Appendix C – Supporting Modeling Data

C.1 – Normalization of Regional, State/Sector Source Apportionment Results

The purpose of this document is to outline a method which was used to normalize the 2028 CAMx model source apportionment results to the overall 2028 visibility projections for each Federal Class I Area. When normalized, the sum of all regional and state/sector apportionment model outputs will correspond to the overall 2028 visibility projections when reviewing the species-specific or total light extinction. *Currently, the regional (high-level) and the state/sector (low-level) model apportionment results are determined solely from the CAMx model output. Meaning, they will not correlate to the 2028 visibility projections until they are normalized.*

Annual average data is used in this document to provide a reasonable representation of the normalized regional, state, and/or sector specific contributions to light extinction in 2028.

<u>Three steps were taken to perform this normalization.</u>

Step 1

Determine species specific normalization factors. Take the 2028 visibility projection (2028 OTBa2EPA) for each species and divide by the 2028 CAMx source contribution model results (2028OTBa2).

The 2028 CAMx model results are found at the TSSv2 model product 1, indicated by the red box in Figure 1:

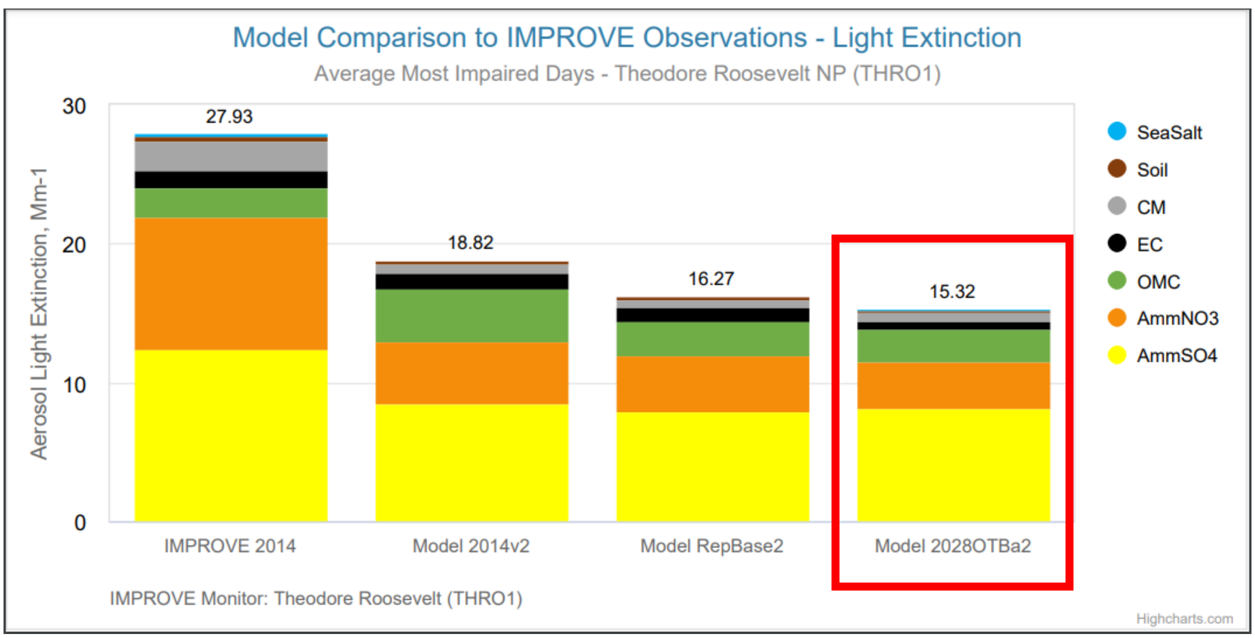

Figure 1: 2014 IMRPOVE data, 2014 Model Results, RepBase Model Results, and 2028 Source Contribution Model Results

The 2028 Visibility projections are found at the TSSv2 Model Product 3, indicated by the red box in Figure 2:

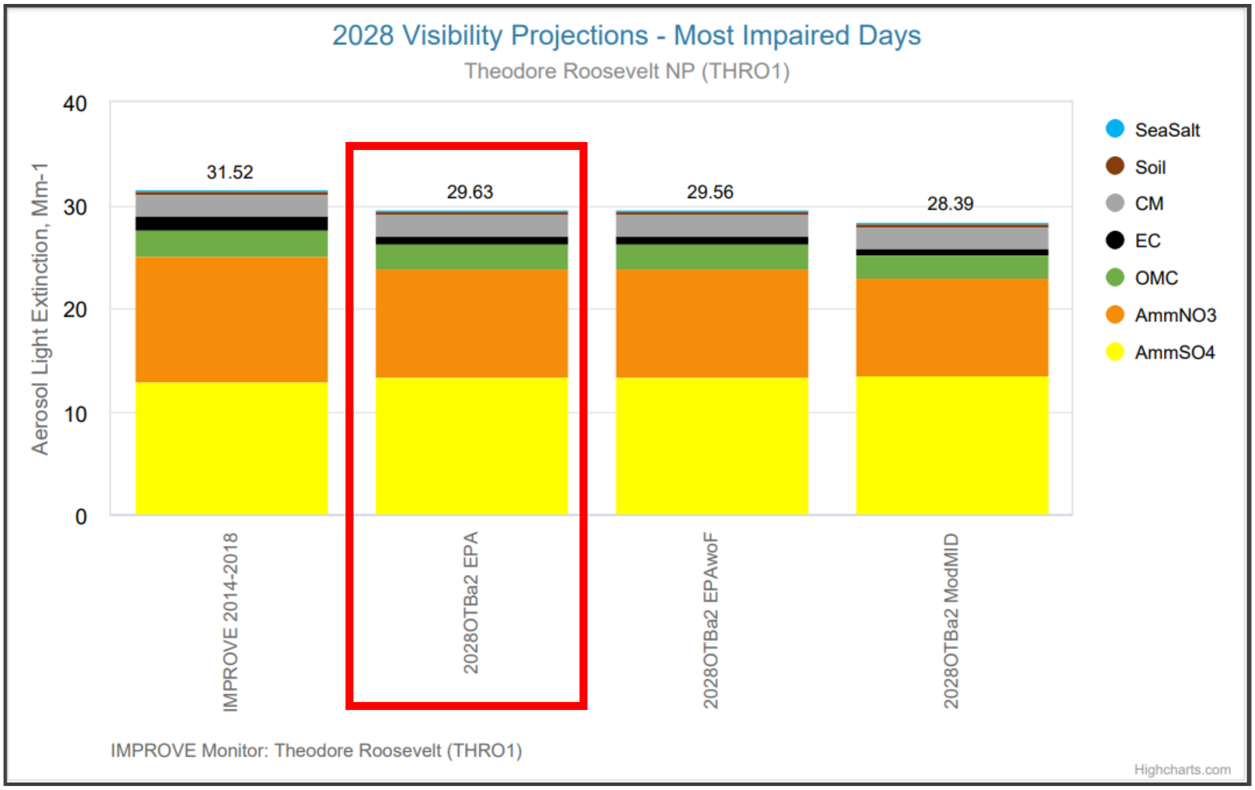

Figure 2: 2014-2018 IMPROVE data and 2028 Visibility Projections Using Different Scenarios

Table 1 shows the species-specific normalization factors for Theodore Roosevelt National Park on the most impaired days.

Table 1: 2028 Model Results, 2028 Visibility Projections, and Normalization Factors

	AmmNO3	AmmSO4	CM	EC	OMC	Sea Salt	Soil	**Total**	Notes
2028OTBa2 EPA	10.56	13.34	2.11	0.80	2.40	0.16	0.26	**29.6**	Model Product 3
Model 2028OTBa2	3.40	8.14	0.59	0.58	2.36	0.05	0.20	**15.3**	Model Product 1
Normalization Factor	**3.11**	**1.64**	**3.58**	**1.38**	**1.02**	**2.88**	**1.27**	-	MP3 ÷ MP1

AmmSO4 example: 13.34/8.14 = 1.64

Step 2

Use normalization factors to calculate regional contributions to the 2028 visibility Projection.

The annual regional source apportionment results can be found in TSSv2 model products 10, 11, and/or 12. Model Product 11 is displayed in Figure 3. The sum of all data in the Figure 3 equals the total modeled light extinction for 2028 (15.3 Mm^{-1}) from Table 1 at the end of Step 1.

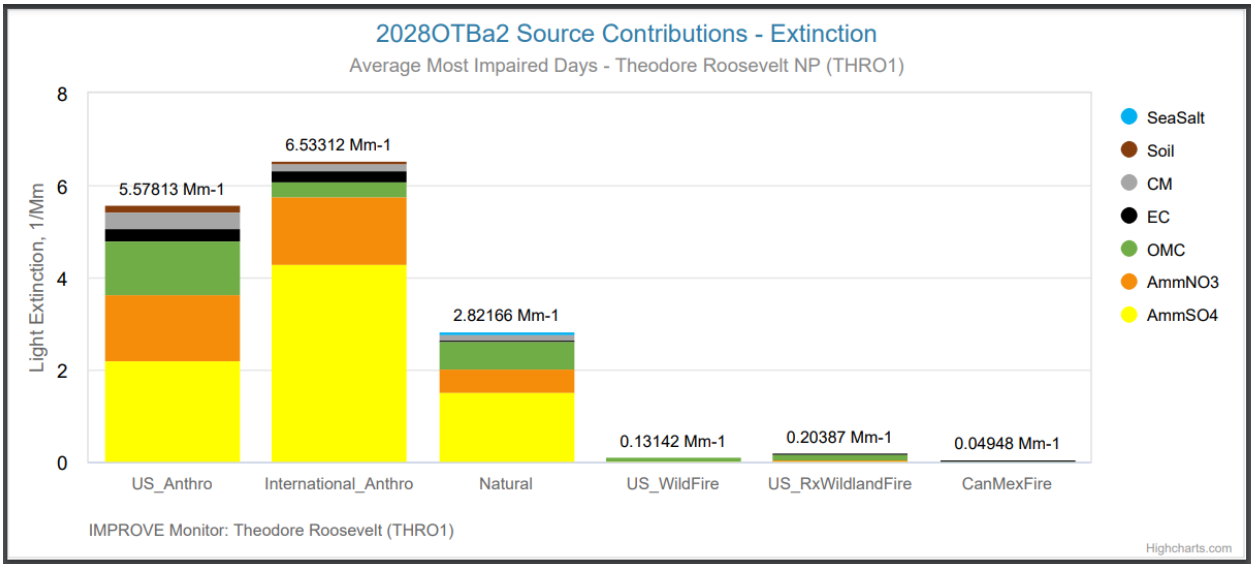

Figure 3:2028 Model Results of Regional Contribution to Light Extinction

15.3 Mm^{-1} can be normalized to the 2028 visibility projection (29.6 Mm^{-1} in Table 1) by applying each species normalization factor, shown in Table 2. Total AmmNO3 example: 3.43 x 3.11 = 10.67. US_Anthro AmmSO4 example: 2.21 x 1.64 = 3.63.

Table 2: 2028 Regional Apportionment Model Results, Species Multiplication Factors, and Normalized Regional Apportionment

Source Category	AmmNO3	AmmSO4	CM	EC	OMC	Sea Salt	Soil	Total
US_Anthro	1.42	2.21	0.35	0.29	1.15	0.00	0.15	**5.58**
Int_Anthro	1.45	4.30	0.14	0.24	0.34	0.00	0.06	**6.53**
Natural	0.52	1.51	0.11	0.02	0.61	0.06	0.00	**2.82**
US_RxWildlandFire	0.02	0.04	0.00	0.02	0.12	0.00	0.00	**0.20**
US_WildFire	0.02	0.02	0.00	0.02	0.07	0.00	0.00	**0.13**
CanMexFire	0.00	0.01	0.00	0.01	0.02	0.00	0.00	**0.05**
Total	**3.43**	**8.10**	**0.60**	**0.59**	**2.32**	**0.06**	**0.21**	**15.32**

Multiplied by

Site	AmmNO3	AmmSO4	CM	EC	OMC	Sea Salt	Soil
THRO1	3.11	1.64	3.58	1.38	1.02	2.88	1.27

Equals the normalized regional apportionment results

Source Category	AmmNO3	AmmSO4	CM	EC	OMC	Sea Salt	Soil	Total
US_Anthro	4.43	3.63	1.26	0.39	1.18	0.00	0.19	**11.07**
Int_Anthro	4.51	7.05	0.49	0.33	0.35	0.00	0.07	**12.81**

Source Category	AmmNO3	AmmSO4	CM	EC	OMC	Sea Salt	Soil	Total
Natural	1.61	2.47	0.40	0.03	0.62	0.16	0.00	**5.29**
US_RxWildlandFire	0.05	0.07	0.01	0.02	0.12	0.00	0.00	**0.28**
US_WildFire	0.07	0.03	0.00	0.02	0.07	0.00	0.00	**0.20**
CanMexFire	0.00	0.02	0.00	0.01	0.02	0.00	0.00	**0.07**
Total	**10.67**	**13.28**	**2.16**	**0.82**	**2.36**	**0.16**	**0.26**	**29.72**

The normalized regional apportionment results are shown in Figure 4. The sum of all data in the figure below equals the 29.7 Mm^{-1} (consistent with the above normalized data).

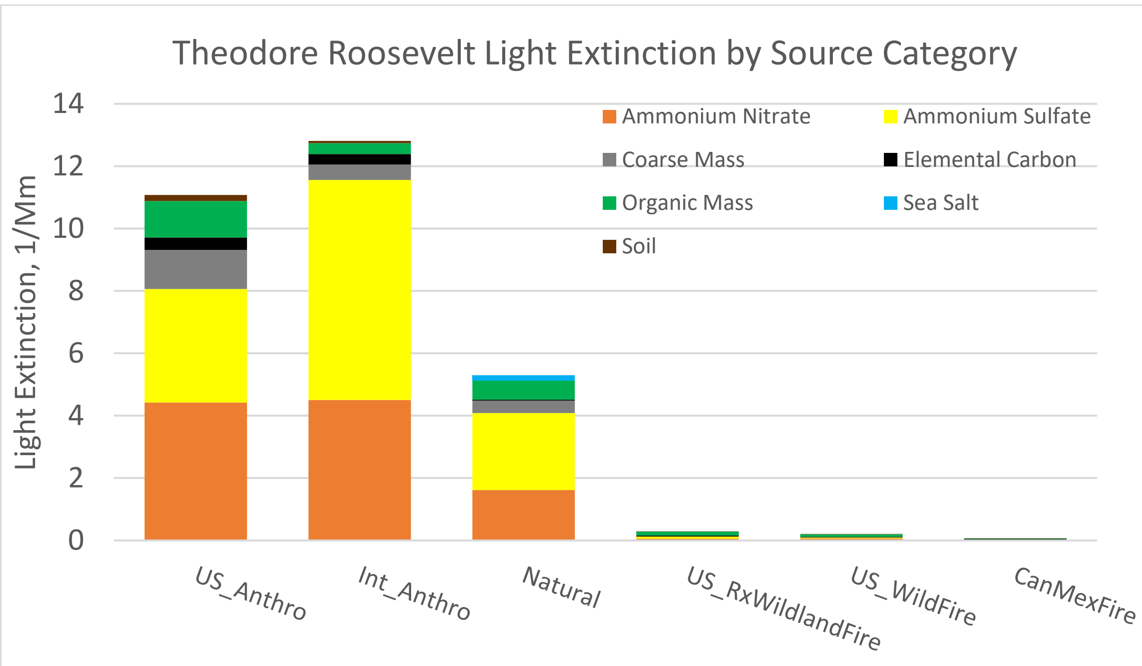

Figure 4: Source Contributions to Light Extinction Normalized to the 2028 Visibility Projection

This source contribution data now corresponds to the 2028 visibility projection. Confirmed by review of TSSv2 model product 4 when looking at the total light extinction projected for 2028. See the red box in Figure 5. The total light extinction projection for Theodore Roosevelt NP is 40.6 Mm^{-1} which consists of 29.72 Mm^{-1} of species extinction and approximately 11 Mm^{-1} of Rayleigh scattering.

Figure 5: Total Light Extinction Projection for 2028, Including Rayleigh

Therefore, 40.6 Mm^{-1} (total light extinction) minus approximately 11 Mm^{-1} (Rayleigh) equals 29.7 Mm^{-1}, consistent with the normalized regional data displayed in Figure 4 and listed in Table 2. With the normalized data, the information can now be discussed in both absolute and relative terms. In other words, for Theodore Roosevelt National Park, it can be said that 40.6 Mm^{-1} is the projected light extinction for 2028. Of the 40.6 Mm^{-1}, 11.1 Mm^{-1} (27%) are from US_Anthro emissions. Of the 11.1 Mm^{-1} from US_Anthro, 3.6 Mm^{-1} (9% overall) are from US_Anthro AmmSO4. In different context, of the 40.6 Mm^{-1}, 13.3 Mm^{-1} (33%) are from AmmSO4. Of the 13.3 Mm^{-1} from AmmSO4, 3.6 Mm^{-1} (9% overall) are from US_Anthro emissions.

Step 3

Use AmmNO3 normalization factors to calculate state/sector contributions to the 2028 light extinction. State/sector contributions to light extinction were only determined for AmmNO3 and AmmSO4. *(Repeat this process for AmmSO4)*

The AmmNO3 annual state/sector source apportionment results can be found in TSSv2 model product 9. Model Product 9 is show in Figure 6 for AmmNO3. The sum of all data in Figure 6 equals the 1.37 Mm^{-1}.

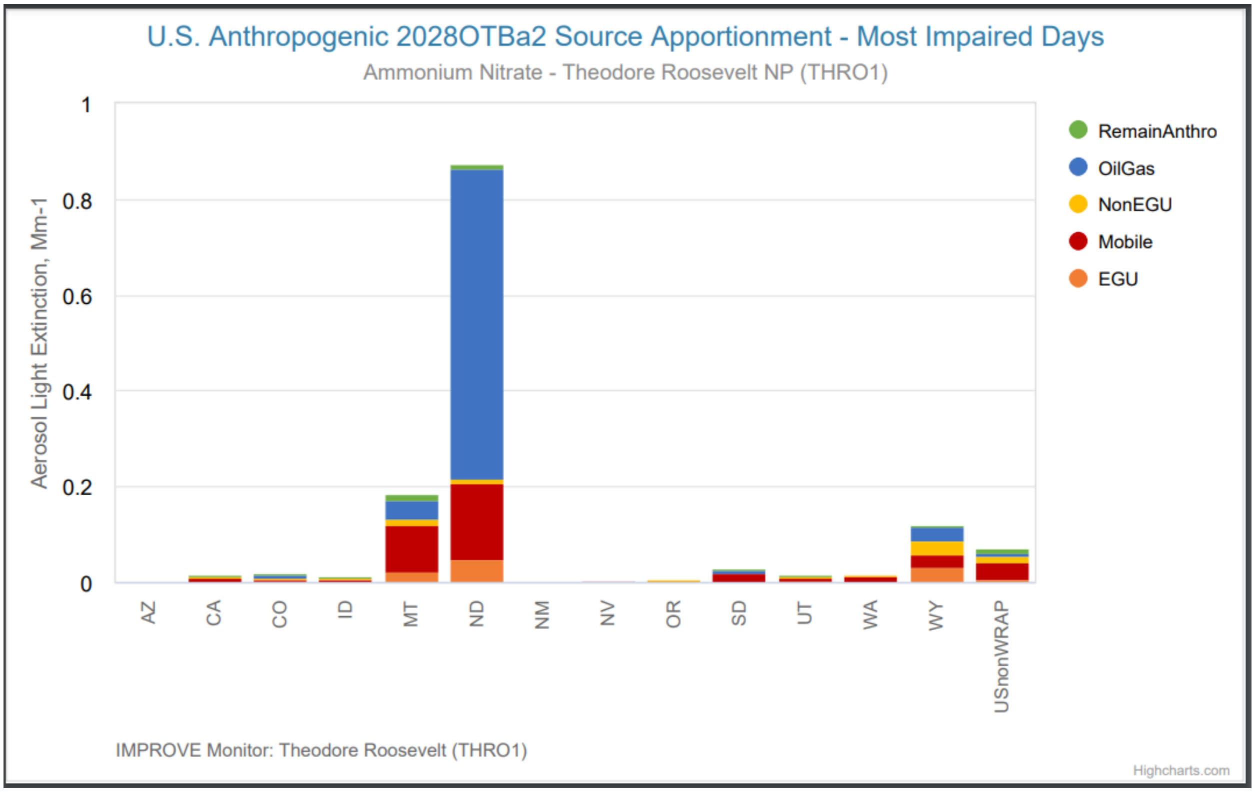

Figure 6: State and Sector Breakdown of AmmNO3 Light Extinction, US Anthropogenetic Sources Only

1.37 Mm^{-1} can be normalized to 4.3 Mm^{-1} by applying the AmmNO3 normalization factor to each of the state/sector values from Figure 6. This normalization is displayed in Table 3:

Table 3: 2028 State/Sector Apportionment Model Results, AmmNO3 Multiplication Factor, and Normalized State/Sector Apportionment

Row Labels	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Grand Total
ND	0.05	0.65	0.16	0.01	0.01	0.87
AZ	0.00	0.00	0.00	0.00	0.00	0.00
CA	0.00	0.00	0.01	0.00	0.00	0.02
CO	0.00	0.01	0.00	0.00	0.00	0.02
ID	0.00	0.00	0.01	0.00	0.00	0.01
MT	0.02	0.04	0.09	0.01	0.01	0.18
NM	0.00	0.00	0.00	0.00	0.00	0.00

Row Labels	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Grand Total
NV	0.00	0.00	0.00	0.00	0.00	0.00
OR	0.00	0.00	0.00	0.00	0.00	0.01
SD	0.00	0.01	0.02	0.00	0.00	0.03
UT	0.00	0.00	0.01	0.00	0.00	0.01
WA	0.00	0.00	0.01	0.00	0.00	0.02
WY	0.03	0.03	0.03	0.03	0.00	0.12
RemUS	0.01	0.01	0.04	0.01	0.01	0.07
Grand Total	**0.12**	**0.74**	**0.38**	**0.08**	**0.05**	**1.37**

Each value multiplied by

Site	Ammonium Nitrate
THRO1	3.11

Equals the normalized state/sector apportionment results

Row Labels	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Grand Total
ND	0.15	2.02	0.49	0.03	0.03	2.71
AZ	0.00	0.00	0.00	0.00	0.00	0.00
CA	0.00	0.00	0.02	0.01	0.01	0.05
CO	0.01	0.02	0.02	0.01	0.01	0.06
ID	0.00	0.00	0.02	0.01	0.01	0.04
MT	0.07	0.12	0.29	0.04	0.05	0.57
NM	0.00	0.00	0.00	0.00	0.00	0.00
NV	0.00	0.00	0.01	0.00	0.00	0.01
OR	0.00	0.00	0.01	0.01	0.00	0.02
SD	0.00	0.02	0.06	0.01	0.01	0.09
UT	0.01	0.01	0.02	0.01	0.00	0.05
WA	0.00	0.00	0.03	0.01	0.01	0.05
WY	0.10	0.09	0.08	0.09	0.01	0.37
RemUS	0.02	0.03	0.12	0.03	0.02	0.22
Grand Total	**0.37**	**2.31**	**1.18**	**0.26**	**0.15**	**4.26**

The normalized state/sector AmmNO3 apportionment result is displayed in Figure 7. The sum of all data in the Figure 7 equals the 4.3 Mm^{-1}. 4.3 Mm^{-1} is slightly lower than the 4.4 Mm^{-1} listed in Table 2. The difference results from the exclusion of US Anthropogenic boundary conditions impacts. These boundary condition impacts accounted for 0.054 Mm^{-1} of the 2028 model results, an insignificant contribution.

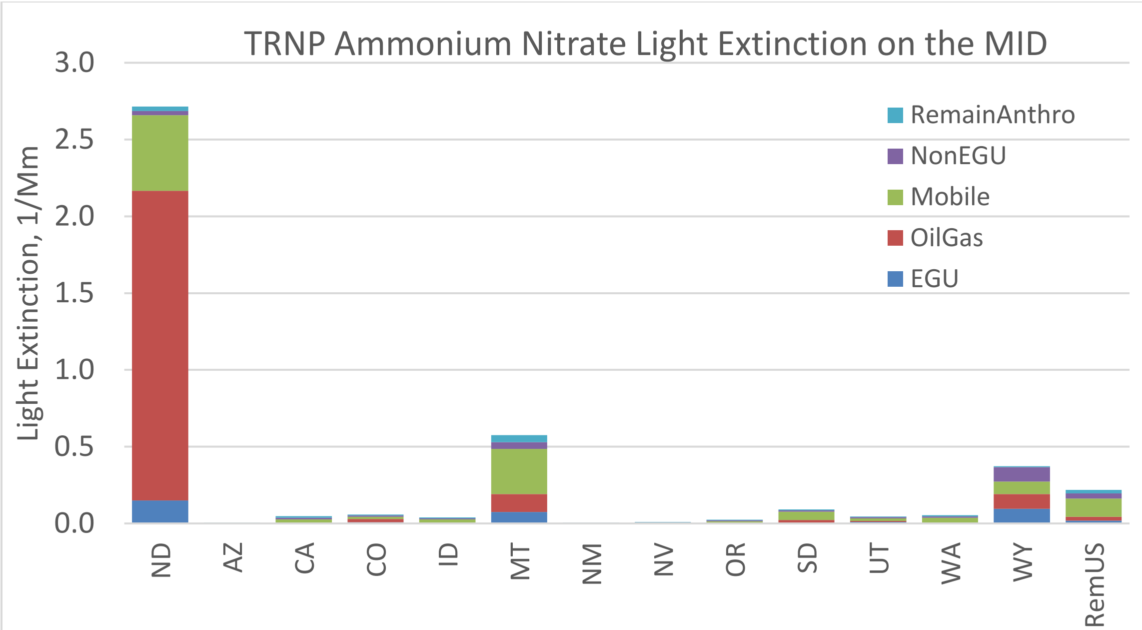

Figure 7: State and Sector Contributions to Light Extinction Normalized to the 2028 Visibility Projection

This state/sector AmmNO3 data now corresponds to the 2028 visibility projection for the US_Anthro component of light extinction. This is confirmed by review of normalized data displayed in Table 2.

The Normalized state/sector data can now be compared to TSSv2 model product 4, for both the total light extinction (Figure 5) and/or the AmmNO3 light extinction projection for 2028. See the red box in Figure 8. 10.6 Mm^{-1} is the total AmmNO3 light extinction.

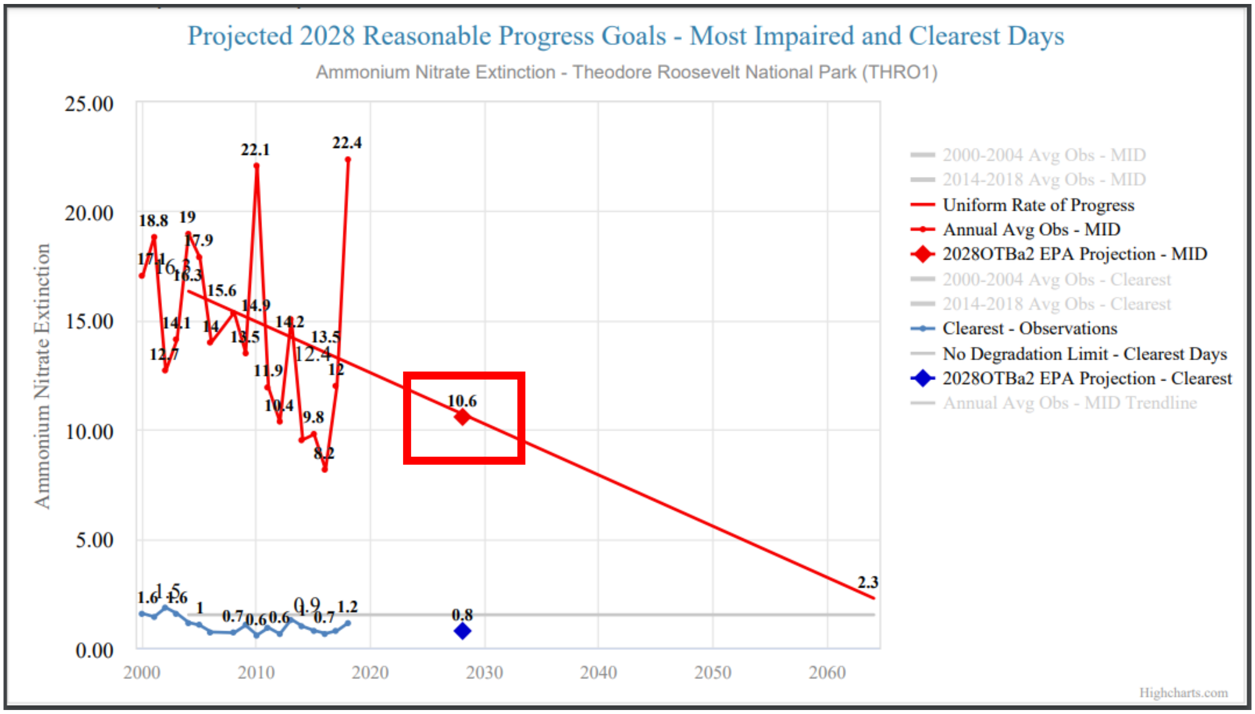

Figure 8: AmmNO3 Light Extinction Projection for 2028 (No Rayleigh)

The normalized state/sector results can now be discussed in absolute or relative terms. In other words, for Theodore Roosevelt National Park, 10.6 Mm^{-1} is the projected AmmNO3 light extinction for 2028, accounting for 26% of the total 2028 projected light extinction. Of the 10.6 Mm^{-1}, 4.3 Mm^{-1} (11% overall) are AmmNO3 from US_Anthro emissions (not including the US boundary conditions extinction, which is very small). Of the 4.3 Mm^{-1} of AmmNO3 light extinction from US_Anthro, 2 Mm^{-1} (5% overall) are from North Dakota Oil and Gas.

Conclusion

Table 4 provides all regional and the North Dakota sector percent contributions to light extinction. North Dakota's species light extinction contributions of coarse mass, elemental carbon, organic mass, sea salt and soil are included in the "Remaining US" row. The modeling was not performed for these species since they are of lesser concern due to small contributions to light extinction on the most impaired days.

Table 4: State Sector and Regional Percent Breakdown of Contributions to Light Extinction

Sector	AmmNO3	AmmSO4	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Total
ND EGU	0.4%	1.7%	--	--	--	--	--	2.1%
ND OilGas	5.0%	3.8%	--	--	--	--	--	8.8%
ND Mobile	1.2%	0.1%	--	--	--	--	--	1.3%
ND NonEGU	0.1%	0.1%	--	--	--	--	--	0.1%
ND RemainAnthro	0.1%	0.1%	--	--	--	--	--	0.1%
BCUS	0.4%	0.6%	--	--	--	--	--	1.0%
Remaining US	3.8%	2.6%	3.1%	1.0%	2.9%	0.0%	0.5%	13.8%
Int_Anthro	11.1%	17.3%	1.2%	0.8%	0.9%	0.0%	0.2%	31.5%
CanMexFire	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%
Natural	4.0%	6.1%	1.0%	0.1%	1.5%	0.4%	0.0%	13.0%
US_RxWildlandFire	0.1%	0.2%	0.0%	0.1%	0.3%	0.0%	0.0%	0.7%
US_WildFire	0.2%	0.1%	0.0%	0.1%	0.2%	0.0%	0.0%	0.5%
Grand Total (non-Rayleigh)	26.2%	32.6%	5.3%	2.0%	5.8%	0.4%	0.6%	73.0%
Rayleigh	--	--	--	--	--	--	--	27.0%
					Source Plus Rayleigh			100%

The information from Table 4 is shown in Figure 9 as the vertical column. The gray dashed line is the unadjusted uniform rate of progress (glidepath). The black line is the adjusted glidepath. The orange line is the 5-year IMPROVE rolling average light extinction data. The blue line is the baseline light extinction from 2000–2004. The black diamond is the 2028 visibility projection. The column is the breakdown of the categories contributing to the 2028 visibility projection organized consistent with the legend from the top down.

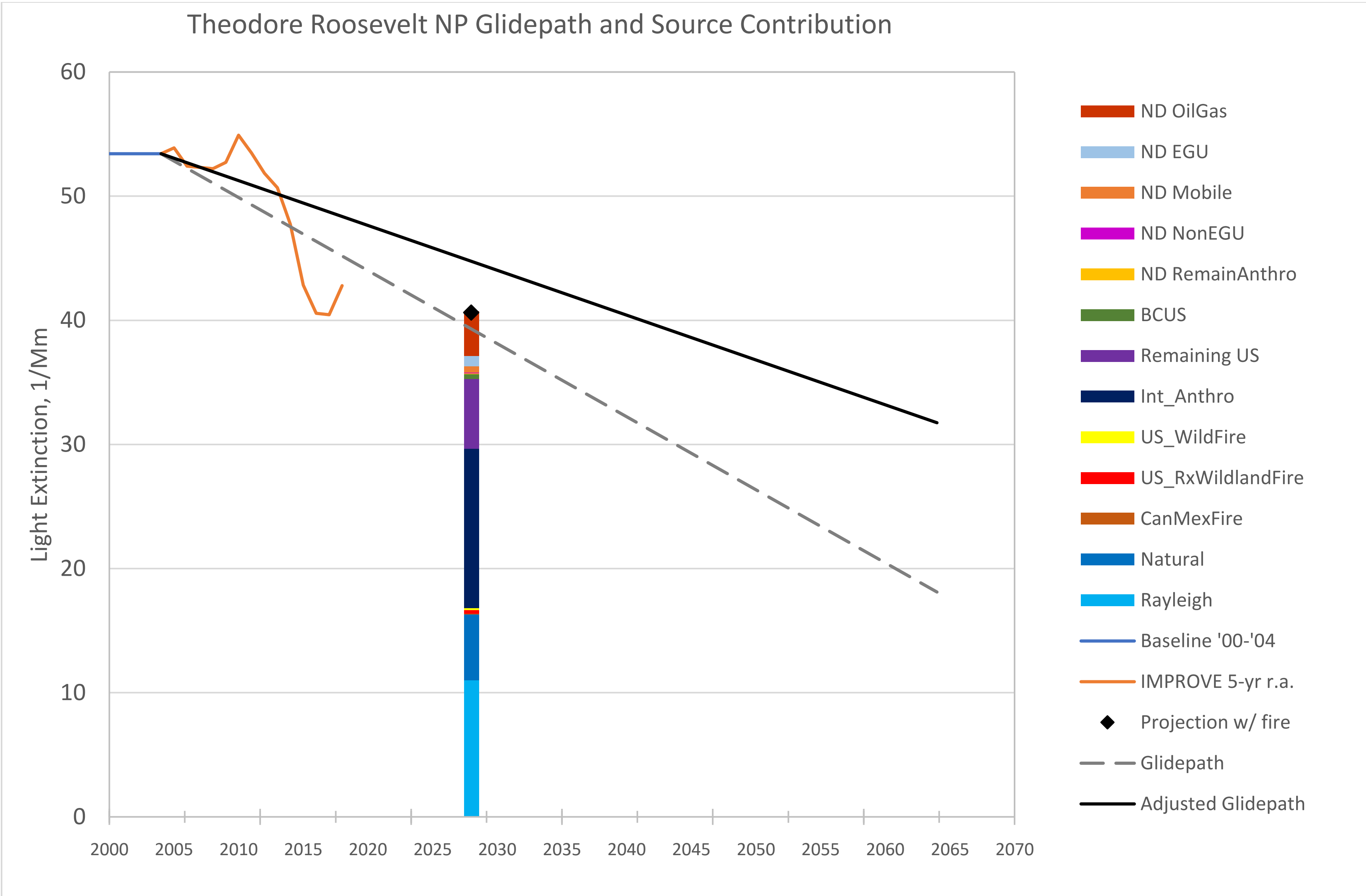

Figure 9: Theodore Roosevelt NP Normalized Apportionment Data Plotted with the 2028 Visibility Projection and Uniform Rate of Progress (with and without adjustment for International and Prescribed Wildland Fires)

C.2 – Regional, State/Sector Source Apportionment Results

1 International and Natural Impacts on North Dakota Visibility

This section contains the data from the high-level source apportionment results from the modeling performed by WRAP.[1] WRAP completed modeling to separate out the impacts of emissions from US anthropogenic sources (US_Anthro), international sources (Int_Anthro), natural sources (Natural), prescribed wildland burning (US_RxWildlandFire), US wildfires (US_WildFire), and Canadian Mexican Wildfire (CanMexFire). This modeling indicates that contributions from international sources significantly impair the visibility in North Dakota Class I areas. US anthropogenic sources also contribute significantly to the visibility impairment and natural sources also have a sizable influence on visibility. The categories of US wildfire, Canadian Mexican wildfire, and prescribed wildland burning typically had little impact on visibility impairment for the most impaired and/or clearest days. When looking at all monitor days or the haziest days, emissions from extreme episodic events (e.g. wildfires) tend to dominate the visibility impairment when impairment is at its highest levels, discussed in Section 3.3 of the main SIP document.

The high-level source apportionment results are discussed in Section 1.1 for the most impaired days and Section 1.2 for the clearest days. The data is further separated by source category and aerosol species contributing to light extinction in the respective subsections.

The aerosol species which contribute to light extinction are ammonium nitrate, ammonium sulfate, organic mass, elemental carbon, coarse mass, soil, and sea salt. The aerosol species of most significance to North Dakota Class I areas are ammonium nitrate and ammonium sulfate.

The modeling was completed for the Representative Baseline (RepBase) and the 2028 inventory projection (2028OTB). For details on RepBase and 2028OTB emission inventories, see Sections 4.1.4 and 4.1.6 of the main SIP document, respectively. Since there are limited expected changes in emissions between the RepBase and 2028 OTB emissions, the model results displayed in in Section 1.1 and Section 1.2 are for the 2028OTB emissions scenario. For both the most impaired days and the clearest days, the US_Anthro light extinction was modeled to be lower in the 2028OTB scenario than the RepBase scenario. These results, however, were not significantly different. The RepBase light extinction projections are available on the WRAP TSSv2.[2]

North Dakota shares a border with the Canadian Provinces of Manitoba and Saskatchewan. These provinces, along with the provinces of Alberta and British Columbia, are upwind of the prevailing wind direction causing North Dakota to be impacted by the airshed. Emissions from Canadian coal fired EGUs along with oil and gas development are significant and contribute to visibility impairment in North Dakota Class I areas. Emissions from nearby Canadian EGUs are discussed in Section 4.7.1 and emissions

[1] Available at: https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/SourceApportionmentSpecifications_WRAP_RepBase2_and_2028OTBa2_High-LevelPMandO3_and_Low-Level_PM_andOptionalO3_Sept29_2020.pdf (Last visited February 22, 2021)

[2] Available at: https://views.cira.colostate.edu/tssv2/Express/ModelingTools.aspx. See model products 10, 11, and 12 for “Most Impaired Days” and “Clearest Days” for model scenario “RepBase”. (Last visited March 9, 2021)

from oil and gas operations are discussed in Section 4.7.2 of the main SIP document. Canadian anthropogenic impairment accounts for 66% of the total international impairment projected for LWA and 50% at TRNP. The remaining international impairment is from international anthropogenic contributions from outside the CAMx 36-km domain boundary as defined by the GEOS-Chem global model (international boundary condition impacts). 32% of LWAs international anthropogenic impairment and 50% of TRNPs is from contributions outside the 36-km modeling domain.[3]

1.1 Most Impaired Days

1.1.1 Source Category Light Extinction on the Most Impaired Days

Figure 1 and Figure 2 display the 2028OTB source apportionment results for the average of the most impaired days for aerosol species within the five major source categories. The five major source categories are: US_Anthro, Int_Anthro, Natural, US_RxWildlandFire, US_WildFire, and CanMexFire. Table 1 and Table 2 display the numerical data corresponding to Figure 1 and Figure 2 for LWA and TRNP, respectively.

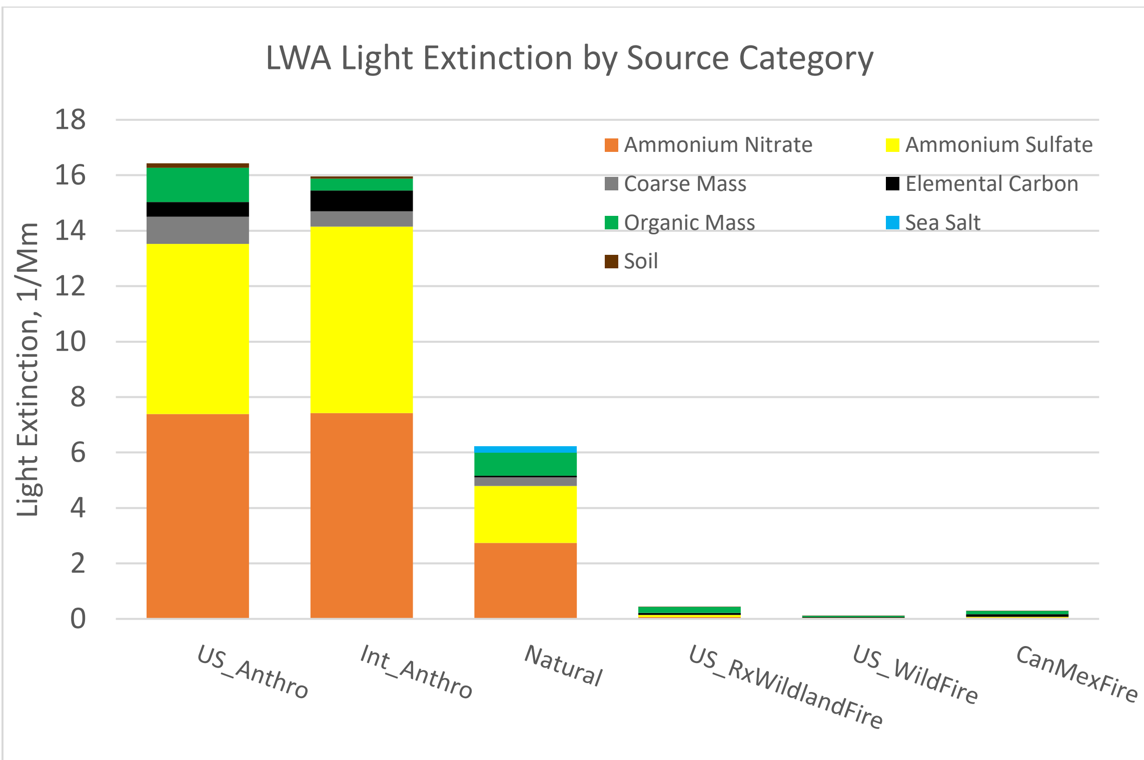

Figure 1: LWA 2028OTB Light Extinction on the Most Impaired Days by Source Category

Figure 1 shows approximately equal light extinction from US_Anthro and Int_Anthro for the species of ammonium nitrate and ammonium sulfate on the most impaired days at LWA. The total light extinction from US_Anthro and Int_Anthro is also very similar at LWA, with organic mass making up the largest

[3] A complete breakdown of the modeled regional source group contributions can be found at: https://views.cira.colostate.edu/tssv2/Express/ModelingTools.aspx. See model product 10 for "Most Impaired Days".

difference in impairment on the most impaired days. Impacts from Natural are the next largest category but are considerably less than US_Anthro and Int_Anthro. US_RxWildlandFire, US_WildFire, and CanMexFire are insignificant for the MID at LWA.

Table 1: LWA 2028OTB Light Extinction on the Most Impaired Days by Source Category

Source Category	**Ammonium Nitrate**	**Ammonium Sulfate**	**Coarse Mass**	**Elemental Carbon**	**Organic Mass**	**Sea Salt**	**Soil**	**Total**	**Percent of Total**
US_Anthro	7.39	6.14	0.98	0.53	1.23	0.00	0.16	**16.43**	42%
Int_Anthro	7.42	6.72	0.55	0.75	0.43	0.00	0.08	**15.96**	40%
Natural	2.75	2.05	0.32	0.06	0.83	0.23	0.00	**6.23**	16%
US_RxWildlandFire	0.06	0.08	0.01	0.07	0.22	0.00	0.00	**0.44**	1%
US_WildFire	0.01	0.03	0.00	0.02	0.05	0.00	0.00	**0.11**	0%
CanMexFire	0.04	0.04	0.01	0.09	0.11	0.00	0.00	**0.28**	1%
Total	**17.67**	**15.05**	**1.86**	**1.52**	**2.88**	**0.23**	**0.24**	**39.45**	**100%**

A review and breakdown of Table 1 shows the following significant contributors to light extinction. The US_Anthro source category accounts for 42% of the total light extinction on the most impaired days at LWA. Much of the total light extinction from US_Anthro is comprised of ammonium nitrate and ammonium sulfate. US_Anthro ammonium nitrate and ammonium sulfate account for 19% and 16% of the total light extinction, respectively. Int_Anthro accounts for 40% of the total light extinction on the most impaired days at LWA. Like US_Anthro, much of the Int_Anthro total light extinction is from ammonium nitrate and ammonium sulfate. Int_Anthro ammonium nitrate and ammonium sulfate account for 19% and 17% of the total light extinction, respectively. The only significant remaining category of total light extinction is Natural at 16%. Much of the total light extinction from Natural is also comprised of ammonium nitrates at 7% and ammonium sulfates at 5%.

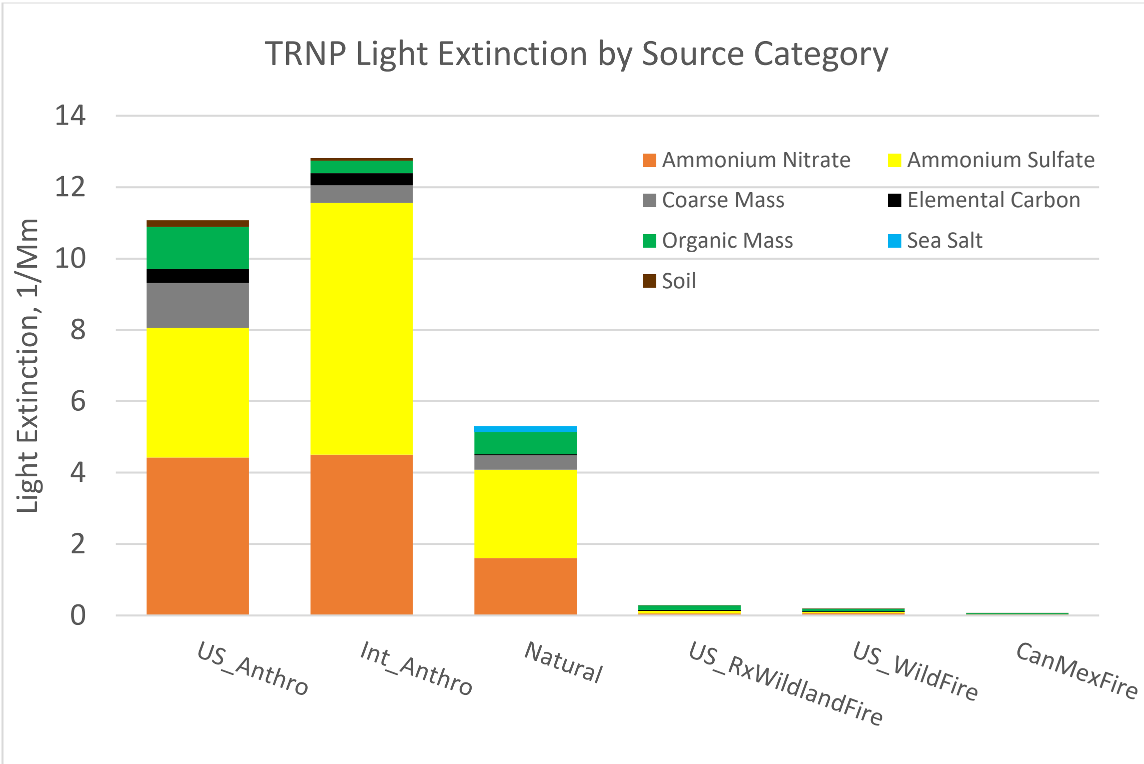

Figure 2: TRNP 2028OTB Light Extinction on the Most Impaired Days by Source Category

Figure 2 shows Int_Anthro ammonium sulfate light extinction is approximately two times the US_Anthro ammonium sulfate extinction on the most impaired days at TRNP. US_Anthro ammonium nitrate light extinction is approximately equal to Int_Anthro ammonium nitrate light extinction on the most impaired days. Combined, US_Anthro ammonium nitrate and ammonium sulfate light extinction is considerably less than the contribution from Int_Anthro. Higher contributions from organic mass and coarse mass from US_Anthro lessen the overall difference in impairment between US_Anthro and Int_Anthro. Impacts from Natural are the next largest category but are considerably less than US_Anthro and Int_Anthro. US_RxWildlandFire, US_WildFire, and CanMexFire are insignificant for the MID at TRNP.

Table 2: TRNP 2028OTB Light Extinction on the Most Impaired Days by Source Category

Source Category	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Total	Percent of Total
US_Anthro	4.43	3.63	1.26	0.39	1.18	0.00	0.19	**11.07**	37%
Int_Anthro	4.51	7.05	0.49	0.33	0.35	0.00	0.07	**12.81**	43%
Natural	1.61	2.47	0.40	0.03	0.62	0.16	0.00	**5.29**	18%
US_RxWildlandFire	0.05	0.07	0.01	0.02	0.12	0.00	0.00	**0.28**	1%
US_WildFire	0.07	0.03	0.00	0.02	0.07	0.00	0.00	**0.20**	1%
CanMexFire	0.00	0.02	0.00	0.01	0.02	0.00	0.00	**0.07**	0%
Total	**10.67**	**13.28**	**2.16**	**0.82**	**2.36**	**0.16**	**0.26**	**29.72**	**100%**

A review and breakdown of Table 2 shows the following significant contributors to light extinction. The US_Anthro source category accounts for 37% of the total light extinction on the most impaired days at TRNP. Much of the total light extinction from US_Anthro is comprised of ammonium nitrate and ammonium sulfate. US_Anthro ammonium nitrate and ammonium sulfate account for 15% and 12% of the total light extinction, respectively. Int_Anthro accounts for 43% of the total light extinction on the most impaired days at TRNP. Like US_Anthro, much of the Int_Anthro total light extinction is from ammonium nitrate and ammonium sulfate. Int_Anthro ammonium nitrate and ammonium sulfate account for 15% and 24% of the total light extinction, respectively. The only significant remaining category of total light extinction is Natural at 18%. Much of the total light extinction from Natural is also comprised of ammonium nitrates at 5% and ammonium sulfates at 8%.

1.1.2 Species Light Extinction on the Most Impaired Days

Figure 3 and Figure 4 display the 2028OTB source apportionment results for the average of the most impaired days for aerosol species within the five major source categories. The five major source categories are: US_Anthro, Int_Anthro, Natural, US_RxWildlandFire, US_WildFire, and CanMexFire. Table 3 and Table 4 display the numerical data corresponding to Figure 3 and Figure 4 for LWA and TRNP, respectively. The data in these figures and tables is the same as Section 1.1.1. The difference is how the data is displayed. The aerosol species are plotted along the x-axis and the light extinction contribution from the source category is separated by species.

