SMOKE-MOVES for MOVES3

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Purpose of SMOKE-MOVES

- SMOKE: Sparse Matrix Operator Kernel Emissions modeling system
  - Software used to process emission inventories into air quality model inputs
  - Outputs hourly gridded emissions for species and formats used by the air quality model
- SMOKE-MOVES: a set of programs in SMOKE used to create onroad emissions based on MOVES emission rates in a format suitable for air quality modeling
- The main inputs to SMOKE-MOVES are activity data, meteorological data, emission factors output from MOVES, and other ancillary data
  - Types of activity data: annual or monthly vehicle miles traveled (VMT), vehicle population (VPOP), vehicle starts, hours of combination long haul truck hoteling, hours of off-network idling
  - Meteorological data: is gridded, hourly data (particularly temperature) postprocessed from the Weather Research and Forecasting (WRF) model outputs
  - Other inputs: speed distribution data, emissions modeling "ancillary data" used to create hourly, gridded, speciated emissions

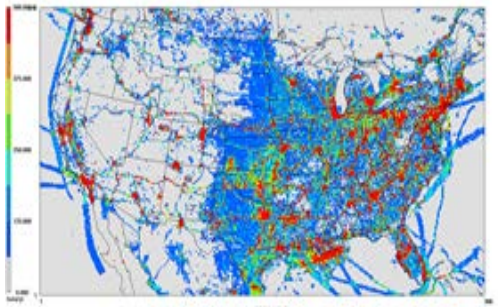
Emissions Modeling Platform

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)

