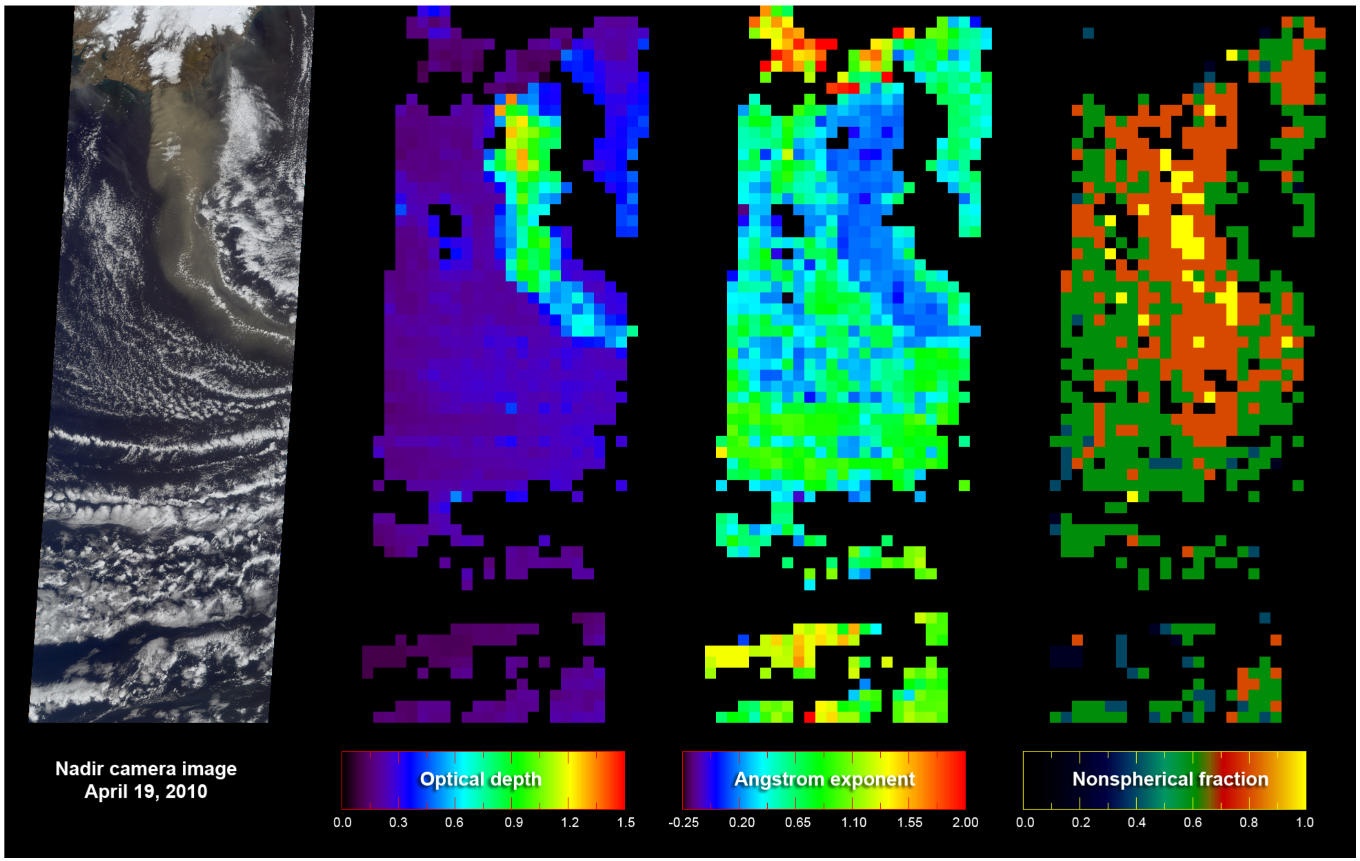
What We've Learned from ~12 Years of MISR Aerosol Observations

Ralph Kahn *NASA Goddard Space Flight Center*

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

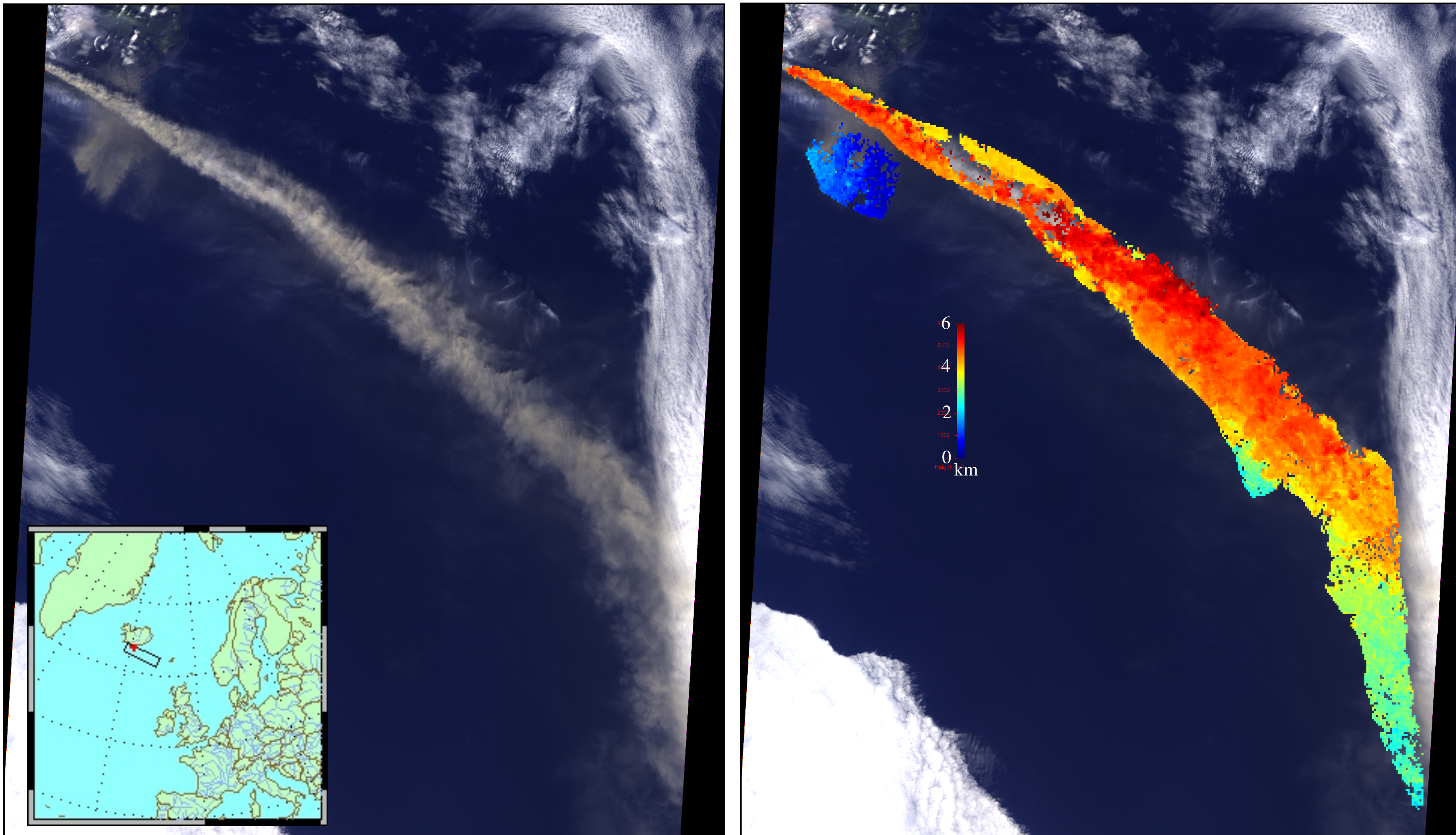


Eyjafjallјökull Volcano Ash Plume – MISR Aerosol Retrieval – April 19, 2010

MISR Team, JPL and GSFC

MISR Stereo-Derived Plume Heights

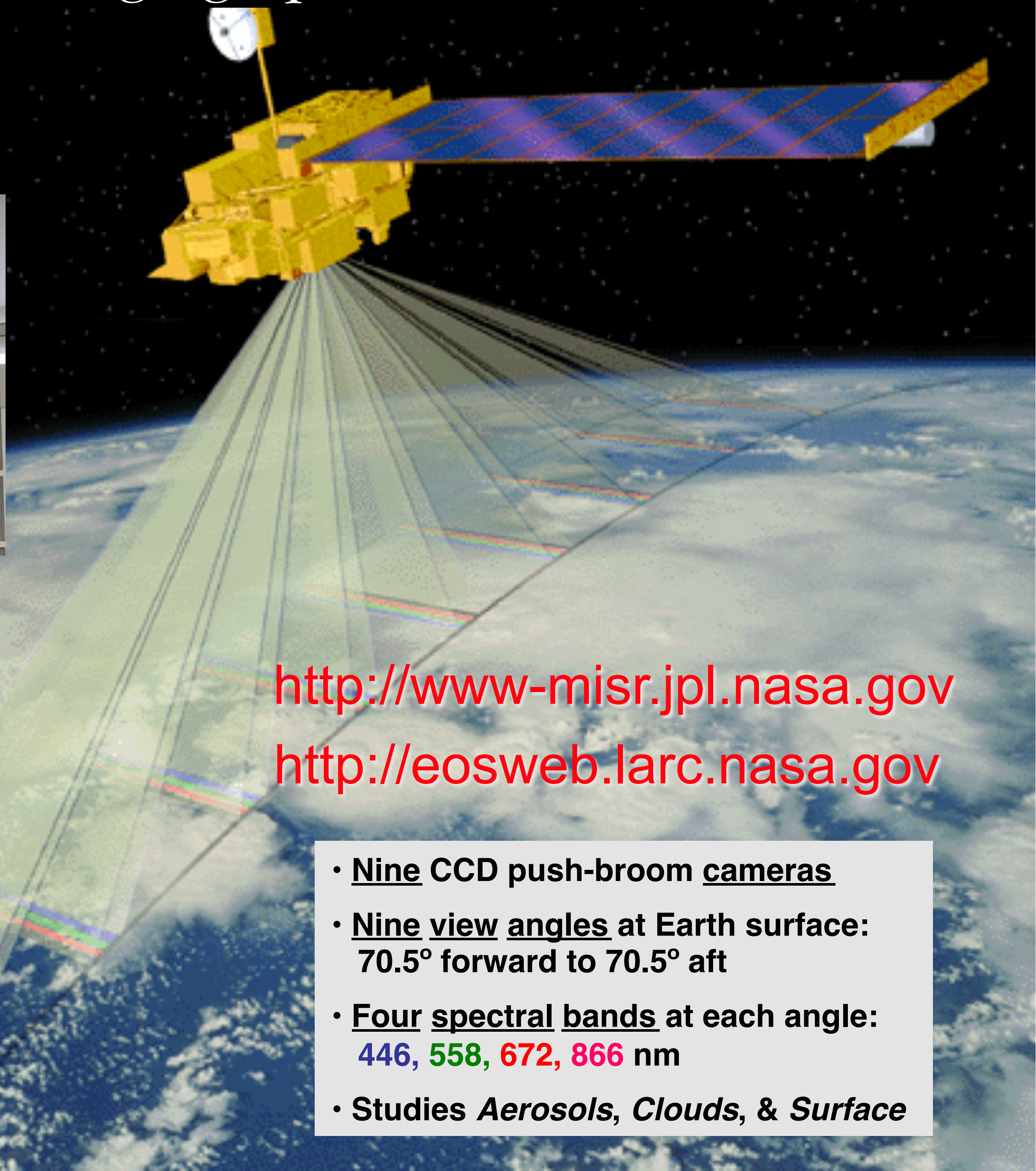
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