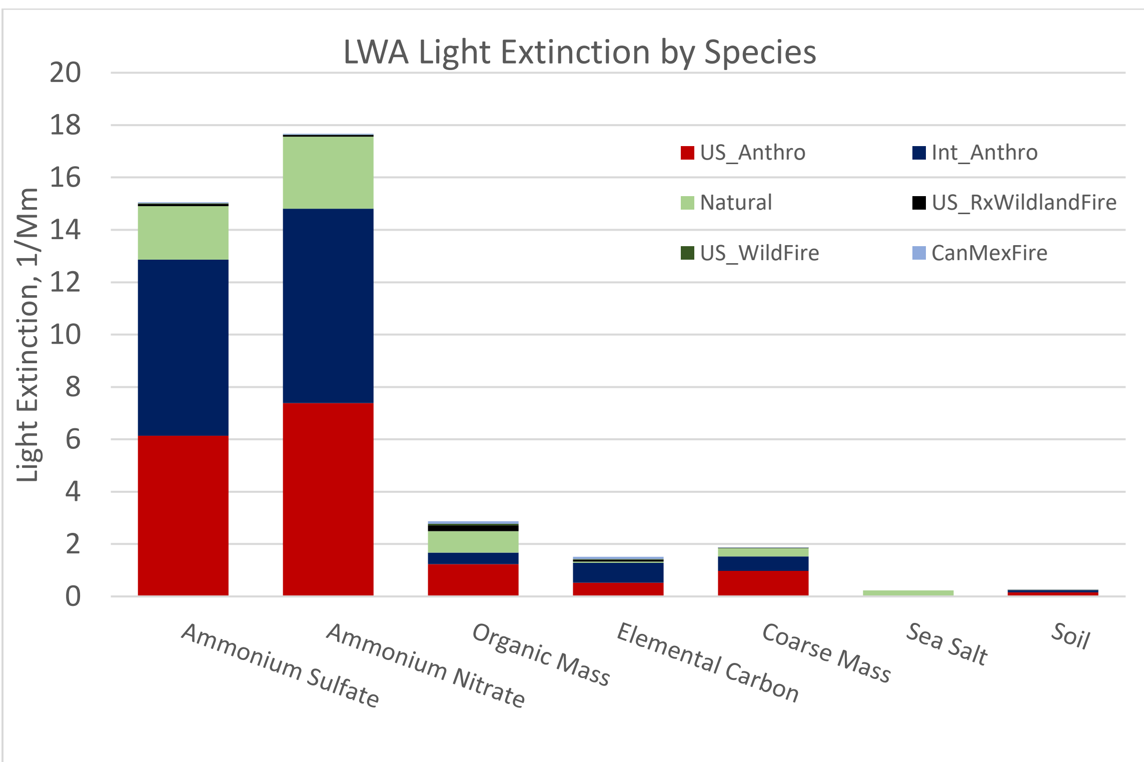

Figure 3: LWA 2028OTB Light Extinction on the Most Impaired Days by Species

Figure 3 emphasizes a few important items for LWA on the most impaired days. The most significant aerosol species contributing to light extinction are ammonium nitrate and ammonium sulfate. Light extinction from US_Anthro and Int_Anthro are nearly equal. The remaining species of light extinction: organic mass, elemental carbon, coarse mass, sea salt, and soil, are minimal.

Table 3: LWA 2028OTB Light Extinction on the Most Impaired Days by Species

Source Category	US_ Anthro	Int_ Anthro	Natural	US_RxWild landFire	US_Wild Fire	CanMex Fire	Total	Percent of Total
Ammonium Sulfate	6.14	6.72	2.05	0.08	0.03	0.04	**15.05**	38%
Ammonium Nitrate	7.39	7.42	2.75	0.06	0.01	0.04	**17.67**	45%
Organic Mass	1.23	0.43	0.83	0.22	0.05	0.11	**2.88**	7%
Elemental Carbon	0.53	0.75	0.06	0.07	0.02	0.09	**1.52**	4%
Coarse Mass	0.98	0.55	0.32	0.01	0.00	0.01	**1.86**	5%
Sea Salt	0.00	0.00	0.23	0.00	0.00	0.00	**0.23**	1%
Soil	0.16	0.08	0.00	0.00	0.00	0.00	**0.24**	1%
Total	**16.43**	**15.96**	**6.23**	**0.44**	**0.11**	**0.28**	**39.45**	**100%**

The light extinction contribution by species from Table 3 shows ammonium sulfate and ammonium nitrate are the most significant. Ammonium sulfate accounts for 38% of the total light extinction on the most impaired days at LWA. 17% of the total light extinction is caused by ammonium sulfate from Int_Anthro, 16% is from US_Anthro, and 5% is from Natural. Ammonium nitrate accounts for 45% of the total light extinction. 19% of the total light extinction is caused by ammonium nitrate from Int_Anthro, 19% is from US_Anthro, and 7% is from Natural. The remaining noteworthy species causing light extinction is organic mass, which contributes only 7% to the total light extinction.

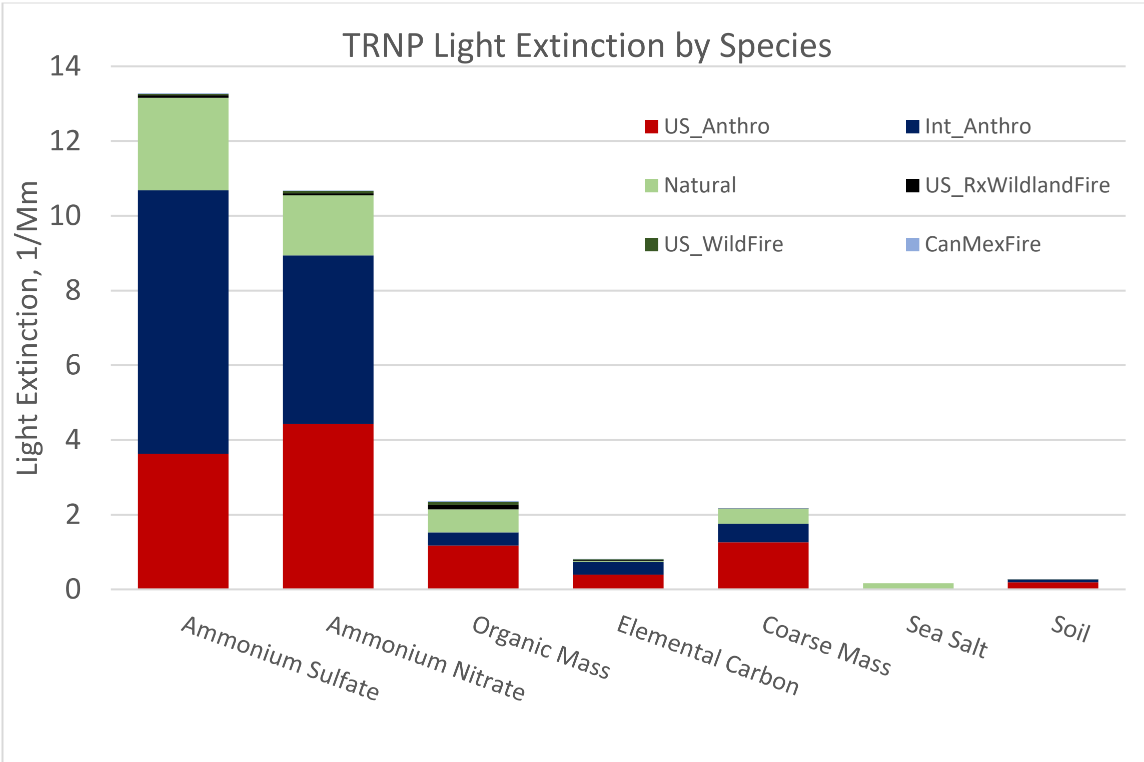

Figure 4: TRNP 2028OTB Light Extinction on the Most Impaired Days by Species

Figure 4 emphasizes a few important items for TRNP on the most impaired days. Light extinction from ammonium sulfate is the most significant aerosol species and Int_Anthro contributes the most to the overall light extinction. Int_Anthro ammonium sulfate light extinction is one and a half times larger than the next largest contributor to light extinction, which is ammonium nitrate from US_Anthro and Int_Anthro. US_Anthro and Int_Anthro light extinction from ammonium nitrate are nearly equal. The most significant remaining contributor to light extinction is US_Anthro ammonium sulfate. The remaining species of light extinction: organic mass, elemental carbon, coarse mass, sea salt, and soil, are much smaller in comparison to ammonium sulfate and ammonium nitrate.

Table 4: TRNP 2028OTB Light Extinction on the Most Impaired Days by Species

Source Category	US_ Anthro	Int_ Anthro	Natural	US_RxWild landFire	US_Wild Fire	CanMex Fire	Total	Percent of Total
Ammonium Sulfate	3.63	7.05	2.47	0.07	0.03	0.02	**13.28**	45%
Ammonium Nitrate	4.43	4.51	1.61	0.05	0.07	0.00	**10.67**	36%
Organic Mass	1.18	0.35	0.62	0.12	0.07	0.02	**2.36**	8%
Elemental Carbon	0.39	0.33	0.03	0.02	0.02	0.01	**0.82**	3%

Source Category	US_ Anthro	Int_ Anthro	Natural	US_RxWild landFire	US_Wild Fire	CanMex Fire	Total	Percent of Total
Coarse Mass	1.26	0.49	0.40	0.01	0.00	0.00	**2.16**	7%
Sea Salt	0.00	0.00	0.16	0.00	0.00	0.00	**0.16**	1%
Soil	0.19	0.07	0.00	0.00	0.00	0.00	**0.26**	1%
Total	**11.07**	**12.81**	**5.29**	**0.28**	**0.20**	**0.07**	**29.72**	**100%**

The light extinction contribution by species from Table 4 shows ammonium sulfate and ammonium nitrate are the most significant. Ammonium sulfate accounts for 45% of the total light extinction on the most impaired days at TRNP. 24% of the total light extinction is caused by ammonium sulfate from Int_Anthro, 12% is from US_Anthro, and 8% is from Natural. Ammonium nitrate accounts for 36% of the total light extinction. 15% of the total light extinction is caused by ammonium nitrate from Int_Anthro, 15% is from US_Anthro, and 5% is from Natural. The remaining noteworthy species causing light extinction is organic mass and coarse mass, which contribute 8% and 7% to the total light extinction, respectively.

1.1.3 Most Impaired Days Conclusion

In summary, the contributors to light extinction on the most impaired days for both LWA and TRNP come from four main areas: Int_Anthro ammonium sulfate, Int_Anthro ammonium nitrate, US_Anthro ammonium sulfate, and US_Anthro ammonium nitrate. Light extinction from Natural are smaller in comparison than US_Anthro and Int_Anthro at both LWA and TRNP, but still account for 16% and 18% of total light extinction, respectively.

The high-level source apportionment data presented in Sections 1.1.1 and 1.1.2 supports the Department's decision to use an adjusted glidepath for both LWA and TRNP to account for international anthropogenic emissions and wildland prescribed fires[4].

1.2 Clearest Days

1.2.1 Source Category Light Extinction on the Clearest Days

Figure 5 and Figure 6 display the 2028OTB source apportionment results for the average of the clearest days for aerosol species within the five major source categories. The five major source categories are: US_Anthro, Int_Anthro, Natural, US_RxWildlandFire, US_WildFire, and CanMexFire. Table 5 and Table 6 display the numerical data corresponding to Figure 5 and Figure 6 for LWA and TRNP, respectively.

[4] 40 CFR 51.308(f)(1)(vi)(B)

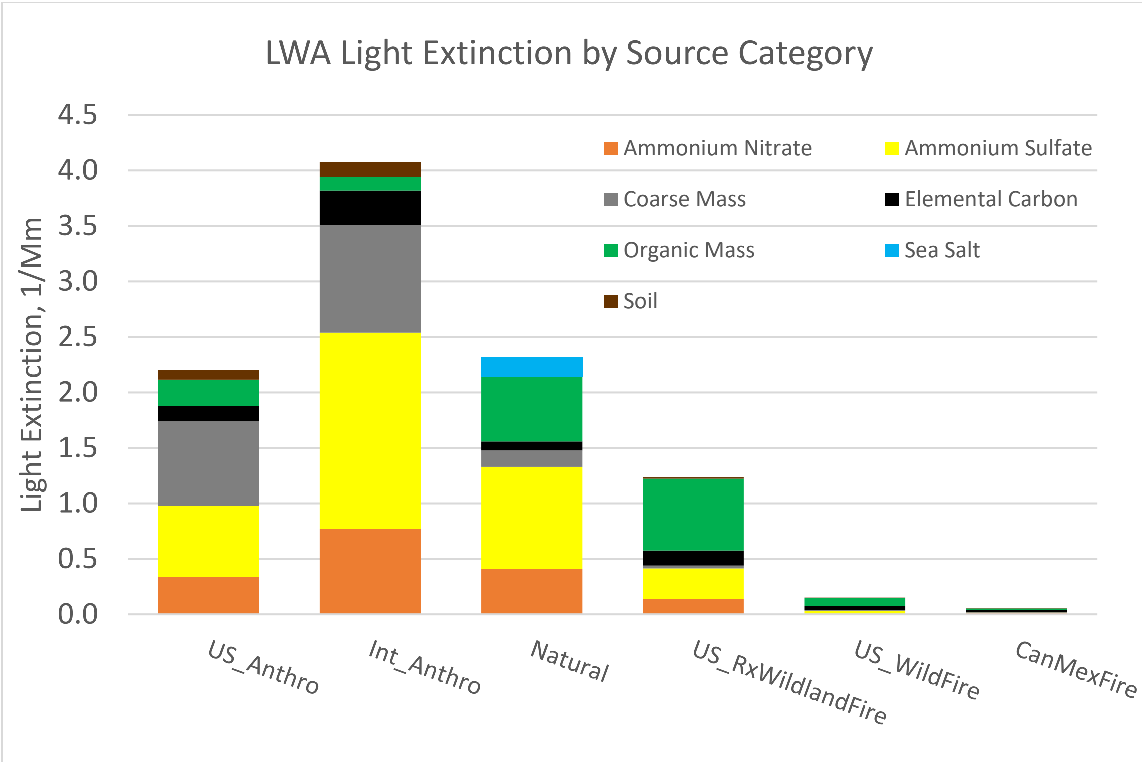

Figure 5: LWA 2028OTB Light Extinction on the Clearest Days by Source Category

Figure 5 shows significantly greater light extinction from Int_Anthro for the species of ammonium nitrate and ammonium sulfate on the Clearest days at LWA. Natural contributes more to total light extinction than US_Anthro sources and even more combined ammonium nitrate and ammonium sulfate light extinction. Prescribed wildland fires also contribute to light extinction on the clearest days where much of this impairment is from organic mass.

Table 5: LWA 2028OTB Light Extinction on the Clearest Days by Source Category

Source Category	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Total	Percent of Total
US_Anthro	0.34	0.64	0.76	0.14	0.24	0.00	0.08	**2.20**	22%
Int_Anthro	0.77	1.77	0.97	0.31	0.12	0.00	0.13	**4.08**	41%
Natural	0.41	0.92	0.15	0.08	0.58	0.18	0.00	**2.32**	23%
US_RxWildlandFire	0.14	0.28	0.03	0.14	0.65	0.00	0.01	**1.23**	12%
US_WildFire	0.00	0.03	0.01	0.04	0.07	0.00	0.00	**0.15**	1%
CanMexFire	0.01	0.01	0.00	0.02	0.01	0.00	0.00	**0.05**	1%
Total	**1.66**	**3.64**	**1.92**	**0.72**	**1.68**	**0.18**	**0.23**	**10.03**	**100%**

A review and breakdown of Table 5 shows the following significant contributors to light extinction. The US_Anthro source category accounts for 22% of the total light extinction on the clearest days at LWA. Much of the total light extinction from US_Anthro is comprised of coarse mass and ammonium sulfate.

US_Anthro coarse mass and ammonium sulfate account for 8% and 6% of the total light extinction, respectively. Int_Anthro accounts for 41% of the total light extinction on the clearest days at LWA. Much of the Int_Anthro total light extinction is from coarse mass, ammonium sulfate, and ammonium nitrate. Int_Anthro coarse mass, ammonium sulfate, and ammonium nitrate account for 10%, 18%, and 8% of the total light extinction, respectively. Unlike the most impaired days, Natural contributes to more impairment than US_Anthro on the clearest days, at 23%. Much of the total light extinction from Natural is comprised of ammonium nitrates at 4%, ammonium sulfates at 9%, and organic mass at 6%. Additionally, on the clearest days, prescribed wildland fires account for 12% of the total light extinction, 6% of which is from organic mass.

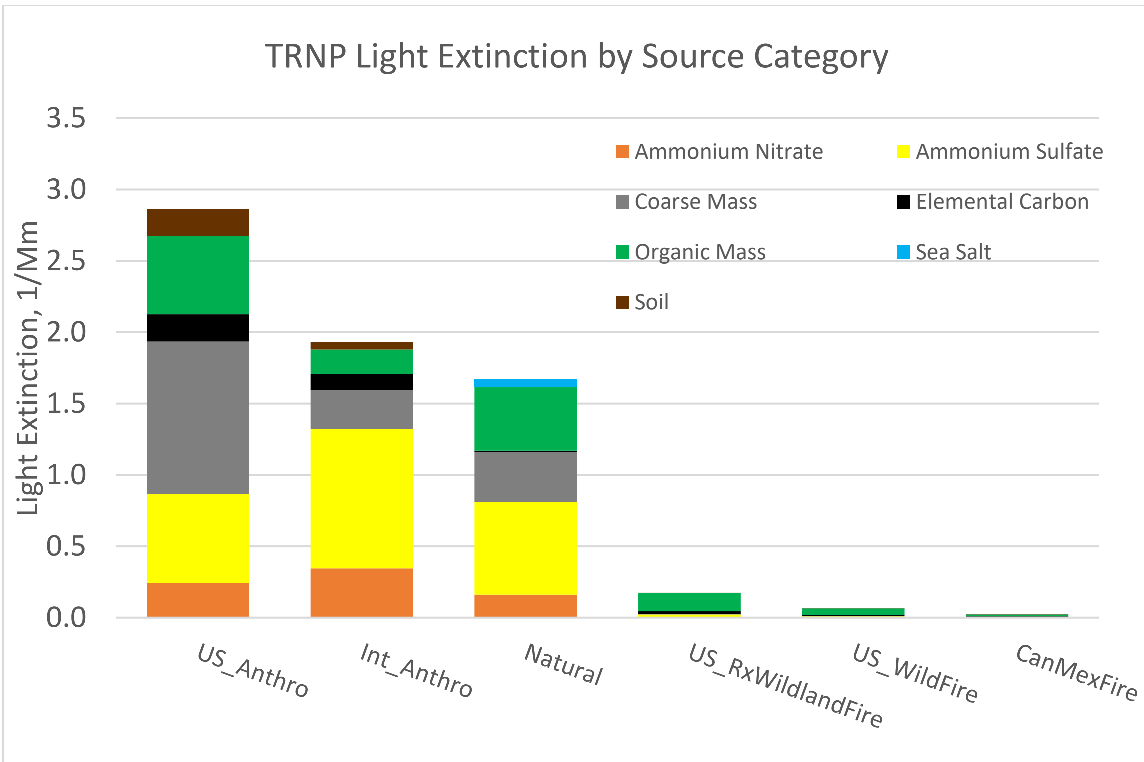

Figure 6: TRNP 2028OTB Light Extinction on the Clearest Days by Source Category

Figure 6 shows Int_Anthro ammonium sulfate light extinction is considerably higher than US_Anthro ammonium sulfate extinction on the clearest days at TRNP, this was also true for the most impaired days. US_Anthro ammonium nitrate light extinction is approximately the same as Int_Anthro on the clearest days. Overall, the light extinction from US_Anthro is the greatest, but a significant portion of the light extinction is from coarse mass and organic mass. Combined US_Anthro coarse mass and organic mass contribute more to light extinction on the clearest days than the combined ammonium sulfates and ammonium nitrates. US_Anthro ammonium nitrate and ammonium sulfate light extinction is also less than the contribution from Int_Anthro for these species. Additionally, Natural contributes significantly to the overall light extinction on the clearest days. Natural also contribute more to ammonium sulfate light extinction than US_Anthro sources and over half of the ammonium nitrate light extinction.

Table 6: TRNP 2028OTB Light Extinction on the Clearest Days by Source Category

Source Category	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Total	Percent of Total
US_Anthro	0.24	0.62	1.07	0.19	0.55	0.00	0.19	**2.86**	43%
Int_Anthro	0.35	0.98	0.27	0.11	0.17	0.00	0.05	**1.93**	29%
Natural	0.16	0.65	0.35	0.01	0.44	0.05	0.00	**1.67**	25%
US_RxWildlandFire	0.00	0.02	0.00	0.02	0.13	0.00	0.00	**0.17**	3%
US_WildFire	0.00	0.01	0.00	0.01	0.05	0.00	0.00	**0.07**	1%
CanMexFire	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**0.02**	0%
Total	**0.75**	**2.28**	**1.70**	**0.34**	**1.35**	**0.05**	**0.25**	**6.73**	**100%**

A review and breakdown of Table 6 shows the following significant contributors to light extinction. The US_Anthro source category accounts for 43% of the total light extinction on the clearest days at TRNP. Only 13% of the total light extinction from US_Anthro is comprised of ammonium nitrates and ammonium sulfates, 4% and 9%, respectively. Meaning, 30% of the overall light extinction from US_Anthro on the clearest is from coarse mass, elemental carbon, organic mass, and soil. Int_Anthro accounts for 29% of the total light extinction on the clearest days at TRNP. Much of the total light extinction from Int_Anthro is comprised of ammonium nitrates and ammonium sulfates. Int_Anthro ammonium nitrate and ammonium sulfate account for 5% and 15% of the total light extinction, respectively. Natural also contribute a significant amount to impairment on the clearest days, at 25%. Much of the total light extinction from Natural is comprised of ammonium sulfates at 10%, coarse mass at 5%, and organic mass at 7%.

1.2.2 Species Light Extinction on the Clearest Days

Figure 7 and Figure 8 display the 2028OTB source apportionment results for the average of the clearest days for aerosol species within the five major source categories. Table 7 and Table 8 display the numerical data corresponding to Figure 7 and Figure 8 for LWA and TRNP, respectively. The data in these figures and tables is the same as Section 1.2.1. The difference is how the data is displayed. The aerosol species are plotted along the x-axis and the light extinction contribution from the source category is separated by species.

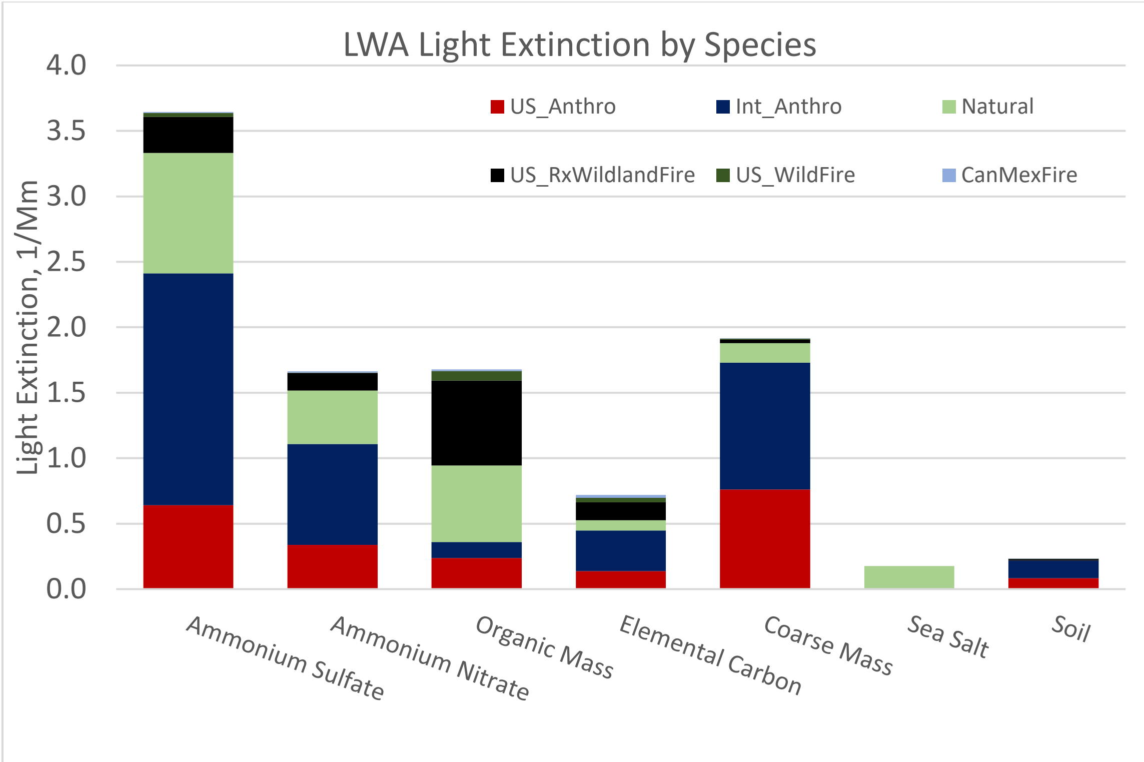

Figure 7: LWA 2028OTB Light Extinction on the Clearest Days by Species

Figure 7 emphasizes a few important items for LWA on the clearest days. Most of the total light extinction comes from ammonium sulfate, followed by ammonium nitrate, organic mass, and coarse mass. For ammonium sulfate and ammonium nitrate, Int_Anthro contributes greater to light extinction than US_Anthro. US_Anthro light extinction contributions from ammonium sulfate, ammonium nitrate, coarse mass, and organic mass are small, each below 1 Mm^{-1}. Natural also contributes significantly to impairment for ammonium sulfate, ammonium nitrate, and organic mass. As noted in the source category breakdown, prescribed wildland fires also account for a sizable portion of the light extinction on the clearest days.

Table 7: LWA 2028OTB Light Extinction on the Clearest Days by Species

Source Category	US_ Anthro	Int_ Anthro	Natural	US_RxWild landFire	US_Wild Fire	CanMex Fire	Total	Percent of Total
Ammonium Sulfate	0.64	1.77	0.92	0.28	0.03	0.01	**3.64**	36%
Ammonium Nitrate	0.34	0.77	0.41	0.14	0.00	0.01	**1.66**	17%
Organic Mass	0.24	0.12	0.58	0.65	0.07	0.01	**1.68**	17%
Elemental Carbon	0.14	0.31	0.08	0.14	0.04	0.02	**0.72**	7%

Source Category	US_ Anthro	Int_ Anthro	Natural	US_RxWild landFire	US_Wild Fire	CanMex Fire	Total	Percent of Total
Coarse Mass	0.76	0.97	0.15	0.03	0.01	0.00	**1.92**	19%
Sea Salt	0.00	0.00	0.18	0.00	0.00	0.00	**0.18**	2%
Soil	0.08	0.13	0.00	0.01	0.00	0.00	**0.23**	2%
Total	**2.20**	**4.08**	**2.32**	**1.23**	**0.15**	**0.05**	**10.03**	**100%**

A review and breakdown of Table 7 shows the following significant contributors to light extinction. Ammonium sulfate accounts for 36% of the total light extinction on the clearest days at LWA, where 18% of the total light extinction is from Int_Anthro, 6% is from US_Anthro, and 9% is from Natural. Coarse mass accounts for the largest species of light extinction after ammonium sulfate at 19% of overall light extinction. Coarse mass from Int_Anthro accounts for 10% and US_Anthro accounts for 8%. Ammonium nitrate accounts for 17% of the total light extinction, where 8% of the total light extinction is from Int_Anthro, 3% is from US_Anthro, and 4% is from Natural. Organic mass also accounts for 17% of the total light extinction, where 1% of the total light extinction is from Int_Anthro, 2% is from US_Anthro, 6% is from Natural, and 6% is from prescribed wildland fires.

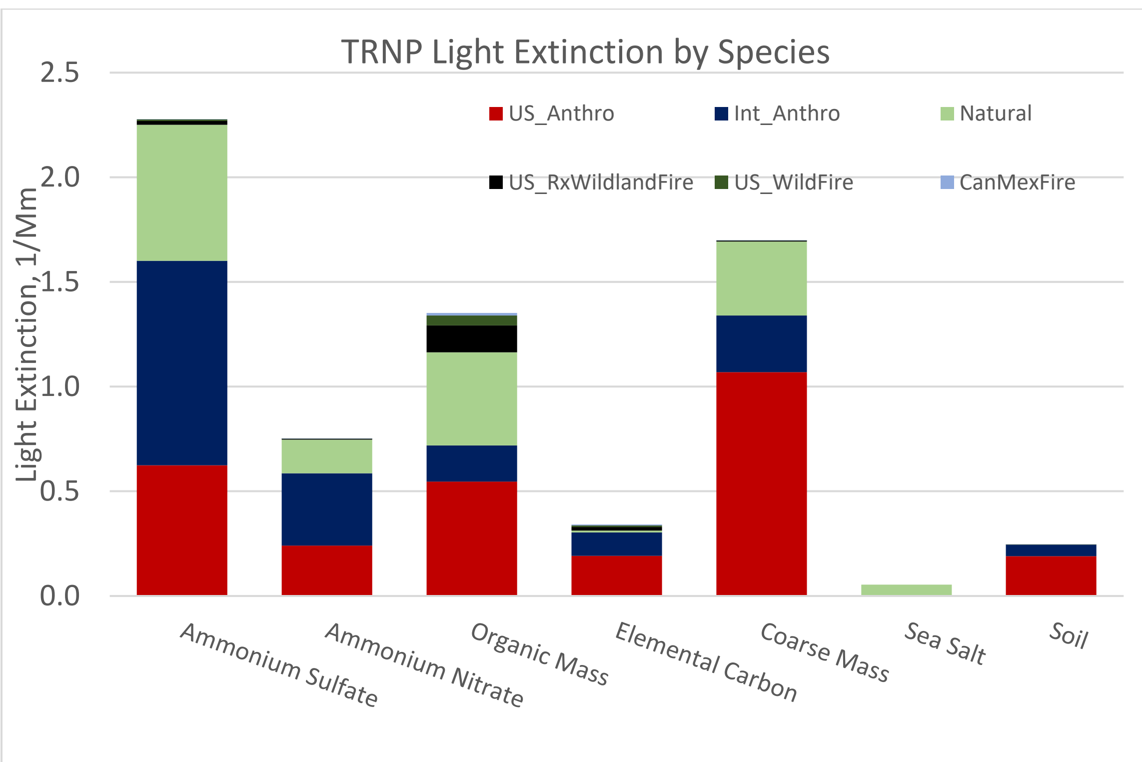

Figure 8: TRNP 2028OTB Light Extinction on the Clearest Days by Species

Figure 8 emphasizes a few important items for TRNP on the clearest days. Light extinction from ammonium sulfate is the most significant aerosol species and Int_Anthro, US_Anthro, and Natural are the primary contributors to the ammonium sulfate light extinction. Coarse mass and organic mass are the next largest contributors to light extinction on the clearest days and each of these species contributes more to light extinction than ammonium nitrate.

Table 8: TRNP 2028OTB Light Extinction on the Clearest Days by Species

Source Category	US_ Anthro	Int_ Anthro	Natural	US_RxWild landFire	US_Wild Fire	CanMex Fire	Total	Percent of Total
Ammonium Sulfate	0.62	0.98	0.65	0.02	0.01	0.00	**2.28**	34%
Ammonium Nitrate	0.24	0.35	0.16	0.00	0.00	0.00	**0.75**	11%
Organic Mass	0.55	0.17	0.44	0.13	0.05	0.01	**1.35**	20%
Elemental Carbon	0.19	0.11	0.01	0.02	0.01	0.00	**0.34**	5%
Coarse Mass	1.07	0.27	0.35	0.00	0.00	0.00	**1.70**	25%
Sea Salt	0.00	0.00	0.05	0.00	0.00	0.00	**0.05**	1%
Soil	0.19	0.05	0.00	0.00	0.00	0.00	**0.25**	4%
Total	**2.86**	**1.93**	**1.67**	**0.17**	**0.07**	**0.02**	**6.73**	**100%**

A review and breakdown of Table 8 shows the following significant contributors to light extinction. Ammonium sulfate accounts for 34% of the total light extinction on the clearest days at TRNP, where 15% of the total light extinction is from Int_Anthro, 9% is from US_Anthro, and 10% is from Natural. Coarse mass accounts for 25% of the total light extinction, where 4% of the total light extinction is from Int_Anthro, 16% is from US_Anthro, and 5% is from Natural. Organic mass accounts for 20% of the total light extinction, where 3% of the total light extinction is from Int_Anthro, 8% is from US_Anthro, and 7% is from Natural. Ammonium nitrate only accounts for 11% of the total light extinction on the clearest days, where 5% of the total light extinction is from Int_Anthro, 4% is from US_Anthro, and 2% is from Natural.

1.2.3 Clearest Days Conclusion

In summary, the contributors to light extinction on the clearest days for both LWA and TRNP come from six main areas: Int_Anthro ammonium sulfate, Int_Anthro ammonium nitrate, US_Anthro ammonium sulfate, US_Anthro ammonium nitrate, Natural ammonium sulfate, and Natural ammonium nitrate. Light extinction from coarse mass and organic mass are also more significant on the clearest days versus the most impaired days. Coarse mass accounts for 19% of the clearest days' total impairment at LWA and 25% of the clearest days' impairment at TRNP. Organic mass accounts for 17% of the clearest days' total impairment at LWA and 20% of the clearest days' total impairment at TRNP.

2 State and Sector Source Impacts on North Dakota Visibility

This section contains the data from the anthropogenic state and sector source apportionment results from the modeling performed by WRAP.[5] WRAP completed modeling to determine the visibility impacts from emissions of US anthropogenic sources by state and sector. This modeling was completed for the species of ammonium nitrates and ammonium sulfates. The sectors included in the modeling were: EGU, OilGas (oil and gas point and area sources with tribal oil and gas assigned to the state), NonEGU (all other point), Mobile (mobile on-road, non-road, rail, commercial marine vessels), and RemainAnthro (all remaining anthropogenic emissions including fugitive dust, agricultural, agricultural fire, residential wood combustion, and all other remaining nonpoint sources). Each of these sector's impairment contribution was determined on a state basis for the 13 continental WRAP states (no Hawaii or Alaska) and from the remaining continental US "RemUS".

The state and sector level source apportionment results are discussed in Section 2.1 for the most impaired days and Section 2.2 for the clearest days.

The aerosol species which contribute to light extinction are ammonium nitrate, ammonium sulfate, organic mass, elemental carbon, coarse mass, soil, and sea salt. The aerosol species of most significance to North Dakota Class I areas are ammonium nitrate and ammonium sulfate. The aerosol species of ammonium nitrate and ammonium sulfate were the only two species tracked for the state and sector breakdown.

The modeling was completed using the 2028 inventory projection (2028OTB). For details on the 2028OTB emission inventory, see Section 4.1.6 of the main SIP document.

2.1 Most Impaired Days

2.1.1 Ammonium Nitrate Light Extinction on the Most Impaired Days

Figure 9 and Figure 10 display the 2028OTB state and sector apportionment results for the average of the most impaired days at LWA and TRNP for aerosol species of ammonium nitrate within the five sector categories. Results are specific to US anthropogenic (US_Anthro) light extinction only. The five major source categories are: EGU, OilGas, NonEGU, Mobile, and RemainAnthro. Table 9 and Table 10 display the numerical data corresponding to Figure 9 and Figure 10 for LWA and TRNP, respectively.

[5] Available at:
https://views.cira.colostate.edu/docs/iwdw/platformdocs/WRAP_2014/SourceApportionmentSpecifications_WRAP_RepBase2_and_2028OTBa2_High-LevelPMandO3_and_Low-Level_PM_andOptionalO3_Sept29_2020.pdf (Last visited February 22, 2021)

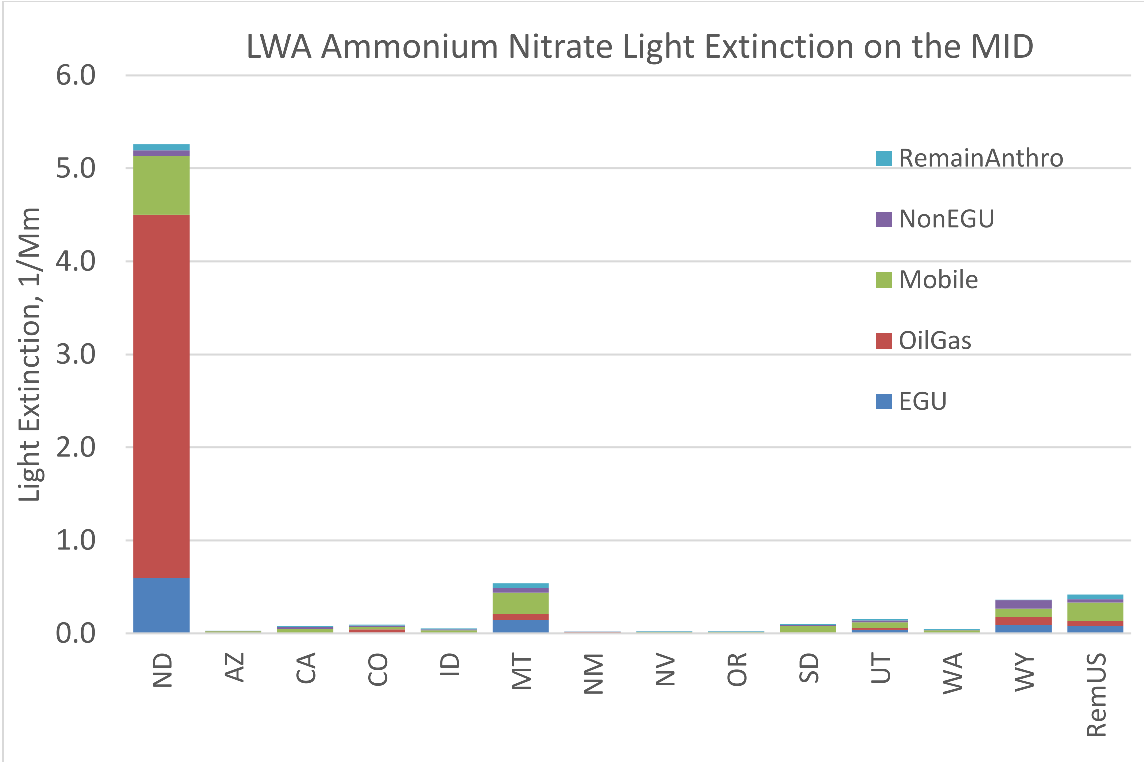

Figure 9: LWA Ammonium Nitrate light Extinction on the Most Impaired Days

Figure 9 shows that much of the projected US anthropogenic ammonium nitrate light extinction at LWA on the most impaired days comes from sources within North Dakota. The primary sectors contributing to the light extinction are OilGas, EGU and Mobile.

Table 9: LWA Ammonium Nitrate light Extinction on the Most Impaired Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.59	3.91	0.63	0.06	0.07	**5.26**	73%
AZ	0.00	0.00	0.02	0.00	0.00	**0.03**	0%
CA	0.00	0.00	0.04	0.02	0.02	**0.08**	1%
CO	0.01	0.03	0.03	0.01	0.01	**0.09**	1%
ID	0.00	0.00	0.03	0.01	0.01	**0.05**	1%
MT	0.14	0.06	0.23	0.05	0.05	**0.54**	7%
NM	0.00	0.01	0.00	0.00	0.00	**0.02**	0%
NV	0.00	0.00	0.01	0.00	0.00	**0.02**	0%
OR	0.00	0.00	0.01	0.01	0.00	**0.02**	0%
SD	0.00	0.01	0.07	0.01	0.01	**0.10**	1%
UT	0.04	0.02	0.06	0.02	0.02	**0.16**	2%
WA	0.00	0.00	0.03	0.01	0.01	**0.05**	1%
WY	0.09	0.09	0.09	0.09	0.01	**0.36**	5%
RemUS	0.08	0.06	0.20	0.03	0.05	**0.42**	6%

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
Total	**0.98**	**4.19**	**1.45**	**0.34**	**0.26**	**7.21**	**100%**

Table 9 shows the state and source category breakdown of ammonium nitrate light extinction contributions on the most impaired days at LWA. North Dakota sources contribute 73% of the total US_Anthro ammonium nitrate light extinction at LWA on the most impaired days. The remaining 27% primarily comes from MT (7%), WY (5%), and RemUS (6%) with all other continental US WRAP states accounting for the remaining 9%. None of the impairment from US sources outside North Dakota is considered significant. The outside impairment is small on a relative or percentage basis, less than 10%. On an overall magnitude basis, US_Anthro impairment from outside of ND is also small. The highest state modeled impairment comes from MT and is 0.54 Mm^{-1}.

North Dakota's 73% contribution is mostly from three sectors, OilGas, EGU, and Mobile. Of the North Dakota contribution, OilGas accounts for 54% of the total US_Anthro light extinction, EGU accounts for 8%, and Mobile accounts for 9%. On a relative basis OilGas accounts for over half of the US_Anthro ammonium nitrate light extinction at LWA. However, the magnitude of the projected OilGas impairment is relatively small at only 3.91 Mm^{-1}, compared to the overall species light extinction of 39.45 Mm^{-1} (Section 1.1) or the total light extinction of 50.45 Mm^{-1} (Section 3.1 of the main SIP document). The magnitude of ammonium nitrate impairment from North Dakota EGUs and Mobile sources is even smaller, where EGUs contribute 0.59 Mm^{-1} of light extinction and Mobile contributes 0.63 Mm^{-1}.

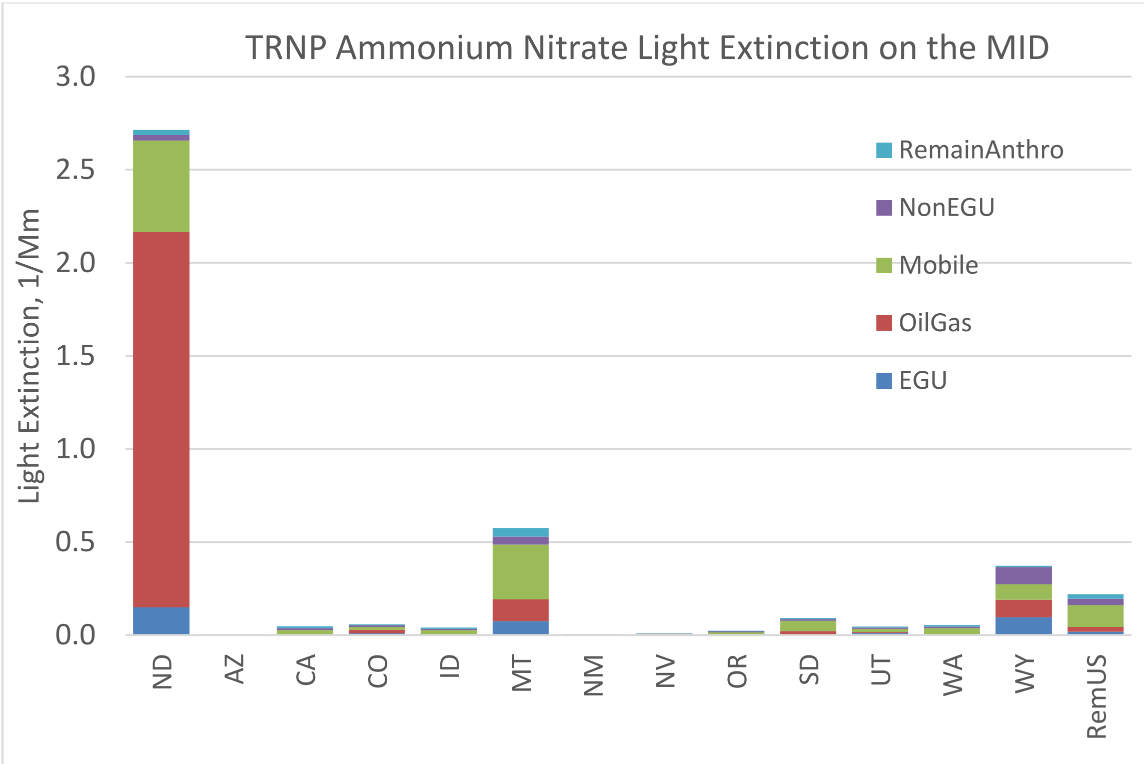

Figure 10: TRNP Ammonium Nitrate light Extinction on the Most Impaired Days

Similar to LWA, Figure 10 shows that the majority of projected US anthropogenic ammonium nitrate light extinction at TRNP on the most impaired days comes from sources within North Dakota. The primary sectors contributing to the light extinction are OilGas, EGU and Mobile.

Table 10: TRNP Ammonium Nitrate light Extinction on the Most Impaired Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.15	2.02	0.49	0.03	0.03	**2.71**	64%
AZ	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CA	0.00	0.00	0.02	0.01	0.01	**0.05**	1%
CO	0.01	0.02	0.02	0.01	0.01	**0.06**	1%
ID	0.00	0.00	0.02	0.01	0.01	**0.04**	1%
MT	0.07	0.12	0.29	0.04	0.05	**0.57**	13%
NM	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
NV	0.00	0.00	0.01	0.00	0.00	**0.01**	0%
OR	0.00	0.00	0.01	0.01	0.00	**0.02**	1%
SD	0.00	0.02	0.06	0.01	0.01	**0.09**	2%
UT	0.01	0.01	0.02	0.01	0.00	**0.05**	1%
WA	0.00	0.00	0.03	0.01	0.01	**0.05**	1%
WY	0.10	0.09	0.08	0.09	0.01	**0.37**	9%
RemUS	0.02	0.03	0.12	0.03	0.02	**0.22**	5%

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
Total	**0.37**	**2.31**	**1.18**	**0.26**	**0.15**	**4.26**	100%

Table 10 shows the state and source category breakdown of ammonium nitrate light extinction contributions on the most impaired days at TRNP. North Dakota sources contribute 64% of the total US_Anthro ammonium nitrate light extinction at TRNP on the most impaired days. The remaining 36% primarily comes from MT (13%), WY (9%), and RemUS (5%) with all other continental US WRAP states accounting for the remaining 9%. None of the impairment from US sources outside North Dakota is considered significant. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment comes from MT and is 0.57 Mm^{-1}.

North Dakota's 64% contribution is mostly from three sectors, OilGas, EGU, and Mobile. Of the North Dakota contribution, OilGas accounts for 47% of the total US_Anthro light extinction, EGU accounts for 4%, and Mobile accounts for 12%. On a relative basis OilGas accounts for almost half of the US_Anthro ammonium nitrate light extinction at TRNP. However, the magnitude of the projected OilGas impairment is relatively small at only 2.02 Mm^{-1}, compared to the overall species light extinction of 29.72 Mm^{-1} (Section 1.1) or the total light extinction of 40.72 Mm^{-1} (Section 3.1 of the main SIP document). The magnitude of ammonium nitrate impairment from North Dakota EGUs and Mobile sources is even smaller, where EGUs contribute 0.15 Mm^{-1} of light extinction and Mobile contributes 0.49 Mm^{-1}.

2.1.2 Ammonium Sulfate Light Extinction on the Most Impaired Days

Figure 11 and Figure 12 display the 2028OTB state and sector apportionment results for the average of the most impaired days for aerosol species of ammonium sulfate within the five sector categories. Results are specific to modeled US anthropogenic light extinction only. The five major source categories are: EGU, OilGas, NonEGU, Mobile, and RemainAnthro. Table 11 and Table 12 display the numerical data corresponding to Figure 11 and Figure 12 for LWA and TRNP, respectively.

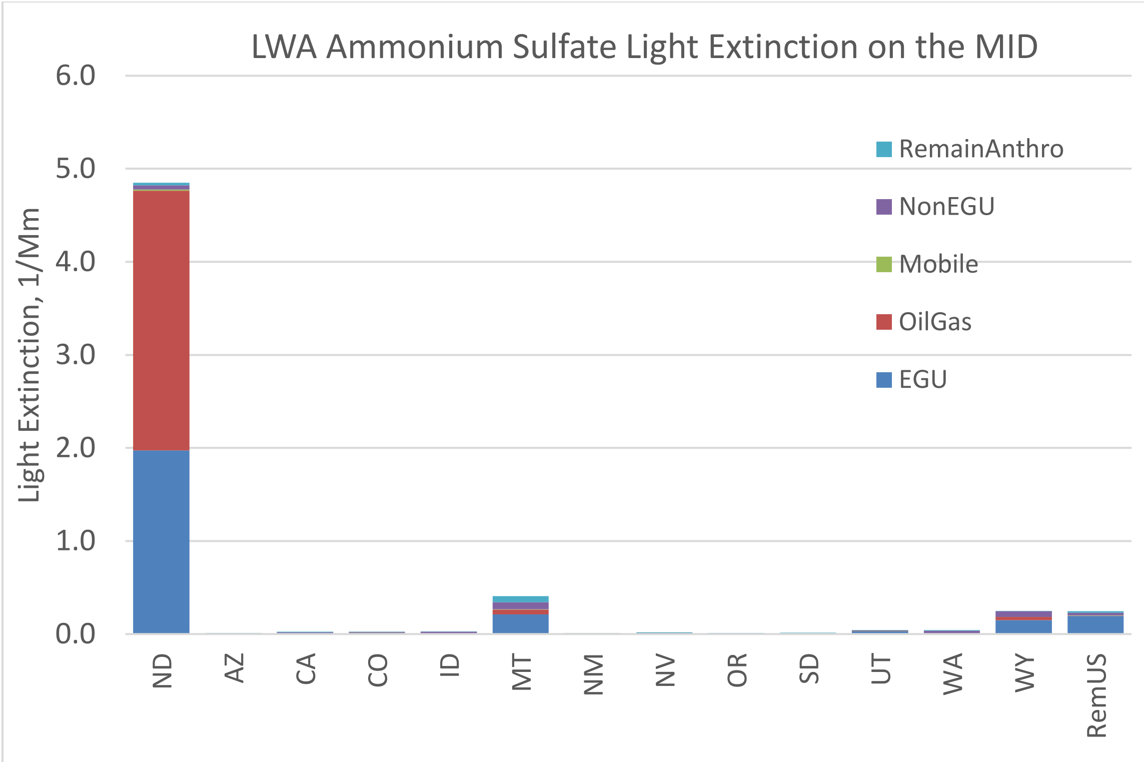

Figure 11: LWA Ammonium Sulfate light Extinction on the Most Impaired Days

Figure 11 shows that much of the modeled US anthropogenic ammonium sulfate light extinction at LWA on the most impaired days comes from sources within North Dakota. The primary sectors contributing to the light extinction are OilGas and EGU.

Table 11: LWA Ammonium Sulfate light Extinction on the Most Impaired Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	1.97	2.79	0.01	0.05	0.03	**4.85**	81%
AZ	0.00	0.00	0.00	0.01	0.00	**0.01**	0%
CA	0.00	0.00	0.00	0.02	0.01	**0.03**	0%
CO	0.01	0.00	0.00	0.01	0.00	**0.02**	0%
ID	0.00	0.00	0.00	0.02	0.00	**0.03**	0%
MT	0.21	0.05	0.00	0.08	0.06	**0.41**	7%
NM	0.00	0.00	0.00	0.00	0.00	**0.01**	0%
NV	0.01	0.00	0.00	0.00	0.01	**0.02**	0%
OR	0.00	0.00	0.00	0.01	0.00	**0.01**	0%
SD	0.00	0.00	0.00	0.01	0.01	**0.02**	0%
UT	0.03	0.00	0.00	0.01	0.00	**0.04**	1%
WA	0.00	0.00	0.00	0.04	0.01	**0.04**	1%
WY	0.15	0.03	0.00	0.06	0.00	**0.25**	4%
RemUS	0.19	0.00	0.00	0.03	0.02	**0.25**	4%

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
Total	**2.59**	**2.89**	**0.03**	**0.32**	**0.15**	**5.98**	100%

Table 11 shows the state and source category breakdown of ammonium sulfate light extinction contributions on the most impaired days at LWA. North Dakota sources contribute 81% of the total US_Anthro ammonium sulfate light extinction at LWA on the most impaired days. The remaining 19% primarily comes from MT (7%), WY (4%), and RemUS (4%) with all other continental US WRAP states accounting for the remaining 4%. None of the impairment from US sources outside North Dakota is considered significant. The outside impairment is small on a relative or percentage basis, less than 10%. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment comes from MT and is 0.41 Mm^{-1}.

North Dakota's 81% contribution is mostly from two sectors, OilGas and EGU. Of the North Dakota contribution, OilGas accounts for 47% of the total US_Anthro light extinction and EGU accounts for 33%. On a relative basis OilGas accounts for nearly half of the US_Anthro ammonium sulfate light extinction at LWA. However, the magnitude of the projected OilGas impairment is relatively small at only 2.79 Mm^{-1}, compared to the overall species light extinction of 39.45 Mm^{-1} (Section 1.1) or the total light extinction of 50.45 Mm^{-1} (Section 3.1 of the main SIP document). The magnitude of ammonium sulfate impairment from North Dakota EGUs is even smaller, where EGUs contribute 1.97 Mm^{-1} of light extinction.

