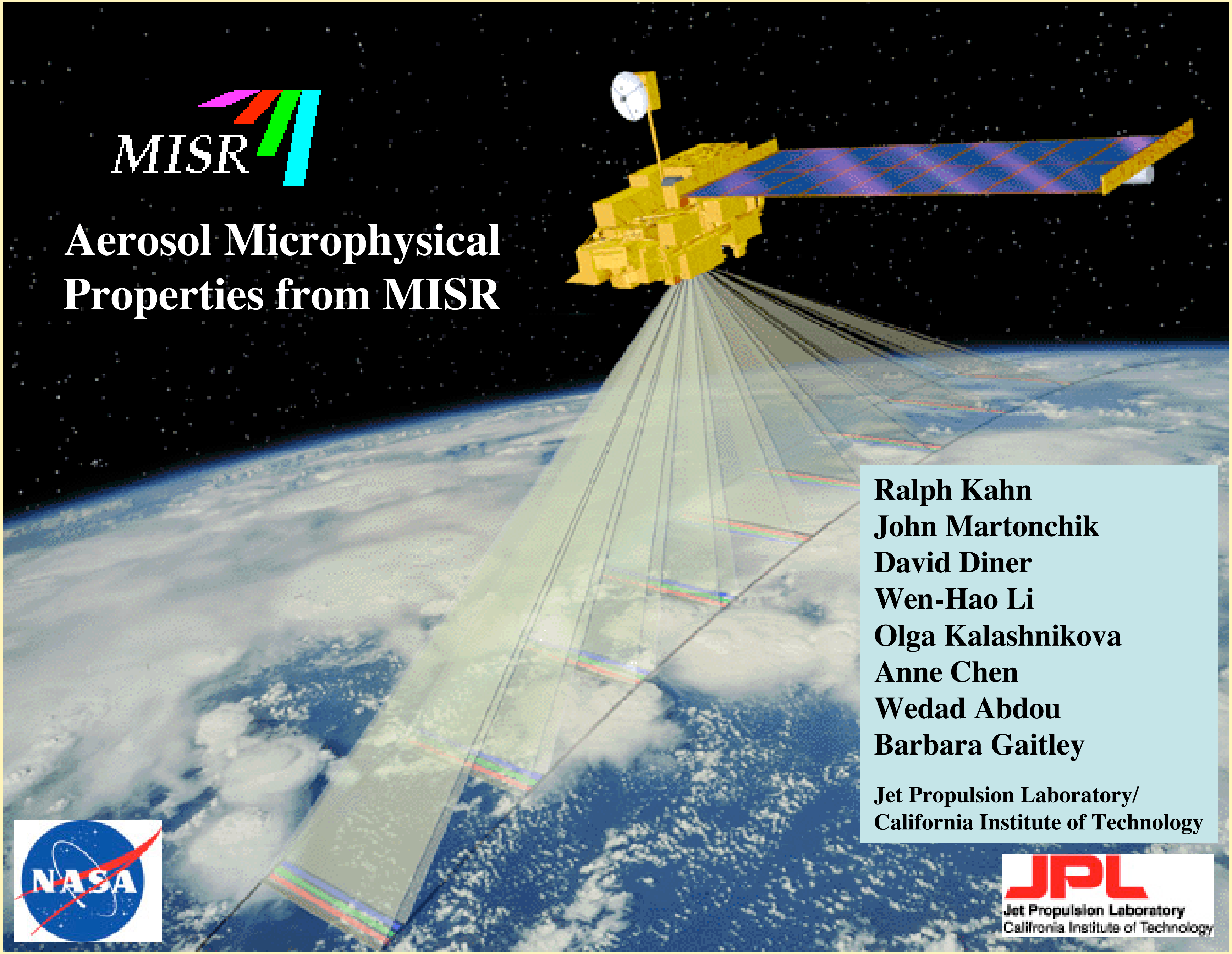
MISR

Aerosol Microphysical Properties from MISR



Ralph Kahn
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MISR MULTI-ANGLE CAPABILITY –
MORE INFORMATION ABOUT AEROSOLS

EXPECATIONS based on simulations over cloud-free, calm ocean:

- **Aerosol Extinction Optical Depth (τ_a)**

  -- to better than 0.05 or 20%, whichever is larger, under typical conditions, for commor aerosol types except soot, even if the particle microphysical properties are poorly know

- **Particle Size (r_a)**

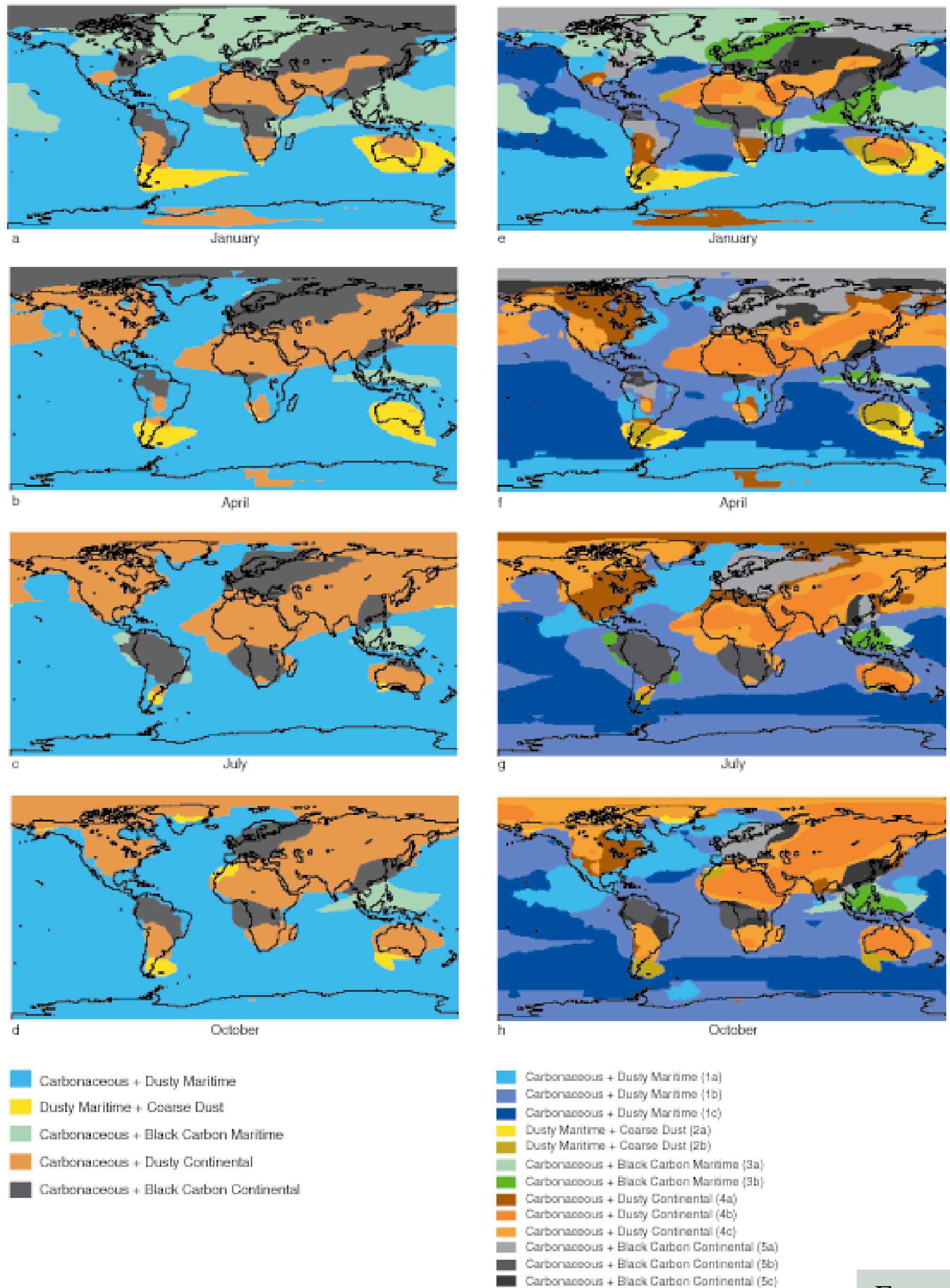
  -- "Small," "Medium," and "Large" size discrimination over Accumulation Mode -- these are the key distinctions needed to assess aerosol impact on vis spectrum

- **Single Scattering Albedo** – two-to-four groups at about **1.0, 0.9, and 0.8**

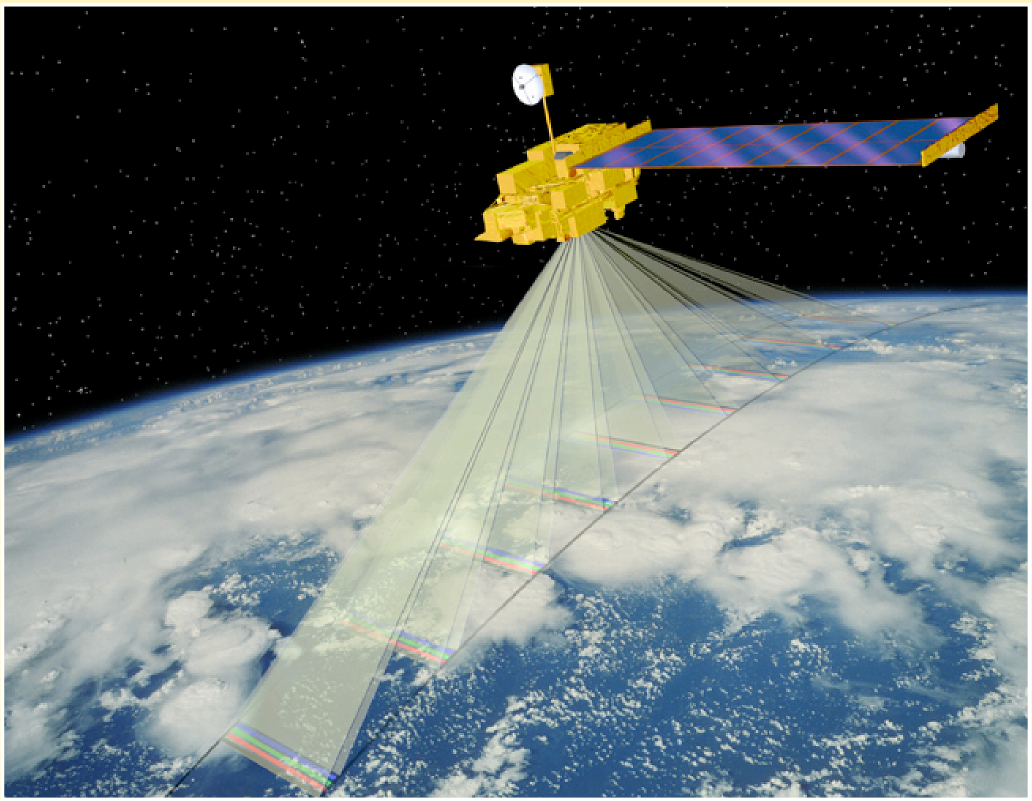
- **Spherical vs. Nonspherical** for Sahara dust, Asian dust, and possibly thin cirrus

➔ Under good conditions, we expect MISR to distinguish **about 12 aerosol types** based on size, shape, and composition

Simulated Global, Monthly Aerosol Maps Based on Expected MISR Sensitivity



From: Kahn et al., 2001



Nine view angles at Earth surface: 70.5° forward to 70.5° aft

Four spectral bands at each angle: 446, 558, 672, 866 nm

Seven minutes to observe each scene at all 9 angles

400-km swath

Eight-day global coverage (two days near poles)

275 m - 1.1 km spatial sampling

MISR Multi-angle Aerosol Retrieval Strengths -

- Ability to retrieve Aerosol Optical Thickness (AOT) over Land
- Ability to retrieve AOT over Very Bright Surfaces (e.g., Desert)
- Ability to retrieve AOT for Optically Thin hazes over land and water
- Ability to retrieve Particle Sphericity at least over dark water
- Ability to retrieve Three-to-Five Size Groupings at least over dark water
- Crude Sensitivity to Single-Scattering Albedo [~ 1.0 vs. 0.88 vs. 0.80 over dark water]
- Ability to retrieve Bi- and even Tri-modal Distributions in some cases
- Ability to retrieve Plume Height; mainly useful in Aerosol Source Regions

MISR Aerosol Retrieval Algorithm Validation

Aimed at **determining quantitatively the unique contributions** multi-angle imaging can make to aerosol science

Must involve:

- Critically **testing and refining** our algorithms

- Quantitatively **assessing the sensitivity** of the best algorithms we can produce

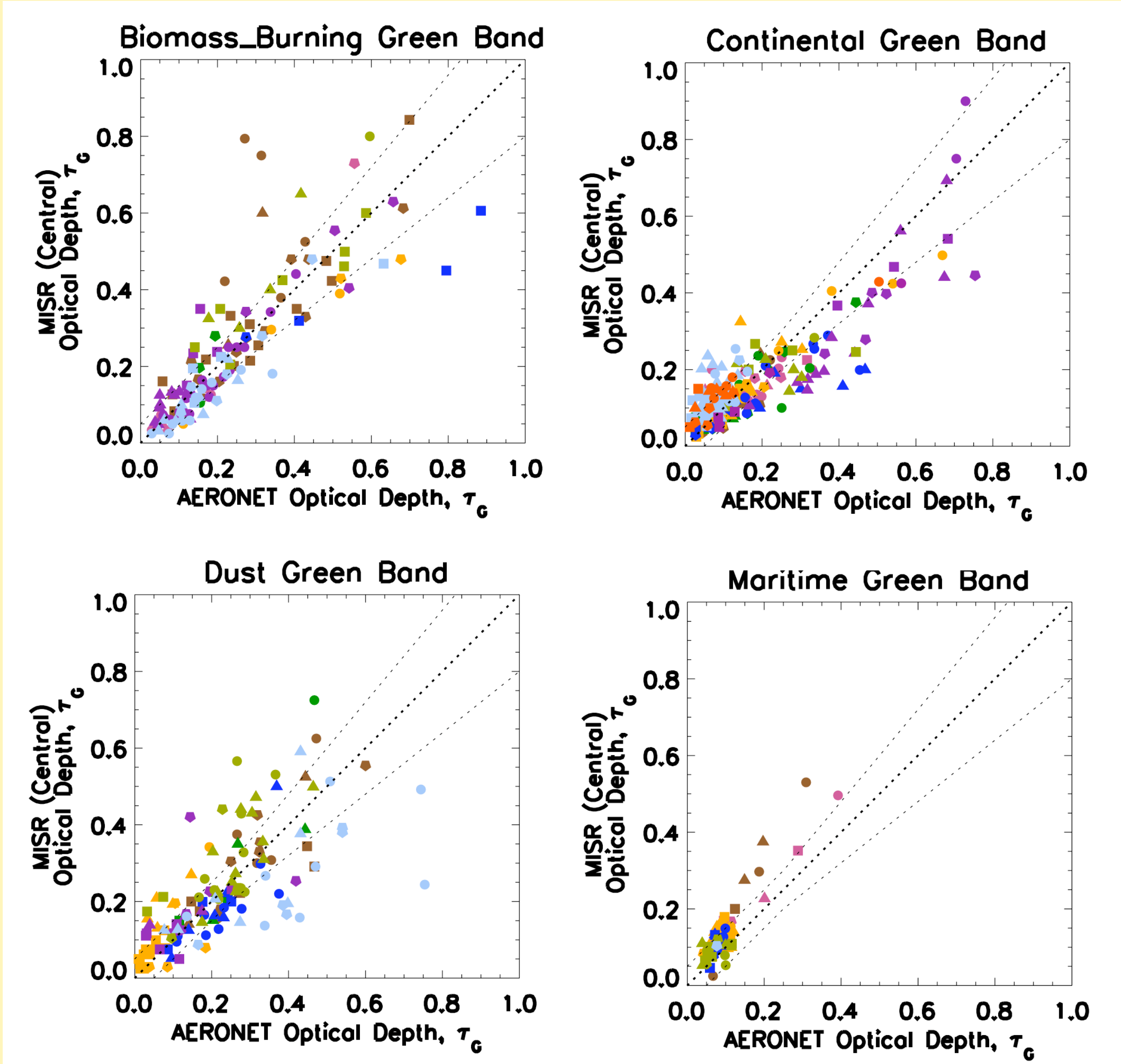
<u>Then</u>: Apply them to the **global, multi-year** MISR data set

