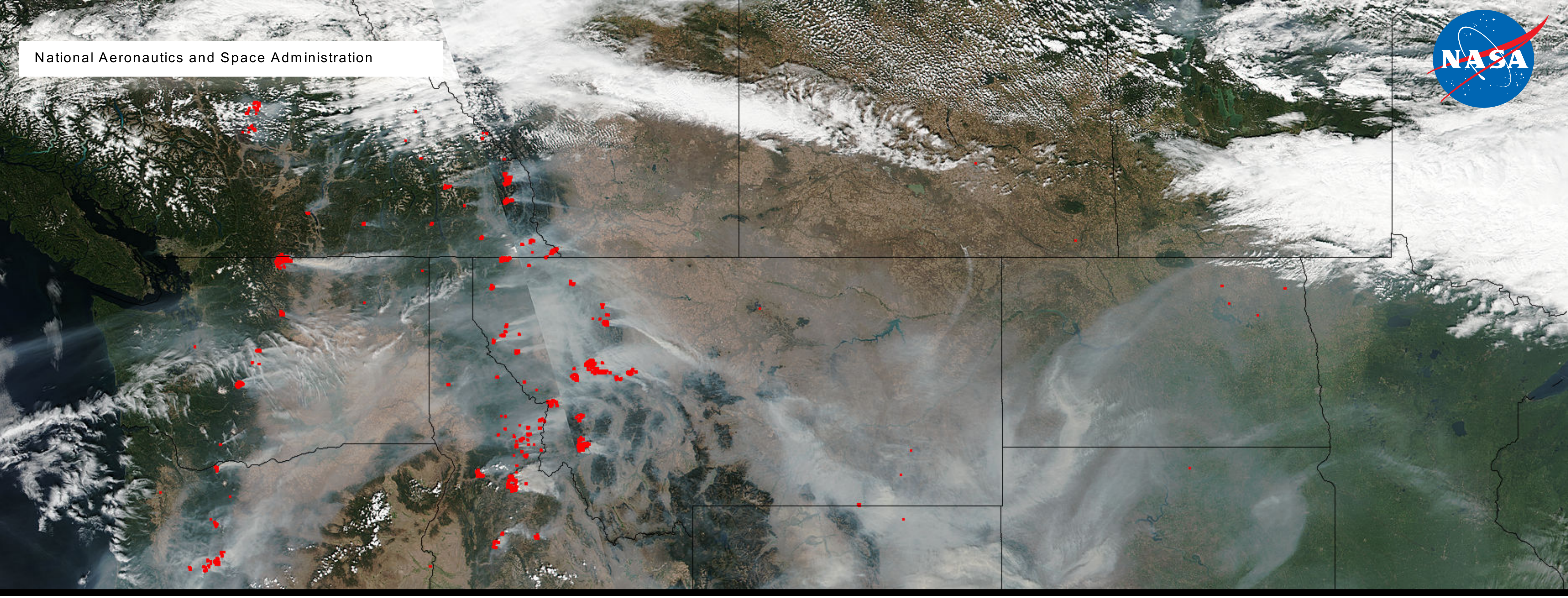
National Aeronautics and Space Administration



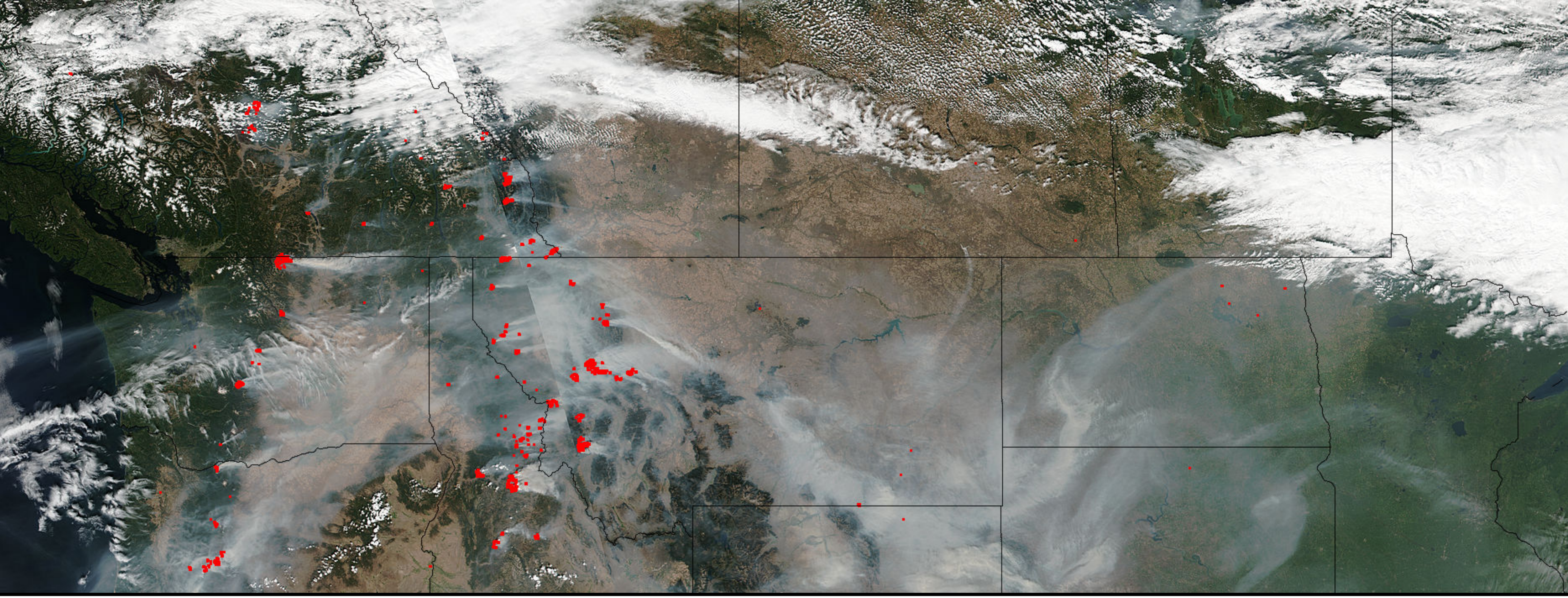
Converting AOD to $PM_{2.5}$: a Statistical Approach

Pawan Gupta, and Melanie Follette-Cook

Satellite Remote Sensing of Dust, Fires, Smoke, and Air Quality, July 10-12, 2018

Objective

- By the end of this exercise, you will be able to
  - convert satellite derived aerosol optical depth into surface level $PM_{2.5}$ mass concentration using a statistical approach



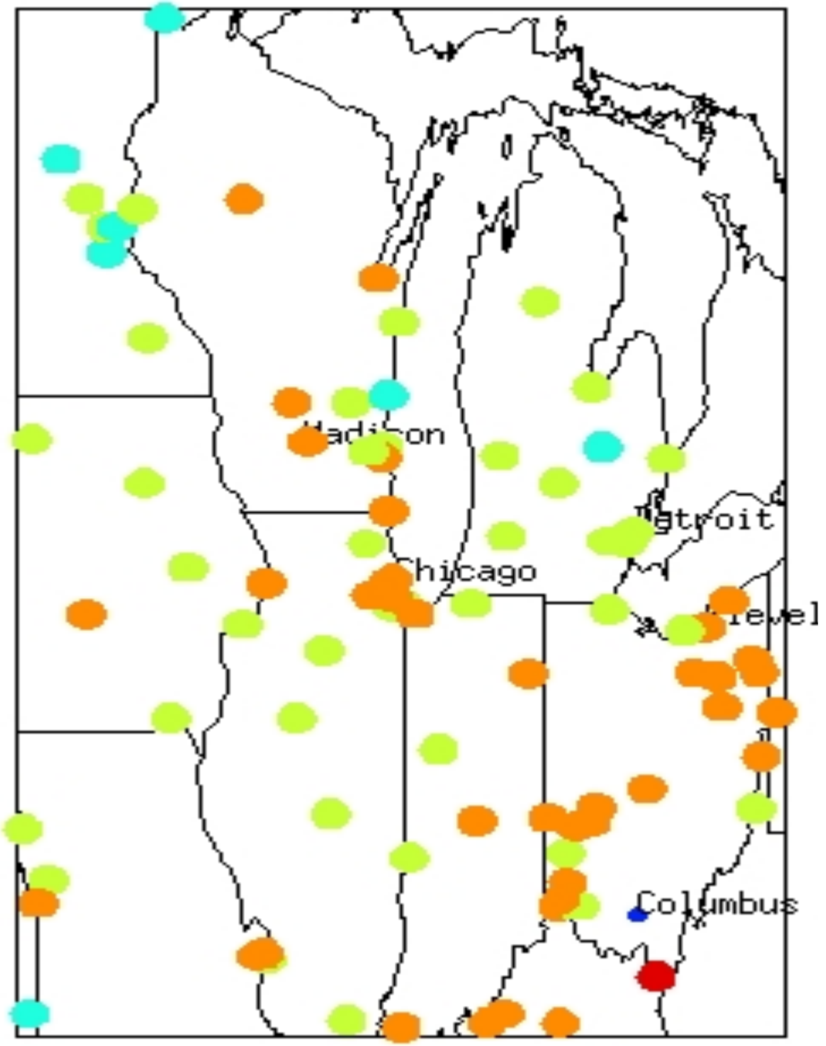
Exercise 1:
Converting AOD to $PM_{2.5}$

