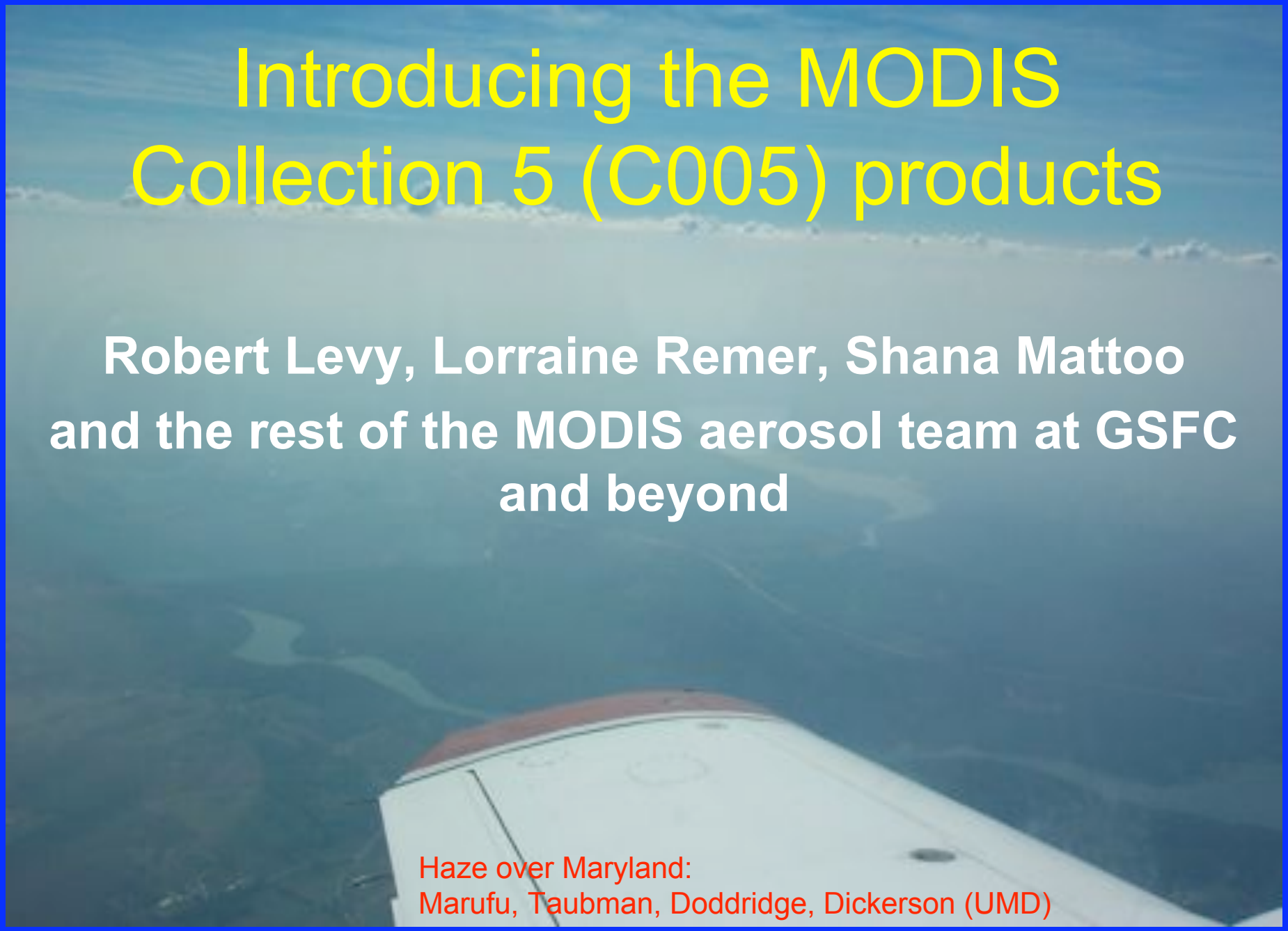
Introducing the MODIS Collection 5 (C005) products

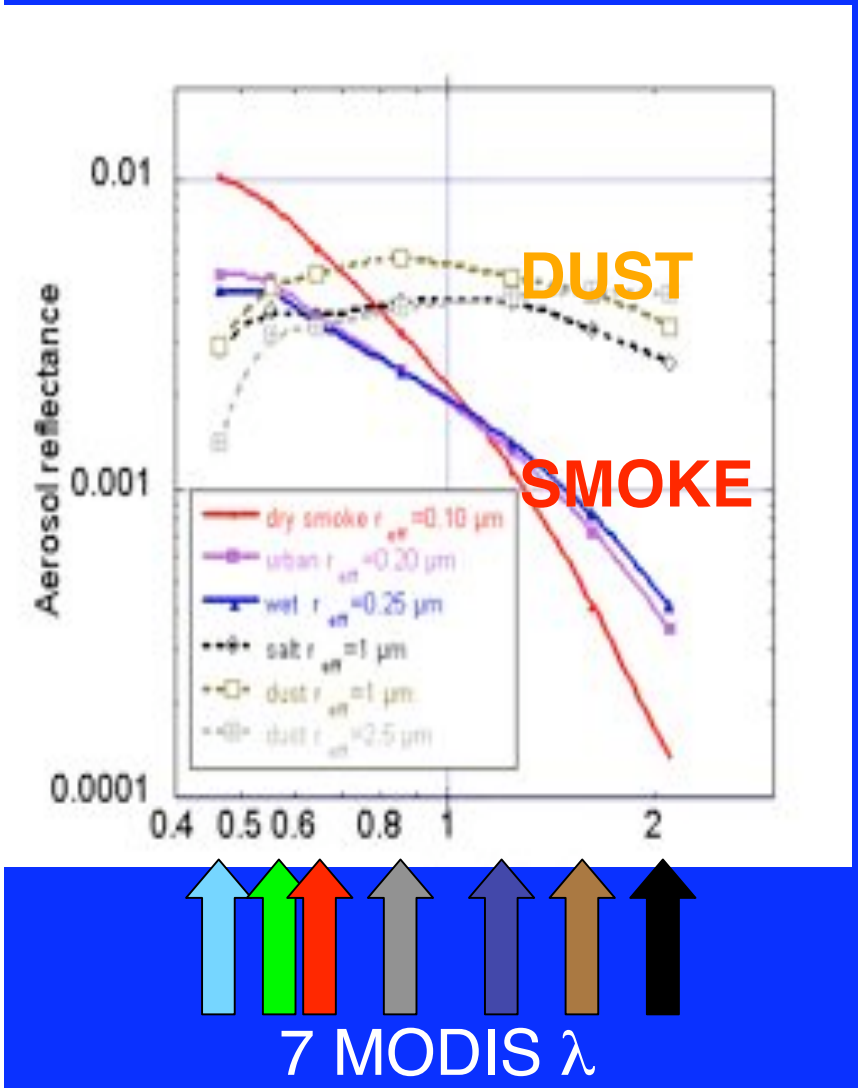
Robert Levy, Lorraine Remer, Shana Mattoo

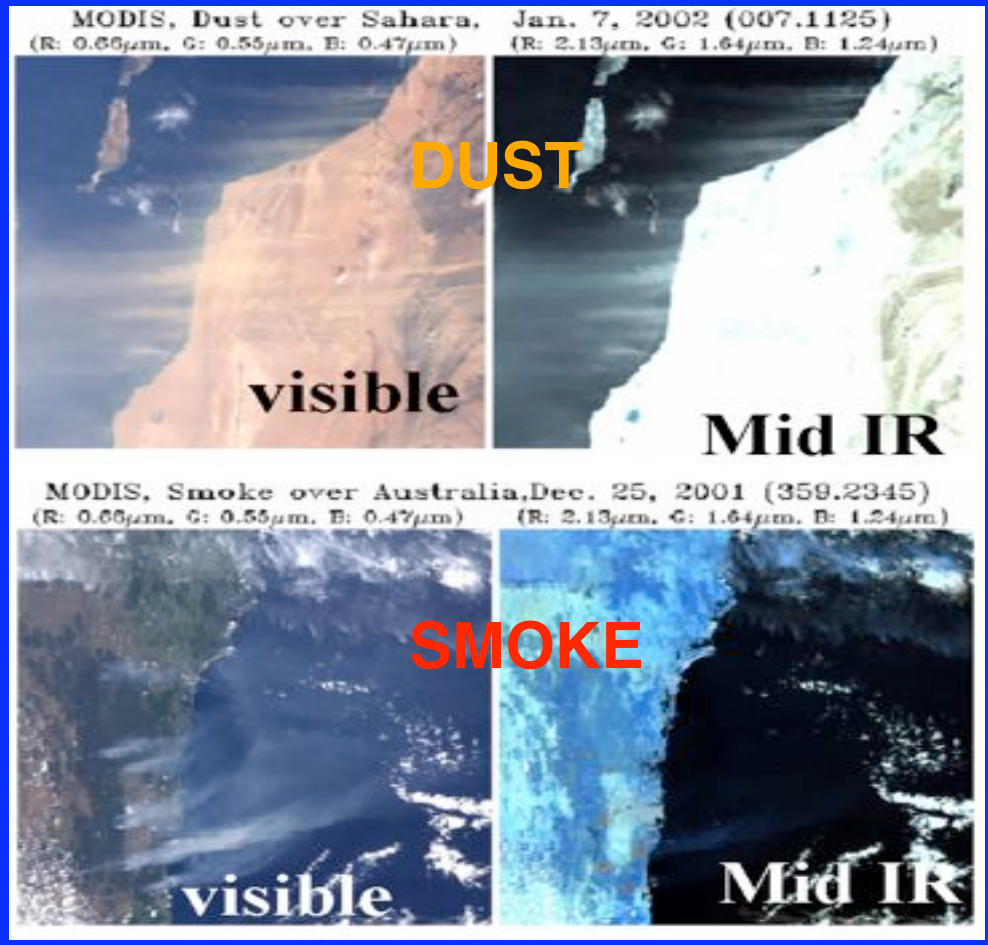
and the rest of the MODIS aerosol team at GSFC and beyond