D. Nelson and the MISR Team, JPL and GSFC

Multi-angle Imaging SpectroRadiometer

MISR

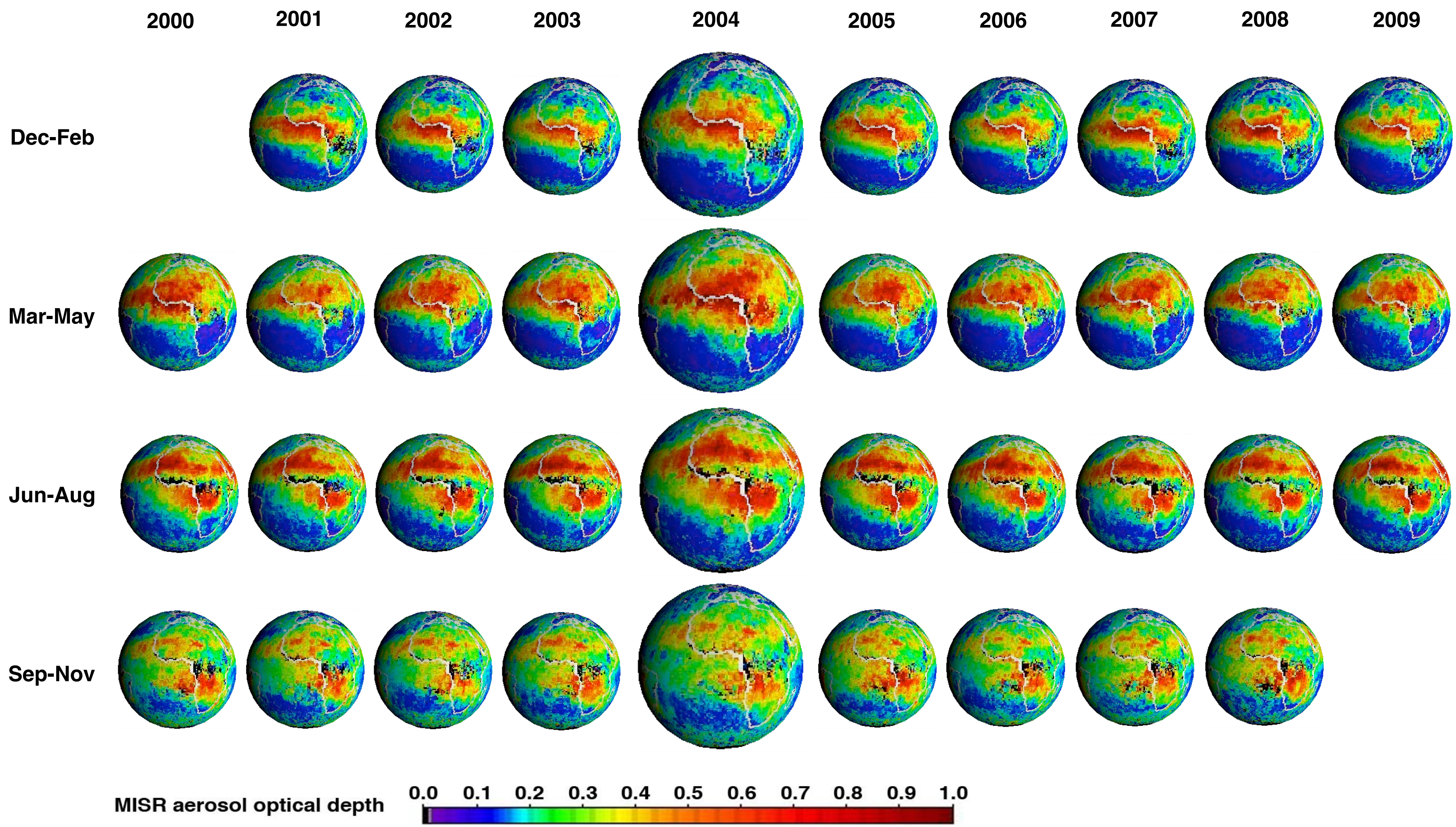


http://www-misr.jpl.nasa.gov

http://eosweb.larc.nasa.gov

- Nine CCD push-broom cameras
- Nine view angles at Earth surface: 70.5° forward to 70.5° 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

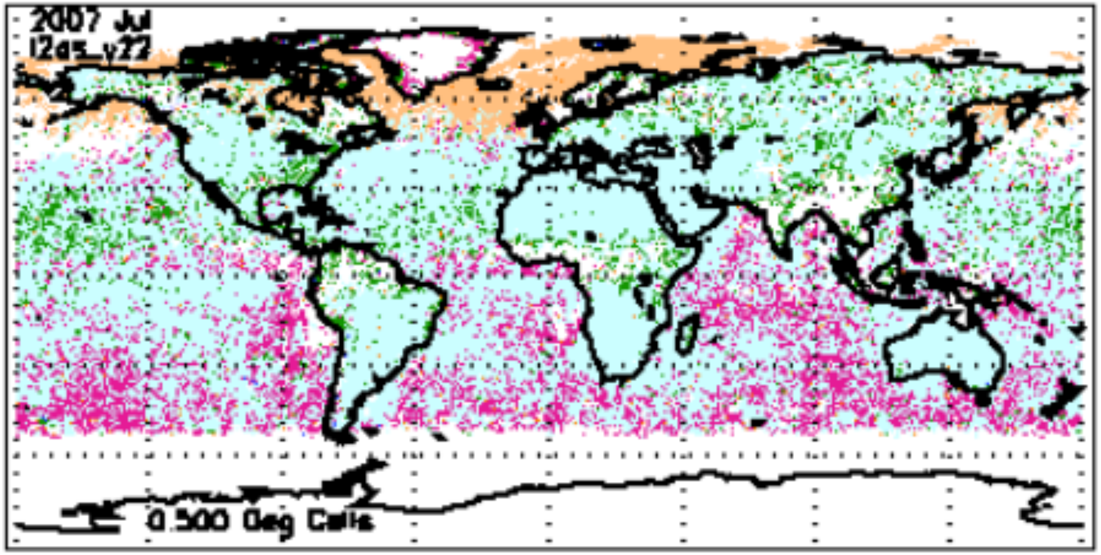


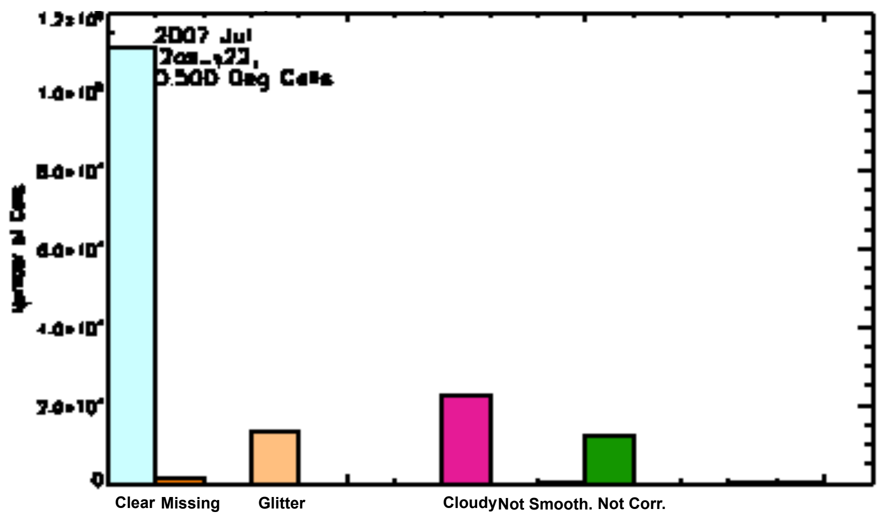
…includes bright desert dust source regions

MISR Team, JPL and GSFC

Most Frequent Mask – Cf (60° forward) Camera

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





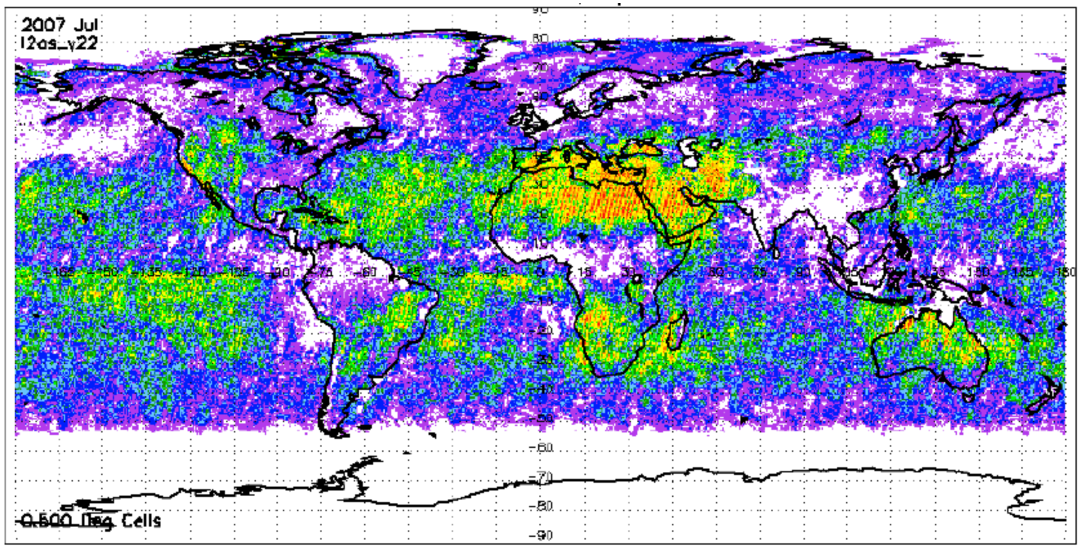
Angular Smoothness Test – Polynomial fit to 4 camera radiances at a time, 1.1 km data

