Effect and Implementation of Vehicle Fleet Age in MOVES and SMOKE-MOVES

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MJO MOVES Workgroup Conference Call
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Effect of Age Distribution

Fleet age distribution is considered one of the most important parameters affecting emissions in MOVES

Effect of Fleet Age
Model Setup

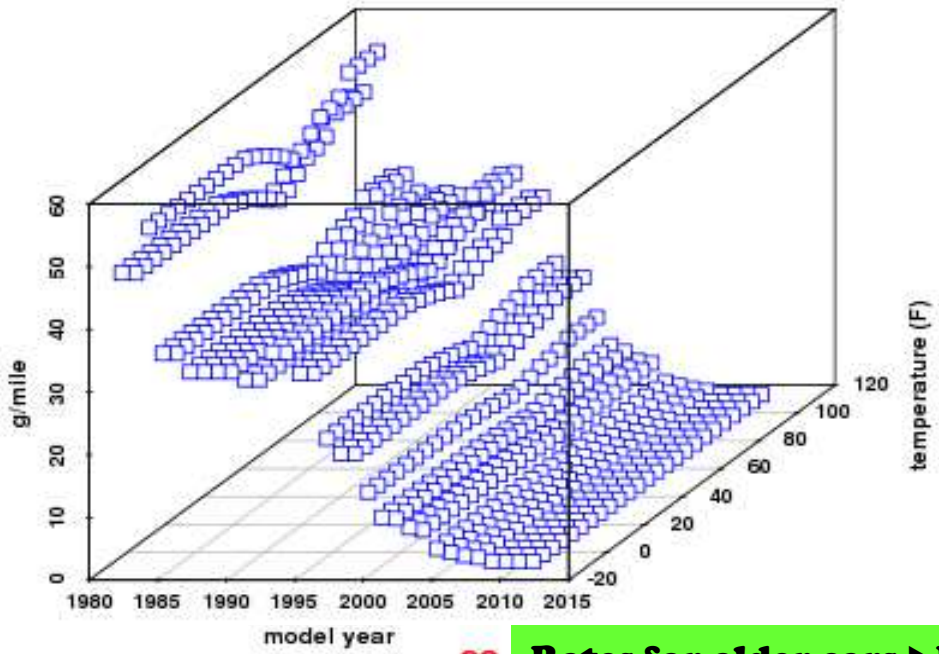
- Version: MOVES2014 (October release)
- County: Fairfax (northern VA, urban county, I&M program)
- Base Year: 2011
- Emission rate mode
- Vehicle Fleet: hypothetical fleet with a constant fraction of 1/31 (0.03225) for all age bins and for all vehicle types
- Temperature: 25 bins from -5F to 110F with an increment of 5F
- Relative Humidity: 24 bins from 8% to 100% with an increment of 4%
- Other inputs identical to those submitted to 2011NEIv1 except for the new inputs required by MOVES2014
- Month=7 (July)
- vehicle model year = TRUE in runspecs
- Additional dimension, vehicle model year, involved in model input/output and post-processing

2201210401

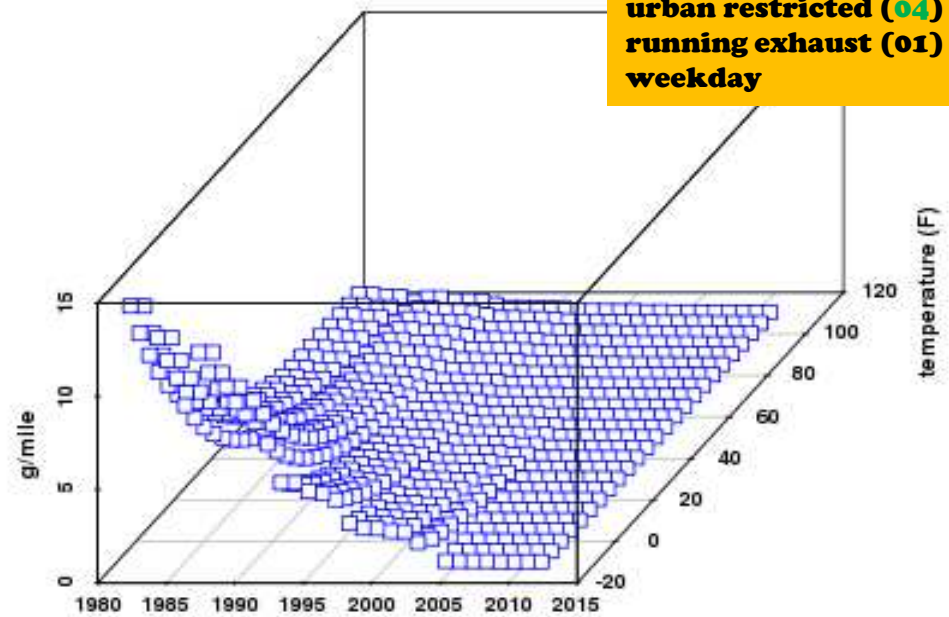
Running Exhaust Rate for Passenger Car (21) at RH=60% (gram/mile)

gasoline (01)
passenger car (21)
urban restricted (04)
running exhaust (01)
weekday

