

# **Interpretation of the WRAP 2018 SO<sub>2</sub> Annex Milestone Modeling Results**

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## **Section 309 SIP Modeling Elements**

- **Demonstrate that in 2018 the SO<sub>2</sub> Annex Milestone strategy is “better than” Command and Controls with Uncertainty**
- **Show visibility progress from 1996 to 2018**
- **Evaluate the “significance” of mobile sources and road dust on visibility**

## **Purpose**

- **Present and discuss visibility air quality metrics based on the modeling results to help evaluate the effectiveness of the SO<sub>2</sub> Annex Milestone control strategy in achieving progress toward the Regional Haze Rule (RHR) visibility goals**

## **RHR Visibility Metrics and Goals**

- **Mean of the Worst 20% observed visibility days**
  - Goal is to achieve clean natural background visibility by 2064
- **Mean of the Best 20% observed visibility days**
  - Goal is to have no degradation in visibility on the cleanest days
- **Applicable to all Federally Mandated Class I Areas**

## **Summary of Projected Future-Year Changes in Visibility from 1996 to 2018**

- **Class I areas on Colorado Plateau**
  - Best 20%: Improvements in 9 out of 16 Areas (56%)
  - Worst 20%: Improvements in 12 out of 16 Areas (75%)
- **Other Class I Areas in 9-State Region (Less CA)**
  - Best 20%: Improvements in 24 out of 40 Areas (60%)
