Aerosol Retrieved from MODIS: Algorithm, Products, Validation and the Future

Presented by: Rob Levy

Re-presenting NASA-GSFC's MODIS aerosol team:

Y. Kaufman, L. Remer, A. Chu, C. Ichoku, R. Kleidman, I. Koren, R-R. Li, J.V. Martins, S. Mattoo, D. Tanre

Outline

- MODIS:
  - Instrument and data
  - "level 1B/2/3,"
  - Collection 3/4
- MODIS aerosol algorithm over land, and over ocean
- Global "validation" of AOD and aerosol size (Level 2)
- Selected topics in aerosol retrieval issues (Level 2):
  - Dust over ocean
  - Single Scattering albedo in SAFARI
  - Surface reflectance over land
- Level 3: Daily vs. Monthly
- MODIS - GOCART "movie"
- New L3 "Tool"

MODIS Quick Facts

Scientific Data

Atmosphere: Cloud and Aerosol
Ocean: Color, Chlorophyll, Temp
Land: Vegetation, Change, Fires

Data Processing "Tree"

L0: Raw signal
L1: Uncalibrated "counts"
L1B: Calibrated radiances
L2: Retrieved Scientific Data
L3: "Gridded - Global"
(daily, 8-day, monthly)

Instrument Specifications

Orbit: 705 km, 10:30AM ↓ (Terra) , 1:30 PM↑ (Aqua) sun-synchronous
Over same point every 16 days
Swath: 2330 km (55° cross track)
Spectral Range: 0.4 - 14.4µm (36 bands)
Spatial Resolution: 250m (2 bands)
500m (5 bands) 1000m (29 bands)
Calibration: On-board
Data: 5 minute - "Granules"

"Collection" Notation

003: Changing algorithms:
09/2000 - 12/2002
004: Fixed algorithm
Re-Process: 03/2000 - 12/2002
Forward Proc: 01/2003 ->

MODIS Aerosol Algorithms

Derived Aerosol Parameters:

Over Land: (*Kaufman et al.*, 1997)

- AOD at 3 λ
- AOD Small Mode Weighting (550 nm)
- Angstrom Exponent (470/660)
- Mass Concentration
- Reflected Flux (3 λ)
- Transmitted Flux (2 λ)

Over Ocean: (*Tanre et al.*, 1997)

- AOD at 7 λ
- AOD Small Mode Weighting (7 λ),
- Effective Radius
- Angstrom Exp (550/870; 870/2130)
- Cloud Condensation Nuclei
- Mass Concentration
- Reflected Flux (7 λ)
- Transmitted Flux (7 λ)
- Assymetry Factor (7 λ)
- Backscattering Ratio (7 λ)

Colored : Not yet "validated"

Aerosol Retrieval Bands

Band	Wavelen (nm)	Resol.	Ocean	Land
1	620-670	250 m	X	X
2	841-876	250 m	X	
3	459-479	500 m	E	X
4	545-555	500 m	X	I
5	1230-1250	500 m	X	
6	1628-1652	500 m	X	
7	2105-2155	500 m	X	

Products at 10 km x 10 km

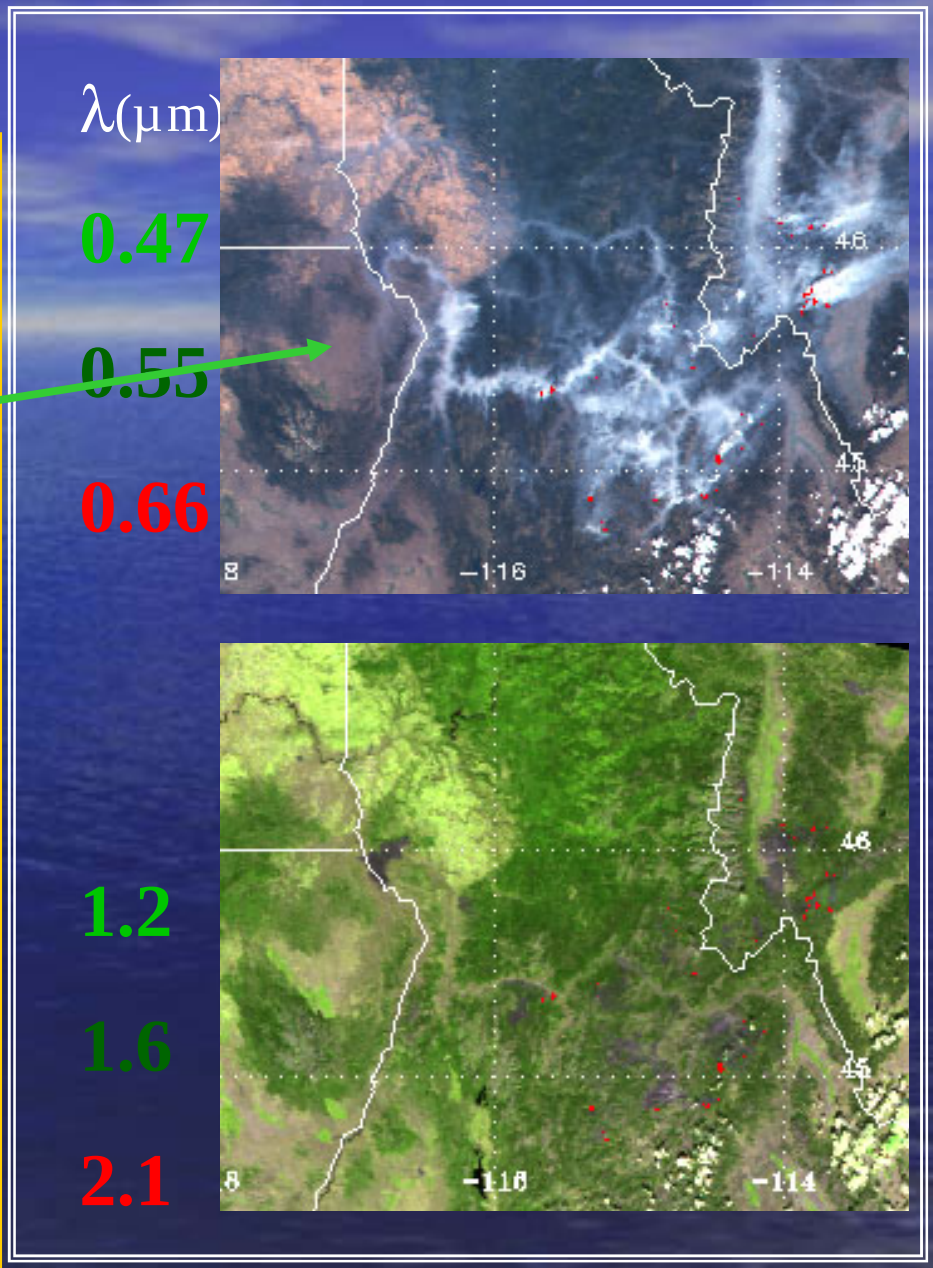
Aerosol over Land

- **Mid-IR is used to observe the surface brightness. Find "Dark" targets.**
- **Estimate surface reflectance in the visible from Mid-IR**

$\tau_{0.66} \sim [\rho^*_{0.66} - 0.5\rho^*_{2.1}]$

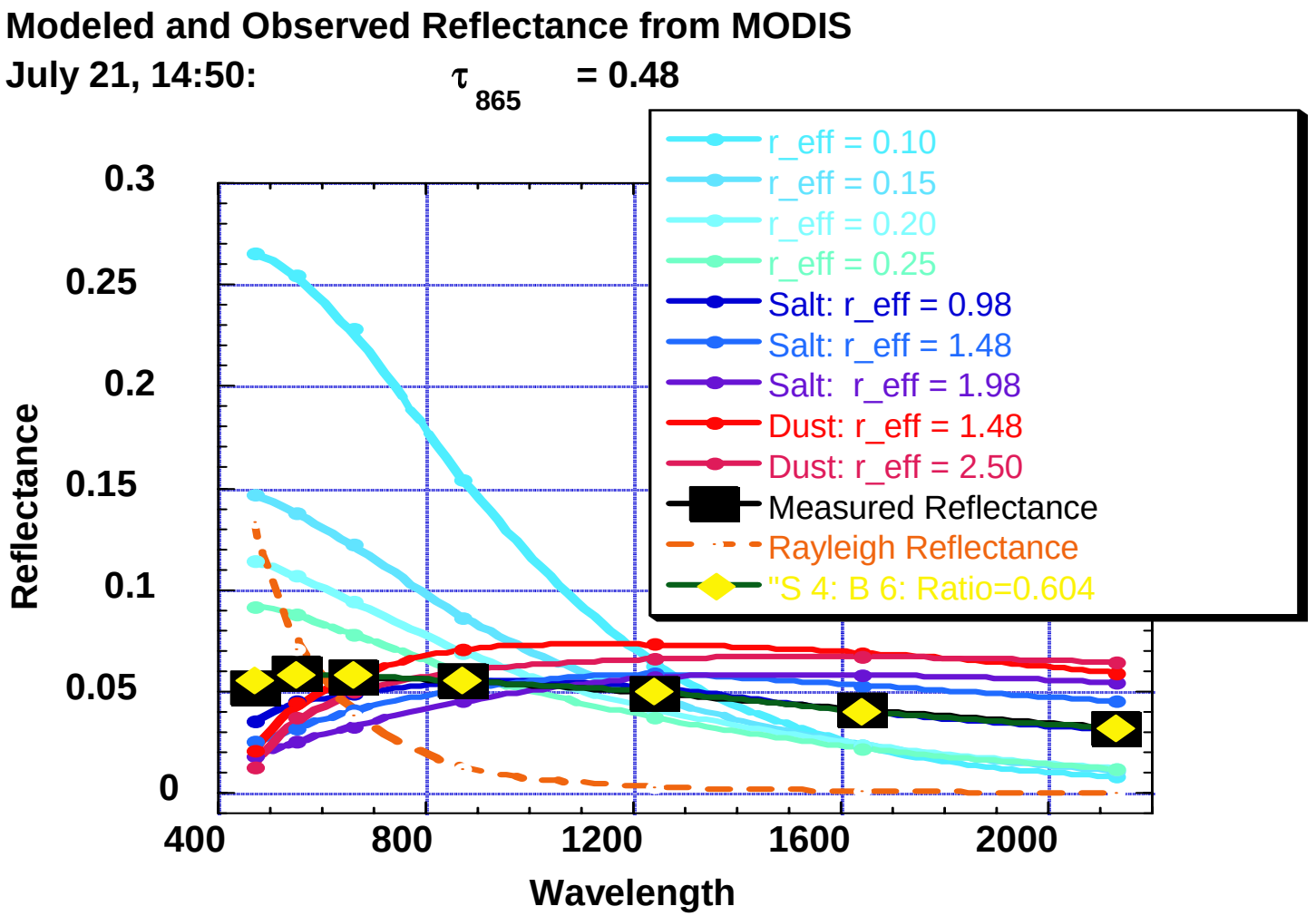
$\tau_{0.47} \sim [\rho^*_{0.47} - 0.25\rho^*_{2.1}]$

