MODIS Aerosol Products for Air Quality Application

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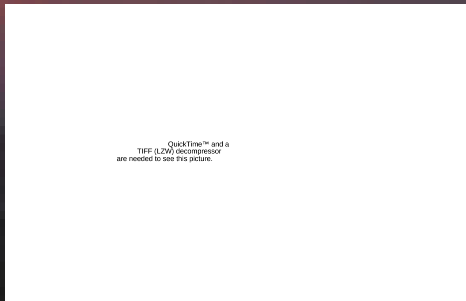
JCET-UMBC/NASA-GSFC

5th AEROCOM Workshop

Virginia Beach, Virginia

October 17-19, 2006



Funded Projects:

(1) NASA 3-D AQS (2006-2009); IDEA (2003-2005)

(2) EPA Pilot Program for evaluation $PM_{2.5}$ formation and transport in San Joaquin Valley, California (2006-2008)

- AOD (Aerosol Optical Depth): Extinction of sunlight by liquid or solid particles suspended in the atmosphere; unitless; columnar measurements

$$I_s = I_o e^{-\tau}$$

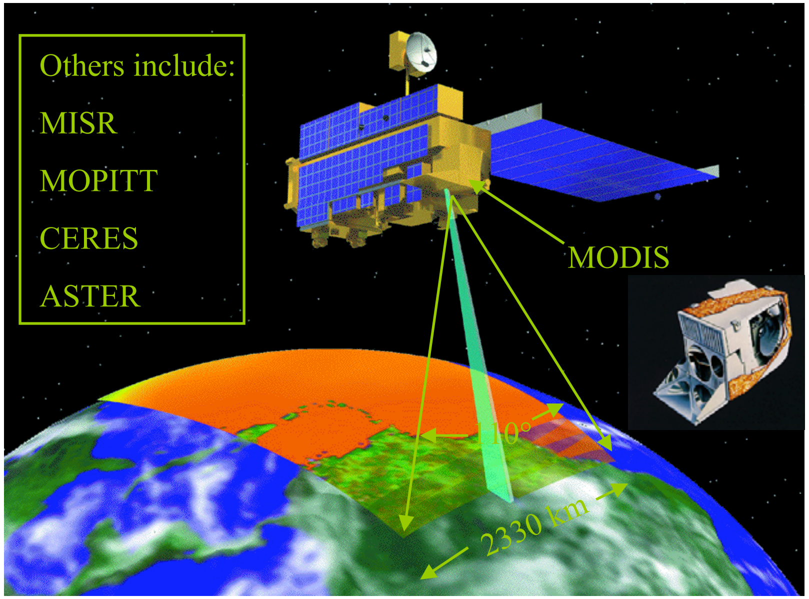
I_s: radiation reaching surface; I_o: radiation at top of the atmosphere; τ : AOD

- $PM_{2.5}$: Particular Matter with (aerodynamic) diameter less than 2.5 μm; $\mu g/m^3$

Focuses

- Near real-time monitoring of pollution (RGB images or AOD retrievals)
- Correlation between AOD and $PM_{2.5}$ (horizontal resolution)
- Vertical scaling (vertical distribution)

Earth Observing System
Terra Satellite



MODIS instrument Specifications:

Bands 1-2 (0.66,0.86 μm): 250 m

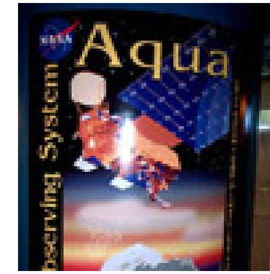
Bands 3-7 (0.47, 0.55, 1.24, 1.64, 2.13 μm): 500 m