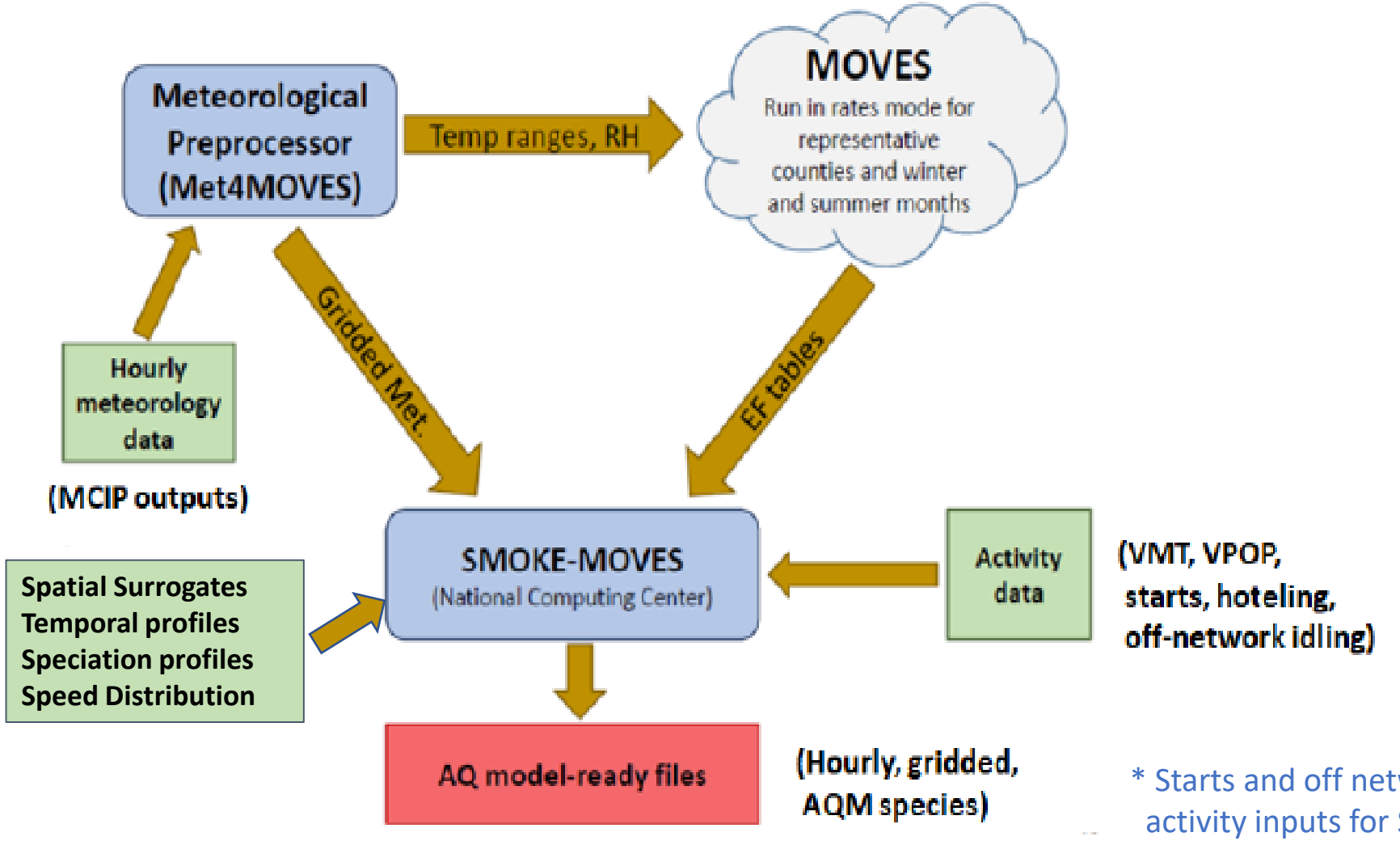
Ancillary Data

Speciation and Temporal Profiles, Spatial Surrogates, Satellite data, Shapefiles

Quality Assurance Logs and Summaries

* For base and future years

SMOKE-MOVES Processing Overview

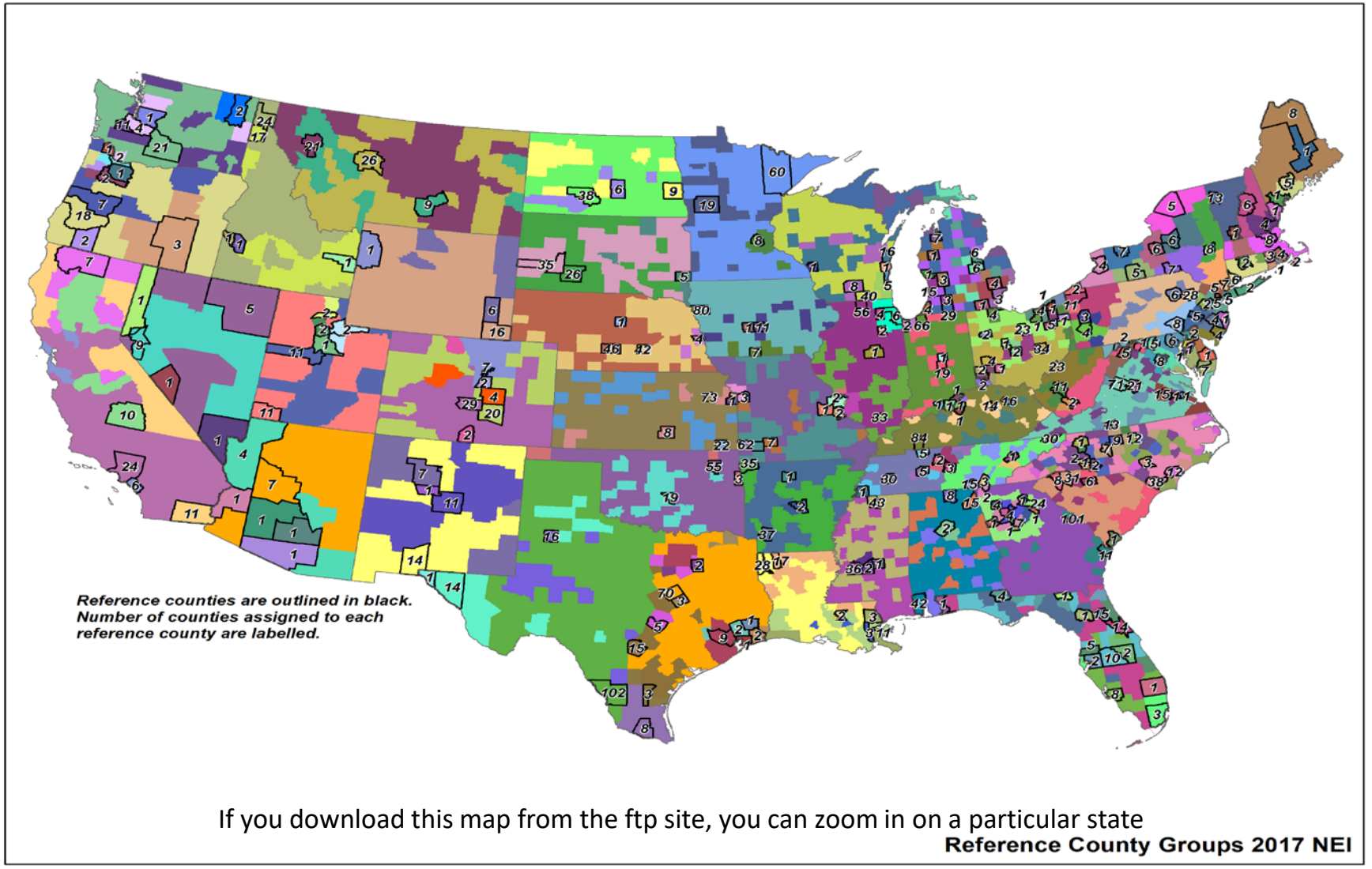


* Starts and off network idling are new activity inputs for SMOKE-MOVES3

Use of Representative Counties for MOVES rates mode runs

- MOVES (rates mode) is not run for every county but is run for "representative" counties where the same emission factors can be used for multiple counties with similar characteristics
- Representative counties are selected based on: state, altitude, fuel region, average light-duty vehicle age, and inspection and maintenance programs
  - Example for 2017 NEI: https://gaftp.epa.gov/air/emismod/2017/2017emissions/reports/onroad/2017_Representative_Counties_Analysis_20191216.xlsx
  - MOVES emission factors are generated for each representative county and for the range of temperatures in that county (and speeds for on-network processes)
  - There are usually about 300 representative counties selected for the continental U.S.
  - SMOKE-MOVES (Movesmrg) pairs emission factors for rep. counties with activity data for every specific county to compute the emissions
  - During the pairing process, temperature and speed are used to select the emission factors

