

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

Jin-Sheng Lin
Virginia Department of Environmental Quality

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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: AA**FF**V**RR****PP**

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

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 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 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

5 HPMS “observation-based” vehicle types

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

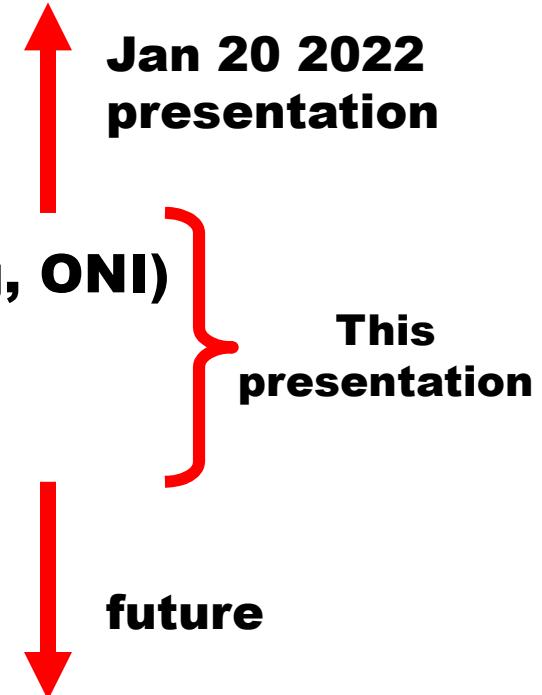
Why Consistency Matters

- 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

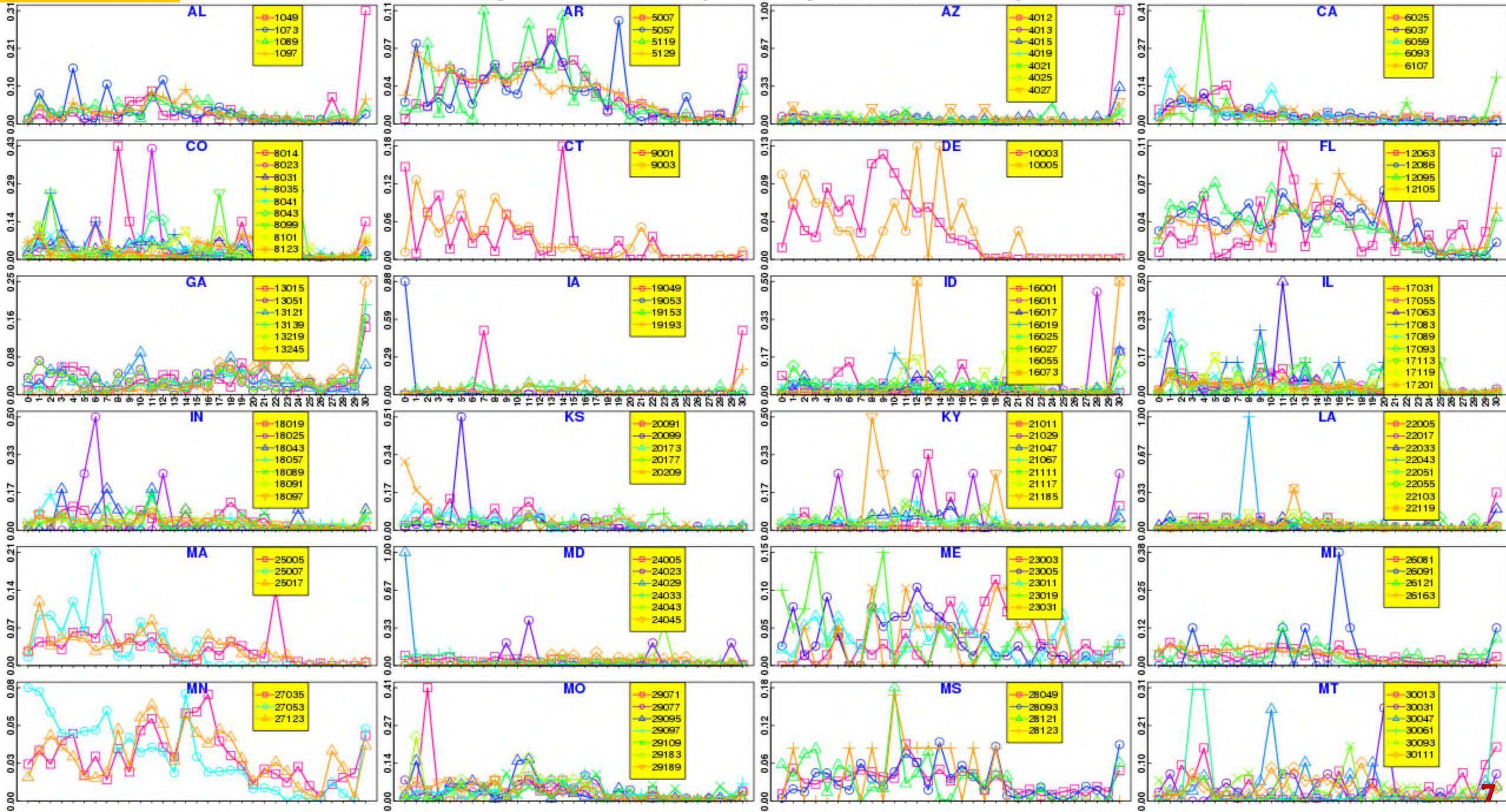
- Representative county In SMOKE-MOVES
- 2009 recession in age distributions in BY and FY
- Age distributions for all vehicle types by state
- Five accumulative activities (VMT, VPOP, Starts, Hoteling, ONI)
- Growth Factors
- Extended idling
- Temporal profiles (CRC and traffic counters)
- Fuel month in SMOKE-MOVES
- MOVES and SMOKE portions of SMOKE-MOVES



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

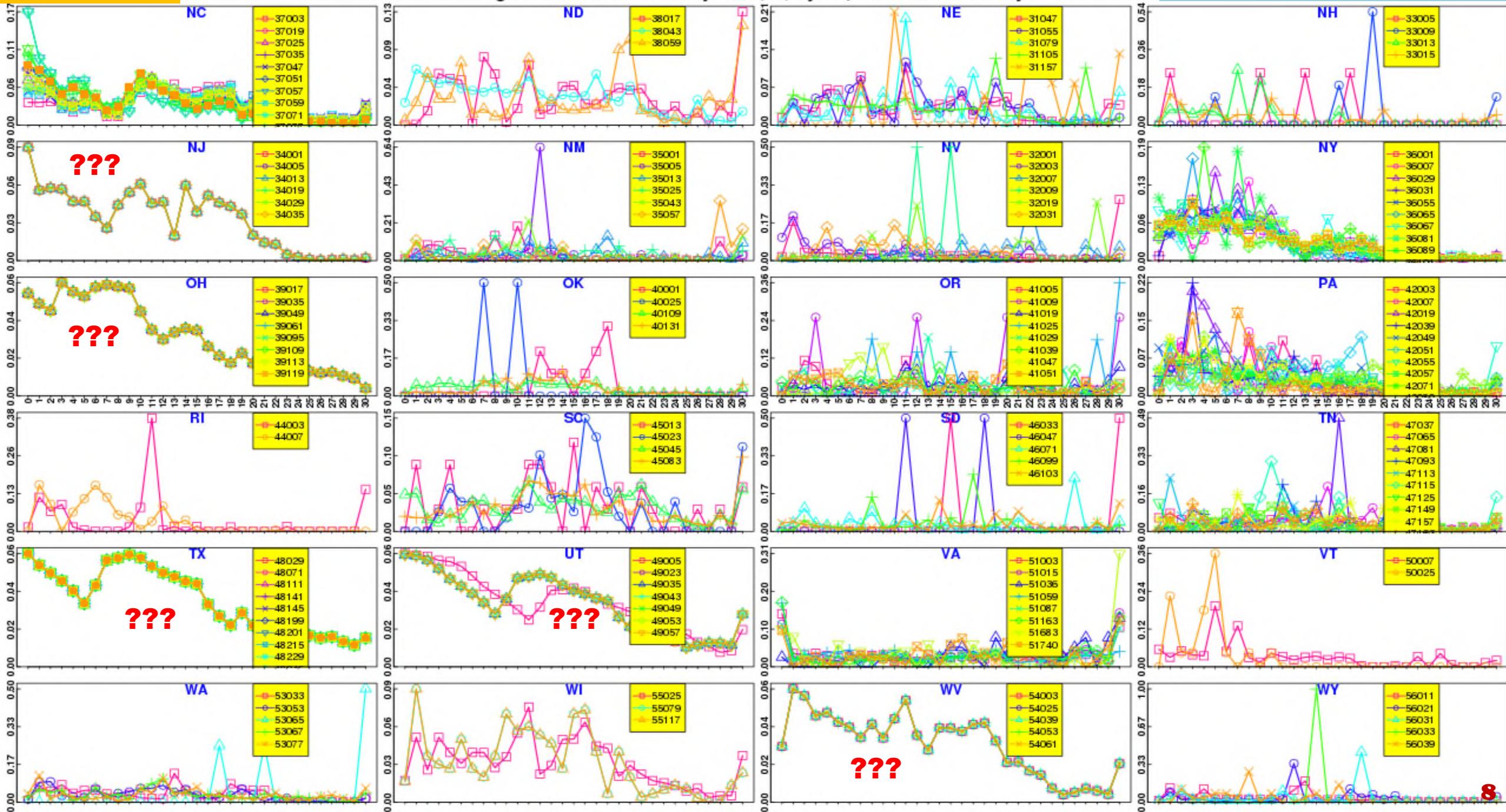
Age Fractions for Intercity Bus (41) by Representative County

2026, 41 fraction, CONUS1



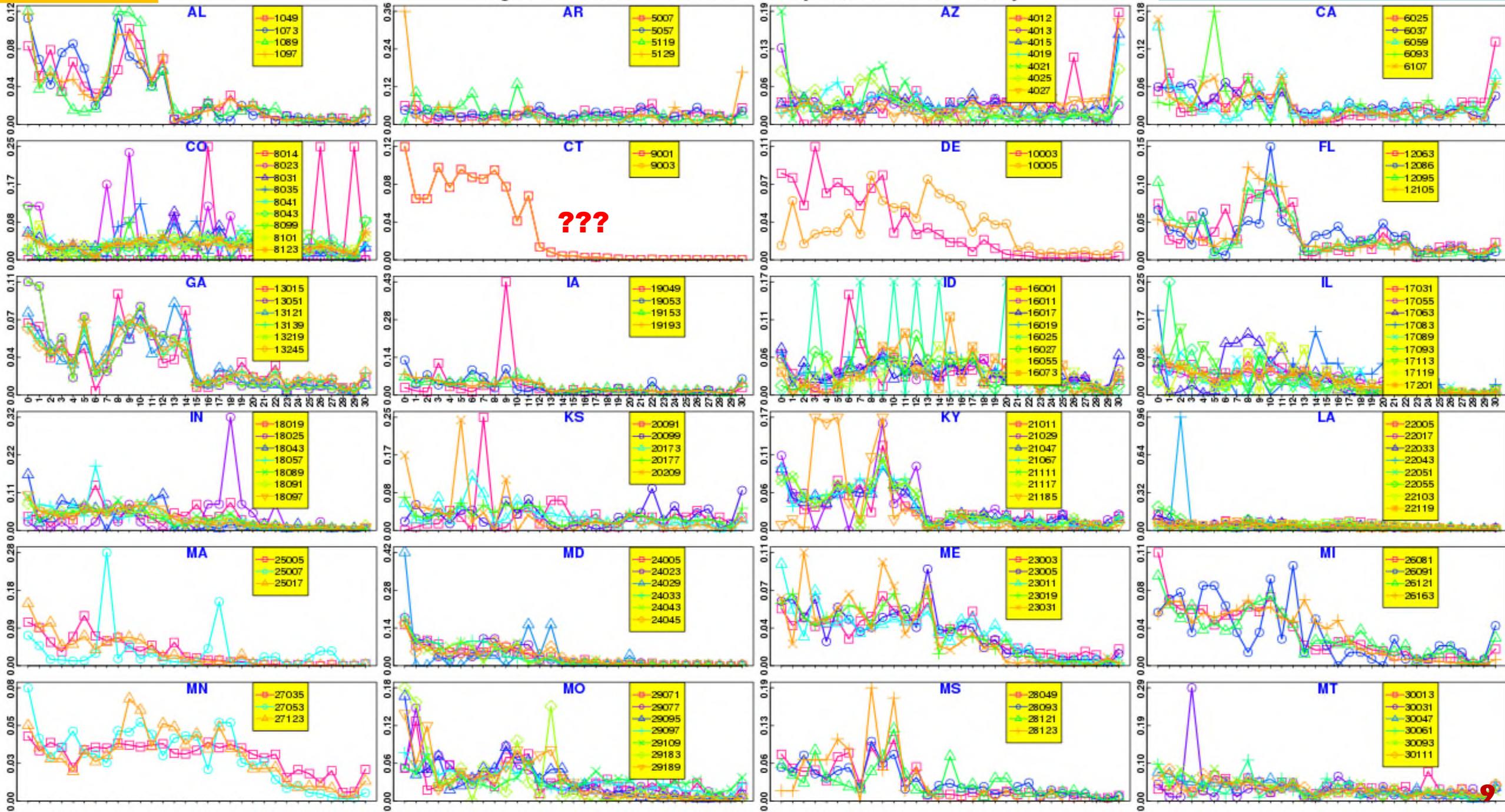
Age Fractions for Intercity Bus (41) by Representative County

2026, 41 fraction, CONUS2



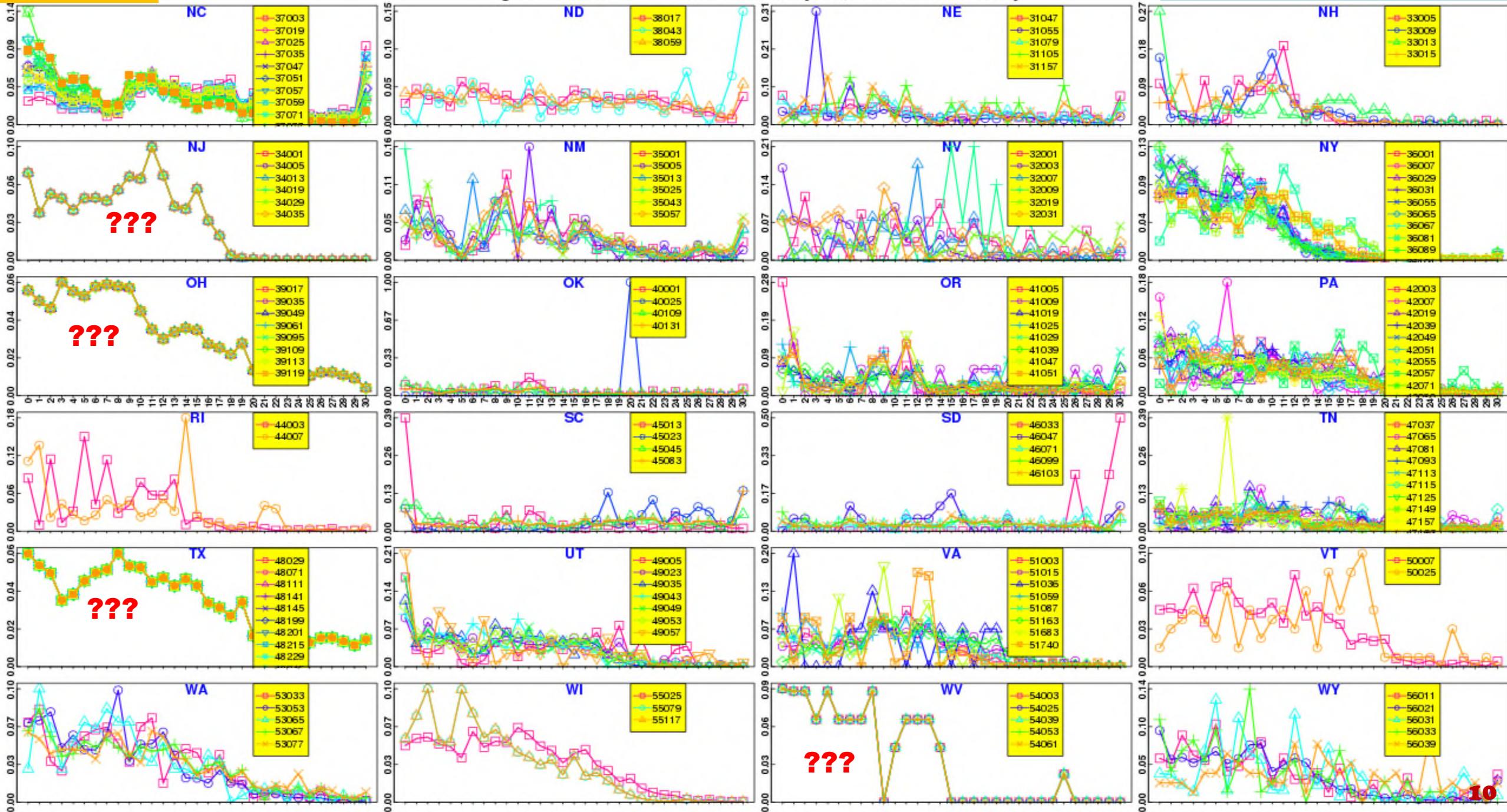
School Bus**Age Fractions for School Bus (43) by Representative County**

