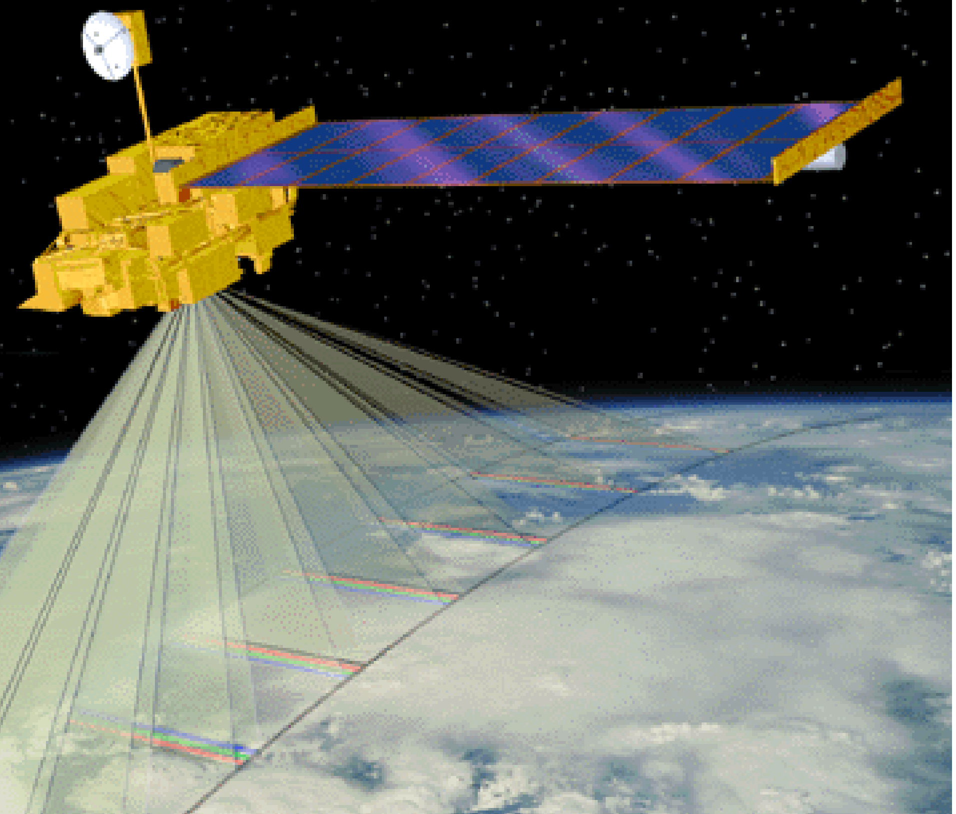
MISR

# Satellite Aerosol Air Mass Type Mapping, And its Role in the Global Picture

*Ralph Kahn*
NASA Goddard Space Flight Center
*and the MISR Team*
JPL and GSFC

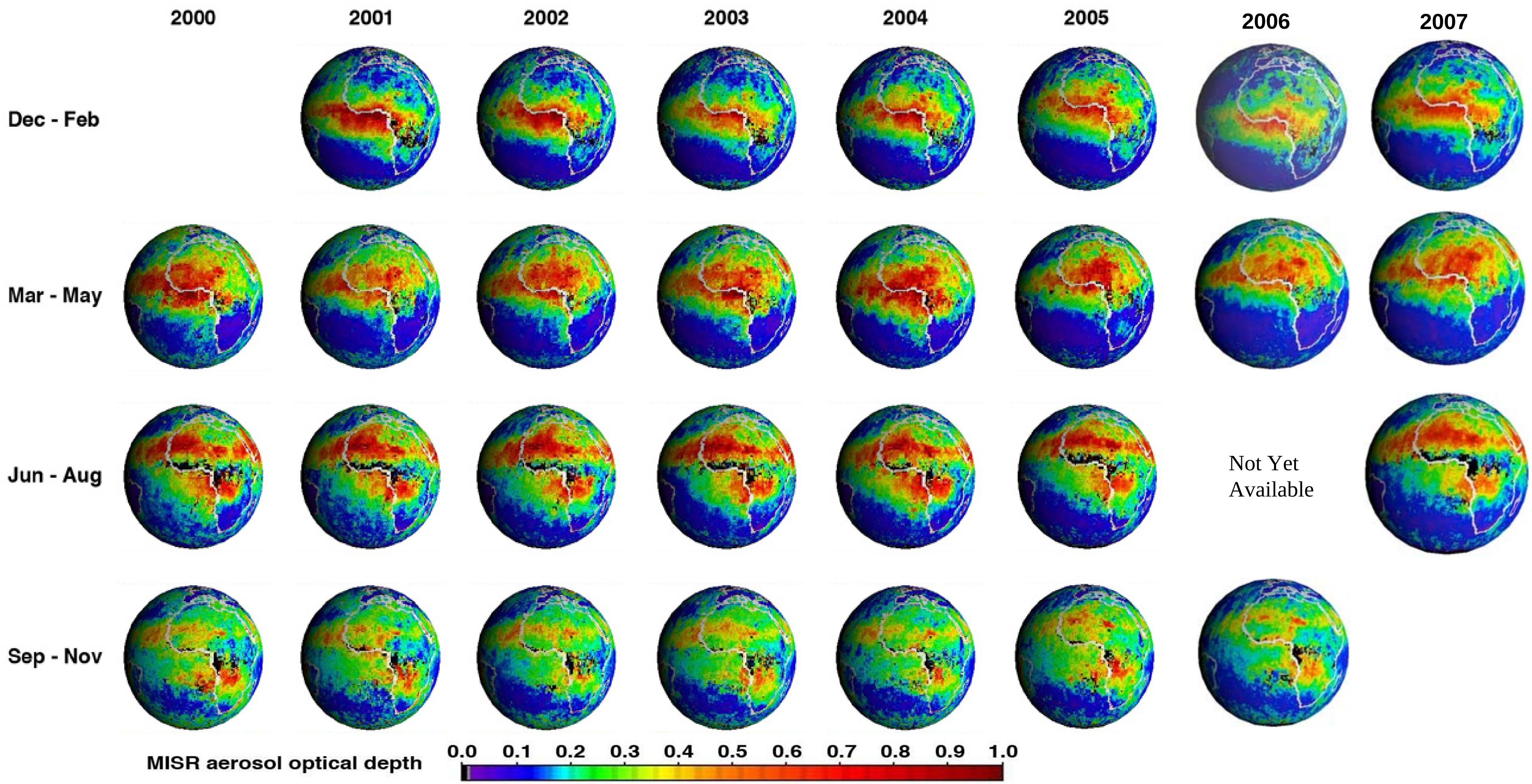


http://www-misr.jpl.nasa.gov

- 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*

NASA

# Eight Years of Seasonally Averaged Mid-visible Aerosol Optical Depth from MISR

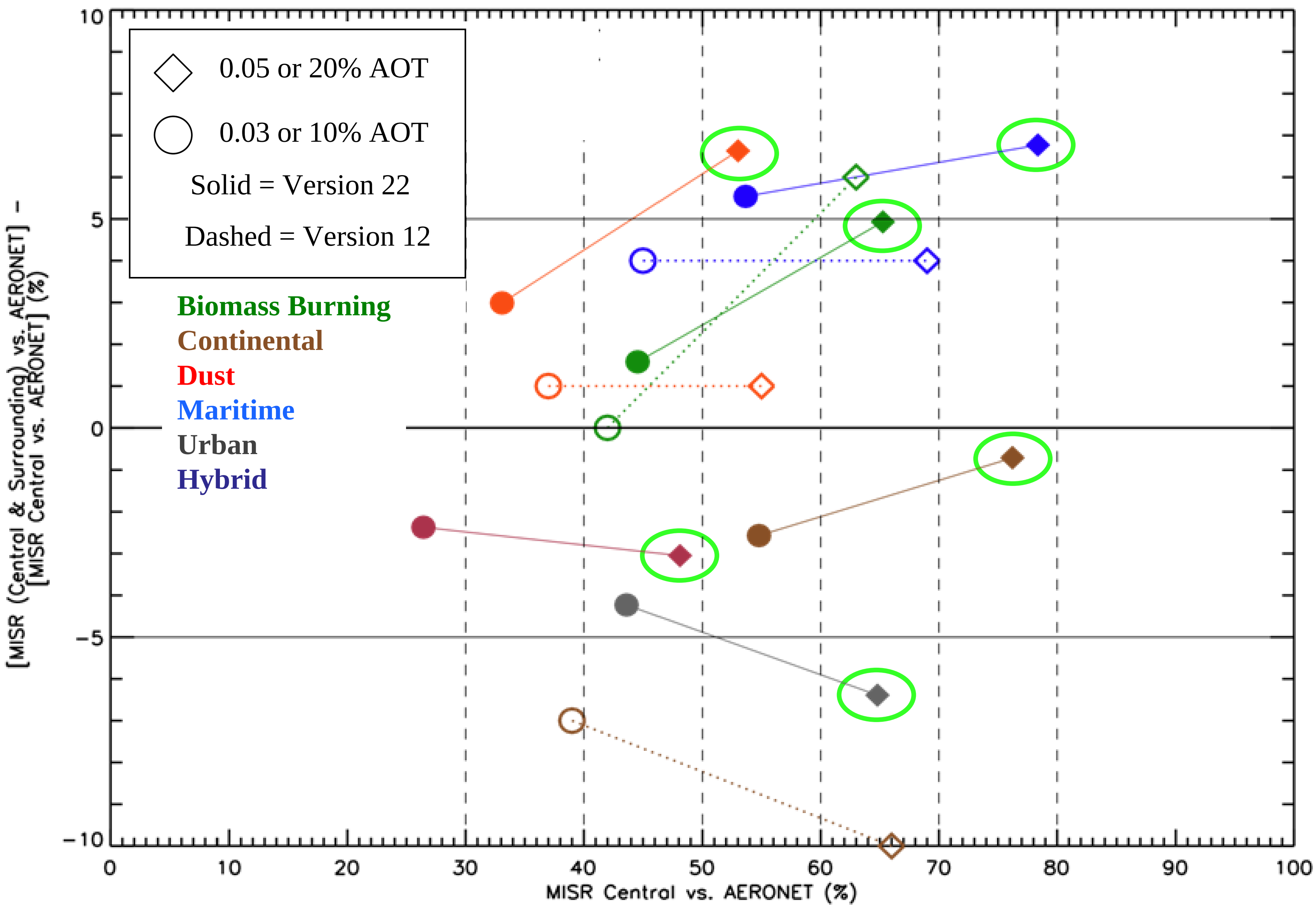



***…includes bright desert dust source regions***

*MISR Team*, JPL and GSFC

# *MISR-AERONET AOT* Comparison for 3,995 Coincidences

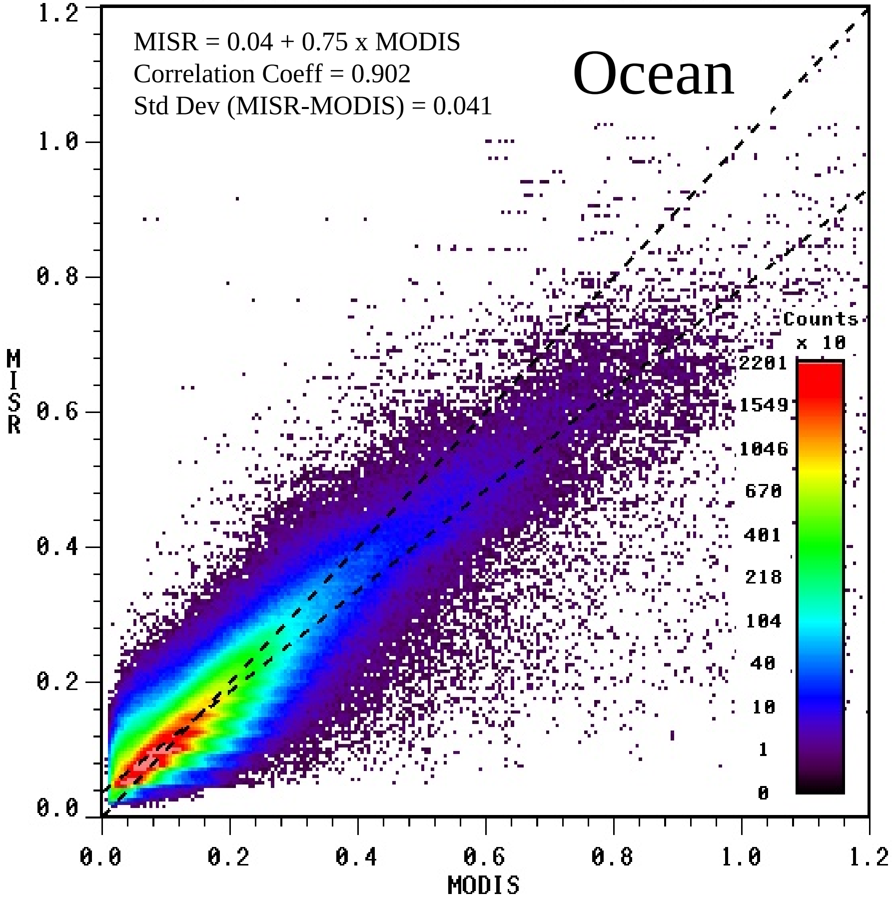
Stratified by expected aerosol air mass type



