Aerosol Observability Workshop:
Validation and Verification of Aerosol Products for Operational Use

Jeffrey S. Reid, Jianglong Zhang, Edward J. Hyer, James A. Hansen, Peng Xian, and James R. Campbell

jeffrey.reid@nrlmry.navy.mil/ 1 (831) 656-4725
http://www.nrlmry.navy.mil/aerosol/
http://www.nrlmry.navy.mil/flambe/

Bottom lines up top.

- There are a lot of products out there. It would be good to use all of them, but the shear numbers is getting difficult to manage.
- Products are not what they appear. It does not matter if a product is uncertain, we just need to know what that uncertainty is per retreival.
- We don’t have the benefit of 30 years of operational history, and due to propagation of error we can’t directly apply their methods.
- Need standardization for error stats and hopefully develop a system.
- For discussion tomorrow: What products and error stats do we want generated?

Aerosol Relevant product lines
(there is a lot to keep track of)

Current:

- CNES: Parasol/POLDER
- ESA: ATSR, AATSR
- EUMETSAT: METEOSAT dust, fire, etc..
- JAXA: GOSAT, TRMM
- NASA: MODIS (Col 5 Land & Ocean, Deep Blue, fire), MISR, OMI/TOMS, CALIOP, Cloudsat, AVHRR/GACP, SeaWiFS (standard and Deep Blue)
- NOAA: AVHRR, GOES-GASP, Geo-ABBA fire constellation

Next generation (that I know of):

- JAXA: GPM, GCOM-C, EarthCARE-CPR
- ESA: EarthCARE-ATLID/MSI
- JPSS: NPP/JPSS VIIRS
- NASA: GLORY, MODIS MAIAC.
- NOAA: GOES-R aerosol and fire

Product Efficacy: Should you be concerned?

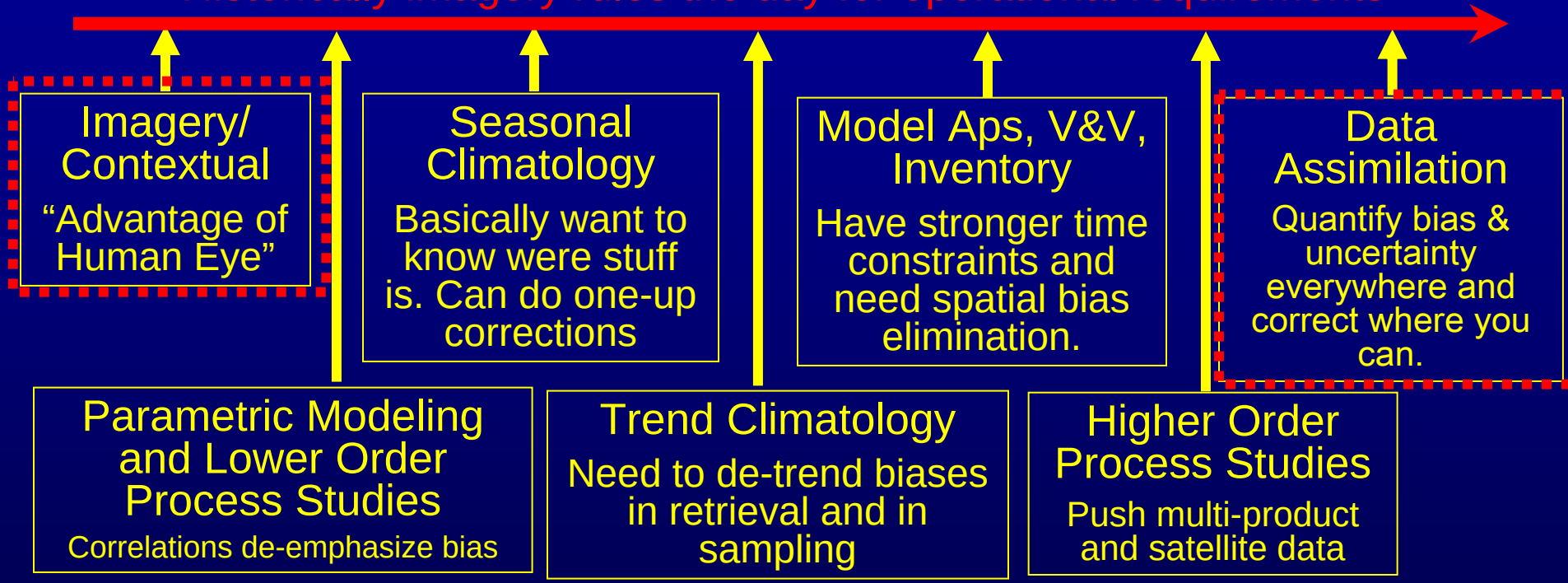
- Historically product developer paint a pretty rosy picture about product efficacy.
- Even so, in many parts of the world, assimilating as is will improve scores. Others, it will degrade the model.
- AERONET, while wonderful, can lead to representativeness bias in assessments.
- No developer has ever published a prognostic error model for their aerosol or fire product. At best you get a slope, Y-intercept, and r value. If lucky, get a mean bias. This leads to “worst case” usage=no impact.

