Coherent evaluation of aerosol data products from multiple satellite sensors

Charles Ichoku, Maksym Petrenko, and Greg Leptoukh

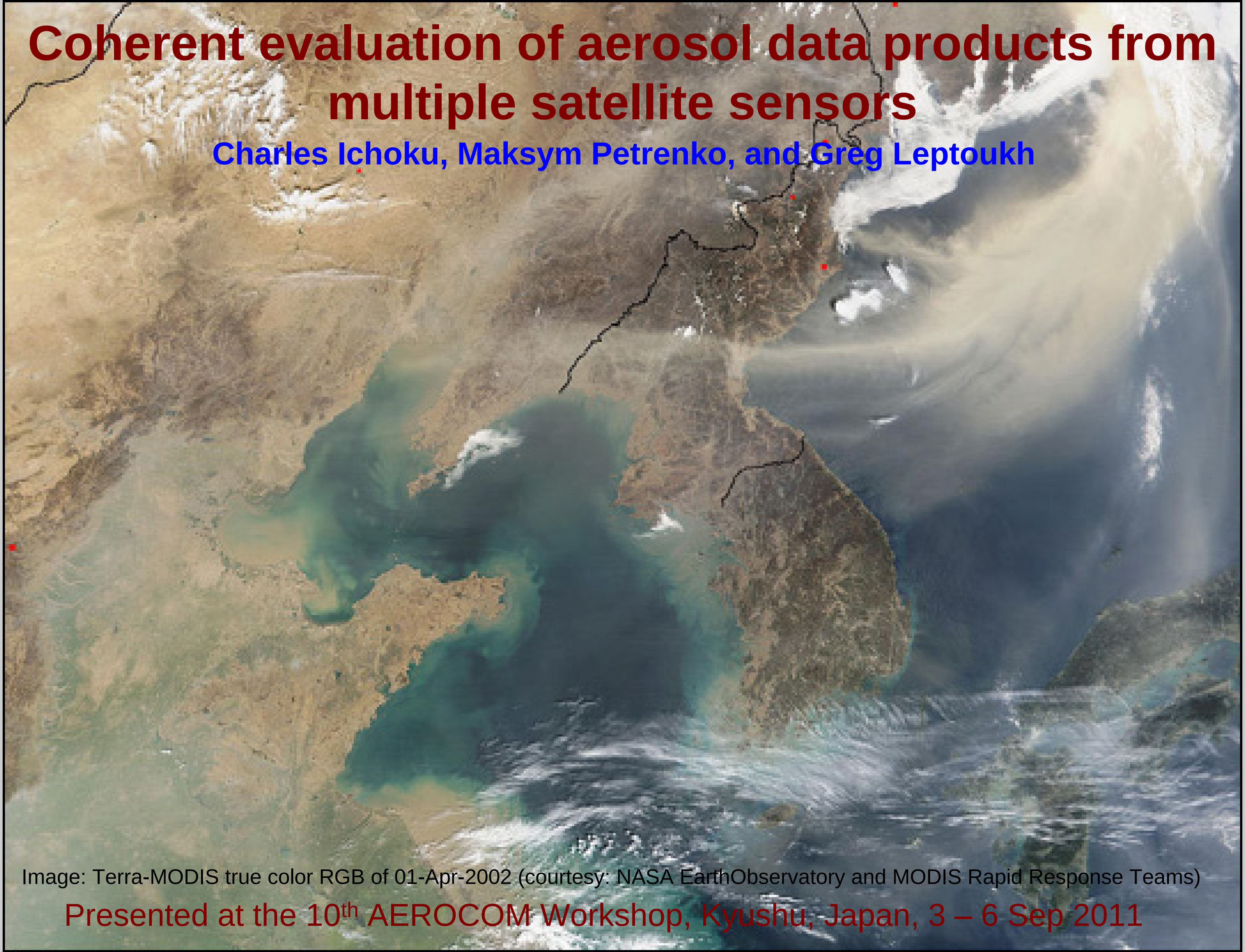


Image: Terra-MODIS true color RGB of 01-Apr-2002 (courtesy: NASA EarthObservatory and MODIS Rapid Response Teams)

Presented at the 10th AEROCOM Workshop, Kyushu, Japan, 3 – 6 Sep 2011

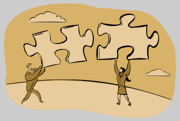
Outline

The MAPSS aerosol data sampling system

Coherent Uncertainty Analysis of Satellite Data

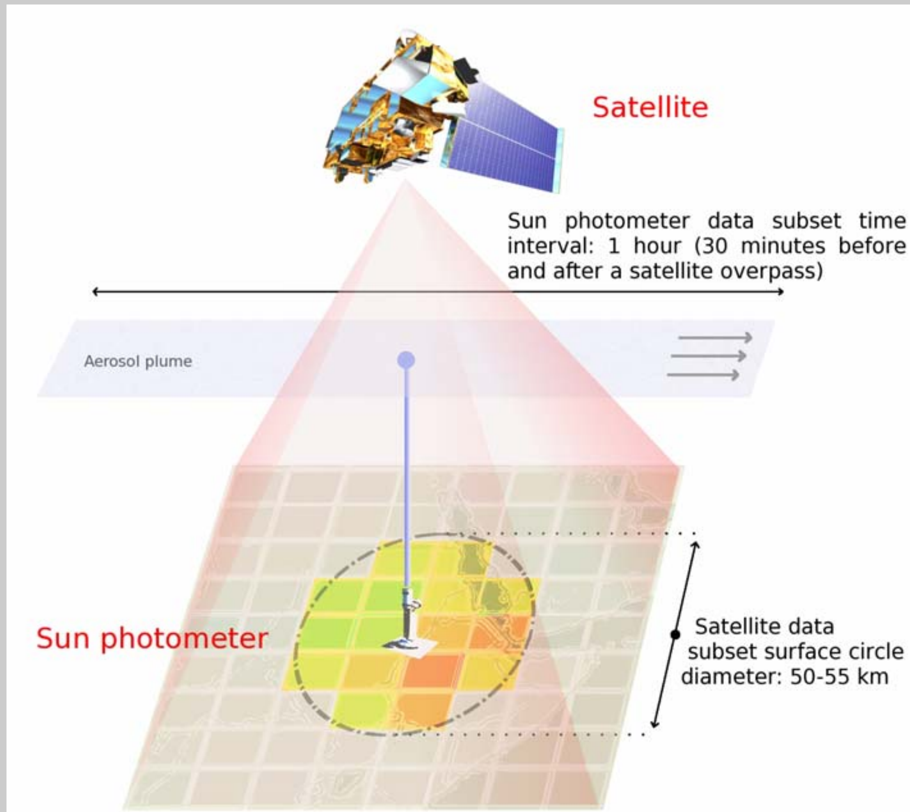
Potential for Model Evaluation using MAPSS

Future Possibilities (Suggestions needed)



MAPSS: Multi-sensor Aerosol Products Sampling System

- 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 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

Subset Statistics

1 Number of pixels in sample space
2 Valid pixel count (Nval)
3 Central pixel value
4 Mean
5 Median
6 Mode
7 Standard Deviation
8 Slope of Plane
9 Azimuth (direction) of slope
10 Multiple Correlation Coefficient
…

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/

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

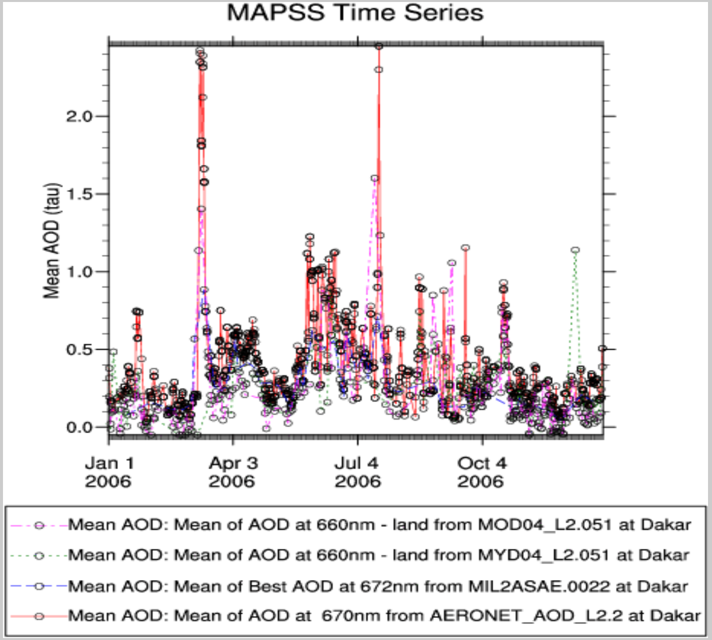
Start Date: 01/01/2007

End Date: 12/31/2007

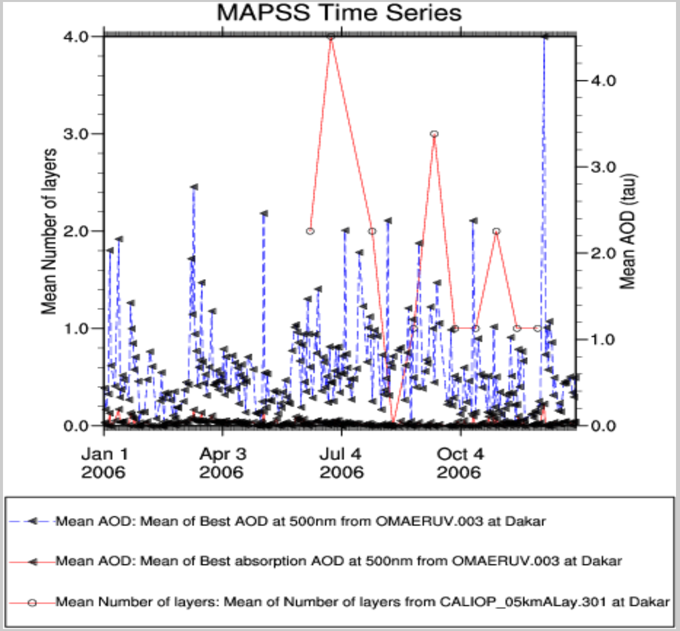
To see time series plots of MAPSS data, choose from the criteria below and click **Get Plot(s)**

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.

