MODIS/AIRS Workshop
MODIS Level 2 Aerosol Product

6 April 2006

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Cooperative Institute for Meteorological Satellite Studies

University of Wisconsin-Madison USA

MODIS Standard Products

Atmosphere

- ***MOD 04 - Aerosol Product***
- *MOD 05 - Total Precipitable Water (Water Vapor)*
- *MOD 06 - Cloud Product* * *(CTP & IRPHASE only)*
- *MOD 07 - Atmospheric Profiles*
- MOD 08 - Gridded Atmospheric Product
- *MOD 35 - Cloud Mask*

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

Definition: Aerosols are suspended droplets or particles that can scatter or absorb incoming sunlight

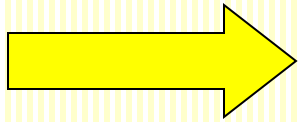
Theory

Deriving aerosol over land.

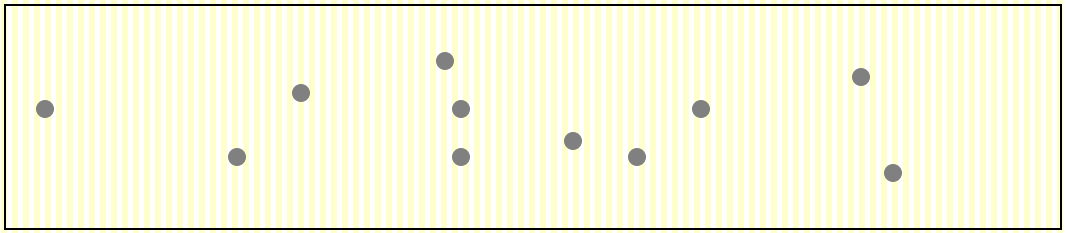
Problem: Land surface variability.

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

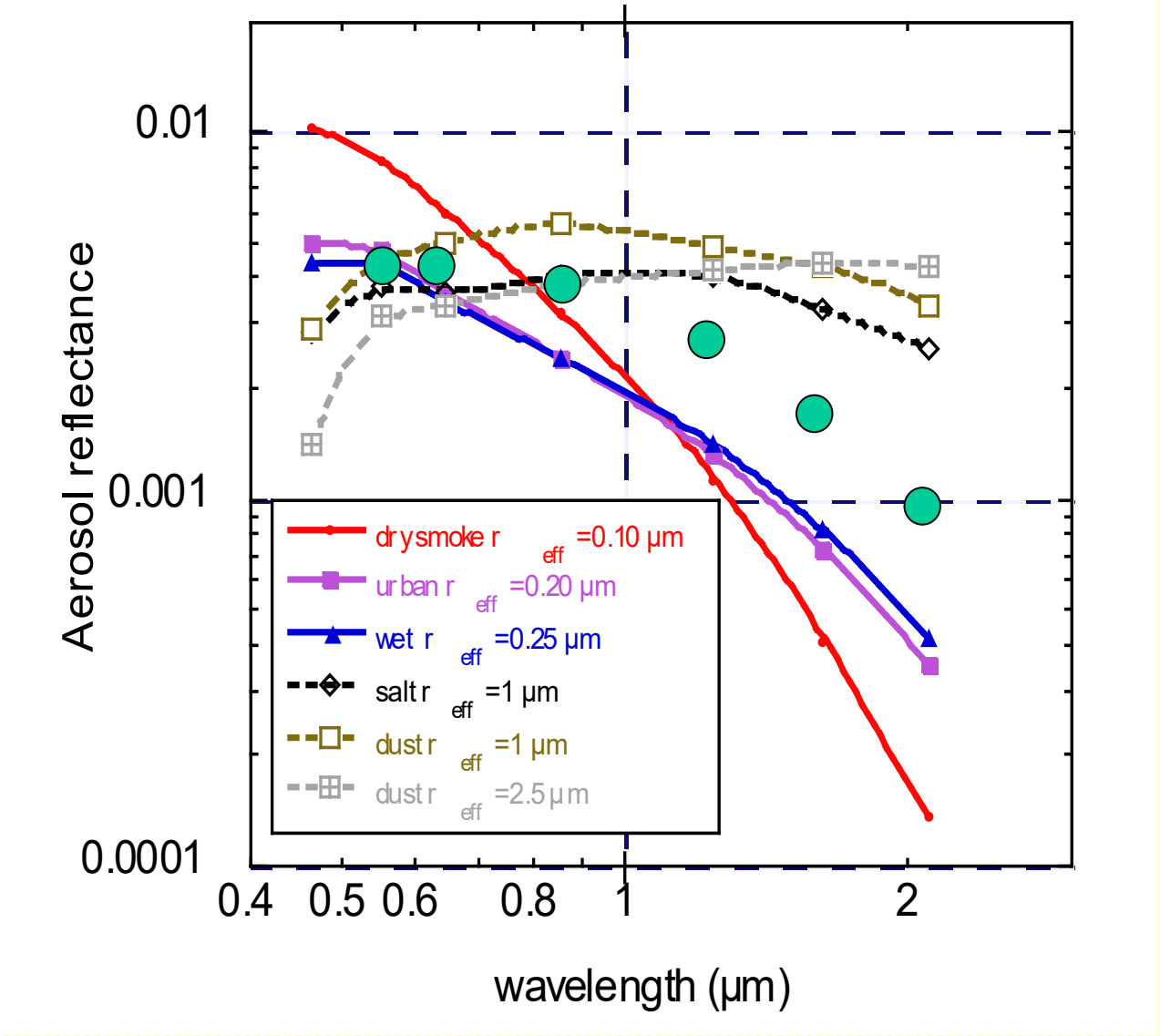
I=Light Detector (W/m²)

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

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

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**

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

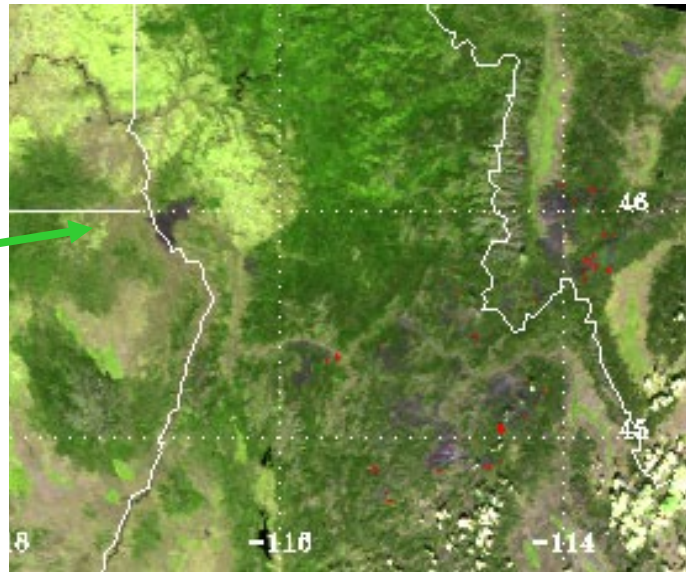
$\tau_{0.47} \sim [\rho^*_{0.47} - 0.25\rho^*_{2.1}]$