Relative Levels of Efficacy Required

(Approximate and not meant to offend…)

Operational Agencies Focus on the Extremes

Historically imagery rules the day for operational requirements



- Inverse modeling is sensitive to spatially and temporally correlated error.
- Forecasting is even more sensitive, as anomalously high data will create a "plumes" in the forecast fields. Forecasters are not used to this.
- Non-linear transfer function between AOD and model mass complicates error propagation, particularly at low AODs.

Types of Bias

Each a talk in themselves

- **Radiometric Bias:** Calibration/characterization at the sensor level.
- **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 level 3 or during analysis.
- **Cognitive Bias:** We, the investigators, misinterpret, withhold, or frame data/results without consideration of the full nature of the data.
- **Other Considerations for multi-sensor work:** **a) Correlated error-** "Independent" products that share similar biases; **b) Tautology -** Circular reasoning or treating non-independent data as independent during tuning.

And we wonder why modelers want to assimilate radiances?????

Components of Level 2 Error Model
(requires lots of data to pull out)

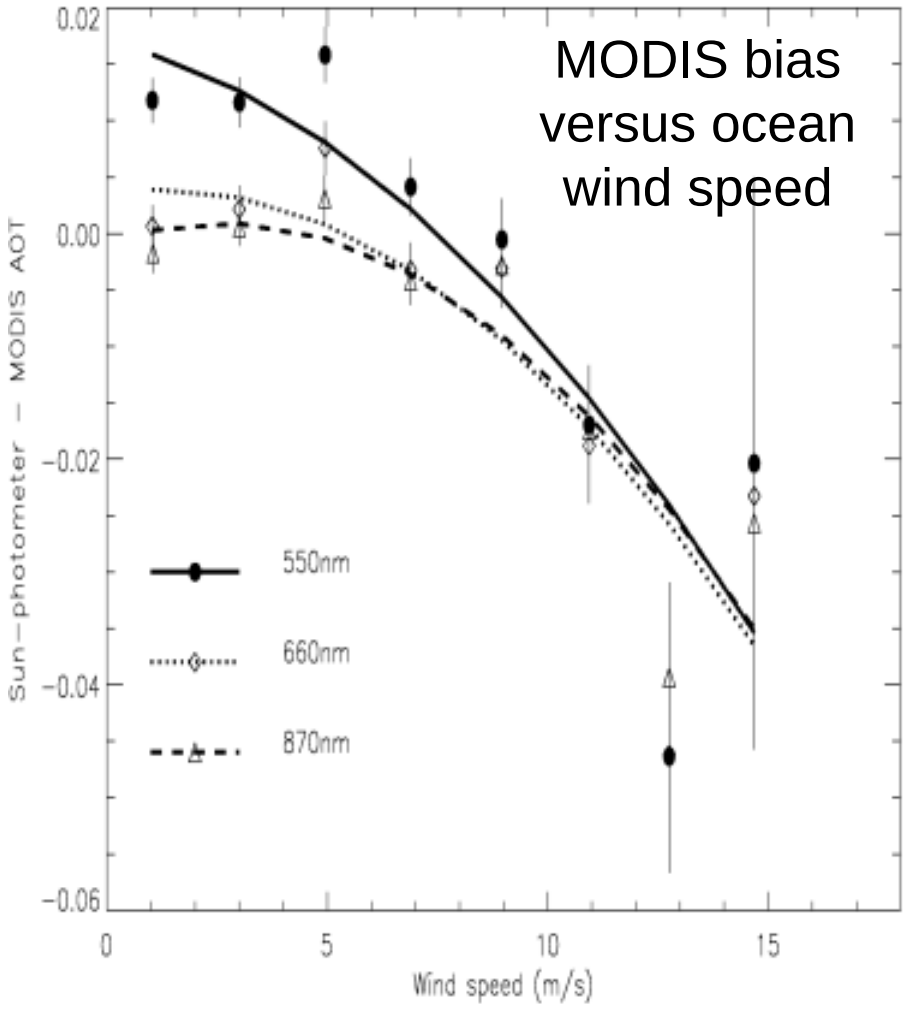
- Can be as simple as RMSE as a function of AOD
  - AOD can be from AERONET (diagnostic) or own AOD (prognostic).
  - But, RMSE is symmetric nor does it address massive outliers which are often the problem
- Terms include:
  - Differential Signal to Noise: Lower boundary minus total, including view angle/optical 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, $P(\theta)/g$, ω_o, AOD
- Biases are often folded into “random” error models. If they are known, why not correct for them?
- Radiance Calibration: Individual wavelengths propagate non-linear through retrievals and are not easy to incorporate.

