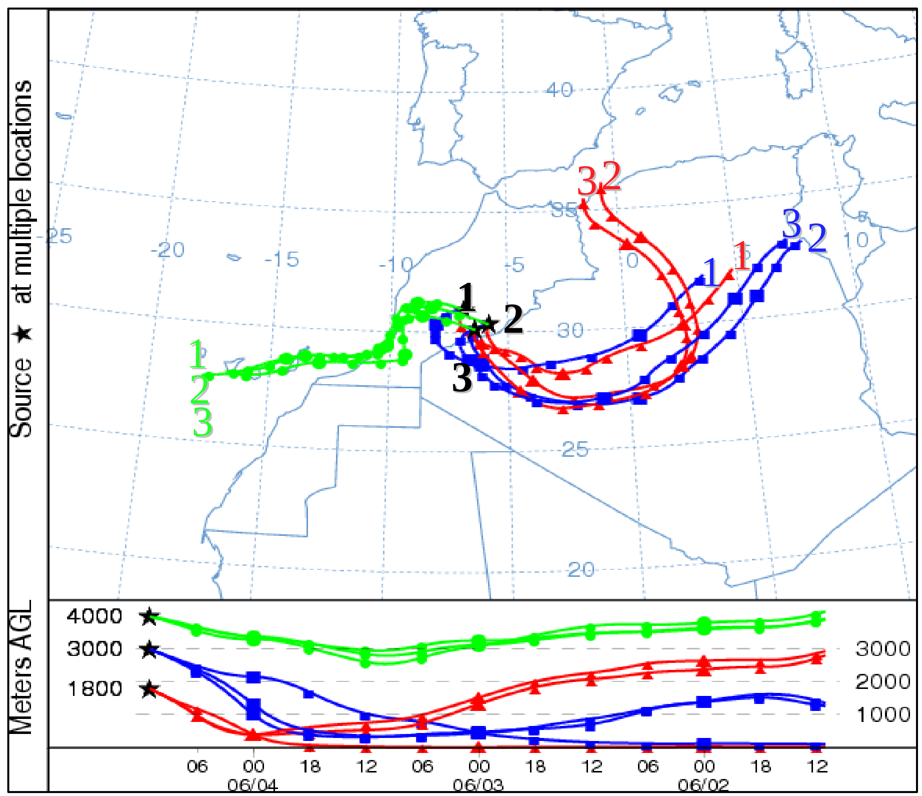
Kahn et al., Tellus 2009

MISR SAMUM Aerosol Air Mass Validation - June 04, 2006



<u>Falcon F-20 HSRL</u>

- Thin layers of small, bright particles



<u>NOAA/HYSPLIT Back Trajectories</u>

-Source in N Algeria for 2, 3 but not 1.

Kahn et al., *Tellus* 2009

MISR Aerosol V22 Algorithm Upgrade Priorities
Supporting Dust, Smoke, & Aerosol Pollution Applications

- Based on ***10 Years of Validation*** Data

-- ***Low-light-level*** gap & quantization noise

-- ***High-AOD underestimation*** of AOD (*missing* ***low-SSA*** *particles; algorithm issues*)

-- Missing ***Medium-mode*** particles (r_{eff} ~ 0.57, 1.28 μm)

-- More spherical, ***absorbing particles*** (*SSA* ~ 0.94, 0.84, maybe 0.74)

-- ***Mixtures of smoke & dust*** analogs; more ***Bi- and Tri-modal*** spherical mixtures

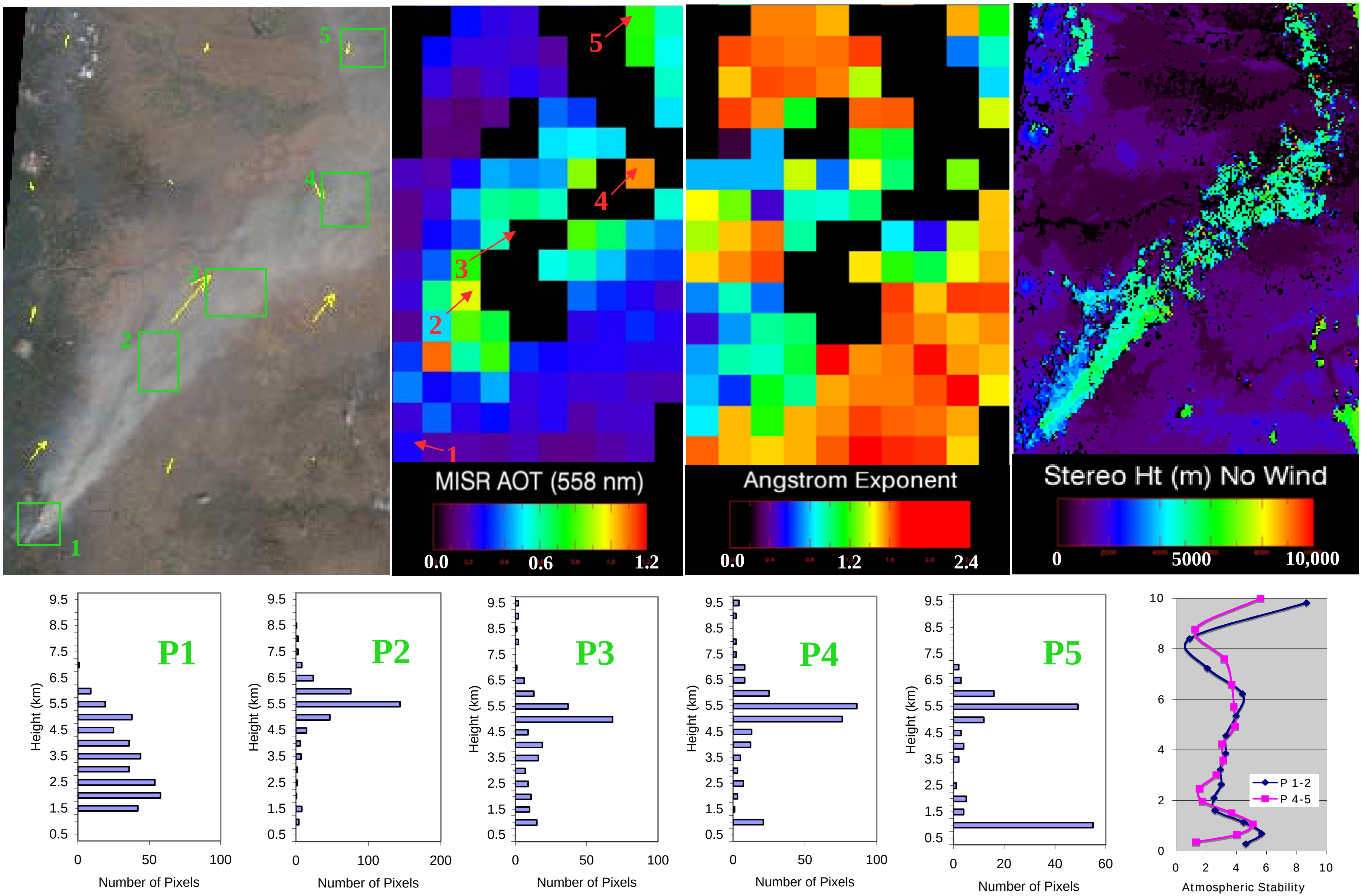
-- ***Flag*** indicating when there is insufficient sensitivity for ***particle property*** retrieval (possibly different retrieval path under this condition)