NOX



PM25

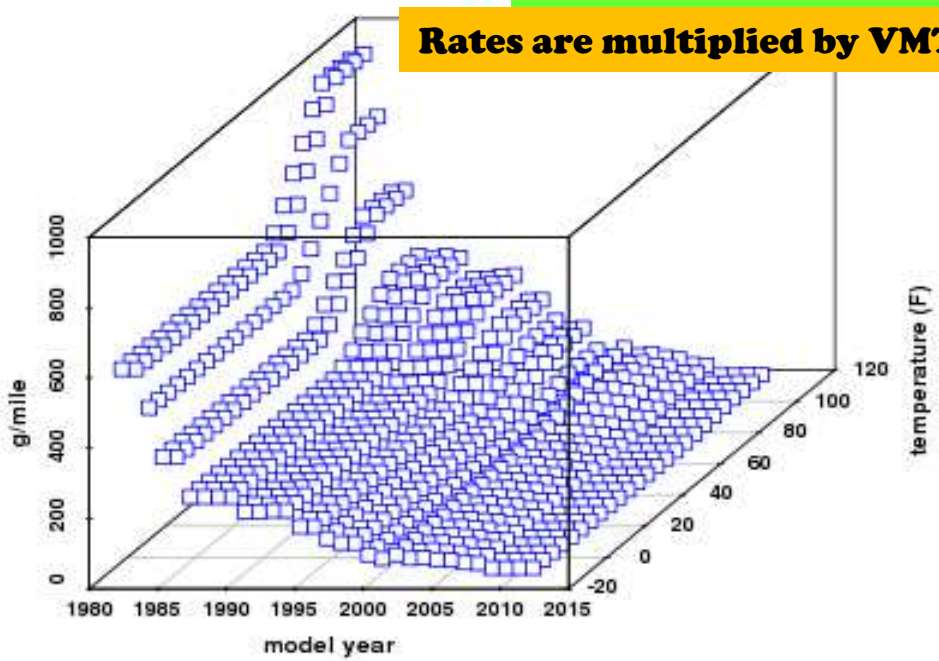


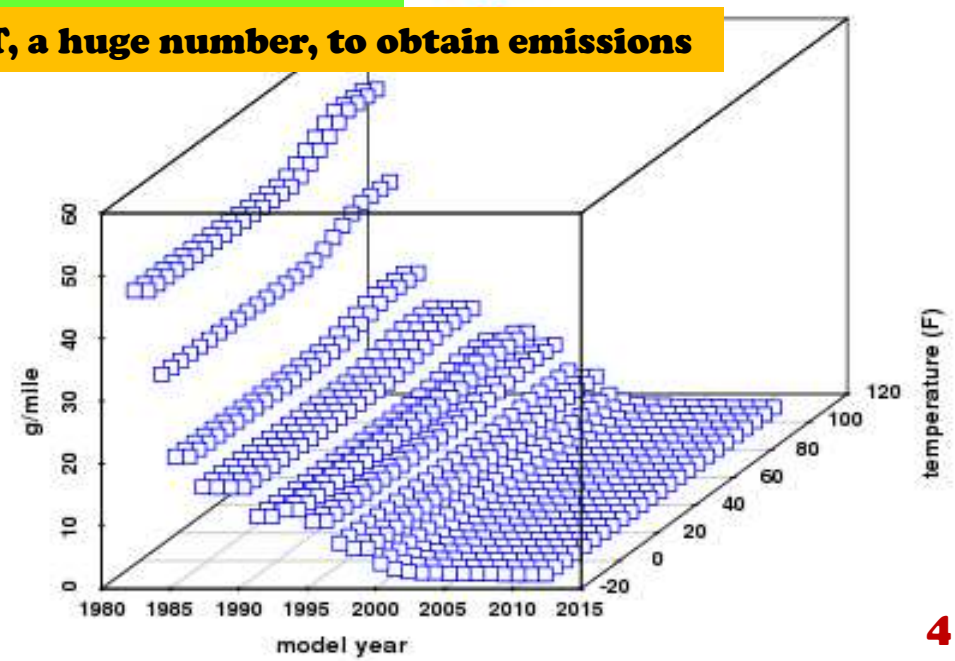
CO

Rates for older cars > Rates for newer cars

VOC

Rates are multiplied by VMT, a huge number, to obtain emissions

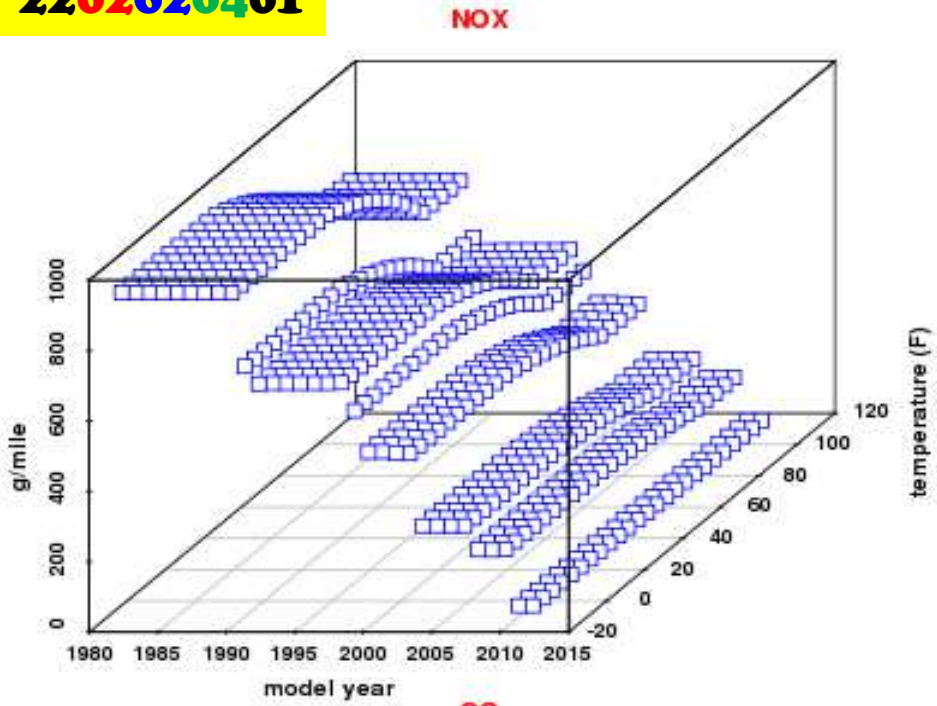