Haze over Maryland:
Marufu, Taubman, Doddridge, Dickerson (UMD)

Spectral optical properties of aerosol

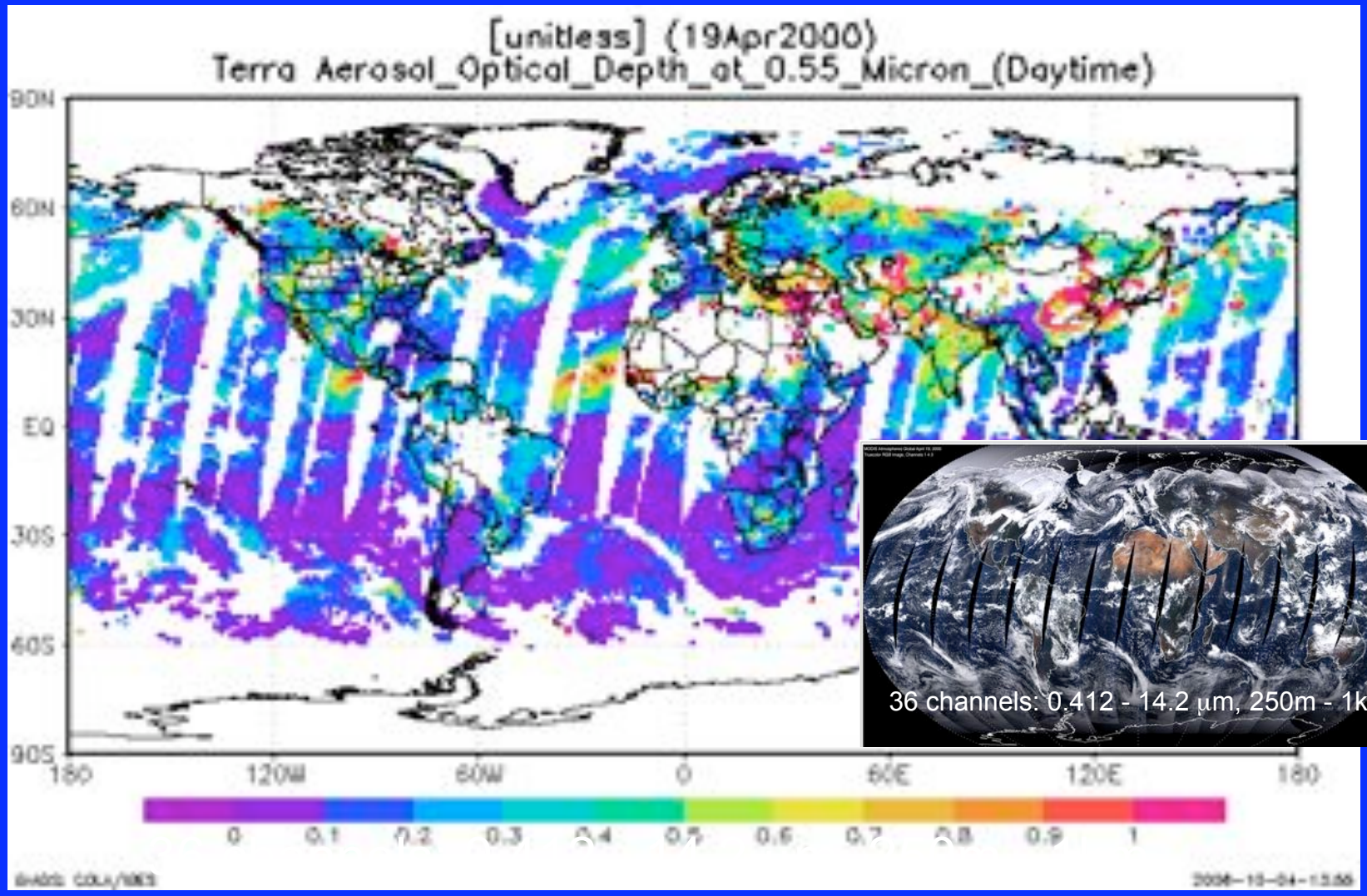




Y. Kaufman

Leads to two separate algorithms, one over land, one over ocean

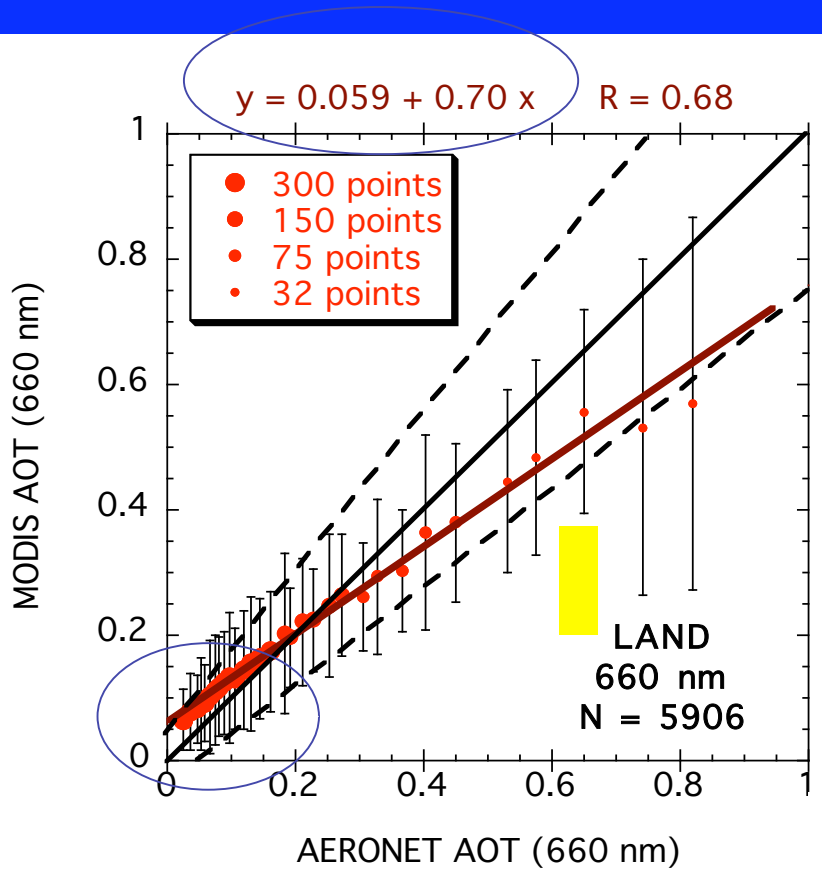
MODIS Aerosol τ product (C004)
Combined land and ocean

