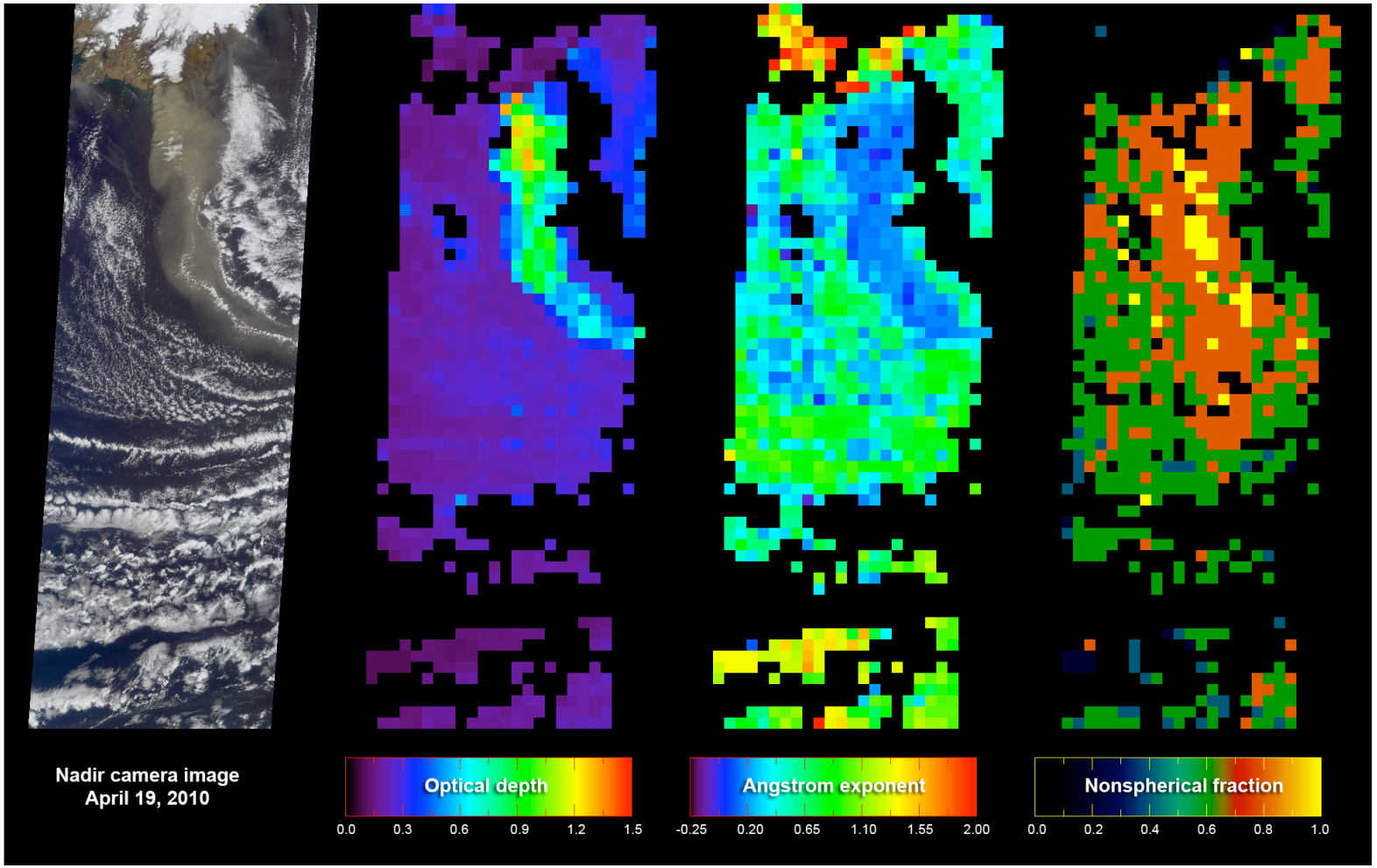
Steps Toward an EOS-Era Aerosol Air Mass Type Climatology

Ralph Kahn *NASA Goddard Space Flight Center*

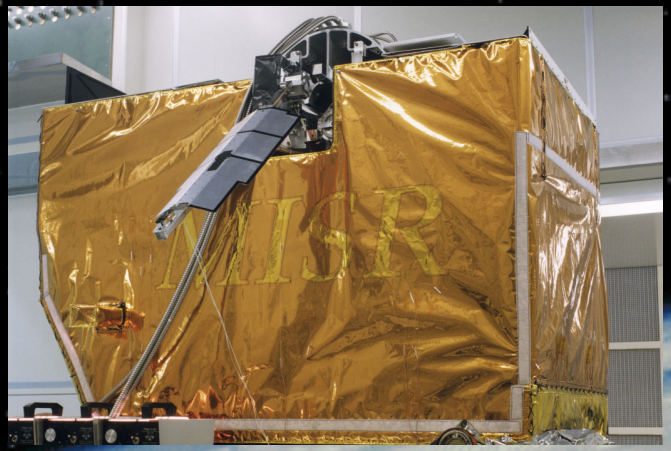


Eyjafjalljökull Volcano Ash Plume – MISR Aerosol Retrieval – April 19, 2010

MISR Team, JPL and GSFC

Multi-angle Imaging SpectroRadiometer

MISR

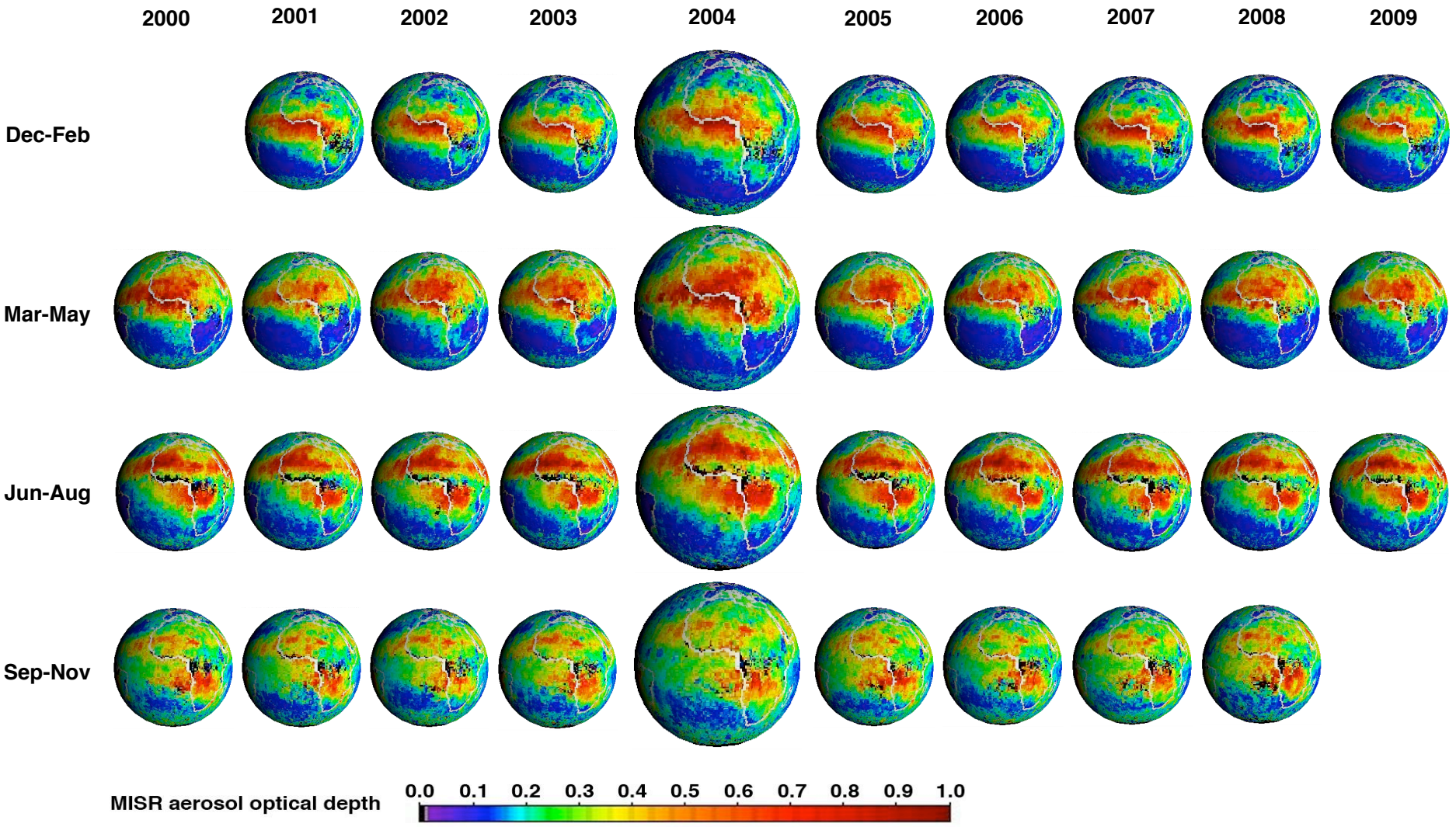


http://www-misr.jpl.nasa.gov

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

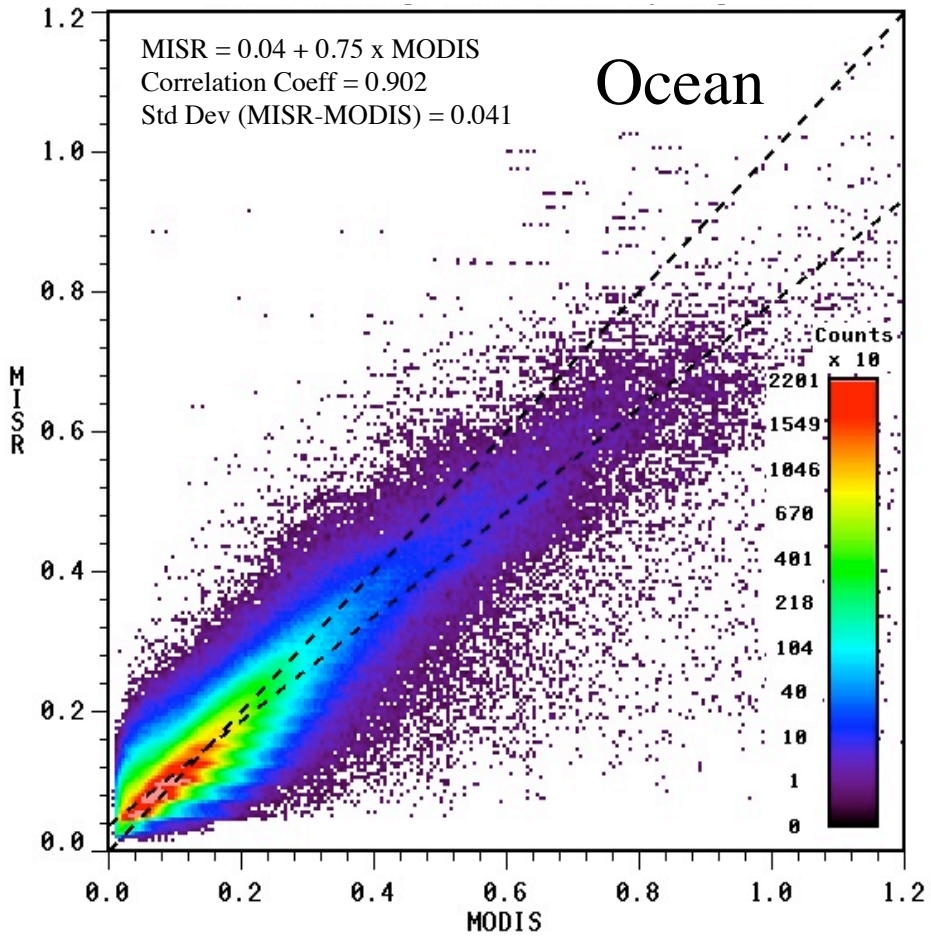


…includes bright desert dust source regions

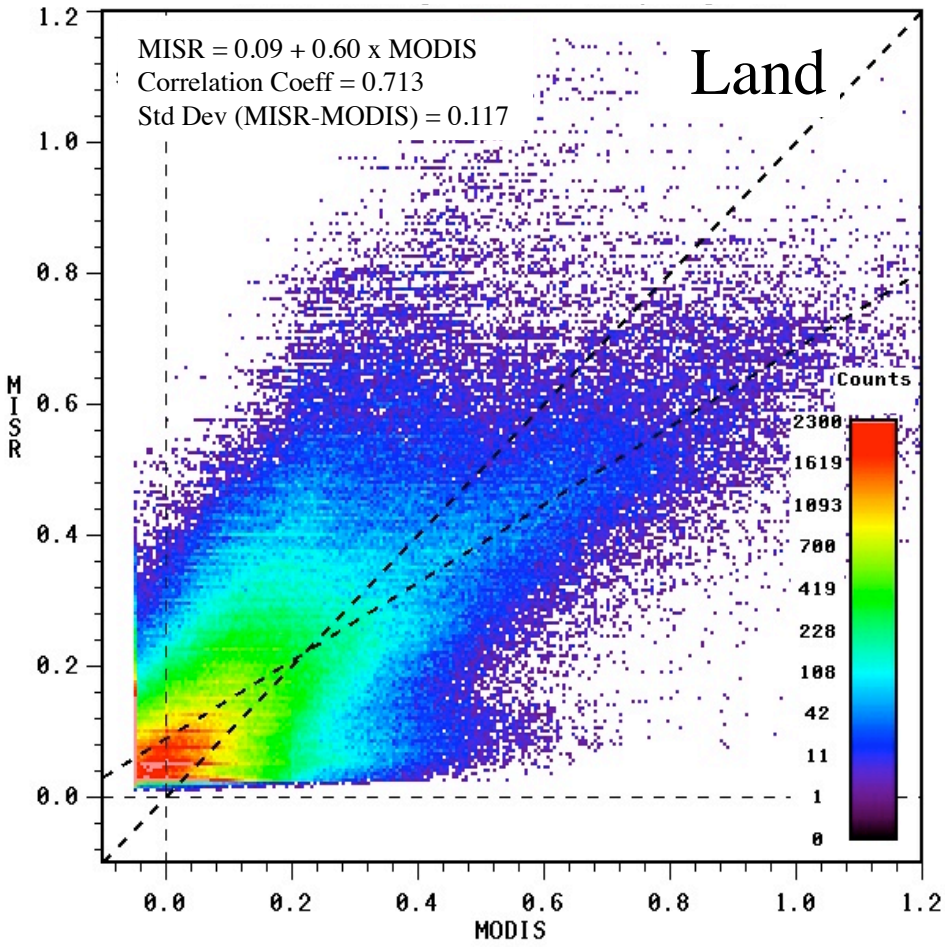
MISR Team, JPL and GSFC

MISR-MODIS *Aerosol Optical Depth* Comparison

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



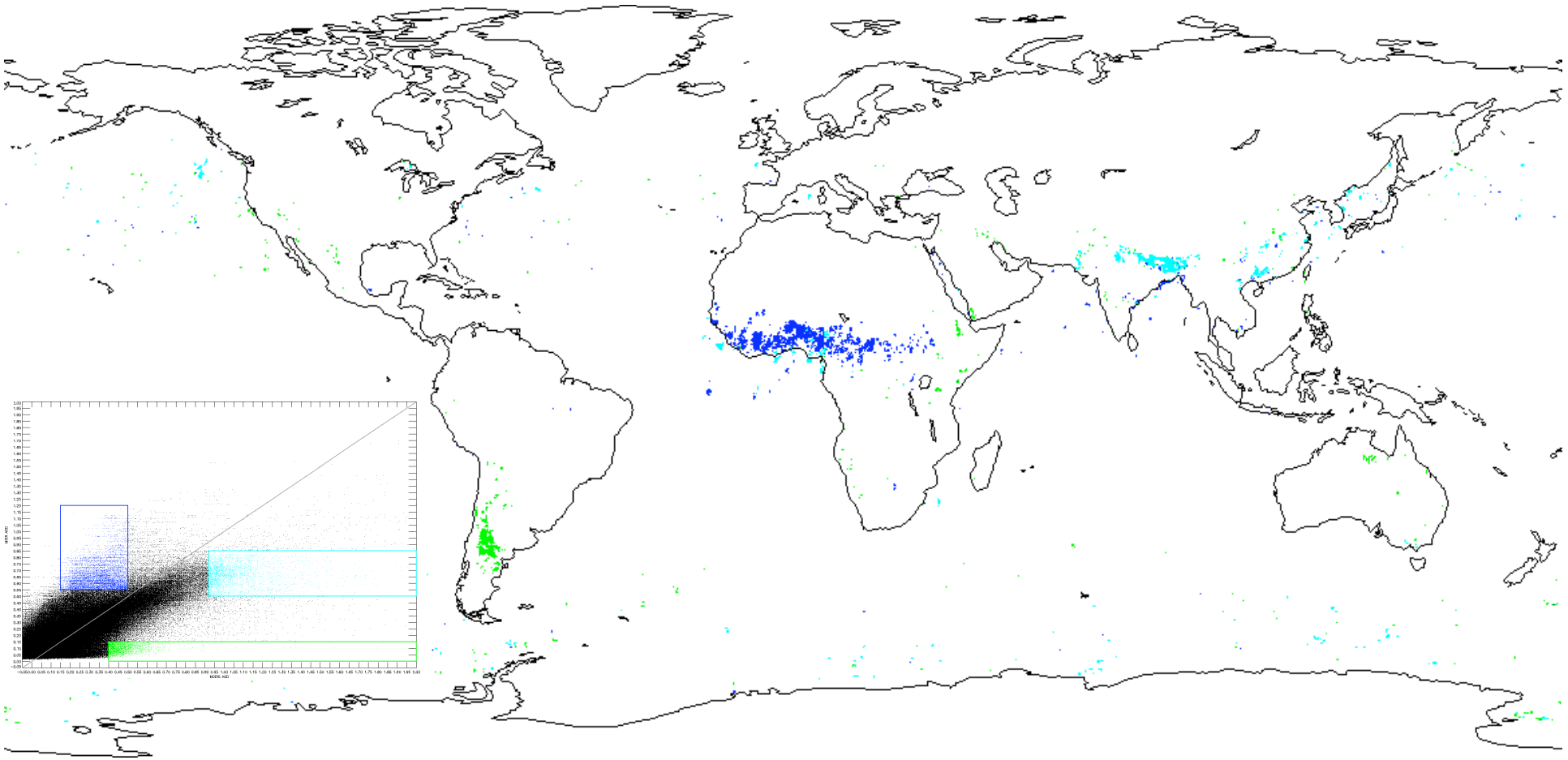
Over-ocean regression coefficient **0.90**
Regression line slope 0.75
MODIS QC ≥ 1



