19 June 2013

MEMORANDUM

To: Ellen Belk, EPA Region 6
Cc: Katherine Heller, RTI International
From: Uarporn Nopmongcol, Greg Yarwood
Subject: 2018 Base Case CAMx Simulation, Texas Regional Haze Evaluation
[Contract EP-W-011-029]

ENVIRON is assisting EPA by performing modeling of regional haze impacts of selected sources in Texas. The analysis builds upon modeling of 2002 and 2018 conducted previously for CENRAP by ENVIRON. The CENRAP database was enhanced to include a 12 km grid over Texas and nearby Class I areas, and updated to use with the latest version of the Comprehensive Air Quality Model with extensions (CAMx; ENVIRON, 2012). A memorandum presenting the 2002 baseline modeling results has been submitted to EPA (ENVIRON, 2013). This memorandum documents the new 2018 base case modeling setup, with changes to emissions at selected units by EPA, and results utilizing PSAT and PiG tools.

INTRODUCTION

The Clean Air Act (CAA) establishes special goals for visibility in many national parks, wilderness areas, and international parks. Through the 1977 amendments to the Clean Air Act, Congress set a national goal for visibility as "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution" (40 CFR 51.300). The goal of the Regional Haze Rule (RHR) is to achieve natural visibility conditions at 156 Federally mandated Class I areas by 2064. To achieve this goal, the RHR has set up milestone years of 2018, 2028, 2038, 2048, 2058, and 2064 to monitor progress toward natural visibility conditions. The 2000-2004 period has been used by states as a baseline from which to demonstrate progress toward natural visibility conditions in 2018.

EPA Region 6 is presently under a court-ordered Consent Decree deadline regarding action on the Texas Regional Haze State Implementation Plan (SIP). Regional haze (RH) is linked to fine particulate matter ($PM_{2.5}$), for which EPA has a new standard. Air quality modeling is an important tool for determining whether a source can be reasonably expected to contribute to visibility impairment at a Class I area. ENVIRON is assisting EPA to evaluate regional haze impacts of sources in Texas that may be used to assess the Texas Regional Haze Implementation Plan.

The Texas RH analysis was built upon the regional photochemical modeling (ENVIRON and CERT, 2007) conducted for CENRAP. In particular, the CENRAP 2002 and 2018 36 km modeling database for CAMx was enhanced to include a 12 km grid over Texas and nearby Class I areas. The overall approach to the project includes the following steps:

- Update CENRAP 2002 and 2018 modeling database to use with the latest release of CAMx (v5.41) when the project began
- Conduct 2002 modeling with Plume-in-Grid (PiG) and a 12-km flexi-nested grid to provide the new 2002 baseline RH modeling
- Conduct 2018 modeling with PiG and the CAMx PM Source Apportionment Technology (PSAT) for sources selected by EPA
- Evaluate impact of individual sources selected by EPA on visibility in Class I areas
- Conduct any additional future-year scenarios to access various control strategies (to be determined)

This memorandum documents the new 2018 base case modeling setup and results.

CAMx MODELING APPROACH

Air quality modeling was performed with version 5.41 of the Comprehensive Air quality Model with extensions (CAMx; ENVIRON, 2012) with input data developed by CENRAP. The CAMx PM PSAT modeling was also conducted for the EPA selected sources' SO_2 and NO_x emissions (see Table 3 for a list of EPA selected sources). CAMx has changed since the CENRAP modeling and many CAMx inputs had to be updated. CAMx Input development and updates are described separately below.

2018 Annual 36 km CENRAP modeling database

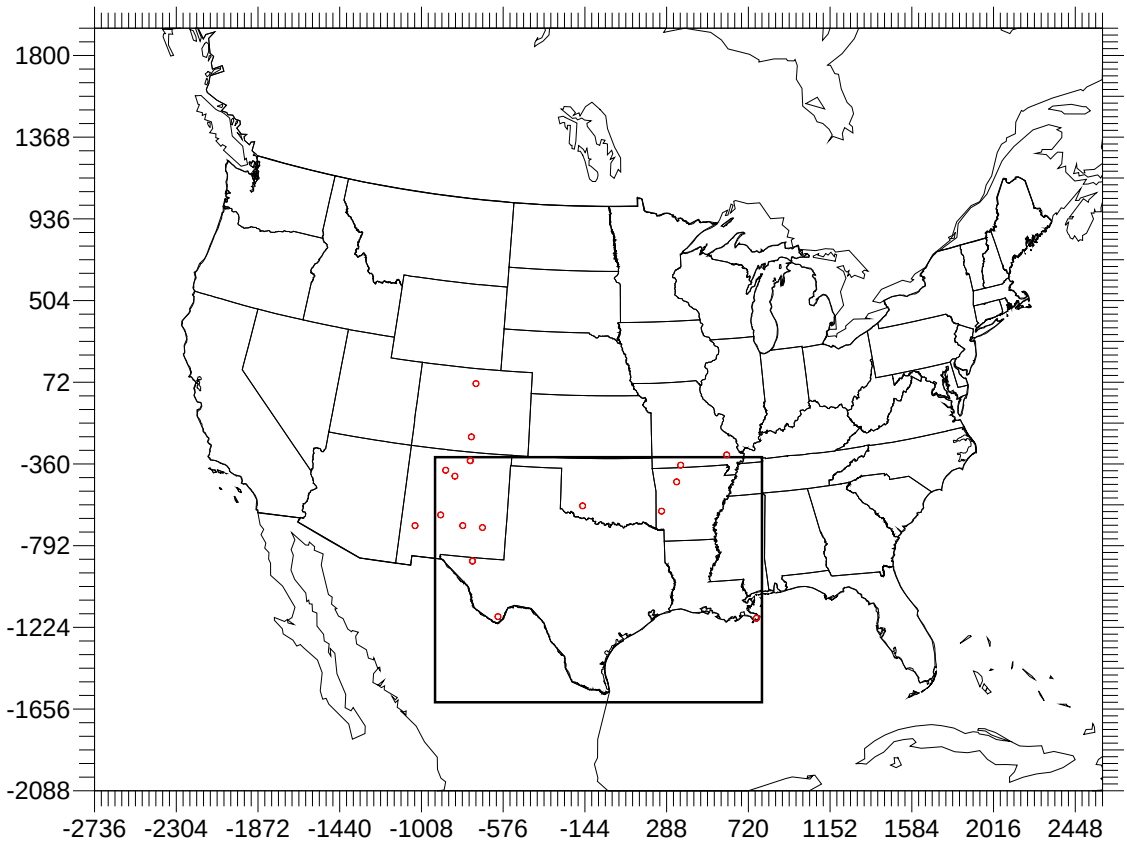
The Texas RH analysis was built upon the 2018 annual regional photochemical modeling database developed as part of the CENRAP (ENVIRON and CERT, 2007). CENRAP developed a 2018 annual modeling database for CAMx on the 36 km unified national Regional Planning Organization (RPO) grid that covers the continental United States. The CENRAP modeling protocol (Morris et al., 2004), CENRAP modeling Quality Assurance Program Plan (QAPP; Morris and Tonnesen, 2004), and base model evaluation (ENVIRON and CERT, 2007) reports provide details on the development of the CENRAP 2002 and 2018 36 km annual modeling database. Emissions inputs for this study were based on the 2018 Base G (Base18G) which was projected from the 2002 Typical G (Typ02G) inventory. CENRAP went through numerous iterations of the emissions modeling before arriving at the final Base G emission inventories (e.g., Morris et al., 2005).

Enhancement to the CENRAP 2018 Modeling Database

Similar to the 2002 modeling setup, the CENRAP Base G 2018 36 km annual CAMx photochemical modeling database was updated to include a 12 km nested-grid that covers Texas and Class I areas in and near Texas including:

- National Parks: Big Bend (BIBE), Guadalupe Mountains (GUMO), and Carlsbad Caverns;
- Wildlife Refuges: Salt Creek (SACR) and Wichita Mountains (WIMO);
- Wilderness Areas: Breton (BRET), White Mountain (WHIT), Caney Creek (CACR), Upper Buffalo (UPBU), Bandeller (BAND), Hercules-Glade (HEGL), and others (see Table 1).

Figure 1 displays the 36/12 km nested grid for the CAMx modeling. The locations of Interagency Monitoring of Protected Visual Environments (IMPROVE) sites that includes Class I areas within and near the 12 km modeling domain are shown in Figure 2. The CAMx flexi-nesting feature was used to specify a 12 km Texas fine grid within the CENRAP 36 km modeling domain. Full flexi-nesting was invoked in which CAMx internally interpolates meteorological data, gridded emissions and other inputs from the 36 km grid to the 12 km grid. Flexi-nesting does not interpolate point source emissions because exact source coordinates are known enabling each point source to be placed within the correct 36 km or 12 km grid cell.

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36km: SW = (-2736,-2088) NX,NY = (148x112) DX,DY = (36x36)
12km: SW = ( -936,-1620) NX,NY = (144,108) DX,DY = (12x12)
LCP Definition: (-97.0,40.0,45.0,33.0)
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Figure 1. Texas RH modeling 36/12 km modeling domain and the locations of the IMPROVE monitoring sites that include Class I areas, indicated by circles.

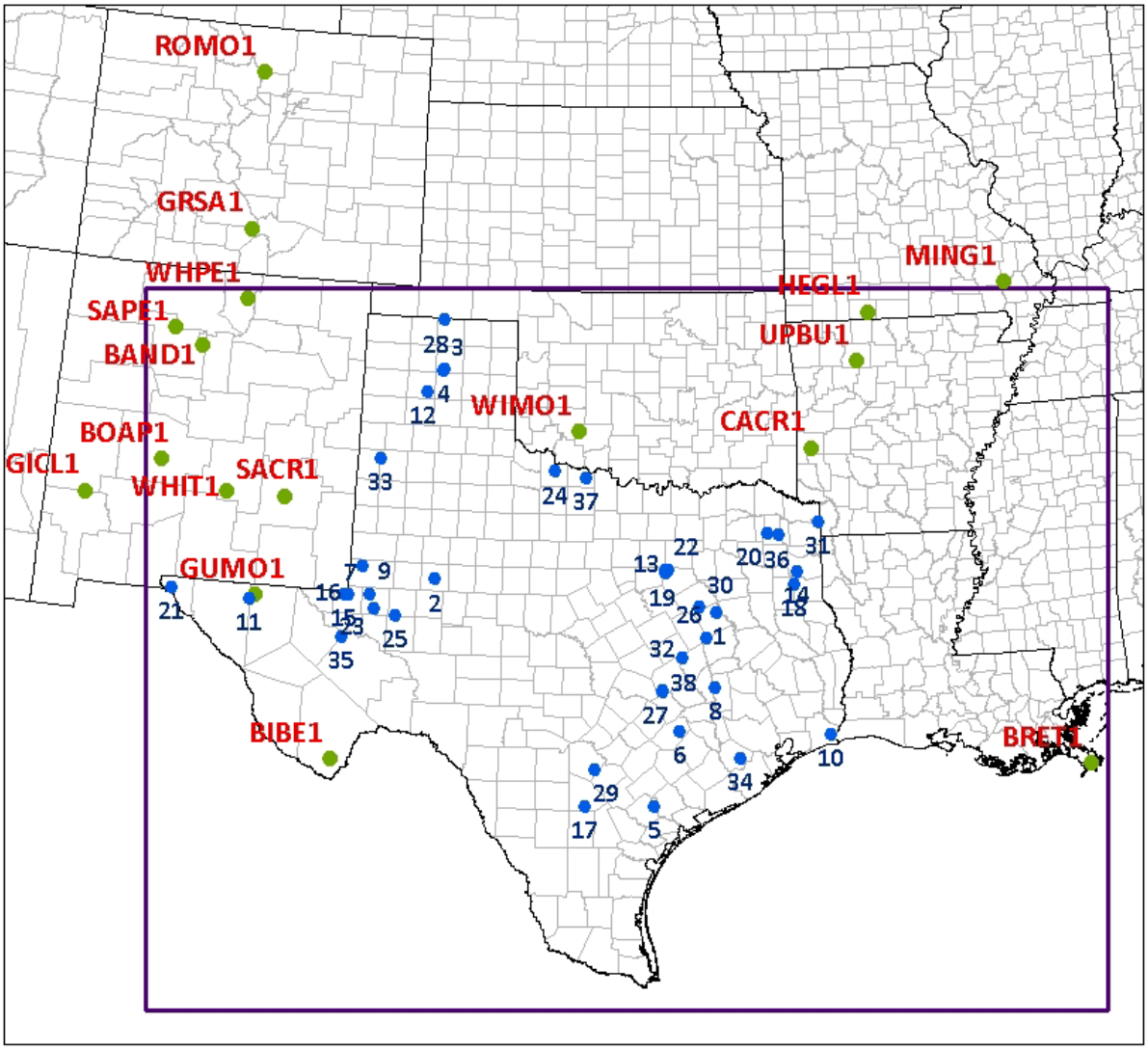


Figure 2. Texas RH modeling 12 km modeling domain, the locations of the IMPROVE monitoring sites (circles) and target sources (indicated by Source ID numbers).

Table 1. Class I areas included in the Texas RH analysis.

Site	State	Code	State FIPS	County	County FIPS	Latitude	Longitude	LCPX (km)	LCPY (km)	Grid
Breton Wilderness Area	LA	BRET1	22	St. Bernard Parish	87	29.1189	-89.2066	763	-1176	12km
Big Bend National Park	TX	BIBE1	48	Brewster County	43	29.3027	-103.178	-604	-1167	12km
Guadalupe Mountains	TX	GUMO1	48	Culberson County	109	31.833	-104.809	-738	-873	12km
Wichita Mountains Wilderness	OK	WIMO1	40	Comanche County	31	34.7323	-98.713	-156	-581	12km
Caney Creek Wilderness Area	AR	CACR1	5	Polk County	113	34.4544	-94.1429	261	-610	12km
Upper Buffalo Wilderness Area	AR	UPBU1	5	Newton County	101	35.8258	-93.203	341	-455	12km

Site	State	Code	State FIPS	County	County FIPS	Latitude	Longitude	LCPX (km)	LCPY (km)	Grid
Bandelier Wilderness Area	NM	BAND1	35	Los Alamos County	28	35.7797	-106.266	-831	-424	12km
Bosque del Apache Wilderness Area	NM	BOAP1	35	Socorro County	53	33.8695	-106.852	-906	-629	12km
Carlsbad Caverns NP.	NM	GUMO1				31.833	-104.809	-738	-873	12km
Gila Wilderness Area	NM	GICL1	35	Catron County	3	33.2204	-108.235	-1042	-686	36km
Pecos Wilderness Area	NM	WHPE1				36.5854	-105.452	-750	-343	12km
Salt Creek Wilderness Area	NM	SACR1	35	Grant County	17	33.4598	-104.404	-685	-696	12km
San Pedro Parks Wilderness Area	NM	SAPE1	35	Rio Arriba County	39	36.0139	-106.845	-880	-393	12km
Wheeler Peak Wilderness Area	NM	WHPE1	35	Taos County	55	36.5854	-105.452	-750	-343	12km
White Mountain Wilderness Area	NM	WHIT1	35	Lincoln County	27	33.4687	-105.535	-790	-686	12km
Hercules-Glades Wilderness Area	MO	HEGL1	29	Taney County	213	36.6138	-92.9221	362	-366	12km
Mingo	MO	MING1	29	Stoddard County	207	36.9717	-90.1432	606	-312	36km
Great Sand Dunes	CO	GRSA1	8	Saguache County	109	37.7249	-105.519	-744	-217	36km
Rocky Mountain National Park	CO	ROMO1	8	Larimer County	69	40.2783	-105.546	-720	65	36km

Preparing Emissions Data

The 2018 emissions were processed consistently with the 2002 emissions. This study used the latest SMOKE version 3.1, although some SMOKE modules came from an older version to maintain compatibility with the format of data from CENRAP. All SMOKE configurations and SMOKE input files were the same as used in CENRAP with selected updates. Provided below is a summary of the emission updates made for this study.

- Updated emissions to 8 facilities and added one new facility:
  - One new unit at Sommers/Deely/Spruce power plant site
  - Two new units at Sandow 5 Generating Plant (new plant)
  - Three new units at WA Parish Station carried over from the 2002 CENRAP inventory and emission changes to one existing unit
  - Emission changes at North Texas Cement (Ash grove) to reflect shutting down two units and rebuilding the third unit
  - Emission changes to reflect recently installed controls or improvements in control efficiencies on power plants at Sommers/Deely/Spruce, Big Brown, Gibbons Creek, Sandown Steam Electric Station, Monticello Steam Electric Station, and Fayette Power Project
- Used CB05 chemical speciation profiles for area and point sources

- Processed point source emissions in CAMx input format to preserve stack parameters and location
- Changed the earth sphere variable (IOAPI_ISPH) in SMOKE from 19 to 20. CENRAP SMOKE setup used IOAPI_ISPH=19 that could cause inconsistencies between point source locations and the meteorological points. IOAPI_ISPH=20 assumes a 6740 km earth radius consistent with MM5 and CAMx
- Selected Plume-in-Grid (PiG) for large SO_2 and NOx sources
- Assigned PSAT tagging group for each EPA selected source
- Added organic aerosol precursor emissions for biogenic sources based on CENRAP BEIS CB4 emissions
- Adjusted primary organic aerosol mass from POC to POA as required by CAMx

The criteria used to specify point sources as elevated and select elevated source for PiG treatment are described below:

Non-Selected sources

- A plume rise cutoff of 50 meter (i.e., any source having estimated plume rise lower than 50 m. was treated as a surface source).
- NOx emissions thresholds for PiG selection varied by region: 5 tons per day (TPD) for Texas, 10 TPD for neighboring states (NM, CO, OK, AR, LA, and KS), and 20 TPD for the rest.

Selected sources

- All target sources were treated as elevated sources
- PiG criteria are stack height of 50 ft and NOx or SO_2 emissions higher than 20 TPD

Emissions Summary

A summary of emission updates at the unit level is shown in Table 2. Stack parameters of major units for the 38 selected sources are listed in Appendix A. Quality assurance of the SMOKE emissions processing conducted for the project included the development of emission summaries based on the raw inventory data input to the SMOKE processing system (IDA files) and daily emission reports from SMOKE. Table 3 summarizes the emission inventory data input to SMOKE from the IDA files (i.e., averages between the 'winter' and 'summer' files) for the 38 selected sources. Table 4 presents the emissions data after SMOKE processing. Note differences between the input and output are related to the temporal and spatial allocation within SMOKE, as well as numerical rounding of the data. Specifically, the discrepancies of emissions at two facilities (about 7%), Tolk Station (FIPS 48279; Plant ID 18) and Harrington Station (FIPS 48375; Plant ID 22), are due to temporal processing. Both plants have monthly temporal profiles which are stack-specific. However, from October-December, the CENRAP temporal cross-reference (stack-specific) points to more generic profiles rather than stack-specific profiles. We note that the 2018 emission inventory includes an estimate of emission reductions due to Clean Air Interstate Rule (CAIR) at Texas electricity generating units (EGUs) and states in the eastern U.S. covered by CAIR. CAIR achieves reductions of NOx and SO_2 from power plants across 27 eastern states through state emission budgets and a cap and trade system to address contributions to ozone and PM in downwind states.

Table 2. Updates to annual emissions (TPY) of EPA selected sources by pollutant in the CENRAP 2018 Base G inventory.

Plant Name	FIPS	Plant ID	Point ID	Stack ID	SCC	CO	VOC	NH_3	CENRAP NOx*	CENRAP SO_2*	adjusted NOx	adjusted SO_2	PM_{10}	$PM_{2.5}$	Note
SOMMERS DEELY SPRUCE PWR	48029	63	95	99	10100226	431.3	88.0	2.3			1158.8	247.1	187.3	119.2	New Unit
SOMMERS DEELY SPRUCE PWR	48029	63	20	20	10100601	189.7	12.4	7.2	198.4	0		3.2	17.5	17.5	Adjusted SO_2 emissions
SOMMERS DEELY SPRUCE PWR	48029	63	22	19	10100601	176.7	11.6	6.7	236.7	0		4.6	16.3	16.3	Adjusted SO_2 emissions
FAYETTE POWER PROJECT	48149	5	7	7	10100226	632.5	75.9	38.0	2308.0	10534.19		438.3	3431.9	1618.4	Adjusted SO_2 emissions
FAYETTE POWER PROJECT	48149	5	8	8	10100226	627.9	75.4	37.7	2695.7	10457.94		451.4	2082.8	1239.9	Adjusted SO_2 emissions
FAYETTE POWER PROJECT	48149	5	16	16	10100226	472.1	56.6	28.3	2786.4	2516.258		417.1	1600.5	948.9	Adjusted SO_2 emissions
W A PARISH STATION	48157	5	2	23	10100601	4.5	2.1	0			145	0.4	2.9	2.9	New Unit
W A PARISH STATION	48157	5	3	24	10100601	7.2	2	0			73.2	0.4	2.8	2.8	New Unit
W A PARISH STATION	48157	5	4	44	10100601	21.3	2	0			287.5	0.8	2.8	2.8	New Unit
W A PARISH STATION	48157	5	5	26	10100601	272.2	17.8	10.4	202.3	0.0		1.9	25.1	25.1	Adjusted SO_2 emissions
BIG BROWN	48161	2	10	10	10100226	652.1	78.3	39.1	3602.6	23327.9	3274.7		236.3	235.2	Adjusted NOx emissions
BIG BROWN	48161	2	11	11	10100226	666.1	79.9	40.0	3754.9	23830.6	3410.1		241.4	240.3	Adjusted NOx emissions
GIBBONS CREEK	48185	2	2	2	10100226	450.1	54.0	27.0	1885.3	2673.2		892.7	540.1	470.9	Adjusted SO_2 emissions
SANDOW STEAM ELECTRIC	48331	5	15	16	10100302	1036.6	120.9	51.8	5552.9	8477.0	1386.9		1701.1	1337.6	Adjusted NOx emissions
SANDOW 5 GENERATING PLANT	48331	12	1	1	10100318	150.4	66.0	28.7			757.4	951.2	218.5	200.0	New Unit
SANDOW 5 GENERATING PLANT	48331	12	2	2	10100318	93.6	66.0	27.7			772.0	1012.8	243.9	104.9	New Unit
MONTICELLO STM ELE STN	48449	3	9	9	10100226	555.0	66.6	33.3	4589.1	19853.3	3427.7		201.0	200.1	Adjusted NOx emissions
MONTICELLO STM ELE STN	48449	3	10	10	10100301	610.3	170.9	73.2	5880.8	11977.7	5742.8		1100.9	983.9	Adjusted NOx emissions
NORTH TEXAS CEMENT CO.	48139	2	2	9	30500706	253.1	7.4	0.0	1453.2	2263.2	0	0	159.0	120.5	Shut down
NORTH TEXAS CEMENT CO.	48139	2	10	8	30500706	233.2	6.8	0.0	1311.8	2698.7	0	0	157.7	119.6	Shut down
NORTH TEXAS CEMENT CO.	48139	2	9	7	30500706	174.7	6.7	0.0	1303.4	2052.2	0	0	155.8	118.1	Shut down
NORTH TEXAS CEMENT CO.	48139	2	99	7	30500706	581.3	65.5	77.5			711.8	189.8	161.8	159.9	New Unit

*CENRAP emissions that were adjusted are highlighted in blue; emissions from new units are highlighted in red.

Table 3. Annual emissions (TPY) of EPA selected sources by pollutant in the updated 2018 base case inventory (before SMOKE processing).

Source ID	Plant Name	FIPS	Plant ID	NOx	CO	VOC	SO_2	$PM_{2.5}$	PM_{10}
1	BIG BROWN	48161	2	6,697	1,322	158	47,159	495	540
2	BIG SPRING CARBON BLACK	48227	2	1,135	7,083	68	17,823	9	137
3	BORGER CARBON BLACK	48233	1	636	17,475	580	4,338	105	147
4	BORGER CARBON BLACK PLT	48233	2	1,048	965	3	6,564	164	360
5	COLETO CREEK PLANT	48175	2	4,295	509	61	16,225	425	514
6	FAYETTE POWER PROJECT	48149	5	7,792	1,733	224	1,307	3,849	7,208
7	FULLERTON GAS PLANT	48003	10	1,861	966	406	3,040	29	29
8	GIBBONS CREEK	48185	2	1,885	450	54	893	474	549
9	GOLDSMITH GASOLINE PLANT	48135	22	1,129	691	259	1,916	9	9
10	GREAT LAKES CARBON LLC	48245	23	824	56	6	12,881	234	322
11	GUADALUPE COMPRESSOR STATION	48109	5	850	130	1	3	5	5
12	HARRINGTON STATION	48375	22	5,581	1,132	136	22,892	586	724
13	HOLCIM (TEXAS) LP	48139	22	5,018	7,198	823	4,518	562	563
14	HW PIRKEY POWER PLT	48203	22	4,902	524	147	19,635	1,298	1,629
15	KEYSTONE COMPRESSOR STN.	48495	30	3,654	788	77	0	24	24
16	KEYSTONE PLANT	48495	6	2,809	455	173	672	37	37
17	LIGNITE-FIRED POWER PLANT	48013	7	4,213	336	136	6,603	1,338	1,745
18	MARTIN LAKE ELECTRICAL STATION	48401	11	19,035	4,407	515	36,027	3,118	3,525
19	MIDLOTHIAN PLANT	48139	9	6,067	1,175	66	3,263	174	457
20	MONTICELLO STM ELE STN	48449	3	12,241	1,706	302	51,133	1,400	1,567
21	NEWMAN STATION	48141	8	50	64	2	0	5	5
22	NORTH TEXAS CEMENT CO.	48139	2	712	581	67	190	348	397
23	ODESSA CEMENT PLANT	48135	23	2,510	1,850	169	469	199	429
24	OKLAUNION POWER STATION	48487	10	6,303	747	90	7,158	764	870
25	PEGASUS GAS PLANT	48329	6	2,666	538	248	107	9	9
26	RELIANT ENERGY LIMESTONE	48293	10	10,907	2,413	288	17,840	2,144	2,502
27	SANDOW STEAM ELECTRIC	48331	5	1,400	1,039	121	8,503	1,340	1,708
28	SHERHAN PLANT	48195	6	3,079	926	374	685	43	43
29	SOMMERS DEELY SPRUCE PWR	48029	63	8,176	1,969	255	26,309	1,767	2,849
30	STREETMAN PLANT	48349	11	973	302	400	4,886	116	214
31	TEXARKANA MILL	48067	5	2,359	1,066	1,933	557	772	858
32	TNP ONE STEAM ELECTRIC ST	48395	13	2,343	12,670	35	1,687	282	394
33	TOLK STATION	48279	18	5,253	1,078	130	22,133	486	603
34	W A PARISH STATION	48157	5	4,393	2,534	291	15,478	2,256	2,501
35	WAHA PLANT	48389	2	594	344	60	4,060	53	53
36	WELSH POWER PLANT	48449	5	6,171	1,477	177	14,284	1,553	1,790
37	WORKS NO 4	48485	15	8,929	18	1	623	634	666
38	SANDOW 5 GENERATING PLANT	48331	12	1,529	244	132	1,964	305	462

Table 4. Annual emissions (TPY) of EPA selected sources by pollutant in the updated 2018 base case inventory (after SMOKE processing).

Target ID	Plant Name	FIPS	Plant ID	NOx	CO	VOC	SO_2	$PM_{2.5}$	PM_{10}
1	BIG BROWN	48161	2	6,688	1,313	157	46,998	492	537
2	BIG SPRING CARBON BLACK	48227	2	1,135	7,083	68	17,891	9	137
3	BORGER CARBON BLACK	48233	1	636	17,475	580	4,919	105	147
4	BORGER CARBON BLACK PLT	48233	2	1,048	965	3	6,568	164	360
5	COLETO CREEK PLANT	48175	2	4,267	506	61	16,182	423	511
6	FAYETTE POWER PROJECT	48149	5	7,728	1,719	222	1,527	3,819	7,153
7	FULLERTON GAS PLANT	48003	10	1,861	966	406	3,445	29	29
8	GIBBONS CREEK	48185	2	1,872	447	54	945	471	546
9	GOLDSMITH GASOLINE PLANT	48135	22	1,129	691	259	2,174	9	9
10	GREAT LAKES CARBON LLC	48245	23	824	56	6	12,887	234	322
11	GUADALUPE COMPRESSOR STATION	48109	5	850	130	1	4	5	5
12	HARRINGTON STATION	48375	22	5,136	1,042	125	21,175	543	671
13	HOLCIM (TEXAS) LP	48139	22	5,018	7,198	823	5,340	562	563
14	HW PIRKEY POWER PLT	48203	22	4,889	523	146	19,729	1,295	1,625
15	KEYSTONE COMPRESSOR STN.	48495	30	3,654	788	77	78	25	25
16	KEYSTONE PLANT	48495	6	2,809	455	173	845	37	37
17	LIGNITE-FIRED POWER PLANT	48013	7	4,197	335	136	6,714	1,333	1,739
18	MARTIN LAKE ELECTRICAL STATION	48401	11	18,911	4,380	512	36,316	3,099	3,503
19	MIDLOTHIAN PLANT	48139	9	6,067	1,175	66	3,329	174	457
20	MONTICELLO STM ELE STN	48449	3	12,209	1,693	300	51,028	1,391	1,558
21	NEWMAN STATION	48141	8	48	62	2	0	5	5
22	NORTH TEXAS CEMENT CO.	48139	2	712	581	67	256	348	397
23	ODESSA CEMENT PLANT	48135	23	2,510	1,850	169	639	199	429
24	OKLAUNION POWER STATION	48487	10	6,302	747	90	7,247	764	870
25	PEGASUS GAS PLANT	48329	6	2,666	538	248	355	9	9
26	RELIANT ENERGY LIMESTONE	48293	10	10,855	2,402	287	18,044	2,134	2,490
27	SANDOW STEAM ELECTRIC	48331	5	1,400	1,033	120	8,574	1,332	1,699
28	SHERHAN PLANT	48195	6	3,079	926	374	1,060	43	43
29	SOMMERS DEELY SPRUCE PWR	48029	63	8,168	1,942	253	26,749	1,774	2,865
30	STREETMAN PLANT	48349	11	973	302	400	5,286	116	214
31	TEXARKANA MILL	48067	5	2,358	1,066	1,933	2,490	772	858
32	TNP ONE STEAM ELECTRIC ST	48395	13	2,327	12,586	35	1,711	281	392
33	TOLK STATION	48279	18	4,883	1,002	120	20,683	453	564
34	W A PARISH STATION	48157	5	4,454	2,636	297	15,669	2,252	2,496
35	WAHA PLANT	48389	2	594	344	60	4,119	53	53
36	WELSH POWER PLANT	48449	5	6,126	1,466	176	14,354	1,541	1,776
37	WORKS NO 4	48485	15	8,929	19	1	624	634	666
38	SANDOW 5 GENERATING PLANT	48331	12	1,527	244	132	1960	304	462

Other CAMx Inputs

All other CAMx inputs including meteorological data, land-use files, albedo-haze-ozone inputs, photolysis rates, boundary and initial conditions were the same as used in the 2002 baseline modeling.

CAMx Model Configuration

The CAMx configuration was the same as used in the 2002 baseline modeling except that the PSAT source tagging feature was turned on (Table 5). The CAMx model was run separately for each of four quarters of 2018 using a 15 day spin up period to limit the influence of the assumed initial concentrations.

Table 5. Model configurations options for CAMx model.

Science Options	Texas RH
Version	Version 5.41
Vertical Grid Mesh	19 Layers
Horizontal Grids	36/12 km using two-way nesting
Initial Conditions	15 days full spin-up
Boundary Conditions	2002 GEOS-CHEM day specific 3-hour average data
Sub-grid-scale Plumes	PiG treatment
Chemistry	
Gas Phase Chemistry	CB05
Aerosol Chemistry	ISORROPIA equilibrium
Secondary Organic Aerosols	SOAP
Cloud Chemistry	RADM-type aqueous chemistry
Meteorological Processor	MM5CAMx v5.2
Horizontal Transport	
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence
Source Apportionment	PSAT (sulfur, nitrogen, and primary PM)
Vertical Transport	
Eddy Diffusivity Scheme	K-Theory
Diffusivity Lower Limit	Kzmin = 0.1 to 1.0 (Land use dependent Kzmin)
Planetary Boundary Layer	From MM5 with PBL below convective clouds raised to cloud top
Deposition Scheme	Zhang
Numerics	
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) solver
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM scheme)
Parallelization	OMP-MPI

PSAT Formulation

PSAT is designed to source apportion the following PM species modeled in CAMx:

- Sulfate (SO4)
- Particulate nitrate (NO3)
- Ammonium (NH4)
- Particulate mercury (Hg(p))
- Secondary organic aerosol (SOA)
- Six categories of primary particulate matter (PM)
  - Elemental carbon (EC)
  - Primary organic aerosol (POA)
  - Fine crustal PM (FCRS)
  - Fine other primary PM (FPRM)
  - Coarse crustal PM (CCRS)
  - Coarse other primary PM (CPRM)

PSAT performs PM source apportionment (also called source tagging) for each selected source group. A source group may consist of a combination of geographic regions and emissions source categories. For this study, each EPA selected facility is assigned a unique PSAT source group. The PSAT "reactive tracers" that are added for each source group (*i*) are described below. In general, a single tracer can track primary PM species, whereas secondary PM species require several tracers to track the relationship between gaseous precursors and the resulting PM. Particulate nitrate and secondary organics are the most complex species to apportion because the emitted precursor gases (NOx and VOCs) are several steps removed from the resulting PM species (NO3 and SOA). There is a PSAT convention that tracer names for particulate species begin with the letter "P." This study tracks sulfur, nitrogen and primary particulate matter tracers:

Sulfur (SO_4 Tracers)

$SO2_i$ Primary SO_2 emissions
$PS4_i$ Particulate sulfate ion from primary emissions plus secondarily formed sulfate

Nitrogen (NO_3 Tracers)

RGN_i Reactive gaseous nitrogen including primary NOx ($NO + NO_2$) emissions plus nitrate radical (NO_3), nitrous acid (HONO) and dinitrogen pentoxide (N_2O_5).
TPN_i Gaseous peroxyl acetyl nitrate (PAN) plus peroxy nitric acid (PNA)
NTR_i Organic nitrates (RNO_3)
$HN3_i$ Gaseous nitric acid (HNO_3)
$PN3_i$ Particulate nitrate ion from primary emissions plus secondarily formed nitrate
$NH3_i$ Gaseous ammonia (NH_3)
$PN4_i$ Particulate ammonium (NH_4)

Primary Particulate Matter (PM Tracers)

PEC_i Primary Elemental Carbon
POA_i Primary Organic Aerosol
PFC_i Fine Crustal PM
PFN_i Other Fine Particulate
PCC_i Coarse Crustal PM
PCS_i Other Coarse Particulate

One fundamental assumption in PSAT is that PM is apportioned back to the primary precursor for each type of PM. For example, SO4 is apportioned to SOx emissions, NO3 is apportioned to NOx emissions, NH4 is apportioned to NH3 emissions, etc.