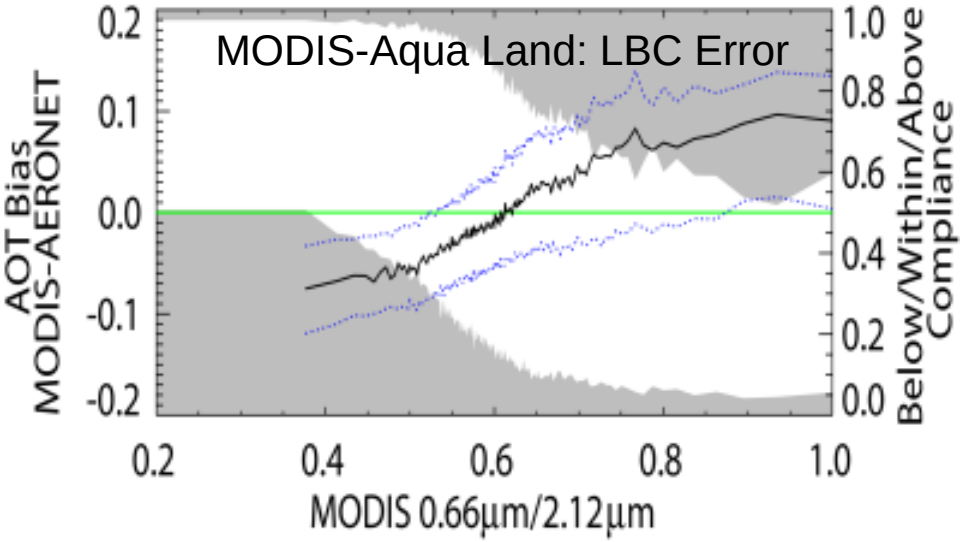
Where do we get validation data?

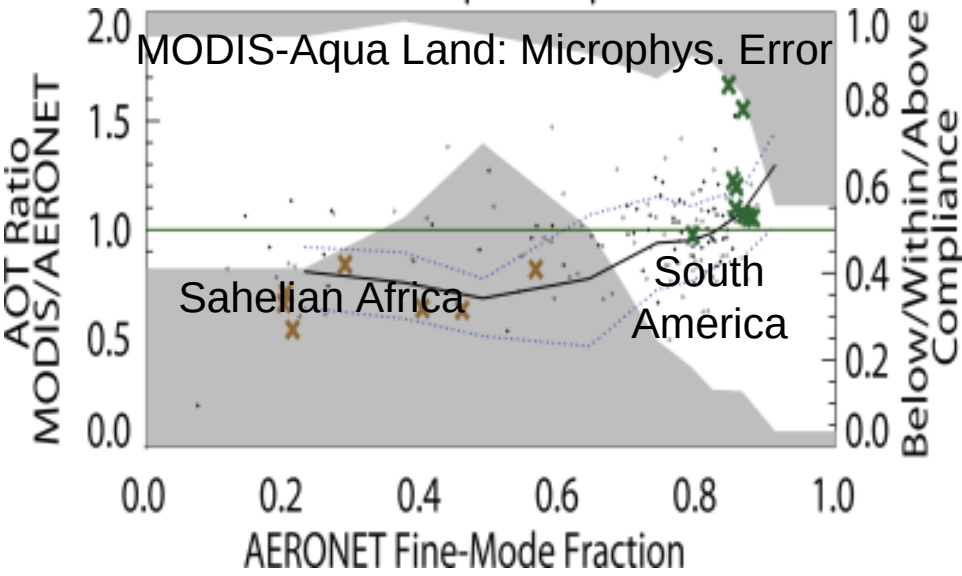
- AOD: Almost exclusively AERONET and the O'Neill Spectral Deconvolution Method. Why? Consistent large global data set of high quality.
- Other AOD sources: higher uncertainty poses a problem with validation. High overhead of bringing in additional regional data sets?
- PM10/2.5: Can be trusted at most US/European data networks, but that is about it. In developing world data has uncertain error characteristics. If you want mass, use gravimetry….
- Isolated super sites: help on model processes and parameterizations but not validation/verification.