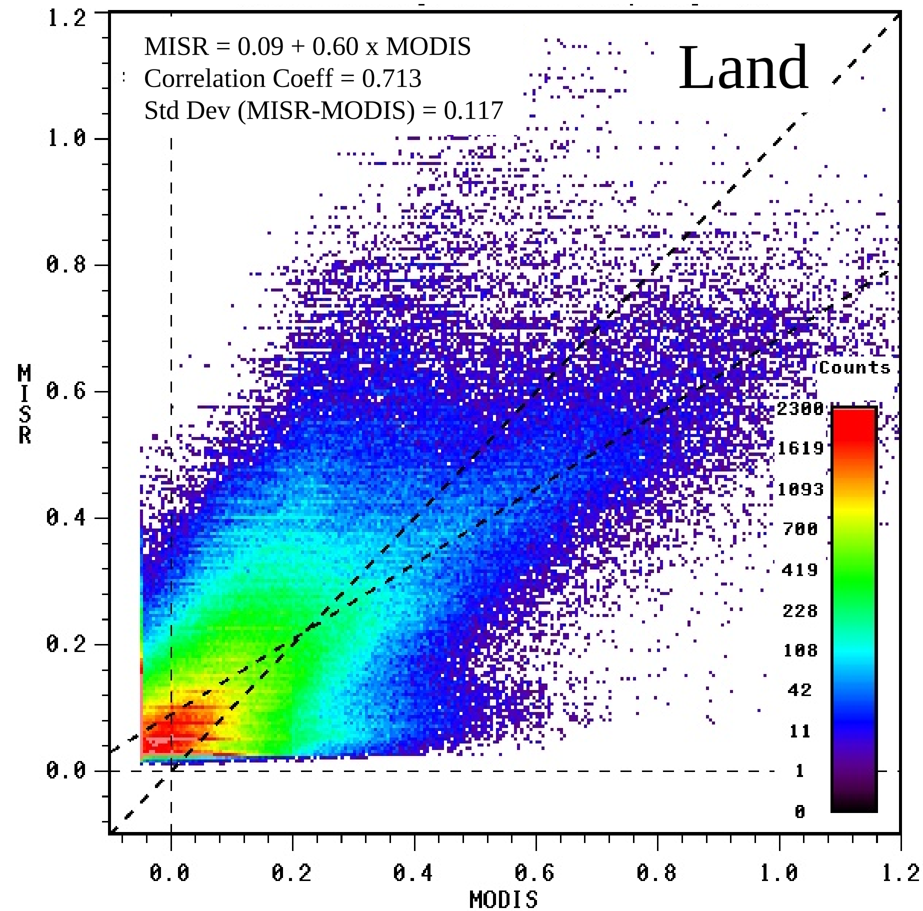

*Kahn, Gaitley et al., JGR in preparation*

# MISR-MODIS *Aerosol Optical Depth* Comparison

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



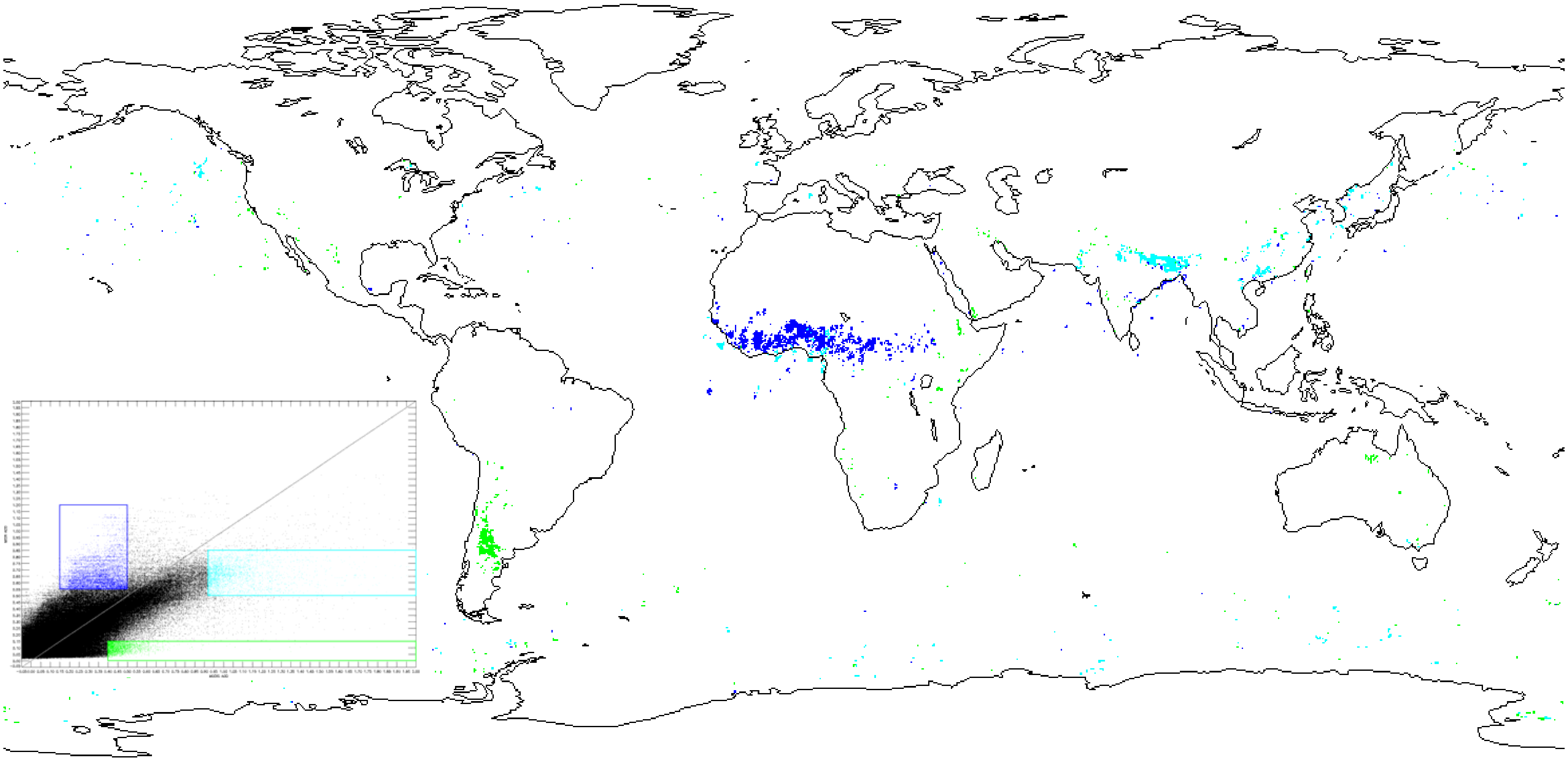

Over-ocean regression coefficient **0.90**
Regression line slope 0.75
MODIS QC ≥ 1




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

*Kahn, Nelson, Garay et al., TGRS 2009 in press*

# ***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***

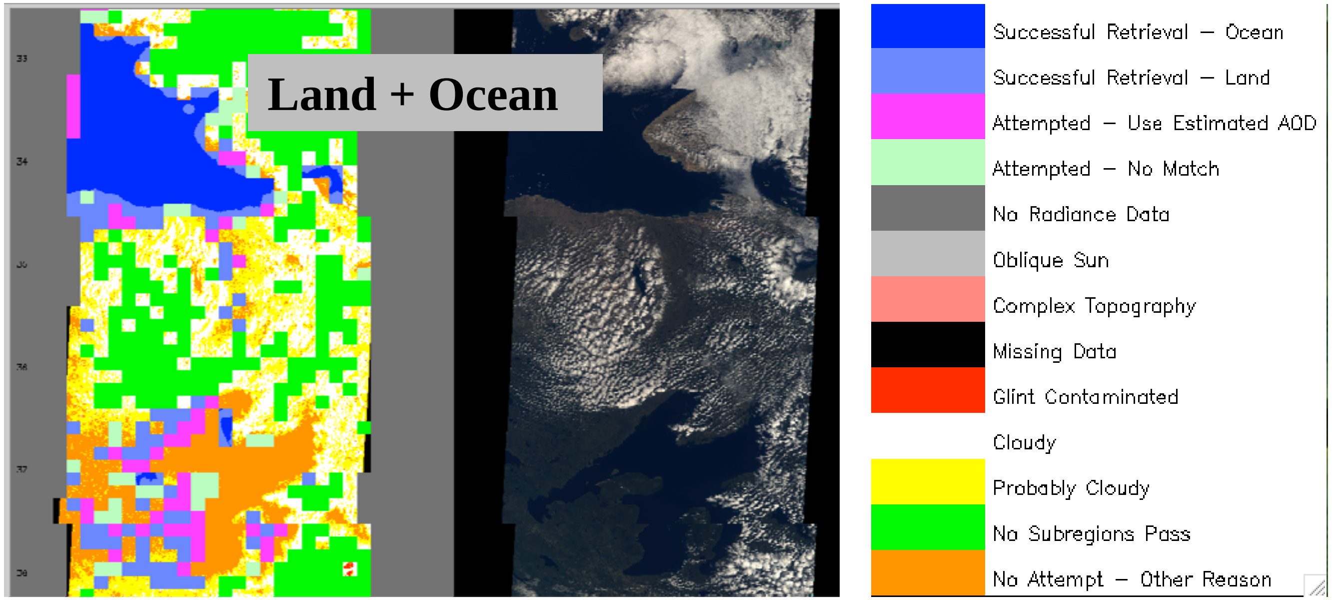
**Green** [MODIS >> MISR] – Patagonia and N. Australia ***MODIS Unscreened Bright Surface***

*Kahn et al.*, *TGARS 2009*, in press

# MISR Retrieval Status Distribution

Overall, about **15%** of Earth's surface produces successful MISR automatic aerosol retrievals

Dark blue = Ocean retrieval
Light blue = Land retrieval




*Kahn, Nelson, Garay et al., TGRS, 2009 in press*

**From experience with MISR & MODIS:**

*For global, ~ 1°× 1°AOD, in general, MISR data need to be aggregated to* ***~ 3-month sampling*** *to converge with MODIS*

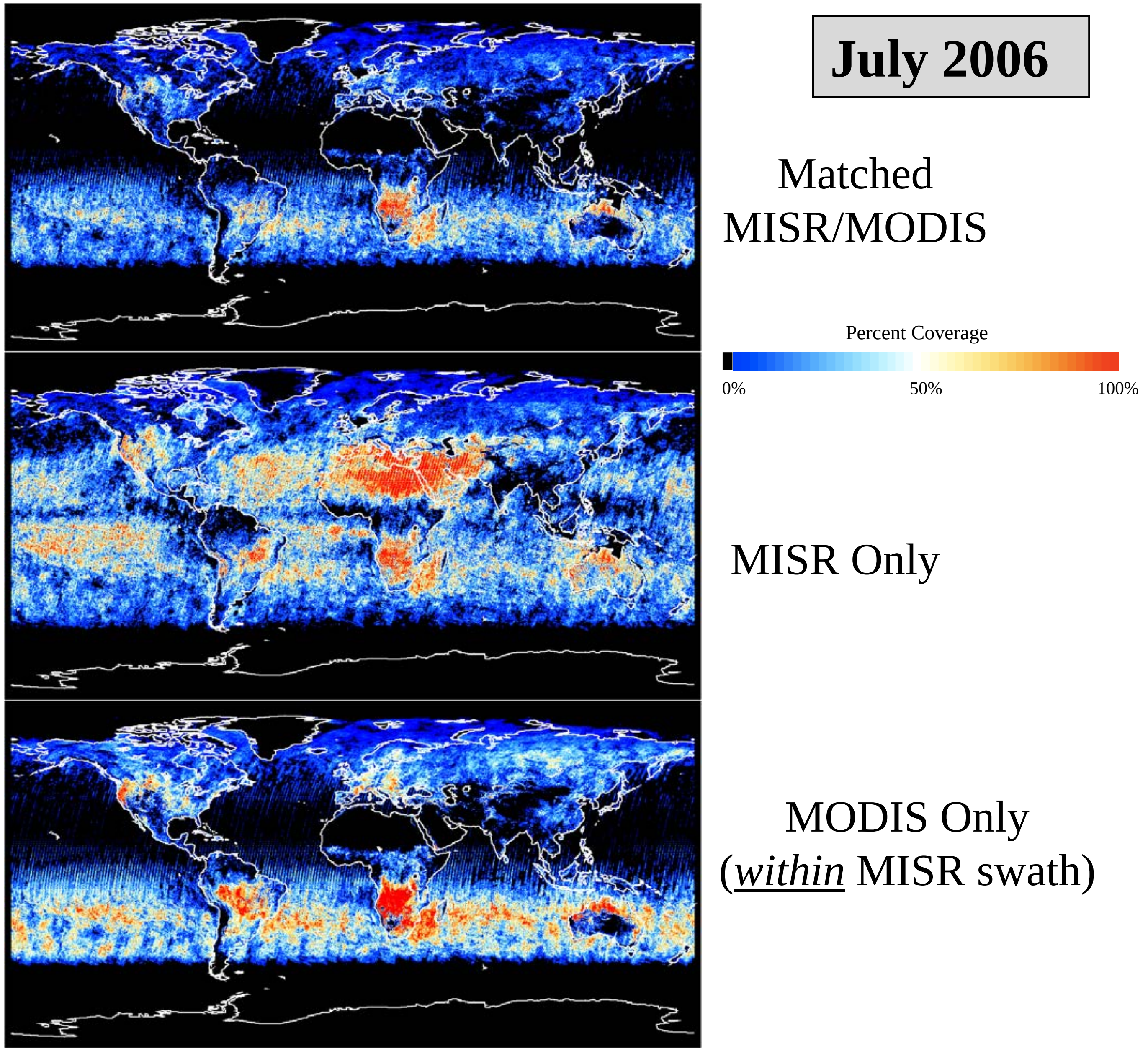
# Global Distribution of MISR & MODIS *Coincident*, Retrieved AOD

Overall, **6% to 7%** of overlapping observations produce ***coincident***, MISR & MODIS aerosol retrievals

Some coincident coverage over much of the planet

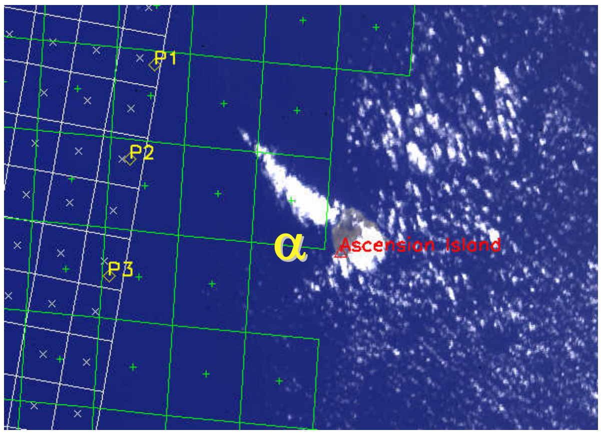
Point density varies

• Desert
• Snow & Ice
• Cloud
• Polar night
• Glint

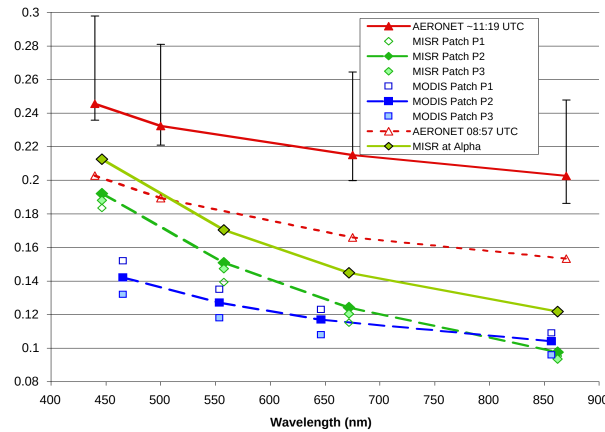



*Kahn, Nelson, Garay et al., TGRS, 2009 in press*

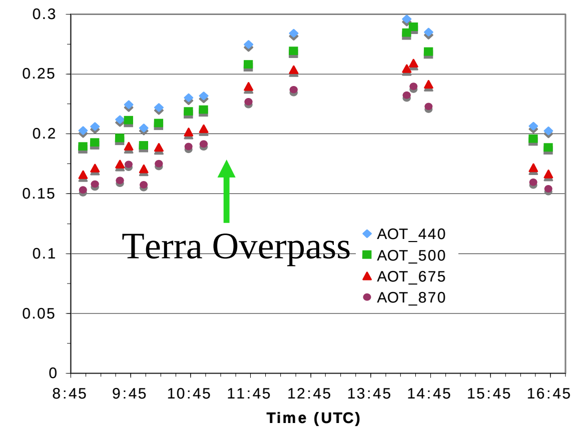
# MISR-MODIS-AERONET *Sampling* Differences
## [Ascension Island 18 February 2005]




Sampling: MISR; MODIS; AERONET




AOT Snapshot: ARNET> MISR >MODIS




AERONET Time Series - Changing AOT

*Kahn et al.*, JGR 2007

Clean, maritime aerosol air mass, but AOT changes 60% across RH boundary

***Using any one of these to represent the entire region AOT --> large errors***
***Taken together, they give a better picture…***

***Sampling Effects* is a continuing story…**

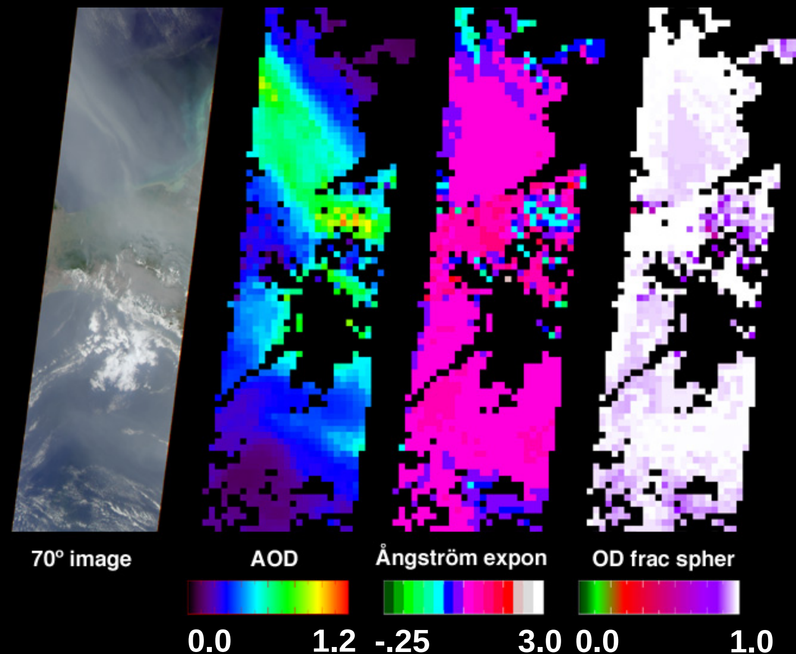
# Smoke from Mexico -- 02 May 2002

Aerosol:

Amount

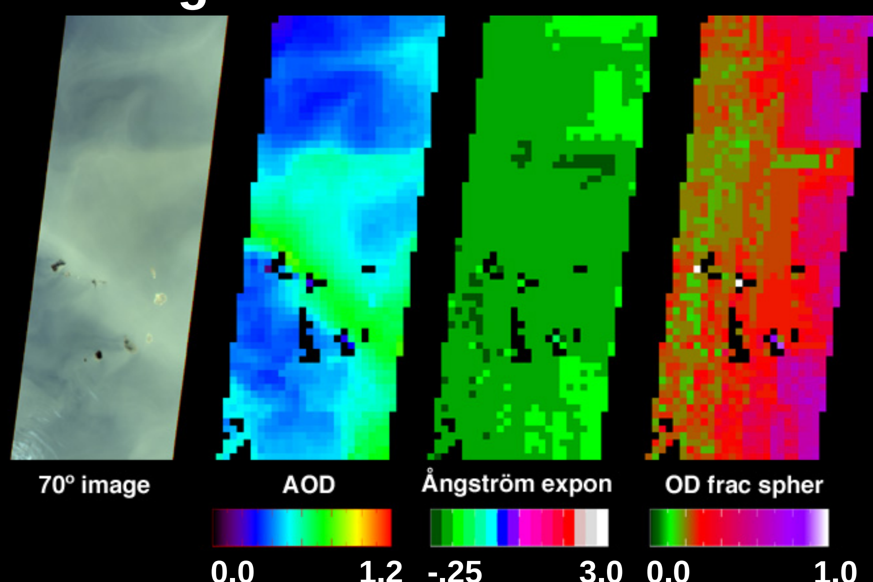
Size

Shape




Medium
Spherical
Smoke
Particles

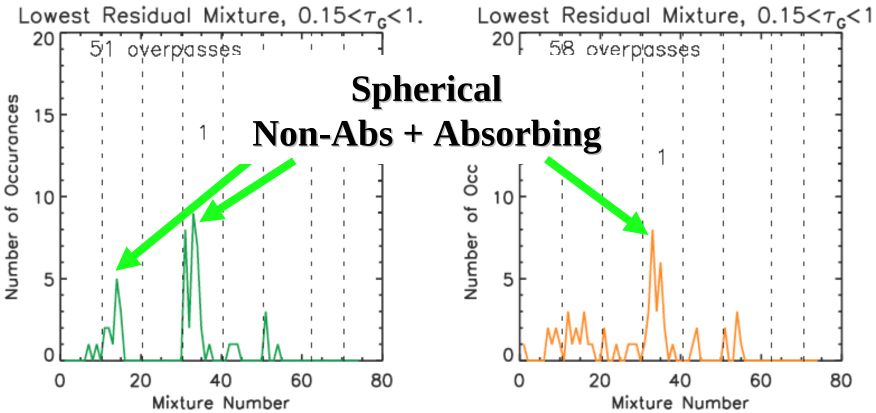
# Dust blowing off the Sahara Desert -- 6 February 2004




Large
Non-Spherical
Dust
Particles

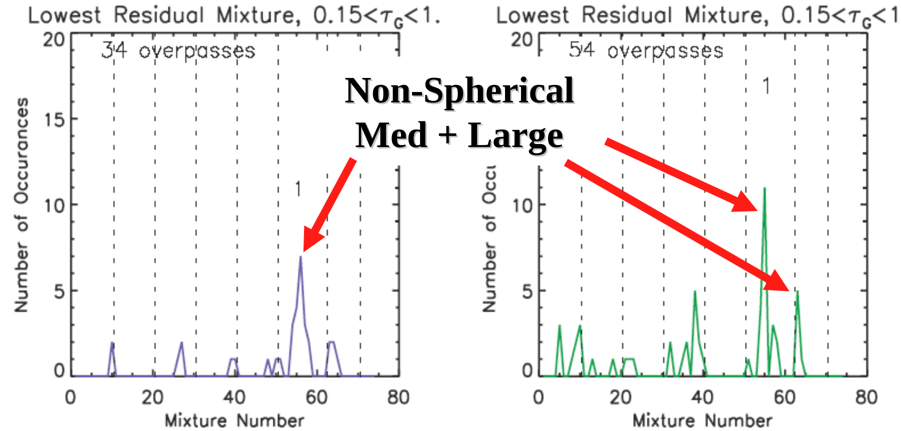
# MISR-retrieved Aerosol Types

[Lowest Residual Mixtures; AOT>0.15]



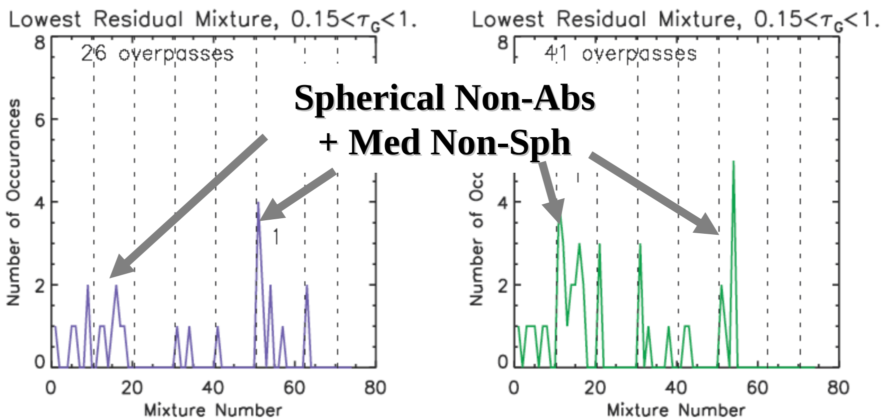

## Biomss Burning

**N. Summer & Autumn Events**



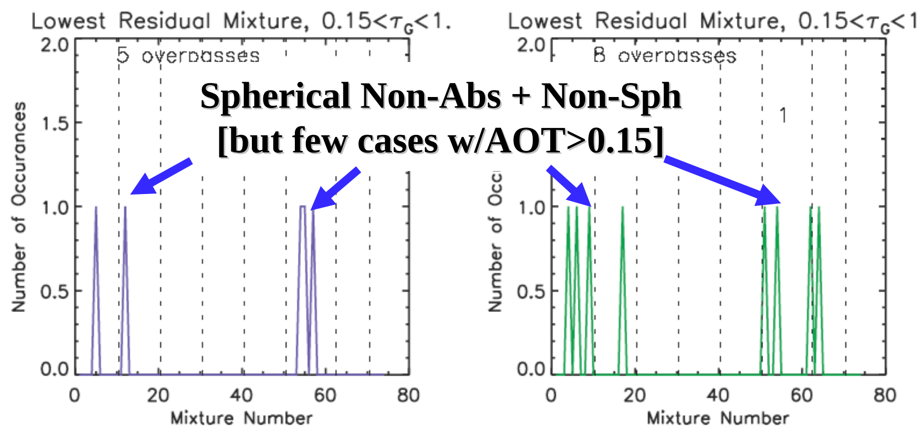

## Dusty

**N. Spring & Summer Events**




## Continental

**N. Spring & Summer**

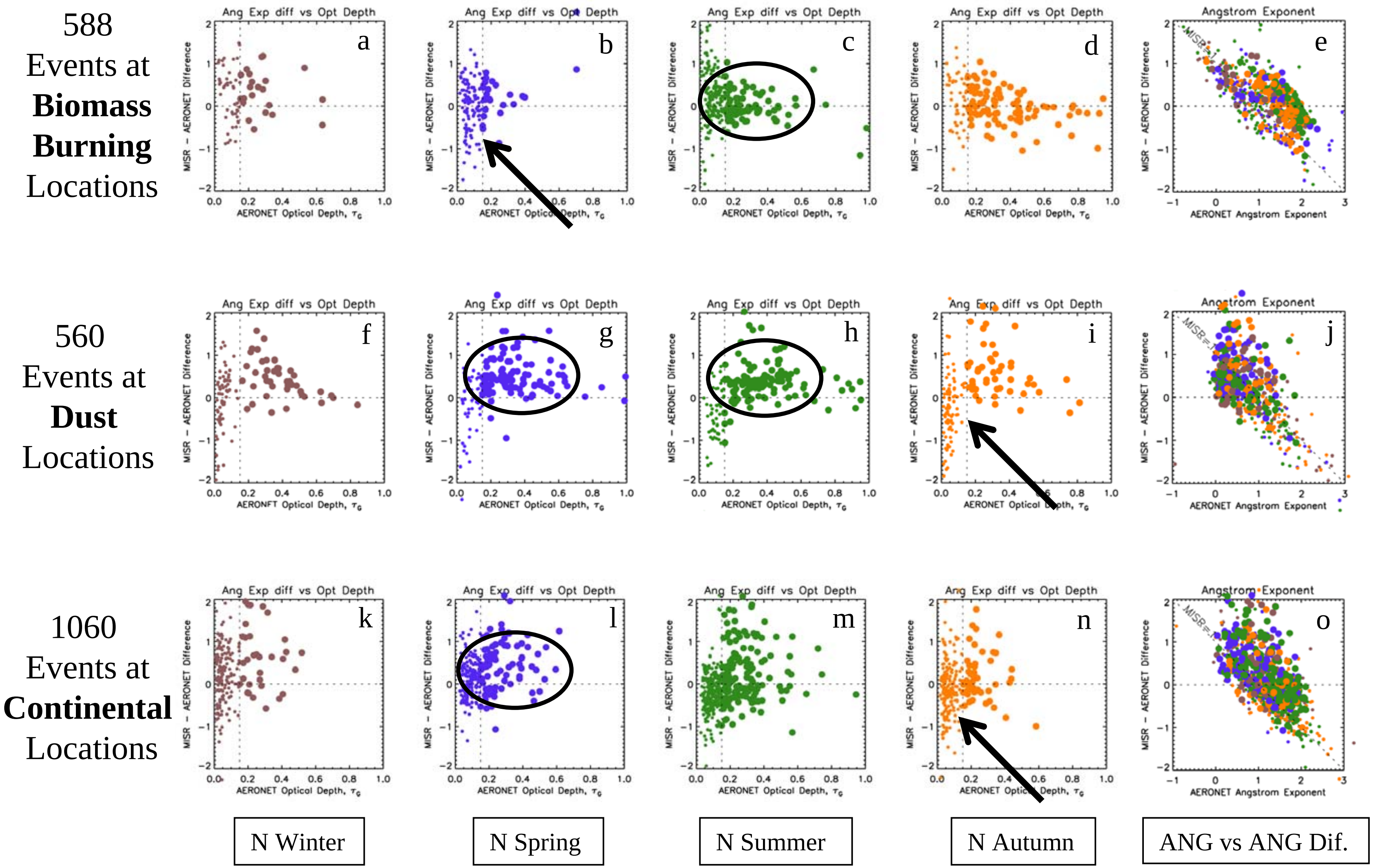



## Maritime

**N. Spring & Summer**

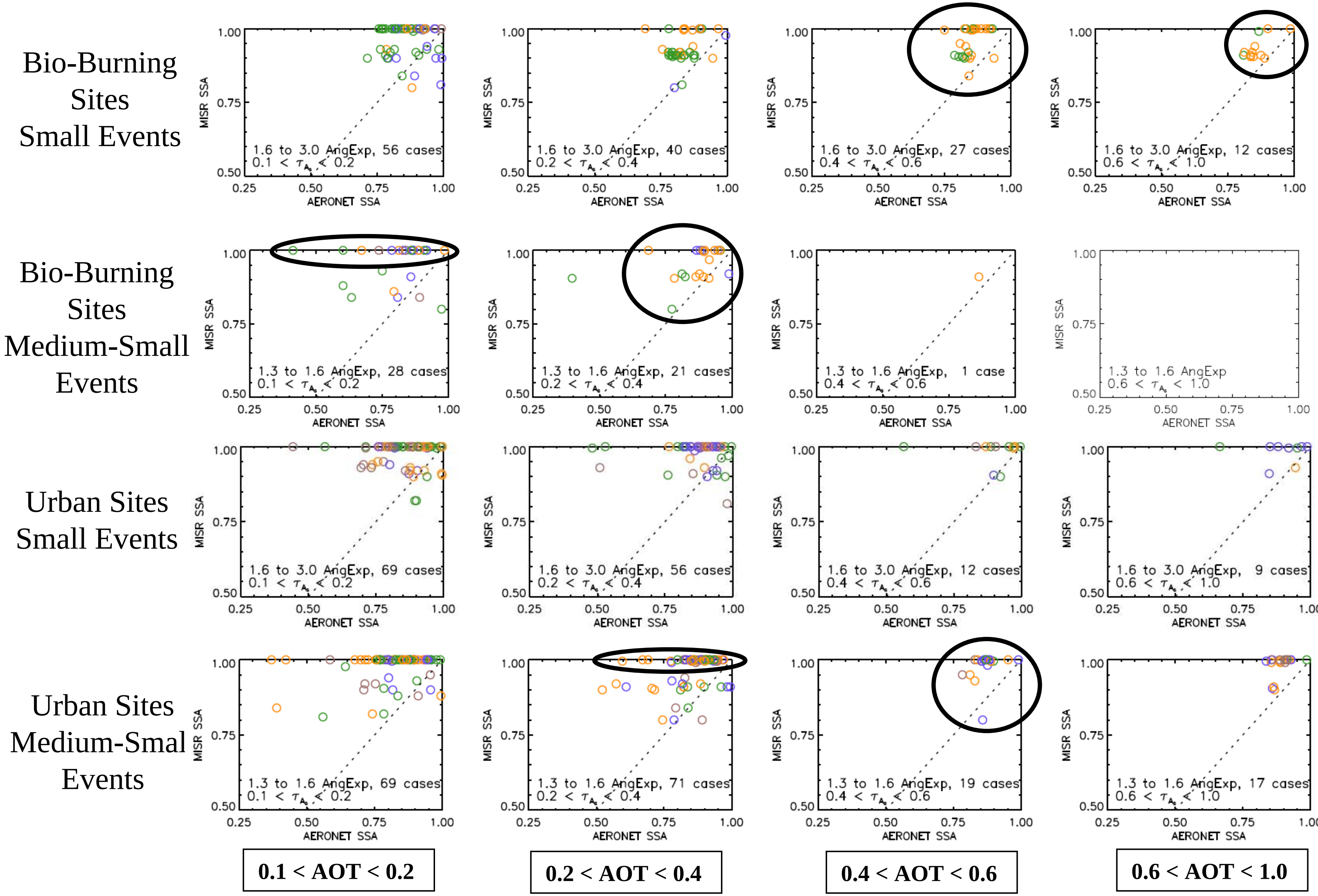
*Kahn, Gaitley, et al* JGR, in preparation