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***



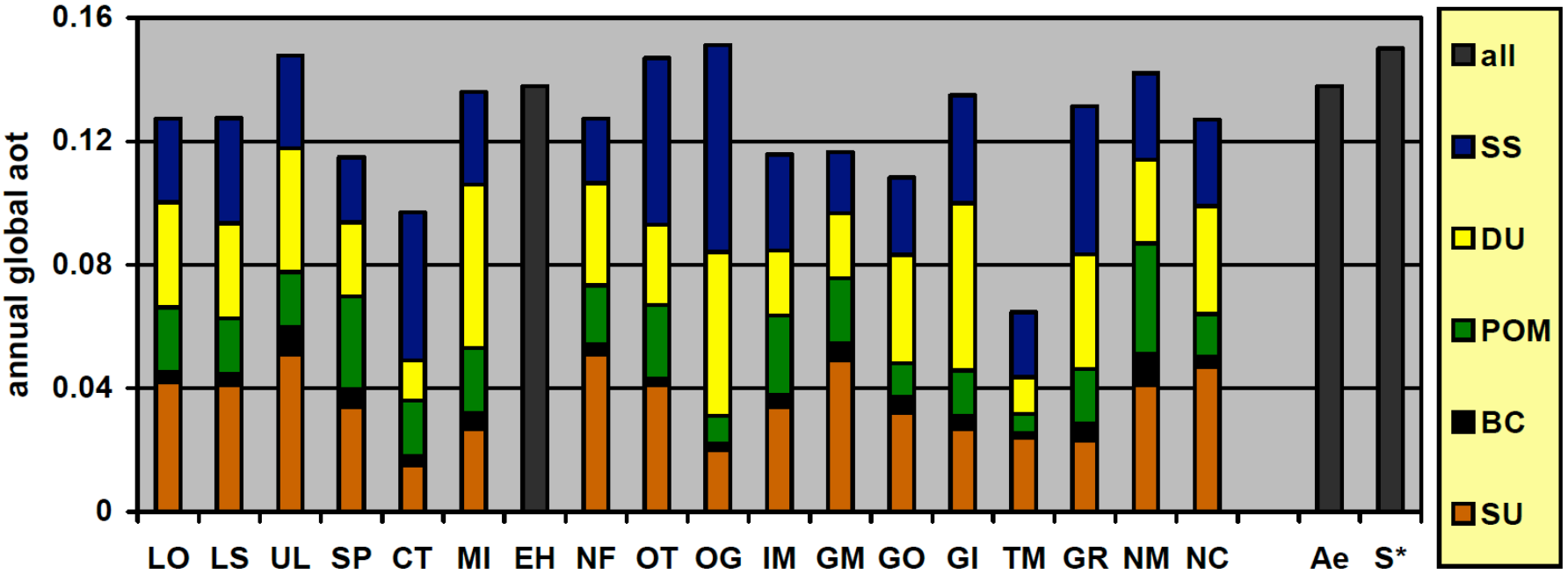
Dark Blue [MISR > MODIS] – N. Africa ***Mixed Dust & Smoke***

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

Constraining DARF – The Next Big Challenge



Ae= AERONET; S*= MISR-MODIS composite

Kinne et al., ACP 2006

- Agreement among models is ***increasingly good for AOD***, given the combined ***AERONET***, ***MISR***, and ***MODIS*** constraints

- The next big observational challenge: Producing ***monthly, global maps of Aerosol Type***

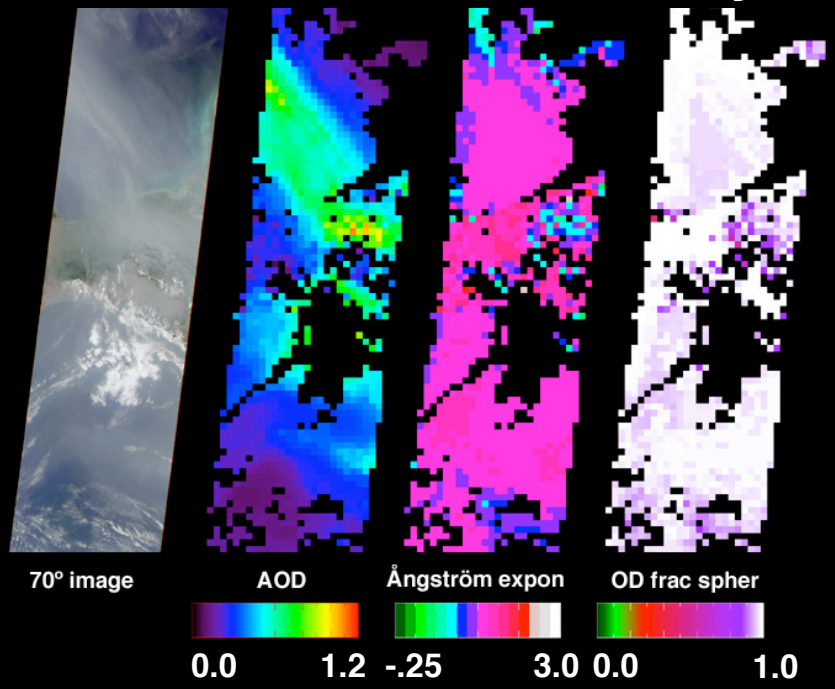
How Good is *Good Enough*?

Instantaneous AOD & ***SSA*** uncertainty upper bounds for ~1 W/m^2 TOA DARF accuracy: **~ 0.02**

CCSP - SAP 2.3, 2009

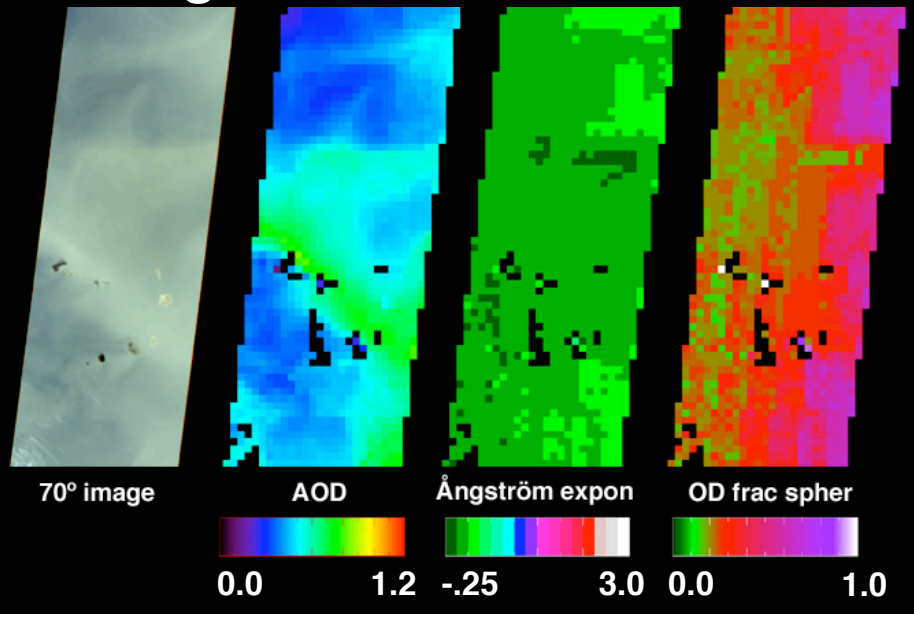
Smoke from Mexico -- 02 May 2002

Aerosol:
Amount
Size
Shape



Medium
Spherical
Smoke
Particles

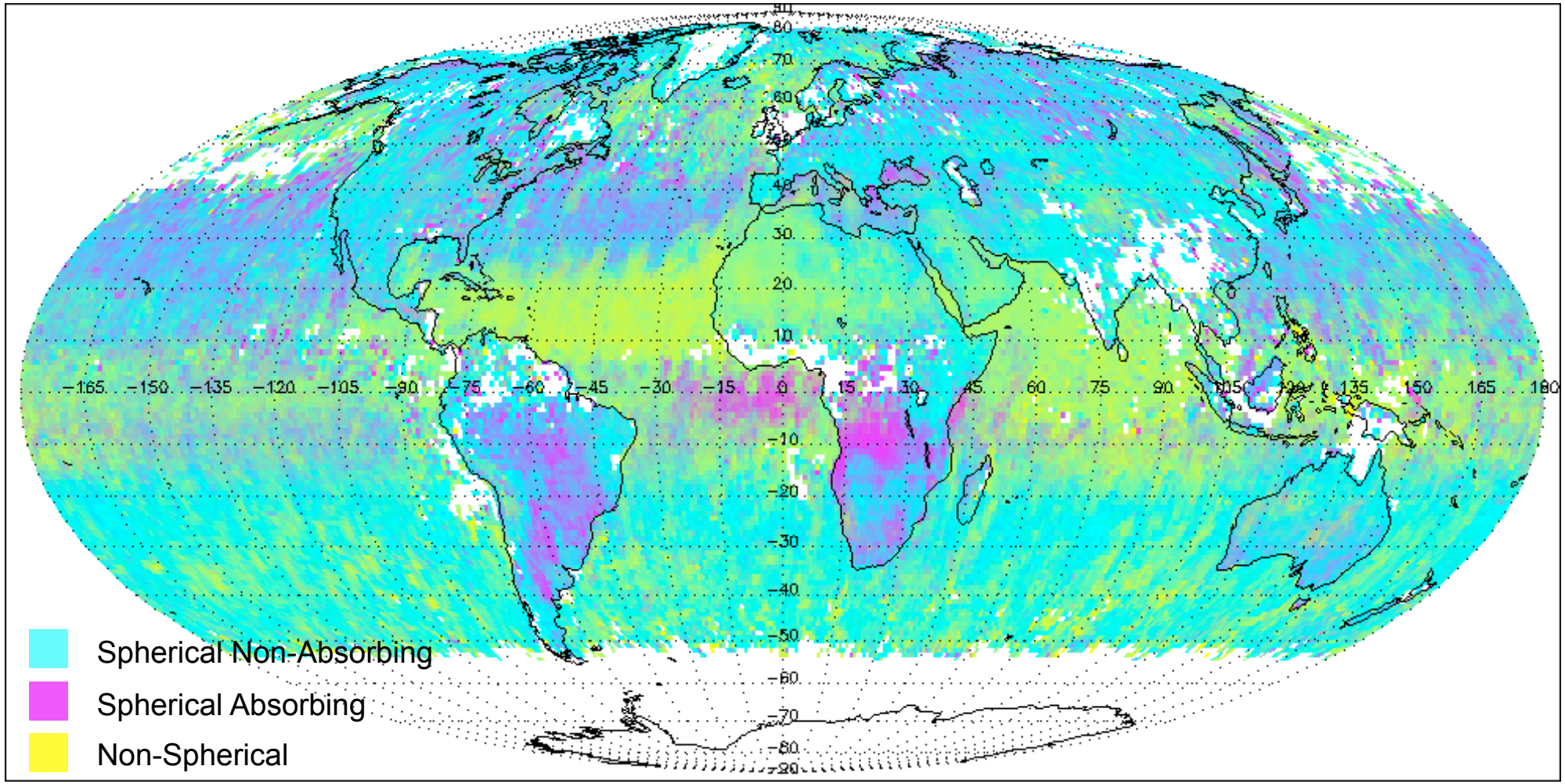
Dust blowing off the Sahara Desert -- 6 February 2004



Large
Non-Spherical
Dust
Particles

MISR *Aerosol Type* Distribution

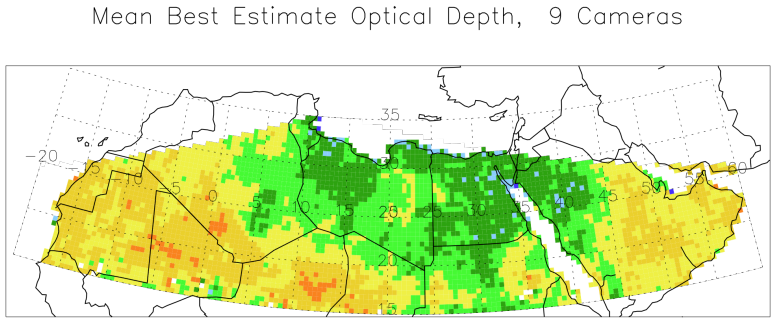
MISR Version 22, July 2007

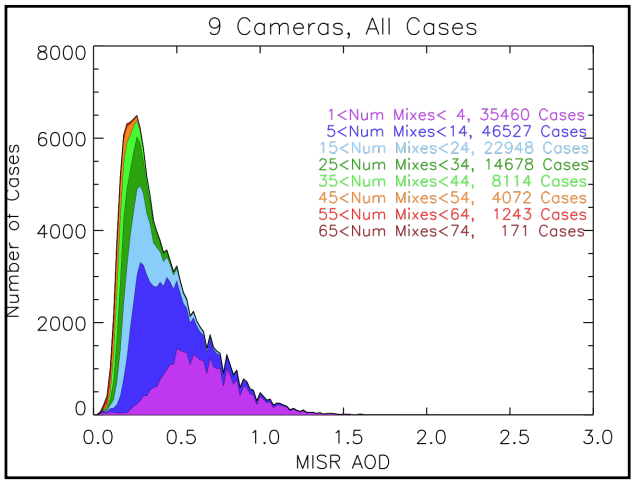


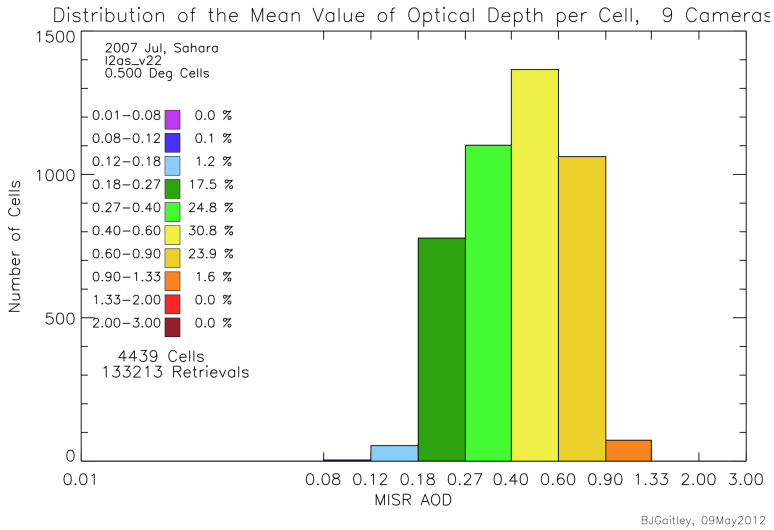
Kahn, Gaitley, Garay, et al., JGR 2010

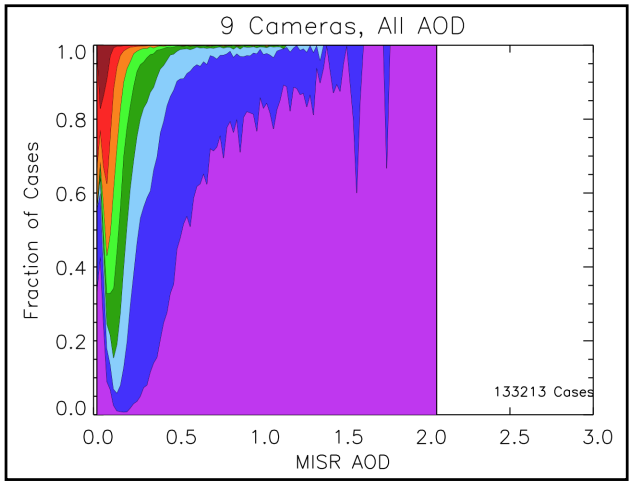
Aerosol Product Validation:
Quality Flag for the MISR *Aerosol Type* Distribution

