PM Source Apportionment Modeling for PM NAAQS Implementation

April 28, 2025

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Implementation Timeline: Designations, SIPs, and Permitting

EPA memo: “Initial Area Designations for the 2024 Revised Primary Annual Fine Particle National Ambient Air Quality Standard” (February 7, 2024)

May 6, 2024: Rule effective date; PSD permitting

January 1, 2025: Air agencies must notify EPA of intent to submit exceptional events demonstration(s)

February 7, 2025: Deadline for states and tribes to submit attainment recommendations based on a five-factor analysis

February 7, 2025: Exceptional events demonstrations due with attainment recommendations

October 9, 2025: EPA ‘120-day letters’ with initial area designations

February 6, 2026: EPA formal attainment designations

-> Option to extend designations process by up to one year

February 2027: ‘Infrastructure’ and Good Neighbor SIPs due

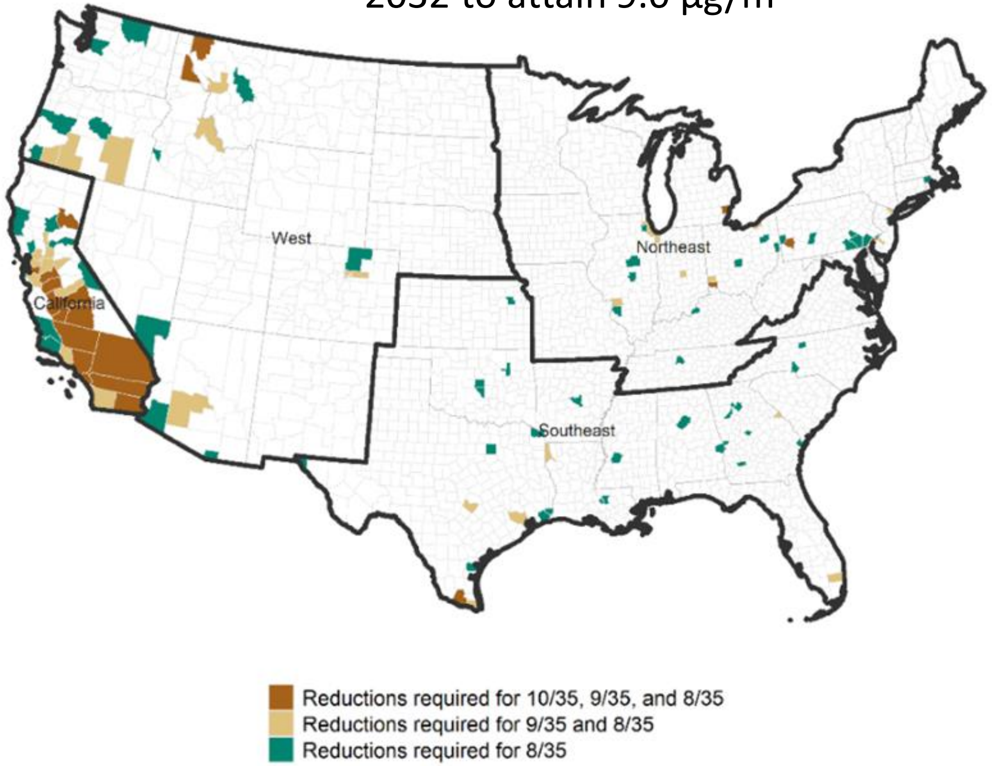
August 2027: Nonattainment area SIPs due

2032: Attainment deadline for Moderate nonattainment areas

Nonattainment for $PM_{2.5}$ NAAQS at 9.0 $\mu g/m^3$

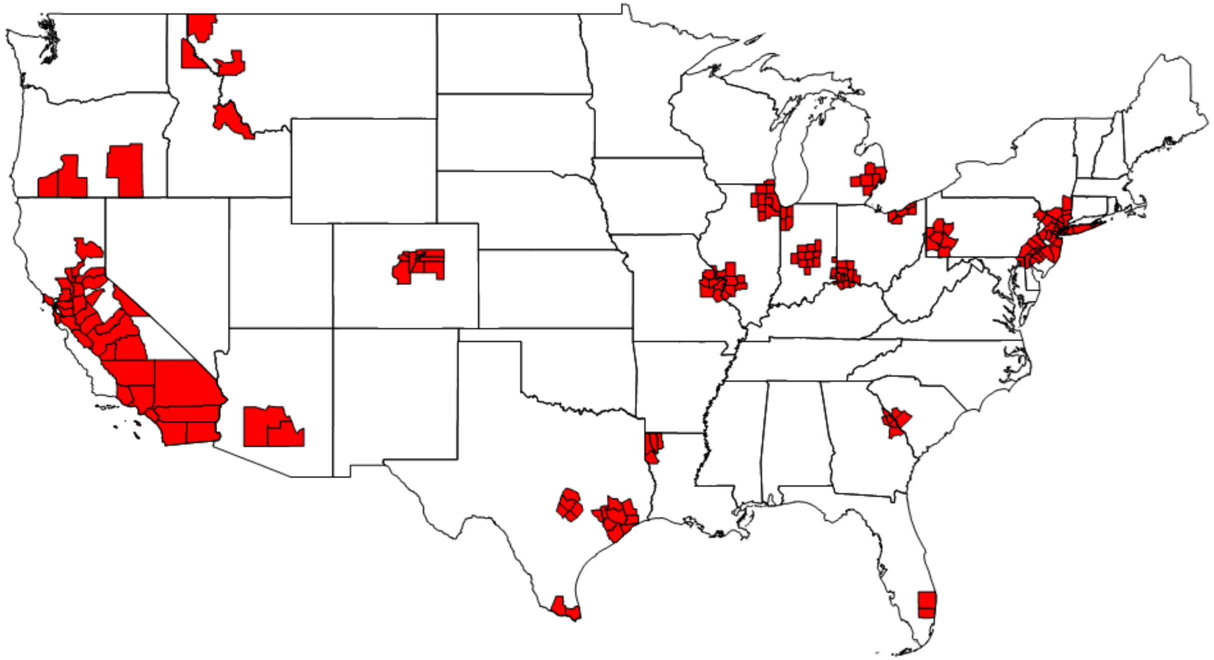
EPA's Monitored County Projection to 2032 (left) and Expanded to CBSAs (right)

EPA says 52 monitored counties would need additional control in 2032 to attain 9.0 $\mu g/m^3$



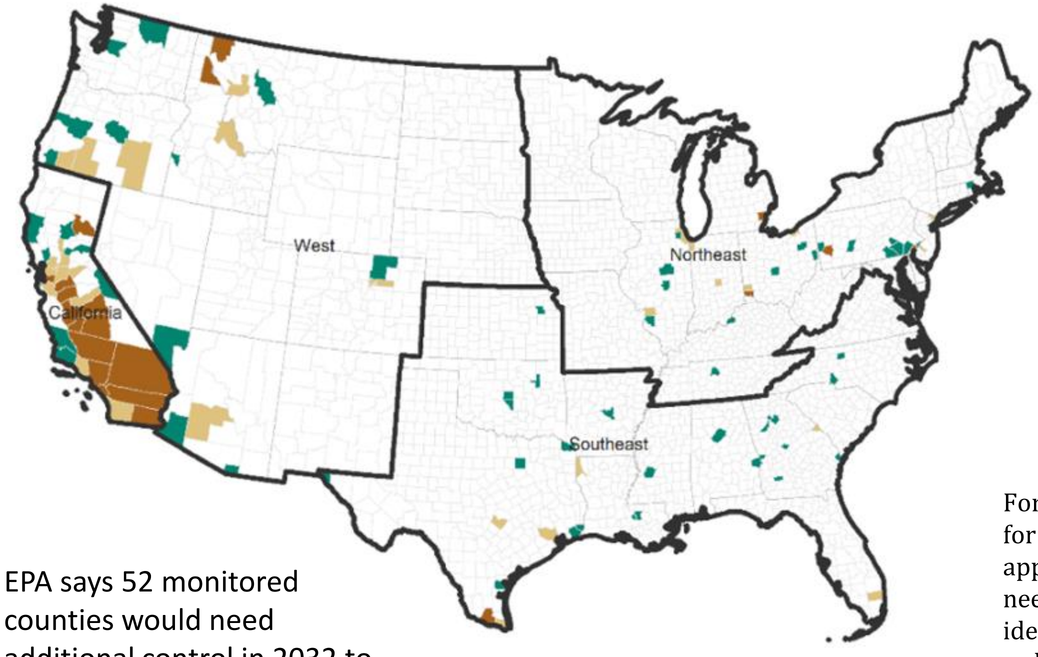
Counties Projected to Exceed in Analytical Baseline for the Revised and Alternative Standard Levels of 10/35 $\mu g/m^3$, 9/35 $\mu g/m^3$, and 8/35 $\mu g/m^3$

187 counties in nonattainment when expanded to CBSA



Source: https://www.epa.gov/system/files/documents/2024-02/naaqs_pm_reconsideration_ria_final.pdf

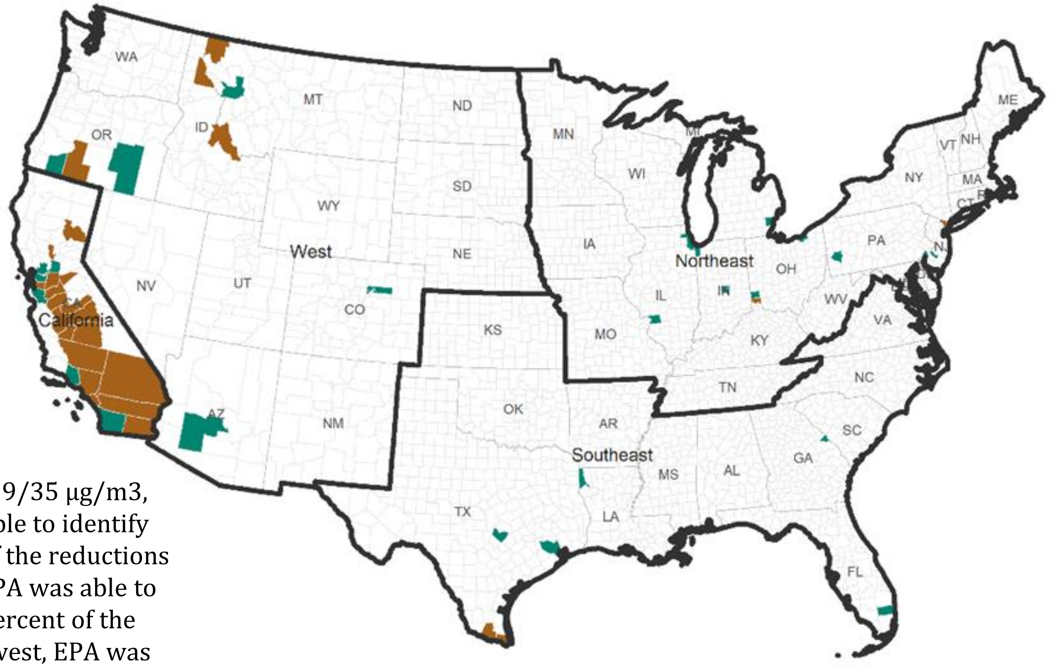
Counties That Will Still Need Controls in 2032 for $PM_{2.5}$ NAAQS at 9.0 μg/m³



EPA says 52 monitored counties would need additional control in 2032 to attain 9 μg/m³

Counties Projected to Exceed in Analytical Baseline for the Revised and Alternative Standard Levels of 10/35 μg/m³, 9/35 μg/m³, and 8/35 μg/m³

For the revised standards of 9/35 μg/m3, for the northeast EPA was able to identify approximately 98 percent of the reductions needed. For the southeast EPA was able to identify approximately 68 percent of the reductions needed. For the west, EPA was able to identify approximately 44 percent of the reductions needed, and for California the percentage is approximately 26 percent.



