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

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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

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

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

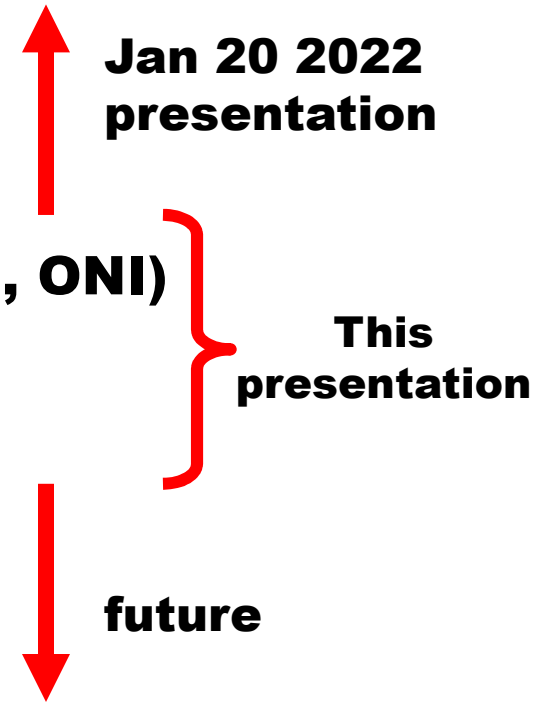
Why Consistency Matters

- 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
- 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

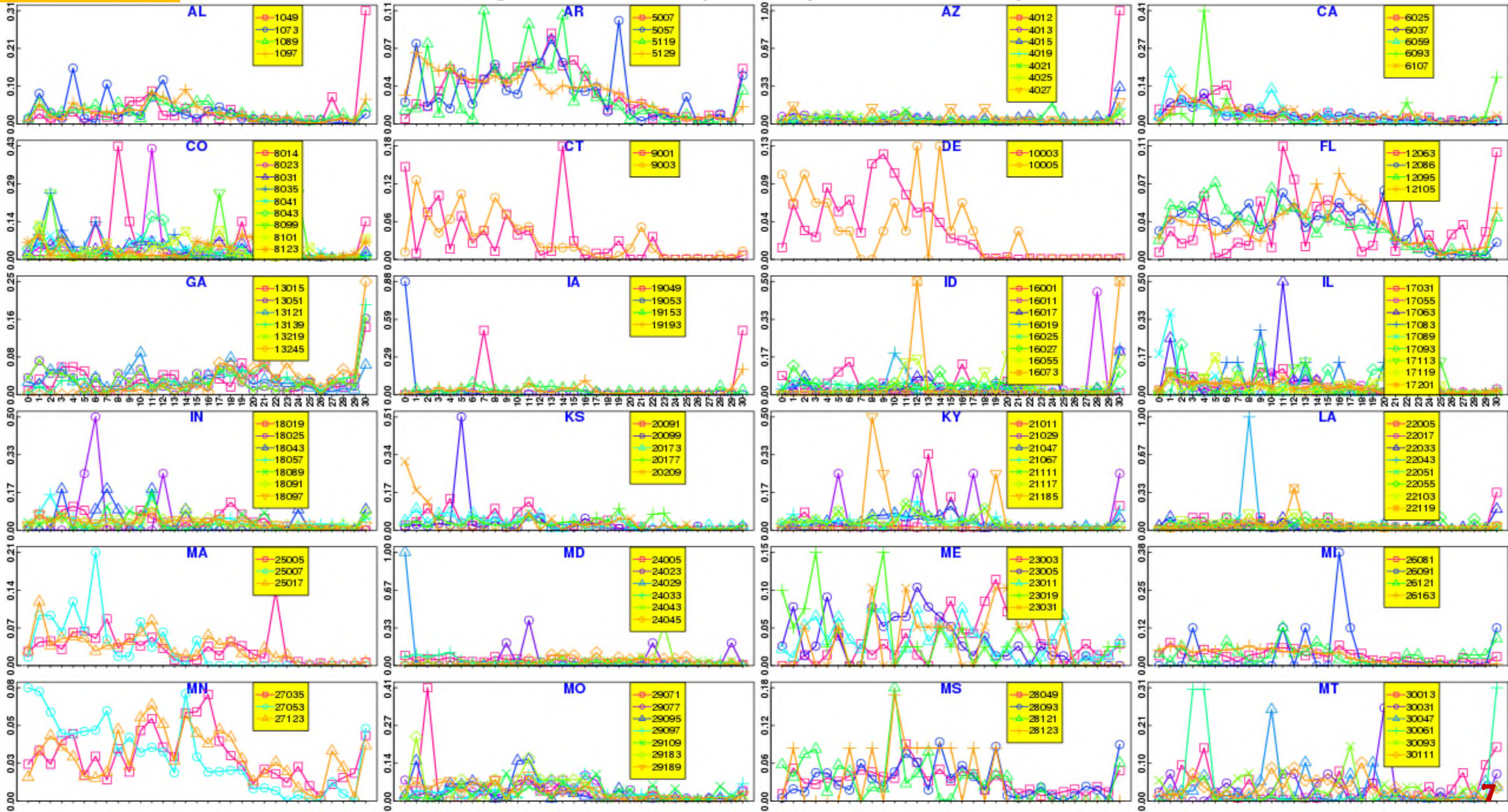


Data points between two vertical lines belong to the state labeled on the right

Intercity Bus

Age Fractions for Intercity Bus (41) by Representative County

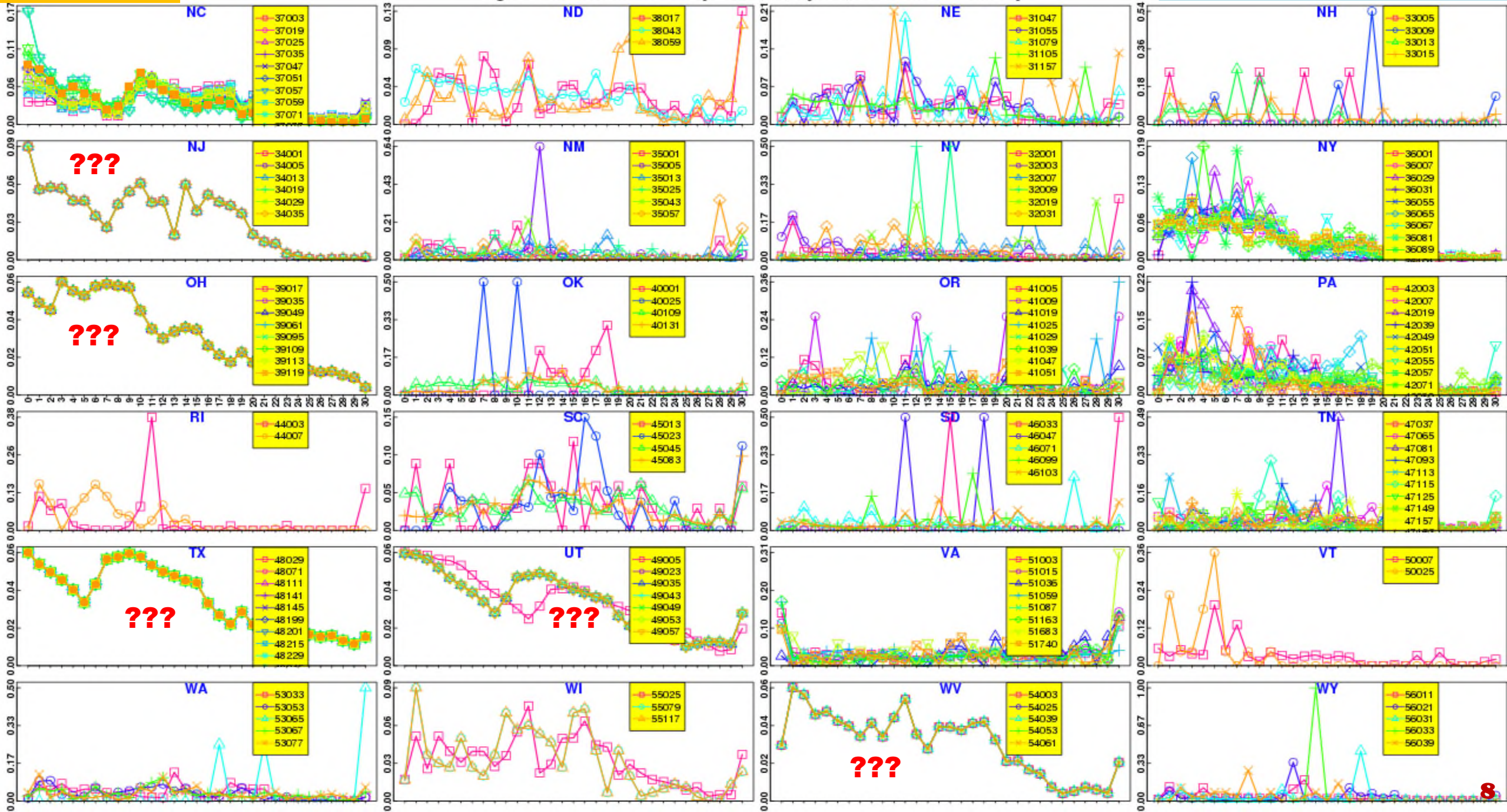
2026, 41 fraction, CONUS1



Intercity Bus

Age Fractions for Intercity Bus (41) by Representative County

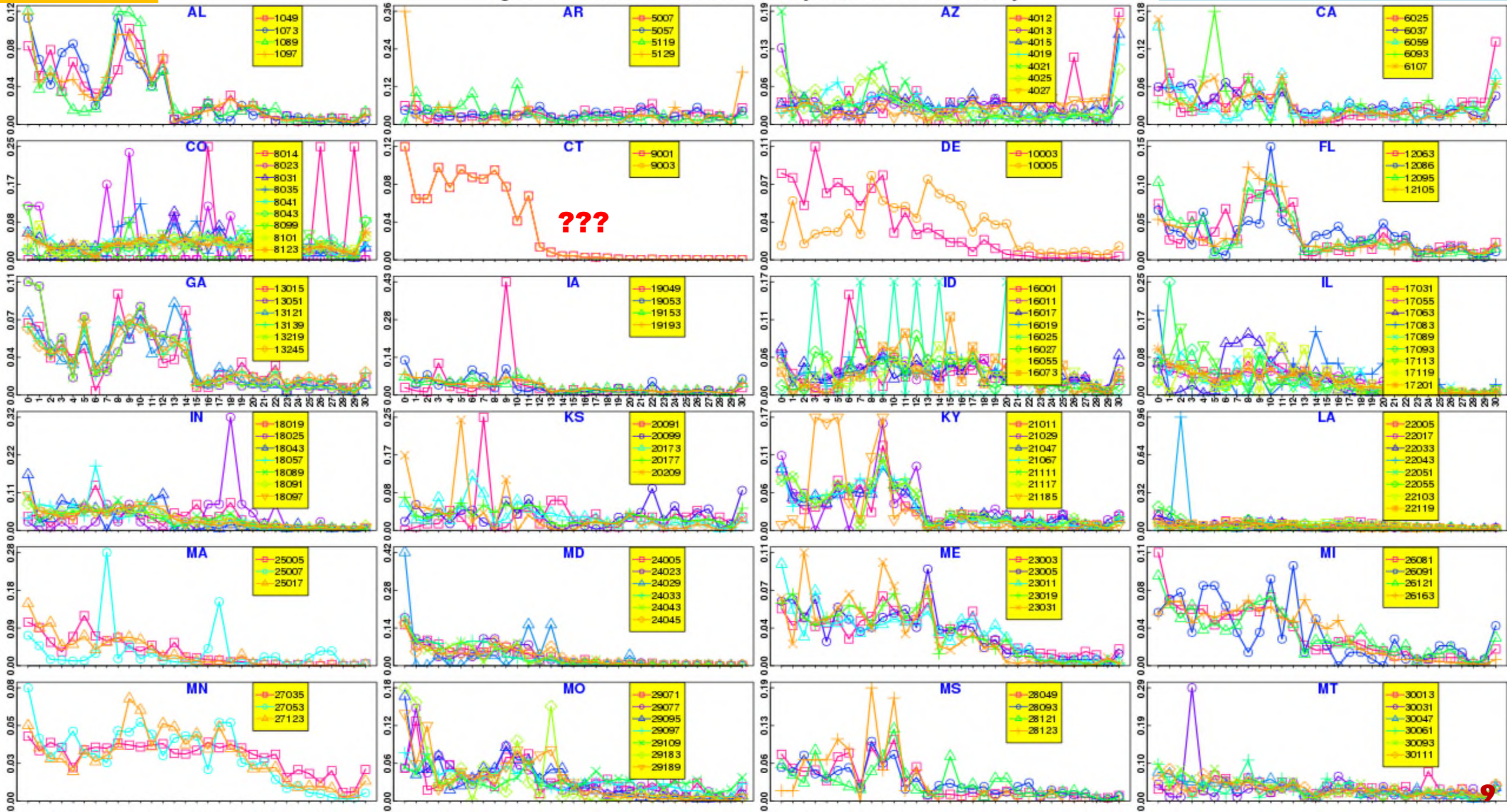
2026, 41 fraction, CONUS2



School Bus

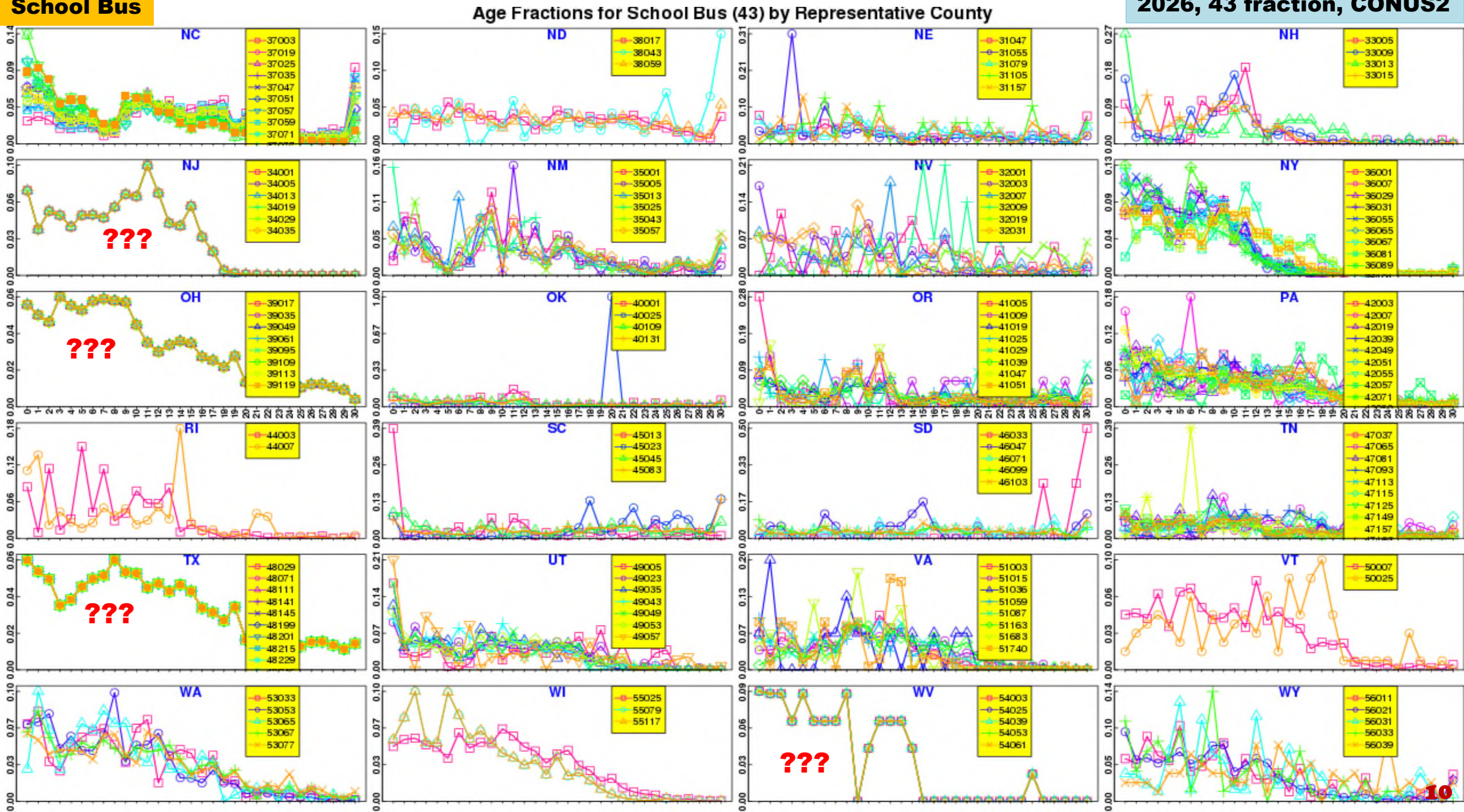
Age Fractions for School Bus (43) by Representative County

