Development of 2018 and 2019 Emissions Modeling Platforms

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Origins of the 2018 and 2019 Modeling Platforms

- Purpose
  - Support annual air quality modeling project that is a collaboration with the Centers for Disease Control and Prevention (CDC)
    - Products: fused data that merges air quality model outputs with measurements of air pollutant concentrations annually, plus with particulate matter and ozone monitoring data
    - Collaboration began with the 2002 platform
    - Fused air quality surface data using downscaling files on EPA's RSIG site
    - CDC National Environmental Public Heath Tracking Indicators and Data
  - Facilitate review of air quality model performance for each of the modeled years
  - In addition to criteria pollutants, supports the Air Toxics Data Update program including the replacement to the National Air Toxics Assessment (NATA)
  - While some modeling platforms are used for regulatory modeling purposes (most recently, the 2016 platform), 2018 and 2019 platforms have not been regulatory
- Emission inventories in the 2018 and 2019 platforms are based on the 2017 National Emissions Inventory (NEI), with updates to represent 2018 and 2019
  - https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data

Background on the National Emissions Inventory (NEI) and Modeling Platforms

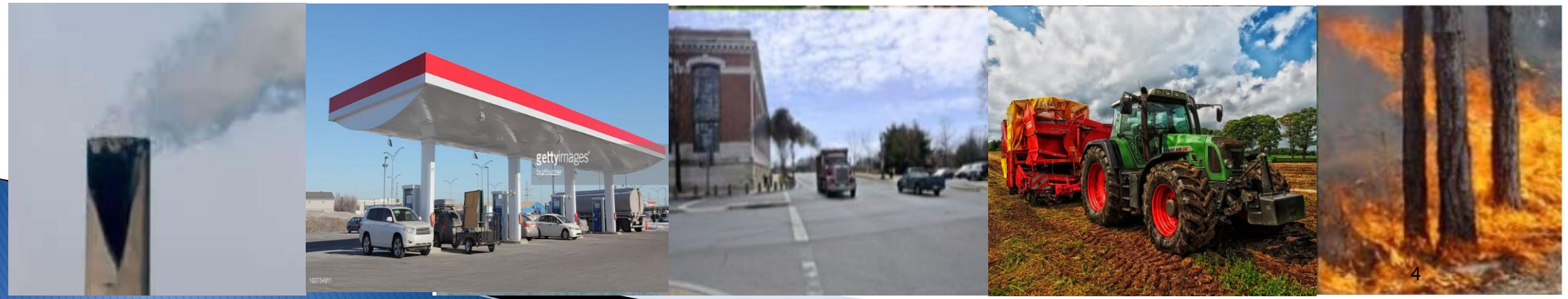
In this section:

Review the basics of the NEI and the concepts of modeling platform, emissions modeling steps and abbreviations, and how these relate to the NEI

These topics are general and not specifically related to 2018 and 2019 data

The National Emissions Inventory (NEI)

- Data are submitted by states, locals, tribes (S/L/T) and by EPA into the Emissions Inventory System (EIS) to create a full inventory *every three years*
- Five NEI data categories – all include annual total emissions except events
  - **Point** (and Facility) Inventory (lat-lon locations): electric generating units (EGUs), point oil and gas sources, commercial and industrial facilities, airports, rail yards
  - **Nonpoint** (county-based): fugitive dust, agricultural, residential, gas stations, fuel combustion, nonpoint oil & gas, residential wood combustion (RWC), agricultural fires, commercial marine vessels (CMV), locomotives, biogenic
  - **Onroad** mobile sources (county): cars and trucks driving on roads
  - **Nonroad** mobile sources (county): mobile sources not on roads including tractors, recreational marine vessels, construction equipment, lawn/garden equipment
  - **Events** (lat-lon, day): wild and prescribed fires



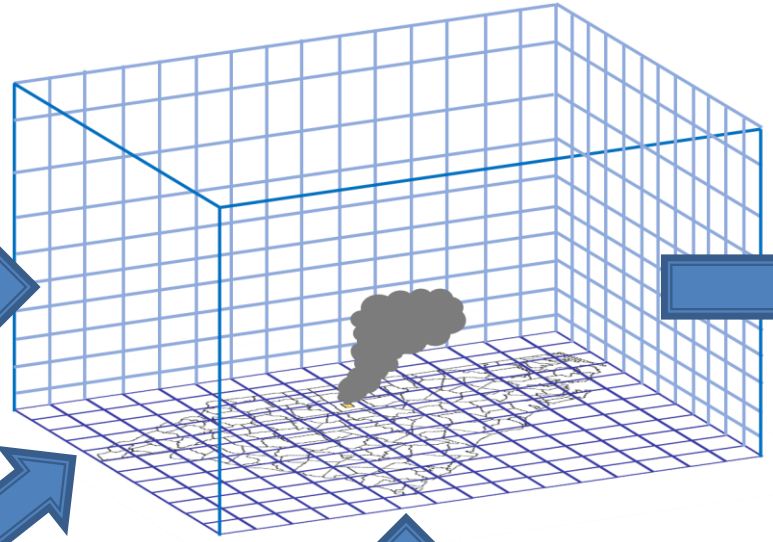
Pollutants in the NEI and Modeling Platforms

- Criteria air pollutants (CAPs):
  - These have ambient concentration limits or are precursors to pollutants with limits
  - Carbon Monoxide (CO)
  - Nitrogen oxides (NO_x)
  - Volatile Organic Compounds (VOC)
  - Sulfur dioxide (SO_2)
  - Particulate matter less than 2.5 microns ($PM_{2.5}$)
  - Particulate matter less than 10 microns (PM_{10})
  - Ammonia (NH_3)
  - Lead (Pb)
- Hazardous air pollutants (HAPs):
  - 187 listed HAPs from Section 112(b) of the 1990 Clean Air Act Amendments
  - Include acid gases (e.g. HCl), heavy metals (e.g., mercury), organic compounds (e.g., formaldehyde)
- Greenhouse gases (GHGs) are included for fires, mobile sources, and point sources (where reported)

Air Quality Modeling Platform Components

Air Quality Model

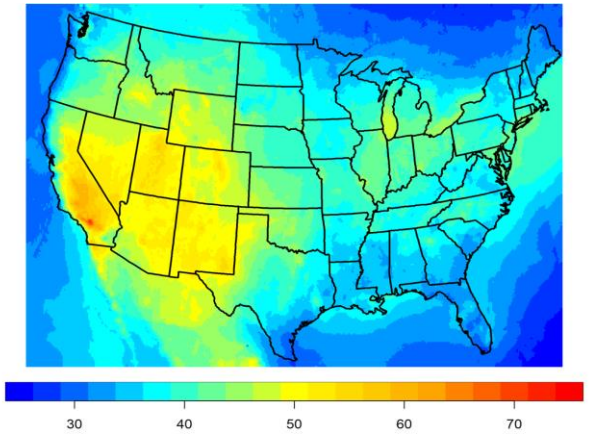
Meteorological Model: wind, temperature, precipitation, radiation, …



Boundary Conditions
Concentrations of species (pollutants) at boundaries

Emissions
Hourly, Gridded or points; Ground level and elevated

Pollutant Concentrations



AQM outputs are hourly and for each of the 3D grid cells

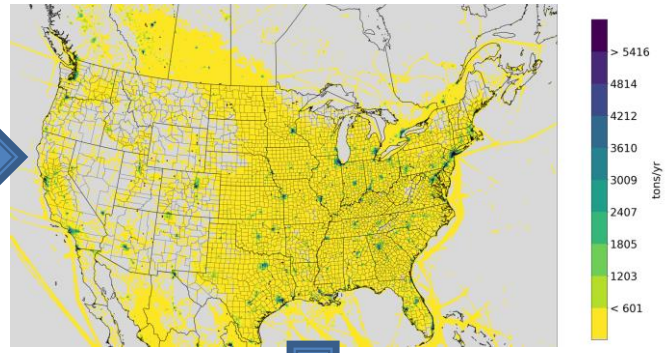
Emissions Modeling Platform

Meteorological Data: humidity, temperature, precipitation, radiation, …

Emissions Modeling Software

SMOKE (+ scripts, models, tools)

Hourly, speciated point and gridded emissions



Emission Inventories*

National Emissions Inventory + Hourly and Year-specific data (e.g., CEMS)

Ancillary Data

Speciation and Temporal Profiles, Spatial Surrogates, County information, Cross references, etc.

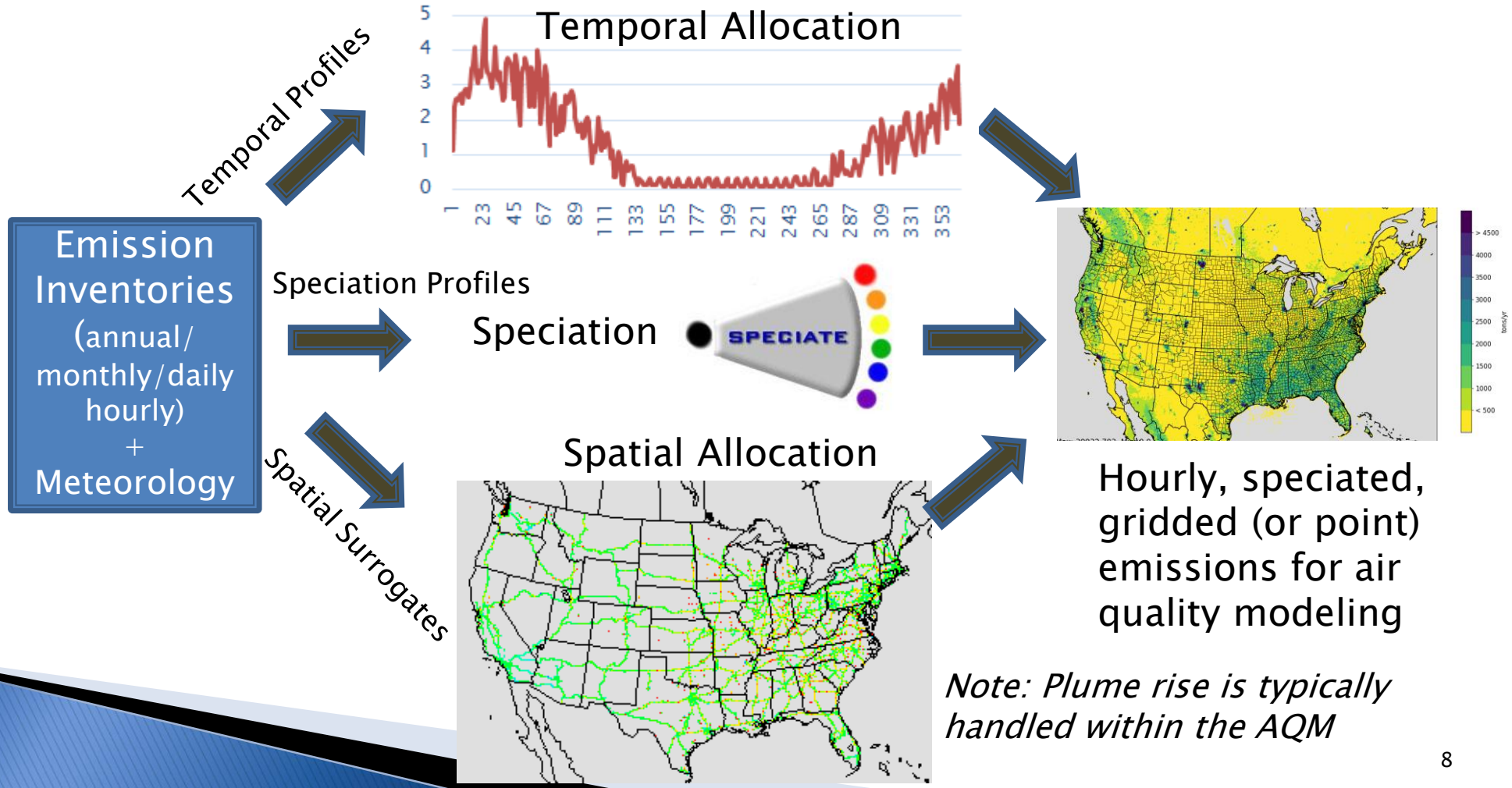
Quality Assurance Logs and Summaries

* For historic and future years

SMOKE stands for Sparse Matrix Operator Kernel Emissions modeling system (see http://cmascenter.org)

Emissions Modeling Process

- Steps and data needed to convert emissions inventories into the resolution and formats needed by air quality models



Note: Plume rise is typically handled within the AQM

Emissions Modeling Sectors and Cases

- The NEI data categories are split into finer "sectors" for emissions modeling
- Each sector is run through SMOKE separately to create speciated, hourly, gridded (or point) emissions (aka "premerged")
  - SMOKE is available from the CMAS center (http://cmascenter.org)
- Each sector has an abbreviation and these will be used in upcoming charts and maps (e.g., *ptegu*, *cmv_c3*, *rwc* – see next slide)
- Additional non-U.S. data are added to cover Canada, Mexico
  - These data are mostly in separate sectors from the U.S. emissions
  - For Caribbean island countries, only fires are included
- Modeling "cases" include a full set of emissions for the AQ model
  - Case labels include the year modeled plus an abbreviation (e.g., 2019ge_cb6_19k)
  - 'g' references 2017 NEI as the basis; 'e' is the fifth iteration of emissions for that NEI platform; cb6 is the speciation in the AQM; and 19k is 2019 meteorology run with configuration 'k' (a specific version + configuration of the meteorological model)

U.S. Emissions Modeling Sector Abbreviations

- **afdust** = area fugitive dust
- **airports** = aircraft + ground support (at points)
- **beis** = biogenic emissions
- **cmv_c1c2** = category 1 and 2 (small-medium) commercial marine vessels (CMV)
- **cmv_c3** = category 3 (large) CMV
- **fertilizer** = agricultural fertilizer
- **livestock** = agricultural livestock
- **nonpt** = other nonpoint sources
- **nonroad** = mobile sources not on roadways
- **onroad** = mobile sources on roadways
- **np_oilgas** and **pt_oilgas** = nonpoint and point oil and gas
- **np_solvents** = nonpoint solvents
- **ptagfire** = agricultural fires as points
- **ptegu** = electric generating units
- **ptfire-wild** = wild fires
- **ptfire-rx** = prescribed fires
- **ptnonipm** = non-EGU point sources
- **rail** = line haul locomotives
- **rwc** = residential wood combustion (RWC)

Emissions Inventory Development plus Emission Modeling and Data Visualization Steps Taken for 2018 and 2019 Platforms

In this section:

Review how the 2018/2019 inventories were developed for key inventory sectors

Provide examples of typical analysis and quality assurance products

Review key pollutants for each sector

Overview of Data Used for 2018 and 2019

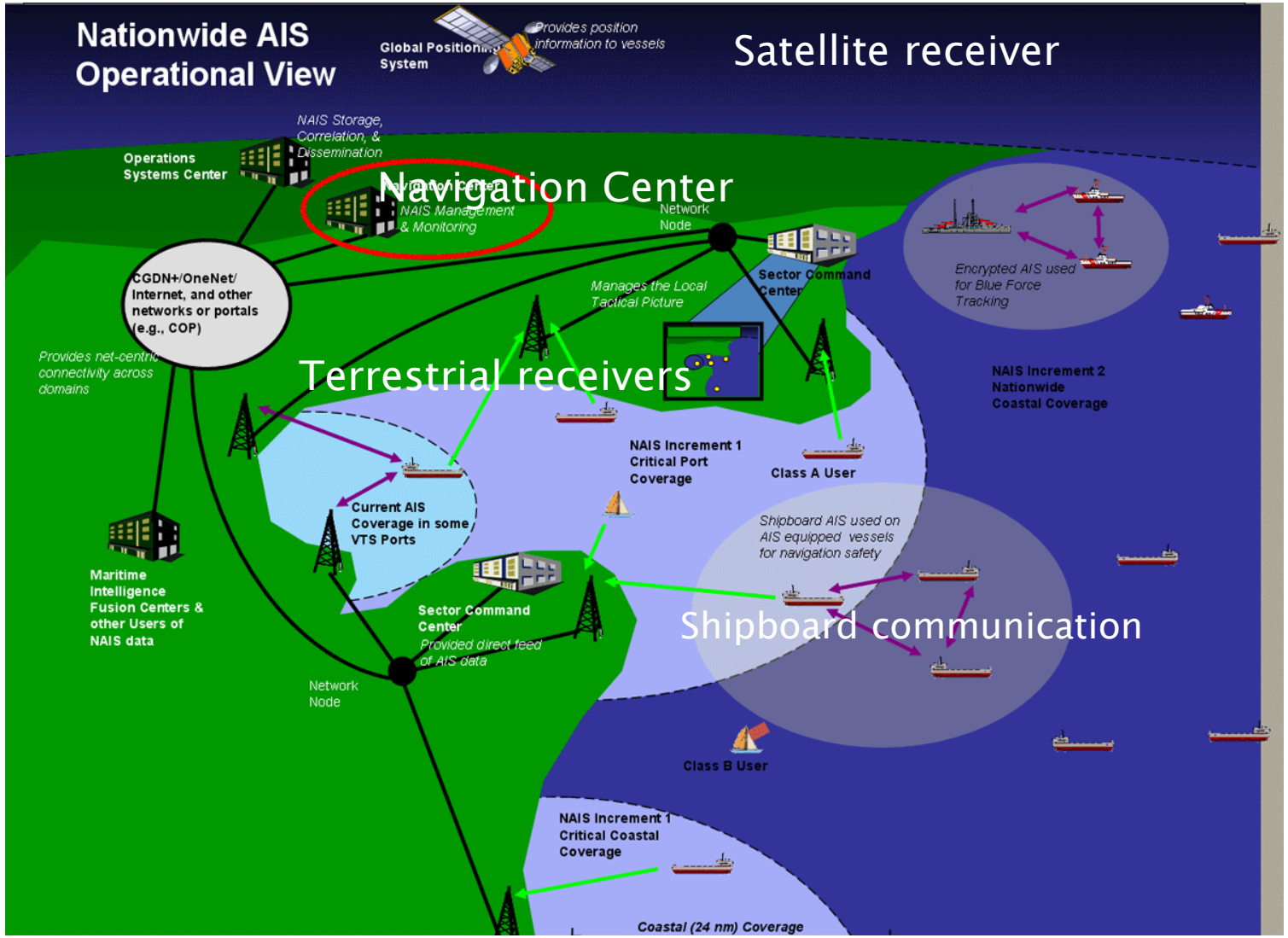
- A full triennial NEI was developed for the year 2017
  - Incorporates 2017-specific data received from state, local, and tribal (S/L/T) agencies coupled with EPA-developed data specific to 2017
- Stationary point sources for 2018/2019 represent year-specific values
  - S/L/T data were collected for point sources only in 2018 and 2019
  - For non-triennial years, S/L/T data are required to be submitted for large "Type A" sources per the Air Emissions Reporting Rule (AERR), although some agencies also submit smaller sources in interim years
  - Sources not submitted by S/L/Ts for interim years (and not marked as closed) are pulled forward from the most recent triennial inventory
- The interim year inventories for other data categories were developed without 2018 and 2019 S/L/T submitted data
  - 2017 NEI was a starting-point and was adjusted with nationally available datasets

2018 and 2019 Platform Mobile Source Emissions Development Methods Overview

- Emissions from aircraft and ground support equipment at airports (part of the NEI point data category) are based on 2017 NEI adjusted to represent 2018 and 2019 based on airport- or state-specific factors computed from the FAA's Terminal Area Forecast
- Nonroad emissions are based on year-specific runs of MOVES3
  - https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves
  - Nonroad year-specific activity data are computed internally to MOVES with year-specific emission factors
- Onroad emissions are based on year-specific runs of MOVES3 in rates mode with activity data projected from 2017 NEI (outside of MOVES); emissions are computed using SMOKE-MOVES
- Line haul locomotive (in NEI nonpoint) and rail yard (mostly point) emissions are adjusted from 2017 NEI using national factors based on fuel use
- Commercial Marine Vessel (CMV) emissions are based on Automated Identification System (AIS) data coupled with a ship registry, a power model and emission factors
  - Emissions are computed for each ship at five-minute intervals
  - For modeling, the emissions are aggregated to hourly totals in each modeling grid cell
  - 2018 CMV inventory was based on 2017 NEI adjusted to 2018 levels using regional factors
  - 2019 CMV inventory was based on actual 2019 data and uses methods consistent with the **2020 NEI**

Automatic Identification System (AIS)