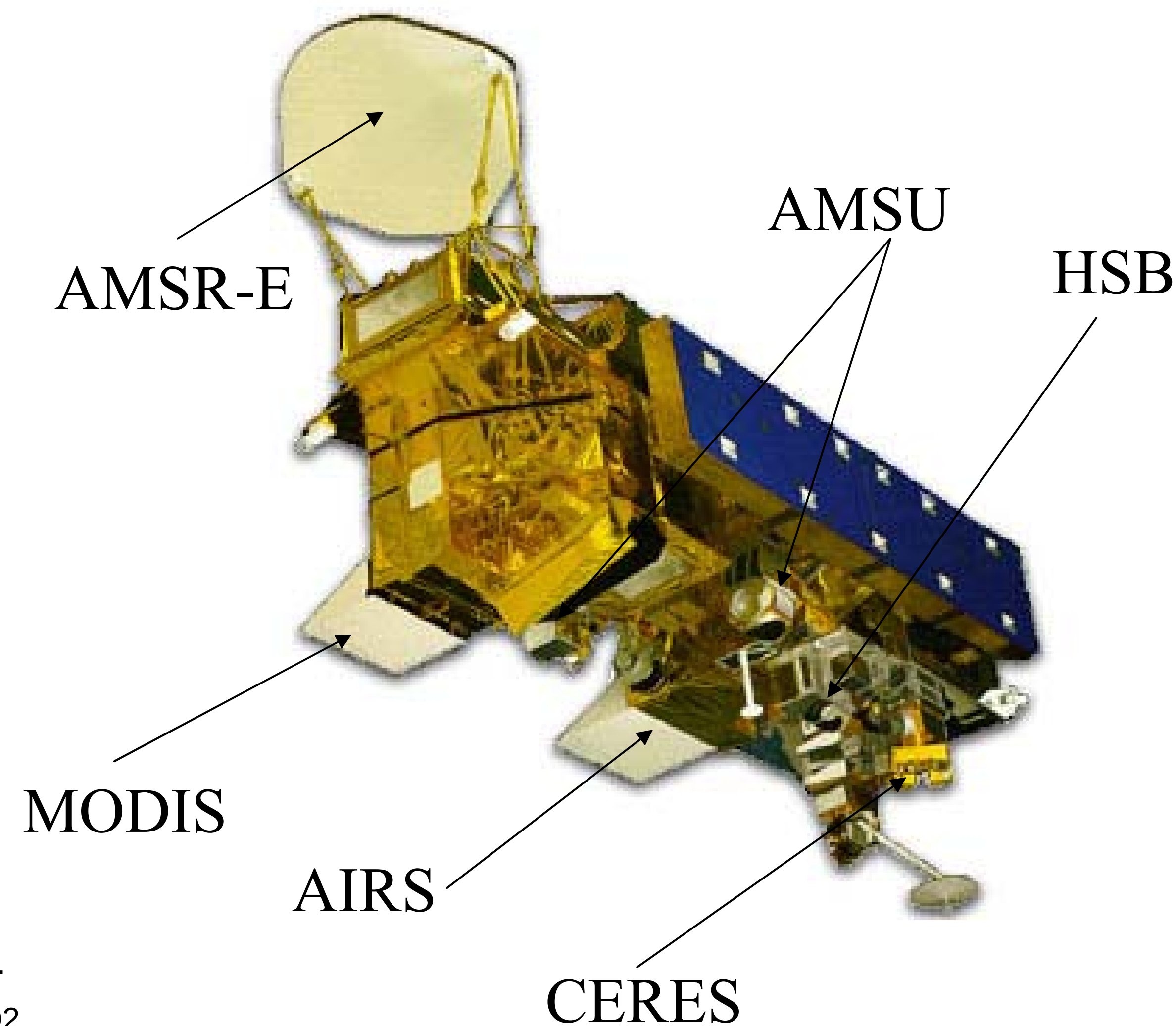
Bands 8-36: 1 km

Launch date: December 18, 1999, 1:57 PT

Earth view door open on February 24, 2001

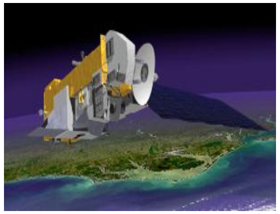
Earth Observing System
Aqua Satellite

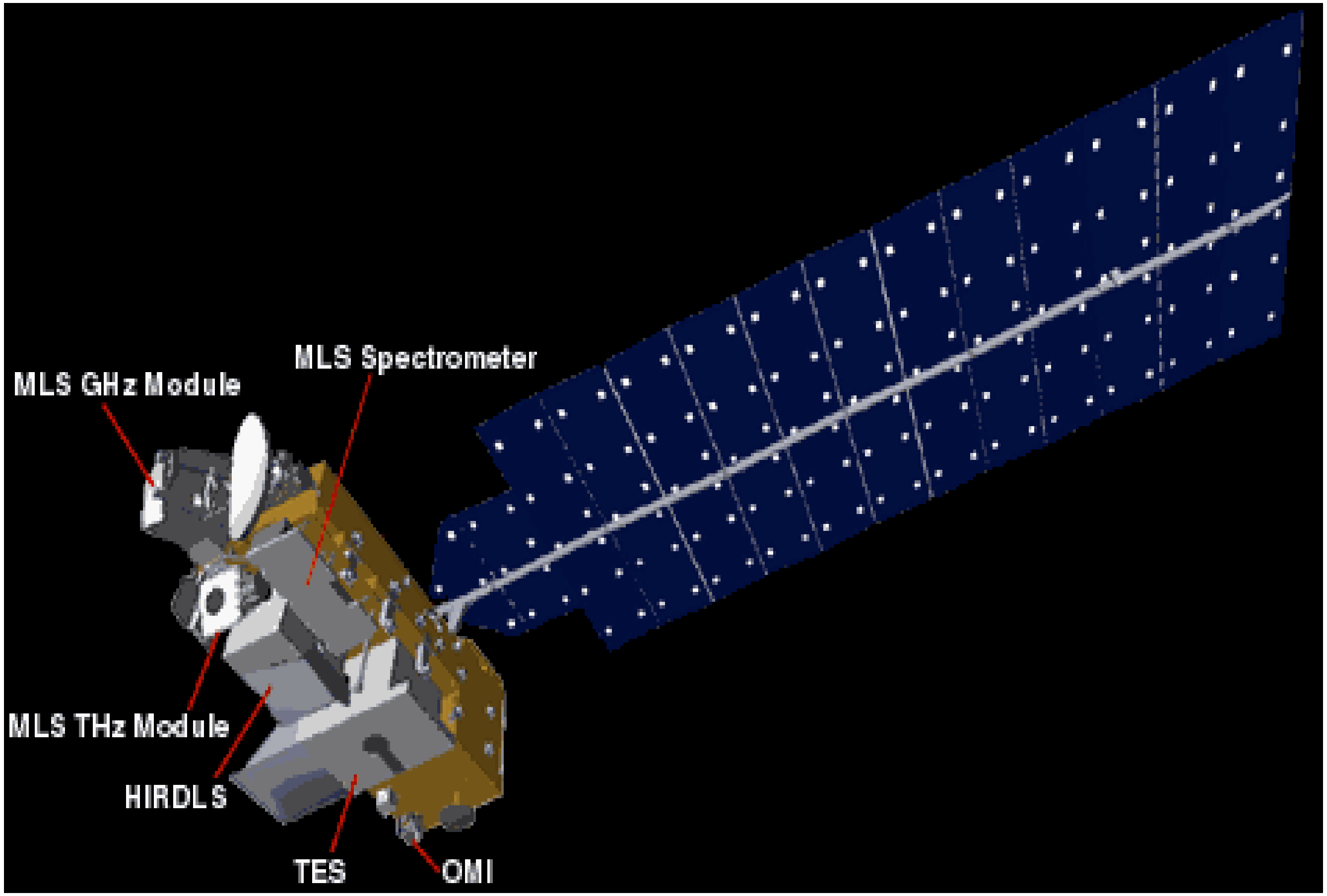




Launch date: May 4, 2002, 2:55 PDT
Earth view door open on June 25, 2002

Earth Observing System
Aura Satellite

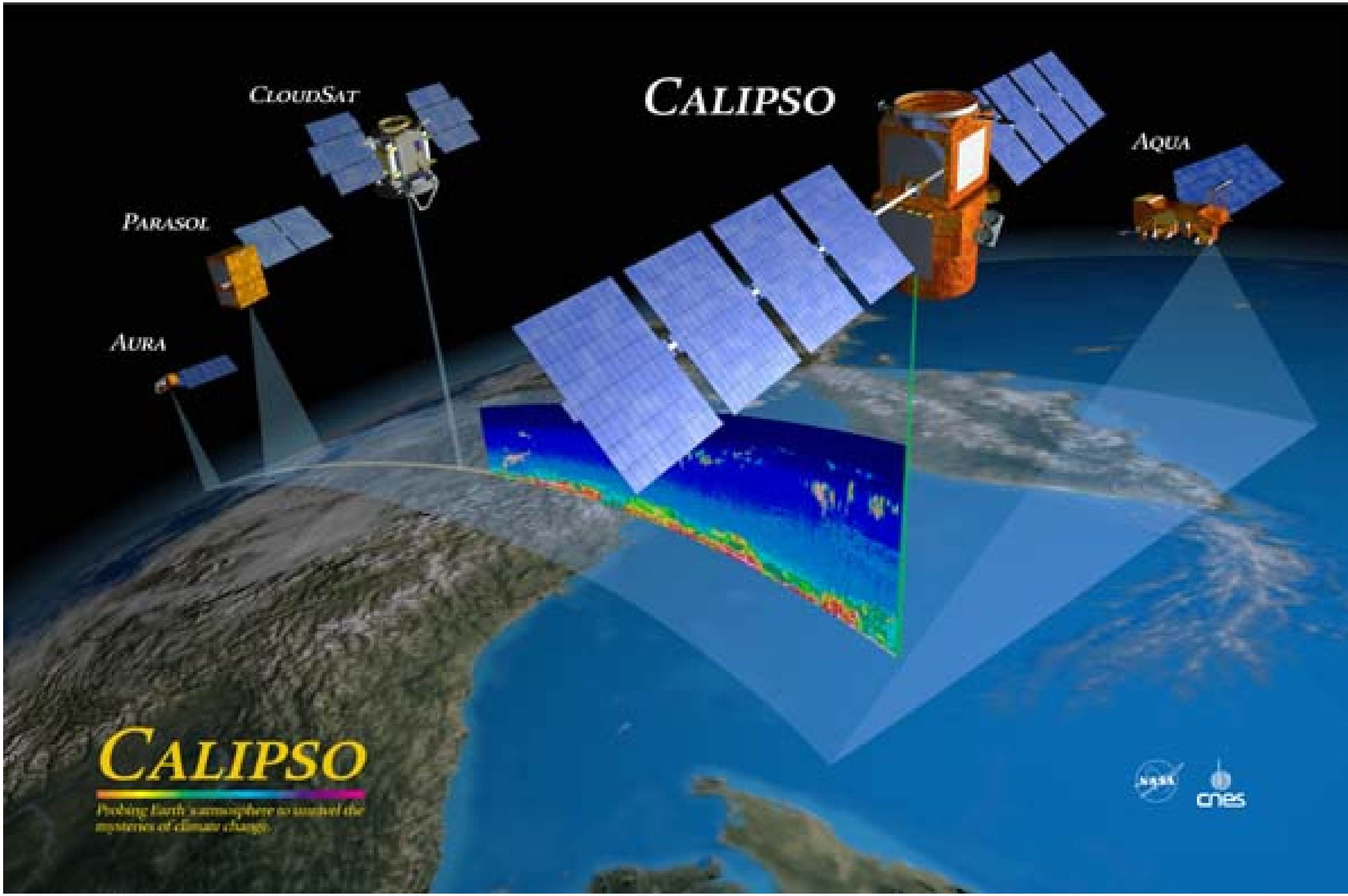




Launch date: July 14, 2004, 2:55 PDT

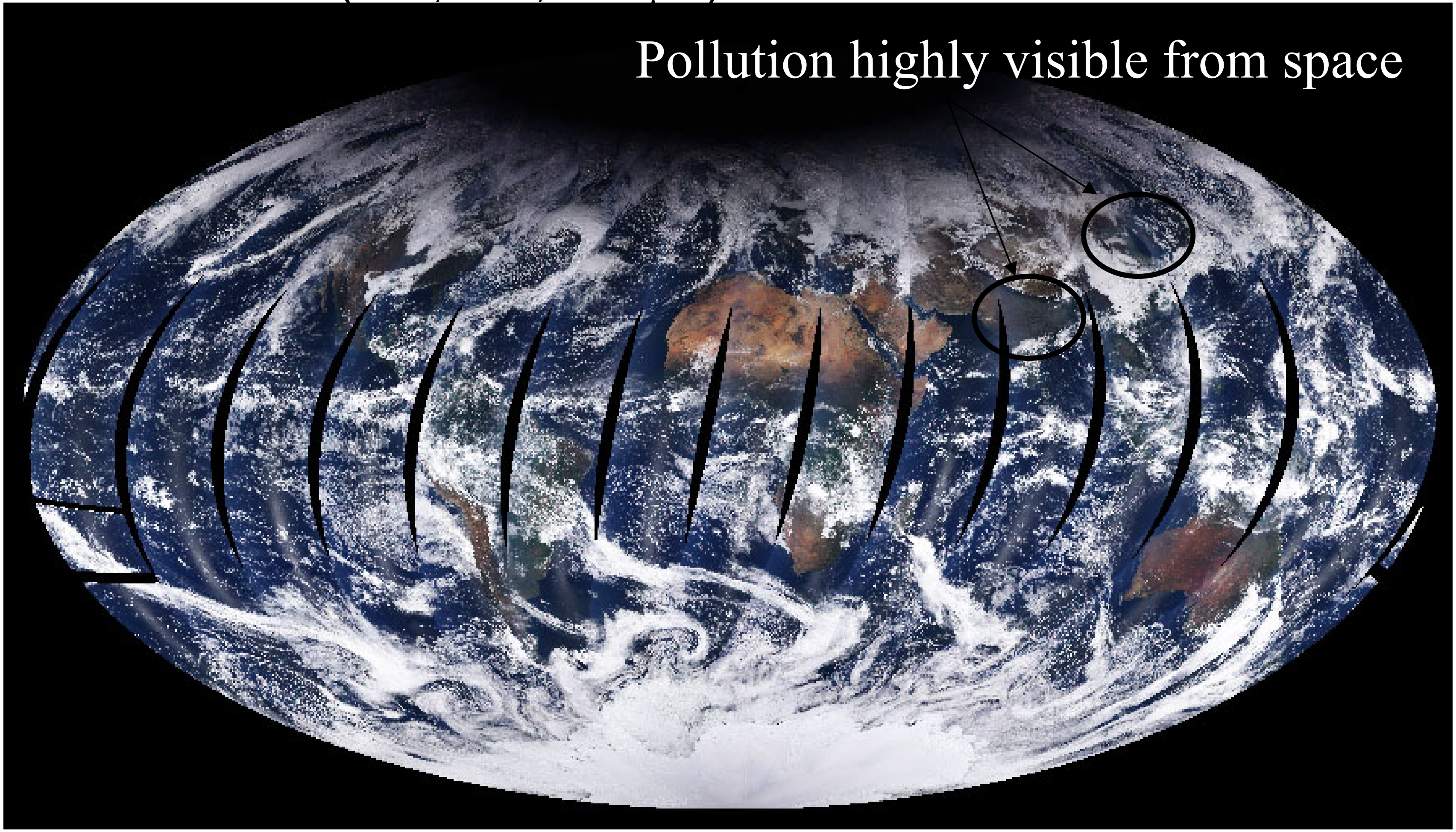
Earth view door open on August 21, 2004

3-D Measurements to tackle Air Pollution



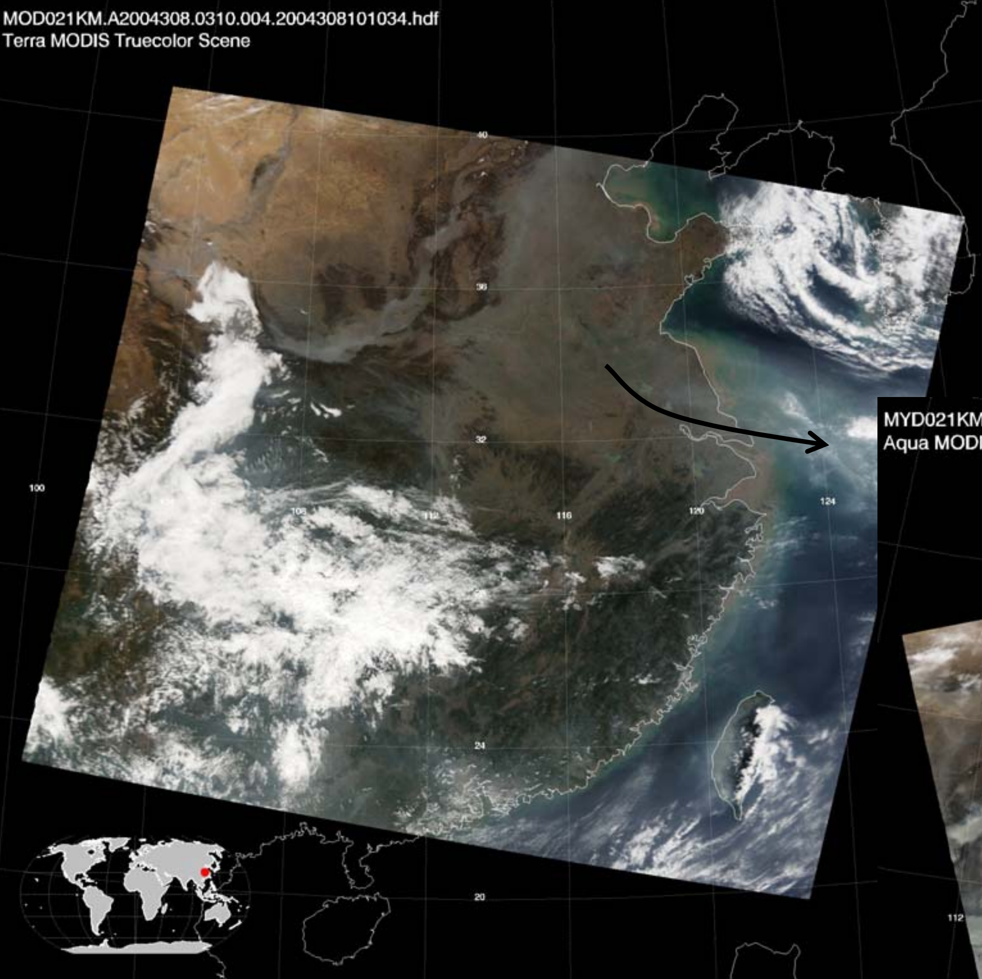
MODIS Daily Snap-Short Global coverage

True Color RGB (0.66, 0.55, 0.47 μm)

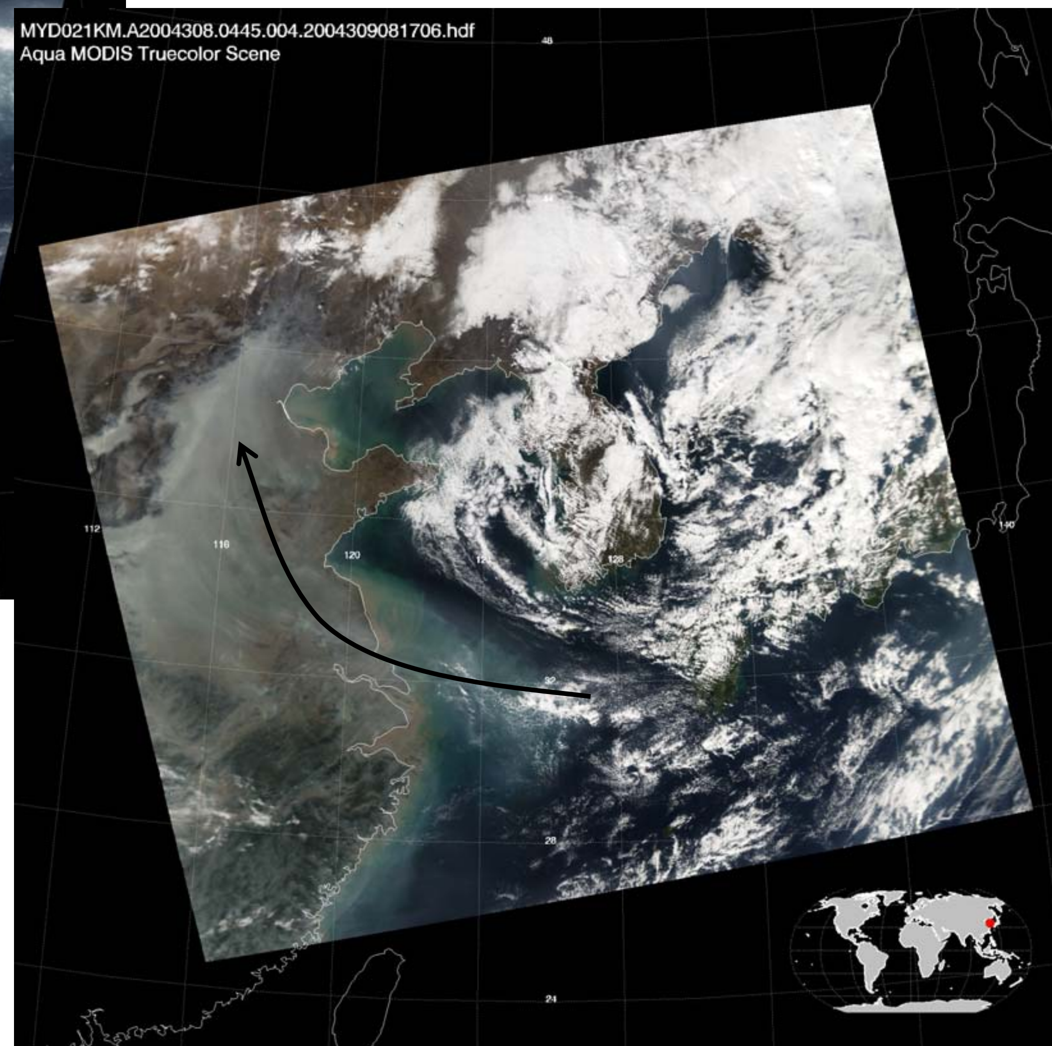


December 1, 2000

Morining (November 3, 2004)

