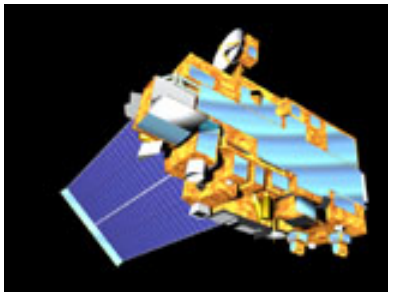
Remote Sensing Training Workshop
MODIS Level 2 Products (cont.)

1 March 2006

Kathleen Strabala



Cooperative Institute for Meteorological Satellite Studies

University of Wisconsin-Madison USA

Viewing Atmospheric Aerosols From the MODIS Satellite Sensor

Lorraine A. Remer
NASA/Goddard Space Flight Center

And the MODIS aerosol team: Y.J. Kaufman, D. Tanré
D.A. Chu, C. Ichoku, R. Kleidman, I. Koren, R. Levy,
R-R. Li, J.V. Martins, S. Mattoo

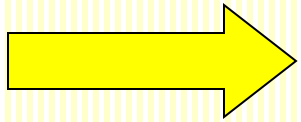
Theory

Deriving aerosol over land.

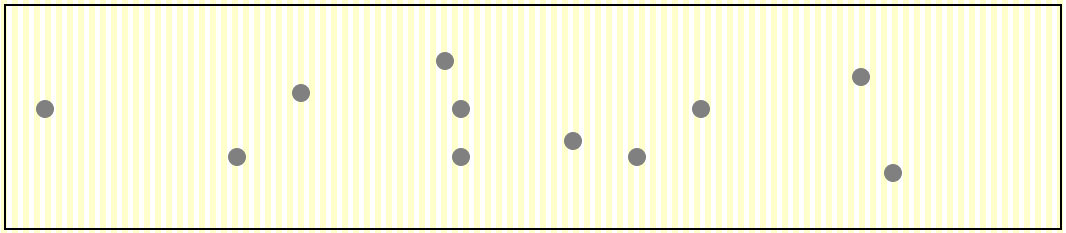
Problem: Land surface variability.

At the satellite, how do we separate signal originating from the atmosphere containing information about the aerosol from signal originating from the land surface?

Scattering and Absorption of Light by Aerosols



I_o=Light Source (W/m²)



L=Path Length

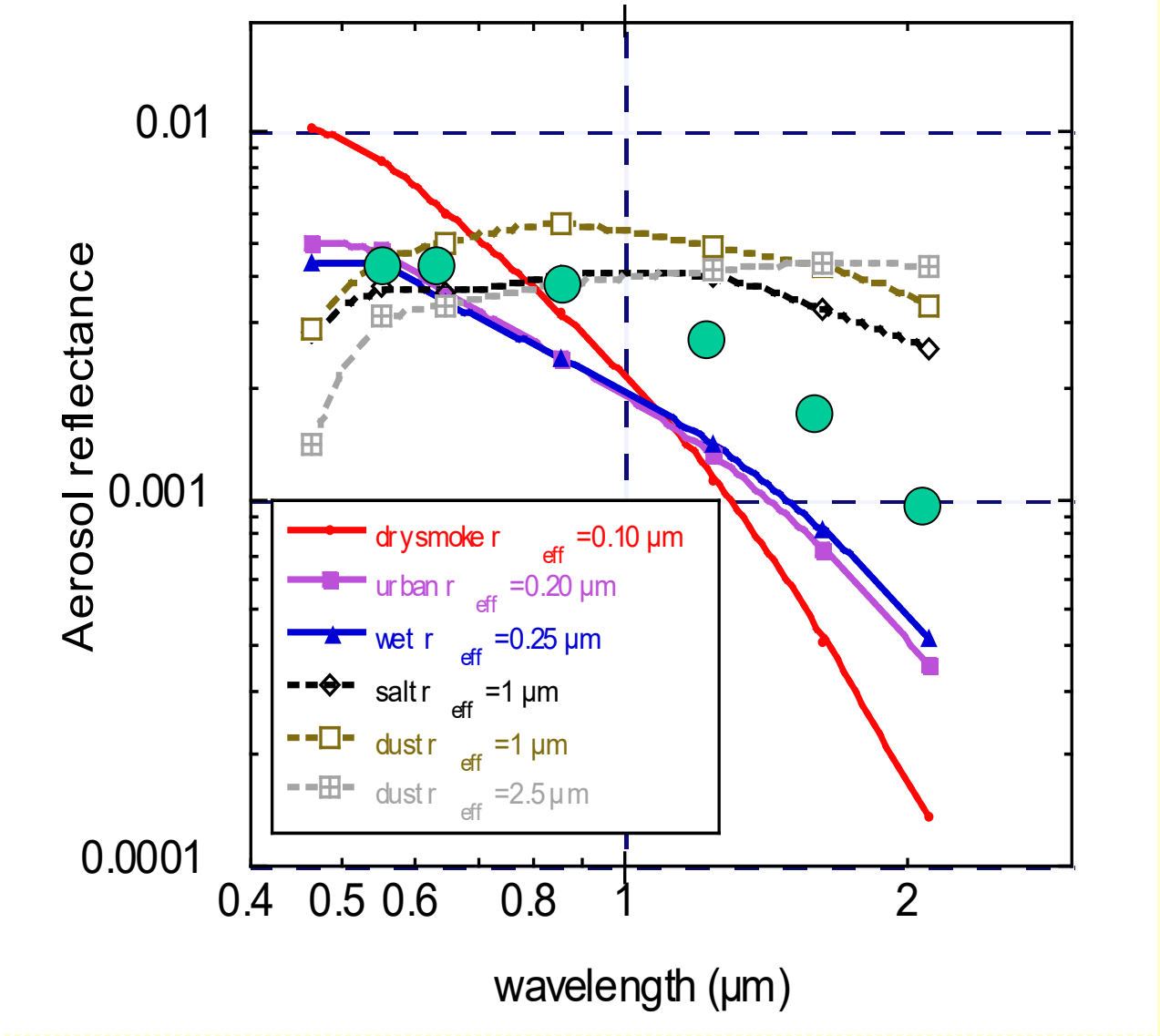
I=Light Detector (W/m²)

$$\frac{I}{I_0} = e^{-\sigma_{ext} L} = e^{-(\sigma_{sp} + \sigma_{ap}) L}$$

$$\tau = (\sigma_{sp} + \sigma_{ap}) * L \qquad \varpi = \sigma_{sp} / (\sigma_{sp} + \sigma_{ap})$$

The quantity L is called the density weighted path length. $\sigma_{ext(\lambda)}$ L is a measure of the cumulative depletion that the beam of radiation has experienced as a result of its passage through the layer and is often called the optical depth τ_λ.

Getting A Best Fit for the Observations
Match Theory and Observations



Wide Spectral Range makes land retrieval possible

- **Mid-IR is used to observe the surface brightness**
- **Then aerosol is derived from estimated surface reflectance in the visible and actual reflectance**

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

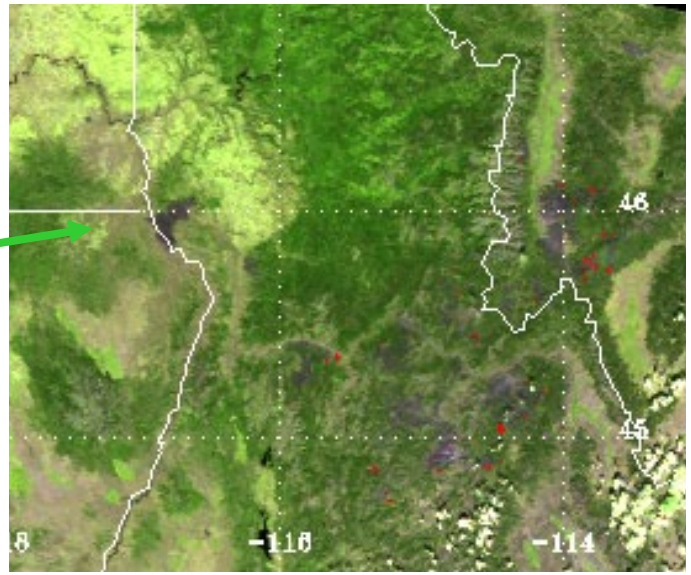
$\tau_{0.47} \sim [\rho^*_{0.47} - 0.25\rho^*_{2.1}]$

