

Aerosol Extinction Assessment and Impact on Regional Haze Rule Implementation

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Proposed EPA Haze Rule Requires Reduction of Light Extinction in National Parks to Background Levels by 2064.

Assessment based on reconstructed, not measured light extinction:

$$\begin{aligned} \text{Bext} = & 3 \text{ f(RH) } [(\text{NH}_4)_2\text{SO}_4 + \text{NH}_4\text{NO}_3] + \\ & 4 [1.4 \text{ OC}] + \\ & 1 [\text{PM}_{2.5} \text{ Soil}] + \\ & 0.6 [\text{Coarse (PM}_{10}\text{-PM}_{2.5}) \text{ Mass}] + \\ & 10 [\text{EC}] + \\ & 10 \text{ Mm}^{-1} \text{ (Rayleigh Scattering)} \end{aligned}$$

Dry Mass Scattering Efficiencies

Assumed constant (3 m²/g for AMSUL and AMNIT, 4 m²/g for OCM, 1 m²/g for soil, 0.6 m²/g for coarse (PM₁₀-PM_{2.5}), [10 m²/g for EC absorption]. 10 Mm⁻¹ for Rayleigh scattering by atmospheric gases

In reality, scattering efficiencies vary with particle size distribution

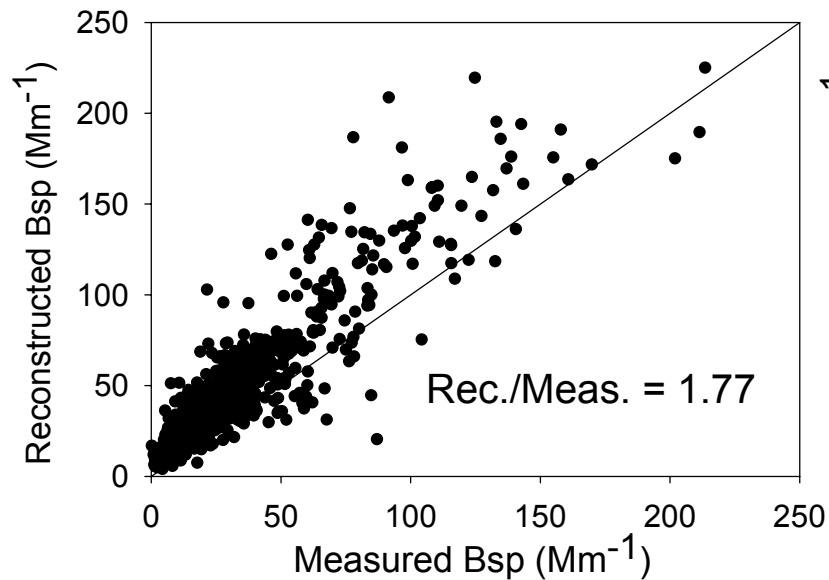
To Assess the IMPROVE
Equation:

Compare measured light scattering
(Bsp) and reconstructed Bsp from
20 IMPROVE sites from 1993-
1999

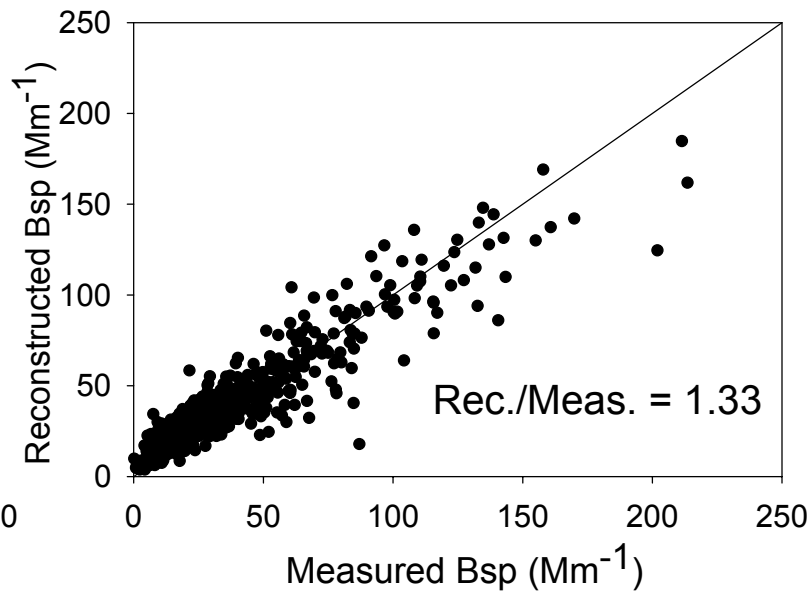
Climatological $f(\text{RH})$: Based on historical RH across U.S. from 1988-1997 (>95% rollback)

Actual $f(\text{RH})$: Based on measured hourly RH with Bsp (>95% omitted)