2026, 43 fraction, CONUS1

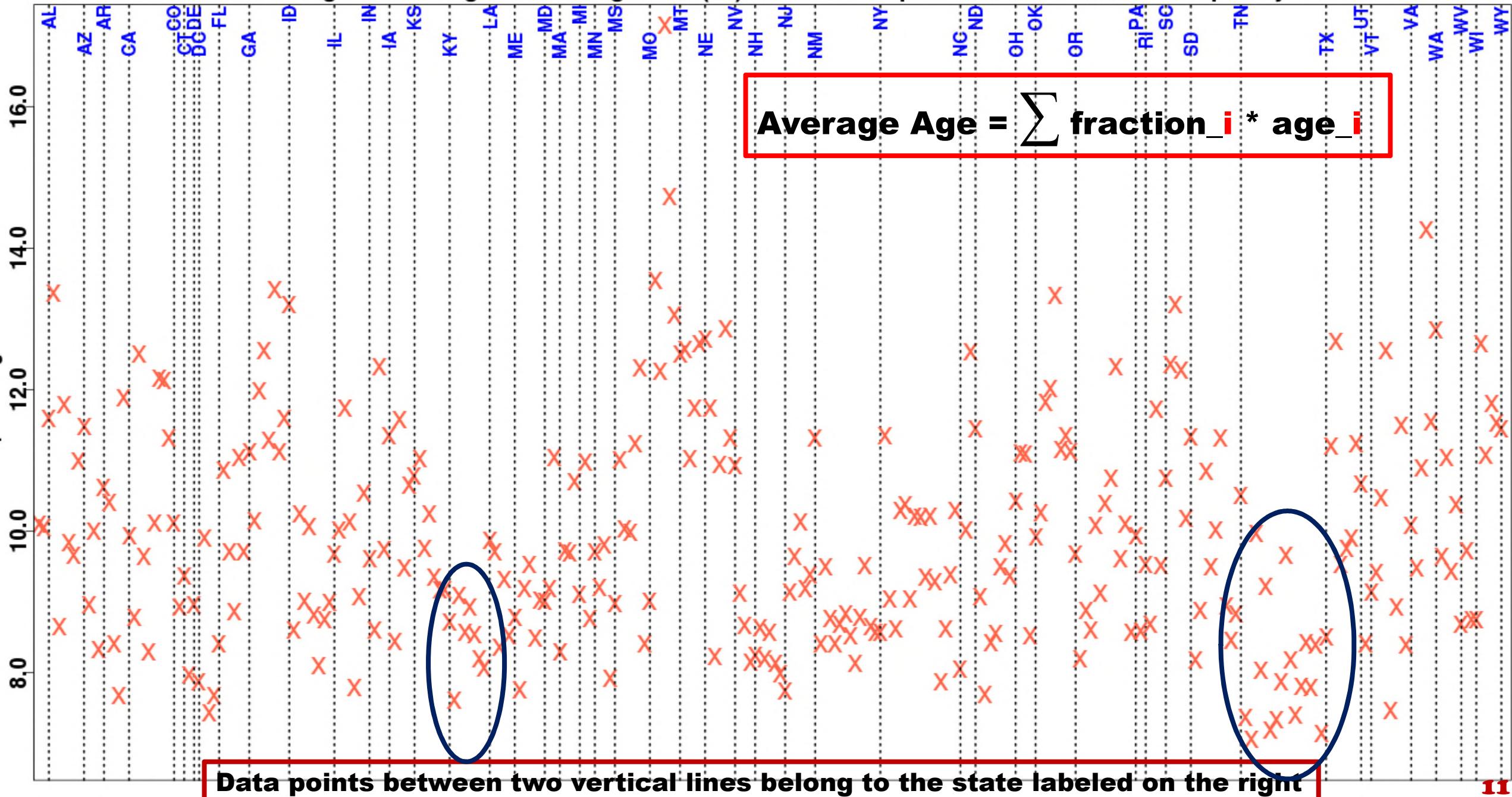


Age Fractions for School Bus (43) by Representative County

2026, 43 fraction, CONUS2

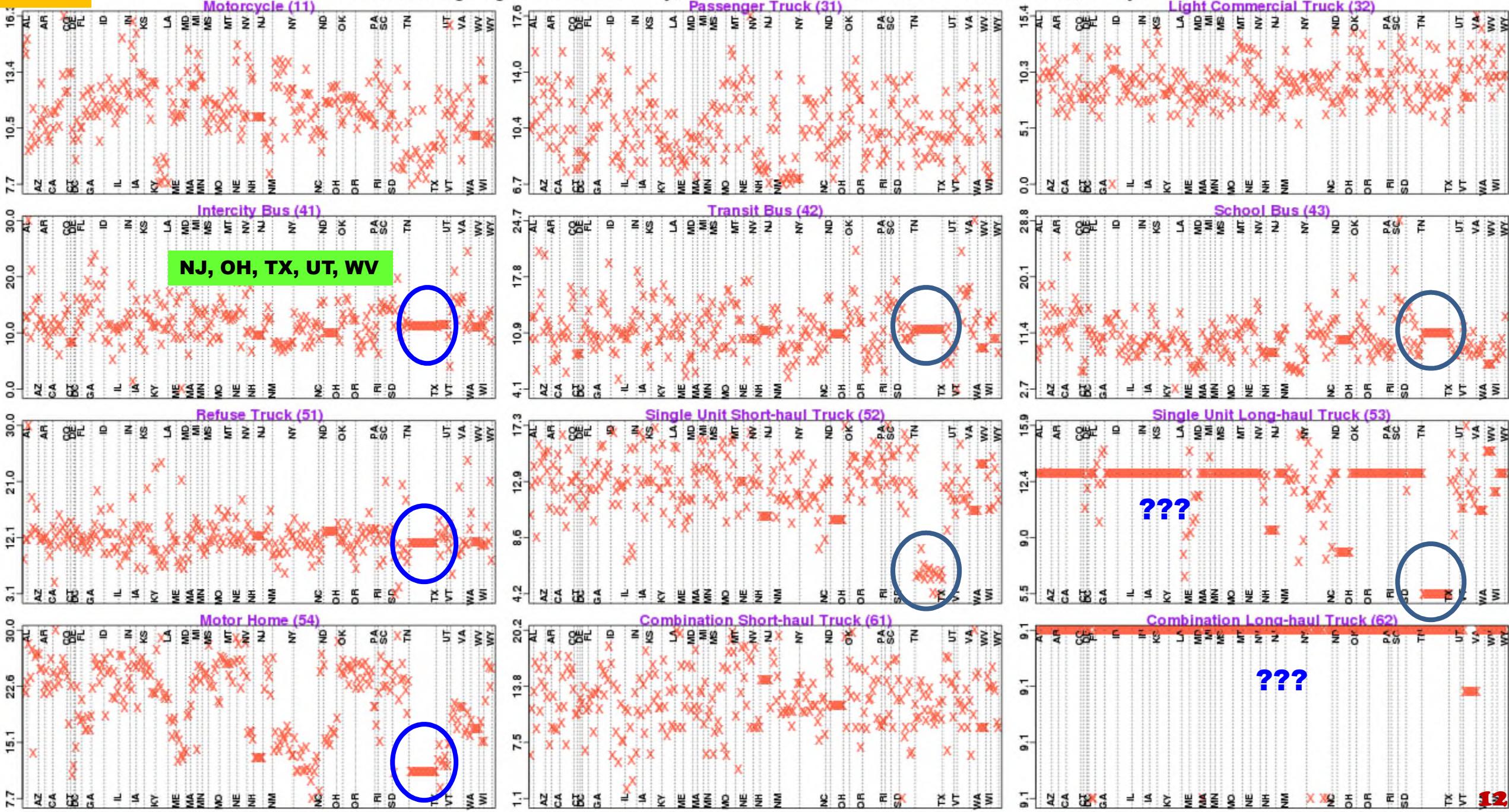


2016v2 Average Vehicle Age of Passenger Car (21) in CONUS Representative Counties Grouped by State



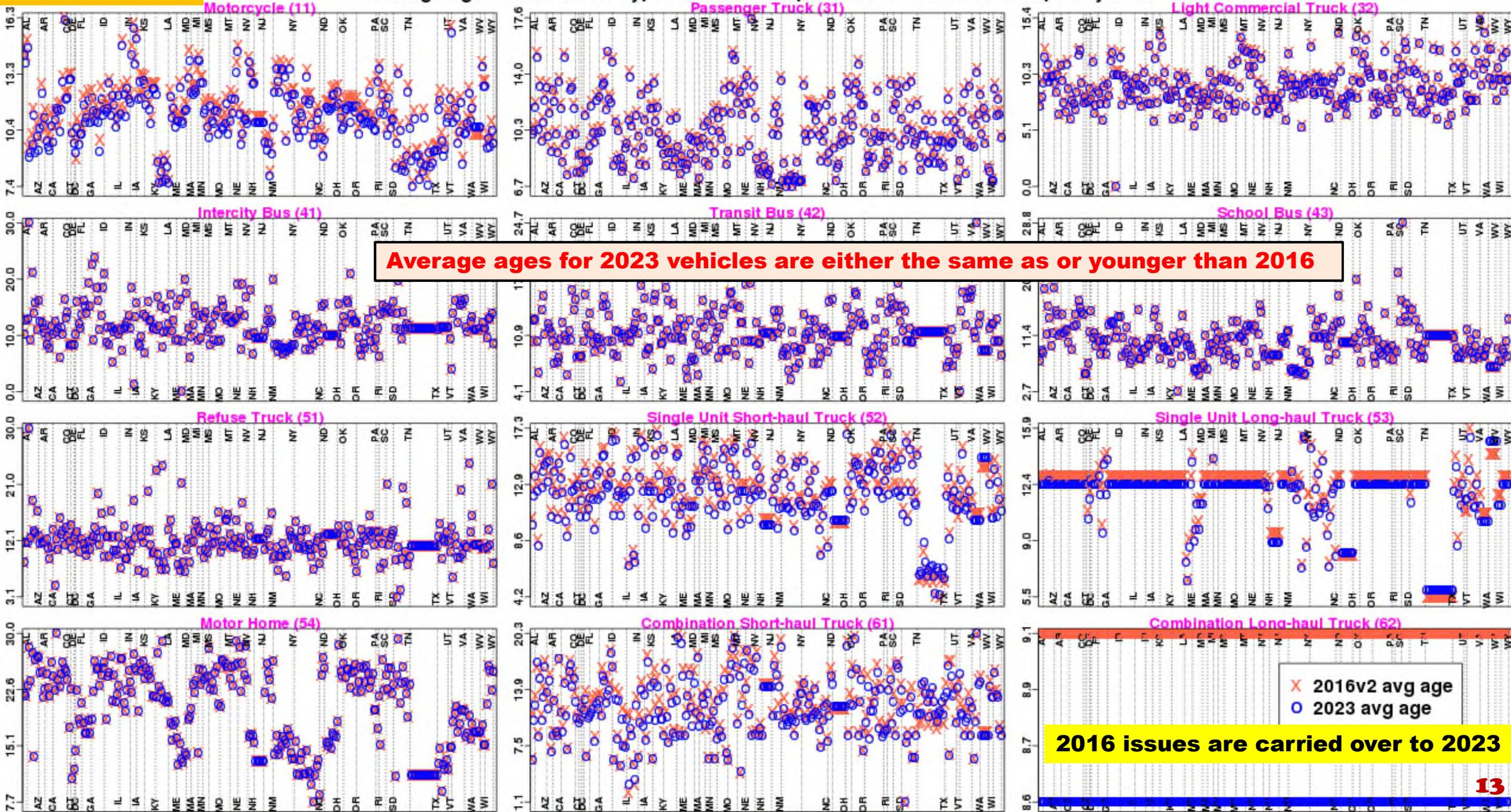
2016v2 Average Ages of 12 Vehicle Types in CONUS Representative Counties Grouped by State