  - Worst 20%: Improvements in 29 out of 40 Areas (73%)
- **California Class I Areas**
  - Best 20%: Improvements in 17 out of 29 Areas (57%)
  - Worst 20%: Improvements in 23 out of 29 Areas (79%)

## **Summary of Visibility Benefits of 2018 SO<sub>2</sub> Annex Milestone vs. Command and Control w/ Uncertainty**

- **Class I areas on Colorado Plateau**
  - Best 20%: The same or better in all 16 Class I Areas
  - Worst 20%: The same or better in 15 out of 16 Class I Areas (exception is Petrified Forest)
- **Other Class I Areas in 9-State Region (Less CA)**
  - Best 20%: The same or better in 39 of 40 Class I Areas (exception is Chiricahua Wilderness)
  - Worst 20%: The same or better in 40 of 40 Areas
- **California Class I Areas**
  - Best and Worst 20%: The same or better in all 29 Areas (mostly the same)

## **Challenges in Evaluating SO<sub>2</sub> Annex Control Strategy**

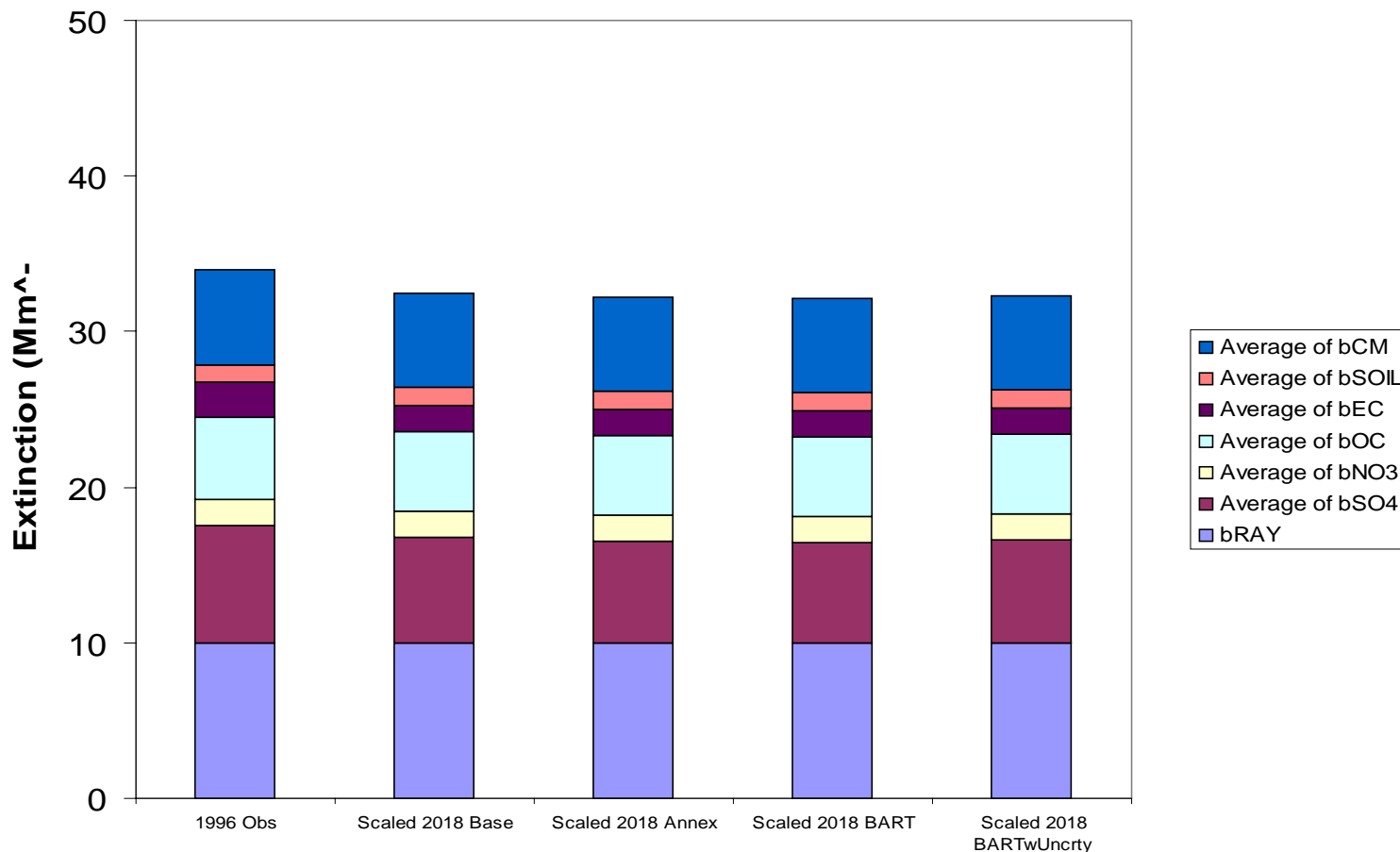
- **Just one control measure addressing just one component of regional haze being analyzed in isolation of other measures**
- **Road toward RHR goal will consist of many control programs on different visibility precursors (e.g., ozone, PM, FP, etc.)**
- **Natural visibility background major component even for Worst 20% days**
- **Need to evaluate SO<sub>2</sub> Annex as one of many emission reduction programs**