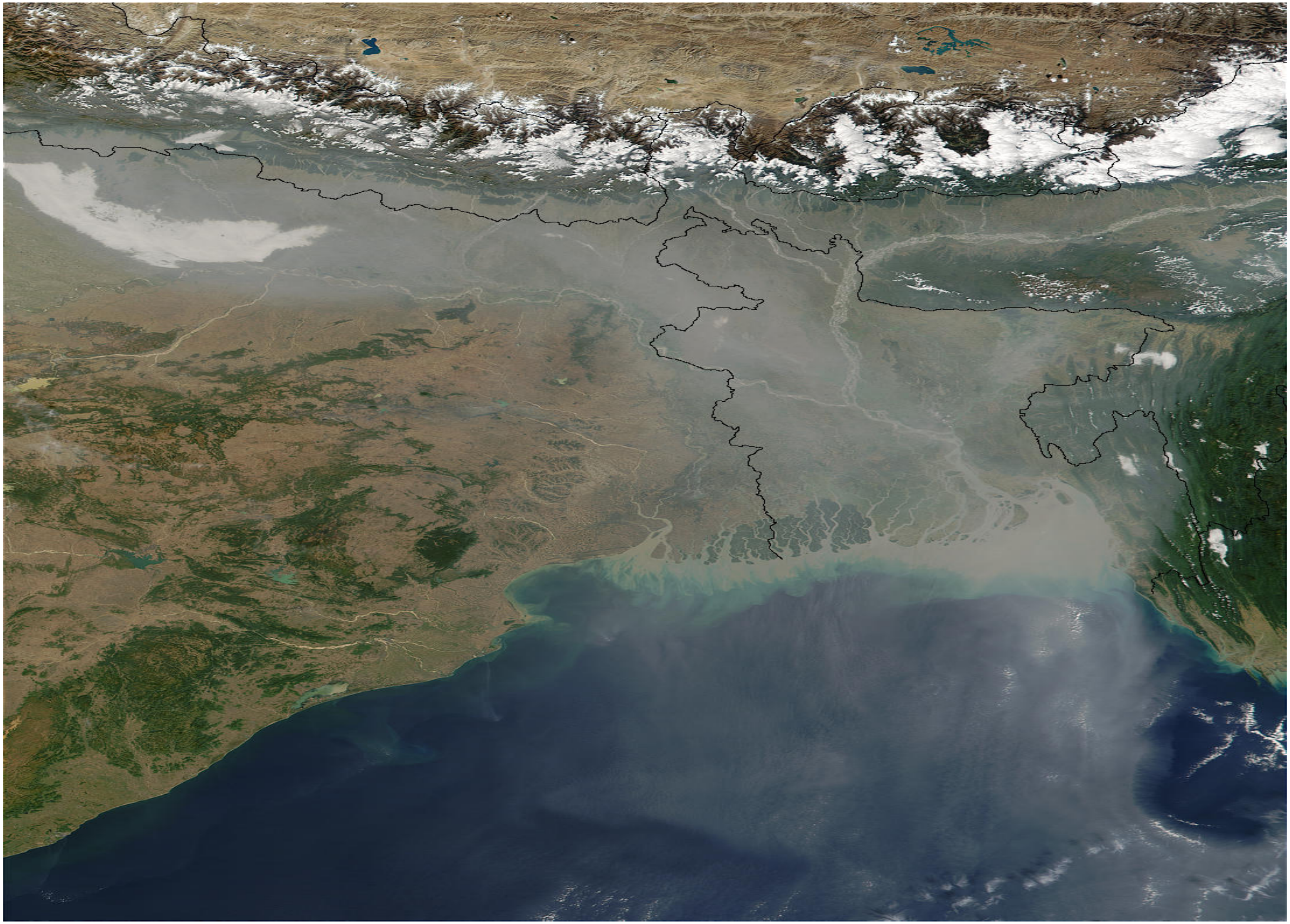


Recycling of Pollution



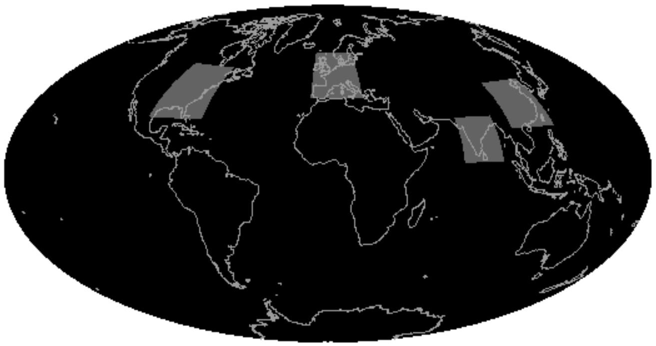
Afternoon

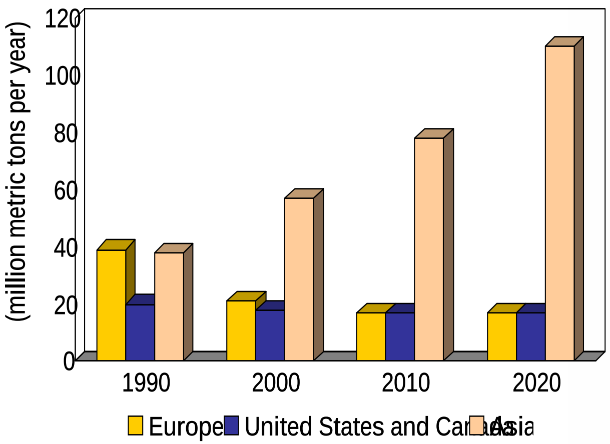
River of Pollution from India and Bangladesh



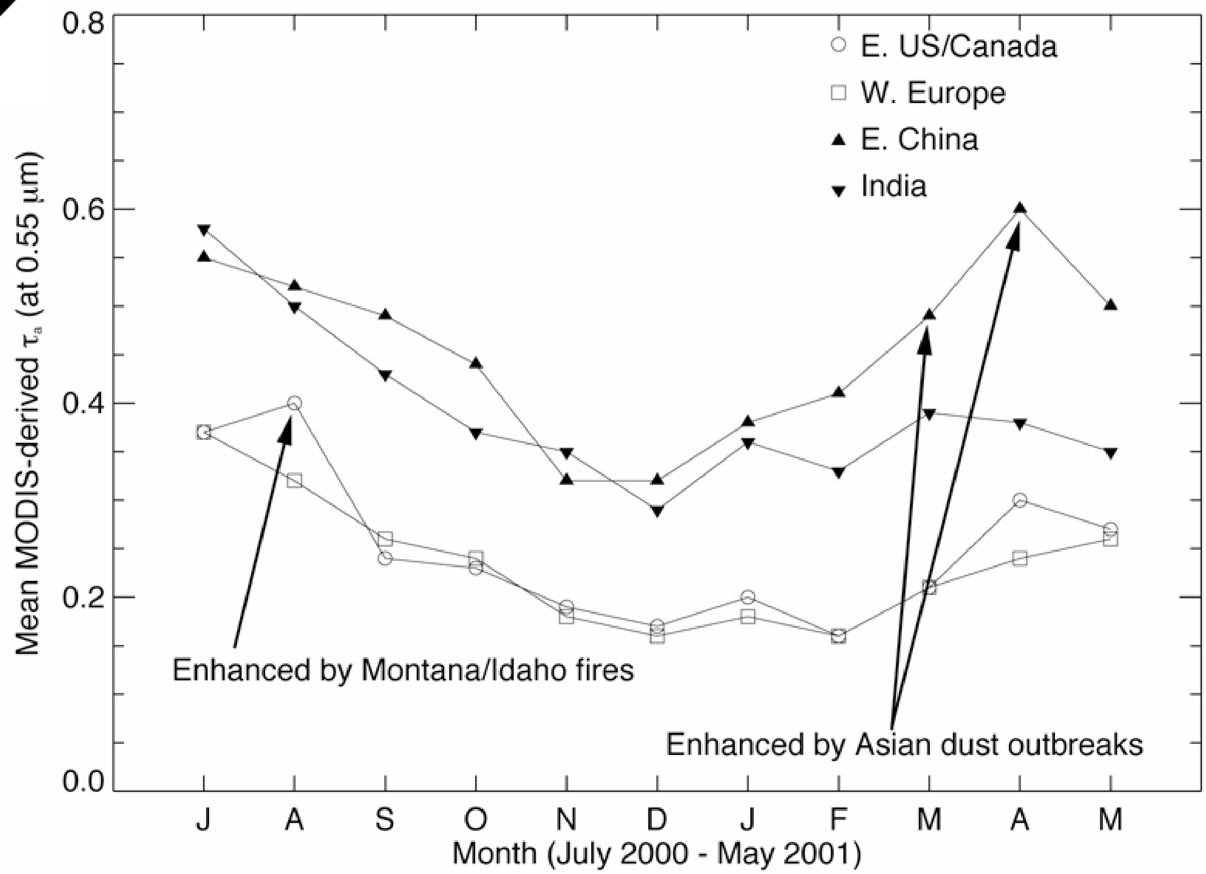
MODIS RGB

Time-series of monthly means of MODIS-τ_a in regions of E. China, India, E. US/Canada, and W. Europe between July 2000 and May 2001 (land only)

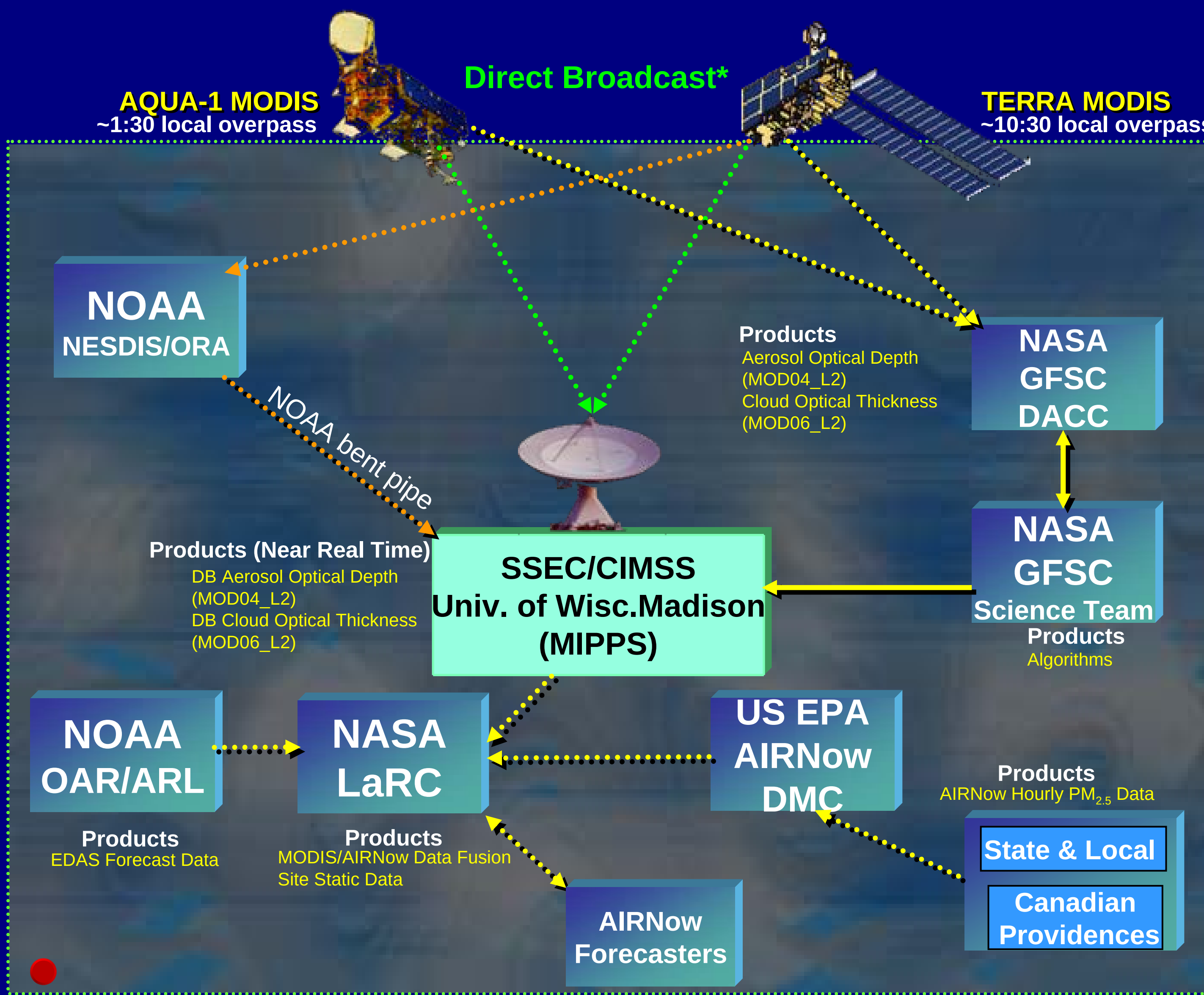




Source: Global Environmental Trends, World Resources Institute, http://www.wri.org/wri/
R. Downing, R. Ramankutty, and J. Shah, RAINS-ASIA: An Assessment Model for Acid Deposition in Asia (The World Bank, Washington, D.C., 1997), p. 11.



