Techniques Utilizing Ambient PM2.5 Air Quality Data to Aid in the 24 hour Designation Process

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What are the techniques?

• **SLICE**
  – Stratify and quantify daily PM2.5 concentrations into regional and urban contributions
  – Estimate the immediate increment by site

• **Residence Time Weighted Emissions**
  – Use of wind trajectories to weight county level emissions
  – Highlights counties whose emissions are upwind of high sites on high days

• **Urban Gradient**
  – Neighboring site gradient estimator
  – Helps to identify sites with a potential local source influence on a daily basis
About the techniques

• Techniques provide important information in regard to the magnitude of area and local influences on PM2.5

• None are meant to be prescriptive but are available to aid in providing a better indication of influencing areas and sources

• All are evolving by varying degrees
1st Technique: SLICE
(Spatially Layered Interpolated Component Estimator)

- Technique clusters ambient monitoring data into “natural” classifications allowing for increments above background to be calculated
- Indicator of possible urban emissions affecting ambient concentrations
- Technique is utilized on daily basis
FRM PM2.5 speciation - 06/27/2005

Large Regional Sulfate Event

- PM2.5 > 95th%ile (pie with white dot)
- PM2.5 > 95th %ile (wo SANDWICH data)
- lower conc value (pie wo white dot)
- Other PM2.5 wo SANDWICH data
- missing STN
- 24-hrDV>35ug/m3 (red=only 24-hr elig.)
Higher concentrations observed in major urban areas in the northern part of the domain
06/27/2005

1st Slice
06/27/2005

3rd Slice

Regional
Regional
Regional
Regional/Urban
Urban
Urban/Microscale

6.0 - 23.0 ug/m³
23.1 - 34.3 ug/m³
34.4 - 42.5 ug/m³
42.6 - 50.3 ug/m³
50.4 - 61.1 ug/m³
61.1 - 79.2 ug/m³
06/27/2005

5th Slice
This base slice is considered to be the underlying regional layer for the domain
The next regional slice is added on top of the base slice
Another regional slice is added on top of the two existing slices
A regional/urban slice is added to the existing three layers
Urban area emissions contribute to “island” effects in Chicago, Detroit/Toledo, Southern IN, Youngstown, Cleveland and Steubenville.
An urban/microscale “island” appears downwind of Detroit in the last slice.
This is the base layer on which all other slices are placed.
Notice demarcation layer along Ohio River Valley

50.4 – 61.1 ug/m³
Up to 18.1 ug/m³
Up to 79.2 ug/m³
2nd Technique: Residence Time Weighted Emissions

- Utilize trajectories on days when PM2.5 is greater than area’s lowest 98th percentile by year
- Incorporate information from SLICE to include sites within an “urban island” rather than just a single site to determine the location of air masses influencing an entire area
- Use the results from the calculated trajectories to determine a trajectory density (i.e. what areas do most of the trajectories pass through) to act as a series of weights for emissions estimates
- Utilize county level emissions estimates to determine those areas with the greatest impact
- Aggregate weighted emissions by season into a Total Influential Emissions Score for high days
Trajectory Density for High Days for 2003-2005 in Milwaukee, WI

Normalized Density
Trajectory Densities times Total PM2.5 Emissions

EQUALS . . . . .
Comparison of Milwaukee Area Total PM2.5 Emissions Before and After Weighting

Greater emphasis is placed on those counties where air on high days passed through
3rd Technique: Urban Gradient

- Identify sites predominantly affected by local sources
- Technique is utilized on a daily basis
- Examines total net gradient between each site and its “neighboring” sites
- Weighted by distance to take into account monitors far apart from one another
- Examine only those sites with net positive gradient
- Utilize meteorological, emissions and satellite data to examine potential sources of gradient
Let's look at one site in particular
Distance weighted gradient:
\((-4 \text{ ug/m}^3 \times 0.06) + (10 \text{ ug/m}^3 \times 0.13) + \ldots + (4 \text{ ug/m}^3 \times 0.13) = 6.2 \text{ ug/m}^3\)

Use percentiles of the gradients’ distribution to distinguish high values
Urban Gradient Legend

- PM2.5 Point Sources from National Emission Inventory

- Windroses
  - Frequency distribution of 24 hour measured wind speeds by wind direction
  - Numbers represent the percentage that the wind speed was coming from that direction during the day
  - Colors represent wind speeds (Cooler colors represent lower wind speeds)
    - Blue: 1-5 mph
    - Green: 5-10 mph
    - Yellow: 10-15 mph
    - Orange: 15-20 mph
    - Red: 20-25 mph
    - Purple: >25 mph

- 0.5 to 5 tons/year
- 6 to 15 tons/year
- 16 to 30 tons/year
- 31 to 50 tons/year
- Greater than 50 tons/year
approximately 110 miles

February 12, 2004
38% calm winds with light winds from the north and southeast (stagnant air mass)

February 12, 2004
Variety of sources upwind of site in question

approximately 40 miles

February 12, 2004
Industrial area with railroads and highways in close proximity to a residential neighborhood approximately 5-7 miles away.