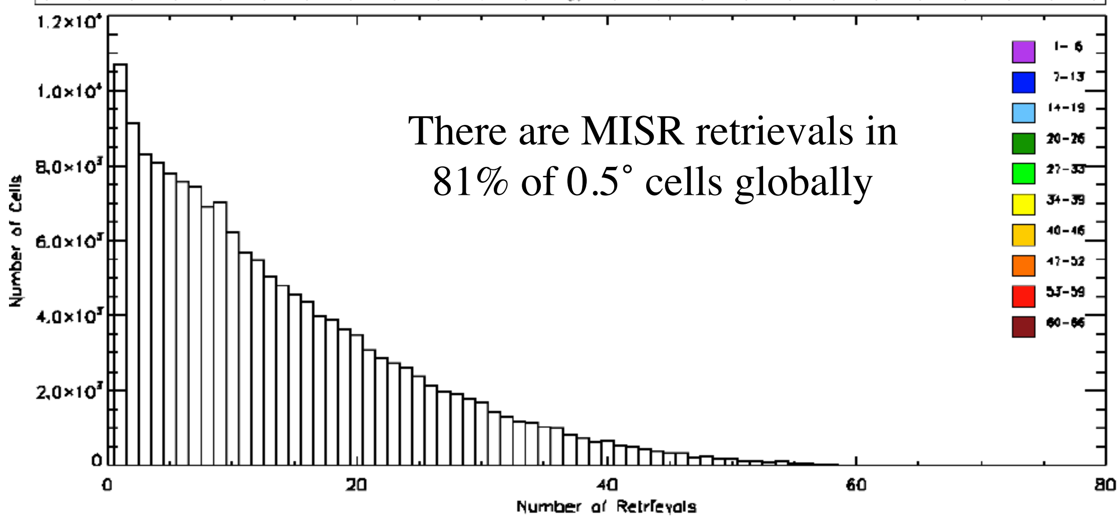
Angular Correlation Test – Each camera vs. 9-cam average of 16 (4 × 4) 275 m pixel arrays

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*]

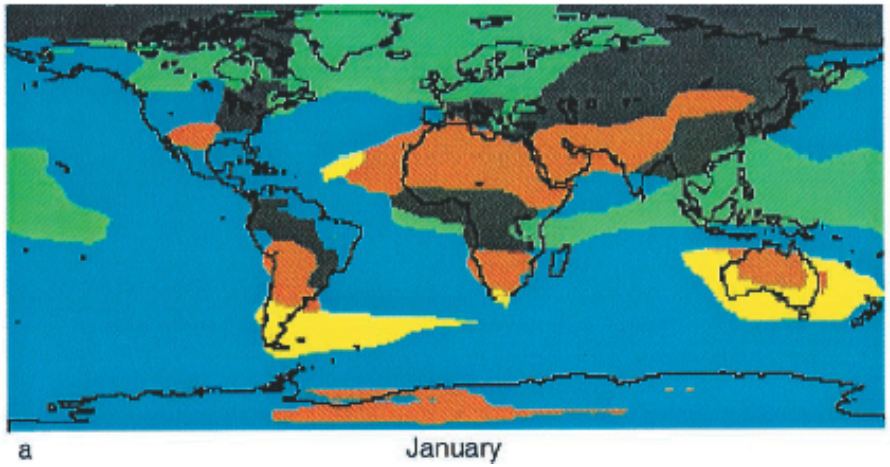




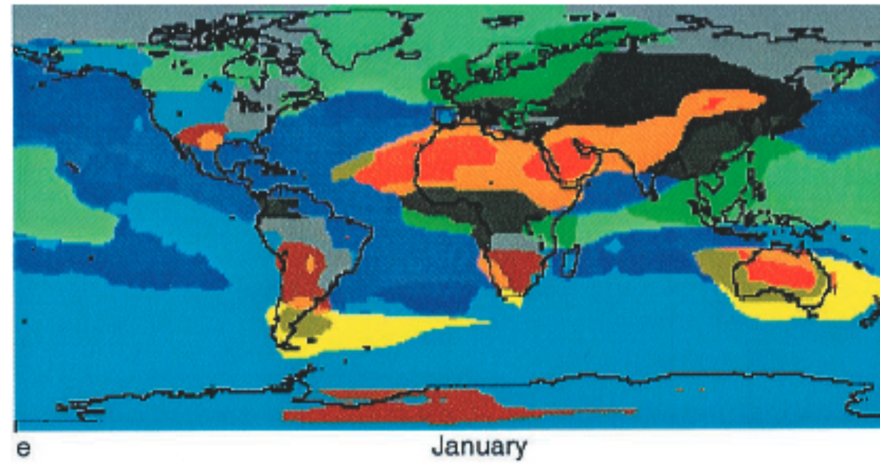
Although ***~85% of 1.1 km pixels*** are rejected overall, ***nearly the entire planet is covered*** at 0.5° resolution, except for perpetually cloudy, ice-covered, or mountainous regions

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…

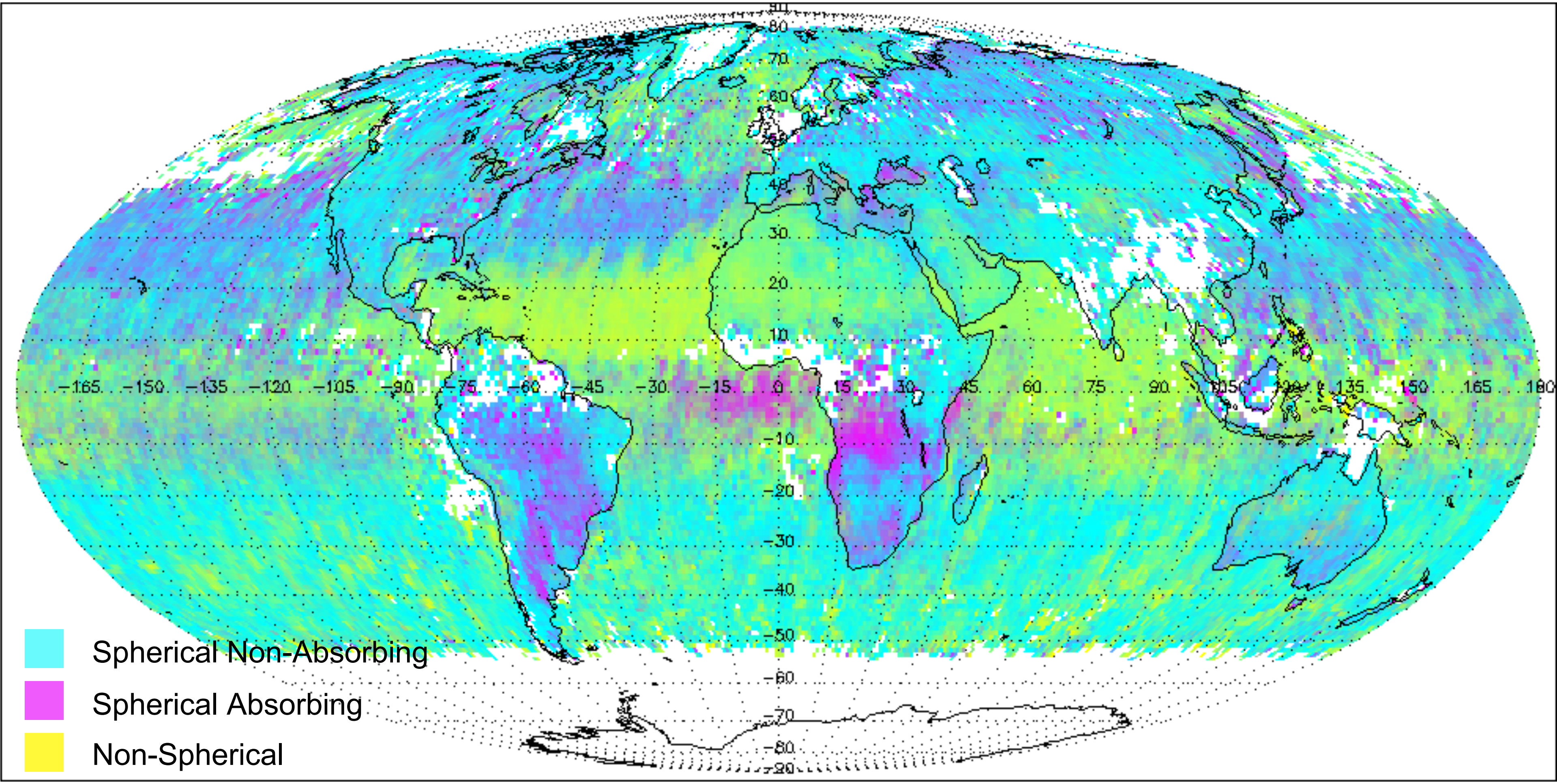
- With MISR – ***About a dozen Aerosol Air Mass type distinctions***, based on 3-5 size bins, 2-4 bins based on SSA, and spherical vs. non
- Sensitivity depends on conditions; ***AOD >~0.15*** needed, etc.

