

Possible Secondary PM Standard Based on Urban Visibility

For Presentation at the IMPROVE Steering
Committee Meeting (10/21/10 – 10/22/10)
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PM NAAQS Review Process

- Last EPA review of PM NAAQS (completed 2006)
 - Solicited comments on a visibility based secondary standard with a sub-daily $PM_{2.5}$ mass concentration indicator
 - Ultimately set the secondary standard equal to the primary standard
 - Court remanded this decision, said EPA failed to identify a protective level and to justify setting primary equal to secondary
- Current review (scheduled completion 2011)
 - Considers three alternative indicators, each as daylight 1-hour values excluding periods with relative humidity > 90%
 - $PM_{2.5}$ mass,
 - Directly measured $PM_{2.5}$ light extinction and
 - Speciated $PM_{2.5}$ mass-calculated light extinction
 - Identifies a range of PM light extinction Candidate Protective Levels (CPL) based on reanalysis of urban visibility preference surveys
 - Assessment entails generating hourly PM light extinction values for 15 urban areas over three year using PM measurements and model output to compare to the CPL
 - Assessment also shows effectiveness of PM light extinction versus PM mass concentration indicators using alternative NAAQS scenarios

Alternate Ways to Determine PM Light Extinction and Relationship to Visual Air Quality

Measured Quantities

(1) Dry PM Mass Concentration

Dry PM Composition

Ambient Relative Humidity

(2) Directly Measured PM Light Extinction

Derived Characteristics

Dry PM Characteristics

IMPROVE Algorithm

(3) Speciated PM Calculated Light Extinction

Ambient PM Light Extinction

Relationship Steps from PM Light Extinction to VAQ

Ambient PM Light Extinction

WinHaze Modeling

Perceived Visual Air Quality (Images)