CAMx MODELING RESULTS

Air quality modeling results for the 2018 base case simulation are presented by pollutant of concern, including ozone and PM. The analysis of air quality results focuses on high ozone and PM levels, i.e. maximum 8-hour ozone and maximum 24-hour PM. Annual average levels for PM and its constituents are also presented. This section also provides analysis of visibility contribution at Class I areas due to selected sources. Comparison of a reasonable progress goal to a glide slope for each Class I area is provided at the end of this section.

Ozone

The annual maximum 8-hour ozone may be susceptible to emissions/model artifacts so we focus on the annual 4th highest 8-hour ozone (Figure 3). Similar to the 2002 results, the 2018 base case shows high values of 4th highest daily maximum 8-hour ozone (above 75 ppb, the current level of the ozone NAAQS) in several western locations associated with wildfire emissions and over water bodies close to major urban/industrial areas near the Great Lakes, Gulf Coast and the Northeast Seaboard, where emissions are transported over water and confined to a shallow boundary layer. The 2018 ozone is lower than the 2002 ozone in most eastern states. Nonetheless, ozone exceeds 75 ppb in several urban areas in Texas including Dallas and Houston. New Orleans and Baton Rouge, Louisiana, also exceed over 75 ppb.

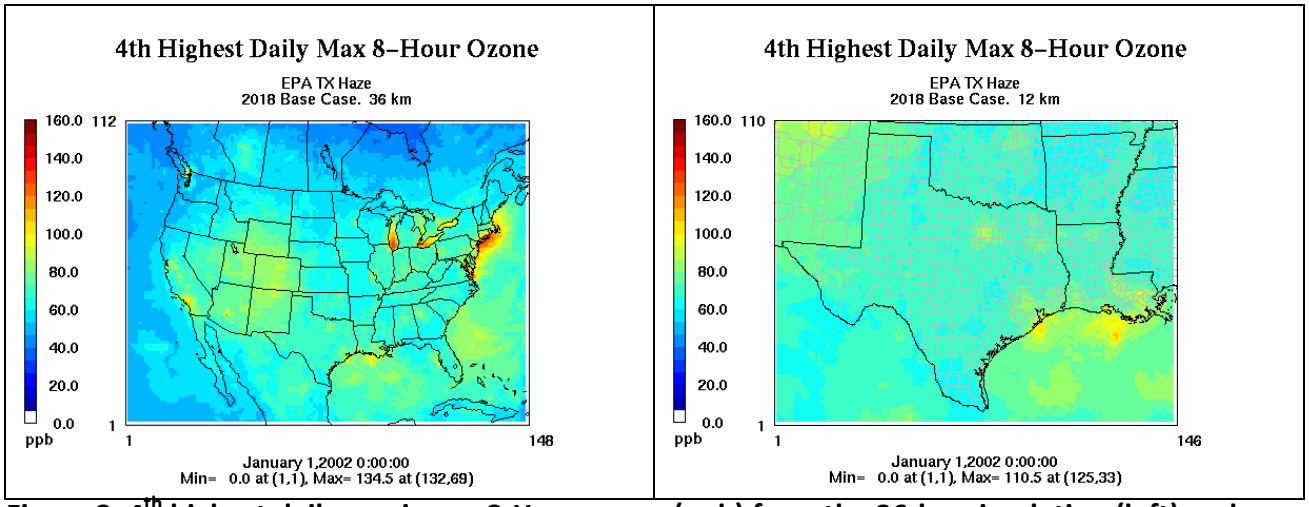


Figure 3. 4th highest daily maximum 8-Hour ozone (ppb) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

Particulate Matter

$PM_{2.5}$ results are presented for daily design-value relevant measures (98th percentile of all daily concentrations) and annual average concentrations. Overall, the 2002 and 2018 results have similar spatial patterns but the 2018 $PM_{2.5}$ concentrations are lower. The 8th highest 24-hour average concentrations of $PM_{2.5}$ (Figure 4) shows the highest peak values occurring in the Western United States but more uniformly high values occurring in the Eastern United States. Elevated $PM_{2.5}$ concentrations in the 12 km domain are seen in western Louisiana and western Arkansas due to fire activities (also observed in the 2002 simulation). Similar PM compositions to the 2002 simulation are seen in the 2018 simulation (show in Appendix B). Specifically, high particulate matter concentrations in the Eastern United States have large sulfate and nitrate contributions with additional contributions from primary organic PM in the south. Urban $PM_{2.5}$ in Texas (characterized by high nitrate and organic carbon) is lower in the 2018 simulation. Annual average concentrations of $PM_{2.5}$ and PM_{10} (Figure 5 and Figure 6) show a similar pattern of widespread but the fire influence is less pronounced.

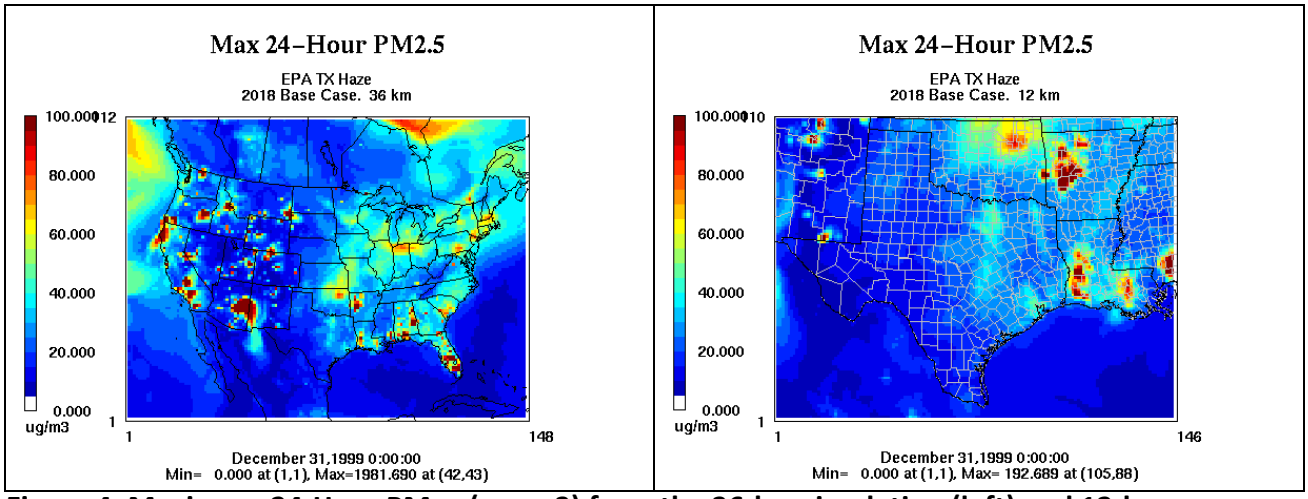


Figure 4. Maximum 24-Hour $PM_{2.5}$ (µg m-3) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

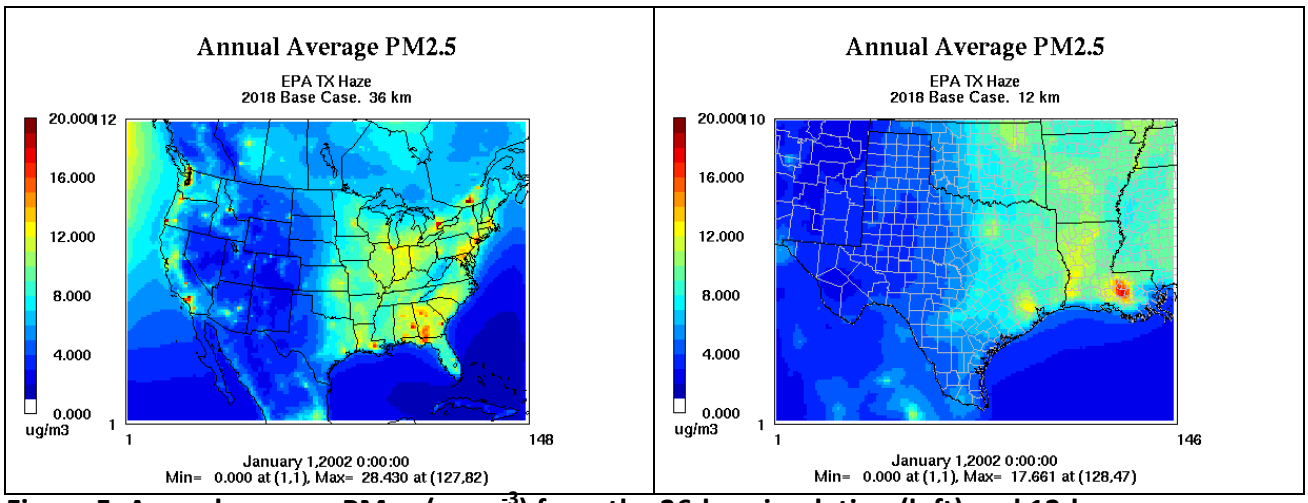


Figure 5. Annual average $PM_{2.5}$ (µg m^{-3}) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

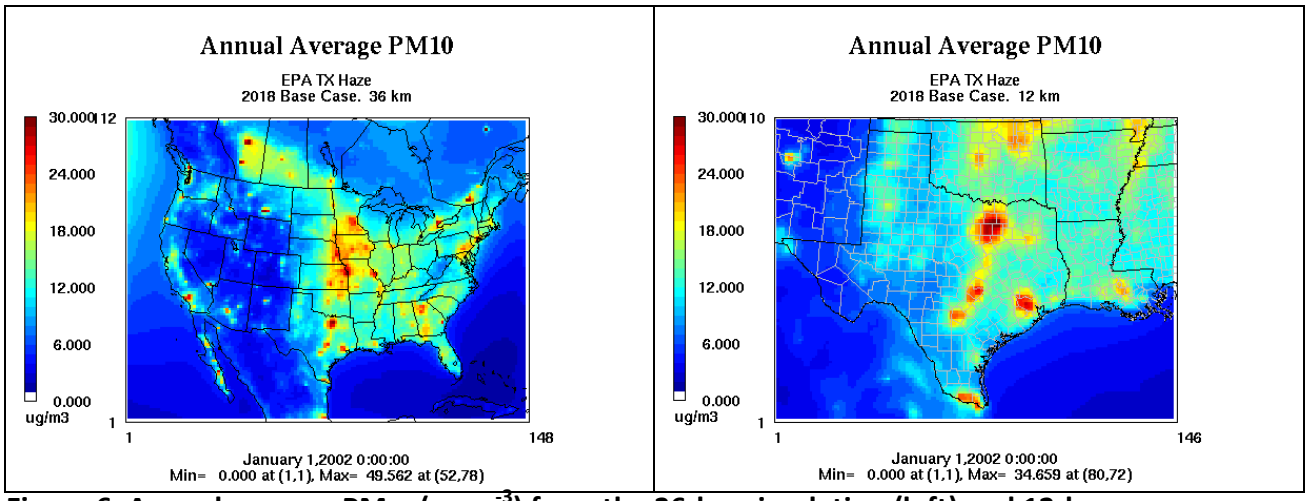


Figure 6. Annual average PM_{10} (µg m^{-3}) from the 36-km simulation (left) and 12-km simulation (right) for the 2018 base case.

Visibility Contributions

Visibility impacts were calculated at each Class I area using 2018 PM concentrations from each PSAT group. Steps in conducting visibility contribution calculations are summarized below:

Step 1. Use Modeled Attainment Test Software (MATS) to compute model-estimated relative response factors (RRFs) that are the ratio of the model-estimated 24-hour $PM_{2.5}$ concentrations for the future-year (2018) to the baseline (2002) emission scenarios.

Step 2. Calculate 2018 modeled visibility conditions and projected visibility conditions (using RRF approach) for 20% worst (W20%) and 20% best (B20%) days

Step 3. To get individual source or group of sources contributions, subtract the PSAT results from the 2018 CAMx output for the source of interest, rerun MATS, and calculate differences of projected visibility conditions by repeating Step 2.

These procedures use the new IMPROVE algorithm (Pitchford et al., 2007) which reconstructs the light-extinction coefficient (bext, expressed in units of inverse megameters, Mm-1) using the following equation:

$$
\begin{aligned}
\text{bext} \approx\ & \\
& 2.2 \times f_S(RH) \times [\text{small sulfate}] + 4.8 \times f_L(RH) \times [\text{large sulfate}] \\
& + 2.4 \times f_S(RH) \times [\text{small nitrate}] + 5.1 \times f_L(RH) \times [\text{large nitrate}] \\
& + 2.8 \times [\text{small organic mass}] + 6.1 \times [\text{large organic mass}] \\
& + 10 \times [\text{elemental carbon}] \\
& + 1 \times [\text{fine soil}] \\
& + 1.7 \times f_{SS}(RH) \times [\text{sea salt}] \\
& + 0.6 \times [\text{coarse mass}] \\
& + \text{Rayleigh scattering (site-specific)} \\
& + 0.33 \times [\text{NO2 (ppb)}]
\end{aligned}
$$

The apportionment of the total concentration of sulfate compounds into the concentrations of small and large size fractions is accomplished using the following equations:

$$
\begin{aligned}
&[\text{large sulfate}] = [\text{total sulfate}/20] \times [\text{total sulfate}], \text{ for } [\text{total sulfate}] < 20\ \mu g/m3 \\
&[\text{large sulfate}] = [\text{total sulfate}], \text{ for } [\text{total sulfate}] \geq 20\ \mu g/m3 \\
&[\text{small sulfate}] = [\text{total sulfate}] - [\text{large sulfate}]
\end{aligned}
$$

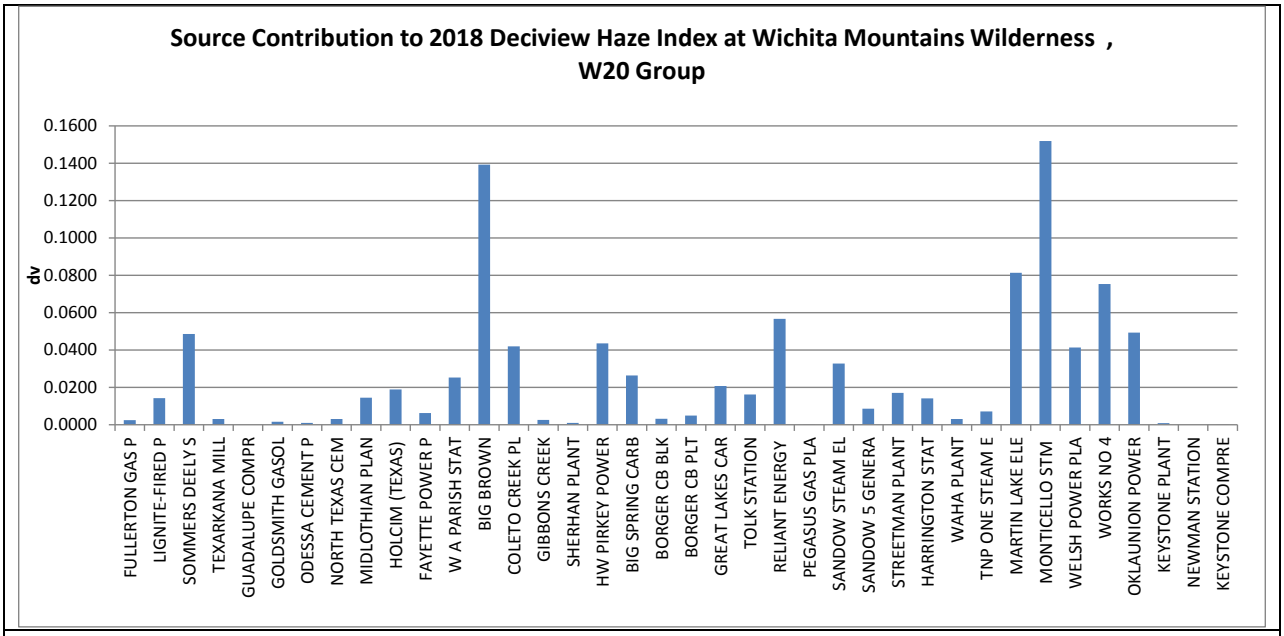
Similar equations are used to apportion total nitrate and total organic mass into small and large size fractions. The new algorithm contains three distinct water growth terms, designated f_S, f_L, and f_{SS} for the small and large sulfate and nitrate fractions, and for sea salt, respectively. Monthly average f(RH) values are used as following FLAG2010 procedure (FLAG, 2010).

Our analysis calculates the day-specific visibility impacts at Class I areas on the B20% and W20% days. Figures 7-14 demonstrate visibility contributions at the Class I areas in Texas (i.e., Big Bend and Guadalupe Mountains) and near Texas (i.e., Caney Creek and Wichita Mountains)

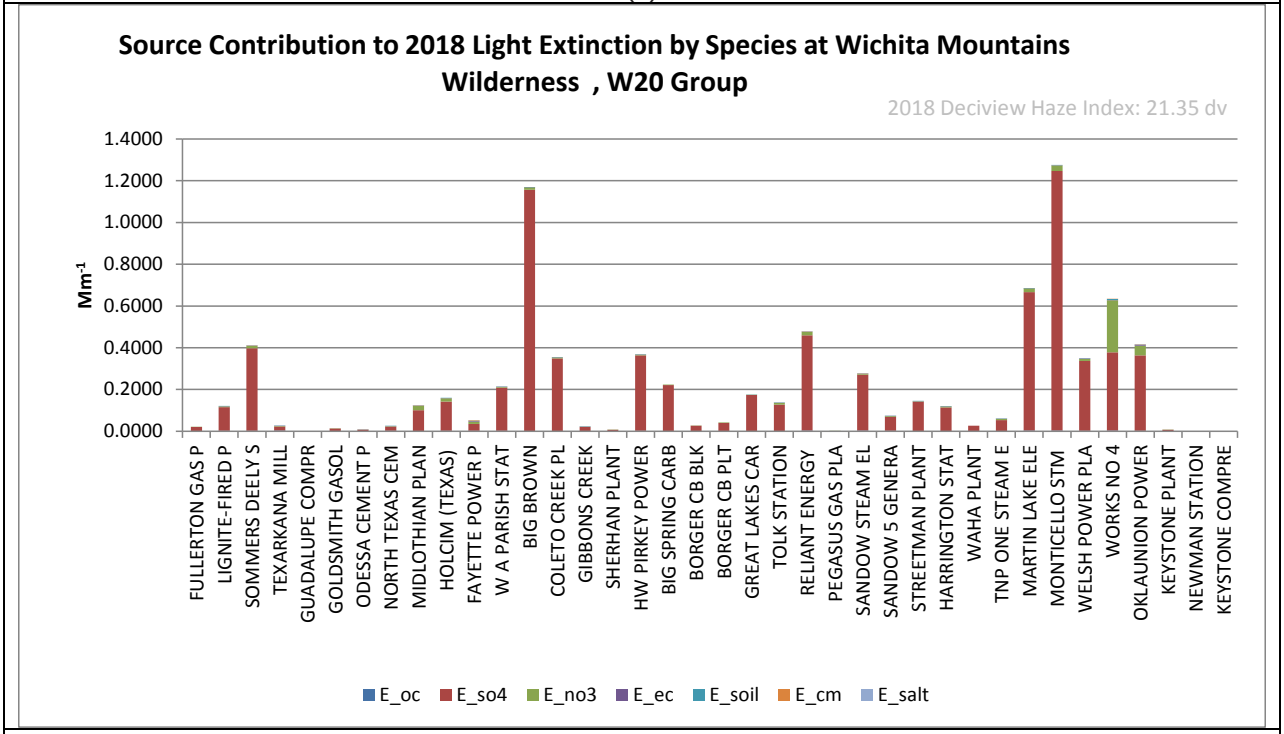
averaged over the B20% and W20% days. Additional types of graphics showing visibility contributions can be found in Appendix C and in supporting Excel Spreadsheets accompanying this memorandum.

Sulfate appears to be the main constituent that contributes to visibility degradation at the Class I areas in/near Texas on both B20% and W20% cases. Although the 2002 visibility model performance shows underestimation of sulfate across all sites on the W20% days, the RRF approach makes use of model results in a relative sense to counter the model biases. The B20% days generally include more winter days than the W20% days, resulting in higher visibility contributions from nitrate. Proximity of the selected sources to Class I areas and magnitude of SO_2 emissions are factors that influence visibility impacts at these four Class I areas. A sensitivity test showed that projected visibility conditions and contributions are relatively unaffected by using an alternate RRF approach with RRF for coarse material and soil set to 1 (not shown here) on both 20% worst and 20% best days.

Top 10 facilities based on average and maximum visibility impacts on the worst 20% days at each Class I area are listed in Table 6.

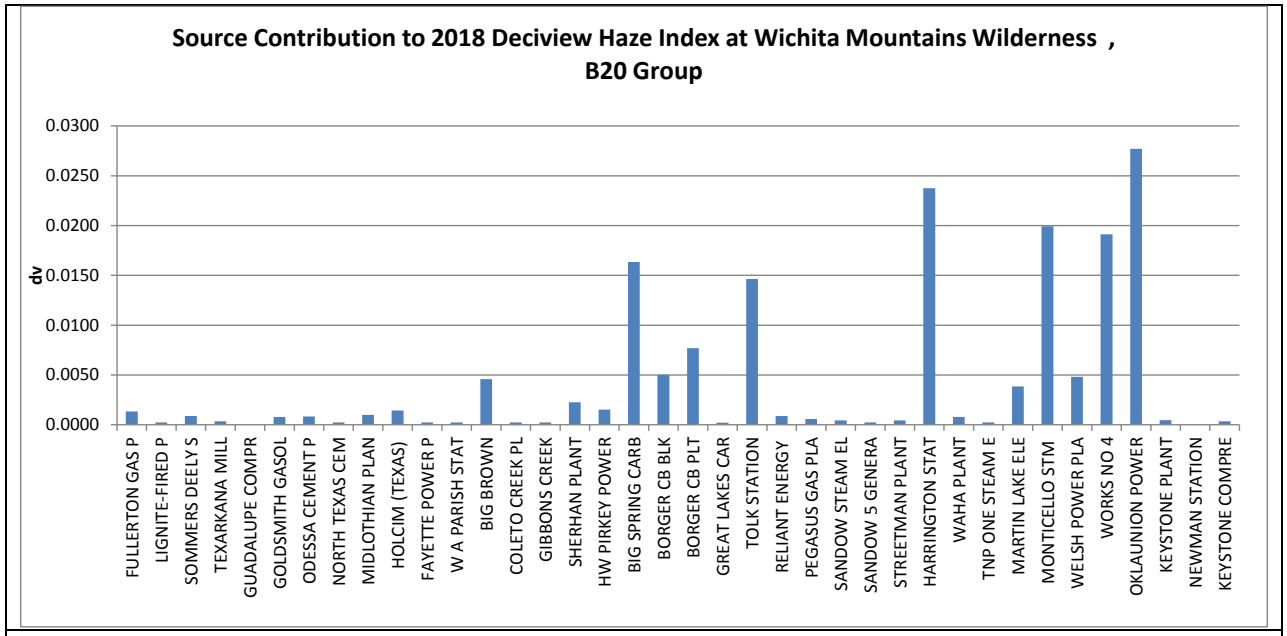


(a)

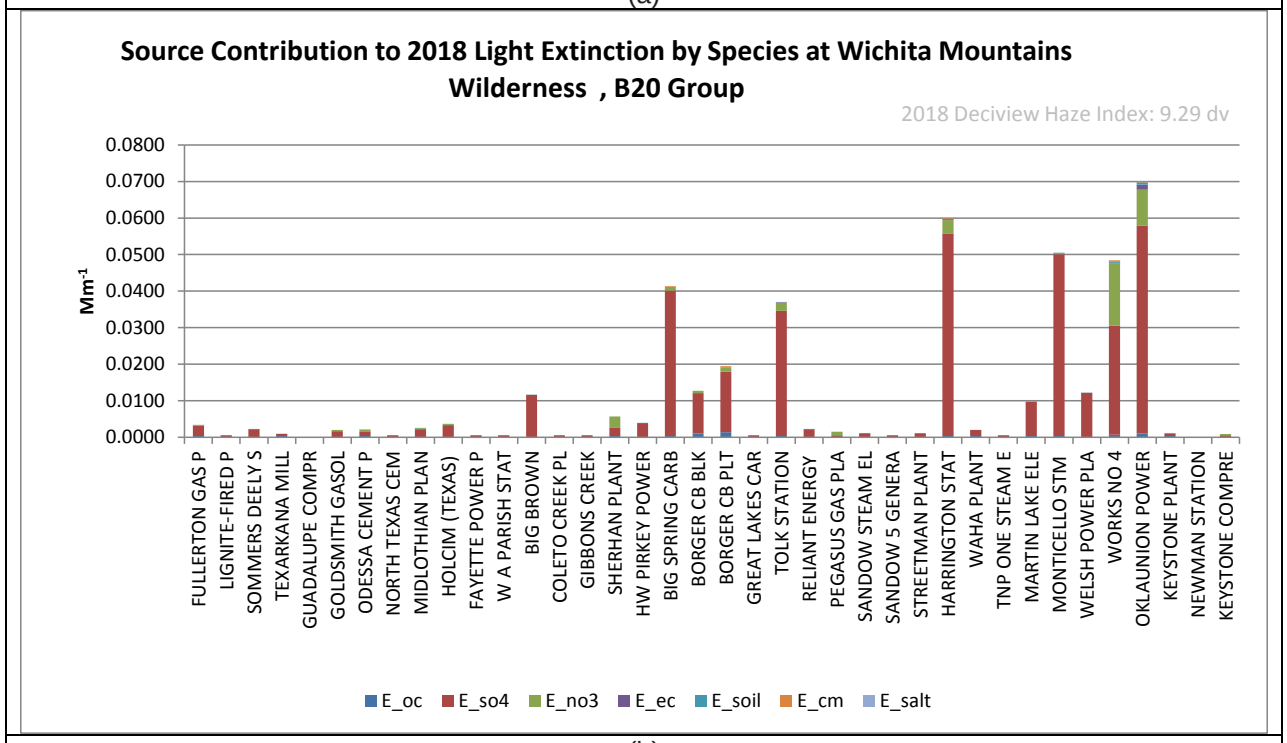


(b)

Figure 7. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Wichita Mountains Wilderness Area (WIMO), Oklahoma averaged over the Worst 20% (W20%) days.

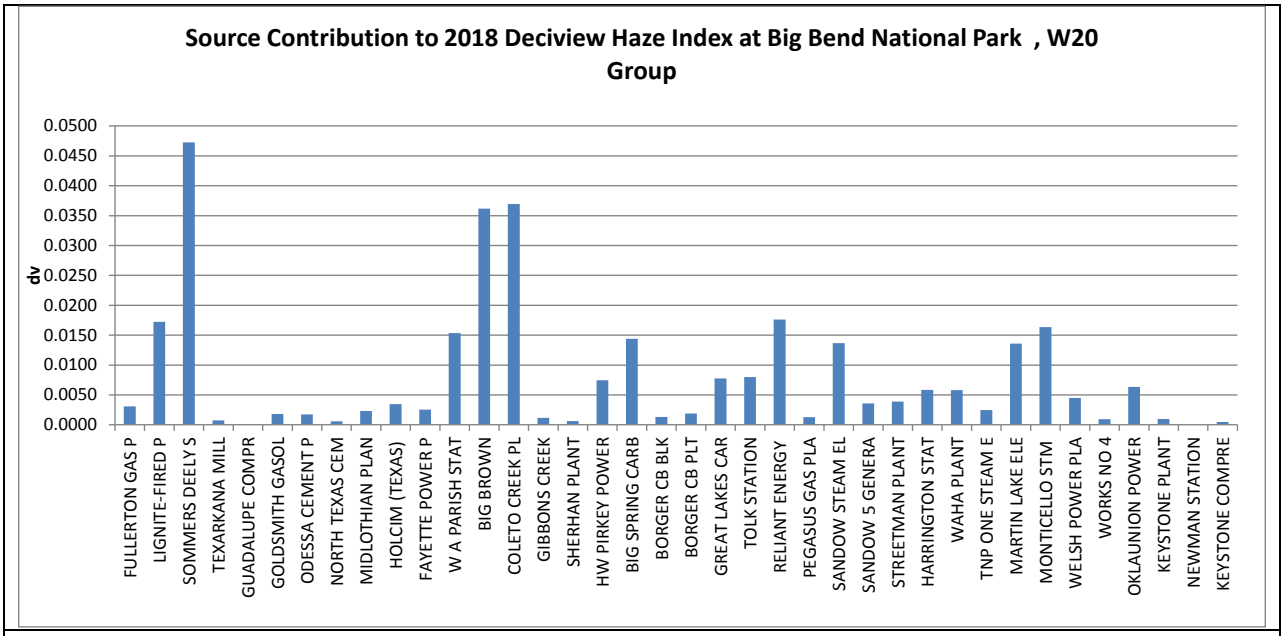


(a)

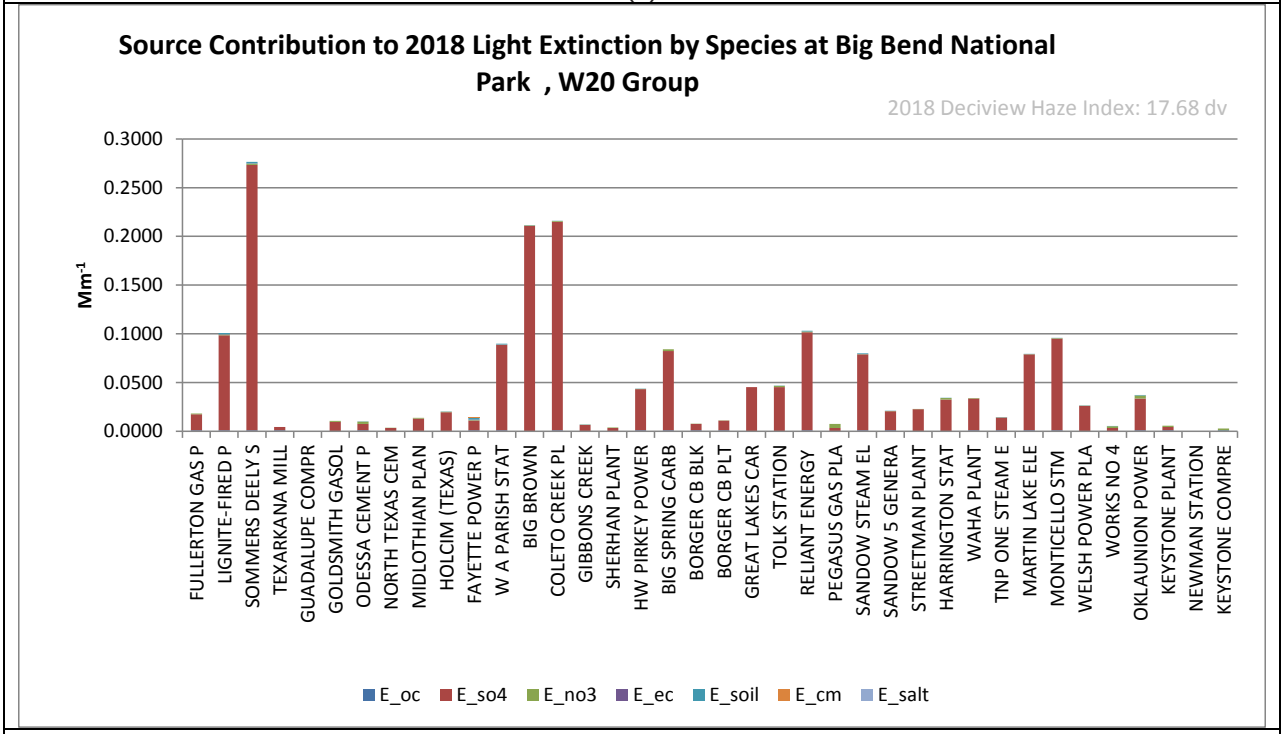


(b)

Figure 8. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Wichita Mountains Wilderness Area (WIMO), Oklahoma averaged over the Best 20% (B20%) days.