Required Data

- $PM_{2.5}$ mass concentration from ground monitors
- Satellite-derived aerosol optical depth
- Meteorological fields (only if working with a multi-variable method)

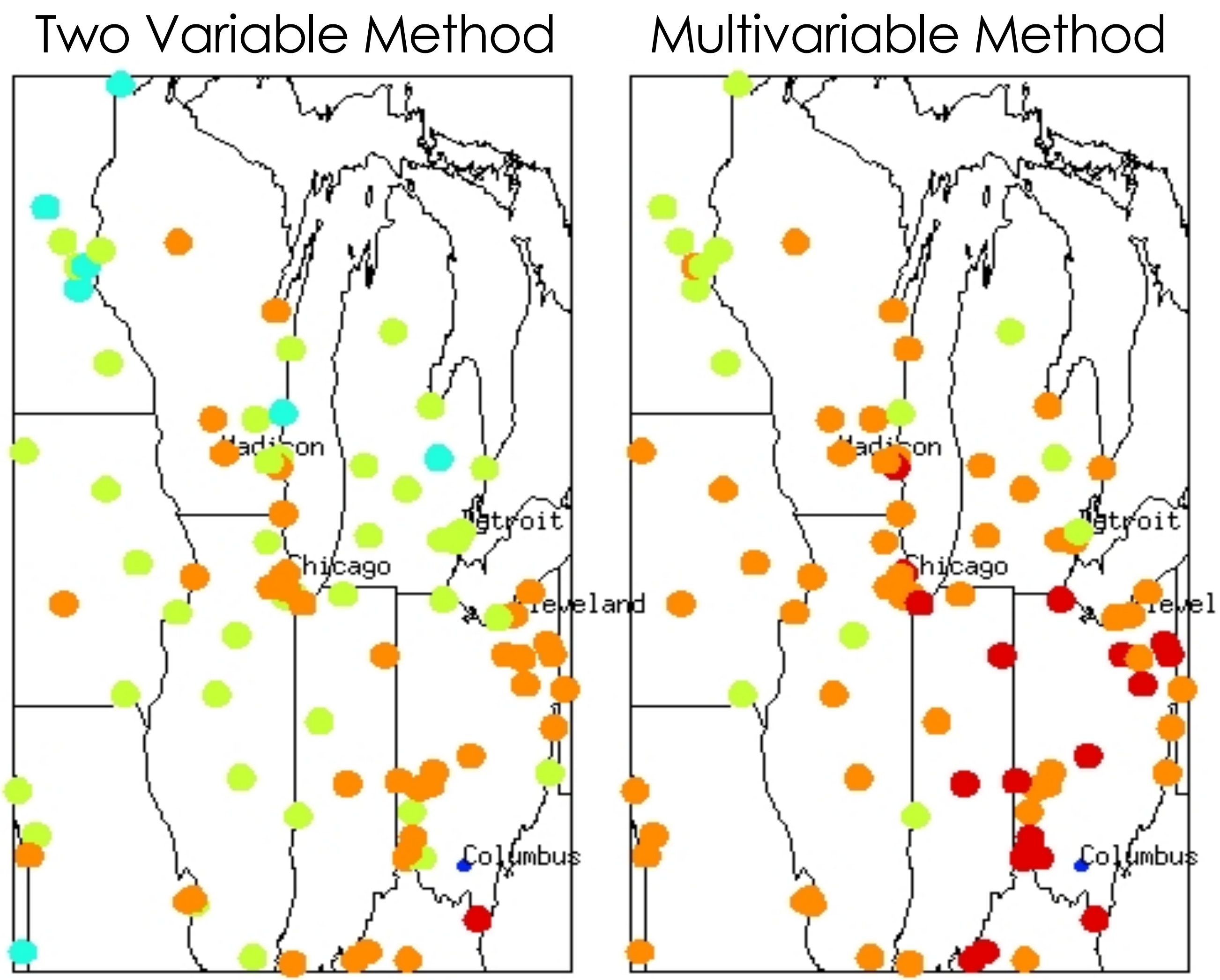
Correlation Between $PM_{2.5}$ and AOD

R
0.00-0.25
0.25-0.50
0.50-0.75
0.75-1.00



Correlation Between $PM_{2.5}$ and AOD

R
0.00-0.25
0.25-0.50
0.50-0.75
0.75-1.00



Converting AOD to $PM_{2.5}$ to AQC

Step 1: Getting Satellite and Surface Data

- Obtain a MODIS AOD data file from a NASA data server for your region, date, and time of interest
  - https://ladsweb.modaps.eosdis.nasa.gov/
  - from an earlier exercise

- To get PM2.5 for your region:
  - For U.S. Data: http://www.epa.gov/airdata/ad_maps.html
  - Global Air Quality Monitoring System: http://aqicn.org
  - Global open data: http://openaq.org
  - Your own data source or measurements

Converting AOD to $PM_{2.5}$ to AQC

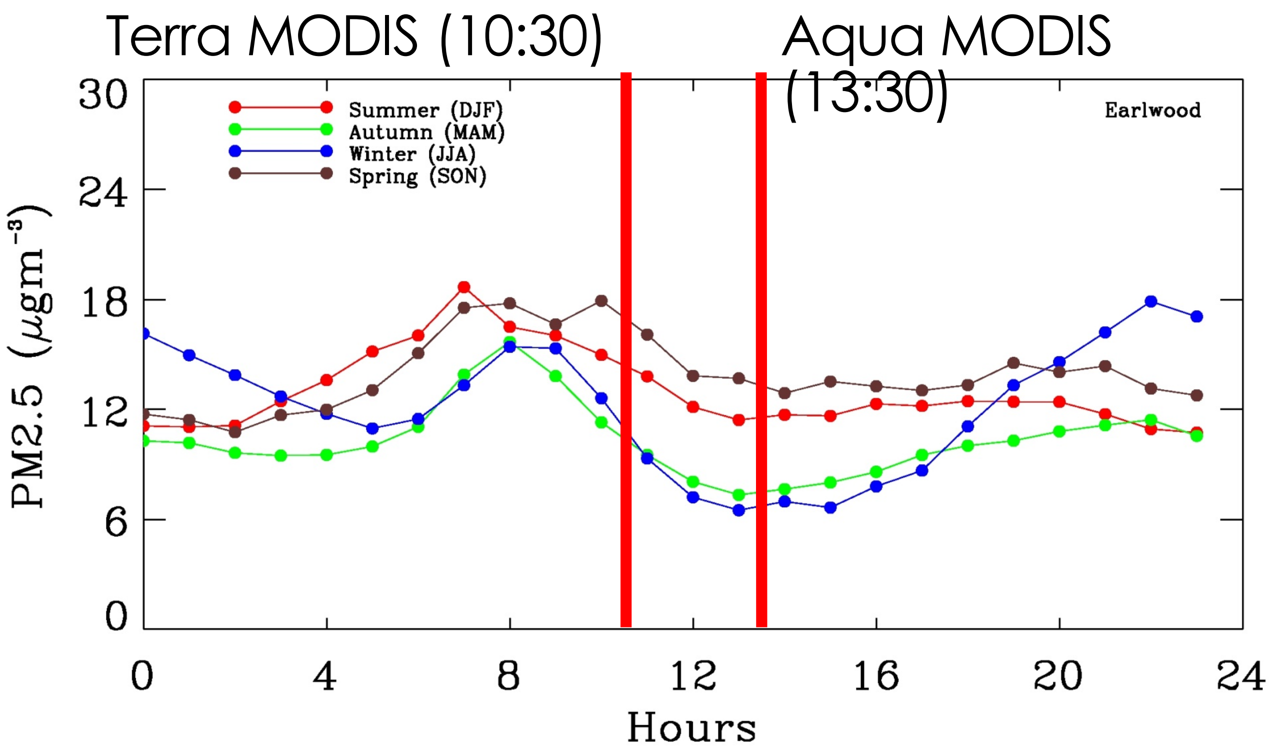
Step 2: Collocating Satellite and Surface Data

- Run IDL, Matlab, HDFLook, Python, etc. code to obtain AOD at the location of the $PM_{2.5}$ ground monitor
  - Python scripts: https://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi
  - IDL code: http://arset.gsfc.nasa.gov/sites/default/files/airquality/workshops/Santa_Cruz_2013/read_mod04_map_aqc.zip

Converting AOD to $PM_{2.5}$ to AQC

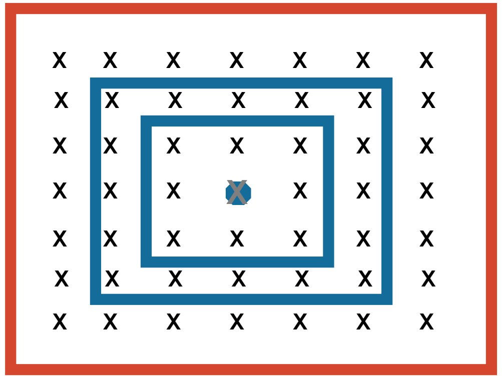
Step 2: Collocating Satellite and Surface Data