<u>Supplemented by</u>: More detailed **surface and *in situ*** data

…to improve regional and **global aerosol climatologies**
for **aerosol budget** and **climate change** applications

Scatter Plots Showing 579 MISR-AERONET Coincident AOT Events

32 sites, during 2001-2002; Stratified by Expected Aerosol Type



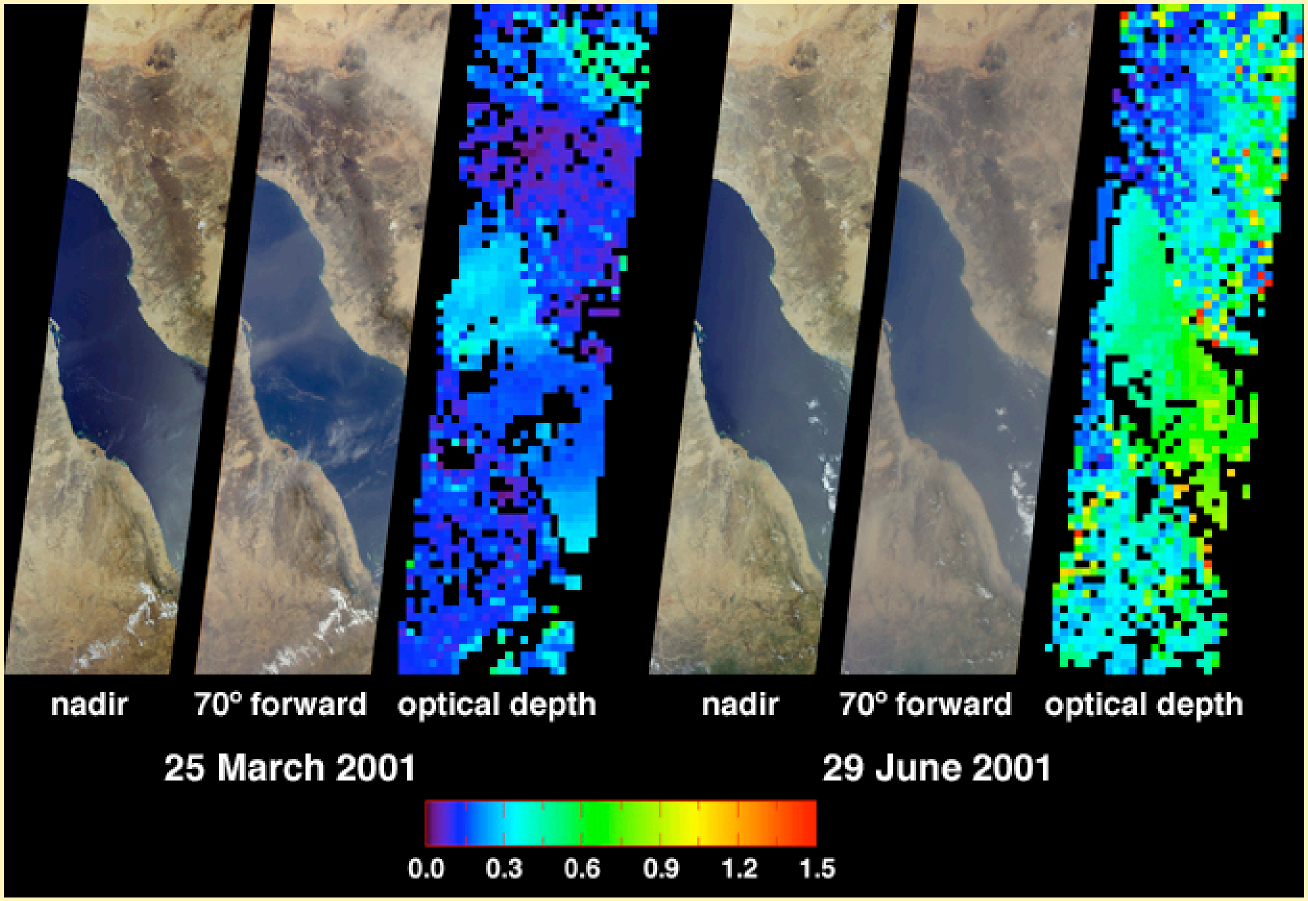
Overall:

- **About 2/3 fall within 0.05 or 20% * AOT**
- **About 1/3 fall within 0.02 or 10% * AOT**

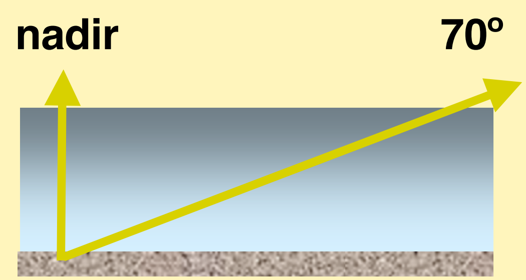
Correlation Coeffs. > 0.8 in all categories except Dusty, which are > 0.72

From: Kahn, et al., 2004, JGR (in press)

Sensitivity to aerosols over bright surfaces



Thin haze over land is difficult to detect in the nadir view due to the brightness of the land surface

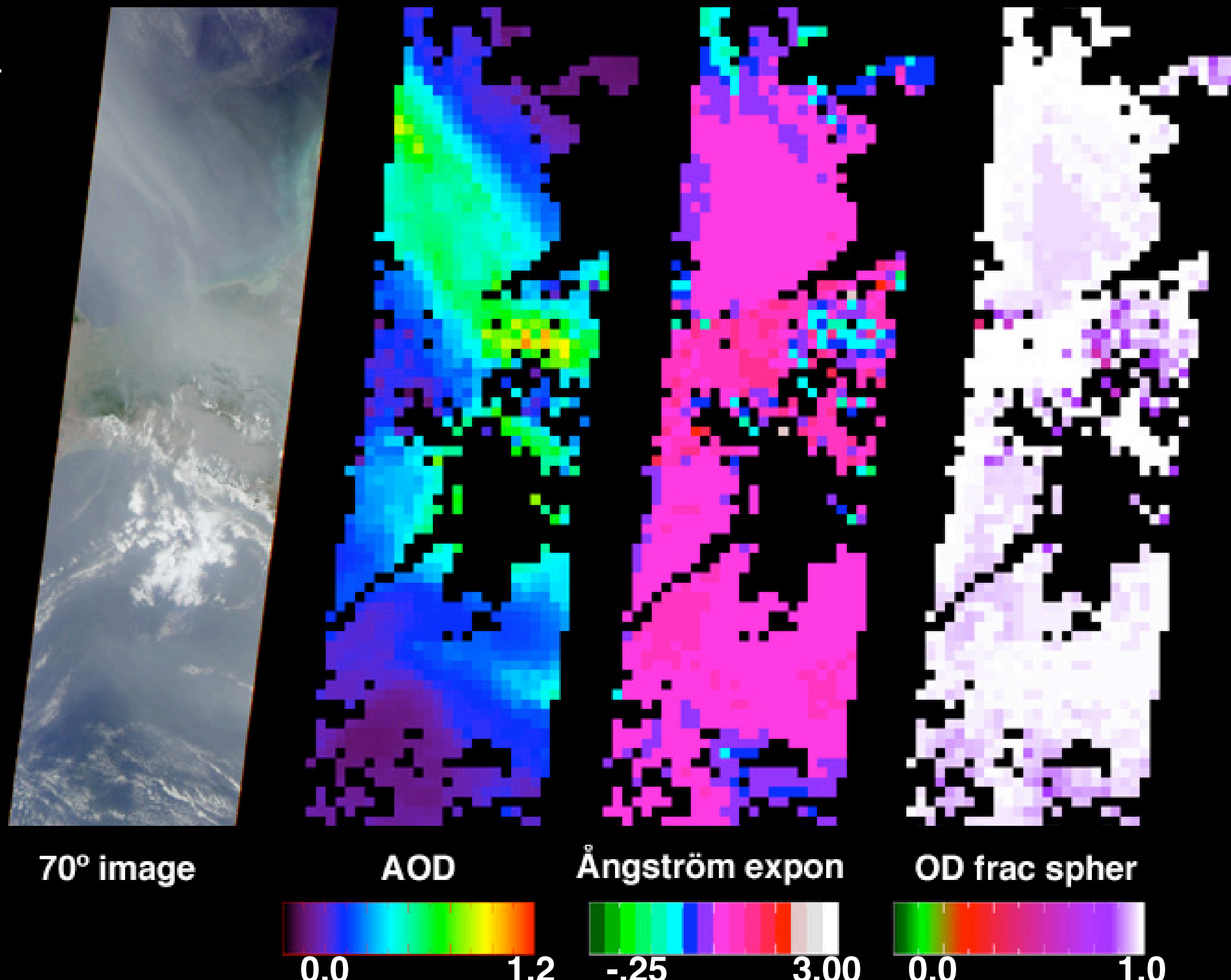


Saudi Arabia, Red Sea, Eritrea

Over Bright Desert Sites, mid-vis. AOT to ±0.07 [Martonchik et al., GRL 2004]

Smoke from Mexico (MISR)
2 May 2002

<u>Aerosol:</u>
Amount
Size
Shape

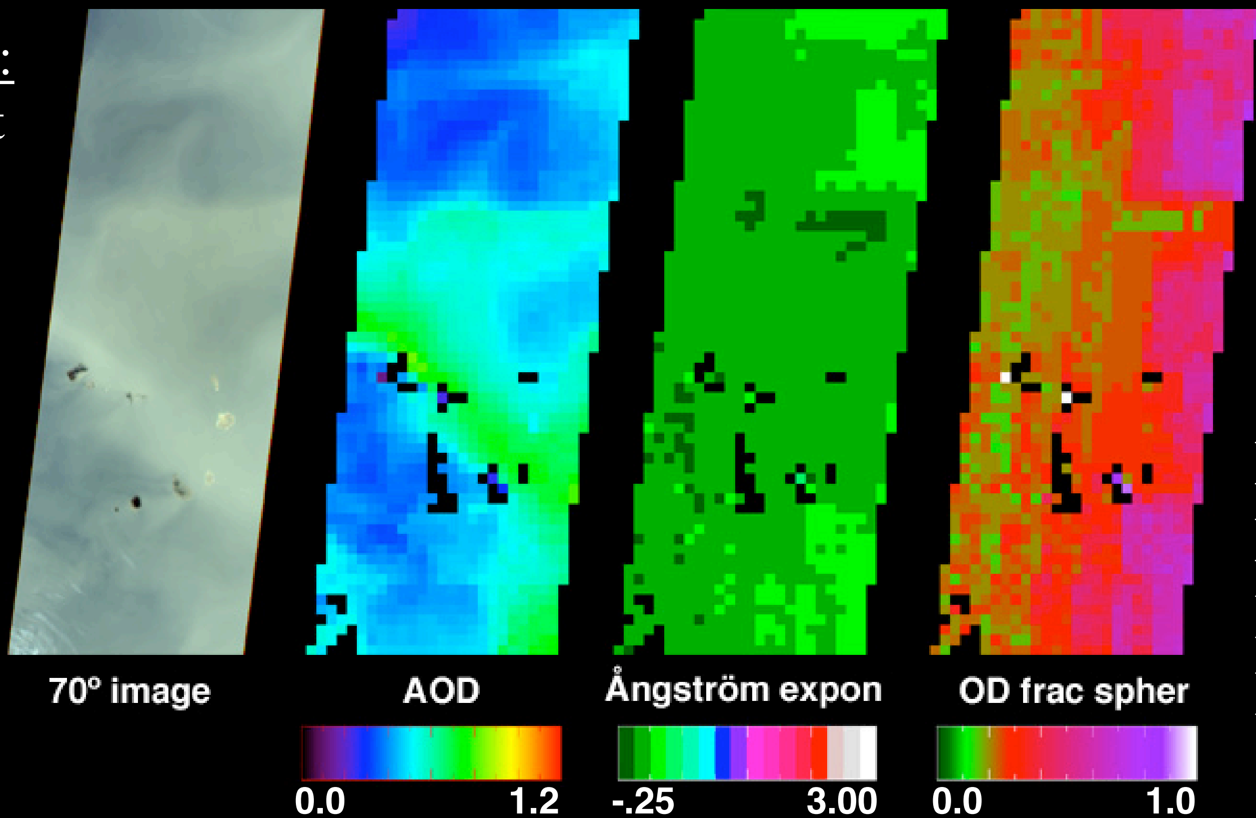


Medium
Spherical
Smoke
Particles

Dust blowing off the Sahara Desert (MISR)