2026, 43 fraction, CONUS1



School Bus

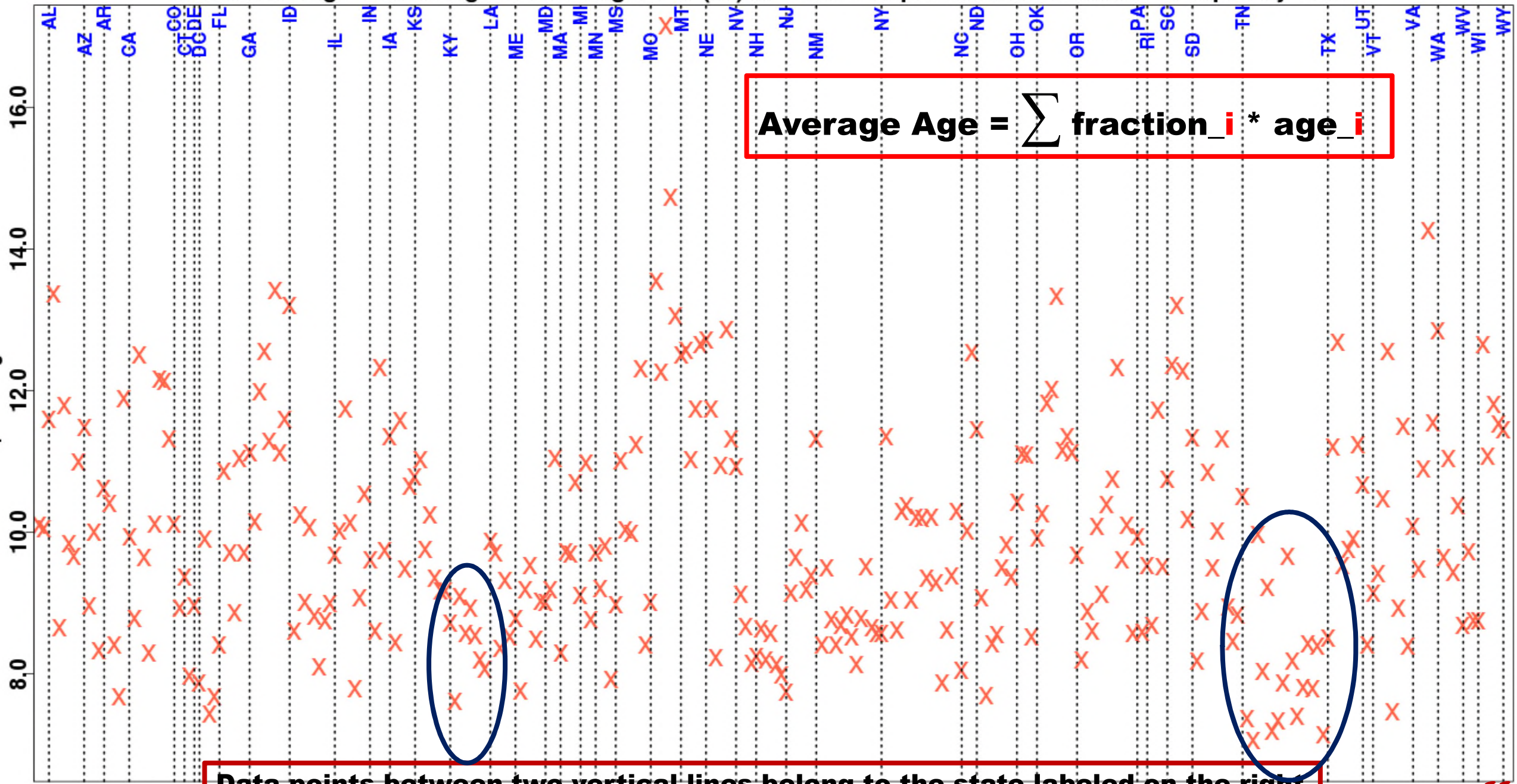
2026, 43 fraction, CONUS2



2016

Class 21

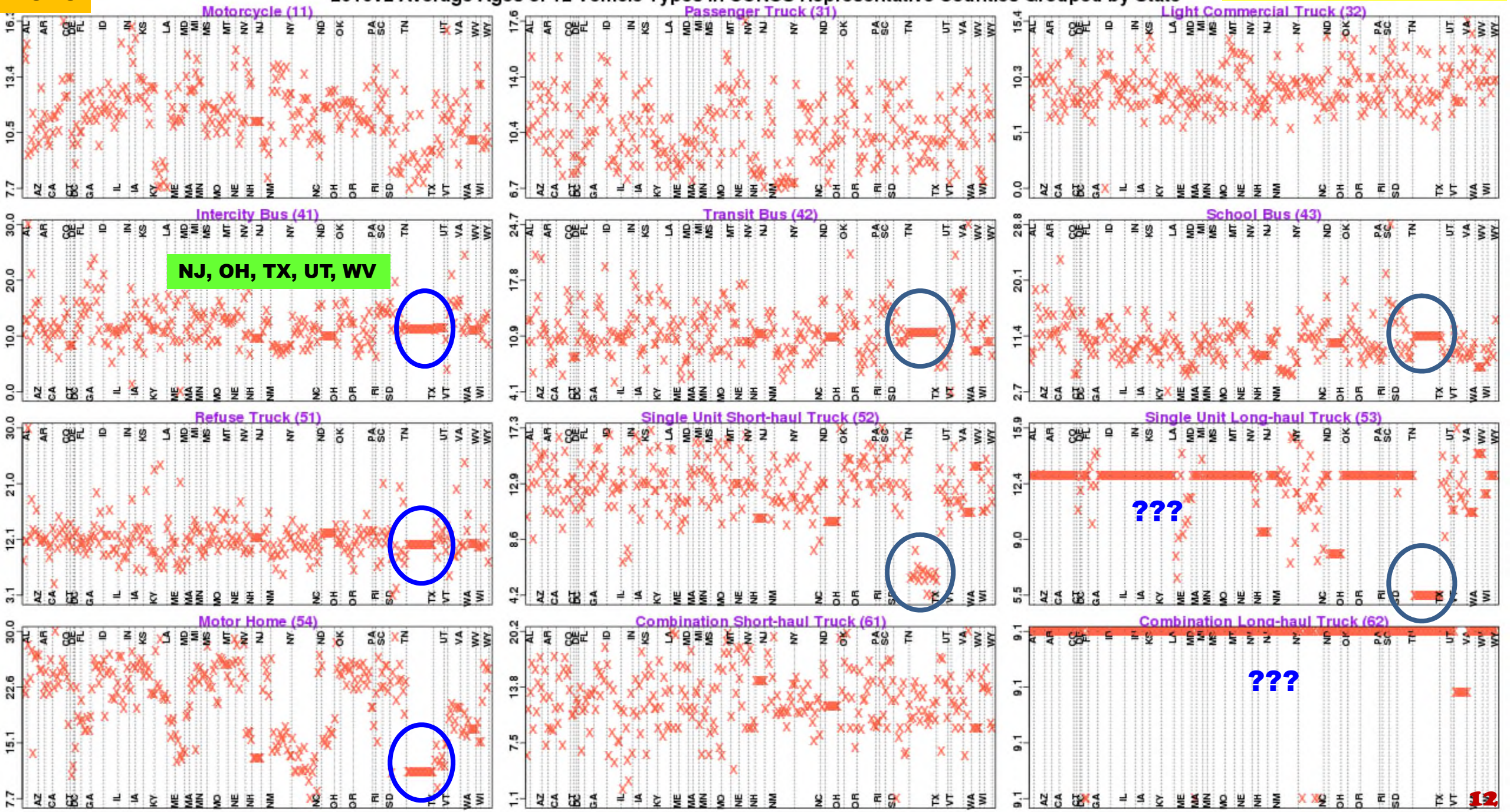
2016v2 Average Vehicle Age of Passenger Car (21) in CONUS Representative Counties Grouped by State



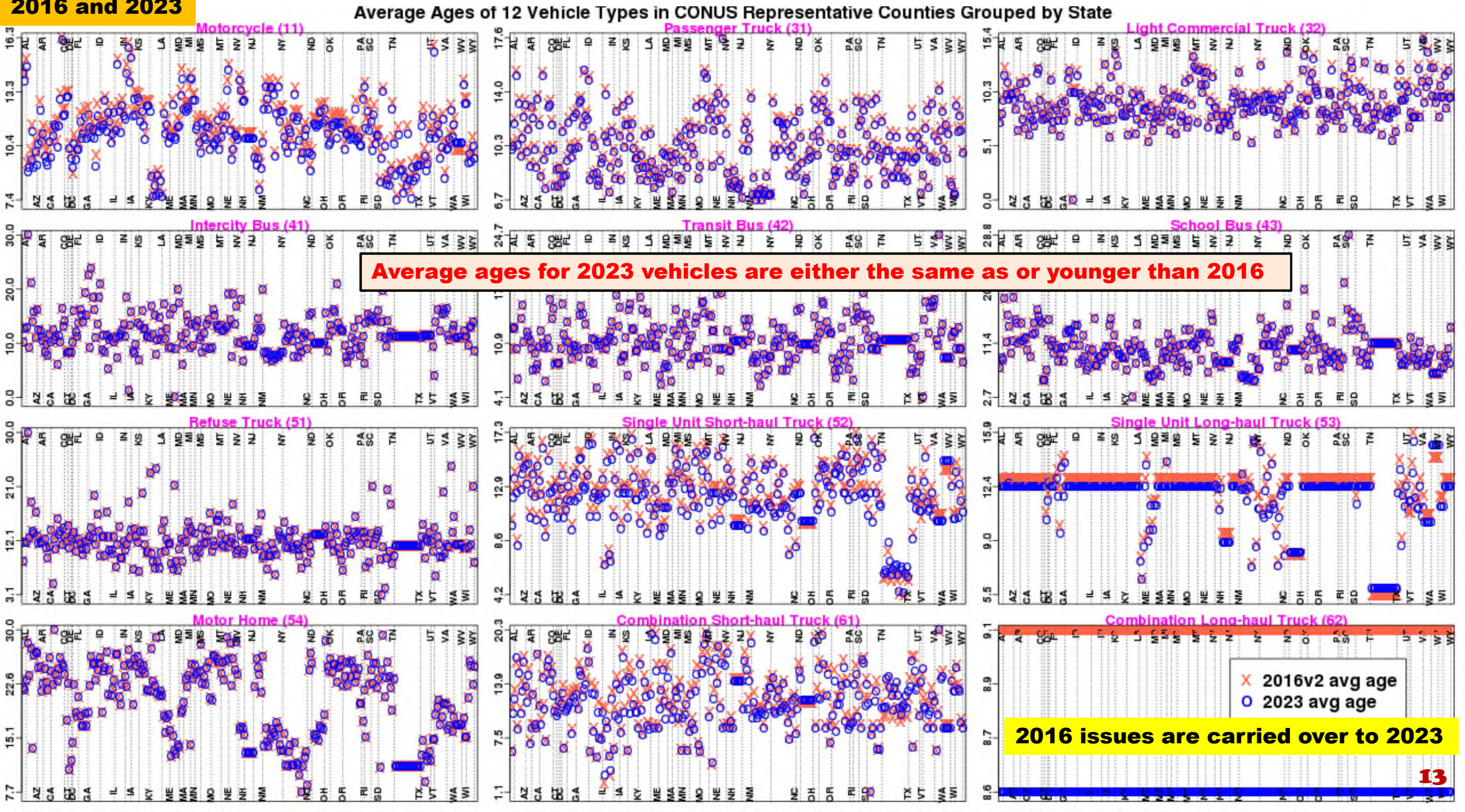
2016

21 is plotted on previous page

2016v2 Average Ages of 12 Vehicle Types in CONUS Representative Counties Grouped by State

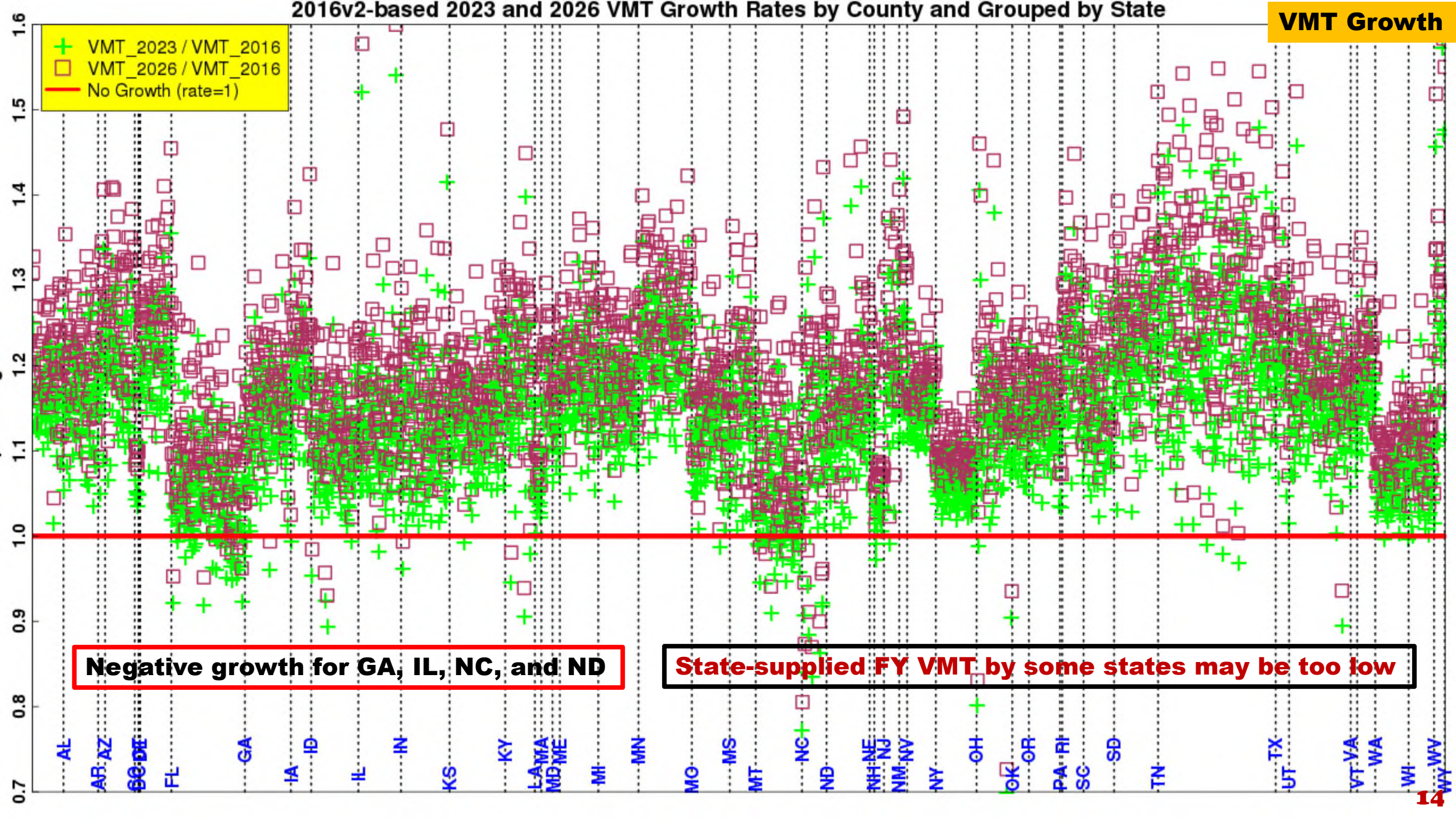


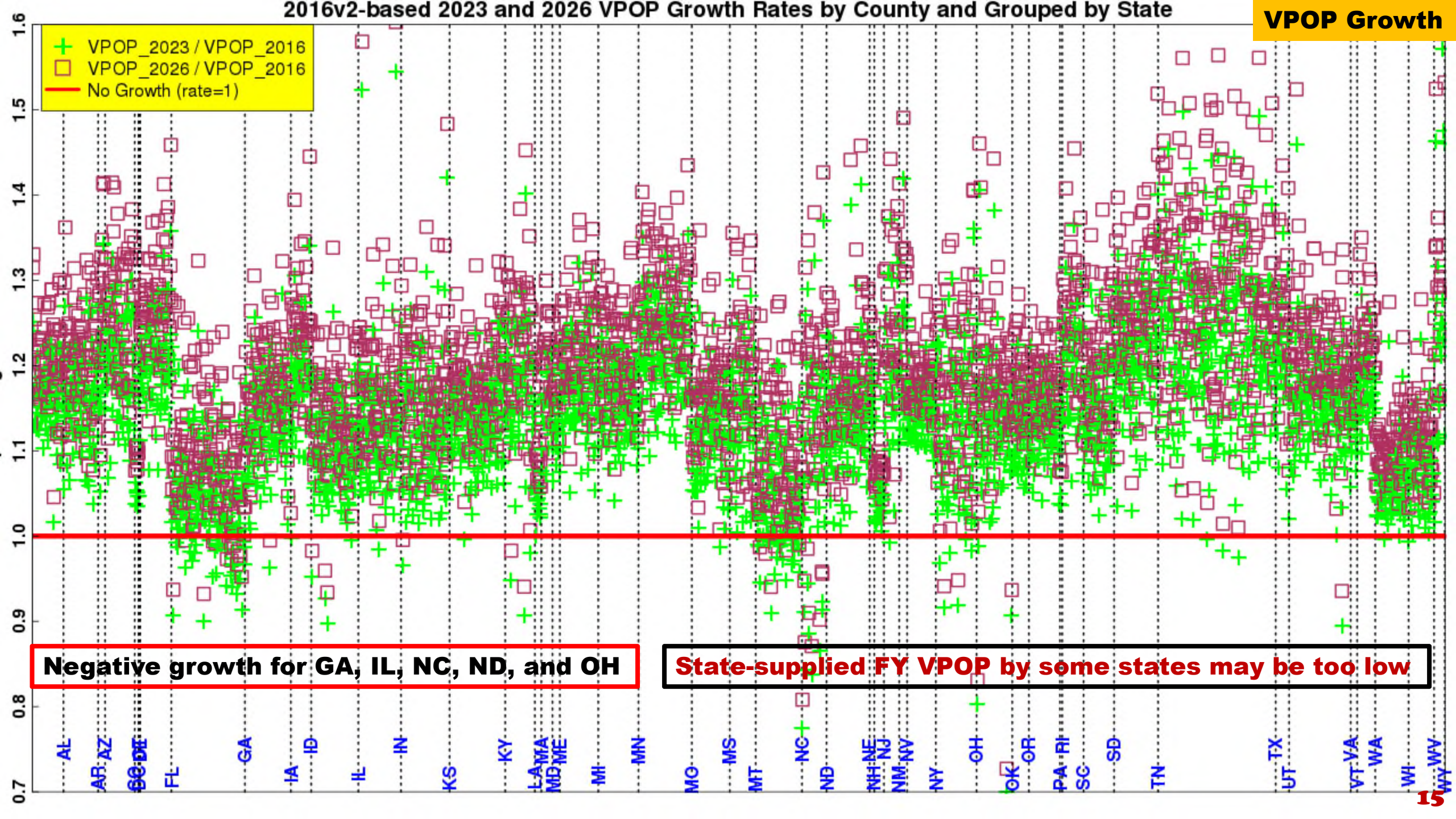
2016 and 2023



Average ages for 2023 vehicles are either the same as or younger than 2016

2016 issues are carried over to 2023


2016v2-based 2023 and 2026 VMT Growth Rates by County and Grouped by State
VMT Growth
VMT_2023 / VMT_2016
VMT_2026 / VMT_2016
No Growth (rate=1)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
AL
AR
AZ
CA
CO
CT
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
Negative growth for GA, IL, NC, and ND
State-supplied FY VMT by some states may be too low


