October 15, 2019

SPECIFICATION SHEET: WILDFIRE AND PRESCRIBED BURN EMISSIONS

Description: Wildfire and prescribed burn source emissions (sector abbreviation is "ptfire") for simulating 2016 and future year U.S. air quality

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Contents

1. EXECUTIVE SUMMARY

The ptfire emissions inventory was developed using currently available fire emissions inventory tools along with year 2016 fire information databases from national, state, and tribal agencies. This document summarizes 1) the inventory tools, 2) the methodologies used to incorporate all fire information data available, 3) the supporting ancillary data and 4) provides emissions summaries. Base year inventories were processed with the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system version 4.7. SMOKE creates emissions in a format that can be input into air quality models. National and state-level emission summaries for key pollutants are provided.

2. INTRODUCTION

Wildfires and prescribed burns that occur during the inventory year are included in the year 2016 version 1 (2016v1) as event and point sources. The agricultural fires (ptagfire) are described in a separate document. Estimated emissions from wildfires and prescribed burns are calculated from burned area data. Input data sets were collected from state/local/tribal (S/L/T) agencies and from national agencies and organizations. Raw burned area data compiled from S/L/T agencies and national data sources are organized and combined to produce a comprehensive burned area data set. Emissions are calculated using fire emission models that rely on burned area as well as fuel and weather information. The resulting emissions are then compiled by date and location.

For purposes of emission inventory preparation, wildland fire (WLF) is defined as "any non-structure fire that occurs in the wildland" (an area in which human activity and development are essentially non-existent, except for roads, railroads, power lines, and similar transportation facilities). Wildland fire activity is categorized by the conditions under which the fire occurs. These conditions influence important aspects of fire behavior, including smoke emissions. In the 2016v1 inventory, data processing is conducted differently depending on the fire type, as defined below:

- Wildfire (WF): "any fire started by an unplanned ignition caused by lightning; volcanoes; other acts of nature; unauthorized activity; or accidental, human-caused actions, or a prescribed fire that has developed into a wildfire."
- Prescribed (Rx) fire: "any fire intentionally ignited by management actions in accordance with applicable laws, policies, and regulations to meet specific land or resource management objectives." Prescribed fire is one type of fuels treatment. Fuels treatments are vegetation management activities intended to modify or reduce hazardous fuels. Fuels treatments include prescribed fires, wildland fire use, and mechanical treatment.

The SCC used and SCC descriptions for the ptfire sources are shown in Table 1 and include separate SCCs for the flaming and smoldering combustion phases for wildfire and prescribed burns. Also, note that prescribed grassland fires specifically for Flint Hills, Kansas have its own SCC in the 2016v1 inventory. The year 2016 fire season also included some major wild grassland fires. These wild grassland fires were assigned the standard Wildfire SCCs shown in Table 1.

Table 1. The SCCs included in the ptfire sector for the 2016v1 inventory

SCC	Description
2801500170	Grassland fires; prescribed
2810001001	Forest Wildfires; Smoldering; Residual smoldering only (includes grassland wildfires)
2810001002	Forest Wildfires; Flaming (includes grassland wildfires)
2811015001	Prescribed Forest Burning; Smoldering; Residual smoldering only
2811015002	Prescribed Forest Burning; Flaming

3. Inventory Development Methods

National Fire Information Data

Numerous fire information databases are available from U.S. national government agencies. Some of the databases are available via the internet while others must be obtained directly from agency staff. Table 2 provides the national fire information databases that were obtained and used in 2016v1 inventory development.

Table 2. National fire information databases used in 2016v1 ptfire inventory.

Dataset Name	Fire Types	Format	Agency	Coverage	Source
Hazard Mapping System (HMS)	WF/RX	CSV	NOAA	North America	https://www.ospo.noaa.gov/ Products/land/hms.html
Geospatial Multi-Agency Coordination (GeoMAC)	WF	SHP	USGS	Entire US	https://rmgsc.cr.usgs.gov /outgoing/GeoMAC/
Incident Command System Form 209: Incident Status Summary (ICS-209)	WF/RX	CSV	Multi	Entire US	https://fam.nwcg.gov/ fam-web/
National Association of State Foresters (NASF)	WF	CSV	Multi	Participating US states	https://fam.nwcg.gov/ fam-web/
Monitoring Trends in Burn Severity (MTBS)	WF/RX	SHP	USGS, USFS	Entire US	https://www.mtbs.gov/ direct-download

Dataset Name	Fire Types	Format	Agency	Coverage	Source
Forest Service Activity Tracking System (FACTS)	RX	SHP	USFS	Entire US	Hazardous Fuel Treatment Reduction: Polygon at https://data.fs.usda.gov/geodata/edw/datasets.php
US Fish and Wildland Service (USFWS) fire database	WF/RX	CSV	USFWS	Entire US	Direct communication with USFWS

The Hazard Mapping System (HMS) was developed in 2001 by the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite and Data Information Service (NESDIS) as a tool to identify fires over North America in an operational environment. The system utilizes geostationary and polar orbiting environmental satellites. Automated fire detection algorithms are employed for each of the sensors. When possible, analysts apply quality control procedures for the automated fire detections by eliminating those that are deemed to be false and adding hotspots that the algorithms have not detected via a thorough examination of the satellite imagery. The HMS product used in 2016v1 inventory development consisted of daily comma-delimited files containing fire detect information including latitude-longitude, satellite used, time detected, and other information. The Visible Infrared Imaging Radiometer Suite (VIIRS) satellite fire detects were introduced into the HMS in late 2016. Since it was only available for a small portion of the year, the VIIRS fire detects were removed for the entire year for consistency reasons. In the 2016alpha version, the grassland fire detects were put in the agricultural burn processing step. However, there were a few significant grassland wildfires in Kansas and Oklahoma in year 2016. Therefore, for the 2016v1 version, all grassland fire detects were processed through SmartFire2 and BlueSky.

GeoMAC (Geospatial Multi-Agency Coordination) is an online wildfire mapping application designed for fire managers to access maps of current fire locations and perimeters in the United States. Historical 2016 wildfire perimeter shapefiles were downloaded from GeoMAC site (see Table 2). The wildfire perimeter data is based upon input from incident intelligence sources from multiple agencies, GPS data, and infrared (IR) imagery from fixed wing and satellite platforms.

The Incident Status Summary, also known as the "ICS-209" is used for reporting specific information on fire incidents of significance. The report is a critical interagency incident reporting tool giving daily 'snapshots' of the wildland fire management situation and individual incident information which include fire behavior, size, location, cost, and other information.

The historical ICS-209 data is archived, and the year 2016 data was downloaded from site in Table 2. Data from two tables in the ICS-209 database were merged and used: the SIT209_HISTORY_INCIDENT_209_REPORTS table contained daily 209 data records for large fires, and the SIT209_HISTORY_INCIDENTS table contained summary data for additional smaller fires.

The National Association of State Foresters (NASF) is a non-profit organization composed of the directors of forestry agencies in the states, U.S. territories, and District of Columbia to manage and protect state and private forests, which encompass nearly two-thirds of the nation's forests. The NASF compiles fire incident reports from agencies in the organization and makes them publicly available. The year 2016 data was downloaded from the website shown in Table 2. The NASF fire information includes dates of fire activity, acres burned, and fire location information.

Monitoring Trends in Burn Severity (MTBS) is an interagency program whose goal is to consistently map the burn severity and extent of large fires across all lands of the United States from 1984 to present. This includes all fires 1000 acres or greater in the western United States and 500 acres or greater in the eastern Unites States. The extent of coverage includes the continental U.S., Alaska, Hawaii and Puerto Rico. Fire occurrence and satellite data from various sources are compiled to create numerous MTBS fire products. The MTBS Burned Areas Boundaries Dataset shapefiles were downloaded. The shapefiles include year 2016 fires and the shapefiles are classified as either wildfires, prescribed burns or unknown fire types. The unknown fire type shapes were omitted in the 2016v1 inventory development due to temporal and spatial problems found when trying to use these data.