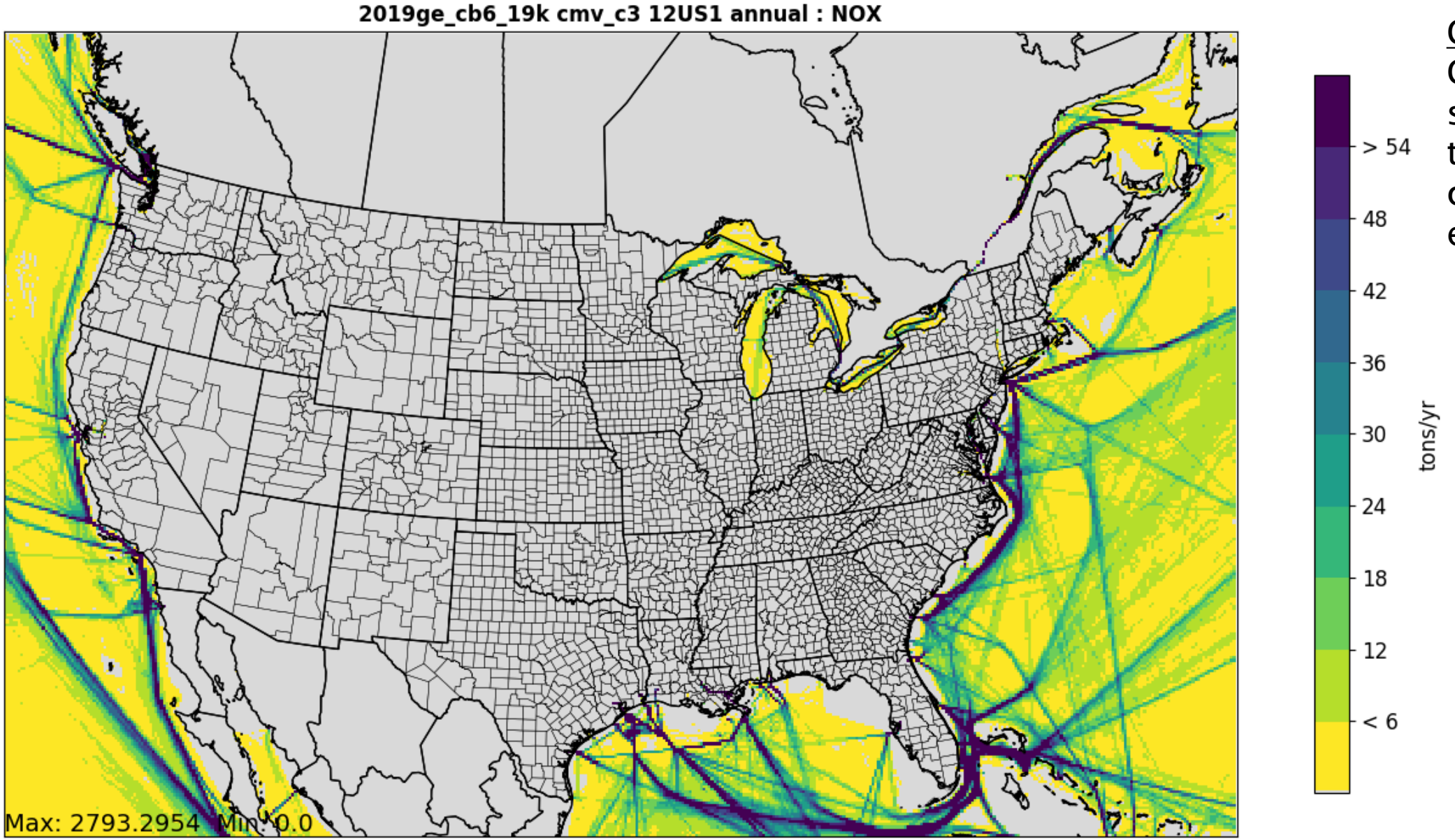
- Vessel locating system using radio transponders on ships
- Designed as a safety protocol for collision avoidance, navigational aid, search and rescue
- Messages sent every 2 to 10 seconds and include Ship ID, position, speed, and ship dimensions
- Internationally mandated on ships greater than 300 GT
- Participation has increased over time to include smaller vessels



http://www.navcen.uscg.gov

2019 annual CMV C3 (large engine) NOx

on 12US1 grid including Canada and Mexico

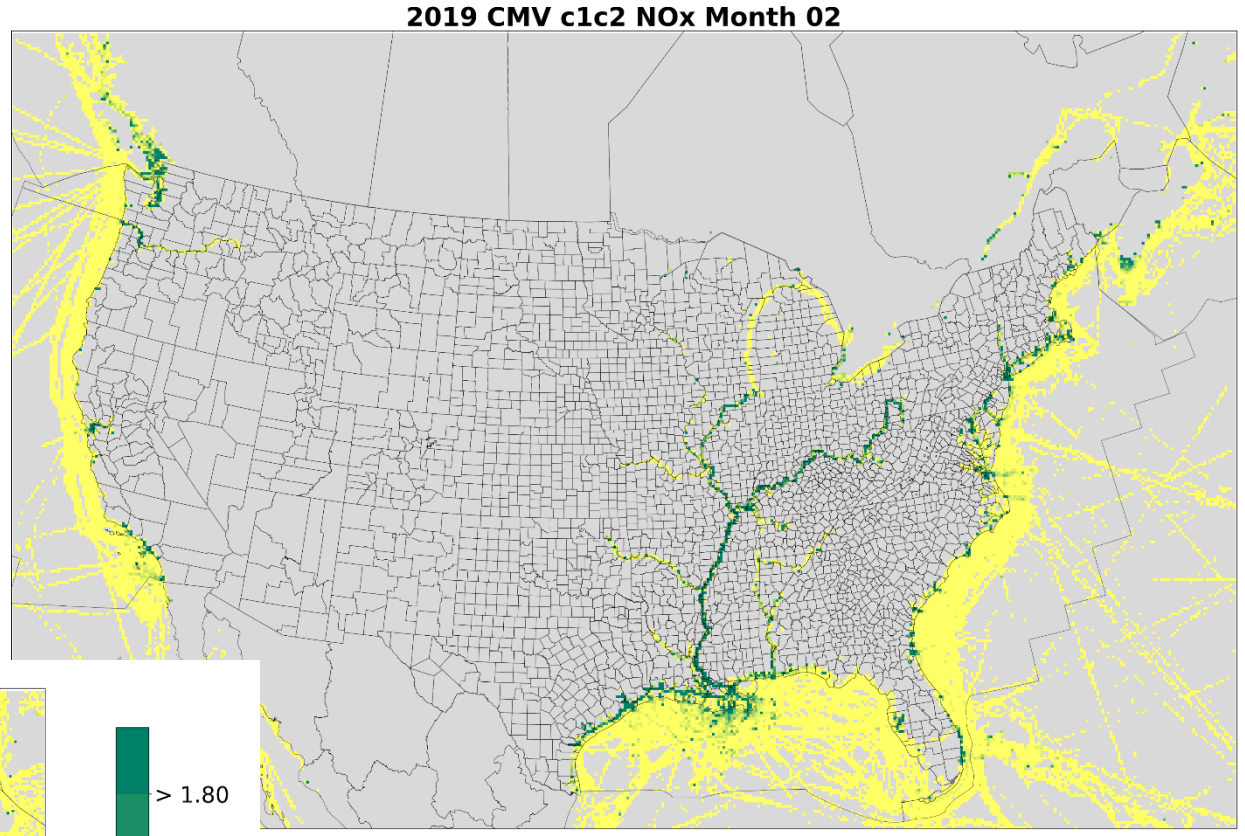


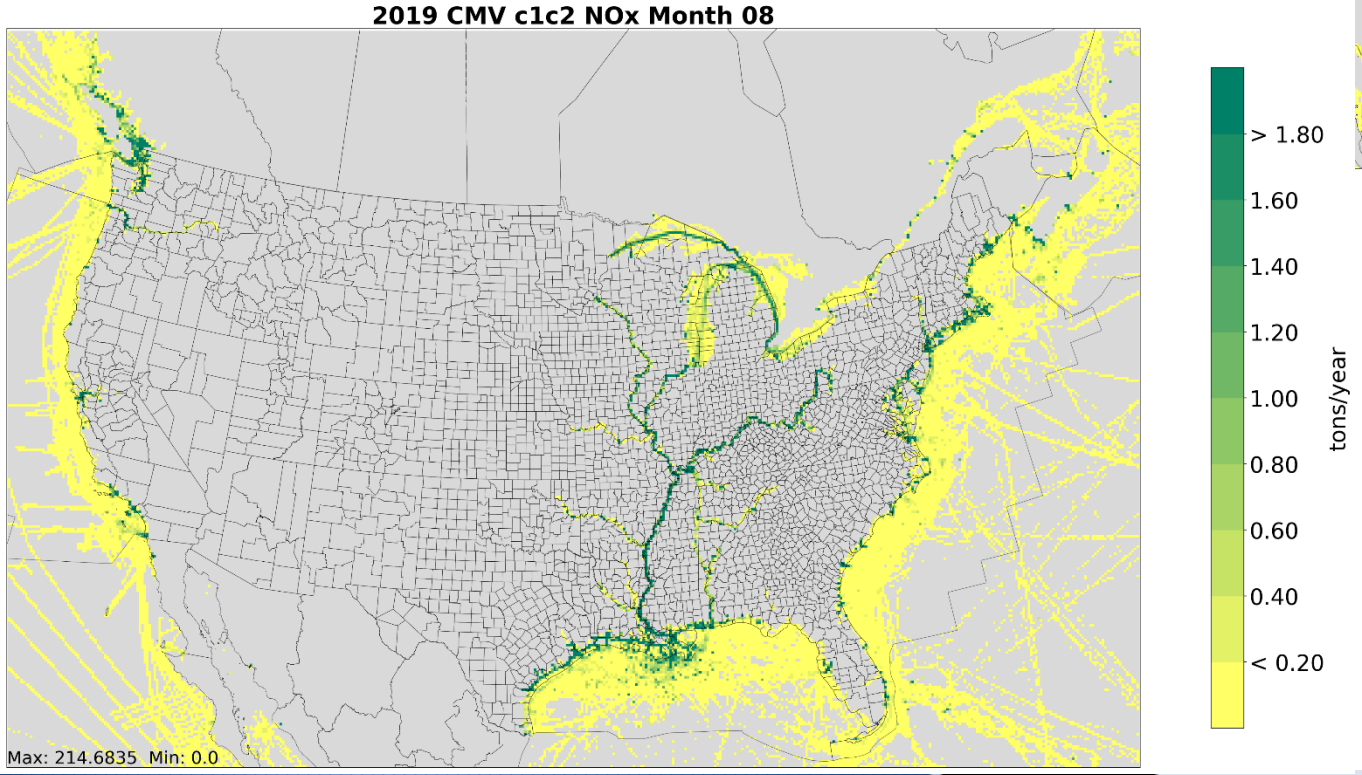
C3 vessels: Container ships, tankers, cruise ships, etc.

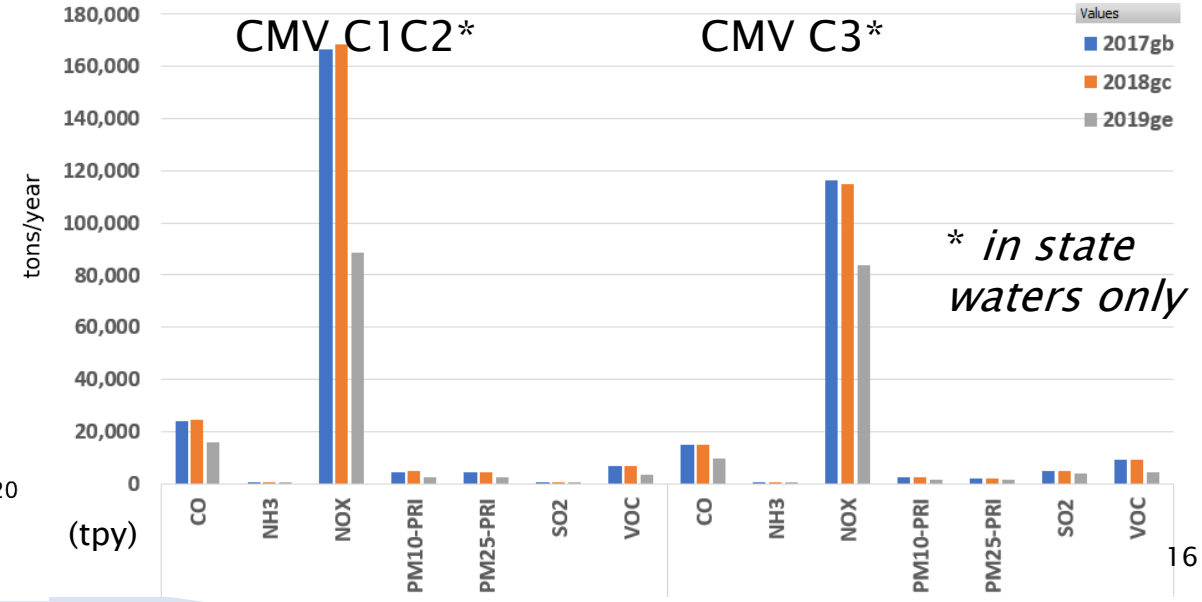
2019 CMV C1C2 NOx

C1C2 (smaller engine) CMV emissions extend into the inland waterways. These include ferries, fishing vessels, and oil and gas platform support vessels

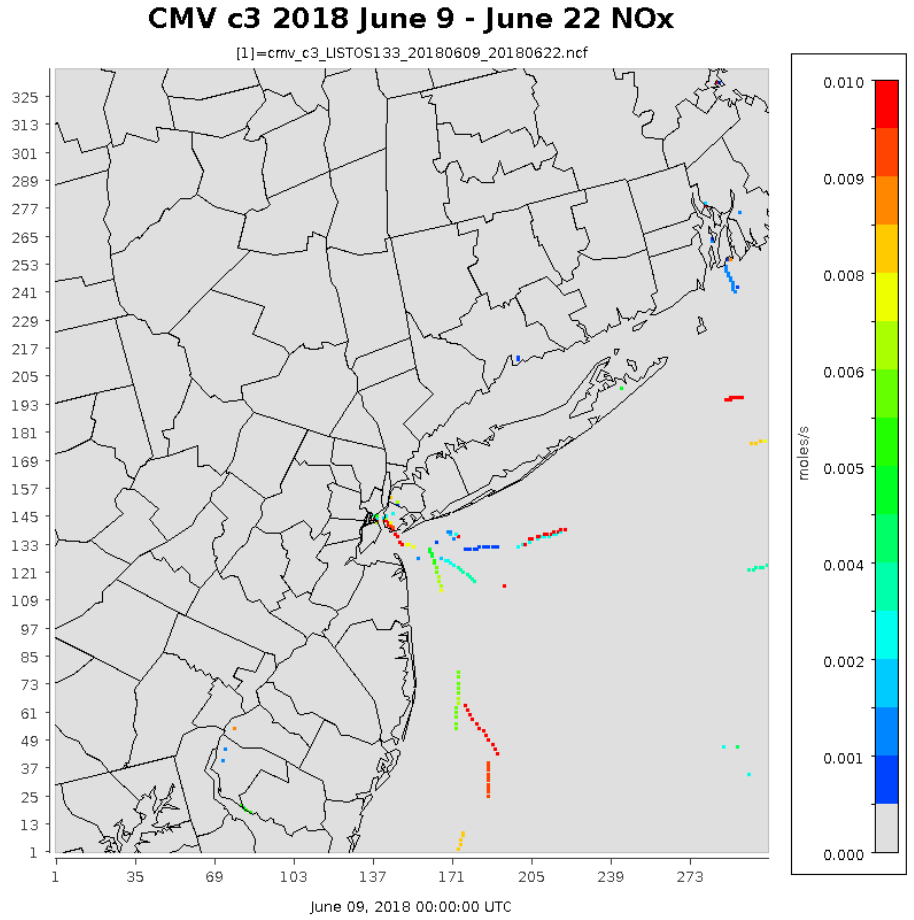
There are clear differences in the Great Lakes in February (top right) versus August (lower left)

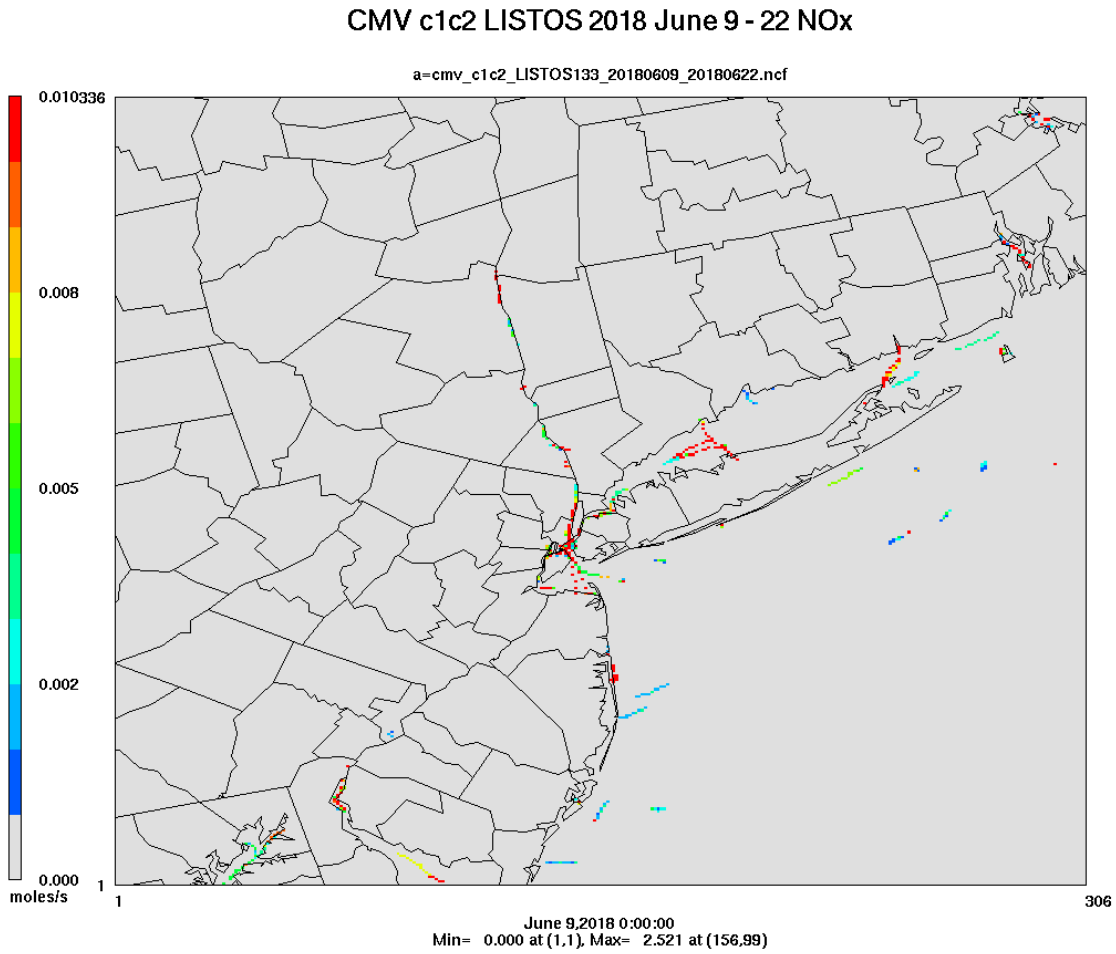






Hourly CMV Animations





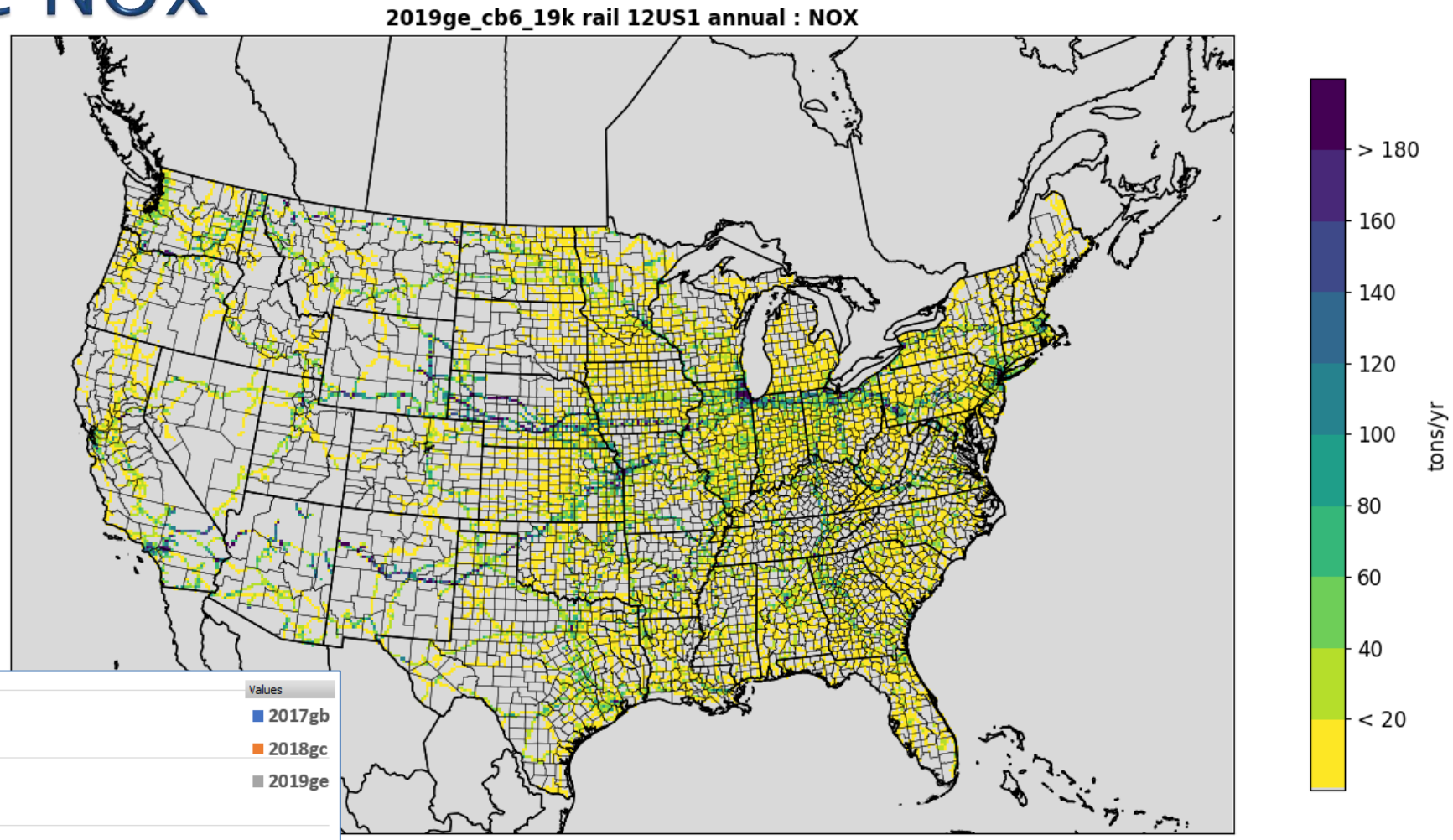
Area shown is New York, New Jersey, Connecticut

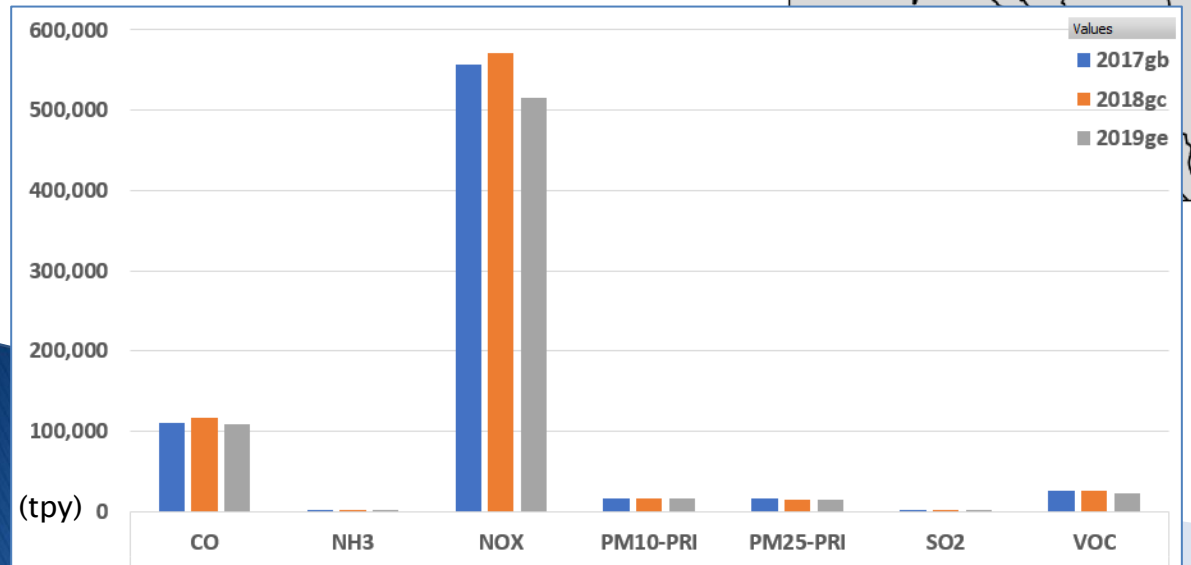
2019 locomotive NOx

Line haul locomotive emissions are projected from 2017 NEI values based on regional fuel use and emission rate trends.

