Preparations for robust model evaluation using integrated aerosol observations

Charles Ichoku and Maksym Petrenko

NASA Goddard Space Flight Center, Greenbelt, MD, USA

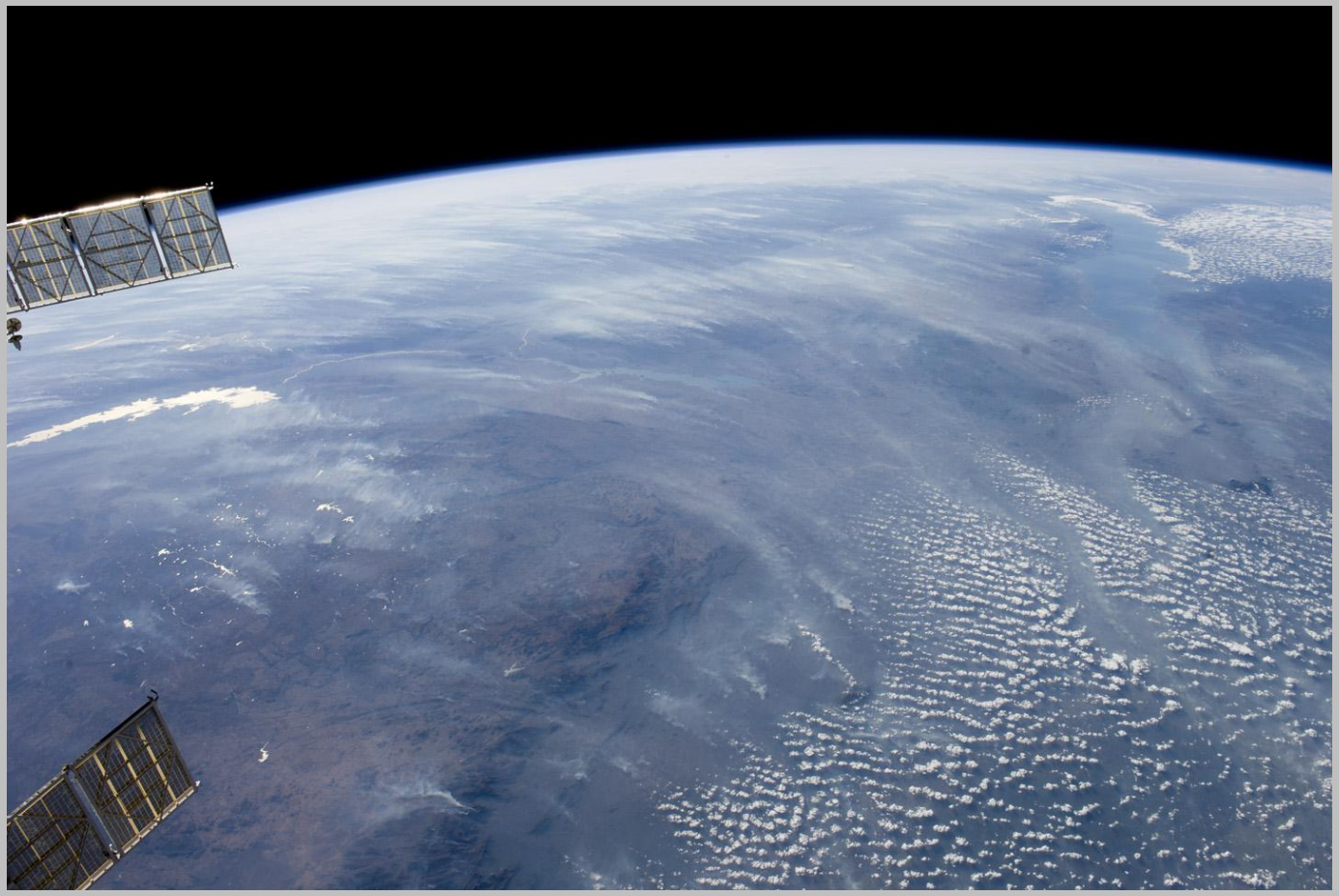
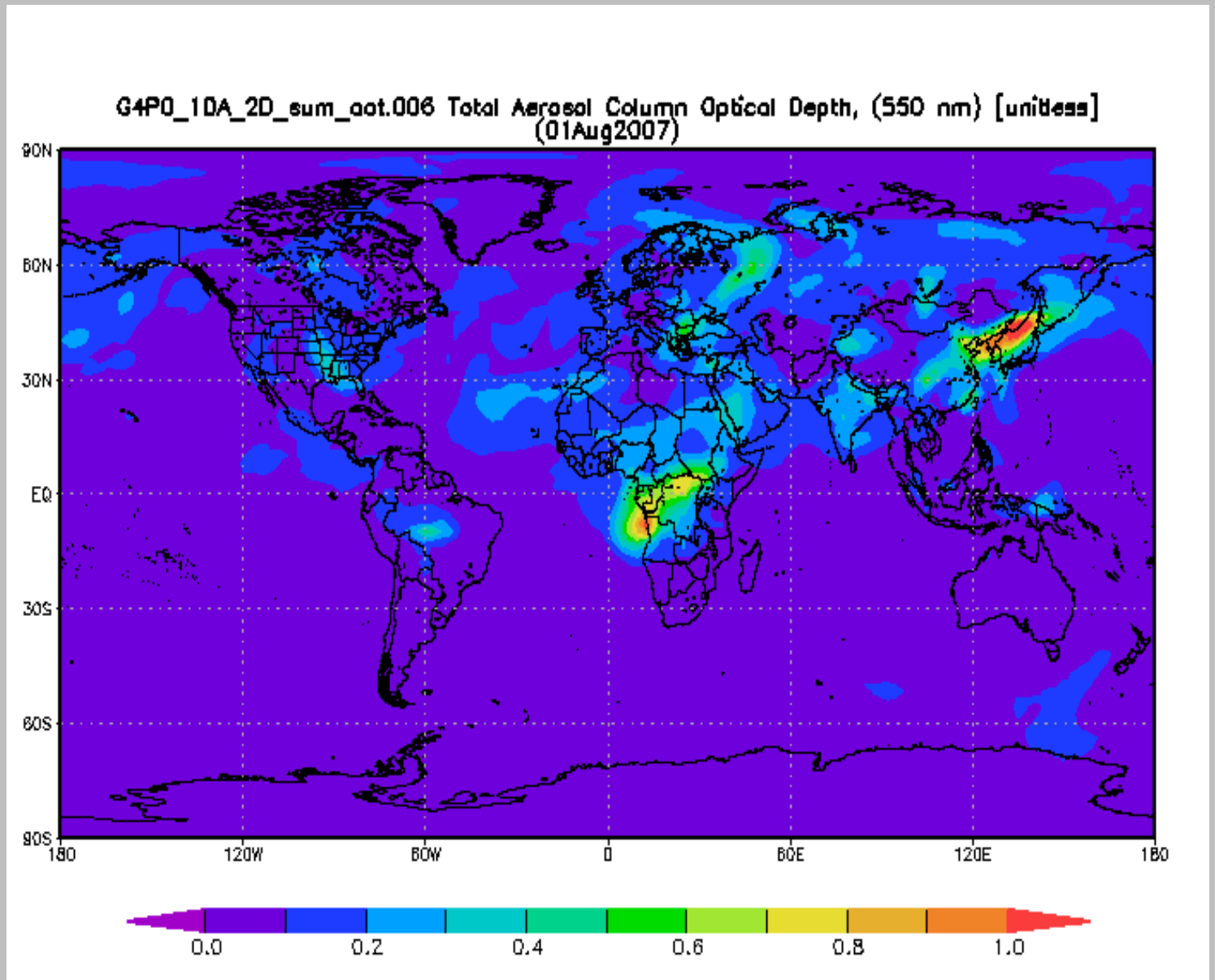


Photo from the Space Station over Southern Africa

Presented at the 11th AEROCOM Workshop, 10-13 Sept. 2012, Seattle, WA

GOCART daily AOD



Outline

Understanding Model Evaluation using Observations

The MAPSS/AeroStat aerosol data sampling/analysis system

Coherent Uncertainty Analysis of Satellite Aerosol Data

Toward Multi-sensor Aerosol Data Synergy

Future Possibilities (Suggestions very welcome)

What is Model Evaluation?

IPCC - AR4: Chap 8 (Climate Models and Their Evaluation)

Section 8.1.1

"A specific prediction based on a model can often be demonstrated to be right or wrong, but the model itself should always be viewed critically."

-Short-term Predictions (Weather, AQ) => Observations

-Long-term Predictions (Climate) => Historical records or Palaeoclimate data

Model Evaluation Types and Metrics

IPCC - AR4: Chap 8 (Climate Models and Their Evaluation)

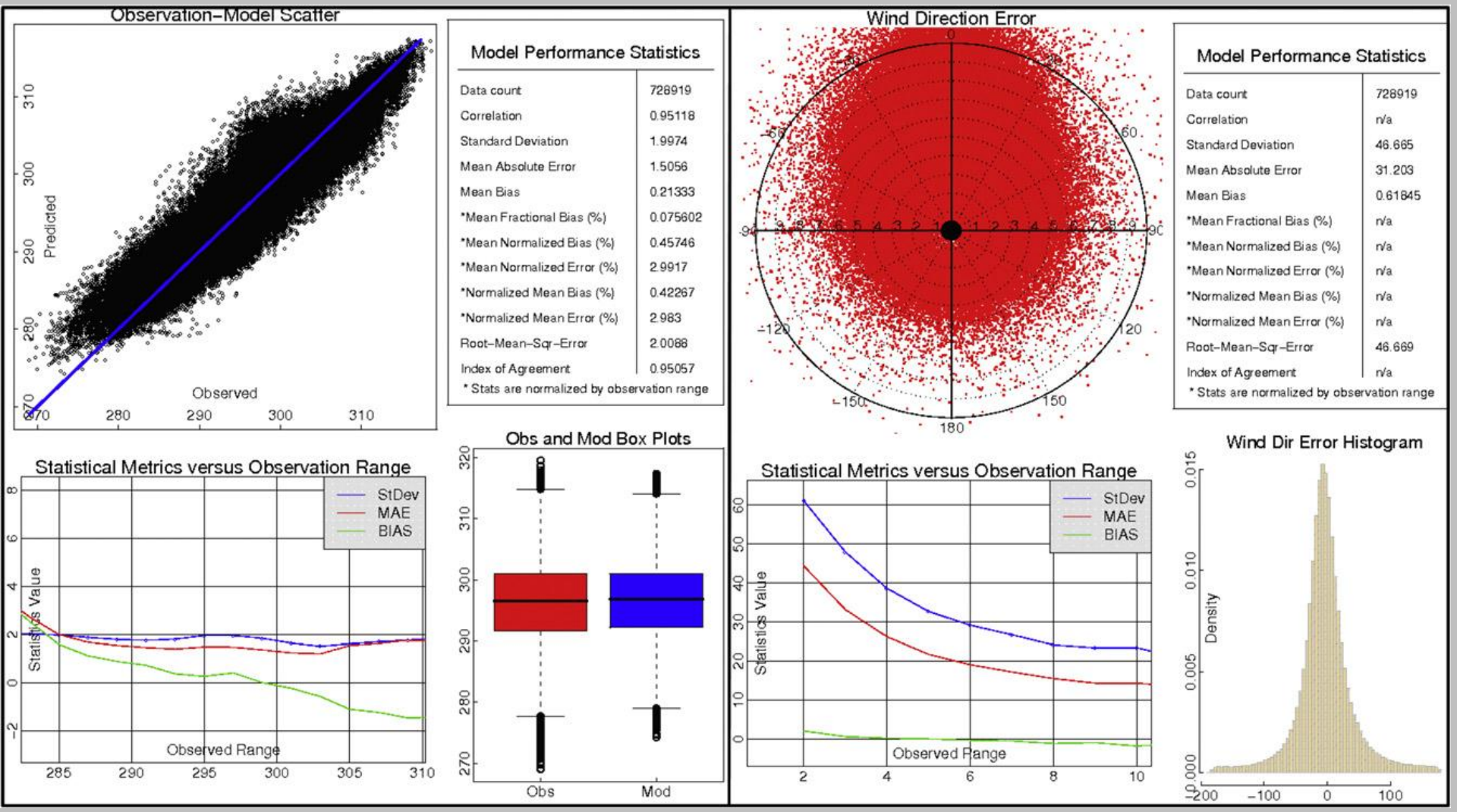
Section 8.1.2 Methods of Evaluation

- System-level => evaluation of the full model output.
- Component-level => testing of particular components

8.1.2.2 Metrics of Model Reliability

"because the development of robust metrics is still at an early stage, the model evaluations presented in this chapter are based primarily on experience and physical reasoning, as has been the norm in the past."

