Converting AOD to PM2.5: A Statistical Approach

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

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17th IUAPP A 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

R
0.00 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1.00
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
  – from earlier exercise

• To get PM2.5 for your region:
  – For U.S. Data: [http://www.epa.gov/airdata/ad_maps.html](http://www.epa.gov/airdata/ad_maps.html)
  – Global open data: [http://openaq.org](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:
  – 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

Terra MODIS (10:30)  Aqua MODIS (1:30)

PM2.5 ($\mu g m^{-3}$)

Hours

Spatial Collocation

National Aeronautics and Space Administration
Applied Remote Sensing Training Program
Converting AOD to PM2.5 to AQC

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

\[ \text{PM2.5} = 46.759 \times \text{AOD} + 7.1333 \]

\[ R^2 = 0.56 \]
Converting AOD to PM2.5 to AQC

Step #4: Estimating PM2.5 from Satellite AOD

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

PM2.5 = AOD * 46.7 + 7.13

\[ y = 0.5618x + 6.8839 \]

\[ R^2 = 0.56, R = 0.75 \]
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Step #5: PM2.5 to Air Quality

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

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

AQC - Obs

AQC - Est
Creating an Air Quality Category Map
Python/IDL Tool

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

Air Quality Category Map from this MODIS AOD Image (y/a): Enter Slope Value: 30
Enter Intercept Value: 5
No Valid AOD Value Found in the File: MOD04_L2.A2011155.1555.061.201156021551.hdf
IDL> [program caused arithmetic error: floating illegal operand]

June 20, 2011

[Map showing air quality categories with coordinates and color legend]

[Map of Hawaii with grid lines and location markers]
June 21, 2011
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

![Excel Table]

The table above shows the relationship between PM1h, PM2.5, and meteorological data using a multiple linear regression model. The equation for PM2.5 estimation is highlighted as follows:

\[ \text{Estimated PM2.5 Mass Concentration} = 17.02 \times A3 + 1.14 \times D3 - 0.52 \times E3 + 0.44 \times F3 - 0.95 \times G3 + 1.04 \times H3 - 0.04 \times I3 - 0.31 \times J3 - 0.031 \times K3 - 0.0022 \times L3 - 177.26 \]

The table includes columns for various data parameters such as PM1h, PM2.5, temperature, humidity, wind speed, and atmospheric pressure, along with the estimated PM2.5 values.
Multiple Linear Regression Method Results

\[ EPM2.5 = OPM2.5 \times 0.8823x \]

\[ R^2 = 0.8582, R=0.93 \]

- Estimated PM2.5 Mass Concentration
- Observed PM2.5 Mass Concentration

Graph showing the relationship between estimated and observed PM2.5 mass concentrations.
!! 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