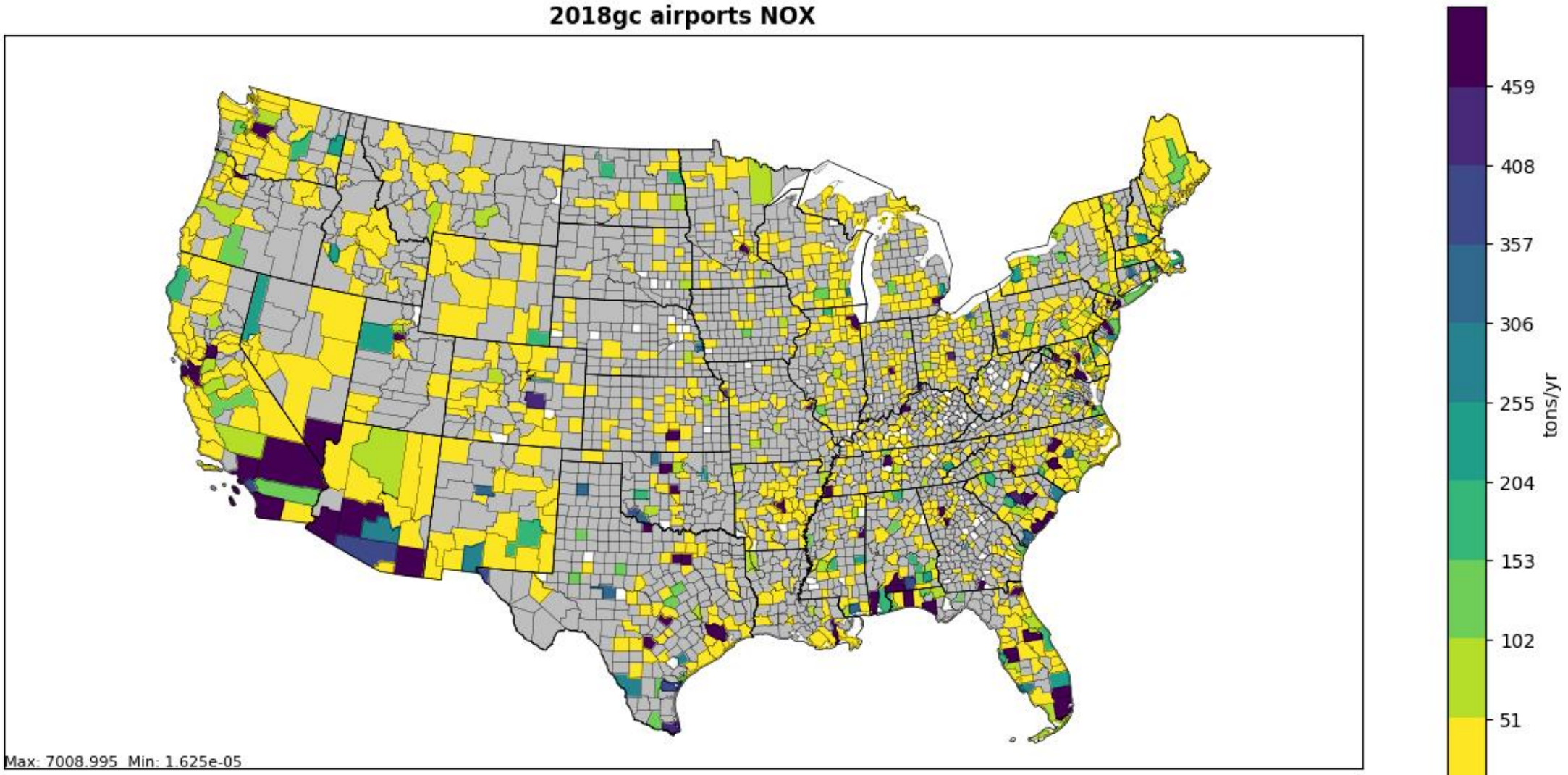
Emissions are spatially allocated to the rail lines. (Rail yards are in ptnonipm)

NOx is the main criteria pollutant from locomotives.



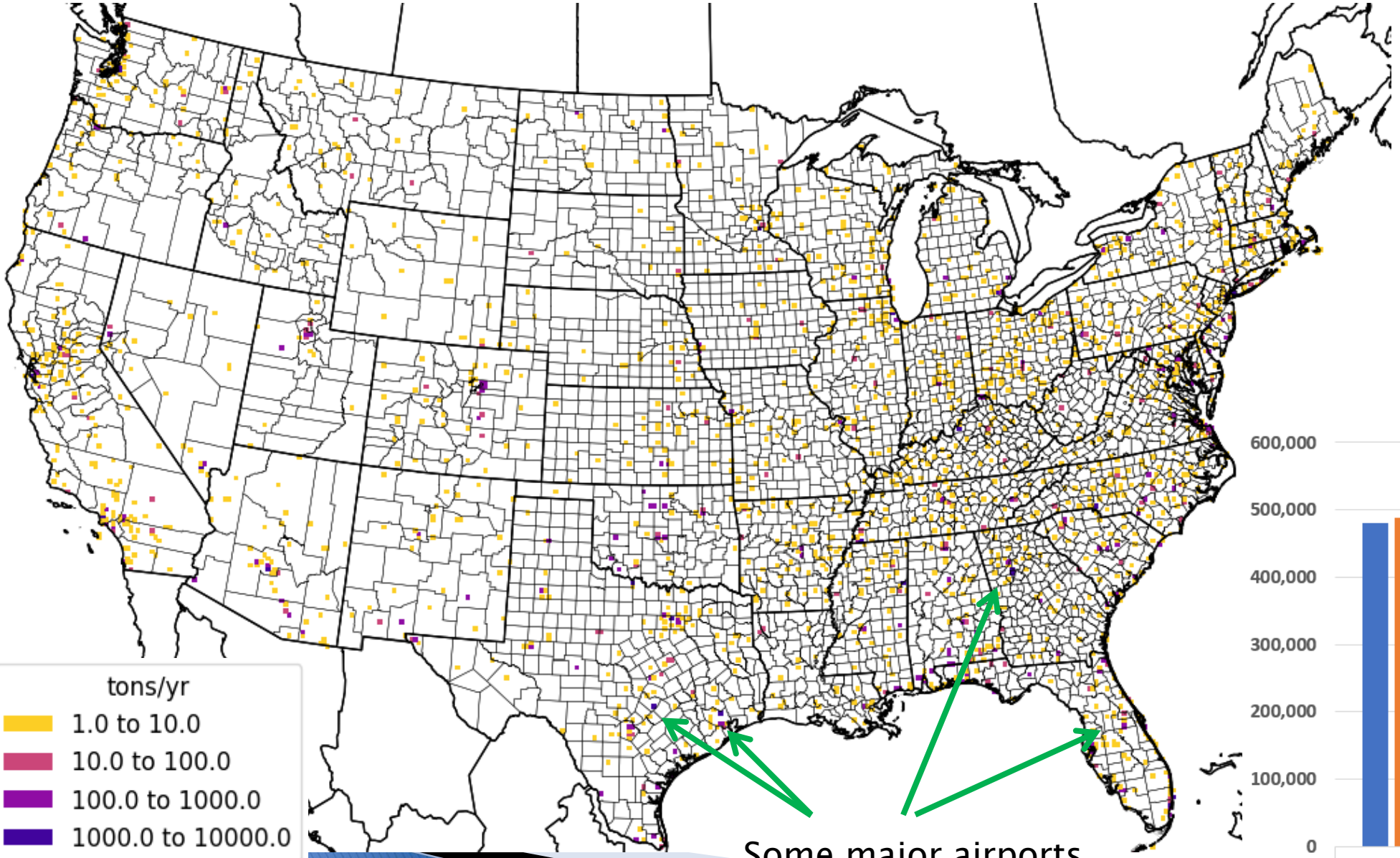


County total plot for 2018 airports



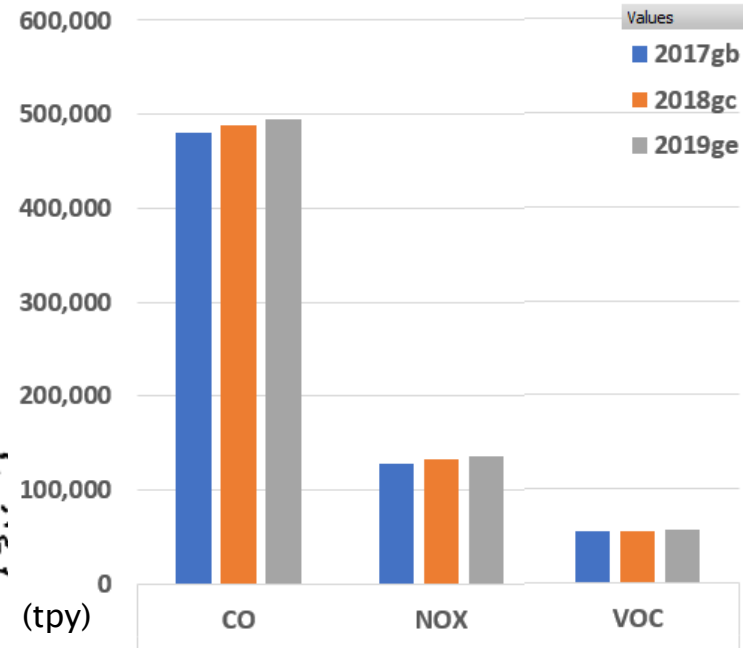
For some source categories, county total plots are easier to see than points

12km gridded plot for NOx emissions at airports (point sources)



Visualizing point source data with gridded plots is difficult

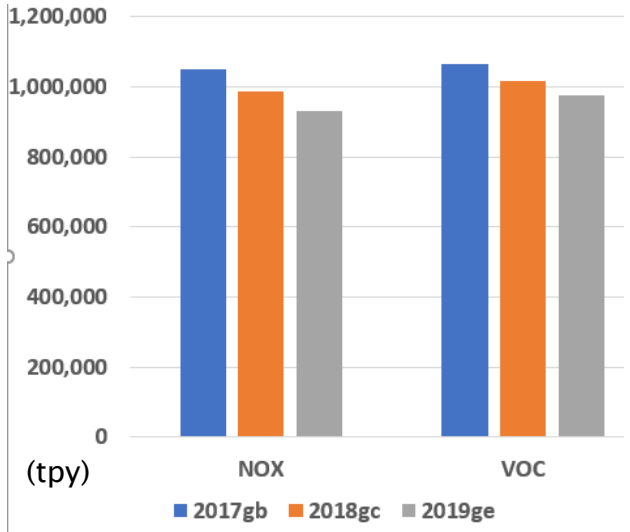
Key pollutants for airports are CO, NOx, and VOC

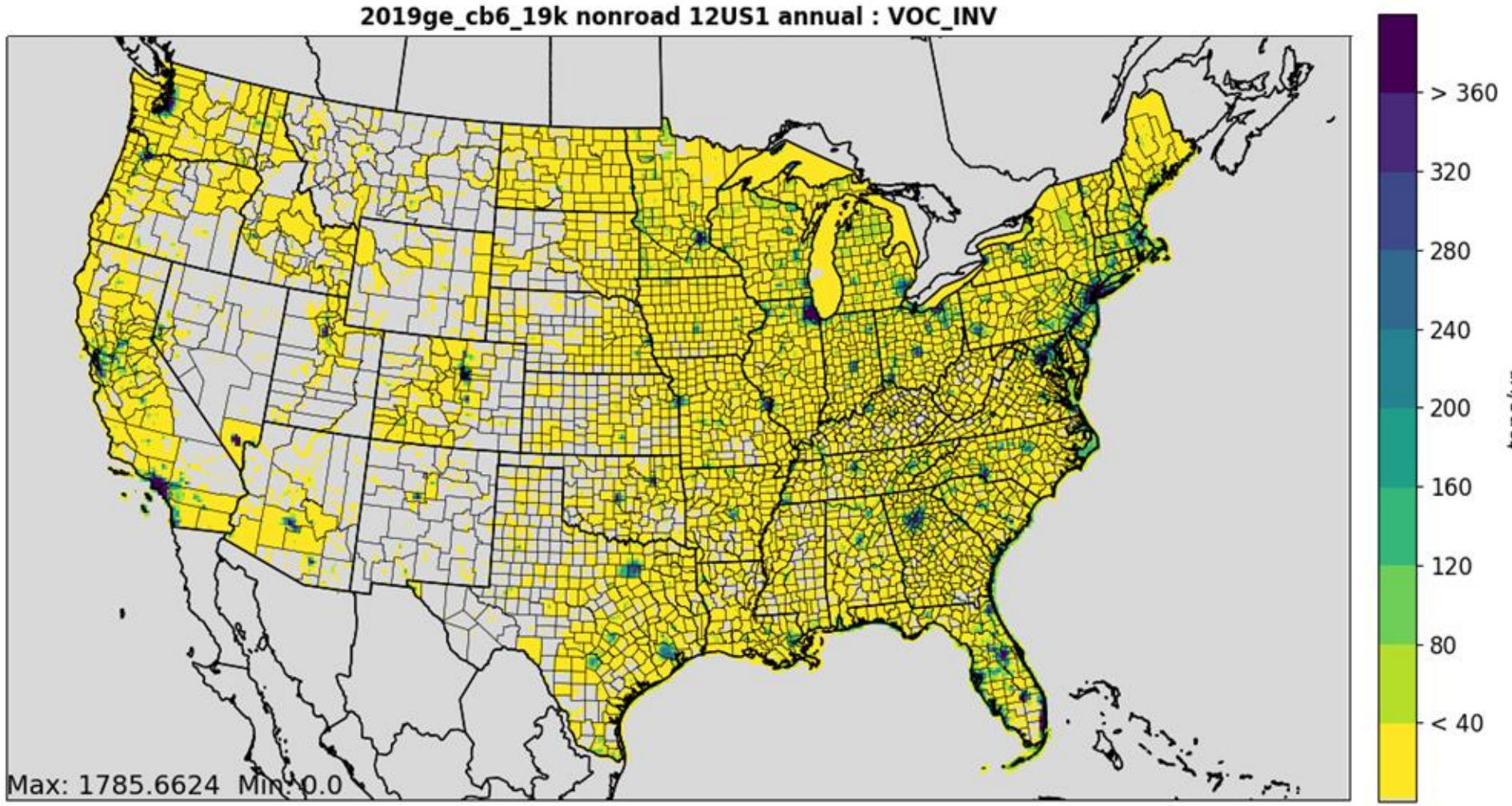


Nonroad Emissions

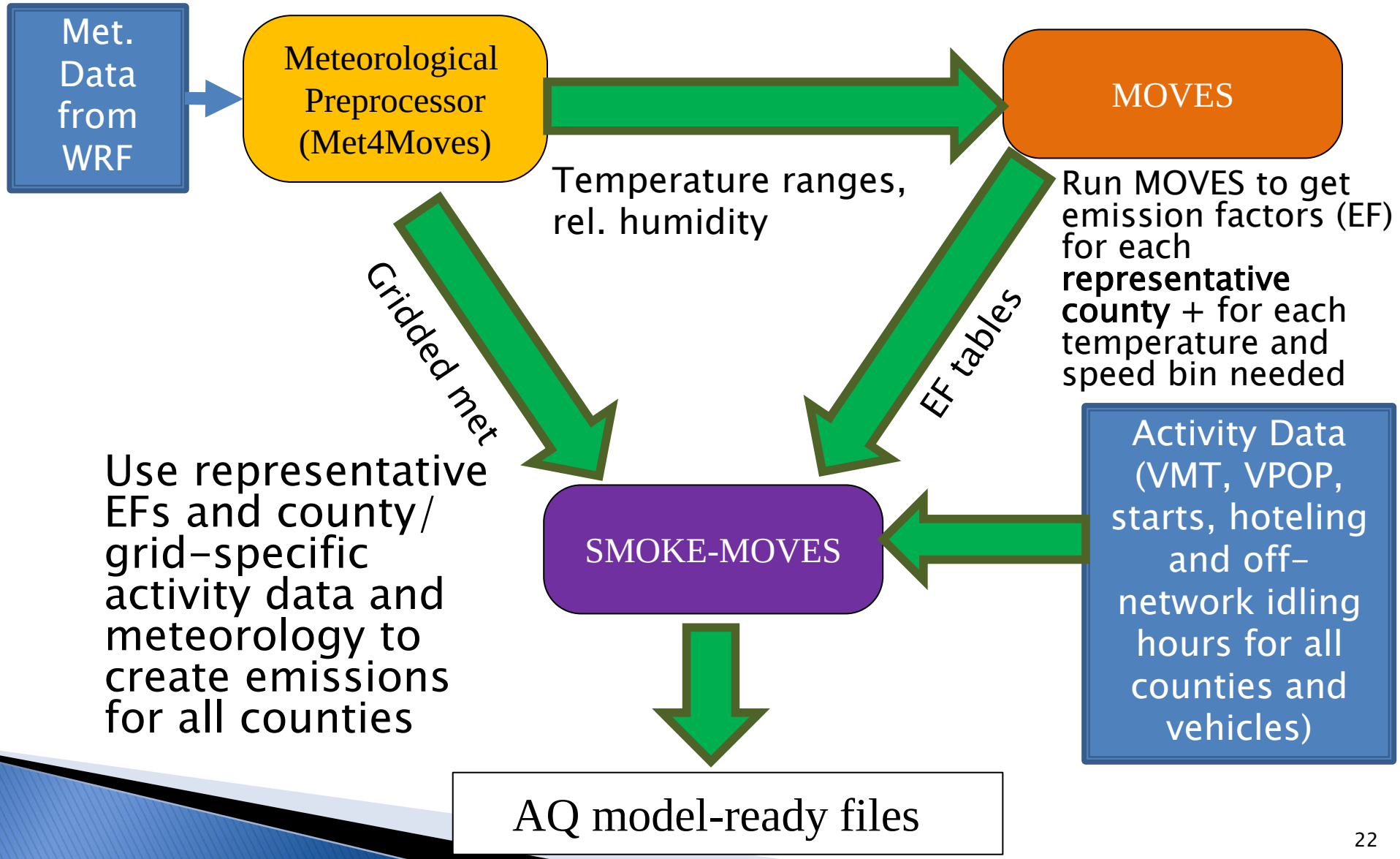
Nonroad emissions are significant in the high population and some other areas
Examples are lawn and garden emissions, construction, recreational marine, logging, and tractors