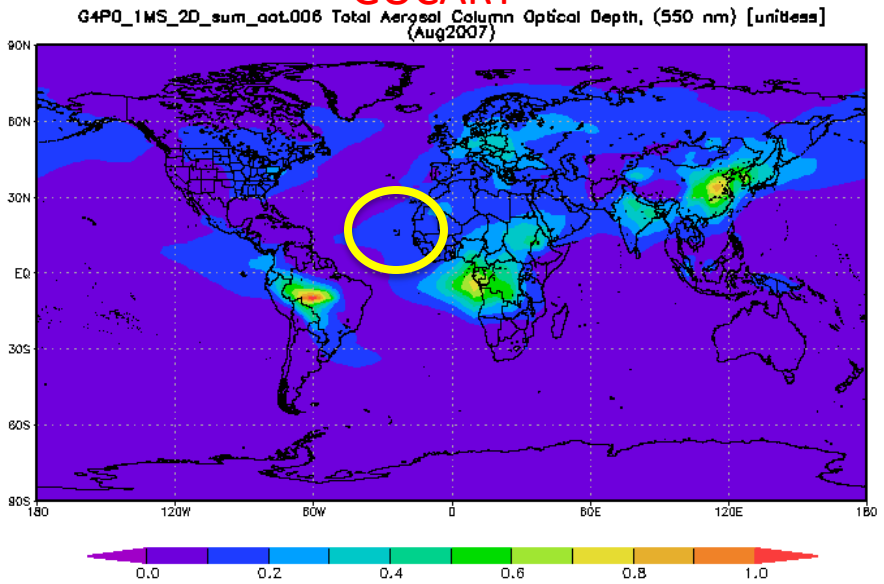
Model Evaluation example:
Atmospheric Model Evaluation Tool (AMET)
Developed by EPA for evaluation of MM5, WRF, CMAQ



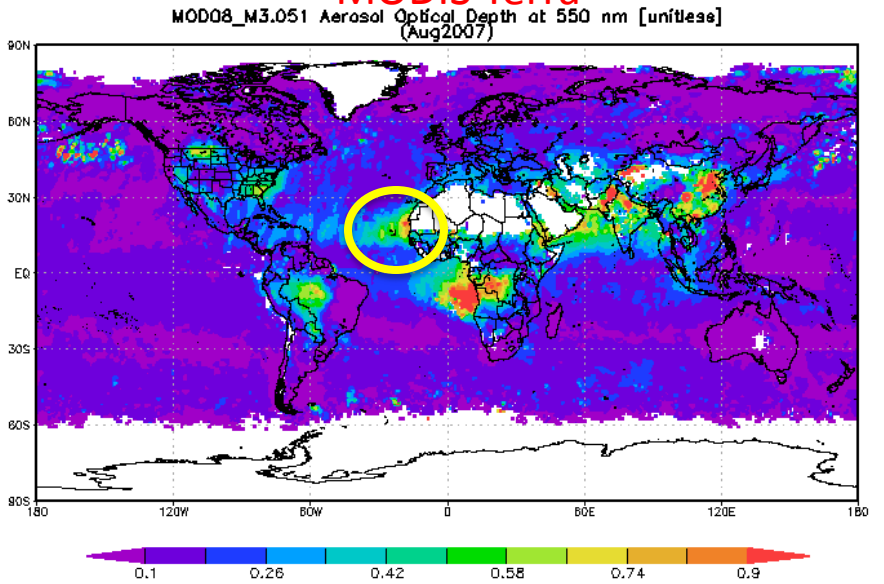
Source: Appel et al., 2011, Environmental Modelling & Software 26, 434-443

