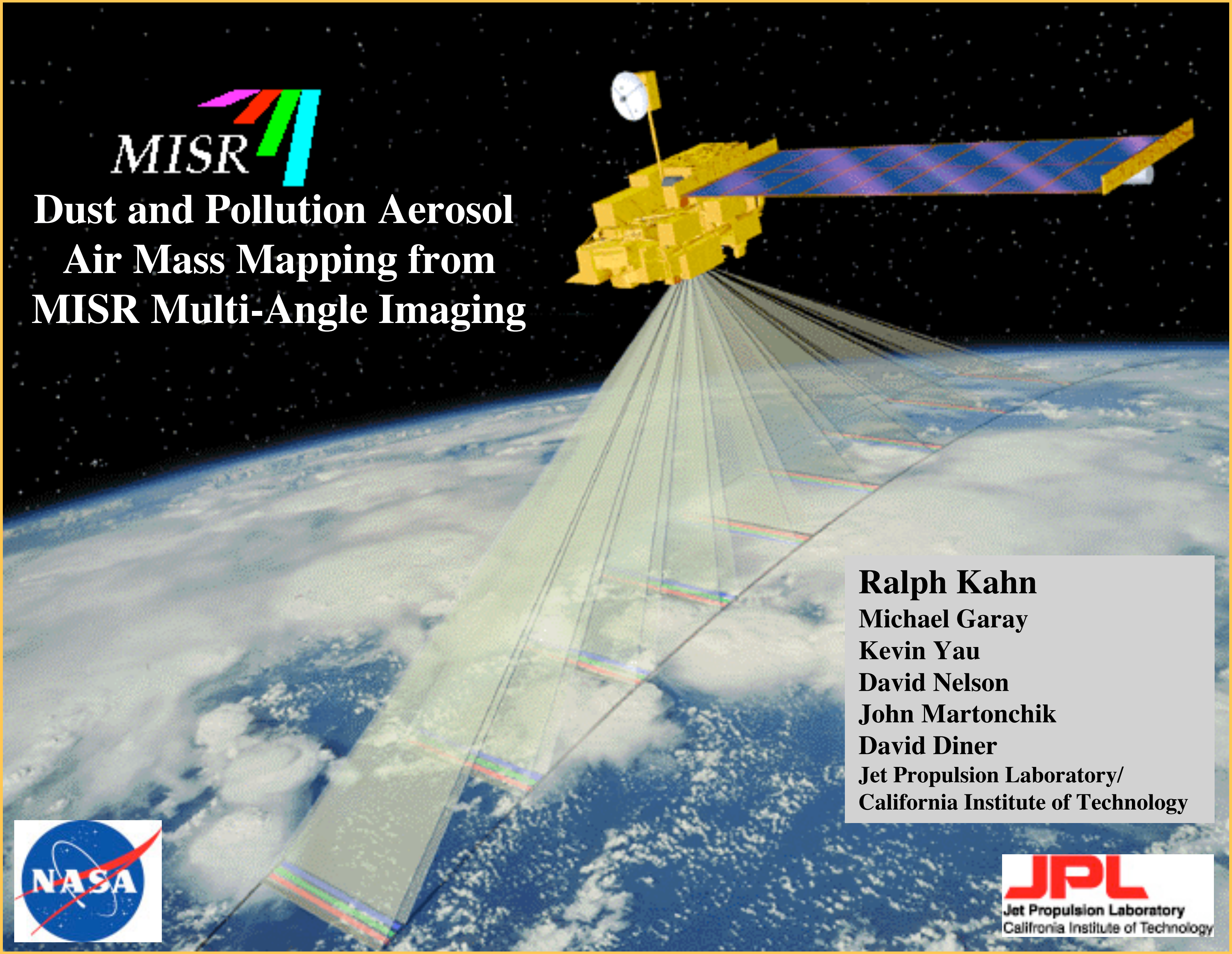
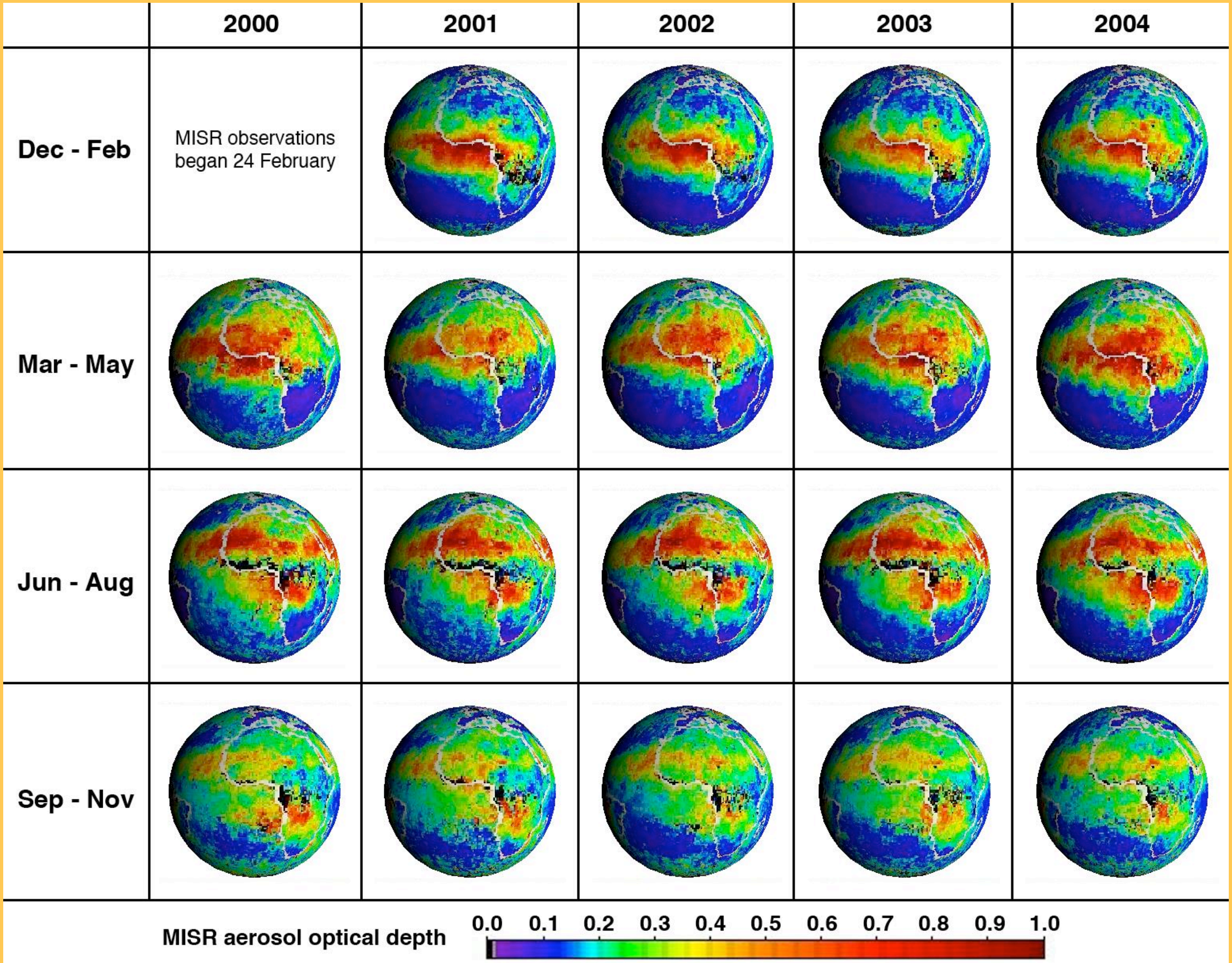
Dust and Pollution Aerosol Air Mass Mapping from MISR Multi-Angle Imaging



Ralph Kahn
Michael Garay
Kevin Yau
David Nelson
John Martonchik
David Diner
Jet Propulsion Laboratory/
California Institute of Technology

Five Years of MISR Global Aerosol Products



Mid-vis AOT

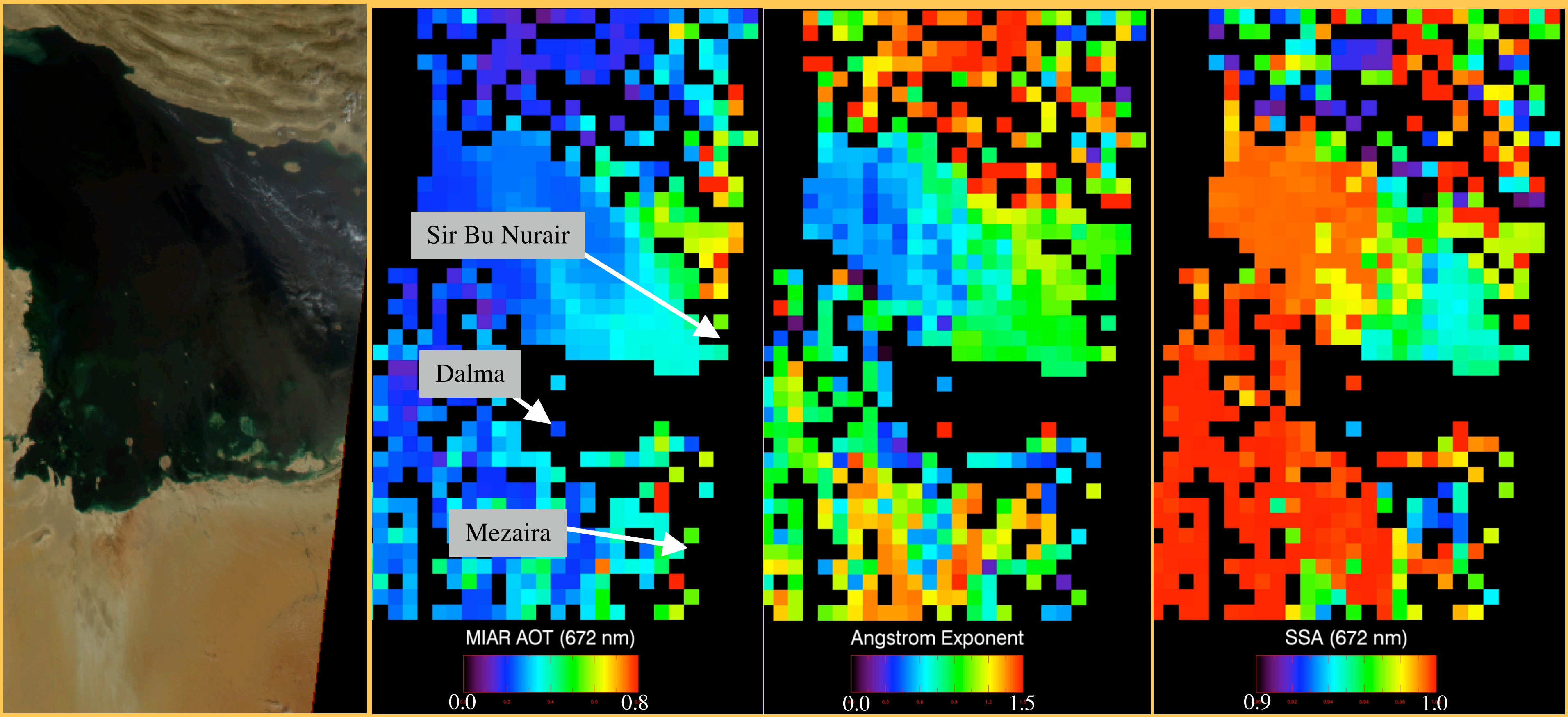
- Land & Water
- Bright Surfaces
- Globe ~ weekly
- ~ 10:30 AM

