

Impacts on a Wildland Emissions Inventory when using the Smoke Emissions Reference Application (SERA) emissions factors: Year 2021 Case Study

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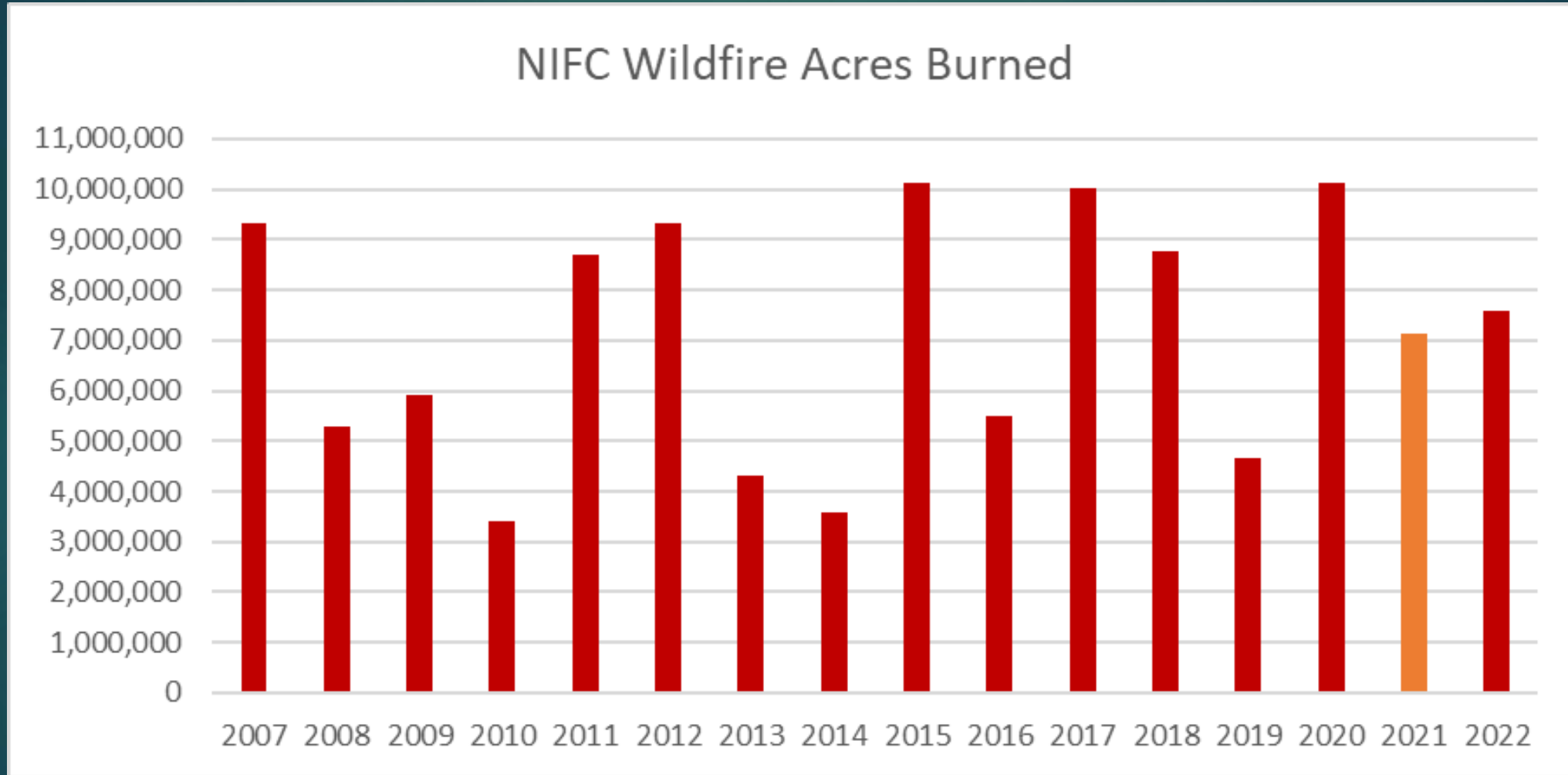
2023 CMAS CONFERENCE

CHAPEL HILL, NC

ACKNOWLEDGE: JAMES BEIDLER (ORD), GEORGE POULIOT (ORD), CHRISTINE ALLEN (GDIT)

2021 Wildfire season: 7.125M acres

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Annual average for period = 7.11M acres

NIFC = National Interagency Fire Center

2021 Wildfire season: Top fires

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Name	State	Start Date	Contain or Last Report Date	Size (acres)
Dixie	CA	7/13	10/23	963,309
Bootleg	OR	7/6	8/13	413,717
Monument	CA	7/31	10/25	223,124
Caldor	CA	8/14	10/20	221,835
River Complex	CA	7/30	10/24	199,359
Telegraph	AZ	6/4	7/2	180,757
Richard Spring	MT	8/8	8/20	171,130
Antelope	CA	8/1	10/14	145,632
McFarland	CA	7/30	9/15	122,653

Key features of 2021 inventory compilation and comparison

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- ▶ Produced **day-specific** emissions for **prescribed burns** and **wildfires**
- ▶ Emissions include Criteria Air Pollutants (CAPs) and Hazard Air Pollutants (HAPs)
- ▶ Used available national/federal **activity databases** with satellite detects from Hazard Mapping System (HMS) (from NOAA/NESDIS¹)
- ▶ Used **Smartfire2** to reconcile detects with all activity databases to produce daily acres burn by fire type (wildfire and prescribed only)
- ▶ Used US Forest Service's **Bluesky Pipeline** to estimate emissions
 - ▶ One run **with Fire Emission Production Simulator (FEPSv2)** emissions factors (used in last 4 NEI cycles)
 - ▶ One run with **Smoke Emissions Reference Application (SERA)** emissions factors
- ▶ Flint Hills grassland prescribed fires handled outside of Bluesky Pipeline
 - ▶ Not using FEPSv2 so not covered in this presentation
- ▶ Emissions are provided for both flaming and smoldering combustion phases

¹ National Oceanic and Atmospheric Administration/National Environmental Satellite, Data, and Information Service

Bluesky Pipeline (BSP)

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- ▶ US Forest Service has significantly updated the Bluesky Framework and named the new system “Bluesky Pipeline”
- ▶ It is open source at <https://github.com/pnwairfire/bluesky>
- ▶ Currently, BSP version 4.2.13 used at EPA
- ▶ EPA has applied BSP for various other years and projects
 - ▶ 2020 NEI Wildland fire emissions (FEPSv2)
 - ▶ EQUATES time series (FEPSv2)
(https://www.epa.gov/cmaq/equates#emissions_modeling)
- ▶ BSP has both SERA and FEPSv2 emissions factors available
- ▶ FEPSv2 factors vary by combustion phase only, limited pollutants
- ▶ SERA factors can vary by phase, fire type, region, fuel type and more pollutants

Smoke Emissions Reference Application (SERA)

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- ▶ SERA is a searchable online database coordinated by the US Forest Service and University of Washington
- ▶ Consists of existing peer-reviewed emission factors (EFs) of 276 known air pollutants
- ▶ EF records include modified combustion efficiency, fuel type, study type, measurement platform (ground, tower or air-based), geographic location and source reference.
- ▶ Database enables the analysis and summaries of existing EFs, and creation of average EFs to be used in decision support tools for smoke management, including BSP
- ▶ SERA was designed to provide a synthesis of existing EFs and summary values for emissions modelling that can facilitate more rapid incorporation of EFs

SMOKE EMISSIONS REFERENCE APPLICATION (SERA)

Emission Factors by Pollutant | [Smoke Emissions References](#)

Filter summaries by:

☐ Include outliers

Combustion Phase

- ☐ Flaming
- ☐ Residual smoldering
- ☐ Smoldering
- ☐ Unspecified

Burn Type

- ☐ Broadcast Rx (Field)
- ☐ Other (Lab)
- ☐ Pile burn (Field)
- ☐ Pile burn (Lab)
- ☐ Wildfire (Field)

Platform*

- ☐ Aerostat
- ☐ Airborne
- ☐ Ground
- ☐ Tower

Region

- ☐ North
- ☐ Southeast
- ☐ West

Vegetation Type

- ☐ Conifer forest
- ☐ Grassland
- ☐ Hardwood forest
- ☐ Mixedwood forest
- ☐ Organic soil
- ☐ Other
- ☐ Shrubland

EPA Pollutant Category

- ☐ Air Toxin (TOX)
- ☐ Critical Air Pollutant (CAP)
- ☐ Greenhouse Gas (GHG)
- ☐ Hazardous Air Pollutant (HAP)
- ☐ Ozone Depleting Substance (ODZ)
- ☐ Ozone Precursor (OZP)
- ☐ Persistent Bioaccumulative Toxic (PBT)

Slash

- ☒ Exclude (default)
- ☐ Include
- ☐ Slash-only

► Advanced search

Use checkboxes in the table below to further limit output to selected pollutants.

Apply filter

Reset

*Platform applies only to field burns (i.e., broadcast Rx, pile burn, or wildfire). Lab burn + platform will yield 0 records.