$\lambda(\mu m)$

1.2

1.6

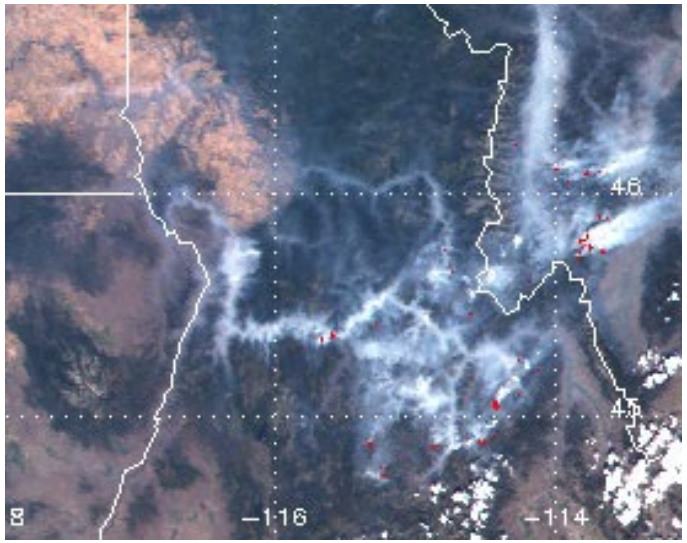
2.1



0.47

0.55

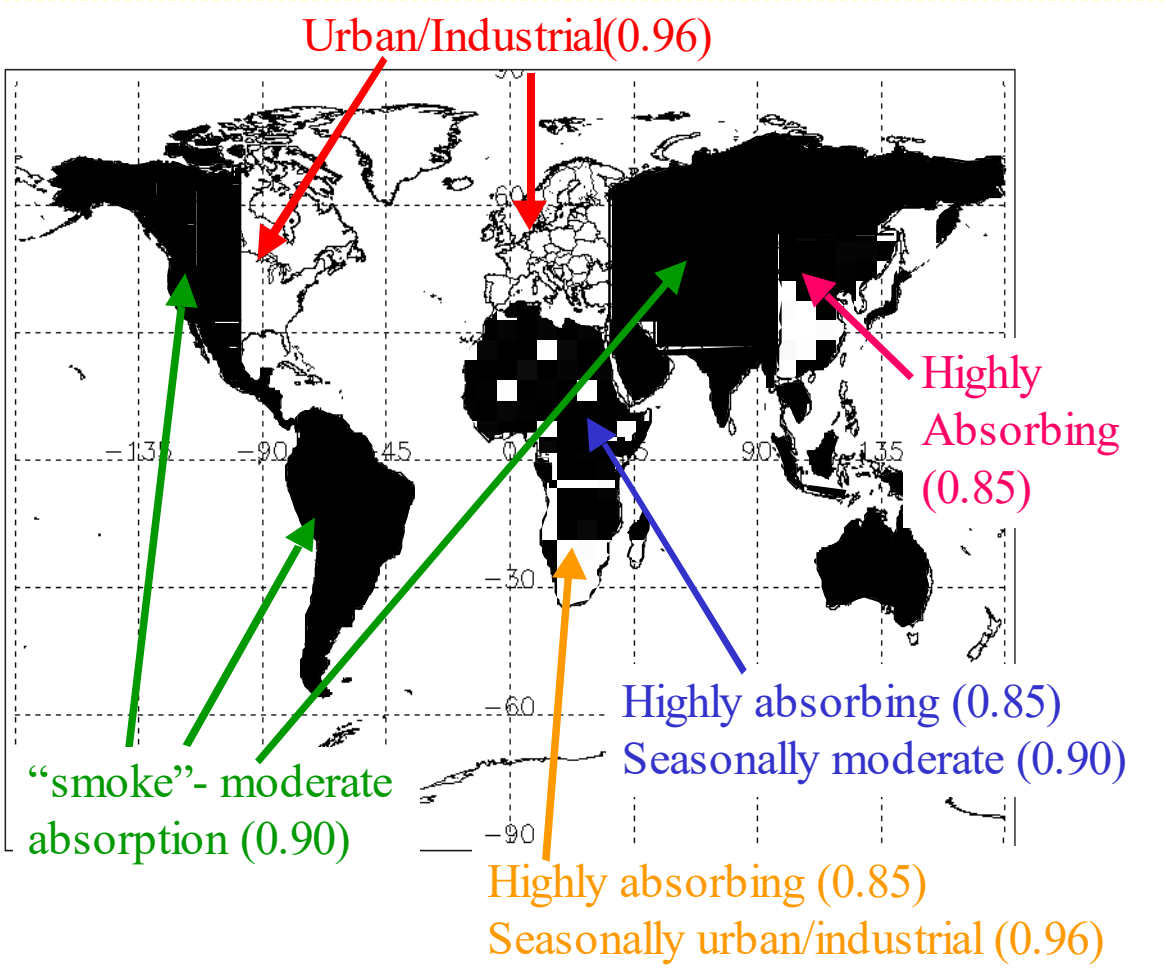
0.66



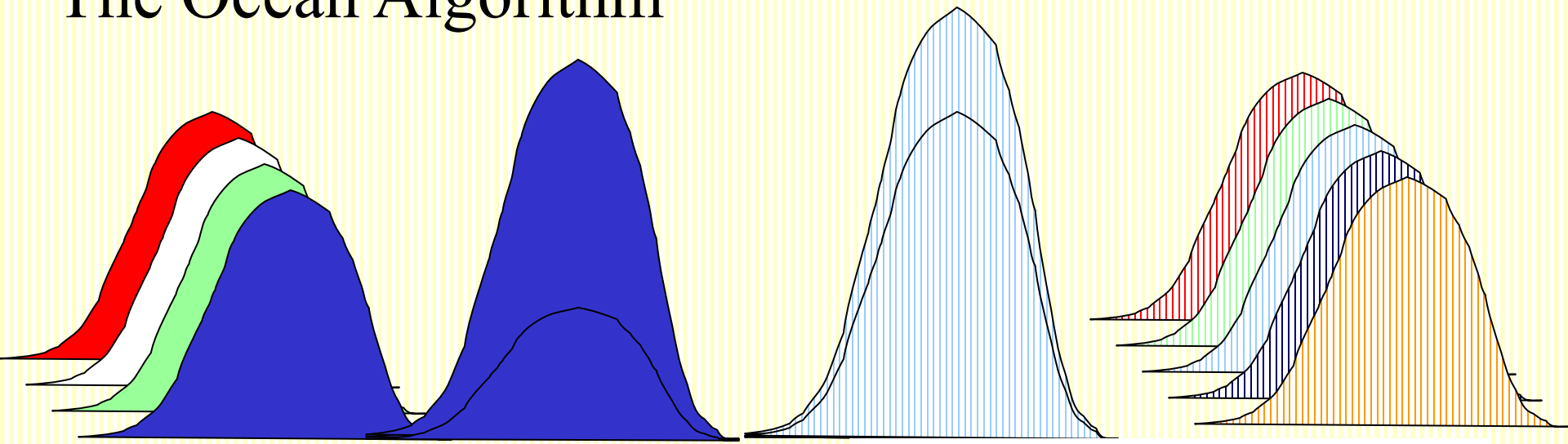
Yoram Kaufman

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

Models are dynamic f(τ)

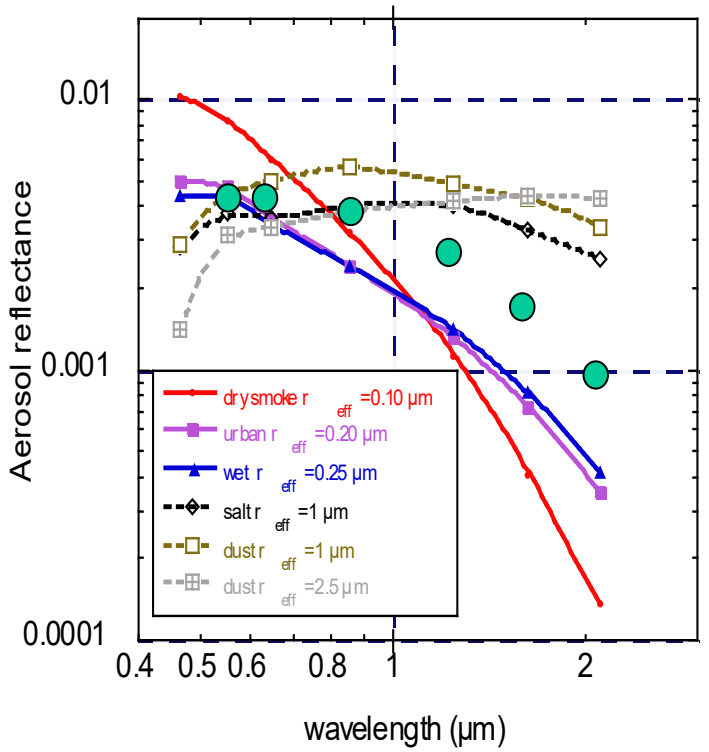


The Ocean Algorithm

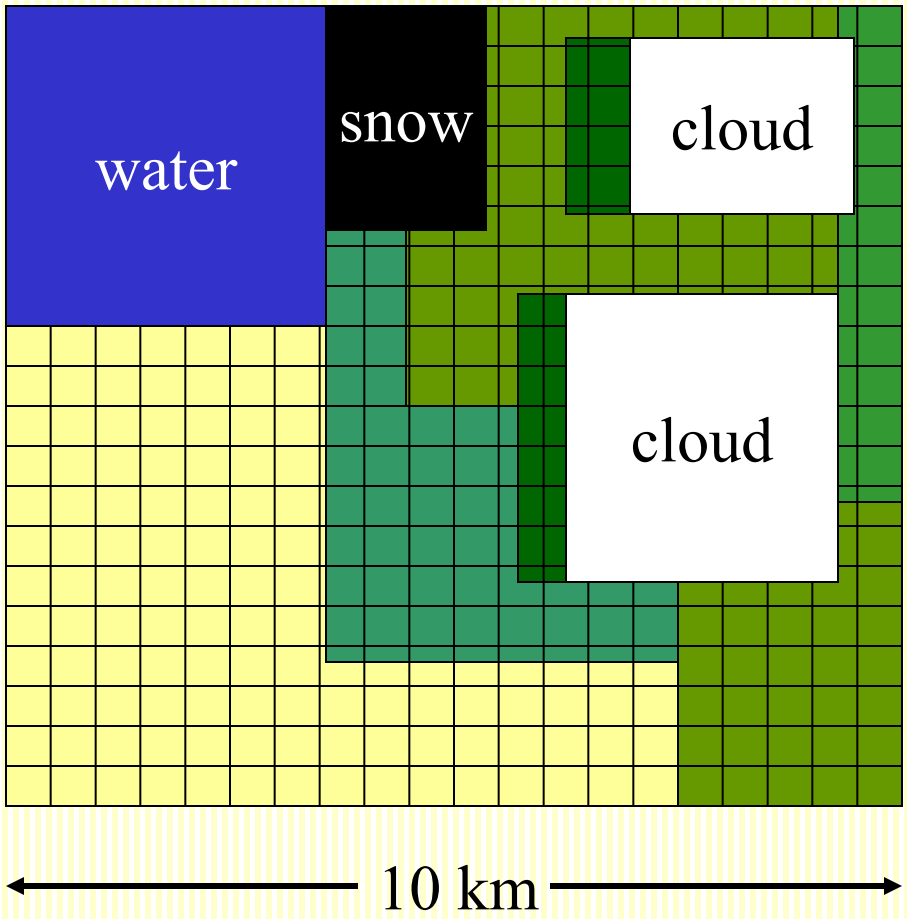


Choice of 4 fine modes
and 5 coarse modes

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

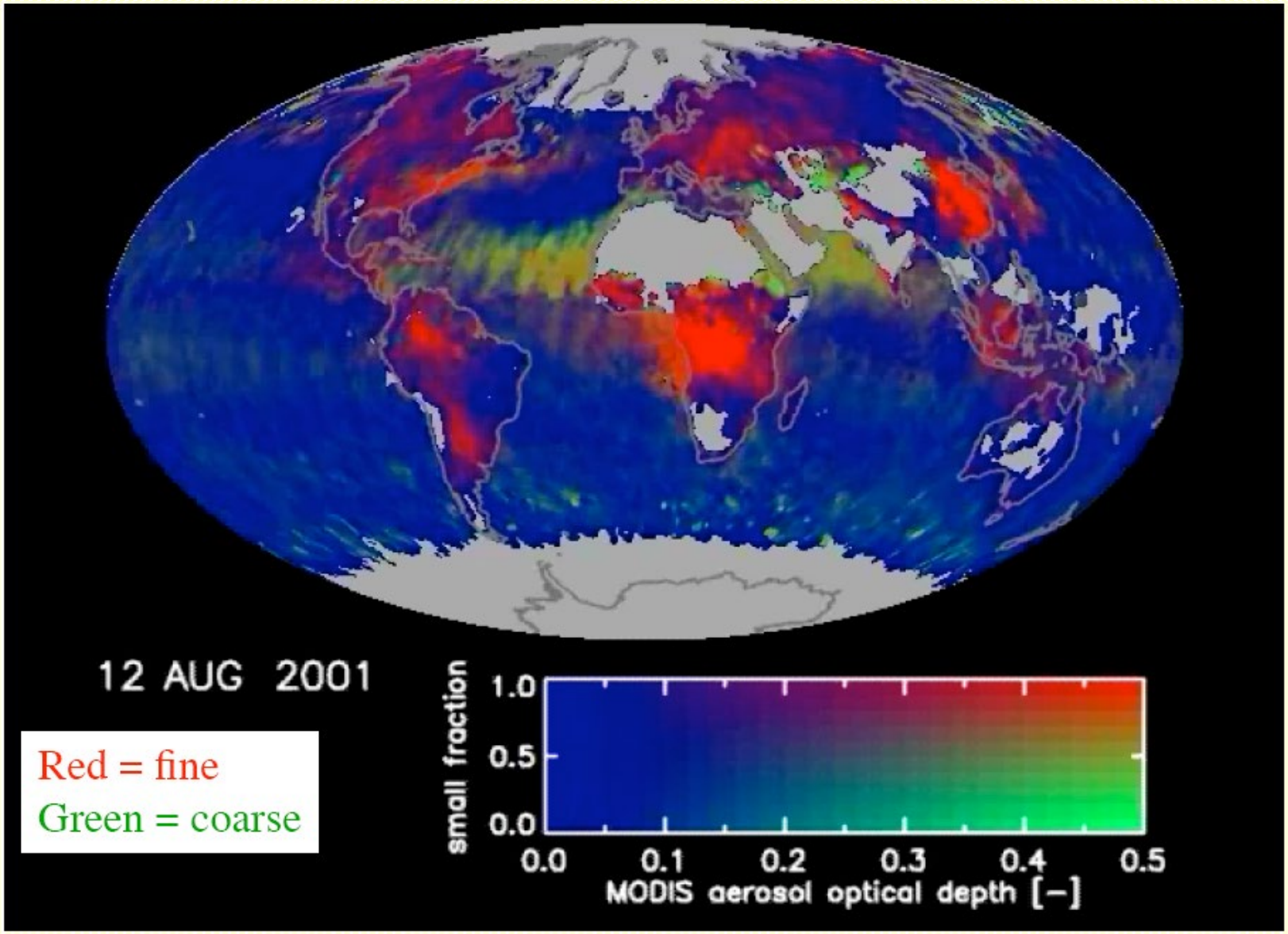
  1 x 1 degree resolution (not mandatory)
  ex: TOAST16_050615.GRB
- Latest 7 days ancillary data and documentation available from:
  ftp://aqua.ssec.wisc.edu/pub/terra/ancillary

