Comprehensive evaluation of satellite based aerosol products: The GEWEX and NRL Aerosol Assessments.

GEWEX Panel: Sundar Christopher, Richard Ferrare, Paul Ginoux, Stefan Kinne, Gregory Leptoukh, Jeffrey Reid, Paul Stackhouse

Navy Team: Jianglong Zhang, Edward Hyer, Jeffrey Reid, Doug Westphal, James Campbell, Yingxi Shi, Peng Xian, Walter Sessions

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The aerosol data product problem….

- The field hosts dozens of both products and applications.
- But, most products are in the twilight zones of “research,” “development,” and “production.”
- This is reinforced with the funding situation where money for product development, maintenance, and verification is limited. Developers spend more time “using” their products than “supporting.”
- By the time the wider community figures out how a product is doing, a new version is released.
- The user community does not have the time or funding to really understand the ins and outs of specific products. The “It’s the only thing out there” attitude is prevalent.
- Situation: Confusion and some rancor in the community as to the proper efficacy and applications of these data.

Examples of Two Responses:

	Reformed GEWEX Aerosol Panel (GAP)	NRL Aerosol Assessment Effort
Focus:	Earth System Science	Operations and Analysis
Basis:	Community	Requirements
Size:	Small	Small
Early Analysis:	Jury Method	Document Error Terms and Bias Removal
Later Analysis:	Level 3 and Reconciliation	Prognostic Error Models
Where are we now?	Middle of Early	Beginning of Later
Final product:	Report, Recommendations and Product	DA Grade Analysis

Sensors Under Investigation

Reformed GEWEX Aerosol Panel (GAP)

AVHRR-GACP
AVHRR-NOAA
MISR
MODIS Col 5
MODIS Deep Blue
OMI
Polder/Parasol

NRL Aerosol Assessment Effort

AVHRR-NOAA
CALIOP/CALIPSO
MISR
MODIS Col 5 (NRTPE and Std)
MODIS Deep Blue (NRTPE and Std)
VIIRS
Soon….
OMI
Geostationary

GAP Panel Members

- Programmatic oversight: NASA Radiation Sciences (Maring and Ichoku)
- GAP selection criteria:
  - Must have extensive expertise in the application of satellite aerosol data to a variety of research and operational problems.
  - To ensure impartiality and a detached review, members were not to be members of the teams generating core products being evaluated.
  - Members were to represent the needs of specific communities, including broad satellite, multi sensor fusion, climate/NWP modeling, and field work

Sundar Christopher (UAH): chair, algorithm development, multi sensor products

Richard Ferrare (NASA LaRC): lidar, field work, multi-sensor products

Paul Ginoux (NOAA GFDL): Global modeling and aerosol sources

Stefan Kinne (Max Plank): GEWEX Cloud, AEROCOM

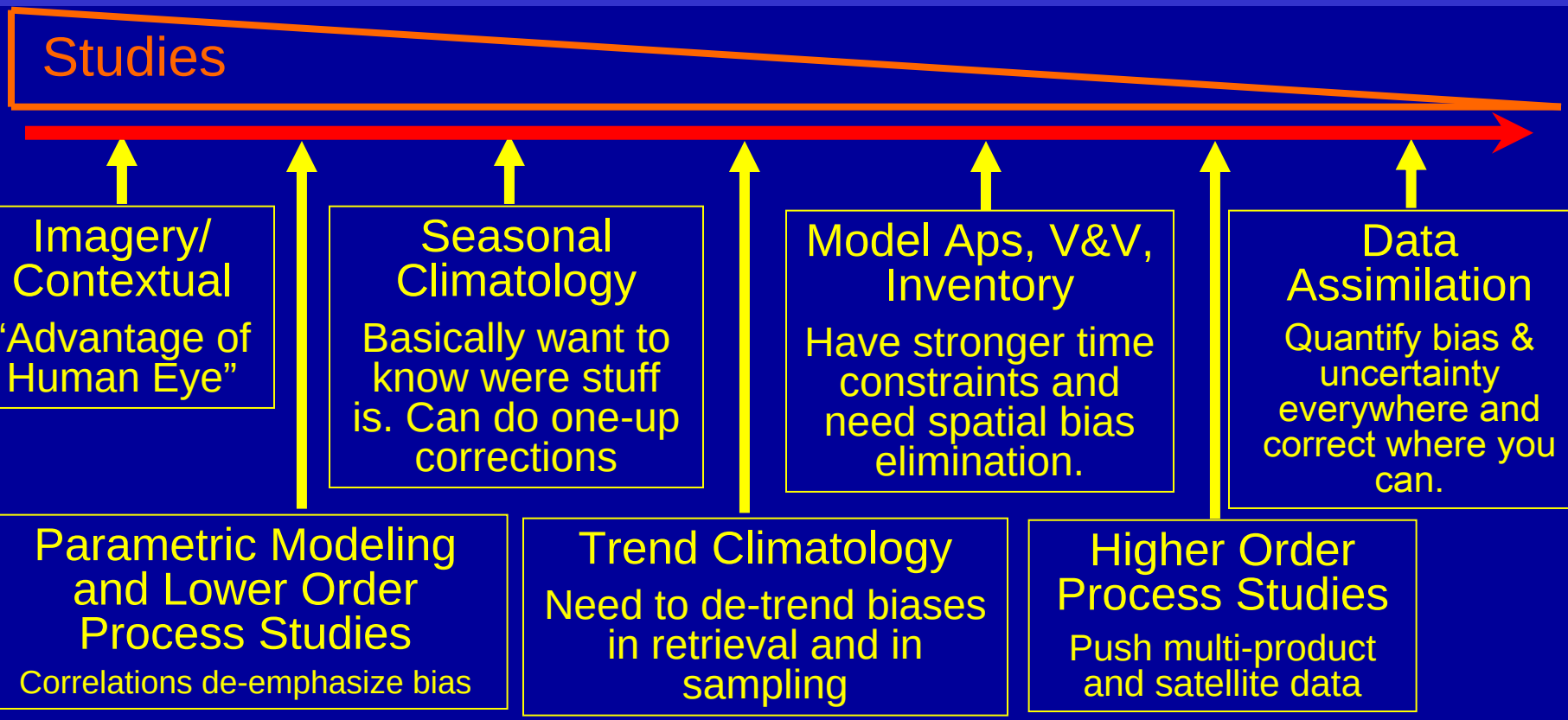
Gregory Leptouchk (NASA GSFC): Level 3 product development and distribution

Jeffrey Reid (NRL): co-chair, observability, field work, operations

Paul Stackhouse(LaRC): GEWEX radiation, atmospheric radiation and energetics.

Relative Levels of Efficacy Required

(Approximate and not meant to offend…)



V&V statistics must speak to these applications!

Hence, there is no "one size fits all" error parameter.

Sorry….