MISR Version 22, July 2007



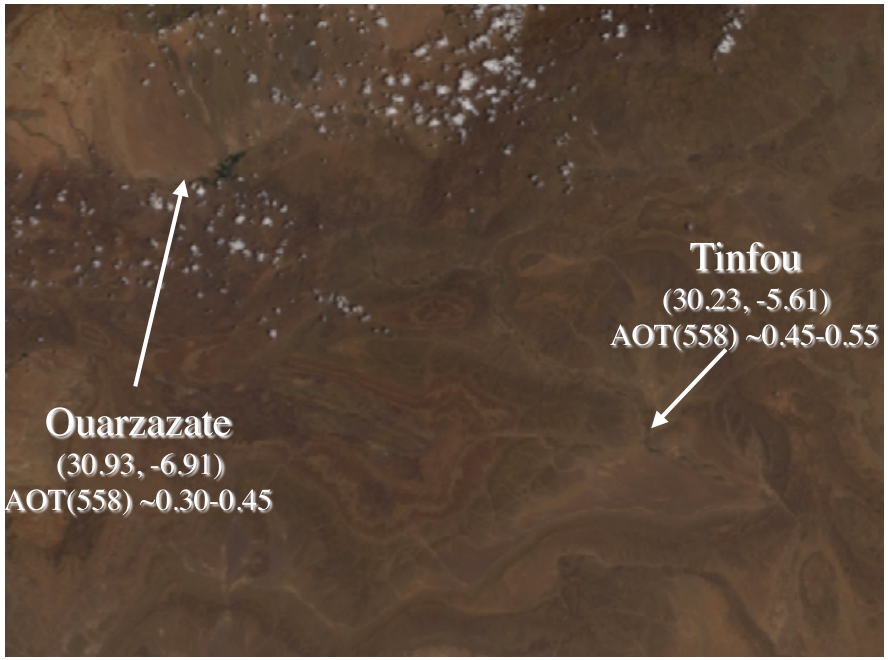


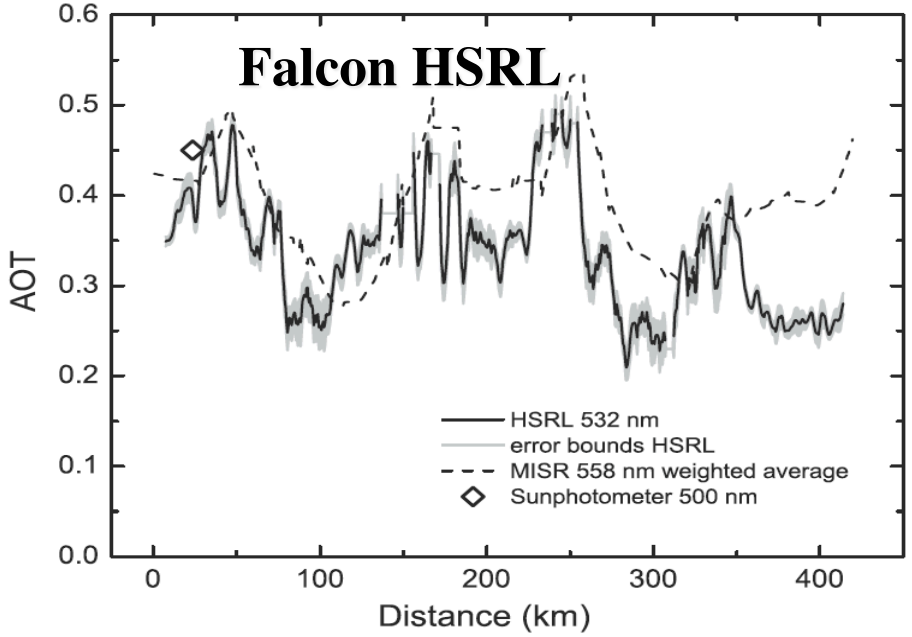


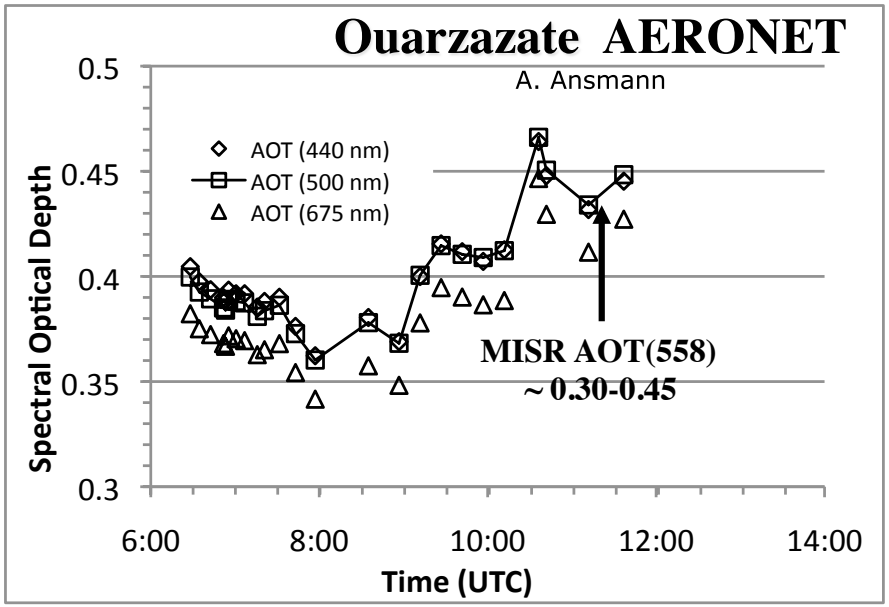


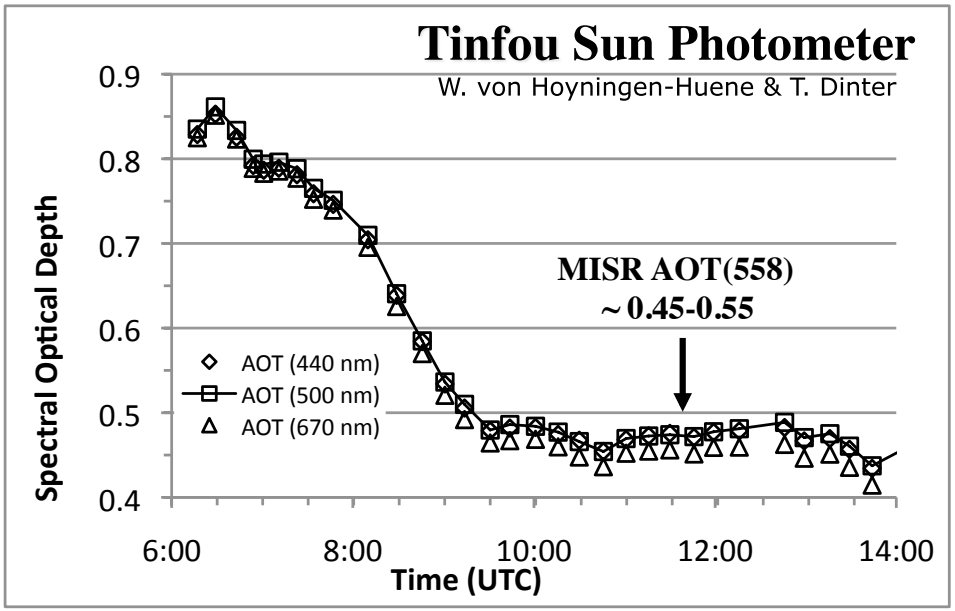
Kahn, Gaitley et al., in preparation

SAMUM Campaign Morocco – June 04, 2006



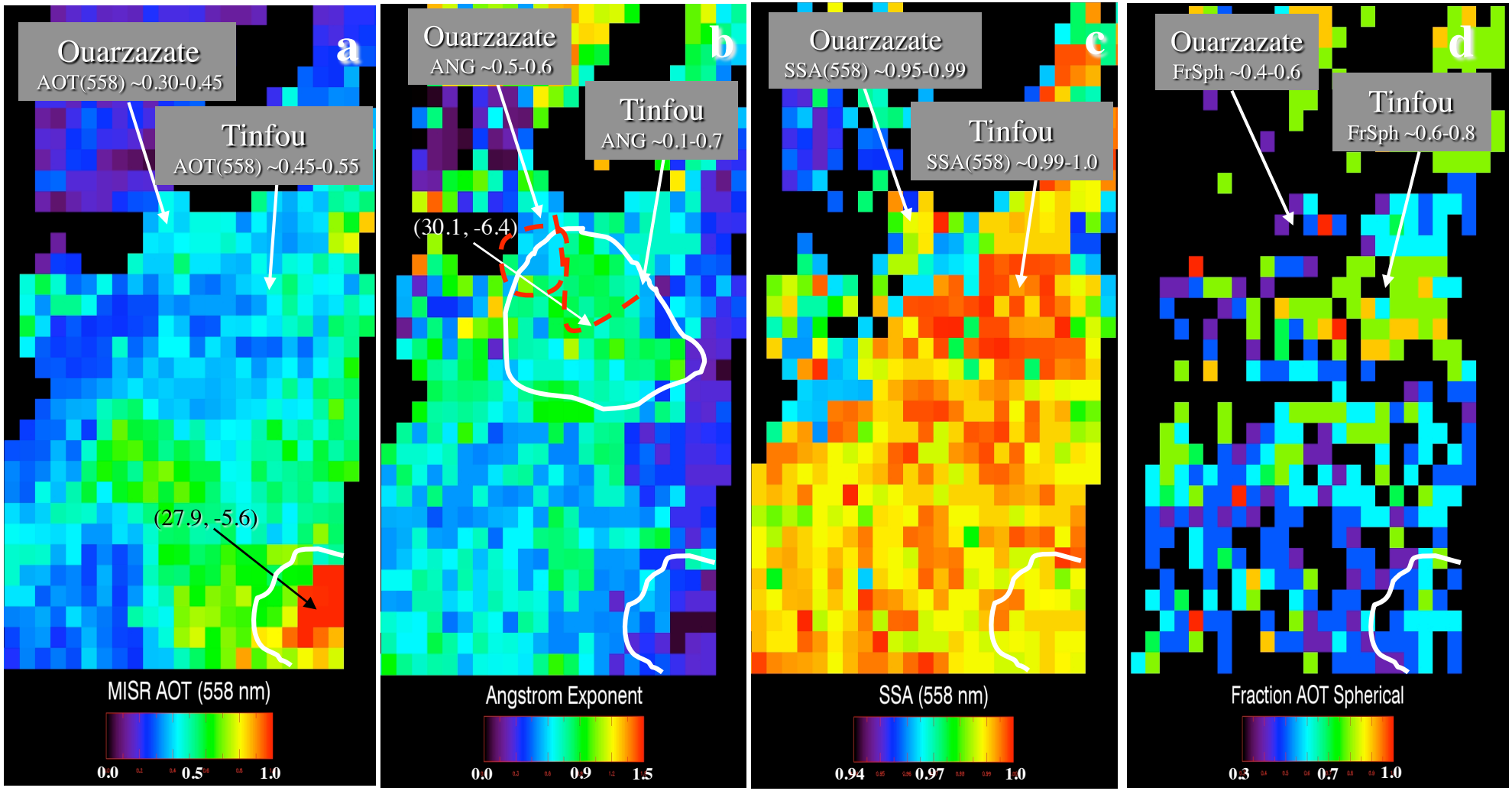






MISR SAMUM Aerosol Air Masses (V19) - June 04, 2006

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

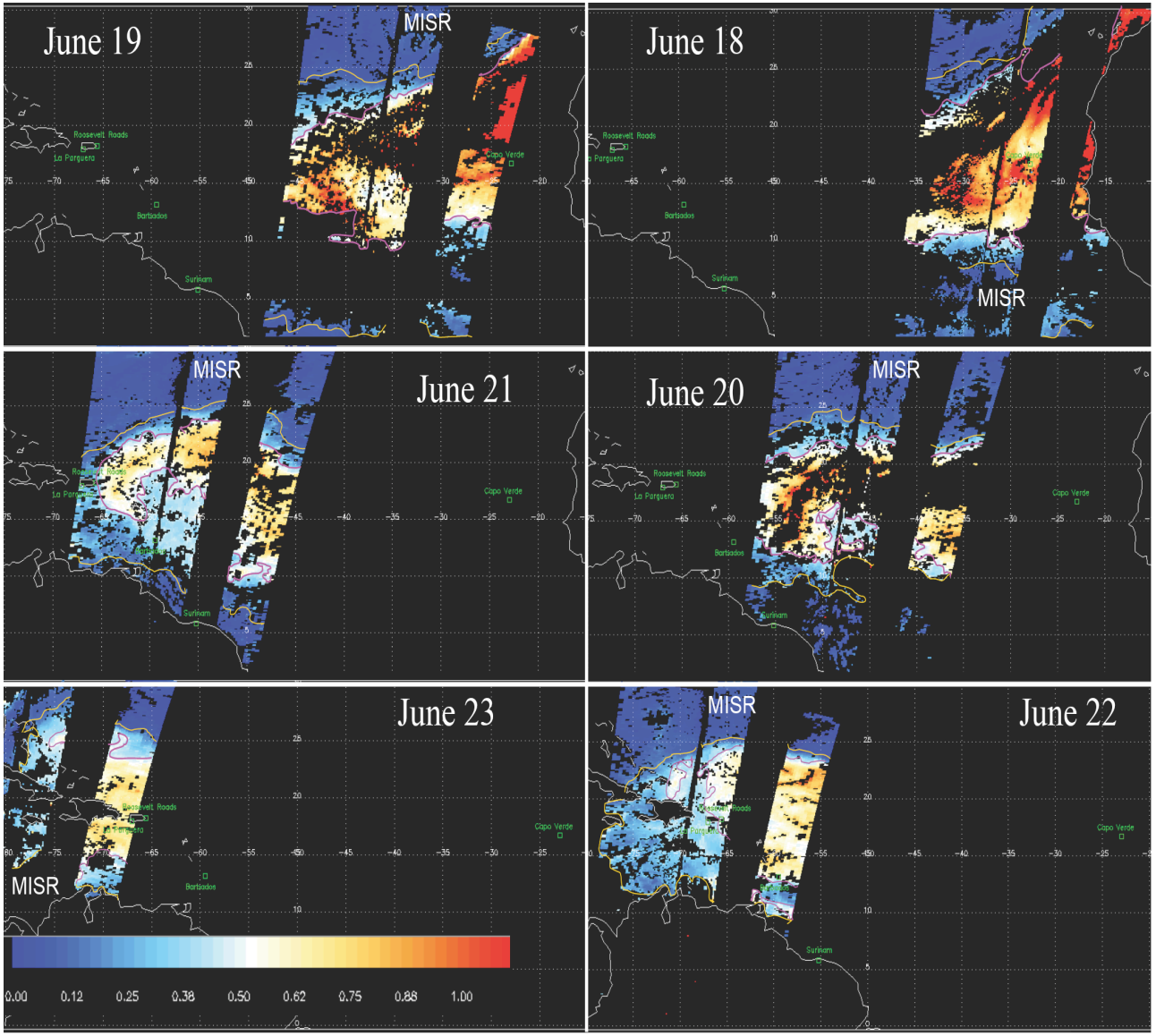
Applications –

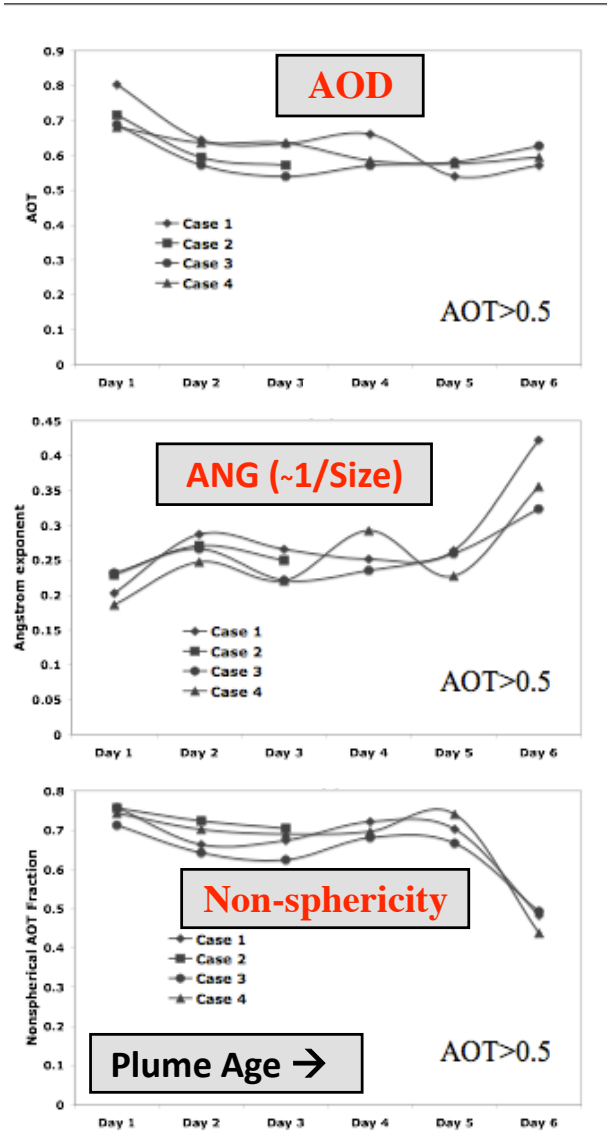
AOD Gradients
Aerosol-Air-Mass-Type Maps
Plume Heights
& Transports