-- Lack of a good ***Coarse-mode Dust Optical Analog*** remains an issue

Kahn, Gaitley, Garay, et al., JGR 2010

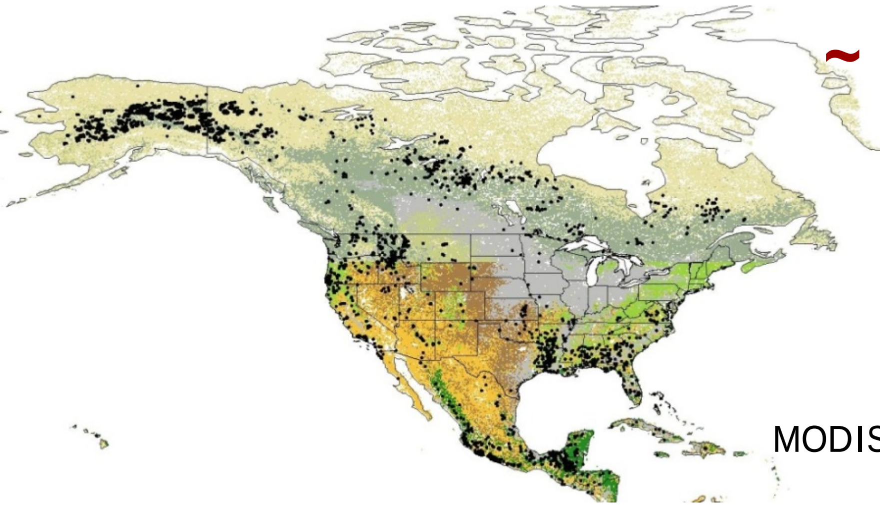
Oregon Fire Sept 04 2003

Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)



Kahn, et al., JGR 2007

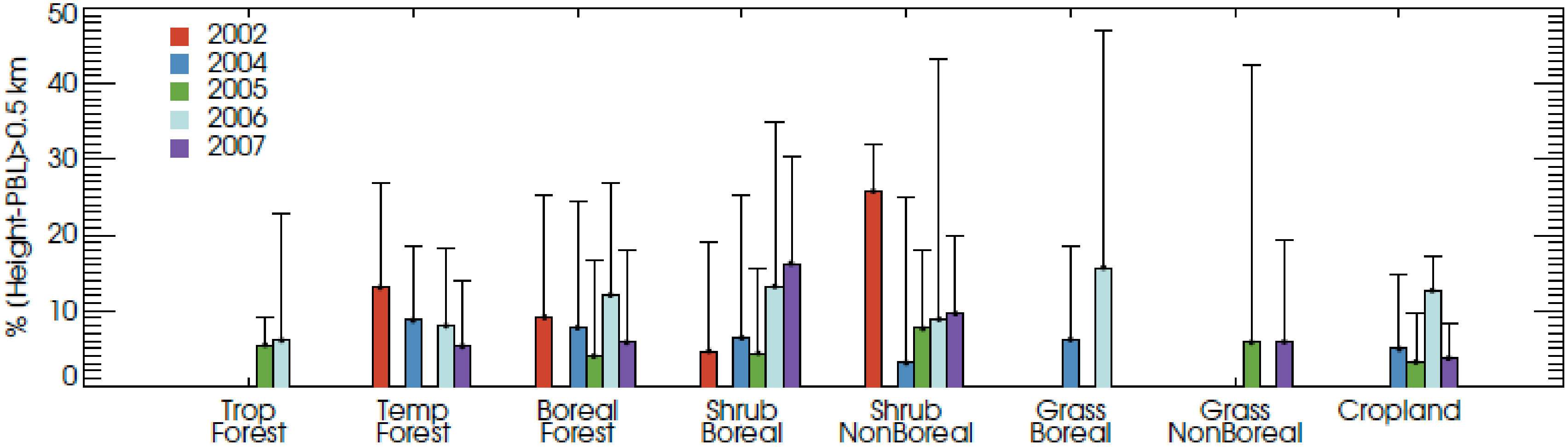
N. America Plume Injection Height Climatology



~ 3400 plumes digitized over North America for 2002, 2004-2007

MODIS IGBP land cover map
(1x1 Km res)

- Tropical Forest
- Temperate Forest
- Boreal Forest
- Boreal Shrubland
- Non-Boreal Shrubland
- Boreal Grassland
- Non-Boreal Grassland
- Cropland