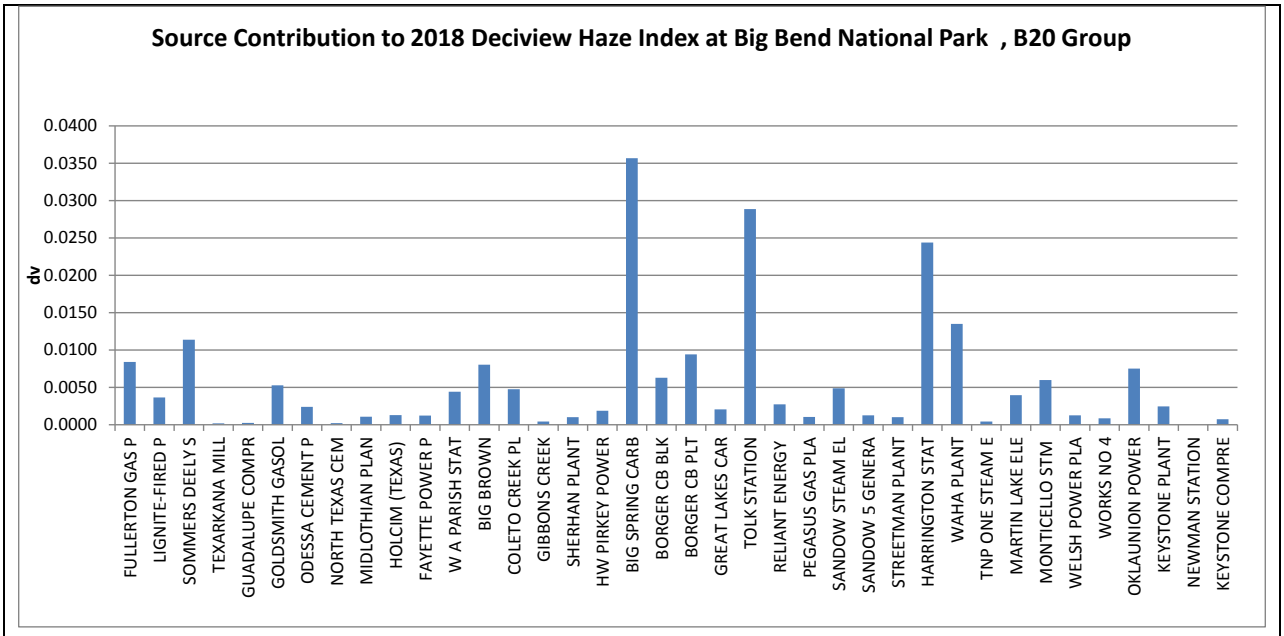


(a)

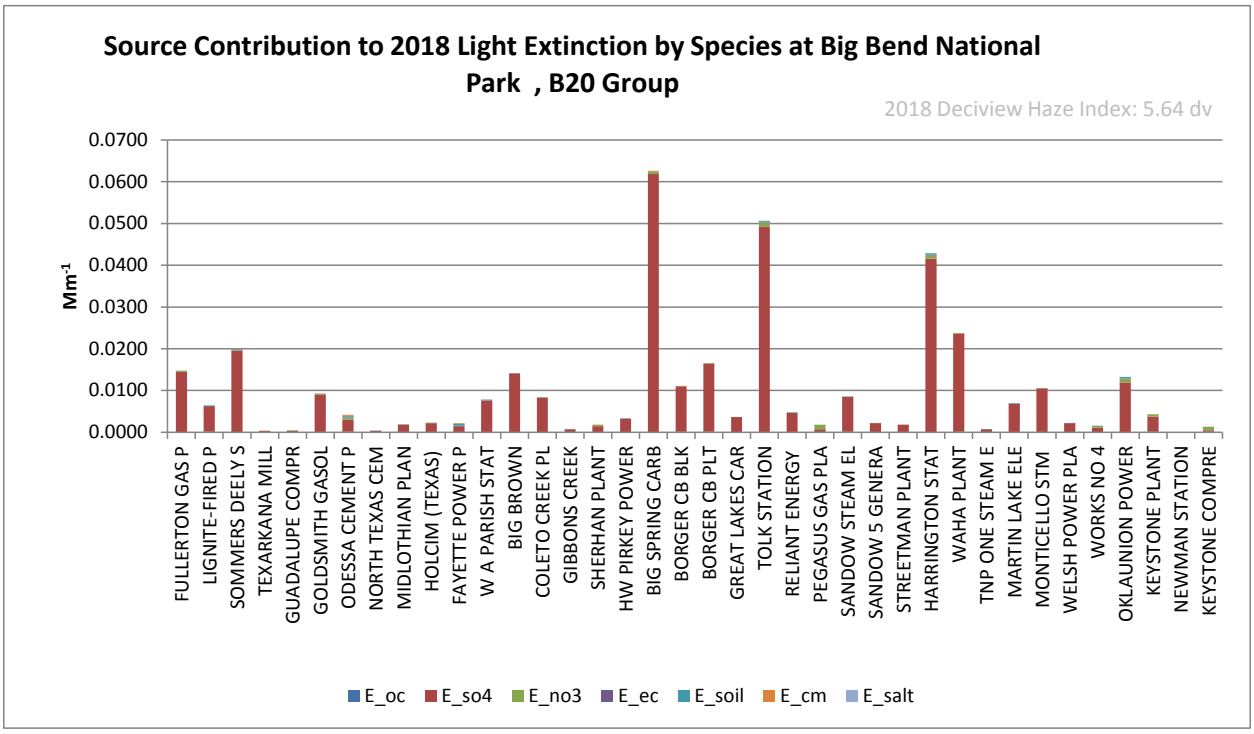


(b)

Figure 9. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Big Bend National Park (BIBE), Texas averaged over the Worst 20% (W20%) days.

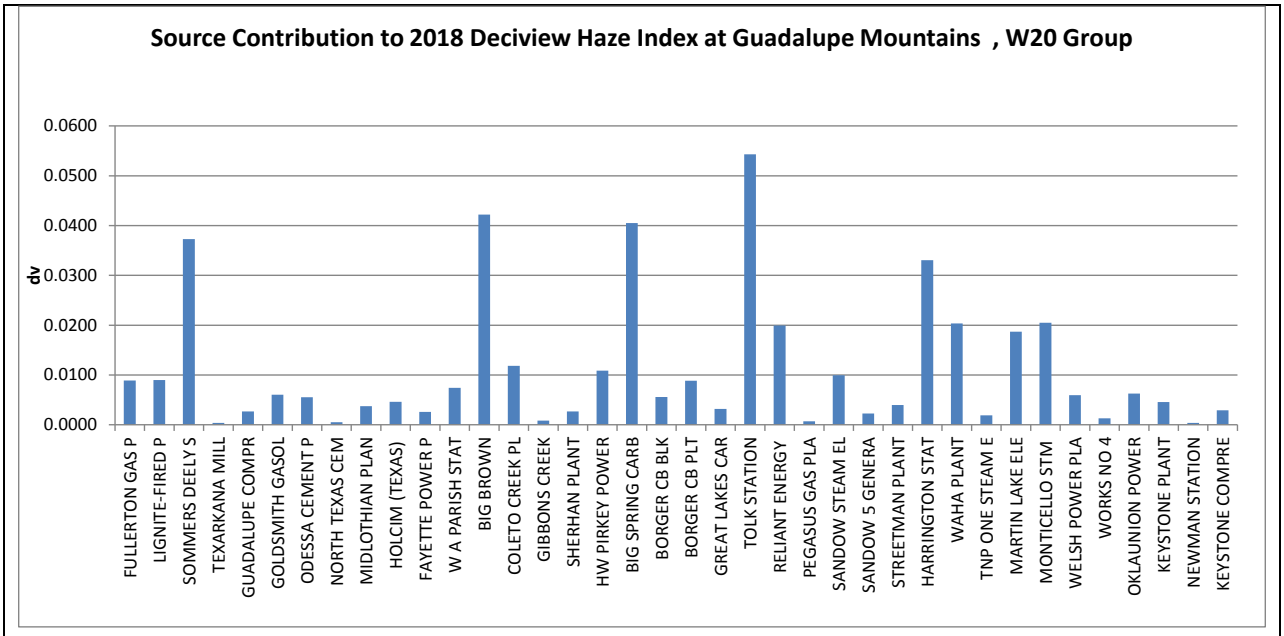


(a)

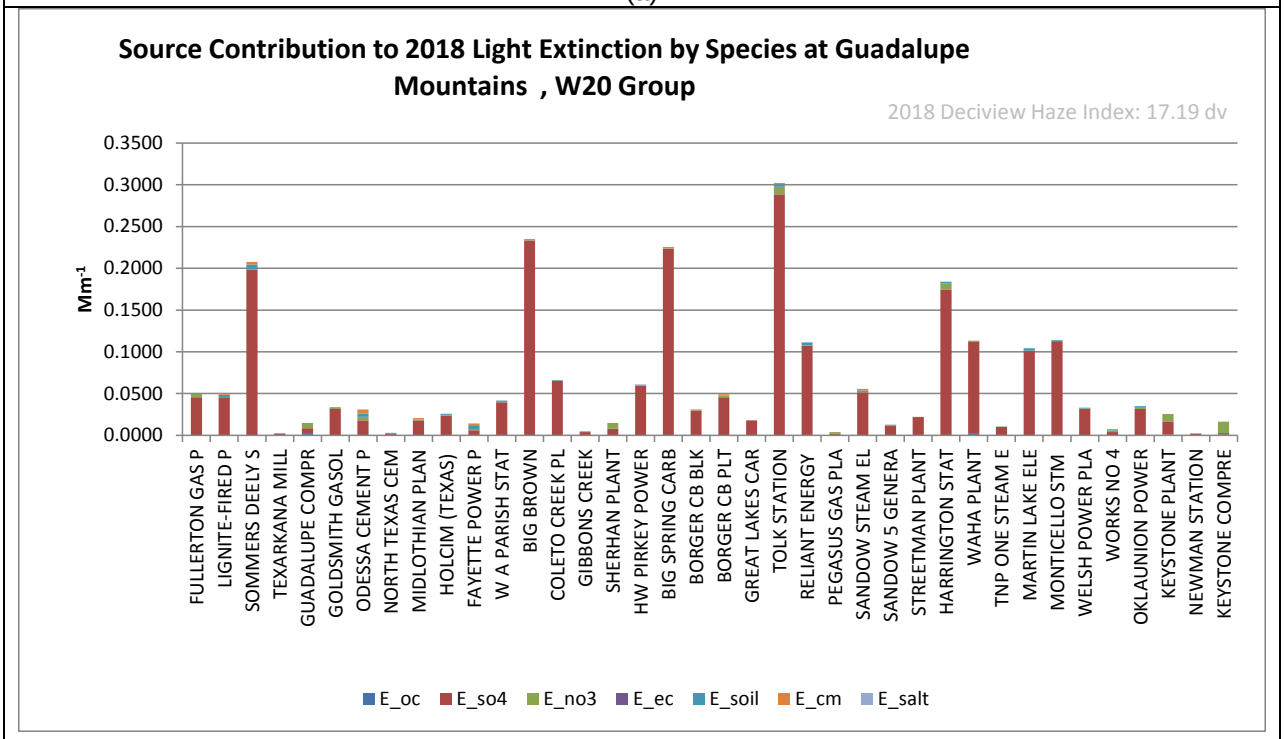


(b)

Figure 10. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Big Bend National Park (BIBE), Texas averaged over the Best 20% (B20%) days.

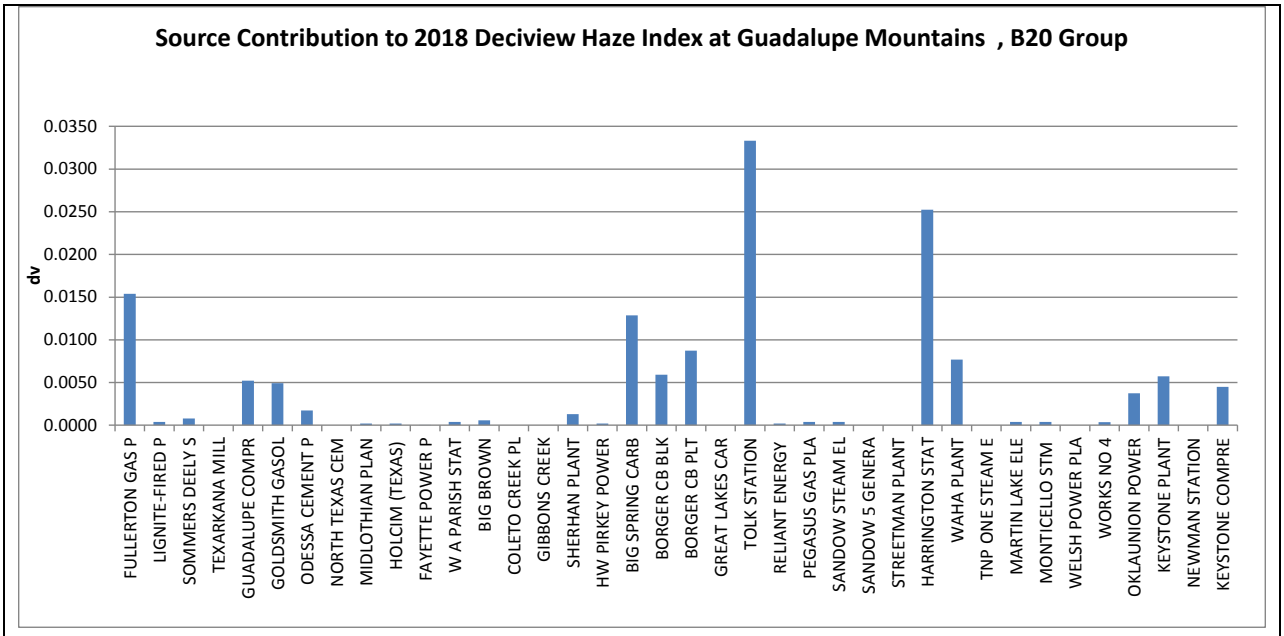


(a)

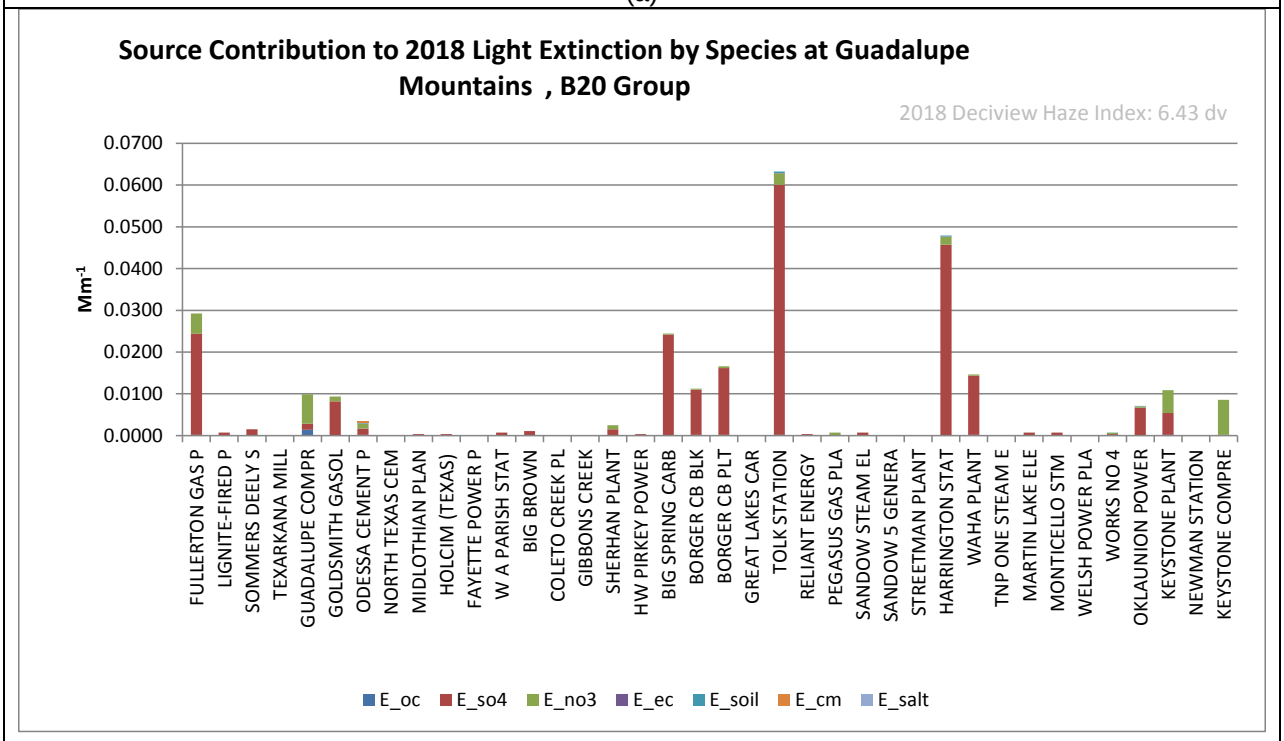


(b)

Figure 11. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Guadalupe Mountains National Park (GUMO), Texas averaged over the Worst 20% (W20%) days.

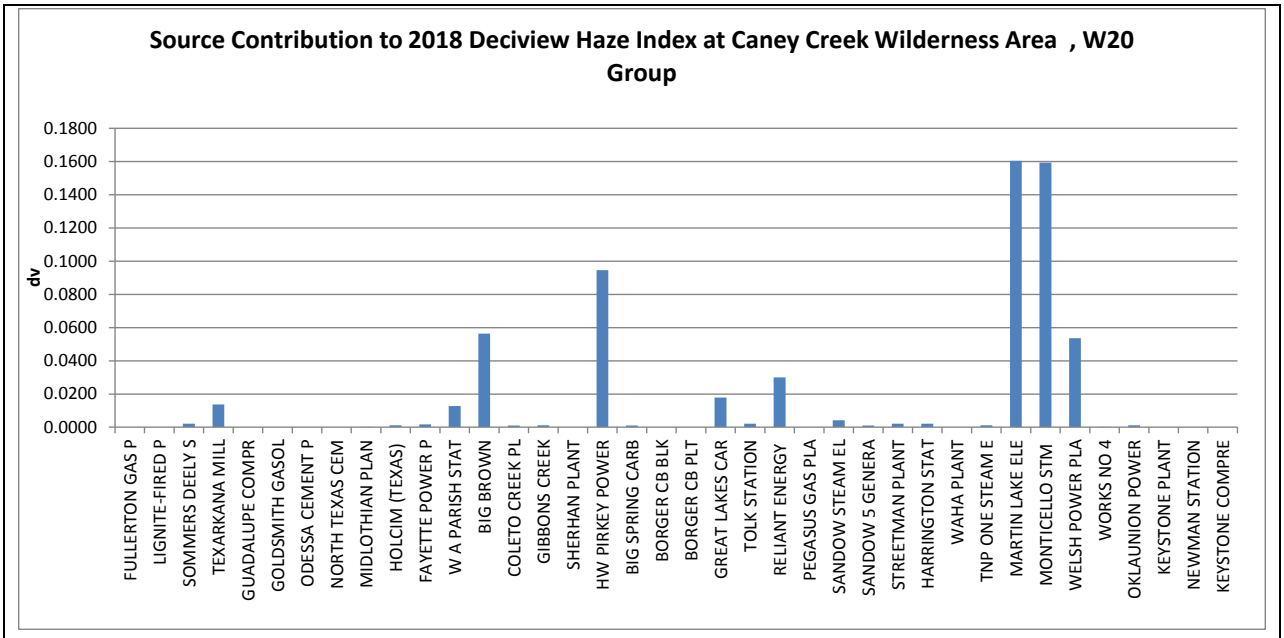


(a)

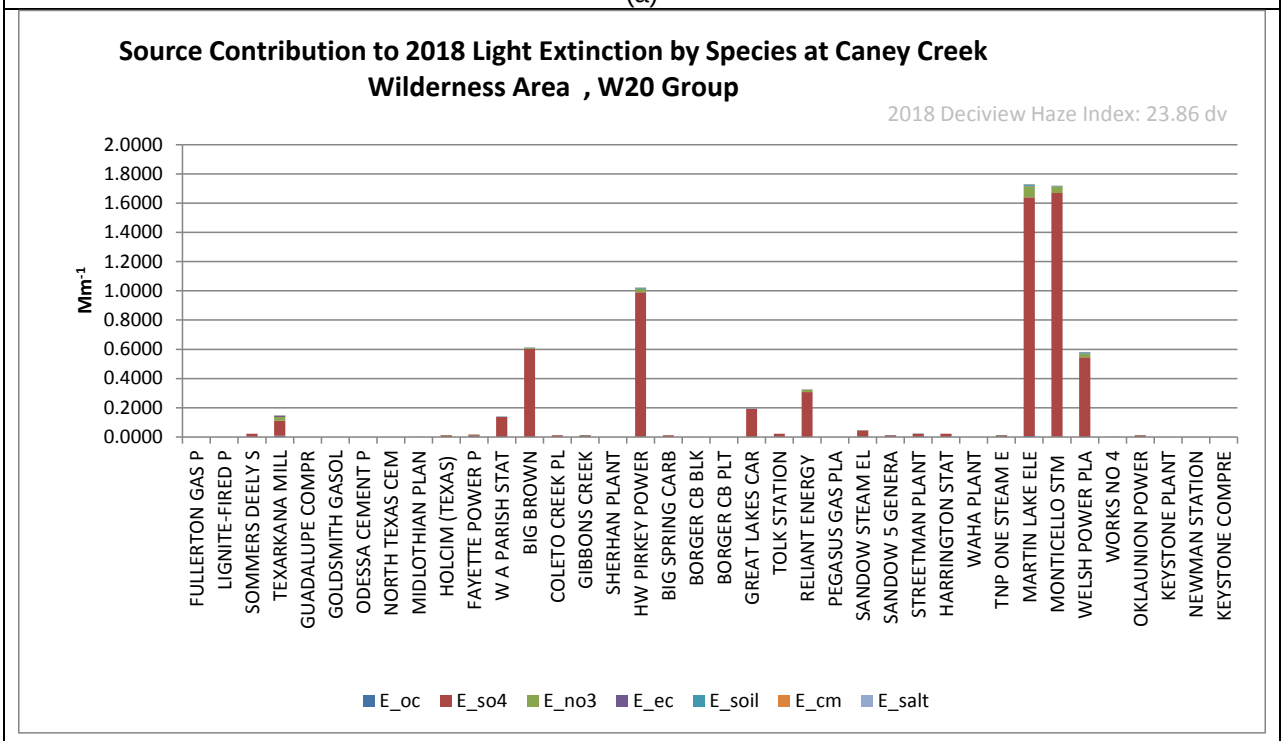


(b)

Figure 12. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Guadalupe Mountains National Park (GUMO), Texas averaged over the Best 20% (B20%) days.

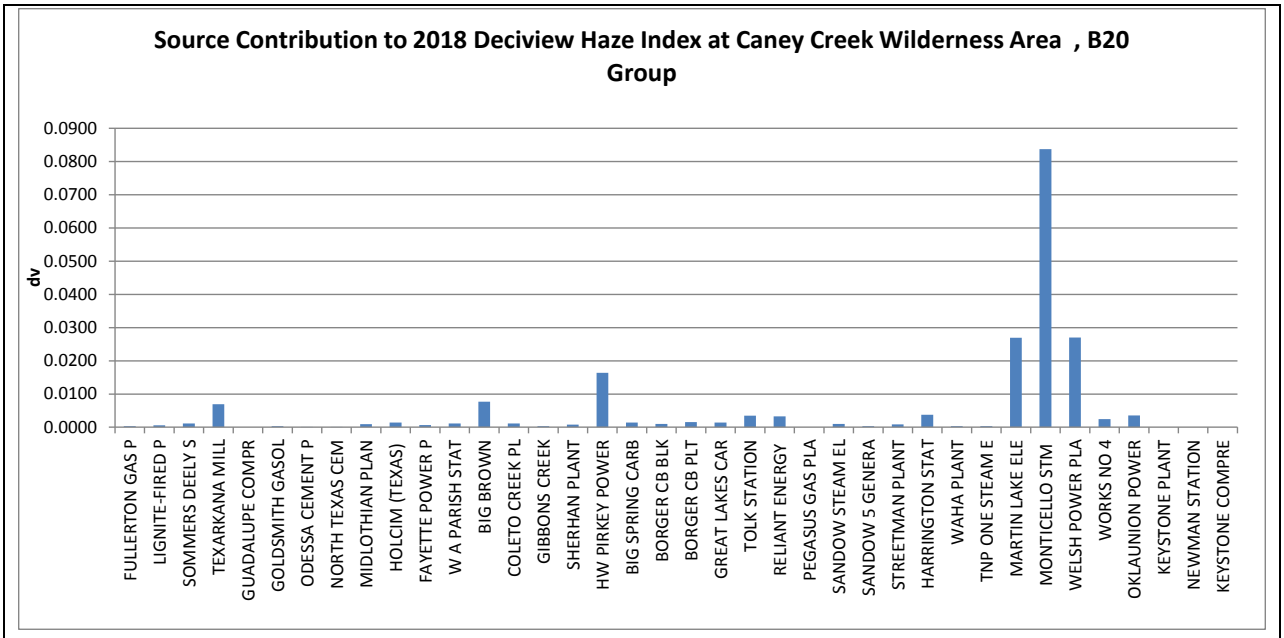


(a)

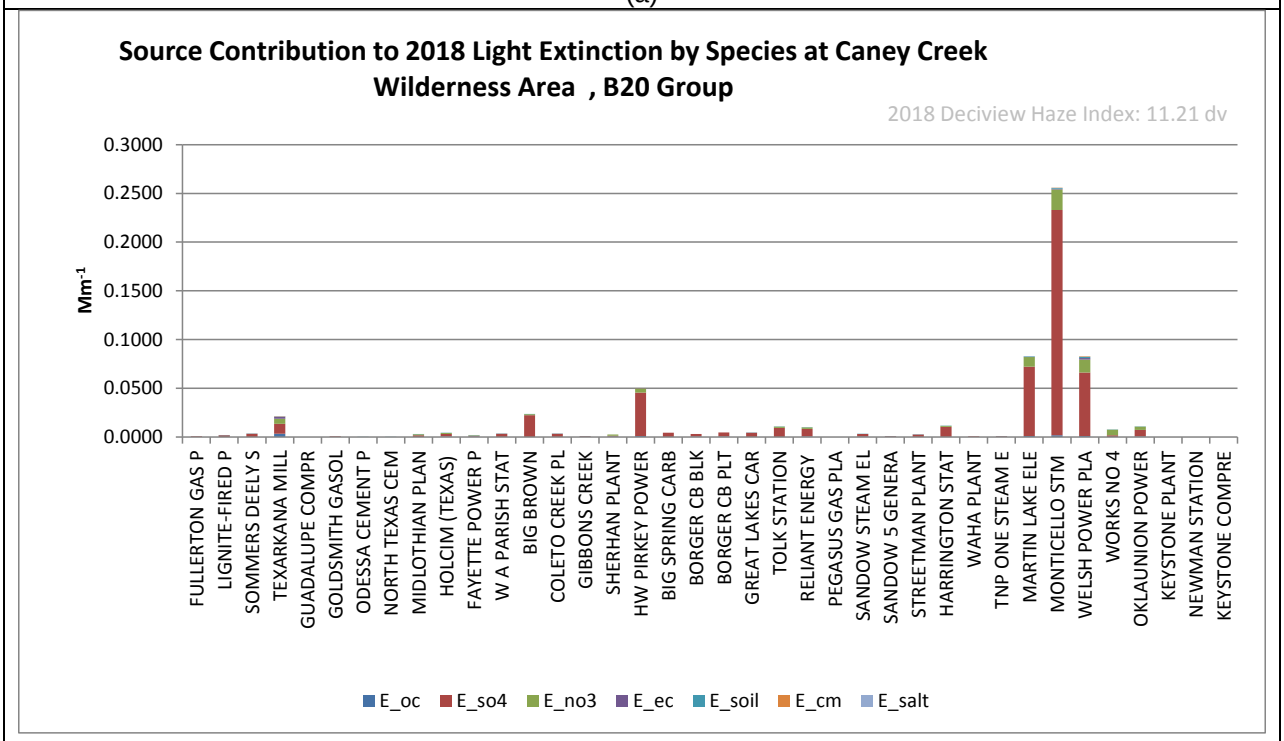


(b)

Figure 13. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Caney Creek (CACR), Arkansas averaged over the Worst 20% (W20%) days.



(a)



(b)

Figure 14. Source contribution to 2018 Haze Index (a) and Light Extinction (b) for Caney Creek (CACR), Arkansas averaged over the Best 20% (B20%) days.

Table 6. Top 10 facilities based on average and maximum visibility impacts on the worst 20% days at each Class I area.

	Average Impact			Maximum Impact		
Top 10	Plant Name	DV	% Contribution	Plant Name	DV	% Contribution
Wichita Mountains Wilderness						
1	MONTICELLO STM	0.1519	6.7%	MONTICELLO STM	0.2391	7.8%
2	BIG BROWN	0.1393	6.1%	BIG BROWN	0.2218	7.2%
3	MARTIN LAKE ELE	0.0814	3.6%	WORKS NO 4	0.1911	6.2%
4	WORKS NO 4	0.0753	3.3%	MARTIN LAKE ELE	0.1272	4.1%
5	RELIANT ENERGY	0.0567	2.5%	RELIANT ENERGY	0.0875	2.8%
6	OKLAUNION POWER	0.0494	2.2%	SOMMERS DEELY S	0.0757	2.5%
7	SOMMERS DEELY S	0.0487	2.1%	OKLAUNION POWER	0.0700	2.3%
8	HW PIRKEY POWER	0.0437	1.9%	HW PIRKEY POWER	0.0692	2.2%
9	COLETO CREEK PL	0.0420	1.8%	COLETO CREEK PL	0.0664	2.2%
10	WELSH POWER PLA	0.0414	1.8%	WELSH POWER PLA	0.0643	2.1%
Total DV from selected sources in 2018		**2.283**	**100.0%**		**3.085**	**100.0%**
Big Bend National Park						
1	SOMMERS DEELY S	0.0473	9.3%	SOMMERS DEELY S	0.1037	9.4%
2	COLETO CREEK PL	0.0369	7.2%	COLETO CREEK PL	0.0814	7.4%
3	BIG BROWN	0.0362	7.1%	BIG BROWN	0.0801	7.2%
4	RELIANT ENERGY	0.0176	3.5%	RELIANT ENERGY	0.0382	3.5%
5	LIGNITE-FIRED P	0.0172	3.4%	LIGNITE-FIRED P	0.0370	3.3%
6	MONTICELLO STM	0.0164	3.2%	MONTICELLO STM	0.0357	3.2%
7	W A PARISH STAT	0.0153	3.0%	W A PARISH STAT	0.0333	3.0%
8	BIG SPRING CARB	0.0144	2.8%	BIG SPRING CARB	0.0309	2.8%
9	SANDOW STEAM EL	0.0136	2.7%	SANDOW STEAM EL	0.0296	2.7%
10	MARTIN LAKE ELE	0.0136	2.7%	MARTIN LAKE ELE	0.0296	2.7%
Total DV from selected sources in 2018		**0.510**	**100.0%**		**1.107**	**100.0%**
Guadalupe Mountains						
1	TOLK STATION	0.0543	7.0%	TOLK STATION	0.1367	7.9%
2	BIG BROWN	0.0422	5.5%	BIG BROWN	0.1100	6.3%
3	BIG SPRING CARB	0.0405	5.3%	BIG SPRING CARB	0.1054	6.1%
4	SOMMERS DEELY S	0.0373	4.8%	SOMMERS DEELY S	0.0936	5.4%
5	HARRINGTON STAT	0.0331	4.3%	HARRINGTON STAT	0.0824	4.7%
6	MONTICELLO STM	0.0205	2.7%	MONTICELLO STM	0.0531	3.1%
7	WAHA PLANT	0.0203	2.6%	WAHA PLANT	0.0524	3.0%
8	RELIANT ENERGY	0.0200	2.6%	RELIANT ENERGY	0.0504	2.9%
9	MARTIN LAKE ELE	0.0187	2.4%	MARTIN LAKE ELE	0.0476	2.7%
10	COLETO CREEK PL	0.0119	1.5%	COLETO CREEK PL	0.0307	1.8%
Total DV from selected sources in 2018		**0.772**	**100.0%**		**1.737**	**100.0%**
Wichita Mountains Wilderness						
1	MARTIN LAKE ELE	0.1605	4.5%	MONTICELLO STM	0.2371	5.4%
2	MONTICELLO STM	0.1594	4.5%	MARTIN LAKE ELE	0.2333	5.3%
3	HW PIRKEY POWER	0.0946	2.7%	HW PIRKEY POWER	0.1403	3.2%
4	BIG BROWN	0.0564	1.6%	BIG BROWN	0.0850	1.9%
5	WELSH POWER PLA	0.0536	1.5%	WELSH POWER PLA	0.0777	1.8%
6	RELIANT ENERGY	0.0300	0.8%	RELIANT ENERGY	0.0435	1.0%
7	GREAT LAKES CAR	0.0178	0.5%	TEXARKANA MILL	0.0275	0.6%
8	TEXARKANA MILL	0.0137	0.4%	GREAT LAKES CAR	0.0272	0.6%
9	W A PARISH STAT	0.0127	0.4%	W A PARISH STAT	0.0193	0.4%
10	SANDOW STEAM EL	0.0042	0.1%	SANDOW STEAM EL	0.0064	0.1%
Total DV from selected sources in 2018		**3.563**	**100.0%**		**4.367**	**100.0%**

Uniform Rates of Progress and Projected 2018 Reasonable Progress Goals

In preparing a regional haze state implementation plan (SIP) each state must "analyze and determine the uniform rate of progress (glide path) needed to attain natural visibility conditions by the year 2064." (40 Code of Federal Regulations (CFR) §51.308(d)(1)(i)(B)) Each state with one or more Class I areas must set a reasonable progress goal (measured in deciviews) for each of its Class I areas and compare the reasonable progress goal to the glide slope for the Class I area.

"The reasonable progress goals must provide for an improvement for the most impaired days [the worst 20 percent of monitored days] over the period of the implementation plan and ensure no degradation in visibility for the least impaired days [the best 20 percent of monitored days] over the same period." (40 CFR §51.308(d)(1)) The period of the first regional haze SIP is from its adoption to 2018. The uniform rate of progress line is a straight line from the 2000 through 2004 base period impairment for the worst 20 percent of monitored days plotted from 2004 to natural conditions plotted for 2064.

The natural visibility conditions goal for the 20% worst days in 2064 in this study are the same as the natural conditions used in the CENRAP Technical Support Document (ENVIRON and CERT, 2007). The baseline values (2000-2004) are calculated by the MATS software using Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring site data. A glide path for the W20% days is a straight line from the baseline to 2064 natural condition at each Class I area; whereas a glide path for the B20% days is a straight horizontal line from the baseline value to the natural condition. Figures 15-18 show glide paths at four Class I areas. The green and red dots shown on each plot are 2018 projected visibility based on the CAMx model results. Additional graphics showing glidepaths can be found in Appendix C and in supporting Excel Spreadsheets accompanying this memorandum.

