Quantifying Emission and Air Quality Impacts of New MOVES3 in 2016v2 Platform by SMOKE-MOVES and CMAQ Modeling -- Part One

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MDE Weekly Modeling and Data Analysis Coordination Call
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Emission and MOVES Versions (in Chronological Order)

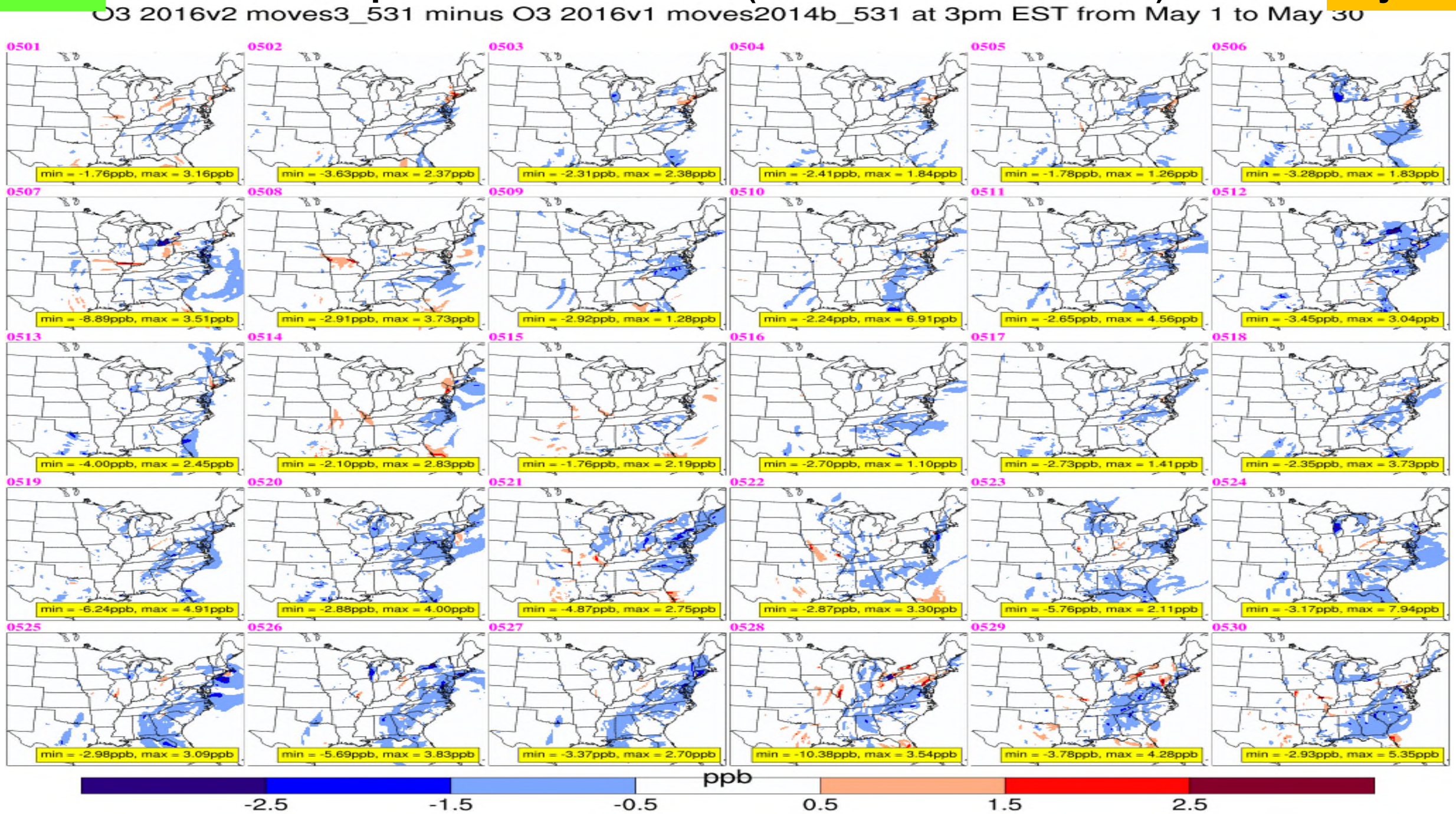
- 2015 -- 2016: 2014NEI in development
- 2018 -- 2019: non-NEI 2016 platform began (beta version)
- 2018 August: MOVES2014b released (a minor update to MOVES2014a)
- 2018 -- 2019: 2017NEI in development
- 2020: 2016v1 continued, 2016v2 in development
- 2020 November: MOVES3 released (a major update to MOVES2014b)
- 2021 March: MOVES3.0.1 (a patch to MOVES3)
- 2021 September: MOVES3.0.2 (another patch)
- 2021 -- 2022: 2020NEI in development
- 2022 January: MOVES3.0.3 (yet another patch)

Major difference between 2016v1 and 2016v2 is MOVES version (from MOVES2014b to MOVES3

preview

O3 Impact of New MOVES Model (MOVES3 minus MOVES2014b)

May 2016



Outlines of Talk

(1) SMOKE-MOVES
(2) Onroad Inventory Review
(3) CMAQ

-- MOVES3 in 2016v2 versus MOVES2014b in 2016v1
-- BY 2016 versus FY 2023/2026

SMOKE-MOVES

- SMOKE-MOVES, not MOVES, is the tool used by EPA to process onroad mobile source emissions for National Emission Inventory (NEI) and photochemical modeling for policy making
- Resolution for SMOKE-MOVES is representative county spatially and two (ozone season and non-ozone season) fuel months temporally
- SMOKE-MOVES is a complicated modeling framework consisting of a suite of pre-processing (for MOVES), MOVES, post-processing (for SMOKE), and SMOKE
- Extensive and excessive computation is involved in the process
- Currently only EPA's contractors know how to run SMOKE-MOVES correctly
- No states have ever done SMOKE-MOVES
- Modeling inputs and outputs are all generated by EPA's contractors
- Available data posted by EPA represents only SMOKE portion of SMOKE-MOVES
- MOVES portion of SMOKE-MOVES is unknown (a black box)
- Massive amount of data have been generated but left unanalyzed over the years
- Control measures or strategies involving mobile sources by RPO/MJO therefore resort to "across-the-board" cut

MOVES Decoder

SCC Code: AAFFVVRRPP

AA: Mobile Source (22)
FF: MOVES Fuel Types
VV: MOVES VPOP Source Types
RR: MOVES Road Types (excluding ramps)
PP: MOVES Emission Processes

5 HPMS "observation-based" vehicle types

MOVES2014 VMT Types

HPMStypeID	Classifications
10	Motorcycles
25	Light Duty Vehicles
40	Buses
50	Single Unit Trucks
60	Combination Trucks

HPMS 25, adopted in MOVES2014, is an aggregation of the HPMS 20 and HPMS 30 classifications in MOVES2010b

MOVES2014 VPOP Types

ID	Sourcetypename
11	Motorcycle
21	Passenger Car
31	Passenger Truck
32	Light Commercial Truck
41	Intercity Bus
42	Transit Bus
43	School Bus
51	Refuse Truck
52	Single Unit Short-haul Truck
53	Single Unit Long-haul Truck
54	Motor Home
61	Combination Short-haul Truck
62	Combination Long-haul Truck

13 MOVES vehicle types

MOVES2014 Road Types

roadTypeID	roadDesc
1	Off-Network
2	Rural Restricted Access
3	Rural Unrestricted Access
4	Urban Restricted Access
5	Urban Unrestricted Access

Ramps are not included

MOVES2014 Fuel Types

fuelTypeID	Fuel Type Description
1	Gasoline
2	Diesel Fuel
3	Compressed Natural Gas (CNG)
4	Liquefied Petroleum Gas (LPG)
5	Ethanol (E85)
9	Electricity

SMOKE-MOVES Sectors

Sector	Emission Factor Table	Activity	Fuels	Temporalization	Run Time (per day)
RPD	rateperdistance	VMT, speed	1,2,3,5,9	yes	2.5 hours
RPS	rateperstart	STARTS	1,2,3,5	yes	25 minutes
RPV	ratepervehicle	VPOP	1,2,3,5	no	8 minutes
RPP	rateperprofile	VPOP	1,2,3,5	no	15 minutes
RPH	rateperhour	HOTELING	2	yes	1 minute
RPHO	rateperhouroni	ONI_IDLING	1,2,3,5	yes	4 minutes

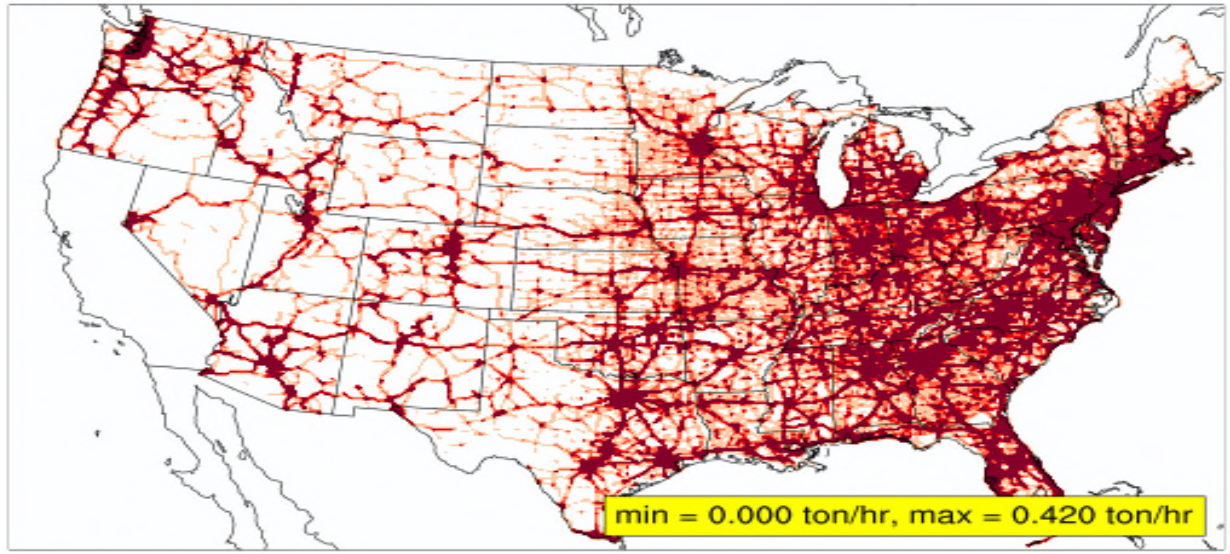
- There are six onroad sectors in 2016v2, an increase by two from four sectors in 2016v1
- For this study, three SMOKE-MOVES runs (2016v1, 2016v2, 2016v2-based 2023) were conducted in-house for five months (May to September). 2016v1-based 2023 run were obtained from NYSDEC
- Total onroad emissions are summed over six sectors
- Temporalization marked with yes means (SCC-specific?) temporal profiles are used in SMOKE
- HOTELING (RPH) is restricted to diesel combination long-haul truck (62) only
- RPV and RPP emit no NOx
- Run time is the time for completing one episodic day on 12US2 domain by SMOKE (4.8.1). It does not include the time for conducting MOVES portion of SMOKE-MOVES

