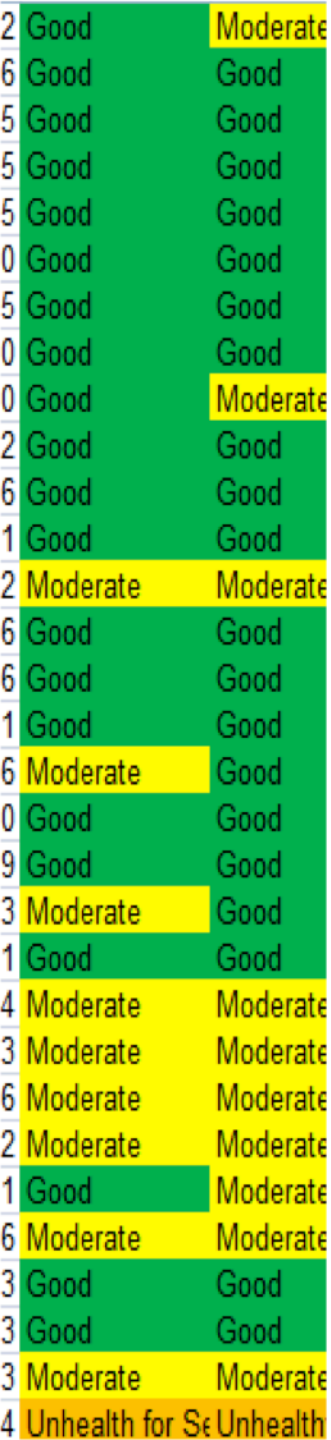

National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

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Converting AOD to PM2.5: A Statistical Approach

NASA ARSET Workshop: NASA Earth Observations, Data and Tools for Air Quality Applications

Sunday, August 28, 2016 to Monday, August 29, 2016
17th IUAPPA World Clean Air Congress and 9th CAA Better Air Quality (BAQ) Conference
Pusan National University, Busan, South Korea

Objective

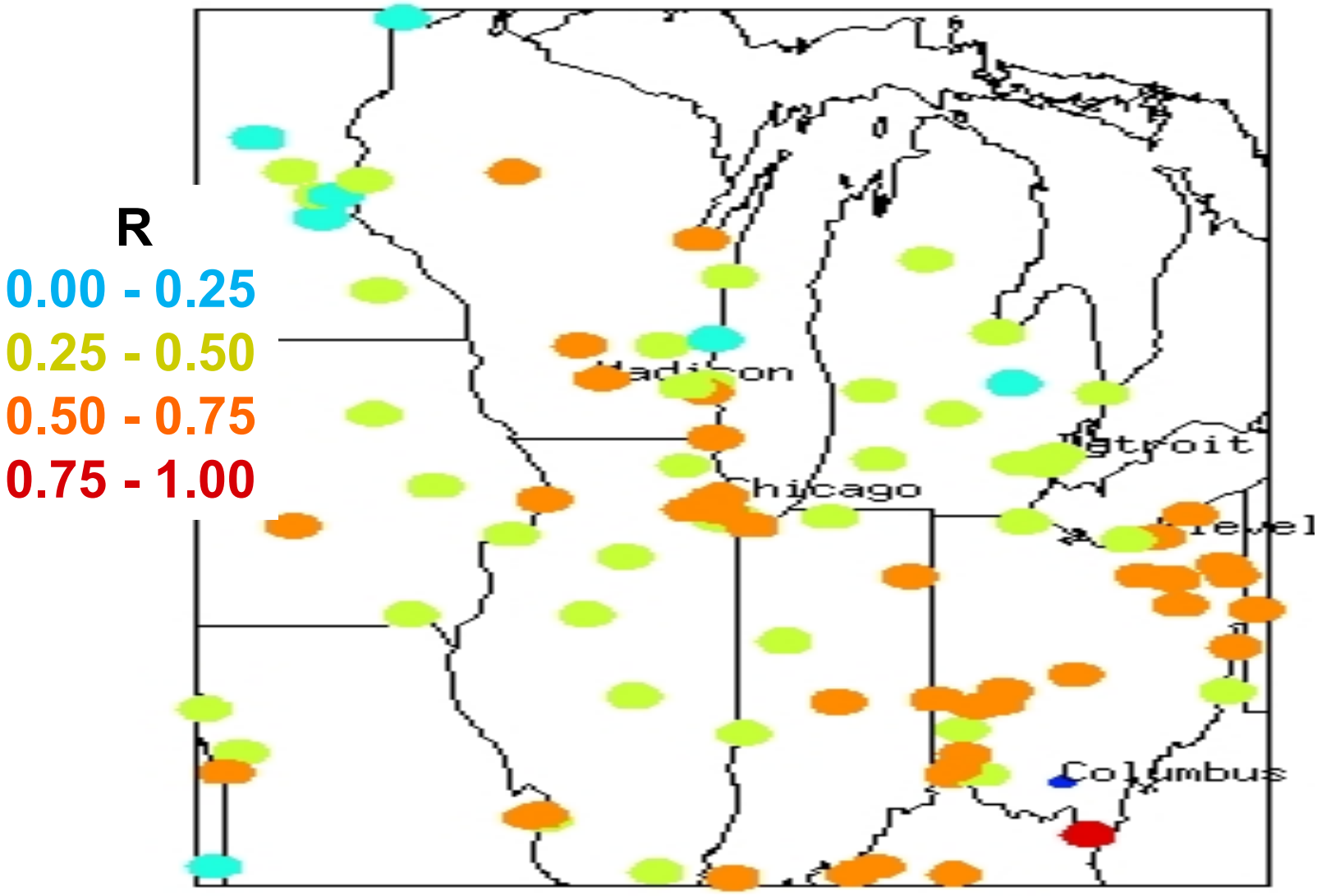
- An exercise to convert satellite derived aerosol optical depth into surface level PM2.5 mass concentration using a statistical approach