2016v2-based 2023 and 2026 VPOP Growth Rates by County and Grouped by State
VPOP_2023 / VPOP_2016
VPOP_2026 / VPOP_2016
No Growth (rate=1)
1.6
1.5
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AL
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MN
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NC
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NE
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NV
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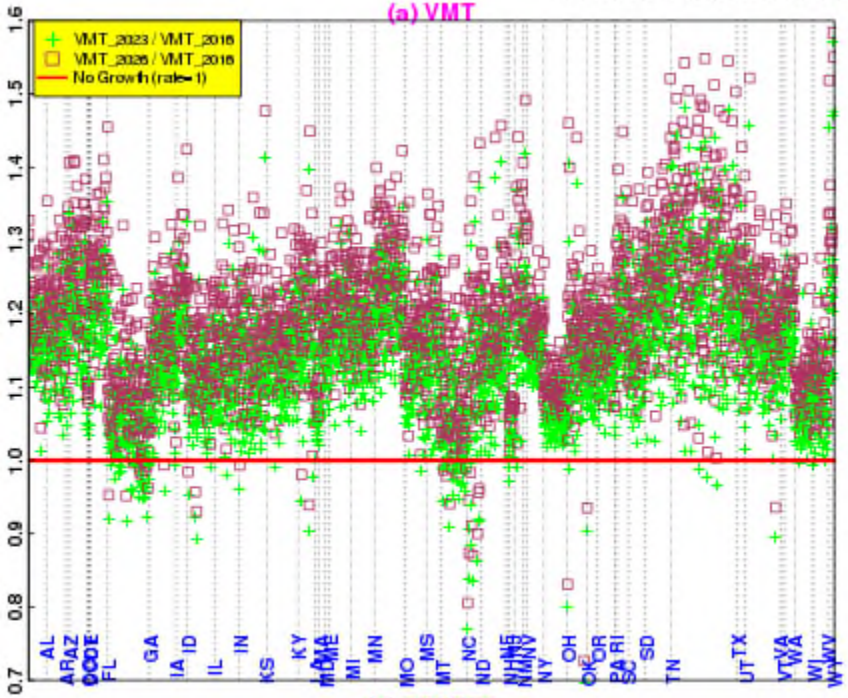
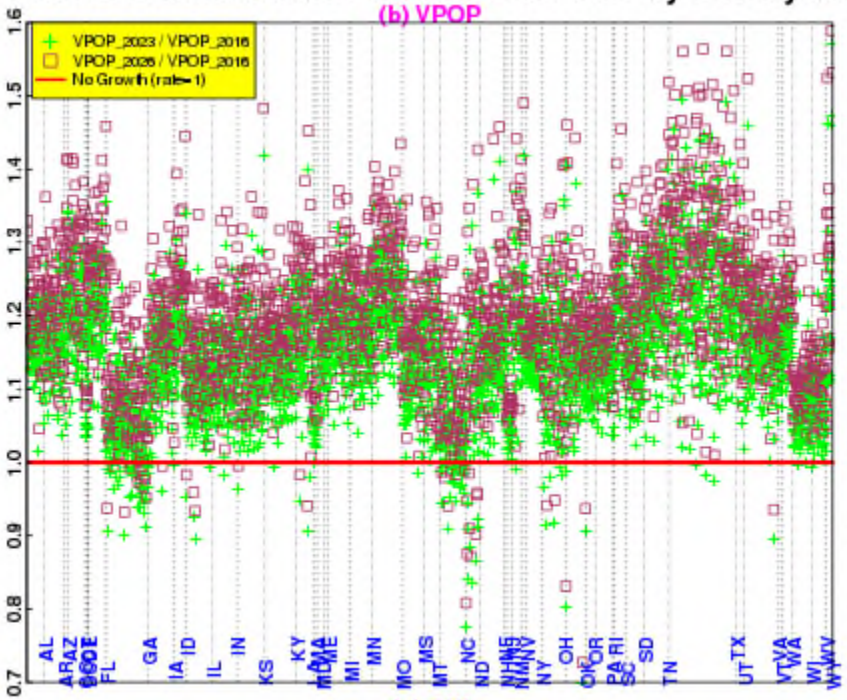
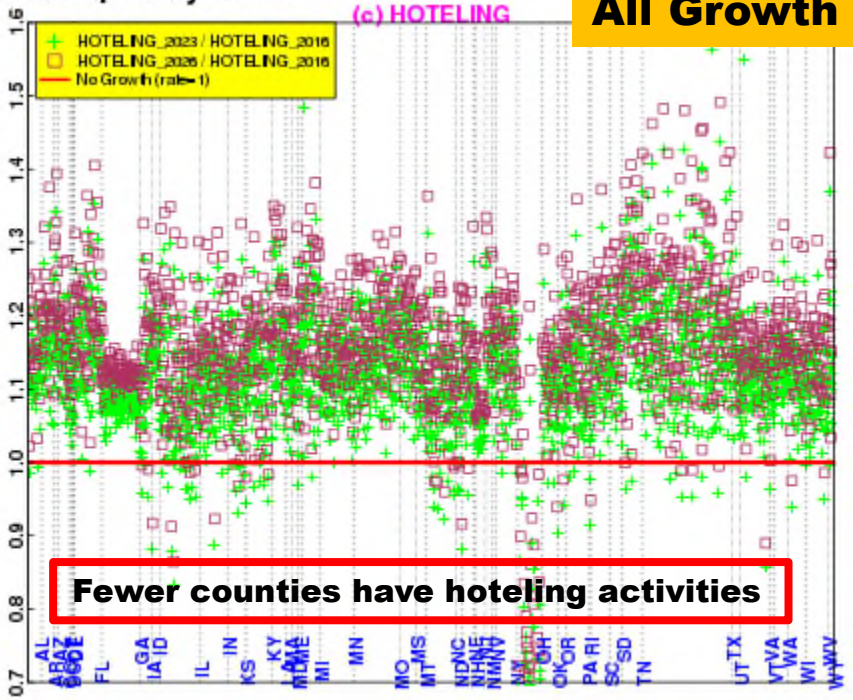
Negative growth for GA, IL, NC, ND, and OH
State-supplied FY VPOP by some states may be too low

2016v2-based 2023 and 2026 Growth Rates for Five Acitivities by County and Grouped by State

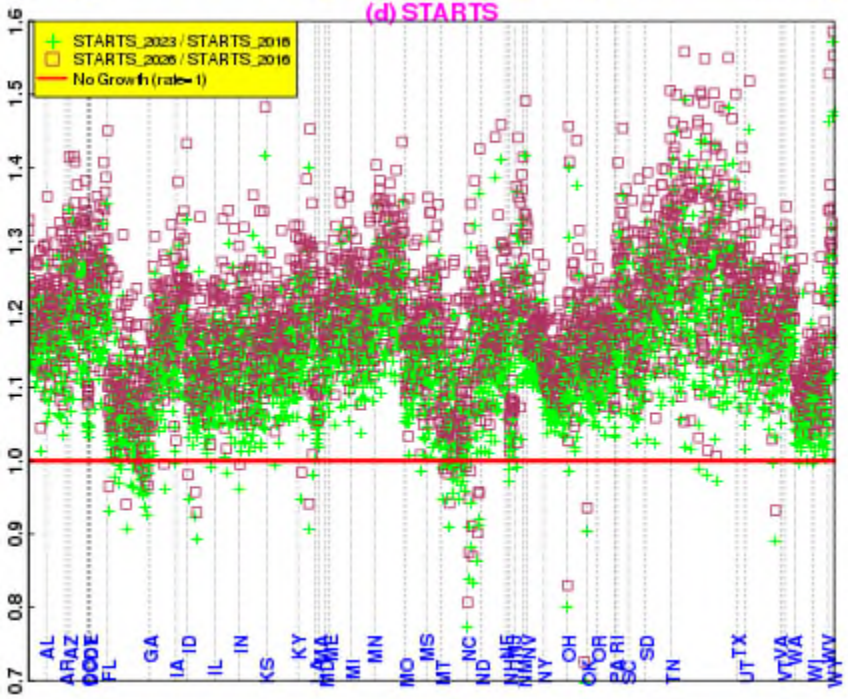
All Growth

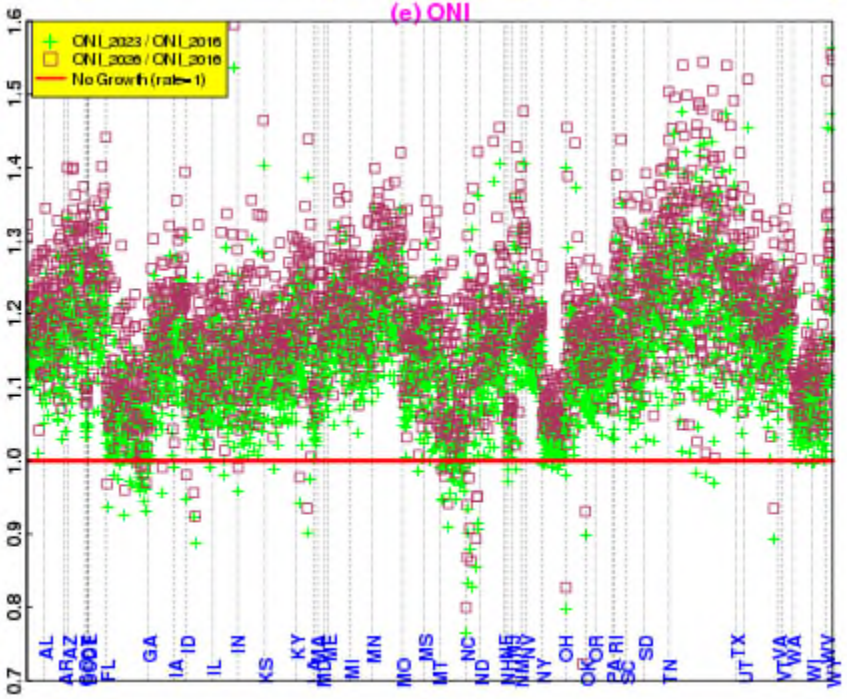






Fewer counties have hoteling activities



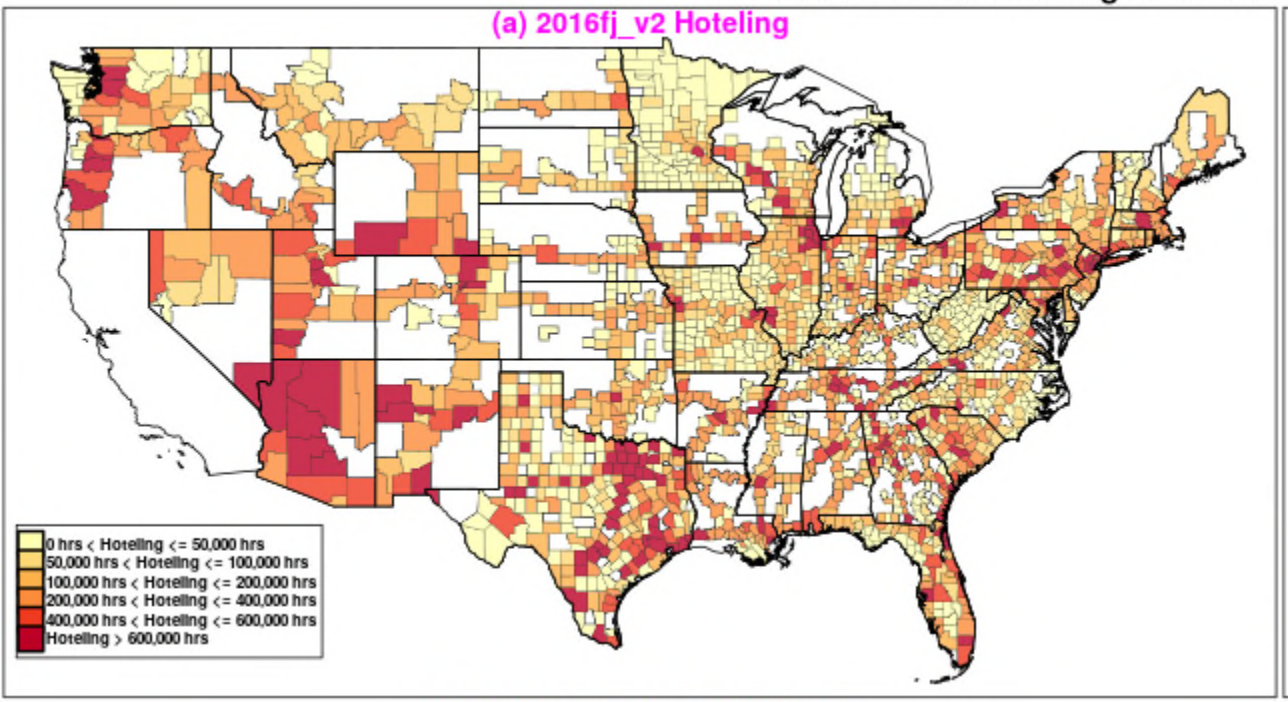


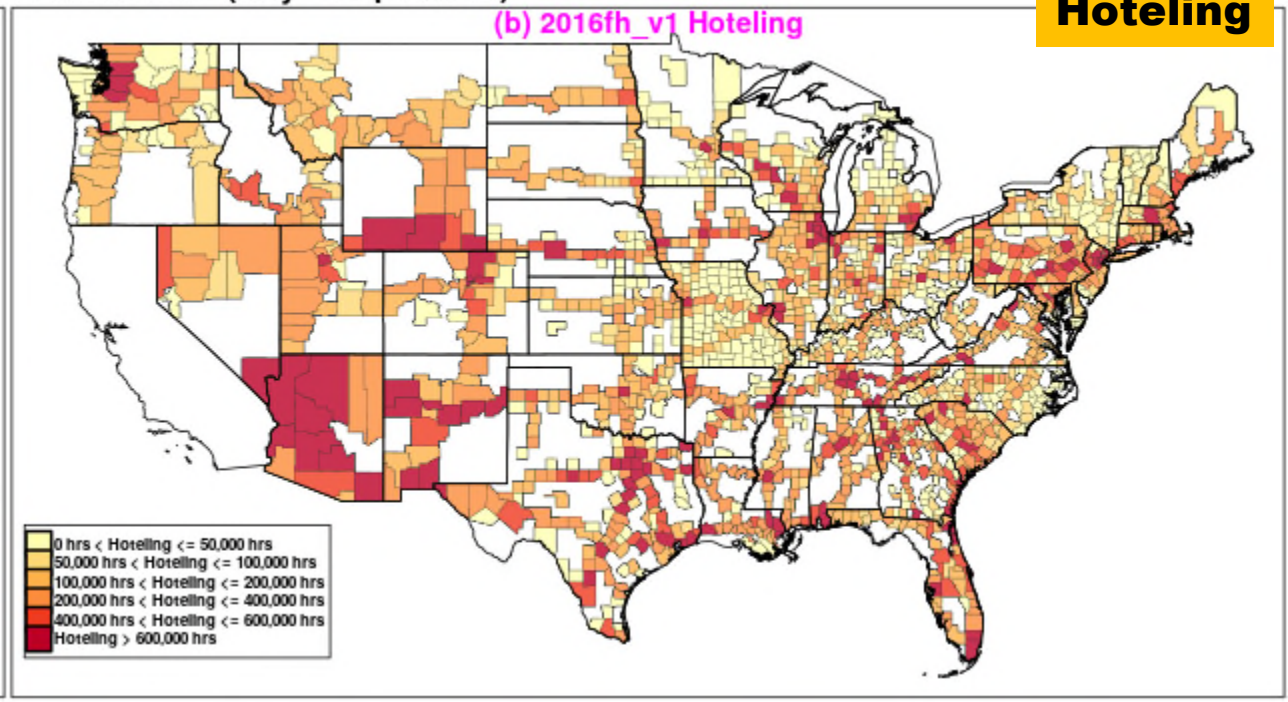
Same county-specific growth factors are applied to VMT, VPOP, STARTS, and ONI. Growth factors for HOTELING are slightly lower