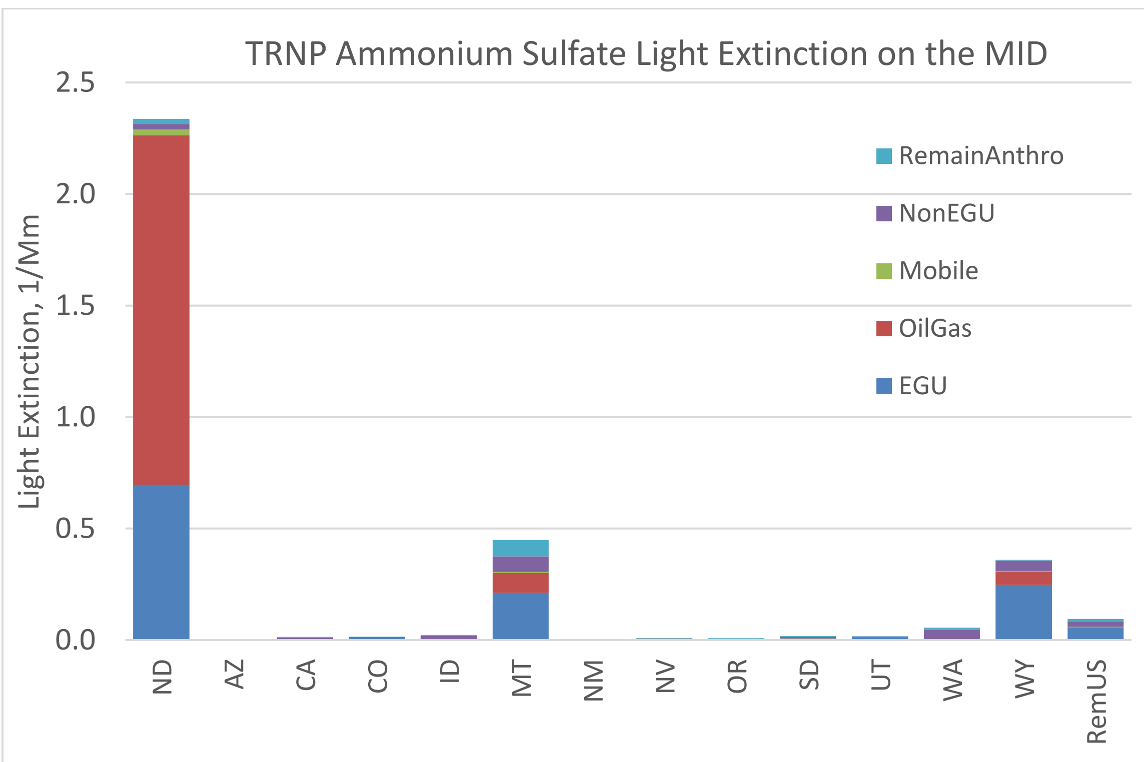

Figure 12: TRNP Ammonium Sulfate light Extinction on the Most Impaired Days

Figure 12 shows that the majority of projected US anthropogenic ammonium sulfate light extinction at TRNP on the most impaired days comes from sources within North Dakota. The primary sectors contributing to the light extinction are OilGas and EGU.

Table 12: TRNP Ammonium Sulfate light Extinction on the Most Impaired Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.70	1.57	0.03	0.02	0.02	**2.34**	69%
AZ	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CA	0.00	0.00	0.00	0.01	0.00	**0.01**	0%
CO	0.01	0.00	0.00	0.00	0.00	**0.02**	0%
ID	0.00	0.00	0.00	0.02	0.00	**0.02**	1%
MT	0.21	0.09	0.00	0.07	0.07	**0.45**	13%
NM	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
NV	0.01	0.00	0.00	0.00	0.00	**0.01**	0%
OR	0.00	0.00	0.00	0.00	0.00	**0.01**	0%
SD	0.00	0.01	0.00	0.01	0.00	**0.02**	1%
UT	0.01	0.00	0.00	0.00	0.00	**0.02**	0%
WA	0.00	0.00	0.00	0.04	0.01	**0.06**	2%
WY	0.25	0.06	0.00	0.05	0.00	**0.36**	11%
RemUS	0.06	0.00	0.00	0.02	0.01	**0.09**	3%
Total	**1.25**	**1.72**	**0.04**	**0.26**	**0.14**	**3.40**	100%

Table 12 shows the state and source category breakdown of ammonium sulfate light extinction contributions on the most impaired days at TRNP. North Dakota sources contribute 69% of the total US_Anthro ammonium sulfate light extinction at LWA on the most impaired days. The remaining 31% primarily comes from MT (13%), WY (11%), and RemUS (3%) with all other continental US WRAP states accounting for the remaining 4%. None of the impairment from US sources outside North Dakota is considered significant. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment comes from MT and is 0.45 Mm^{-1}.

North Dakota's 69% contribution is mostly from two sectors, OilGas and EGU. Of the North Dakota contribution, OilGas accounts for 46% of the total US_Anthro light extinction and EGU accounts for 20%. On a relative basis OilGas accounts for nearly half of the US_Anthro ammonium sulfate light extinction at TRNP. However, the magnitude of the projected OilGas impairment is relatively small at only 1.57 Mm^{-1}, compared to the overall species light extinction of 29.72 Mm^{-1} (Section 1.1) or the total light extinction of 40.72 Mm^{-1} (Section 3.1 of the main SIP document). The magnitude of ammonium sulfate impairment from North Dakota EGUs is even smaller, where EGUs contribute 0.70 Mm^{-1} of light extinction.

2.1.3 North Dakota Sector Contribution on the Most Impaired Days

The impairment caused by North Dakota sectors can also be compared to the overall species light extinction projection for 2028. The following is a breakdown of species light extinction: US anthropogenic (US_Anthro), International anthropogenic (Int_Anthro), Natural, prescribed wildland fire (US_RxWildlandFire), US wildfire, and Canada Mexico Fires (CanMexFire) is discussed in detail and is included in Section 1.1. The following breakdown shows the impairment caused by the North Dakota sectors as compared to the species light extinction for the 2028OTB scenario. US_Anthro sources have been broken down into the following sectors: North Dakota electrical generating utilities (ND EGU); North Dakota Oil and Gas point and area sources including tribal Oil and Gas operation (ND OilGas); North Dakota mobile onroad, non-road, rail, and commercial marine vessels (ND Mobile); Other North Dakota point sources (ND NonEGU); all remaining anthropogenic emissions including fugitive dust, agriculture, agricultural fire, residential wood combustion, and all remaining nonpoint sources (ND RemainAnthro); all US_Anthro minus the North Dakota sectors (Remaining US); and the Boundary Conditions from US emissions (BCUS). The species breakdown for all US_Anthro sources and sectors was limited to ammonium nitrate and ammonium sulfate. Therefore, impairment from the species of coarse mass, elemental carbon, organic mass, sea salt, and soil for all US_Anthro sources (including North Dakota sources) are included in the "Remaining US" row for Table 13 and Table 14. Note that Tribal oil and gas emissions are assigned to the ND OilGas category.

Table 13: LWA Sector and Source Category Contributions to Species Light Extinction on MID

Source Category/Sector	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Grand Total
ND EGU	2%	5%	--	--	--	--	--	**7%**
ND OilGas	10%	7%	--	--	--	--	--	**17%**
ND Mobile	2%	0%	--	--	--	--	--	**2%**
ND NonEGU	0%	0%	--	--	--	--	--	**0%**
ND RemainAnthro	0%	0%	--	--	--	--	--	**0%**
Remaining US	5%	3%	2%	1%	3%	0%	0%	**15%**
BCUS	0%	0%	--	--	--	--	--	**1%**
Int_Anthro	**19%**	**17%**	**1%**	**2%**	**1%**	**0%**	**0%**	**40%**
CanMexFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**
Natural	**7%**	**5%**	**1%**	**0%**	**2%**	**1%**	**0%**	**16%**
US_RxWildlandFire	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**1%**
US_WildFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Grand Total	**45%**	**38%**	**5%**	**4%**	**7%**	**1%**	**1%**	**100%**

Table 13 shows the percent breakdown of the total species light extinction contributions from different source categories and sectors at LWA. US_Anthro sources contribute to 42% of the total light extinction, with 19% and 16% attributed to ammonium nitrate and ammonium sulfate, respectively. ND sectors contribute to 26% of the total light extinction. The largest source category contributor is ND OilGas at

17%, with ND EGU being less than half of that at a 7% contribution. Similar to US_Anthro, Int_Anthro contributes 40% to the total light extinction. The only other significant contributor outside of these is Natural at 16%.

ND OilGas light extinction consists of North Dakota point and area sources and tribal oil and gas operations. North Dakota area oil and gas sources (upstream development and operation) consists of over 15,000 individual wells spread out amongst over 8,000 sites. Meaning the 17% combined ammonium nitrate and ammonium sulfate impairment comes from many individual sources, and a significant portion (tribal oil and gas) is outside of the State of North Dakota's control. The largest point sources emitters were evaluated under the four-factor analysis (Section 5.2 of the main SIP document).

Table 14: TRNP Sector and Source Category Contributions to Species Light Extinction on MID

Source Category/Sector	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Grand Total
ND EGU	1%	2%	--	--	--	--	--	**3%**
ND OilGas	7%	5%	--	--	--	--	--	**12%**
ND Mobile	2%	0%	--	--	--	--	--	**2%**
ND NonEGU	0%	0%	--	--	--	--	--	**0%**
ND RemainAnthro	0%	0%	--	--	--	--	--	**0%**
Remaining US	5%	4%	4%	1%	4%	0%	1%	**19%**
BCUS	1%	1%	--	--	--	--	--	**1%**
Int_Anthro	**15%**	**24%**	**2%**	**1%**	**1%**	**0%**	**0%**	**43%**
CanMexFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Natural	**5%**	**8%**	**1%**	**0%**	**2%**	**1%**	**0%**	**18%**
US_RxWildlandFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**
US_WildFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**
Grand Total	**36%**	**45%**	**7%**	**3%**	**8%**	**1%**	**1%**	**100%**

Table 14 shows the percent breakdown of the total species light extinction contributions from different source categories and sectors at TRNP. US_Anthro sources contribute to 37% of the total light extinction, with 15% and 12% attributed to ammonium nitrate and ammonium sulfate, respectively. ND sectors contribute to 17% of the total light extinction. The largest source category contributor is ND OilGas at 12%, with ND EGU being a quarter of that at a 3% contribution. Int_Anthro has a higher contribution than US_Anthro, contributing 43% to the total light extinction. The only other significant contributor outside of these is Natural at 18%.

2.2 Clearest Days

2.2.1 Ammonium Nitrate Light Extinction on the Clearest Days

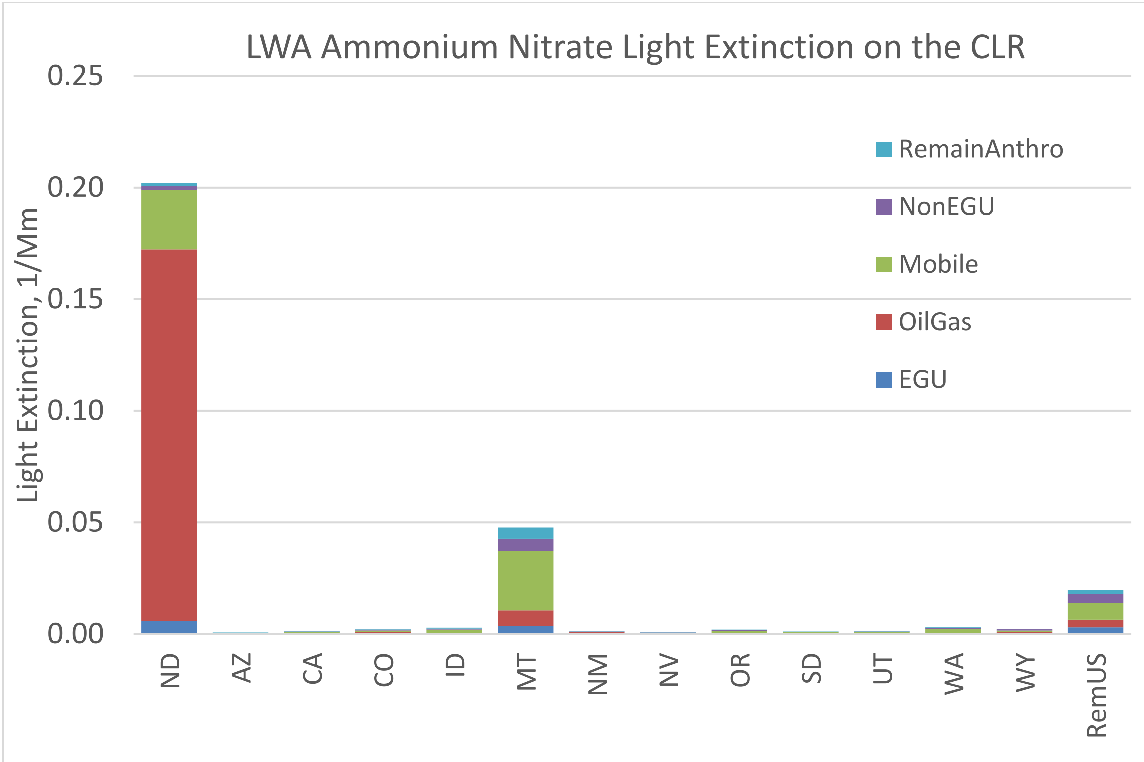

Figure 13: LWA Ammonium Nitrate light Extinction on the Clearest Days

Figure 13 shows that the majority of projected US anthropogenic ammonium nitrate light extinction at LWA on the clearest days comes from sources within North Dakota.

Table 15: LWA Ammonium Nitrate light Extinction on the Clearest Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.01	0.17	0.03	0.00	0.00	**0.20**	70%
AZ	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CA	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CO	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
ID	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
MT	0.00	0.01	0.03	0.01	0.00	**0.05**	17%
NM	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
NV	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
OR	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
SD	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
UT	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
WA	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
WY	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
RemUS	0.00	0.00	0.01	0.00	0.00	**0.02**	7%
Total	**0.01**	**0.18**	**0.07**	**0.01**	**0.01**	**0.29**	100%

Table 15 shows the state and source category breakdown of ammonium nitrate light extinction contributions on the clearest days at LWA. North Dakota sources contribute 70% of the total US_Anthro ammonium nitrate light extinction at LWA on the clearest days. The remaining 30% primarily comes from MT (17%) and RemUS (7%), with all other continental US WRAP states accounting for the remaining 6%. None of the impairment from US sources outside North Dakota is considered significant. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment comes from MT and is 0.05 Mm^{-1}.

North Dakota's 70% contribution is mostly from two sectors, OilGas and Mobile. Of the North Dakota contribution, OilGas accounts for 58% of the total US_Anthro light extinction and Mobile accounts for 9%. On a relative basis OilGas accounts for over half of the US_Anthro ammonium nitrate light extinction at LWA on the clearest days. However, the magnitude of the projected OilGas impairment is small at only 0.17 Mm^{-1}. The magnitude of ammonium nitrate impairment from North Dakota Mobile is even smaller, where Mobile contributes 0.03 Mm^{-1} of light extinction.

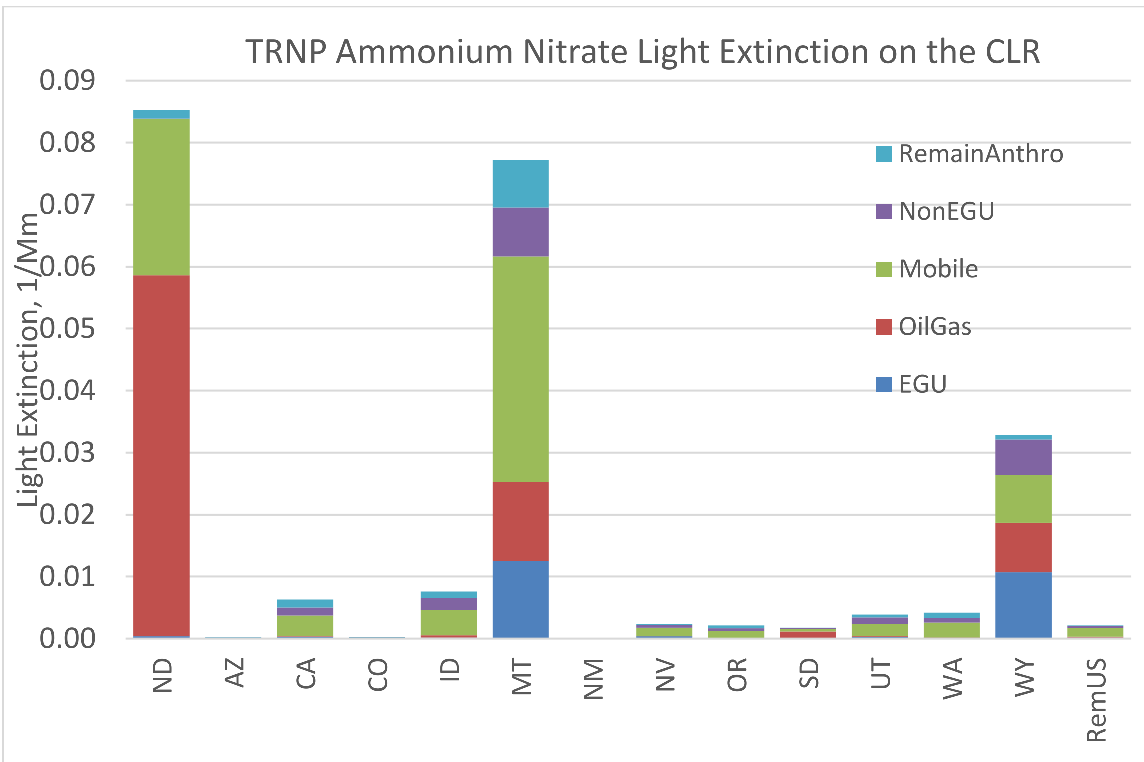

Figure 14: TRNP Ammonium Nitrate light Extinction on the Clearest Days

Figure 14 shows that the majority of projected US anthropogenic ammonium nitrate light extinction at TRNP on the clearest days comes from sources within North Dakota.

Table 16: TRNP Ammonium Nitrate light Extinction on the Clearest Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.00	0.06	0.03	0.00	0.00	**0.09**	38%
AZ	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CA	0.00	0.00	0.00	0.00	0.00	**0.01**	3%
CO	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
ID	0.00	0.00	0.00	0.00	0.00	**0.01**	3%
MT	0.01	0.01	0.04	0.01	0.01	**0.08**	34%
NM	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
NV	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
OR	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
SD	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
UT	0.00	0.00	0.00	0.00	0.00	**0.00**	2%
WA	0.00	0.00	0.00	0.00	0.00	**0.00**	2%
WY	0.01	0.01	0.01	0.01	0.00	**0.03**	15%
RemUS	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
Total	**0.03**	**0.08**	**0.09**	**0.02**	**0.01**	**0.23**	100%

Table 16 shows the state and source category breakdown of ammonium nitrate light extinction contributions on the clearest days at TRNP. North Dakota sources contribute 38% of the total US_Anthro ammonium nitrate light extinction at TRNP on the clearest days, with Montana sources contributing 34%. The remaining 28% primarily comes from WY (15%), with all other continental US WRAP states accounting for the remaining 13%. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment from MT is 0.08 Mm^{-1}.

North Dakota's 38% contribution is mostly from two sectors, OilGas and Mobile. Of the North Dakota contribution, OilGas accounts for 26% of the total US_Anthro light extinction and Mobile accounts for 11%. The magnitude of the projected OilGas impairment is small at only 0.06 Mm^{-1}. The magnitude of ammonium nitrate impairment from North Dakota Mobile is even smaller, where Mobile contributes 0.03 Mm^{-1} of light extinction.

2.2.2 Ammonium Sulfate Light Extinction on the Clearest Days

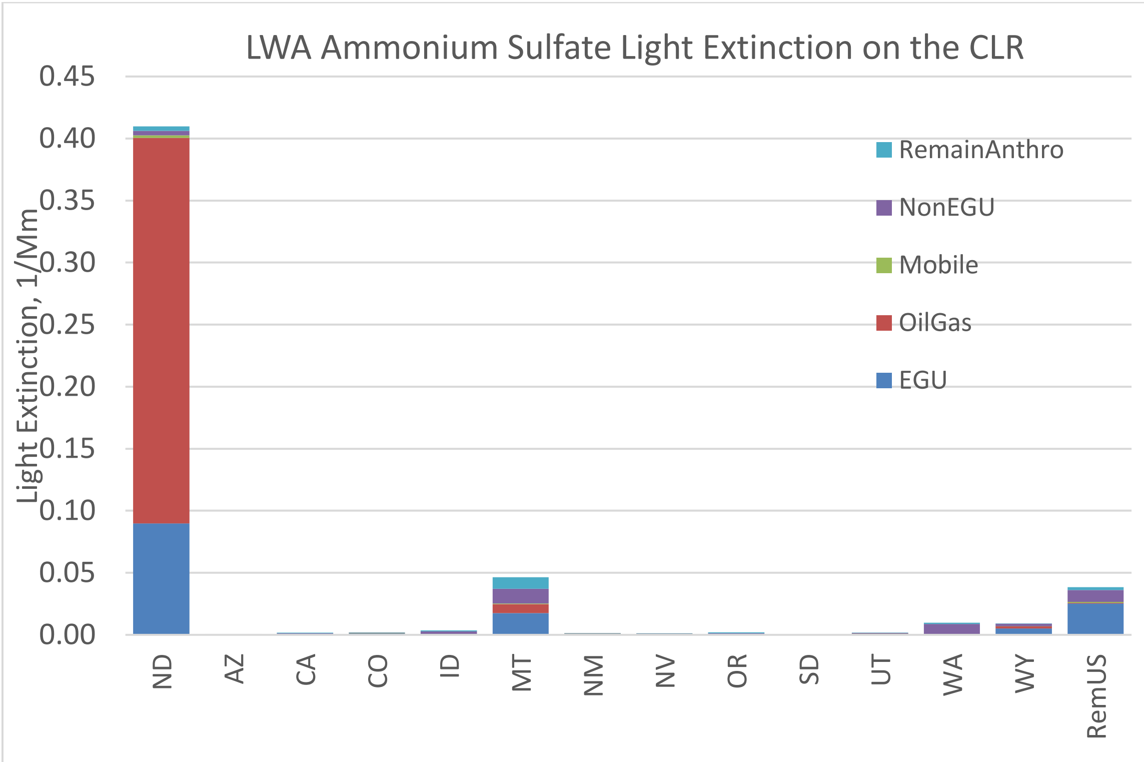

Figure 15: LWA Ammonium Sulfate light Extinction on the Clearest Days

Figure 15 shows that the vast majority of projected US anthropogenic ammonium sulfate light extinction at LWA on the clearest days comes from sources within North Dakota. The primary sectors contributing to the light extinction are OilGas and EGU.

Table 17: LWA Ammonium Sulfate light Extinction on the Clearest Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.09	0.31	0.00	0.00	0.00	**0.41**	78%
AZ	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CA	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CO	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
ID	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
MT	0.02	0.01	0.00	0.01	0.01	**0.05**	9%
NM	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
NV	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
OR	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
SD	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
UT	0.00	0.00	0.00	0.00	0.00	**0.00**	0%

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
WA	0.00	0.00	0.00	0.01	0.00	**0.01**	2%
WY	0.01	0.00	0.00	0.00	0.00	**0.01**	2%
RemUS	0.03	0.00	0.00	0.01	0.00	**0.04**	7%
Total	**0.14**	**0.32**	**0.00**	**0.04**	**0.02**	**0.53**	100%

Table 17 shows the state and source category breakdown of ammonium sulfate light extinction contributions on the clearest days at LWA. North Dakota sources contribute 78% of the total US_Anthro ammonium sulfate light extinction at LWA on the clearest days. The remaining 22% primarily comes from MT (9%) and RemUS (7%), with all other continental US WRAP states accounting for the remaining 6%. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment from MT is 0.05 Mm^{-1}.

North Dakota's 38% contribution is mostly from two sectors, OilGas and EGU. Of the North Dakota contribution, OilGas accounts for 59% of the total US_Anthro light extinction and EGU accounts for 17%. The magnitude of the projected OilGas impairment is small at only 0.31 Mm^{-1}. The magnitude of ammonium sulfate impairment from North Dakota EGUs is even smaller, where EGUs contributes 0.09 Mm^{-1} of light extinction.

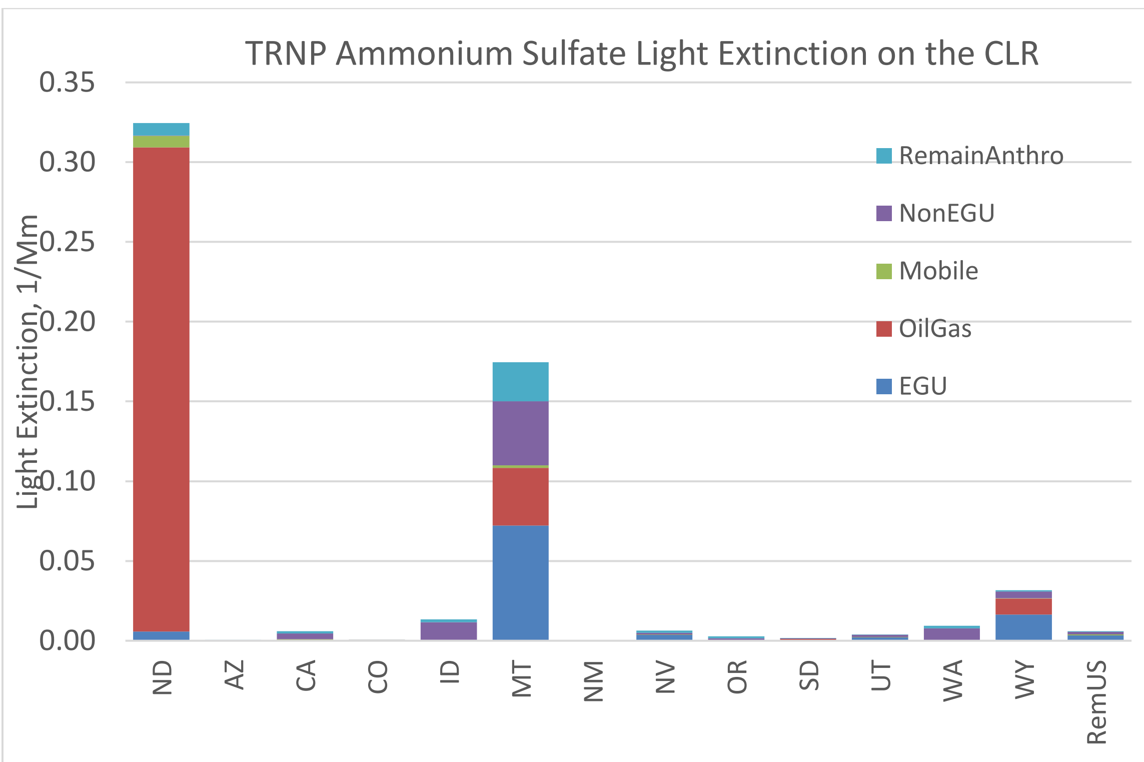

Figure 16: TRNP Ammonium Sulfate light Extinction on the Clearest Days

Figure 16 shows that the majority of projected US anthropogenic ammonium sulfate light extinction at TRNP on the clearest days comes from sources within North Dakota. The primary sector contributing to the light extinction is OilGas.

Table 18: TRNP Ammonium Sulfate light Extinction on the Clearest Days

State	EGU	OilGas	Mobile	NonEGU	RemainAnthro	Total	Percent of Total
ND	0.01	0.30	0.01	0.00	0.01	**0.32**	56%
AZ	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
CA	0.00	0.00	0.00	0.00	0.00	**0.01**	1%
CO	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
ID	0.00	0.00	0.00	0.01	0.00	**0.01**	2%
MT	0.07	0.04	0.00	0.04	0.02	**0.17**	30%
NM	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
NV	0.00	0.00	0.00	0.00	0.00	**0.01**	1%
OR	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
SD	0.00	0.00	0.00	0.00	0.00	**0.00**	0%
UT	0.00	0.00	0.00	0.00	0.00	**0.00**	1%
WA	0.00	0.00	0.00	0.01	0.00	**0.01**	2%
WY	0.02	0.01	0.00	0.00	0.00	**0.03**	5%
RemUS	0.00	0.00	0.00	0.00	0.00	**0.01**	1%
Total	**0.10**	**0.35**	**0.01**	**0.07**	**0.04**	**0.58**	100%

Table 18 shows the state and source category breakdown of ammonium sulfate light extinction contributions on the clearest days at TRNP. North Dakota sources contribute 56% of the total US_Anthro ammonium sulfate light extinction at TRNP on the clearest days, with Montana sources contributing 30%. The remaining 14% primarily comes from WY (5%), with all other continental US WRAP states accounting for the remaining 9%. On an overall magnitude basis, US_Anthro impairment from outside of ND is small. The highest state modeled impairment from MT is 0.17 Mm^{-1}.

North Dakota's 56% contribution is mostly from the OilGas sector. Of the North Dakota contribution, OilGas accounts for 52% of the total US_Anthro light extinction. The magnitude of the projected OilGas impairment is small at only 0.30 Mm^{-1}.

2.2.3 North Dakota Sector Contribution on the Clearest Days

The impairment caused by North Dakota sectors can also be compared to the overall species light extinction projection for 2028. The following is a breakdown of species light extinction: US anthropogenic (US_Anthro), International anthropogenic (Int_Anthro), Natural, prescribed wildland fire (US_RxWildlandFire), US wildfire, and Canada Mexico Fires (CanMexFire) is discussed in detail and is included in Section 1.2. The following breakdown shows the impairment caused by the North Dakota sectors as compared to the species light extinction for the 2028OTB scenario. US_Anthro sources have been broken down into the following sectors: North Dakota electrical generating utilities (ND EGU);

North Dakota Oil and Gas point and area sources (ND OilGas); North Dakota mobile onroad, non-road, rail, and commercial marine vessels (ND Mobile); Other North Dakota point sources (ND NonEGU); all remaining anthropogenic emissions including fugitive dust, agriculture, agricultural fire, residential wood combustion, and all remaining nonpoint sources (ND RemainAnthro); all US_Anthro minus the North Dakota sectors (Remaining US); and the Boundary Conditions from US emissions (BCUS). The species breakdown for all US_Anthro sources and sectors was limited to ammonium nitrate and ammonium sulfate. Therefore, impairment from the species of coarse mass, elemental carbon, organic mass, sea salt, and soil for all US_Anthro sources (including North Dakota sources) are included in the "Remaining US" row for Table 19 and Table 20. Note that Tribal oil and gas emissions are assigned to the ND OilGas category.

Table 19: LWA Sector and Source Category Contributions to Species Light Extinction on Clearest Days

Sector	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Grand Total
ND EGU	0%	1%	--	--	--	--	--	**1%**
ND OilGas	2%	3%	--	--	--	--	--	**5%**
ND Mobile	0%	0%	--	--	--	--	--	**0%**
ND NonEGU	0%	0%	--	--	--	--	--	**0%**
ND RemainAnthroND	1%	1%	--	--	--	--	--	**1%**
Remaining US	1%	1%	8%	1%	2%	0%	1%	**14%**
BCUS	0%	0%	--	--	--	--	--	**0%**
Int_Anthro	**8%**	**18%**	**10%**	**3%**	**1%**	**0%**	**1%**	**41%**
CanMexFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**1%**
Natural	**4%**	**9%**	**1%**	**1%**	**6%**	**2%**	**0%**	**23%**
US_RxWildlandFire	**1%**	**3%**	**0%**	**1%**	**6%**	**0%**	**0%**	**12%**
US_WildFire	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**1%**
Grand Total	**17%**	**36%**	**19%**	**7%**	**17%**	**2%**	**2%**	**100%**

Table 19 shows the percent breakdown of the total species light extinction contributions from different source categories and sectors at LWA. US_Anthro sources contribute to 22% of the total light extinction, with approximately 3% and 6% attributed to ammonium nitrate and ammonium sulfate, respectively. ND sectors contribute to 7% of the species light extinction. The largest source category contributor is ND OilGas at 5%, with ND EGU being approximately 1%. Int_Anthro contributes 41% to the species light extinction. The other significant contributors outside of these is Natural at 23% and prescribed fires at 12%.

Table 20: TRNP Sector and Source Category Contributions to Species Light Extinction on Clearest Days

Sector	Ammonium Nitrate	Ammonium Sulfate	Coarse Mass	Elemental Carbon	Organic Mass	Sea Salt	Soil	Grand Total
ND EGU	0%	0%	--	--	--	--	--	**0%**
ND OilGas	1%	5%	--	--	--	--	--	**5%**
ND Mobile	0%	0%	--	--	--	--	--	**0%**
ND NonEGU	0%	0%	--	--	--	--	--	**0%**
ND RemainAnthroND	0%	0%	--	--	--	--	--	**1%**
Remaining US	2%	4%	16%	3%	8%	0%	3%	**36%**
BCUS	0%	0%	--	--	--	--	--	**0%**
Int_Anthro	**5%**	**15%**	**4%**	**2%**	**3%**	**0%**	**1%**	**29%**
CanMexFire	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Natural	**2%**	**10%**	**5%**	**0%**	**7%**	**1%**	**0%**	**25%**
US_RxWildlandFire	**0%**	**0%**	**0%**	**0%**	**2%**	**0%**	**0%**	**3%**
US_WildFire	**0%**	**0%**	**0%**	**0%**	**1%**	**0%**	**0%**	**1%**
Grand Total	**11%**	**34%**	**25%**	**5%**	**20%**	**1%**	**4%**	**100%**

Table 20 shows the percent breakdown of the total species light extinction contributions from different source categories and sectors at TRNP. US_Anthro sources contribute to 42% of the species light extinction, with approximately 4% and 9% attributed to ammonium nitrate and ammonium sulfate, respectively. ND sectors only contribute to 7% of the species light extinction. The largest source category contributor is ND OilGas at 5%, with ND EGU being less than 1%. Int_Anthro contributes 29% to the species light extinction. The other significant contributor outside of these is Natural at 25%.

C.3 – Weighted Emissions Potential and Area of Influence Summary Results

1 Introduction and Background

Weighted Emissions Potential (WEP) and Area of Influence (AOI) products were made available for Regional Haze planning uses in the western U.S. The analysis was performed for the Most Impaired Days (MID) during each year of the 5-year period from 2014 through 2018 at 76 IMPROVE monitoring sites representing 116 Class I Areas (CIAs) in the 13 states of the contiguous WESTAR-WRAP region and neighboring states. The results were calculated for the 12WUS2 modeling domain aggregated to 36-kilometer resolution. Plots were provided for the 100m and 1000m trajectory heights and for a combined analysis in which data from all four trajectory heights were aggregated. For the purpose of this document the Department evaluated the combined analysis. Emissions originating from outside the 12WUS2 modeling domain were not included in this analysis. For example, the emissions from the nearby Canadian Electric Generating Units (EGU) are included but impacts from the Canadian oil sands are not. See Section 4.7 of the SIP for discussion on emissions from Canadian sources. International emissions were not placed into source categories and are only shown in Total Anthropogenic WEP figures.

The WEP is obtained by overlaying the extinction weighted residence time (EWRT) results with 2028 OTB emissions of light extinction precursors. The results were then normalized by the sum of the WEP for the total anthropogenic emissions. The dark green and light green isopleths in the WEP plots correspond to the 0.5 and 0.1 percent frequency, respectively, from the corresponding EWRT. This document shows the WEP analysis for nitrogen oxides (NO_x) and sulfur dioxide (SO_2) at each North Dakota and nearby CIA for five source sectors: Total Anthropogenic, Oil and Gas, EGUs, On-road mobile, and off highway mobile (Non-road). For each CIA, SO_2 for the on-road and off highway source sectors provided negligible results and were not included.

Complete species, including organic aerosol and elemental carbon, can be found for each western CIAs through the WRAP Technical Support System webpage.[1]

2 North Dakota

2.1 Theodore Roosevelt National Park

Figures 1 through 4 shows the WEP results for Theodore Roosevelt National Park.

[1] Available at: https://views.cira.colostate.edu/tssv2/WEP-AOI/ (Last Visited December 30, 2020)

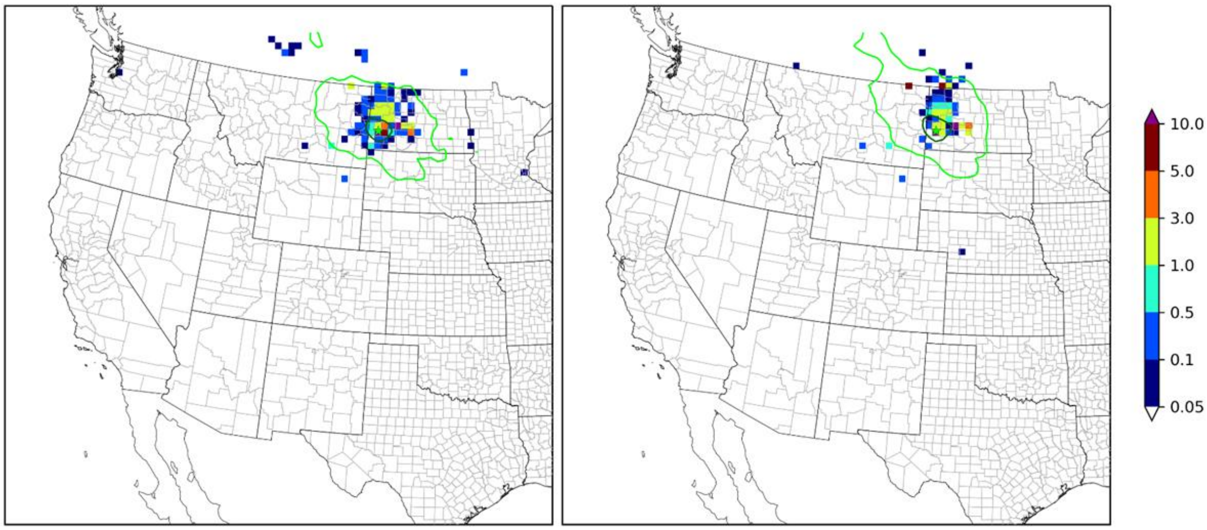

Figure 1: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 1 displays the NO_x and SO_2 WEP for total anthropogenic emissions. Most potential anthropogenic impairment comes from sources within North Dakota. A few areas outside of North Dakota show up at minimal levels, none of which were large enough to warrant additional review from North Dakota.

It is difficult to determine any individual sector impacts when looking at all source sectors combined, therefore, Figures 2 through 4 have been provided to show the results at the source category level for Theodore Roosevelt National Park.

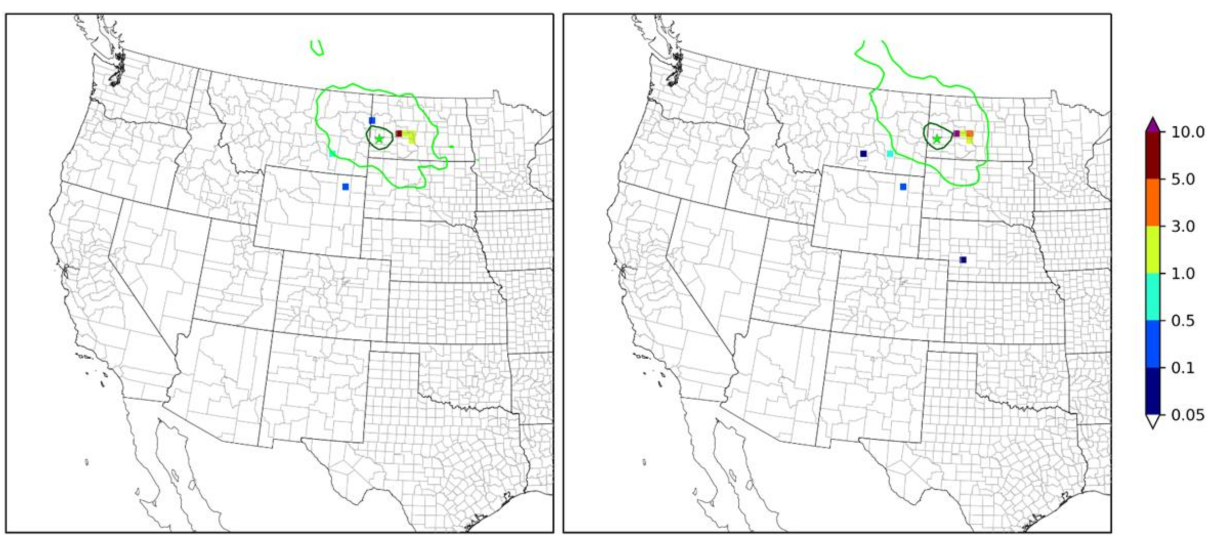

Figure 2: EGU WEP for NO_x (left) and SO_2 (right)

As displayed in Figure 2, most of the potential EGU impairment comes from sources within North Dakota. The potential impairment contribution from EGUs outside of the state were too minor to warrant further review from North Dakota during this planning period. Emissions from North Dakota EGU activity are included in Section 4.2.1 of the SIP.

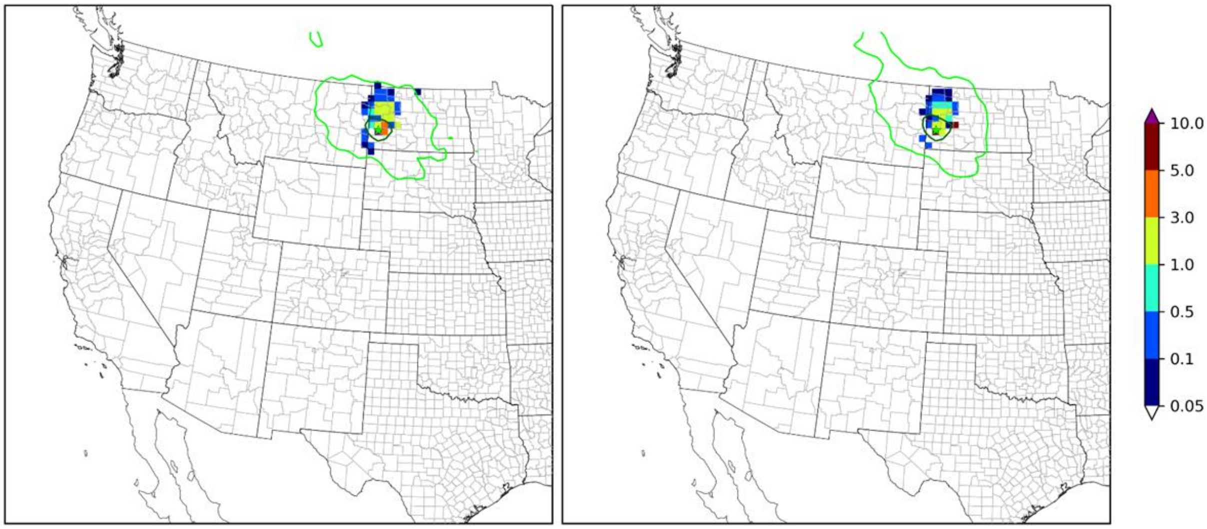

Figure 3: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 3 indicates that the potential impairment from the oil and gas sector comes from sources located within the state, with some very minor potential contributions along the Montana border. As such, oil and gas sources outside of the state did not warrant further review. Emissions from North Dakota oil and gas activity are included in Section 4.3.1 of the SIP. North Dakota is monitoring the development of the oil and gas field and will address impacts from this sector in future planning periods, as needed.

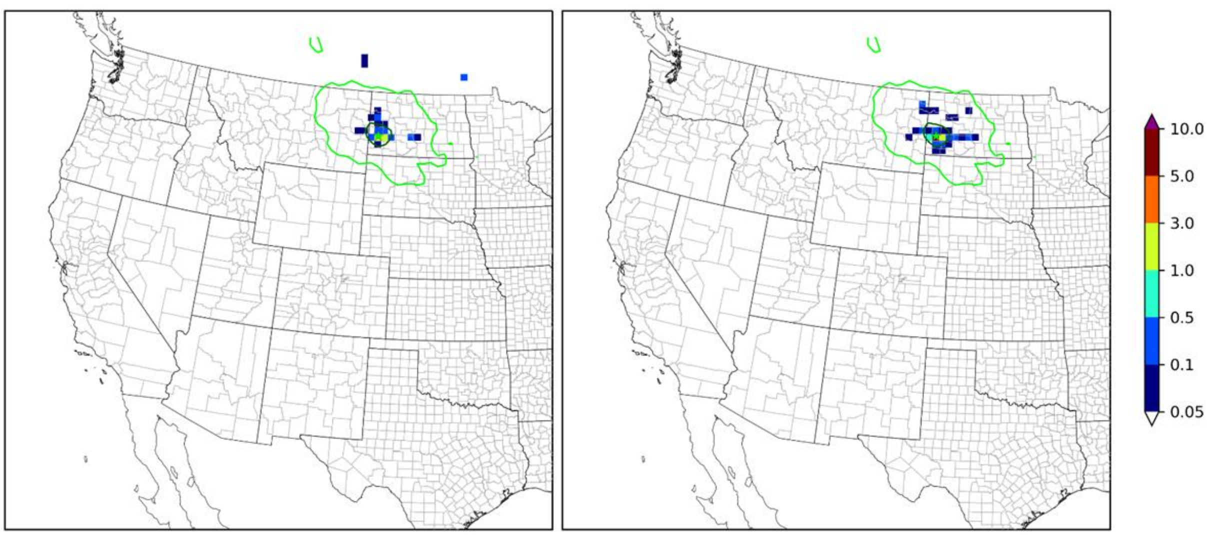

Figure 4: On-road (left) and Non-road (right) WEP for NO_x

Figure 4 shows that the contributions of the on-road and non-road sectors to potential impairment are minimal. As expected, much of the potential contribution follow the main transportation corridor in North Dakota, Interstate 94. Emissions from North Dakota non-road and on-road sectors are included in Section 4.4 and Section 4.5, respectively, in the SIP. The basis of the 2028 OTB mobile source emission inventories utilized both the WRAP 2014NEIv2 dataset as well as the 2014-2016 National Emissions

Modeling Collaborative 2016v1 future year 2028 inventory, with revisions per state agency input. North Dakota did not have any suggested changes to this dataset.

2.2 Lostwood National Wildlife Refuge

Figures 5 through 8 shows the WEP results for Lostwood National Wildlife Refuge.

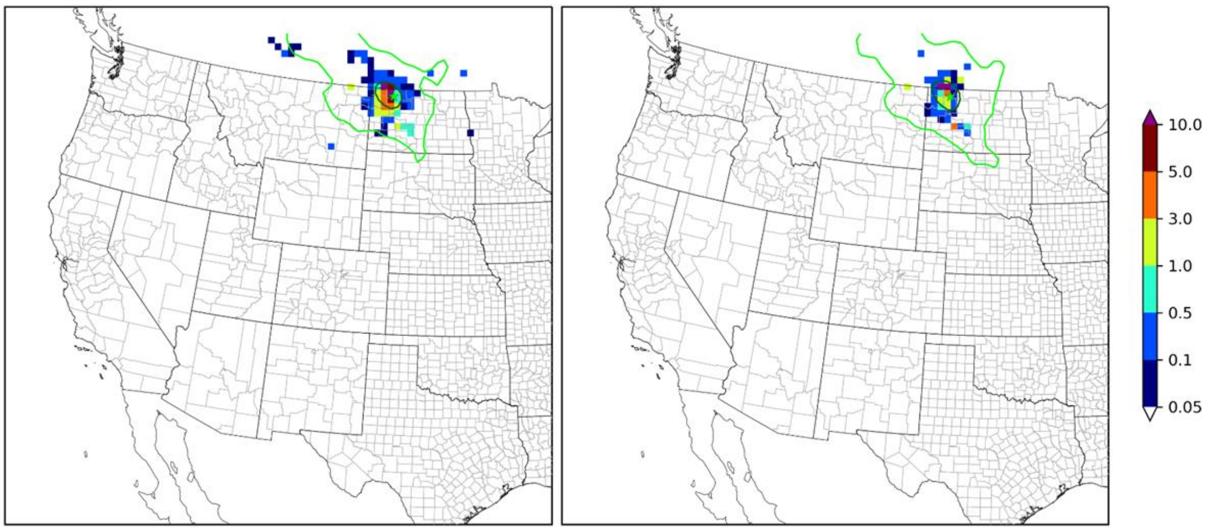

Figure 5: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 5 displays the NO_x and SO_2 WEP for total anthropogenic emissions. Most potential anthropogenic impairment comes from sources within North Dakota and just north of the Canadian border. International contributions are not able to be addressed. Potential impairment from Montana source's is minimal, not warranting additional review.

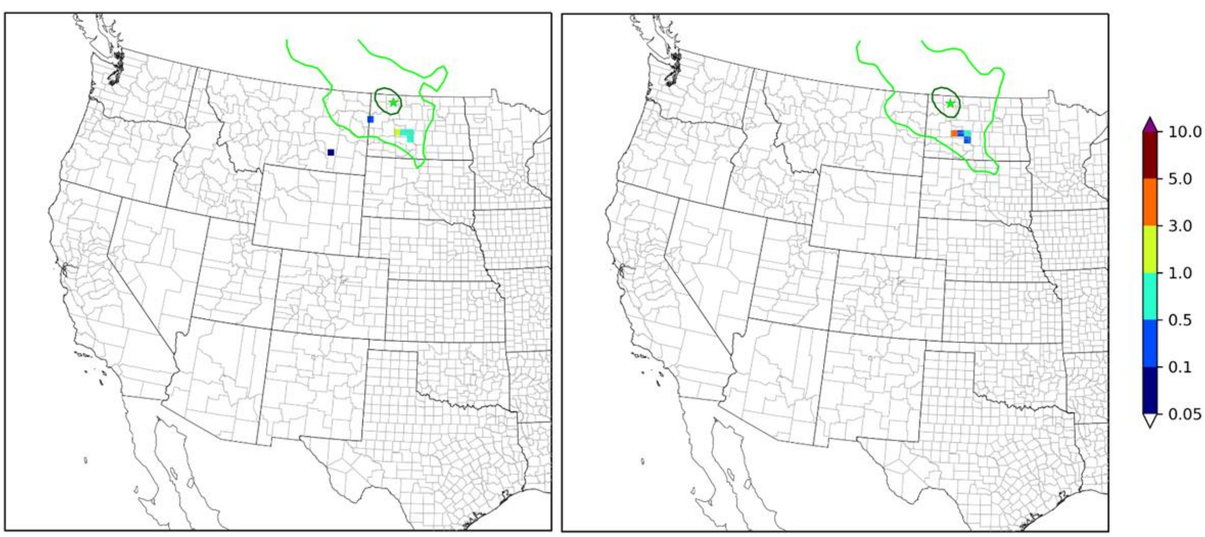

Figure 6: EGU WEP for NO_x (left) and SO_2 (right)

Figure 6 shows that the only EGU sources with an impairment potential that warrants review are located within North Dakota. The potential impairment contribution from EGUs outside of the state were too minor to warrant further review from North Dakota during this planning period. Emissions from North Dakota EGUs are included in Section 4.2.1 of the SIP.

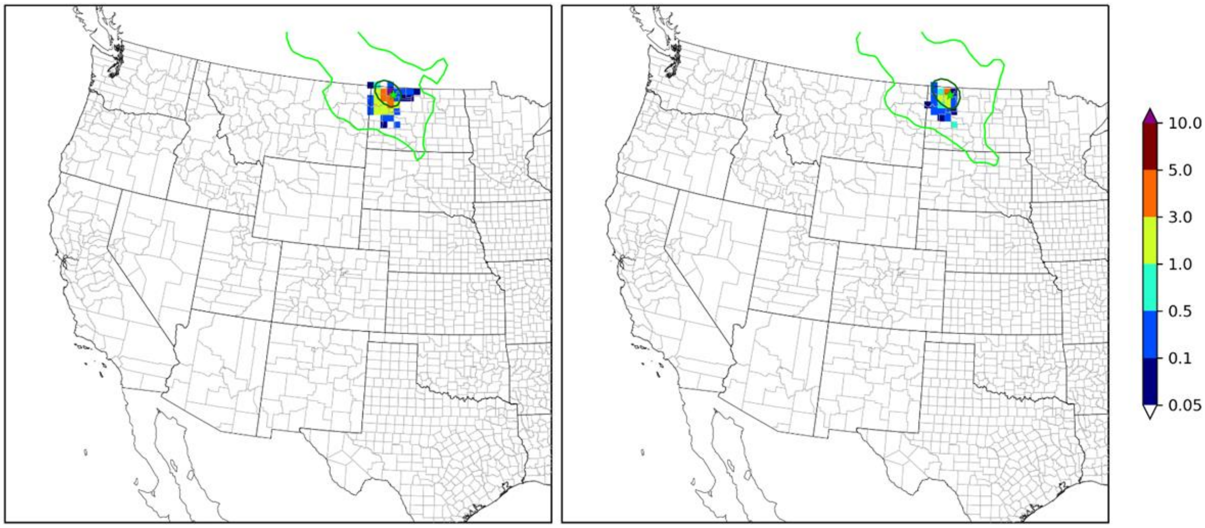

Figure 7: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 7 shows that no oil and gas area sources outside of the state have a significant potential to contribute to visibility impairment at Lostwood Wildlife Refuge. Emissions from North Dakota oil and gas activity are included in Section 4.3.1 of the SIP. North Dakota is monitoring the development of the oil and gas field and will address impacts from this sector in future planning periods, as needed.