Key nonroad pollutants are CO, NOx, and VOC

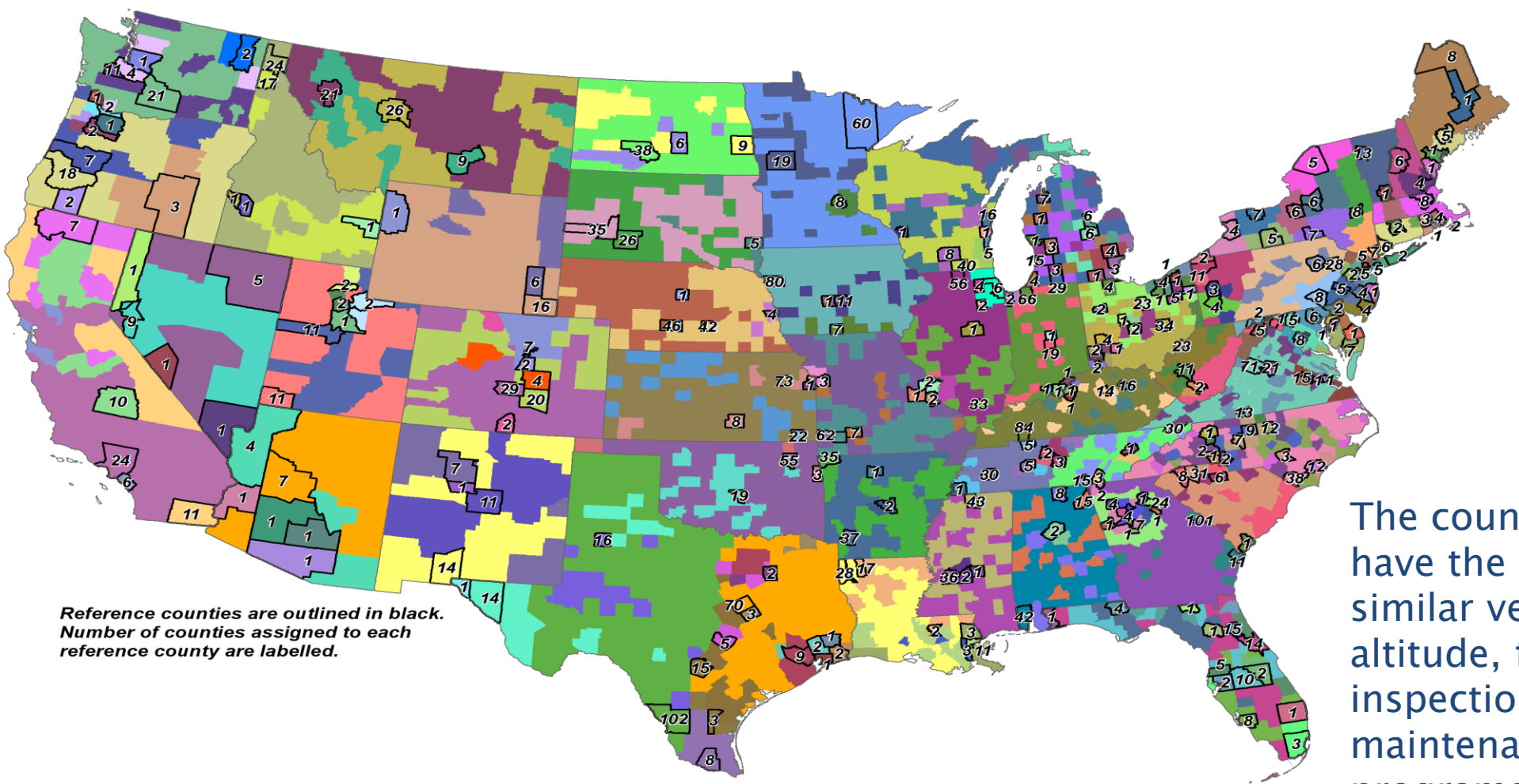




Onroad Inventory Preparation



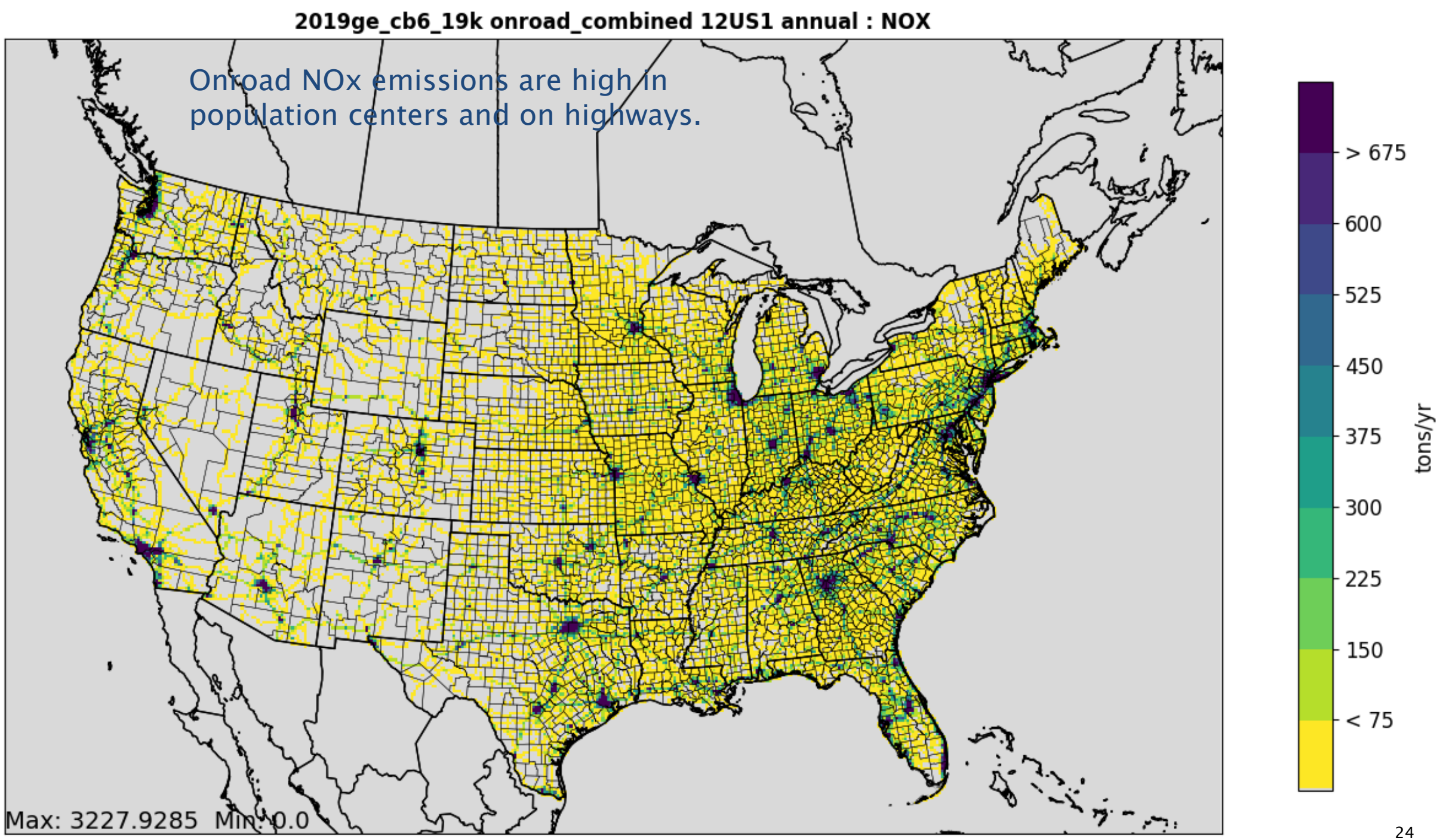
2017 NEI Representative Counties: 296 for Continental U.S.



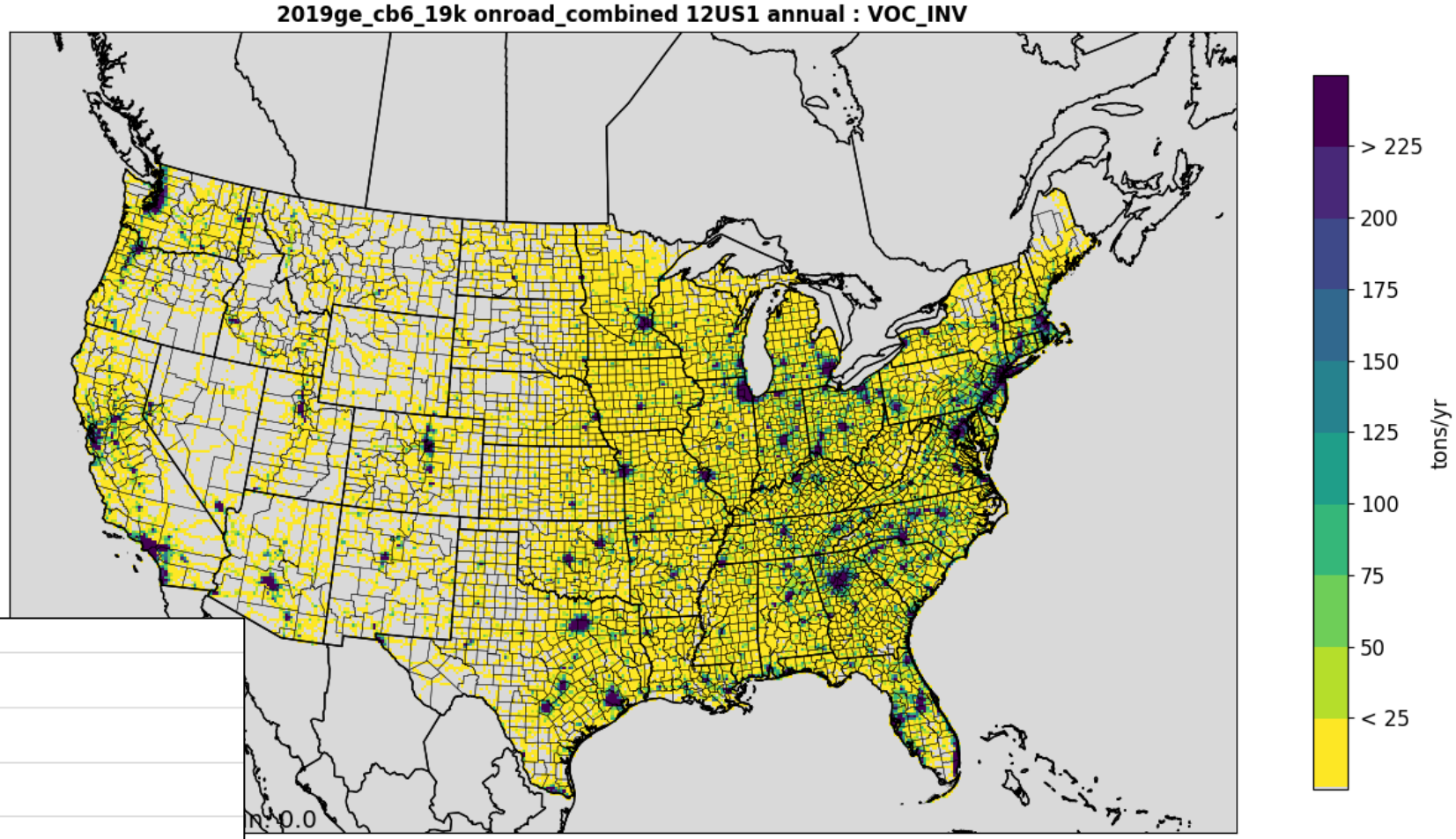
The county groups have the same state, similar vehicle ages, altitude, fuels and inspection and maintenance programs

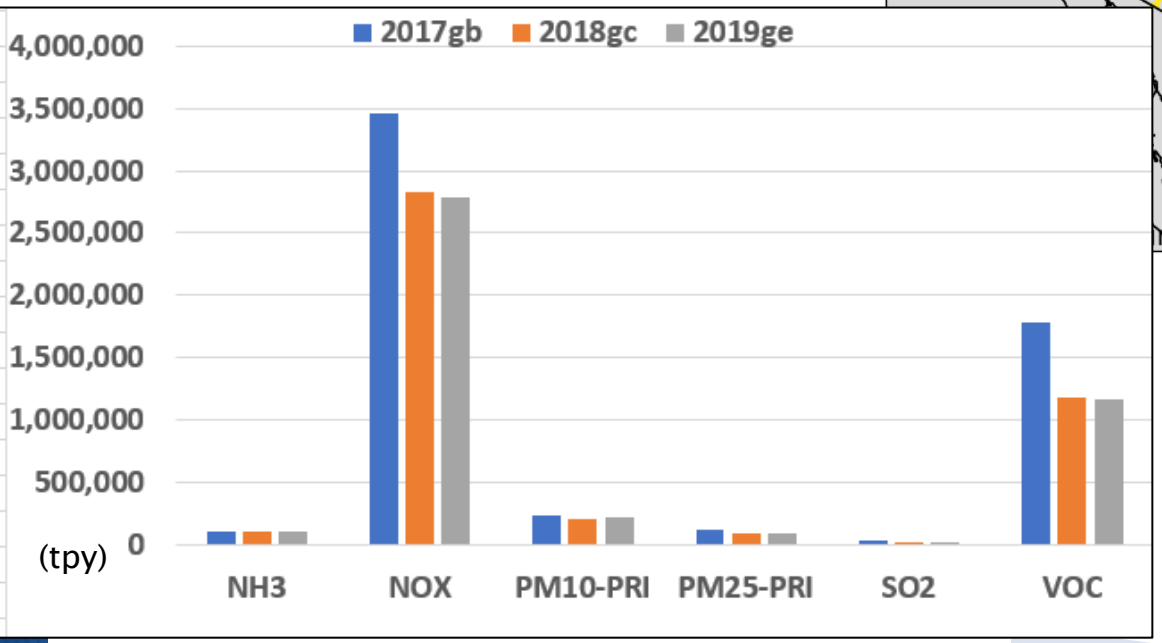
If you download this map from the ftp site, you can zoom in on a particular state

Reference County Groups 2017 NEI


2019ge_cb6_19k onroad_combined 12US1 annual : NOX
Onroad NOx emissions are high in population centers and on highways.
Max: 3227.9285 Min: 0.0
> 675
600
525
450
375
300
225
150
< 75
tons/yr

Onroad VOC emissions are more heavily weighted towards population centers due to more contributions from off-network processes (e.g., starts, idling)





Key onroad pollutants: CO, NOx, VOC

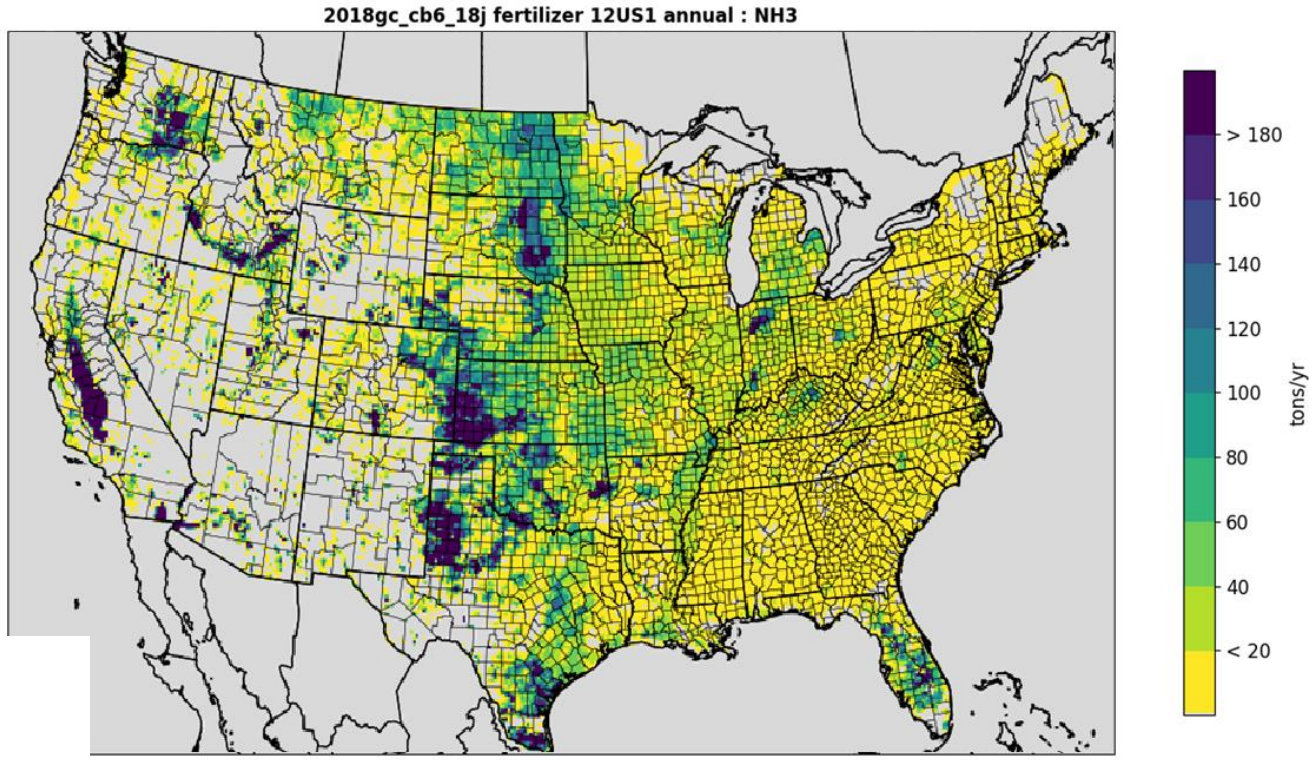
Not shown: CO = 19M tpy in 2017, 16.6M in 2019

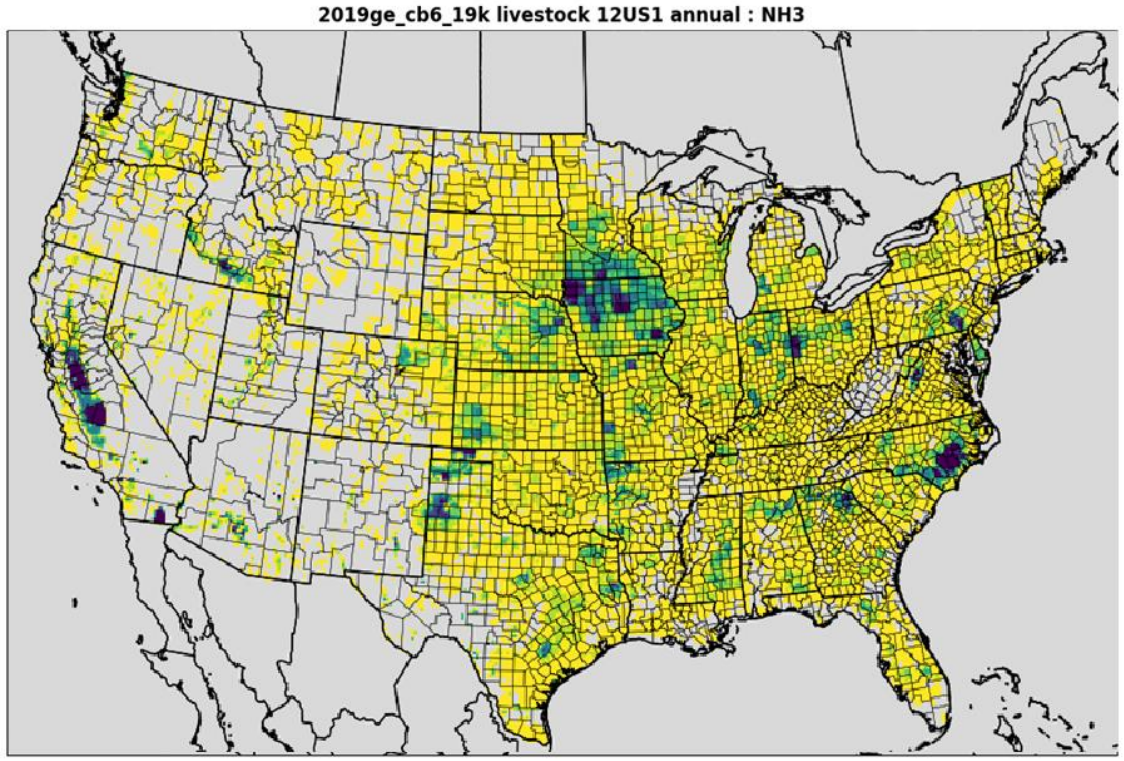
2018 and 2019 Methods for Nonpoint Sources

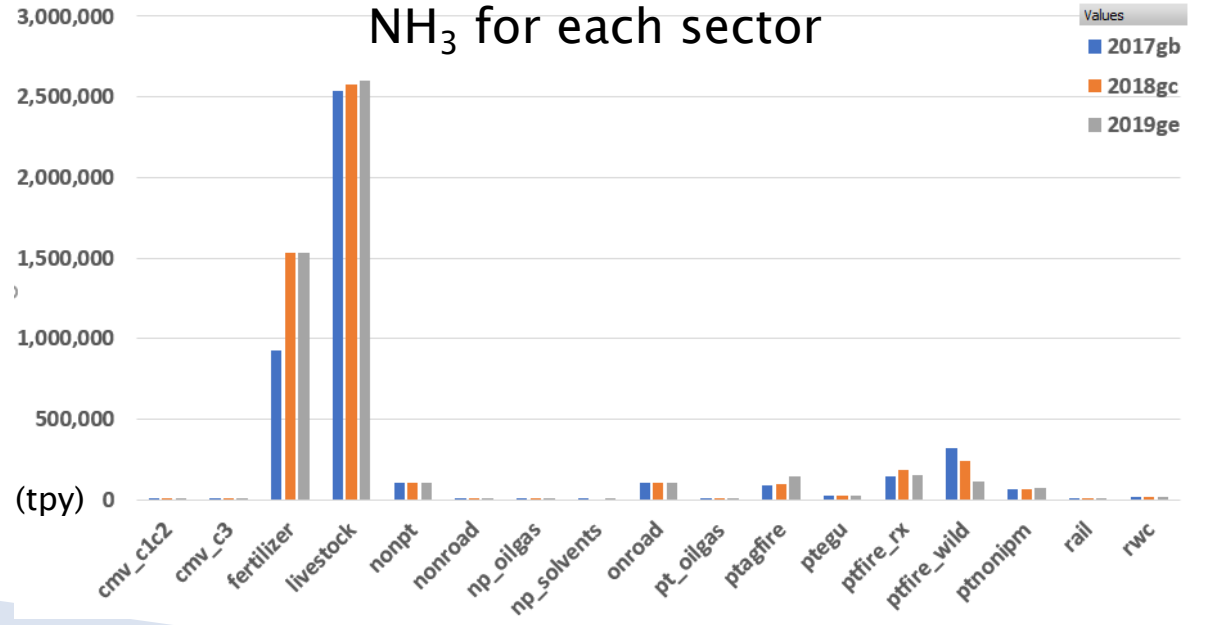
- Area fugitive dust sources (e.g., construction, tilling, dust from hooves, road dust) are the same as 2017 NEI except that paved road dust is projected based on Vehicle Miles Traveled (VMT) changes from 2017 to 2018 and 2019
- Agricultural livestock emissions are based on 2017 NEI with adjustments by animal type based on USDA data and temporally allocated according to year-specific meteorology
- Agricultural fertilizer emissions are computed based on fertilizer application and using bi-directional processes including year-specific meteorology and are saved during the Community Multiscale Air Quality (CMAQ) model run for each year
- Nonpoint oil and gas emissions for 2018 are adjusted from 2017 NEI based on production changes, but for 2019 are computed directly with the oil and gas tool based on year-specific data
- Solvent emissions are computed with year-specific usage data using a method consistent with 2020 NEI (Seltzer, et. al)
- Residential wood combustion sources are kept constant from 2017 NEI but many are temporally allocated to colder days of the year according to year-specific meteorology
- Other nonpoint sources are kept constant from 2017 NEI

Agricultural sources

Agricultural fertilizer and livestock emissions comprise the bulk of ammonia (NH_3) emissions in the inventory, but the spatial patterns differ