Types of Bias

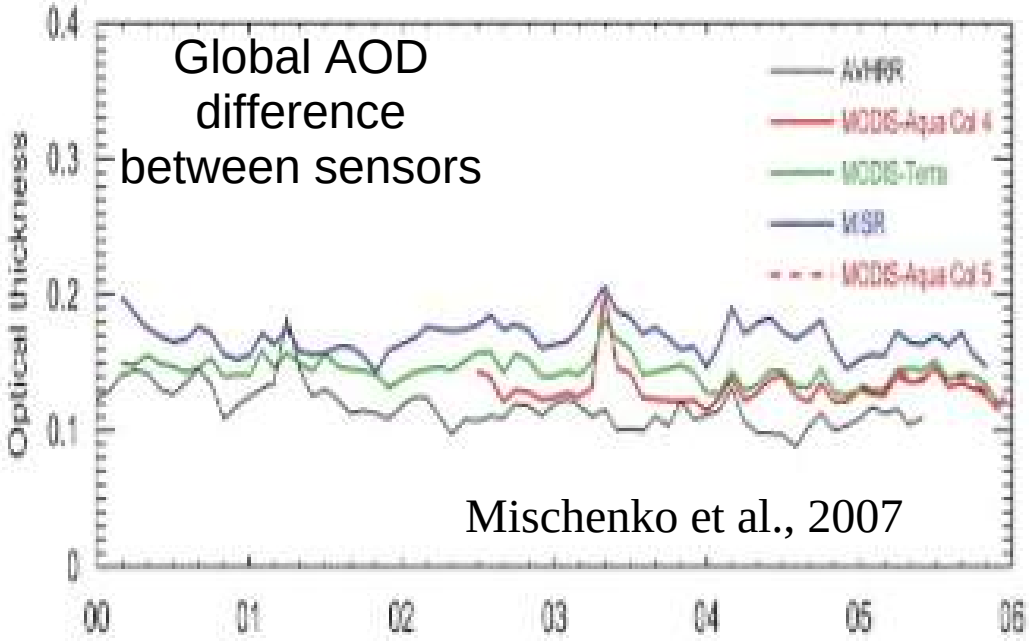
Each a talk in themselves

- **Radiometric Bias:** Biases due to uncharacterized or ill applied sensor calibration.
- **Retrieval Bias:** Biases related to shortcomings in the retrieval itself.
- **Sampling/Contextual Bias:** Biases related to where a retrieval is/is not performed or contextually related uncertainty in a scene. This leads to a skewed data population relative to what is thought to have been collected.
- **Aggregation/Data Reduction Bias:** Loss of required information during conversion to a gridded product or during analysis.
- **Cognitive Bias:** We, the investigators, misinterpret, withhold, or frame data/results contrary to full nature of the data. Statistics are the rhetoric of science…..
- **Other Considerations:** **a) Correlated error-**"Independent" products that share similar biases; **b) Tautology -**Circular reasoning or treating non-independent data as independent.

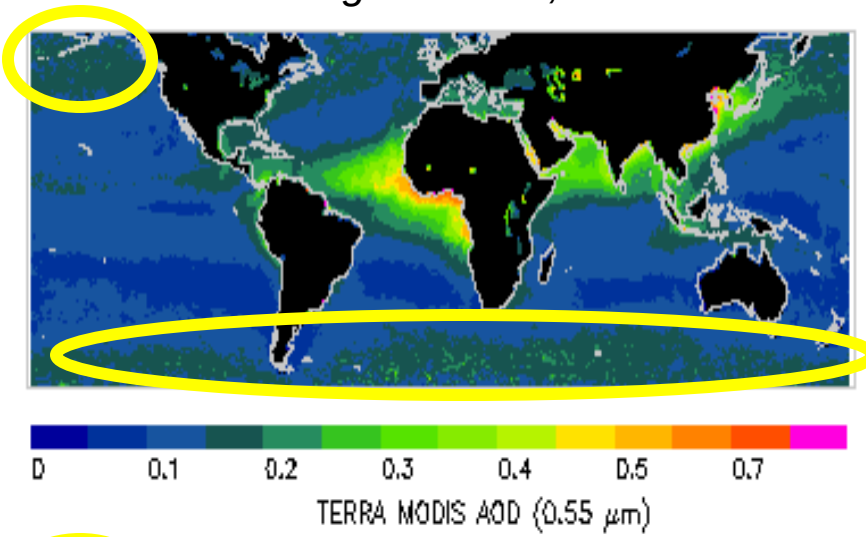
And we wonder why modelers want to assimilate radiances….

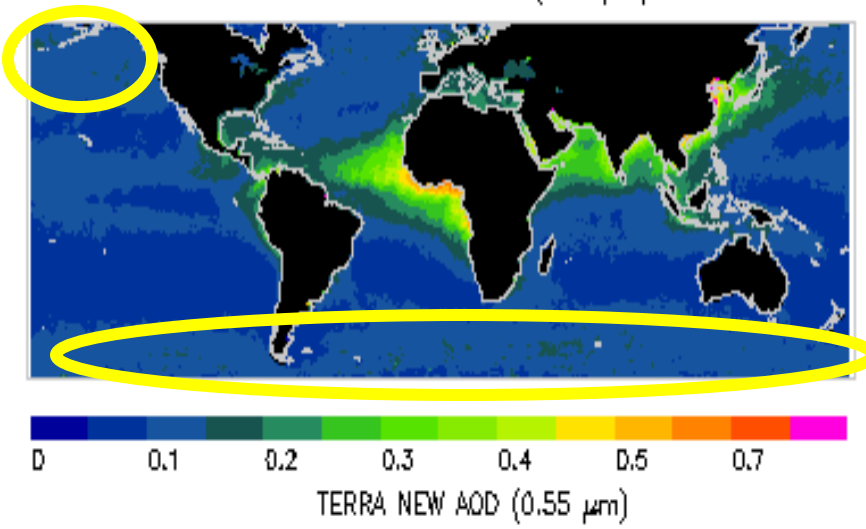
Anatomy of Bias: Simple Example
Global Average Time Series Over Water

The “big” differences over ocean between sensors can largely be explained by a combination of radiometric bias, cloud bias, and lastly microphysical bias coupled with sampling differences/contextual bias. The big problem is coordinating groups.