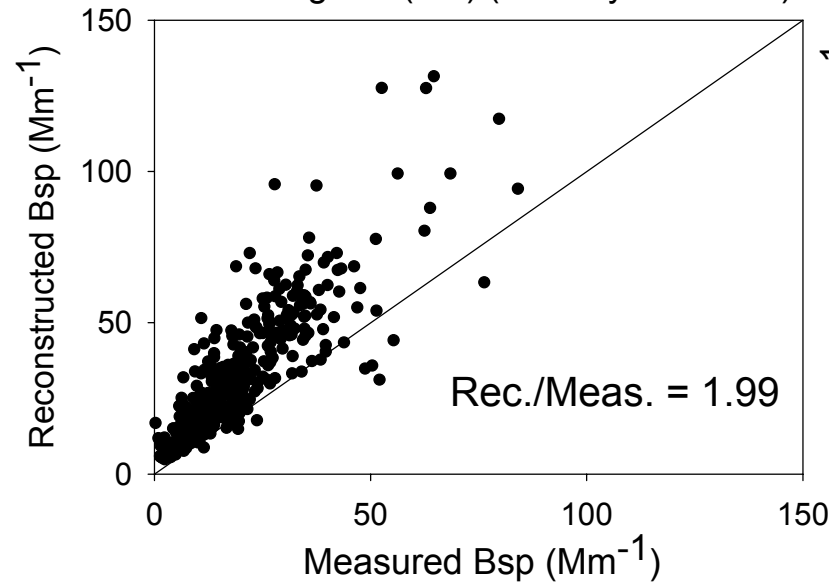
Climatological f(RH) (all data)



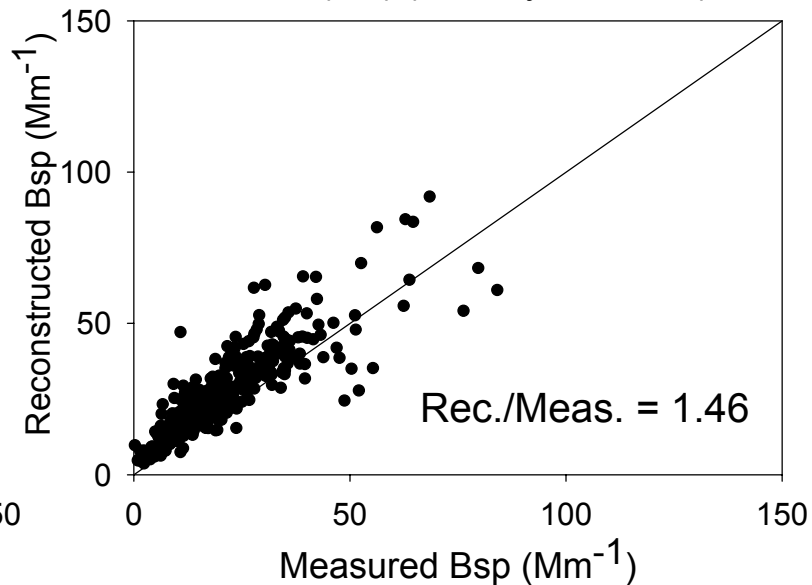
Actual f(RH) (all data)