Global monthly AOD for August 2007

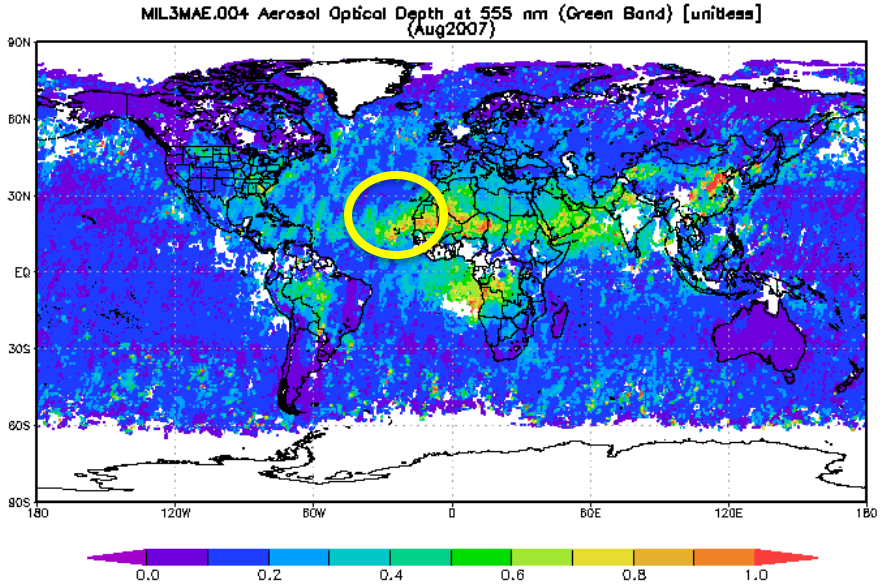
GOCART



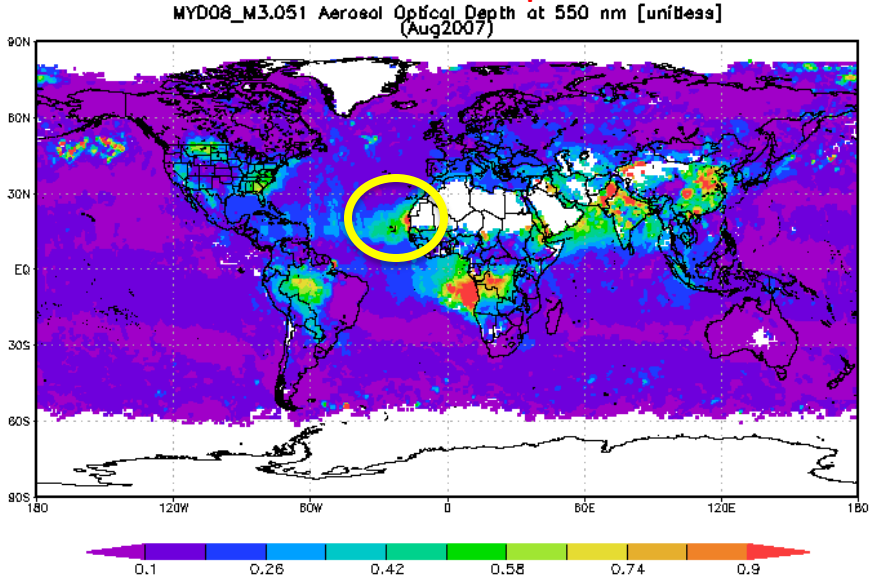
MODIS Terra



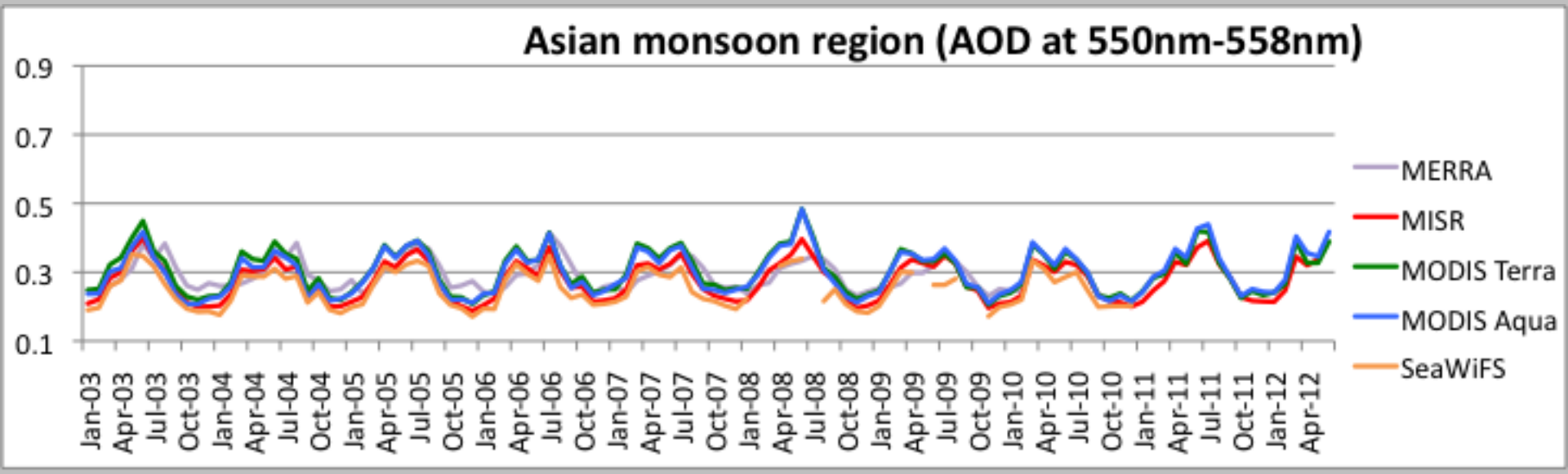
MISR

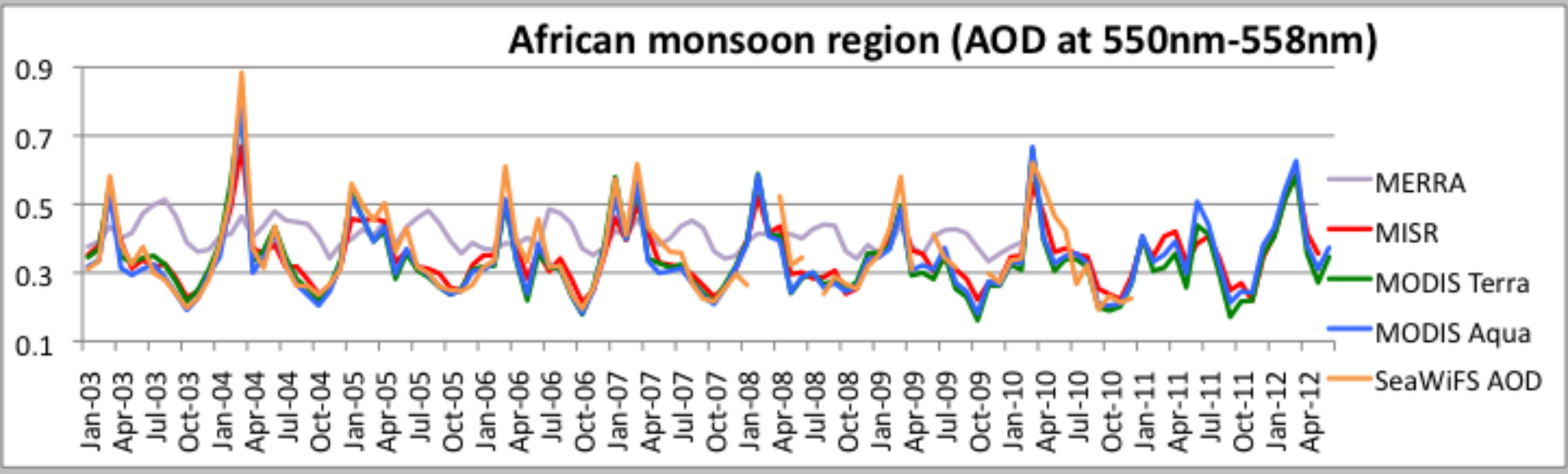


MODIS Aqua

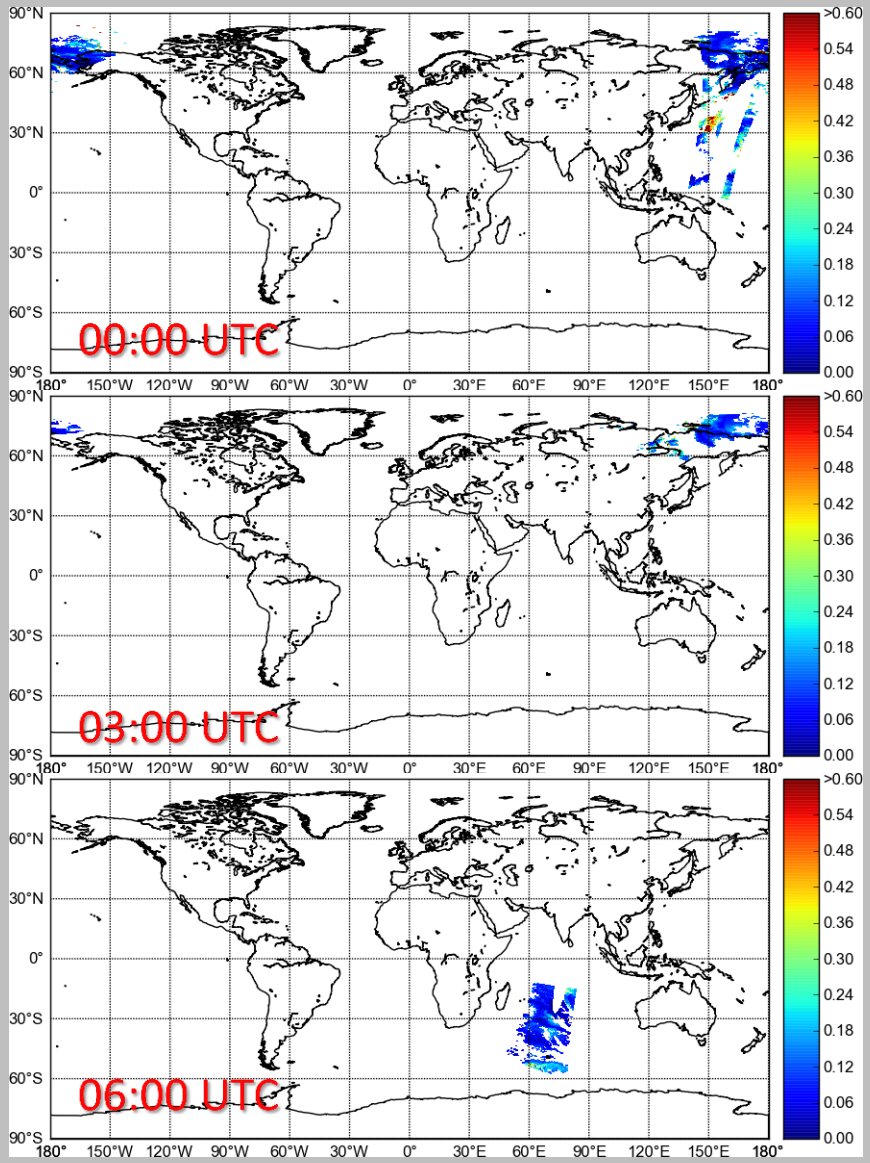


AOD at Asian and African monsoon regions

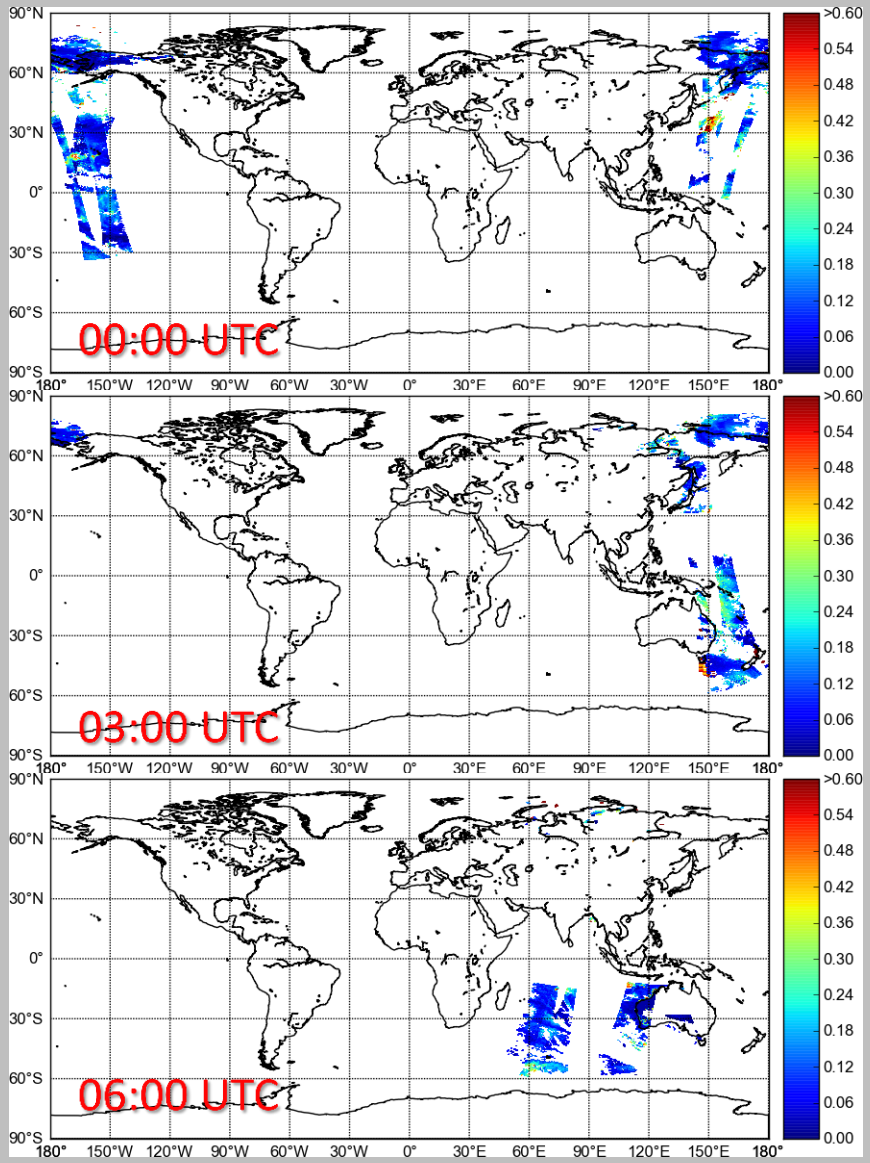




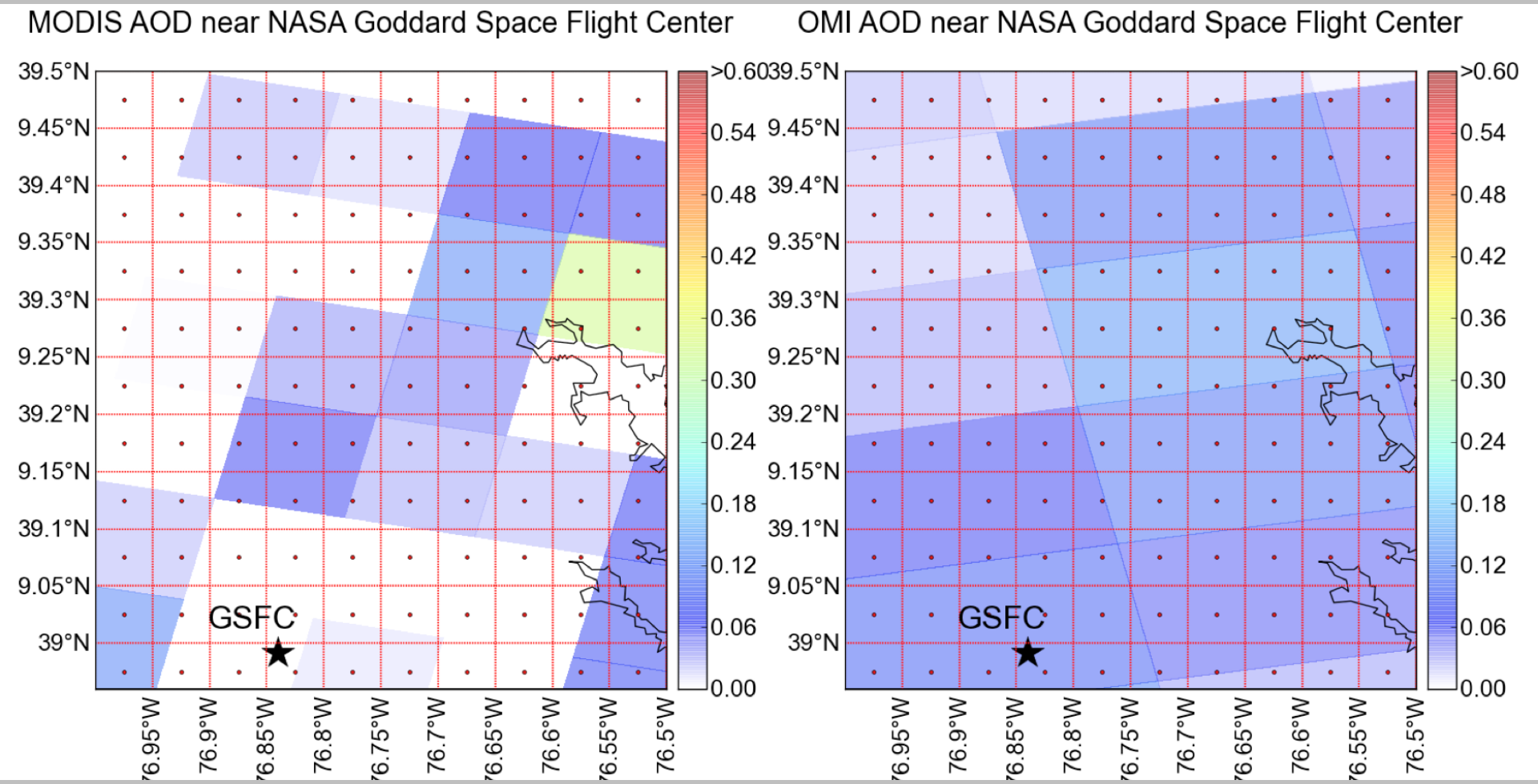
±30 minute MODIS Terra swath cutouts for evaluation of 3-hour model snapshots on 2008-08-22



