

# The MODIS aerosol algorithms: Past, Present and Future

Lorraine A. Remer

YoramKaufman DidierTanré ShanaMattoo RobertLevy  
RichardKleidman BrentHolben AllenChu RongRongLi  
CharlesIchoku VanderleiMartins IlanKoren  
ZiaAhmad TomEck BoCaiGao AndrewWald RobertFraser  
EricVermote

**PAST**

**1989 - 1991**



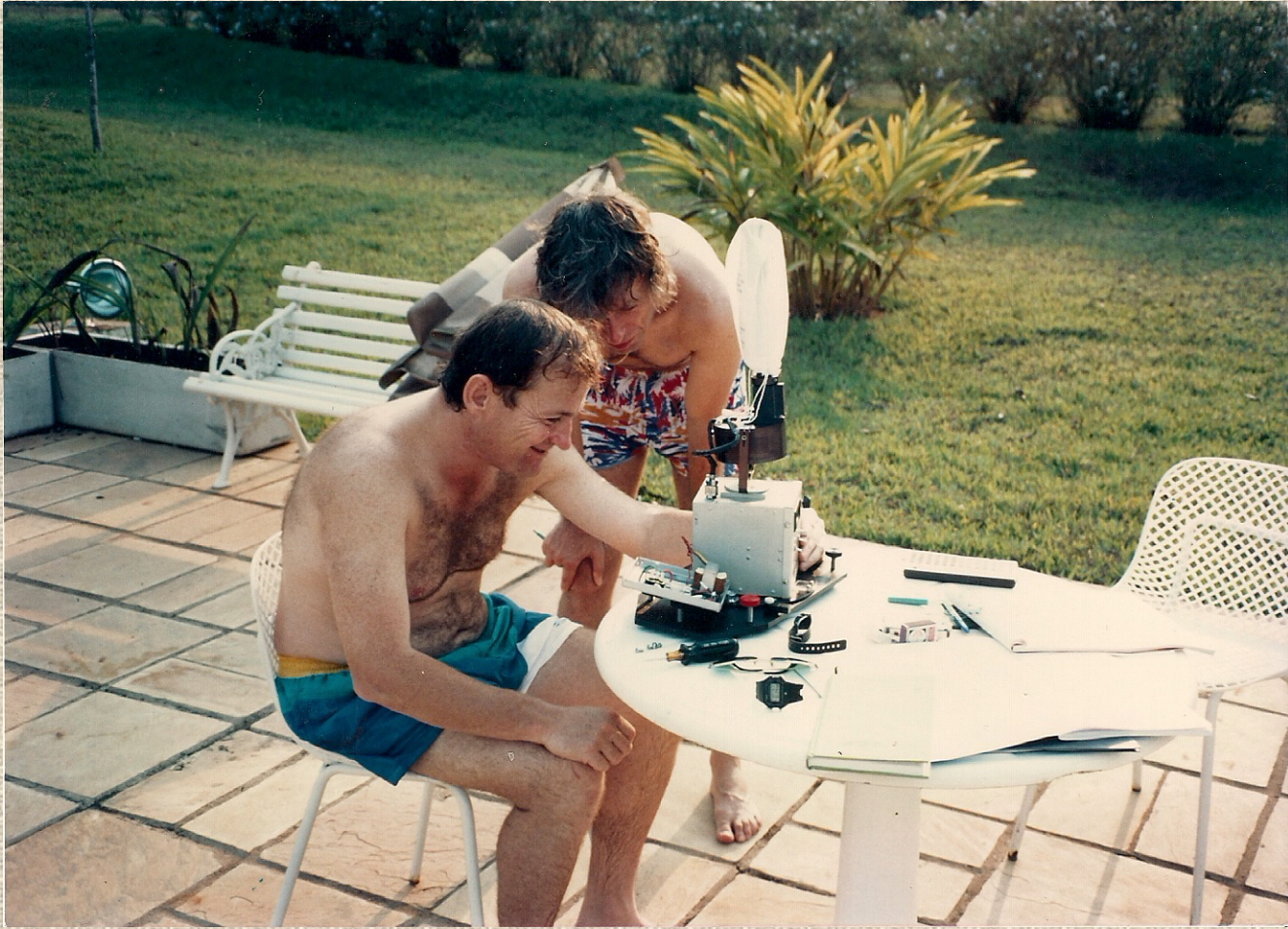


Didier Tanré



Yoram Kaufman









Brent Holben

Both Yoram...





And Didier

Submitted proposals to  
the forming MODIS  
science team and

both were selected



## Beginning concepts:

1. Apply experience obtained with AVHRR and Landsat
2. Use multiple channels simultaneously over ocean for a true inversion
3. Retrieve particle size information, as well as loading
4. Use mid-IR channel to “see through” the particles to characterize the surface reflectance for land retrievals