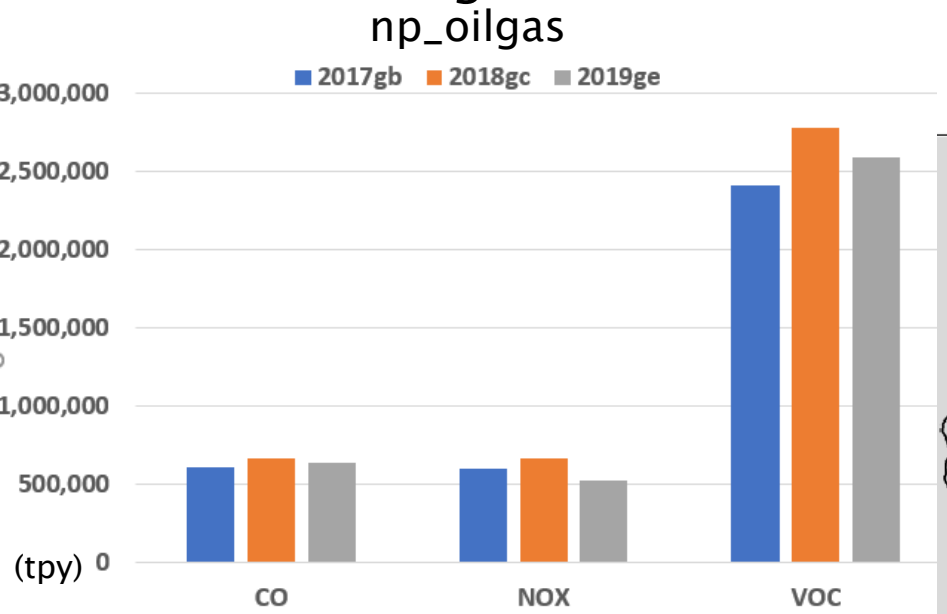


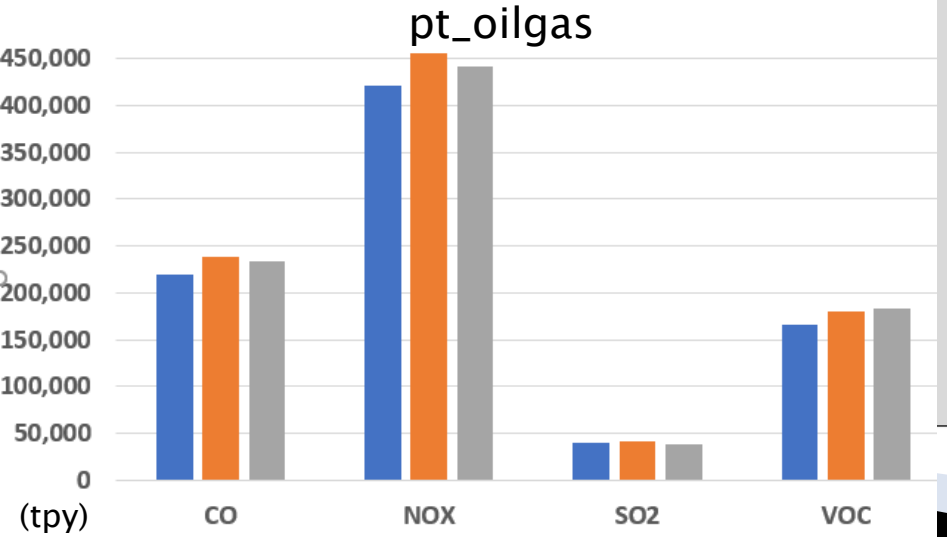


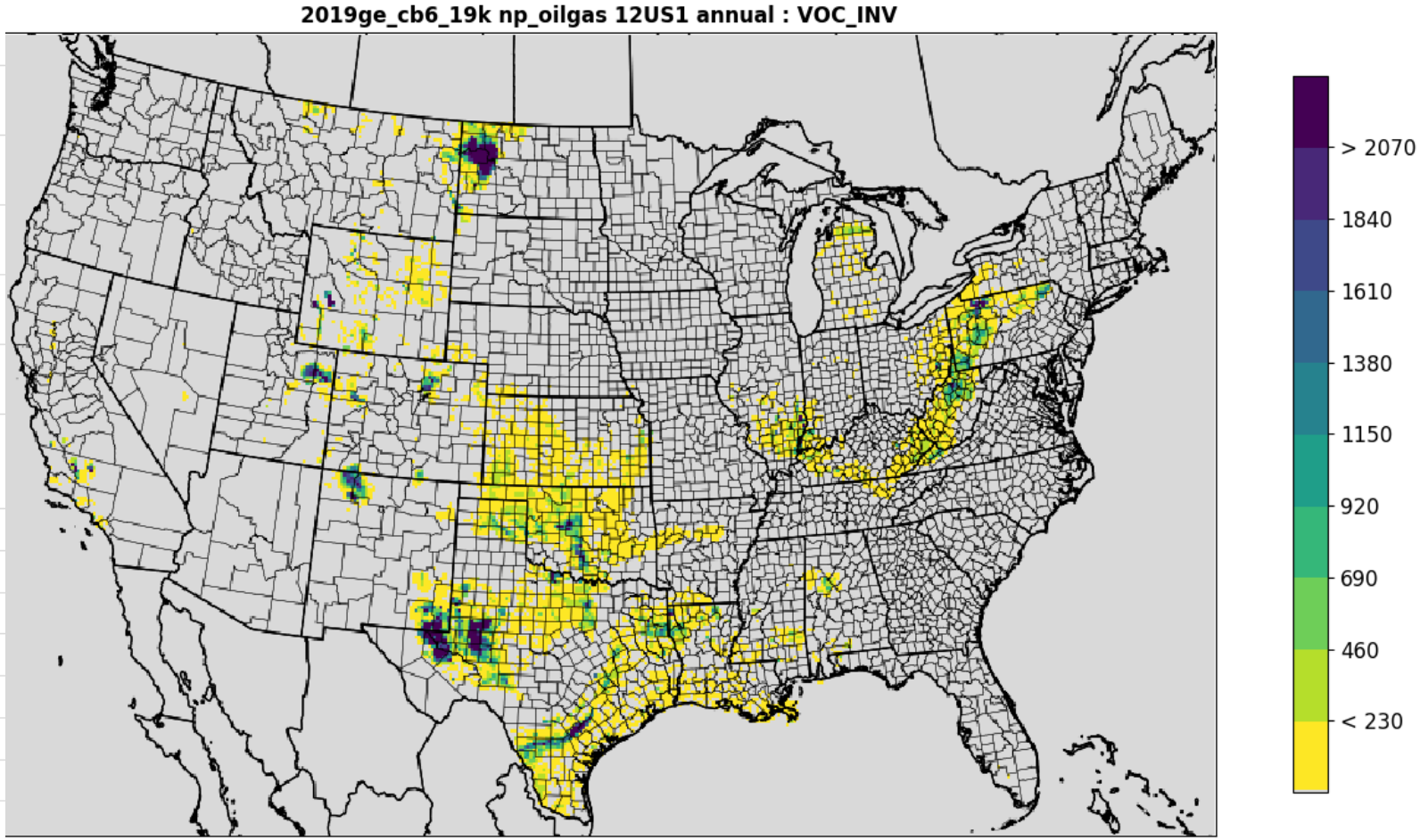
Oil and gas sources

Nonpoint oil and gas sources are dominated by VOC due to evaporative emissions

Point oil and gas sources have more NOx because they include many compressor engines

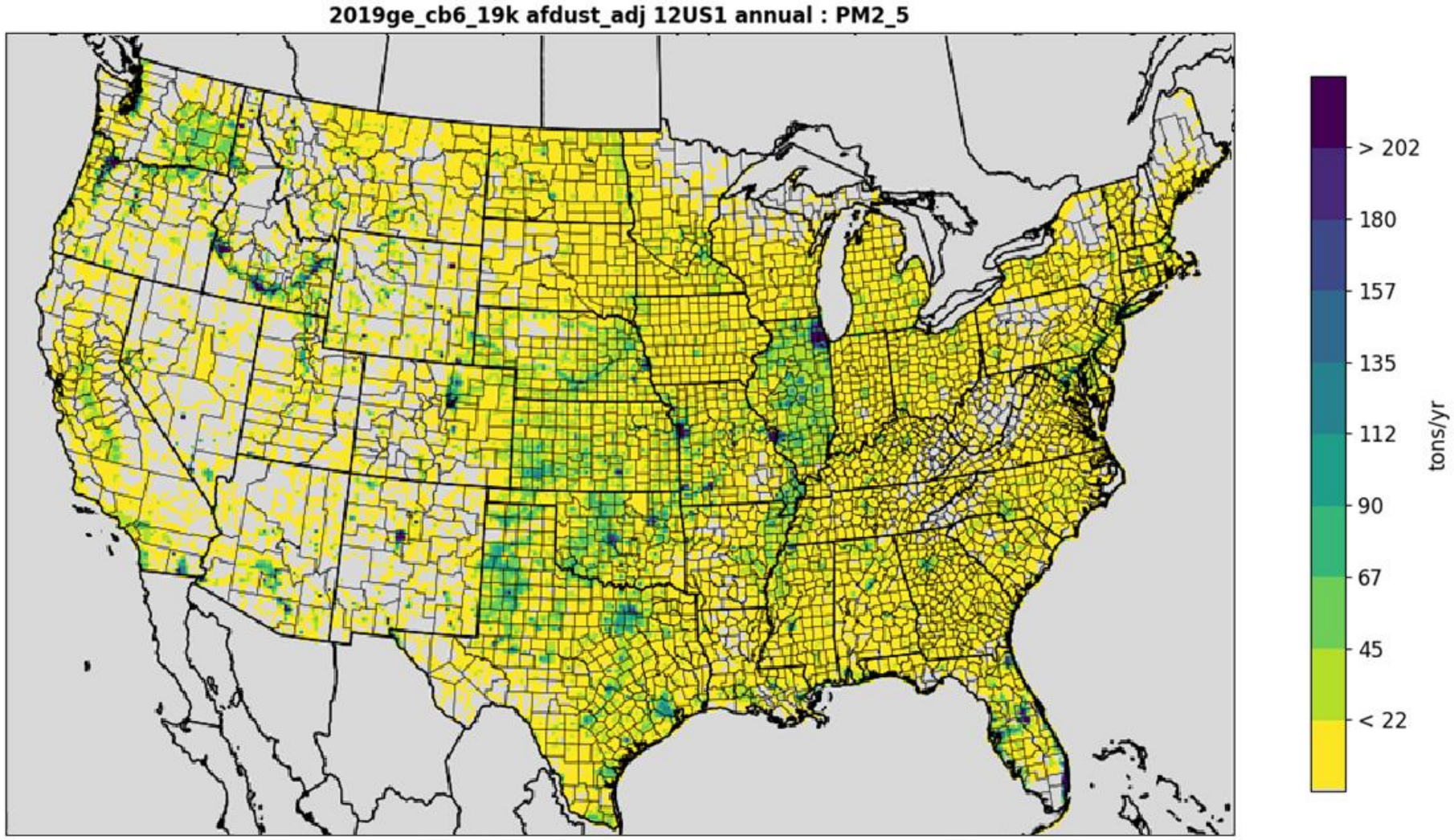






Area Fugitive Dust $PM_{2.5}$ Emissions

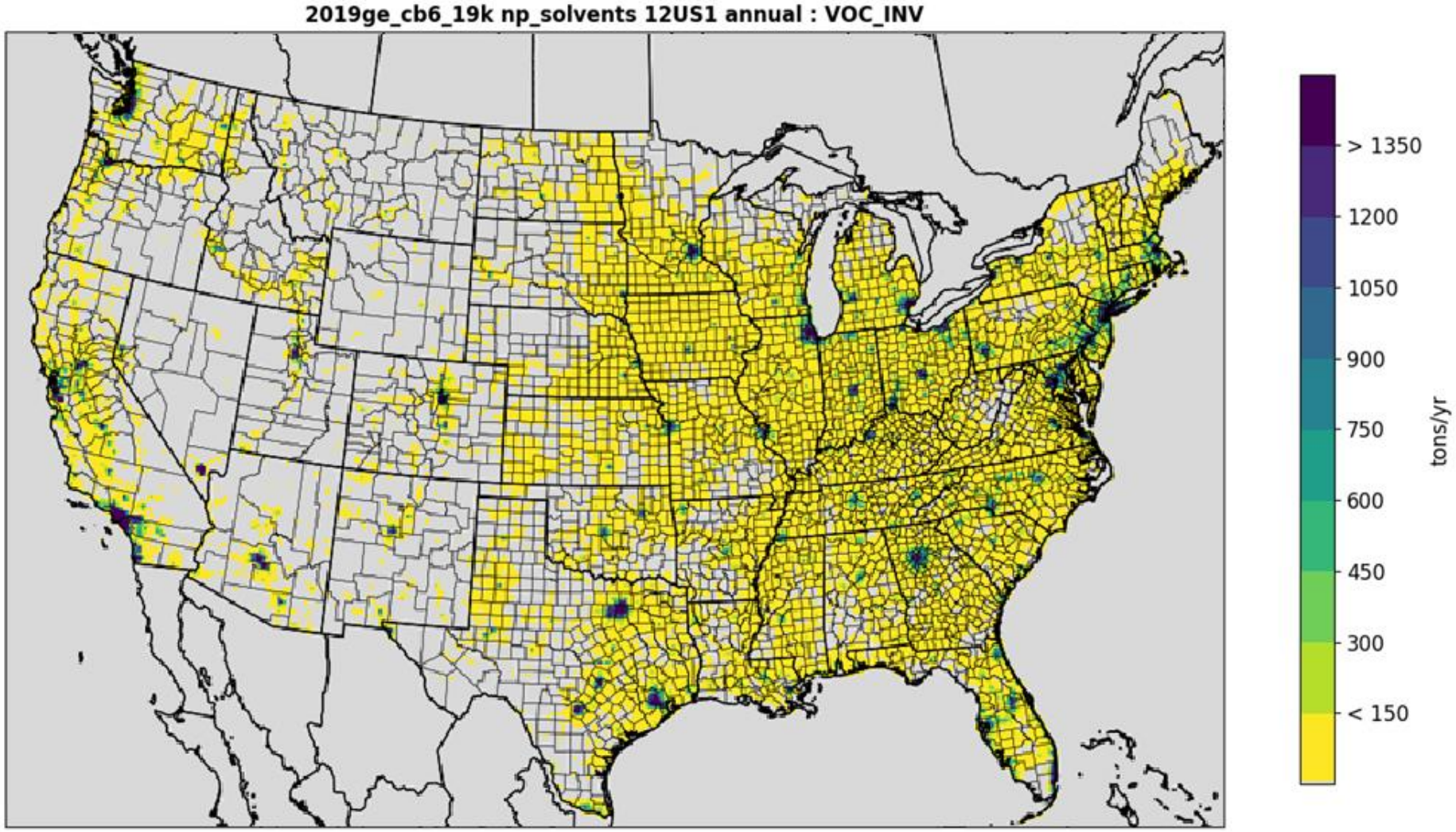
- PM_{10} and $PM_{2.5}$ fugitive dust sources are a very large contributor of PM in the NEI.
- They include building and road construction, agricultural dust, and paved and unpaved road dust (paved road dust is adjusted based on VMT).
- In modeling, dust emissions are reduced according to a transport fraction (related to land use) and are zeroed out for specific hours based on year-specific gridded hourly precipitation and snow/ice cover.



Solvent VOC Emissions

Solvent emissions are organic gases that evaporate from cleaners, personal care products, adhesives, architectural and aerosol coatings, printing inks, fragrances, emollients and pesticides.

These sources span residential, commercial, institutional, and industrial settings.

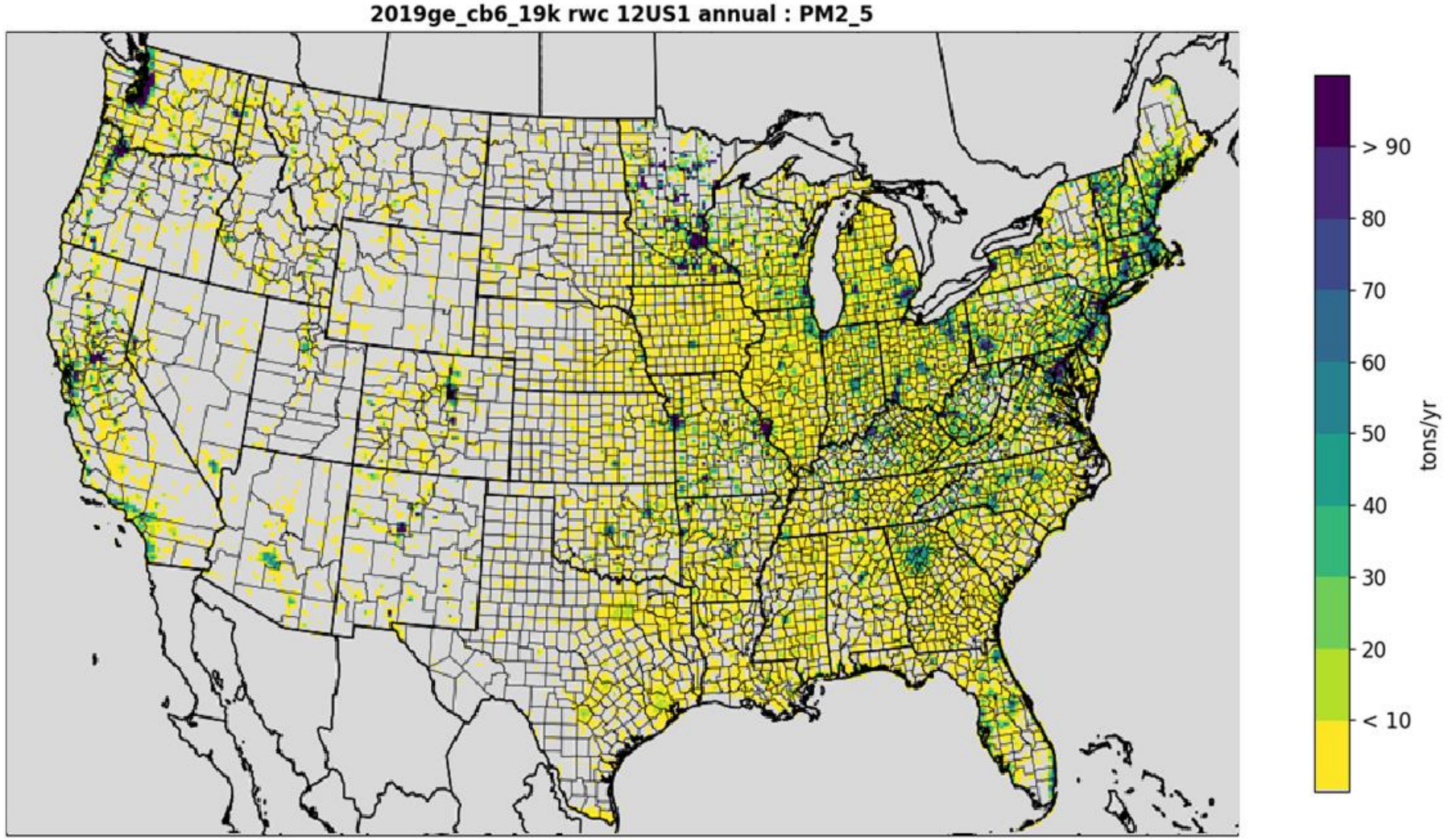


Residential Wood Combustion $PM_{2.5}$ Emissions

Residential wood combustion sources include emissions from fireplaces, wood stoves, outdoor wood boilers, firepits, and chimneas.

Emissions are denser in the northern states.

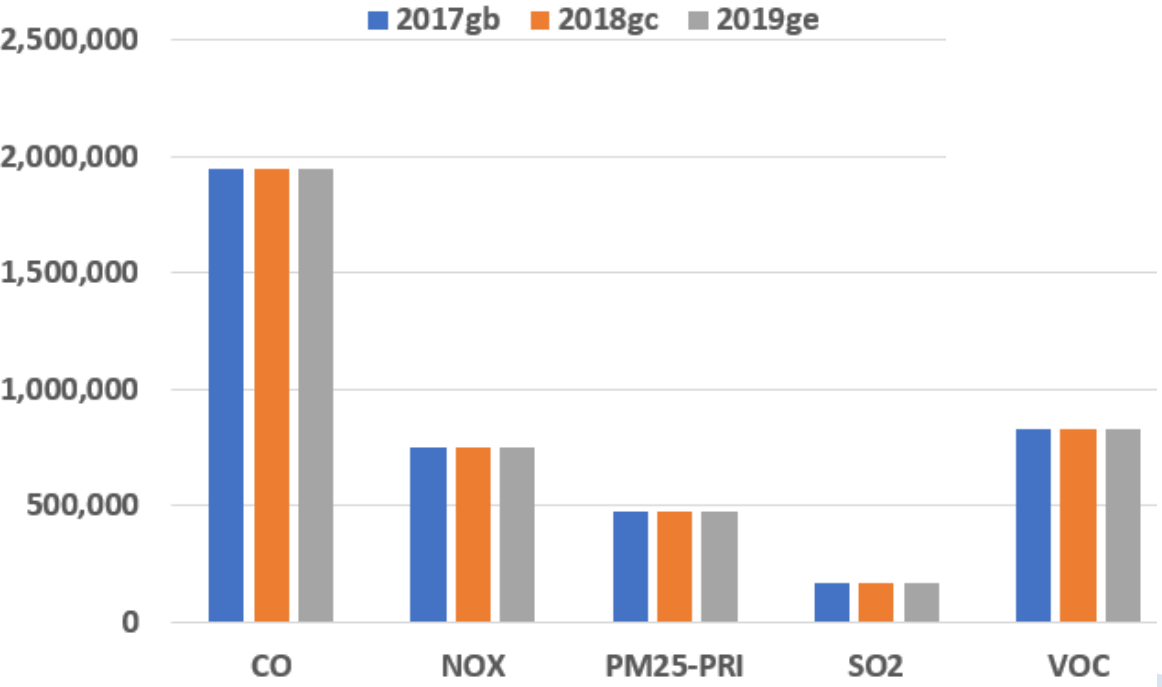
Most rwc emissions are temporally allocated to the colder days of the year (lows less than 50 degrees in the north and 60 degrees in the south).