Annual RPD run in serial = (2.5 * 365) / 24 = 38 days

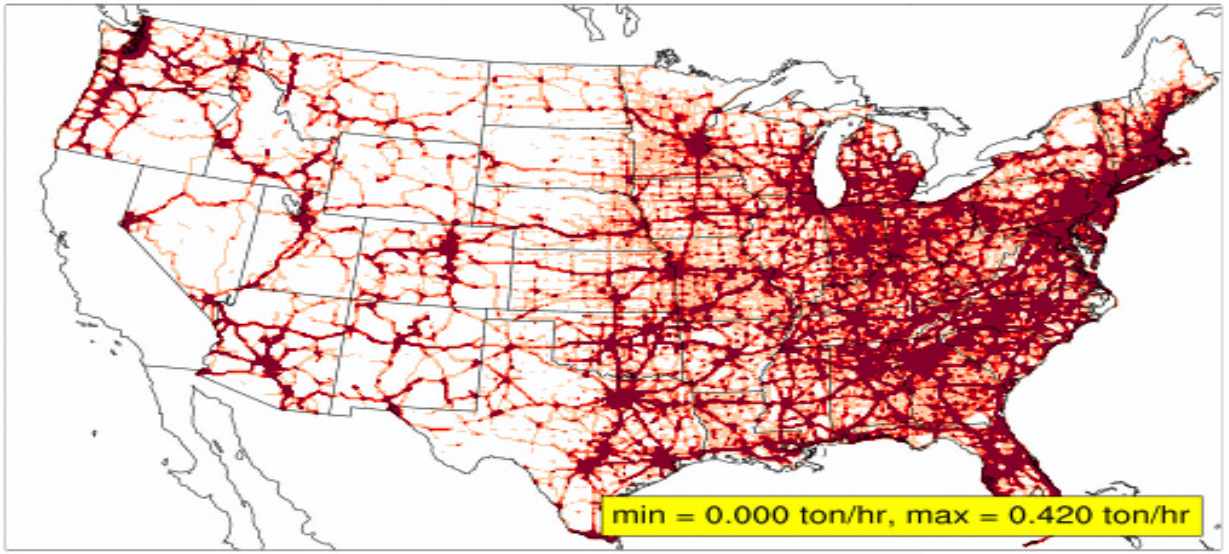
Comparison between In-House Modeling and EPA Modeling

NOx for Onroad (Non-Diesel) Gas at 3pm EST July 22, 2016

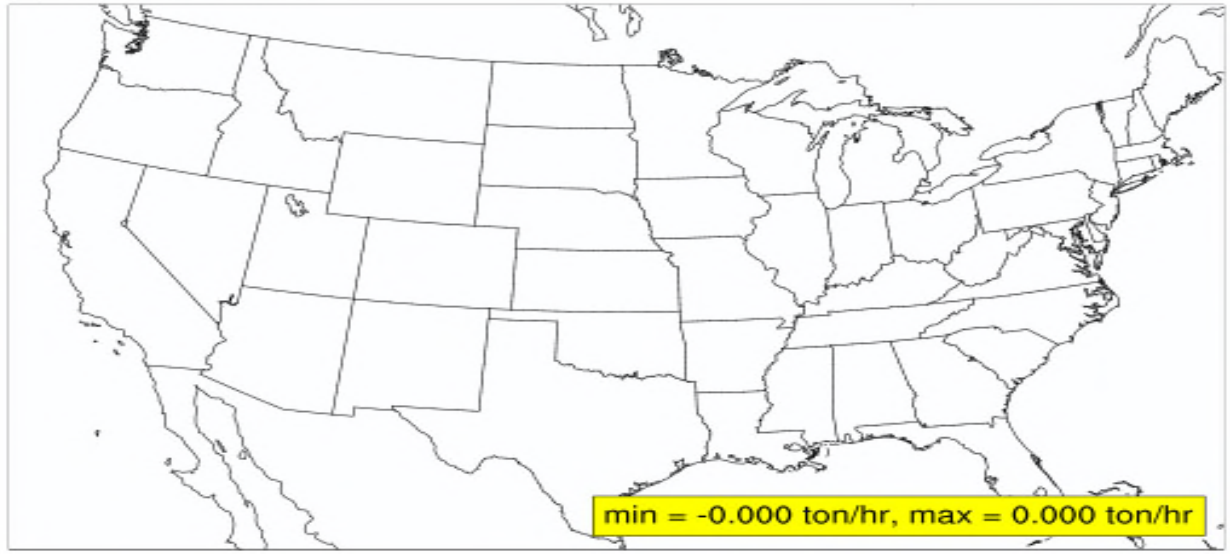
(a) VADEQ (summed over six subsectors)



(b) EPA (aggregated outputs)



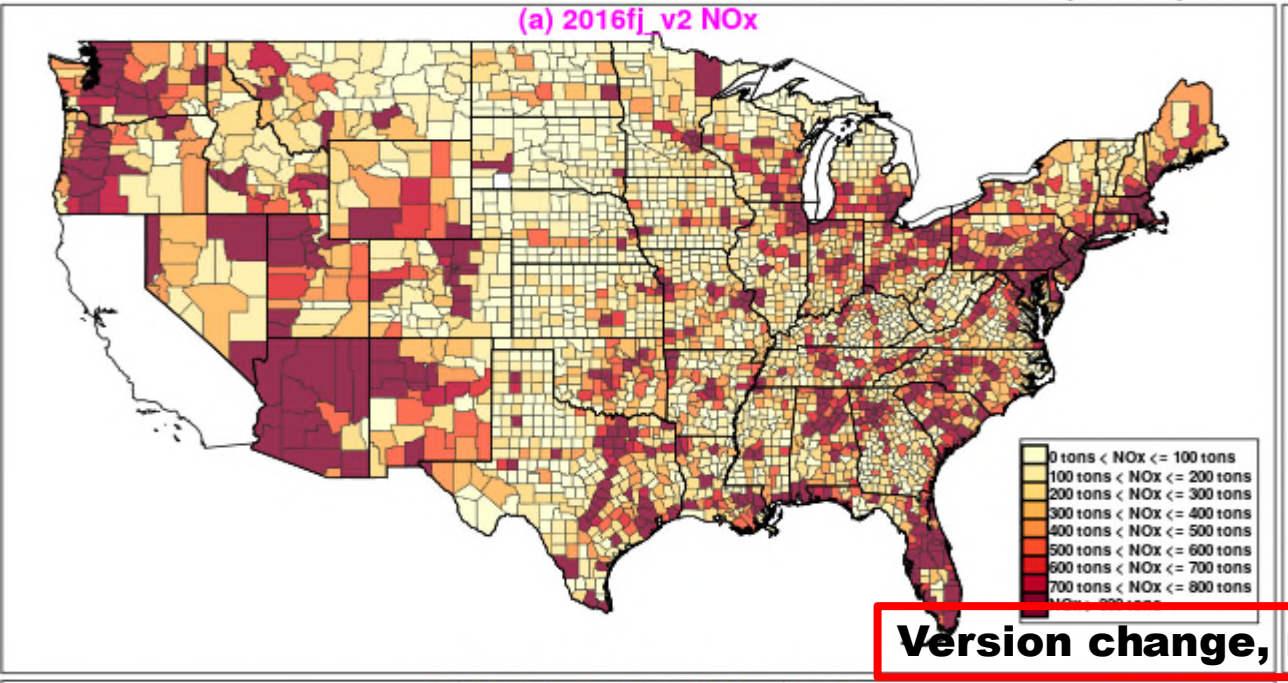
(c) VADEQ minus EPA

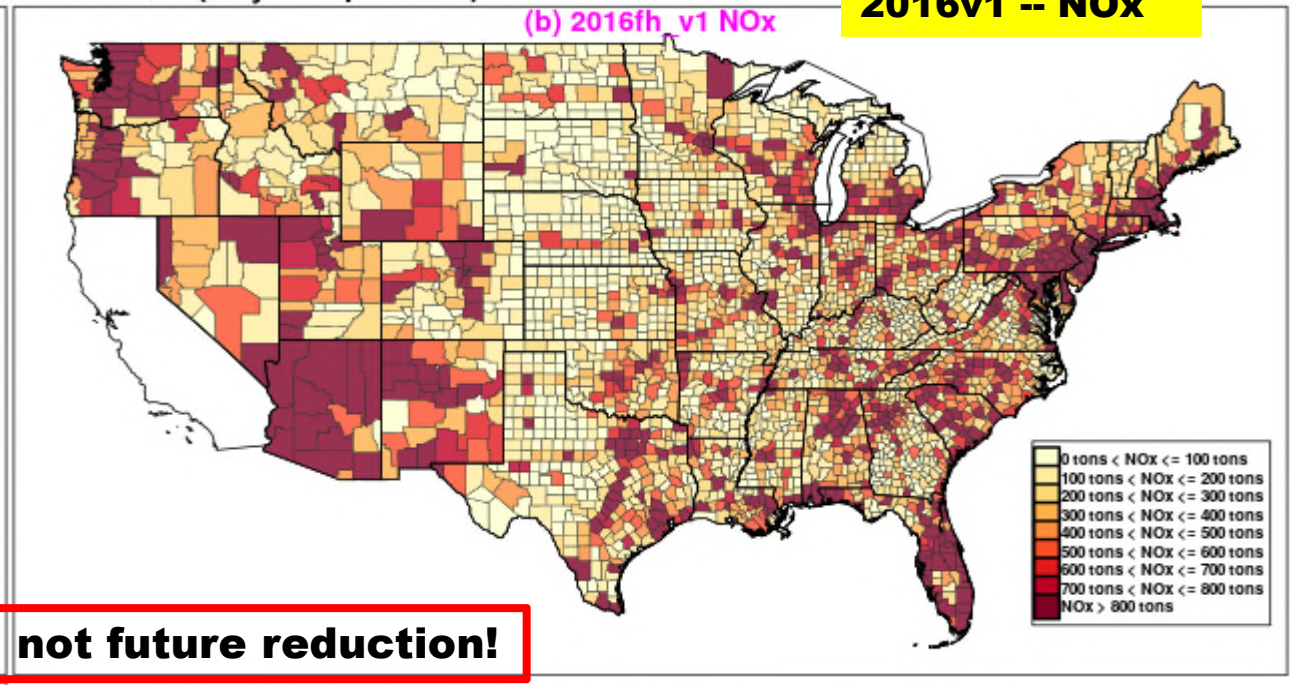


-- VADEQ NOx were aggregated from six sectors;
-- EPA NOx were extracted from already merged (or aggregated) outputs provided by Alison Eyth of OAQPS;
-- Panel (c) indicates no differences between modeling by DEQ and by EPA

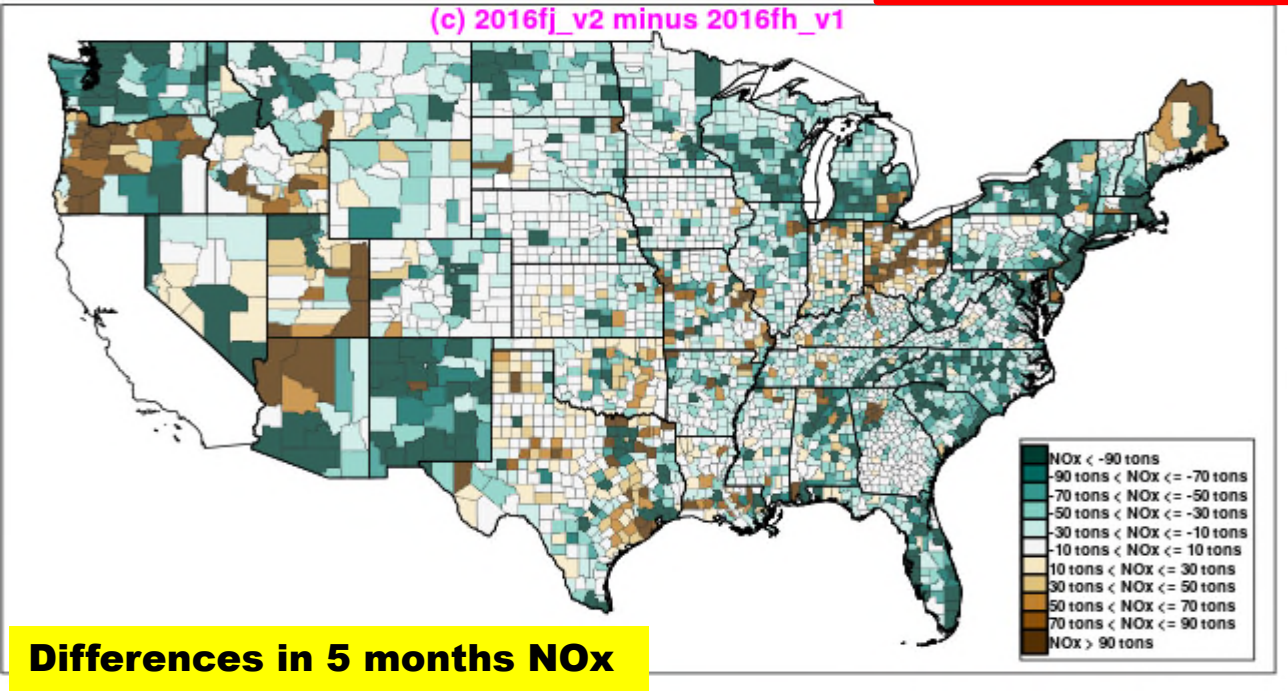
2016v2 versus 2016v1 -- NOx

NOx Differences (in tons) over Five Months (May -- September)

