

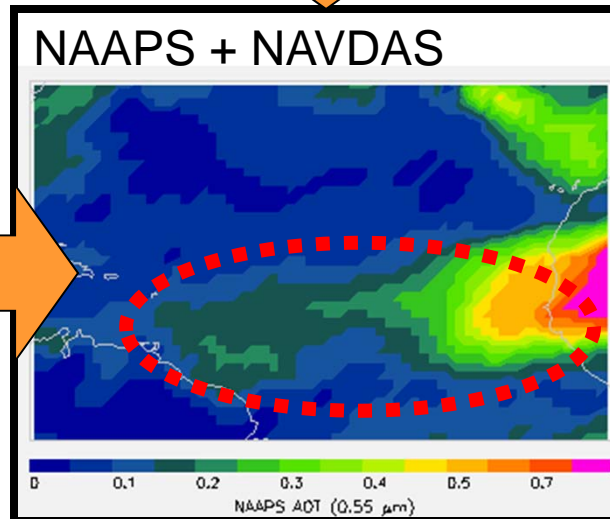
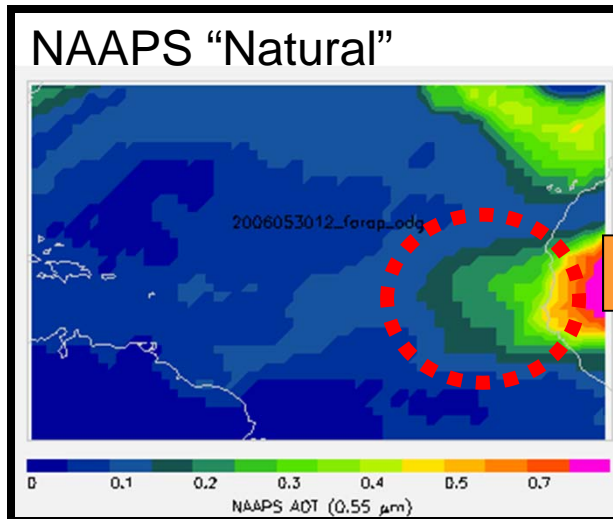
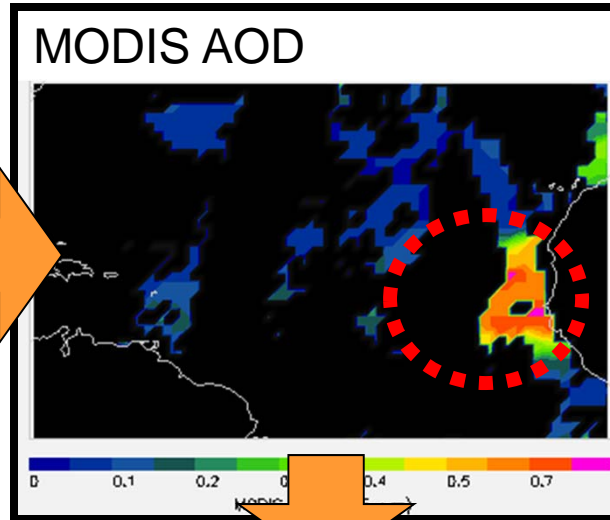
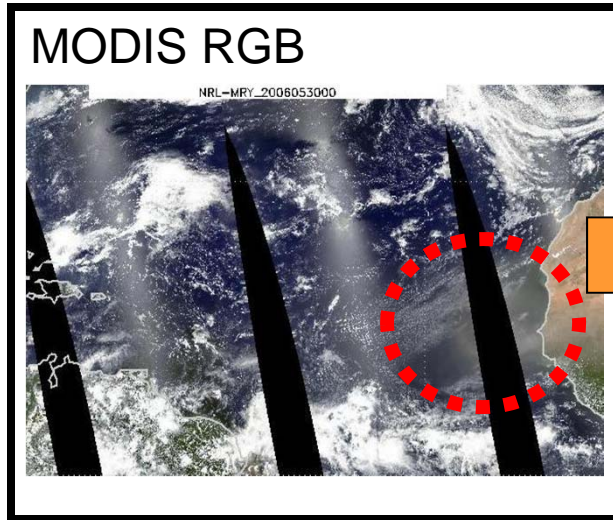
Satellite inputs for aerosol data assimilation

Edward Hyer

NRL Aerosol & Radiation Group

May 19, 2011

NAVDAS-AOD Data Assimilation



•J.L. Zhang et al.,
“A System for
Operational
Aerosol Optical
Depth Data
Assimilation over
Global Oceans”,
JGR 2008.

•Operational at
FNMOC from
September 2009

•Over-land is
being prepared
for transition in
FY11

Objectives of QA/QC of satellite AOD for data assimilation

- Minimize outliers
- “a few good obs”
- Reduce bias
 - Offsets
 - Slopes
- Quantify residual uncertainty
 - For each ob: as much detail as possible
- Minimize outliers

Details of MODIS-AERONET comparison

This is for over-land, over-ocean work was slightly different

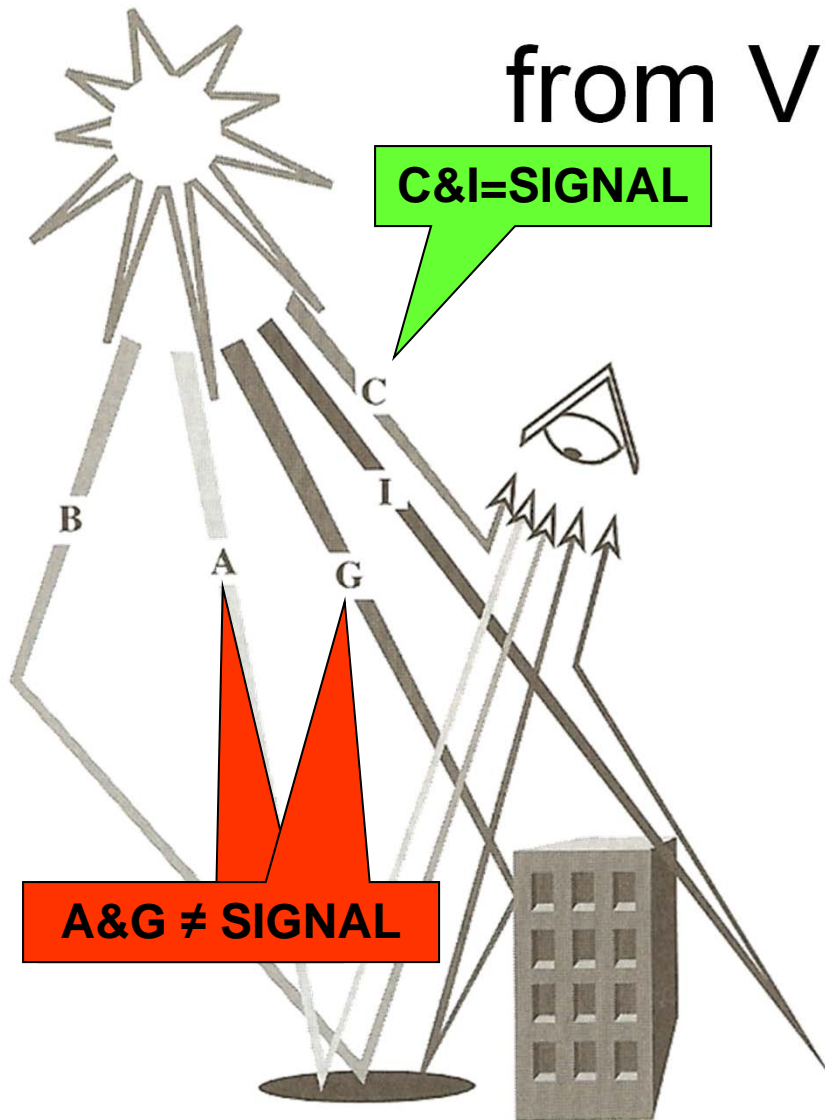
- AERONET L2.0
 - 2005-2008
 - 550nm AOD by quadratic interpolation (O'Neill et al. 2003)
- MOD04 Level 2, c5
 - 550nm Corrected Optical Thickness
 - + LOTS of metadata
- Matched
 - ± 30 km, ± 30 minutes
 - 4.1m retrieval pairs

