

Air Quality and Visual Range – A Story

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

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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
- $PM_{2.5} * VR = 450$

Home » [Wildfire Smoke Updates](#) » Breakpoints

Breakpoints and Associated Visibility for Particulate Concentrations



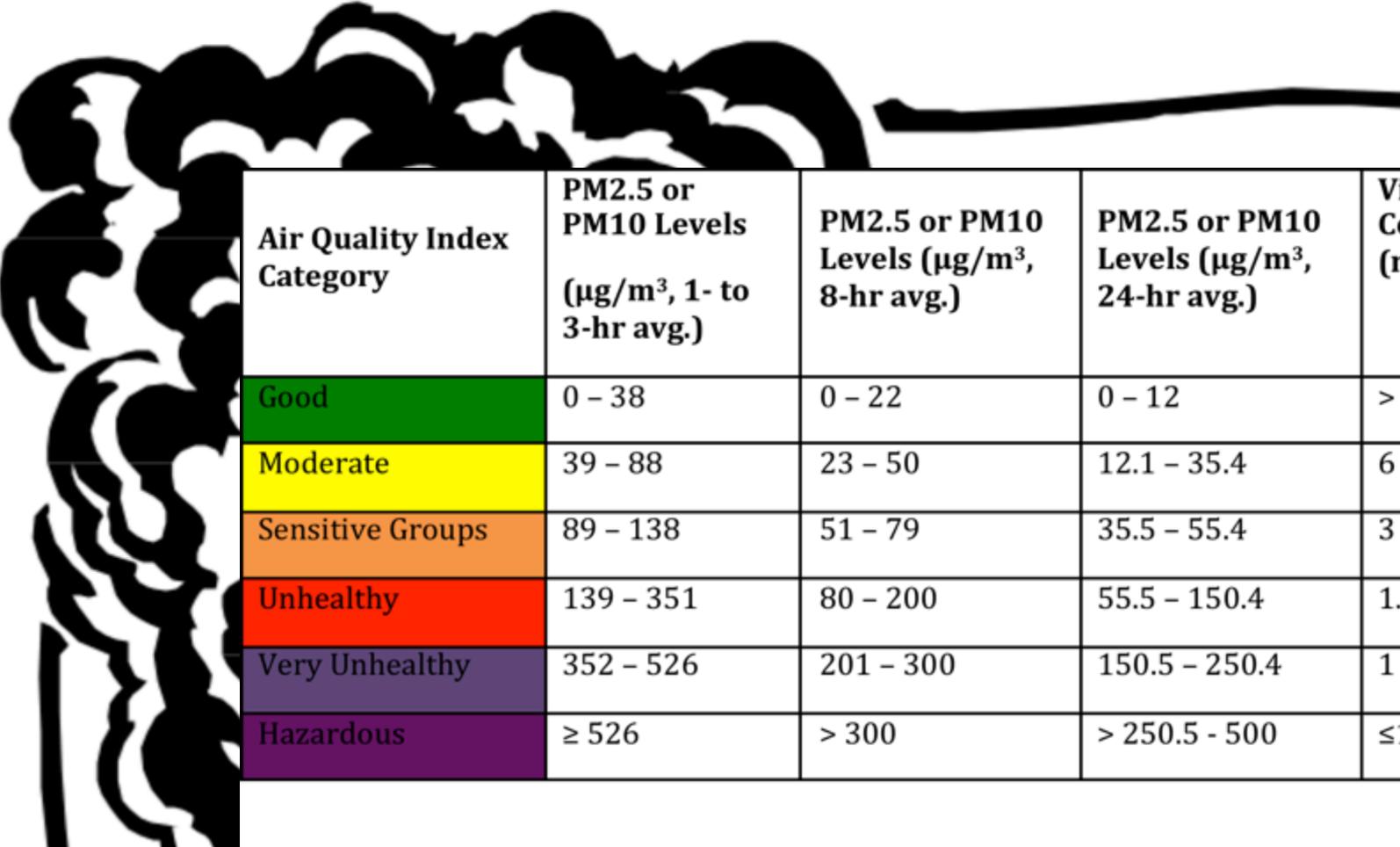
Health Effect Categories	Visibility (miles) ³	24-Hour BAM (ug/m ³) ¹	8-Hour BAM (ug/m ³) ²	1-Hour BAM (ug/m ³) ³
Hazardous	< 1.3	>135.4	> 193.4	> 338.5
Very Unhealthy	2.1 - 1.3	80.5 - 135.4	115.0 - 193.4	201.1 - 338.5
Unhealthy	5.0 - 2.2	35.5 - 80.4	50.7 - 114.9	88.6 - 201.0
Unhealthy for Sensitive Groups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

1. Washington State Department of Ecology, Washington Air Quality Advisory (2007), at <https://fortress.wa.gov/ecy/enviwa>.
2. Applied U.S. EPA SCREEN adjustment factor for 8-hour, 0.7, multiplied to the 24-hour PM-2.5 Pollutant Standards Index.
3. John Coefield, Cyra Cain, Montana Department of Environmental Quality empirical study (July 2000) presented at Fire, Smoke and Health Workshop, Seattle, WA, June 5 - 6, 2001.