Counties that Still Need $PM_{2.5}$ Emissions Reductions for Revised Standard Levels of 9/35 μg/m³

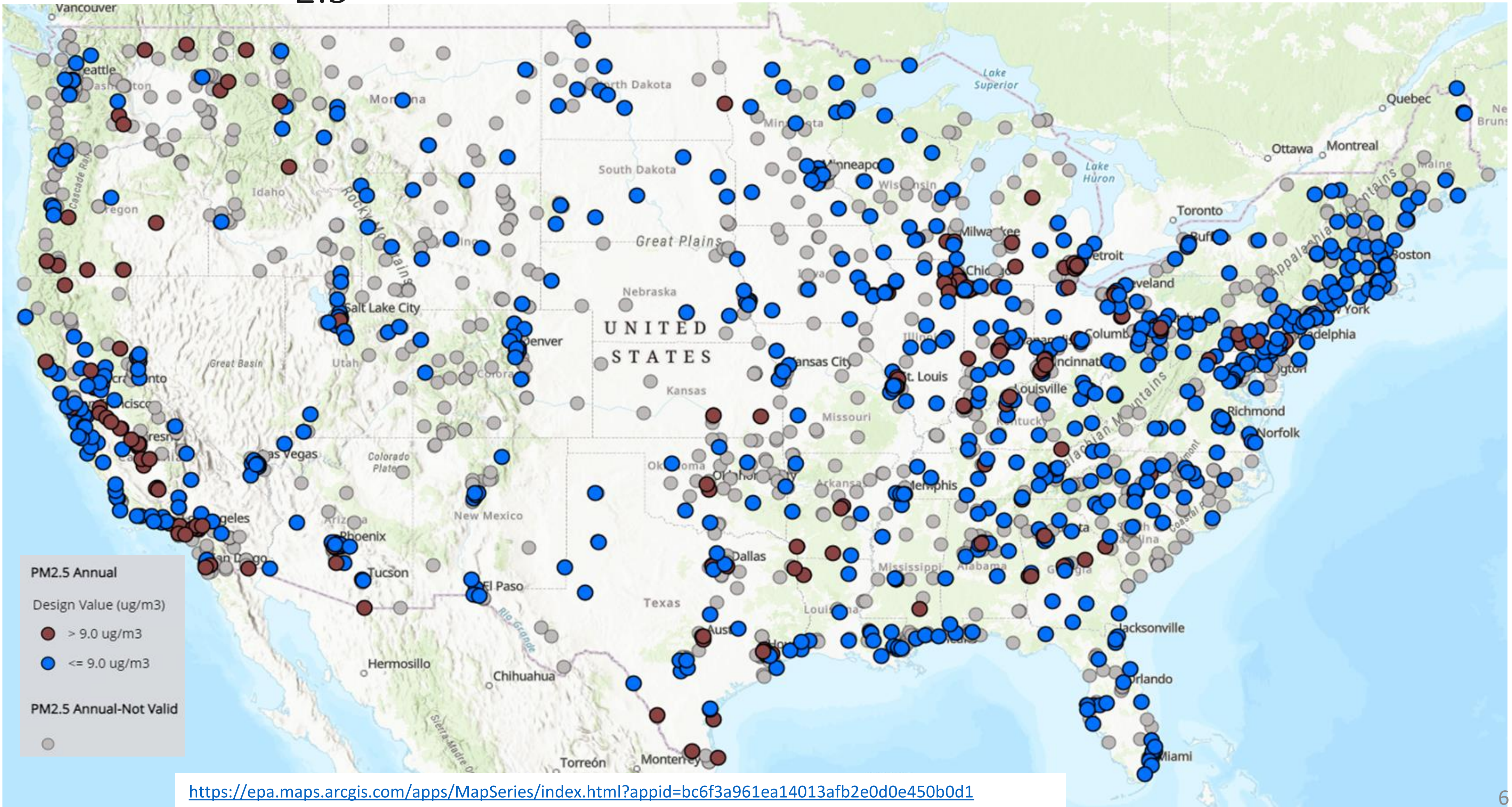
Source: https://www.epa.gov/system/files/documents/2024-02/naaqs_pm_reconsideration_ria_final.pdf

PM Nonattainment Designation

- Five Factor Analysis
  - Most recent three years of monitoring data
  - Emissions data from current sources
  - Meteorology
  - Geography/topography
  - Area boundaries

- Also cited are weight of evidence using
  - Air quality modeling
  - Source apportionment modeling

2023 Design Value Interactive Map – Annual $PM_{2.5}$ Design Values



https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=bc6f3a961ea14013afb2e0d0e450b0d1

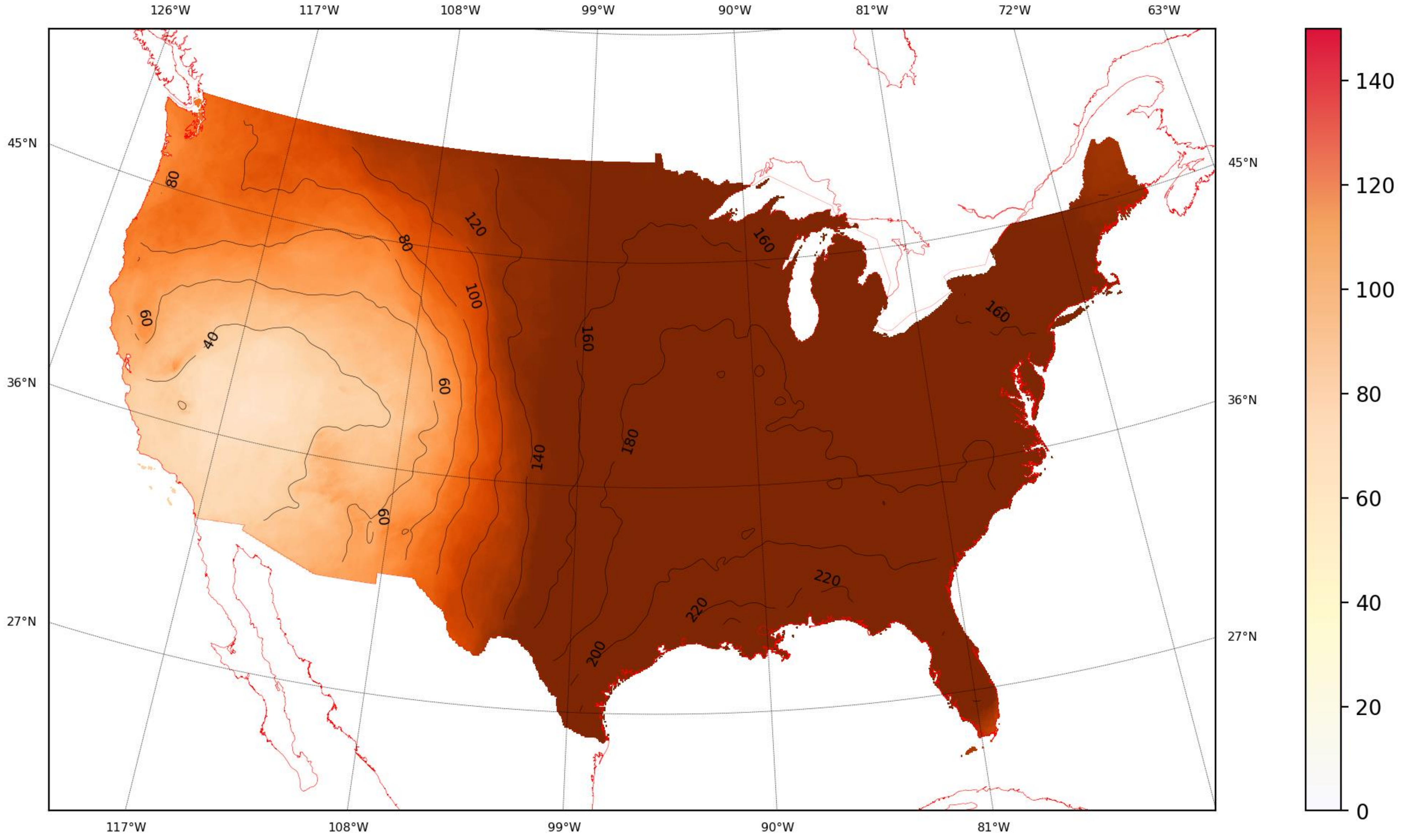
Influence of Wildfire Smoke on PM Concentrations

- 2023 and 2024 have measured exceedance days triggering the opportunity for exceptional events demonstrations to remove concentrations from design value calculations

- 2023 saw widespread influence of wildfire and prescribed fire smoke in eastern and Midwestern states

- 2024 saw influence of wildfire smoke in western states

Cumulative Smoke Distribution (CONUS) 2023

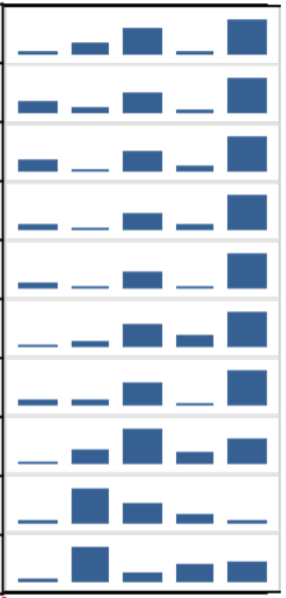


NOAA/NESDIS Hazard Mapping System

2023 Fires Dramatically Increase $PM_{2.5}$ Design Values

Annual Mean PM-2.5 Values (ug/m3)

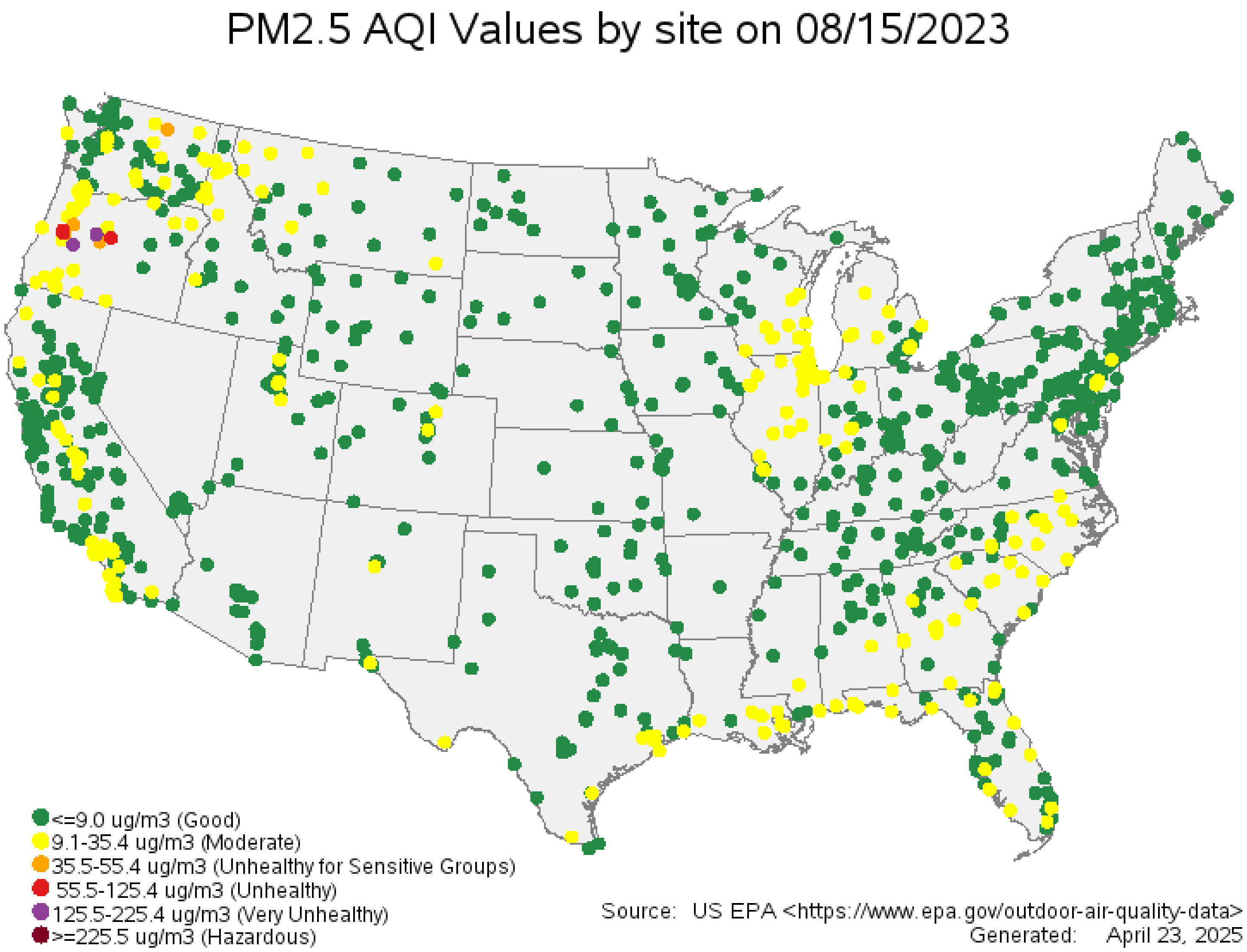
EPA Region	2019	2020	2021	2022	2023	5-Year Trend
1	5.9	6.2	6.7	5.9	7.0	
2	7.1	6.9	7.5	6.7	8.2	
3	7.8	7.1	8.4	7.5	9.2	
4	7.8	7.6	8.4	7.9	9.1	
5	8.2	7.8	8.9	7.9	10.3	
6	8.1	8.2	8.6	8.3	8.8	
7	7.5	7.4	8.5	7.2	9.1	
8	5.2	6.2	7.6	5.9	7.0	
9	6.9	10.7	9.1	7.8	7.3	
10	7.7	10.1	8.3	8.8	9.2	