# MISR *Angstrom Exponent* Validation vs. AERONET



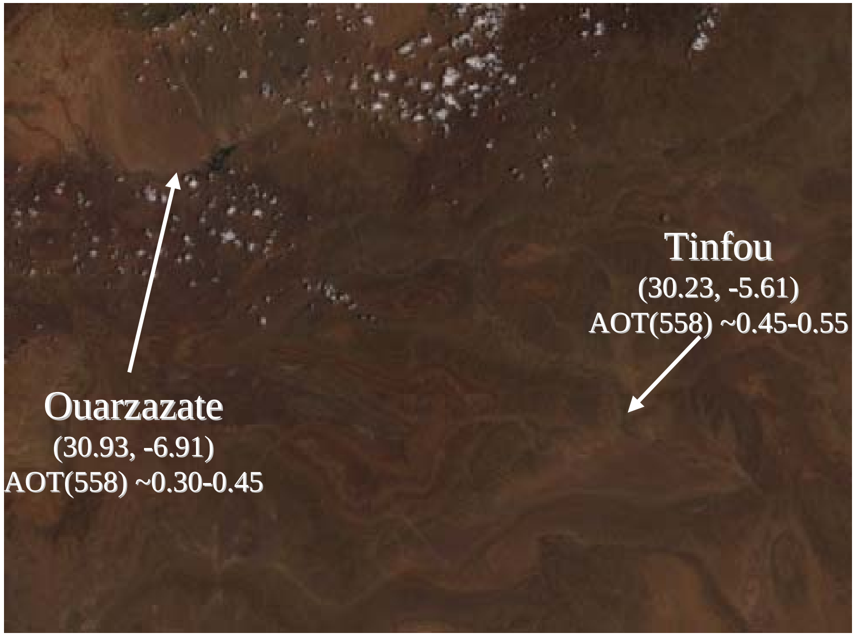

*Kahn, Gaitley, et al* JGR, in preparation

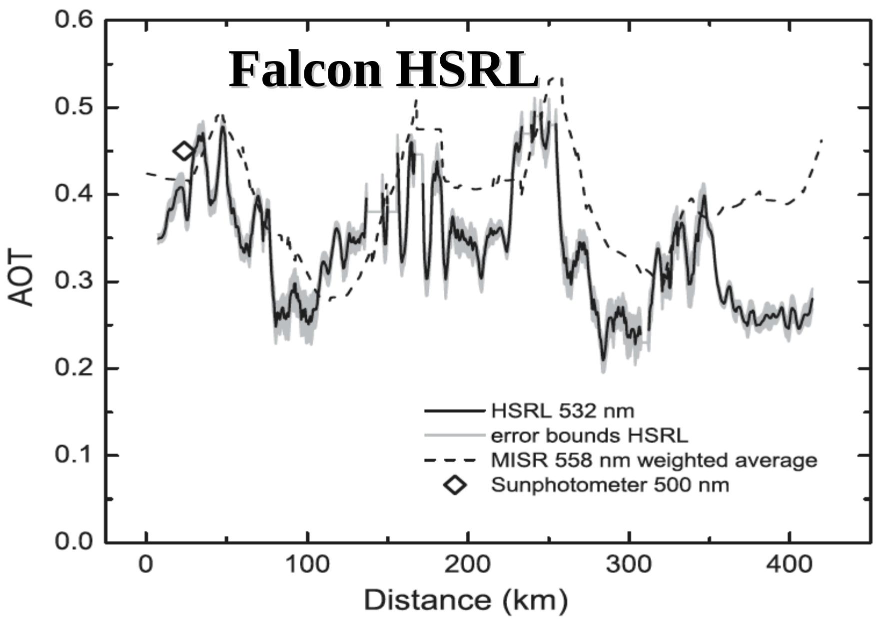
# MISR ***SSA*** Validation vs. AERONET

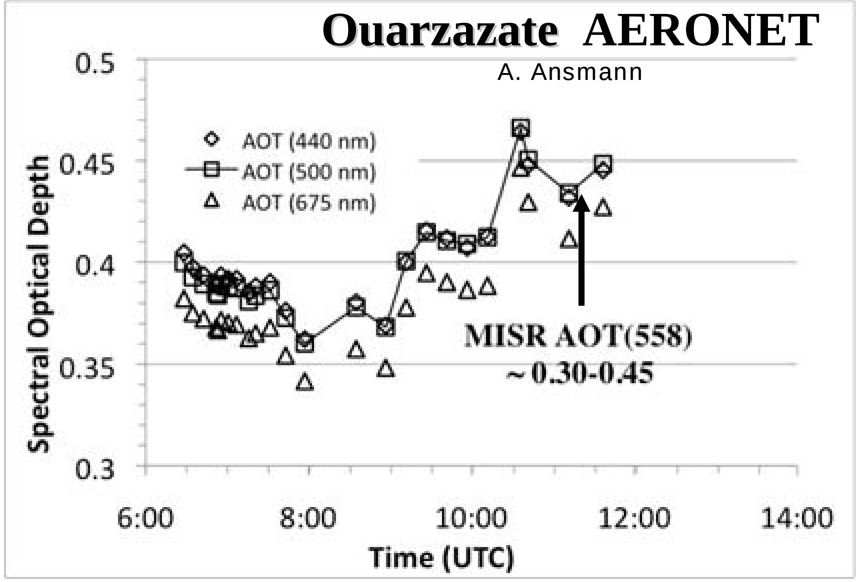


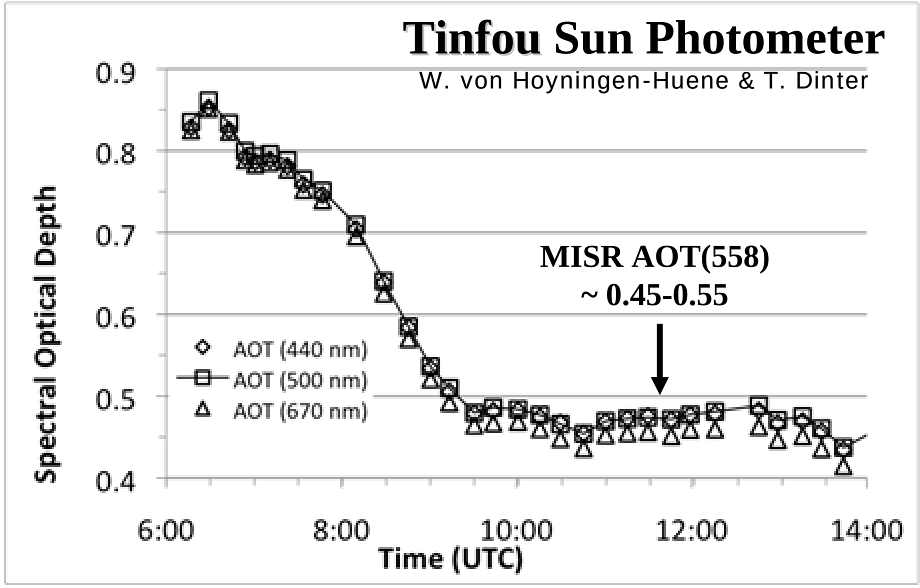

*Kahn, Gaitley, et al* JGR, in preparation

# SAMUM Campaign Morocco – June 04, 2006



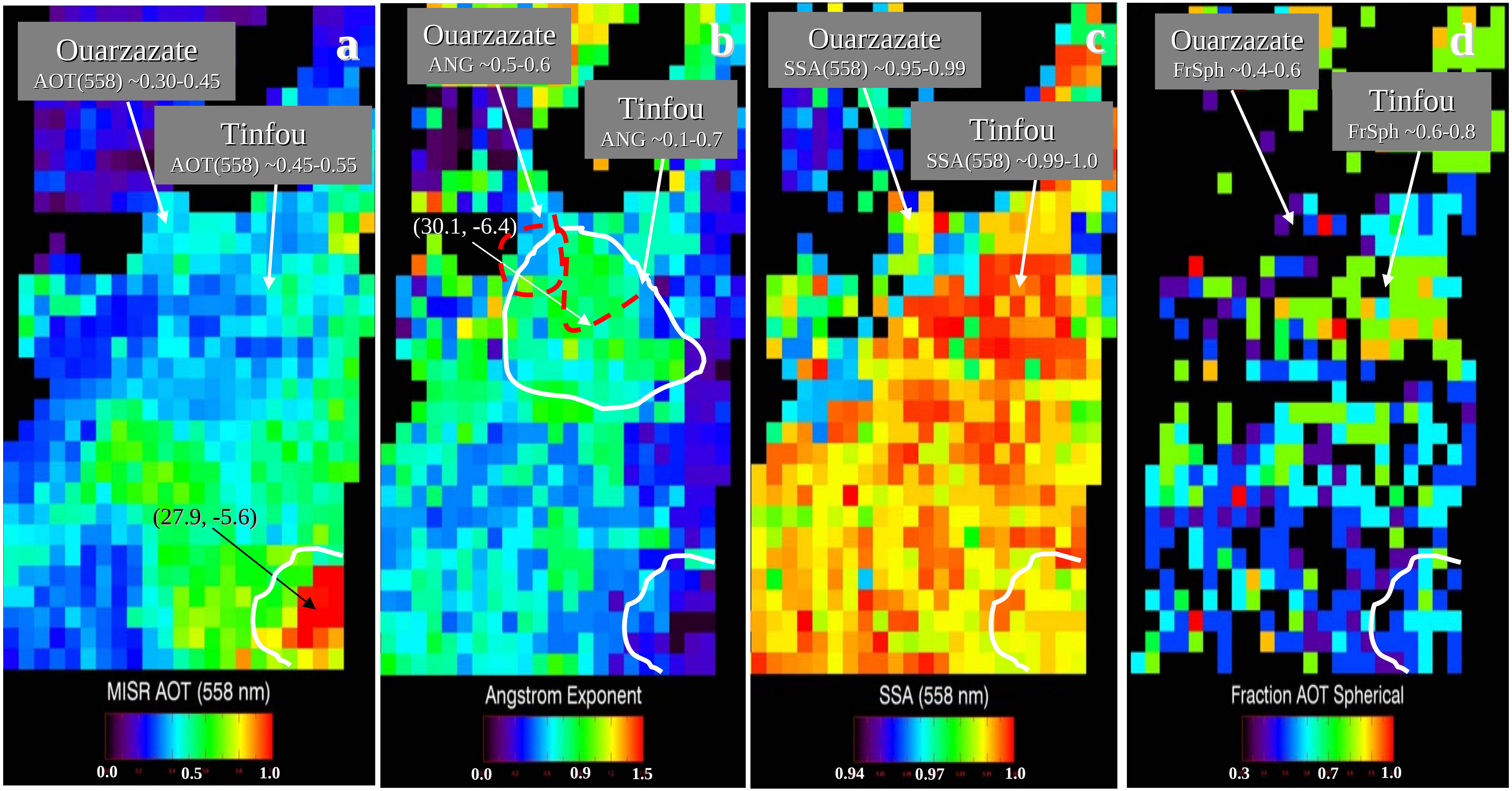



# MISR SAMUM Aerosol Air Masses (V19) - June 04, 2006

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

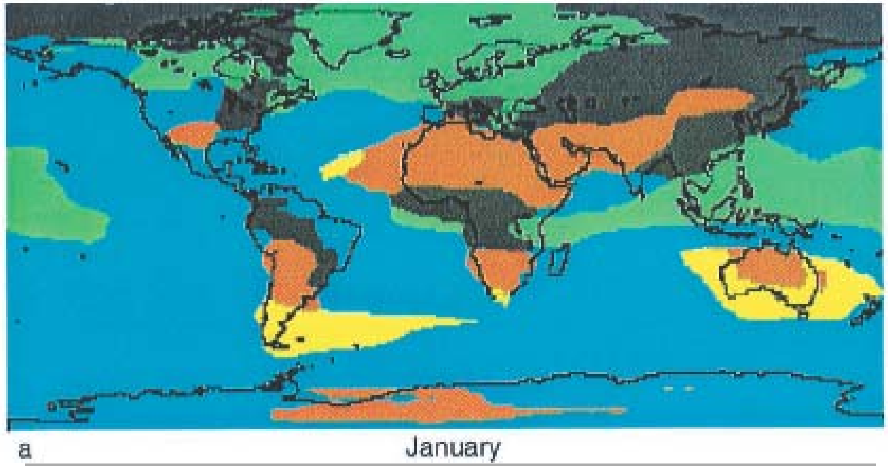



- A **dust-laden density flow in the SE** corner of the MISR swath
- **High SSA, ANG** & **Fraction Spherical** region SE of Ouarzazate, includes Zagora

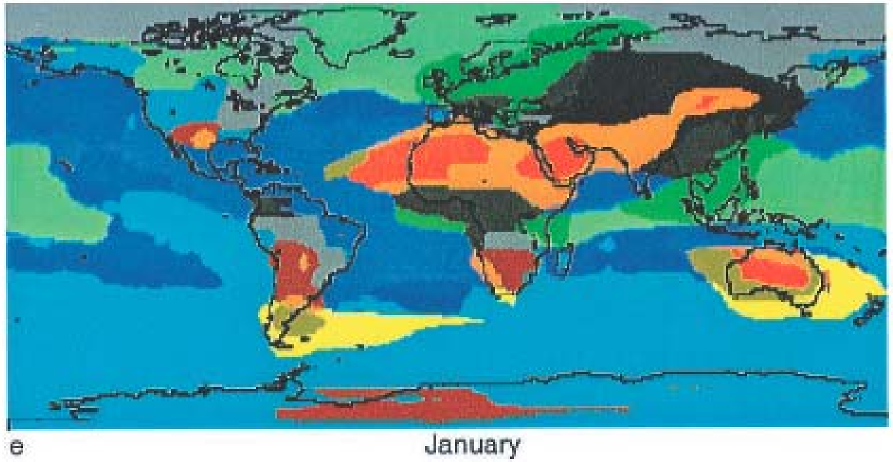
*Kahn et al., Tellus* 2009

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 <u>simulated</u> 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

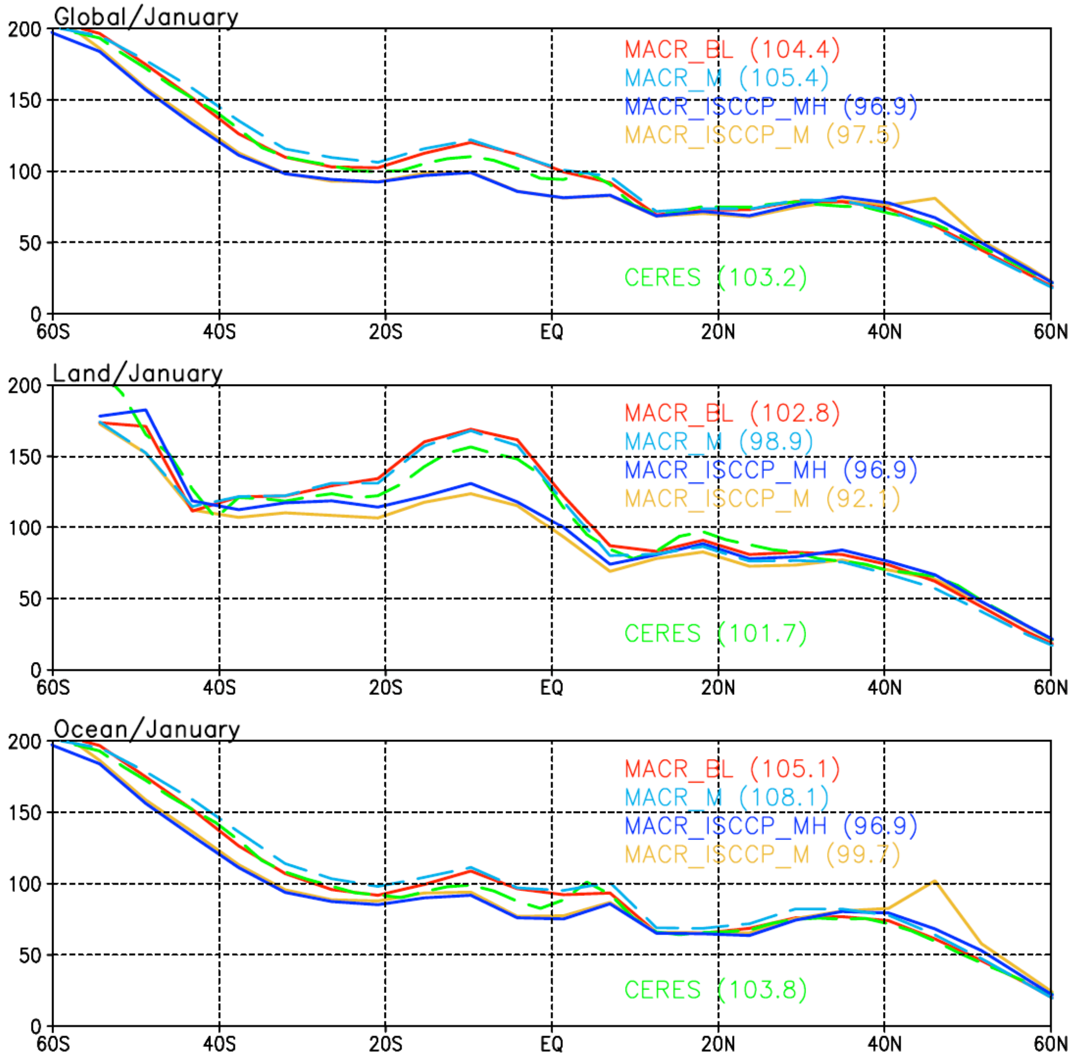
*Kahn et al.*, JGR 2001

# *Pre-Launch*, *Model-Derived* Aerosol Air Mass Types

| CLASSIFICATION | Component 1 | Component 2 | Component 3 | Component 4 |
|---|---|---|---|---|
| 1. **Carbonaceous + Dusty Maritime** | Sulfate | Sea Salt | Carbonaceous | Accum. Dust |
| 1a. | **0.67** | 0.13 | 0.10 | 0.10 |
| 1b. | 0.41 | 0.13 | **0.27** | **0.19** |
| 1c. | 0.40 | **0.32** | 0.17 | 0.11 |
| 2. **Dusty Maritime + Coarse Dust** | Sulfate | Sea Salt | Accum. Dust | Coarse Dust |
| 2a. | **0.52** | 0.17 | 0.21 | 0.10 |
| 2b. | 0.29 | 0.13 | **0.39** | **0.19** |
| 3. **Carbonaceous + Black Carbon Maritime** | Sulfate | Sea Salt | Carbonaceous | Black Carbon |
| 3a. | **0.51** | 0.18 | 0.26 | 0.05 |
| 3b. | 0.35 | 0.10 | **0.47** | **0.08** |
| 4. **Carbonaceous + Dusty Continental** | Sulfate | Accum. Dust | Coarse Dust | Carbonaceous |
| 4a. | **0.61** | 0.21 | 0.05 | 0.10 |
| 4b. | 0.40 | **0.35** | 0.09 | **0.16** |
| 4c. | 0.22 | **0.51** | **0.16** | 0.11 |
| 5. **Carbonaceous + BC Continental** | Sulfate | Accum. Dust | Carbonaceous | Black Carbon |
| 5a. | **0.59** | 0.12 | 0.23 | 0.06 |
| 5b. | 0.25 | 0.12 | **0.54** | 0.09 |
| 5c. | 0.44 | **0.23** | **0.26** | 0.07 |

*Kahn et al.*, JGR

# **Measurement Synthesis:** Aerosol Short-wave Direct Radiative Forcing




**Outgoing zonal TOA fluxes** calculated with Monte-Carlo Aerosol-Cloud-Radiation model constrained with ***MISR AOD***, ***AERONET*** particle properties, ***GOCART*** interpolation, and using ***four choices of cloud data*** from ISCCP and CERES (hourly monthly and monthly mean).