Outputs

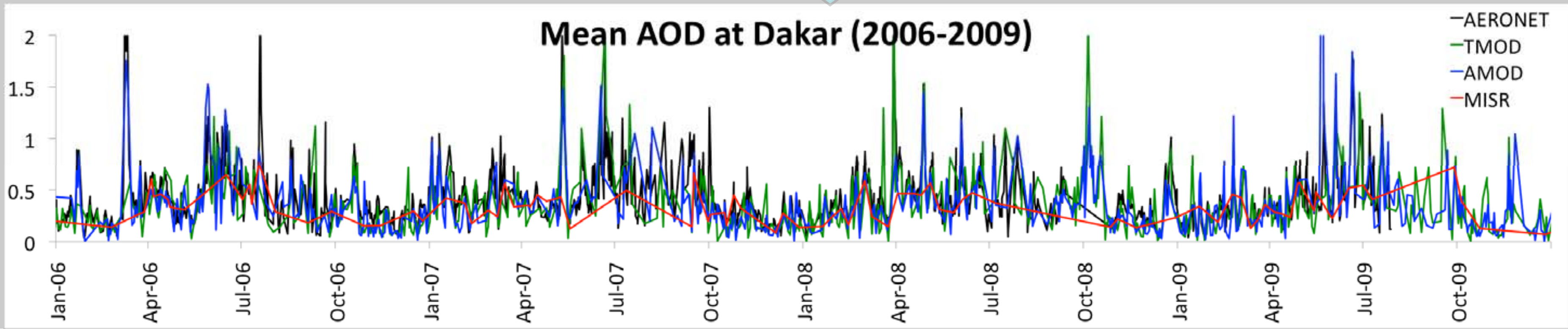


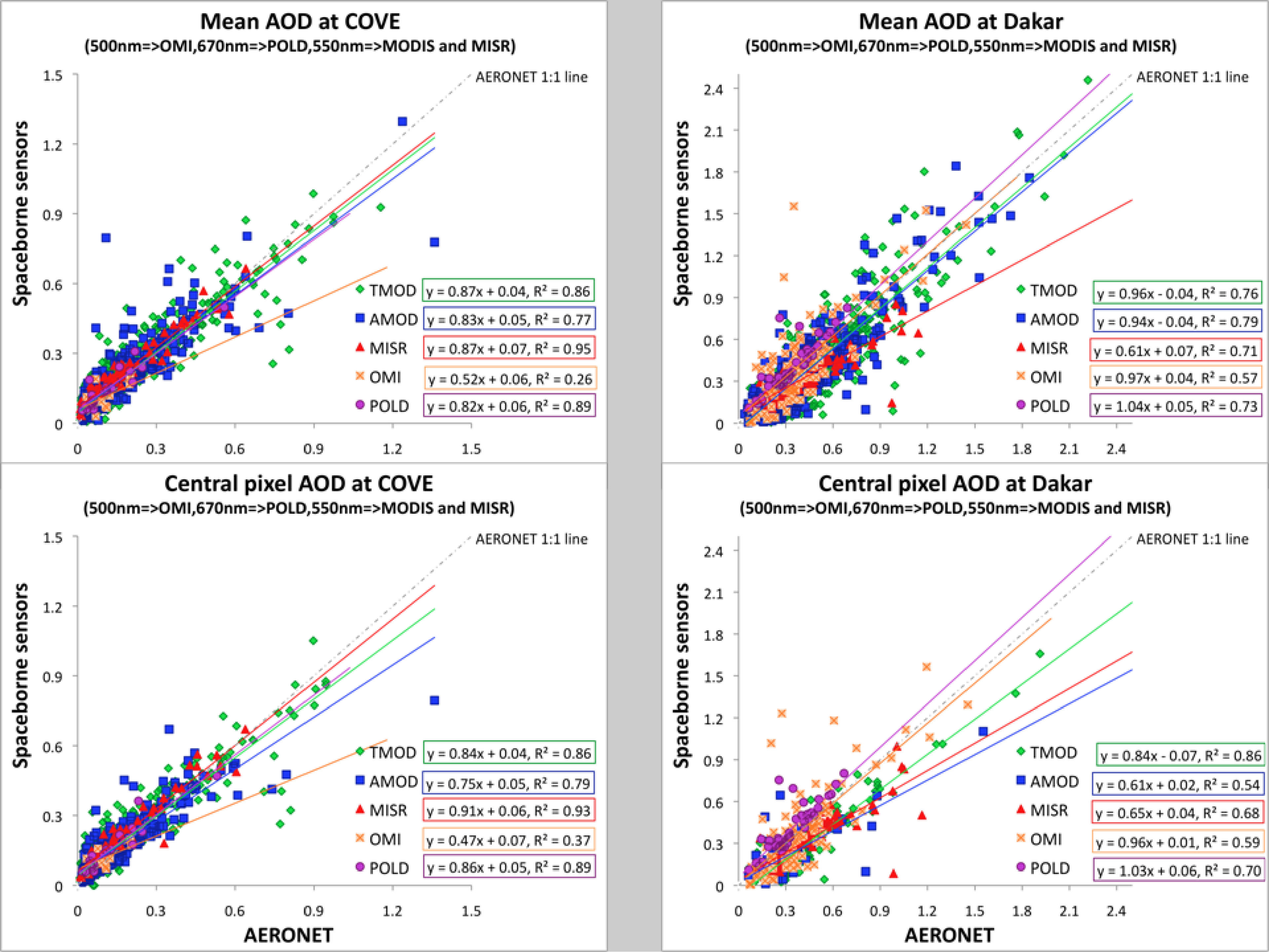
Time series



Data Table for Spreadsheet

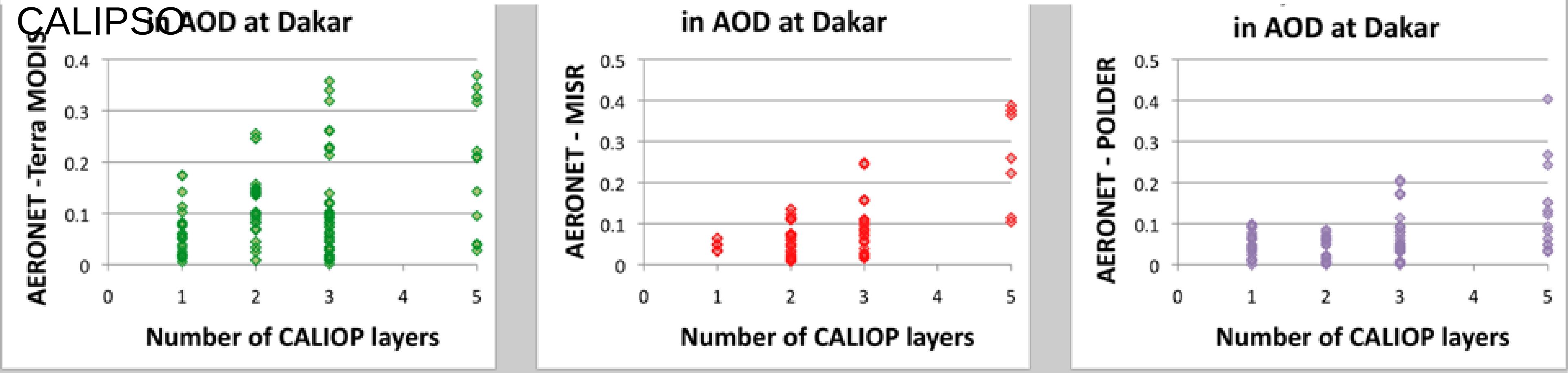
Title: MAPSS MAPSS Time Series				
Start date: 2006-01-01				
End date: 2007-12-31				
Station(s):				
datetime	mean_AERONET_AOD_L2_2_AOD0670_Dakar	mean_MOD04_L2_051_AOD0660corr_l_Dakar	mean_MYD04_L2_051_AOD0660corr_l_Dakar	mean_MIL2ASAE_0022_AOD0672b_Dakar
1/1/06 12:20	0.38	0.19		
1/4/06 14:15			0.49	
1/5/06 11:55		0.11		
1/9/06 11:30	0.22	-0.04		
1/9/06 14:33			-0.01	
1/12/06 12:00		0.14		
1/13/06 14:09	0.23		0.1	
1/13/06 14:24	0.23			
1/14/06 11:45	0.3	0.18		
1/14/06 11:49				0.08



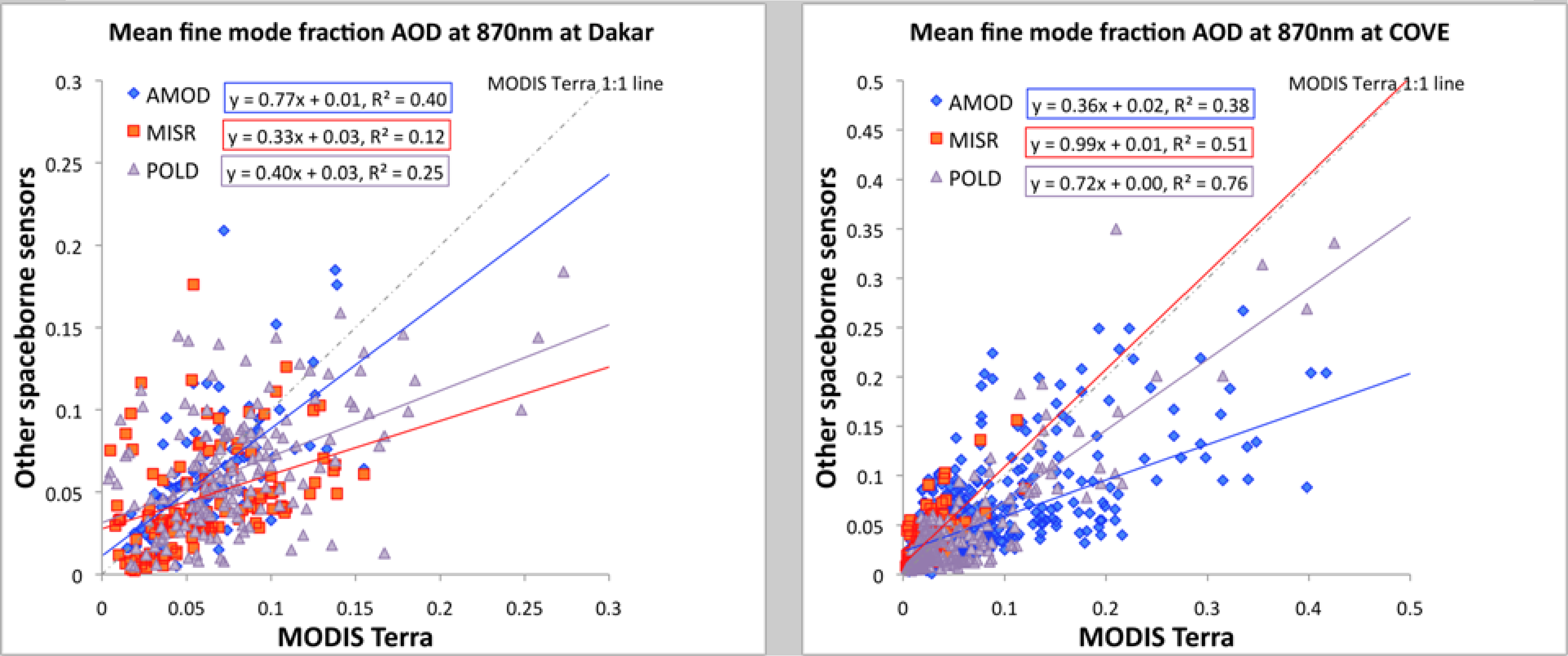


Mean AOD at COVE
(500nm=>OMI,670nm=>POLD,550nm=>MODIS and MISR)
Mean AOD at Dakar
(500nm=>OMI,670nm=>POLD,550nm=>MODIS and MISR)
Central pixel AOD at COVE
(500nm=>OMI,670nm=>POLD,550nm=>MODIS and MISR)
Central pixel AOD at Dakar
(500nm=>OMI,670nm=>POLD,550nm=>MODIS and MISR)
AERONET 1:1 line
Spaceborne sensors
AERONET
TMOD
AMOD
MISR
OMI
POLD
y = 0.87x + 0.04, R² = 0.86
y = 0.83x + 0.05, R² = 0.77
y = 0.87x + 0.07, R² = 0.95
y = 0.52x + 0.06, R² = 0.26
y = 0.82x + 0.06, R² = 0.89
y = 0.96x - 0.04, R² = 0.76
y = 0.94x - 0.04, R² = 0.79
y = 0.61x + 0.07, R² = 0.71
y = 0.97x + 0.04, R² = 0.57
y = 1.04x + 0.05, R² = 0.73
y = 0.84x + 0.04, R² = 0.86
y = 0.75x + 0.05, R² = 0.79
y = 0.91x + 0.06, R² = 0.93
y = 0.47x + 0.07, R² = 0.37
y = 0.86x + 0.05, R² = 0.89
y = 0.84x - 0.07, R² = 0.86
y = 0.61x + 0.02, R² = 0.54
y = 0.65x + 0.04, R² = 0.68
y = 0.96x + 0.01, R² = 0.59
y = 1.03x + 0.06, R² = 0.70

AERONET-Satellite AOD Differences as a Function of Number of Layers from CALIPSO



Comparison of Satellite-Satellite Fine Mode Fraction at 870 nm at two locations



Ongoing Work

Recently Funded (2011) under ROSES 2009 Uncertainty Analysis

“Coherent uncertainty analysis of aerosol data products from multiple satellites”

PI: Charles Ichoku
Postdoc: Maksym Petrenko
Collaborators: Greg Leptoukh, Oleg Dubovik, Ali Omar

PROJECT METHODOLOGY: Utilize MAPSS and AeroStat to do:

- Uncertainty Analysis at Individual Sites
- Global Uncertainty Analysis Maps
- Identification of Sources of Uncertainty
- Integration of Aerosol Products from Future Sensors