21 is plotted on previous page



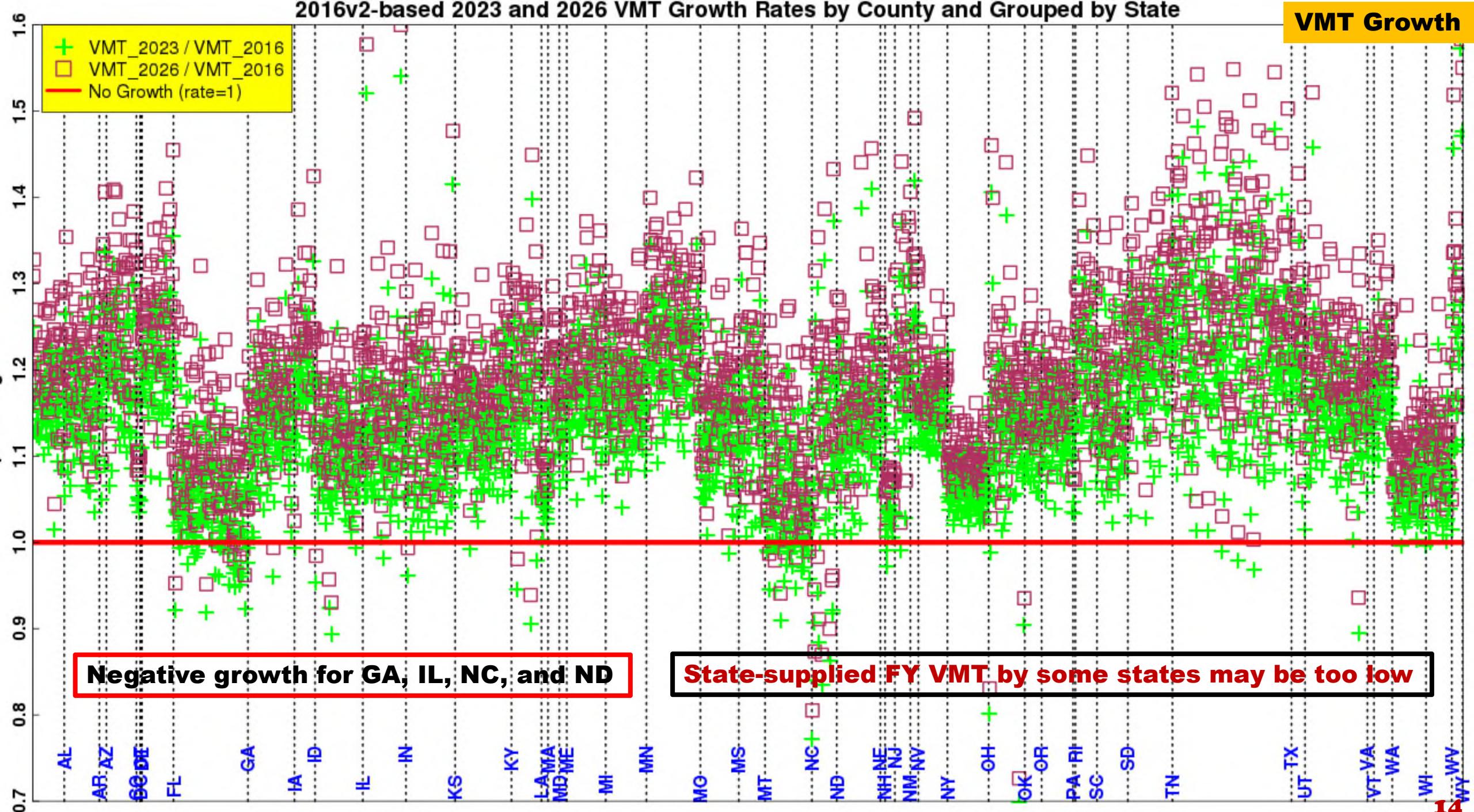
2016 and 2023

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



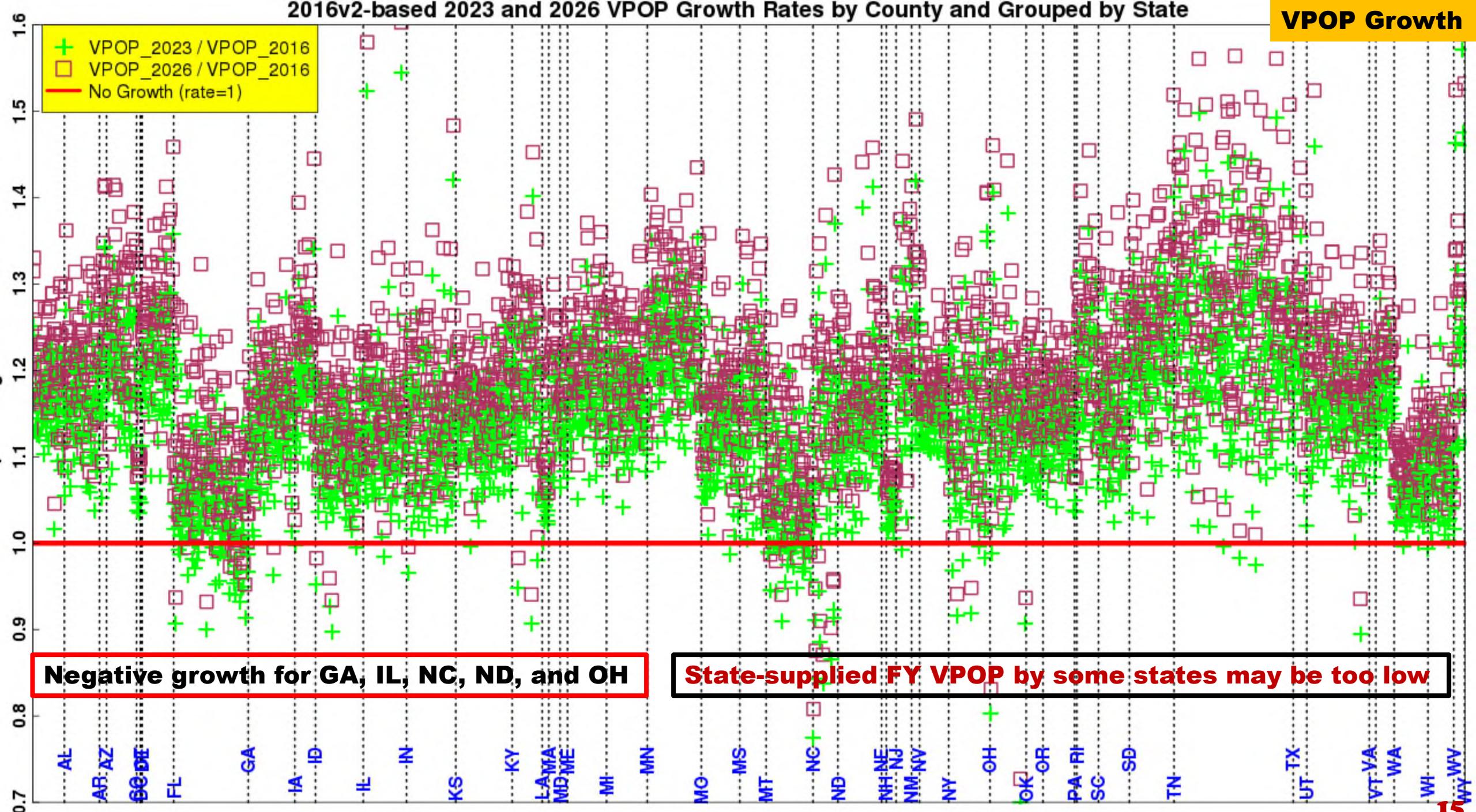
2016v2-based 2023 and 2026 VMT Growth Rates by County and Grouped by State

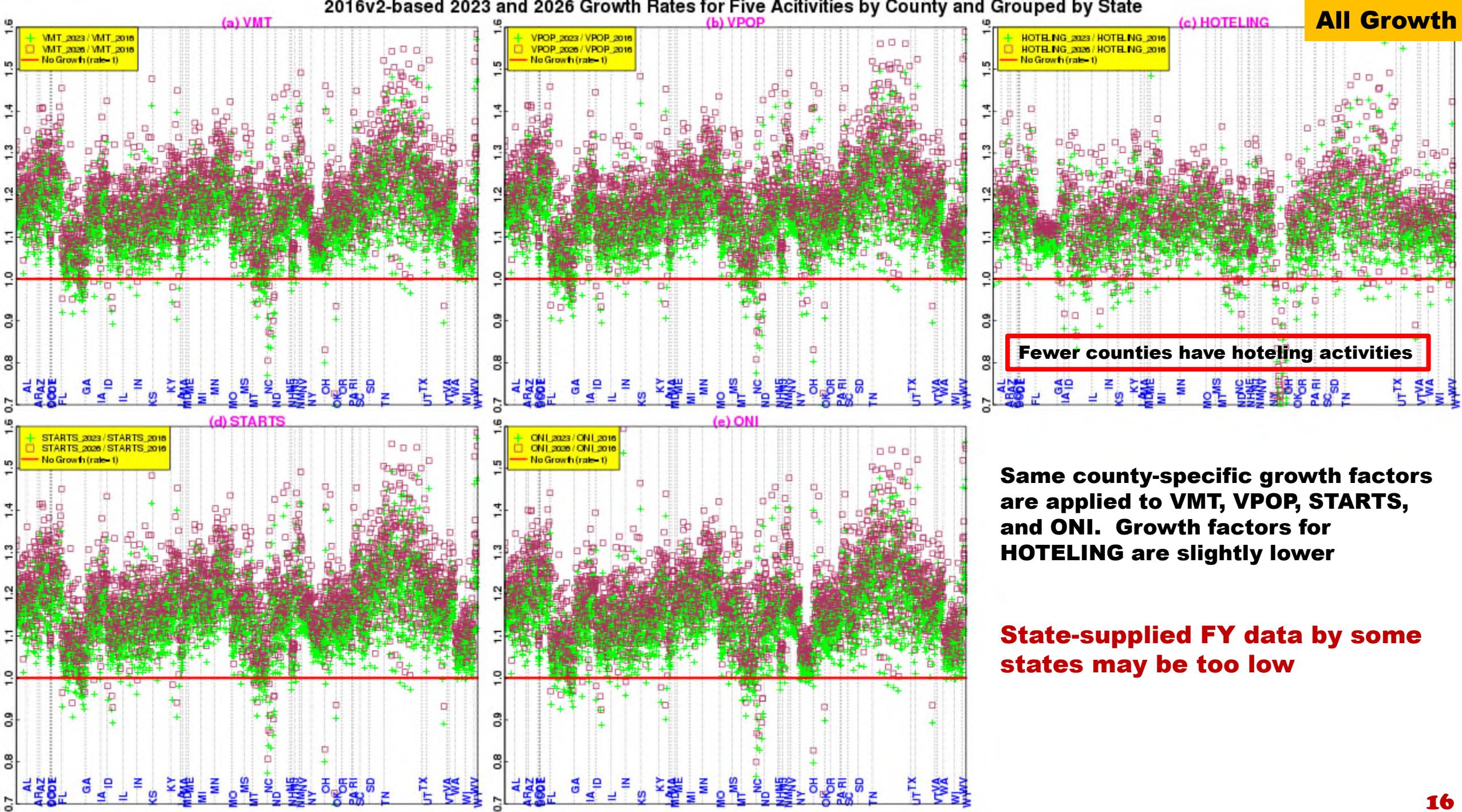
VMT Growth



2016v2-based 2023 and 2026 VPOP Growth Rates by County and Grouped by State

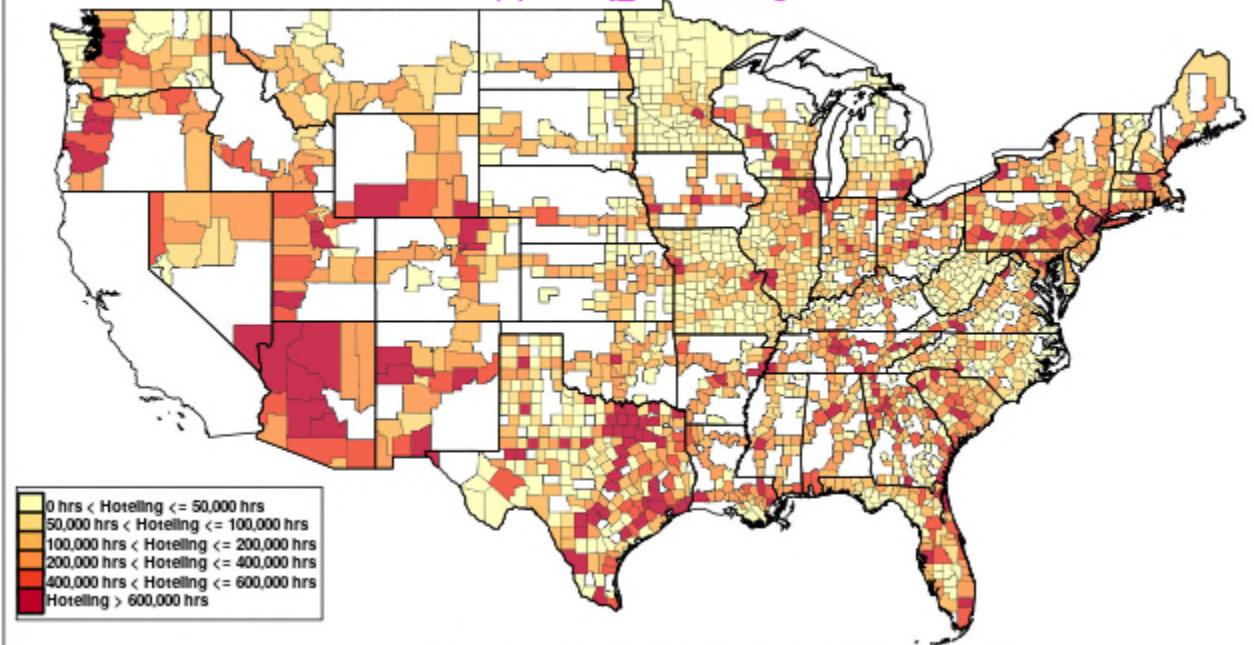
VPOP Growth



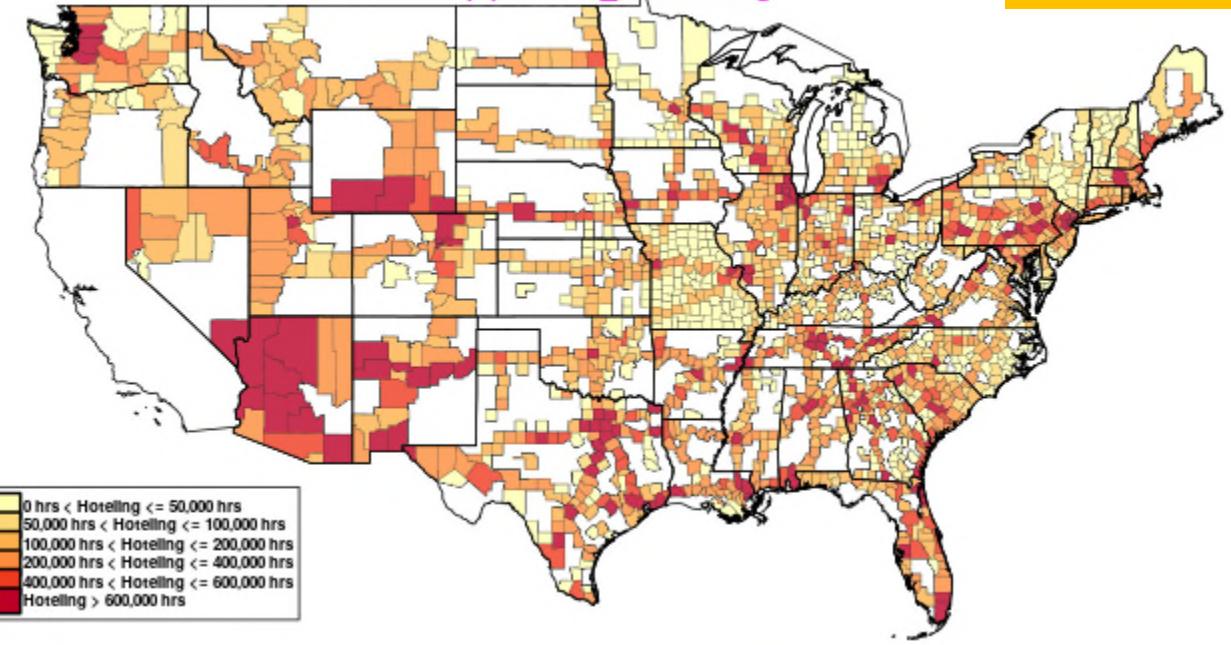


Differences in Hoteling Hours over Five Months (May – September)

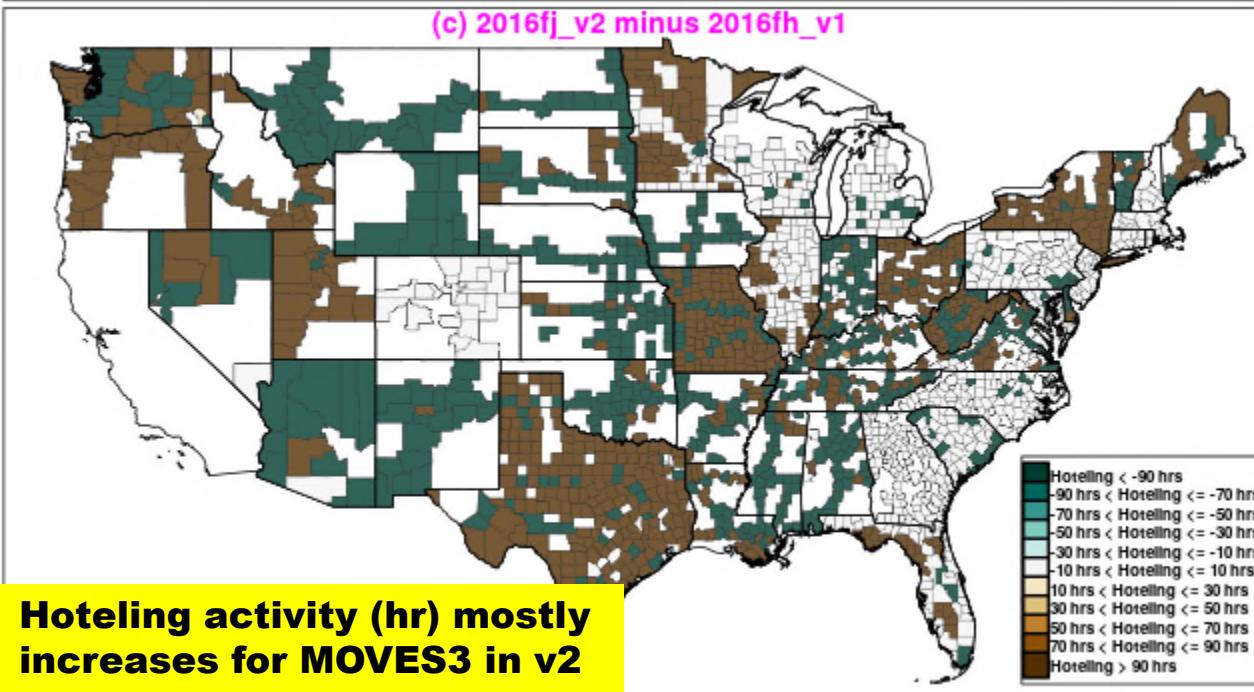
(a) 2016fj_v2 Hoteling



(b) 2016fh_v1 Hoteling



(c) 2016fj_v2 minus 2016fh_v1



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**

2016fj_v2 Five SMOKE-MOVES Annual Activities Ranked by State

(a) VMT

TX	(1)	277,192,881,304
FL	(2)	215,437,173,280
NY	(3)	122,180,161,163
OH	(4)	118,392,482,860
GA	(5)	117,017,683,801
NC	(6)	116,900,758,242
IL	(7)	105,876,258,178
PA	(8)	101,359,463,795
MI	(9)	99,185,667,588
VA	(10)	84,462,648,980
IN	(11)	82,974,453,225
NJ	(12)	76,881,995,959
TN	(13)	76,213,841,200
MO	(14)	74,289,726,021
AL	(15)	69,226,970,887
WI	(16)	52,523,463,616
AZ	(17)	51,902,313,177
WA	(18)	51,020,909,996
MA	(19)	59,412,656,949
MD	(20)	58,973,652,480
MN	(21)	58,856,547,322
SC	(22)	54,403,528,842
CO	(23)	52,205,698,596
LA	(24)	49,155,613,001
KY	(25)	49,091,720,414
OK	(26)	49,013,277,822
MS	(27)	40,754,708,897
OR	(28)	36,736,647,566
AR	(29)	35,754,796,937
IA	(30)	33,336,768,993
KS	(31)	32,102,609,785
UT	(32)	31,477,832,357
CT	(33)	29,554,009,844
NM	(34)	27,885,520,965
NV	(35)	27,244,249,458
NE	(36)	20,699,915,915
WV	(37)	19,097,889,999
ID	(38)	17,226,766,931
ME	(39)	15,044,512,420
NH	(40)	13,858,017,782
MT	(41)	12,598,722,865
DE	(42)	10,177,414,714
ND	(43)	9,739,208,732
SD	(44)	9,506,534,300
WY	(45)	9,322,542,419
RI	(46)	7,700,694,891
VT	(47)	7,385,899,178
DC	(48)	3,595,396,831