Similar analysis based on CMAQ simulation results was conducted by CENRAP for the worst and best 20% days and documented in Appendix D of the CENRAP Technical Support Document (ENVIRON and CERT, 2007). CENRAP analysis was provided here in Table 7 for comparison. In this study, the 2018 progress goals on the worst 20% days are not reached at all four Class I areas shown. However, the CENRAP modeling predicted that the 2018 goal is met at Caney Creek. No degradation in visibility occurs on the best 20% days. Overall, the projected visibilities appears to be comparable to the CENRAP projections on the worst and best 20% days (this study predicted slightly higher projected visibility)

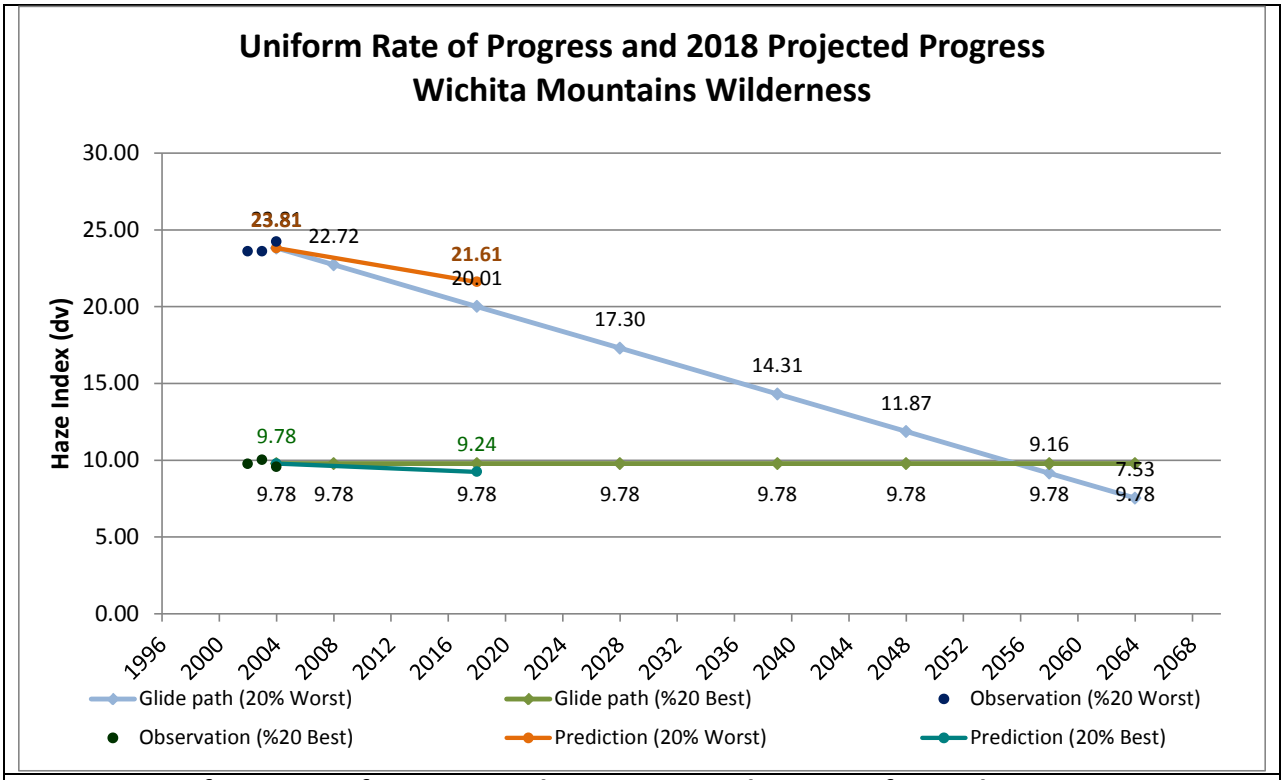


Figure 15. Uniform Rate of Progress and 2018 projected progress for Wichita Mountains Wilderness Area (WIMO).

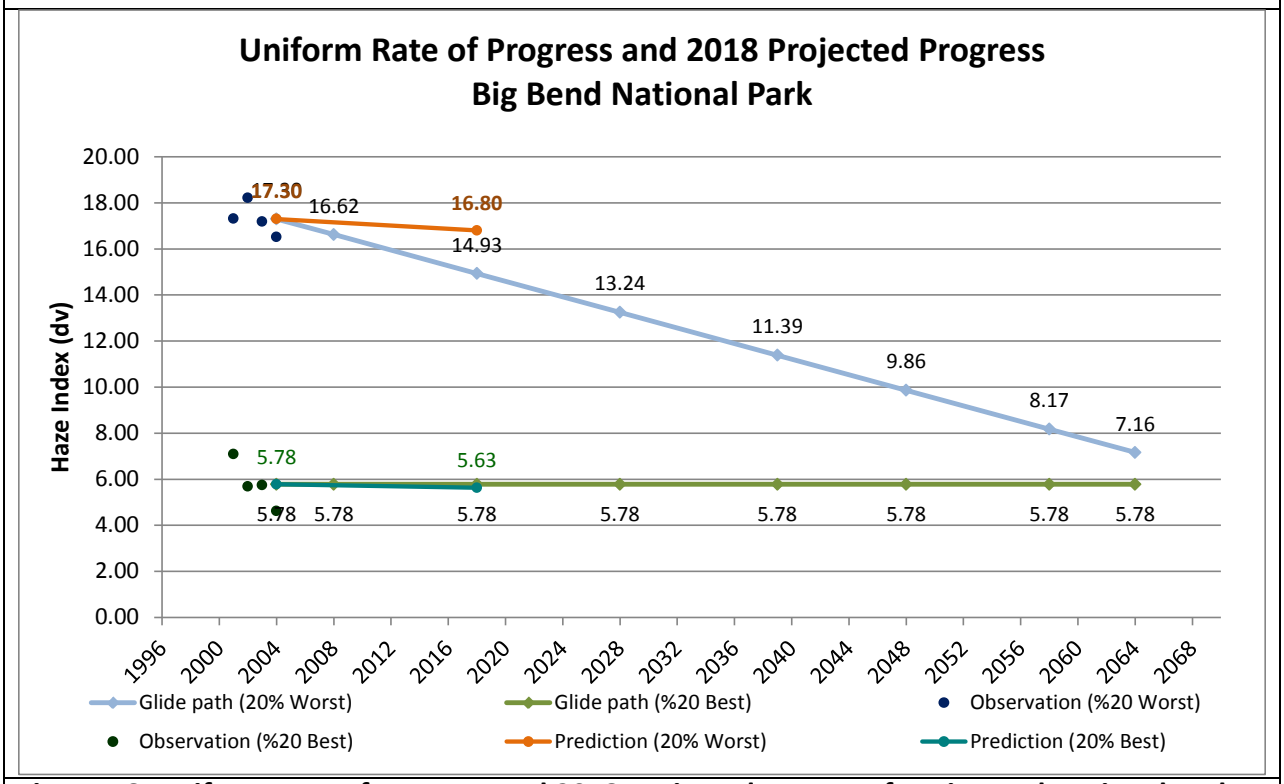


Figure 16. Uniform Rate of Progress and 2018 projected progress for Big Bend National Park (BIBE).

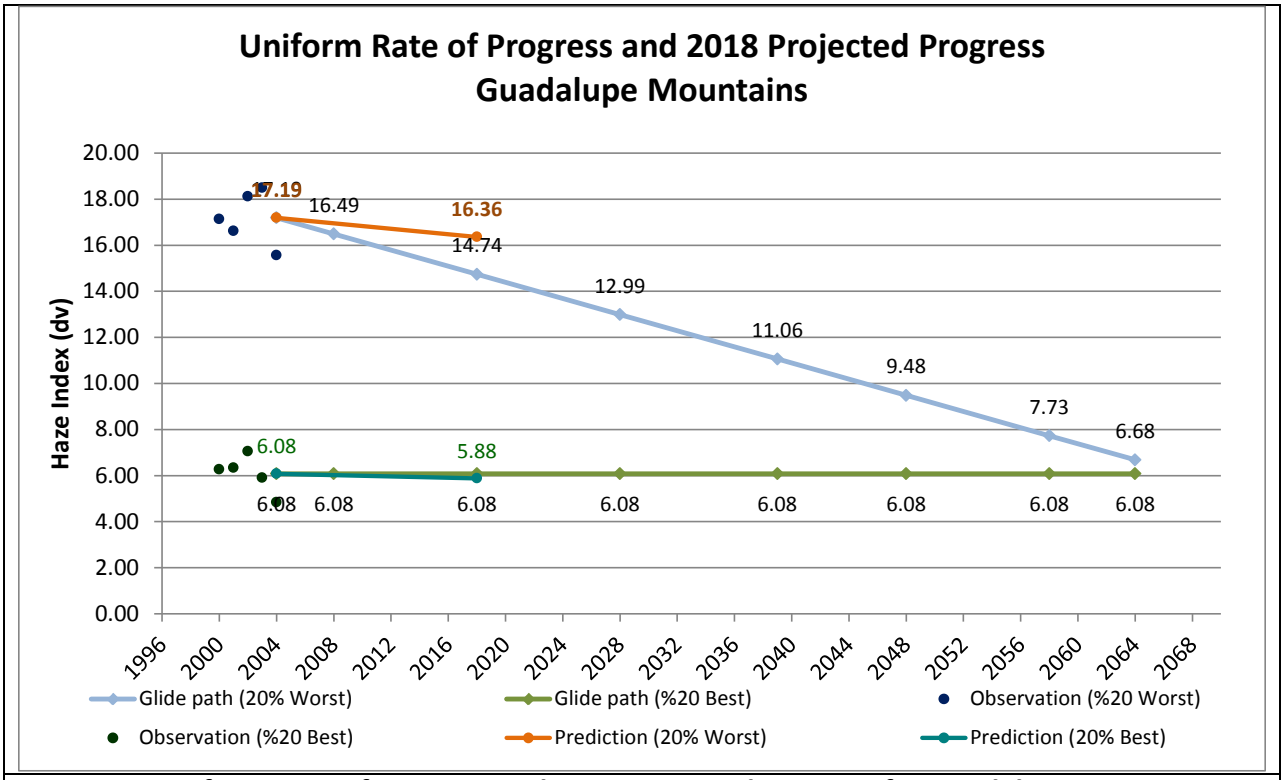


Figure 17. Uniform Rate of Progress and 2018 projected progress for Guadalupe Mountains National Park (GUMO).

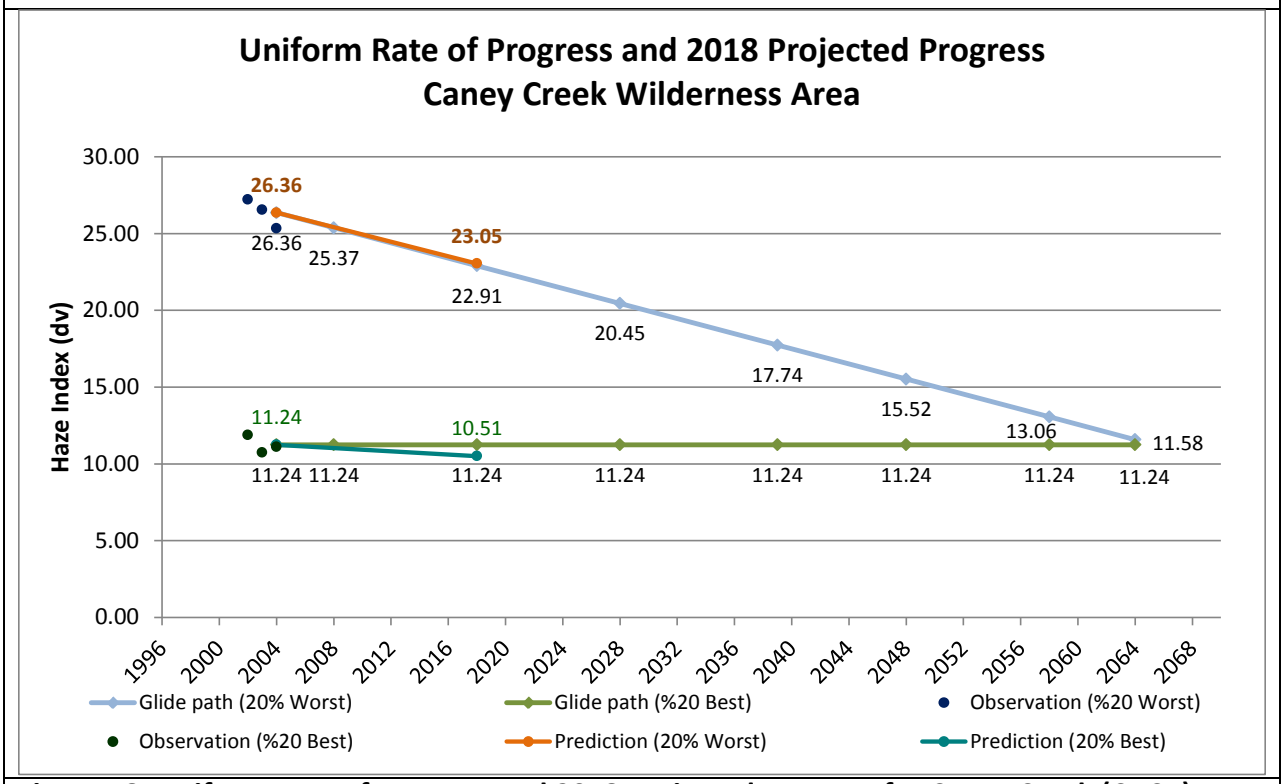


Figure 18. Uniform Rate of Progress and 2018 projected progress for Caney Creek (CACR).

Table 7. Haze Index (dv) of Uniform Rate of Progress and 2018 Projected Progress from this study compared to CENRAP modeling.

Site	State	Code	W20% days					B20% days		
			Glide path			Predicted 2018		Glide Path	Predicted 2018	
			2004	2018	2064	CENRAP	This study	2004	CENRAP	This study
Caney Creek Wilderness Area	AR	CACR1	26.36	22.91	11.58	22.48	23.05	11.24	10.35	10.51
Wichita Mountains Wilderness	OK	WIMO1	23.81	20.01	7.53	21.47	21.01	9.78	9.23	9.24
Big Bend National Park	TX	BIBE1	17.3	14.93	7.16	16.69	16.80	5.78	5.64	5.63
Guadalupe Mountains	TX	GUMO1	17.19	14.74	6.68	16.35	16.36	5.95/ 6.08 *	5.74	5.88

* CENRAP reported different baseline DV value (5.95)

SUMMARY

Air quality modeling results for the 2018 base case simulation are presented by pollutant of concern, including ozone and PM. Overall, the air quality maps show consistent spatial patterns between the 2002 and 2018 results with lower concentrations predicted in the 2018 base case. PM composition between the two simulations also is similar. The predicted 2018 ozone and PM concentrations are within reasonable ranges.

Sulfate appears to be the main constituent that contributes to visibility degradation at the Class I areas in/near Texas on both B20% and W20% cases. Proximity of the selected sources to Class I areas and magnitude of SO_2 emissions are factors that influence visibility impacts at nearby Class I areas. The Excel Spreadsheets accompanying this memorandum can be a useful tool in identifying sources that contribute to modeled visibility degradation.

The glide path analysis shows that the 2018 progress goals on the worst 20% days are not reached at all four Class I areas shown in this report (i.e., WIMO, CACR, BIBE and GUMO). However, the CENRAP modeling predicted that the 2018 goal is met at Caney Creek. No degradation in visibility occurs on the best 20% days.

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APPENDIX A

Stack Parameters of Major Units at the Selected 38 Facilities

Appendix A: Stack Parameters of Major Units at the Selected 38 Facilities

Plant Name	FIPS	Plant ID	Point ID	Stack ID	ORIS ID	Boiler ID	Segment	Latitude	Longitude	SCC	SIC	Height (ft)	Diameter (ft)	Temperature (F)	Flow Rate (ft^3/s)	Velocity (ft/s)
BIG BROWN	48161	2	10	10	3497	1	0	31.8197	-96.055	10100226	4911	400	22.2	366	30075.75	77.7
BIG BROWN	48161	2	11	11	3497	2	0	31.8203	-96.0553	10100226	4911	400	22.2	366	30075.75	77.7
BIG SPRING CARBON BLACK	48227	2	1	14	0		0	32.2778	-101.408	30100503	2895	166	12	900	5089.38	45
BIG SPRING CARBON BLACK	48227	2	3	14	0		0	32.2778	-101.408	30100501	2895	166	12	900	5089.38	45
BIG SPRING CARBON BLACK	48227	2	5	14	0		0	32.2778	-101.408	30100599	2895	166	12	900	5089.38	45
BIG SPRING CARBON BLACK	48227	2	4	4	0		0	32.2778	-101.408	30100507	2895	198	4.3	550	1336.03	92
BIG SPRING CARBON BLACK	48227	2	2	2	0		0	32.2772	-101.408	30100507	2895	198	5.41	550	2114.74	92
BIG SPRING CARBON BLACK	48227	2	9	2	0		0	32.2772	-101.408	30100507	2895	198	5.41	550	2114.74	92
BIG SPRING CARBON BLACK	48227	2	10	2	0		0	32.2772	-101.408	30100507	2895	198	5.41	550	2114.74	92
BORGER CARBON BLACK	48233	1	12	8	0		0	35.6661	-101.433	10200710	2895	98	10	421	4515.25	57.49
BORGER CARBON BLACK PLT	48233	2	4	3	0		0	35.6636	-101.435	10200602	2895	160	9.9	447	2309.31	30
BORGER CARBON BLACK PLT	48233	2	6	87	0		0	35.6628	-101.435	39990003	2895	198	7.5	800	1325.36	30
BORGER CARBON BLACK PLT	48233	2	10	88	0		0	35.6653	-101.435	39990003	2895	198	9	800	1908.52	30
BORGER CARBON BLACK PLT	48233	2	8	88	0		0	35.6653	-101.435	39990003	2895	198	9	800	1908.52	30
BORGER CARBON BLACK PLT	48233	2	9	88	0		0	35.6653	-101.435	39990003	2895	198	9	800	1908.52	30
BORGER CARBON BLACK PLT	48233	2	3	3	0		0	35.6636	-101.435	10200602	2895	160	9.9	477	2309.31	30
BORGER CARBON BLACK PLT	48233	2	7	87	0		0	35.6628	-101.435	39990003	2895	198	7.5	800	1325.36	30
COLETO CREEK PLANT	48175	2	1	1	6178	1	0	28.7108	-97.2139	10100212	4911	303	20	314	27331.83	87
FAYETTE POWER PROJECT	48149	5	7	7	6179	1	0	29.9233	-96.7539	10100226	4911	600	23	316	37185.04	89.5
FAYETTE POWER PROJECT	48149	5	8	8	6179	2	0	29.9233	-96.7539	10100226	4911	600	23	307	39470.15	95
FAYETTE POWER PROJECT	48149	5	16	16	6179	3	0	29.9156	-96.7503	10100226	4911	533	25.75	273	45827.55	88

Plant Name	FIPS	Plant ID	Point ID	Stack ID	ORIS ID	Boiler ID	Segment	Latitude	Longitude	SCC	SIC	Height (ft)	Diameter (ft)	Temperature (F)	Flow Rate (ft^3/s)	Velocity (ft/s)
FULLERTON GAS PLANT	48003	10	72	5	0		0	32.3814	-102.775	39990013	1321	215	3.17	1000	520.9	66
FULLERTON GAS PLANT	48003	10	7	7	0		0	32.4247	-102.808	20200252	1321	30	0.83	550	21.96	40.6
FULLERTON GAS PLANT	48003	10	1	1	0		0	32.3814	-102.775	20200252	1321	30	0.83	550	21.96	40.6
FULLERTON GAS PLANT	48003	10	4	4	0		0	32.3819	-102.775	20200252	1321	30	0.83	550	21.96	40.6
FULLERTON GAS PLANT	48003	10	6	6	0		0	32.4247	-102.808	20200252	1321	30	0.83	550	21.96	40.6
GIBBONS CREEK	48185	2	2	2	6136	1	0	30.6186	-96.0817	10100226	4911	465	20	349	22619.45	72
GOLDSMITH GASOLINE PLANT	48135	22	133	19	0		0	31.975	-102.631	30609903	1321	175	4.25	1000	895.15	63.1
GOLDSMITH GASOLINE PLANT	48135	22	138	140	0		0	31.9786	-102.635	20200201	1321	50	0.75	700	41.53	94
GOLDSMITH GASOLINE PLANT	48135	22	139	141	0		0	31.9786	-102.635	20200201	1321	50	0.75	700	41.53	94
GOLDSMITH GASOLINE PLANT	48135	22	92	92	0		0	31.9814	-102.637	20200252	1321	30	1.16	727	73.97	70
GOLDSMITH GASOLINE PLANT	48135	22	93	93	0		0	31.9814	-102.637	20200252	1321	30	1.17	727	75.25	70
GOLDSMITH GASOLINE PLANT	48135	22	94	94	0		0	31.9814	-102.637	20200252	1321	30	1.17	727	75.25	70
GOLDSMITH GASOLINE PLANT	48135	22	95	95	0		0	31.9814	-102.637	20200252	1321	25	0.83	800	48.68	90
GREAT LAKES CARBON LLC	48245	23	6	5	0		0	29.8347	-93.9639	30601401	2999	175	16.47	363	10632.34	49.92
GREAT LAKES CARBON LLC	48245	23	4	8	0		0	29.8347	-93.9633	30601401	2999	150	13.5	1200	8588.33	60
GREAT LAKES CARBON LLC	48245	23	5	9	0		0	29.8347	-93.9633	30601401	2999	150	13.5	350	7872.64	55
GREAT LAKES CARBON LLC	48245	23	3	3	0		0	29.835	-93.9628	30601401	2999	125	10.5	1200	4199.62	48.5
GUADALUPE COMPRESSOR STATION	48109	5	1	1	0		0	31.7711	-104.904	20200201	4922	50	4	775	287.77	22.9
HARRINGTON STATION	48375	22	4	7	6193	061B	0	35.2969	-101.748	10100226	4911	250	19	300	25148.98	88.7
HARRINGTON STATION	48375	22	5	8	6193	062B	0	35.2975	-101.747	10100226	4911	300	19	300	25148.98	88.7
HARRINGTON STATION	48375	22	7	9	6193	063B	0	35.2978	-101.746	10100226	4911	300	19	300	25148.98	88.7
HOLCIM (TEXAS) LP	48139	22	46	46	0		0	32.51	-96.9714	30500606	3241	310	13.7	446	10169.9	69
HOLCIM (TEXAS) LP	48139	22	7	7	0		0	32.5111	-96.9706	30500606	3241	273	13.5	446	8015.77	56

Plant Name	FIPS	Plant ID	Point ID	Stack ID	ORIS ID	Boiler ID	Segment	Latitude	Longitude	SCC	SIC	Height (ft)	Diameter (ft)	Temperature (F)	Flow Rate (ft^3/s)	Velocity (ft/s)
HW PIRKEY POWER PLT	48203	22	1	1	7902	1	0	32.4608	-94.4844	10100301	4911	525	4	329	1068.14	85
KEYSTONE COMPRESSOR STN.	48495	30	13	13	0		0	31.9478	-103.108	20200252	4922	29	1.62	704	113.07	55.02
KEYSTONE COMPRESSOR STN.	48495	30	14	14	0		0	31.9478	-103.108	20200252	4922	29	1.62	704	113.07	55.02
KEYSTONE COMPRESSOR STN.	48495	30	15	15	0		0	31.9481	-103.108	20200252	4922	33	1.67	560	153.31	70
KEYSTONE COMPRESSOR STN.	48495	30	12	12	0		0	31.9464	-103.107	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	9	9	0		0	31.9464	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	11	11	0		0	31.9464	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	8	8	0		0	31.9464	-103.107	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	10	10	0		0	31.9464	-103.107	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	2	2	0		0	31.9467	-103.107	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	4	4	0		0	31.9467	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	3	3	0		0	31.9467	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	7	7	0		0	31.9464	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	6	6	0		0	31.9467	-103.107	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	5	5	0		0	31.9467	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE COMPRESSOR STN.	48495	30	1	1	0		0	31.9467	-103.108	20200252	4922	32	1.67	560	204.91	93.56
KEYSTONE PLANT	48495	6	1	1	0		0	31.9458	-103.044	31000202	1321	100	1.5	577	23.16	13.11
KEYSTONE PLANT	48495	6	33	34	0		0	31.9458	-103.04	20200252	1321	26	2	650	203.58	64.8
KEYSTONE PLANT	48495	6	34	35	0		0	31.9456	-103.04	20200252	1321	26	2	650	162.42	51.7
KEYSTONE PLANT	48495	6	35	36	0		0	31.9456	-103.04	20200252	1321	26	2	650	162.42	51.7
KEYSTONE PLANT	48495	6	23	24	0		0	31.9461	-103.042	20200252	1321	20	1	650	54.98	70
KEYSTONE PLANT	48495	6	22	23	0		0	31.9461	-103.042	20200252	1321	20	1	650	54.98	70
LIGNITE-FIRED POWER PLANT	48013	7	1	13	6183	SM-1	0	28.7072	-98.4722	10100301	4911	450	20	165		118.3
MARTIN LAKE ELECTRICAL STATION	48401	11	6	5	6146	1	0	32.2603	-94.5711	10100302	4911	452	23	349	37143.49	89.4
MARTIN LAKE	48401	11	7	6	6146	2	0	32.2597	-94.5706	10100302	4911	452	23	349	38223.73	92

Plant Name	FIPS	Plant ID	Point ID	Stack ID	ORIS ID	Boiler ID	Segment	Latitude	Longitude	SCC	SIC	Height (ft)	Diameter (ft)	Temperature (F)	Flow Rate (ft^3/s)	Velocity (ft/s)
ELECTRICAL STATION																
MARTIN LAKE ELECTRICAL STATION	48401	11	8	7	6146	3	0	32.2589	-94.5703	10100302	4911	452	23	349	38223.73	92
MIDLOTHIAN PLANT	48139	9	71	11	0		0	32.46	-97.0253	30500706	3241	200	8	365	2605.76	51.84
MIDLOTHIAN PLANT	48139	9	74	14	0		0	32.46	-97.0247	30500706	3241	200	9	383	2381.19	37.43
MIDLOTHIAN PLANT	48139	9	215	253	0		0	32.465	-97.0217	30500606	3241	310	18	250	12723.45	50
MIDLOTHIAN PLANT	48139	9	73	13	0		0	32.46	-97.025	30500706	3241	200	8	365	2605.76	51.84
MONTICELLO STM ELE STN	48449	3	7	7	6147	1	0	33.0906	-95.0372	10100226	4911	400	21.5	356	29407.05	81
MONTICELLO STM ELE STN	48449	3	9	9	6147	2	0	33.0911	-95.0378	10100226	4911	400	21.5	356	29407.05	81
MONTICELLO STM ELE STN	48449	3	10	10	6147	3	0	33.0922	-95.0378	10100301	4911	460	25.5	329	44431.31	87
NEWMAN STATION	48141	8	#CT1	41	3456	CT1	1	31.983	-106.432	20100201	4911	73	10.2	375	6945.61	85
NEWMAN STATION	48141	8	#CT2	41	3456	CT2	1	31.983	-106.432	20100201	4911	73	10.2	375	6945.61	85
NEWMAN STATION	48141	8	4	4	3456	HRSG1	0	31.7592	-106.375	20100201	4911	73	10.2	350	6945.58	85
NEWMAN STATION	48141	8	12	5	3456	HRSG2	0	31.7592	-106.375	20100201	4911	73	10.2	350	6945.58	85
NORTH TEXAS CEMENT CO.	48139	2	99	7	0		0	32.5183	-97.0042	30500706	3241	105	11.5	321.8		21.22
ODESSA CEMENT PLANT	48135	23	47	15	0		0	31.7447	-102.544	30500606	3241	65	10	300	392.7	5
ODESSA CEMENT PLANT	48135	23	4	18	0		0	31.7442	-102.545	30500606	3241	96	10	250	1963.5	25
OKLAUNION POWER STATION	48487	10	2	2	127	1	0	34.0825	-99.1756	10100222	4911	452	23	303	40134.91	96.6
PEGASUS GAS PLANT	48329	6	53	5	0		0	31.6606	-102.133	31000205	1321	60	36.68	1000	69307.69	65.6
PEGASUS GAS PLANT	48329	6	24	23	0		0	31.6589	-102.139	20200252	1321	43	1	600	63.38	80.7
PEGASUS GAS PLANT	48329	6	26	25	0		0	31.6589	-102.138	20200252	1321	43	1	560	43.59	55.5
PEGASUS GAS PLANT	48329	6	28	27	0		0	31.6592	-102.138	20200252	1321	43	1	560	43.59	55.5
PEGASUS GAS PLANT	48329	6	31	30	0		0	31.6592	-102.138	20200252	1321	42	1.33	600	32.79	23.6
PEGASUS GAS PLANT	48329	6	30	29	0		0	31.6592	-102.138	20200253	1321	43	1	560	43.59	55.5
PEGASUS GAS PLANT	48329	6	29	28	0		0	31.6592	-102.138	20200252	1321	43	1	560	43.59	55.5
RELIANT ENERGY LIMESTONE	48293	10	2	2	298	LIM1	0	31.4175	-96.2544	10100302	4911	563	26.9	349	51092.1	89.9
RELIANT ENERGY	48293	10	3	3	298	LIM2	0	31.4214	-96.2533	10100226	4911	563	26.9	349	51092.1	89.9

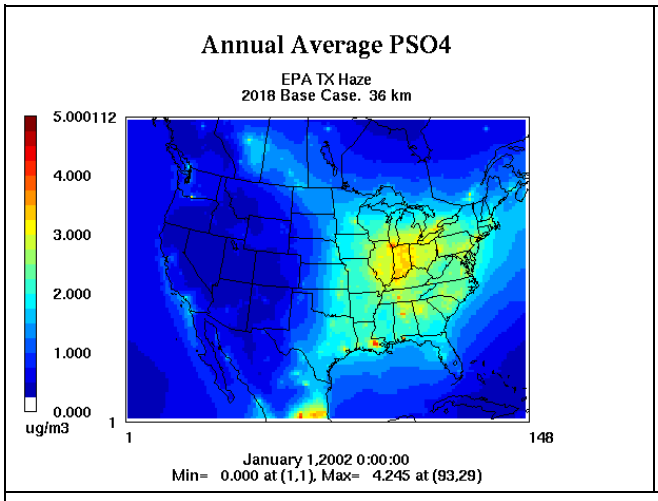
Plant Name	FIPS	Plant ID	Point ID	Stack ID	ORIS ID	Boiler ID	Segment	Latitude	Longitude	SCC	SIC	Height (ft)	Diameter (ft)	Temperature (F)	Flow Rate (ft^3/s)	Velocity (ft/s)
LIMESTONE																
SANDOW 5 GENERATING PLANT	48331	12	1	1	52071	5A		30.56722	-97.0603	10100318	4911	335	16	345		75.0328
SANDOW 5 GENERATING PLANT	48331	12	2	2	52071	5B		30.56694	-97.0608	10100318	4911	335	16	345		75.0328
SANDOW STEAM ELECTRIC	48331	5	15	16	6648	4	0	30.5658	-97.0631	10100302	4911	400	21.5	349	35578.9	98
SHERHAN PLANT	48195	6	26	51	0		0	36.4925	-101.462	31000205	1321	60	2.66	1800	365.65	65.6
SHERHAN PLANT	48195	6	7	12	0		0	36.4914	-101.463	20200252	1321	32	2.5	800	409.49	83.42
SHERHAN PLANT	48195	6	8	42	0		0	36.4914	-101.463	20200252	1321	32	2.5	800	409.49	83.42
SHERHAN PLANT	48195	6	4	6	0		0	36.4914	-101.463	20200252	1321	32	2.5	800	409.54	83.43
SHERHAN PLANT	48195	6	24	49	0		0	36.4908	-101.466	20200252	1321	28	1.17	800	76.43	71.1
SHERHAN PLANT	48195	6	2	2	0		0	36.4914	-101.463	20200252	1321	32	1.16	800	62.34	59
SHERHAN PLANT	48195	6	3	4	0		0	36.4914	-101.463	20200252	1321	32	1.17	800	62.35	58
SOMMERS DEELY SPRUCE PWR	48029	63	2	2	6181	1	0	29.3053	-98.3228	10100212	4911	700	1	309	78.07	99.4
SOMMERS DEELY SPRUCE PWR	48029	63	4	2	6181	2	0	29.3053	-98.3228	10100212	4911	700	1	309	78.07	99.4
SOMMERS DEELY SPRUCE PWR	48029	63	17	16	7097	BLR1	0	29.3064	-98.3206	10100226	4911	525	26	300	31855.72	60
SOMMERS DEELY SPRUCE PWR	48029	63	20	20	3611	2	0	29.3061	-98.3233	10100601	4911	240	20	275	16650.43	53
SOMMERS DEELY SPRUCE PWR	48029	63	22	19	3611	1	0	29.3061	-98.3242	10100601	4911	240	20	275	16650.43	53
SOMMERS DEELY SPRUCE PWR	48029	63	95	99	7097	BLR2		29.3061	-98.3189	10100226	4911	600	28	329		60
STREETMAN PLANT	48349	11	15	21	0		0	31.9108	-96.3486	30501604	3295	115	5	153	1309.65	66.7
TEXARKANA MILL	48067	5	1	1	0		0	33.2536	-94.0692	10200901	2621	219	12	351	6785.84	60
TEXARKANA MILL	48067	5	6	6	0		0	33.2528	-94.0686	30700110	2621	217	9.12	348	3571.41	54.69
TEXARKANA MILL	48067	5	6	7	0		0	33.2531	-94.0686	30700110	2621	217	9.12	348	3571.41	54.69
TEXARKANA MILL	48067	5	60	56	0		0	33.2547	-94.0692	30700199	2621	70	6.55	152	235.87	7
TNP ONE STEAM ELECTRIC ST	48395	13	17	17	7030	U2	0	31.0931	-96.6958	10100238	4911	340	12.5	300	8590.29	70
TNP ONE STEAM ELECTRIC ST	48395	13	21	21	7030	U1	0	31.0928	-96.6961	10100238	4911	340	12.5	300	8590.29	70
TOLK STATION	48279	18	1	1	6194	171B	0	34.1797	-102.575	10100226	4911	400	22.5	270	35784.67	90
TOLK STATION	48279	18	2	2	6194	172B	0	34.1797	-102.575	10100226	4911	400	22.5	270	31808.6	80
W A PARISH STATION	48157	5	1	1	3470	GT1	0	29.4819	-95.6317	20100201	4911	28	9.5	772	5741.45	81
W A PARISH STATION	48157	5	5	26	3470	WAP4	0	29.4833	-95.6297	10100601	4911	182	18	281	16413.24	64.5
W A PARISH STATION	48157	5	6	6	3470	WAP5	0	29.4767	-95.6356	10100202	4911	600	24	332	38453.06	85
W A PARISH	48157	5	7	7	3470	WAP6	0	29.4758	-95.635	10100202	4911	600	24	332	38453.06	85