Temporal Collocation



pick the PM2.5 measurement from the ground closest to satellite overpass time

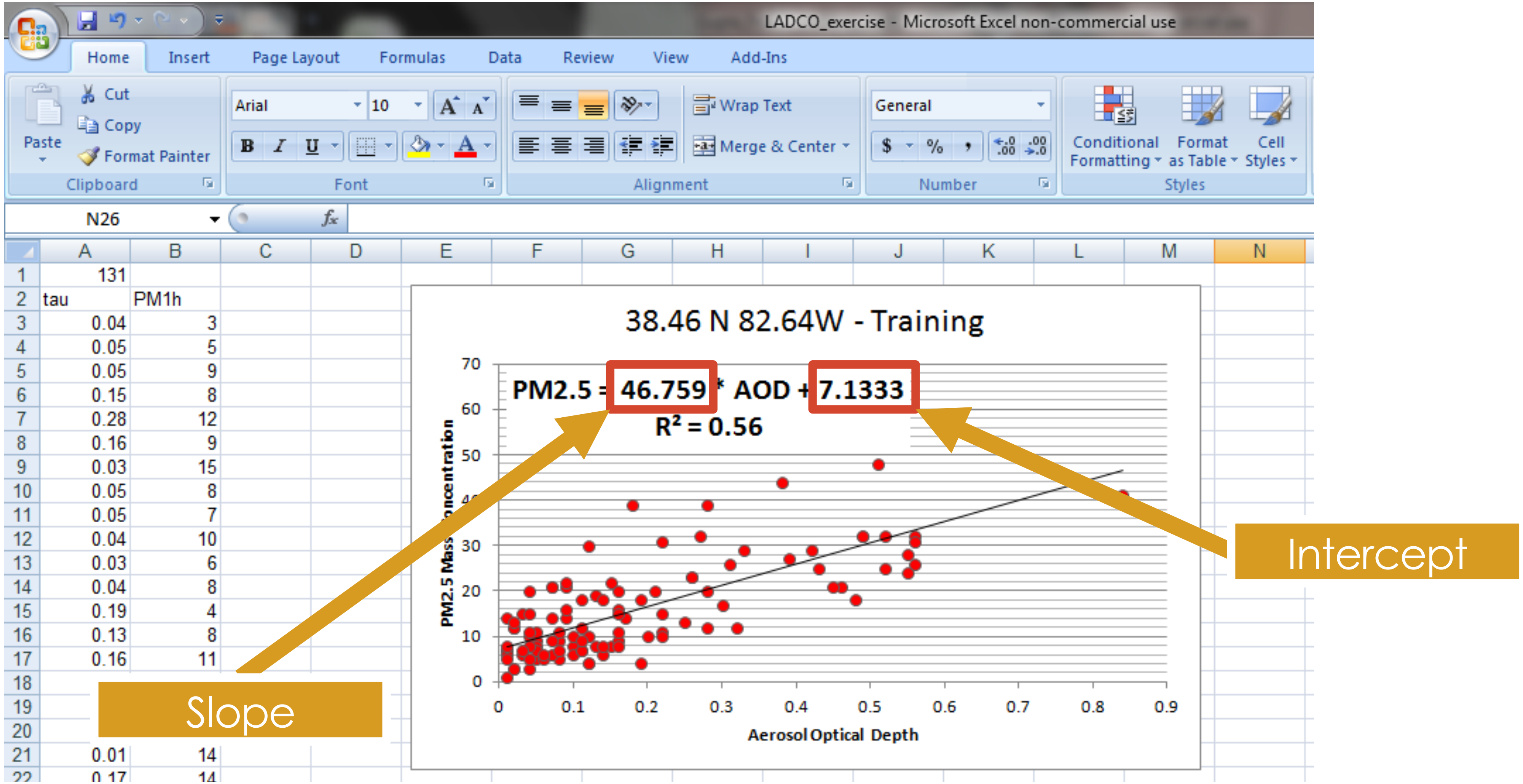
Spatial Collocation



pick the nearest pixel or average over 3x3 or 5x5 pixels

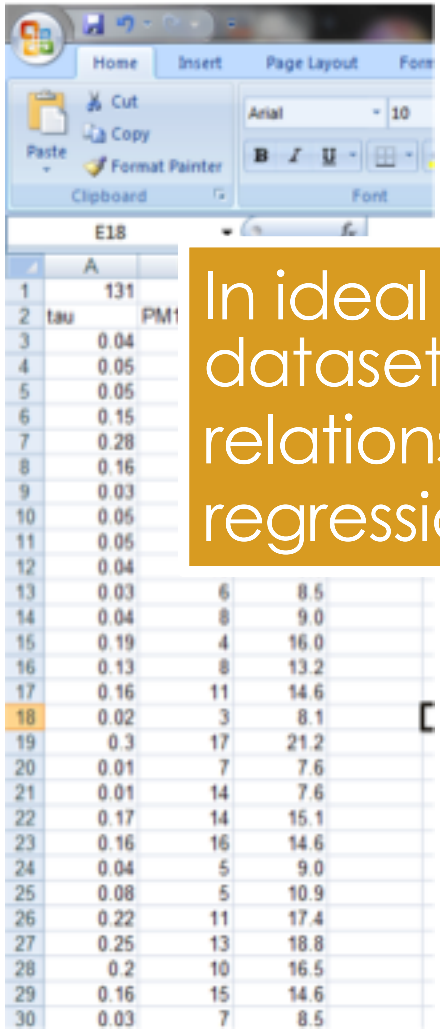
Converting AOD to $PM_{2.5}$ to AQC

Step 3: Developing a Relationship Between AOD & PM2.5



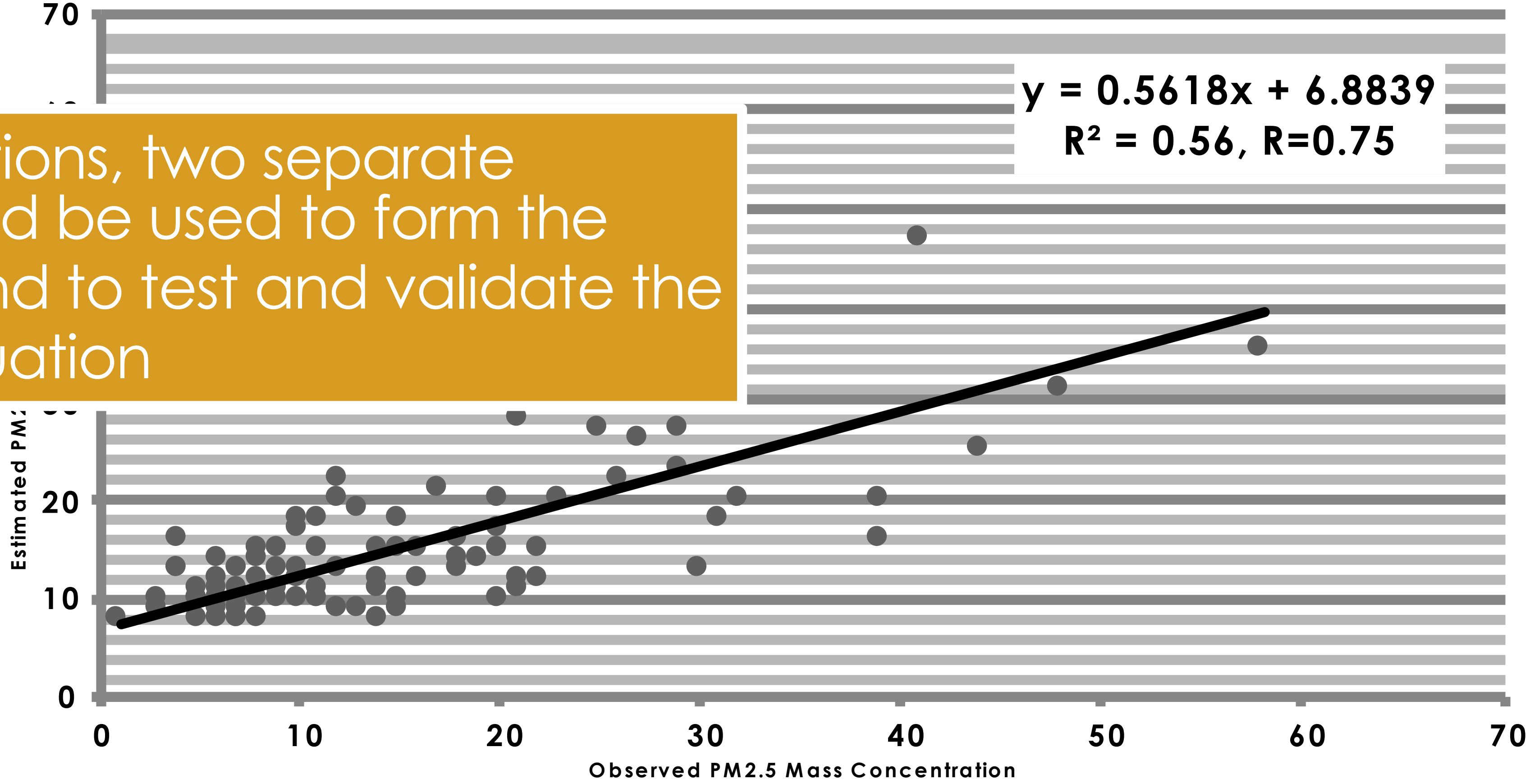
Converting AOD to $PM_{2.5}$ to AQC

Step 4: Estimating PM2.5 from Satellite AOD



	A	B	C
1	131		
2	tau	PM1	
3	0.04		
4	0.05		
5	0.05		
6	0.15		
7	0.28		
8	0.16		
9	0.03		
10	0.05		
11	0.05		
12	0.04		
13	0.03	6	8.5
14	0.04	8	9.0
15	0.19	4	16.0
16	0.13	8	13.2
17	0.16	11	14.6
18	0.02	3	8.1
19	0.3	17	21.2
20	0.01	7	7.6
21	0.01	14	7.6
22	0.17	14	15.1
23	0.16	16	14.6
24	0.04	5	9.0
25	0.08	5	10.9
26	0.22	11	17.4
27	0.25	13	18.8
28	0.2	10	16.5
29	0.16	15	14.6
30	0.03	7	8.5