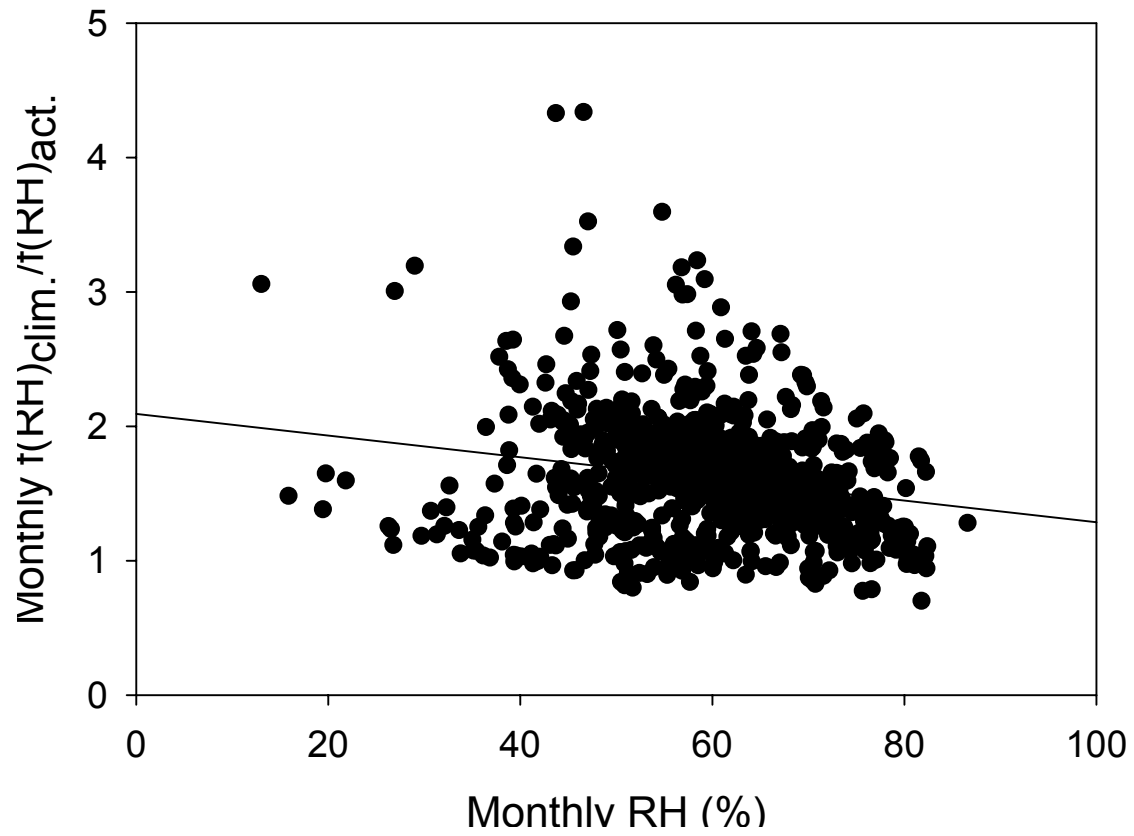


Climatological f(RH) (monthly RH<60%)



Actual f(RH) (monthly RH<60%)





% Sulfate Contribution

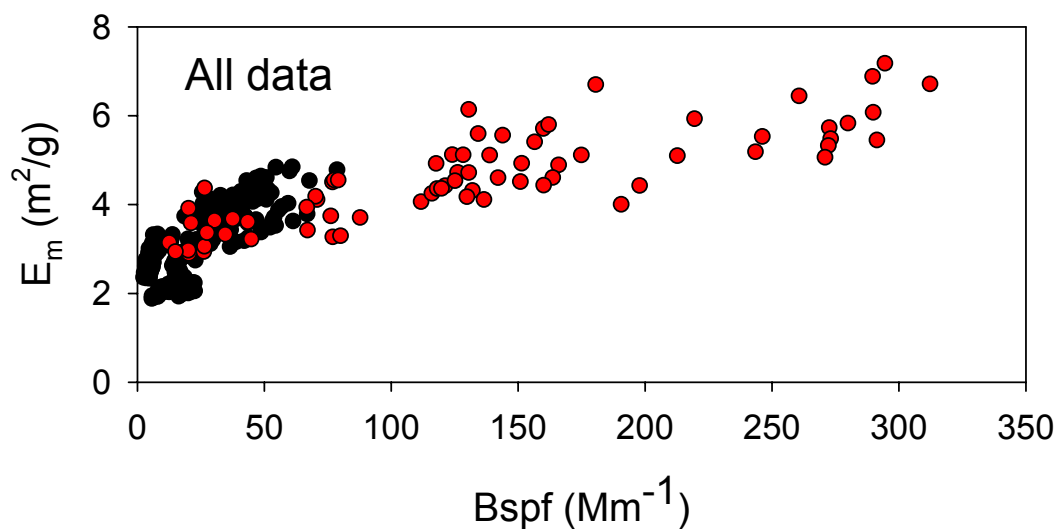
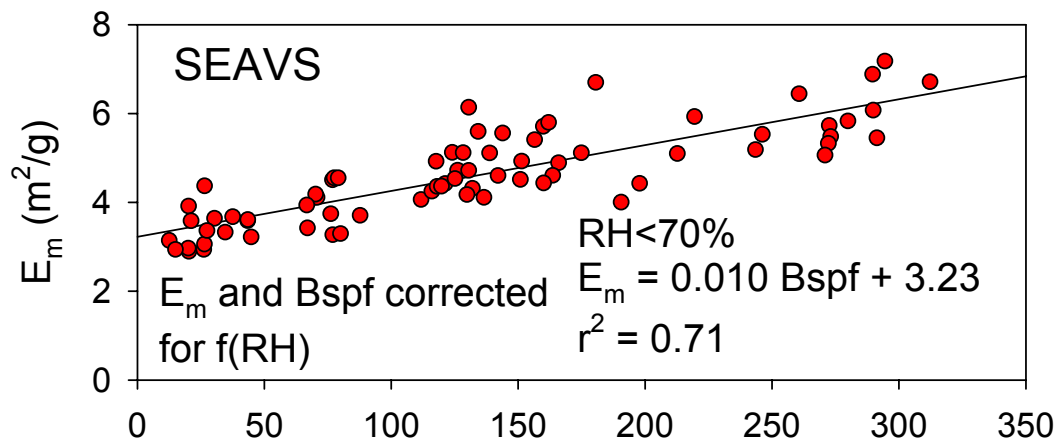
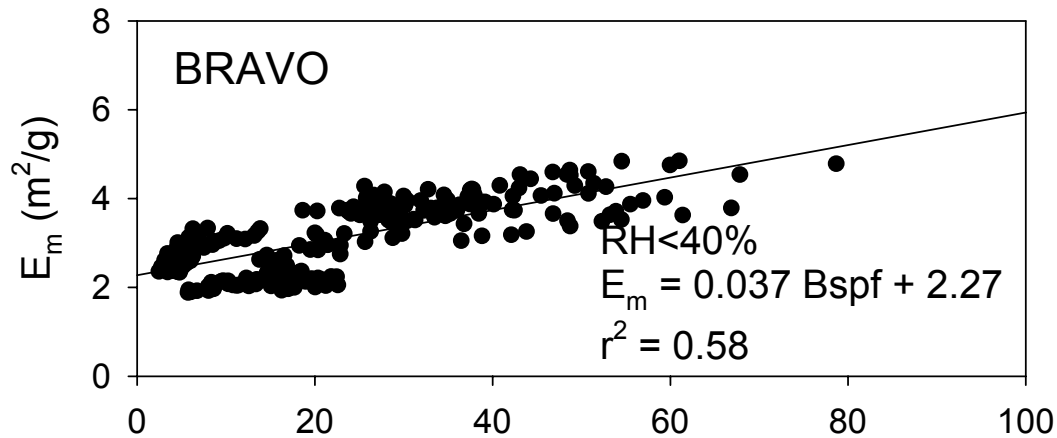
f(RH) Efficiency ^b	Climatological	Actual ^a	Actual	Actual
OCM/OC	3.0	3.0	2.5	2.5
	1.4	1.4	1.4	2.1
Average	32	29	26	24