Smoke Aerosols in Alta-Floresta, Brazil

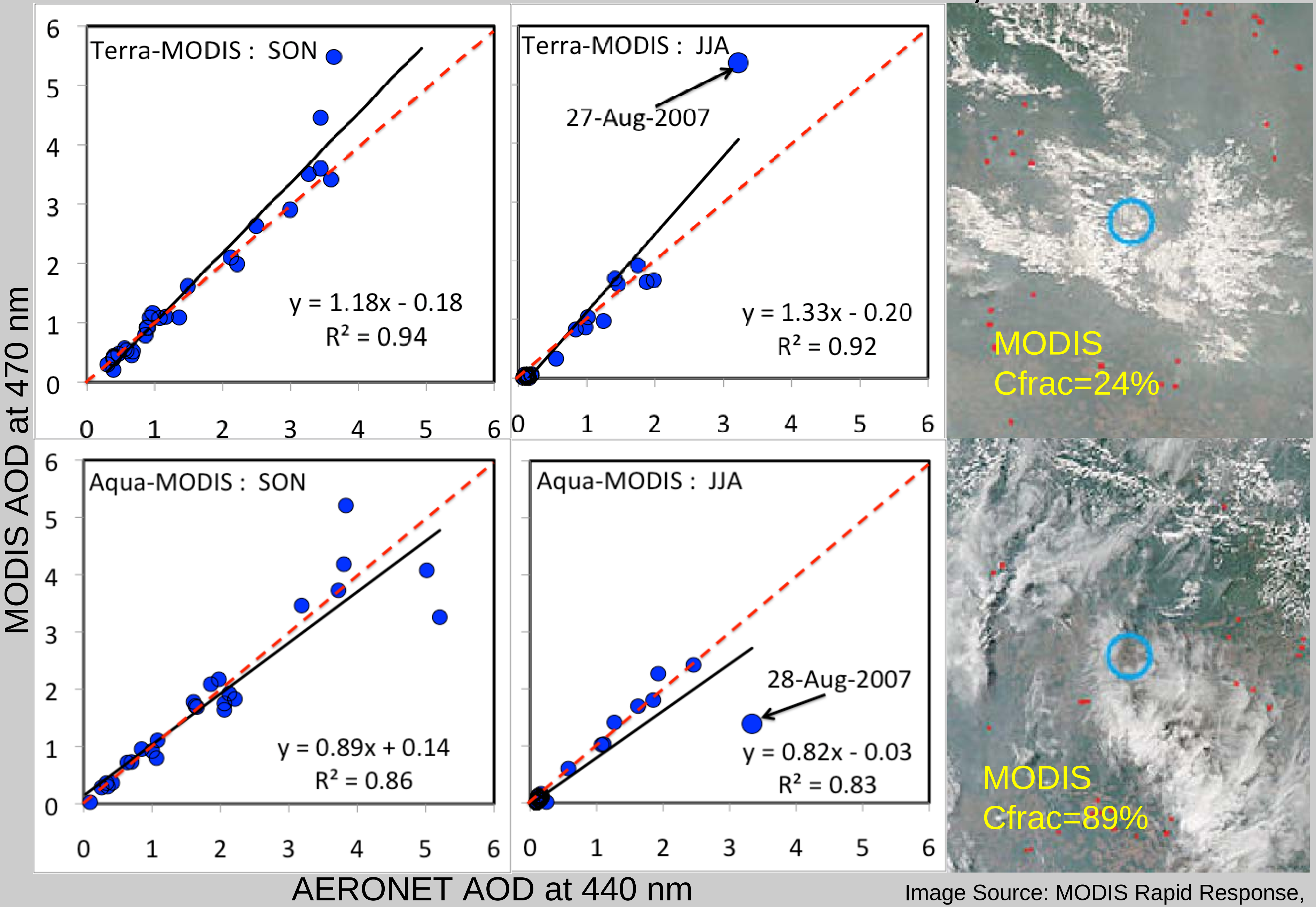
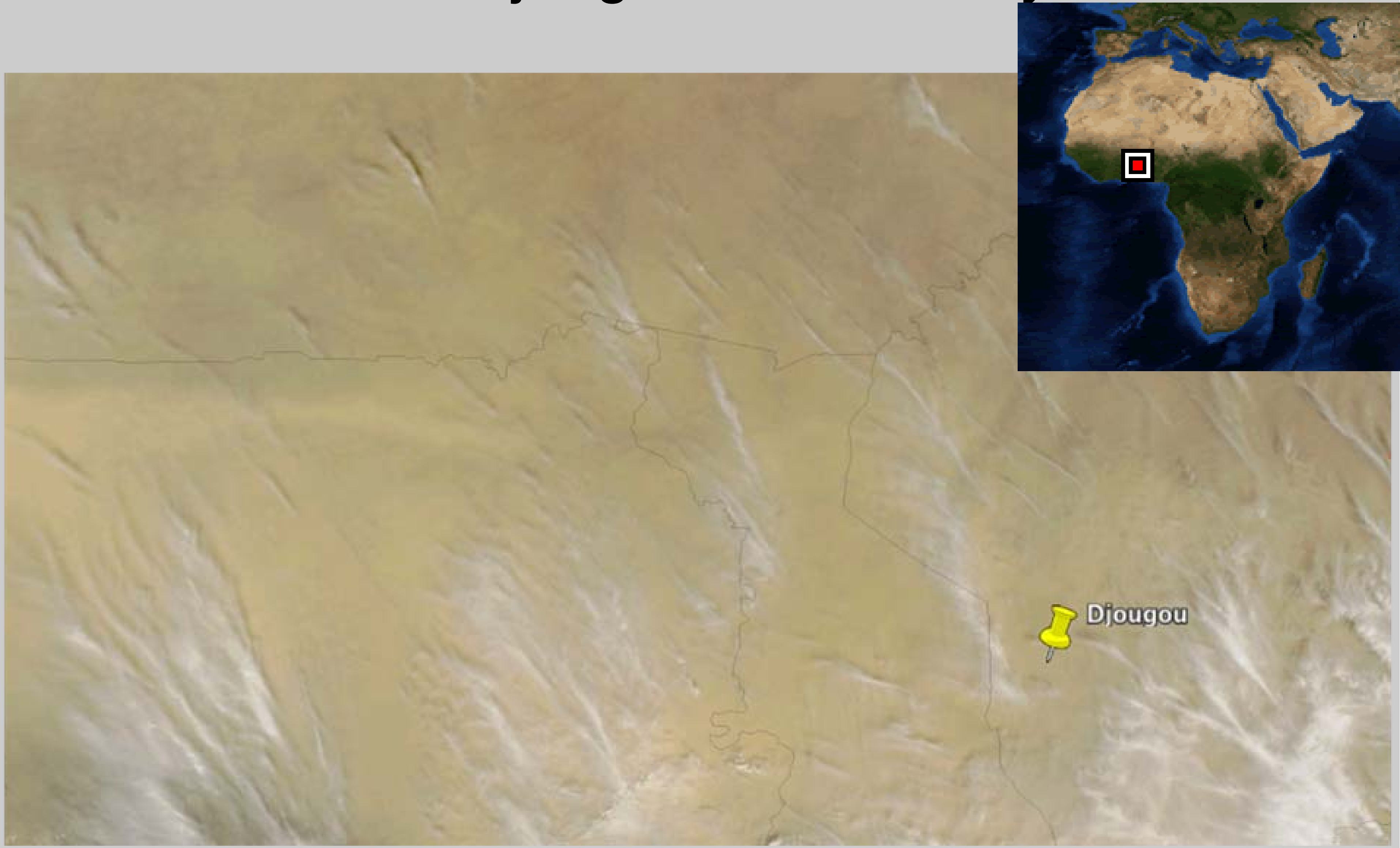
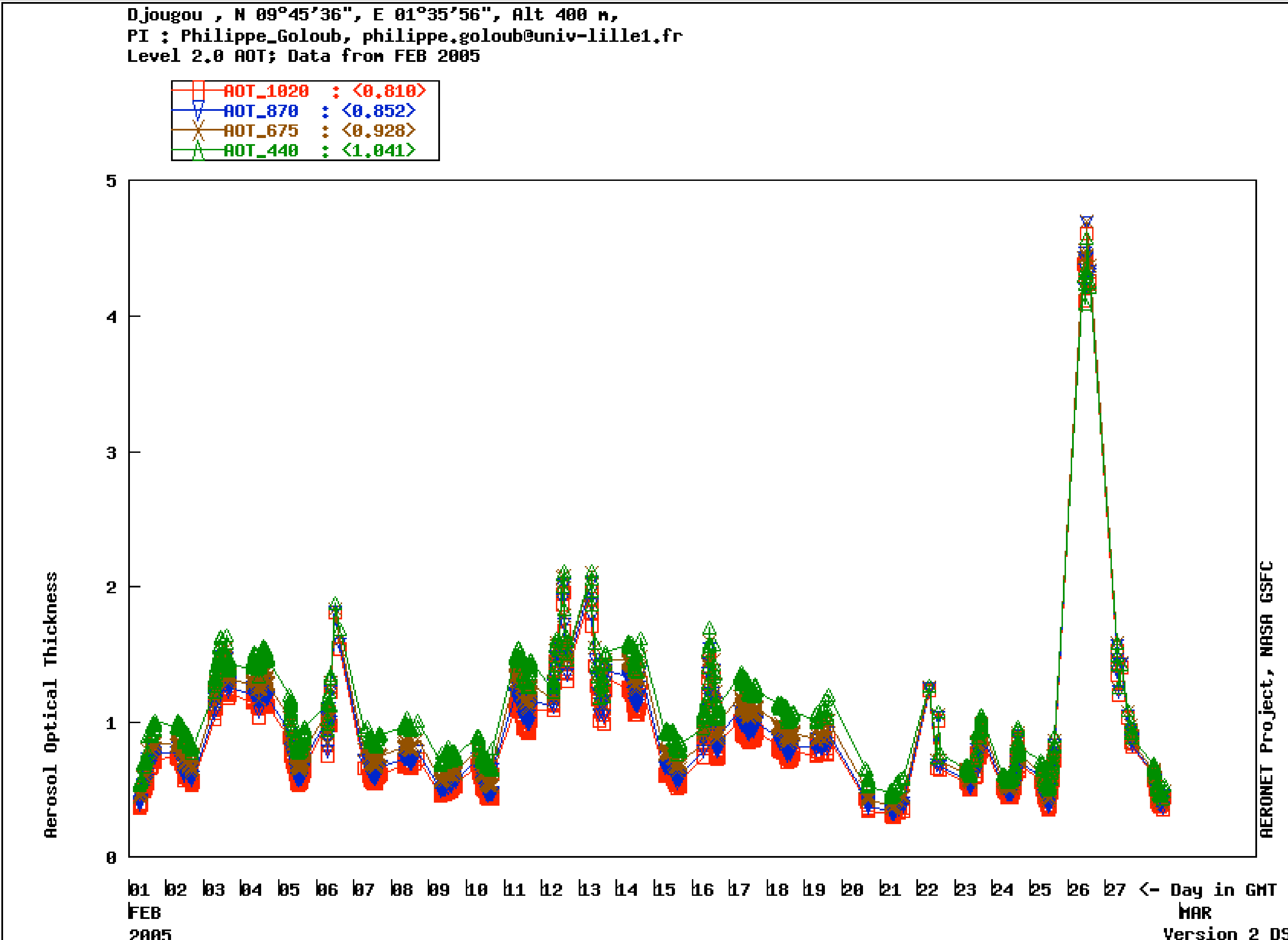


Image Source: MODIS Rapid Response, and AERONET Data Synergy Tool

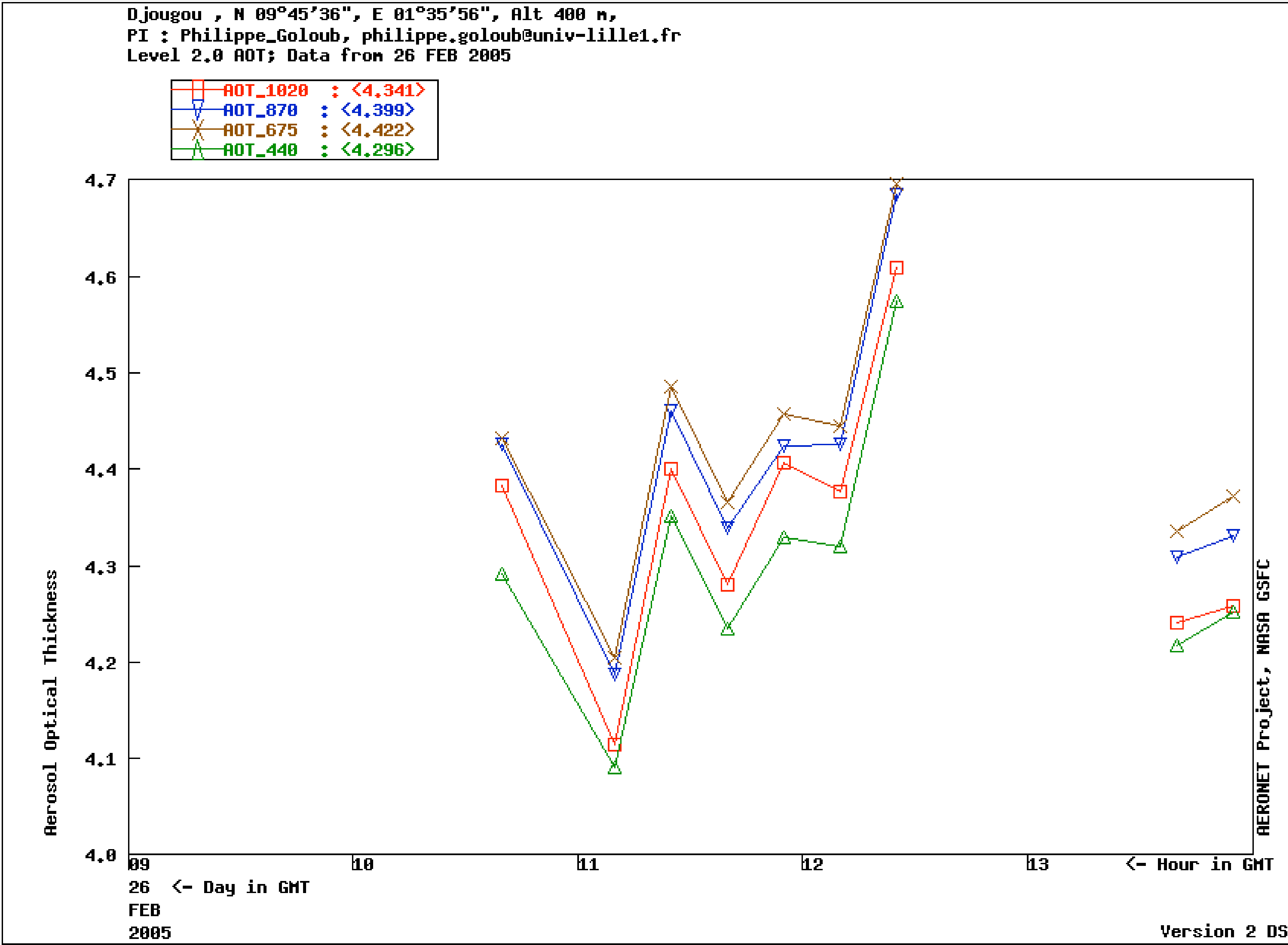
Dust storm in Djougou on February 26, 2005



