# Recent Developments in Global Aerosol Forecasting at NRL

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November, 2013

http://www.nrlmry.navy.mil/aerosol/

# Updates

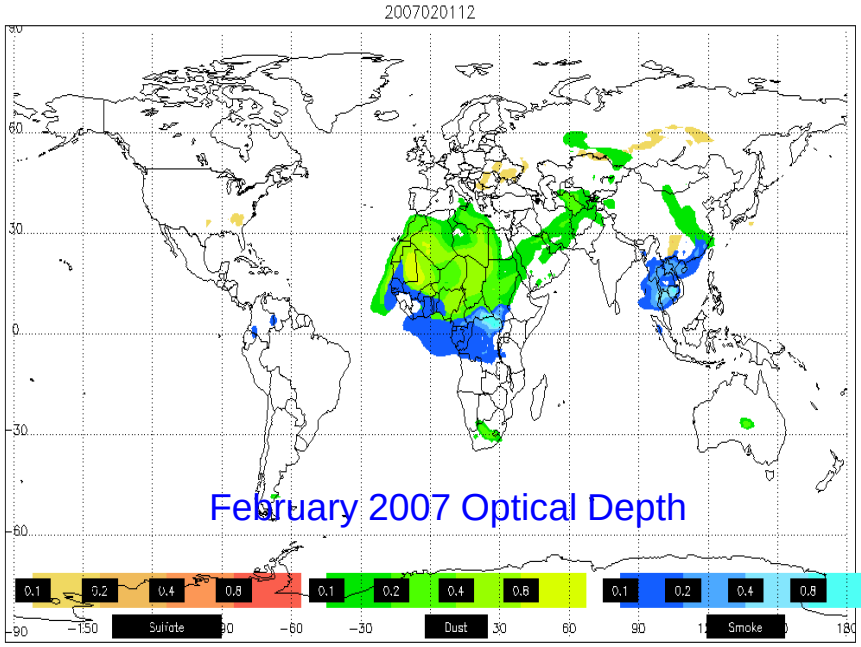
- Modeling Overview
- ICAP-MME: More at end of the meeting
- Satellite Data Assessment

# Navy Aerosol Modeling Spanning Global to Mesoscale

http://www.nrlmry.navy.mil/aerosol/

## Global Modeling: Navy Aerosol Analysis and Predication System (NAAPS)

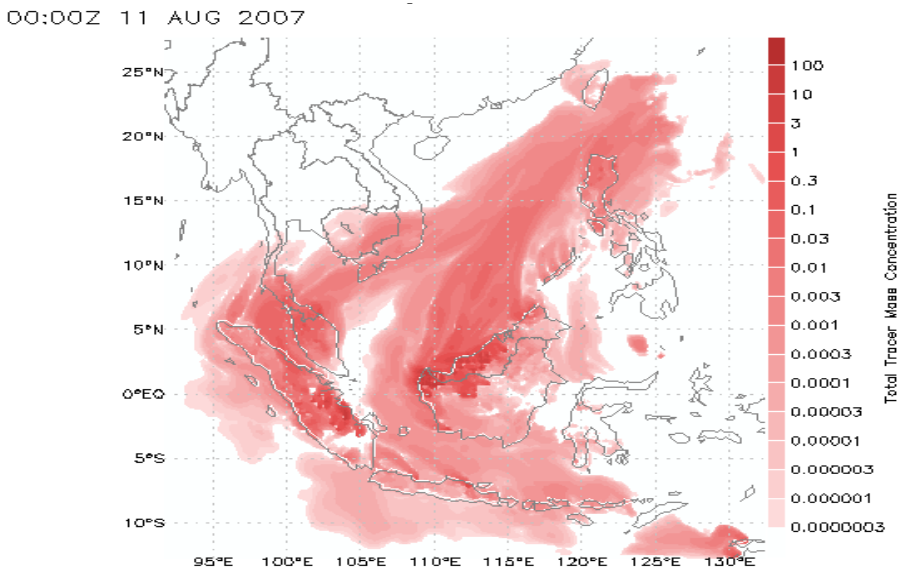
- Navy's operational global aerosol model; now at 1/3 degree resolution using NAVGEM meteorology.
- 6-day forecasts of dust, smoke, pollution, and sea salt run 4x/day
- Assimilates quasi-operational MODIS aerosol & geostationary fire data streams.




February 2007 Optical Depth

## Mesoscale Modeling: Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS®)

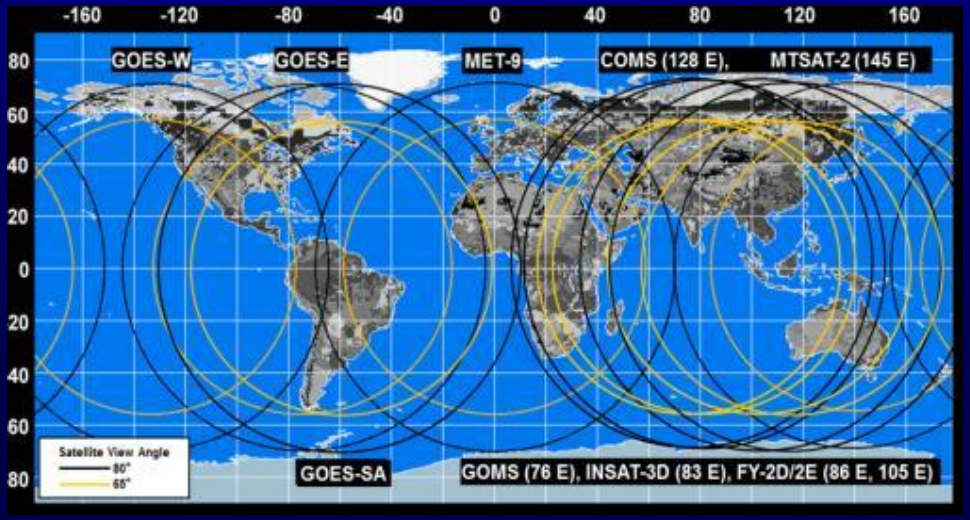
- COAMPS® is a mesoscale atmospheric model fully coupled with the ocean.
- Dust forecasts are operational at FNMOC and additional aerosol species fully coupled with the model are being added by NRL.
- COAMPS® can be used to study complicated coastal flows where aerosol particles, winds, and water vapor covary.



# Operational Satellite Data Inputs to NAAPS

- Aerosol Optical Depth
  - Worked closely w/ NASA developers to characterize and reduce errors in satellite aerosol products.
  - Retrieved AOD products corrected and aggregated before assimilation
  - Terra and Aqua MODIS used operationally
  - Research evaluating VIIRS, MISR, AVHRR products
- Aerosol vertical profiles
  - Experimental 2D/3DVAR system to assimilate CALIOP backscatter data (Zhang et al. GRL 2011)

- Satellite fire observations
  - Products based on thermal anomalies
  - Terra and Aqua MODIS, GOES-EAST, and GOES-WEST used operationally
  - Currently evaluating global geostationary observations
    - METEOSAT, MTSAT, COMS




Geostationary constellation for fire detection. Currently launched geostationary satellttes have the potential for global fire monitoring between 40S-40N latitude, but fire products are not yet available from all sensors.

# What's in a model? Pick your flavor

## NAAPS Global Model

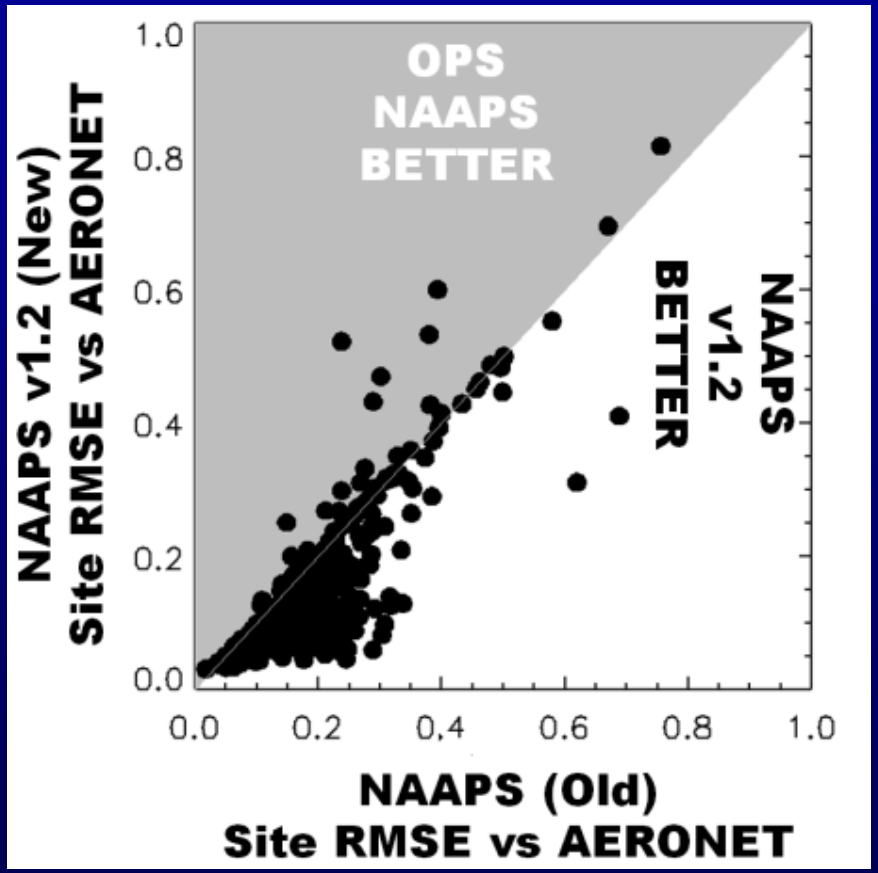
- FNMOC Operational: Now 1/3 degree running off of NAVGEM.
- eNAAPS: Quasi-operational still at 1 degree and on 20 member NOGAP ensemble.
- 10 Year Reanalysis: Our best available 1 degree model with everything but the kitchen sink data assimilation. 2003-2012. Now with SOA!
- Impact studies: Multiple configurations running at any one time.