PM2.5 = AOD * 46.7 + 7.13



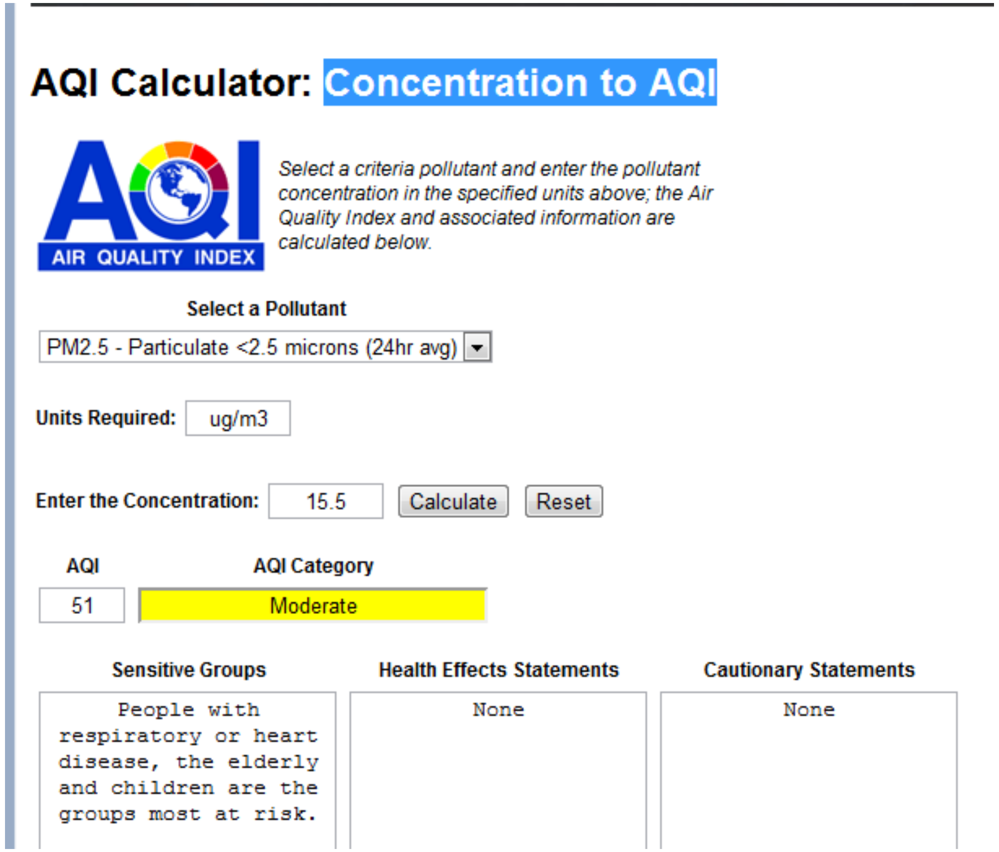
In ideal conditions, two separate datasets should be used to form the relationship and to test and validate the regression equation

Converting AOD to $PM_{2.5}$ to AQC

Step 5: $PM_{2.5}$ to Air Quality

Category	AQI Estimated 24-hour avg. µg/m^3
Good (0 - 50)	0 to 15.4
Moderate (51 - 100)	15.5 to 40.4
Unhealthy for Sensitive Groups (101 - 150)	40.5 to 65.4
Unhealthy (151 - 200)	65.5 to 150.4
Very Unhealthy (201 - 300)	150.5 to 250.4
Hazardous (301 - 500)	>250.4

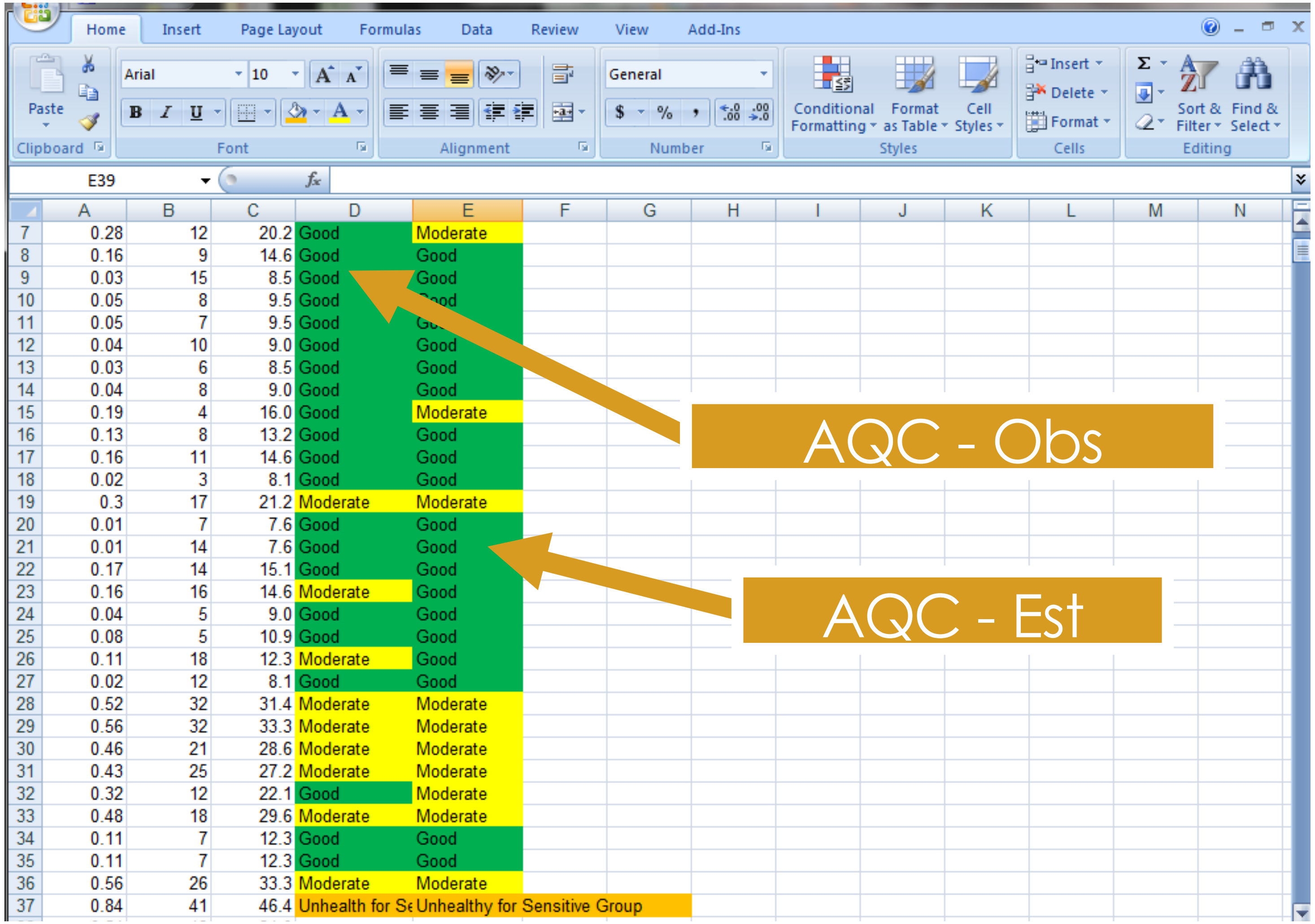
Online Tool



This is based on the U.S. EPA's definition of AQI, which can be different in other countries