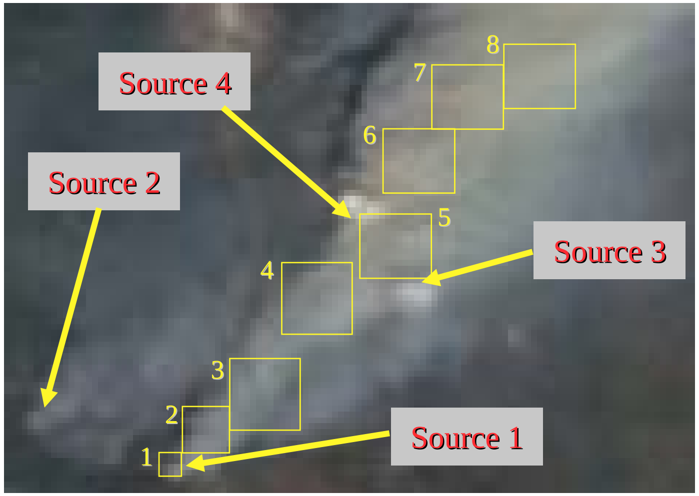


Percent of plumes >0.5 km ***above BL***, stratified by year and vegetation type

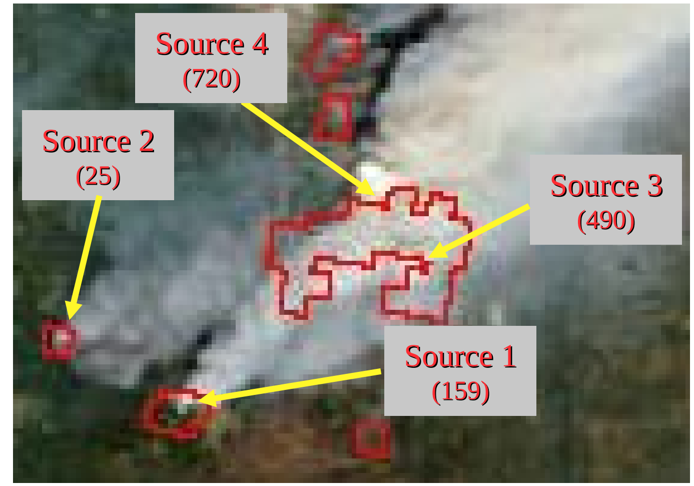
Val Martin et al. ACP 2010

Detail of Wildfire Source Region

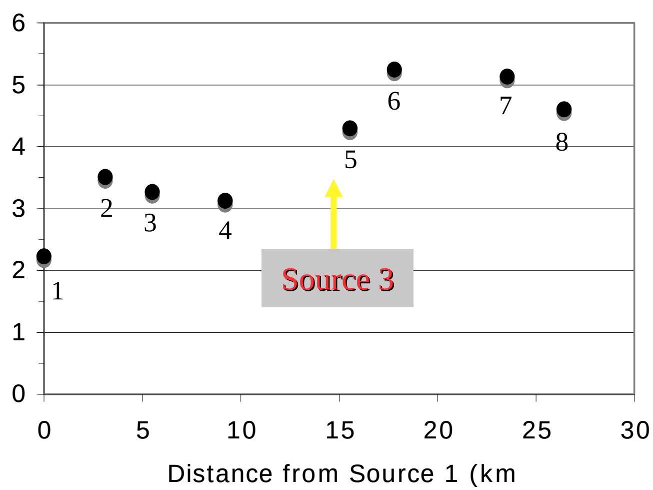
Oregon Fire Sept 04 2003



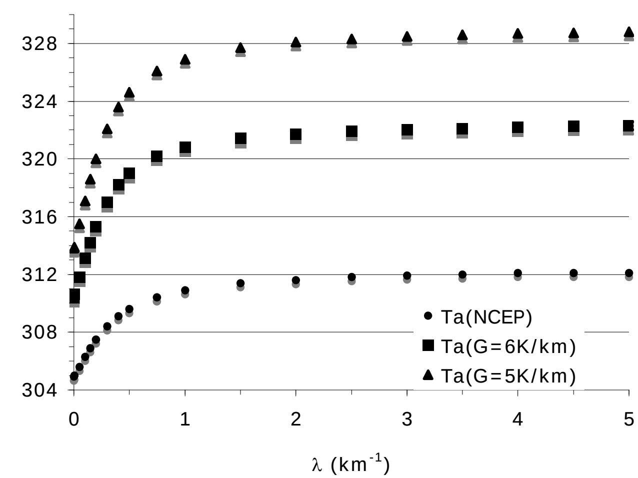
MISR Nadir **275 m** Image



MODIS Image + **Fire Power**



MISR **Plume Heights** for Sub-patches

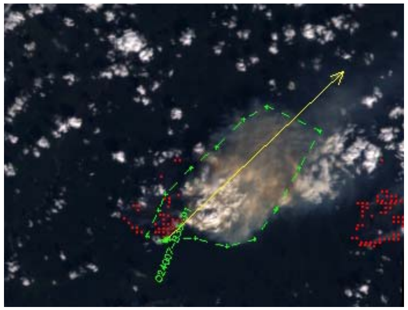


Very Simple Plume Parcel Model

→ ***Broad swath + high spatial resolution*** needed to characterize sources

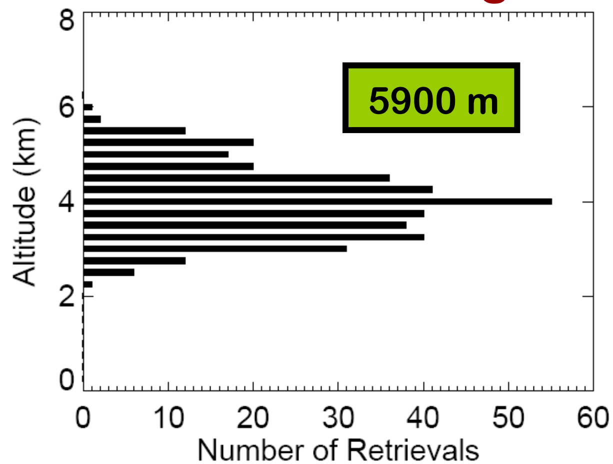
Evaluation of a 1D plume-rise model: Towards a parameterization of smoke injection heights

MISR Smoke Plume

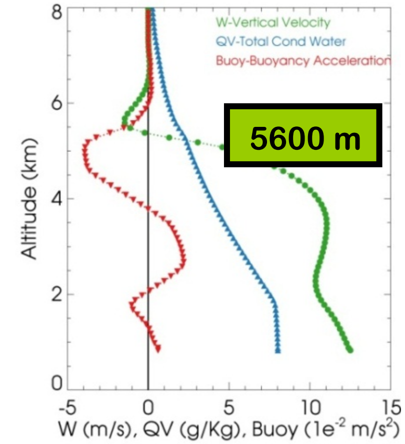


Fire Area = 300 Ha
FRP (~Heat Flux)= 18 kW/m^2

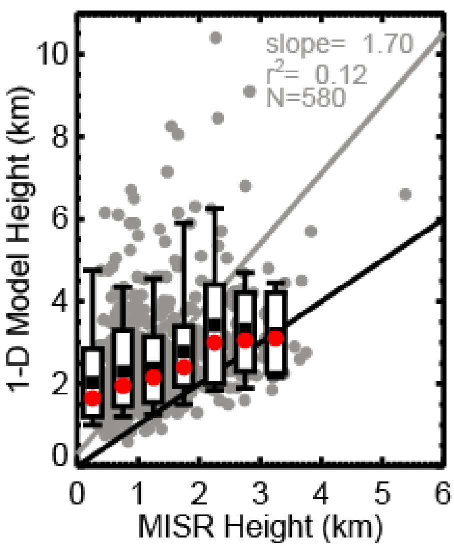
MISR Retrieved Heights



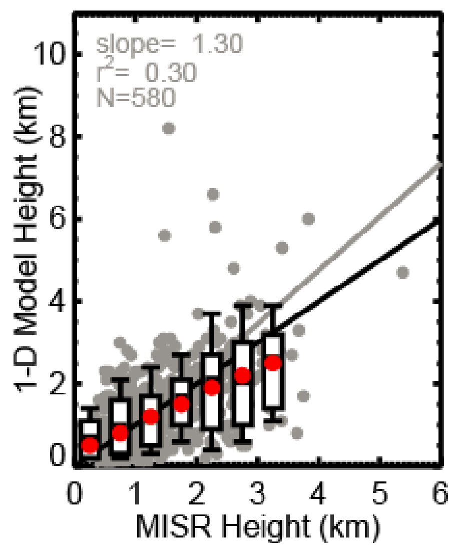
1D Plume-rise Model



Fire properties typically used overestimate injection heights



Improving parameterization using MISR and MODIS

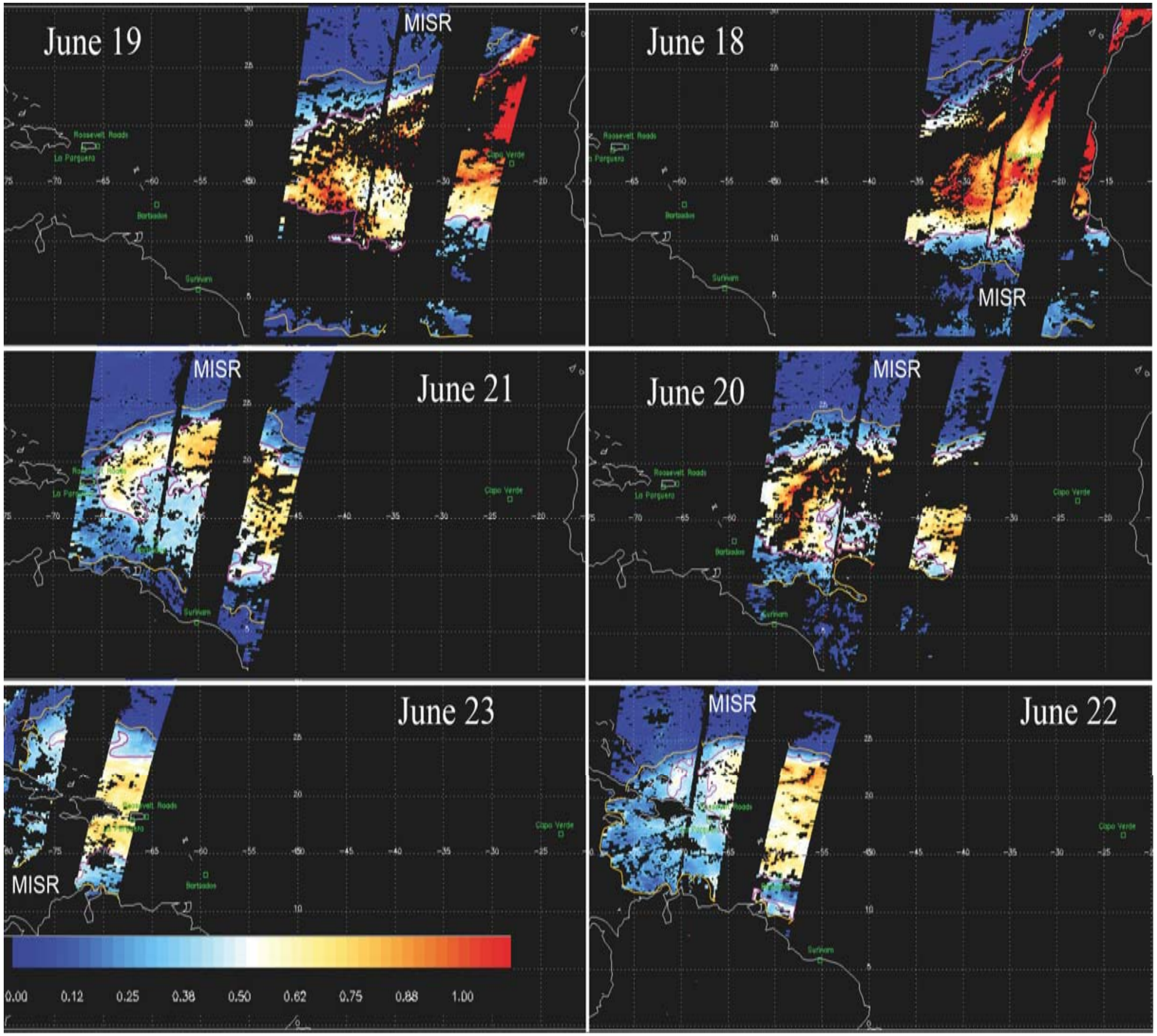


Factors Considered:
- Fire Area
- FRP
- Veg. Type
- Fuel Load/ Combust. Efficiency
- Fuel Moisture
- BL Height/Atm. Stab.
- (•Entrainment Param.)
- (•Latent Heat)
- (•Ambient Wind)