Exercise 1:
Converting AOD to PM2.5

Required Data

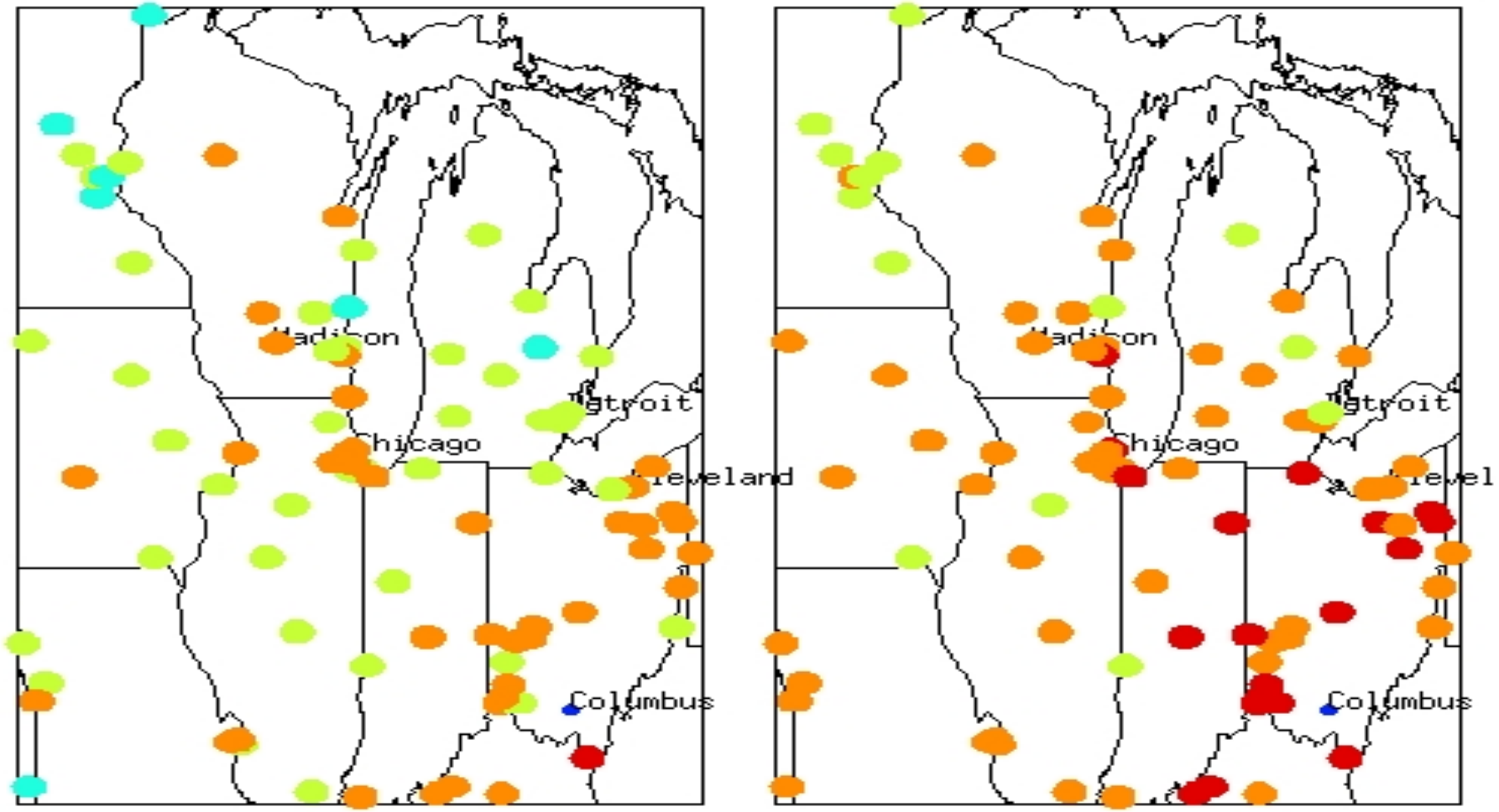
- PM2.5 mass concentration from ground monitors
- Satellite derived aerosol optical depth
- Meteorological Fields – only if working with a multi-variable method

Correlation Between PM2.5 & AOD



Two Variable Method

Multi Variable Method



R

0.00-0.25 0.25-0.50

0.50-0.75 0.75-1.00

Converting AOD to PM2.5 to AQC

Step #1: Getting Satellite and Surface Data

- Obtain MODIS AOD data file from NASA data server for your region, date, and time of interest
  - http://ladsweb.nascom.nasa.gov/
  - from 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