- **Estimate AOD in visible (using LUT)**
- **Correct for season and location.**



Y. J. Kaufman

Aerosol Over Ocean

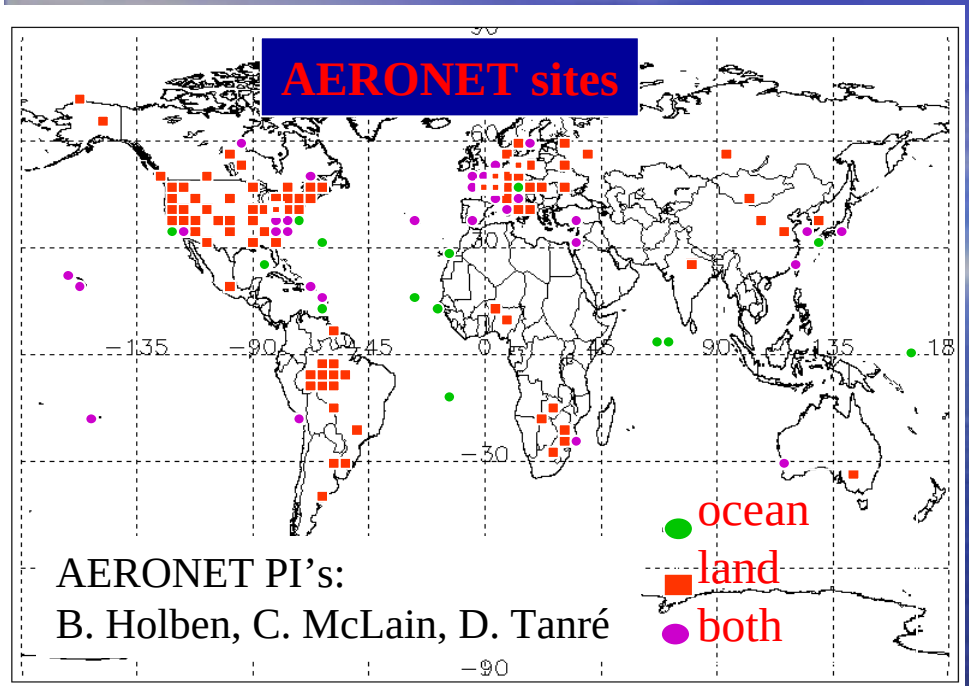


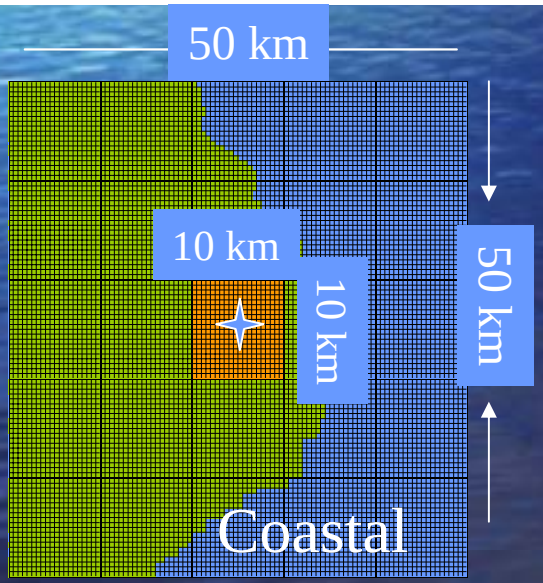
Use reflectance in 6 wavelengths to invert τ^{λ}

Constrained by 4 fine mode and 5 coarse mode aerosol models.