Smoke Dust
Pollution Particles
Volcanic Ash

Constraining Aerosol Sources, Transports, & Sinks

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



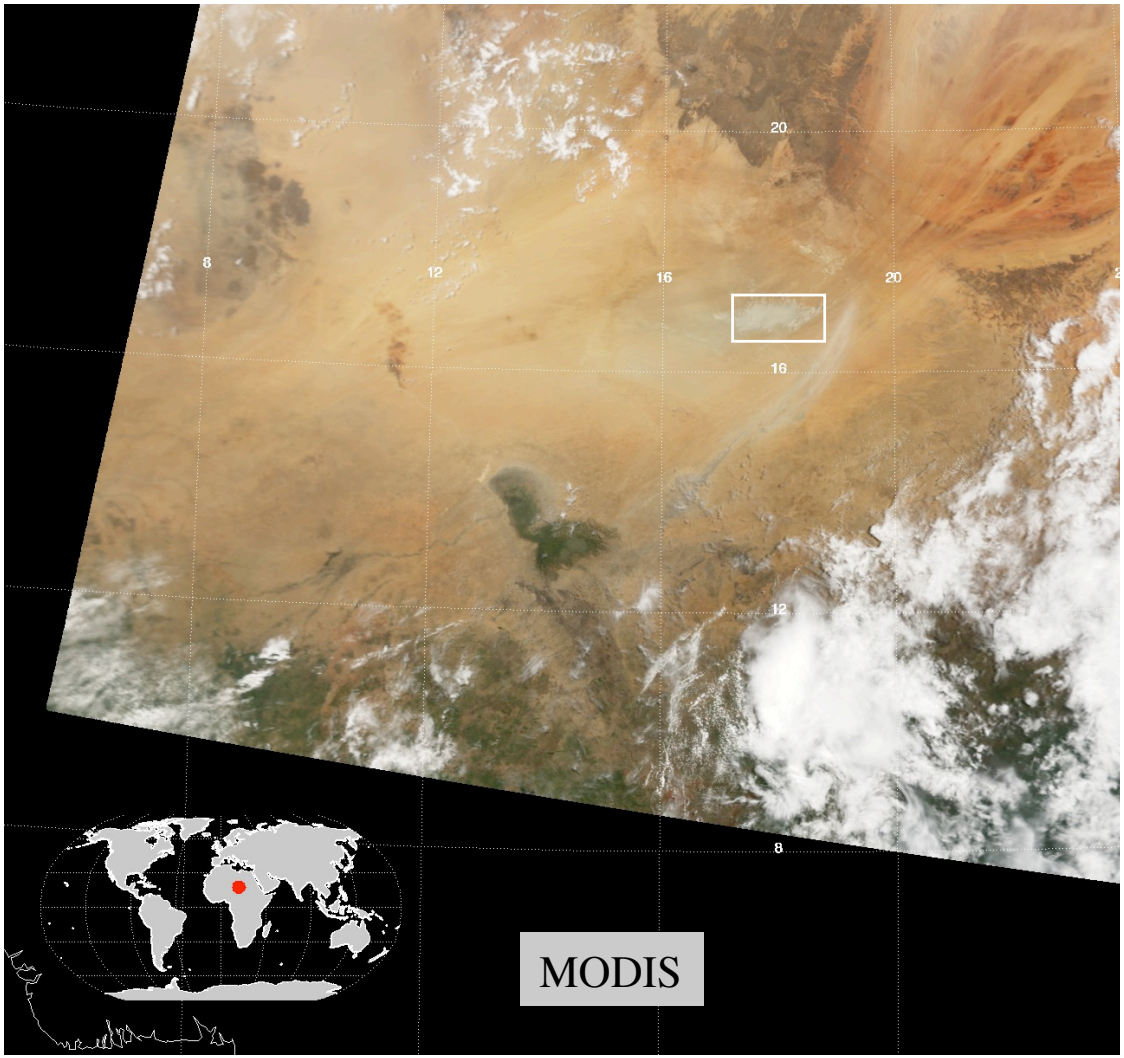


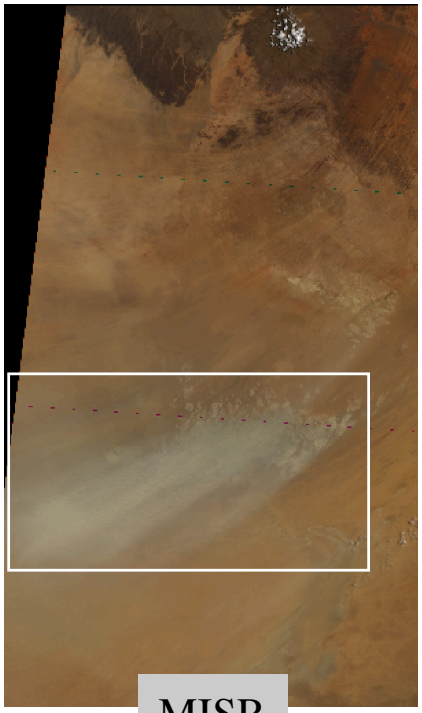
Contours: AOT=0.15 (yellow); AOT=0.5 (purple)

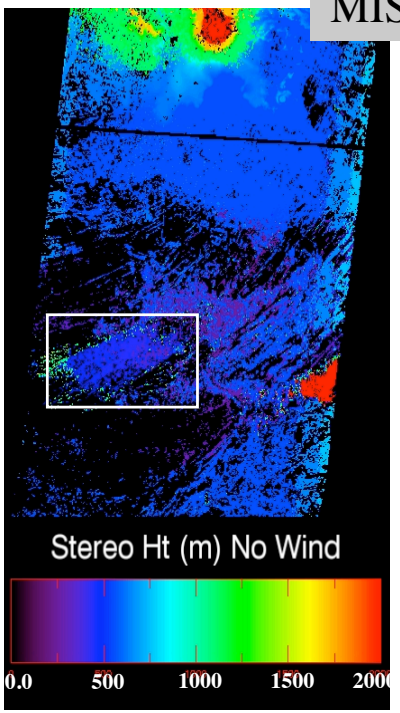
Kalashnikova and Kahn, JGR 2008

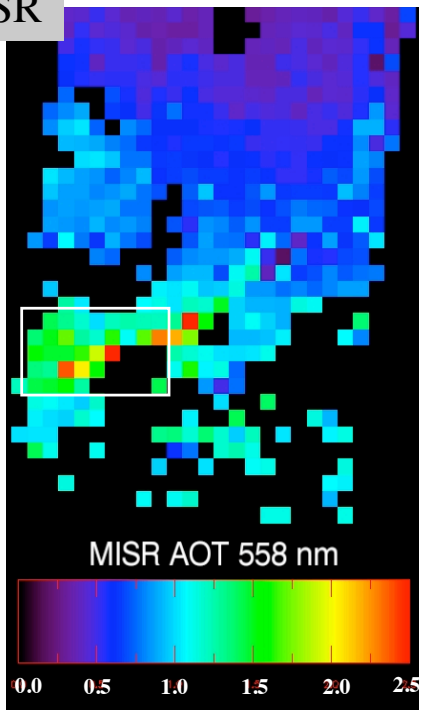
Saharan Dust Source Plume

Bodele Depression Chad June 3, 2005 Orbit 29038







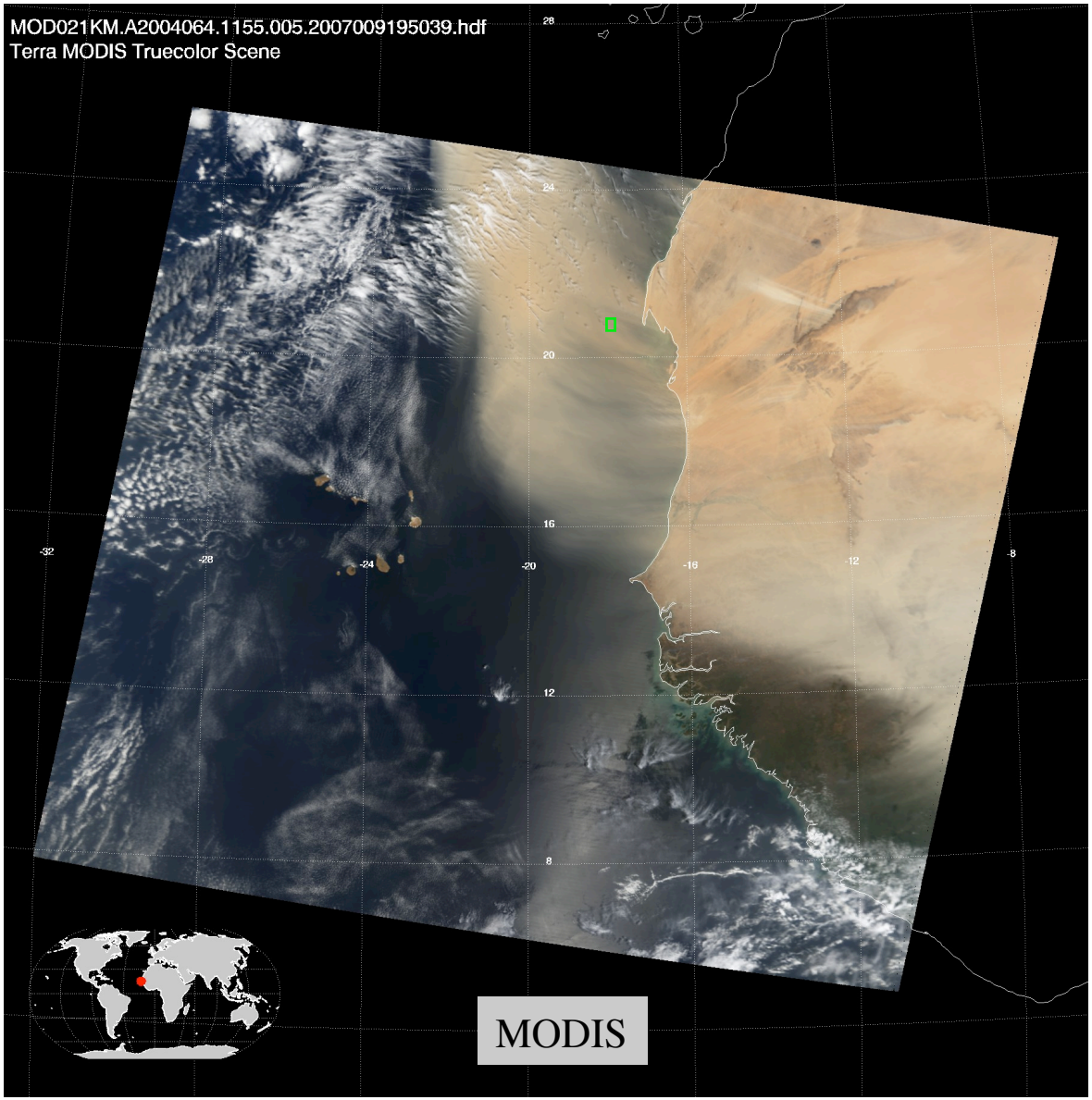


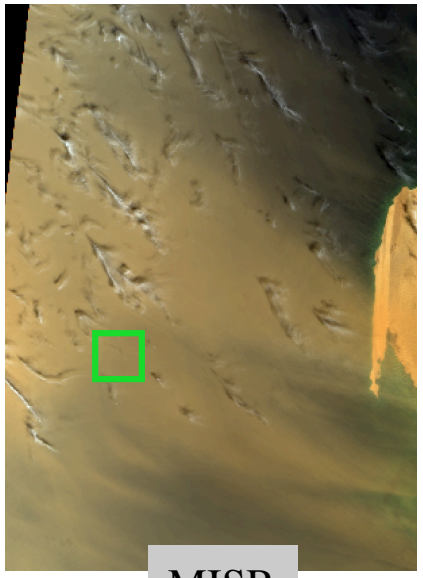
Dust is injected near-surface…

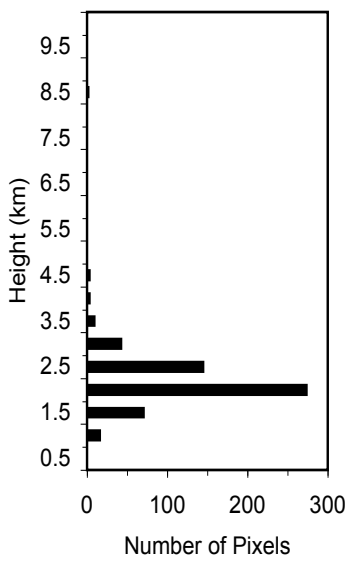
Kahn et al., JGR 2007

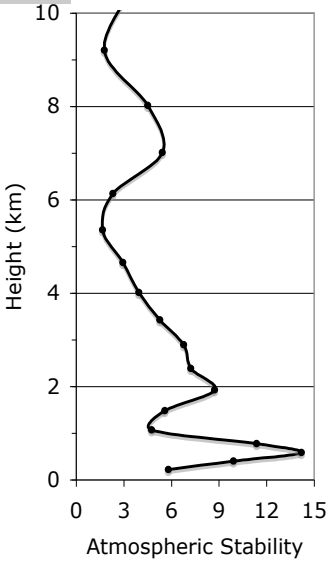
Transported Dust Plume

Atlantic, off Mauritania March 4, 2004 Orbit 22399







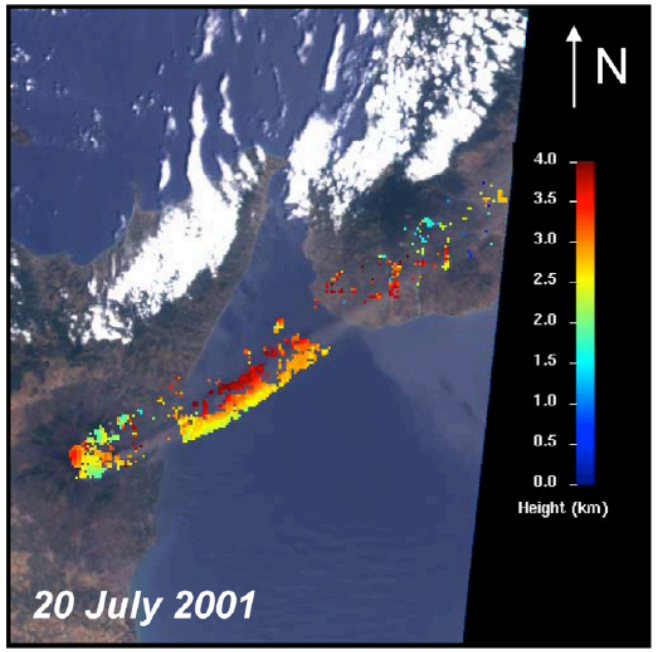


Transported dust finds elevated layer of relative stability…

Kahn et al., JGR 2007

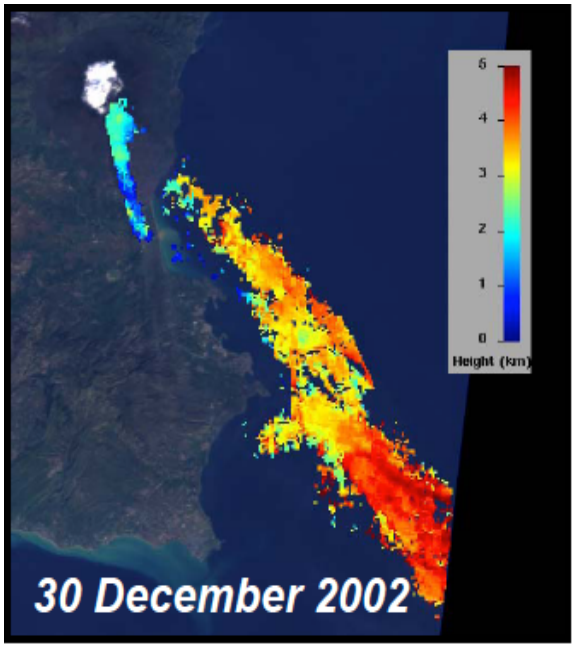
Mount Etna Plume Height and Eruption Style from MISR