Wildfire Smoke

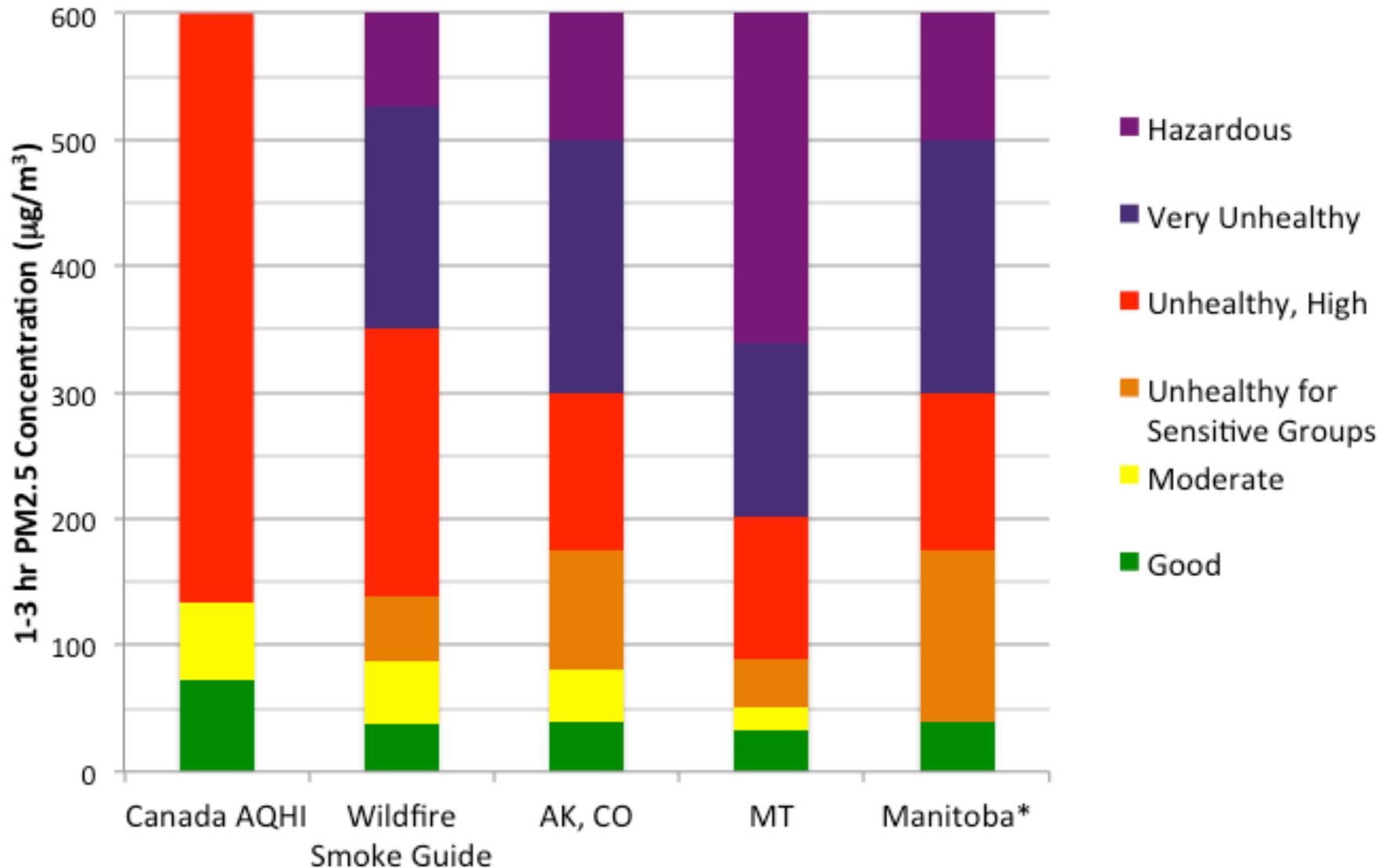
A Guide for Public Health Officials

Revised July 2008
(With 2012 AQI Values)



Air Quality Index Category	PM2.5 or PM10 Levels ($\mu\text{g}/\text{m}^3$, 1- to 3-hr avg.)	PM2.5 or PM10 Levels ($\mu\text{g}/\text{m}^3$, 8-hr avg.)	PM2.5 or PM10 Levels ($\mu\text{g}/\text{m}^3$, 24-hr avg.)	Visibility - Arid Conditions (miles)
Good	0 - 38	0 - 22	0 - 12	> 11
Moderate	39 - 88	23 - 50	12.1 - 35.4	6 - 10
Sensitive Groups	89 - 138	51 - 79	35.5 - 55.4	3 - 5
Unhealthy	139 - 351	80 - 200	55.5 - 150.4	1.5 - 2.75
Very Unhealthy	352 - 526	201 - 300	150.5 - 250.4	1 - 1.25
Hazardous	≥ 526	> 300	> 250.5 - 500	≤ 1