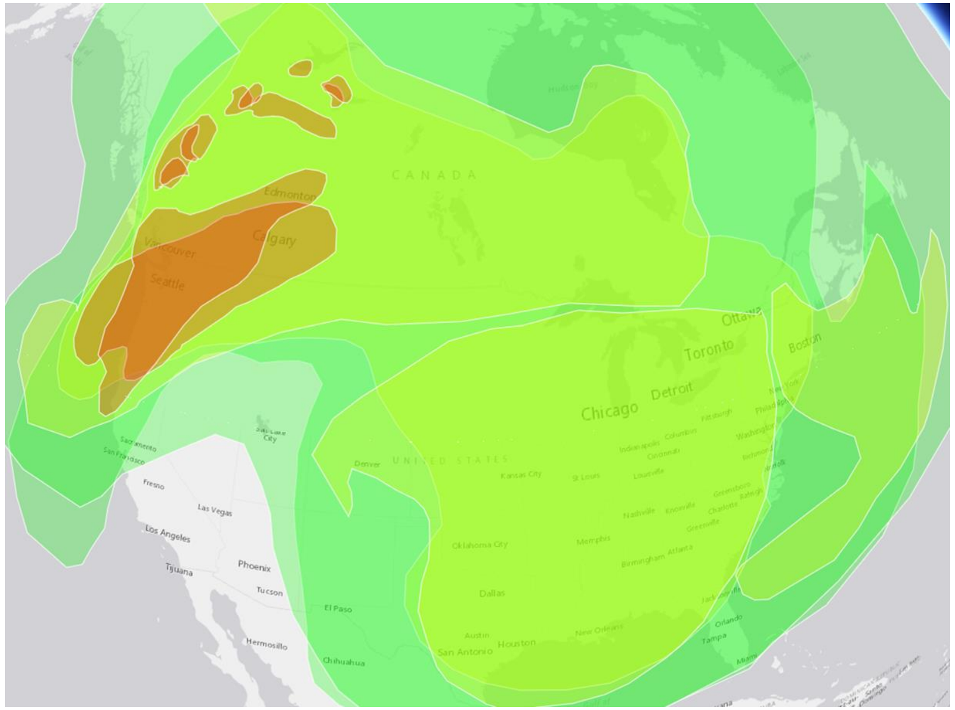
Used for 2021 DV

Used for 2023 DV

August 2023 Episode – Canadian Wildfires

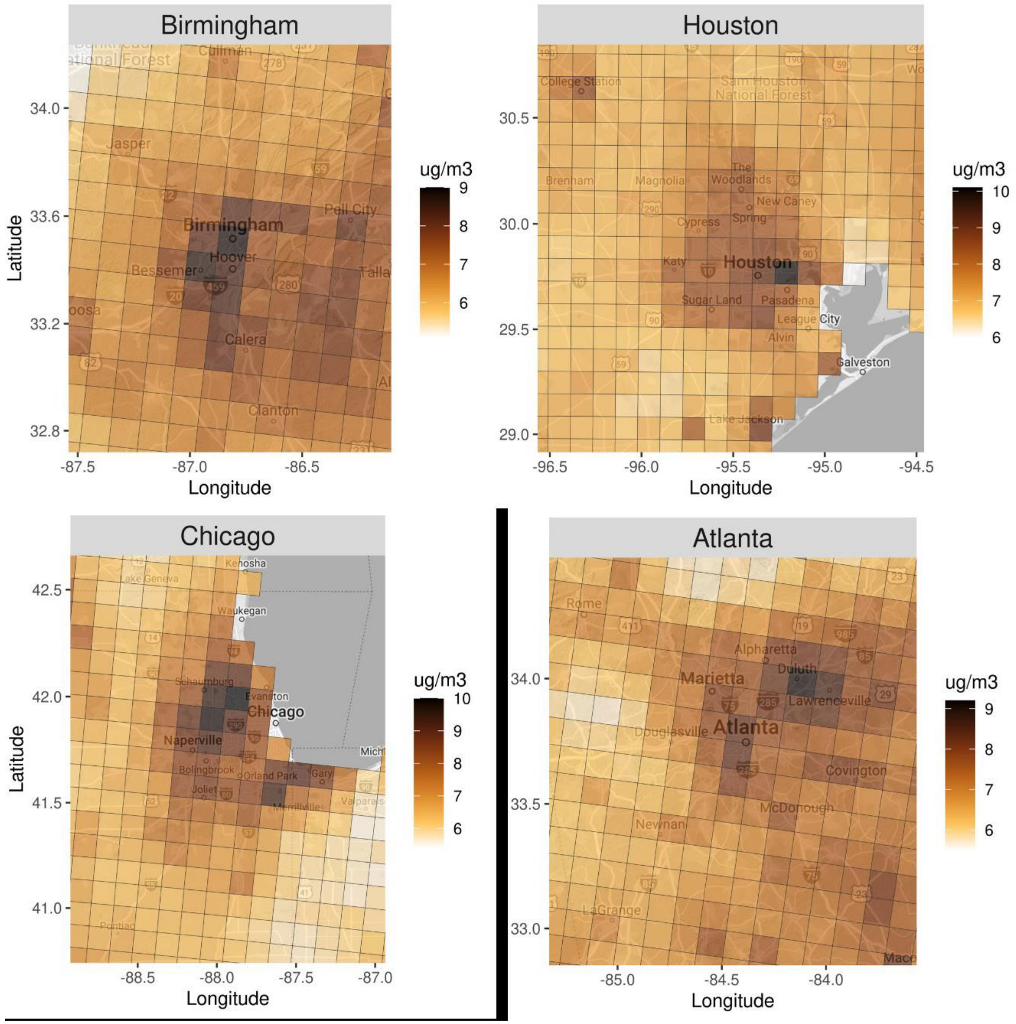


- August 15-23, 2023 we see Canadian wildfire smoke influence in PM concentration observations across northwestern states



HMS Smoke Map August 20, 2023

EPA Findings on Spatial Extent of Contribution



- Gridded $PM_{2.5}$ concentrations over selected urban areas based on the 2032 modeling case with the enhanced Voronoi Neighbor Averaging (VNA) approach
- A common feature of these diverse locations is the relatively high $PM_{2.5}$ concentrations over the urban area and lower concentrations just outside of the urban core
- $PM_{2.5}$ concentrations in the urban core of these Eastern U.S. areas exceed revised and alternative standards levels considered in the RIA, whereas concentrations surrounding the urban core are below the revised and alternative standard levels

Project Objective, Processing, Methods, Configuration, Documentation

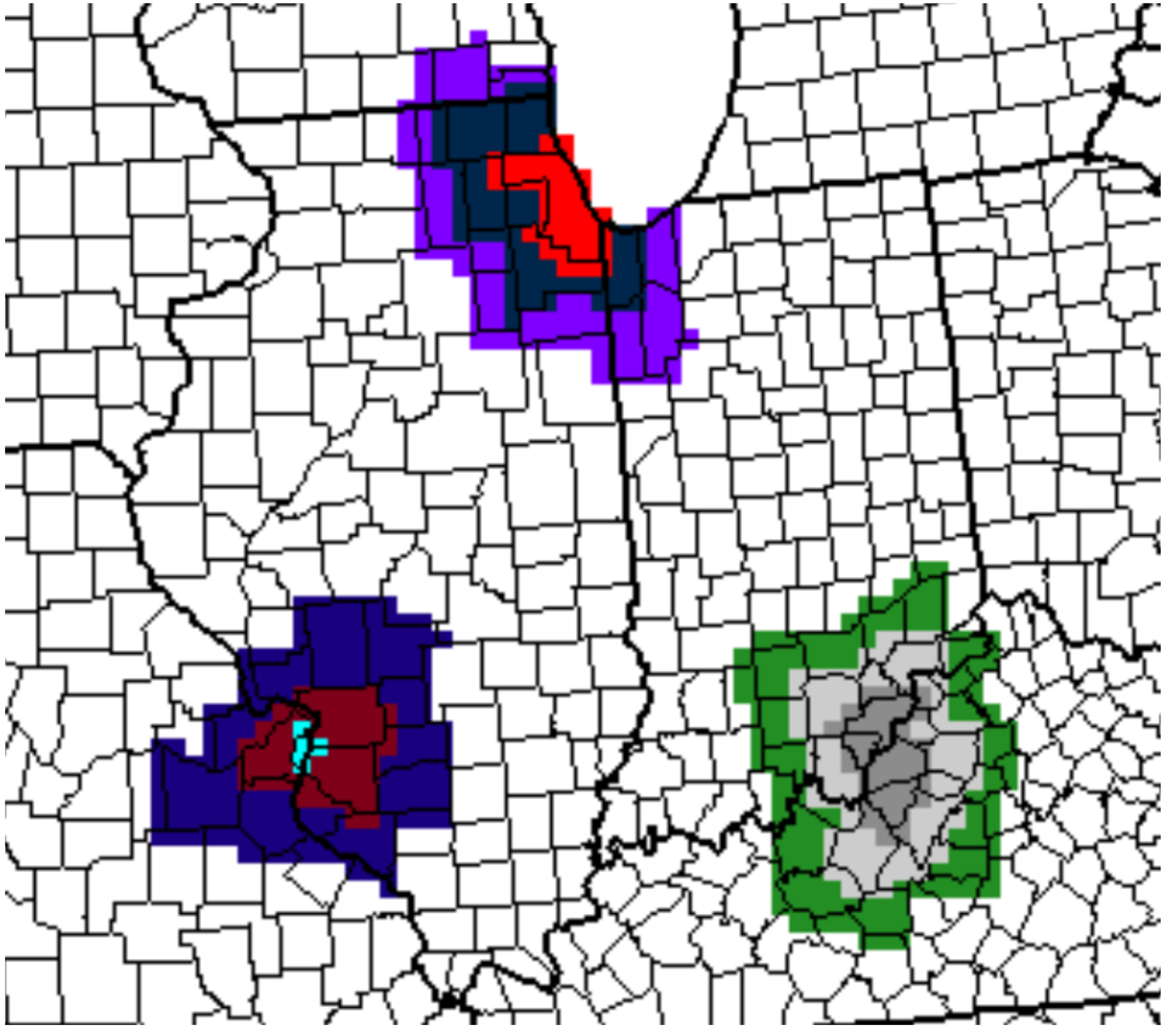
- Alpine Geophysics adapted an EPA developed nationwide one-atmosphere photochemical grid modeling platform (2016v3 + projections) to assess identified source region and group combinations and to report the relative $PM_{2.5}$ impact from each of these combinations on downwind monitor locations

- We performed a PM source apportionment modeling run using the Comprehensive Air-quality model with extensions (CAMx) Particulate Matter Source Apportionment Technique (PSAT) algorithms

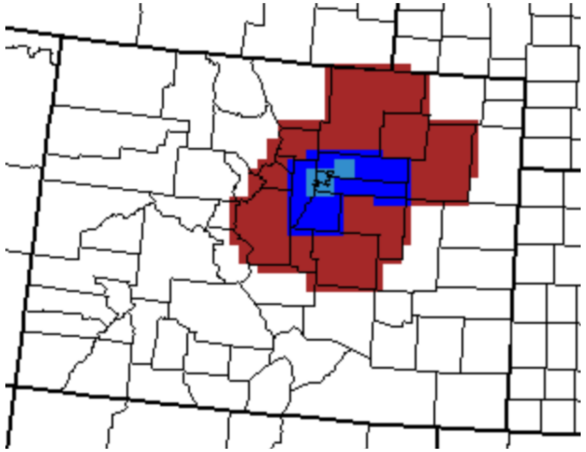
- *Particulate Source Apportionment Technology Analysis of $PM_{2.5}$ for Multiple Domains and Categories - Final Report*, Alpine Geophysics, July 2024