Output Product Description

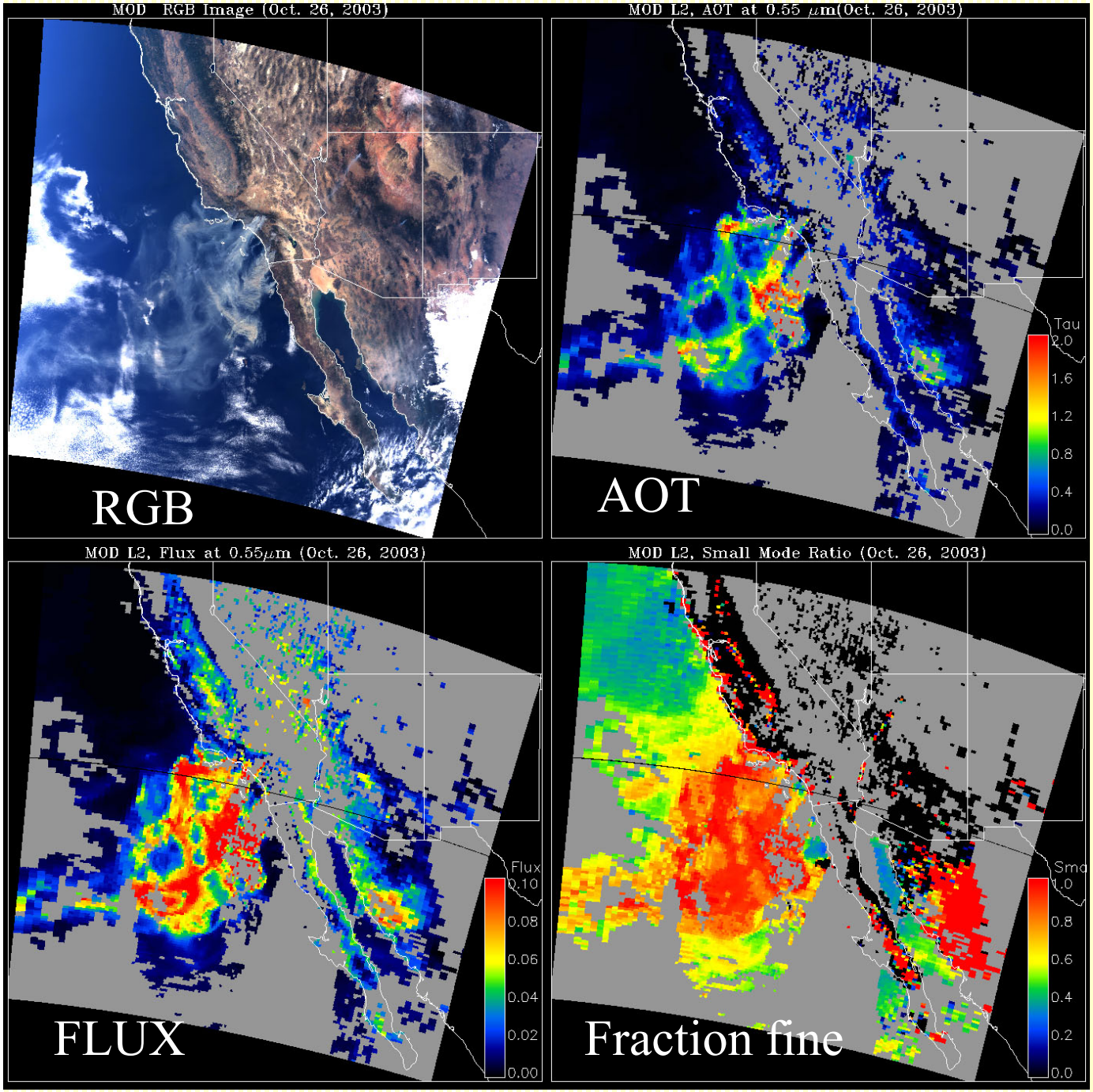
MOD04 Key Output Parameters

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



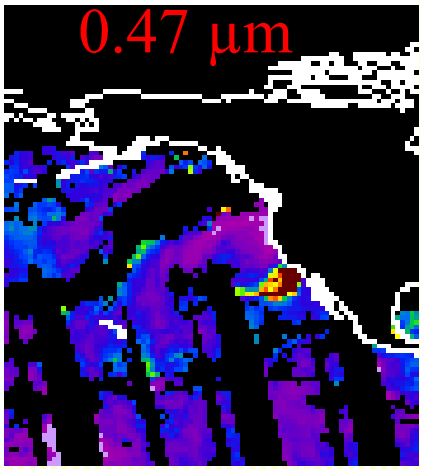
Separating fine mode from coarse mode aerosol