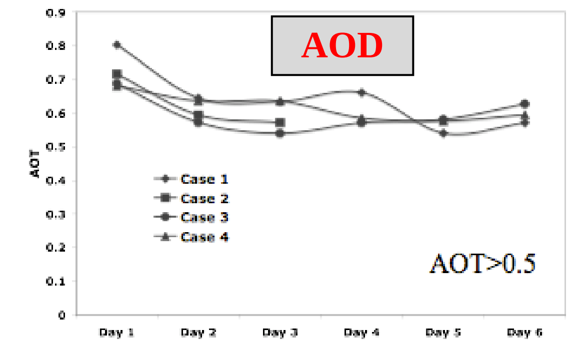
Val Martin et al. in preparation

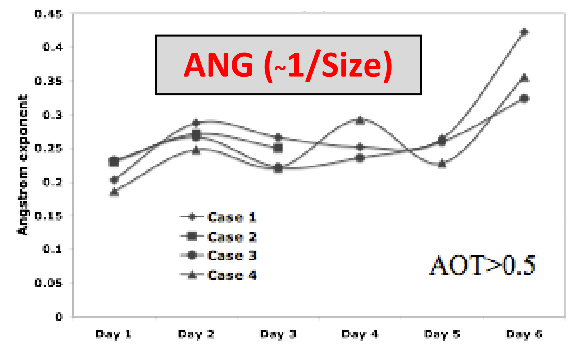
Constraining Aerosol Sources, Transports, & Sinks

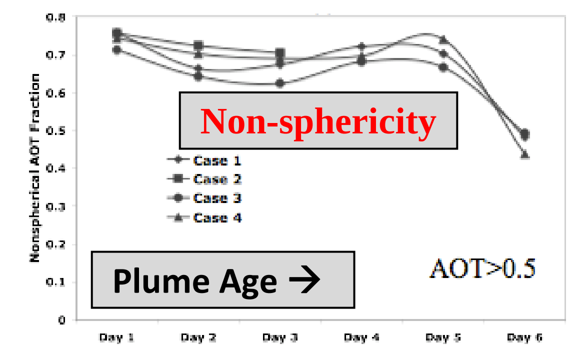
Complementary MISR & MODIS AOD; Saharan Dust Plume over Atlantic June 19-23, 2000



Contours: AOT=0.15 (yellow); AOT=0.5 (purple)