^a f(RH) calculated with RH rolled back to 95%.

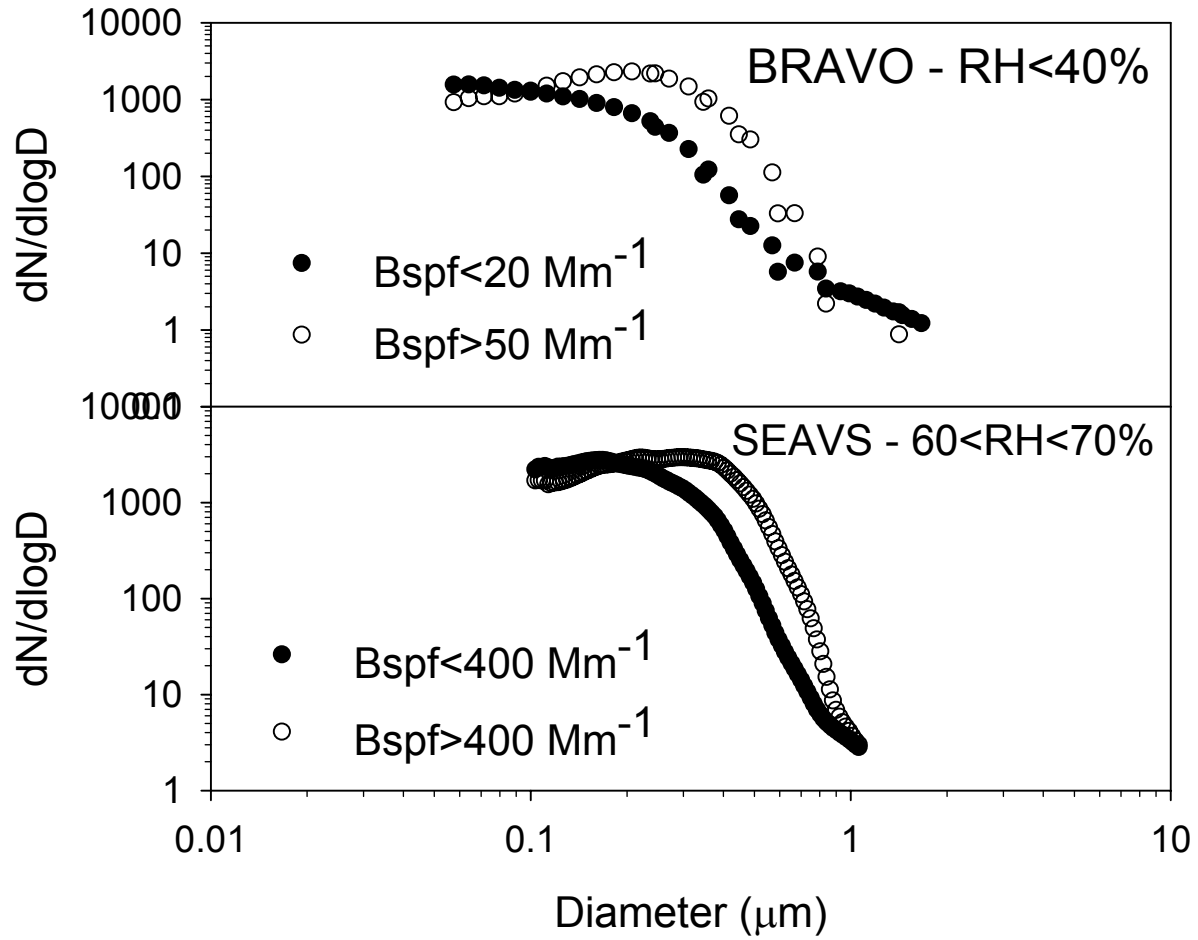
^b dry ammonium sulfate and ammonium nitrate mass scattering efficiency (m^2/g).