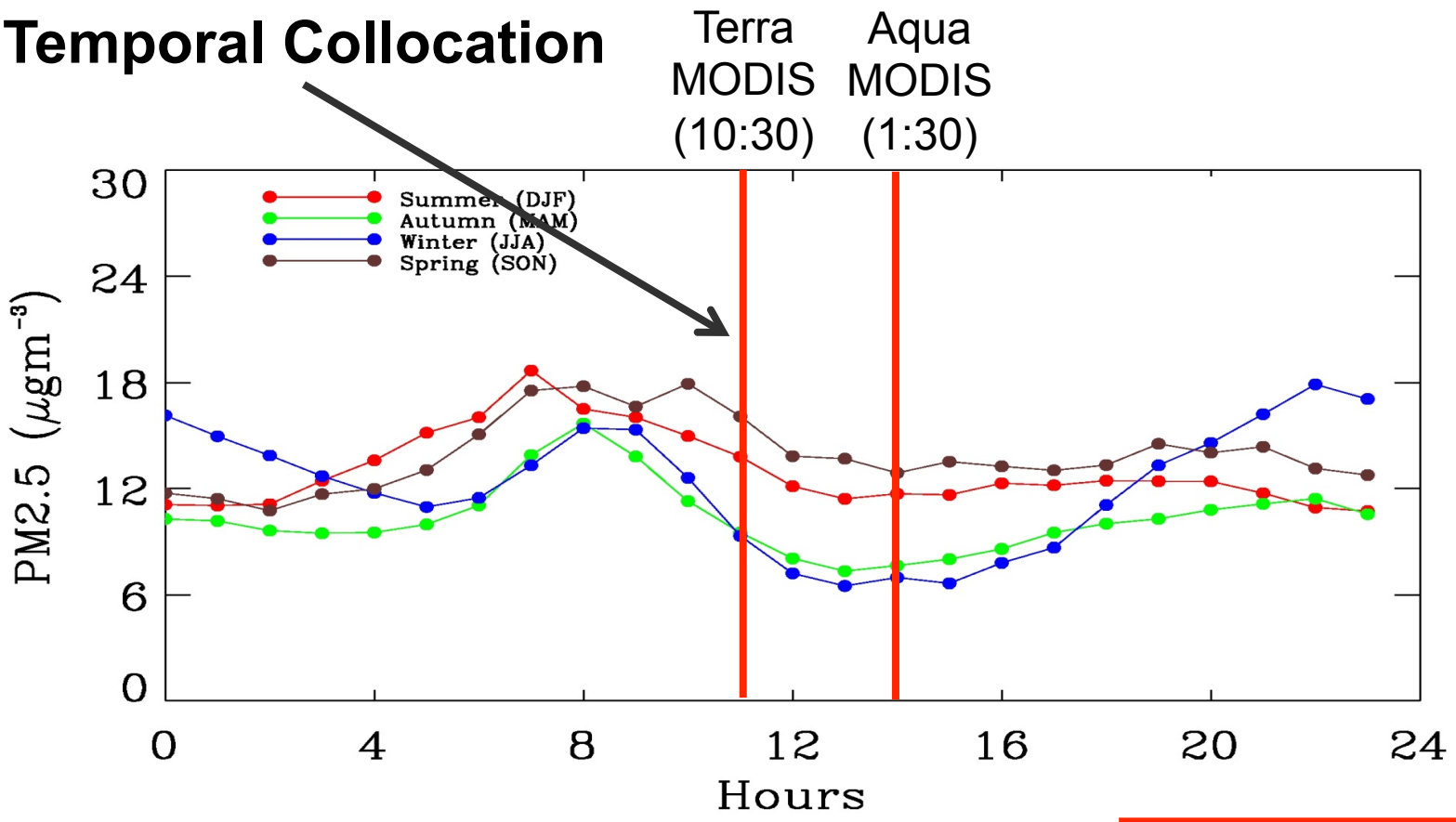
Converting AOD to PM2.5 to AQC

Step #2: Collocating Satellite and Surface Data

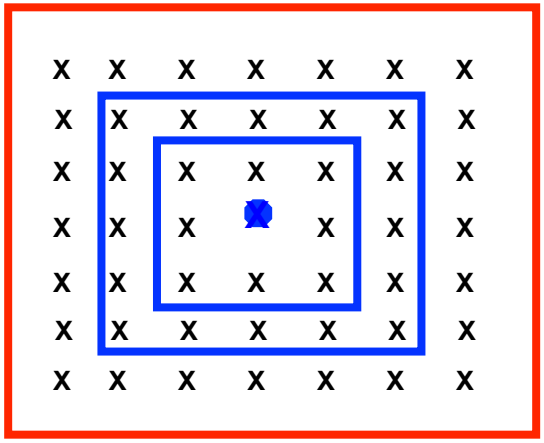
- Run IDL, Matlab, HDFLook, Python, etc. code to obtain AOD at the location of the PM2.5 ground monitor
  - Python scripts: https://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi
  - IDL code: http://arset.gsfc.nasa.gov/sites/default/files/airquality/workshops/Santa_Cruz_2013/read_mod04_map_aqc.zip

- Spatial and Temporal Collocation Methods
  - pick the nearest pixel or average over 3x3 or 5x5 pixels
  - pick the closes PM2.5 measurement from ground to satellite overpass time
    - If hourly data is unavailable, then daily mean data can be used as well