  https://www.midwestozonegroup.com/technical-support-documents

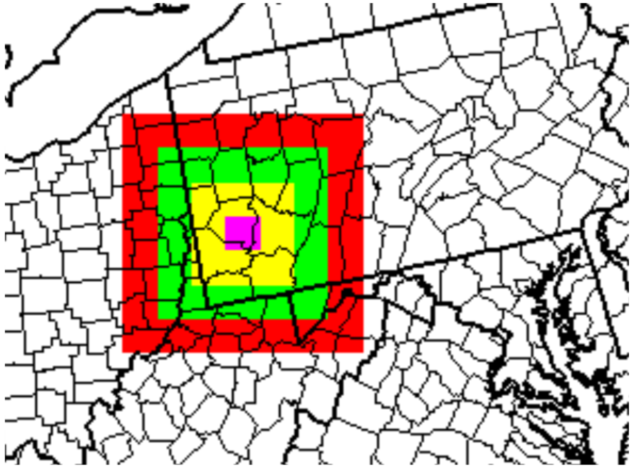
Seven Selected Source Regions



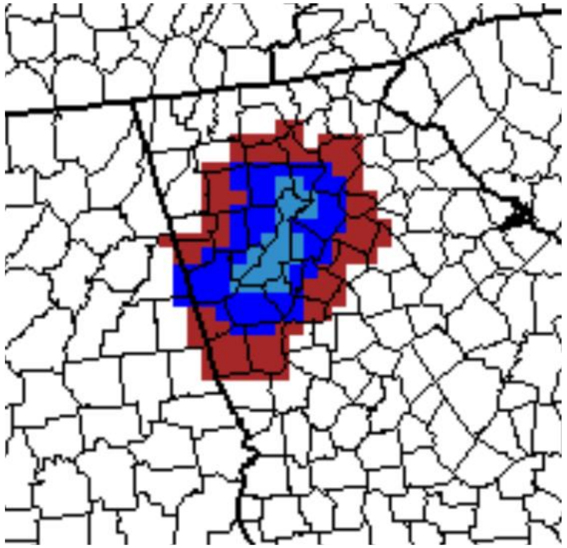
Chicago, St. Louis, and Louisville



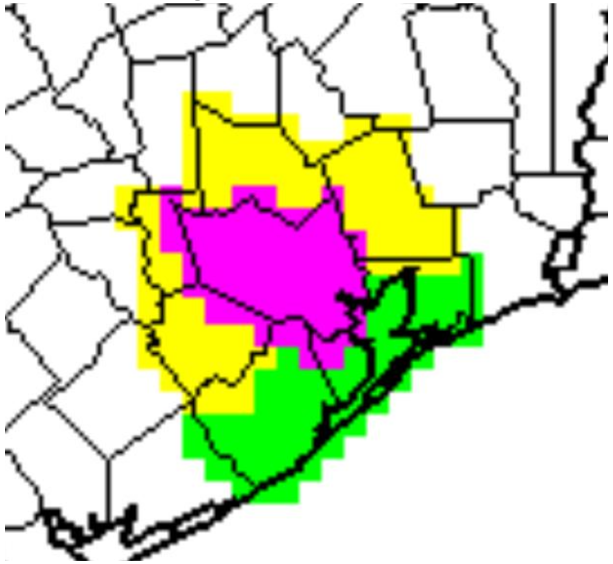
Denver



Pittsburgh

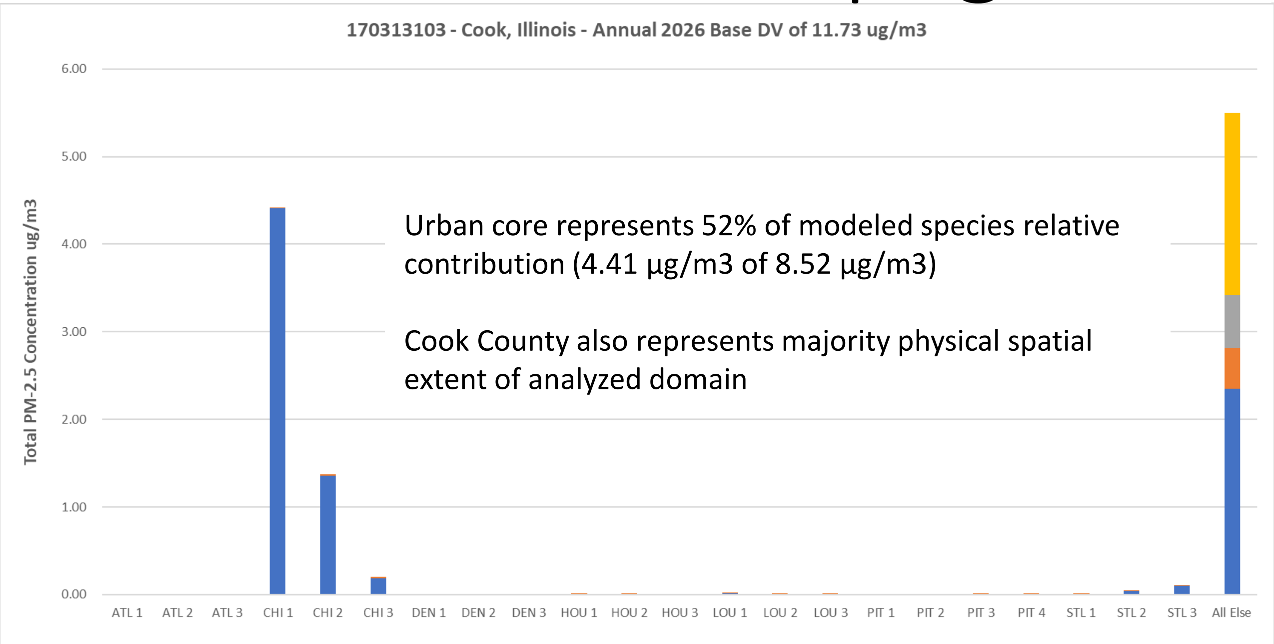


Atlanta



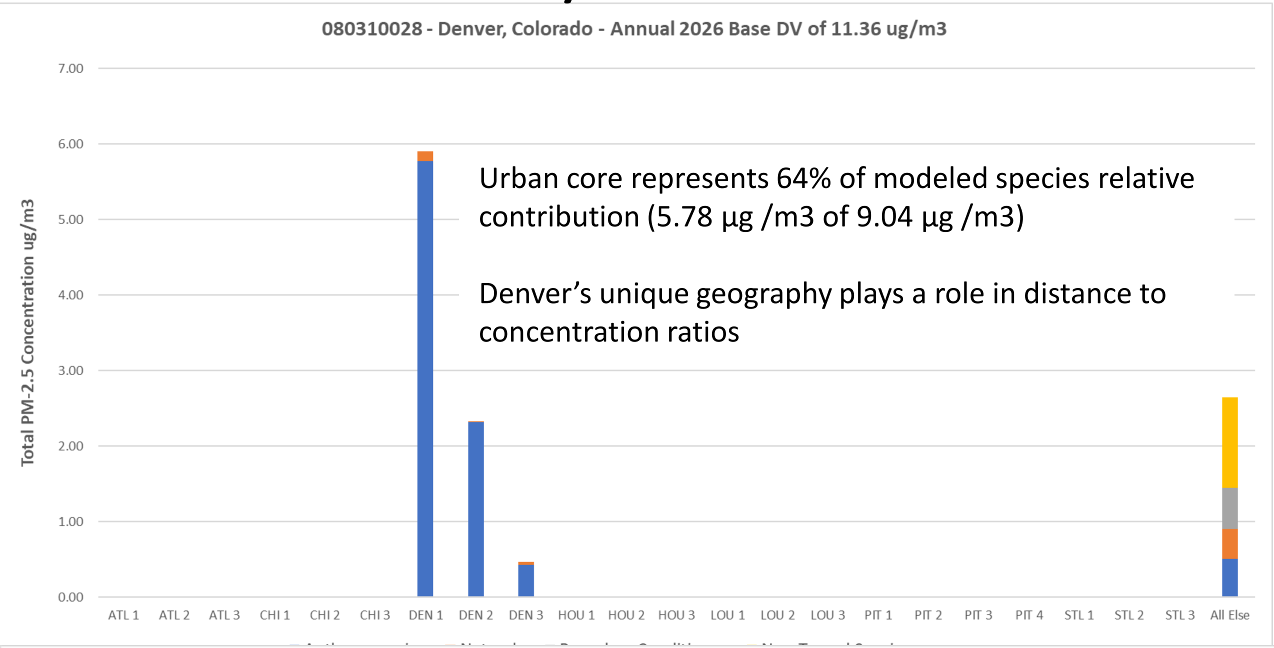
Houston

Relative Anthropogenic Contribution by Distance



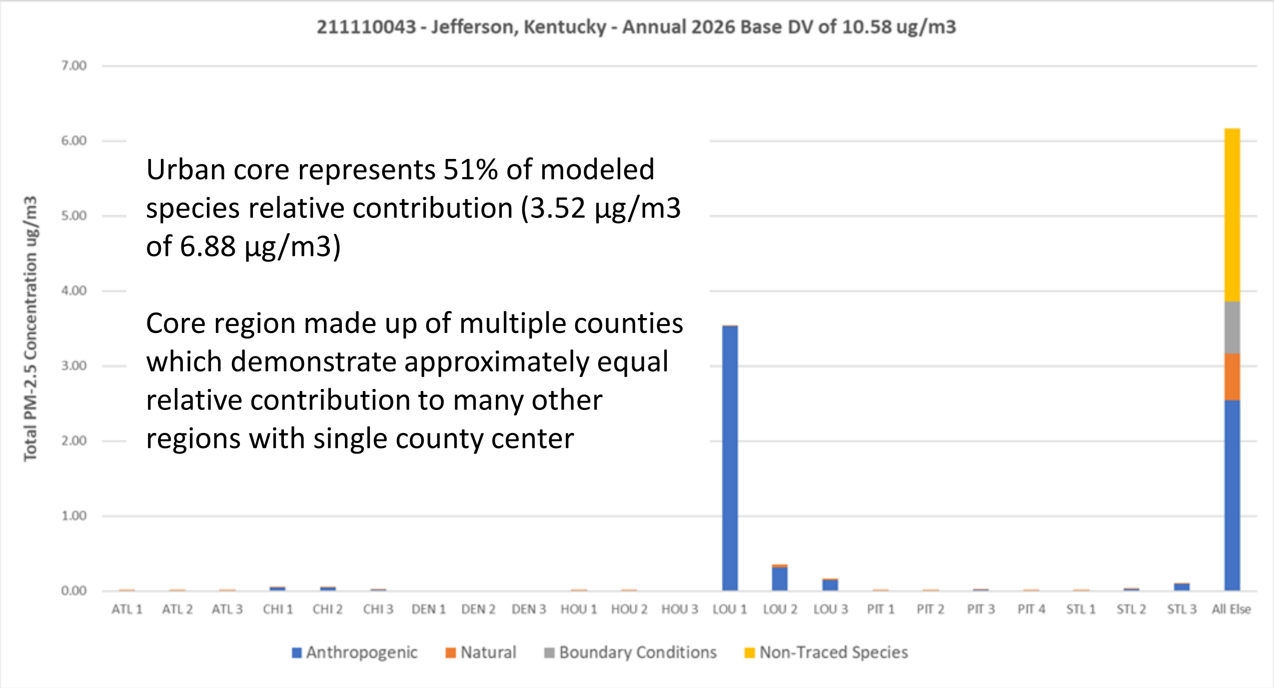
Urban core represents 52% of modeled species relative contribution (4.41 µg/m3 of 8.52 µg/m3)

Cook County also represents majority physical spatial extent of analyzed domain



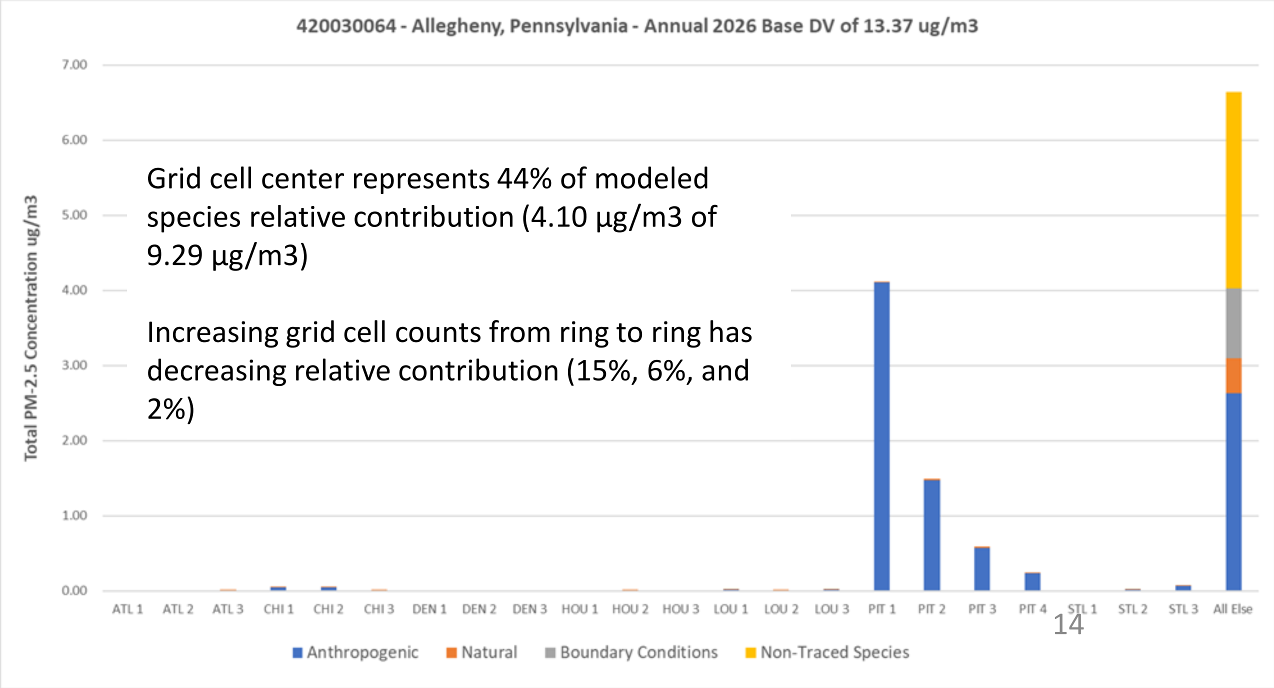
Urban core represents 64% of modeled species relative contribution (5.78 µg /m3 of 9.04 µg /m3)