The US Forest Service (USFS) compiles a variety of fire information every year. Year 2016 data from the Forest Service's Natural Resource Manager (NRM) Forest Activity Tracking System (FACTS) was acquired and used for 2016v1 emissions inventory development. This database includes information about activities related to fire/fuels, silviculture, and invasive species. The FACTS database consists of shapefiles for prescribed burns that provide acres burned, and start and ending time information.

The US Fish and Wildland Service (USFWS) also compiles wildfire and prescribed burn activity on their federal lands every year. Year 2016 data was acquired from USFWS through direct communication with USFWS staff and was used for 2016v1 emissions inventory development. The USFWS fire information provided fire type, acres burned, latitude-longitude, and start and ending times.

State/Local/Tribal fire information

During the 2016 emissions modeling platform development process, S/L/T agencies were invited by EPA and 2016 Fire Workgroup to submit all fire occurrence data for use in developing the 2016v1 fire inventory. A template form containing the desired format for data submittals was provided. The list of S/L/Ts that submitted fire data is provided in Table 3. Overall, the 2016v1 inventory development comprised of using data sets from 9 individual states and one Indian Nation.

Table 3. List of S/L/T agencies that submitted fire data for 2016v1 with types and formats.

S/L/T name	Fire Types	Format
NCDENR	WF/RX	CSV
KSDAQ	RX/AG	CSV
CO Smoke Mgmt Program	RX	CSV
Idaho DEQ	AG	CSV
Nez Perce Tribe	AG	CSV
GA DNR	ALL	EIS
MN	RX/AG	CSV
WA ECY	AG	CSV
NJ DEP	WF/RX	CSV
Alaska DEC	WF/RX	CSV

The data provided by S/L/Ts were evaluated by EPA and further feedback from agencies was requested at times. Table 4 provides a summary of the type of data submitted by each agency which includes spatial, temporal, acres burned and other information.

Table 4. Brief description of fire information submitted for 2016v1 inventory use.

S/L/T name	Fire Types	Description
NC DENR	WF/RX	Fire type, period-specific, latitude-longitude and acres burned information. Technical direction was to remove all fire detects that were not reconciled with any other national or state agency database.
Kansas DAQ	RX/AG	Day-specific, county-centroid located, acres burned for Flint Hills prescribed burns for Feb 27-May 4 time period. Also reclassified fuels for some agricultural burns. A grassland gridding surrogate was used to spatially allocate the day-specific grassland fire emissions.
Colorado Smoke Mgmt Program	RX	Day-specific, latitude-longitude, and acres burned for prescribed burns
Idaho DEQ	AG	Day-specific, latitude-longitude, acres burned for agricultural burns. Total replacement of 2016 alpha fires for Idaho.

S/L/T name	Fire Types	Description
Nez Perce Tribe	AG	Day-specific, latitude-longitude, acres burned for agricultural burns. Total replacement of 2016 alpha fires for this tribal region.
Georgia DNR	ALL	Data submitted included all fires types via EIS. The wildfire and prescribed burn data were provided as daily, point emissions sources. The agricultural burns were provided as day-specific point emissions sources.
Minnesota	RX/AG	Corrected latitude-longitude, day-specific and acres burned for some prescribed and agricultural burns.
Washington ECY	AG	Month-specific, latitude-longitude, acres burned, fuel loading and emissions for agricultural burns. Not day-specific so allocation to daily implemented by EPA. Also note WA state direction included to continue to use the 2014NEIv2 pile burns that were included in the non-point sector for 2016v1.
New Jersey DEP	WF/RX	Day-specific, latitude-longitude, and acres burned for wildfire and prescribed burns.
Alaska DEC	WF/RX	Day-specific, latitude-longitude, and acres burned for wildfire and prescribed burns.

Emissions Estimation Methodology

Preparation of the 2016v1 wildfire and prescribed burn emissions begins with the national and S/L/T data mentioned earlier and ends with daily estimates of emissions from flaming combustion and smoldering combustion phases. Flaming combustion is combustion that occurs with a flame. Flaming combustion is more complete combustion and is more prevalent with fuels that have a high surface-to-volume ratio, a low bulk density, and low moisture content. Smoldering combustion is combustion that occurs without a flame. Smoldering combustion is less complete and produces some pollutants, such as PM2.5, VOCs, and CO at higher rates than flaming combustion. Smoldering combustion is more prevalent with fuels that have low surface-to-volume ratios, high bulk density, and high moisture content. Models sometimes differentiate between smoldering emissions that are lofted with a smoke plume and those that remain near the ground (residual emissions), but for the purposes of the 2016v1 inventory the residual smoldering emissions were allocated to the smoldering SCCs mentioned in Table 1. The lofted smoldering emissions were allocated along with the flaming emissions to the flaming emissions SCCs in Table 1.

Figure 1a shows the processing stream for the 2016v1 inventory for wildfire and prescribe burn sources. The emissions estimate methodology consists of two tools or systems. The first system is called Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2 (SMARTFIRE2). SMARTFIRE2 is an algorithm and database system that operate within a geographic information system (GIS) framework. SMARTFIRE combines multiple sources of

fire information and reconciles them into a unified GIS database. It reconciles fire data from space-borne sensors and ground-based reports, thus drawing on the strengths of both data types while avoiding double-counting. At its core, SMARTFIRE2 is an association engine that links reports covering the same fire in any number of multiple databases. In this process, all input information is preserved, and no attempt is made to reconcile conflicting or potentially contradictory information (for example, the existence of a fire in one database but not another). In the 2016v1 inventory case, the national and S/L/T fire information is input into SMARTFIRE2 and then all information is merged and associated together based on user-defined weights for each fire information dataset. The output from SMARTFIRE2 is daily acres burned by fire type, and latitude-longitude coordinates for each fire. The fire type assignment is made using the fire information datasets but if the only information is a satellite detect for fire activity then Figure 1b is used to make fire type assignment by state and by month.