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

Kahn et al., JGR 2001

MISR *Aerosol Type* Distribution

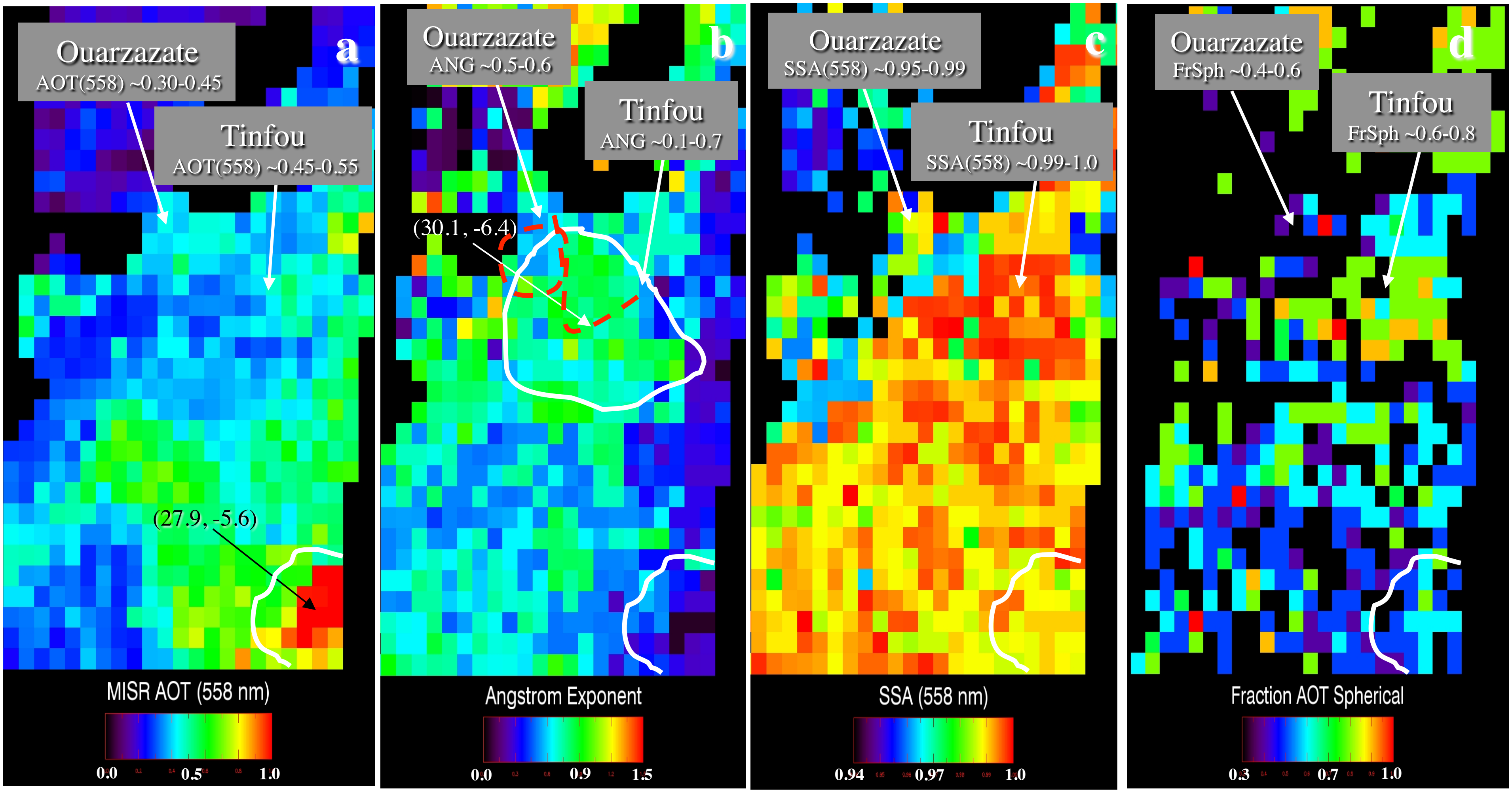
MISR Version 22, July 2007



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 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

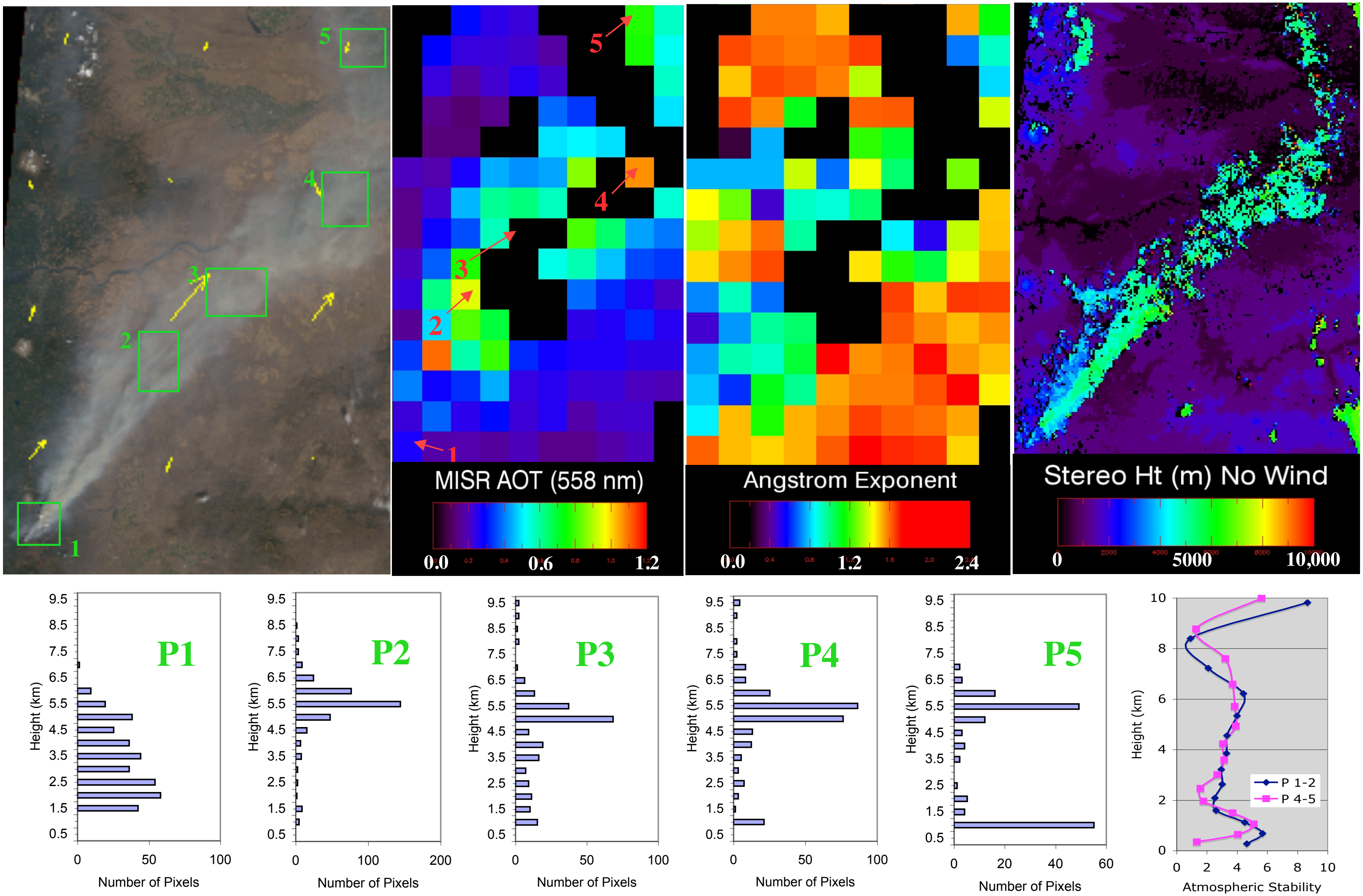
  -- ***Flag*** indicating when there is insufficient sensitivity for ***particle property*** retrieval (possibly different retrieval path under this condition)

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

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

Oregon Fire Sept 04 2003

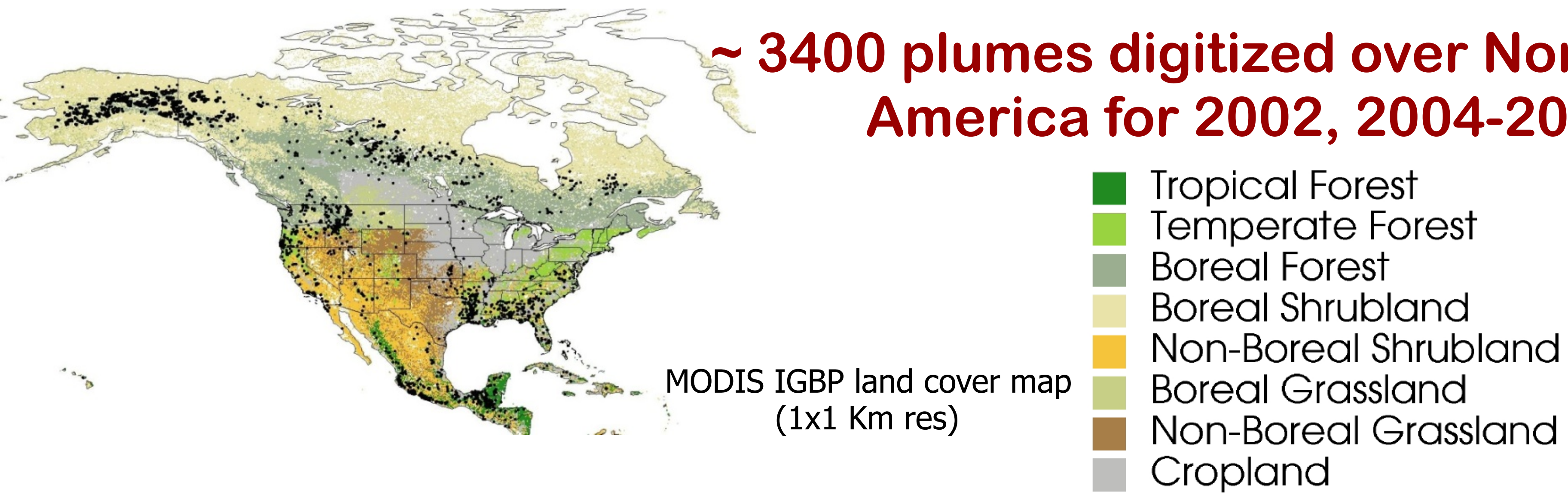
Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)