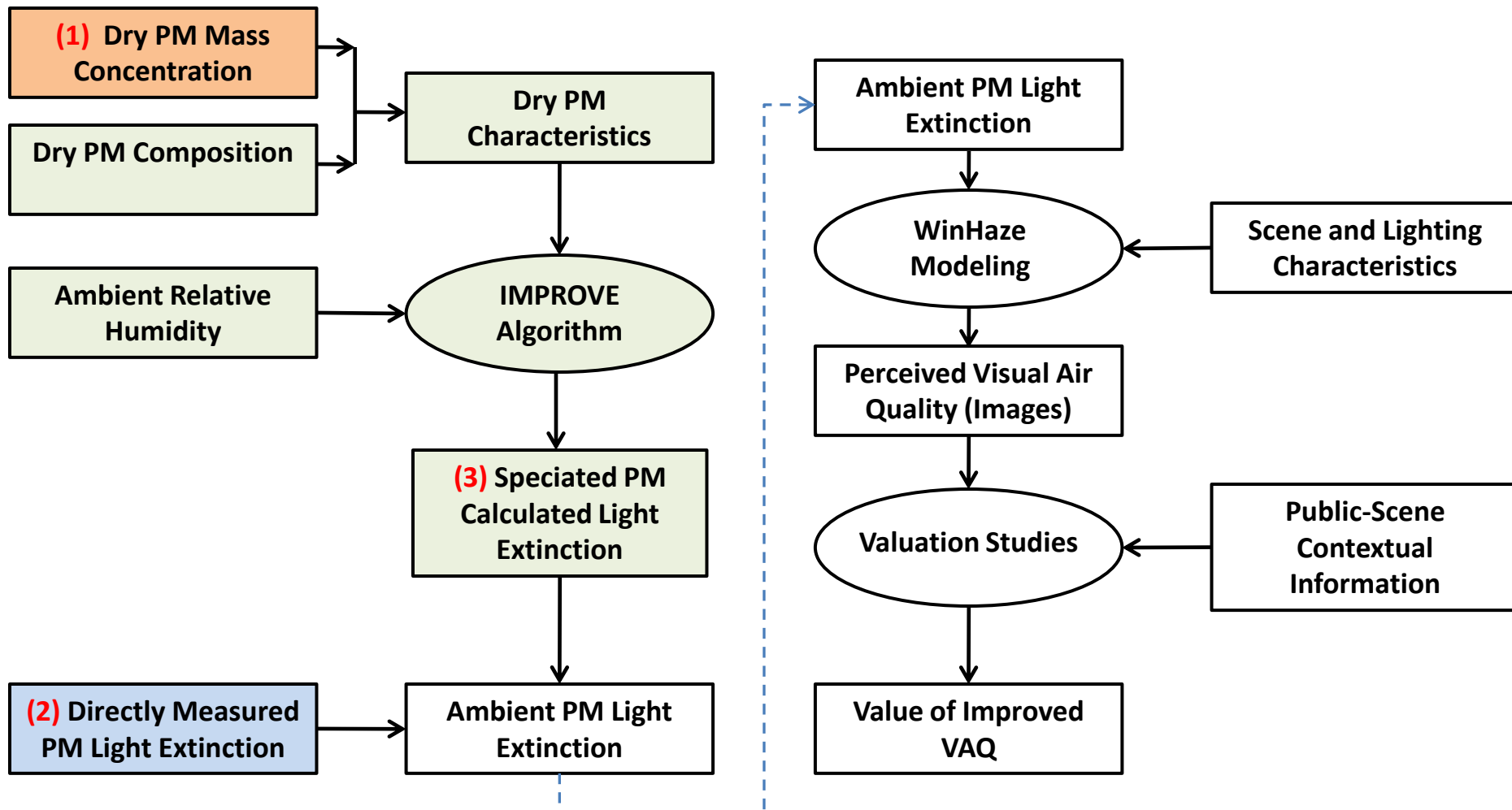
Valuation Studies

Value of Improved VAQ

Non-Air Quality Information

Scene and Lighting Characteristics

Public-Scene Contextual Information



Thoughts on Alternative Indicators

- **PM_{2.5} mass** measured by continuous FEM instruments does not include the effects of humidity and composition making its relationship to PM light extinction both noisy and regionally/seasonally biased, so it is not favored.
- **Directly measured PM_{2.5} light extinction** by optical instrumentation is considered the most accurate approach to monitoring light extinction, but there is no EPA approved FRM for it and approval is a multiyear effort, so it can't be used in this review cycle.
- **Speciated PM_{2.5} mass-calculated light extinction**, while not as accurate as direct measurements, better estimates PM_{2.5} light extinction, than PM_{2.5} mass and can be determined using existing EPA approved monitoring methods, so it is the favored indicator.

Speciated PM_{2.5} mass-calculated light extinction

Original IMPROVE algorithm without Rayleigh and coarse mass terms.

Rearranged terms to show how the relationship between PM_{2.5} light extinction and PM_{2.5} mass concentration depends on PM_{2.5} composition and relative humidity

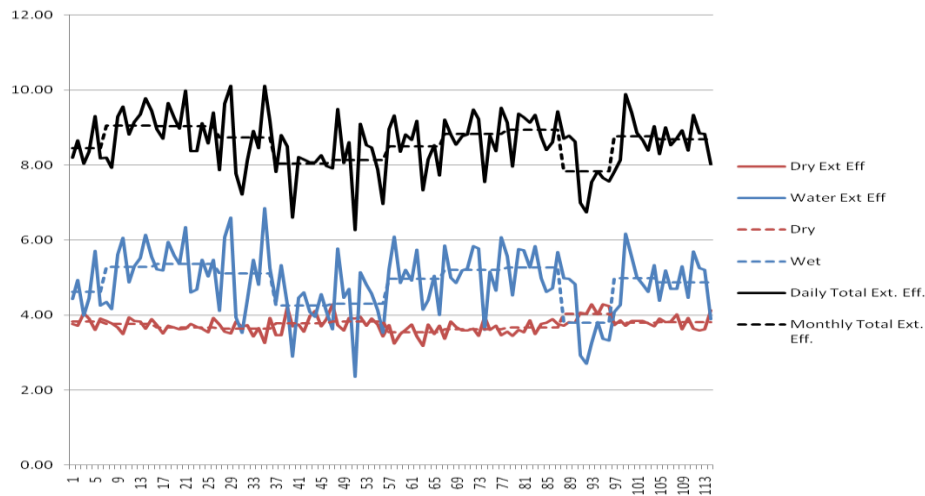
$$\begin{aligned} \text{PM}_{2.5} \text{ LE} \approx & 3 \times f(\text{RH}) \times [\text{Sulfate}] \\ & + 3 \times f(\text{RH}) \times [\text{Nitrate}] \\ & + 4 \times [\text{Organic Mass}] \\ & + 10 \times [\text{Elemental Carbon}] \\ & + 1 \times [\text{Fine Soil}] \end{aligned}$$

$$\text{PM}_{2.5} \text{ LE} \approx \{(3 \times (f(\text{RH}) - 1) \times \text{HF} + \text{DLEE})\} \times \text{PM}_{2.5}$$

where HF is the hygroscopic fraction and DLEE is the dry light extinction efficiency, both only dependent on PM_{2.5} composition