Converting AOD to $PM_{2.5}$ to AQC

Step 5: PM2.5 to Air Quality

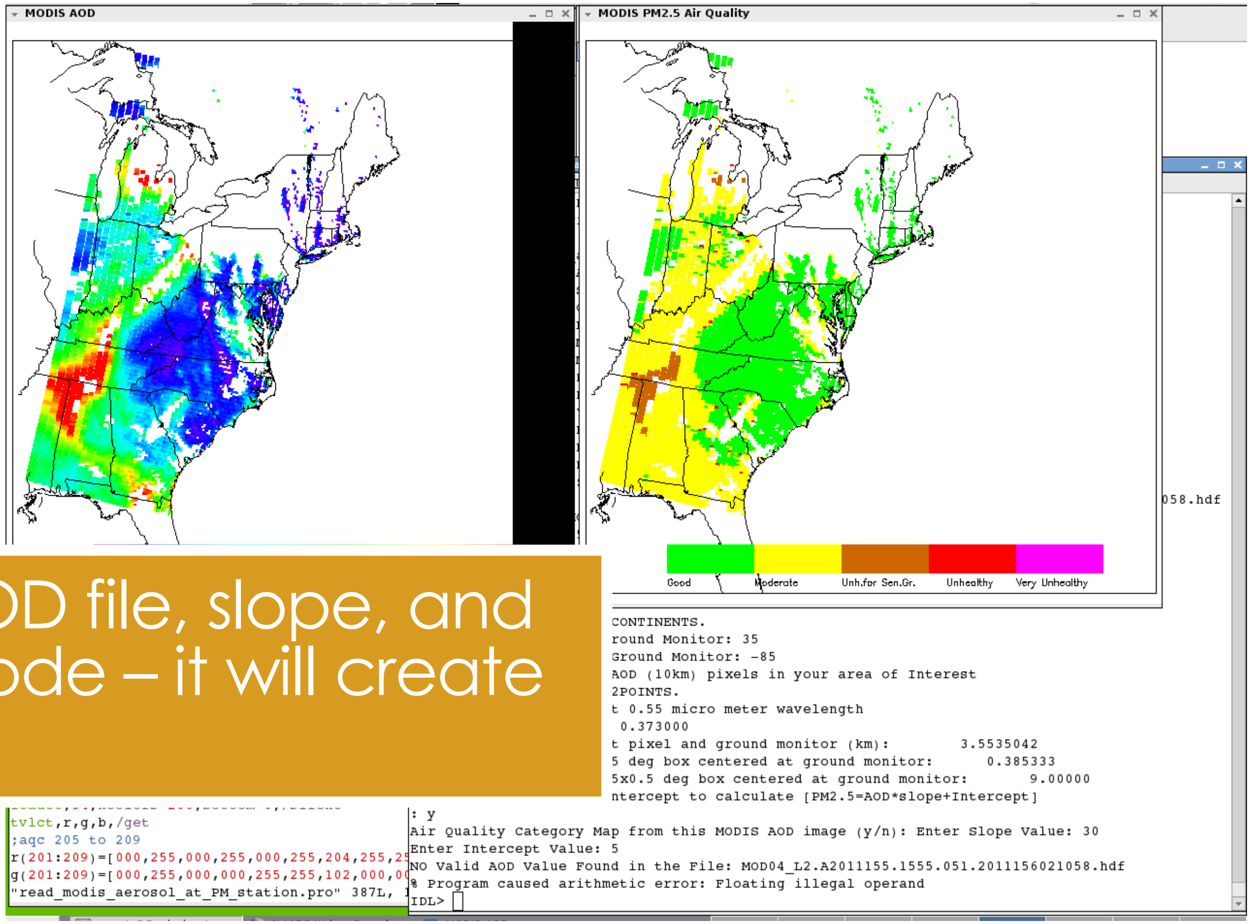


	A	B	C	D	E
7	0.28	12	20.2	Good	Moderate
8	0.16	9	14.6	Good	Good
9	0.03	15	8.5	Good	Good
10	0.05	8	9.5	Good	Good
11	0.05	7	9.5	Good	Good
12	0.04	10	9.0	Good	Good
13	0.03	6	8.5	Good	Good
14	0.04	8	9.0	Good	Good
15	0.19	4	16.0	Good	Moderate
16	0.13	8	13.2	Good	Good
17	0.16	11	14.6	Good	Good
18	0.02	3	8.1	Good	Good
19	0.3	17	21.2	Moderate	Moderate
20	0.01	7	7.6	Good	Good
21	0.01	14	7.6	Good	Good
22	0.17	14	15.1	Good	Good
23	0.16	16	14.6	Moderate	Good
24	0.04	5	9.0	Good	Good
25	0.08	5	10.9	Good	Good
26	0.11	18	12.3	Moderate	Good
27	0.02	12	8.1	Good	Good
28	0.52	32	31.4	Moderate	Moderate
29	0.56	32	33.3	Moderate	Moderate
30	0.46	21	28.6	Moderate	Moderate
31	0.43	25	27.2	Moderate	Moderate
32	0.32	12	22.1	Good	Moderate
33	0.48	18	29.6	Moderate	Moderate
34	0.11	7	12.3	Good	Good
35	0.11	7	12.3	Good	Good
36	0.56	26	33.3	Moderate	Moderate
37	0.84	41	46.4	Unhealth for Se	Unhealthy for Sensitive Group

