Emission Modeling Profiles Updates for 2020 Platform

11/17/2023

Background

- A number of updates to speciation, temporal allocation, and spatial surrogates were made for 2020 and 2021 platforms and those are summarized here
- For more information on methods used for 2020 including additional plots, see the TSD available here:
  - https://www.epa.gov/air-emissions-modeling/2020-emissions-modeling-platform

Speciation Updates in 2020 Platform

- Profiles are based on SPECIATE 5.2

- For PM2.5:
  - The profile for grass fires was updated to profile 95809.
  - The profile for hydrogen boilers were updated to a gas combustion profile.
  - Assignments for new PM2.5 SCCs in the 2020 point and nonpoint inventories were developed.

- For VOC:
  - The profile for wildfires and prescribed fires was updated to profile 95861.
  - Assignments for new VOC SCCs in the 2020 point and nonpoint inventories were included (e.g., agricultural silage and asphalt paving).
  - Several point and nonpoint SCCs which were previously assigned the overall average profile were reassigned to more appropriate profiles.
  - Speciation is now done outside of MOVES instead of MOVES generating EF tables with speciated pollutants

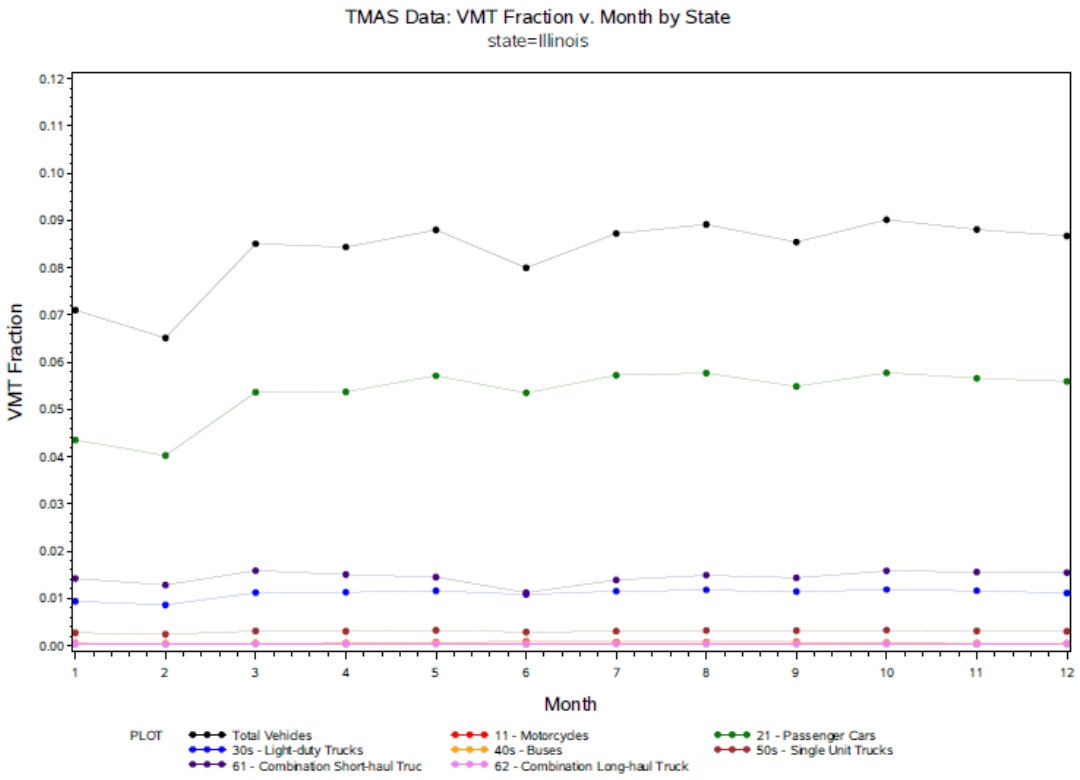
Onroad Speciation Outside of MOVES

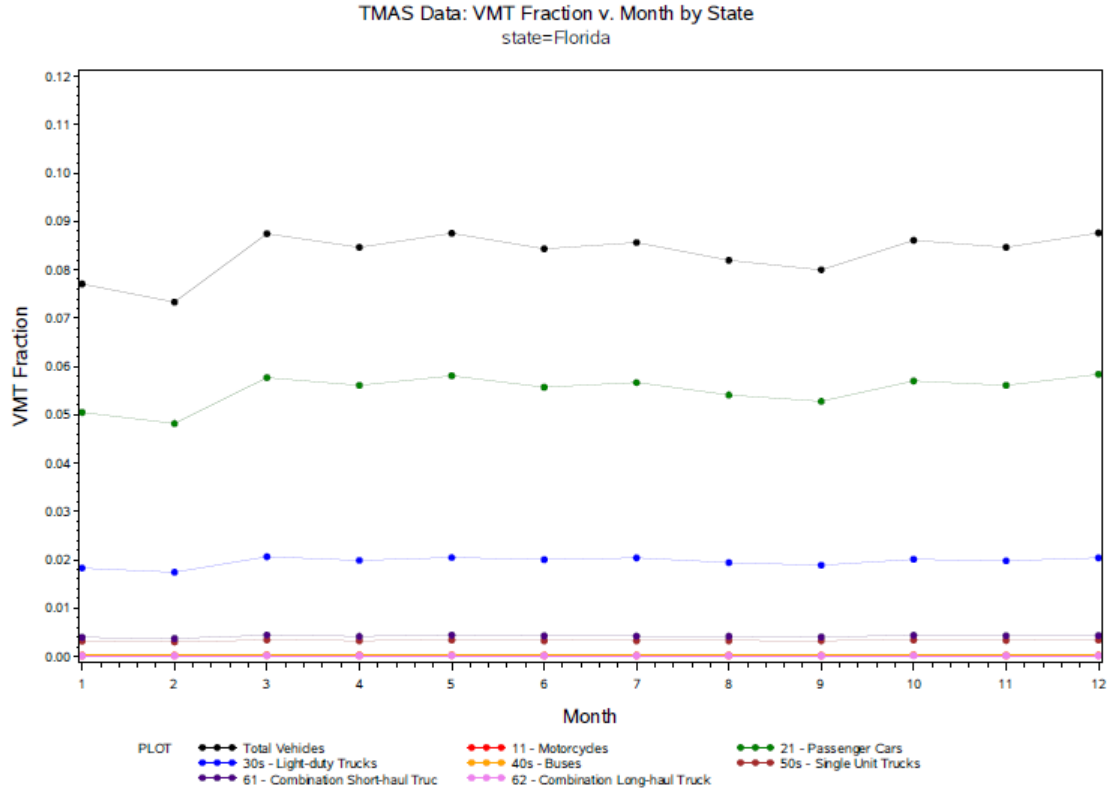
- Some speciation is done inside MOVES for “integrated species” – species of gases and particulate matter which are calculated directly by MOVES. In many cases, these integrated species have effects like temperature or fuel effects which are not always well captured by external speciation profiles.
- For total organic gases, MOVES calculates 15 integrated species, such as methane and benzene, and the remainder is called NonHAPTOG which is speciated outside MOVES. [*starting in 2020 platform*]
- There are fewer PM integrated species, such as elemental carbon (EC), sulfate, organic carbon, and non-carbon organic matter but the concept is the same. The remaining unspeciated particulate mass is called Residual PM and is also speciated outside MOVES [*starting in 2021 platform*]
- In MOVES, speciation profiles for both gaseous and PM emissions are assigned by emission process, fuel subtype, regulatory class, and model year. Each of these dimensions are available in MOVES output except for fuel subtype, which is aggregated as part of each fuel type.
- To apply speciation outside of MOVES and make it compatible with the needs of SMOKE, we need to determine the speciation profile mapping by SMOKE process (aggregation of MOVES emission processes) and SMOKE Source Classification Code (SCC), which are defined by fuel type, source type, and road type
    1. MOVES runs were performed in **inventory mode** for each representative county to get NonHAPTOG and Residual PM output by emission process, fuel type, regulatory class, and model year. Emissions were then disaggregated by fuel subtype using the market share of each fuel blend in each county, so that speciation profiles can be accurately assigned.
    2. After this step, emissions are normalized and aggregated to calculate the percentage of total NonHAPTOG and Residual PM emissions that should be speciated by each profile for each SMOKE SCC and process.
    3. Finally, these percentages are applied in SMOKE_MOVES to all counties based on their representative county

Temporal Allocation Highlights in 2020 Platform

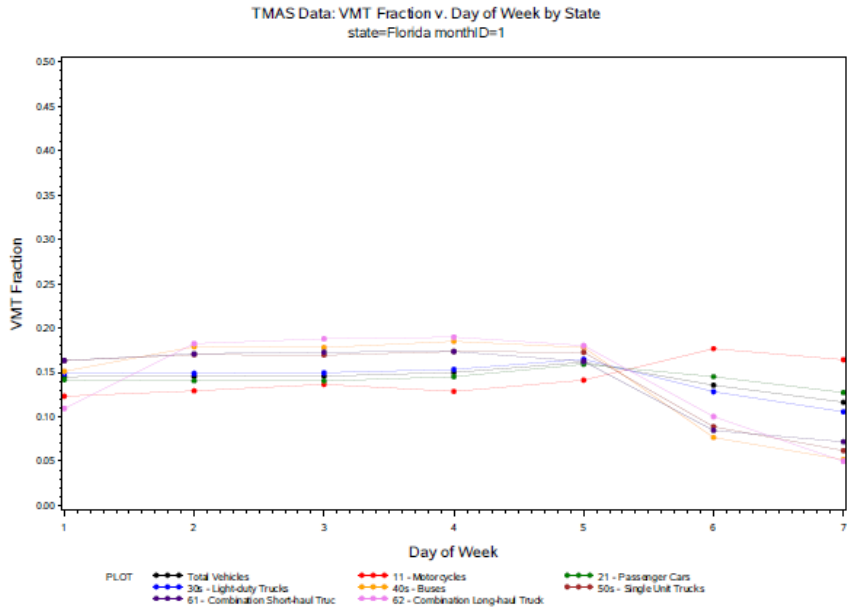
- Profiles for small-EGUs without CEMS reflect 2020
- Year-specific profiles are used for oil and gas sources
- Fugitive dust emissions have reductions based on hour / grid-cell specific meteorological data for soil moisture and snow cover (not a new method) and also transport fraction
- Airport temporal profiles (diurnal, month to day, and annual to month) reflect pandemic impacts with airport-specific for major airports and state defaults (*see TSD for plots*)
- Nonroad temporal allocation was unchanged be we wondered if LADCO profiles for agricultural equipment may be applicable in other places
- Biogenic emissions are based on year-specific meteorological data
- Onroad temporal profiles are based on 2020 data
  - For 2021, EPA used statewide 2021 volume counts from FHWA (TMAS) to derive annual to month, month to day, and diurnal profiles for four groups of vehicle types; speeds were carried over from December 2020
  - We recommend a similar approach for 2022v1, but hope for better data in 2022v2
- Ammonia profiles are based on year-specific meteorological data

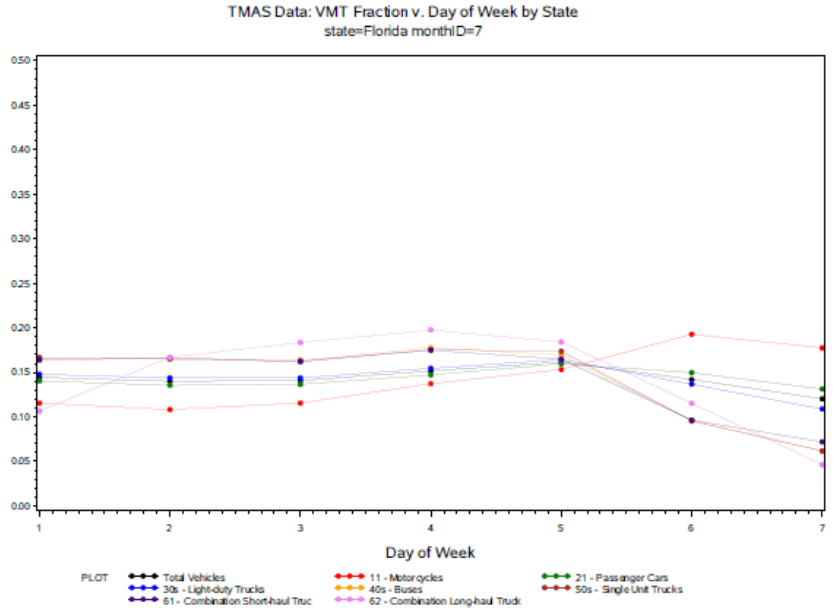
Examples of 2021 TMAS Data (monthly)