(a) VPOP

TX	(1)	21,656,959
FL	(2)	17,181,704
NY	(3)	10,810,373
OH	(4)	10,568,512
IL	(5)	10,466,764
PA	(6)	9,772,813
GA	(7)	9,068,642
MI	(8)	8,973,522
NC	(9)	7,705,846
WA	(10)	7,305,583
VA	(11)	6,903,827
NJ	(12)	6,665,949
IN	(13)	6,205,434
MO	(14)	5,669,289
AZ	(15)	5,518,669
TN	(16)	5,507,250
MN	(17)	5,435,298
WI	(18)	5,373,581
MA	(19)	5,279,123
CO	(20)	4,950,795
AL	(21)	4,816,726
MD	(22)	4,691,805
OK	(23)	4,505,283
SC	(24)	4,176,977
LA	(25)	4,078,752
KY	(26)	4,057,607
OR	(27)	3,916,625
IA	(28)	3,191,028
CT	(29)	2,862,322
KS	(30)	2,734,311
MS	(31)	2,642,966
AR	(32)	2,570,864
UT	(33)	2,435,446
NV	(34)	2,100,172
NE	(35)	1,893,222
NM	(36)	1,845,095
ID	(37)	1,699,506
WV	(38)	1,524,082
MT	(39)	1,423,297
NH	(40)	1,362,182
ME	(41)	1,253,047
SD	(42)	988,781
RI	(43)	880,597
ND	(44)	860,223
DE	(45)	821,514
WY	(46)	629,258
VT	(47)	589,258
DC	(48)	292,461

(c) Engine Starts

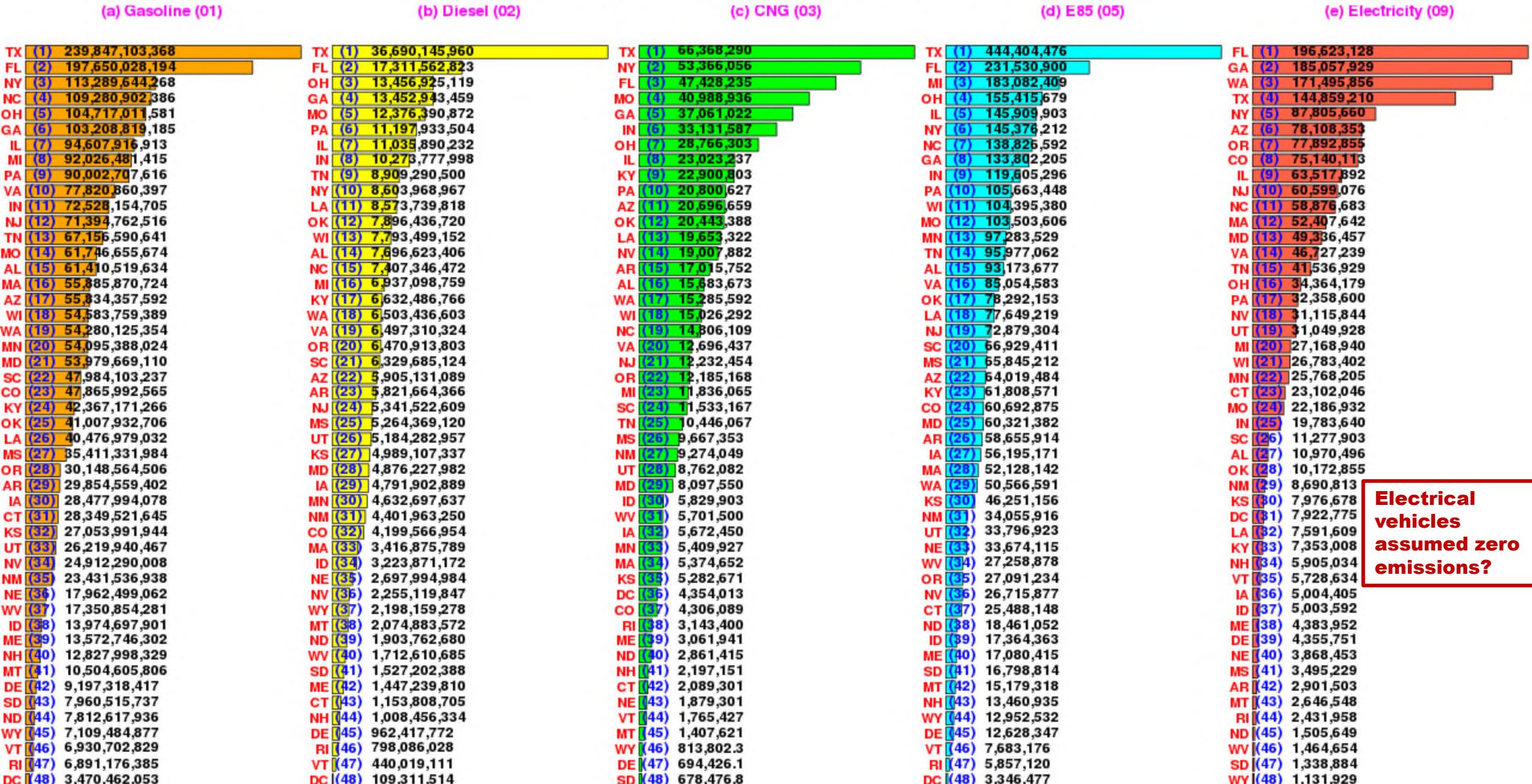
TX	(1)	29,870,047,956
FL	(2)	26,082,696,578
NY	(3)	14,735,407,154
OH	(4)	13,912,184,005
IL	(5)	13,717,329,108
PA	(6)	13,218,405,753
GA	(7)	12,530,121,984
MI	(8)	11,524,591,088
NC	(9)	10,601,887,878
WA	(10)	10,052,835,594
VA	(11)	9,964,234,869
NJ	(12)	9,357,195,399
IN	(13)	8,060,139,070
TN	(14)	7,648,313,090
MO	(15)	7,416,332,699
AZ	(16)	7,265,605,744
MN	(17)	6,9
MD	(18)	6,605,313,032
OK	(19)	5,986,182,343
SC	(20)	5,389,904,627
OR	(21)	5,300,187,350
LA	(22)	5,228,138,128
KY	(23)	5,207,693,153
CT	(24)	4,135,825,150
IA	(25)	4,130,303,872
KS	(26)	3,558,032,912
MS	(27)	3,463,351,148
AR	(28)	3,390,586,632
UT	(29)	3,385,418,110
NV	(30)	2,965,864,386
NE	(31)	2,494,265,245
NM	(32)	2,402,420,411
ID	(33)	2,368,476,029
WV	(34)	2,146,343,188
NH	(35)	1,785,527,497
ME	(36)	1,770,228,493
MT	(37)	1,687,057,886
SD	(38)	1,219,916,987
RI	(39)	1,190,327,584
DE	(40)	1,089,616,080
ND	(41)	1,075,252,359
WY	(42)	800,049,050
VT	(43)	767,159,285
DC	(44)	385,495,224

(d) Off-Network Idling (HOTELING)

TX	(1)	104,963,493
GA	(2)	25,712,496
IL	(3)	23,419,496
TN	(4)	19,159,427
PA	(5)	16,423,772
FL	(6)	13,181,154
IN	(7)	12,917,677
OH	(8)	12,100,244
MO	(9)	11,984,543
NY	(10)	11,591,133
SC	(11)	9,778,243
LA	(12)	9,656,766
AR	(13)	9,434,818
NJ	(14)	9,103,833
AZ	(15)	9,081,659
WI	(16)	8,461,578
IA	(17)	8,208,898
OR	(18)	8,052,940
NM	(19)	7,916,961
VA	(20)	7,723,807
KY	(21)	7,566,411
WA	(22)	7,262,042
AL	(23)	7,074,457
CO	(24)	6,587,590
UT	(25)	6,395,868
OK	(26)	6,302,123
MI	(27)	6,123,657
NC	(28)	6,056,465
MS	(29)	5,435,508
KS	(30)	5,390,001
ID	(31)	4,622,595
WY	(32)	4,489,174
NE	(33)	4,453,616
MD	(34)	3,835,480
MN	(35)	3,637,007
MA	(36)	3,438,990
MT	(37)	2,902,905
NV	(38)	2,715,929
SD	(39)	2,411,531
DE	(40)	1,960,467
WV	(41)	1,850,908
ME	(42)	1,717,258
CT	(43)	1,689,204
NH	(44)	842,501
RI	(45)	567,689
VT	(46)	340,683
DE	(47)	307,239
DC	(48)	14,162

(e) On-Network Idling (ONI)

TX	(1)	1,332,052,254
FL	(2)	874,056,618
NY	(3)	627,691,754
OH	(4)	608,043,736
NC	(5)	605,559,368
GA	(6)	555,721,066
PA	(7)	523,550,630
IL	(8)	522,926,041
MI	(9)	507,017,816
VA	(10)	451,744,411
IN	(11)	439,241,870
NJ	(12)	432,704,559
TN	(13)	400,839,463
MO	(14)	371,606,398
AL	(15)	351,106,276
MD	(16)	321,328,348
WI	(17)	313,423,182
SC	(18)	303,196,268
AZ	(19)	300,914,590
MN	(20)	289,633,084
WA	(21)	287,288,808
MA	(22)	285,328,619
OK	(23)	263,827,593
LA	(24)	260,018,386
KY	(25)	238,427,736
MS	(26)	205,153,614
AR	(27)	182,409,693
CO	(28)	177,141,712
IA	(29)	164,872,745
CT	(30)	163,351,162
OR	(31)	153,254,492
KS	(32)	146,392,972
NM	(33)	138,726,207
UT	(34)	133,850,875
NV	(35)	110,445,215
WV	(36)	96,998,234
NE	(37)	87,154,912
ME	(38)	75,941,775
NH	(39)	72,849,364
DE	(40)	56,345,752
ID	(41)	56,254,224
MT	(42)	48,362,073
ND	(43)	45,639,346
RI	(44)	39,888,014
SD	(45)	39,475,434
VT	(46)	39,340,604
WY	(47)	38,727,982
DC	(48)	2,716,867

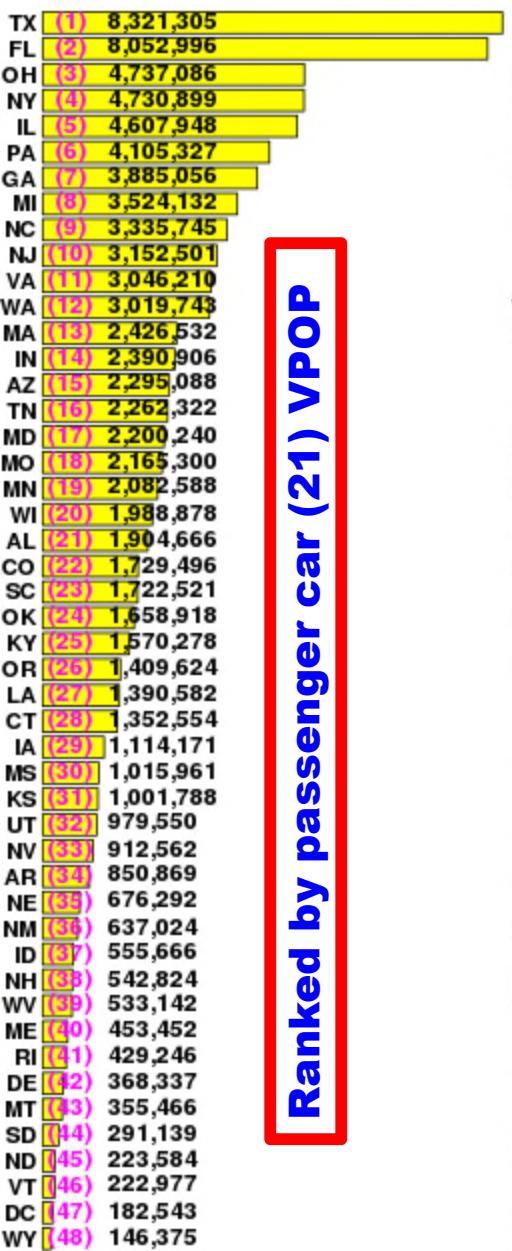


CA excluded

Gasoline (1) Diesel (2) CNG (3) E85 (5) Electricity (9)