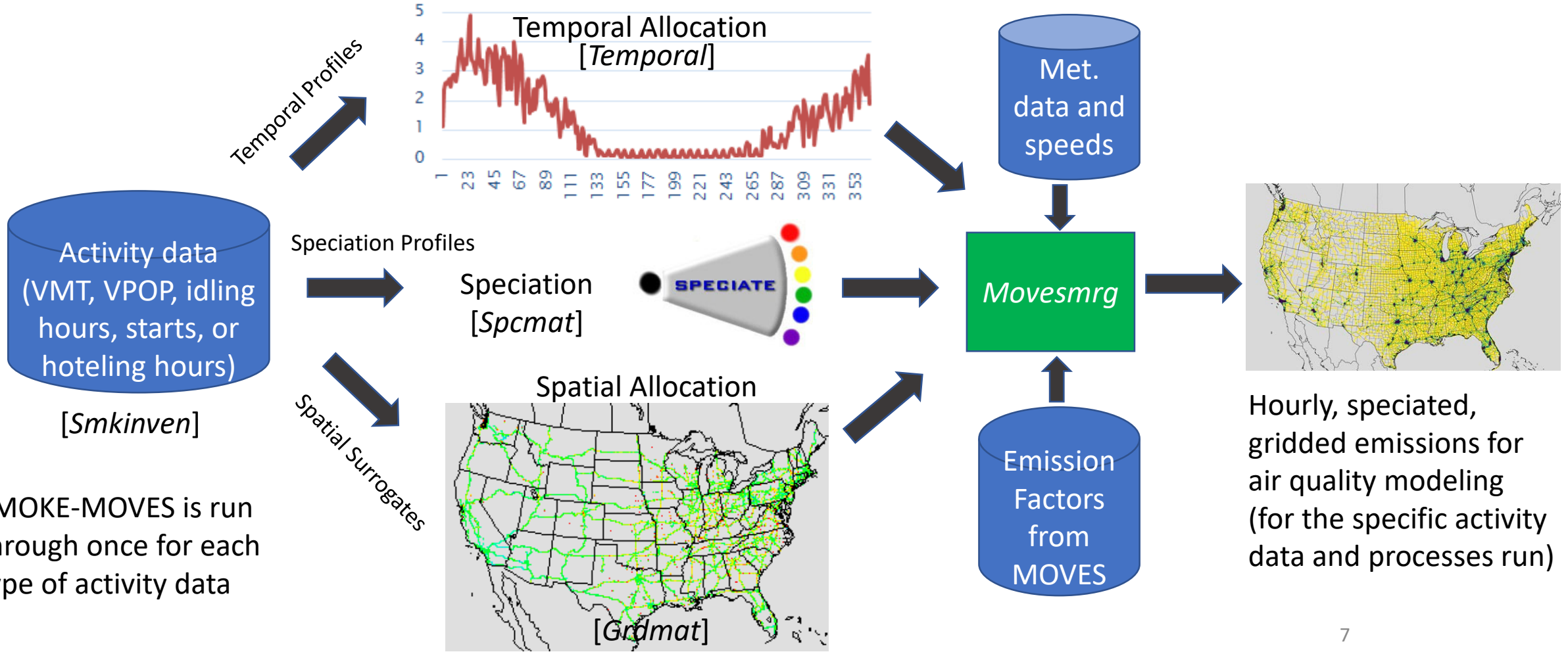
2017 NEI Representative Counties: 296 for CONUS + 38 for AK/HI/PR/VI