- Metrics
 - Mean Bias
 - 25th & 75th percentile bias
 - Target error:

$$\tau_{MODIS} = \tau_{AERONET} \pm \left(0.05 + \frac{\tau_{AERONET}}{5} \right)$$

- MOD43 Albedo
 - 0.05° nearest neighbor
 - black-sky hemispheric albedo

The basics of aerosol retrieval from VIS/NIR radiance



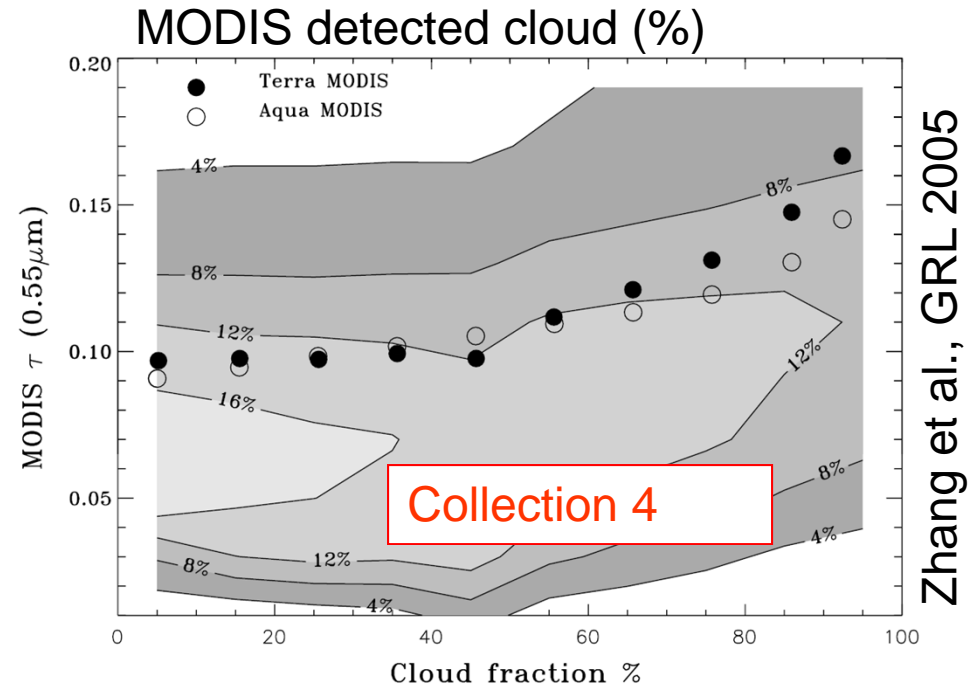
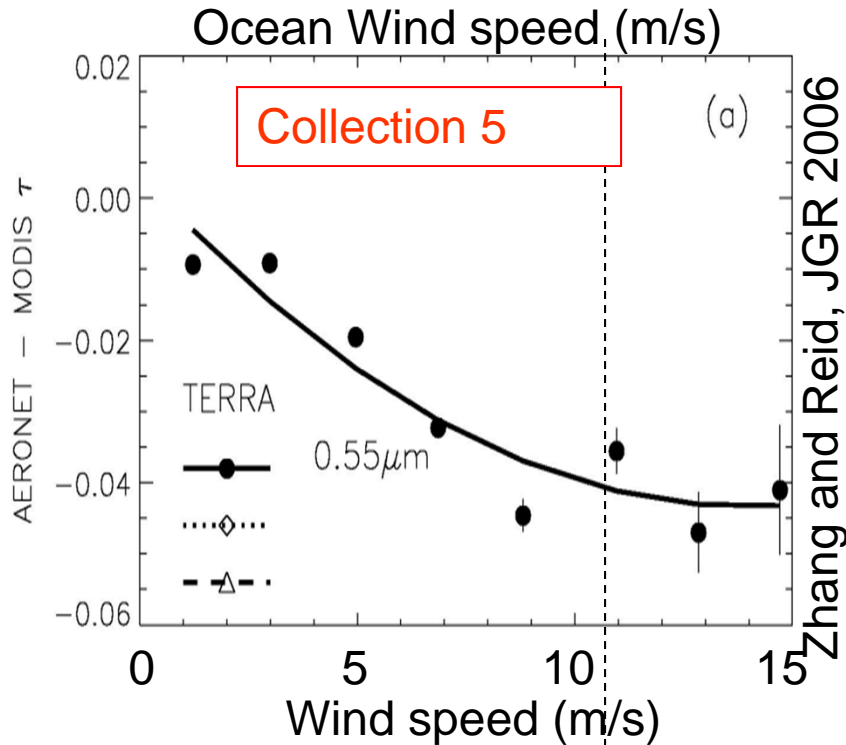
Schott, 1997, Figure 3.1

- Aerosol “signal” =

$$\frac{L_{OBS} - L_{EST, CLEARSKY}}{L_{OBS}}$$

- Implications:
 - Aerosol scattering (C+I) retrieved simultaneously with surface reflectance (A)
 - Multiple scattering can be important at higher concentrations