$\lambda(\mu m)$

1.2

1.6

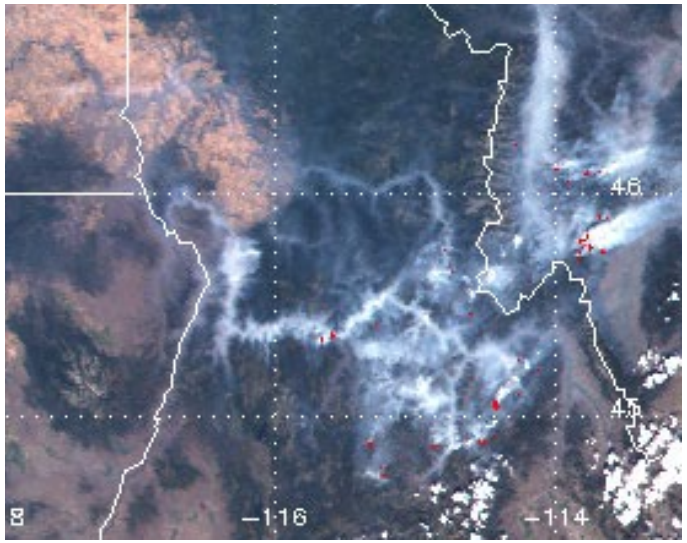
2.1



0.47

0.55

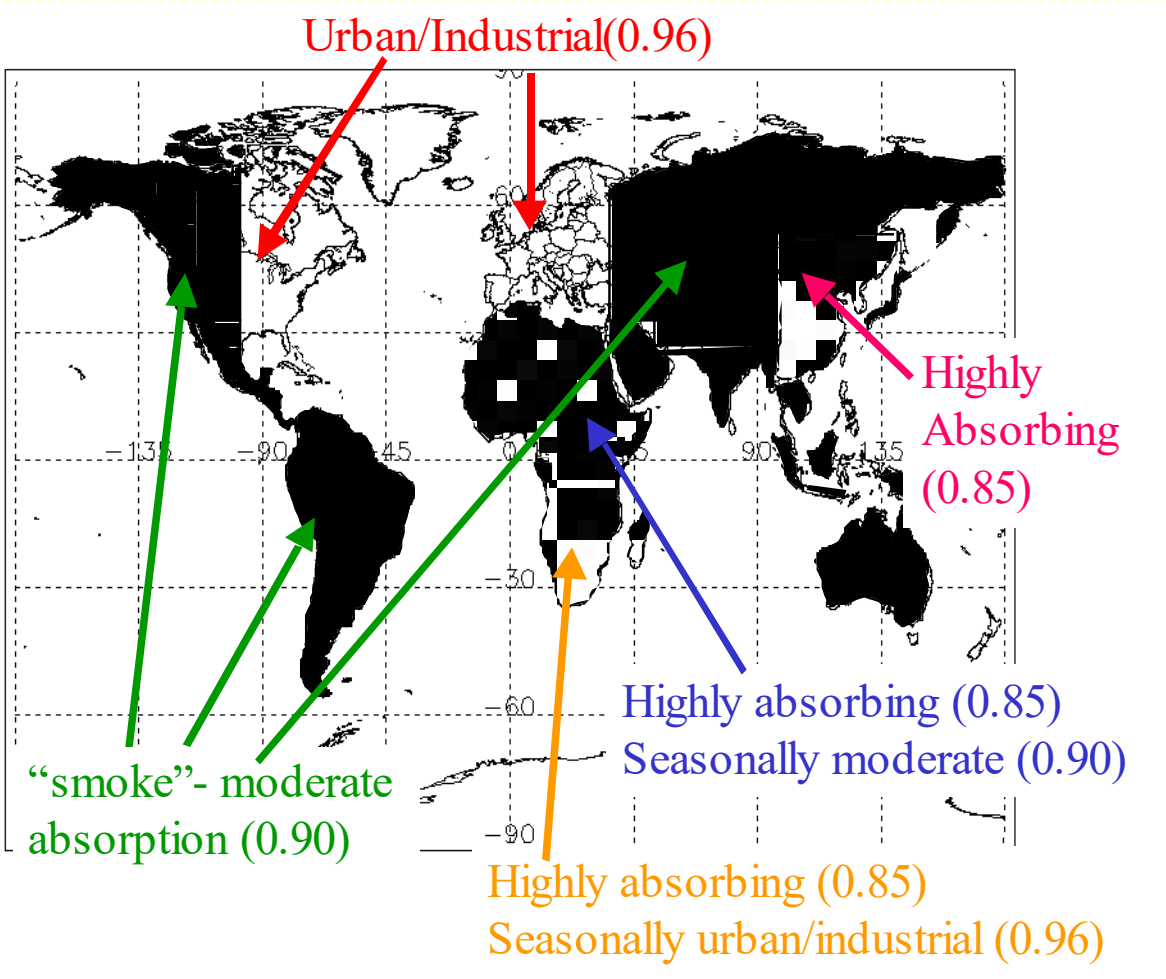
0.66



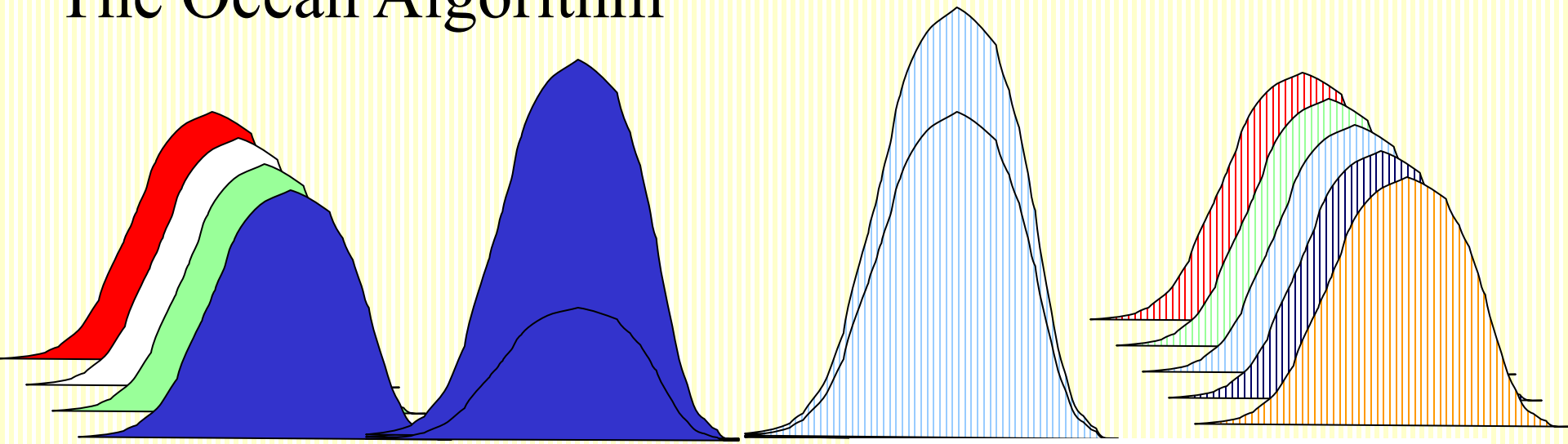
Yoram Kaufman

3 non-dust models
plus dust
Set by geography and
season

Models are dynamic f(τ)

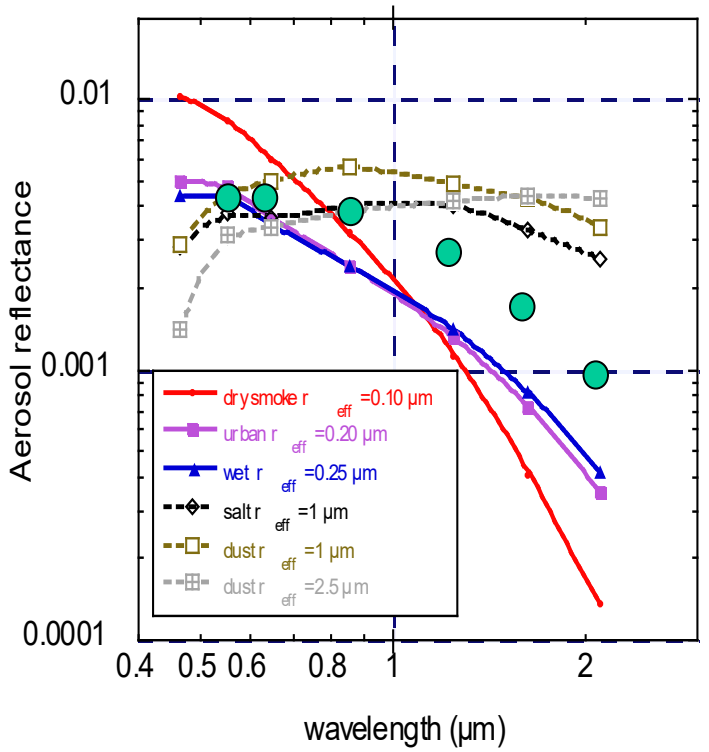


The Ocean Algorithm

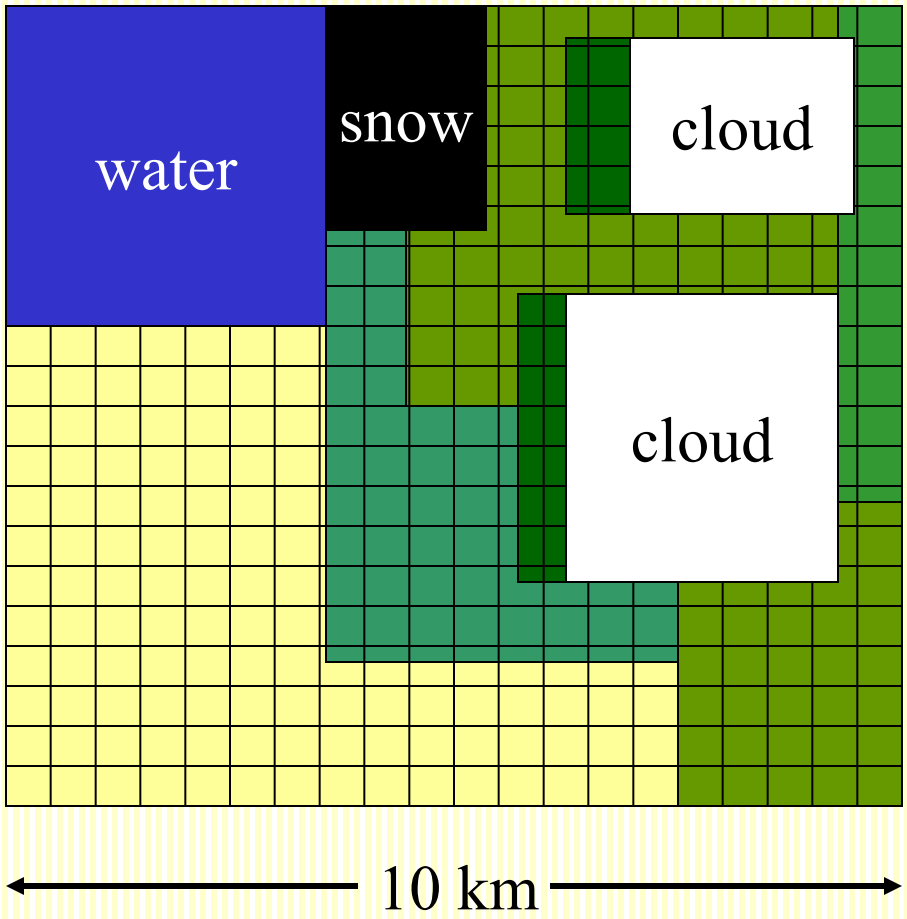


Choice of 4 fine modes
and 5 coarse modes

In order to minimize
$(\rho_{meas} - \rho_{LUT})$ over 6 wavelengths



MODIS Over Land Algorithm
20 x 20 pixels at 500 m resolution
(10 km at nadir)



400 total
- 56 water

344
- 24 snow

320
- 55 cloud

265
-116 “bright”

149 “good”

Discard brightest 50% and darkest 20% of the 149 good pixels.

44 pixels

Non-static Inputs

- MODIS L1B (MOD021KM, MOD02HKM, MOD02QKM) and geolocation file (MOD03)
- MODIS Cloud Mask (MOD35)
- 6 hourly Global Data Assimilation System T126 resolution analysis from NCEP (Land Surface Temperature) Water vapor information (not mandatory)
  ex: gdas1.PGrbF00.020430.00z
- Daily TOVS and SBUV/2 Total Ozone from NESDIS