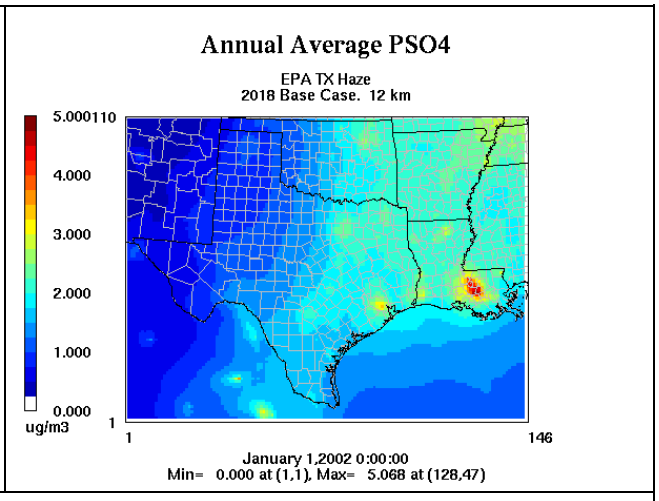
Plant Name	FIPS	Plant ID	Point ID	Stack ID	ORIS ID	Boiler ID	Segment	Latitude	Longitude	SCC	SIC	Height (ft)	Diameter (ft)	Temperature (F)	Flow Rate (ft^3/s)	Velocity (ft/s)
STATION																
W A PARISH STATION	48157	5	8	8	3470	WAP7	0	29.4744	-95.6339	10100212	4911	500	22	290	31550.99	83
W A PARISH STATION	48157	5	14	18	3470	WAP8	0	29.4736	-95.6339	10100226	4911	500	22.5	290	33001.42	83
W A PARISH STATION	48157	5	2	23	3470	WAP1	0	29.4825	-95.6306	10100601	4911	168	10.5	292	4017.78	46.4
W A PARISH STATION	48157	5	3	24	3470	WAP2	0	29.48194	-95.6311	10100601	4911	168	10.5	292	4017.78	46.4
W A PARISH STATION	48157	5	4	44	3470	WAP3	0	29.48278	-95.63	10100601	4911	181	12.5	260	6172.733	50.3
WAHA PLANT	48389	2	31	4	0		0	31.2894	-103.12	30609903	4922	199	6	850	876.5	31
WAHA PLANT	48389	2	1	1	0		0	31.2717	-103.131	20200201	4922	50	8.5	777	3972.15	70
WELSH POWER PLANT	48449	5	10	11	6139	3	0	33.0564	-94.8458	10100202	4911	300	14.4	275	13843.1	85
WELSH POWER PLANT	48449	5	11	12	6139	2	0	33.0564	-94.8458	10100202	4911	300	14.4	275	13843.1	85
WELSH POWER PLANT	48449	5	12	13	6139	1	0	33.0564	-94.8458	10100222	4911	300	14.4	275	13843.1	85
WORKS NO 4	48485	15	20	23	0		0	33.9969	-98.5525	30501403	3211	95	10	382	4162.61	53
WORKS NO 4	48485	15	19	22	0		0	33.9969	-98.5522	30501403	3211	95	10	382	3926.99	50

APPENDIX B

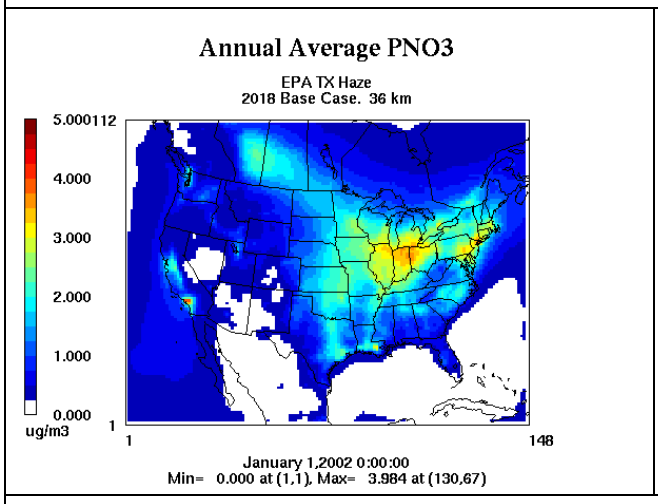
Annual Average PM Constituents from the CAMx 2018 Base Case Results

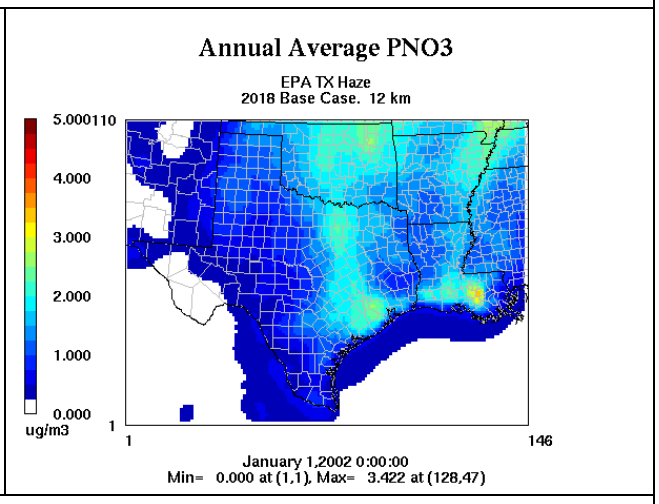
Appendix B: Annual Average PM Constituents from the CAMx 2018 Base Case Results



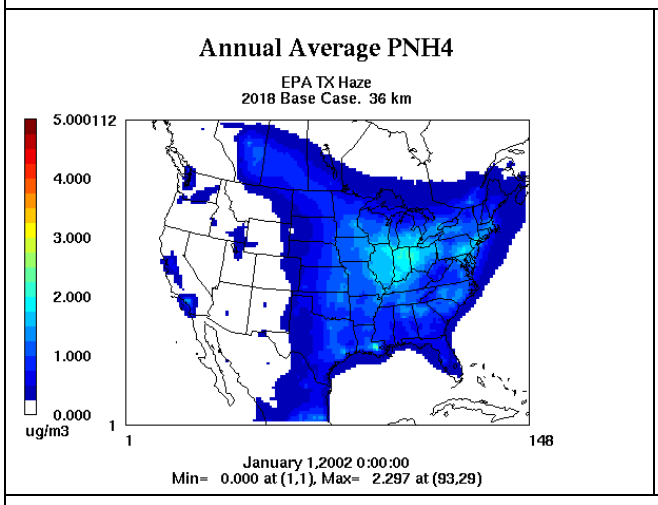


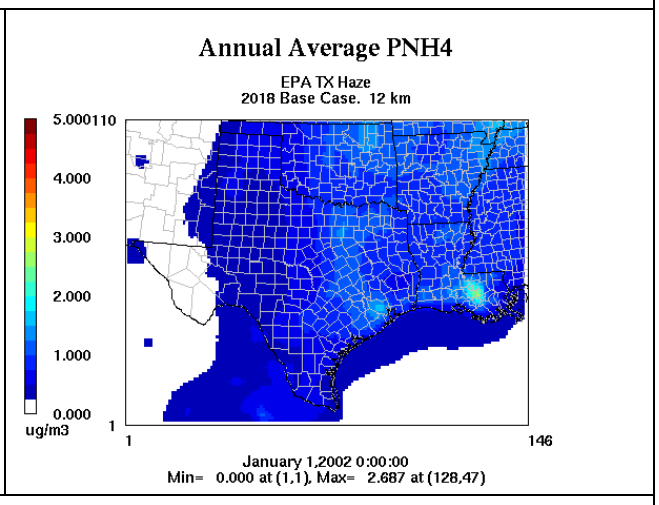
(a) Sulfate



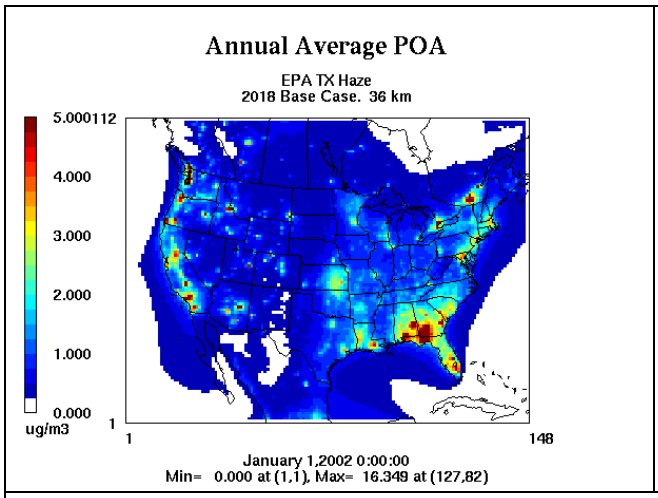


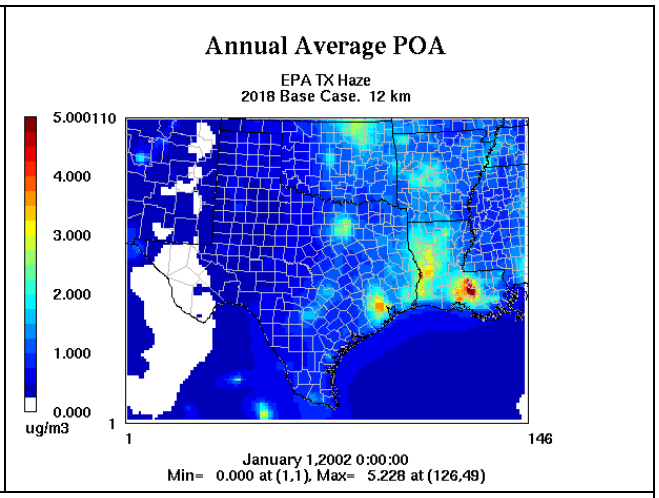
(b) Nitrate



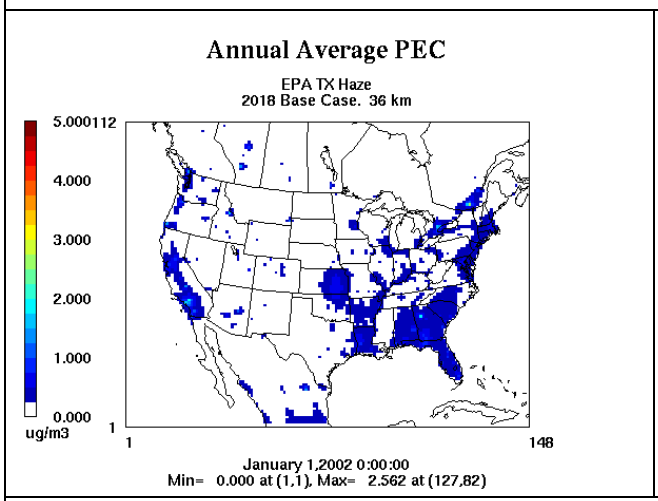


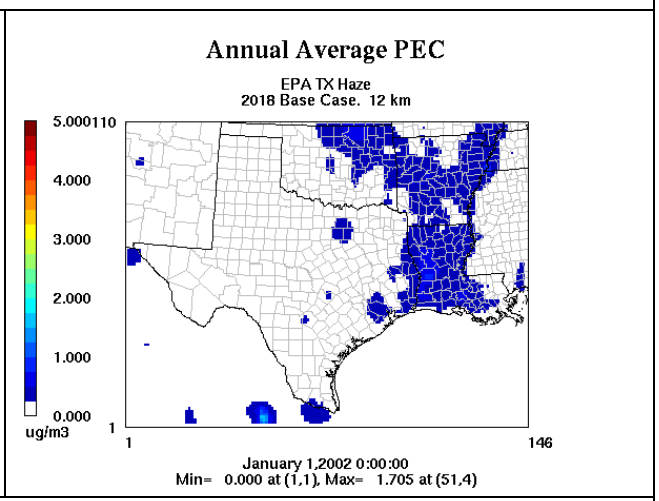
(c) Ammonium



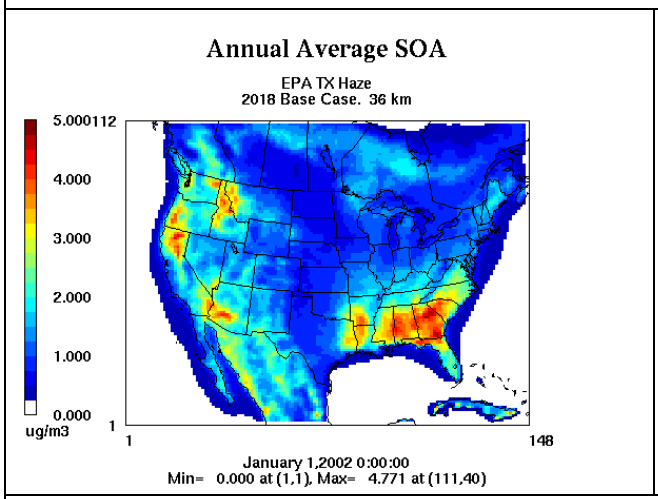


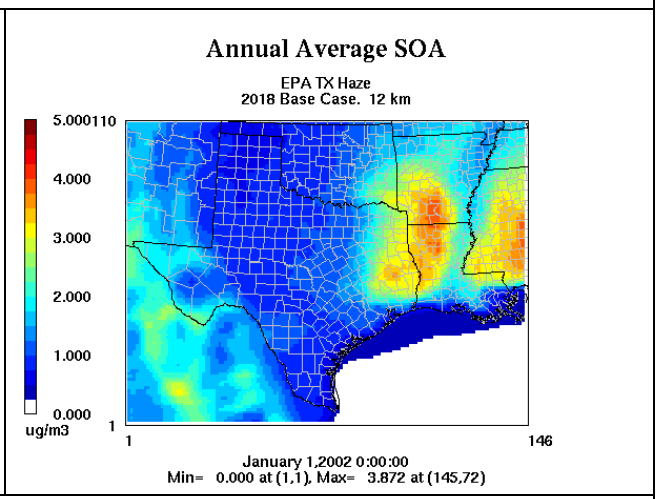
(d) Organic aerosols



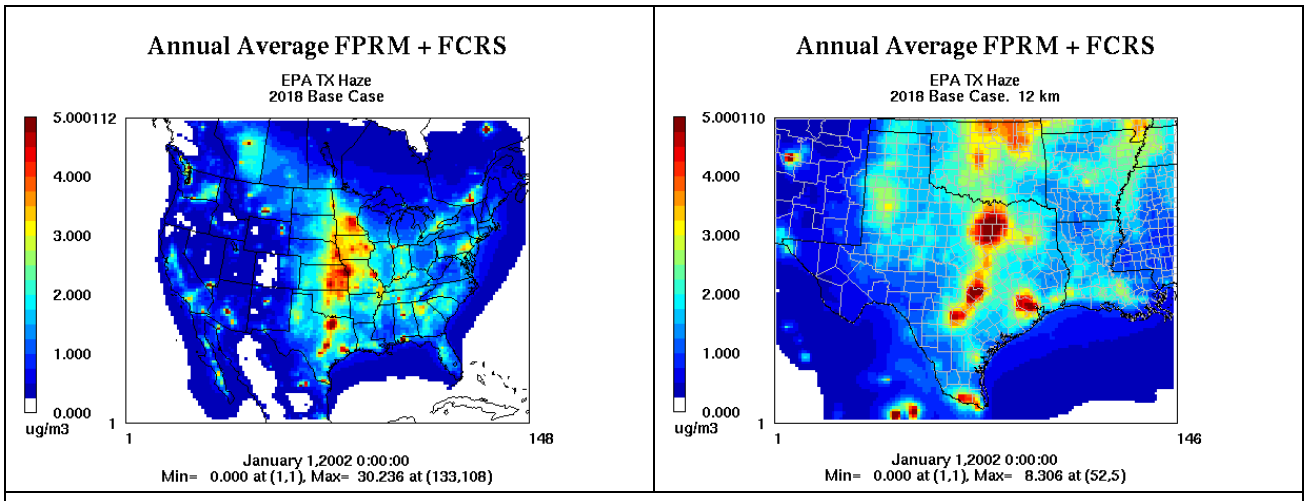


(e) Elemental Carbon





(f) Secondary organic aerosols



(g) Other fine particulates and fine crustal materials

APPENDIX C

Visibility Analysis for 2018 Base Case Emission Scenario

Appendix C: Visibility Analysis for 2018 Base Case Emission Scenario

Figures C-1: Caney Creek Wilderness Area (CACR), AR
Figures C-2: Upper Buffalo Wilderness Area (UPBU), AR
Figures C-3: Breton Wilderness Area (BRET), LA
Figures C-4: Bandelier Wilderness Area (BAND), NM
Figures C-5: Salt Creek Wilderness Area (SACR), NM
Figures C-6: White Mountain Wilderness Area (WHIT), NM
Figures C-7: Wichita Mountains Wilderness (WIMO), OK
Figures C-8: Big Bend National Park (BIBE), TX
Figures C-9: Guadalupe Mountains (GUMO), TX

Subcategories

(a) Source Contribution to 2018 Deciview Haze Index
(b) Source Contribution to 2018 Light Extinction by Species
(c) Percentage of Total Extinction
(d) Percent of Total Extinction by Species
(e) Uniform Rate of Progress and 2018 Projected Progress

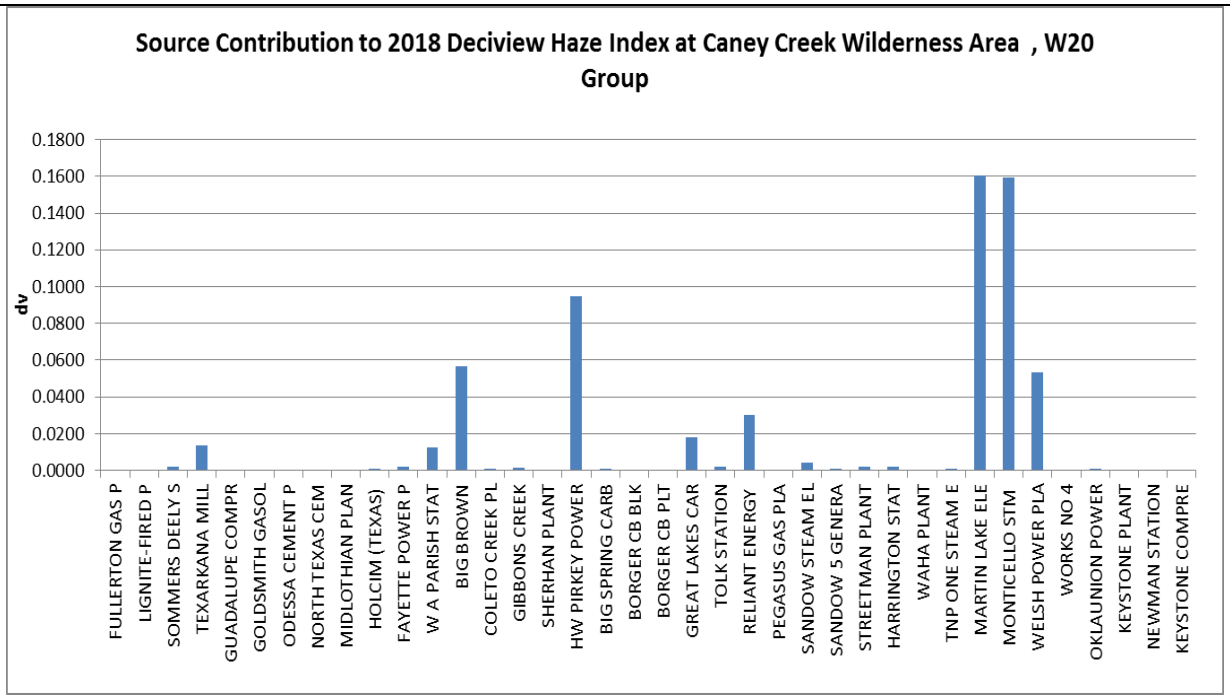


Figure C-1(a): Source Contribution to 2018 Deciview over 20% worst days at Caney Creek (CACR), AR

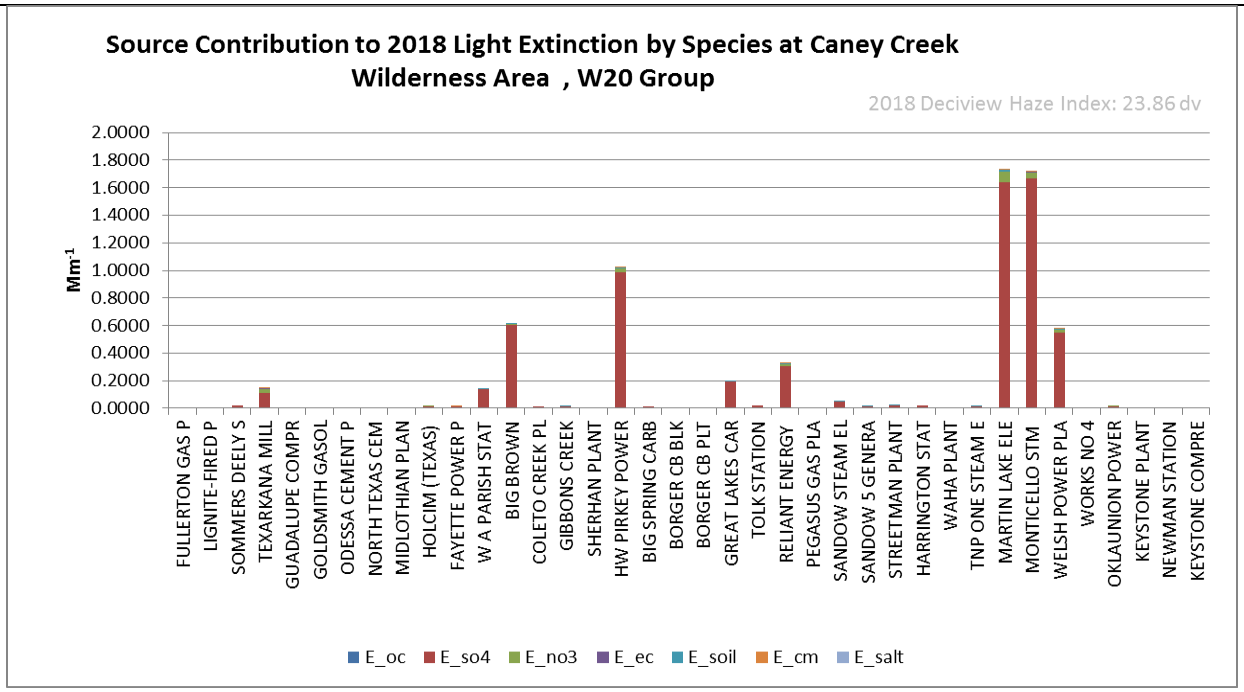


Figure C-1(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Caney Creek (CACR), AR

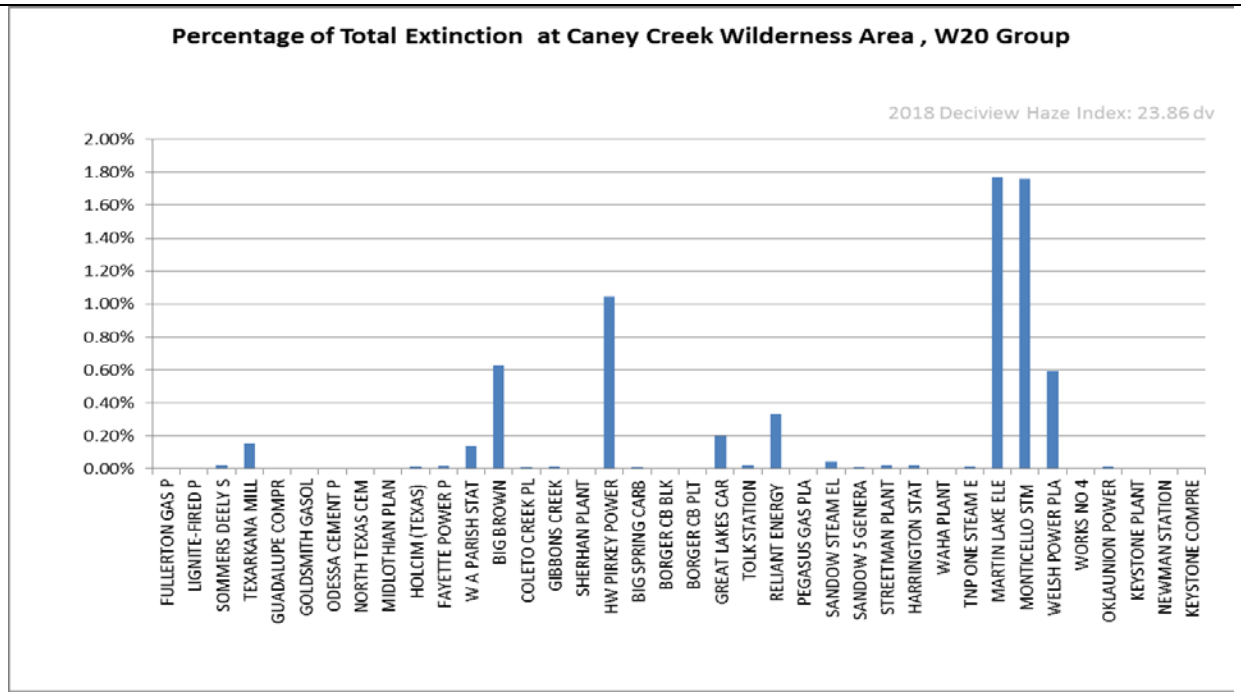


Figure C-1(c): Percentage of Total Extinction over 20% worst days at Caney Creek (CACR), AR

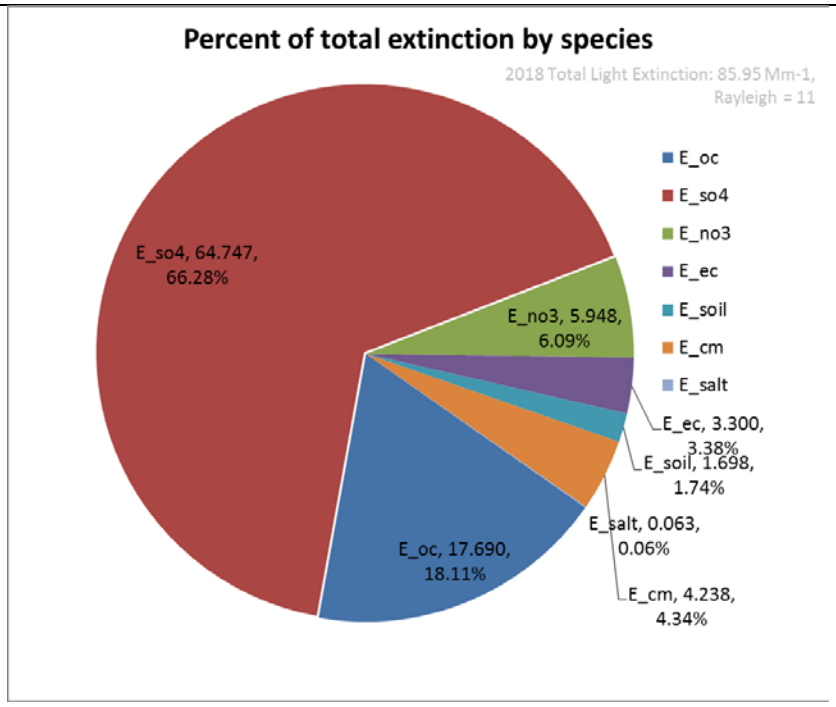


Figure C-1(d): Percent of Total Extinction by Species over 20% worst days at Caney Creek (CACR), AR

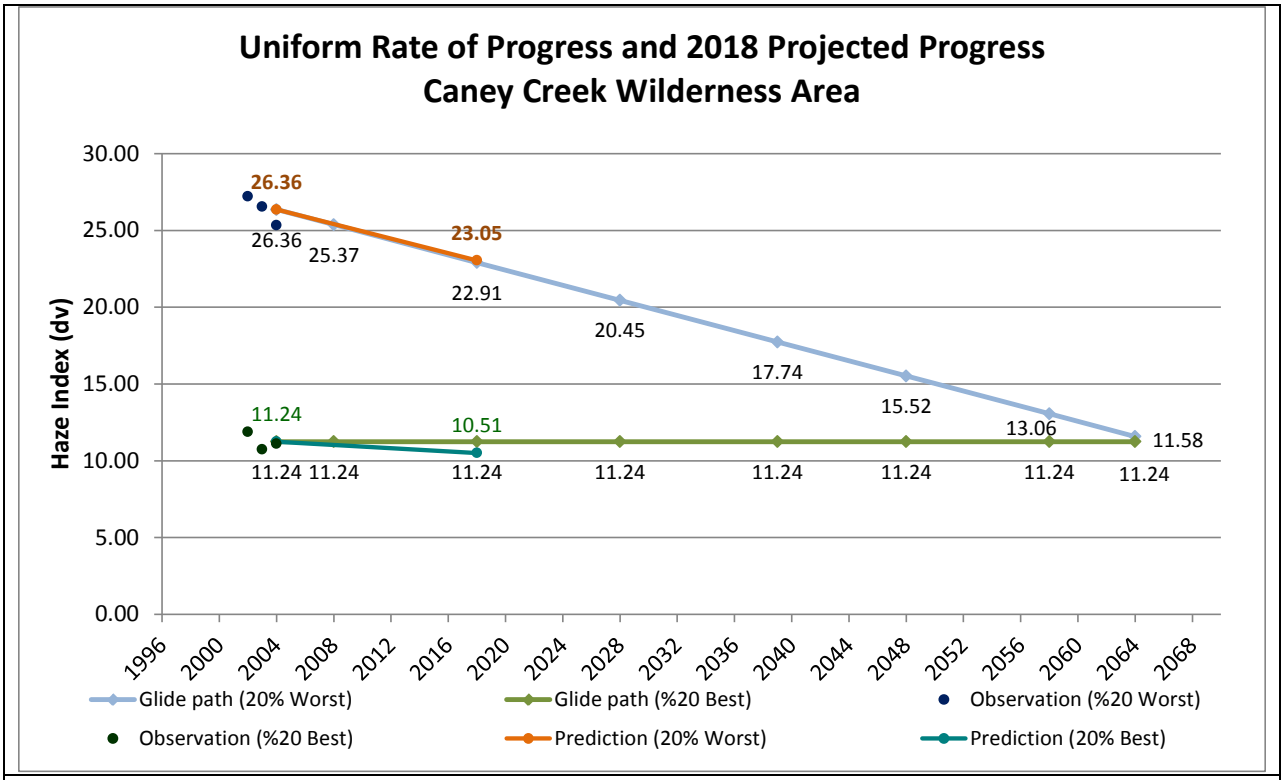


Figure C-1(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Caney Creek (CACR), AR

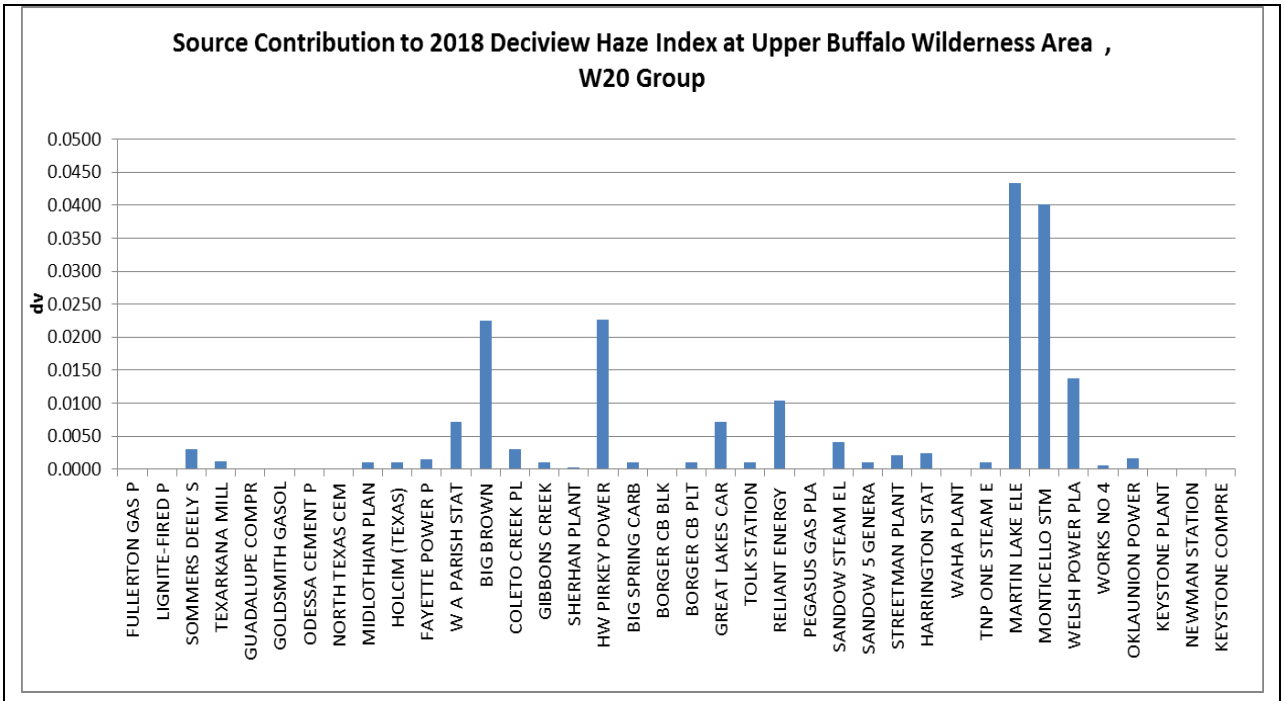


Figure C-2(a): Source Contribution to 2018 Deciview over 20% worst days at Upper Buffalo Wilderness Area (UPBU), AR