## **Example Modeling Results for Grand Canyon**

- **Presented at July WRAP Technical Conference**
- **1996 Baseline**
- **Mean of the Worst 20% Observed Visibility Days**
- **Modeling results used to scale 1996 observed visibility to obtain 2018 projected visibility for:**
  - 2018 Base Case
  - 2018 SO<sub>2</sub> Annex Milestone
  - 2018 Command and Control w/ Uncertainty
  - 2018 Command and Control (BART)

# Grand Canyon -- Mean of Worst 20% Days

Grand Canyon NP



## **Comments on Grand Canyon Worst 20% Visibility Days Modeling Results**

- **Some change in visibility from 1996 to 2018**
- **No discernible change in visibility among 2018 emissions scenarios**
- **Point Source SO<sub>2</sub> emission reductions across 9 GC States**
  - ~130,000 TPY 1996 Base to 2018 Base
  - ~130,000 TPY 2018 Base to 2018 SO<sub>2</sub> Annex

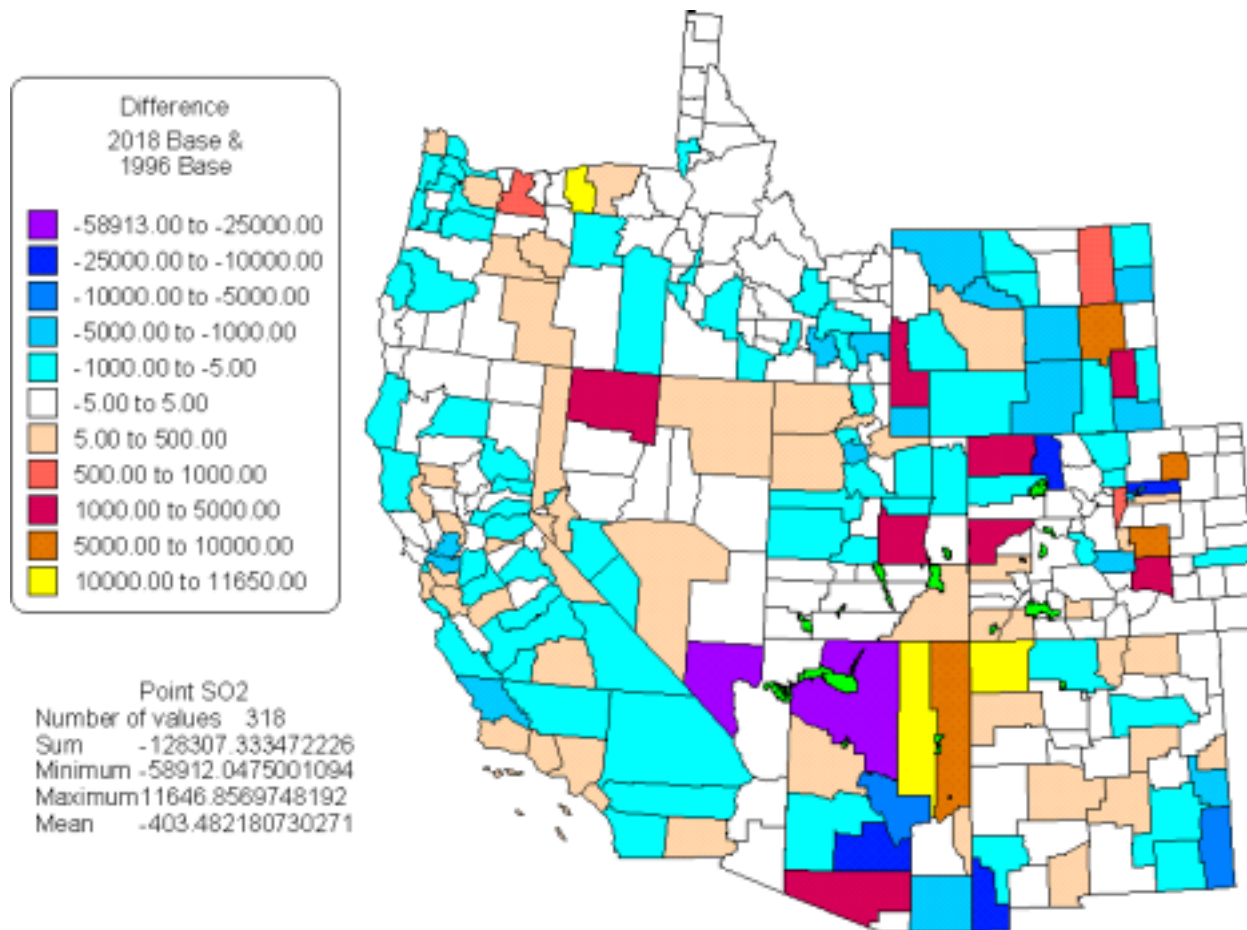
# Summary of SO<sub>2</sub> Emissions in 9 GC States

<b>Source Category</b>	<b>1996 Base (TPY)</b>	<b>2018 Base Case</b>		<b>2018 SO2 Annex Milestone</b>	
		<b>(TPY)</b>	<b>(%)</b>	<b>(TPY)</b>	<b>(% of 1996)</b>
Area	61,008	74,694	+ 22%	74,694	+ 22%
On-Road	20,628	5,443	-74%	5,443	-74%
Non-Road	140,214	175,616	+ 25%	175,616	+ 25%
Point	770,441	642,134	-17%	510,000	-33%
Total	992,291	897,887	-10%	765,754	-22%