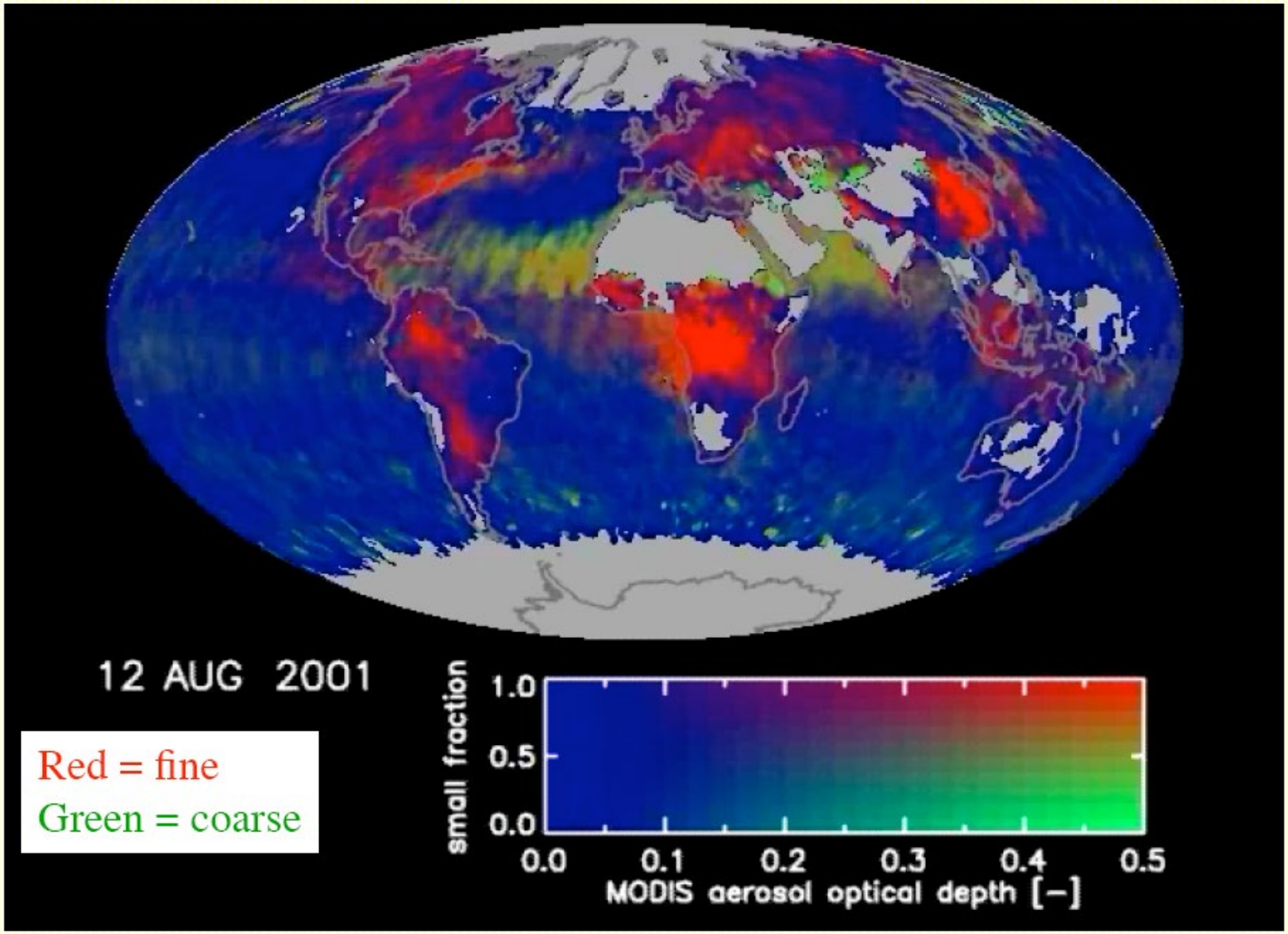
  1 x 1 degree resolution (not mandatory)
  ex: TOAST16_050615.GRB
- Latest 7 days ancillary data and documentation available from:

Output Product Description

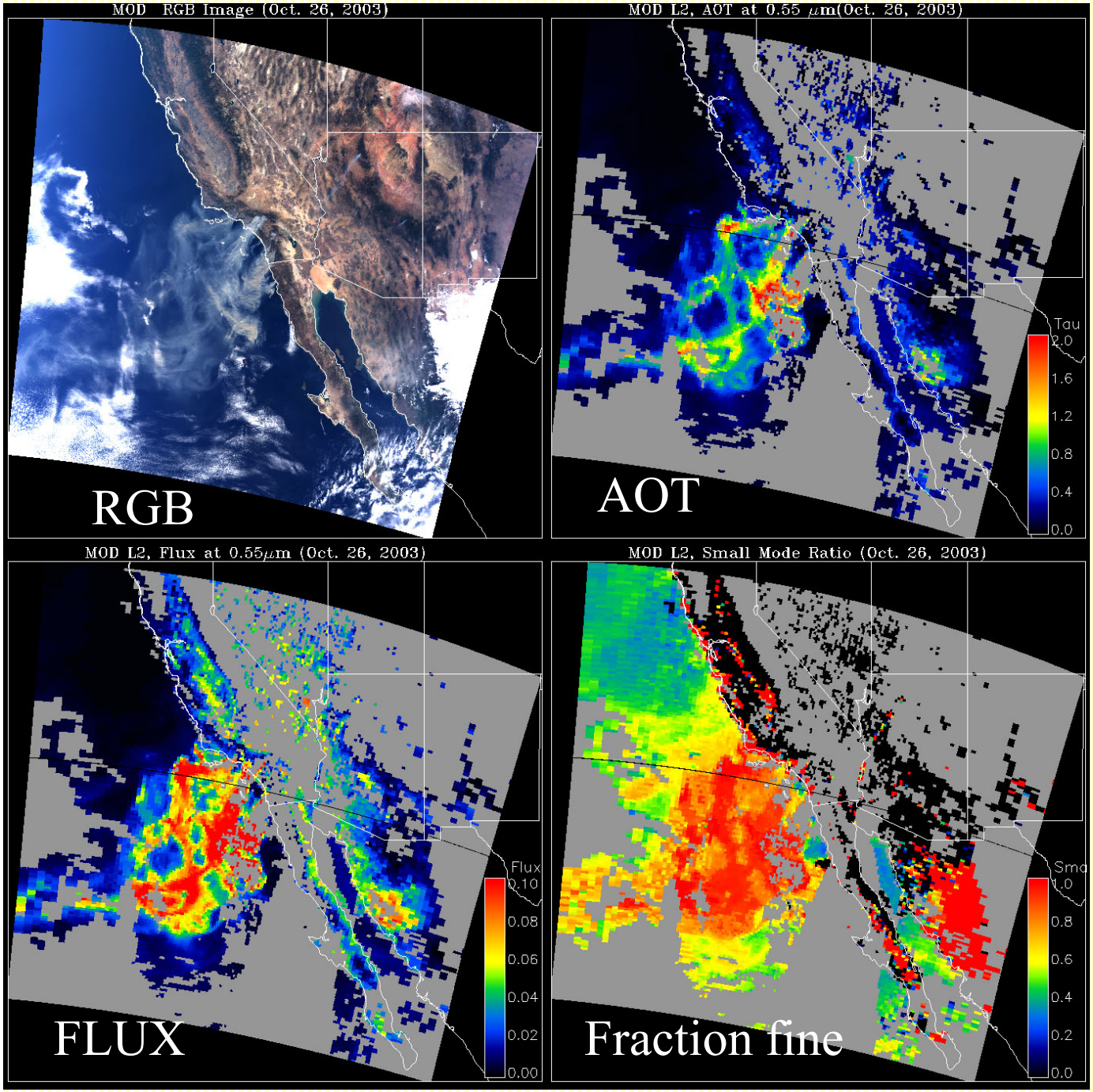
MOD04 Key Output Parameters

10x10 pixel (1km) resolution

- Optical_Depth_Land_And_Ocean – Aerosol Optical Thickness (AOT) at 0.55 microns for both ocean (best) and land (corrected)
- Optical_Depth_Ratio_Small_Land_And_Ocean - Ratio of small mode optical depth to total at 0.55 microns
- Corrected_Optical_Depth_Land (3 bands) - Corrected optical thickness at 0.47, 0.55, and 0.66 microns
- Effective_Optical_Depth_Average_Ocean (7 bands) - AOT at seven bands for average solution at .47, .55, .66, .86, 1.2, 1.6 and 2.1



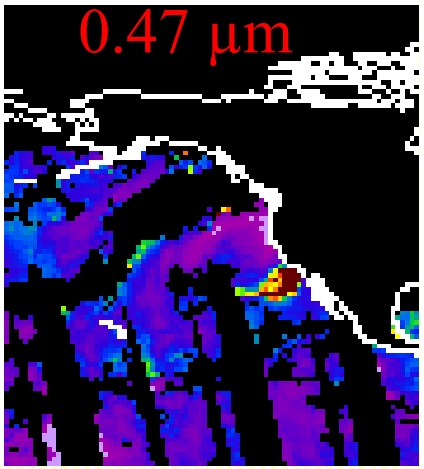
Separating fine mode from coarse mode aerosol