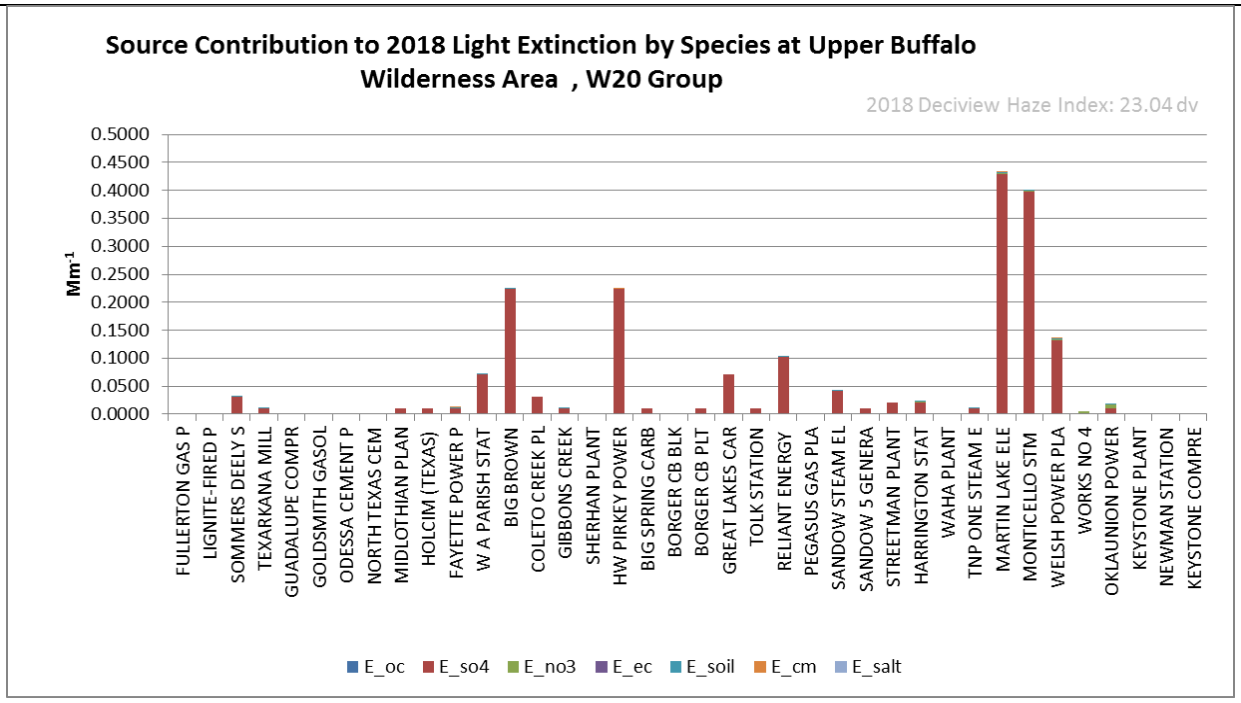


Figure C-2(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Upper Buffalo Wilderness Area (UPBU), AR

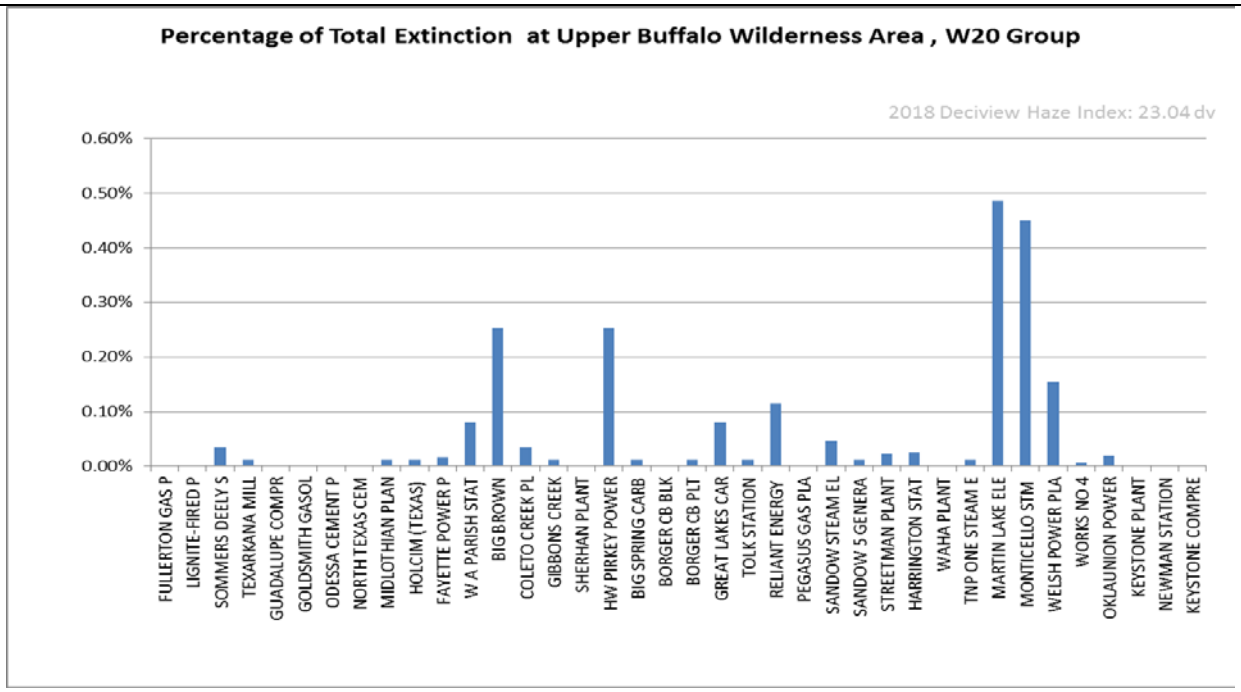


Figure C-2(c): Percentage of Total Extinction over 20% worst days at Upper Buffalo Wilderness Area (UPBU), AR

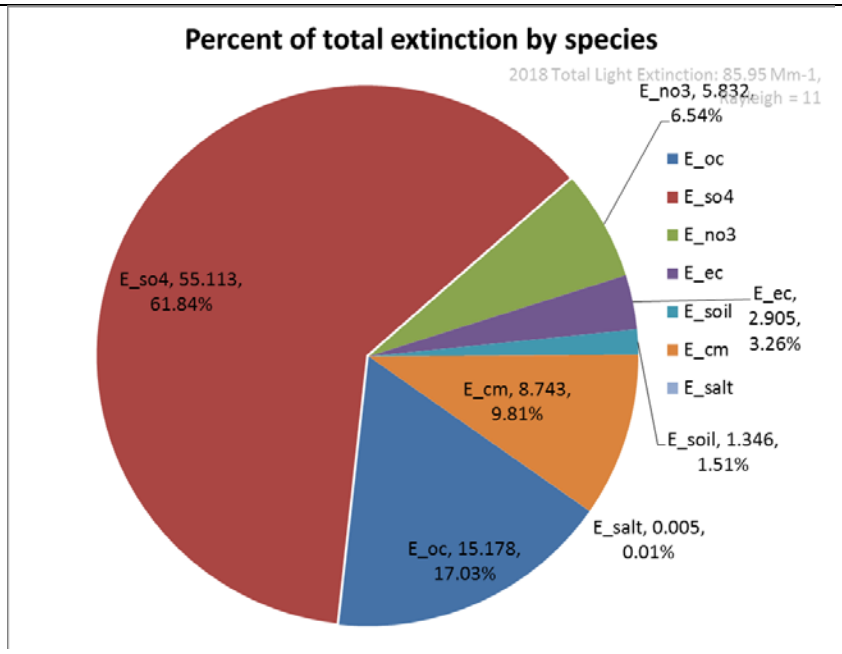


Figure C-2(d): Percent of Total Extinction by Species over 20% worst days at Upper Buffalo Wilderness Area (UPBU), AR

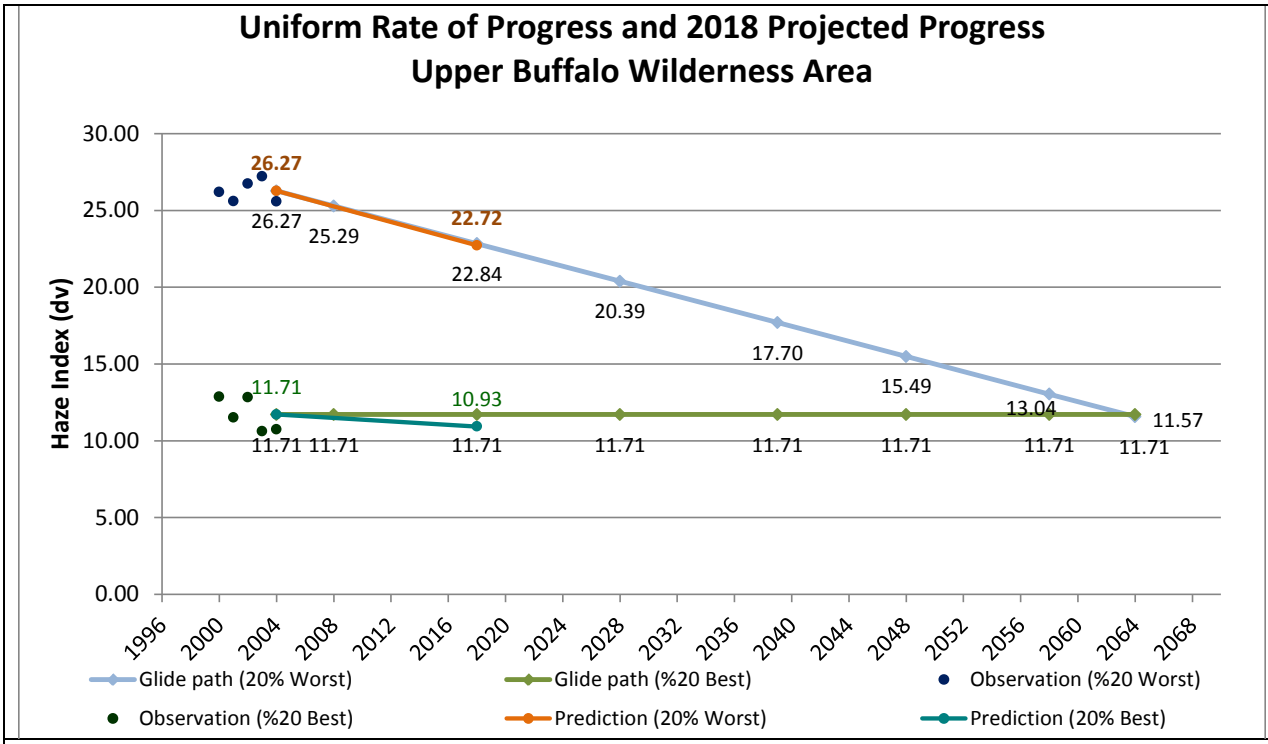


Figure C-2(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Upper Buffalo Wilderness Area (UPBU), AR

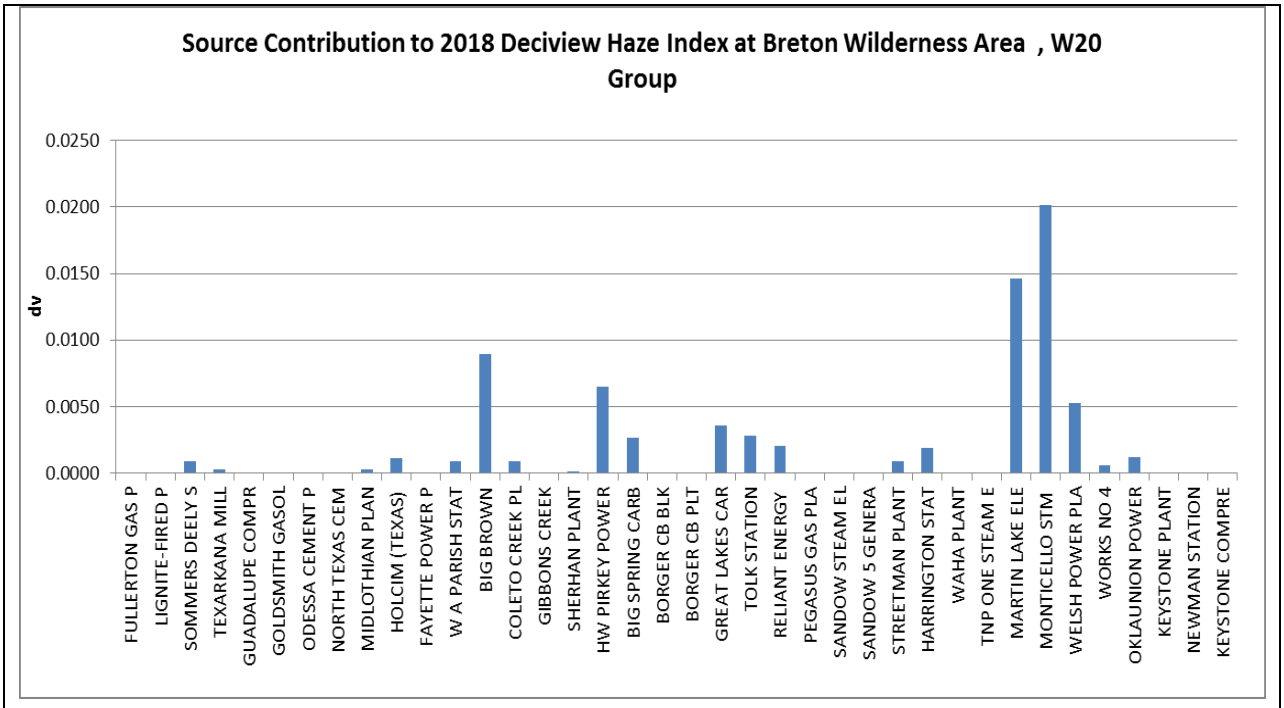


Figure C-3(a): Source Contribution to 2018 Deciview over 20% worst days at Breton Wilderness Area (BRET), LA

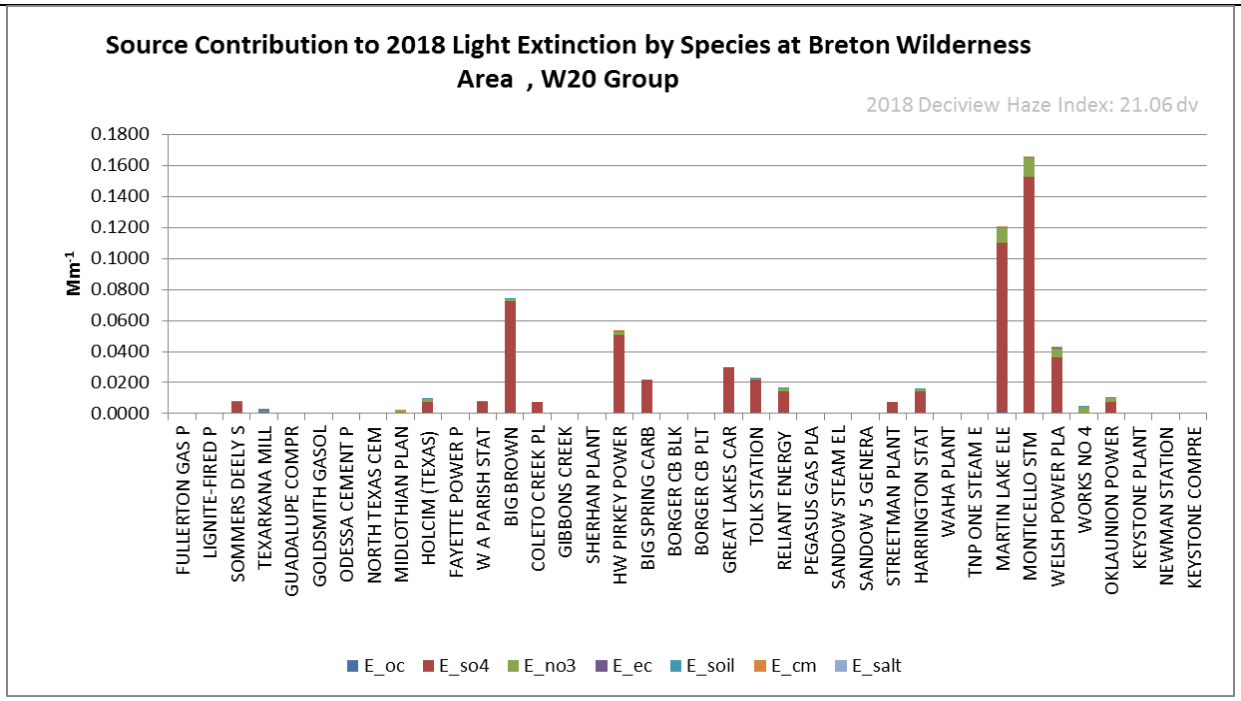


Figure C-3(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Breton Wilderness Area (BRET), LA

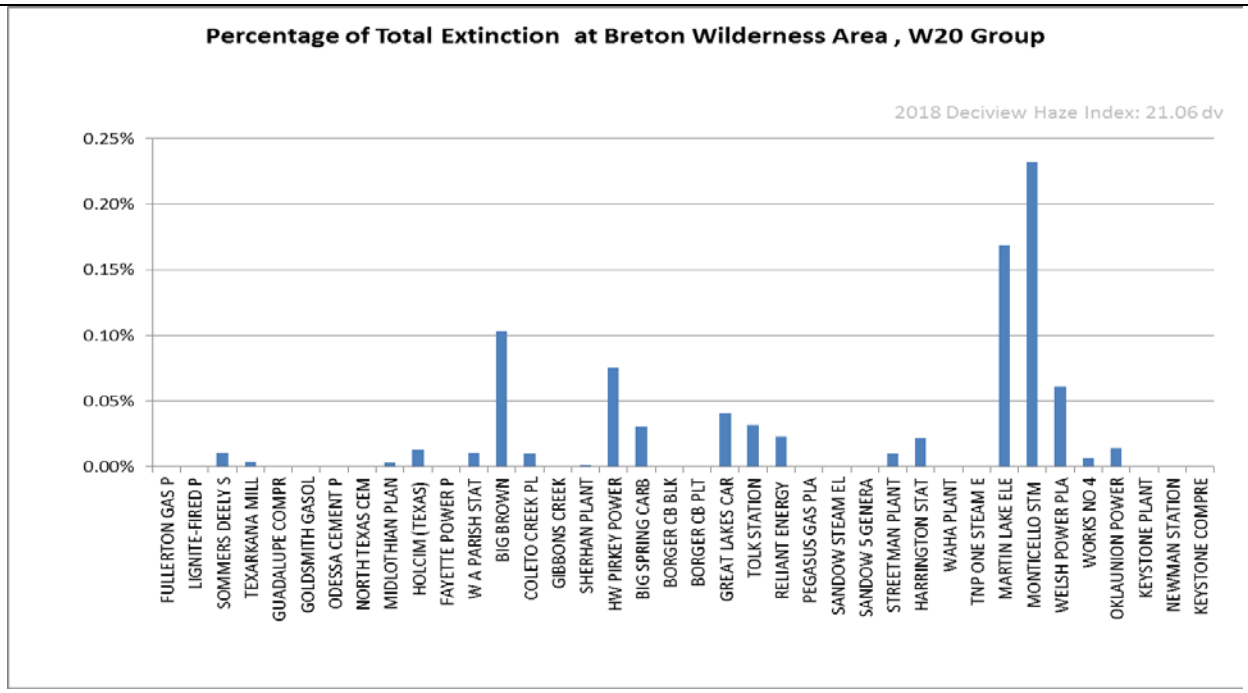


Figure C-3(c): Percentage of Total Extinction over 20% worst days at Breton Wilderness Area (BRET), LA

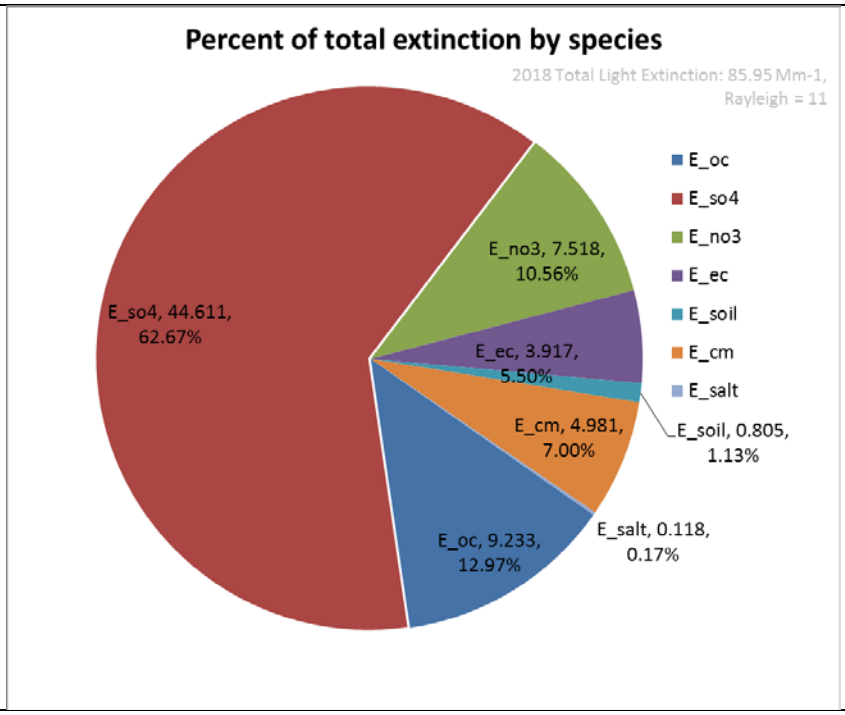


Figure C-3(d): Percent of Total Extinction by Species over 20% worst days at Breton Wilderness Area (BRET), LA

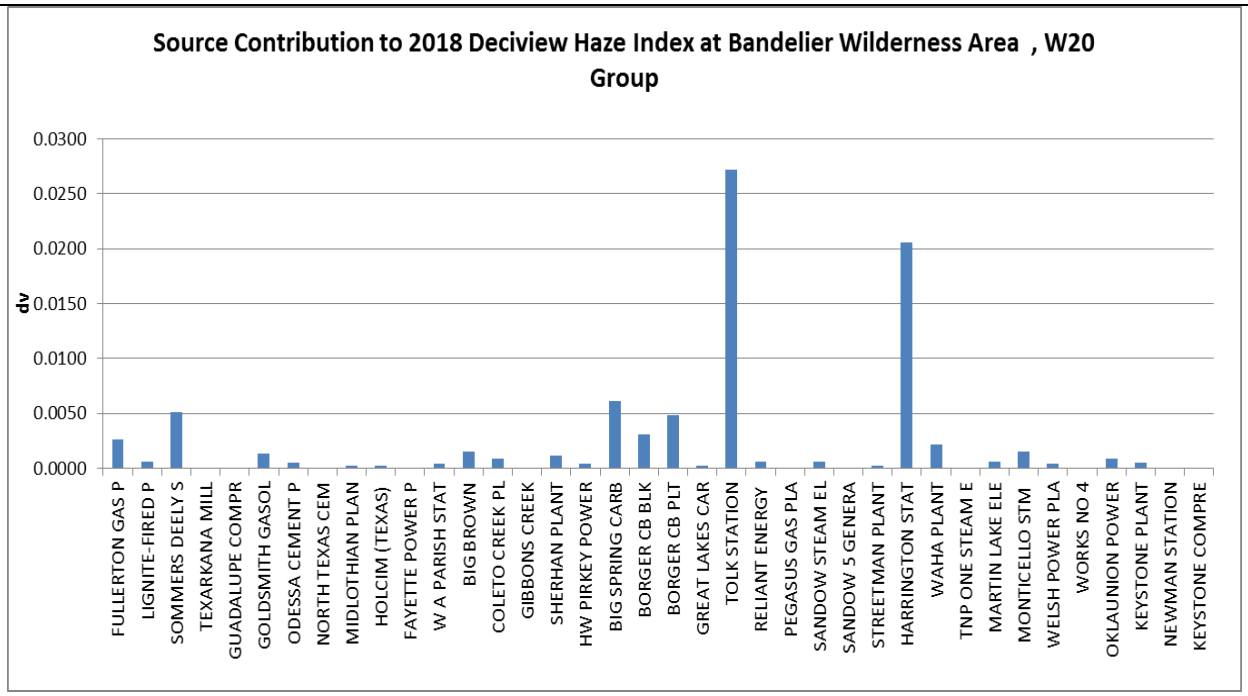


Figure C-4(a): Source Contribution to 2018 Deciview over 20% worst days at Bandelier Wilderness Area (BAND), NM

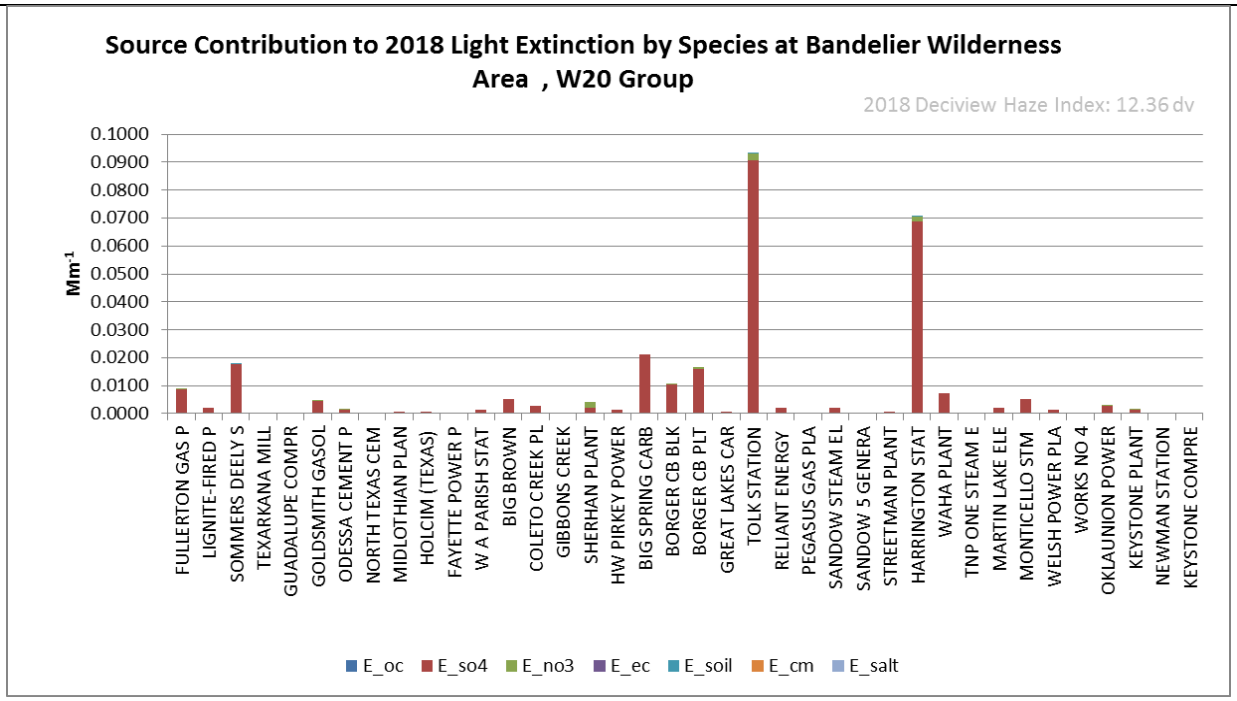


Figure C-4(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Bandelier Wilderness Area (BAND), NM

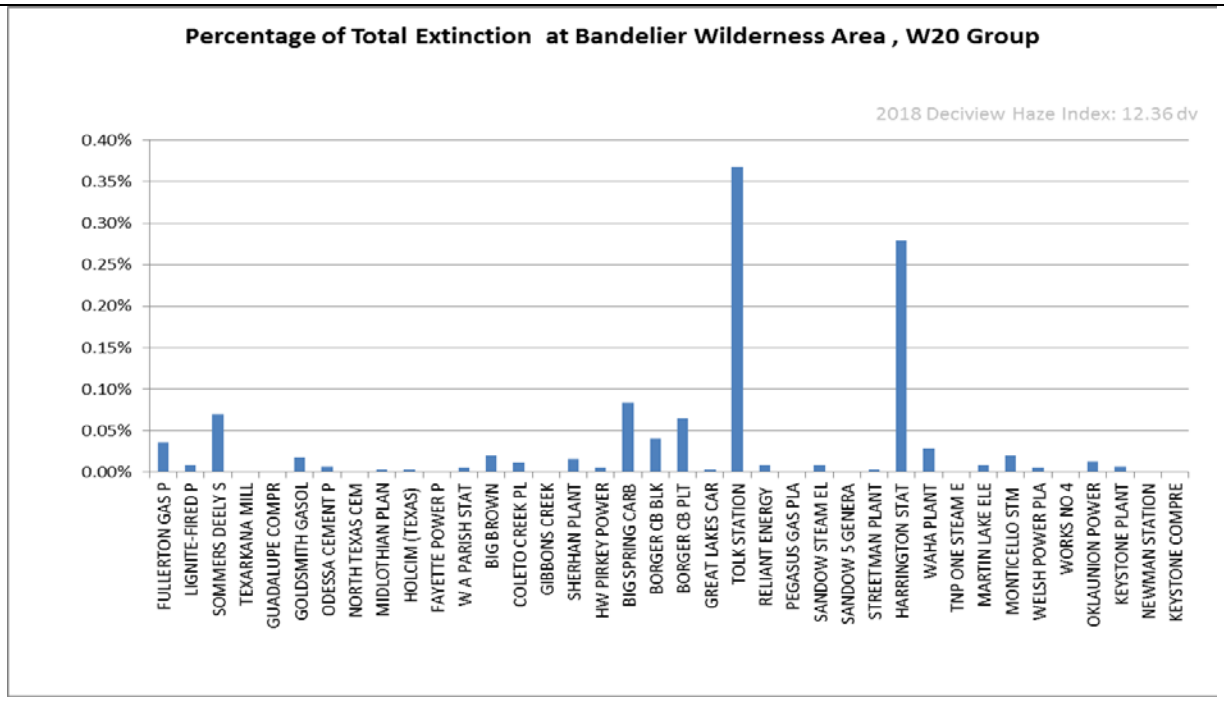


Figure C-4(c): Percentage of Total Extinction over 20% worst days at Bandelier Wilderness Area (BAND), NM

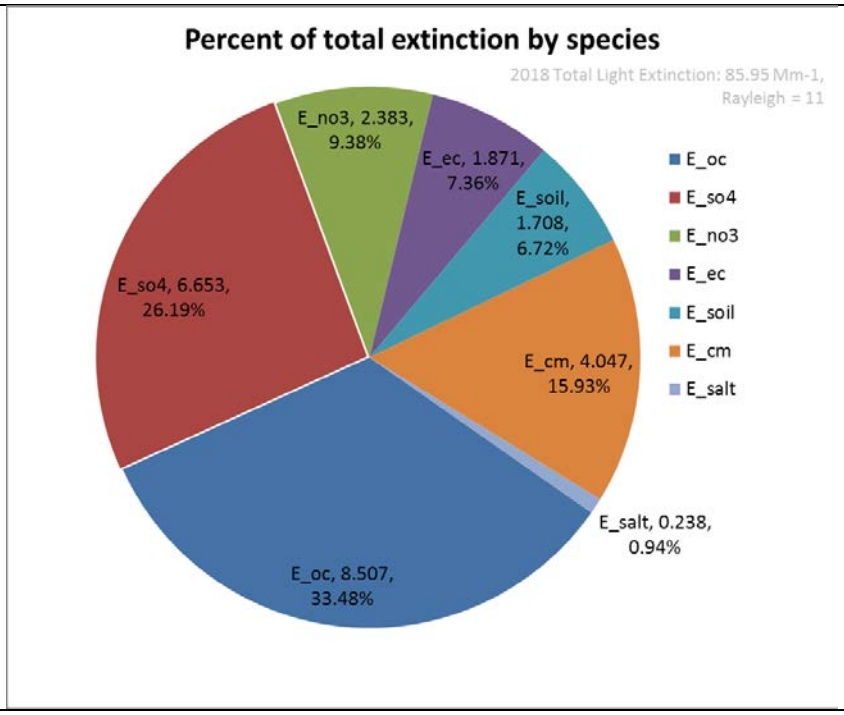


Figure C-4(d): Percent of Total Extinction by Species over 20% worst days at Bandelier Wilderness Area (BAND), NM

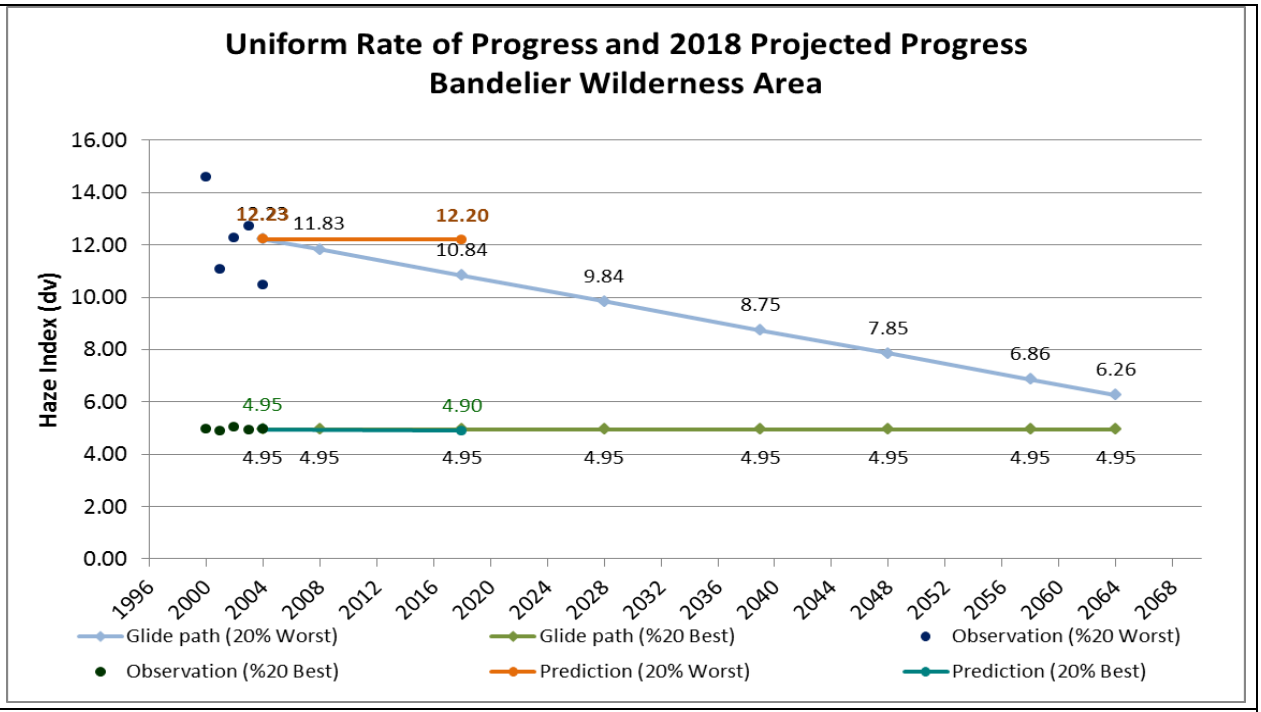


Figure C-4(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Bandelier Wilderness Area (BAND), NM