Short Term (1-3 hr) Air Quality Categories

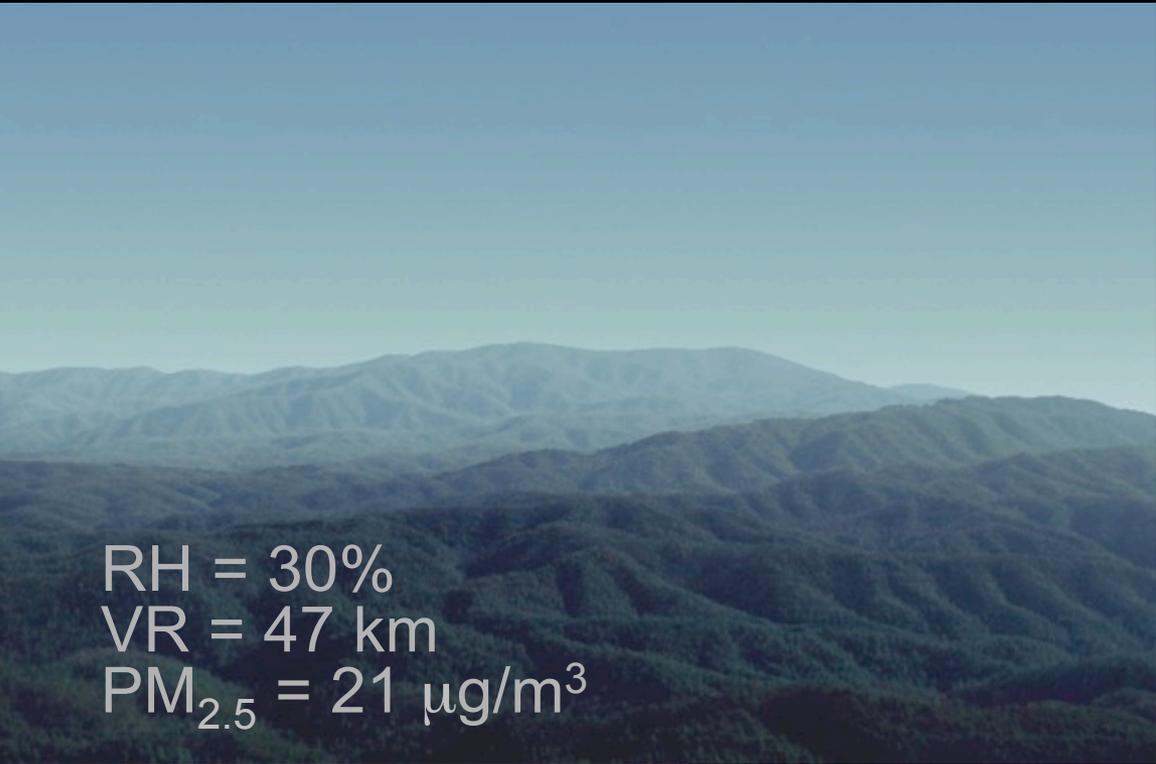




Discussion

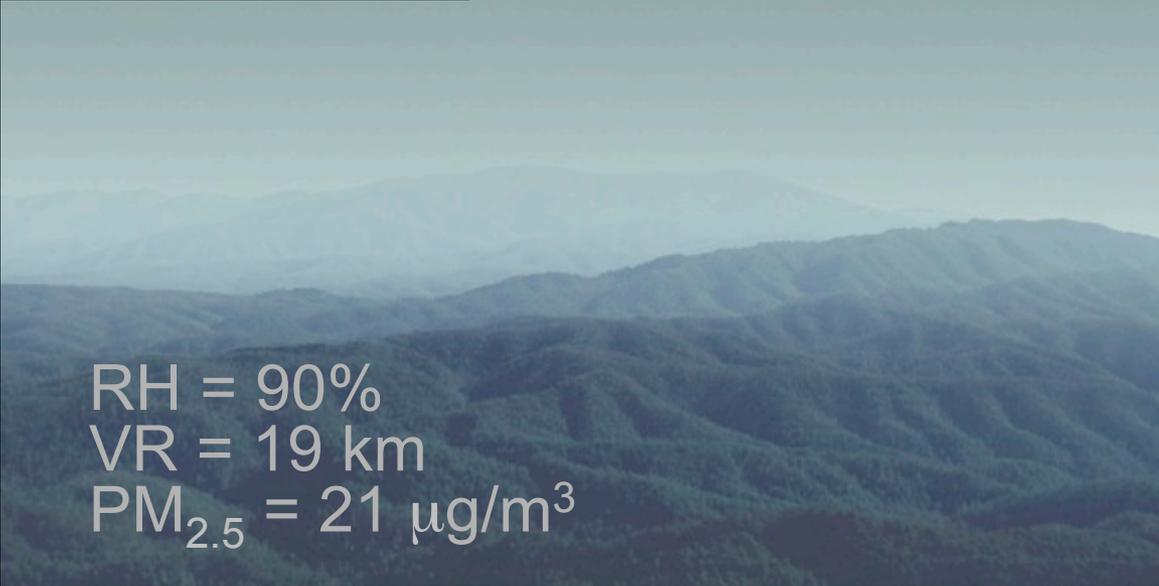
- National Wildfire Coordinating Group (NWCG) Smoke Committee (SmoC)
- Concerns:
 - Consequences of a human-sighted visual range
 - Multiple Approaches Currently in-use
 - Need for a Short-Term (1-3 hr) Health Impact Index
 - Influence of relative humidity, aerosol hygroscopicity, and other anthropogenic 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 $\mu\text{g}/\text{m}^3$