Inversion chooses 1 fine and 1 coarse mode, plus relative concentration

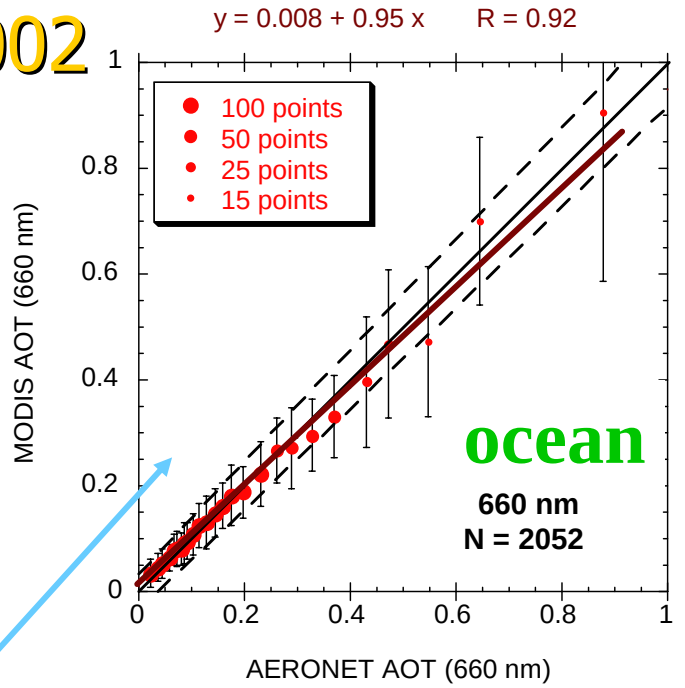
Global AOD "Validation" : 2000-2002

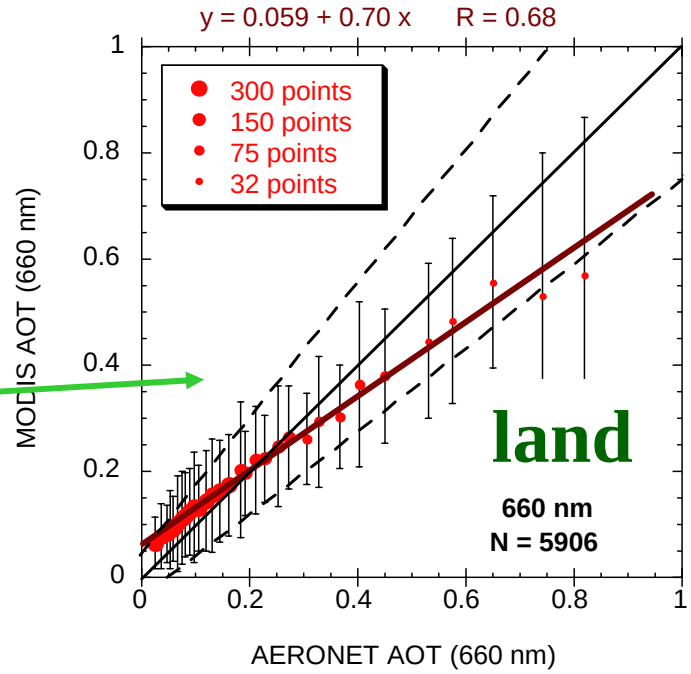




66% of retrievals over OCEAN fall within expected uncertainty

71% of retrievals over LAND fall within expected uncertainty

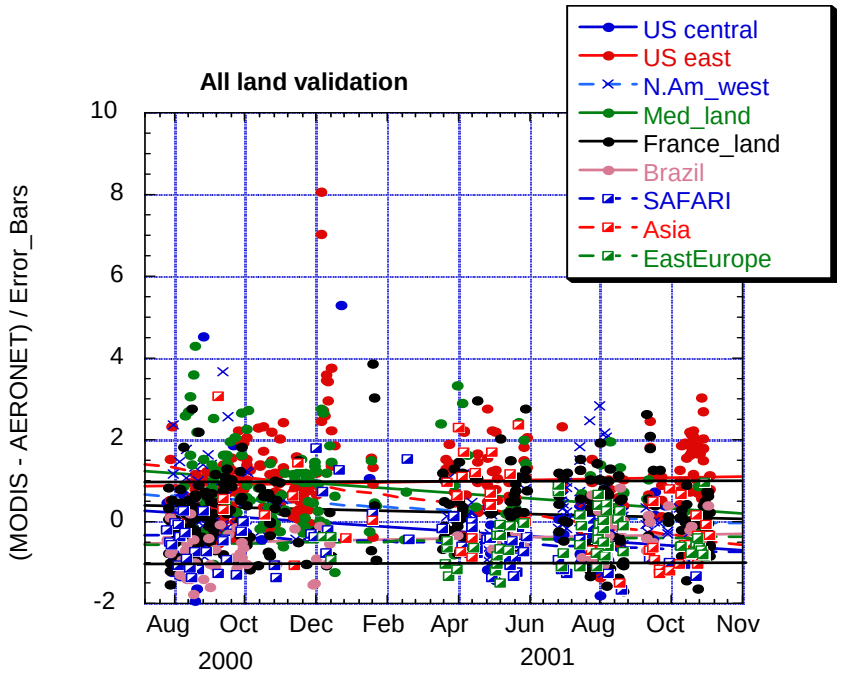


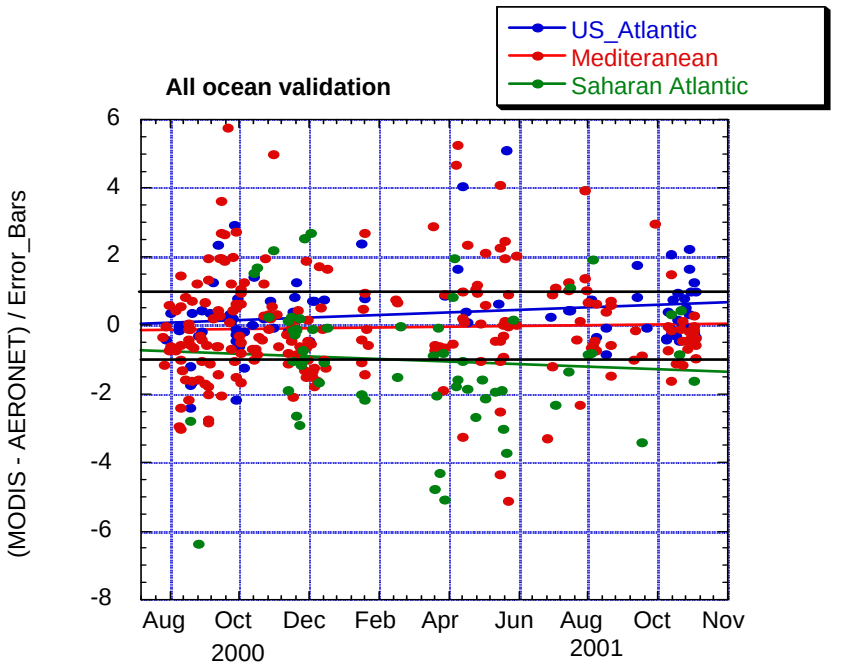


Regional AOD "Time Series" 2000-2001

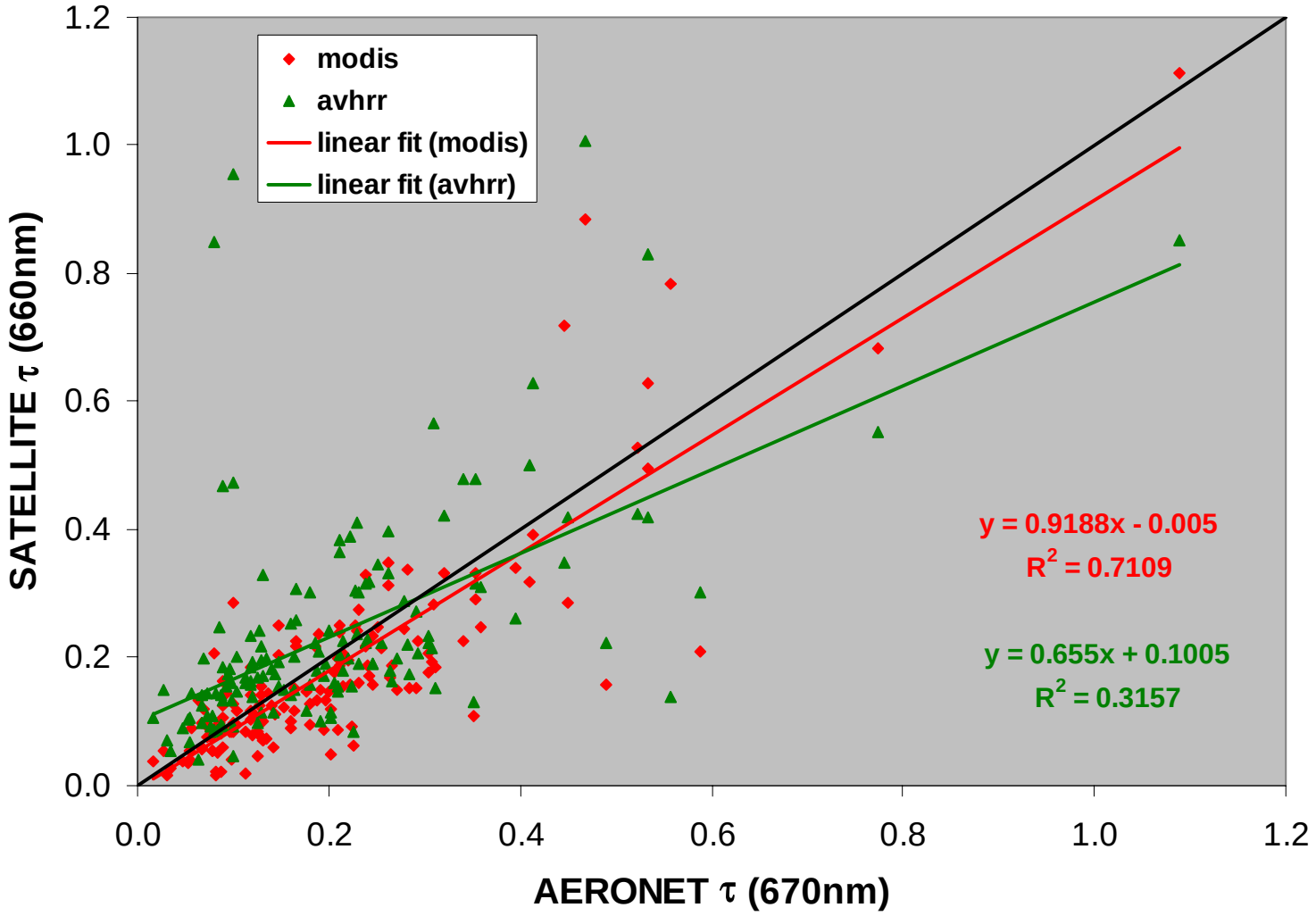
LAND location	N	% within error
France_land	332	77%
US east	282	56%
NA_west	168	85%
Med_land	139	60%
Brazil	102	82%
US central	100	72%
SAFARI	89	72%
East_Europe	58	84%
Asia	45	64%

OCEAN location	N	within error
Med_ocean	222	59%
US_Atlantic	86	77%
Saharan	63	37%