CALIBRATION -- 500 m RESOLUTION -- WIDE SPECTRAL RANGE



PAST

1991-2000



Shana Mattoo



Lorraine Remer





Richard Kleidman



Rong-Rong Li



Allen Chu





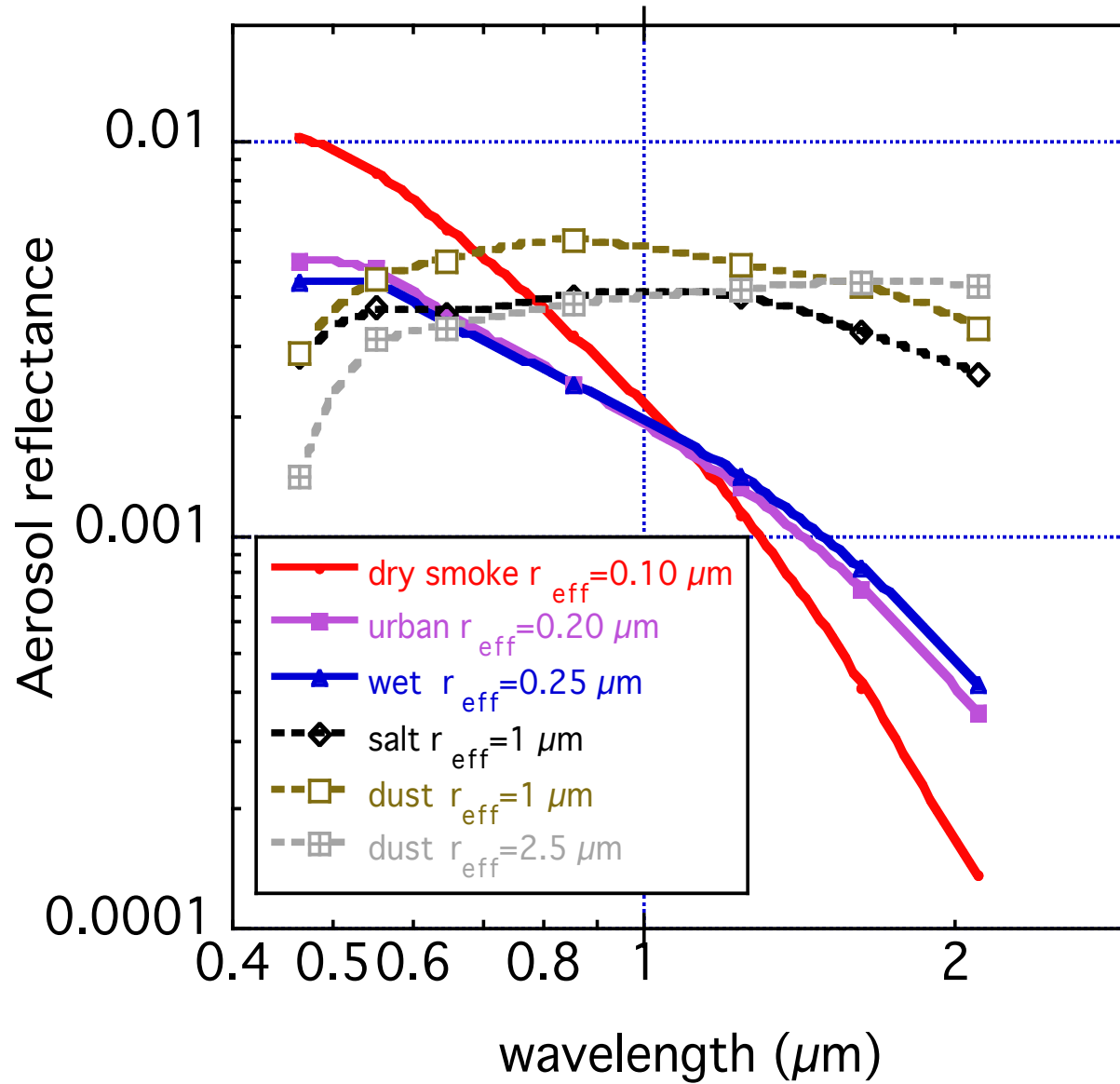
Charles Ichoku



Robert Levy



## Wide spectral range allows retrieval of particle size



## 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

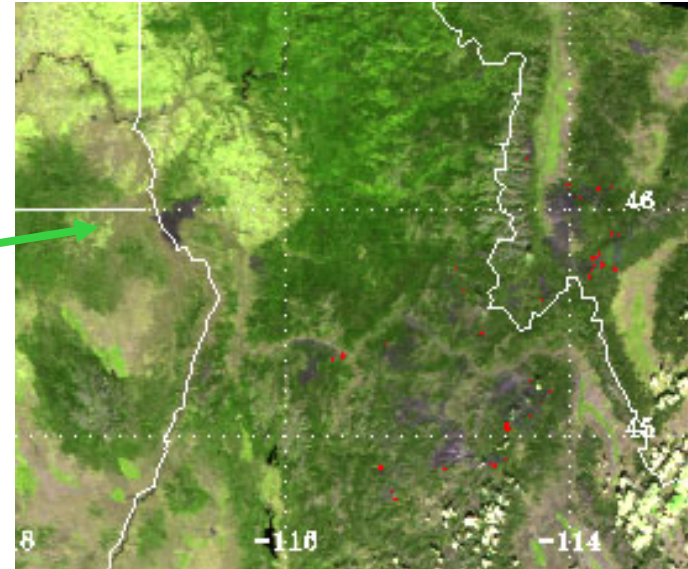
$$\tau_{0.66} \sim [\rho^*_{0.66} - 0.5\rho^*_{2.1}]$$