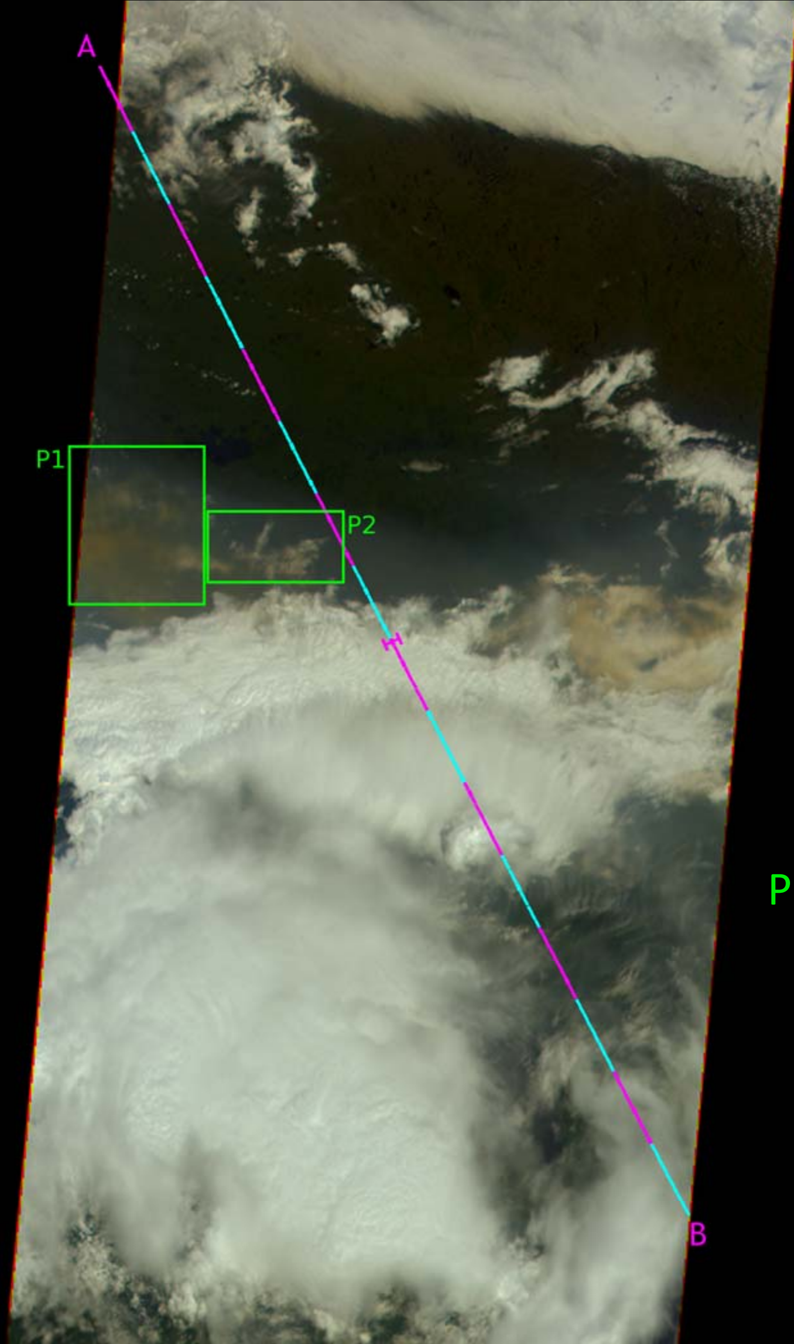


Kalashnikova and Kahn, JGR 2008

ARCTAS – Central Canada 01 July 2008

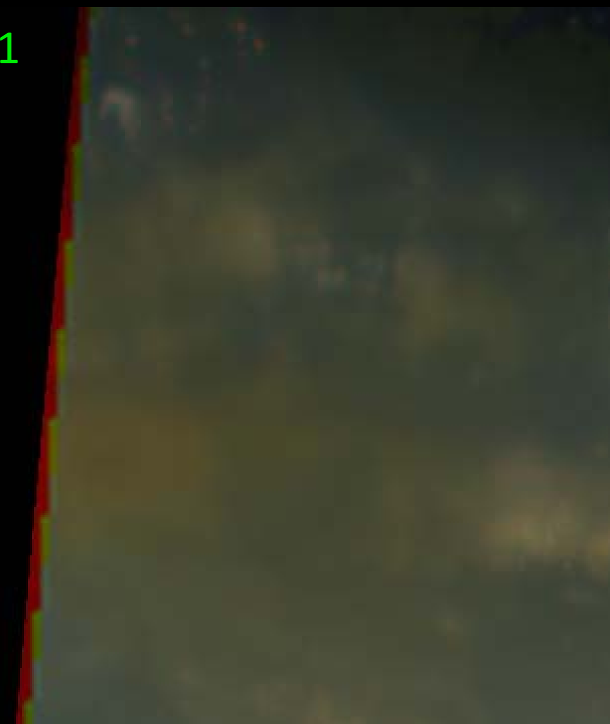
1 July, 2008

MISR
Orbit 45411
Path 26



MISR RGB - CA Camera - Blocks 46 - 51

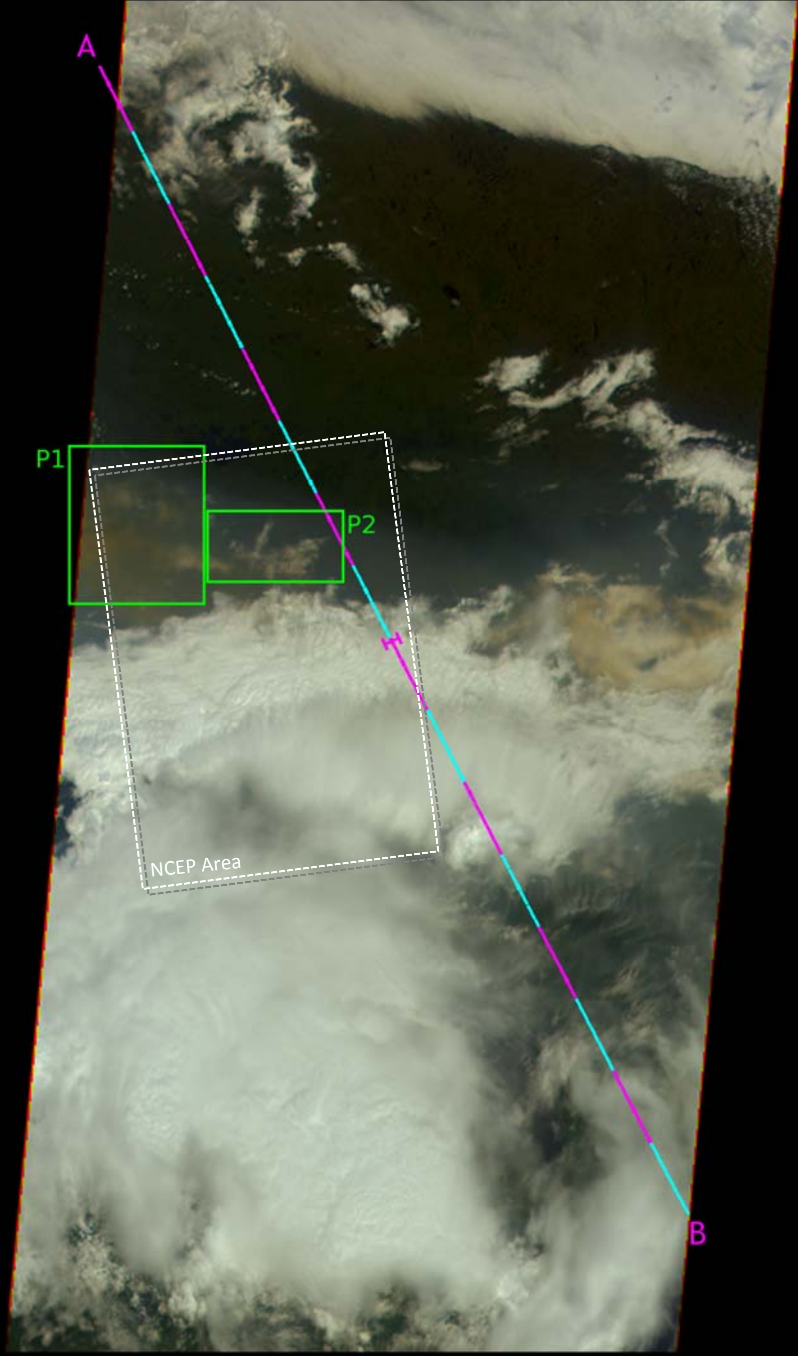
P1



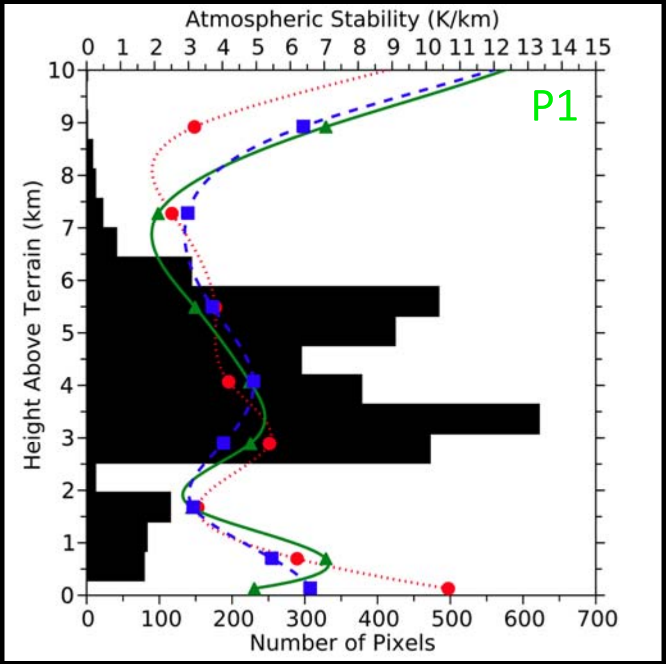
P2

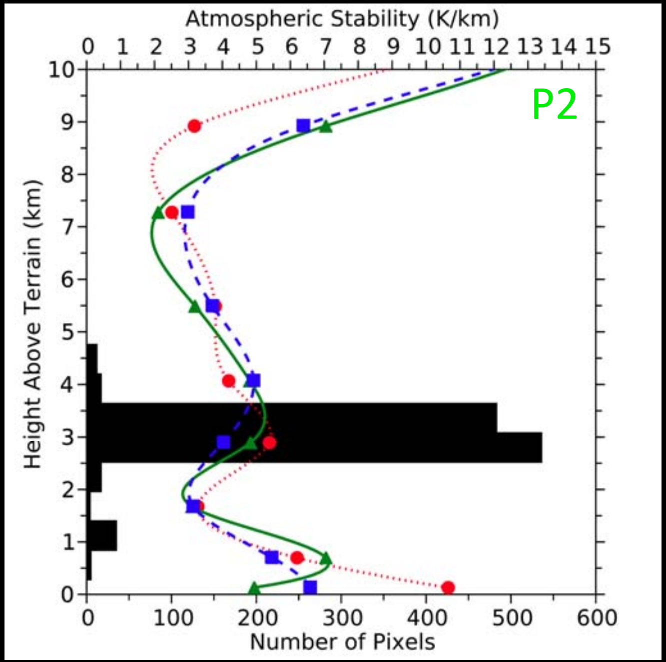
1 July, 2008

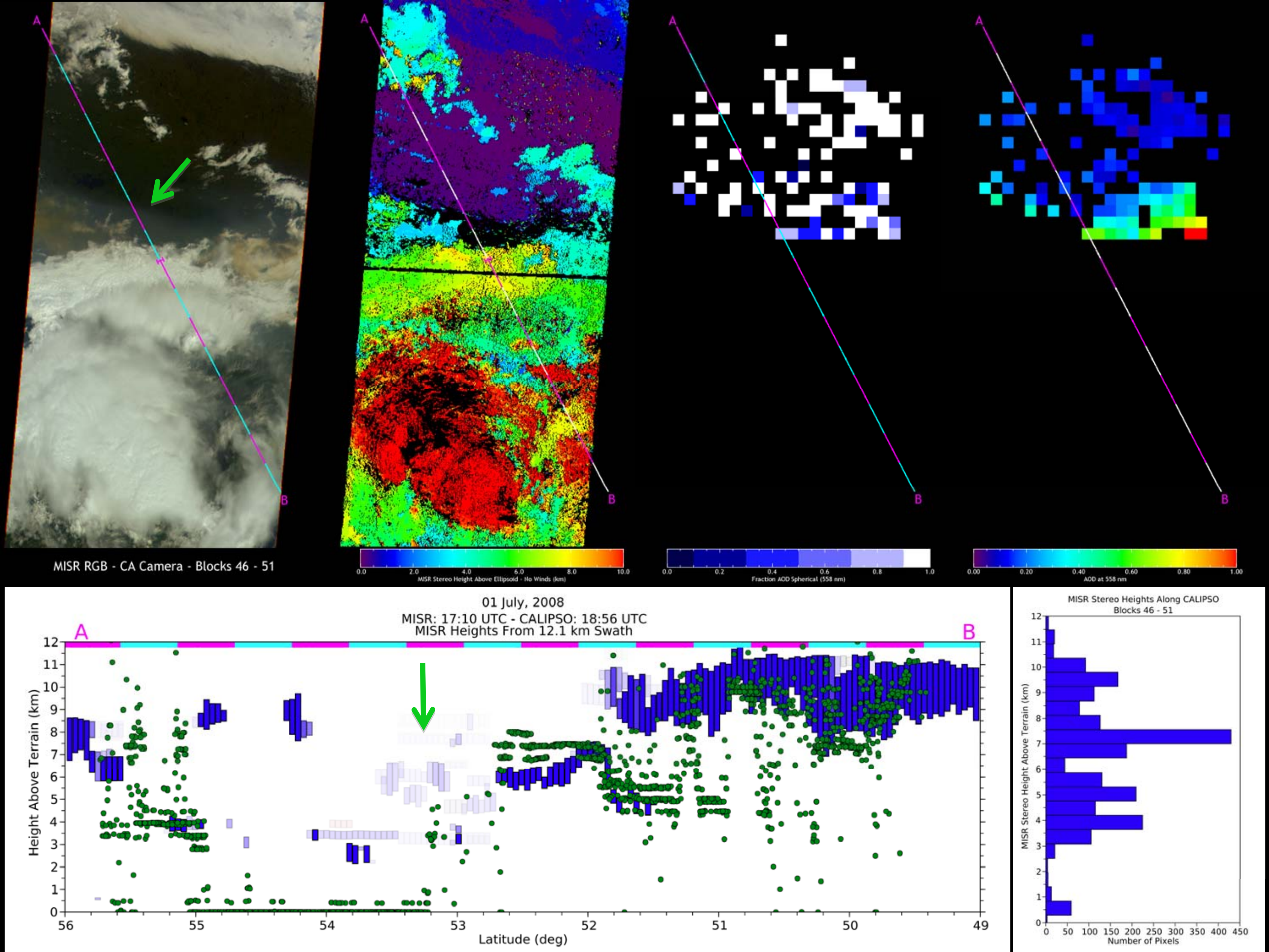
MISR
Orbit 45411
Path 26



MISR RGB - CA Camera - Blocks 46 - 51

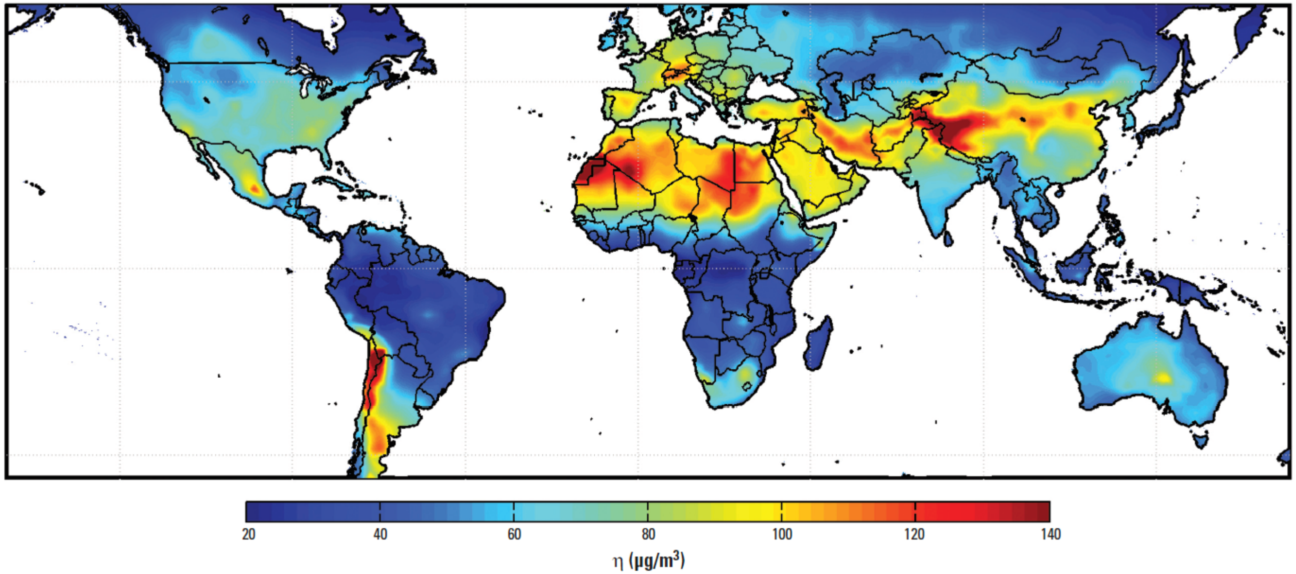




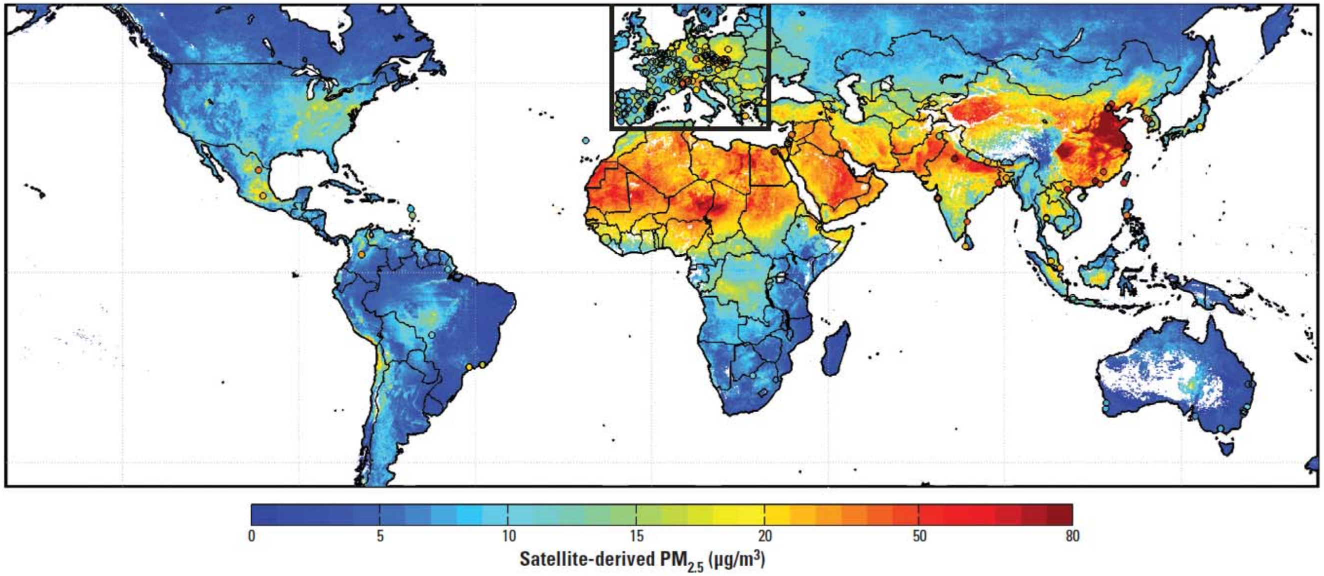