## COAMPS Mesoscale Model

- Inline COAMPS dust components operational at FNMOC since 2001
- Current development is to port all NAAPS species into COAMPS.
- COAMPS will have ‘infinite scalars’ capability to allow flexible microphysics
- Any aerosol characteristic can be advected.
- Has ensemble versions of dust components ported to DART

# Components of NAAPS and recent operational upgrade to 1/3 degree in NAVGEM

- NAAPS: Recent transition to NAVGEM
  - Upgraded from 1° to 1/3 ° resolution to run using NAVGEM. Errors down by 30%
  - Same species: Dust, smoke, sea salt, sulfate
  - Semi-Lagrangian transport scheme modified so each species can have its own complete microphysics
- NAVDAS-AOD: AOD assimilation for NAAPS
  - 2d Var scheme upgraded to use NAVGEM
  - MODIS AOD pre-processor upgraded to assimilate higher resolution obs
- FLAMBE: Smoke source model for NAAPS
  - Latency improved from 12-36 hours after overpass to 3-6 hours
  - Separate processing for each sensor




Model evaluation vs. AERONET in situ AOD data. The new NAAPS is clearly more accurate with a lower RMSE in 280 of 341 (82%) of the sites with 100+ AERONET AOD observations, and 141 of 154 (92%) sites where mean NAAPS AOD differed by 0.1 or more between the two systems.

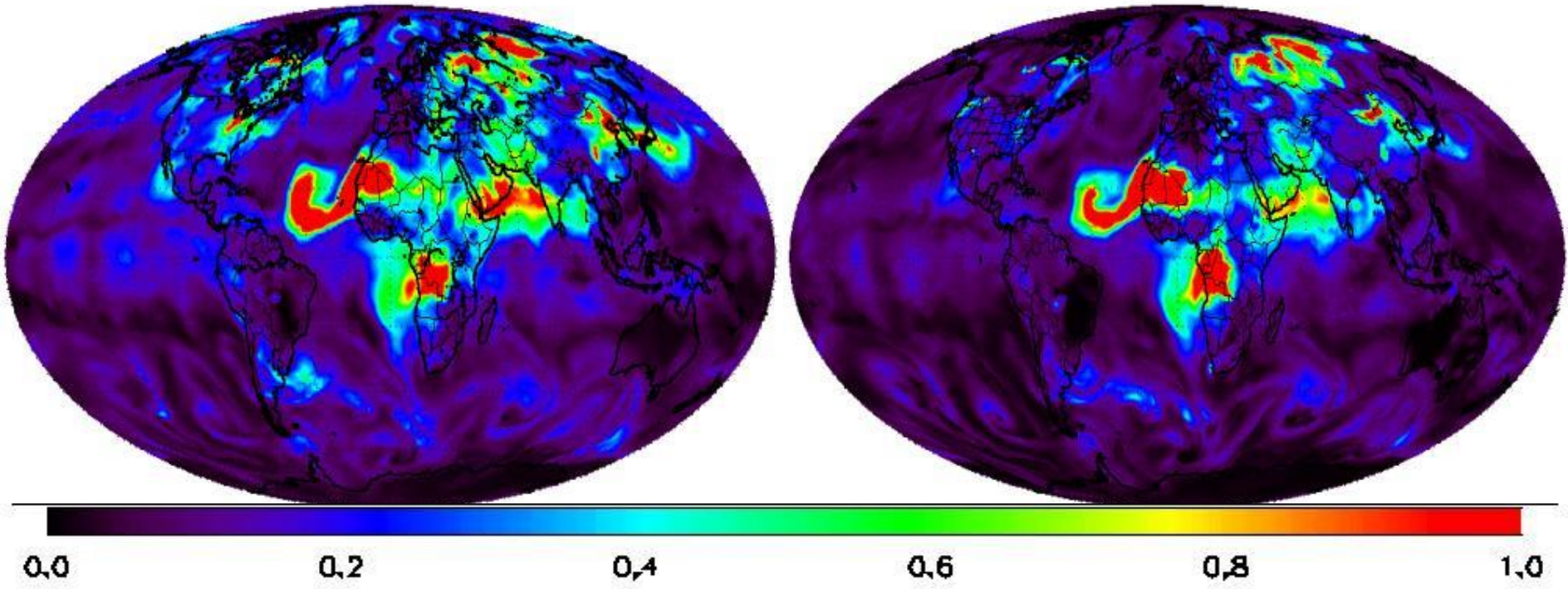
# OPS NAAPS vs NAAPS v1.2 Differences

**OPS NAAPS AOT**

**2013.08.01.00**

**NAAPS v1.2 AOT**

**2013.08.01.00**



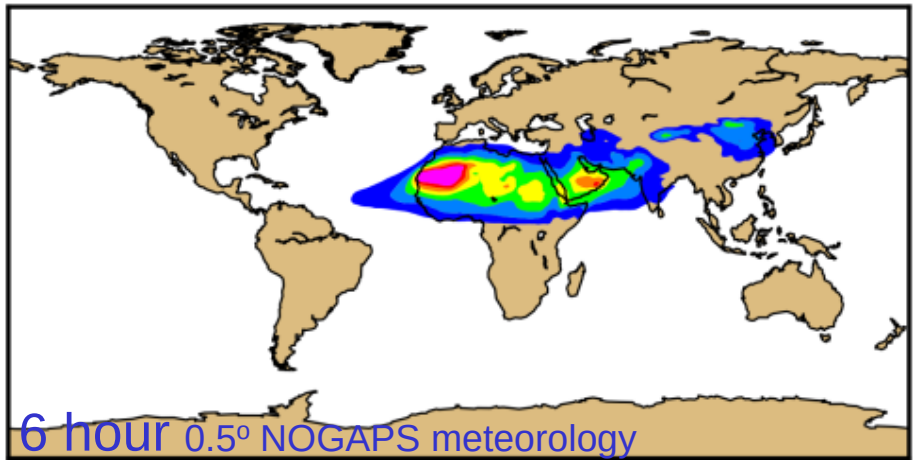

**550 nm Aerosol Optical Thickness**

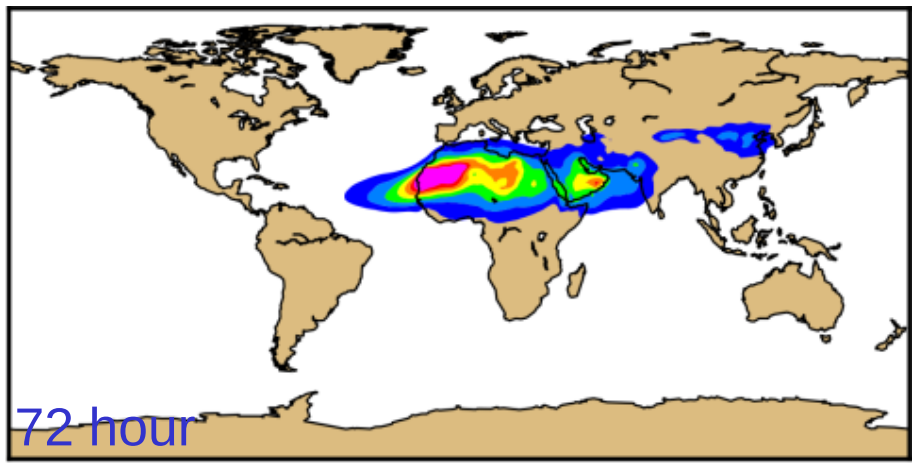
NAAPS v1.2 AODs show extensive additional detail
(Bay of Bengal, South American outflow, tropical Atlantic)

# eNAAPS: The impact of meteorology on overall dust loading.

Analysis versus forecast have minor climatological differences-but varies by study period.

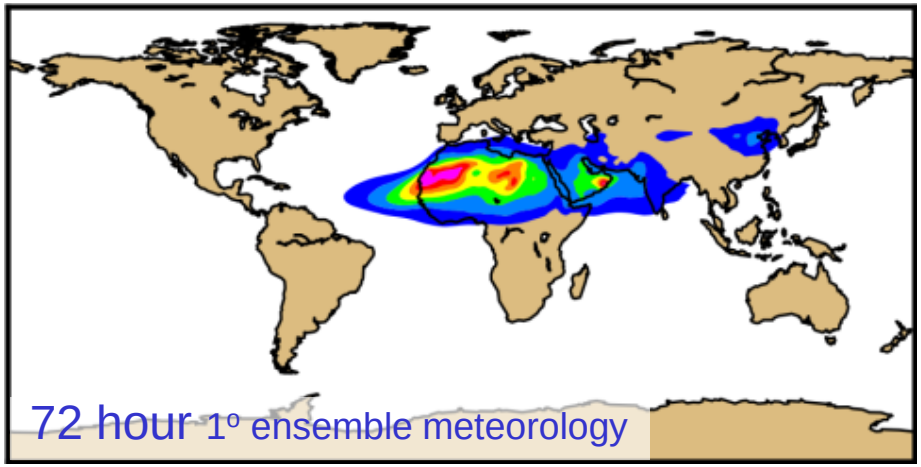
Deterministic Dust Forecast April-Sept 2011 Mean



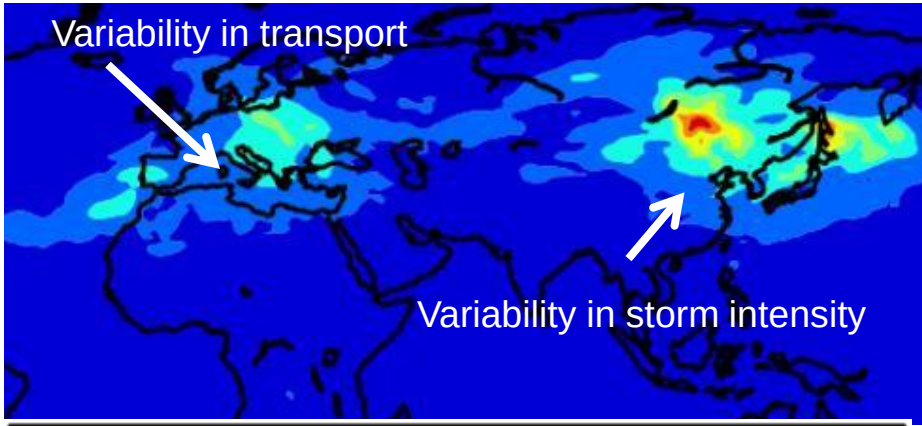



Aerosol Optical Thickness (550 nm)