6 February 2004

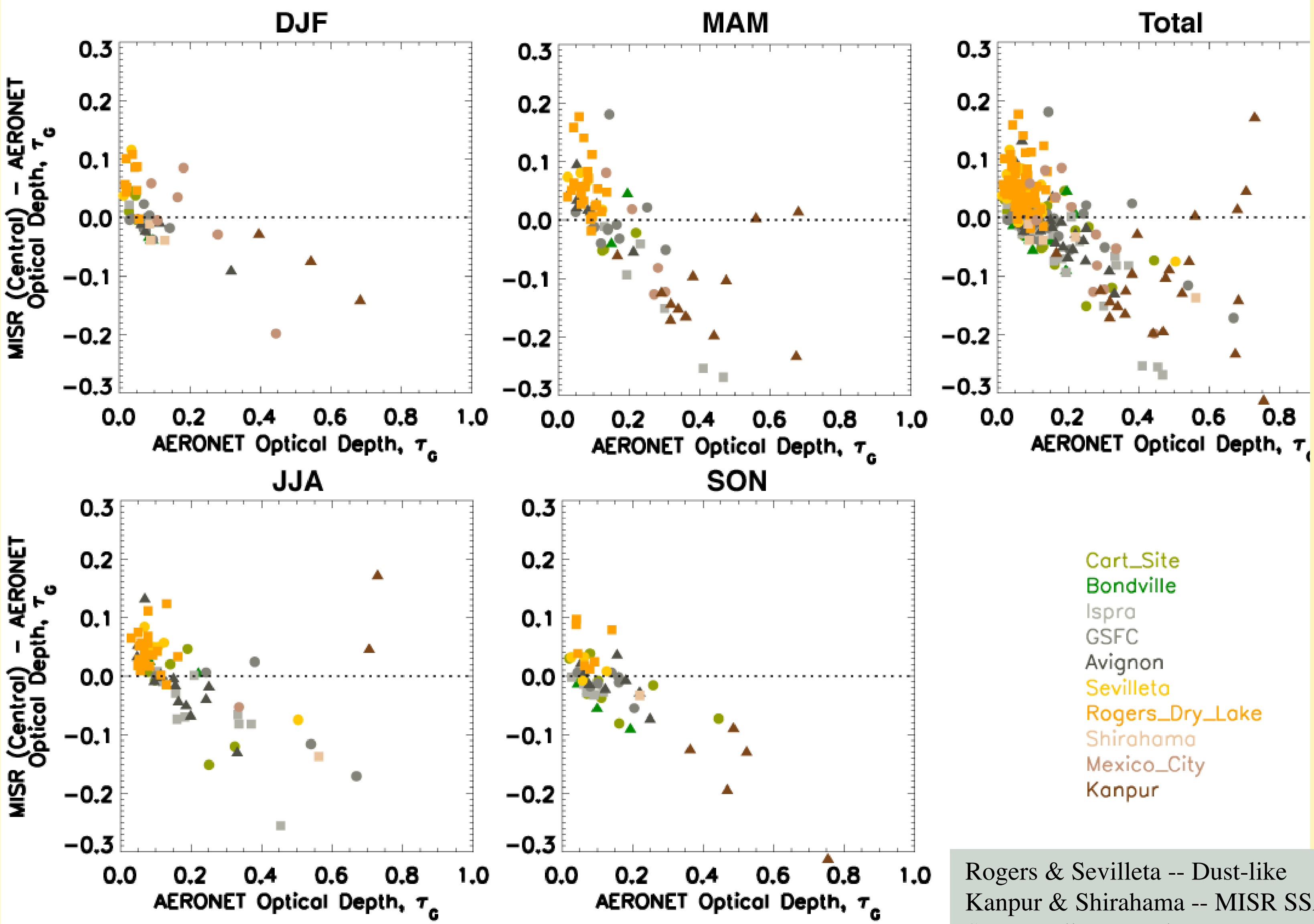
<u>Aerosol:</u>
Amount
Size
Shape



Large
Non-Spherical
Dust
Particles

247 MISR-AERONET Coincident AOT Difference Plots

Continental Sites; 2001-2002; Stratified by Season

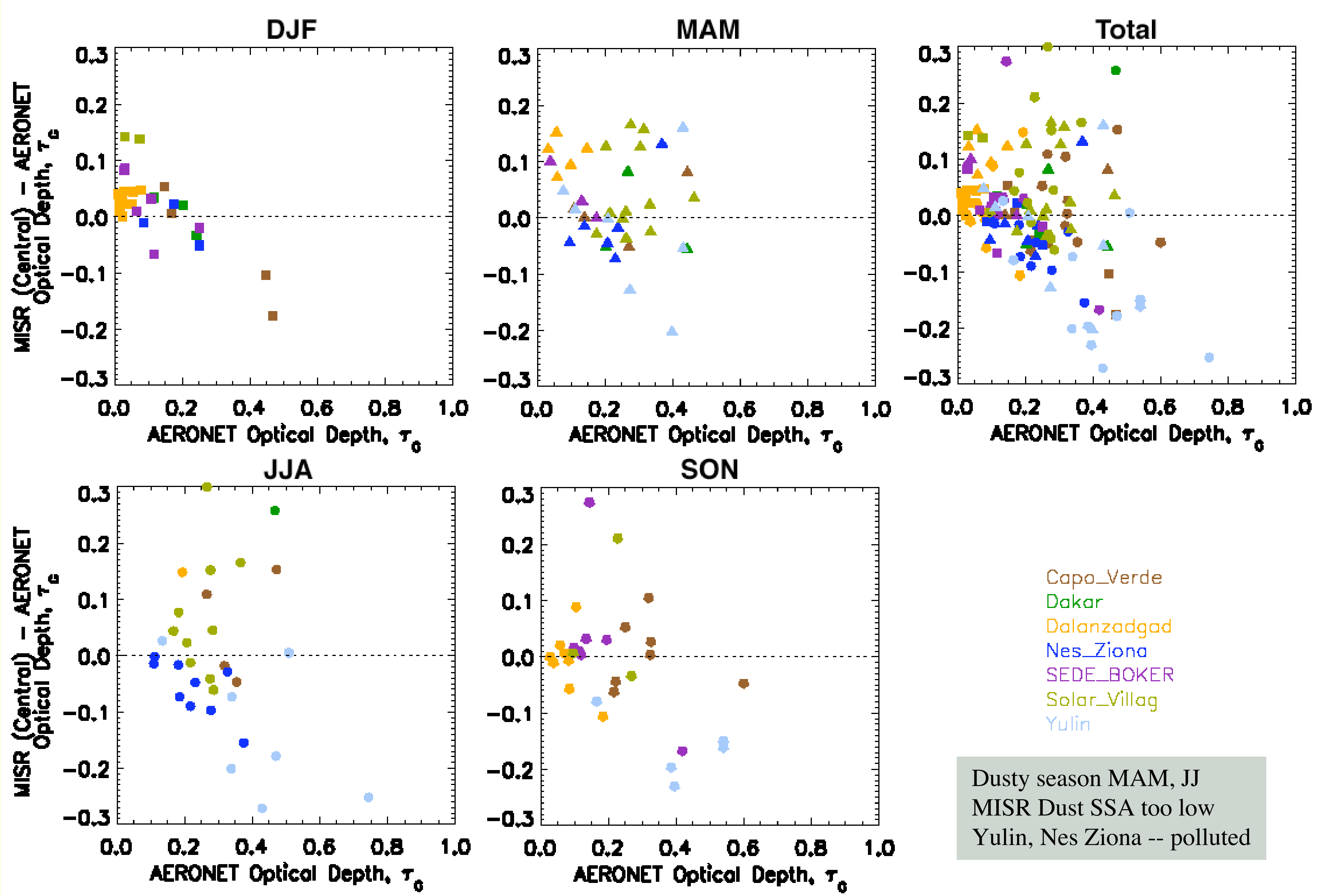


Rogers & Sevilleta -- Dust-like
Kanpur & Shirahama -- MISR SSA too low
Some outliers --> plumes

From: Kahn, et al., 2004, JGR (in press)

132 MISR-AERONET Coincident AOT Difference Plots

Dusty Sites; 2001-2002; Stratified by Season



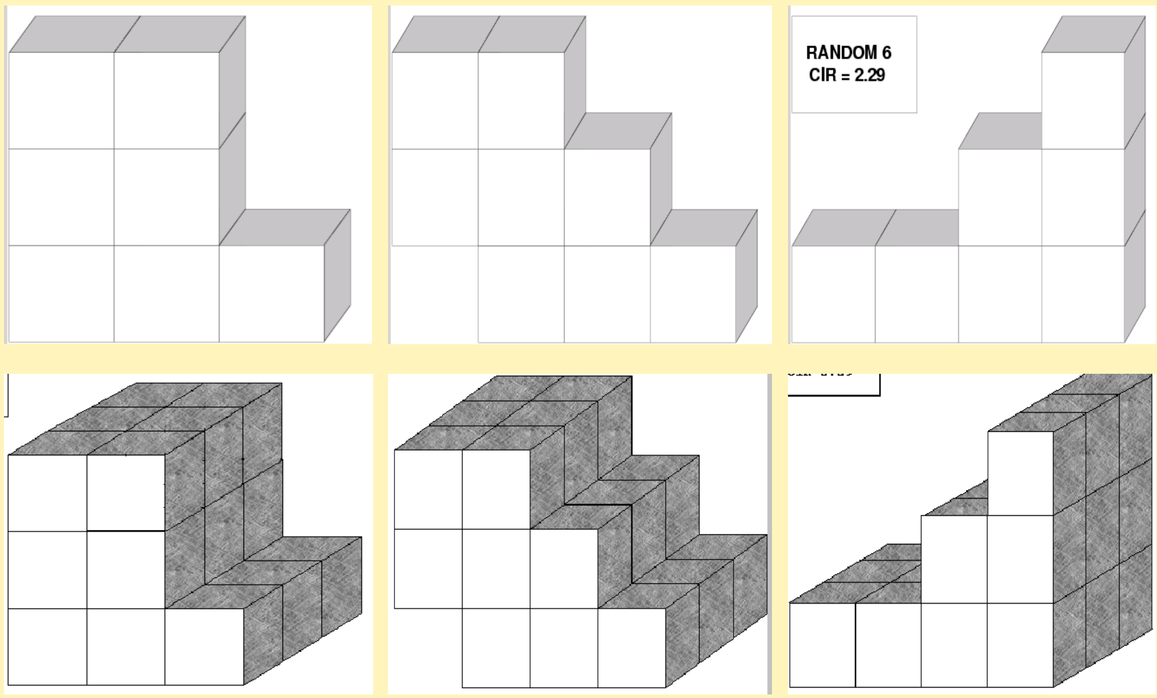
Dusty season MAM, JJ
MISR Dust SSA too low
Yulin, Nes Ziona -- polluted

From: Kahn, et al., 2004, JGR (in press)

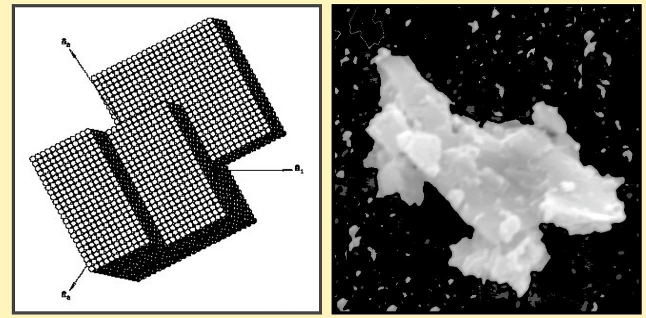
Representative shapes

Irregular plates and grains:

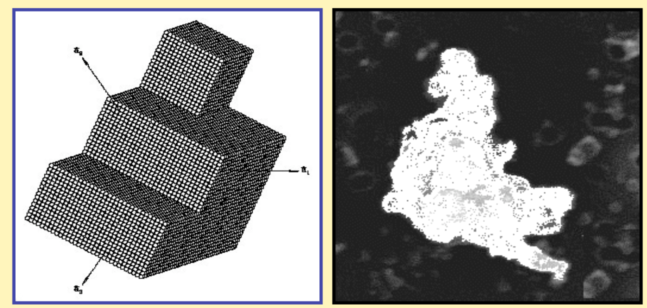
Random4, CIR=1.64 | Random5, CIR=1.93 | Random6, CIR=2.29