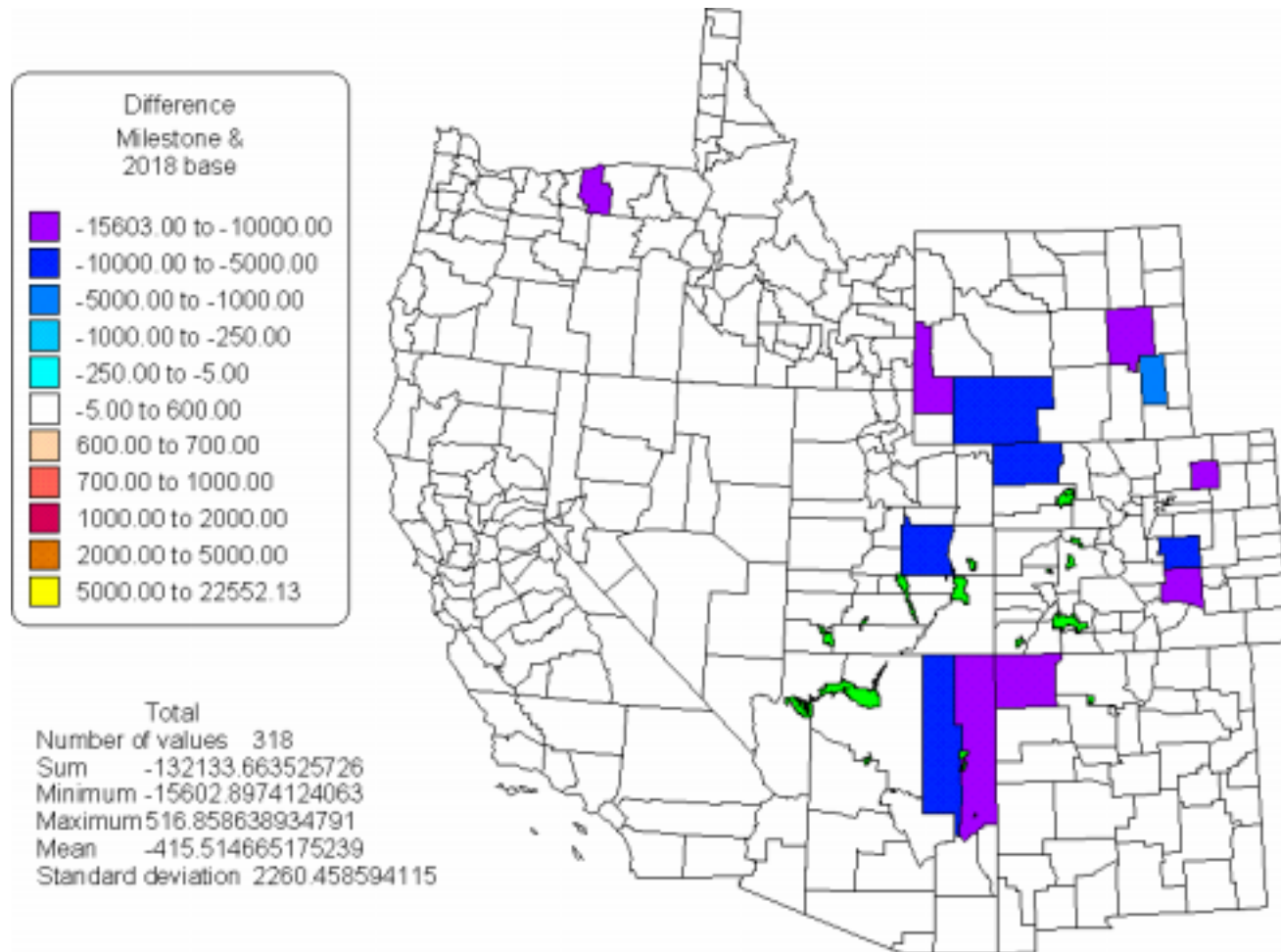
## **Grand Canyon Mean of Worst 20% Days**

- **1996 Base to 2018 Base -- 10% Reduction in SO<sub>2</sub> Emissions in 9 GC States**
  - Sulfate component of extinction is reduced from 7.54 Mm<sup>-1</sup> to 6.75 Mm<sup>-1</sup> -- 10% reduction
- **2018 Base to 2018 SO<sub>2</sub> Annex -- 15% Reduction in SO<sub>2</sub> Emissions in 9 GC States**
  - Sulfate component of extinction is reduced from 6.75 Mm<sup>-1</sup> to 6.51 Mm<sup>-1</sup> -- 4% reduction.
- **Differences due to locations of SO<sub>2</sub> emission reductions**

## Point Source SO<sub>2</sub> Emission Changes 1996 Base to 2018 Base



## Point Source SO<sub>2</sub> Emission Decreases 2018 Base to 2018 SO<sub>2</sub> Annex Milestone



## Summary of Grand Canyon Visibility Results

- **1996/2018 10% reduction in SO<sub>2</sub> emissions results in 10% reduction in sulfate because major SO<sub>2</sub> reductions are occurring at sources near the Grand Canyon (e.g., Mojave and Navajo)**
- **2018 Base/2018 SO<sub>2</sub> Annex 15% reduction in SO<sub>2</sub> emissions results in 4% reduction in sulfate at Grand Canyon because most reductions are occurring to the east and north downwind from the Grand Canyon**

## Metric #1: RHR Mean Best/Worst 20% Obs Days

Class I Area	Average Deciview (dv)			Chngs in dv frm 1996	
	1996Obs	2018 Base	2018Annex	2018Base	2018Annex
<b><i>Mean of the Worst 20% Visibility Days</i></b>					
Bryce Canyon	12.96	12.24	12.21	-0.73	-0.75
Canyonlands	12.83	12.29	12.21	-0.53	-0.62
Grand Canyon	12.23	11.79	11.71	-0.44	-0.52
Mesa Verde	12.37	12.06	11.89	-0.31	-0.48
Petrified Forest	12.65	11.99	11.76	-0.66	-0.89
Weiminuche	11.54	10.89	10.72	-0.65	-0.82
<b><i>Mean of the Best 20% Visibility Days</i></b>					
Bryce Canyon	3.51	3.26	3.25	-0.25	-0.26
Canyonlands	4.98	4.72	4.68	-0.26	-0.30
Grand Canyon	5.02	4.75	4.70	-0.27	-0.32
Mesa Verde	4.62	4.24	4.21	-0.38	-0.41
Petrified Forest	5.77	5.18	5.14	-0.59	-0.63
Weminuche	4.25	3.95	3.91	-0.30	-0.34