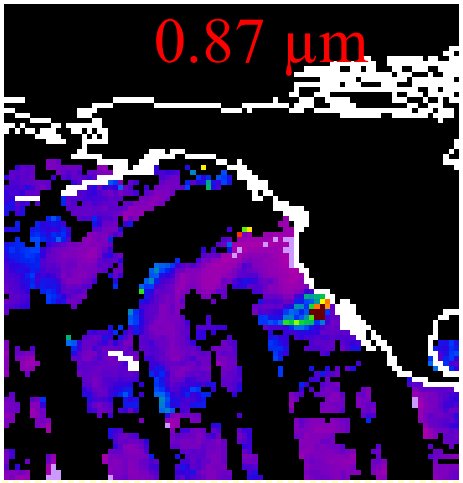


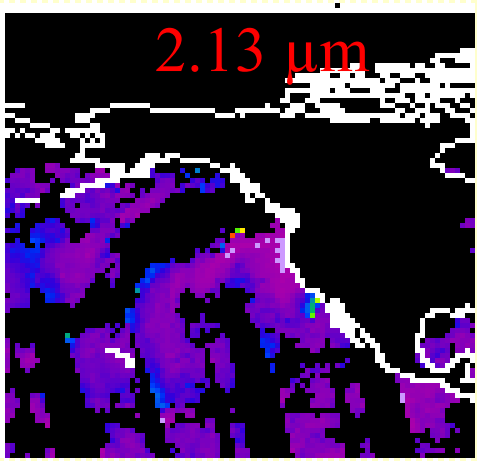
California Wildfires Oct. 26, 2003

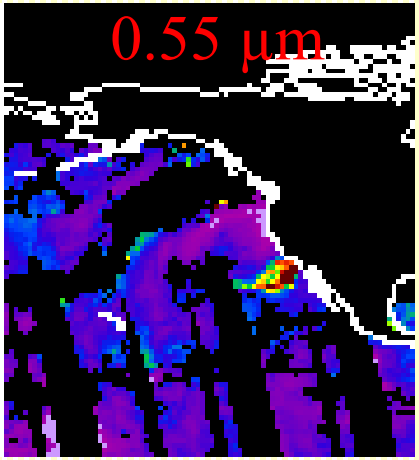
From Terra-MODIS

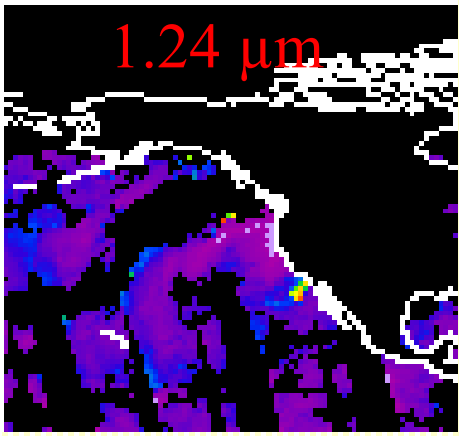
Rong-Rong Li







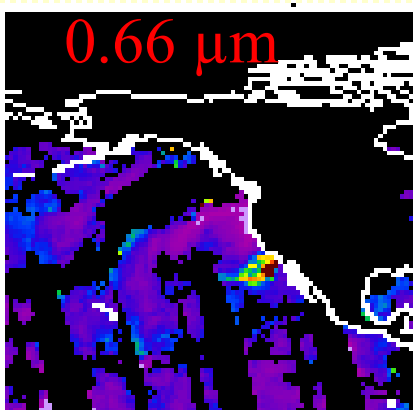


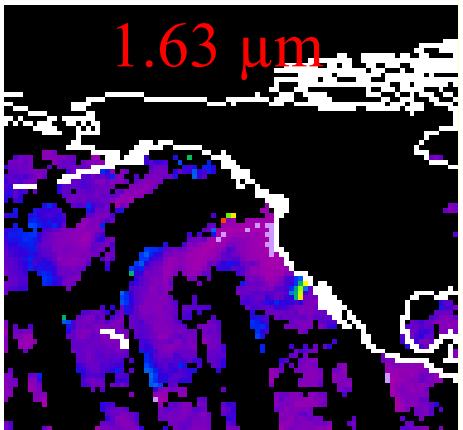


Spectral Optical Thickness

7 wavelengths over ocean

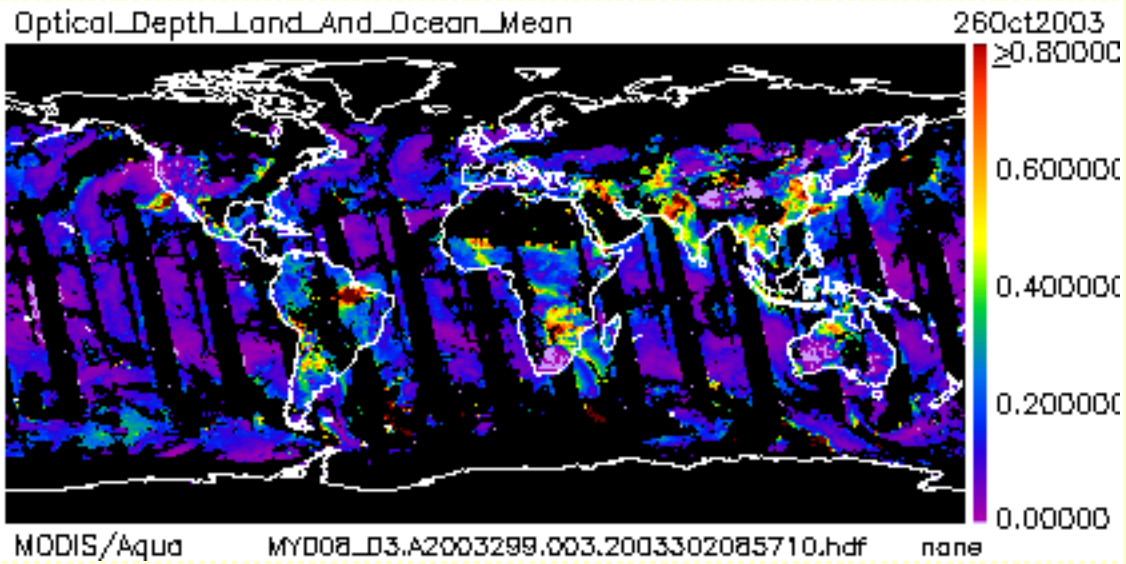
3 wavelengths over land



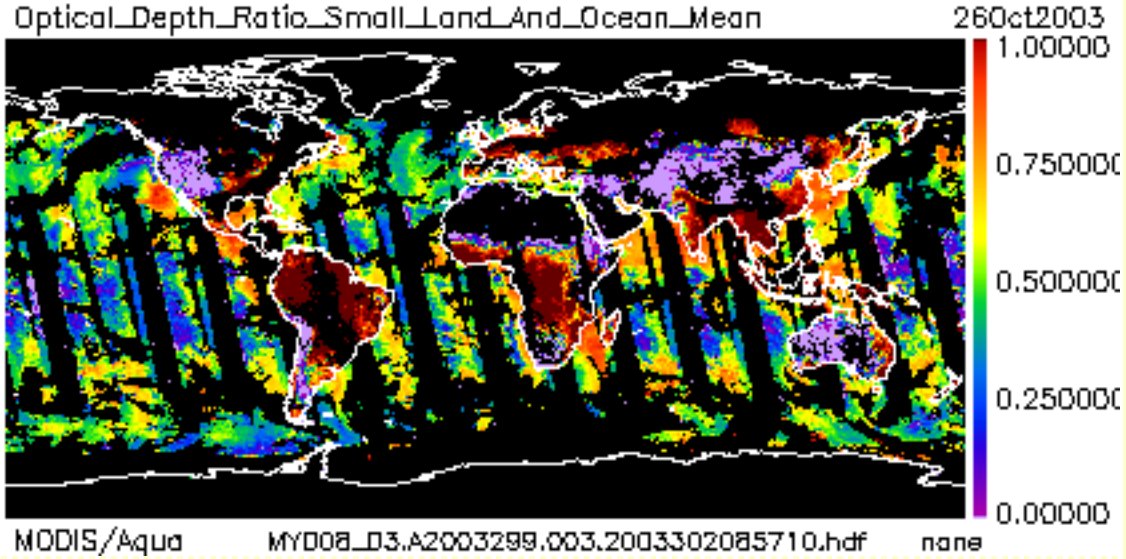


Cropped from images by Paul Hubanks

Aerosol Optical Thickness



Fine mode fraction



The global aerosol

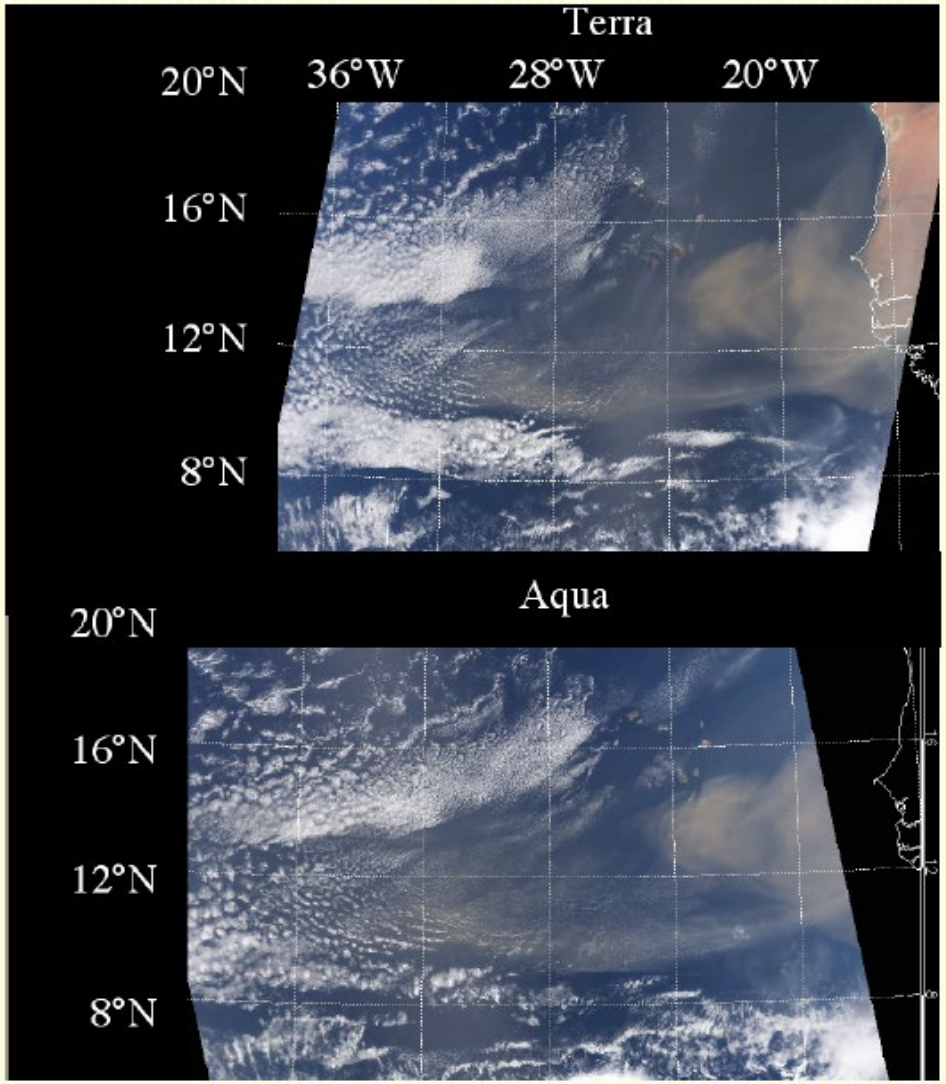
MOD08_D3

Daily Level 3
1 degree data

October 26, 2003

http//:modis-atmos.gsfc.nasa.gov

Paul Hubanks



Two MODIS instruments.

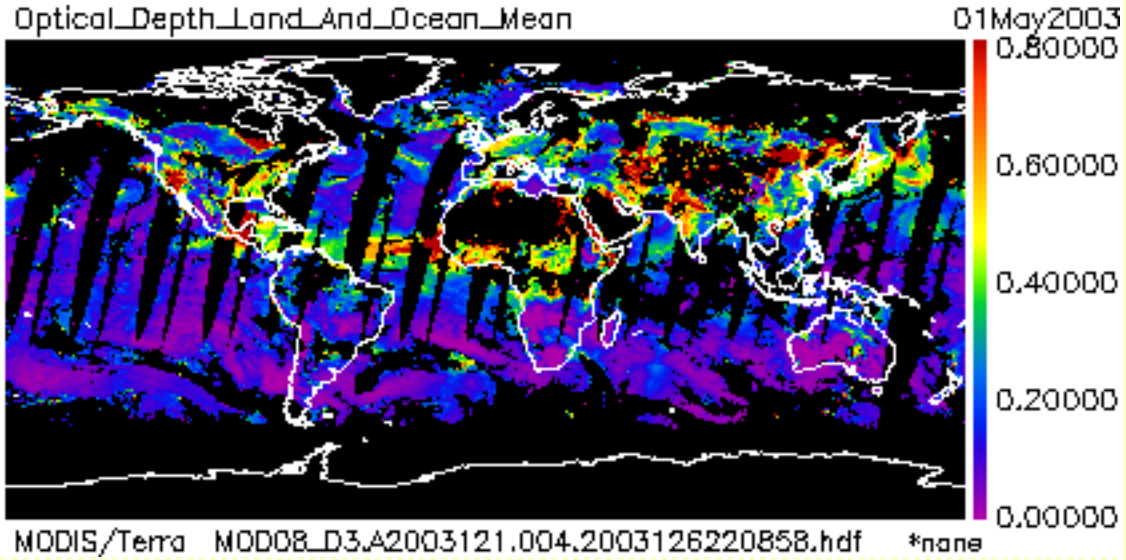
Terra (10:30 am local time) and Aqua (1:30pm local time)

May 1st, 2003.