Identify & quantify uncertainties in collection 5 over ocean MODIS AOD

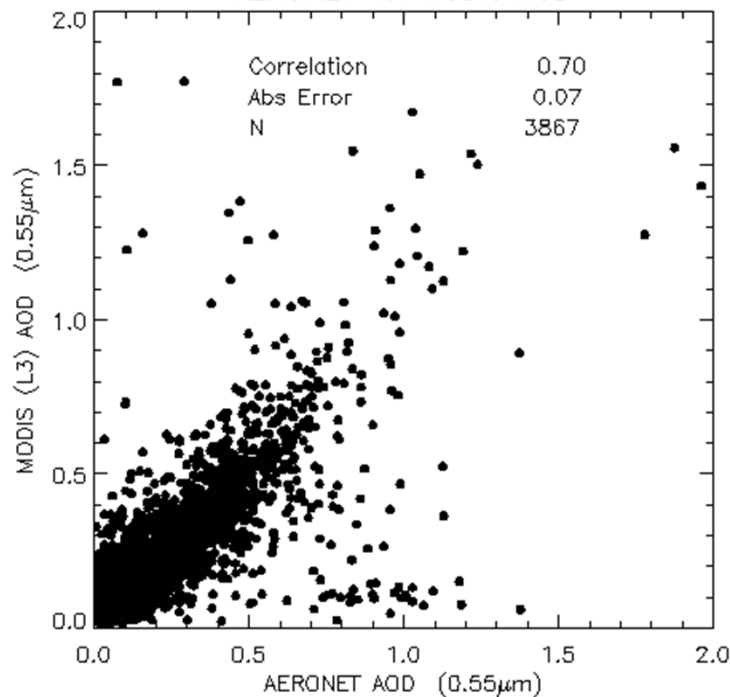


- Wind speed \rightarrow whitecap lifting \rightarrow brighter surface \rightarrow positive bias in satellite AOD
 - This will be corrected in MODIS Collection 6
- Cloud is hard to remove 100%: Cloud can occupy any fraction of pixel
 - Residual cloud reflectance \rightarrow increased radiance \rightarrow positive bias in satellite AOD

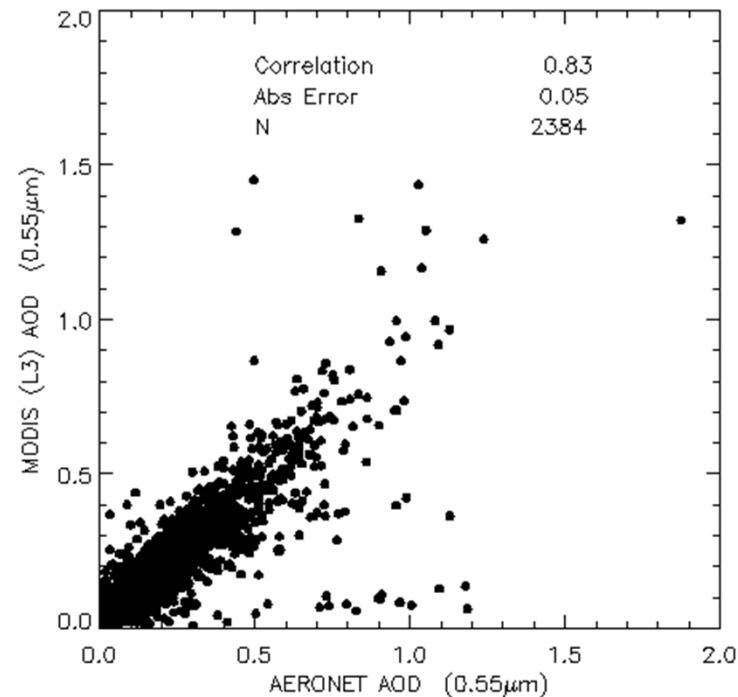
Results of QC and QA of collection 5 over ocean MODIS AOD

- Biases due to lower boundary condition strongly reduced
- Biases due to cloud contamination and artifacts strongly reduced
- 20% reduction in absolute errors

a) Terra+Aqua MODIS AOD (Level 3 daily average), before QA and QC, Jan. – Dec. 2006

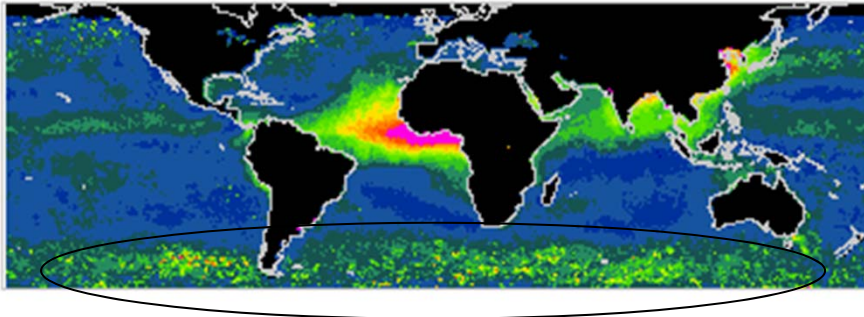


b) Terra+Aqua MODIS AOD (Level 3 daily average), after QA and QC, Jan. – Dec. 2006

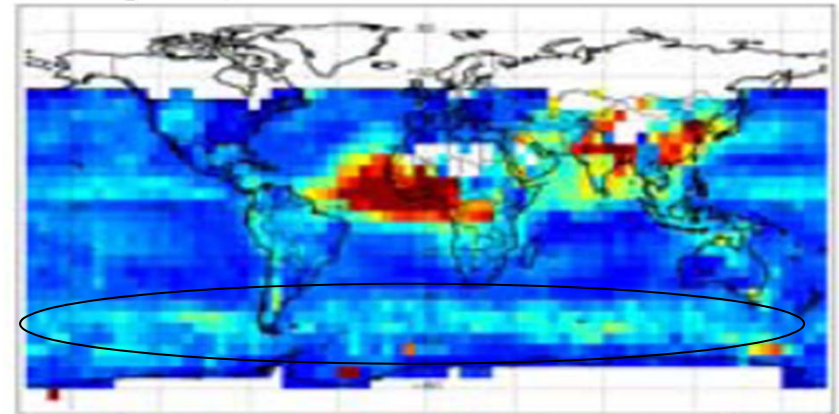


Results of QC and QA of collection 5 over ocean MODIS AOD

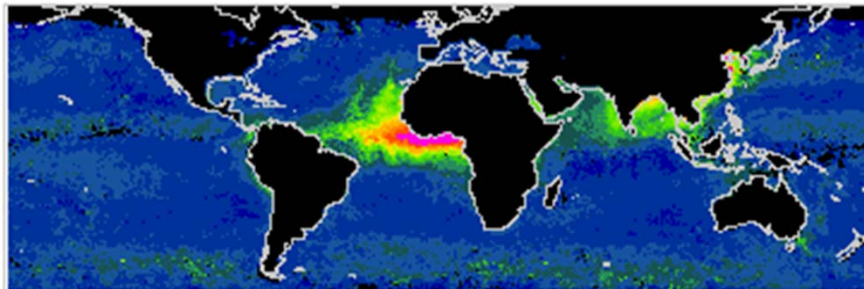
a) Terra+Aqua MODIS AOD, before QA and QC, Jan 2007