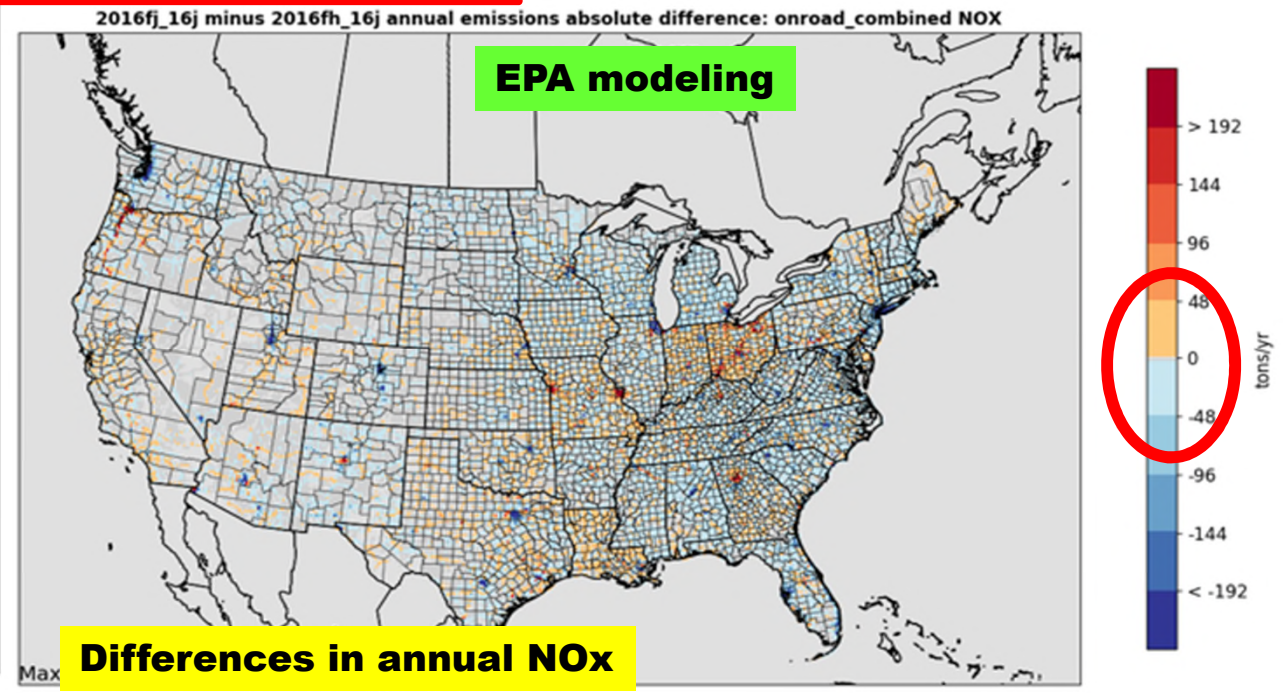




Version change, not future reduction!



Differences in 5 months NOx

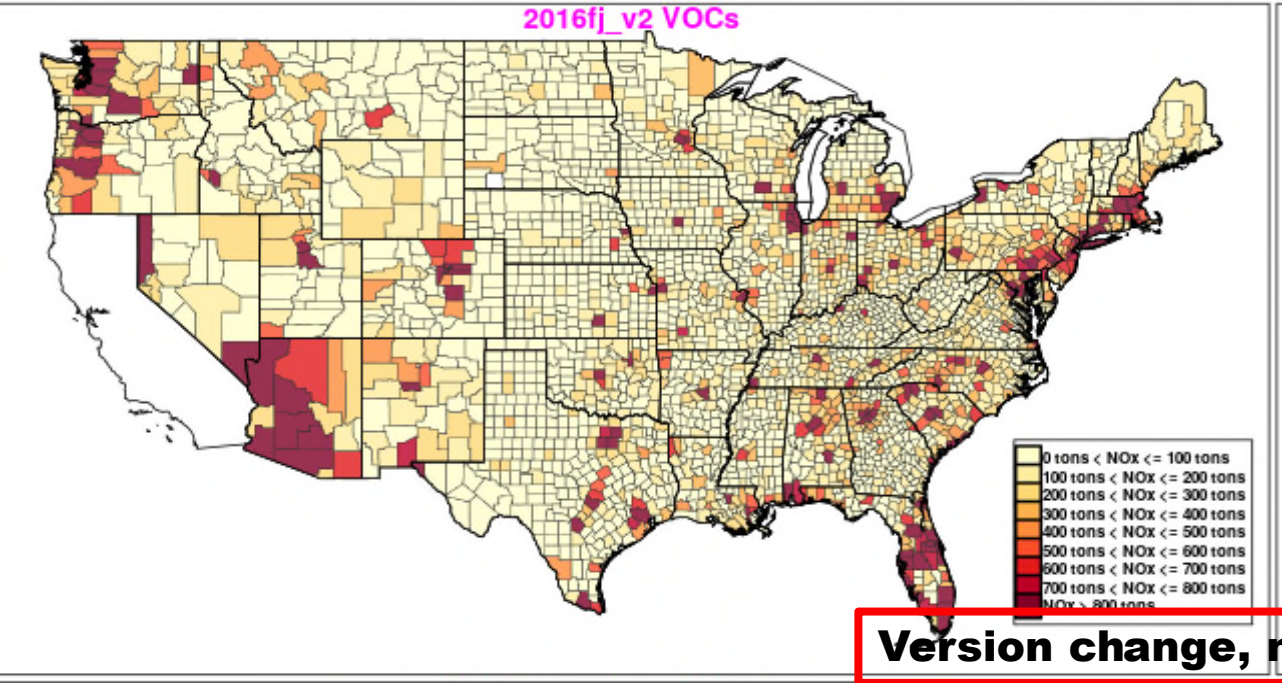


Differences in annual NOx

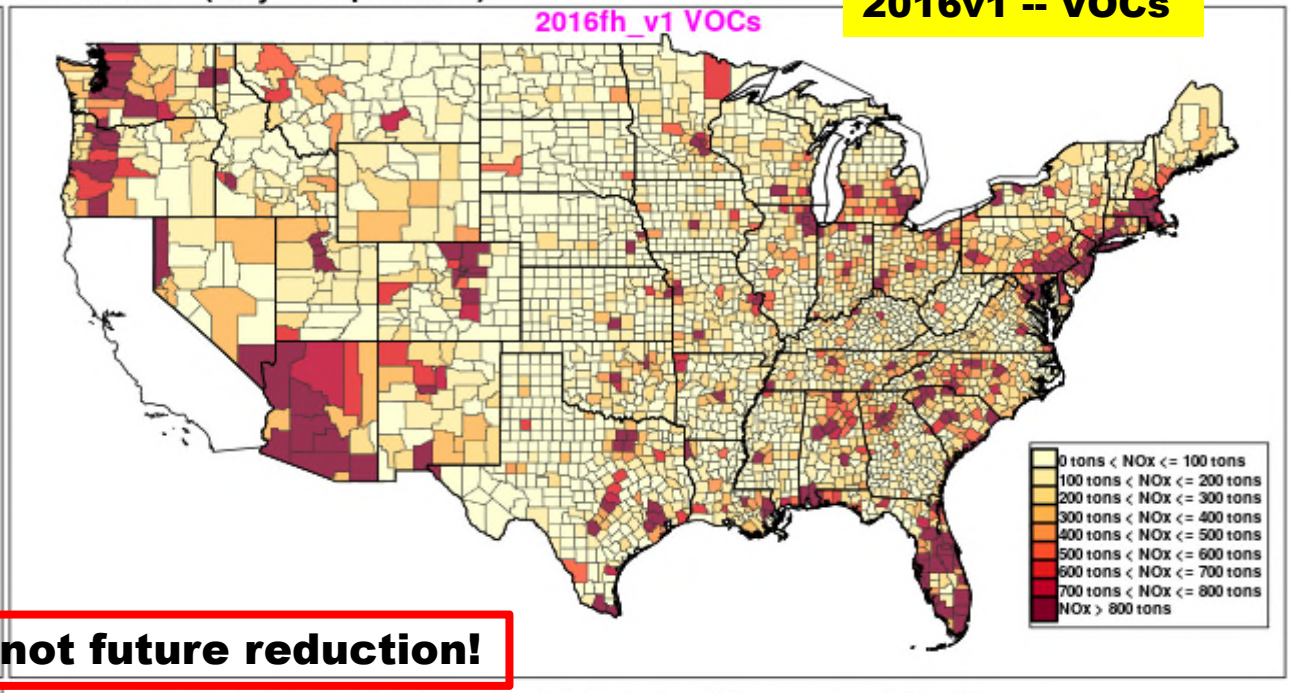
2016v2 versus 2016v1 -- VOCs

VOCs Differences (in tons) over Five Months (May -- September)

2016fj_v2 VOCs

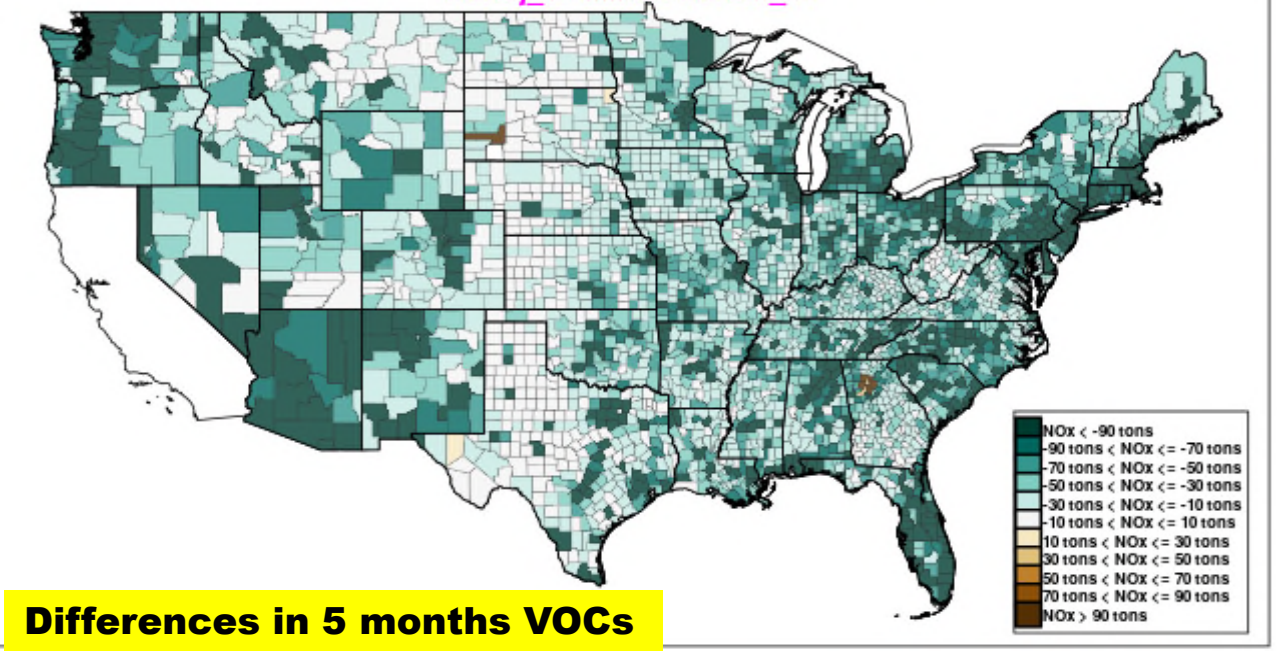


2016fh_v1 VOCs



Version change, not future reduction!