\+ particle size, shape

Distinct Regional Aerosol Air Mass Types Identified

Dust + Pollution -- UAE-2 Campaign MISR Data

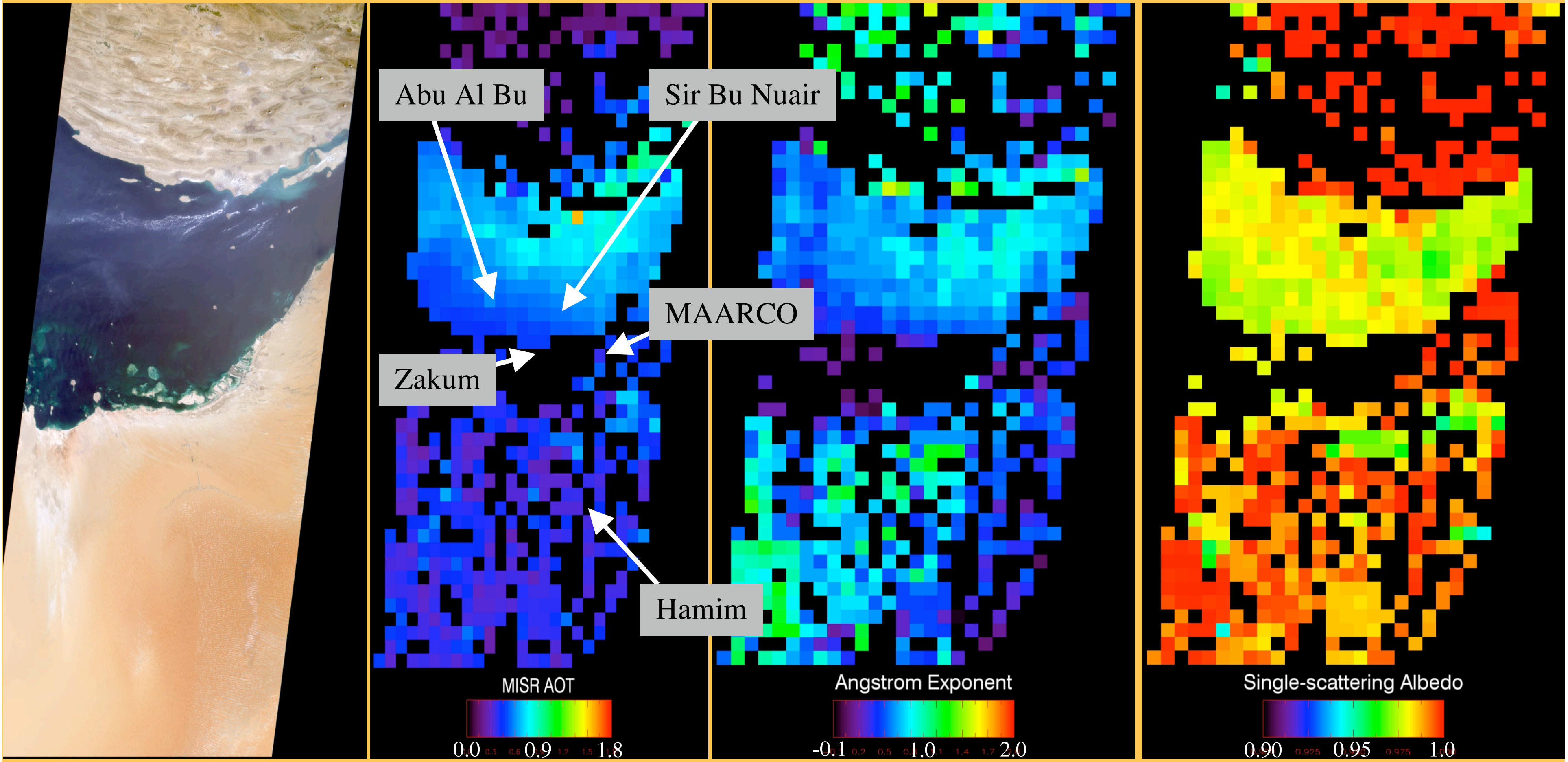
September 01, 2004 Orbit 25032 Path 162 Blocks 68-72 V16



MISR 26˚F Image **MISR AOT** **Angstrom Exponent** **SSA**

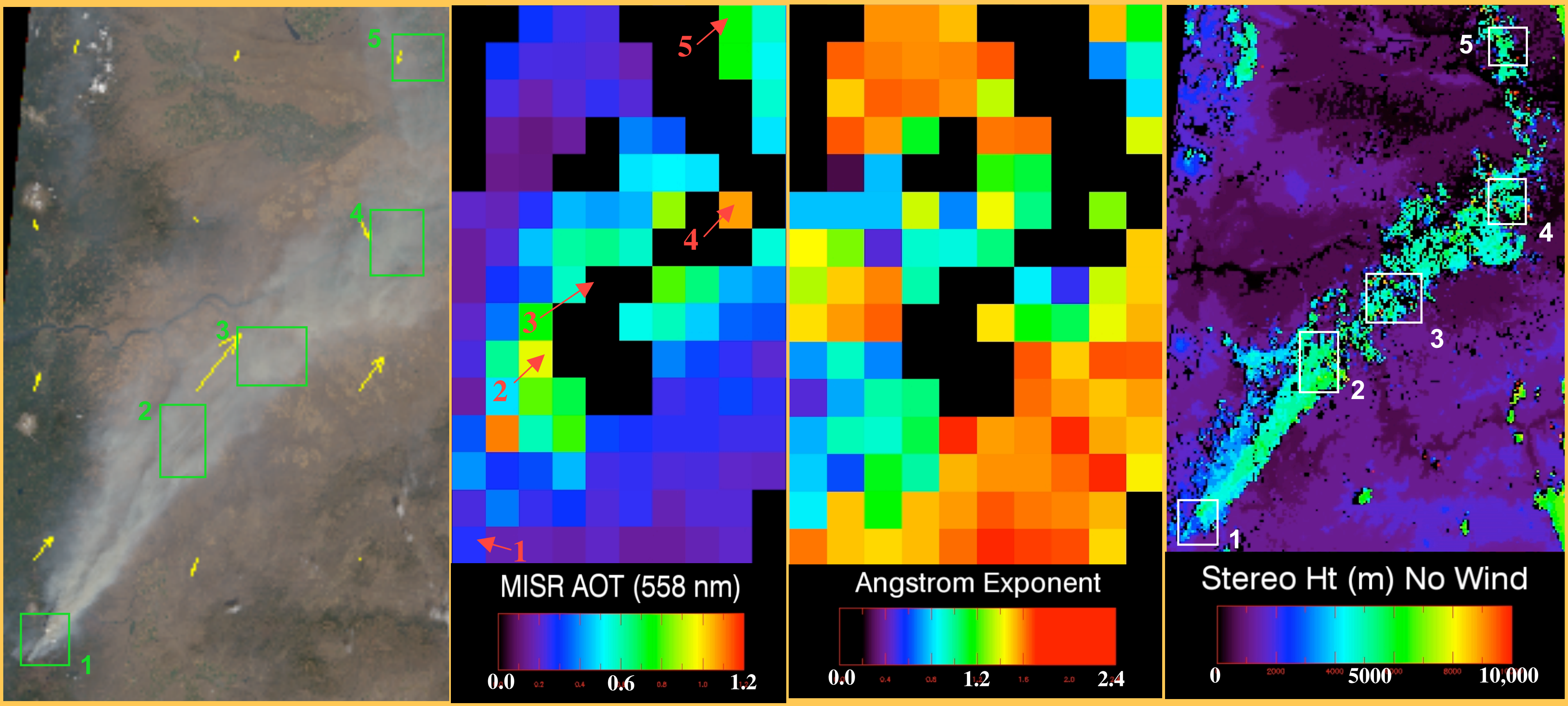
UAE-2 Campaign MISR Data

September 10, 2004 Orbit 25163 Path 161 Blocks 68-73 V16



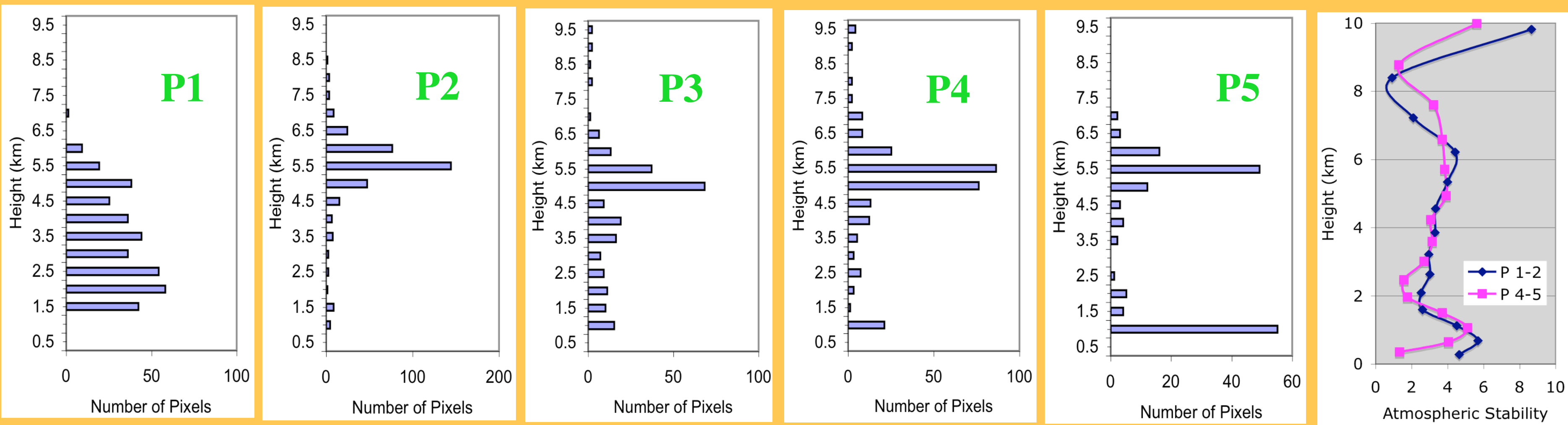
MISR Nadir Image **MISR AOT** **Angstrom Exponent** **SSA**

Oregon Fire Sept 04 2003
Orbit 19753 Blks 53-55 MISR Aerosols V17, Heights V13 (no winds)



From: *Kahn, et al.*, JGR, submitted

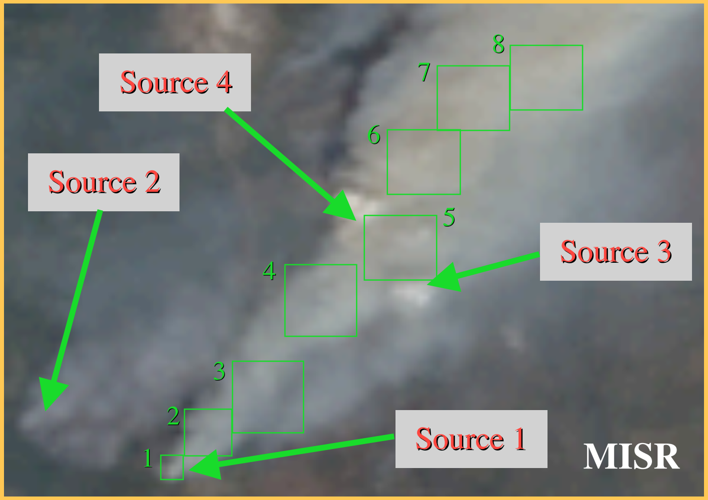
Oregon Fire Sept 04 2003
Orbit 19753 MISR Stereo Heights V13 (no winds)