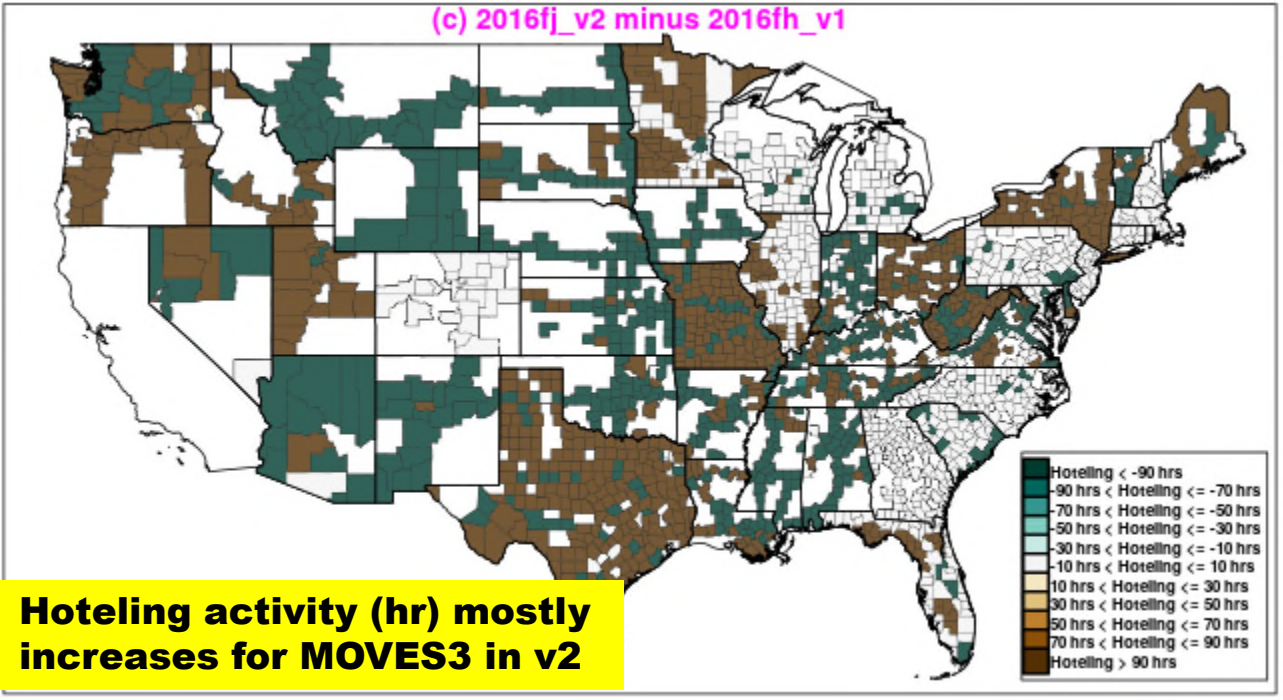
State-supplied FY data by some states may be too low

Differences in Hoteling Hours over Five Months (May -- September)

Hoteling







Hoteling activity (hr) mostly increases for MOVES3 in v2

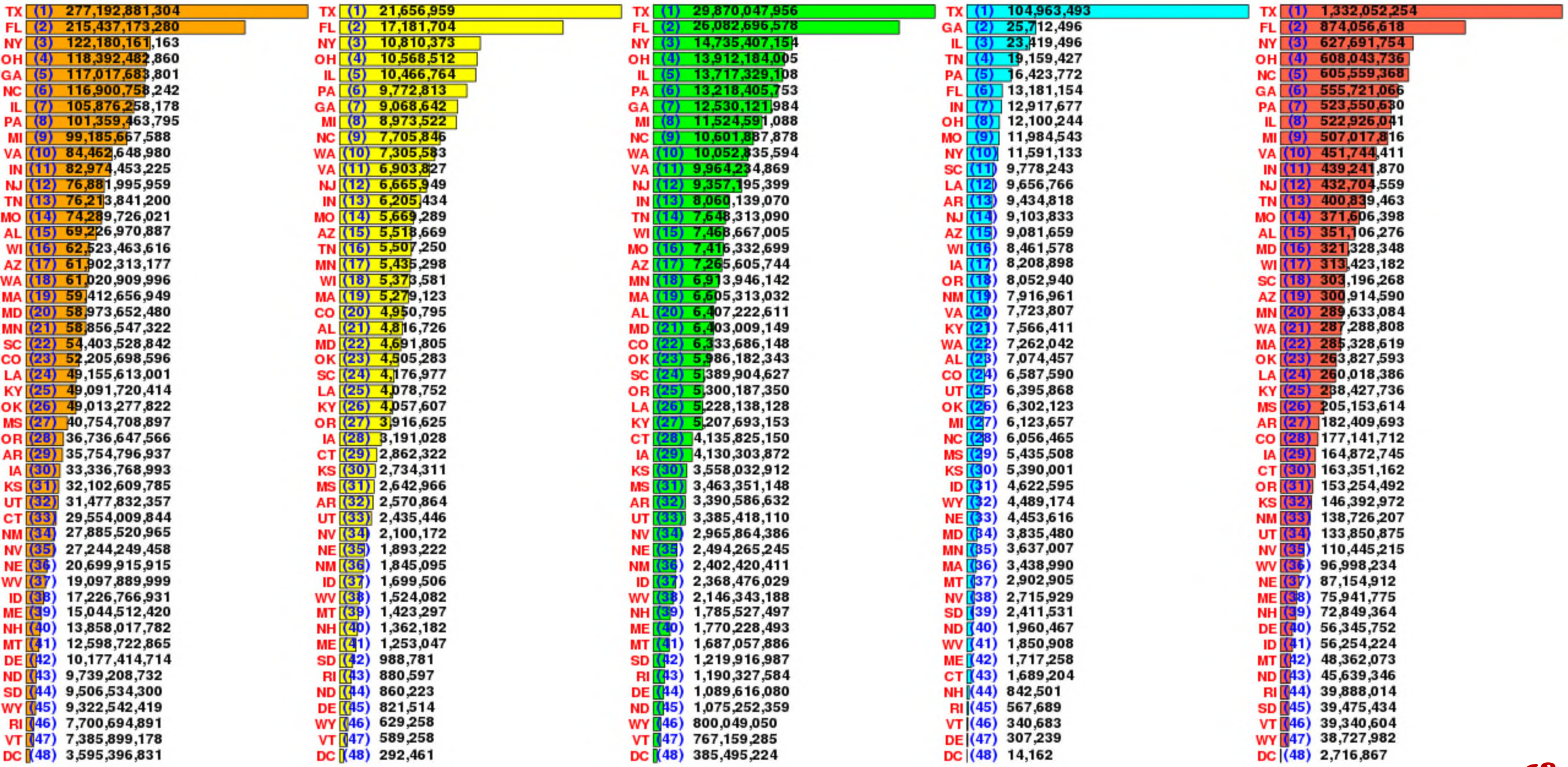
HOTELING is implemented inconsistently among states. Some states have the activity in every single county (IL, IN, MO, SC, TX, WI)

SMOKE EXT surrogates were based on rest stops developed by VADEQ;
Surrogates isolating only rest stops on interstates should improve EXT estimates

CA excluded

2016fj_v2 Five SMOKE-MOVES Annual Activities Ranked by State

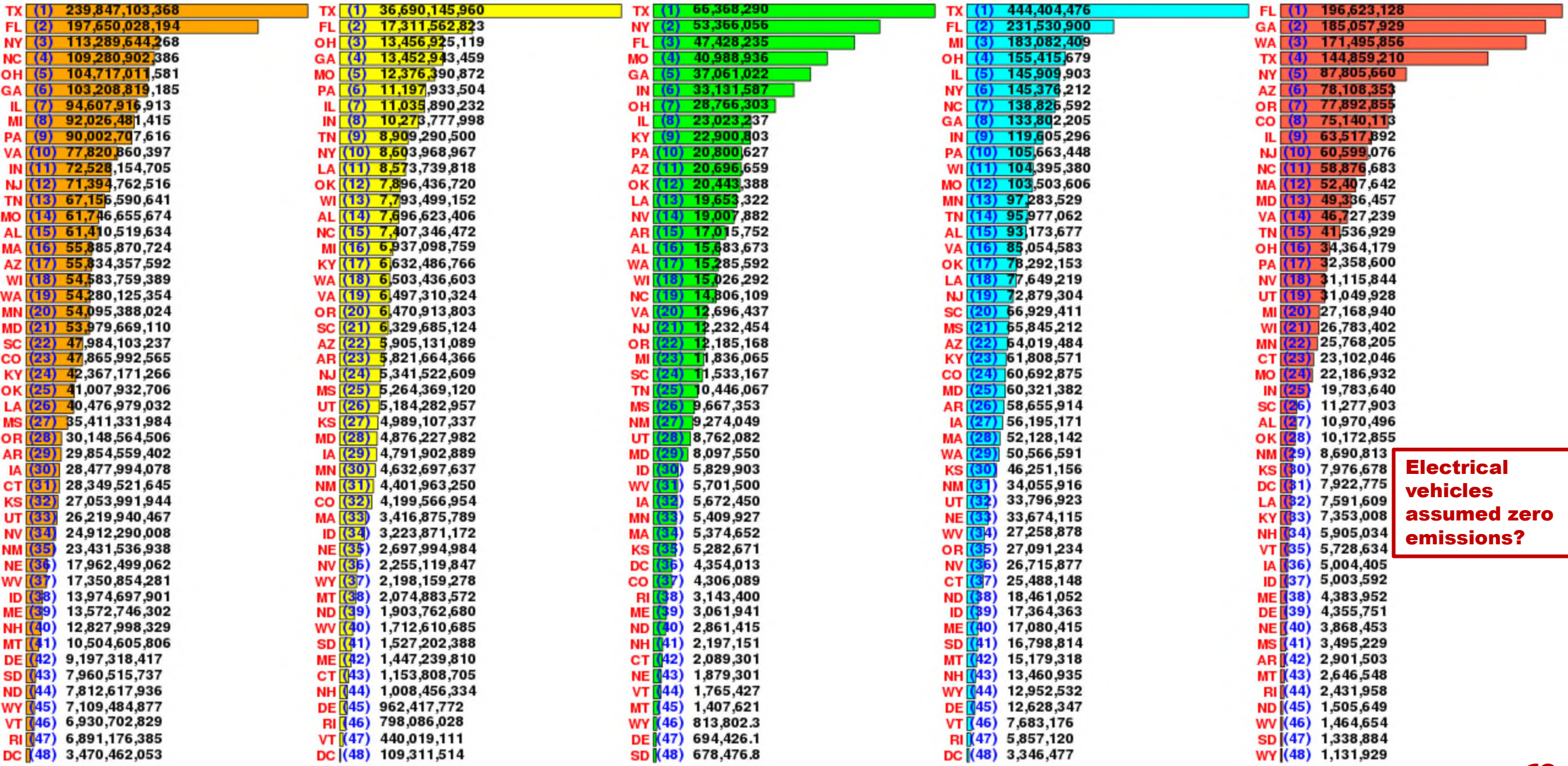
Five Activities



CA excluded

2016fj_v2 Annual VMT Fuel Rank by State

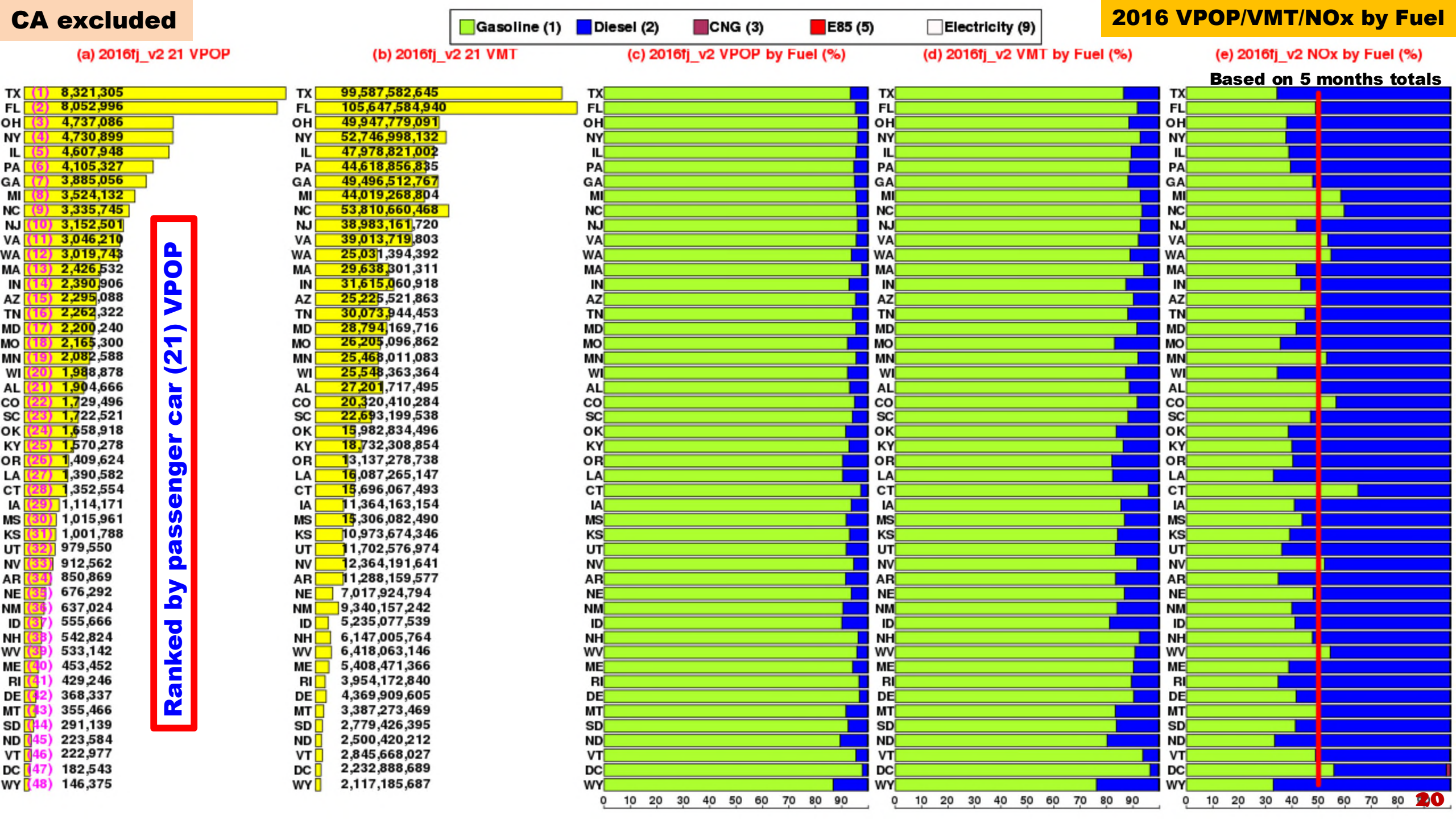
VMT by Fuel



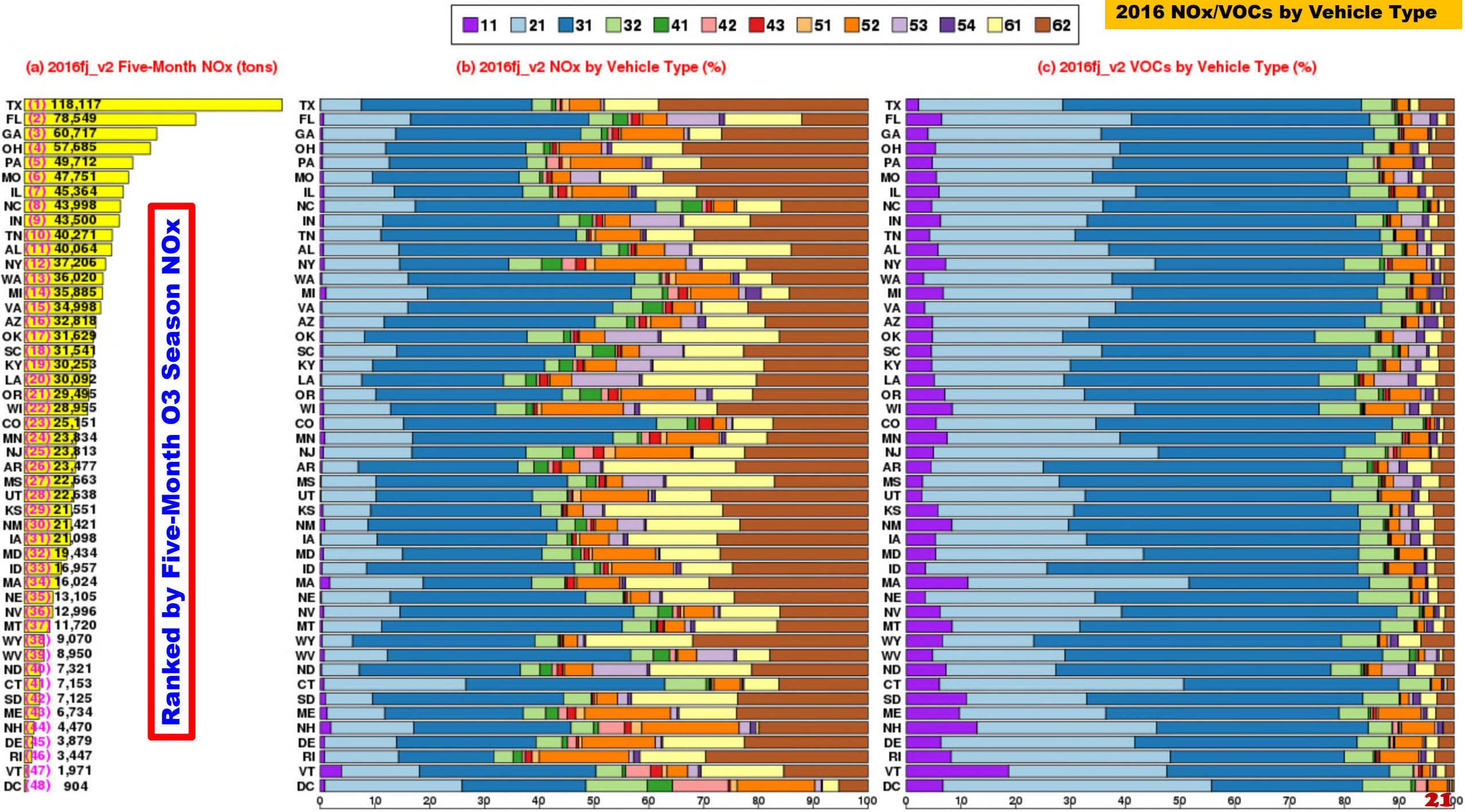
Electrical vehicles assumed zero emissions?