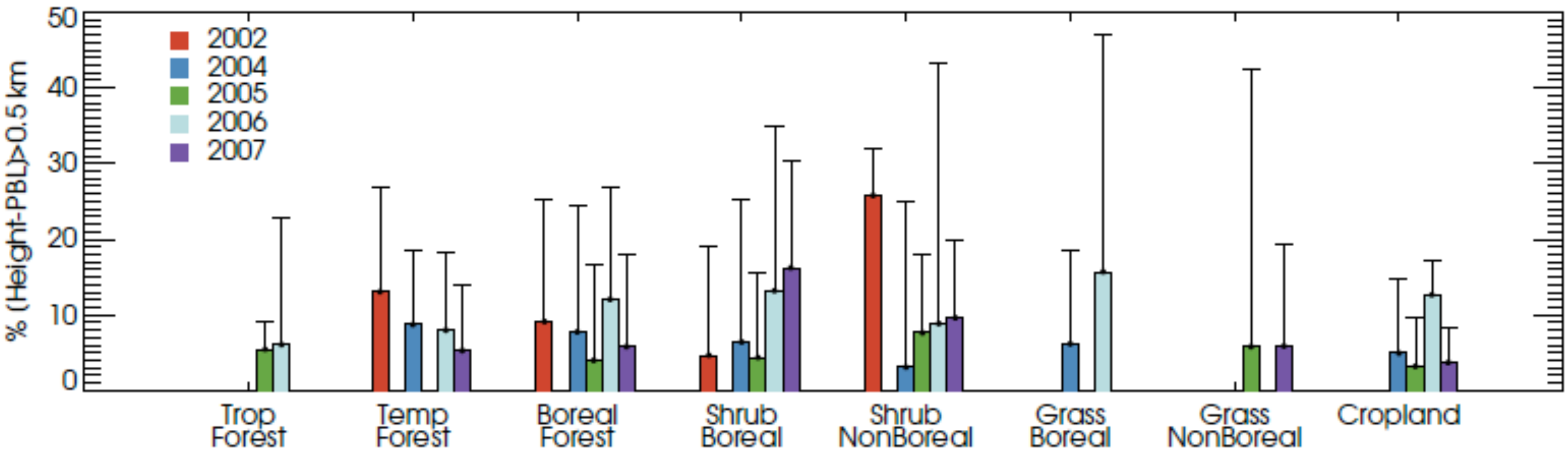
Kahn, et al., JGR 2007

N. America Plume Injection Height Climatology

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



MODIS IGBP land cover map
(1x1 Km res)

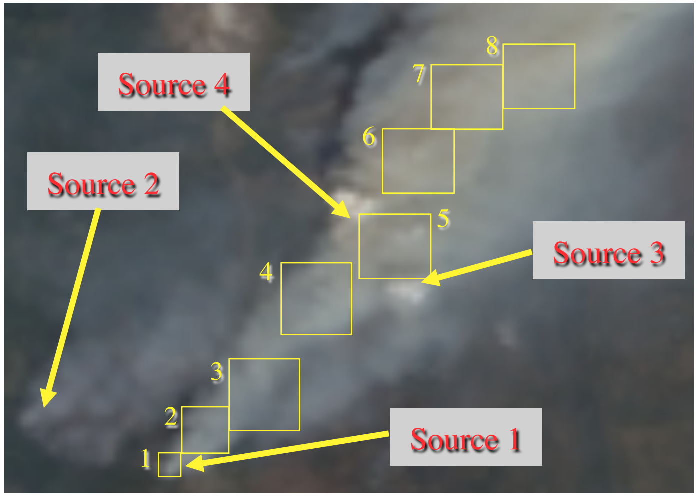


Percent of plumes >0.5 km ***above BL***, stratified by year and vegetation type

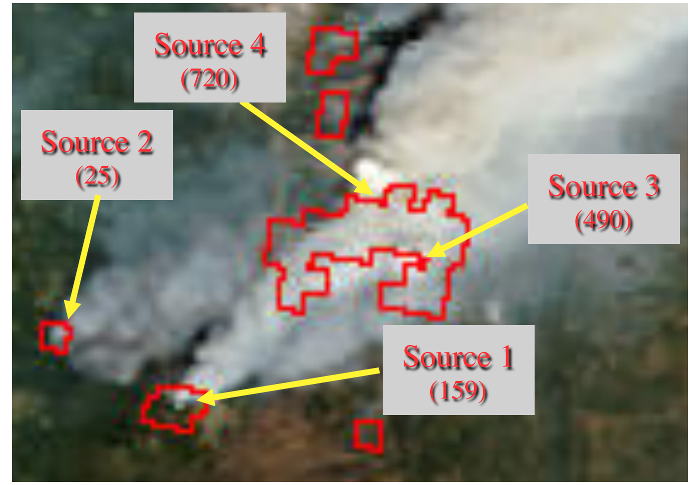
Val Martin et al. ACP 2010

Detail of Wildfire Source Region

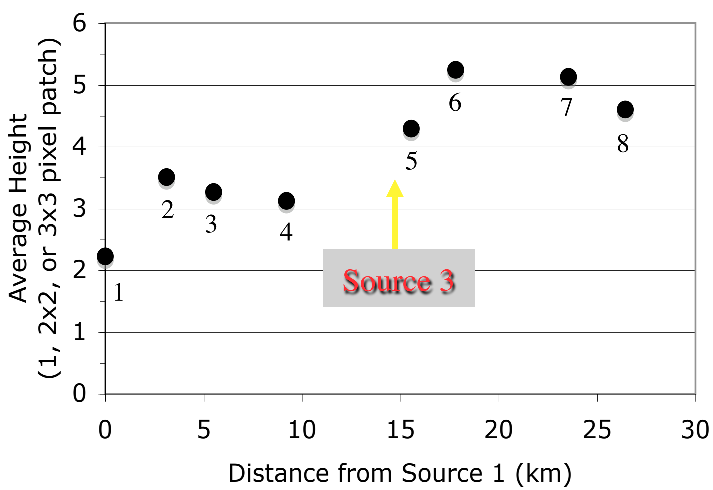
Oregon Fire Sept 04 2003



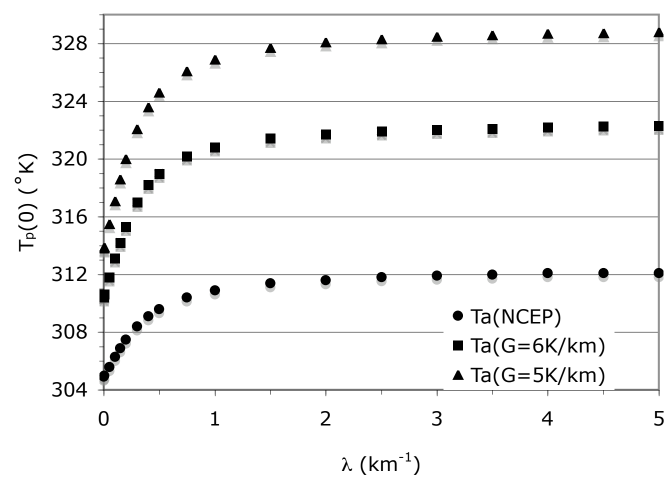
MISR Nadir **275 m** Image



MODIS Image + **Fire Power**



MISR **Plume Heights** for Sub-patches

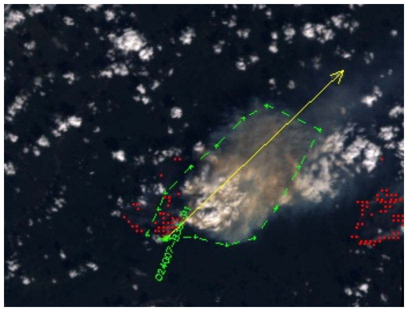


Very Simple Plume Parcel Model

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

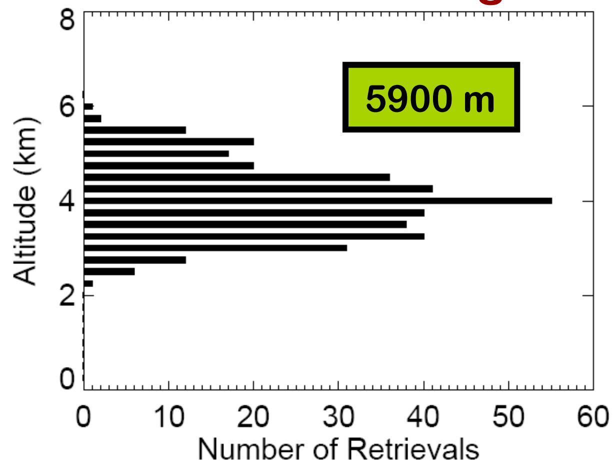
Evaluation of a 1D plume-rise model: Towards a parameterization of smoke injection heights