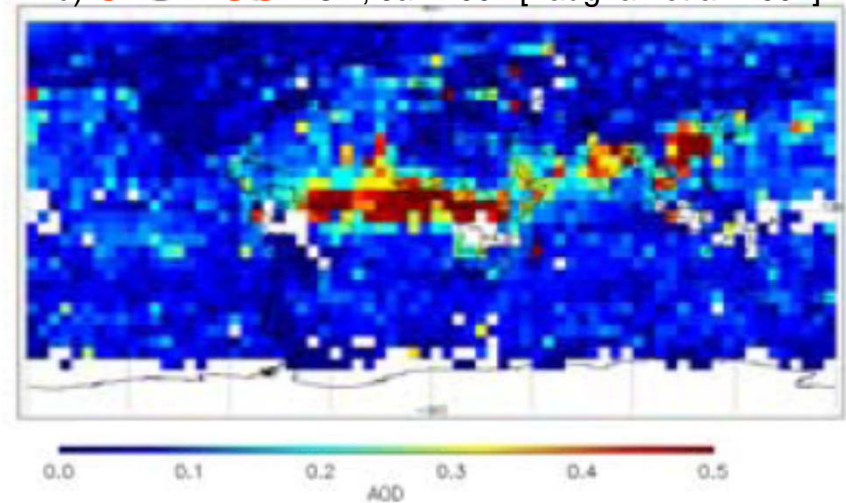
b) Aqua MODIS AOD, Jan 2007 [Vaughan et al. 2007]



c) Terra+Aqua MODIS AOD, After QA and QC, Jan 2007

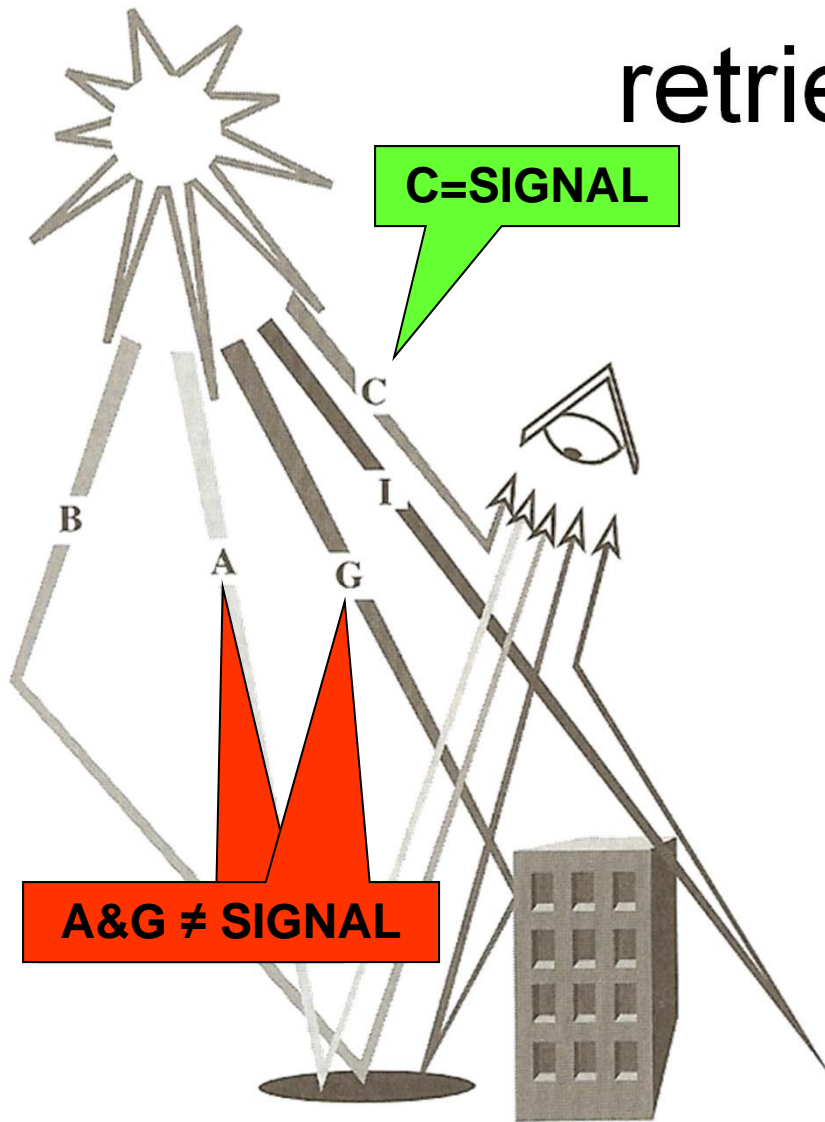


d) **CALIPSO** AOD, Jan 2007 [Vaughan et al. 2007]



Figures b and d are from Mark Vaughan and co-authors, CALIPSO Aerosol Backscatter and Extinction Characterization Using the MODIS and OMI Products, *Eos Trans. AGU*, 88(52), Fall Meet. Suppl., Abstract A23A-0882 .

What's so hard about AOD retrieval over land?



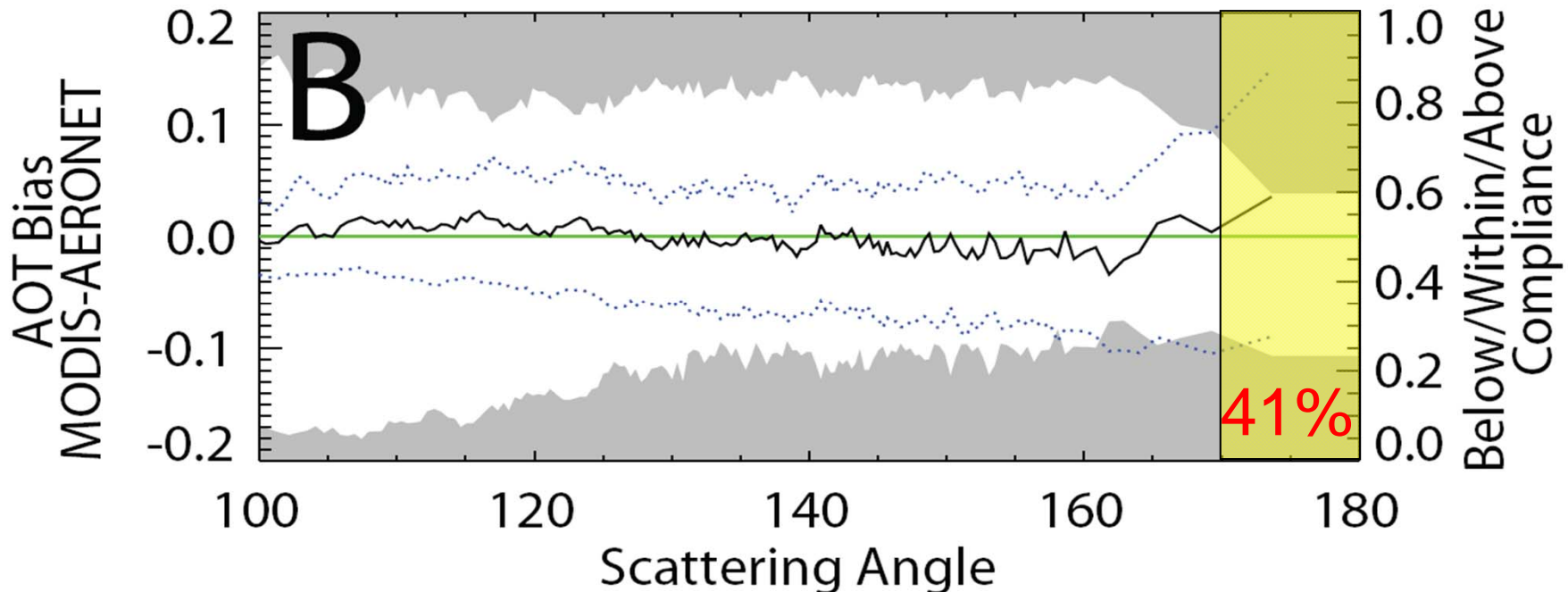
Schott, 1997, Figure 3.1

- Aerosol “signal” =

$$\frac{L_{OBS} - L_{EST, CLEARSKY}}{L_{OBS}}$$

- Higher surface reflectance:
 - directly reduces this signal by increasing L_{OBS}
 - places greater demands on model (L_{EST})