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

SMOKE-MOVES Emissions Modeling Steps

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



SMOKE-MOVES is run through once for each type of activity data

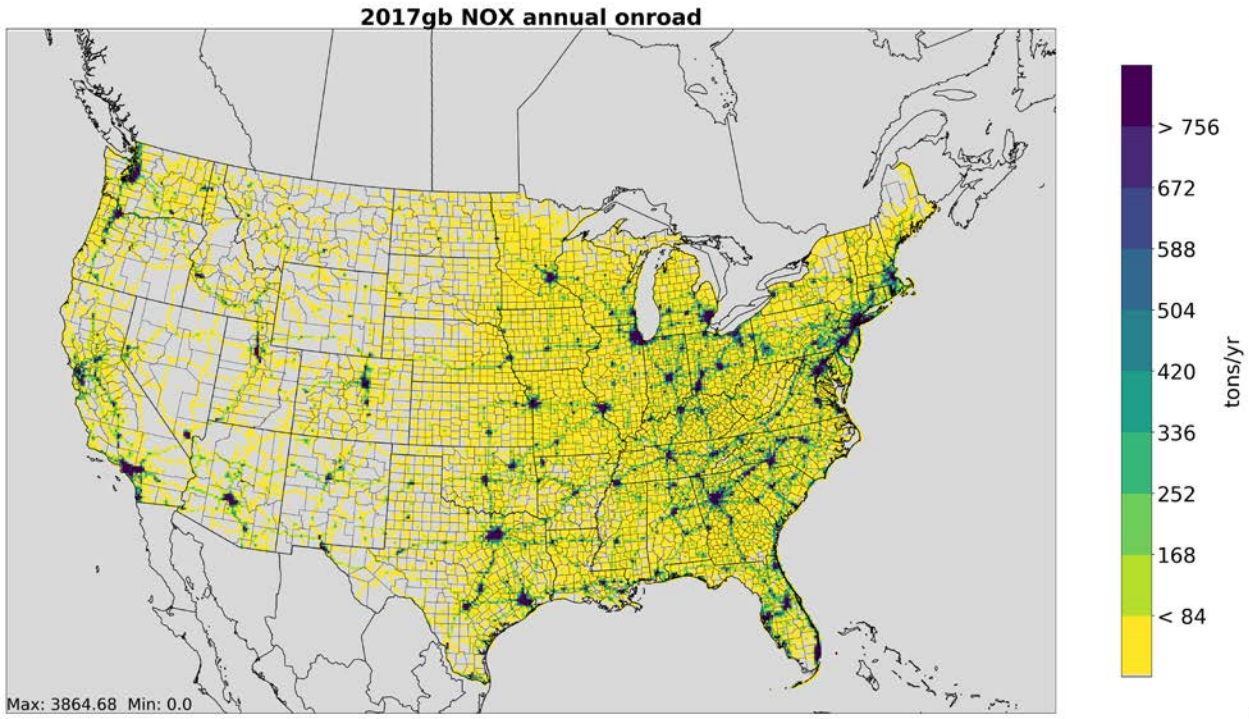
Hourly, speciated, gridded emissions for air quality modeling (for the specific activity data and processes run)

Key Sources of Onroad Data Inputs for 2017 NEI

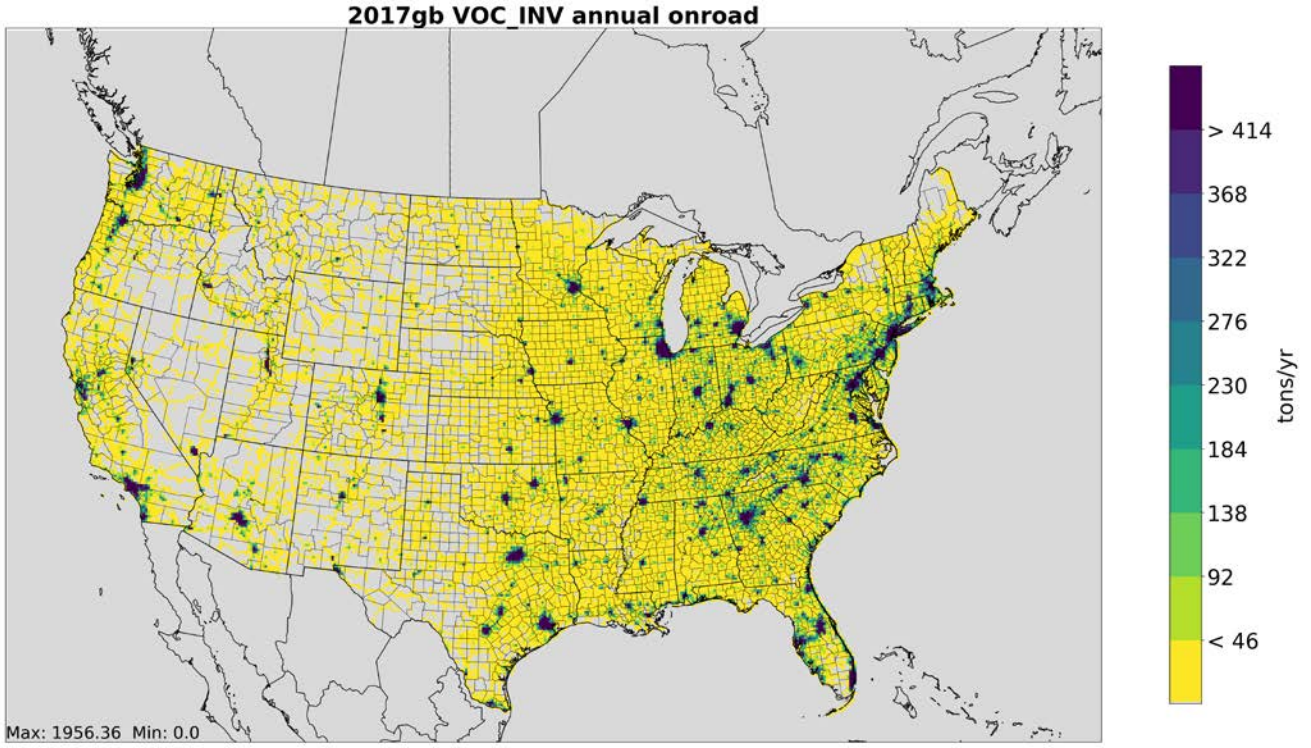
- State-submitted data (activity, speeds, temporal profiles)
- 2017 vehicle registration data from the Coordinating Research Council (CRC) A-115 project used where there is no acceptable submitted S/L/T data
  - Vehicle Population (POP), age distribution, and fuel fractions
- Vehicle speed and vehicle-miles traveled (VMT) temporal distributions from the CRC A-100 used where there is no acceptable S/L/T submitted
  - Based on vehicle telematics data
  - County-specific
  - SMOKE temporal profiles based on this