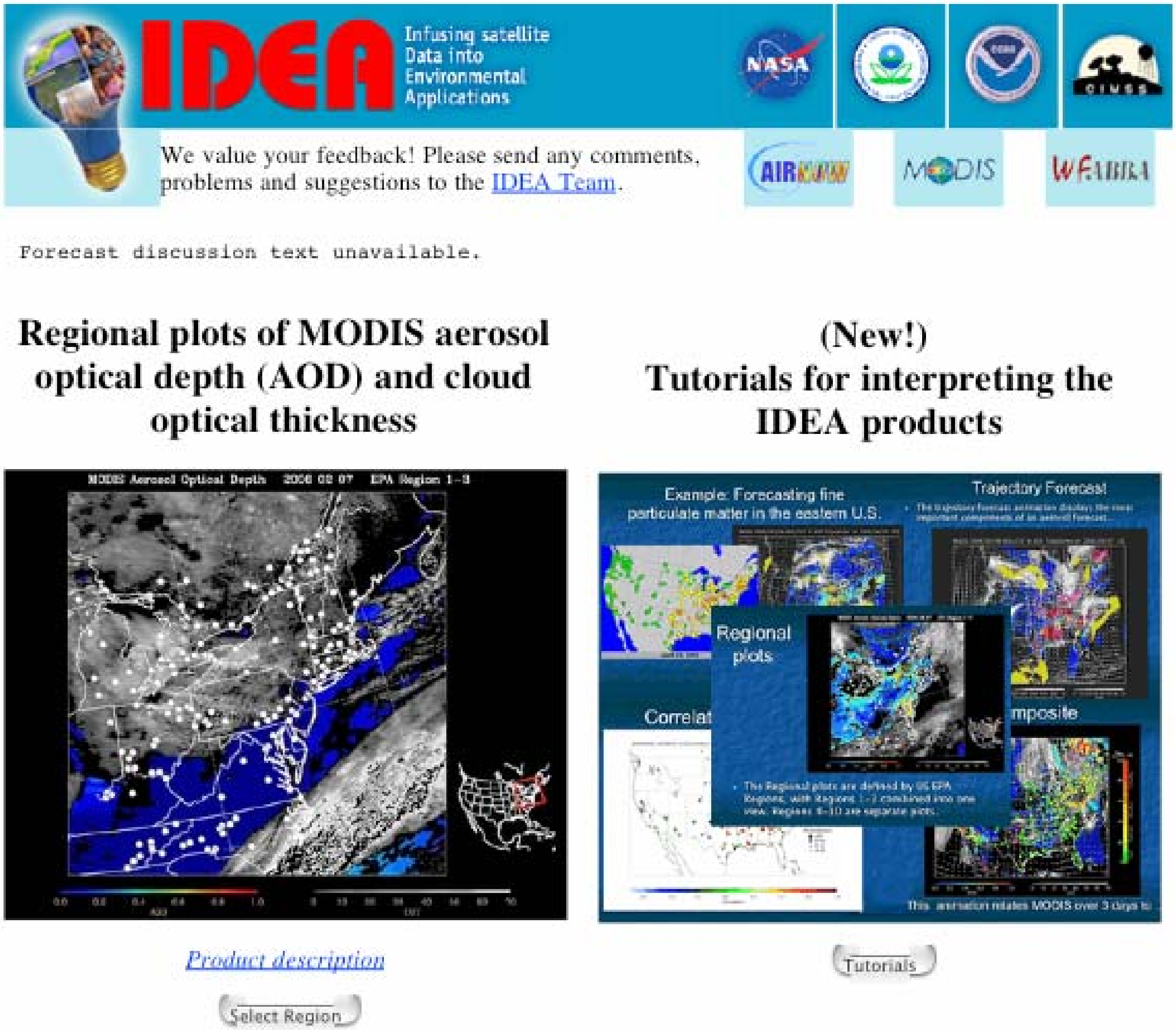
US EPA AIRNow Use of MODIS Data



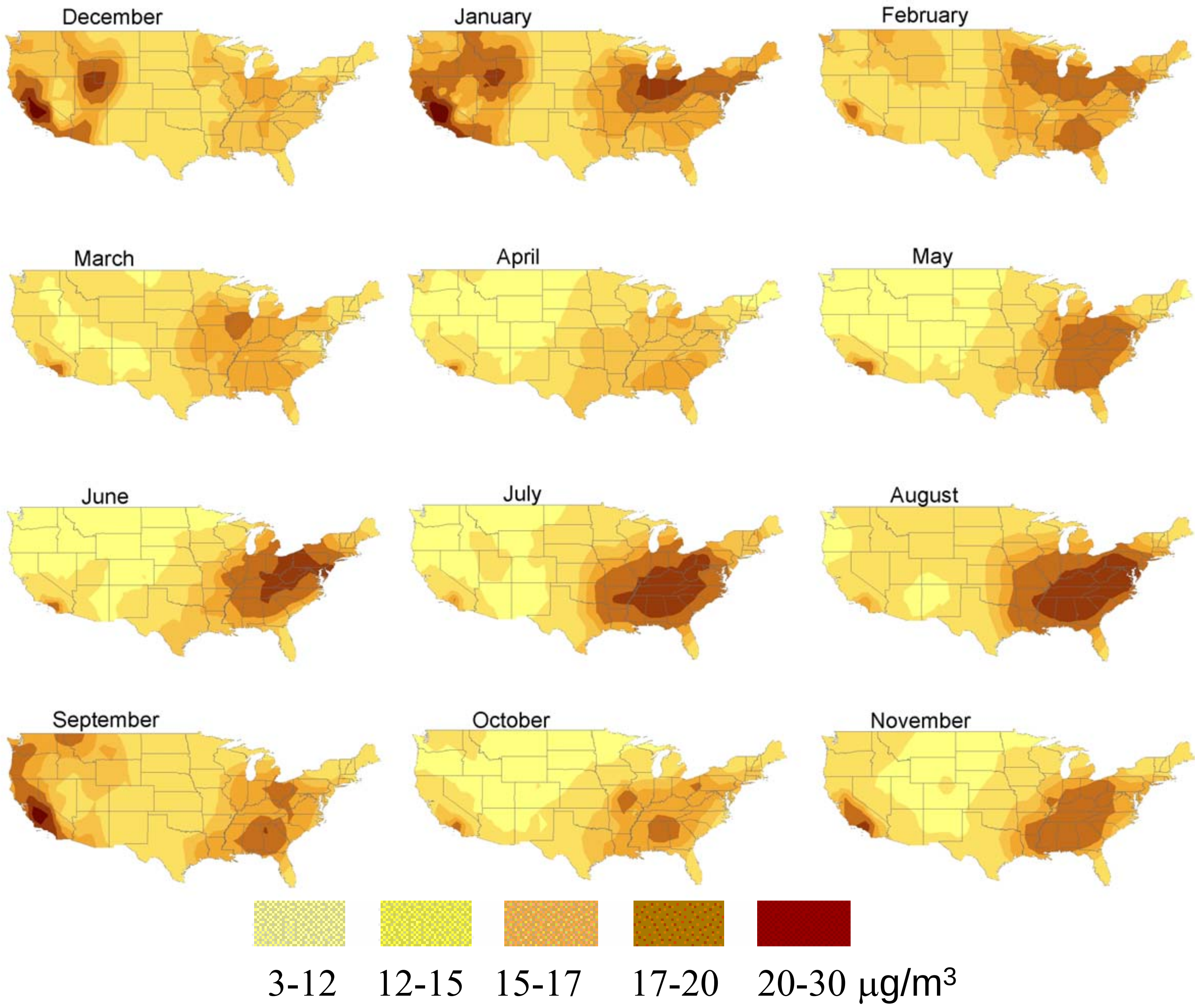
*Note: SSEC/CIMSS indicated that DB will not be implemented until the end of the summer. Current plan is to use NOAA bent pipe to generated NRT for prototype, until DB begins.

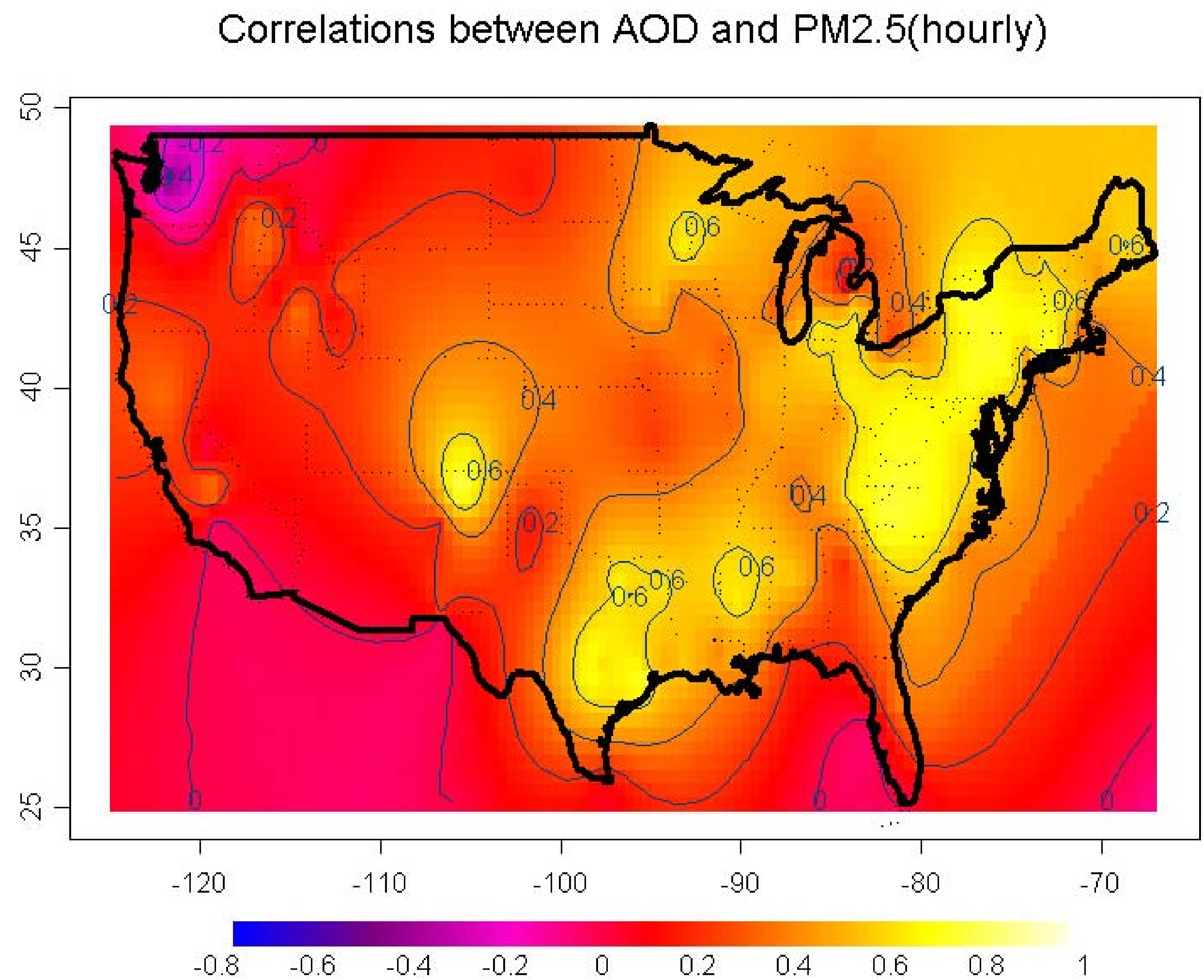
< Back

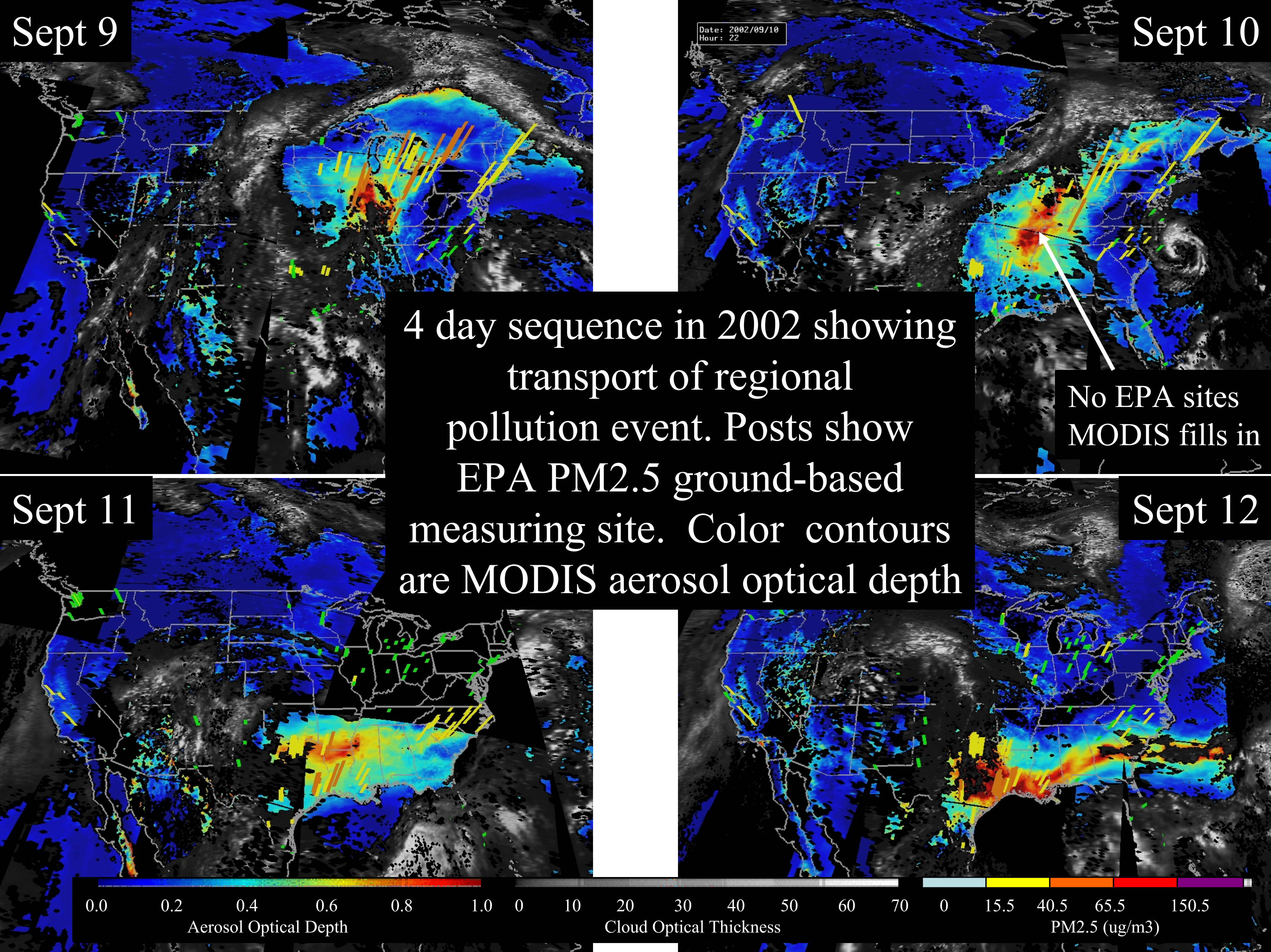
Since IDEA debuted in September 2003, it has been widely recognized by air quality forecasters, decision makers, educators,……………



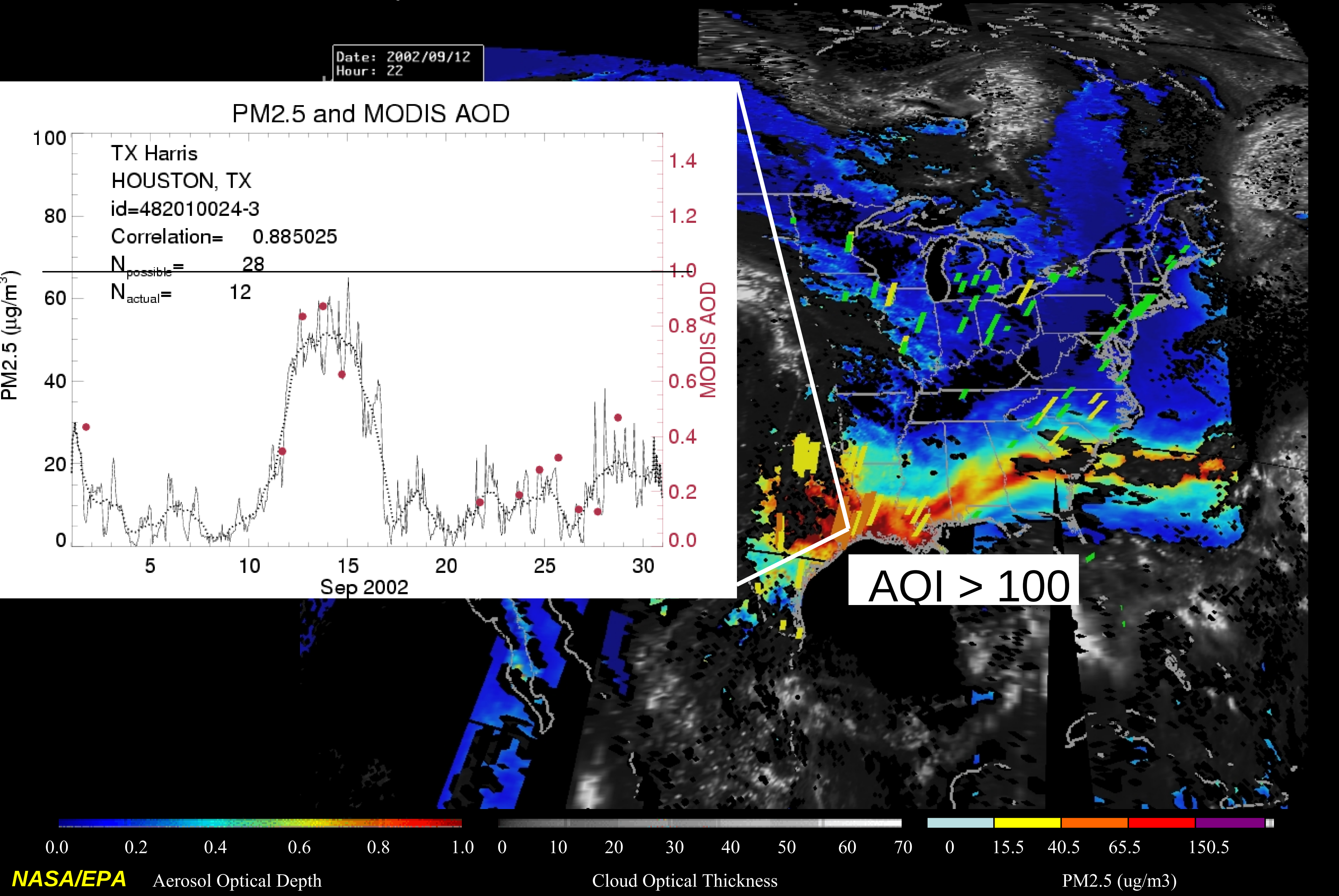
3-yr average of $PM_{2.5}$ measurements from 1100 FRM monitors