Denver's unique geography plays a role in distance to concentration ratios



Urban core represents 51% of modeled species relative contribution (3.52 µg/m3 of 6.88 µg/m3)

Core region made up of multiple counties which demonstrate approximately equal relative contribution to many other regions with single county center



Grid cell center represents 44% of modeled species relative contribution (4.10 µg/m3 of 9.29 µg/m3)

Increasing grid cell counts from ring to ring has decreasing relative contribution (15%, 6%, and 2%)

Preliminary Observations

- In majority of regions, urban core dominates the modeled $PM_{2.5}$ concentration
- This is consistent with the NAAQS exceedances being driven by the urban $PM_{2.5}$ increment as documented in EPA's RIA, the relatively high responsiveness of $PM_{2.5}$ concentrations to primary $PM_{2.5}$ emission reductions, and the reductions in regional $PM_{2.5}$ concentrations from the large SO2 and NOx emission reductions in recent decades and in the 2032 projection
- Analysis supports that designation should focus on local areas around monitored exceedances
- The Alpine analysis appears informative in providing corroborating data to support $PM_{2.5}$ designations and distance from monitors with respect to relative contribution
  - Results could support 5-factor test within each domain

PSAT Results Analysis – Category Contribution

- Processed data to provide speciated relative contribution of contribution by species and category
- Data available for total $PM_{2.5}$, particulate sulfate, particulate nitrate, elemental carbon, organic carbon, and crustal material
- Presentation today focuses on result output which can be generated for all monitors in CONUS modeling domain
  - Appendix B of Alpine's PSAT TSD

PSAT Simulation Results

- Base case 2026 DV calculated used EPA methods
- Look at relative contribution of source sector at monitor from modeled concentrations by traced species and as whole
- Relative contribution using EPA attainment test tool (SMAT-CE) and ratio of averaged modeled tag concentration to base case total

- Traced Species = sulfate + nitrate + ammonium + OC + EC
- Non-Traced Species = secondary organic aerosols + sea salt + particle bound water + blank mass

Tagged Source Categories

Ag dust (livestock)
Ag dust (tilling)
Ag Fires
Ag Nonroad
Airports
All Other EGUs
All Other Fuel Combustion
Biogenics
Biomass Fuel Combustion
Boundary Conditions

C1 & C2 & C3 Marine
Canadian & Mexican Anthropogenic
Canadian & Mexican Fires
Cement Manufacturing
Coal Fuel Combustion
Coal-Fired EGUs
Commercial Cooking
Construction
Construction/Industrial
Diesel Vehicles

Fertilizer
Initial Conditions
Lawn & Garden
Livestock
Mining
Non-diesel Vehicles
Oil & Gas
Other Non-Point
Other Nonroad
Paved Roads

Petroleum Refineries
Prescribed Fires
Pulp & Paper
Railroads
Rec Marine
Residential Wood Combustion
Stationary Non-EGU
Unpaved Roads
Waste Disposal
Wildfires

2026v3 Projected Annual $PM_{2.5}$ DV ($\mu g/m^3$)

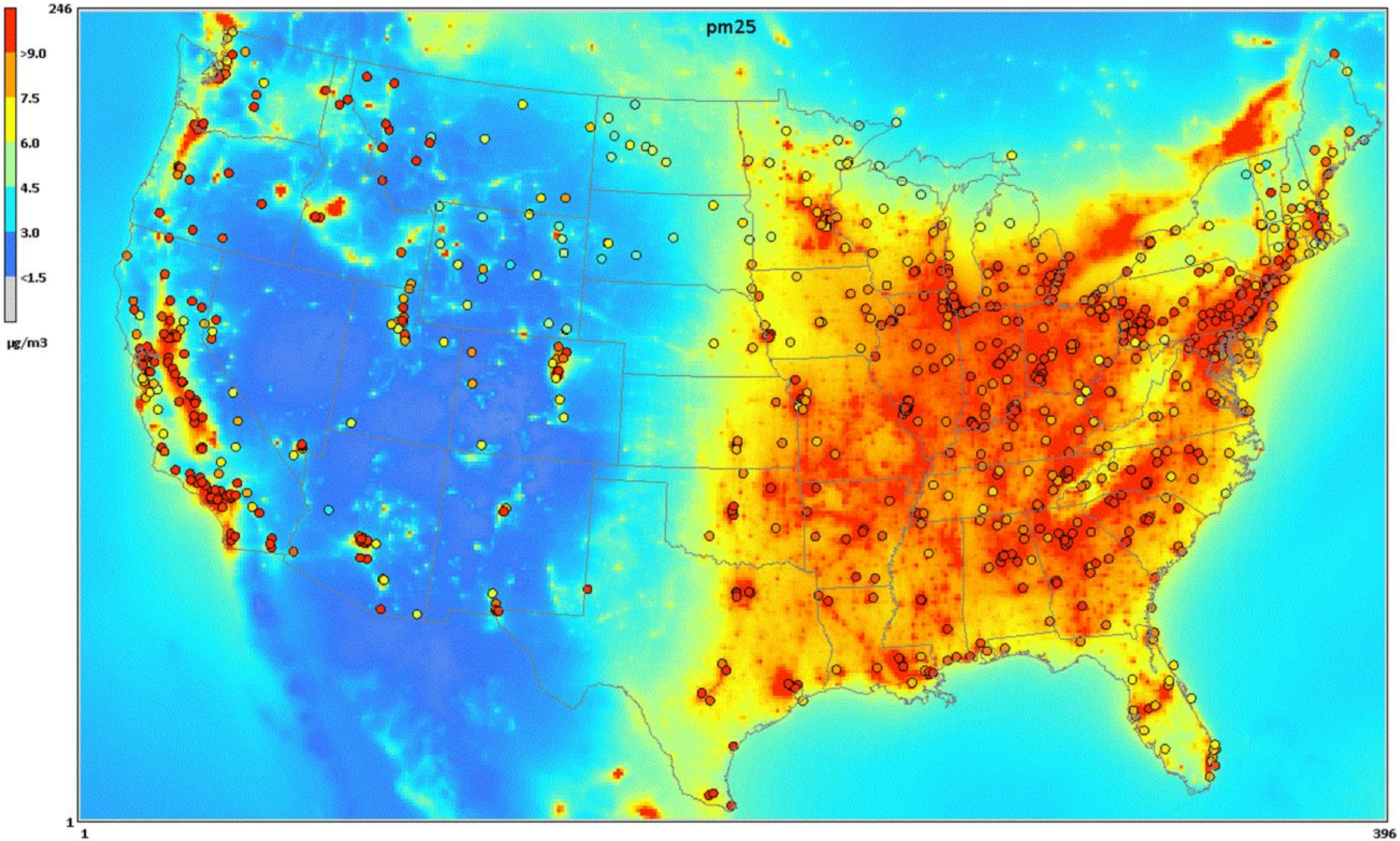


Table 3-7 Summary of Estimated $PM_{2.5}$ Emissions Reductions from CoST by Inventory Source Classification Code Sectors for Alternative Primary Standard Levels of 10/35 μg/m³, 10/30 μg/m³, 9/35 μg/m³, and 8/35 μg/m³ in 2032 (tons/year)

Sector	SCC Sector	10/35	10/30	9/35	8/35
Non-EGU Point	Agriculture - Livestock Waste	0	6.2	6.8	6.8
	Fuel Combustion - Commercial/Institutional Boilers - Biomass	0	0	0	15.6
	Fuel Combustion - Commercial/Institutional Boilers - Coal	0	0	8.0	8.0
	Fuel Combustion - Commercial/Institutional Boilers - Natural Gas	0	0	0	85.9
	Fuel Combustion - Commercial/Institutional Boilers - Other	64.7	64.7	64.7	69.8
	Fuel Combustion - Industrial Boilers, ICEs - Biomass	0	76.0	5.2	402.2
	Fuel Combustion - Industrial Boilers, ICEs - Coal	0	0	16.4	211.2
	Fuel Combustion - Industrial Boilers, ICEs - Natural Gas	6.1	75.4	81.7	405.8
	Fuel Combustion - Industrial Boilers, ICEs - Oil	0	0	0	18.1
	Fuel Combustion - Industrial Boilers, ICEs - Other	110.9	140.7	689.5	1,023.9
	Industrial Processes - Cement Manufacturing	0	0	89.8	688.5
	Industrial Processes - Chemical Manufacturing	29.3	40.3	136.5	953.8
	Industrial Processes - Ferrous Metals	142.8	150.1	836.0	2,378.0
	Industrial Processes - Mining	0	7.4	239.4	326.9
	Industrial Processes - Non-ferrous Metals	55.9	55.9	502.1	918.0
	Industrial Processes - Not Elsewhere Classified	304.3	456.1	2,169.9	6,818.0
	Industrial Processes - Petroleum Refineries	178.5	216.6	875.8	2,204.2
	Industrial Processes - Pulp & Paper	0	18.3	119.5	848.1
	Industrial Processes - Storage and Transfer	8.9	18.0	186.7	887.4
	Waste Disposal - Excavation/Soils Handling	0	0	0	5.8
	Waste Disposal - General Processes	0	0	7.0	7.0
	Waste Disposal - Landfill Dump	0	0	0	5.5
Oil & Gas Point	Industrial Processes - Not Elsewhere Classified	0	0	0	3.6
	Industrial Processes - Oil & Gas Production	0	0	0	54.9
	Industrial Processes - Petroleum Refineries	0	0	0	1.8

"For the revised standard levels of 9/35 μg/m³, the inventory sectors with the most potentially controllable emissions are the non-point (area) and area fugitive dust sectors. "

– PM NAAQS RIA

Sector	SCC Sector	10/35	10/30	9/35	8/35
Non-Point (Area)	Commercial Cooking	950.2	1,176.5	2,336.9	6,823.5
	Fuel Combustion - Commercial/Institutional Boilers - Biomass	16.3	20.2	52.8	258.6
	Fuel Combustion - Commercial/Institutional Boilers - Coal	0	0	0	0.5
	Fuel Combustion - Commercial/Institutional Boilers - Natural Gas	18.9	22.2	49.8	95.5
	Fuel Combustion - Commercial/Institutional Boilers - Oil	0	0	3.0	14.4
	Fuel Combustion - Industrial Boilers, ICEs - Biomass	66.0	103.3	345.0	1,499.0
	Fuel Combustion - Industrial Boilers, ICEs - Coal	0	2.4	17.8	39.1
	Fuel Combustion - Industrial Boilers, ICEs - Natural Gas	4.0	4.0	32.7	65.5
	Fuel Combustion - Industrial Boilers, ICEs - Oil	1.0	1.0	1.0	5.4
	Fuel Combustion - Industrial Boilers, ICEs - Other	2.0	2.0	2.0	2.0
	Industrial Processes - Chemical Manufacturing	0	0	77.4	199.1
	Waste Disposal - All Categories	603.2	880.0	2,641.3	14,623.5
	Waste Disposal - Residential	109.2	360.5	709.[illegible]	3,725.4
Residential Wood Combustion	Fuel Combustion - Residential - Wood	296.2	555.6	1,275.9	4,193.4
Area Source Fugitive Dust	Dust - Paved Road Dust	199.9	611.0	768.9	4,903.3
	Dust - Unpaved Road Dust	392.7	1,319.3	861.3	6,523.6
Total		3,561.0	6,383.7	15,210.0	61,320.7