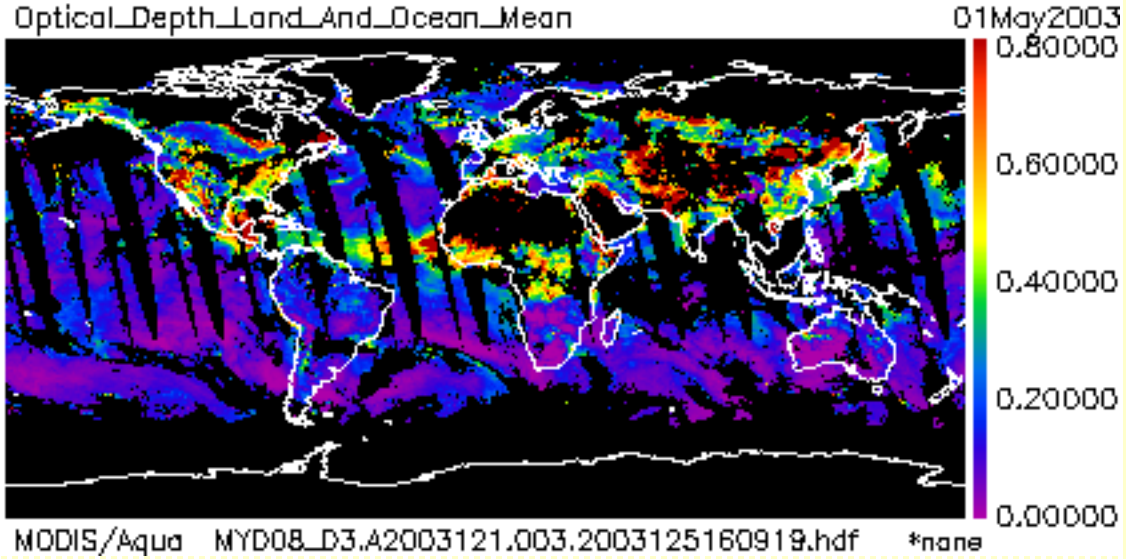
The dust storm moved 120 kms between the Terra and Aqua observations, corresponding to wind speed in the dust layer of 11m/s.