Gridded 2017 Onroad NOx and VOC Emissions

2017 NEI Onroad NOx



2017 NEI Onroad VOC



Interstates are more noticeable for NOx (on-roadway)

VOC is concentrated in high vehicle population areas (off-network)

Summary of Updates in MOVES3

- Key updates in MOVES3:
  - Incorporates the latest data on vehicle populations, travel activity, and emission rates as well as updated fuel supply information at the county level.
  - Modeling better accounts for long-haul truck hoteling, added activity for **vehicle starts**, and **off-network idling**.
  - Incorporates the impacts of the Heavy-Duty Greenhouse Gas Phase 2 rule and the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule.
  - Improves the user interface to make the model easier to use and updating the platform for compatibility with newer software.
- More information on MOVES3 is available from https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

Updates in MOVES3 that Impact SMOKE-MOVES

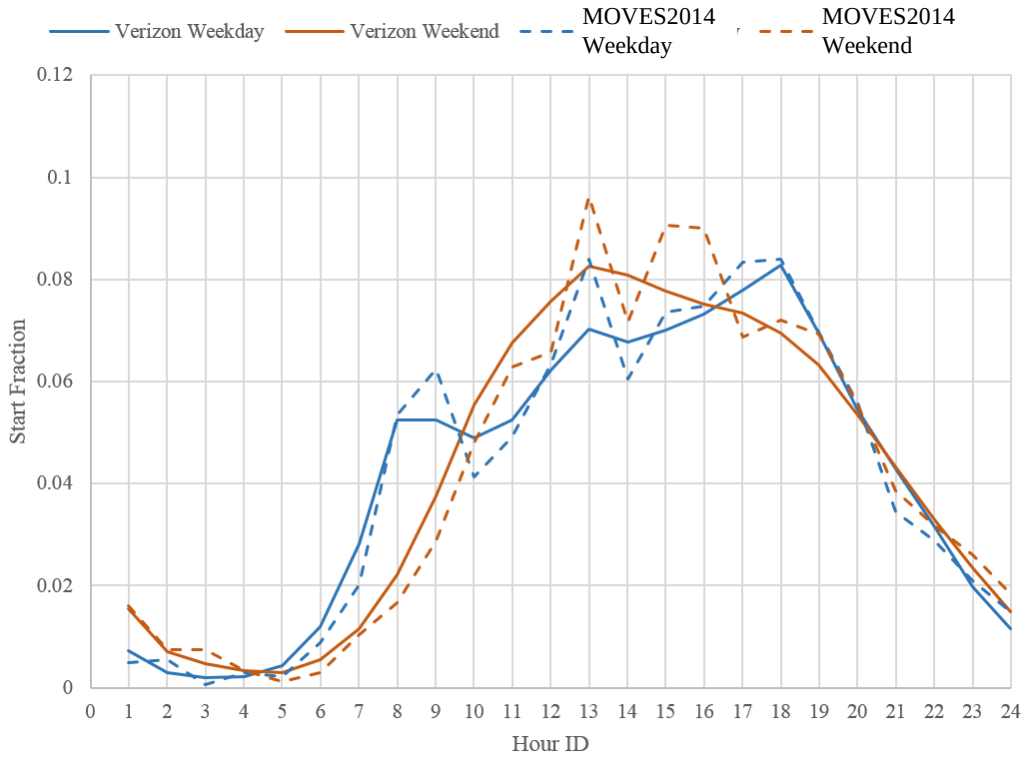
- Additional source type + fuel combinations are supported in MOVES3
  - Gasoline: other buses (41) [also 41 is now “other buses”, not just “intercity buses”]
  - CNG: other buses (41), school buses (43), refuse trucks (51), single unit short and long haul trucks (52/53), motor homes (54), combination short haul (61)
  - Electric: passenger cars (21), passenger trucks (31), light commercial trucks (32)
  - The new combinations resulted in new Source Classification Codes (SCCs) in the activity data used by SMOKE (e.g. VPOP, VMT)
  - **Existing 2017 NEI activity data had to be modified to add these new combinations**
  - This was done based on fuel type splits in MOVES3 by county+vehicle+year
- A new chemical speciation mechanism (CB6R3AE7) that better supports formation of secondary organic aerosols is available
  - To be used with future versions of CMAQ
- Activity data for starts and off-network idling (ONI) are needed
  - These also have new processing streams through SMOKE [5 total]

