Air Quality and Visual Range – A Story

Wildland Fire Smoke Health Effects Research and Tools to Inform Public Health Policy and Recommendations

April 2015, Boise, Idaho

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Visual Range and PM2.5

What do you do when you know the atmosphere is smokey but you don’t have a PM2.5 measurement?

24-hr Measurement – can compare to the NAAQS

But what do you do in the case of wildfires when smoke can vary a lot hour by hour?
Visual Range and PM2.5
- Steps -

1) Human-sighted Visual Range (VR)
2) VR -> PM2.5 (1-3 hr avg)
3) PM2.5 (1-3 hr avg) -> Recommended Action

Uncertainties associated with each step.
What is Visual Range?

Visual Range has been defined in the context of how far away a black object has to be such that it is just noticeable or visible (Malm and Schichtel, 2013).
Montana – Circa turn of the Century (2000)

- Correlated 1-hr PM2.5 concentrations with ASOS data
- Helena, Montana during a period of wildfire impacts
- Low Relative Humidity
- PM2.5 * VR = 450

**Breakpoints and Associated Visibility for Particulate Concentrations**

<table>
<thead>
<tr>
<th>Health Effect Categories</th>
<th>Visibility (miles)</th>
<th>24-Hour BAM (ug/m3) 1</th>
<th>8-Hour BAM (ug/m3) 2</th>
<th>1-Hour BAM (ug/m3) 3</th>
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</thead>
<tbody>
<tr>
<td>Hazardous</td>
<td>&lt; 1.3</td>
<td>&gt; 135.4</td>
<td>&gt; 193.4</td>
<td>&gt; 338.5</td>
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<tr>
<td>Very Unhealthy</td>
<td>2.1 - 1.3</td>
<td>80.5 - 135.4</td>
<td>115.0 - 193.4</td>
<td>201.1 - 338.5</td>
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<tr>
<td>Unhealthy</td>
<td>5.0 - 2.2</td>
<td>35.5 - 80.4</td>
<td>50.7 - 114.9</td>
<td>88.6 - 201.0</td>
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<tr>
<td>Unhealthy for Sensitive Groups</td>
<td>8.7 - 5.1</td>
<td>20.5 - 35.4</td>
<td>29.2 - 50.6</td>
<td>51.1 - 88.5</td>
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<tr>
<td>Moderate</td>
<td>13.3 - 8.8</td>
<td>13.5 - 20.4</td>
<td>19.2 - 29.1</td>
<td>33.6 - 51.0</td>
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<tr>
<td>Good</td>
<td>&gt; 13.4 +</td>
<td>0.0 - 13.4</td>
<td>0.0 - 19.1</td>
<td>0.0 - 33.5</td>
</tr>
</tbody>
</table>

2. Applied U.S. EPA SCREEN adjustment factor for 8-hour, 0.7, multiplied to the 24-hour PM-2.5 Pollutant Standards Index.
## Wildfire Smoke
A Guide for Public Health Officials
Revised July 2008
(With 2012 AQI Values)

<table>
<thead>
<tr>
<th>Air Quality Index Category</th>
<th>PM2.5 or PM10 Levels (µg/m³, 1- to 3-hr avg.)</th>
<th>PM2.5 or PM10 Levels (µg/m³, 8-hr avg.)</th>
<th>PM2.5 or PM10 Levels (µg/m³, 24-hr avg.)</th>
<th>Visibility - Arid Conditions (miles)</th>
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<tbody>
<tr>
<td>Good</td>
<td>0 – 38</td>
<td>0 – 22</td>
<td>0 – 12</td>
<td>&gt; 11</td>
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<td>39 – 88</td>
<td>23 – 50</td>
<td>12.1 – 35.4</td>
<td>6 – 10</td>
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<td>Sensitive Groups</td>
<td>89 – 138</td>
<td>51 – 79</td>
<td>35.5 – 55.4</td>
<td>3 – 5</td>
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<td>Unhealthy</td>
<td>139 – 351</td>
<td>80 – 200</td>
<td>55.5 – 150.4</td>
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<td>201 – 300</td>
<td>150.5 – 250.4</td>
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<td>≥ 526</td>
<td>&gt; 300</td>
<td>&gt; 250.5 - 500</td>
<td>≤1</td>
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</table>
Short Term (1-3 hr) Air Quality Categories

1-3 hr PM2.5 Concentration (µg/m³)

- Hazardous
- Very Unhealthy
- Unhealthy, High
- Unhealthy for Sensitive Groups
- Moderate
- Good