Direct Comparison: MODIS

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



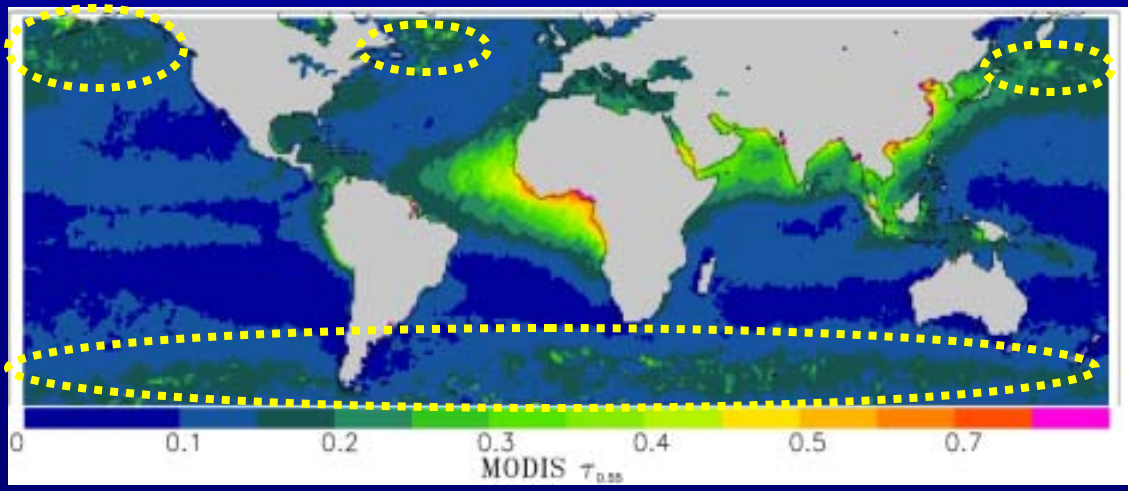


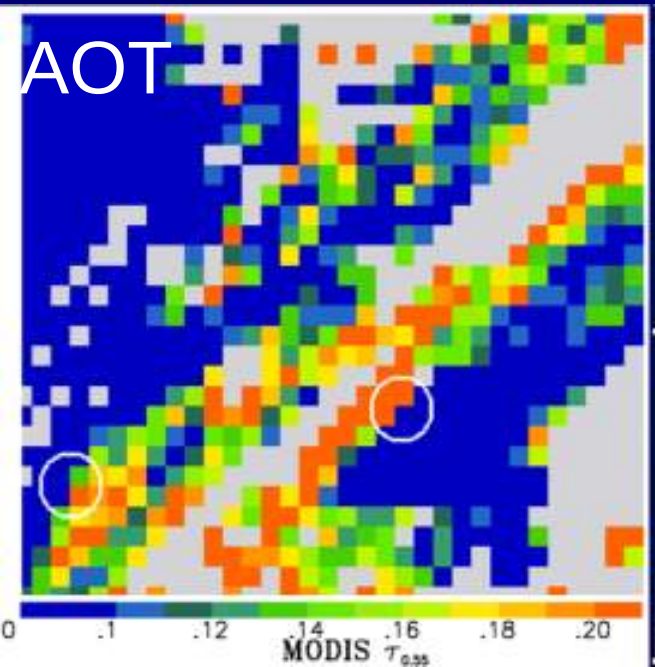


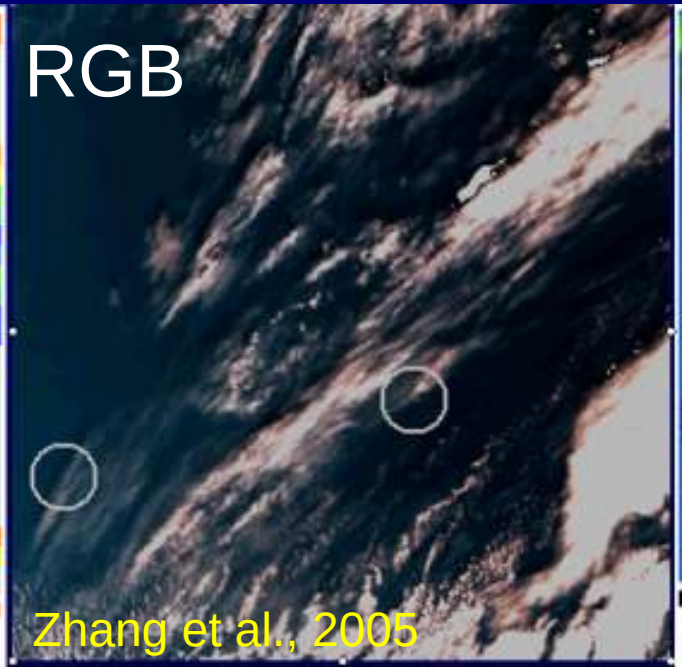
Key to data assimilation: Quality Assurance