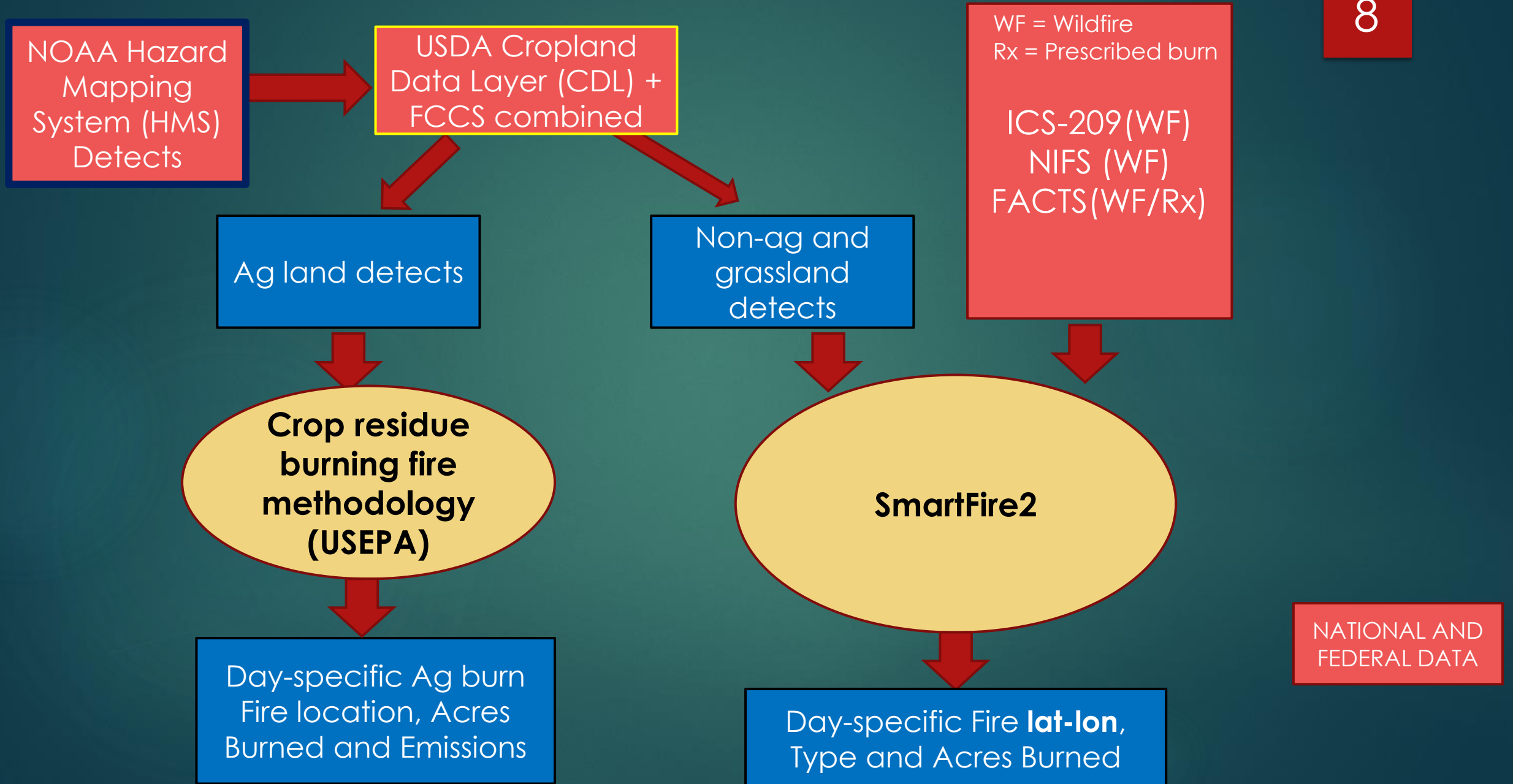
[Download this summary table](#) | [Download source EFs for this summary table](#)

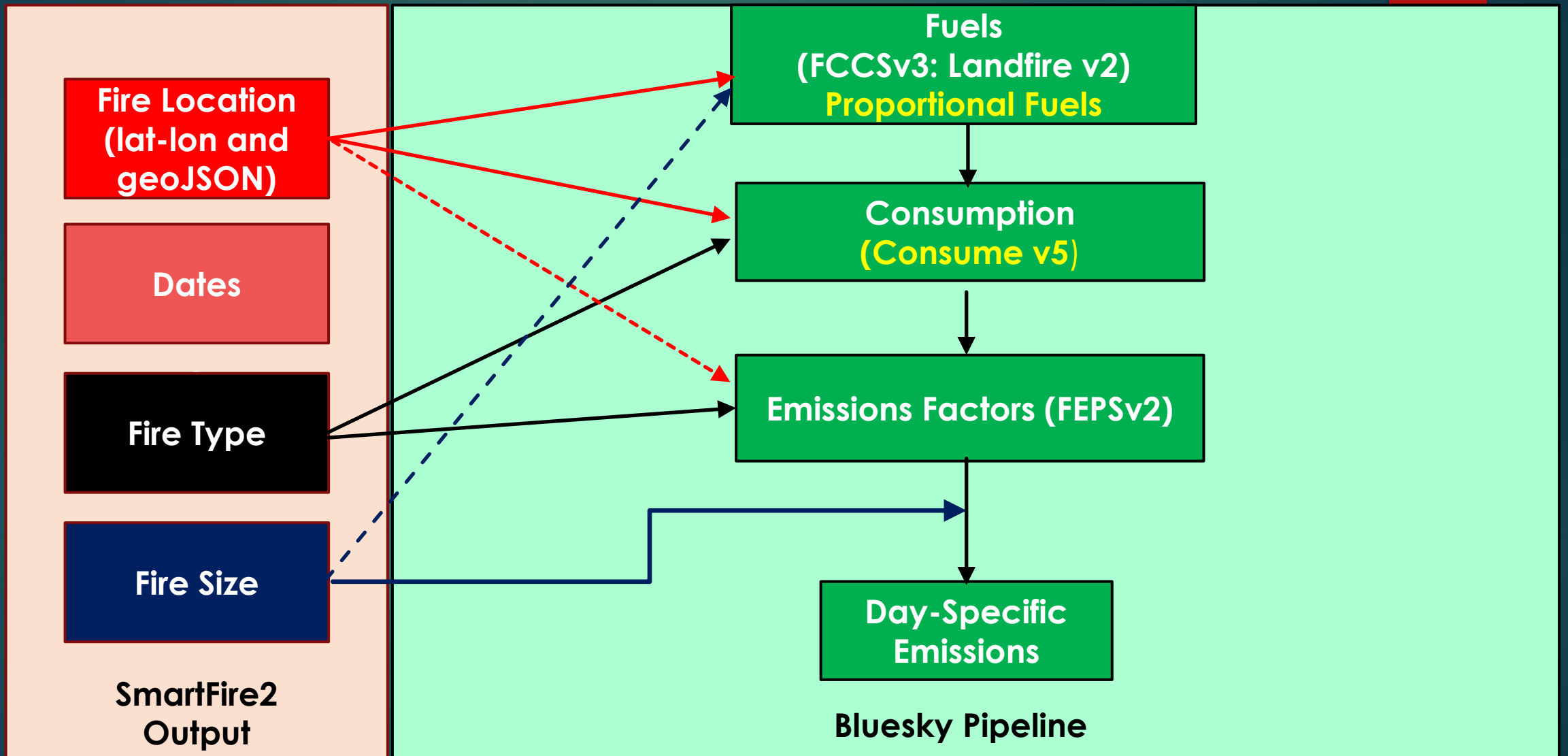
Emission Factor Summaries: Showing all 279 pollutants, across all categories (excluding outliers and slash)

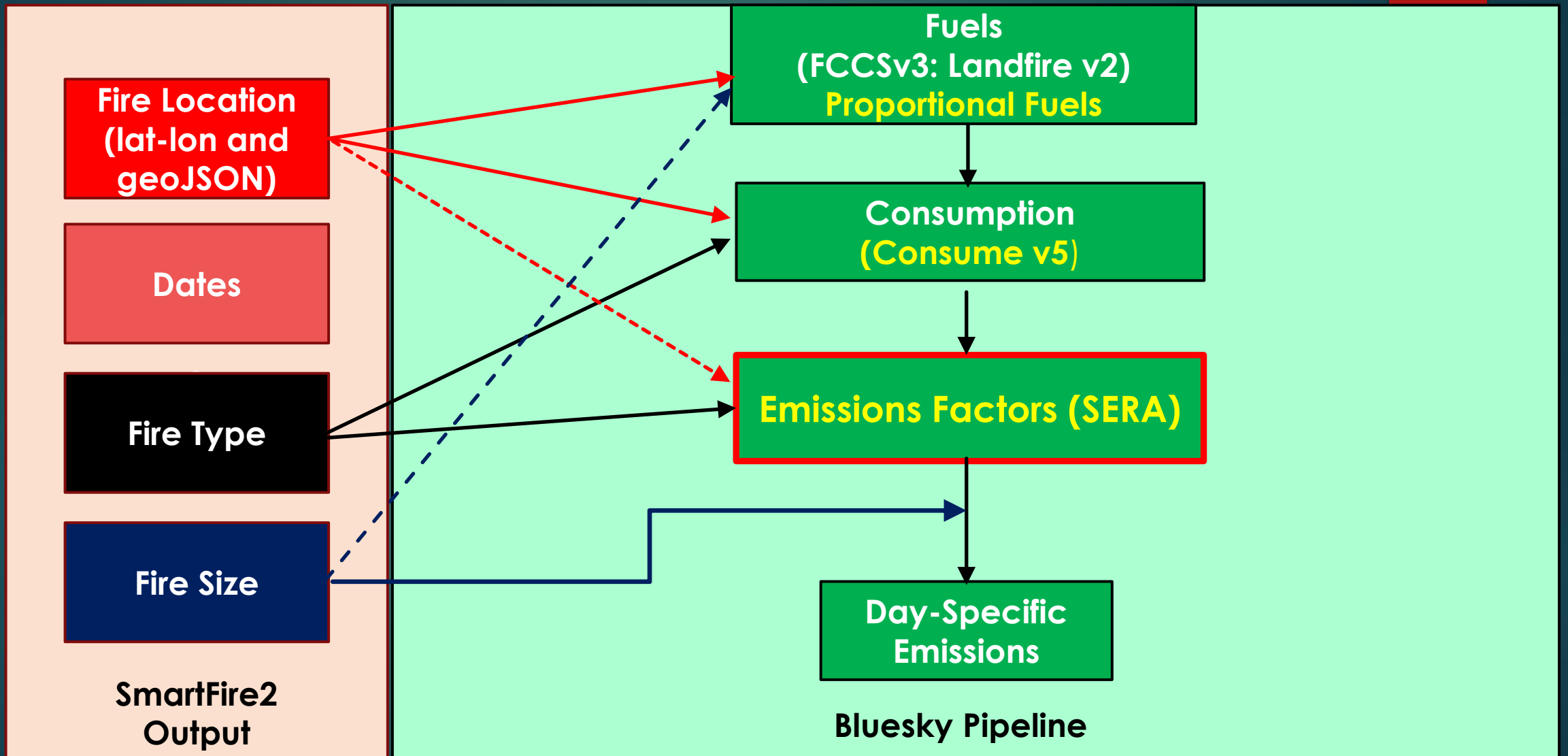
	Pollutant	Formula	Pollutant Category	Molecular Wt	Count	EF (g/kg) Mean	EF (g/kg) SD	MCE (0-1) Mean	MCE (0-1) SD
Primary Gases/Aerosols									
☐	ammonia	NH ₃	inorganic gases	17.031	199	1.386	1.445	0.910	0.059
☐	carbon dioxide	CO ₂	inorganic gases	44.009	599	1,605.958	154.744	0.906	0.047
☐	carbon monoxide	CO	inorganic gases	28.01	658	98.678	49.264	0.901	0.056
☐	methane	CH ₄		16.043	481	4.657	3.456	0.904	0.047
☐	nitric oxide	NO	nitrogen oxides	30.006	186	2.148	1.600	0.928	0.038