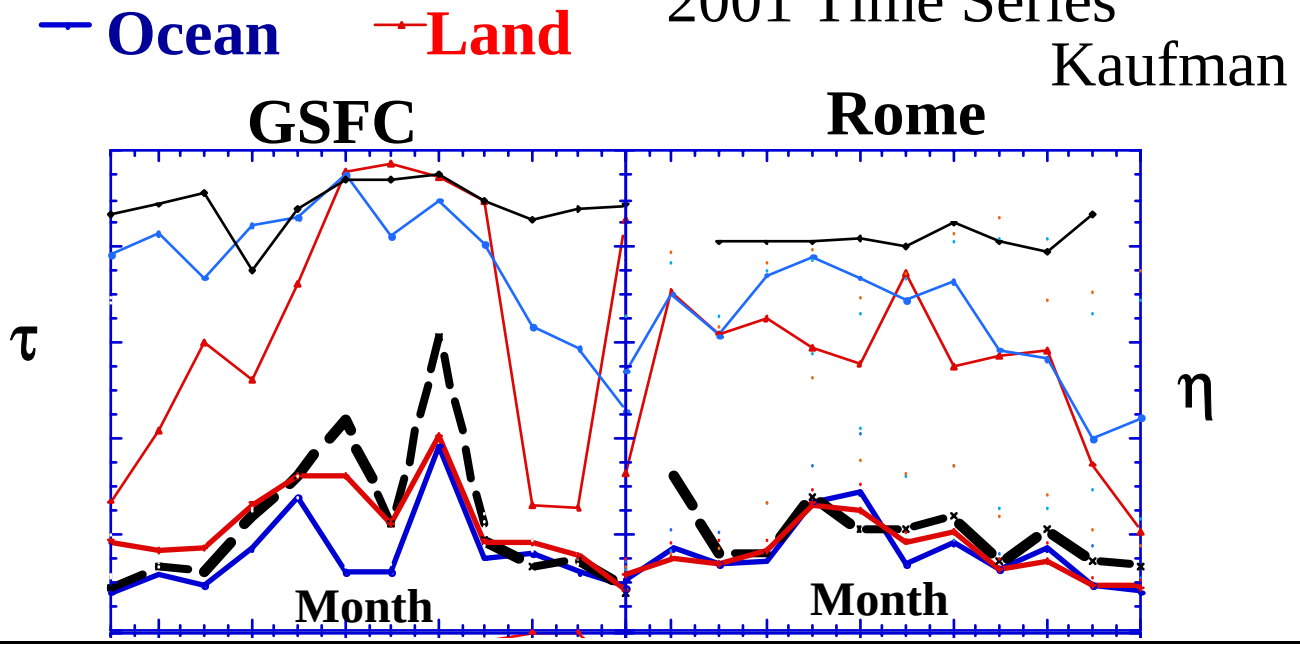




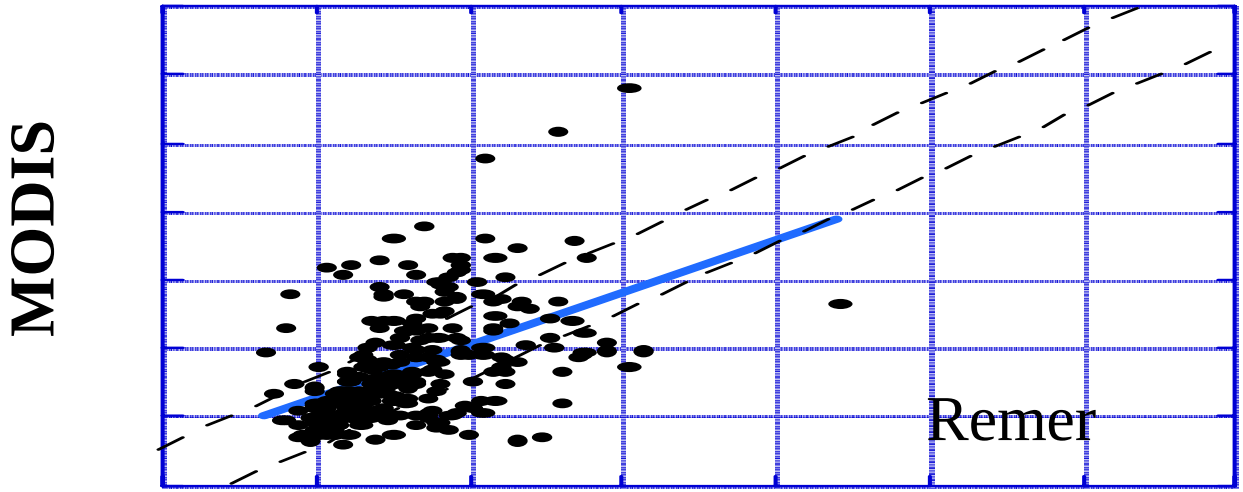
MODIS vs AVHRR over Ocean



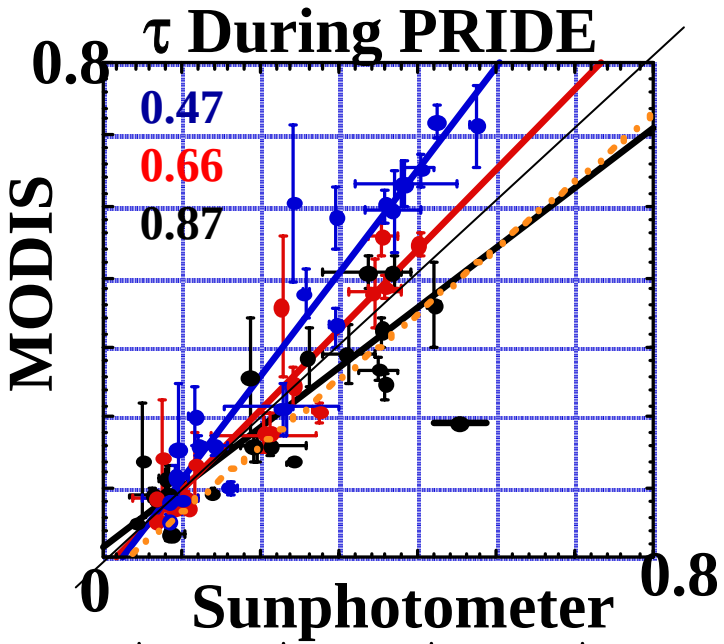
Courtesy of Xuepeng (Tom) Zhao, CIRA/NOAA

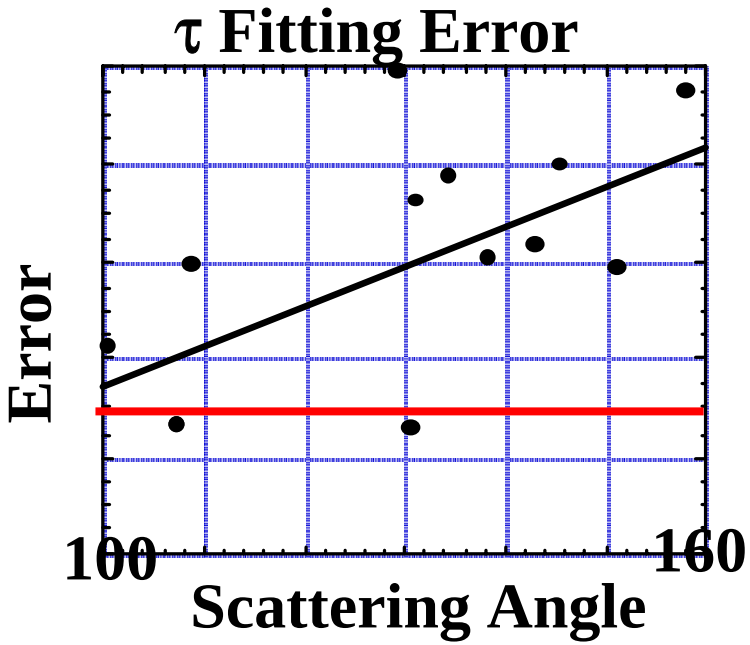


Wide Spectral Range-> Aerosol Size

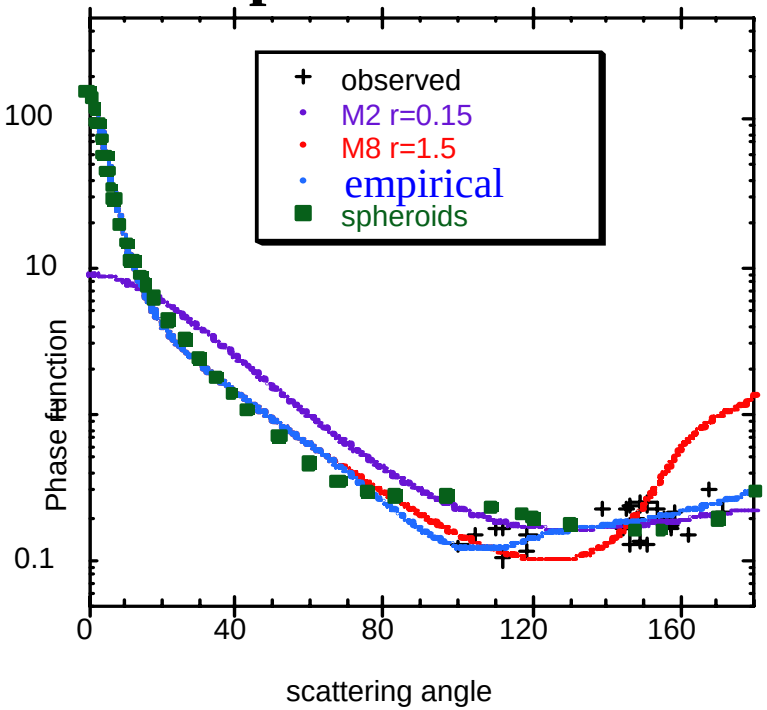


No filtering of dust.
271 co-located points with $\tau > 0.15$
from ~500 points for all τ.
62% fall with ±0.10 µm





PRIDE
(Jul 2000)