Scollo, S. R.A. Kahn, D.L. Nelson, M. Coltelli, D.J. Diner, M.J. Garay, and V.J. Realmuto
MISR observations of Etna volcanic plumes. *J. Geophys. Res*. 2012



MISR nadir-viewing, true-color image showing Etna, with stereo-derived plume height superposed

29 Sept. 2006 – MISR retrieved mostly small spherical particles, indicating a sulfate/water-dominated plume



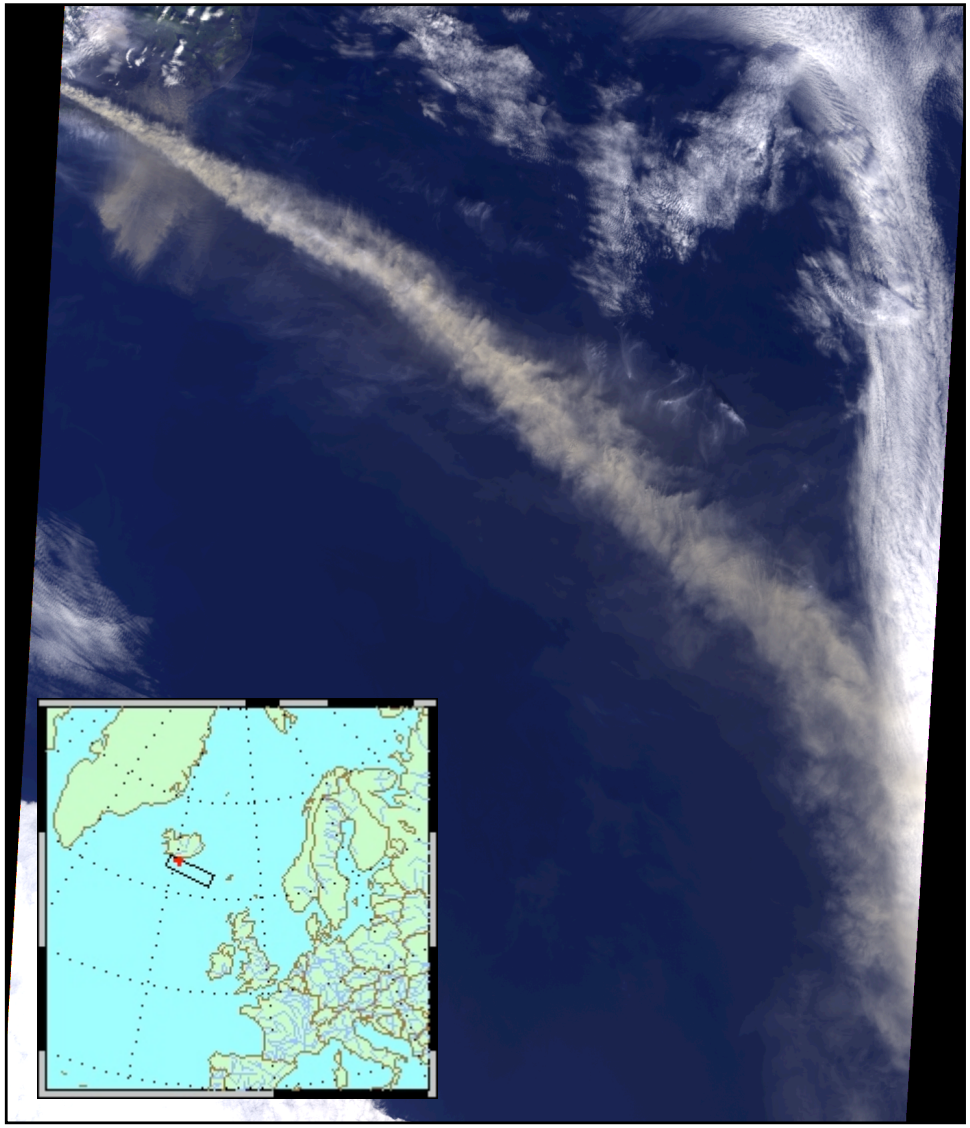
MISR stereo heights for the ash-dominated plume on 30 December 2002

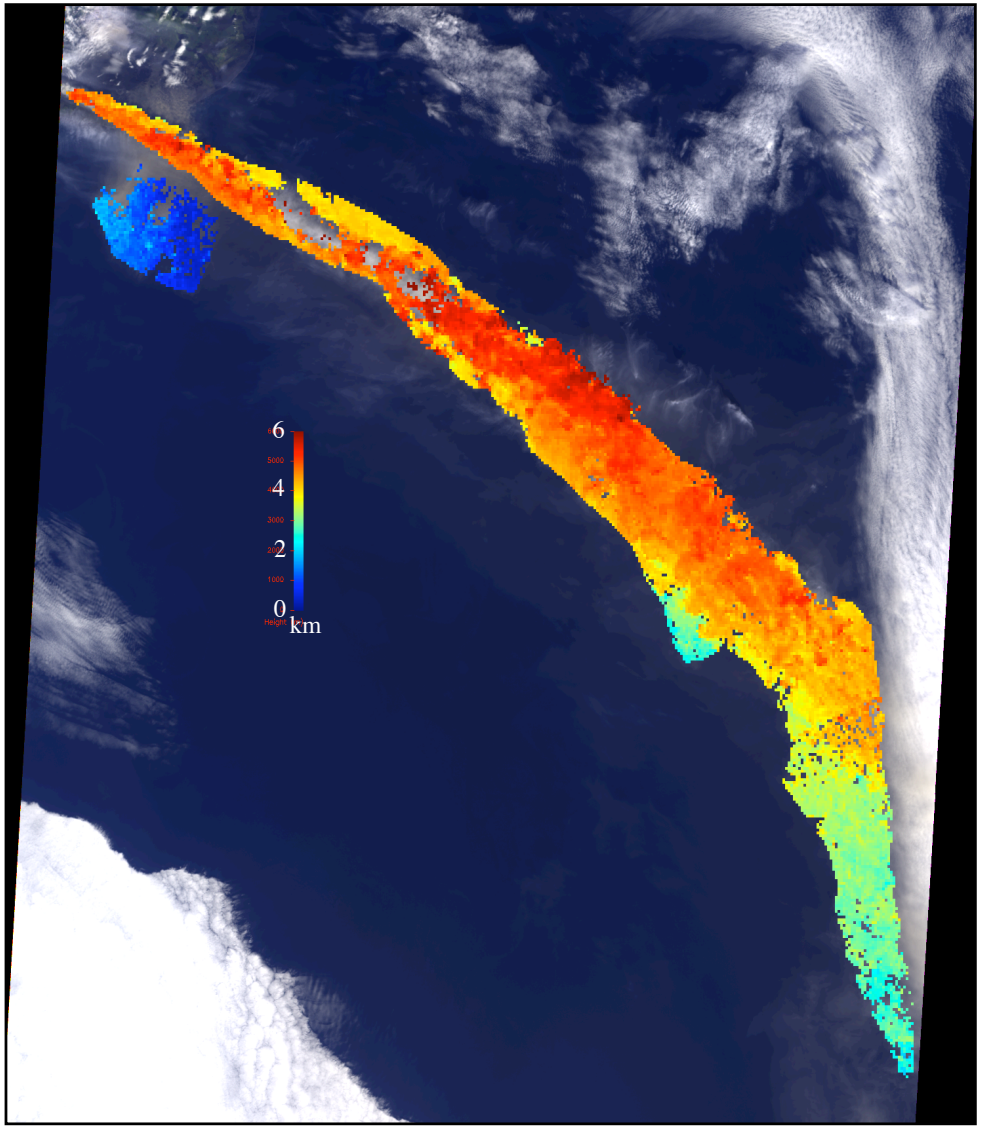
Indications of Eruption Strength:

- ***Plume Height*** from MISR stereo imaging
- ***Ash to Sulfate/Water particle AOD ratio*** from MISR-retrieved particle shape and size

MISR Stereo-Derived Plume Heights

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

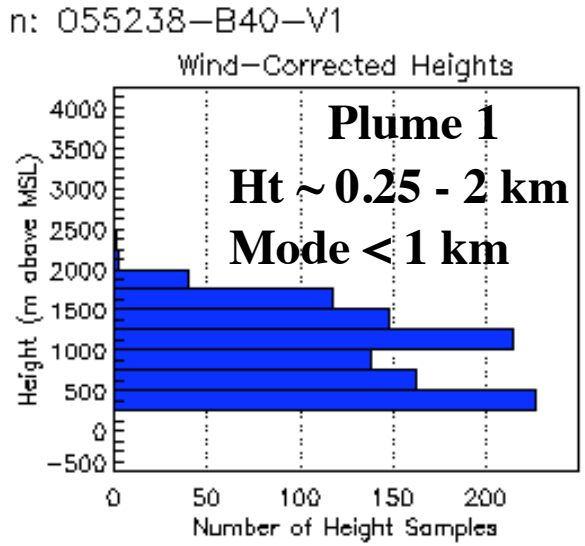




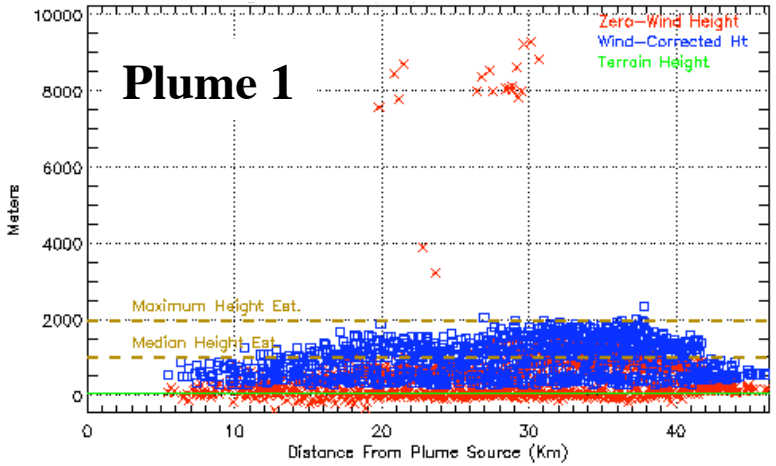
D. Nelson and the MISR Team, JPL and GSFC

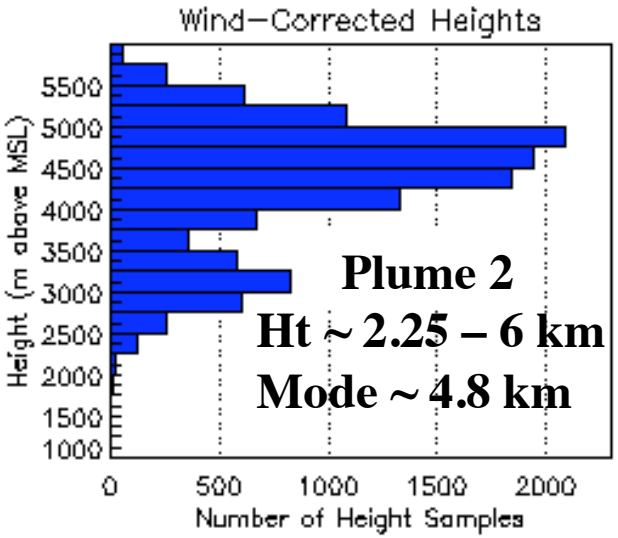
MISR Stereo-Derived Plume Heights

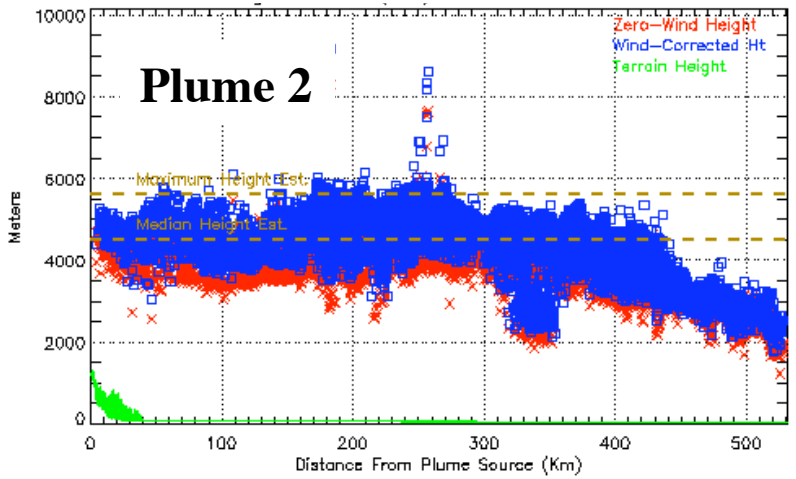
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39