CA excluded

2016 VPOP/VMT/NOx by Fuel



2016 NOx/VOCs by Vehicle Type



Outlines of Talk

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

-- MOVES3 in 2016v2 versus MOVES2014b in 2016v1 (MOVE version change)
-- BY 2016 versus FY 2023/2026 (future year reduction)

2016 BY CMAQ Air Quality Modeling Platforms

Category/Platform	Platform beta	Platform v1	Platform "post v1"
Domain Size	OTC12 (172 x 172) original OTC12 domain	12OTC2 (273 x 246) expanded OTC12 domain	12OTC2 (273 x 246) Expanded OTC12 domain
Baseline Model	CMAQv5.3	CMAQv5.3.1	CMAQ5.3.1
Probing Tool	none	none	none
Meteorology	WRF v3.8, MCIP v4.3	WRF v3.8, MCIP v5.0	WRF v3.8 MCIP v5.0
Vertical Layer	35	35	35
Emissions	EPA 2016ff (beta)	EPA 2016fh (v1)	2016fh (v1) with ERTAC
(a) surface	anthropogenic + biogenic	anthropogenic + biogenic	anthropogenic + biogenic
(b) point	inline	inline	inline
Boundary Condition	EPA 36km CMAQ	NY CMAQ w/ 2016 v1	???

Outdated

-- Post v1 platform, developed by NYSDEC for OTC states, includes correction to airport emissions and time-shift fix for ERTAC2.1.3 EGUs;
-- The platform is used in this study as CMAQ baseline runs for 2016 BY and 2023 FY;
-- Baseline emissions need modifications to be able to quantify impact of new MOVES3 (next page)

2016 ozone episodes: 05/24 – 05/26
07/21 – 07/22

Emission Modification for CMAQ Sensitivity

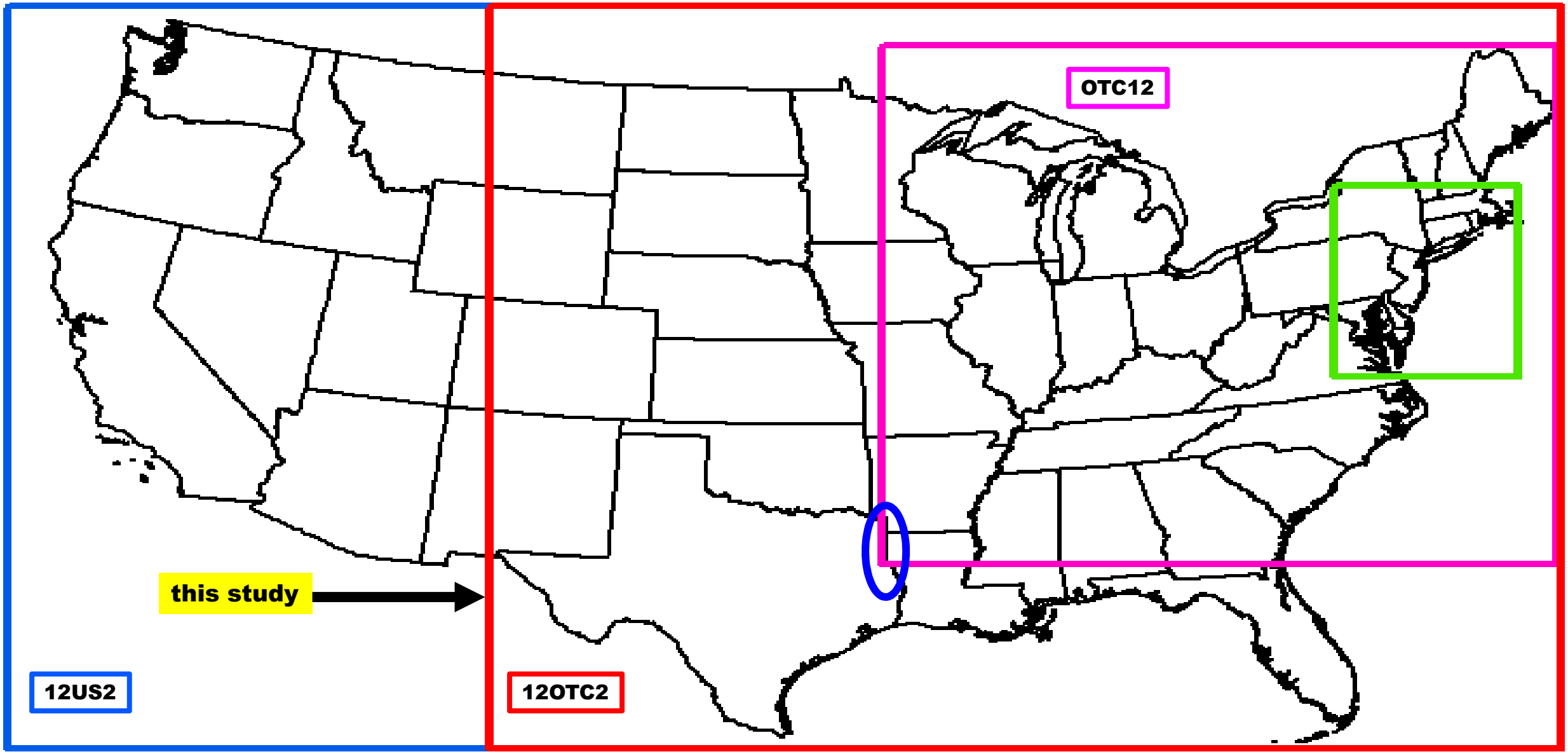
- **Sensitivity = Baseline + Delta Change**
  - **Sensitivity: CMAQ sensitivity with modified emissions**
  - **Baseline: CMAQ with "original" emissions of 2016fh (v1) 2d surface emissions and ERTAC point inline emissions (see previous page)**
  - **Delta Change: change in mobile sector to be quantified for ozone impact**

  Delta Change = MOVES3 onroad – MOVES2014b onroad
  - **Delta Change includes four SMOKE-MOVES onroad runs (2 MOVES versions, 2 years 2016/2023):**
    - **2016v1 (MOVES2014b)**
    - **2016v1-based 2023**
    - **2016v2 (MOVES3)**
    - **2016v2-based 2023**

Delta includes only differences between two MOVES versions, and nothing else

- **Four CMAQ runs (two baseline runs and two sensitivity runs) have been conducted for five months from May to September to quantify ozone impacts of switching to MOVES3 from MOVES2014b**
  - **2016 baseline (OTC platform developed by NYSDEC, previous page)**
  - **2023 baseline (OTC platform developed by NYSDEC, previous page)**
  - **2016 sensitivity (w/ "baseline + delta" emissions prepared by DEQ using mrggrid)**
  - **2023 sensitivity (w/ "baseline + delta" emissions prepared by DEQ using mrggrid)**

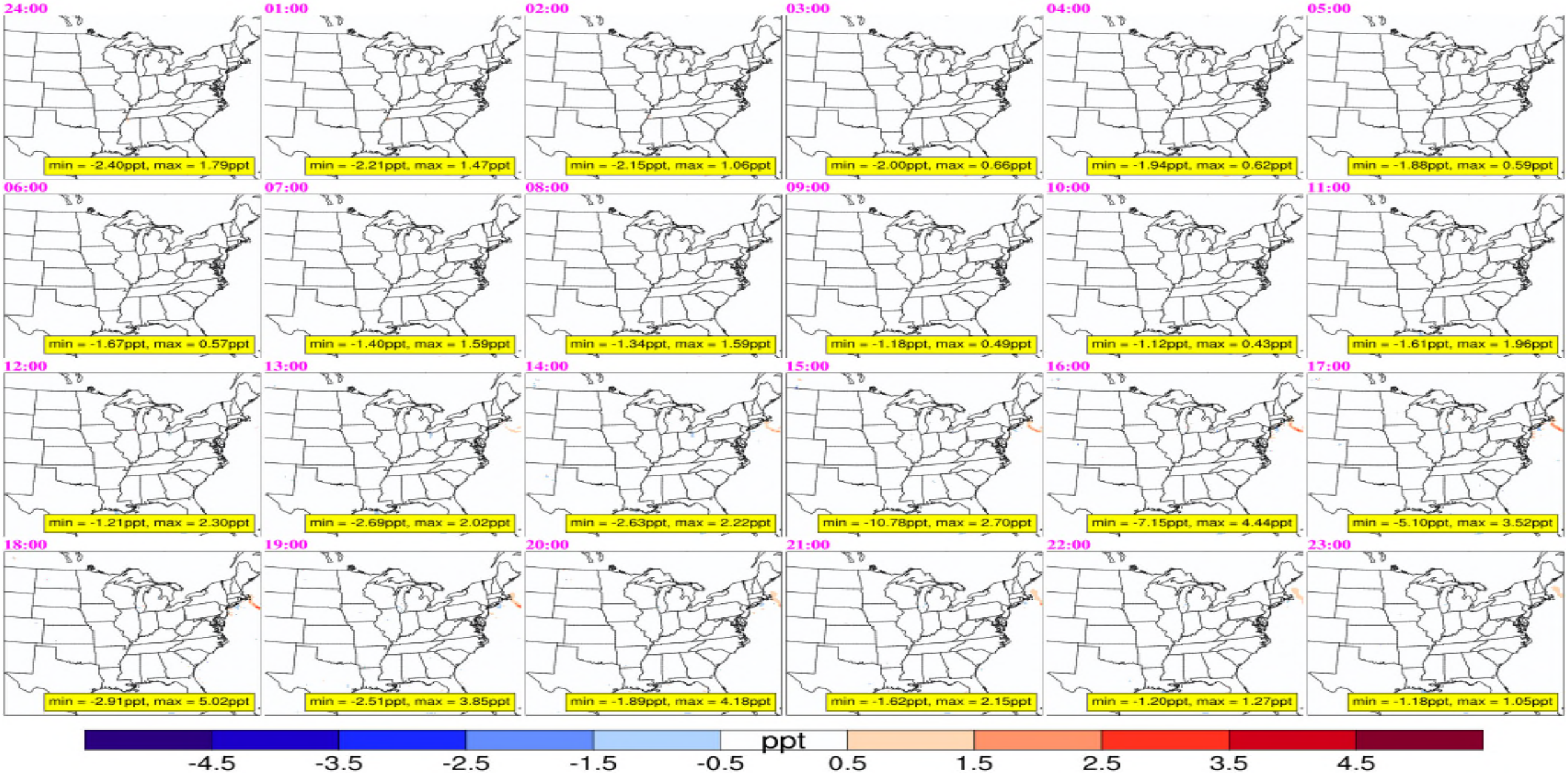
Modeling Domains



-- OTC12 (172 x 172): Original OTC12 domain;
-- 12OTC2 (273 x 246): Expanded OTC12 domain;
-- 12US2 (396 x 246): EPA 12US2 domain

Comparison between NYSDEC and VADEQ Modeling – 2016 CMAQ Baseline

O3 2016v1_base_531 NYSDEC minus O3 2016v1 base_531 VADEQ in 24 hours (GMT) on May 25

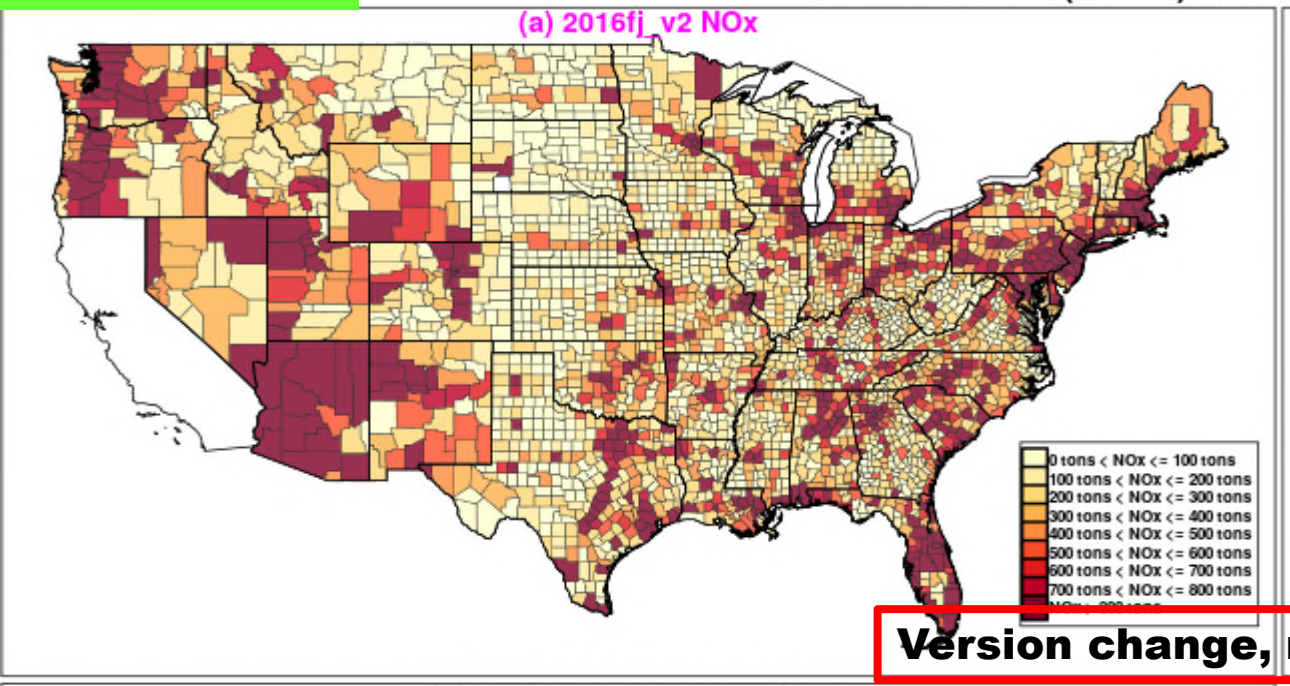


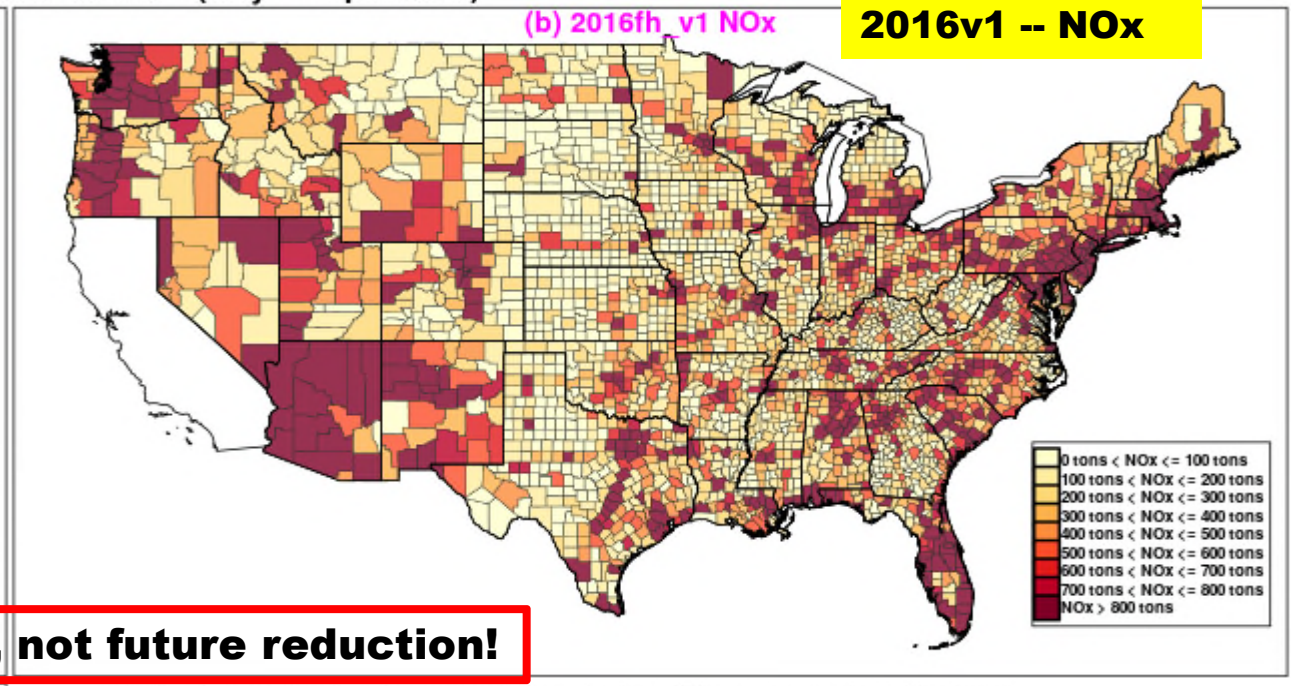
Differences in hourly O3 on May 25 (a high O3 day) between two modeling centers are barely visible (a few ppt)