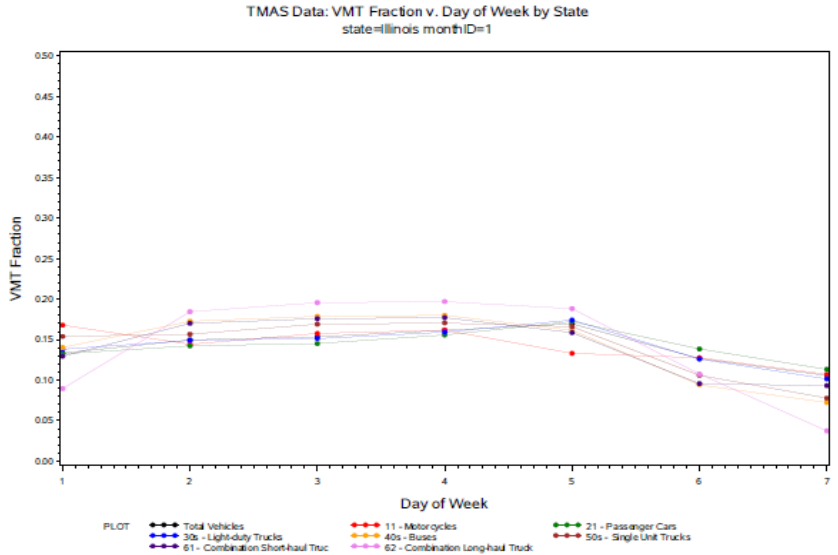


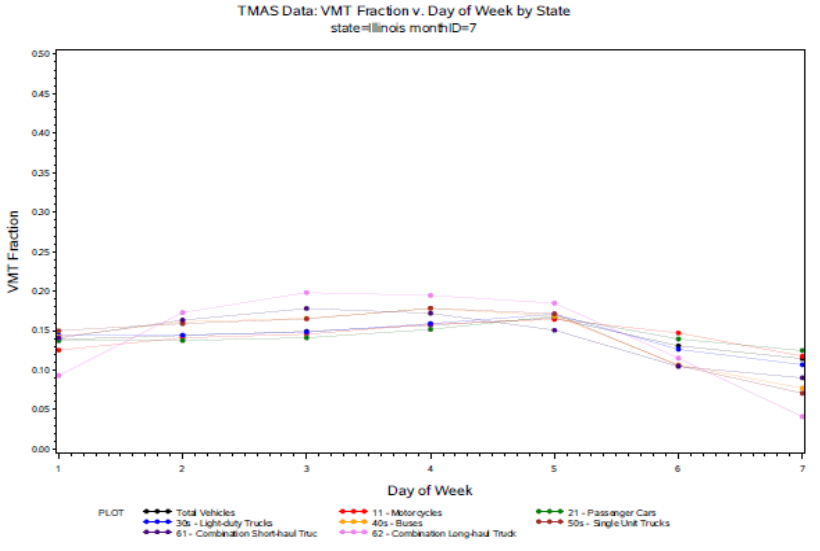


Examples of 2021 TMAS Data (day of week)

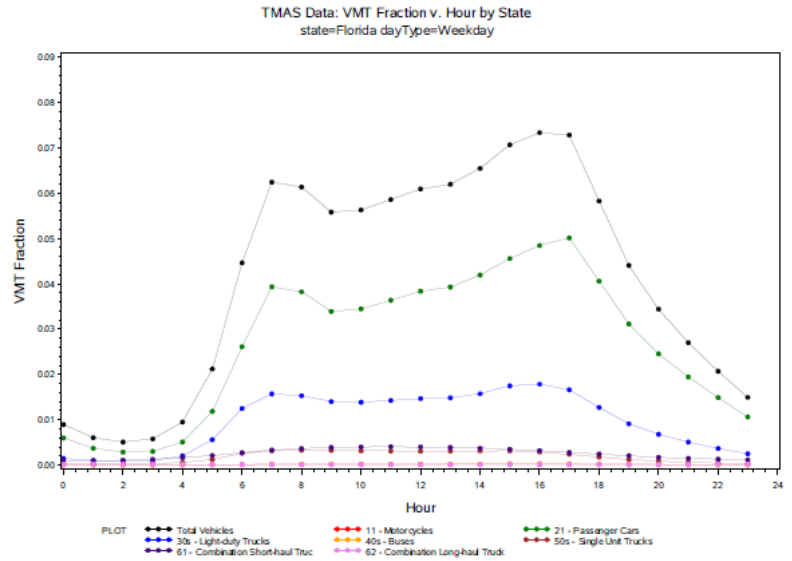


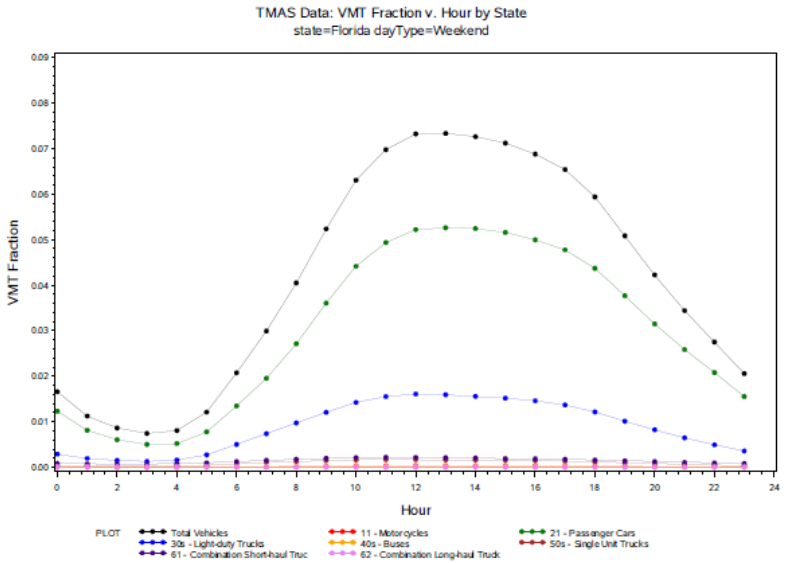


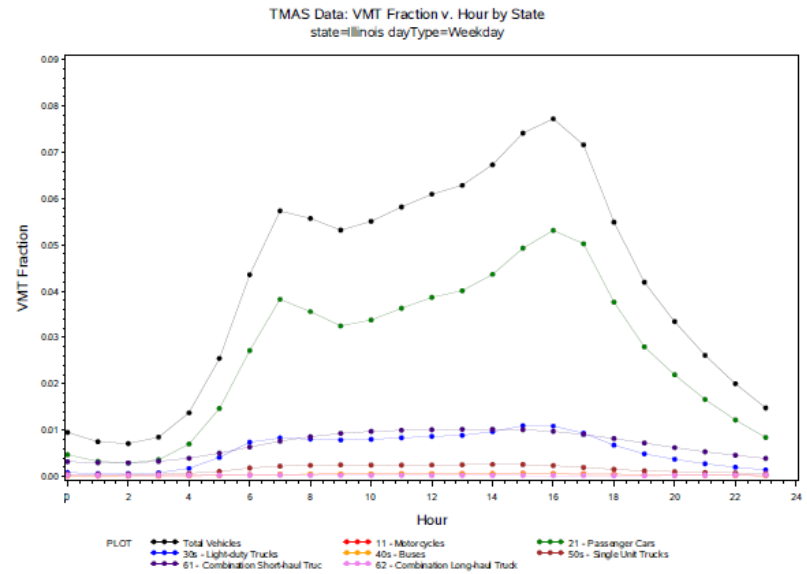


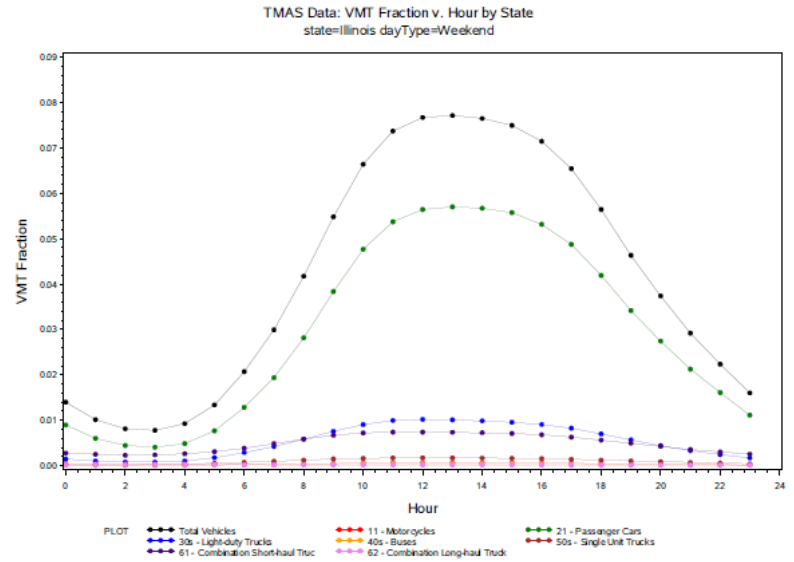


Examples of 2021 TMAS Data (hour of day)