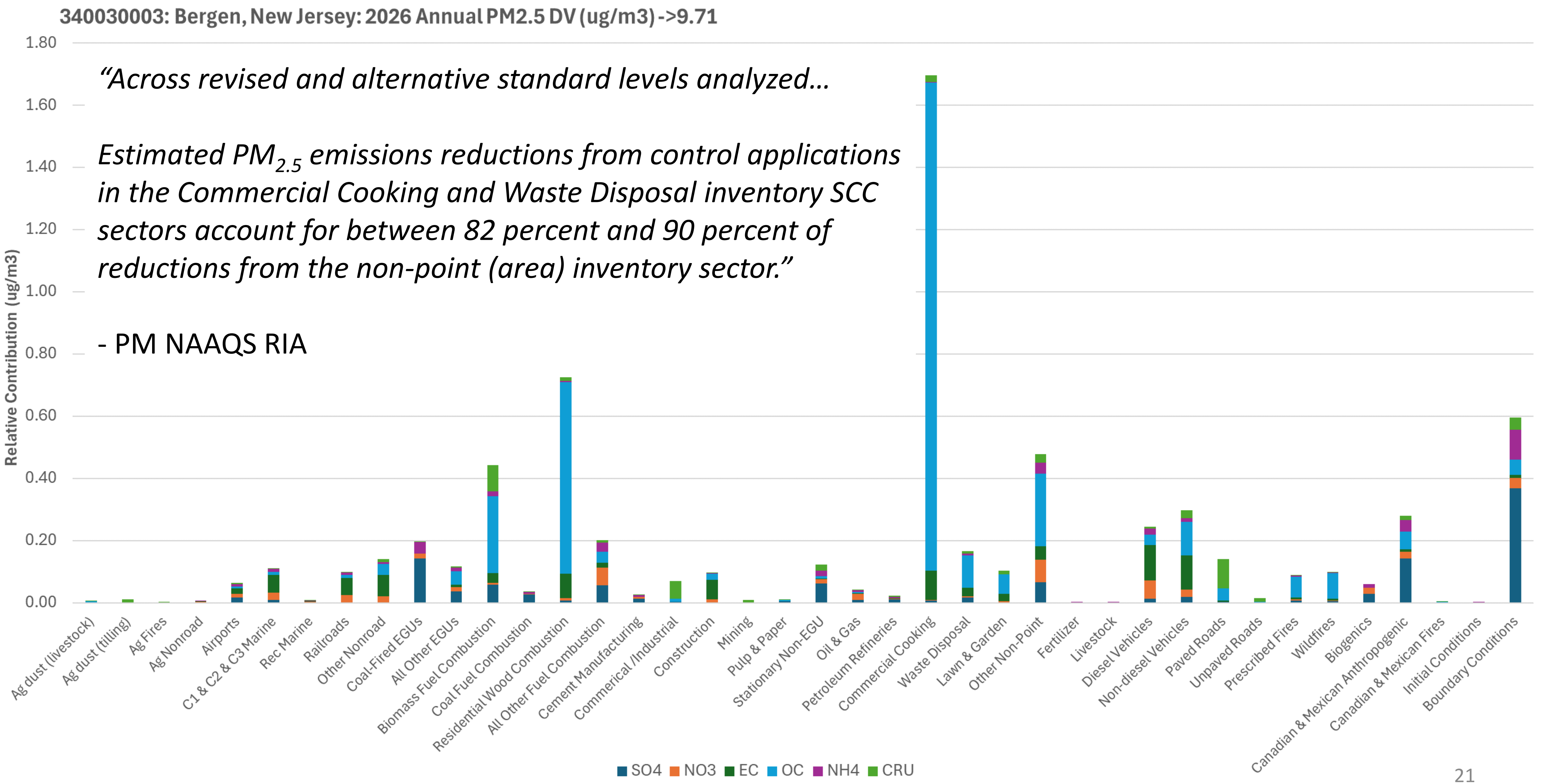
Source: https://www.epa.gov/system/files/documents/2024-02/naaqs_pm_reconsideration_ria_final.pdf

Relative Contribution by $PM_{2.5}$ Species and Monitor

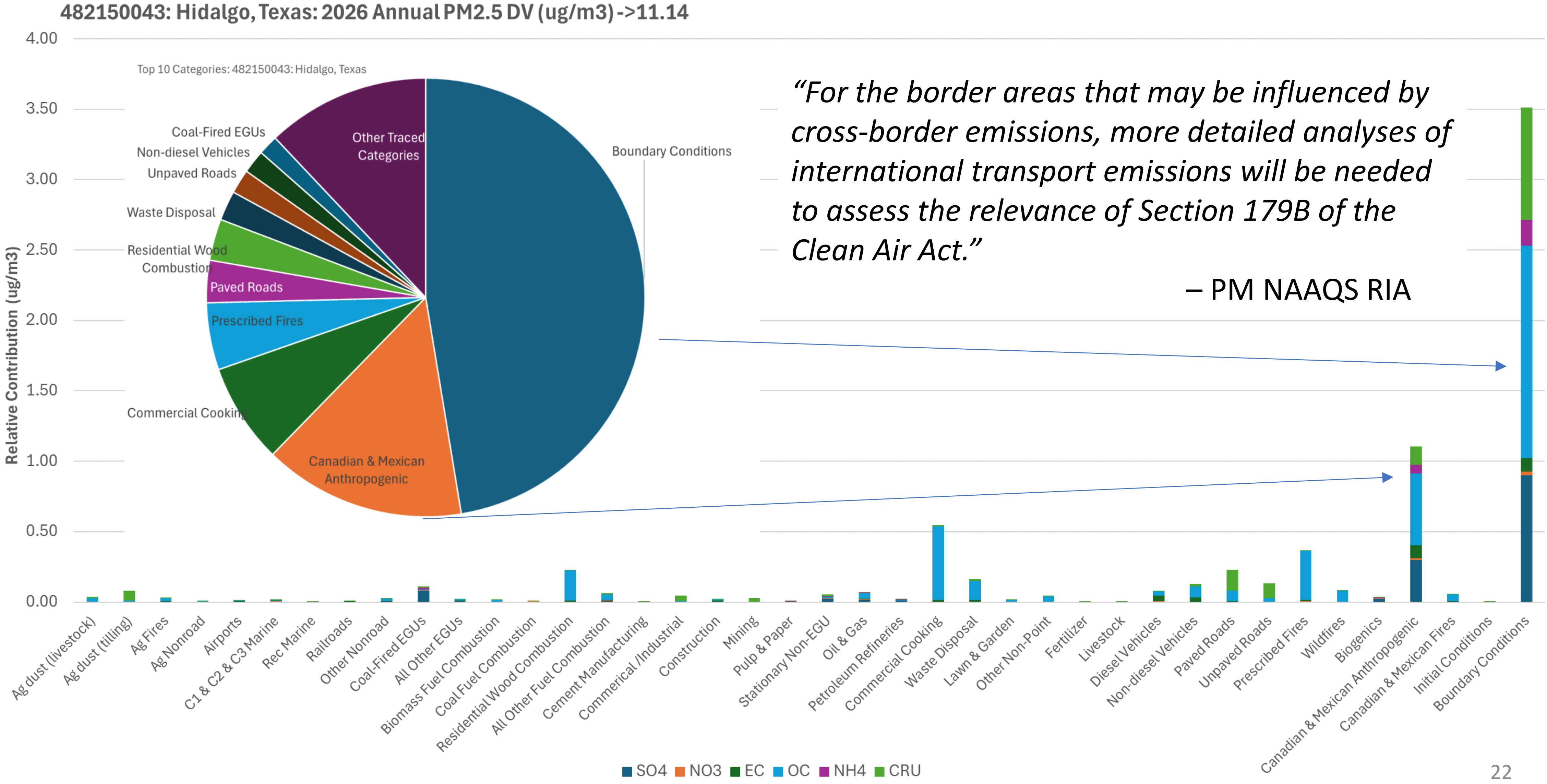
"Across revised and alternative standard levels analyzed…

Estimated $PM_{2.5}$ emissions reductions from control applications in the Commercial Cooking and Waste Disposal inventory SCC sectors account for between 82 percent and 90 percent of reductions from the non-point (area) inventory sector."

- PM NAAQS RIA



Relative Contribution by $PM_{2.5}$ Species and Monitor



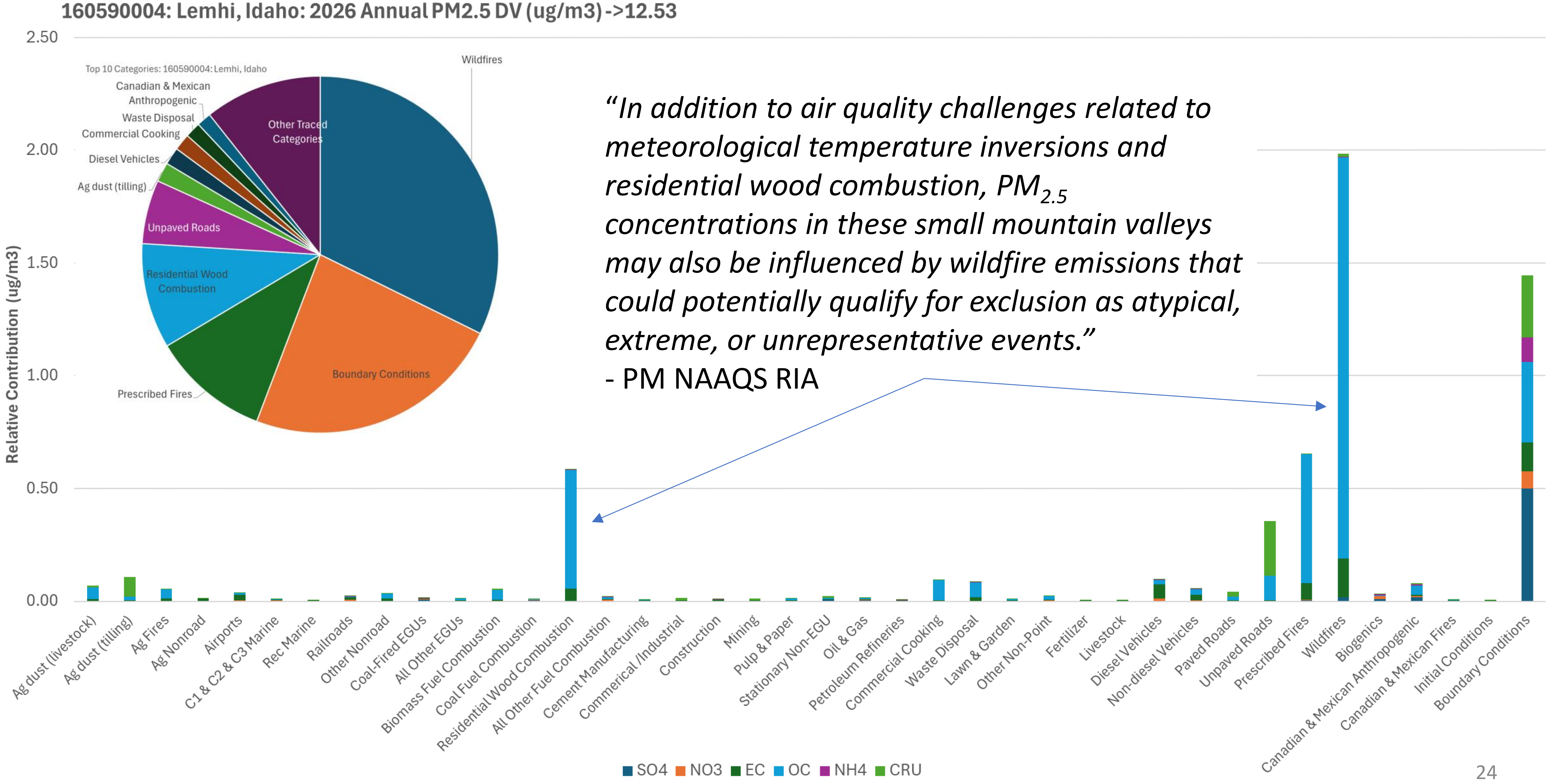
"For the border areas that may be influenced by cross-border emissions, more detailed analyses of international transport emissions will be needed to assess the relevance of Section 179B of the Clean Air Act."

– PM NAAQS RIA

Top 10 Relative Contributing Categories and Traced $PM_{2.5}$ Species

482150043: Hidalgo, Texas			2026 Annual PM2.5 DV (ug/m3) ->					**11.14**
	Relative Contribution (ug/m3)							
Top 10 Categories	**Species Total**	**SO4**	**NO3**	**EC**	**OC**	**NH4**	**CRU**	
Boundary Conditions	3.513	0.900	0.026	0.094	1.507	0.185	0.800	
Canadian & Mexican Anthropogenic	1.105	0.298	0.013	0.093	0.508	0.063	0.129	
Commercial Cooking	0.546	0.000	0.000	0.013	0.527	0.000	0.006	
Prescribed Fires	0.367	0.004	0.000	0.009	0.350	0.001	0.002	
Paved Roads	0.231	0.001	0.000	0.004	0.075	0.000	0.150	
Residential Wood Combustion	0.227	0.000	0.000	0.009	0.215	0.000	0.003	
Waste Disposal	0.163	0.002	0.000	0.015	0.132	0.000	0.013	
Unpaved Roads	0.132	0.001	0.000	0.000	0.027	0.000	0.104	
Non-diesel Vehicles	0.128	0.003	0.001	0.027	0.080	0.001	0.016	
Coal-Fired EGUs	0.109	0.082	0.001	0.001	0.003	0.016	0.005	
SO4 = Particulate Sulfate								
NO3 = Particulate Nitrate								
EC = Elemental Carbon								
OC= Organic Carbon								
NH4 = Ammonium								
CRU = Crustal Material								

Relative Contribution by $PM_{2.5}$ Species and Monitor



"In addition to air quality challenges related to meteorological temperature inversions and residential wood combustion, $PM_{2.5}$ concentrations in these small mountain valleys may also be influenced by wildfire emissions that could potentially qualify for exclusion as atypical, extreme, or unrepresentative events."