Version change

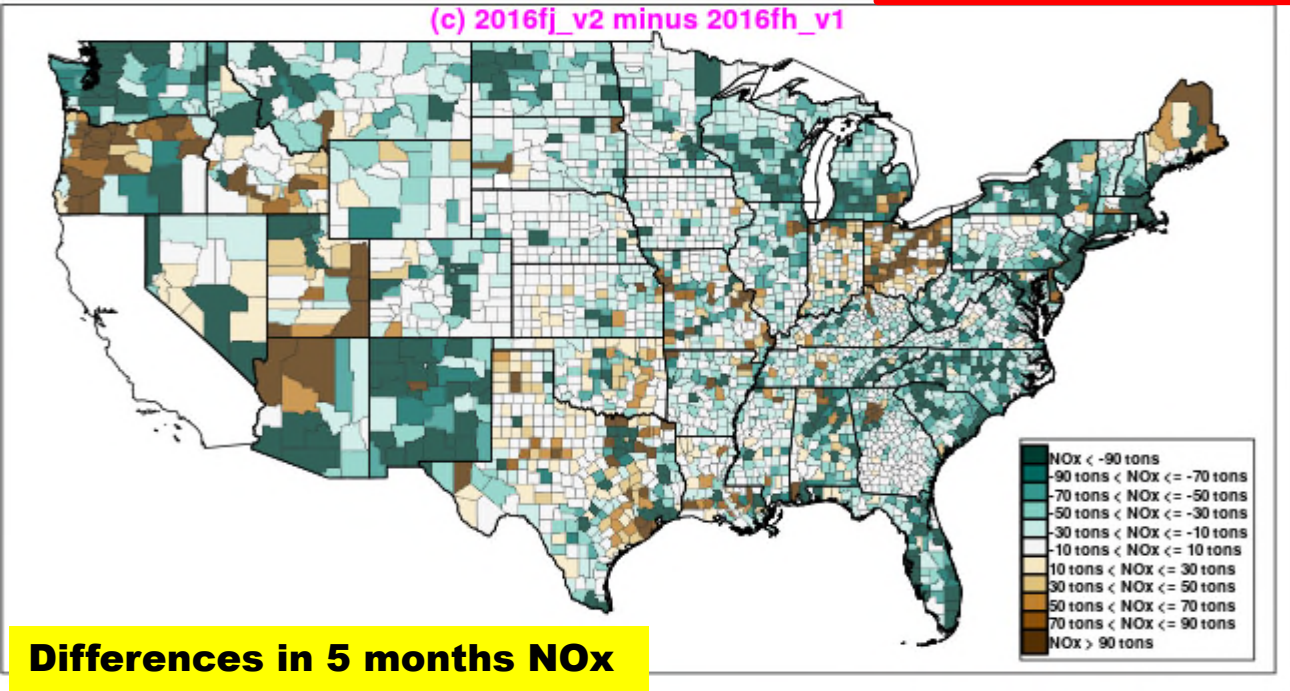
2016v2 versus 2016v1 -- NOx

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

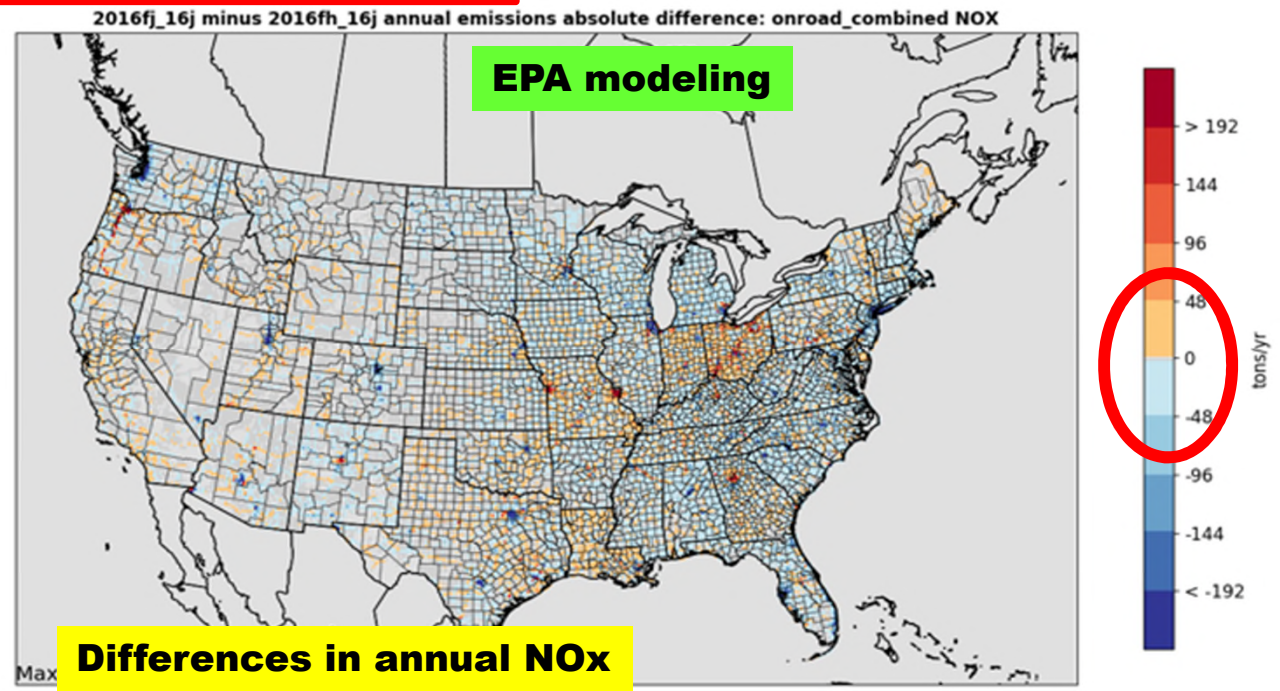




Version change, not future reduction!



Differences in 5 months NOx



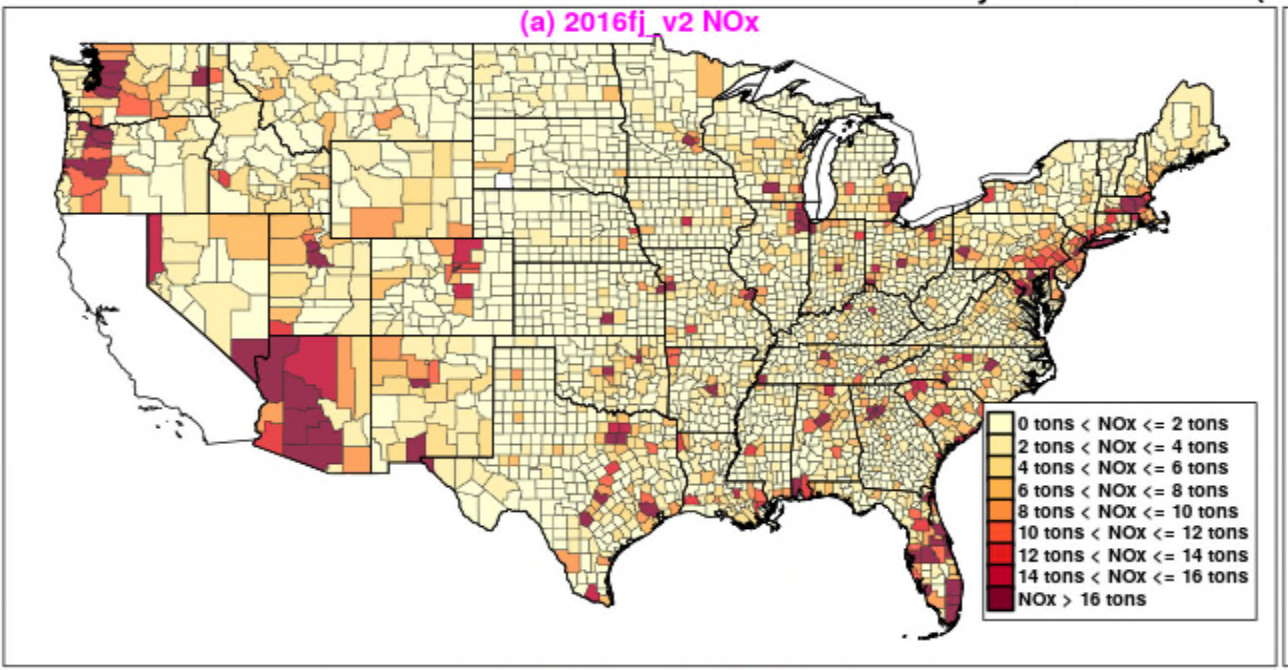
Differences in annual NOx

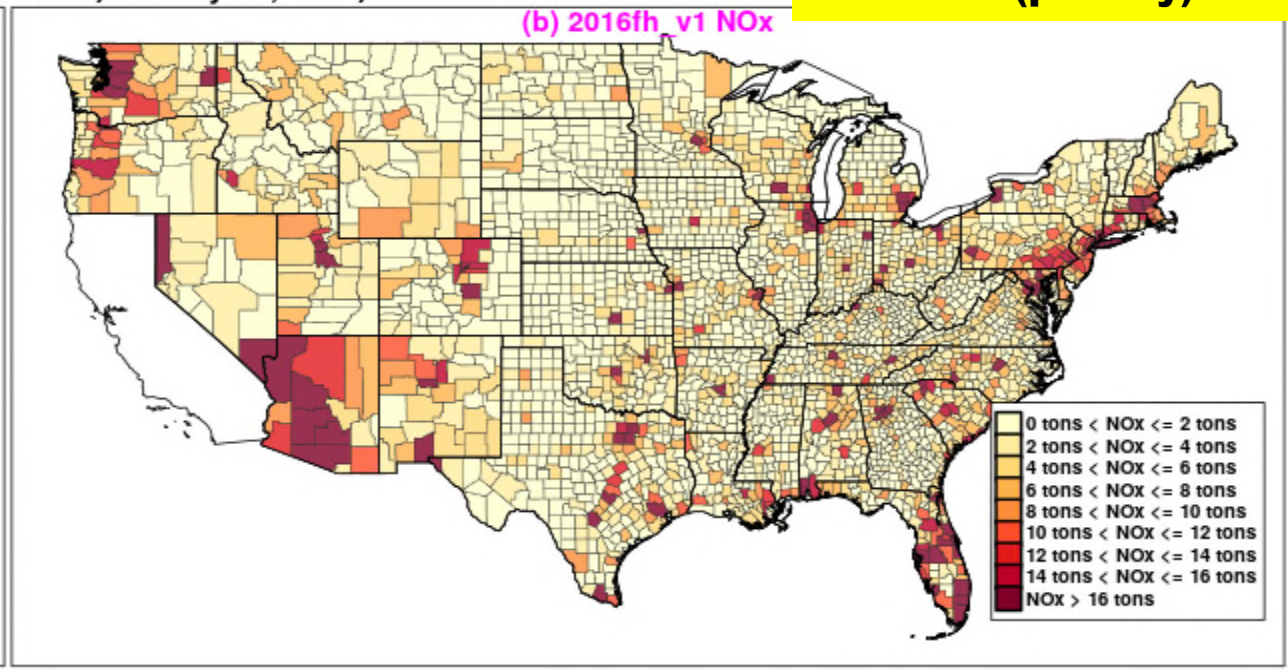
Version change

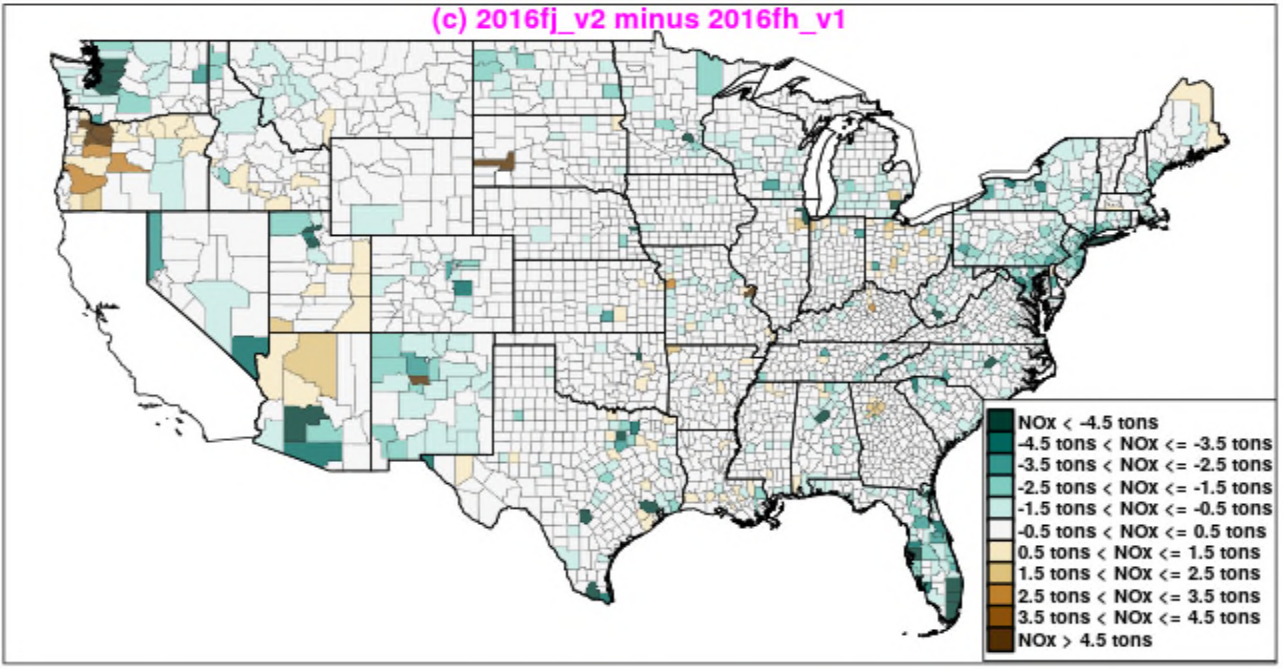
Significance of NOx Change

Daily NOx Differences (in tons) on July 22, 2016)

2016v2 versus 2016v1 – NOx (per day)