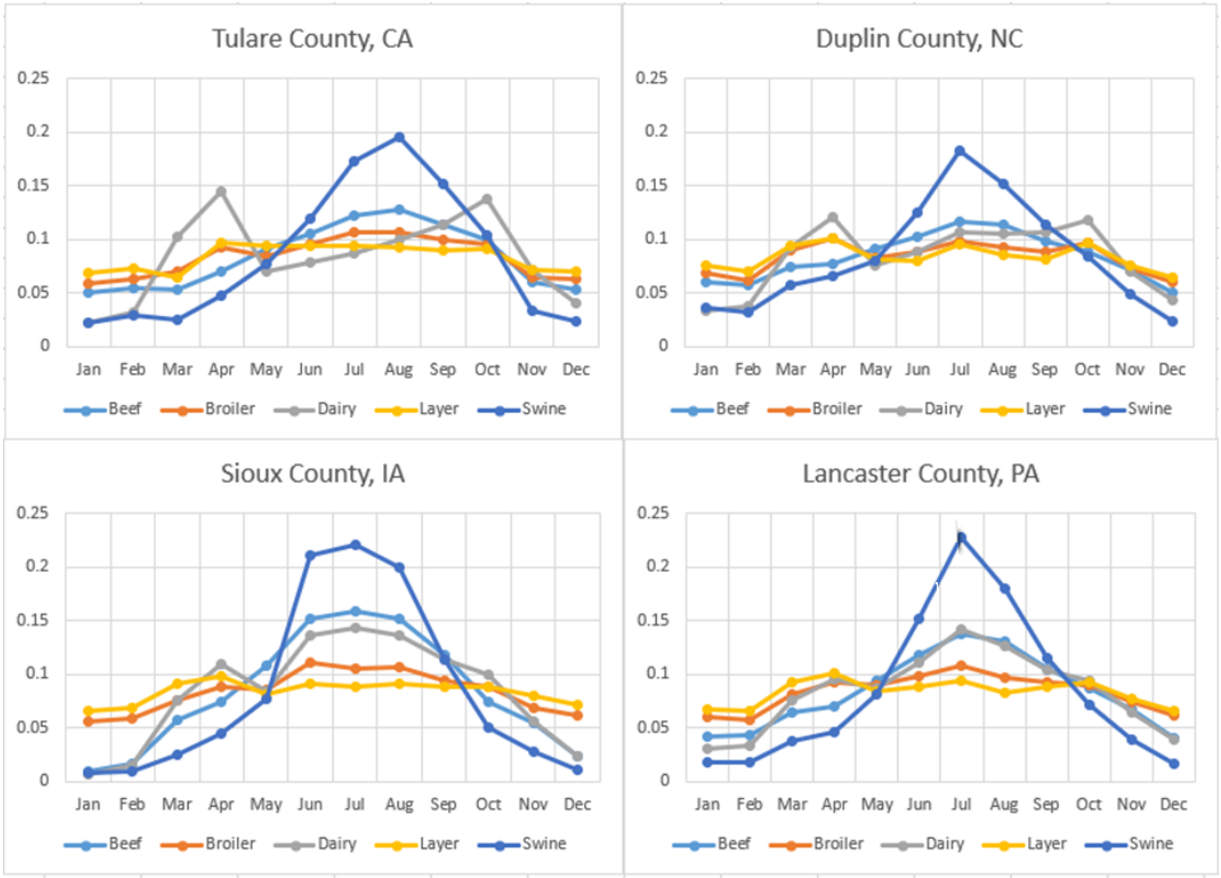


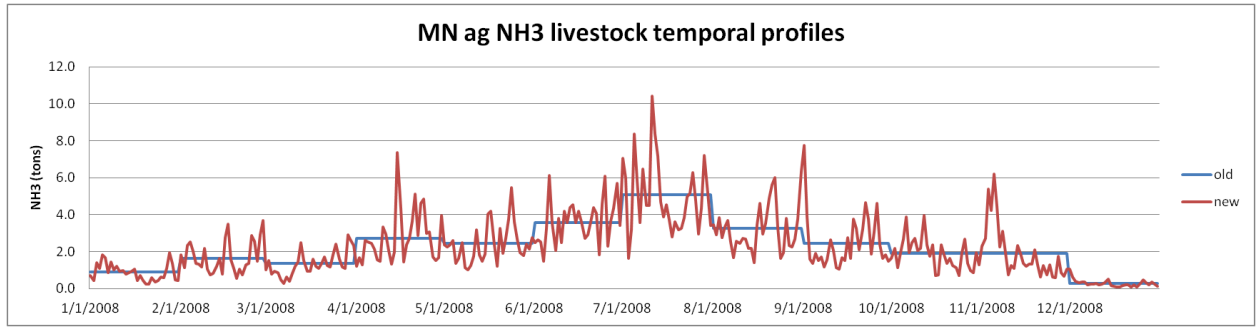






Examples of 2020 Agricultural Livestock Profiles

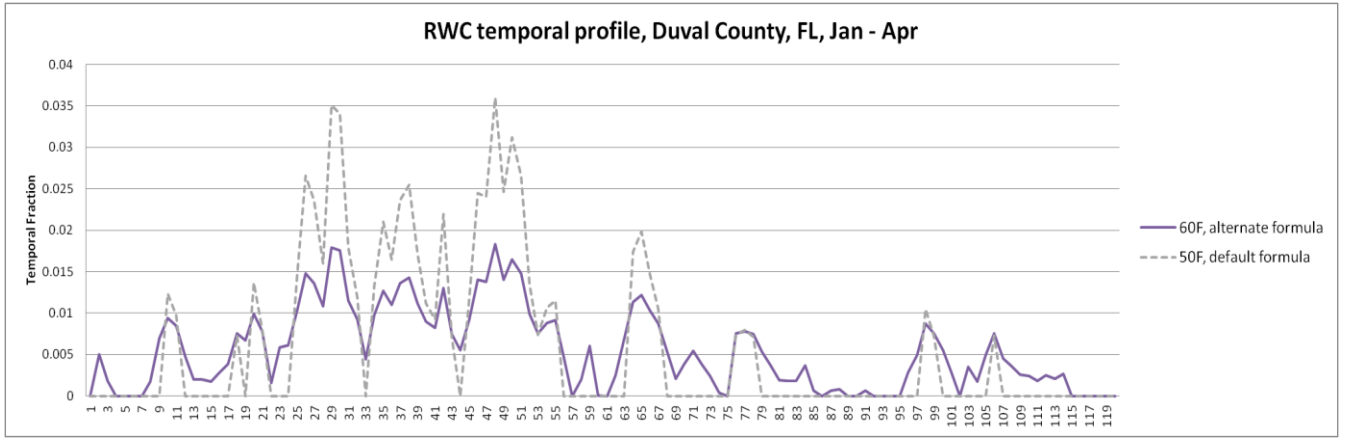




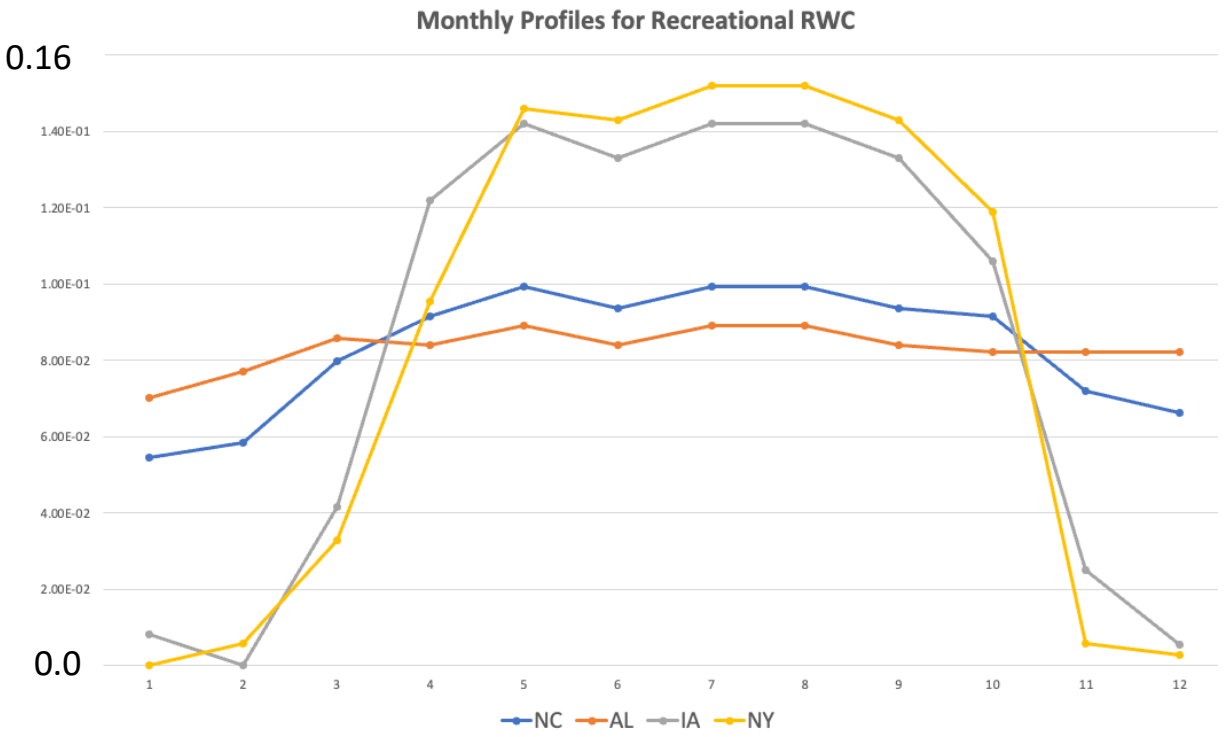
RWC Temporal Profiles

- RWC annual to day profiles are based on year-specific meteorology
- A new annual-to-day approach to allocate recreational wood burning emissions (e.g., firepits) was implemented: emissions are allocated only to days in which the temperature falls within a range of 50°F and 80°F at some point during the day.
- Recent studies show that the formula used to attribute most RWC emissions to specific days of year may need to be refined (Tt is 50°F in most states and 60°F in southern states)

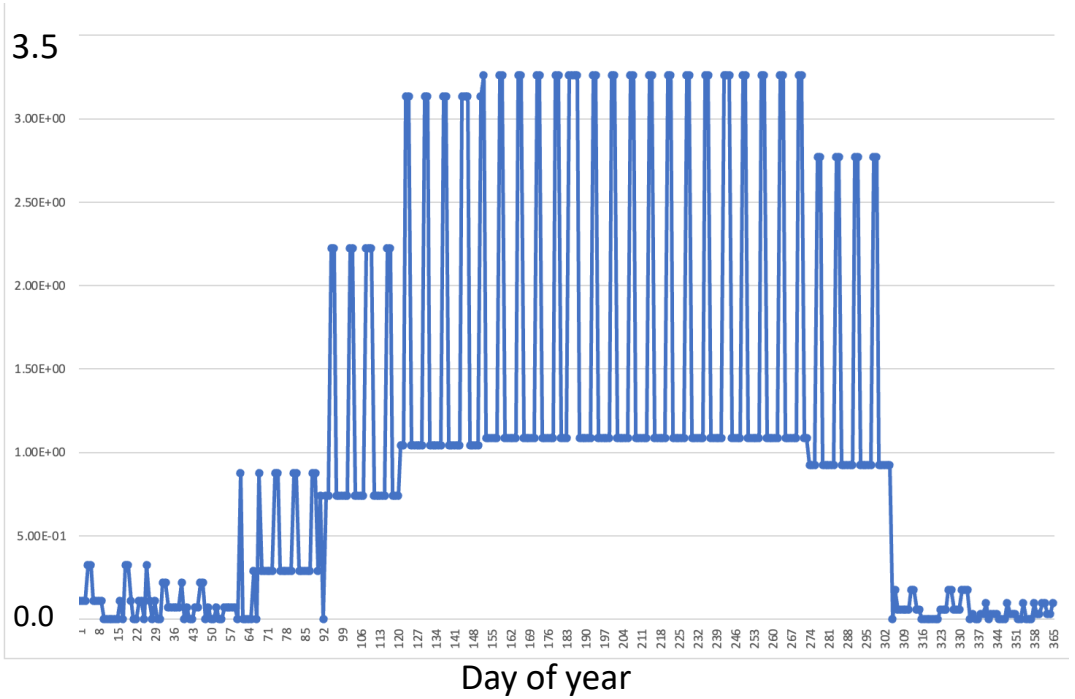
$$PE_{i,d} = \begin{cases} 0 & if\ T_{i,d} \geq T_t \\ 0.79 \times \left(T_t - T_{i,d}\right) \Big/ \sum_d \left(0.79 \times \left(T_t - T_{i,d}\right)\right) & if\ T_{i,d} < T_t \end{cases}$$



Recreational Wood Burning Profiles (new in 2020)



Annual to day output based on meteorology



Northern states now have more emissions in the warmer months
All profiles are county-specific and incorporate day-of-week variations with higher emissions on weekends (33% each weekend day)

Spatial Surrogate Updates in 2020 Platform

- County boundaries used for all surrogates were updated to use the 2020 TIGER boundaries.
- Oil and gas surrogates were updated to represent 2020.
- American Community Survey-based surrogates were updated to use the 2020 ACS from 2016.
- Updated surrogates for residential wood combustion were developed based on ACS data.
- NLCD-based surrogates were updated to use NLCD 2019 from 2011.
- Animal specific livestock waste surrogates were derived from National Pollutant Discharge Elimination System (NPDES) animal operation water permits and Food and Agriculture Organization (FAO) gridded livestock count data.
- New surrogates for fuel stations, asphalt surfaces, and unpaved roads were created using data from the OpenStreetMap database and corresponding cross reference updates were made.
- Gravel and lead mines were split out to their own surrogates from the more general United States Geological Survey mining surrogate and corresponding cross reference updates were made.
- RWC SCCs now use ACS Detached Housing and Single and Dual Unit Housing instead of NLCD Low Intensity Dev. (but we think further improvements could be made to better reflect structure locations)
- Canadian surrogates were updated with circa 2020 data, but Mexico surrogates are old (looking into updates)

Top 15 surrogates for Total CAPs

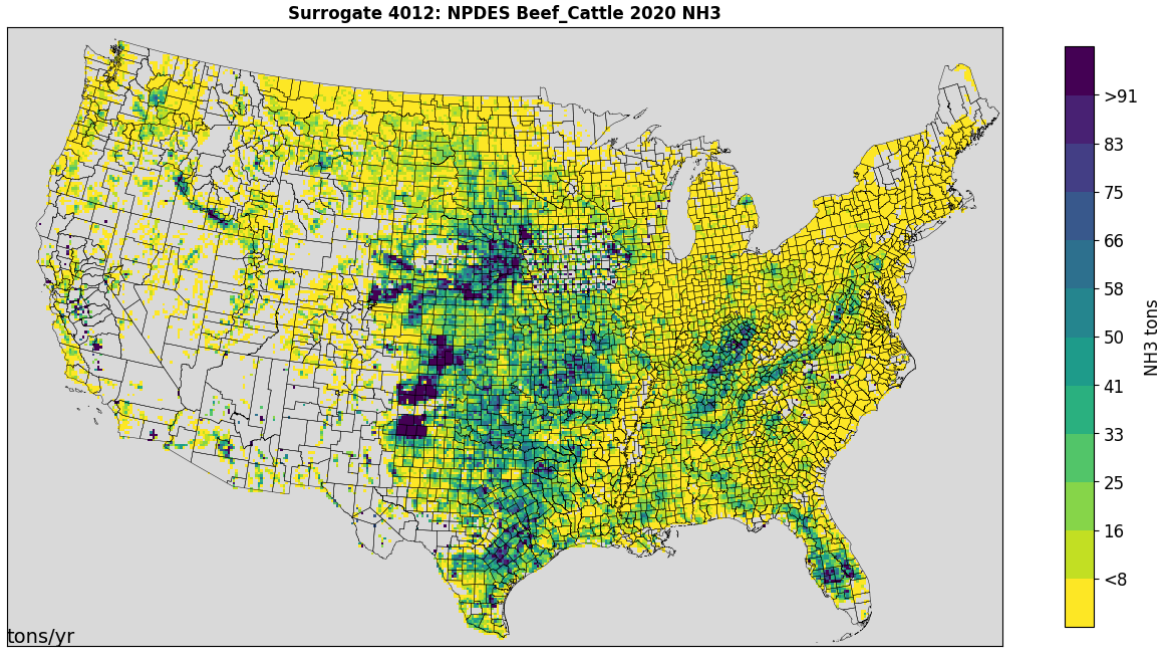
Surrogate	NH3	NOX	PM2_5	SO2	VOC	ALL CAPS
NLCD Total Agriculture	1,833,469	257,391	521,516	197	181,096	2,793,669
NLCD Med + High	19,120	503,164	437,296	85,883	675,979	1,721,442
All Unrestricted AADT	54,906	1,215,064	45,715	6,043	394,564	1,716,292
NLCD All Development	80,094	240,831	150,808	11,547	1,022,344	1,505,624
Population	454	0	0	0	1,405,603	1,406,057
OSM Unpaved Roads	0	0	960,028	0	0	960,028
NPDES 2020 Beef Cattle	702,119	0	191,878	0	56,170	950,167
All Restricted AADT	29,464	783,301	20,867	3,049	103,641	940,322
NPDES 2020 Swine	838,696	0	658	0	67,096	906,450
Well Count - Oil Wells	0	159,345	4,270	104,961	619,896	888,472
Oil Production at Oil Wells	0	3,060	4	26,019	805,474	834,557
Single and Dual Unit Housing	15,780	46,570	318,302	8,430	421,911	810,993
Well Count - Gas Wells	0	281,181	4,185	212	504,727	790,305
NPDES 2020 Dairy Cattle	572,321	0	15,033	0	45,786	633,140
NLCD Low + Med + High	1,725	260,644	162,104	5,943	115,228	545,644