Height: Blue = Wind-corrected



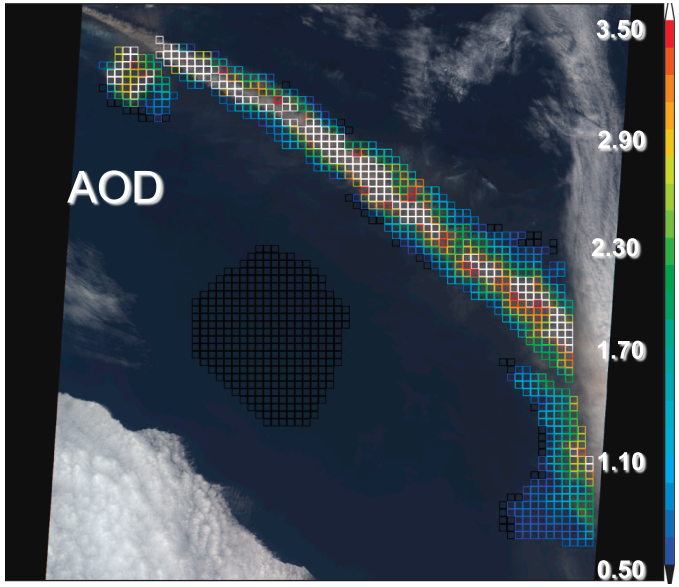


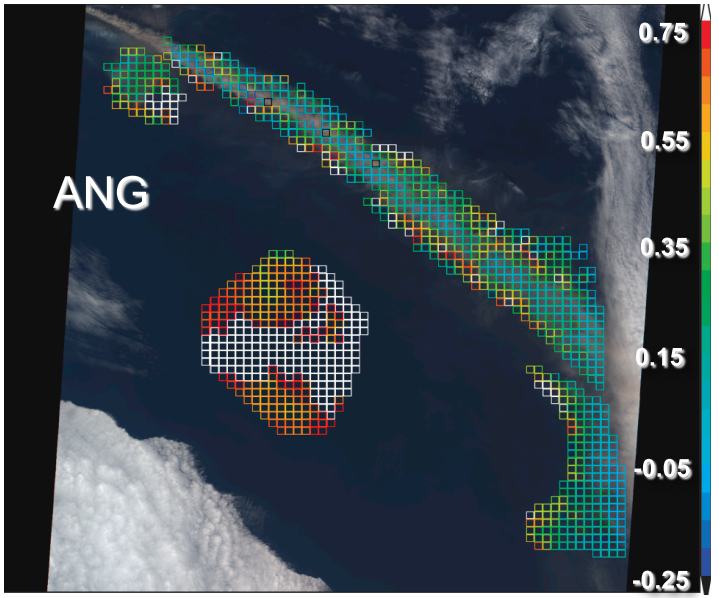


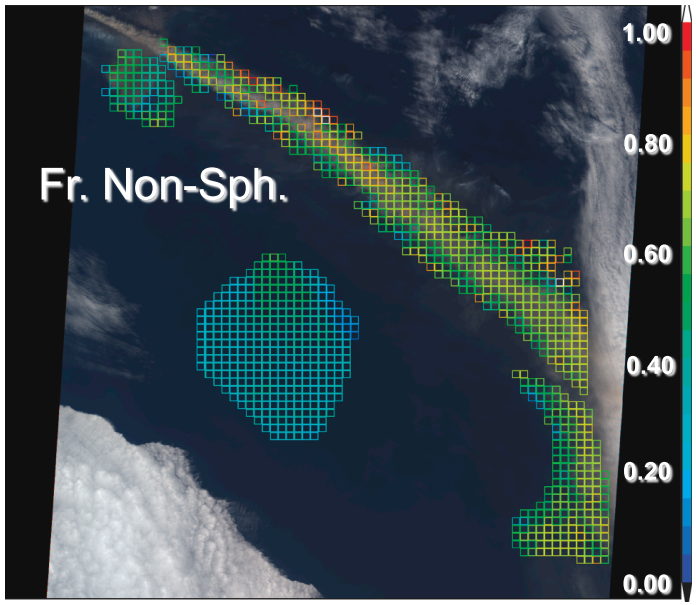
D. Nelson and the MISR Team

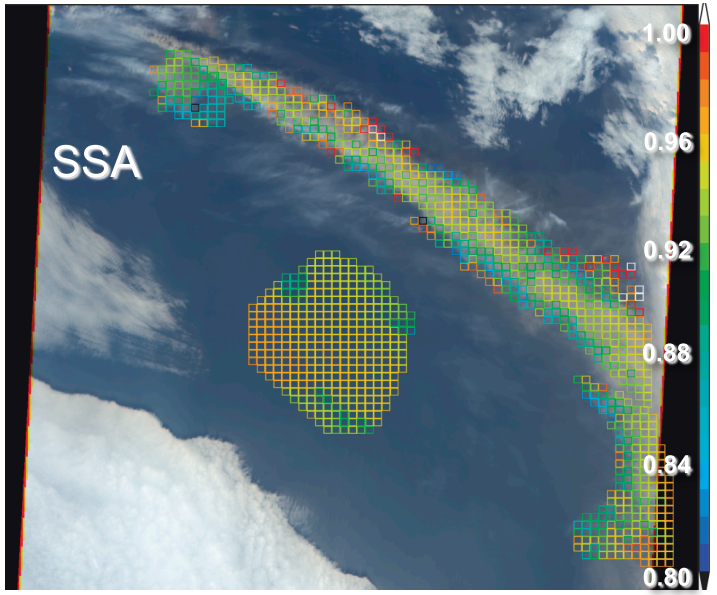
MISR Research Aerosol Retrievals

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









Kahn & Limbacher, ACP 2012

MISR Research Aerosol Retrievals

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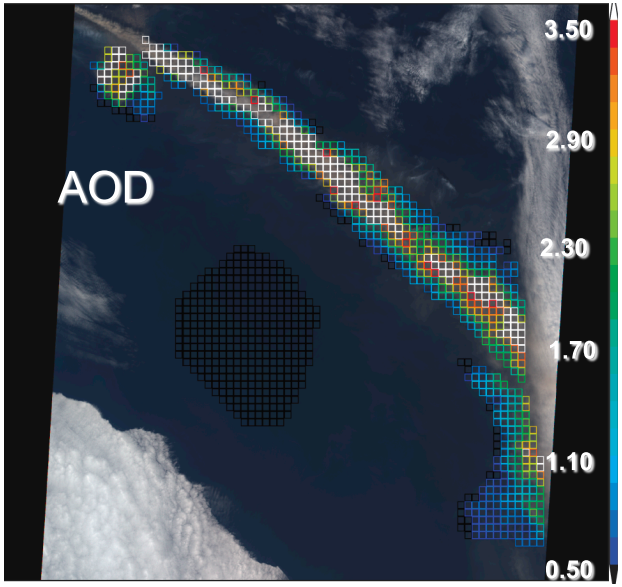
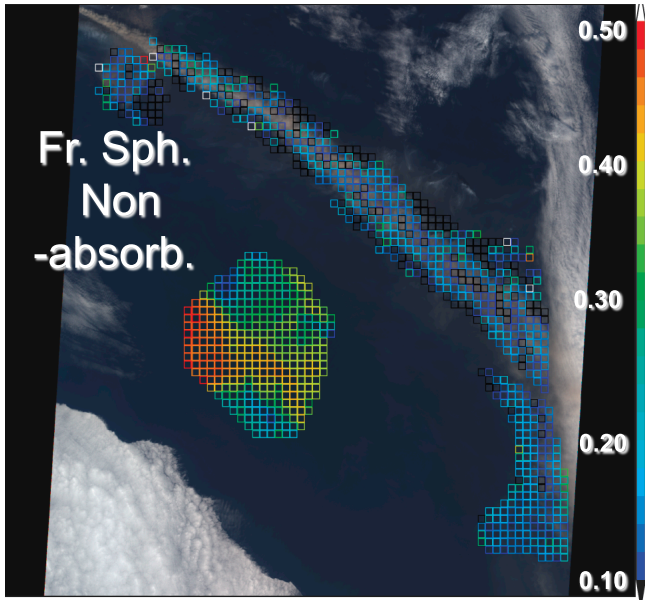
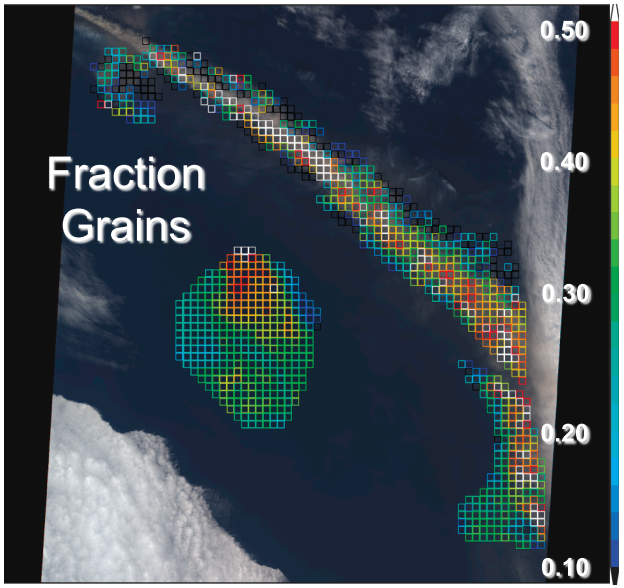
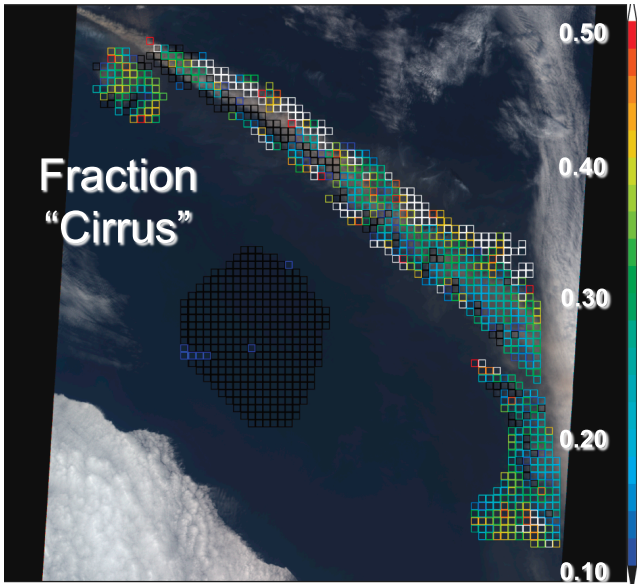




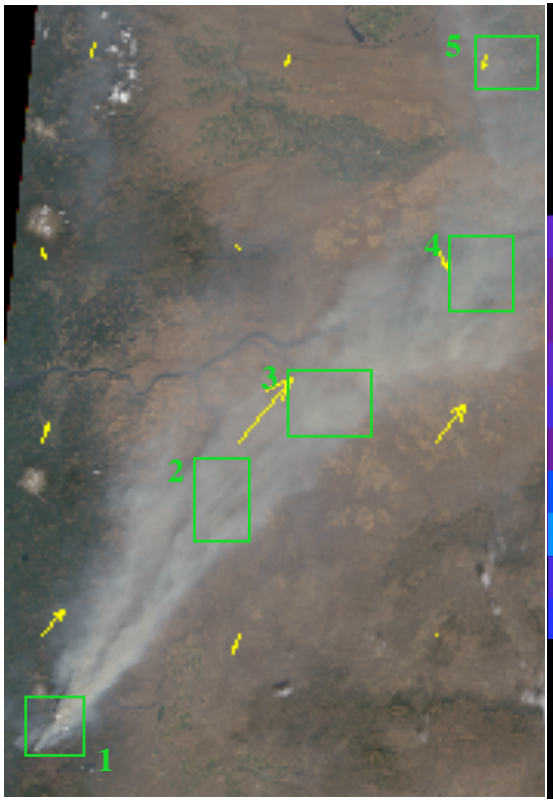


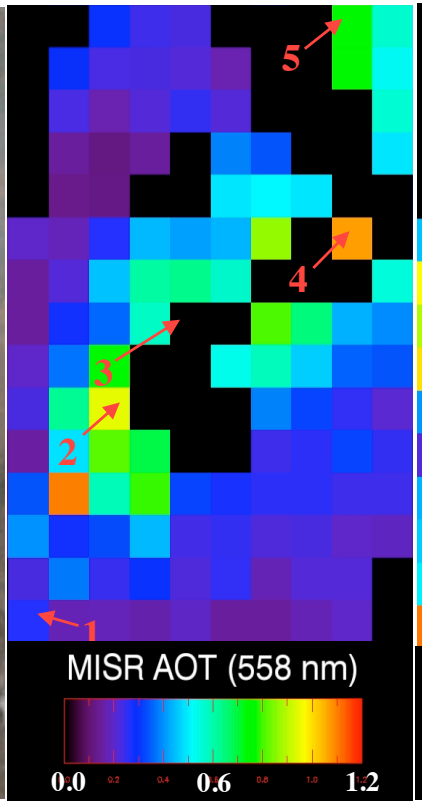


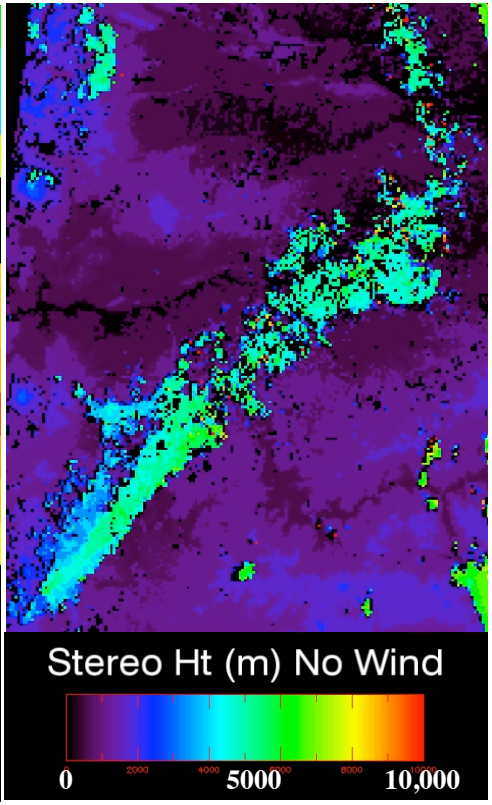
Kahn & Limbacher, ACP 2012

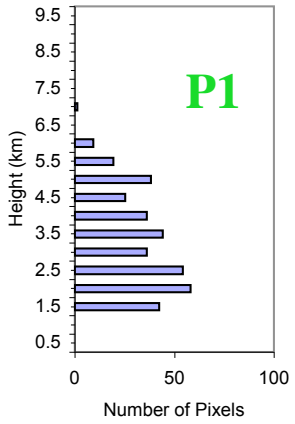
Oregon Fire Sept 04 2003

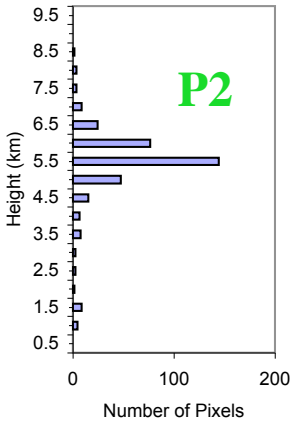
Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)

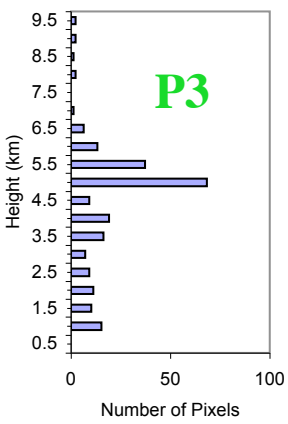


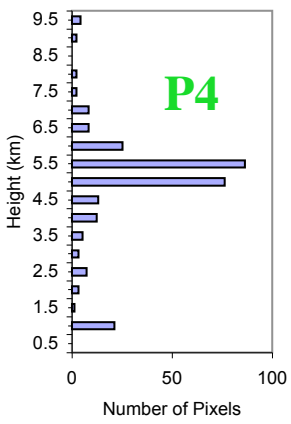


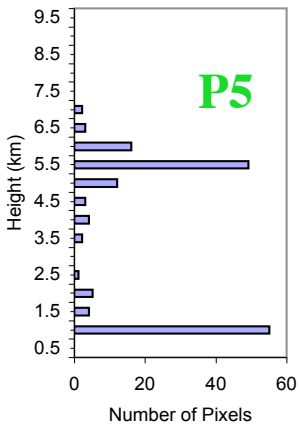


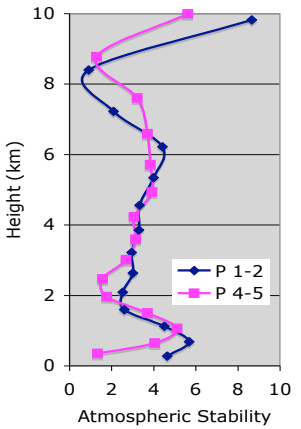






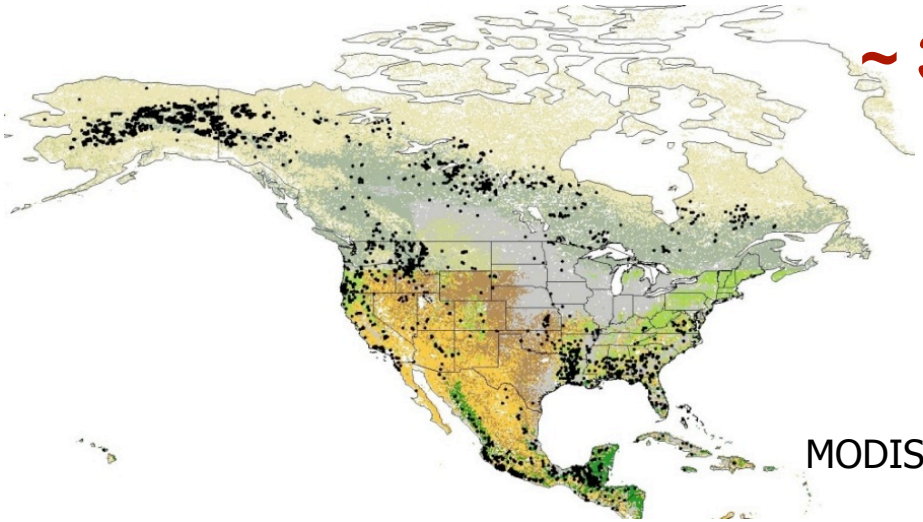






Kahn, et al., JGR 2007

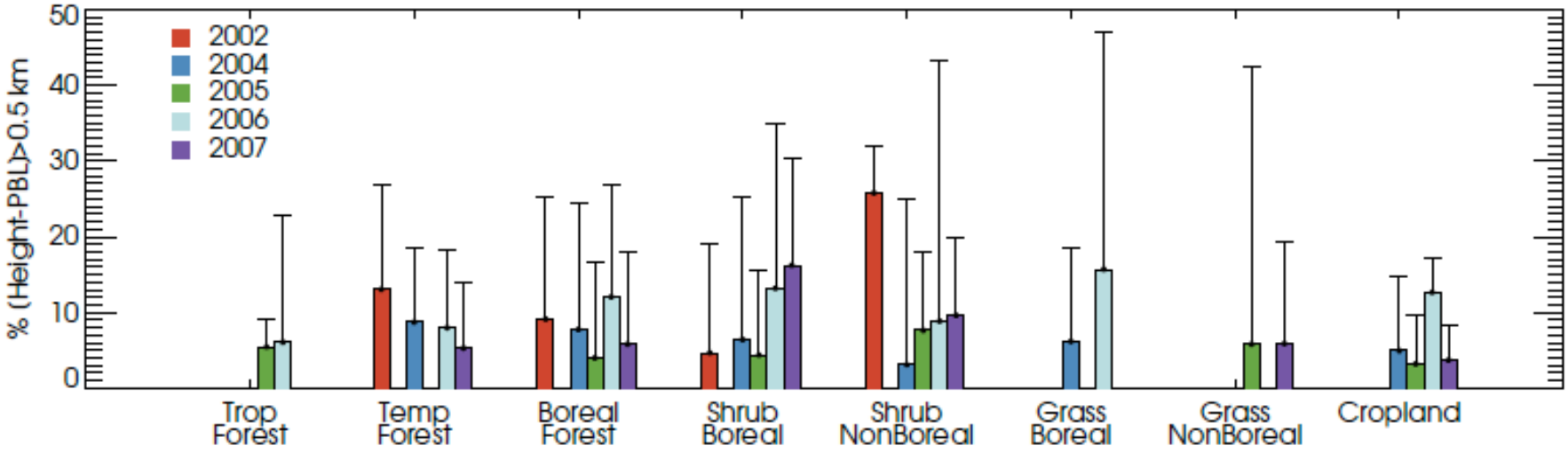
N. America Plume *Injection Height* Climatology