Results are ***compared to CERES*** and validated using BSRN.

***"Overall, such agreements suggest that global data sets of aerosols and cloud parameters released by recent satellite experiments (MISR, MODIS and CERES) meet the required accuracy to use them as input to simulate the radiative fluxes within instrumental errors." -- Kim & Ramanathan JGR 2008***

# Over-Land Aerosol Short-wave Radiative Forcing w/Consistent Data

***The slope of***:

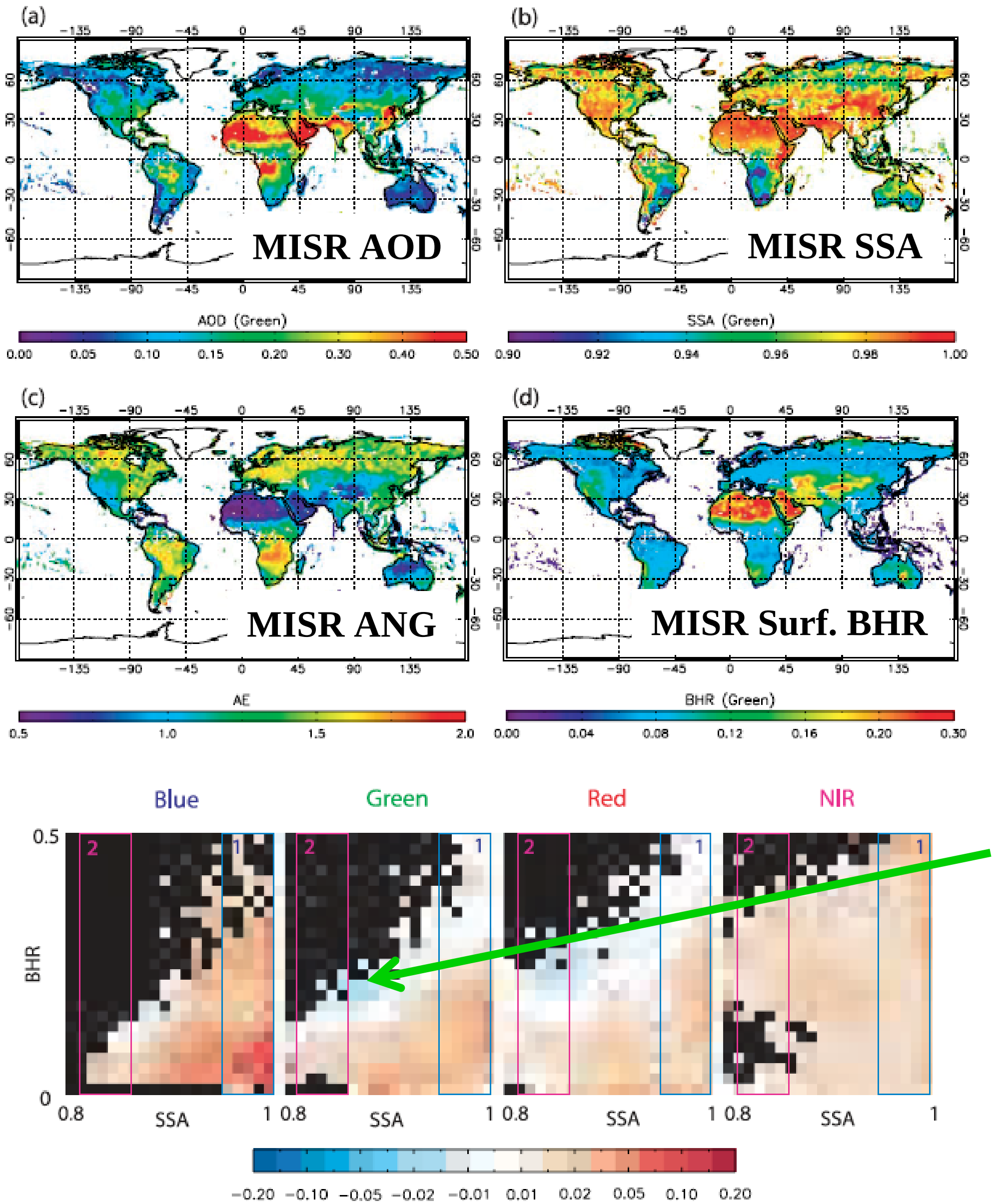
**TOA albedo vs. AOD**

***For data stratified by***:

**Surface BHR**

***Produces***:

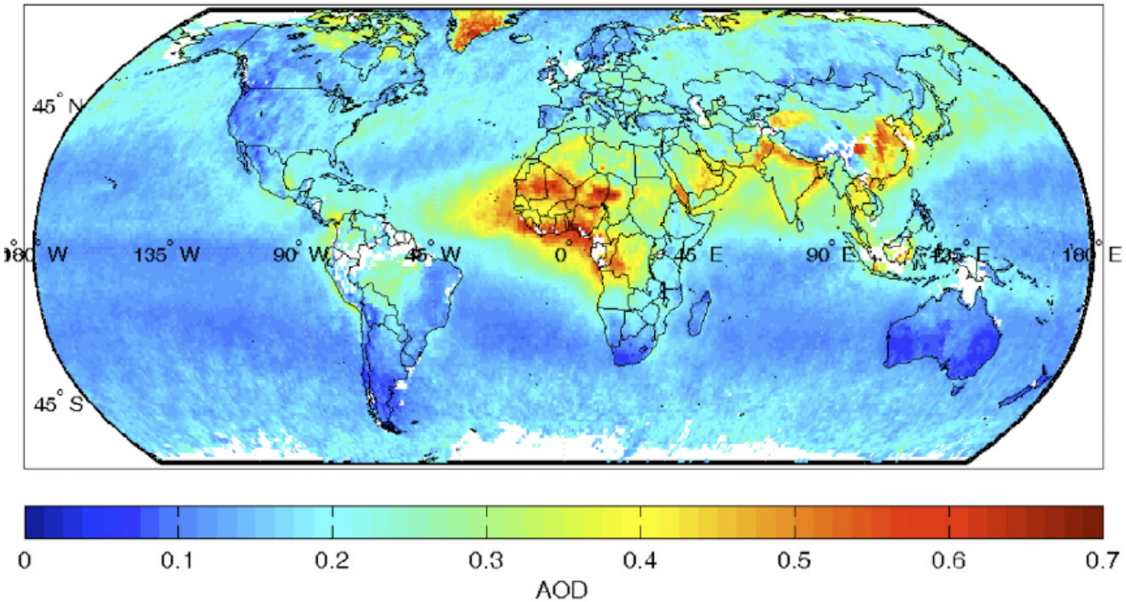
**Spectral aerosol radiative efficiency**



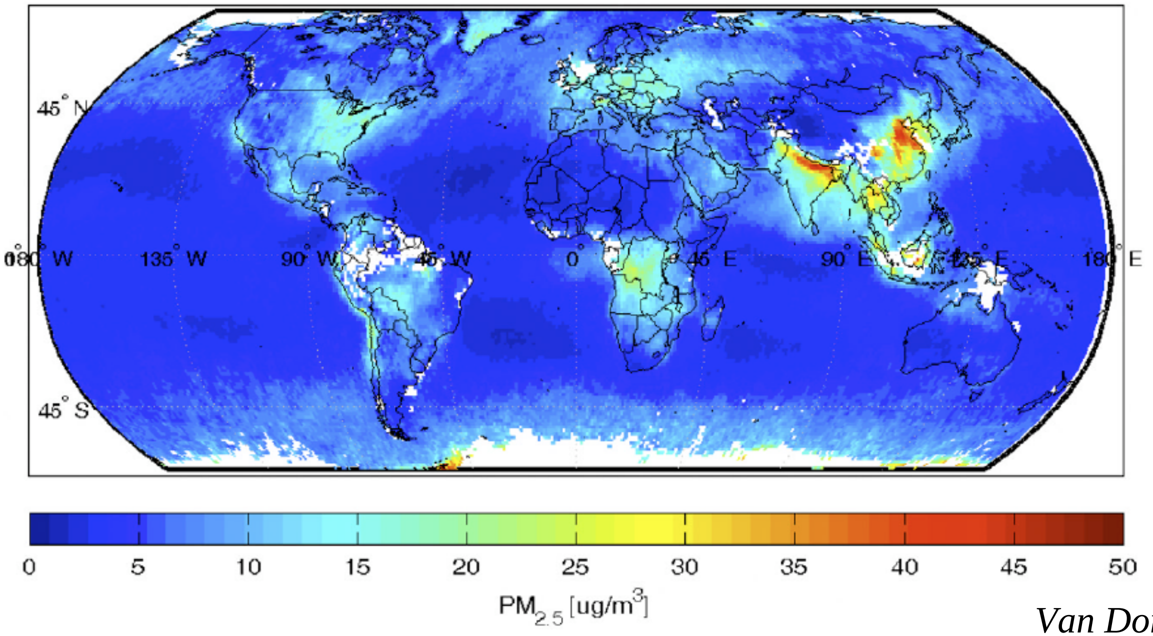

Bright surface + dark aerosol = decreasing albedo w/AOD

*Y. Chen et al. JGR 2009*

# **Air Quality**: MISR Column AOD + GEOS-Chem AOD Fraction in the BL




**MISR AOD**
Jan 2001- Oct 2002




**Derived $PM_{2.5}$**

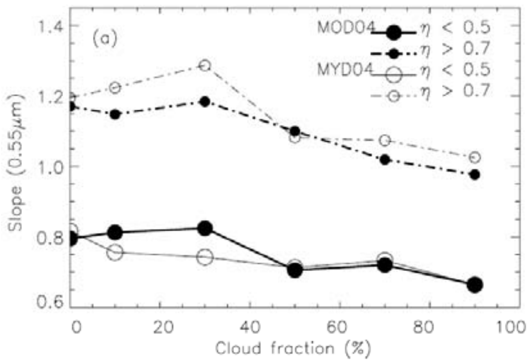
*Van Donkelaar et al. JGR 2006*

# ***Assimilating*** **MODIS Over-Ocean AOD into the NAAPS Operational Aerosol Forecast Model**

**Filtering** & **Empirical Corrections** to MODIS Collection 4 AOD - assimilating the ***best*** data produces forecast improvements

- **Quality Tests** – Use only QC=2, 3; AOD < 3.0; Cloud Fr. < 80%; Removes ~30% of data
- **De-spike** – Remove ~10% of data, where 3x3 pixel Standard Error exceeds threshold

- ~ 25,000 AERONET coincidences used to assess MODIS
- Linear relationship for mid-visible AOD < 0.6, slope >~ 0.92



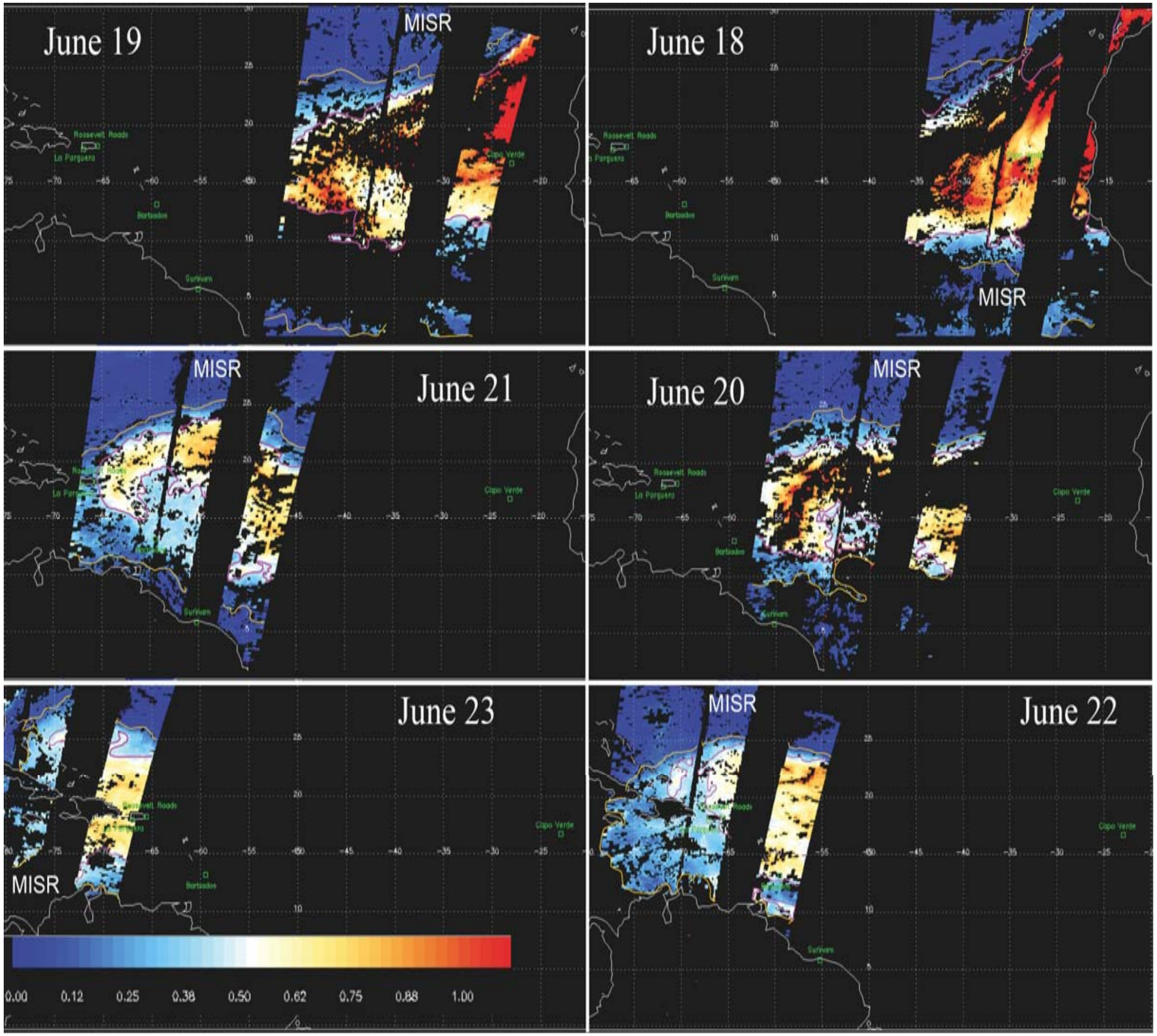

- **Wind speed** [6 m/s assumed] – glint & whitecap lower BC
  - -- AOD correction based on NOGAPS wind speed (~ ±0.02)
  - -- Use correlation coeffs. as functions of glint angle
- **Cloud contamination** – increases with cloud fraction
  - -- Use MODIS cloud fraction to empirically correct AOD
- **Aerosol microphysical properties** – correlate w/fine-mode fraction for AOD > 0.2
  - -- AOD underestimated for low SSA particles (smoke & pollution)
  - -- AOD overestimated for non-spherical dust