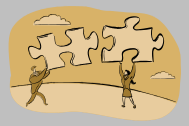
Combined swath cutouts from MODIS Aqua&Terra, MISR, OMI, SeaWiFS, and POLDER



Spatial Heterogeneity of Aerosol Retrieval from Satellite



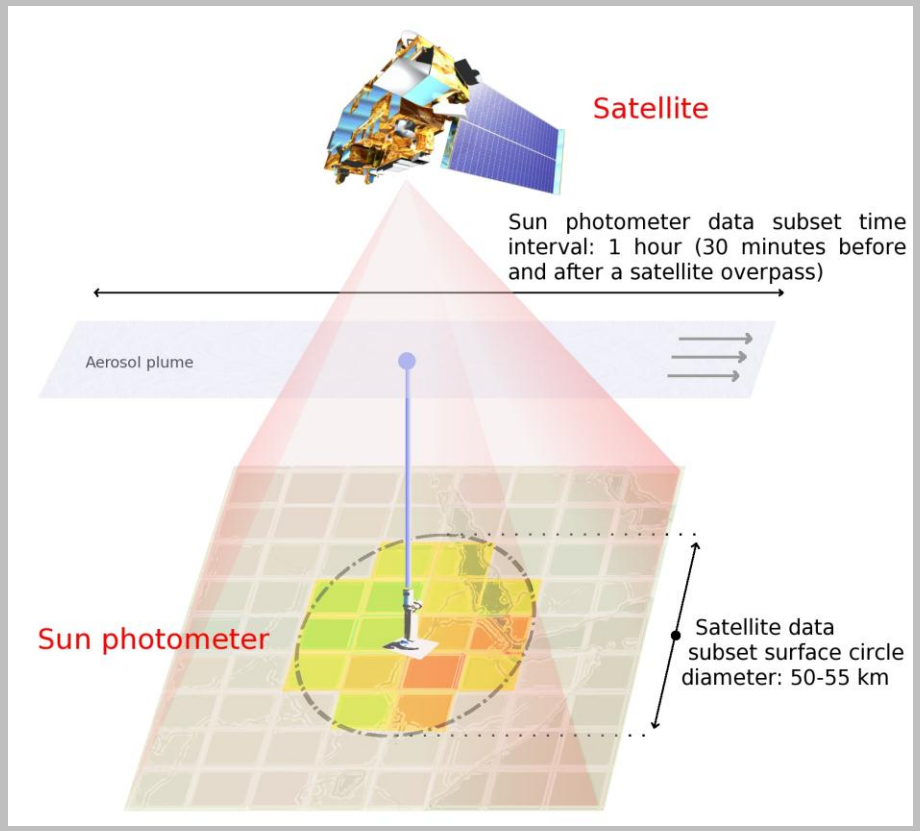
Aerosol Optical Depth (AOD) retrieved on 08/31/2008 by Terra-MODIS and Aura-OMI spaceborne sensors over NASA Goddard Space Flight Center (GSFC) in Greenbelt, MD (black star). Red squares are regularly spaced 0.05˚x0.05˚ grid cells, with tiny red dots indicating their centers. Near nadir, a single MODIS pixel (10x10km) can cover 4-5 grid cells, while a single OMI pixel (13.7x23.7km) can cover about 15 cells.



- Aerosol data are available from different sensors
  - AERONET
  - MODIS
  - MISR
  - OMI
  - POLDER
  - CALIOP
  - SeaWiFS

- Hard to compare and inter-validate
  - Different spatial and temporal resolution
  - Different data access strategies

MAPSS: Multi-sensor Aerosol Products Sampling System



- MAPSS uniformly samples Level-2 aerosol products and stores resulting statistics in simple CSV files

- Giovanni-based WEB interface for MAPSS provides a convenient customized access to the data, with on-line plotting and data export capabilities

Petrenko et al., 2012, AMT

This user interface is used to obtain selected parameter statistics from the MAPSS database for a chosen location and time period. Time Series Plot is the available service. Plot output is rendered as a graph and is also available in ASCII format.

Data Selection | Results

To see time series plots of MAPSS data, choose from the criteria below and click **Get Plot(s)**

Select Stations

GSFC,Dakar [Select]

Select Parameters

*To select parameters, make a **single** selection from each list below (beginning with the left-most list), and then click 'Add'. Selected parameters will be added to the summary. Repeat for additional parameters.*

(•) Basic ( ) Advanced

Product (info)	Parameter	Layer	Variable
AERONET aerosols L2, ver. 2	AOD	Angstrom exponent for 380–500nm	*Measurement*
AERONET deconvolution L2, ver. 41	Angstrom exponent	Angstrom exponent for 440–670nm (Polar)	Central value
AERONET inversions L1.5, ver. 2	Water vapor	Angstrom exponent for 440–670nm	Mean
AERONET inversions L2, ver. 2		Angstrom exponent for 440–870nm	Median
CALIPSO column and layer aerosols L2, ver. 301		Angstrom exponent for 550–870nm	Standard deviation

[Add]

Summary

MODIS aerosols L2 (Aqua), ver. 051:AOD at 550 nm with best QA – land and ocean:AOD at 550nm:Mean	Delete
MISR aerosols L2, ver. 0022:Best estimate of AOD:Best estimate of AOD at 558nm:Mean	Delete
AERONET aerosols L2, ver. 2:Angstrom exponent:Angstrom exponent for 550–870nm:Mean	Delete

Select Date Range

Start Date: 01/01/2007

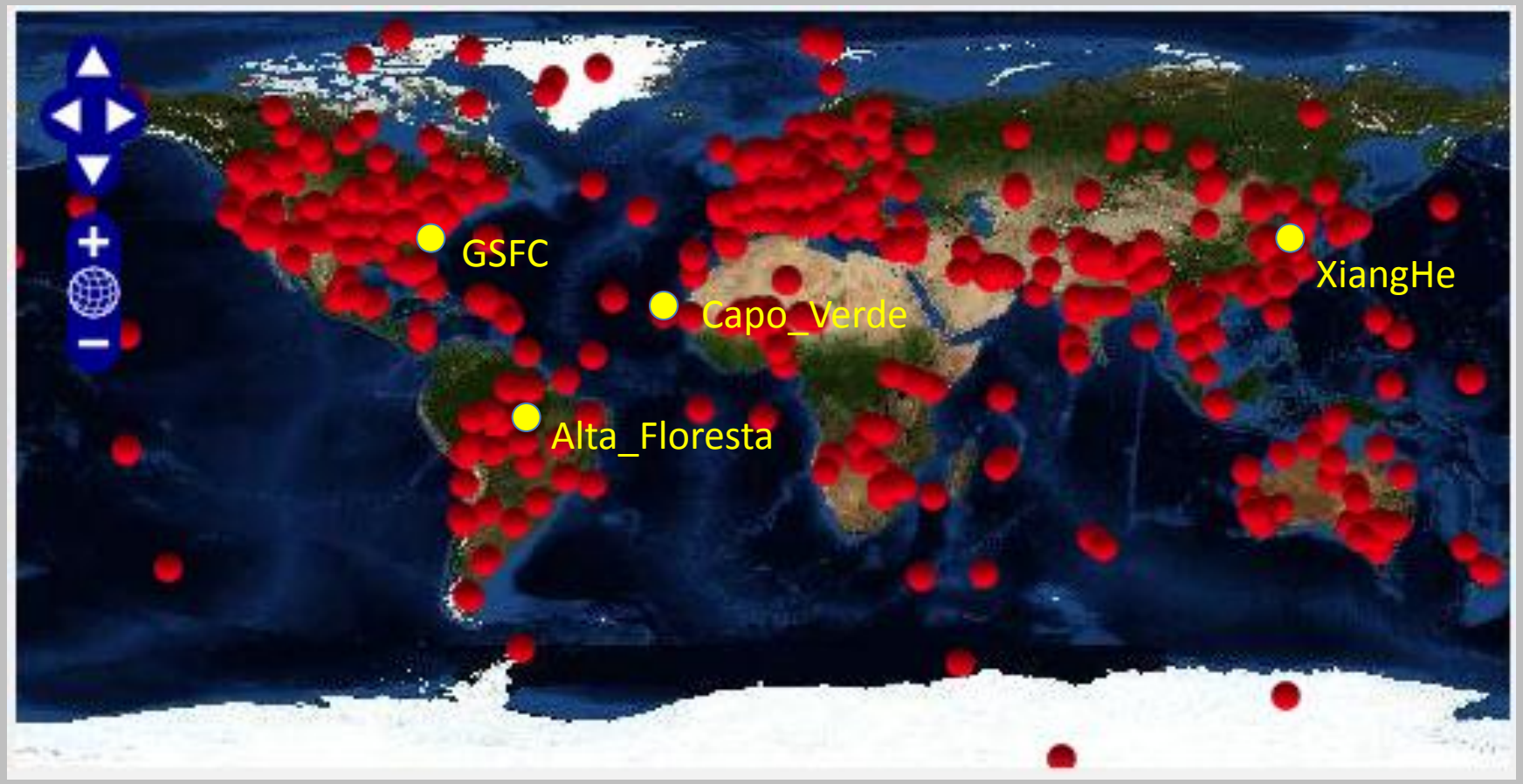
End Date: 12/31/2007

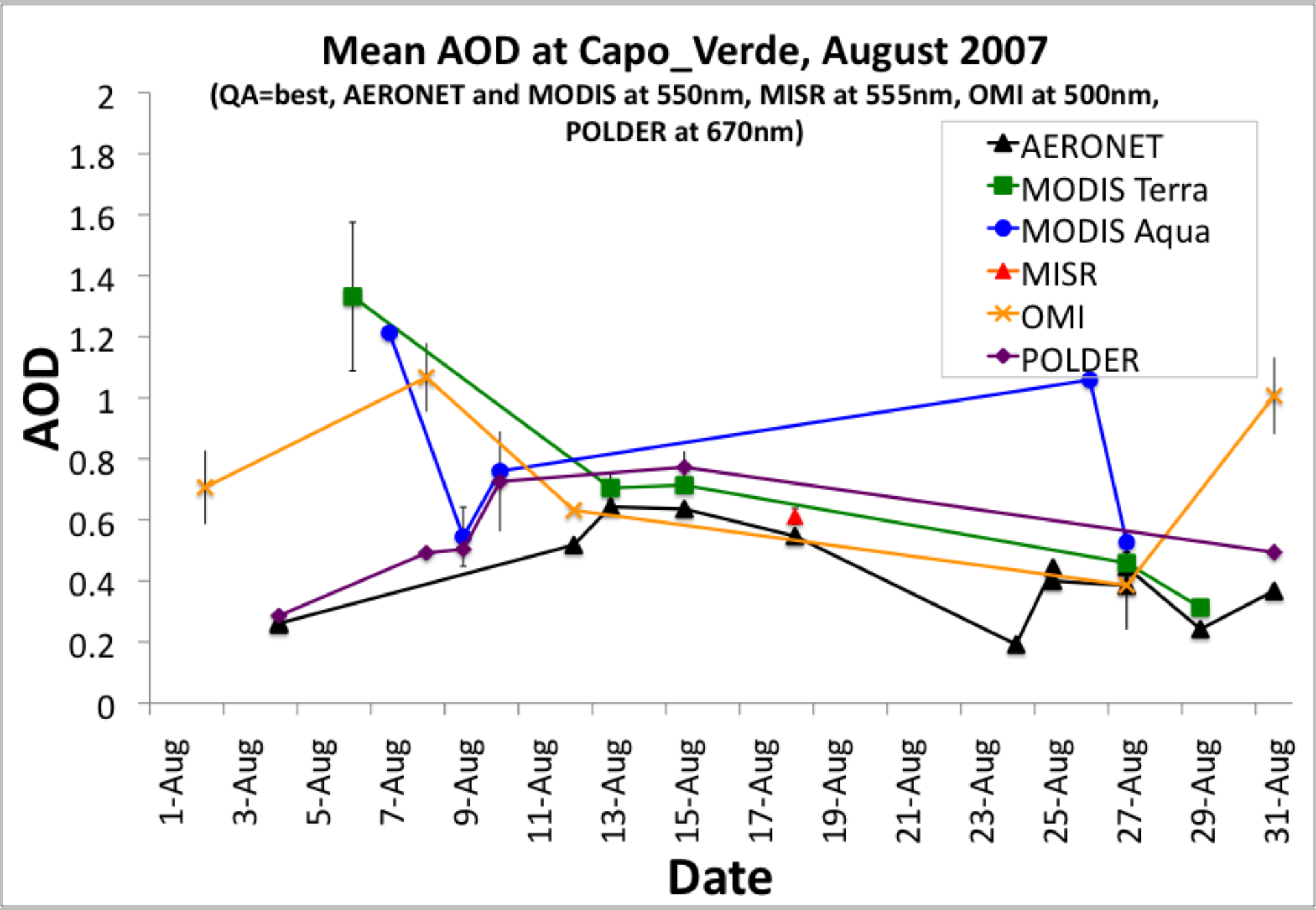
To see time series plots of MAPSS data, choose from the criteria below and click **Get Plot(s)**