Smartfire2 and Agriculture burn processing for 2021

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CONUS Wildland Criteria Air Pollutant Emissions Totals (tons)

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	FEPS Wildland fires (tons)	SERA Wildland fires (tons)	SERA-FEPS Wildland fires difference (tons)	SERA-FEPS Wildland fires % difference
ACRESBURNED	18,123,141	18,123,141	0	0.0%
PM2_5	2,336,938	4,774,648	2,437,710	104.3%
PM10	2,757,587	5,244,266	2,486,679	90.2%
SO2	204,842	251,029	46,187	22.5%
VOC	6,386,970	6,798,178	411,208	6.4%
CO	27,065,770	23,569,110	-3,496,660	-12.9%
NOX	374,027	286,099	-87,928	-23.5%
NH3	444,311	252,003	-192,308	-43.3%

CONUS Emissions Totals (tons) by fire type

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	FEPS Prescribed Burns (tons)	SERA Prescribed Burns (tons)	SERA-FEPS Prescribed burns difference (tons)	SERA-FEPS Prescribed burns % difference	FEPS Wildfires (tons)	SERA Wildfires (tons)	SERA-FEPS Wildfires difference (tons)	SERA-FEPS Wildfires % difference
ACRESBURNED	10,704,618	10,704,618	0	0.0%	7,418,523	7,418,523	0	0.0%
PM2_5	728,879	1,192,107	463,228	63.6%	1,608,059	3,582,541	1,974,482	122.8%
PM10	860,077	1,385,423	525,346	61.1%	1,897,510	3,858,843	1,961,333	103.4%
SO2	72,168	82,475	10,308	14.3%	132,674	168,553	35,879	27.0%
VOC	1,930,204	1,903,837	-26,367	-1.4%	4,456,766	4,894,341	437,575	9.8%
CO	8,138,629	7,463,283	-675,345	-8.3%	18,927,141	16,105,827	-2,821,315	-14.9%
NOX	147,042	127,073	-19,969	-13.6%	226,984	159,026	-67,958	-29.9%
NH3	134,275	85,589	-48,686	-36.3%	310,036	166,414	-143,622	-46.3%

NIFC Wildfire acres burned = 7.125M

CONUS Emissions Totals (tons) by phase type

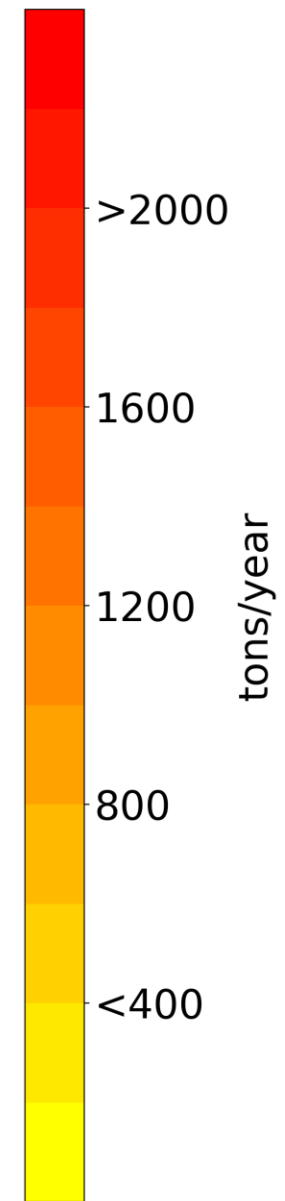
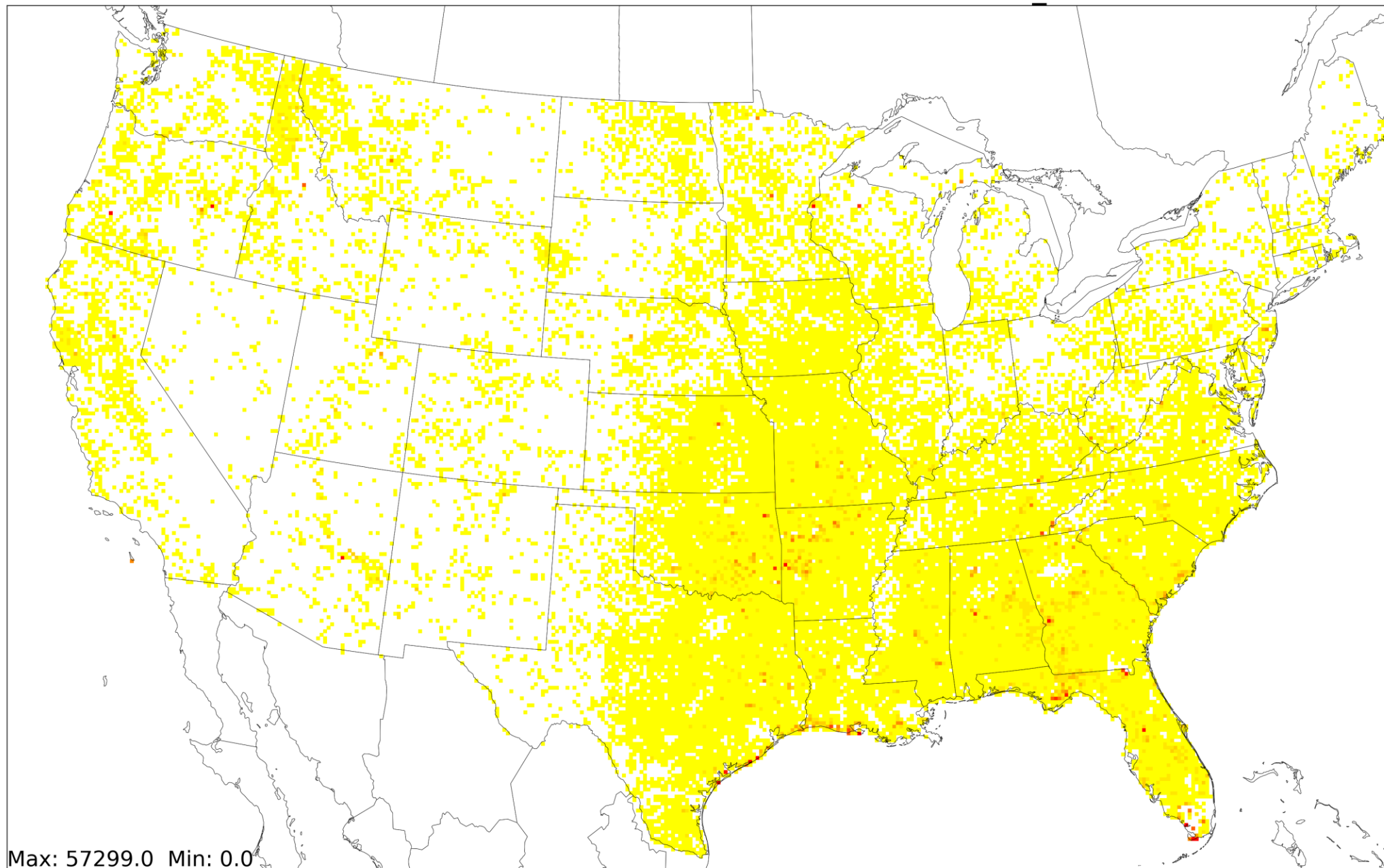
13

FEPS EFs used	Prescribed burns residual smoldering (tons)	Prescribed burns flaming (tons)	Prescribed burns residual smoldering (% of total)	Prescribed burns flaming (% of total)	Prescribed burns total (tons)	Wildfires residual smoldering (tons)	Wildfires residual flaming (tons)	Wildfires residual smoldering (% of total)	Wildfires flaming (% of total)
ACRESBURNED	10,704,618				10,704,618	7,418,523			
CO	1,247,227	6,891,402	15.3%	84.7%	8,138,629	6,130,508	12,796,634	32.4%	67.6%
NH3	20,244	114,031	15.1%	84.9%	134,275	99,507	210,529	32.1%	67.9%
NOX	5,390	141,652	3.7%	96.3%	147,042	26,492	200,492	11.7%	88.3%
PM2_5	98,724	630,155	13.5%	86.5%	728,879	485,259	1,122,800	30.2%	69.8%
SO2	5,817	66,350	8.1%	91.9%	72,168	28,593	104,082	21.6%	78.4%
VOC	291,012	1,639,191	15.1%	84.9%	1,930,204	1,430,417	3,026,349	32.1%	67.9%