- WINHAZE Program
- IMPROVE Data

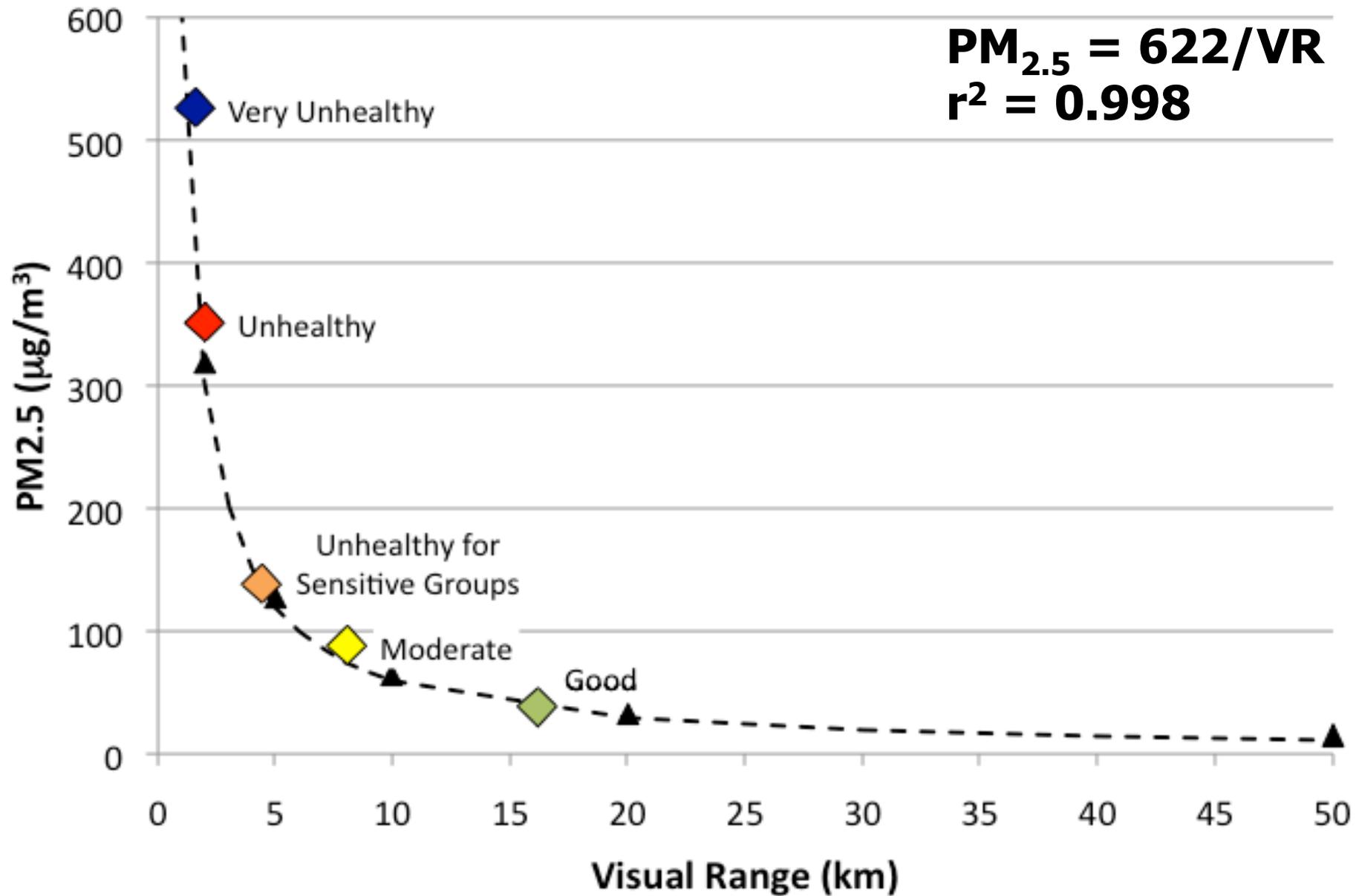


RH = 90%
VR = 19 km
PM_{2.5} = 21 $\mu\text{g}/\text{m}^3$

IMPROVE Light Extinction (β_{ext}) Equation

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

$$\beta_{\text{ext}} = K/V_R, \text{ where, } K = \text{the Koschmieder Coefficient, } 3.9$$