## **Metric #1: RHR Mean Worst 20% Obs Days**

- **Reduction in deciview ( $\Delta dv$ ) from 1996 to 2018 Base Case range from -0.31 to -0.73 ( $\Delta Bext$  range from -3% to -7%)**
- **$\Delta dv$  from 2018 Base to 2018 Annex ranges from -0.03 to -0.23 ( $\Delta Bext$  range from -0.3% to -2.3%)**
  - Reductions are smaller at more western Class I areas (e.g., -0.03  $\Delta dv$  at Bryce Canyon) and higher at more eastern Class I areas (e.g., -0.17  $\Delta dv$  at Weminuche)

## **Alternative Visibility Metrics**

- **20% Worst Modeled Sulfate Days**
  - Absolute model results (no scaling)
  - Metric #2: Change in Extinction over clean background
  - Metric #3: Change in Sulfate Concentration
- **RHR Best/Worst Observed 20% Days**
  - Metric #4: Anthropogenic Contribution to Extinction (Bext - Background)
  - Shows percent progress toward 2064 clean natural background

## Metric #2: Change in Extinction for 20% Worst Modeled Sulfate Days

Class I Area	Natural Background	Bext -- Extinction ( $\text{Mm}^{-1}$ )		2018 Base–Annex Change	
		2018 Base	2018 Annex	( $\text{Mm}^{-1}$ )	% of NB
Bryce Canyon	20.117	36.239	36.067	-0.172	-0.9%
Canyonlands	20.077	51.517	51.216	-0.301	-1.5%
Grand Canyon	20.077	37.099	36.772	-0.326	-1.6%
Mesa Verde	20.178	45.895	45.134	-0.760	-3.8%
Petrified Forest	20.077	40.541	39.613	-0.928	-4.6%
Weminuche	20.198	42.378	41.853	-0.525	-2.6%

## Metric #3: Change in Sulfate for 20% Worst Modeled Sulfate Days

Class I Area	Sulfate ( $\mu\text{g}/\text{m}^3$ )		2018 Base–Annex Change	
	2018 Base	2018 Annex	( $\mu\text{g}/\text{m}^3$ )	(%)
Bryce Canyon	1.166	1.128	0.038	-3.3%
Canyonlands	1.334	1.270	0.064	-4.8%
Grand Canyon	1.312	1.254	0.058	-4.4%
Mesa Verde	1.672	1.534	0.138	-8.3%
Petrified Forest	1.657	1.514	0.144	-8.7%
Weminuche	1.339	1.235	0.104	-7.8%

## **Comments on Worst 20% Modeled Sulfate Days Metrics 2018 Base vs 2018 SO<sub>2</sub> Annex**

- **Change in extinction (1%-5% reduction) larger than for RHR Worst 20% observed visibility days (0.3% to 2% reduction)**
- **Reduction in sulfate concentrations (3% to 9%) consistent with emission reductions (15%)**
- **More sulfate reductions at eastern Class I areas on the CO Plateau (~8%) than the western Class I areas (~4%) consistent with where emission reductions occur (PEFO exception)**

## **Metric#4: RHR Best/Worst 20% Days Anthropogenic Component of Extinction**

- **Calculate mean extinction on Best and Worst 20% visibility days**
- **Subtract out clean natural visibility background for Best/Worst days**
- **Can present as a percentage progress toward the RHR 2064 clean natural background visibility goal**
- **1996 to 2018 is 32% of the way toward 2064 assuming linearity**

## Metric#4: RHR Worst 20% Obs Days Anthropogenic Component of Extinction

Class I Area	Natural Bckgrnd	1996 Base (Mm <sup>-1</sup> )	2018 Bext (Mm <sup>-1</sup> )		% □ Anthro Bext	
			Base	Annex	Base	Annex
Bryce Canyon	20.12	36.55	34.01	33.91	-15.5%	-16.0%
Canyonlands	20.08	36.07	33.91	33.91	-11.8%	-13.5%
Grand Canyon	20.08	33.97	32.51	32.25	-10.5%	-12.4%
Mesa Verde	20.18	34.45	38.40	32.84	-7.4%	-11.3%
Petrified Forest	20.08	35.43	33.17	32.41	-14.7%	-19.7%
Weminuche	20.20	31.71	29.71	29.21	-17.4%	-21.7%