Ensemble AOT Forecast AOT April-Sept 2011 Mean



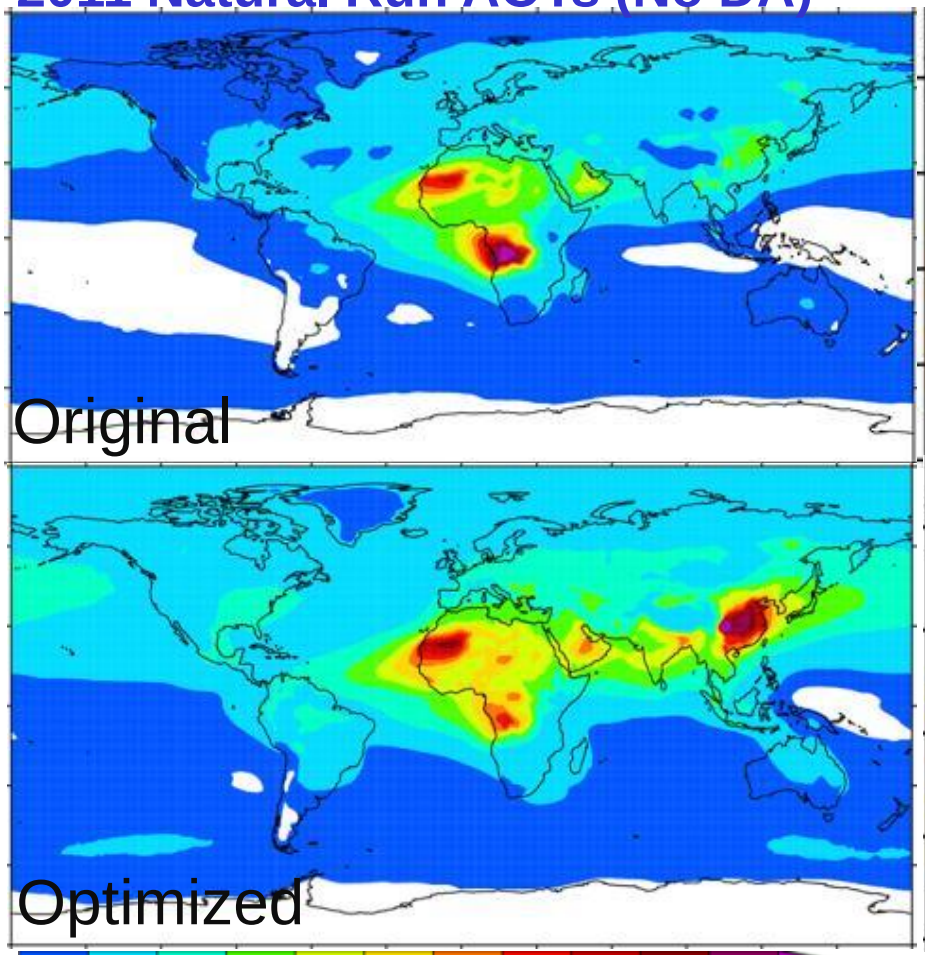

72 hr Dust Standard Deviation/Mean



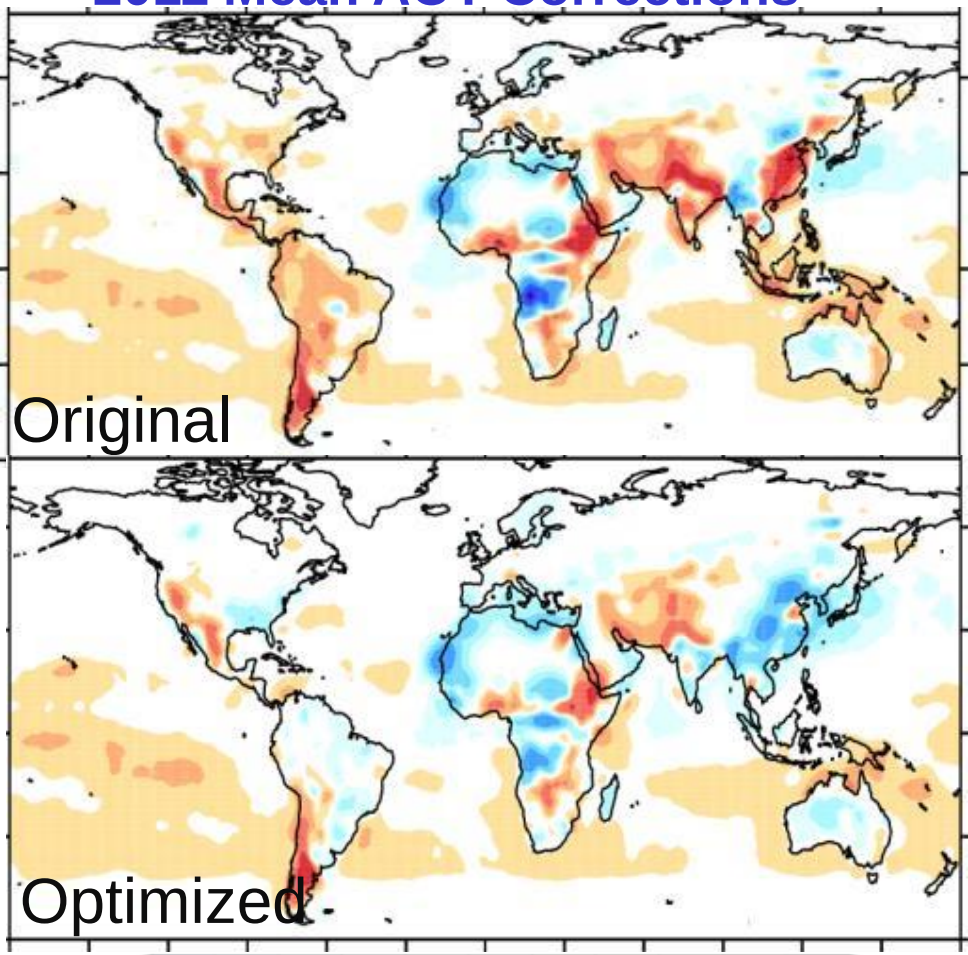
AOT Fractional Standard Deviation (550 nm)

# Recent Improvements to NAAPS sources and microphysics from an ensemble of deterministic runs: Ready for transition.

## 2011 Natural Run AOTs (No DA)




## 2011 Mean AOT Corrections



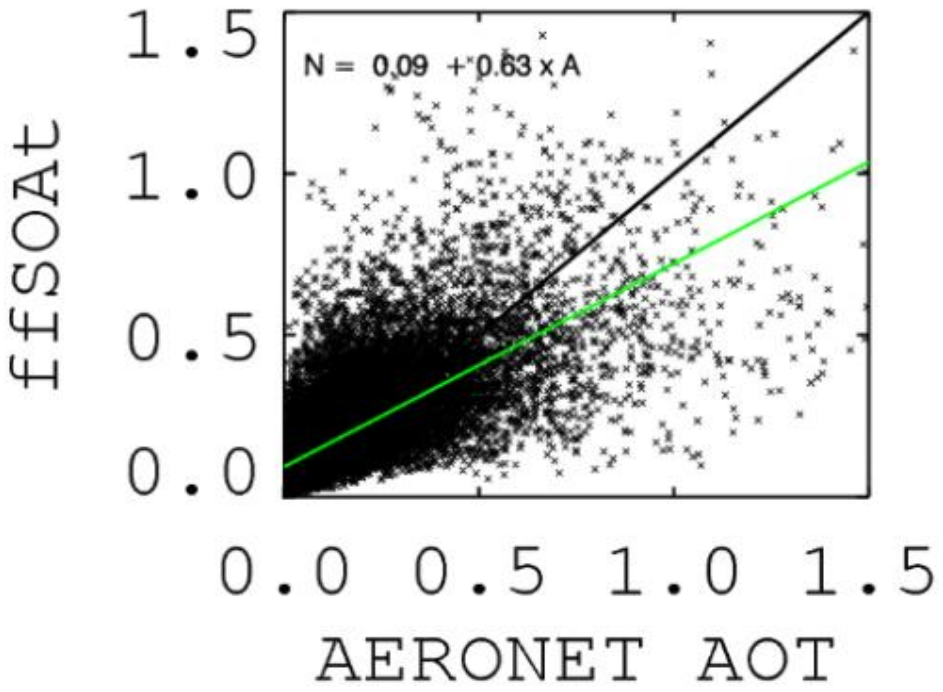
# SOA in Reanalysis Slated for Transition: Approach

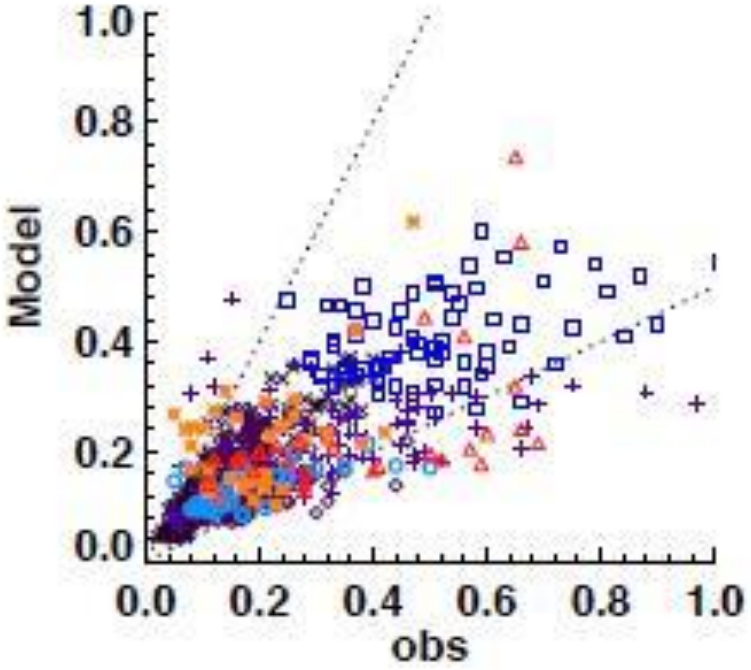
- Put VOC (MACC) / Primary Organic Aerosol (Bond) emissions inventories in model
- Updated S emissions inventory
- Carry the SOA, POA, etc in the model in the SO4 field (i.e., “SO4” = POA+SO4 + etc.)
- Deal with SOA as an effective yield X VOC (i.e., effective instantaneous oxidation) using VBS 4 approach with 4 VOC “classes”: aromatics, monoterpenes, alkenes, and isoprene
- Note that all of this is PRE-PROCESSING