Zhang and Reid, 2006

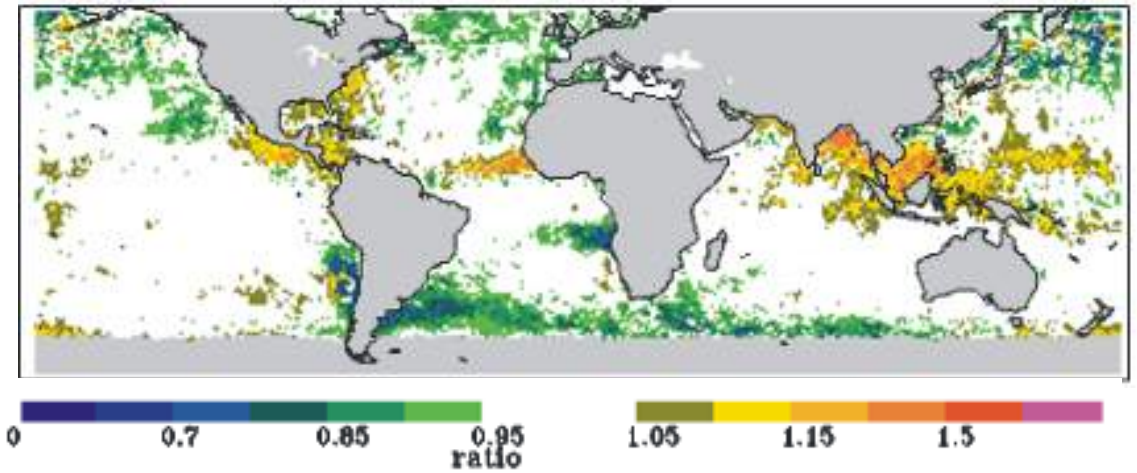




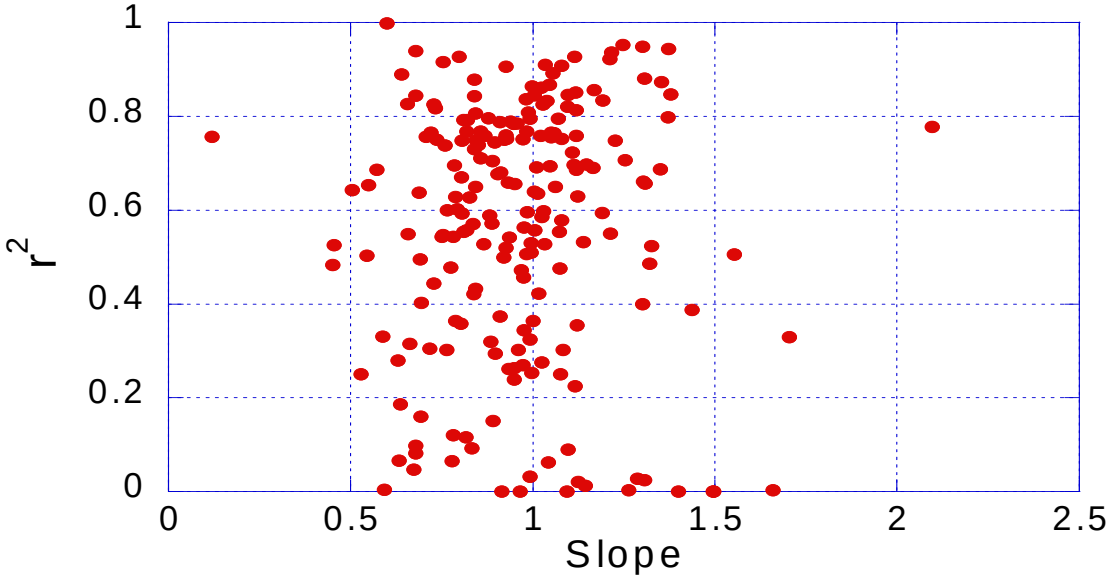
Anatomy of Bias: Hard Examples

- Appropriate consideration of “What the satellite is actually seeing” is often overlooked in the field.
- Performing even the most basic matchups between sensors is not trivial.
- The core retrieval biases related to clouds, lower boundary condition, and microphysics are non-random, but spatially and temporally correlated-invalidating most commonly used V&V method.

ASO Clear Sky Bias, Zhang and Reid 2009



MODIS Versus AERONET Summary Statistics, AOD>0.2



Everyone wants an error bar, so why cant they get it? Have to build to suit application. The NRL DA Product

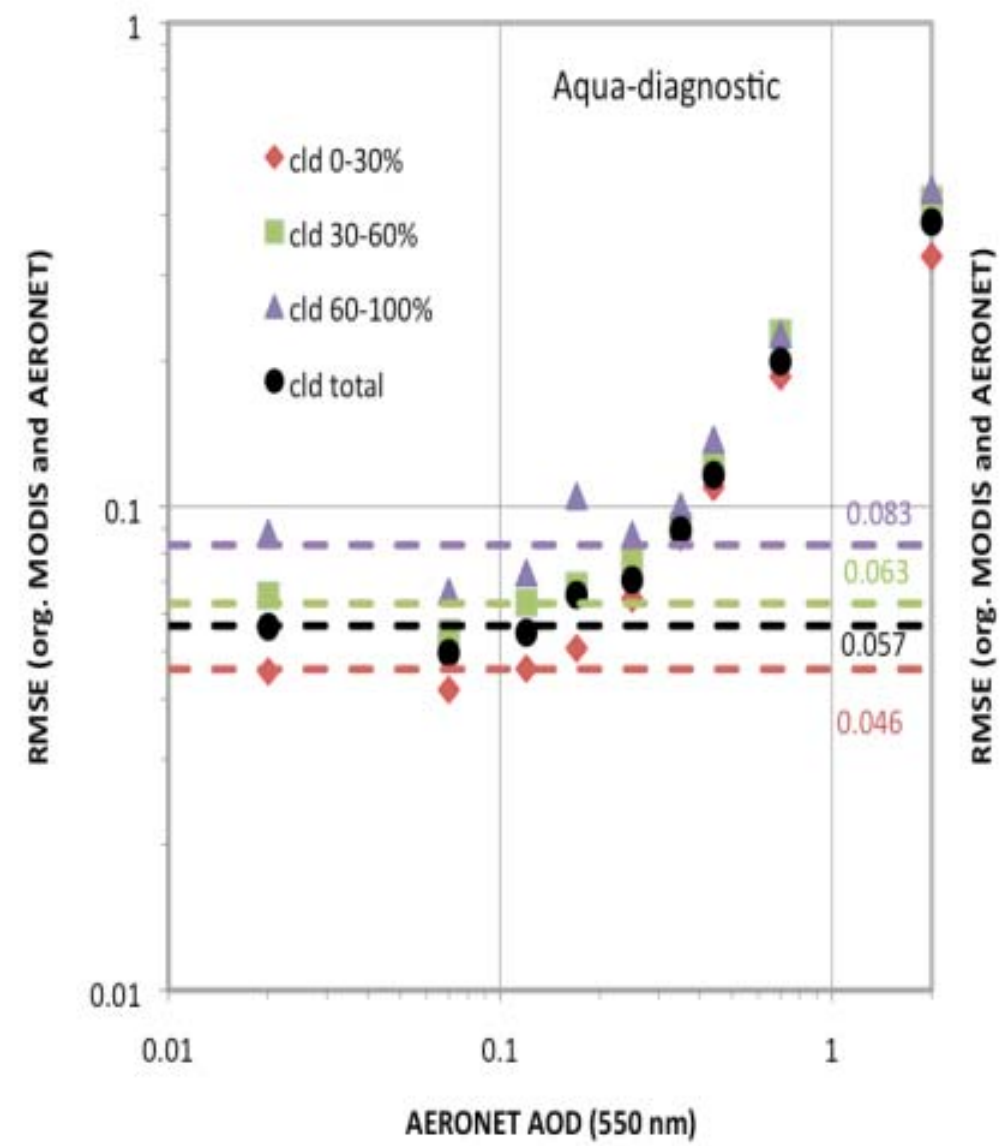
- NRL aerosol program has a mandate to develop data assimilation grade satellite products for use by operational customers.
- This requires bias removal coupled with a prognostic error model.
- We are ok with certain contextual biases, especially if we treat the model like the low pass filter it is.