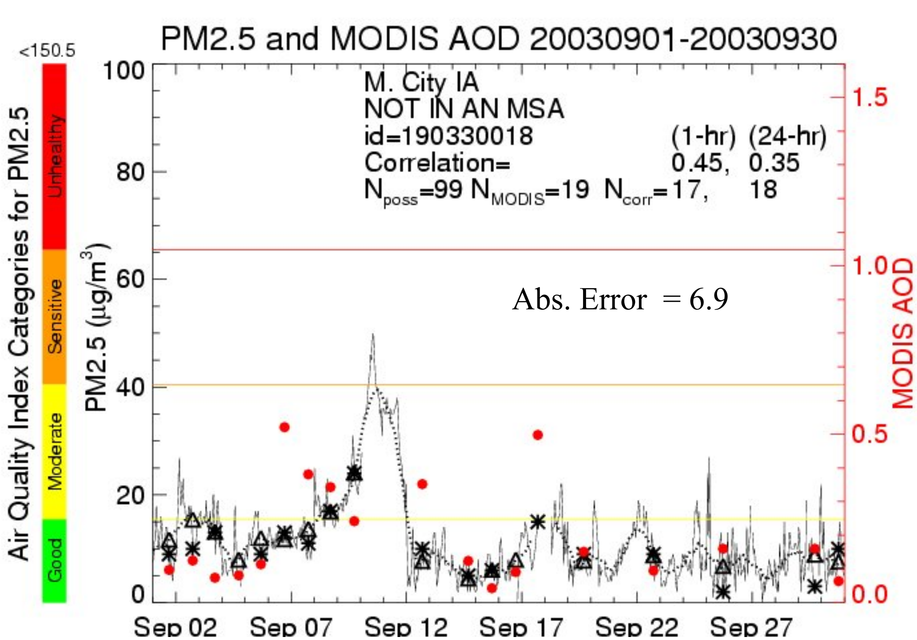

Correlations between AOD and PM2.5(hourly)
50
45
40
35
30
25
-120
-110
-100
-90
-80
-70
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

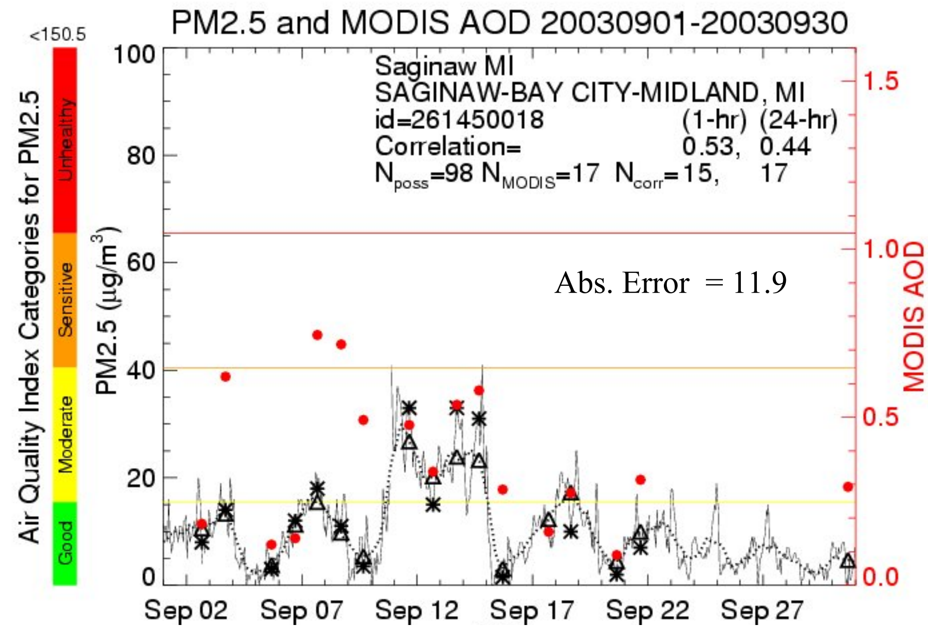

Sept 9
Date: 2002/09/10
Hour: 22
Sept 10
4 day sequence in 2002 showing transport of regional pollution event. Posts show EPA PM2.5 ground-based measuring site. Color contours are MODIS aerosol optical depth
No EPA sites MODIS fills in
Sept 11
Sept 12
0.0 0.2 0.4 0.6 0.8 1.0
Aerosol Optical Depth
0 10 20 30 40 50 60 70
Cloud Optical Thickness
0 15.5 40.5 65.5 150.5
PM2.5 (ug/m3)

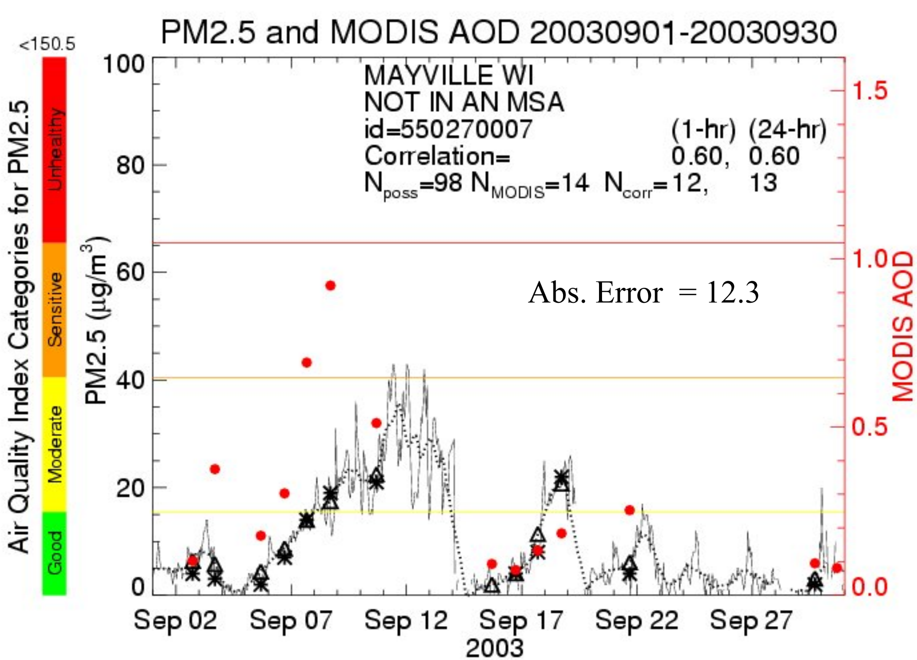
12 Sept. 2002-The high AOD from MODIS is seen stretching along the entire Gulf Coast and extending out into the Atlantic Ocean. This transport was caused by T.S. Gustav pulling off into the North Atlantic and the development of T.S. Hanna in the Gulf.