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

1.2

1.6

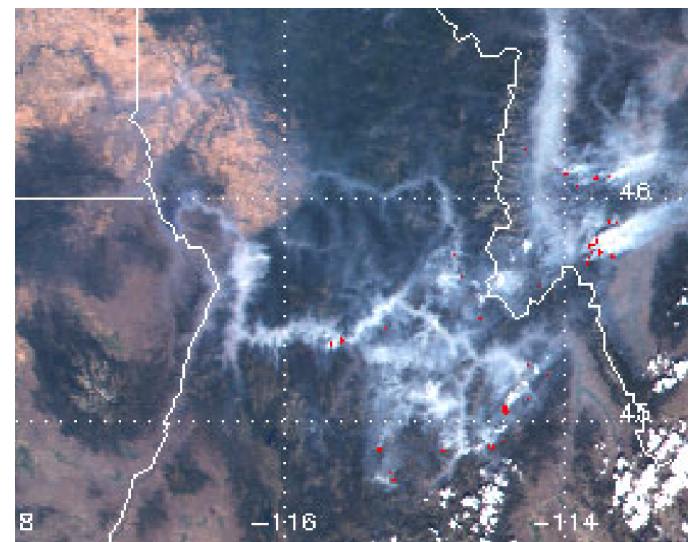
2.1



0.47

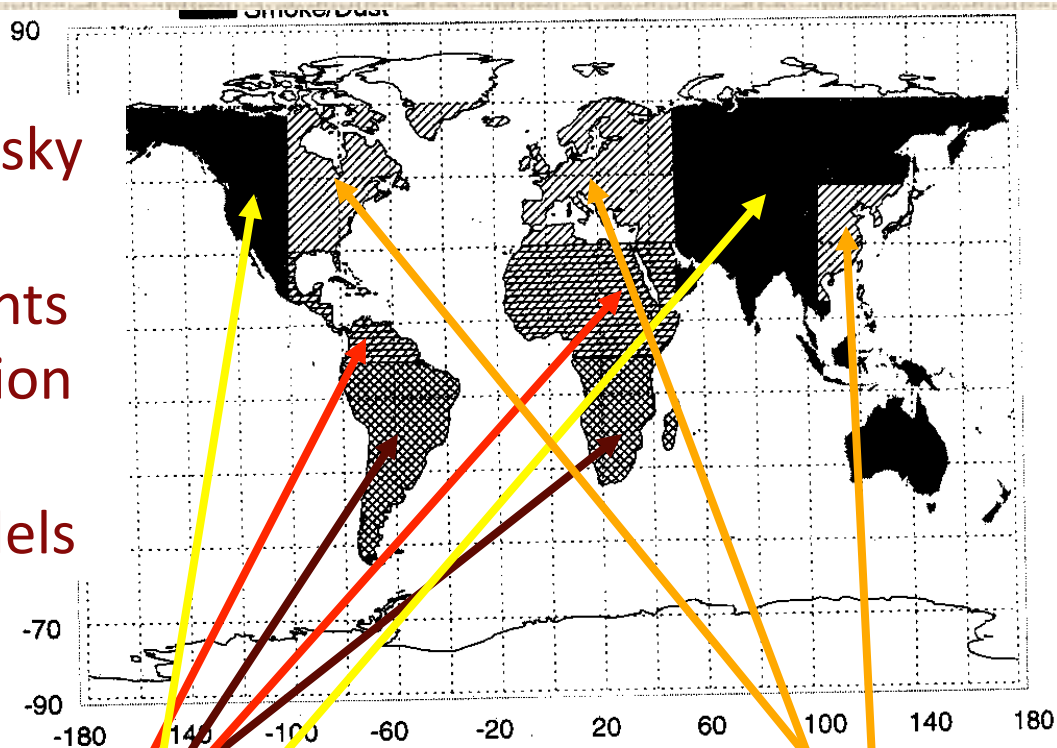
0.55

0.66

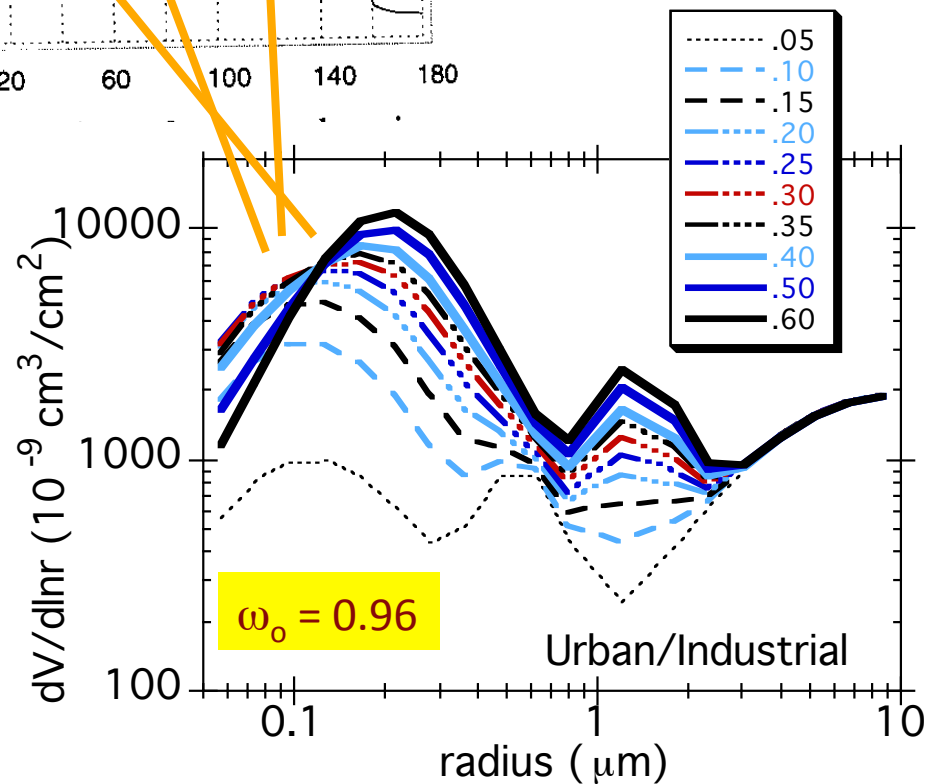
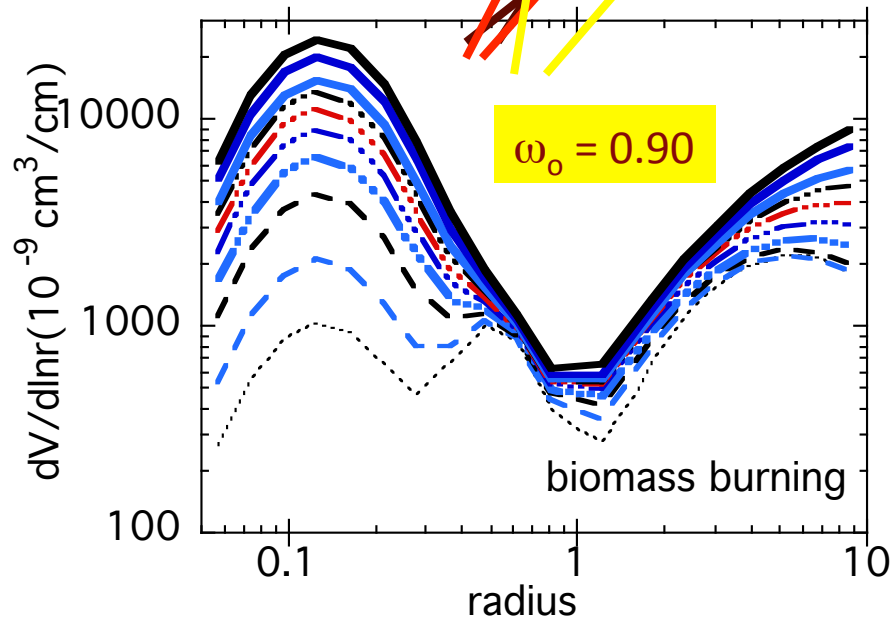




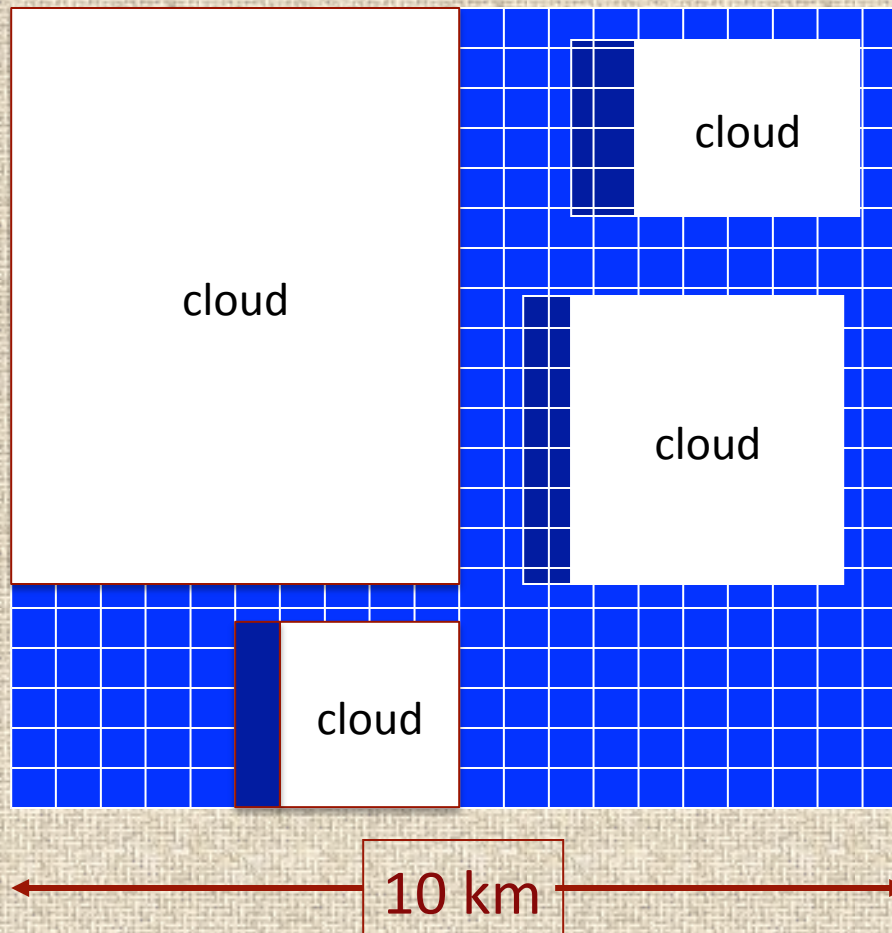
Inversion of sky radiance measurements allows creation of dynamic aerosol models



Operational aerosol models (1995 knowledge)



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



500 m  
resolution  
allows retrieval  
of  
aerosol in close  
proximity to  
clouds



## At launch algorithm

1. One of the first attempts at operational quantitative retrievals over land
2. Quantitative size retrievals over ocean
3. Retrievals closer to clouds
4. Comprehensive automatic collocation and validation software (MAPPS)