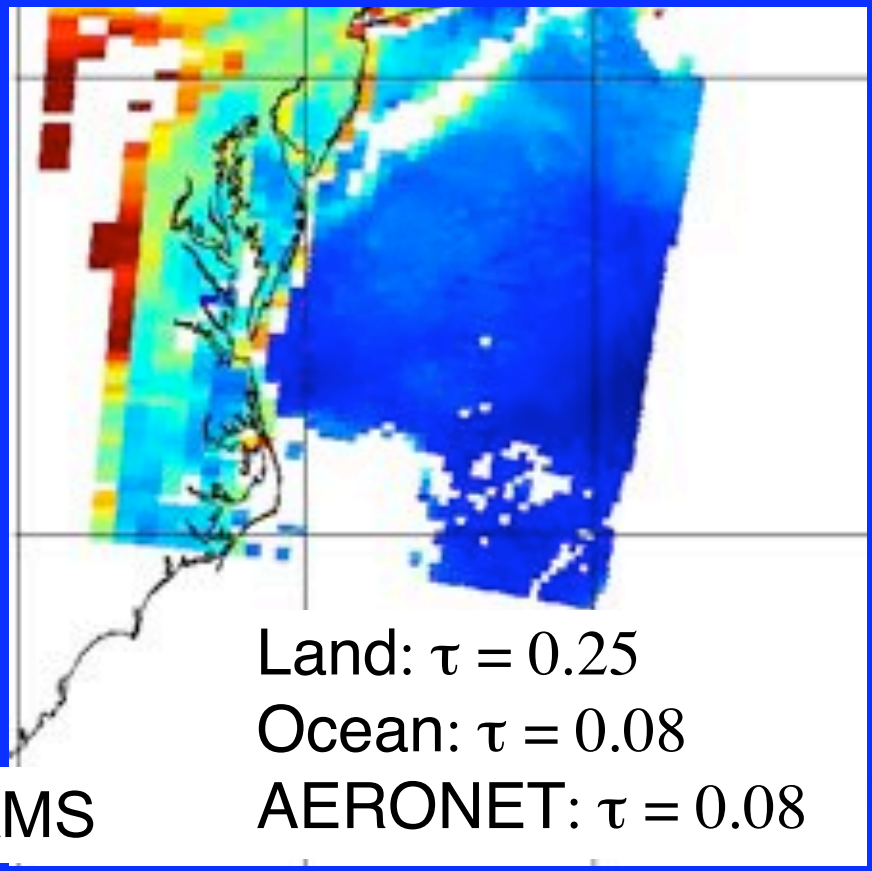


http://g0dup05u.ecs.nasa.gov/Giovanni/

But, Collection ‘004’ has issues…

…τ over Land





CLAMS

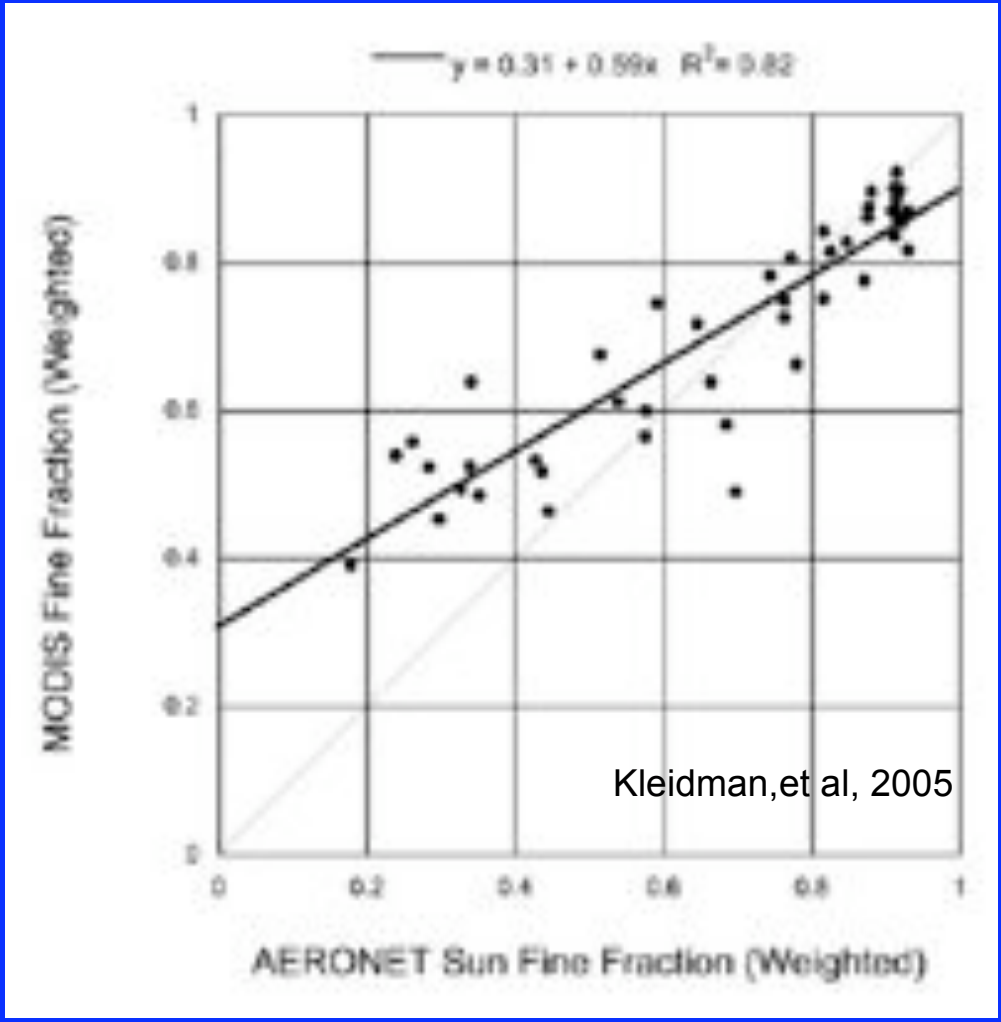
Land: $\tau = 0.25$

Ocean: $\tau = 0.08$

AERONET: $\tau = 0.08$

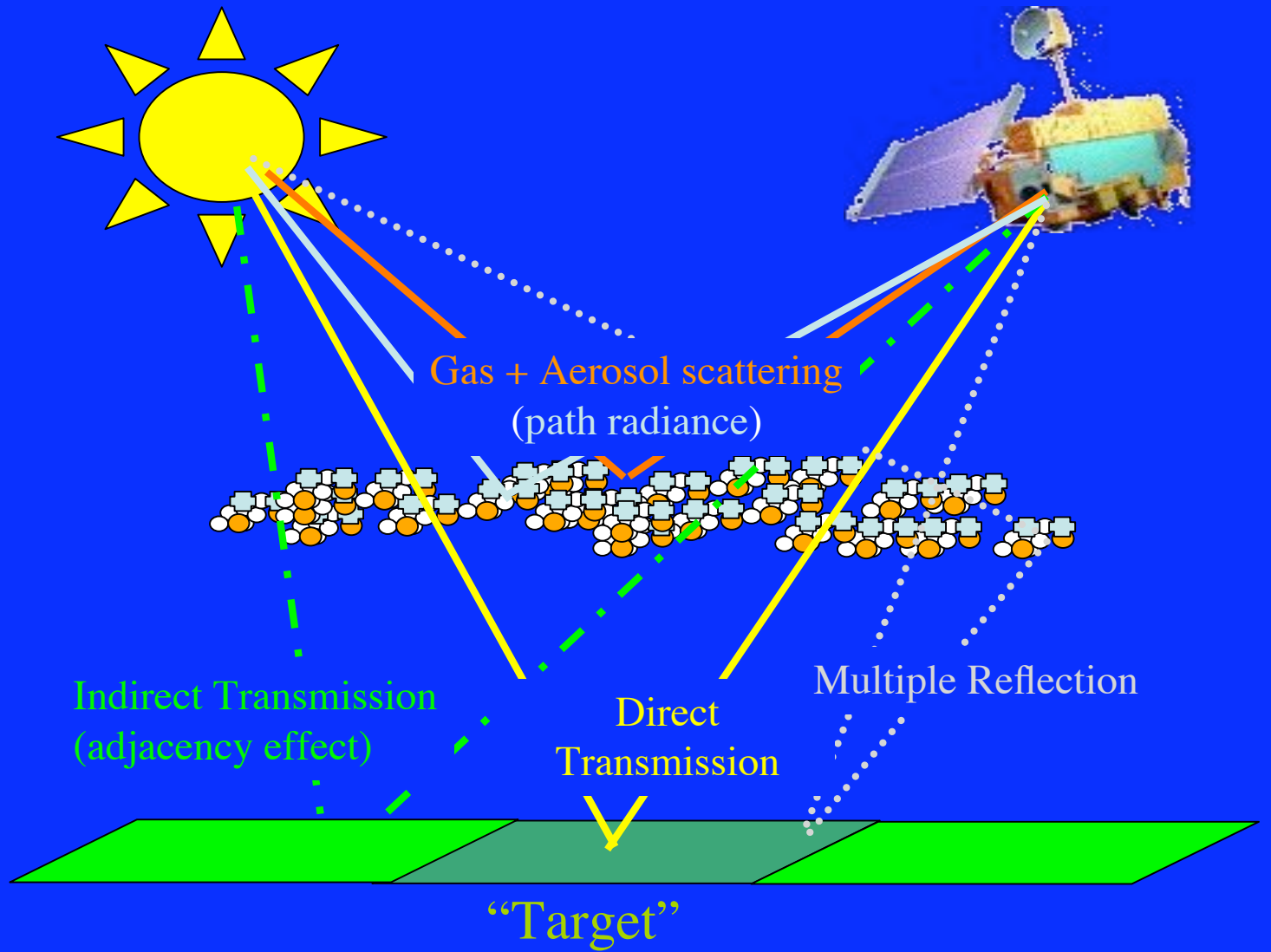
- Useful and "validated" MODIS τ over land
- But, y-offset > 0 and slope < 1 in τ regression and discontinuities between land and ocean
- Global and/or regional bias?

…η over Ocean



- Useful /validated MODIS τ and η (Fine fraction) over ocean
- But, y-offset > 0 and slope < 1 in η regression
- Global and/or regional bias to size?