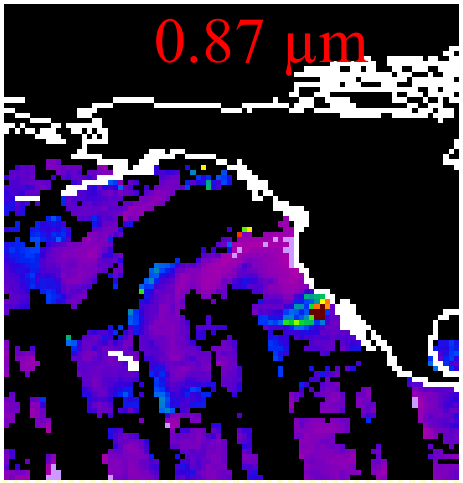


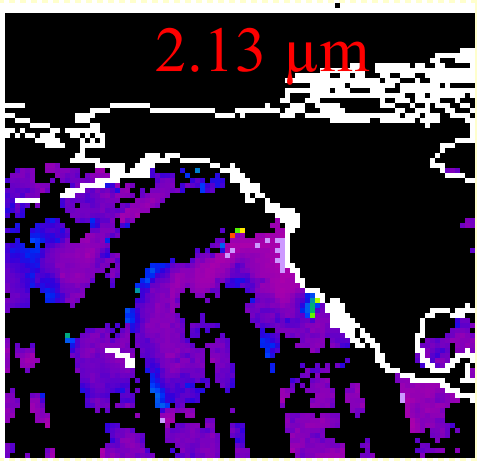
California Wildfires Oct. 26, 2003

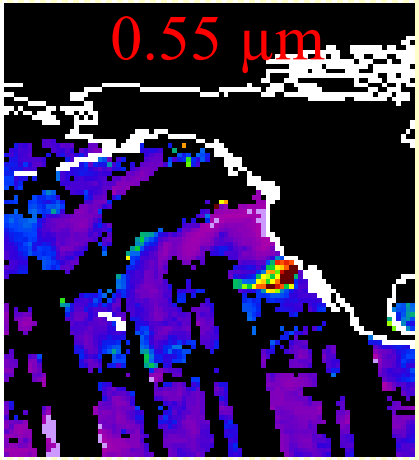
From Terra-MODIS

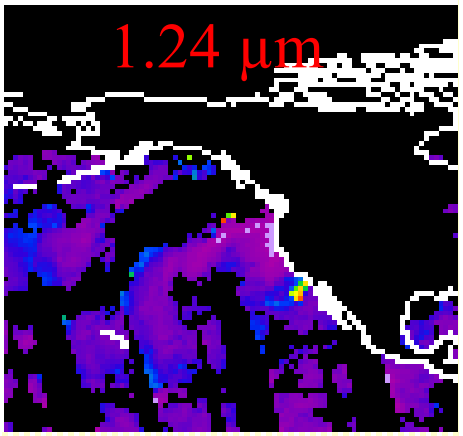
Rong-Rong Li







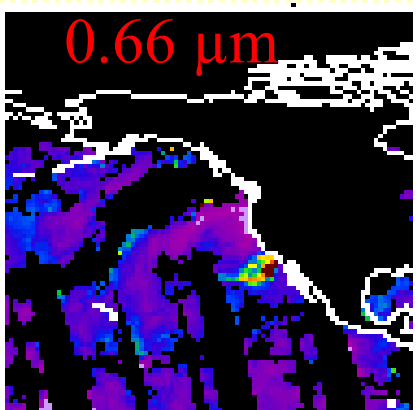


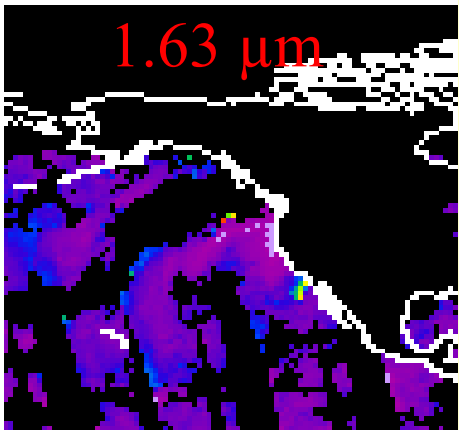


Spectral Optical Thickness

7 wavelengths over ocean

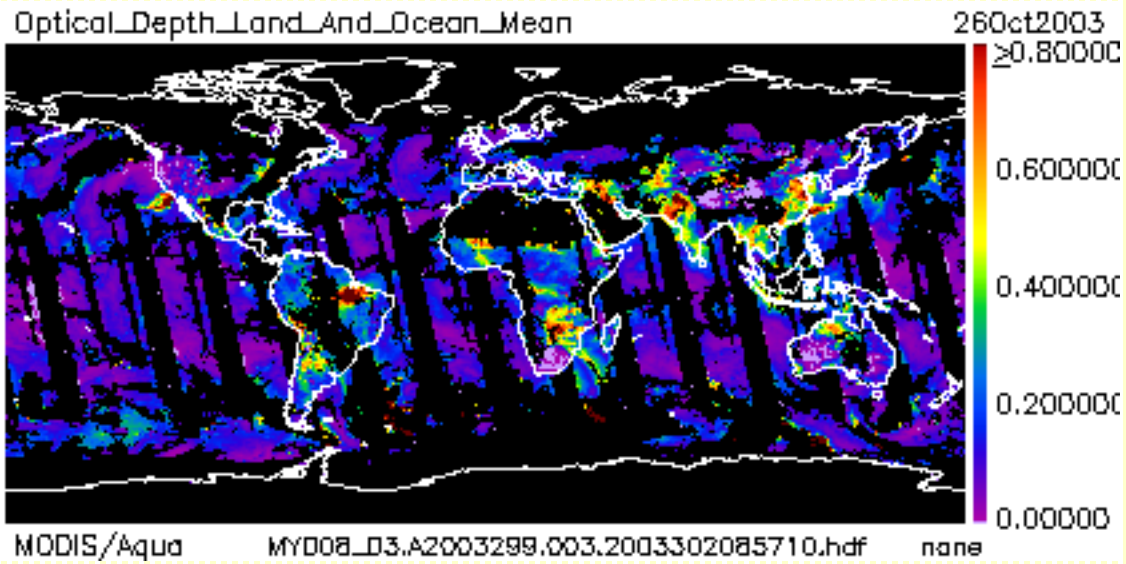
3 wavelengths over land



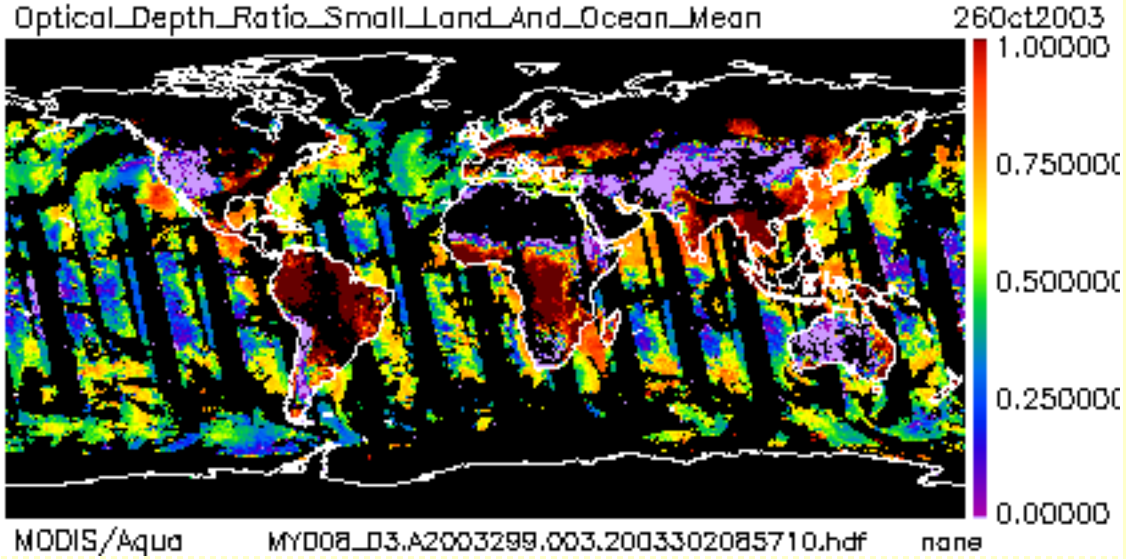


Cropped from images by Paul Hubanks

Aerosol Optical Thickness



Fine mode fraction



The global aerosol

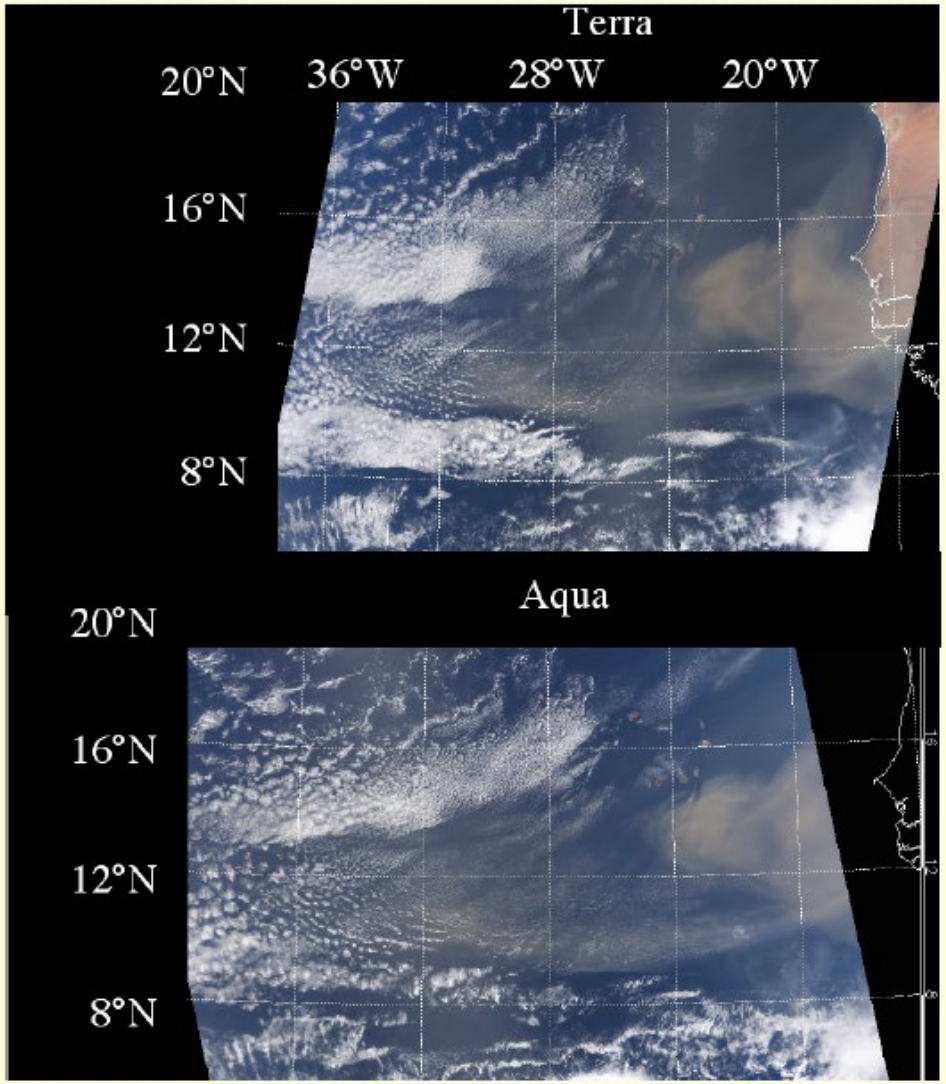
MOD08_D3

Daily Level 3
1 degree data

October 26, 2003

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

Paul Hubanks



Two MODIS instruments.

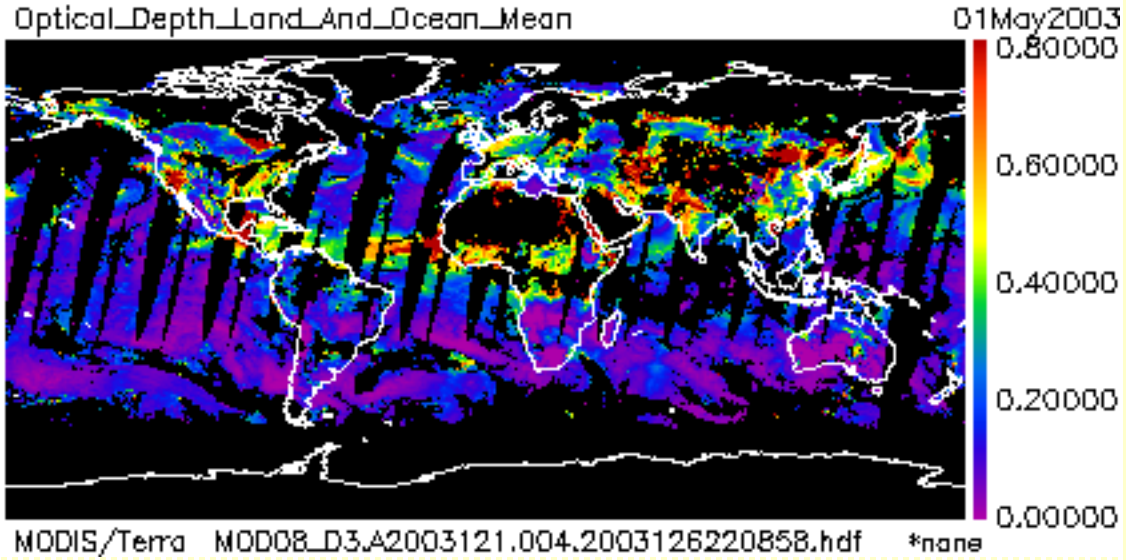
Terra (10:30 am local time) and Aqua (1:30pm local time)

May 1st, 2003.

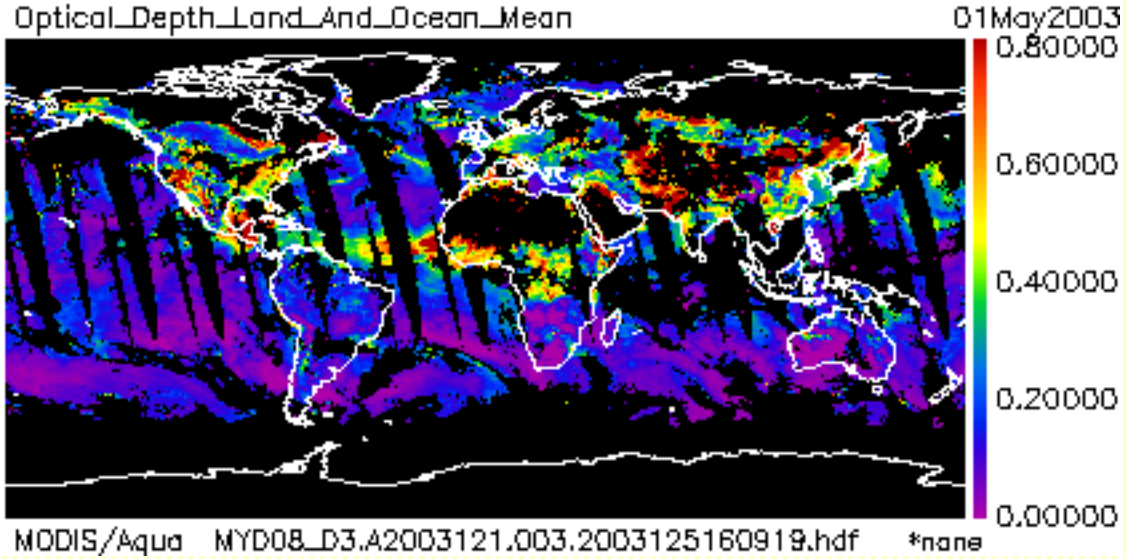
The dust storm moved 120 km between the Terra and Aqua observations, corresponding to wind speed in the dust layer of 11m/s.