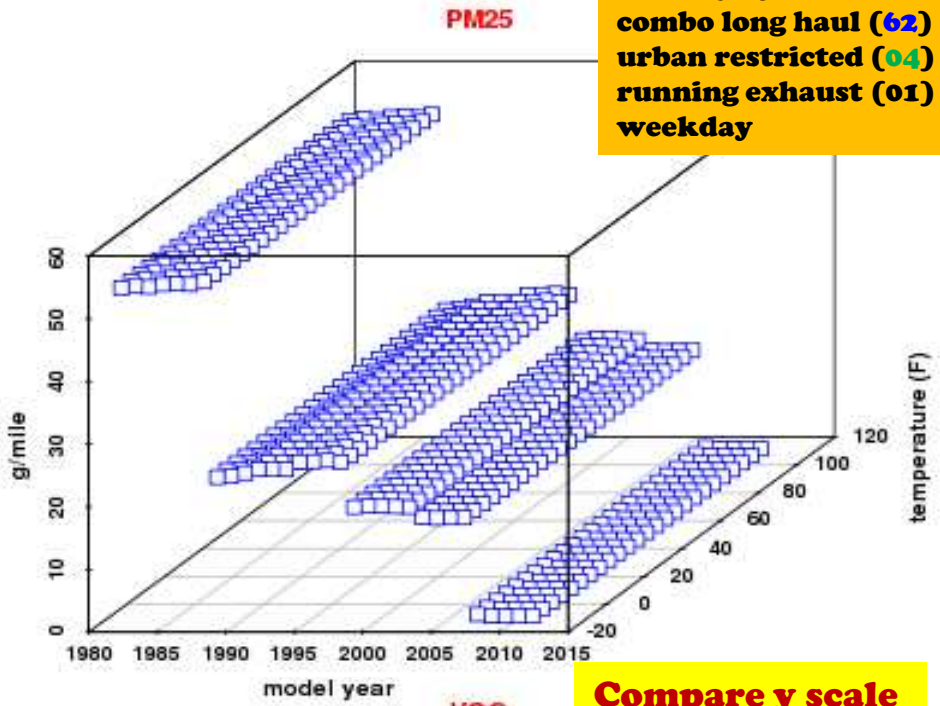


2202620401

Running Exhaust Rate for Combination Long-haul Truck (62) at RH=60% (gram/mil

diesel (02)
combo long haul (62)
urban restricted (04)
running exhaust (01)
weekday