Ilan Koren and Yoram Kaufman

Terra



Aqua



MOD08_D3

Daily Level 3 aerosol optical thickness on a 1 degree global grid

May 1, 2003

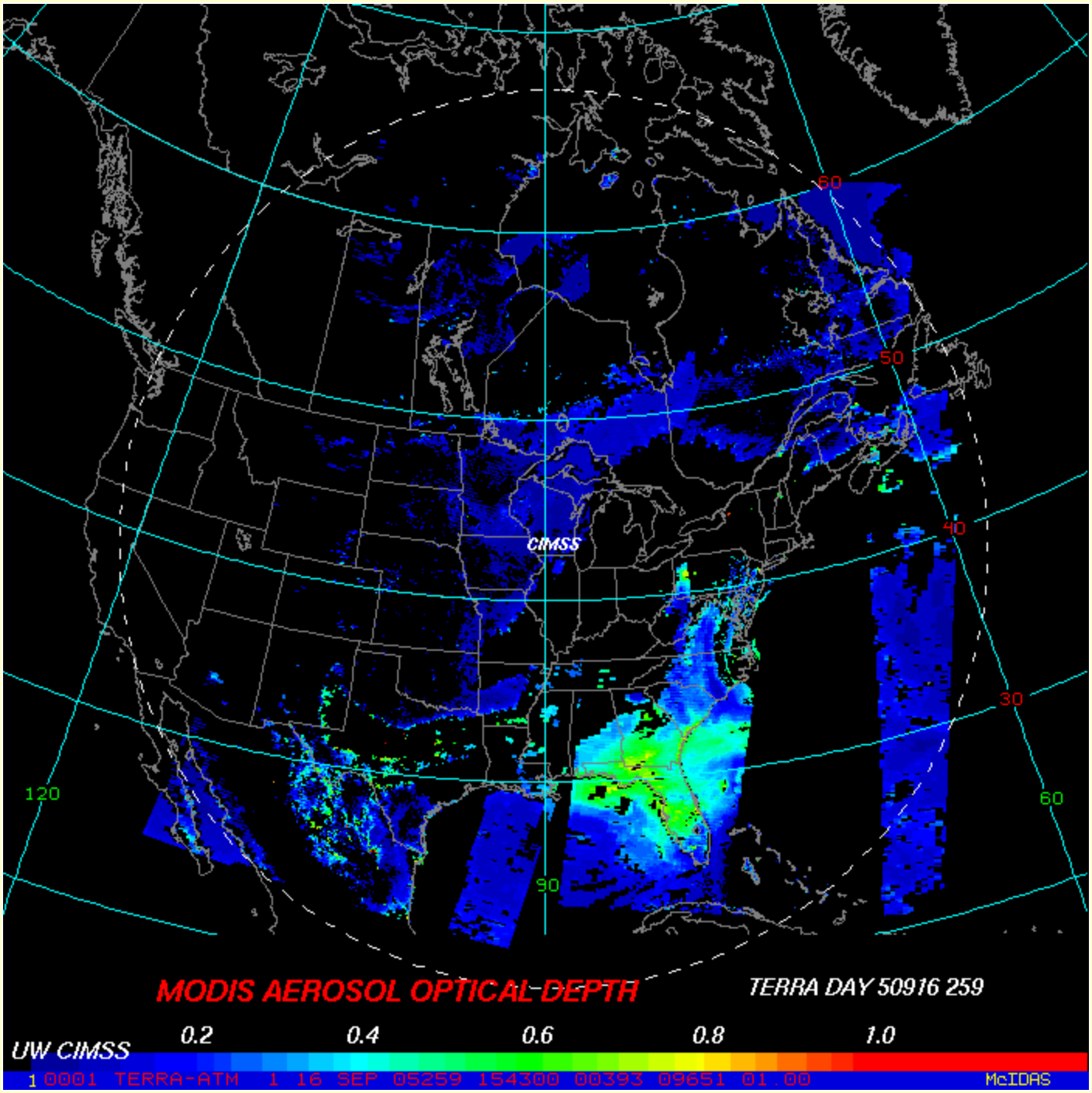
http//:modis-atmos.gsfc.nasa.gov

Paul Hubanks

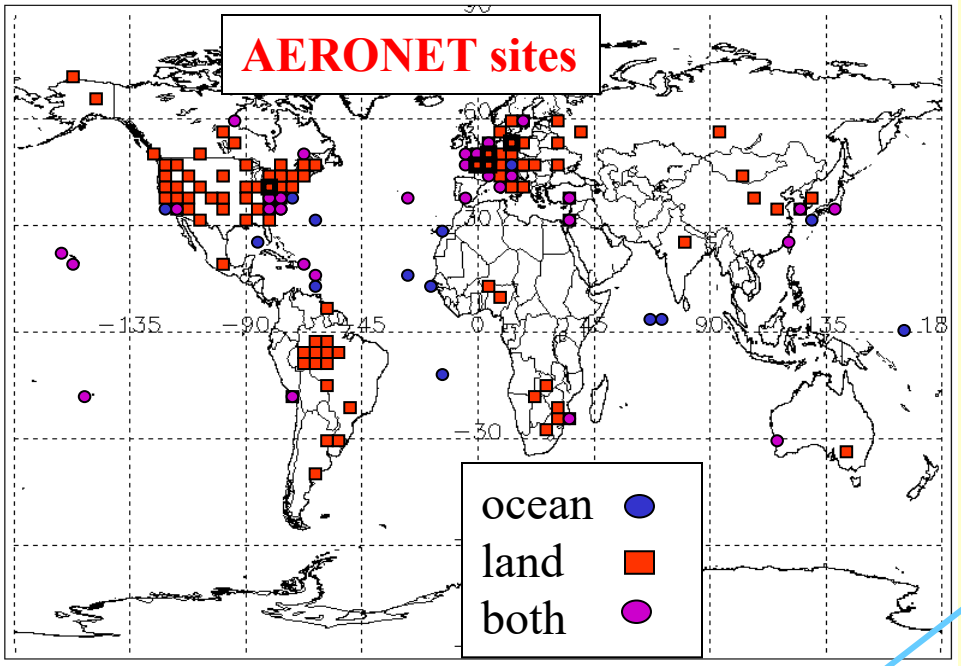
MODIS

Aerosol Optical Thickness Product

University of Wisconsin – Madison Direct Broadcast

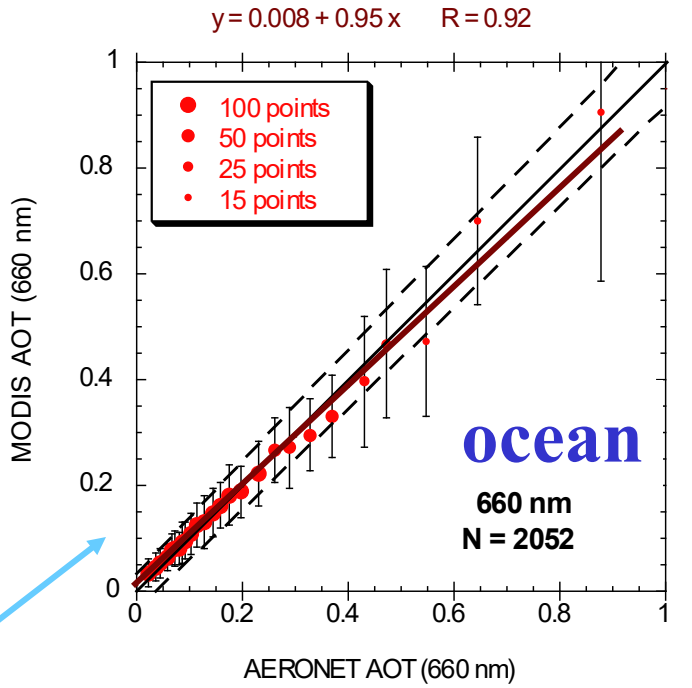


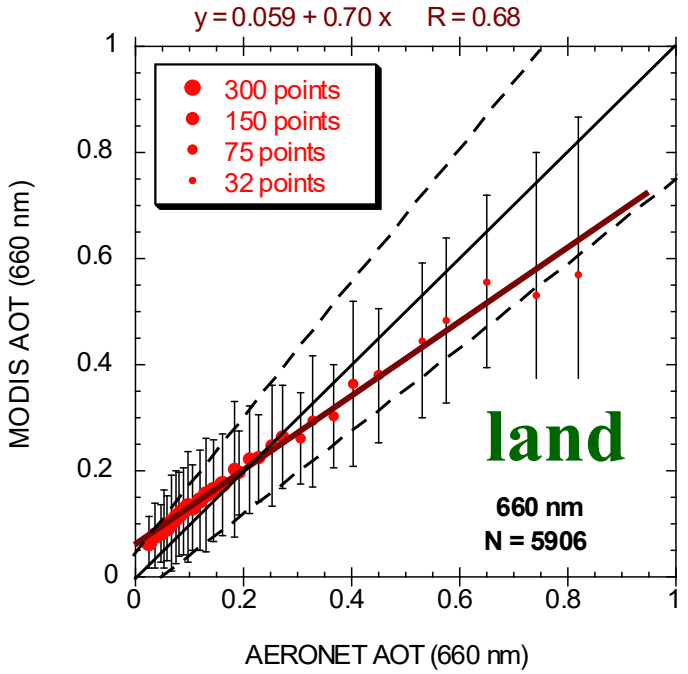
MODIS aerosol validation 2000-2002



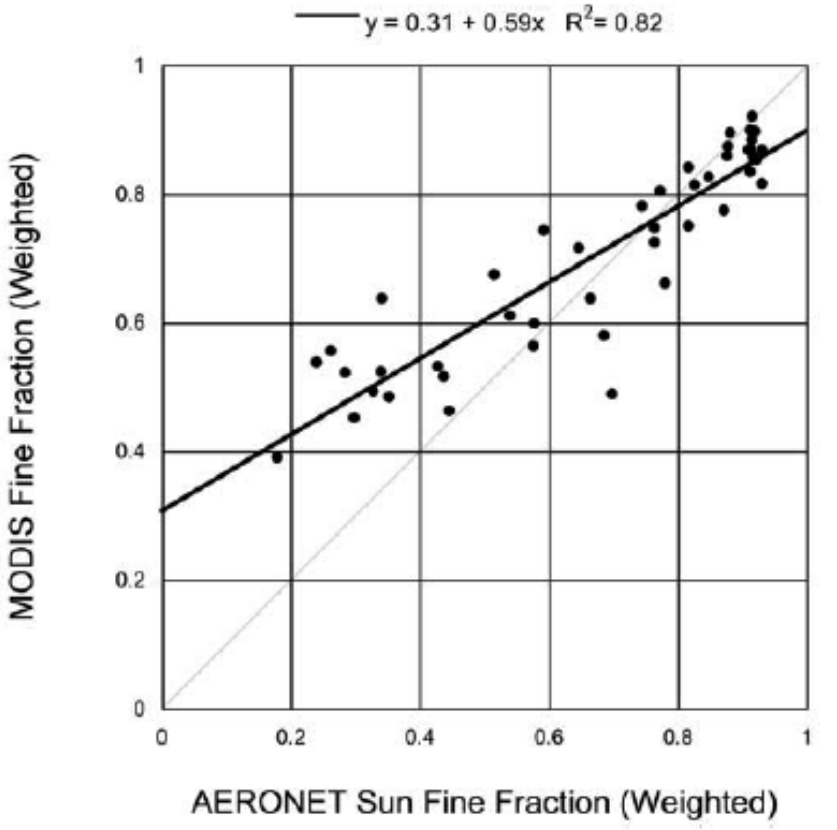
66% of MODIS aerosol retrievals
over ocean fall within expected uncertainty

71% of MODIS aerosol retrievals
over land fall within expected uncertainty

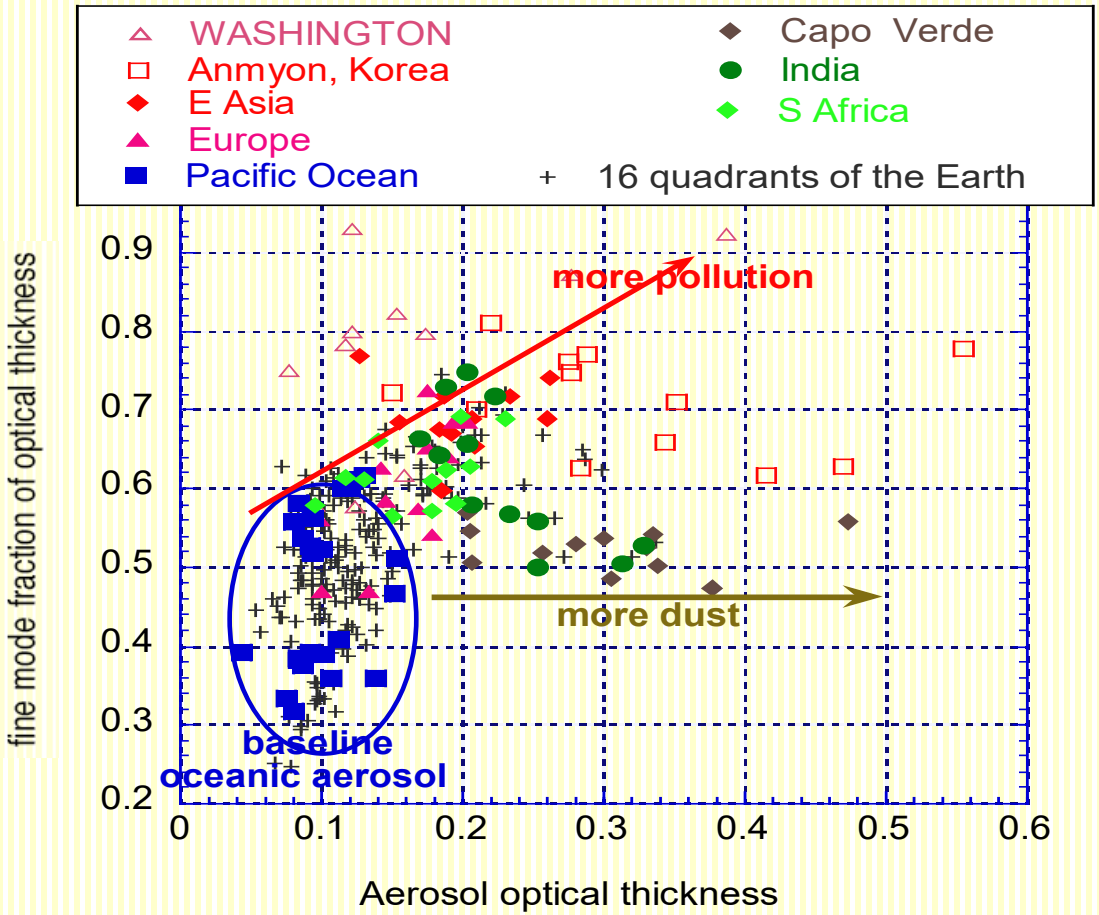




Over ocean retrievals of aerosol fine fraction



Fine fraction is the fraction of AOT due to the fine mode.
A value of 0 means the aerosol is all large particles.
A value of 1 means the aerosol is all small particles.
Monthly means plotted against each other.



Yoram Kaufman

Summary before Applications:

1. MODIS algorithms take advantage of instrument's wide spectral range (both land and ocean), excellent calibration (essential for size retrievals), 500 m spatial resolution (proximity to clouds).

2. MODIS products validated with AERONET and uncertainties are well-chararacterized. Known problems listed at the DAAC or at http://modis-atmos.gsfc.nasa.gov/validation.html

3. Algorithm under constant review and modification. Track history of changes at http://modis-atmos.gsfc.nasa.gov/products_history.html

Applications:

1. Direct radiative forcing (different methods)

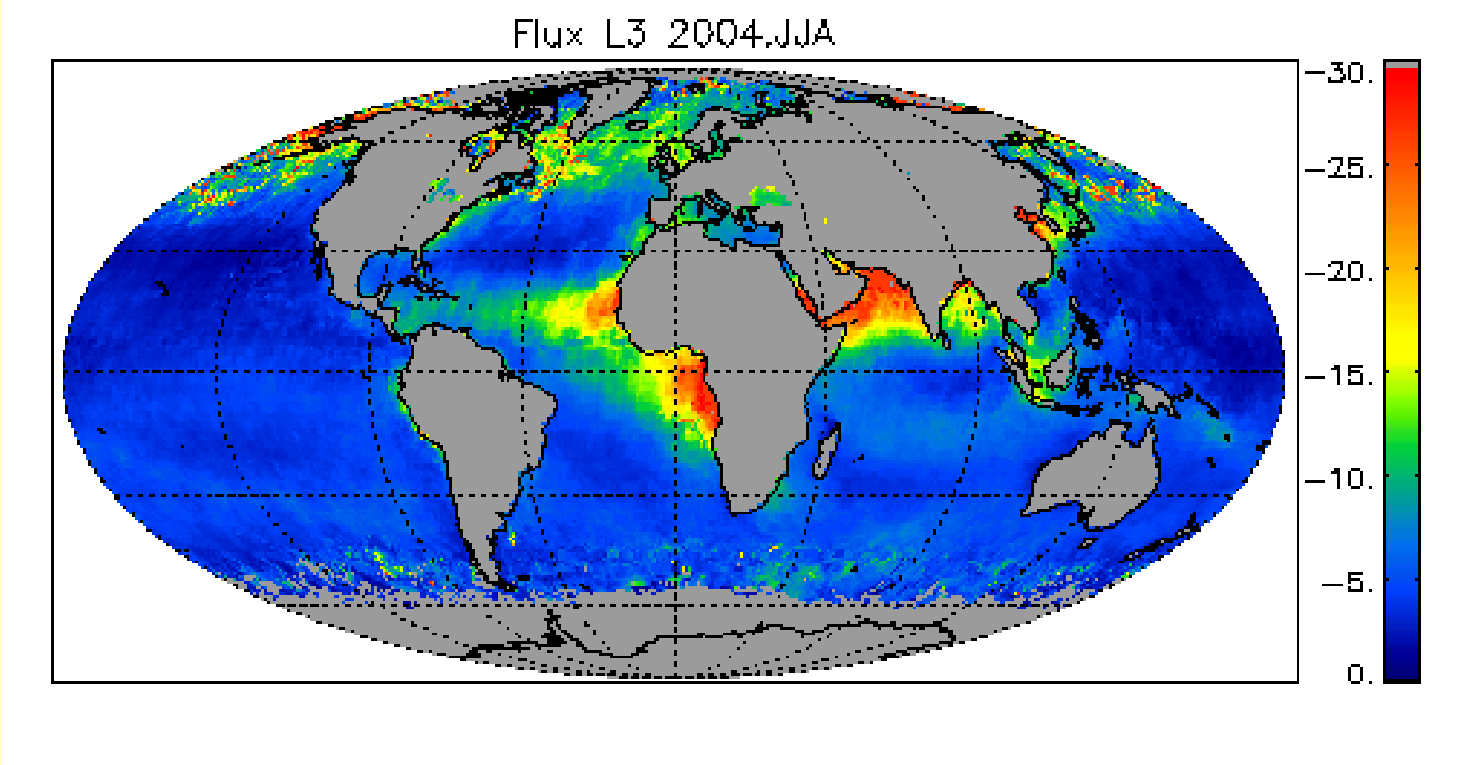
2. Indirect radiative forcing

3. Semi-direct forcing

4. Air Quality

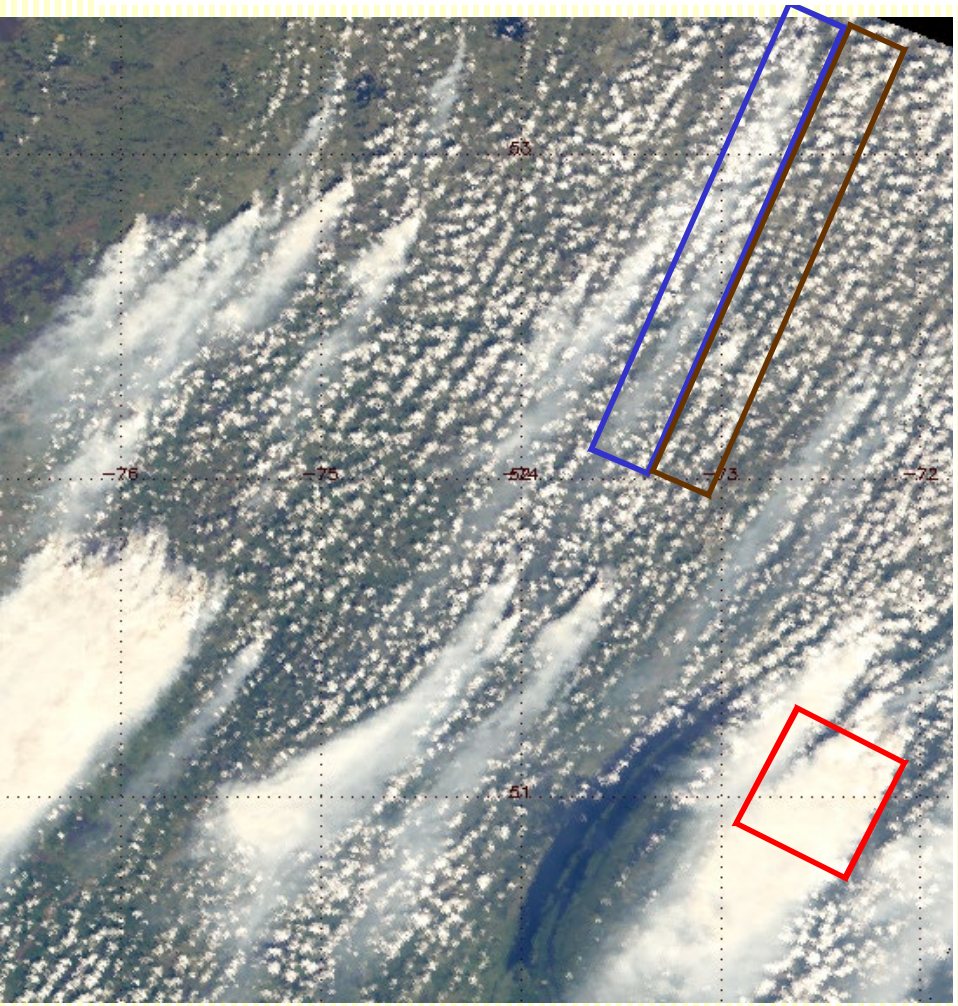
5. Estimating biomass burning sources

Aerosol direct radiative effect



MODIS 2004

Aerosol Indirect Forcing from MODIS



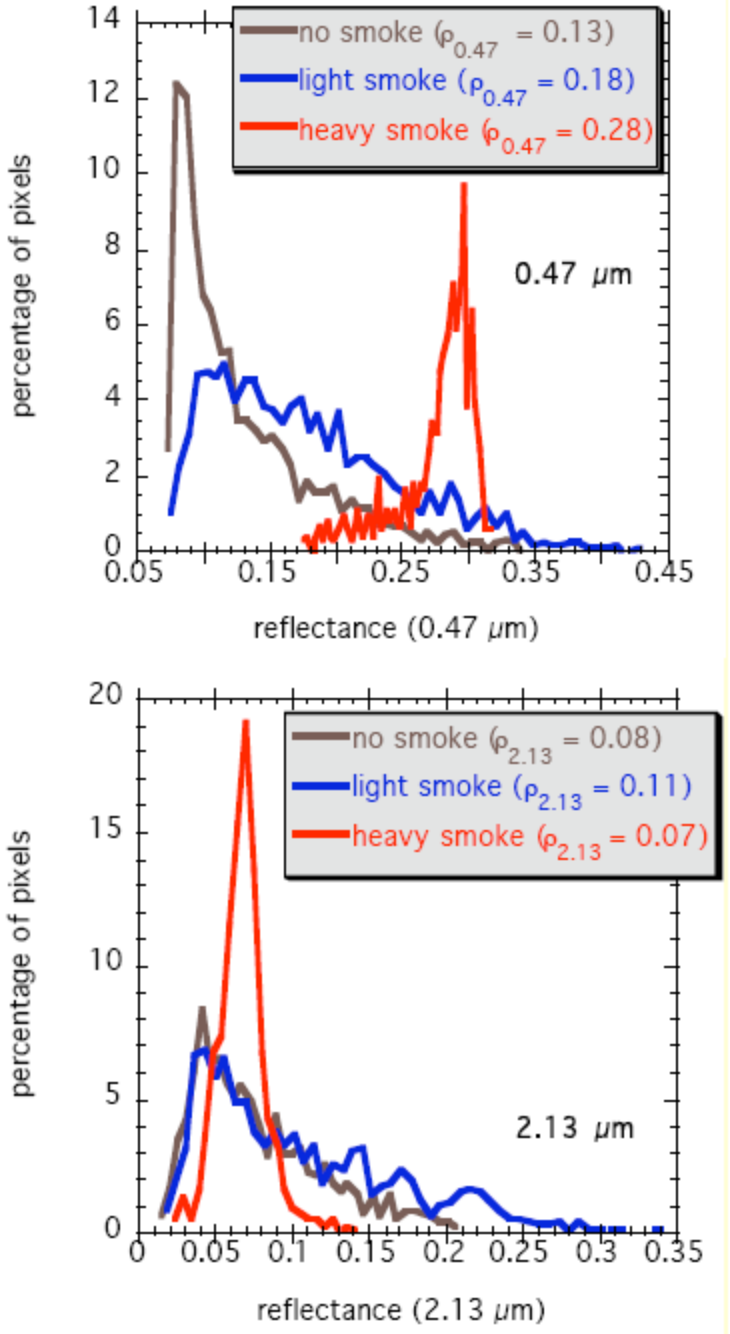
Visible (0.66, 0.55, 0.47 μm)

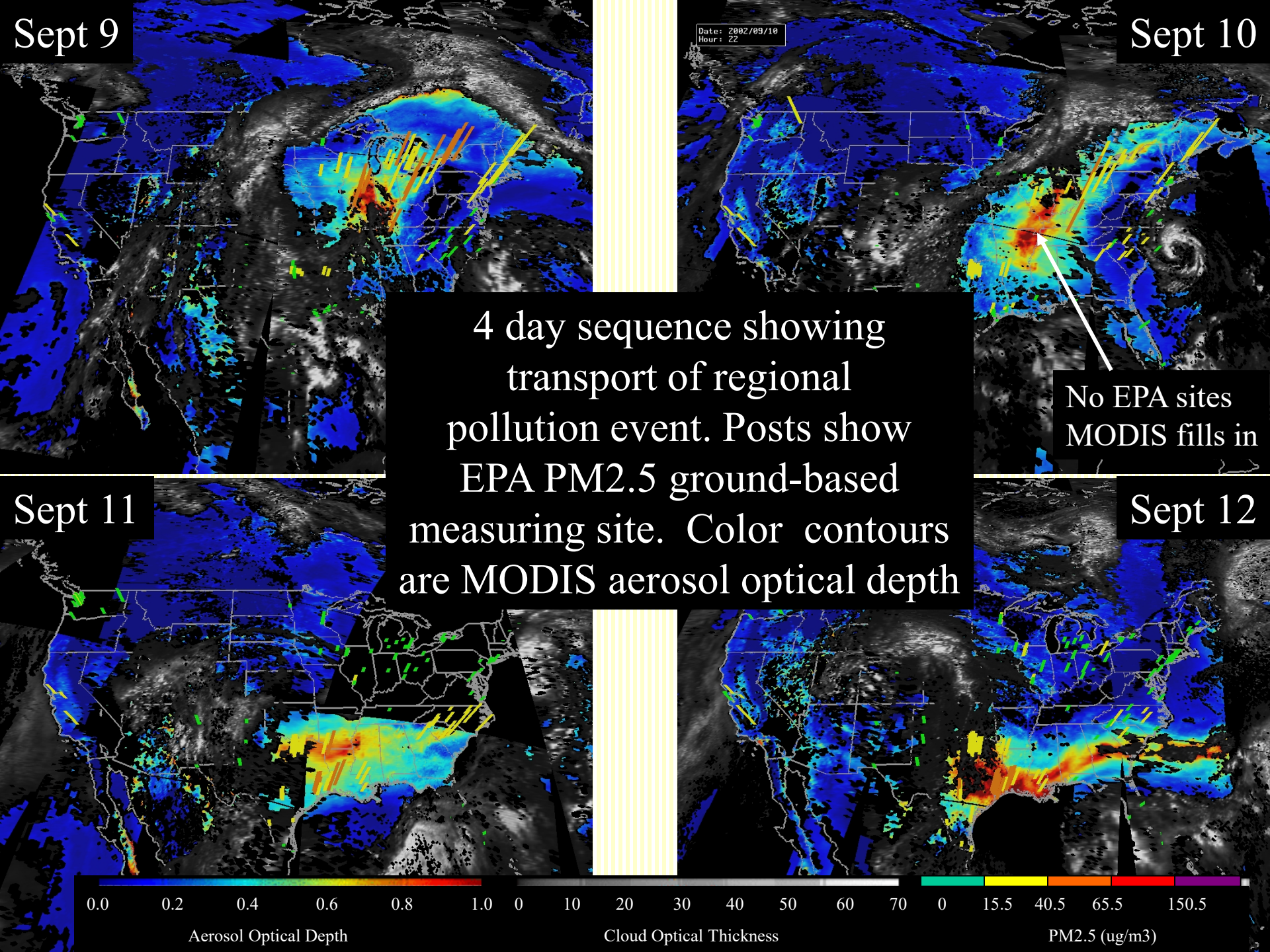
Mid-IR (2.1, 1.6, 1.2 μm)

Terra-MODIS, July 5, 2002, 16:45 UTC
Fires burning in Quebec

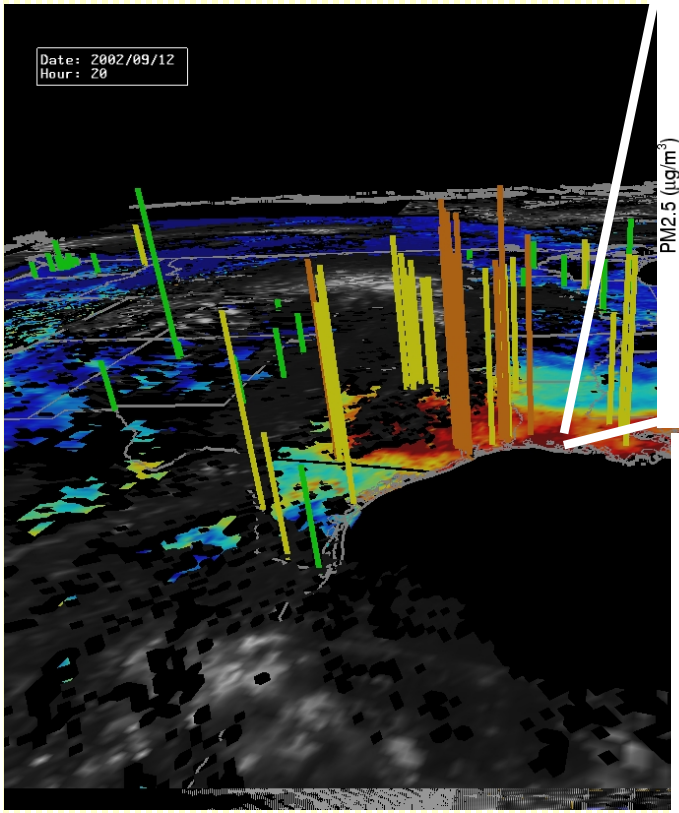
In visible…
Areas brighten as smoke increases
Smoke + Clouds