Terra launch  
Dec. 1999



**PAST**

**2000 - Present**



Vanderlei Martins

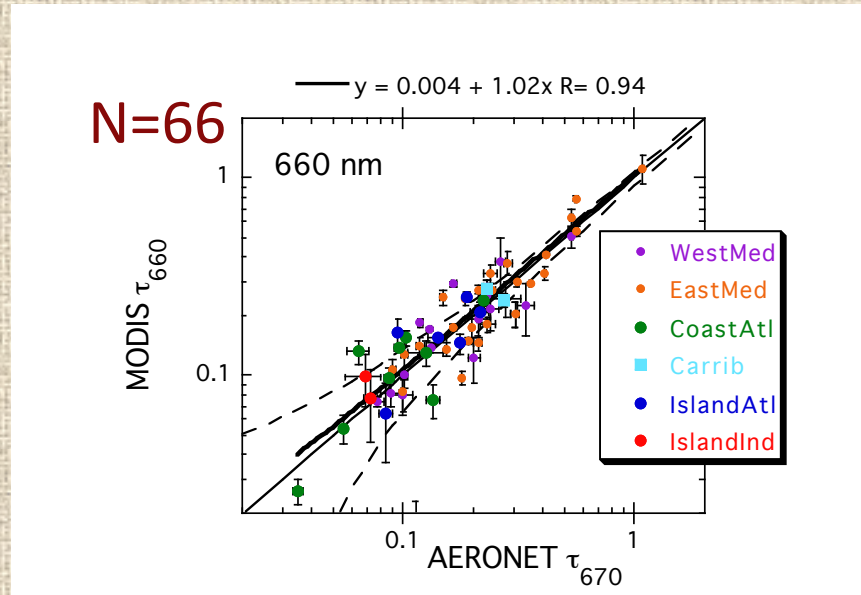


Ilan Koren

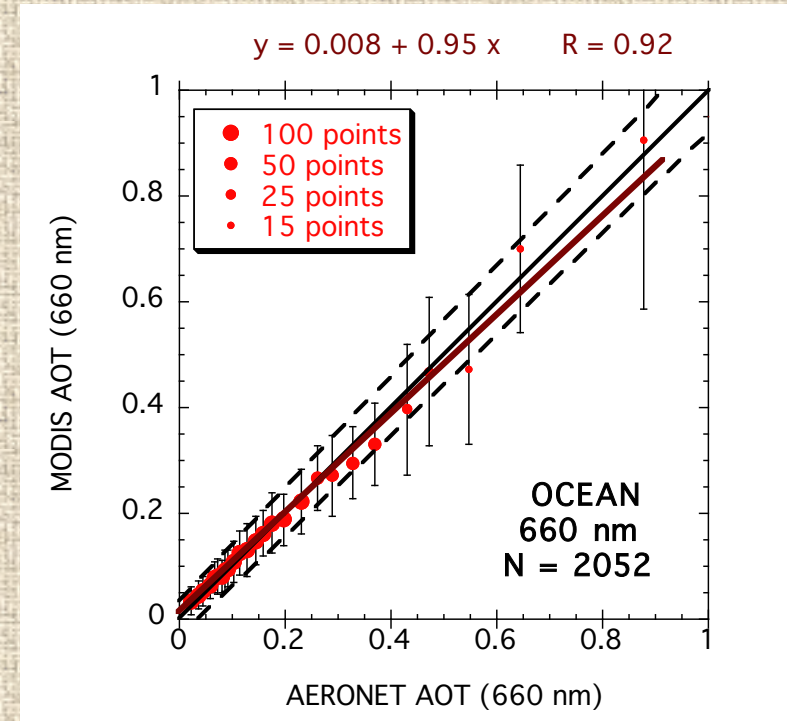


Because of MAPPs validation began immediately.

Remer et al. 2002



Remer et al 2005



Over ocean validation

## Lessons learned early:

1. Need a dedicated cloud mask to protect the aerosol retrieval  
*Leads to the Martins et al (2002) spatial variability cloud mask*
2. Need a more absorbing aerosol model over land  
*Follows from the Ichoku et al. (2003) study of SAFARI2000*
3. Land developing a high bias and showing little size information  
*Eventually leads to the Levy second generation algorithm*



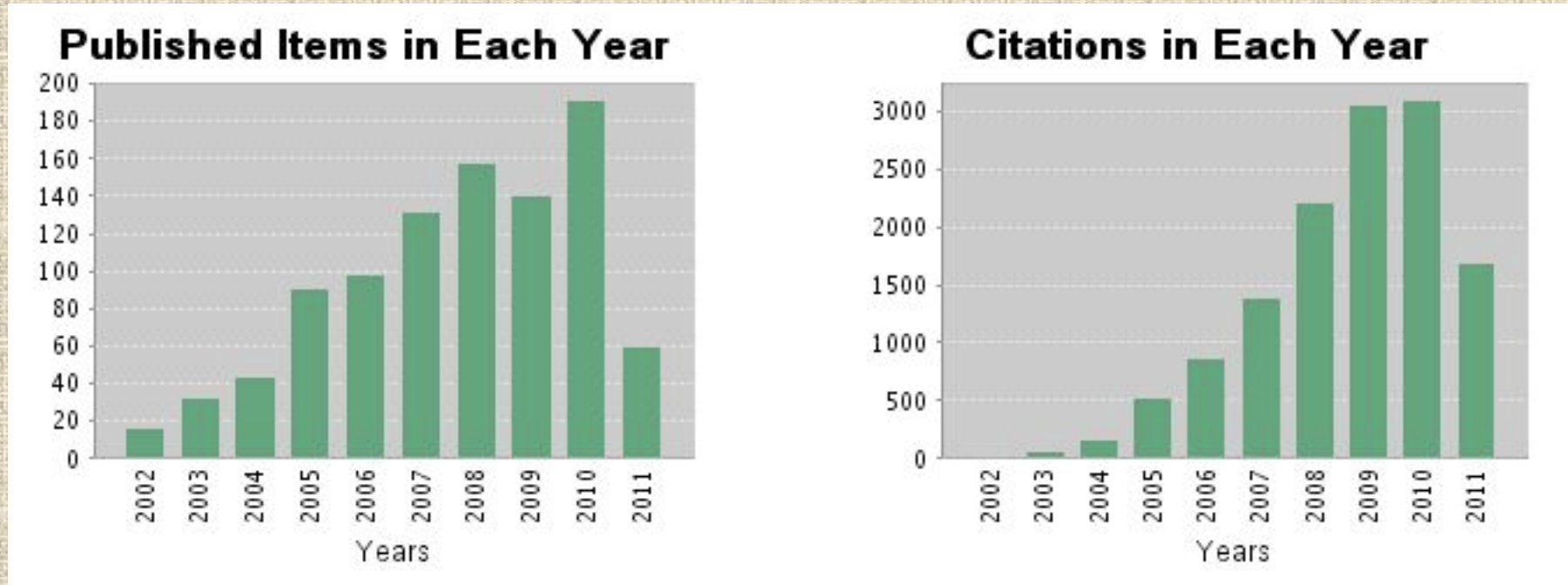




**PRESENT**



# Aerosol\* AND MODIS 2002 - 2011



966 results

13,083 citations

13.54 average citations per article

H-factor: 51

## From the 10 most highly cited (aerosol\* AND MODIS) papers

Remer LA, Kaufman YJ, Tanre D, et al

The MODIS aerosol algorithm, products, and validation. J. ATMOS. SCI. (2005).

531 citations **BASIC REFERENCE**

King MD, Menzel WP, Kaufman YJ, et al.

Cloud and aerosol properties, precipitable water, and profiles of temperature and water vapor from MODIS. Source: IEEE TGARS (2003)

267 citations **LEVEL 3**

Stier P, Feichter J, Kinne S, et al.

The aerosol-climate model ECHAM5-HAM . ATMOS CHEM PHYS (2005)

204 citations **COMPARISON WITH MODELS**

Levy RC, Remer LA, Mattoo S, et al. Second-generation operational algorithm: Retrieval of aerosol properties over land from inversion of Moderate Resolution Imaging Spectroradiometer spectral reflectance

J. GEOPHYS. RES.-ATMOS. (2007)

171 citations **BASIC REFERENCE**

**Continues on next page**



Vermote EF, El Saleous NZ, Justice CO

Atmospheric correction of MODIS data in the visible to middle infrared: first results REM. SENS. ENVIRON. (2002

169 citations **ATMOSPHERIC CORRECTION**

Yu H, Kaufman YJ, Chin M

A review of measurement-based assessments of the aerosol direct radiative effect and forcing. ATMOS. CHEM. PHYS. (2006

145 citations. **DIRECT RADIATIVE FORCING**

Chu DA, Kaufman YJ, Zibordi G

Global monitoring of air pollution over land from the Earth Observing System-Terra Moderate Resolution Imaging Spectroradiometer (MODIS) J. GEOPHYS RES.-ATMOS. (2003

141 citations **AIR QUALITY**

Kaufman YJ, Koren I, Remer LA

The effect of smoke, dust, and pollution aerosol on shallow cloud development over the Atlantic Ocean.