Figure 1a. Processing flow for fire emission estimates in the 2016v1 inventory

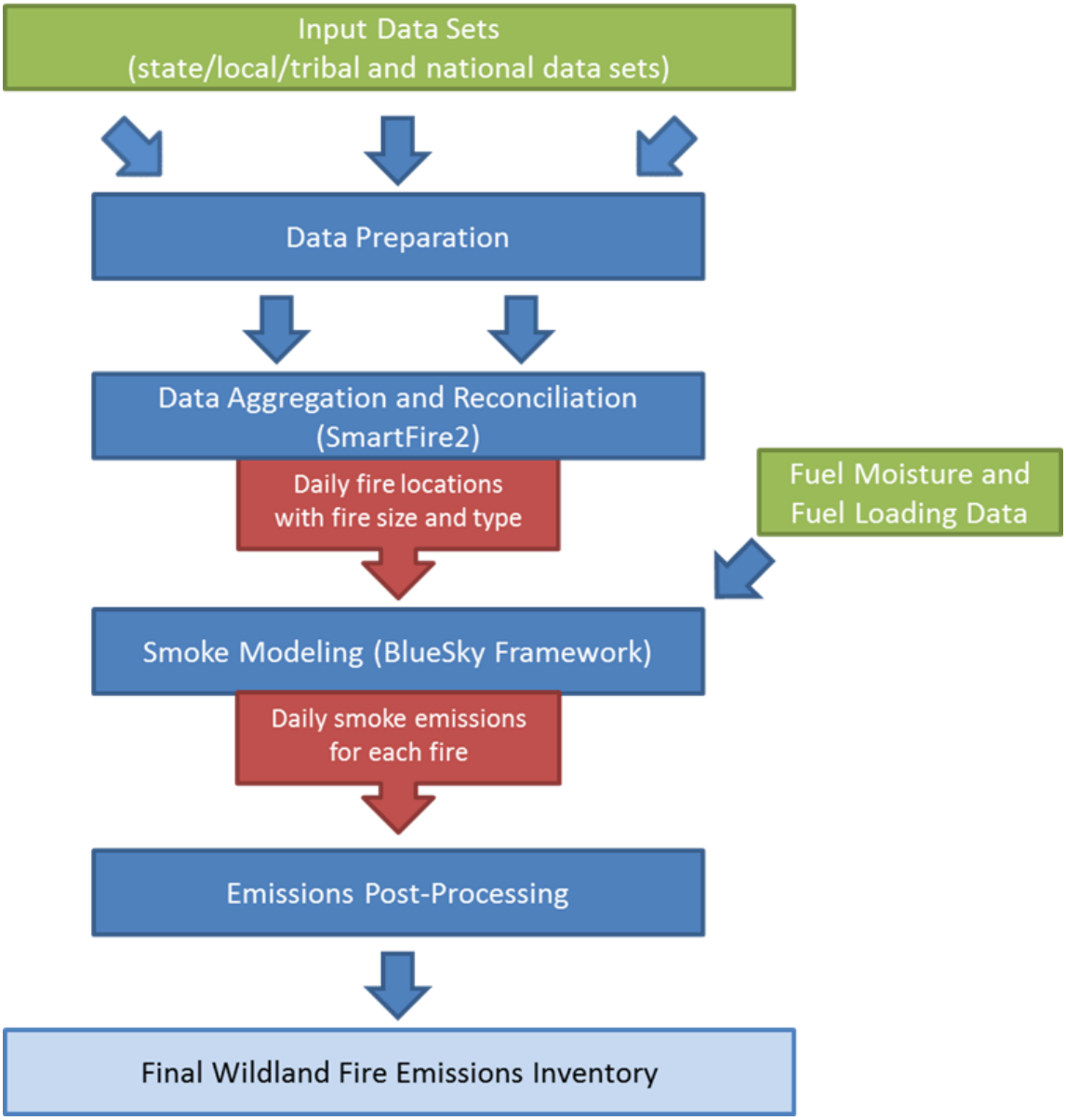
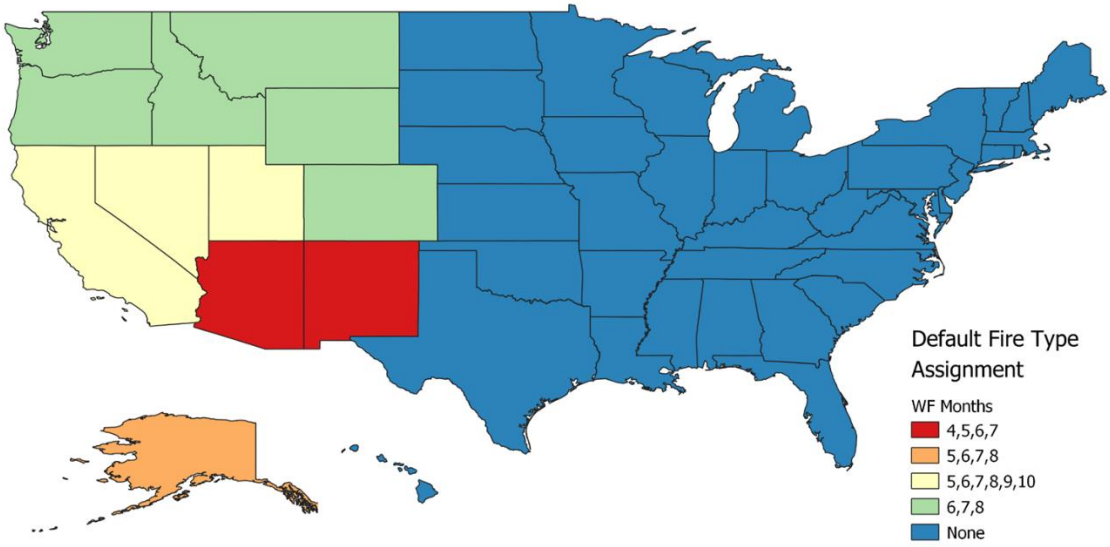
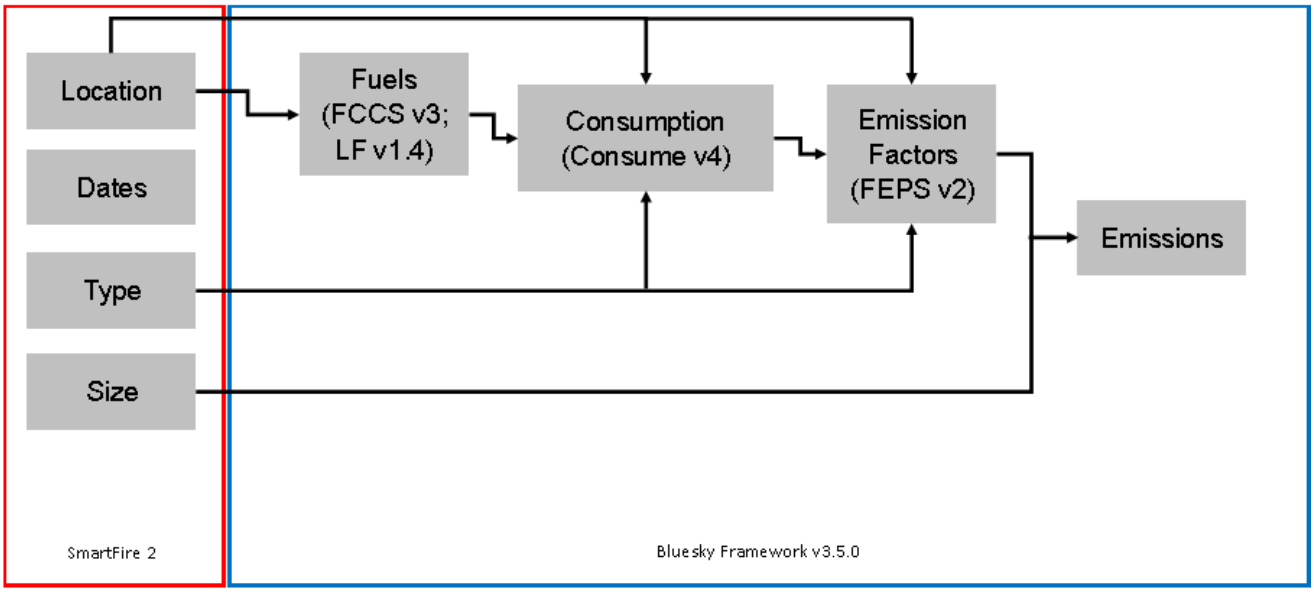


Figure 1b. Default fire type assignment by state and month in cases where a satellite detect is only source of fire information.



The second system used to estimate emissions is the BlueSky Modeling Framework version 3.5 (revision #38169). The framework supports the calculation of fuel loading and consumption, and emissions using various models depending on the available inputs as well as the desired results. The contiguous United States and Alaska, where Fuel Characteristic Classification System (FCCS) fuel loading data are available, were processed using the modeling chain described in Figure 2. The Fire Emissions Production Simulator (FEPS) in the Bluesky Framework generates all the CAP emission factors for wildland fires used in the 2016v1 inventory (need note about HAPS factors).

Figure 2. Blue Sky Modeling Framework



For the 2016v1 inventory, the FCCSv2 spatial vegetation cover was upgraded to the LANDFIRE v1.4 fuel vegetation cover (See: https://www.landfire.gov/fccs.php). The FCCSv3 fuel bed characteristics were implemented along with LANDFIREv1.4 to provide better fuel classification for the BlueSky Framework. The LANDFIREv1.4 raster data was aggregated from the native resolution and projection to 200 meter using a nearest-neighbor methodology. Aggregation and reprojection was required for the proper function on BSF.