MISR Smoke Plume

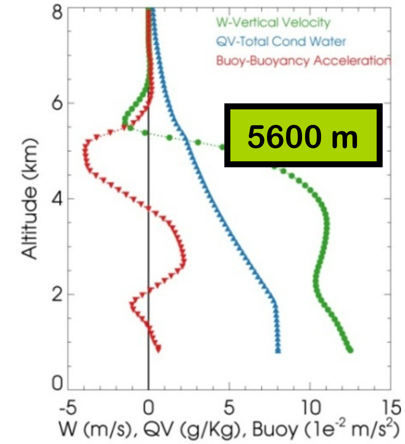


Fire Area = 300 Ha
FRP (~Heat Flux)= 18 kW/m^2

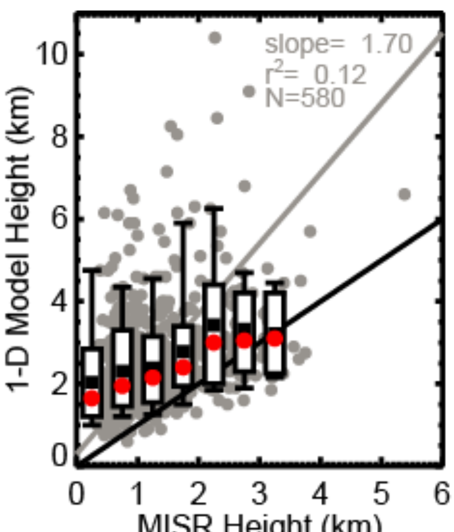
MISR Retrieved Heights



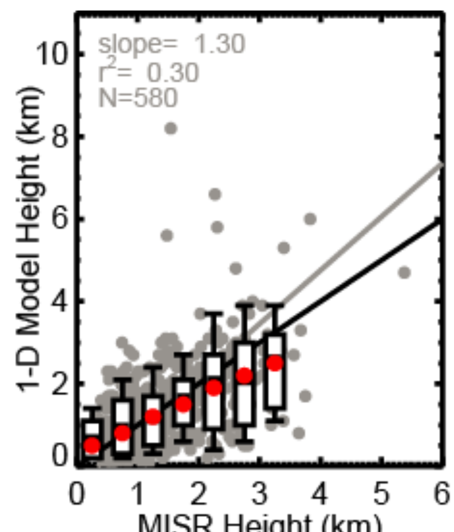
1D Plume-rise Model



Fire properties typically used overestimate injection heights



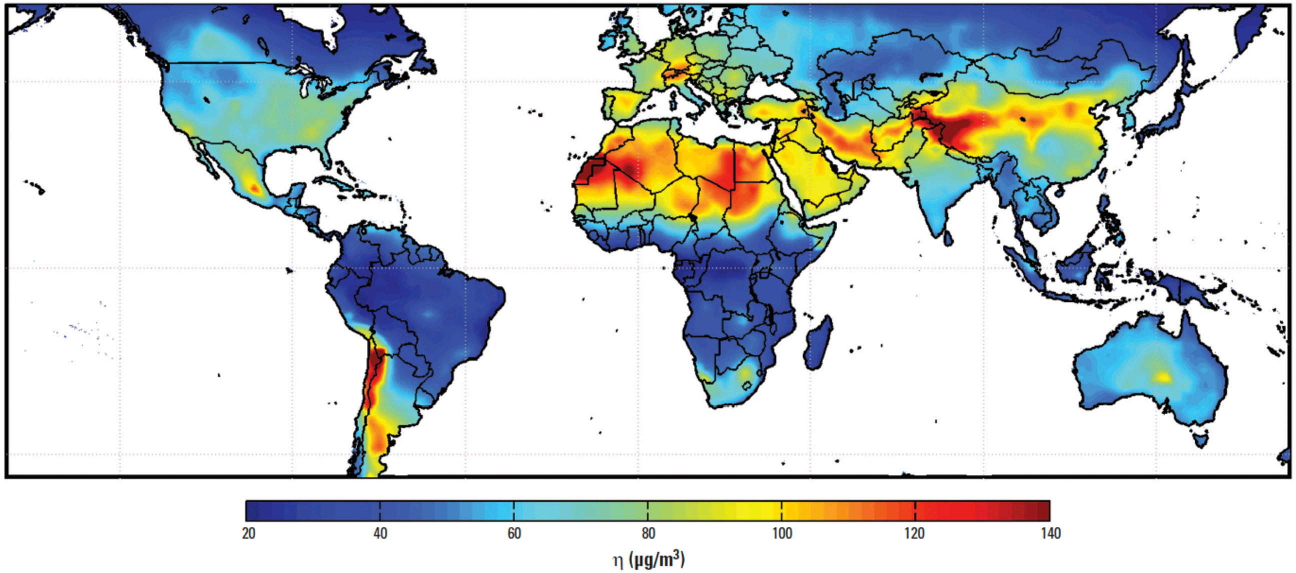
Improving parameterization using MISR and MODIS



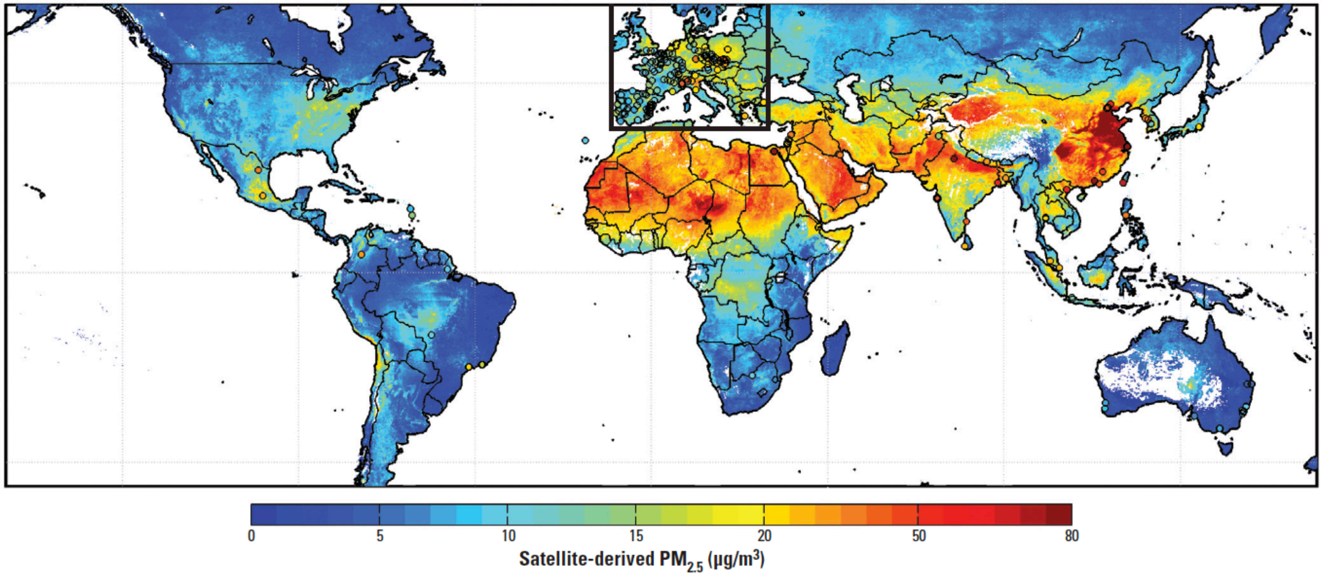
Factors Considered:
- •Fire Area
- •FRP
- •Veg. Type
- •Fuel Load/ Combust. Efficiency
- • Fuel Moisture
- •BL Height/Atm. Stab.
- (•Entrainment Param.)
- (•Latent Heat)
- (•Ambient Wind)

Val Martin et al. in preparation

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



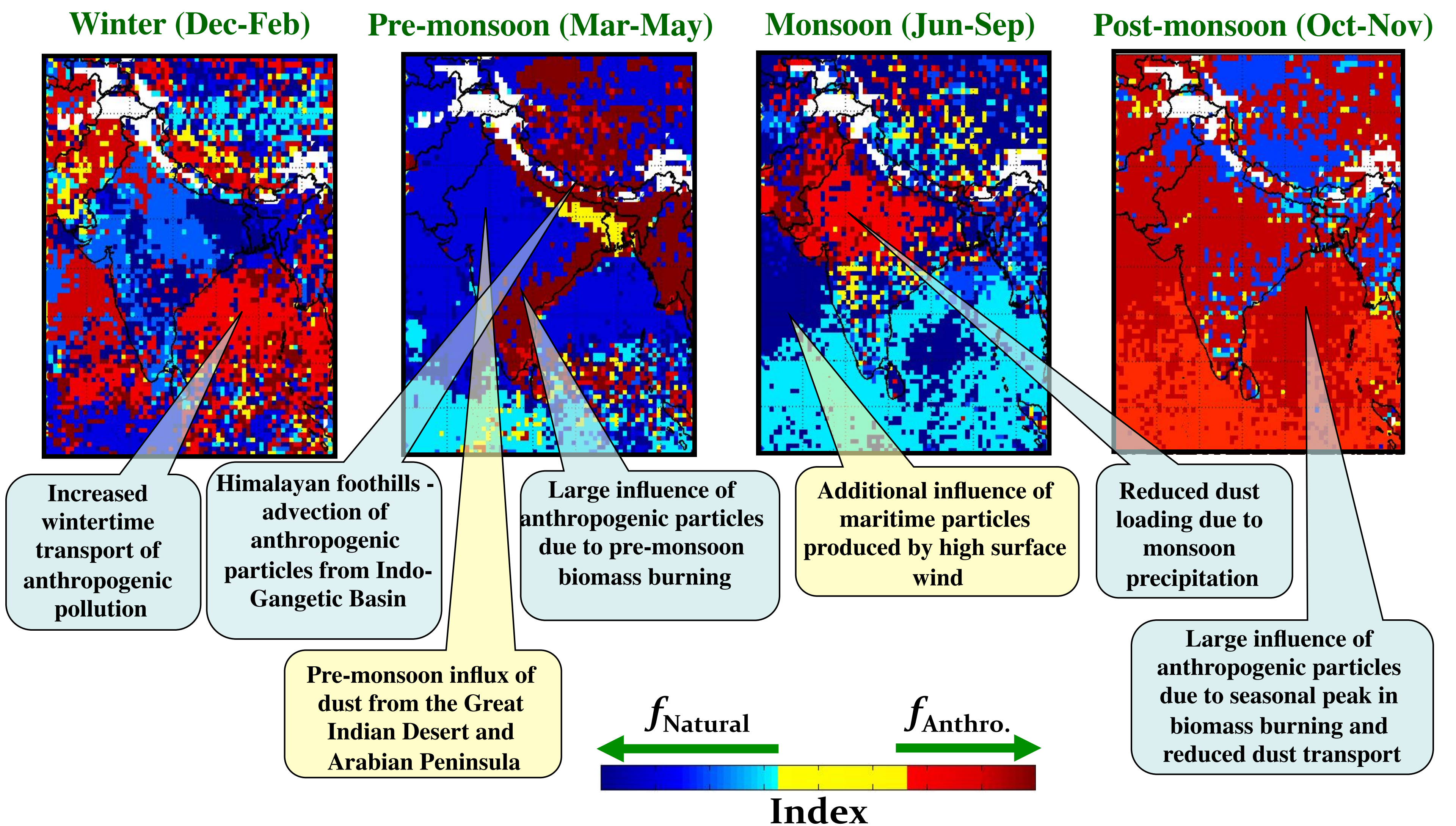
[BL $PM_{2.5}$] / [Total-col. AOD]
2001- 2006