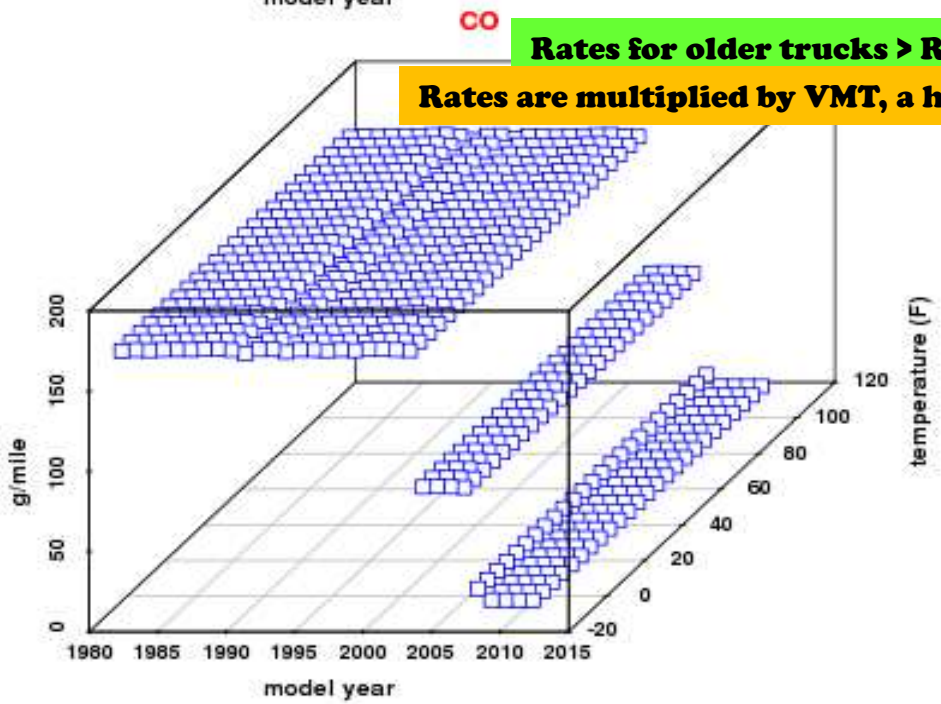


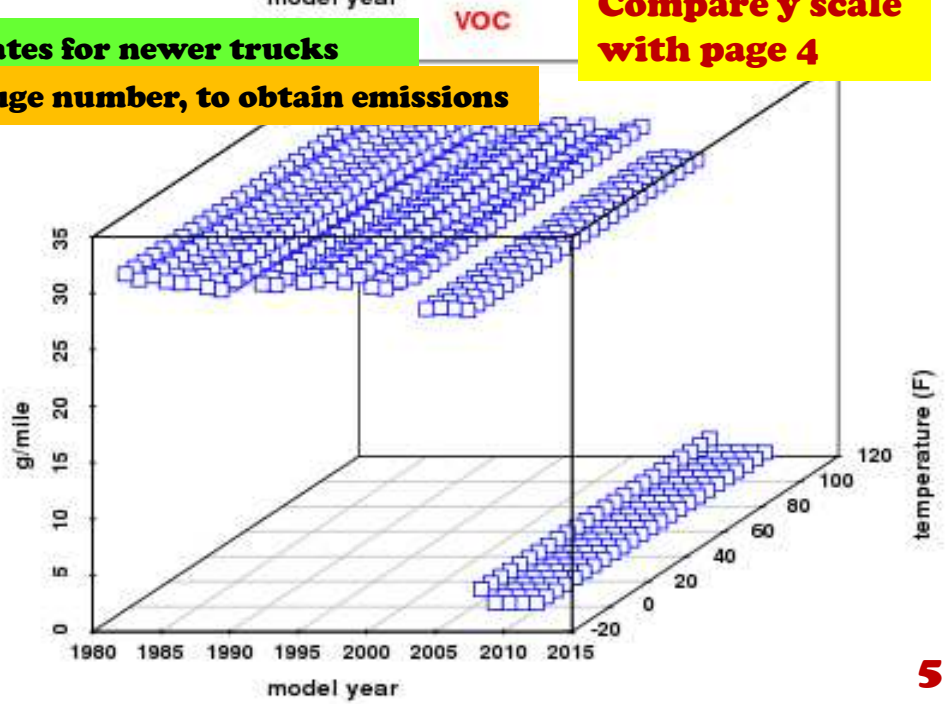


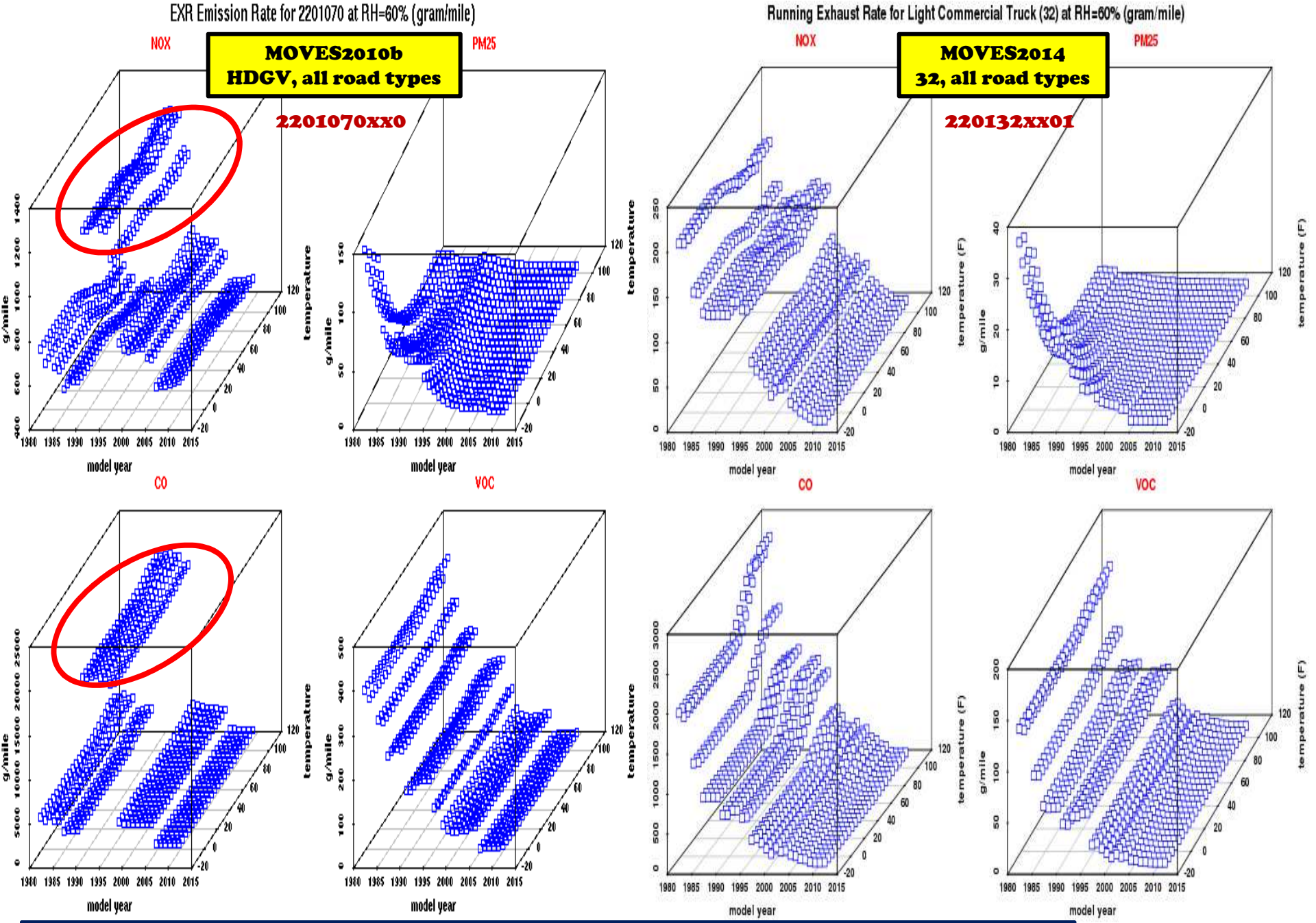
Compare y scale with page 4

Rates for older trucks > Rates for newer trucks

Rates are multiplied by VMT, a huge number, to obtain emissions







High rates in MOVES2010b for some mid model year HDGV appear to have been corrected in MOVES2014