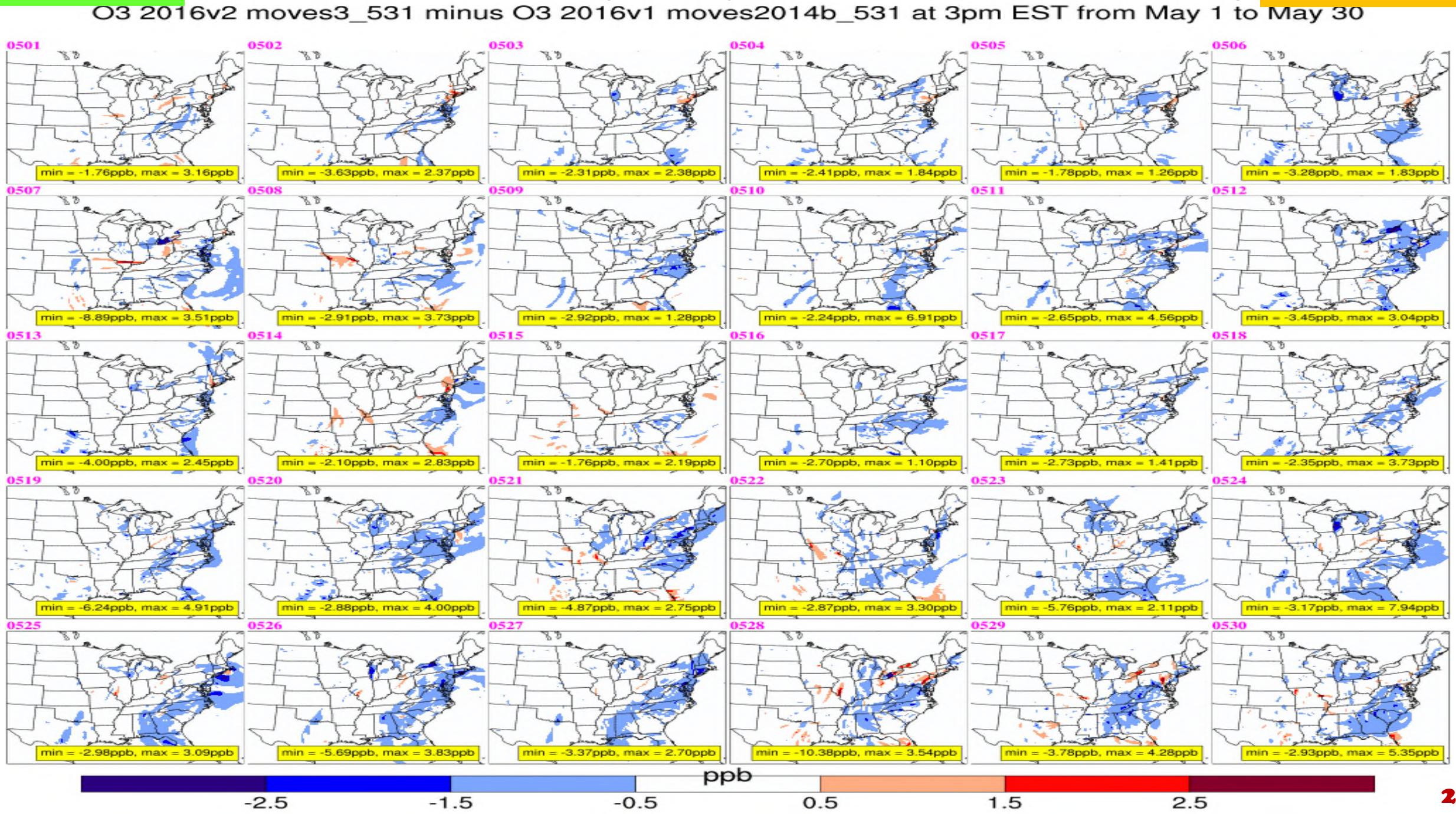




Rule of thumb (by Doris McLeod):
5 -- 10 tons/day of NOx =~ 0.5 -- 1ppb of O3 (for EGUs)

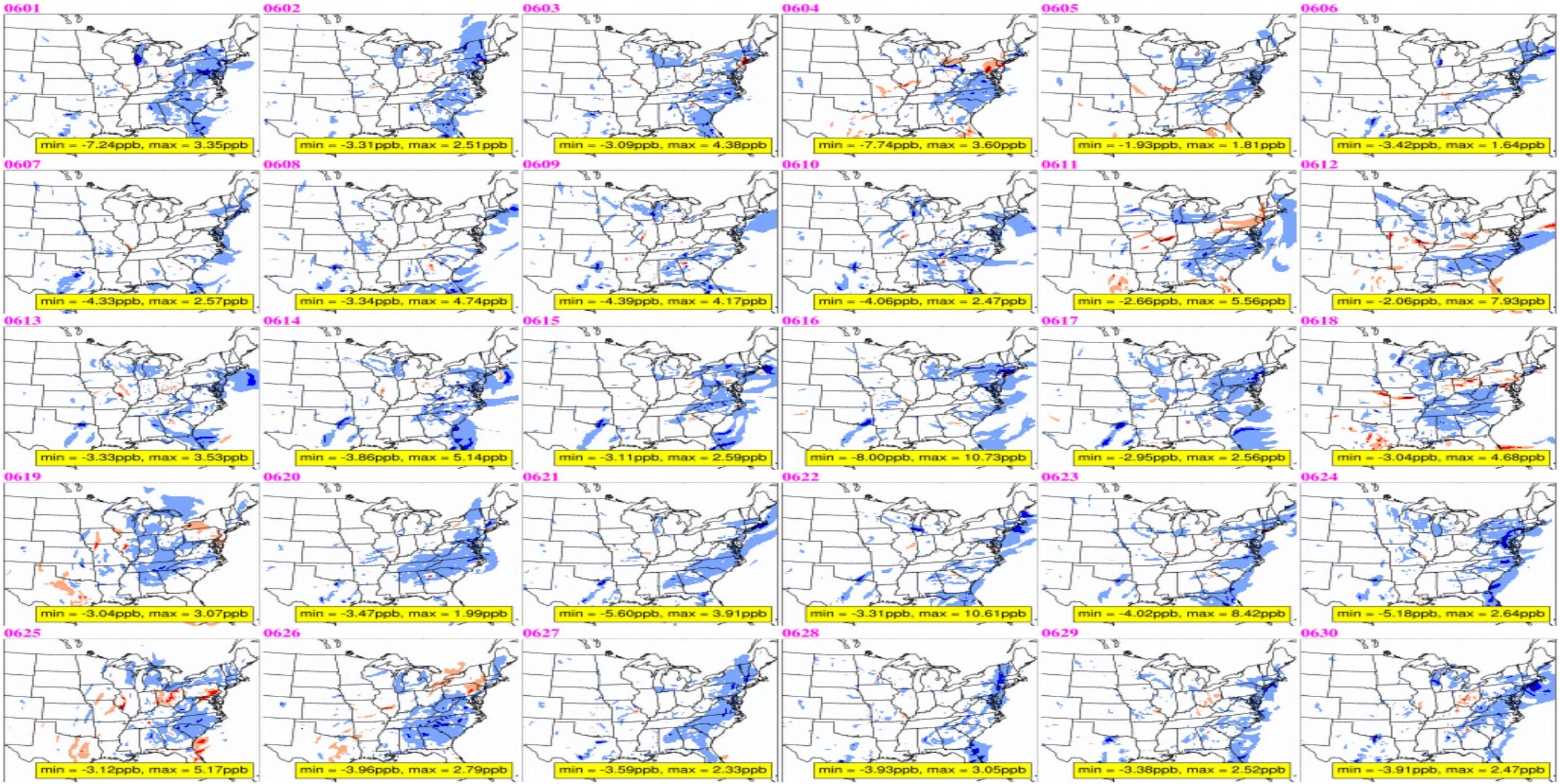
- -- The plots show daily NOx (ton/day) on July 22, a high O3 day;
- -- The "rule" was originally estimated years ago for EGUs;
- -- Meteorology and chemistry have changed over the year;
- -- CMAQ runs are being planned to re-do the analysis and obtain more suitable estimates for area sources (infinite point sources) such as onroad

Version change **O3 Impact of New MOVES Model (Sensitivity minus Baseline, MOVES3 -- MOVES2014b)** **3pm May 2016**

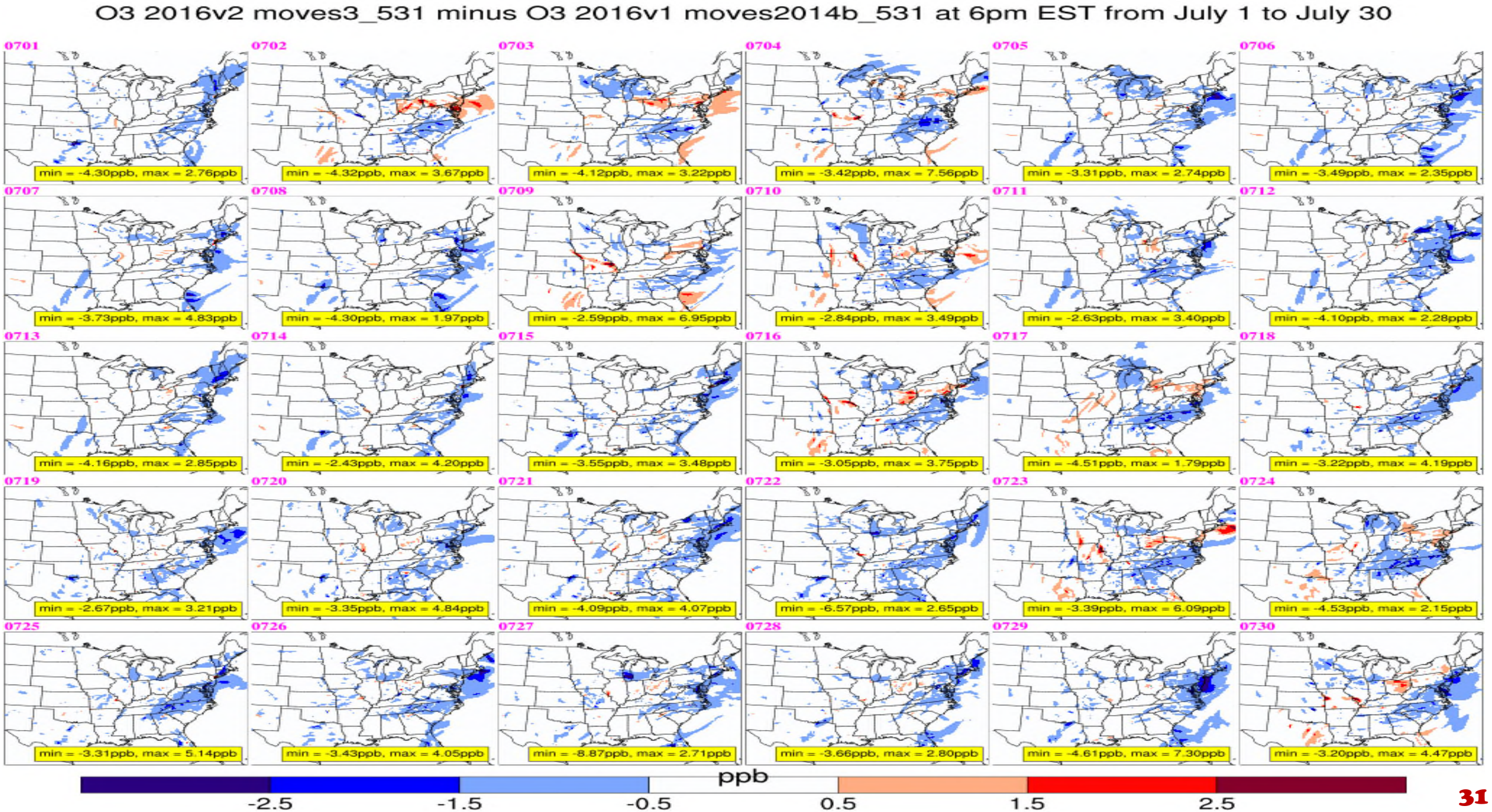


Version change **O3 Impact of New MOVES Model (Sensitivity minus Baseline, MOVES3 -- MOVES2014b)** **5pm June 2016**

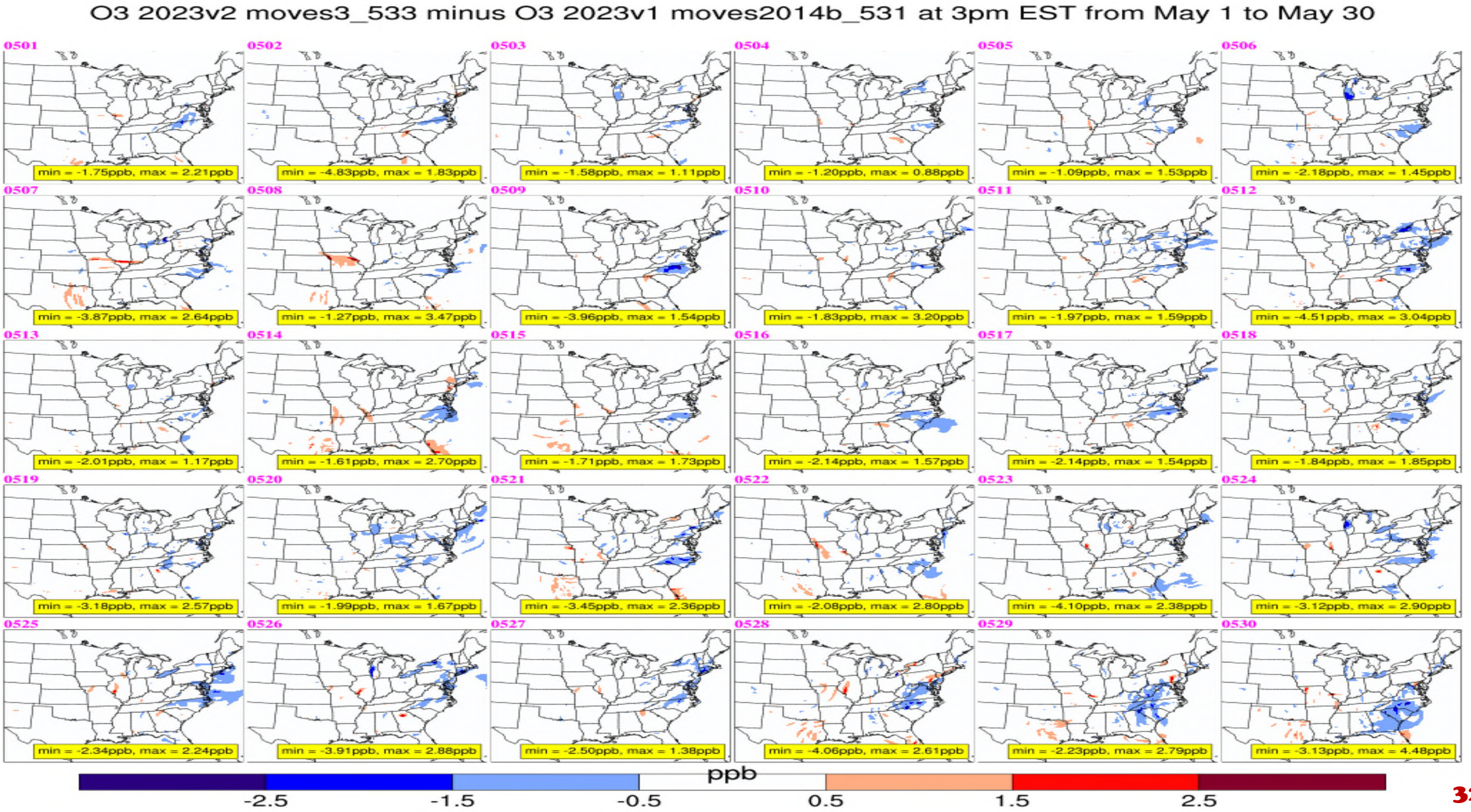
O3 2016v2 moves3_531 minus O3 2016v1 moves2014b_531 at 5pm EST from June 1 to June 30



Version change **O3 Impact of New MOVES Model (Sensitivity minus Baseline, MOVES3 -- MOVES2014b)** **6pm July 2016**



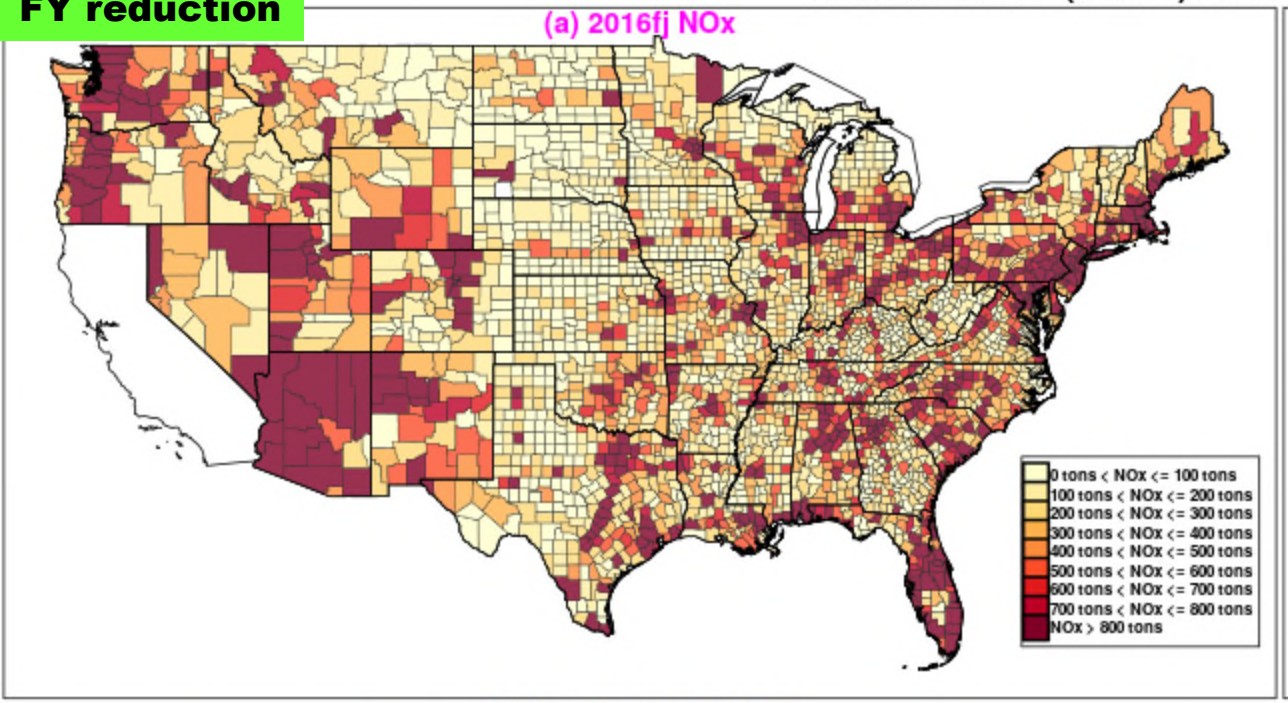
Version change **O3 Impact of New MOVES Model (Sensitivity minus Baseline, MOVES3 -- MOVES2014b)** **3pm May 2023**