MISR RGB - CA Camera - Blocks 46 - 51
MISR Stereo Height Above Ellipsoid - No Winds (km)
Fraction AOD Spherical (558 nm)
AOD at 558 nm
01 July, 2008
MISR: 17:10 UTC - CALIPSO: 18:56 UTC
MISR Heights From 12.1 km Swath
Height Above Terrain (km)
Latitude (deg)
MISR Stereo Heights Along CALIPSO
Blocks 46 - 51
MISR Stereo Height Above Terrain (km)
Number of Pixels

Air Quality: BL Aerosol Concentration
[MISR + MODIS] AOD & GEOS-Chem Vertical Distribution



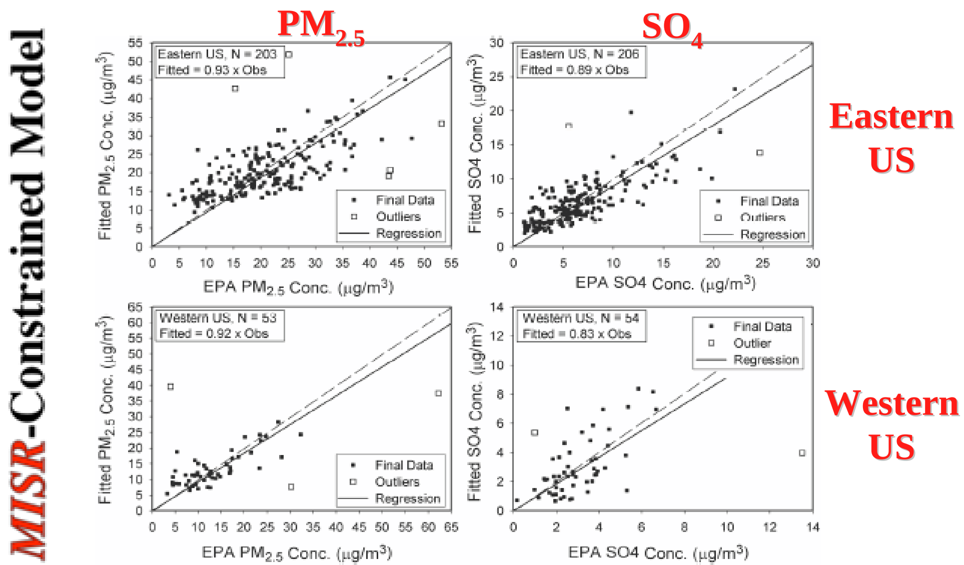
[BL $PM_{2.5}$] / [Total-col. AOD]
2001- 2006