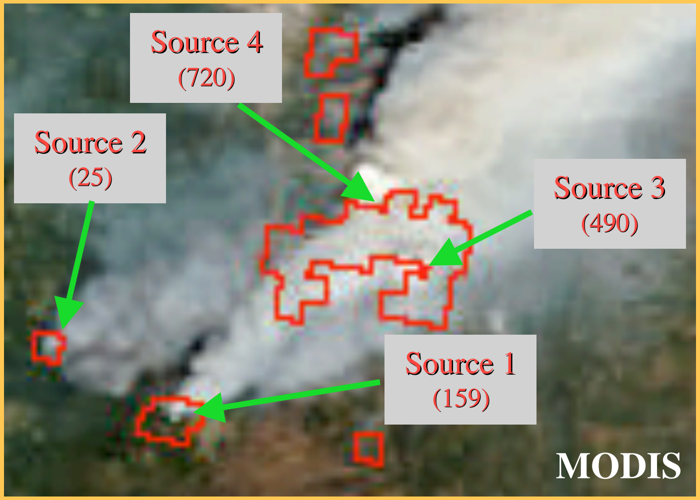


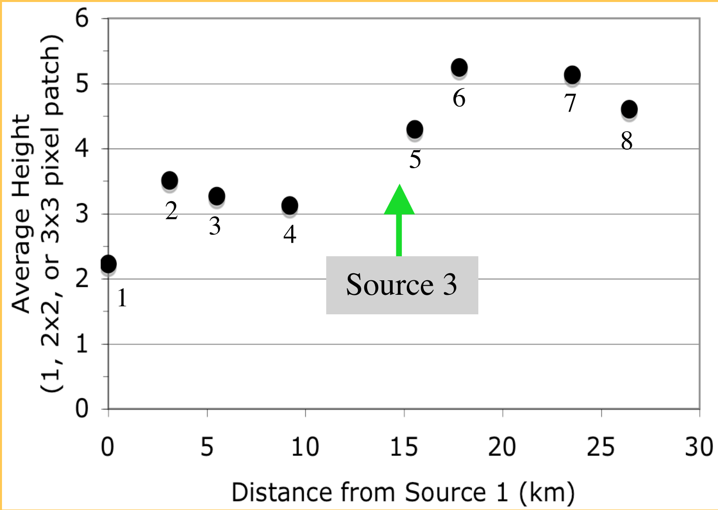
Atmospheric stability derived from NCEP re-analysis

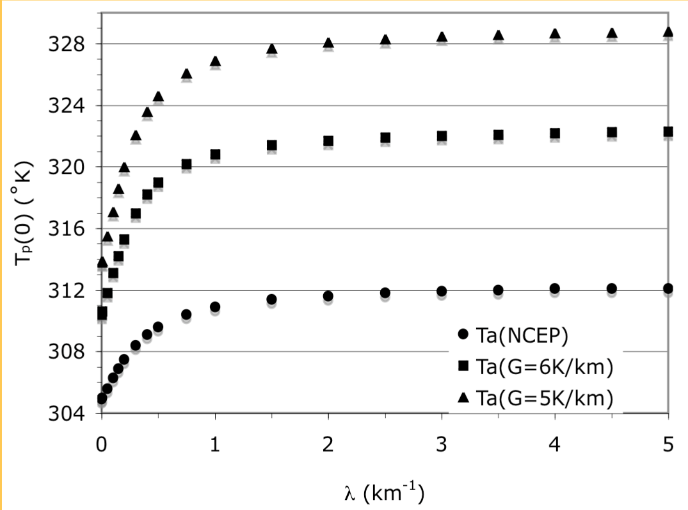
From: *Kahn, et al.*, JGR, submitted

Oregon Fire Sept 04 2003 Orbit 19753
Detail of Patch 1









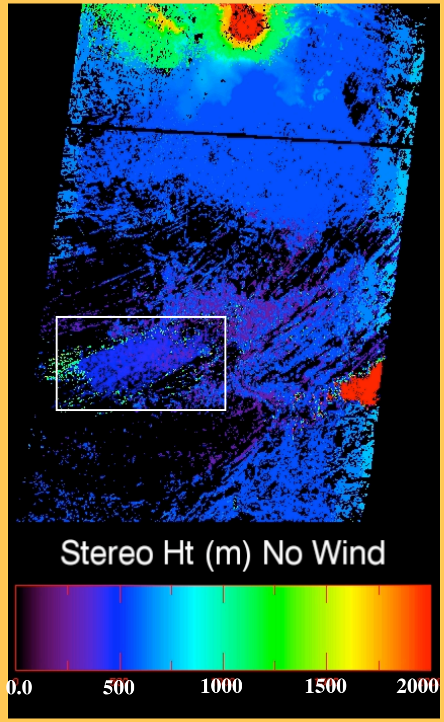
From: *Kahn, et al.*, JGR, submitted

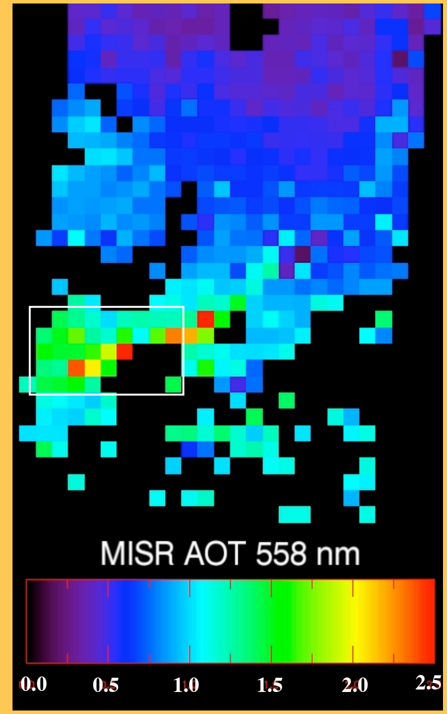
Saharan Dust Plumes

Source Plume

Bodele Depression, Chad

June 6, 2006 Orbit 29038

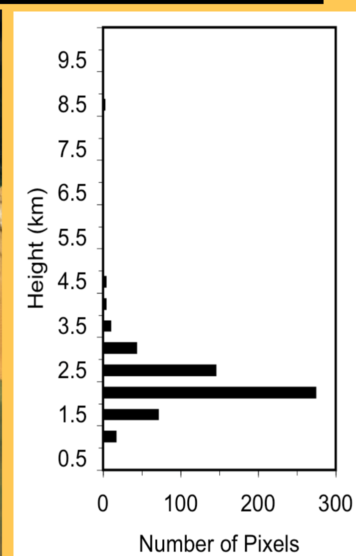


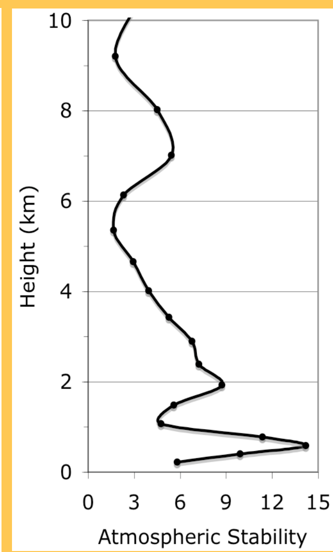


Transported Dust

Atlantic, off Mauritania

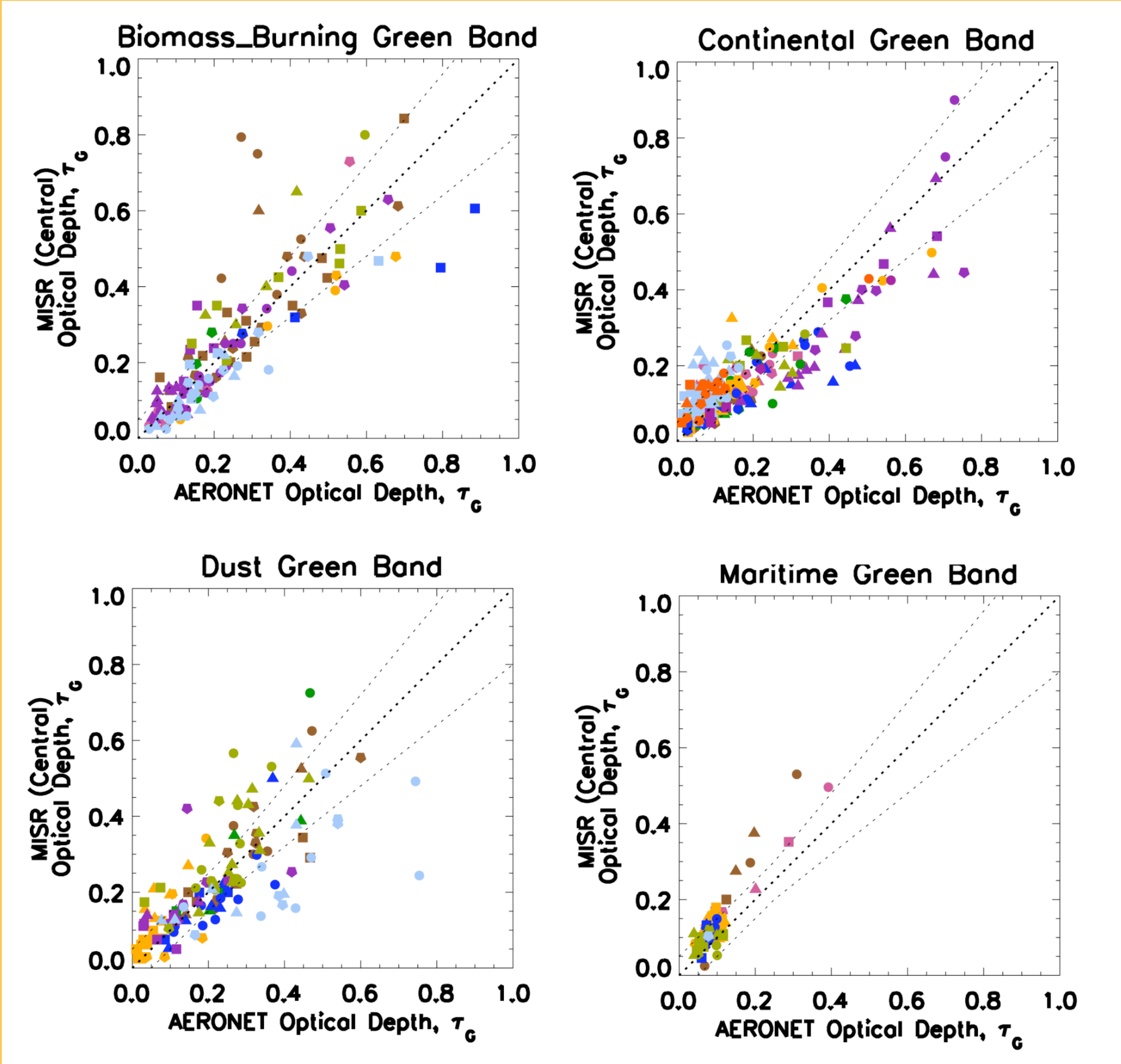
March 4, 2004 Orbit 22399





From: *Kahn, et al.*, JGR, submitted

Scatter Plots Showing 579 MISR-AERONET Coincident AOT Events
32 sites, during 2001-2002; Stratified by Expected Aerosol Type



Overall:

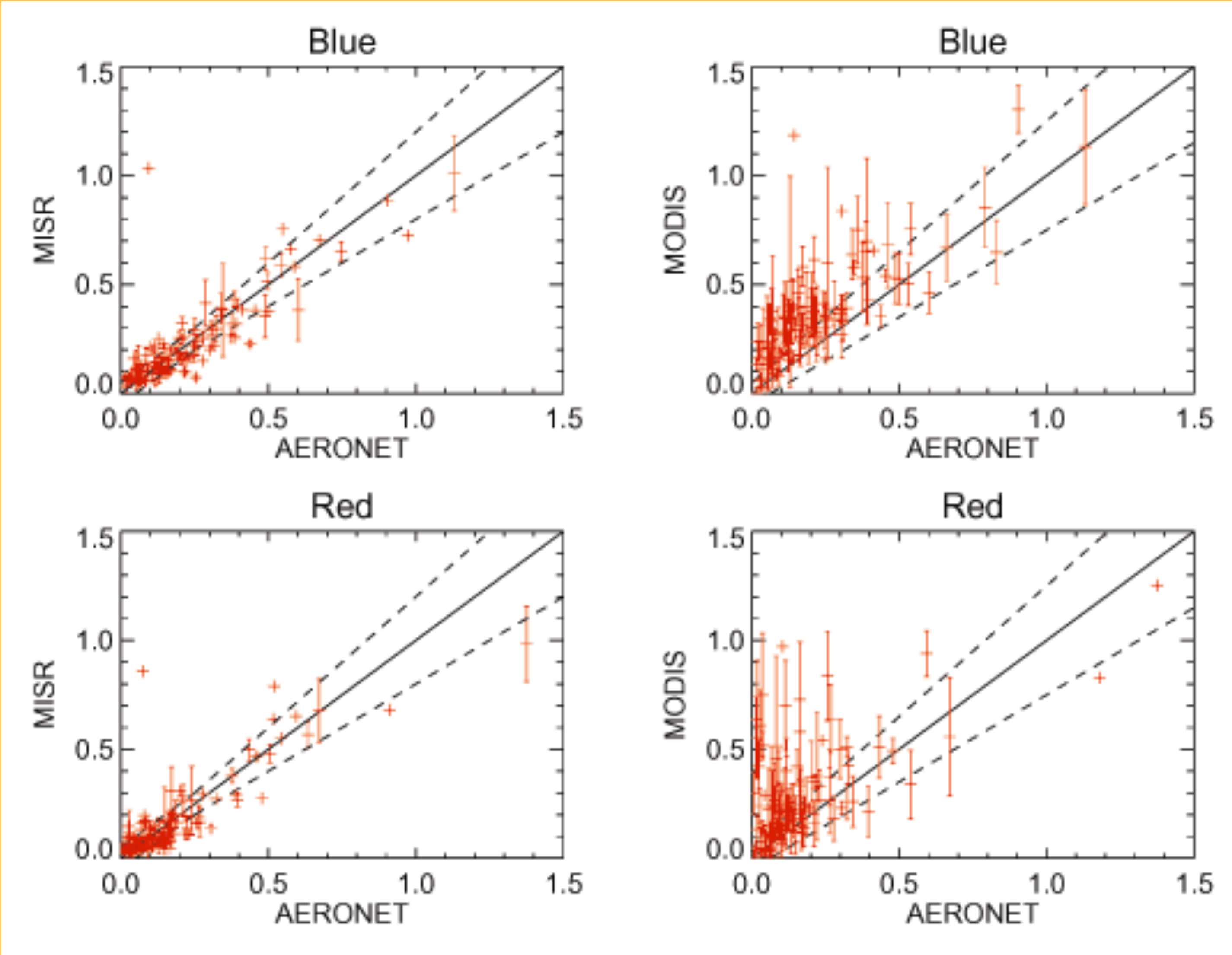
- **About 2/3 fall within 0.05 or 20% * AOT**
- **About 1/3 fall within 0.02 or 10% * AOT**

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

From: *Kahn, et al.*, JGR 2005

127 MISR- AERONET & 113 MODIS-AERONET Coincident AOT Comparisons

Over Land; March, June, and September 2002



From: *Abdou, et al.*, JGR 2005

Mid-Visible AOT Sensitivities Reported Currently

- MISR: **0.05 or 20% * AOT** overall; ***better over dark water***
  [*Kahn et al*., 2005]

- MODIS: **0.05 or 20% * AOT** over land
  0.03 or 5% * AOT over dark water [*Remer et al*. 2005]

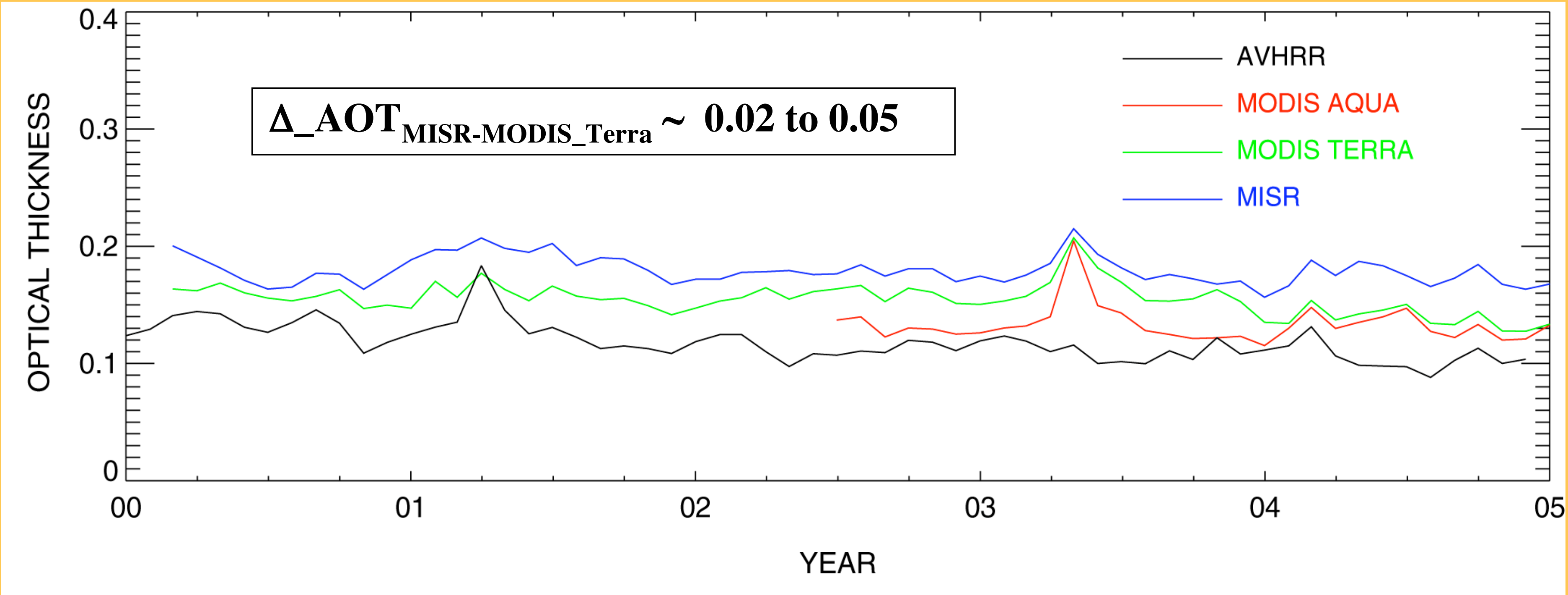
Based on AERONET coincidences (cloud screened by *both* sensors)

--> For global, monthly AOT, AEROCOM uses

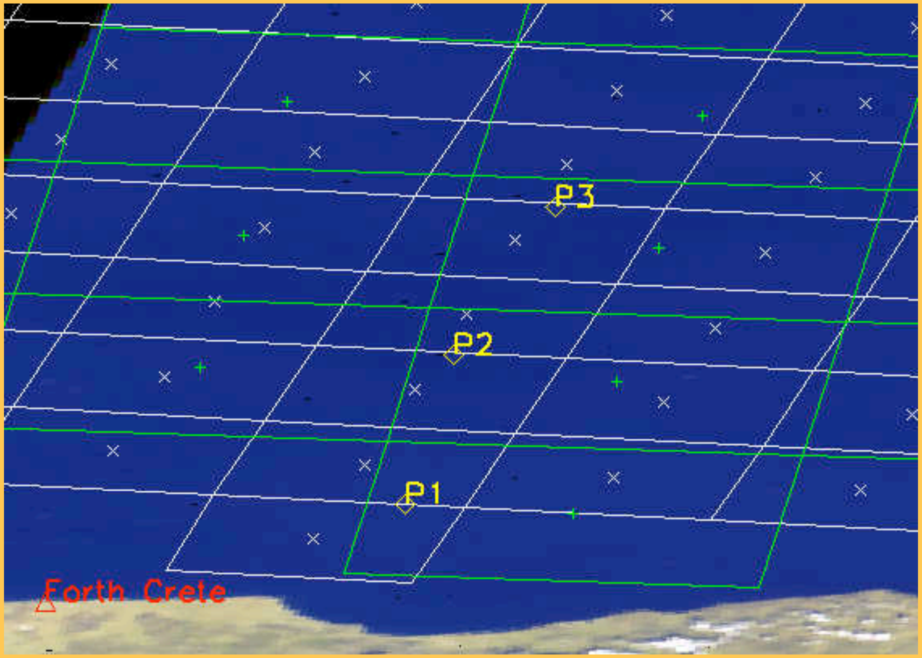
MISR over land, MODIS over water

MISR - MODIS - AVHRR Five-Year Monthly, Global AOT Comparison

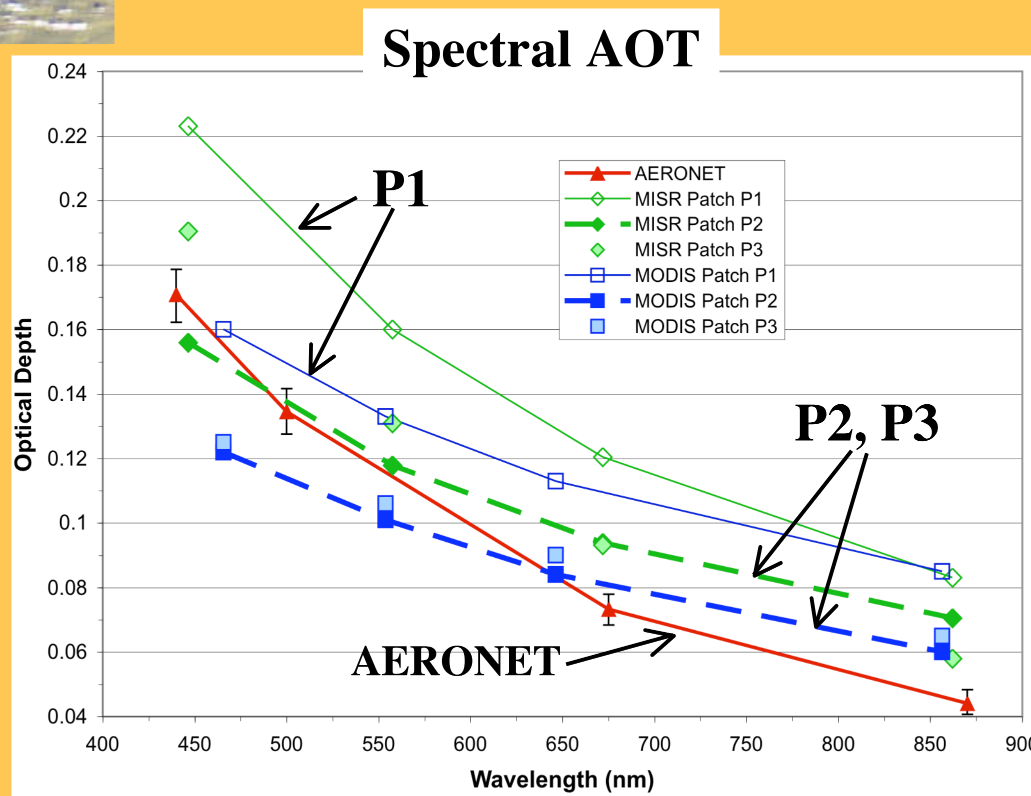
Based on Standard "Level 3" Gridded Products