4. Ancillary Data

Temporal Allocation

The output from the BlueSky Framework are daily emissions totals for criteria and GHG pollutants. The standard air quality models used by the community for air quality research and regulatory use require emissions at an hourly time scale. SMOKE version 4.7 was used to import the daily inventory files. The temporal program within SMOKE was used to apply available diurnal profiles to generate the required hourly emissions. Figures 3 and 4 display the state-specific diurnal profiles for wildfires and prescribed burns that were used for 2016v1 processing.

Figure 3. State-specific diurnal profiles for wildfires

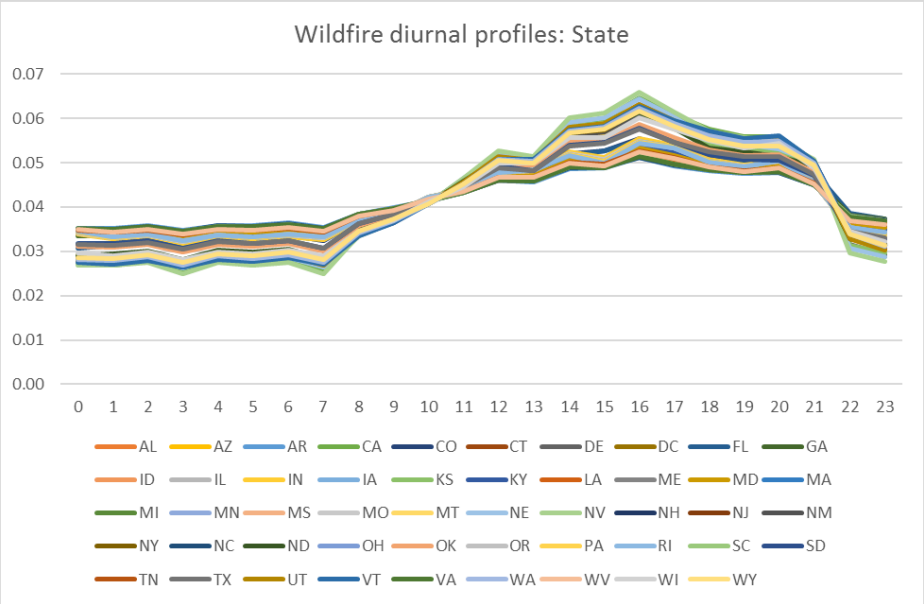
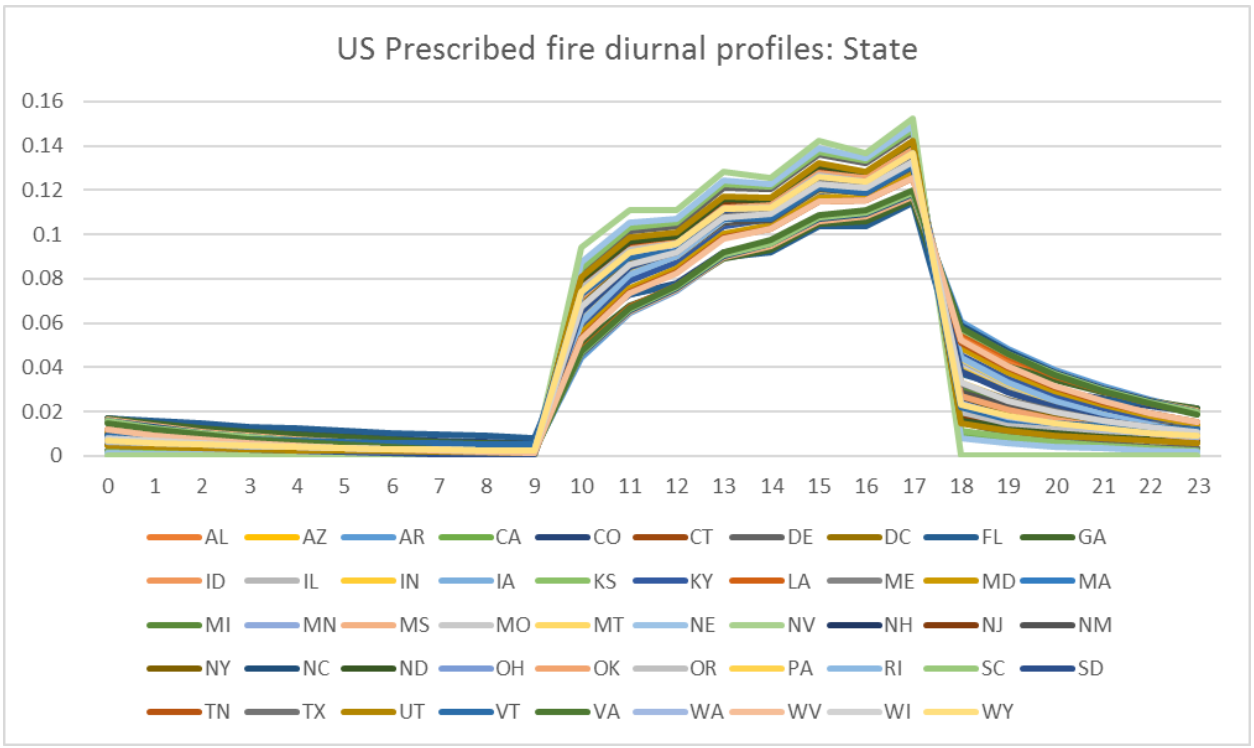


Figure 4. State-specific diurnal profiles for prescribed burns



Chemical Speciation

Chemical speciation is another emissions modeling step taken to support the desired chemical mechanism for an air quality model simulation. SMOKE was used to support Carbon Bond version 6 (CB6) speciation for the 2016v1 inventory. Figures 5 and 6 display the speciation profiles applied for wildfires and prescribed burns for Total Organic Gases (TOG) emissions. Figure 7 displays the speciation profile for wildfire and prescribed burns for PM2.5 emissions. The PM2.5 speciation profile was changed for 2016v1 to use an updated profile available in SPECIATE. Profile 3766AE6 is the new PM2.5 speciation profile. This profile decreases Elemental Carbon (PEC) factor from 9-11% in older profiles to about 3%. The other significant change from the new profile is that the PM other (PMO) factor is increased to 16% from 2% in older profiles.

Figure 5. Total Organic Gases (TOG) speciation profiles for wildfires and map where profile applied for 2016v1