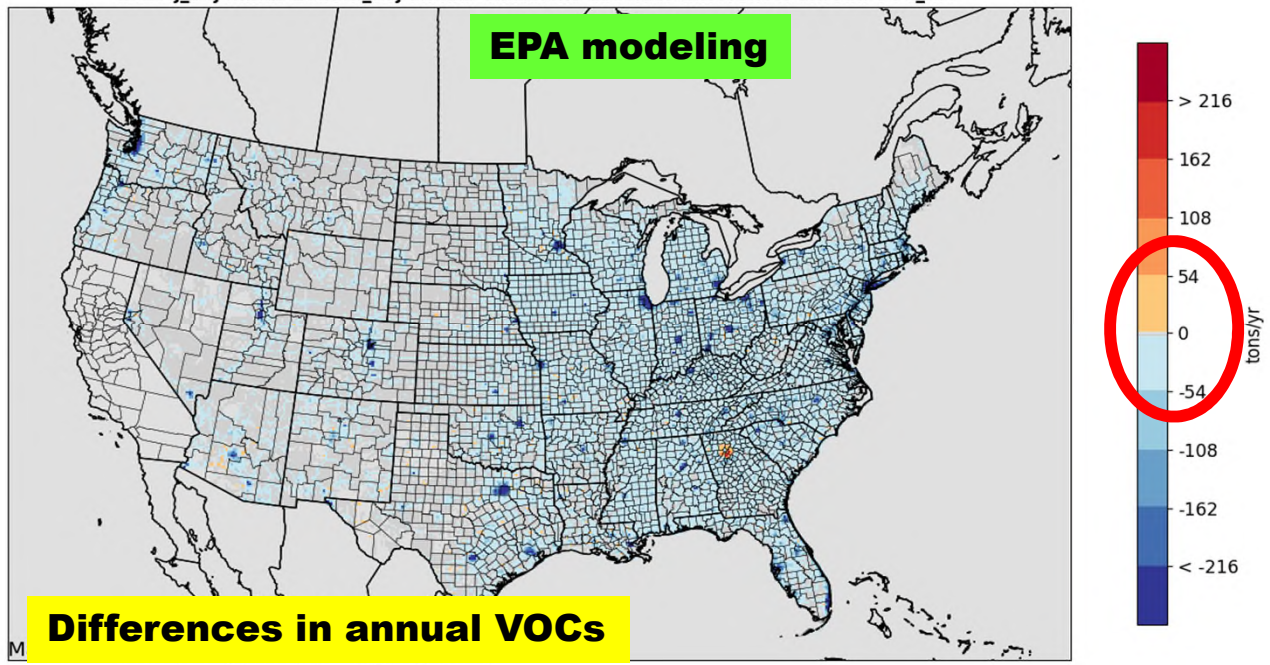
2016fj_v2 minus 2016fh_v1



Differences in 5 months VOCs

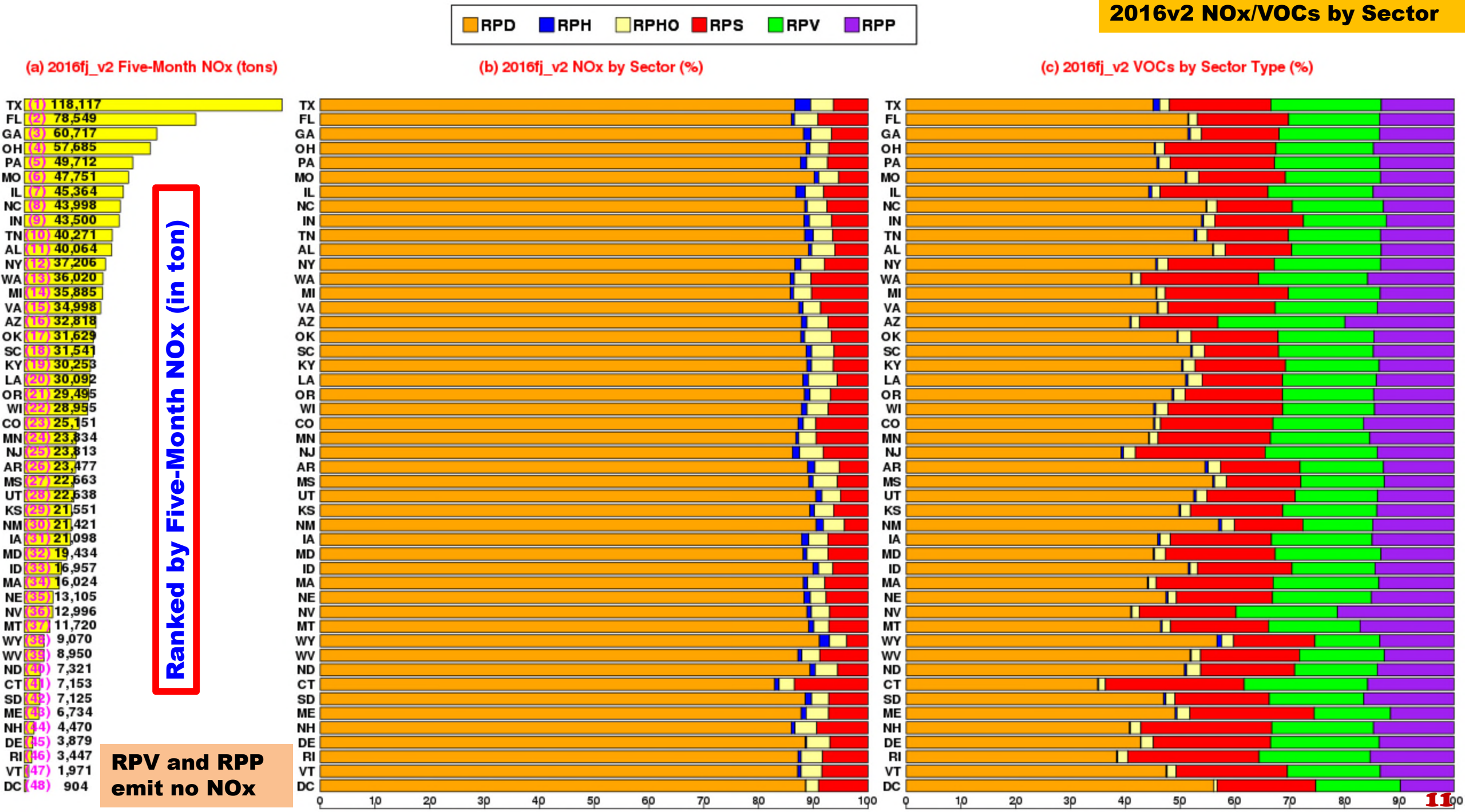
2016fj_16j minus 2016fh_16j annual emissions absolute difference: onroad VOC_INV

EPA modeling



Differences in annual VOCs

2016v2 NOx/VOCs by Sector



Ranked by Five-Month NOx (in ton)

RPV and RPP emit no NOx

Outlines of Talk

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-- MOVES3 in 2016v2 versus MOVES2014b in 2016v1
-- BY 2016 versus FY 2023/2026

Why Consistency Matters

- Inconsistencies are the result of ambiguous or insufficient guidelines for data gathering and not because of better local data collected by states
  - Vehicle splits: 31/32, 52/53, 61/62 (MOVES design issue)
  - Extended idling (changing methodologies over past 5 years)
  - Speed profiles and VMT temporal profiles (few sources for suitable data prior to 2014NEI)
  - State data of unknown origins in replacement of data derived in regional efforts
- Inconsistent emission inventory results propagate into air quality modeling, often amplifying questionable data
- Contribution-to-monitor type of air quality modeling that includes inconsistencies unfairly favors some states while targeting other states
- Inconsistency must be corrected by either implementing the same methodologies across the board or revising MOVES internal design

Clear unambiguous guidelines will help alleviate the problems

2016v2 Onroad Inventory Review

- Representative county In SMOKE-MOVES
- 2009 recession in age distributions in BY and FY
- Age distributions for all vehicle types by state

This presentation

- Five accumulative activities (VMT, VPOP, Starts, Hoteling, ONI)
- Growth Factors
- Extended idling
- Temporal profiles (CRC and traffic counters)
- Fuel month in SMOKE-MOVES
- MOVES and SMOKE portions of SMOKE-MOVES

Future call

Data points between two vertical lines belong to the state labeled on the right

Representative County Approach

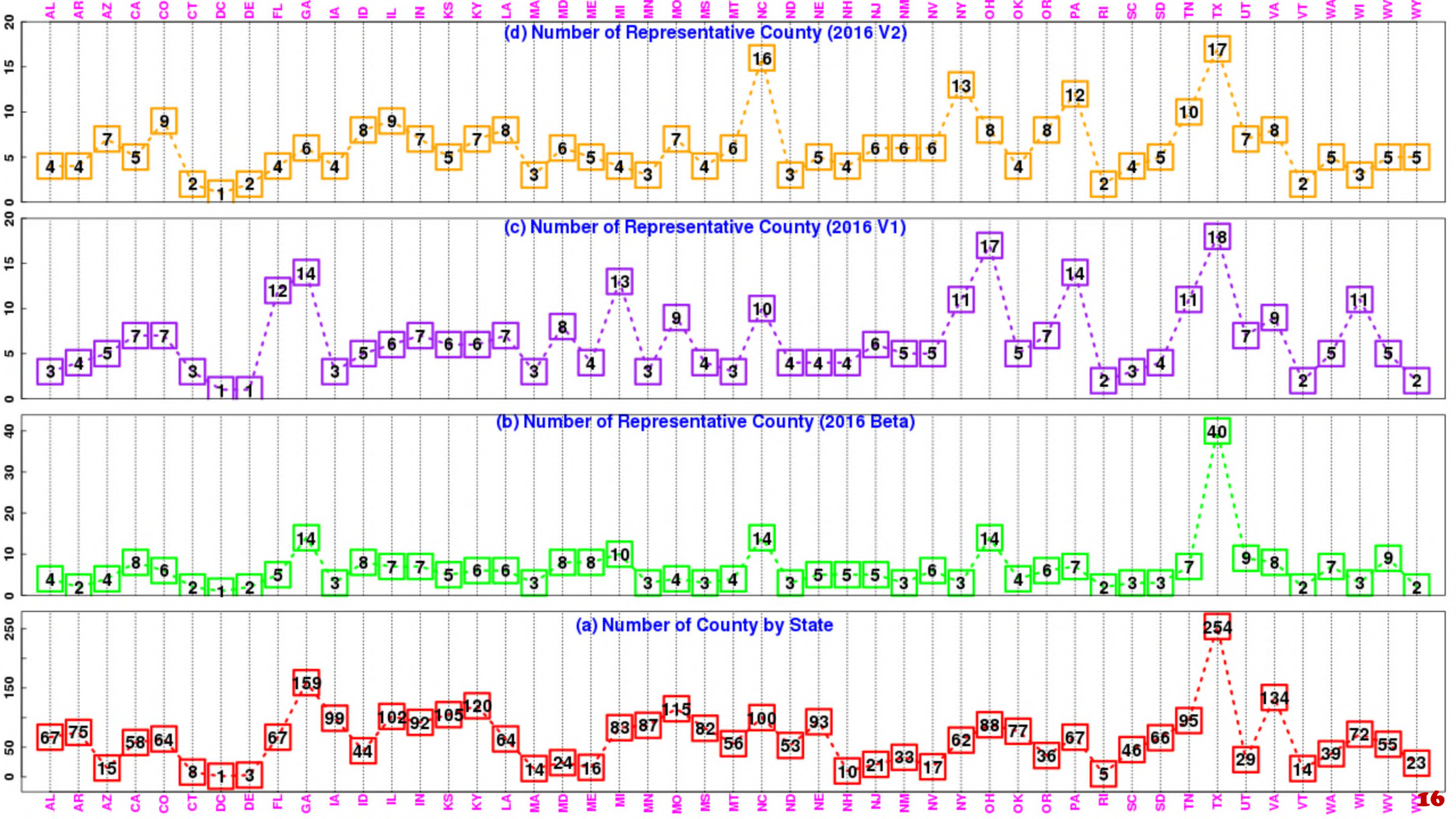
In SMOKE-MOVES, the role which age distribution plays is not entirely clear (it's one of the factors used in representative county grouping)