# Comparison of model performance with a much more elaborate (chemistry) model

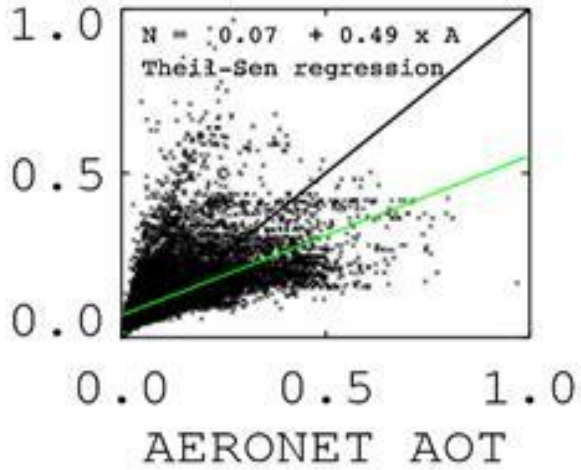
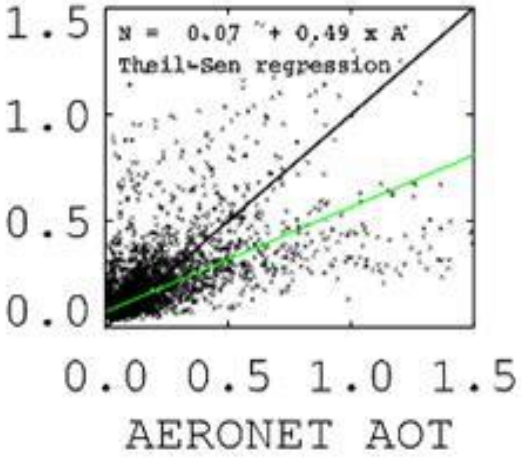
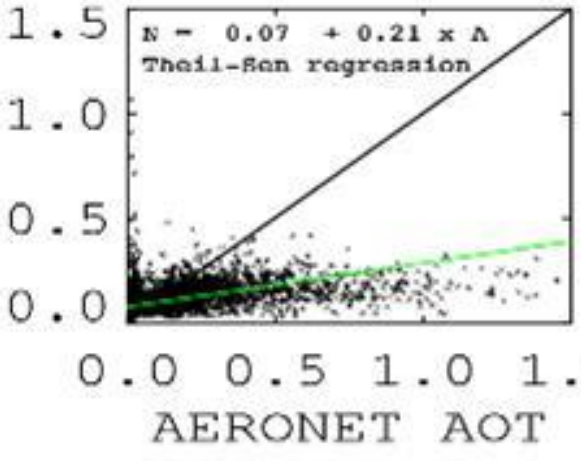
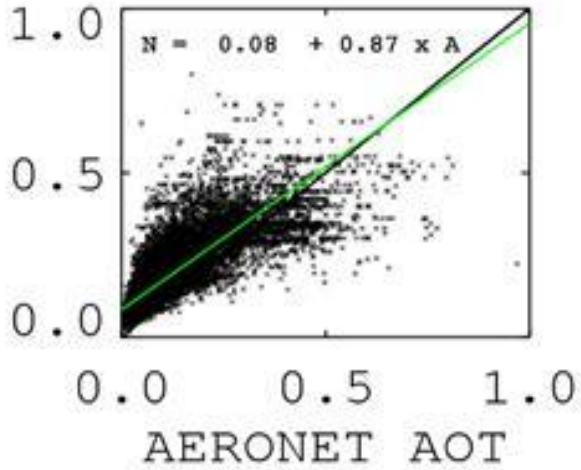
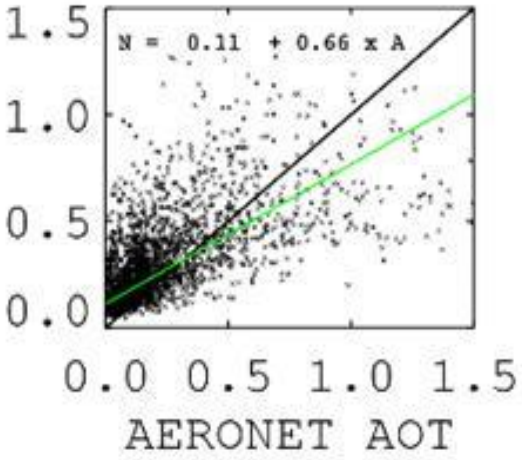
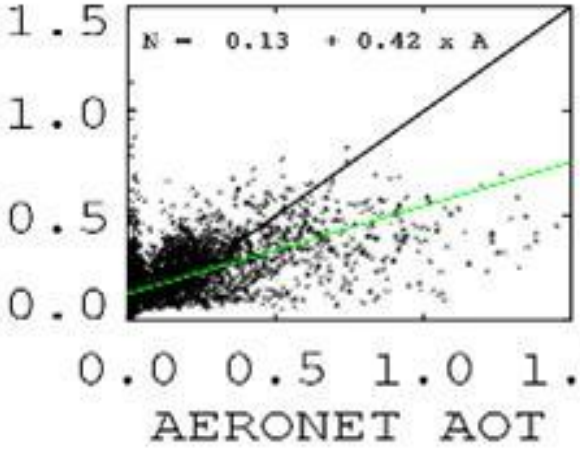
- NAAPS: $R^2$=0.52,
- bias = 0.051, slope=0.63

- PNNL-MMF: $R^2$=0.55,
- bias= -0.13, slope ~ 0.66



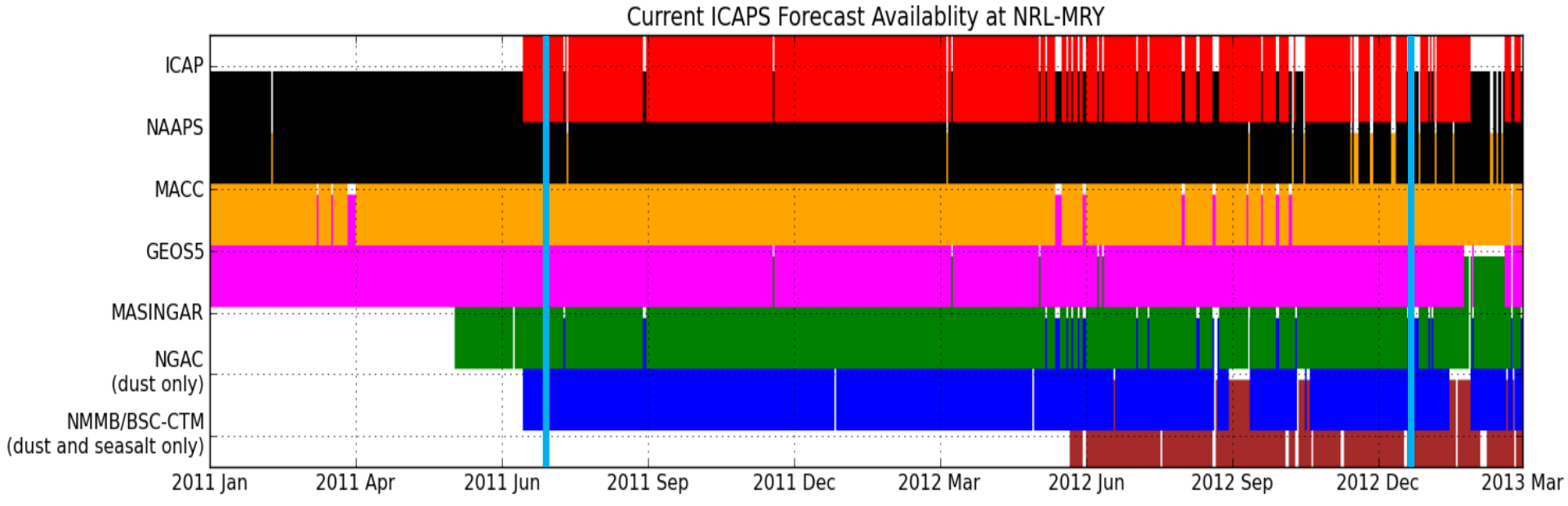
# SOA Regional Impacts

| | E CONUS<br>$R^2$ 0.3->0.6 | East Asia<br>$R^2$ 0.29->0.42 | Indian Subcont<br>$R^2$ 0.14->0.428 |
|---|---|---|---|
| Control<br>nso2x3 |  |  |  |
| Hegg Routine<br>ffSOAt |  |  |  |

# ICAP- Multi Model Ensemble

# The Unglamorous Engineering Side: Gathering all of the world's forecast data

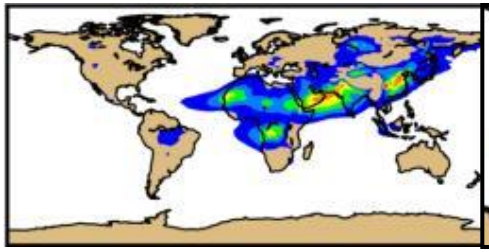
- ICAP-MME warehousing all the world's global aerosol forecast data to feed the ICAP multi-model ensemble. Hope UKMO will be coming soon.
- While July 2011-Dec 2012 is our focus, we are still collecting data.
- Thanks to Hogan and McLay we have a much more contiguous NOGAPS ensemble.
- NASA also has rerun for the MME



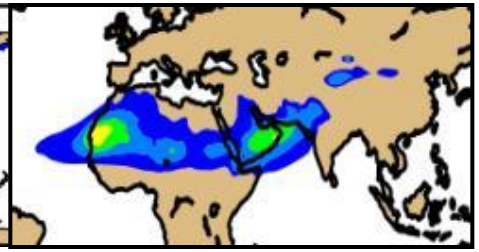
# ICAP Multi-model ensemble: How do models compare on average?