Ilan Koren and Yoram Kaufman

Terra



Aqua



MOD08_D3

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

May 1, 2003

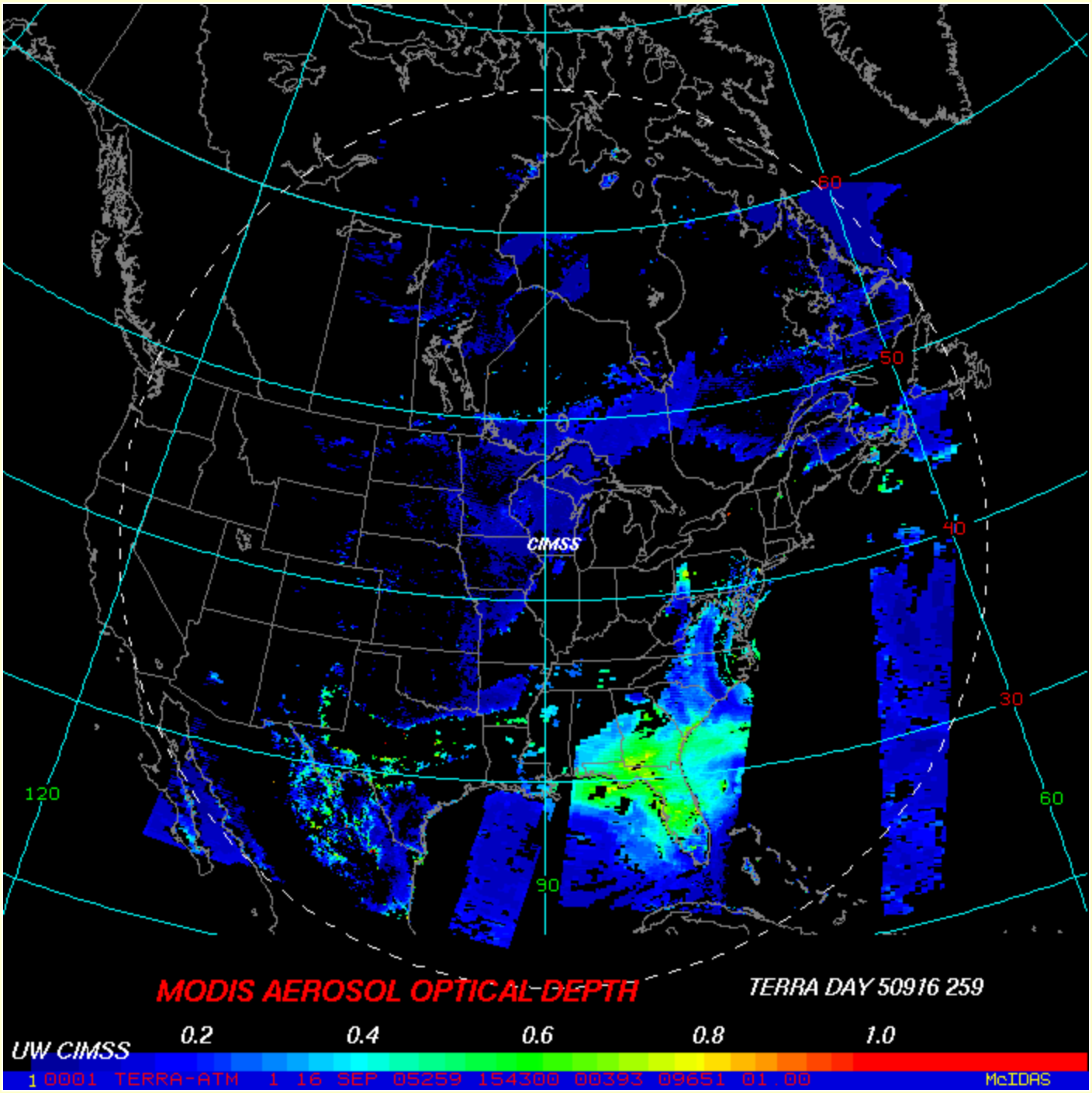
http//:modis-atmos.gsfc.nasa.gov

Paul Hubanks

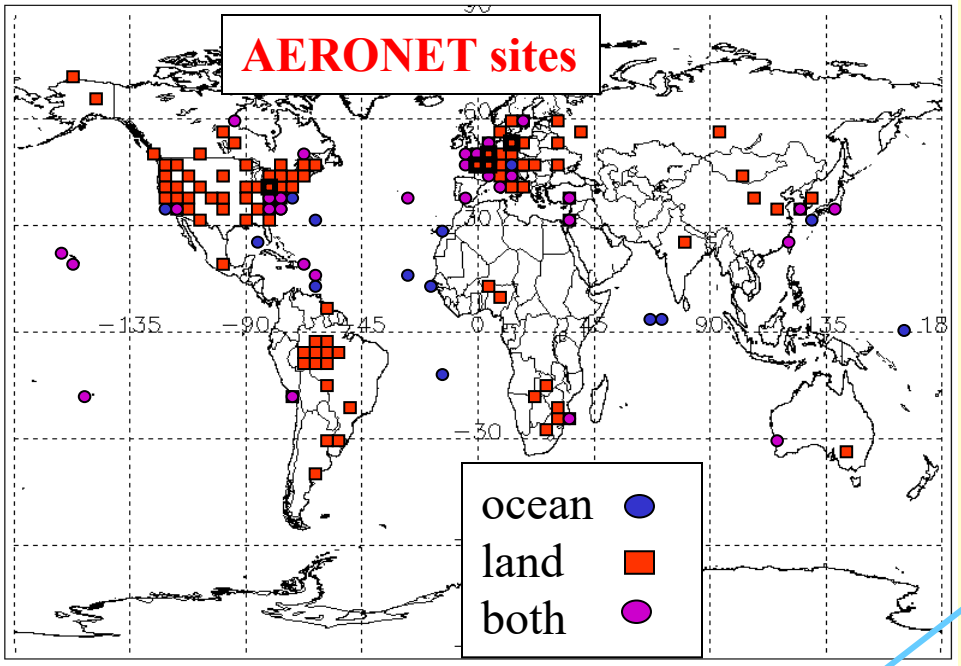
MODIS

Aerosol Optical Thickness Product

University of Wisconsin – Madison Direct Broadcast

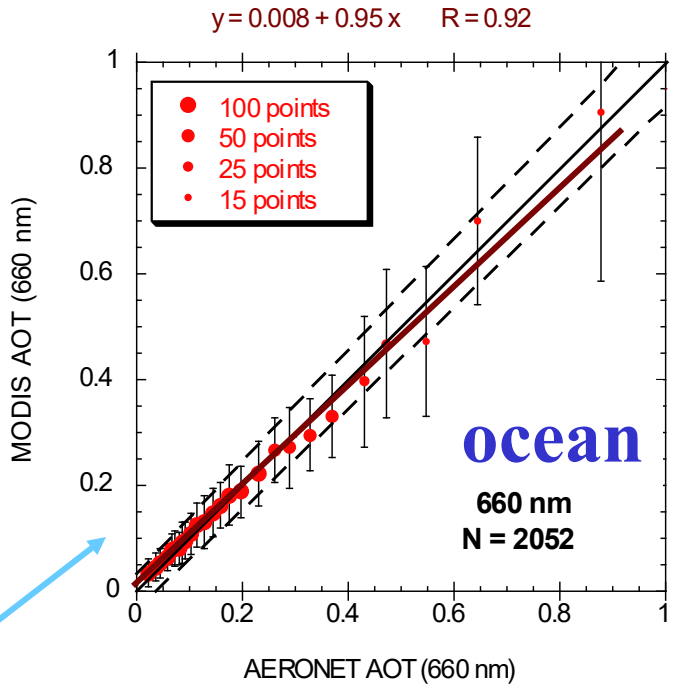


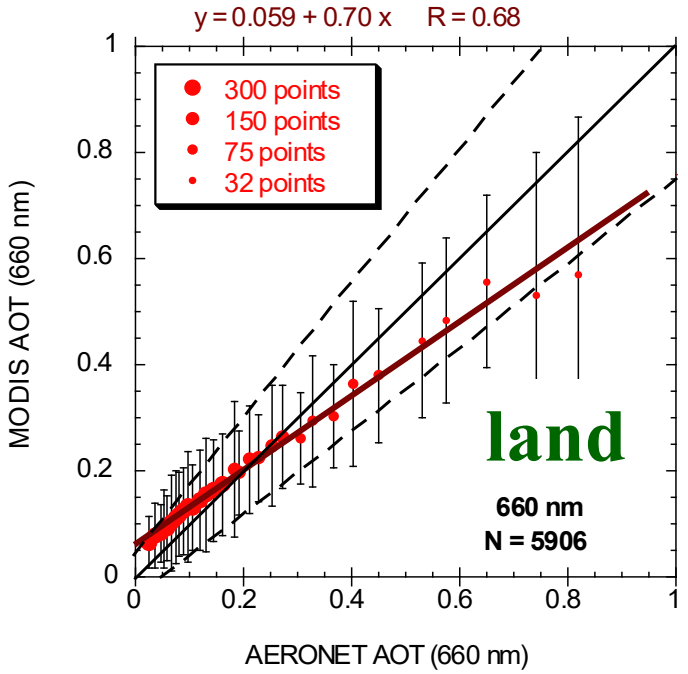
MODIS aerosol validation 2000-2002



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

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





Summary :

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

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

AERONET PIs: (SIMBIOS) C. McLain, G. Fergion, C. Pietras

MODIS Atmospheres: M. King, P. Menzel , B-C. Gao, S. Ackerman, R. Frey , M. Gray, L. Gumley, P. Hubanks, R. Hucek, E. Moody, W. Ridgway, K. Strabala

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

IDEA Infusing satellite Data into Environmental Applications

NASA

CIMSS

MODIS AIRNOW WFABBA

MODIS Real Time Applications
IDEA (Infusing Satellite Data into Environmental Applications)
http://idea.ssec.wisc.edu

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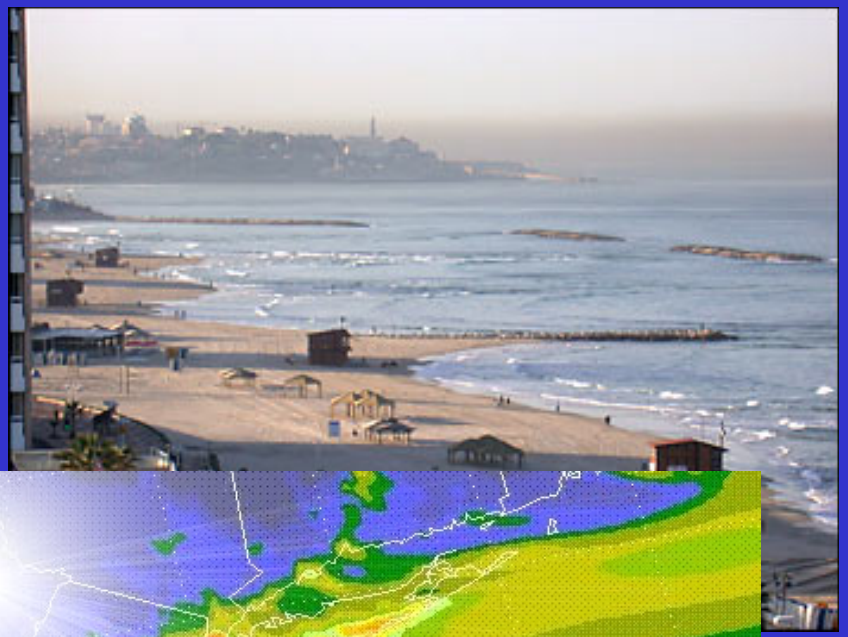
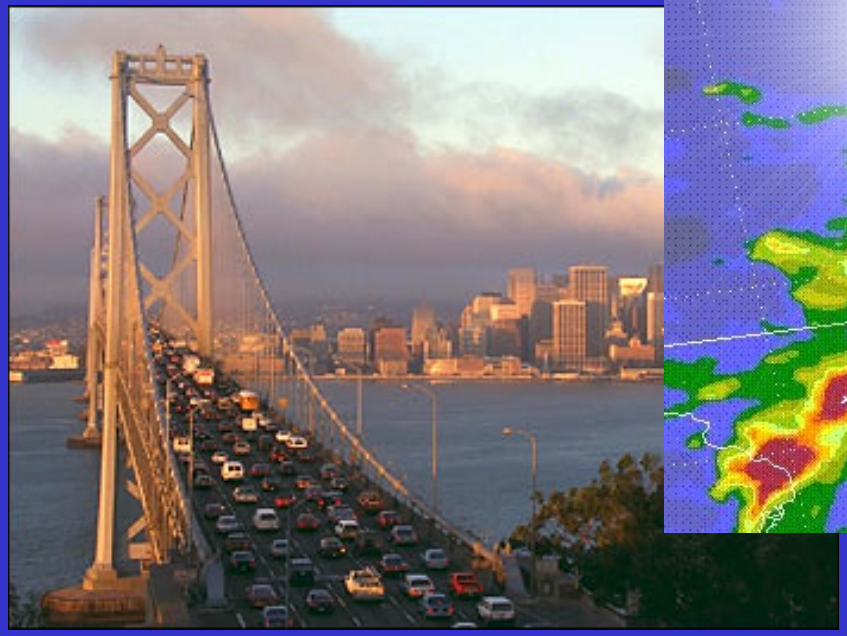
Space Science and Engineering Center
University of Wisconsin - Madison

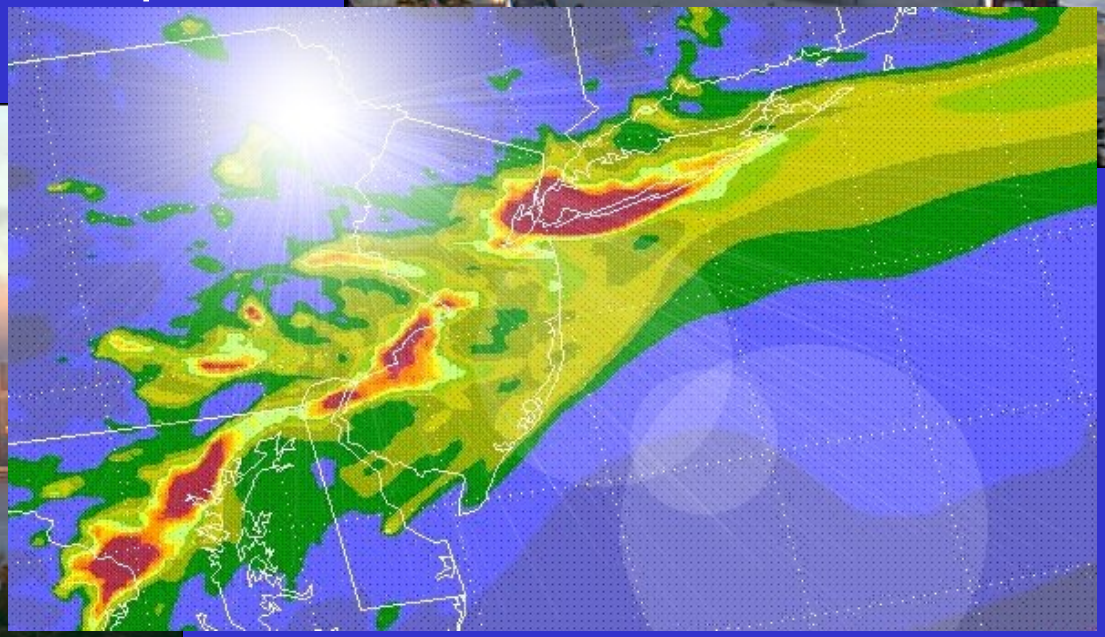
And a cast of thousands
Tony Wimmers, Steve Ackerman, Jerry Robaidek, Scott Bachmeier, James Szykman,
John White, Brad Pierce, Jassim Al-Saadi, Doreen Neil,
Chieko Kittaka, Allen Chu, Lorraine Remer, Liam Gumley, and Elaine Prins

IMAPP Radiative Transfer Workshop
2 March 2006

IDEA: NASA-EPA-NOAA partnership to improve air quality assessment, management, and prediction by infusing (NASA) satellite measurements into (EPA, NOAA) analyses for public benefit.