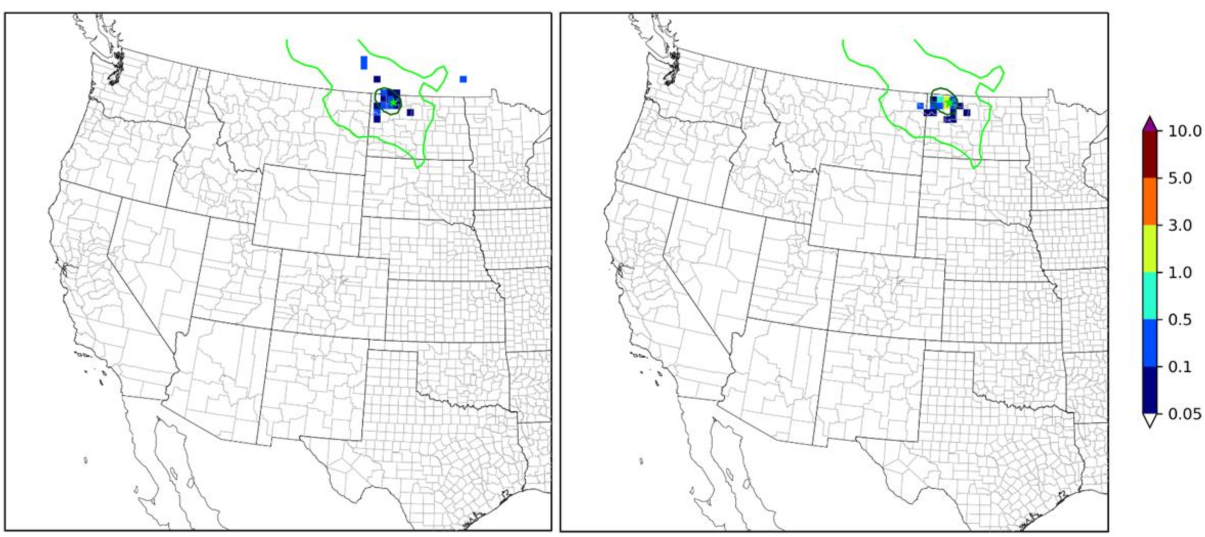

Figure 8: On-road (left) and Non-road (right) WEP for NO_x

Figure 8 shows that the contributions of the on-road and non-road sectors to impairment potentials are minimal and did not warrant review. Emissions from North Dakota non-road and on-road sectors are included in Section 4.4 and Section 4.5, respectively, in the SIP.

3 Minnesota

3.1 Voyageurs National Park

Figures 9 through 12 shows the WEP results for Voyageurs National Park. These results are also considered reflective of any potential impairment at Boundary Waters Canoe Area that emanates from North Dakota sources. This correlation was used since WEP results for Boundary Waters Canoe Area were not completed by WRAP. Additionally, Voyageurs National Park is located roughly 140 kilometers northwest of Boundary Waters Canoe Area. Therefore, Voyageurs National Park is closer to North Dakota and thus more likely to experience any potential impairment from North Dakota sources.

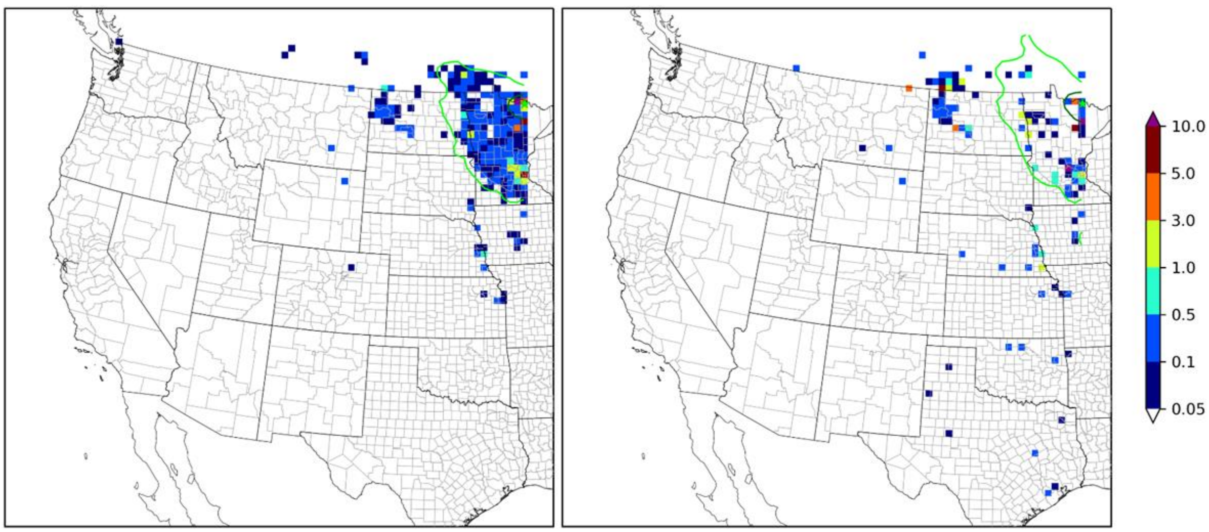

Figure 9: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 9 demonstrates that North Dakota sources have a minimal potential to impair visibility at Voyageurs National Park. The contributions along the northern border of North Dakota are Canadian contributions, which were not separated into source categories. Therefore, they are only shown in the Total Anthropogenic WEP.

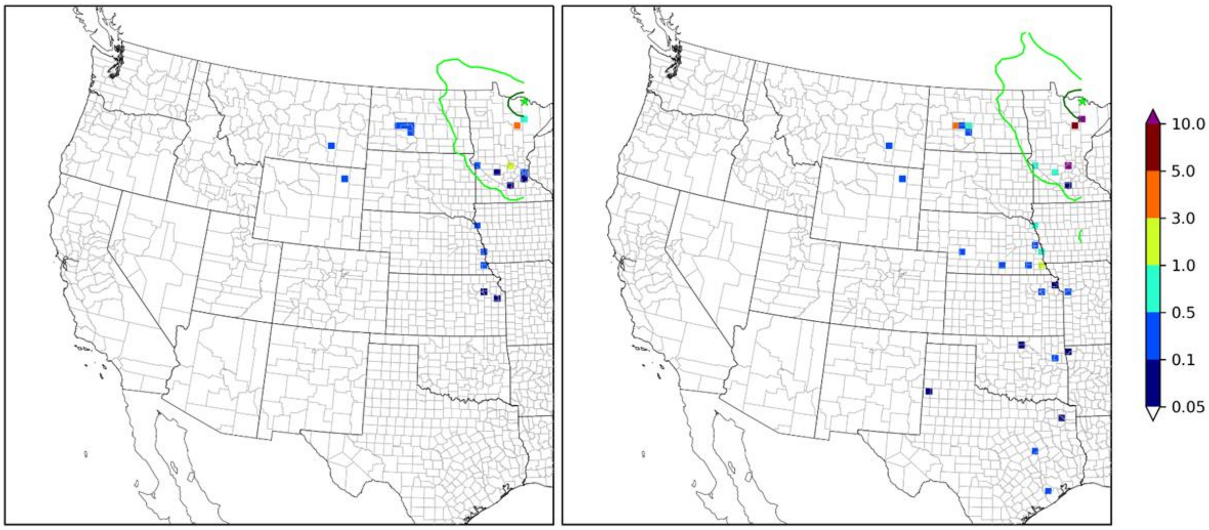

Figure 10: EGU WEP for NO_x (left) and SO_2 (right)

As stated before, Figure 10 shows that North Dakota sources have minimal contributions to impairment potentials at Voyageurs National Park. North Dakota EGU sources show some potential for impairment regarding SO_2, justifying the Department's consideration of additional controls for reasonable progress. The four-factor analyses can be found in Section 5.2, Appendix A, and Appendix B of the SIP.

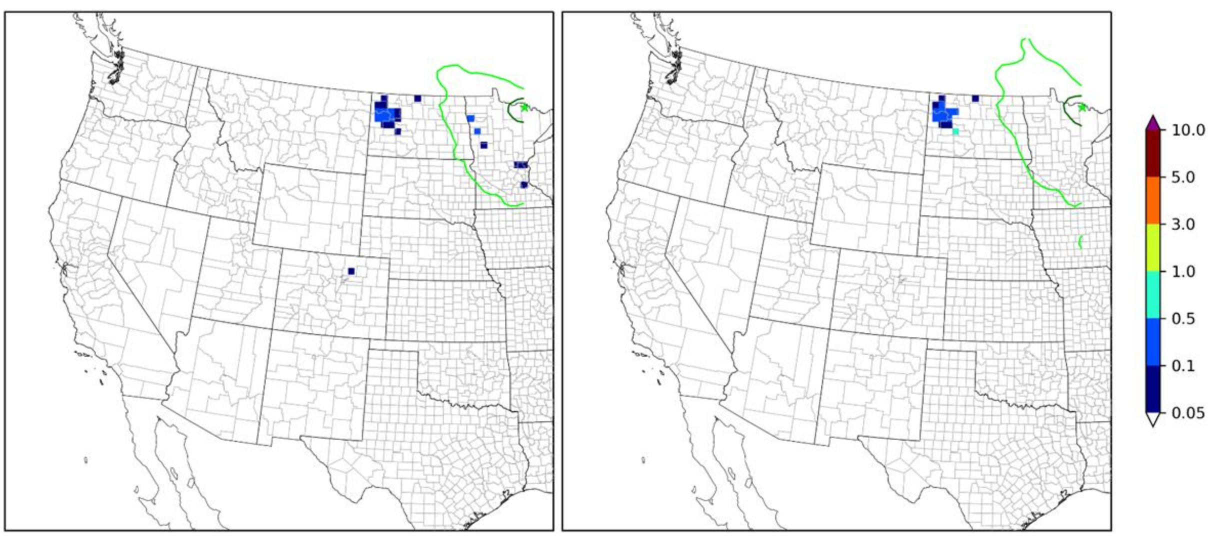

Figure 11: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 11 demonstrates that North Dakota oil and gas sources have a minimal impairment potential at Voyageurs National Park. Oil and gas activity is currently being monitored by the Department and is addressed in Section 5.2.11 of the SIP.

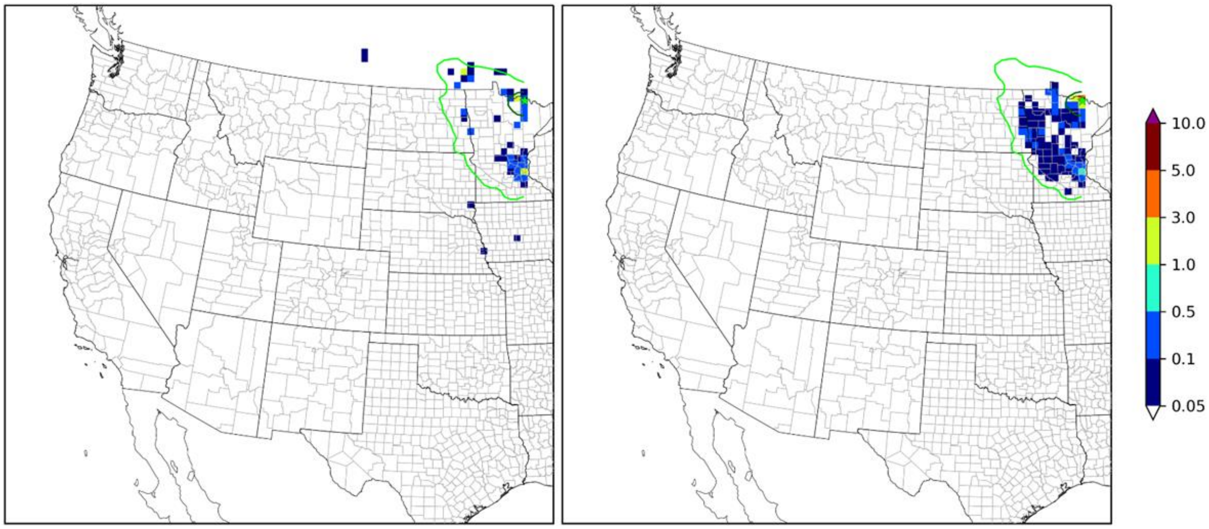

Figure 12: On-road (left) and Non-road (right) WEP for NO_x

As shown in Figure 12, much of the potential impairment from on-road and non-road sources comes from within Minnesota. On-road and non-road contributions to potential impairment at Voyageurs National Park are minimal along the North Dakota and Minnesota border and did not warrant review.

4 Montana

4.1 Medicine Lake Wilderness Area

Figures 13 through 16 shows the WEP results for Medicine Lake Wilderness Area.

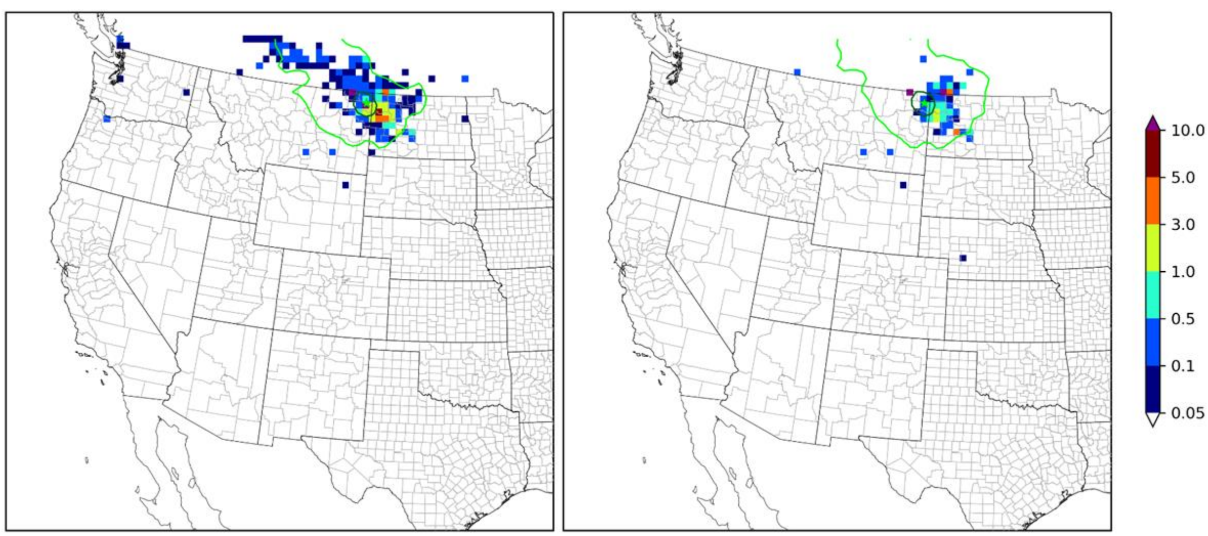

Figure 13: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 13 displays the NO_x and SO_2 WEP for total anthropogenic emissions. The following figures will demonstrate that North Dakota's contributions to impairment potential are limited to the EGU and oil and gas sectors, justifying the Department’s consideration of additional controls for reasonable progress.

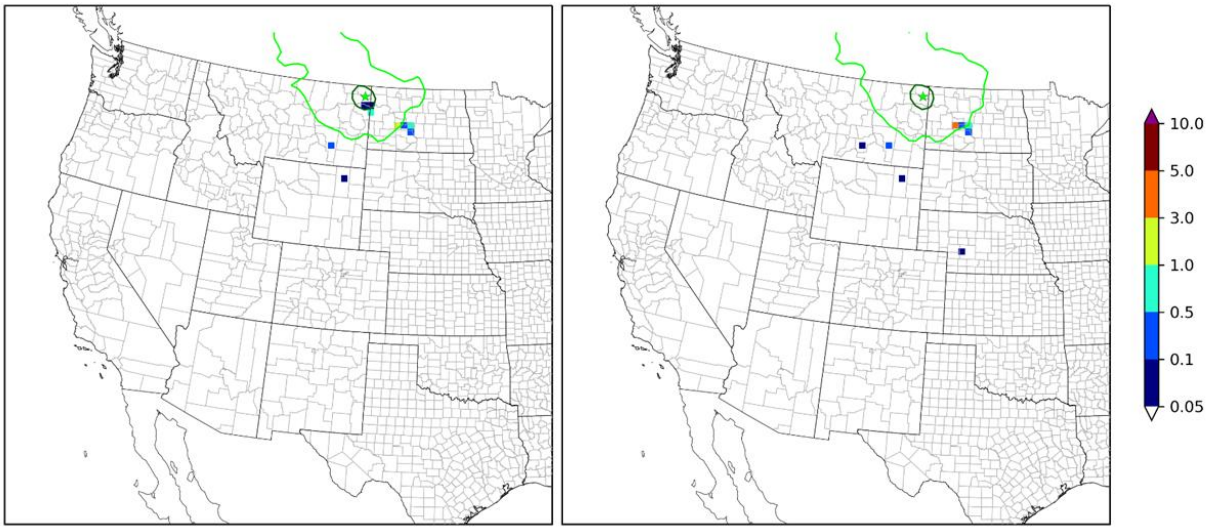

Figure 14: EGU WEP for NO_x (left) and SO_2 (right)

Figure 14 shows that North Dakota EGU sources have some potential for impairment regarding SO_2 and NO_X. This supports the Department’s consideration of additional controls for reasonable progress on those sources, see SIP Section 5.2.

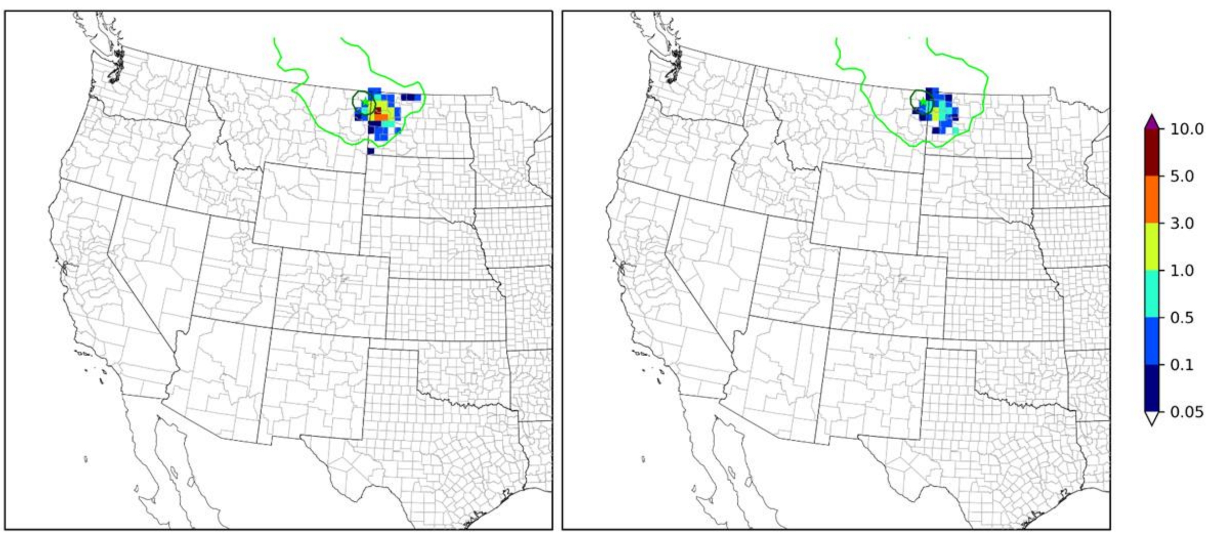

Figure 15: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 15 demonstrates the potential for impairment from North Dakota oil and gas sources, validating the Department’s review of this activity. Oil and gas activity is currently being monitored by the Department and is addressed in Section 5.2.11 of the SIP.

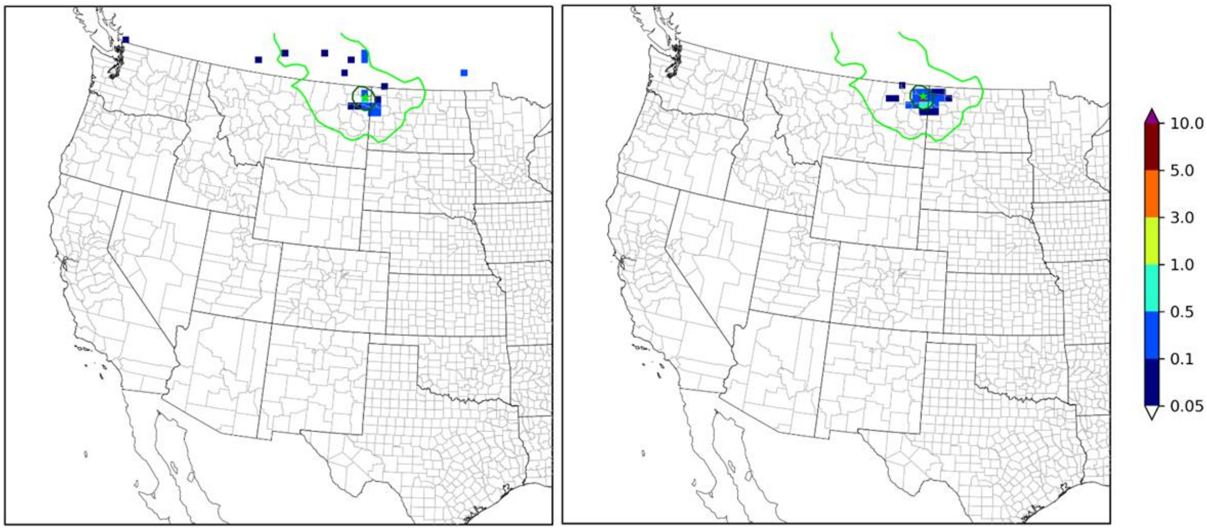

Figure 16: On-road (left) and Non-road (right) WEP for NO_x

Figure 16 indicates that the more significant potential impairment from on-road and non-road sources comes from Northeastern Montana and northwester North Dakota. Overall, on-road and non-road contributions to potential impairment at Medicine Lake Wilderness Area are minimal and did not warrant review.

4.2 UL Bend Wilderness Area

Figures 17 through 20 shows the WEP results for UL Bend Wilderness Area.

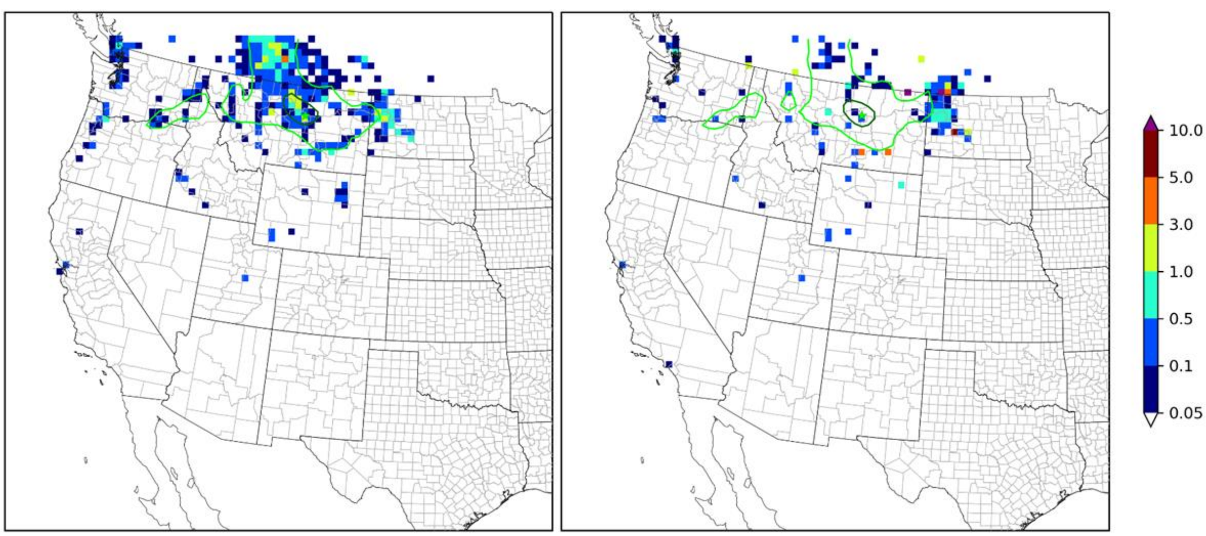

Figure 17: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 17 displays the NO_x and SO_2 WEP for total anthropogenic emissions. North Dakota contributions to the potential for impairment are minimal outside of the potential impact from EGU and oil and gas sectors.

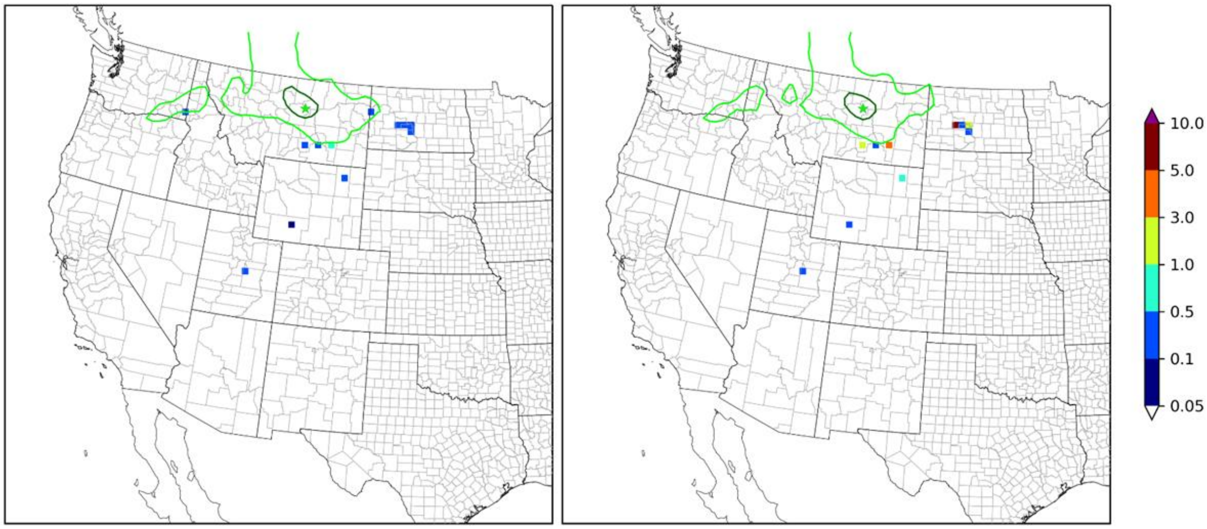

Figure 18: EGU WEP for NO_x (left) and SO_2 (right)

Figure 18 indicates that North Dakota EGU sources contribute to potential impairment regarding SO_2 at UL Bend Wilderness Area. This validates the consideration of additional controls for reasonable progress on those sources, see SIP Section 5.2.

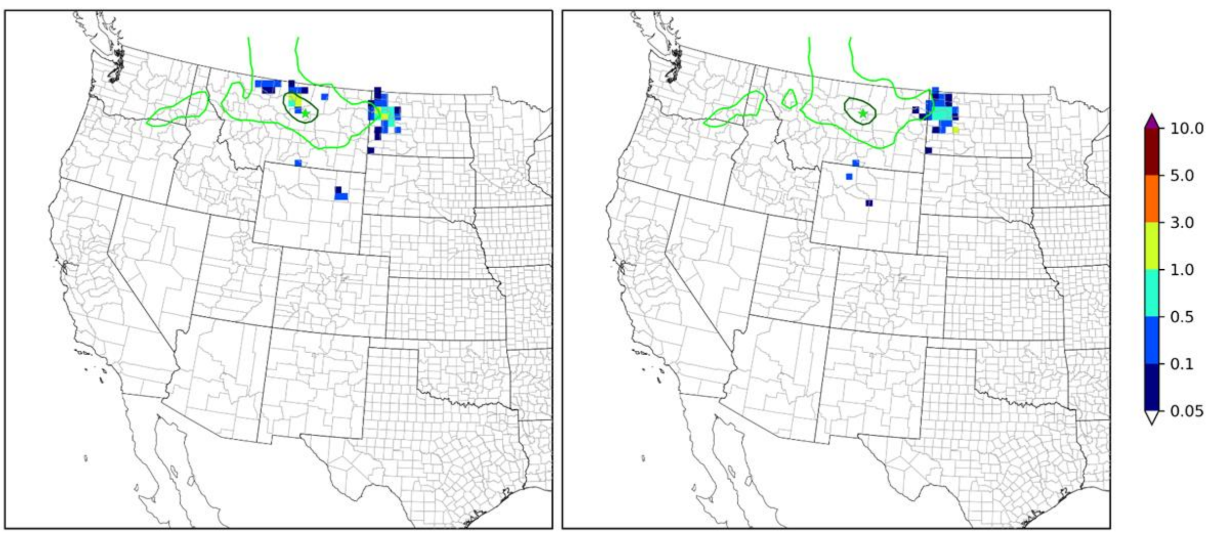

Figure 19: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 19 shows that North Dakota oil and gas sources have a minimal impairment potential at UL Bend Wilderness Area. Oil and gas activity is currently being monitored by the Department and is addressed in Section 5.2.11 of the SIP.

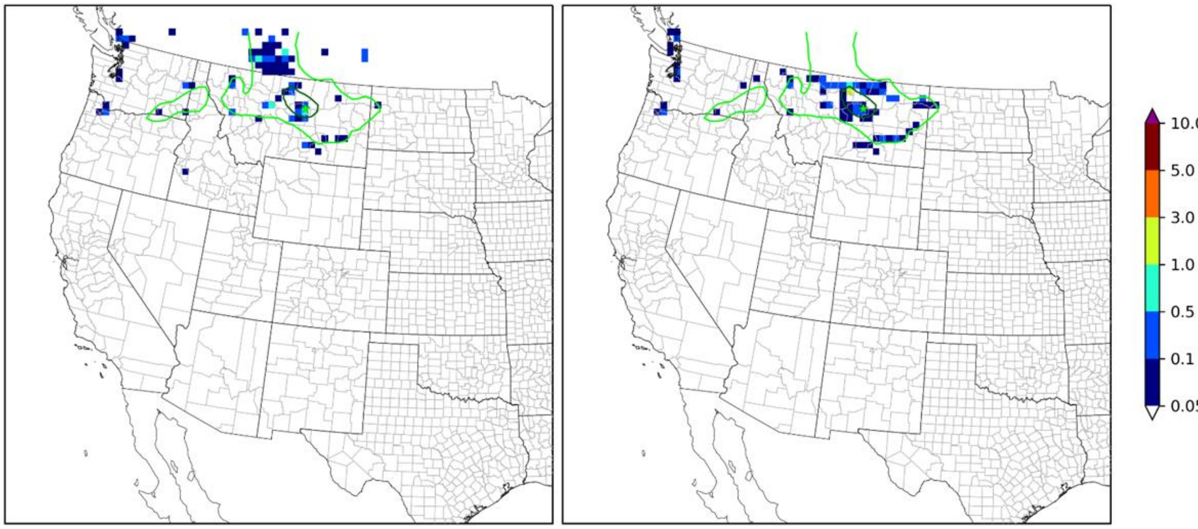

Figure 20: On-road (left) and Non-road (right) WEP for NO_x

Figure 20 indicates that the potential impairment from on-road and non-road sources at UL Bend Wilderness Area comes from within Montana. North Dakota on-road and non-road contributions to potential impairment are very minimal and did not warrant review.

5 South Dakota

5.1 Badlands National Park

Figures 21 through 24 shows the WEP results for Badlands National Park.

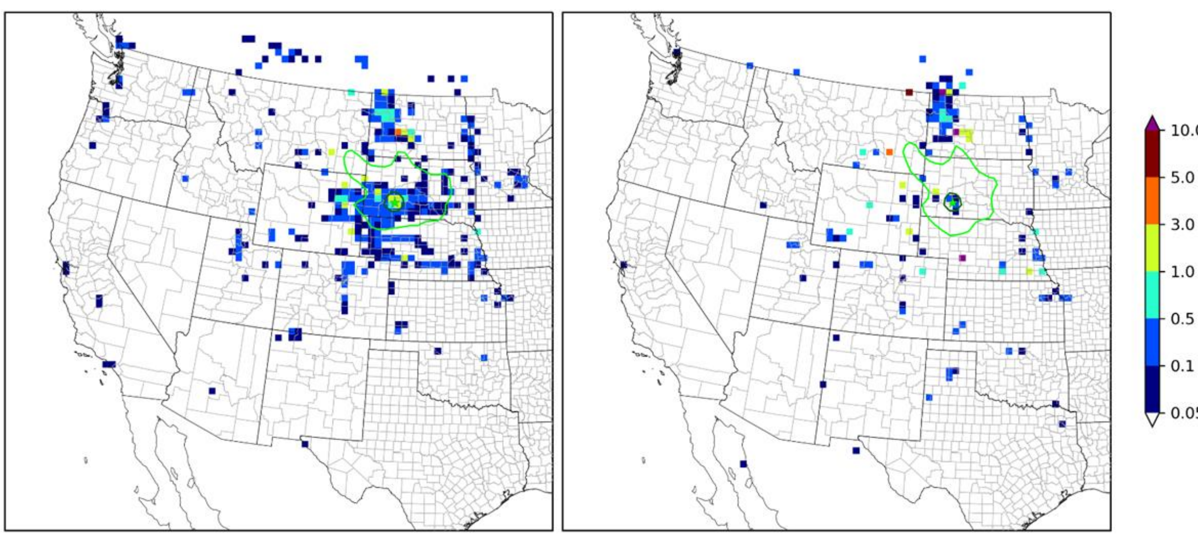

Figure 21: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 21 displays the NO_x and SO_2 WEP for total anthropogenic emissions. The following figures will demonstrate that North Dakota's contributions to impairment potential are limited to the EGU and oil and gas sectors, justifying the Department’s consideration of additional controls for reasonable progress.

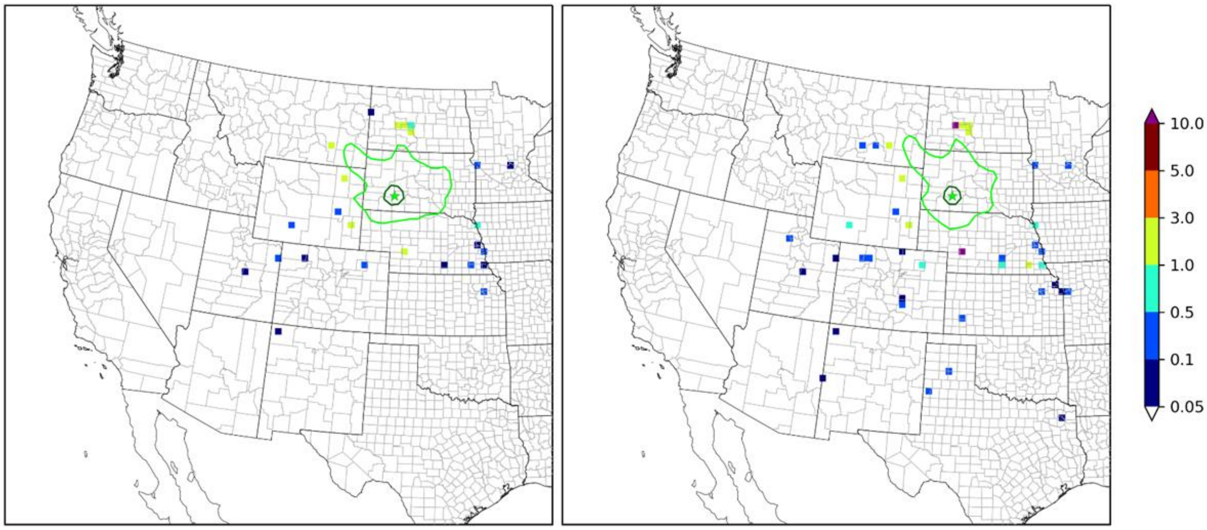

Figure 22: EGU WEP for NO_x (left) and SO_2 (right)

Figure 22 displays North Dakota EGU’s impairment potential at Badlands National Park, supporting the consideration of additional controls for reasonable progress, see SIP Section 5.2.

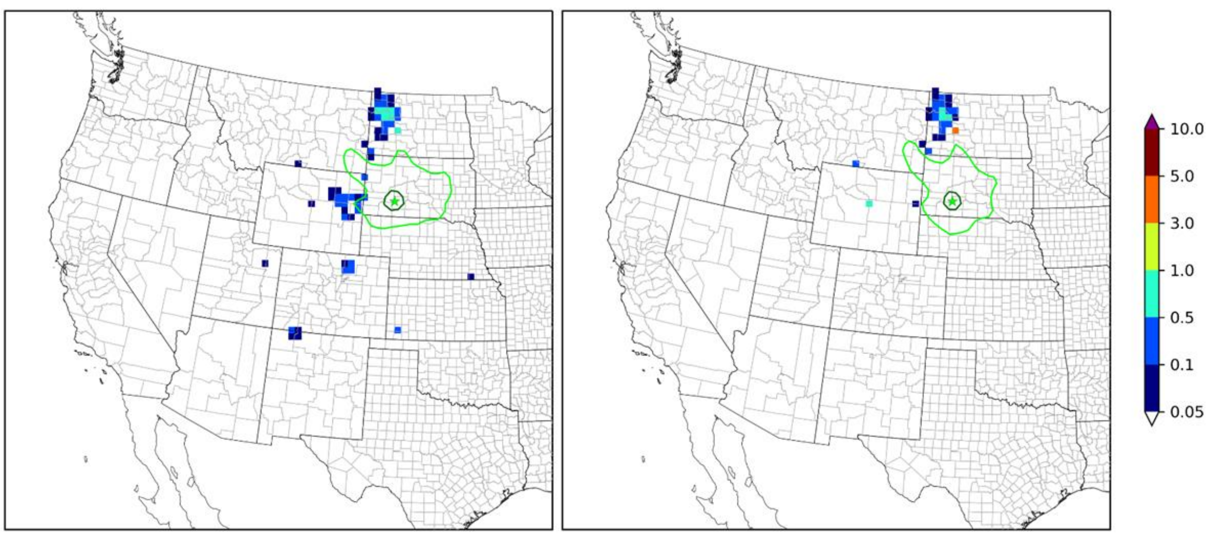

Figure 23: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 23 shows that North Dakota oil and gas sources have minimal impairment potential for NO_x, with some potential for SO_2. This supports the review of this sector. Oil and gas activity is currently being monitored by the Department and is addressed in Section 5.2.11 of the SIP.

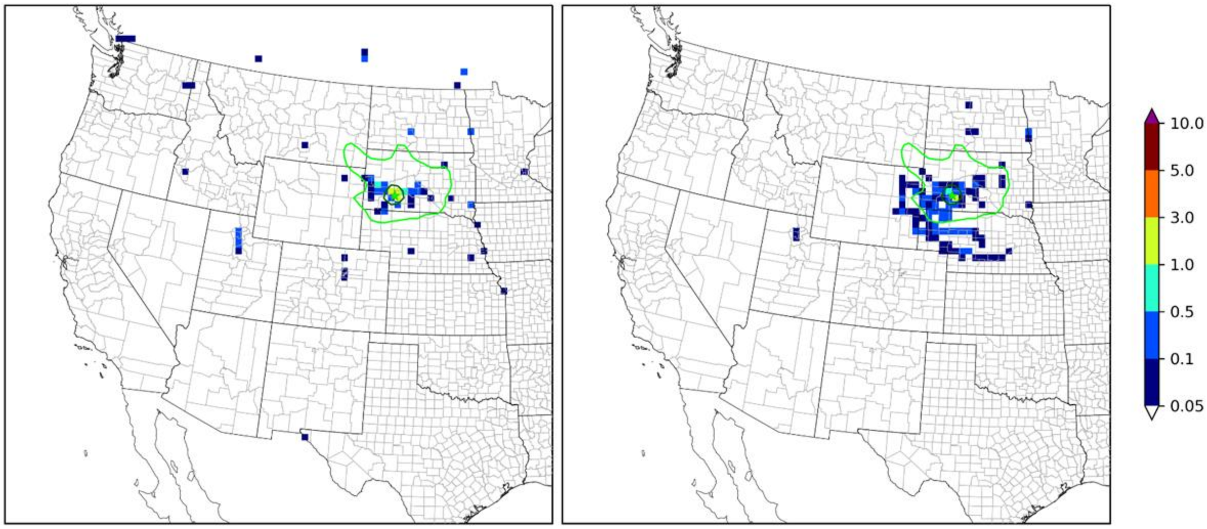

Figure 24: On-road (left) and Non-road (right) WEP for NO_x

Figure 24 indicates that the potential impairment from on-road and non-road sources at Badlands National Park largely comes from South Dakota, Wyoming and Nebraska. North Dakota on-road and non-road contributions to potential impairment at Badlands National Park are almost nonexistent and did not warrant review.

5.2 Wind Cave National Park

Figures 25 through 28 shows the WEP results for Wind Cave National Park.

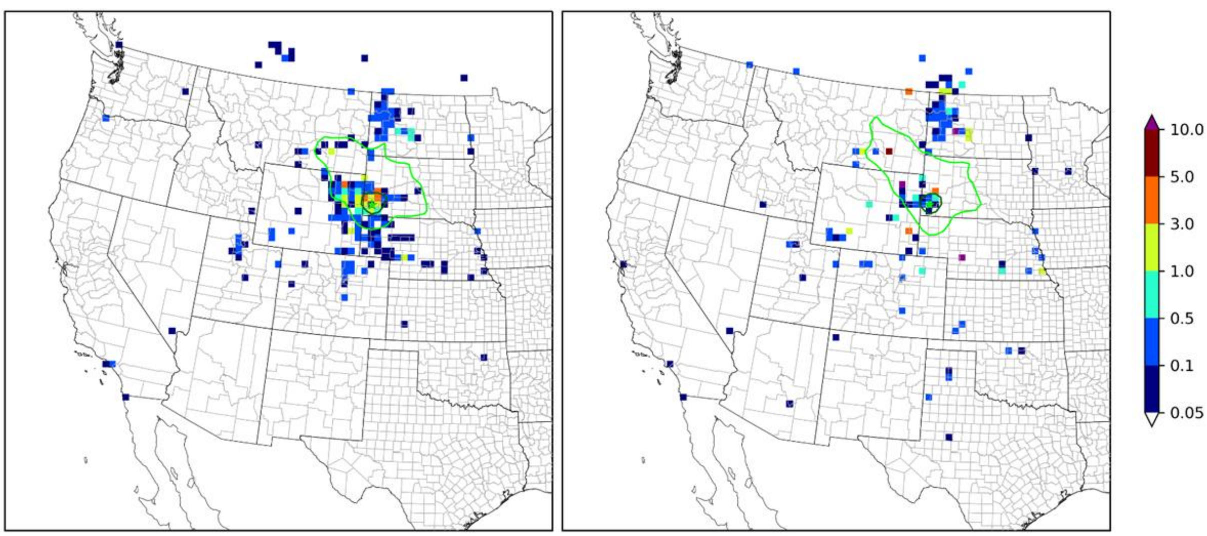

Figure 25: Total Anthropogenic WEP for NO_x (left) and SO_2 (right)

Figure 25 displays the NO_x and SO_2 WEP for total anthropogenic emissions. North Dakota contributions to the potential for impairment are minimal outside of the EGU and oil and gas sector.

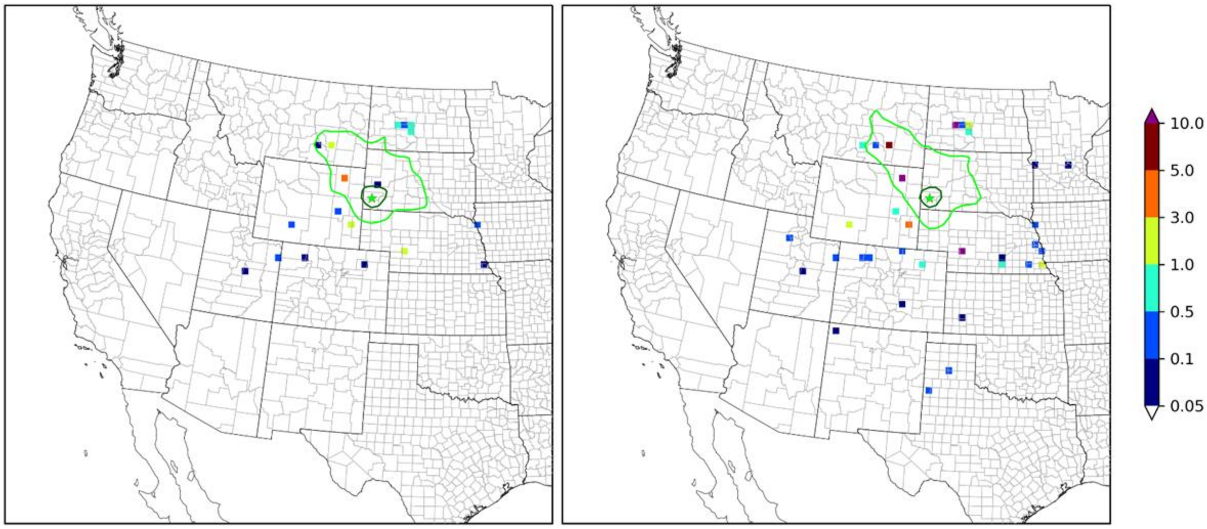

Figure 26: EGU WEP for NO_x (left) and SO_2 (right)

Figure 26 shows that North Dakota EGU sources contribute to potential impairment regarding SO_2 at Wind Cave National Park. This supports the consideration of additional controls for reasonable progress, see SIP Section 5.2.

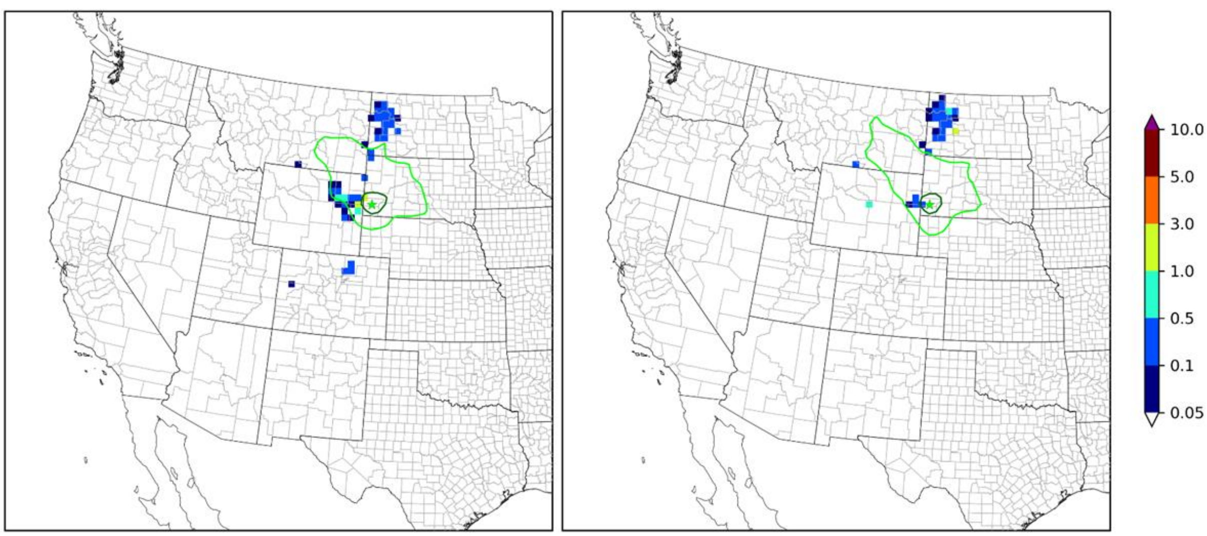

Figure 27: Oil and Gas WEP for NO_x (left) and SO_2 (right)

Figure 27 shows that North Dakota oil and gas sources have a minimal impairment potential at Wind Cave National Park. Oil and gas activity is currently being monitored by the Department and is addressed in Section 5.2.11 of the SIP.

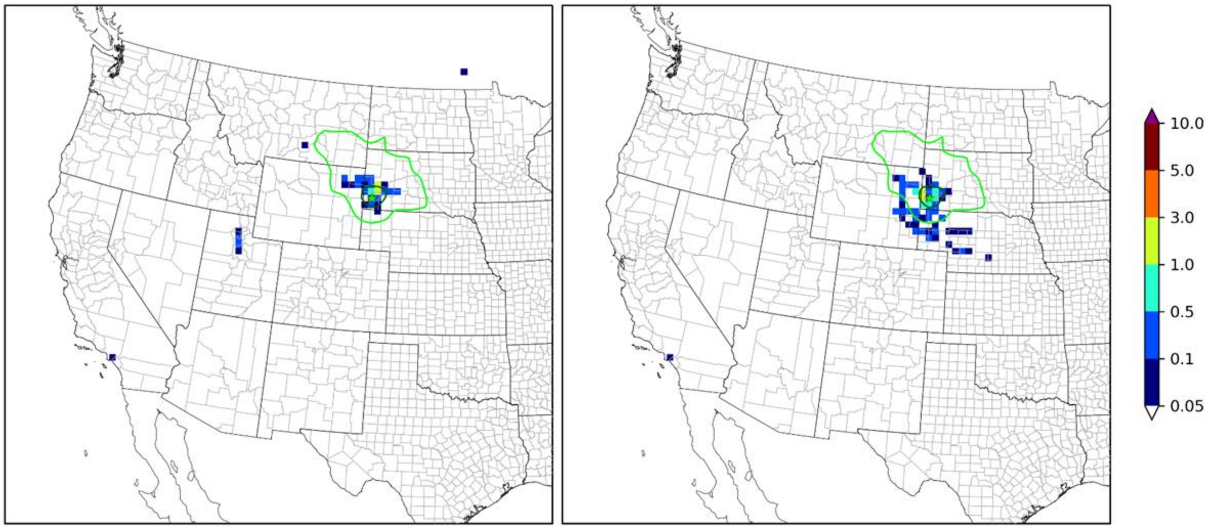

Figure 28: On-road (left) and Non-road (right) WEP for NO_x

Figure 28 indicates that the potential impairment from on-road and non-road sources at Wind Cave National Park largely comes from South Dakota, Wyoming and Nebraska. North Dakota has zero on-road and non-road contributions to potential impairment at Wind Cave National Park and did not warrant review.

6 Summary and Conclusions

The WEP analyses for Theodore Roosevelt National Park and Lostwood National Park support North Dakota's decision to evaluate the upstream oil and gas and EGU sources, as these are the major sectors that showed a potential for visibility impairment in the Class I areas. The WEP analyses also demonstrate that the potential impairment contribution from sources outside of North Dakota were minor and did not warrant further review from North Dakota during this planning period. The analyses of the nearby Montana, South Dakota, and Minnesota CIAs further support the decision to evaluate the oil and gas and EGU sources, as the potential for impairment was mostly limited to these sectors.

C.4 – WRAP Modeling Delays

February 8, 2021

To: WESTAR States and all WRAP member agencies

Re: Regional Haze modeling delays letter

Attached please find the letter from Ramboll U.S. Contracting - Environment and Health unit, detailing and explaining the reasons for delays in completing Regional Haze modeling under contract to WESTAR. The letter thoroughly describes the chronology of issues Ramboll experienced. The Regional Haze modeling effort for the 100+ Class I areas in the WESTAR-WRAP region is complex, involving a significant amount of data processing and assimilation from multiple data sources.

The modeling is largely complete at this point and Ramboll has made extra efforts to correct the cascade of problems at their expense. WESTAR-WRAP staff have been closely monitoring and sequencing the delivery of the modeling results for application in the Regional Haze SIPs and for the western regional modeling platform applications in the future. Ramboll is completing a comprehensive analysis to address western U.S. Regional Haze planning topics. As has been the case, WESTAR-WRAP staff are available to meet on the analysis and any issues with the delays.