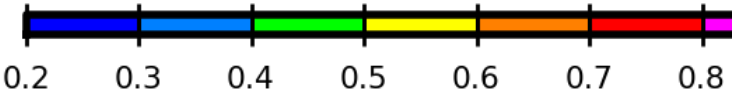
## ICAP MMD Jun-Dec 2012 6 hr Statistics

Total AOT

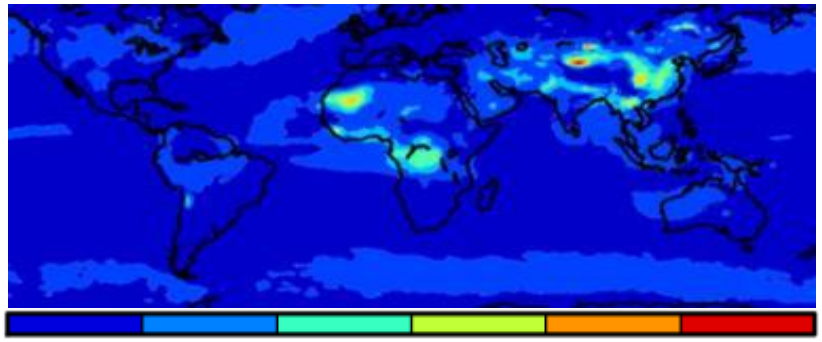


Dust AOT





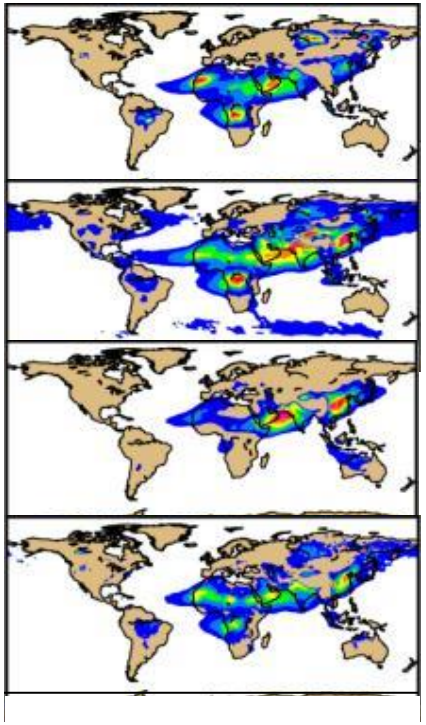

Aerosol Optical Thickness (550 nm)



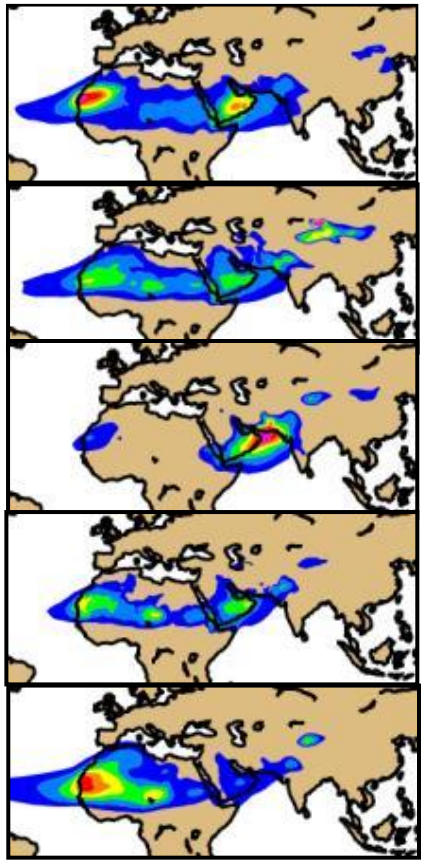

Average AOT Standard Deviation (550 nm)

## Individual Models

Total AOT



Dust AOT

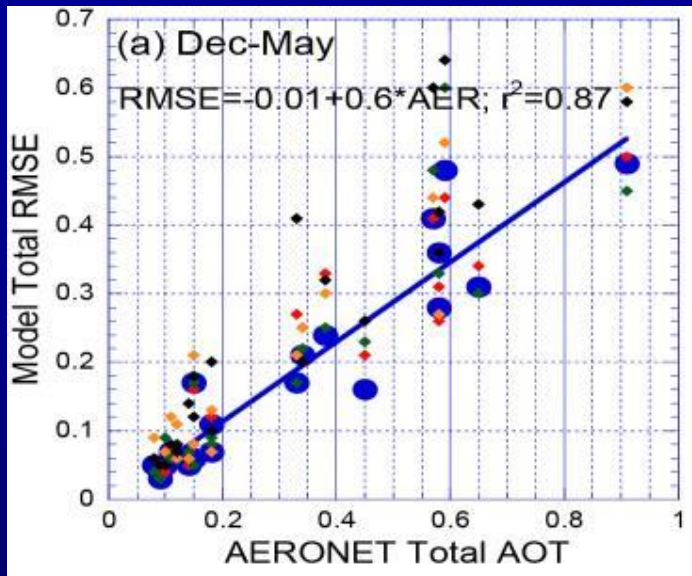


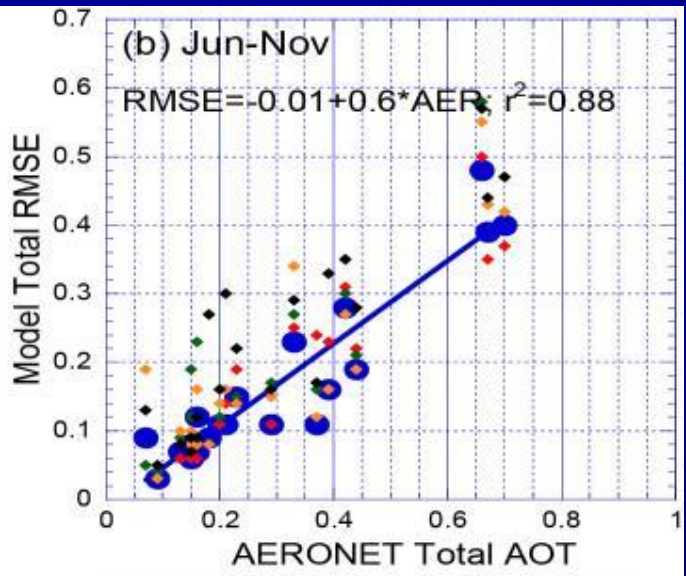
- Often large differences between individual events.
- Most models underestimate dust/smoke and overestimate sea salt AOT.
- Large differences between species in heterogeneous environments.
- Tendencies to tune the climatological averages and the MME mean.

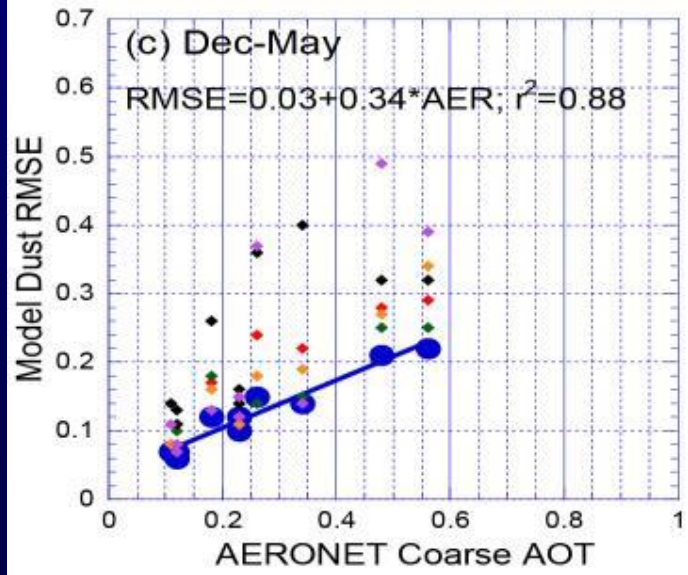
# Well, So what about the ensemble? For RMSE, FGE, etc, ICAP-MME is top performer

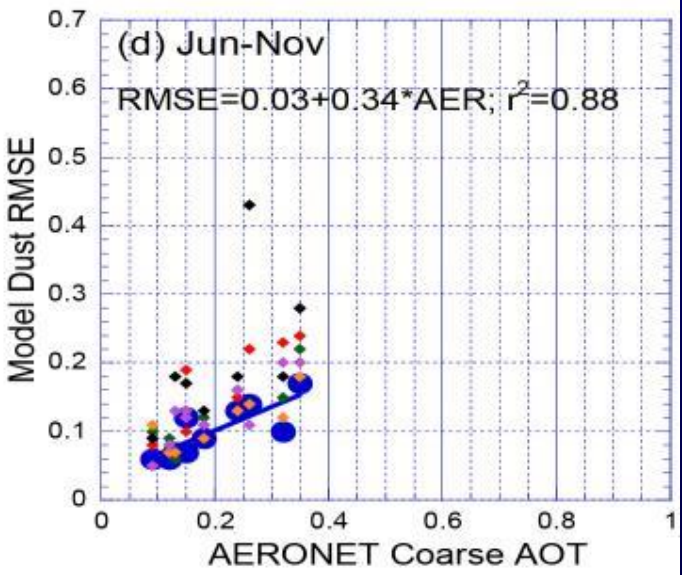
96 hour forecast
21 agreed on AERONET Sites