Temporal Collocation

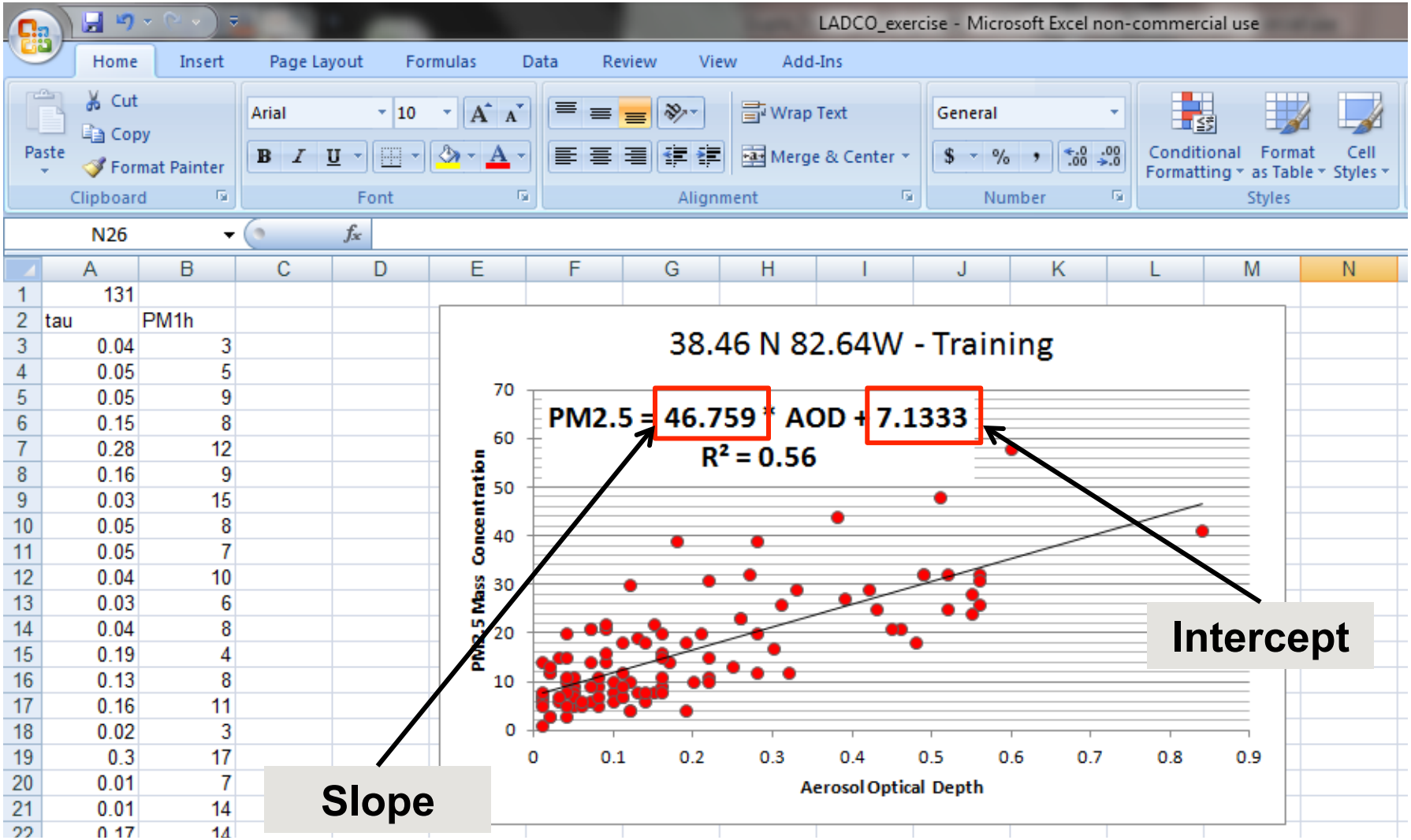


Spatial Collocation



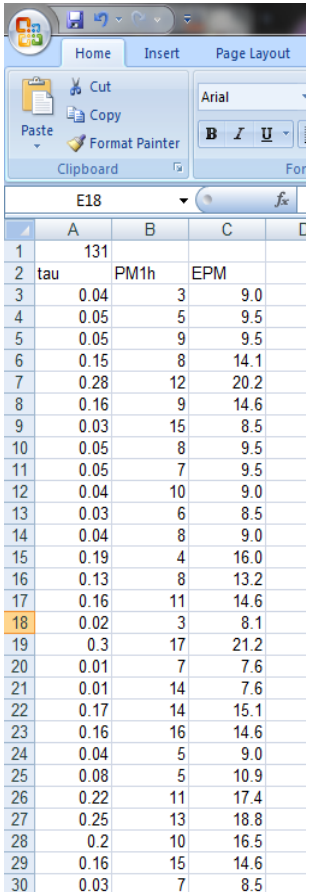
Converting AOD to PM2.5 to AQC

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

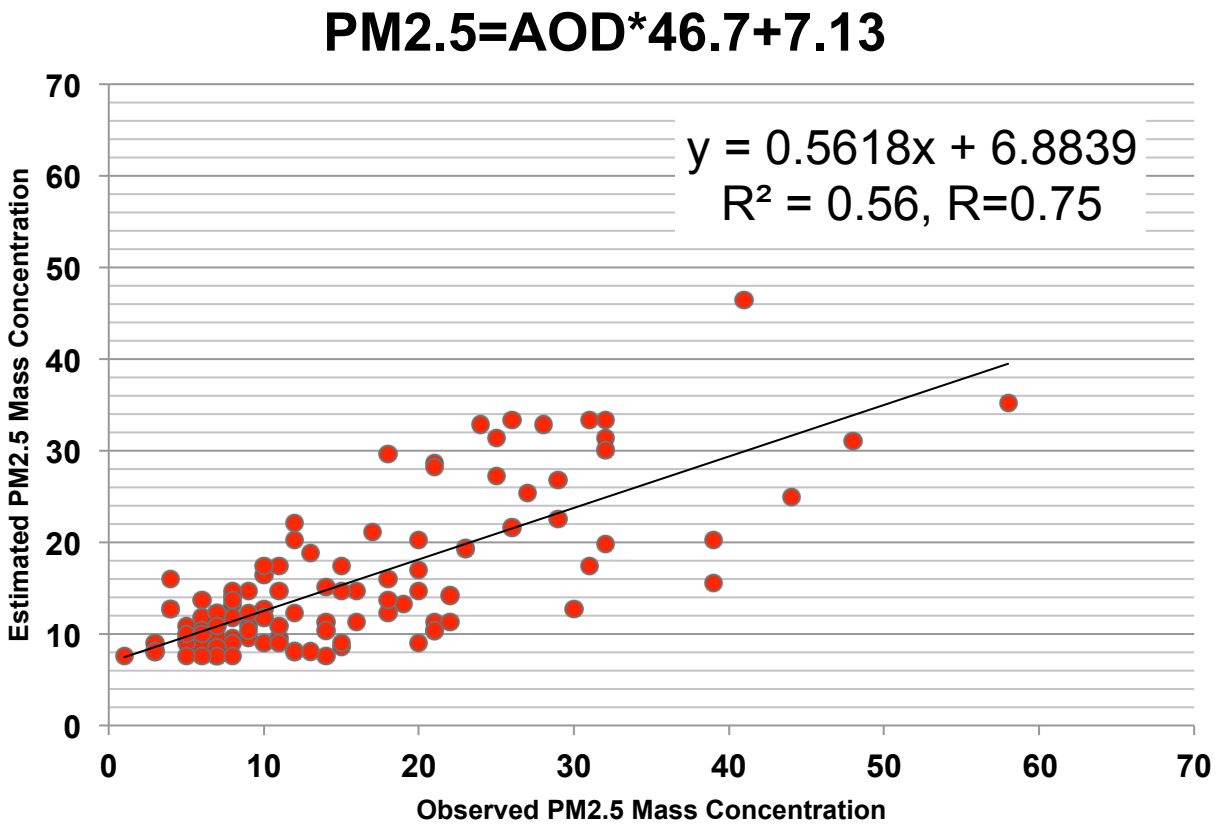


Converting AOD to PM2.5 to AQC

Step #4: Estimating PM2.5 from Satellite AOD



	A	B	C
1	131		
2	tau	PM1h	EPM
3	0.04	3	9.0
4	0.05	5	9.5
5	0.05	9	9.5
6	0.15	8	14.1
7	0.28	12	20.2
8	0.16	9	14.6
9	0.03	15	8.5
10	0.05	8	9.5
11	0.05	7	9.5
12	0.04	10	9.0
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

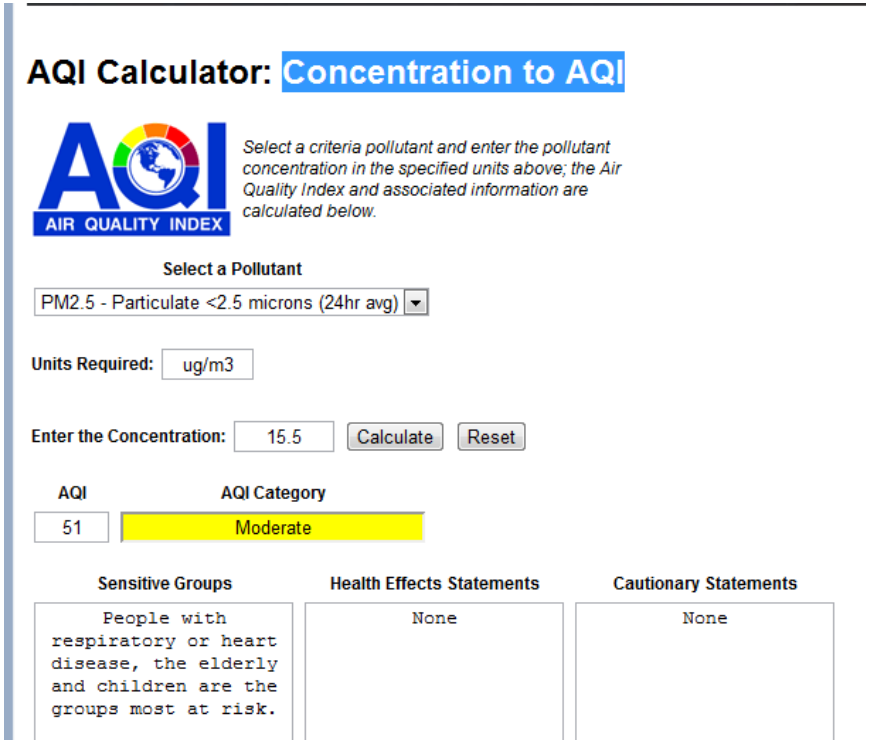


In ideal conditions, two separate data sets should be used to form the relationship and to test and validate the regression equation