- Input data sources being considered
 - Hourly PM_{2.5} mass from FEM continuous monitors
 - Hourly Relative Humidity from continuous monitors
 - Monthly averaged HF and DLEE from collocated CSN monitors
- Issues of concern
 - FEM continuous monitors occasionally generate 1-hour outliers – use of screening and/or multi-hour averaging and causes of the outliers are being investigated
 - Use of monthly averaged composition approximates the light extinction quite but makes it harder to know the components responsible for any hourly value

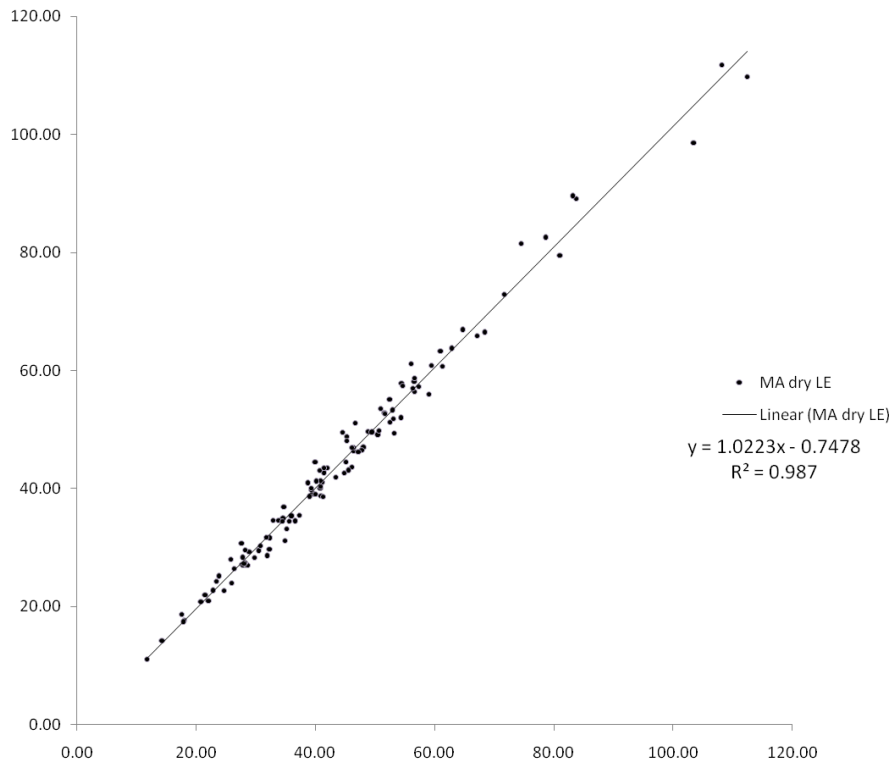
Daily and Monthly Averaged Dry and Water Extinction Efficiencies by Sample Day for Washington DC 2008