Gasoline (01)

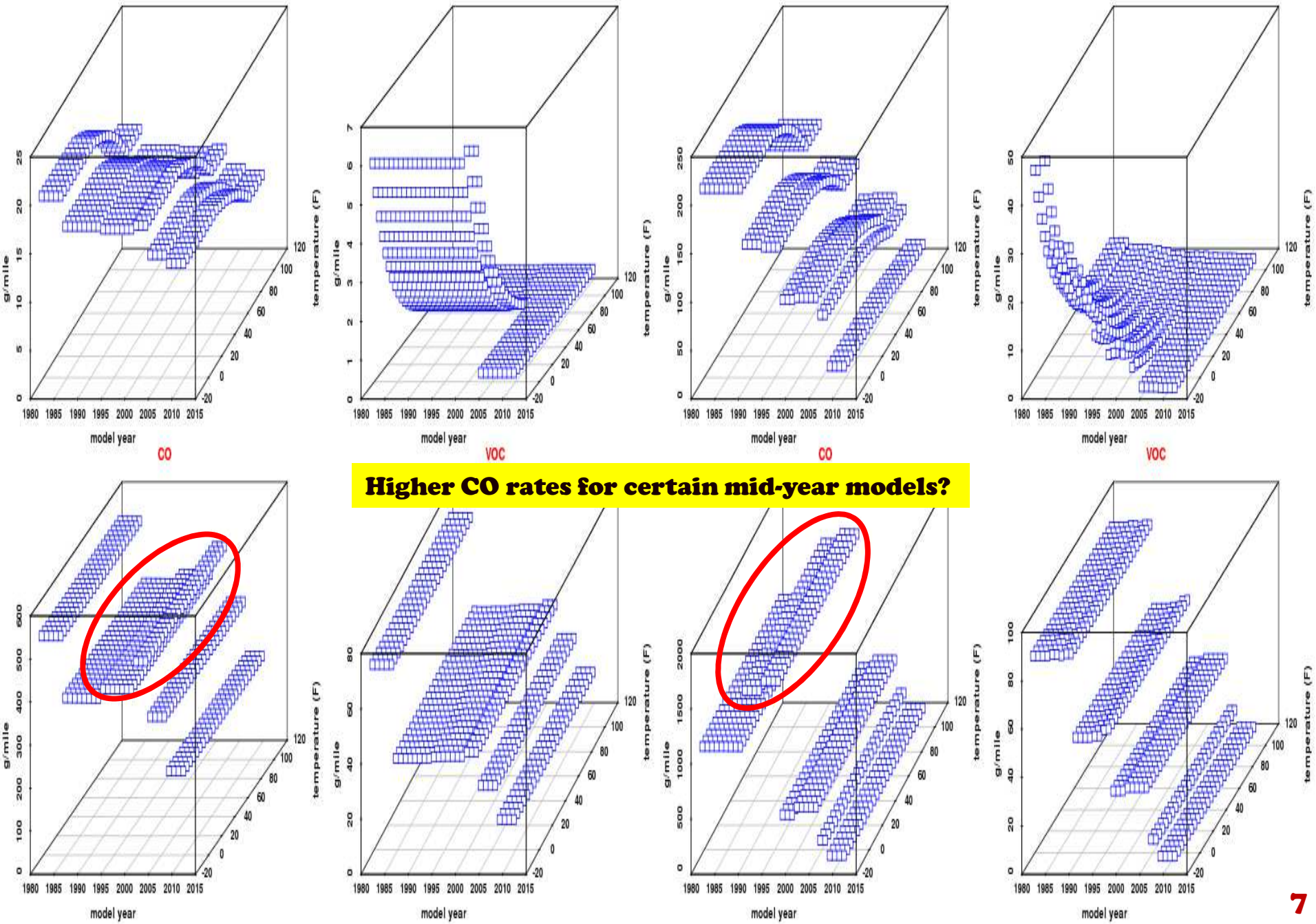
MOVES2014

Running Exhaust Rate for Motorcycle (11) at RH=60% (gram/mile)

2201110401

Running Exhaust Rate for School Bus (43) at RH=60% (gram/mile)

2201430401



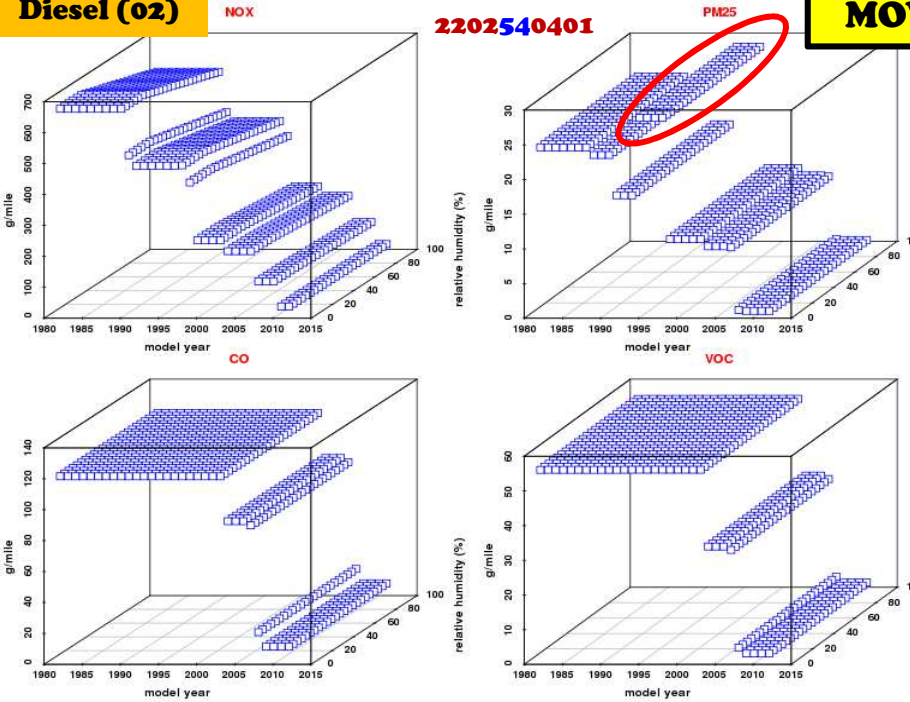
Higher CO rates for certain mid-year models?