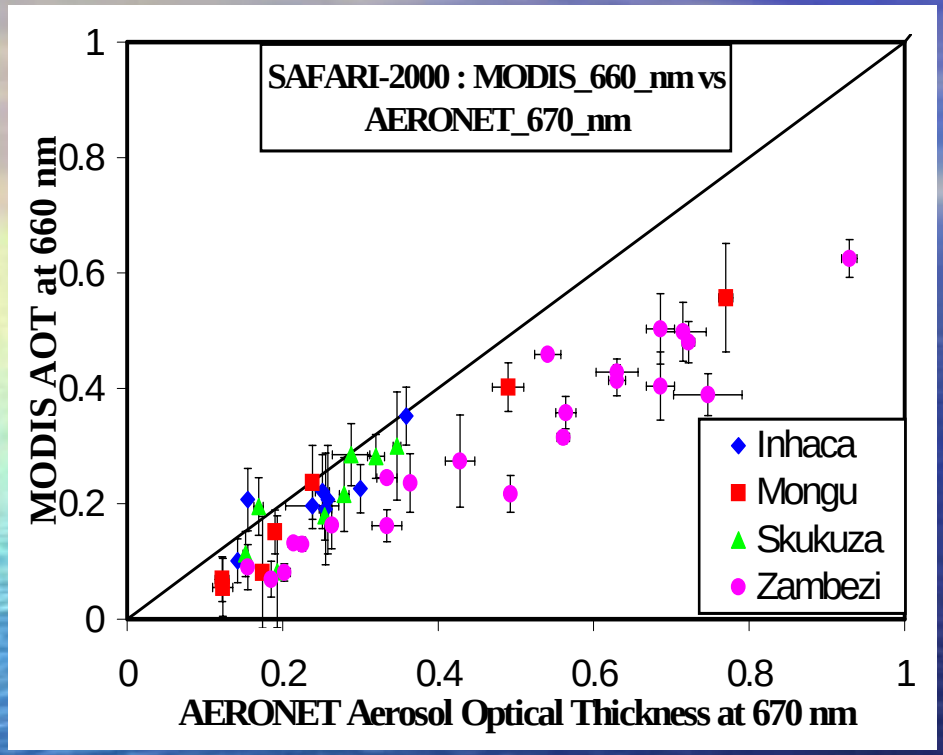
Dust phase function

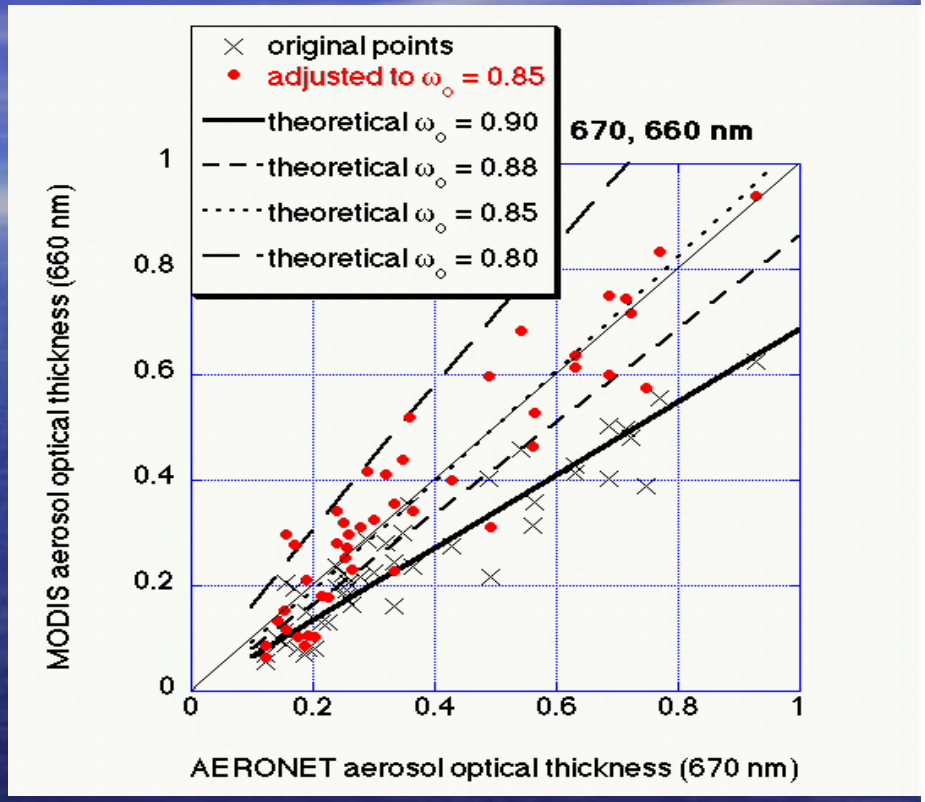
Currently MODIS systematically overpredicts spectral dependence (underpredicts size) without finding a good fit.

Empirical phase functions developed without any assumption of particle shape.

QuickTime™ and a
GIF decompressor

Smoke SSA: SAFARI-2000

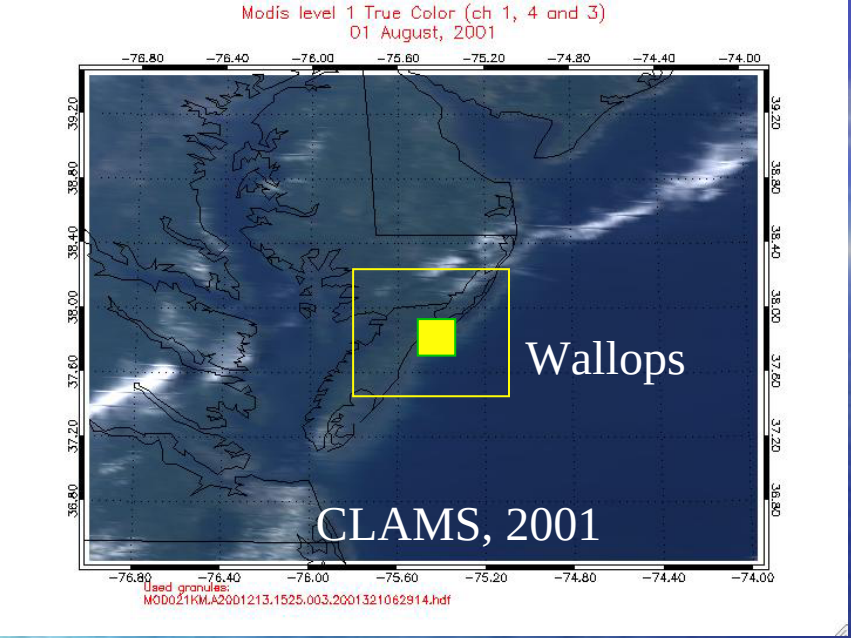


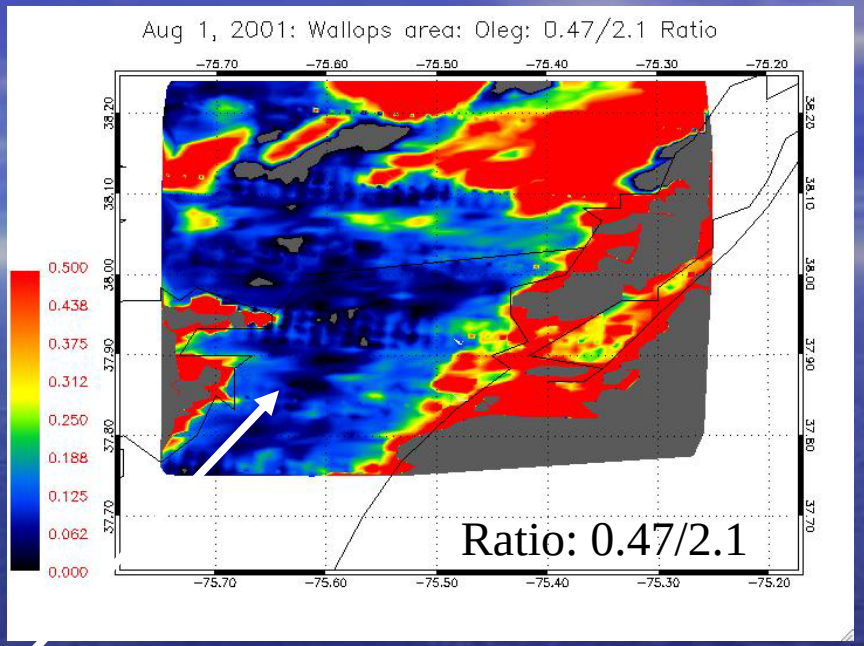


MODIS underestimates AOT during SAFARI-2000 especially in Zambia with heavy fresh smoke.
SSA (ω_0) suspected. (Also 440 nm)

Problem solved by decreasing ω_0 in region. (Ichoku et al., 2002, submitted to JGR, SAFARI 2000 special issue.

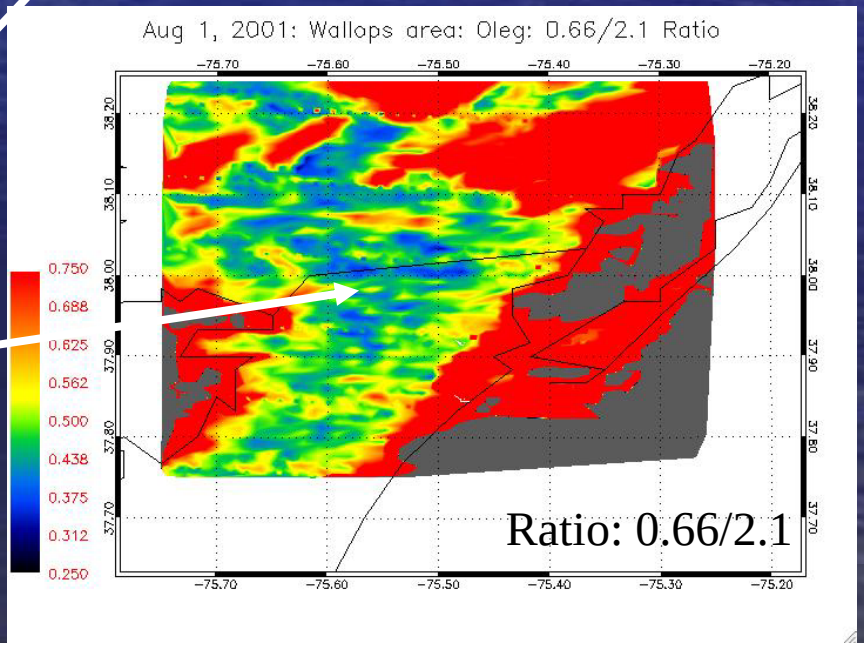
Surface Reflectance Ratio (Land)