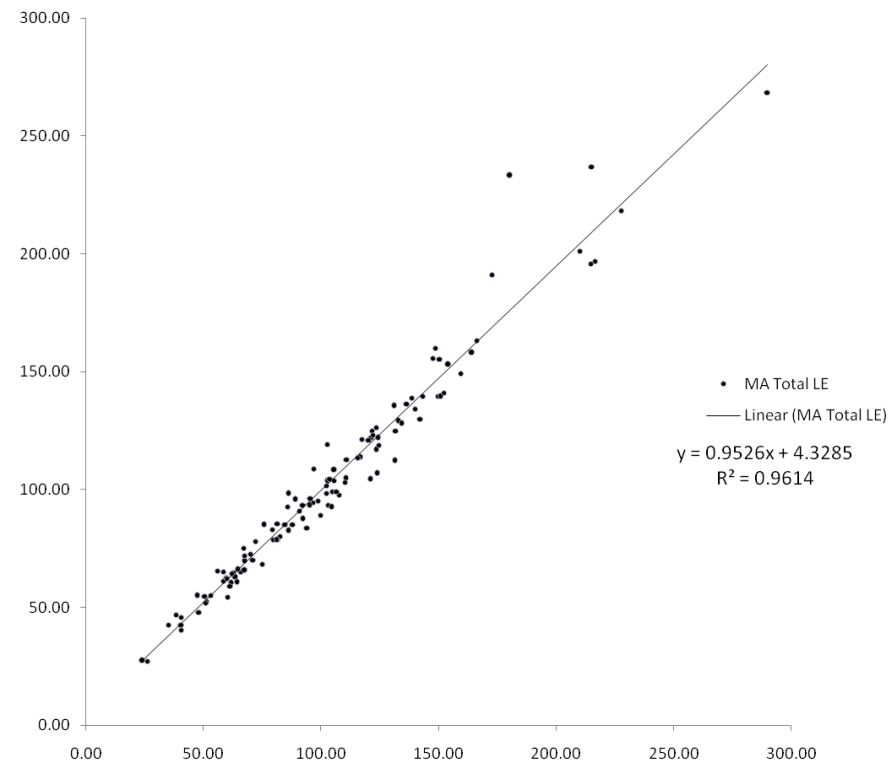
Washington

- Dry extinction efficiency is stable with annual average = 3.74 ± 0.2
- Water extinction efficiency is stable with annual average = 4.85 ± 0.8
- Monthly calculated LE is well correlated with daily calculated values
 - Dry: slope=1.02, intercept=0.7, $R^2=0.99$
 - Wet: slope=0.95, intercept=4.3, $R^2=0.96$

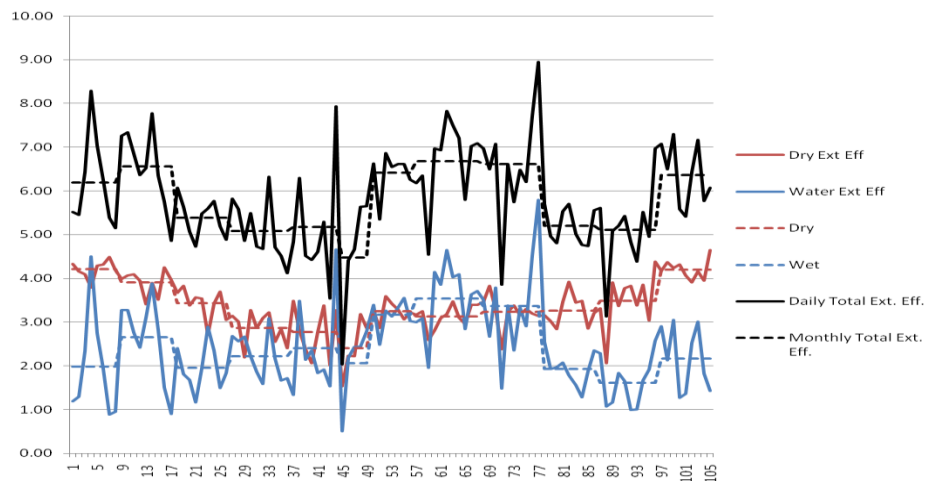
Monthly-Average Composition Calculated Total LE versus Day-Specific Calculated Total LE for the Low Relative Humidity Case ($f(RH)=1$): Washington DC



Monthly-Average Composition Calculated Total LE versus Day-Specific Calculated Total LE for the High Relative Humidity Case ($f(RH)=4$): Washington DC



Daily and Monthly Averaged Dry and Water Extinction Efficiencies by Sample Day for Phoenix 2008