Creating an Air Quality Category Map

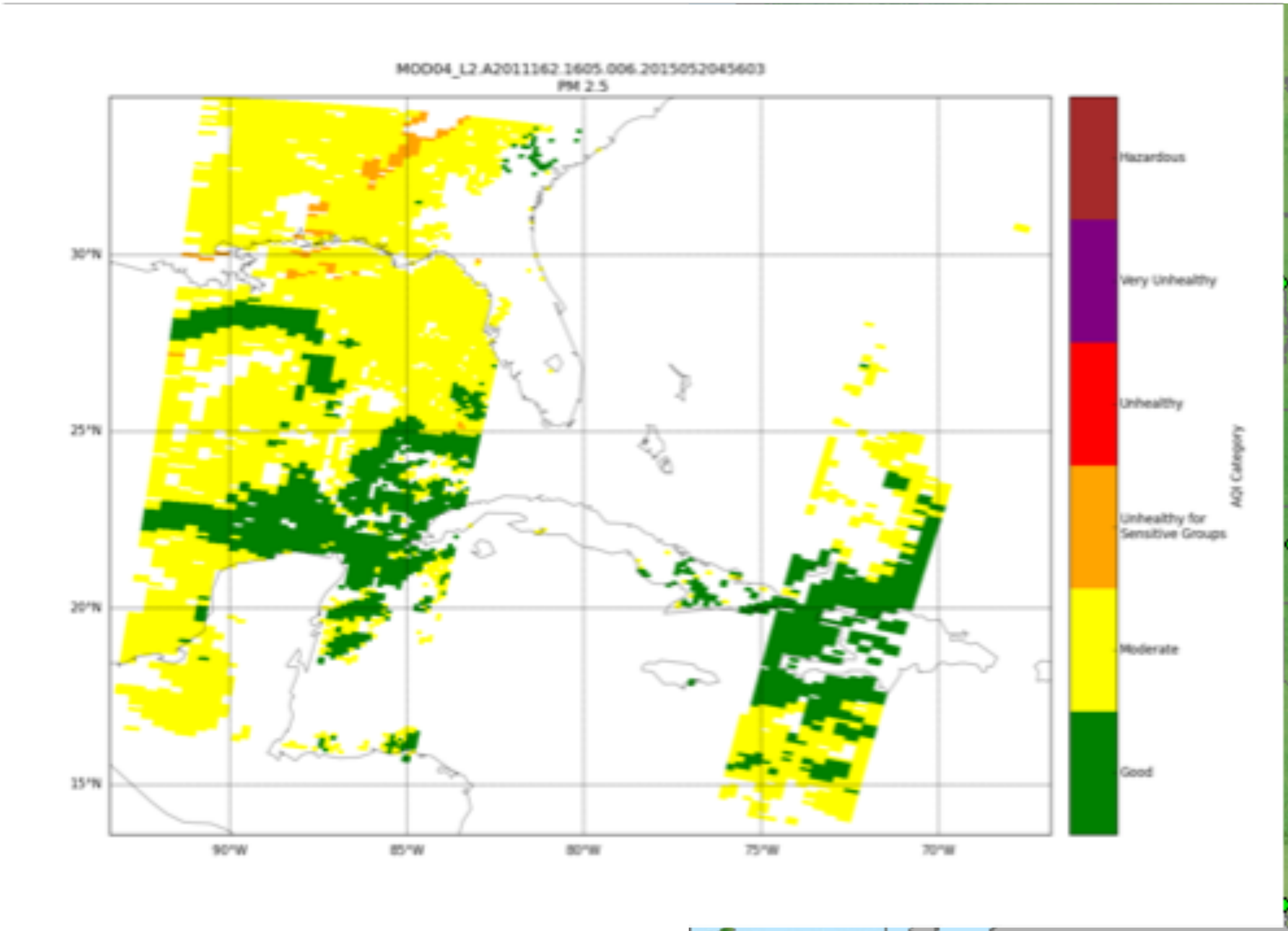
Python/IDL Tool

http://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi

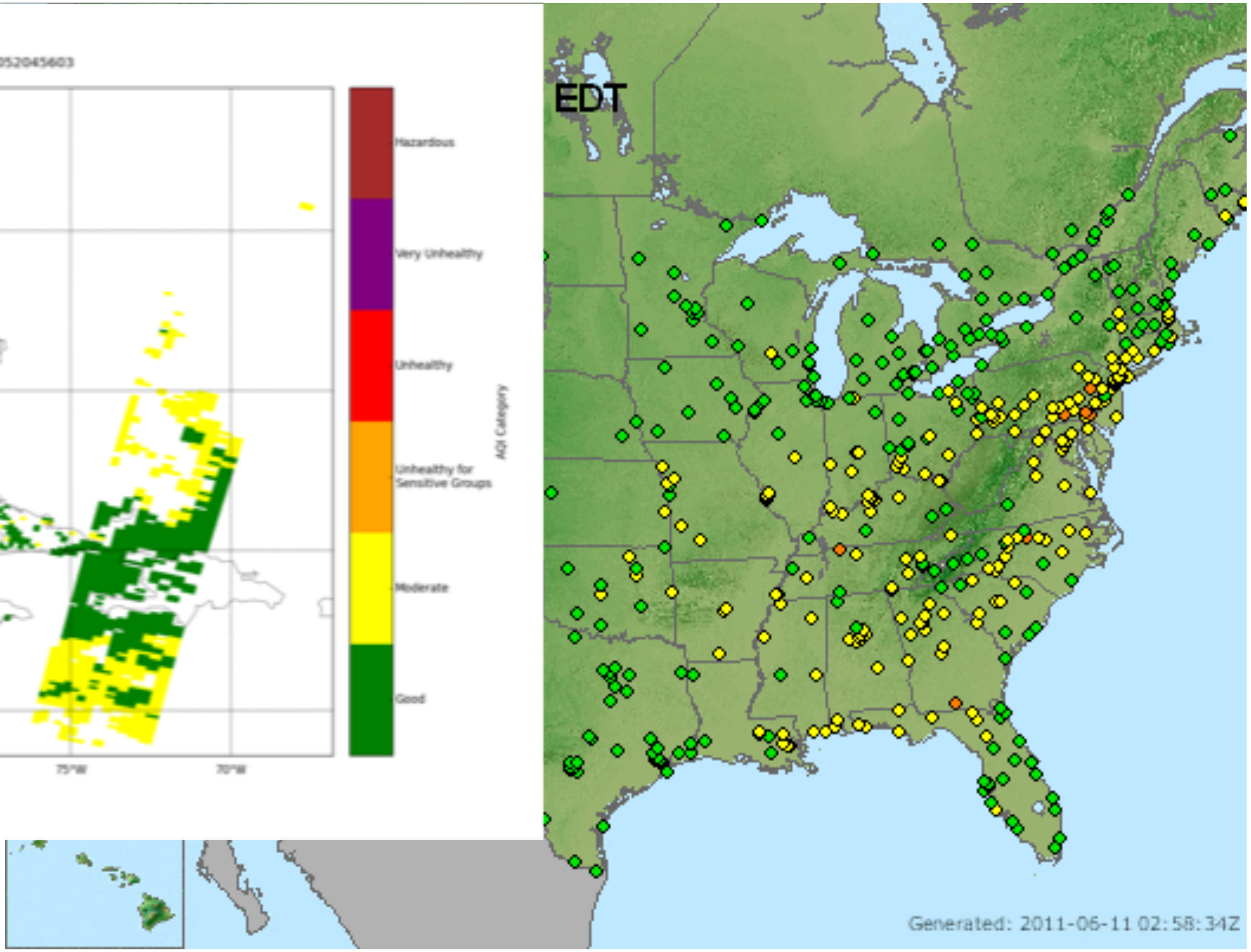


Provide MODIS AOD file, slope, and intercept to this code – it will create AQC map

June 10, 2011

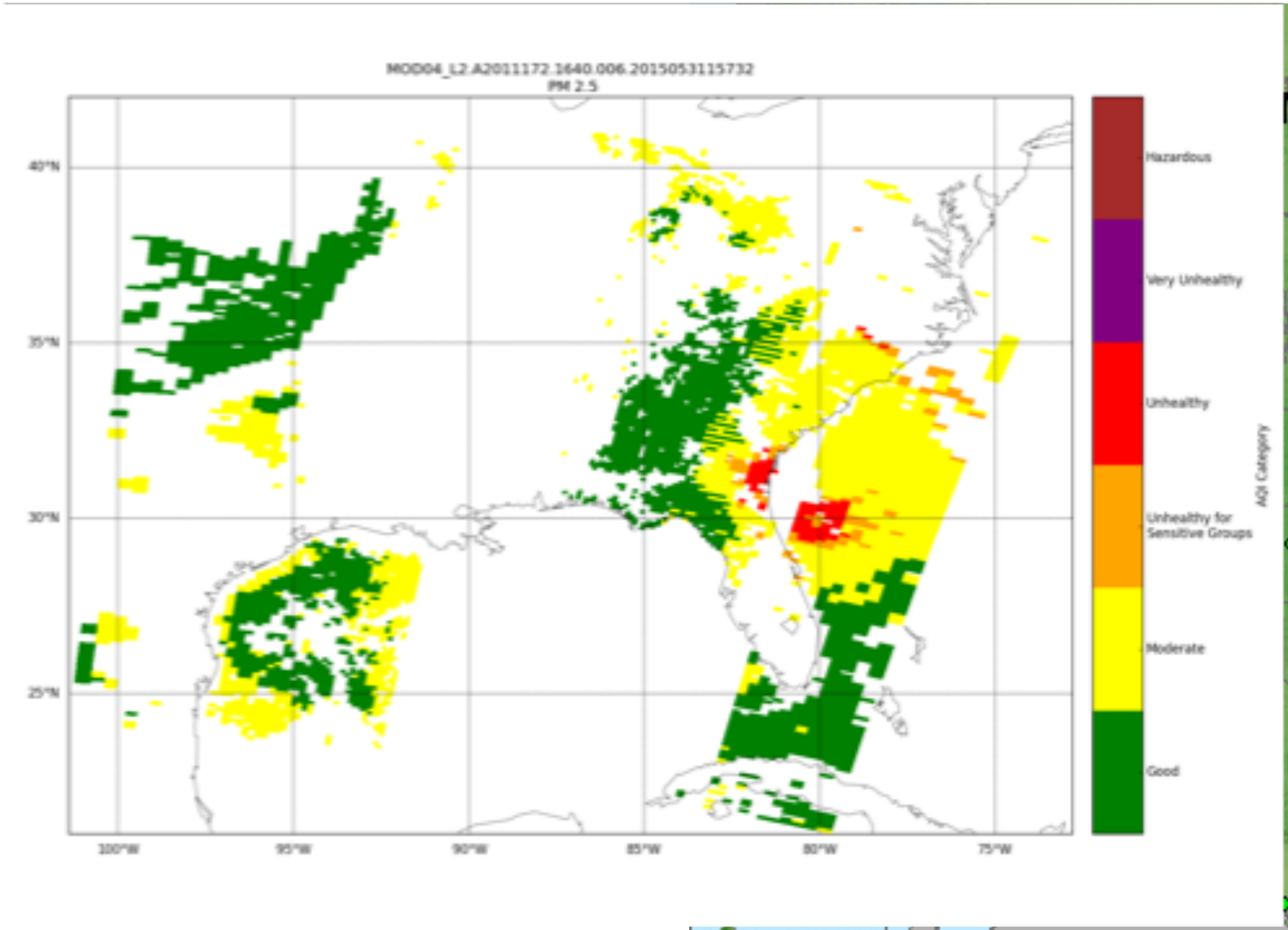


MOD04_L2.A2011162.1605.006.2015052045603
PM 2.5
30°N
25°N
20°N
15°N
90°W
85°W
80°W
75°W
70°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category