From: *Mike Mishchenko*, AGU presentation, Fall 2005; used by permission

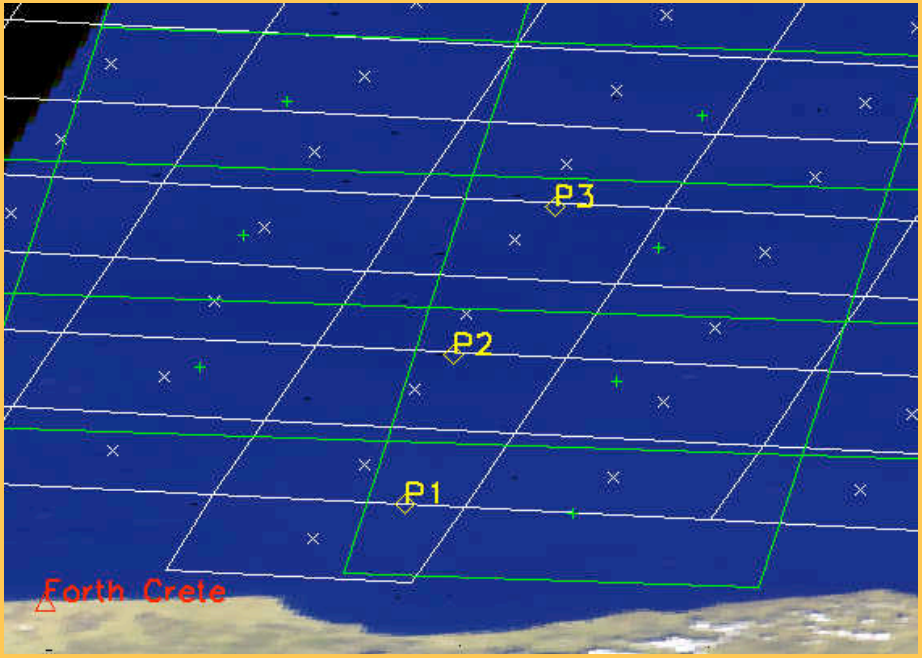


AOT Comparison
Forth Crete Sept 13 2003
Orbit 19898 Path 180 Block 62



- **$AOT_{mid\text{-}vis}$ >~ 0.1**
- **P1 $\Delta\_AOT_{mid\text{-}vis}$ ~ +0.03 to 0.04**
- **P2, P3 match ARNT to ~ 0.01**

From: *Kahn et al.*, JGR in preparation



P1 - Surface or Atmosphere Effect?

Forth Crete Sept 13 2003

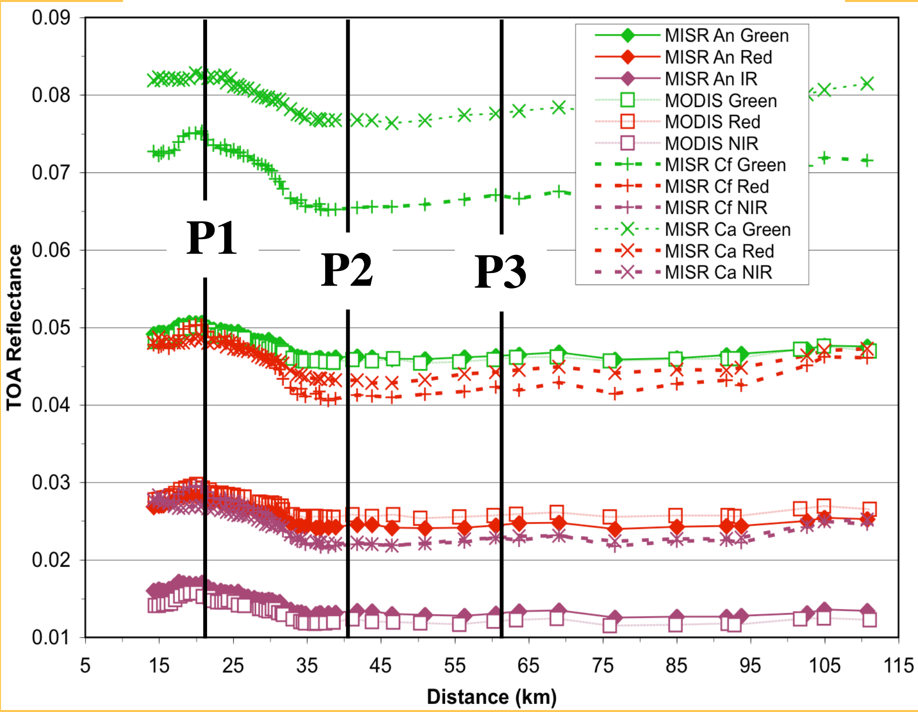
Orbit 19898 Path 180 Block 62

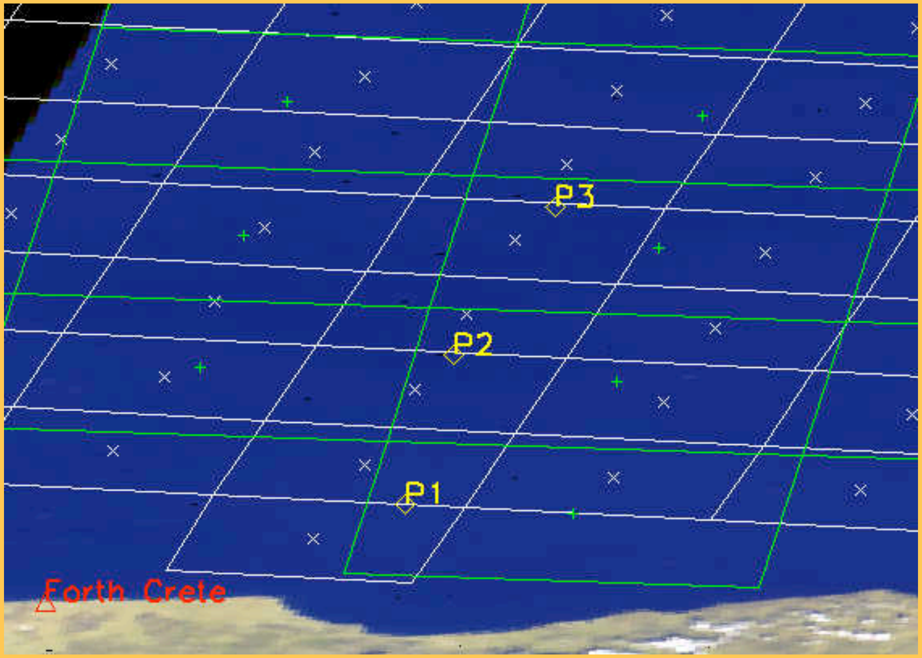
- P1 Δ_refl ~ +0.005 [G, R, NIR]
  --> A "gray" TOA reflectance increase
- For the MISR ±60° cameras
  --> reflectance increase similar size, roughly fore-aft symmetric

P1 is most likely a subtle surface feature

From: *Kahn et al.*, JGR, in preparation

TOA Nadir Reflectance Trace





MISR Nadir v. MODIS Reflectance Comparison

Forth Crete Sept 13 2003

Orbit 19898 Path 180 Block 62

Band-specific Simulations

- **AERONET-retrieved aerosols**
- **Observed wind speed (3.6 m/s)**
- **$A_0(\lambda)$ as in each algorithm**
- **Known ~3% MI-MO Absolute Cal. Dif.**

Small numbers, but Systematic

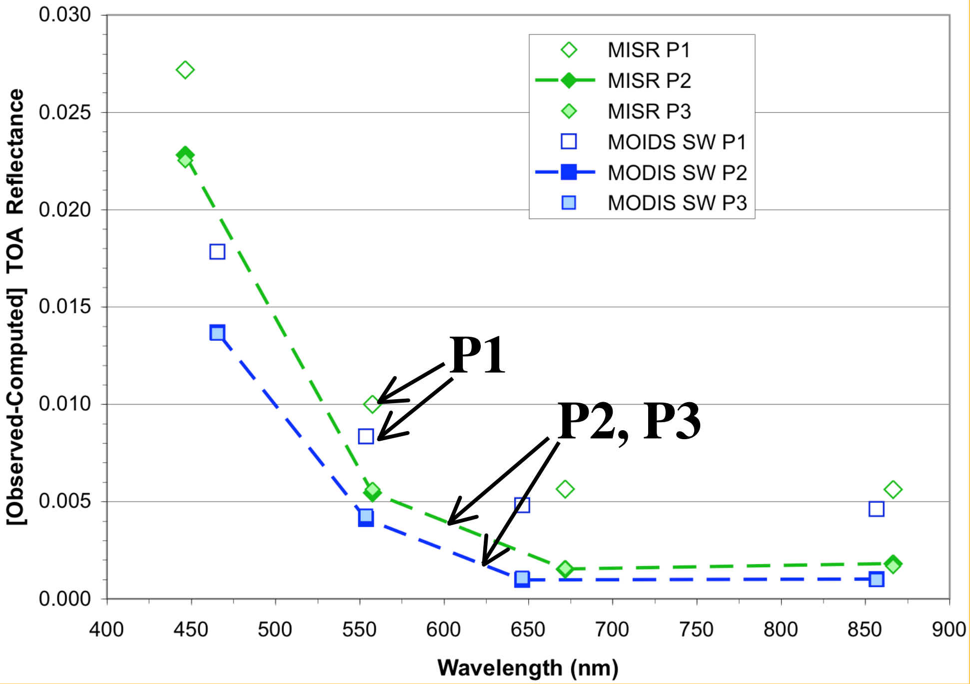
$MODIS_{Grn,NIR}$ ~ 10% above nominal model

$MISR_{Grn,NIR}$ ~ 15% above nominal model

$\Delta\_refl_{MISR\text{-}ARNT}$(P2, P3) --> Δ_AOT ~ 0.01(G); 0.02 (R)

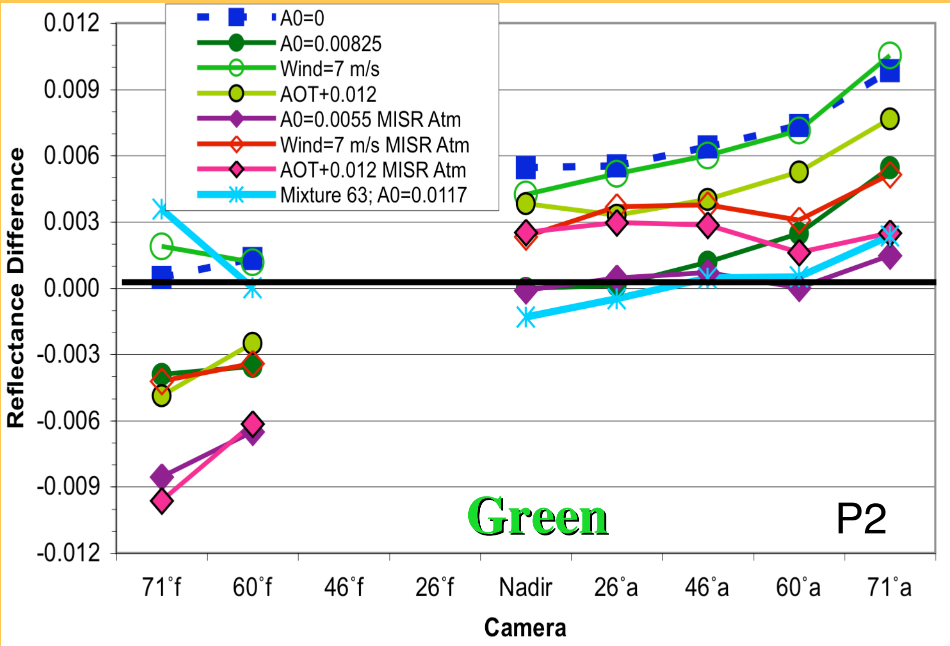
From: *Kahn et al.*, JGR, in preparation