Are dry efficiencies constant?

Use measured dry particle size distributions in BRAVO and SEAVS and measured fine Bsp to look at variations in mass efficiency (Bspf/mass). Volume from dry size, dry density from IMPROVE chemistry, dry Bspf for SEAVS from $f(\text{RH})$.



Result: Mass efficiency increases
with the degree of pollution
(Bspf) in remote national parks.



Dry mass efficiency increases for typical pollution aerosol distributions with $0.1 < \text{diameter} < 0.6 \mu\text{m}$ (Watson, 2002)

The shift of the ambient dry particle size distribution over this size range under more polluted conditions causes the variation in efficiency.

OCM/OC Ratio Affects Apportionment of Bext to Organics and Sulfates

Assumed Ratio = 1.4 (urban – unoxidized)

Calculate OCM/OC from IMPROVE Data (1988-1999):

$$\text{Ratio} = (\text{PM}_{2.5} - (\text{AMSUL} + \text{AMNIT} + \text{EC} + \text{SOIL} + \text{Other}))/\text{OC}$$

Assume: $\text{conc} > 3\sigma$, $N > 20$, $\text{soil} = \text{soil}/0.91$ (based on DRI soil profiles), $0 < \text{Ratio} < 10$ (remove outliers).

Average OCM/OC (partial list)

<u>Site</u>	<u>Ratio</u>	<u>Std.</u>	<u>N</u>
BIBE	2.00	0.72	105
GRSM	2.33	1.23	262
GRCA	2.19	1.10	89
PORE	2.00	1.02	194
YELL	1.90	0.39	43
ALL	2.06	0.30	9597

Implementation Effects of Regional Haze Rule Process (STI)

- Estimation of the Natural Background Variation from Current IMPROVE Reconstructed Extinction
- Parameterization of Dry Efficiencies as a Function of Ammonium Sulfate + Ammonium Nitrate Concentrations

EPA Natural Condition Approach

- Annual Average Aerosol Concentrations are as follows:

SPECIES	AVERAGE NATURAL CONCENTRATION		DRY EXTINCTION EFFICIENCY (M ² /G)
	West (µg/m ³)	East (µg/m ³)	
Ammonium sulfate ^b	0.11	0.23	3
Ammonium nitrate	0.10	0.10	3
Organic Mass of Carbon ^c	0.47	1.40	4
Elemental Carbon	0.02	0.02	10
Soil	0.50	0.50	1
Coarse Mass	3.00	3.00	0.6

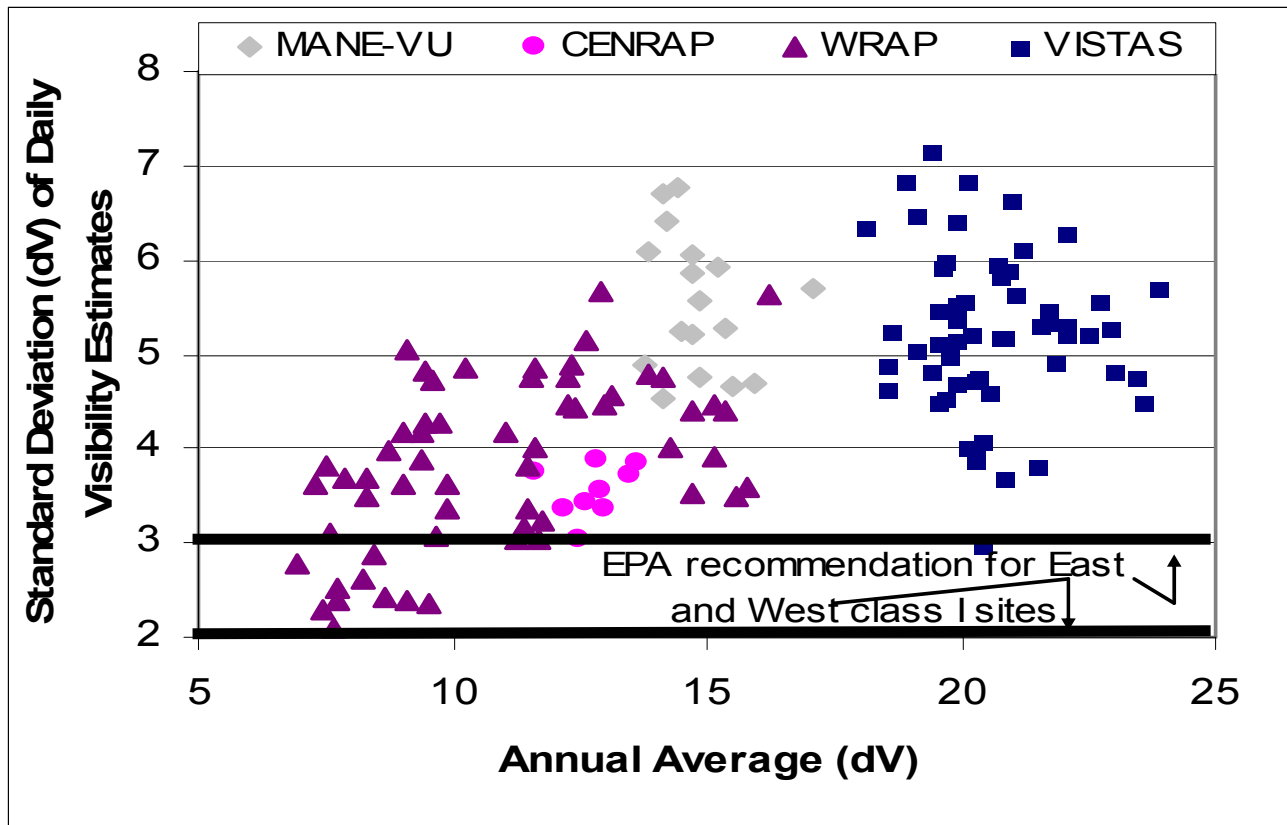
annual average as follows:

$$20\% \text{ Worst (dV)} = \text{Annual Average (dV)} + 1.28 [1.4]\sigma$$

$$\sigma = 2 \text{ dV (sites in West) and } 3 \text{ dV (sites in East)}$$

STI Peer Review of Approach

- Review of Reported Standard Deviation of Daily Data: EPA
-> $\sigma = 2$ dV (sites in West) & 3 dV (sites in East)

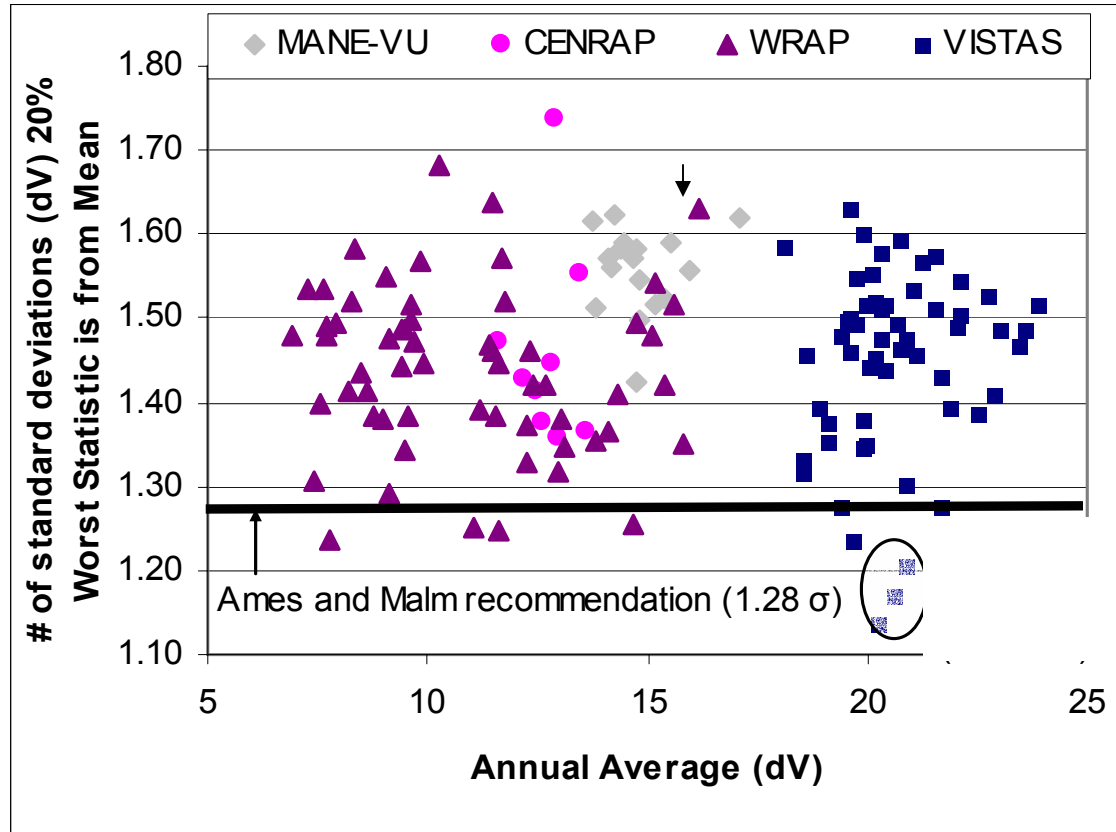


$$\text{STI} - \sigma \text{ (dV)} = 2.43 + 0.14 \text{ Annual Average (dV)}; \quad r = 0.61$$

$$\text{Pooled West } \sigma \text{ (dV)} = 3.8; \quad \text{Pooled East } \sigma \text{ (dV)} = 5.3$$

STI Peer Review of Approach

- 141 site years of daily data analyzed.
- One part of analysis identifies:
20% Worst (dV) = Annual (dV) + 1.5 σ (not 1.28 σ)



Effect of STI Alternative Approach

- 20% worst natural condition visibility ranges from 8.8 to 13.1 dV for five sites.
- These estimates are 1.2 to 2.0 dV greater than those determined using the EPA default method (7.0 to 11.5 dV).