PNAS (2005

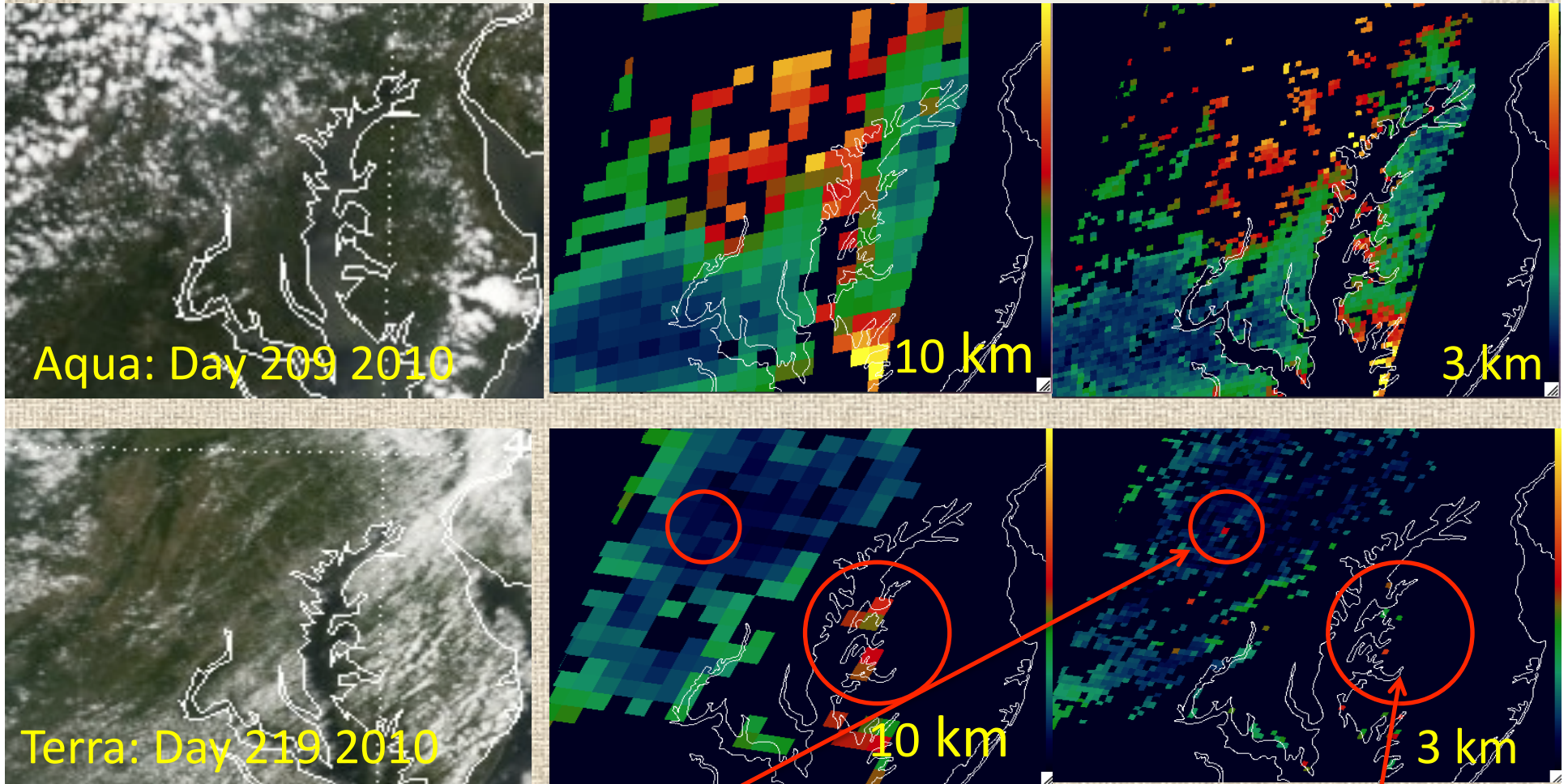
140 citations. **AEROSOL-CLOUD INTERACTION**

**NEAR FUTURE**

**(beginning in 2012)**



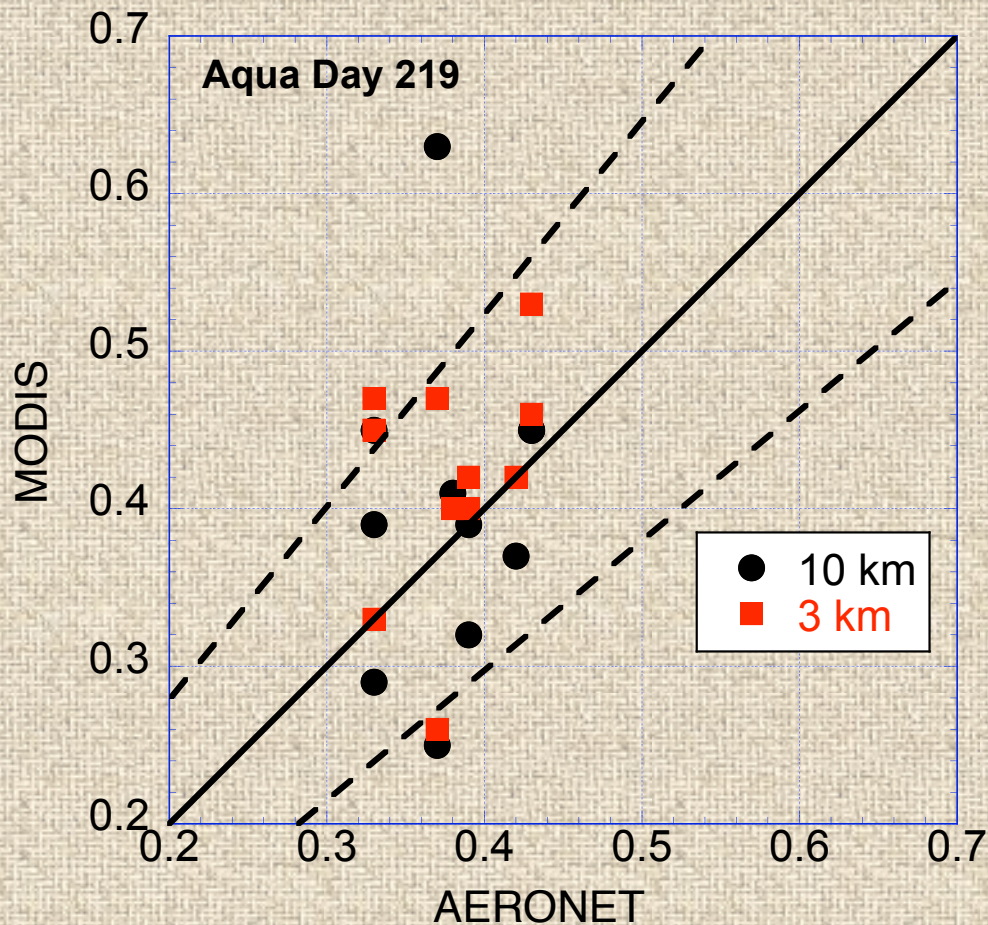
# MODIS 3 km product over suburban (MD) landscape (DRAGON, summer 2010)