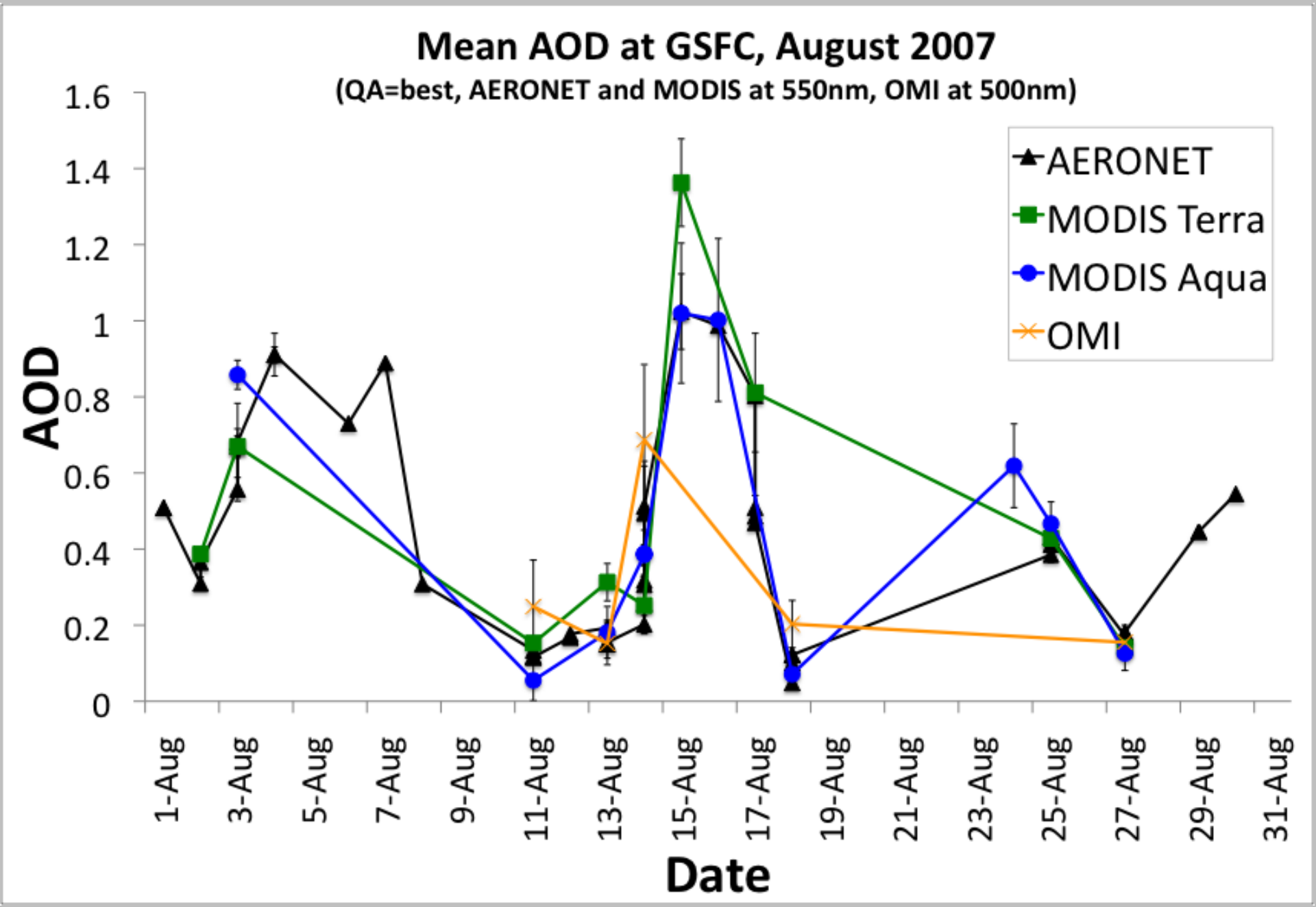
ACKNOWLEDGMENT: Support for the development of this data access system for integrated validation, intercomparison, and analysis of aerosol products from multiple satellites has been provided by NASA HQ through the ROSES 2006 ACCESS Program under Grant Number NNX08AN39A.

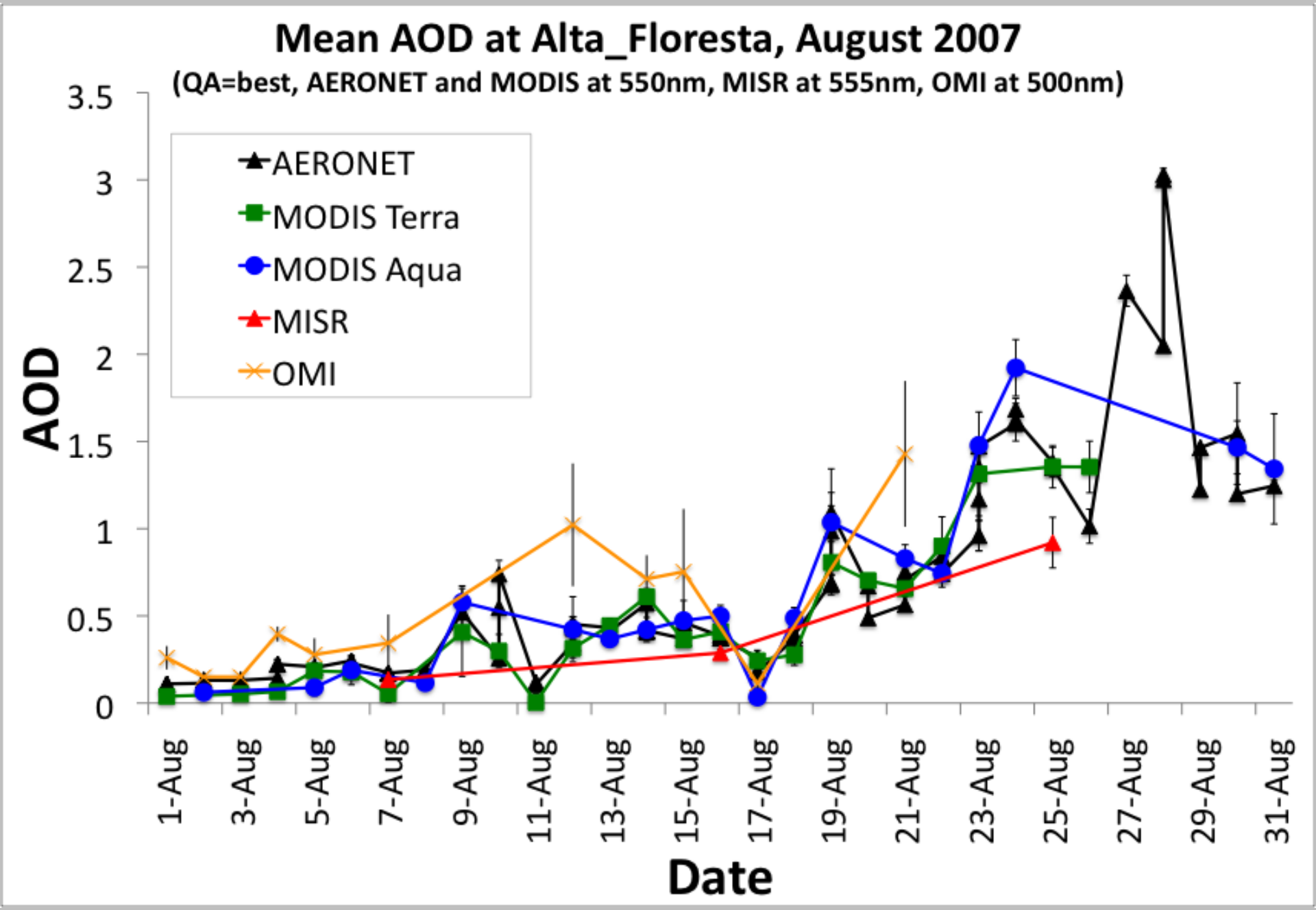
Satellite Aerosol Data Evaluation using MAPSS