Grouping Criteria:
Fleet age distribution
Fuel properties
Control programs
Others (Extended idling)

In inventory mode, age distribution is one of the most important parameters affecting onroad emissions. For SMOKE-MOVES, the impact of age distribution is hidden or embedded in emission factor (lookup) tables

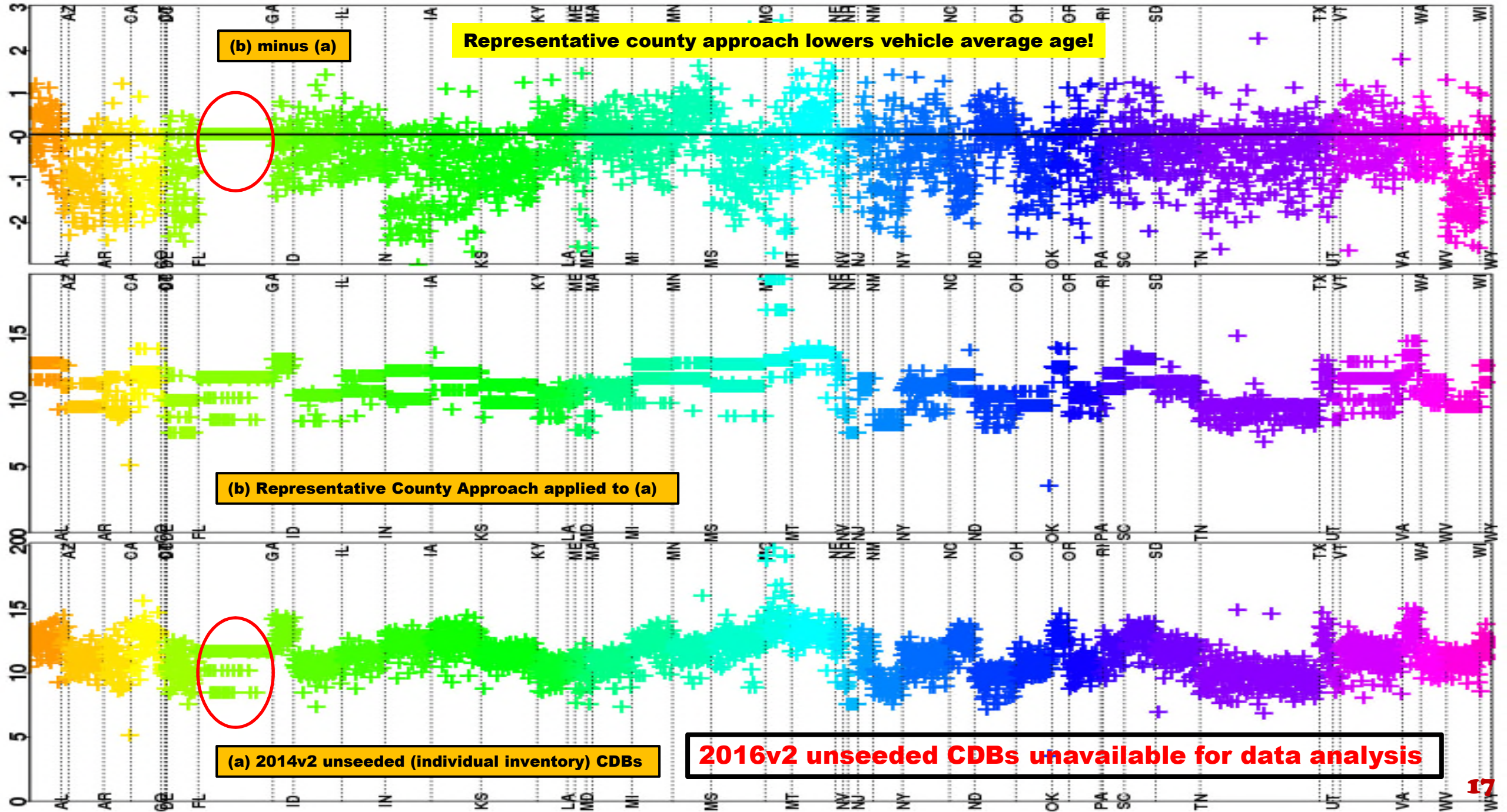
Prior to 2014 NEI, the representative county approach had used data properties of the county with the highest VMT to represent a group of inventory counties ("old" practice)

Starting from 2014 NEI, EPA has revised the practice and used "population-weighted" age distributions ("new" practice) to represent a group of counties. No other change was made to representative county approach


(d) Number of Representative County (2016 V2)
(c) Number of Representative County (2016 V1)
(b) Number of Representative County (2016 Beta)
(a) Number of County by State
AL AR AZ CA CO CT DC DE FL GA IA ID IL IN KS KY LA MA MD ME MI MN MO MS MT NC ND NE NH NJ NM NV NY OH OK OR PA RI SC SD TN TX UT VA VT WA WI WV WY

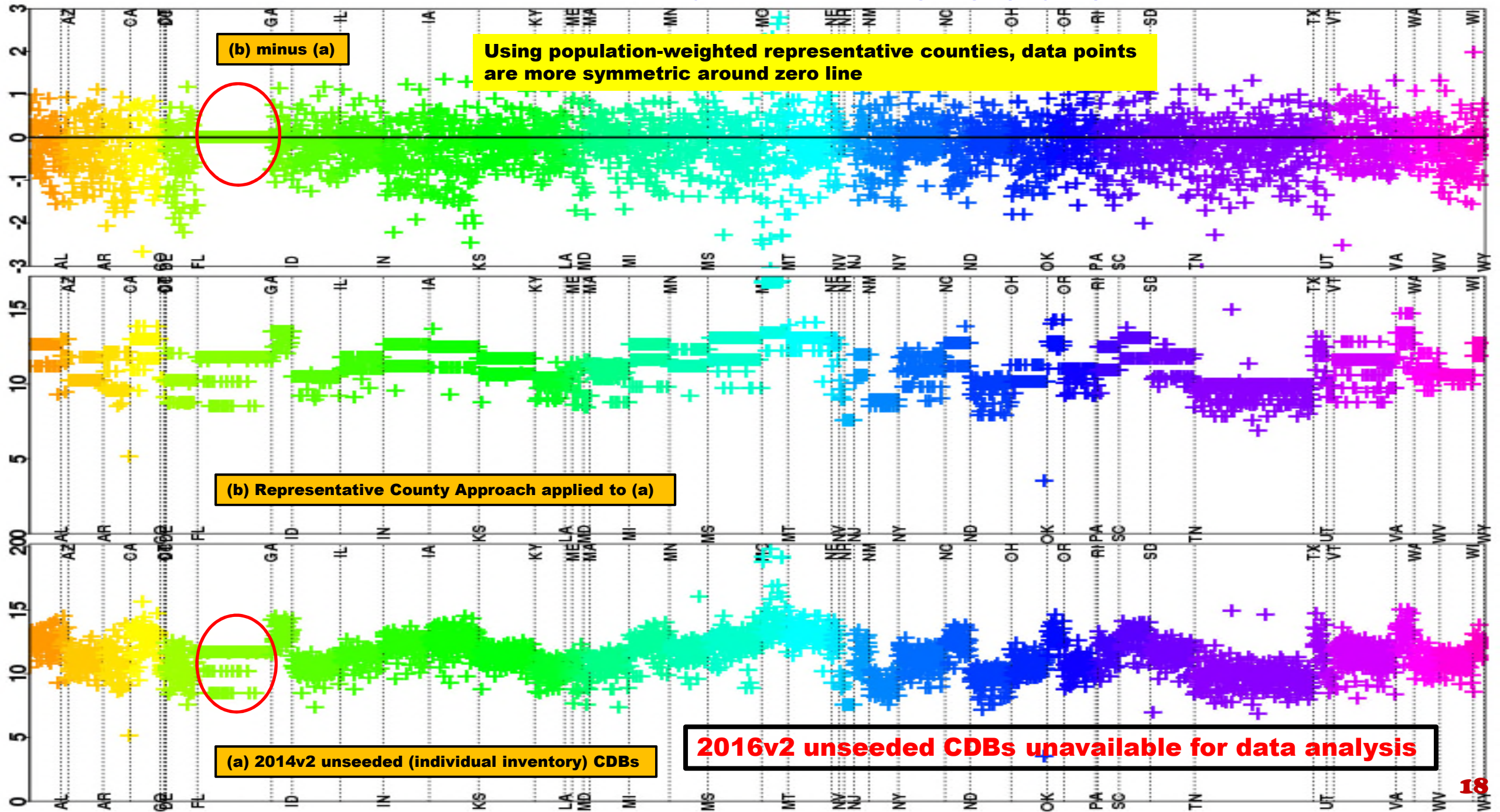
Effect of Representative County on Vehicle Average Age (in year) for 21