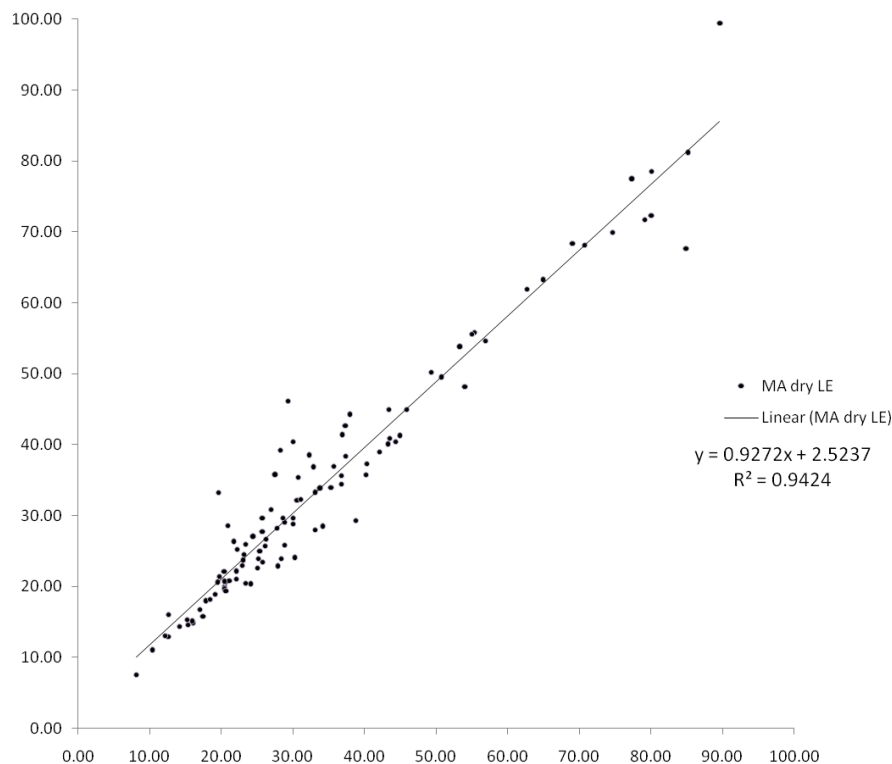


Phoenix

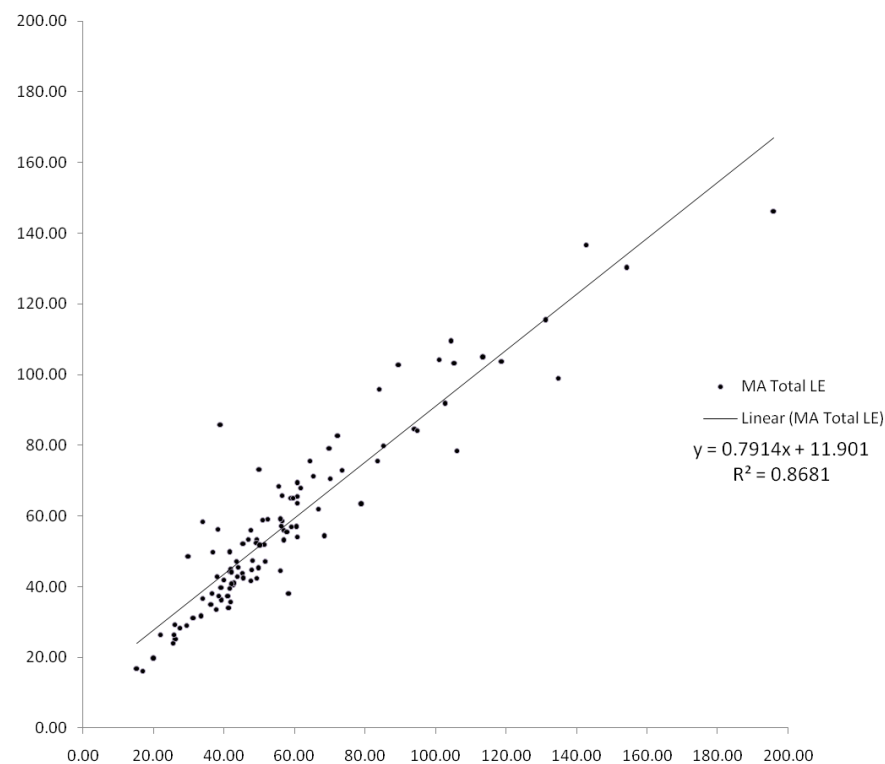
- Dry extinction efficiency is higher in winter months (3 to 4) than summer (<3)
- Water extinction efficiency is higher in summer/fall months (>3) than winter (~2)
- Monthly calculated LE is well correlated with daily calculated values when dry
 - Dry: slope=0.93, intercept=2.5, $R^2=0.94$
 - Wet: slope=0.79, intercept=12, $R^2=0.87$

Note that Phoenix rarely has very high RH, so dry case is more applicable

Monthly-Average Composition Calculated Total LE versus Day-Specific Calculated Total LE for the Low Relative Humidity Case ($f(RH)=1$): Phoenix