Source: MODIS Terra Rapid Response, AERONET Data Synergy Tool

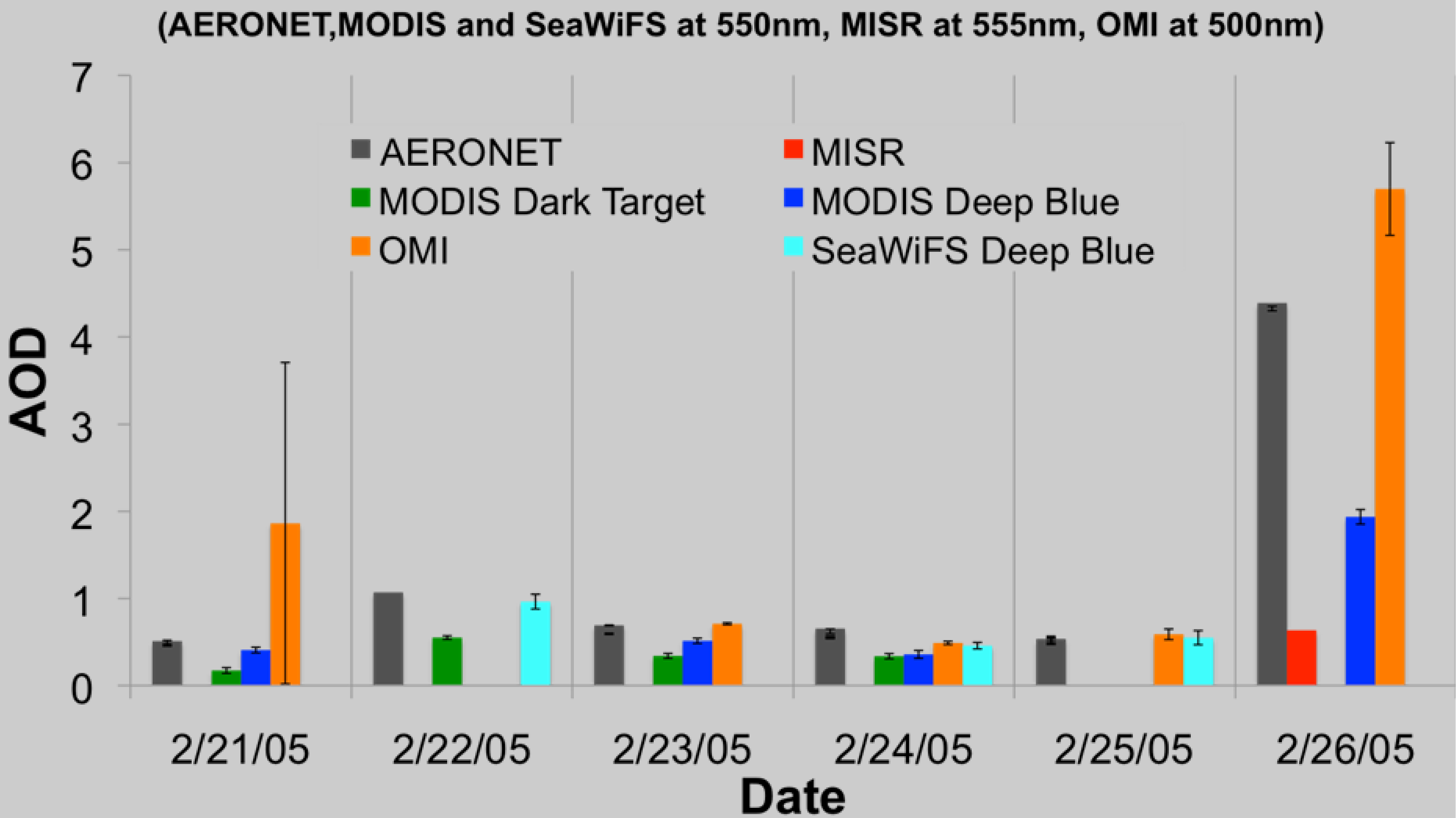


Djougou , N 09°45'36", E 01°35'56", Alt 400 m,
PI : Philippe_Goloub, philippe.goloub@univ-lille1.fr
Level 2.0 AOT; Data from FEB 2005
AOT_1020 : <0.810>
AOT_870 : <0.852>
AOT_675 : <0.928>
AOT_440 : <1.041>
Aerosol Optical Thickness
0
1
2
3
4
5
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 <- Day in GMT
FEB
2005
MAR
AERONET Project, NASA GSFC
Version 2 DS

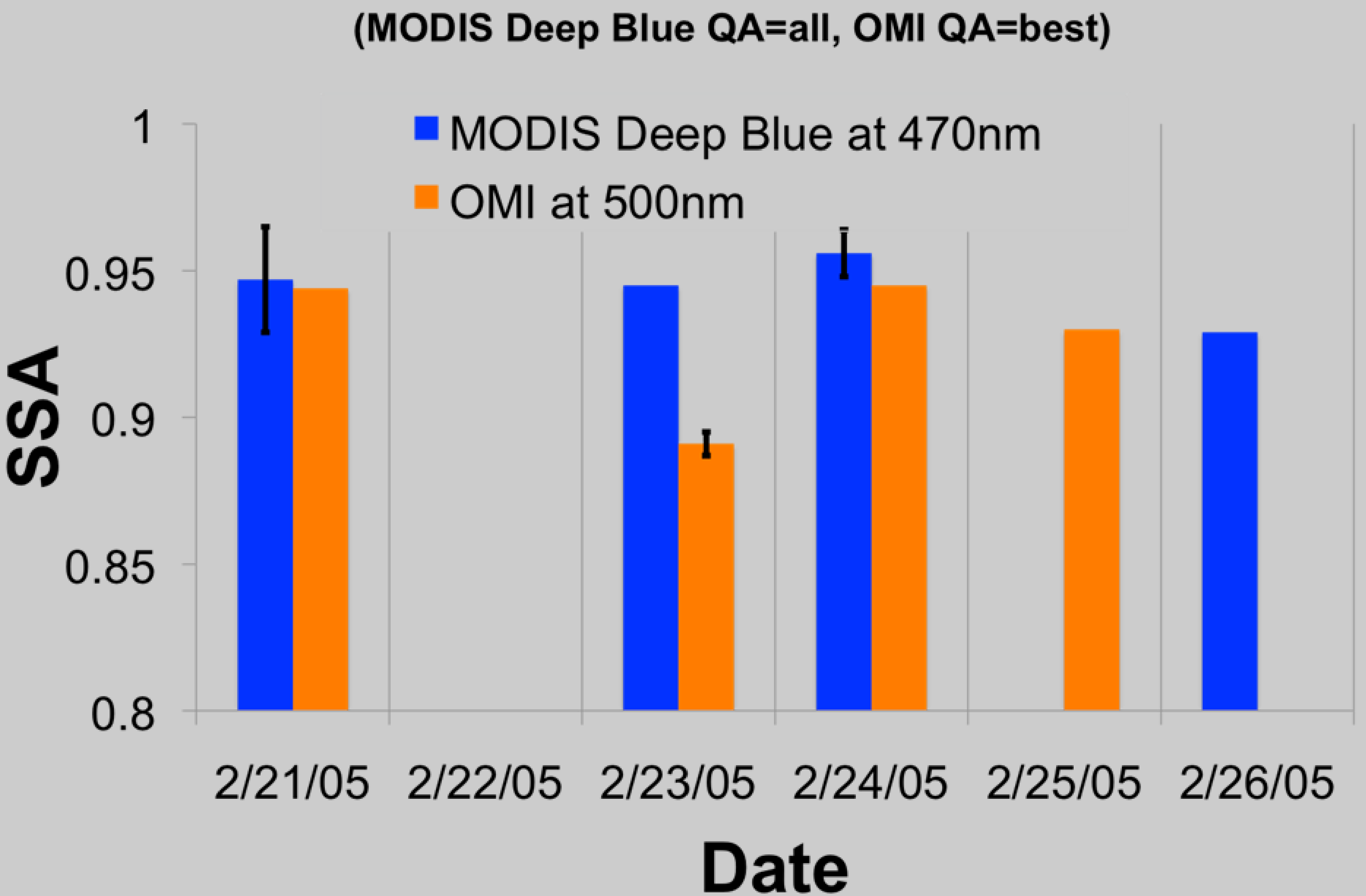


Djougou , N 09°45'36", E 01°35'56", Alt 400 m,
PI : Philippe_Goloub, philippe.goloub@univ-lille1.fr
Level 2.0 AOT; Data from 26 FEB 2005
AOT_1020 : <4.341>
AOT_870 : <4.399>
AOT_675 : <4.422>
AOT_440 : <4.296>
Aerosol Optical Thickness
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
09
10
11
12
13
<- Hour in GMT
26 <- Day in GMT
FEB
2005
AERONET Project, NASA GSFC
Version 2 DS

All-QA AOD from multiple sensors over Djougou

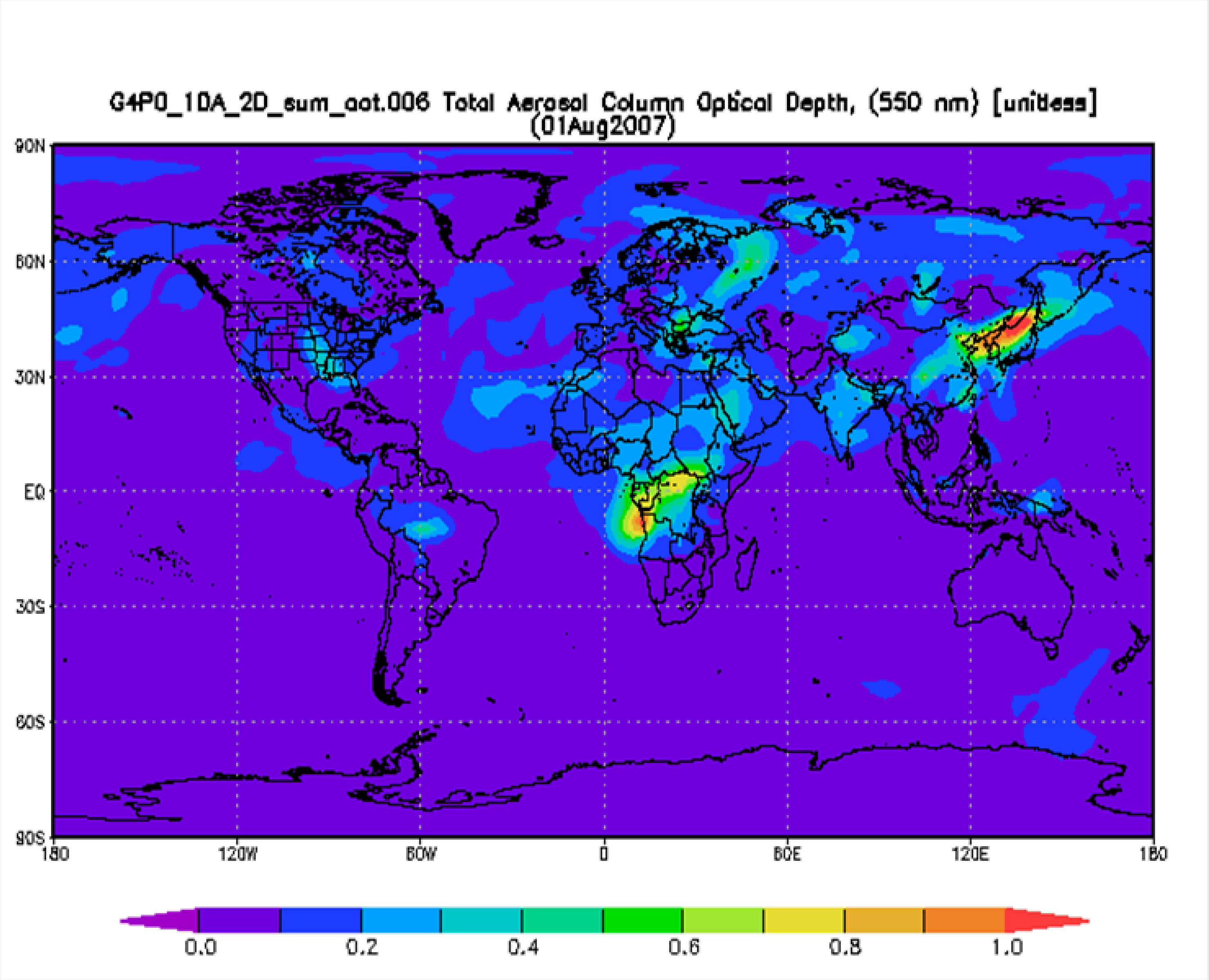


Mean Single Scattering Albedo at Djougou



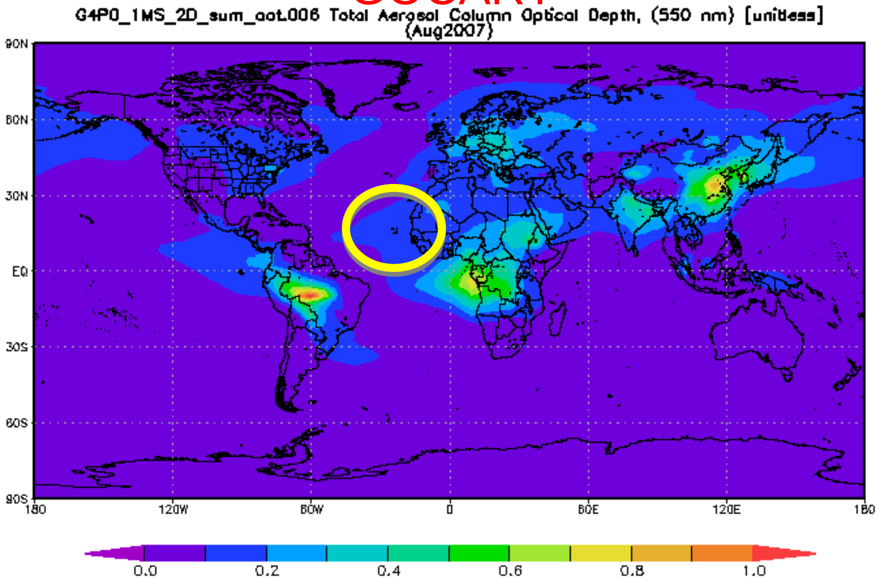
Potential of Model Evaluation using MAPSS