SERA EFs used	Prescribed burns residual smoldering (tons)	Prescribed burns flaming (tons)	Prescribed burns residual smoldering (% of total)	Prescribed burns flaming (% of total)	Prescribed burns total (tons)	Wildfires residual smoldering (tons)	Wildfires residual flaming (tons)	Wildfires residual smoldering (% of total)	Wildfires flaming (% of total)
ACRESBURNED	10,704,618				10,704,618	7,418,523			
CO	1,360,672	6,102,611	18.2%	81.8%	7,463,283	6,901,647	9,204,179	42.9%	57.1%
NH3	7,432	78,157	8.7%	91.3%	85,589	37,680	128,734	22.6%	77.4%
NOX	1,683	125,390	1.3%	98.7%	127,073	7,758	151,269	4.9%	95.1%
PM2_5	192,507	999,600	16.1%	83.9%	1,192,107	975,950	2,606,592	27.2%	72.8%
SO2	3,875	78,600	4.7%	95.3%	82,475	19,394	149,159	11.5%	88.5%
VOC	291,402	1,612,434	15.3%	84.7%	1,903,837	1,479,840	3,414,501	30.2%	69.8%

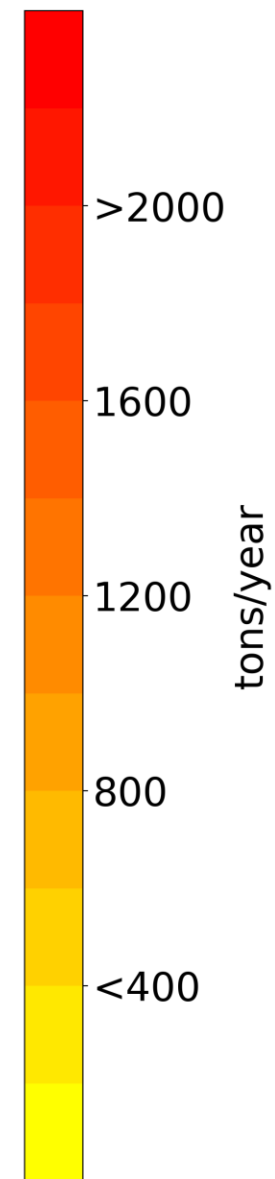
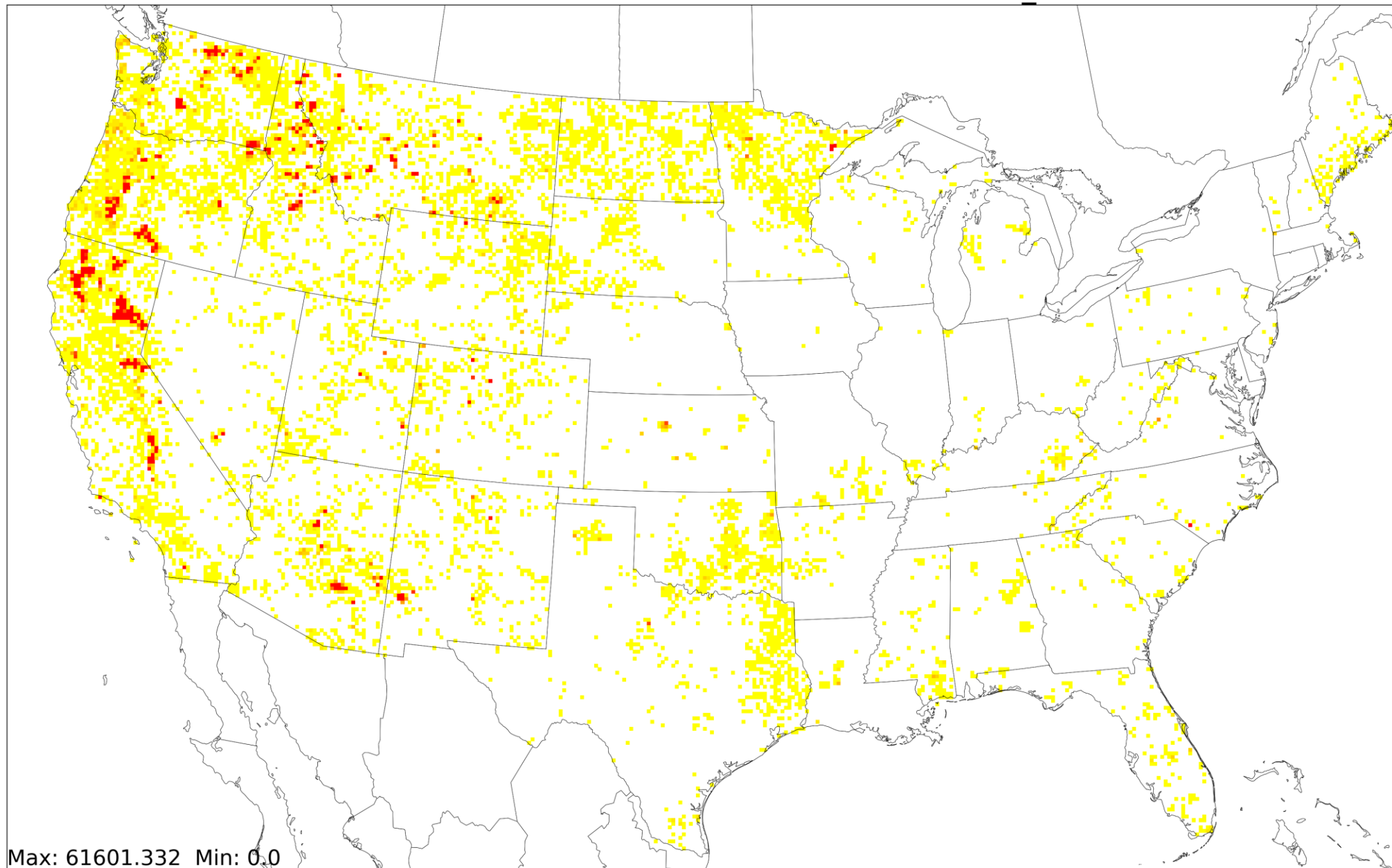
2021 Prescribed fire