Converting AOD to PM2.5 to AQC

Step #5: PM2.5 to Air Quality

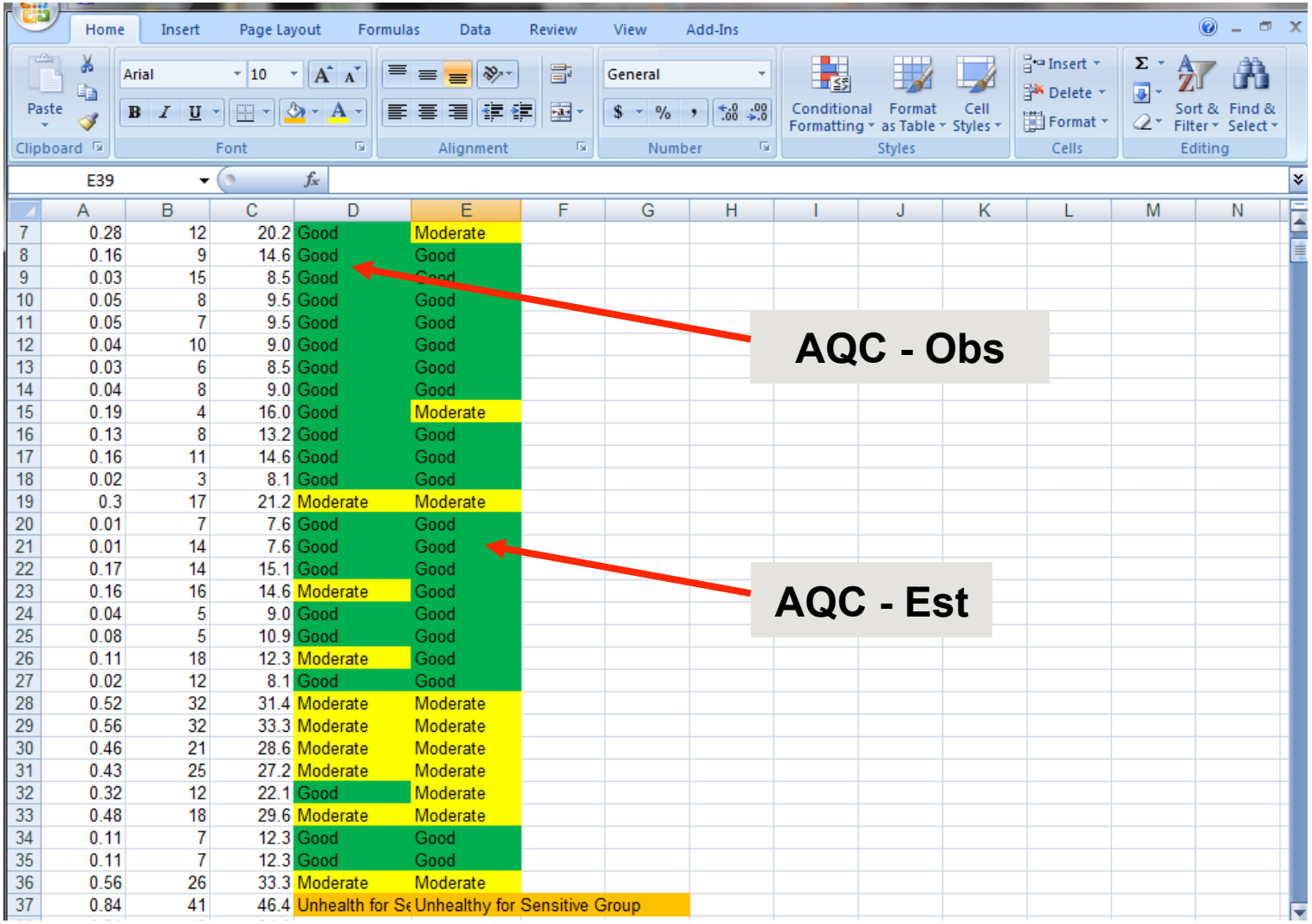
Category	AQI Estimated 24-hour avg. $\mu g/m^3$
Good (0 - 50)	0 to 15.4
Moderate (51 - 100)	15.5 to 40.4
Unhealthy for Sensitive Groups (101 - 150)	40.5 to 65.4
Unhealthy (151 - 200)	65.5 to 150.4
Very Unhealthy (201 - 300)	150.5 to 250.4
Hazardous (301 - 500)	>250.4