Derived $PM_{2.5}$

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

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

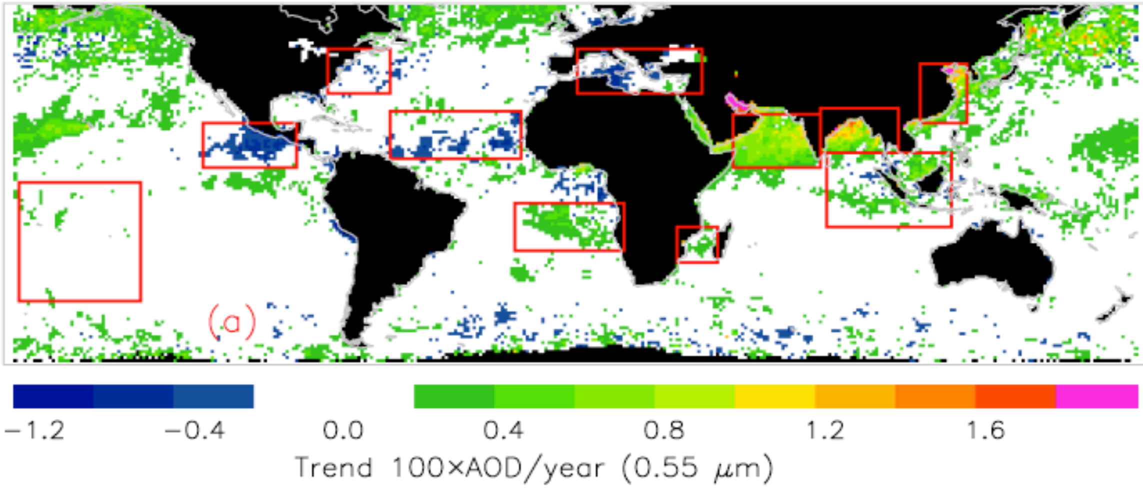


Index uses MISR-retrieved particle shape and size constraints to separate natural from anthorpogenic aerosol

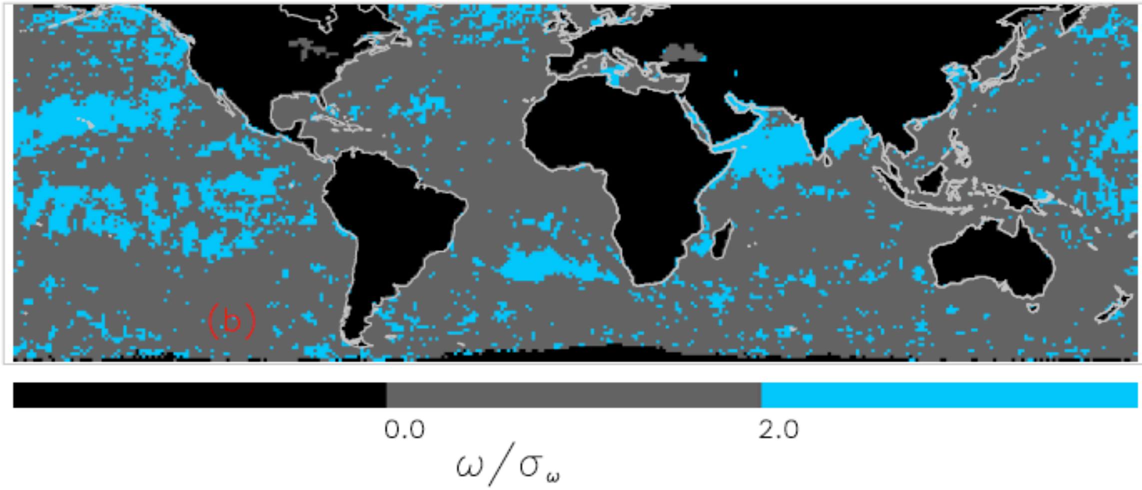
Dey & Di Girolamo JGR 2010

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

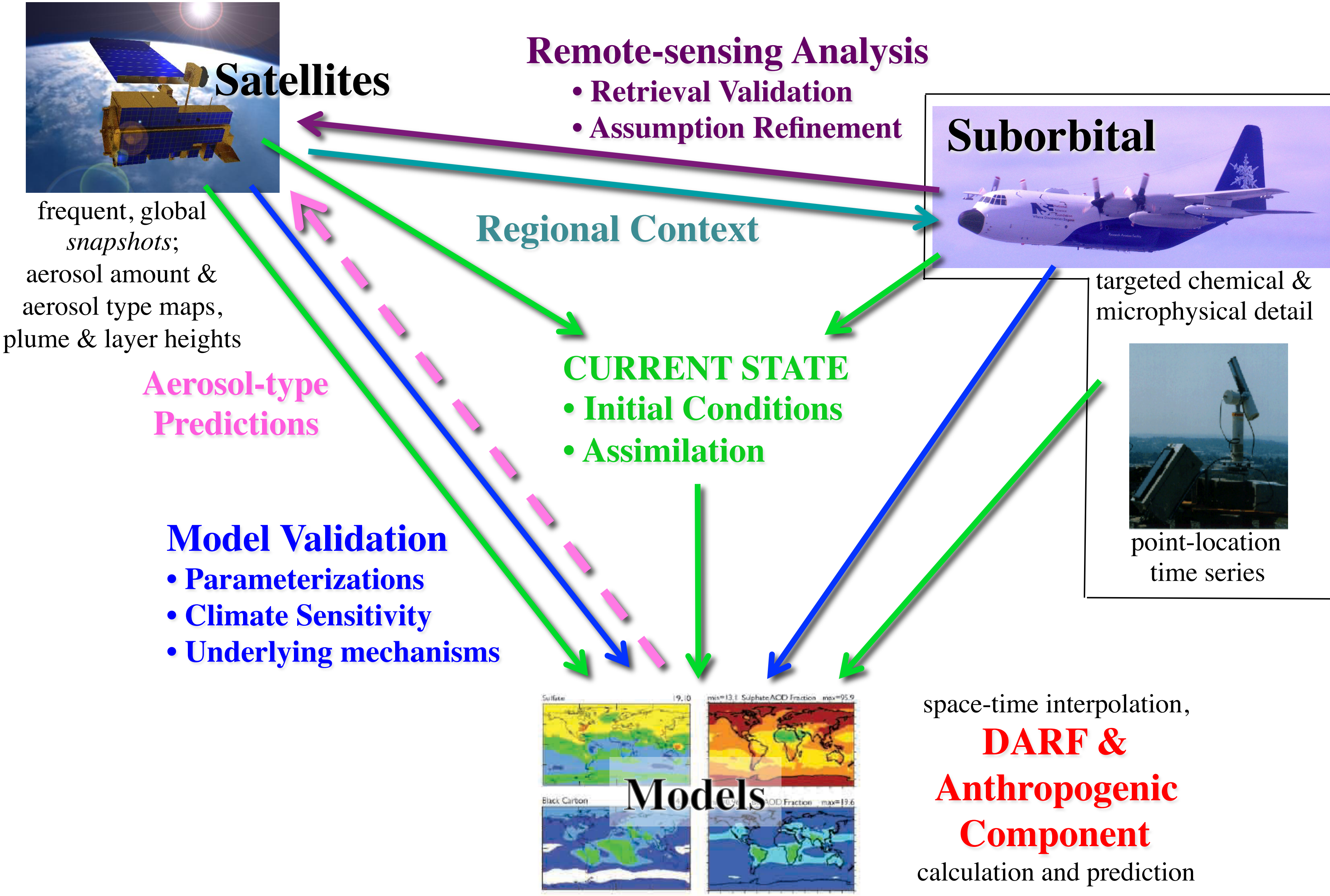
- MISR: **0.05 or 20% * AOD** overall; ***better over dark water*** [*Kahn et al*., 2010]
- MODIS: **0.05 ± 20% * AOD** over dark target land
  0.03 ± 5% * AOD over dark water [*Remer et al*. 2008; *Levy et al*. 2010]