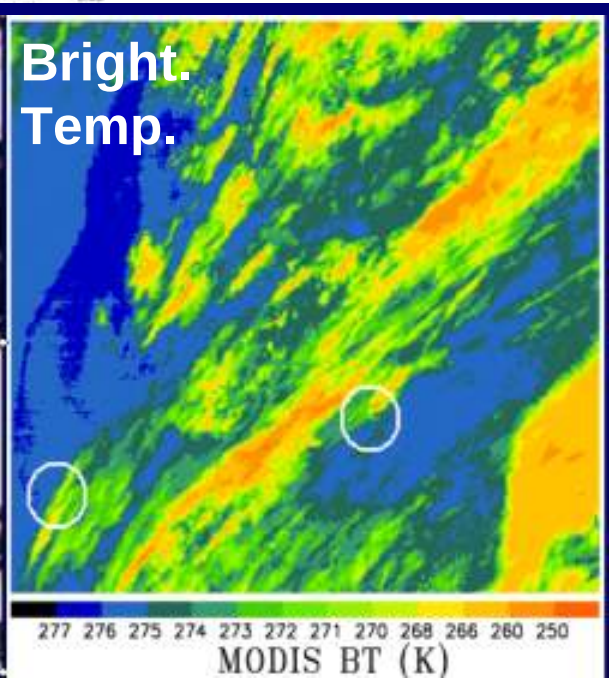
Can clear out a lot of junk through spatial tests

- 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.