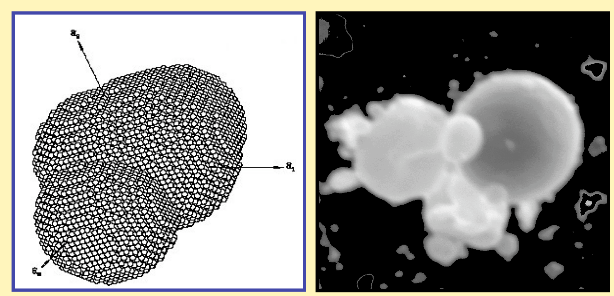
Random1



Random2



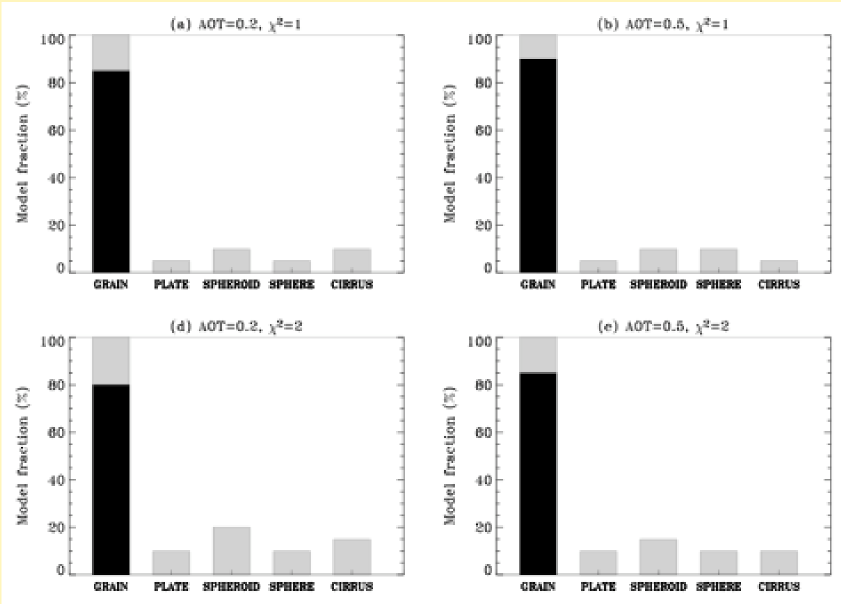
Random3

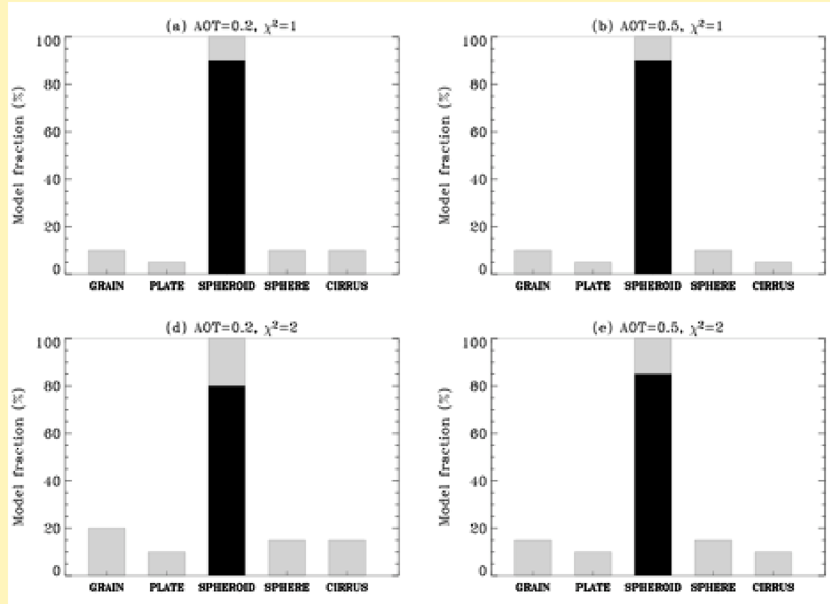


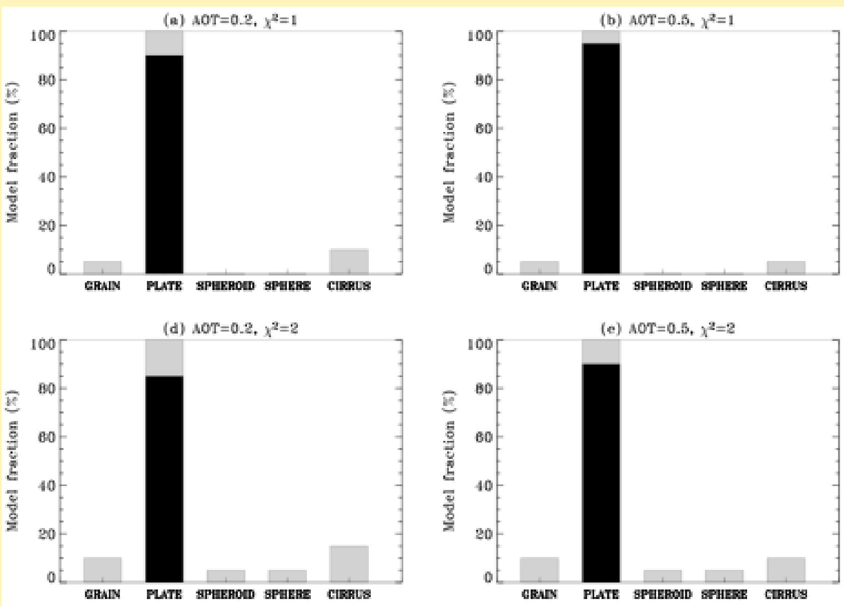
Representative shapes were constructed to match measured values of particle aspect ratio and circularity.

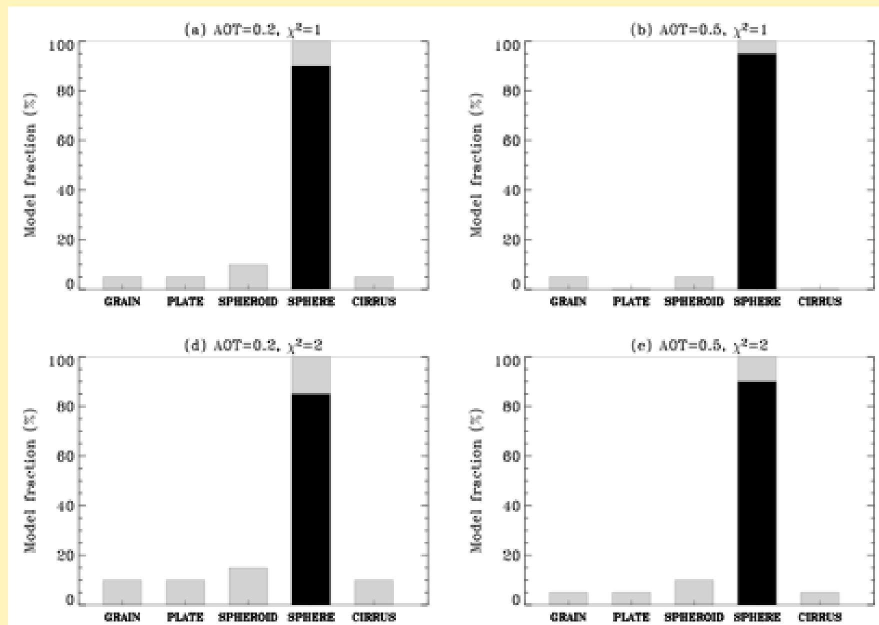
(Kalashnikova et al., 2002, 2004)

SHAPE SENSITIVITY FOR MINERAL DUST





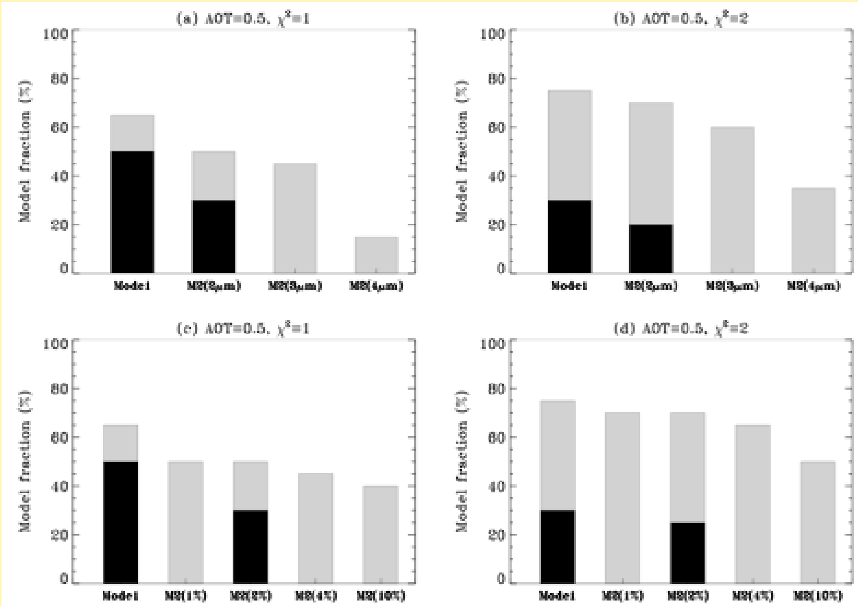




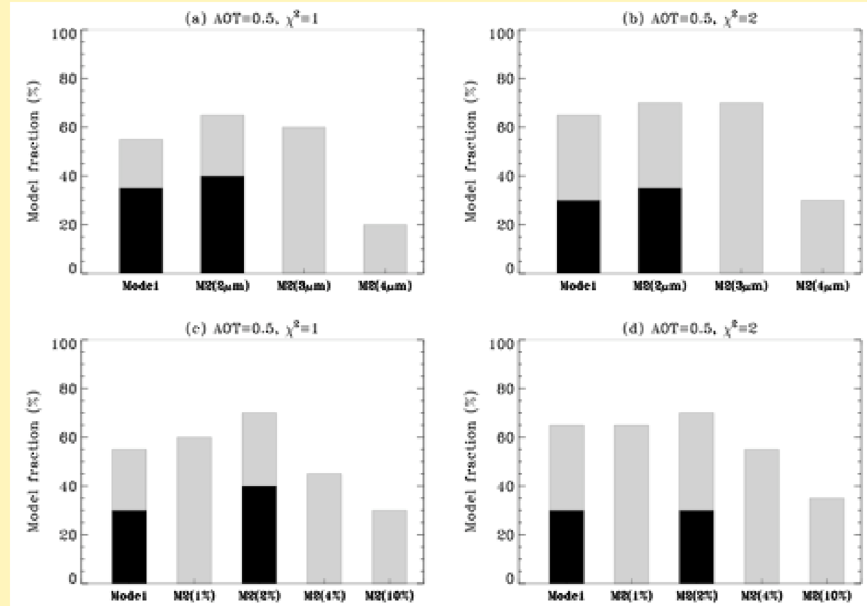
Fraction mid-vis AOT of successful models is gray

From: Kalashnikova et al., 2004, submitted

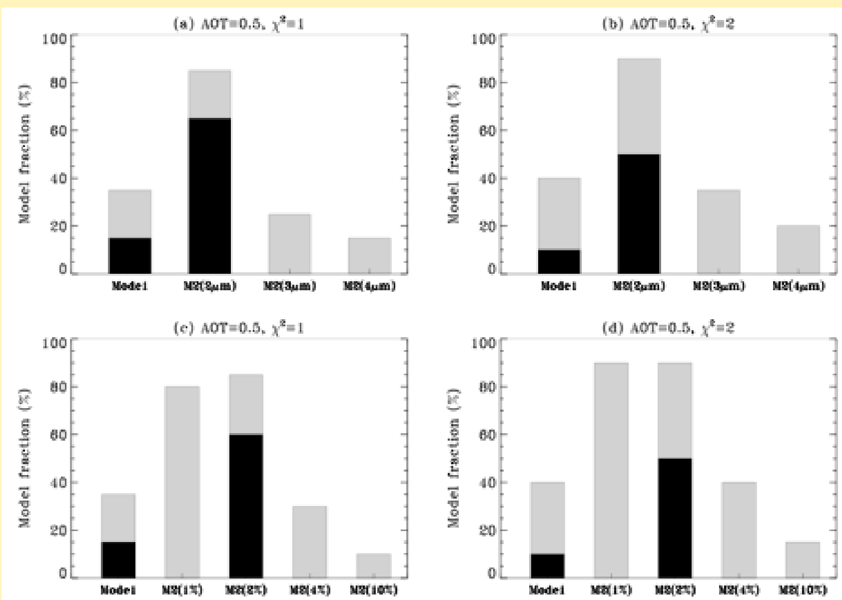
Size & Composition Sensitivity for Mineral Dust



Atmosphere mid-vis AOT = 60% Mode 1, 40% Mode 2



Atmosphere mid-vis AOT = 40% Mode 1, 60% Mode 2



Atmosphere mid-vis AOT = 20% Mode 1, 80% Mode 2

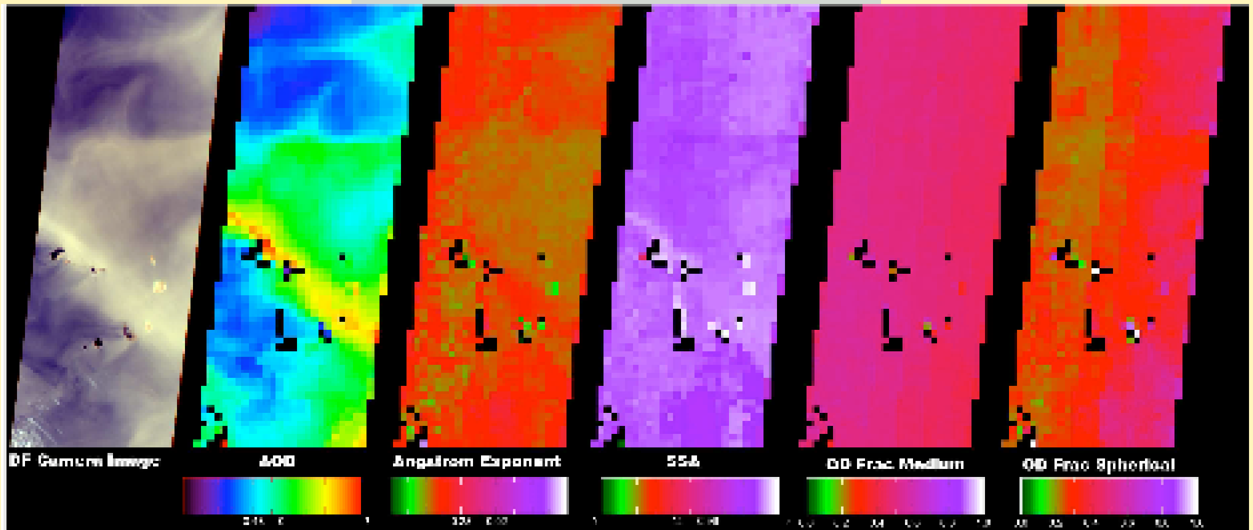
Mode 1 => r_0 = 0.5 μm, σ =1.6
Mode 2 => r_0 = 2, 3, or 4 μm, σ =2.0
% in model definitions are percent Hematitie

Fraction mid-vis AOT of successful models is gray

From: Kalashnikova et al., 2004, submitted

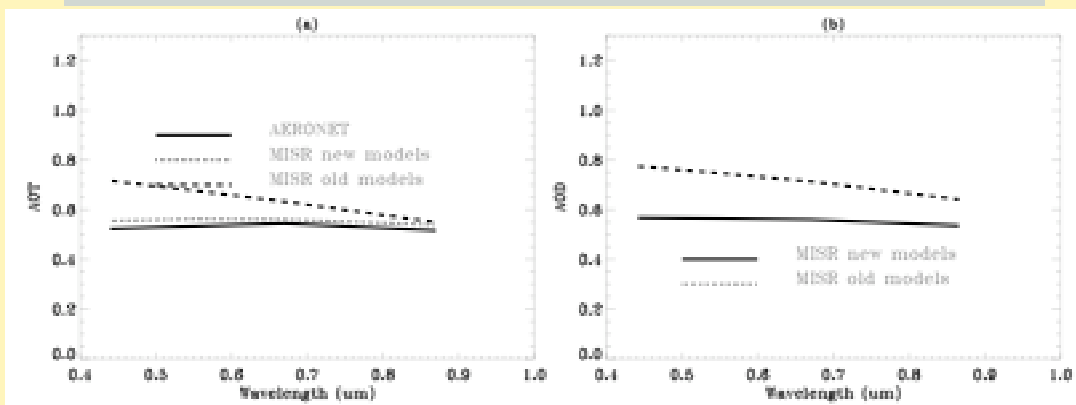
Cape Verde Islands, February 06, 2004
Orbit 22006