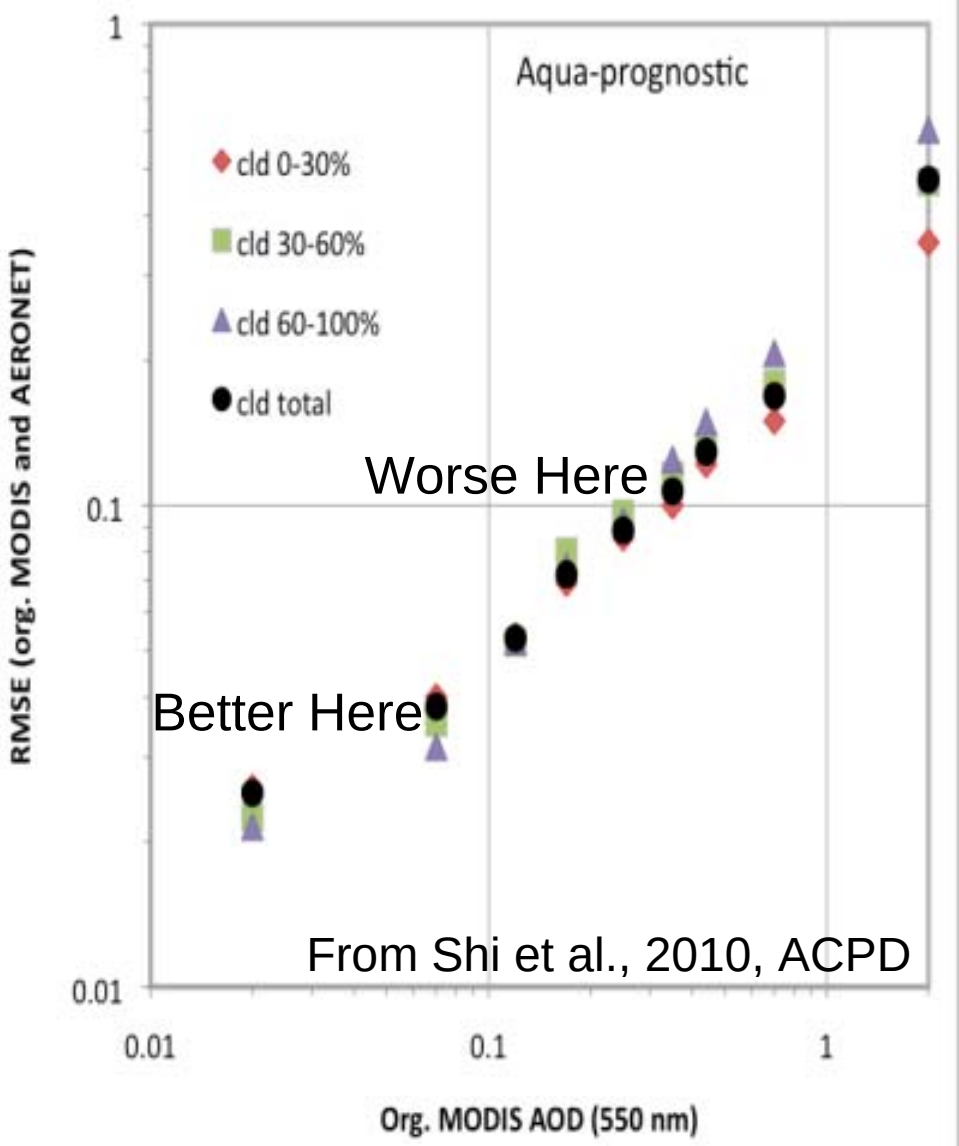
James Campbell (NRL): Lidar
Edward Hyer (NRL): Over land AOD and fire
Jeffrey Reid (NRL): Aerosol science, metrics
Walter Sessions (CSC): Reanalyses, ensemble DA and verification
Yingxi Shi (UND): MISR and Deep Blue
Doug Westphal (NRL): Global modeling
Peng Xian (ASEE): Precipitation
Jianglong Zhang (UND): Data assimilation

Components of an Error Model
(requires lots of data to pull out)

- Can be as simple as RMSE as a function of AOD
- AOD can be from AERONET (diagnostic) or own AOD (prognostic).
  - But, RMSE is symmetric, includes BOTH noise and bias, and it does not easily address massive outliers which are often the problem for DA.
- Terms include:
  - Differential Signal to Noise: Lower boundary minus total, including view angle/optical path length.
  - Lower Boundary Condition:
    - Ocean: Wind/glint/whitecap, class 2 waters, sea ice
    - Land: Surface reflectance model, snow, view angle/BRDF/hotspot
  - Cloud mask
  - Microphysical: Fine coarse/partition, P(q)/g, w_o, AOD
- Biases are often folded into “random” error models out of necessity. If they are known, why not correct for them?
- Radiance Calibration: Individual wavelengths propagate non-linear through retrievals and are not easy to incorporate.

Diagnostic versus prognostic error models: A MODIS over ocean example

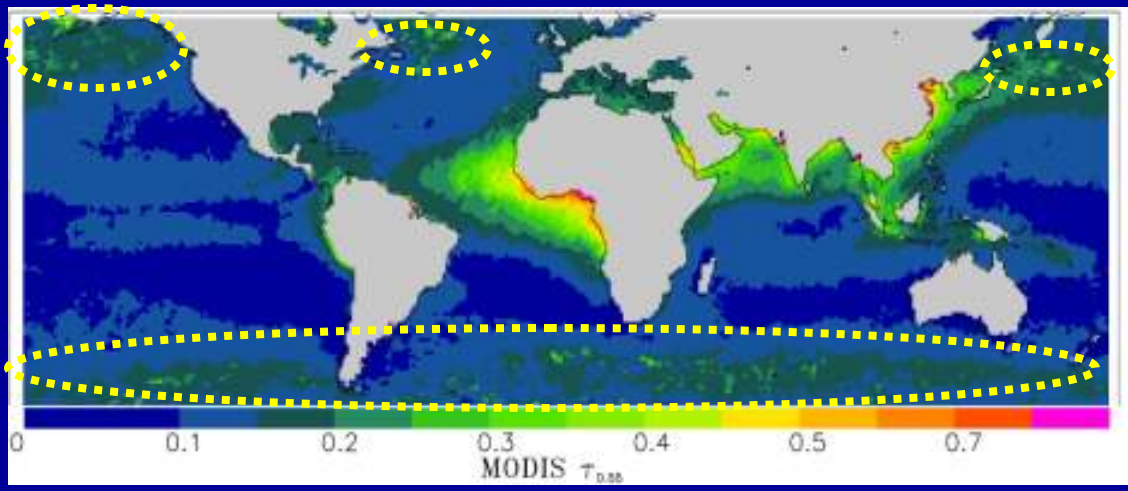


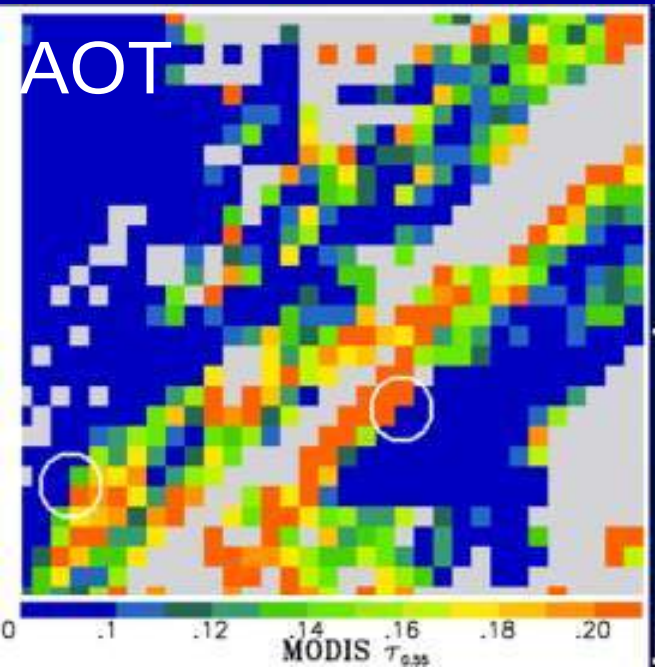


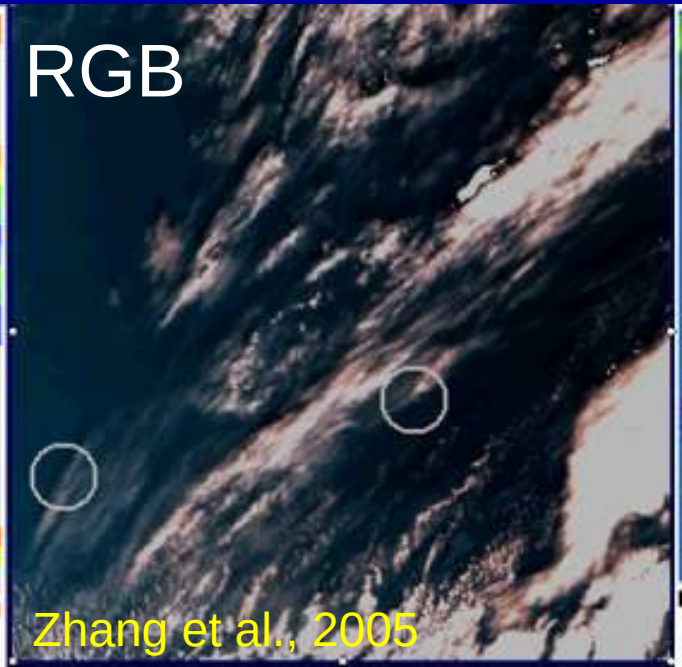
Data Assimilation Applications: Quality Assurance