Each group is tops in something

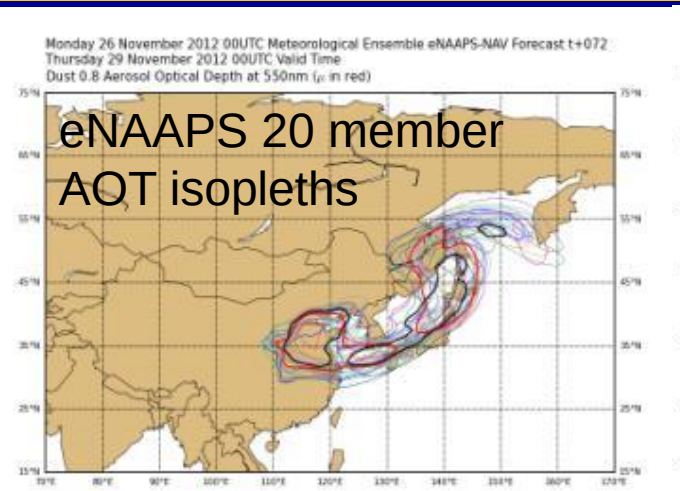


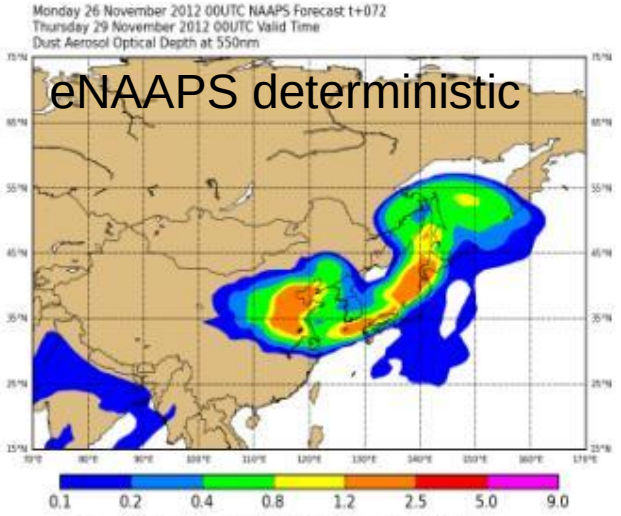



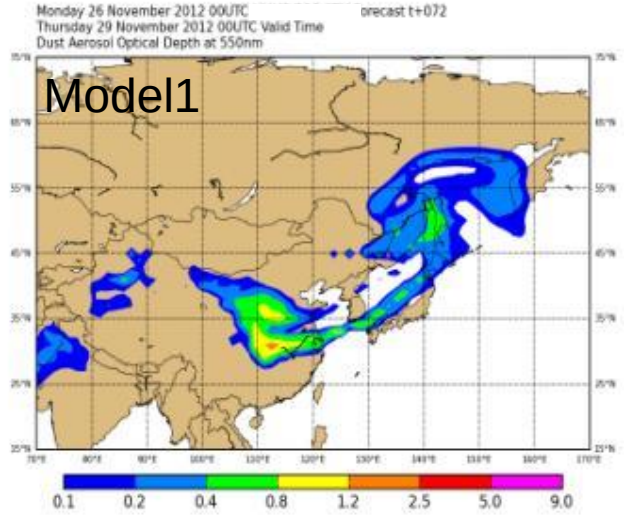



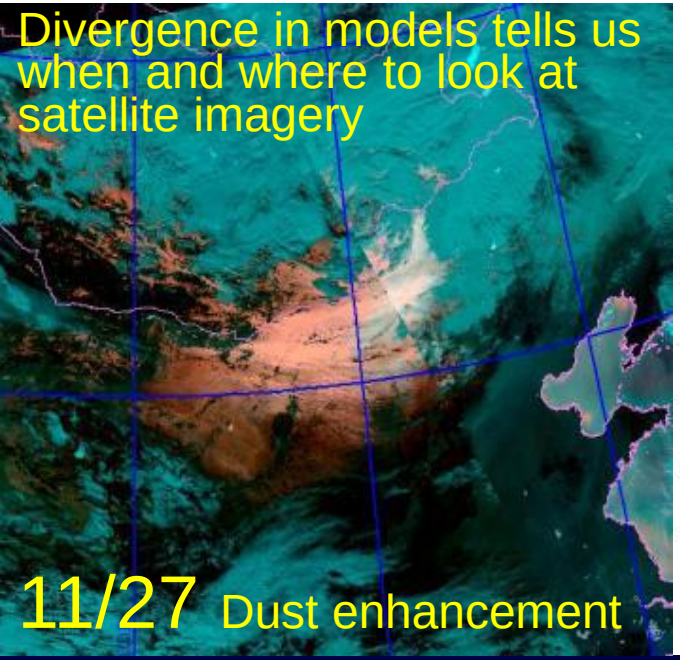



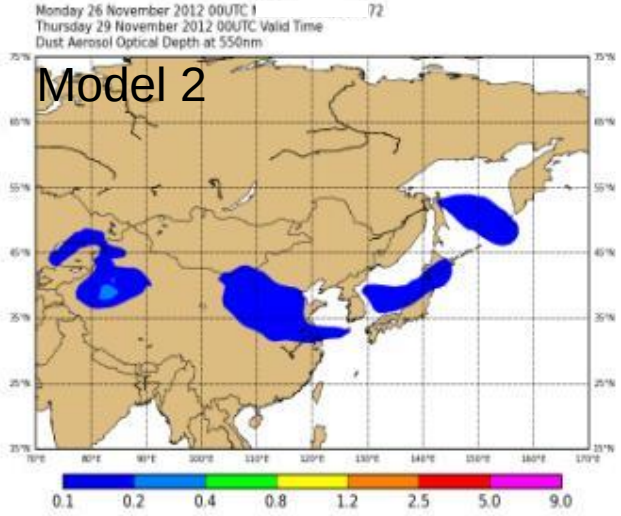
# Forecast Example: November 29 2012 Dust AOT: 72 hour forecast of eNAAPS and MME.