[Obs. - Calc.] Nadir TOA Reflectance



Forth Crete September 13 2003

[Observed - Calculated] Multi-angle TOA Reflectance



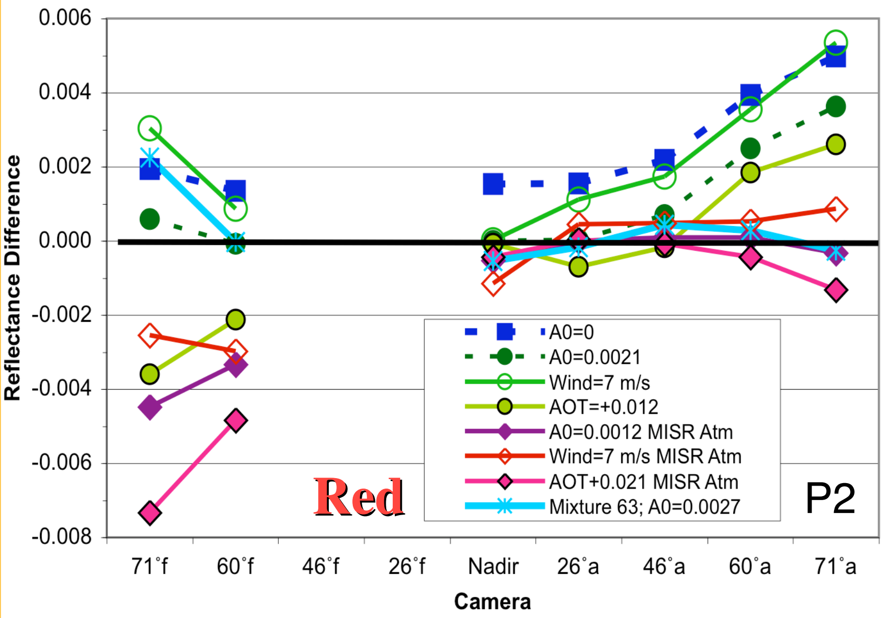
Cases Shown

- AERONET & MISR-retrieved aerosols
  - $A_0(\lambda)$ = 0 & Adjusted
  - Observed & Adjusted wind speed
  - AOT = AERONET & Adjusted

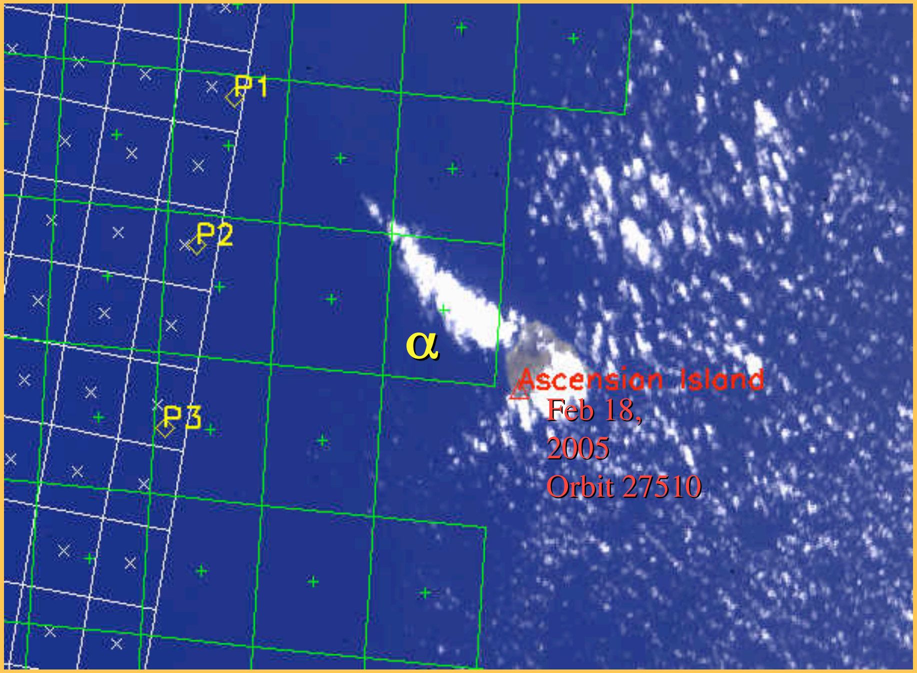
Water-leaving Reflectance $A_0(\lambda)$ Values Needed

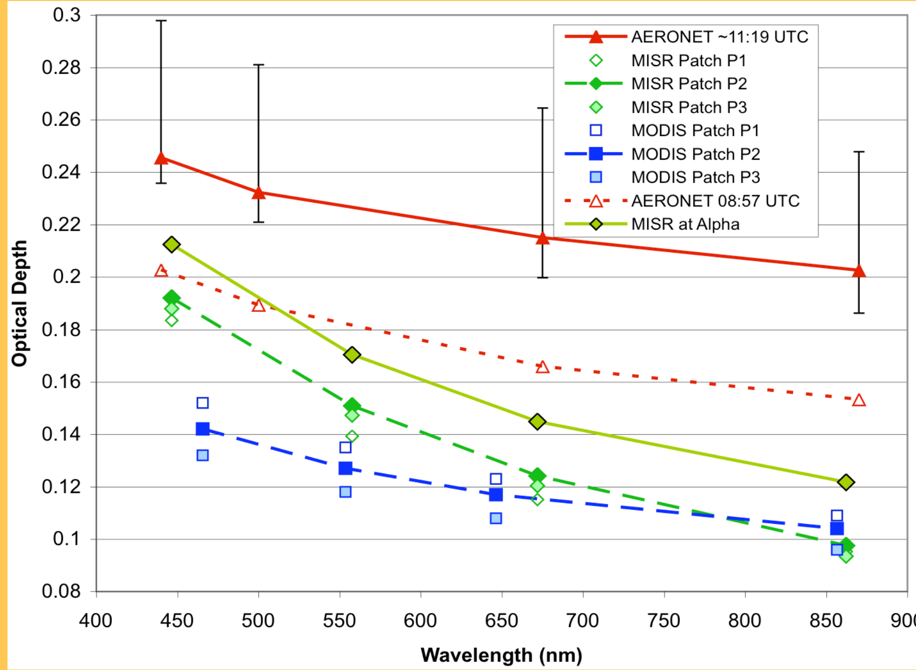
(AERONET Atmosphere used)

	MISR Nadir P1	MODIS SW P1	MISR Nadir P2	MODIS SW P2	“Typical” Dark Water
Blue	0.0445	0.0280	0.0375	0.0220	0.0300
Green	0.0150	0.0127	0.0083	0.0062	0.0070
Red	0.0078	0.0069	0.0021	0.0015	0.0020
NIR	0.0072	0.0062	0.0023	0.0015	0.0007

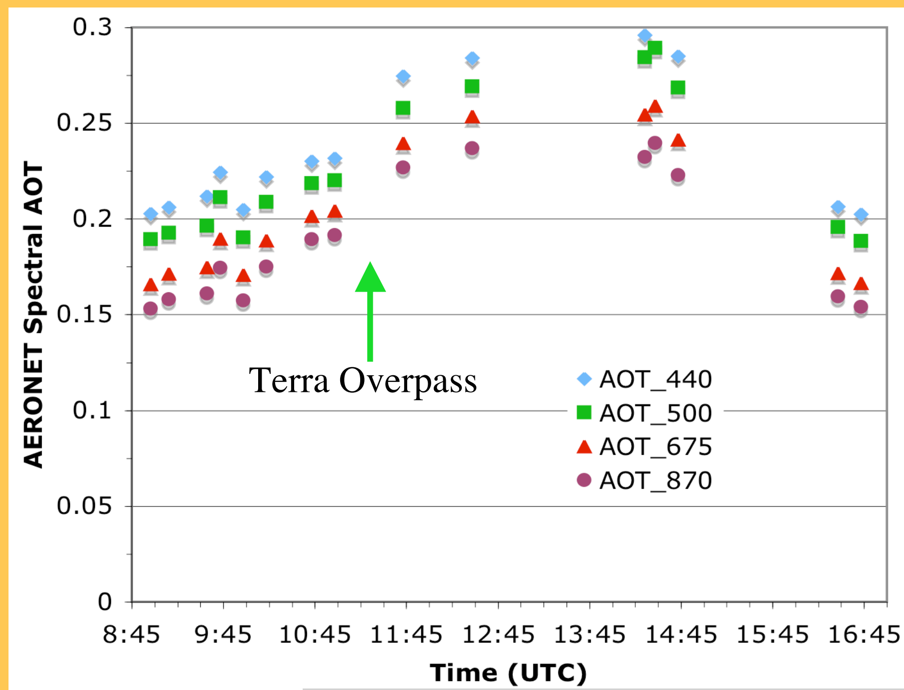


From: *Kahn et al.*, JGR, in preparation





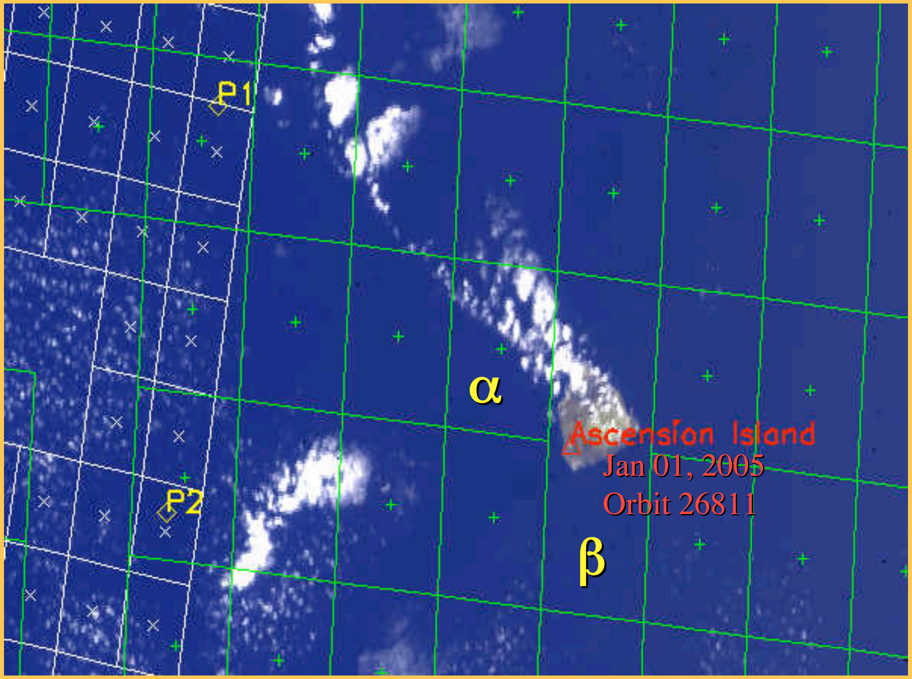
Ascension Island Feb 18 2005
Orbit 27510 Path 200 Blk. 97

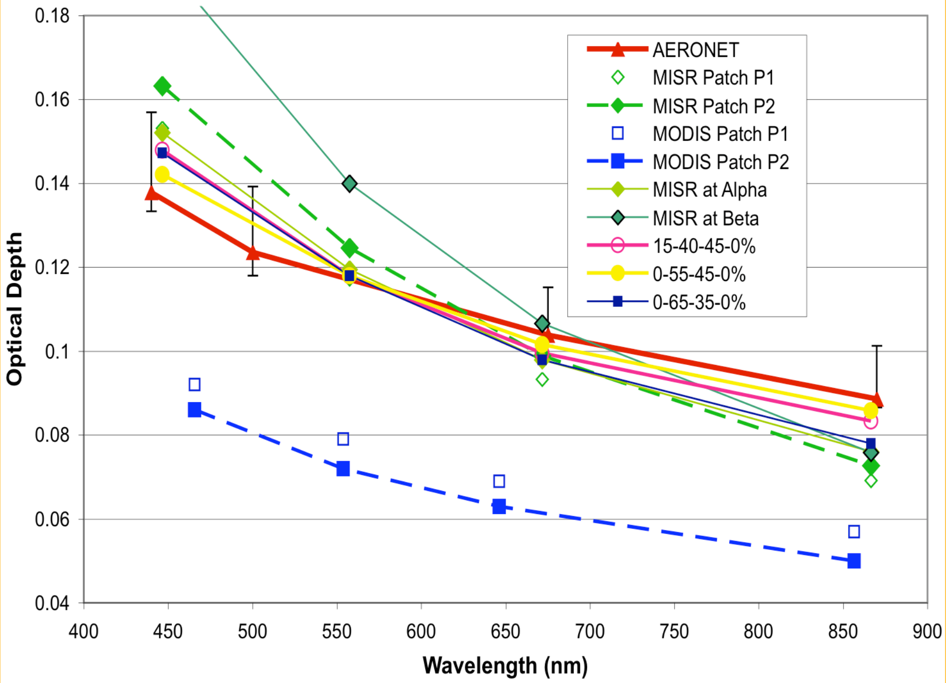


Sampling and Level 3

- **Clean Maritime** aerosol air mass
- **>60% AOT change** across RH boundary
- **Using *any one* of these AOT data sets to represent the entire region --> large errors**