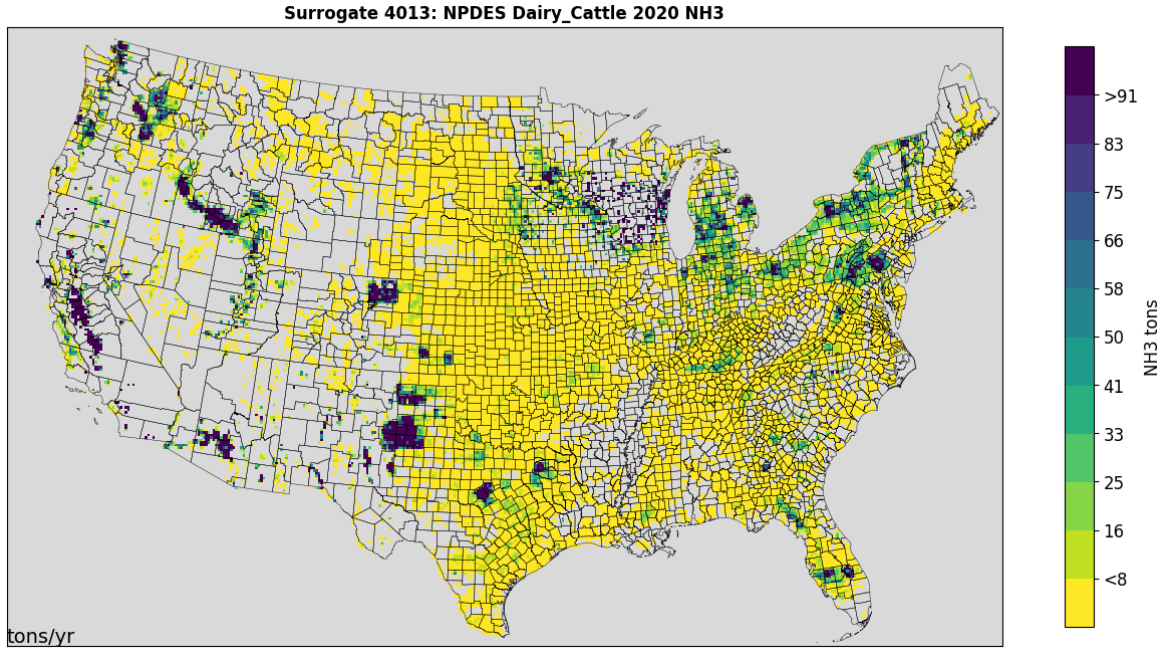
Surrogates 15-30 for Total CAPs

Surrogate	NH3	NOX	PM2_5	SO2	VOC	ALL CAPS
NPDES 2020 Chicken	426,996	0	5,069	0	34,157	466,222
Gas Production at Gas Wells	0	42,067	228	1,120	400,686	444,101
NTAD Class 1 2 3 Railroad Density	269	400,799	9,861	336	18,552	429,817
Detached Housing (rwc)	7,054	29,363	213,791	6,359	143,793	400,360
NLCD Water	203	115,290	4,502	112	258,398	378,505
Total Road Miles	0	0	333,425	0	41,753	375,178
OSM Asphalt Surfaces	0	0	0	0	339,778	339,778
FAO 2010 Large Cattle Operations	0	0	0	0	295,993	295,993
Residential Heating - Natural Gas	44,524	214,626	2,669	1,436	12,680	275,935
OSM Fuel	0	0	0	0	209,354	209,354
NLCD Recreational Land	80	12,898	5,082	35	185,202	203,297
NPDES 2020 Turkey	83,001	0	1,959	0	6,640	91,600
Refineries and Tank Farms	0	0	0	0	90,120	90,120
NLCD Open + Low + Med	133	21,682	1,301	64	50,114	73,294
Produced water at oil wells	0	0	0	0	69,418	69,418

Livestock Surrogates

- 2010 Animal-specific FAO raster data at ~10 km resolution
  - Masked with NLCD agriculture areas to improve spatial resolution for fine scales
- NPDES water waste animal feedlot (AFO) permits for states where available
  - IA, NC, SC, MN, WI, CA have public datasets with varying coverage by animal type
- Animal types: beef cattle, dairy cattle, chicken, swine, sheep, horse, turkey



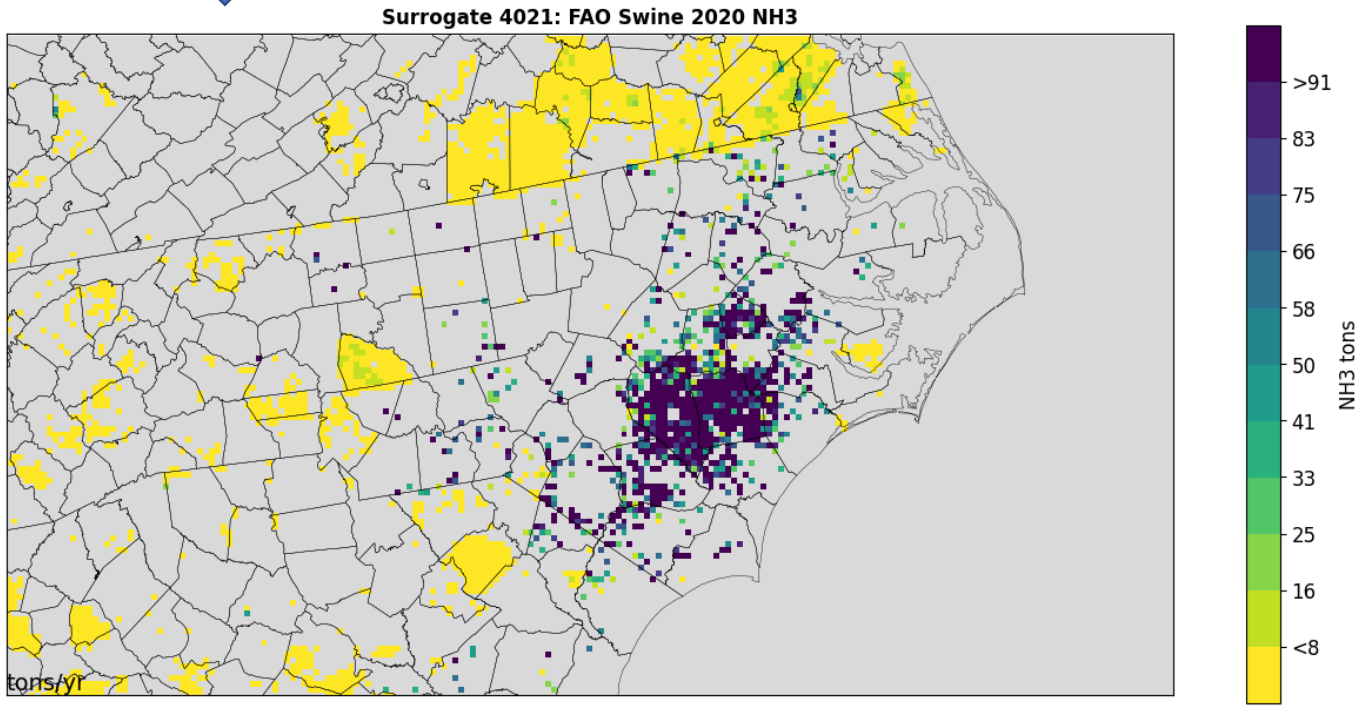


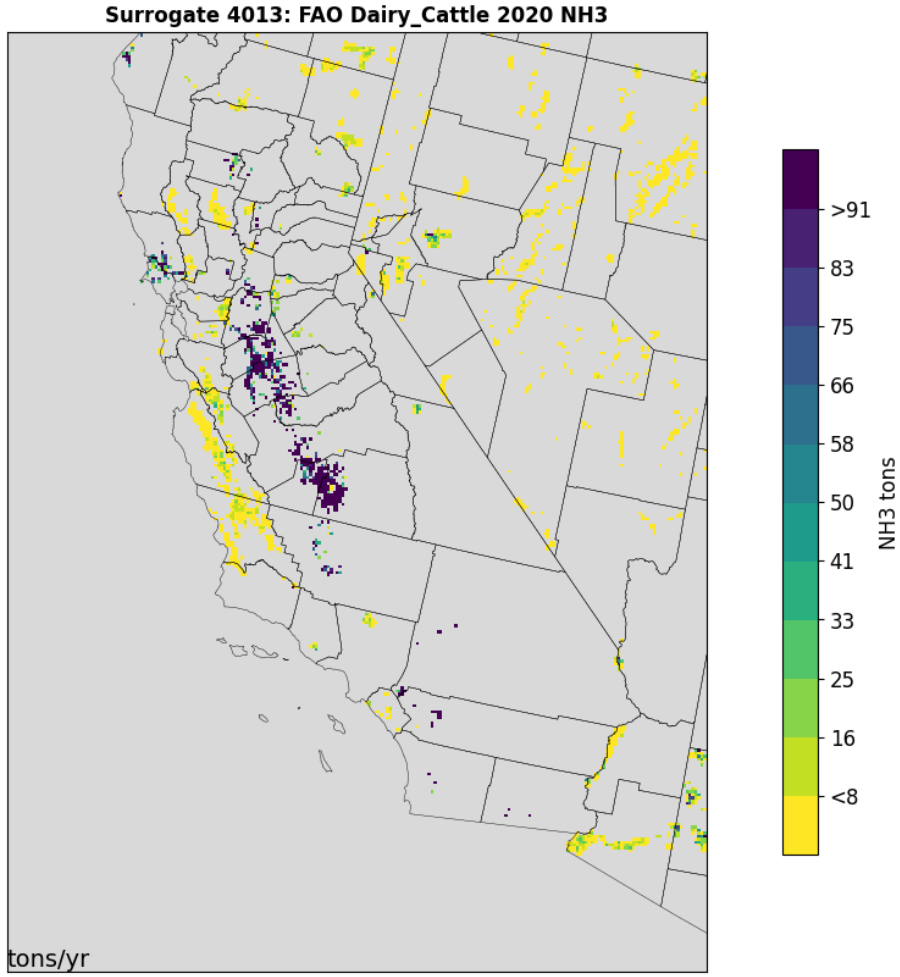
NPDES Impact on Livestock Surrogates

NPDES point data improves allocation at 4 km

NC Swine

CA Dairies





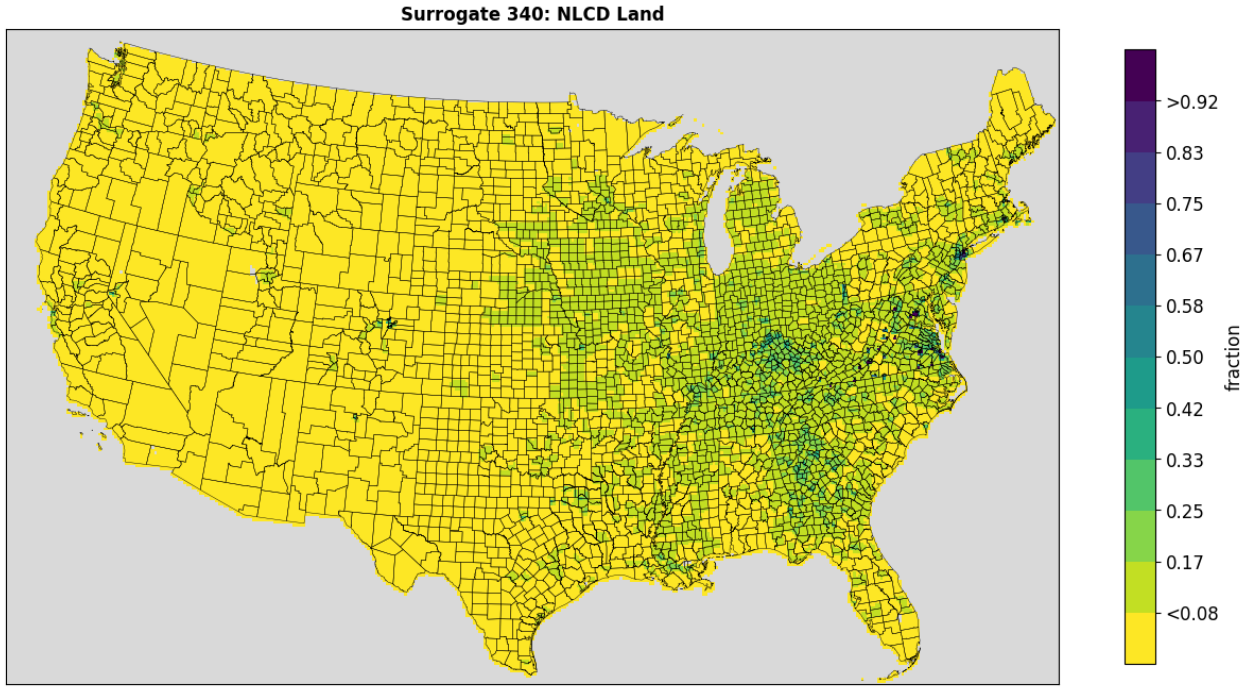
2020 livestock emissions by surrogate (CONUS 12km)