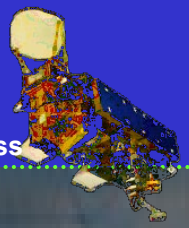


IDEA (Infusing satellite data into environmental air quality applications)

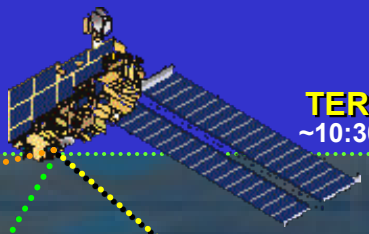
Part of NASA Earth Science Enterprise (ESE) Applications Program strategy to demonstrate practical uses of NASA sponsored observations from remote sensing systems and predictions from scientific research.

IDEA Data Flow Diagram

Not a Simple Straightforward Accomplishment



AQUA-1 MODIS
~1:30 equator overpass



TERRA MODIS
~10:30 equator overpass

NOAA
NESDIS/ORA

NOAA bent pipe

Products
Aerosol Optical Depth (MOD04_L2)
Cloud Optical Thickness (MOD06_L2)

NASA GFSC DACC

NASA GFSC Science Team

Products
Algorithms

Products (Near Real Time)
DB Aerosol Optical Depth (MOD04_L2)
DB Cloud Optical Thickness (MOD06_L2)
GOES 12 WF-ABBA fire counts

SSEC/CIMSS
Univ. of Wisc.Madison

US EPA AIRNow DMC

Products
MODIS/AIRNow Data Fusion, Analysis, Distribution, and Archive

NOAA NCEP & OAR/ARL

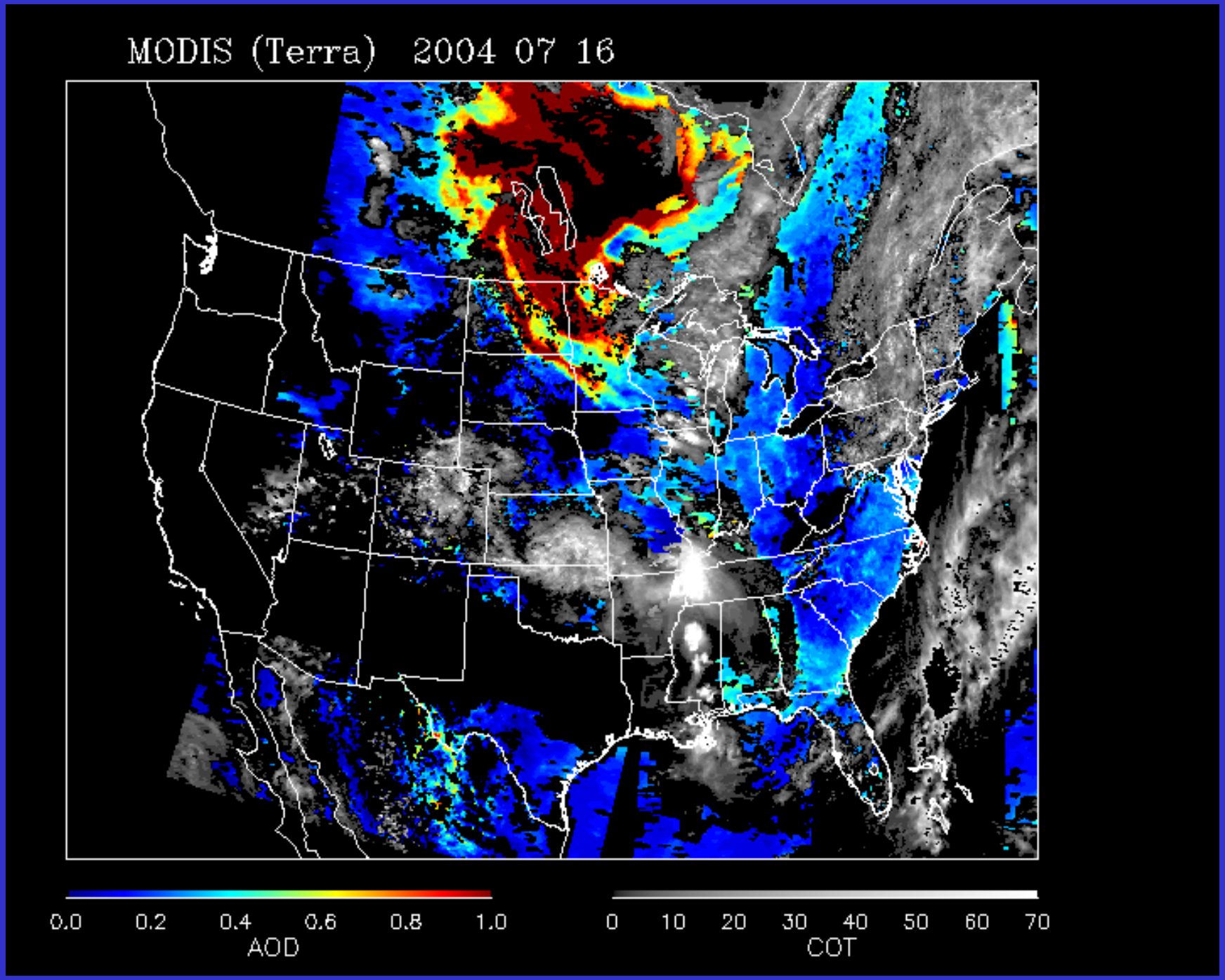
Products
Eta and EDAS Meteorological Data

AIRNow Forecasters

Products
AIRNow Hourly $PM_{2.5}$ Data

State & Local

Canadian Provinces

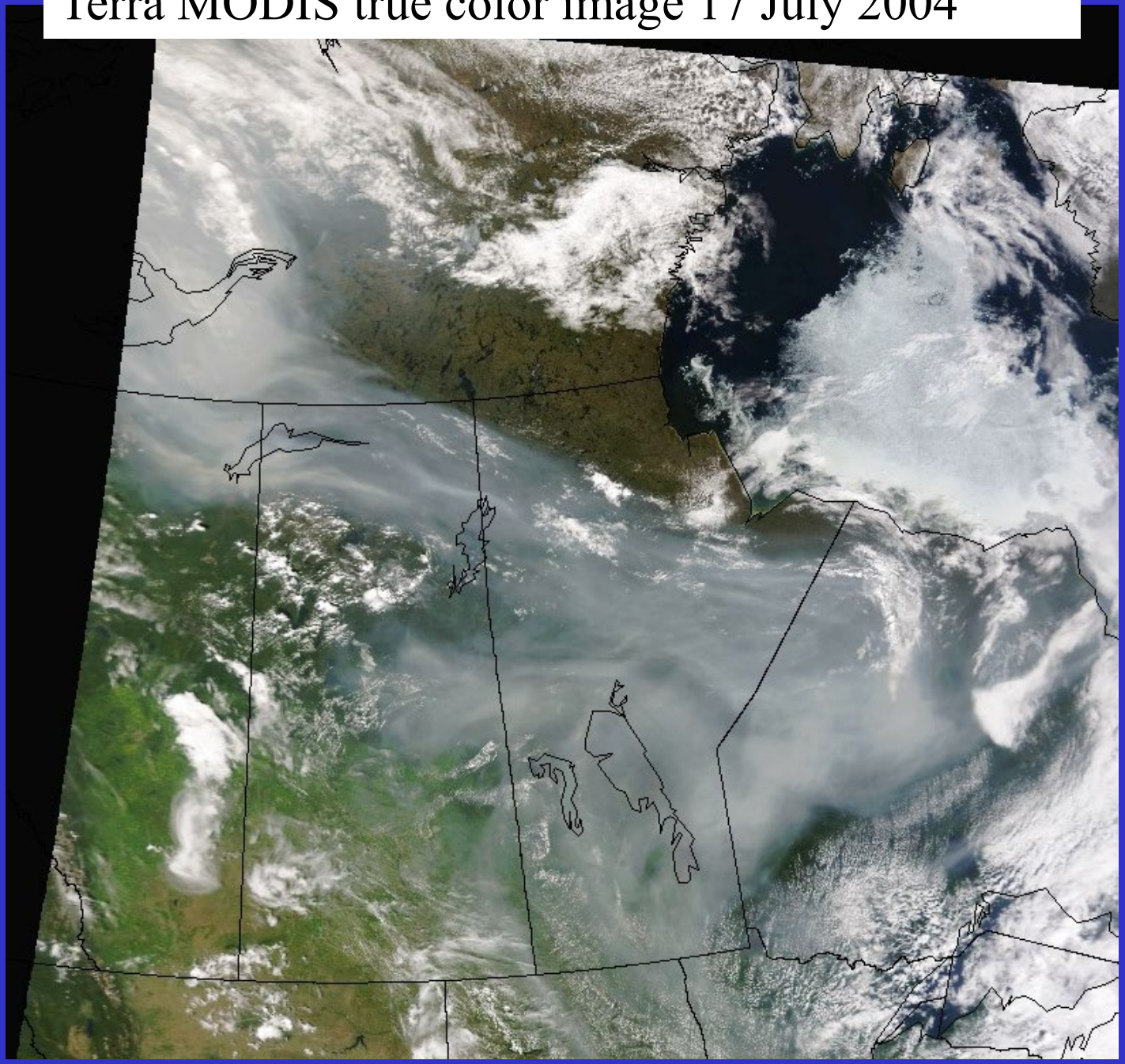

MODIS (Terra) 2004 07 16
0.0 0.2 0.4 0.6 0.8 1.0
AOD
0 10 20 30 40 50 60 70
COT

Air Quality Index for Particles

Index Values	Category	Cautionary Statements	$PM_{2.5}$ (ug/m^3)	PM_{10} (ug/m^3)
0-50	Good	None	0-15.4	0-54
51-100	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion	15.5-40.4	55-154
101-150	Unhealthy for Sensitive Groups	Sensitive groups should reduce prolonged or heavy exertion	40.5-65.4	155-254
151-200	Unhealthy	Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion	65.5-150.4	255-354
201-300	Very Unhealthy	Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion	150.5-250.4	355-424