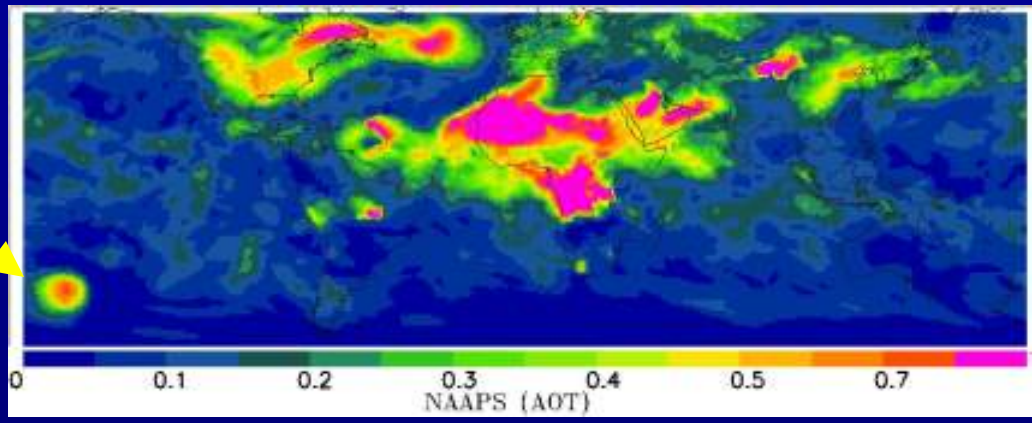


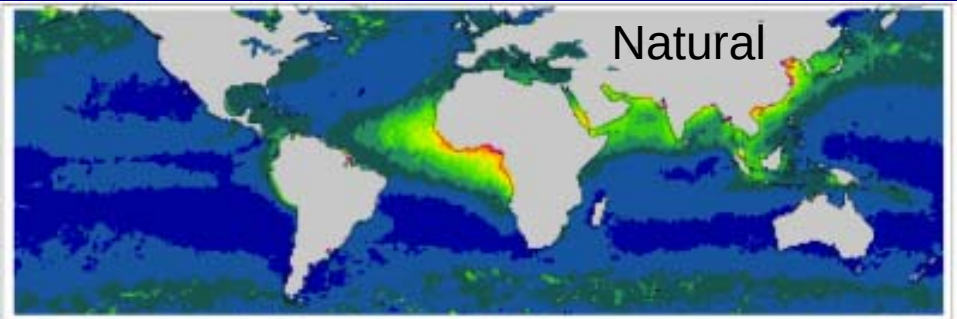


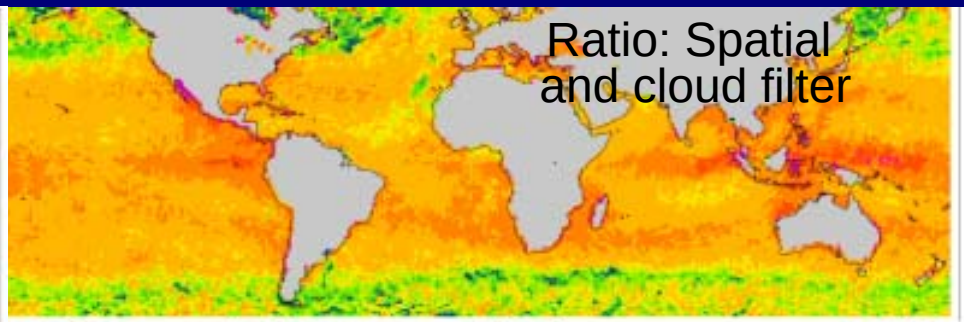


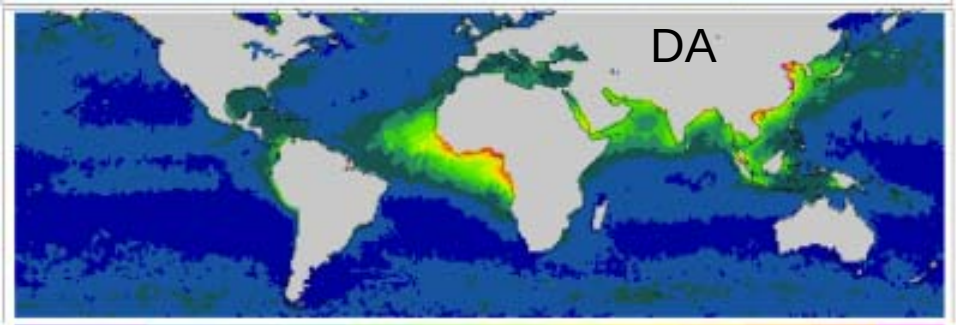
Impact of QA process

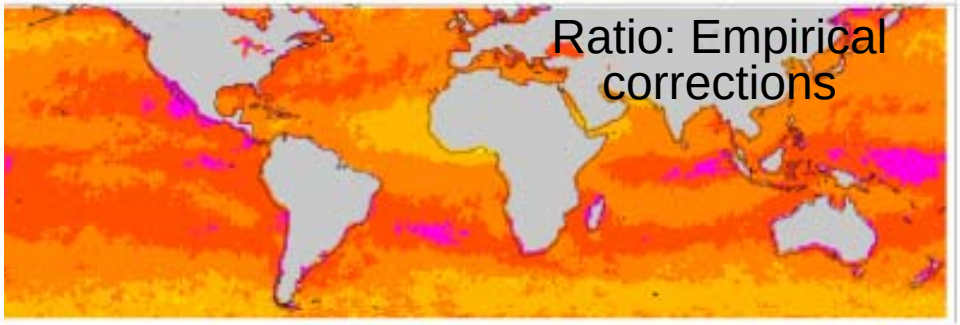