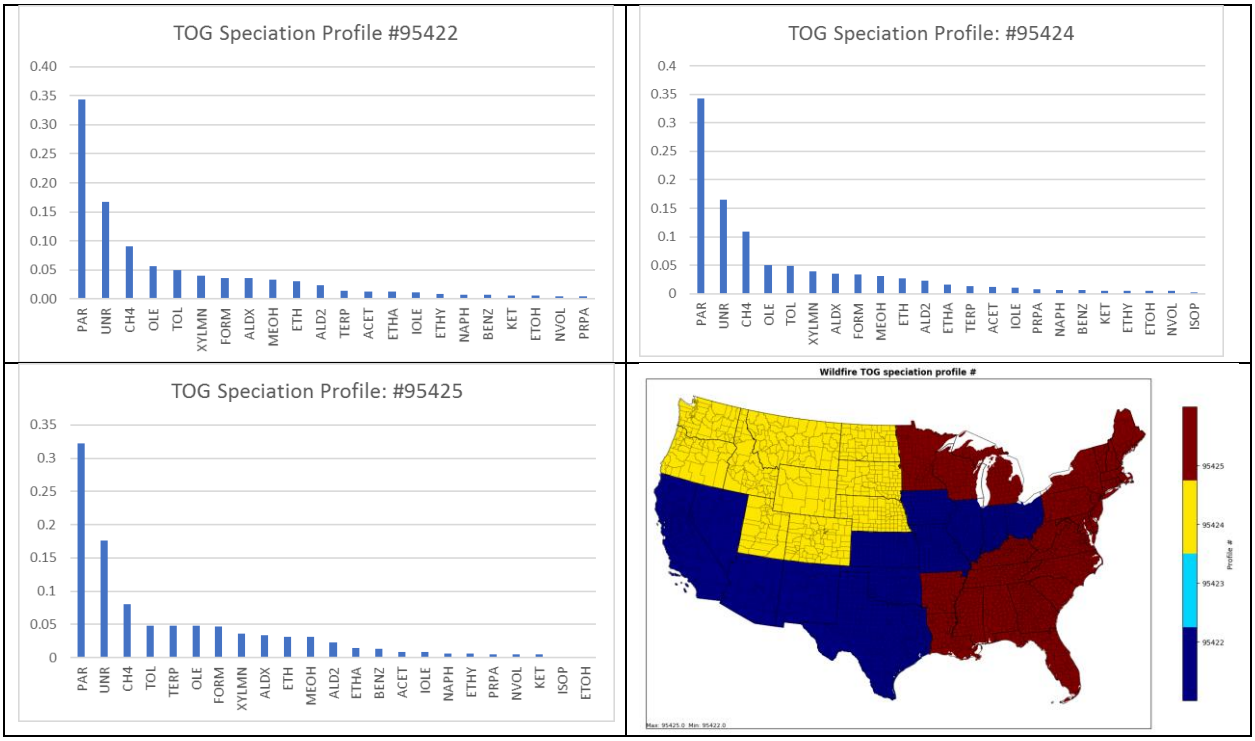


Figure 6. Total Organic Gases (TOG) speciation profiles for prescribed burns and map where profile applied for 2016v1

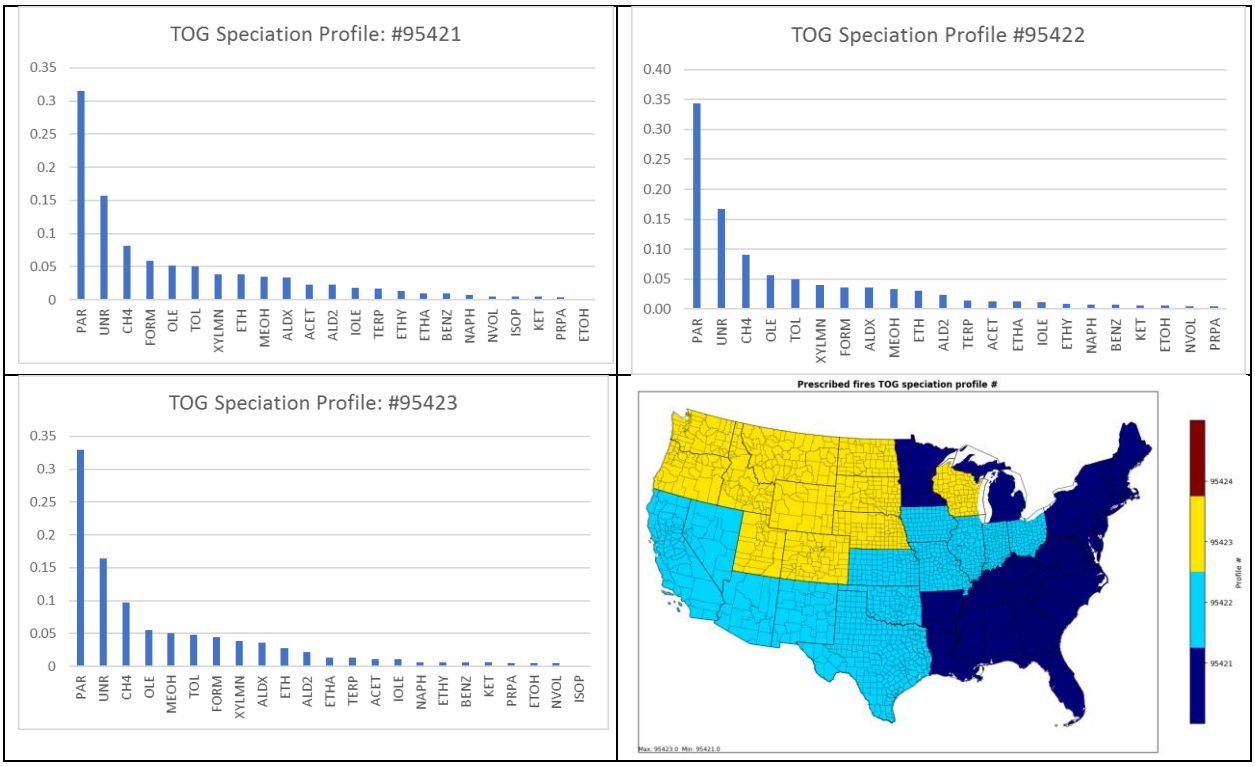
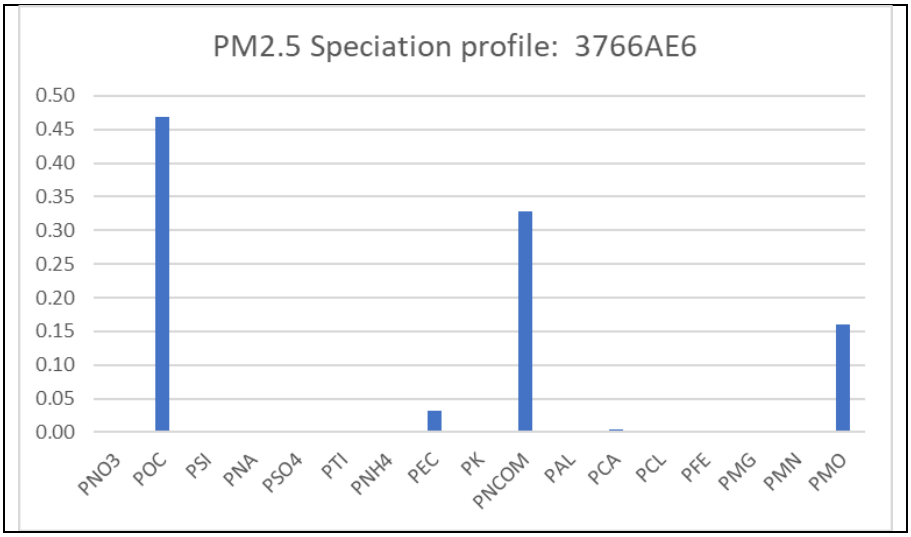


Figure 7. PM2.5 speciation profile for prescribed burns and wildfires for 2016v1



5. Emissions Projection Methods

There are no future-year projections for fires in 2016v1 modeling platform.