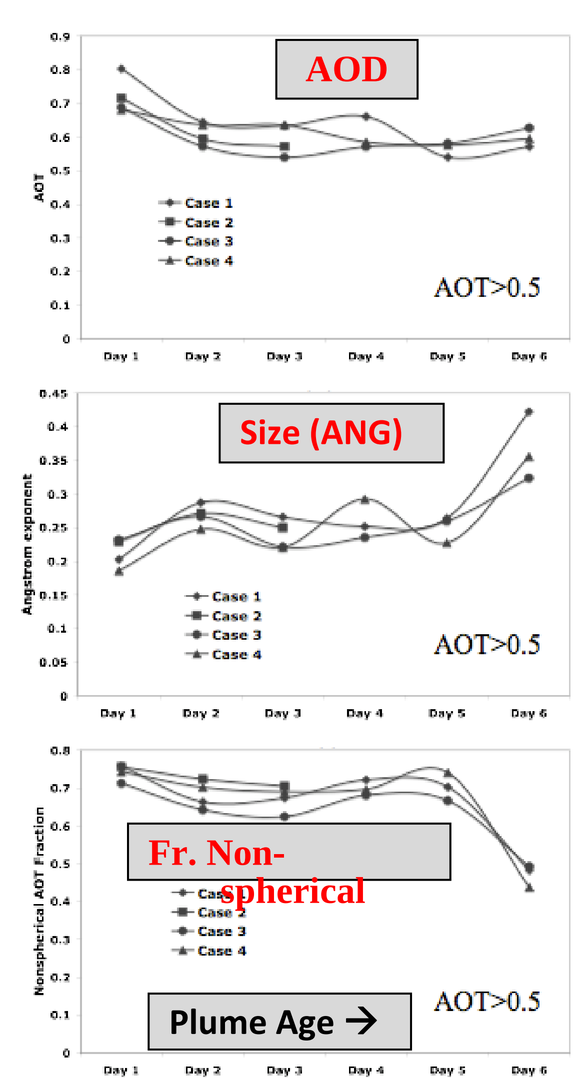
Significant forecast improvement for at least 48 hrs – Zhang et al. JGR 2008

*Zhang & Reid* JGR 2006

# Constraining Aerosol Sources, Transports, & Sinks

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

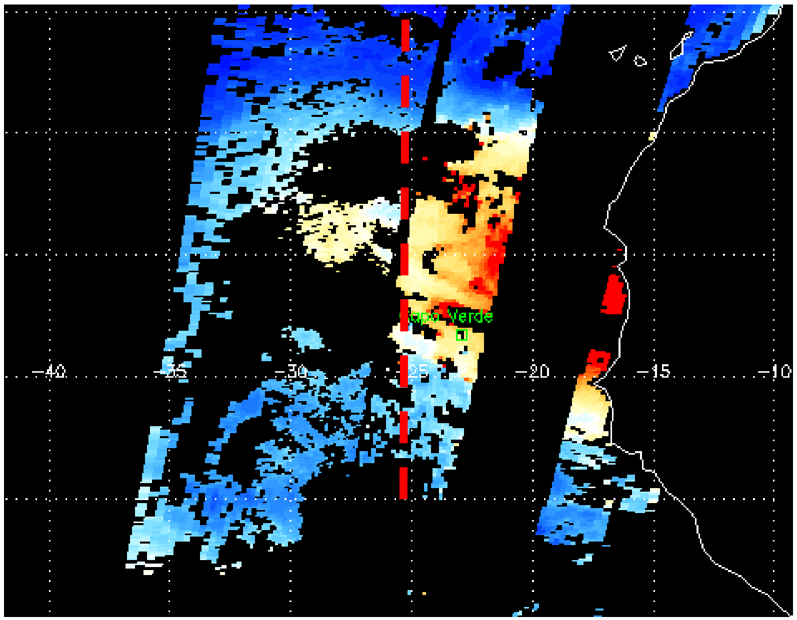


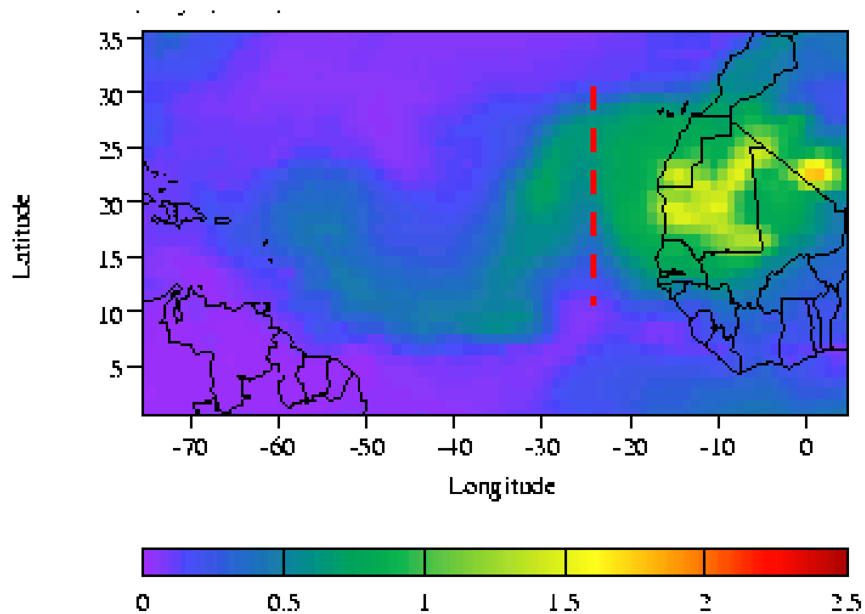

Contours: AOT=0.15 (yellow); AOT=0.5 (purple)

*Kalashnikova and Kahn*, JGR 2008

# MISR-MODIS-NAAPS (July 4, 2000)




MISR and MODIS AOD




NAAPS Dust

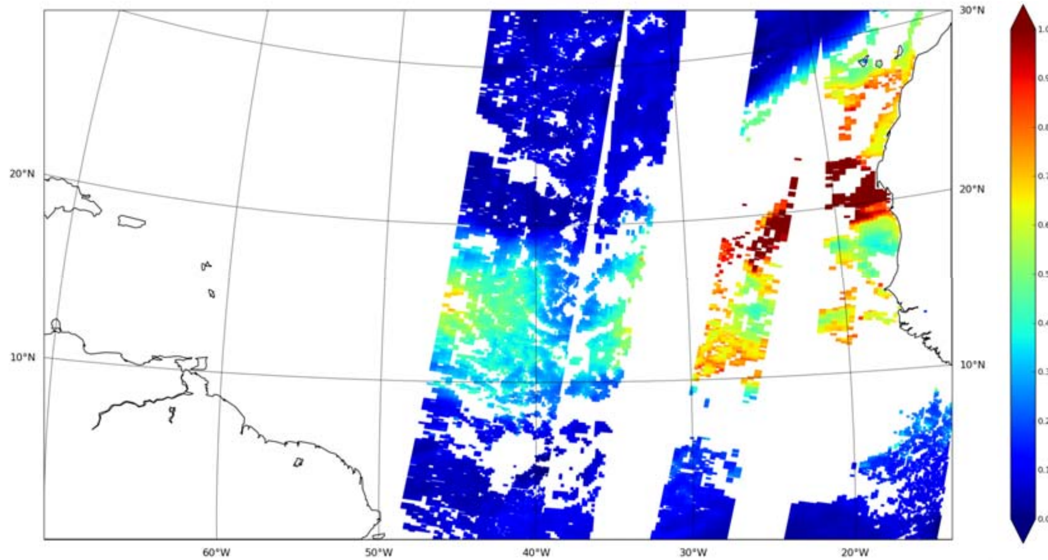
**NAAPS dust plume extent predictions:**

- **In qualitative agreement with MISR & MODIS**
- **Magnitudes differ… constrains dust Source Strength & Removal Rate**