Impact of bad pixel





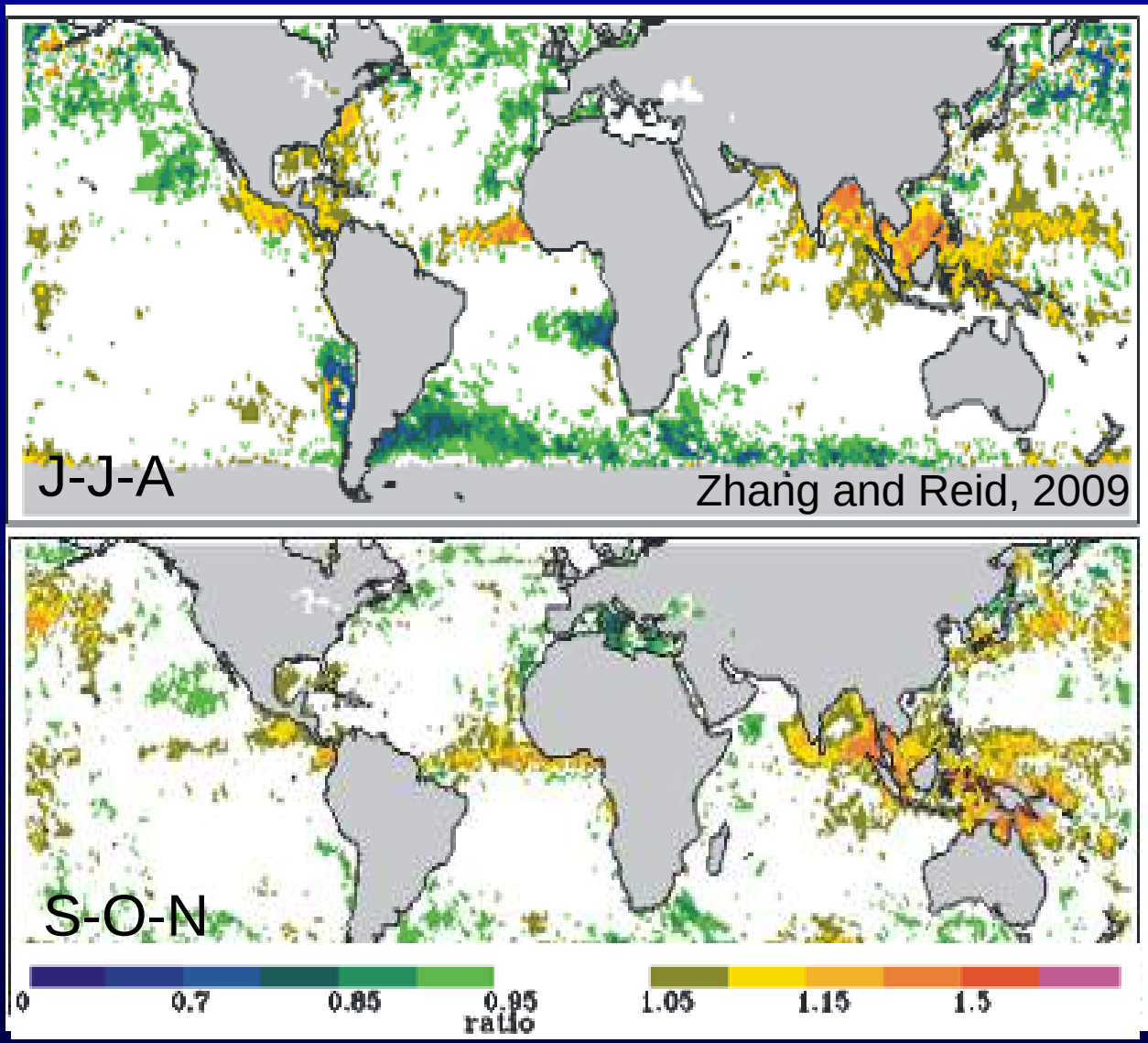






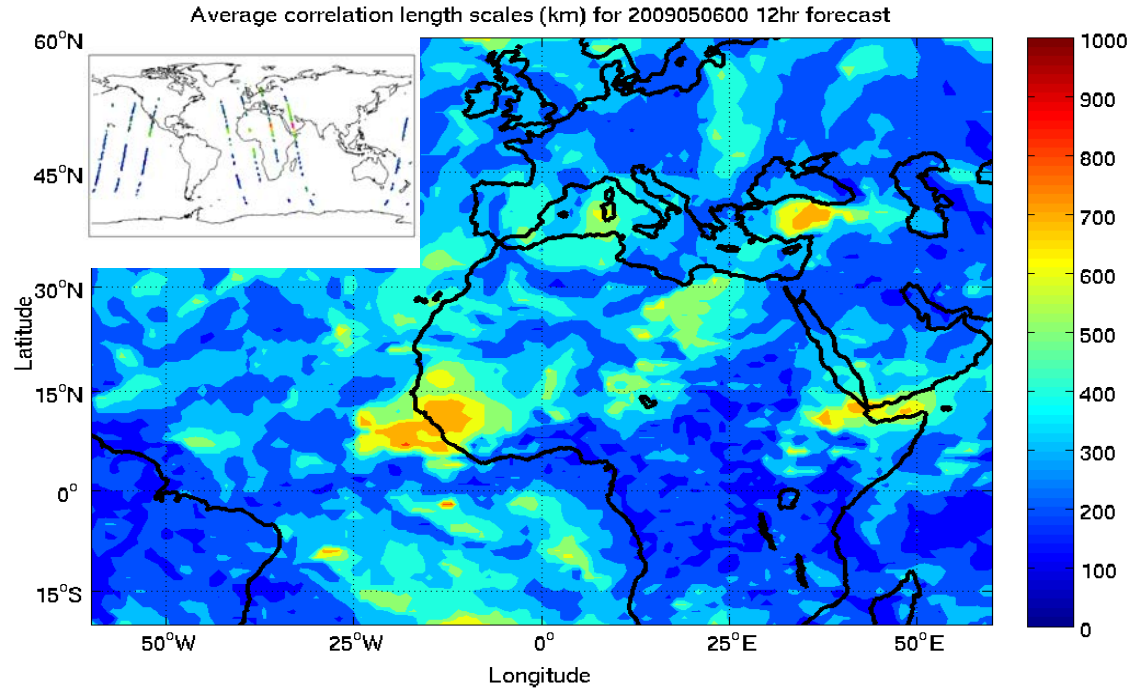
Another cost of QA:
Sampling/Contextual Biases
Clear sky, Scale/Amplitude, Species, Land Surface, Dynamical