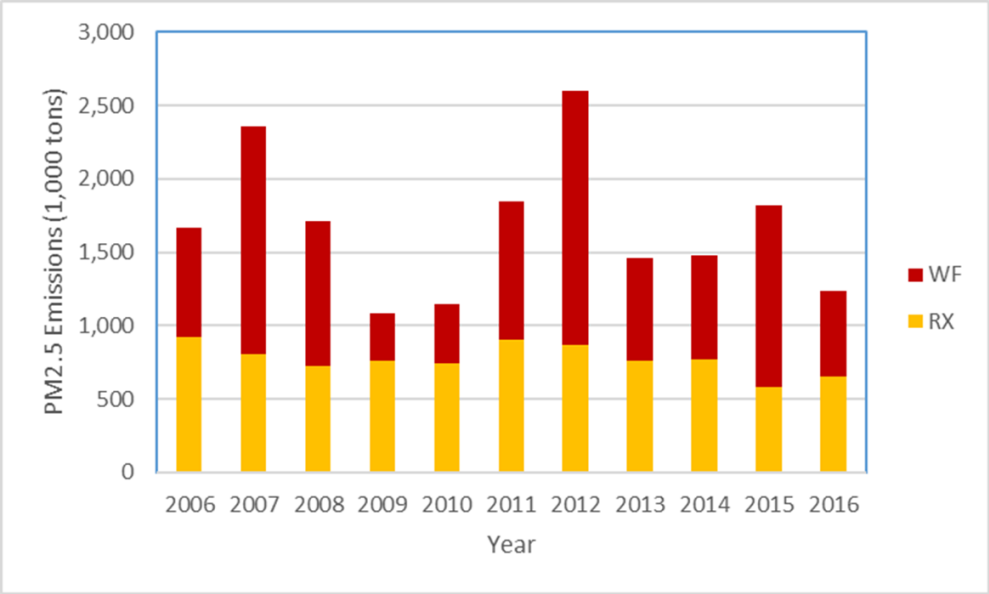
6. Emissions Processing Requirements

The emissions are processed using SMOKE v4.7[1]. Vertical allocation of the fire emissions is usually performed by a plume rise algorithm either in the air quality model (e.g. CMAQ) or outside the air quality model (e.g. using SMOKE). SMOKE has a specific plume-rise calculation for fires.[2] Whichever option is used for plume-rise/vertical allocation, it is recommended that the smoldering emissions from wildfires and prescribed burns be put into the first layer in the in the air quality model (typically 20 or 40 meters high depending on layer profile).

7. Emissions Summaries

Graphical

Figure 8. Annual comparison of PM2.5 emissions for lower 48 states (NEI years are 2008, 2011 and 2014; other years except 2016v1 generated with limited national fire information databases)



[1] see https://www.cmascenter.org/smoke/documentation/4.6/html/

[2] https://www.cmascenter.org/smoke/documentation/4.6/html/ch06s06.html

Figure 9. CONUS and Alaska fire type information for 2016v1 inventory.

Fire Type	Millions of Acres Burned	PM2.5 (tons)	VOC (tons)	NOX (tons)
CONUS Wildfires *	4.7	580,000	1,562,000	99,900
CONUS Prescribed Fires	11.9	655,000	1,547,000	127,500
CONUS Ag Burns	2.0	24,000	18,300	10,800
Alaska All Fires	0.5	263,000	743,000	30,000
Total	19.1	1,522,000	3,870,300	268,200

Figure 10. Wildfire acres burned density by county for 2016v1 inventory

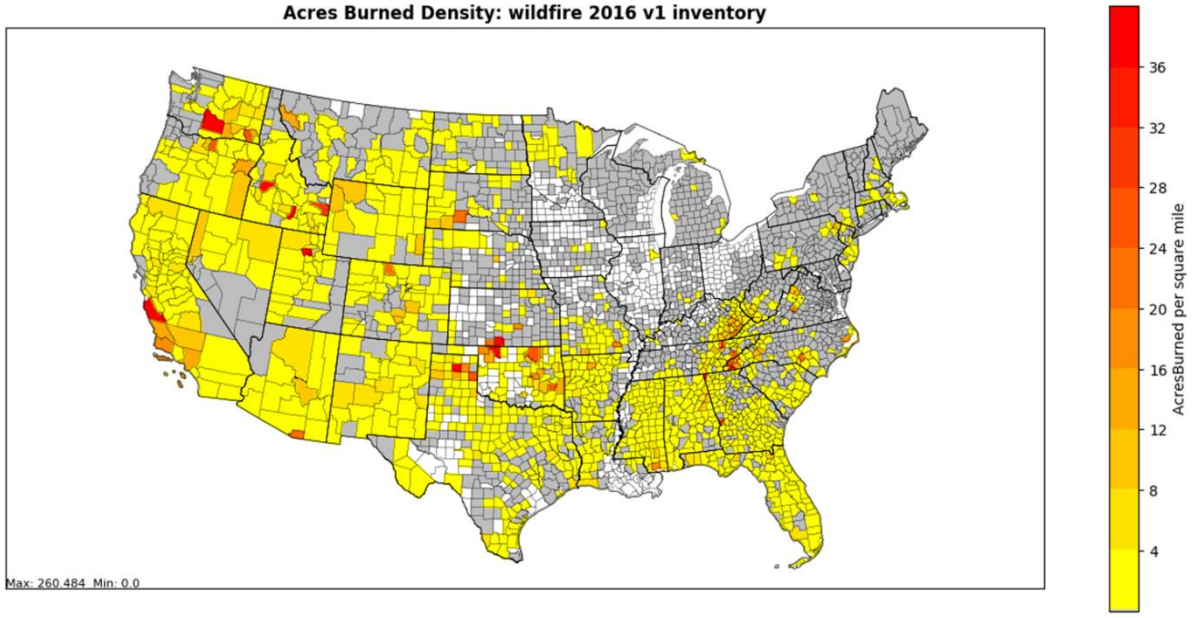


Figure 11. Prescribed acres burned density by county for 2016v1 inventory.

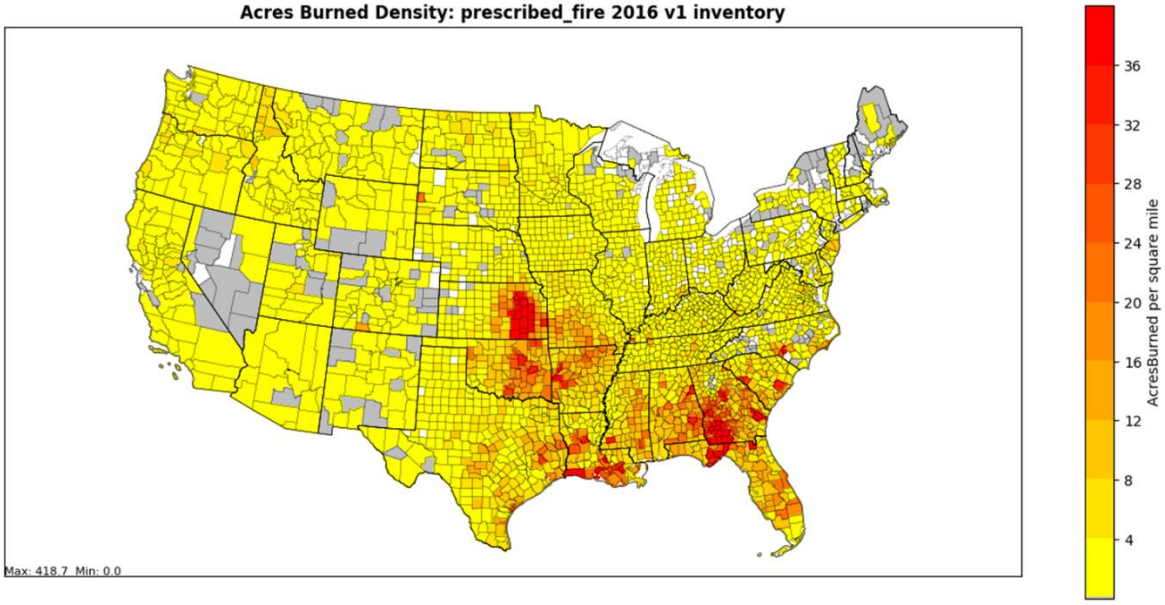


Figure 12. Monthly acres burned (left) and PM2.5 emissions (right) by fire type for 2016v1.