Diesel (02)

MOVES2014

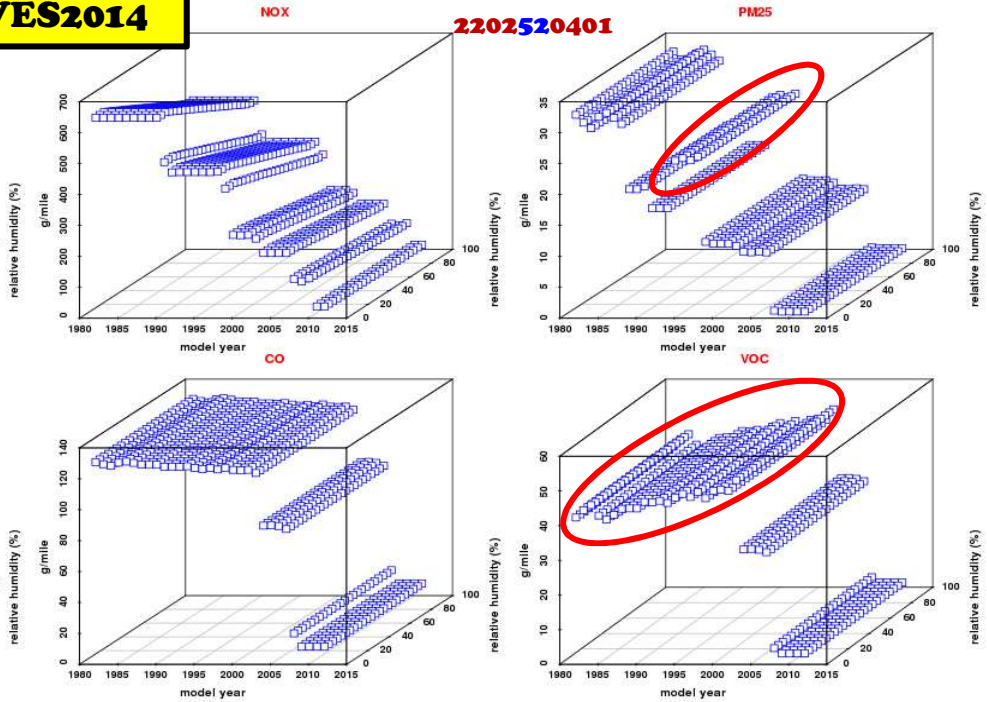
Running Exhaust Rate for Motor Home (54) at T=60F (gram/mile)

2202540401



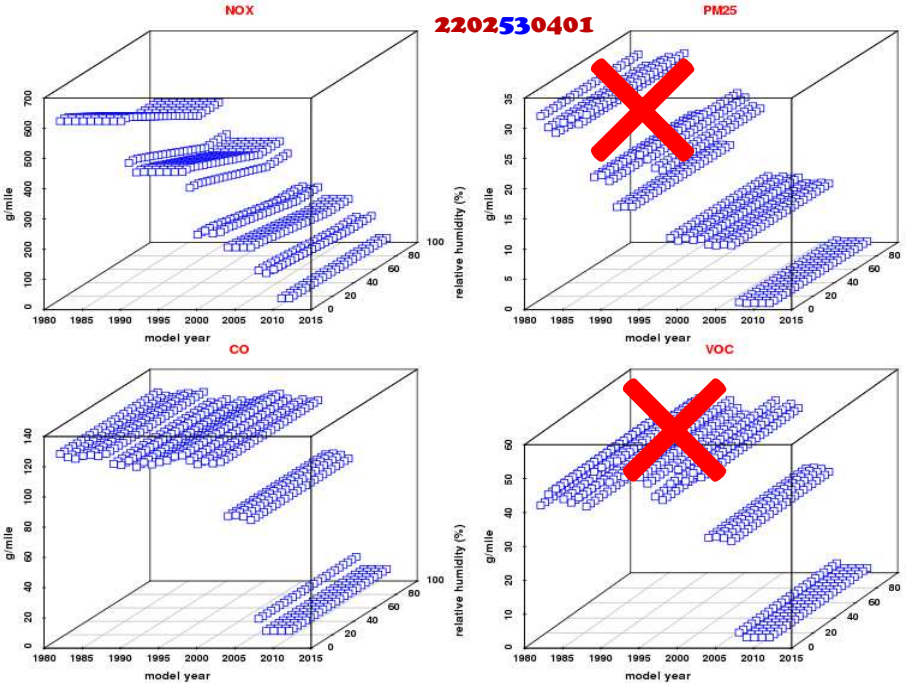
Running Exhaust Rate for Single Unit Short-haul Truck (52) at T=75F (gram/mile)