- 3 km mirrors 10 km product (pattern and magnitude)
- 3 km introduces **noise**, but also can reduce spatial impact of **outliers**

# MODIS 3 km product over Maryland, Summer 2010

## Compare with AERONET (DRAGON)



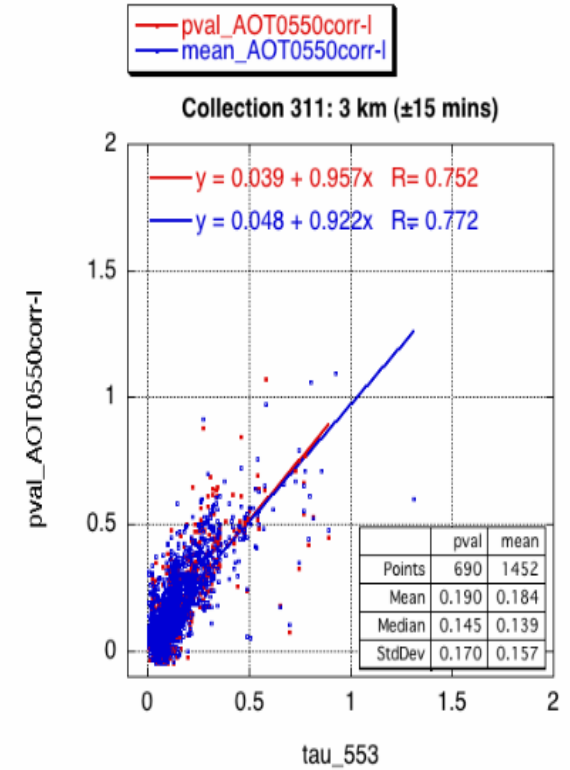
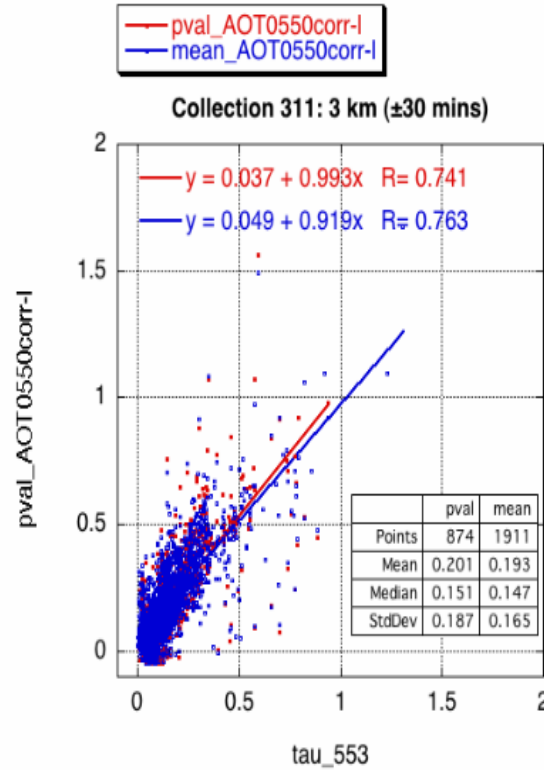
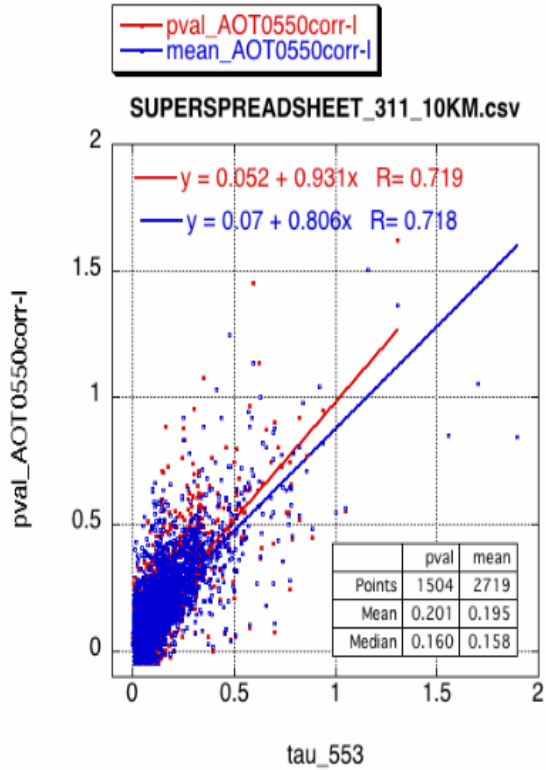
11 AERONET stations from Baltimore to College Park; Olney to Bowie.

station	AERO NET	MODIS 3 km	MODIS 10km
BLTIM	0.29	0.28	0.17
LAUMD	0.26	0.24	0.20
OLNES	0.23	0.22	0.09
RCKMD	0.25	0.33	0.19

- Overall, 3 km mirrors 10 km “validation”.
- 3 km validation sometimes improves with higher resolution matching