Start Activity Computation for SMOKE-MOVES

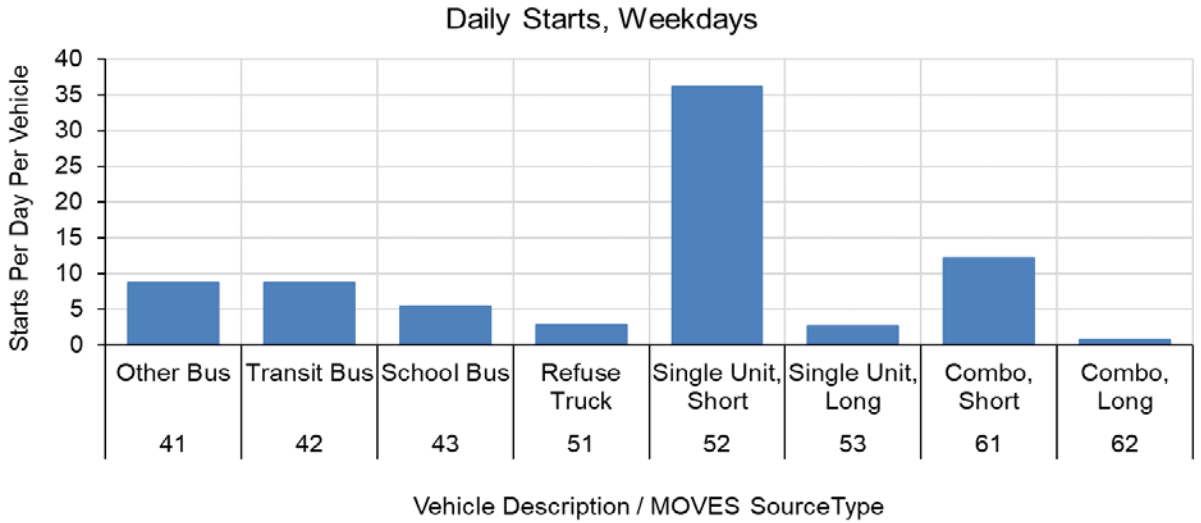
- Steps to calculate Starts Activity
  - By county, SCC, monthID into the STARTS flat file that is input to SMOKE
- Input Files:
  - Vehicle POP Flat file (FF10) – tabular file similar to a .csv file
    - Vehicle population by county, fuel type, and MOVES source type
  - StartsPerVehicleByMonth = startsperDayPerVehicle*allocationFraction*monthAdjustment
    - Supporting MOVES3 Default Start Input Files:
      - StartsPerDayPerVehicle (by source type and day type)
      - StartsMonthAdjust (by source type and month – like a monthly temporal profile)
      - StartsHourFraction gives diurnal temporal profile by source type and weekday/weekend
- Calculations for base year:
  - Starts (county, SCC[fuel, sourceTypeID], monthID) = POP (SCC [fuel, sourceTypeID], county) x StartsPerVehiclebyMonth (sourcetypeID, monthID)
- Other Years: grown proportionally based on Vehicle Population growth