Relative Humidity and Visual Range

VR (miles)	VR (km)	RH 10%	RH 20%	RH 30%	RH 40%	RH 50%	RH 60%	RH 70%	RH 80%	RH 90%	RH 95%
19	30.6										
18	29.0										
17	27.4										
16	25.8										
15	24.2										
14	22.6										
13	21.0										
12	19.4										
11	17.7	39	39	39							
10	16.1	43	43	43	39						
9	14.5	47	47	47	44	42	40				
8	12.9	53	53	53	49	48	46	43	38		
7	11.3	60	60	60	56	55	53	50	45		
6	9.7	69	69	69	66	64	62	59	55	43	
5.50	8.9	75	75	75	72	70	68	65	61	49	
5.00	8.1	82	82	82	79	77	75	73	68	56	
4.50	7.3	91	91	91	88	86	84	81	77	65	41
4.00	6.5	102	102	102	99	97	95	93	88	76	52
3.50	5.6	116	116	116	113	111	109	107	102	90	66
3.00	4.8	135	135	135	132	130	128	126	121	109	85
2.50	4.0	162	162	162	158	157	155	152	147	135	111
2.00	3.2	201	201	201	198	196	194	192	187	175	151
1.50	2.4	267	267	267	264	262	260	258	253	241	217
1.00	1.6	399	399	399	396	394	392	390	385	373	349
0.75	1.2	532	532	532	528	527	525	522	517	505	481
0.50	0.8	796	796	796	792	791	789	786	782	769	746
0.25	0.4	1589	1589	1589	1585	1584	1582	1579	1574	1562	1538

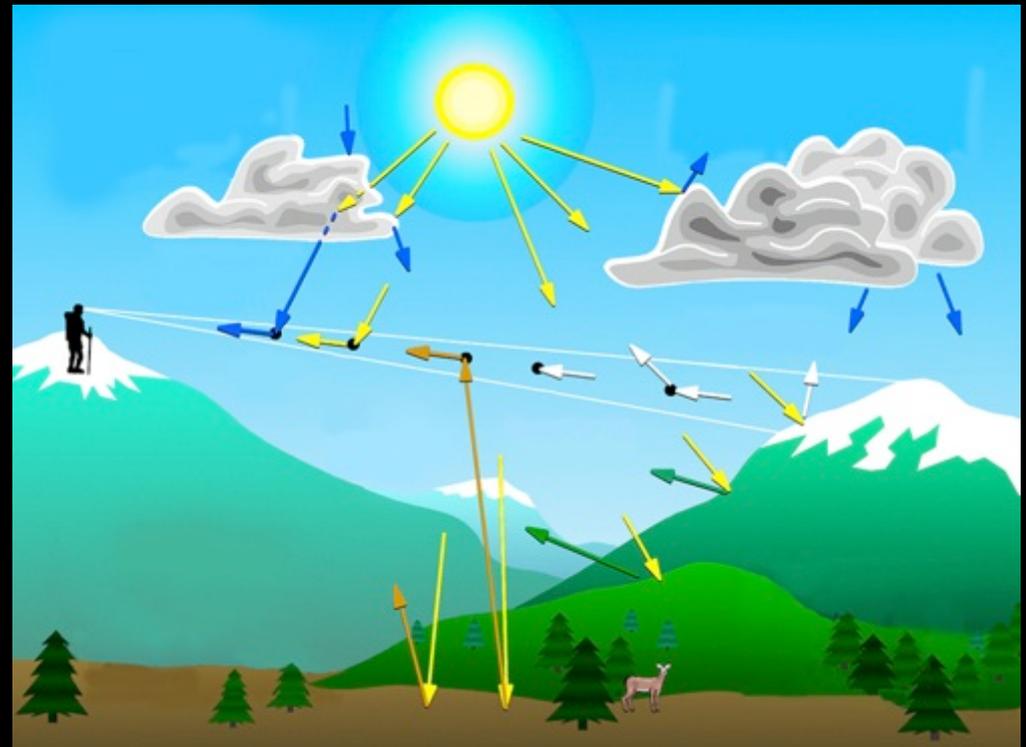
Joint Fire Science Program Project

- 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 PM_{2.5} from a VR
 - Make recommendations for the form of the VR*PM relationship
 - Examine how the VR/PM_{2.5} 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