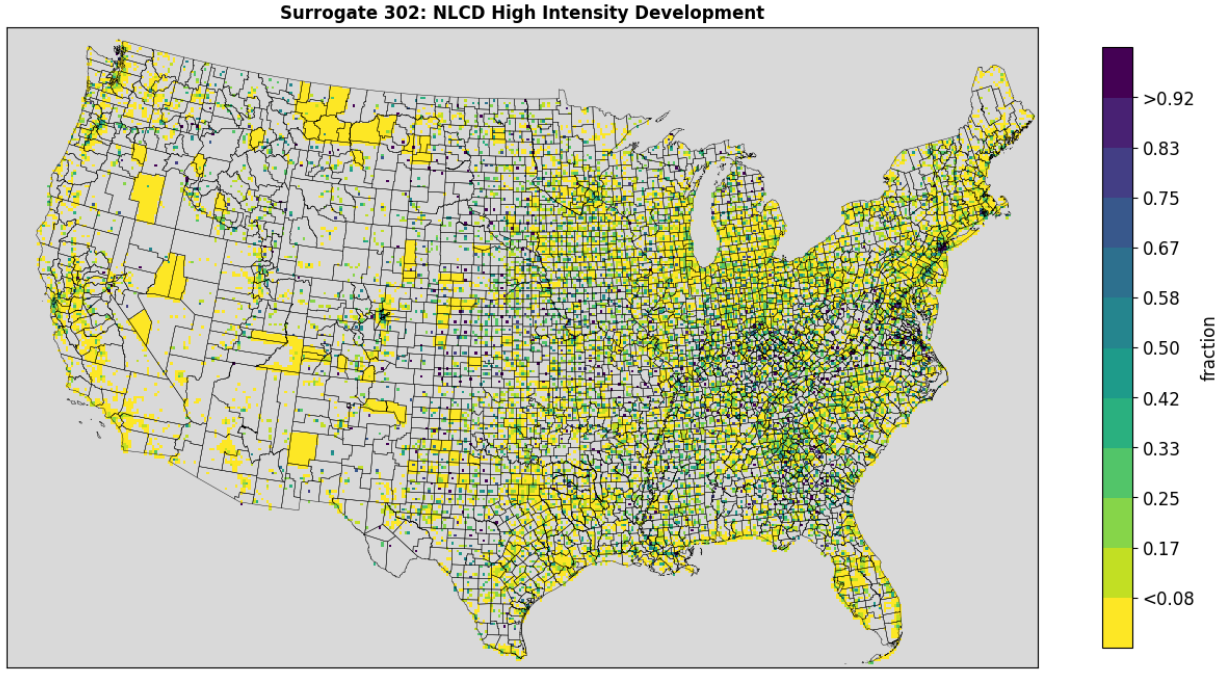
ID	Description	NH3	NOX	PM2_5	SO2	VOC
310	FAO 2010 Horse	31,969	0	0	0	2,558
405	FAO 2010 Sheep	19,235	0	0	0	1,539
406	NPDES 2020 Beef Cattle	702,119	0	0	0	56,170
4012	NPDES 2020 Dairy Cattle	572,321	0	0	0	45,786
4013	NPDES 2020 Swine	838,696	0	0	0	67,096
4031	NPDES 2020 Chicken	426,996	0	0	0	34,157
4041	NPDES 2020 Goat	19,231	0	0	0	1,538
4071	NPDES 2020 Turkey	83,001	0	0	0	6,640

* NPDES surrogates are also used for dust emissions (shown later)

NLCD Surrogates

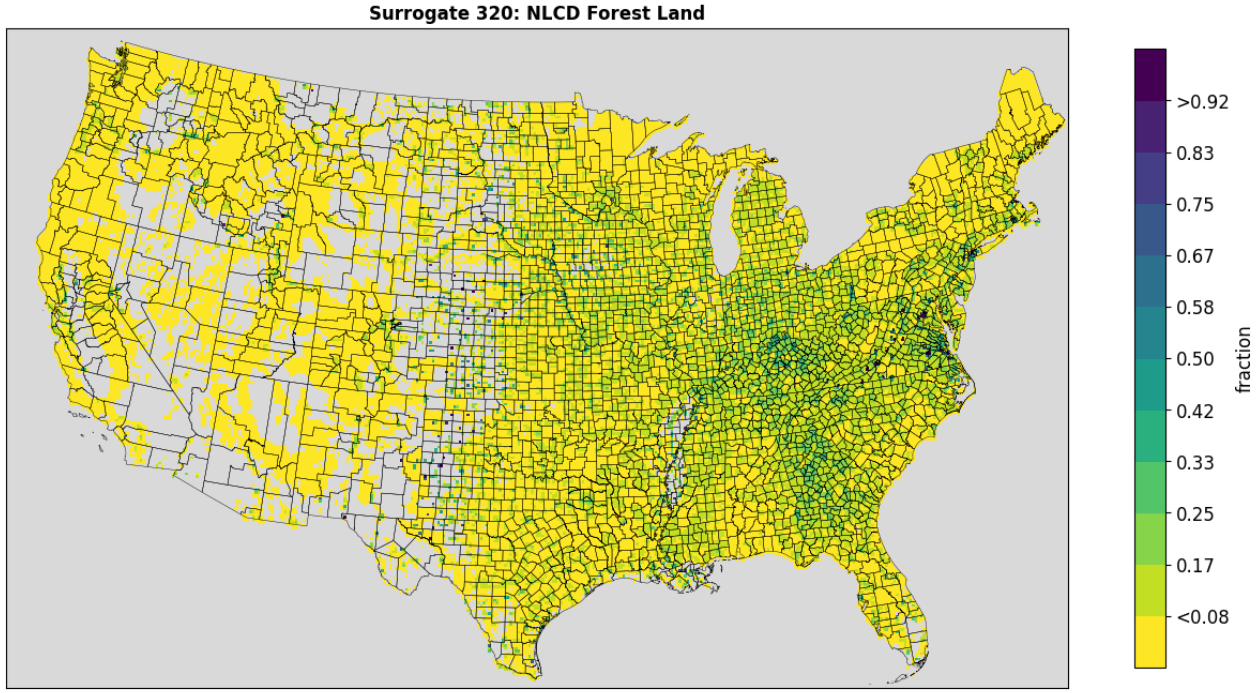
- National Land Cover (NCLD) data were updated to 2019 from 2011
  - Land use with percent developed impervious surface
  - Used to define land area, water, and development related surrogates
  - NLCD surrogates commonly used as a gapfiller for other surrogates
  - Downscaled to 250 m from 30 m using NN approach

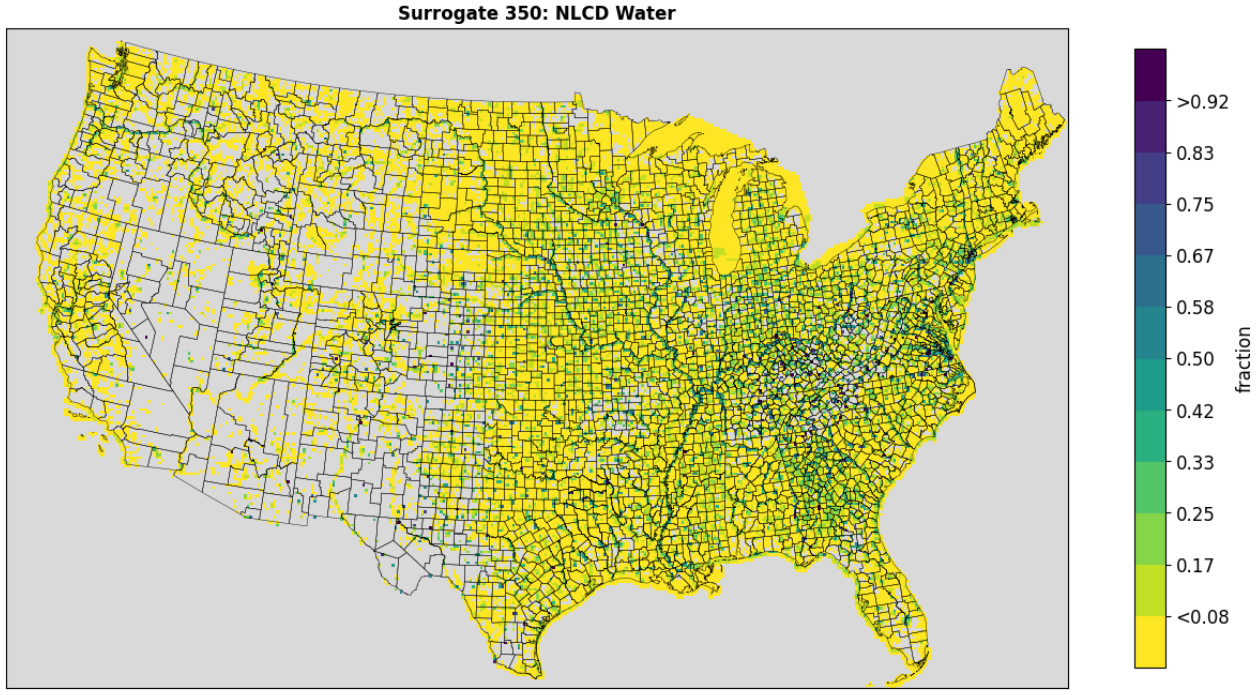




Available NLCD Surrogates

- Open Space (< 20% impervious)
- Low Development (20-49% impervious)
- Med Development (50-79% impervious)
- High Development (80%+ impervious)
- Combinations of Open, Low, Med, and Hig
- Total Agriculture (pasture, hay, row crops)
- Forest Land (all tree types)
- Recreational Land
- All Land
- All Water