The modeling effort has identified issues and lessons learned about the Regional Haze Rule requirements, affecting the process and timing of modeling for western U.S. Regional Haze planning:

- The delays in Summer and Fall 2019 prior to the Covid pandemic then cascaded into more delays in the 10 months from March 2020 to the present.
- To meet the Regional Haze Rule and planning guidance objectives to focus control strategies on U.S. anthropogenic emission contributions, the series of scenarios most affected by the issues in the letter (RepBase, 2028OTBa and 2002DynamicEvaluation) had to use those more computationally- and time-intensive source apportionment methods – that decision occurred in November 2019 in response to the national EPA modeling results. Those methods are necessary to separate fire and international anthropogenic emissions contributions at each Class I area for both the 2028 Reasonable Progress Goal visibility projections and to enable the “end-of-glidepath” adjustments. Those analyses now completed by Ramboll offer options for the Regional Haze SIP planners to analyze and consider in selecting Reasonable Progress Goals.
- WESTAR-WRAP members collaborated on the National Emissions Inventory Collaborative (the NEIC or “2016v1 + projections” modeling platform) at the same time the western Regional Haze modeling effort was underway. The two parallel processes certainly created some confusion and extra effort. While the NEIC data have utility in our modeling, mostly outside the WESTAR-WRAP region, for the overall required effort on Regional Haze modeling, the simultaneous projects were difficult to perfectly align, and issues emerged for individual states’ data.

Via E-Mail

February 8, 2021

Mary Uhl
Executive Director
Western Air Resources Council (WESTAR)
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Subject: Explanations for Delay in Western States Regional Haze Modeling

Dear Mary:

This letter documents and provides reasons for delays in the chronology of Ramboll's completion and delivery of the Regional Haze (RH) photochemical modeling results since late 2018, for the western states on the WRAP Technical Support System (TSS). The TSS is our delivery target since western states and other WRAP partners use it for Round 2 RH State Implementation Plans (SIPs) due July 2021. This work for WESTAR-WRAP has been done mainly under WESTAR Contract 19-01. First and foremost, I want to emphasize how much we value WESTAR-WRAP membership and the western states in particular as important clients and these delays in no way indicate a lack of commitment by Ramboll or us not placing this work as highest priority. This is the most important project that I and my staff have right now, and we are trying to finish delivery of high quality RH technical work products as quickly as we can.

The WRAP western state RH CAMx source apportionment is quite complex and complicated integrating numerous sources of data (e.g., 2014NEI, WRAP states data, EPA 2016v1 platform, natural and international emissions, data products of WRAP workgroups and projects etc.), because the vast majority of emissions affecting RH planning are out of the control of the states, but must be thoroughly assessed with photochemical modeling per EPA RH planning guidance. The work tasks in Contract 19-01 involved a lot of moving parts and pieces of data that needed to be properly implemented presenting multiple opportunities for mistakes. However, that is not an excuse as Ramboll has a reputation and track record on performing such complicated and high-quality air quality modeling studies.

In my over 40 years as an air quality consultant, I have never had a project that had so many setbacks for so many different reasons. Ramboll is not blameless in this as some delays are our fault and we have taken a financial penalty by all the re-running of modeling scenarios, not to mention the emotional and stressful aspects of these delays. But many of the delays have been unique and due to unforeseen circumstances that were out of our control, including:

- Federal government shut-down in December 2018 and January 2019 delayed getting EPA's 2014 modeling platform at the outset of the project.

- EPA's 2014 GEOS-Chem simulation that we planned to use for Boundary Conditions (BCs) was flawed with June & July SO2/SO4 overestimation and year-round ozone overestimation. As a result, we had to conduct our own unplanned 2014 GEOS-Chem simulation to correct it that took several months.

- Delays and data processing decisions at EPA in releasing the National Emissions Inventory Collaborative (NEIC) 2016v1 modeling platform and 2023 and 2028 future year emission projections caused delays in getting future year emissions, as well as errors in the data, as noted below.

- Ramboll modeling computer servers for this work are located in northern California. The Pacific Gas & Electric utility instituted Public Service Power Shutoffs (PSPS) to prevent wildfires that shut down the power to the computers doing the modeling during portions of September-October 2019.

- In November 2019, California Air Resources Board discovered errors in the 2014v2/RepBase fugitive dust emissions they provided that caused delays while we re-processed the emissions and re-ran model simulations.

- COVID-19 Shelter-in-place from March 2020 to the present disrupted and slowed down the modeling. It took a while to figure out how to work effectively remotely. Also with no one in the office, when a computer goes down, hangs or there is a need to mount a new disk to make disk space, there are longer delays than normal as someone has to make a trip to the office.

- In June 2020 we found that some anthropogenic state-controllable sources for RH planning were both incorrect and/or double-counted in the NEIC 2016v1 modeling platform data, in both of the key scenarios for RH planning, the already-completed RepBase and 2028OTBa projection scenarios in the WESTAR-WRAP modeling effort, that caused a 3-month delay (Jun-Jul-Aug 2020). The emissions had to be reviewed by Ramboll and the states for corrections, updated and fixed and SMOKE emissions modeling of re-done so new RepBase2 and 2028OTBa2 could be done.

- Because of the problems and reprocessing required for the NEIC 2016v1 and 2028 emissions, technical decisions were made by WESTAR-WRAP members in RH work groups, to change some of the emissions sector datasets to be used in the new RepBase2 and 2028OTBa2 scenarios from what was in Ramboll's contract necessitating re-processing and some additional delays. The effect of these decisions was non-zero in terms of Ramboll effort, but were timely and improved the representativeness of the RepBase2 and 2028OTBa2 modeling results for RH planning.

- Unprecedented wildfires in Northern California August through November 2020 interfered with staff working as $PM_{2.5}$ concentrations in excess of 200 µg/m^3 blanketed the region making going outdoors and travel dangerous. Many staff were on-call prepared for evacuation and worked much less efficiently under stressful conditions.

- Coding errors in the Ramboll CAMx model caused two re-runs of the CAMx RepBase2 and 2028OTBa2 source apportionment simulations in late 2020. As these runs take ~28 days to run, each re-run can cause a 1-2 month delay as we have to debug what the error is, fix it and re-run.

Ramboll was originally teamed with a Subcontractor whose role was to do most of the SMOKE emissions modeling. The same Subcontractor had a similar role when Ramboll developed the WRAP WestJumpAQMS 2008 and IWDW-WAQS 2011 modeling platforms and performed well.

Attachment 1 has a chronology of events that occurred and caused delays in delivering products on schedule. Below we discuss how some of these specific events delayed some of the key project deliverables.

- The schedule for the first big deliverable was WRAP-WAQS Shake-Out 2014v1 CMAQ and CAMx platforms, model evaluation and Close-Out meeting by March 2019. The Close-Out meeting occurred in April 2019 and delivery of the 2014v1 platform to IWDW in May. The causes for these delays are as follows:
    - Initial contract award was received December 11, 2018, affecting the proposed schedule from Ramboll. If we have started December 1, 2018 as originally planned we likely would have noticed the missing files for EPA's 2014 platform on their ftp site before the unexpected government shut-down.
    - Federal government shut-down December 22, 2018 through January 25, 2019 that delayed getting the EPA 2014 modeling platform by over a month as the EPA ftp site did not include all of the files and EPA staff were unavailable to provide them.
    - In February 2019 we found that the EPA 2014 GEOS-Chem had overestimation issues and in March 2019 EPA re-ran June and July to fix one of the problems so that final 2014v1 CMAQ/CAMx simulations, MPE and database transfer were delayed from the March target timeframe until April-May 2019.
- The next big deliverables, as identified in the May 29, 2019 WESTAR 19-01 Amendment#2 (A2), was 2014v2 emissions modeling, 2014 GEOS-Chem modeling and 2014v2 CMAQ/CAMx modeling to be completed by July 2019 and Representative Baseline (RepBase) modeling to be completed by August 2019. In reality, the first CAMx 2014v2 simulation was not completed until September 2019 and a series of emission updates were made so that the final 2014v2 CAMx base case was not completed until early December 2019. The first RepBase run was not completed until January 2020. The reasons for the delays of the final 2014v2 and initial RepBase simulations are as follows:
    - The July 2019 deadline for the 2014v2 platform was probably overly ambitious, but August should have been doable.
    - A key update in the 2014v2 platform was 2014 emissions for California that CARB provided to the SMOKE emissions Subcontractor in May 2019. In July the Subcontractor started asking questions and needing updates to the 2014 California inventory, so it appears they sat on and didn't look at the data for two months. 2014v2 SMOKE emissions processing was delayed as the Subcontractor's SMOKE modeler had many trips, such as to Korea (June), South America (July) and the EPA Emissions Inventory Conference in Dallas (August). Ramboll finally received the disk drive with the 2014v2 emissions on August 29, 2019. Note that Ramboll has worked very well with this Subcontractor in past studies (e.g., 2008 and 2011 platforms), but personnel

changes appear to have affected their ability to deliver in a timely fashion. Ramboll ultimately took over the SMOKE emissions modeling so that it could be performed in a more timely manner.

    - Ramboll's initial CAMx 2014v2 simulation in September 2019 produced high ozone in northeast Wyoming that was traced to an emissions modeling error that allocated all the annual average O&G emissions to January in some counties.

    - The Subcontractor corrected the 2014v2 O&G emissions and a revised CAMx 2014v2 simulation was conducted in October 2019.

    - The California Air Resources Board informed us in November 2019 that there were errors in California's 2014v2/RepBase fugitive dust emissions and sent corrections that were incorporated into the RepBase emissions delaying the RepBase CAMx simulation until January 2020.

    - Also in November 2019, we discovered errors in the RepBase fire emissions files provided by the WRAP Fire & Smoke Work Group (FSWG) contractor that produced negative $PM_{2.5}$ emissions that had to be corrected by the FSWG contractor. Identification of these sort of issues for fire and many other source categories is a common and required task for assembly of air quality modeling scenarios in a platform. The evaluation and correction of the fire emissions files was another delay in the sequence to assemble RepBase.

    - Errors in EPA's proprietary and lightly documented AMET MPE Tool that EPA did not fix until January 2020 (and only EPA can fix), that we use to calculate performance statistics to be in compliance with EPA modeling guidance, meant that some of the model performance evaluation (MPE) products for the 2014v2 simulations were delayed.

- WESTAR Contract 19-01 Amendment#5 (A5) dated November 22, 2019 had several deliverables with the key ones as follows: (1) 2002 Dynamic Evaluation (2002DE) CAMx simulation completed by February 2020; (2) 2028OTB CAMx done by February 2020; and (3) CAMx 2028 source apportionment done by March 2020. There were numerous iterations in these simulations so that they were not finally completed until January 2021 for the following reasons:

    - After these milestones were set in the contract and in discussion with Regional Technical Operations Work Group Co-Chairs and WESTAR-WRAP staff and to meet objectives (e.g., obtain separate fire and U.S. anthropogenic emission contributions), the RepBase, 2028OTBa and 2002DE were turned into source apportionment simulations each of which takes ~28 days to run. Thus, the original schedule in A5 as the awarded contract required was physically impossible to meet given the changes in the run times from a CAMx standard model run (~5 days) to a source apportionment run (~28 days).

    - The delays in the 2014v2 and RepBase simulations meant that A5 modeling could not start until January 2020 instead of November 2019 as originally envisioned. This meant that the 2028OTB emissions and first CAMx 2028OTB simulations and visibility projections were completed in March-April instead of February 2020.

- In March 2020, shelter-in-place orders were mandated due to the COVID-19 pandemic that caused a slow-down in the modeling for several reasons:
  - People had to move their work stations from the office to home where they do not have as efficient a work space (e.g., copier machines, access to computers, etc.).
  - It took some time for people to figure out how to work from home effectively and efficiencies suffered.
  - Schools and day cares closed so parents had full time responsibility for their children and had to assist teaching from home.
  - When the high performance Linux computers in the office went down, hung or we needed to mount disks for backups to make more disk space, someone had to physically come in to the office and there were restrictions on how that could be done.
- The 2002 Dynamic Evaluation emissions development to backcast 2014 emissions to 2002 turned out to be a much bigger task than originally scoped by Ramboll and as awarded in the contract. It was deemed less critical than the 2028OTB modeling so was de-emphasized compared to getting the 2028 visibility projections done.
- How to treat fires in the 2028 MID projections caused some delays as there were modeled fires on some days in the IMPROVE MID; MID are selected in part to limit fire contributions.
- Double-counted and/or incorrect anthropogenic state-controllable sources for RH planning were discovered in the NEIC 2016v1 modeling platform due in part to EPA emissions processing of the 2016v1 files having O&G sources in the Non-EGU Point files instead of in the O&G files. Several WESTAR-WRAP region states also identified incorrect emissions rates in the 2016v1 files. This caused a series of state-by-state review and correction actions and a 3-4 month delay at a critical point in the regional haze modeling. This was probably the single biggest issue that caused delays in the project and required the following corrective action:
  - Ramboll conducts intensive review of the EPA 2016v1 platform emissions to identify the problems.
  - Western states review and update their RepBase and 2028OTBa emissions to now be RepBase2 and 2028OTBa2 inputs.
  - The WESTAR-WRAP project manager decides not to continue to use the NEIC 2028 projections for some source sectors (e.g., WRAP non-EGU Point), in response to requests from the WESTAR-WRAP region states, in 2028OTBa2 modeling and use 2014 instead.
  - Ramboll creates harmonized emission inventories for RepBase2 and 2028OTBa2 and conducts SMOKE modeling.
  - Re-run RepBase2 and 2028OTBa2 source apportionment simulations.

- WESTAR Contract 19-01 Amendment#10 (A10) provided funding for updating the RepBase2 and 2028OTBa2 emissions to address the EPA double counting issue and had a detailed schedule: (1) CAMx RepBase2 H-L SA run done by Nov 17, 2020; (2) CAMx 2028OTBa2 H-L SA run done by Nov 28, 2020; (3) CAMx 2028OTBa2 L-L SA run done by Dec 30, 2020. In reality, the final RepBase2 and 2028OTBa2 H-L SA runs were not done until January 2021 due to multiple re-runs:

    - The RepBase2 and 2028OTBa2 H-L SA simulations take approximately 28 days to run. The first RepBase2 and 2028OTBa2 H-L SA runs were completed within the A10 schedule (Nov 2020), but a series of issues were discovered that caused re-runs as follows:

        - The way lightning NOx emissions were treated was changed from millions of virtual point sources to a netCDF 3-D input to be more computationally efficient. However, a coding error in the CAMx v7.0 model caused the netCDF 3-D inputs not to work correctly and it adversely affected the source apportionment results necessitating going back to the virtual point source input approach.

        - The second round of RepBase2 H-L SA runs was performed in December 2020, but was invalid due to missing New Mexico Non-EGU Point emissions (Ramboll's fault).

        - A third set of RepBase2 and 2028OTBa2 simulations were conducted the end of December 2020 into January 2021 and another coding error was discovered in CAMx v7.0 that dropped point source SO2 emissions.

        - The fourth set of RepBase2 and 2028OTBa2 H-L SA simulations finished in late January 2021 and were post-processed and transferred to the TSS by end of January.

I hope you find this letter useful in helping to explain why the regional haze modeling for the WESTAR-WRAP region is delayed. I believe these issues are behind us and the regional haze modeling results are now being populated onto the WRAP TSS. I do not foresee any remaining modeling or data delivery issues for the remaining tasks over the next 2-3 months, and Ramboll is closely coordinating with WESTAR-WRAP staff and the RTOWG Co-Chairs.

If you need more information or want me to personally talk to EPA or any of the States with WESTAR-WRAP staff in attendance, please let me know as I am always available and always try to live up to my commitments and responsibilities.

Best Regards,

Ralph E. Morris
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cc. Tom Moore

Attachment 1. Timeline of events that caused delays in the WRAP western states regional haze modeling.

Approximate Date	Event
Dec 11, 2018	Initial WESTAR Contract 18-12 to development 2014 Shake-Out platform was received 10 days after project start date (Dec 1, 2018)
Dec 2018-Jan 2019	Federal government shut-down Dec 22, 2018 – Jan 25, 2019 caused over a month plus delay in getting all files from EPA's 2014 modeling platform as the 2014 platform files on the EPA ftp site were incomplete.
Feb 2019	Found that EPA's 2014 GEOS-Chem run that was planned to be used for BCs was flawed as it had too high SO2/SO4 in Jun & Jul and overstated O3 year-round. This meant Ramboll had to perform an unplanned 2014 GEOS-Chem run that took several months to complete.
Mar 2019	EPA re-runs GEOS-Chem for Jun & Jul without volcano eruption fixing Jun & Jul SO2/SO4 overestimation problem in BCs but causing delays in delivering the 2014v1 Shake-Out modeling platform in March 2019.
Jun – Aug 2019	2014v2 SMOKE emissions modeling delayed 3 months due to unavailability of Subcontractors SMOKE modeler.
Sep 2019	Corrections needed for error in SMOKE emissions modeling of 2014v2 (overstates Wyoming Jan O&G emissions) caused another month delay.
Sep – Oct 2019	PG&E Public Service Power Shutoffs (PSPS) cut-off power to Ramboll's Linux computers in their Novato, CA office shutting down progress on 2014v2, RepBase2 and 2028OTB modeling.
Nov 2019	California Air Resources Board informs us that California Fugitive Dust emissions are in error in 2014v2/RepBase and sends update that caused delays.
Nov 2019	The RepBase fires from the FSWG have errors that produce negative $PM_{2.5}$ emission that need to be fixed
Dec 2019	EPA's AMET MPE tool does not work right and does not generate all the MPE products that are needed. EPA AMET contact goes on holiday and issue is not fixed until after they come back in Jan 2020.
Jan 2020	Modeling for 2028OTB and 2002DE that was supposed to start in November 2019 started in Jan 2020 instead due to delays and finishing up 2014v2 and RepBase modeling.
Mar 2020 - present	COVID-19 shelter-in-place disrupts modeling as people can no longer go to the office and must work from home. That reduces efficiency and modeling takes longer due to more computer down time.
Apr – May 2020	Extra time to determine how to treat modeled fires in visibility projections for the MID that are not supposed to have any episodic fire.
Jun – Sep 2020	Double counted sources in EPA's 2016v1 modeling platform caused a stop of the modeling and have Ramboll and the states re-work the emissions, fix them and redo the SMOKE modeling causing a 3-4 month delay.
Jun – Sep 2020	Given problems with EPA 2016v1 platform 2028 emission projections, WRAP decides to change what emissions are being used in 2028OTB emission scenarios from what was in Ramboll's contract.
Aug – Nov 2020	Massive wildfires in California caused extremely high $PM_{2.5}$ concentrations, limited travel in the region and caused inefficiencies in work.
Nov 2020	RepBase2 and 2028OTBa2 H-L SA runs have to be re-done due to coding error in CAMx v7.0 treatment of netCDF 3-D lighting NOx inputs.
Dec 2020	Second RepBase2 H-L SA run has to be re-done due to missing New Mexico non-EGU point source emissions.
Dec 2020 – Jan 2021	Third RepBase2 and 2028OTBa2 H-L SA runs have to be re-done due to coding error in source apportionment species mappings that dropped point source SO2 emissions.
Jan 2021	Fourth RepBase2 and 2028OTBa2 H-L SA runs have satisfied all the QA checks and appear correct so that 2028 visibility projections and other data will be transferred to the WRAP TSS by the end of January 2021.

C.5 – WRAP Technical Support System for Regional Haze Planning: Modeling Methods, Results, and References

WRAP Technical Support System for Regional Haze Planning:

Modeling Methods, Results, and References

September 30, 2021 - Final

Contents	**Page Number**

1.0 Purpose:

The Western Regional Air Partnership and Western Air Quality Study (WRAP-WAQS) 2014 Regional Haze modeling platform is the latest of a series of regional modeling efforts supporting western U.S. air quality planning and management. The WRAP technical analyses follow the Environmental Protection Agency's (EPA) Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze (November 2018) and the Technical Support Document for EPA's updated 2028 regional haze modeling (September 2019). The analyses fulfill the objectives of the WRAP 2018-2019 Workplan as updated and approved by the WRAP Board on April 3, 2019 and have been collectively designed, implemented, and reviewed by the WRAP Technical Steering Committee and its workgroups and subcommittees.

The Western Regional Air Partnership (WRAP) Technical Support System (TSS) hosts the visibility monitoring, emissions, and air quality modeling analyses that support the 15 western states in developing regional haze state implementation plans (SIPs). This reference document describes the WRAP emissions and modeling analyses and illustrates how the TSS products can be applied and interpreted to support the 2028 visibility progress demonstrations for western U.S. Class I areas.

2.0 Background:

The Regional Haze Rule requires states to demonstrate progress every ten years toward the Clean Air Act goal of no manmade visibility impairment. EPA guidance for tracking visibility progress (December 2018) defines a visibility impairment tracking metric (measured in deciview) using observations from the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring network sites that represent Class I areas. EPA defined in the Regional Haze Rule and guidance a Uniform Rate of Progress glidepath for the 20% most impaired days as the straight line from the 2000-2004 IMPROVE 5-year average baseline to EPA estimates of future natural visibility conditions, plotted at 2064. In the first regional haze planning period, 2000-2018, EPA guidance interpreted most impaired days as those days with highest total haze. States were required to demonstrate visibility progress by 2018 compared to the Uniform Rate of Progress glidepath for the haziest days and no degradation of visibility on the clearest days from the 2000-2004 IMPROVE 5-year average baseline. Visibility on the clearest days improved between 2000 and 2018 across the Class I areas in the western U.S. However, smoke from wildfire and wildland prescribed fire events and dust events on the haziest days made tracking the visibility benefits due to reducing U.S. anthropogenic emissions more difficult.

For the second regional haze implementation period, 2018-2028, states are required to demonstrate visibility progress by 2028 for the most impaired days and no visibility degradation for the clearest days. EPA guidance (December 2018) defined most impaired days as those days with the highest fractional contribution to aerosol light extinction from anthropogenic sources. EPA statistical methods use IMPROVE measurements of carbon and crustal materials to separate contributions from episodic extreme natural events (e.g., wildfire or dust) from routine natural and anthropogenic contributions. Ammonium sulfate and ammonium nitrate are assigned primarily to anthropogenic emissions with smaller contributions from routine natural sources. This statistical approach does not separate contributions due to U.S. anthropogenic emissions from those of international anthropogenic emissions. Since states do not have authority to reduce international emissions, WRAP conducted source apportionment modeling analyses to evaluate U.S. anthropogenic contributions to haze and progress in reducing U.S. anthropogenic contributions to haze over time.

Table 1 summarizes the emissions and modeling scenarios, source apportionment runs, and alternative visibility progress analyses that were performed to support state regional haze planning.

Table 1. WESTAR-WRAP Emissions and Modeling Scenarios – update of January 18, 2021
Intermountain West Data Warehouse (IWDW) and Technical Support System (TSS) displays

Scenario Name	**Model Performance Evaluation** (2014v2 actual emissions / BCs and meteorology)	**Planning – Baseline** (mix of emissions inputs 2014-18 with 2014 meteorology)	**Planning – 2028 Projections** (2014 meteorology)	**Alternative Methods: 2028 Projections, Glidepath Endpoints, and Rate of Progress**	**Alternate Outcome Scenarios** (2014meteorology)
IWDW	Display emissions, model results, and site-level MPE results)	Display emissions and model results	Display emissions and model results		
TSS	Display emissions and model results	Display emissions and model results	Calculate and Display 2028 RPGs Display emissions and model results	Display alternative 2028 projections, glidepath endpoints, rate of progress	Calculate and Display 2028 RPGs. Display emissions and model results
Purpose	**Compare 2014v2 to RepBase2**	**Compare to RepBase2 to 2014v2, 2028OTBa2, 2028PAC2**	**Compare 2028OTBa2 to Repbase2, 2028PAC2, 2028FFS1, 2028FFS2**	**Focus on contributions of US anthropogenic emissions**	**Evaluate state source contributions and future fire scenarios**
CAMx Modeling Scenarios	**2014v2**	**RepBase2** Current Baseline (w/ RepFire). High-level CAMx PSAT source apportionment*	**2028OTBa2** (w/ RepFire) ** High-level PSAT source apportionment	**3 projection methods:** EPA default MID EPA MID w/o fires Modeled MID	**2028OTBa2 w/ SOxNOx PSAT** low-level (state by source sector contributions)
			2028PAC2 PotentialAddtlControls	Alternative 2064 glidepath endpoints	**2028FF1** Future Fire Sensitivity 1: Wildfire ****
			2028Adopted AddtlControls ***	U.S. Anthropogenic Modeled Rate of Visibility Progress ******	**2028FF2** Future Fire Sensitivity 2: WildlandRxFire *****

* 2014 International Anthro contribution adjustment option available from this modeling scenario (by difference)
** RepBase fires applied to 2028OTBa2
*** controls adopted by states in SIPs, this scenario is likely not possible until 2021 (*unfunded at present, not in Workplan*)
**** fire not paired in space or time with 2014 or RepFire activity, these sensitivity scenarios could give potential future wildfire contribution relative to 2028OTBa2
***** fire *is* paired in space *and* time with RepFire activity; this sensitivity scenario gives potential future Wildland Prescribed fire contribution relative to 2028OTBa2
******Dynamic Evaluation compare US anthropogenic contributions for 2002 Hindcast, RepBase2, and 2028OTBa2 to demonstrate alternative rate of visibility improvement

3.0 Emissions Scenarios:

The WRAP 2014v2 inventory was based on the 2014v2 National Emissions Inventory (NEI) plus updates provided by western states through WRAP Regional Haze workgroup's Emissions and Modeling Protocol subcommittee.

Table 2 defines the emissions data sources used for the WRAP 2014v2, Representative Baseline (RepBase2), and 2028 On the Books (2028OTBa2) emissions scenarios. Sector-specific data sources and assumptions are discussed in the companion TSS Emissions References document (September 2021). Future fire emissions sensitivities and 2002 hindcast emissions are also detailed in the TSS Emissions References document.

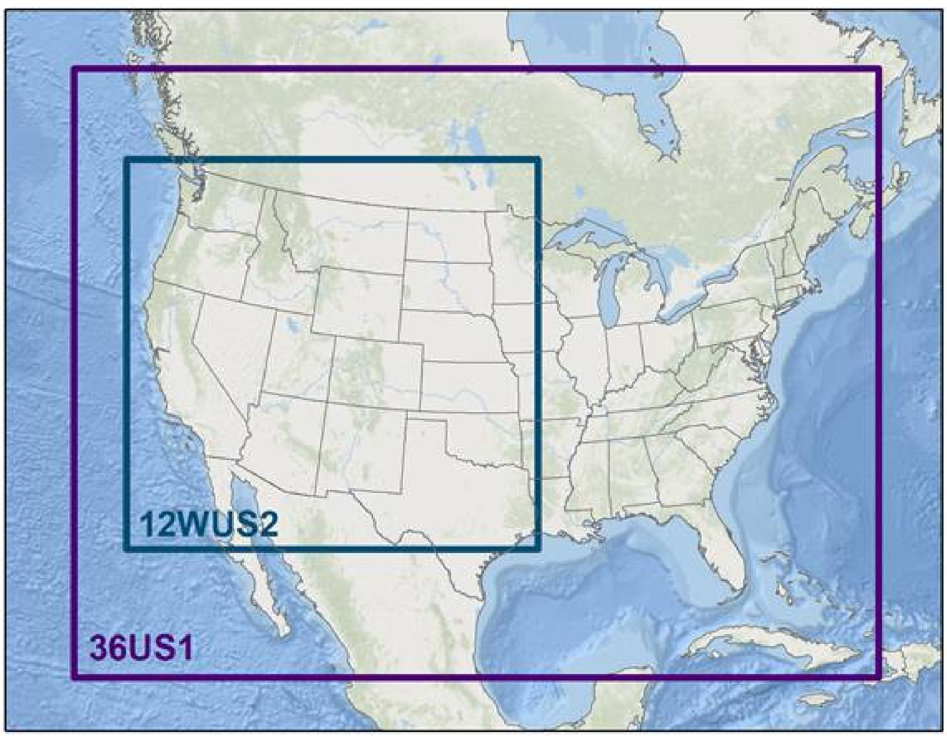
Table 2. Data sources for WRAP emissions sectors for the 12-km 12WUS2 and 36-km US domains for the 2014v2, Representative Baseline (RepBase2) and 2028 On the Books (2028OTBa2) scenarios.

Source Sector	**2014v2**	**RepBase2**	**2028OTBa2**
California All Sectors 12WUS2	CARB-2014v2	CARB-2014v2	CARB-2028
WRAP Fossil EGU w/ CEM	WRAP-2014v2	WRAP-RB-EGU [1]	WRAP-2028-EGU [1]
WRAP Fossil EGU w/o CEM	EPA-2014v2	WRAP-RB-EGU [1]	WRAP-2028-EGU [1]
WRAP Non-Fossil EGU	EPA-2014v2	EPA-2016v1	EPA-2028v1
Non-WRAP EGU	EPA-2014v2	EPA-2016v1	EPA-2028v1
O&G WRAP O&G States	WRAP-2014v2	WRAP-RB-O&G [2]	WRAP-2028-O&G [2]
O&G WRAP Other States	EPA-2014v2	EPA-2016v1	EPA-2016v1 [3]
O&G non-WRAP States	EPA-2014v2	EPA-2016v1	EPA-2016v1 [3]
WRAP Non-EGU Point	WRAP-2014v2	WRAP-2014v2 [4]	WRAP-2014v2 [4]
Non-WRAP non-EGU Point	EPA-2014v2	EPA-2016v1	EPA-2016v1
On-Road Mobile 12WUS2	WRAP-2014v2	WRAP-2014v2	WRAP-2028-Mobile [5]
On-Road Mobile 36US	EPA-2014v2	EPA-2016v1	EPA-2028v1
Non-Road 12WUS2	EPA-2014v2	EPA-2016v1	WRAP-2028-Mobile [5]
Non-Road non-WRAP 36US	EPA-2014v2	EPA-2016v1 [6]	EPA-2028v1 [6]
Other (Non-Point) 12WUS2	EPA-2014v2	EPA-2014v2 [7]	EPA-2014v2 [7]
Other (Non-Point) 36US	EPA-2014v2	EPA-2016v1	EPA-2016v1
Can/Mex/Offshore 12WUS2	EPA-2014v2	EPA-2016v1	EPA-2016v1
Fires (WF, Rx, Ag)	WRAP-2014-Fires	WRAP-RB-Fires [8]	WRAP-RB-Fires [8]
Natural (Bio, etc.)	WRAP-2014v2	WRAP-2014v2	WRAP-2014v2
Boundary Conditions (BCs)	WRAP-2014-GEOS	WRAP-2014-GEOS	WRAP-2014-GEOS

4.0 Model Development:

The WRAP-WAQS 2014 modeling platform was developed and performed by Ramboll, Inc., under contract to WESTAR-WRAP. The 2014 modeling platform used the Weather Research and Forecasting (WRF) meteorological model, the Sparse Matrix Operator Kernel Emissions (SMOKE) model and the Comprehensive Air Quality Model with Extensions (CAMx) to project air quality for the 2014 base year. The Goddard Earth Observing System global chemical model (GEOS-Chem) provided global boundary conditions for the regional CAMx model for the 2014 base year. The CAMx 2014v2 final model configuration is defined in Table 1 of the WRAP-WAQS 2014 modeling platform webpage. CAMx version 7beta 6 was used for the 2014v2 model performance run, while CAMx version 7.0 was used for the subsequent model scenarios. **Figure 1** below illustrates the CAMx 36-km modeling domain covering the Continental United States and the 12-km modeling domain covering the western states.

Figure 1. 36-km continental U.S. (36US1) and 12-km western U.S. (12US2) modeling domains used in the WRAP-WAQS 2014 modeling platform.



In addition to the 2014v2 model year, model runs were made using 2014 meteorology and with Representative Baseline (2014-2018, RepBase2), 2028 On the Books (2028OTBa2), 2028 Potential Additional Controls (2028PAC2), 2002 Hindcast, and Future Fire Sensitivities emission scenarios. Details are provided in model run specification sheets:

- Representative Baseline (RepBase2) and 2028 On the Books (2028OTBa2) CAMx simulations
- Dynamic Evaluation – 2002 Simulations
- Future Fire Sensitivity Simulations

5.0 WRAP-WAQS 2014v2 model performance

The WRAP-WAQS 2014v2 modeling platform webpage includes statistical model performance measures compared to EPA goals and criteria, spatial data plots and timeseries plots for the aerosol species listed below. For aerosol species concentrations, CAMx 2014v2 model outputs are compared to 2014 observations from the IMPROVE, Chemical Speciation Network (CSN) and Clean Air Status and Trends (CASTNET) monitoring network.

- Ozone model performance is reported on the Intermountain West Data Warehouse.

CAMx 2014v2 performance was evaluated using the EPA Atmospheric Model Evaluation tool (AMET) to compare model outputs to 2014 ambient air quality measurements (in μg/m3) for:

- Particulate matter less than 2.5 micrometers (PM2.5)
- Nitrate (NO3)
- Sulfate (SO4)
- Organic mass from carbon (OMC)
- Elemental carbon (EC)
- Fine soil (Soil)
- Coarse mass (particulate matter between 2.5 and 10 micrometers).
- Seasalt: performance is tracked separately for Sodium and Chloride

For example, **Figures 2a to 2d** are spatial plots of the Normalized Mean bias statistic for the winter months January - March and Summer months July – September, for Nitrate and Sulfate, respectively. IMPROVE sites are illustrated as circles, CSN sites as triangles, and CASTNET sites as squares. In Winter, Nitrate is overpredicted in the Pacific Northwest and CA and underpredicted in the northern plains. Performance is generally mixed in the Rocky Mountains and Southwestern interior. In Summer, Nitrate is overpredicted in the Pacific Northwest and under predicted in CA. Sulfate is generally overpredicted in the Pacific Northwest in winter and underpredicted in the Southwest in summer.

Figure 2a. Normalized mean bias for 2014v2 modeled Nitrate compared to the IMPROVE, CSN, and CASTNET monitoring networks for Winter (Jan – Mar). (2014v2 MPE summary)

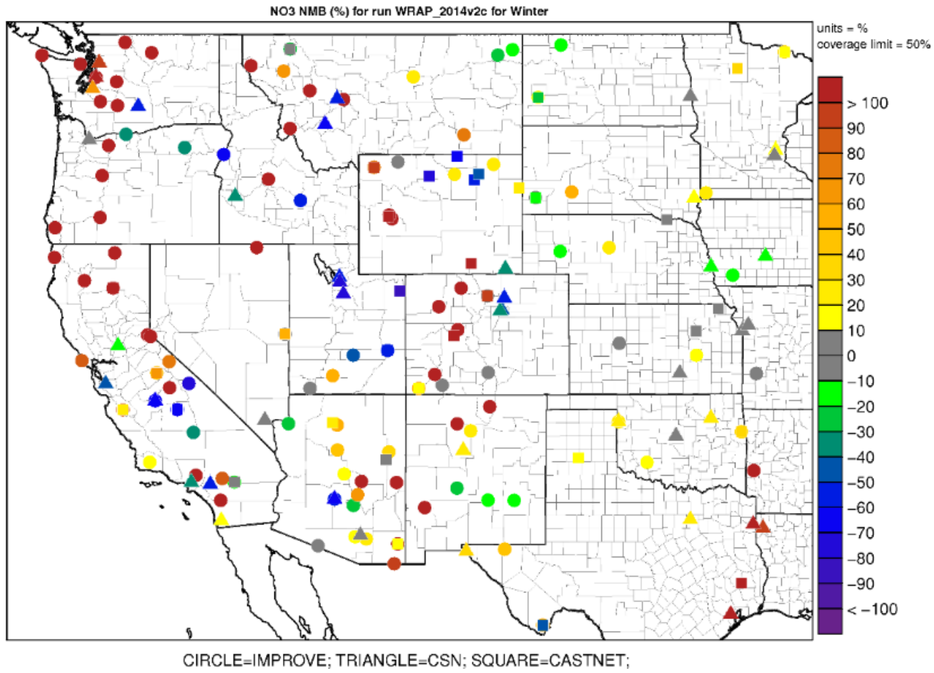


Figure 2b. Normalized mean bias for 2014v2 modeled Nitrate compared to the IMPROVE, CSN, and CASTNET monitoring networks for Summer (Jul – Sep). (2014v2 MPE summary)

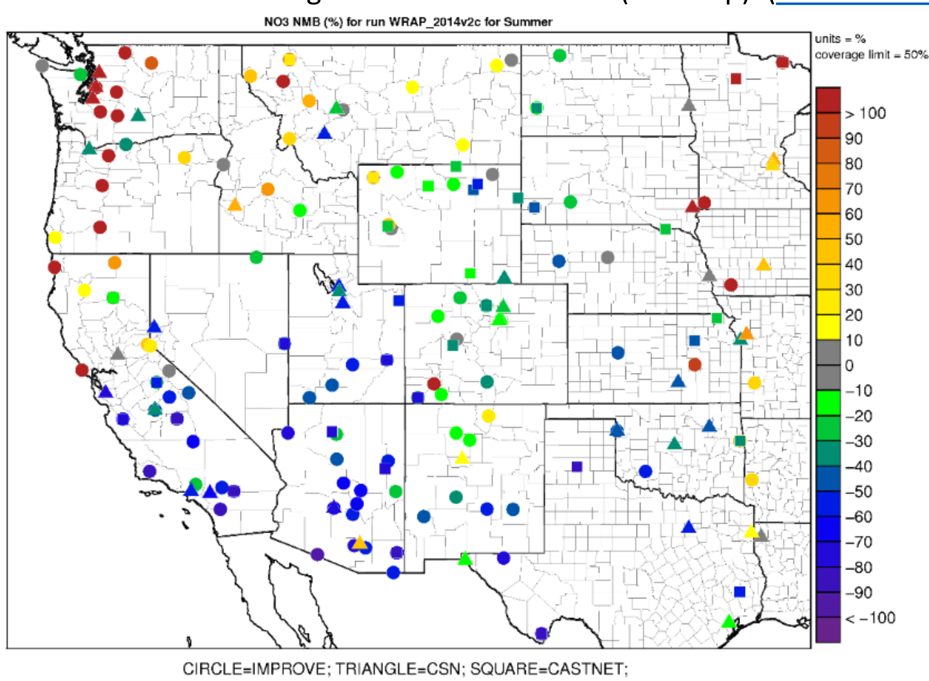


Figure 2c. Normalized mean bias for 2014v2 modeled Sulfate compared to the IMPROVE, CSN, and CASTNET monitoring networks for Winter (Jan – Mar). (2014v2 MPE summary)

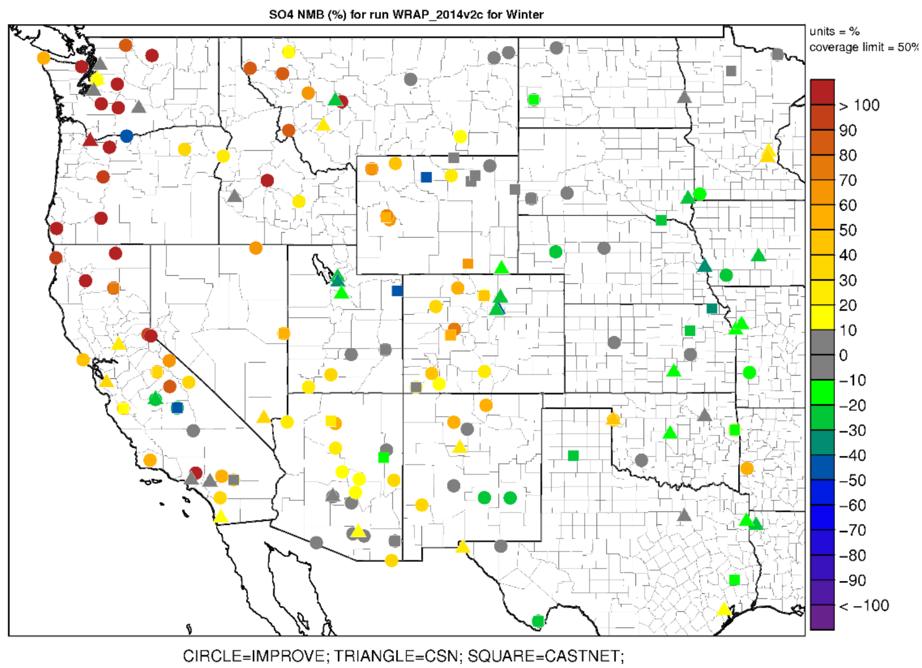
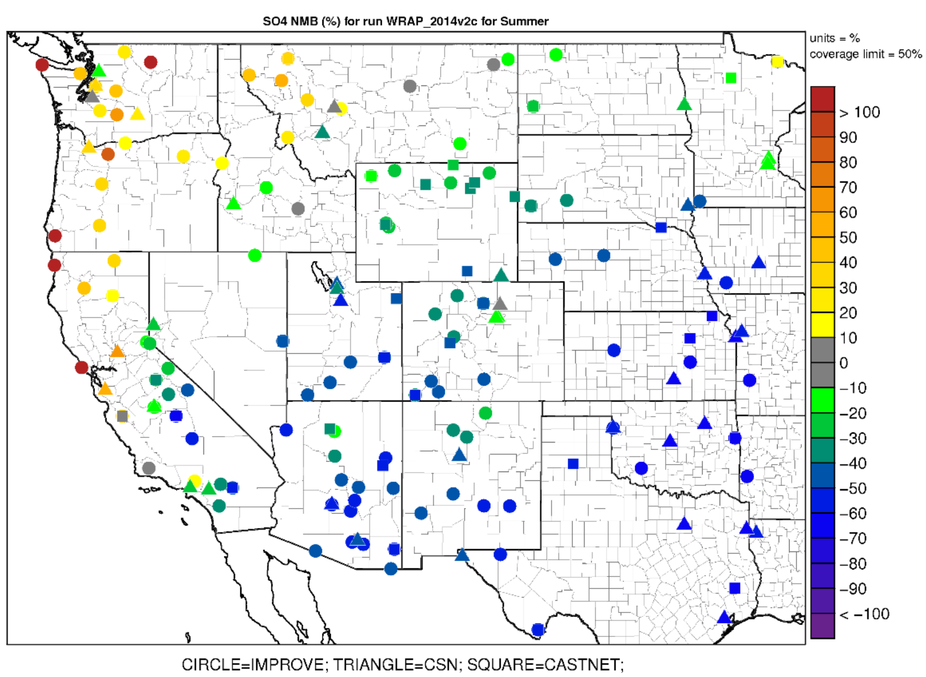


Figure 2d. Normalized mean bias for 2014v2 modeled Sulfate compared to the IMPROVE, CSN, and CASTNET monitoring networks for Summer (Jul – Sep). (2014v2 MPE summary)



CAMx 12-km gridded annual anthropogenic nitrogen oxide and anthropogenic sulfur dioxide emissions (tons per year) for 2028OTBa emissions (from the WRAP 2028 Weighted Emissions Potential analyses) are mapped in **Figures 3a and 3b**.

Figure 3a. 2028 On the Books CAMx gridded 12-km annual anthropogenic nitrogen oxide emissions (tons per year) (Weighted Emissions Potential)

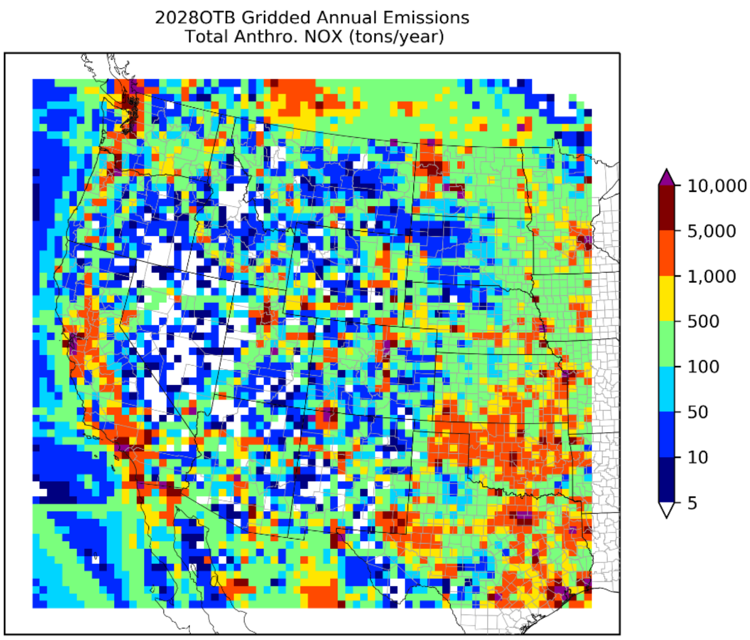
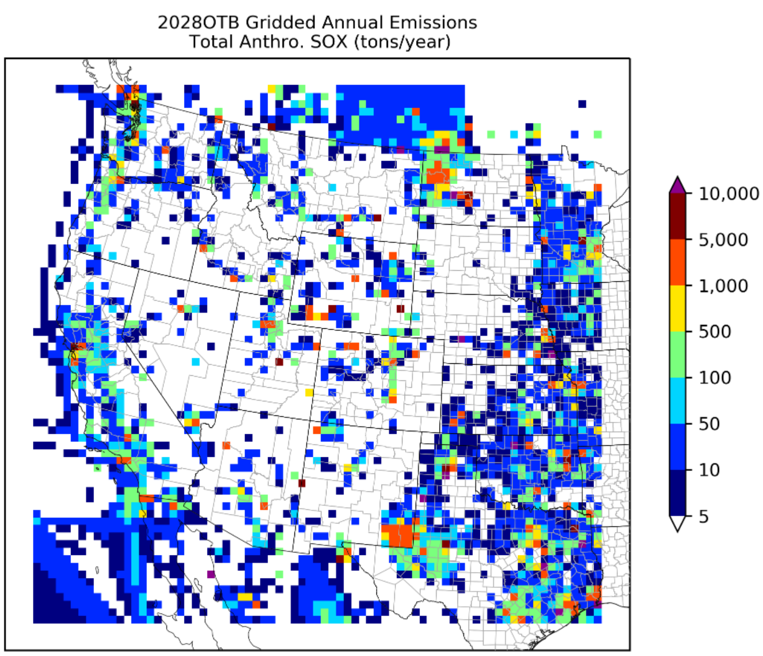


Figure 3b. 2028 On the Books CAMx gridded 12-km annual anthropogenic sulfur oxides emissions (tons per year) (Weighted Emissions Potential)



6.0 Model Comparisons to Observations

Yellowstone National Park, in a fire-dominated ecosystem in the northern Rocky Mountains, and Mesa Verde National Park, in a drier southwestern ecosystem, are used as example Class I areas to interpret WESTAR-WRAP 2014v2 model performance, source contributions to haze, and projected visibility progress by 2028.

Comparisons of 2014 IMPROVE observations to the 2014v2, RepBase2, and 2028OTBa2 model scenarios are illustrated in **Figures 7a through 7d** (TSS Modeling Express Chart #1) for IMPROVE monitors in Yellowstone (YELL2) and Mesa Verde (MEVE1) National Parks, respectively. The charts display speciated aerosol light extinction for the averages of the most impaired days or clearest days. These are absolute model results; the model outputs are not adjusted to IMPROVE data. Comparison of 2014 IMPROVE observations to 2014v2 model results illustrates the accuracy of the model performance on the selected days. Comparison of the 2014v2, RepBase2, and 2028OTBa2 model scenario results demonstrates the aerosol responses to changes in emissions across these scenarios. Natural, fire, and international emissions are held constant at RepBase2 levels in 2028OTBa2, so the only differences between the two scenarios are due to changes in U.S. anthropogenic emissions.

Interpretation: Comparing 2014 IMPROVE observations to 2014v2 model results on most impaired days (**Figures 7a and 7b**) at both YELL2 and MEVE1, ammonium sulfate, elemental carbon, and coarse mass are under predicted, while ammonium nitrate and organic carbon are over predicted. At both YELL2 and MEVE1 organic carbon is slightly higher in RepBase2 than 2014v2; this reflects changes for wildfire emissions in the RepBase2 scenario. At both YELL2 and MEVE1 ammonium nitrate shows small reductions between the RepBase2 and 2028OTBa2 scenarios, all other aerosol species show little change.

On the clearest days at both YELL2 and MEVE1 (**Figure 7c and 7d**) all aerosol species are overestimated, likely because aerosol concentrations are very low and small differences in light extinction are reflected as large percentage differences.

TSS Modeling Express charts for the clearest days are formatted the same as for the most impaired days and will not be displayed in this document forward.