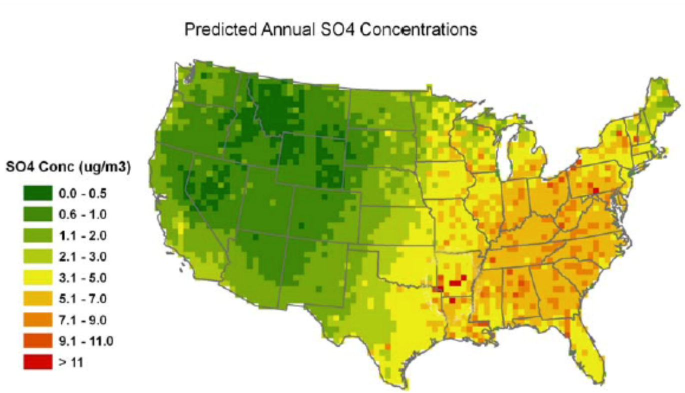
Derived $PM_{2.5}$

Van Donkelaar et al., Environ. Health Prespect. 2010

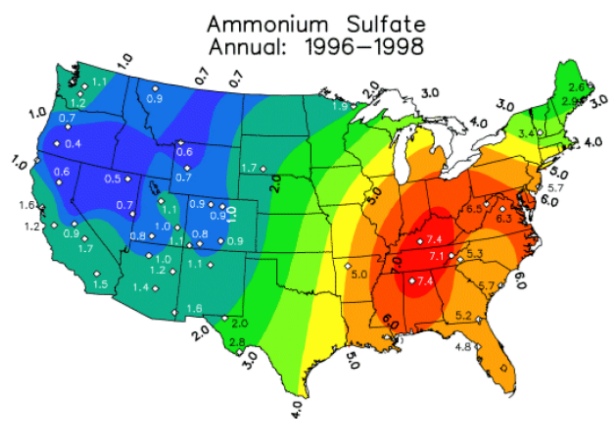
MISR - GEOS-Chem Regression Model To Map **Near-surface Aerosol Pollution**



EPA *Surface* Measurements



MISR / GEOS-CHEM ***Retrieval***

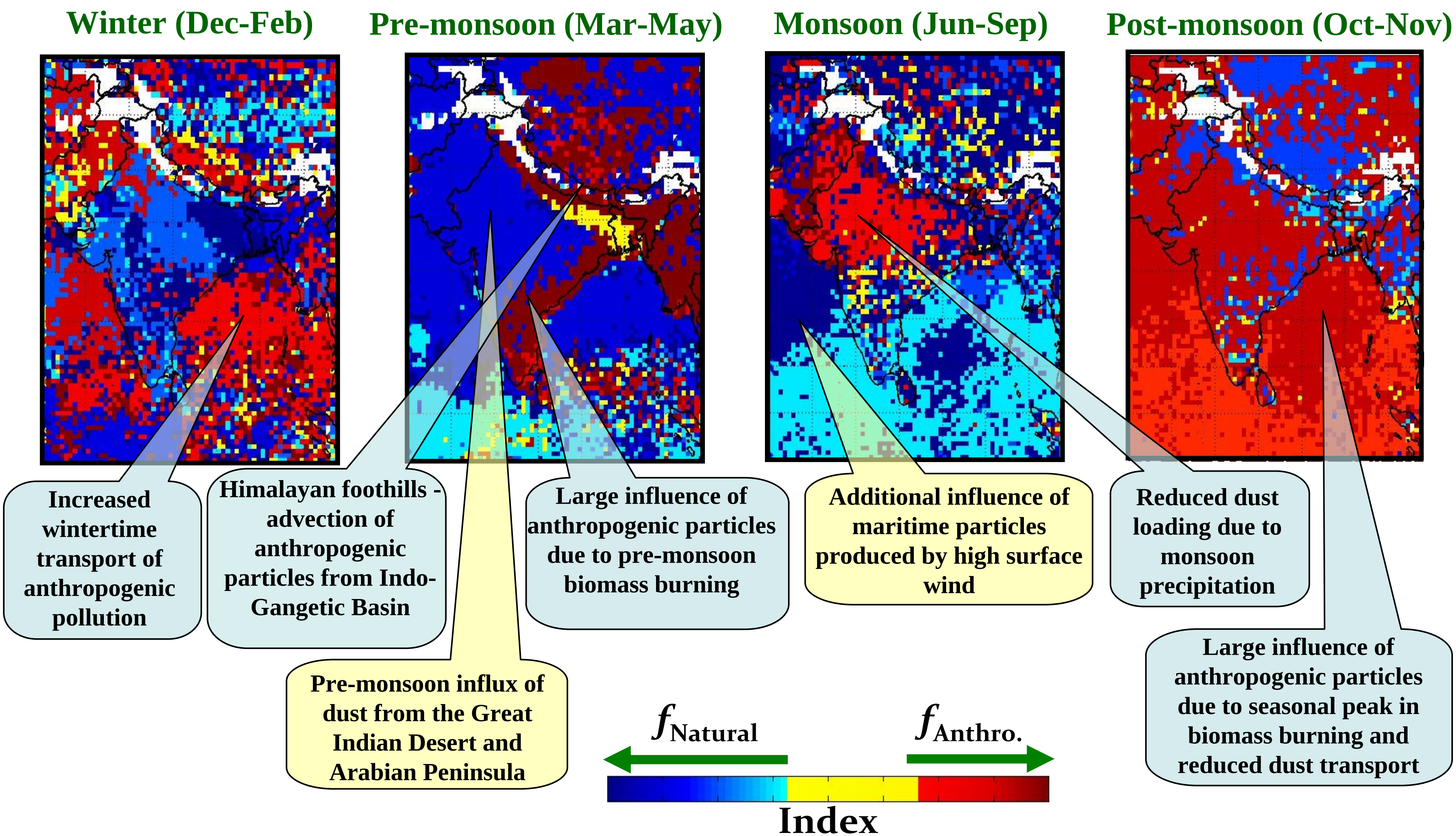


Surface network (IMPROVE) measurements

- Using MISR ***Particle Shape*** as well as AOT to constrain model --> much better result
- Will add column Size and SSA information when MISR retrieval is more robust

Y. Liu et al, JAWMA 2007

Characterizing seasonal changes in anthropogenic and natural aerosols w.r.t. preceding season over the Indian Subcontinent

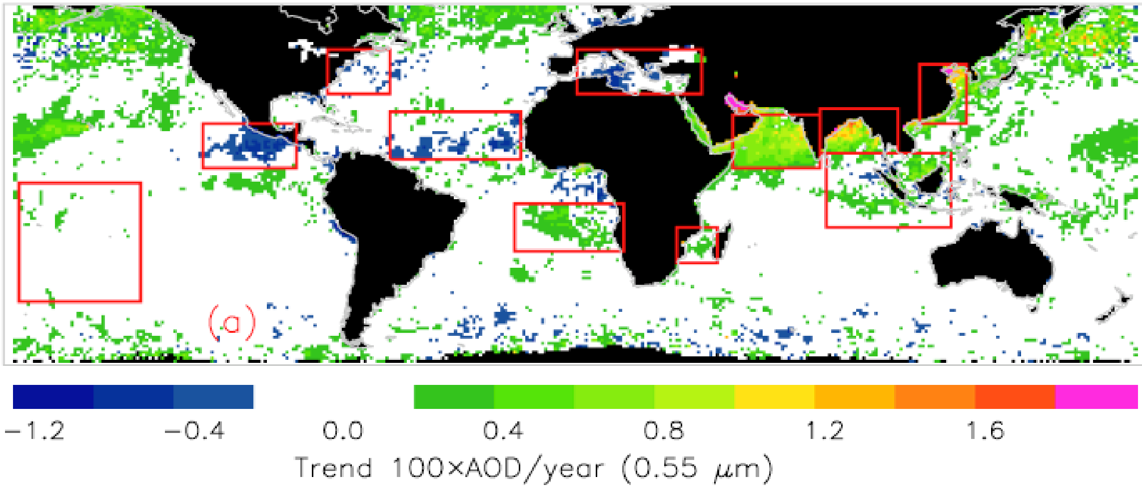


Index uses MISR-retrieved particle shape and size constraints to separate natural from anthorpogenic aerosol