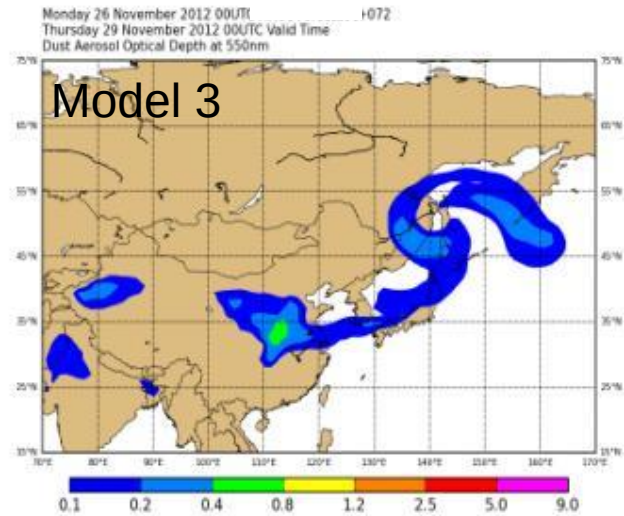


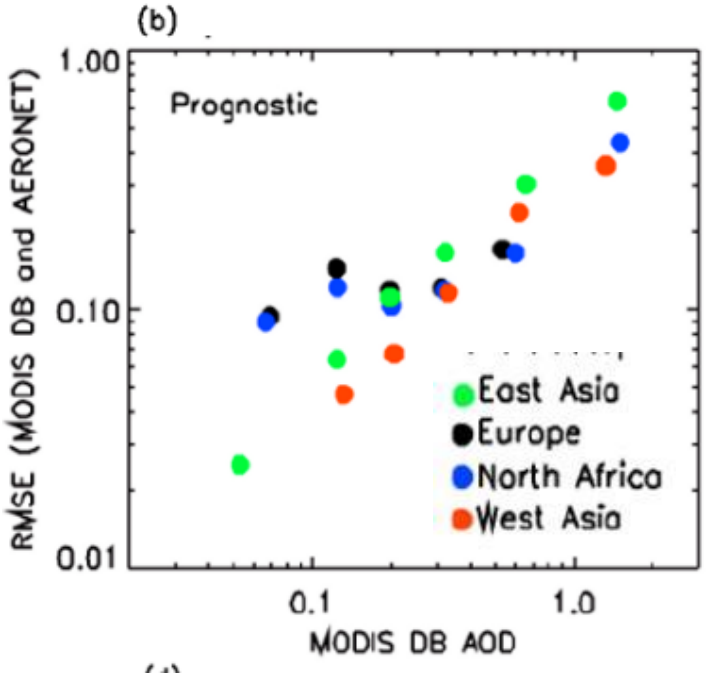



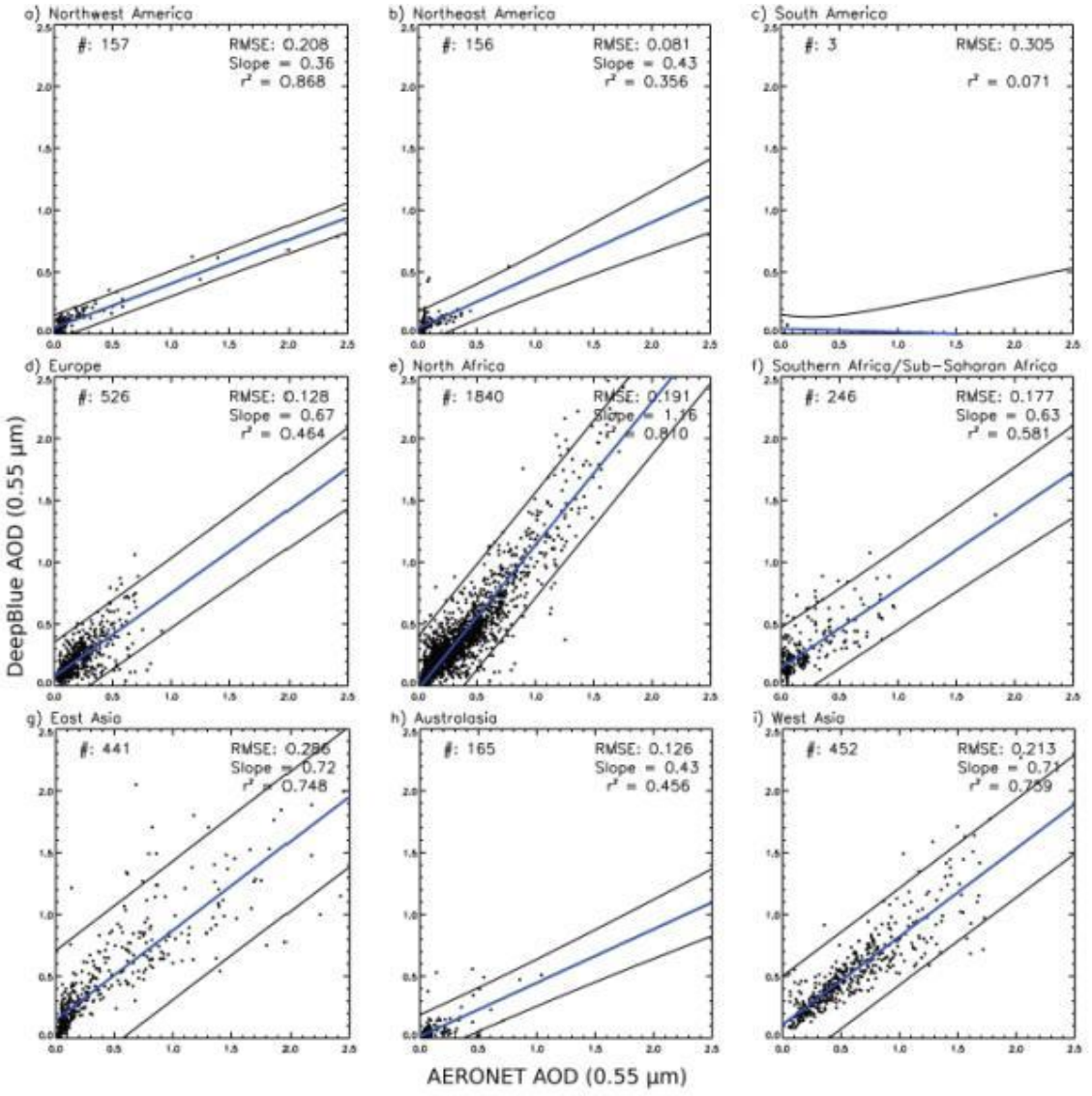
# Satellite Data Evaluation

(what we spend most of our time on)

# Independent validation of Deep Blue 5.1 Shi et al., 2013

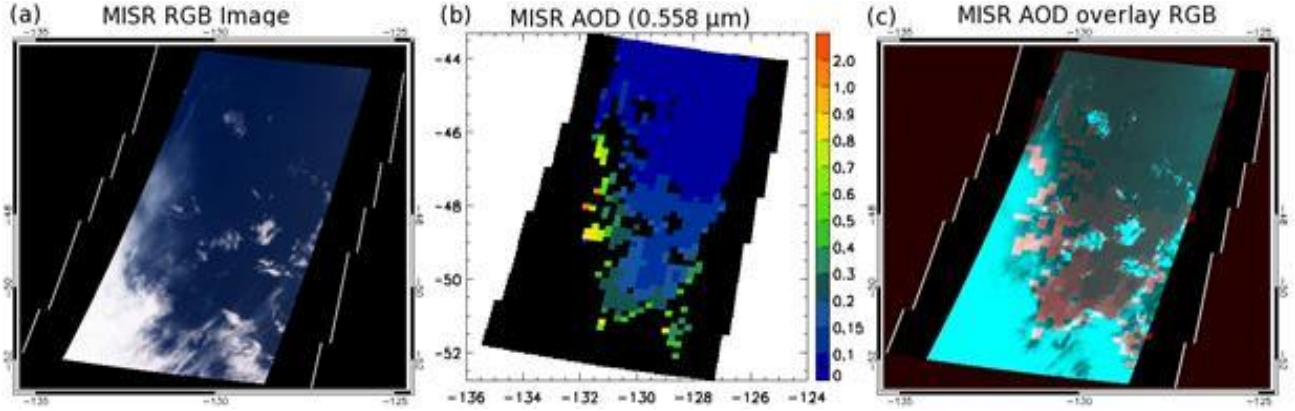
- Bottom line: Good correlations but strong regional biases.
- Be careful about data quality flags!