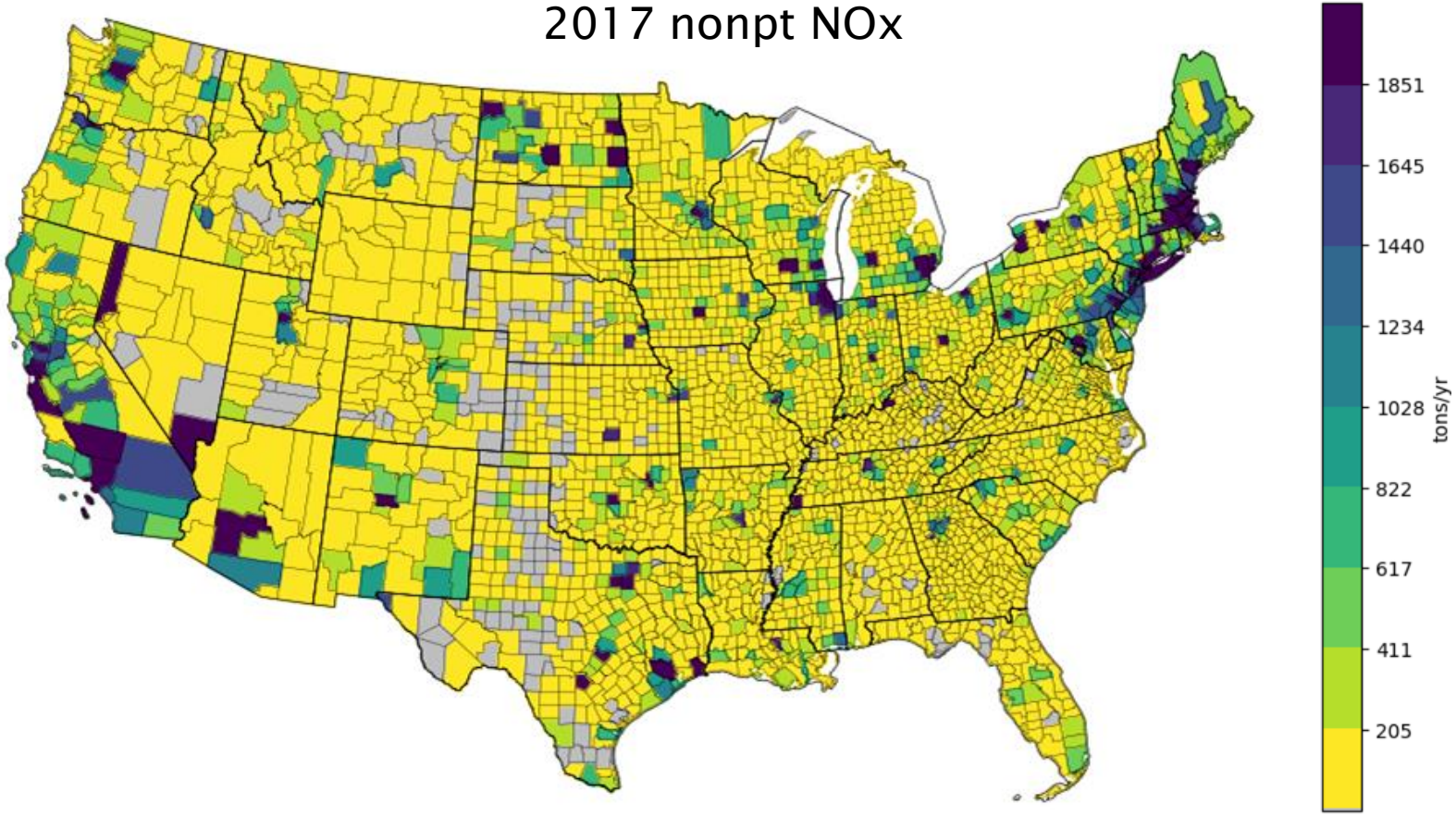
Other Nonpoint Sources

Key pollutants are CO, NOx, VOC

Emissions are held constant at 2017 levels



2017 nonpt NOx

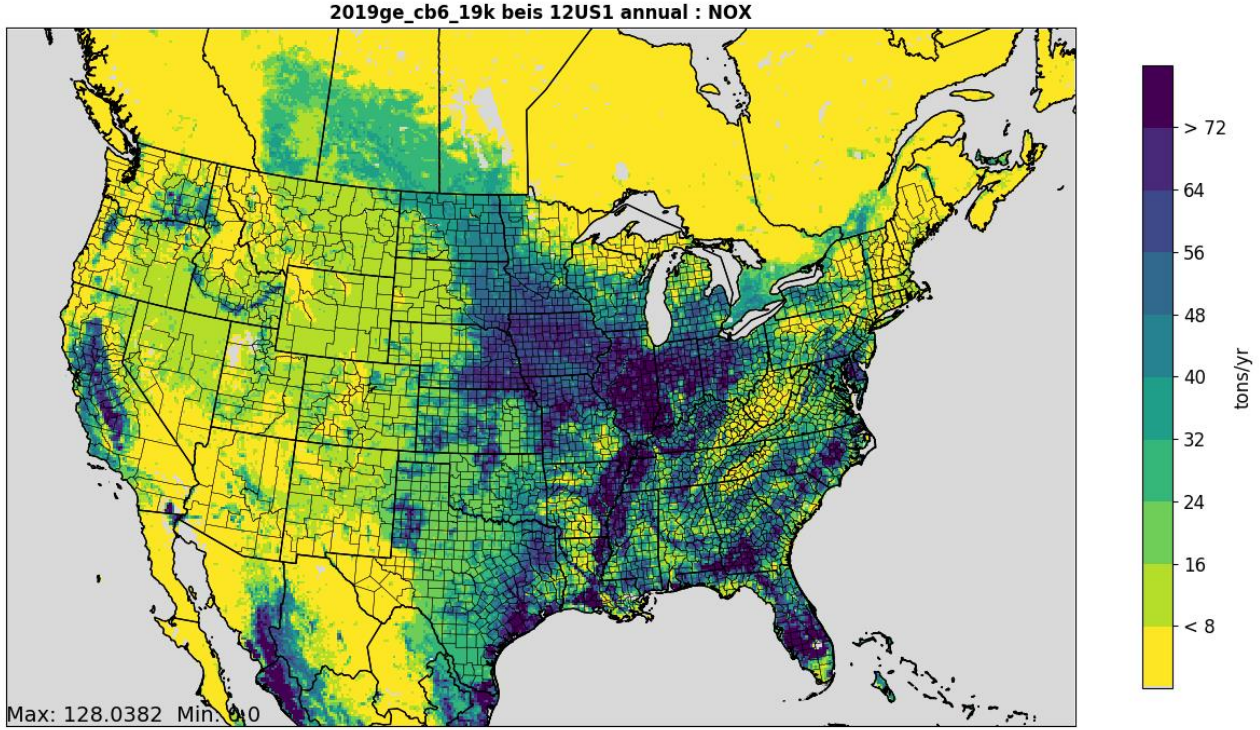


The largest nonpt NOx sources residential and commercial natural gas combustion and industrial boilers (those not included in the point inventory)

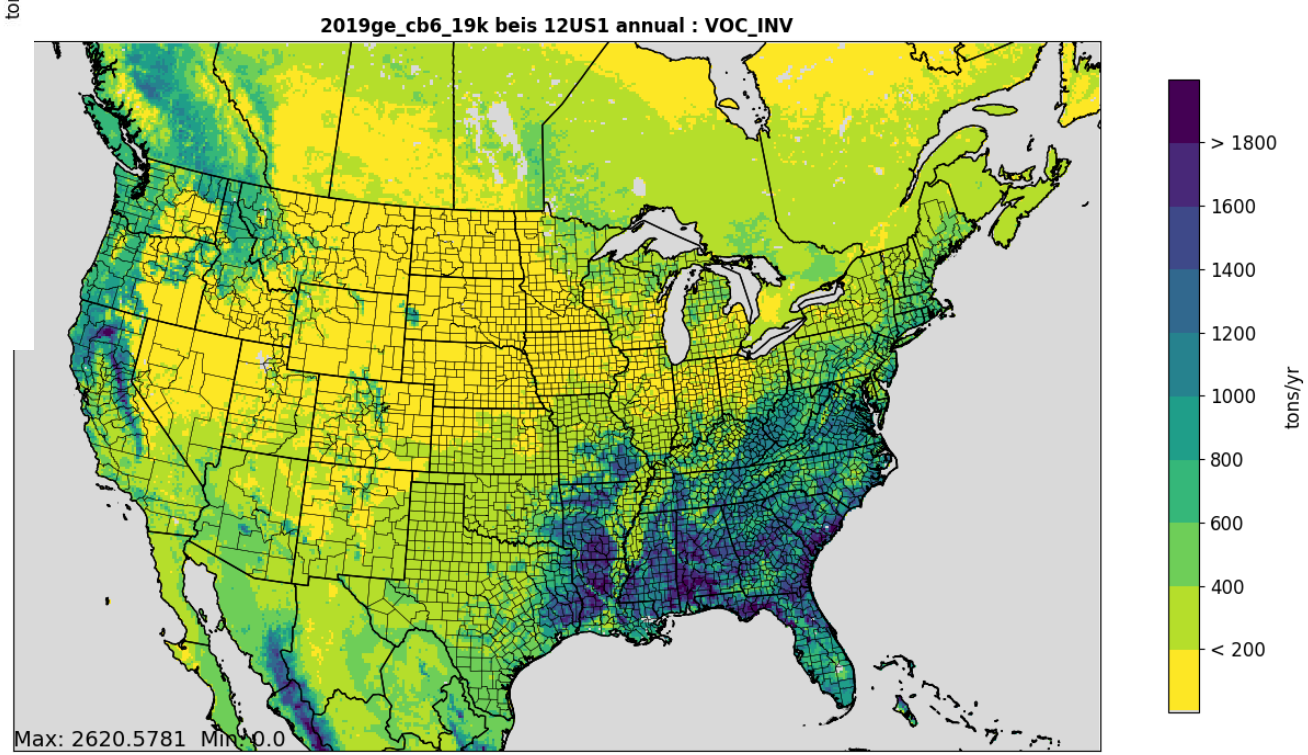
The largest nonpt VOC sources are gasoline storage and gas stations, open burning of waste, and composting

Key PM sources are open burning and industrial wood combustion.

Biogenic Emissions



Biogenic emissions were computed consistently with the 2017 NEI using BEIS 3.70 and the biogenic emissions land use database version 5 (BELD5)



Higher levels of NOX emissions are found in agricultural areas

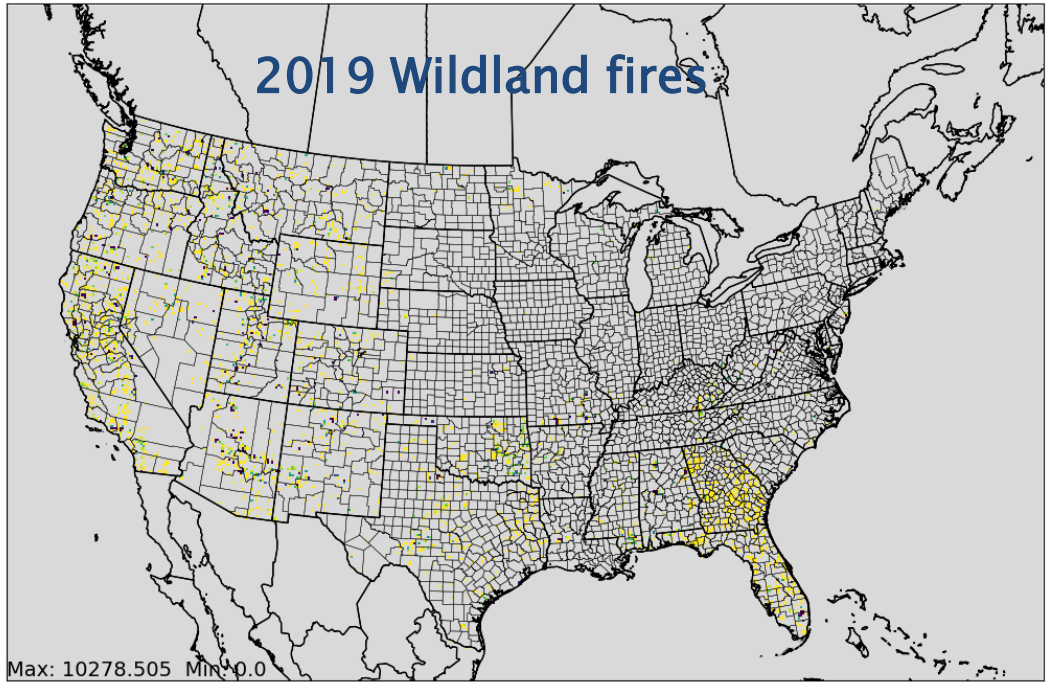
Higher levels of VOC emissions are found in the Southeast due to oaks and forests

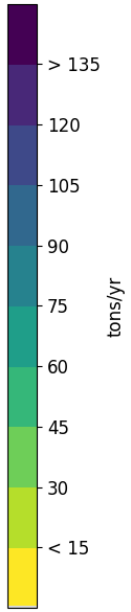
2018 and 2019 Methods for Fires

- Wild and prescribed fires are computed for each year using SMARTFIRE2 with BlueSky Pipeline and nationally available data sets
  - US Forest Service, US Fish and Wildlife Services, Department of Interior prescribed fire data, GeoMAC shapefiles, ICS209 fire reports, Monitoring Trends in Burn Severity (MTBS) burn scar data, Georgia DNR and Florida DEP
  - 2018 was a very active wildfire season (with over 8M acres burned) while 2019 was inactive in CONUS with only about 2.1M acres burned, although Alaska had a record-breaking year in 2019 for wildfires with 2.5M acres burned
- Agricultural fires were computed for each year based on satellite detects (Pouliot method) plus data from Georgia and Florida
  - The agricultural fire method is integrated with the wild and prescribed fire computations to prevent double counting
- The Fire INventory from NCAR (FINN) are used for Canada, Mexico, and areas outside of the Continental U.S.
  - Satellite-based daily fire emissions product for atmospheric chemistry models
  - Available from https://www.acom.ucar.edu/Data/fire/

2019ge_cb6_19k ptfire-wild 12US1 annual : PM2_5

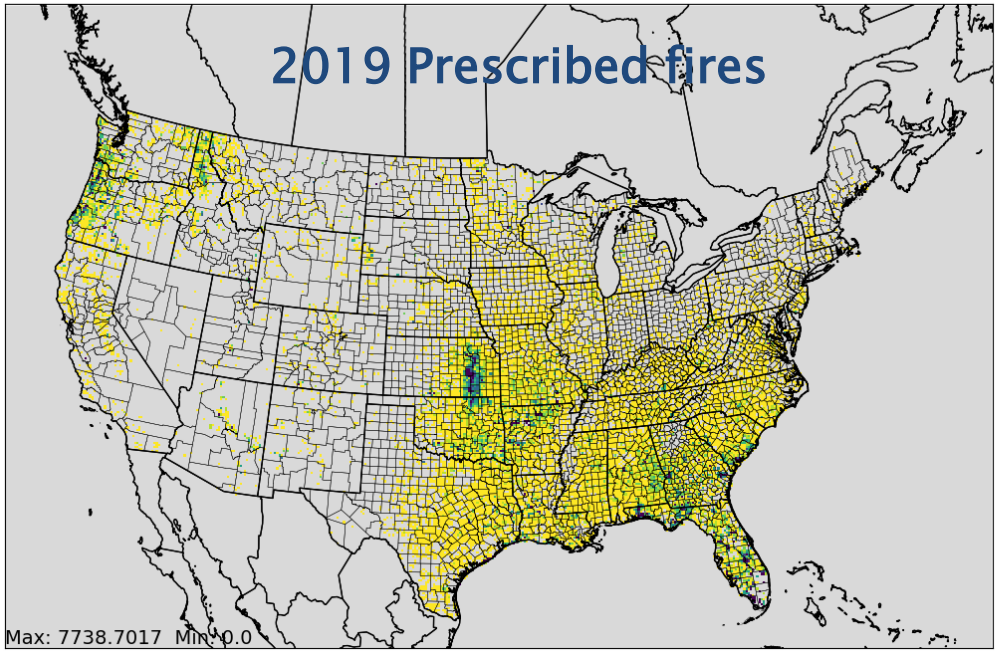
2019 Wildland fires

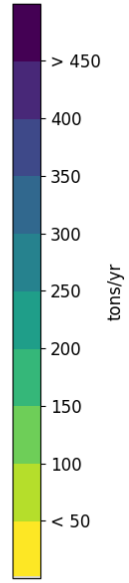




2019ge_cb6_19k ptfire-rx 12US1 annual : PM2_5

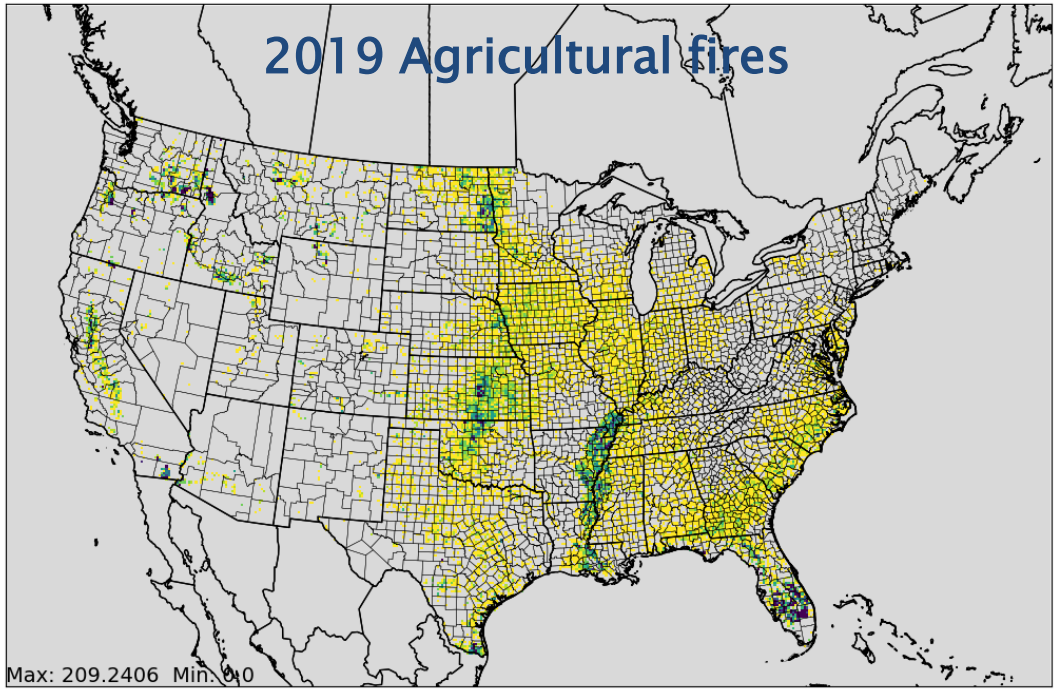
2019 Prescribed fires

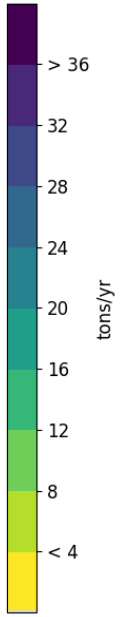




2019ge_cb6_19k ptagfire 12US1 annual : PM2_5

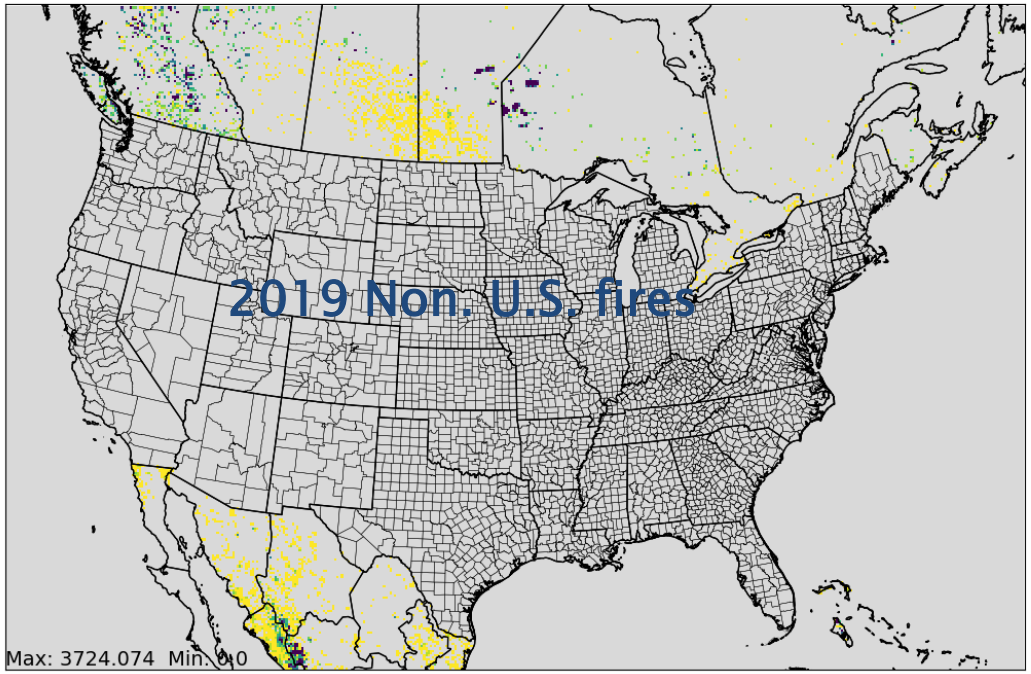
2019 Agricultural fires

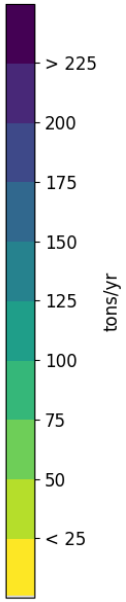




2019ge_cb6_19k ptfire_othna 12US1 annual : PM2_5

2019 Non-U.S. fires





Non-US Inventories

- Canadian inventories were provided by Environment and Climate Change Canada (ECCC) for 2016
  - Canada emissions include agricultural, dust, oil and gas, point, onroad, nonroad, and other nonpoint sources
  - Onroad and nonroad inventories were projected to 2018 / 2019 based on U.S. emissions trends for similar source types
  - Canada only emissions sectors: othafdust, othptdust, onroad_can
- Mexico inventories for point, nonpoint, and nonroad are based on Mexico's Secretariat of Environment and Natural Resources (SEMARNAT) data for 2016
  - Onroad emissions are based on MOVES-Mexico outputs interpolated to 2018/2019
  - Mexico only platform sector: onroad_mex
- Sectors with data for both Canada and Mexico: othpt, othar
- Non-U.S. fires are based on FINN (sector: ptfire_othna)

Total Emissions in the 2018 and 2019 Platforms

In this section we review the CAPs and the key sectors that contribute to the total emissions modeled by the air quality model

Pollutants other than CAPs are discussed briefly

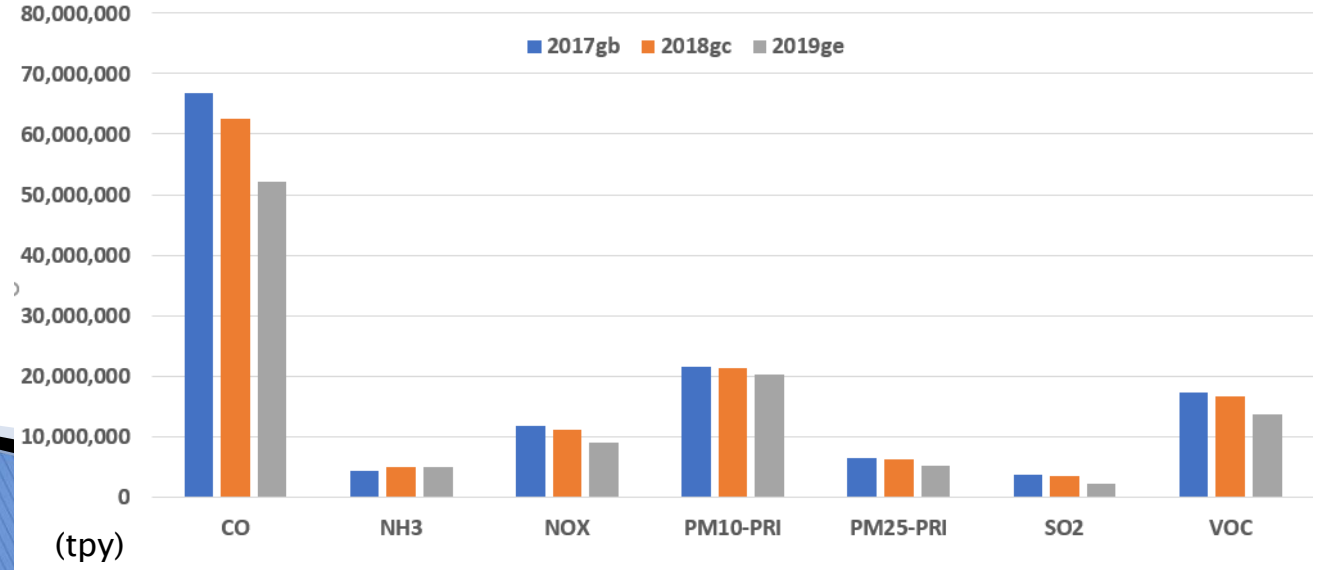
2018 and 2019 Modeling Status

- Air quality modeling has already been performed for 2018
  - Completed for Continental U.S. (ConUS), and for non-CONUS areas (Alaska, Hawaii, and Puerto Rico/Virgin Islands)
  - Computation of emissions for some sectors (e.g., onroad, cmv, fires, biogenics) requires processing in non-ConUS areas
- 2019
  - Continental U.S. inventories for 2019 are available
  - ConUS modeling for 2019 will happen during the spring of 2022
  - 2019 fertilizer is not yet available
  - Inventories outside of the Continental U.S. are not yet complete for biogenics, onroad, fires, cmv