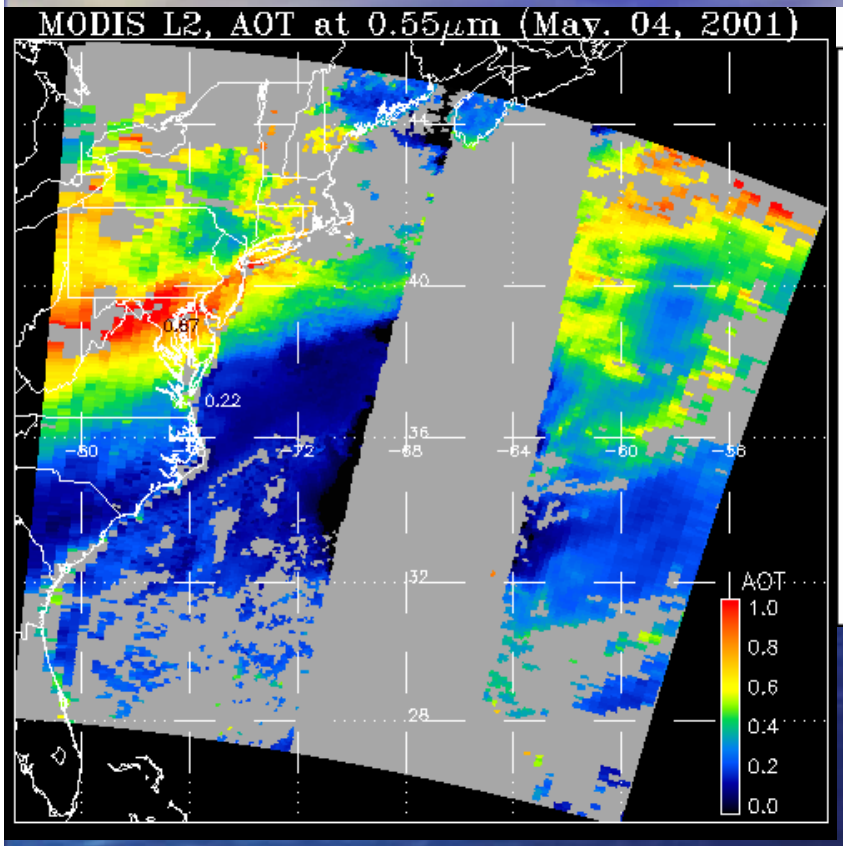


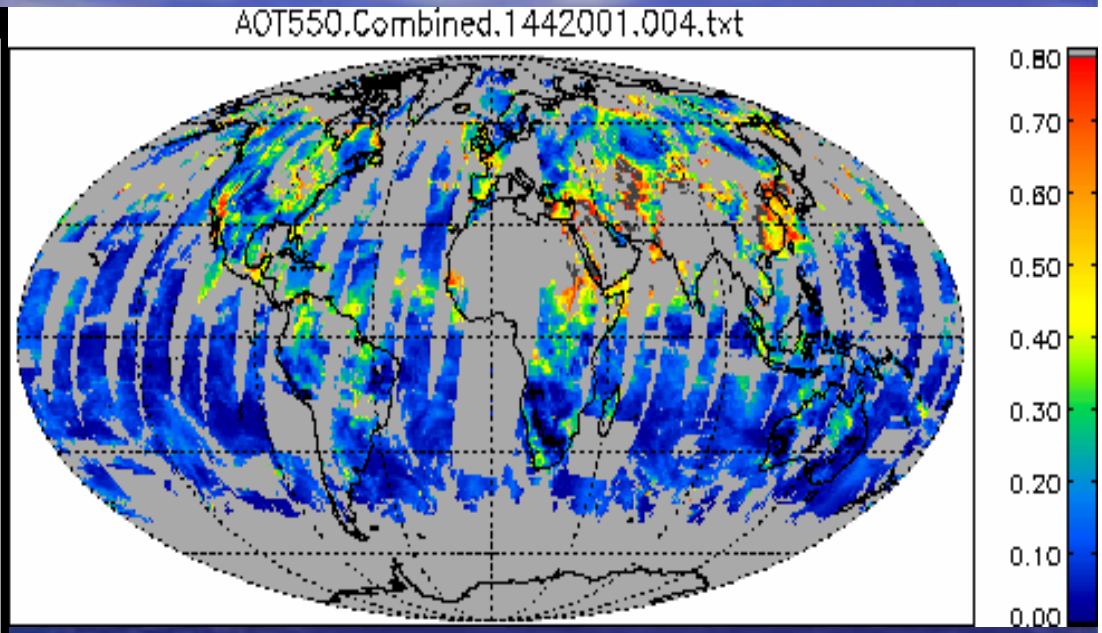
- Atmospheric correction with 6S
- Use AERONET from Wallops
- Examine surface reflectance ratios

- 0.47/2.1 = 0.15?
- 0.66/2.1 = 0.5?
- Over-estimating AOD in blue!!!



Level 2 ----------> Level 3 (daily)





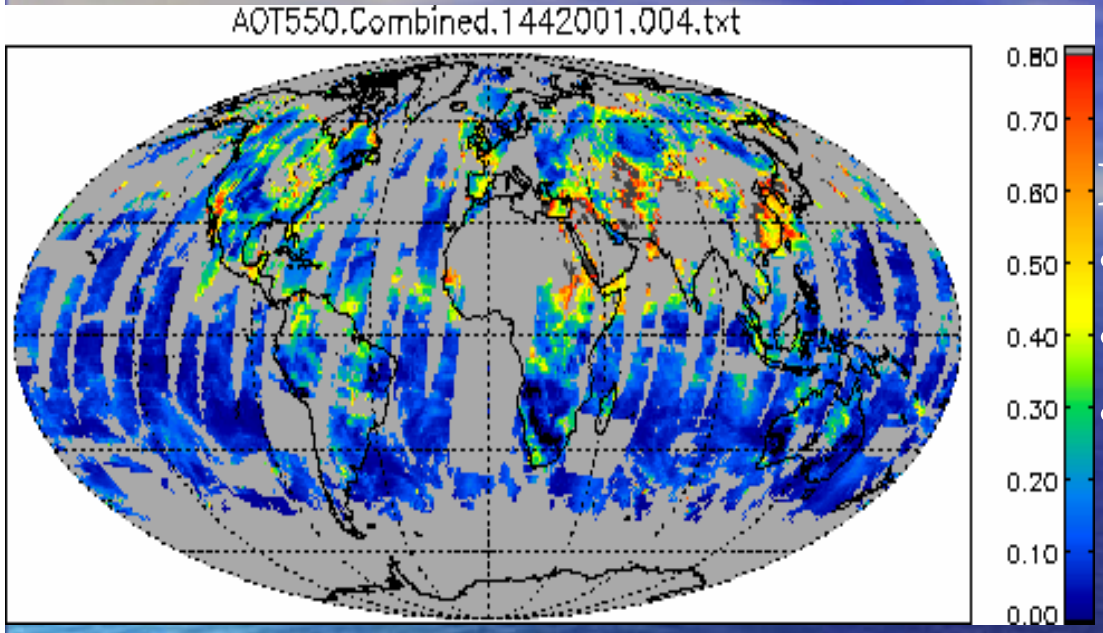
Level 2

- 10 x 10 km retrievals (irregular lat/long)
- 5 minute "granules"

Level 3 (daily)

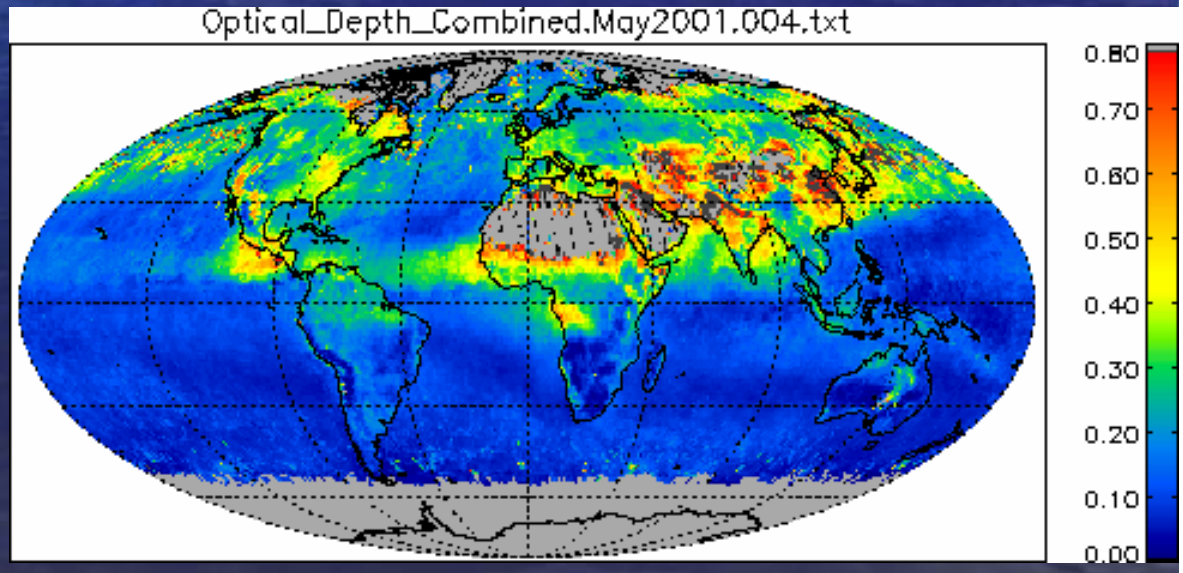
- 1º x 1º (regular lat/long)
- 5 minute granules "tiled"
- Statistics are produced
  - Mean, Stddev, Pixel Count, Histo
  - Quality Control / Confidence