2202520401



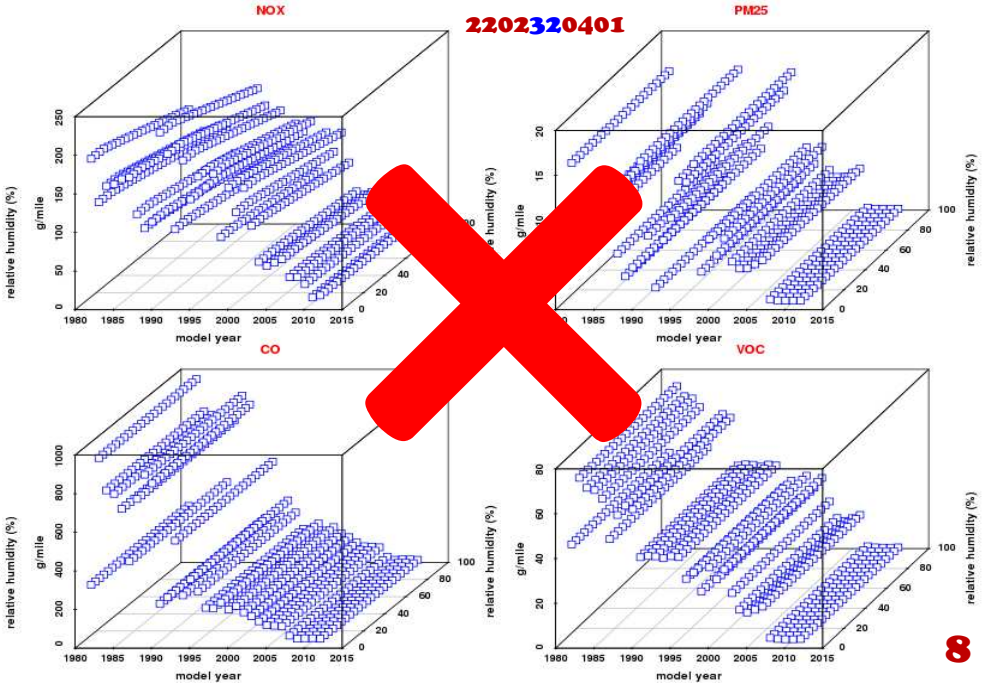
Running Exhaust Rate for Single Unit Long-haul Truck (53) at T=80F (gram/mile)

2202530401



Running Exhaust Rate for Light Commercial Truck (32) at T=70F (gram/mile)

2202320401



Summary on Age Distribution

- Emission rates of older model year vehicles are higher than emission rates of newer model year vehicles
- Emission rates for certain mid-model year vehicles are higher than emission rates of older model year vehicles
  - Gasoline vehicles: CO
  - Diesel vehicles: all pollutants
- MOVES mechanisms for "adjusting" pollutant emission rates focus mostly on NOx and yield unusual results, particularly for diesel light commercial trucks

Representative County

Representative County

How can this be implemented in practice??

- **Original** county grouping criteria:

  (a) control programs (CALEV, NLEV, I/M, stageII);

  (b) fleet age distribution;

  (c) fuel parameters

  (state-supplied data overwritten by EPA);

local, state-specific data

- **Proposed** county grouping criteria (May 27 2014 joint GA-VA presentation):

  (a) control programs;

  (b) fleet age distribution;

  (c) fuel parameters;

  (d) ramp fraction;

  (e) VMT/VPOP ratio (by vehicle type);

  (if no activity aggregation)

  (f) Extended Idling

Reconsider with new CRC data

new suggestion for grouping

additional criterion

Representative County

Simple Analogy

Representative County		Range of Actual Values	Example Modeled Value
County Blue		1 - 5	5
County Yellow		6 - 10	7
County Red		11 - 15	14

-- Number 5 used to model County Blue cannot fully cover actual number range from 1 to 5 (likewise for Counties Yellow and Red), causing incorrect representation.

-- Options: (1) phase out current representative county approach using data from a single representative county and aggregate actual values to correctly represent the entire county group or (2) use inventory mode.