Class I site	EPA Default approach (dV)	STI recommendation (dV)	Increase (dV)
Acadia	11.48	13.09	1.61
Big Bend	6.99	8.84	1.85
Grand Canyon	6.97	8.81	1.84
Great Smokey	11.51	12.72	1.21
Mount Rainier	7.85	9.87	2.02

IMPROVE Reconstruction Equation

Sulfate & Nitrate (S&N) Scattering Efficiency

- How did we arrive at concentration varying scattering efficiency?
- FB statistic computed varying S&N scattering efficiency by deciView range of data.
- OCM/OC assumed to be 2.

dV Range	#	$[\text{NH}_4]_2\text{SO}_4/\text{NO}_3$	$e_d = 1.8$	$e_d = 2.5$	$e_d = 3.0$	$e_d = 3.2$	$e_d = 3.9$
0-10	321	2 $\mu\text{g}/\text{m}^3$	-0.01	0.14	0.22	0.25	0.34
10-20	788	5 $\mu\text{g}/\text{m}^3$	-0.12	0.00	0.07	0.09	0.17
20-30	330	11 $\mu\text{g}/\text{m}^3$	-0.17	-0.07	-0.02	0.00	0.06
30-40	30	21 $\mu\text{g}/\text{m}^3$	-0.22	-0.13	-0.08	-0.07	0.00

IMPROVE Reconstruction Equation Sulfate & Nitrate (S&N) Scattering Efficiency

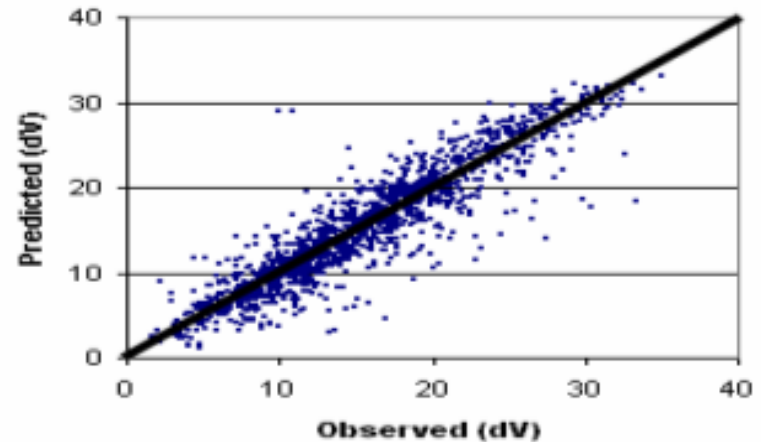
Concentration varying scattering efficiency is as follows:

$$e[\text{NH}_4]_2\text{SO}_4/\text{NO}_3(\text{m}^2/\text{g}) = 1.5 (\text{S}+\text{N})^{0.3}$$

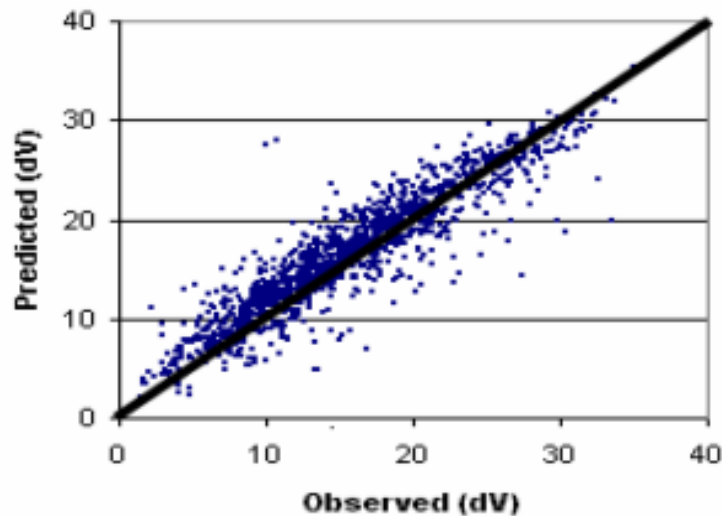
S = ammonium sulfate ($\mu\text{g}/\text{m}^3$)

N = ammonium nitrate ($\mu\text{g}/\text{m}^3$)