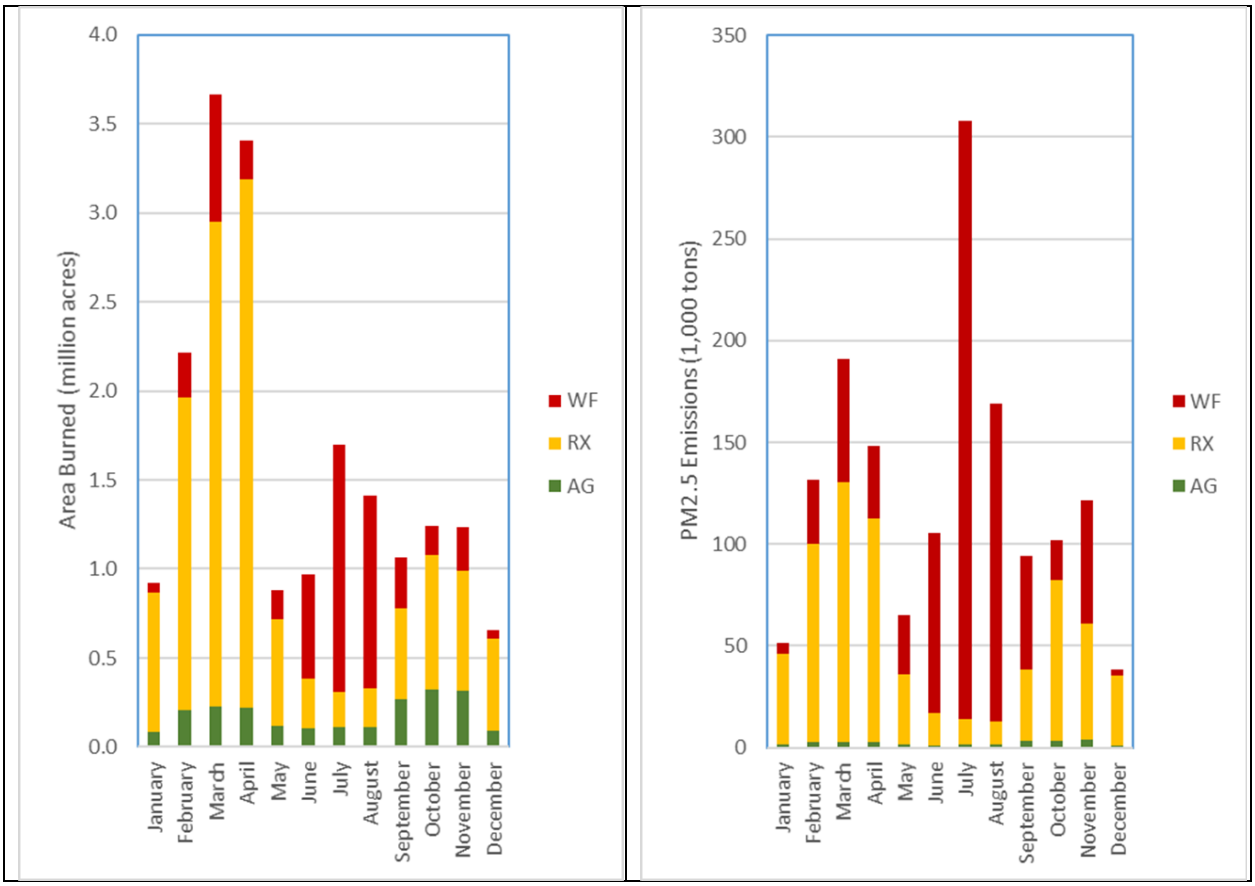
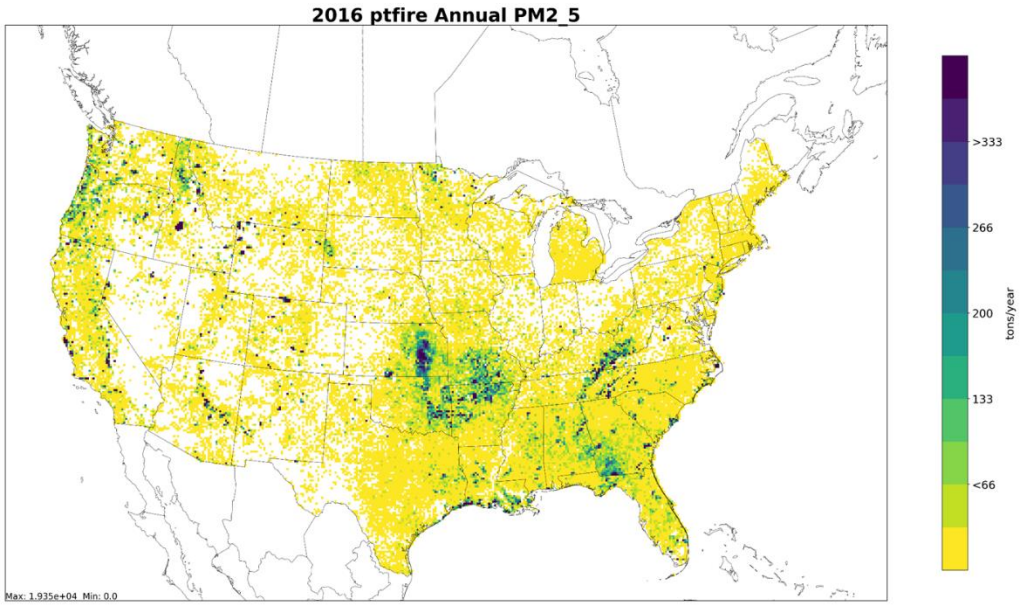


Figure 13. Total annual PM2.5 gridded emissions at 12km resolution for wildfires and prescribed burns.



Tables

National and state totals by pollutant for the 2016v1 platform cases are provided here. Additional plots and maps are available through the LADCO website[3] and the Intermountain West Data Warehouse[4]. The case descriptions are as follows:

2011en, 2023en, 2028el = Final 2011, 2023, and 2028 cases from the 2011v6.3 platform

2014fd = 2014NEIv2 and 2014 NATA

2016fe = 2016 alpha platform

2016ff = 2016 beta platform

2016fh = 2016 v1 platform

Table 5. Comparison of national total annual CAPS ptfire emissions (tons/yr)

Pollutant	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
CO	22,802,146	19,144,792	37,929,946	20,635,054	16,883,233
NH3	365,813	308,886	621,059	352,471	291,300
NOX	352,996	271,366	441,873	287,252	256,984
PM10	2,389,921	1,963,429	3,790,993	2,072,874	1,771,642
PM2.5	2,028,892	1,665,175	3,212,706	1,749,920	1,496,731

[3] https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/

[4] http://views.cira.colostate.edu/iwdw/eibrowser2016

Pollutant	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
SO2	179,118	143,091	261,903	152,735	130,939
VOC	5,213,612	4,440,901	8,927,717	4,731,912	3,852,584

Table 6. Comparison of state total annual NOx ptfire emissions (tons/yr)

State	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
Alabama	14,551	16,472	16,397	7,751	8,673
Alaska	19,093	17,930	108,762	54,958	29,647
Arizona	21,311	4,842	5,287	5,218	5,138
Arkansas	10,967	8,072	17,018	11,865	12,949
California	12,127	37,036	35,009	21,441	16,776
Colorado	4,701	975	1,888	5,898	4,600
Connecticut	12	17	21	43	46
Delaware	22	38	37	20	18
Florida	21,279	23,665	15,750	6,861	7,722
Georgia	38,888	15,668	21,066	15,245	15,245
Hawaii	487	6,153			
Idaho	8,046	7,870	15,689	12,318	12,384
Illinois	1,004	1,997	3,513	1,229	1,390
Indiana	430	925	1,512	562	697
Iowa	1,349	2,745	4,793	1,493	1,417
Kansas	23,338	6,030	8,575	21,443	21,072
Kentucky	3,018	5,044	8,943	6,516	6,624
Louisiana	12,050	9,732	15,269	5,769	5,898
Maine	46	63	171	92	97
Maryland	293	298	213	85	87
Massachusetts	59	57	131	124	125
Michigan	442	487	794	597	435
Minnesota	9,850	4,015	10,200	2,341	2,607
Mississippi	6,791	6,156	6,901	4,501	5,135
Missouri	7,457	9,393	19,038	11,686	12,320
Montana	9,775	3,426	5,699	4,091	4,175
Nebraska	2,529	1,648	972	1,355	1,412
Nevada	1,671	1,552	1,427	1,873	1,752
New Hampshire	9	12	65	58	69
New Jersey	143	765	488	209	473
New Mexico	14,567	1,447	3,226	2,541	2,630
New York	117	207	546	576	406
North Carolina	3,466	2,212	12,711	5,940	5,276
North Dakota	2,344	1,859	2,387	1,704	1,627
Ohio	165	621	1,051	469	459
Oklahoma	20,193	8,454	17,035	17,477	16,729
Oregon	14,222	18,828	14,233	8,384	8,679
Pennsylvania	295	538	1,766	902	956
Rhode Island	15	4	14	3	4
South Carolina	4,011	4,856	4,992	2,782	2,927