SERA Annual PM2_5



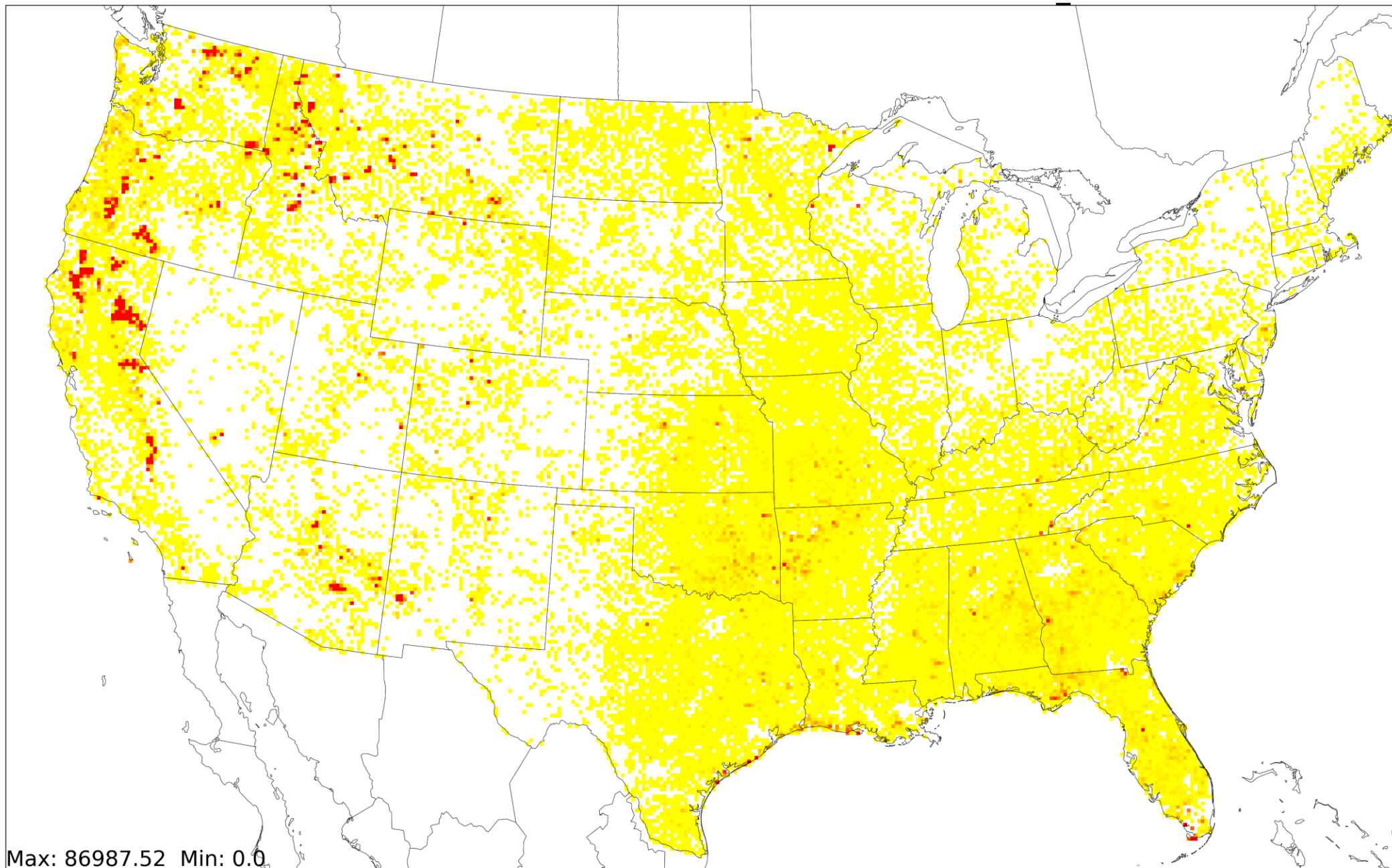
Max: 57299.0 Min: 0.0

2021 Wildfires fire WF SERA Annual PM2_5



Max: 61601.332 Min: 0.0

2021 Wildfires+Prescribed SERA Annual PM2_5



>2000

1600

1200

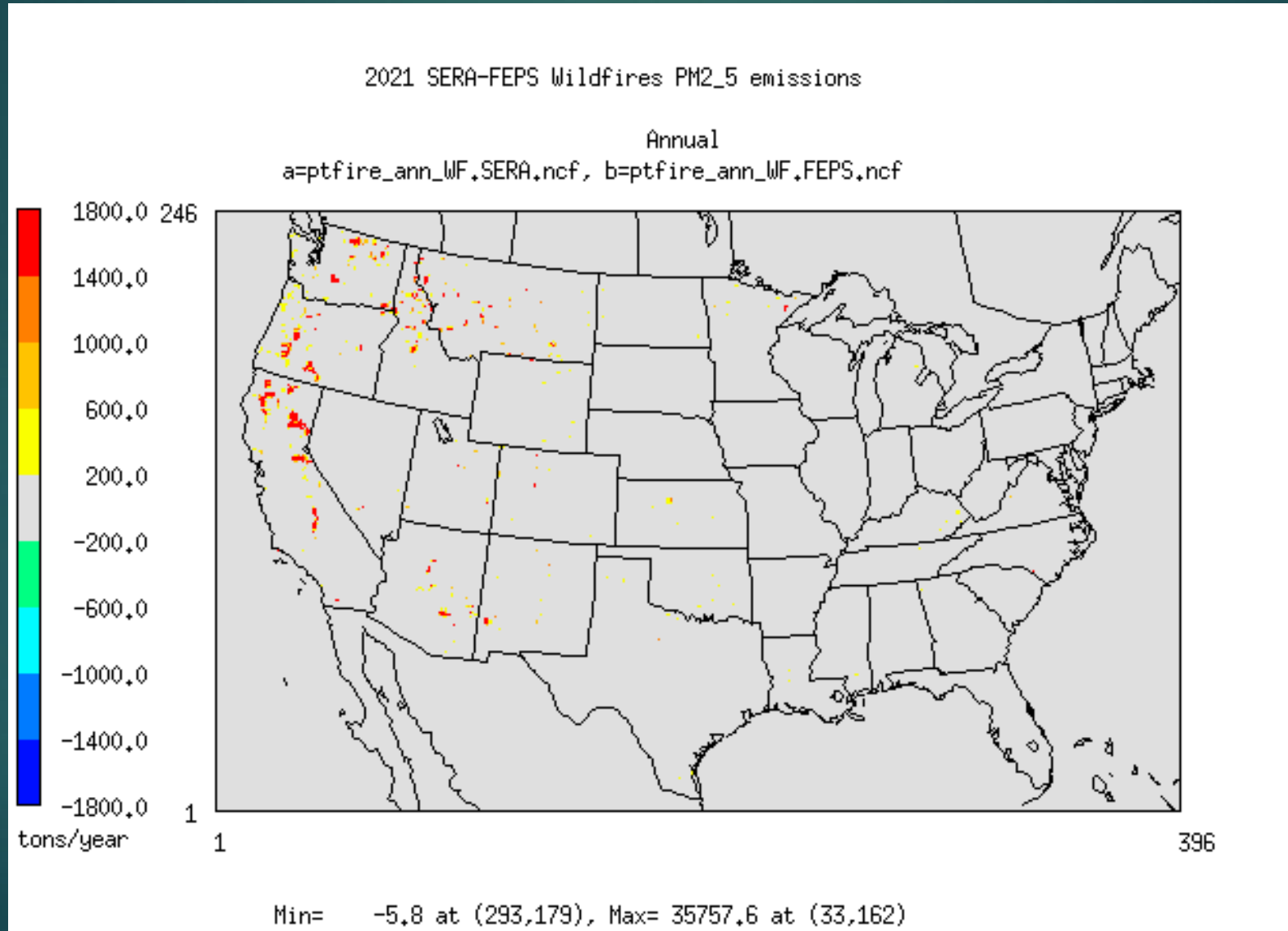
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tons/year

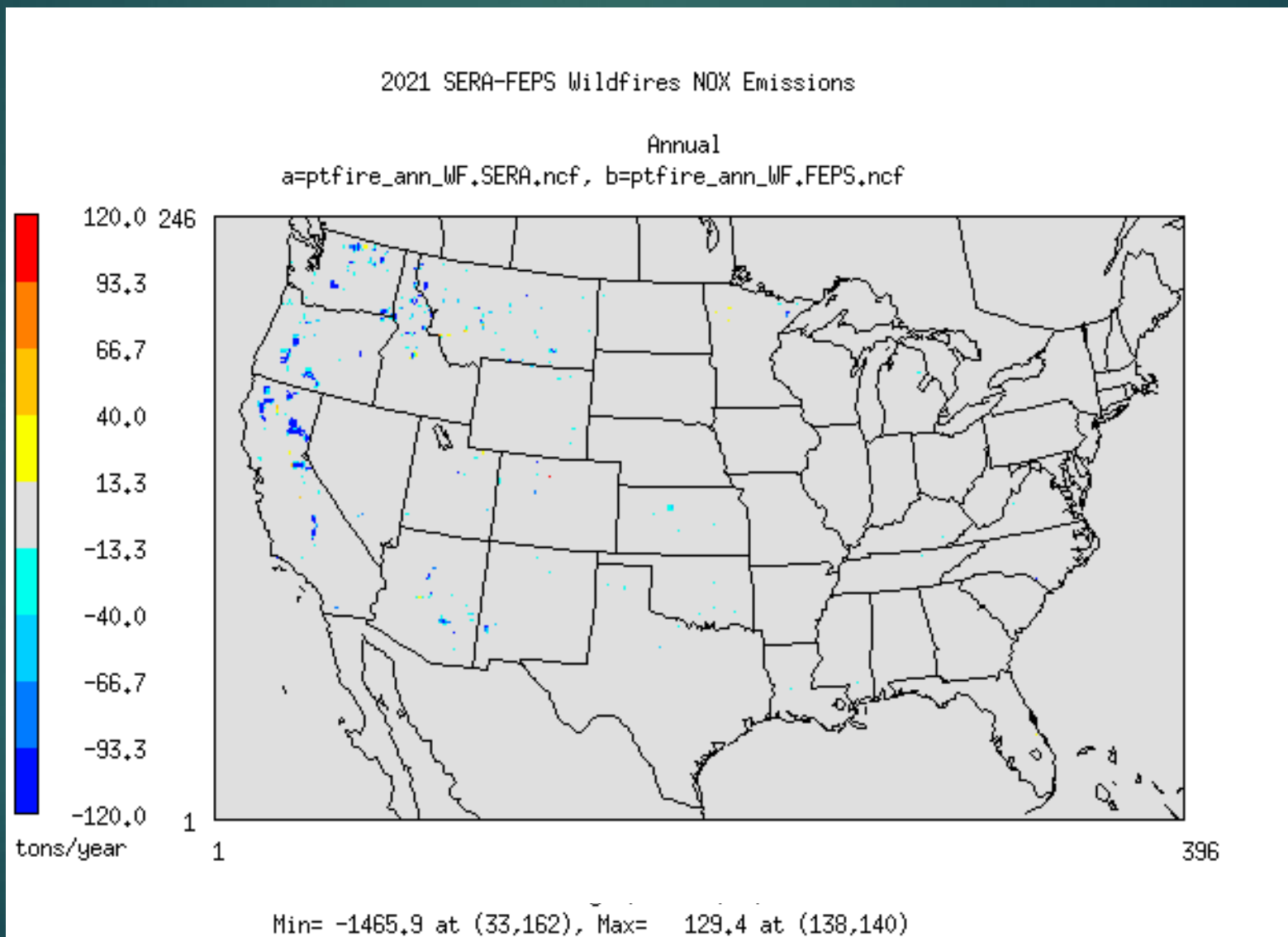
PM2.5 Wildfire emissions difference: SERA minus FEPS

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NOx Wildfire emissions difference: SERA minus FEPS

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Top Wildfires emissions changes (tons) by state