U.S. CAP Emissions from 2017 to 2019

Pollutant	2017gb* (tons)	2018gc* (tons)	2019gc* (tons)	2019-2017 (%)
CO	68,892,015	62,498,551	52,198,183	-22%
NH_3	4,321,808	4,935,316	4,864,748	13%
NO_x	11,719,842	11,129,843	8,979,764	-23%
PM_{10}	21,539,102	21,316,155	20,191,529	-6%
$PM_{2.5}$	6,342,048	6,135,507	5,168,012	-19%
SO_2	3,575,606	3,474,744	2,209,963	-38%
VOC	17,305,382	16,576,312	13,729,915	-18%

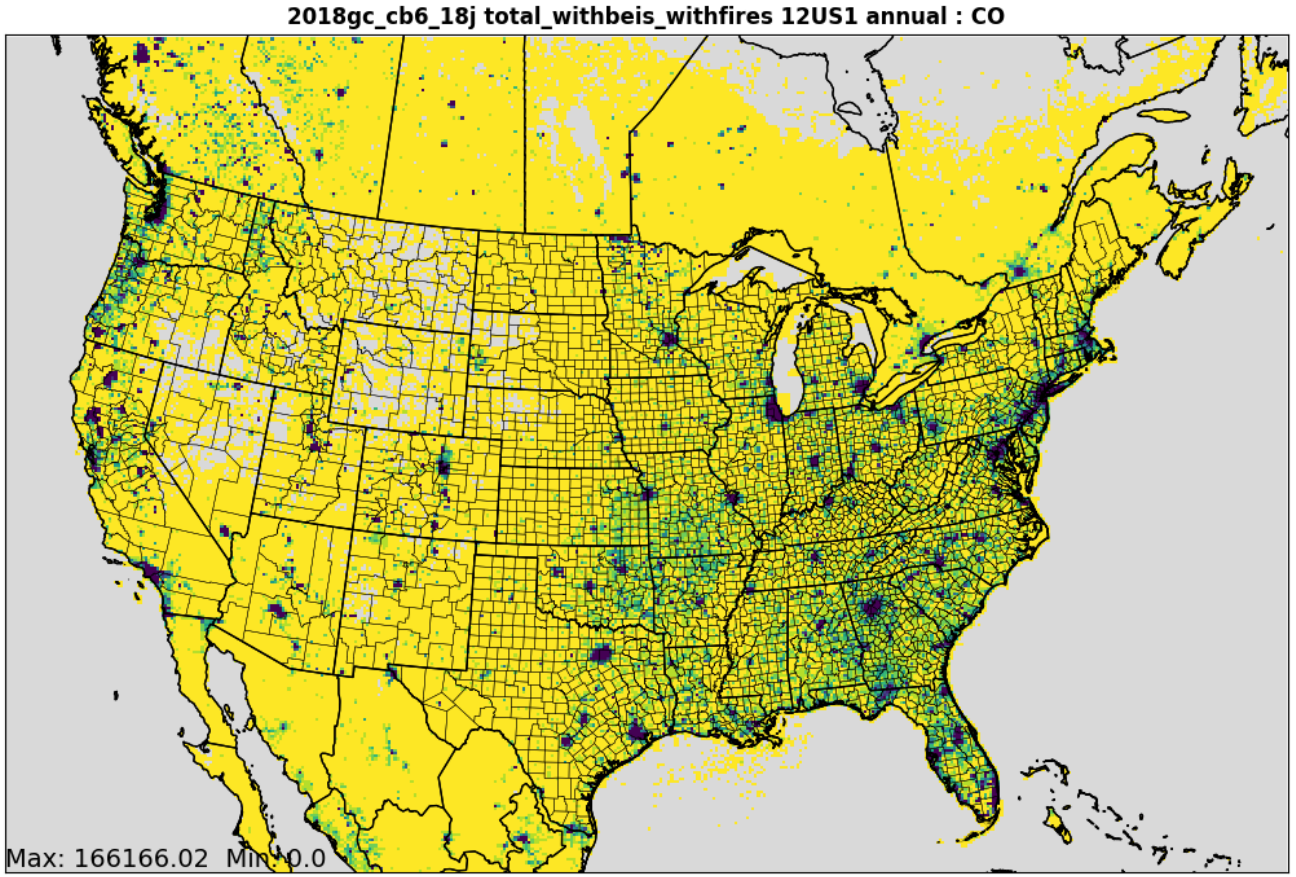
** National emission totals include fires but do not include biogenic emissions*

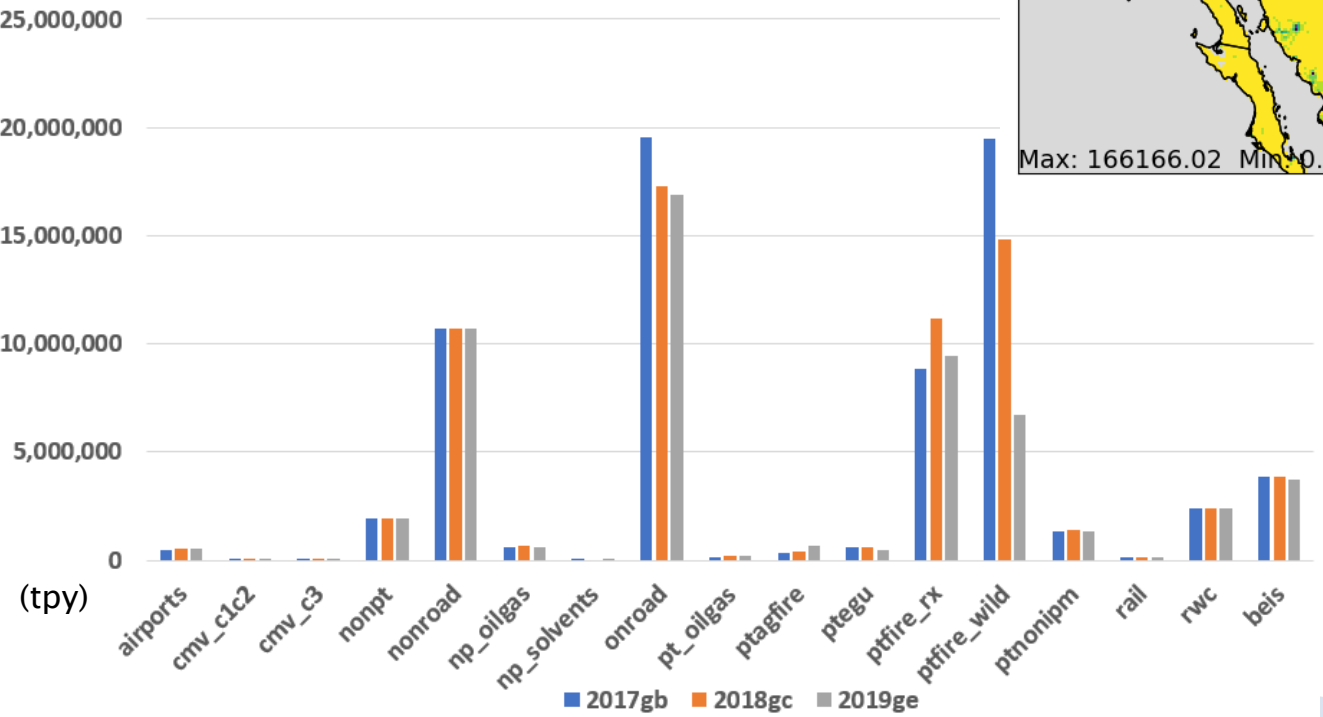


2019 emissions for fertilizer and for some sectors in AK, HI, PR, and VI are approximated from 2018 levels

Total CO

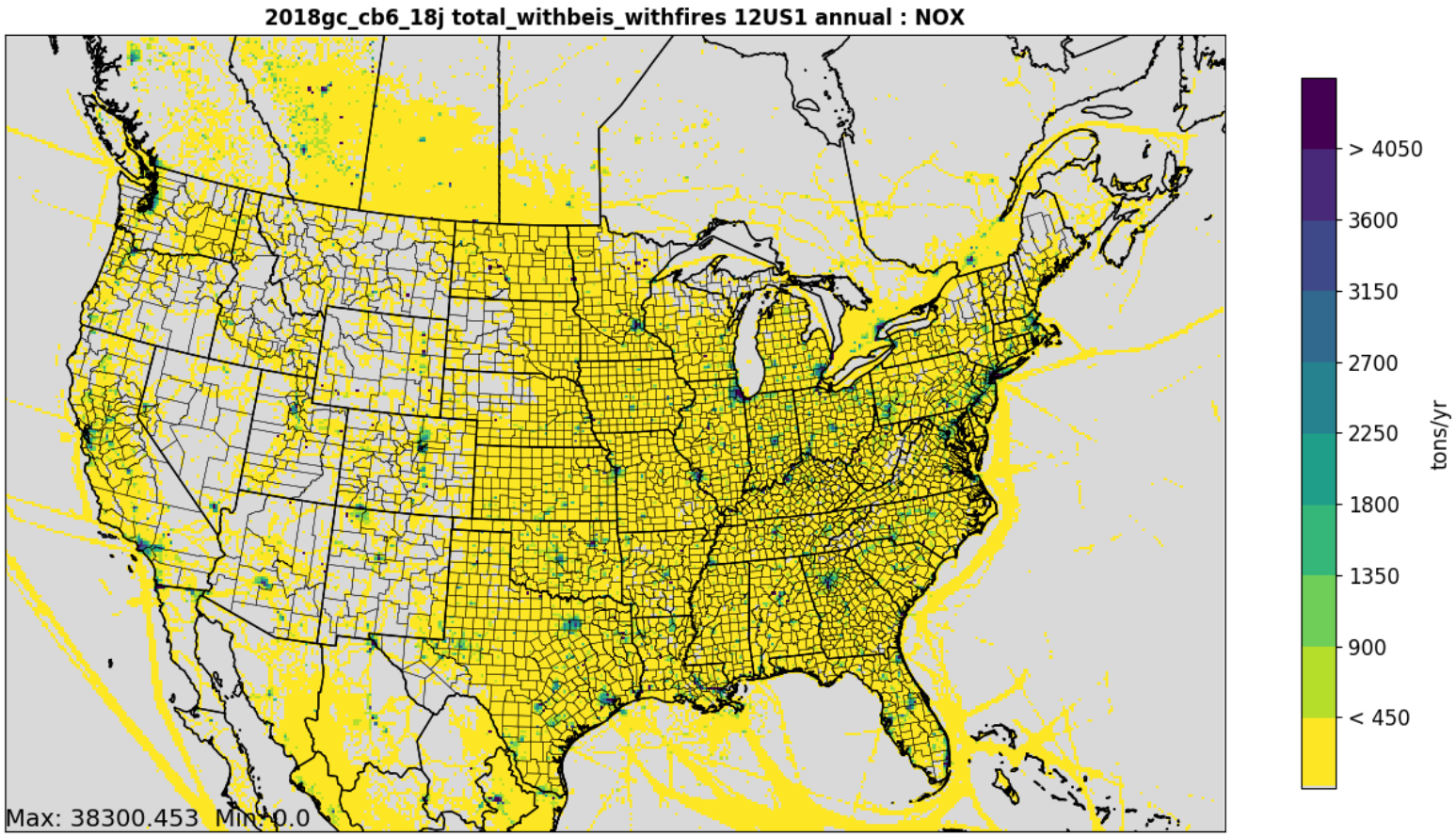
CO emissions are primarily from fires and onroad and nonroad sources. Onroad emissions show decreases from 2017 through 2019. Fire emissions are lowest in 2019.

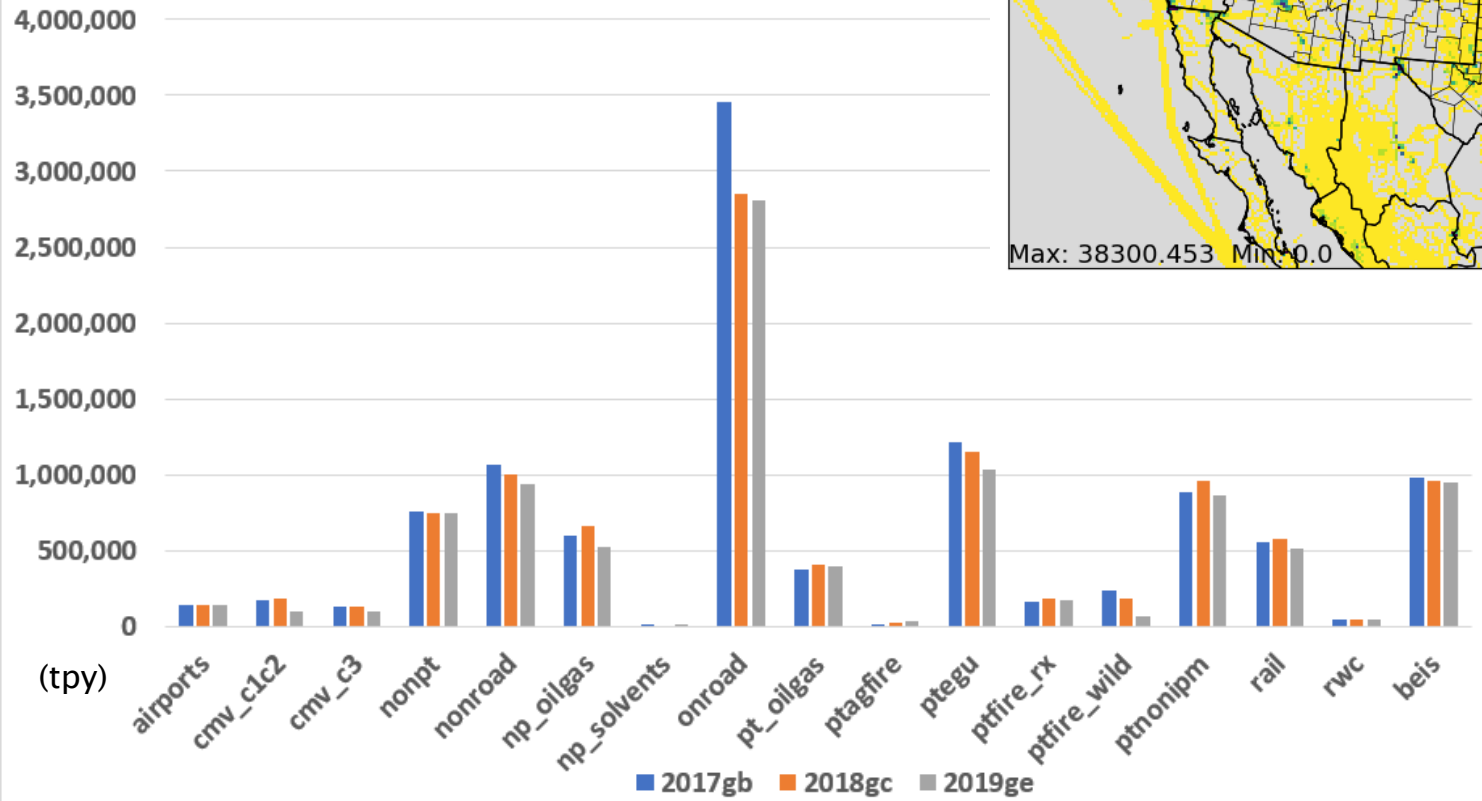




Total NOx

NO_x emissions are primarily from onroad, commercial marine vessels (CMV), EGU (ptegu), nonroad, non-EGU point (ptnonipm, pt_oilgas), biogenic (beis) and locomotive emissions. Many sectors decreased from 2017 to 2019, but a few show different patterns.

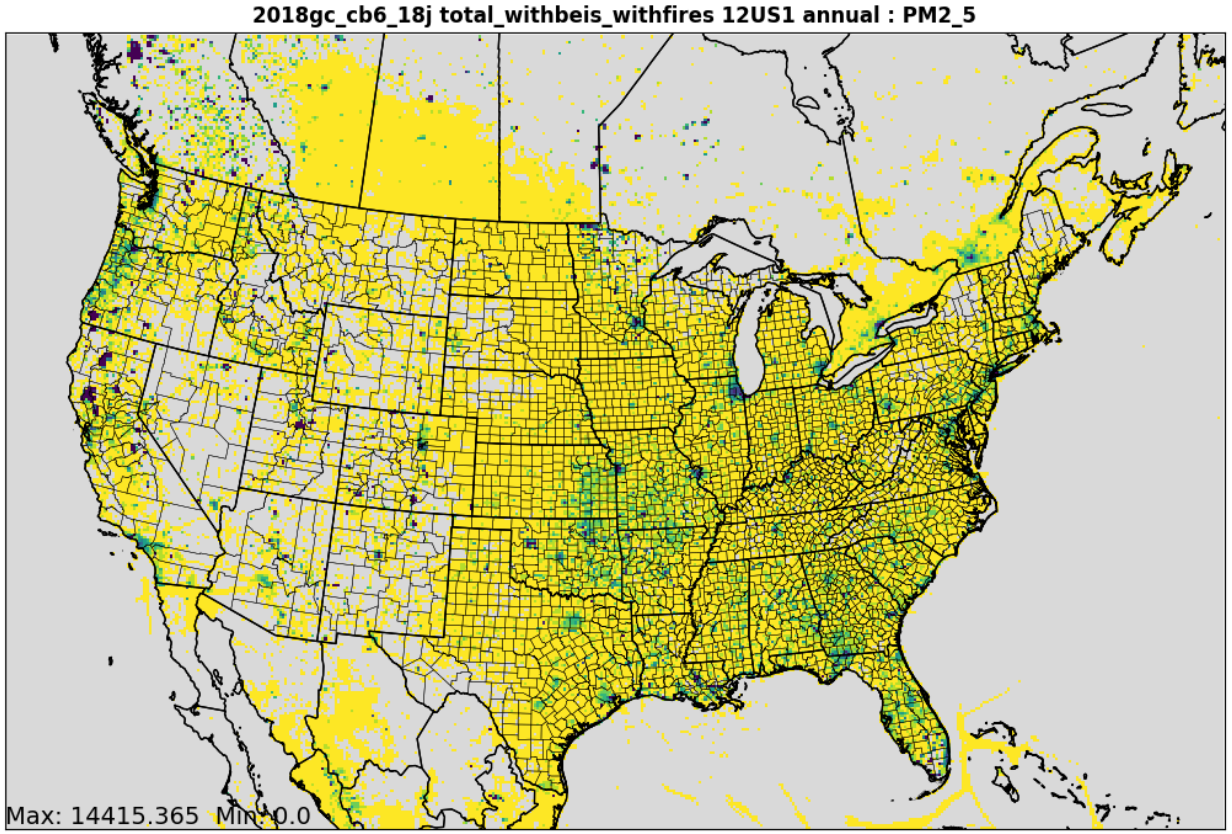


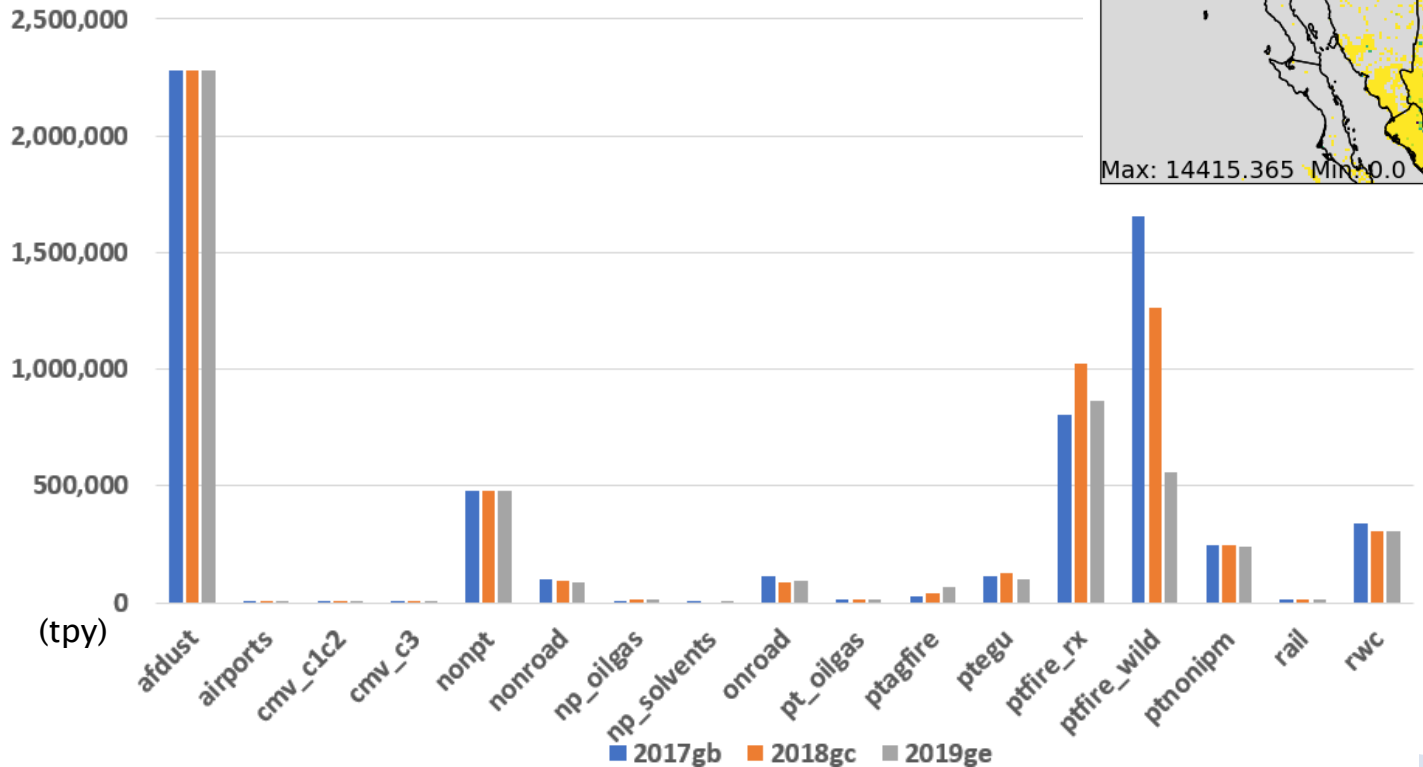


CMV emissions shown are in state waters only

Total $PM_{2.5}$

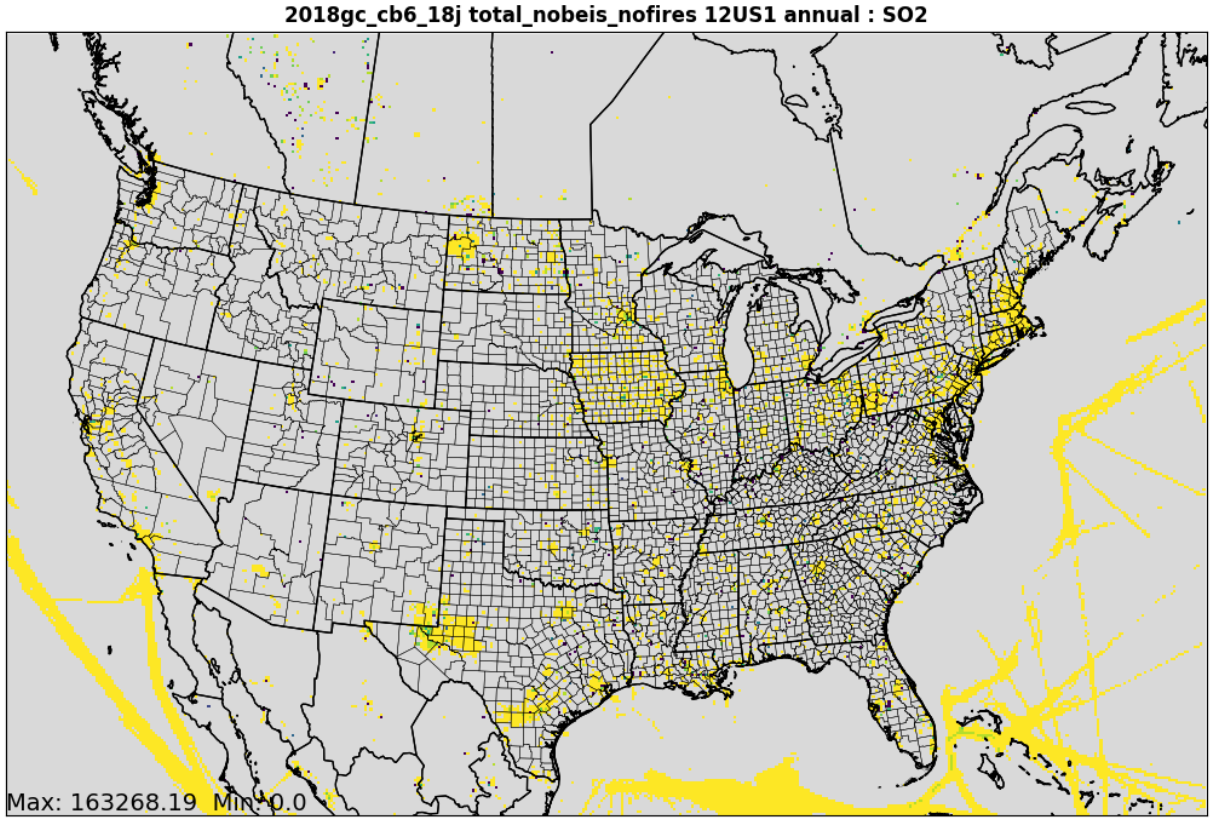
$PM_{2.5}$ emissions are primarily from wildland and prescribed fires (ptfire), fugitive dust (afdust), res. wood combustion (rwc), and other nonpoint (nonpt) sources. Fires were higher in 2017 than in 2018 or 2019.