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

Converting AOD to PM2.5 to AQC

Step #5: PM2.5 to Air Quality

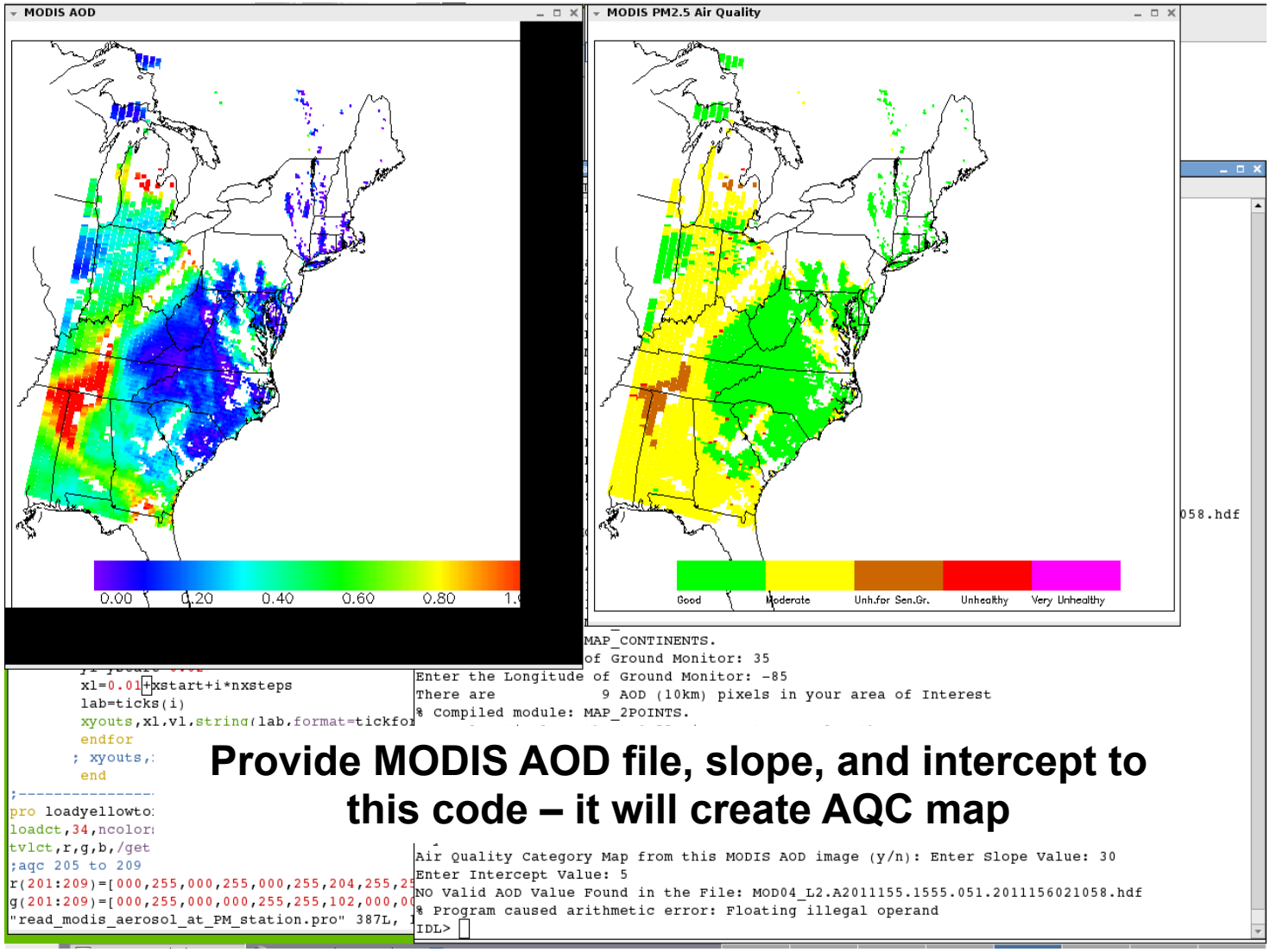


	A	B	C	D	E
7	0.28	12	20.2	Good	Moderate
8	0.16	9	14.6	Good	Good
9	0.03	15	8.5	Good	Good
10	0.05	8	9.5	Good	Good
11	0.05	7	9.5	Good	Good
12	0.04	10	9.0	Good	Good
13	0.03	6	8.5	Good	Good
14	0.04	8	9.0	Good	Good
15	0.19	4	16.0	Good	Moderate
16	0.13	8	13.2	Good	Good
17	0.16	11	14.6	Good	Good
18	0.02	3	8.1	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