MODIS IGBP land cover map
(1x1 Km res)

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

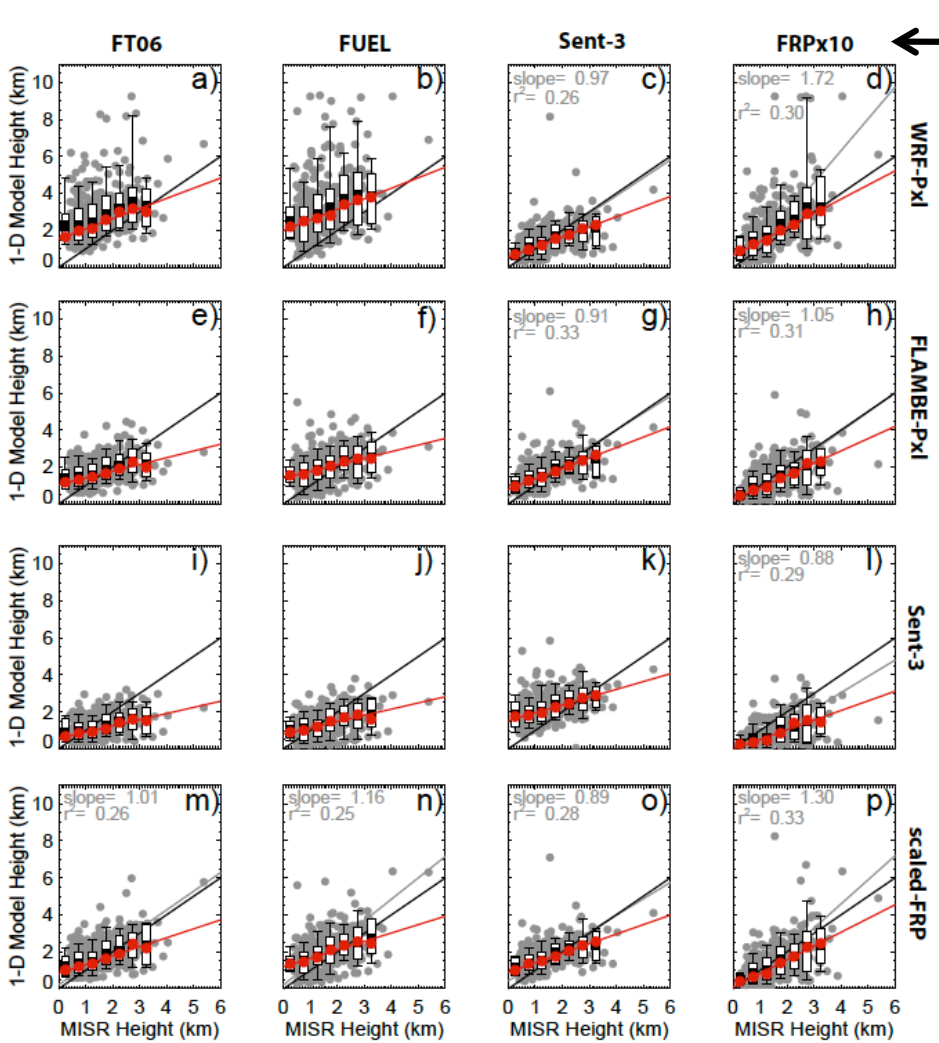
- Tropical Forest
- Temperate Forest
- Boreal Forest
- Boreal Shrubland
- Non-Boreal Shrubland
- Boreal Grassland
- Non-Boreal Grassland
- Cropland



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

Val Martin et al. ACP 2010

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



To Constrain models:

Need to assess the

Parameterizations

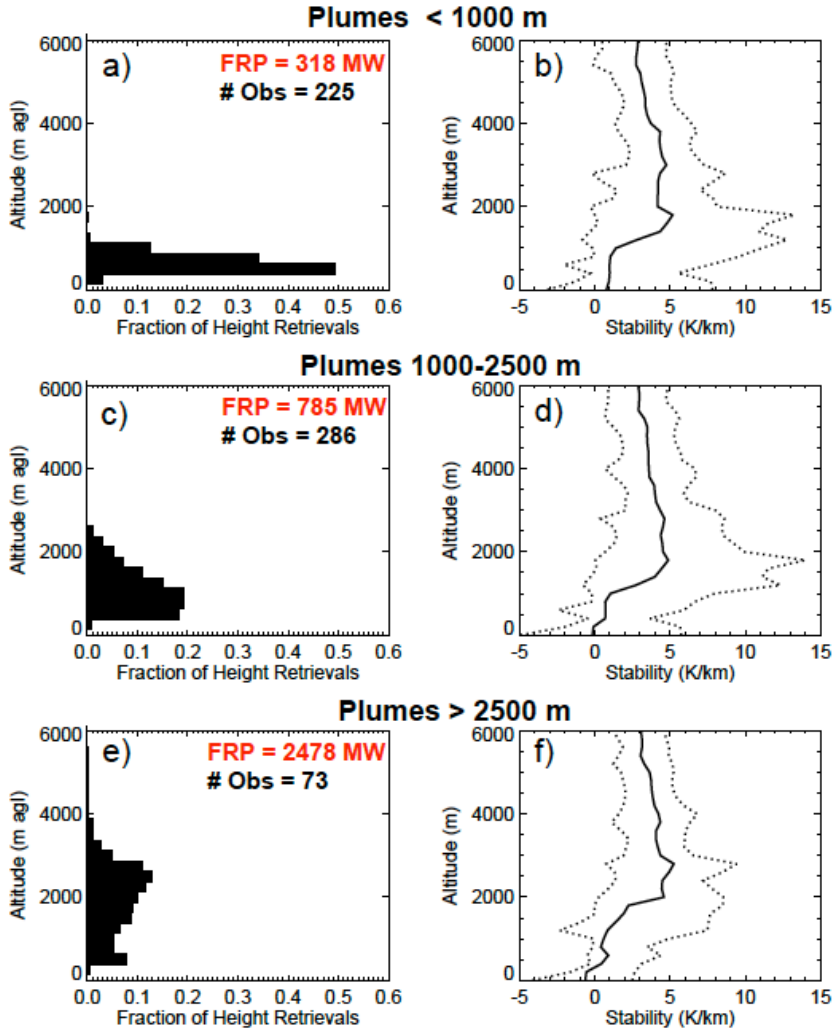
actually used

1-D Plume-rise model heights vs. MISR-observed max. plume heights

-- Models have ***lower dynamic range than observed***, but very variable

Val Martin et al., JGR 2012

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



The key factors:

- ***Fire Energy***
  (fire area; heat flux, FRP)
- ***Atmospheric Stability***
- ***Entrainment***

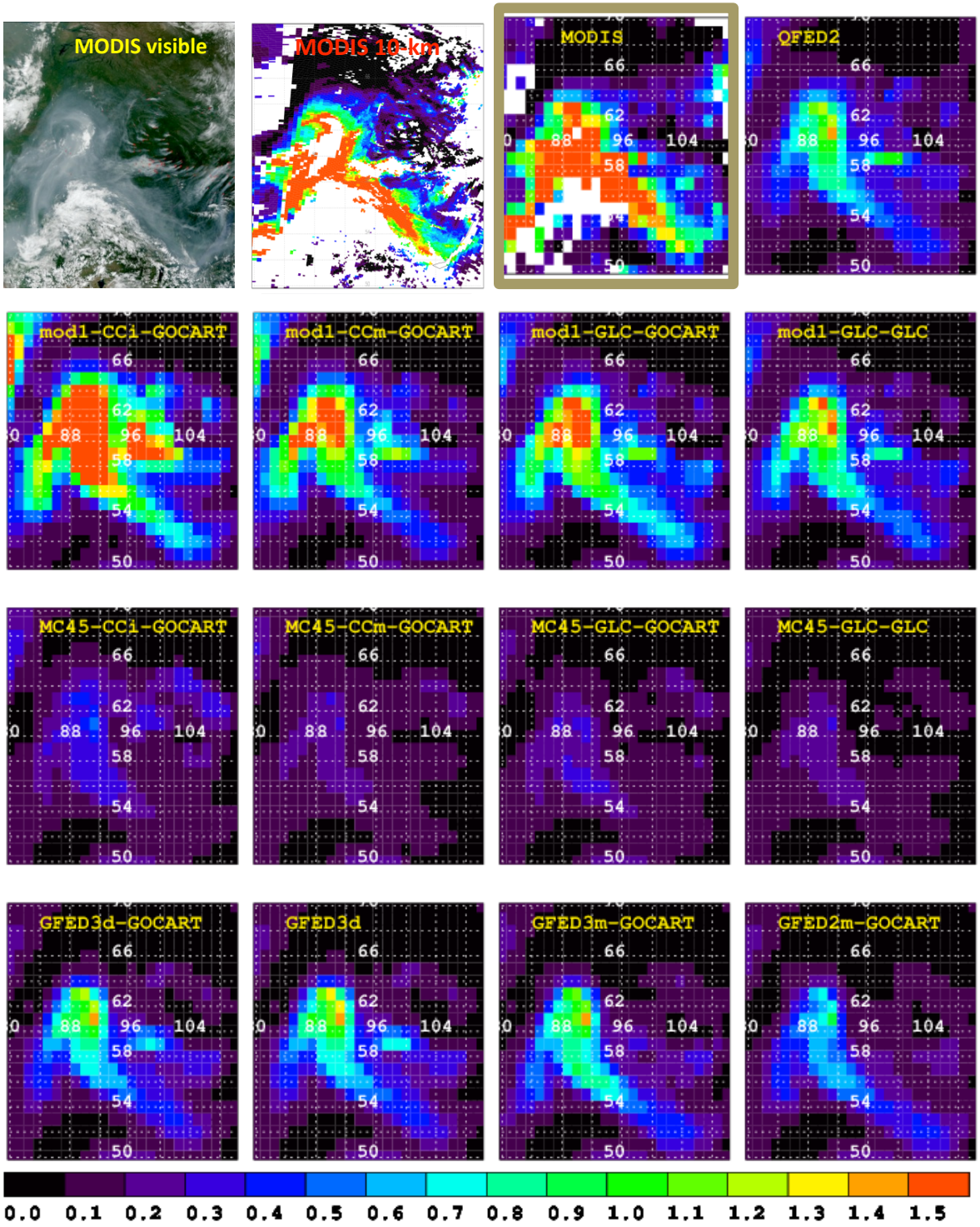
Plume height increases systematically as ***FRP*** increases and ***Atmospheric Stability*** decreases

Val Martin et al., JGR 2012

Sample Case: Russia 2006-07-20

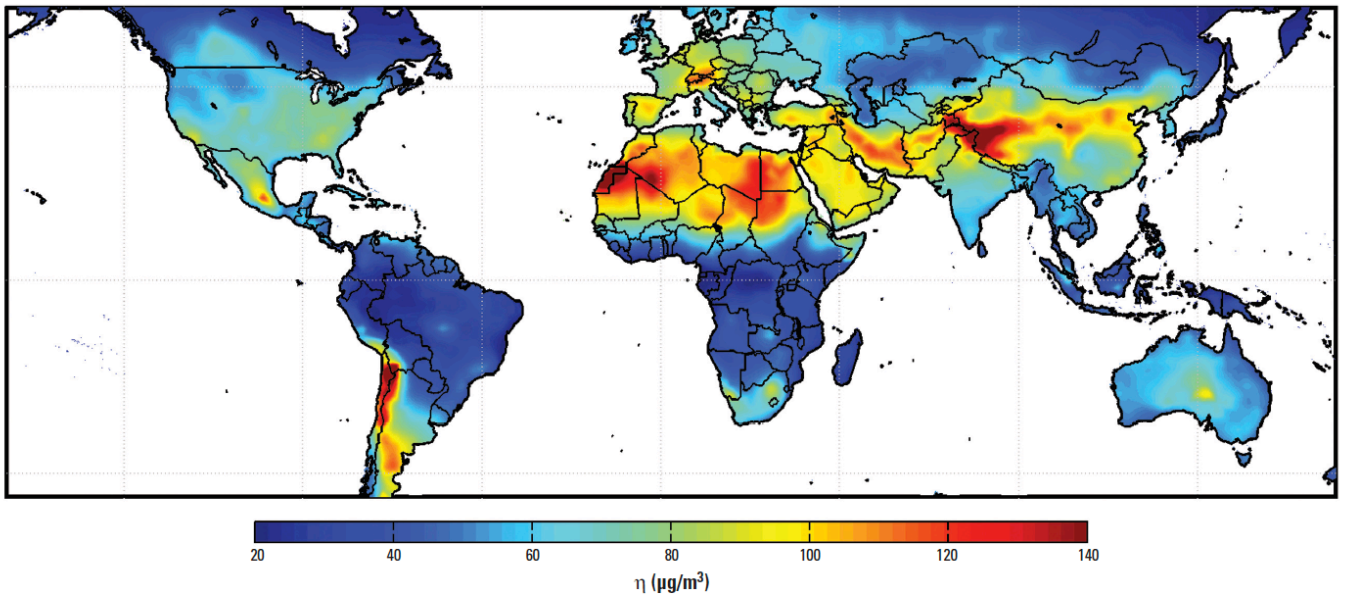
Comparison of MODIS and GOCART total column AOD