February 12, 2004
Urban Gradient

• Exploring how often gradients in areas with high 24 hour concentrations occur on days greater than 35 ug/m3

• Attempting to quantify the magnitude of the gradient in relation to regional and urban influences to determine the local source influence above and beyond the regional and urban contributions
Integrating the Three Techniques

• Envision using all three techniques for areas across the country
  – *Residence time weighted emissions:* Isolate geographic areas which may be substantial contributors to the area’s ambient PM2.5 concentrations on more of a regional scale
  – *SLICE + Urban Gradient:* Integrate between the two techniques to isolate specific days with gradients above and beyond the overall urban contribution
An Example of Utilizing All Three Techniques in Milwaukee, WI

• When did the high days in Milwaukee occur?

The high days in Milwaukee mostly occur during the winter months.
Milwaukee High Day SLICE Results

- **Urban/Microscale**
  - Mean: 2.9 ug/m³
  - Range: 0.0-16.6 ug/m³

- **Regional/Urban**
  - Mean: 5.4 ug/m³
  - Range: 0.0-10.5 ug/m³

- **Regional**
  - Mean: 28.8 ug/m³
  - Range: 19.9-41.0 ug/m³
Trajectory densities for the high days in Milwaukee CSA.

A lot of the trajectories coming into Milwaukee go through central Illinois and Northwest Indiana as well as the “collar” counties surrounding Milwaukee.
Weighted crustal and total carbon emissions would suggest local impacts from the Milwaukee CSA as well as possible impacts from Chicagoland area.
Residence Time
Weighted Emissions

SO2 weighted emissions
NOx weighted emissions

SO2 and NOx as an indicator of secondary PM2.5 suggest emission influences from the Chicago area with some indication that there are also contributions from emissions within Milwaukee County.
Creating a Total Influential Emissions Score

- Look at the average species composition across the high days by season for the daily increment over and above the seasonal average.

Example of the average winter composition:
- Sulfates: 24%
- Crustal: 1%
- Nitrates: 63%
- Total Carbon: 11%

Other seasonal compositions will look different (e.g. summer will have a majority of sulfates).
Total Influential Emissions Score

- Multiplying the corresponding seasonal weight by each component and summing over all seasons give the total influential emissions score for the area (CSA + surrounding counties)

<table>
<thead>
<tr>
<th>County</th>
<th>Total Influential Emissions Score</th>
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<tbody>
<tr>
<td>Dodge</td>
<td>3848</td>
</tr>
<tr>
<td>Fond du Lac</td>
<td>4010</td>
</tr>
<tr>
<td>Jefferson</td>
<td>4176</td>
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<tr>
<td>Kenosha</td>
<td>63986</td>
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<td>Milwaukee</td>
<td>74107</td>
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<td>Ozaaukee</td>
<td>18083</td>
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<td>Racine</td>
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<tr>
<td>Walworth</td>
<td>4700</td>
</tr>
<tr>
<td>Washington</td>
<td>3900</td>
</tr>
<tr>
<td>Waukesha</td>
<td>13110</td>
</tr>
</tbody>
</table>
Milwaukee Site Gradients

February 18, 2004
What did the winds look like?

approximately 20 miles

February 18, 2004

High winds from the southwest
What local sources are nearby?

approximately 5-7 miles
Less than one mile

Rail line and spur

Residential neighborhoods
What does the example show?

• High days in Milwaukee can have high regional concentrations even before the urban contribution is added into the total PM2.5 concentration

• Winds on the high days in Milwaukee predominantly come from the south blowing across central Illinois and also includes the Chicagoland area
What does the example show?

- Total Influential Emissions Scores show that emissions from counties outside the Milwaukee CSA influence the ambient PM2.5 concentrations in Milwaukee.

- Urban Gradients
  - More analysis is needed to determine frequency of days with higher gradients.
  - Need to determine magnitude of the gradient in relation to the regional and urban contributions to better estimate the contribution from the local sources versus the regional/urban contributions for control strategy purposes.