Default Start Data: Instrumented Vehicle Studies

Light-duty Start Data: Verizon Telematics Data Collected from 5 US States



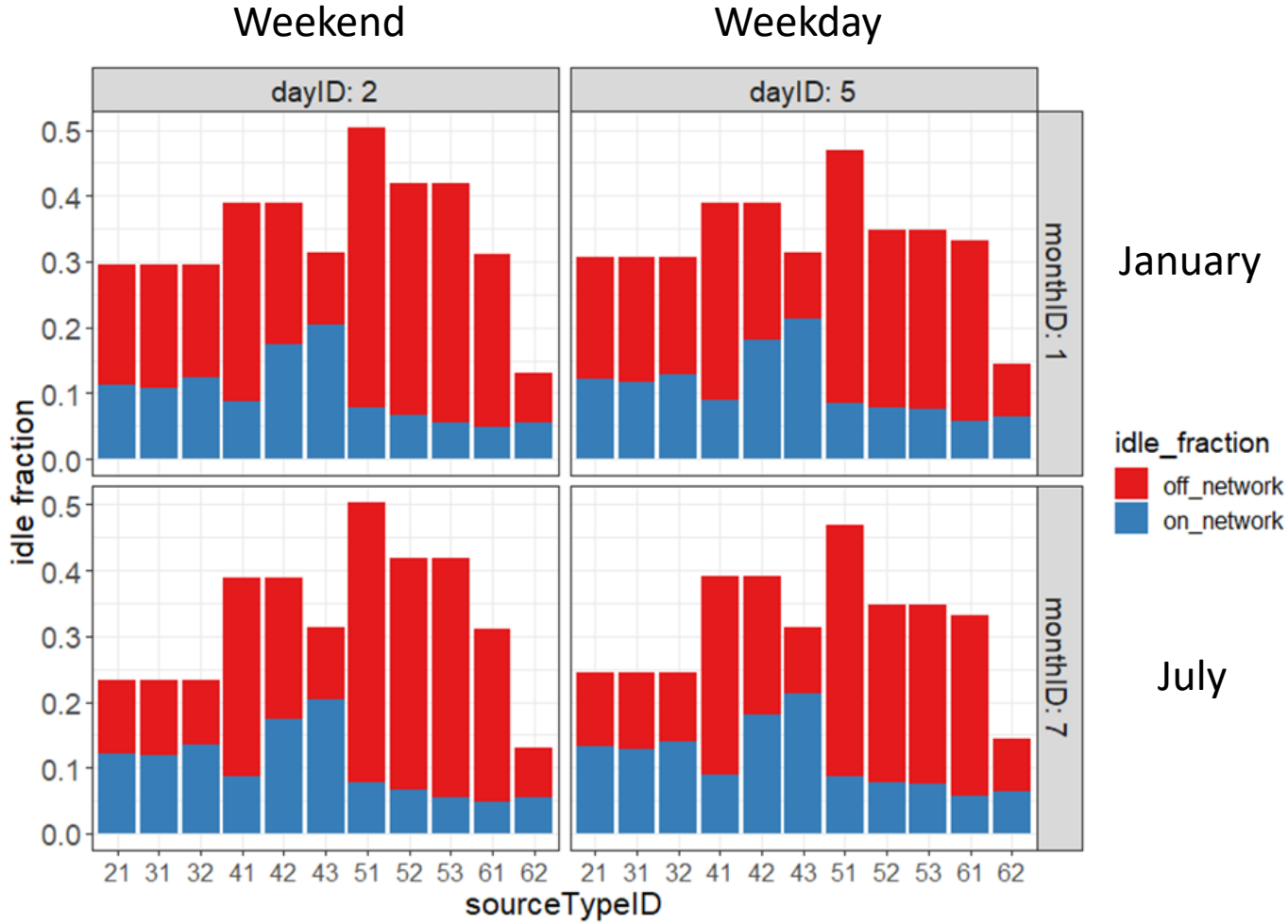
Heavy-Duty Start Data: Fleet DNA Collected by National Renewable Energy Laboratory



Additional Data in the MOVES3 Population and Activity Technical Report

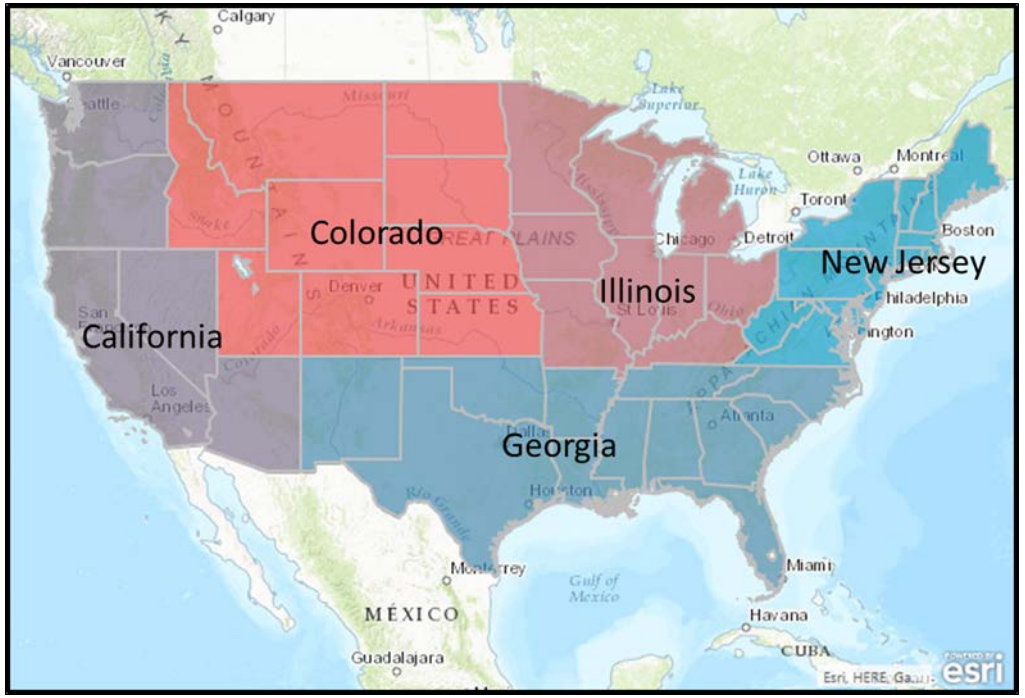
Off-Network Idling

- ***Total Idle = Off-network Idle + On-network Idle***
  - "Off-network idle" accounts for emissions beyond the idling that is already considered in the MOVES drive cycles;
  - Total Idling Fraction estimated from instrumented vehicle studies (Verizon + Fleet DNA)
- Off-network Idle activity are calculated during the MOVES run
  - Needed to be converted into the form needed for the SMOKE FF10 file