The Satellite Signal is complicated

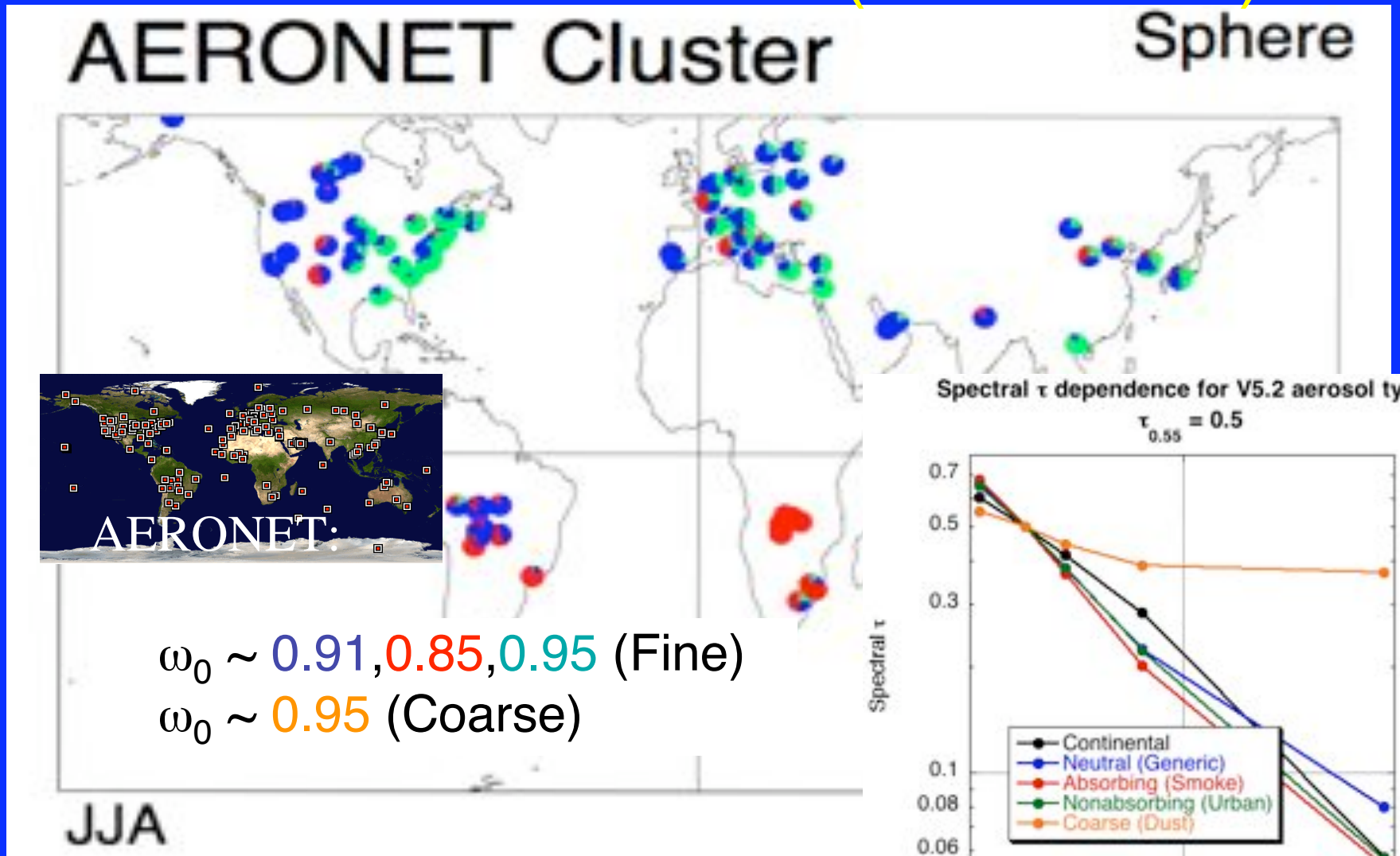


(not to mention cloud effects)

Changes to Land retrieval

- Recomputed center wavelengths and Rayleigh OD
- Radiative transfer includes atmospheric polarization
- Aerosol models based on Dubovik (2002) and new geographic distribution
- Surface reflectance relationships are functions of vegetation index and scattering angle
- New inversion algorithm implemented
- Valid range of τ extended to -0.05
- Subpixel snow mask implemented
- Cloud mask adjusted and QA flag set to 0 in some cases
- Mass concentration now multiplied by exp(4.5σ)
- New products

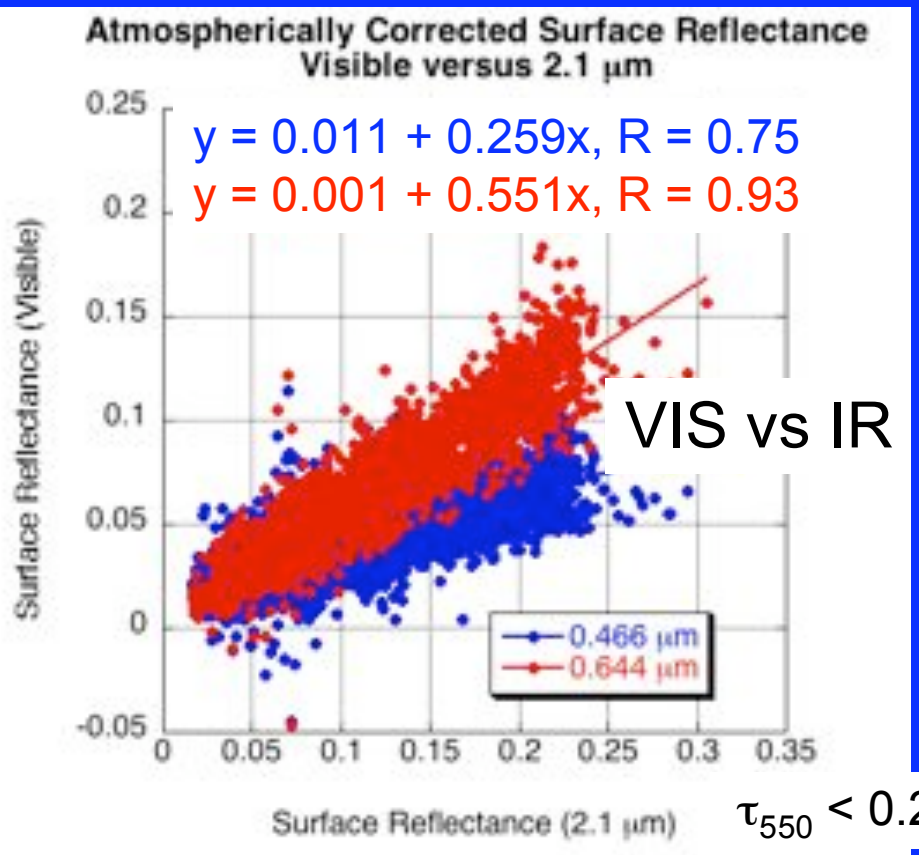
Global aerosol optical models
An AERONET view (since 1994)

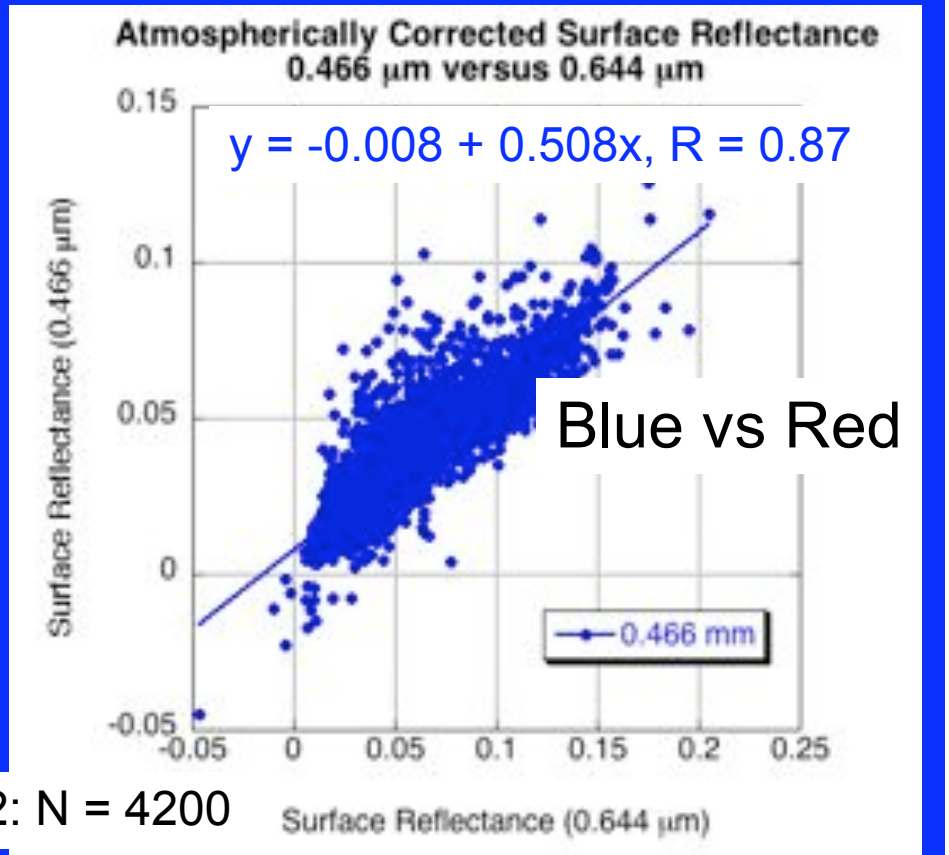


Surface reflectance: global

C004 (Global fixed ratio of VIS to 2.1 μm)

$\rho_s^{0.66} = 0.5(\rho_s^{2.1})$; $\rho_s^{0.47} = 0.25(\rho_s^{2.1})$





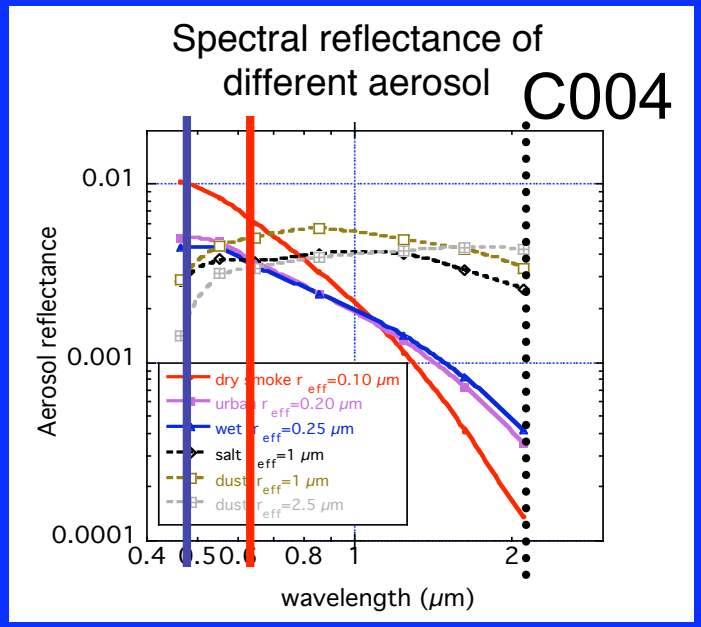
$\tau_{550} < 0.2$: N = 4200

C005 (parameterization of 2.1 μm, angle, and surface)