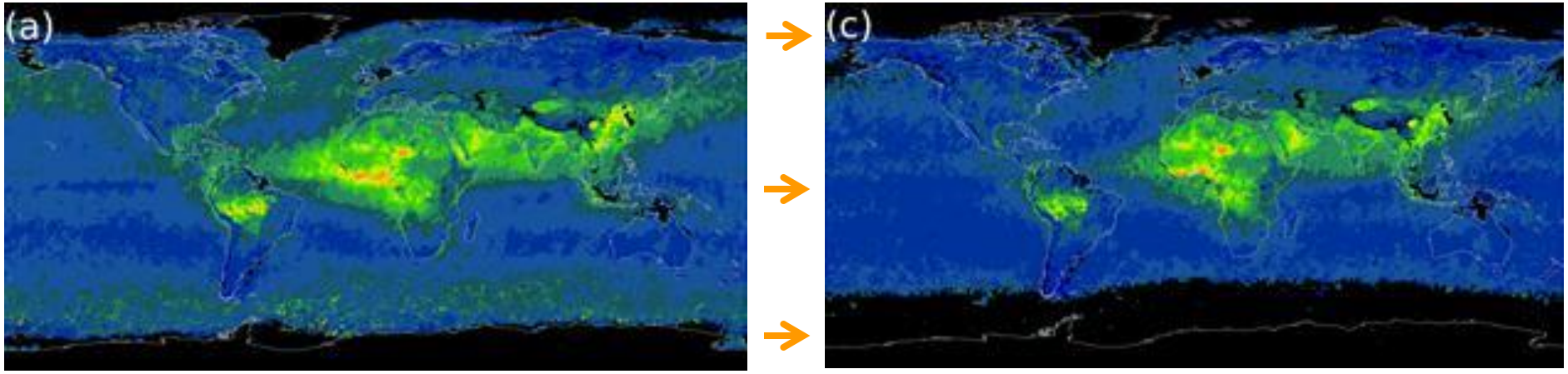


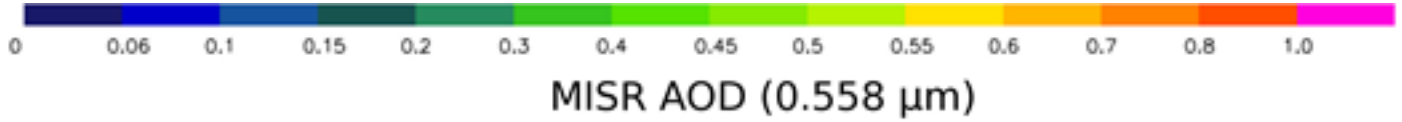



# MISR Cloud Clearing-Needed to fuse MODIS+MISR (Shi et al., 2013-submitted)

Cloud issues
Solution:
Use MODIS cloud mask on MISR as an additional filter

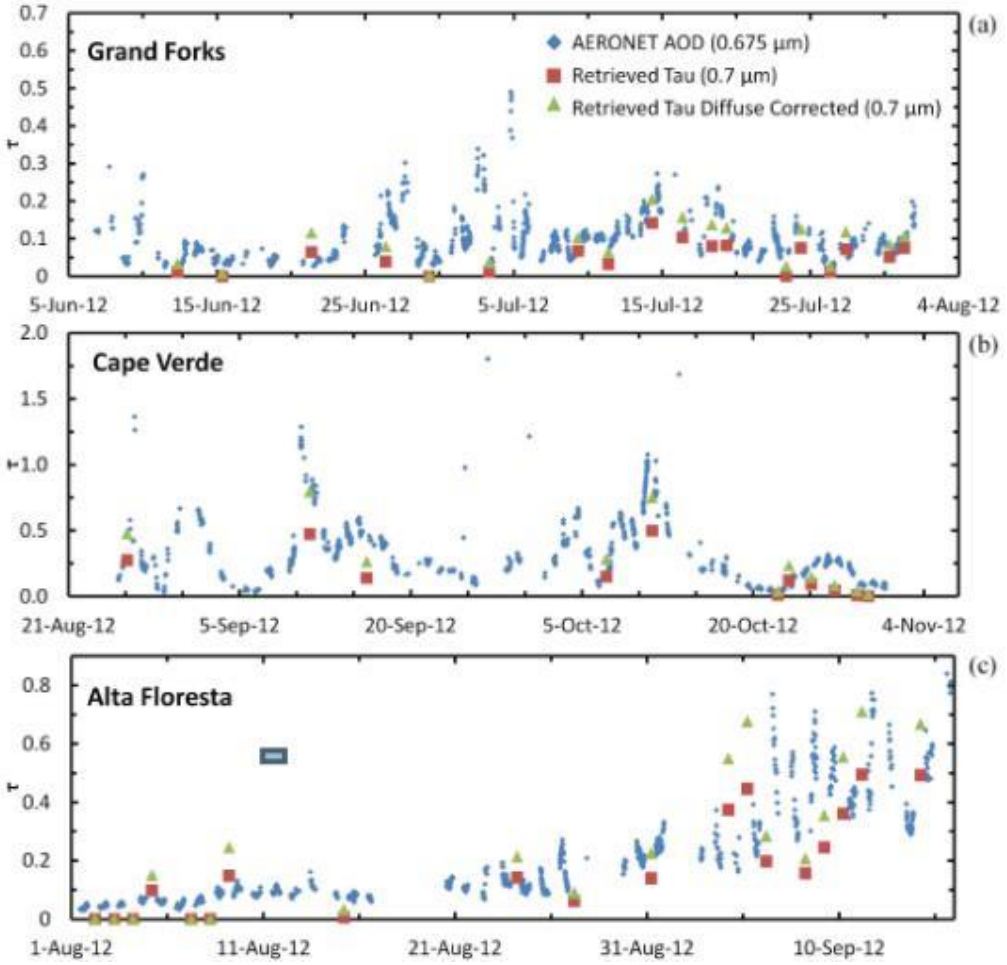


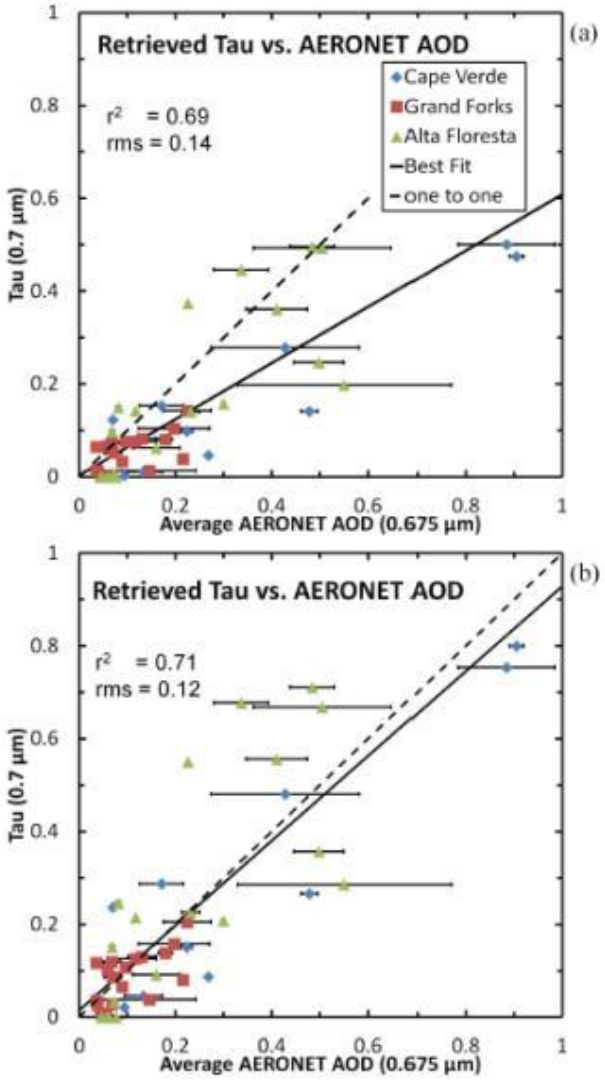



# VIIRS Nighttime AOT
## (Johnson et al., 2013)

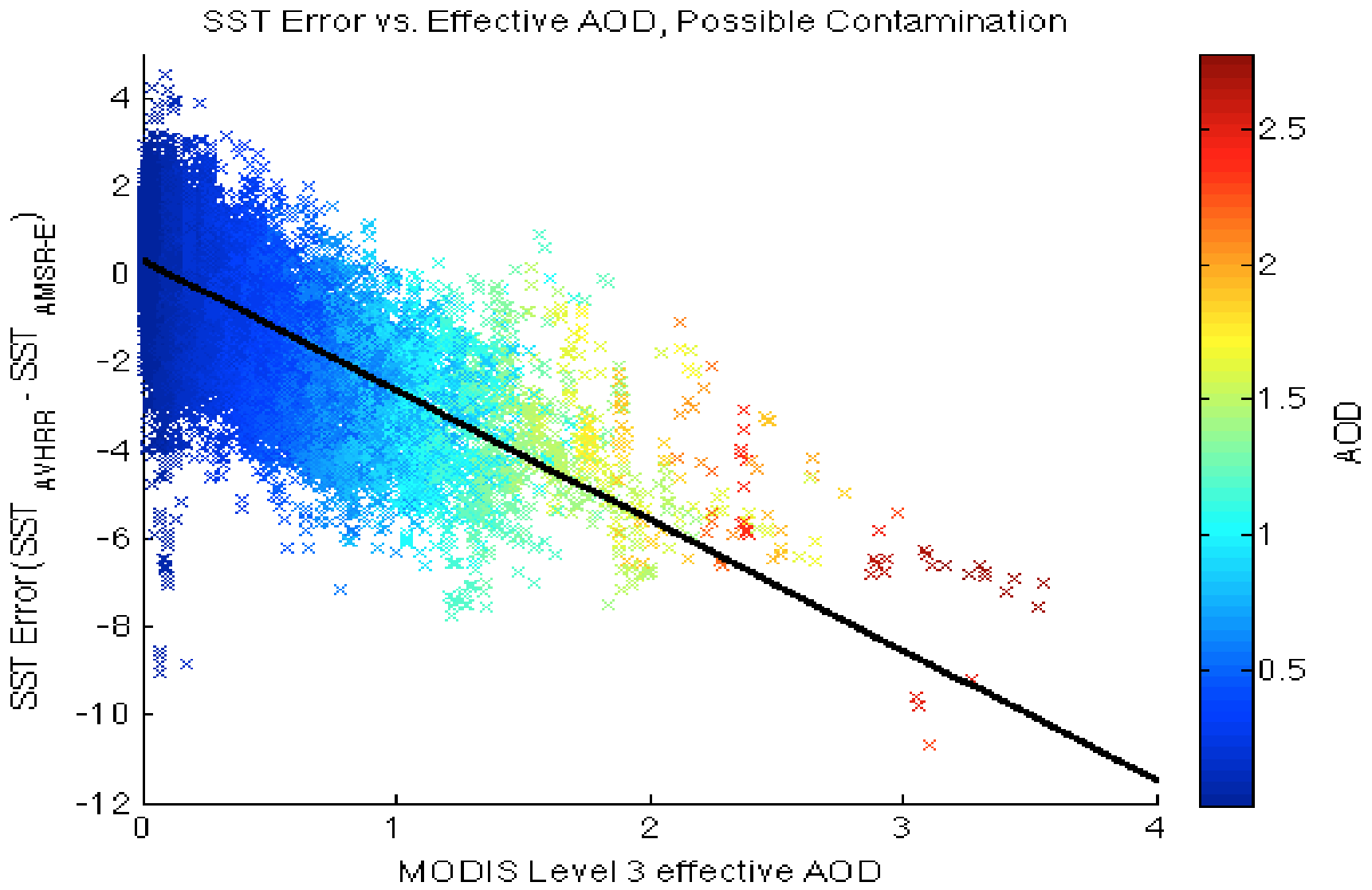
Use city light brightness to estimate AOT



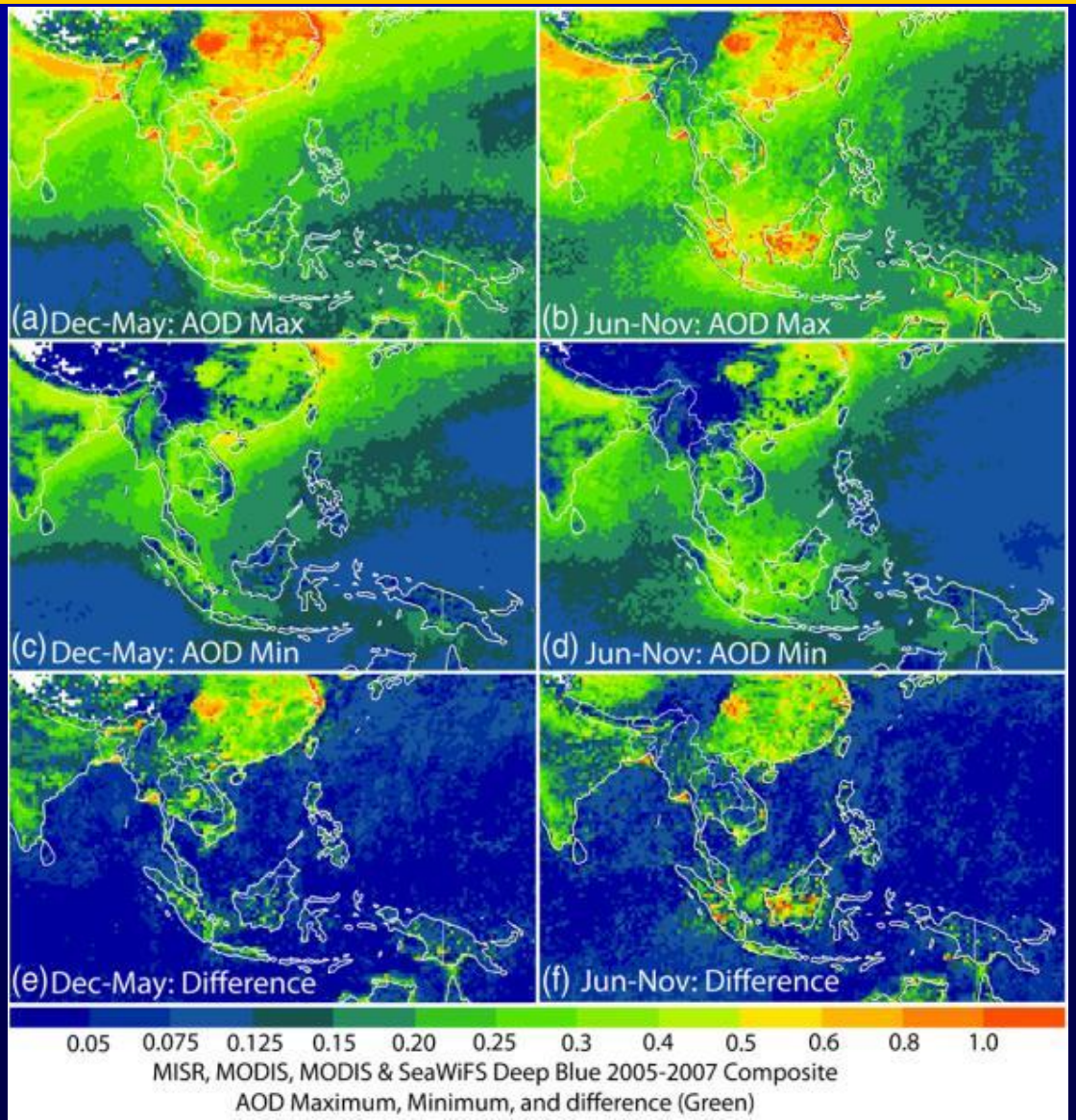
# SST Impacts

(Bogdanoff, submitted)



# Potting it all together: Can we really monitor a region by AOT. Sometimes… (Reid et al., 2013)

- Satellite data quality? Depends on what you want to do with it.
- Good news is that this community is shinning a light on data quantification.
- Every product has its place, but whole trust is not warranted at this time.
- GEWEX aerosol report will reflect our concerns.
- Looking forward to Col 6.



# Conclusion
# Our plans for the year ahead

- Implemented 0.33 degree NAAPS operationally at FNMOC 25Sept 2013. Next, push SOA to ops.
- COAMPS aerosol to mimic NAAPS
- Start FLAMBE2 quasi-operationally.
- No rush on VIIRS DA product
- More modeling focus on COAMPS, particularly with the SEAC4RS field work.
- Preparation for CATS lidar data.
- Advancing development of EnKF aerosol DA to run quasi-operationally.
- UND: Forward models for radiance assimilation.
- Playing with the ICAP multi-model ensemble!