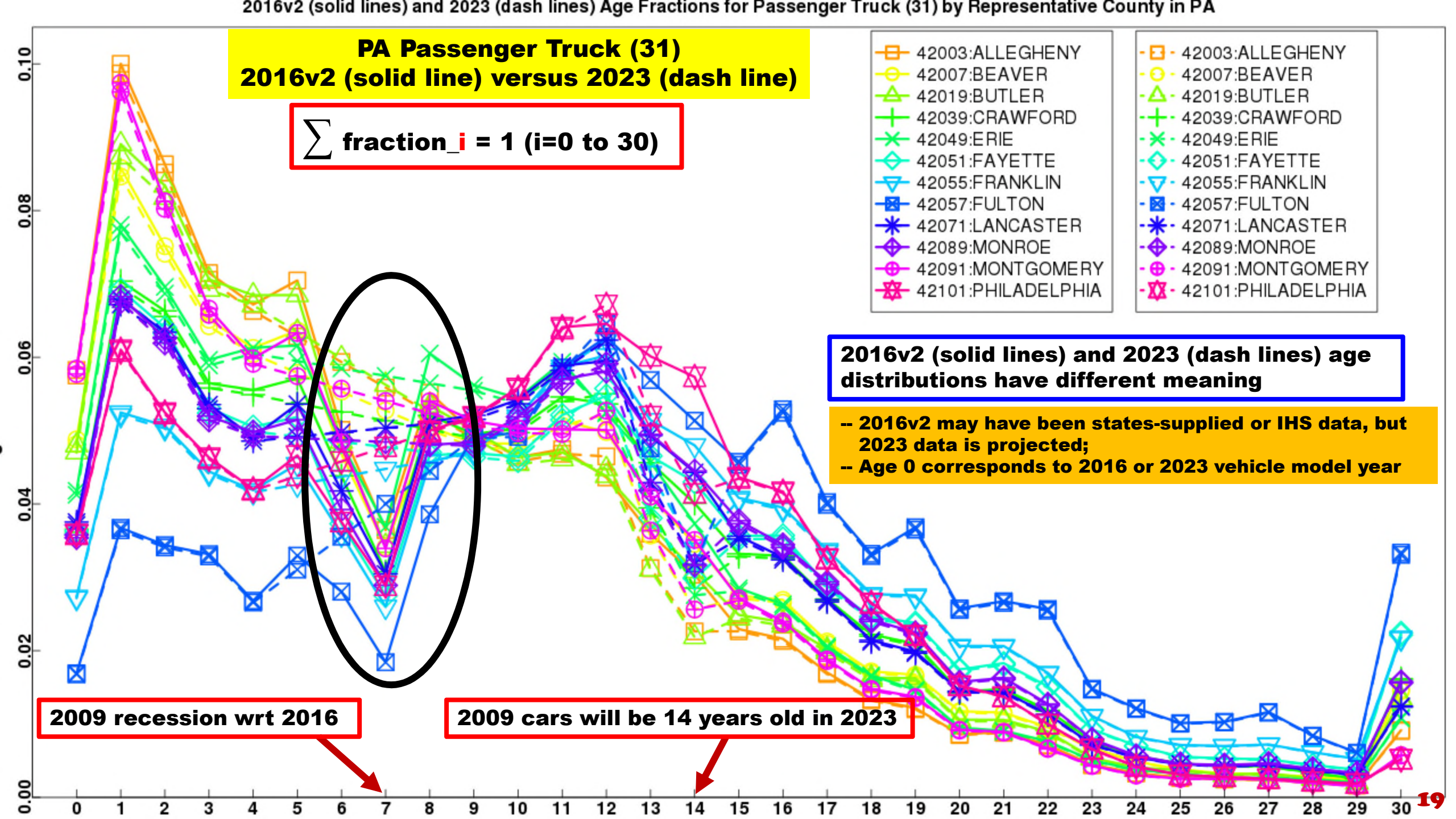
2014, old practice



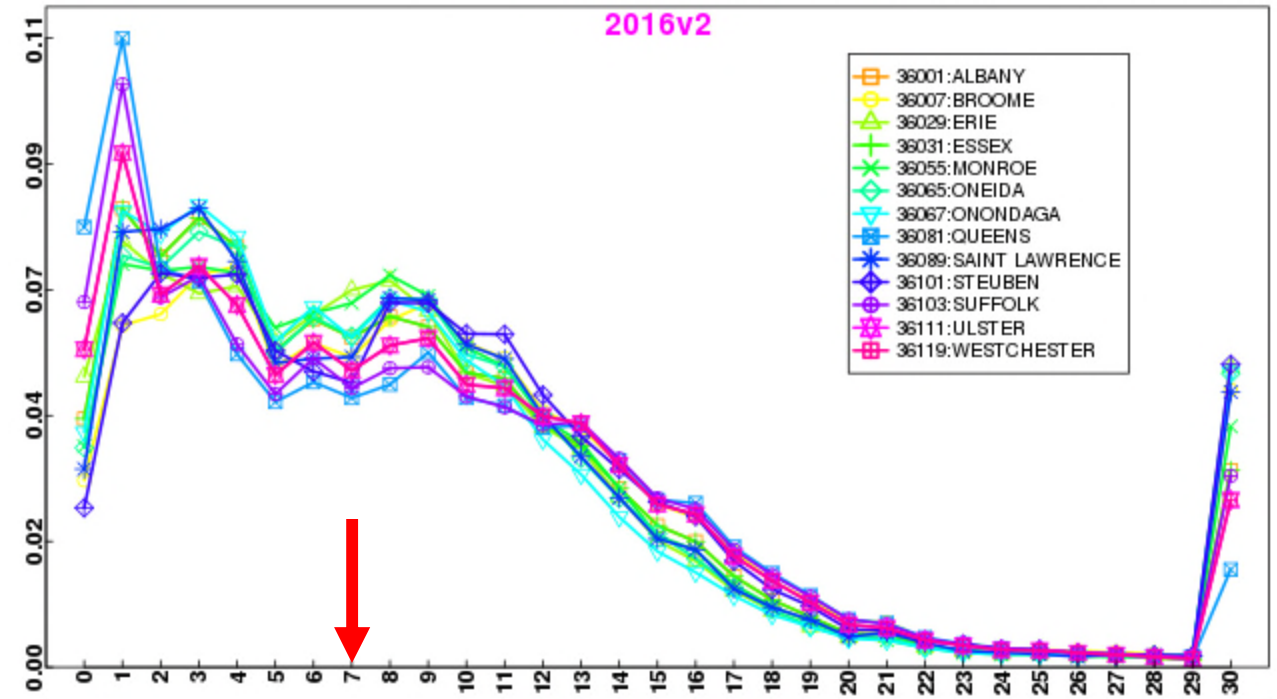
Effect of Representative County on Vehicle Average Age (in year) for 21

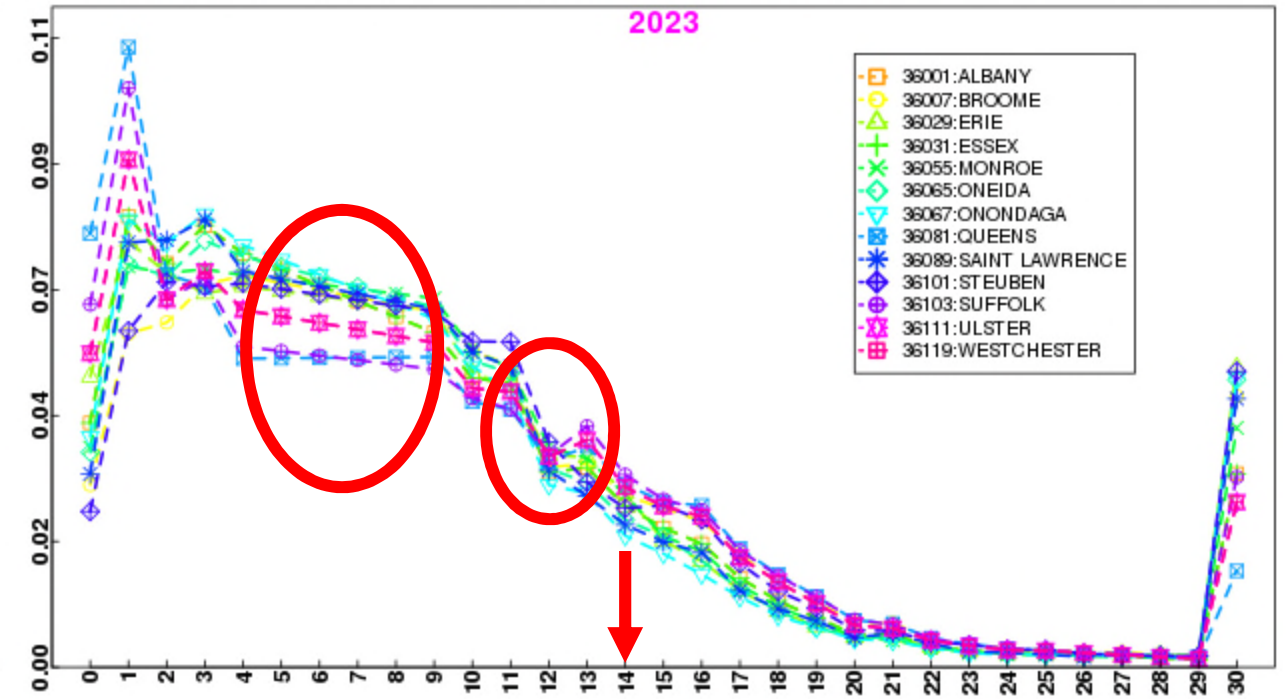
2014, new practice

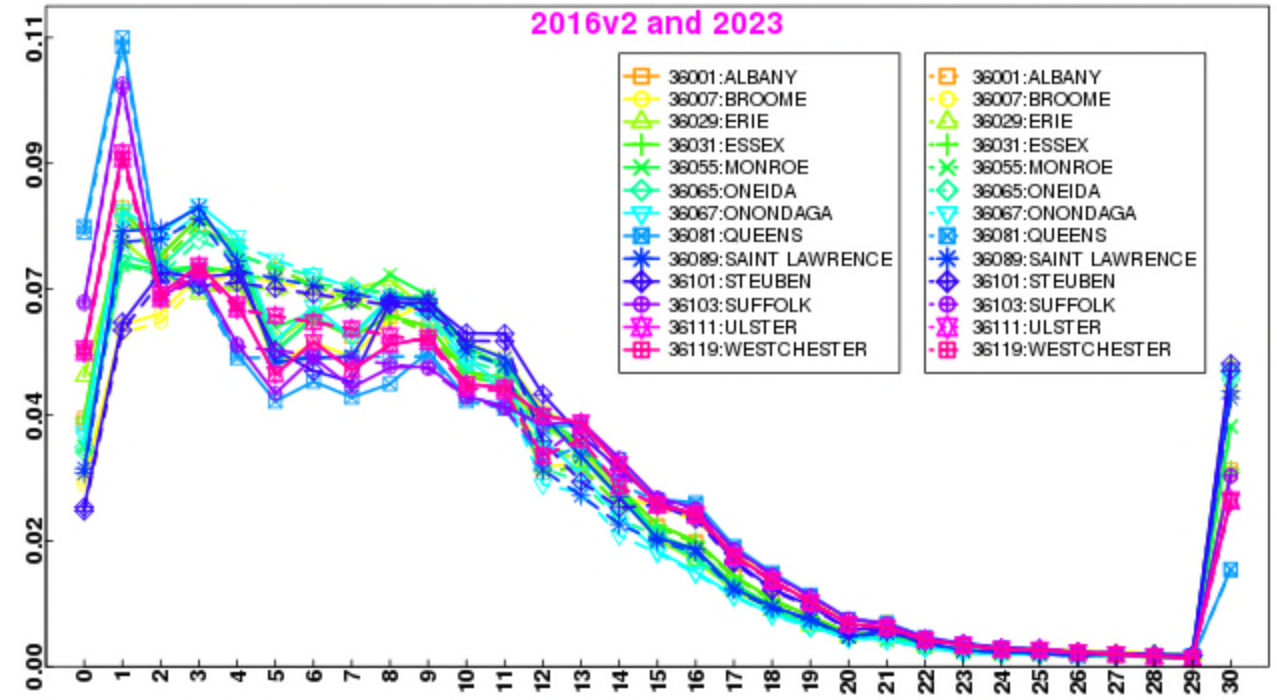



2016v2 (solid lines) and 2023 (dash lines) Age Fractions for Passenger Truck (31) by Representative County in PA
PA Passenger Truck (31)
2016v2 (solid line) versus 2023 (dash line)
∑ fraction_i = 1 (i=0 to 30)
42003:ALLEGHENY
42007:BEAVER
42019:BUTLER
42039:CRAWFORD
42049:ERIE
42051:FAYETTE
42055:FRANKLIN
42057:FULTON
42071:LANCASTER
42089:MONROE
42091:MONTGOMERY
42101:PHILADELPHIA
2016v2 (solid lines) and 2023 (dash lines) age distributions have different meaning
-- 2016v2 may have been states-supplied or IHS data, but 2023 data is projected;
-- Age 0 corresponds to 2016 or 2023 vehicle model year
2009 recession wrt 2016
2009 cars will be 14 years old in 2023
0.00
0.02
0.04
0.06
0.08
0.10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

2016v2 (solid lines) and 2023 (dash lines) Age Fractions for Passenger Truck (21) by Representative County in NY