124 cases globally

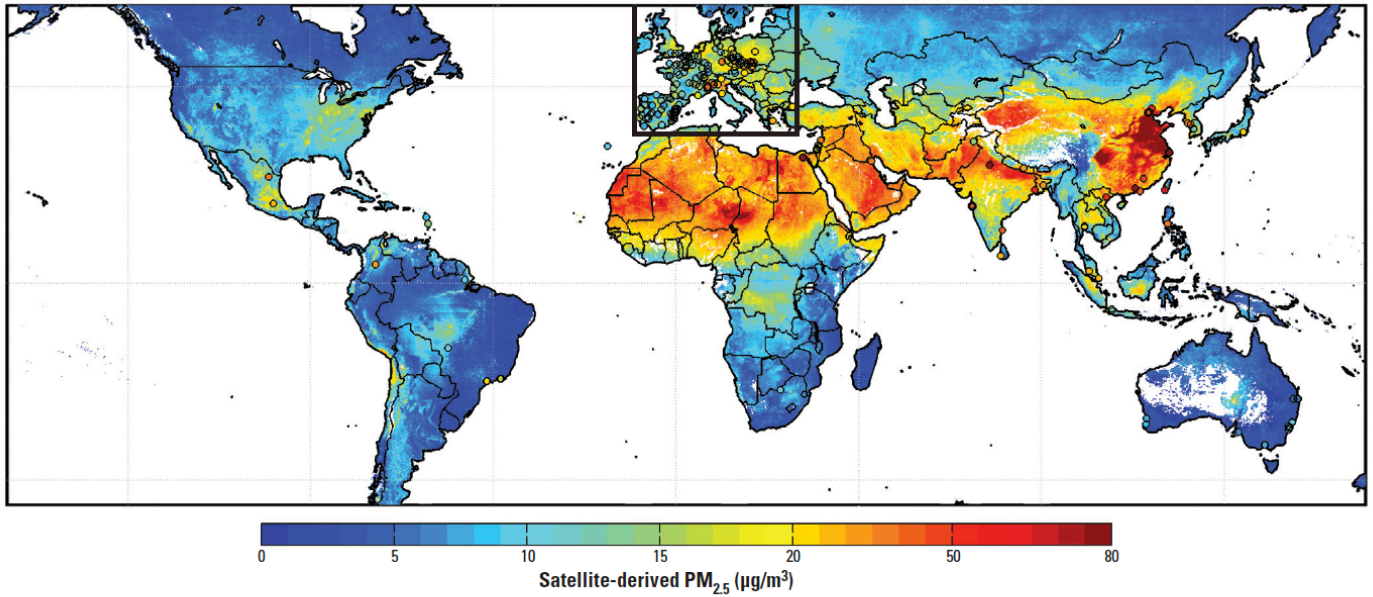


Petrenko et al., JGR 2012

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



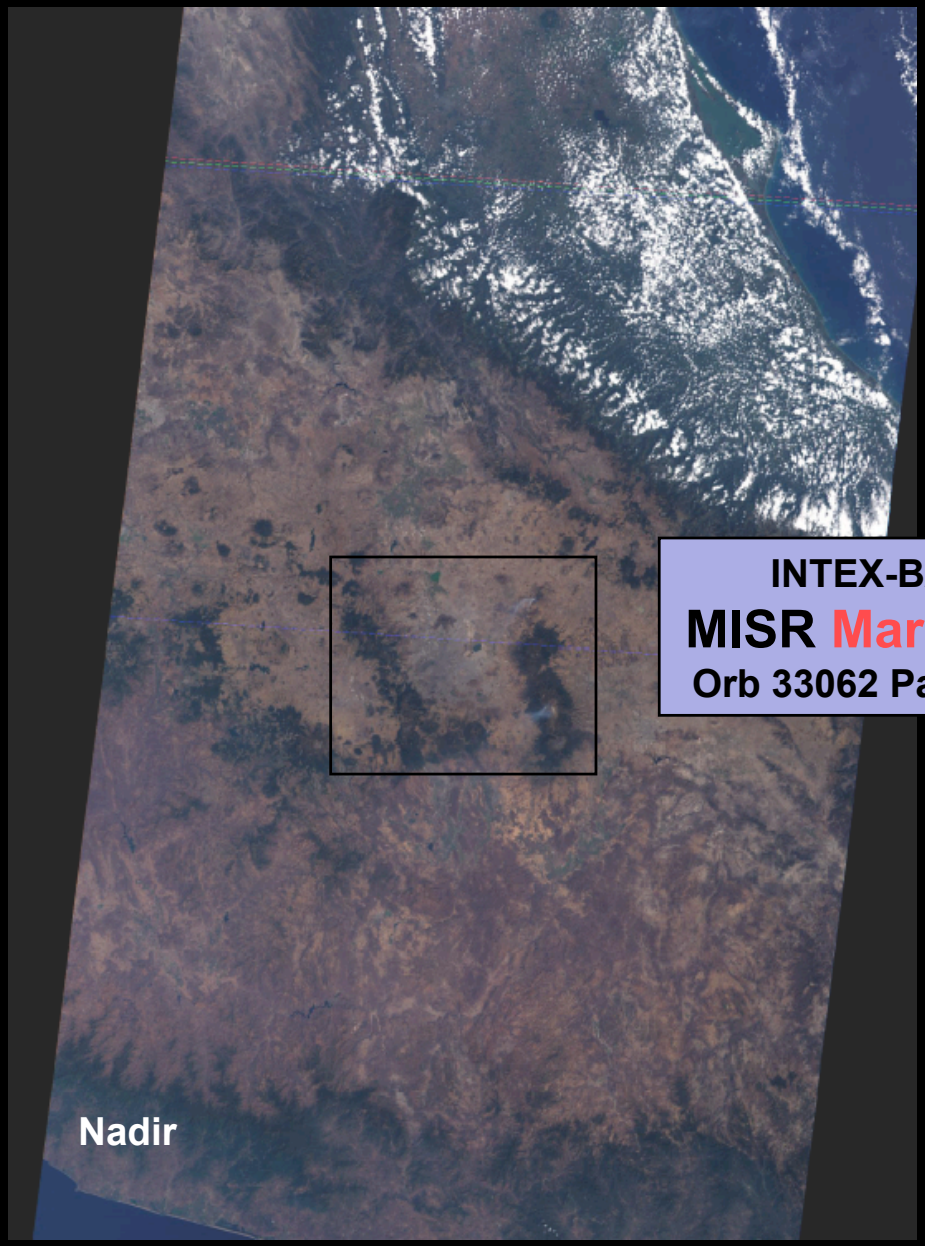
[BL $PM_{2.5}$] / [Total-col. AOD]
2001- 2006

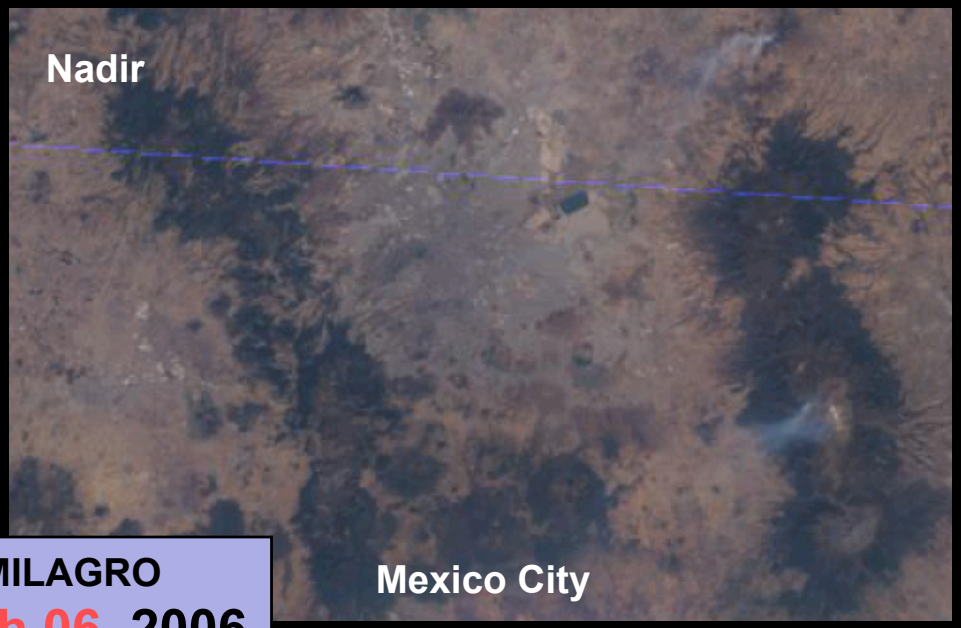


Derived $PM_{2.5}$

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

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

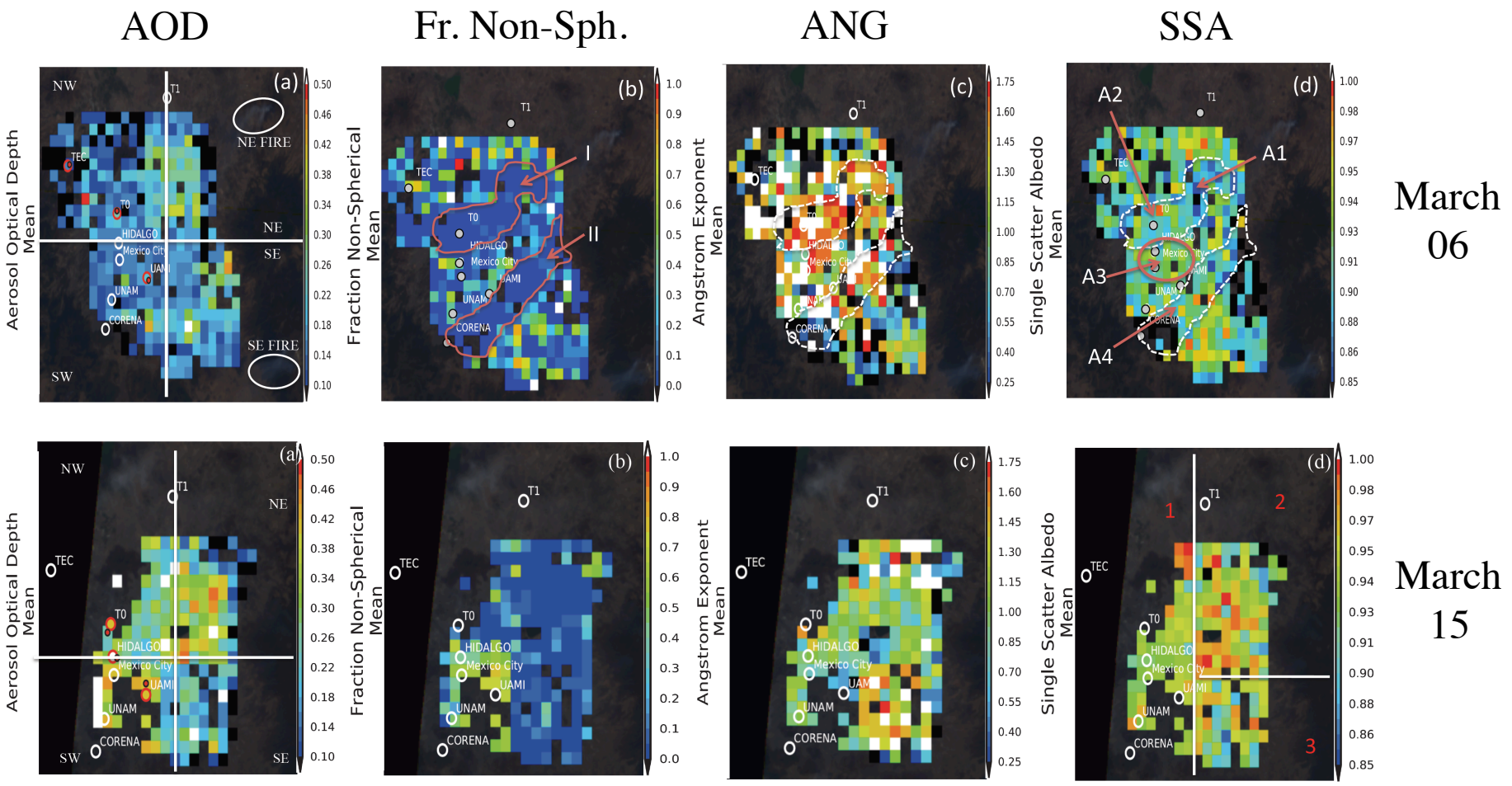




INTEX-B/MILAGRO
MISR March 06, 2006
Orb 33062 Path 26 Block 75

Patadia et al.

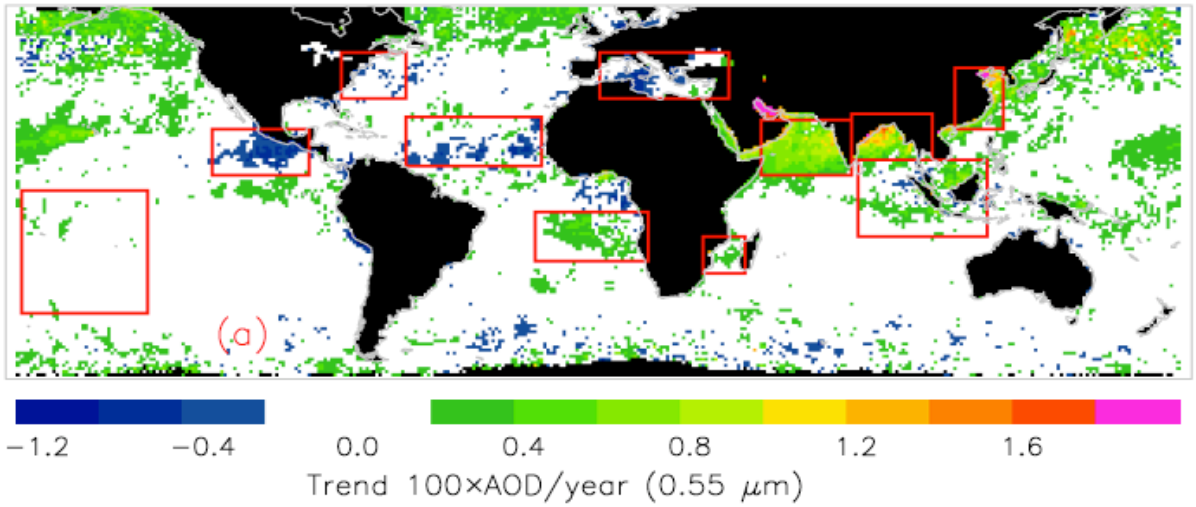
Urban Pollution AOD & Aerosol Air Mass Type Mapping
INTEX-B, 06 & 15 March 2006



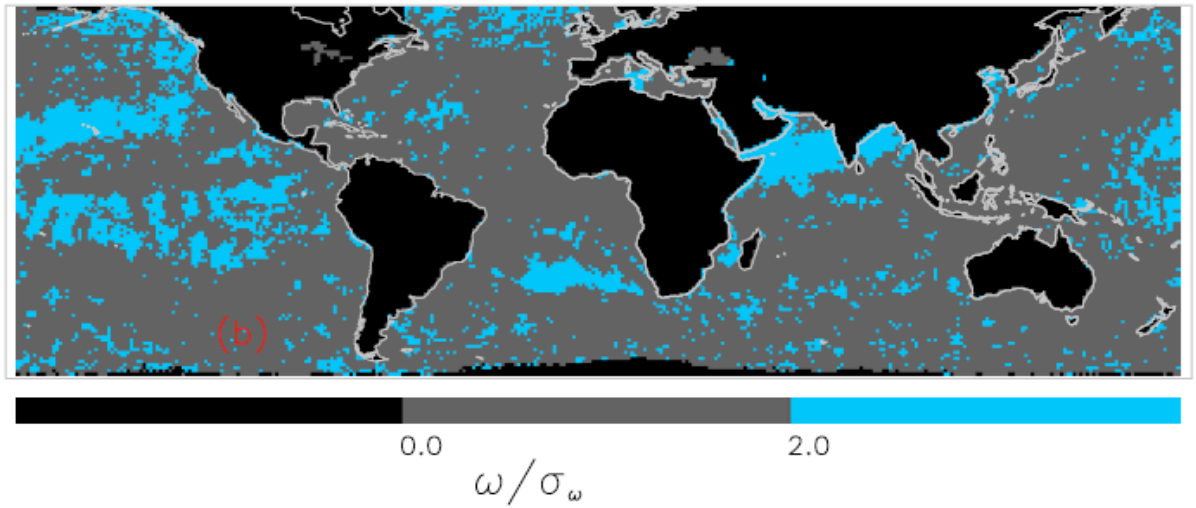
Aerosol Air Masses: ***Dust*** (non-spherical), ***Smoke*** (spherical, spectrally steep absorbing), and ***Pollution*** particles (spherical, spectrally flat absorbing) dominate specific regions

Patadia et al., to be submitted

MODIS 10-Year Global/Regional Over-Water AOD Trends



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***

Satellites

frequent, global *snapshots*; aerosol amount & aerosol type maps, plume & layer heights

Remote-sensing Analysis
- Retrieval Validation
- Assumption Refinement

Suborbital

targeted chemical & microphysical detail

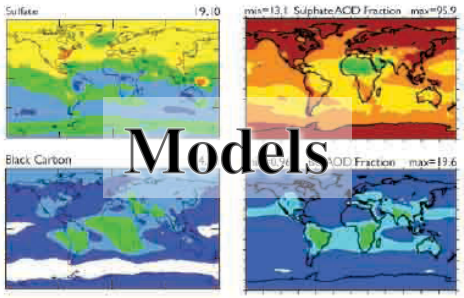
point-location time series

Regional Context

Aerosol-type Predictions

CURRENT STATE
- Initial Conditions
- Assimilation

Model Validation
- Parameterizations
- Climate Sensitivity
- Underlying mechanisms



Models

space-time interpolation,

DARF & Anthropogenic Component

calculation and prediction

Kahn, Survy. Geophys. 2012