$\rho_s^{0.66} = f^{0.66}(\rho_s^{2.1}, \Theta, NDVI_{SWIR})$

$\rho_s^{0.47} = g^{0.47}(\rho_s^{0.66}, \Theta, NDVI_{SWIR})$

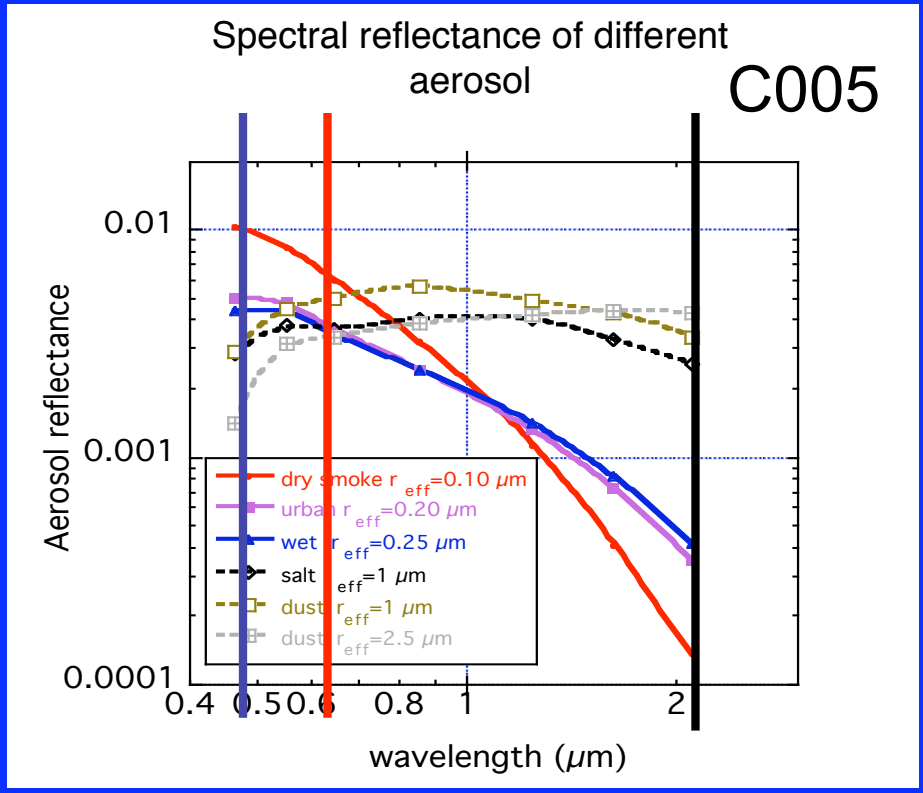
Retrieval technique



C004:
Aerosol ~ transparent at 2.1 μm

2.1 μm used to estimate surface only

Independent τ at 0.47 & 0.66 μm



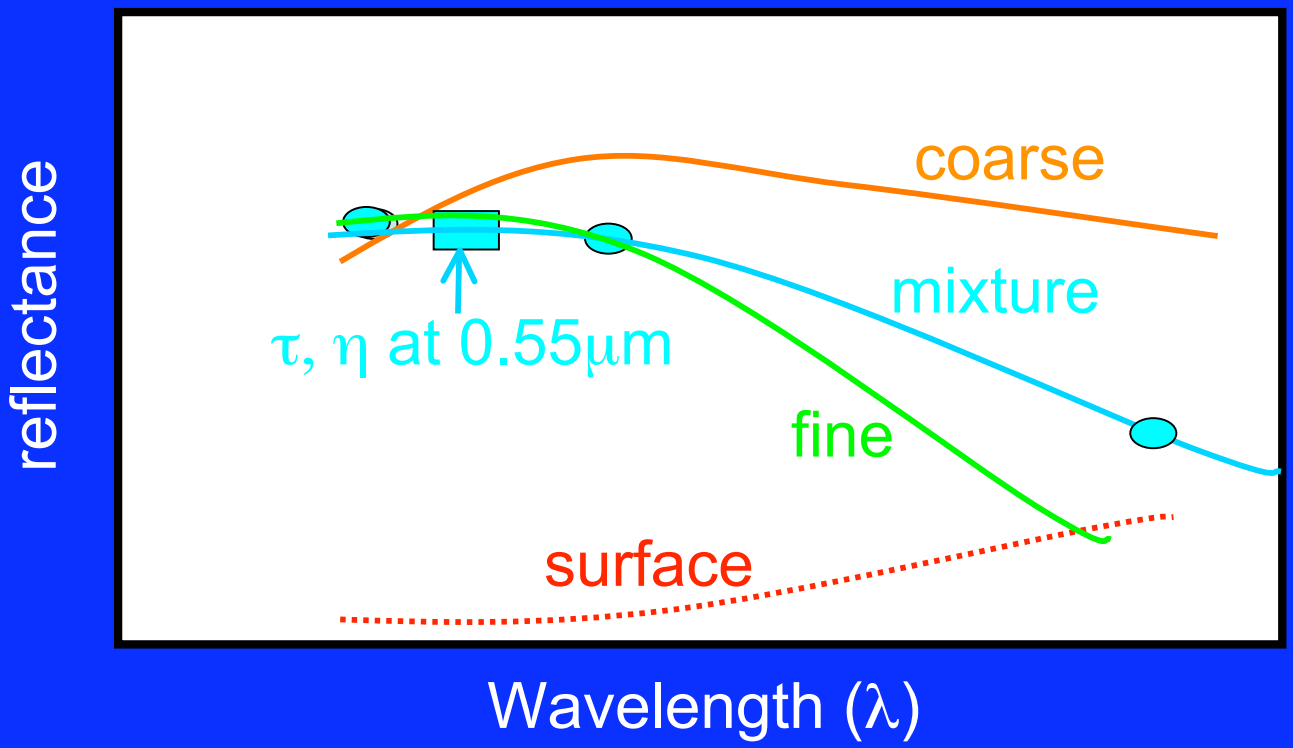
C005:

Aerosol information at 2.1 μm

Simultaneous inversion of 3 channels yields 2.5 pieces of information: τ,η and ρ_s

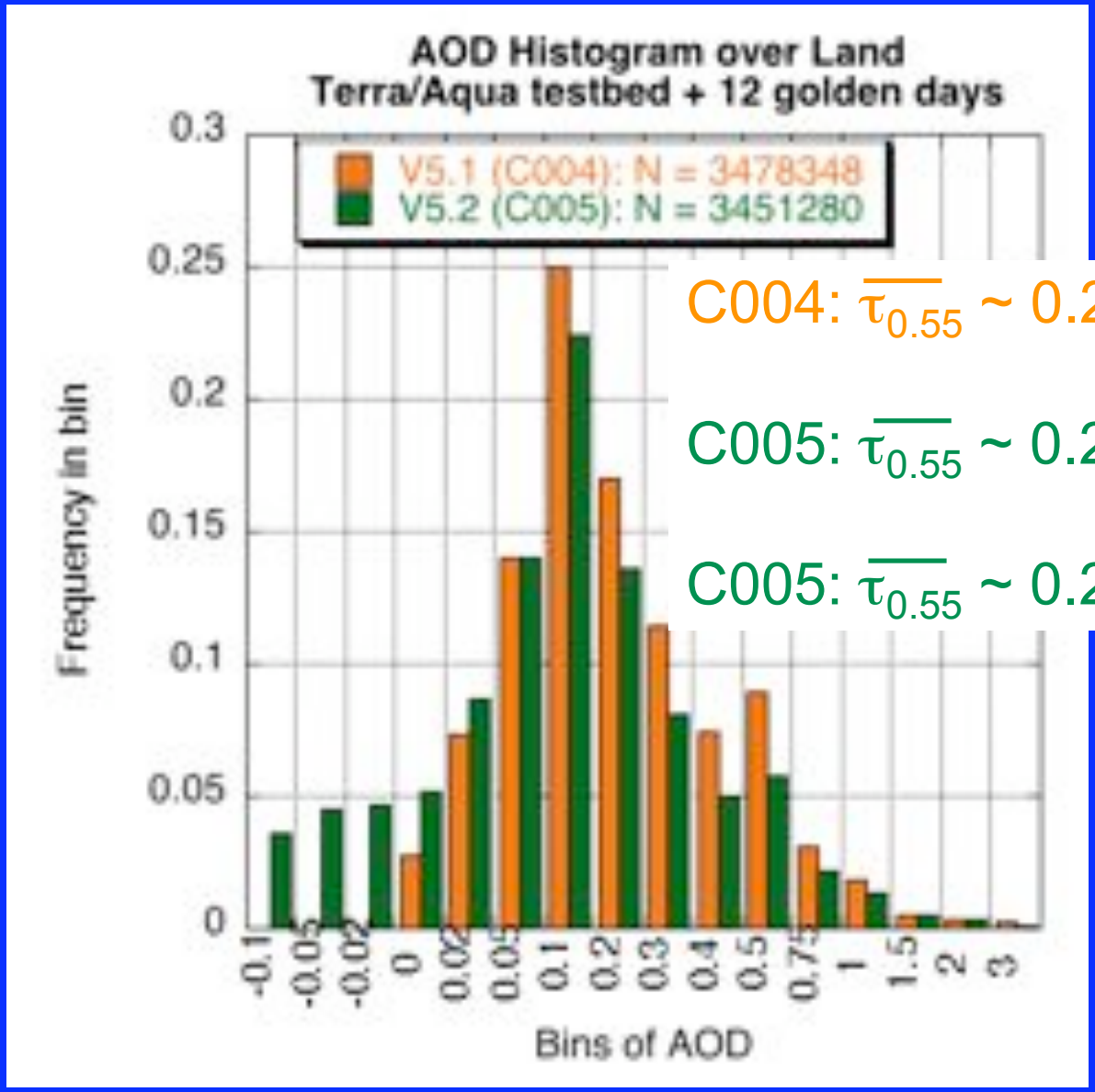
Philosophically like over-ocean retrieval