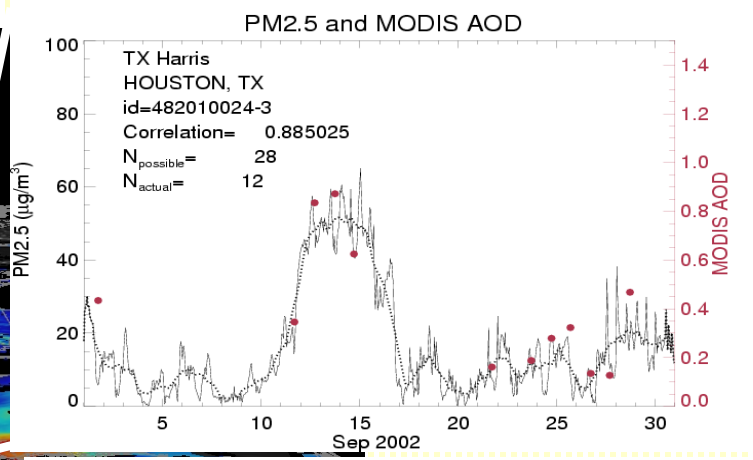
In mid-IR…
Background reflectance constant
Tail elongates in light smoke area
Clouds brighten as smoke increases
Smaller cloud droplets
No clouds in heavy smoke




Sept 9
Date: 2002/09/10
Hour: 22
Sept 10
4 day sequence showing transport of regional pollution event. Posts show EPA PM2.5 ground-based measuring site. Color contours are MODIS aerosol optical depth
No EPA sites
MODIS fills in
Sept 11
Sept 12
0.0 0.2 0.4 0.6 0.8 1.0
Aerosol Optical Depth
0 10 20 30 40 50 60 70
Cloud Optical Thickness
0 15.5 40.5 65.5 150.5
PM2.5 (ug/m3)

Do MODIS total column optical thickness products correspond quantitatively to Air Quality parameters measured at the surface (PM2.5)?

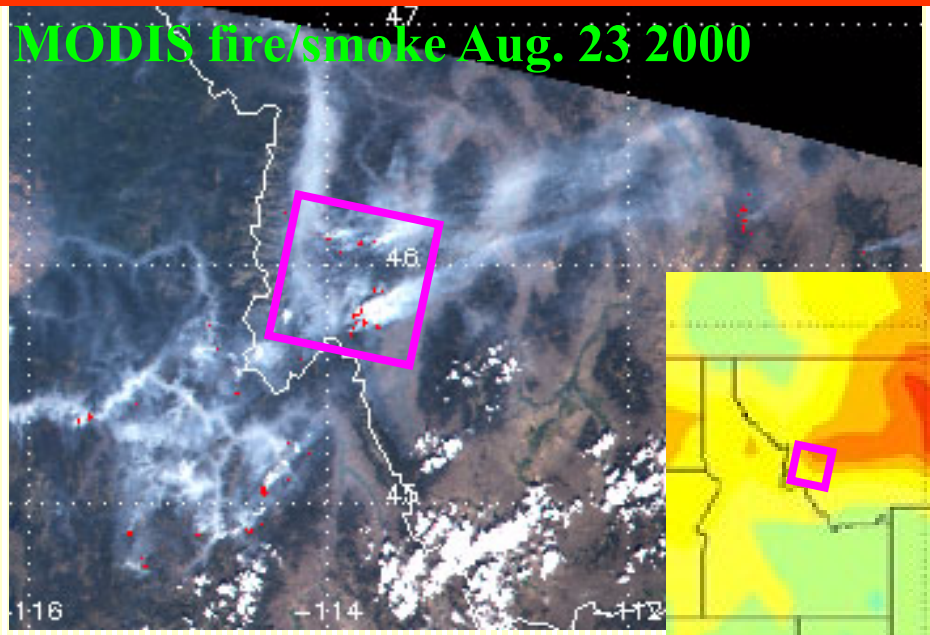


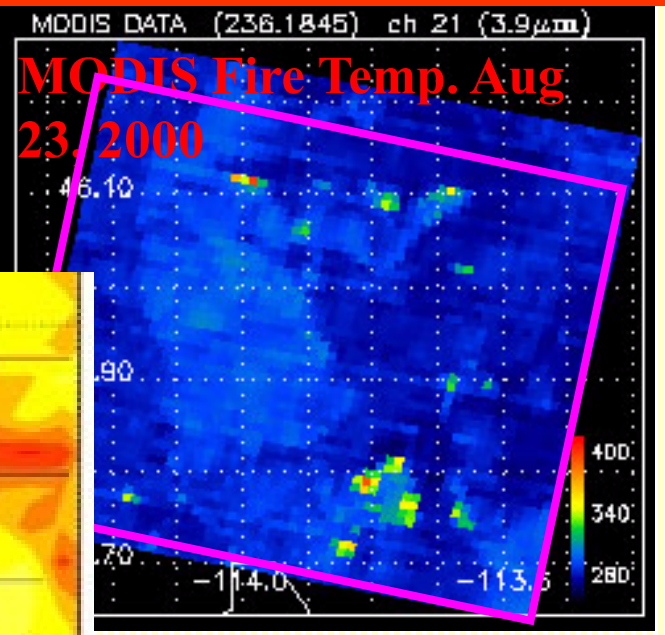


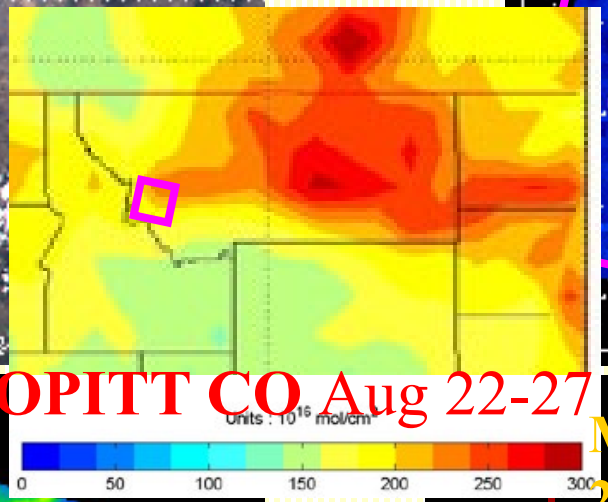
Time Series shows agreement of hourly PM2.5 Concentrations (Surface Monitor) and Aerosol Optical Depth in Coincident MODIS pixel. Correlation Coefficient > 0.88.

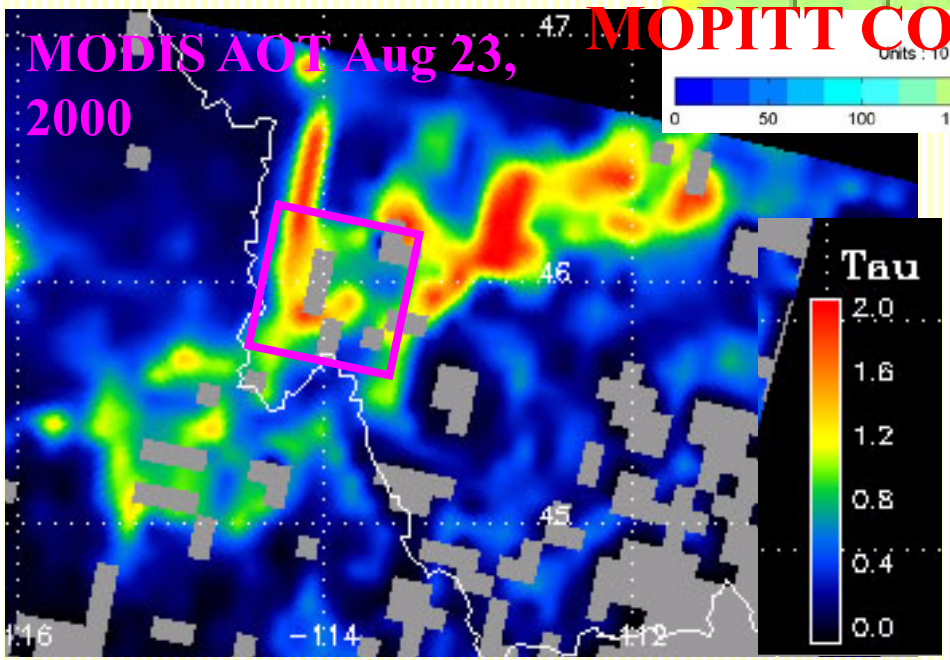
J. Szykman (EPA), D.A. Chu

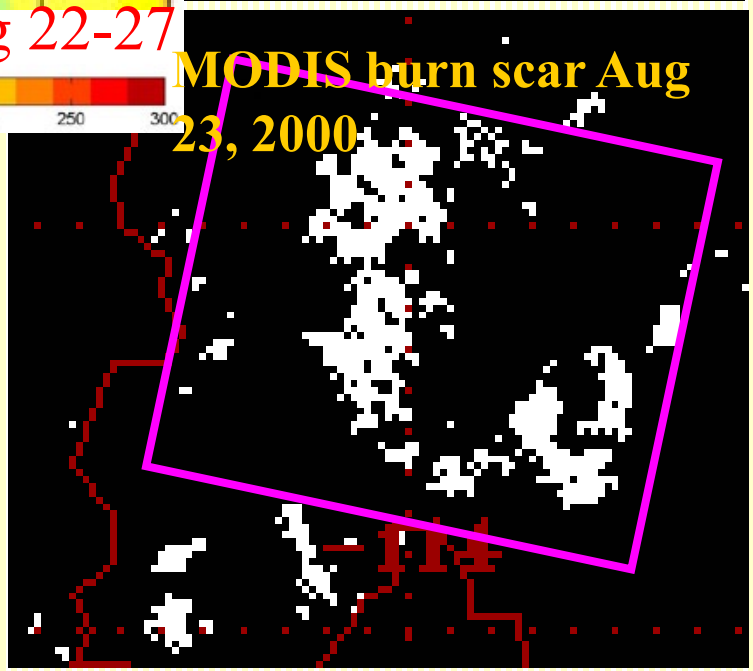
Fires in MT/ID, Aug 2000 : Ichoku, Kaufman, Hao











Acknowledgements

MODIS Aerosol Team: D.A. Chu, C. Ichoku, R. Kleidman, I. Koren, R. Levy, R-R. Li, J.V. Martins, S. Mattoo, Z. Ahmad

AERONET: B. Holben, O. Dubovik, T. Eck, I. Slutsker, A. Smirnov

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MODIS Land/ Univ. of Maryland: E. Vermote

NOAA/NESDIS/ORA: A. Ignatov, X. Zhao

Climate and Radiation Branch (code 913): M-D. Chou, M. Suarez

Atmospheric Chemistry Branch (code 916): M. Chin, P. Ginoux, O. Torres

Univ. Alabama Huntsville: C. Sundar, J. Zhang