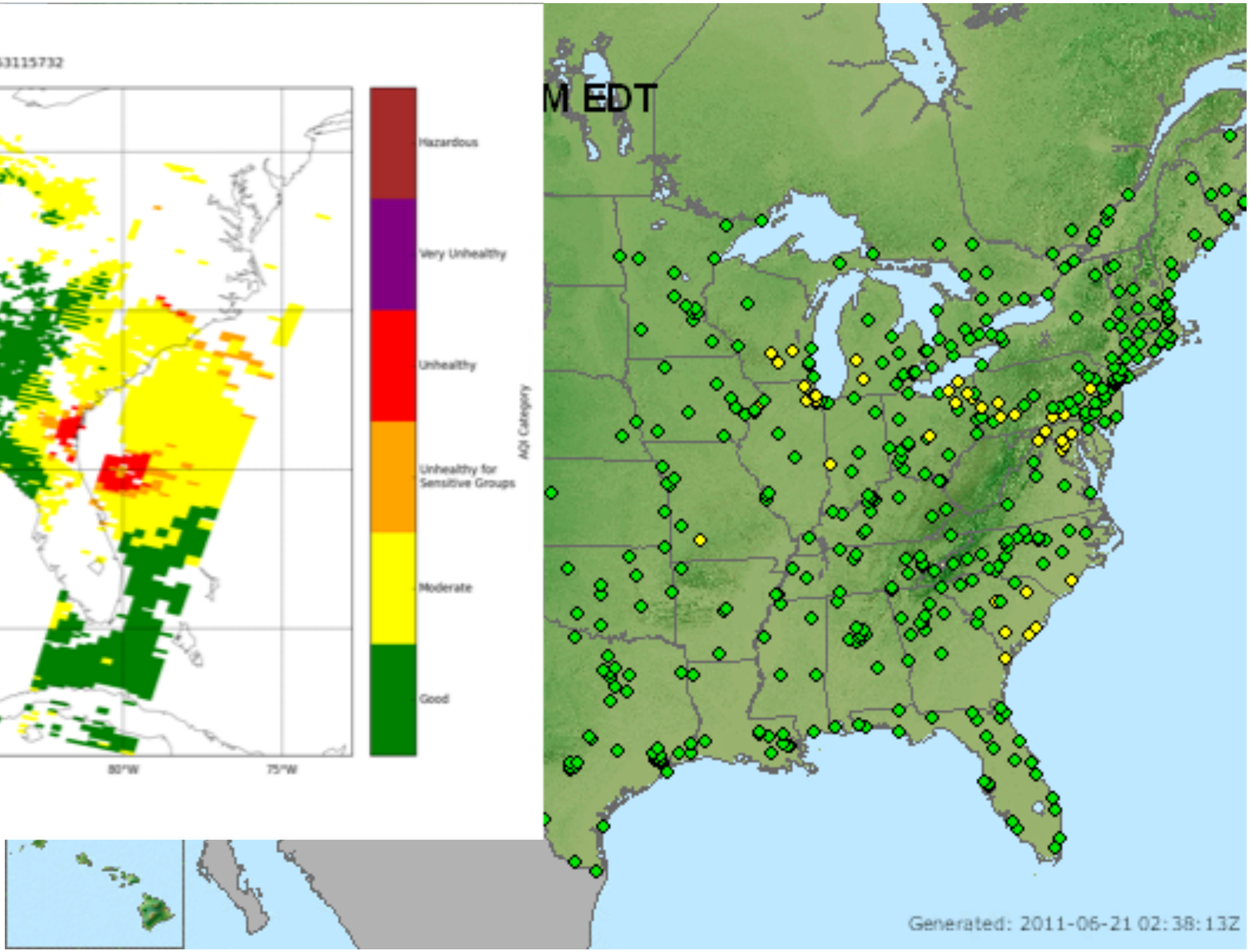


EDT
Generated: 2011-06-11 02:58:34Z

June 10, 2011

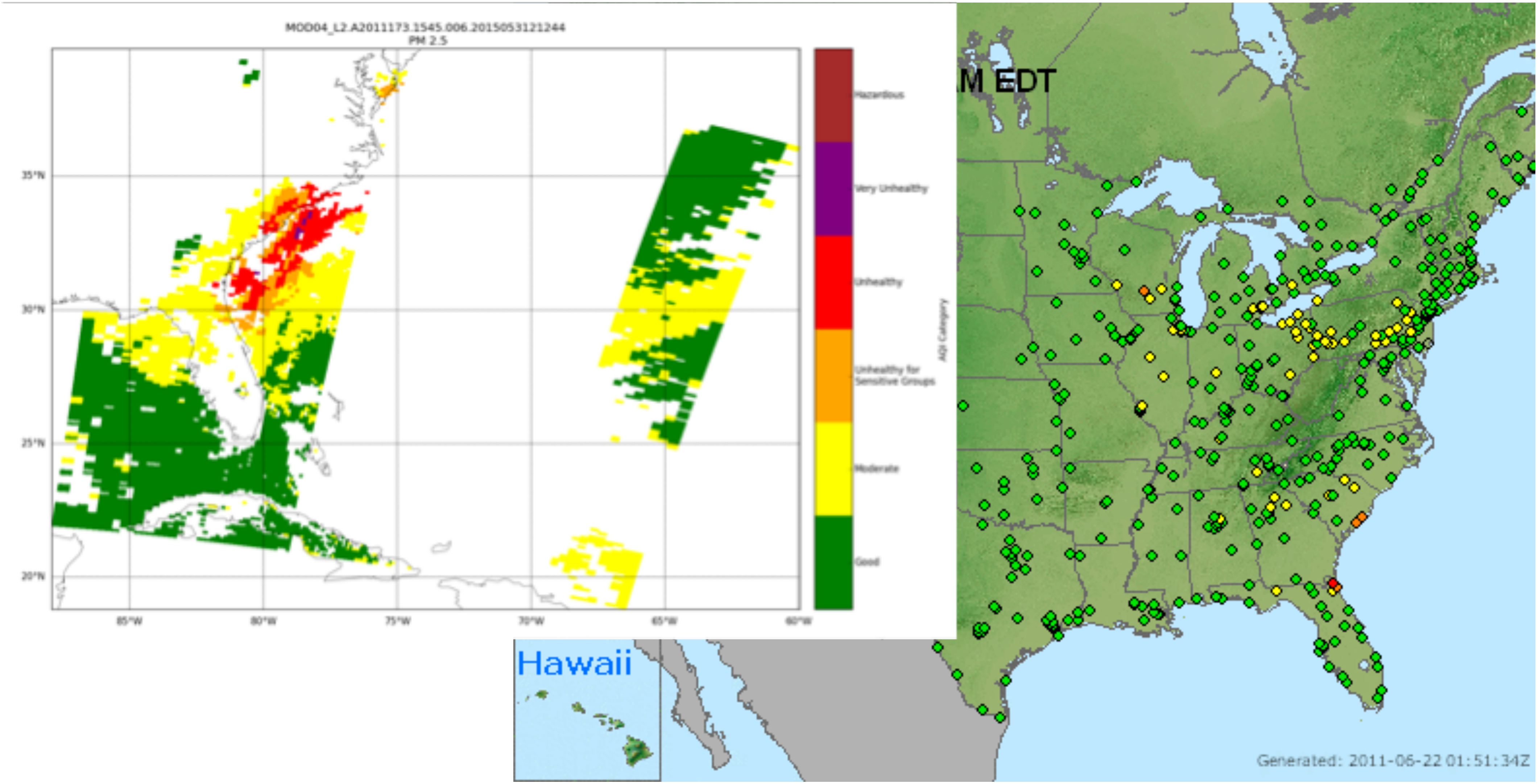


MOD04_L2.A2011172.1640.006.2015053115732
PM 2.5
40°N
35°N
30°N
25°N
100°W
95°W
90°W
85°W
80°W
75°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category



M EDT
Generated: 2011-06-21 02:38:13Z

June 21, 2011


MOD04_L2.A2011173.1545.006.2015053121244
PM 2.5
35°N
30°N
25°N
20°N
85°W
80°W
75°W
70°W
65°W
60°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category
M EDT
Hawaii
Generated: 2011-06-22 01:51:34Z

Multiple Linear Regression Method

$$PM_{2.5} = \beta_0 + \alpha \times \tau + \sum (\beta_n \times M_n)$$

- This method requires AOD, meteorological fields, more data processing, and more expertise
- Most of the time this produces a more accurate $PM_{2.5}$ estimation

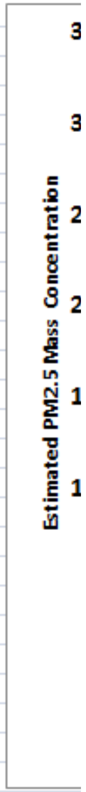
Multiple Linear Regression Models

AOD, $PM_{2.5}$, and Meteorological Data

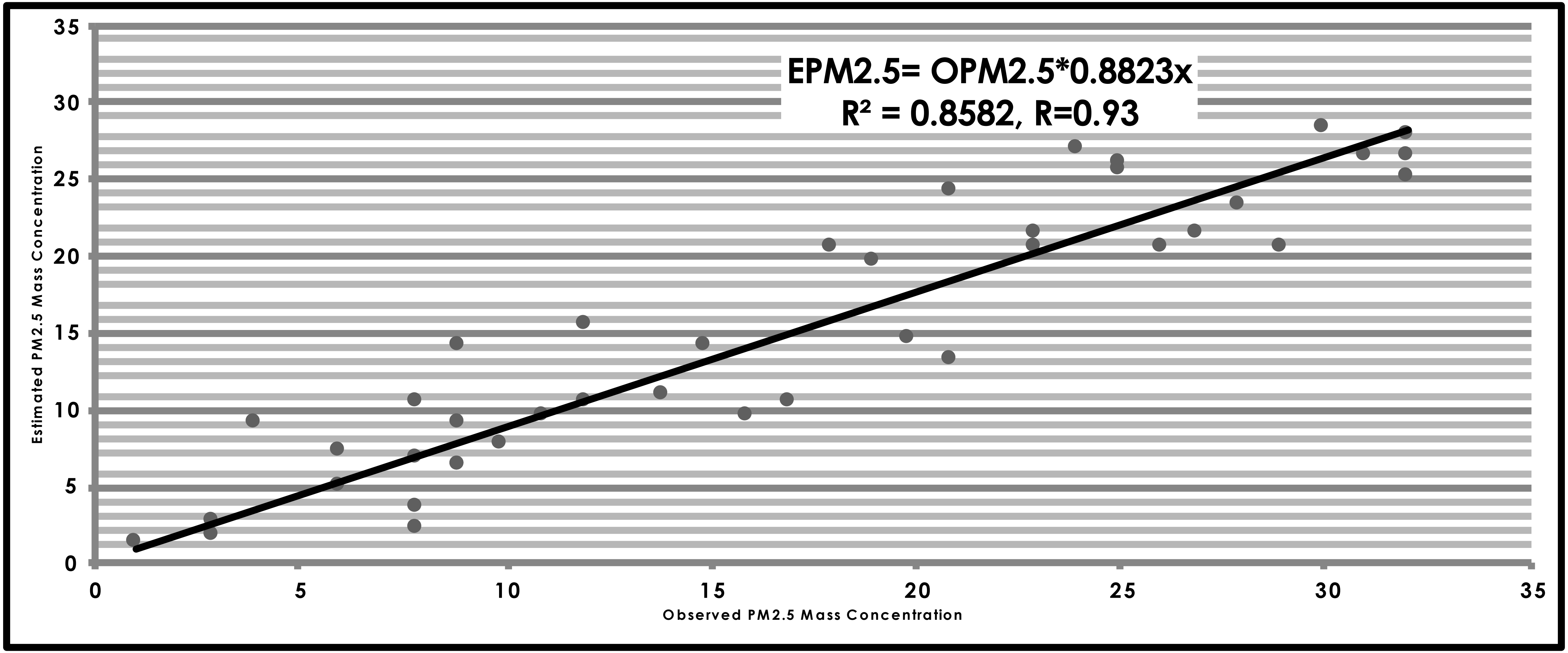
N3 =17.02*A3+1.14*D3-0.92*E3+0.44*F3-0.95*G3+1.04*H3-0.04*I3-0.31*J3-0.031*K3-0.0022*L3-177.26