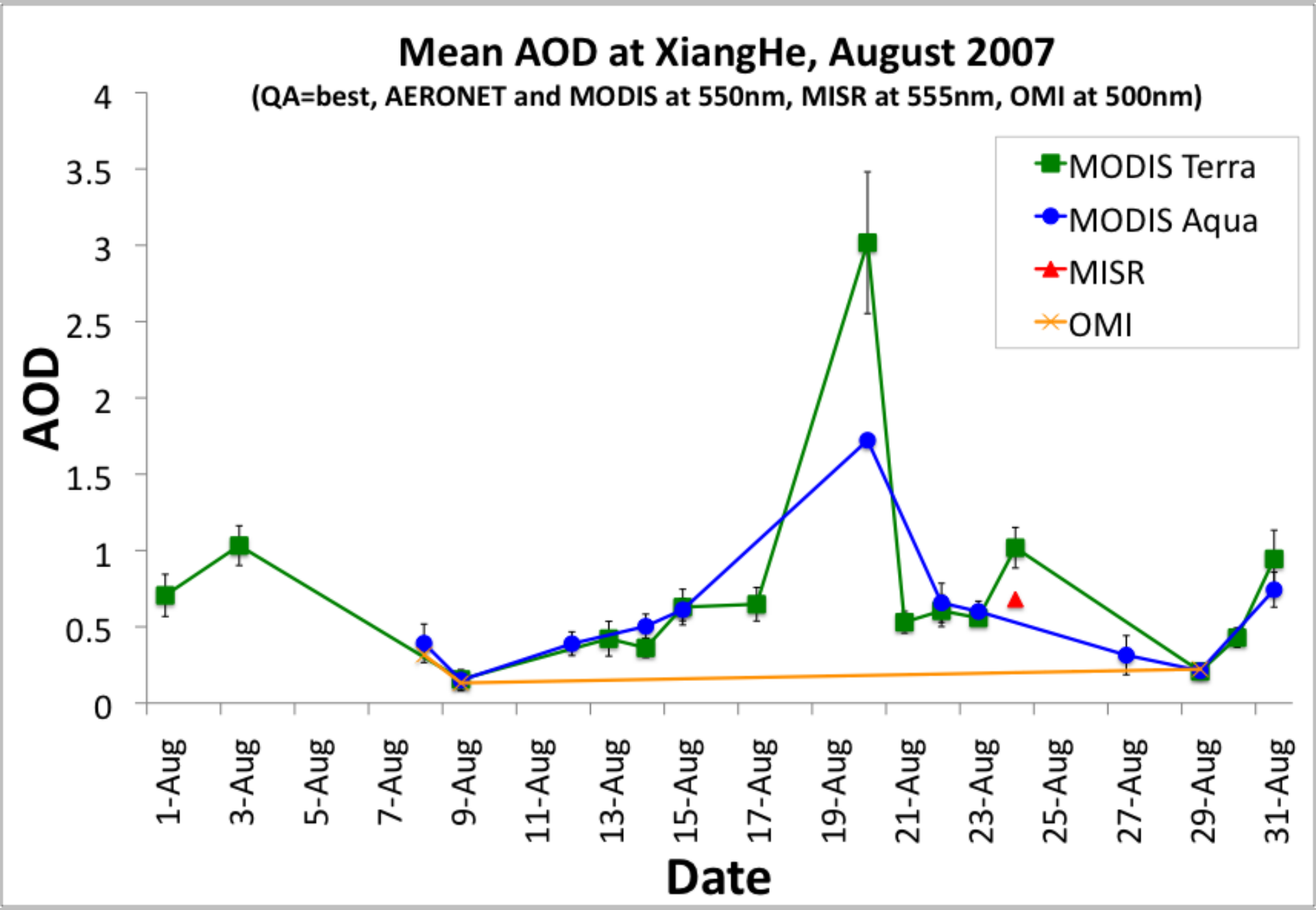
MAPSS coverage and selected sites



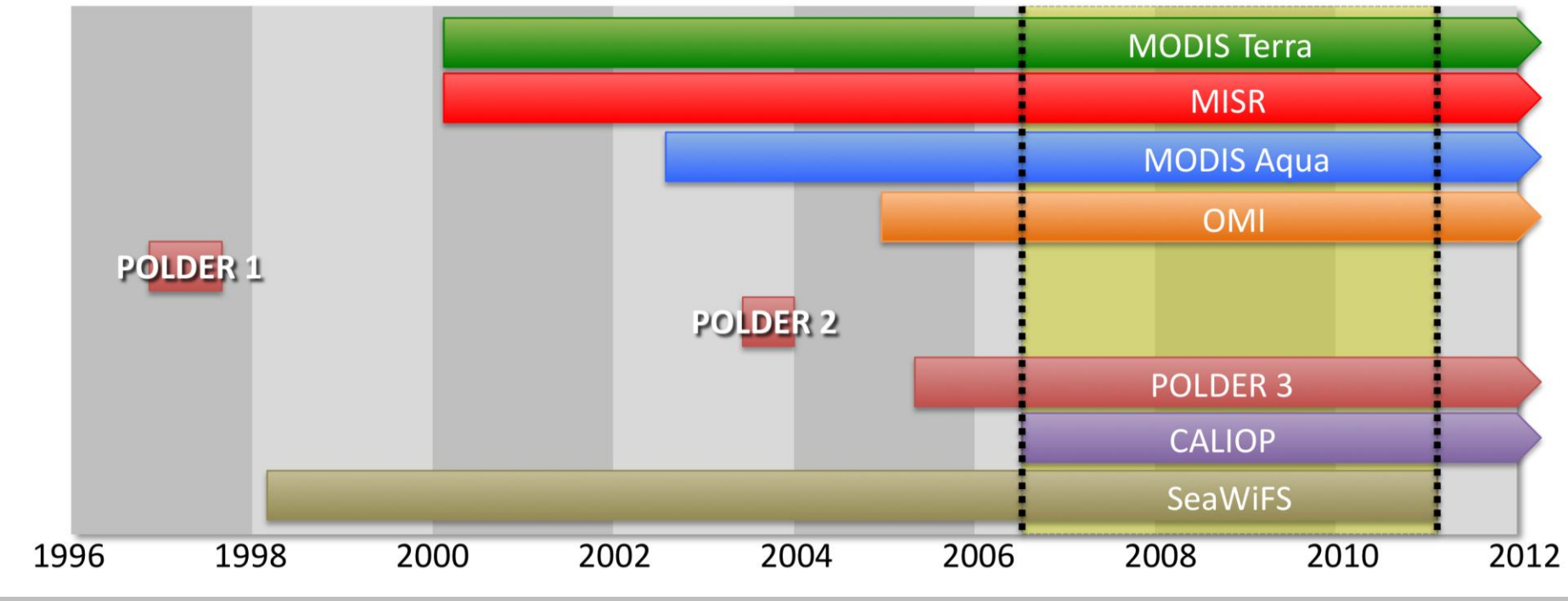

Mean AOD at Capo_Verde, August 2007
(QA=best, AERONET and MODIS at 550nm, MISR at 555nm, OMI at 500nm, POLDER at 670nm)
AERONET
MODIS Terra
MODIS Aqua
MISR
OMI
POLDER
AOD
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1-Aug
3-Aug
5-Aug
7-Aug
9-Aug
11-Aug
13-Aug
15-Aug
17-Aug
19-Aug
21-Aug
23-Aug
25-Aug
27-Aug
29-Aug
31-Aug
Date


Mean AOD at GSFC, August 2007
(QA=best, AERONET and MODIS at 550nm, OMI at 500nm)
AERONET
MODIS Terra
MODIS Aqua
OMI
AOD
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1-Aug
3-Aug
5-Aug
7-Aug
9-Aug
11-Aug
13-Aug
15-Aug
17-Aug
19-Aug
21-Aug
23-Aug
25-Aug
27-Aug
29-Aug
31-Aug
Date

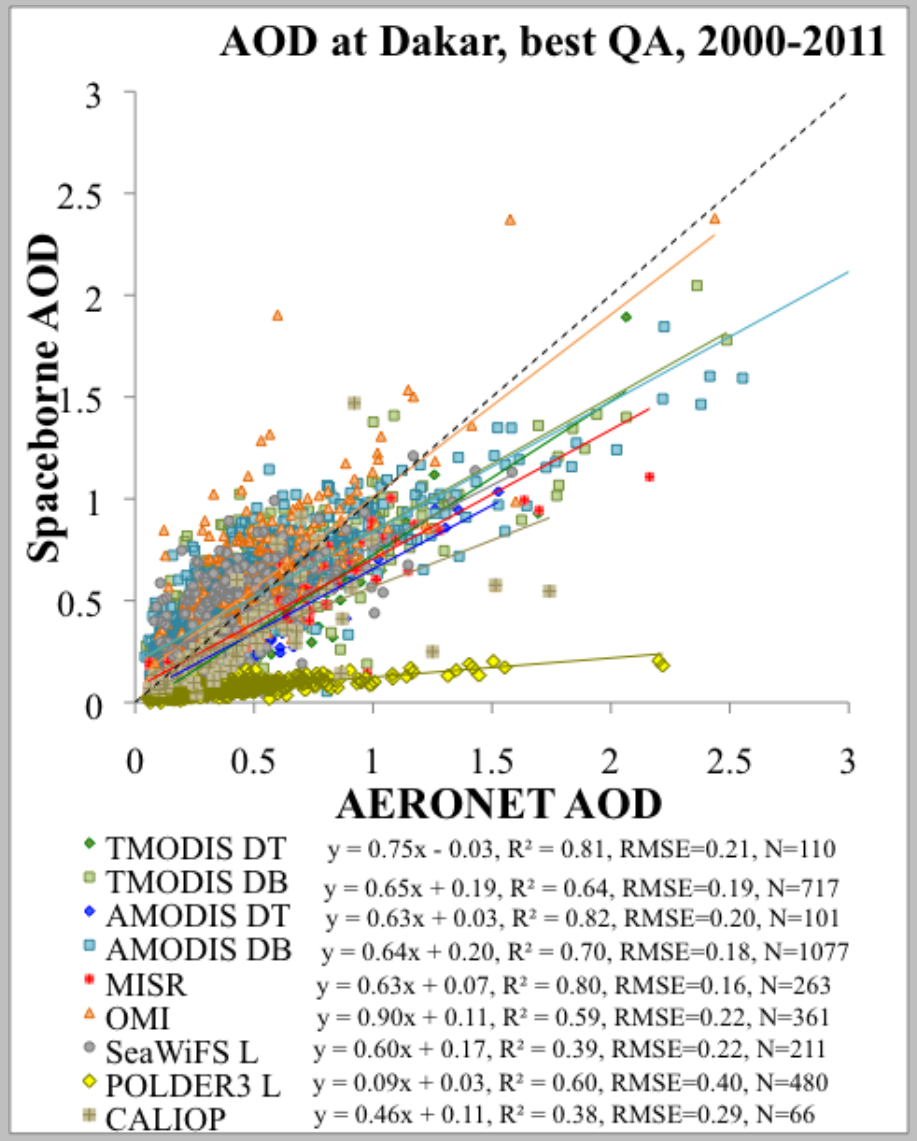

Mean AOD at Alta_Floresta, August 2007
(QA=best, AERONET and MODIS at 550nm, MISR at 555nm, OMI at 500nm)
AERONET
MODIS Terra
MODIS Aqua
MISR
OMI
AOD
3.5
3
2.5
2
1.5
1
0.5
0
1-Aug
3-Aug
5-Aug
7-Aug
9-Aug
11-Aug
13-Aug
15-Aug
17-Aug
19-Aug
21-Aug
23-Aug
25-Aug
27-Aug
29-Aug
31-Aug
Date

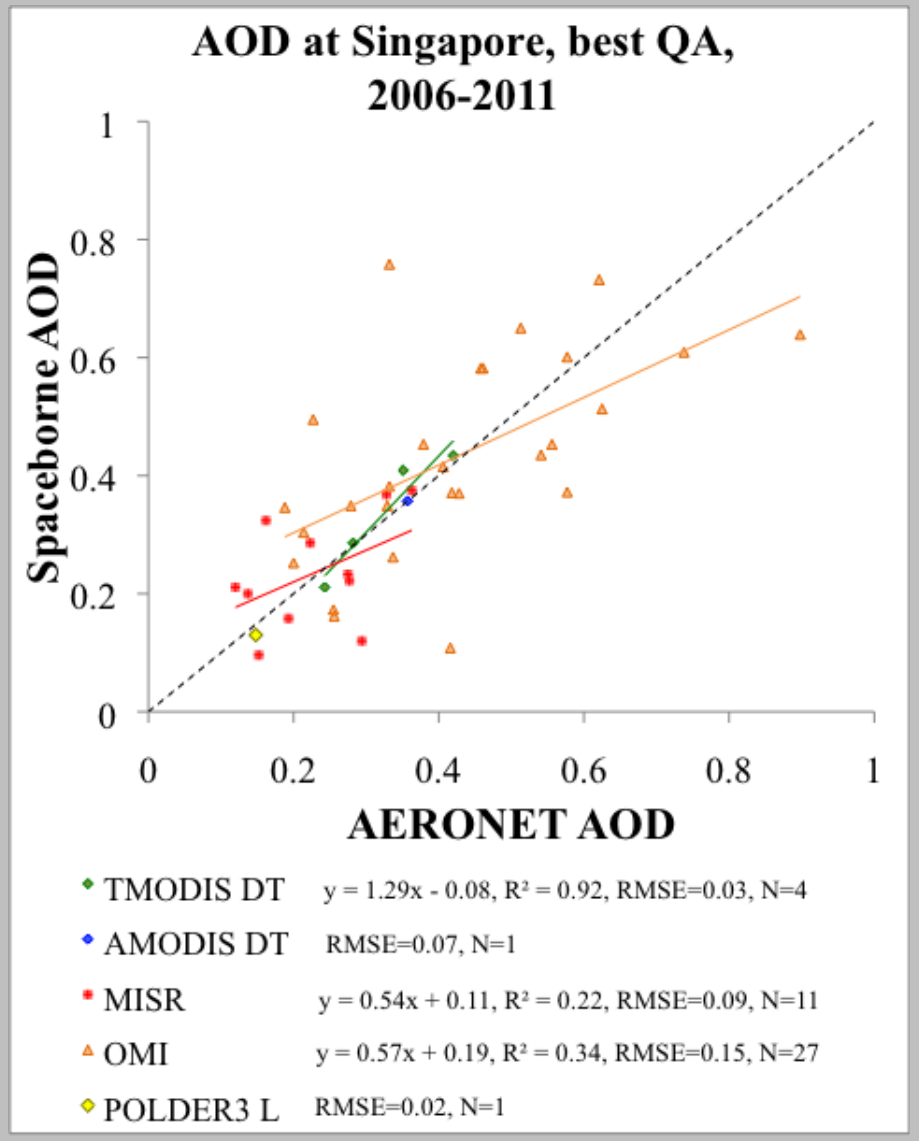

Mean AOD at XiangHe, August 2007
(QA=best, AERONET and MODIS at 550nm, MISR at 555nm, OMI at 500nm)
MODIS Terra
MODIS Aqua
MISR
OMI
AOD
0
0.5
1
1.5
2
2.5
3
3.5
4
1-Aug
3-Aug
5-Aug
7-Aug
9-Aug
11-Aug
13-Aug
15-Aug
17-Aug
19-Aug
21-Aug
23-Aug
25-Aug
27-Aug
29-Aug
31-Aug
Date