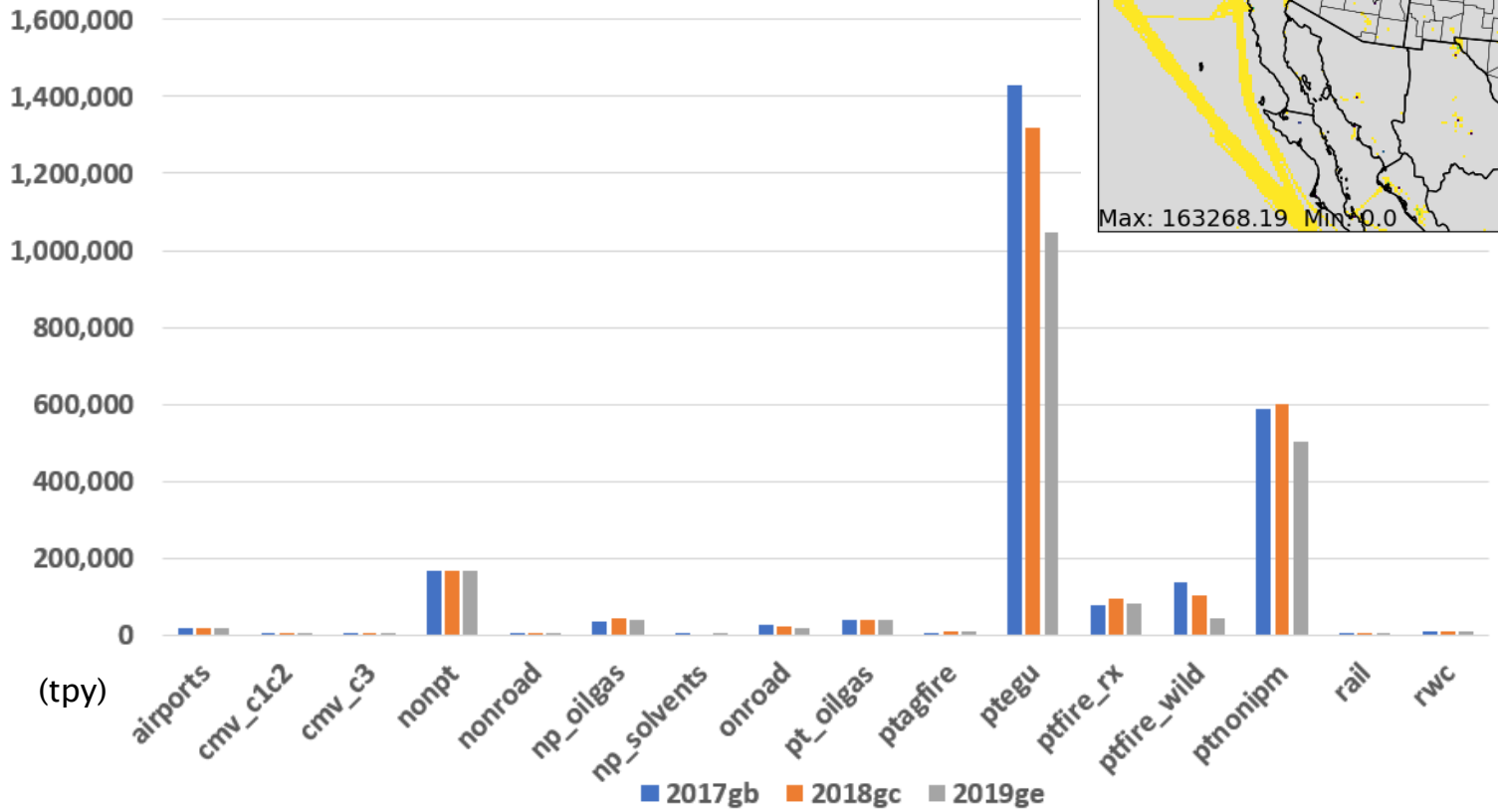




Total SO_2

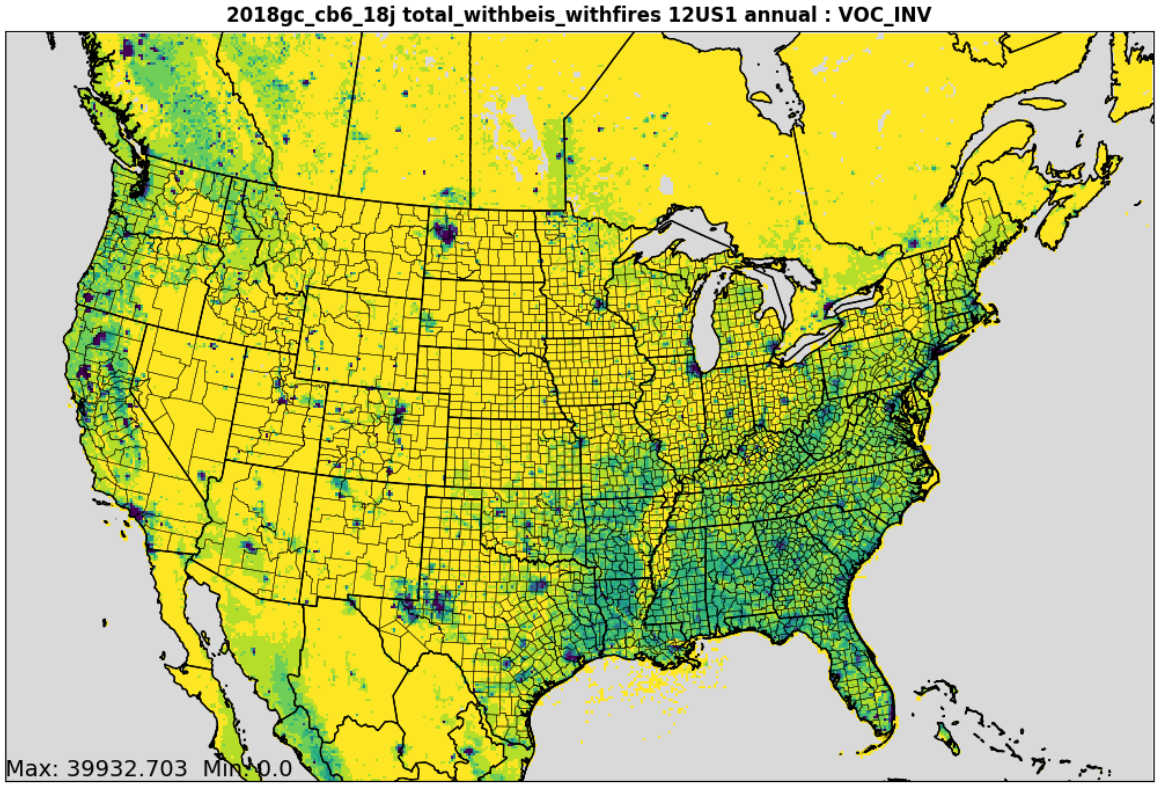
SO2 emissions are primarily from EGU and non-EGU point sources. The EGU and non-EGU SO2 reduced substantially from 2017 through 2019.

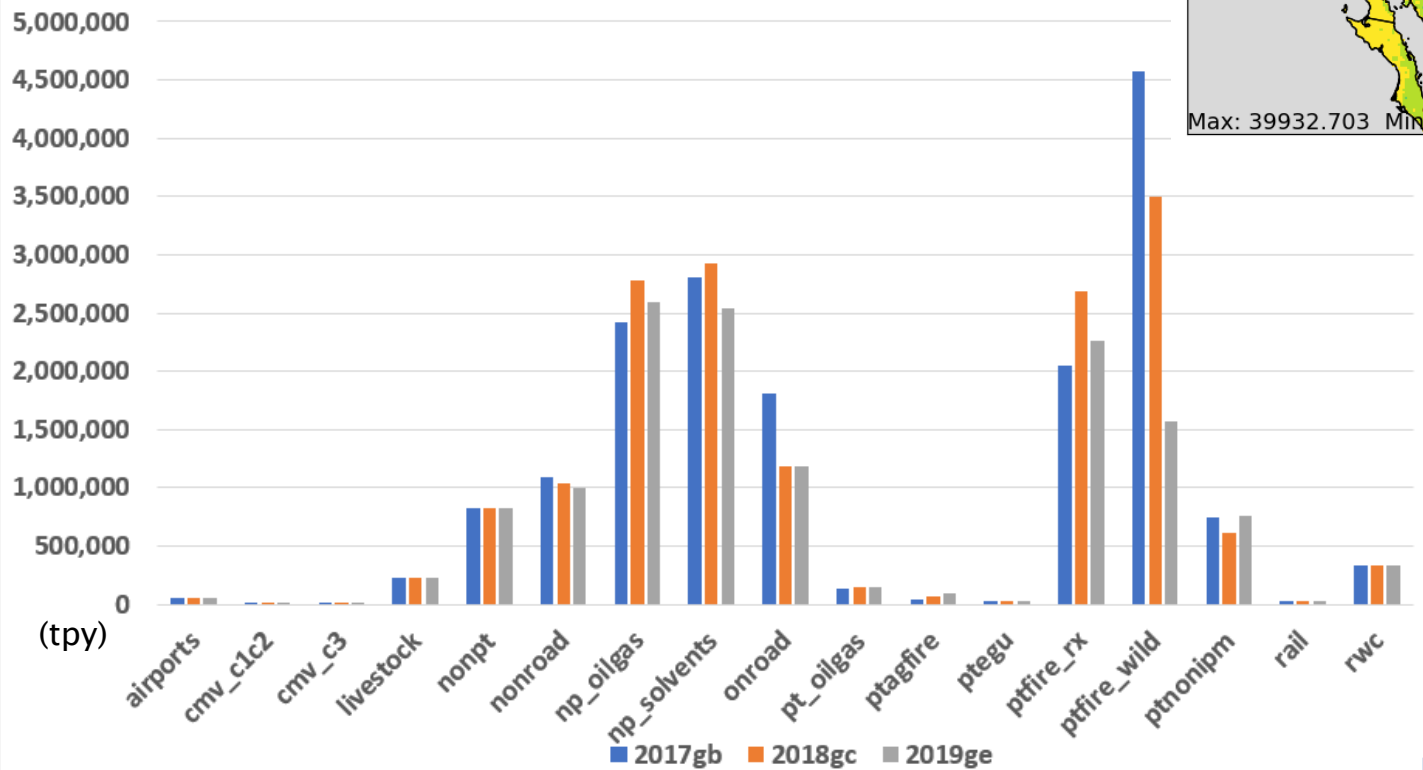




Total VOC

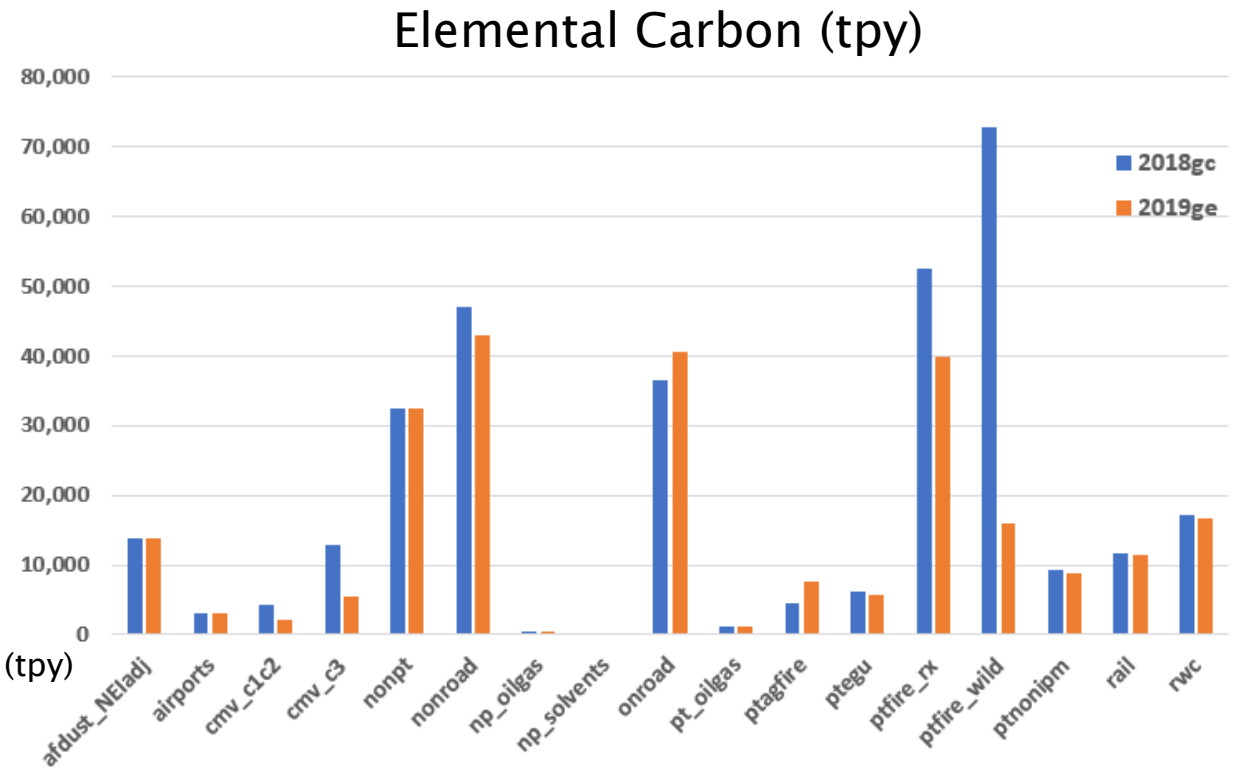
VOC emissions are primarily from biogenic (beis*), fires, solvents, oil and gas, onroad and nonroad sources.

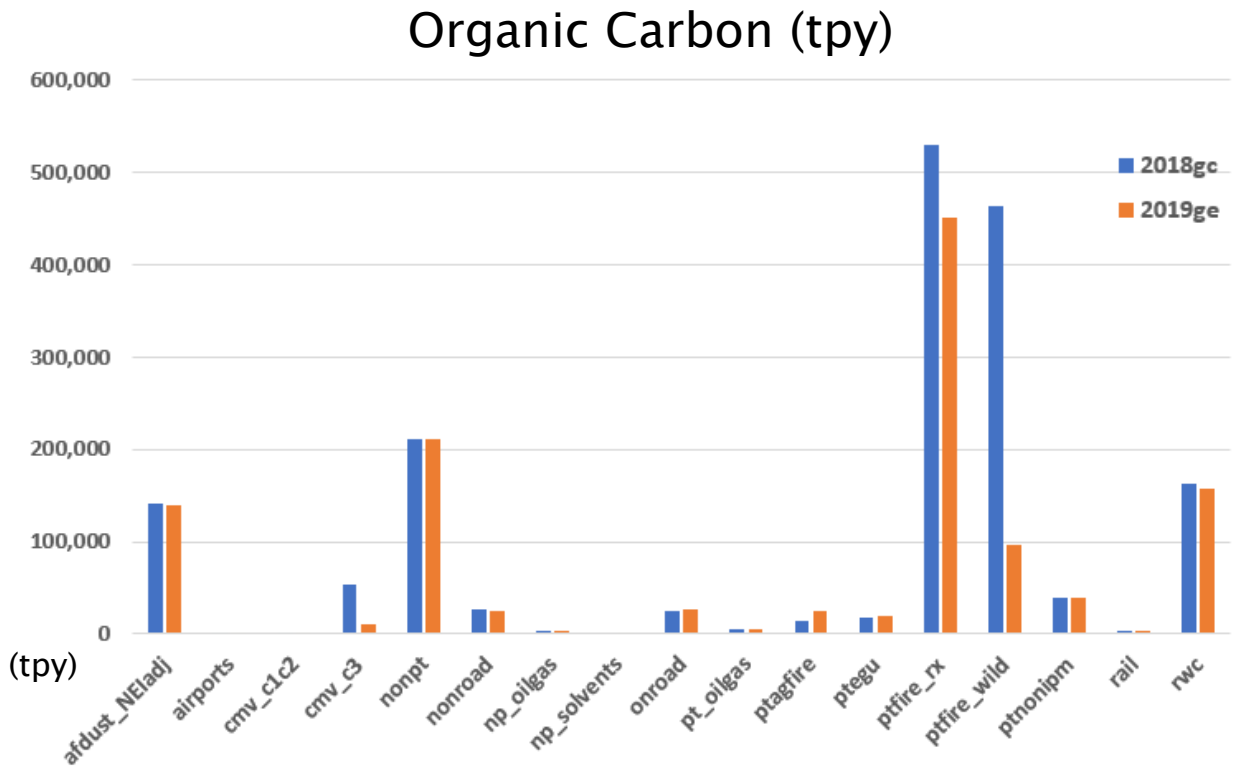




* beis contributes 25M tons of VOC

Elemental and Organic Carbon by Sector





Elemental (aka black) and organic carbon are important pollutants:
EC as a short-lived climate forcer and OC as a contributor to ambient PM.
They have different magnitudes in terms of their tons per year.
Fires, RWC, nonpt, and dust are important sectors for both, but the other key contributing sectors differ. EC includes larger contributions from diesel fueled mobile sources including onroad, nonroad, rail, airports and cmv sources

HAPs Included in Air Quality Modeling

- Some HAPs are included explicitly in gridded photochemical air quality modeling
  - naphthalene, benzene, acetaldehyde, formaldehyde, methanol, and HCl are part of Carbon bond 6 (CB6)
- Additional gaseous and particulate matter HAPs can be included in special multi-pollutant Community Multiscale Air Quality (CMAQ) model runs with an additional focus on toxics
  - Gaseous HAPs include
    - Acetonitrile
    - Acrolein
    - Acrylic acid
    - Acrylonitrile
    - Benzo[a]Pyrene
    - 1,3-Butadiene
    - Carbon tetrachloride
    - Carbonyl sulfide
    - Chloroform
    - Chloroprene
    - 1,4-Dichlorobenzene(p)
    - 1,3-Dichloropropene
    - Ethylbenzene
    - Ethylene dibromide (Dibromoethane)
    - Ethylene dichloride (1,2-Dichloroethane)
    - Ethylene oxide
    - Hexamethylene-1,6-diisocyanate
    - Hexane
    - Hydrazine
    - Maleic anhydride
    - Methyl chloride
    - Propylene dichloride (1,2-Dichloropropane)
    - Quinoline
    - Styrene
    - 1,1,2,2-Tetrachloroethane
    - Tetrachloroethylene (Perchloroethylene)
    - Toluene
    - 2,4-Toluene diisocyanate,
    - Trichloroethylene
    - Triethylamine
    - Xylenes
    - Vinyl chloride
  - Polycyclic aromatic hydrocarbons (PAH) can be modeled as grouped species with similar unit risk estimates
  - Particulate HAPs include forms of arsenic, beryllium, cadmium, chromium, lead, manganese, mercury, and nickel
- Dispersion models like AERMOD can model the CMAQ-supported HAPs plus:
  - Over 100 additional gaseous organic HAPs
  - antimony, cobalt, selenium, acid gases, calcium cyanamide, phosphine, phosphorus, titanium tetrachloride

Data Availability

- EPA's emissions modeling platforms are released on the Air Emissions Modeling website
  - https://www.epa.gov/air-emissions-modeling/emissions-modeling-platforms
  - Sidebar menu shows 2017-2019 Air Emissions Modeling Platforms
  - 2018 data for all sectors and a technical support document (TSD) are currently available
  - 2019 point source emissions and fire data are currently available
    - More data and documentation will be incrementally posted during 2022

For More Information on Emissions Modeling

- The technical support documents available for each platform discuss inventory development and emissions modeling steps
  - Introduction
  - Emission inventory development
  - Emissions modeling:
    - Chemical speciation, temporal allocation, spatial allocation
  - Emissions summaries
  - Future year inventory projection approaches (where relevant)
  - References
- Training materials on emissions modeling can be found here:
  - https://www.epa.gov/air-emissions-modeling/emissions-modeling-training
- For follow up questions contact emissionsmodeling@epa.gov