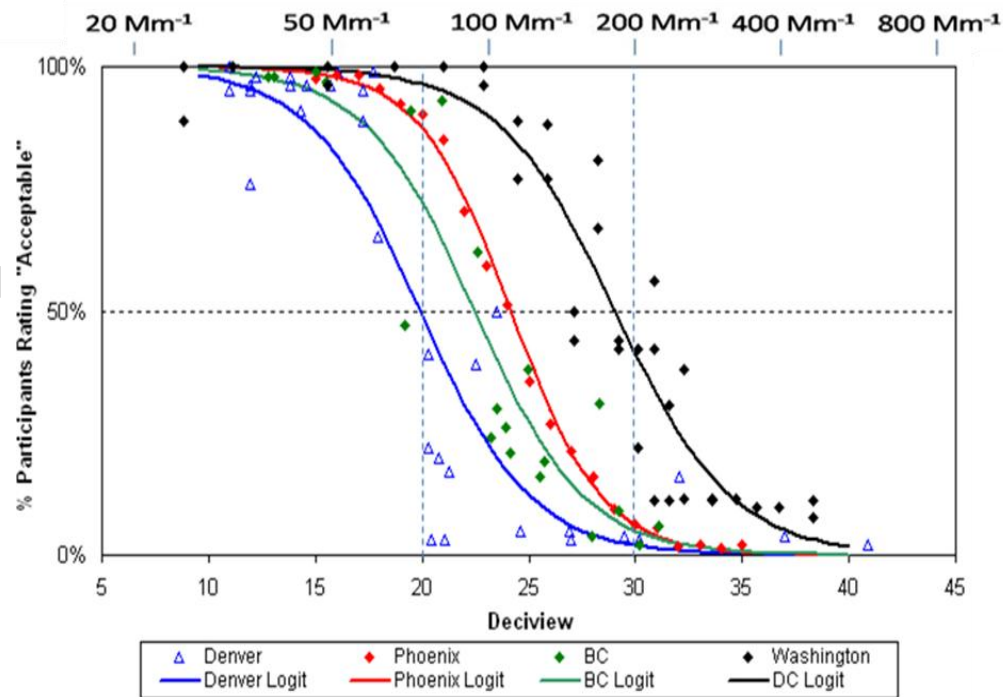


Monthly-Average Composition Calculated Total LE versus Day-Specific Calculated Total LE for the High Relative Humidity Case ($f(RH)=4$): Phoenix



Results of Urban Visibility Preference Studies: Basis for a Range of Candidate Protective Levels

- Preference survey participants were shown urban scenic slides of differing VAQ in random order and asked to rate them
 - on a 1 to 7 scale for visual air quality when shown in a warm-up session
 - as having acceptable or unacceptable visibility when shown again in random order
- Results are summarized as the fraction of participants rating each scene as having acceptable visibility
 - Four areas have similar results though displaced on the VAQ scale (x-axis)
 - A practical range for the CPL from 20 dv to 30 dv was selected based on the 50th percentile values of the four studies (with a middle value of 25 dv)
 - Corresponding PM light extinction values for the low, middle and high CPL are 64 Mm⁻¹, 112 Mm⁻¹ and 191 Mm⁻¹.