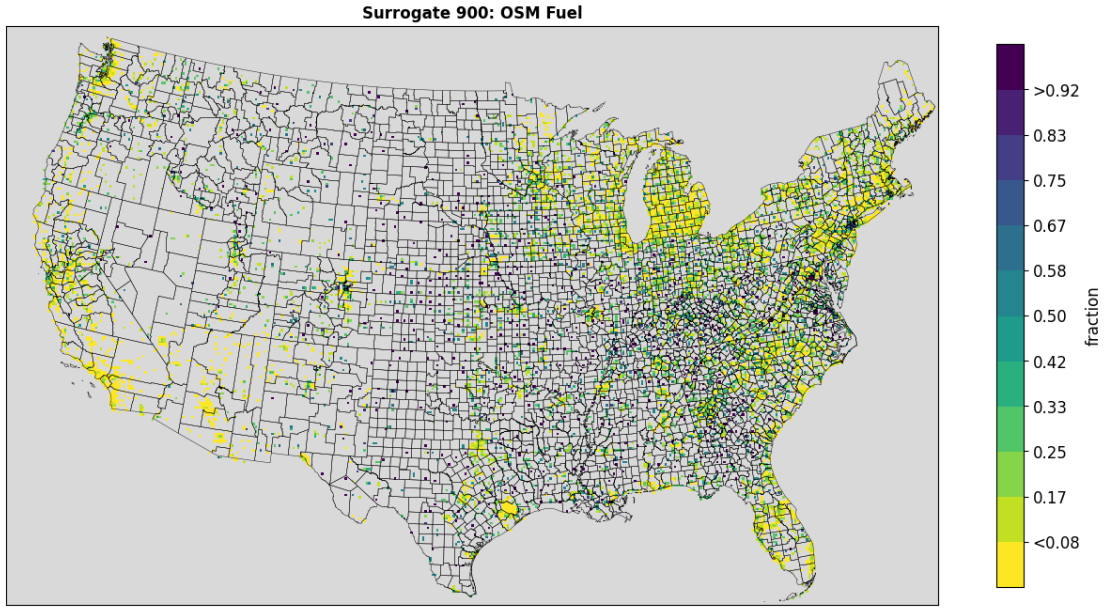


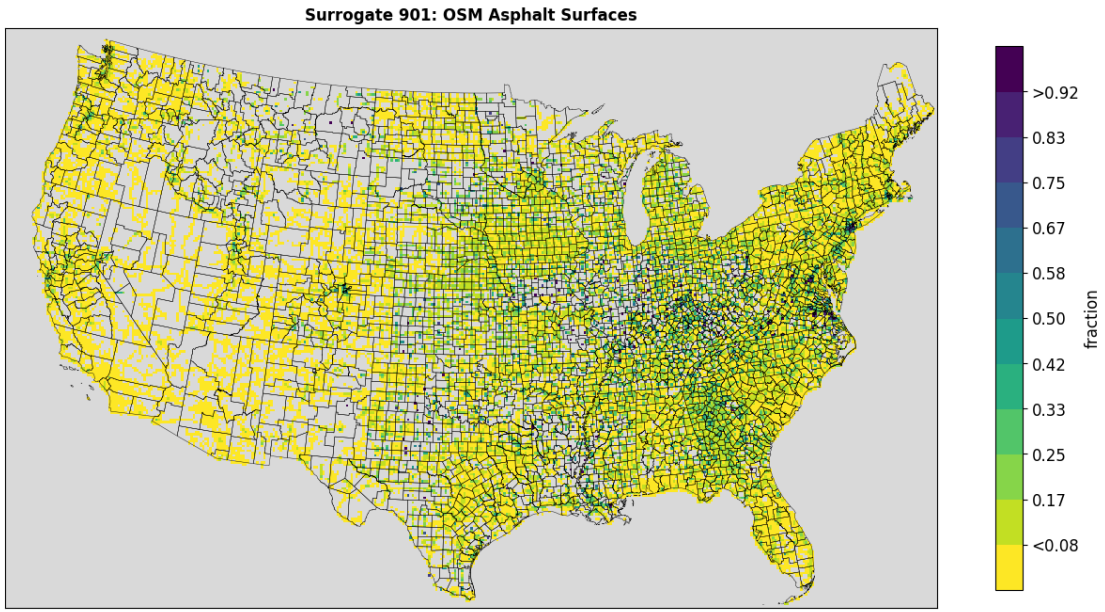
NLCD Surrogate Uses in 2020 Platform

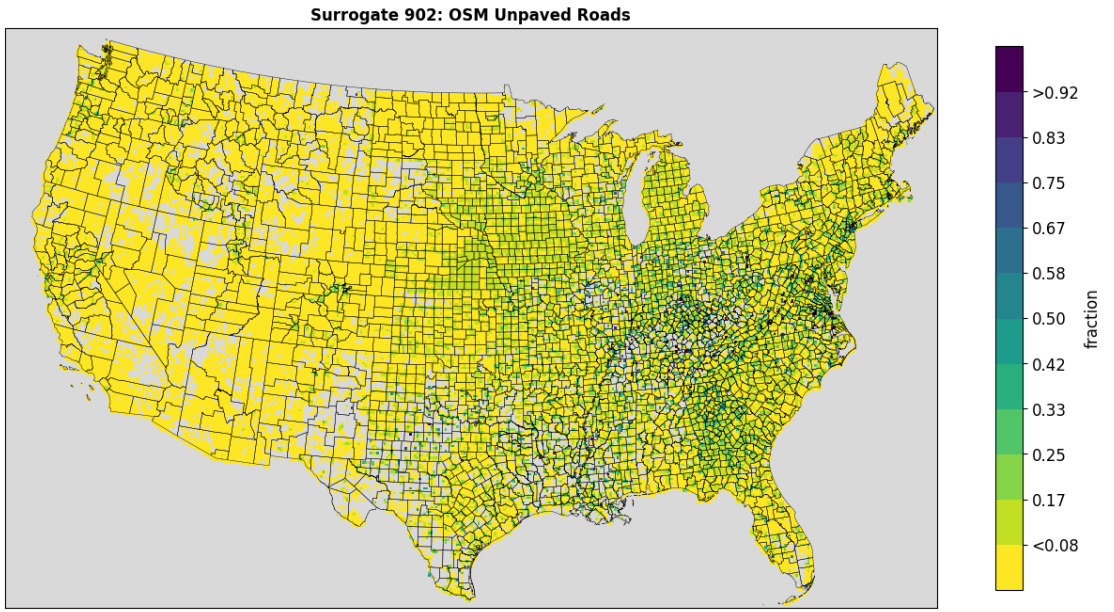
- Most off-network onroad emissions
- Almost all nonroad emissions
- All fertilizer emissions are assigned to NLCD Total agriculture
- They are also used for 650K tons of fugitive dust PM2.5
- About 800K tons of solvent emissions use NLCD surrogates
- They are used for significant amounts of other nonpoint NOx and VOC
- **Totals by CAP**: 1.4M tons of NOx, 2M tons of NH3, 1.3M tons PM2.5, 2.6M tons VOC and 104K tons of SO2

OpenStreetMap (OSM) Surrogates

- Crowd-sourced open geographic database
  - Network of nodes, lines, and polygons
  - Contains attributes indicating
    - Road amenities such as fueling stations
    - Surface types of roads and parking areas
- Fuel stations, asphalt surfaces, unpaved roads





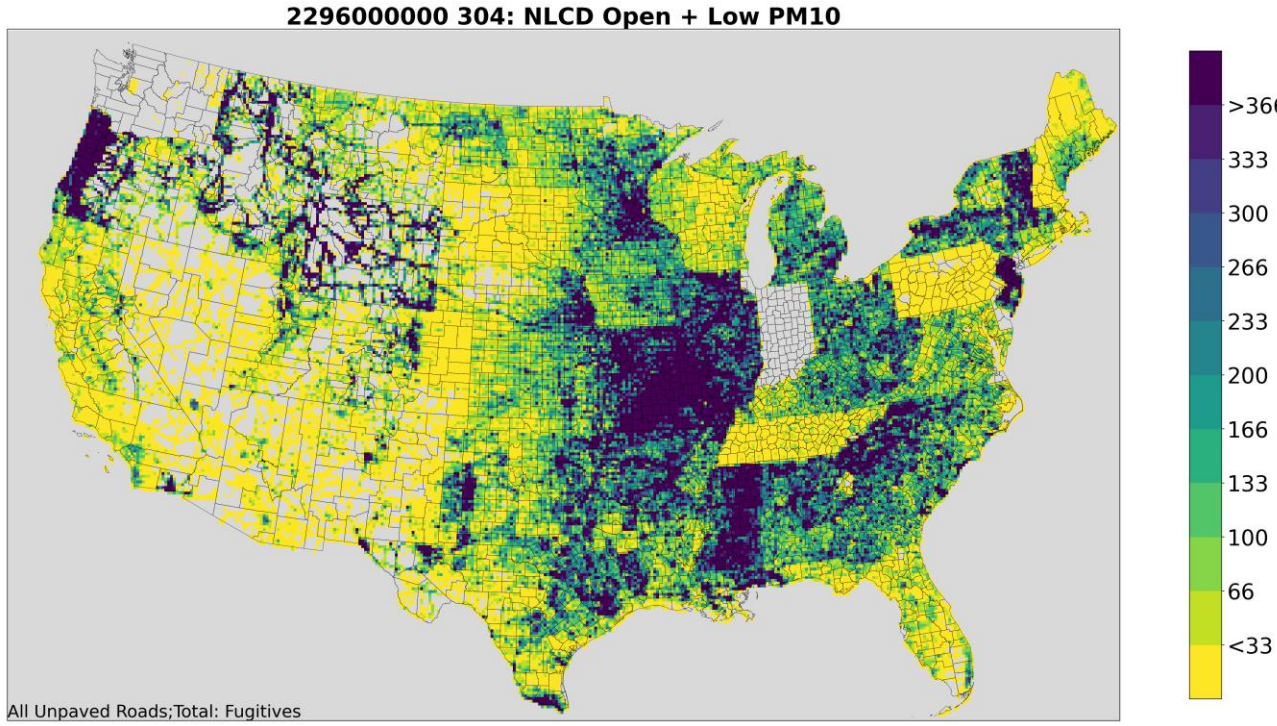


Uses of OpenStreetMap Surrogates in 2020 Platform (CONUS 12km grid)

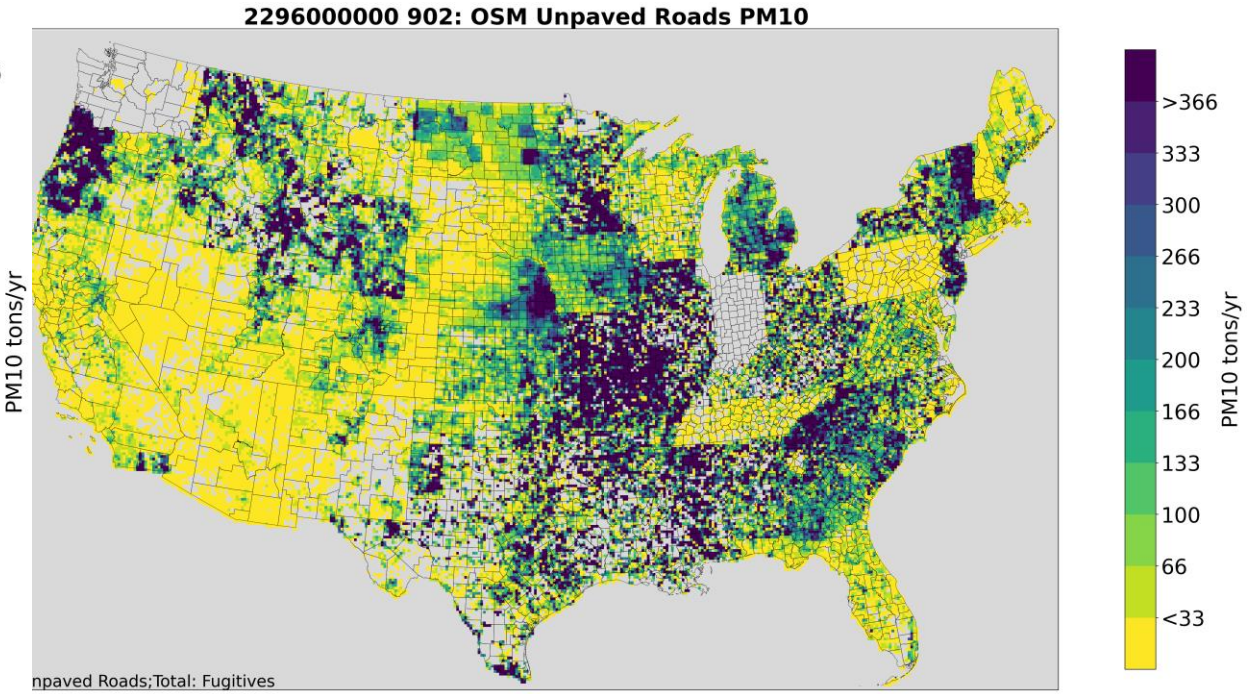
Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
afdust	902	OSM Unpaved Roads	0	0	960,028	0	0
nonpt	900	OSM Fuel	0	0	0	0	209,354
np_solvents	901	OSM Asphalt Surfaces	0	0	0	0	339,778

OpenStreetMap Surrogates (ctd.)

Unpaved roads are a key source of fugitive dust (PM)



Previous platforms used NLCD Open Space and Low Development surrogate



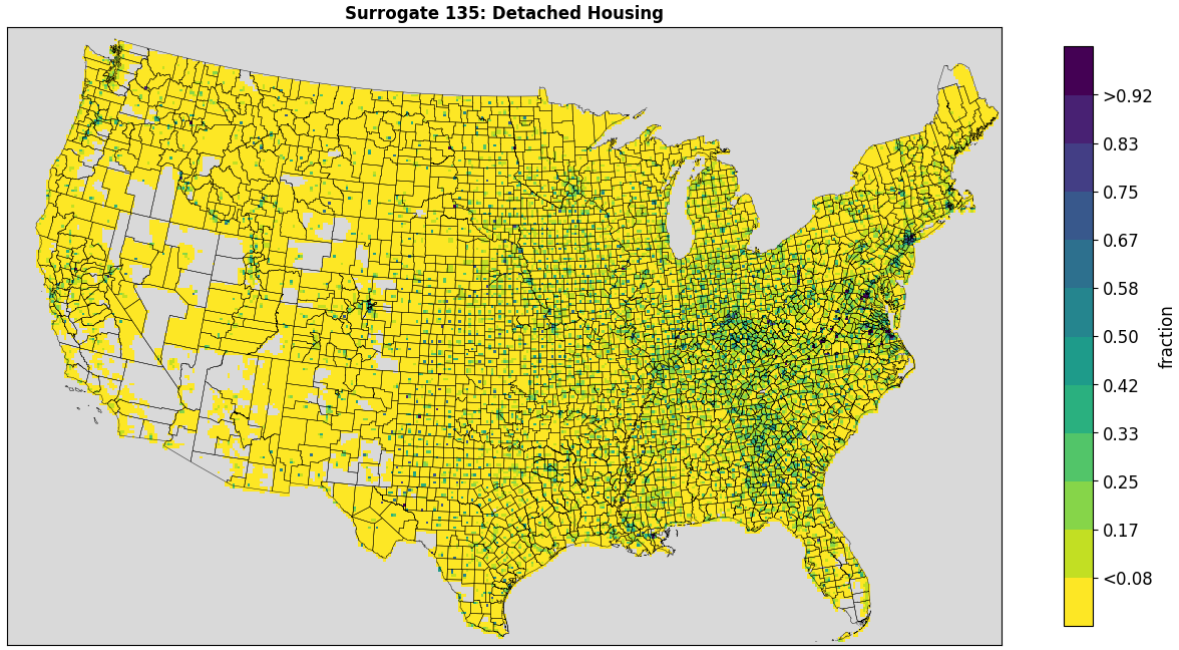
New surrogate uses lines/roads with unpaved surface types