Retrieval: The Inversion



Calculate amount τ and weighting η of fine-dominated model (to coarse-dominated model), combined with the surface reflectance ρ_s, that best matches the observed spectral reflectance (0.47, 0.66 and 2.1μm)

Retrievals of $-0.05 \leq \tau < 0.0$ are allowed



C004: $\overline{\tau_{0.55}} \sim 0.28$

C005: $\overline{\tau_{0.55}} \sim 0.21$ (12% are $\tau \leq 0.0$)

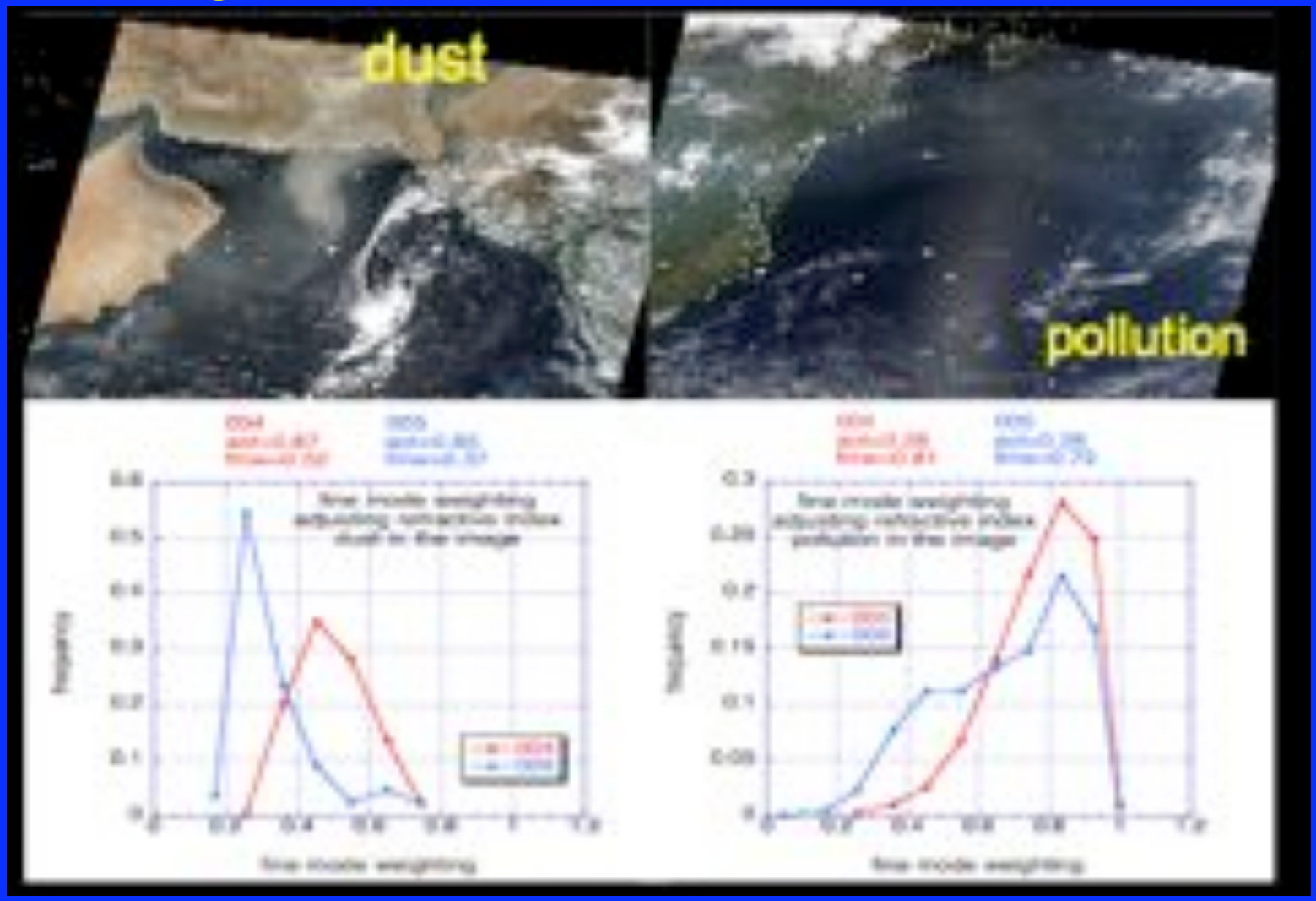
C005: $\overline{\tau_{0.55}} \sim 0.22$ (only $\tau > 0.0$)

-'s improve statistics of "near zero" τ (measurement "noise")

Changes to ocean retrieval

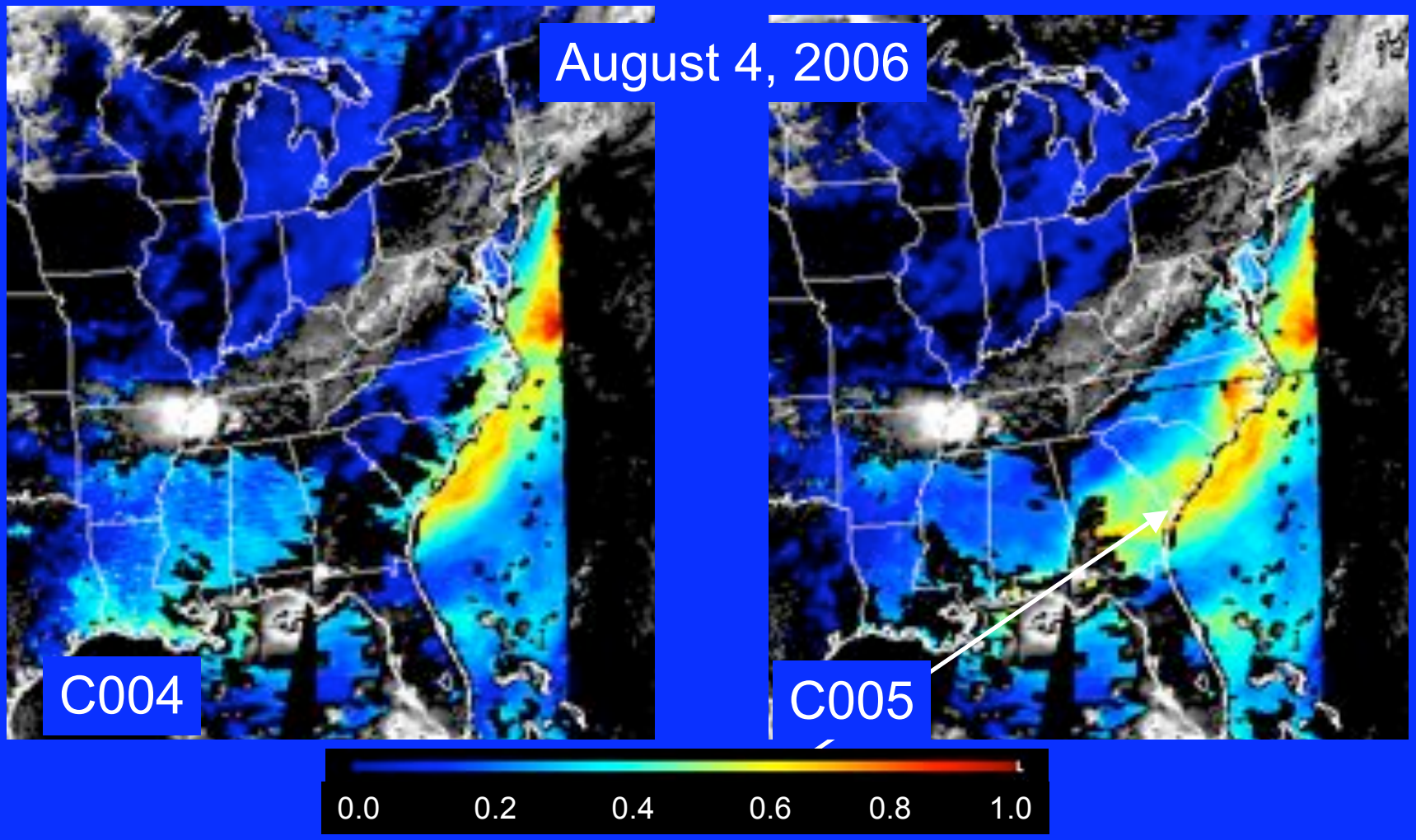
- Real and imaginary refractive indices changed for 3 of the 5 coarse modes in the Look Up Table
- CCN units corrected.
- Mass concentration now multiplied by $4\pi/3$

Changes to Coarse Mode Refractive Index



New refractive Indices for coarse modes #7,8 and 9 (of 1.35-0.001*i*) result in lower η values in areas of coarse aerosol, without affecting retrievals of fine aerosol or the total τ.