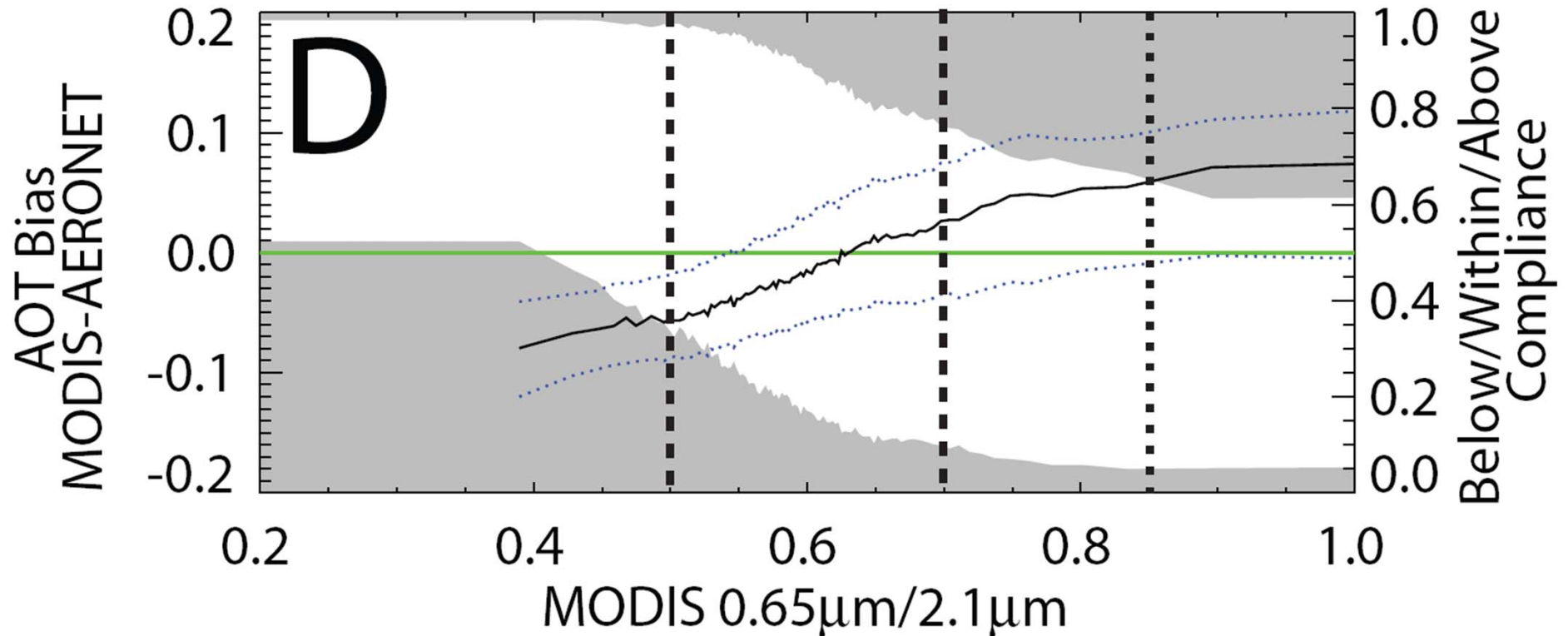
Signal-to-Noise 2



As scattering angle increases:

- shadowing decreases
- scene brightness increases
- signal/noise drops
- Because increase is more in VIS than NIR, correction is necessary
- **MODIS c5 correction works well for most scattering angles**

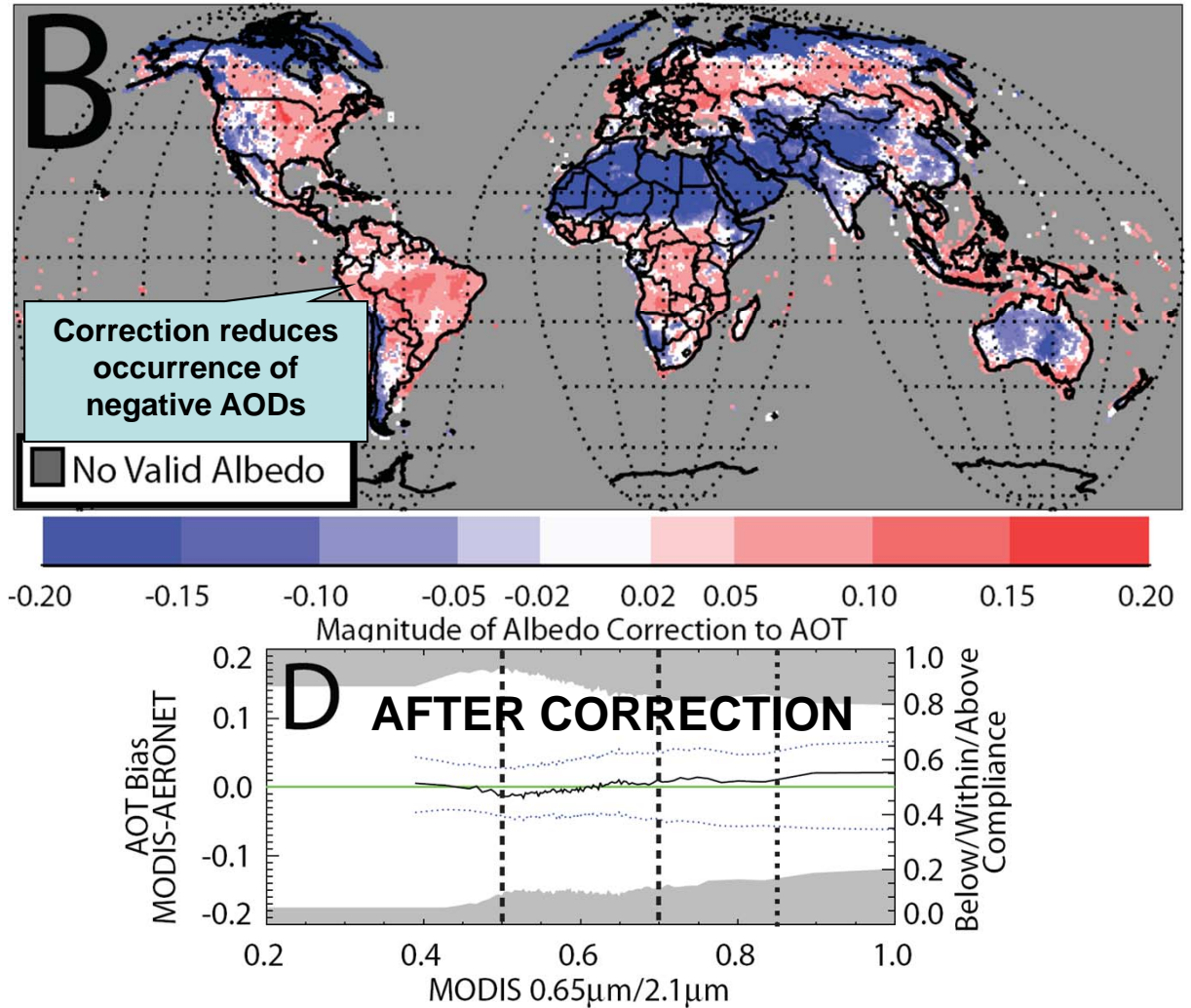
Surface Boundary Condition Issues in over-land MODIS AOD