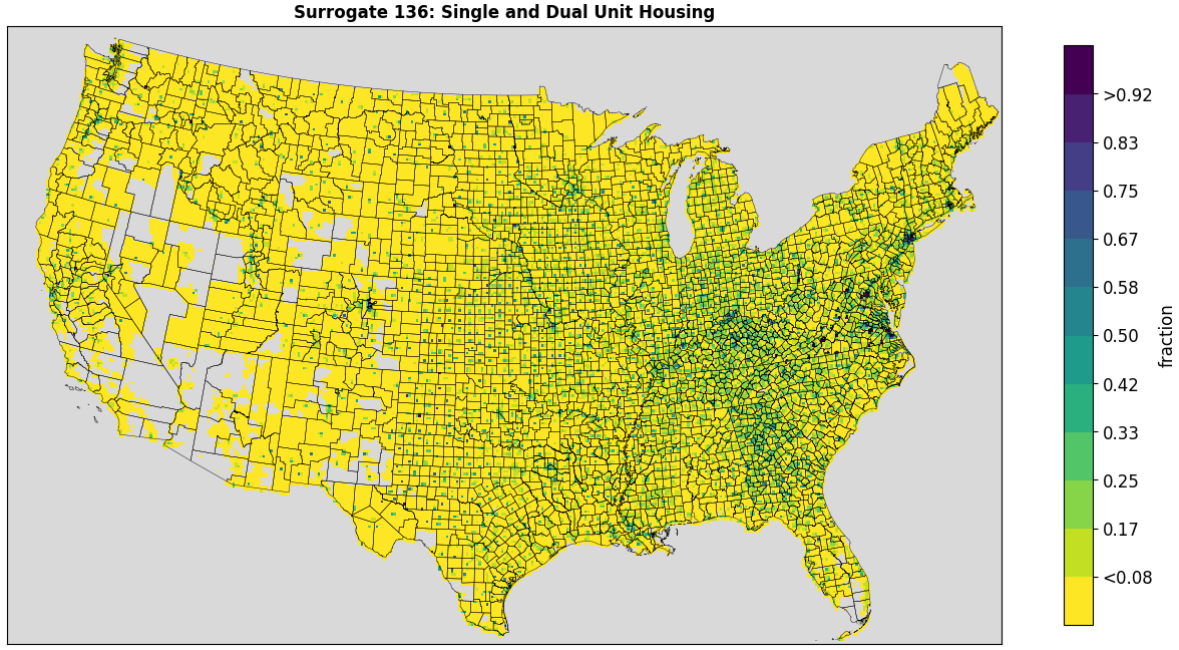
2020 fugitive dust emissions by surrogate (CONUS 12km)

ID	Description	NH3	NOX	PM2_5	SO2	VOC
240	Total Road Miles	0	0	333,425	0	0
306	NLCD Med + High	0	0	41,167	0	0
308	NLCD Low + Med + High	0	0	122,726	0	0
310	NLCD Total Agriculture	0	0	502,702	0	0
861	Sand and Gravel Mines	0	0	271	0	0
863	Crushed Stone Mines	0	0	291	0	0
902	OSM Unpaved Roads	0	0	960,028	0	0
4012	NPDES 2020 Beef Cattle	0	0	191,878	0	0
4013	NPDES 2020 Dairy Cattle	0	0	15,033	0	0
4021	NPDES 2020 Swine	0	0	658	0	0
4031	NPDES 2020 Chicken	0	0	5,069	0	0
4071	NPDES 2020 Turkey	0	0	1,959	0	0

American Community Survey (ACS) Surrogates

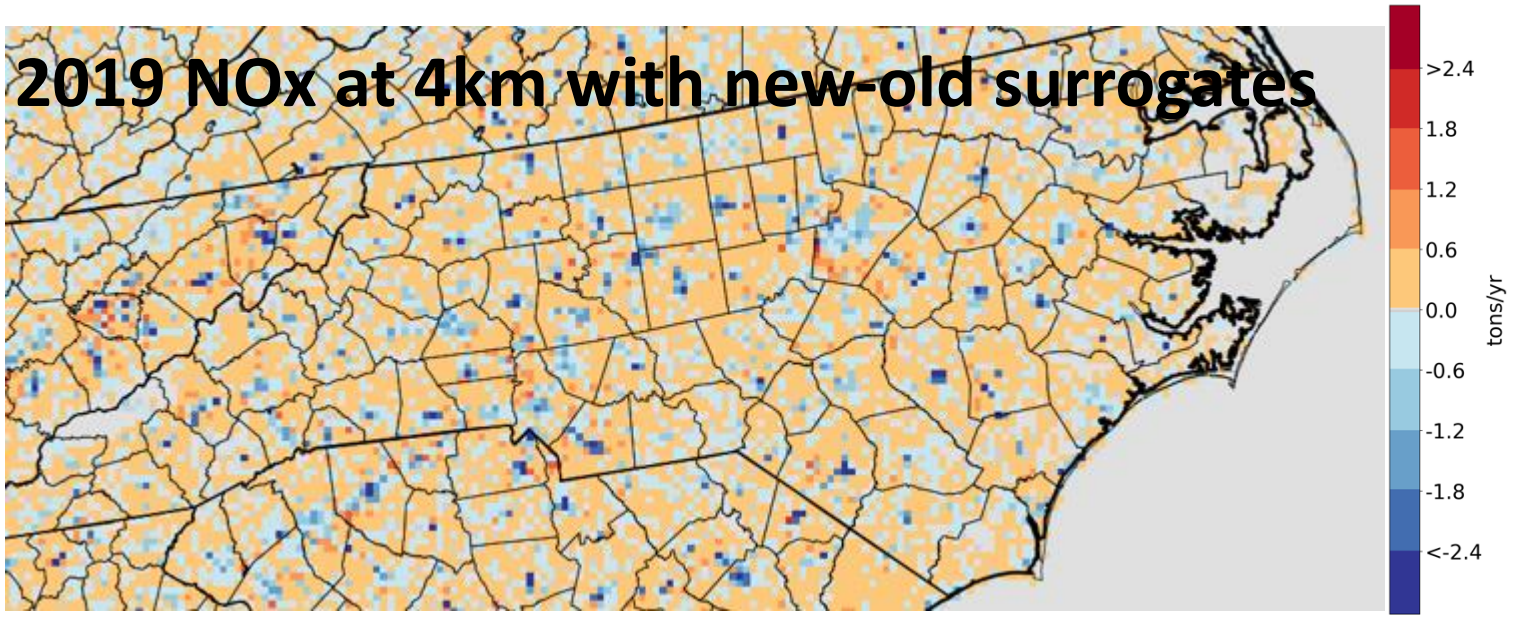
- 2020 release of 5-year data
- Data by census block group
- Population, housing, primary home heating
- Detached homes and single/dual units
  - New and can be used for residential wood combustion sources

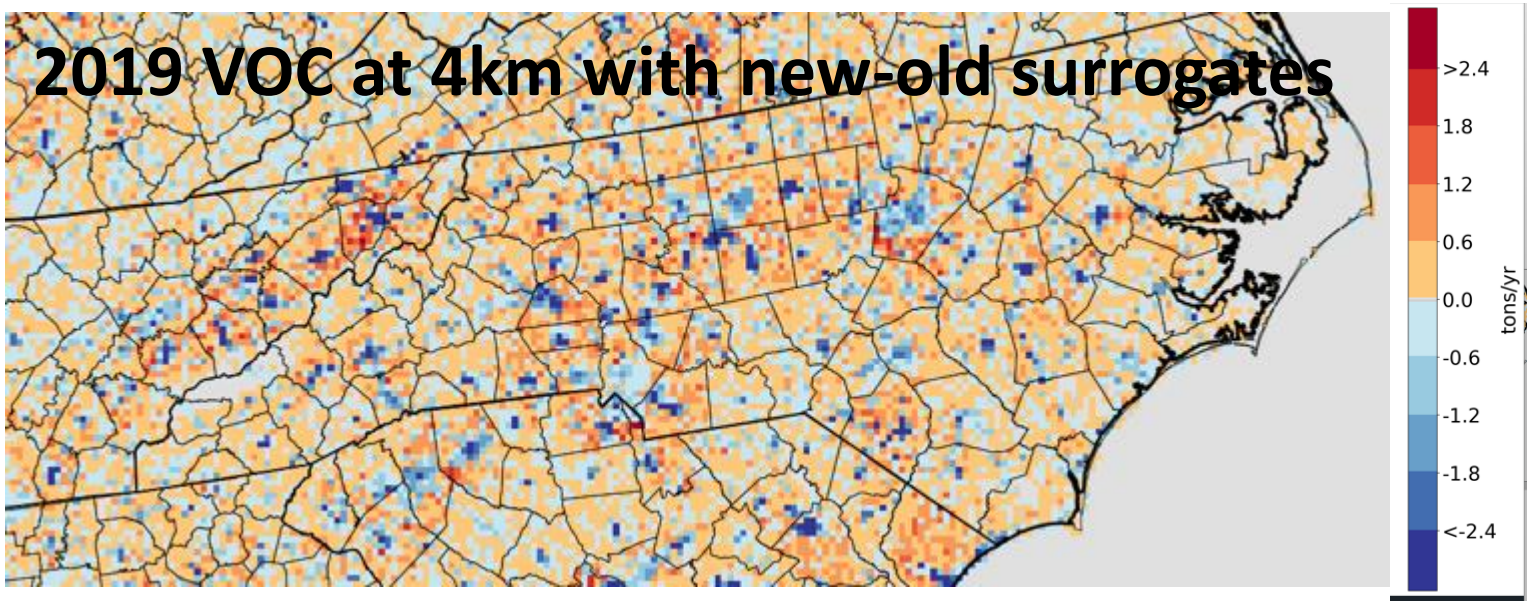




Onroad Surrogate updates

- Onroad uses updated surrogates from the new NLCD
- Shifts in emissions are noticeable in areas where suburbs are growing
  - More VOC is spatially allocated with NLCD than for NOx (which uses more AADT)