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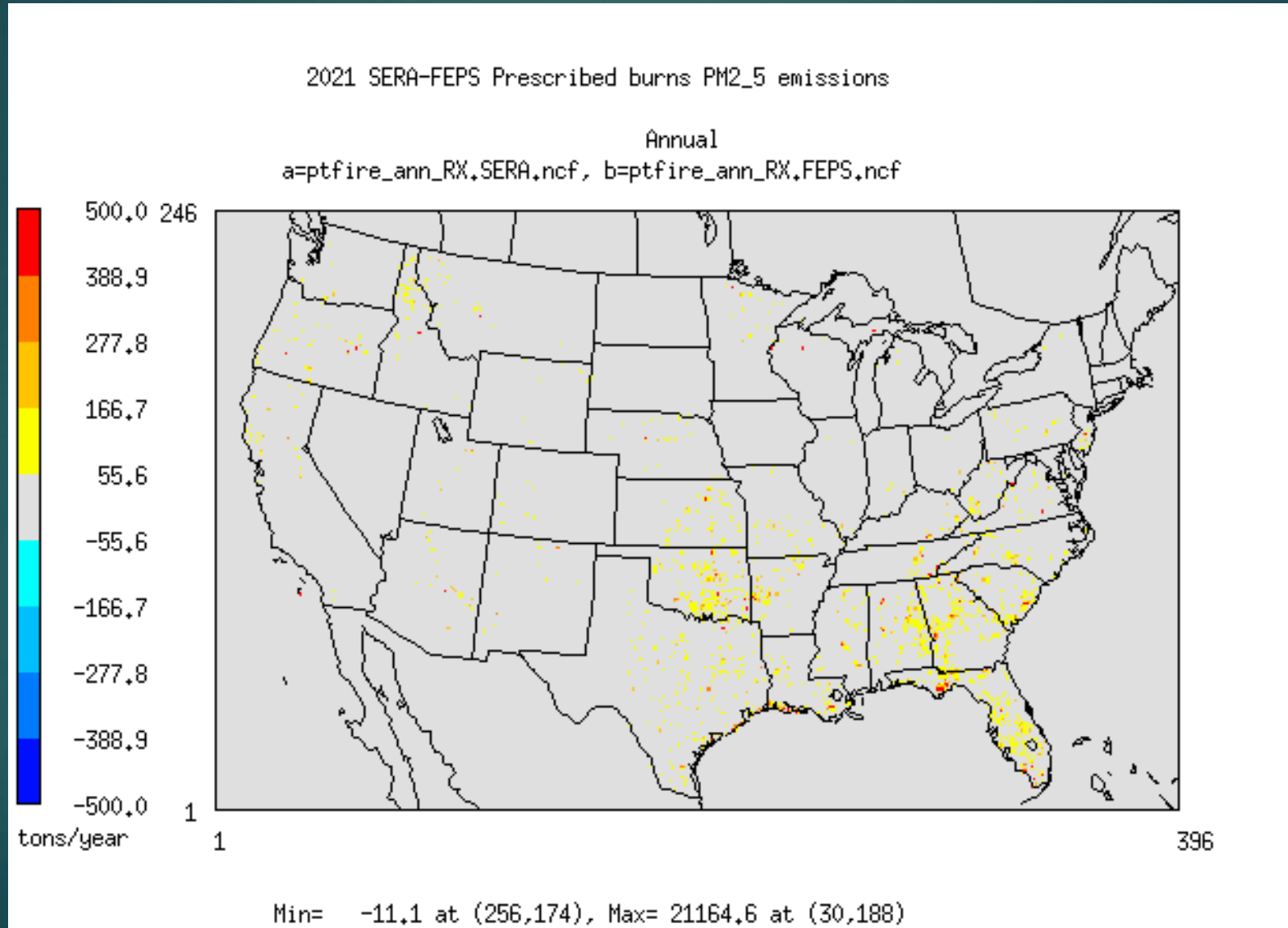
Wildfires	ACRES BURNED	FEPS PM2_5	SERA PM2_5	SERA- FEPS PM2_5	SERA- FEPS PM2_5 %diff
California	2,585,064	752,929	1,709,715	956,786	127.1%
Oregon	986,379	292,980	627,778	334,798	114.3%
Washington	772,674	162,071	367,362	205,291	126.7%
Montana	805,762	138,262	292,054	153,792	111.2%
Idaho	515,262	112,484	241,905	129,422	115.1%

Wildfires	ACRES BURNED	FEPS NOX	SERA NOX	SERA- FEPS NOX	SERA- FEPS NOX %diff
California	2,585,064	101,881	67,650	-34,231	-33.6%
Oregon	986,379	40,998	29,035	-11,963	-29.2%
Washington	772,674	24,215	16,338	-7,877	-32.5%
Montana	805,762	20,112	15,792	-4,321	-21.5%
Idaho	515,262	15,161	11,060	-4,102	-27.1%

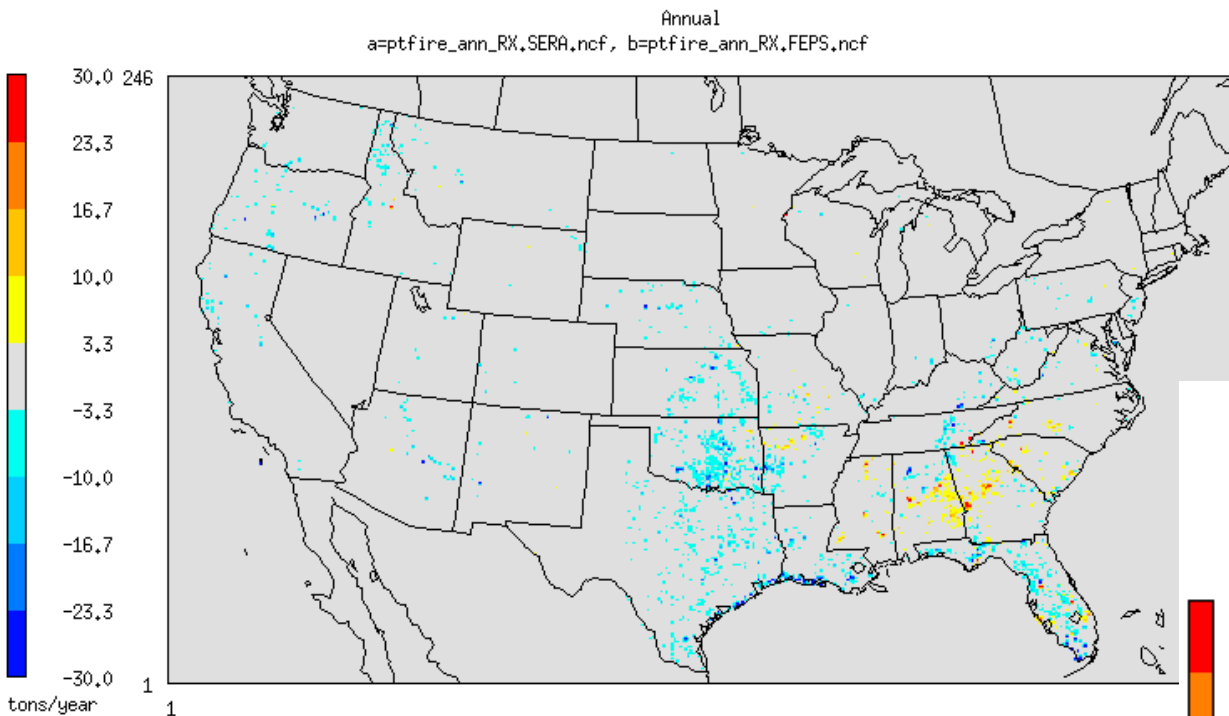
Wildfires	ACRES BURNED	FEPS VOC	SERA VOC	SERA- FEPS VOC	SERA- FEPS VOC %diff
California	2,585,064	2,095,710	2,329,959	234,249	11.2%
Washington	772,674	446,460	507,852	61,393	13.8%
Oregon	986,379	812,726	856,260	43,533	5.4%
Montana	805,762	381,983	416,395	34,413	9.0%
Idaho	515,262	313,209	343,831	30,623	9.8%
Minnesota	60,534	123,389	91,187	-32,201	-26.1%

PM2.5 Prescribed burn emissions difference: SERA minus FEPS

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2021 SERA - FEPS Prescribed burn NOx emissions difference



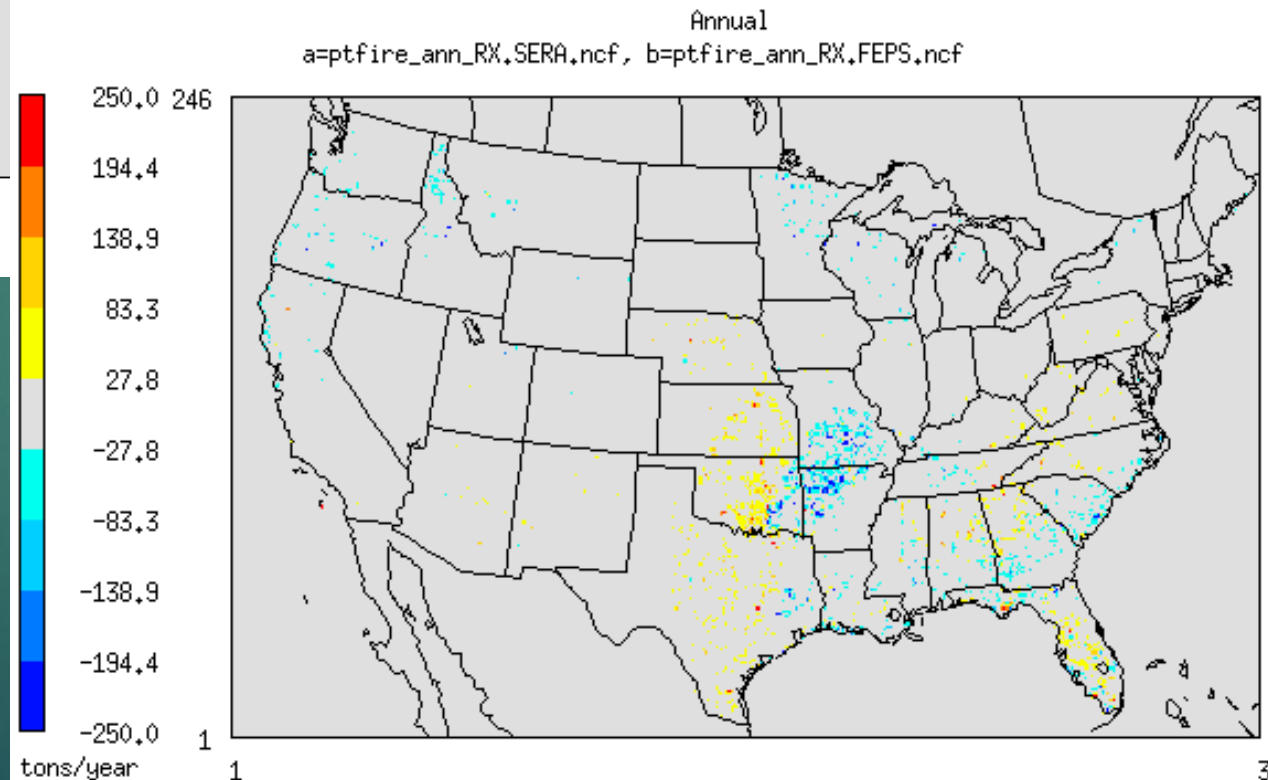
Min= -1358,5 at (30,188), Max= 80,9 at (297,72)