New MOVES Table: Total Idling Fraction

- Default total idling fraction in MOVES is a function of:
  - Source Type
  - Day Type
    - Weekend or Weekday
  - Month
  - Urban or Rural County
  - Idle Region
    - 5 Regions shown in map



Estimating Off-Network Activity for SMOKE-MOVES

- Off-Network Idling Fraction
  - ONI_Fraction = ONI Hours/Source Hours Operating (SHO)
- ONI and SHO estimated from 10 separate MOVES runs
  - 1 Urban and 1 Rural County for each Region
    - 2 X 5 = 10
  - Updated the road type distribution to represent the VMT road distribution from all the urban or rural counties within an idle region
- ONI Fraction calculated ONI_Fraction by
  - Idle Region
  - County Type
  - Source Type
  - Month
- Example output shown in table

Idle Region ID	county TypeI D	st	Jan_ONI fraction	Feb_ONI fraction	Mar_ONI fraction		Dec_ONI fraction	Annual_ONI fraction
101	0	11	0	0	0		0	0
101	0	21	0.245877	0.223726	0.184467		0.181425	0.179785
101	0	31	0.255039	0.232684	0.193071		0.190001	0.188328
101	0	32	0.236321	0.214301	0.175279		0.172256	0.170611
101	0	41	0.550102	0.550103	0.550103		0.550103	0.550103
101	0	42	0.440004	0.440004	0.440003		0.440004	0.440004
101	0	43	0.283901	0.283901	0.283901		0.283902	0.283901
101	0	51	0.827406	0.827405	0.827407		0.827406	0.827406
101	0	52	0.549491	0.549492	0.549492		0.549491	0.549492
101	0	53	0.547255	0.547255	0.547256		0.547256	0.547255
101	0	54	0	0	0		0	0

Estimating Off-Network Activity for SMOKE-MOVES

- Steps to calculate ONI hours
  - By county, SCC, monthID, ONI FF10 table
- Starting Files:
  - Vehicle Source Hours Operating (SHO) FF10
    - Vehicle on-network source hours operating
    - Calculated from VMT and average speed file from the CRC A100 project
  - ONI Fraction Table (Previous slide)
- Calculations for Base year:

$$ONI_{county,s,m} = ONI\ fraction_{i,c,s,m} \times SHO_{county,s,r,m}$$

Where: ONI fraction is from the idleRegionID (i), and countytypeID (c), corresponding to the county.

- Values for other years are grown proportionally to VMT growth

SMOKE-MOVES3 Package based on EQUATES

- An example package for using SMOKE-MOVES3 is available based on the EPA's air Quality Time Series project (EQUATES)
  - Running emissions, met, and CMAQ for years 2002-2017
- MOVES3 was run for each NEI year: 2002, 2005, 2008, 2011, 2014, 2017
- SMOKE-MOVES run for every year with year-specific met. data
  - Representative counties are similar to 2016v1 and 2017 with some added (328 total)
  - Interim years incorporate adjustment factors from the nearest NEI year
- See ftp://newftp.epa.gov/Air/emismod/MOVES3/ (or see https://gaftp.epa.gov/Air/emismod/MOVES3)
  - Package includes all SMOKE-MOVES inputs for 2017 including EF tables and scripts
  - Also includes the MOVES input county databases (CDBs) for representative counties for all of the NEI years, the LEV database, and the CDB table that needs to be used to prevent NOx adjustments from being included into the emission factors by MOVES

Special Methods for EQUATES

- SMOKE processing streams (activity data):
  Rate per distance (VMT), Rate per hour (hoteling hours),
  Rate per profile (VPOP), Rate per Vehicle (VPOP), Rate per Start (starts per month), Rate per hour ONI (off-network idling hours)
  - Note that some processes previously part of RPV (MOVES2014b) are now in RPS
  - Diesel and gas (i.e. non-diesel) were run as separate processing streams for all but RPV and RPP to support ORD needs related to secondary organic aerosols and CMAQ *[Note: SMOKE 4.8.1 can output both sectors from a single run]*
  - California is run separate to match their total EMFAC emissions
- Time (minutes) required per stream for 7 day run on EPA system:

	RPD	RPH	RPHO	RPP	RPS	RPV
US gas	350	n/a	55	17	80	45
US diesel	205	45	45	n/a	70	n/a
CA gas	41	n/a	5	2	5	5
CA diesel	19	4	5	n/a	4	n/a

Helpful Links and Contact Information

National Emissions Inventory:
https://www.epa.gov/air-emissions-inventories

National Emissions Modeling Platforms:
https://www.epa.gov/air-emissions-modeling

SMOKE (distributed by the CMAS Center):
https://www.cmascenter.org/smoke/

If you have questions about SMOKE-MOVES, contact Alison Eyth (eyth.alison@epa.gov)