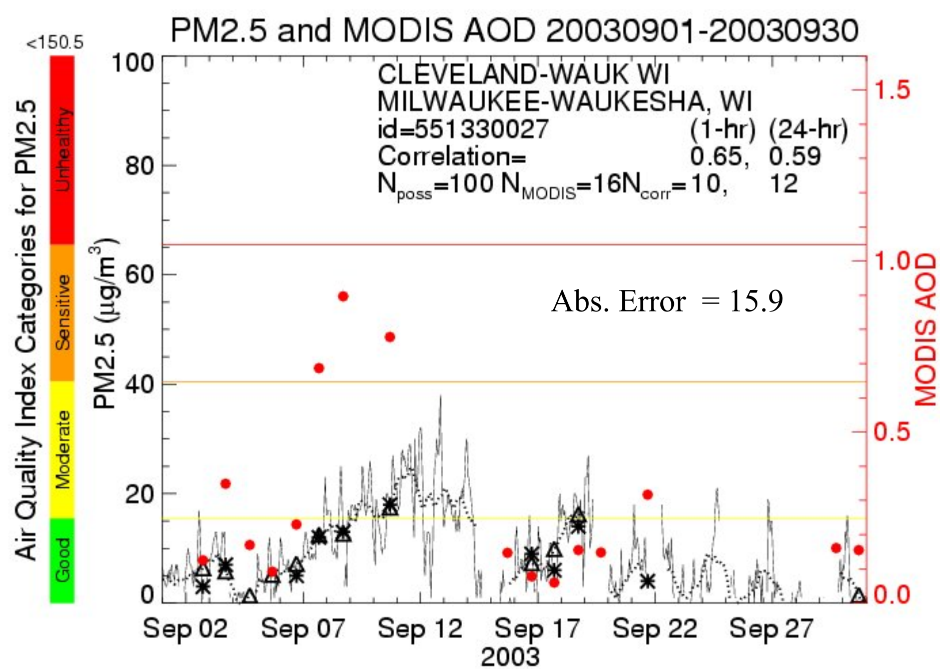


Affected by Transported Smoke

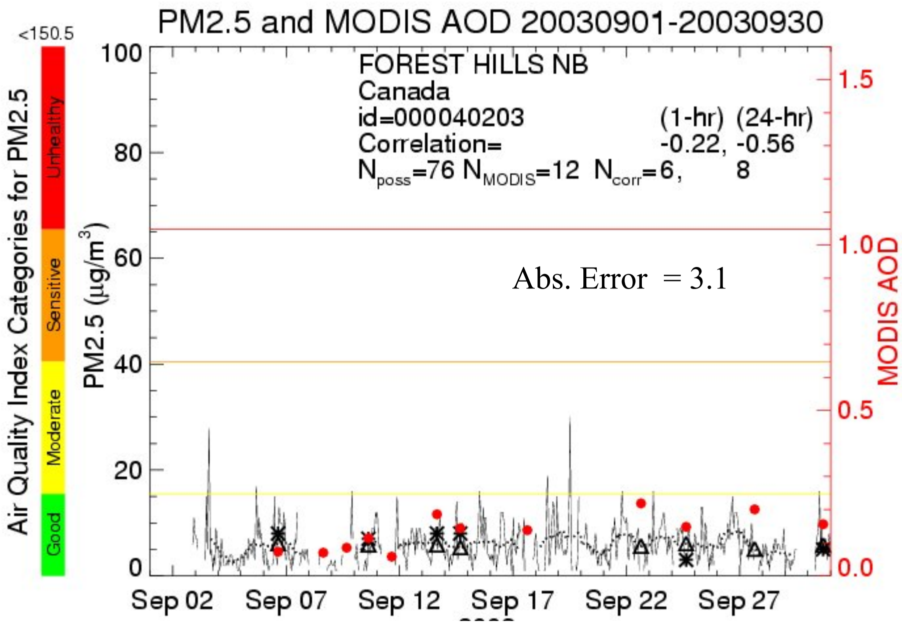


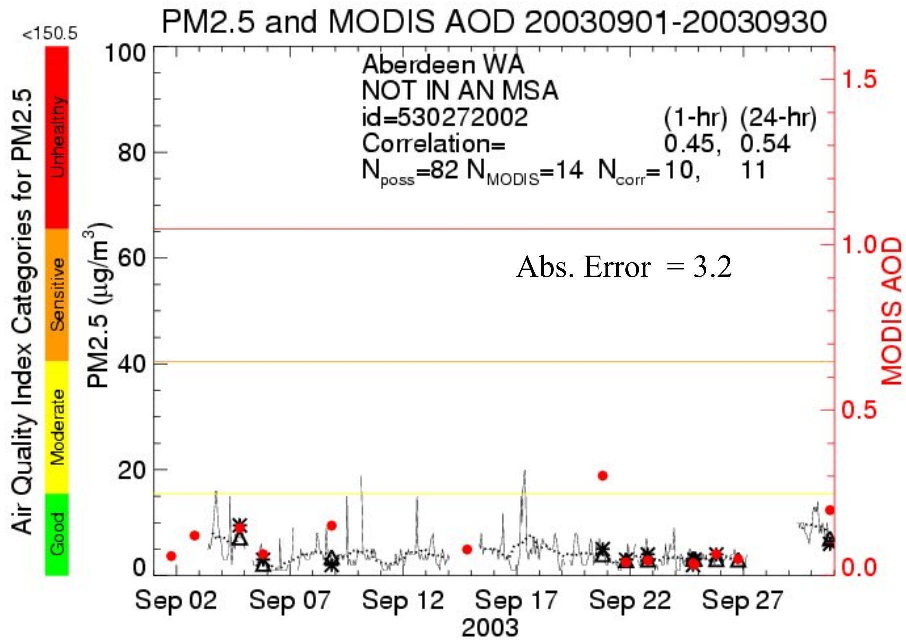


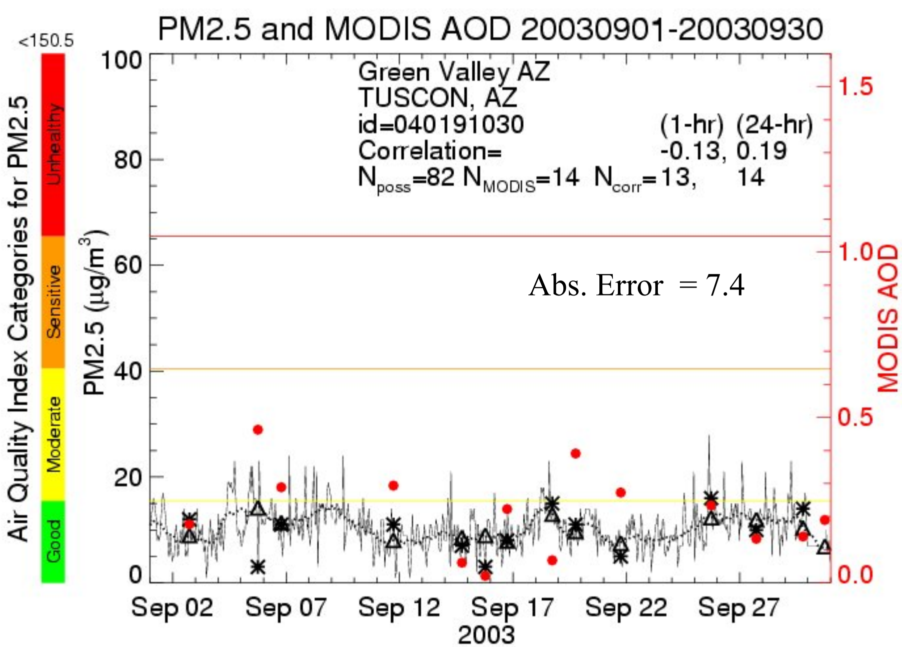


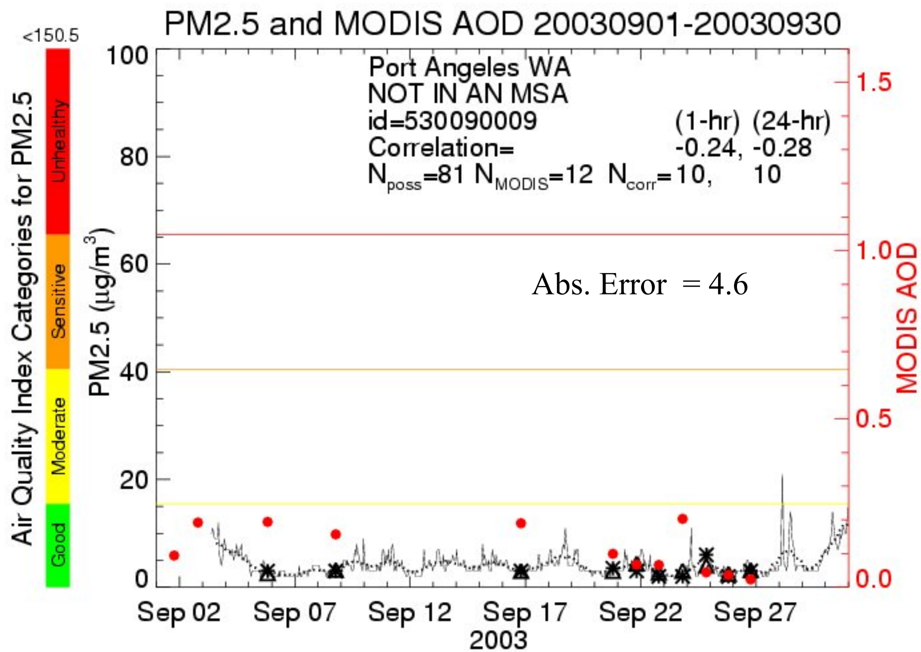


Good Air Quality, Low Correlation

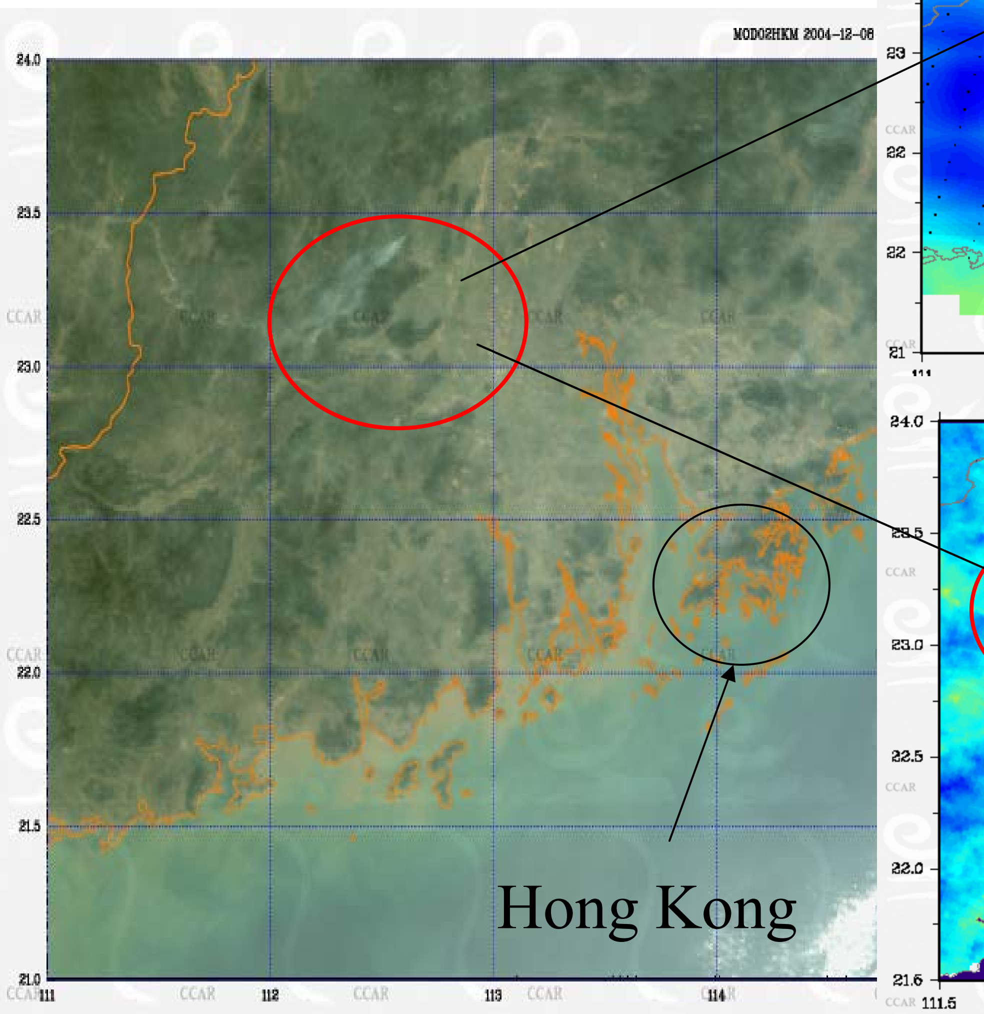


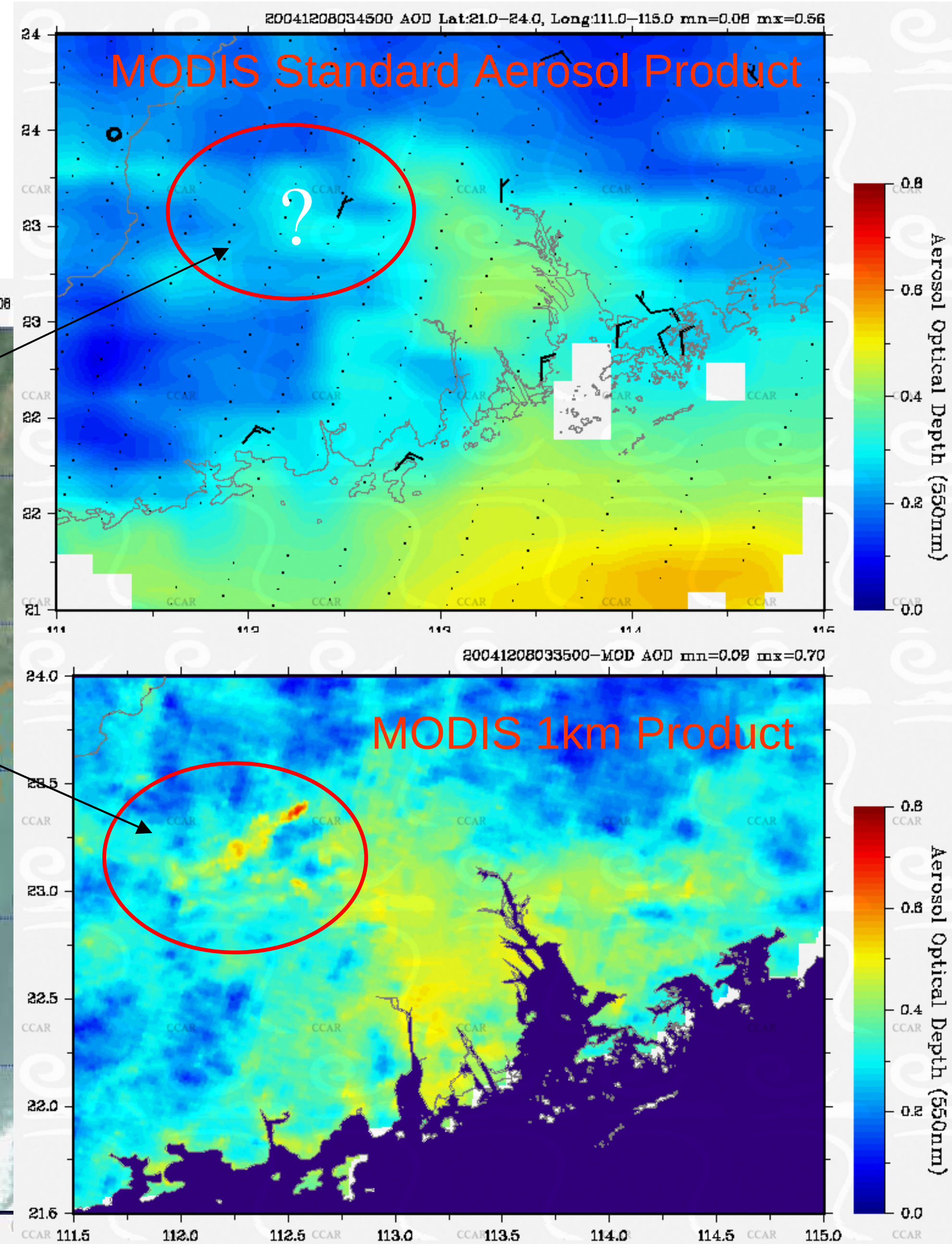






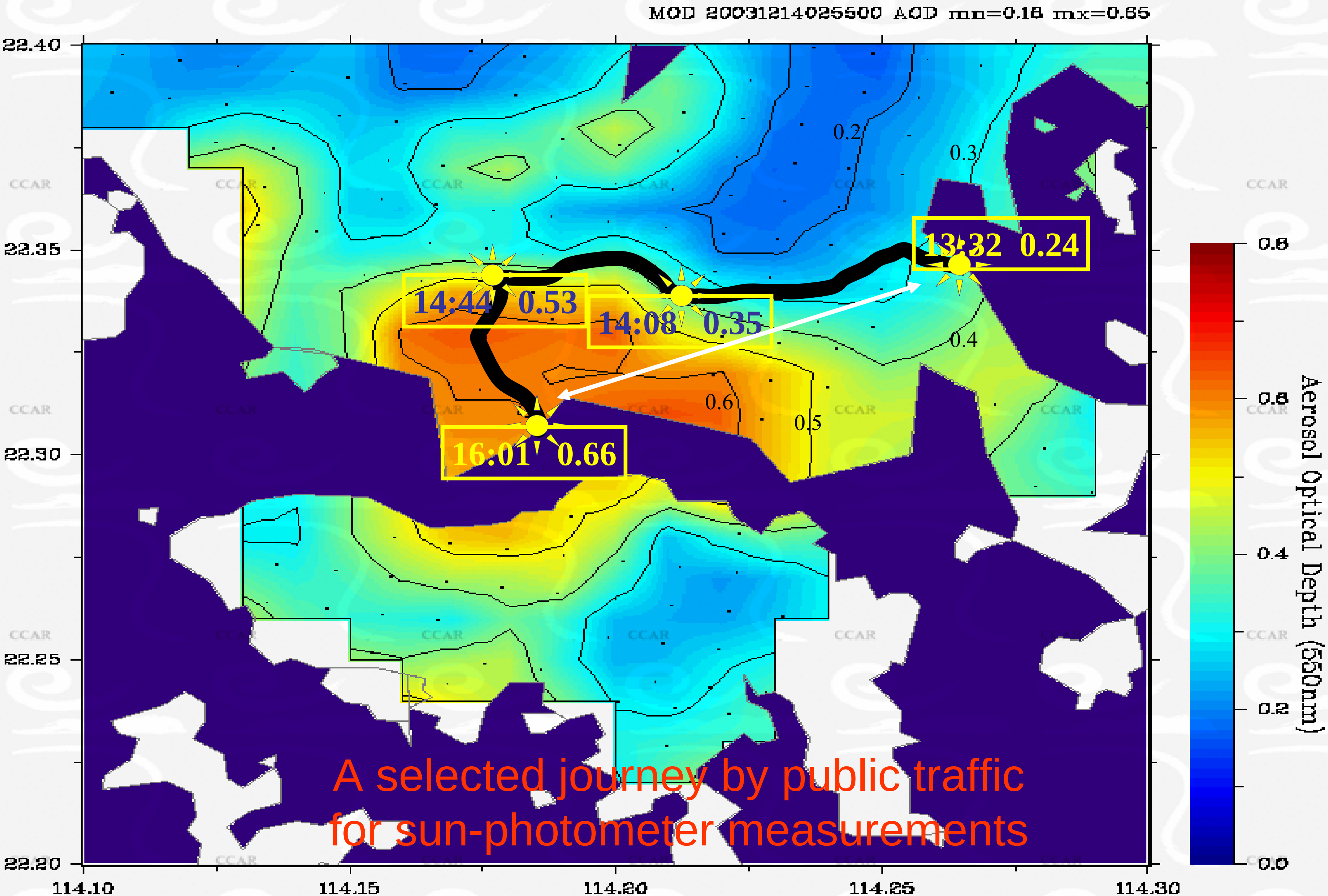
The need of High Resolution AOD data to Resolve Fine-Scale Emission Sources