Level 3 Daily -------> Level 3 Monthly

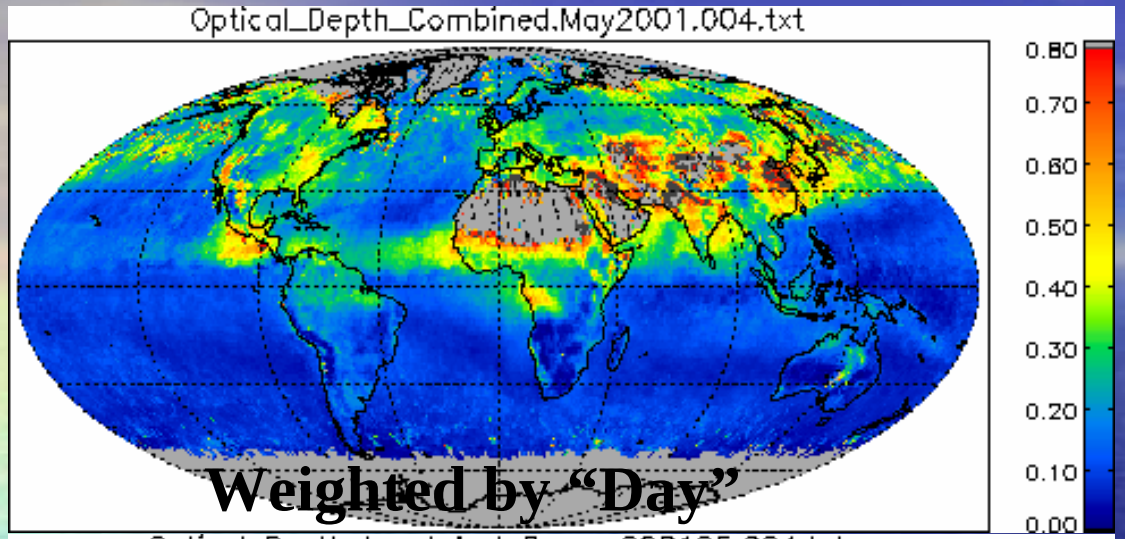


Level 3 (monthly)

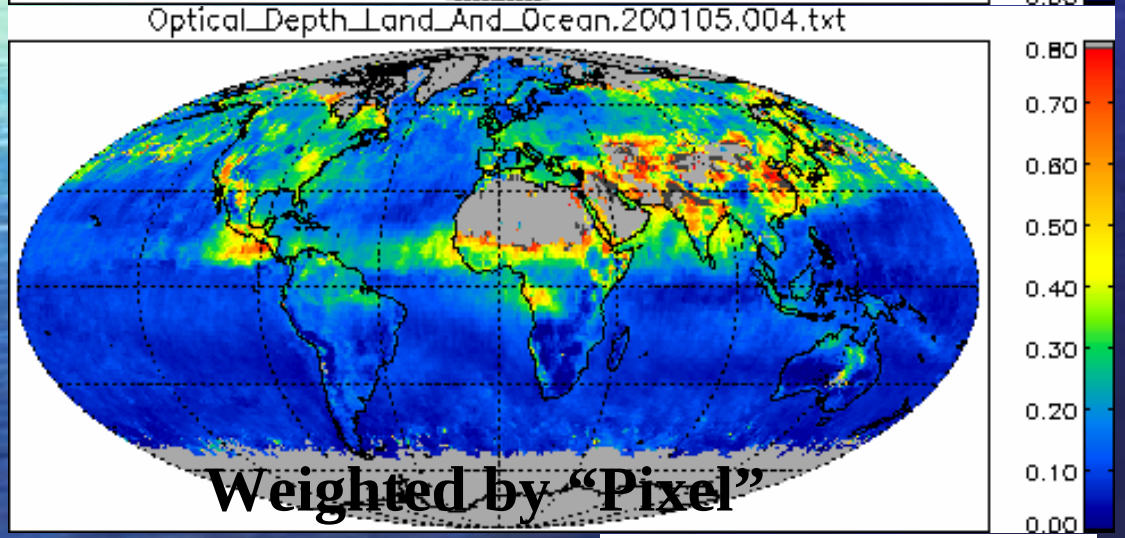
- 1º x 1º (regular lat/long)
- Daily values are "averaged"
- Statistics are produced
  - Mean, Stddev, Pixel Count, His
  - Quality Control / Confidence



Level 3 Monthly ISSUES



Weighted by "Day"

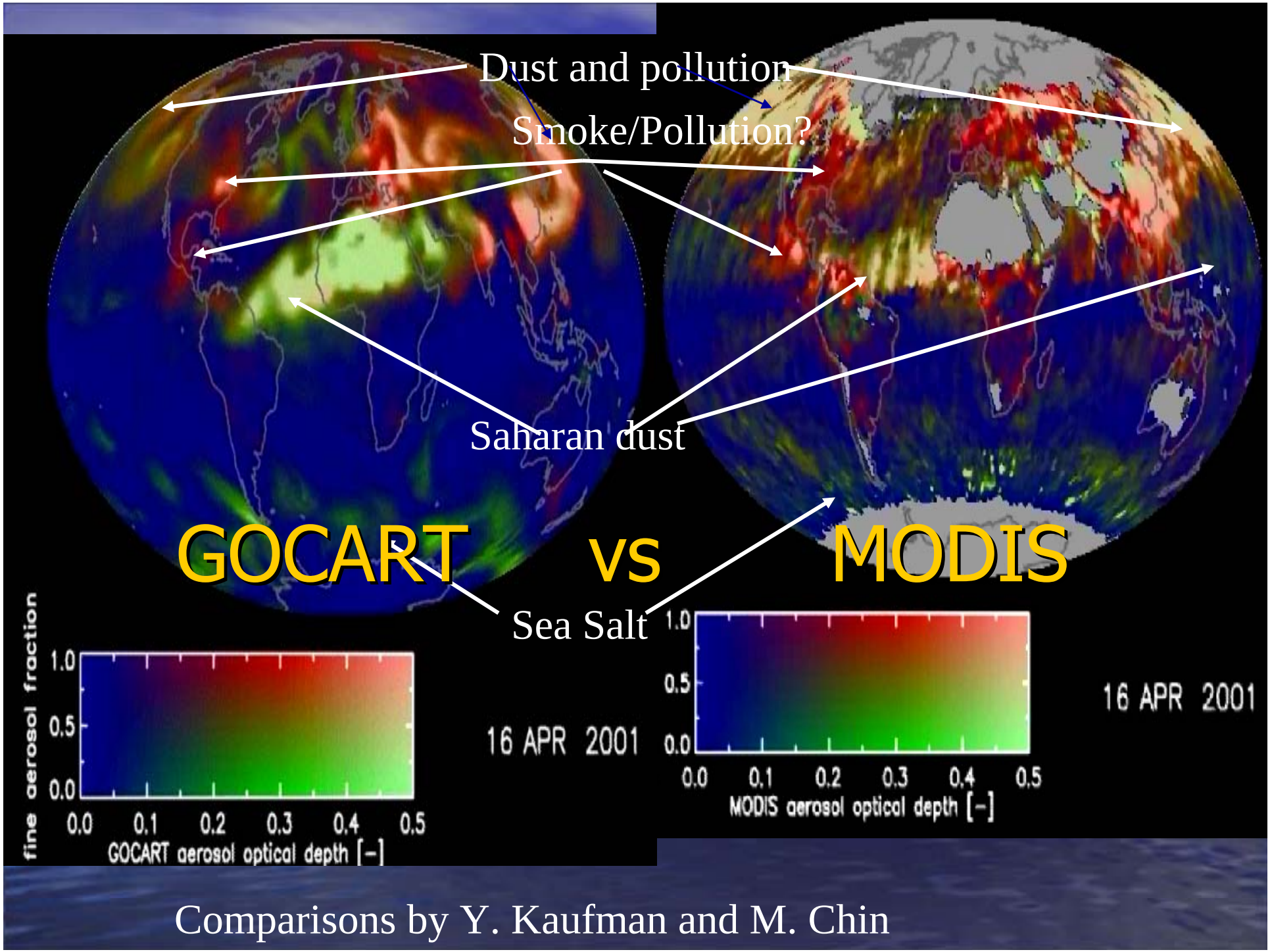


Weighted by "Pixel"

- **What is the high AOD in the North Pacific? Asian dust? Cloud contamination?**
- **Is the "average" of "daily" values a meaningful value?**
- **What happens when there is only one 10 x 10 km "pixel" in a 1° x 1° box? (Red spots in Southern Oceans)**

Pixel Weighted Average = $\bar{\tau}_m = 1/n_t \sum_{d}^{\#days} \tau_d n_d$

- **Reduces global AOD by 0.02**
- **Removes red "spots"**
- **Can put minimum on n_d**



Comparisons by Y. Kaufman and M. Chin

MODIS and GOCART L3 Movie

Imagery by Reto Stockli

New MODIS Daily L3 Tool (Area Plot)

MODIS/Terra Aerosol Cloud Water Vapor Ozone Online Visualization and Analysis

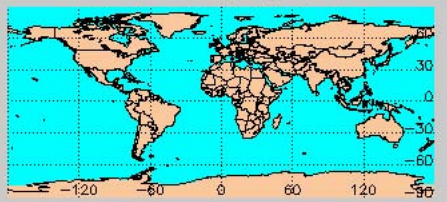
This interface is designed for visualization and analysis of the MODIS Level-3 atmosphere monthly global product (MOD08_M3). Users can plot area average (area plot) and time series (time plot) or generate ASCII output for selected area and time period.