atitude = 38.46, Longitude = -82.64

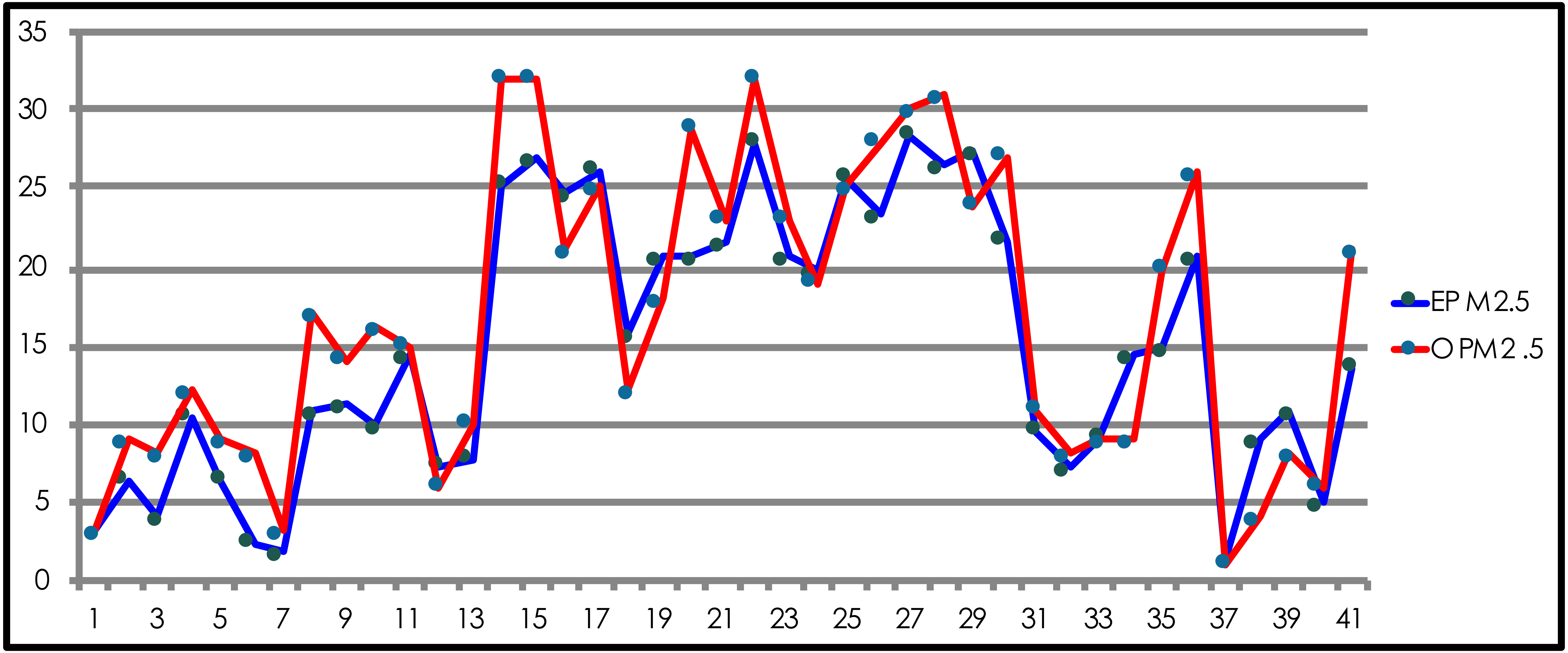
	PM1h	tmp0	tmp1000	tmp700	rh0	rh1000	rh700	ws0	ws925	hpbl	EPM2.5
3	3	277.47	277.4	266.05	71.26	71	70.32	4.14	16.22	63.33	2.995254
4	9	287.25	285.97	270.8	28.95	29.41	39.34	2.76	1.41	623.5	6.35489
5	8	274.13	273.1	260.93	63.01	63.56	17.28	4	8.79	675.67	3.911136
6	12	287.43	286.53	269.72	46.23	46.52	23.82	3.64	9.04	800.67	10.58439
7	9	275.9	275.85	264.3	59.98	60.34	11.2	3.39	5.76	53	6.47774
8	8	283.18	281.67	265.93	35.44	35.57	79.54	0.65	2.47	676.83	2.494904
9	3	286.07	283.98	265.25	36.55	36.66	42.77	4.46	9.49	1325.83	1.748084
10	17	297.03	297.98	275.33	52.06	51.57	81.85	4.04	13.09	925.5	10.67131
11	14	296.88	294.37	274.78	29.43	29.35	27.39	2.18	6.37	1633.33	11.1627
12	16	297.05	295.72	275.03	25.06	25.43	44.91	4.98	16.45	914.83	9.828424
13	15	299.85	297.52	275.25	42.4	42.92	42.66	3.17	6.19	1281.5	14.36151
14	6	289.07	287.65	269.45	57.64	58.14	68.48	4.43	34.55	478.83	7.372424
15	10	295.3	293.57	273.68	42.91	43.34	88.06	3.94	17.43	1226	7.74657
16	32	301.9	299.88	282.63	51.67	51.79	32.02	2.83	9.8	585.17	25.24983
17	32	303.42	300.45	282.27	50.19	50.36	23.46	2.64	6.74	833.5	26.84926
18	21	299.68	297.82	279.97	80.46	80.25	68.37	2.38	6.51	75	24.58039
19	25	304.13	301.87	283.48	64.15	64.42	31.91	3.5	6.1	541.17	26.09083
20	12	295.48	295.2	276.62	64.84	63.68	18.02	4.36	6.28	849.83	15.65489
21	18	300.6	297.15	276.12	45.32	45.23	21.52	1.03	2.05	1799.67	20.49068
22	29	302.4	299.1	279.78	60.49	60.86	47.22	3.41	5.88	1457.67	20.51765
23	23	303.7	300.62	282.55	60.82	60.86	12.18	2.56	6.53	1655.67	21.5245
24	32	307.48	303.73	284.97	63.16	63.1	57.85	1.99	6.4	969.83	27.92127
25	23	306.27	304.75	282.85	59.03	58.51	43.11	2.42	6.73	880.5	20.54857
26	19	307.38	304.78	283.63	51.07	51.09	34.56	4.67	7.7	777.83	19.60247
27	25	306.15	303.15	283.25	60.33	60.41	56.95	4.62	6.13	953.83	25.84764
28	28	304.92	303.35	283.4	63.96	63.78	81.48	2.4	6.46	1561.83	23.25351
29	30	302.98	302.9	281.58	59.39	59.84	94.25	3.08	6.66	1391.33	28.37551
30	31	301.35	300.05	282.43	60.76	60.4	33.71	2.94	7.29	89.33	26.44508
31	24	305.43	302.2	280.67	55.96	56.51	23.92	2.29	3.24	1058.83	27.27383



Multiple Linear Regression Method Results



Multiple Linear Regression Method Results



!! CAUTION !!

- Regression analysis provides the first approximation of surface $PM_{2.5}$ mass concentration and air quality
- Its accuracy depends on training data and varies in space and time
- Careful data quality control, testing, and validation should be performed before using this method for quantitative analysis
- Works best when the boundary layer is well mixed, there is no significant aerosol aloft, and in small particle dominated regions

Existing Data Satellite Based Sets for CONUS

- IDEA
  - https://www.star.nesdis.noaa.gov/smcd/spb/aq/
- e-IDEA
  - https://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea/
- ASDP
  - https://asdp.airnowtech.org/about.php
- Dalhousie
  - http://fizz.phys.dal.ca/~atmos/martin/?page_id=140
- Smog Blog
  - http://alg.umbc.edu/usaq/