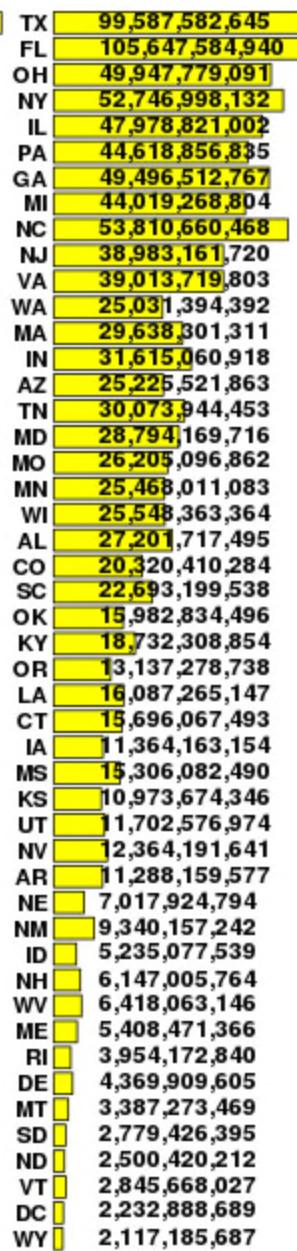
2016 VPOP/VMT/NOx by Fuel

(a) 2016fj_v2 21 VPOP

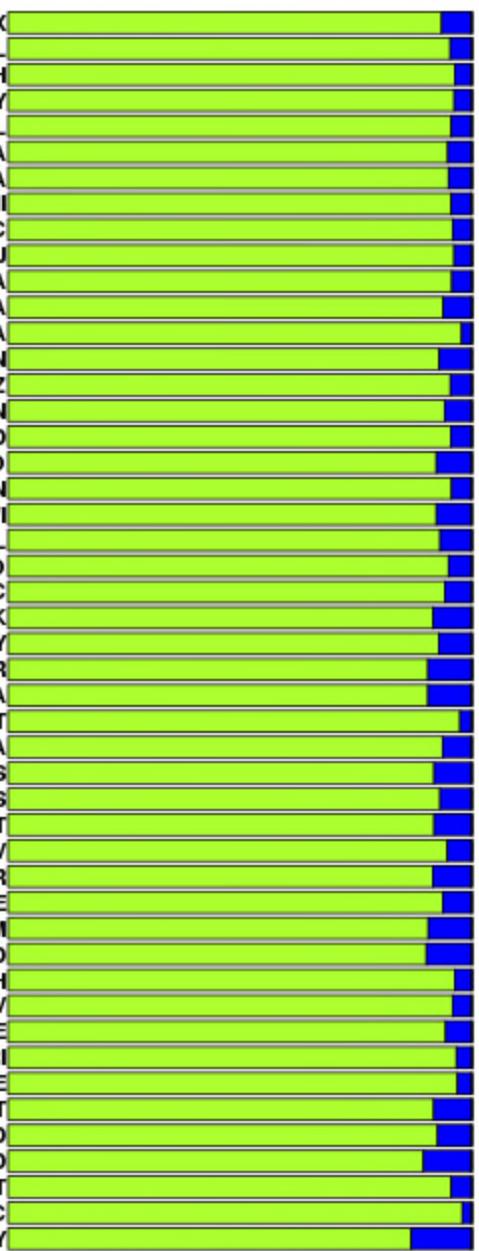


Ranked by passenger car (21) VPOP

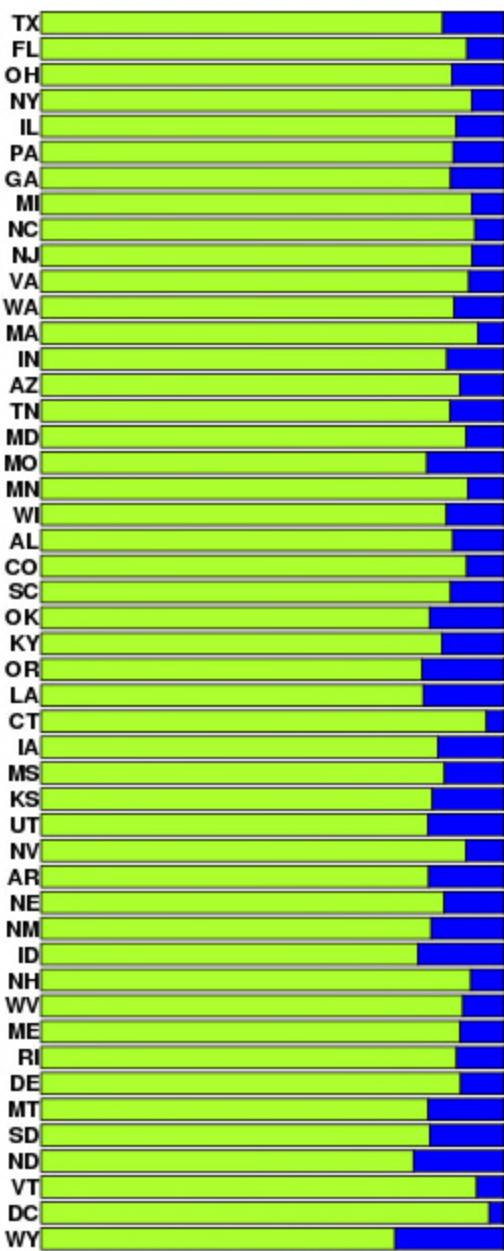
(b) 2016fj_v2 21 VMT



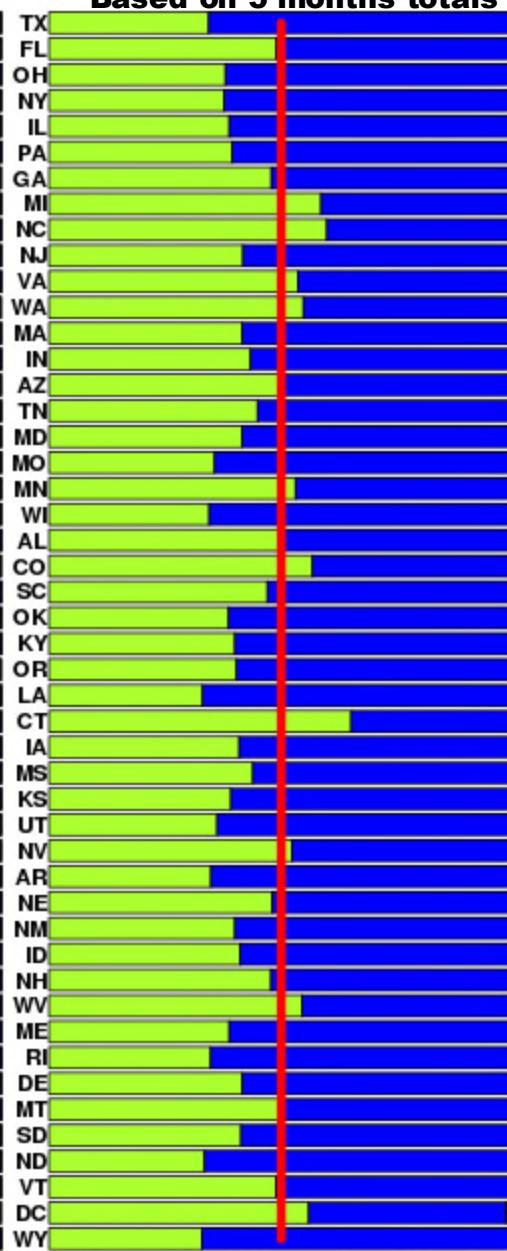
(c) 2016fj_v2 VPOP by Fuel (%)



(d) 2016fj_v2 VMT by Fuel (%)

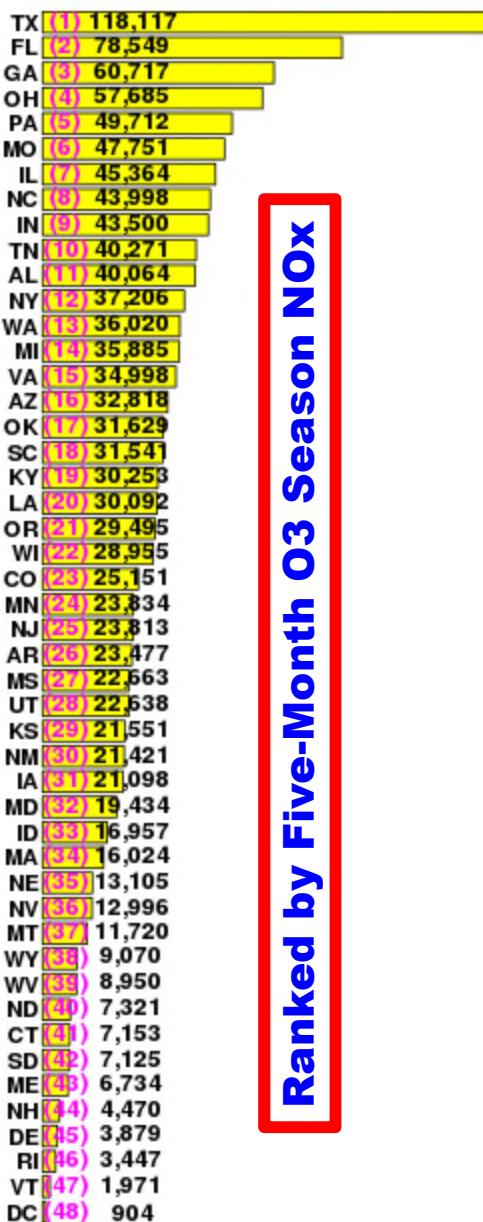


(e) 2016fj_v2 NOx by Fuel (%)



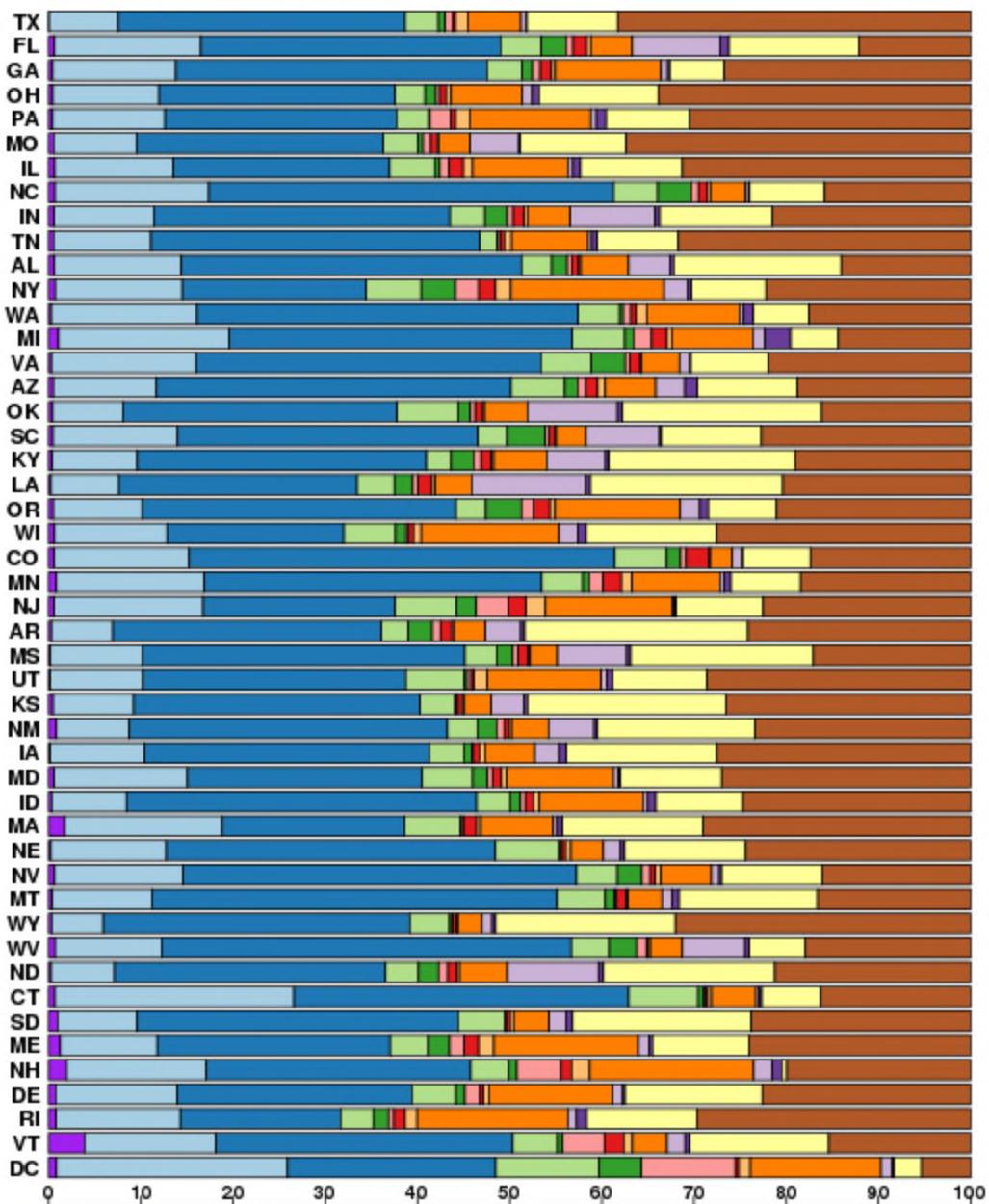
Based on 5 months totals

(a) 2016fj_v2 Five-Month NOx (tons)

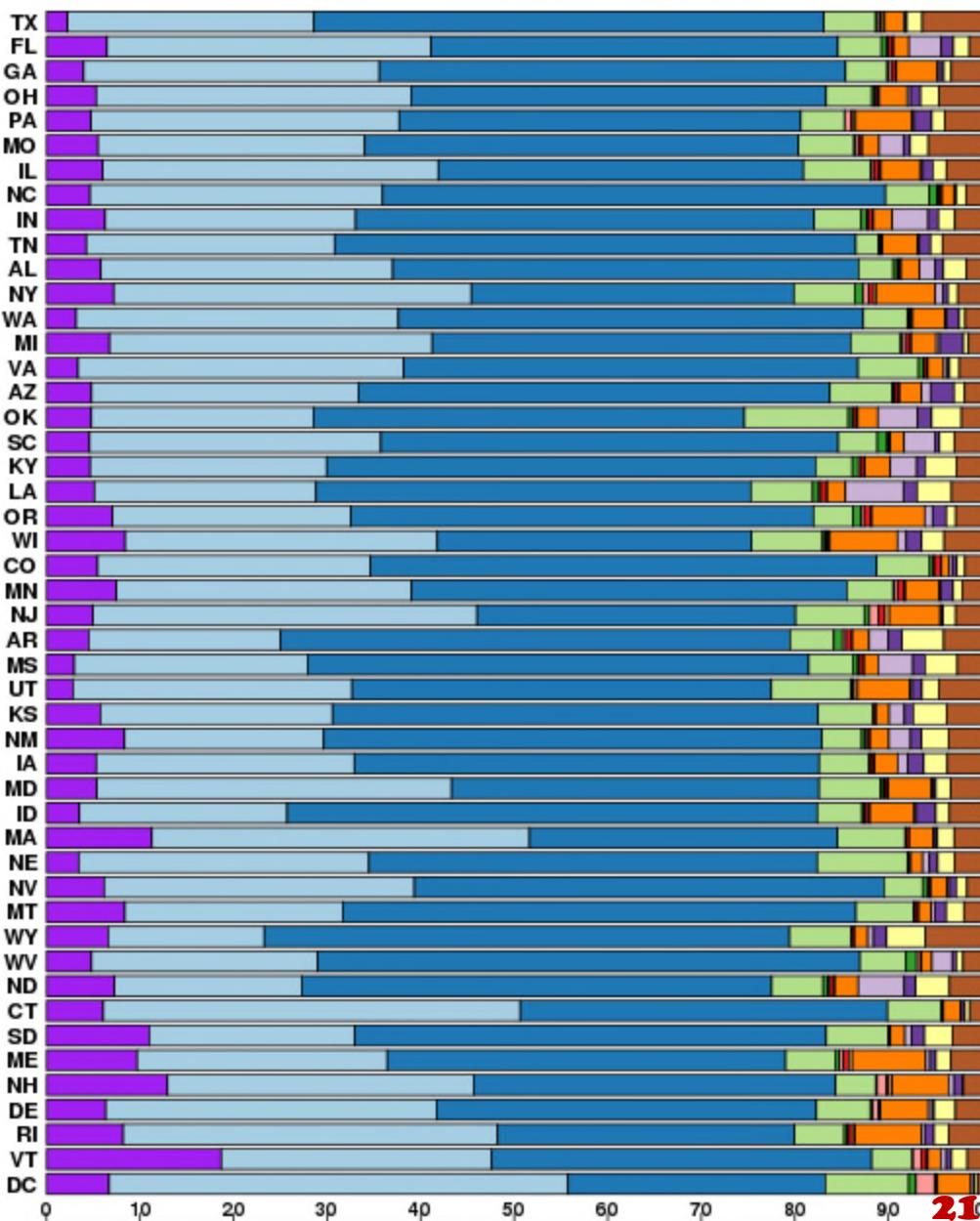


Ranked by Five-Month O3 Season NOx

(b) 2016fj_v2 NOx by Vehicle Type (%)



(c) 2016fj_v2 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)