Timeline of Aerosol-measuring Satellite Sensors Considered



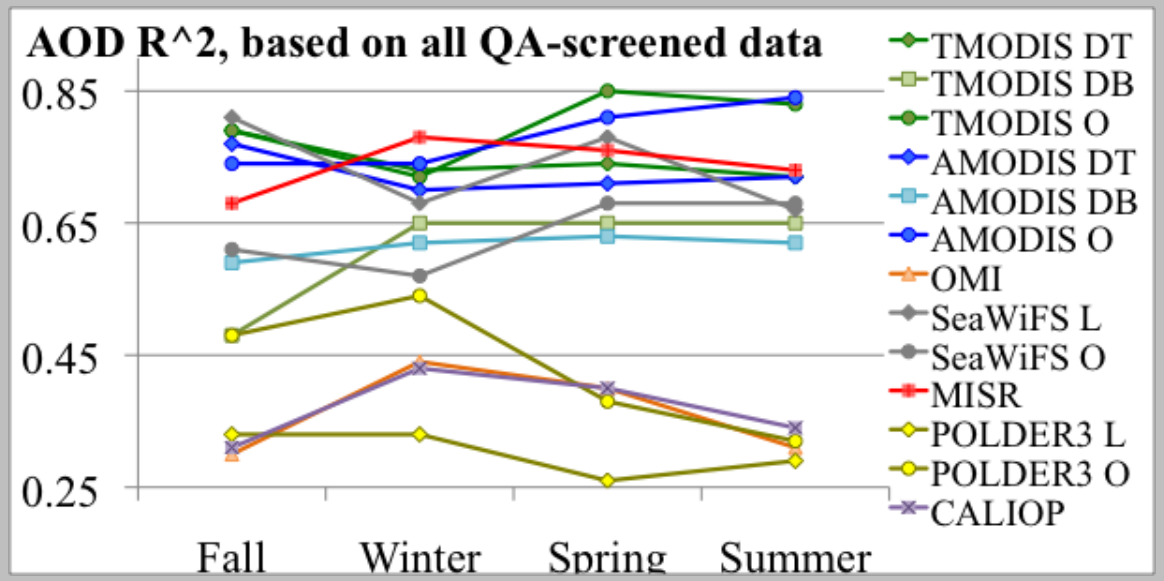
Accuracy of spaceborne AOD retrievals

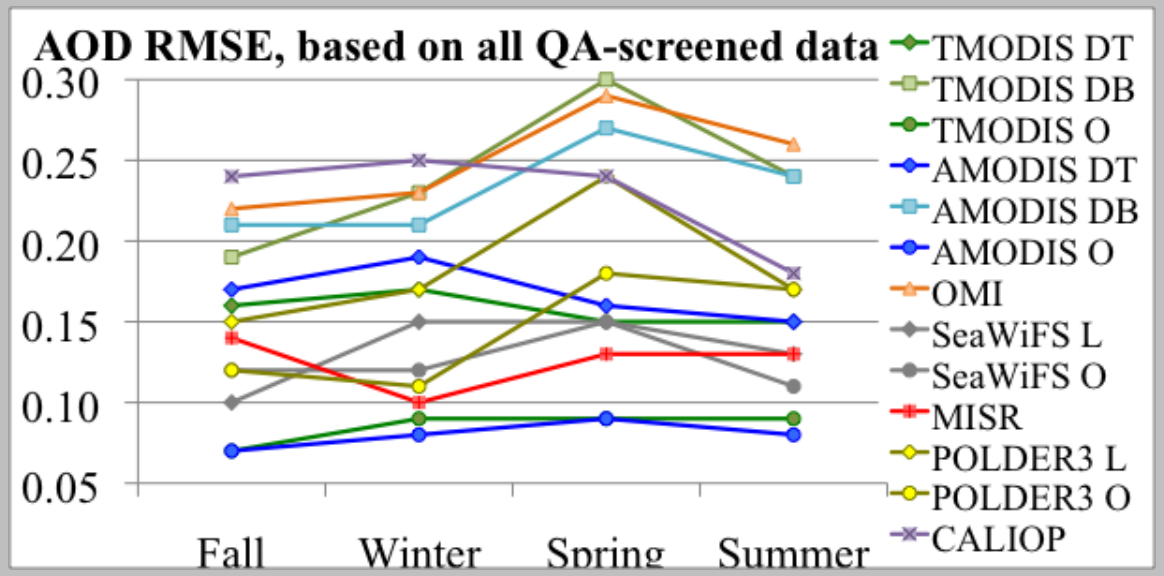




Global performance of multiple AOD sensors

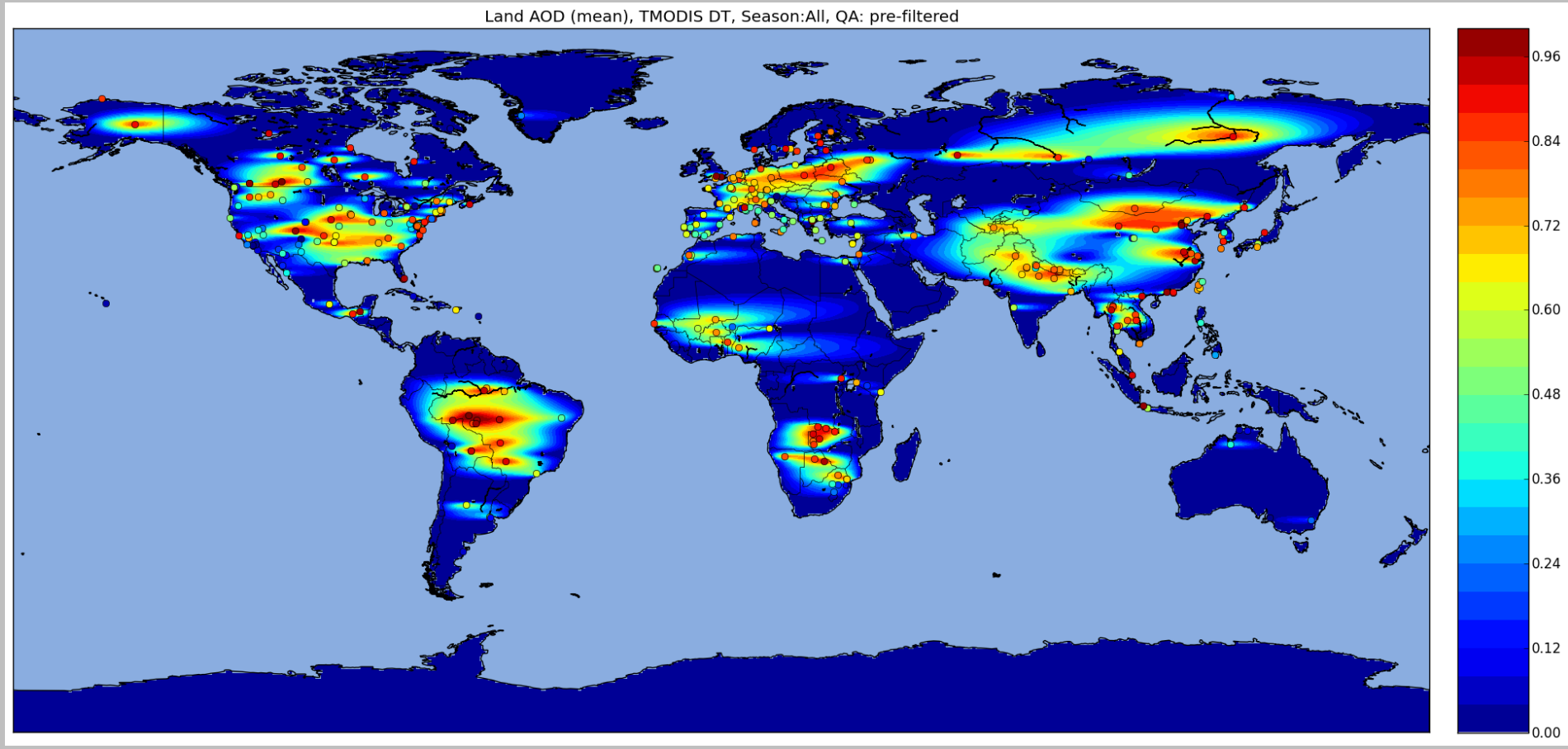
(based on collocation with AERONET observations)