- PM NAAQS RIA

Top 10 Relative Contributing Categories and Traced $PM_{2.5}$ Species

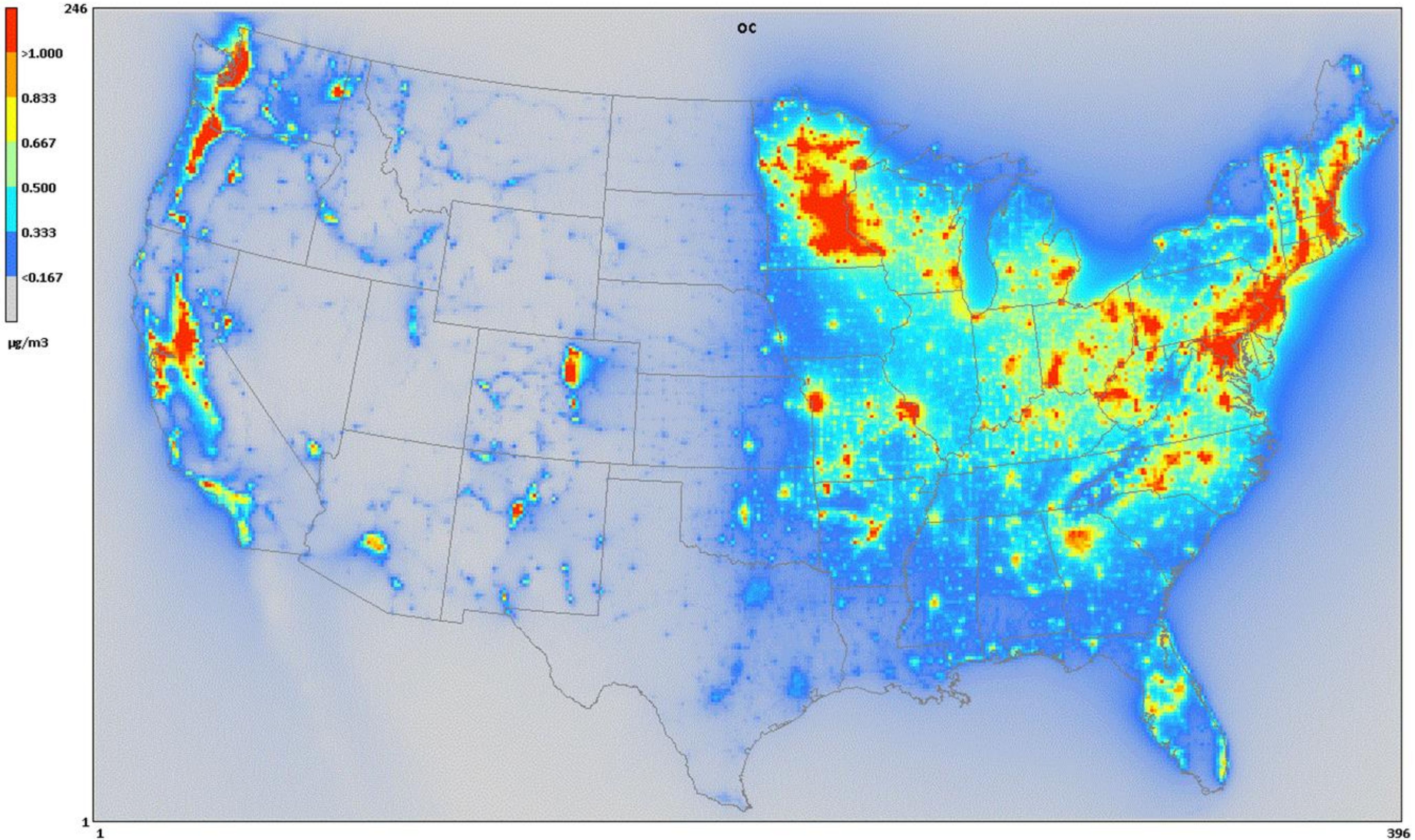
160590004: Lemhi, Idaho		2026 Annual PM2.5 DV (ug/m3) ->					**12.53**
		Relative Contribution (ug/m3)					
Top 10 Categories	**Species Total**	**SO4**	**NO3**	**EC**	**OC**	**NH4**	**CRU**
Wildfires	1.984	0.019	0.000	0.169	1.780	0.004	0.012
Boundary Conditions	1.445	0.499	0.077	0.127	0.358	0.109	0.274
Prescribed Fires	0.655	0.005	0.001	0.074	0.573	0.001	0.001
Residential Wood Combustion	0.586	0.001	0.001	0.055	0.527	0.000	0.003
Unpaved Roads	0.356	0.002	0.000	0.003	0.108	0.000	0.243
Ag dust (tilling)	0.108	0.000	0.000	0.003	0.019	0.000	0.086
Diesel Vehicles	0.097	0.000	0.011	0.064	0.018	0.003	0.001
Commercial Cooking	0.093	0.000	0.000	0.005	0.087	0.000	0.000
Waste Disposal	0.087	0.001	0.000	0.017	0.066	0.000	0.002
Canadian & Mexican Anthropogenic	0.081	0.016	0.006	0.008	0.040	0.005	0.006

SO4 = Particulate Sulfate
NO3 = Particulate Nitrate
EC = Elemental Carbon
OC= Organic Carbon
NH4 = Ammonium
CRU = Crustal Material

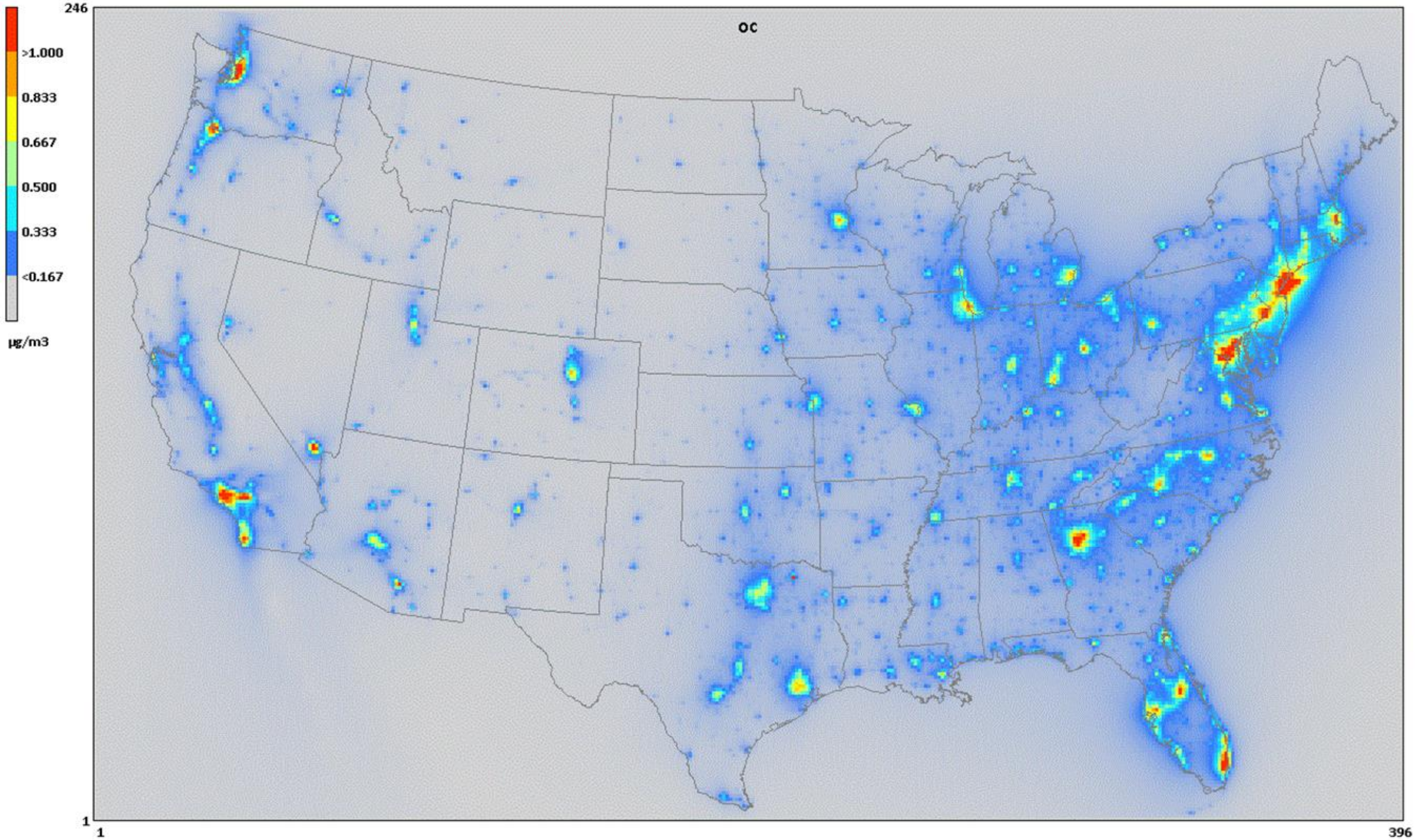
Frequency of Category Modeled in Top 10

Category	Number of Times in Top 10			
	All Conc #	All Conc %	> 9.0 µg/m³ #	> 9.0 µg/m³ %
All Monitors	834	-	306	-
Boundary Conditions	834	100%	306	100%
Residential Wood Combustion	818	98%	303	99%
Commercial Cooking	669	80%	296	97%
Waste Disposal	643	77%	216	71%
Coal-Fired EGUs	614	74%	196	64%
Prescribed Fires	582	70%	186	61%
Stationary non-EGUs	555	67%	188	61%
Wildfires	480	58%	182	59%
Can/Mex Anthopogenic	432	52%	111	36%
Biomass Fuel Combustion	373	45%	147	48%
Diesel Vehicles	373	45%	170	56%
Non-Diesel Vehicles	318	38%	163	53%

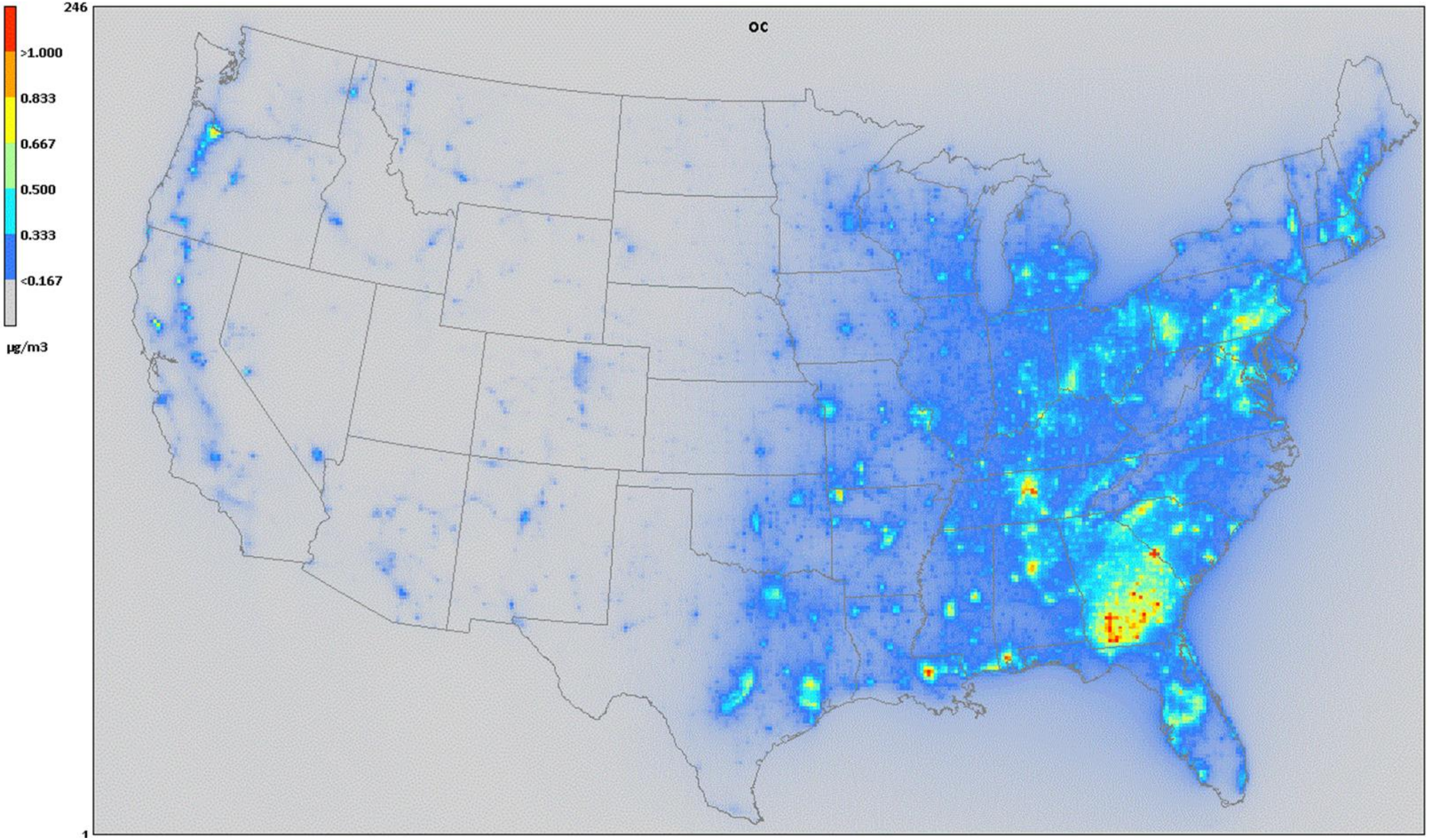
Species-Category Specific Relative Modeled Contribution Example: Organic Carbon from Residential Wood Combustion