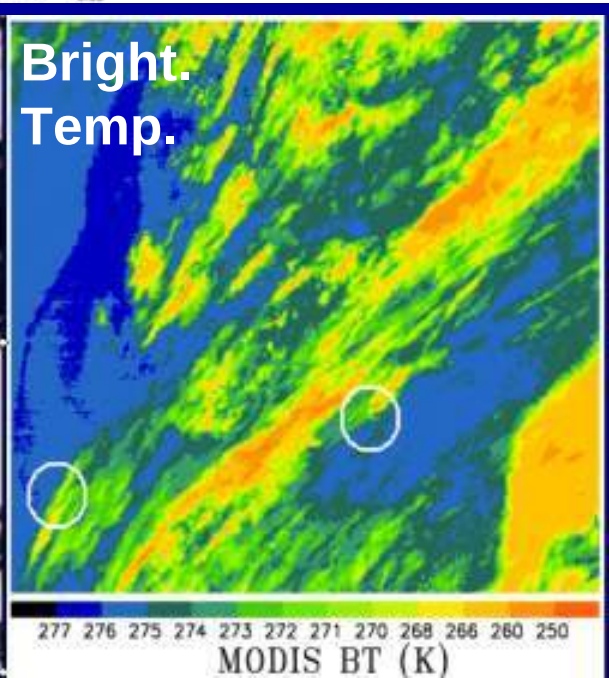
Can clear out a lot of junk through spatial tests

- Southern ocean aerosol anomaly: Fact or cloud bias?
- Northern oceans have same problem, but people quickly attributed it to China and CONUS.
- Spatial tests get rid of it.

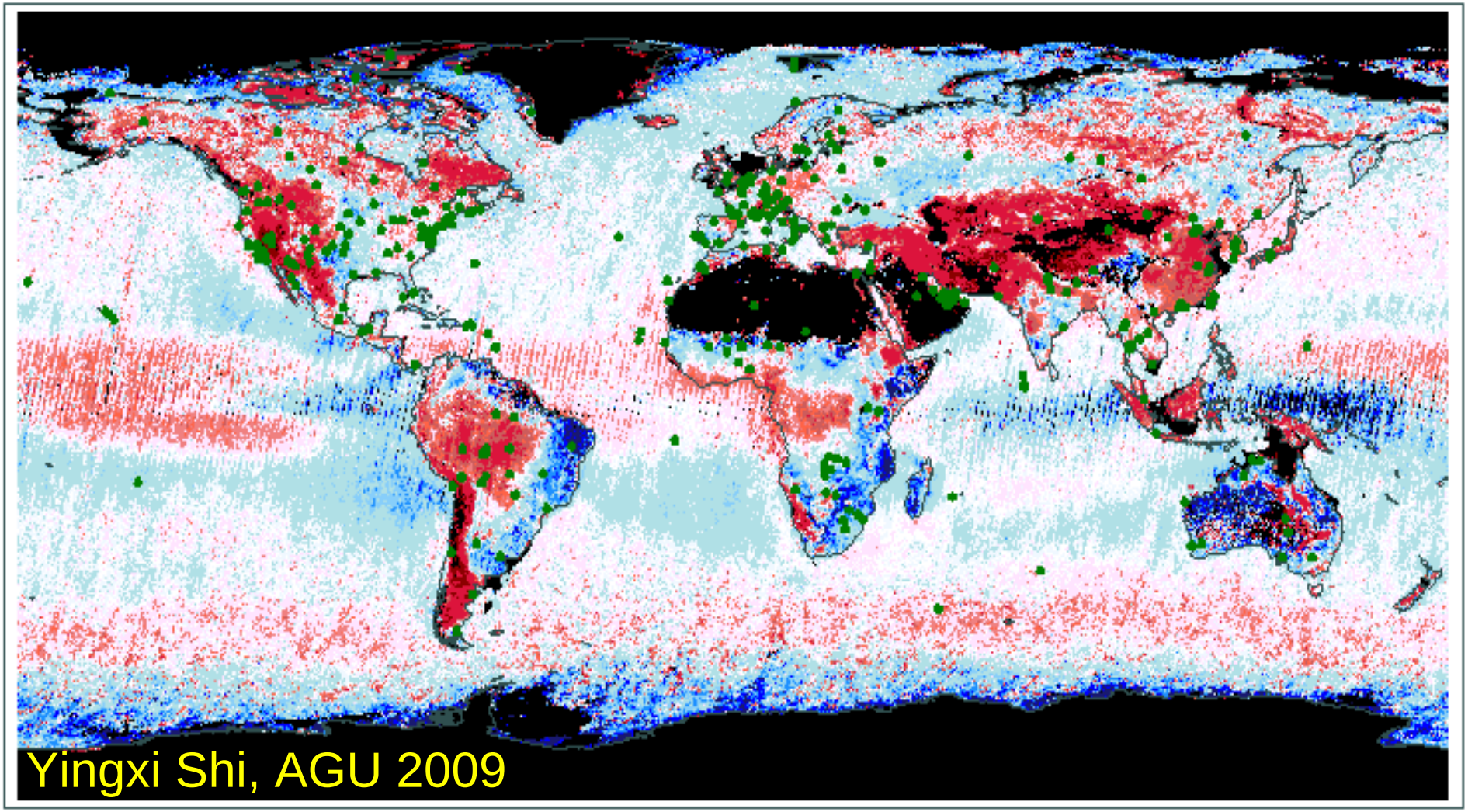








More on correlated bias: Ratio of MODIS to MISR. These features dominate innovation vectors and hence any inverted quantity