Quantification of Uncertainty



Observer judging
when a target is at
a threshold
constant

- Uncertainty = 0.2
– 0.3

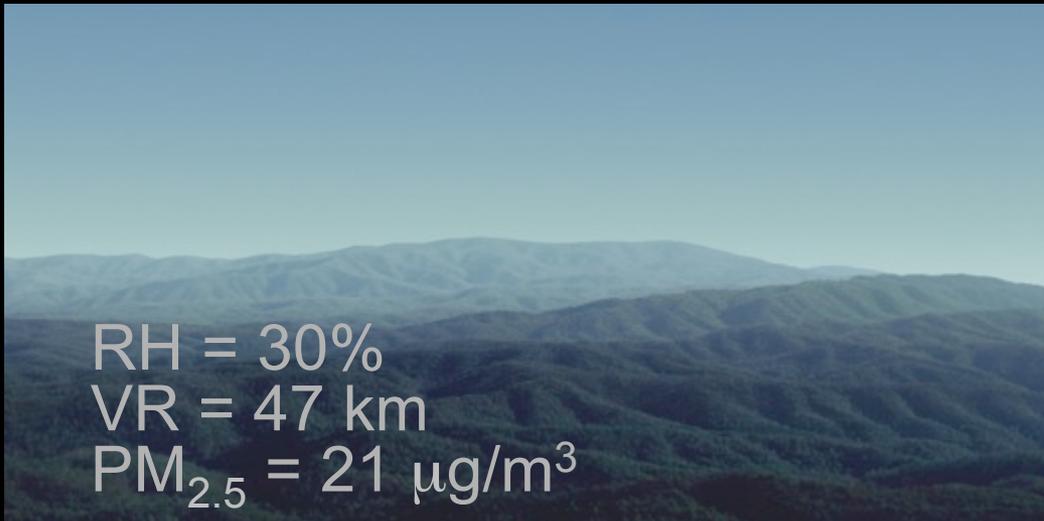
Quantification of Uncertainty

Non-uniform
aerosol
distribution
between the
observer and
the target



Uncertainty = 0.5

Quantification of Uncertainty



RH = 30%
VR = 47 km
PM_{2.5} = 21 μg/m³

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

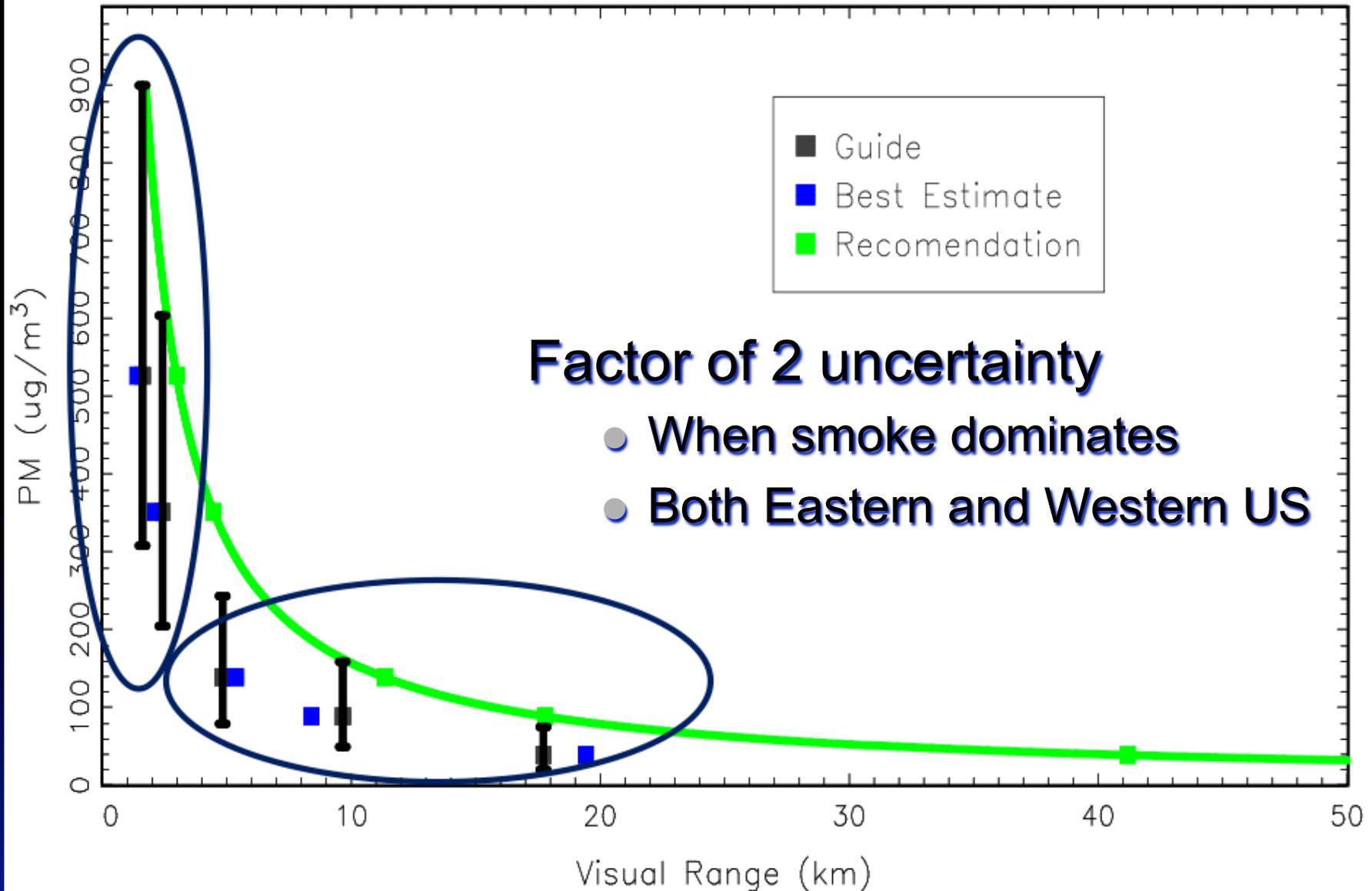
- Uncertainty = 0.7 – 1.0
- Varies across the US