NOx

21

Prescribed burn emissions difference: SERA minus FEPS

2021 SERA-FEPS Prescribed burn VOC emissions difference



VOC

Top Prescribed burn emissions changes (tons) by state

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Prescribed burns	ACRES BURNED	FEPS PM2_5	SERA PM2_5	SERA-FEPS PM2_5	SERA-FEPS PM2_5 %diff
Texas	1,550,344	70,857	128,449	57,592	81%
Florida	1,314,320	88,732	144,539	55,807	63%
Georgia	1,072,810	67,128	102,665	35,537	53%
Oklahoma	853,114	46,777	81,606	34,830	74%
Oregon	176,392	49,675	79,899	30,224	61%

Prescribed burns	ACRES BURNED	FEPS NOX	SERA NOX	SERA-FEPS NOX	SERA-FEPS NOX %diff	Prescribed burns	ACRES BURNED	FEPS VOC	SERA VOC	SERA-FEPS VOC	SERA-FEPS VOC %diff
Georgia	1,072,810	15,927	16,563	636	4%	Texas	1,550,344	184,725	205,083	20,358	11%
Alabama	673,033	10,741	11,253	512	5%	Kansas	502,336	37,964	48,140	10,176	27%
South Carolina	372,238	5,400	5,696	297	5%	Oklahoma	853,114	121,116	130,483	9,368	8%
Mississippi	326,276	4,893	5,143	250	5%	Nebraska	177,288	16,280	19,866	3,586	22%
North Carolina	244,709	3,795	3,924	129	3%	Virginia	125,065	24,429	27,093	2,664	11%
Louisiana	432,332	6,555	4,876	-1,679	-26%	Idaho	101,379	37,854	34,147	-3,706	-10%
Oregon	176,392	5,690	3,730	-1,960	-34%	Florida	1,314,320	234,410	229,180	-5,231	-2%
Florida	1,314,320	18,179	15,527	-2,653	-15%	Missouri	538,550	107,143	92,703	-14,439	-13%
Oklahoma	853,114	10,791	7,942	-2,850	-26%	Oregon	176,392	140,368	121,241	-19,127	-14%
Texas	1,550,344	15,727	11,395	-4,332	-28%	Arkansas	552,864	144,322	124,086	-20,236	-14%

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Top PM2₅
Emitting Acres
Burned-Fuels
In 2021 for
Wildfires

State	FCCS fuel description	Wildfires acres burned	FEPS PM2 ₅ (tons)	SERA PM2 ₅ (tons)	SERA- FEPS (tons)	SERA- FEPS % diff
California	Giant sequoia-white fir-sugar pine forest	523,673	210,782	457,486	246,703	117.0%
Oregon	Western hemlock-Douglas-fir-western redcedar/vine maple forest	182,097	132,214	284,724	152,510	115.4%
California	Red fir-mountain hemlock-lodgepole pine-western white pine forest	283,454	82,638	189,460	106,822	129.3%
California	Douglas-fir-tanoak-madrone-bay forest	98,733	40,711	95,624	54,913	134.9%
California	Sugar pine-Douglas-fir-oak forest	159,496	25,331	73,589	48,257	190.5%
Oregon	Pacific ponderosa pine forest	140,224	29,715	71,456	41,741	140.5%
Washington	Western hemlock-western redcedar-Douglas-fir forest	69,646	30,781	70,936	40,154	130.4%
Washington	Douglas-fir-Pacific ponderosa pine/oceanspray forest	168,597	27,276	70,685	43,409	159.1%
California	Jeffrey pine-red fir-white fir/greenleaf-snowbrush forest	40,640	30,240	64,759	34,519	114.2%

State	FCCS fuel description	Prescribed burns acres burned	FEPS PM2 ₅ (tons)	SERA PM2 ₅ (tons)	SERA- FEPS (tons)	SERA- FEPS % diff
Oregon	Western hemlock-Douglas-fir-western redcedar/vine maple forest	60,599	38,033	60,310	22,277	58.6%
Louisiana	Smooth cordgrass-black needlerush grassland	136,962	17,791	29,320	11,529	64.8%
Florida	Mangrove forest	41,674	16,036	23,299	7,263	45.3%
Arkansas	White oak-northern red oak forest	99,286	17,045	17,115	70	0.4%
Texas	Smooth cordgrass-black needlerush grassland	29,753	9,605	15,864	6,258	65.2%
Texas	Pasture, hay, or alfalfa field - grazed or harvested	195,645	7,163	15,320	8,157	113.9%
Georgia	Slash pine plantation forest	203,748	13,905	14,410	505	3.6%
Missouri	White oak-northern red oak forest	70,272	12,860	12,824	-36	-0.3%
Oklahoma	Post-blackjack oak forest	117,642	5,571	11,788	6,218	111.6%

Top PM2₅
Emitting Acres
Burned-Fuels
In 2021 for
Prescribed
burns

PM2.5 Emissions Budget: 2020NEI Anthropogenic + 2021 CONUS Wildland fires

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FEPS

SERA

2020NEI w/ 2021 fires	PM2.5 (tons)	% contribution		2020NEI w/ 2021 fires	PM2.5 (tons)	% contribution
Wildfires (FEPS)	1,608,059	28.2%		Wildfires (SERA)	3,582,541	44.0%
Fugitive Dust	886,379	15.5%		Prescribed Burning (SERA)	1,192,107	14.6%
Fuel Combustion	851,158	14.9%		Fugitive Dust	886,379	10.9%
Prescribed Burning (FEPS)	728,879	12.8%		Fuel Combustion	851,158	10.5%
Miscellaneous	719,484	12.6%		Miscellaneous	719,484	8.8%
Industrial	657,637	11.5%		Industrial	657,637	8.1%
Off-Highway	105,741	1.9%		Off-Highway	105,741	1.3%
Onroad	79,256	1.4%		Onroad	79,256	1.0%
Agricultural Fires	66,666	1.2%		Agricultural Fires	66,666	0.8%
TOTAL	5,703,259	100.0%		TOTAL	8,140,969	100.0%

Doesn't include Flint Hills prescribed fires or Alaska wildfires

Conclusions and Plans

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- ▶ SERA database enables the analysis and summaries of existing EFs, and creation of average EFs now available in BSP
- ▶ Unlike the FEPSv2 factors that only vary by phase the SERA factors can vary by phase, fire type, region, fuel type and more pollutants
- ▶ In this year 2021 case, the CONUS PM_{2.5} wildland emissions doubled using the SERA EFs vs the old FEPSv2 EFs; NOX emissions dropped ~23%
- ▶ EPA to conduct air quality model simulation with year 2021 emissions soon
- ▶ EPA plans to use the SERA factors in BlueSky Pipeline in upcoming emissions inventory/modeling platforms including year 2022 Collaboration and the 2023 NEI

Any questions about 2020 NEI fires
please contact
Vukovich.Jeffrey@epa.gov

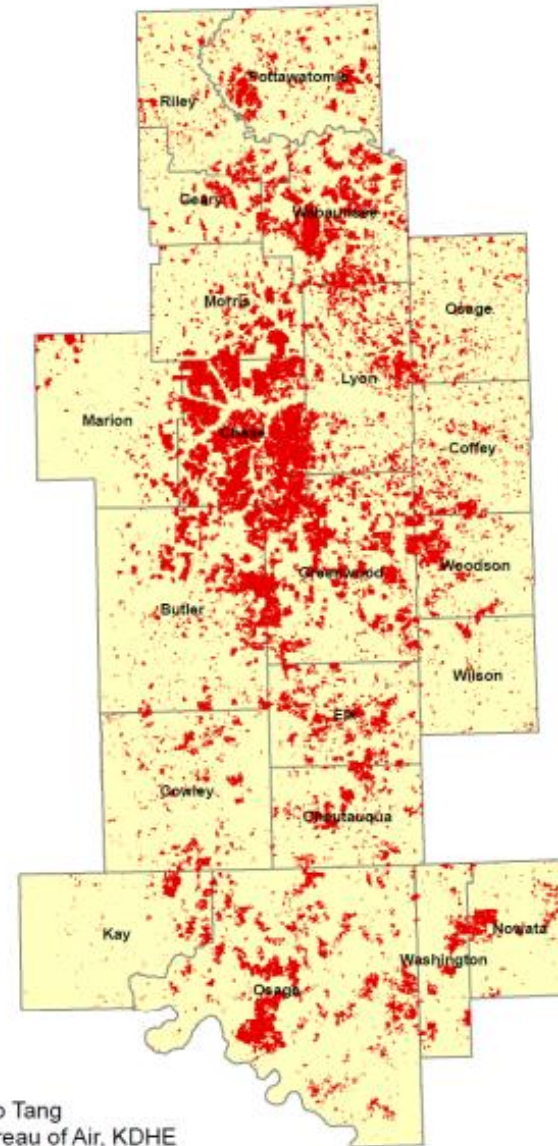
THE END

BUT
EXTRA SLIDES: FYI

Estimating Area Burned Flint Hills Prescribed Burning Spring 2021

- Use all “Grass” HMS detects in these counties for the time of the prescribed Burning
- Use SMOKE EMISSIONS REFERENCE APPLICATION (SERA) grass emission factors to estimate pollutants except PM2.5
- PM2.5 from measurements in Flint Hills Amara Holder (EPA-ORD): 12.68 g/kg