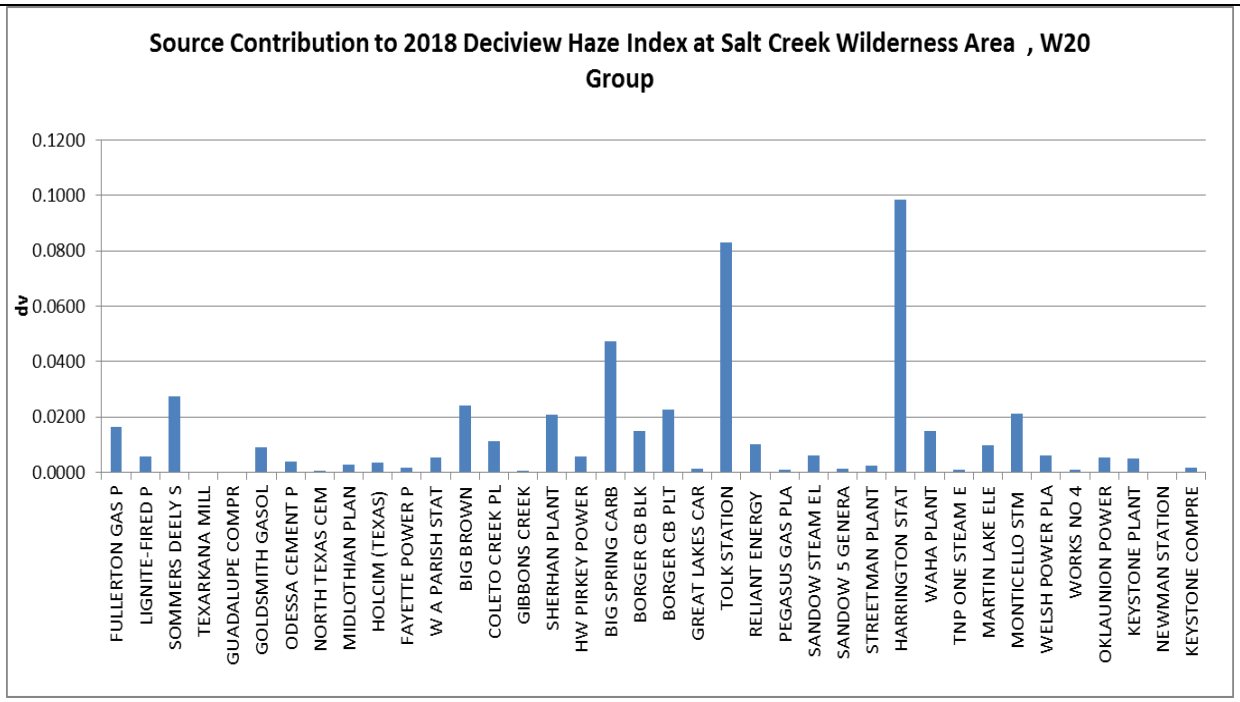


Figure C-5(a): Source Contribution to 2018 Deciview over 20% worst days at Salt Creek Wilderness Area (SACR), NM

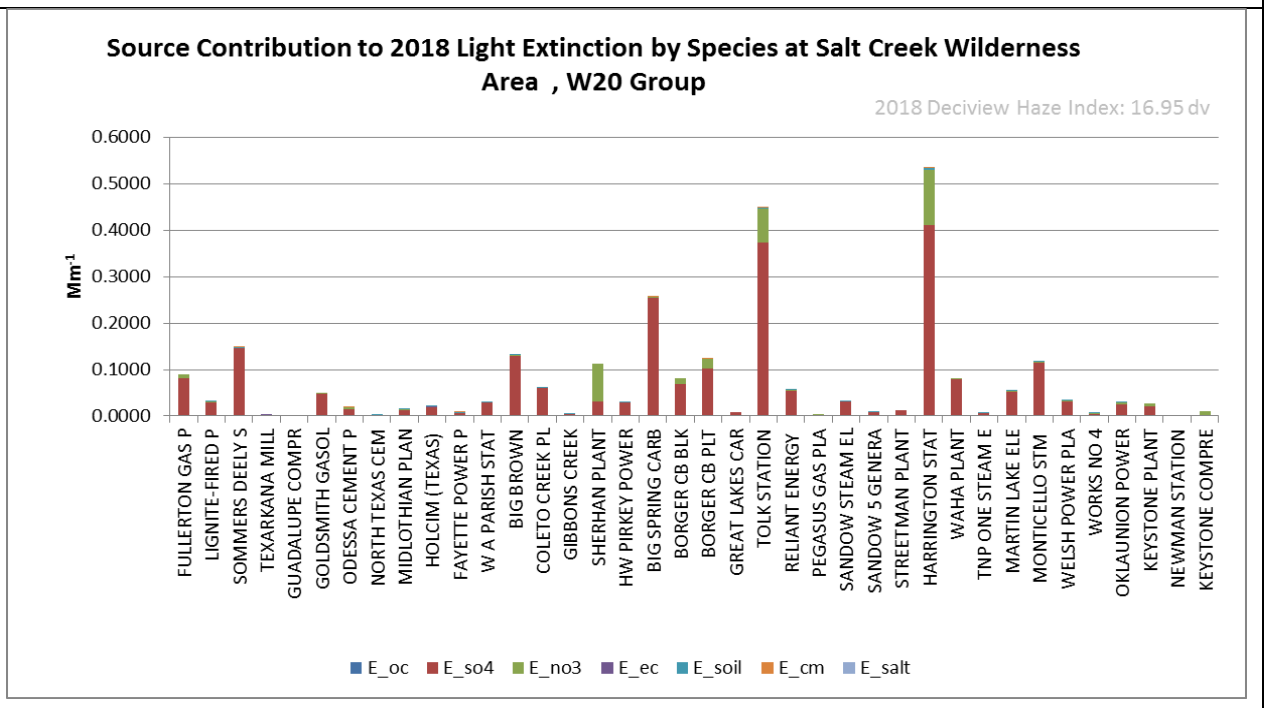


Figure C-5(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Salt Creek Wilderness Area (SACR), NM

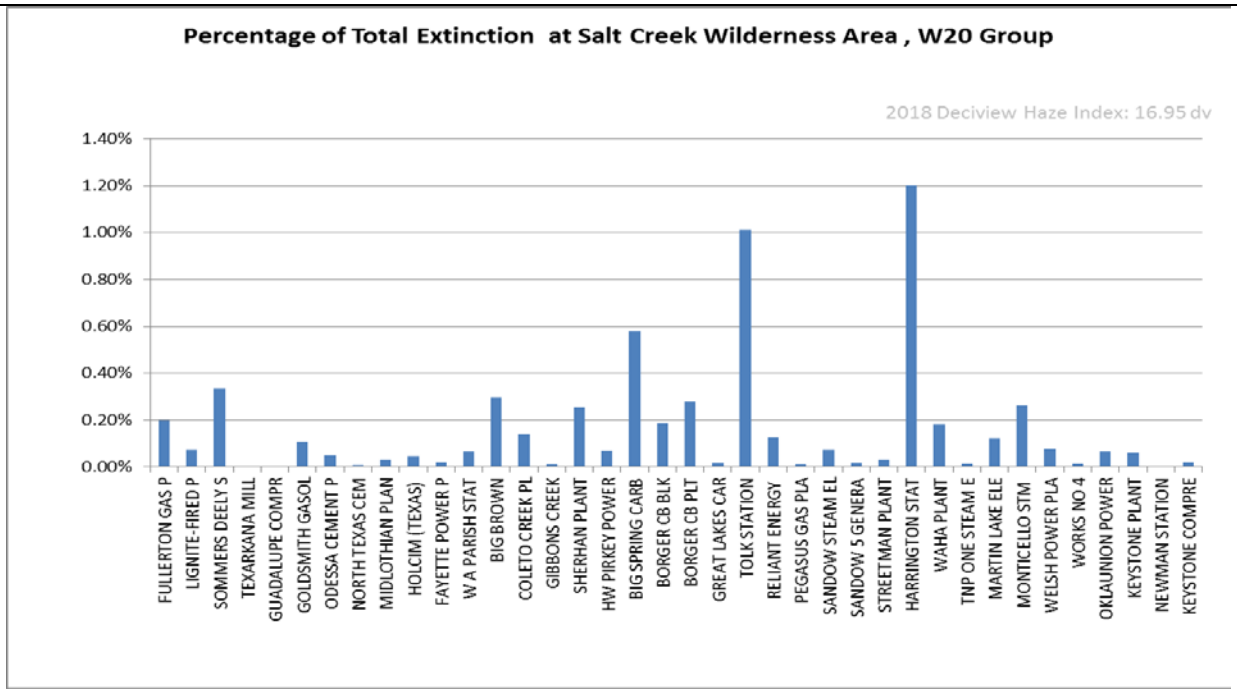


Figure C-5(c): Percentage of Total Extinction over 20% worst days at Salt Creek Wilderness Area (SACR), NM

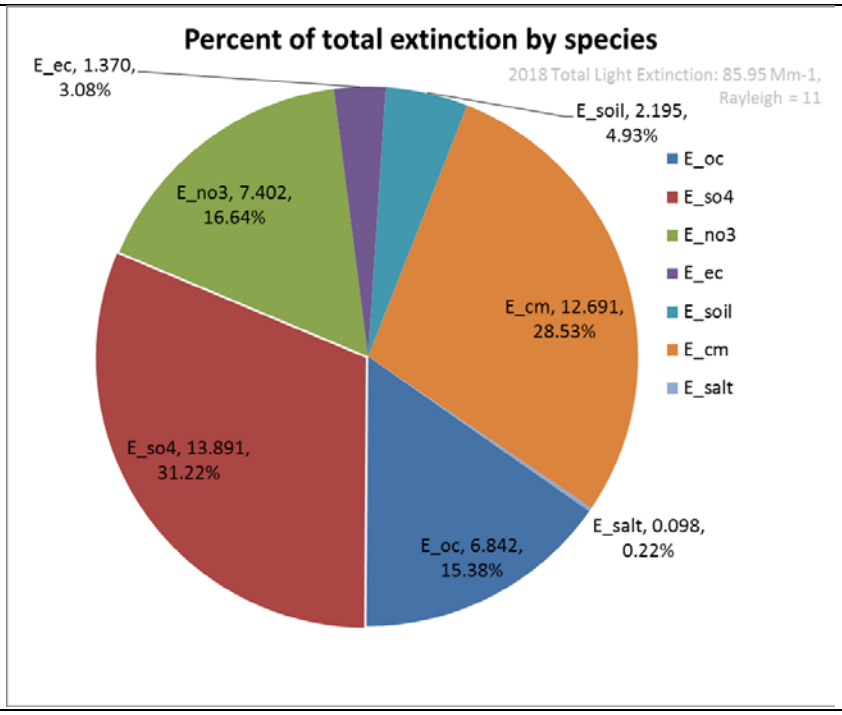


Figure C-5(d): Percent of Total Extinction by Species over 20% worst days at Salt Creek Wilderness Area (SACR), NM

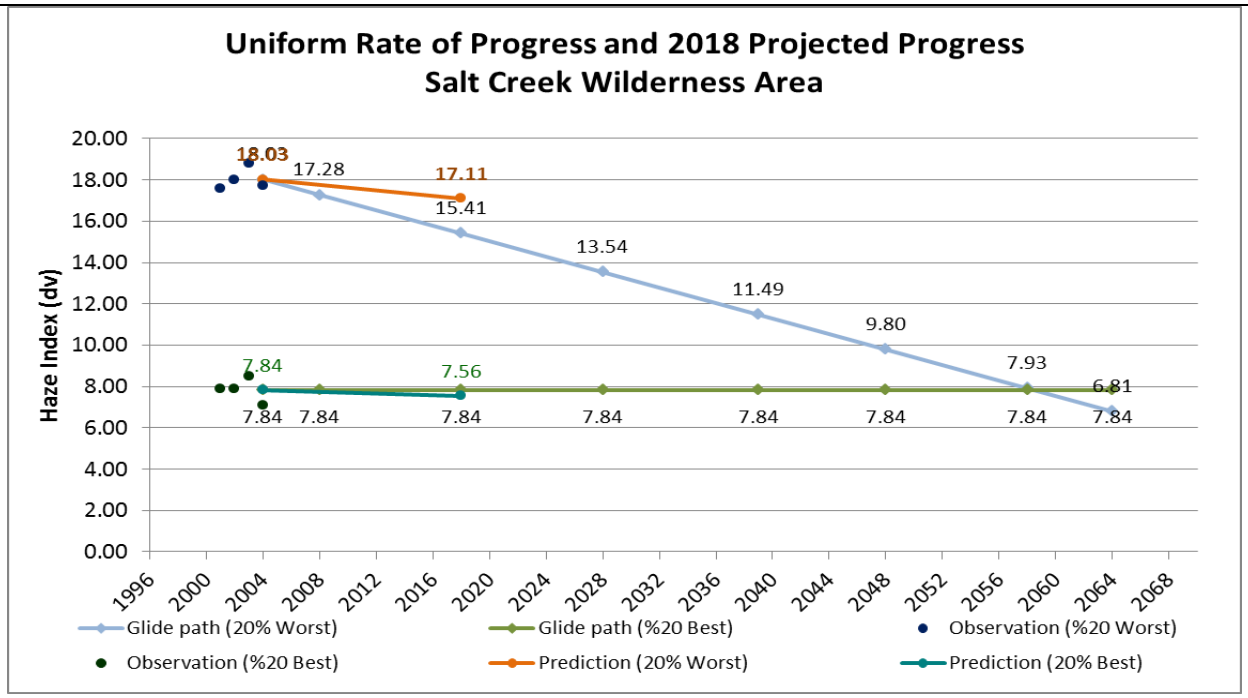


Figure C-5(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Salt Creek Wilderness Area (SACR), NM

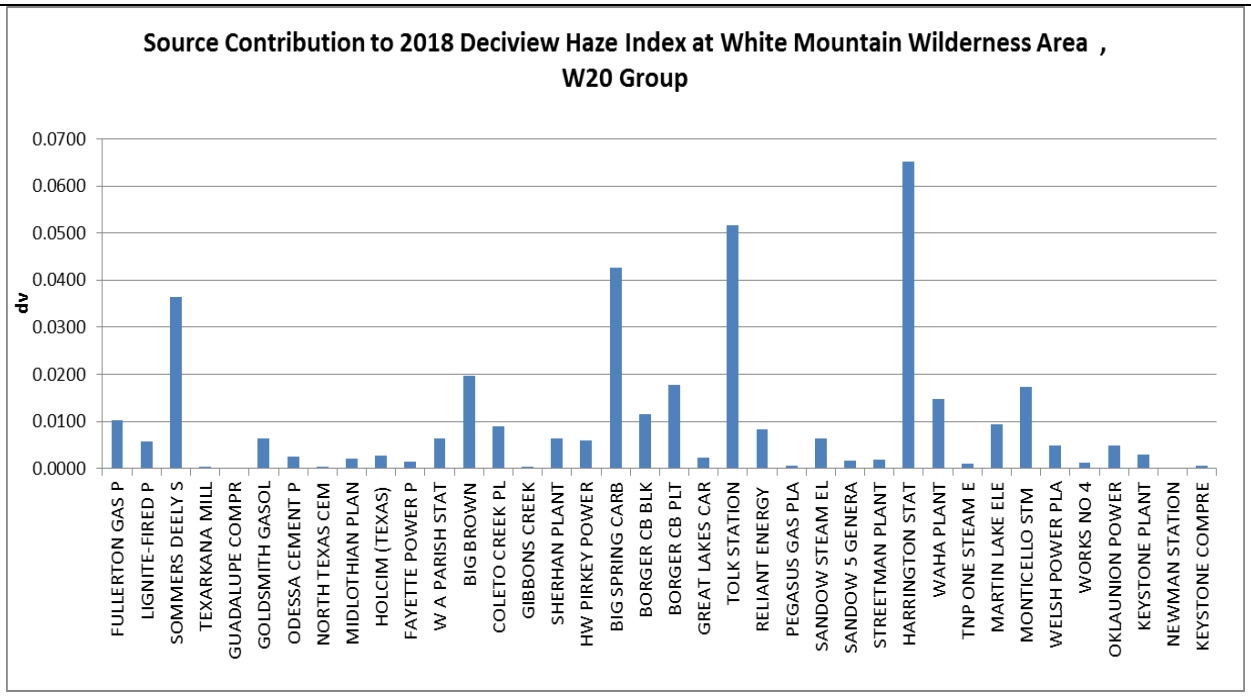


Figure C-6(a): Source Contribution to 2018 Deciview over 20% worst days at White Mountain Wilderness Area (WHIT), NM

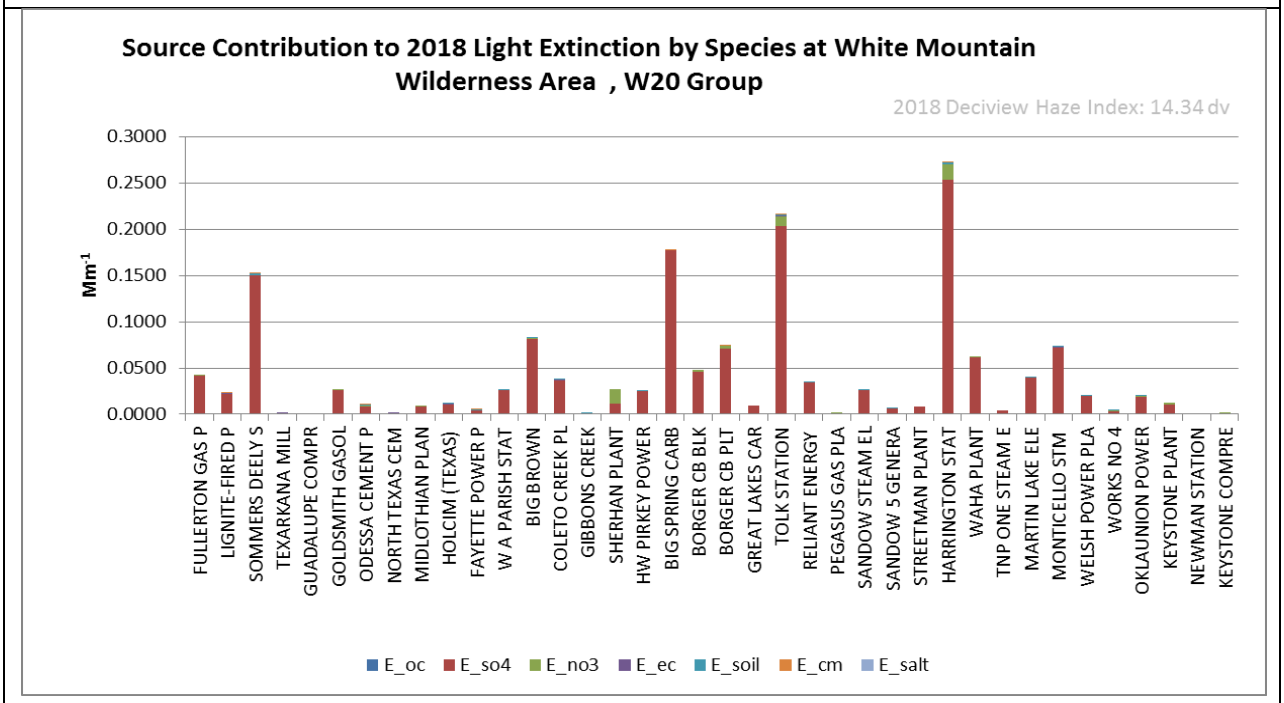


Figure C-6(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at White Mountain Wilderness Area (WHIT), NM

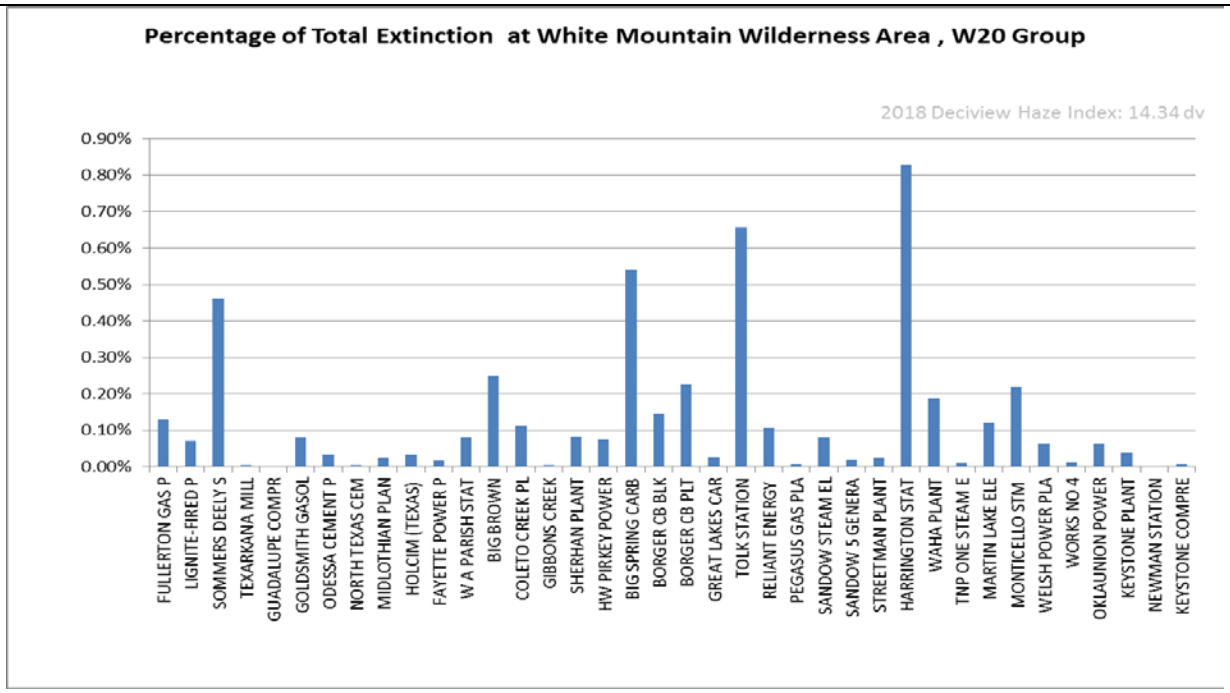


Figure C-6(c): Percentage of Total Extinction over 20% worst days at White Mountain Wilderness Area (WHIT), NM

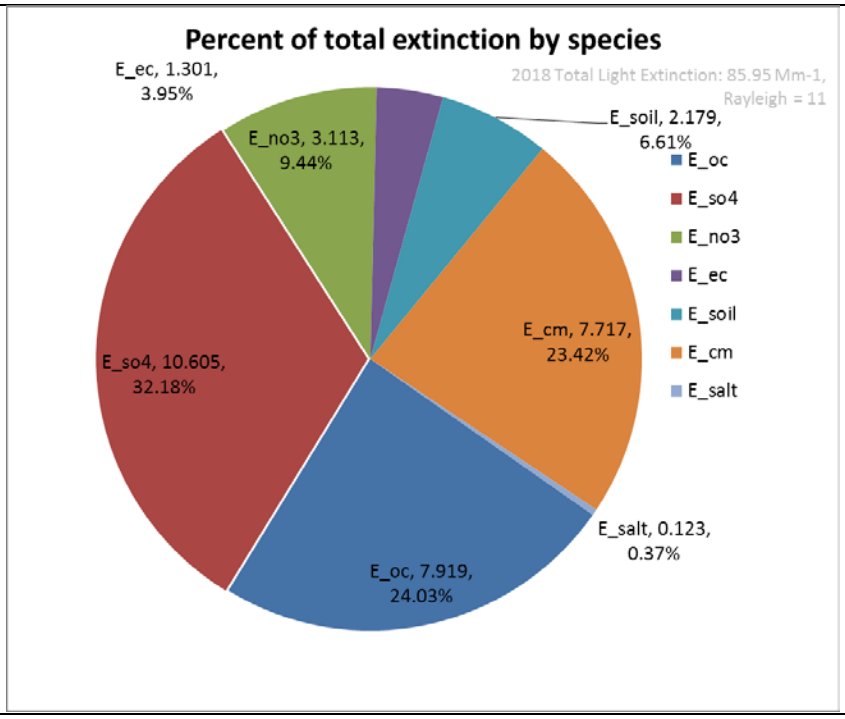


Figure C-6(d): Percent of Total Extinction by Species over 20% worst days at White Mountain Wilderness Area (WHIT), NM

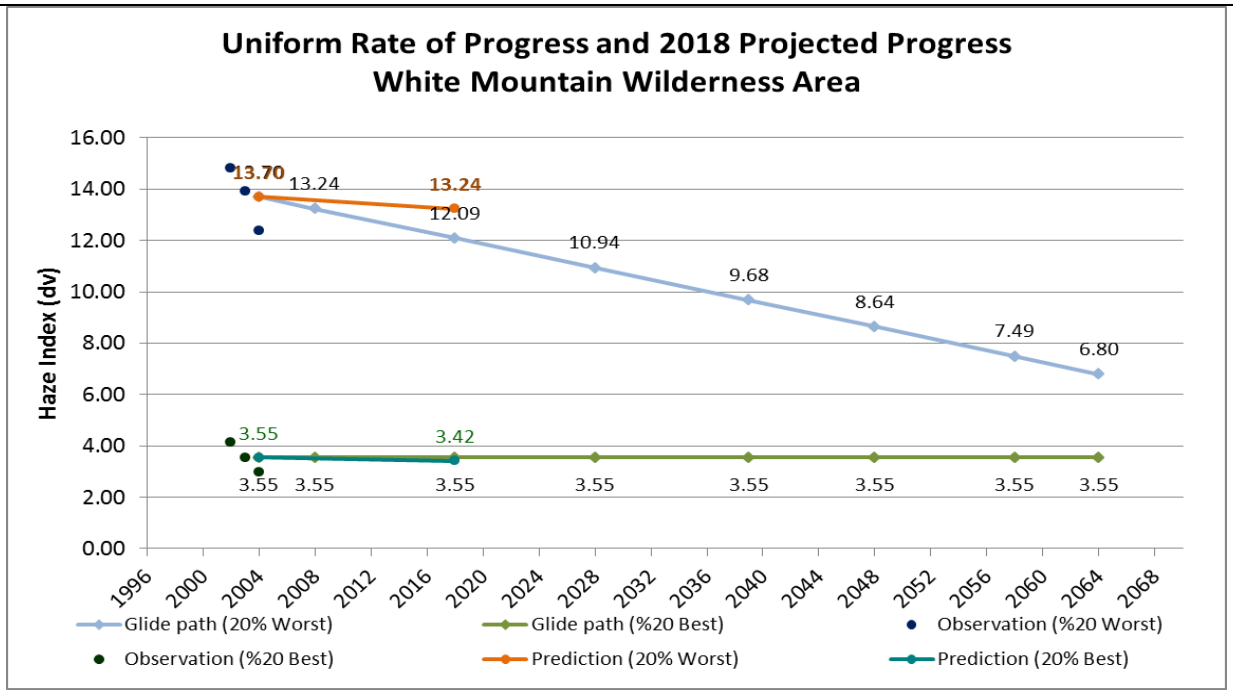


Figure C-6(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at White Mountain Wilderness Area (WHIT), NM

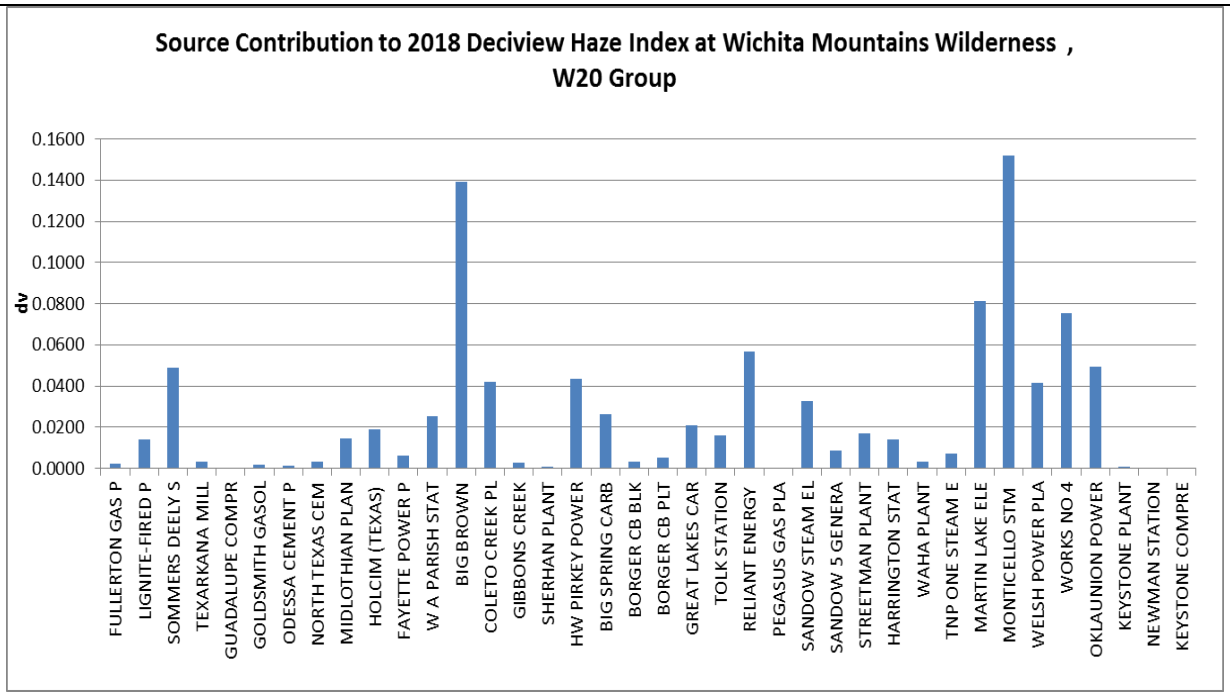


Figure C-7(a): Source Contribution to 2018 Deciview over 20% worst days at Wichita Mountains Wilderness (WIMO), OK

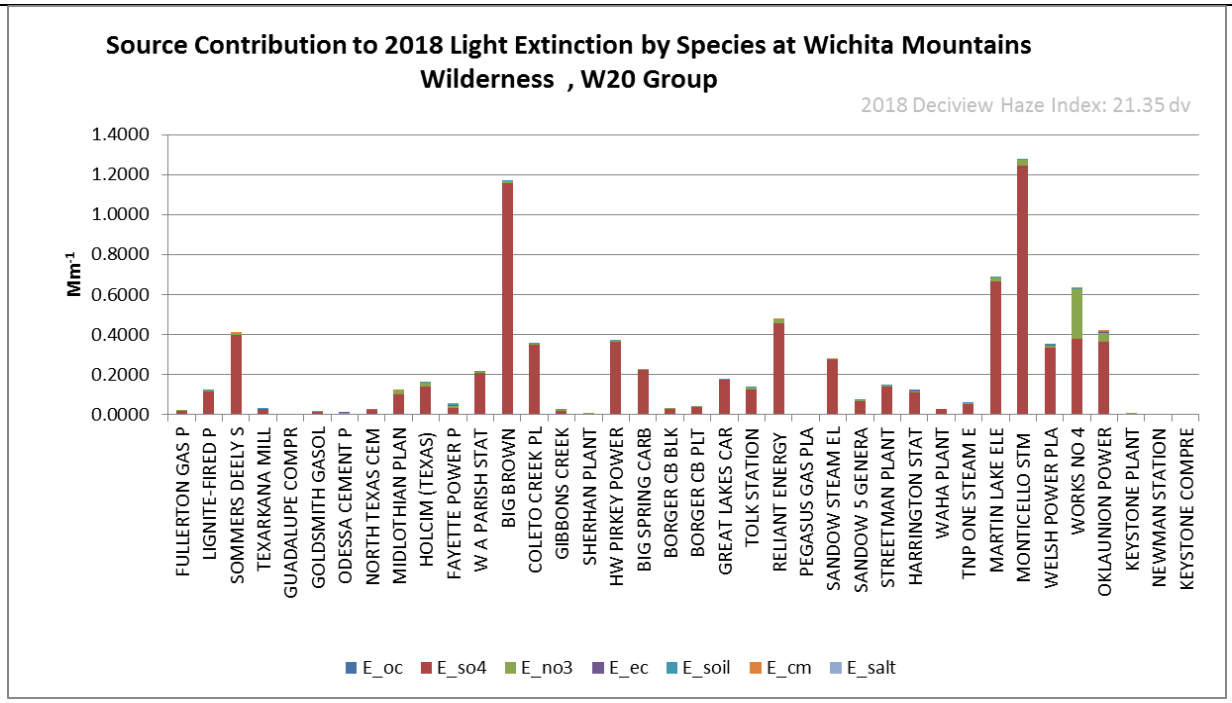


Figure C-7(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Wichita Mountains Wilderness (WIMO), OK