RH = 90%
VR = 19 km
PM_{2.5} = 21 μg/m³

WEST

Conclusion



$V_r=37.5$ km

$V_r=17.7$ km

$V_r=8.4$ km



$V_r=19.2$ km

$V_r=9.7$ km

$V_r=4.9$ km



Malm and Schichtel, 2013

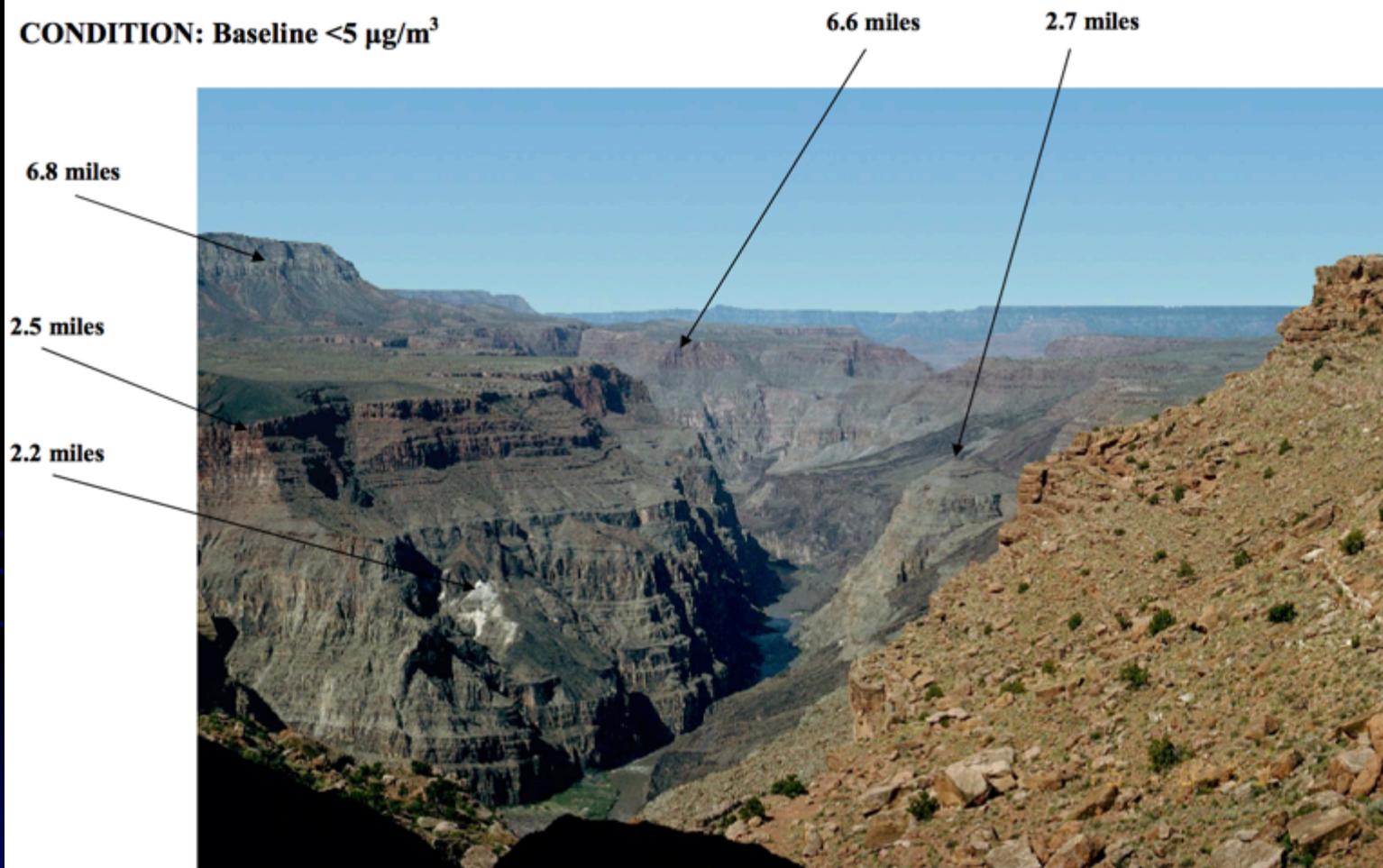
$38 \mu\text{g}/\text{m}^3$

$88 \mu\text{g}/\text{m}^3$

Smoke Photoguide, JFSP 10-1-03-2

GRAND CANYON NATIONAL PARK, AZ

CONDITION: Baseline $<5 \mu\text{g}/\text{m}^3$

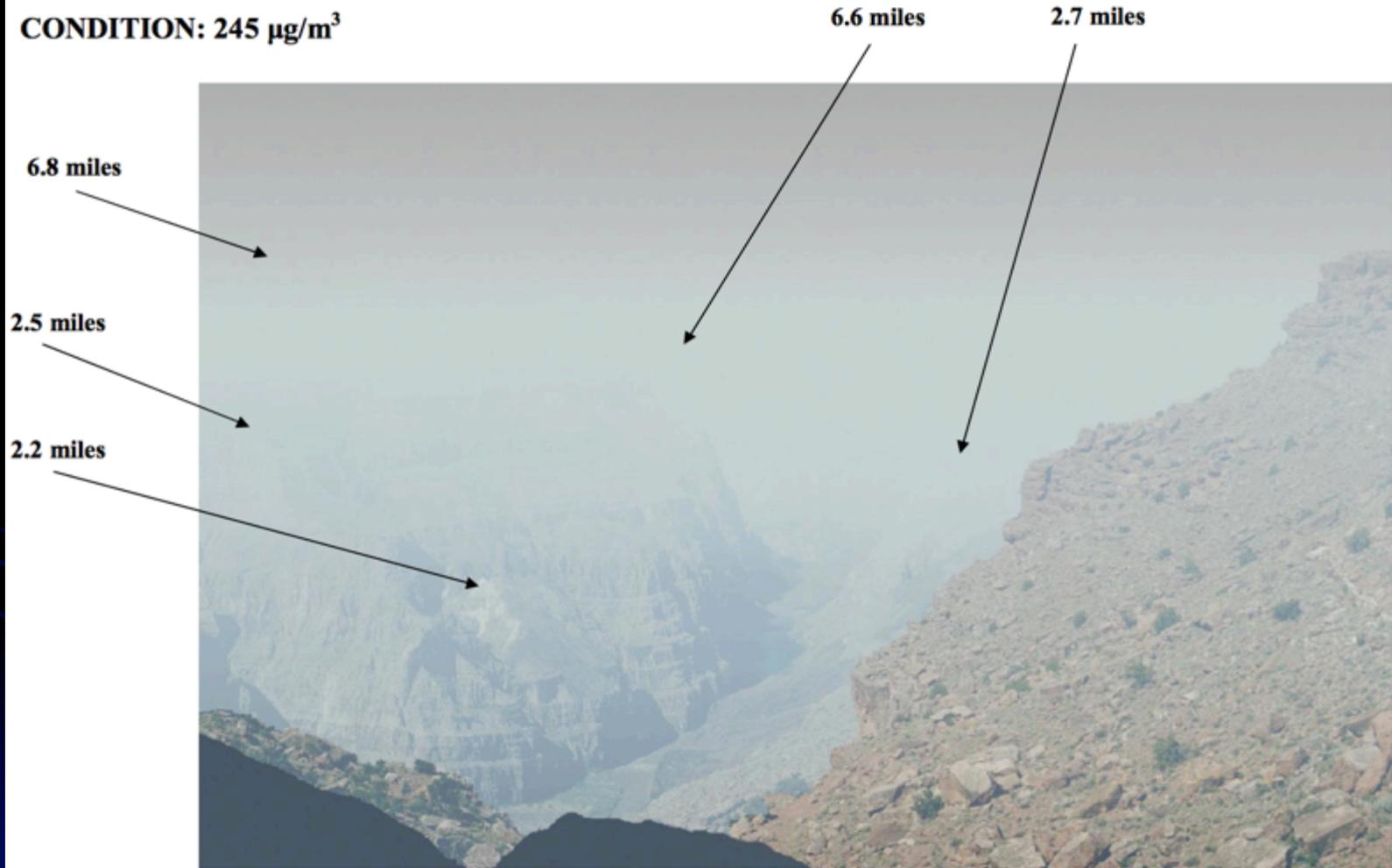


PM 2.5	$<5 \mu\text{g}/\text{m}^3$
Relative Humidity	20 %
Visual Range	148.5 miles

Smoke Photoguide, JFSP 10-1-03-2

GRAND CANYON NATIONAL PARK, AZ

CONDITION: 245 $\mu\text{g}/\text{m}^3$



PM 2.5	245 $\mu\text{g}/\text{m}^3$
Relative Humidity	20% - 40%
Visual Range	2.3 miles

Resources/References

- Malm and Schichtel, 2013. Uncertainty associated with estimating a short-term (1-3 hr) particulate matter concentration from a human-sighted visual range. Joint Fire Science Program Report.
https://www.firescience.gov/projects/13-C-01-01/project/13-C-01-01_final_report.pdf