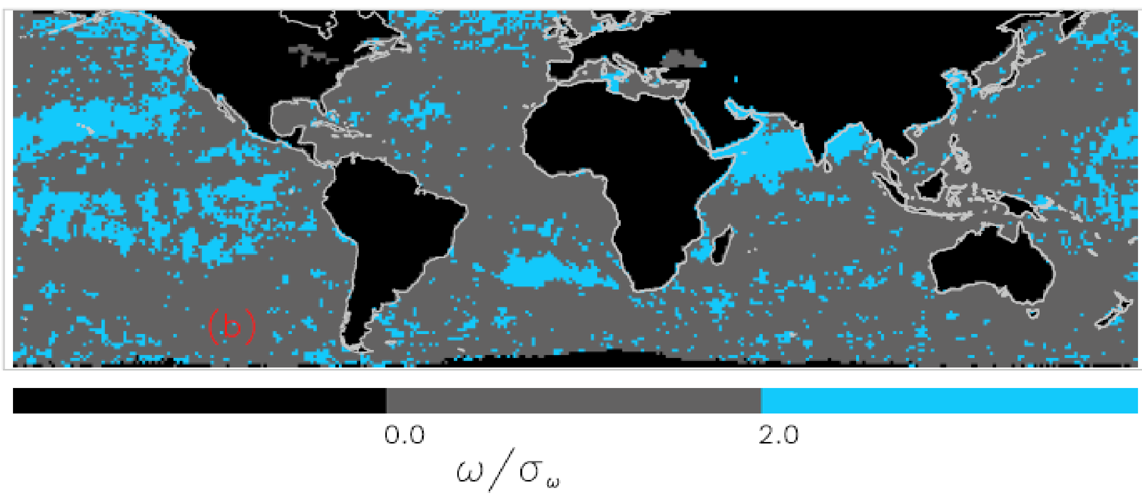
Dey & Di Girolamo JGR 2010

MODIS10-Year Global/Regional Over-Water AOD Trends

Constrained by MISR and AERONET



Trend



Statistical Significance

- Statistically ***negligible*** ***(±0.003/decade)*** ***global-average*** over-water AOD trend
- Statistically ***significant*** ***increases*** over the Bay of Bengal, E. Asia coast, Arabian Sea

Zhang & Reid, ACP 2010

Key Attributes of the MISR **Version 22** Aerosol Product

- **AOT Coverage** – ***Global but limited sampling*** on a monthly basis
- **AOT Accuracy** – Maintained even when particle property information is poor
- **Particle Size** – ***2-3 groupings reliably***; quantitative results vary w/conditions
- **Particle Shape** – ***spherical vs. non-spherical robust***, except for coarse dust
- **Particle SSA** – useful for ***qualitative*** distinctions
- **Aerosol Type Information** – diminished when ***AOT < 0.15*** or 0.2
- **Particle Property Retrievals** – ***improvement expected*** w/algorithm upgrades
- **Aerosol Air-mass Types** – ***more robust*** than individual properties

PLEASE READ THE QUALITY STATEMENT!!!

… and more details are in publications referenced therein

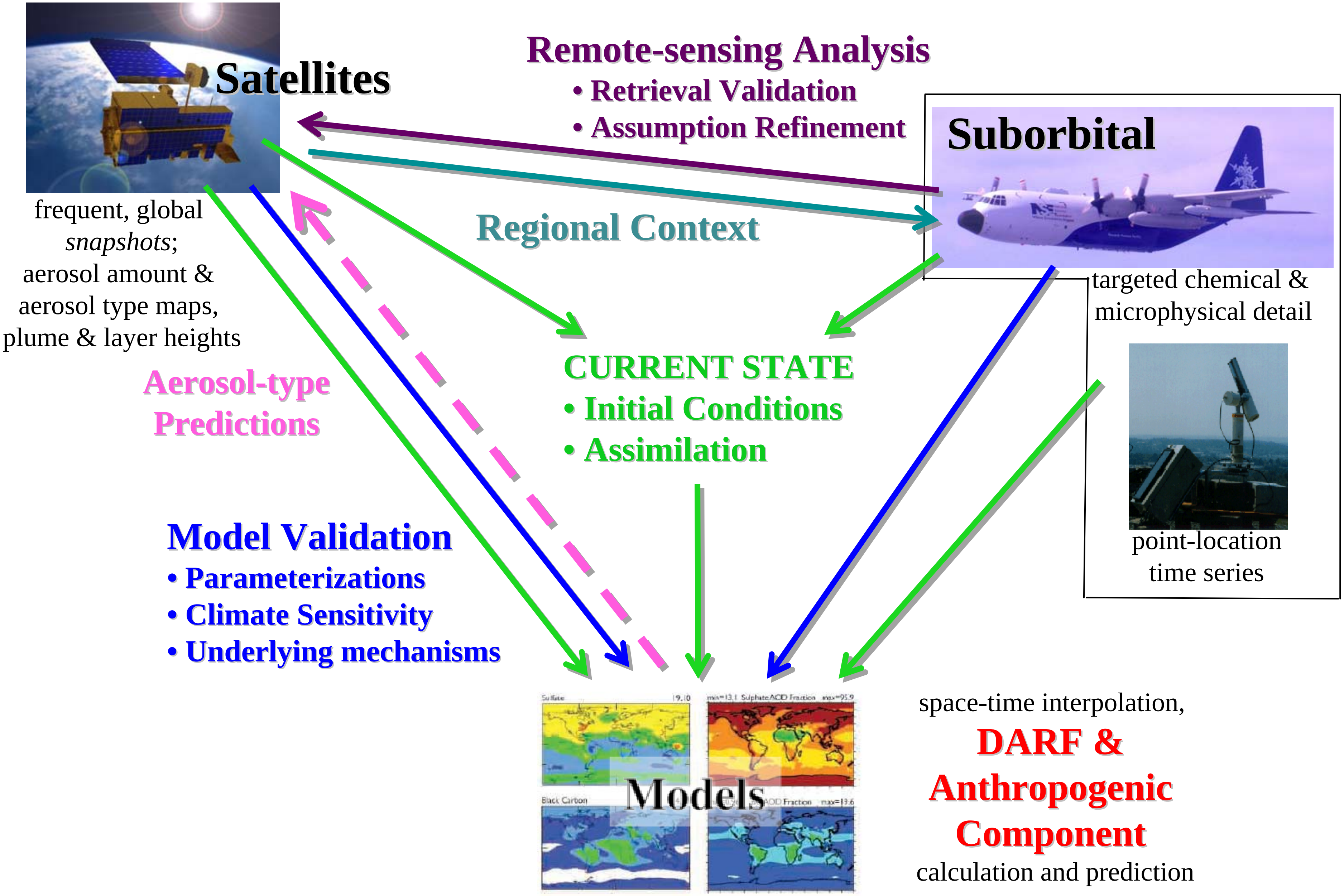
Current MISR & MODIS Mid-Visible AOD Sensitivities

- MISR: **0.05 or 20% * AOD** overall; ***better over dark water*** [*Kahn et al*., 2010]
- MODIS: **0.05 ± 20% * AOD** over dark target land
  0.03 ± 5% * AOD over dark water [*Remer et al*. 2008; *Levy et al*. 2010]

  Based on AERONET coincidences (cloud screened by ***both*** sensors)
- Global, monthly MODIS & MISR AOD ***is used to constrain IPCC models***

→***For global, Direct Aerosol Radiative Forcing (DARF), instantaneous measurement accuracy needed** (e.g., McComiskey et al., 2008)**:***

- ***AOD to ~ 0.02 uncertainty***
- ***SSA to ~ 0.02 uncertainty***



Kahn, Survy. Geophys., in review