GOCART daily AOD

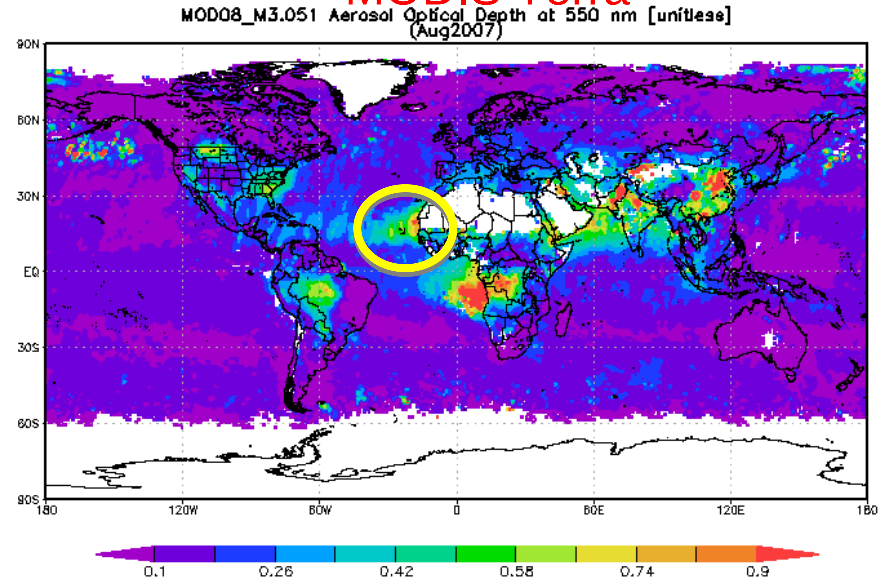


Global monthly AOD for August 2007

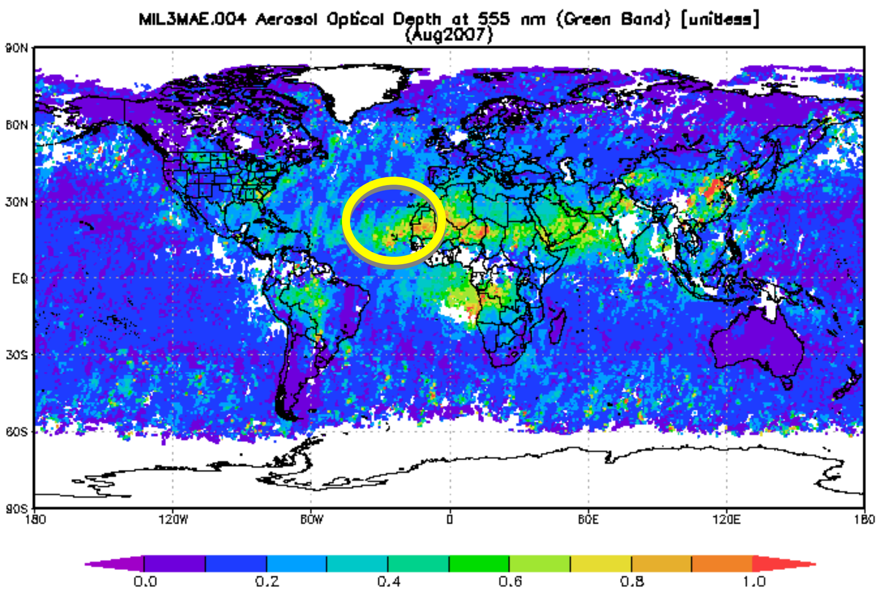
GOCART



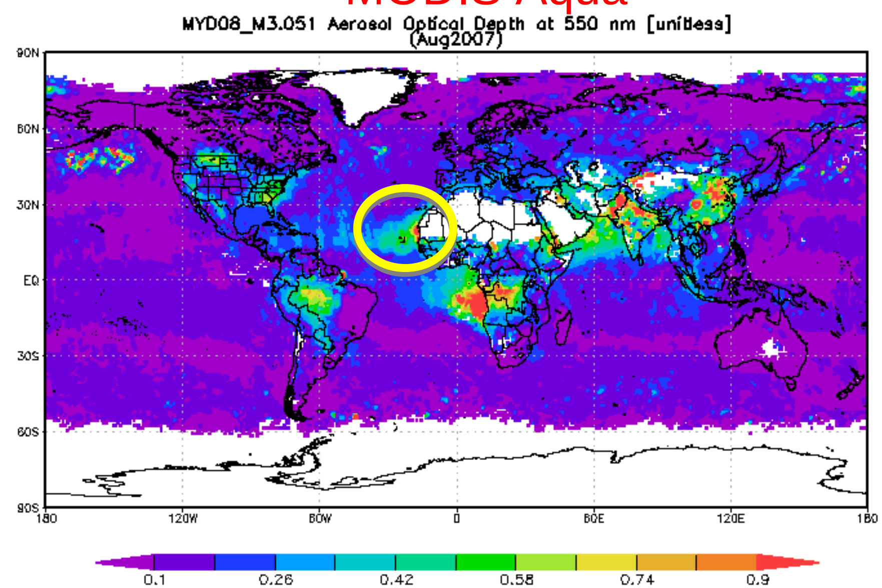
MODIS Terra



MISR

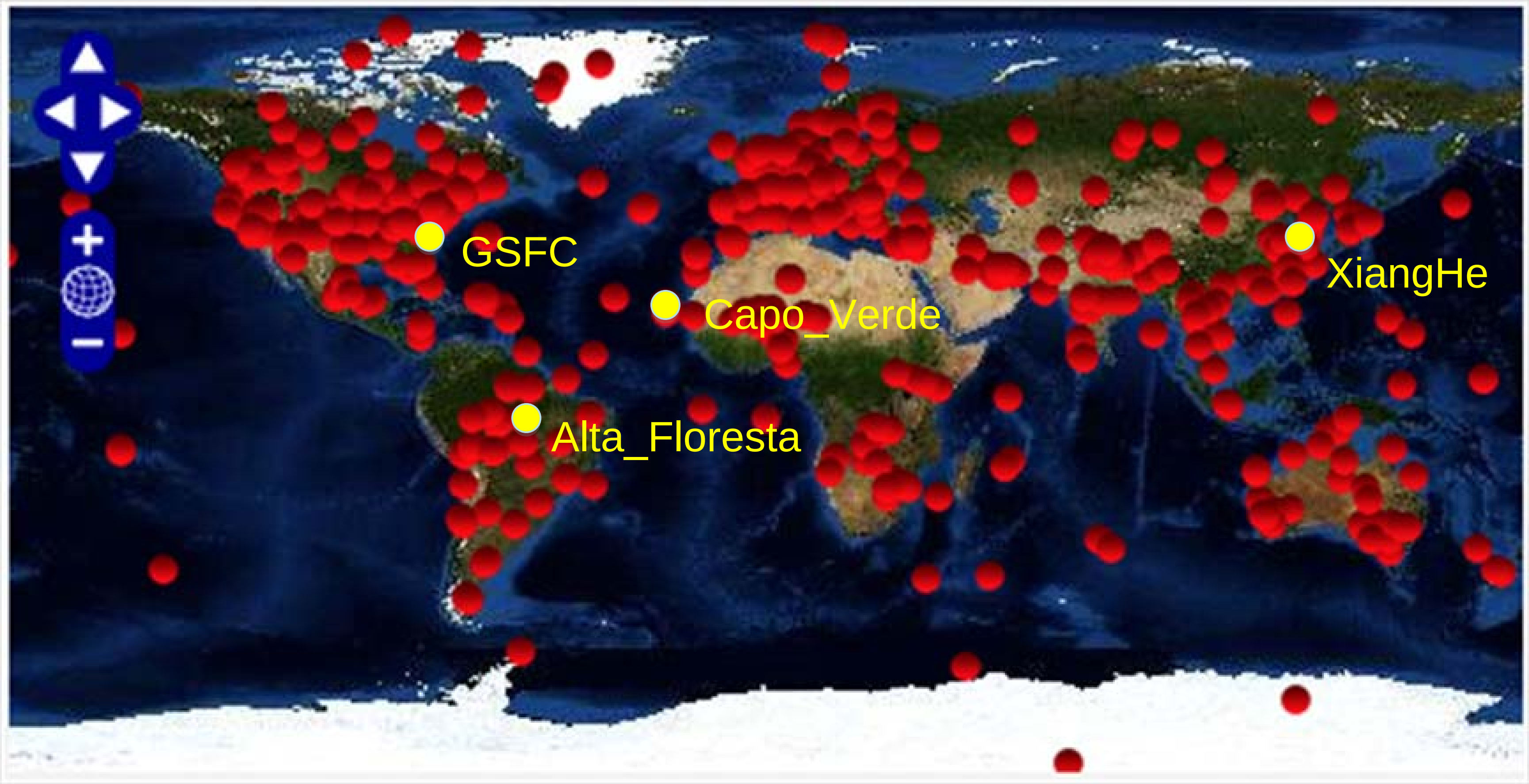


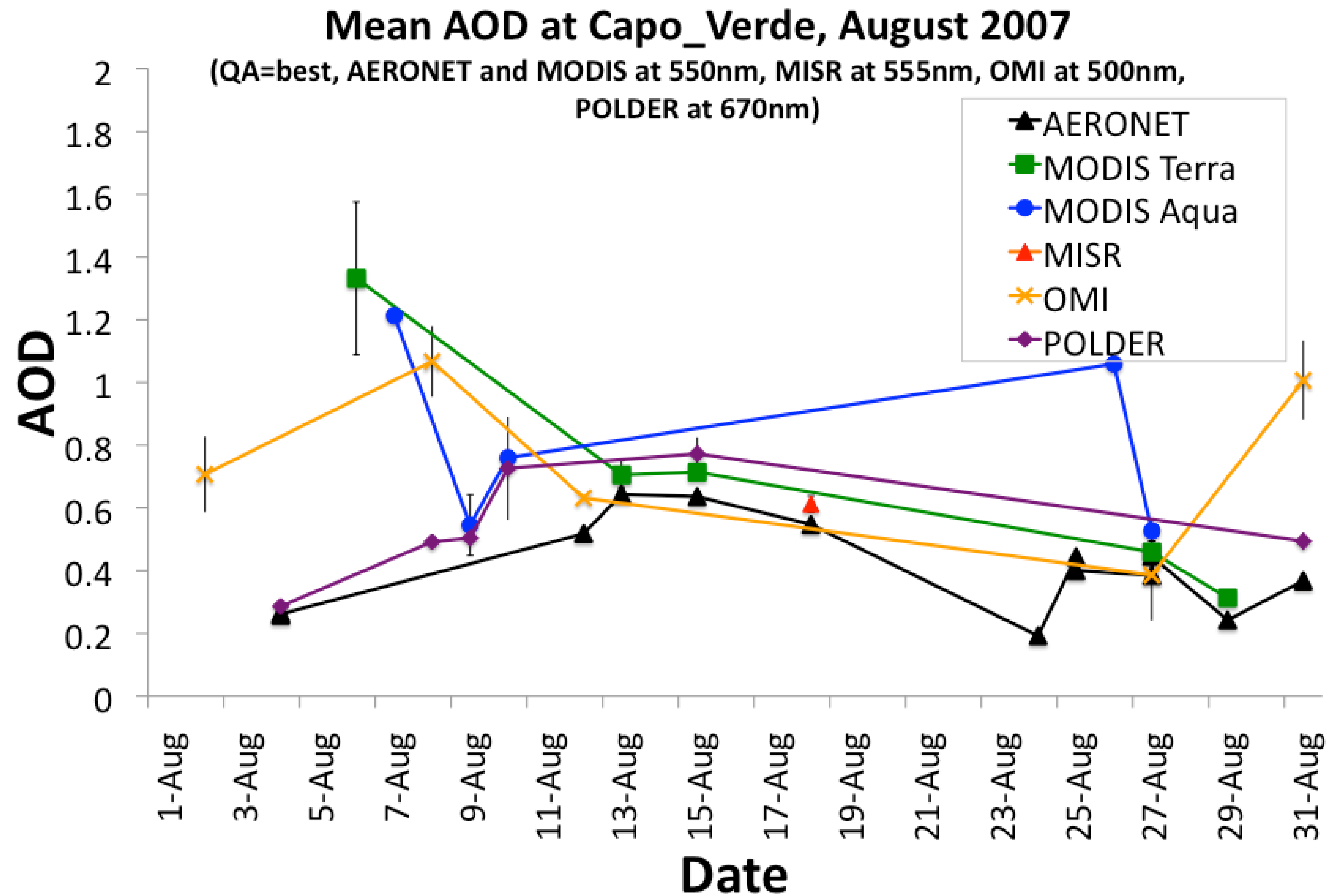
MODIS Aqua



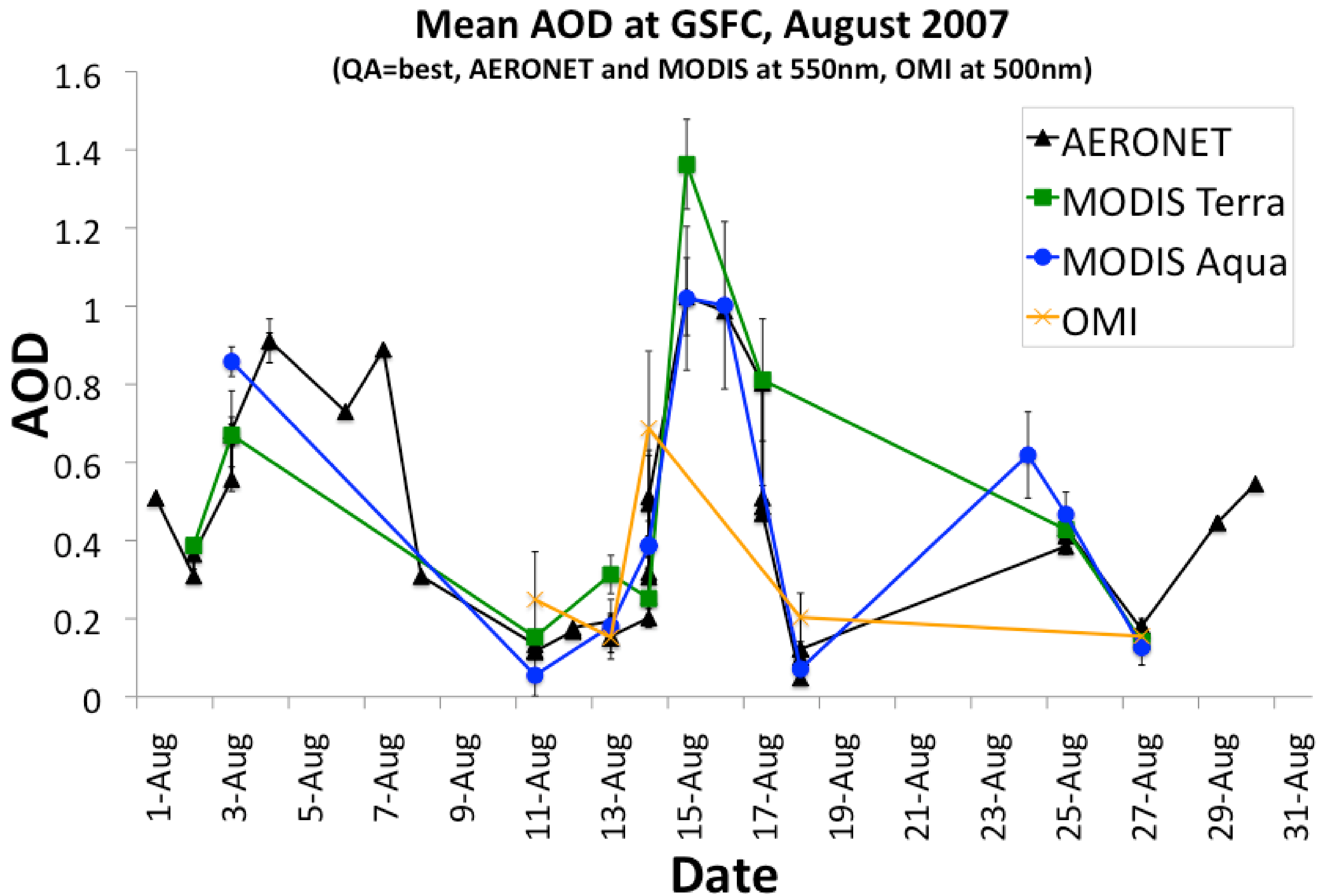
Current Possibility of Model Evaluation using MAPSS

MAPSS coverage and selected sites

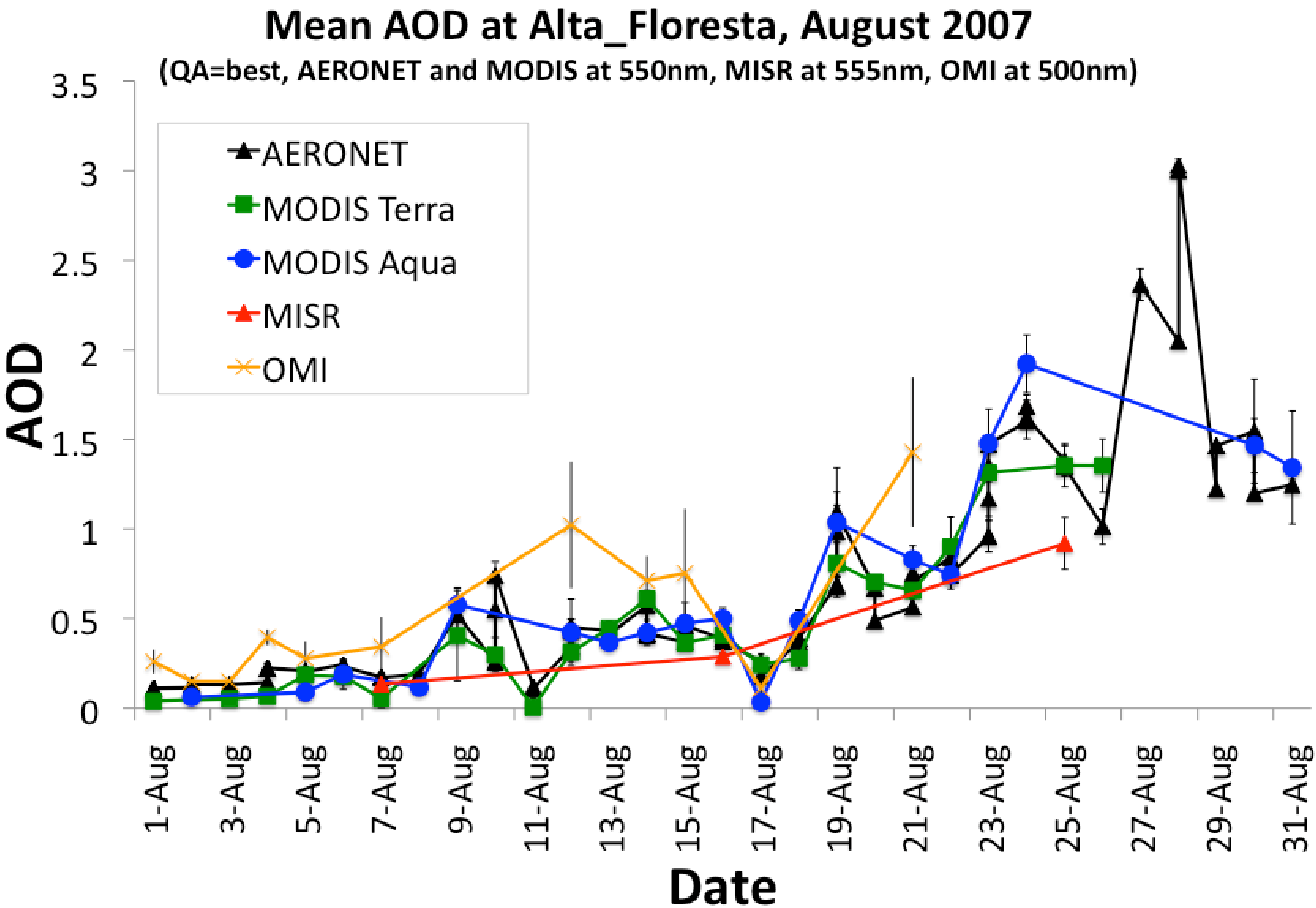




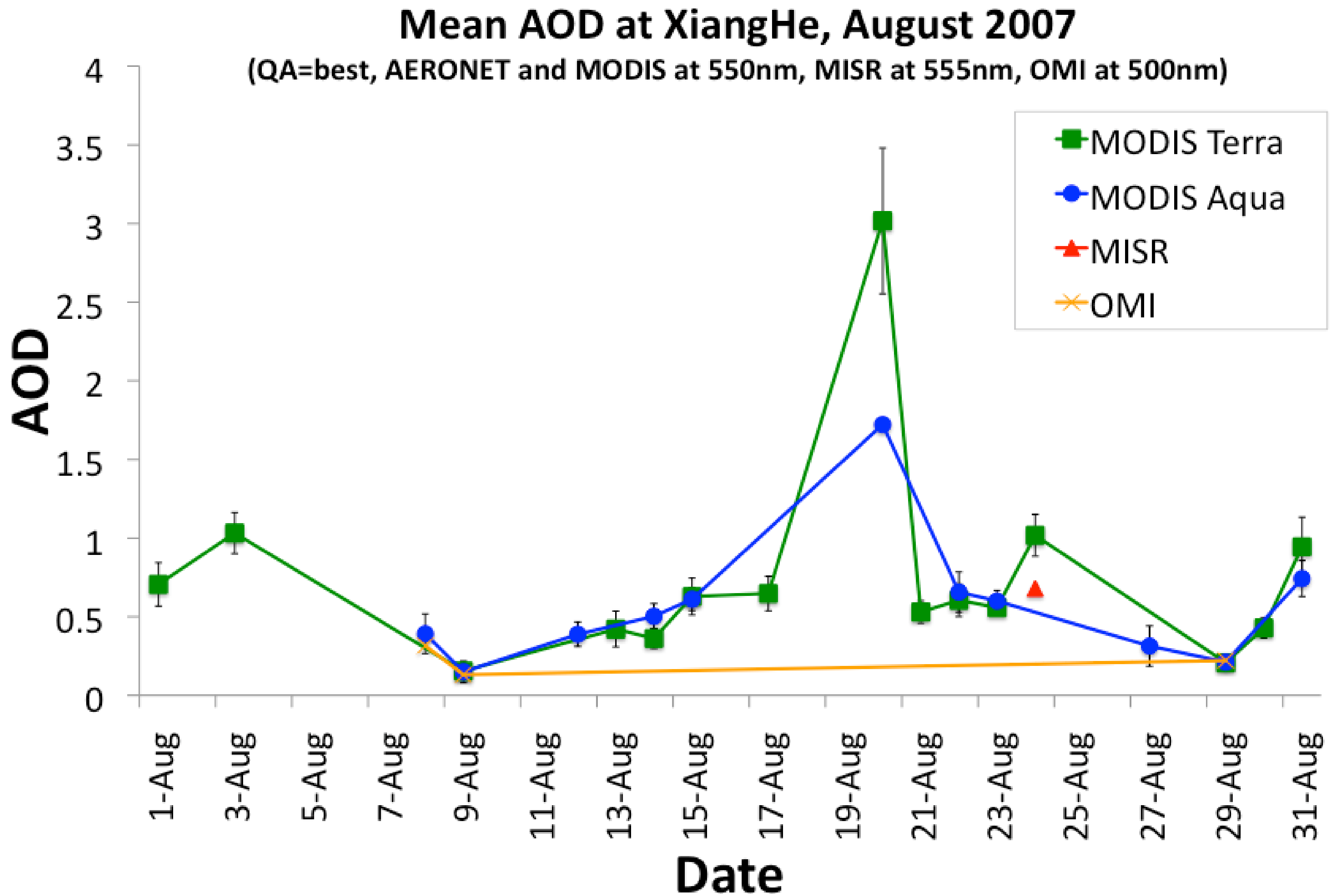
Mean AOD at Capo_Verde, August 2007
(QA=best, AERONET and MODIS at 550nm, MISR at 555nm, OMI at 500nm, POLDER at 670nm)
AERONET
MODIS Terra
MODIS Aqua
MISR
OMI
POLDER
AOD
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1-Aug
3-Aug
5-Aug
7-Aug
9-Aug
11-Aug
13-Aug
15-Aug
17-Aug
19-Aug
21-Aug
23-Aug
25-Aug
27-Aug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



Mean AOD at GSFC, August 2007
(QA=best, AERONET and MODIS at 550nm, OMI at 500nm)
AOD
Date
AERONET
MODIS Terra
MODIS Aqua
OMI
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
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



Mean AOD at Alta_Floresta, August 2007
(QA=best, AERONET and MODIS at 550nm, MISR at 555nm, OMI at 500nm)
AOD
3.5
3
2.5
2
1.5
1
0.5
0
AERONET
MODIS Terra
MODIS Aqua
MISR
OMI
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