Source: US EPA, 1997

Terra MODIS true color image 17 July 2004

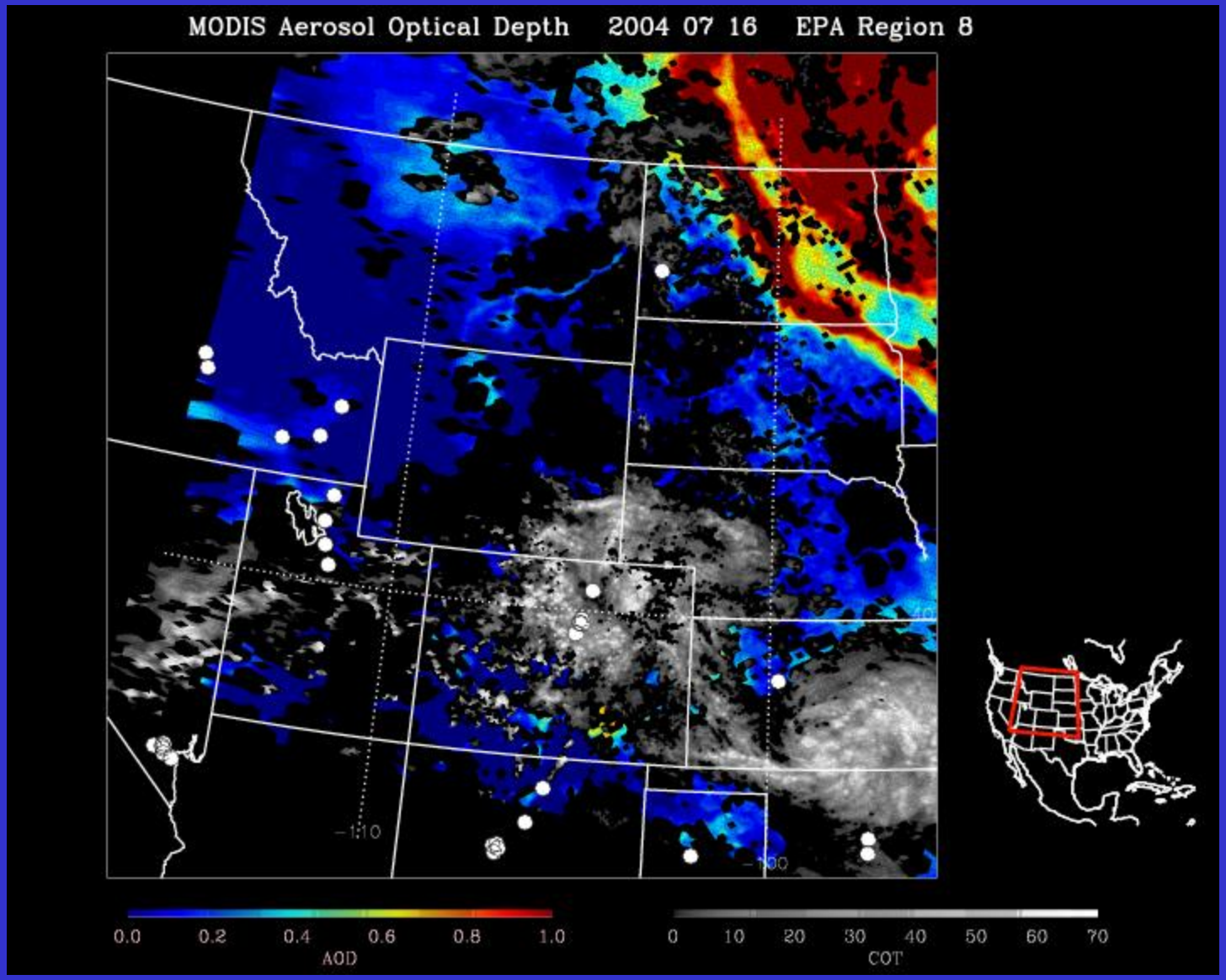


IDEA
Forecast Tool Products

(Example from July 2004 Aerosol Outbreak)

- Regional Summary Plots of MODIS Aerosol Optical Depth and Cloud Optical Thickness
- MODIS Aerosol Optical Depth 48 hour Trajectories Forecast
- Composite PM2.5/MODIS Aerosol Optical Depth Data Fusion 3-day Animation
- Time-series between MODIS Aerosol Optical Depth and PM2.5 (1hr and 24hr) Mass Concentration
- National Correlation Map between PM2.5 and MODIS Aerosol Optical Depth
- Daily Forecast Discussion and Blog

Regional Summary Plots of MODIS Aerosol Optical Depth and Cloud Optical Thickness



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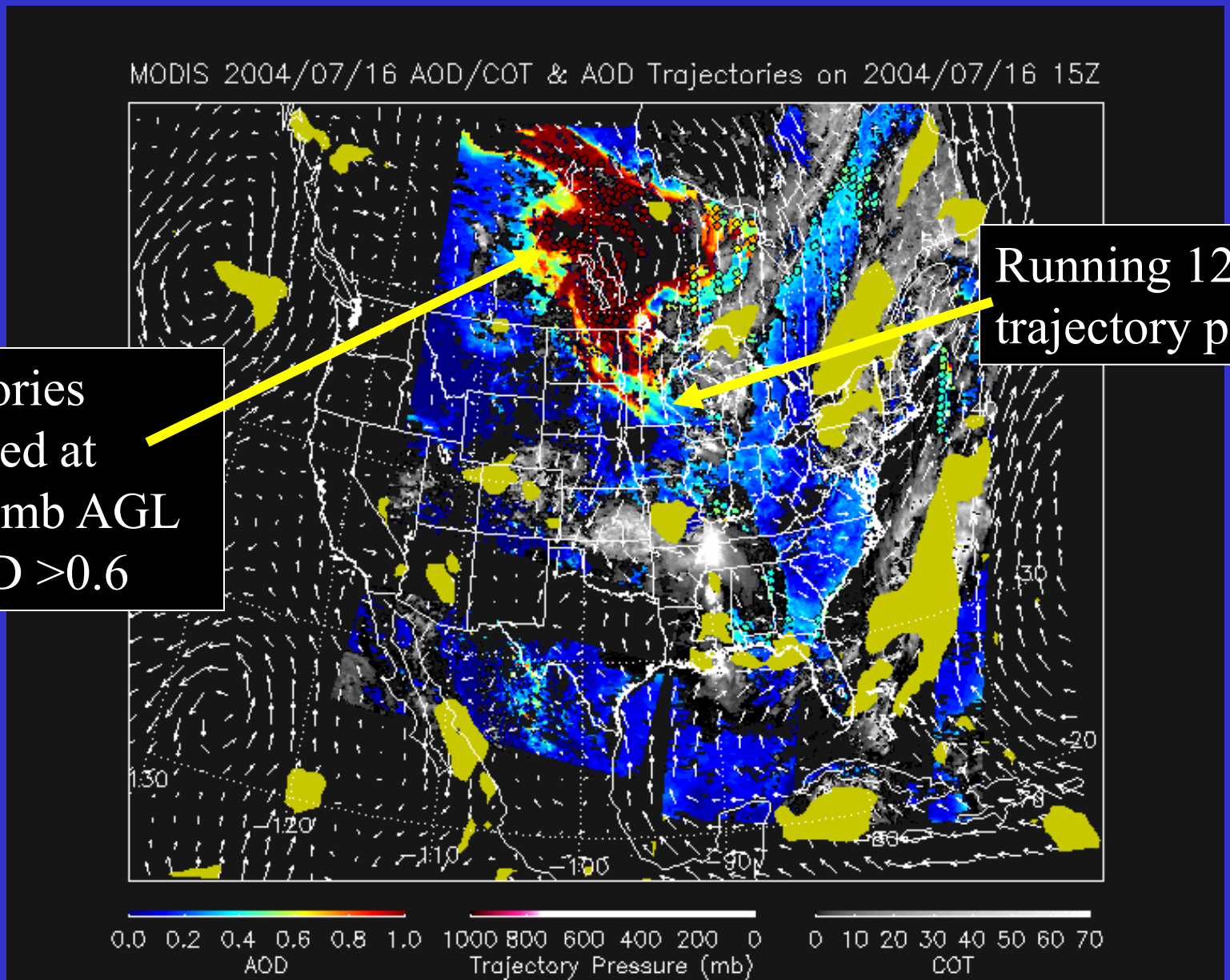
MODIS Aerosol Optical Depth 48 hour Air Parcel Forecast Trajectories (16 July 2004)



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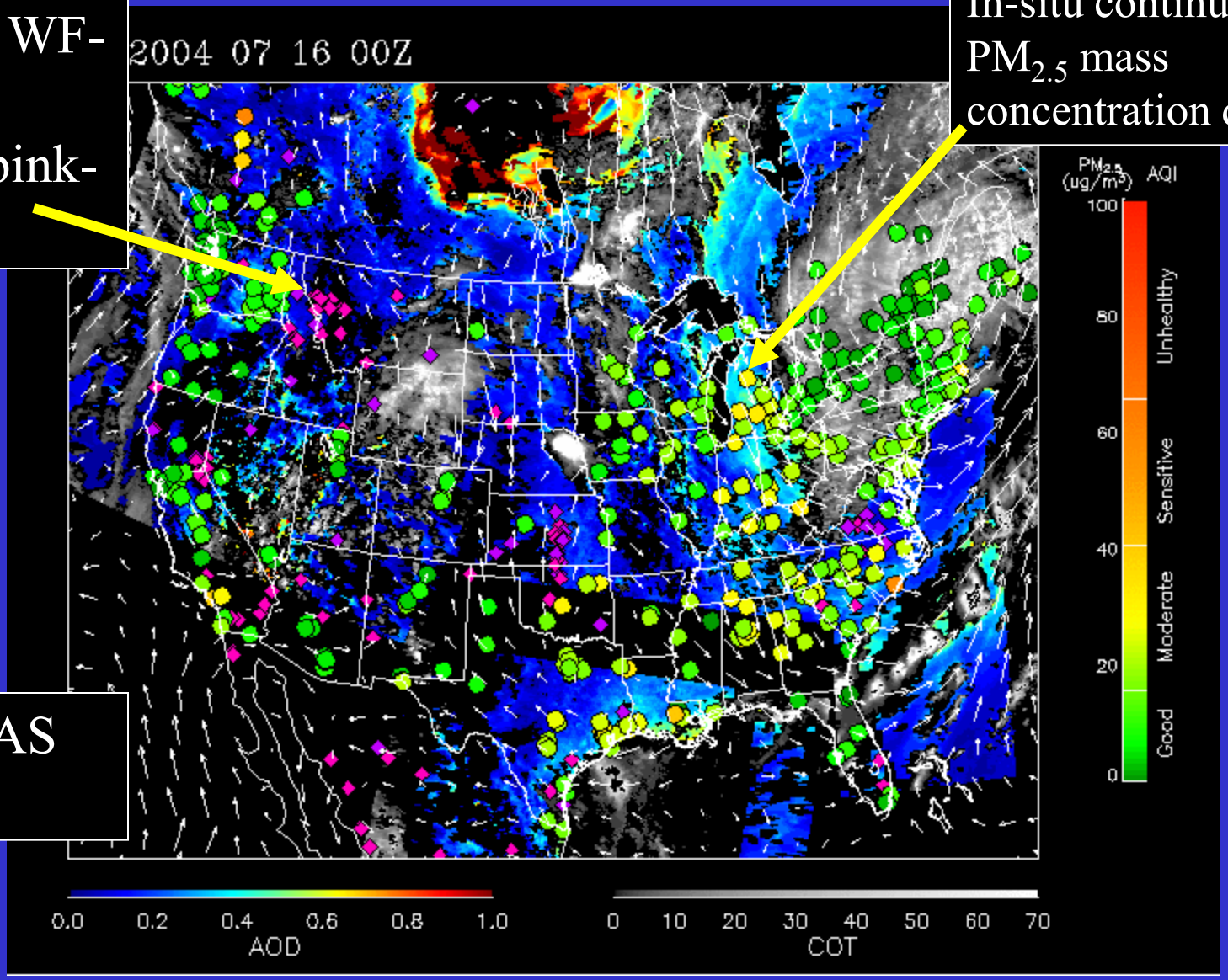
Composite PM2.5/MODIS Aerosol Optical Depth Data Fusion 3-day Animation

Half-hourly WF-ABBA Fire Locations (pink-purple)