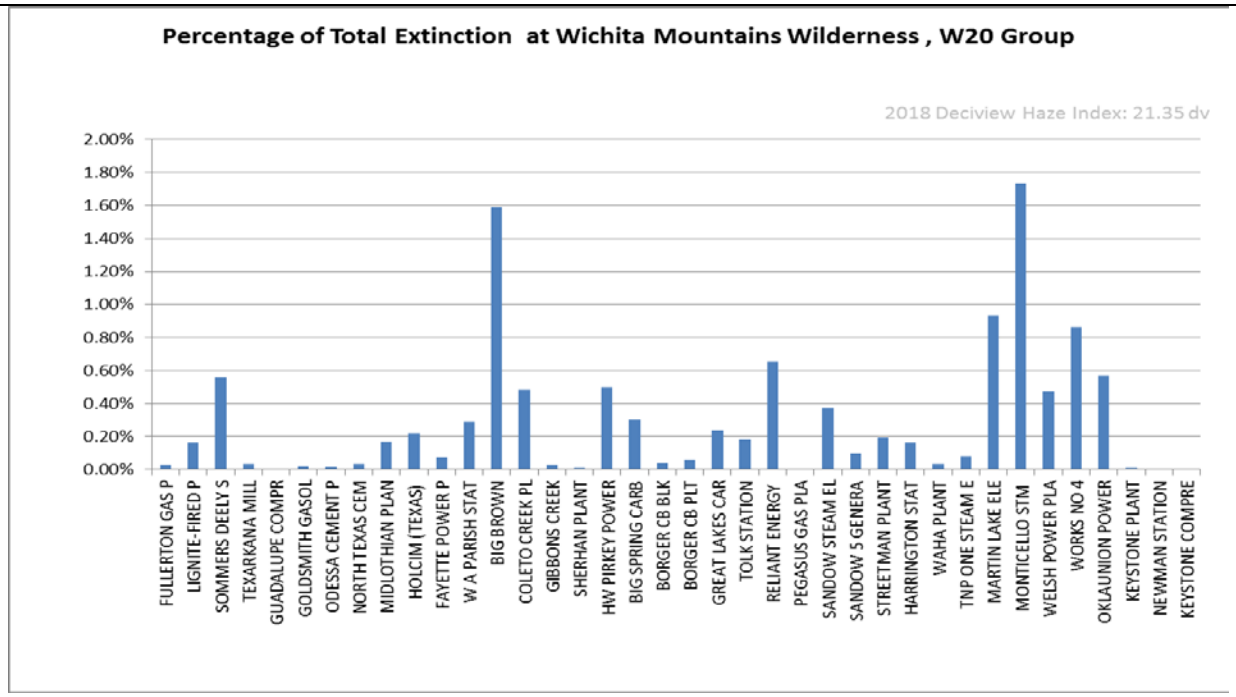


Figure C-7(c): Percentage of Total Extinction over 20% worst days at Wichita Mountains Wilderness (WIMO), OK

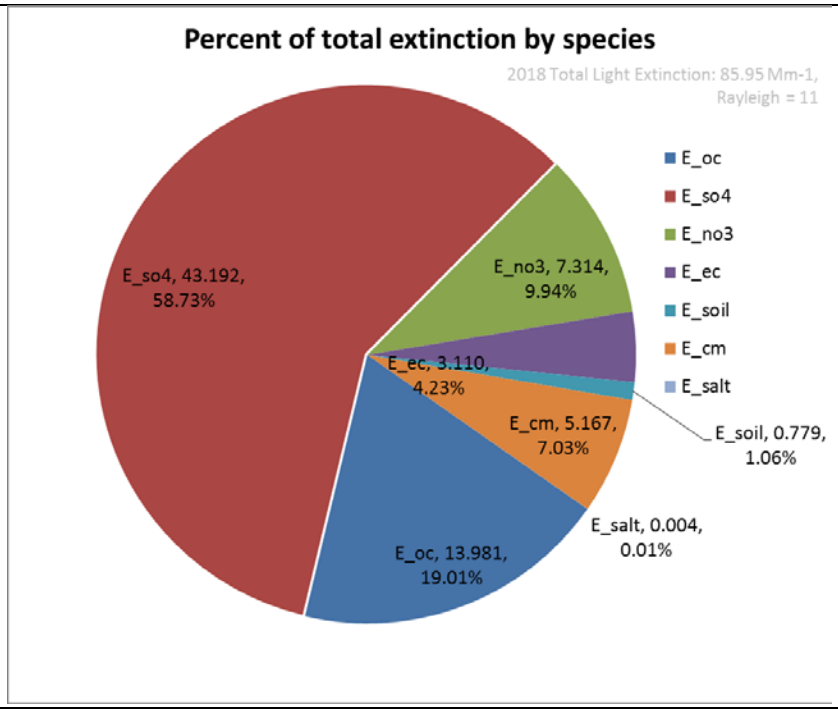


Figure C-7(d): Percent of Total Extinction by Species over 20% worst days at Wichita Mountains Wilderness (WIMO), OK

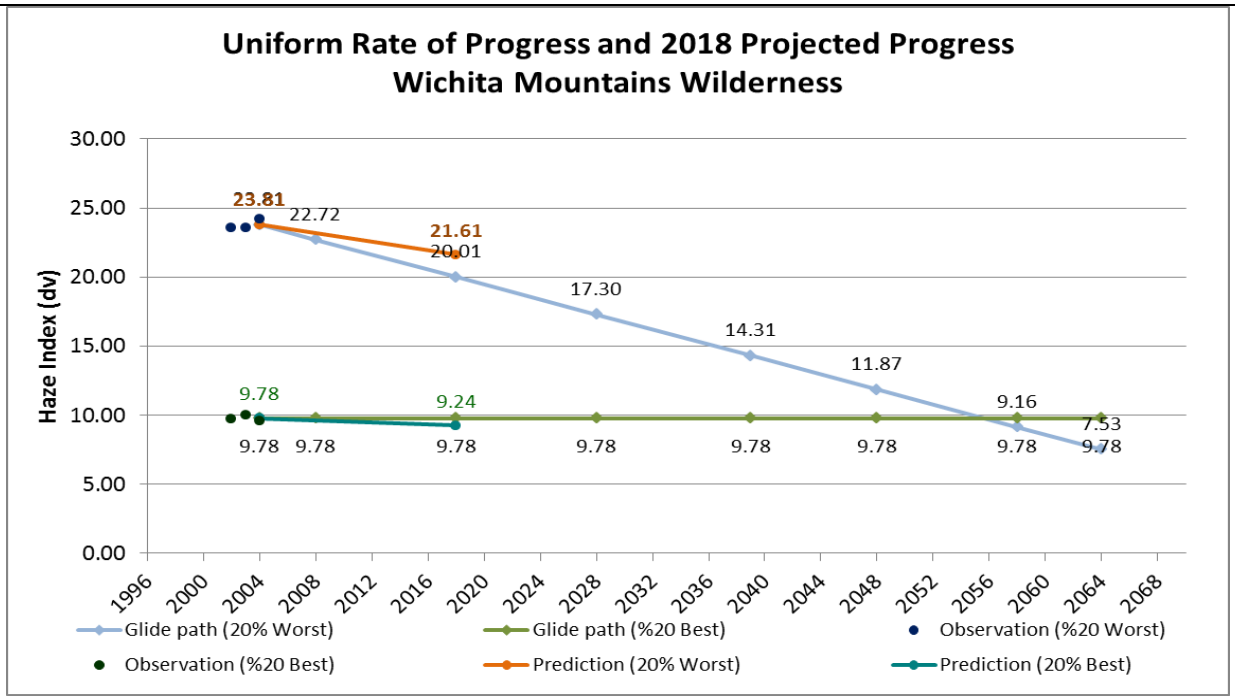


Figure C-7(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Wichita Mountains Wilderness (WIMO), OK

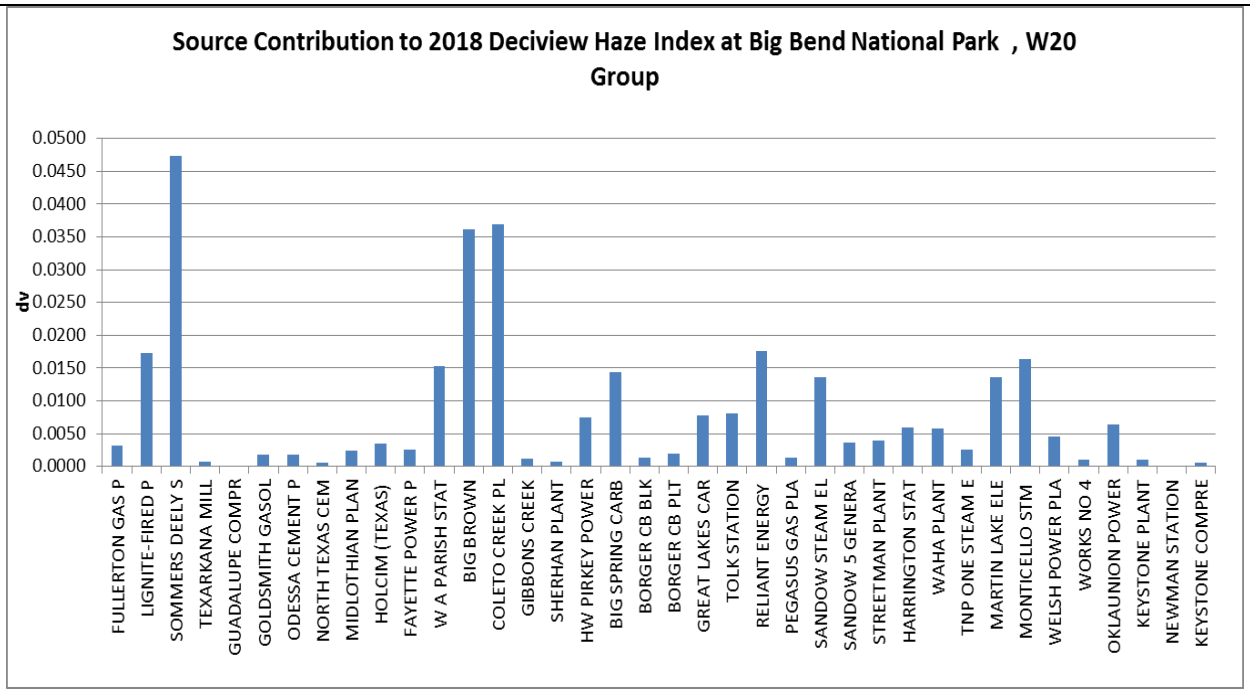


Figure C-8(a): Source Contribution to 2018 Deciview over 20% worst days at Big Bend National Park (BIBE), TX

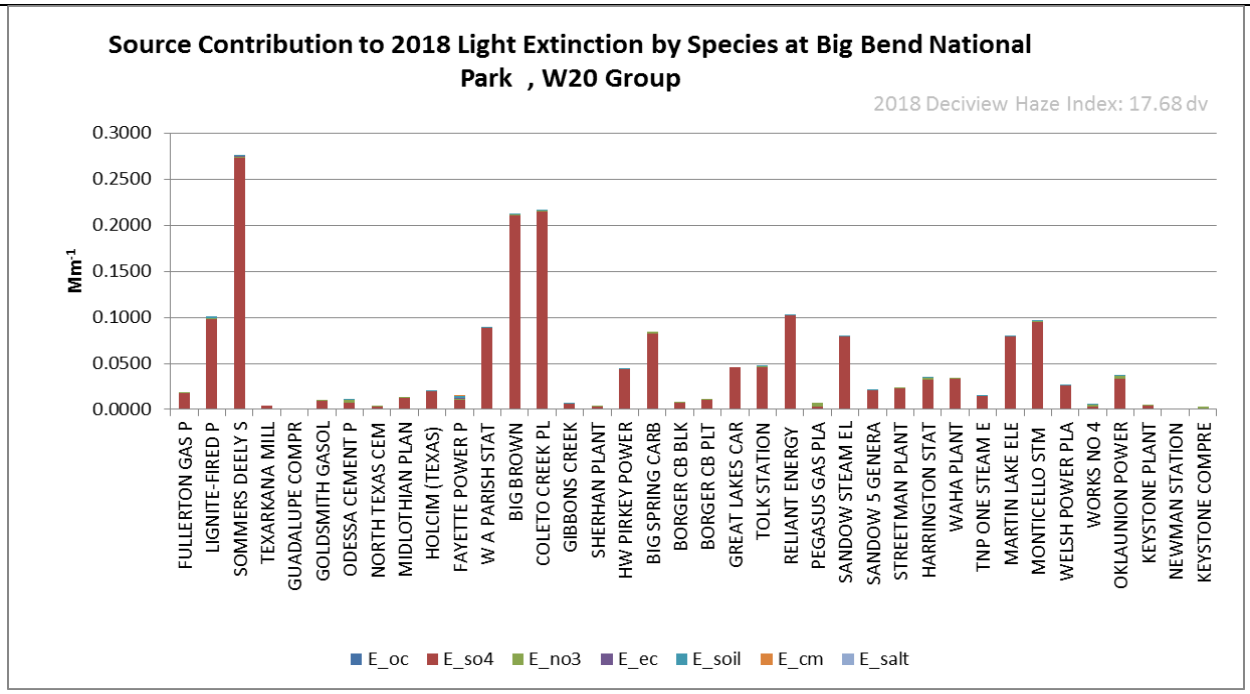


Figure C-8(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Big Bend National Park (BIBE), TX

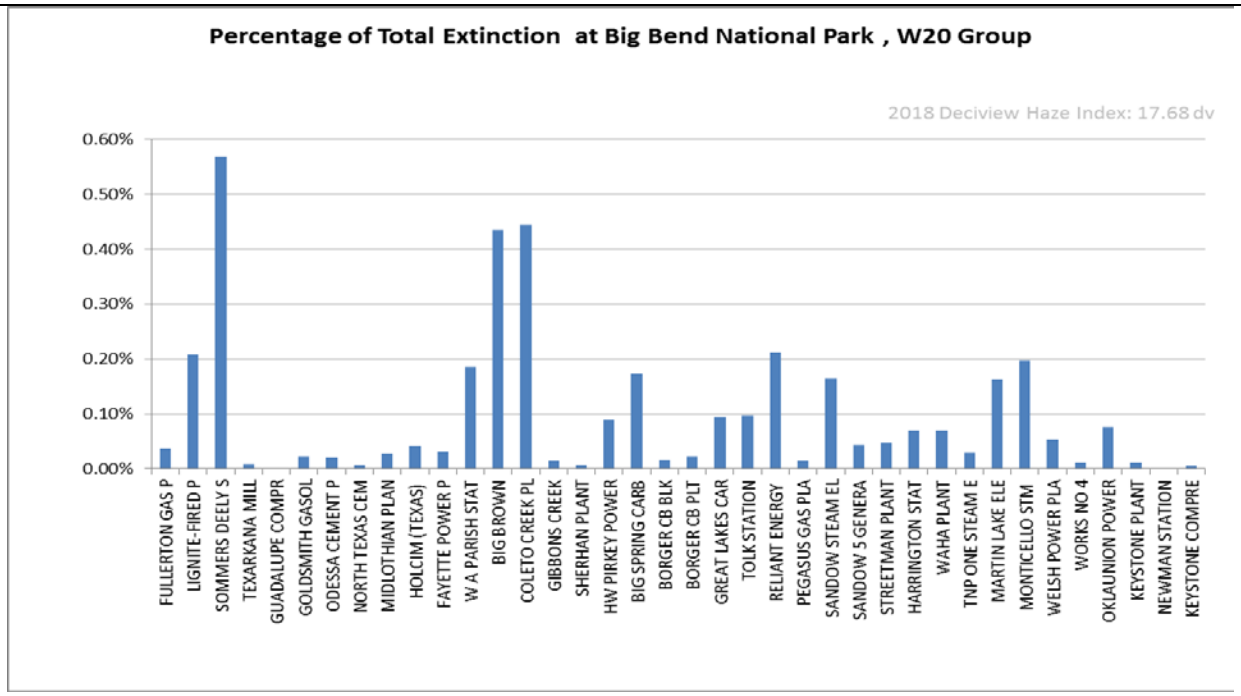


Figure C-8(c): Percentage of Total Extinction over 20% worst days at Big Bend National Park (BIBE), TX

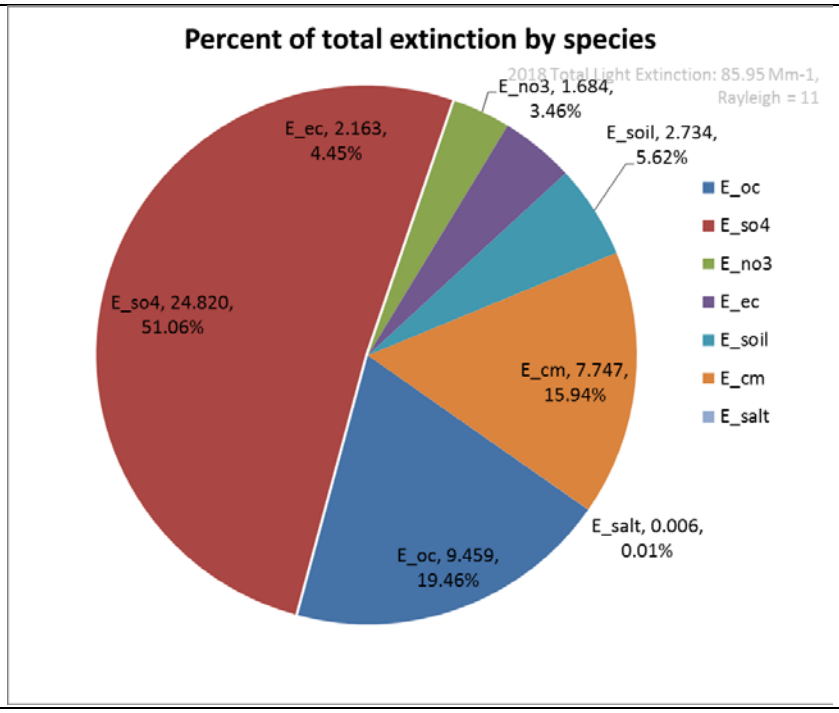


Figure C-8(d): Percent of Total Extinction by Species over 20% worst days at Big Bend National Park (BIBE), TX

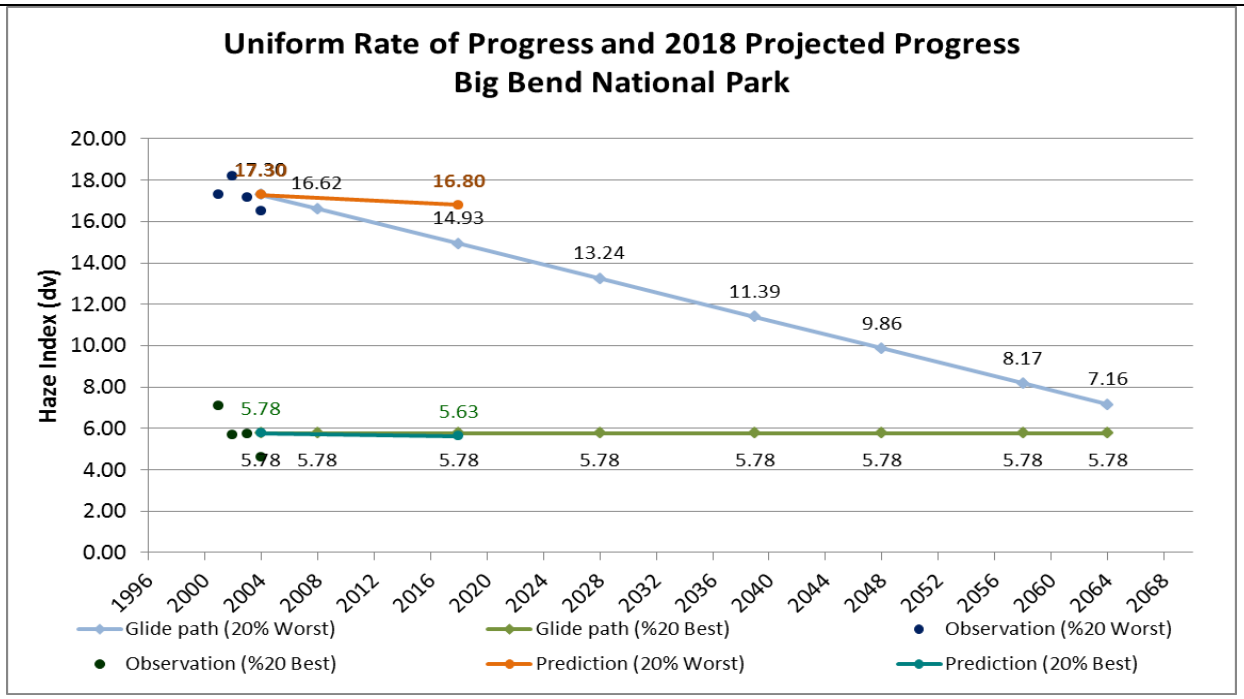


Figure C-8(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Big Bend National Park (BIBE), TX

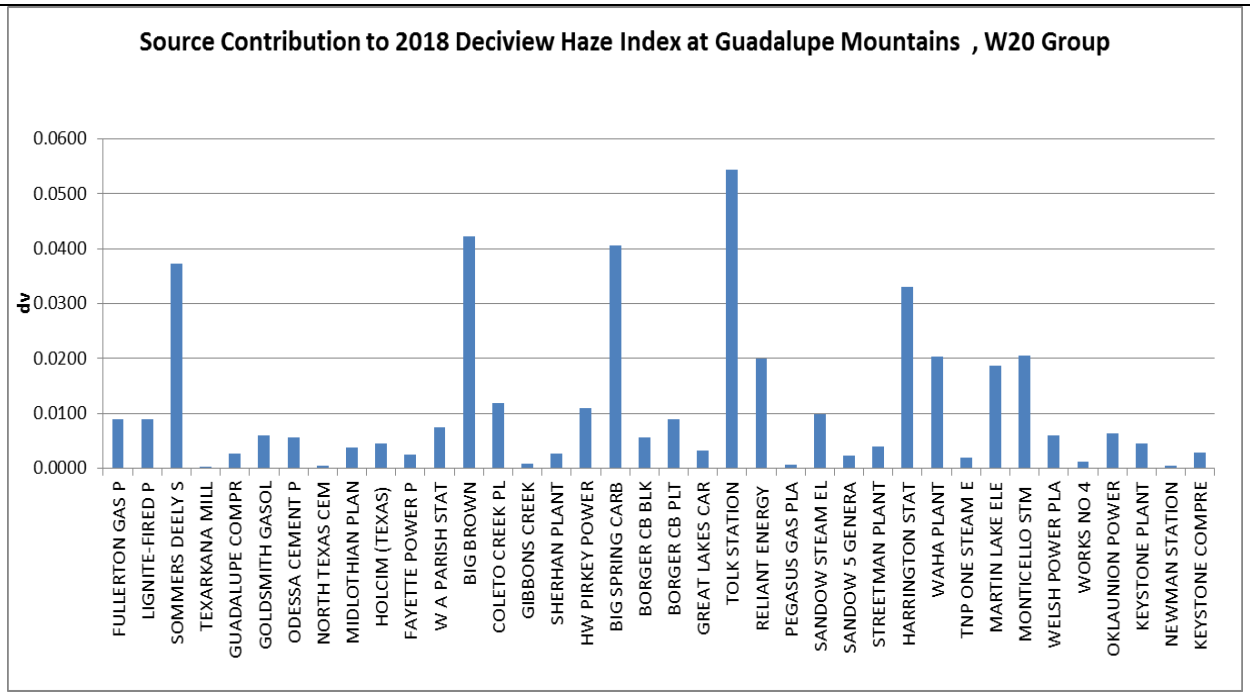


Figure C-9(a): Source Contribution to 2018 Deciview over 20% worst days at Guadalupe Mountains (GUMO), TX

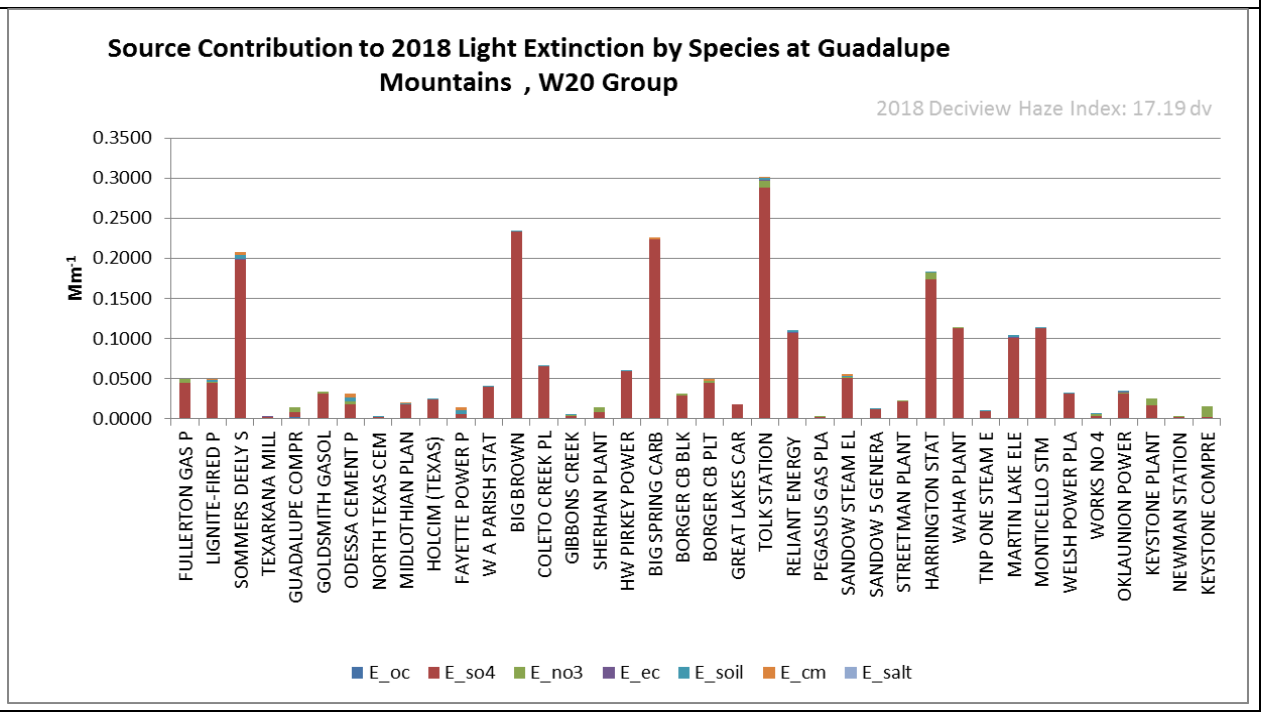


Figure C-9(b):Source Contribution to 2018 Light Extinction by species over 20% worst days at Guadalupe Mountains (GUMO), TX

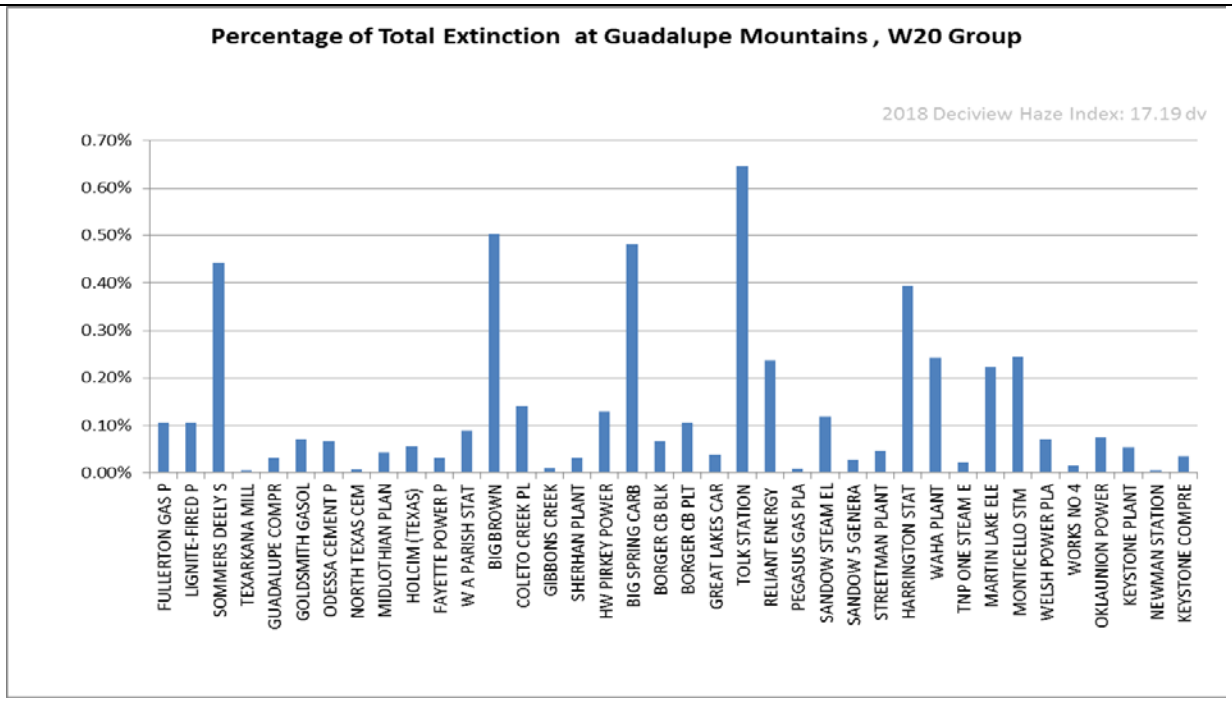


Figure C-9(c): Percentage of Total Extinction over 20% worst days at Guadalupe Mountains (GUMO), TX

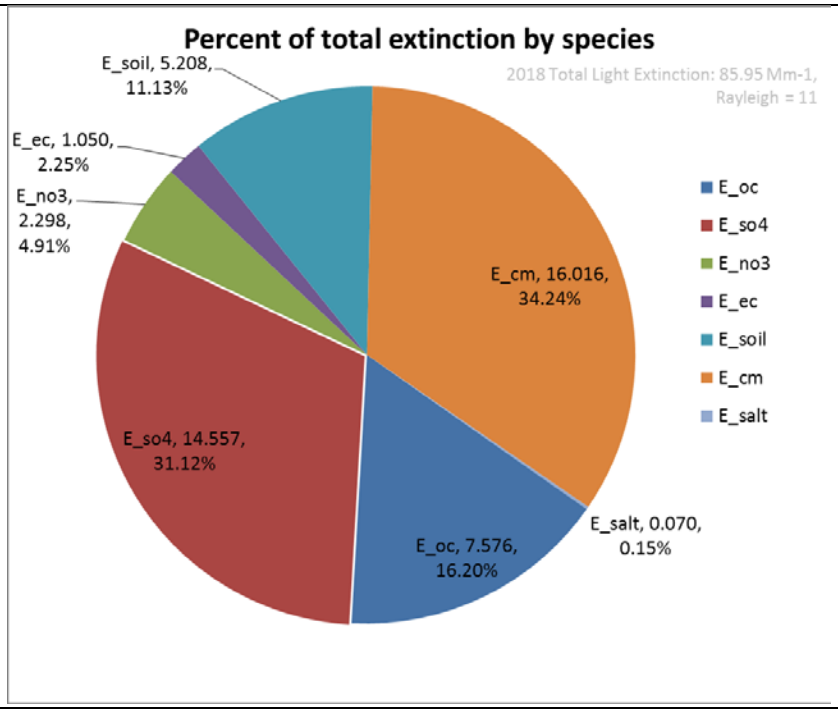


Figure C-9(d): Percent of Total Extinction by Species over 20% worst days at Guadalupe Mountains (GUMO), TX

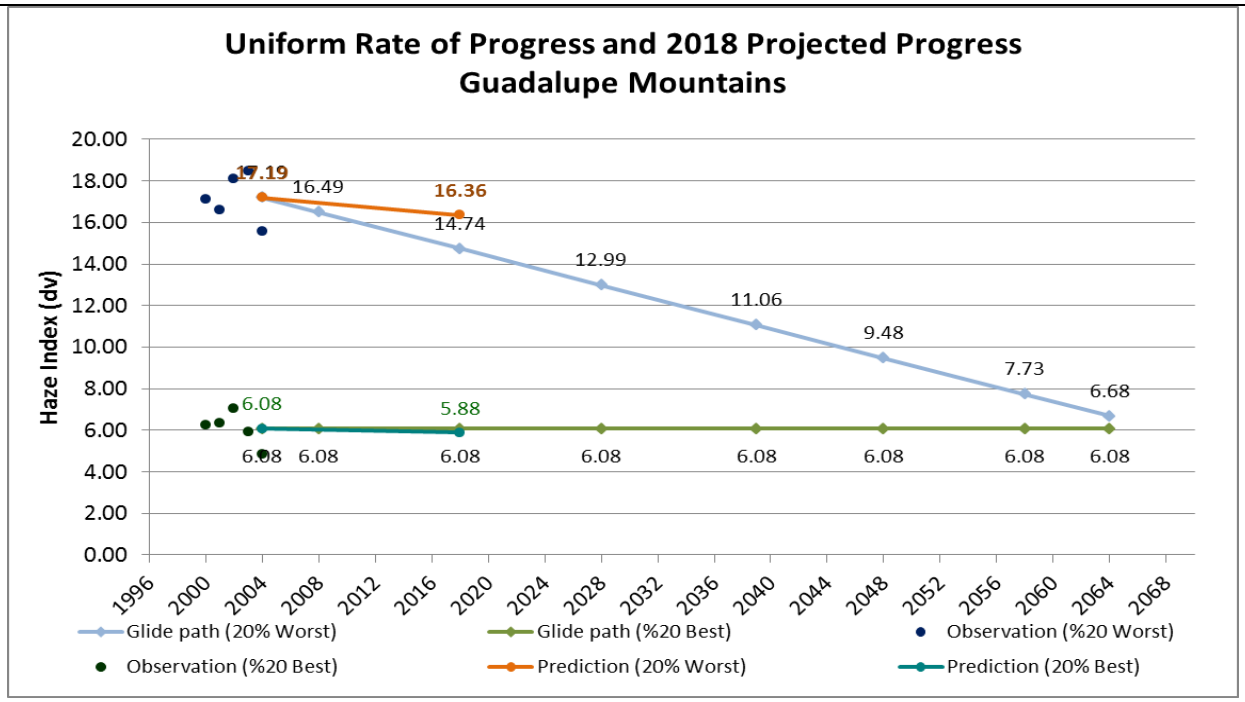


Figure C-9(e): Uniform Rate of Progress and 2018 Projected Progress over 20% worst days at Guadalupe Mountains (GUMO), TX