- Strong systematic bias with surface albedo
- Positive or negative biases for different land areas

Surface Boundary Condition Issues in over-land MODIS AOD

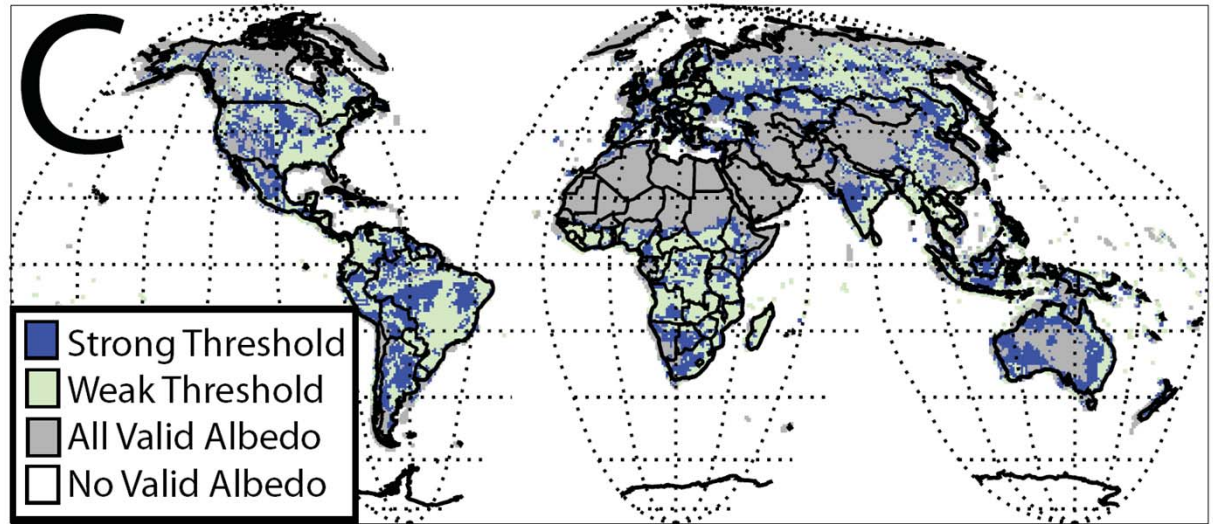
- Albedo correction calculated empirically
- Corrects negative bias in S. America, positive bias over arid surfaces



Surface Boundary Condition Issues in over-land MODIS AOD

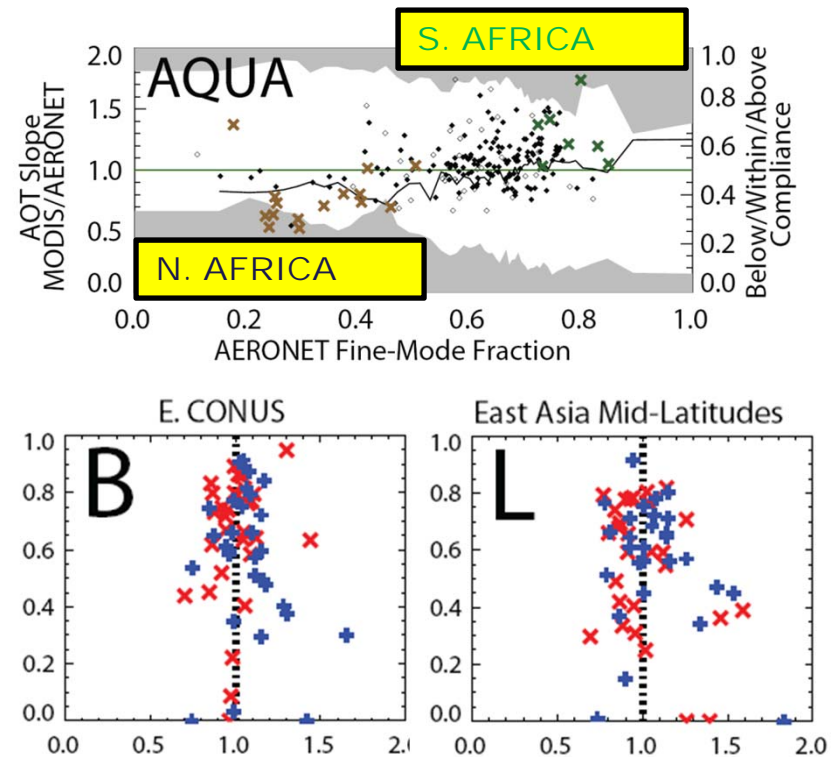
- Correction expands usable area of MODIS AOD
- More to do: AOD still not available everywhere

- Good compliance without albedo correction
- Good compliance with albedo correction
- Not recommended, even with correction
 - SW CONUS
 - Central China



Microphysical bias

- MODIS c5 uses a coarse climatology of aerosol optical properties
- Two problems:
 - Bias over regions
 - Uncaptured variability
- Above: Bias has general regional trends
- Below: High correlation + variable bias = uncaptured variability in aerosol properties
- Result: NRL L3 product has a regional correction applied

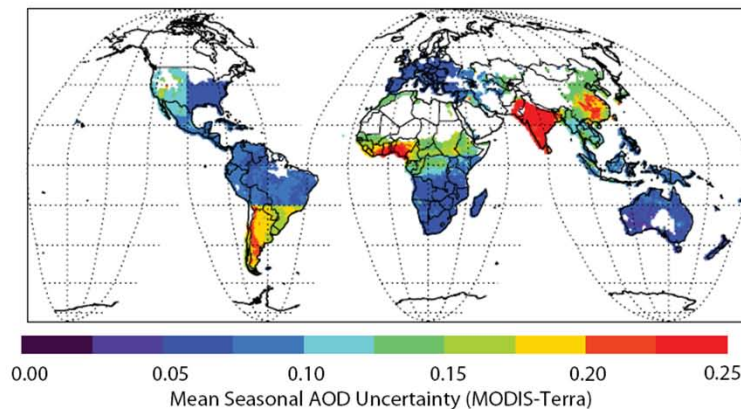


Regional slope correction improves global correlation of MODIS AOD vs AERONET from $r^2=0.62-0.65$ to $r^2=0.71-0.73$