Phoenix



0 deciview; PM light extinction = 0 Mm^{-1}

25 deciview; PM light extinction = 112 Mm^{-1}



20 deciview; PM light extinction = 64 Mm^{-1}

30 deciview; PM light extinction = 191 Mm^{-1}

Washington, DC



0 deciview; PM light extinction = 0 Mm^{-1}



25 deciview; PM light extinction = 112 Mm^{-1}



20 deciview; PM light extinction = 64 Mm^{-1}



30 deciview; PM light extinction = 191 Mm^{-1}

Dallas



0 deciview; PM light extinction = 0 Mm^{-1}



25 deciview; PM light extinction = 112 Mm^{-1}



20 deciview; PM light extinction = 64 Mm^{-1}



30 deciview; PM light extinction = 191 Mm^{-1}

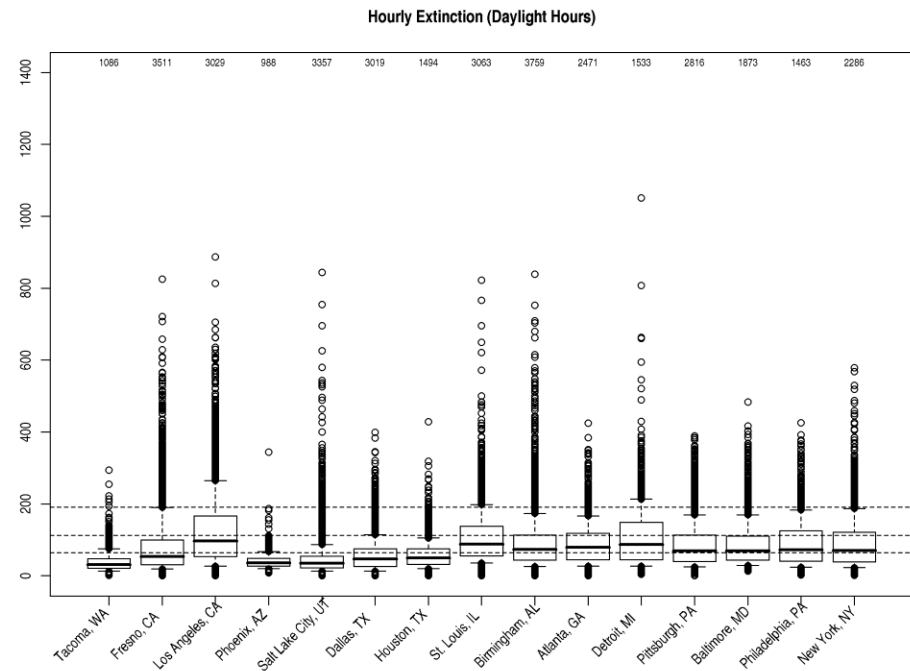
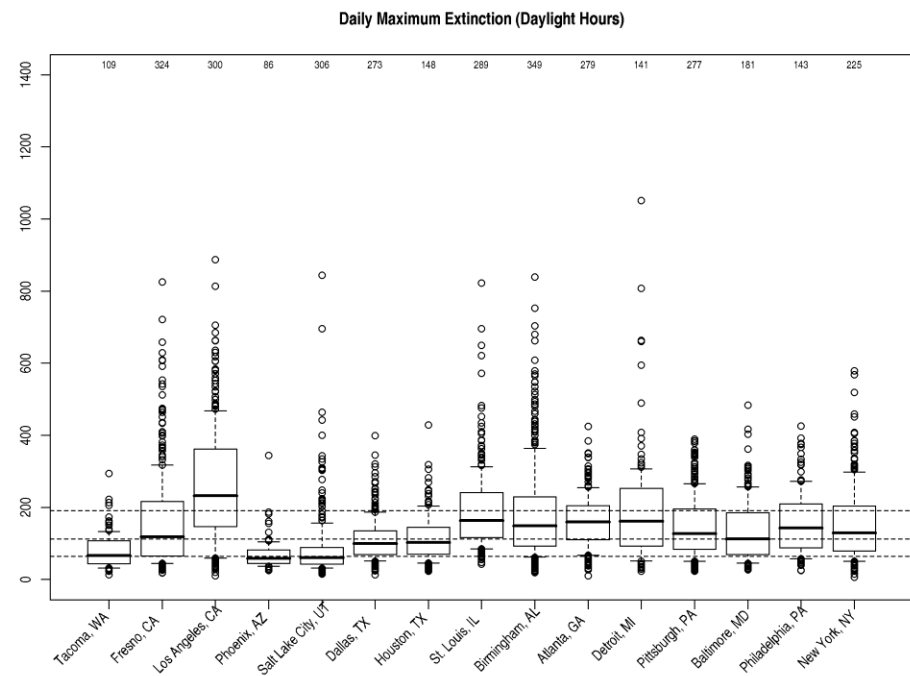
Current PM Light Extinction

- Box plots

- Box– 25th to 75th percentile;
- Whiskers – 10th and 90th percentile,
- Open circles – all extreme data
- Number of data points for each city shown at the top
- Horizontal dashed lines – CPL
- Maximum daily 1-hour daylight light extinction (top); All 1-hour daylight light extinction (bottom)

- Result highlights

- All cities have some hours exceeding the high CPL
- California and Eastern cities have the highest PM light extinction
- Los Angeles is the haziest of the 15 urban areas; Phoenix is the least hazy
- Sulfate and nitrate are the largest contributors to hazy hours at most the cities (not shown in these figures)
- Phoenix worst hours are from coarse mass; Tacoma are from carbonaceous PM (not shown in these figures)