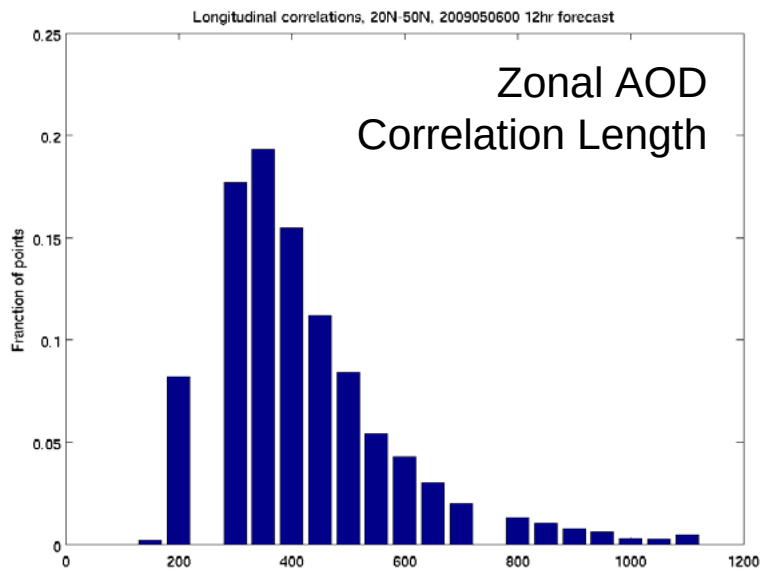
- Analyses now require a number of “qualifiers” to describe what you are really seeing-especially for model and high level process studies.
- Clear sky bias for MODIS was calculated during 2 year data assimilation run by comparing 24 hour forecasts to that next days MODIS sampling.
- As expected, positive clear sky biases in tropics, negative bias in the mid-latitude due to storm track (usually-see Pacific).
- Individual events have bigger biases.
- This is why we need data assimilation

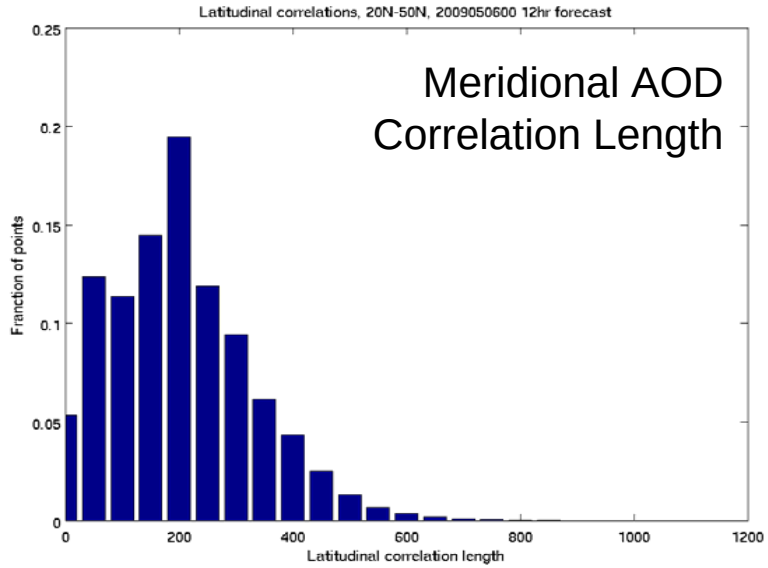


Spreading information on aerosol properties and error?

- Need ways to spread information and uncertainty from isolated observations, such as lidar and surface.
- Ensemble data assimilation/EnKF may help.
- Able to reproduce satellite method work on aerosol correlation length scales in 1 week.
- Very promising, but data intensive. We cannot do climatology runs efficiently except perhaps as consensus or multi model ensemble.







Why NOT Radiance Assimilation?

- Historically, centers go to radiance assimilation and away from product assimilation as soon as possible.
- Why? Products are at times inconsistent with model fields, resulting in low impact, 2) With radiances you can spread information more consistently, as well as cope with spatial/temporal correlated error, 3) With radiances, you can be consistent across sensors.
- Why not? 1) very data and computational intensive in the shortwave; background performance is poor and lower boundary condition not an output variable. 2) Hence, for the most part, need to go through the retrieval process anyway; 3) If so, take advantage of community product development and cal/val; Meet half way? Cleaned up radiance product at level 2 resolution and joint parameterizations?

Conclusion: What we need (I think)

- We need to work towards a consistent validation data set Even if it is for one year.
- Product developers should develop products which are tailored to model uncertainty requirements.
- We need to provide specifications on error models and agreed upon baselines.
- Retrievals: Program offices need to hold developers feet to the fire:
  - Science teams are responsible to their customers.
  - Prognostic error models need to be a deliverable for any retrieval proposal intended for public consumption.
- Model corollary: No easy way to validate the models. Need an equivalent to 500 hPa anomaly? Yes and no.
  - Test the super-ensemble hypothesis-all add skill to the ensemble?