In-situ continuous $PM_{2.5}$ mass concentration data

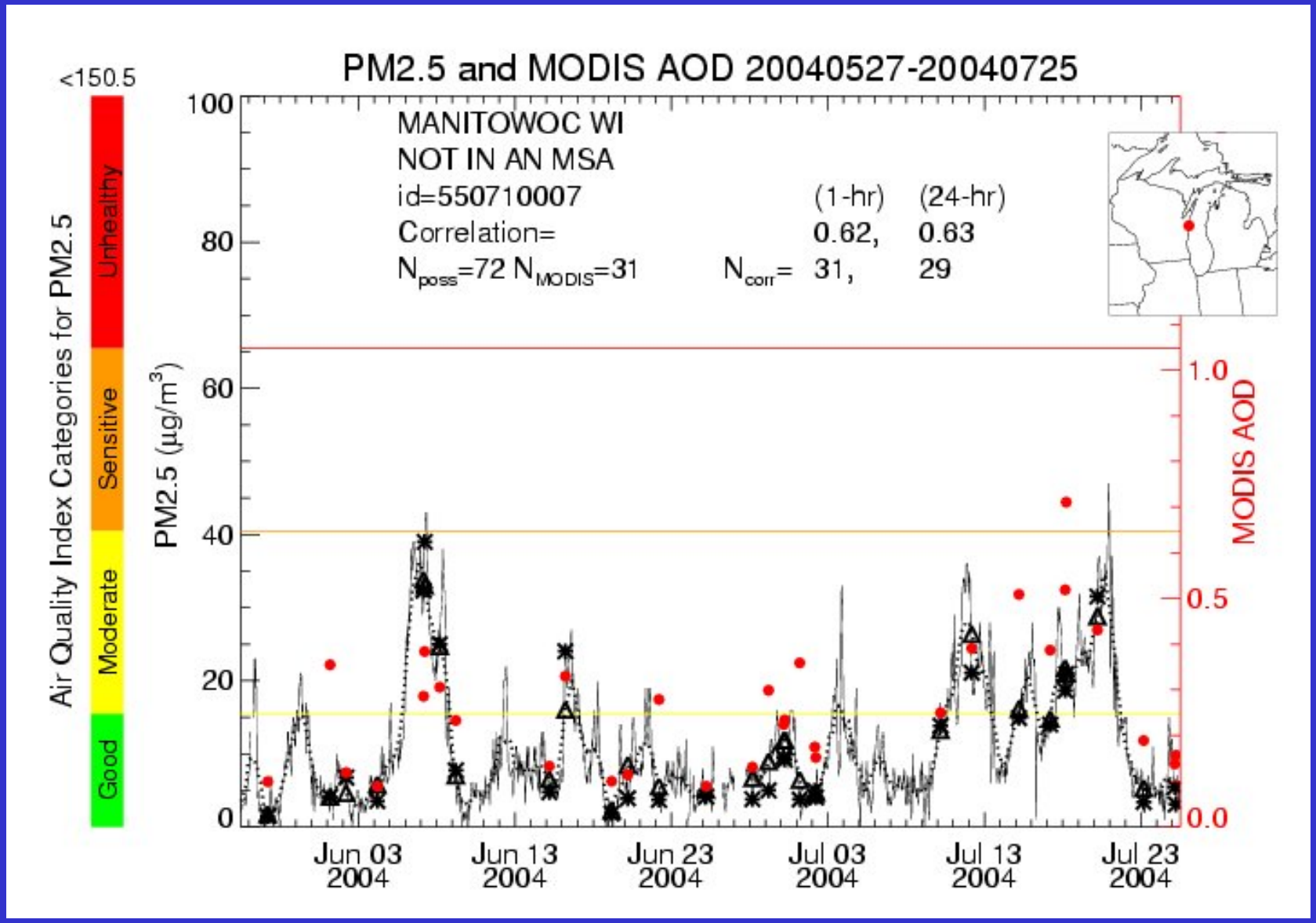


850 mb EDAS wind fields

IDEA
Forecast Tool Products

- Regional Summary Plots of MODIS Aerosol Optical Depth and Cloud Optical Thickness
- MODIS Aerosol Optical Depth 48 hour Trajectories Forecast
- Composite PM2.5/MODIS Aerosol Optical Depth Data Fusion 3-day Animation
- Time-series between MODIS Aerosol Optical Depth and PM2.5 (1hr and 24hr) Mass Concentration
- National Correlation Map between PM2.5 and MODIS Aerosol Optical Depth
- Daily Forecast Discussion and Blog

Time-series between MODIS Aerosol Optical Depth and PM2.5 (1hr and 24hr) Concentrations



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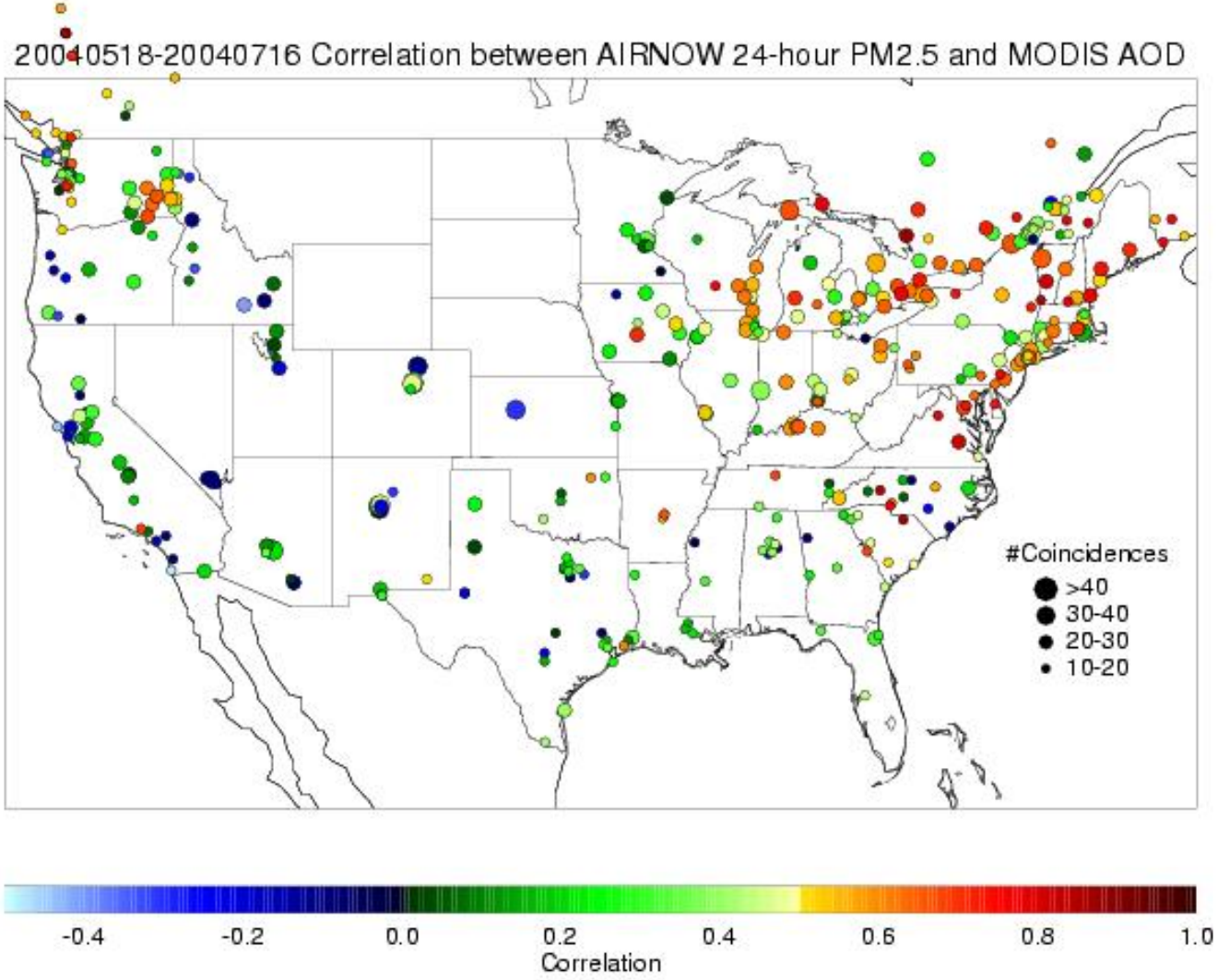
National Correlation Map between PM2.5 Mass Concentration and MODIS Aerosol Optical Depth



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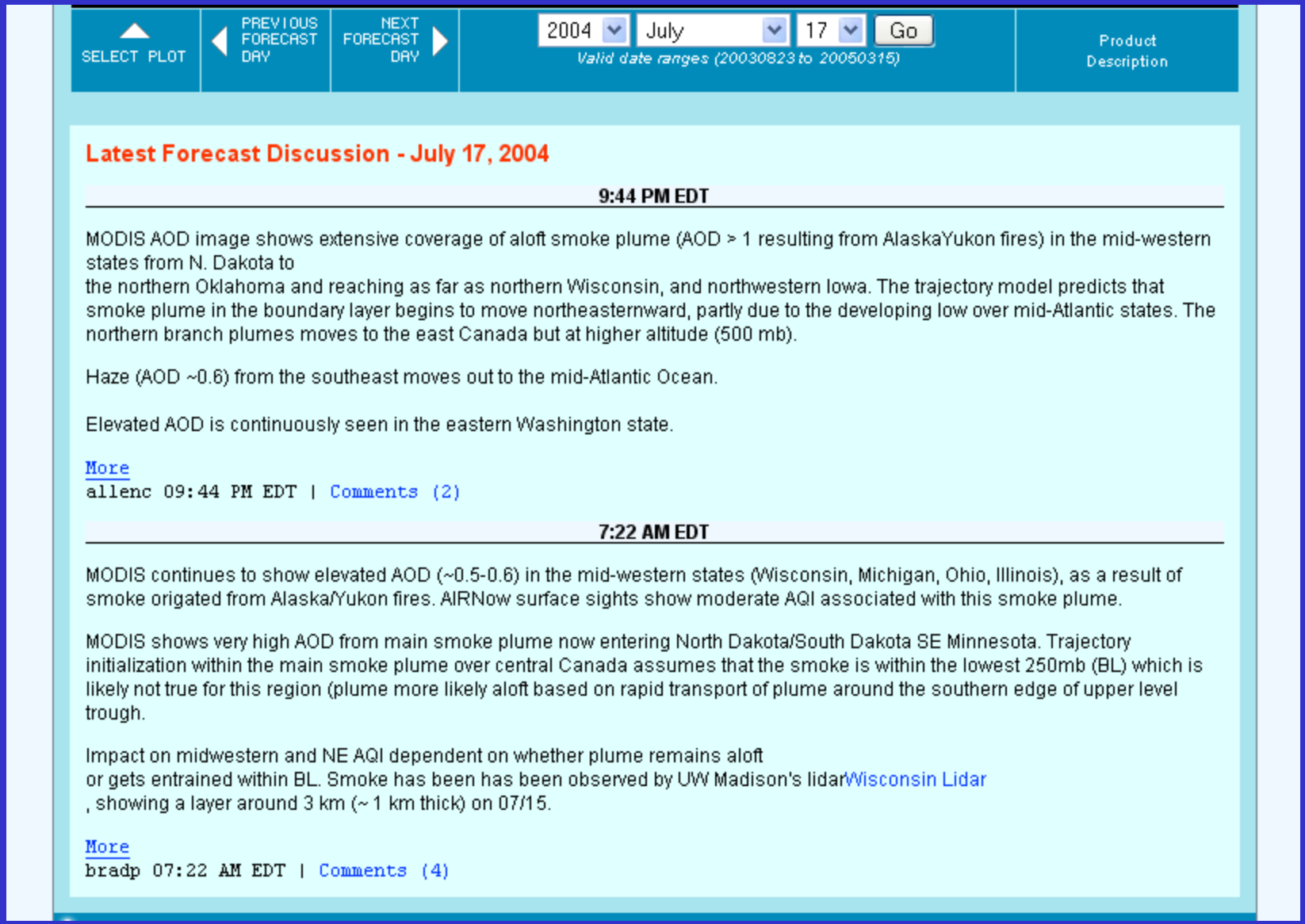
IDEA Forecast Discussions



IDEA Web Site Conclusions
User Feedback

Successfully demonstrated the utility of producing and combining multi-source products for improving Air Quality forecasts.

Comments compiled by John White (EPA) and Jim Szykman (LaRC):

"I try to check the IDEA web site daily as it is helpful for PM2.5 forecasting. I particularly use the animated 48-hour trajectory forecast. It would be nice if it were possible for the user to stop the animation at specific times since it runs continuously. Each morning I also read the forecast discussion that comes out the previous evening. It might be nice if the forecast discussion was moved to the morning since it would be timelier for forecasters. It is an excellent product."

I think we should make it a priority to migrate the IDEA graphical products into the AniS applet as soon as possible, to allow a higher level user control andd interactivity -- it sounds like they (the users) would appreciate such an improvement. -Jim

IDEA Real-time Web Site

http://idea.ssec.wisc.edu/