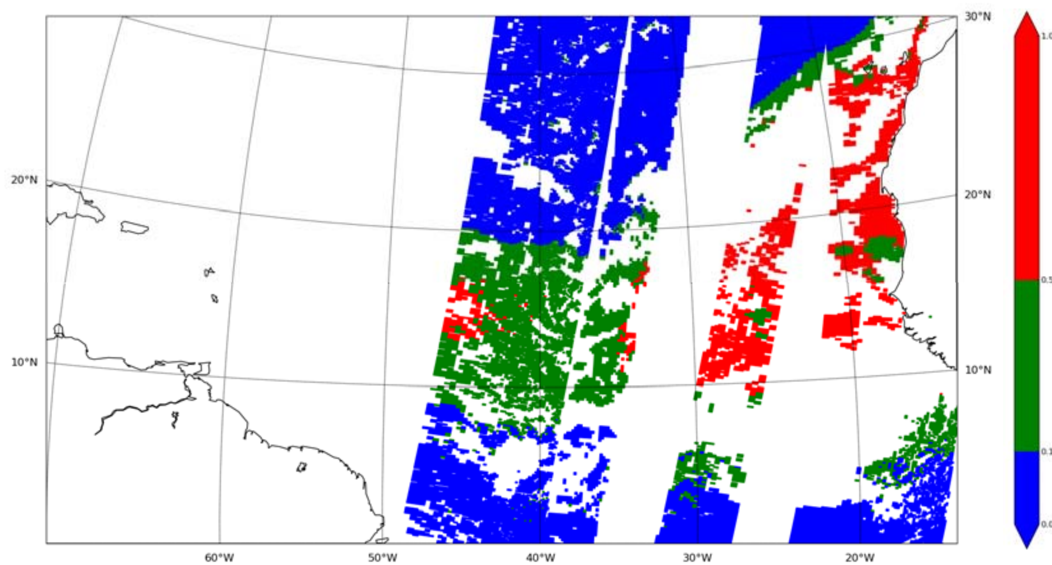
*Kalashnikova et al.*, 2008

# **Atlantic Transported Dust Plume Climatology**

**[*In Development*]**



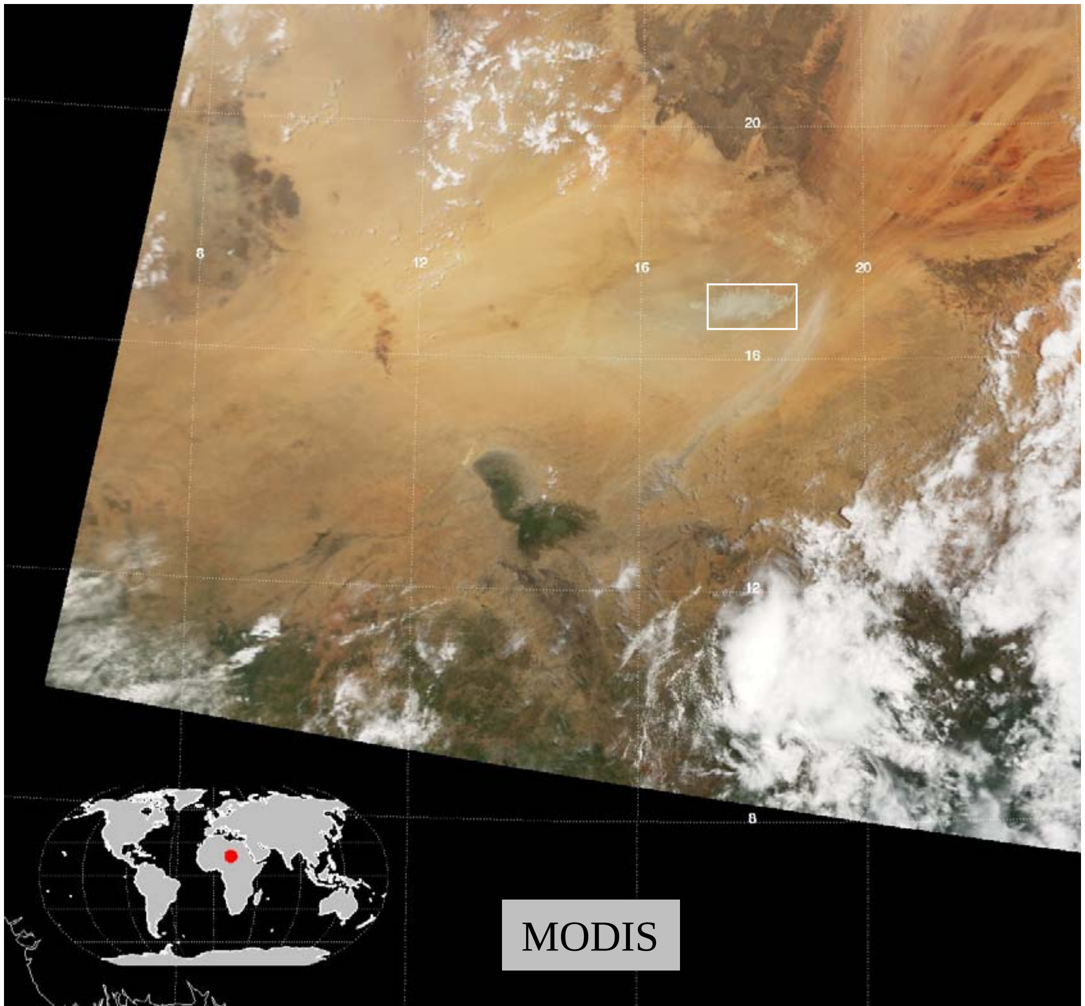

**MISR + MODIS**
**AOD Map**

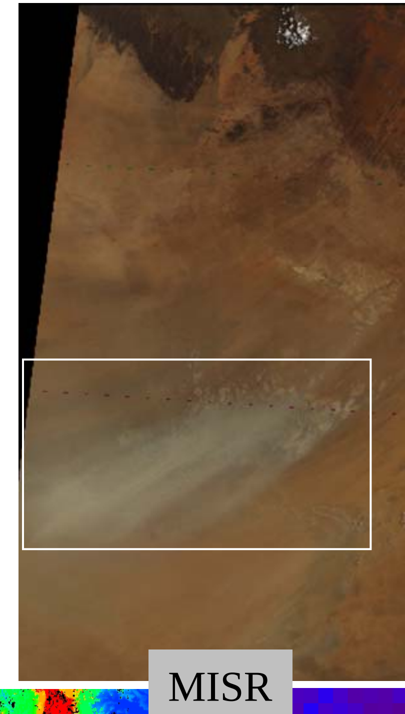


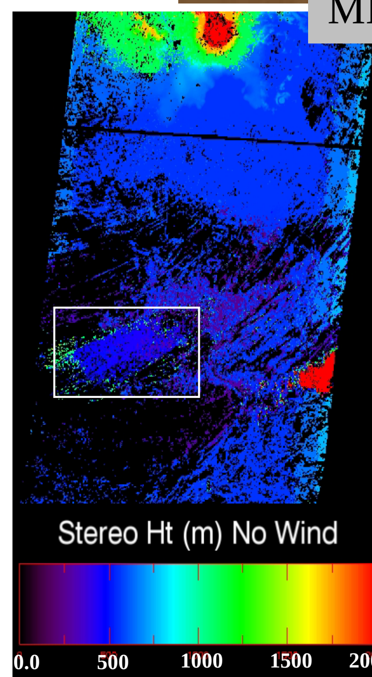

**AOD Contoured**
**at 0.15 & 0.5**
**to map**
**Extent & Properties**

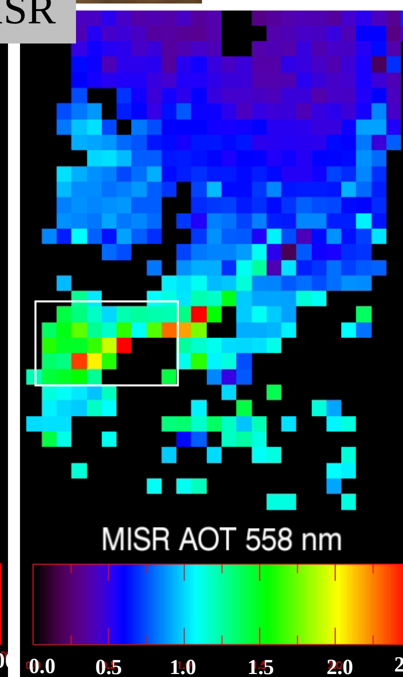
# Saharan Dust Source Plume

**Bodele Depression** **Chad June 3, 2005 Orbit 29038**



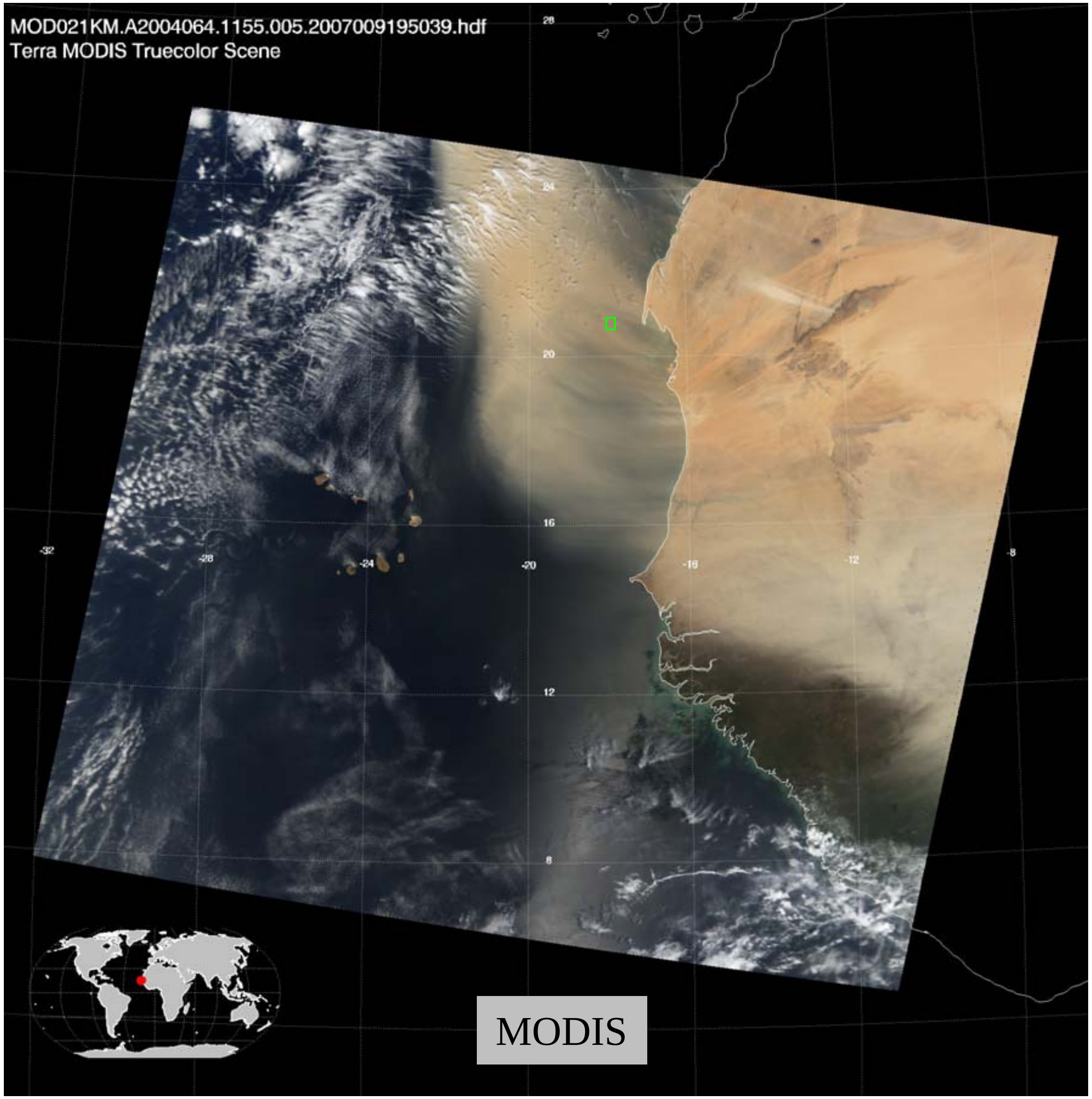



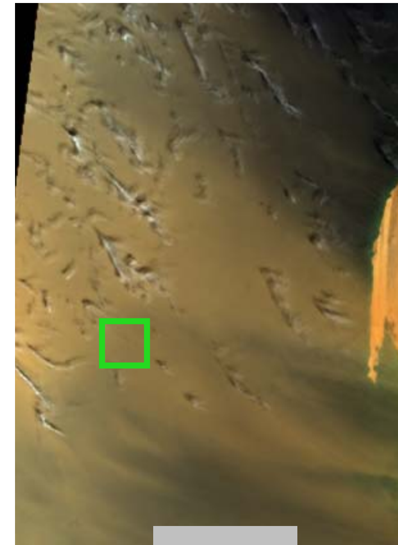

***Dust is injected near-surface…***

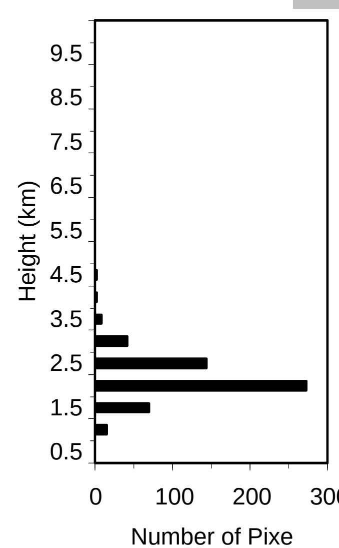
*Kahn et al.*, JGR 2007

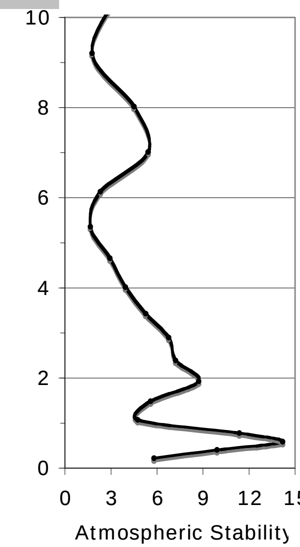
# Transported Dust Plume

**Atlantic, off Mauritania March 4, 2004 Orbit 22399**



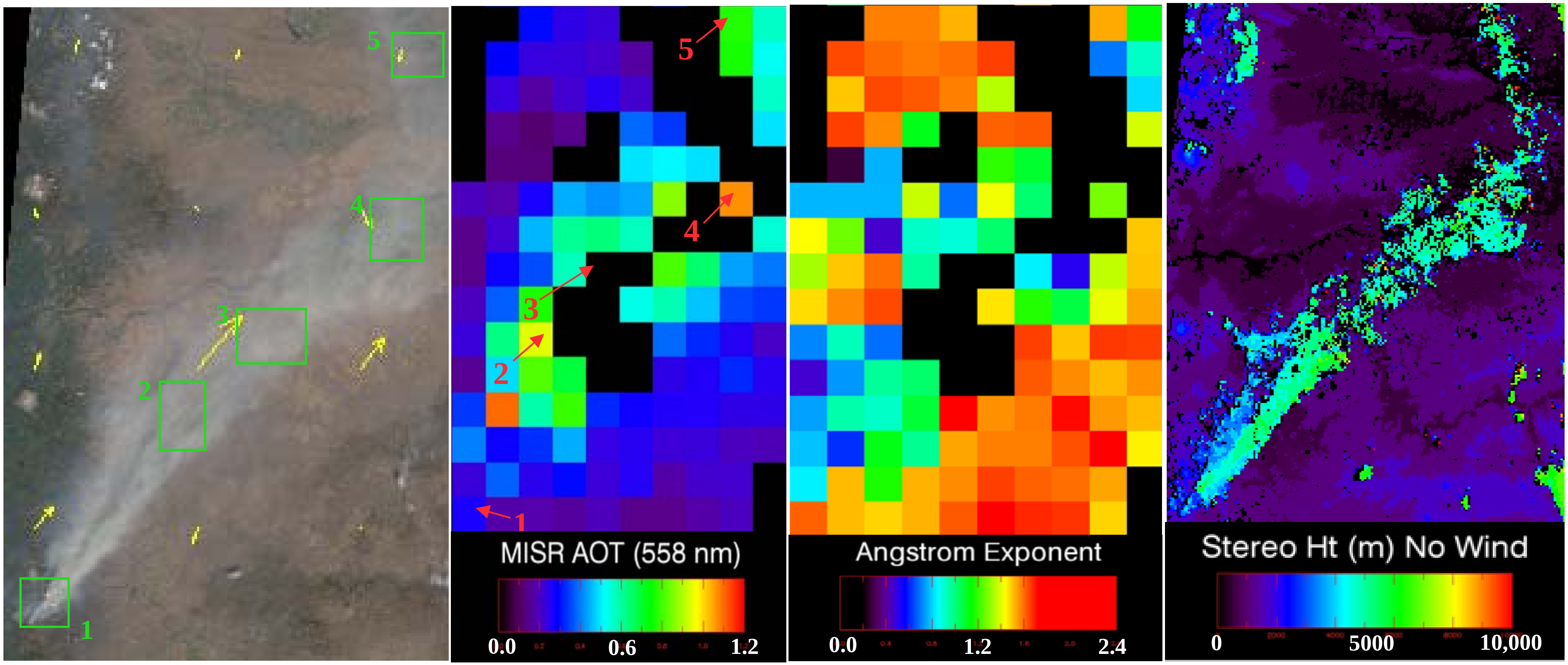



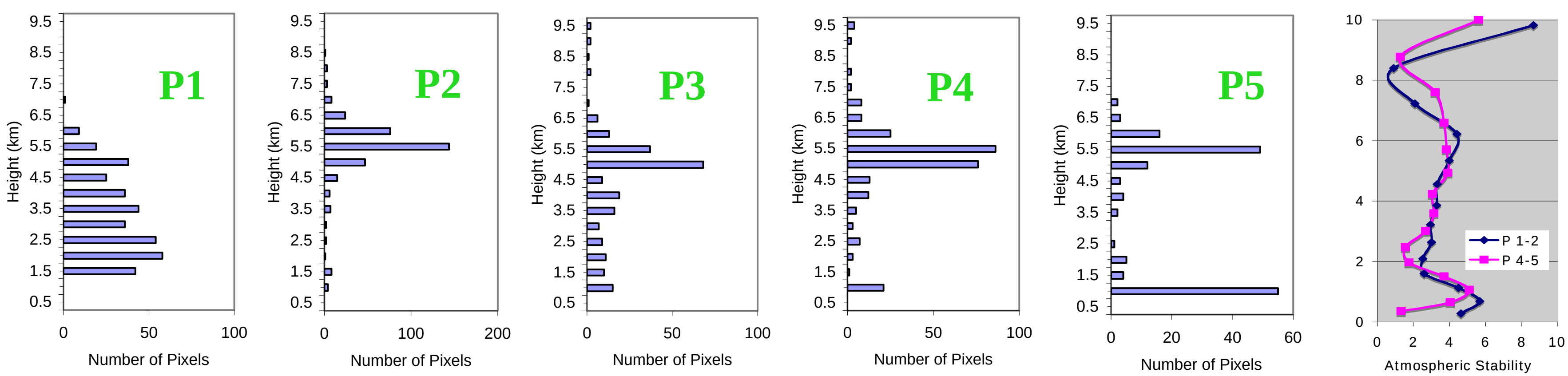

***Transported dust finds elevated layer of relative stability…***

*Kahn et al.*, JGR 2007

# Oregon Fire Sept 04 2003

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

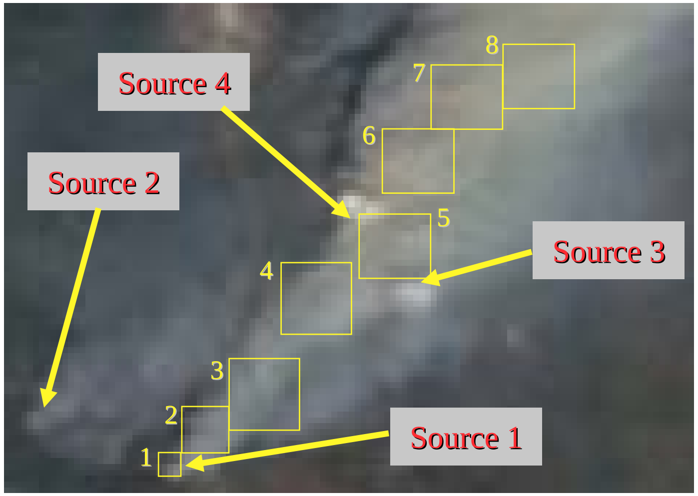


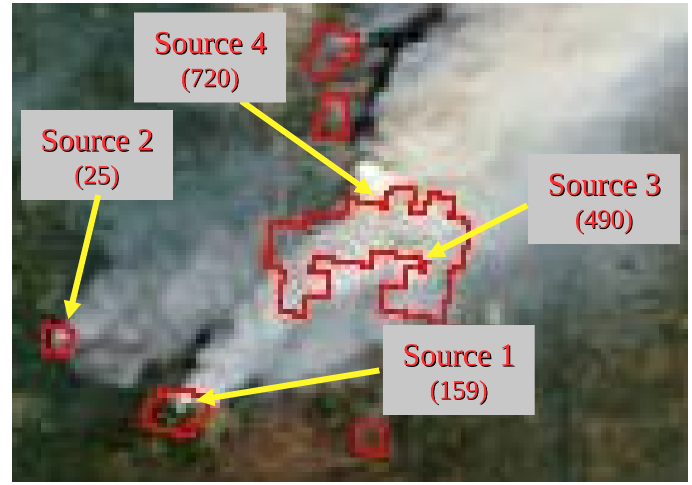

*Kahn, et al.*, JGR 2007

# Detail of Wildfire Source Region

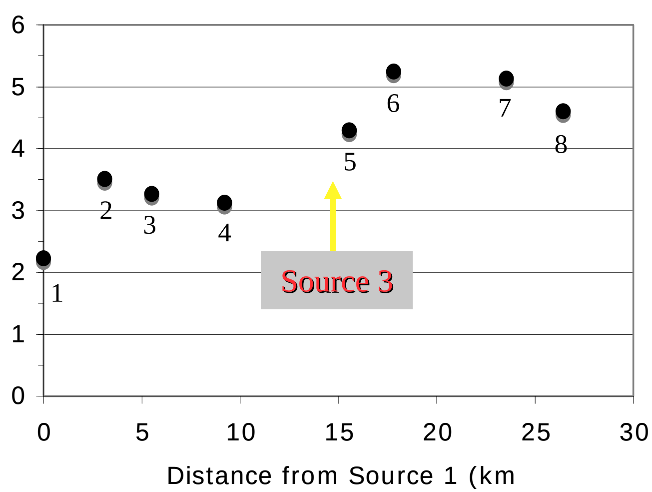
**Oregon Fire Sept 04 2003**



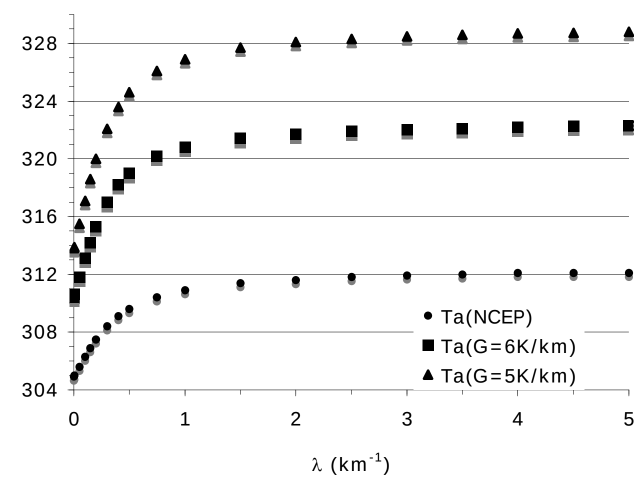

**MISR Nadir 275 m Image**




**MODIS Image + Fire Power**



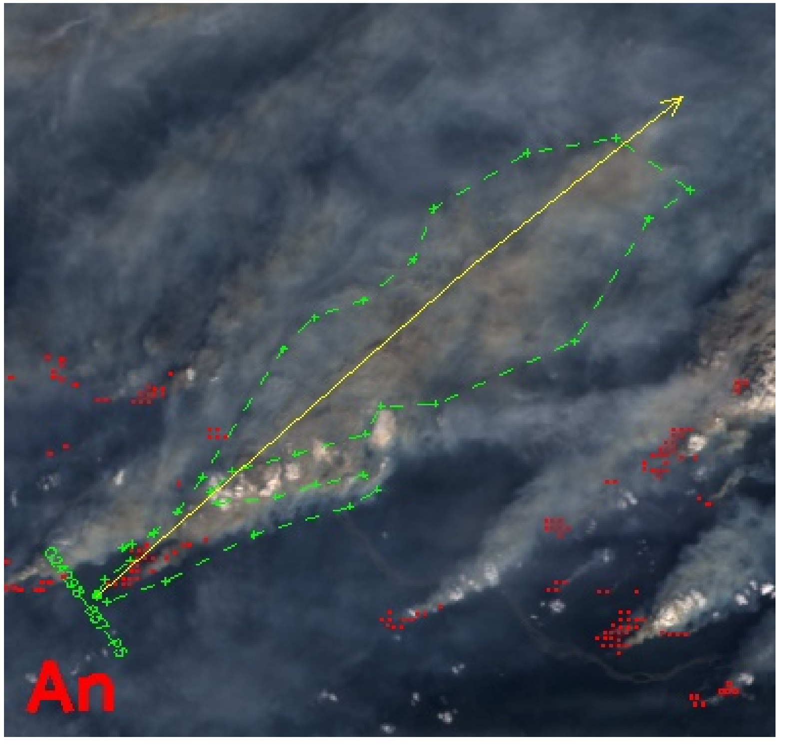

**MISR Plume Heights for Sub-patches**

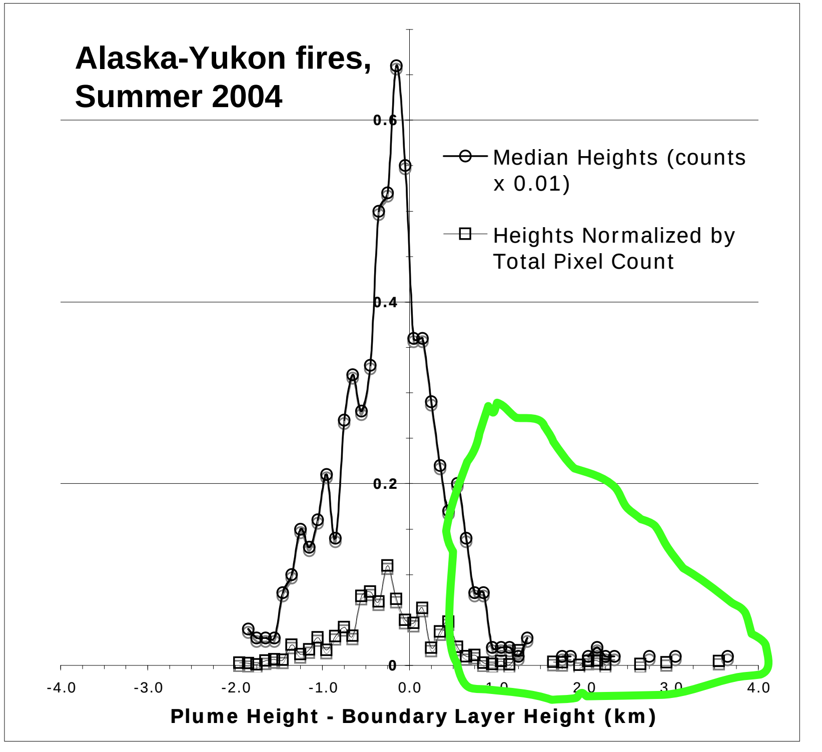



**Very Simple Plume Parcel Model**

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

# Wildfire Smoke Environmental Impact



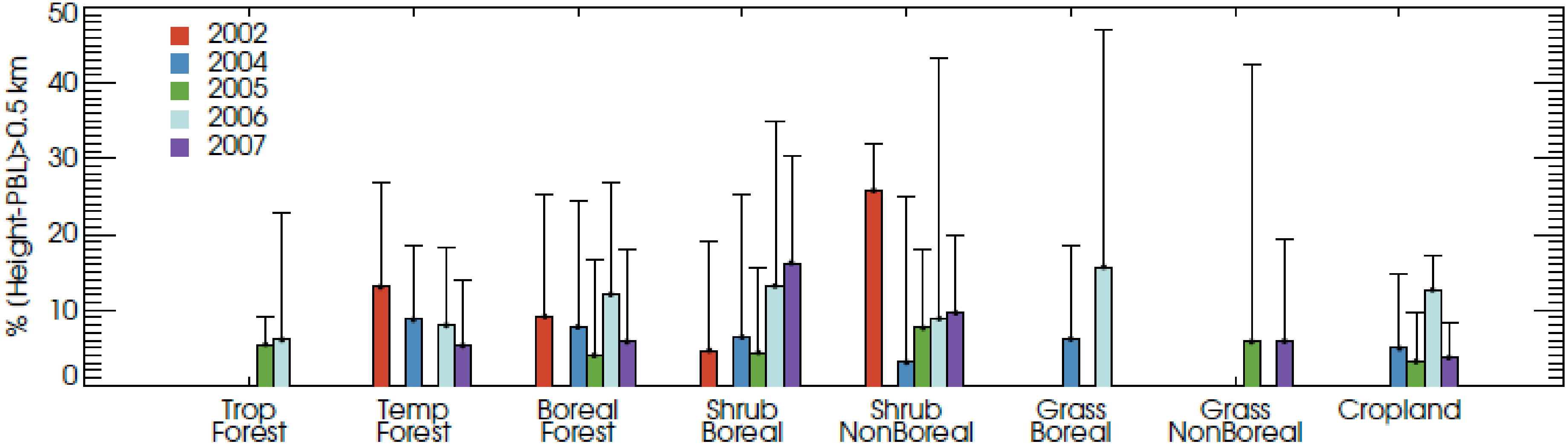




**MISR and MODIS data are changing the way smoke is represented in Chemical Transport Models (CTMs), used to predict air quality and climate impacts.**

- MISR stereo-derived smoke plume heights are showing that between 10% and 30% of wildfires inject smoke above the near-surface atmospheric boundary layer (ABL) in many regional studies.