Flint Hills Acreage Burned (February 23 – April 30, 2021)

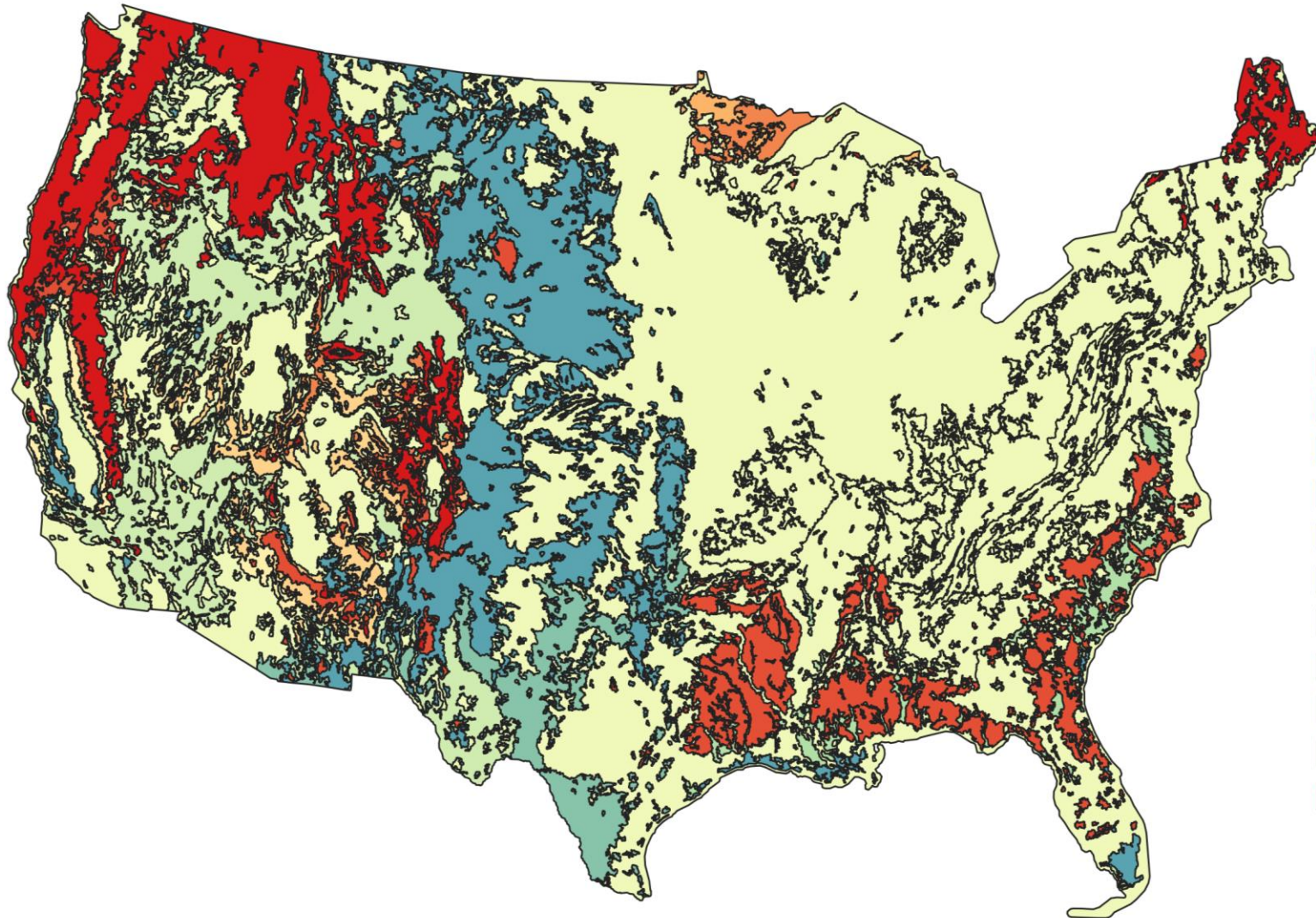


<u>Counties</u>	<u>Acres Burned</u>	
Butler	145,393	
Chase	314,833	
Chautauqua	56,171	
Coffey	55,028	
Cowley	57,422	
Elk	84,975	
Geary	34,889	
Greenwood	219,155	
Lyon	115,879	
Marion	40,711	
Morris	78,288	
Osage (KS)	45,144	
Pottawatomie	77,361	
Riley	41,561	
Wabaunsee	169,966	
Wilson	16,093	
Woodson	53,762	
Nowata (OK)	33,344	
Osage (OK)	197,565	
Washington (OK)	31,877	
Kay (OK)	29,808	
Total	1,899,225	
* Denotes county was partly or completely covered by clouds during latest analysis.		

Yao Tang
Bureau of Air, KDHE

2020 NEI Acres Per HMS Detect

29



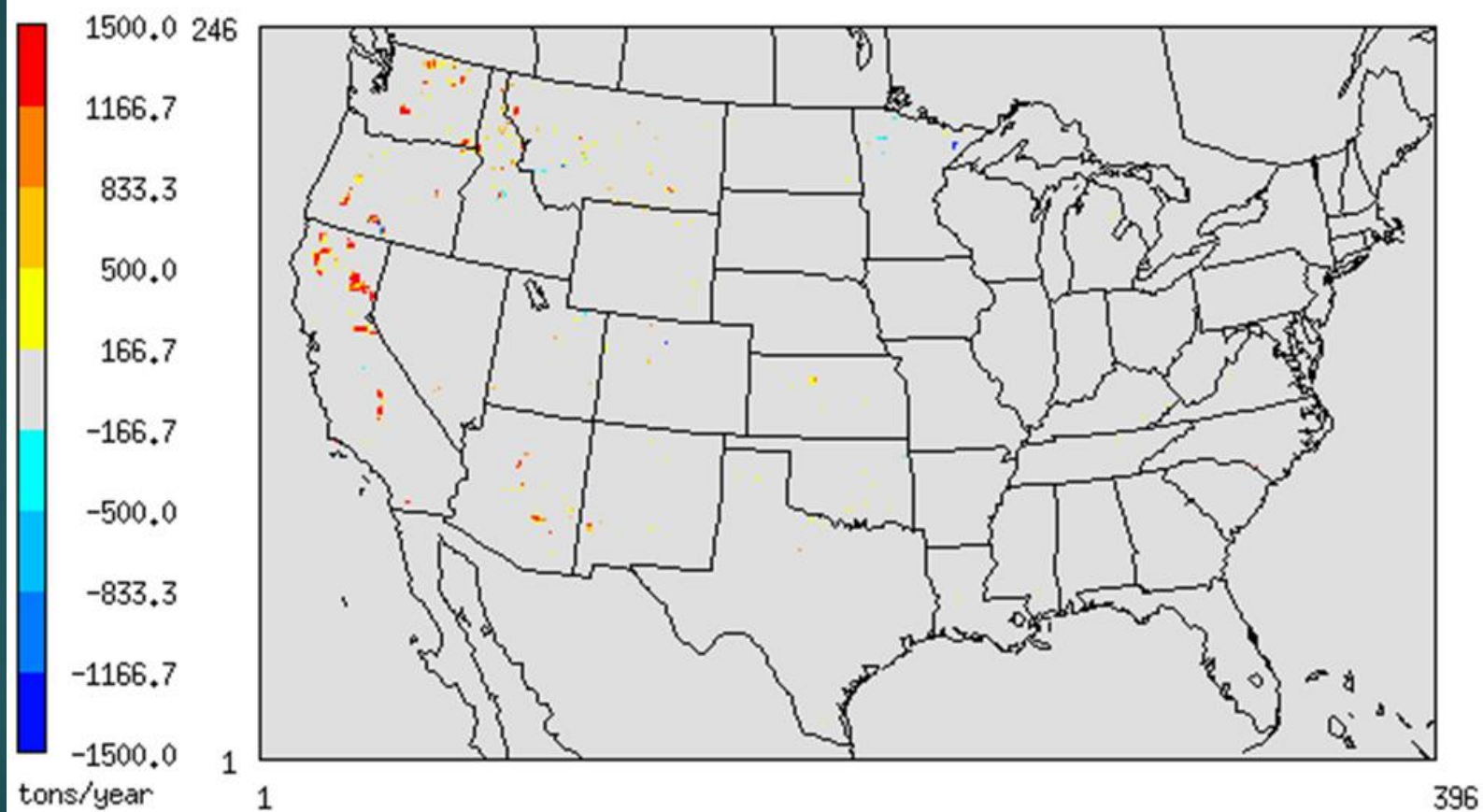
Acres Per HMS Detect

12	Closed Conifer Forest
15	Open Conifer Forests
18	Aspen
22	Boreal
27	Juniper
33	Pacific broadleaved Forest
39	Eastern Deciduous Forest
41	Other
41	Shrubland
57	Riparian
59	Savanna
62	Grassland

2021 SERA-FEPS Wildfires VOC Emissions

Annual

a=ptfire_ann_WF.SERA.ncf, b=ptfire_ann_WF.FEPS.ncf



January 1, 2016 0:00:00

Min=-15072.4 at (235,207), Max= 11120.1 at (33,162)