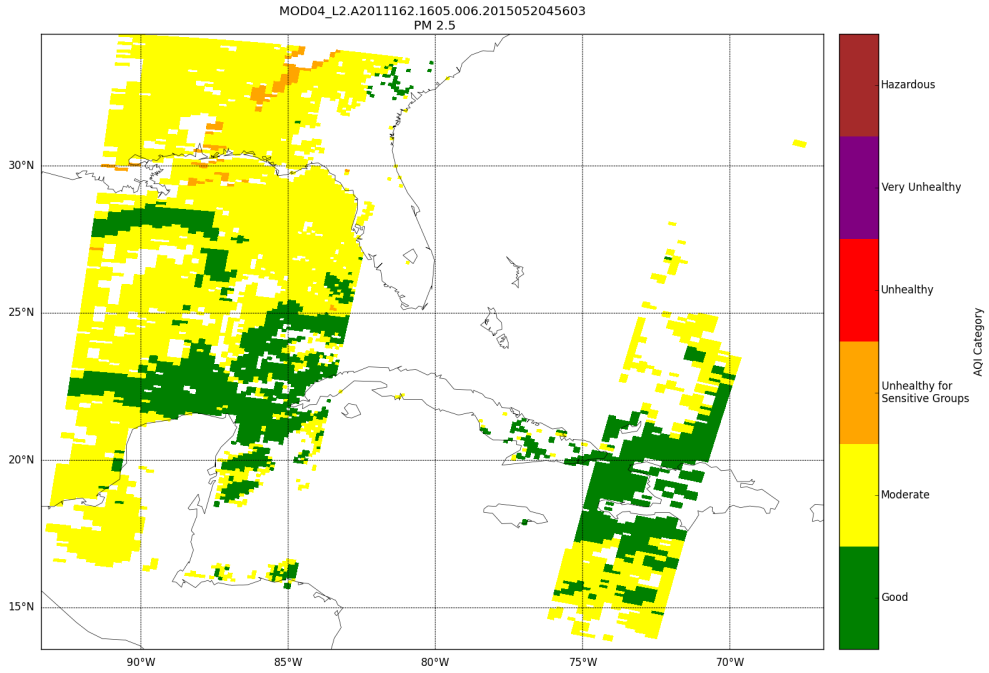
Python/IDL Tool

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



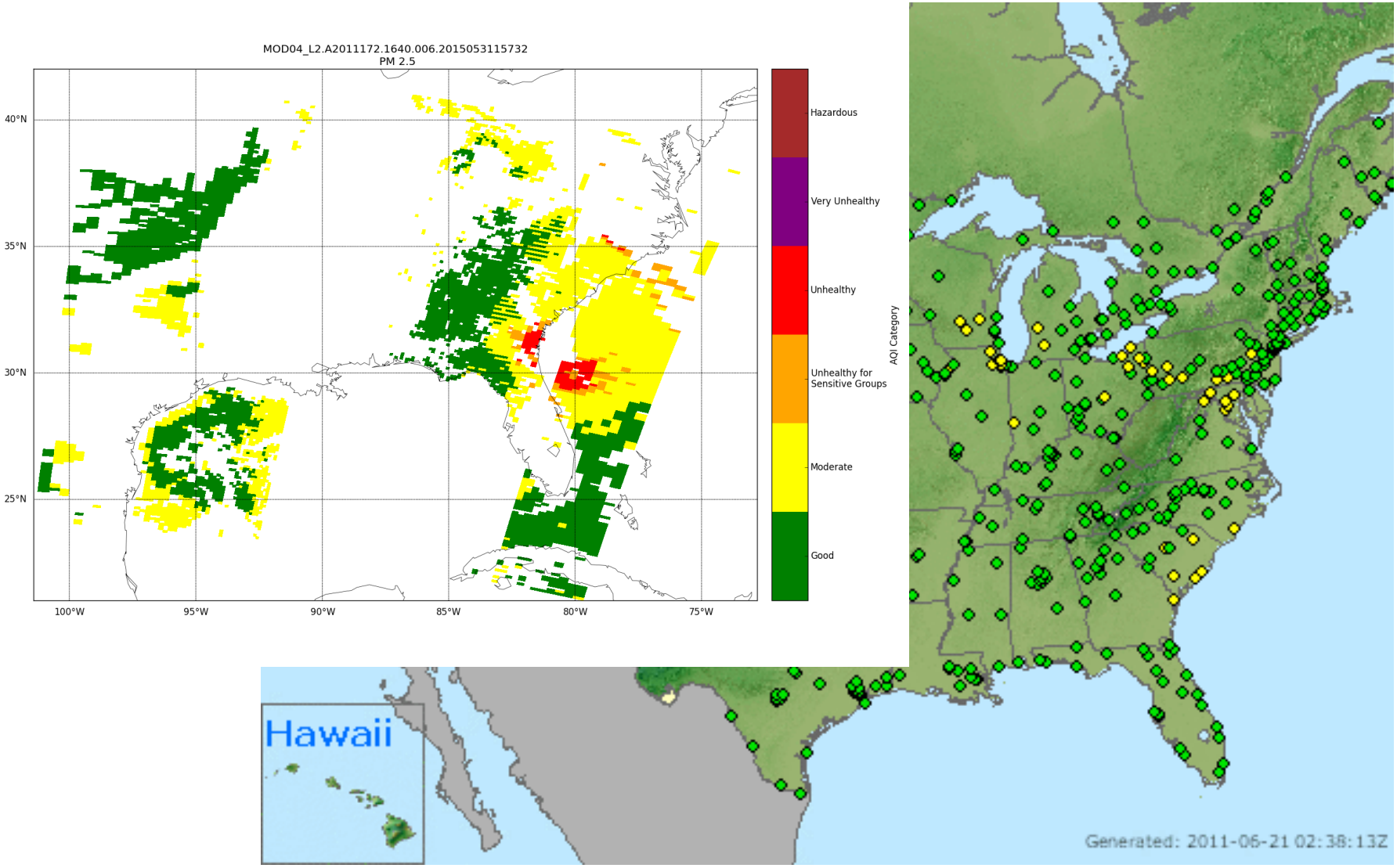
Provide MODIS AOD file, slope, and intercept to this code – it will create AQC map

June 10, 2011

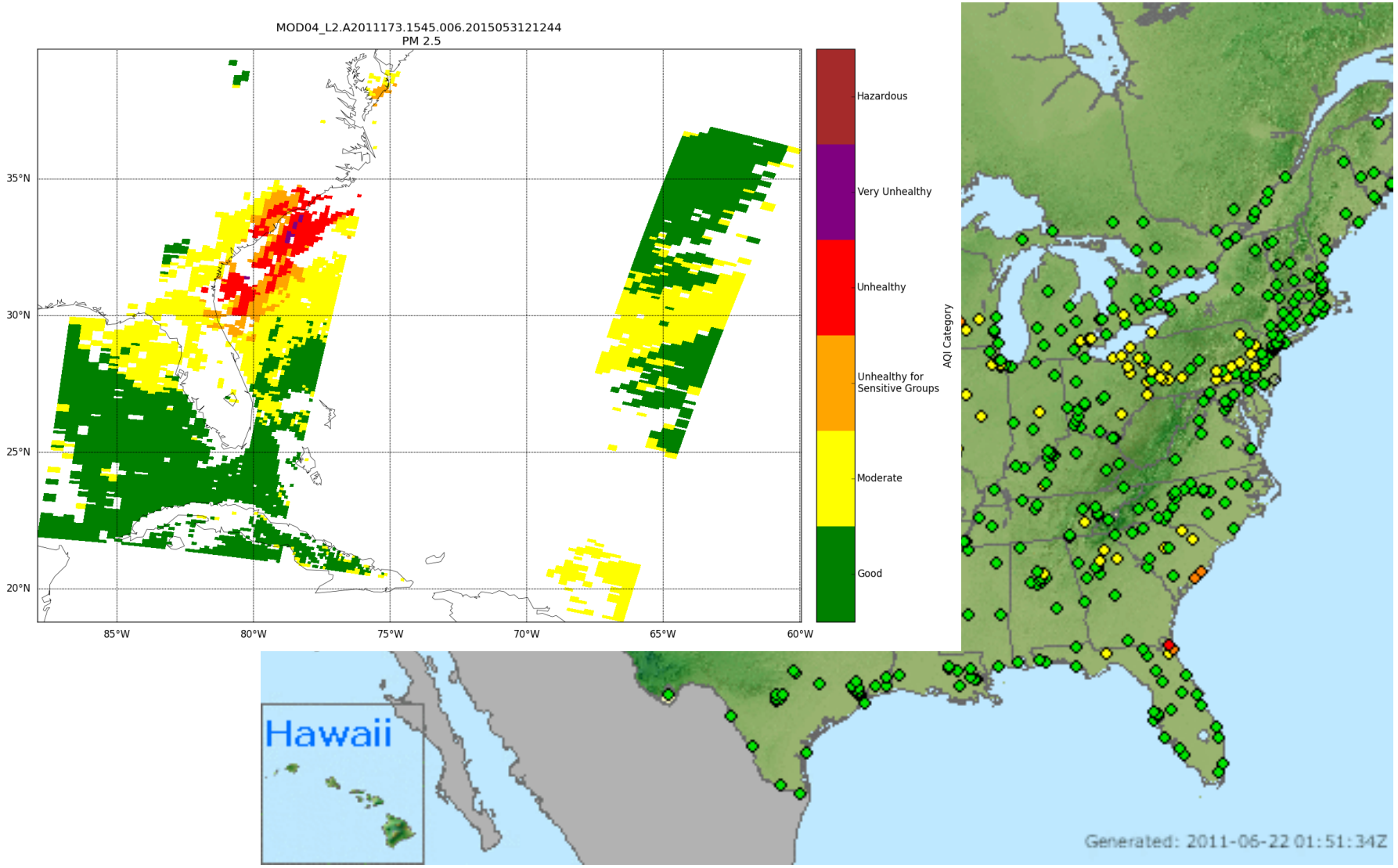

MOD04_L2.A2011162.1605.006.2015052045603
PM 2.5
30°N
25°N
20°N
15°N
90°W
85°W
80°W
75°W
70°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category