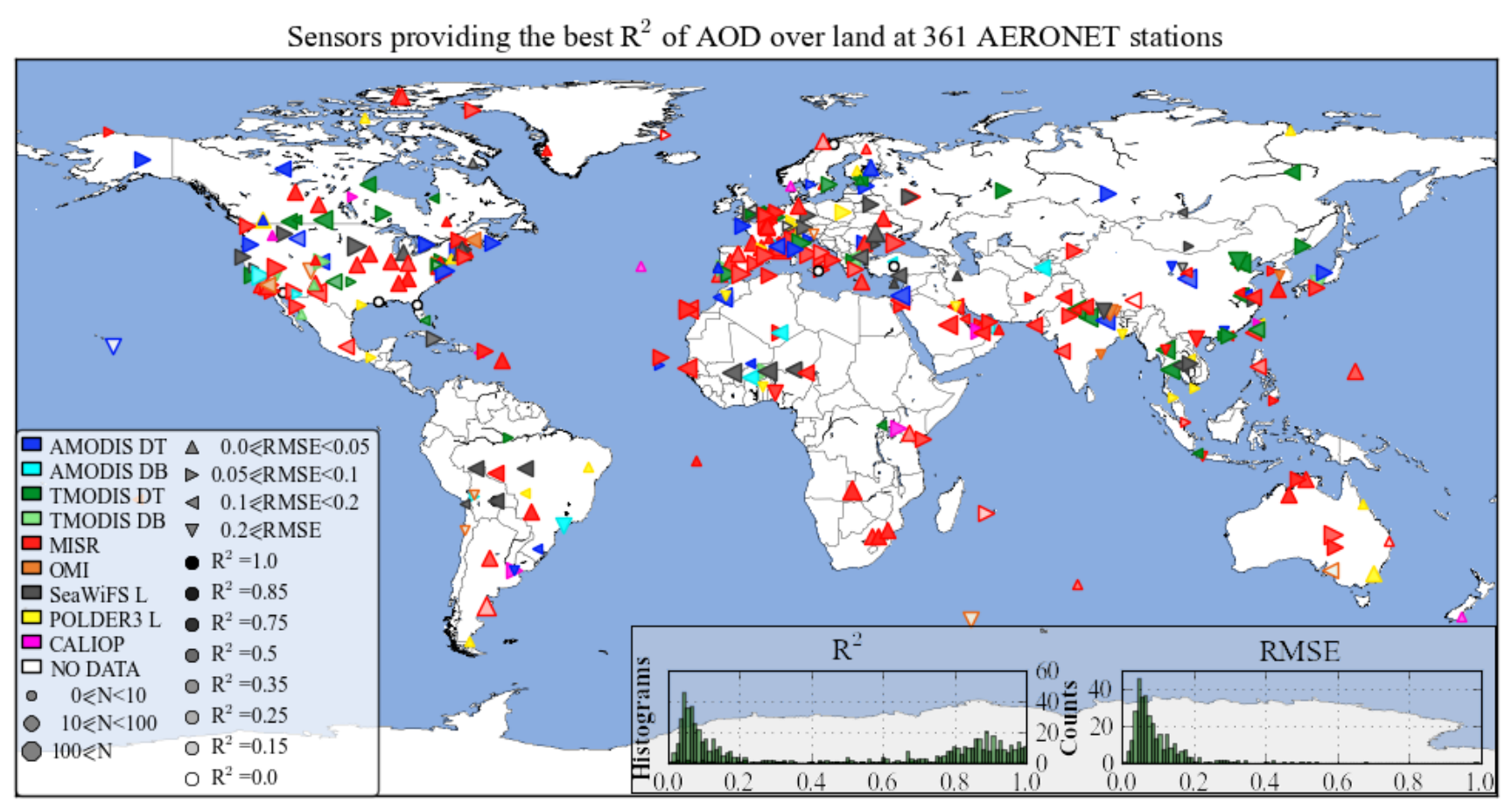


Sensor	Compared at wavelength (nm)
TMODIS	550
AMODIS	550
OMI	388
SeaWiFS	550
MISR	558
POLDER3 L	865
POLDER3 O	670
CALIOP	532

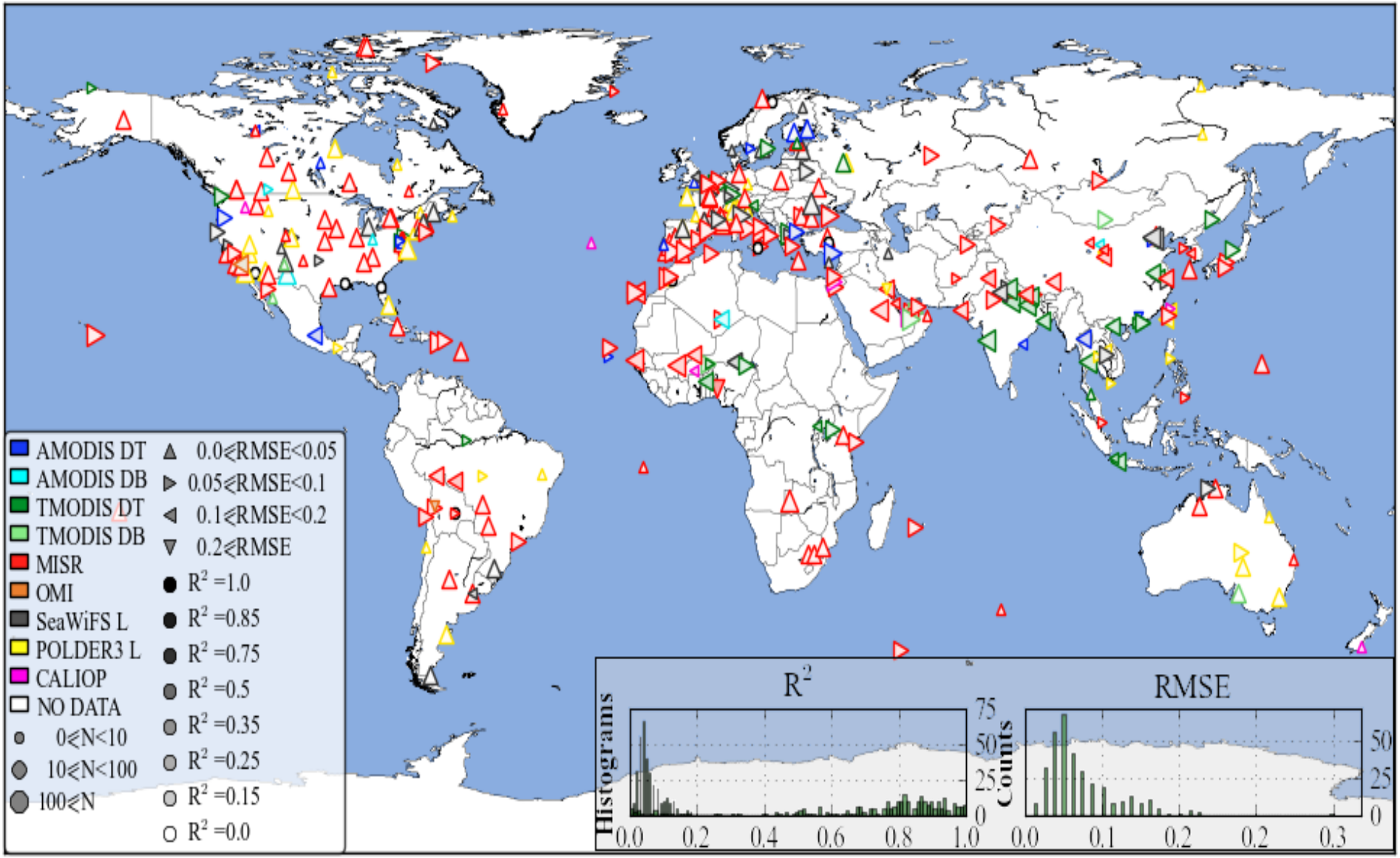
Data confidence maps for individual products



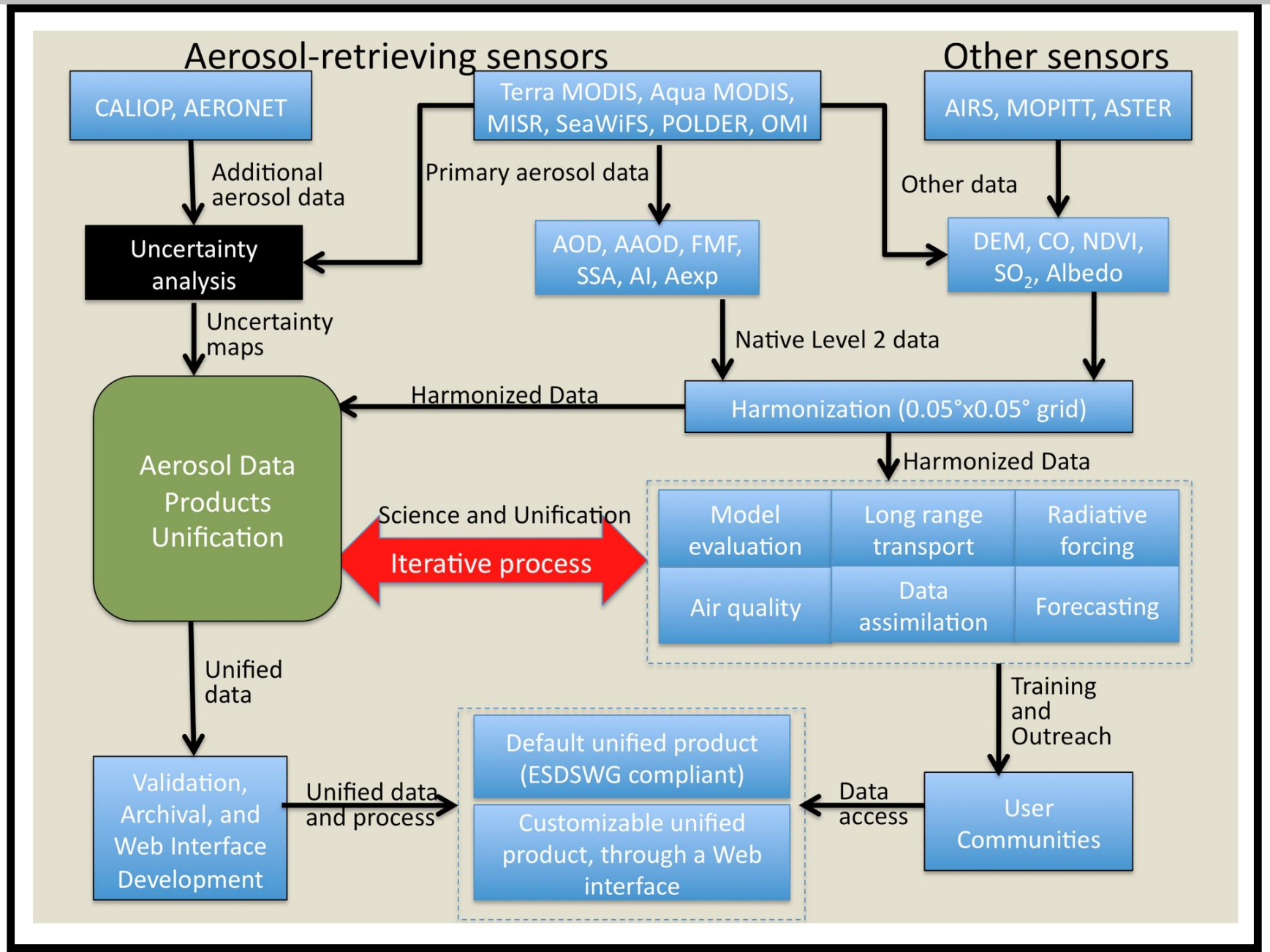
Merging multiple products



Multi-sensor AOD Accuracy Distribution



Proposed Satellite Aerosol Integration Approach



Conclusions

- There is considerable disagreement in AOT between different satellite sensors during different seasons in different regions

- Multi-sensor synergy can help restore harmony and improve understanding in aerosol loading and impacts

- We are currently evaluating the satellite retrievals with a view toward robust integration of aerosol products from multiple sensors

- Such integrated evaluation of satellite observations can help enhance model evaluation significantly

Acknowledgement

- NASA HQ Program Managers:
  - Hal Maring.
  - Martha Maiden.
  - Steve Berrick.

  For tag-team Funding support of this series of aerosol projects.

- Aerosol PI Teams
  - AERONET: Brent Holben, David Giles, Ilya Slutsker
  - MODIS: Lorraine Remer, Rob Levy
  - MISR: Ralph Kahn
  - OMI: Omar Torres
  - POLDER: Didier Tanre, Fabrice Ducos, Jacques Descloitres
  - CALIOP: Dave Winker, Ali Omar
  - SeaWiFS: Christina Hsu
  - GOCART Model: Mian Chin

Functions and Web Sites

GIOVANNI – Level 3 Earth Science Data Visualization and Analysis

http://disc.sci.gsfc.nasa.gov/giovanni/

MAPSS – Level 2 Aerosol Point Sampling: Timeseries & Spreadsheet

http://giovanni.gsfc.nasa.gov/mapss/

AeroStat – Level 2 Aerosol Point Sampling: Scatterplots & Statistics

http://giovanni.gsfc.nasa.gov/aerostat/