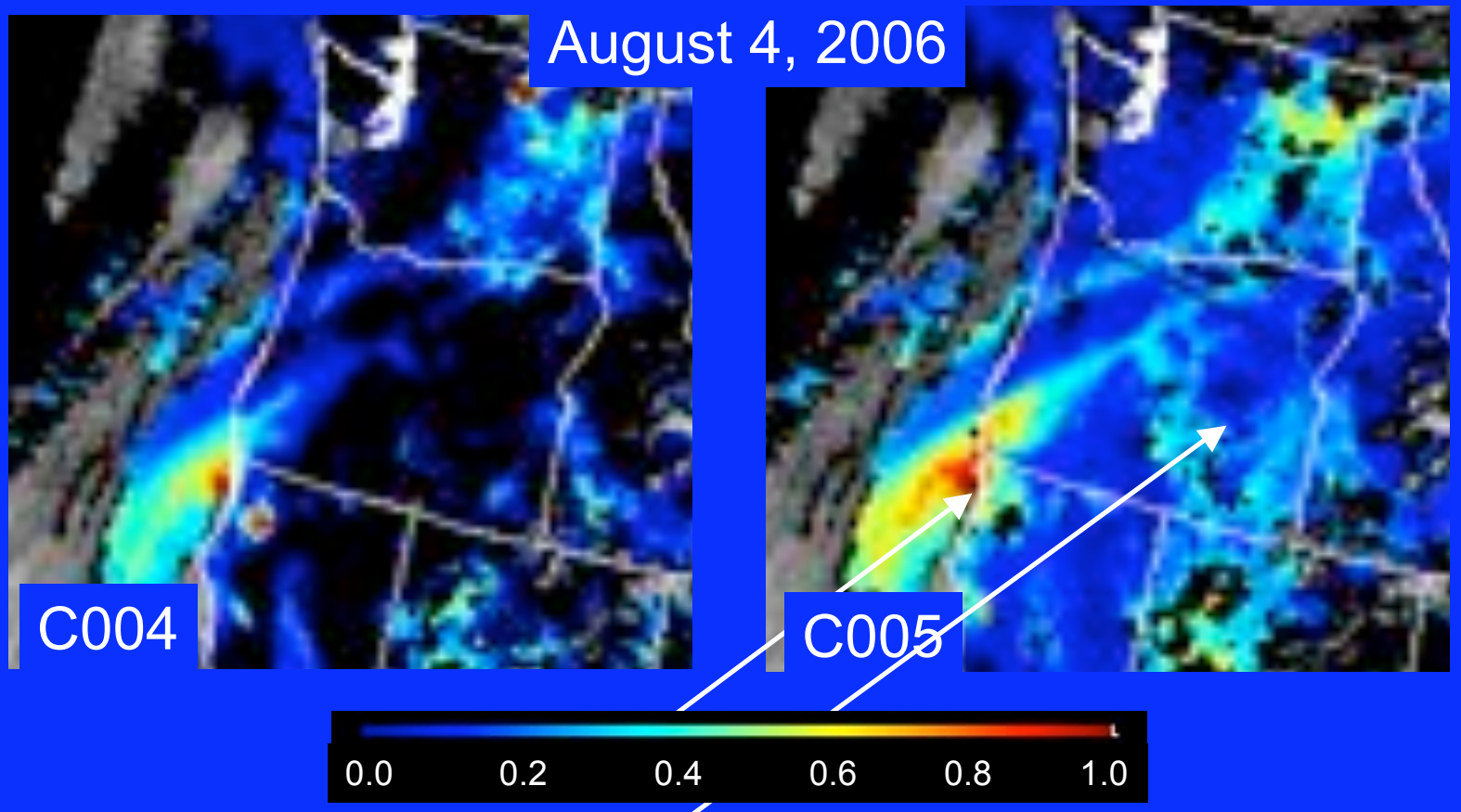
Sanity Check: Images
1. τ over US East Coast



C005: Coherent Plumes from land to ocean

Anthony Wimmers, CIMMS

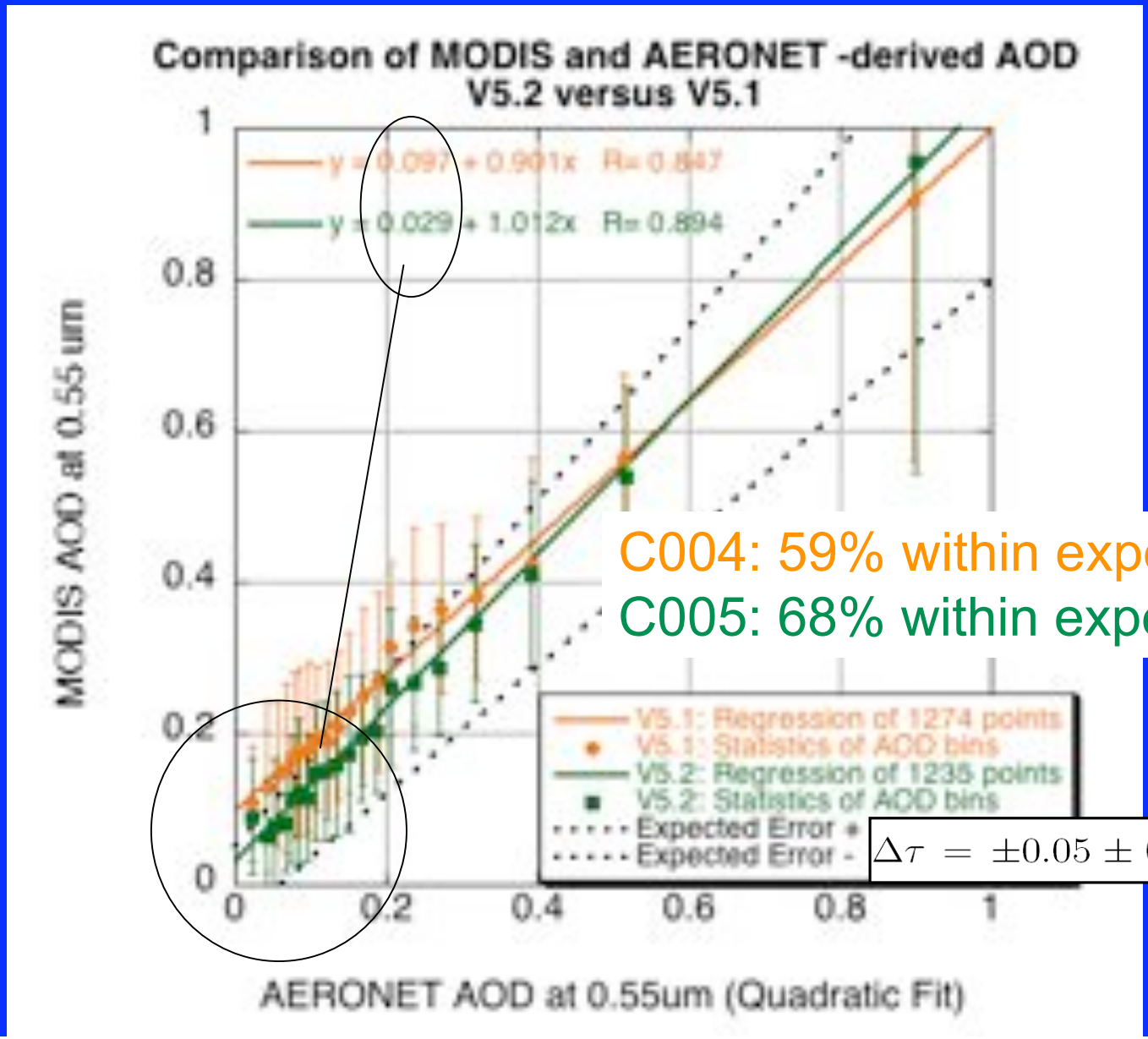
Sanity Check: Images
2. τ over Western U.S.



C005: Coherent Plumes from land to ocean
(and lots more retrievals over high terrain)

Anthony Wimmers, CIMMS

Comparison: Land
MODIS vs AERONET (τ)