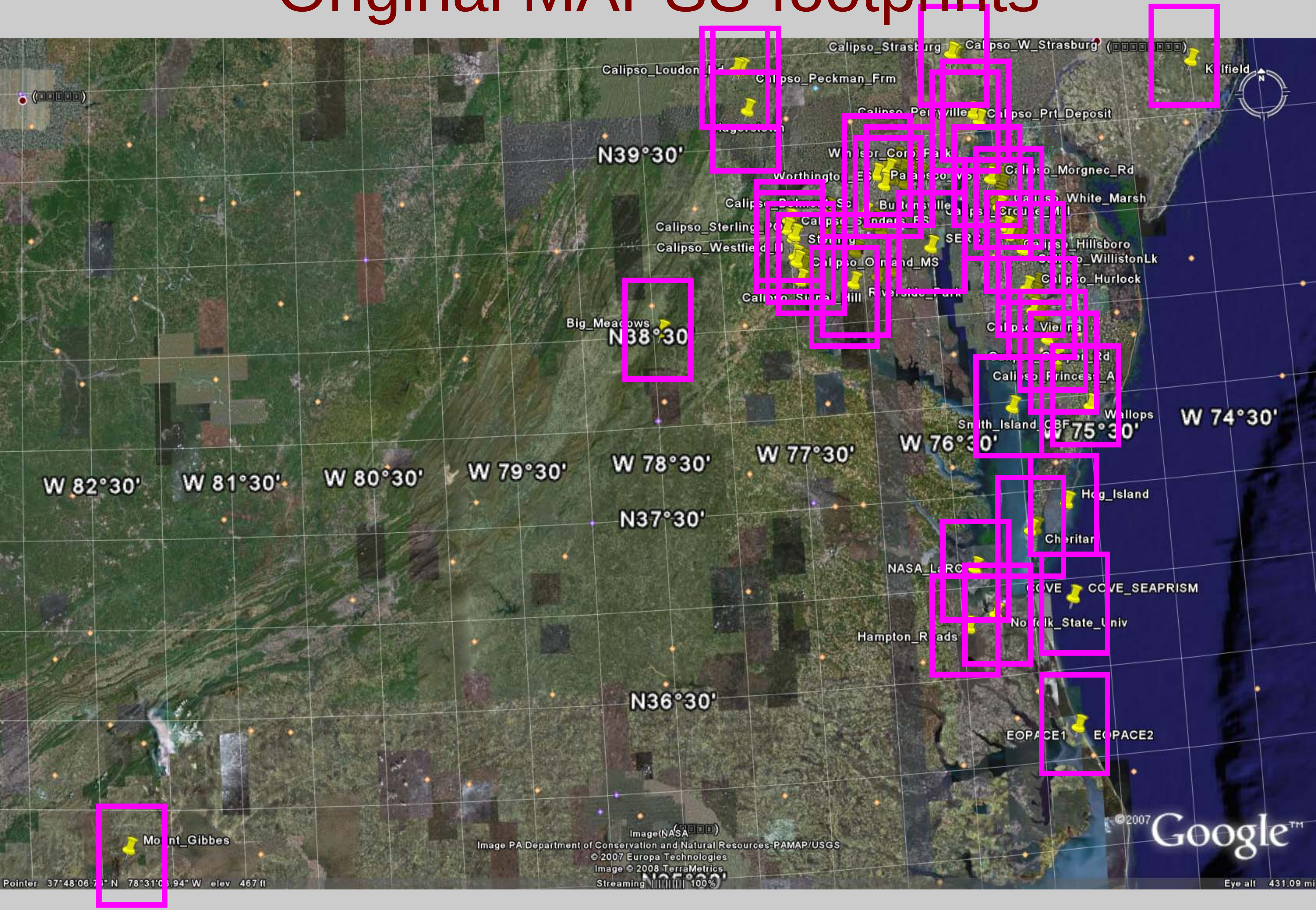


Mean AOD at XiangHe, August 2007
(QA=best, AERONET and MODIS at 550nm, MISR at 555nm, OMI at 500nm)
AOD
4
3.5
3
2.5
2
1.5
1
0.5
0
MODIS Terra
MODIS Aqua
MISR
OMI
1-Aug
3-Aug
5-Aug
7-Aug
9-Aug
11-Aug
13-Aug
15-Aug
17-Aug
19-Aug
21-Aug
23-Aug
25-Aug
27-Aug
29-Aug
31-Aug
Date

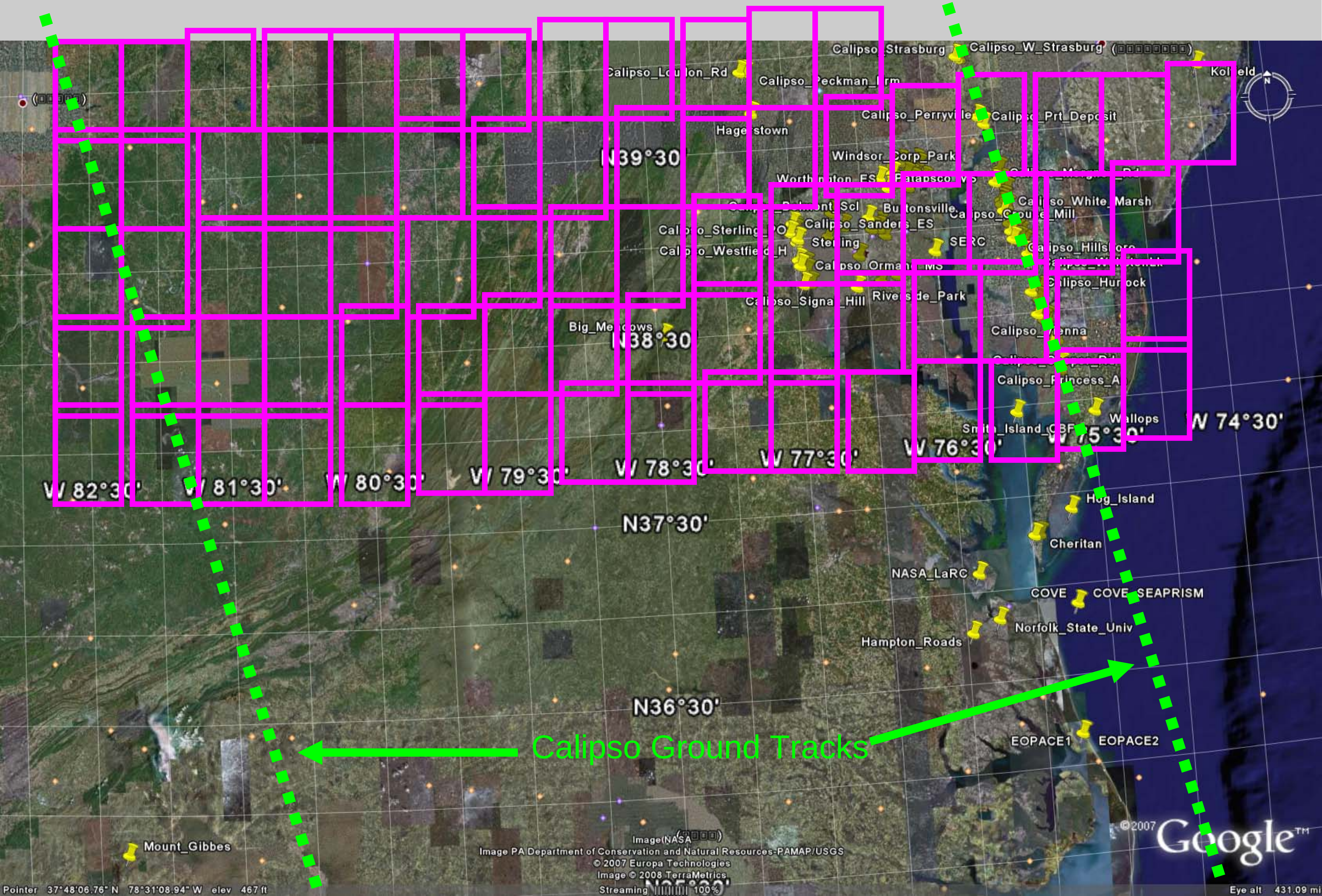
Future Potential
Option 1

Input needed

Original MAPSS footprints



Proposed Multi-sensor footprints



It is not the same as Level 3 satellite data

Level 3	Validation data
Grid-oriented	Point-oriented
Daily averages	Time-segregated
Grid-box area decreases poleward	Same 50x50 km everywhere
Sensor-specific aggregation	Uniform aggregation for all data
Not suited for validation	Designed for validation

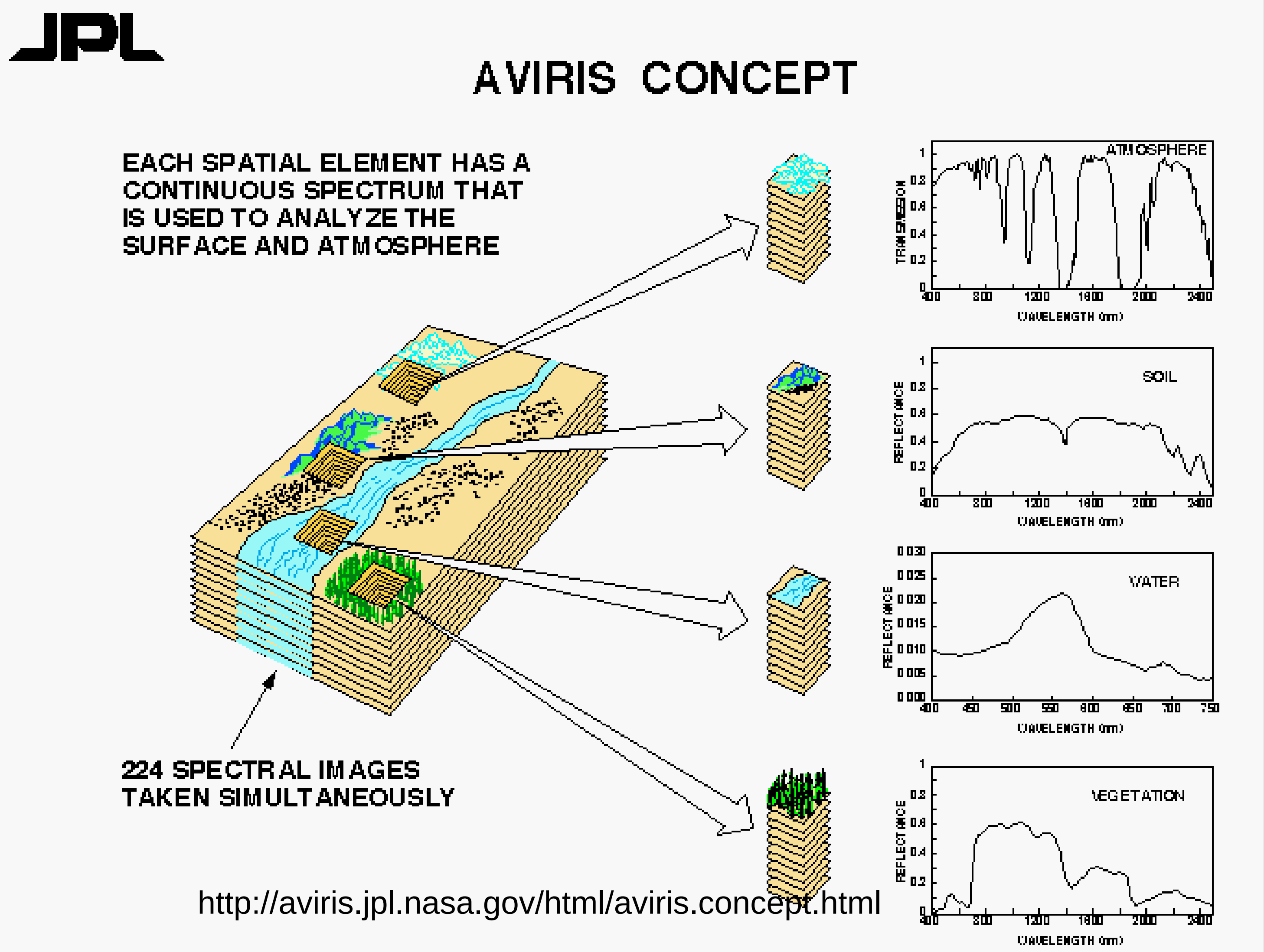
Advantages

- Horizontal/time resolutions tested for satellite aerosol validation (MAPSS).
- Uniform framework for analysis, calibration, comparison, and validation.
- Points are global, fixed to earth, and can be easily referenced and mapped.
- No need to memorize location name: Lon/Lat coordinates are sufficient.
- Existing In situ measurements can be easily linked to boxes.
- Finer resolution analyses performed within specific (50x50 km) boxes.
- Plan future field campaigns with reference to precise box locations.
- Other atmospheric, land, and ocean data easily integrated eventually.
- Long term: aerosol impacts tracked at various scales (local, regional, global).