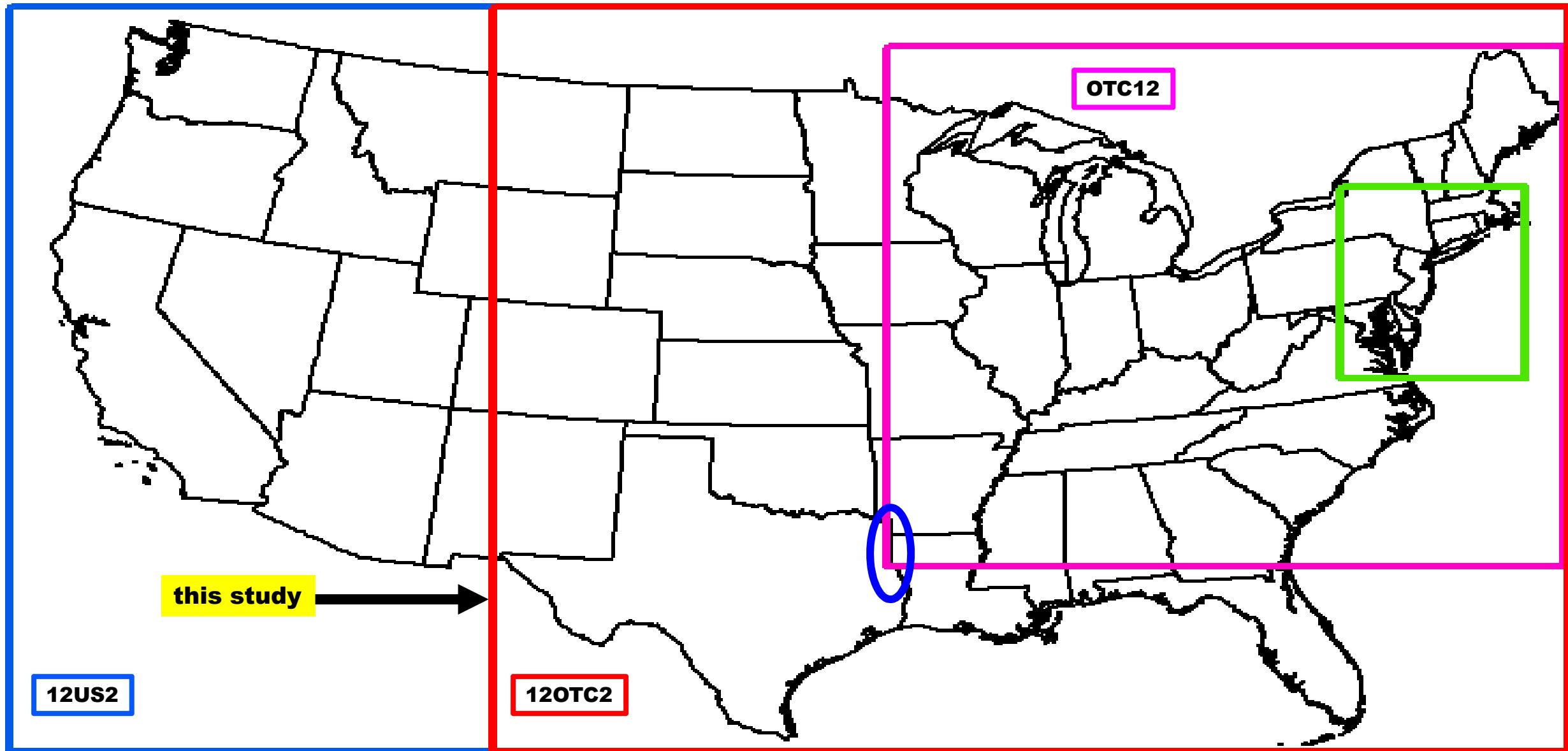
**2016 ozone episodes: 05/24 – 05/26
07/21 – 07/22**

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
- **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)

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

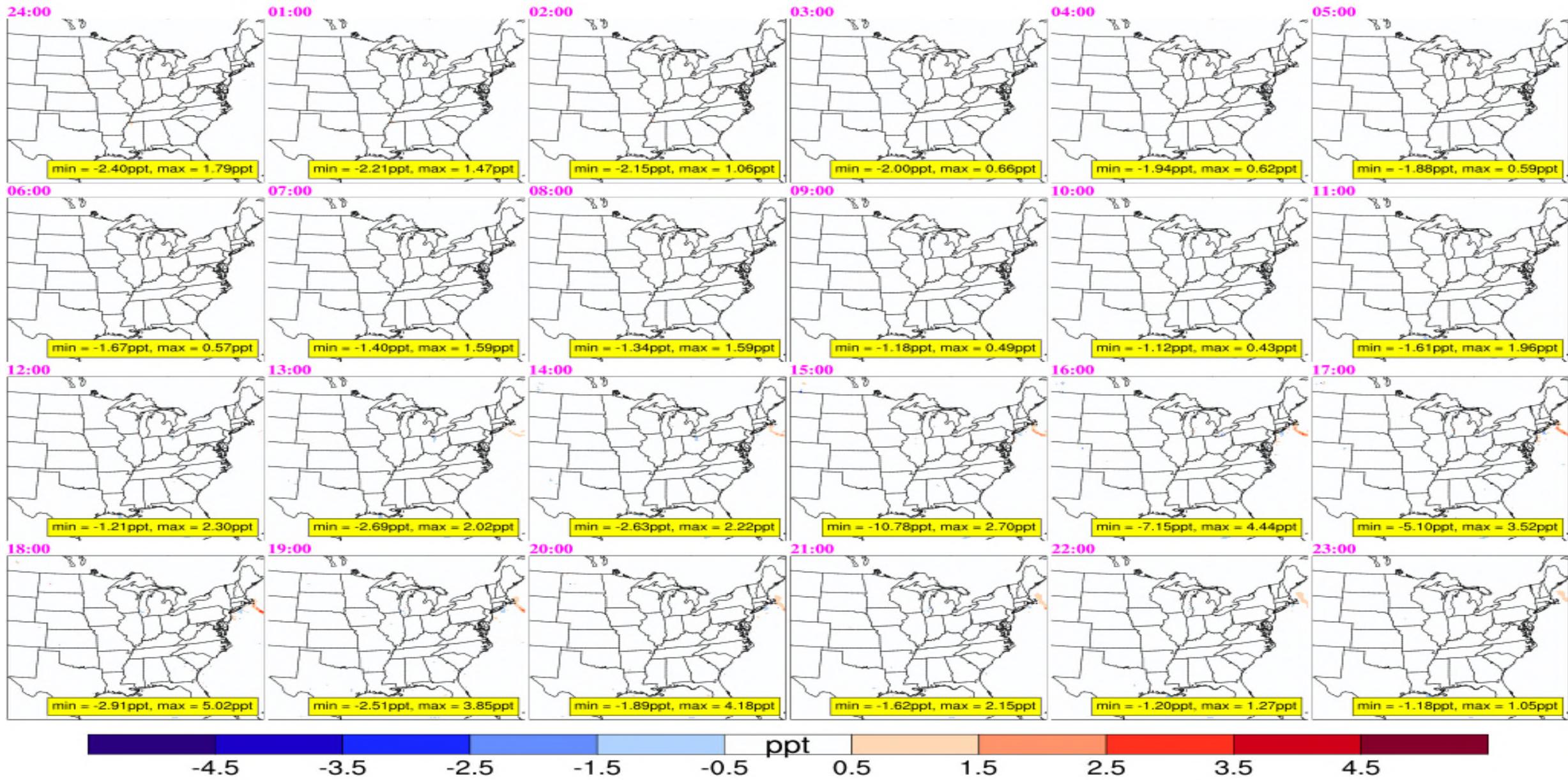
Modeling Domains



- **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

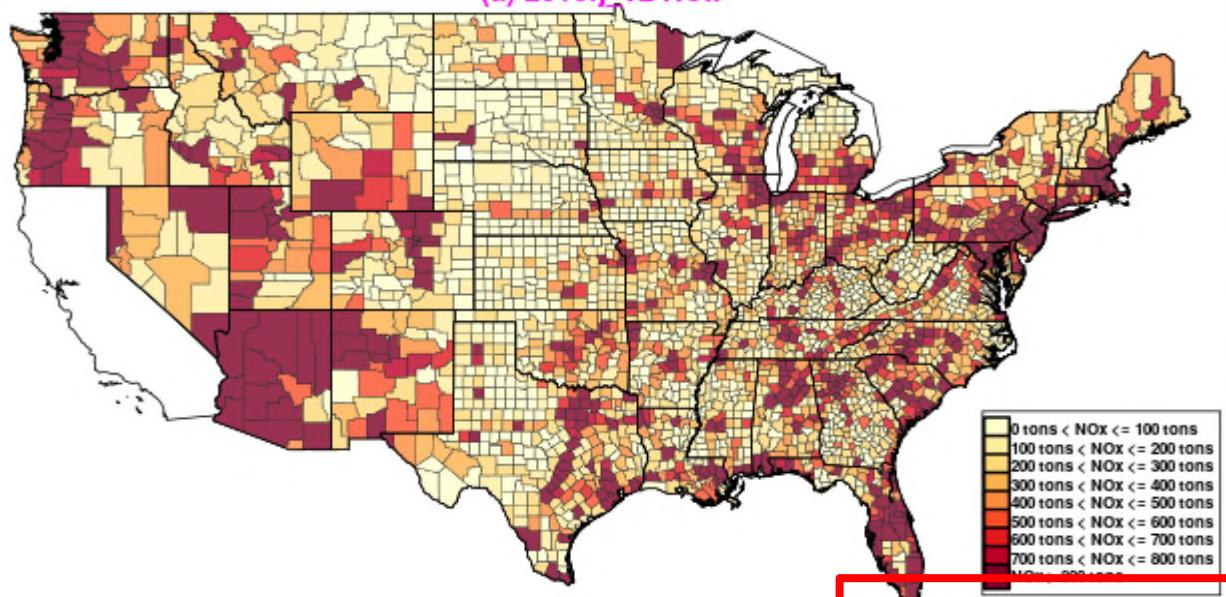
O3 2016v1_base_531 NYSDEC minus O3 2016v1 base_531 VADEQ in 24 hours (GMT) on May 25



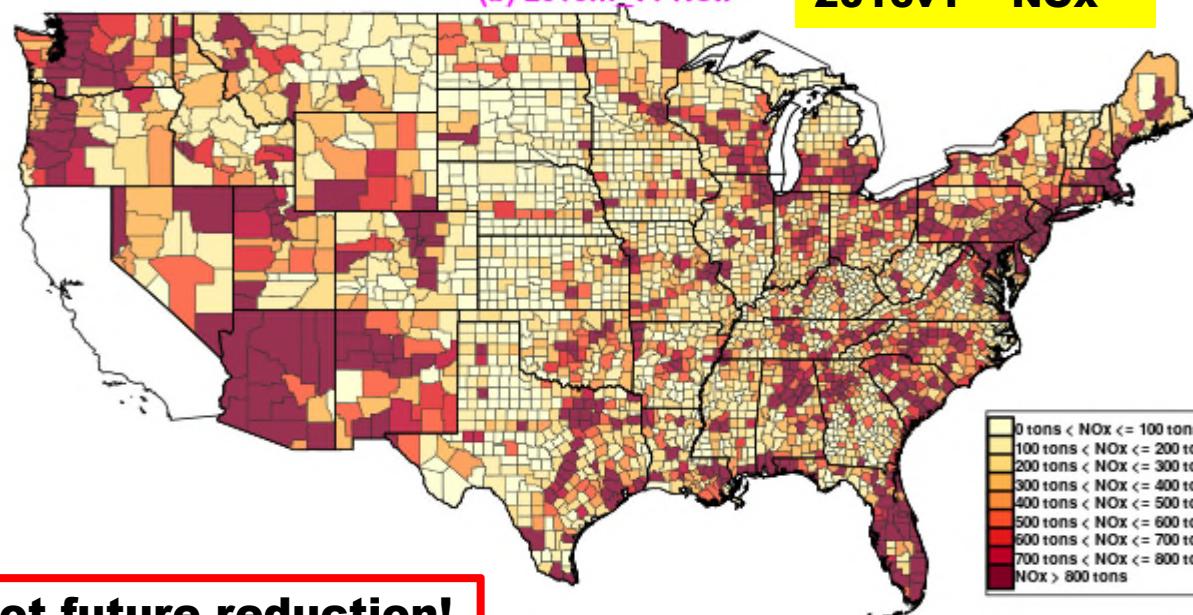
Differences in hourly O3 on May 25 (a high O3 day) between two modeling centers are barely visible (a few ppt)

Version change**NOx Differences (in tons) over Five Months (May – September)****2016v2 versus
2016v1 -- NOx**

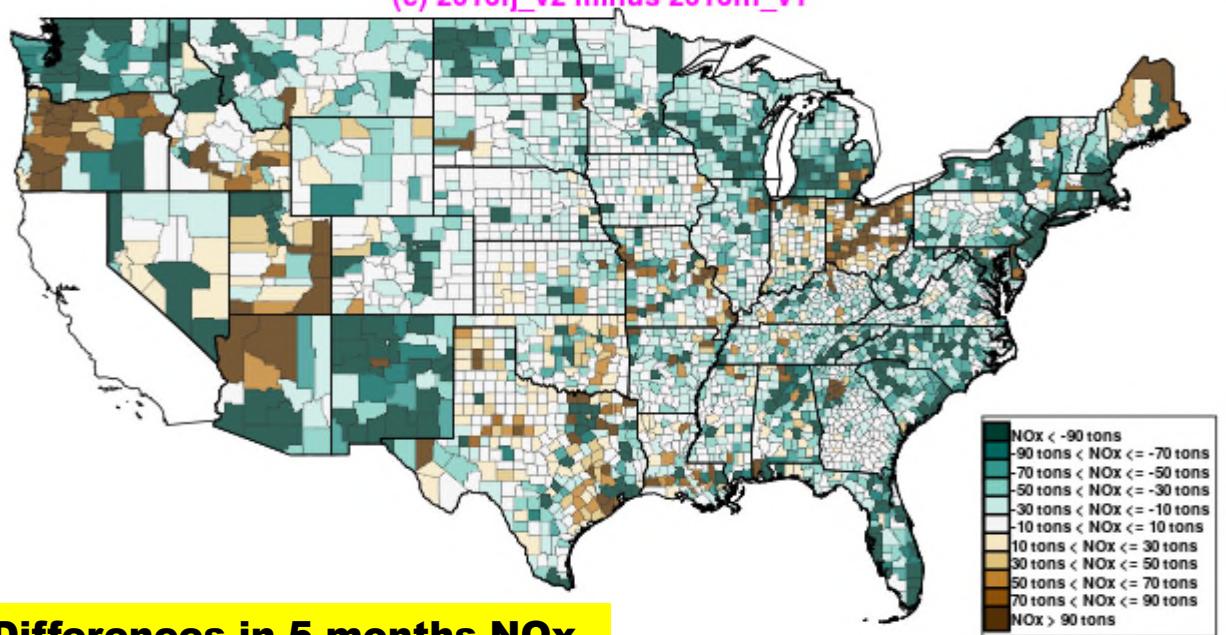
(a) 2016fj_v2 NOx



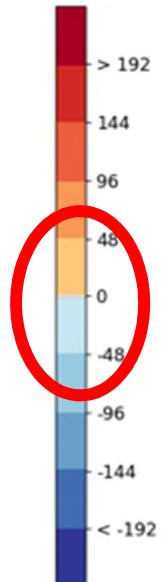
(b) 2016fh_v1 NOx

**Version change, not future reduction!**

(c) 2016fj_v2 minus 2016fh_v1

**Differences in 5 months NOx**

2016fj_16j minus 2016fh_16j annual emissions absolute difference: onroad_combined NOX

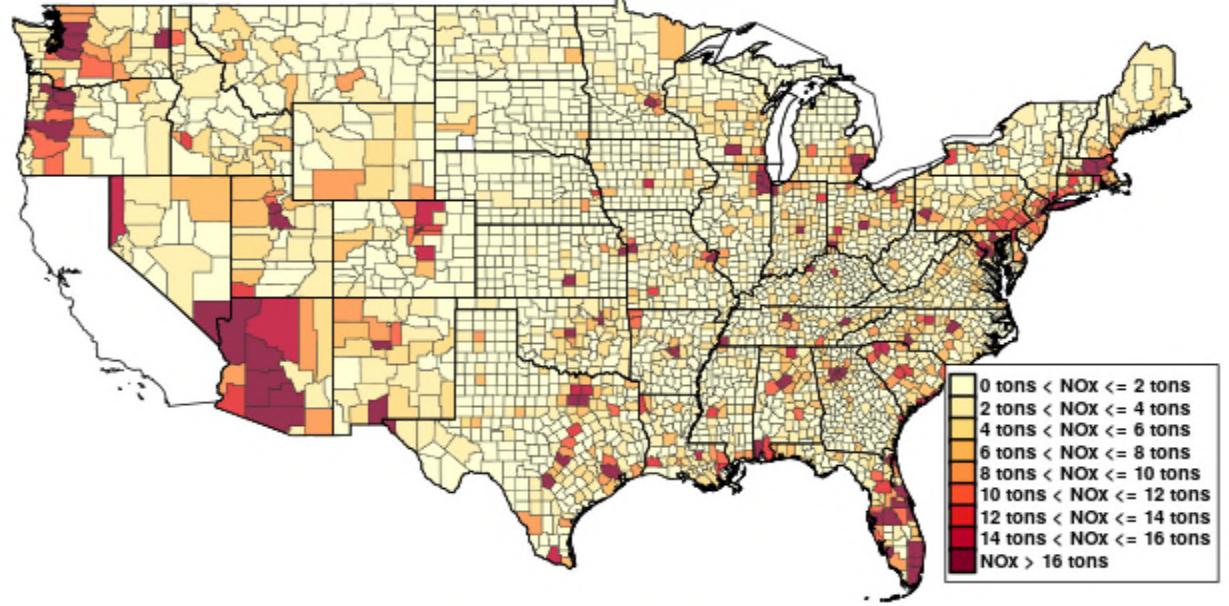
EPA modeling**Differences in annual NOx**