Figure 4a. Model Scenarios Compared to 2014 IMPROVE Observations for Aerosol Light Extinction (Mm^{-1}) on the most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. TSS Modeling Express Chart #1

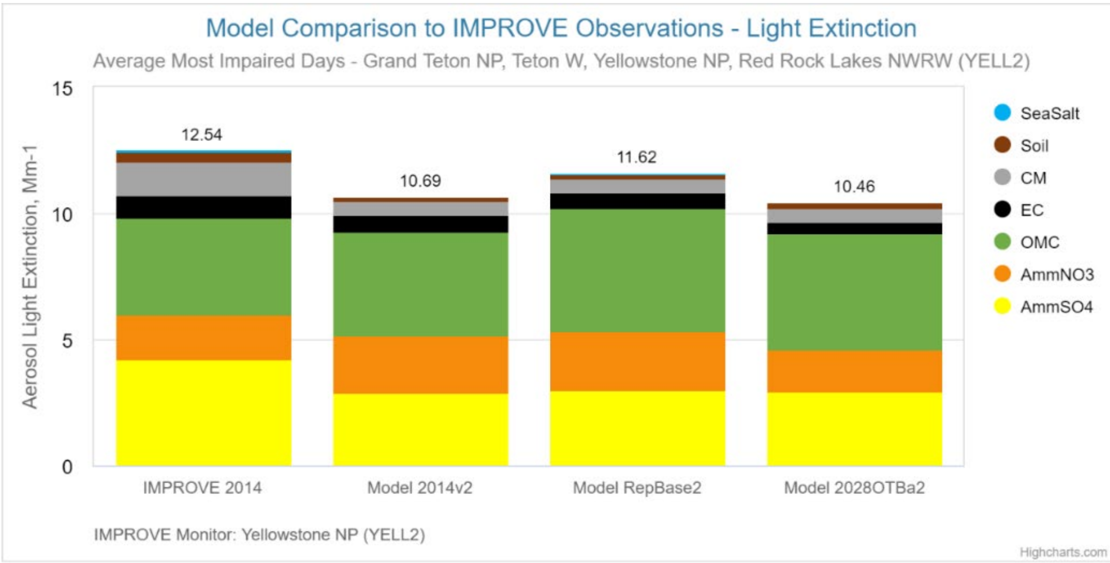


Figure 4b. Model Scenarios Compared to 2014 IMPROVE Observations for Aerosol Light Extinction (Mm^{-1}) on the most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Chart #1

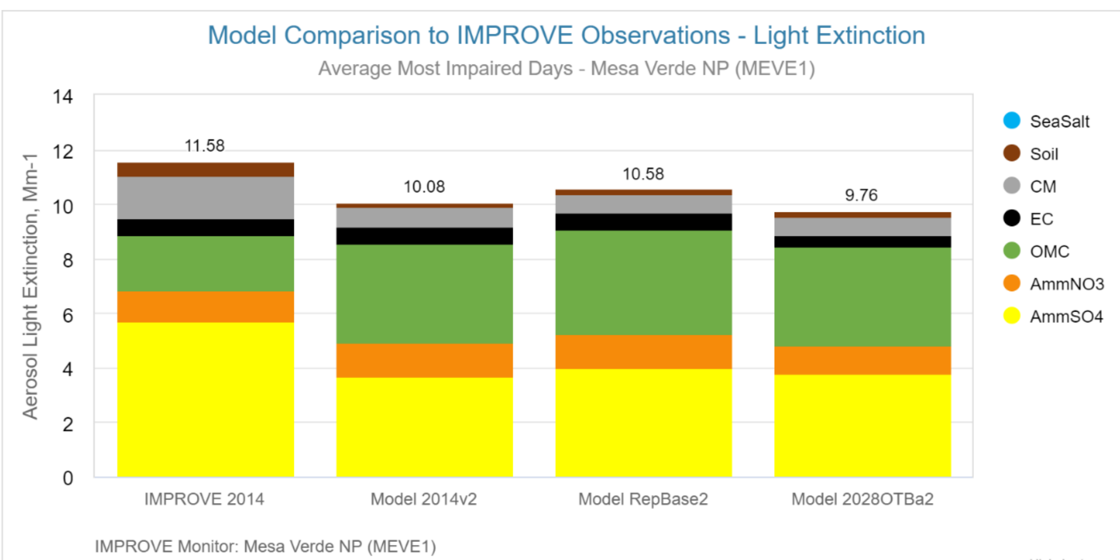


Figure 4c. Model Scenarios Compared to 2014 IMPROVE Observations for Aerosol Light Extinction (Mm^{-1}) on the clearest days at the Yellowstone National Park (YELL2) IMPROVE monitor. [TSS Modeling Express Chart] #1

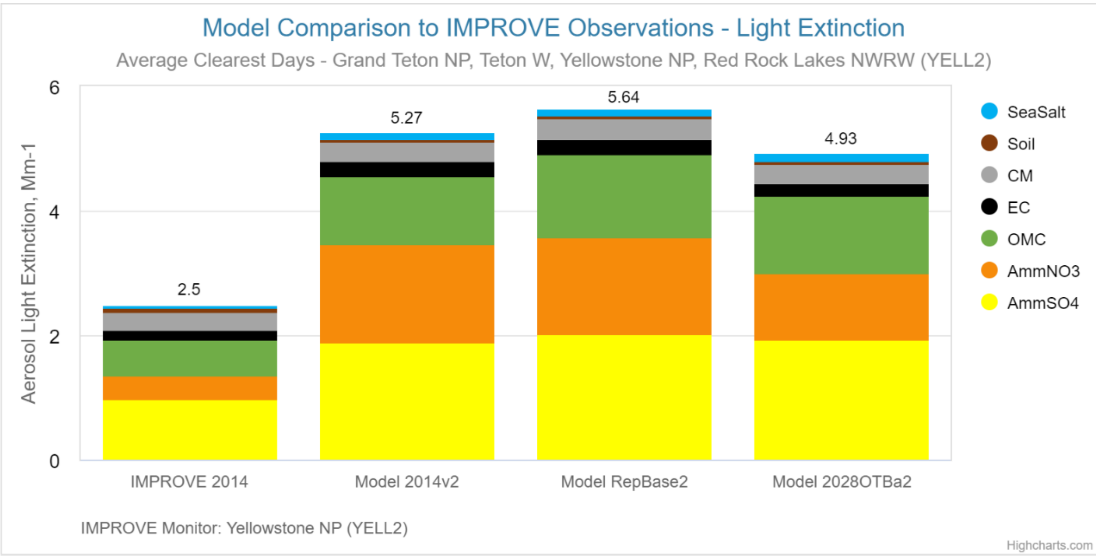
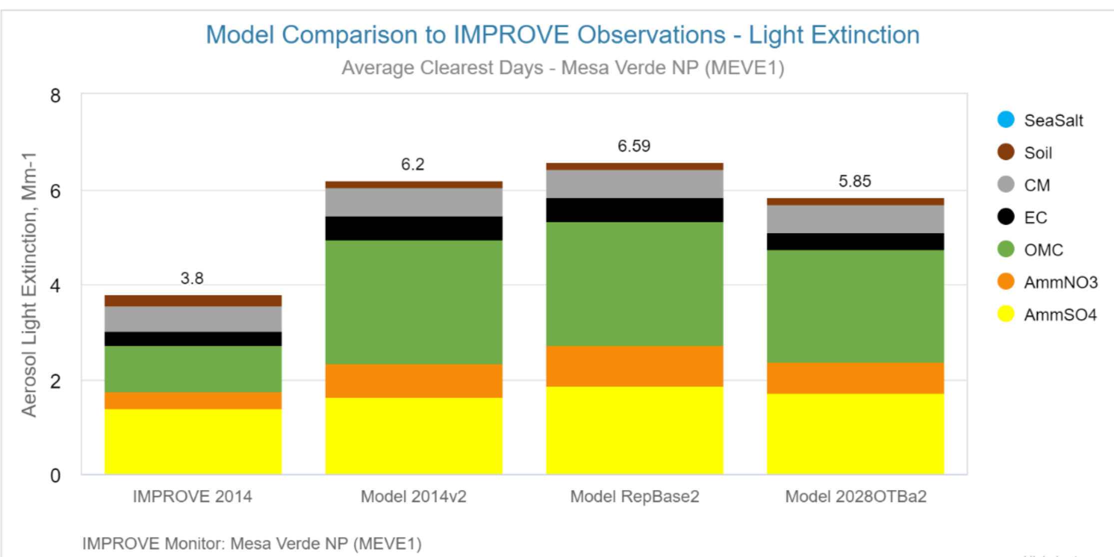


Figure 4d. Model Scenarios Compared to 2014 IMPROVE Observations for Aerosol Light Extinction (Mm^{-1}) on the clearest days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. [TSS Modeling Express Chart] #1



Figures 5a and 5b display [TSS Modeling Express Chart]() #2 for daily 2014 IMPROVE most impaired days at Yellowstone (YELL2) and Mesa Verde (MEVE1) National Parks, respectively, compared to the 2014v2, RepBase2, and 2028OTBa2 model scenarios.

Interpretation: Overall, comparing 2014 IMPROVE data to the 2014v2 modeled aerosol light extinction, CAMx showed credible skill for most impaired days at YELL2 and MEVE1. Maximum IMPROVE daily aerosol extinction on most impaired days is 24 Mm^{-1} at YELL2 and 20 Mm^{-1} at MEVE1. Daily ammonium nitrate (AmmNO3) is well represented on most impaired days at these two sites. On a few most impaired days at both YELL2 and MEVE1, 2014v2 modeled ammonium sulfate (AmmSO4) is more than 50% lower than IMPROVE observations. Under estimates of coarse mass are likely due to poor model skill in representing windblown dust. At both sites, organic carbon (OMC) is a large fraction of total aerosol extinction on several 2014 IMPROVE most impaired days. OMC is somewhat over predicted on several days. Differences in OMC on the most impaired days between the 2014v2 and RepBase2 scenarios are likely due to differences in wildfire activity assumptions for RepBase2 (covering the period the 2014 to 2018) compared to the single year 2014v2. Differences in total aerosol extinction between RepBase2 and 2028OTBa2 are small on all most impaired days, indicating little visibility progress.

Figure 5a. Model Scenarios Compared to 2014 IMPROVE Observations for Aerosol Light Extinction (Mm^{-1}) on most impaired days at the Yellowstone National Park (YELL1) IMPROVE monitor. [TSS Modeling Express Chart]() #2

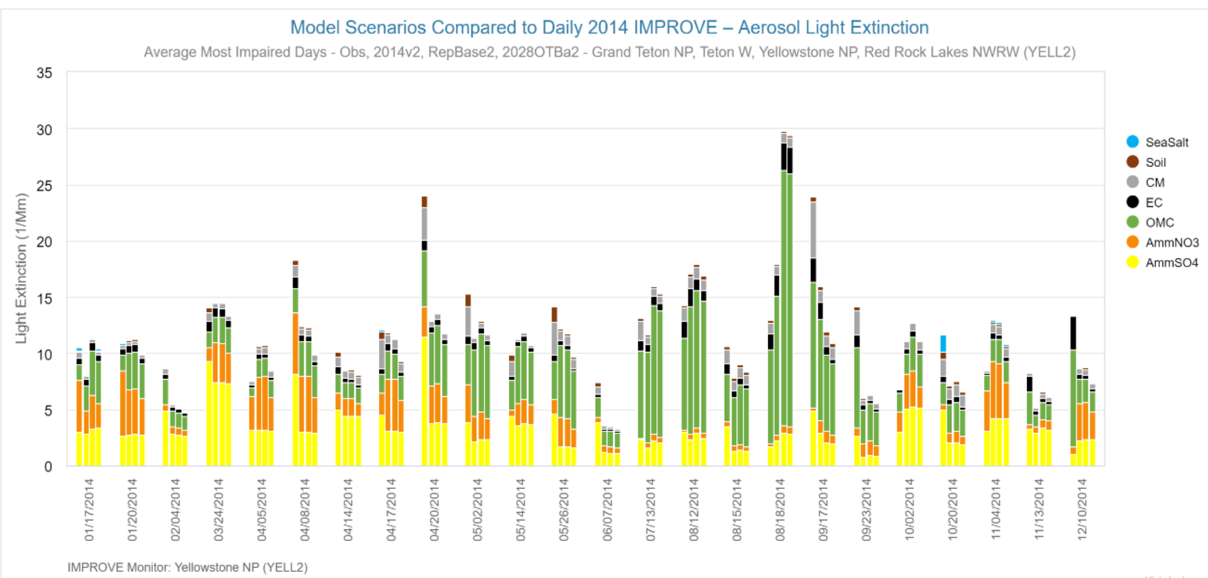
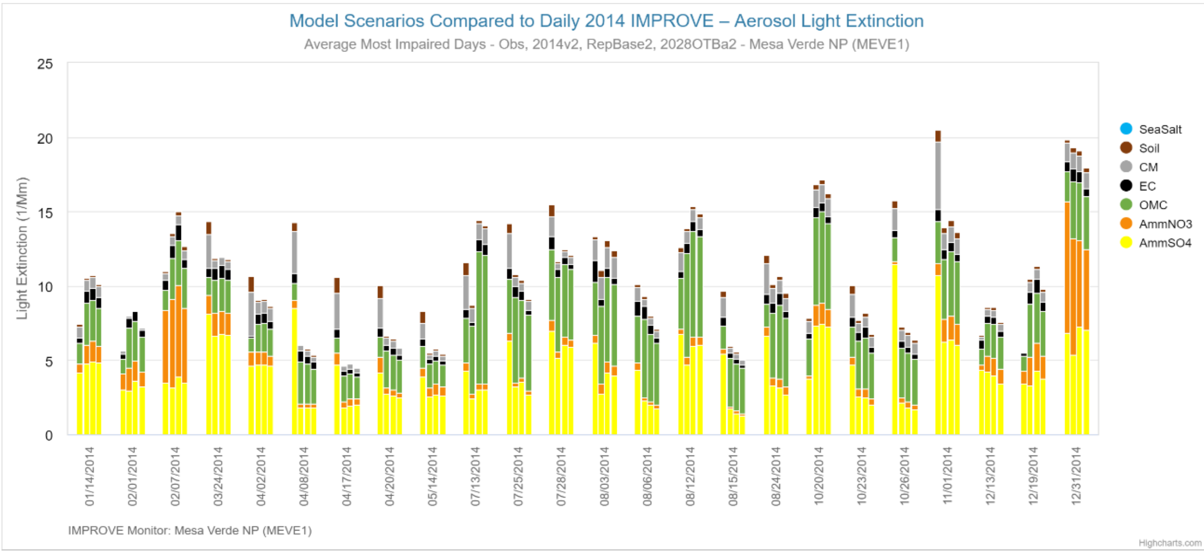


Figure 5b. Model Scenarios Compared to 2014 IMPROVE Observations for Aerosol Light Extinction (Mm^{-1}) on most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Chart #2



7.0 2028 Visibility Projections

2028 visibility projections for the most impaired or clearest days are calculated following EPA guidance for ozone, PM2.5 and regional haze modeling (November 2018) using the EPA default projection method and using two WRAP alternative projection methods that are intended to reduce aerosol contributions from sources other than U.S. anthropogenic emissions on the most impaired days.

The EPA recommended projection procedures are used for all three WRAP projection methods (see WRAP Procedures for Making Visibility Projections and Adjusting Glidepaths, March 2021 final draft.) EPA's Software for the Model Attainment Test (SMAT) was used to perform the projection calculations. CAMx model results are used in a relative sense, meaning that the aerosol concentrations are scaled to the IMPROVE monitoring data for the 2014-2018 period. The fractional differences between the 2028OTBa2 and the RepBase2 modeled aerosol concentrations are used to define scaling factors, also called relative response factors (RRFs), that are calculated for each aerosol species on each 2014 IMPROVE most impaired day (or clearest day) and then averaged for all most impaired days (or clearest days). These average relative response factors are multiplied by the daily aerosol concentration on each most impaired day or clearest day for the IMPROVE 2014-2018 5-year period to define daily projected aerosol concentrations, as indicated by the equations below.

$$\text{Relative Response Factor, } RRF_{SO4} = \sum 2028OTBa2_{SO4} / \sum RepBase2_{SO4}$$

$$\text{Projected\_SO4}_{2028OTBa2} = \text{IMPROVE\_SO4}_{2014\text{-}2018} \times \text{RRF}_{SO4}$$

The daily projected 2028 aerosol concentrations for each of the 2014-2018 IMPROVE most impaired days (or clearest days) are converted to light extinction and then converted to deciview. The daily deciview values are averaged for each year and the annual averages are averaged for the 5-year period to define the 2028 visibility projections. The three WRAP projection methods:

- The **EPA default projection method** follows EPA guidance without deviation.
- The **EPA without fire projection method** uses the same 2014 IMPROVE most impaired days as the EPA default projection method. RepBase2 and 2028OTBa2 modeled source apportionment results are used to identify and remove modeled aerosol contributions from U.S. wildfire, U.S. wildland prescribed fire, and Non-U.S. (Canada and Mexico) fire on these days. After modeled fire contributions have been removed from the daily aerosol values, the EPA default projection procedures are used to calculate the relative response factors and 2028 visibility projections.
- The **Modeled MID projection method** selects the modeled RepBase2 days with the highest fraction of modeled U.S. anthropogenic contributions as the modeled most impaired days for both the RepBase2 and 2028OTBa2 scenarios. RepBase2 and 2028OTBa2 modeled source apportionment results are used to remove the fire contributions from the modeled most impaired days before calculating relative response factors and 2028 visibility projections.

In TSS Modeling Express Chart #3 users can choose to illustrate, for one, two, or three projection methods, for either the most impaired days or clearest days, the visibility projections for 2028 On the Books (2028OTBa2) or 2028 Potential Additional Controls (2028PAC2) in aerosol light extinction. These aerosol contributions are the basis for the 2028 visibility projections in deciview that define the regional haze tracking metric and are displayed in TSS TSS Modeling Express Chart #4 (see Section 8.0). Changes in aerosol species extinction across the 2028 projection scenarios and methods illustrate which aerosol species are responsible for the projected changes in the regional haze visibility tracking metric in deciviews.

Figures 6a and 6b illustrate the IMPROVE 2014-2018 aerosol contributions and the 2028OTBa2 visibility projections in aerosol light extinction using the 3 WRAP projection methods for Yellowstone and Mesa Verde National Parks, respectively.

Interpretation: For YELL2, AmmNO3, OMC, and EC are projected to decrease between the 2014-2018 IMPROVE observations and modeled 2028OTBa2 following the EPA default projection methods. The EPA without fire method has slight decreases in OMC and EC compared to the EPA default method, while the Modeled MID method, which selects different days as most impaired, has slight decreases in OMC, EC, and AmmSO4 (0.3 Mm^{-1}). At MEVE1, AmmNO3 and AmmSO4 are reduced slightly between 2014-2018 IMPROVE observations and

2028OTBa2 projections using EPA default methods. The EPA without fire and Modeled MID methods display slight changes to OMC and EC compared to the EPA default method. As will be illustrated under Section 10.0 Regional Source Apportionment, biogenic and anthropogenic sources of carbon are significant and unchanged fractions of OMC and EC at these two sites. Thus, for these two sites, removing fire contributions from most impaired days only changes a fraction of the total carbon and the EPA without fire projection method has only small changes in the 2028 visibility projection.

Nonetheless, WRAP recommended that EPA without fire projection method be the default 2028 visibility projection displayed because this method removes the contributions of fire on the most impaired days and most closely focuses on anthropogenic contributions to haze.

Figure 6a. 2028 Visibility Projections on most impaired days in Aerosol Light Extinction (Mm^{-1}) compared to 2014-2018 IMPROVE observations for Yellowstone National Park (YELL2). [TSS Modeling Express Chart](#) #3

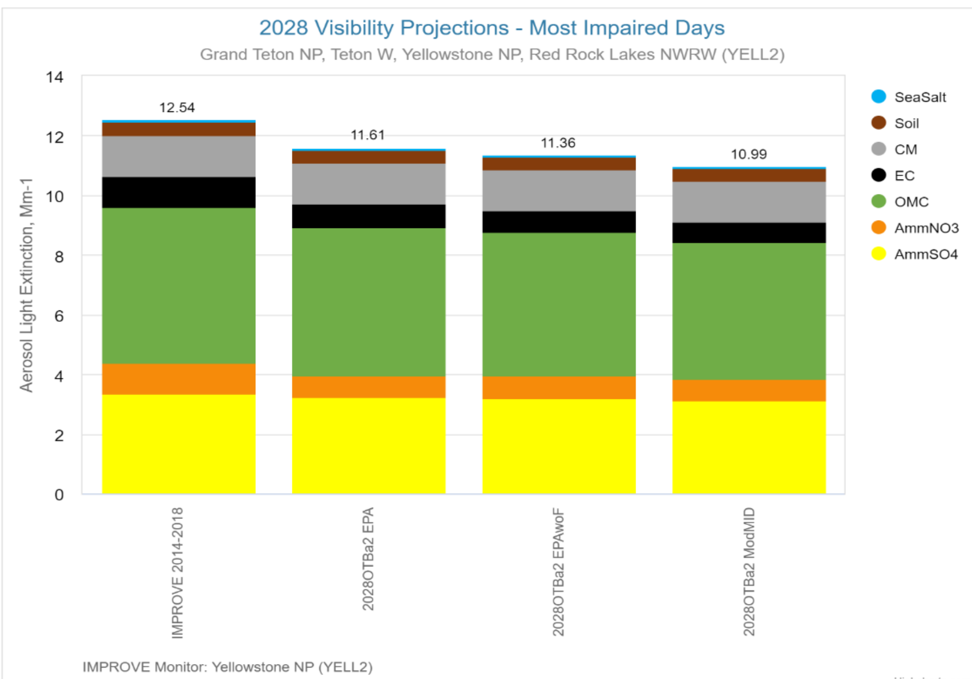
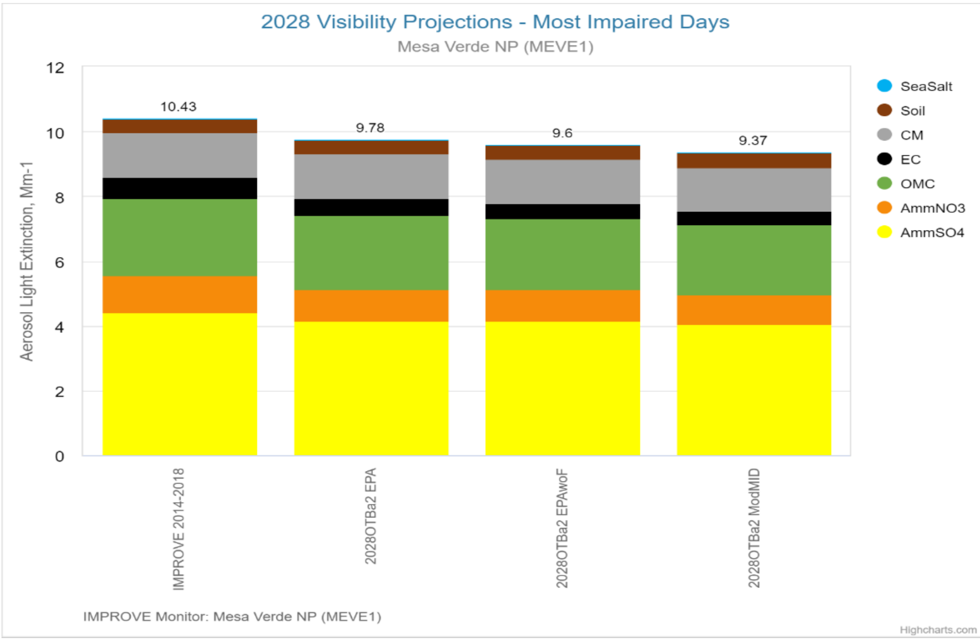


Figure 6b. 2028 Visibility Projections on most impaired days in Aerosol Light Extinction (Mm^{-1}) compared to 2014-2018 IMPROVE observations for Mesa Verde National Park (YELL2). TSS Modeling Express Chart #3



8.0 Visibility Projections compared to the Uniform Rate of Progress Glidepath

TSS Modeling Express Chart #4 displays 2028 visibility projections in deciview compared IMPROVE measurements for the period 2000-2018 and to the Uniform Rate of Progress (URP) glidepath as defined by EPA guidance (Dec 2018). The 2028 visibility projections in deciview are calculated from aerosol concentrations and extinction as described in Section 7. Users can also select to display chart data by aerosol light extinction for individual species or Total Light Extinction.

The URP glidepath is constructed (in deciviews) for the 20% most impaired days (MID) or clearest days using observations from the IMPROVE monitoring site representing a Class I area. The URP glidepath starts with the IMPROVE most impaired days for the 2000-2004 5-year baseline and draws a straight line to estimated natural conditions displayed for the year 2064. For clearest days, the goal is no degradation of visibility from the 2000-2004 5-year baseline, therefore the glidepath for clearest days is a straight line from the 2000-2004 baseline to 2064. In the second regional haze planning period, 2064 natural visibility condition estimates use the 15-year average of natural conditions on IMPROVE most impaired days in each year 2000-2014. IMPROVE annual average values are presented in this chart as points. IMPROVE 5-year average values are presented as solid lines covering the periods 2000-2004 and 2014-2018.

The 2028OTBa2 and 2028PAC2 visibility projections were processed using EPA's Software for the Model Attainment Test (SMAT) for the three WRAP projection methods described in Section 7 (see also WRAP Procedures for Making Visibility Projections and Adjusting Glidepaths, March 2021 final draft):

- EPA default projection method
- EPA without fire projection method
- Modeled MID projection method

2028 On the Books (2028OTBa2) and 2028 Potential Additional Controls (2028PAC2) visibility projections in deciview are illustrated as points that can be compared to the Uniform Rate of Progress glidepath. A state can select among the 2028 projection methods to define a 2028 Reasonable Progress Goal (RPG) for a Class I area for Regional Haze planning purposes.

The 2028 visibility projection is compared to the URP Glidepath at 2028 to determine whether visibility at the Class I areas is projected to be on, above, or below the URP Glidepath. Comparison of 2028 projections to the URP Glidepath defines how well the modeled trend in visibility tracks the straight-line uniform rate of progress to 2064. EPA guidance (August 2019) clarifies that the URP Glidepath is not a bright line test for reasonable visibility progress by 2028 and describes additional considerations for defining reasonable progress. Uncertainties in the glidepath assumptions are discussed in the U.S. Anthropogenic Emissions Rate of Progress (September 2021) document.

Figures 7a and 7b display TSS Modeling Express Chart #4 results for the 2028OTBa2 scenario for Yellowstone and Mesa Verde National Parks, respectively. Users could choose to also display results for the 2028PAC2 control scenario. Regional source apportionment data discussed in Section 10 will assist interpretation of 2028 visibility projections displayed in Chart #4.

Interpretation: For YELL2 (**Figure 7a**), the IMPROVE annual average deciview for the most impaired days varies widely between 2000 to 2018 and the 2000-2018 monitoring trend line (blue line) is above the URP Glidepath (red line). The IMPROVE 2014-2018 5-year average deciview for the most impaired days intersects the URP glidepath. The 2028OTBa2 visibility projections for all 3 WRAP methods are above the URP glidepath, although the EPA without fire and Modeled MID projection methods yield slightly lower 2028 projections than the EPA default projection. The IMPROVE annual average deciview for the clearest days show steady improvement between 2000 and 2018 and the 2028OTBa2 projection indicates further improvement on the clearest days.

At MEVE1 (**Figure 7b**) the IMPROVE annual average deciview for the most impaired days shows a consistent reduction between 2000 and 2018. The IMPROVE 2000-2018 monitoring trendline and the IMPROVE 2014-2018 5-year average deciview for the most impaired days are well below the URP glidepath. All 3 projection methods for 2028OTBa2 are also well below the URP glidepath. The clearest days at MEVE1 also show continuous improvement and the 2028OTBa2 projections are below the 2014-2018 5-year average deciview.

Figure 7a. 2028 Visibility Projections for clearest days and most impaired days, compared to the Uniform Rate of Progress Glidepath at the Yellowstone National Park (YELL2) IMPROVE monitor. [TSS Modeling Express Chart](#) #4

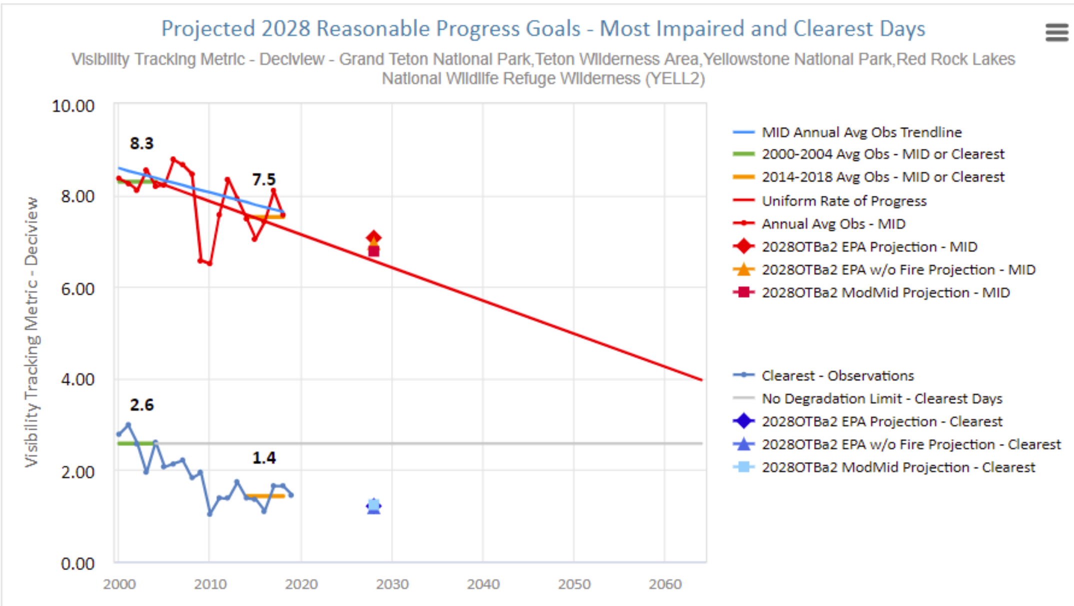
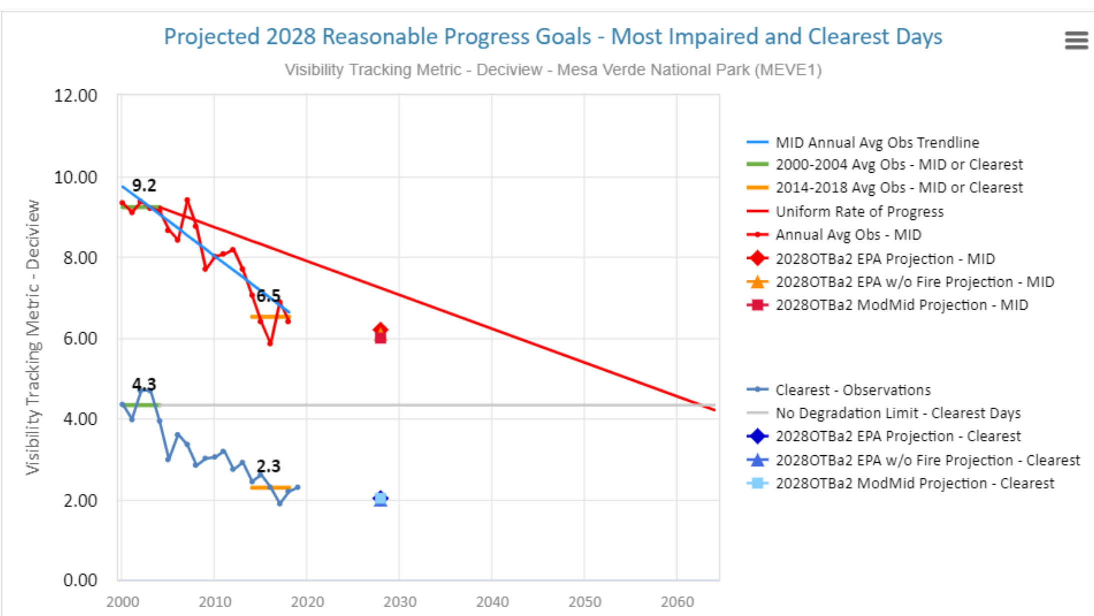


Figure 7b. 2028 Visibility Projections for clearest days and most impaired days, compared to the Uniform Rate of Progress Glidepath at the Mesa Verde National Park (MEVE1) IMPROVE monitor. [TSS Modeling Express Chart](#) #4



In general, western Class I areas near urban areas or major point sources demonstrate visibility improvement in the IMPROVE monitoring data between 2000 to 2018 and the 2028 visibility projections are below the URP glidepath. Ammonium nitrate and ammonium sulfate are major contributors on most impaired days at many of these sites, including Mesa Verde NP (see **Figure 6b**). Class I areas near oil and gas development do not display as much visibility improvement by 2028OTBa2 as more remote sites. Class I areas where carbon is a significant fraction of aerosol contributions on most impaired days, including Yellowstone NP (see **Figure 6a**) show more variable visibility progress in the IMPROVE monitoring data 2000-2018 and in the 2028 visibility projections.

Clearest days at all western Class I areas have improved between 2000 and 2018 and are projected to continue to improve by 2028 at almost all western Class I areas.

EPA Volcanic adjustment (August 2021) for IMPROVE monitors at Hawai'i Volcano (HAVO1) and Haleakalā (HALE1) National Parks:

EPA defined an adjustment to ammonium sulfate to account for episodic volcanic events at Hawai'i Volcano (HAVO1) and Haleakalā (HALE1) National Parks. EPA's adjustment follows the same methodology as defined in December 2018 guidance to account for episodic extreme fire or dust events using IMPROVE measurements of carbon or crustal materials. EPA's adjustment for volcanic contributions uses IMPROVE daily ammonium sulfate measurements for the years 2000-2014, defines the average 95th percentile value for each year, and selects the lowest annual value as the threshold to assign ammonium sulfate daily measurements above that threshold as episodic volcanic (natural) contributions. After accounting for episodic volcanic contributions to ammonium sulfate, impairment is calculated following EPA guidance. By assigning maximum ammonium sulfate values as natural rather than anthropogenic, the days that are defined as most impaired by anthropogenic contributions shift. Ammonium sulfate still dominates the most impaired days, suggesting that not all volcanic contributions are accounted for using a 95th percentile threshold.

In addition to the volcanic adjustment, to assure a complete IMPROVE data set for Haleakalā National Park, EPA also applied data substitution methods to merge data from two separate IMPROVE monitor locations that have represented the Haleakalā NP Class I area over the 2000-2018 period (HALE1 and Haleakala Crater, HACR1). The combined data set is referred to as HALE_RHTS.

EPA also provided 2028 visibility projections for the volcano adjusted data sets, HAVO1_VADJ and HALE_RHTS_VADJ, as described in EPA's Technical Support Document for Updated 2028 Regional Haze Modeling for Hawaii, Virgin Islands, and Alaska (August 2021). EPA 2028 visibility projections for HAVO1_VADJ and HALE_RHTS_VADJ are displayed in aerosol extinction in TSS Modeling Express Chart #20 (equivalent to TSS Modeling Chart #3). TSS Modeling Express Chart #21 (equivalent to TSS Modeling Chart #3) displays 2028 visibility projections in deciview for HAVO1_VADJ and HALE_RHTS_VADJ, the 2000-2018 volcano-adjusted monitoring data, estimated natural conditions in 2064, and the Uniform Rate of Progress for the volcano adjusted data for the most impaired days or clearest days at these two Class I areas.

TSS Modeling Express Tool #8 displays a table for each state listing all federal Class I areas in that state comparing the 2014-2018 5-year average IMPROVE observations to the 2028OTBa2 and 2028PAC2 visibility projections in deciview, calculated using the 3 WRAP projection methods. **Table 11** illustrates the 2028 visibility projection results for the state of Colorado. Note that Colorado did not define Potential Additional Controls for sources in Colorado for 2028PAC2, nonetheless, small changes in visibility were projected for 2028PAC2 due to PAC2 control assumptions in other WRAP states.

Table 11. 2028 Visibility Projections for the most impaired days at Class I areas in Colorado for the 2028 On the Books (2028OTBa2) and 2028 Potential Additional Controls (2028PAC2) model scenarios and 3 WRPA projection methods. TSS Modeling Express Tool #8

CO - 2028 Visibility Projections Summary

Most Impaired Days *(defined by EPA guidance [1])*

Class I Area IMPROVE Monitor	IMPROVE 2014-2018	2028 OTBa2 Model: EPA M.I.D.	2028 OTBa2 Model: EPA MID w/o Fire	2028 OTBa2: Modeled MID	2028 PAC2 Model: EPA M.I.D.	2028 PAC2 Model: EPA MID w/o Fire	2028 PAC2: Modeled MID
GRSA1	8.02 dv	7.55 dv	7.5 dv	7.33 dv	7.53 dv	7.49 dv	7.31 dv
MEVE1	6.51 dv	6.19 dv	6.1 dv	5.97 dv	6.18 dv	6.08 dv	5.94 dv
MOZI1	5.47 dv	4.96 dv	4.93 dv	4.94 dv	4.95 dv	4.92 dv	4.92 dv
ROMO1	8.41 dv	7.6 dv	7.56 dv	7.46 dv	7.59 dv	7.55 dv	7.44 dv
WEMI1	6.55 dv	6.12 dv	6.03 dv	5.89 dv	6.1 dv	6.02 dv	5.86 dv
WHRI1	4.98 dv	4.53 dv	4.49 dv	4.39 dv	4.52 dv	4.48 dv	4.37 dv

1) U.S. EPA. December 2018. Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program. EPA-454/R-18-010

9.0 Adjustments to the Uniform Rate of Progress Glidepath

EPA guidance (December 2018) allows a State to propose an adjustment to the URP glidepath to account for visibility contributions from anthropogenic emissions outside the U.S. or from emissions from wildland prescribed fires that meet specific land management objectives and apply basic smoke management practices. The EPA Administrator may approve proposed adjustments to the URP glidepath that follow “scientifically valid data and methods.” EPA’s regional haze modeling Technical Support Document (September 2019) demonstrates adjustments to the 2064 endpoint of the URP glidepath using source apportionment results for international anthropogenic or wildland prescribed fire emissions from the EPA 2028 model scenario.

WRAP methods to adjust the 2064 endpoints for the URP glidepath to account for international emissions or wildland prescribed fire emissions are described in detail in WRAP Procedures for Making Visibility Projections and Adjusting Glidepaths (March 2021). The WRAP adjustments to the URP glidepath are based on 2028OTBa2 source apportionment results for international anthropogenic and wildland prescribed fire. Consistent with the methods evaluated in the EPA Technical Support Document, WRAP evaluated five approaches using 2028OTBa2 source apportionment results to adjust the 2064 endpoints. 2028 source apportionment results were applied in a relative sense (model results normalized to 2028 visibility projections) or an absolute sense (unadjusted absolute model results). 2064 endpoints were defined using IMPROVE natural conditions estimated for 2000-2014 or using 2028 source apportionment results for natural source contributions.

After review of the initial glidepath adjustment results, WRAP recommended that adjustment of the URP glidepath for Class I areas in western states use 2028 source apportionment results in a relative sense and use EPA estimated natural conditions for the 2064 endpoint for one of two options:

- International anthropogenic contribution normalized to IMPROVE monitoring data and added to EPA estimated natural conditions (International).
- International anthropogenic plus Wildland Prescribed fire combined contributions normalized to IMPROVE monitoring data and added to EPA estimated natural conditions (International + wildland Rx fire)

Note that wildland prescribed fire events in the 2028 OTBa2model scenario reflect the same events as modeled for 2014v2. Wildland prescribed fire events may not occur on most impaired days in 2014v2. Location, timing, frequency, magnitude, and duration of wildland prescribed fire events vary geographically, seasonally, and year to year. Therefore, interpretation of wildland prescribed fire contributions on most impaired days for the 2028OTBa2 source apportionment results and for the 2064 adjustment to the URP glidepath is uncertain.

TSS Modeling Express Chart #5 illustrates the Regional Haze Uniform Rate of Progress (URP) Glidepath as defined by EPA guidance and the two WRAP alternative glidepath end point adjustments for 2064 (International, International + Wildland Prescribed Fire.)

The URP glidepath (in deciviews) for most impaired days and the optional glidepath adjustments all start from the 2000-2004 5-year baseline for most impaired days and draw a straight line to estimated natural conditions in 2064. All 2064 endpoints use EPA estimates of natural conditions based on 2000-2014 IMPROVE data. Annual average deciview for 2000 to

2018 most impaired days are illustrated as points. IMPROVE 2000-2004 and 2014-2018 5-year average deciview values are illustrated as solid lines. Users can choose to display 2028OTBa2 and/or 2028PAC2 visibility projections for 1-3 projection methods and to display 2064 endpoint without adjustment or adjustment for either international anthropogenic emissions or international anthropogenic plus wildland prescribed fire emissions. The 2028OTBa2 EPA without fire projection method is the default setting for purposes of comparing 2028 visibility projections to the adjustment glidepath.

Figures 8a and 8b illustrate examples of TSS Modeling Express Chart #5 for Yellowstone (YELL2) and Mesa Verde (MEVE1) National Parks.

Interpretation: At YELL2, the 2028OTBa2 EPA without fire projection is above the URP glidepath. Adding International anthropogenic contributions to the 2064 endpoint raises the adjusted glidepath in 2028 to be above the 2028OTBa2 EPA without fire projection value. The second adjustment to the 2064 endpoint (adding wildland prescribed fire contribution to the international anthropogenic contribution) slightly raises the slope of the glidepath compared to international emissions alone.

At MEVE1, the 2028 visibility projection is below the URP glidepath. Adjustment of the 2064 endpoint for the international anthropogenic contribution raises the slope of the glidepath; adjustment for wildland prescribed fire has a negligible change to the adjusted glidepath.

At most Class I areas in the western U.S., application of the recommended methods to adjust the 2064 endpoint raises the slope of the URP glidepath. Western states will independently determine whether or not to use the URP glidepath adjustments in their regional haze planning.

Figure 8a. 2028 Visibility Projections compared to adjustments to the Uniform Rate of Progress Glidepath for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. TSS Modeling Express Chart #5.

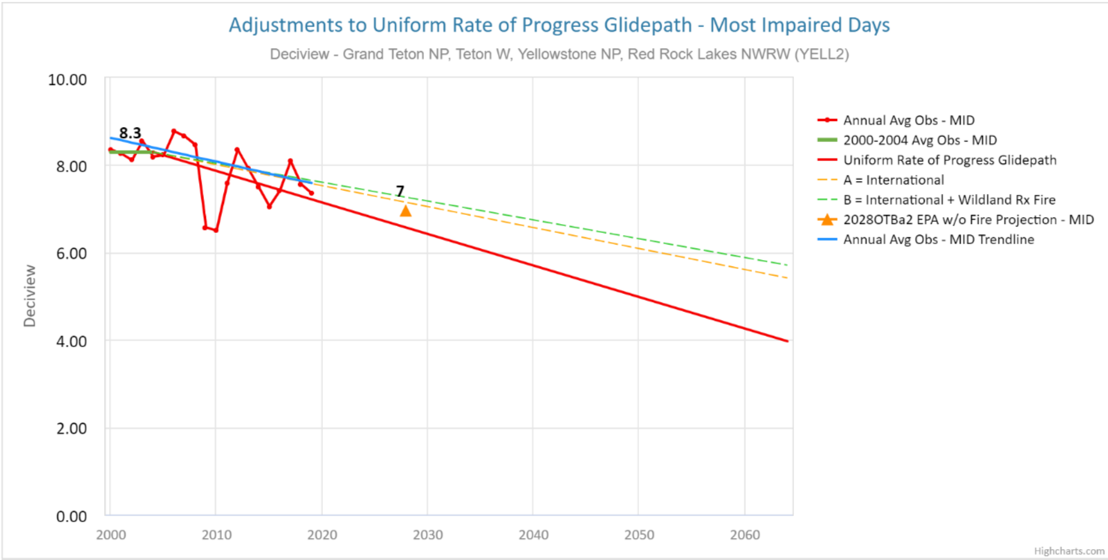
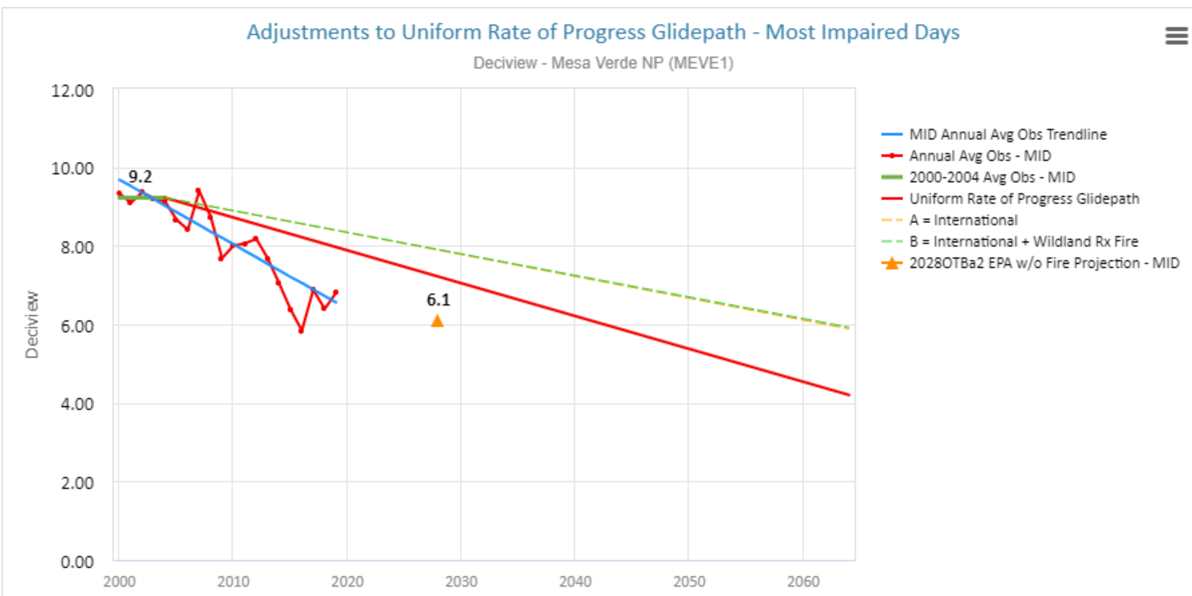


Figure 8b. 2028 Visibility Projections compared to adjustments to the Uniform Rate of Progress Glidepath for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. [TSS Modeling Express Chart](#) #5



10.0 Regional (High-level) Source Apportionment

WRAP Source Apportionment methods are described in the run specification sheet for High-Level and Low-Level Source Apportionment Modeling using the RepBase2 and 2028OTBa2 model scenarios (September 2020).

Purpose: Regional source apportionment results for U.S. anthropogenic, international anthropogenic, fire, and natural source contributions at each IMPROVE site representing western Class I areas were used as follows:

- Modeled most impaired days (ModMID) were defined based on RepBase2 source apportionment results. ModMID days were ranked by modeled U.S. anthropogenic contributions as a fraction of total aerosol light extinction. ModMID days are used as one of the WRAP alternative 2028 projection methods (see Section 7).
- 2028OTBa2 modeled international and U.S. wildland prescribed fire contributions were used as an option to adjust the 2064 endpoint of the URP glidepath for the most impaired days (see Section 9).
- Along with 2002 Hindcast scenario, RepBase2 and 2028OTBa2 regional source apportionment results for total aerosol light extinction were used to define a U.S. Anthropogenic Emissions Rate of Progress (see Section 12).

The CAMx photochemical model version 7.0 with the Particle Source Apportionment tool (PSAT) was applied at a regional level to separate U.S. anthropogenic contributions from those of fire, natural, and international anthropogenic contributions for the representative baseline period (2014-2018, RepBase2) and a future year, 2028OTBa2. CAMx with PSAT tracked gaseous and particle air emissions from sources through atmospheric dispersion, photochemical reactions, and transport to receptors (the 12-km modeling grid cell where the IMPROVE monitor is located), as defined in **Table 12**. Aerosol concentrations at the receptor include the direct products of primary gaseous and particle emissions and secondary aerosol formation.

Source contributions were defined for the following aerosols:

- Ammonium nitrate (AmmNO3)
- Ammonium sulfate (AmmSO4)
- Organic mass from carbon (OMC)
    - Primary Organic Aerosol (POA)
    - Secondary Organic Aerosols
        - Anthropogenic (SOAA)
        - Biogenic (SOAB)
- Primary Elemental Carbon (EC)
- Primary Fine Soil
- Primary Coarse Mass
- Seasalt

Table 12. PSAT emissions tracers mapped to IMPROVE aerosol species at the model receptor

PSAT Tracer Description	IMPROVE Species Name (TSS label)	Mapping between IMPROVE and PSAT species (concentration in µg/m3)	Notes
Particulate Sulfate (PS4)	Ammonium Sulfate (AmmSO4)	AmmSO4 = 1.375 * PS4	Factor 1.375 converts sulfate ion to fully neutralized ammonium sulfate
Particulate Nitrate (PN3)	Ammonium Nitrate (AmmNO3)	AmmNO3 = 1.29 * PN3	Factor 1.29 converts nitrate ion to fully neutralized ammonium nitrate
Primary Elemental Carbon (PEC)	Elemental Carbon (EC)	EC = PEC	
Primary Organic Aerosol (POA)	Organic Mass from Carbon (OMC)	OMC = POA +SOAA + SOAB	Secondary Organic Aerosols (SOA) are not explicitly tracked by source group. SOA are derived from AVRG concentration files and are operationally assigned to anthropogenic (SOAA) or biogenic (SOAB) source groups. All SOAA is assigned to U.S. anthropogenic source category and all SOAB is assigned to Natural source category.
Aluminum (PAL)	Fine Soil (Soil)	Soil = 2.2*PAL + 2.49*PSI + 1.63*PCA + 2.42*PFE + 1.94*PTI	Soil mapping is consistent with IMPROVE definition
Silicon (PSI)			
Calcium (PCA)			
Iron (PFE)			
Titanium (PTI)			
Coarse Crustal PM (PCC)	Coarse Mass (CM)	CM = PCC + PCS	
Other Coarse Particulate (PCS)			
Chloride (PCL)	Sea Salt	Sea Salt = 1.8 * PCL	Chloride is not tracked by Source Apportionment. It is obtained from the AVRG concentration files. All Chloride is assigned to sea salt. All sea salt is assigned to the "natural" source group. All other source group contributions to sea salt are 0.

Due to computational constraints, the secondary organic aerosols (SOA) family of reactive tracers were not used to track SOA at the receptor; rather SOA were operationally assigned to anthropogenic (SOAA) or biogenic (SOAB) contributions based on the chemical signatures (e.g., isoprene was assigned as biogenic in origin; benzene was assigned as anthropogenic in origin.) For purposes of compositing regional source categories, all SOAA were assigned to the U.S. anthropogenic source category and all SOAB were assigned to the Natural source category.

Regional source apportionment results for RepBase2 and 2028OTBa2 aerosol light extinction are displayed in TSS Modeling Express Tools # 10-16 for 15 source groups that are composited into 6 source categories as listed below. Abbreviations correspond to the source labels used in TSS Modeling Express Tools #10-16.

- U.S. Anthropogenic (USAnthro)
  - U.S. anthropogenic (AntUS)
  - U.S. agricultural fire (AgfireUS)
  - Secondary Organic Aerosol-Anthropogenic (SOAA)
  - Commercial Marine Vessels (CMVUS)
  - U.S. anthropogenic contributions from outside the CAMx 36-km domain boundary as defined by the GEOS-Chem global model. (BC-US)
- U.S. Wildfire (WFUS)
- U.S. Wildland Prescribed fire (RxUS)
- Canadian and Mexican fires (OthFr)
- Natural
  - Natural (Nat)
  - Secondary Organic Aerosol -Biogenic (SOAB)
  - Natural contributions from outside the CAMx 36-km domain boundary as defined by the GEOS-Chem global model. (BC-Nat)
- International Anthropogenic (IntlAnthro)
  - International Anthropogenic contributions from outside the CAMx 36-km domain boundary as defined by the GEOS-Chem global model. (BC-Int)
  - Canadian Anthropogenic (AntCAN)
  - Mexican Anthropogenic (AntMEX)
  - Commercial Marine vessels – International (beyond 200km from U.S. coast) (CMV_nonUS)

Users can choose to display source apportionment results in TSS Modeling Express Tools # 10-16 for most impaired days (EPA default 2014 IMPROVE days), modeled most impaired days, or clearest days. Charts in this document provide examples for 2014 IMPROVE most impaired days only.

Users can choose to display source apportionment results for total aerosol extinction or for individual aerosols species extinction.

Modeled source contributions to light extinction in TSS Modeling Express Tools # 10-16 are not normalized to IMPROVE monitoring data. Model performance should be considered when interpreting source apportionment results. Average and daily model performance for most impaired days as displayed in TSS Modeling Express Tool # 1 and 2 provide insight to confidence to place in source apportionment results for individual aerosol species.

TSS Modeling Express Tool # 10 defines in a single stacked barchart the light extinction contributions from 15 source groups for the RepBase2 or 2028OTBa2 model scenarios. **Figures 9a and 9b** illustrate regional source apportionment for 2028OTBa2 for Yellowstone NP (YELL2) and Mesa Verde NP (MEVE1), respectively.

Interpretation: At YELL2, U.S. anthropogenic emissions in 2028OTBa2 are projected to contribute less than 20% of total aerosol light extinction (left chart) and less than 30% of extinction due to AmmNO3 extinction (right chart). At MEVE1, U.S. anthropogenic emissions in 2028OTBa2 are projected to contribute less than 30% of total extinction (left) and 54% of AmmNO3 extinction (right).

Figure 9a. 2028OTBa2 Regional Source Apportionment for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor for 15 source group contributions to total aerosol light extinction (Mm^{-1}) (left) or to Ammonium nitrate light extinction (right). TSS Modeling Express Tool # 10.

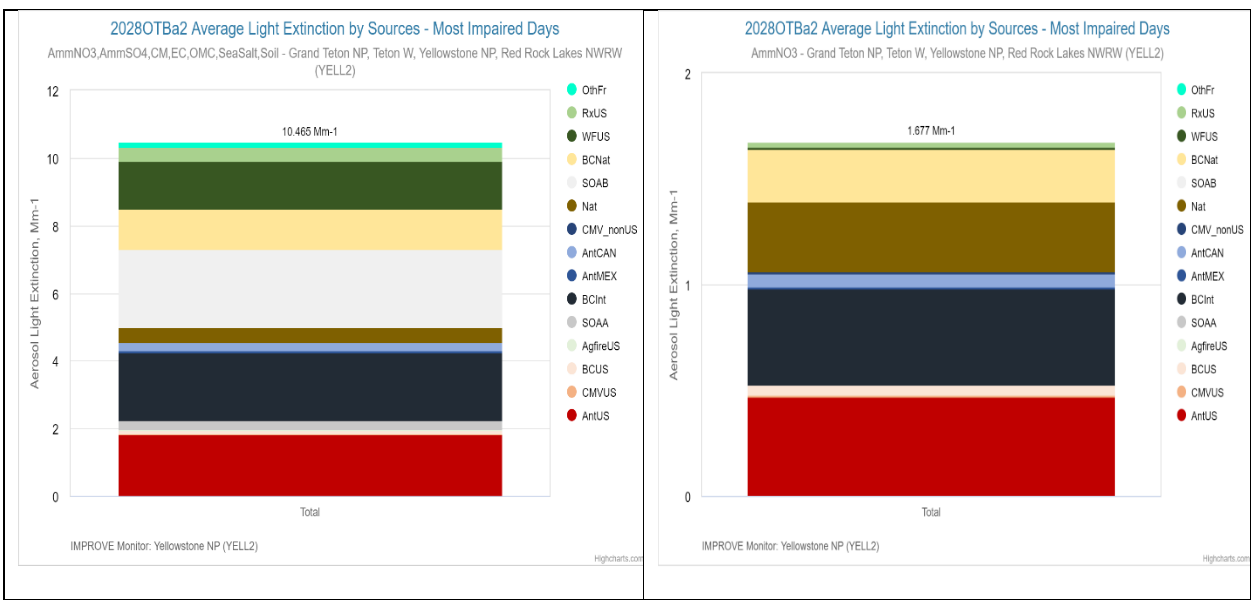
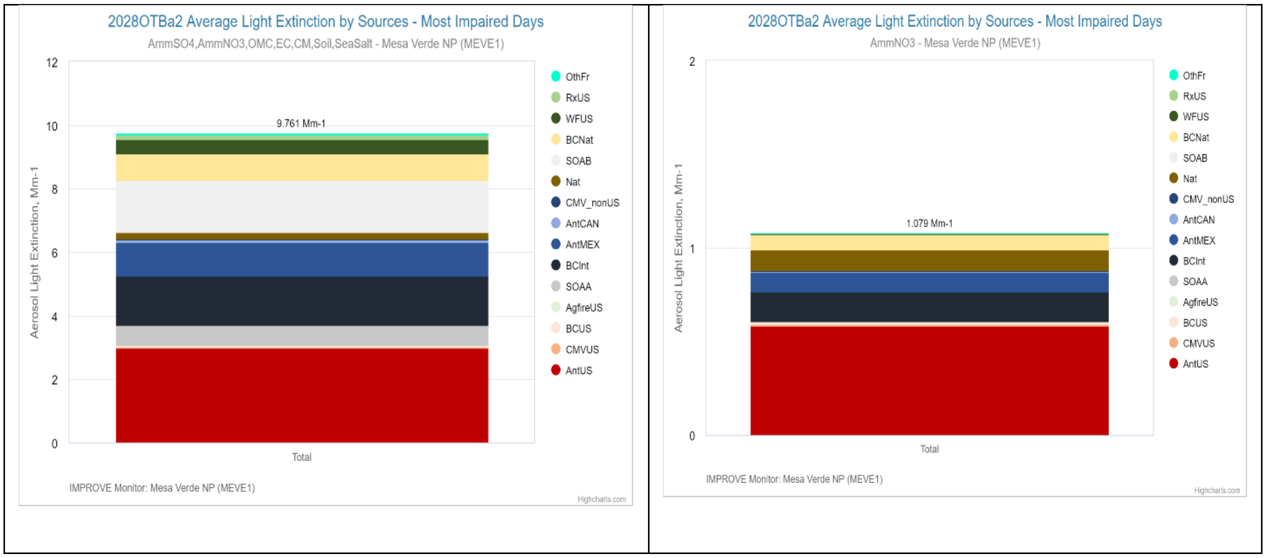


Figure 9b. 2028OTBa2 Regional Source Apportionment for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor for 15 source group contributions to total aerosol light extinction (Mm^{-1}) (left) or to Ammonium nitrate light extinction (right). TSS Modeling Express Tool # 10.