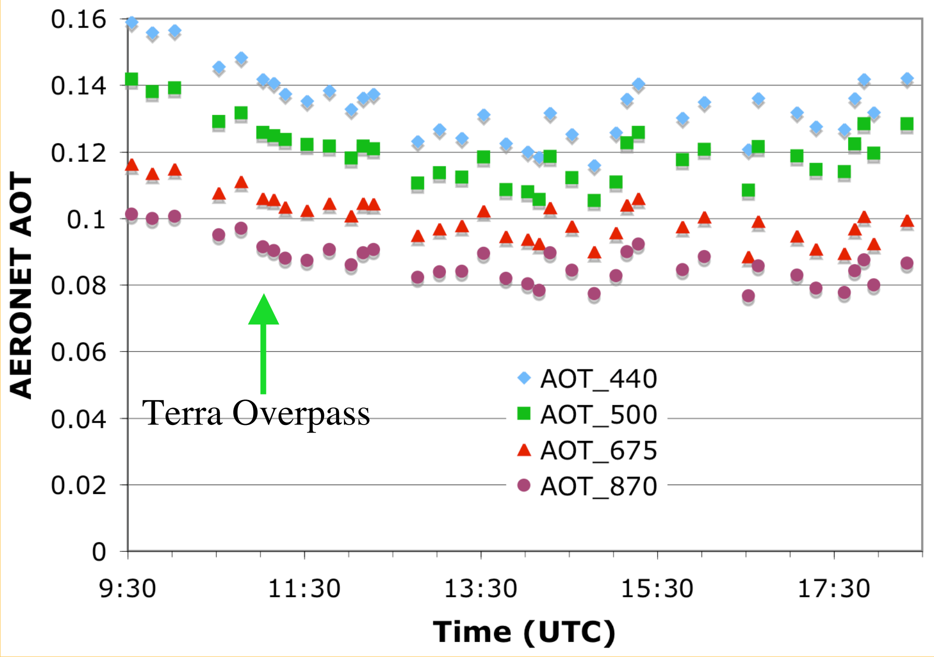
From: *Kahn et al.*, JGR, in preparation





Ascension Island Jan 01 2005

Orbit 26811 Path 200 Blk. 97



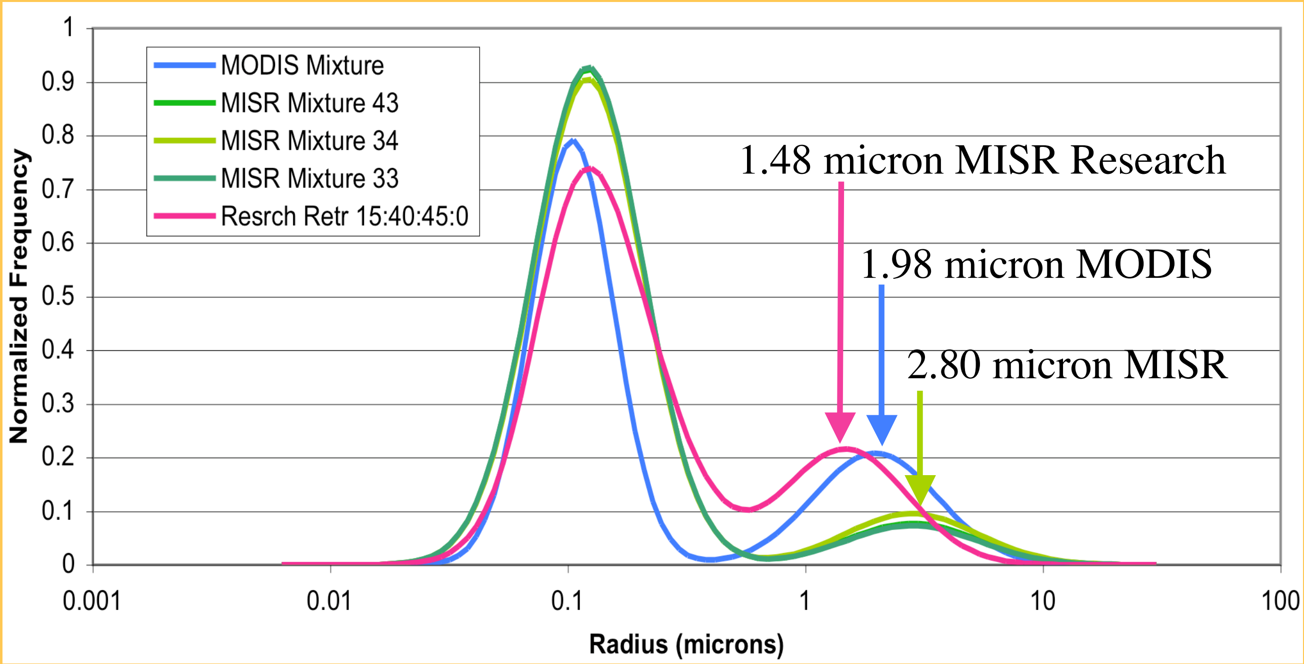
Particle Properties Question

- **Clean Maritime** aerosol air mass
- **No AOT decrease** toward P1 & P2
- **SSA**: MODIS 0.92; MISR 0.84; ARNT 0.73
- MISR spectral AOT slope **too steep**

  --> particle sizes(?)

Ascension Island Jan 01 2005

Orbit 26811 Path 200 Blk. 97



MISR, MODIS, and AERONET Retrieved Particle Size Distributions

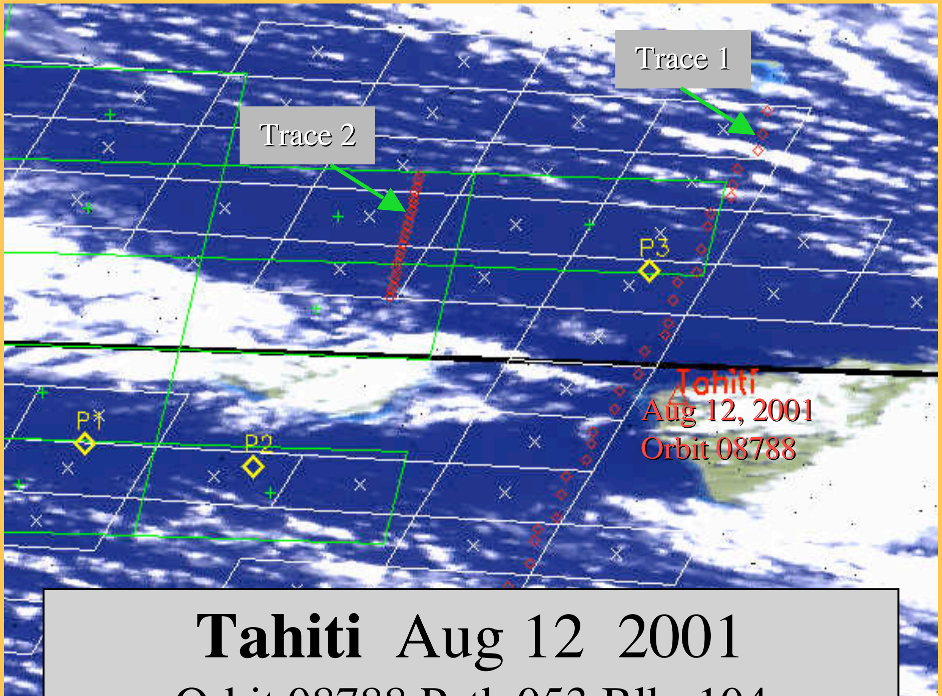
- ARNT **spectral AOT independent** of ARNT-retrieved size distribution
- Good ARNT **spectral AOT fit** with **MODIS particles**
- MISR **V17** Standard Algorithm **lacks spherical aerosol between 1 and 2.80** micron

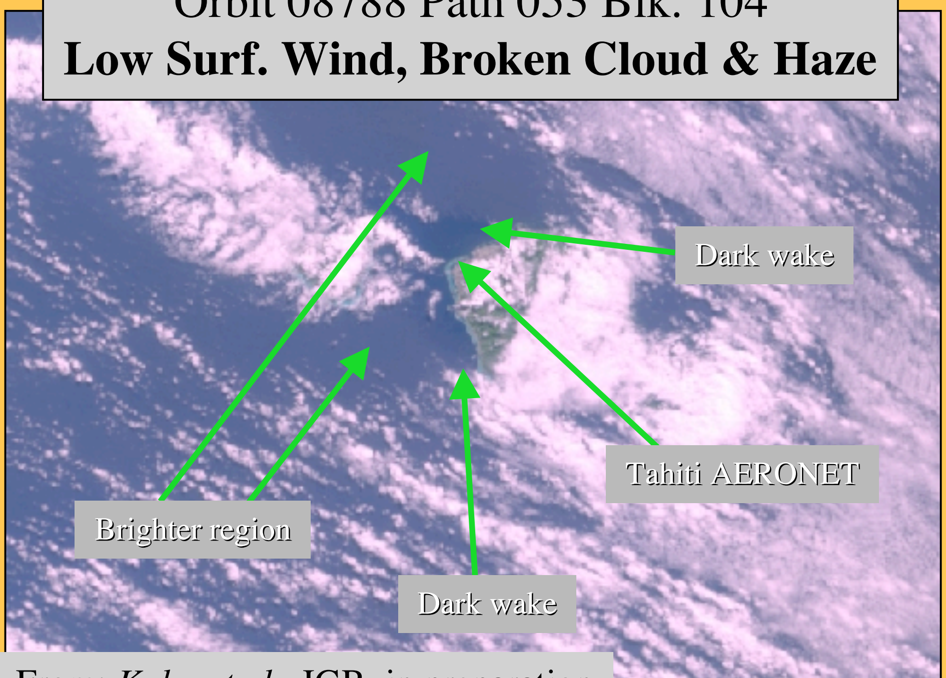
--> **Add 1.28, 1.5 and 2** micron aerosol back into MISR Standard algorithm