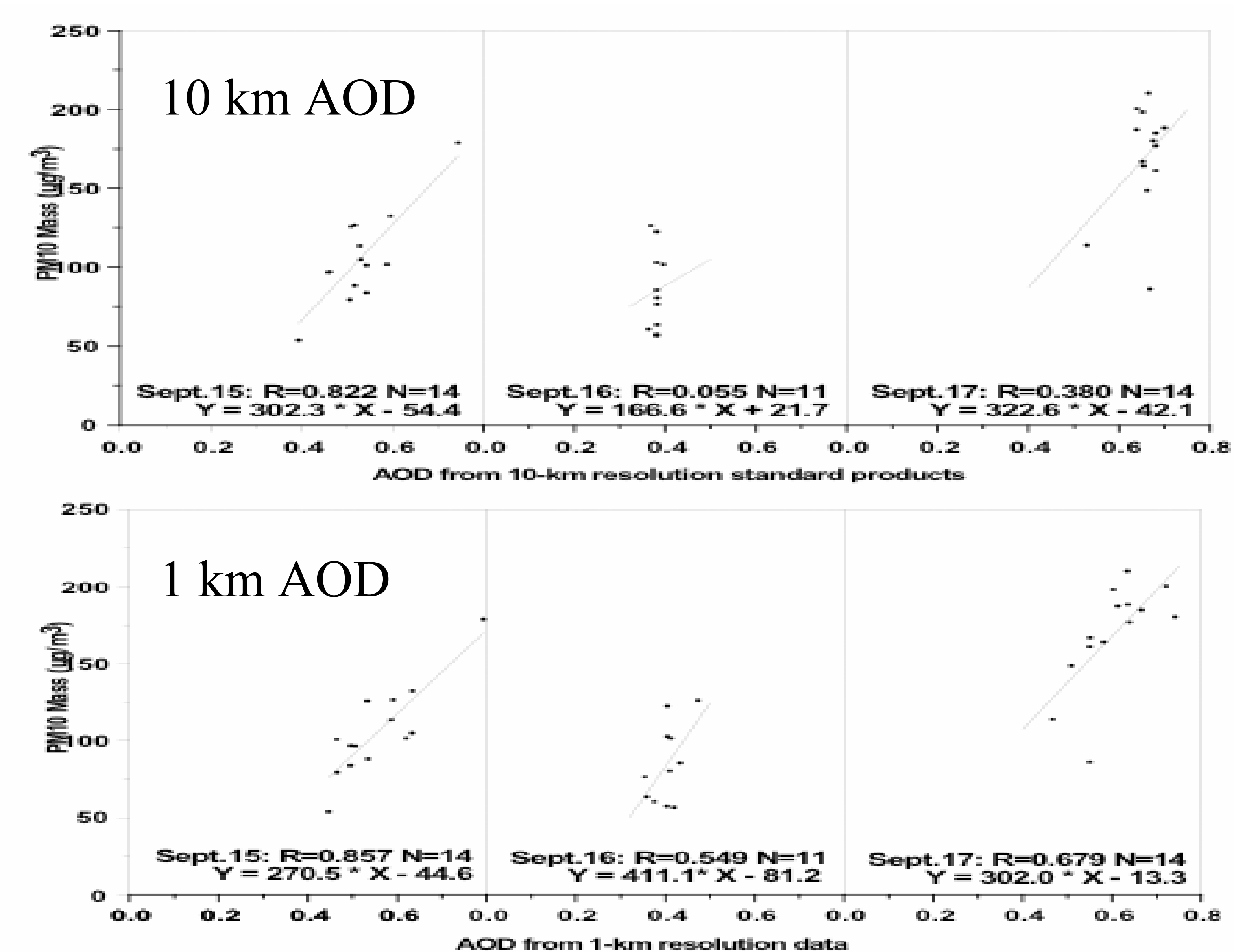


Co-author of Li et al. (2005)

Large spatial variability in a short distance (< 10 km)



Improvement of Correlation from 1-km AOD with PM_{10} than standard 10-km AOD Products



Synergetic MODIS AOD and UMBC Lidar Measurements

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

$PM_{2.5}$ = 30 (μg/m^3)

AOD = 0.82

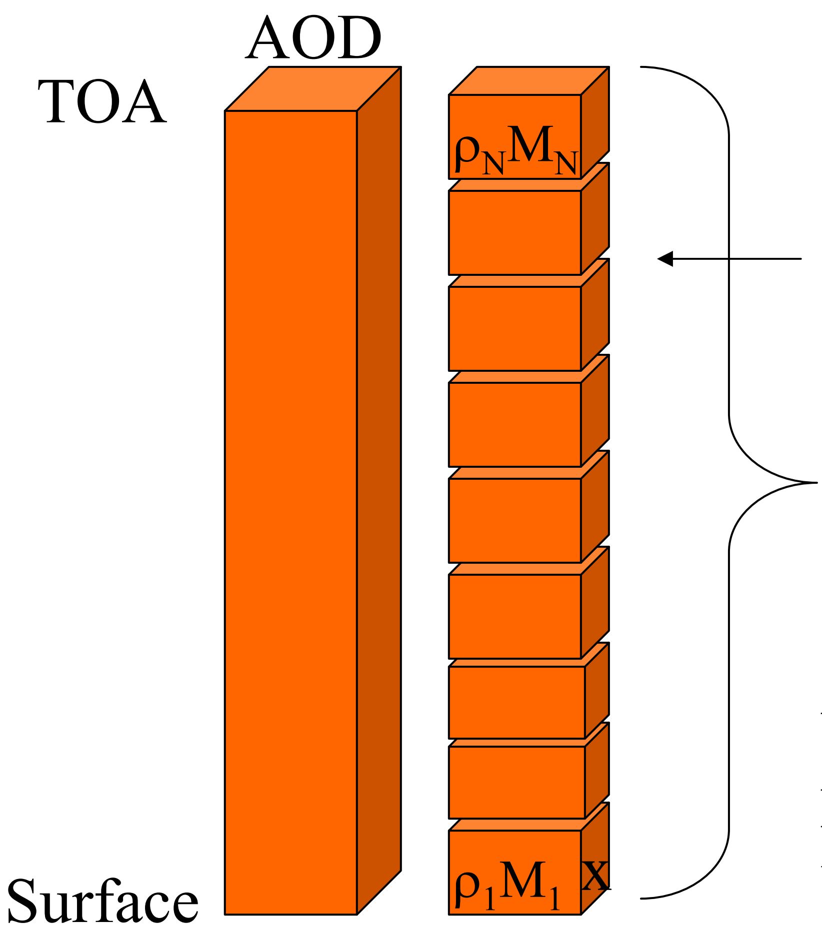
(~52 μg/m^3)

There is a mismatch!

42% above boundary layer

(0.82 x 0.58) x 62.5 =<u>29.7 (μg/m^3)</u>

Relationship between aerosol optical depth and mass concentration measured at surface



Aerosol vertical distribution

$$\Sigma \rho_{\square} M_{\square} = AOD$$

Aerosol type
Aerosol properties (e.g., absorption, hydration, etc.)

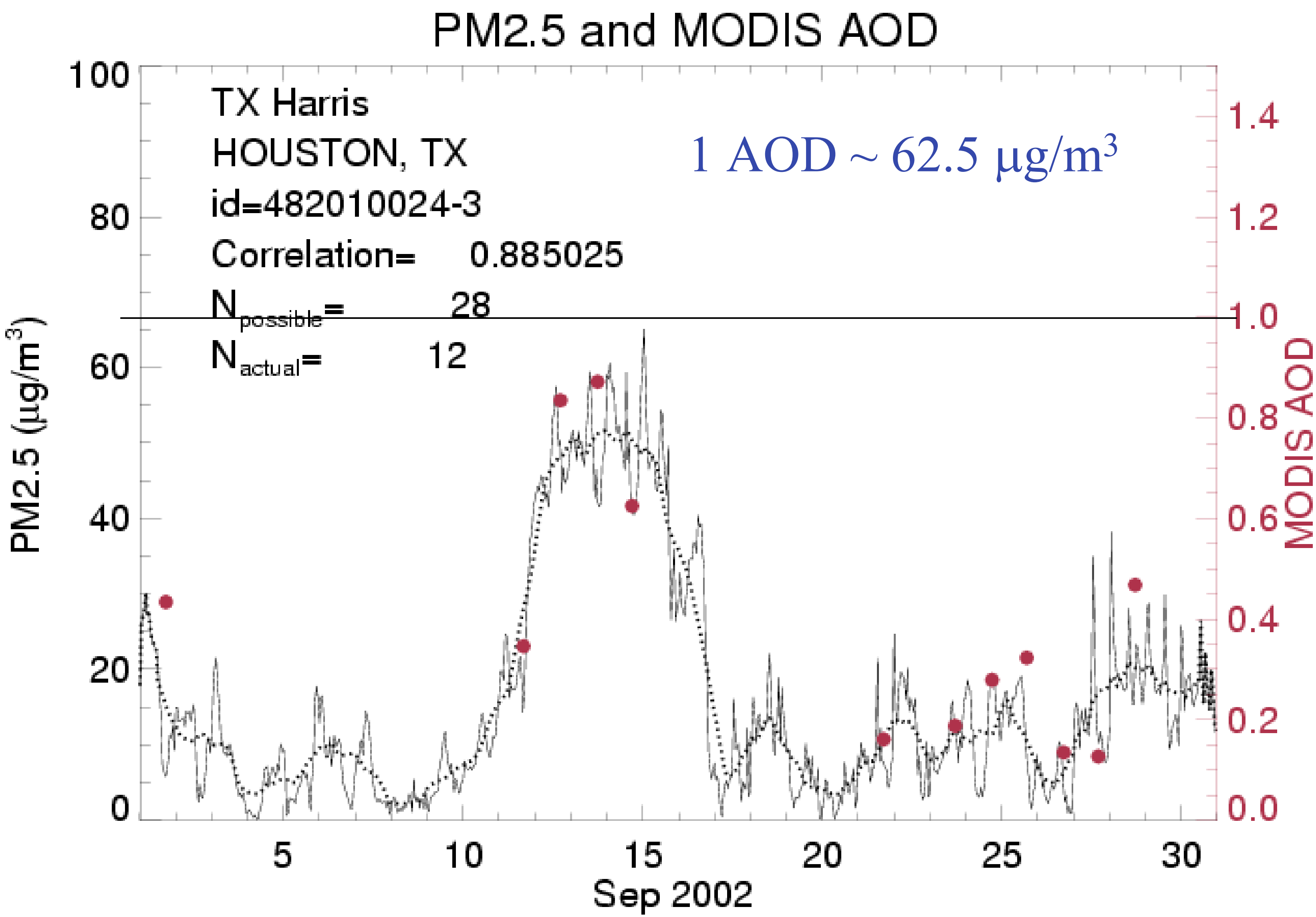
Converting aerosol optical depth to mass concentration measured at surface

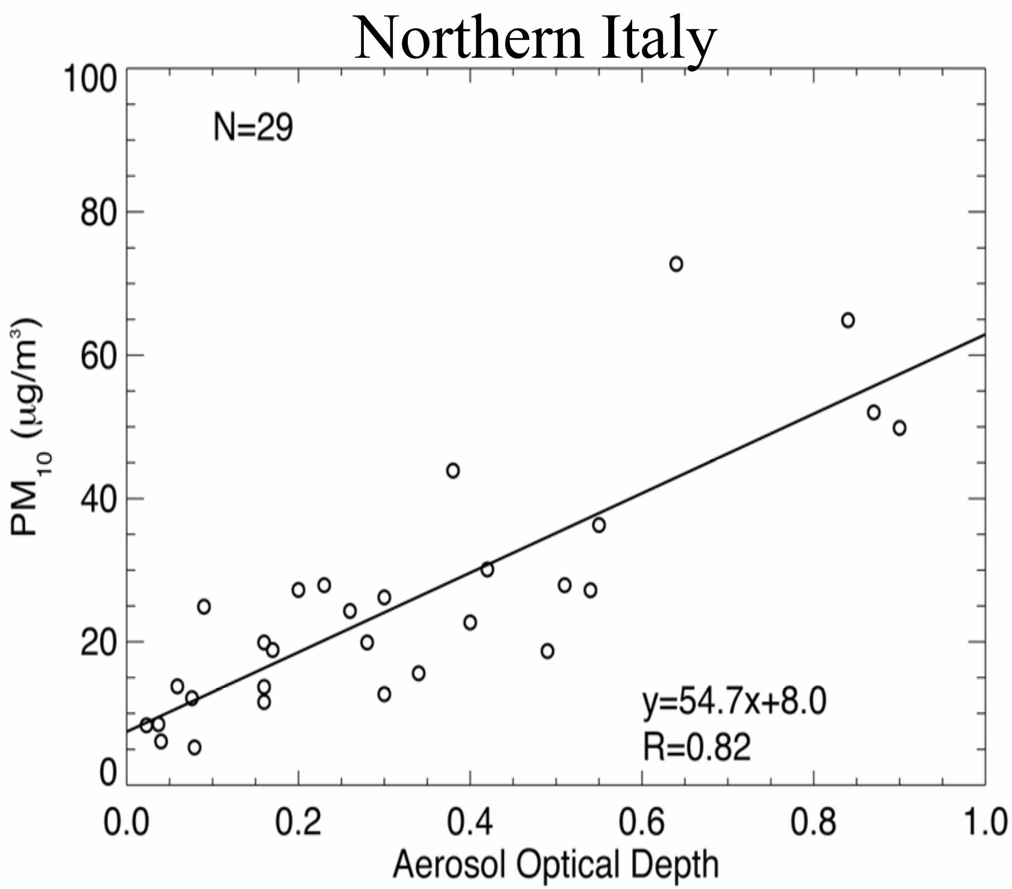
$$\Sigma\ \rho_{\square}\ M_{\square} = AOD$$

Mie theory: 54 - 80 $\mu g/m^3$ (assuming 1.5 km - 1.0 km aerosol height)

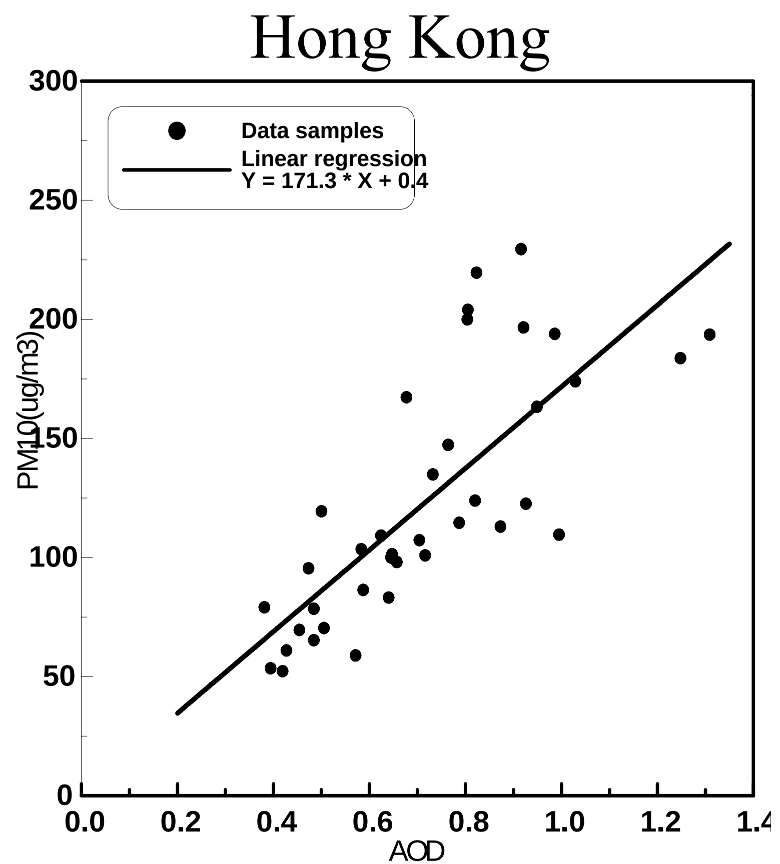
MODIS AOD & $PM_{2.5}$: 50 - 70 $\mu g/m^3$

$\Delta\ PM_{2.5}$ = 10 $\mu g/m^3$


PM2.5 and MODIS AOD
TX Harris
HOUSTON, TX
id=482010024-3
Correlation= 0.885025
N possible= 28
N actual= 12
1 AOD ~ 62.5 μg/m3
PM2.5 (μg/m3)
MODIS AOD
Sep 2002
100
80
60
40
20
0
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
25
30



Relationship between 24-hour PM_{10} concentrations and daily-averaged AERONET τ_a measurements from August to October 2000 in Northern Italy



Relationship between 24-hour PM_{10} concentrations and hand-held AOD measurements from August to October 2003 in Hong Kong

Chu et al. (2003)

Li et al. (2005)

Mean Absolute Error (MAE) = $\sum$ | predicted - measured | / N Over US

September 2003

MAE = 7.38 μg/m³

0<MAE<5	44	(13%)
0<MAE<10	224	(67%)
0<MAE<15	294	(88%)
0<MAE<20	309	(92%)
0<MAE<25	318	(95%)
0<MAE<30	327	(98%)

Number of sites = 335

July -September 2003

MAE = 9.97 μg/m³

0<MAE<5	44	(13%)
0<MAE<10	219	(64%)
0<MAE<15	298	(87%)
0<MAE<20	315	(92%)
0<MAE<25	321	(94%)
0<MAE<30	326	(95%)

Number of sites = 342

Table 1. Cumulative percentage of $PM_{2.5}$ sites (number of sites) in terms of mean absolute error (MAE) for September 2003 and for July to September 2003, respectively. The Eastern and Western US are separated by 100°W.