MISR Aerosol Products



0.14 0.87 -0.20 1.0 0.90 1.0

MISR-AERONET Spectral AOT Comparison



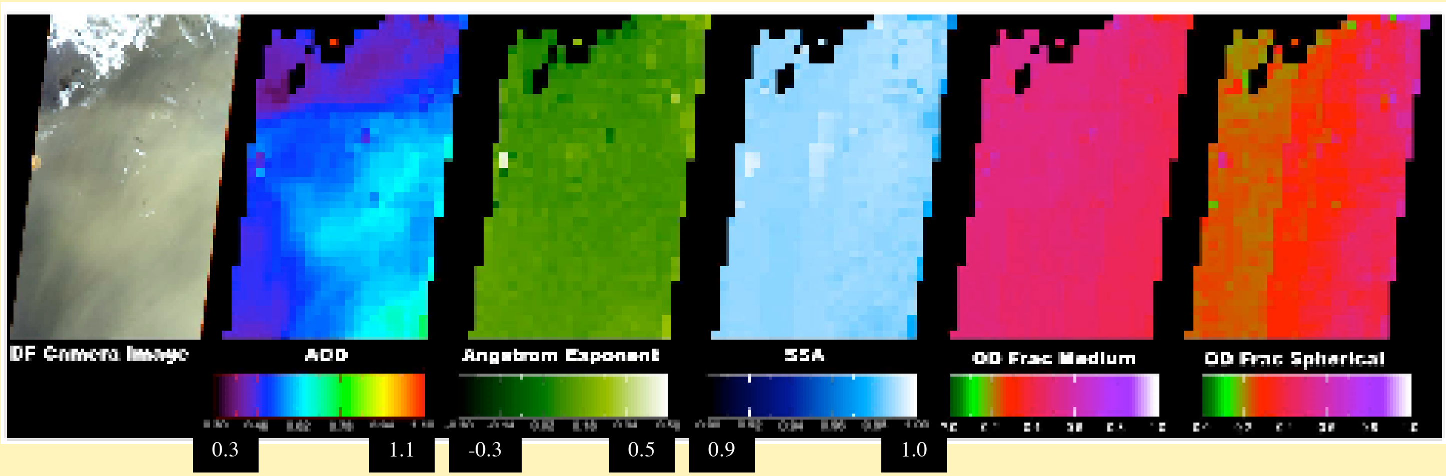
Dust Directly over ARNT site | **New vs. Old MISR Dust Models**

From: Kalashnikova et al., SPIE, 2004

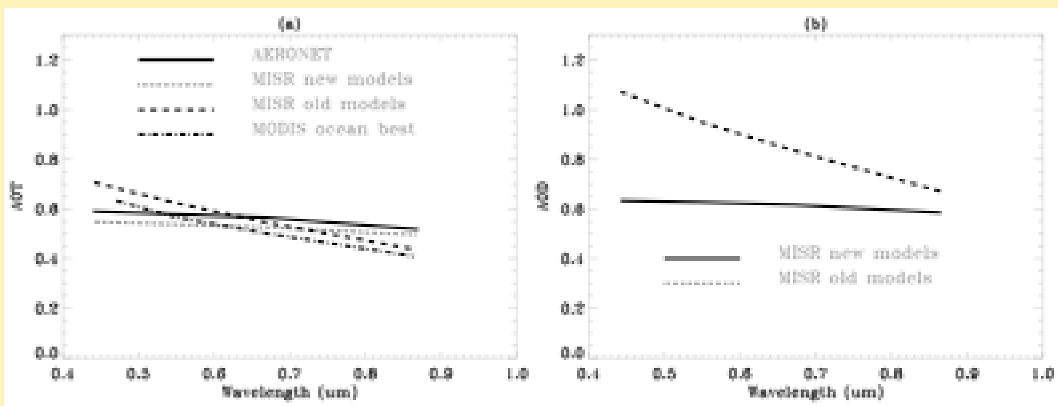
Cape Verde Islands, February 08, 2004

Orbit 22035

MISR Aerosol Products



MISR-AERONET Spectral AOT Comparison

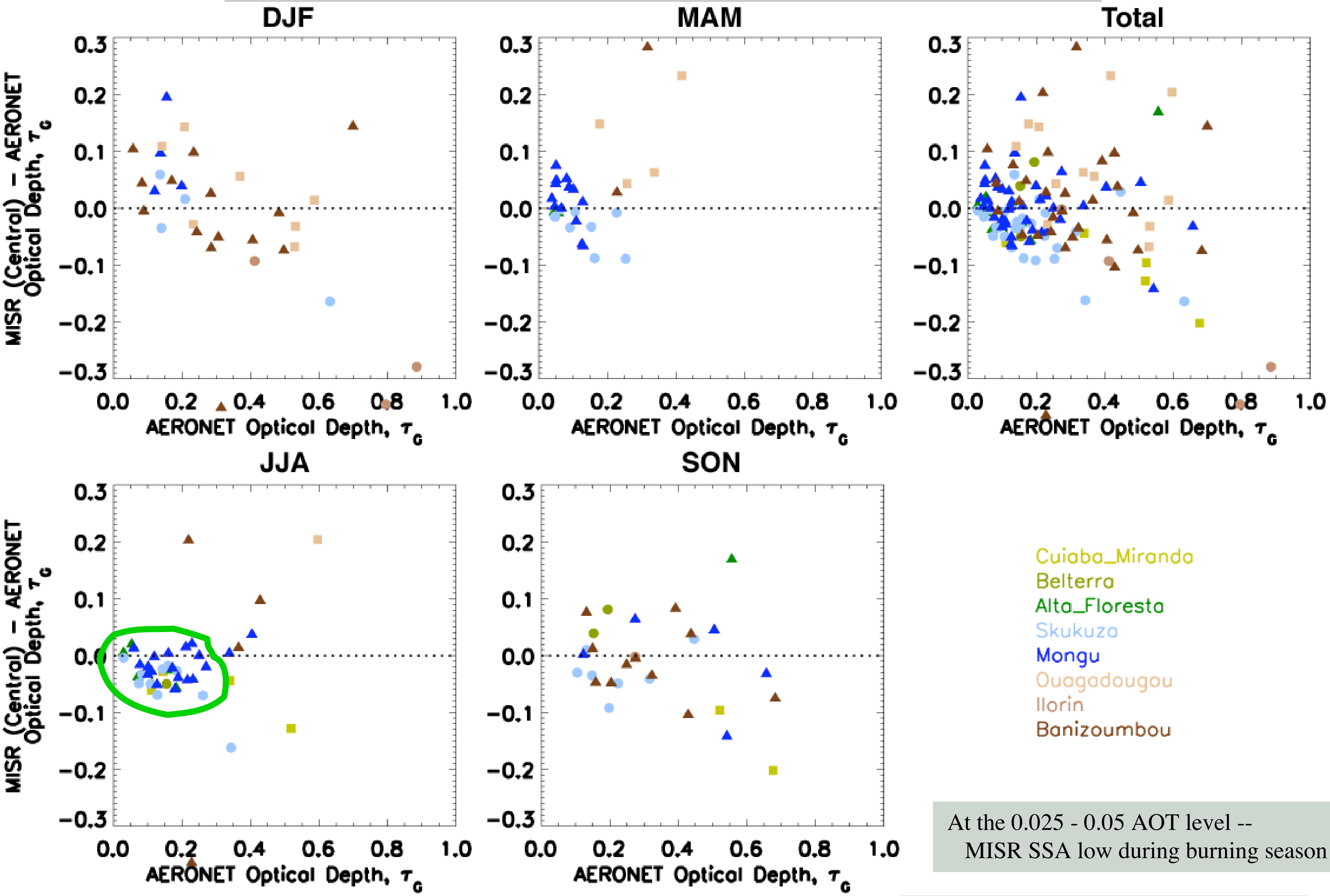


MISR-MODIS-ARNT **New vs. Old MISR Dust Models**

From: Kalashnikova et al., SPIE, 2004

135 MISR-AERONET Coincident AOT Difference Plots

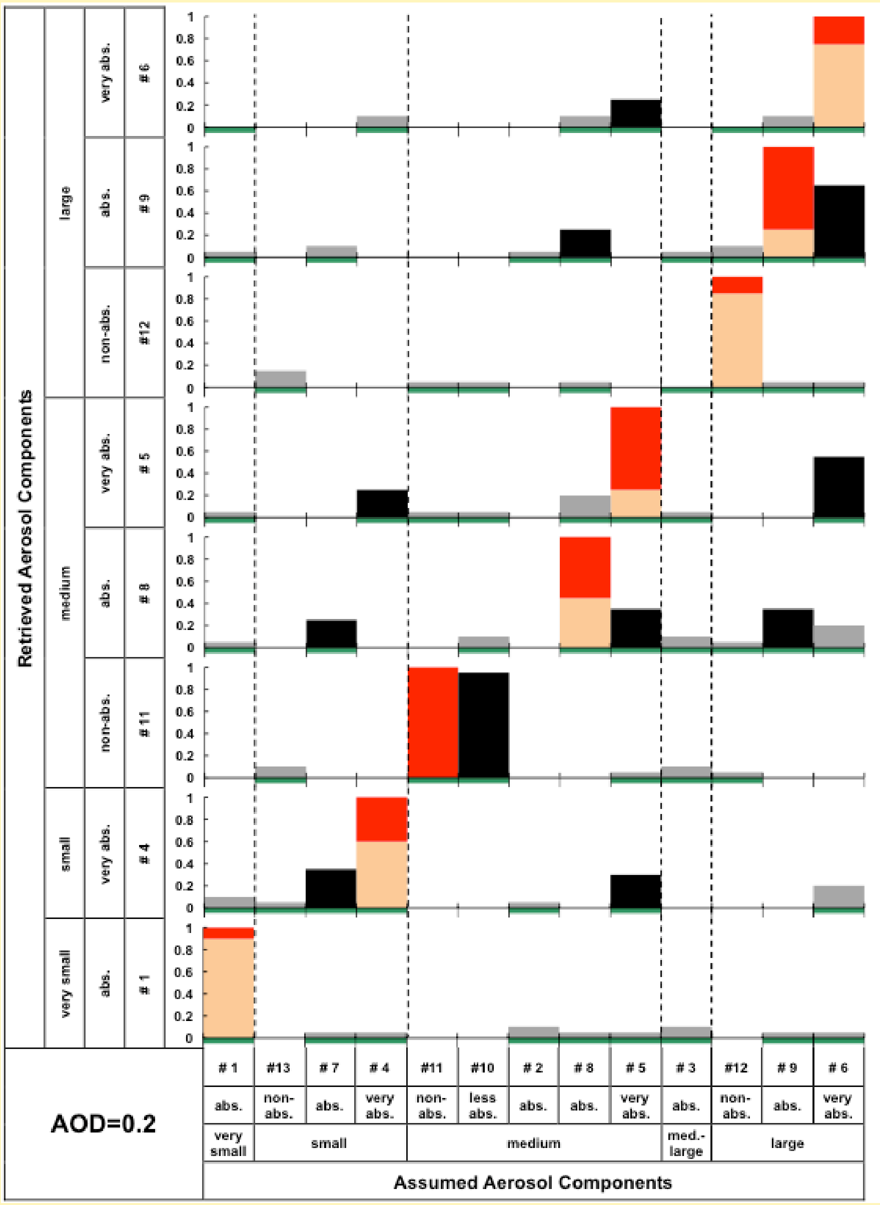
Biomass Burning Sites; 2001-2002; Stratified by Season

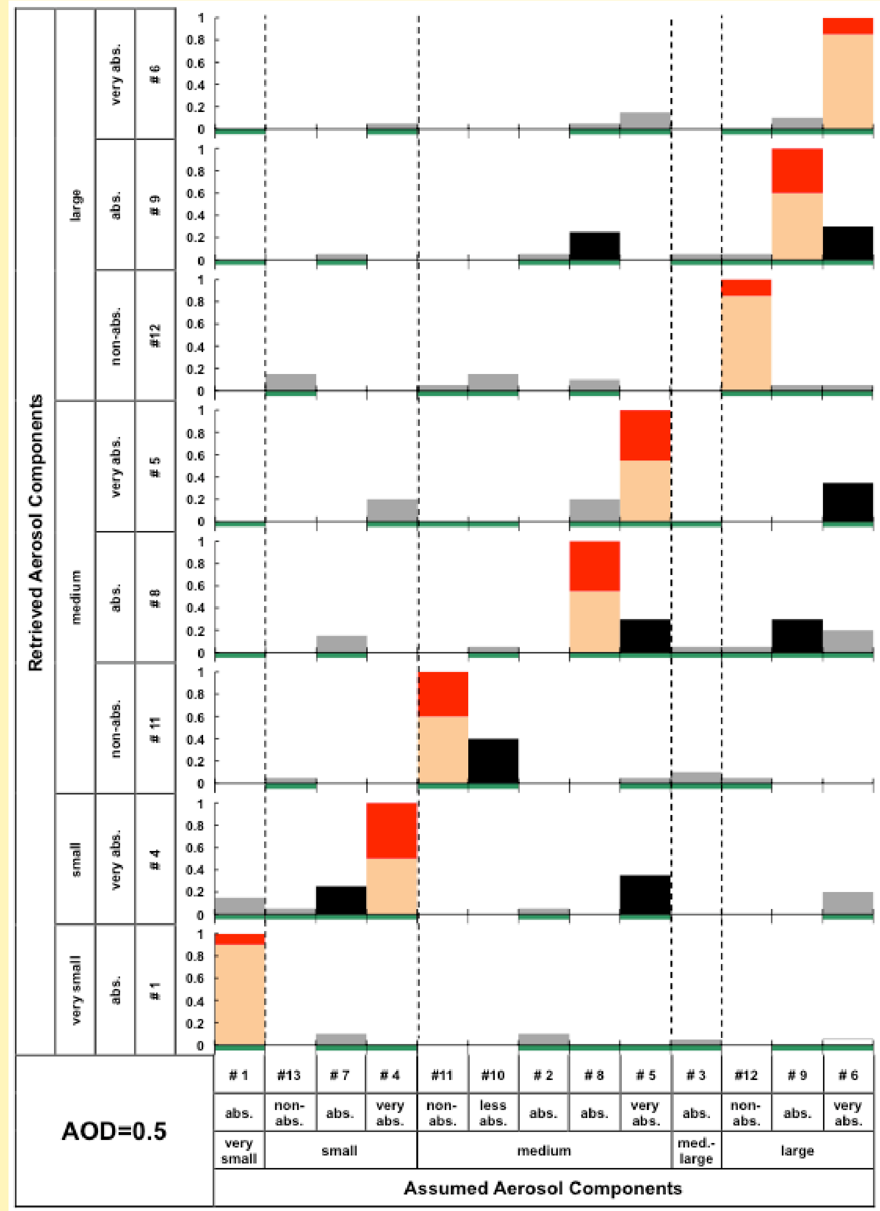


At the 0.025 - 0.05 AOT level --
MISR SSA low during burning season

From: Kahn, et al., 2004, JGR (in press)