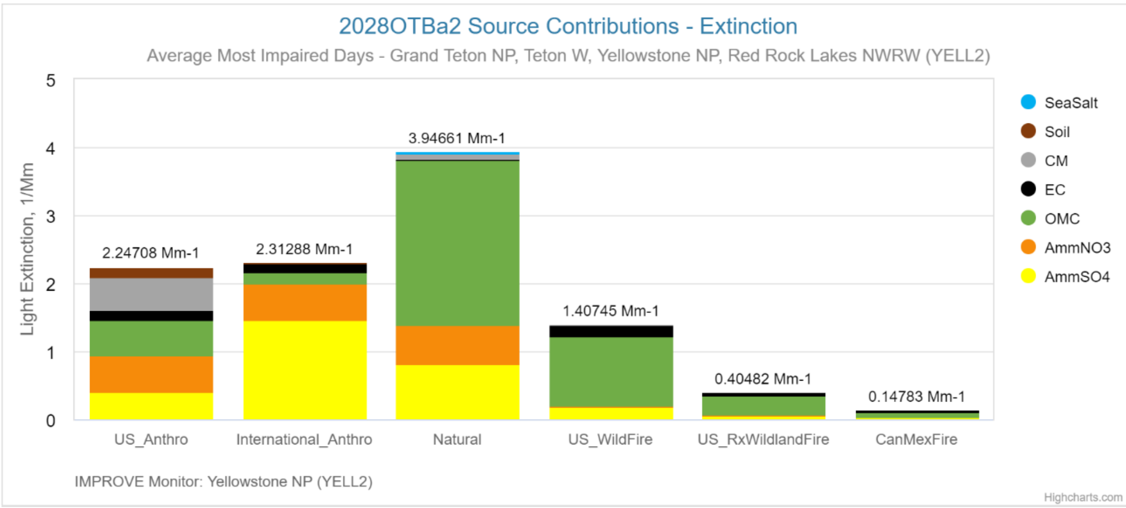


TSS Modeling Express Tool # 11, illustrated in **Figure 10a** for YELL2 and **Figure 10b** for MEVE1, displays speciated aerosol light extinction on most impaired days for RepBase2 or 2028OTBa2, by pollutant, for each of 6 source categories.

Interpretation: For YELL2, in 2028OTBa2, the natural source category is the largest source contribution, even on the most impaired days. Organic carbon dominates the natural and fire categories. International anthropogenic source contributions are equal to U.S. anthropogenic contributions and smaller than natural plus fire contributions. Ammonium sulfate and ammonium nitrate dominate the international anthropogenic category. For U.S. anthropogenic contributions, ammonium nitrate, ammonium sulfate, organic carbon, and coarse mass are projected to have similar contributions. U.S. wildland prescribed fire has very small contributions at YELL2.

The 2028OTBa2 visibility projections for YELL2 are projected to be above the URP glidepath (see **Figure 7a**, TSS Modeling Express Tool # 4) because U.S. anthropogenic sources are a smaller fraction of total aerosol extinction compared to natural, international, and fire contributions. Adding the 2028OTBa2 international contribution to the 2064 endpoint raises the URP glidepath above the 2028OTBa2 visibility projection for YELL2 (see **Figure 8a**, TSS Modeling Express Tool # 5). Adding 2028OTBa2 wildland prescribed fire to the 2064 endpoint has a very small impact on the slope of the URP glidepath because U.S. wildland prescribed fire has a small contribution to total aerosol extinction.

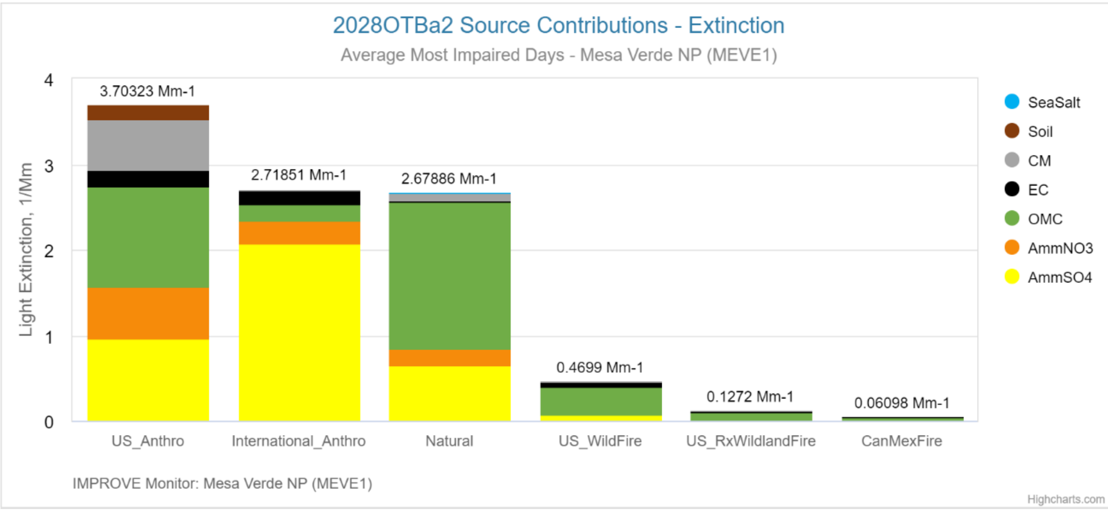
Figure 10a. 2028OTBa2 Regional Source Apportionment of Speciated Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor for U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories, with component species contributions. TSS Modeling Express Tool # 11.



Interpretation: For MEVE1, in 2028OTBa2, U.S. anthropogenic emissions have the largest contributions to total aerosol extinction, divided between ammonium sulfate, ammonium nitrate, organic carbon, and coarse mass (**Figure 10b**). International anthropogenic and natural sources have equivalent, somewhat smaller contributions than U.S. anthropogenic sources. International anthropogenic contributions are dominated by ammonium sulfate, while natural sources and fires are dominated by organic carbon. U.S. wildland prescribed fire has very small contributions at MEVE1.

The 2028OTBa2 visibility projections for MEVE1 are projected to be below the URP glidepath (see **Figure 10a**, TSS Modeling Express Tool # 4) because U.S. anthropogenic sources are a larger fraction of total aerosol extinction compared to natural, international, and fire contributions and changes in the U.S. anthropogenic emissions between RepBase2 and 2028OTBa2 are reflected in changes to 2028OTBa2 visibility projections. Adding the 2028OTBa2 international contribution to the 2064 endpoint raises the URP glidepath for MEVE1 (see **Figure 11a**, TSS Modeling Express Tool # 5). Adding 2028OTBa2 wildland prescribed fire to the 2064 endpoint has a very small impact on the slope of the URP glidepath because U.S. wildland prescribed fire has a small contribution to total aerosol extinction.

Figure 10b. 2028OTBa2 Regional Source Apportionment of Speciated Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor for U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories, with component species contributions. TSS Modeling Express Tool # 11.



TSS Modeling Express Tool # 12 illustrated in **Figure 11a** for Yellowstone NP, YELL2, and **Figure 11b** for Mesa Verde NP, MEVE1, displays speciated aerosol light extinction on most impaired days for RepBase2 or 2028OTBa2, by source category, for each of 7 pollutants.

Interpretation: At YELL2, in 2028OTBa2, on the most impaired days, organic carbon is the largest contributor to total aerosol extinction and natural and fire sources are the largest contributors to organic carbon. International anthropogenic emissions are the largest contributor to AmmSO4. Natural, international anthropogenic, and U.S. anthropogenic emissions have comparable contributions to AmmNO3.

At MEVE1, in 2028OTBa2, on most impaired days, AmmSO4 and organic carbon are the largest contributors to total aerosol extinction. International emissions are the largest contributor to AmmSO4 and natural emissions are the largest contributor to organic carbon. U.S. anthropogenic emissions are the second largest contributors to AmmSO4 and organic carbon.

Figure 11a. 2028OTBa2 Regional Source Apportionment of Speciated Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor for 7 pollutants, with component U.S. Anthropogenic, International anthropogenic, Natural, and Fire contributions to each pollutant. [TSS Modeling Express Tool]() # 12.

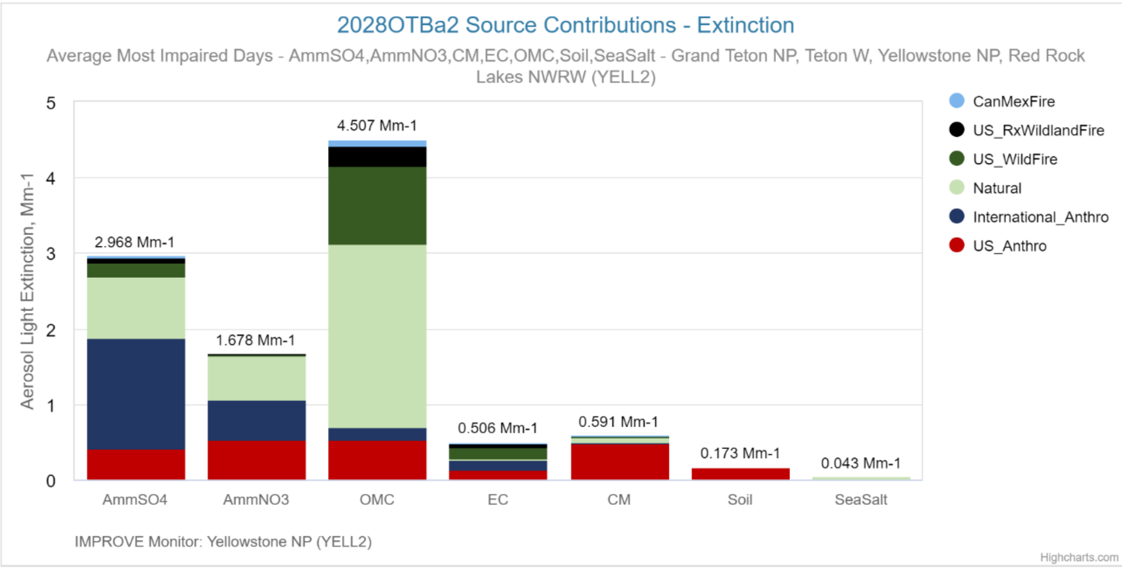
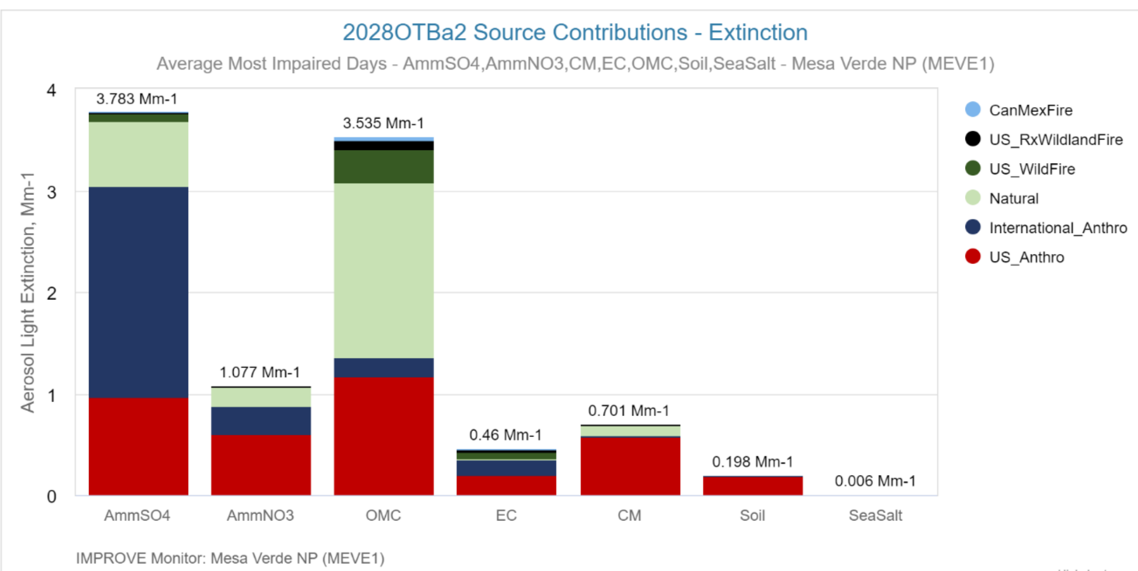


Figure 11b. 2028OTBa2 Regional Source Apportionment of Speciated Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor for 7 pollutants, with component U.S. Anthropogenic, International anthropogenic, Natural, and Fire contributions to each pollutant. [TSS Modeling Express Tool]() # 12.



TSS Modeling Express Tool # 13 illustrated in **Figure 12a** for Yellowstone NP (YELL2) and **Figure 12b** for Mesa Verde NP (MEVE1), displays aerosol light extinction on individual 2014 IMPROVE most impaired days for RepBase2 or 2028OTBa2 source apportionment, by source category.

Interpretation: Comparing Figures 15a and 15b, U.S. anthropogenic contributions in 2028OTBa2 are a larger fraction of daily aerosol light extinction at Mesa Verde NP than at Yellowstone NP. U.S. anthropogenic contributions dominate on the two most impaired days with the highest total aerosol extinction at MEVE1. At YELL2, international anthropogenic and natural sources are equal or greater contributors to daily aerosol light extinction than U.S. anthropogenic sources. These source apportionment results are consistent with the 2028OTBa2 visibility projections for these two sites (see **Figure 7a**, TSS Modeling Express Tool # 4).

Figure 12a. 2028OTBa2 Regional Source Apportionment of Aerosol Light Extinction (Mm^{-1}) for 2014 IMPROVE daily most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor for U.S. Anthropogenic, International anthropogenic, Natural, and Fire emissions. TSS Modeling Express Tool # 13.

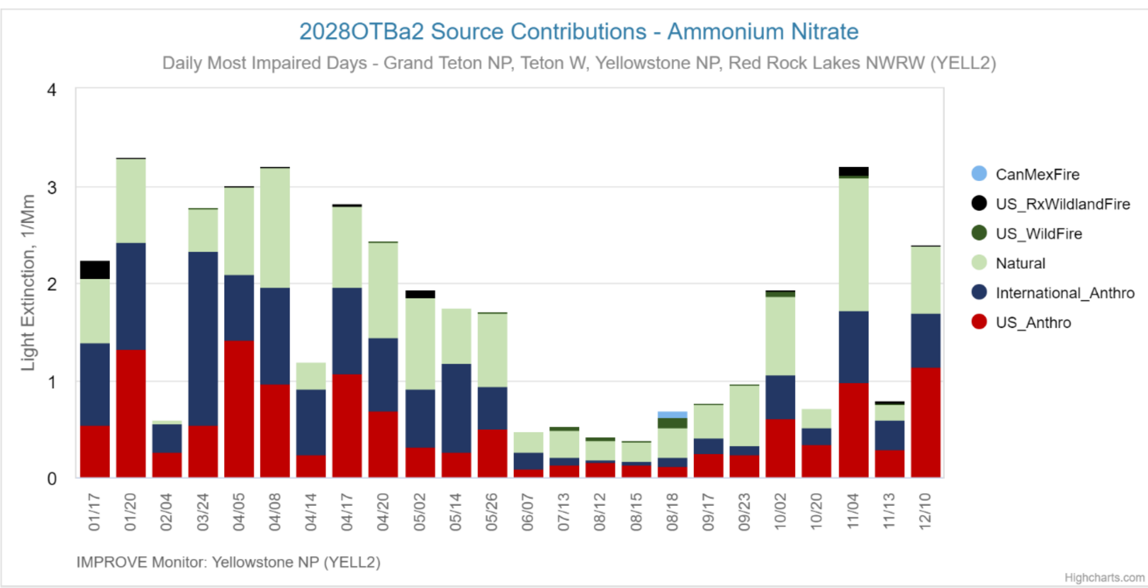
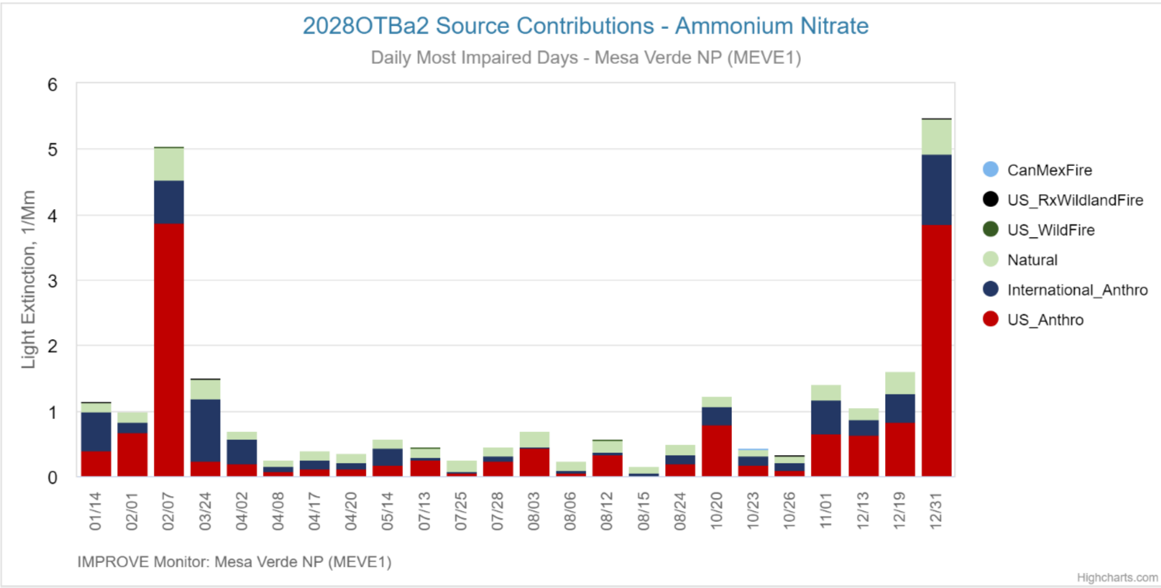


Figure 12b. 2028OTBa2 Regional Source Apportionment of Aerosol Light Extinction (Mm^{-1}) for daily 2014 IMPROVE most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor for U.S. Anthropogenic, International anthropogenic, Natural, and Fire emissions. TSS Modeling Express Tool # 13.



TSS Modeling Express Tool # 14 illustrated in **Figures 13a and 13b** for Yellowstone NP (YELL2) and **Figures 13c and 13d** for Mesa Verde NP (MEVE1) displays RepBase2 or 2028OTBa2 source apportionment results as a treemap (used to display hierarchal data.) Source categories are displayed in block colors with component source groups outlined within each source category total. Users can choose to display source apportionment results for total aerosol light extinction or single aerosol species extinction. Results in Figures 13a and 13c display total aerosol light extinction for 2028OTBa2; results in Figures 13b and 13d display light extinction due to AmmNO3 for 2028OTBa2.

Interpretation: at YELL2, for total aerosol extinction, natural sources are the largest contributors. International anthropogenic and U.S. anthropogenic have similar contributions, and wildfire is also an important source contribution. For AmmNO3, Natural, International anthropogenic and U.S. anthropogenic sources have very similar contributions. As shown in Figure 9a, at YELL2, U.S. anthropogenic emissions in 2028OTBa2 are projected to contribute less than 20% of total aerosol light extinction and less than 30% of extinction due to AmmNO3. These low fractions mean that it is more difficult to demonstrate changes visibility in response to changes in U.S. anthropogenic emissions.

At MEVE1, U.S. anthropogenic emissions are the largest source category for total aerosol extinction and for extinction due to AmmNO3 (Figures 13c, 13d). Visibility is more likely to respond to changes in U.S. anthropogenic emissions at MEVE1 than at YELL2.

Figure 13a. 2028OTBa2 Regional Source Apportionment of Total Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Yellowstone National Park (YELL2) for source groups contributing to U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories. TSS Modeling Express Tool # 14.

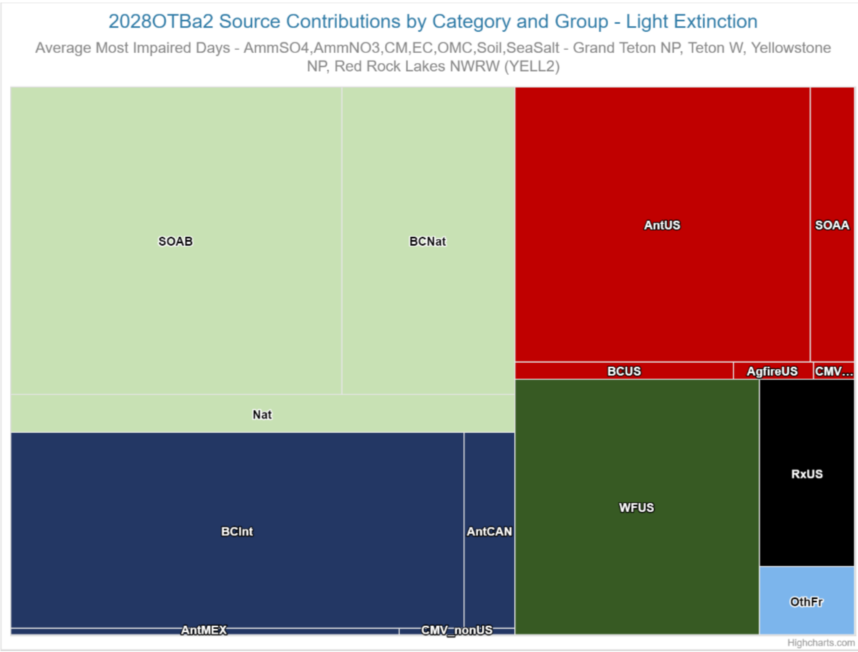


Figure 13b. 2028OTBa2 Regional Source Apportionment of Aerosol Light Extinction (Mm^{-1}) due to Ammonium nitrate for most impaired days at the Yellowstone National Park (YELL2) for source groups contributing to U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories. TSS Modeling Express Tool # 14.

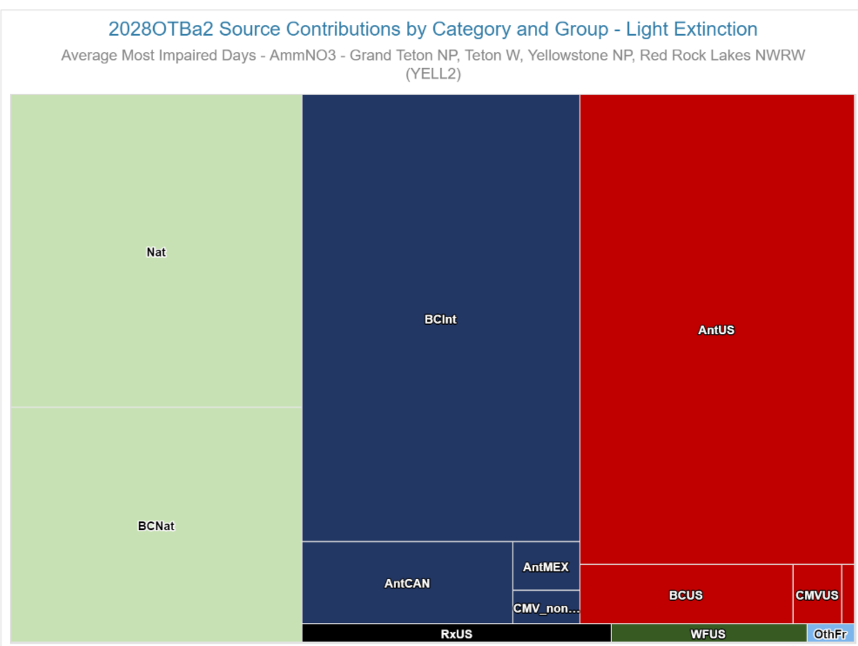


Figure 13c. 2028OTBa2 Regional Source Apportionment of Total Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Mesa Verde National Park (MEVE1) for source groups contributing to U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories. TSS Modeling Express Tool # 14.

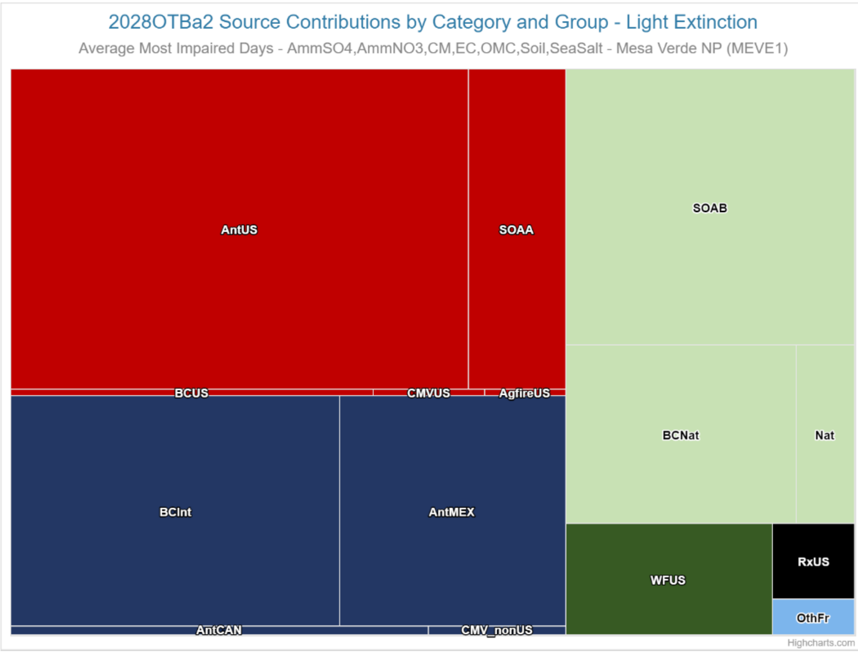
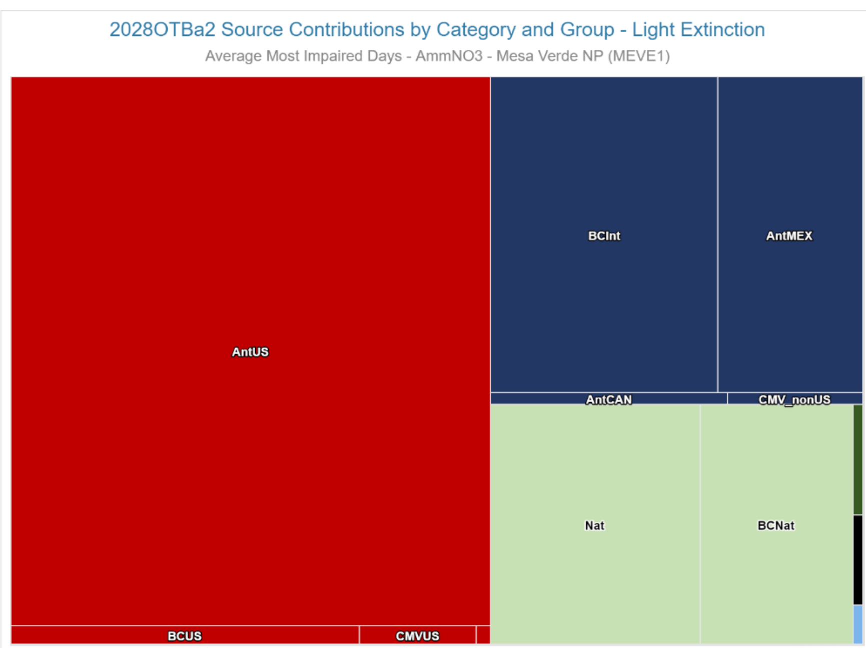


Figure 13d. 2028OTBa2 Regional Source Apportionment of Aerosol Light Extinction (Mm^{-1}) due to Ammonium Nitrate for most impaired days at the Mesa Verde National Park (MEVE1) for source groups contributing to U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories. TSS Modeling Express Tool # 14.



[TSS Modeling Express Tool](#) # 15 illustrated in **Figure 14a** for Yellowstone NP (YELL2) and **Figure 14b** for Mesa Verde NP (MEVE1), displays RepBase2 or 2028OTBa2 source apportionment results as a treemap (used to display hierarchal data.) Source categories are displayed in block colors with component aerosol species contributions outlined within each source category total. Users can choose to display source apportionment results for total aerosol light extinction or single aerosol species extinction. Results in Figures 14a and 14b display total aerosol light extinction for 2028OTBa2.

The same data are presented in TSS Modeling Express Tool #11 (Figures 10a and 10b.)

Interpretation: the tree map shows the aerosol species contributions to each source category. At both YELL2 and MEVE1, OMC is a large fraction of U.S. anthropogenic contributions, in addition to AmmNO3 and AmmSO4. OMC is also a large fraction of natural and fire contributions.

Figure 14a. 2028OTBa2 Regional Source Apportionment of Total Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Yellowstone National Park (YELL2) for aerosol species contributions to U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories. TSS Modeling Express Tool # 15.

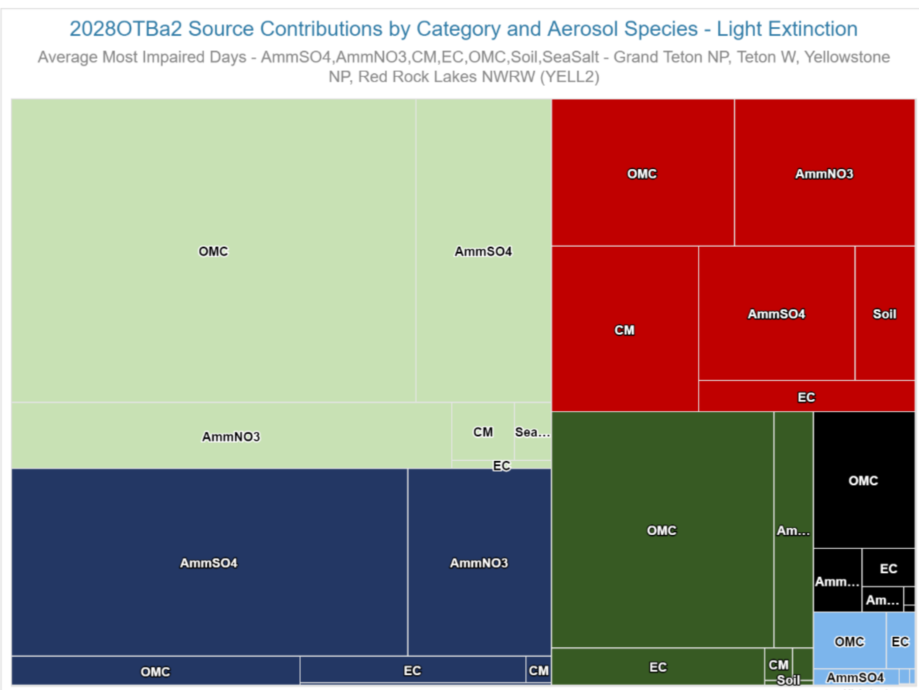
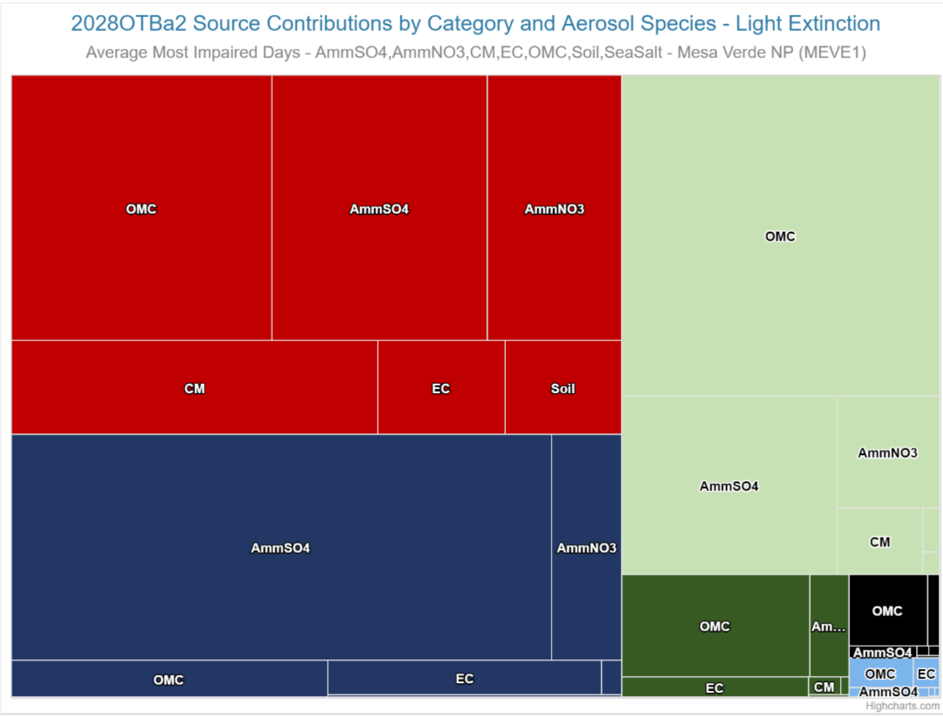


Figure 14b. 2028OTBa2 Regional Source Apportionment of Total Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Mesa Verde National Park (MEVE1) for aerosol species contributions to U.S. Anthropogenic, International anthropogenic, Natural, and Fire source categories. TSS Modeling Express Tool # 15.



TSS Modeling Express Tool # 16 illustrated in **Figure 15a** for Yellowstone NP (YELL2) and **Figure 15b** for Mesa Verde NP (MEVE1), displays RepBase2 or 2028OTBa2 source apportionment results as a treemap (used to display hierarchal data.) Aerosol species contributions are displayed in block colors with component source groups outlined within each aerosol species. total. Users can choose to display source apportionment results for total aerosol light extinction or single aerosol species extinction. Results in Figures 15a and 15b display total aerosol light extinction for 2028OTBa2.

The same data are presented in TSS Modeling Express Tool #12 (Figures 11a and 11b.)

Interpretation: at YELL2, U.S. anthropogenic contributions are the third most important for OMC, AmmSO4, and AmmNO3. At MEVE1 U.S. anthropogenic contributions are the largest factor for AmmNO3 and the second largest for AmmSO4 and OMC.

Figure 15a. 2028OTBa2 Regional Source Apportionment of Total Aerosol Light Extinction (Mm^{-1}) for most impaired days at Yellowstone National Park (YELL2) for source category contributions to individual aerosol species. [TSS Modeling Express Tool](#) # 16.

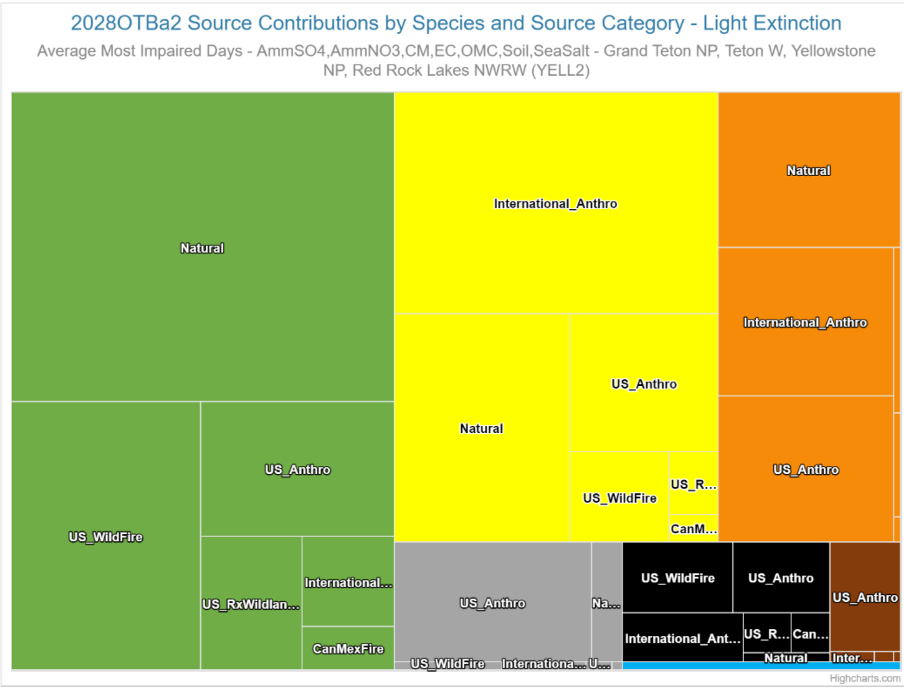
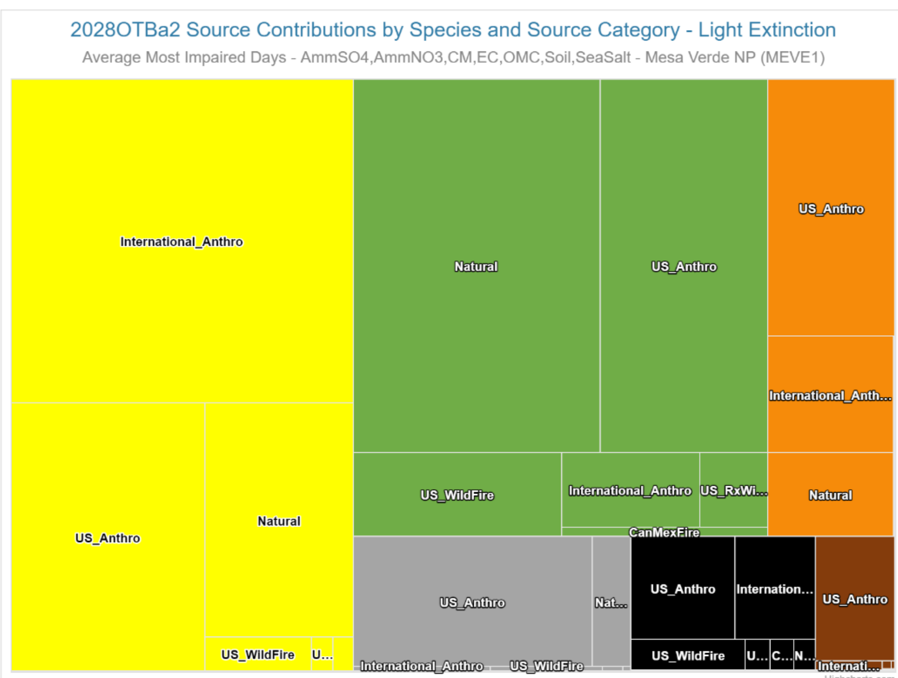


Figure 15b. 2028OTBa2 Regional Source Apportionment of Total Aerosol Light Extinction (Mm^{-1}) for most impaired days at Mesa Verde National Park (MEVE1) for source category contributions to individual aerosol species. [TSS Modeling Express Tool](#) # 16.



11.0 State and Sector (Low-level) Source Apportionment

For the future year 2028OTBa2 model scenario, PSAT was applied to further define U.S. anthropogenic contributions to AmmNO3 and AmmSO4 aerosols at western Class I areas from each of 13 WESTAR-WRAP states and all other non-WRAP U.S. states combined. Methods are further detailed in the run specification sheet for High-Level and Low-Level Source Apportionment Modeling using the RepBase2 and 2028OTBa2 model scenarios (September 2020).

State contributions to AmmNO3 and AmmSO4 were subdivided into five anthropogenic source categories:

- electric generating units (EGU)
- oil and gas (area plus point sources) (OilGas)
- remaining point sources (non-EGU)
- Mobile onroad, nonroad, rail, and commercial marine vessels (CMV 1, 2, and 3 within 200 km of U.S. coast) (Mobile)
- remaining anthropogenic sources (including Fugitive dust, Agriculture, Agricultural fire, residential wood combustion, and all remaining nonpoint sources)

For each Class I area, these results identify which source sectors and states are projected to have the greatest contributions in 2028OTBa2 to visibility impairment due AmmSO4 and AmmNO3. These results can assist states to prioritize which emissions reductions strategies might be most effective in improving visibility at western Class I areas.

The state and sector source apportionment results in TSS Modeling Express Tools # 9 are absolute model outputs; results are not normalized to IMPROVE monitoring data. Users can choose to display state and sector source apportionment results for most impaired days (EPA default 2014 IMPROVE days), modeled most impaired days, or clearest days. This document provides examples for most impaired days only.

TSS Modeling Express Tool # 9 illustrated in **Figures 16a and 16b** for Yellowstone NP (YELL2) and **Figures 16c and 16d** for Mesa Verde NP (MEVE1), displays RepBase2 or 2028OTBa2 source apportionment results for western states and source sectors for AmmNO3 or AmmSO4 light extinction, respectively.

Interpretation: at YELL2 PSAT projects that AmmNO3 contributions from individual states are 0.2 Mm^{-1} or less. PSAT identifies mobile sources from several western states as the most important U.S. anthropogenic contributors to AmmNO3 at YELL2 (**Figure 16a**). Idaho is shown as having the largest contributions to AmmNO3 from mobile, non-EGU and area sources.

For AmmSO4 at YELL2, PSAT projects that individual state contributions are small (0.15 Mm-1 or less). Non-EGU, EGU, and area sources in several states are identified as contributors.

Figure 16a. 2028OTBa2 State and Sector Source Apportionment of Ammonium Nitrate Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. [TSS Modeling Express Tool](#) # 9

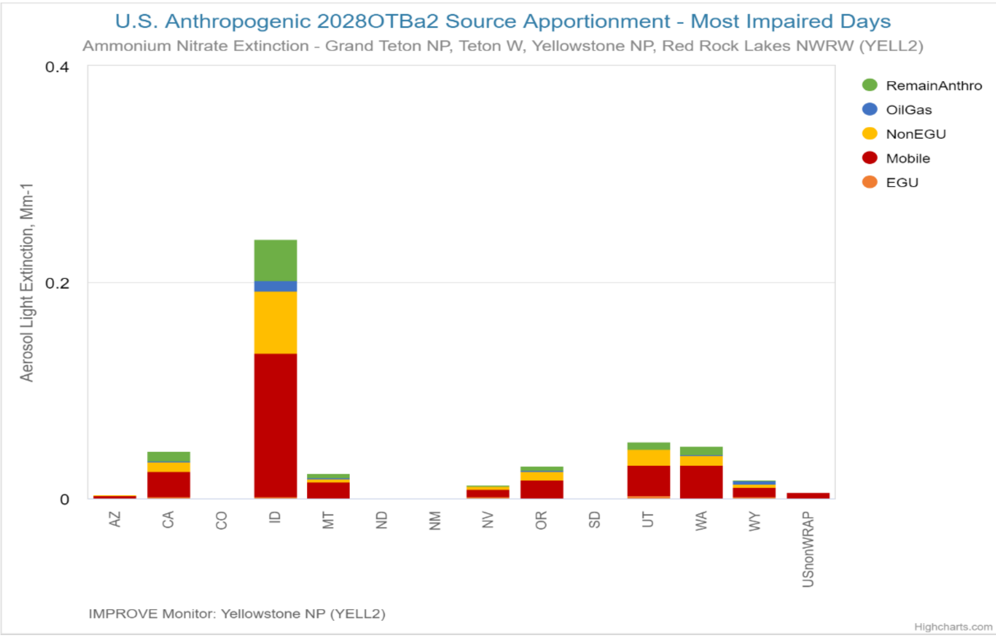


Figure 16b. 2028OTBa2 State and Sector Source Apportionment of Ammonium Sulfate Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. [TSS Modeling Express Tool](#) # 9

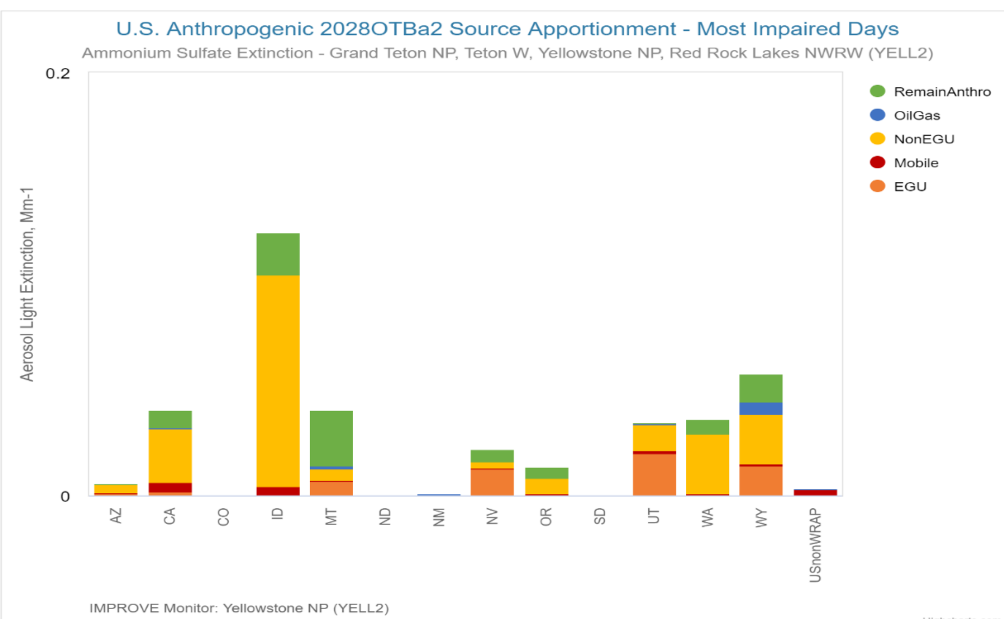


Figure 16c. 2028OTBa2 State and Sector Source Apportionment of Ammonium Nitrate Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Tool # 9

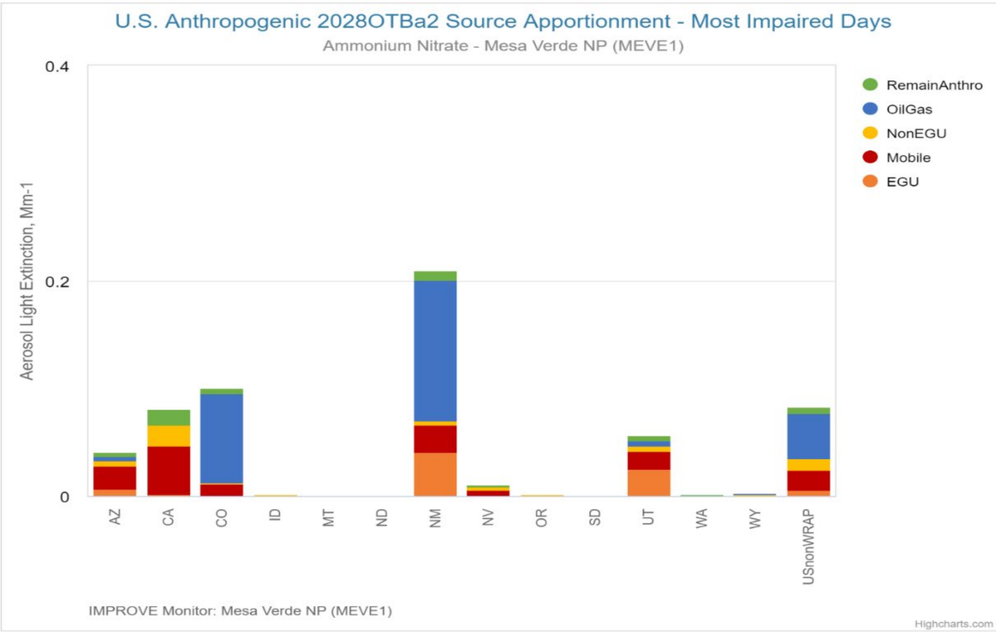
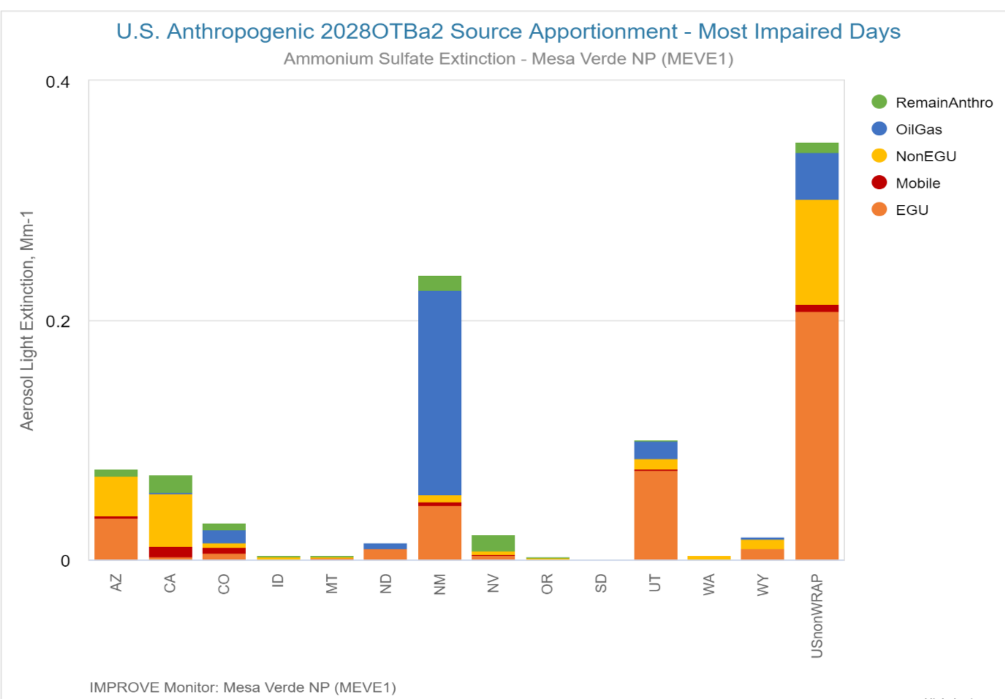


Figure16d. 2028OTBa2 State and Sector Source Apportionment of Ammonium Sulfate Aerosol Light Extinction (Mm^{-1}) for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Tool # 9



At MEVE1, AmmNO3 contributions from individual states are 0.2 Mm^{-1} or less. Oil and gas in NM, CO, and non-WRAP states are major contributors; oil and gas on tribal lands is included in the state contributions (see Table 3 in Section 3 of the TSS Emissions Reference document for breakdown of tribal vs non-tribal NOx emissions.) EGU and mobile source sectors are also contributors to AmmNO3. EGU from non-WRAP states and oil and gas in NM are the largest contributors to AmmSO4 at MEVE1. Weighted Emissions Potential plots for MEVE1 confirm the Four Corners region and Arizona as the highest transport area for AmmNO3 and that EGU in Texas contribute to AmmSO4 loadings.

In general, at western Class I areas mobile emissions and oil and gas emissions are significant contributors to AmmNO3, while electric generating units and remaining point sources are more important source categories for AmmSO4.