Significance of NOx Change

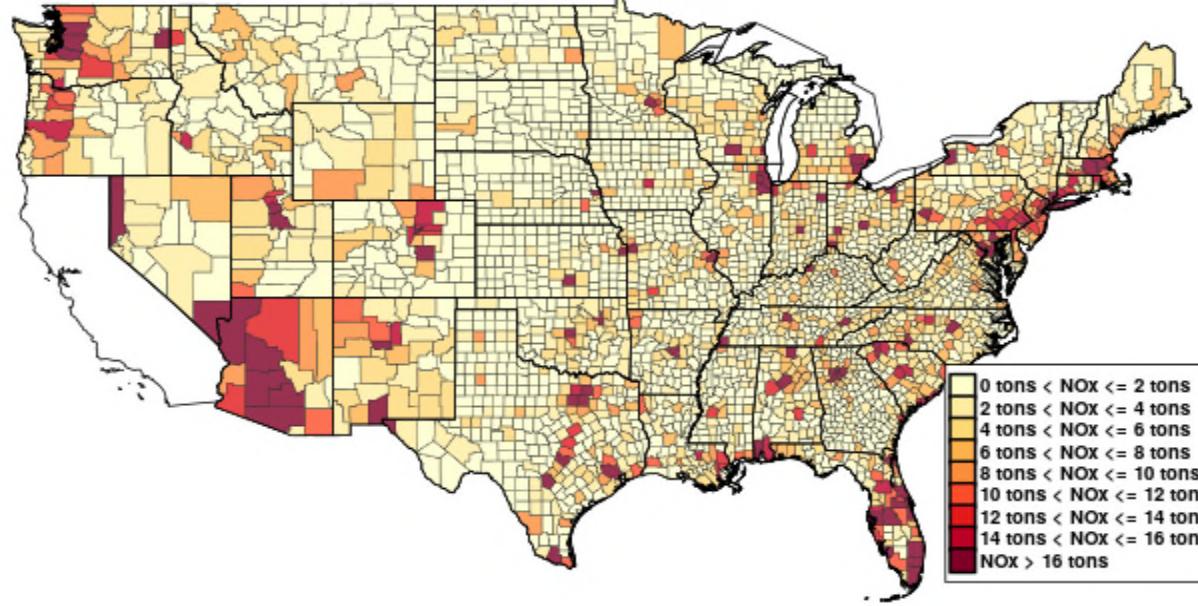
Daily NOx Differences (in tons) on July 22, 2016

2016v2 versus 2016v1
- NOx (per day)

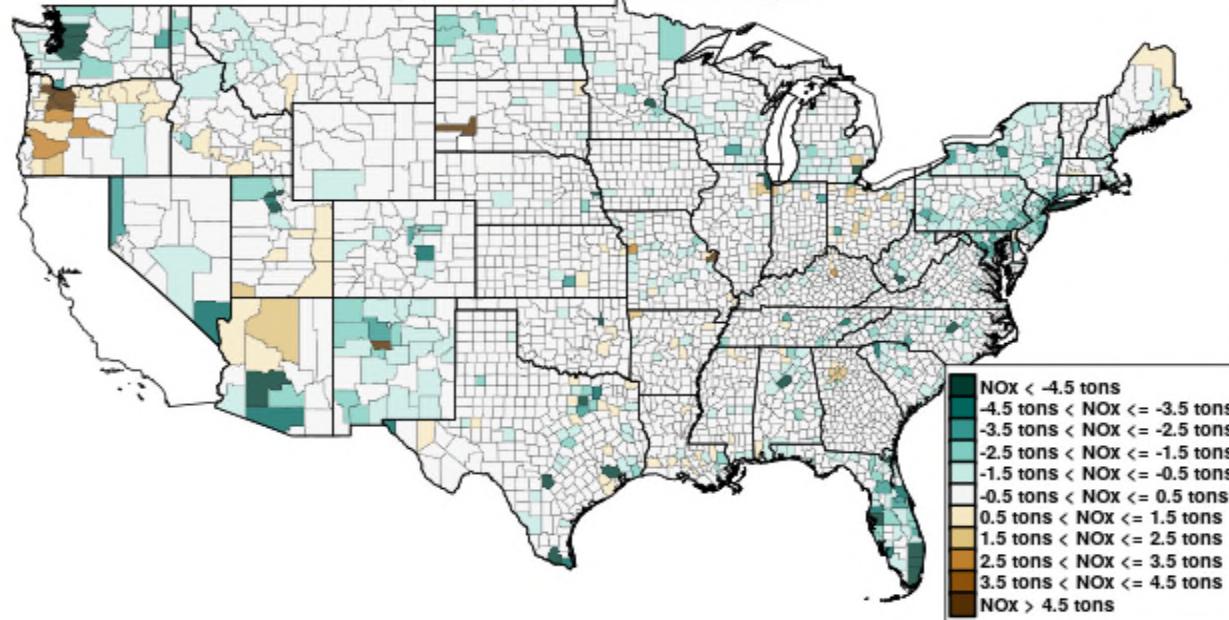
(a) 2016fj_v2 NOx



(b) 2016fh_v1 NOx



(c) 2016fj_v2 minus 2016fh_v1

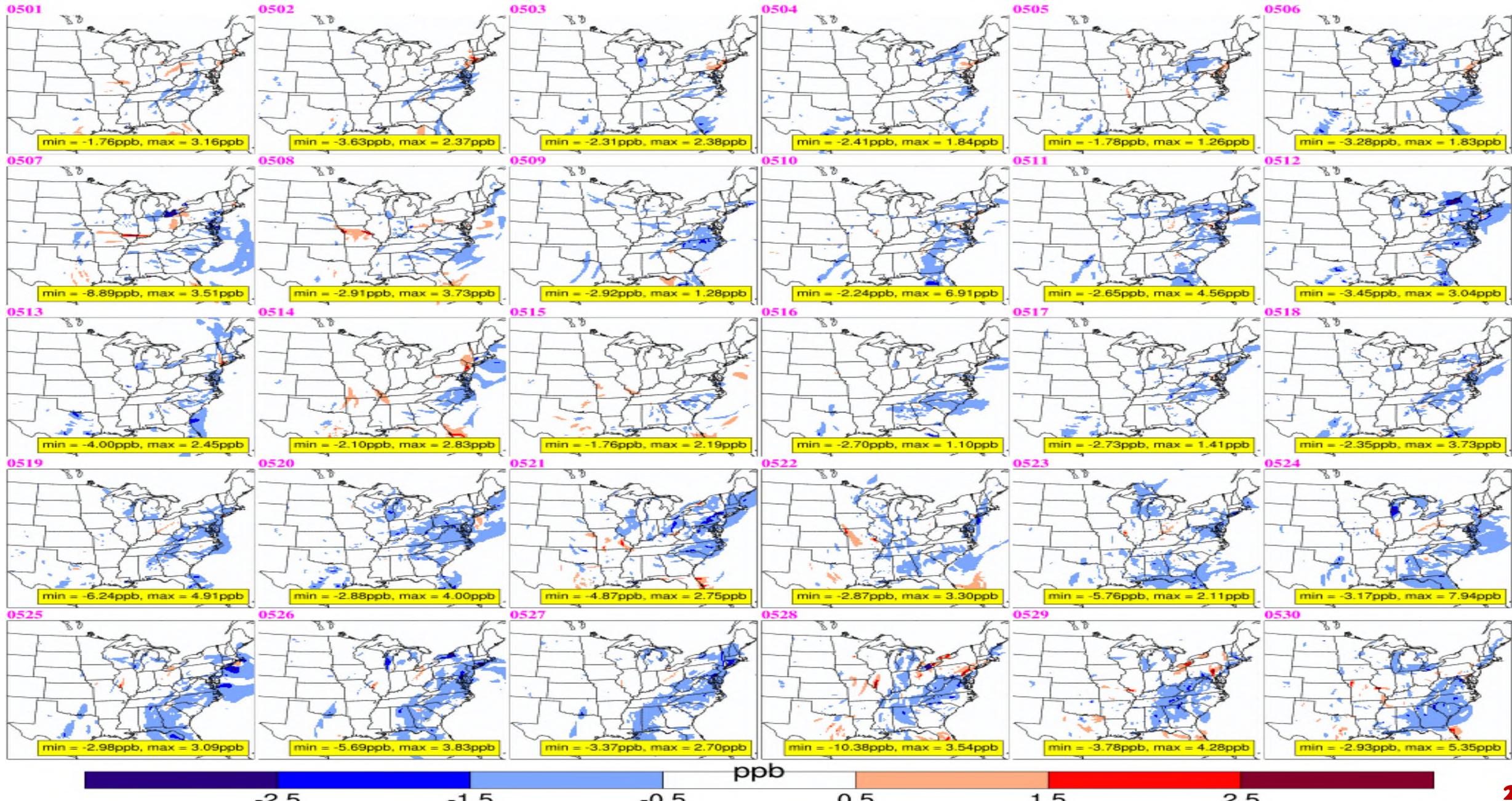


Rule of thumb (by Doris McLeod):
5 -- 10 tons/day of NOx =~ 0.5 -- 1 ppb of O₃ (for EGUs)

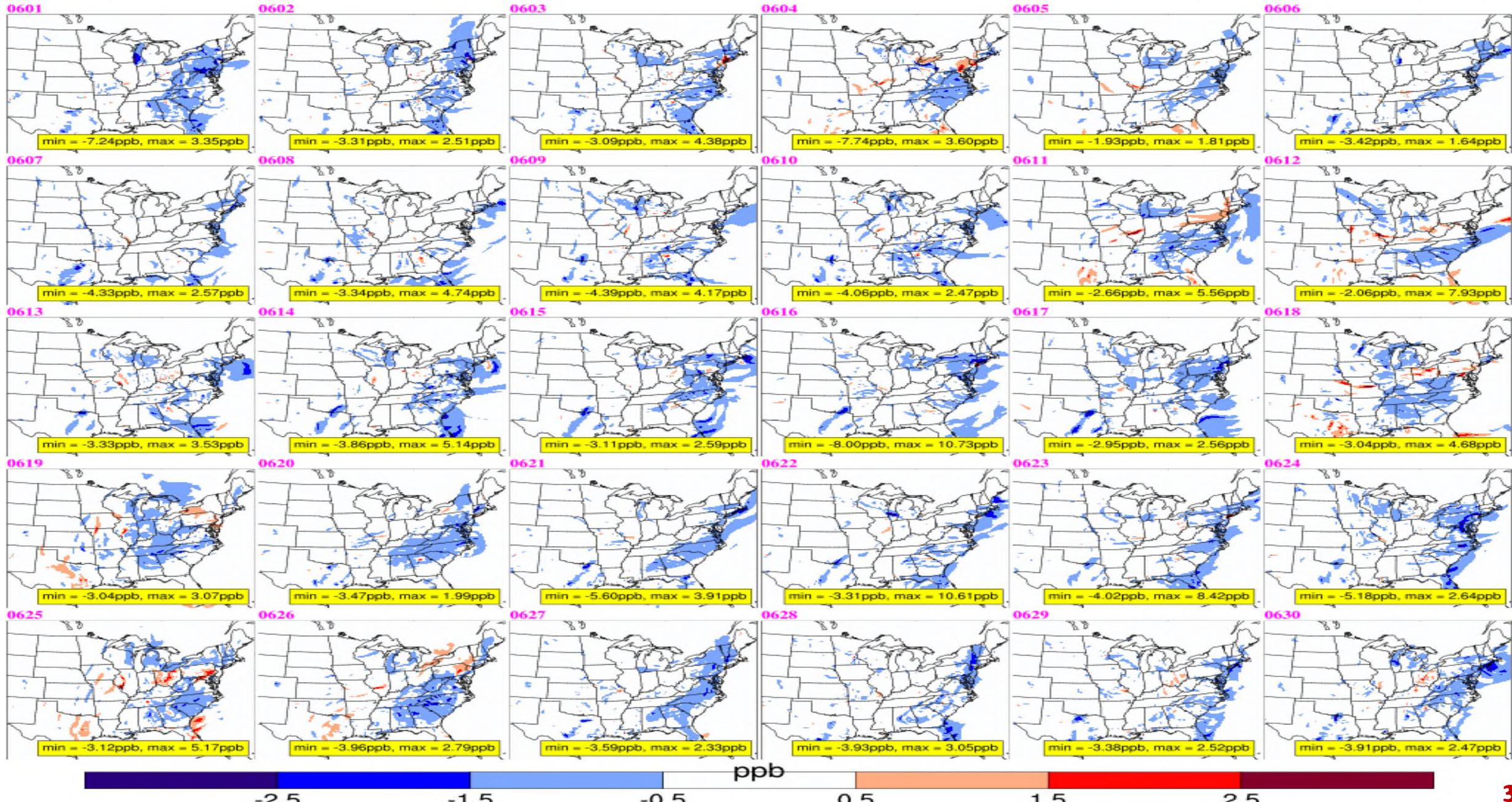
- The plots show daily NOx (ton/day) on July 22, a high O₃ day;
- The “rule” was originally estimated years ago for EGUs;
- Meteorology and chemistry have changed over the year;
- CMAQ runs are being planned to re-do the analysis and obtain more suitable estimates for **area sources** (infinite point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

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

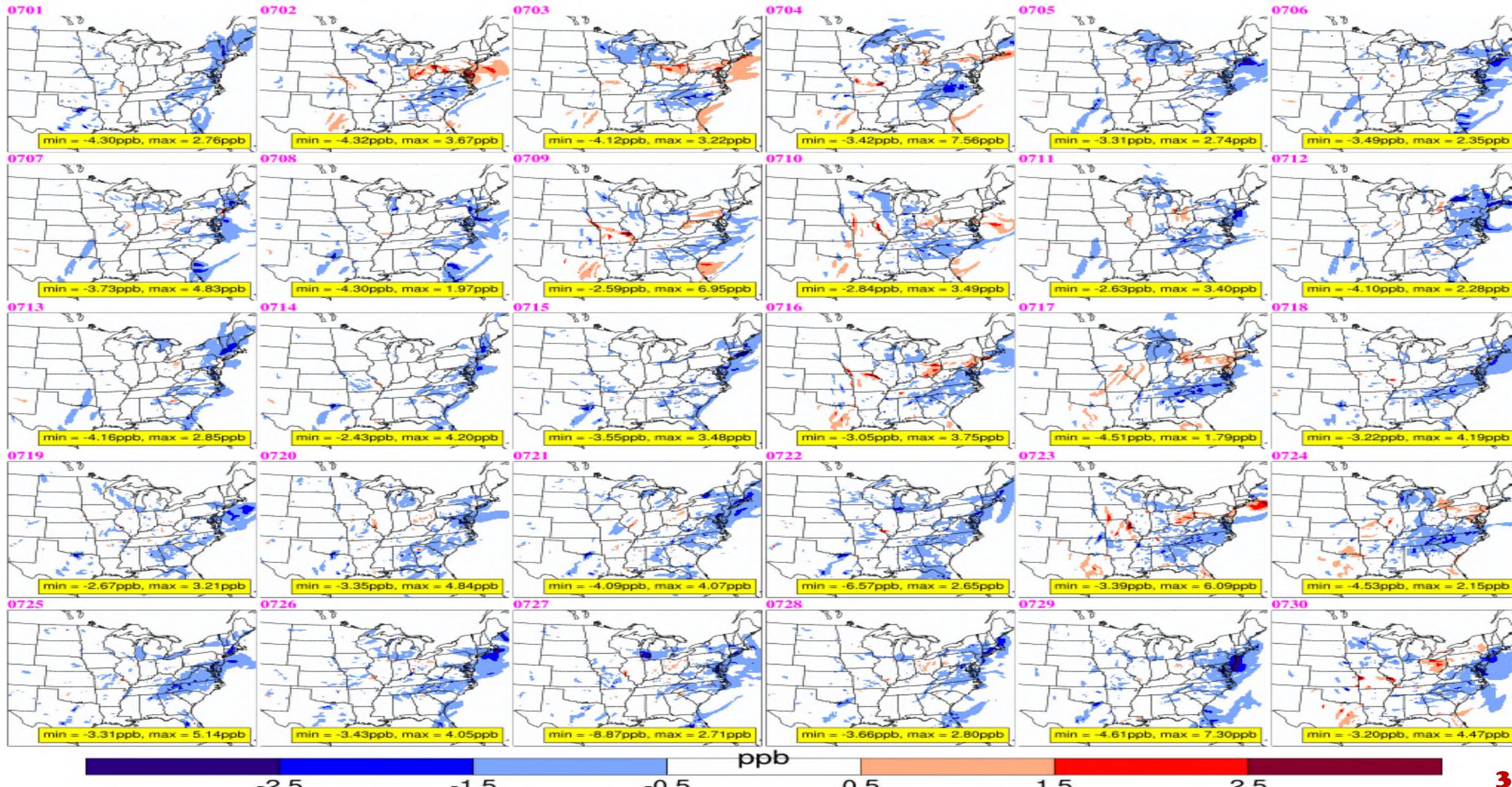
O3 2016v2 moves3_531 minus O3 2016v1 moves2014b_531 at 3pm EST from May 1 to May 30