Spatial coverage: 90°S - 90°N
Spatial resolution: 1° x 1°
Temporal resolution: Monthly
Documentation: MODIS/Terra Aerosol Cloud Water Vapor Ozone README
Data Access: Search and order the original data files
FTP download the GrADS data files

For other MODIS products, please visit http://daac.gsfc.nasa.gov/MODIS/products.shtml.

Continued funding for improvement of this online tool and production and dissemination of these data sets depends on you, our users, to let us know how you have used this tool and these data, and what are their value to your research. Please send your comments to the MODIS Data Support Team (modis-dst@daac.gsfc.nasa.gov).

Click and drag to select area; maximum area is 90°S ~ 90°N and 180°W ~ 180°E; or input latitudes (-90.0 ~ 90.0) and longitudes (-180.0 ~ 180.0).
Please do not use "Shift" button in the Java Applet yet (Related function is being implemented.).



Shift Map | Clear

West Longitude | North Latitude

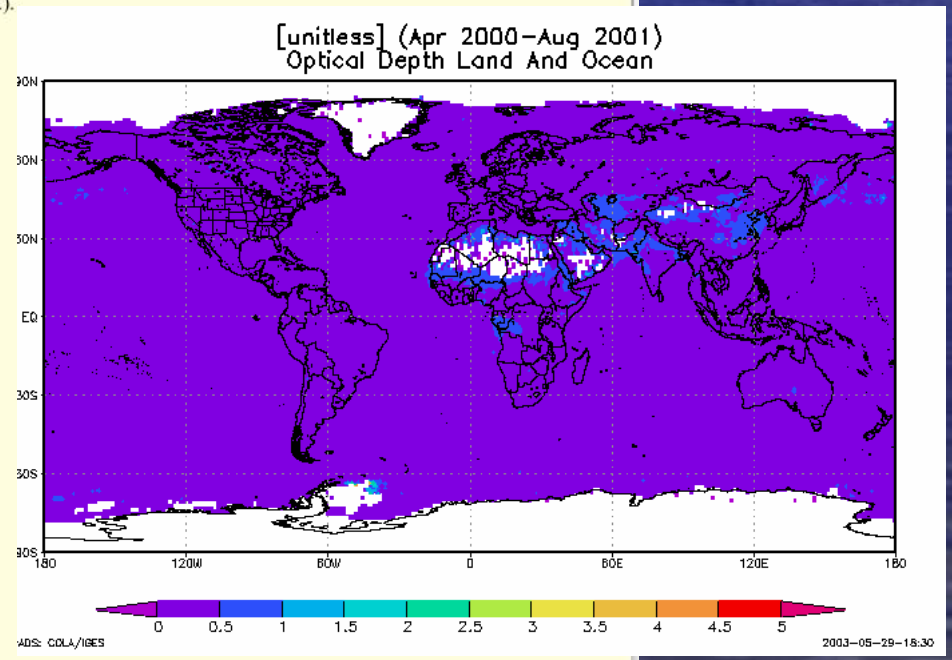
East Longitude | South Latitude

Click for non Java/JavaScript version

Parameter: Optical Depth Land And Ocean
Plot type: Area Plot

	Year	Month	Data Available
Begin date	2000	March	(Begin: 2000/04)
End date	2001	August	(End: 2003/03)

Generate Plot | ASCII Output | Reset Form



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Continued funding for improvement of this online tool and production and dissemination of these data used this tool and these data, and what are their value to your research. Please send your comments to t

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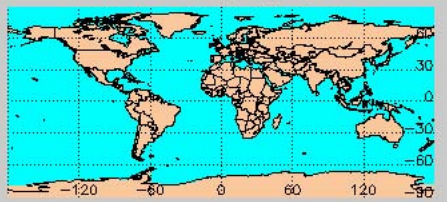

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	Year	Month	Data Available
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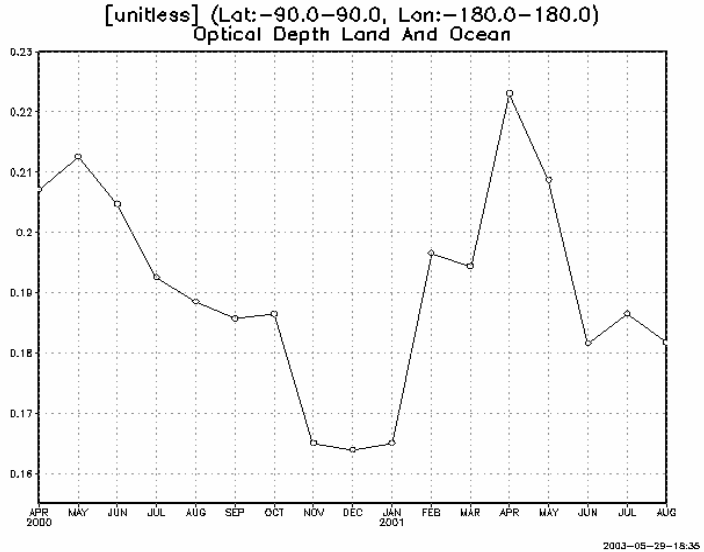
Generate Plot | ASCII Output | Reset Form

Online Analysis Output Image



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NASA Official: Steve Kempler, DAAC Manager -- Steven.J.Kempler@nasa.gov
Last updated: Mon Mar 24 12:29:05 EST 2003

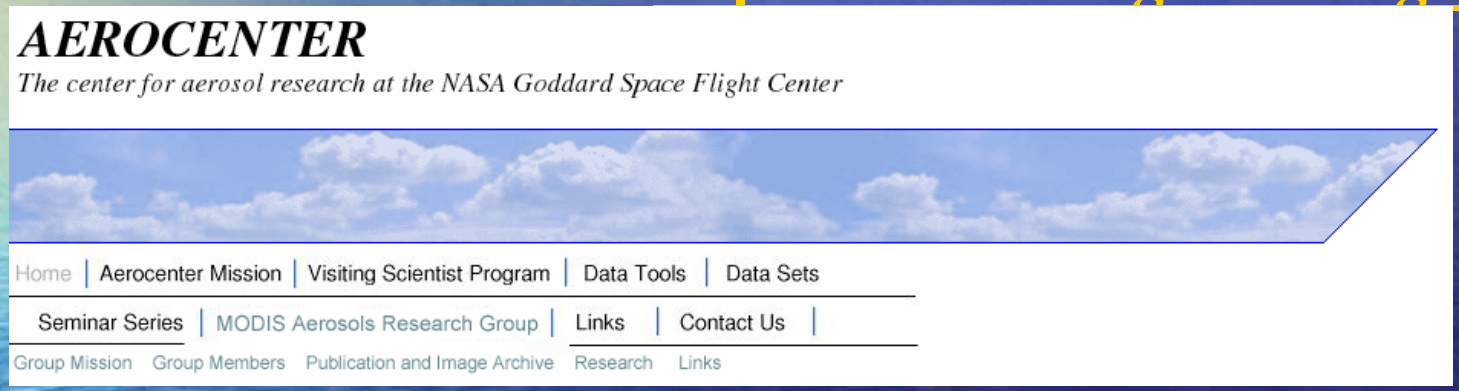
Conclusions

1. MODIS provides accurate τ retrievals over ocean (error cut in half)
2. One of the first attempts at operational τ retrievals over land
3. Both land/ocean τ retrievals are meeting expectations
4. Retrieval of quantitative size information over ocean
5. However there are "issues we are working on including:
   - Creating improved dust models (phase functions)
   - Examining Single Scattering Albedo
   - Evaluating surface reflectance assumptions
6. Level 2 "granules" are being made into meaningful Level 3 "daily" products. Nice web tool in the future
7. Level 3 "monthly" data products are being evaulated

Web Sites

Links to Data, Publications and other goodies

- **Aerocenter Web Site: http://aerocenter.gsfc.nasa.gov**



- **MODIS web site: http://modis.gsfc.nasa.gov**
- **MODIS atmosphere : http://modis-atmos.gsfc.nasa.gov**