- Previously, most CTMs represented smoke sources as injecting smoke only into the ABL.
- Smoke injected above the ABL travels farther and remains airborne longer, increasing environmental impacts.
- New relationships between smoke injection height, atmospheric stability profile, fuel type, and MODIS fire radiant energy, being developed, will help extrapolate injection heights to the much larger MODIS coverage.

*R. Kahn, Y. Chen, D. Nelson, et al.*, GRL 2008

# Wildfire Smoke Plume Database
## [*In Development*]

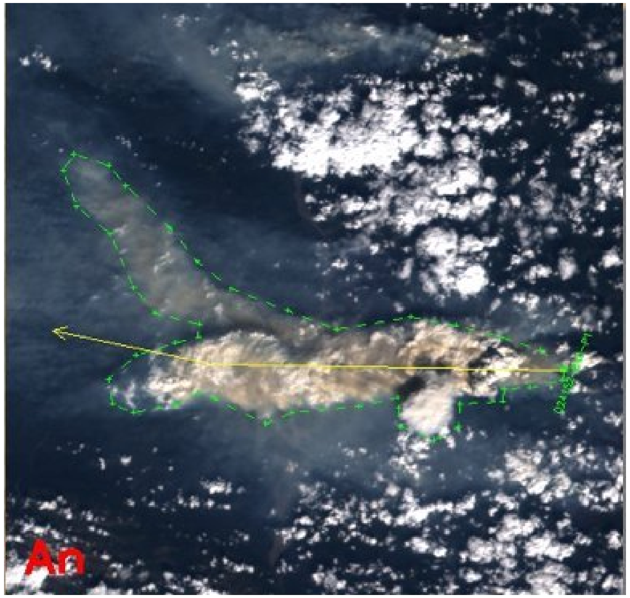


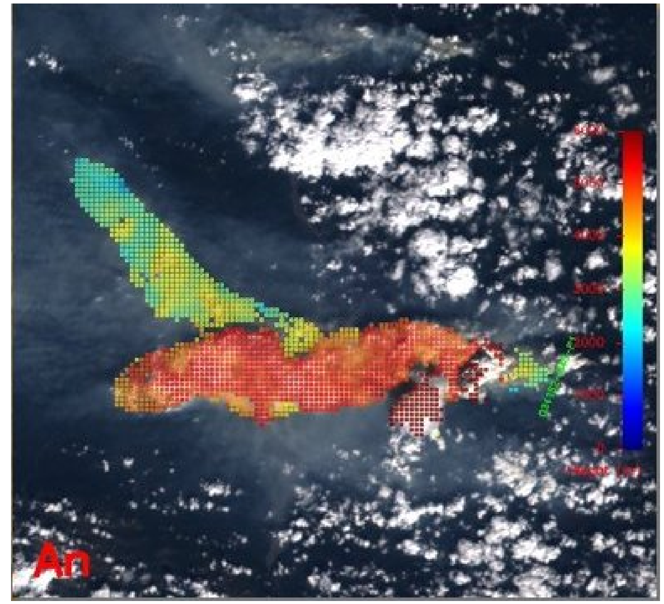

Percent of plumes >0.5 km ***above BL***, stratified by year and vegetation type [North America]

**http://www-misr2.jpl.nasa.gov/EPA-Plumes/**

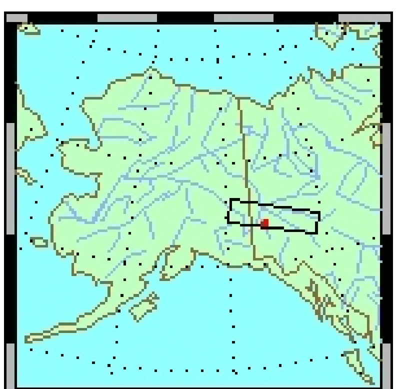
*Val Martin, et al.*, ACPD 2009

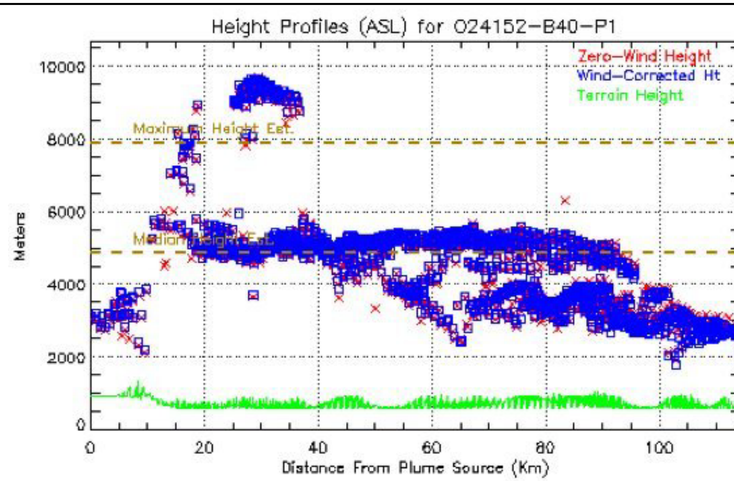
# Wildfire Smoke Plume Database
***[In Development]***




**http://www-misr2.jpl.nasa.gov/EPA-Plumes/**






**N. America**
2002, 2004-2007

**Africa**
2005, 2006

*David Nelson, et al.*, 2009

# MISR Aerosol Product Applicability

• On a *Monthly*, *Global* basis, the MISR Aerosol Data Set provides ***Limited Statistical Representation*** of AOT & Type

-- ***Cloud-Free Bias***

-- ***High-AOT Bias*** for Aerosol Type

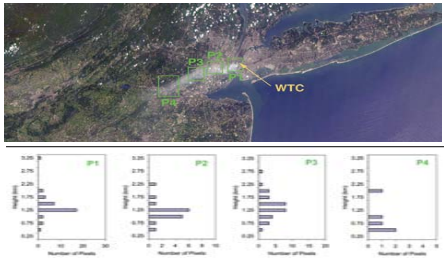
-- Overall ***Sampling*** – gradients, plumes, diurnal variations

• For some applications, this ***is NOT critical***

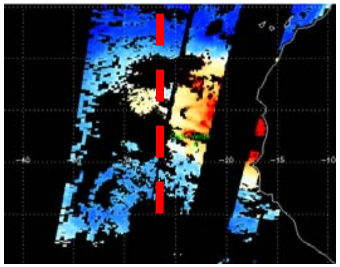
-- ***Plume Heights***

-- AOT contours to constrain ***Aerosol Transports***

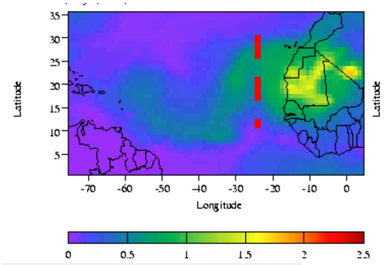
-- Aerosol ***Air Mass Type Mapping***



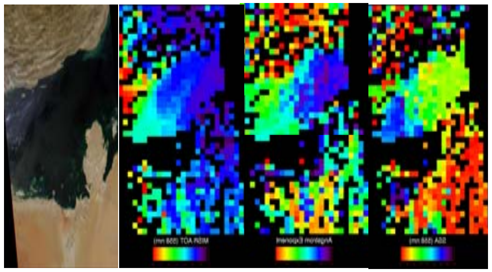

WTC Smoke Plume Heights



MISR & MODIS AOD

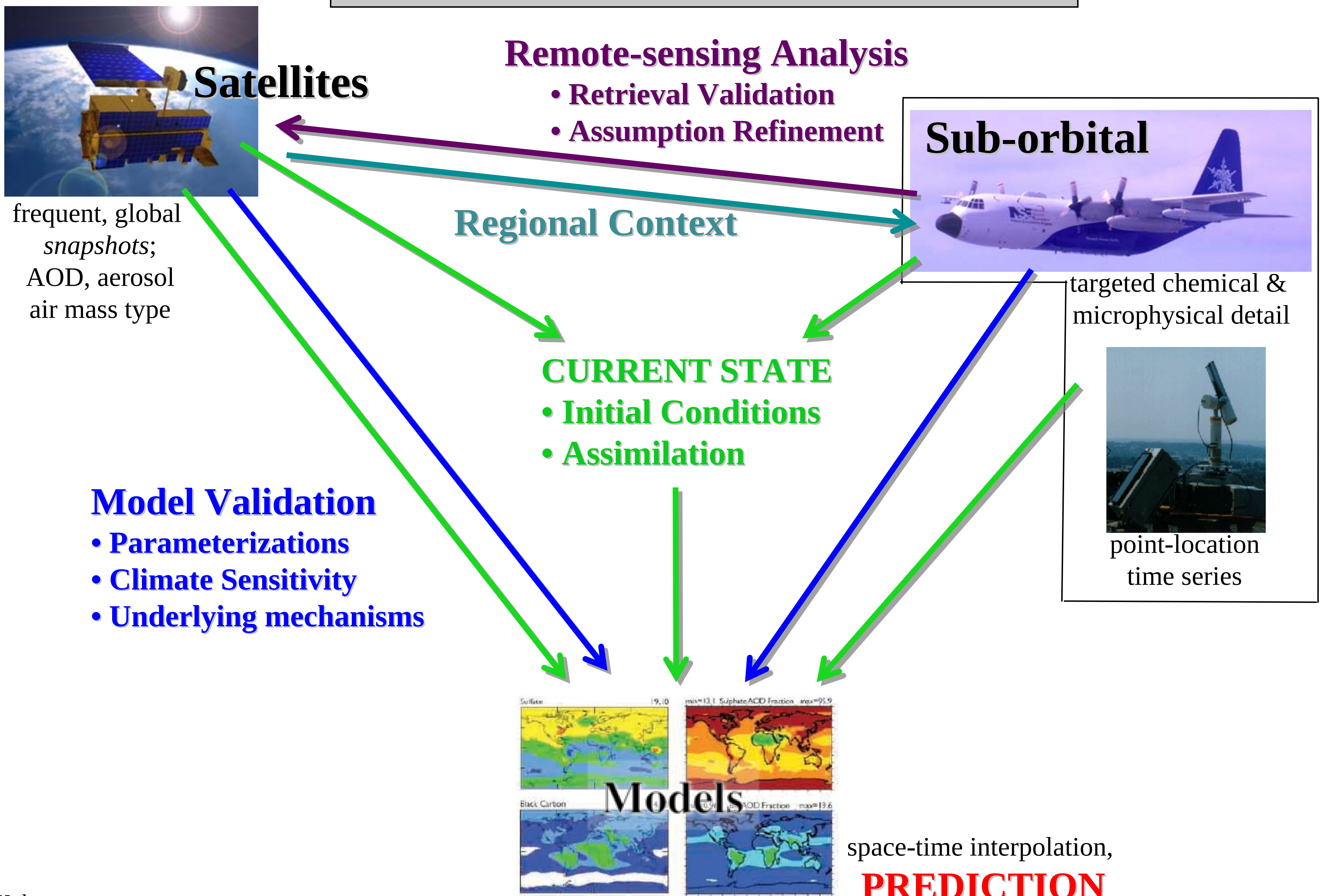



NAAPS Dust



MISR UAE-2 Aerosol Air Masses

# Aerosol-Climate Prediction




*R. Kahn*