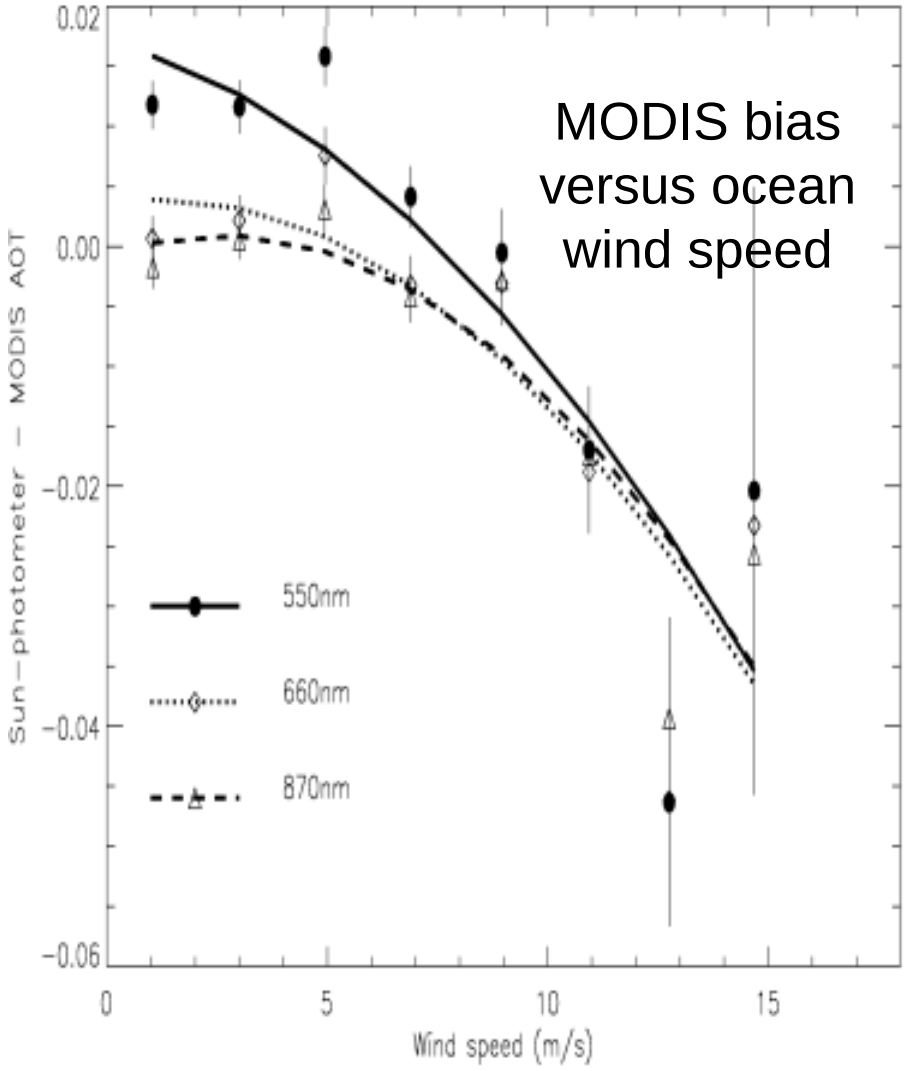


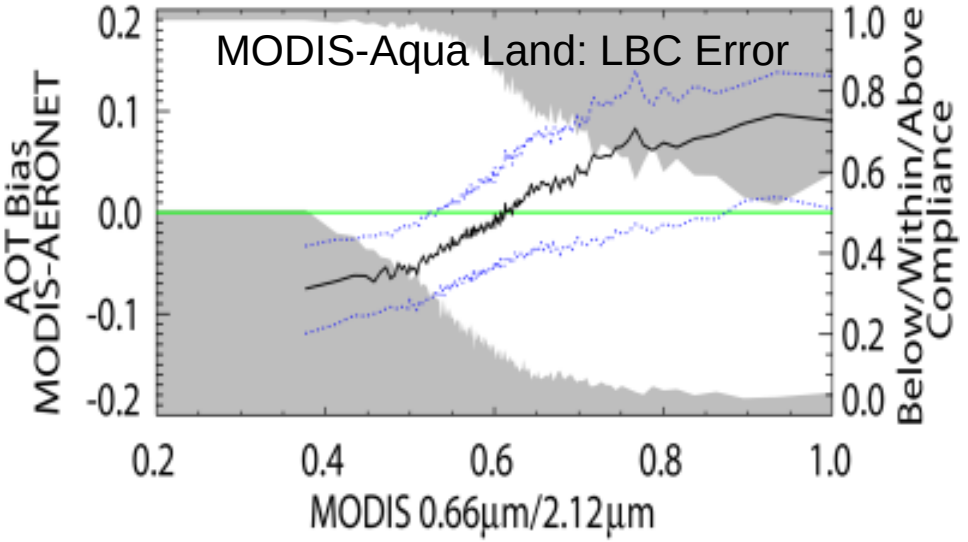
.2 0.5 0.7 0.95 1.1 1.3 3.0

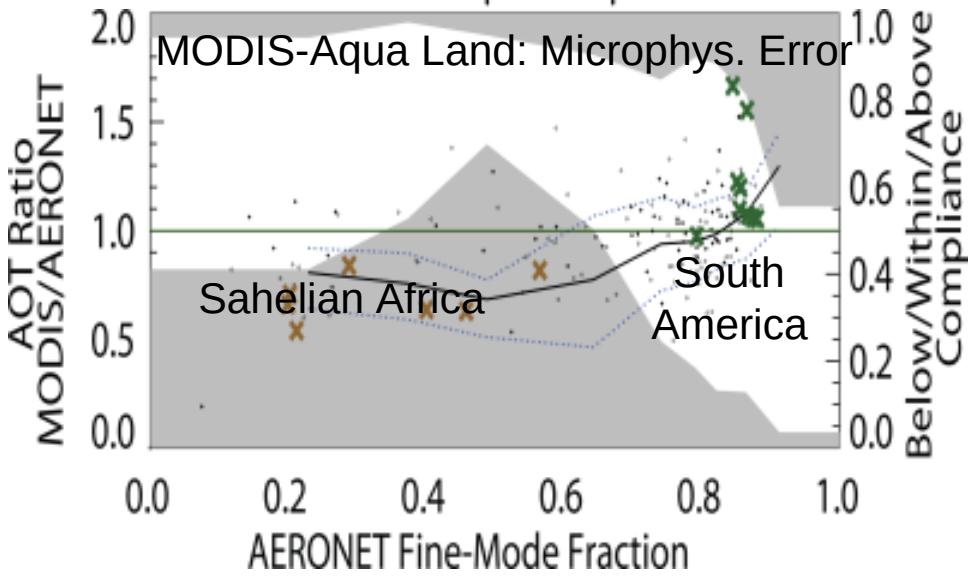
MODIS/MISR AOD (0.55 μm)

Examples of Bias Removal

Need years of Global Data (Zhang's and Hyer's papers)