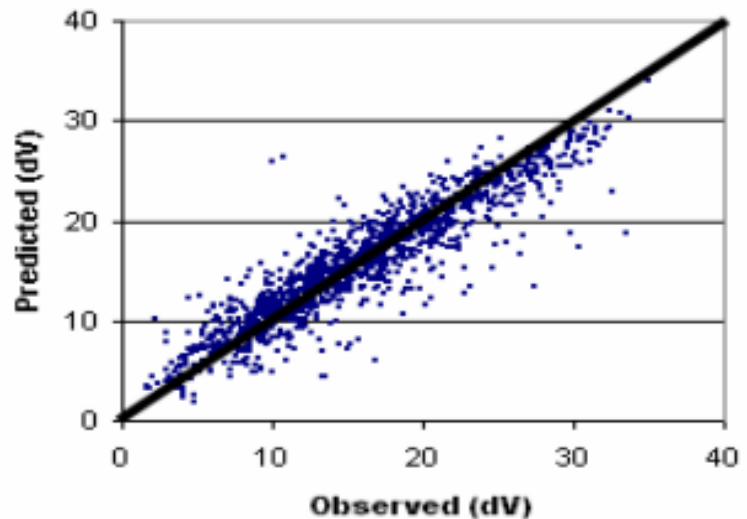
Limited to range of 1.2 to 3.7 m^2/g



$e[\text{NH}_4]_2\text{SO}_4/\text{NO}_3(\text{m}^2/\text{g})$

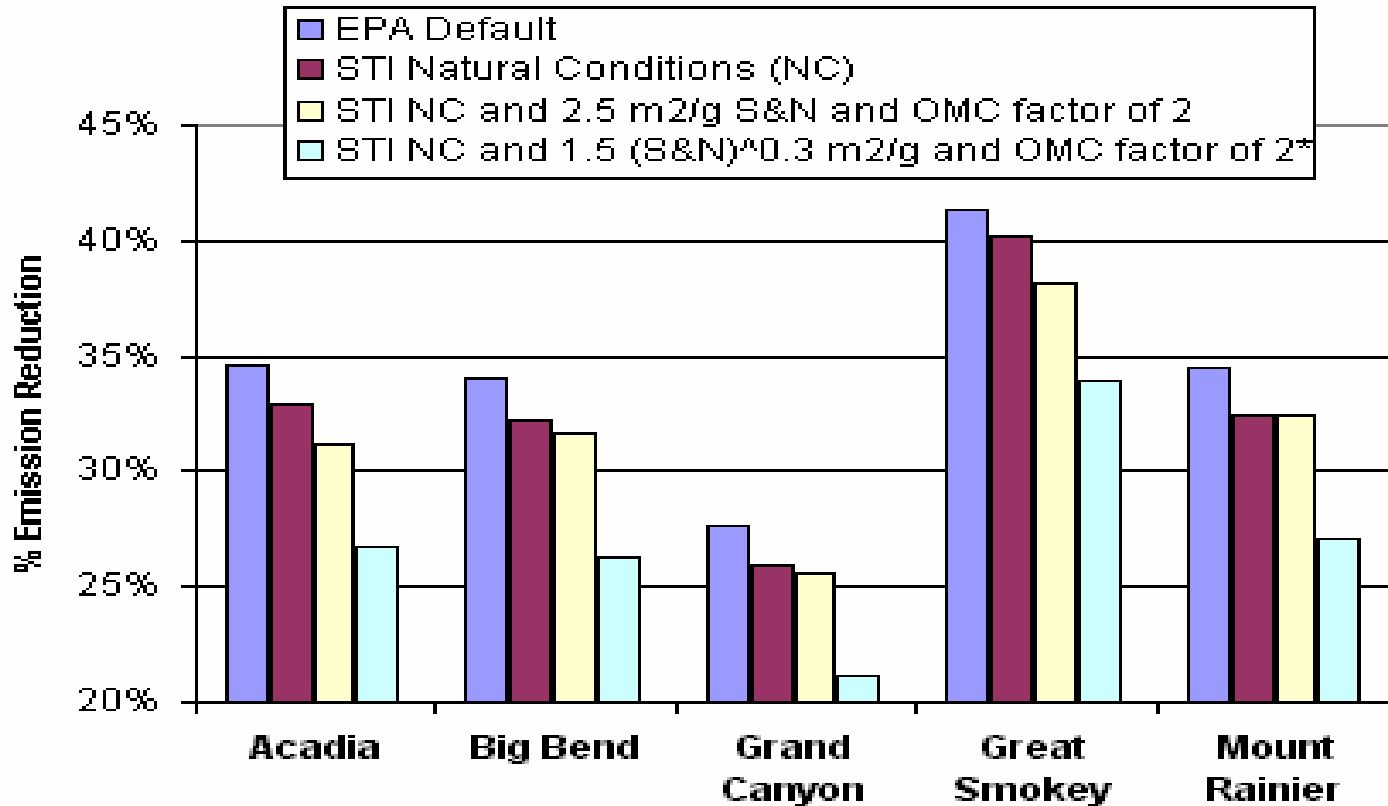


IMPROVE Reconstruction Equation



2.5 m^2/g

Requiring uniform visibility reduction of all species to achieve Progress Goal.



*** Proportional Reduction of SO₂ and NO_x Reflects Decreasing Dry Efficiencies as Bext is Reduced Over Time**

Acknowledgements

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