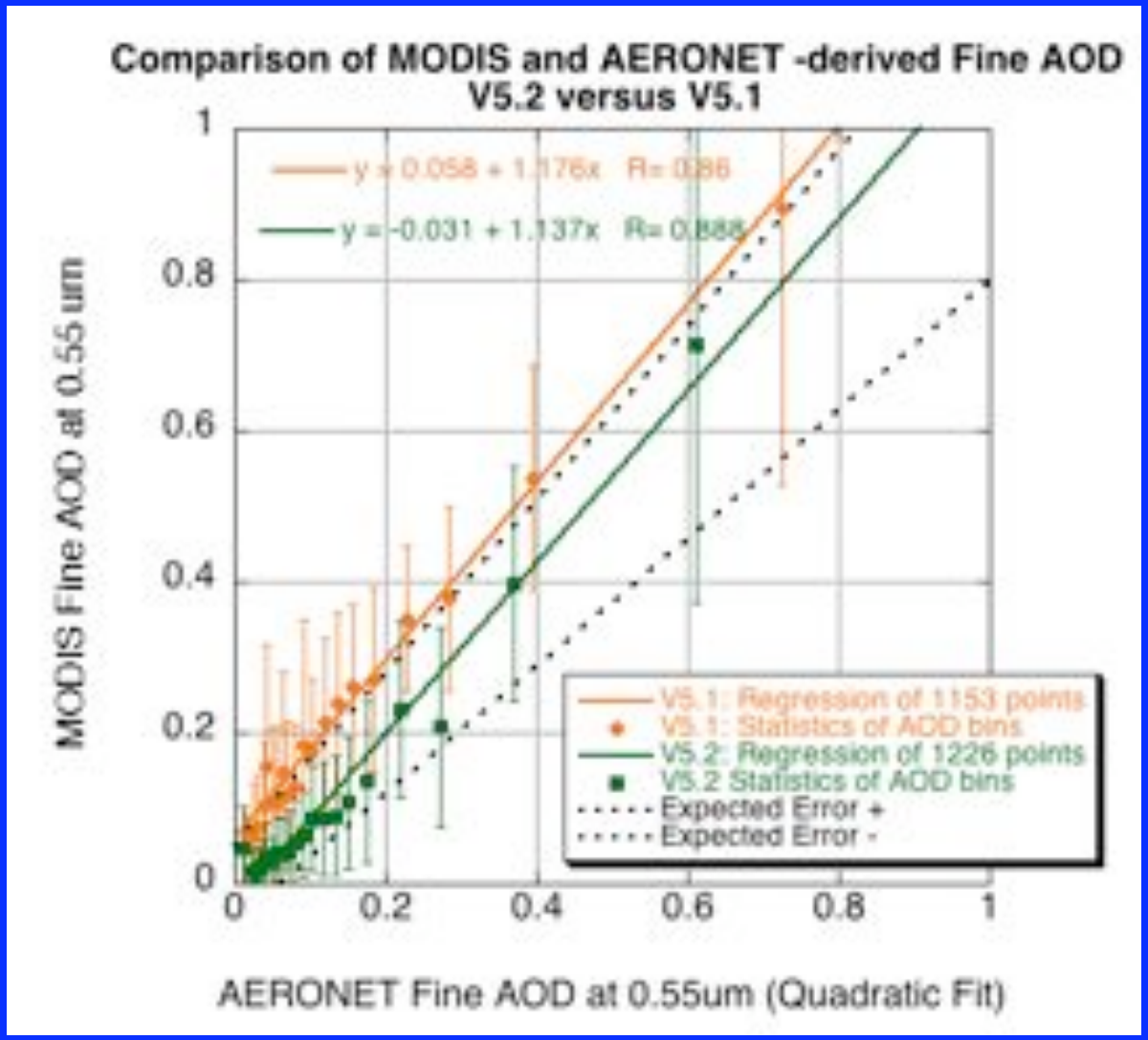


C004: 59% within expected

C005: 68% within expected

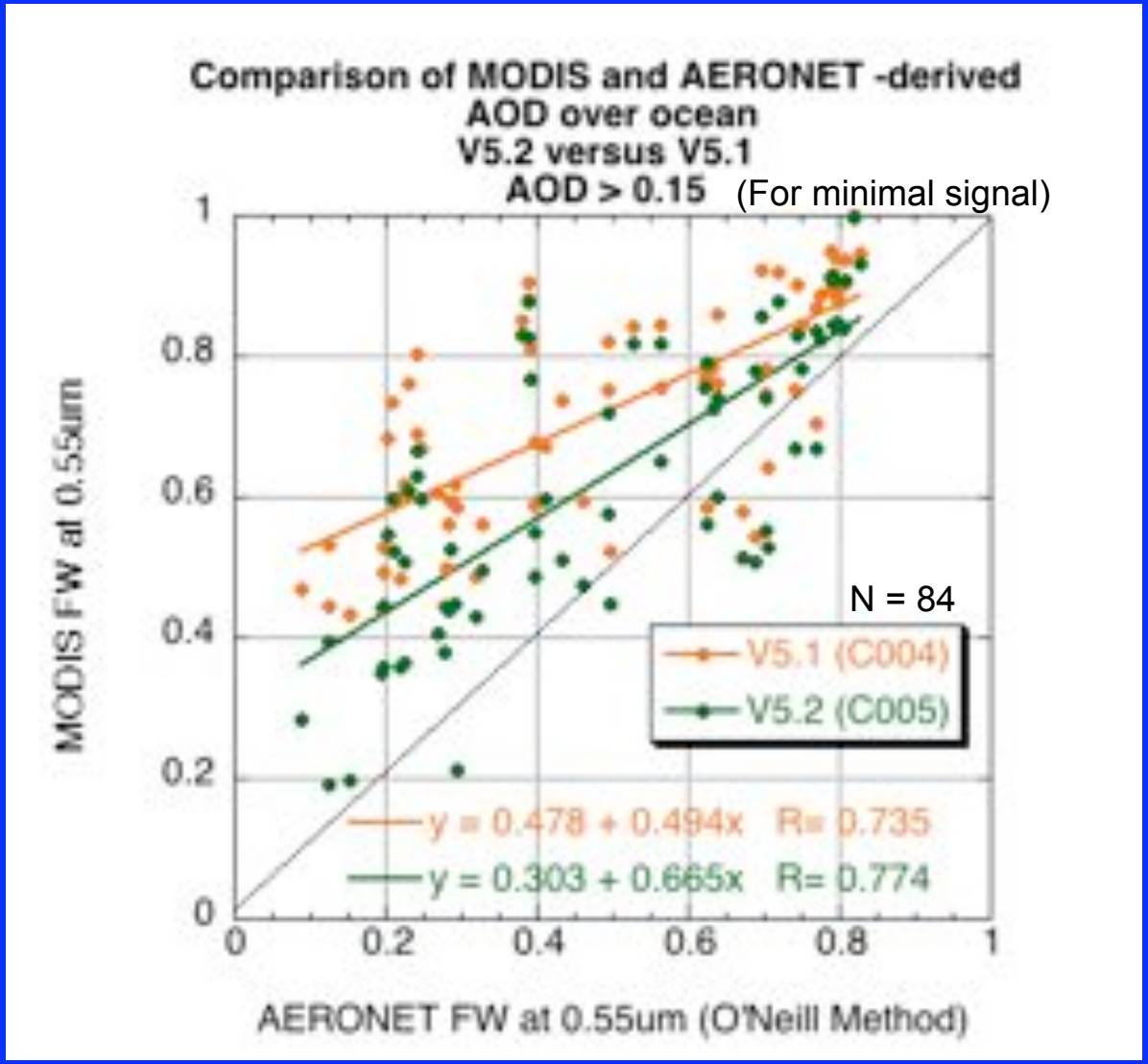
$\Delta\tau = \pm 0.05 \pm 0.15\tau$

Comparison: Land: MODIS vs AERONET (τ-Fine = τ x η)



Proxy for anthropogenic?

Comparison: Ocean: MODIS vs AERONET (FW or η)



Some improvement in the FW comparison

The bottom line

Aqua Land: 2005	Aqua Ocean: 2005	Aqua Ocean: 2005
N ~ 7e+07	N ~ 1.5e+08	
C004: $\overline{\tau_{0.55}}$ ~ 0.29	C004: $\overline{\tau_{0.55}}$ ~ 0.153	C004: $\overline{\eta_{0.55}}$ ~ 0.58
C005: $\overline{\tau_{0.55}}$ ~ 0.19	C005: $\overline{\tau_{0.55}}$ ~ 0.154	C005: $\overline{\eta_{0.55}}$ ~ 0.47

1. Computed via Level 3 (1°x1°) data: $\overline{x} = \Sigma(x_{QA}*P)/ \Sigma(P)$, where "$x_{QA}$" is the "quality assured" value of the variable within the gridbox and "P" is the number of L2 pixels used to make L3. Summation is entire globe and entire year (N = total # of L2 pixels). Note that "area weighting" will not significantly affect the result.
2. Lower τ over land, lower η over ocean
3. Values WILL vary depending on sampling, restrictions on "P", etc.
4. 2005 was relatively low τ compared to entire mission. Slight differences between Terra and Aqua (~ 5%)

Summary

- MODIS has unique capability to monitor global aerosol
- MODIS Aerosol products (e.g. C004) have been used for many applications (e.g. AEROCOM)
- But, C004 products had deficiencies and biases fixed for C005.
- Over land, we:
  - Determined a climatology of the global distribution of aerosol types and optical properties (AERONET)
  - Found a parameterization for estimating surface reflectance properties
  - Discovered coarse aerosol information in the 2.1μm channel, even over land.
  - reduced τ biases compared to AERONET
  - Reduced the over-land average τ from ~0.28 to ~0.19.
- Over ocean, we:
  - Derived more realistic coarse mode refractive index
  - Reduced η biases compared to AERONET
  - Retained the over-ocean average τ at ~0.15

More about C005

- New user-friendly quality assurance (QA)
- New products over land: Fine-τ, Column Mass, surface reflectance, fitting error
- New "Image" combined land/ocean τ (high QA)
- Operational as of April 2006
- Aqua re-processing completed: July 2006 (Wow!)
- Terra re-processing complete: Dec 2006 (completed: 2000, 2005-2006)
- Two papers (land) are being revised after review, and we have a new ATBD for both land and ocean: http://modis-atmos.gsfc.nasa.gov
- http://ladsweb.nascom.nasa.gov for C005 data!

Final thought

The MODIS aerosol algorithm is not a “dead” algorithm. MODIS has more information to offer, both by itself (such as “Deep Blue”, and anglular information), and synthesized with other sensors.

Acknowledgments:

Charles Ichoku, Peter Colarco, Oleg Dubovik, Eric Vermote, Tony Wimmers, Tianle Yuan, Santiago Gassó, Didier Tanré

Thank you