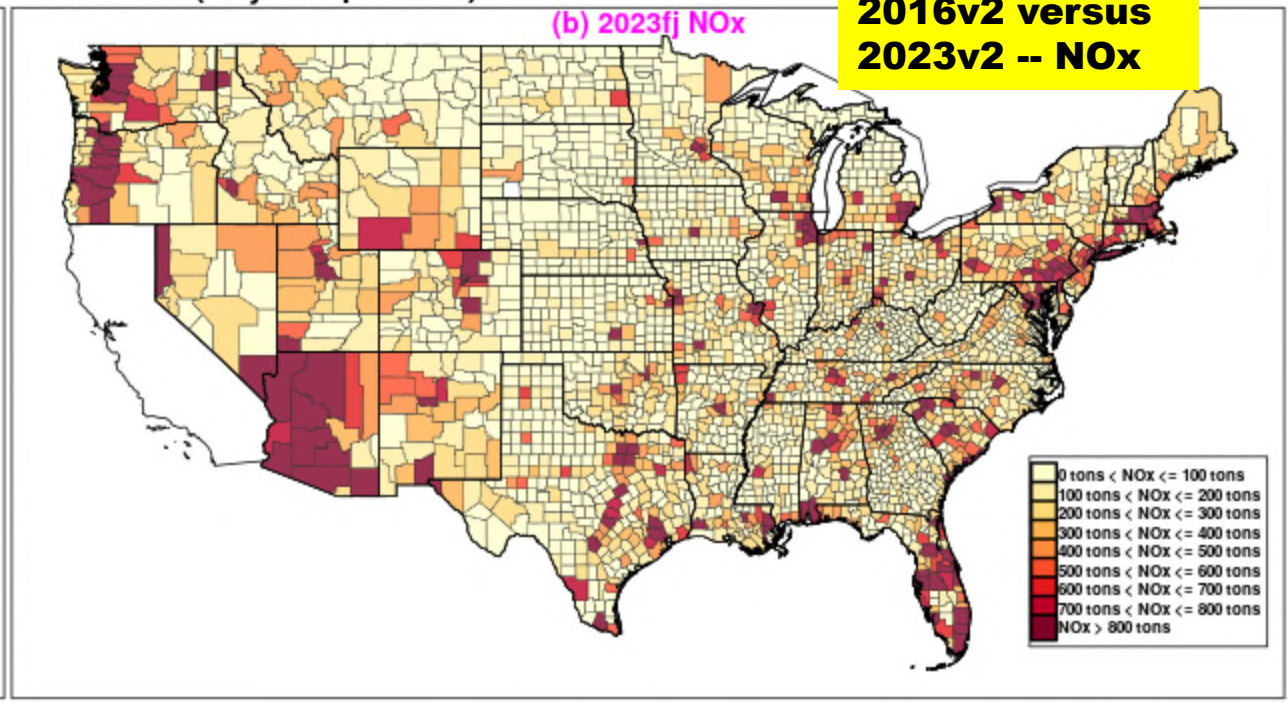


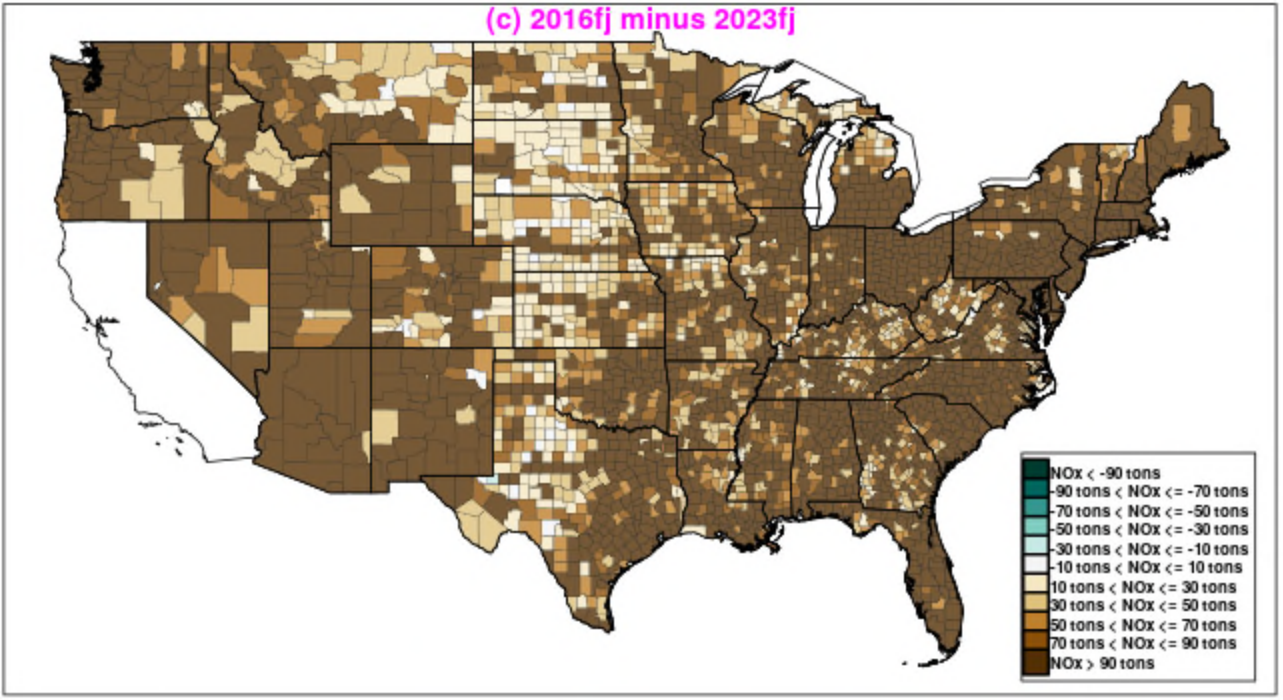
FY reduction

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

2016v2 versus 2023v2 -- NOx







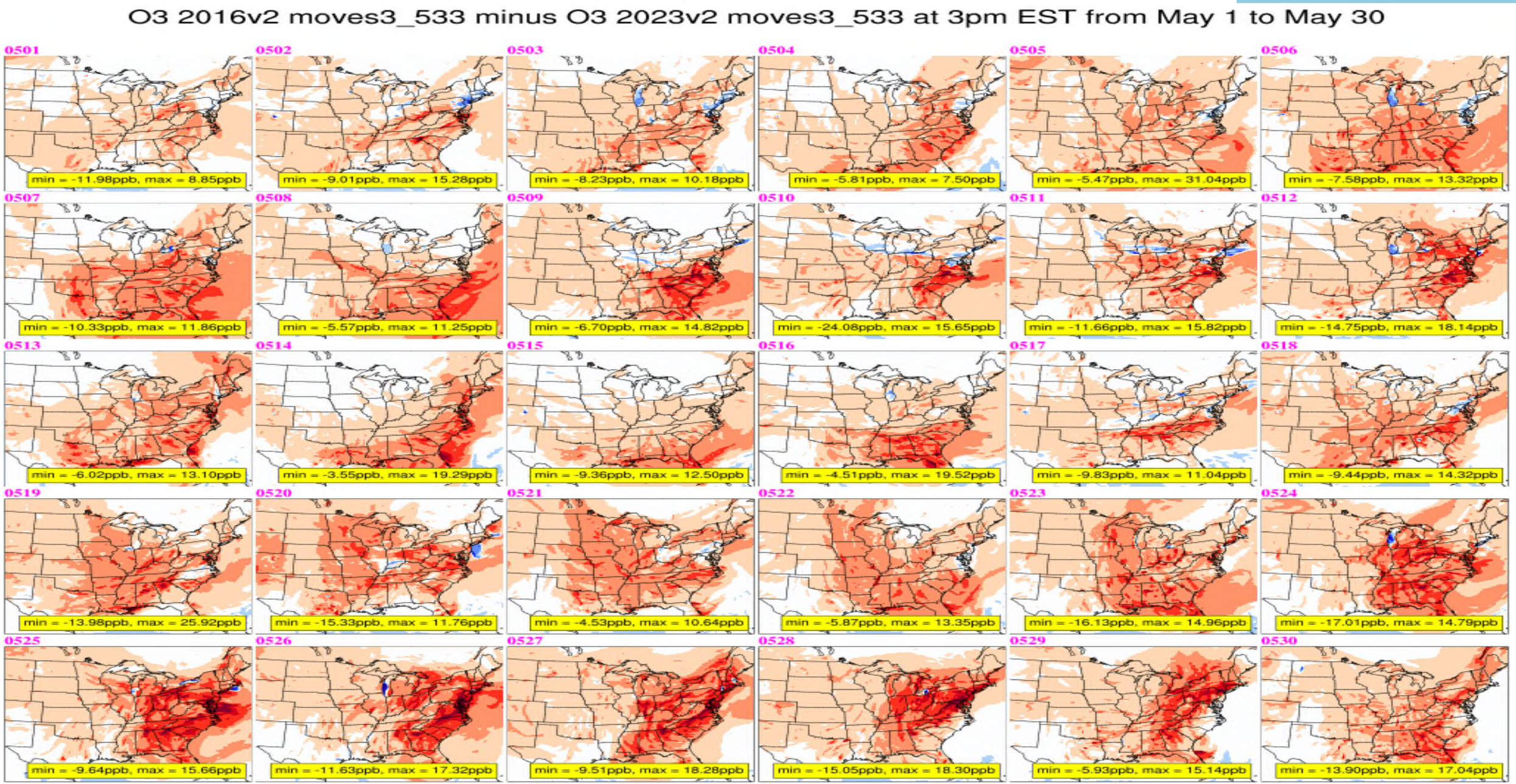
2016v2 > 2023
==> Future year 2023 NOx Reduction

Is 2023 (next year!) projection reasonable??
-- modeling goals (what we want to achieve/answer)?
-- differences in meteorology (BY 2016 vs FY 2023)
-- emission estimates based on AEO growth
-- bottom-up approach for all sectors (issue not limited to onroad)

FY reduction

Differences in O3 (2016 minus 2023) – Reduction in 7-year Time Span

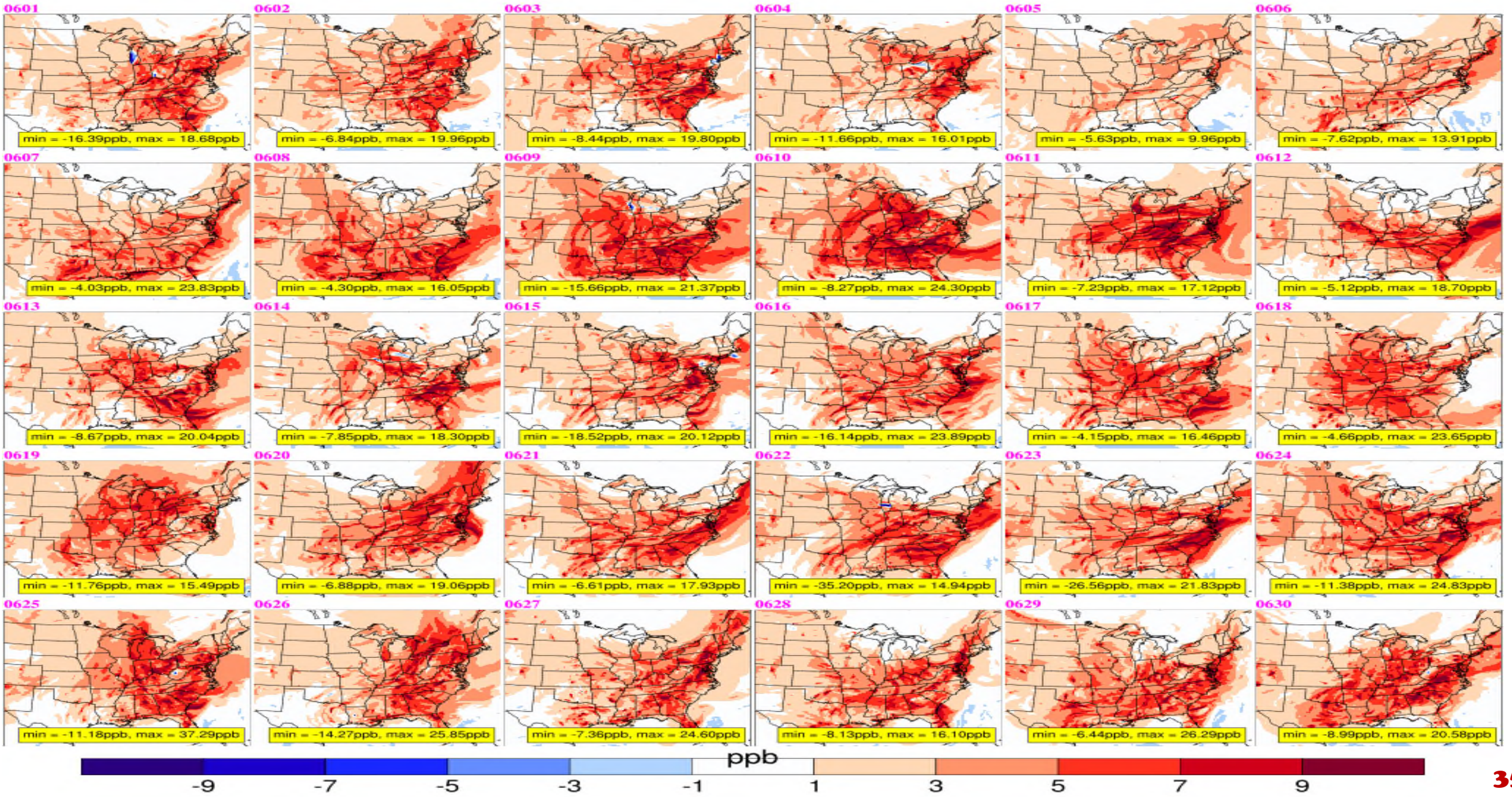
3pm May 2016/2023



FY reduction

Differences in O3 (2016 minus 2023) – Reduction in 7-year Time Span

5pm June 2016/2023



Summary

- 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 (from Part one)
- Four SMOKE-MOVES runs (2016v1, 2016v1-based 2023, 2016v2, 2016v2-based 2023) and four CMAQ runs (2016 baseline, 2023 baseline, 2016 sensitivity, and 2023 sensitivity) have been conducted to quantify emission and air quality impacts of new MOVES3 model for BY and FY
- Age distributions for combination long-haul trucks (class 62) show no county-to-county or state-to-state variations; consequently there is only one age distribution for the 62 vehicle class for the entire continental US
- Similarly, age distributions for single-unit long-haul trucks (class 53) show no county or state variations for a great majority of states. However, a handful of states show county-to-county variations (GA, ME, MD, NH, NY, NC, UT, and VT)
- Texas seems to have submitted its own data to replace EPA's regional data. In addition to creating inconsistency, data supplied by TX shows much younger fleets overall for several vehicle types, decreasing its onroad emissions comparatively (Already highest-in-the-nation onroad emissions in TX could be even higher)
- In general, future year vehicles are projected to be younger than base year while activities are projected to steadily increase
- All five accumulative onroad activities -- VMT, VPOP, hoteling, engine starts, and on-network idling (ONI) -- are projected to increase in future years (growth factors greater than one)

Summary (cont.)

- A few state (GA, NC, OH, and WI) have much lower growth factors than other states. In addition, counties in some states (GA, IL, NC, and ND) have negative growth (growth factors less than one)
- Combination long-haul truck (62) appears to be the only vehicle type simulating extended idling on interstates (hoteling)
- Hoteling activity is applied inconsistently among states. In many states, the activity is confined to counties with interstate highways, while in other states (IL, IN, MO, NC, SC, TX) the activity is included for every county, even those without interstates
- Diesel vehicles account for only a small percentage of total VPOP or VMT but contribute a significant portion (~60%) of total NOx
- Switching to MOVES3 in 2016v2 from MOVES2014b in 2016v1 lowers O3 precursors and yields less O3. Reduction in hourly O3 due to MOVES version change is approximately 2 to 5 ppb for BY, and slightly lower in magnitude and more confined in space for FY
- Because the version change reduces O3 for both BY and FY along with various averaging in calculations, effect on future design values (DVF) is expected to be minimal
- Real impact of the version change will be in contribution source apportionment or episodic modeling. Less O3 by MOVES3 decreases importance of onroad sector while increasing importance of other sectors (eg., EGUs or nonroad) -- in comparison to MOVES2014b
- Projected O3 reduction for a not-so-distant 2023 (from 2016) may be too much and may not be in step with yet-to-be-observed air quality measurements (future work)