MAE Range ($\mu g/m^3$)	US	Eastern US	Western US
September 2003			
0 Š MAE Š 10	67% (224)	72% (171)	55% (53)
0 Š MAE Š 15	88% (294)	95% (225)	70% (69)
0 Š MAE Š 20	92% (309)	98% (233)	78% (76)
0 Š MAE Š 25	95% (318)	99% (237)	84% (81)
0 Š MAE Š 30	98% (327)	100% (238)	92% (89)
Total Number of Sites	335	238	97
July Š September 2003			
0 Š MAE Š 10	64% (219)	70% (171)	48% (48)
0 Š MAE Š 15	87% (298)	95% (232)	66% (66)
0 Š MAE Š 20	92% (315)	98% (238)	77% (77)
0 Š MAE Š 25	94% (321)	99% (240)	81% (81)
0 Š MAE Š 30	95% (326)	100% (242)	84% (84)
Total Number of Sites	342	242	100

Table 2. Correlation coefficient and mean absolute error derived for selected cities.

$PM_{2.5}$ site name	Correlation Coefficient	MAE ($\mu g/m^3$)
	Metropolitan	
New York, New York	0.84	10.0
Chicago, Illinois	0.87	9.9
Houston, Texas	0.88	5.2
	Good Air Quality	
Aberdeen, Washington	0.45	3.2
Port Angeles, Washington	-0.24	4.6
Tuscon, Arizona	-0.13	7.4
Forest Hill, Canada	-0.22	3.1
	Good Trend	
Decatur, Illinois	0.57	6.5
Tulsa, Oklahoma	0.55	5.6
Vikinglk, Iowa	0.57	3.5
Austin-San Marcos, Texas	0.46	5.1
	Bright surface	
Las Vegas, Nevada	-0.17	31.5
Las Cruces, New Mexico	0.15	23.1
Tuscon, Arizona	-0.45	31.1
El Paso, Texas	0.68	29.5
	California	
Oakland, California	-0.15	9.9
Sacramento, California	0.54	6.7
Corcoran, California	0.56	5.2
Vallejo-Fairfield, California	0.06	8.2
	Los Angles	
Burbank-W. Palm Ave	0.15	49.1
Banning-S. Hathaway St.	0.74	7.4

Conclusions

- Correlation should not be the only measure for evaluating the relationship between AOD and $PM_{2.5}$ especially at locations with good air quality (AOD < 0.3 or $PM_{2.5} < 15$ $\mu g/cm^3$)

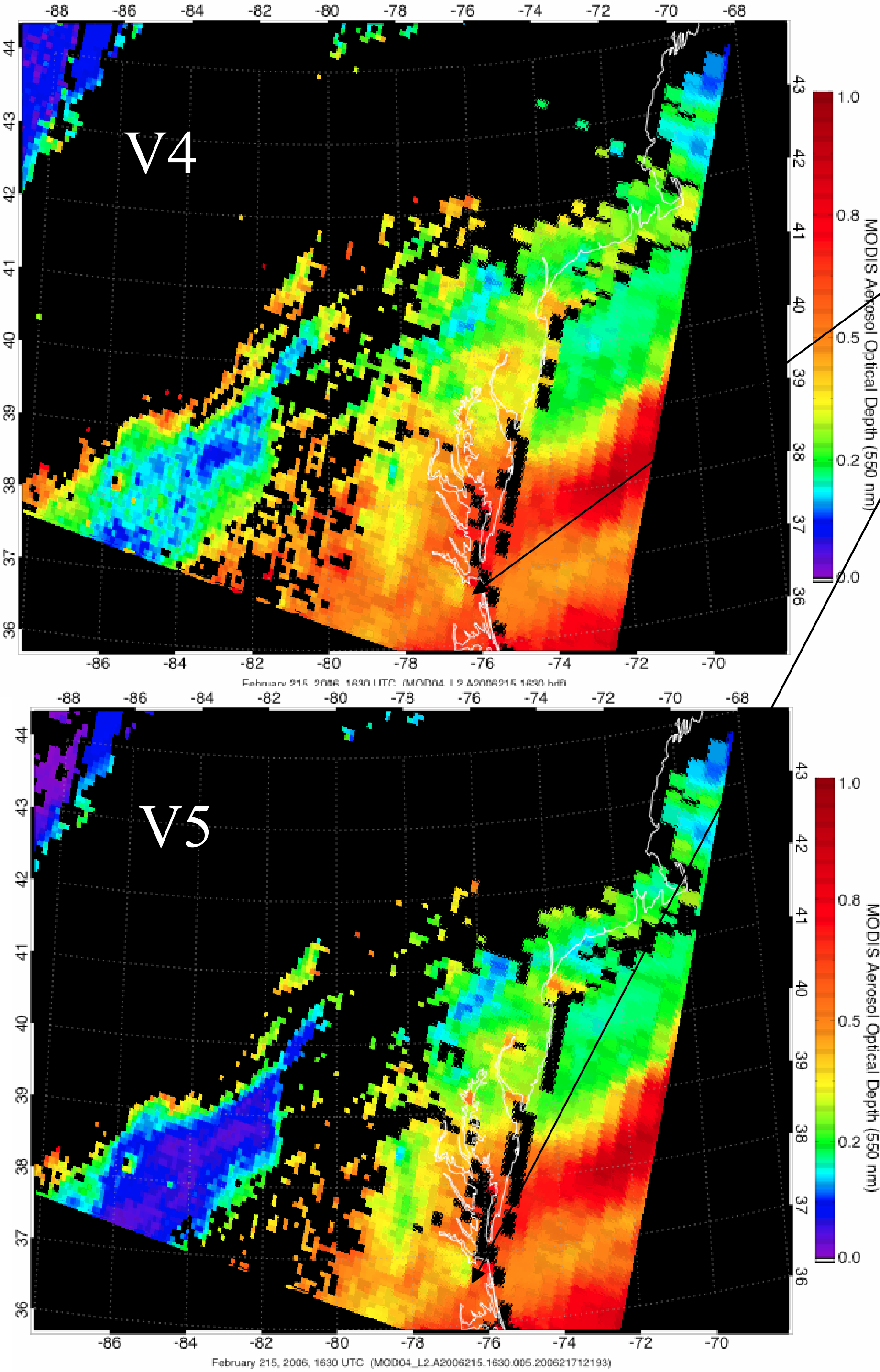
- Regional and long-range transport can alter correlation significantly; vertical distribution of AOD is necessary to be included in the analysis

- Western US (Nevada, New Mexico, Arizona) is shown to be more difficult for deriving good relationship between AOD and $PM_{2.5}$ (due to bright surface)

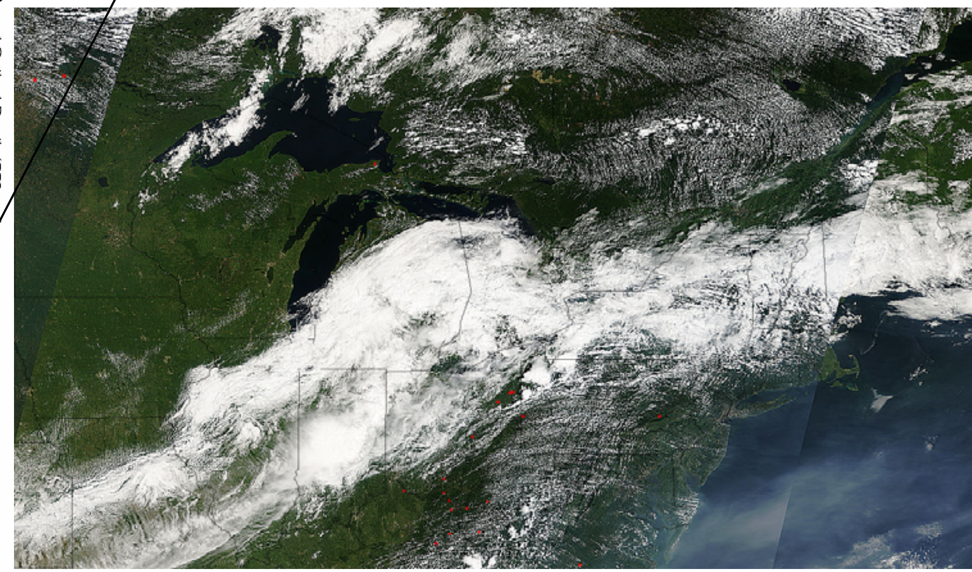
• MODIS Version 5 aerosol products are currently under evaluation for air quality application. Generally, less number of V5 AOD retrievals are shown due to more restrictive cloud screening (e.g., removing cumulus) and low AOD values (<0.1) may be too low (e.g., altitude correction) compared to V4 in the Eastern US.

In the western US (west of 100°W), V5 is better than V4.

However, the removal of cumulus, impair our ability to monitor air quality in locations where appear to be important in the summer time.



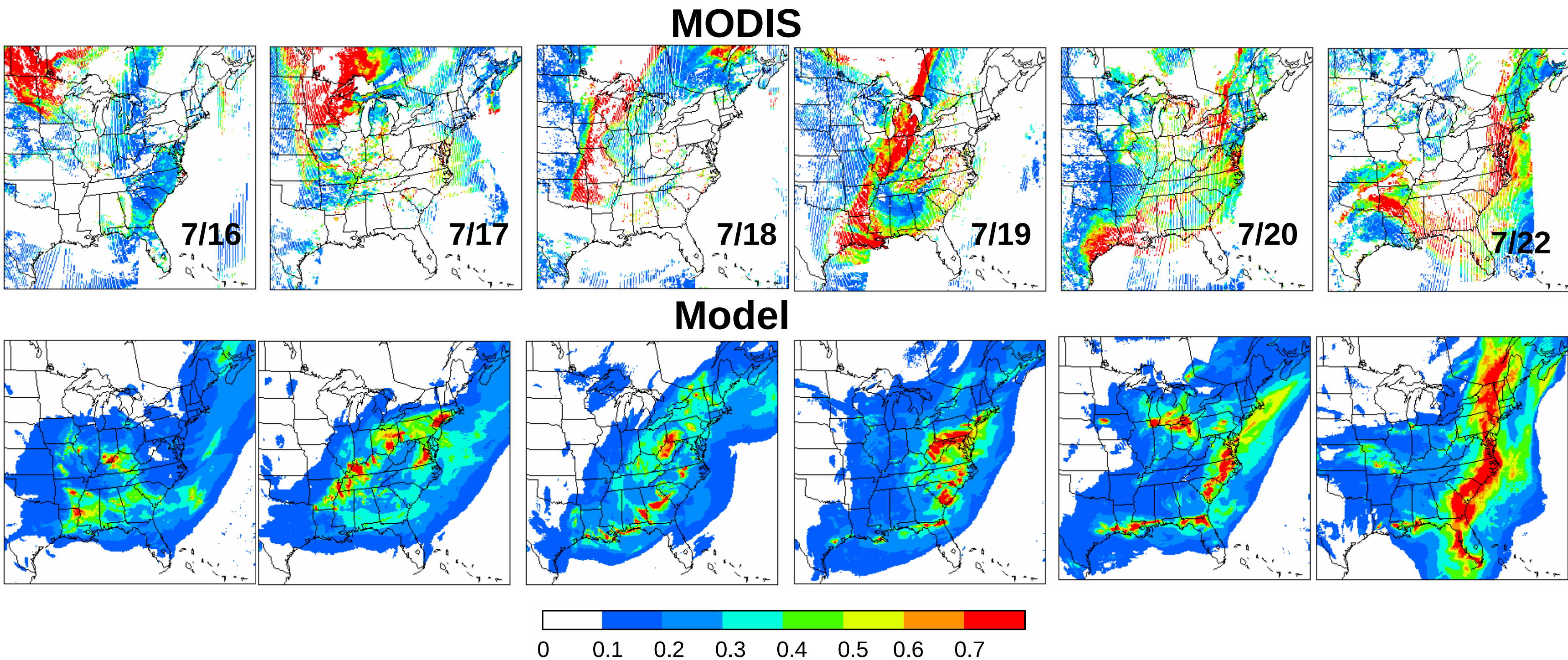
Virginia Beach



August 3, 2006

July 16-22, 2004: Evidence of Effects of Long Range Transport Originating Outside the Modeled Domain

Evolution of Model and Observed Aerosol Optical Depth



Transport from outside the domain influences observed **PM concentrations which are grossly under-predicted during this period**

- Model picks up spatial signatures ahead of the front
- Under predictions behind the front (due to LBCs)

July 17 July 18 July 19