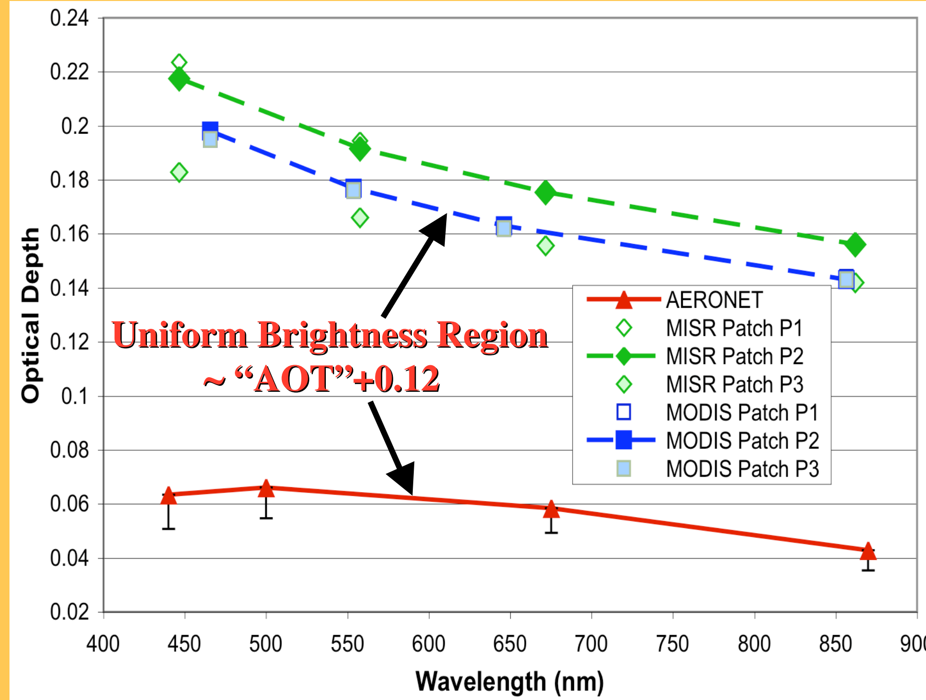
Tahiti Aug 12 2001

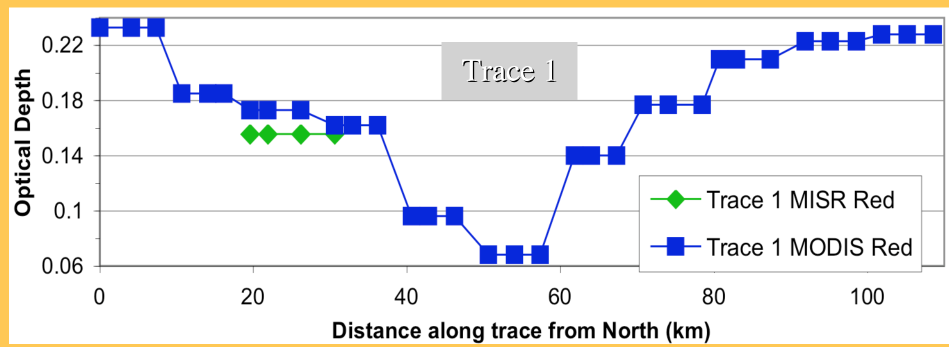
Orbit 08788 Path 053 Blk. 104

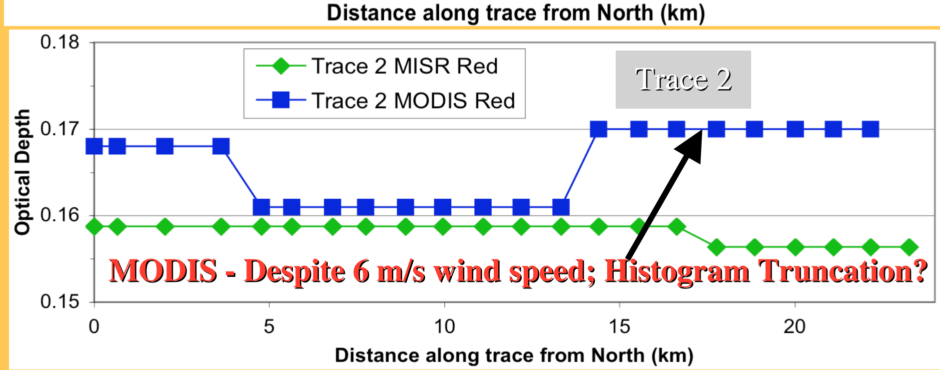
Low Surf. Wind, Broken Cloud & Haze



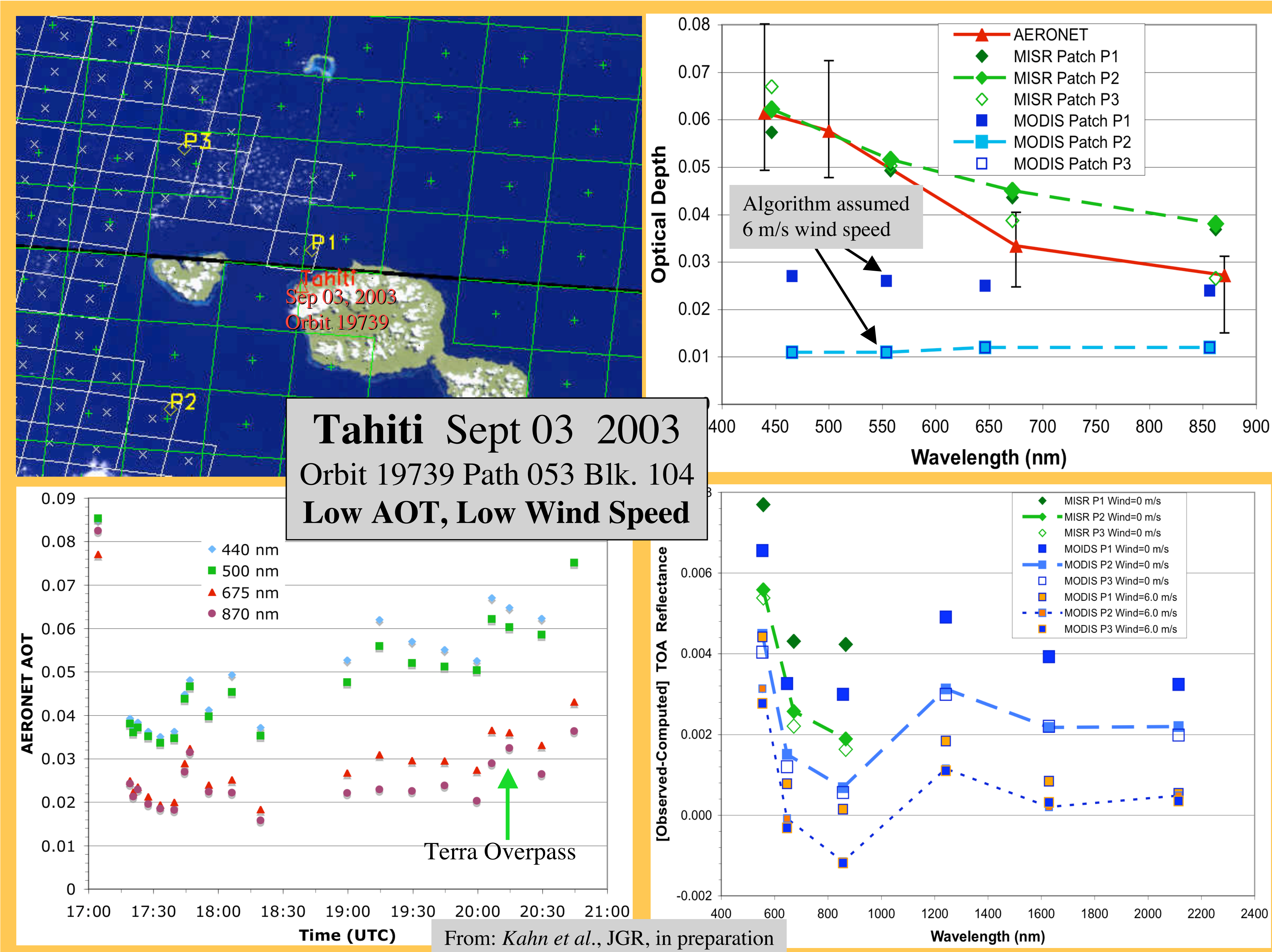








From: *Kahn et al.*, JGR, in preparation



Tahiti Sept 03 2003
Orbit 19739 Path 053 Blk. 104
Low AOT, Low Wind Speed
P3
P1
P2
Tahiti
Sep 03, 2003
Orbit 19739
Optical Depth
Wavelength (nm)
AERONET
MISR Patch P1
MISR Patch P2
MISR Patch P3
MODIS Patch P1
MODIS Patch P2
MODIS Patch P3
Algorithm assumed
6 m/s wind speed
AERONET AOT
Time (UTC)
440 nm
500 nm
675 nm
870 nm
Terra Overpass
[Observed-Computed] TOA Reflectance
Wavelength (nm)
MISR P1 Wind=0 m/s
MISR P2 Wind=0 m/s
MISR P3 Wind=0 m/s
MOIDS P1 Wind=0 m/s
MODIS P2 Wind=0 m/s
MODIS P3 Wind=0 m/s
MODIS P1 Wind=6.0 m/s
MODIS P2 Wind=6.0 m/s
MODIS P3 Wind=6.0 m/s
From: Kahn et al., JGR, in preparation

Conclusions (1)

Current State of MISR-MODIS Aerosol Capabilities

What we can do <u>routinely now</u>

- **AOT over water and land *with published sensitivities***. But not yet in scattered <u>cloudy</u> regions, some <u>snow & ice</u> situations, <u>Case 2 water</u>
- **Medium/large** aerosol ratio; [MODIS; possibly **dust** from **pollution** from **small** particles]
- **Spherical vs. Non-spherical** [MISR; **plates** from **grains** from **spheres** at least in some cases]
- **Aerosol <u>Layer</u> Height** [TOMS uv, GLAS, now CALIPSO]
- **Aerosol <u>Plume</u> Height** to ~0.5 km [MISR; mainly forest fire, volcano, and dust source regions]
- **Fire Occurrence** [MODIS, AVHRR and other instruments w/mid-IR channels]

What we can do now in *<u>individual cases</u>*, & with available satellite data, could do routinely

- **3-5 size bins** [MISR; need to complete the validation]
- **2-4 single-scattering albedo groupings** [MISR; need to complete the validation]
- Aerosol amount & properties over **Case 2 waters** [MISR; algorithm development underway]

There is more to be said about other of the newer satellite instruments as well:

POLDER, CERES, GLAS, AIRS, CALIPSO, (GLORY), etc.

Conclusions (2)

Suggestions for Large-scale, Long-term MISR & MODIS Aerosol Studies

using current products

• Aim for **Targeted Regional** rather than naïve global analyses if possible

For applications that look at individual cases

[e.g., source plumes, process studies, …]

--> Using 'Level 2' data can avoid many issues

• Use consistent, validated **Versions of the Products**

• Take seriously the caveats in **Product Quality Statements**

[e.g., *Cloud Screening* limitations; *Validation Sensitivity* study results]

• Account for **Sampling**

-- Instrument **Coverage**

-- Especially for **Severe, Short-lived Aerosol Event** observations

-- Seasonal, or multi-year 'January' **Aggregates** may help

• Be aware: As field data are acquired, these **Products are Being Refined**

Conclusions (3)

Known Remaining Issues
(each is under study by MISR/MODIS teams)

• 3% MISR-MODIS **Absolute Calibration Difference**

[Surface albedo (*Lyapustin*) + AOT statistical ground truth]

• **Surface Model** Uncertainties

-- Assumed spectral **water-leaving reflectances**

[*Martonchik et al*. multi-angle $A_0(\lambda)$ retrieval]

-- Assumed near-ocean-surface **wind speed**

[Adaptive glint width (*Fox et al*.; *Breon et al*.) or external source]

• **Aerosol Properties** used in Standard Retrieval Algorithms

[Global comparisons and field campaigns (*Kahn et al*.)]

• **Cloud Screening**

[Regional statistical analyses (*Diner et al*.; *Kaufman, Remer* et al.)]

• **Spatial Sampling…** [needs work]

The accuracy limits that can be achieved with these strategies remain to be explored

Satellite-related Topic for AeroCom:

Use of Satellite Data for Models -- Validation, Initialization, Assimilation

- **Information Content**
- **Quality**
- **Sampling**
- How to **Aggregate** or incorporate satellite data products at **Spatial and Temporal Scales** needed by models