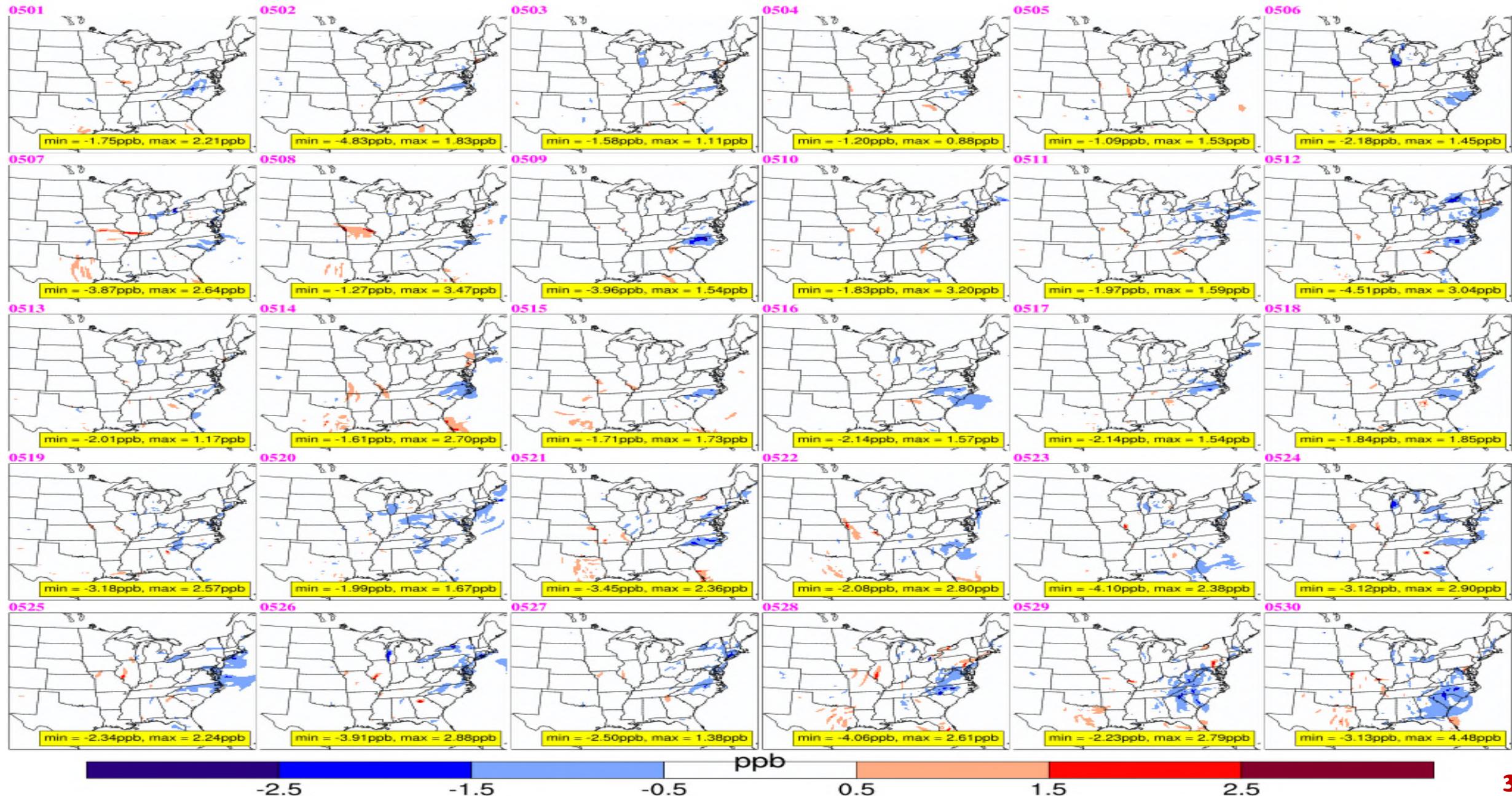
O3 2016v2 moves3_531 minus O3 2016v1 moves2014b_531 at 5pm EST from June 1 to June 30

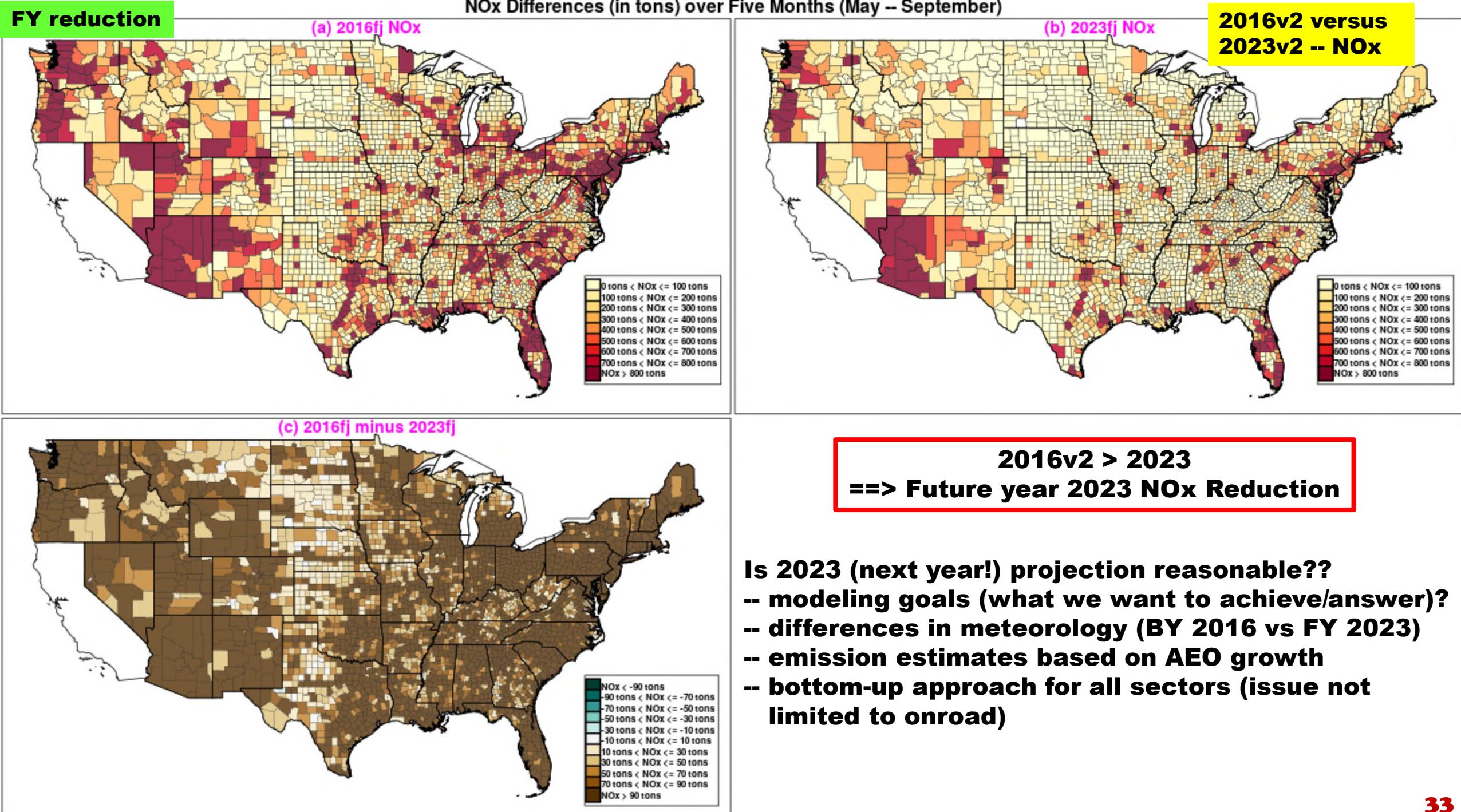


O3 2016v2 moves3_531 minus O3 2016v1 moves2014b_531 at 6pm EST from July 1 to July 30

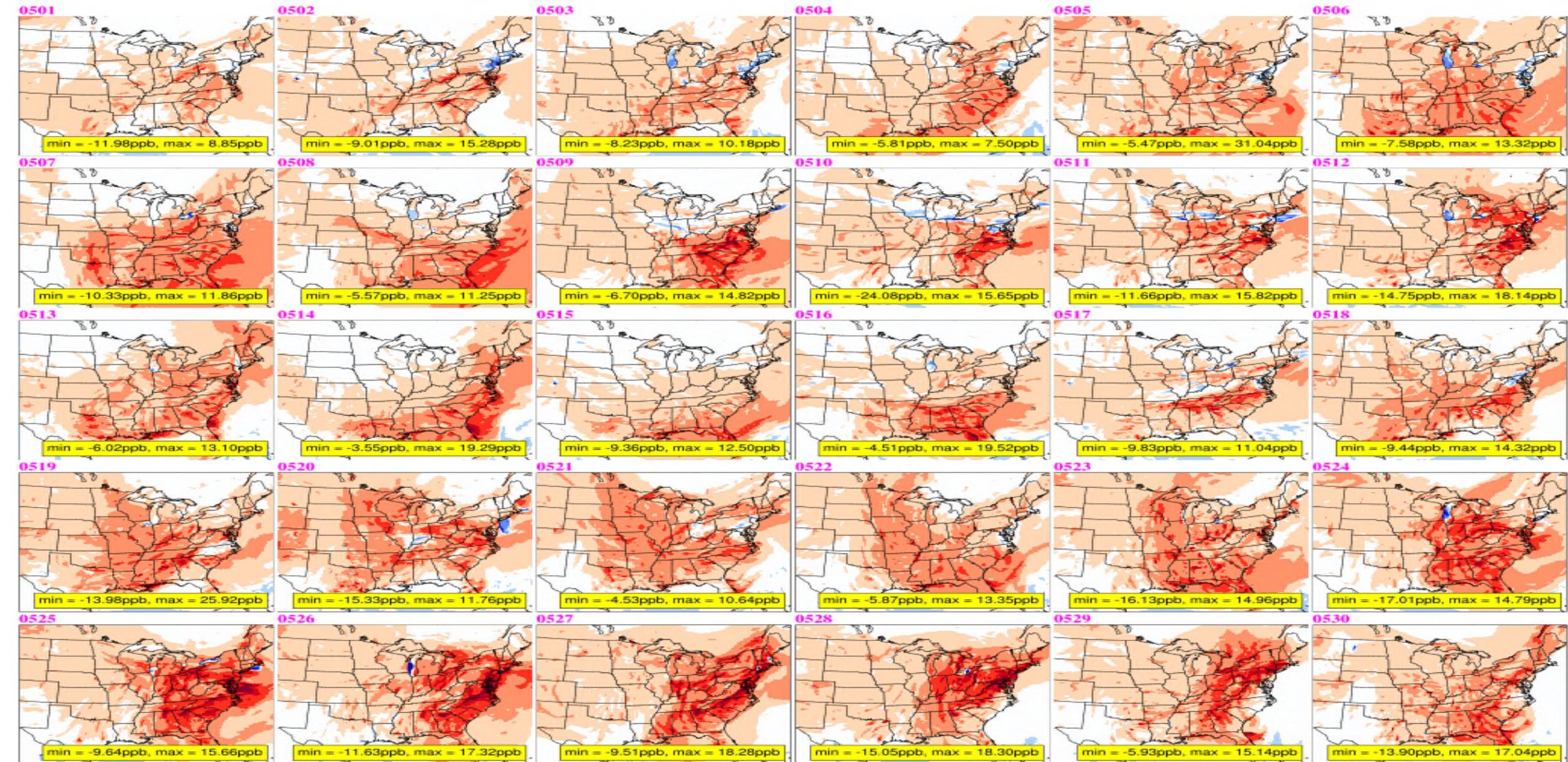


O3 2023v2 moves3_533 minus O3 2023v1 moves2014b_531 at 3pm EST from May 1 to May 30





O3 2016v2 moves3_533 minus O3 2023v2 moves3_533 at 3pm EST from May 1 to May 30



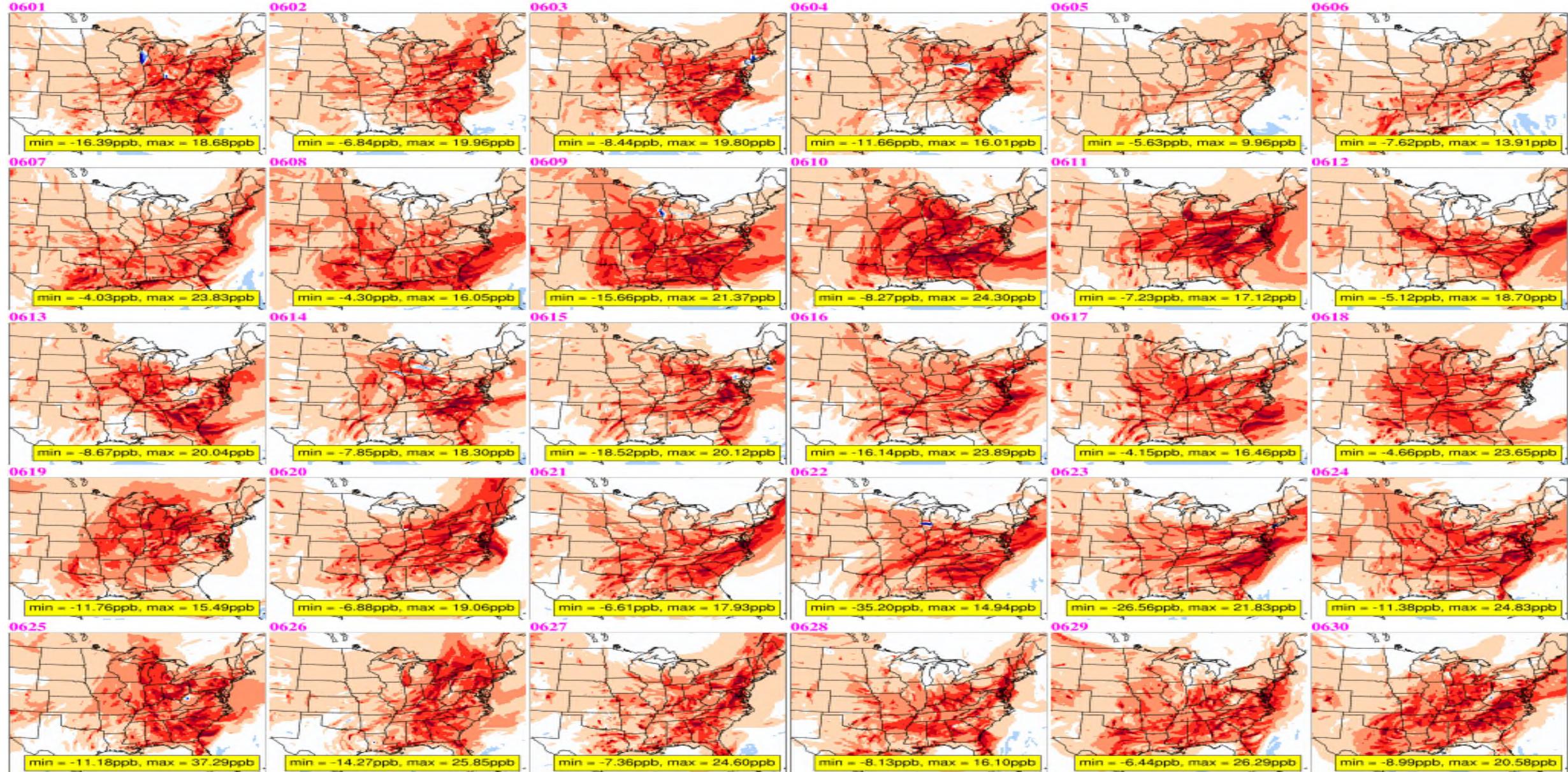
ppb

FY reduction

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

5pm June 2016/2023

O3 2016v2 moves3_533 minus O3 2023v2 moves3_533 at 5pm EST from June 1 to June 30



ppb

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**)