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

June 20, 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
Hawaii
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
Hawaii
Generated: 2011-06-22 01:51:34Z

Multiple Linear Regression Method

$$PM2.5 = \beta_0 + \alpha \times \tau + \sum_{n=1}^{m}(\beta_n \times M_n)$$

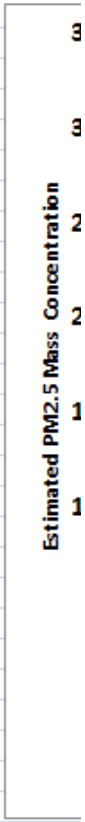
Requires AOD, meteorological fields, more data processing, and more expertise, but most of the time produces more accurate PM2.5 estimation

Multiple Linear Regression Model

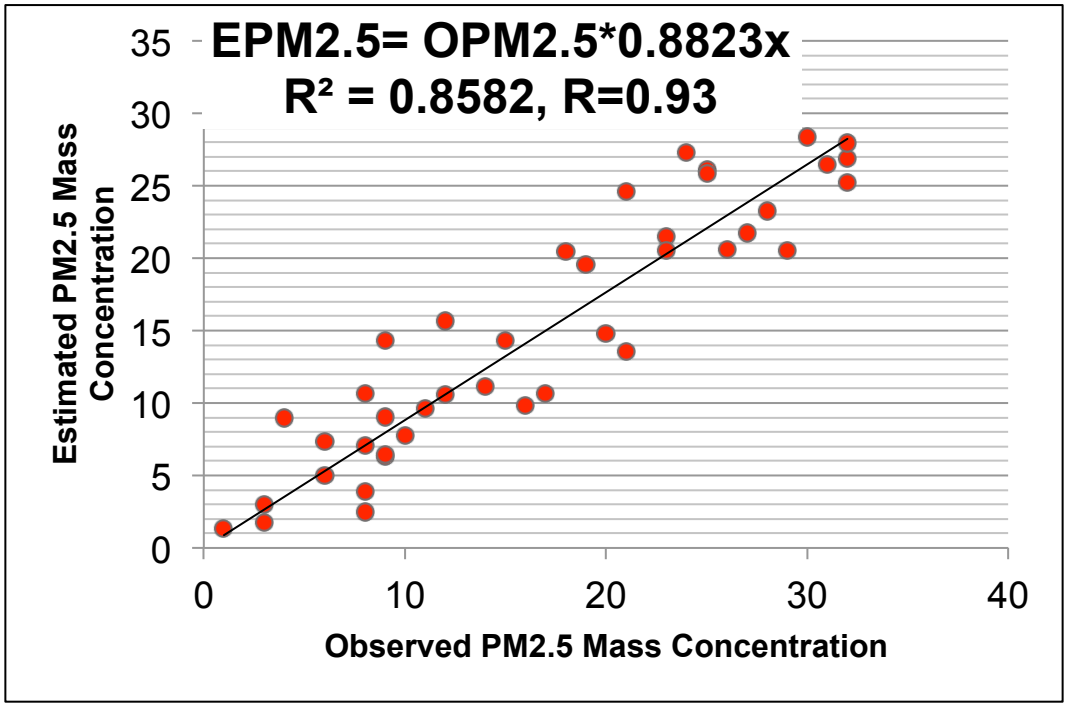
AOD, PM2.5, and Meteorological Data

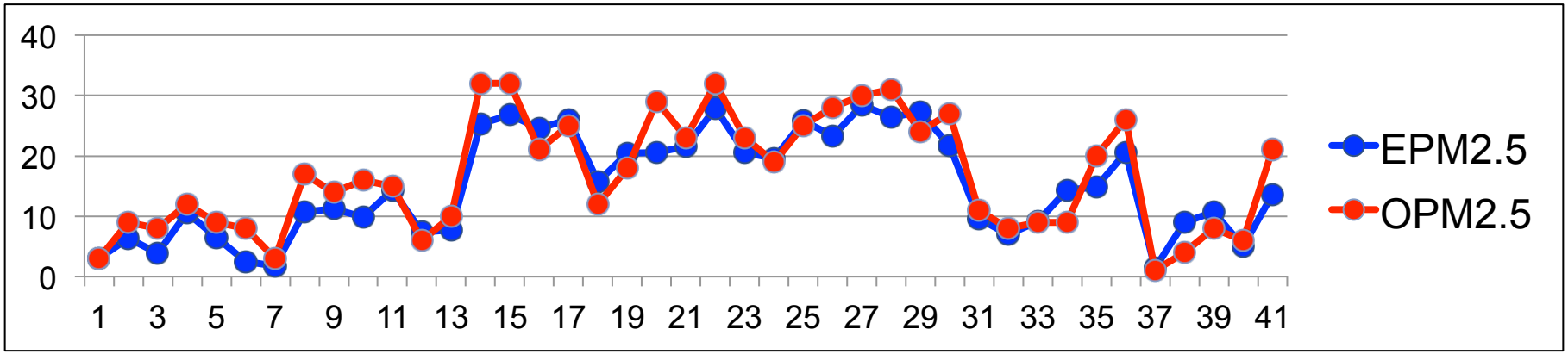
N3 | =17.02*A3+1.14*D3-0.92*E3+0.44*F3-0.95*G3+1.04*H3-0.04*I3-0.31*J3-0.031*K3-0.0022*L3-177.26

	C	D	E	F	G	H	I	J	K	L	M	N	O
1	atitude = 38.46, Longitude = -82.64												
2	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





!! CAUTION !!

- Regression analysis provides the first approximation of surface PM2.5 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