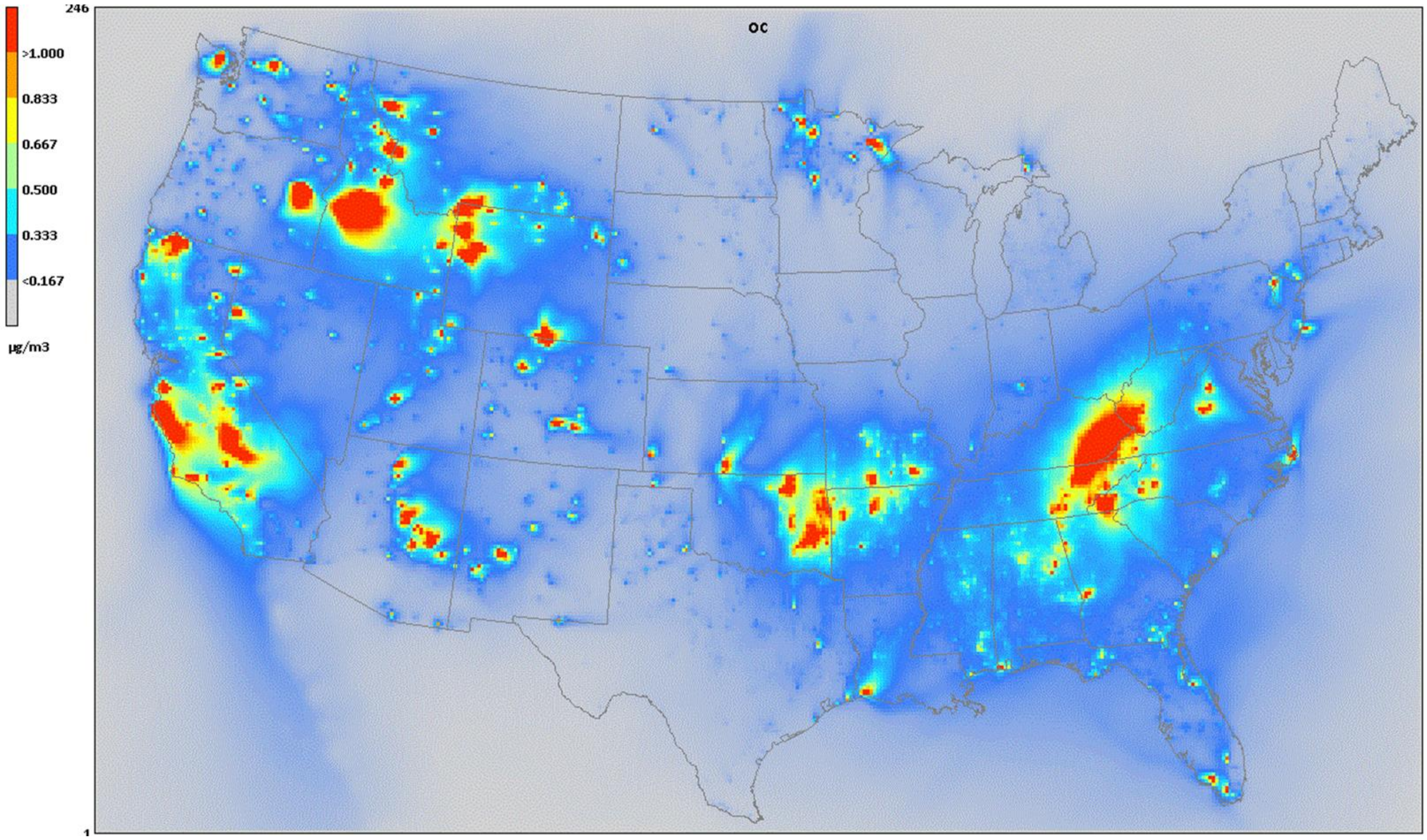
Species-Category Specific Relative Modeled Contribution Example: Organic Carbon from Commercial Cooking



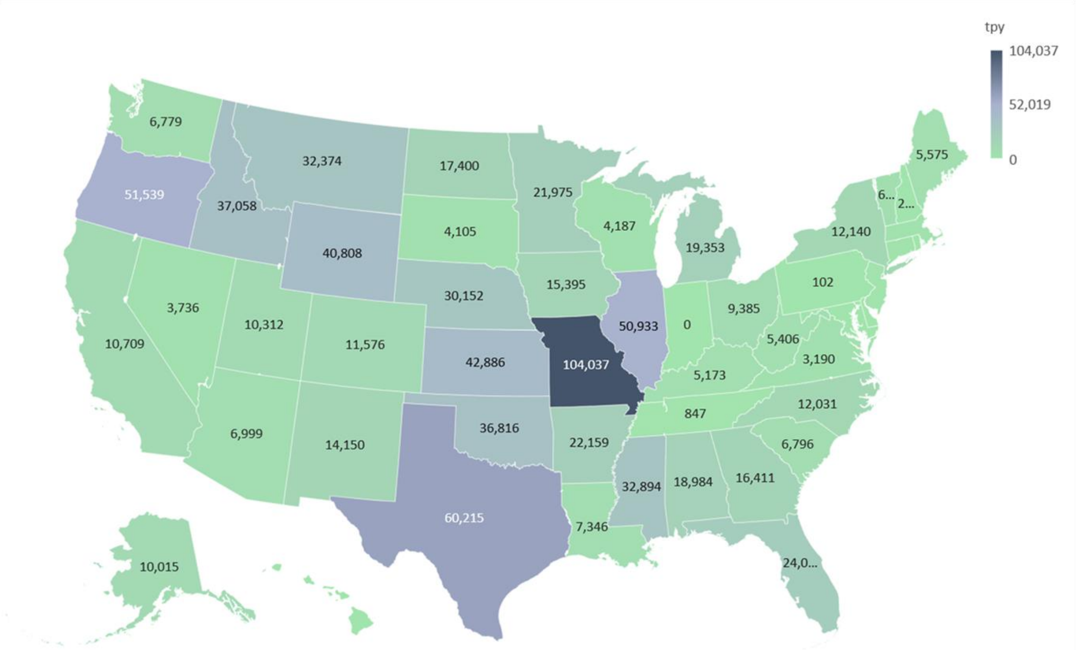
Species-Category Specific Relative Modeled Contribution Example: Organic Carbon from Waste Disposal



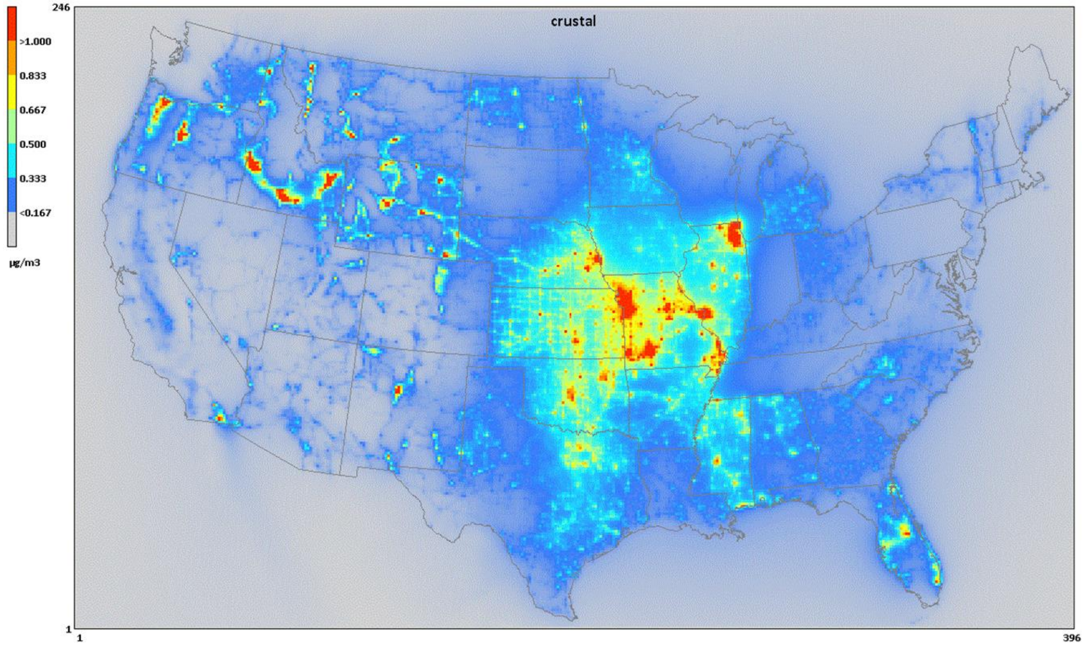
Species-Category Specific Relative Modeled Contribution Example: Organic Carbon from Wildfires



Inventory Issues
Example: Unpaved Roads – Consistency in Reporting



Annual $PM_{2.5}$ Emissions- 2023v2 Projections



Crustal $PM_{2.5}$ Concentrations - 2026v3 Projections

FIPSST 18, Indiana, still missing in EPA's 2022 NEI

See also: MO, PA, TN

State FIP	State	EIS Sector	Pollutant	2016	2017	2018	2019	2020	2021	2022
1	Alabama	Dust - Unpaved Road Dust	PM25-PRI	5,199	4,582	4,090	4,709	3,125	4,442	4,681
2	Alaska	Dust - Unpaved Road Dust	PM25-PRI	1,148	1,191	1,275	1,959	627	3,738	11,352
4	Arizona	Dust - Unpaved Road Dust	PM25-PRI	4,296	4,445	4,476	4,395	1,265	4,220	3,775
5	Arkansas	Dust - Unpaved Road Dust	PM25-PRI	5,859	6,070	5,289	4,951	3,750	6,201	6,247
6	California	Dust - Unpaved Road Dust	PM25-PRI	5,410	5,484	5,901	5,387	5,293	6,194	5,945
8	Colorado	Dust - Unpaved Road Dust	PM25-PRI	5,043	5,234	5,476	4,829	2,534	5,563	4,613
9	Connecticut	Dust - Unpaved Road Dust	PM25-PRI	148	145	123	134	108	153	145
12	Florida	Dust - Unpaved Road Dust	PM25-PRI	12,211	12,479	12,716	12,902	1,880	3,751	3,441
13	Georgia	Dust - Unpaved Road Dust	PM25-PRI	4,252	4,084	3,364	3,853	2,779	3,848	4,203
15	Hawaii	Dust - Unpaved Road Dust	PM25-PRI	166	169	168	155	181	159	245
16	Idaho	Dust - Unpaved Road Dust	PM25-PRI	17,578	16,740	18,068	17,590	6,776	15,505	11,512
17	Illinois	Dust - Unpaved Road Dust	PM25-PRI	16,535	19,253	15,807	13,501	10,072	16,996	17,547
19	Iowa	Dust - Unpaved Road Dust	PM25-PRI	5,069	6,353	4,274	3,877	3,222	6,255	6,005
20	Kansas	Dust - Unpaved Road Dust	PM25-PRI	21,787	23,289	21,406	19,355	8,241	20,358	20,237
21	Kentucky	Dust - Unpaved Road Dust	PM25-PRI	1,134	1,087	860	1,016	734	1,016	1,294

Observations

- In most urban area locations, anthropogenic emissions from commercial cooking, residential wood combustion, and waste disposal have the highest relative percentage of modeled $PM_{2.5}$ concentrations
- At monitors near international borders, total traced species from boundary conditions and Canadian and Mexican anthropogenic categories dominate the modeled contribution to the overall annual $PM_{2.5}$
- At remote mountain monitors, wildfire, boundary conditions, prescribed fires, and residential wood combustion dominate the composition to the total annual $PM_{2.5}$ concentrations

Observations (con't)

- Modeled attainment of 9.0 µg/m^3 annual NAAQS may prove challenging in areas where limited anthropogenic control options are available
- Current, available modeling may prove to be best option in determining relative contributing categories until (and if) EPA generates category-specific PM source apportionment modeling with 2022v1 platform
- Additional findings in Alpine TSD (not presented here) corroborate EPA's findings of NAAQS exceedances being driven by the urban $PM_{2.5}$ increment and the relatively high responsiveness of $PM_{2.5}$ concentrations to primary $PM_{2.5}$ emission reductions within these urban cores

ALPINE GEOPHYSICS

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