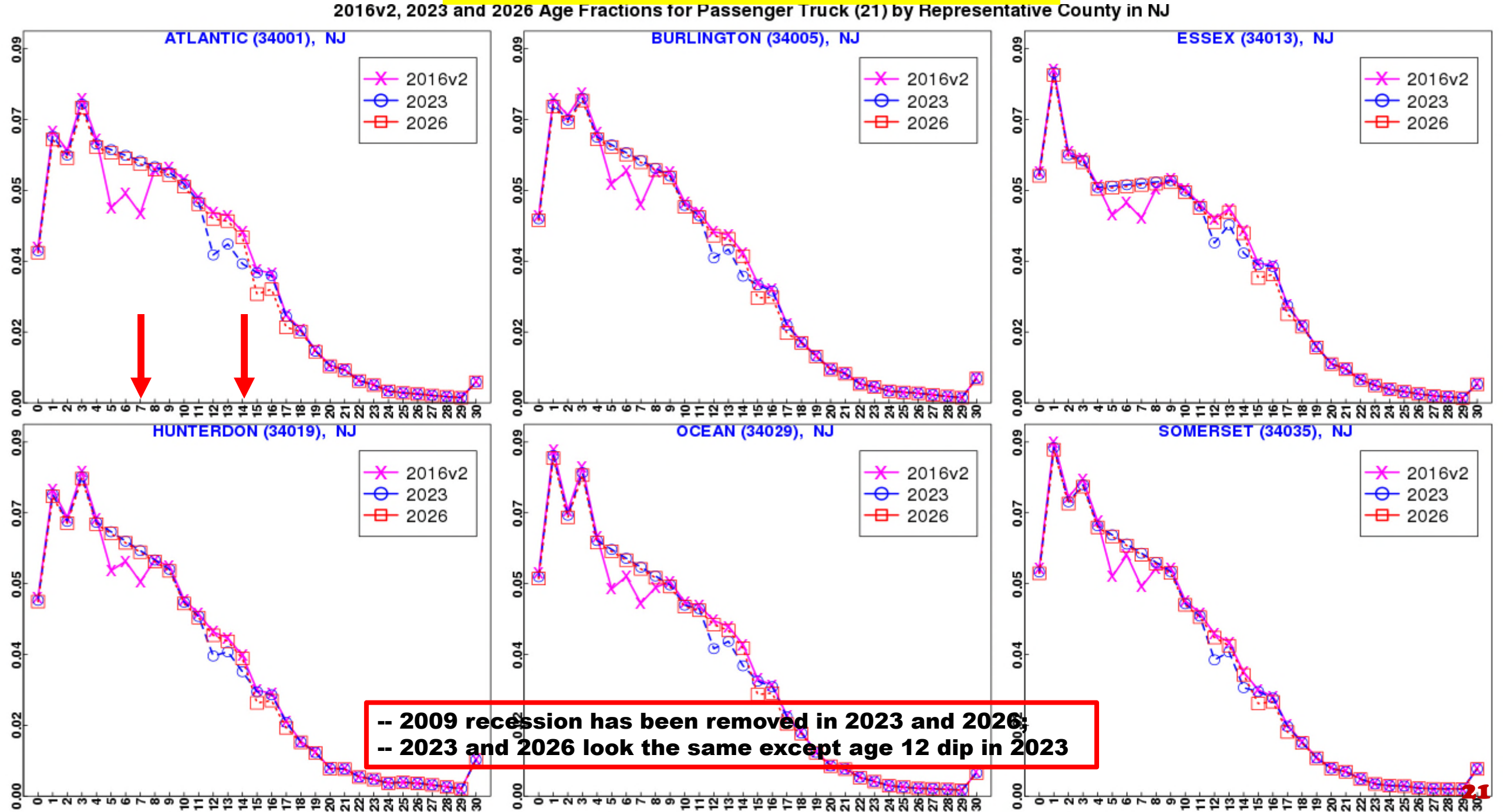




NY Passenger Car (21) –
2016v2 (upper left) versus 2023 (upper right)

Removing the recession in 2023 is obvious, but there is a dip in age 12 bin

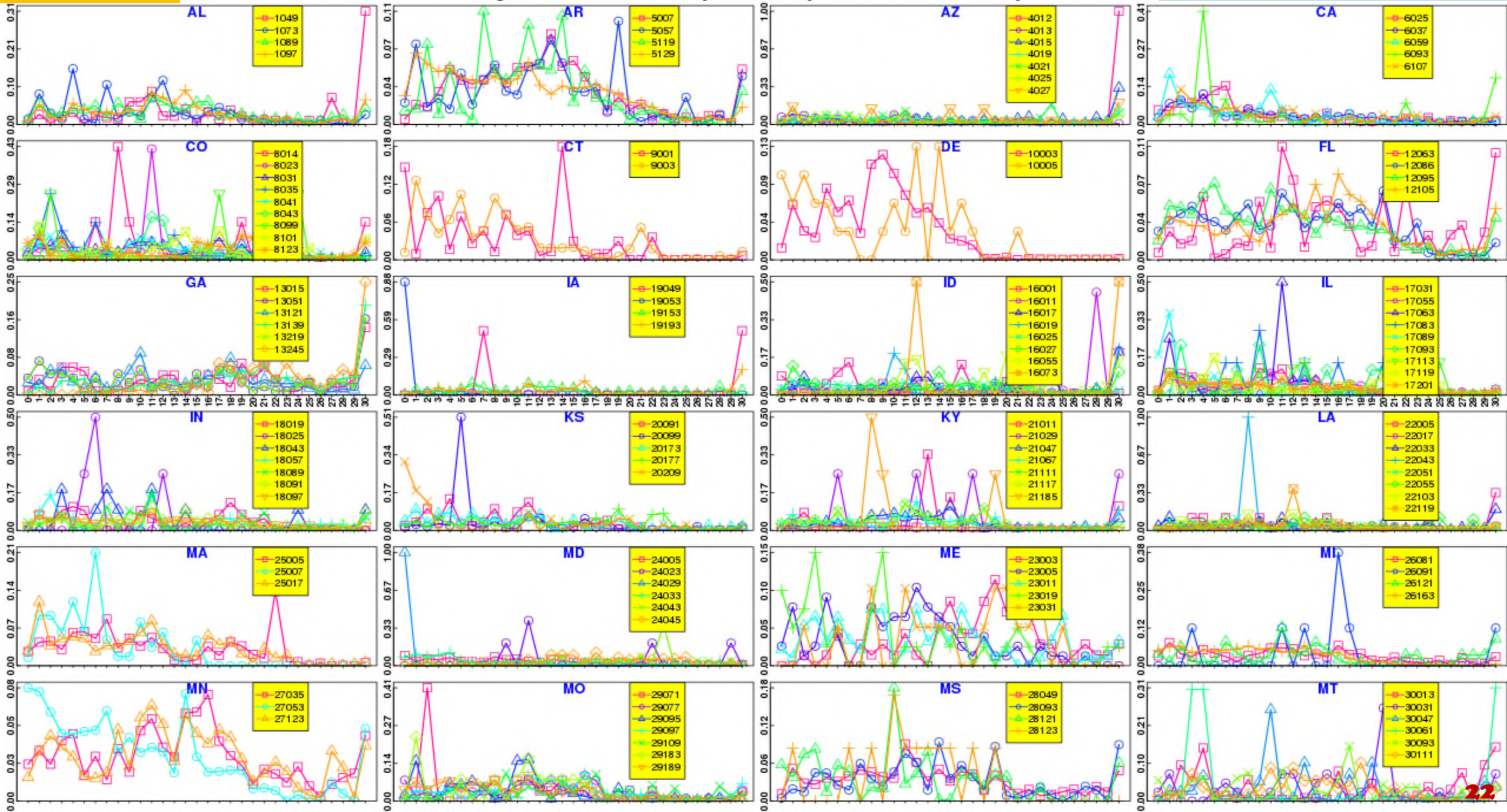
NJ Passenger Car (21) in 2016v2, 2023, and 2026