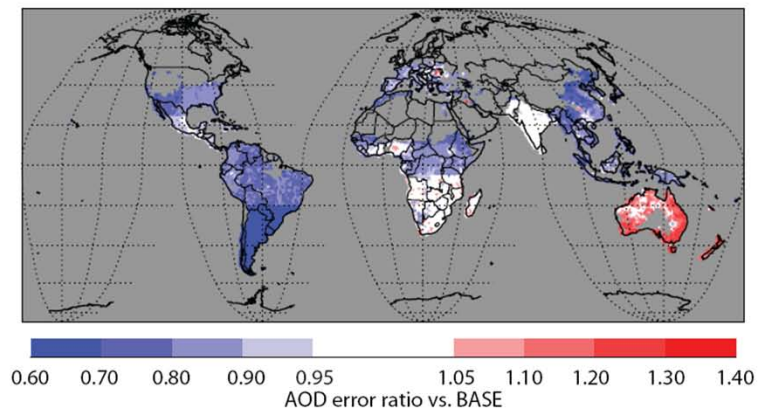
Error Estimation

- Obs. Uncertainty = instrument error + representativeness error
- Representativeness error = SD of AOD within grid cell
- Instrument error:
 - Over ocean: $f(\text{AOD}, \text{fine mode fraction})$
 - Over land: $f(\text{AOD}, \text{region})$
 - Error = MAX("noise floor", linear relation)
- Below left: Estimated uncertainty for over-land product without corrections
 - QA=Very Good, Cloud =0
- Below right: Error ratio of corrected vs. uncorrected AOD
 - Australia: filtering changes distribution of AOD, increases noise floor error

BASE



NEW



Detailed Analysis

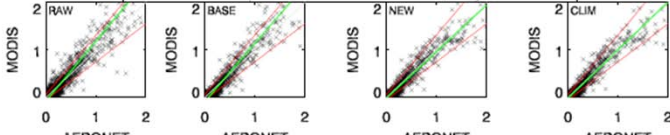
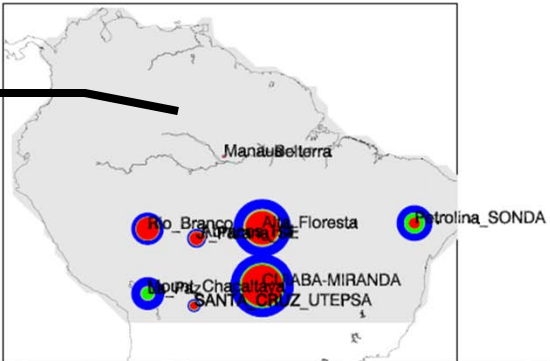
RAW: All QA, no filtering
BASE: QA=VG, Cloud=0
NEW: filtered/corrected
STRONG: restricted albedo

AERONET sites and data density

- Included in Supplement to AMT paper
- Statistics for aggregated L3 product organized by regions.
- Data density, data quality, and plots to permit detailed examination of data

T 6.50S 60.50W South America
 AERONET AOD: N= 2172 $\bar{\tau}$ =0.29 eta=0.59

MODIS τ
 x RAW
 x BASE
 x NEW
 x STRONG



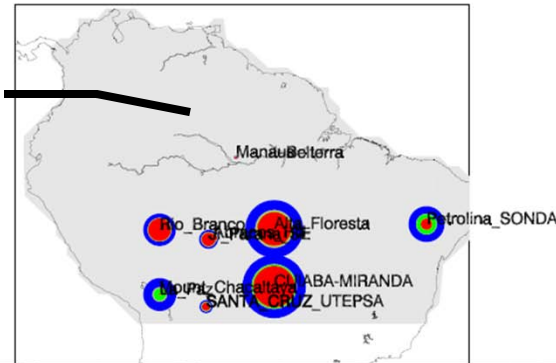
Which	AERONET	MODIS AOD			MODIS-AERONET		-/+		Regression		
		Mean	>0.2	>1.0	Mean Bias	RMSE	Tolerance	Slope	r ²		
RAW	(N= 2168)	0.286	0.30	0.07	-0.000	0.205	25/62/11	1.013	0.75		
BASE	(N= 1400)	0.309	0.30	0.09	-0.014	0.212	26/65/ 7	0.988	0.76		
NEW	(N= 1350)	0.284	0.32	0.08	-0.022	0.149	12/81/ 6	0.956	0.82		
CLIM	(N= 1317)	0.279	0.31	0.07	-0.011	0.136	10/62/ 7	0.987	0.82		
AERONET AOD > 0.2											
RAW	(N= 698)	0.749	0.83	0.23	0.069	0.342	13/65/20	1.007	0.72		
BASE	(N= 520)	0.740	0.79	0.24	0.043	0.337	19/62/17	0.987	0.77		
NEW	(N= 491)	0.644	0.83	0.22	-0.022	0.236	15/71/13	0.955	0.80		
CLIM	(N= 461)	0.639	0.84	0.21	-0.001	0.225	13/71/14	0.985	0.81		
Noise vs IA vs IM Est. @ Est. @ Est. @ Est. @ Est. @											
Which	Floor	Diagnostic	vs IM		Prognotic		0.1	0.2	0.4	0.6	1.0
RAW	0.079	0.00 +	0.271	0.03 +	0.171	0.08	0.08	0.10	0.13	0.20	
BASE	0.068	0.00 +	0.271	0.03 +	0.141	0.07	0.07	0.09	0.11	0.17	
NEW	0.050	0.04 +	0.131	0.02 +	0.161	0.05	0.05	0.08	0.11	0.17	
CLIM	0.047	0.02 +	0.201	0.02 +	0.161	0.05	0.05	0.08	0.11	0.16	

Detailed Analysis

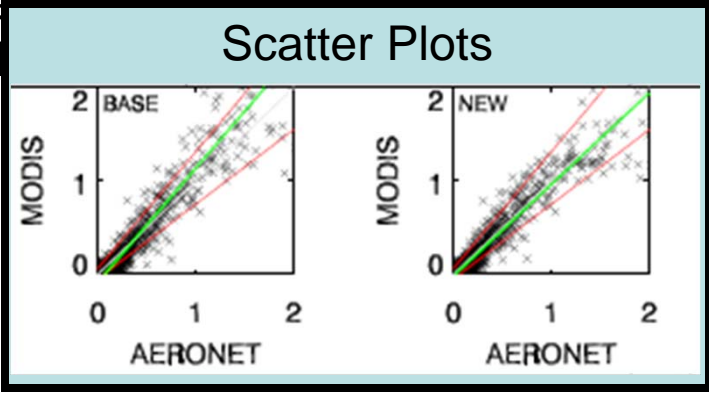
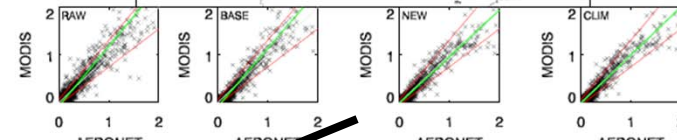
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 MODIS τ
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BASE	(N= 1400)	0.309	0.30	0.09	-0.014	0.212	26/65/ 7	0.988	0.76
NEW	(N= 1350)	0.284	0.32	0.08	-0.022	0.149	12/81/ 6	0.956	0.82
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Noise									
	Floor	vs TA	Diagnostic	vs TM	Prognostic	Est. @	Est. @	Est. @	Est. @
RAW	0.079	0.00 +	0.271	0.03 +	0.171	0.08	0.08	0.10	0.13
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NEW	0.050	0.04 +	0.131	0.02 +	0.161	0.05	0.05	0.08	0.11
CLIM	0.047	0.02 +	0.201	0.02 +	0.161	0.05	0.05	0.08	0.11