  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***

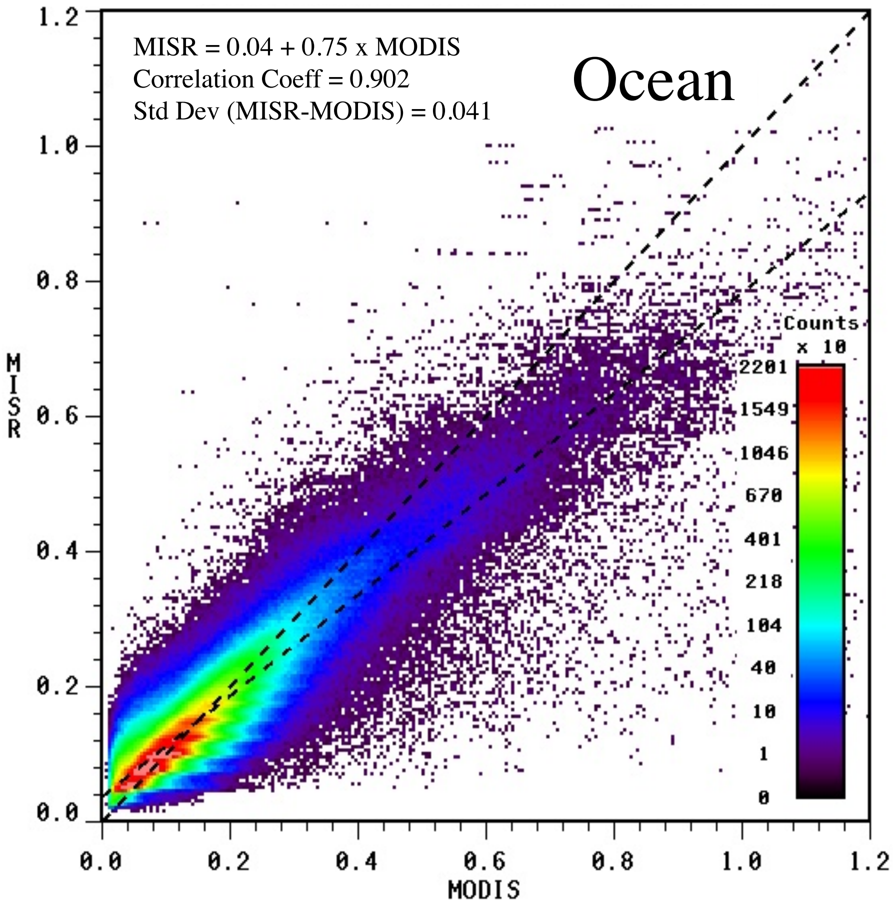


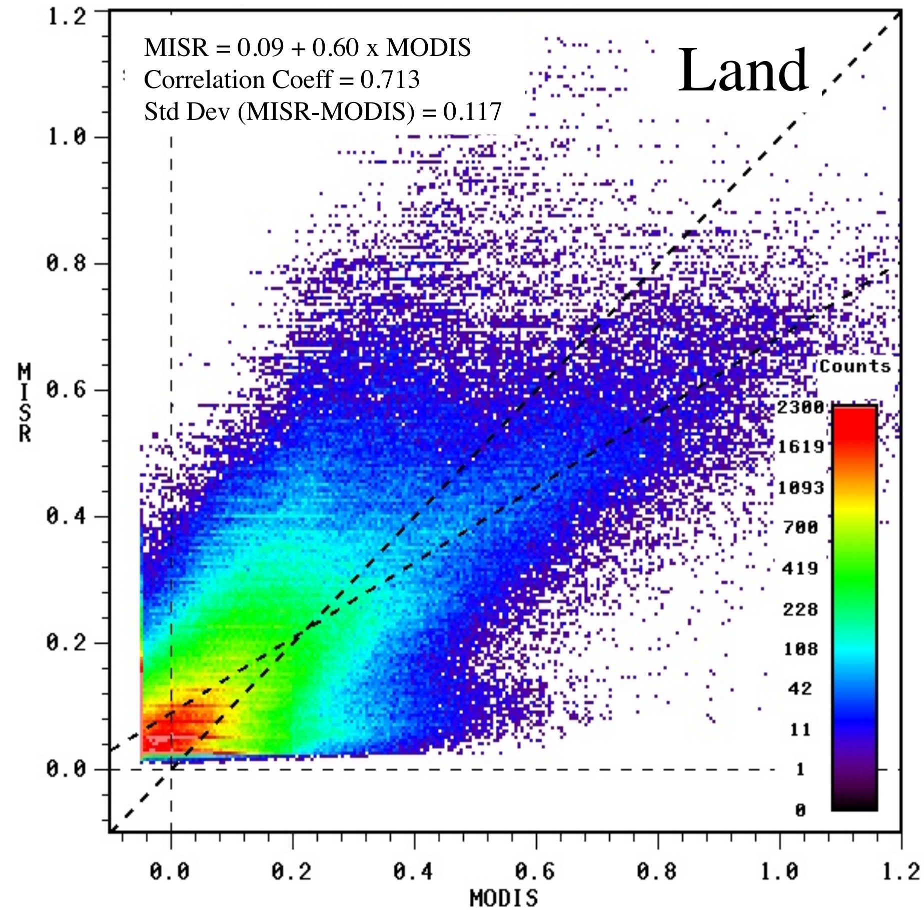
Kahn, Survy. Geophys., in review

Backup Slides

MISR-MODIS *Aerosol Optical Depth* Comparison

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



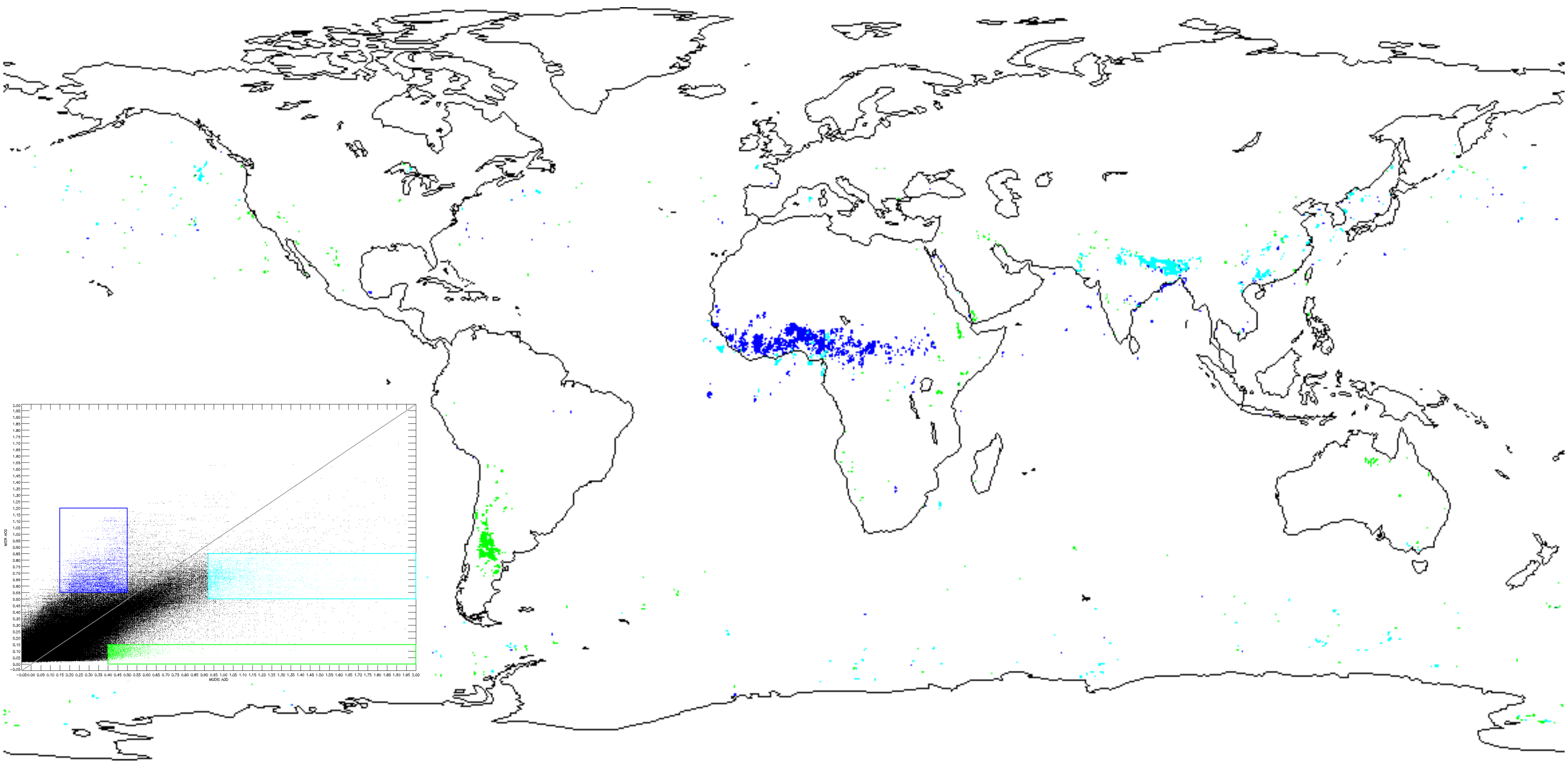


Over-ocean regression coefficient **0.90**
Regression line slope 0.75
MODIS QC ≥ 1

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

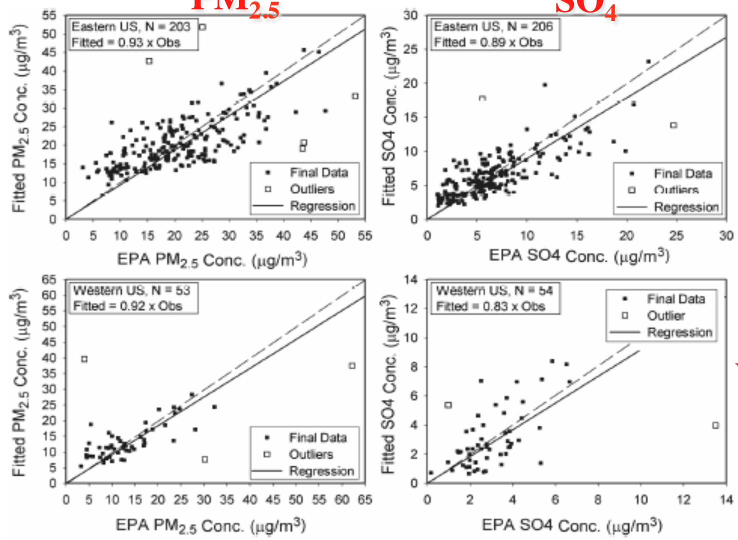
MISR - GEOS-Chem Regression Model To Map **Near-surface Aerosol Pollution**

MISR-Constrained Model

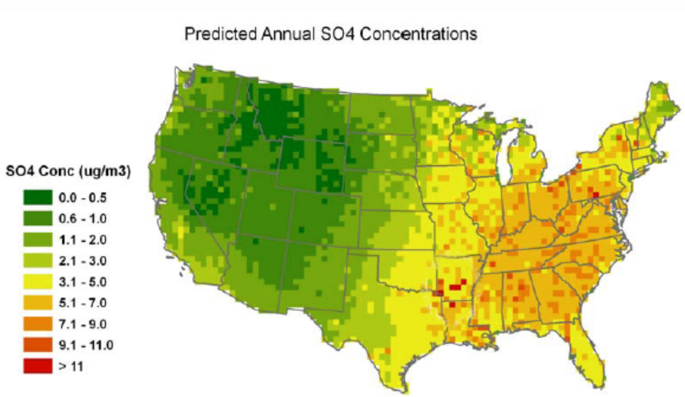
$PM_{2.5}$ SO_4

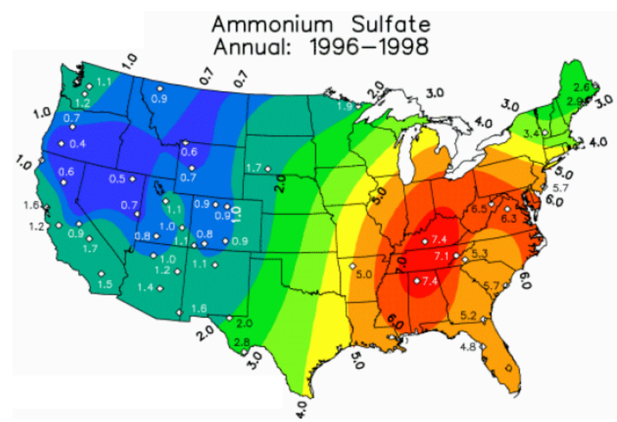
Eastern US

Western US



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