State	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
South Dakota	3,777	2,199	3,542	3,784	1,439
Tennessee	2,429	3,570	9,655	6,445	7,083
Texas	38,843	8,737	15,187	10,312	9,862
Utah	1,007	1,175	2,714	1,467	1,865
Vermont	8	20	60	38	40
Virginia	2,890	2,988	4,838	2,973	2,863
Washington	3,037	16,461	7,600	5,833	4,955
West Virginia	1,268	1,965	3,272	2,020	2,110
Wisconsin	566	857	1,366	698	709
Wyoming	8,019	872	10,052	7,262	7,382
Puerto Rico	18	414			

Table 7. Comparison of state total annual Primary PM2.5 ptfire emissions (tons/yr)

State	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
Alabama	61,573	69,117	68,796	35,443	38,572
Alaska	183,808	171,533	1,166,514	499,002	262,669
Arizona	128,329	26,939	31,071	33,601	33,001
Arkansas	64,964	48,493	89,777	62,800	67,923
California	79,353	295,438	252,595	133,588	101,362
Colorado	32,261	6,312	13,544	40,866	32,027
Connecticut	50	68	91	244	237
Delaware	105	160	157	125	112
Florida	88,968	97,306	70,126	33,950	36,936
Georgia	132,861	56,283	89,526		54,423
Hawaii	801	11,150			
Idaho	61,683	54,357	107,288	88,352	88,150
Illinois	5,561	9,901	16,002	7,074	7,662
Indiana	2,275	5,306	7,255	3,302	3,849
Iowa	6,833	12,396	20,730	8,984	8,230
Kansas	84,235	24,405	33,440	100,330	93,432
Kentucky	15,976	30,106	54,026	32,176	31,566
Louisiana	105,165	86,691	163,097	40,240	40,372
Maine	367	477	1,465	664	682
Maryland	2,604	2,836	1,368	500	495
Massachusetts	413	284	740	731	687
Michigan	2,694	2,710	5,294	4,265	3,133
Minnesota	68,168	22,630	111,109	20,267	24,918
Mississippi	29,805	26,913	31,663	21,168	23,394
Missouri	53,610	63,143	99,238	61,471	62,919
Montana	84,736	27,392	40,803	28,762	28,692
Nebraska	10,771	7,530	4,622	7,036	6,508
Nevada	7,124	9,466	7,247	10,072	8,812
New Hampshire	47	56	480	363	392
New Jersey	1,416	7,327	4,974	1,473	3,092

State	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
New Mexico	84,896	9,005	15,663	14,666	15,307
New York	664	1,207	2,911	3,768	2,429
North Carolina	11,744	13,881	86,614	35,156	26,840
North Dakota	14,241	9,870	10,637	10,340	9,414
Ohio	876	3,511	5,390	2,594	2,492
Oklahoma	93,067	41,022	79,147	82,032	73,666
Oregon	121,632	135,074	121,253	68,312	70,649
Pennsylvania	1,867	3,338	11,068	5,639	5,788
Rhode Island	64	16	53	20	20
South Carolina	18,263	22,180	25,104	14,527	15,239
South Dakota	32,403	15,265	30,067	25,069	8,003
Tennessee	11,280	16,576	46,767	30,217	31,863
Texas	194,224	50,670	86,943	48,471	43,198
Utah	6,758	6,486	16,916	9,066	12,120
Vermont	55	112	407	251	247
Virginia	14,698	16,682	27,002	15,262	14,563
Washington	22,503	119,131	53,858	41,750	33,599
West Virginia	7,495	12,676	19,588	10,524	10,720
Wisconsin	3,179	4,314	7,129	4,237	4,200
Wyoming	72,405	6,863	73,151	51,167	52,130
Puerto Rico	19	576			

Table 8. Comparison of state total annual VOC ptfire emissions (tons/yr)

State	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
Alabama	158,720	177,887	177,057	92,637	100,329
Alaska	523,379	488,198	3,346,808	1,414,503	743,119
Arizona	349,159	72,545	84,280	92,157	90,488
Arkansas	176,392	131,900	239,971	167,944	181,406
California	218,043	828,310	701,387	364,981	275,900
Colorado	89,113	17,325	37,587	112,997	88,600
Connecticut	128	172	235	659	632
Delaware	183	413	404	344	305
Florida	228,822	249,469	182,442	89,883	97,263
Georgia	74,976	31,010	230,961	29,964	29,964
Hawaii	2,062	29,665			
Idaho	172,302	150,248	296,242	245,181	244,428
Illinois	14,966	26,219	41,798	19,136	20,607
Indiana	6,082	14,346	19,116	8,957	10,356
Iowa	18,156	32,332	53,655	24,440	22,289
Kansas	210,152	62,376	84,830	166,148	145,805
Kentucky	42,725	81,822	147,052	85,156	83,072

State	2011en, 2023en, 2028el	2014fd	2016fe	2016ff	2016fh
Louisiana	297,155	245,363	467,811	111,344	111,485
Maine	1,029	1,330	4,135	1,845	1,888
Maryland	7,370	8,069	3,751	1,356	1,337
Massachusetts	1,145	754	1,997	1,986	1,845
Michigan	7,342	7,297	14,578	11,831	8,699
Minnesota	188,466	61,048	319,104	57,230	70,912
Mississippi	77,346	69,792	82,802	55,589	61,106
Missouri	148,807	174,023	264,801	164,243	167,380
Montana	239,299	76,815	113,208	79,651	79,266
Nebraska	27,798	19,676	12,160	18,764	17,031
Nevada	18,389	25,796	19,264	26,995	23,389
New Hampshire	125	148	1,336	992	1,058
New Jersey	4,040	20,854	14,222	4,079	8,494
New Mexico	230,032	24,600	41,344	39,687	41,467
New York	1,792	3,269	7,795	10,353	6,603
North Carolina	6,671	37,957	239,063	95,446	71,360
North Dakota	38,791	26,408	27,678	28,161	25,483
Ohio	2,343	9,475	14,346	6,981	6,689
Oklahoma	243,573	108,272	207,421	215,346	191,279
Oregon	343,104	374,844	341,923	191,890	198,439
Pennsylvania	5,109	9,114	30,261	15,414	15,757
Rhode Island	164	42	134	55	52
South Carolina	47,699	57,959	66,628	38,772	40,655
South Dakota	91,426	42,217	84,761	68,980	21,551
Tennessee	29,559	43,436	123,401	79,310	83,045
Texas	515,030	137,205	235,031	127,274	112,059
Utah	18,622	17,449	46,219	24,747	33,278
Vermont	151	303	1,124	691	674
Virginia	39,077	44,946	72,746	40,630	38,717
Washington	62,651	330,883	149,273	115,833	92,690
West Virginia	20,346	34,773	53,255	28,081	28,496
Wisconsin	8,571	11,452	19,025	11,540	11,404
Wyoming	205,153	19,216	203,297	141,729	144,432
Puerto Rico	76	1,878			