Assessment of Alternative Secondary PM NAAQS Scenarios

- 18 PM light extinction scenarios considered
 - 3 alternative CPL values;
 - 2 alternative indicators: maximum daily 1-hour and all daylight hours PM light extinction
 - 3 alternative frequencies: the 3-year mean of the 98th, 95th and 90th annual percentile values
- 2 PM_{2.5} mass concentration scenarios
 - Current NAAQS: 15 µg/m³ – annual; 35 µg/m³ – daily
 - 12 µg/m³ – annual; 25 µg/m³ – daily
- Process to simulate meeting alternative scenarios
 - Subtract daily air quality model estimates of policy relevant background (PRB) levels from current conditions
 - Determine the amount of linear rollback of the hourly or daily non-PBR PM needed to achieve the scenario requirements

Percentage Reductions Required In Non-PRB PM Light Extinction or PM Mass

	NAAQS Scenarios Based on Daily Maximum 1-hour Daylight PM light extinction, Average of Percentile Value Over Three Years								
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Level (Mm-1)	191	191	191	112	112	112	64	64	64
Percentile	90 th	95 th	98 th	90 th	95 th	98 th	90 th	95 th	98 th
Area	Percentage Reduction Required in Non-PRB PM light extinction								
Tacoma	0	0	10	22	34	53	61	70	80
Fresno	45	60	65	69	77	81	84	88	90
Los Angeles	61	67	71	78	82	84	88	90	91
Phoenix	0	0	29	0	23	60	42	59	78
Salt Lake C.	0	25	54	33	57	74	63	76	85
Dallas	0	21	39	42	55	66	70	76	83
Houston	2	20	36	45	57	64	71	79	81
St. Louis	39	51	61	66	73	78	82	86	89
Birmingham	48	61	67	71	78	82	85	88	90
Atlanta	25	35	44	58	64	69	78	81	84
Detroit	39	61	71	66	78	84	82	88	91
Pittsburgh	32	40	48	61	66	70	79	81	84
Baltimore	23	35	43	57	64	68	77	81	83
Philadelphia	34	45	52	63	68	73	80	83	85
New York	39	48	59	65	70	77	81	84	88

Percentage Reduction Required in Non-PRB Mass	
15 µg/m ³ 35 µg/m ³	12 µg/m ³ 25 µg/m ³
19	43
45	61
37	55
0*	22
37	56
0*	7
6	27
10	37
22	45
8	30
19	43
19	43
6	33
8	35
17	41
* These areas meet this NAAQS scenario under current conditions.	

Example Table Showing Some of the Results of Rollback to Meet Scenario NAAQS

	Percent of Days with Maximum Hour Above 191 Mm ⁻¹										
NAAQS Level Mm ⁻¹	191	191	191	112	112	112	64	64	64		
NAAQS Percentile											
Form	90	95	98	90	95	98	90	95	98		
Annual/ 24-hour										15/ 35	12/ 25
Area	Percentage of days										
Tacoma	8	7	3	1	1	0	0	0	0	1	0
Fresno	10	5	3	2	0	0	0	0	0	10	5
Los Angeles	10	6	3	1	0	0	0	0	0	39	20
Phoenix	9	5	1	3	1	0	1	0	0	1	1
Salt Lake C.	9	5	1	4	1	0	1	0	0	4	2
Dallas	11	5	1	1	0	0	0	0	0	10	8
Houston	11	6	2	1	1	0	0	0	0	11	3
St. Louis	11	5	3	2	1	0	0	0	0	36	21
Birmingham	10	5	2	1	0	0	0	0	0	24	13
Atlanta	11	4	2	0	0	0	0	0	0	25	8
Detroit	10	4	3	4	1	0	1	0	0	33	10
Pittsburgh	9	6	1	0	0	0	0	0	0	16	5
Baltimore	12	6	2	1	0	0	0	0	0	19	8
Philadelphia	8	5	1	0	0	0	0	0	0	28	9
New York	10	6	2	1	0	0	0	0	0	19	8
Average	10	5	2	1	0	0	0	0	0	18	8

PM NAAQS Review Schedule - *Annotated*

- Integrated Science Assessment
 - Finalized December 2009
- Risk and Exposure Assessments
 - Quantitative Health Risk Assessment finalized June 2010
 - Urban-Focused Visibility Assessment finalized July 2010
- Policy Assessment
 - Second draft released for CASAC and public review in June 2010
 - Final document targeted for October 2010. *More likely done in November.*
- Proposed rulemaking – February 2011 *Secondary NAAQS might be separated from the primary to allow more time to deal with issues and to get more public feedback on options. Decision should be made in a month or two.*
- Final rulemaking – October 2011 *If separated, the secondary standard could be delayed by as much as a year.*
- For more information:

http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html