SIZE AND SSA SENSITIVITY FOR BIOMASS BURNING PARTICLES



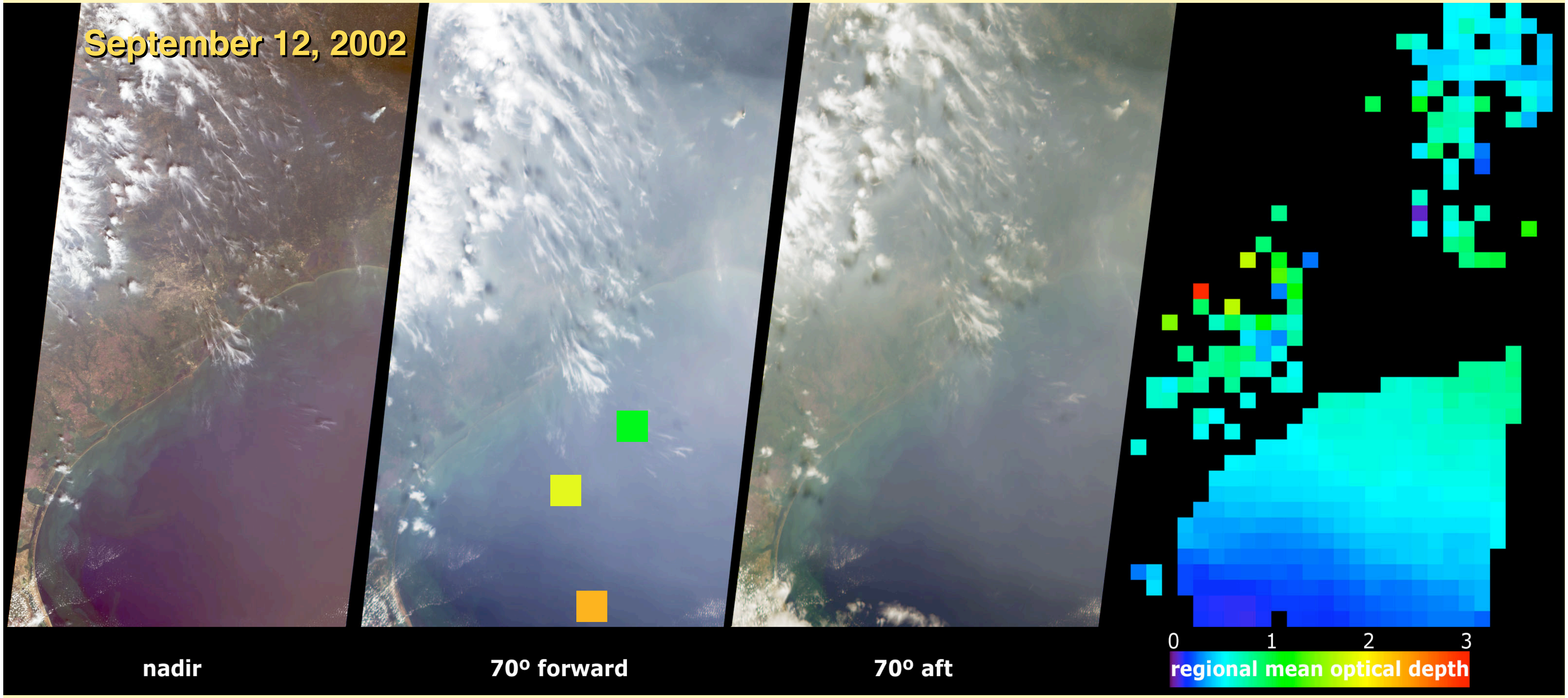


Fraction mid-vis AOT of successful models is red, black, or gray

From: Chen et al., to be submitted

Pollution Particle Amount, Size, and Single Scattering Properties

Galveston Bay near Houston, TX, September 12, 2002



MISR Research retrieval: mixtures of small & medium, spherical, low-absorbing particles

558 nm AOT	Component 1	Component 2	Component 3
0.60	60% spherical $r_{eff} = 0.12\ \mu m$	35% spherical $r_{eff} = 0.26\ \mu m$	5% cirrus
0.45	85% spherical $r_{eff} = 0.12\ \mu m$	15% spherical $r_{eff} = 0.57\ \mu m$	--
0.25	85% spherical $r_{eff} = 0.12\ \mu m$	15% spherical $r_{eff} = 0.57\ \mu m$	--

-- in agreement with field results measured upwind [Engle-Cox, Haymet, et al.]

DUST & **BIOMASS BURNING** **SENSITIVITY STUDY SUMMARY**

- Simulated **good but realistic viewing conditions** over dark water –

  [cloud-free, wind speed 2.5 m/s; chisq ~ 1.5; AOT >~ 0.2]

- For components contributing **>20%** to the total mid-vis AOT,

  MISR Can Distinguish:

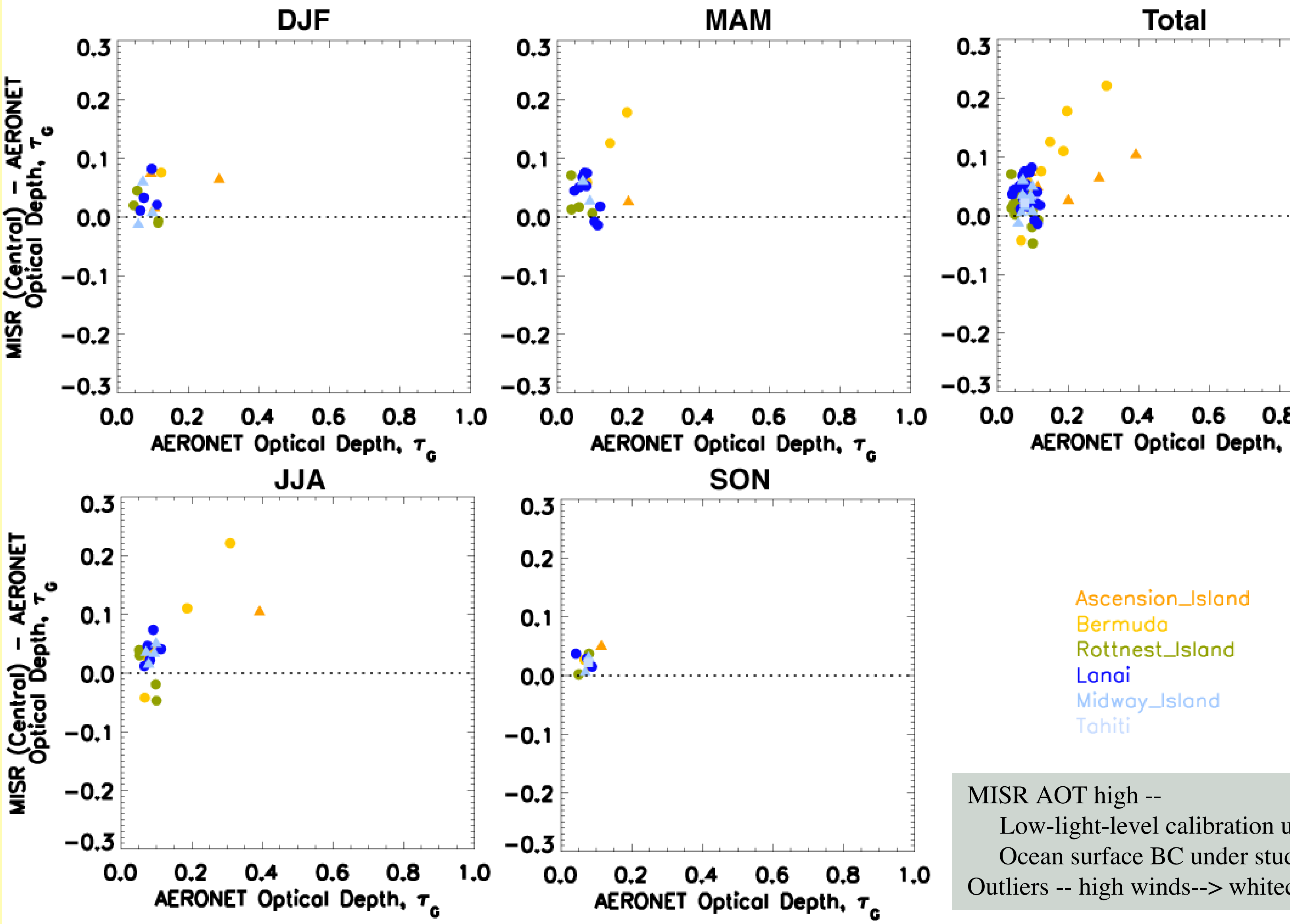
- **Shape**: **Plates** from **grains** from **spheroids** from **spheres**
- **Size**: **Three-to-Five** Size Bins between D_c ~ 0.2 and 2.5 μm
- **SSA**: **Weakly from strongly** absorbing dust (~2% vs. 10% hematite)

  Also for spheres, can separate **SSA ~ 0.75** from **0.85** from **0.95**

- **Size discrimination** for small-medium spheres- poorer **for SSA <~0.85**

65 MISR-AERONET Coincident AOT Difference Plots

Maritime Sites; 2001-2002; Stratified by Season



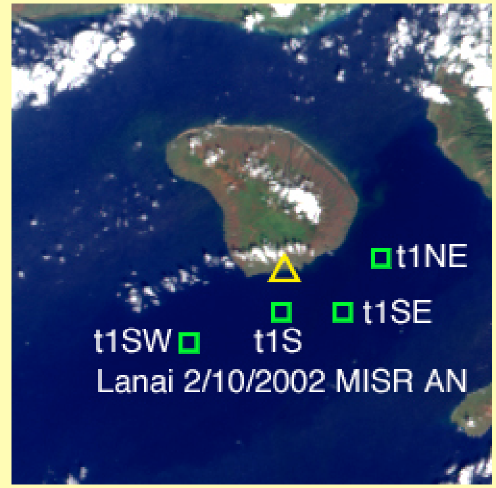
MISR AOT high --
Low-light-level calibration under study
Ocean surface BC under study
Outliers -- high winds--> whitecaps

From: Kahn, et al., 2004, JGR (in press)

Island events

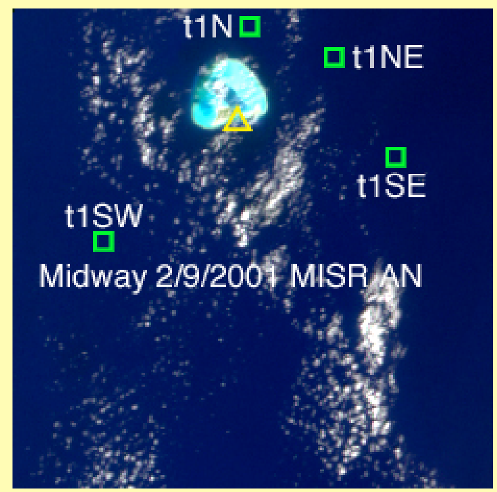
Selection criteria:

- Isolated from major land (Case 1 waters)
- Mostly cloud-free
- High-quality AERONET retrieval
- AOT < 0.3
- AOT variability low
- Near-surface wind-speed low
- Aerosol air mass likely to be Clean Maritime



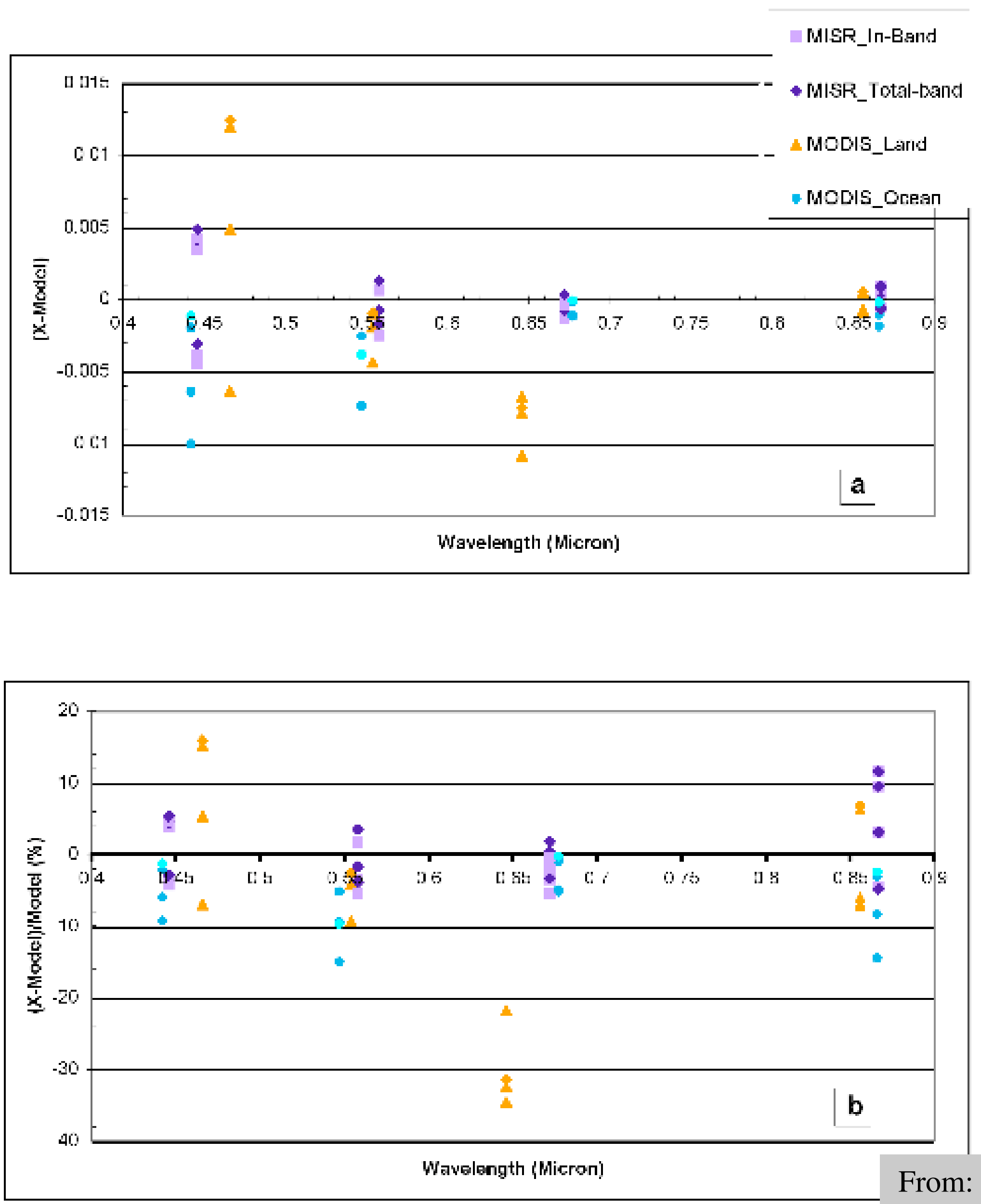
Data collected for each event:

- Wind speed (local Met. Station, scatterometer)
- Wind speed variability (local Met. Station, scatterometer)
- Surface pressure (local Met. Station)
- Column ozone amount (TOMS)
- Airmass history (NOAA HYSPLIT)
- AOT (AERONET)
- AOT variation (AERONET time series)
- Aerosol refractive indices (AERONET)
- Aerosol size distribution (AERONET)



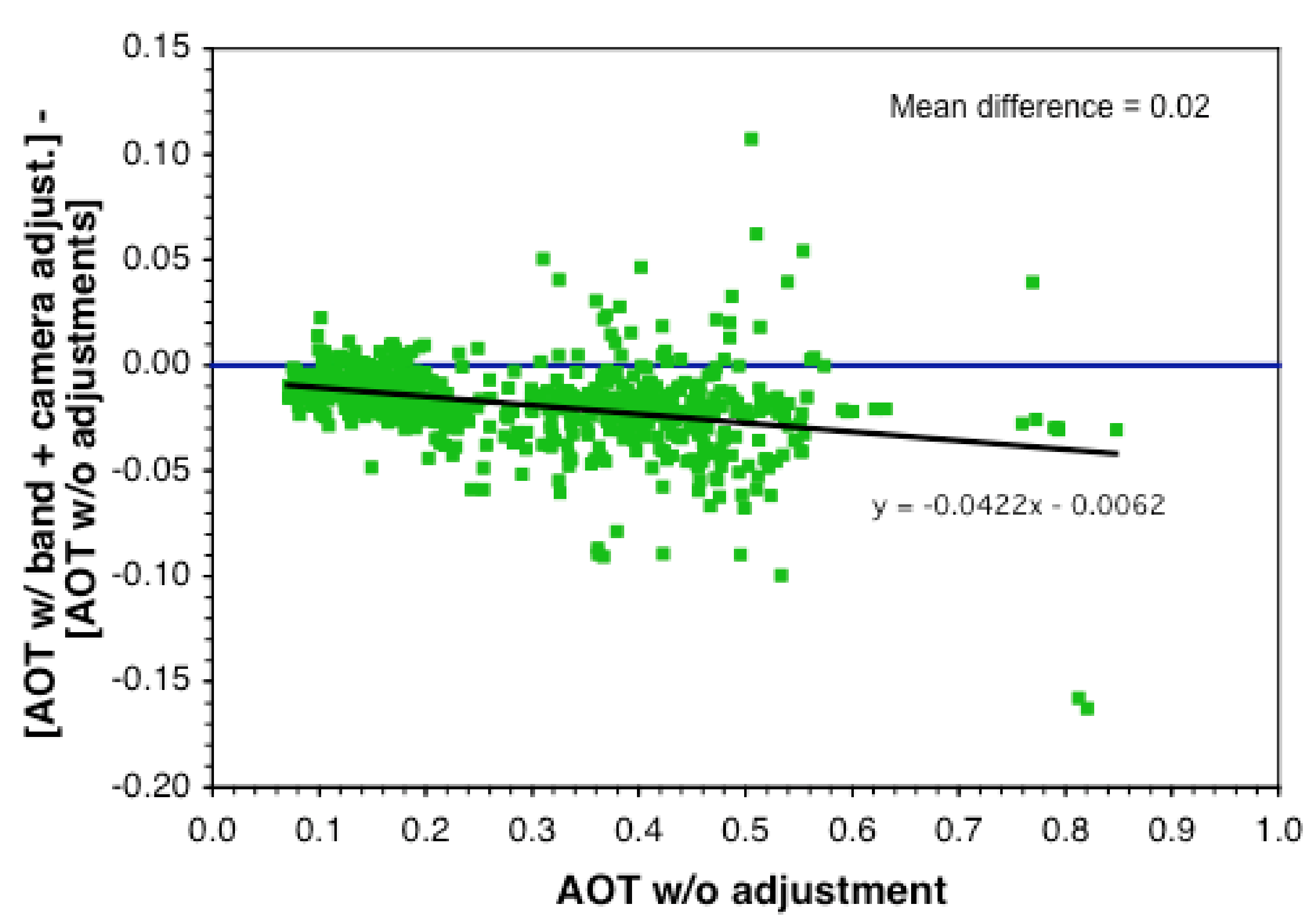
Use Mie code to calculate SSA, Q_{ext}, $P(\theta)$

MISR Low-Light-Level Nadir Reflectance Inter-Comparison
Clean Island Sites;MODIS-Land, MODIS-Ocean, AERONET+Model



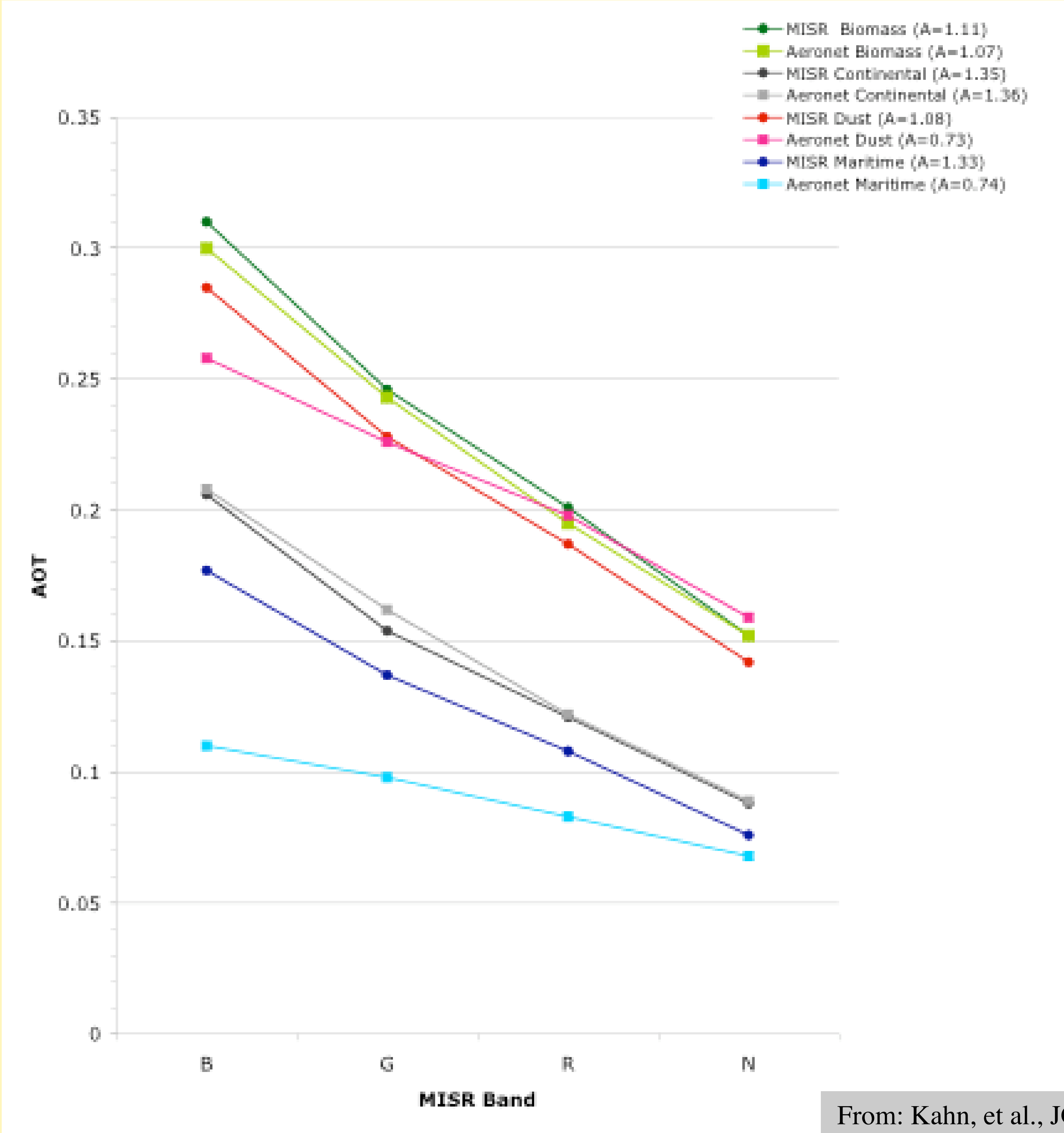
From: Kahn, et al., JAS, 2004 (in press)

MISR-Retrieved AOT With & Without Band + Camera Calibration Adjustments



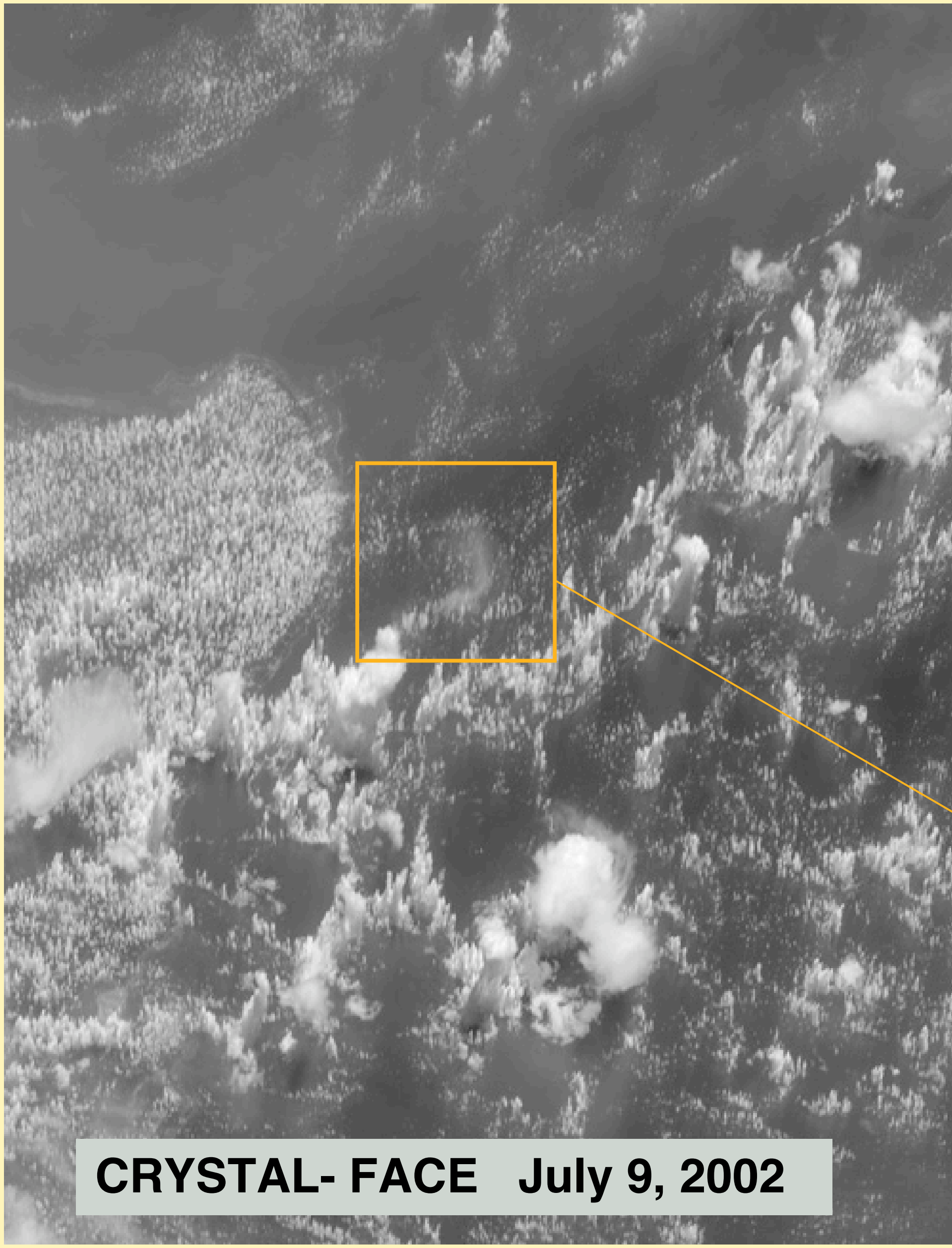
From: Kahn, et al.,JAS, 2004 (in press)

MISR and AERONET Spectral AOT by Expected Aerosol Type



From: Kahn, et al., JGR, 2004 (in press)

Multi-Modal Distributions and Particle Sphericity



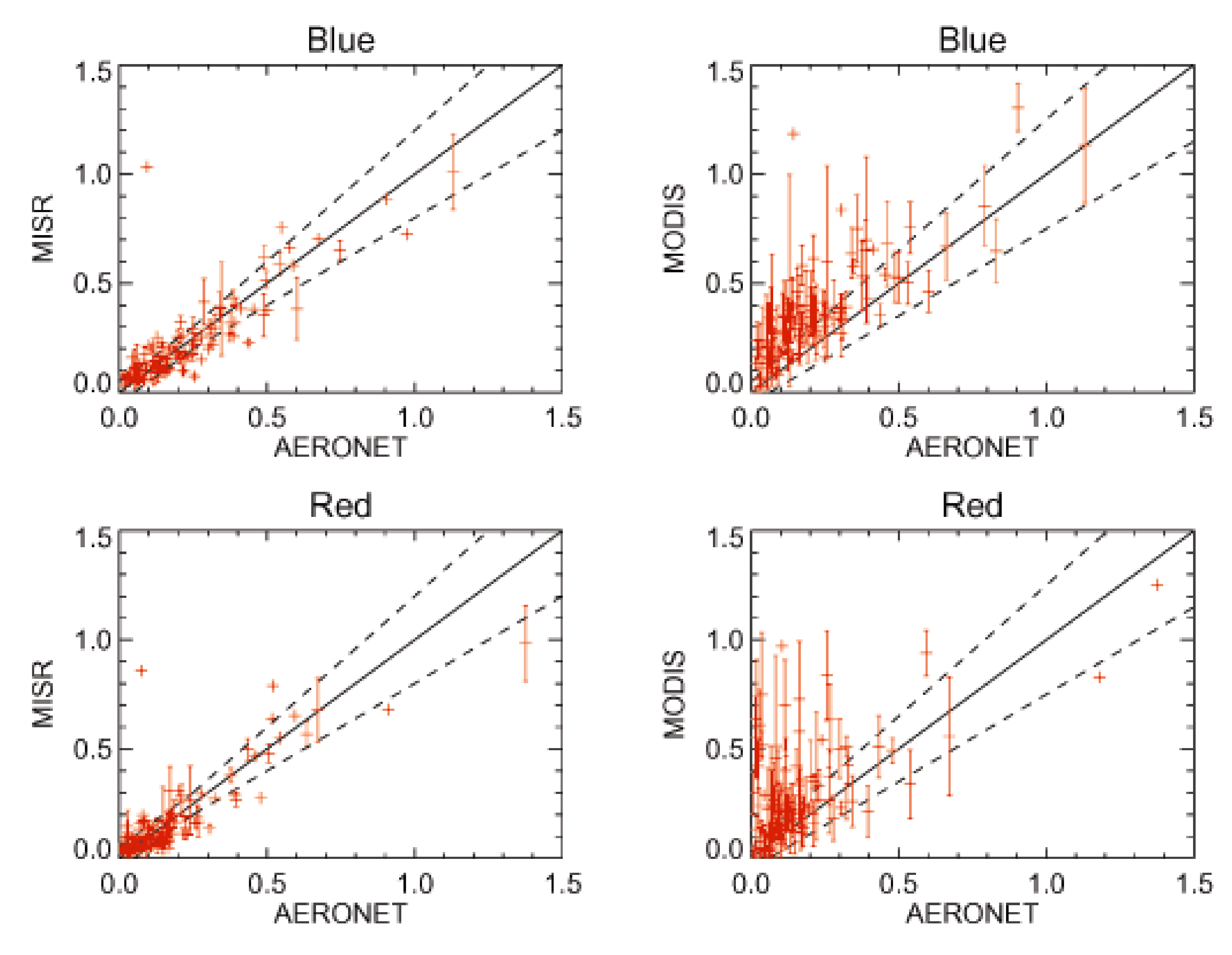
MISR Research retrieval Identified Three aerosol components:

- **Thin Cirrus**
  - confirmed by MAS instrument
- **Background Maritime**
  - medium, spherical, non-absorbing
- **Sahara Dust**
  - predicted by NAPS model
  - measured by PALMS

Optical depth (558 nm) = 0.20
35% cirrus
50% small spherical non-absorbing
15% dust

Kahn et al., 2004, in preparation

127 MISR- AERONET & 113 MODIS-AERONET Coincident AOT Comparisons
Over Land; March, June, and September 2002



From: Abdou, et al., 2004, JGR (in press)

Near-term Upgrades to the MISR Aerosol Retrieval Standard Algorithm (Version 16 +)

- **More realistic Mineral Dust optical models**
- **Additional, Darker Spherical Pollution and Biomass Burning analogs**
- **A Richer Selection of Bi-modal Mixtures**

+ Refined MISR Radiometric Calibration, affecting MISR low-light-level Aerosol Retrievals

Upgrades should reduce remaining discrepancies with sun photometers by at least half.

MISR data available from the NASA Langley Atmospheric Sciences Data Center

http://eosweb.larc.nasa.gov/

RECENT MISR AEROSOL VALIDATION TEAM PUBLICATIONS

Kahn, R., B. Gaitley, J. Martonchik, D. Diner, K. Crean, and B. Holben, 2004, MISR global aerosol optical depth validation based on two years of coincident AERONET observations, *J. Geophys. Res.,* doi:jd004706R, in press.

Abdou, W.A., D.J. Diner, J.V. Martonchik, C.J. Bruegge, R.A. Kahn, B.J. Gaitley, K.A. Crean, L.A. Remer, and B. Holben, 2004, Comparison of coincident MISR and MODIS aerosol optical depths over land and ocean scenes containing AERONET sites, *J. Gelphys. Res.*, in press.

Kalashnikova, O.V., R.A. Kahn, and W-H. Li, 2004, The ability of multi-angle remote sensing observations to identify and distinguish mineral dust types: Part 2. Sensitivity data analysis, *J. Geophys. Res.*, submitted.

DiGirolamo, L., T.C. Bond. D. Bramer. D.J. Diner, F. Fettinger, R.A. Kahn, J.V. Martonchik, M.V. Ramana, V. Ramanathan, and P.J. Rasch, 2004, Analysis of Multi-angle Imaging SpectroRadiometer (MISR) aerosol optical depths over greater India during winter 2001-2004, *Geophys. Res. Let.,* in press.

Diner, D.J., J.V. Martonchik, R.A. Kahn, , B. Pinty, N. Gobron, D.L. Nelson, and B.N. Holben, 2004, Using angular and spectral shape similarity constraints to improve MISR aerosol and surface retrievals over land, *Remt. Sens. Environ.*, in press.

Bruegge, Carol J., Wedad A. Abdou, David J. Diner, Barbara J. Gaitley, Mark C. Helmlinger, Ralph A. Kahn, and John V. Martonchik, 2004, Validation of the MISR radiometric scale for the ocean aerosol science communities. Proceedings of the The International Workshop on Radiometric and Geometric Calibration, December 2-5, 2003, Gulfport, Mississippi. A.A. Balkema Publishers, Rotterdam, Netherlands.

Kahn, R., W-H. Li, J. Martonchik, C. Bruegge, D. Diner, B. Gaitley, W.Abdou, O. Dubovik, B. Holben, S. Smirnov, Z. Jin, and D. Clark, 2005. MISR low-light-level calibration, and implications for aerosol retrieval over dark water, *J. Atmosph, Sci.*, in press.

Redemann, J., B. Schmid, J.A. Eilers, R. Kahn, R.C. Levy, P.B. Russell, J.M. Livingston, P.V. Hobbs, W.L. Smith, Jr., and B.N. Holben, 2004, Suborbital measurements of spectral aerosol optical depth and its variability at sub-satellite-grid scales in support of CLAMS, 2001, *J. Atmosph. Sci.*, in press.

Kalashnikova, O.V., R. Kahn, I.N. Sokolik, and W-H. Li, 2004, The ability of multi-angle remote sensing observations to identify and distinguish mineral dust types: Part 1. Optical models and retrievals of optically thick plumes, *J. Geophys. Res.*, in press.

Martonchik, J.V., D.J. Diner, R.A. Kahn, B.J. Gaitley, and B.N. Holben, 2004, Comparison of MISR and AERONET aerosol optical depths over desert sites, *Geophys. Res. Let.,31*, doi:10.1029/2004GL019807.

Kahn, R., and 39 co-authors, 2004, Environmental snapshots from ACE-Asia. *J. Geophys. Res.* Doi:2003jd004339.

Kalashnikova, O.V., D.J. Diner, R.A. Kahn, and B. Gaitley, Dust aerosol retrieval results from MISR, 2004, *Proc. SPIE*, *Fourth Intern. Asia-Pacific Environ. Remt. Sens. Symp.* Nov. 8-11.

Key Question…

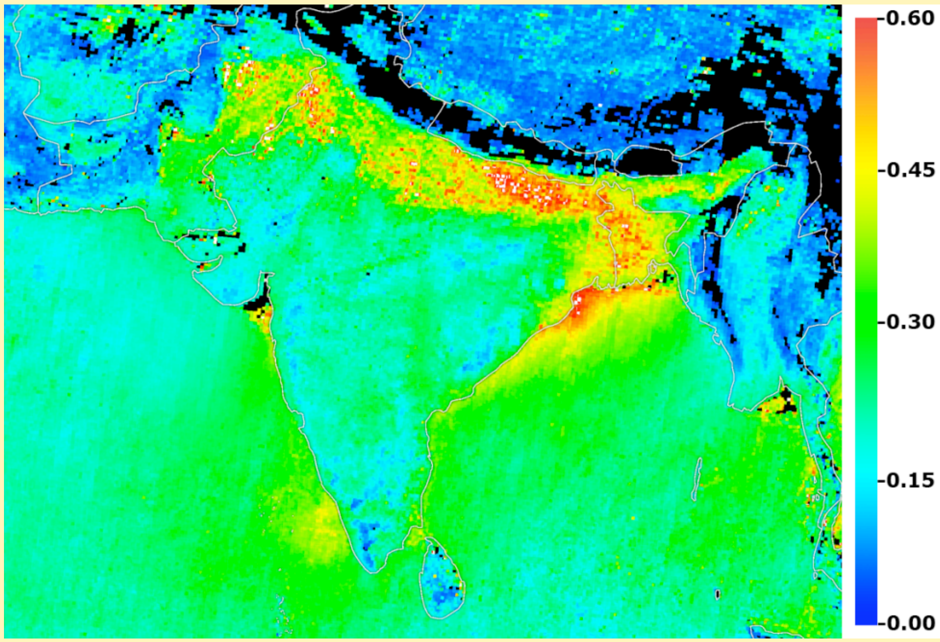
What must each component:

- **Satellites**
- **In Situ** & **Surface** Observations
- Transport **Models**

bring to the table, and how must these inputs be combined, to produce a sufficiently accurate and complete global aerosol/cloud picture to understand Aerosol Climate Impacts?

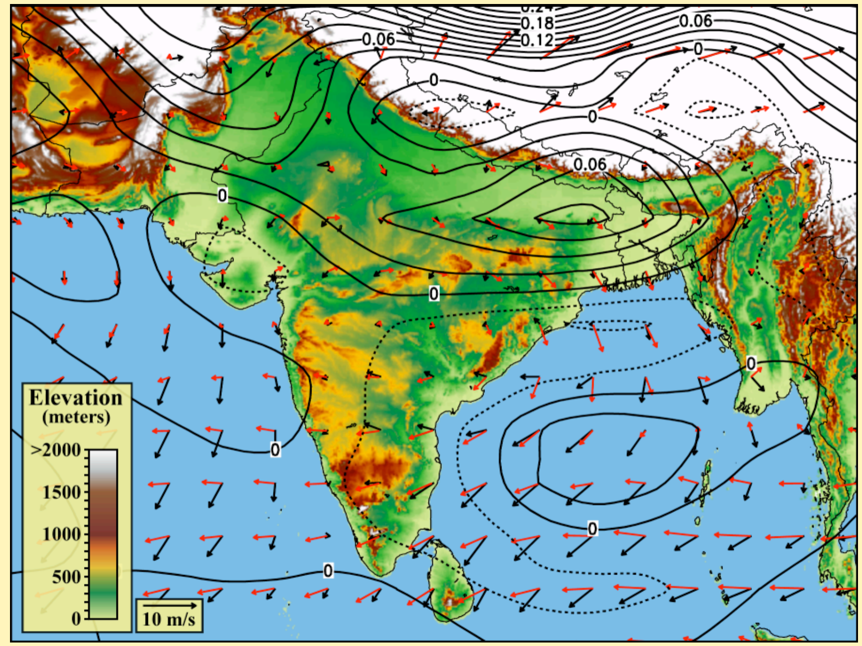
Ref. -- The "PARAGON" papers, BAMS, October 2004

Pollution Aerosol Concentrated in Ganges Valley near Kanpur, India (MISR)



MISR mid-visible AOD

[Winter, 2001-2004; white --> AOD >0.6]



NCEP Winds + Topography

[Black=surface; Red=850 mb; contours=vertical, solid=subsidence]

L. DiGirolamo et al., GRL, 2004, in press

MISR Early Post-Launch Component Aerosol Optical Models (Version 15)

Component Name	r_1 (µm)	r_2 (µm)	r_c (µm)	r_e (µm)	σ	SSA (446)	SSA (558)	SSA (672)	SSA (866)	AOT((446) /AOT(558)	AOT(672)/ AOT(558	AOT(867)/ AOT(558)	g (558)	Particle Size/Shape Category
sph_nonabsorb_0.06	0.001	0.4	0.03	0.06	1.65	1.00	1.00	1.00	1.00	1.95	0.55	0.23	0.352	Small Spherical
sph_nonabsorb_0.12	0.001	0.75	0.06	0.12	1.7	1.00	1.00	1.00	1.00	1.54	0.66	0.35	0.609	Small Spherical
sph_nonabsorb_0.26	0.01	1.5	0.12	0.26	1.75	1.00	1.00	1.00	1.00	1.18	0.82	0.58	0.717	Medium Spherical
sph_nonabsorb_0.57	0.01	4	0.24	0.57	1.8	1.00	1.00	1.00	1.00	0.98	0.99	0.91	0.722	Large Spherical
sph_nonabsorb_1.28	0.01	8	0.5	1.28	1.85	1.00	1.00	1.00	1.00	0.96	1.04	1.10	0.728	Large Spherical
nonsph_absorb_1.18_lo	0.05	2	0.47	1.18	2.6	0.805	0.880	0.914	0.980	0.97	1.03	1.08	0.730	Medium Dust Low
nonsph_absorb_1.18_hi	0.05	2	0.47	1.18	2.6	0.805	0.880	0.914	0.980	0.97	1.03	1.08	0.730	Medium Dust High
nonsph_absorb_7.48	0.5	15	1.9	7.48	2.6	0.612	0.694	0.734	0.900	1.00	1.00	1.00	0.881	Coarse Dust
sph_absorb_0.04	0.001	0.5	0.012	0.04	2.0	0.250	0.209	0.172	0.123	1.37	0.77	0.54	0.337	Black Carbon

MISR Component Aerosol Optical Models (Version 16+)

Component Name	r_1 (μm)	r_2 (μm)	r_c (μm)	r_e (μm)	σ	SSA (446)	SSA (558)	SSA (672)	SSA (866)	AOT(446)/ AOT(558)	AOT(672)/ AOT(558)	AOT(867)/ AOT(558)	g (558)	Particle Size/Shape Category
sph_non-absorb_0.06	0.001	0.4	0.03	0.06	1.65	1.00	1.00	1.00	1.00	1.95	0.55	0.23	0.352	Very Small Spherical
sph_non-absorb_0.12	0.001	0.75	0.06	0.12	1.7	1.00	1.00	1.00	1.00	1.54	0.66	0.35	0.609	Small Spherical
sph_non-absorb_0.26	0.01	1.5	0.12	0.26	1.75	1.00	1.00	1.00	1.00	1.18	0.82	0.58	0.717	Medium Spherical
sph_non-absorb_2.80	0.1	50	1.0	2.80	1.90	1.00	1.00	1.00	1.00	0.99	1.02	1.06	0.776	Large Spherical
sph_absorb_ssa0.9_0.12	0.001	0.75	0.06	0.12	1.7	0.91	0.90	0.89	0.85	1.48	0.68	0.37	0.612	Small Spherical Absorbing
sph_absorb_ssa0.8_0.12	0.001	0.75	0.06	0.12	1.7	0.82	0.80	0.77	0.72	1.47	0.69	0.40	0.614	Small Spherical Very Absorbing
grains_mode1_h1	0.1	1	0.5	1.5	2.60	0.92	0.98	0.99	1.0	0.90	1.06	1.08	0.711	Medium non-spherical dust
spheroidal_mode2_h1	0.1	6	1.0	2.0	2.60	0.81	0.90	0.97	0.98	0.99	1.02	1.05	0.772	Large non-spherical dust