12.0 Weighted Emissions Potential

WRAP 2028 Weighted Emissions Potential maps were developed to illustrate the geographic areas of greatest emissions influence for aerosol extinction on most impaired days at 76 IMPROVE monitors representing 116 Class I areas in the 13 WESTAR-WRAP states and neighboring states. 72-hour back trajectory analyses (defined every 6 hours for multiple start heights) for most impaired days for the 5-year period 2014-2018 were used to define frequency of atmospheric transport. Gridded 2028 modeled emissions in 36-km grid cells, residence time defined by back trajectory transport frequency, residence time weighted aerosol extinction for most impaired days (also called area of influence), and weighted emission potential for gridded emissions can be downloaded from the Weighted Emissions Potential webpage. The weighted emissions potential defines relative source importance for each Class I area. These analyses provide weight of evidence in support of state and sector source apportionment results in Section 11.0.

Figure 17a (left) displays the areas of highest influence from NOx emissions, weighted by AmmNO3 extinction on the most impaired days for YELL2, highlighted in burgundy and orange elliptical shapes overlaying eastern Idaho and western Wyoming. **Figure 17a (right)** displays the individual 36-km model grid cells, color graded by importance of mobile source NOx emissions for AmmNO3 extinction on most impaired days at YELL2 (burgundy, orange, and green grid cells have the highest importance). **Figure 17b (left)** displays areas of highest influence from SO2 emissions, weighted by AmmSO4 extinction on the most impaired days for YELL2.

Interpretation: The Weighted Emissions Potential maps agree with the PSAT results (Section 11.0) for YELL2 and MEVE1. For YELL2 the geographic area of influence is similar for AmmNO3 and AmmSO4 extinction (**Figures 17a, left and 17b, left**.) For mobile sources, the highest contributors to AmmNO3 extinction on most impaired days at YELL2 include the mobile source corridors in Idaho and grid cells in Montana, Utah, Oregon and Washington (**Figure 17a, right**). Non-Electric generating point sources (non-EGU) in several states are seen as important contributors to AmmSO4 extinction on most impaired days at YELL2 (**Figure 17b right**). These results agree with PSAT results that identify mobile sources as largest contributors to AmmNO3 (**Figure 16a**) and non-EGU point sources as largest contributors to AmmSO4 extinction at YELL2 (**Figure 16b**).

Figure 17a. 2028OTBa2 Extinction Weighted Residence Time for Ammonium Nitrate (AmmNO3) Light Extinction (Mm^{-1}) (left) and NOx Weighted Emissions Potential for On-Road Mobile sources (right) for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. [Weighted Emissions Potential]

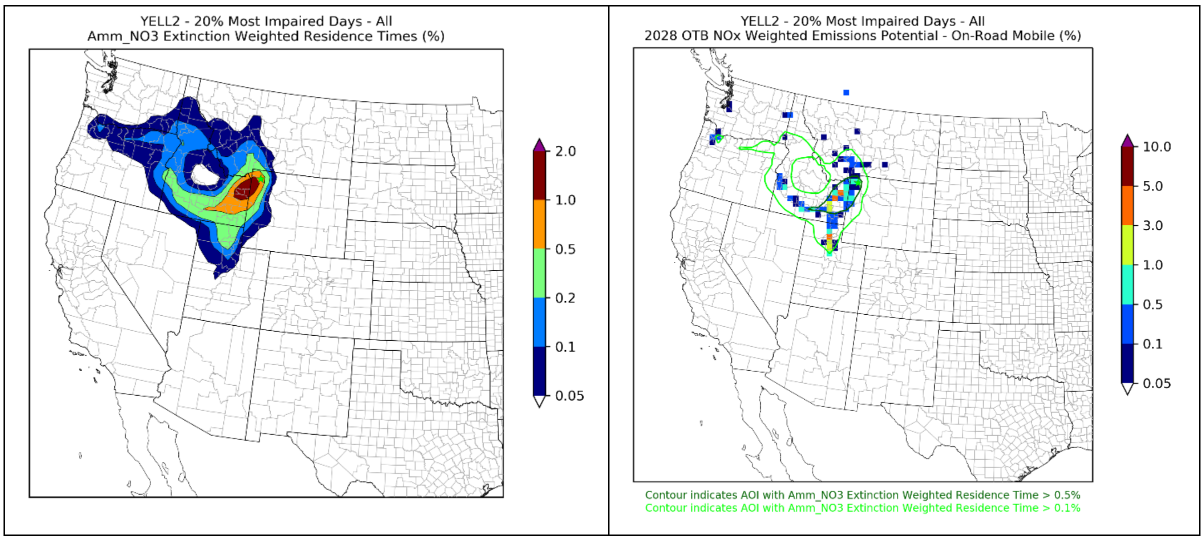
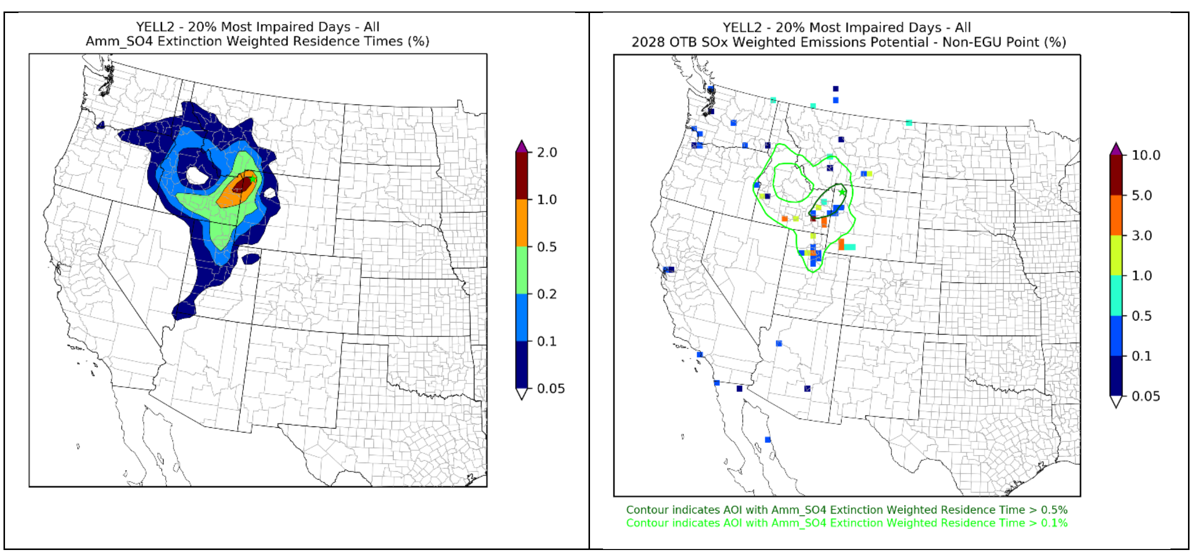
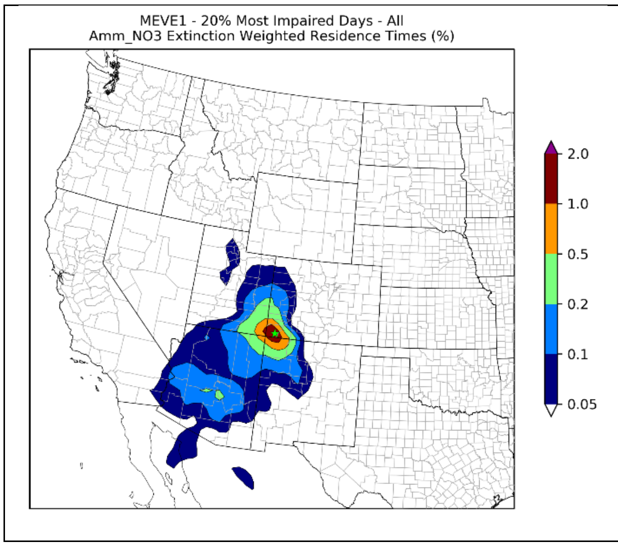


Figure 17b. 2028OTBa2 Extinction Weighted Residence Time for Ammonium Sulfate (AmmSO4) Light Extinction (Mm^{-1}) (left) and SO2 Weighted Emissions Potential for Non-Electric Generating Point sources (right) for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. [Weighted Emissions Potential]



For MEVE1, **Figure 17c, left** display the geographic areas of highest influence for NOx emissions, weighted by AmmNO3 extinction on the most impaired days. In **Figure 17c, right** the areas of highest influence are outlined in dark green and light green boundaries and oil and gas point and area sources contributions to AmmNO3 are defined in color-graded 36-km grid cells. **Figure 17d, left** displays a very similar geographic area of influence for SO2 emissions, weighted by AmmSO4 extinction on most impaired days. **Figure 17d, right** illustrates that electric generating units that influence AmmSO4 extinction at MEVE1 on most impaired days are geographically dispersed and not restricted to the geographic area of highest influence for total AmmSO4.

Figure 17c. 2028OTBa2 Extinction Weighted Residence Time for Ammonium Nitrate (AmmNO3) Light Extinction (Mm^{-1}) (left) and NOx Weighted Emissions Potential for On-Road Mobile sources (right) for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. Weighted Emissions Potential



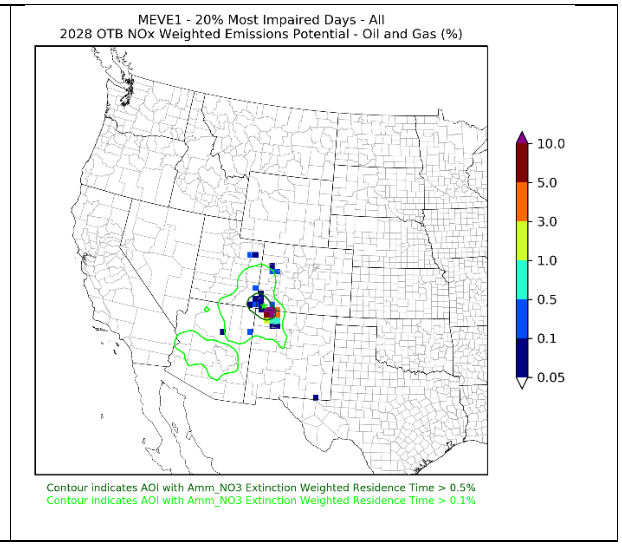
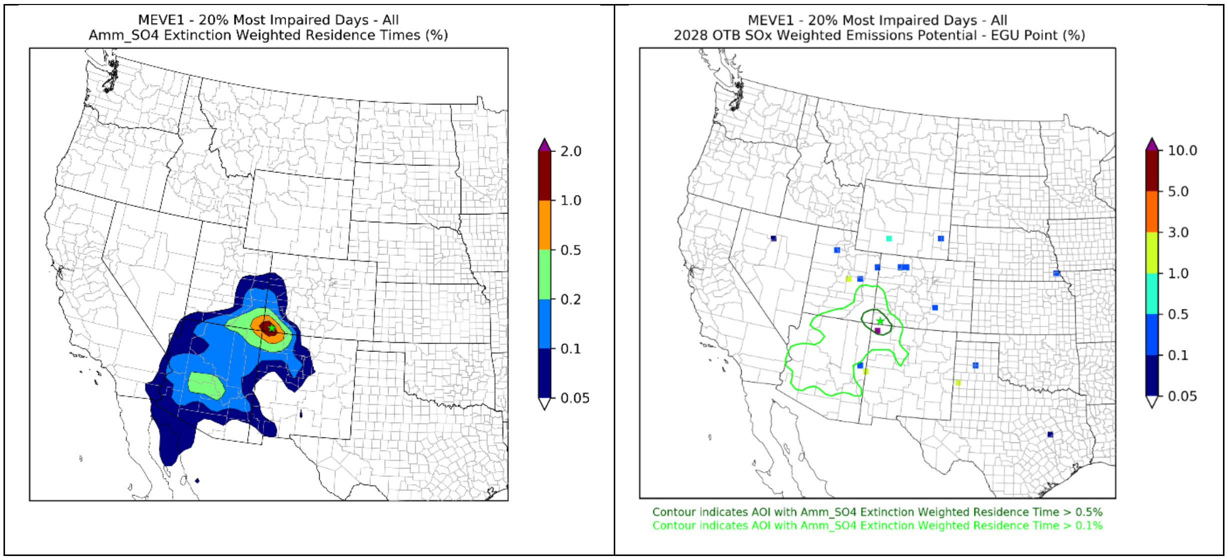


Figure 17d. 2028OTBa2 Extinction Weighted Residence Time for Ammonium Sulfate (AmmSO4) light Extinction (Mm^{-1}) (left) and SO2 Weighted Emissions Potential for Electric Generating Units (EGU) sources (right) for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. [Weighted Emissions Potential]



The area of greatest influence for AmmNO3 extinction on most impaired days at MEVE1 (**Figure 17c, left)** is centered over the Four Corners area. In **Figure 17c, right** the area of greatest influence is outlined in the dark green elliptical boundary over the Four Corners and the lighter green boundary over portions of the four states: AZ, CO, NM, and UT. On the same plot, the 36-km grid cells are color coded by importance of NOx emissions from oil and gas area and point sources. The oil and gas contributions are primarily located within the inner dark green area of influence.

The areas of greatest influence for AmmSO4 extinction on most impaired days at MEVE1 are illustrated in **Figure 17d, left** and **17d, right.** The areas of influence are similar to those for AmmNO3 extinction at MEVE1. The EGU plot illustrates emissions from elevated EGU point sources can influence visibility at a distant Class I area even if transport from the EGU point source is infrequent. These maps are consistent with the PSAT state and sector source apportionment for AmmNO3 and AmmSO4 at MEVE1 (Section 11.0)

13.0 Dynamic Model Evaluation

As part of the WRAP-WAQS 2014 modeling study, a dynamic model evaluation was conducted to test the model's ability to project changes in ambient aerosol visibility extinction at IMPROVE monitoring sites in response to changes in U.S. anthropogenic emissions. To conduct the dynamic model evaluation, in addition to the 2014v2, RepBase2 and 2028OTBa2 model scenarios already discussed, an additional scenario representing U.S. anthropogenic emissions for 2002 (2002 Hindcast) was run using the CAMx-PSAT photochemical grid model platform with 2014 meteorology and RepBase2 emissions for all other natural, fire, and international source groups. Only U.S. anthropogenic emissions changed between the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios. 2002 U.S. Anthropogenic emissions were back cast from the 2014 National Emissions Inventory (NEI) using scaling factors based on EPA's NEI trends for most sectors, with exceptions that California Air Resources Board provided 2014 to 2002 scaling factors for California, and western states supplied 2002 emissions for point sources (electric generating units (EGU), oil and gas point sources, and other non-EGU point sources.) Methods for the 2002 Hindcast are further defined in the U.S. Anthropogenic Emissions Rate of Progress document (September 2021).

The dynamic model evaluation applied the same future year projection methods defined by Environmental Protection Agency modeling guidance (December 2018) to project 2014-2018 visibility from the 2002 Hindcast forward to the RepBase2 scenario. Relative response factors for each aerosol species were calculated (RepBase2 model results divided by 2002 Hindcast model results) and then multiplied by 2000-2004 IMPROVE observations for each species to project RepBase2 visibility. Model projected RepBase2 aerosol light extinction closely matched IMPROVE observed light extinction for 2014-2018 5-year average (**Figure 18a**). This confirmation increases confidence that the CAMx model and EPA projection methods can produce credible 2028 visibility projections. Backward projections of 2002 visibility from RepBase2 (relative response factors calculated as 2002 Hindcast divided by RepBase2 and then multiplied by 2014-2018 IMPROVE observations) had larger discrepancies from 2000-2004 IMPROVE observations than forward projections from 2002 to RepBase2, but still showed good agreed for most western IMPROVE sites (**Figure 18b**). The larger discrepancies for the 2002 Hindcast are likely due to a combination of (i) using RepBase2 levels of fire and international emissions for the 2002 Hindcast model run that differed from the actual emissions that contributed to 2000-2004 IMPROVE observations and (ii) using scaling factors to calculate 2002 Hindcast emissions from 2014v2 National Emissions Inventory that introduces errors for U.S. anthropogenic emissions (e.g., over estimating 2002 emissions for Commercial Marine Vessel emissions). A future dynamic model evaluation may want to back cast natural, fire and international emissions as well as U.S. anthropogenic emissions.

Figure 18a. Dynamic Model Evaluation applying EPA projection methods and comparing total aerosol light extinction for 2014-2018 IMPROVE observations (x-axis) to modeled RepBase2 (y-axis) for Class I areas in the 13 western states. U.S. Anthropogenic Emissions Rate of Progress

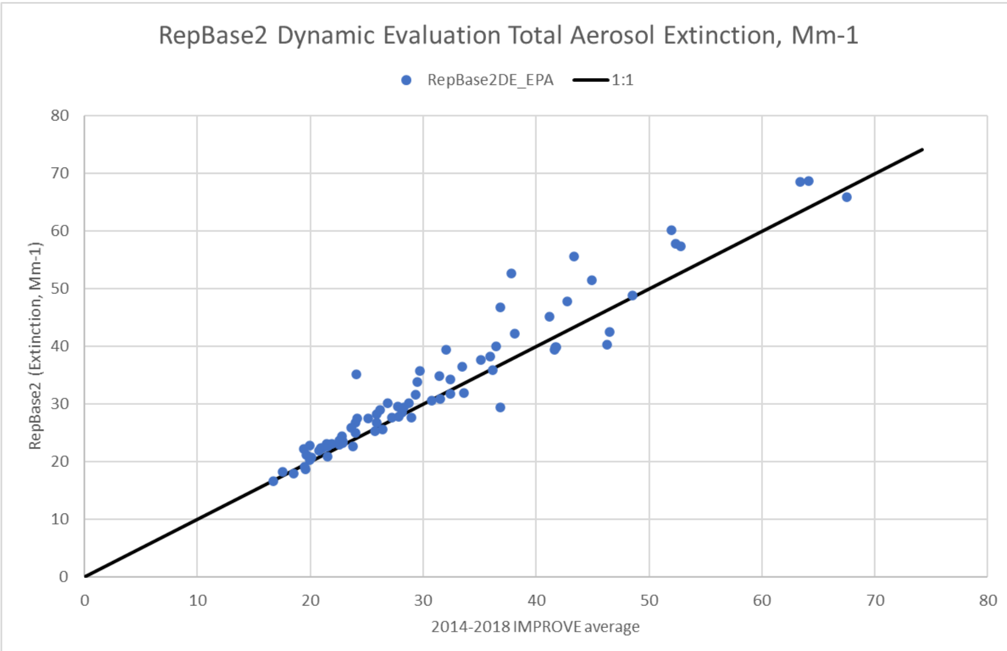
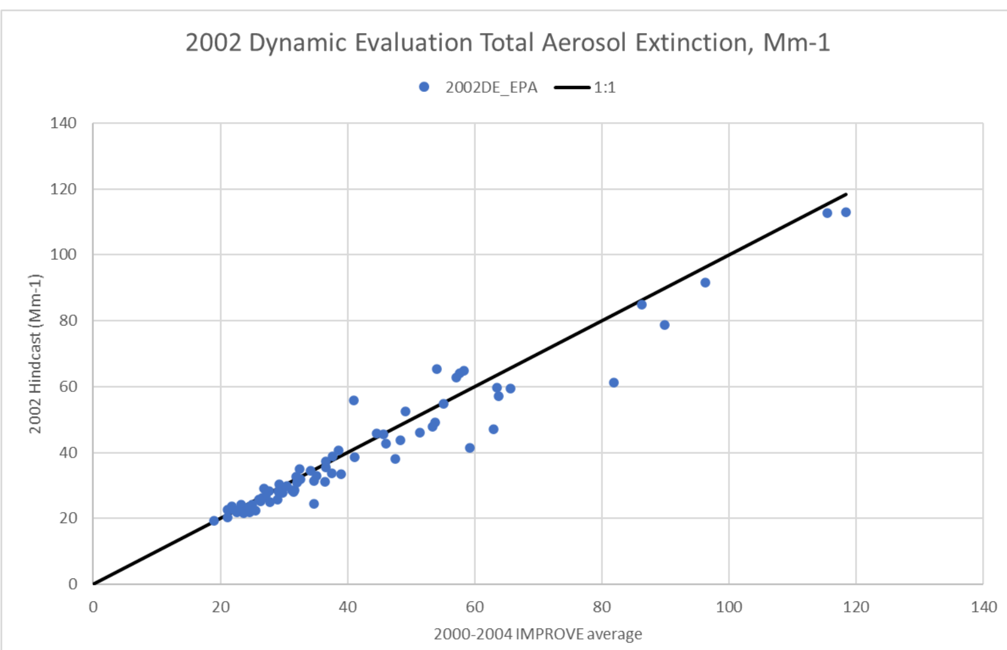


Figure 18b. Dynamic Model Evaluation applying EPA projection methods and comparing total aerosol light extinction for 2000-2004 IMPROVE observations (x-axis) to modeled 2002 Hindcast (y-axis) for Class I areas in the 13 western states. U.S. Anthropogenic Emissions Rate of Progress



14.0 U.S. Anthropogenic Emissions Rate of Progress

WRAP has defined a U.S. Anthropogenic Emissions Rate of Progress to demonstrate visibility progress at western Class I areas due to changes in U.S. Anthropogenic emissions between the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios. Methods for the 2002 Hindcast, RepBase2 and 2028OTBa2 scenario development are further defined in the WRAP-WAQS run specification sheets

- Representative Baseline v2 and 2028OTBa2
- U.S. Anthropogenic Emissions Rate of Progress

The URP glidepath represents total haze from all source contributions on most impaired days. In the western U.S., haze is caused by international, natural, and fire emissions as well as U.S. anthropogenic emissions. Uncertainties in the URP glidepath construction are further described in the U.S. Anthropogenic Emissions Rate of Progress webpage.

The objective of the U.S. Anthropogenic Emissions Rate of Progress is to isolate the contributions of U.S. anthropogenic emissions to visibility at Class I areas in the WESTAR-WRAP states and to demonstrate the progress in improving visibility in response to changes in U.S. anthropogenic emissions between the 2002 Hindcast, RepBase2, and 2028OTBa2 scenarios.

- Only U.S. anthropogenic emissions change in the three model scenarios.
    - Any differences in aerosol extinction between the 2002, RepBase2, and 2028OTBa2 scenarios are due to changes in U.S. anthropogenic emissions.
    - We have greatest confidence in U.S. anthropogenic emissions.

- All other emissions (natural, fire, and international) are held constant at RepBase2 levels for the 2002 Hindcast and 2028OTBa2 scenarios.
    - Because RepBase2 international, fire, and natural emissions are used in the 2002 Hindcast scenario, the 2002 Hindcast results are not fully comparable to the 2000-2004 IMPROVE monitoring data.

- The source apportionment model results are not adjusted to the IMPROVE monitoring data.

- The U.S. Anthropogenic Emissions Rate of Progress is intended as an alternative to adjusting the 2064 endpoint of the URP glidepath using 2028 source apportionment results for international and U.S. wildland prescribed fire, per EPA guidance.

TSS Modeling Express Tool # 6, illustrated in **Figures 19a and 19b** displays US Anthropogenic, International Anthropogenic, Natural, Fire, and Rayleigh contributions to total light extinction for the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios for the IMPROVE monitors at Yellowstone (YELL2) and Mesa Verde (MEVE1) National Parks, respectively.

Interpretation: at YELL2 U.S. Anthropogenic contributions are projected to be reduced by 2 Mm^{-1} (39%) between 2002 Hindcast and RepBase2 and by 1 Mm^{-1} (30%) between RepBase2 and 2028OTBa2. This rate of progress is below the straight line drawn from 2002 U.S. anthropogenic contribution to zero U.S. anthropogenic contribution in 2064. This is in contrast to conclusions following EPA guidance, where 2028OTBa2 visibility projections for YELL2 are not below the URP glidepath (Section 8.0). The modeled rate of U.S. anthropogenic progress is below the glidepath to no U.S. anthropogenic contribution.

At MEVE1, U.S. anthropogenic contributions are projected to be reduced by 3 Mm^{-1} (41%) between 2002 Hindcast and RepBase2 and by 0.8 Mm^{-1} (18%) between RepBase2 and 2028OTBa2. This rate of progress is below the straight line drawn from 2002 U.S. anthropogenic contribution to zero U.S. anthropogenic contribution in 2064.

Figure 19a. Contributions to Aerosol Light Extinction from U.S. Anthropogenic, International Anthropogenic, Natural, and Fire emissions, plus Rayleigh light scattering, for the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios for most impaired days at Yellowstone National Park (YELL2) IMPROVE monitor. TSS Modeling Express Tool # 6

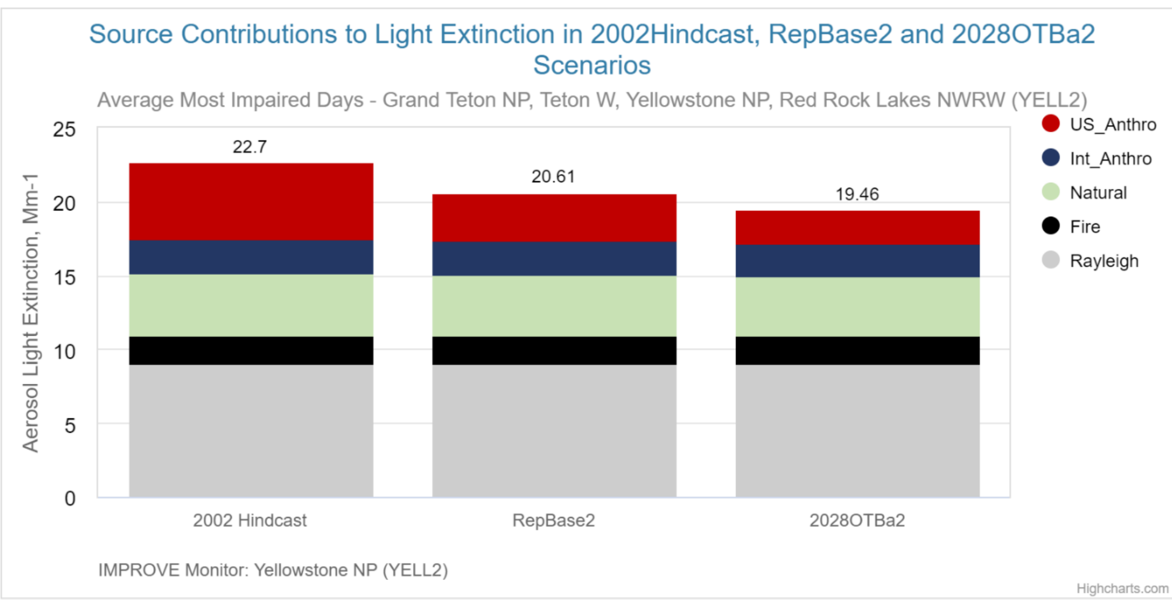
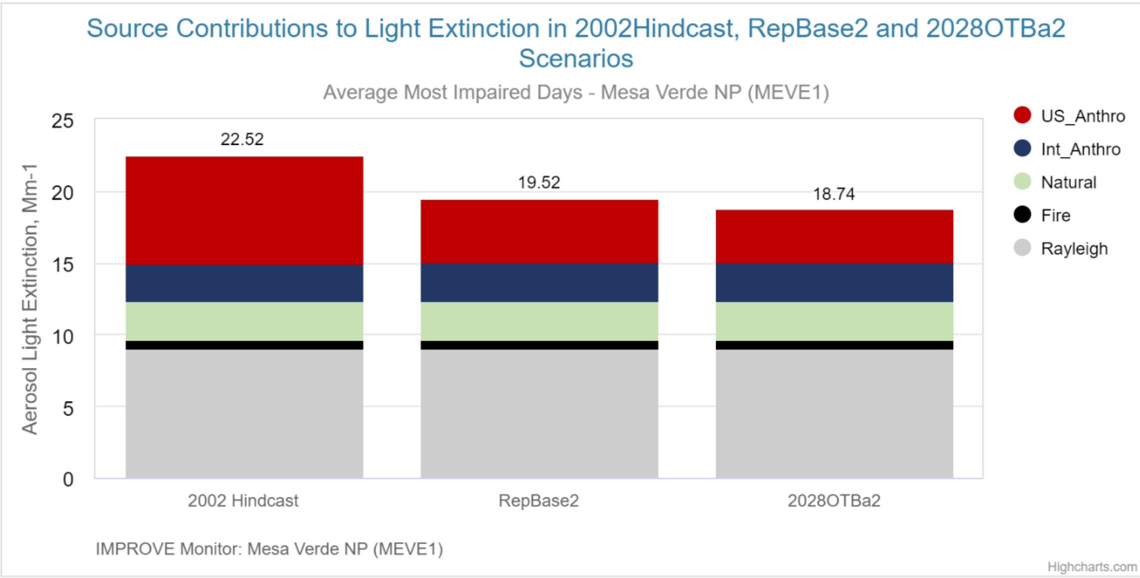


Figure 19b. Contributions to Aerosol Light Extinction from U.S. Anthropogenic, International Anthropogenic, Natural, and Fire emissions, plus Rayleigh light scattering, for the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios for most impaired days at Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Tool # 6



TSS Modeling Express Tool # 7, illustrated in **Figures 20a and 20b** displays aerosol species contributions to just the U.S. Anthropogenic fraction of total light extinction for the 2002 Hindcast, RepBase2 and 2028OTBa2 model scenarios for the IMPROVE monitors at Yellowstone (YELL2) and Mesa Verde (MEVE1) National Parks, respectively.

- TSS Chart 7 does not address aerosol light extinction from sources other than U.S. Anthropogenic contributions.
- The source apportionment model results are not adjusted to the IMPROVE monitoring data.

Interpretation: at both YELL2 and MEVE1, reductions in U.S. anthropogenic contributions between 2002 Hindcast and RepBase2 are primarily due to reductions in AmmSO4 and OMC. At YELL2, reductions projected to occur between RepBase2 and 2028OTBa2 are primarily due to reductions in AmmNO3. At MEVE1, reductions in U.S. anthropogenic contributions between RepBase2 and 2028OTBa2 are projected due to small reductions in AmmNO3 and AmmSO4.

Figure 20a. U.S. Anthropogenic Contributions to Speciated Aerosol Light Extinction for the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios for most impaired days at Yellowstone National Park (YELL2) IMPROVE monitor. [TSS Modeling Express Tool](#) # 7

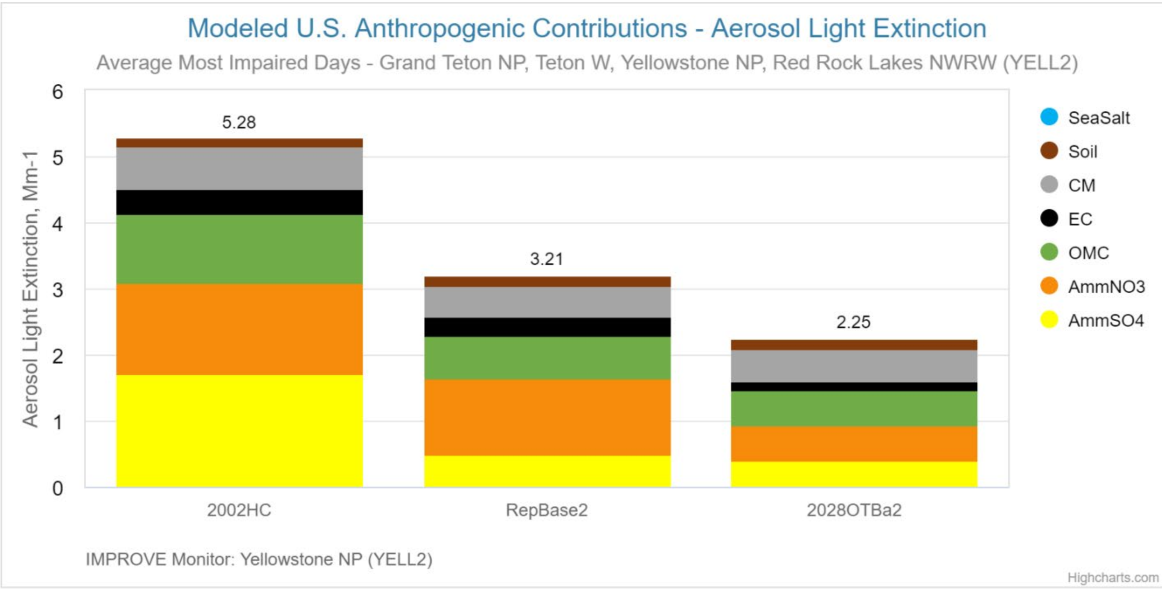
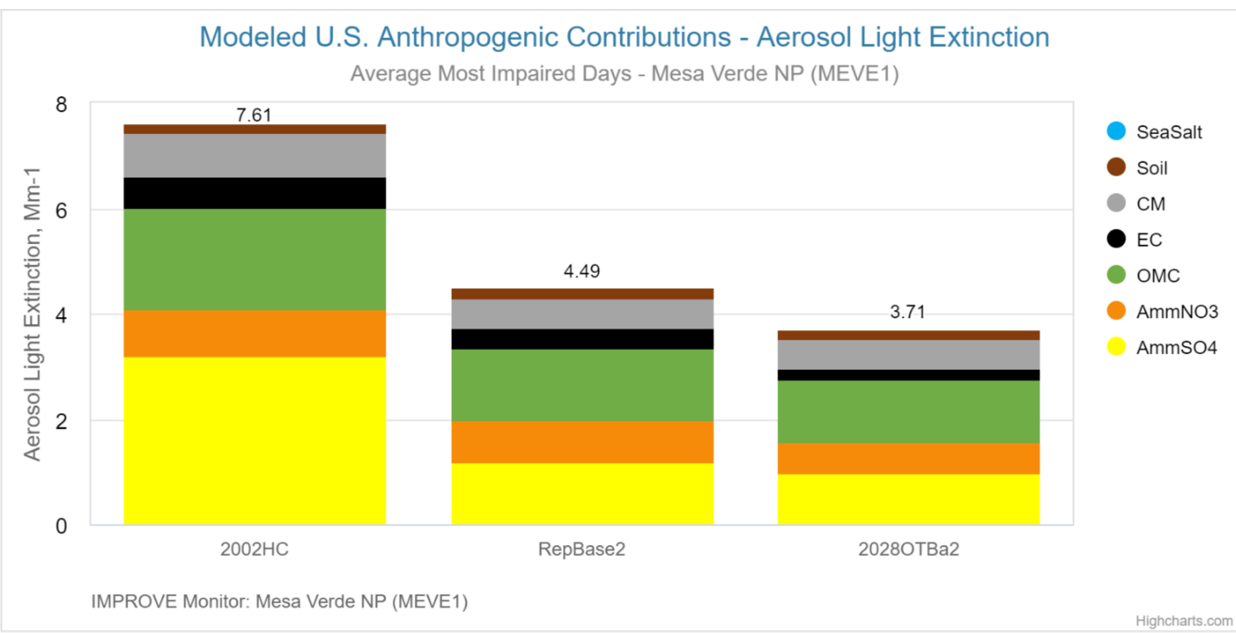


Figure 20b. 2028 U.S. Anthropogenic Contributions to Speciated Aerosol Light Extinction for the 2002 Hindcast, RepBase2, and 2028OTBa2 model scenarios for most impaired days at Mesa Verde National Park (MEVE1) IMPROVE monitor. [TSS Modeling Express Tool](#) # 7



15.0 Future Fire Sensitivities

Future fire sensitivities added wildfire emissions (FFS1) or wildland prescribed fire emissions (FFS2) as two potential future variations in fire activity that are not specific to any single future year. The fire sensitivities are added to the 2028OTBa2 reference case scenario to replace historic fire emissions used in the RepBase2 and 2028OTBa2 scenarios. All other 2028OTBa2 emissions: U.S. anthropogenic, international, natural, and non-US fire emissions are held constant. The only differences between the 2028OTBa2 and the fire sensitivities are due to the FFS1 and FFS2 assumptions.

- **FFS1** examines the effects of potential future changes in the timing, frequency, and intensity in terms of acres burned for **wildfires** compared to the Representative Baseline fires.
- **FFS2** examines the effects of potential future enhanced forest management practices defined as increases in **wildland prescribed burns**.

Emissions development of the future fire sensitivities is described in the Air Sciences, Inc. report Fire Emissions Inventories for Regional Haze Planning: Methods and Results (April 2020).

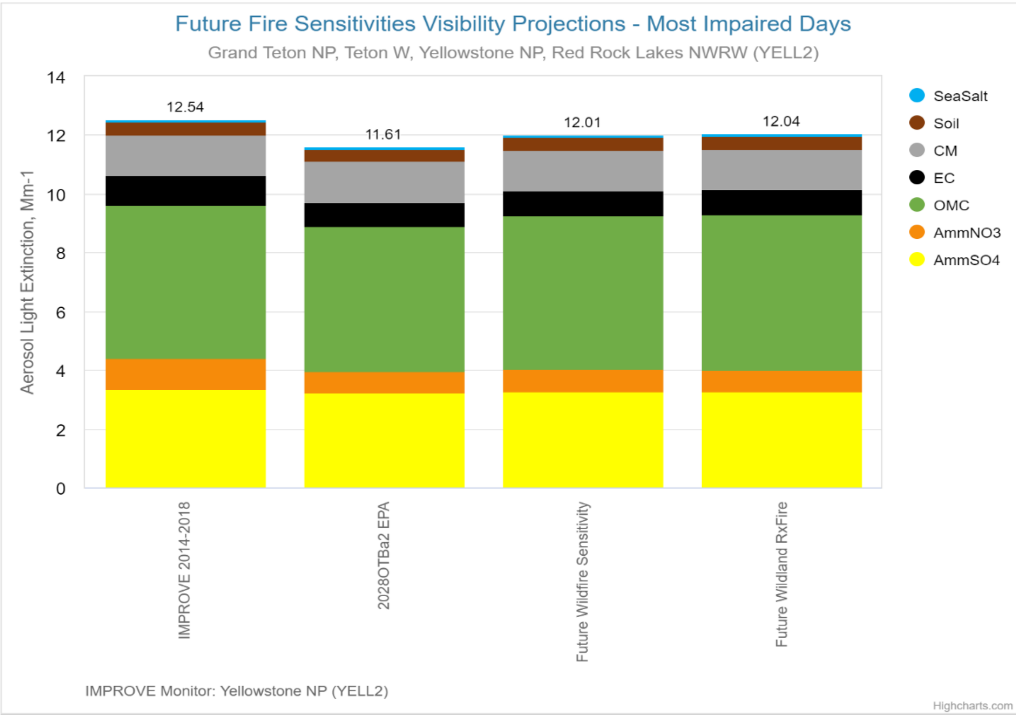
Modeling procedures are detailed in the run specification sheet for the Future Fire Simulations (August 2021).

TSS Modeling Express Tool # 18, illustrated in **Figures 21a and 21b**, displays IMPROVE 2014-2018 aerosol light extinction (Mm^{-1}) compared to the 2028 visibility projections for the 2028OTBa2, Future Wildfire Sensitivity, and Future Wildland Prescribed Fire Sensitivity scenarios for the IMPROVE monitors at Yellowstone (YELL2) and Mesa Verde (MEVE1) National Parks, respectively.

In TSS Modeling Express Tool # 18, fire sensitivities have been processed through the EPA Software for Modeled Attainment Test (normalized to IMPROVE 2014-2018 observations) to test the impact of changing fire regimes on 2028 regional haze visibility projections. The fire sensitivities for wildfire and wildland prescribed fire are compared to the 2028OTBa2 visibility projections for most impaired days or clearest days.

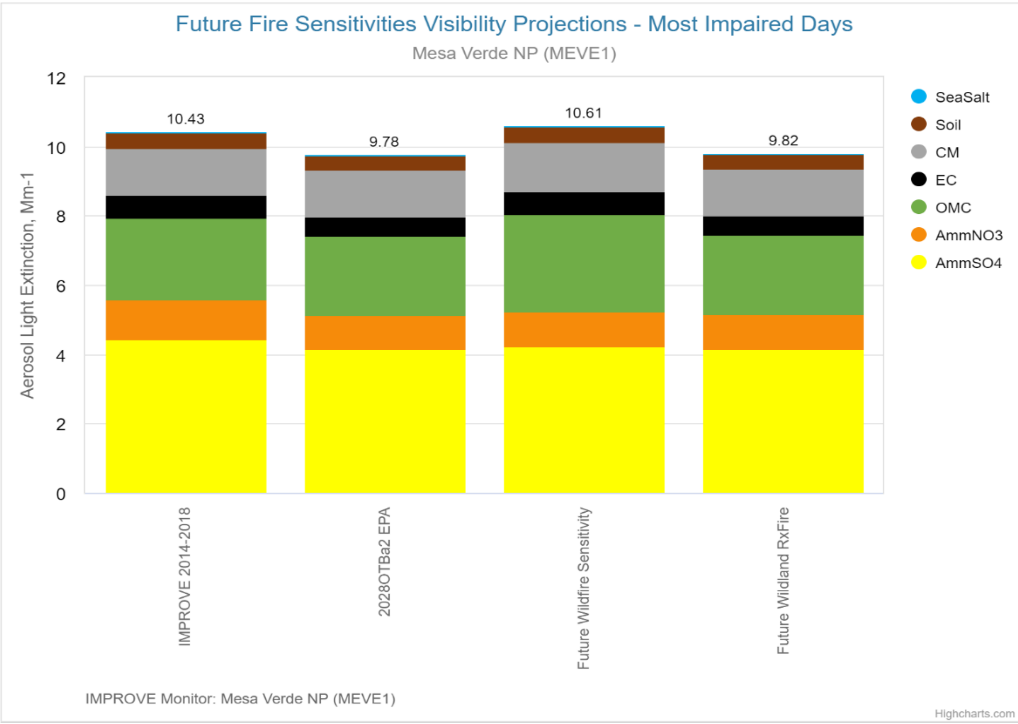
Interpretation: Added fire activity does not necessarily occur on 2014 IMPROVE most impaired days. The impacts of changing fire activity on the regional haze metrics are site-specific and may be small. IMPROVE 2014-2018 observations are included in TSS Modeling Express Tool #18 as the baseline data used with the relative response factors to calculate the 2028 visibility projections. At YELL2 (**Figure 21a)**, the 2028OTBa2 visibility projection shows small decreases in AmmNO3, OMC, and EC compared to 2014-2018 observations. The Future Wildfire Sensitivity and the Future Wildland Prescribed fire sensitivity show minor increases in OMC that can be attributed to changes in fire activity on some most impaired days in these sensitivities.

Figure 21a. IMPROVE 2014-2018 aerosol light extinction (Mm^{-1}) compared to the 2028 visibility projections (following EPA guidance) for the 2028OTBa2, Future Wildfire Sensitivity, and Future Wildland Prescribed Fire Sensitivity scenarios for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. TSS Modeling Express Tool # 18



At MEVE1 (**Figure 21b**), OMC is a smaller contributor on most impaired days than at YELL2. 2028OTBa2 visibility projection shows small decreases in AmmSO4 and AmmNO3 compared to the 2014-2018 IMPROVE observations. OMC increases in the Future Wildfire sensitivity indicating increased fire emissions on some most impaired days for this sensitivity. OMC is little changed in the Future Wildland Prescribed fire sensitivity compared to 2028OTBa2.

Figure 21b. IMPROVE 2014-2018 aerosol light extinction (Mm^{-1}) compared to the 2028 visibility projections (following EPA guidance) for the 2028OTBa2, Future Wildfire Sensitivity, and Future Wildland Prescribed Fire Sensitivity scenarios for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Tool # 18



TSS Modeling Express Tool # 19, illustrated in **Figures 22a and 22b**, displays absolute model results (not adjusted to IMPROVE observations) for 2028OTBa2 and the future fire sensitivities as monthly averages for all IMPROVE sample collection days. This chart illustrates when changes in wildfire or wildland prescribed fire activity are projected to occur and how the changes affect visibility compared to the 2028OTBa2 fire assumptions. These results are not 2028 visibility projections (adjusted to IMPROVE data) for regional haze planning purposes.

Interpretation: at YELL2 (**Figure 22a**) in several months there are small differences in AmmSO4, AmmNO3, and OMC between the 2028OTBa2 scenario and the Future Fire Sensitivities. The Future Wildfire Sensitivity is higher than 2028OTBa2 in July, September and October, while the Future Wildland Prescribed Fire Sensitivity is higher in January, February, April, May, October, and November. Not all the fire activity changes occurred on most impaired days so the impacts on the 2028 visibility projections are small.

Figure 22a. Monthly average aerosol extinction (Mm^{-1}) for the 2028OTBa2, Future Wildfire Sensitivity, and Future Wildland Prescribed Fire Sensitivity scenarios for most impaired days at the Yellowstone National Park (YELL2) IMPROVE monitor. TSS Modeling Express Tool # 19

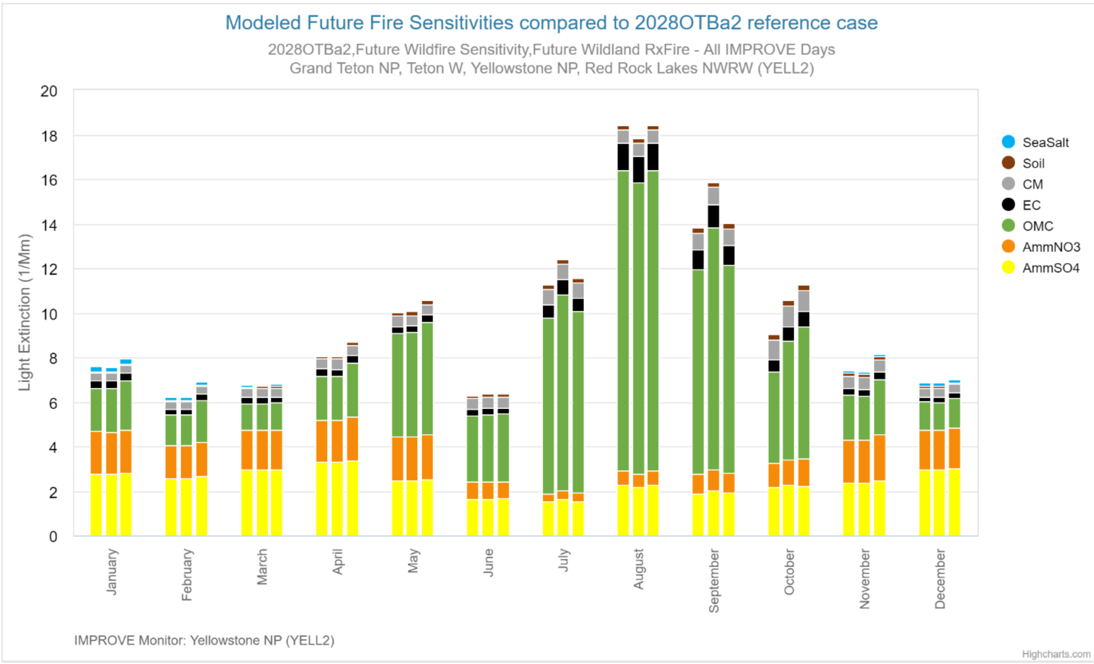
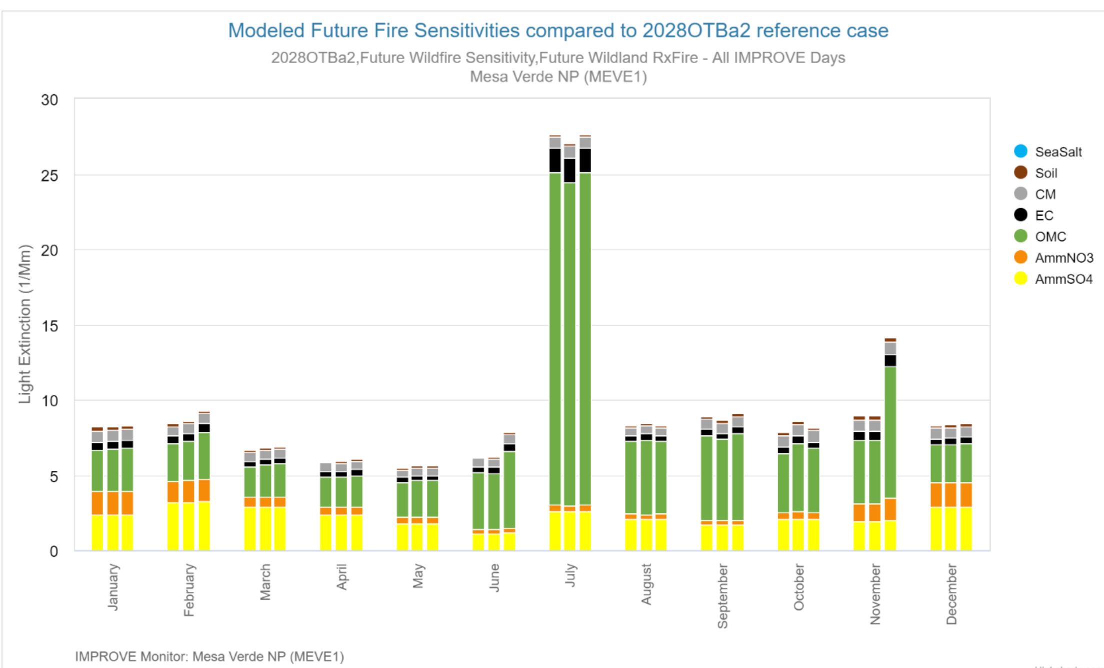


Figure 22b. Monthly average aerosol extinction (Mm^{-1}) for the 2028OTBa2, Future Wildfire Sensitivity, and Future Wildland Prescribed Fire Sensitivity scenarios for most impaired days at the Mesa Verde National Park (MEVE1) IMPROVE monitor. TSS Modeling Express Tool # 19

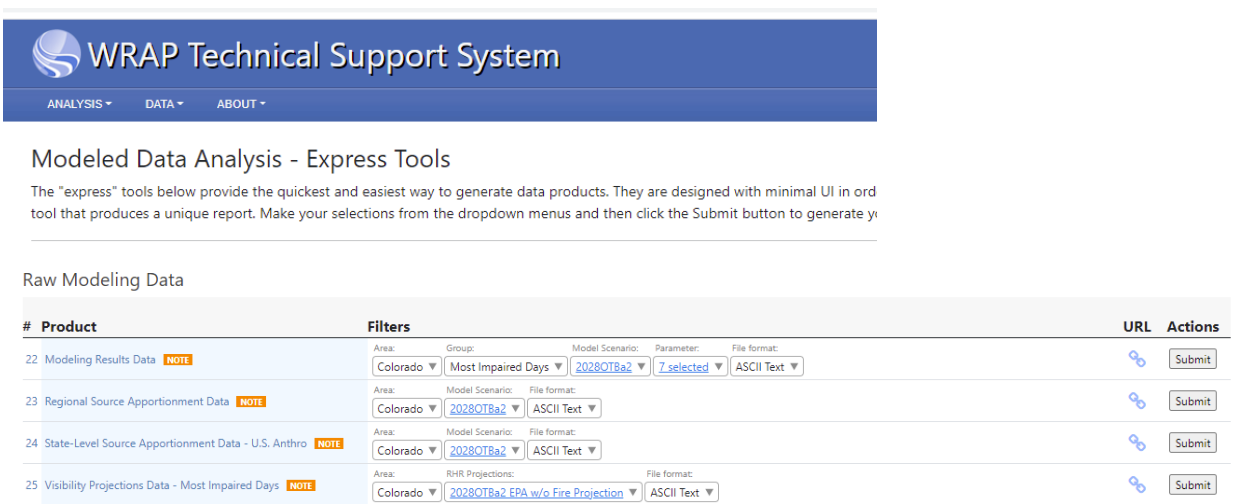


At MEVE1 (**Figure 22b**) the Future Wildfire Sensitivity shows very slight monthly differences compared to the 2028OTBa2 scenario, even though the Future Wildfire visibility projection has slightly higher OMC than the 2028OTBa2 projection (**Figure 21b**). This suggests that wildfire activity added on a few most impaired days was offset by decreased wildfire activity on other days in the monthly averages. The Future Wildland Prescribed Fire Sensitivity in June and November show slightly higher OMC than 2028OTBa2, but little change in the 2028 visibility projection.

At some western Class I areas, the added future fire sensitivities have larger impacts than seen as these two sites. Fires will continue to be a major contributor to haze in western states, however the regional haze tracking metric may not be the best measure of changes in future fire activity.

16.0 Modeling Data files

Raw modeling data files can be downloaded from the TSS Modeling Express Tools #22-25 as illustrated below. Data are sorted by geographic area, by IMPROVE data groups, Model scenarios, pollutant parameters, and regional haze projection methods. Data can be downloaded as ASCII text, Microsoft Excel, or JSON format.



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(no new citations in Sections 9.0-15.0)