- O'Neill, S.M., P.W. Lahm, M.J. Fitch, M. Broughton (2013). Summary and analysis of approaches linking visual range, PM2.5 concentrations, and air quality health impact indices for wildfires. Journal of the Air & Waste Management Association, 63:9, 1083-1090, DOI: 10.1080/10962247.2013.806275
<http://dx.doi.org/10.1080/10962247.2013.806275>
- Wildfire Smoke: A Guide for Public Health Officials
<http://www.arb.ca.gov/carpa/toolkit/data-to-mes/wildfire-smoke-guide.pdf>
- WINHAZE: http://vista.cira.colostate.edu/improve/tools/win_haze.htm
- Canada AQHI: David M. Stieb, Richard T. Burnett, Marc Smith-Doiron, Orly Brion, Hwashin Hyun Shin & Vanita Economou (2008): A New Multipollutant, No-Threshold Air Quality Health Index Based on Short-Term Associations Observed in Daily Time-Series Analyses, Journal of the Air & Waste Management Association, 58:3, 435-450
<http://dx.doi.org/10.3155/1047-3289.58.3.435>
- Smoke Photoguide
<https://www.frames.gov/partner-sites/emissions-and-smoke/perceptions/smoke-examples/>

Thank you!

Questions, Comments, Discussion

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