Detailed Analysis

Which		MODIS AOD			MODIS-AERONET		% -/in/+ Tolerance	Regression	
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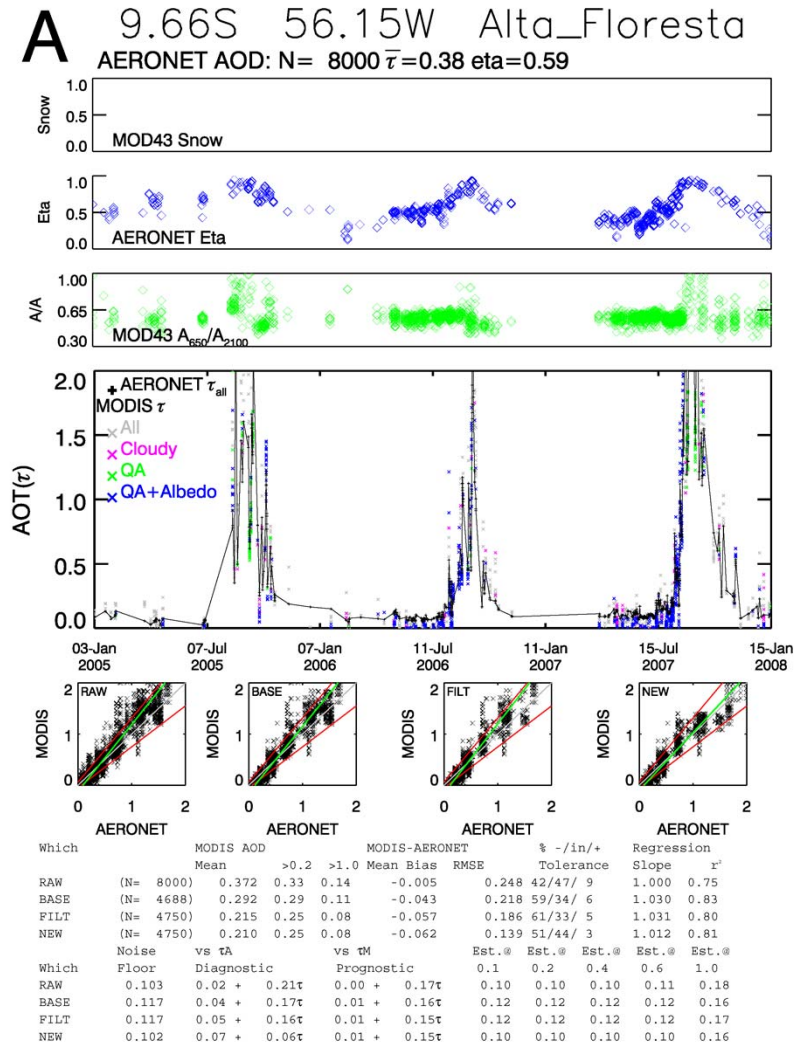
Which	Noise	vs TA		vs TM		Est. @	Est. @	Est. @	Est. @	Est. @
	Floor	Diagnostic		Prognostic		0.1	0.2	0.4	0.6	1.0
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CLIM	0.047	0.02 +	0.20†	0.02 +	0.16†	0.05	0.05	0.08	0.11	0.18

RAW: All QA, no filtering
 BASE: QA=VG, Cloud=0
 NEW: filtered/corrected
 STRONG: restricted albedo

- Included in Supplement to AMT paper
- Statistics for aggregated L3 product organized by regions.
- Data density, data quality, and plots to permit detailed examination of data

Even More: Level 2 Statistics for every AERONET site

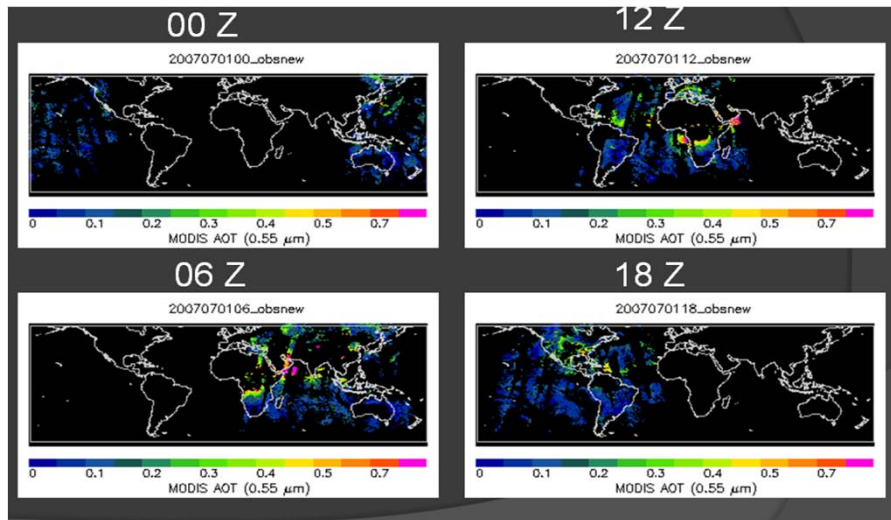
- Directly diagnose surface effects
- Separate stats for raw, basic QA, filtered, filtered+corrected
- Can analyze individual events
- AMT Supplement includes only examples: can supply all on request



Products now available on GODAE

http://usgodae.org/cgi-bin/datalist.pl?Data_Type=ALL&Parameter=ALL&Provider=nrl&meta=Go#nrl_modis_l3

- Latency 24 hours
- Can retrieve land/ocean, Aqua/Terra separately
- Currently staged 2010-



GODAE Global Ocean Data Assimilation Experiment

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Data_Type: ALL | Parameter: ALL | Provider: nrl | Go | Reset

USGODAE Data Catalog - Query Results

MODIS L3 - Level 3 filtered, corrected, and aggregated
MODIS AOD

Data Access
[HTTP](#)
[FTP](#)

Sample dataset image [MODIS L3 AOD](#)
[NRL Monterey Aerosol Page](#)

Documentation
 Data Provider [NRL Monterey](#)
[MODIS L3 Documentation and Format](#)

This is an official U.S. Navy Web site

Approved for Public Release on 01 December 2008
 Naval Research Laboratory Marine Meteorology Division Monterey, CA
 7 Grace Hopper Avenue, STOP 2
 Monterey, CA 93943-5502

Access via FTP/HTTP

Documentation