Future Potential Option 2

Input needed

Implementation: Open Search based on Hyperspectral image Concept



Data structure:

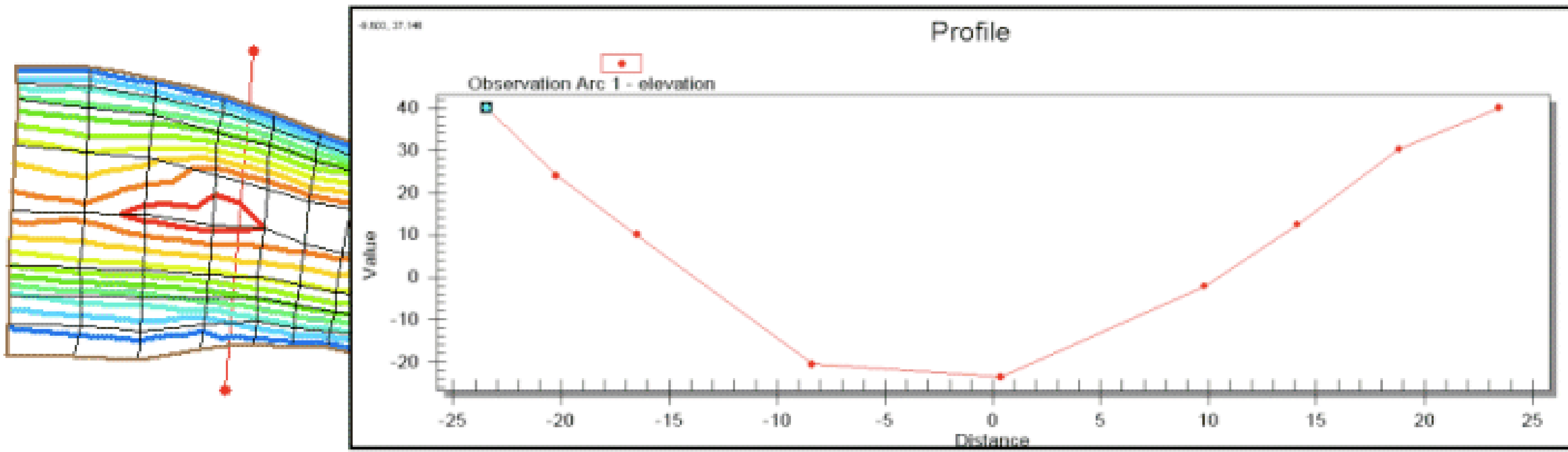
Globally, 1 file per year (e.g. MODIS AOD550 at 10-km res) ~ 4000x2000x366x2 = ~6 Mb X ~250 parameters per sensor X ~8-15 sensors X 20 years = ~450 Gb per Collection

Use FORTRAN90 for efficient point subset extraction and statistics calculation.

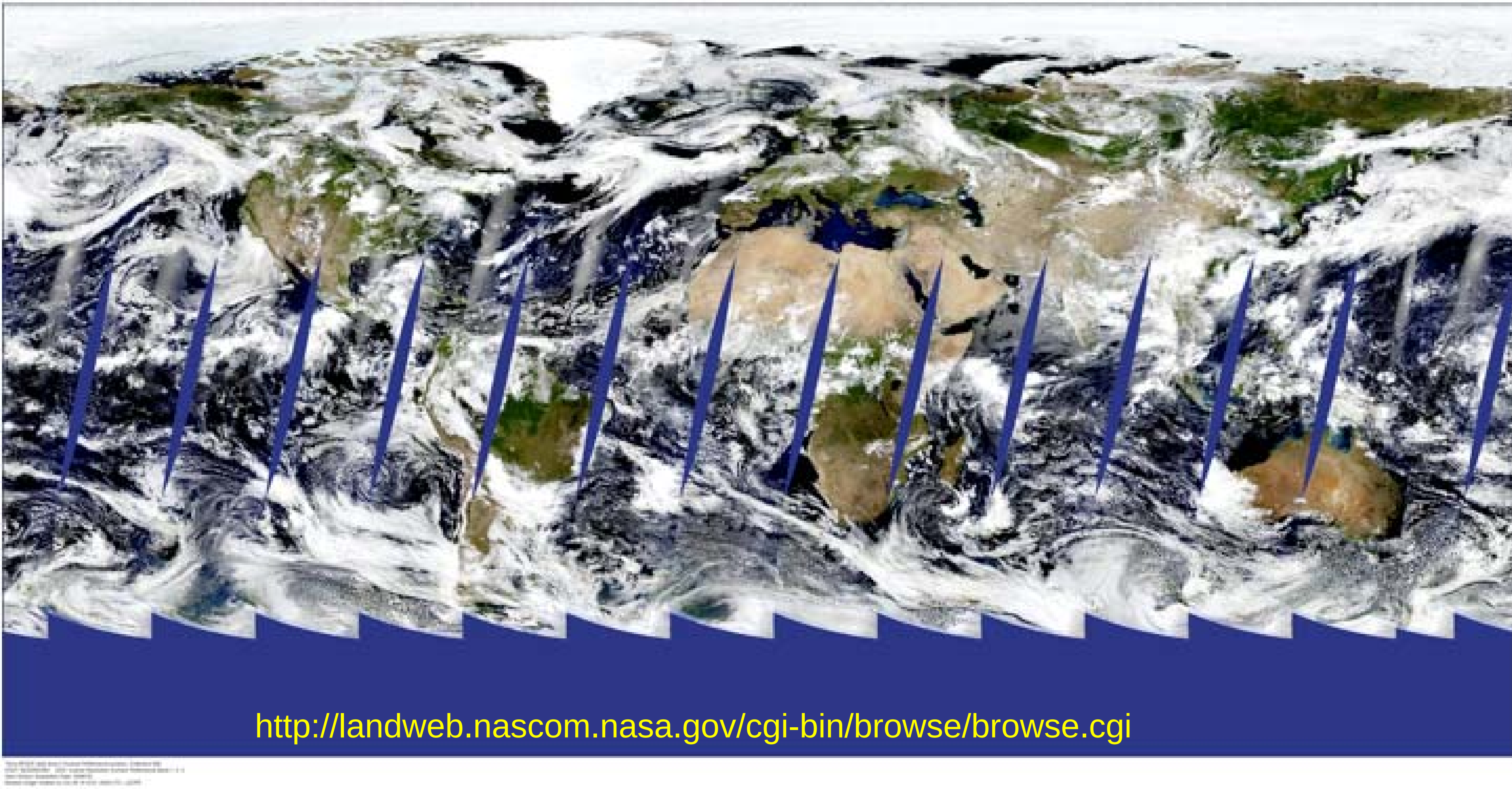
Cross-section plots of multiple parameters along a transect (e.g. Calipso tracks or other straight line or polygon)

Profile Plot

A Profile plot is used to display the variation of one or more scalar Data Sets associated with a mesh or grid along observation arcs in the Observation Coverage. Profile plots are created in the Plot Options dialog by setting the Plot Type to *Observation Profile*. When an arc is selected, two small arrows appear at either end of the arc. These arrows indicate the viewing direction for the plots. To change the viewing direction, select the arc and execute the "Feature Objects | Reverse Arc Direction" command. A sample plot is shown in the figure.



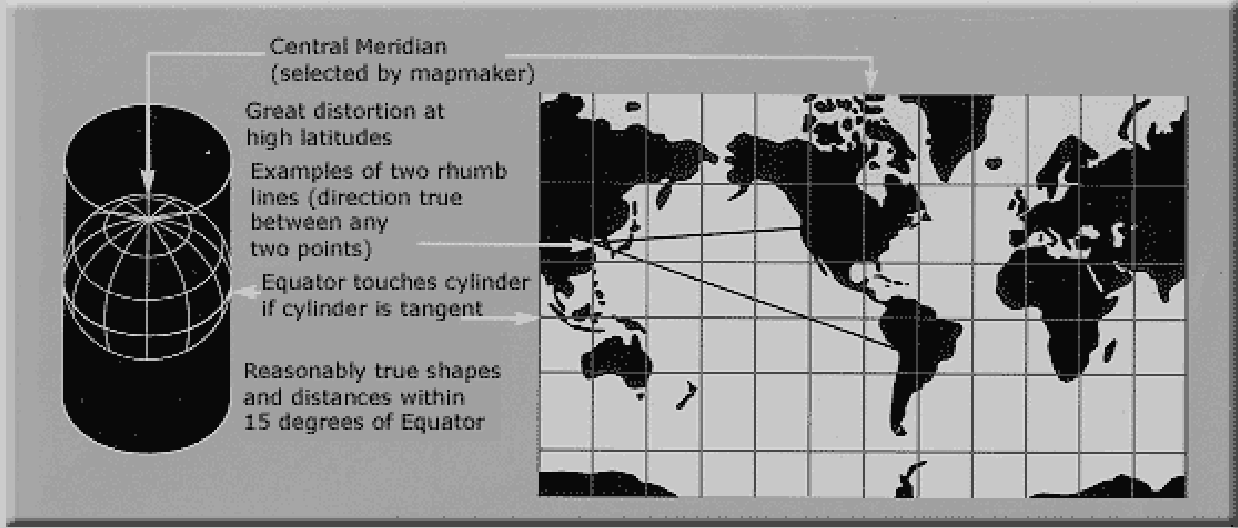
What projection is optimal for holding data



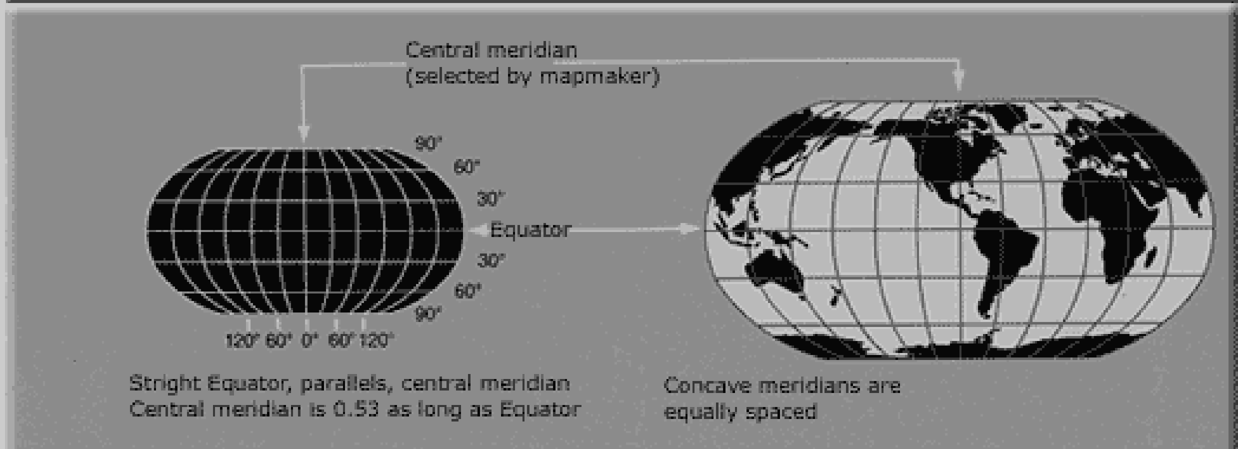
Mercator	: Conformal, True-direction	(2)
Miller Cylindrical	: Compromise	
Robinson Pseudocylindrical	: Compromise	(3)
Sinusoidal Equal Area	: Equal-area, Equidistant	(1)
Space Oblique Mercator	: Conformal	

Projections

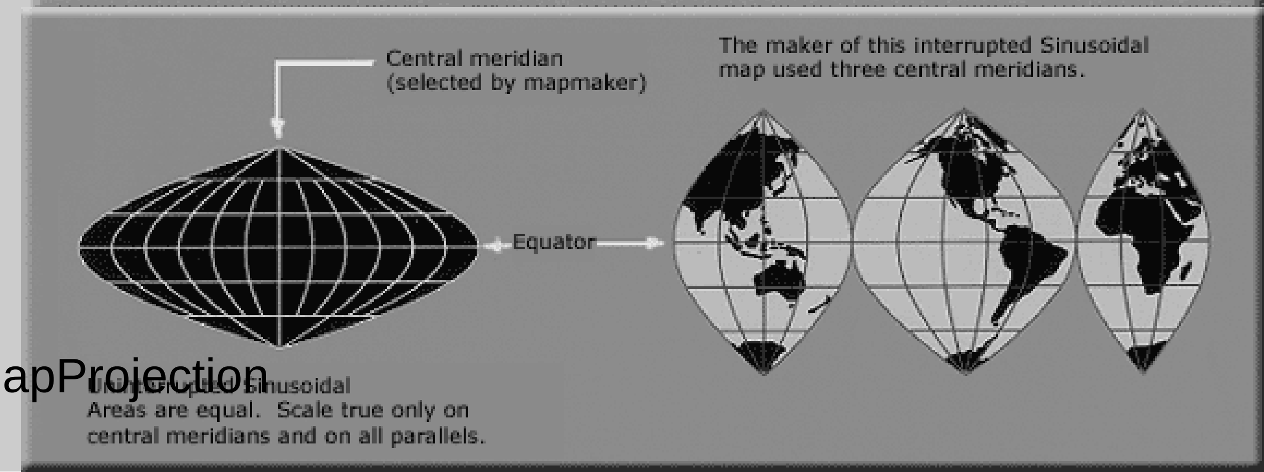
Mercator



Robinson
Pseudocylindrical



Sinusoidal
Equal Area



http://erg.usgs.gov/isb/pubs/MapProjections/projections.html

Acknowledgement

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

  For tag-team Funding support of this series of 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