Intercity Bus

Age Fractions for Intercity Bus (41) by Representative County

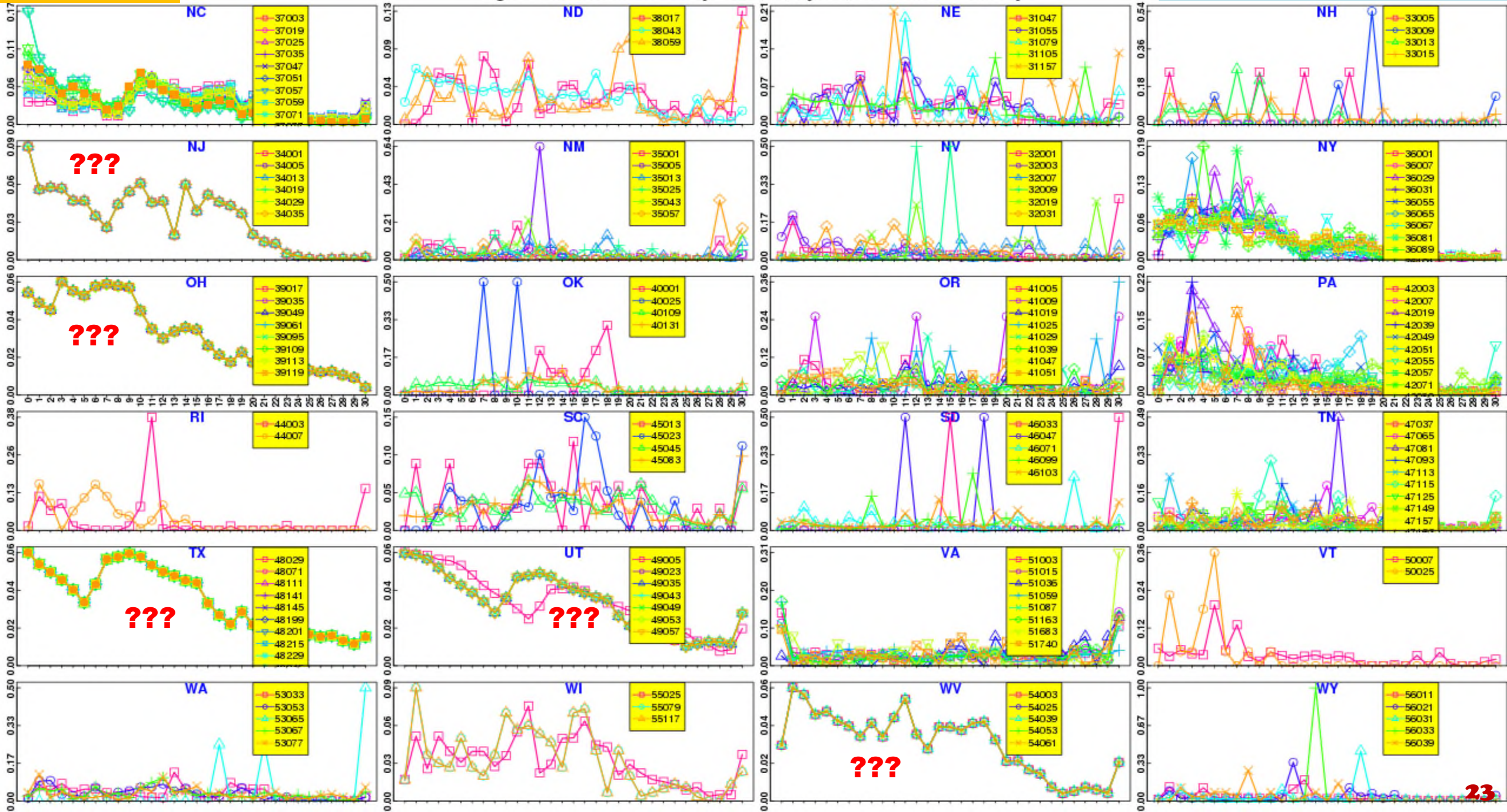
2026, 41 fraction, CONUS1



Intercity Bus

Age Fractions for Intercity Bus (41) by Representative County

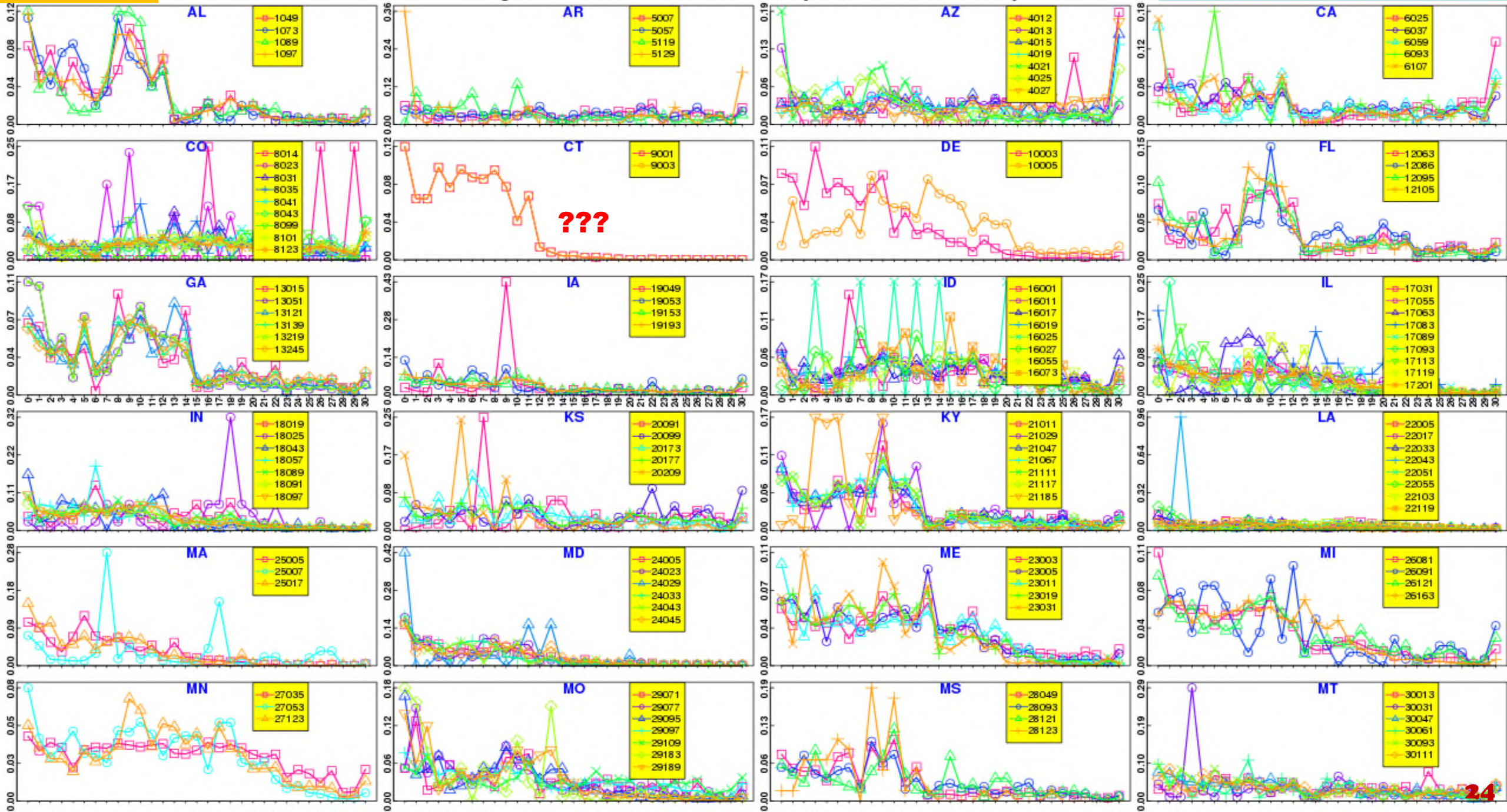
2026, 41 fraction, CONUS2



School Bus

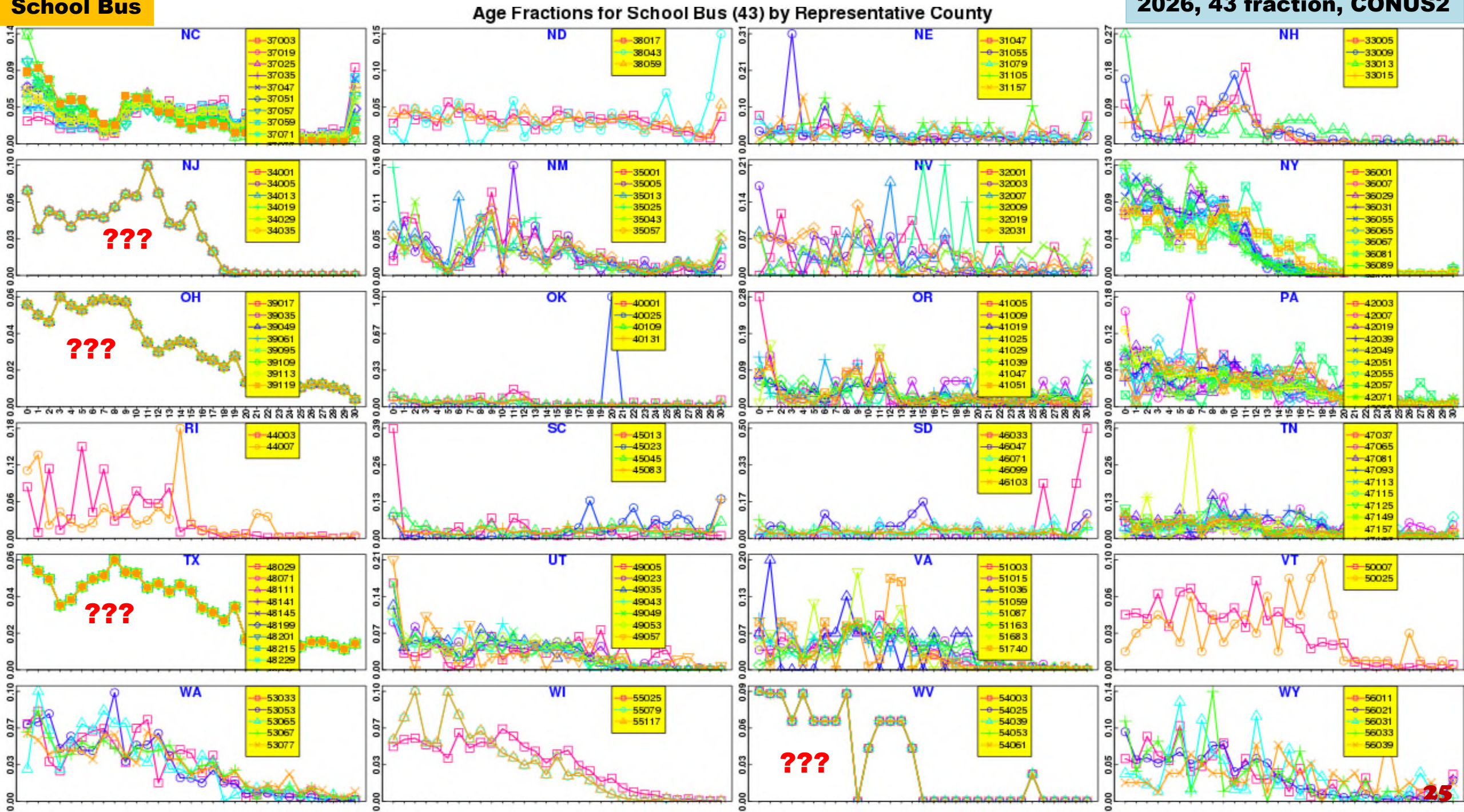
Age Fractions for School Bus (43) by Representative County

2026, 43 fraction, CONUS1



School Bus

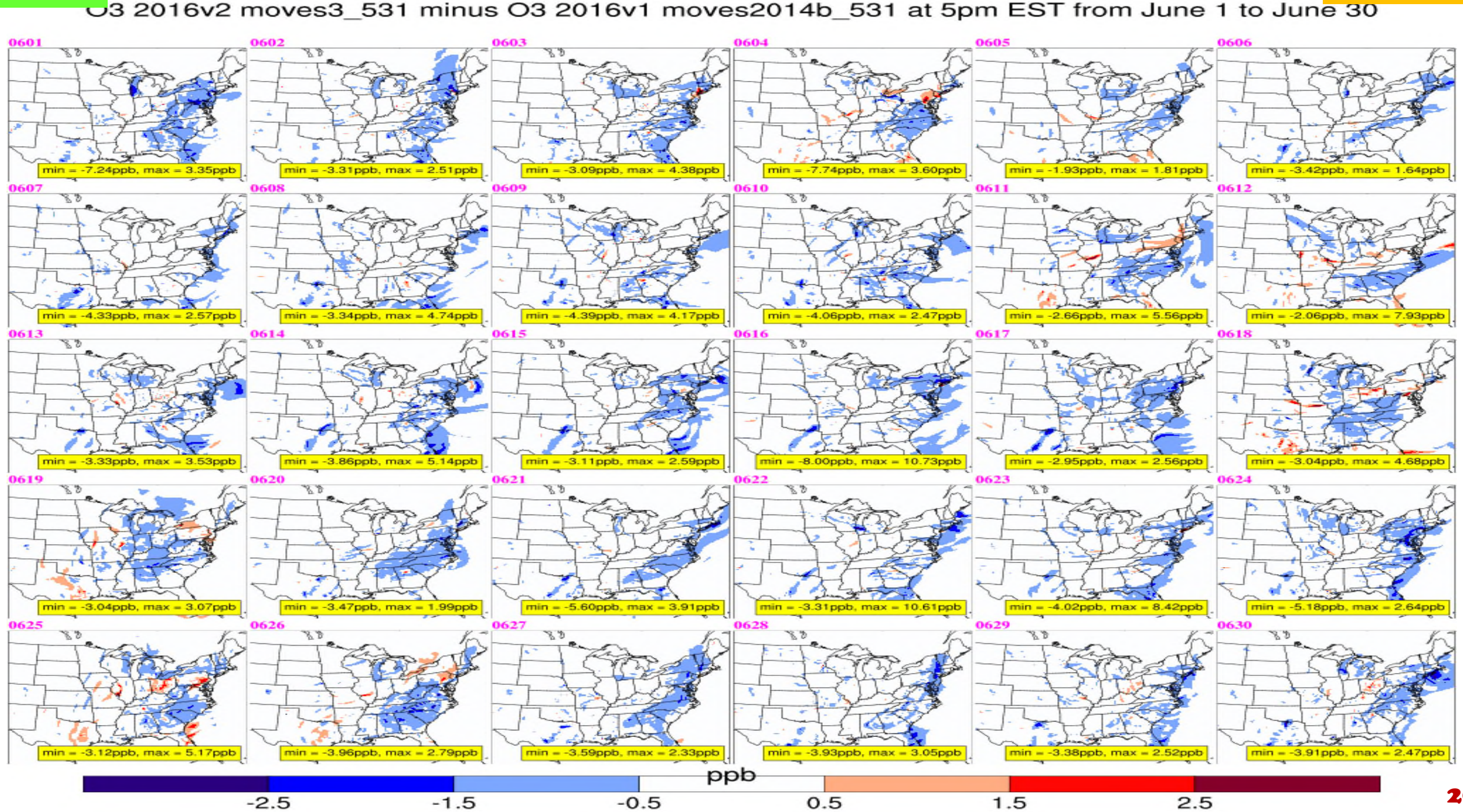
2026, 43 fraction, CONUS2



preview

O3 Impact of New MOVES Model (MOVES3 minus MOVES2014b)

June 2016



Summary

- SMOKE-MOVES, not MOVES, is the tool used by EPA to process onroad mobile source emissions for National Emission Inventory (NEI) and photochemical modeling for policy making
- Four SMOKE-MOVES runs (2016v1, 2016v1-based 2023, 2016v2, 2016v2-based 2023) are needed to be able to quantify emission impact of new MOVES3 model
- MOVES3 gives less NOx and less VOCs than MOVES2014b
- Of the six onroad sectors in 2016v2 (RPD, RPS, RPV, RPP, RPH, RPHO), RPD is the dominating sector, making up the biggest chunk of NOx (>85%). For VOCs, RPD still dominates (~40%), but three other sectors (RPV, RPS, and RPP) also contribute
- The representative county approach in SMOKE-MOVES results in younger vehicle fleets than those in actual state Department of Motor Vehicle (DMV) data for individual counties
- The vehicle fleet age distribution in the 2016 base year was affected by the 2009 recession. EPA eliminated the impact of the recession in future year age distributions. This is a sound and suitable methodology for future year estimates
- The fleet age distributions for some states (NJ, OH, TX, UT, WV) have no county-specific variations for certain vehicle types (41 intercity bus and 43 school bus) which, due to the use of representative county, effectively results in one age distribution for the entire state. In addition, the lone age distributions for those states are much too smooth
- Switching to MOVES3 in 2016v2 from MOVES2014b in 2016v1 yields less O3 as a result of less precursors. Reduction in hourly O3 due to MOVES version change is around 2 to 5 ppb