# Global 3 km validation (5 months of collocations)



10 km ±30 minutes

$Y = 0.052 + 0.931x$   $R=0.719$

$Y = 0.07 + 0.806x$   $R=0.718$

3 km ±30 minutes

$Y = 0.037 + 0.993x$   $R=0.741$

$Y = 0.049 + 0.919x$   $R=0.763$

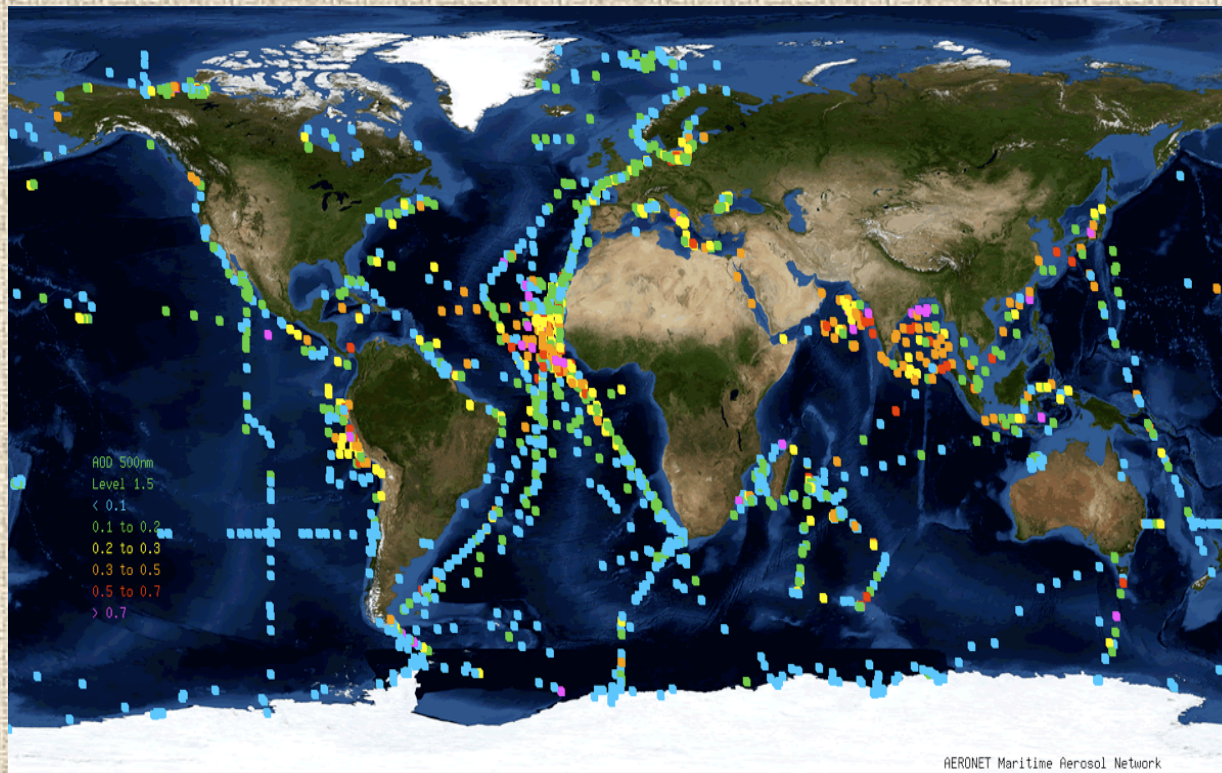
3 km ±15 minutes

$Y = 0.039 + 0.957x$   $R=0.752$

$Y = 0.048 + 0.922x$   $R=0.772$

Work by R. Levy

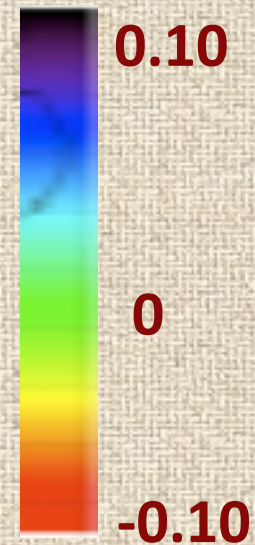
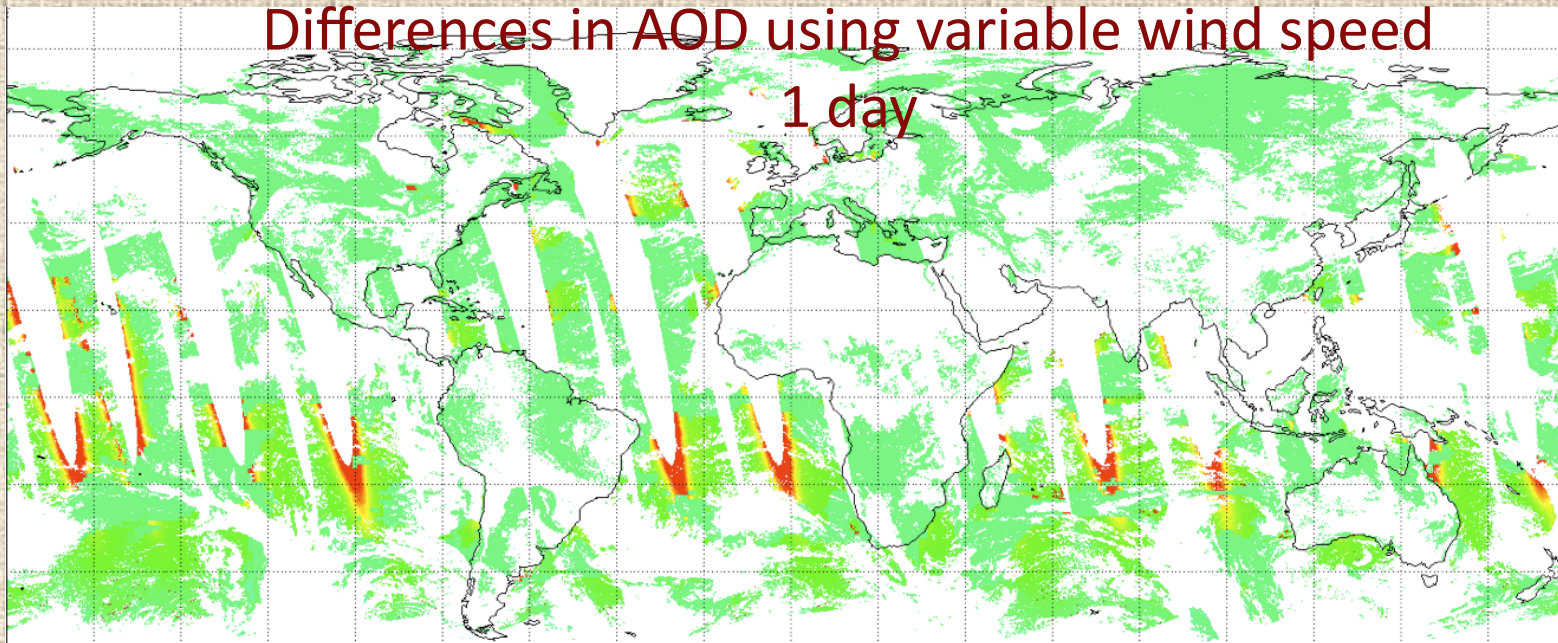
## Marine Aerosol Network



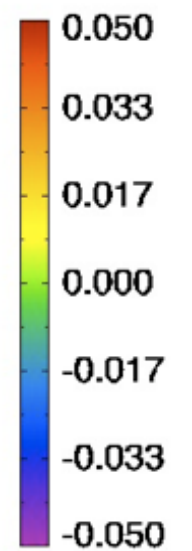
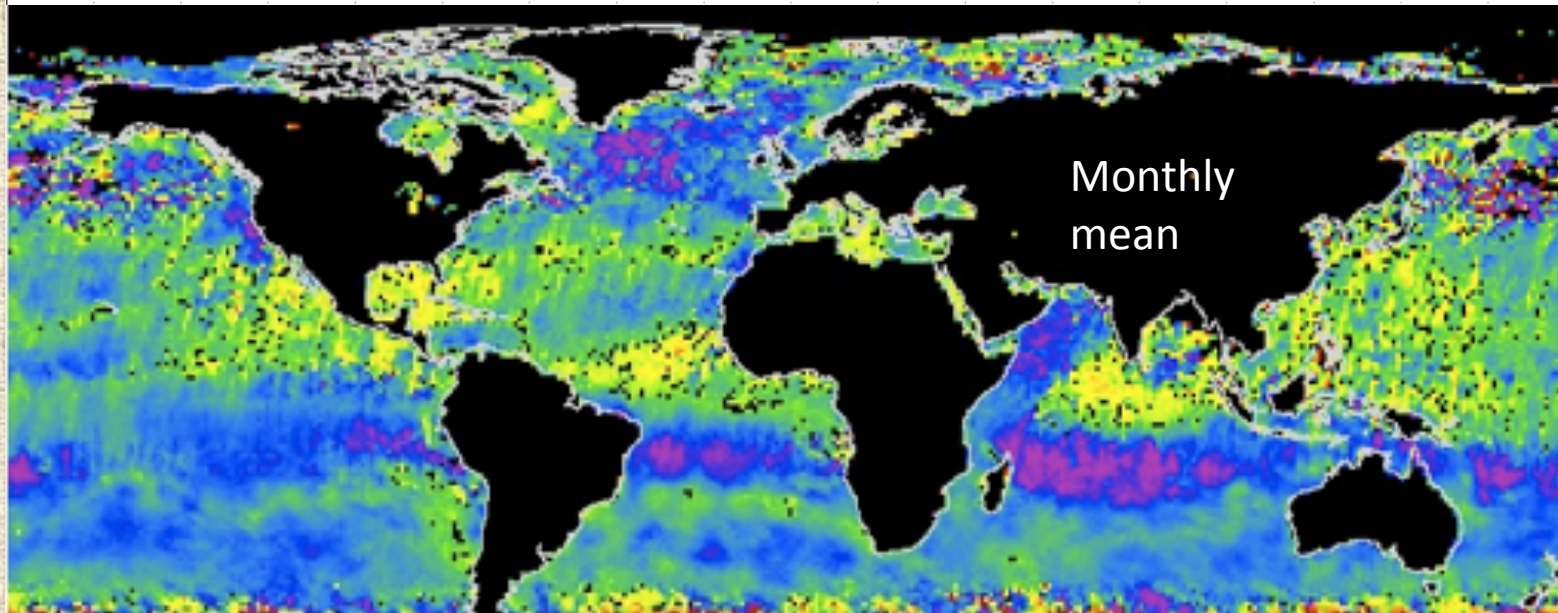
(Smirnov et al. 2009)