Canada AQHI, Wildfire Smoke Guide, AK, CO, MT, Manitoba*
Discussion

- National Wildfire Coordinating Group (NWCG) Smoke Committee (SmoC)
- Concerns:
  - Consequences of a human-sighted visual range
  - Multiple Approaches Currently in-use
  - Need for a Short-Term (1-3 hr) Health Impact Index
  - Influence of relative humidity, aerosol hygroscopicity, and other anthropogenic sources on the VR/PM2.5 relationship for smoke-filled atmospheres
Great Smoky Mountains National Park

RH = 30%
VR = 47 km
PM$_{2.5}$ = 21 µg/m$^3$

WINHAZE Program
IMPROVE Data

RH = 90%
VR = 19 km
PM$_{2.5}$ = 21 µg/m$^3$
IMPROVE Light Extinction ($\beta_{ext}$) Equation

$$\beta_{ext} = 2.2 \times f_s(RH) \times [\text{Small Sulfate}]$$
$$+ 4.8 \times f_l(RH) \times [\text{Large Sulfate}]$$
$$+ 2.4 \times f_s(RH) \times [\text{Small Nitrate}]$$
$$+ 5.1 \times f_l(RH) \times [\text{Large Nitrate}]$$
$$+ 2.8 \times [\text{Small Organic Mass}]$$
$$+ 6.1 \times [\text{Large Organic Mass}]$$
$$+ 10 \times [\text{Elemental Carbon}]$$
$$+ 1 \times [\text{Fine Soil}]$$
$$+ 1.7 \times f_{ss}(RH) \times [\text{Sea Salt}]$$
$$+ 0.6 \times [\text{Coarse Mass}]$$
$$+ \text{Rayleigh Scattering (Site Specific)}$$
$$+ 0.33 \times [\text{NO}_2 \text{ (ppb)}]$$

$$\beta_{ext} = \frac{K}{VR}, \text{ where, } K = \text{the Koschmieder Coefficient, } 3.9$$
$PM_{2.5} = \frac{622}{VR}$

$r^2 = 0.998$
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<th>VR (miles)</th>
<th>VR (km)</th>
<th>RH 10%</th>
<th>RH 20%</th>
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Joint Fire Science Program Project

- Bill Malm and Bret Schichtel
  Cooperative Institute for Research in the Atmosphere (CIRA) and the National Park Service (NPS) Air Resource Division

- 7 Goals, some of which are:
  - Quantify uncertainties in estimating VR, and PM2.5 from a VR
  - Make recommendations for the form of the VR*PM relationship
  - Examine how the VR/PM2.5 relationship may change as a function of season and location
Quantification of Uncertainty

When the target is not black

- Uncertainty = 0.15 (for green/forested target)
- Uncertainty is higher for lighter colored surfaces such as red or white

Malm and Schichtel, 2013
Quantification of Uncertainty

Observer judging when a target is at a threshold constant

- Uncertainty = 0.2 – 0.3

Malm and Schichtel, 2013
Quantification of Uncertainty

Non-uniform aerosol distribution between the observer and the target

Uncertainty = 0.5

Malm and Schichtel, 2013
Quantification of Uncertainty

Uncertainty in the wet mass extinction efficiency (effects of RH)

- Uncertainty = 0.7 – 1.0
- Varies across the US

Malm and Schichtel, 2013
Conclusion

Factor of 2 uncertainty

- When smoke dominates
- Both Eastern and Western US

Malm and Schichtel, 2013
38 μg/m³

Vr=37.5 km

Vr=17.7 km

Vr=8.4 km

88 μg/m³

Vr=19.2 km

Vr=9.7 km

Vr=4.9 km

Malm and Schichtel, 2013
Smoke Photoguide, JFSP 10-1-03-2

GRAND CANYON NATIONAL PARK, AZ

CONDITION: Baseline <5 μg/m³

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>PM 2.5</td>
<td>&lt;5 μg/m³</td>
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<tr>
<td>Relative Humidity</td>
<td>20 %</td>
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<tr>
<td>Visual Range</td>
<td>148.5 miles</td>
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6.6 miles

2.7 miles

6.8 miles

2.5 miles

2.2 miles
### Grand Canyon National Park, AZ

**Condition:** 245 µg/m³

<table>
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<th>Parameter</th>
<th>Value</th>
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<tbody>
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<td>PM 2.5</td>
<td>245 µg/m³</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>20% - 40%</td>
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<tr>
<td>Visual Range</td>
<td>2.3 miles</td>
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</table>

- 6.6 miles
- 2.7 miles
- 6.8 miles
- 2.5 miles
- 2.2 miles


WINHAZE: http://vista.cira.colostate.edu/improve/tools/win_haze.htm


Smoke Photoguide https://www.frames.gov/partner-sites/emissions-and-smoke/perceptions/smoke-examples/
Thank you!

Questions, Comments, Discussion

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206-732-7851