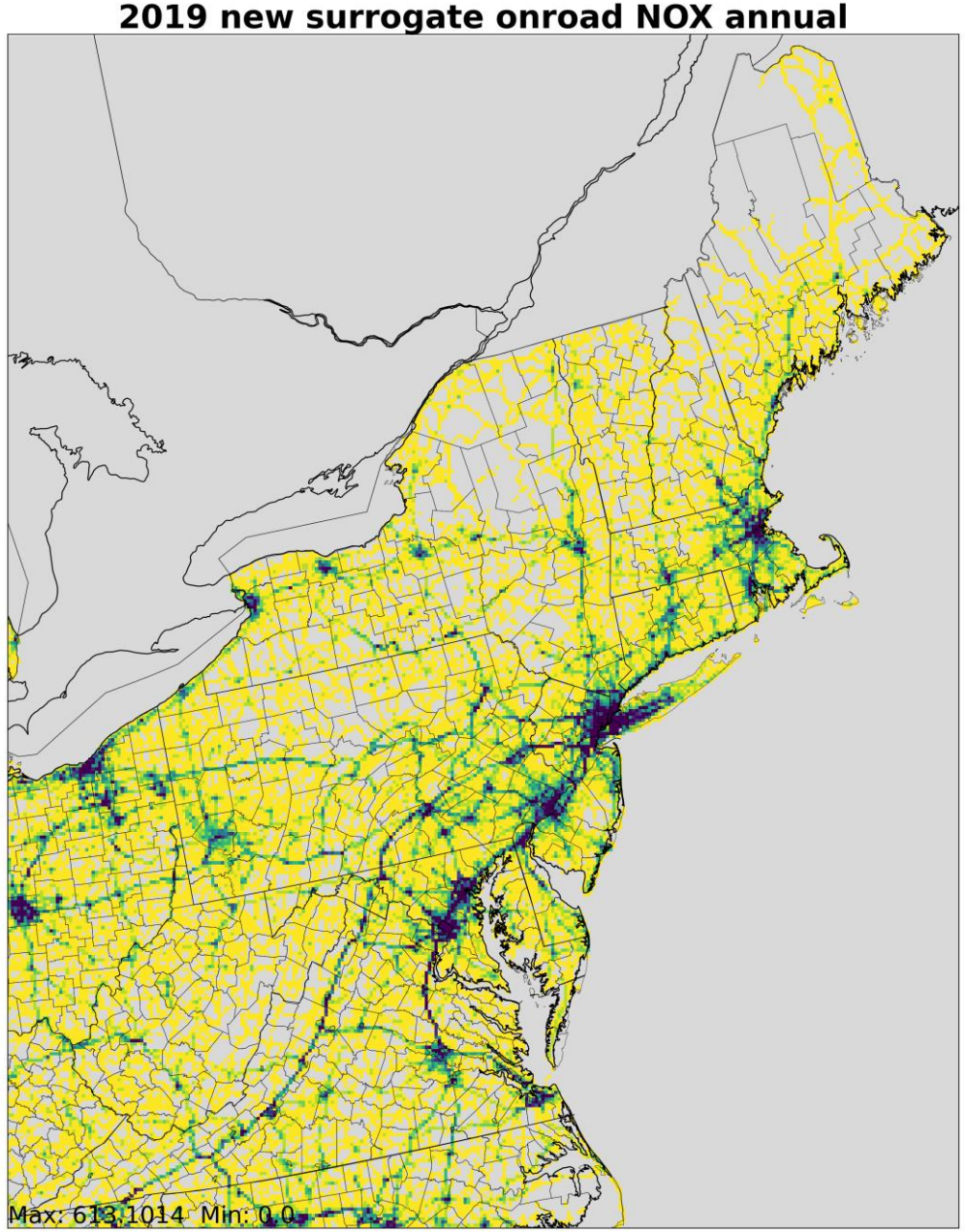


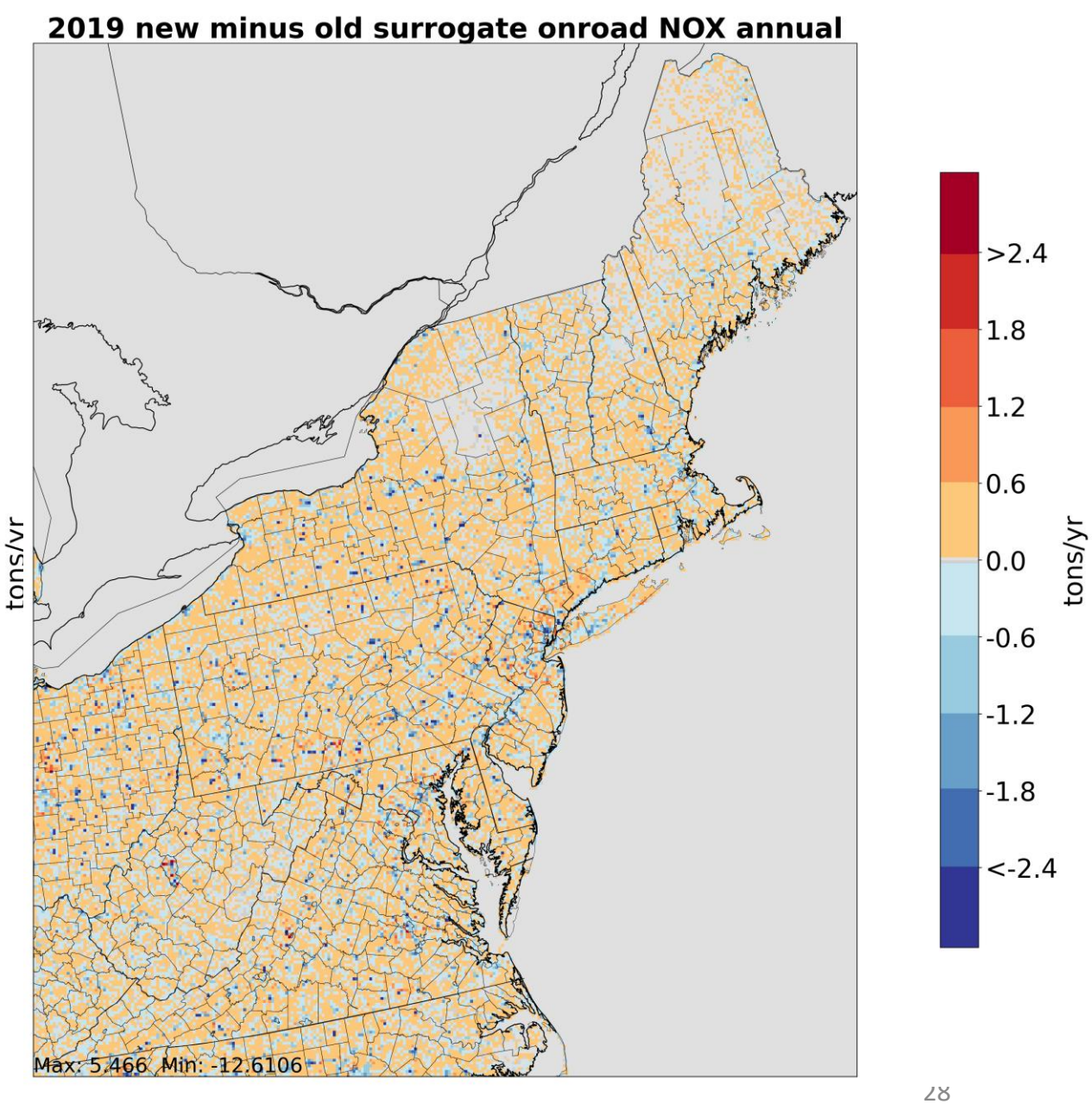


2020 Onroad Emissions by Surrogate

ID	Description	NH3	NOX	PM2_5	SO2	VOC
205	Extended Idle Locations	290	33,058	750	14	3,717
242	All Restricted AADT	29,464	783,301	20,867	3,049	103,641
244	All Unrestricted AADT	54,906	1,215,064	45,715	6,043	303,973
259	Transit Bus Terminals	42	1,539	37	1	476
304	NLCD Open + Low		510	13	0	2,811
306	NLCD Med + High	914	91,100	2,823	67	26,456
307	NLCD All Development	3,519	182,771	7,802	578	559,726
308	NLCD Low + Med + High	179	18,151	535	32	29,126
508	Public Schools	13	1,589	72	1	440

2019 Onroad NOx emissions over Northeast at 4km and Impact of New Surrogates





Gapfilling of Spatial Surrogates

- Surrogates may be gap-filled using other surrogates as generalized fallbacks when the weighting spatial data has incomplete coverage
  - This helps ensure emissions are not dropped if there is no data in a county for the primary weight surrogate
  - Tools support up to four levels of gapfilling
  - Example, the Beef Cattle surrogate is gap-filled by the NLCD Agriculture surrogate
  - NLCD Land or Population are used to gapfill many surrogates

Possible Future Updates

- Recreational waters surrogate
  - Currently uses all NLCD all water, not necessarily representative of activity
- Parking (on/off street)
  - Exhaust and evaporative off-network emissions
  - Currently uses NLCD all-development which includes all impervious surfaces
- Airport areas
  - Used for av-gas refueling, largest airport by area in a county may not have highest GA activity
- Rail activity
  - About 10 years old, current data source not updated with line specific activity

Appendix A. Updated Cross-reference Entries for 2020

Sector	SCC	SCC Description	Surrogate Code	Surrogate Description	New Surrogate	New Surrogate Description
livestock	2802004001	Miscellaneous Area Sources; Agricultural Crop Usage; Agriculture Silage; Storage	310	NLCD Total Agriculture	4011	Large Cattle Operations
livestock	2802004002	Miscellaneous Area Sources; Agricultural Crop Usage; Agriculture Silage; Mixing	310	NLCD Total Agriculture	4011	Large Cattle Operations
livestock	2802004003	Miscellaneous Area Sources; Agricultural Crop Usage; Agriculture Silage; Feeding	310	NLCD Total Agriculture	4011	Large Cattle Operations
livestock	2805002000	Miscellaneous Area Sources; Agriculture Production - Livestock; Beef cattle production c	310	NLCD Total Agriculture	4012	Beef cattle
livestock	2805007100	Miscellaneous Area Sources; Agriculture Production - Livestock; Poultry Waste; Poultry P	310	NLCD Total Agriculture	4031	Chicken
livestock	2805009100	Miscellaneous Area Sources; Agriculture Production - Livestock; Poultry production - bro	310	NLCD Total Agriculture	4031	Chicken
livestock	2805010100	Miscellaneous Area Sources; Agriculture Production - Livestock; Poultry production - turk	310	NLCD Total Agriculture	4071	Turkey
livestock	2805018000	Miscellaneous Area Sources; Agriculture Production - Livestock; Dairy cattle composite; M	310	NLCD Total Agriculture	4013	Dairy cattle
livestock	2805025000	Miscellaneous Area Sources; Agriculture Production - Livestock; Swine production compo	310	NLCD Total Agriculture	4021	Swine
livestock	2805035000	Miscellaneous Area Sources; Agriculture Production - Livestock; Horses and Ponies Waste	310	NLCD Total Agriculture	405	Horse
livestock	2805040000	Miscellaneous Area Sources; Agriculture Production - Livestock; Sheep and Lambs Waste	310	NLCD Total Agriculture	406	Sheep
livestock	2805045000	Miscellaneous Area Sources; Agriculture Production - Livestock; Goats Waste Emissions;	310	NLCD Total Agriculture	4041	Goat
afdust	2805100010	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4012	Beef cattle
afdust	2805100020	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4013	Dairy cattle
afdust	2805100030	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4031	Chicken
afdust	2805100040	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4031	Chicken
afdust	2805100050	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4021	Swine
afdust	2805100060	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4071	Turkey
afdust	2325030000	Industrial Processes; Mining and Quarrying: SIC 10 and SIC 14; Sand and Gravel; Total	306	NLCD Med + High	861	Sand and Gravel Mines
afdust	2325060000	Industrial Processes; Mining and Quarrying: SIC 10 and SIC 14; Lead Ore Mining and Millin	306	NLCD Med + High	862	Lead Mines
afdust	2325020000	Industrial Processes; Mining and Quarrying: SIC 10 and SIC 14; Crushed and Broken Stone;	306	NLCD Med + High	863	Crushed Stone Mines
afdust	2296000000	Mobile Sources; Unpaved Roads; All Unpaved Roads; Total: Fugitives	304	NLCD Open + Low	902	Unpaved roads
solvents	2461022000	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Emulsified Asphalt; Total	307	NLCD All Development	901	Asphalt surfaces
nonpt	2501060051	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stati	239	Total Road AADT	900	Gas stations

Appendix A. Updated Cross-reference for 2020 cont.

Sector	SCC	SCC Description	Surrogate Code	Surrogate Description	New Surrogate	New Surrogate Description
nonpt	2461025100	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Asphalt Paving: Hot and V	307	NLCD All Development	901	Asphalt surfaces
solvents	2461021000	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Cutback Asphalt; Total: A	307	NLCD All Development	901	Asphalt surfaces
nonpt	2501060201	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stati	239	Total Road AADT	900	Gas stations
nonpt	2501060053	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stati	239	Total Road AADT	900	Gas stations
nonpt	2461025200	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Asphalt Paving: Hot and V	307	NLCD All Development	901	Asphalt surfaces
rwc	2104008310	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, non-E	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
nonroad	2265004033	Mobile Sources; Off-highway Vehicle Gasoline; Lawn and Garden Equipment; 4-Stroke La	305	NLCD Low + Med	136	Single and Dual Unit Housing
rwc	2104008320	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, EPA c	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008620	Stationary Source Fuel Combustion; Residential; Wood; Hydronic heater: indoor	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008330	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, EPA c	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008510	Stationary Source Fuel Combustion; Residential; Wood; Furnace: Indoor, cordwood-fired	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008210	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: fireplace inserts; no	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008220	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: fireplace inserts; EP	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008300	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, gener	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104009000	Stationary Source Fuel Combustion; Residential; Firelog; Total: All Combustor Types	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008230	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: fireplace inserts; EP	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rwc	2104008100	Stationary Source Fuel Combustion; Residential; Wood; Fireplace: general	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
nonpt	2610030000	Waste Disposal, Treatment, and Recovery; Open Burning; Residential; Household Waste	300	NLCD Low Intensity Deve	135	Detached Housing
rwc	2104008610	Stationary Source Fuel Combustion; Residential; Wood; Hydronic heater: outdoor	300	NLCD Low Intensity Deve	135	Detached Housing
rwc	2104008700	Stationary Source Fuel Combustion; Residential; Wood; Outdoor wood burning device, N	300	NLCD Low Intensity Deve	135	Detached Housing
rwc	2104008400	Stationary Source Fuel Combustion; Residential; Wood; Outdoor wood burning device, N	300	NLCD Low Intensity Deve	135	Detached Housing
rwc	2104008400	Stationary Source Fuel Combustion;Residential;Wood;Woodstove: pellet-fired, general	300	NLCD Low Intensity Deve	135	Detached Housing
rwc	2104008530	Stationary Source Fuel Combustion;Residential;Wood;Furnace: Indoor, pellet-fired, gen	300	NLCD Low Intensity Deve	135	Detached Housing
rwc	2104008630	Stationary Source Fuel Combustion;Residential;Wood;Hydronic heater: pellet-fired	300	NLCD Low Intensity Deve	135	Detached Housing