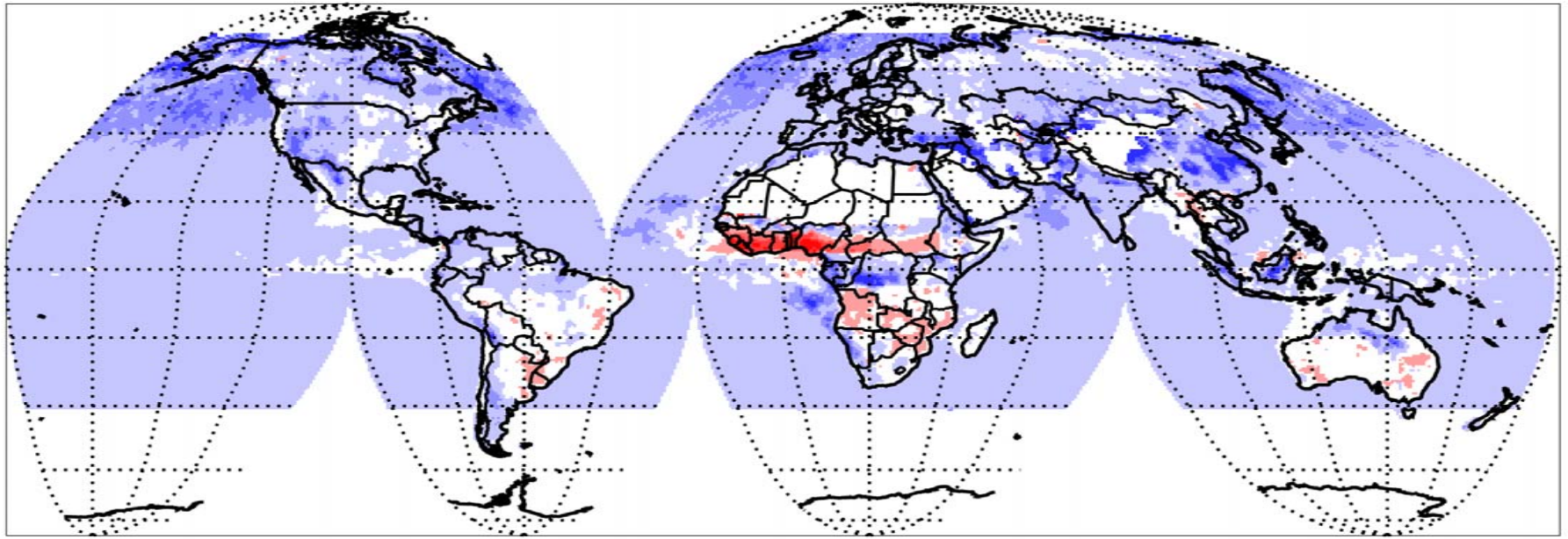


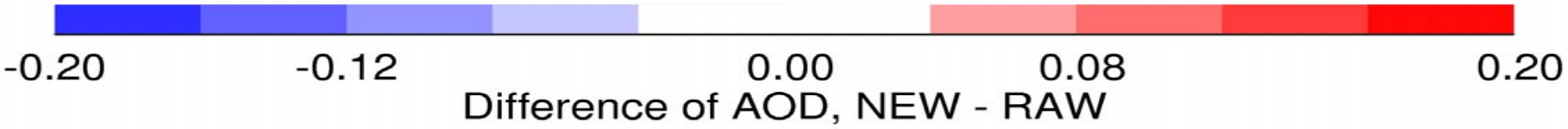


Bottom line product-2009 Annual Differences.

Be warned, there is some cancellation of errors and we are still not entirely happy.