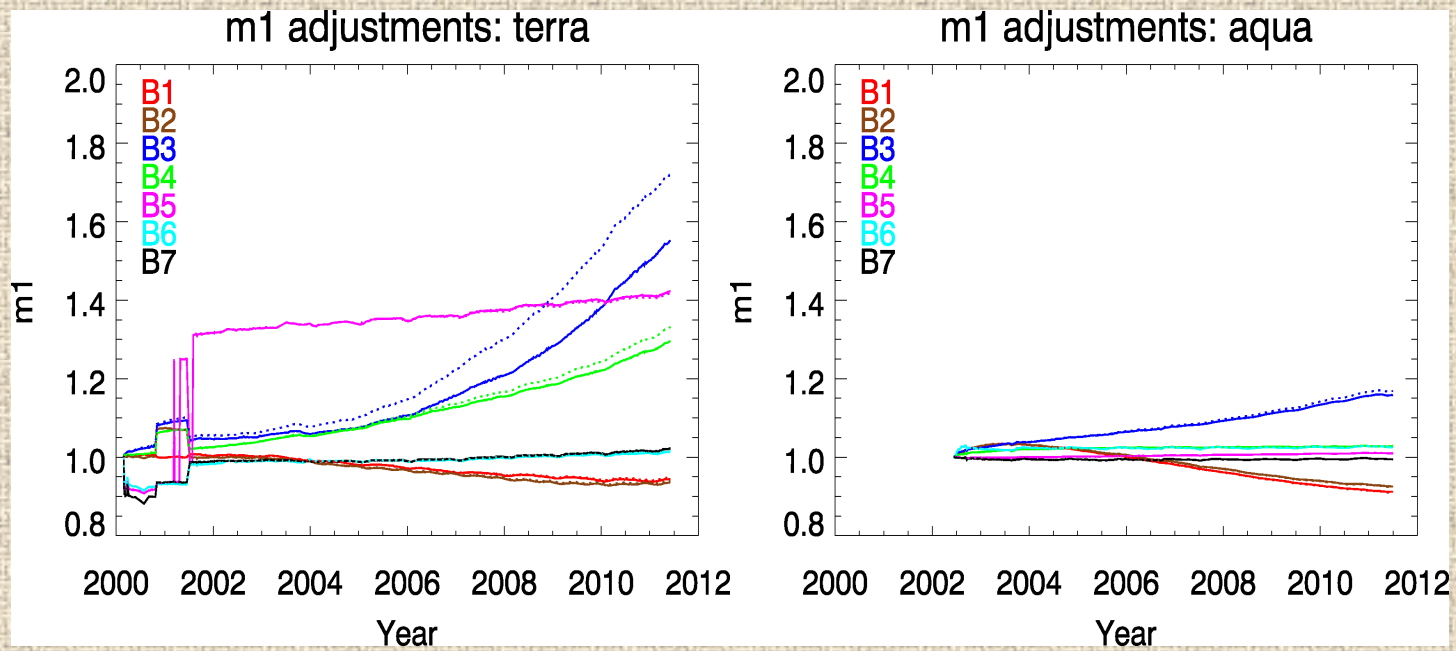
Differences in AOD using variable wind speed  
1 day



Monthly mean



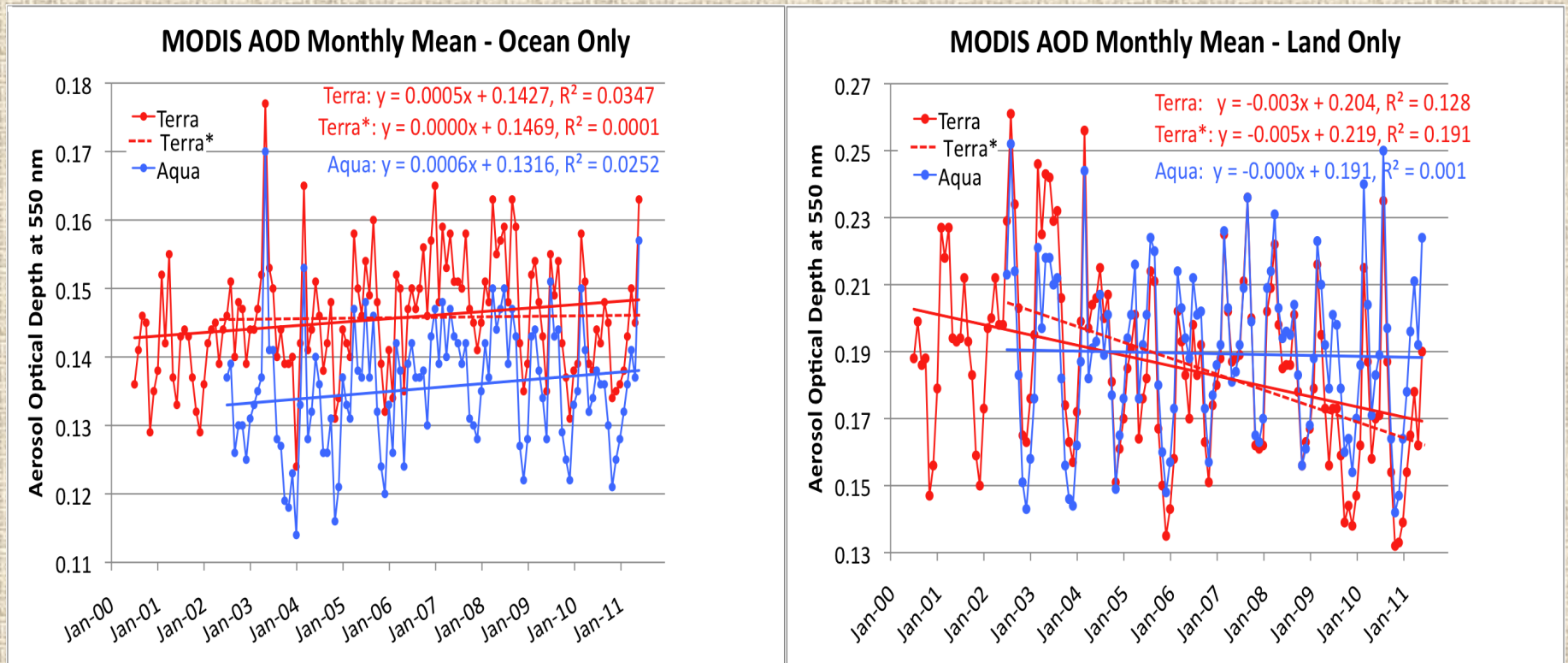
# Calibration



Levy et al. (in prep)



# Terra land trends due to artificial drift in band calibration



Levy et al. (in prep)

**FAR FUTURE**



Need one more collection. Collection 7

Will focus on the entire data record, not day-to-day operations

Will use sum total of all acquired information (like surface albedo)

Will attempt to merge data record to other sensors' (like VIIRS)