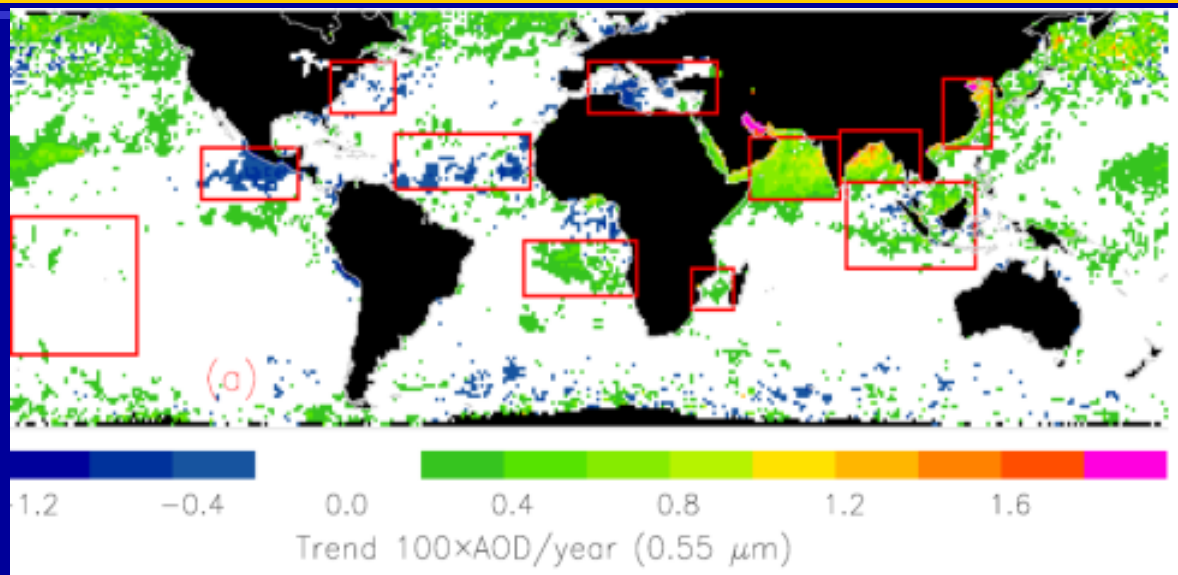
2009all NEW - RAW Difference of AOD

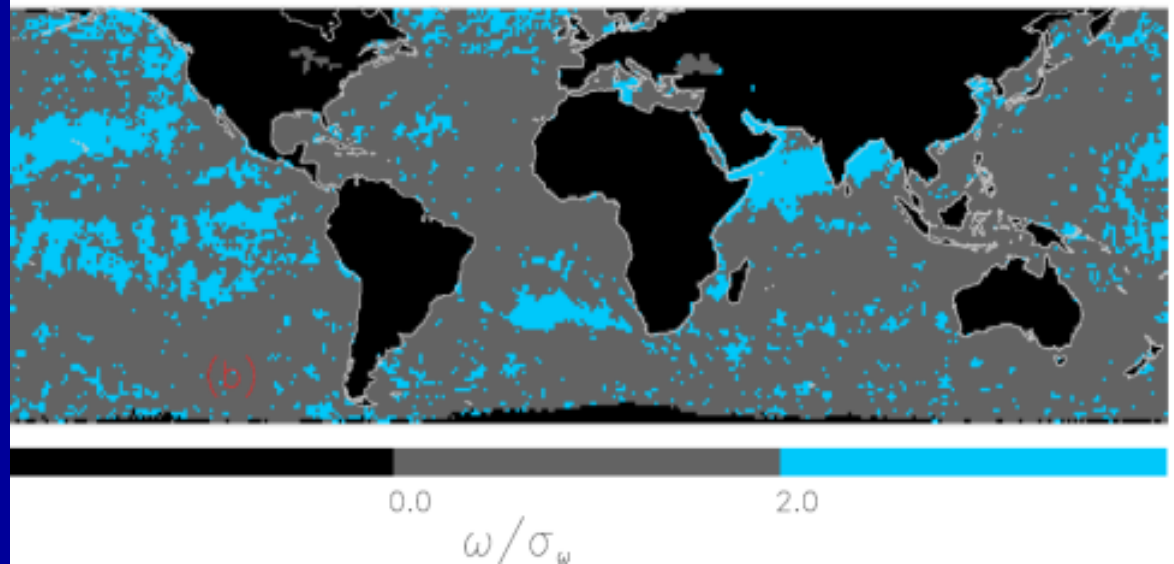




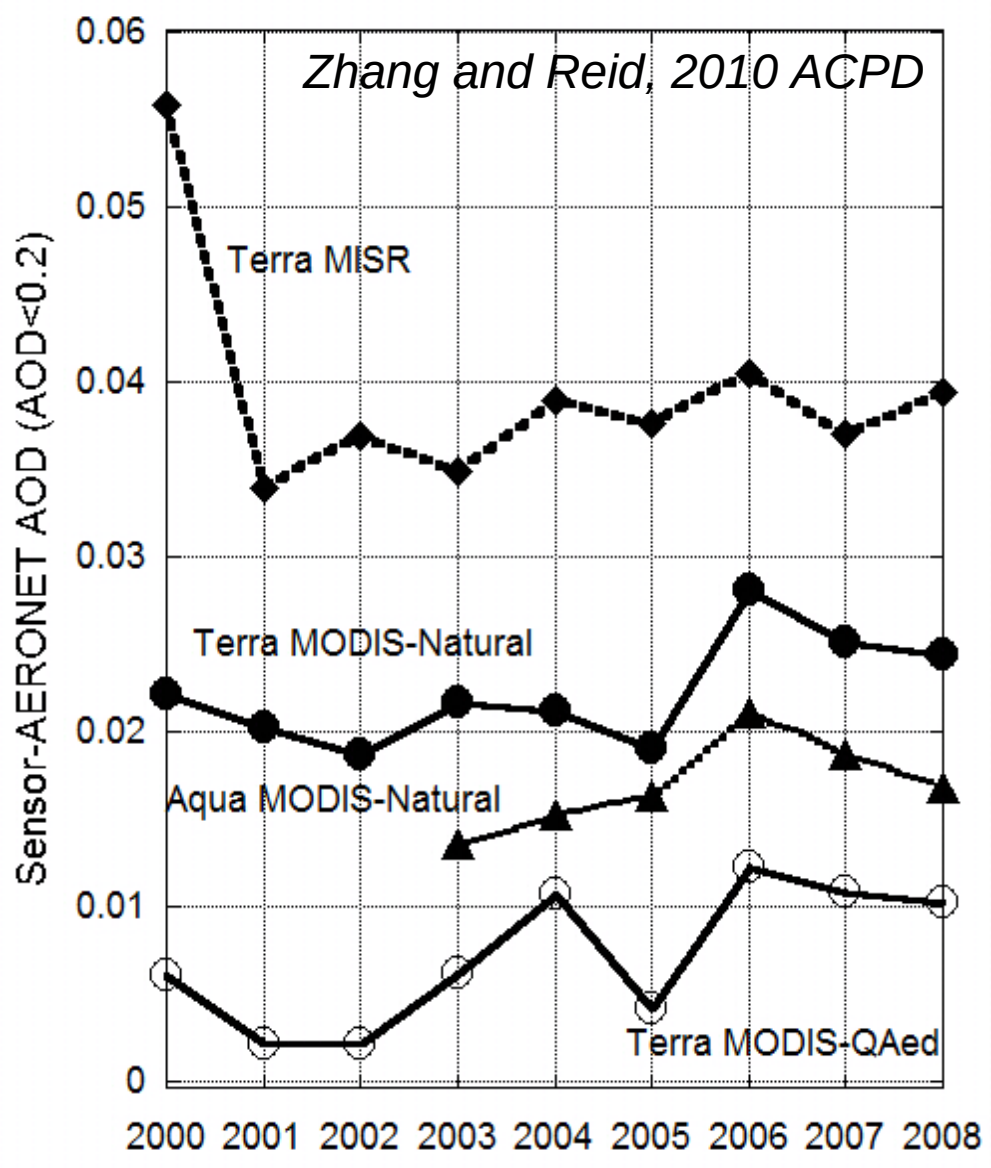
Applications of an Operational Product- Another view on aerosol trends

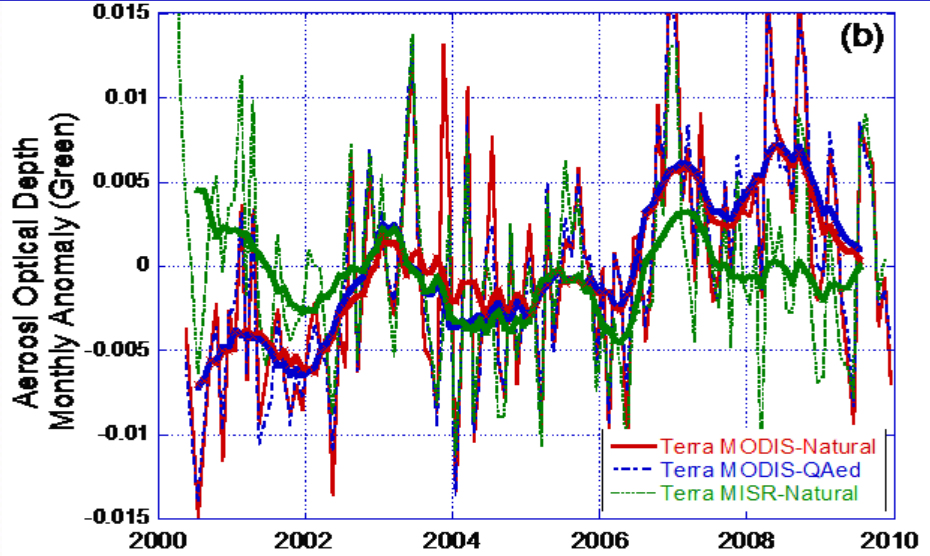
- We examined 10 years MODIS and MISR trends over ocean.
- The first step was to assign areas of statistical significance.
- The next, step was to debias calibration errors.
- Bottom line no trend over ocean except around Arabian Gulf, India and China.

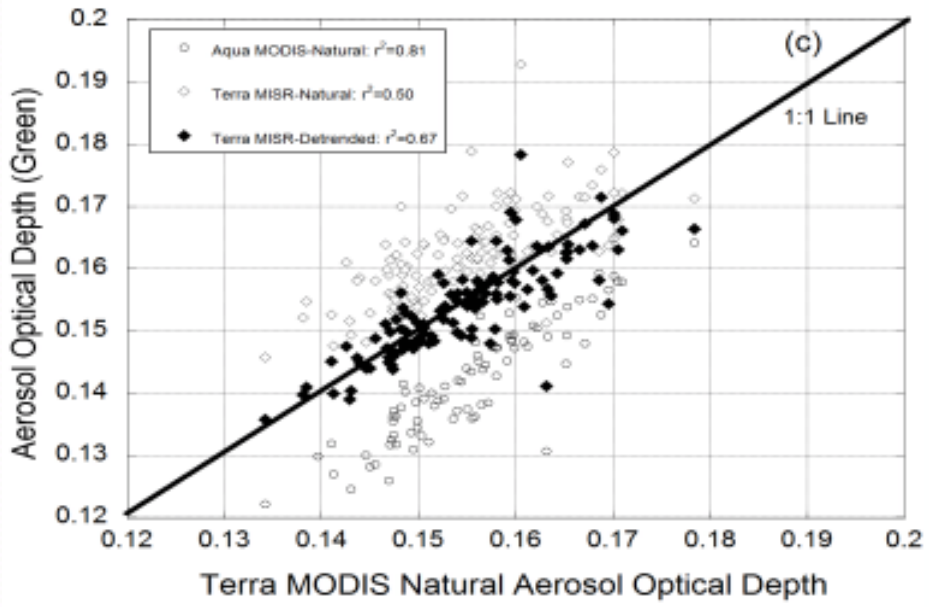




Calibration Issues?







Where to get…

- Images can always be found on the NRL aerosol webpage: http://www.nrlmry.navy.mil/aerosol/
- The big data repository for NRL and Navy is GODAE and the product will appear there as soon. http://www.usgodae.org/
- Also data will appear on Jianglong Zhang's website. http://bobcat.aero.und.edu/jzhang/index.php
- We are trying to push it to LANCE.
- AERONET stats in Hyer's ancillary materials at AMTD. http://www.atmos-meas-tech-discuss.net/3/4091/2010/
- If you need something specific ask….

Summary

- Different groups are doing many intercomparisons and efficacy studies.
- This is ok as long as all work is predicated on an application (trends, forecasting, radiation, process studies, etc…). This is truly a case where one size fits none.
- The GEWEX Aerosol Panel is formed along a ‘Jury Method’ for basic ESS applications followed by specific hypotheses to test.
- The NRL DA assessment is specifically tuned for operational users and prognostic error modeling, although it can be useful for specific ESS questions too.