CRC Data in 2011NEIv2

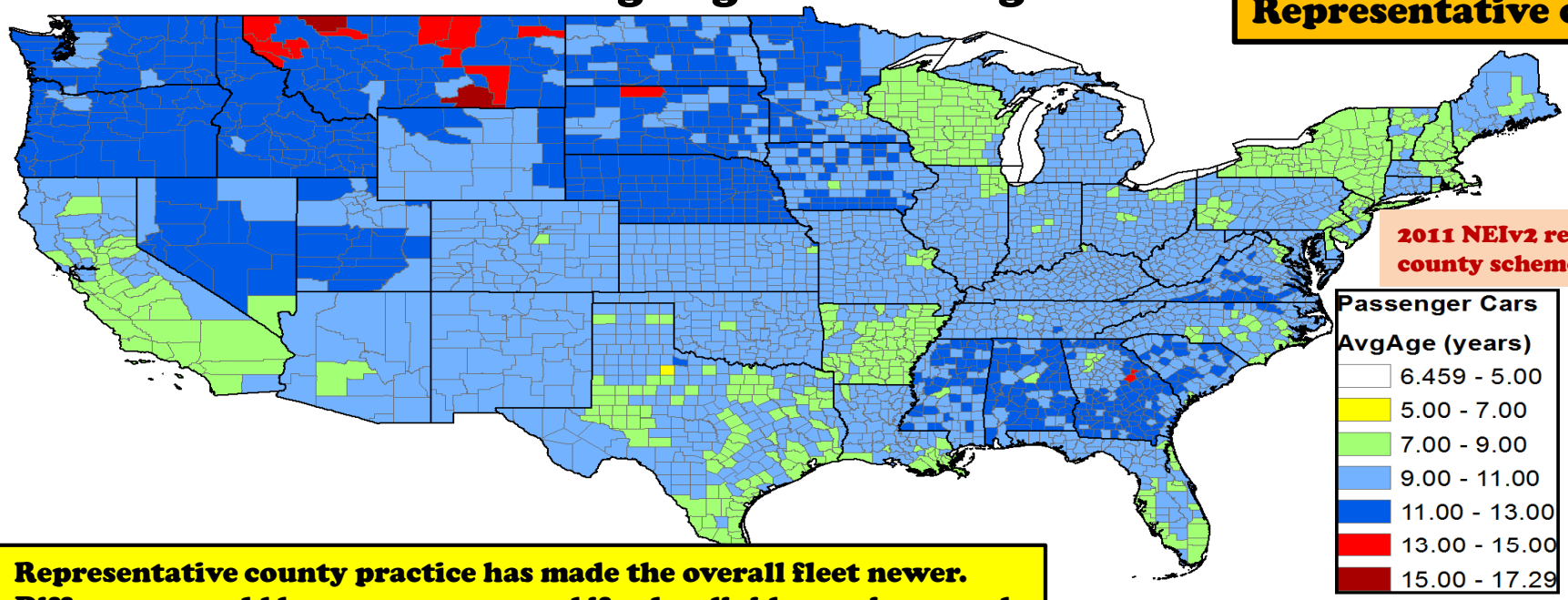
- **CRC project goal was to improve the default inputs used by USEPA in MOVES modeling**
- **Selected critical inputs to improve:**
  - Passenger car & truck age distribution
  - Passenger car & truck population
  - Combination long-haul VMT
  - Heavy-duty extended idling
- **For age and population, IHS data for passenger cars (21) and passenger trucks (31, 32) were obtained for 2011**
- **CRC data (21, 31, 32) has been incorporated into 2011NEIv2 via external MySQL CDBs (but not in MOVES database)**
- **Evaluation: average age for a source vehicle type:**

$$\text{Average Age} = \sum_{i=0}^{i=30} \text{fraction_}i * \text{age_}i$$

Effect of Representative County

Average Age for Passenger Cars

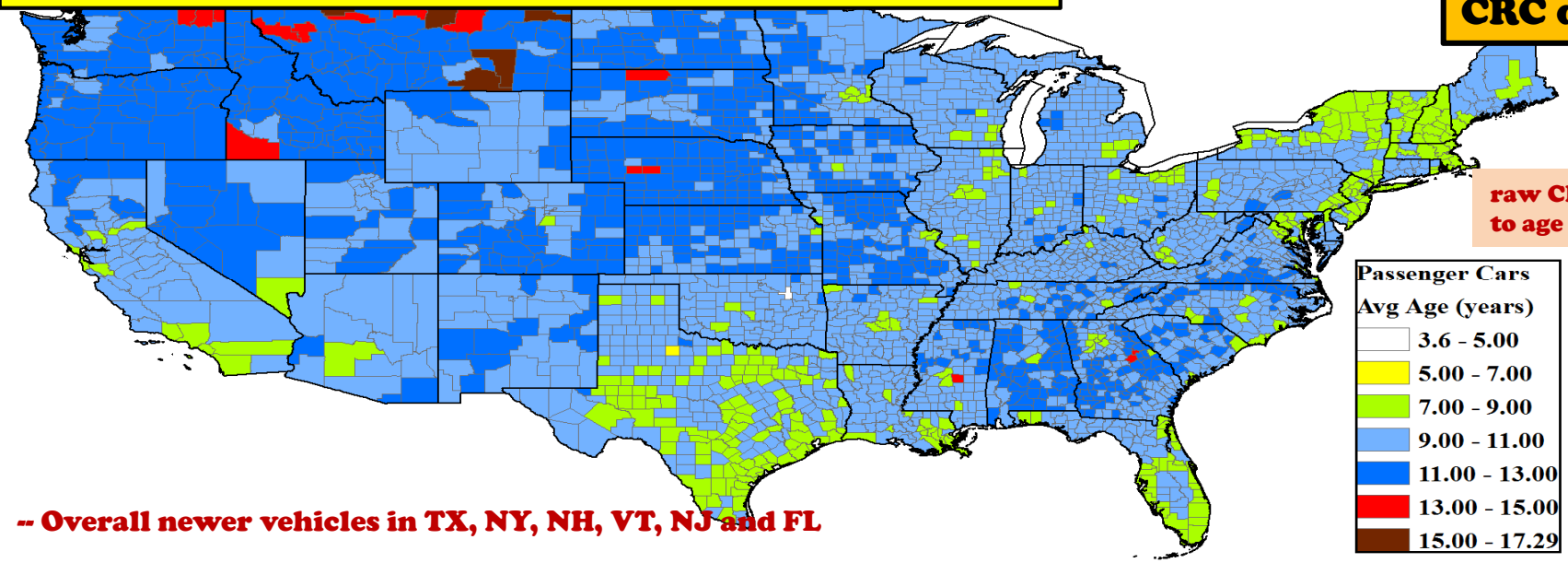
Representative county



2011 NEIv2 representative county scheme applied

Representative county practice has made the overall fleet newer. Difference would be more pronounced if color divides are increased.

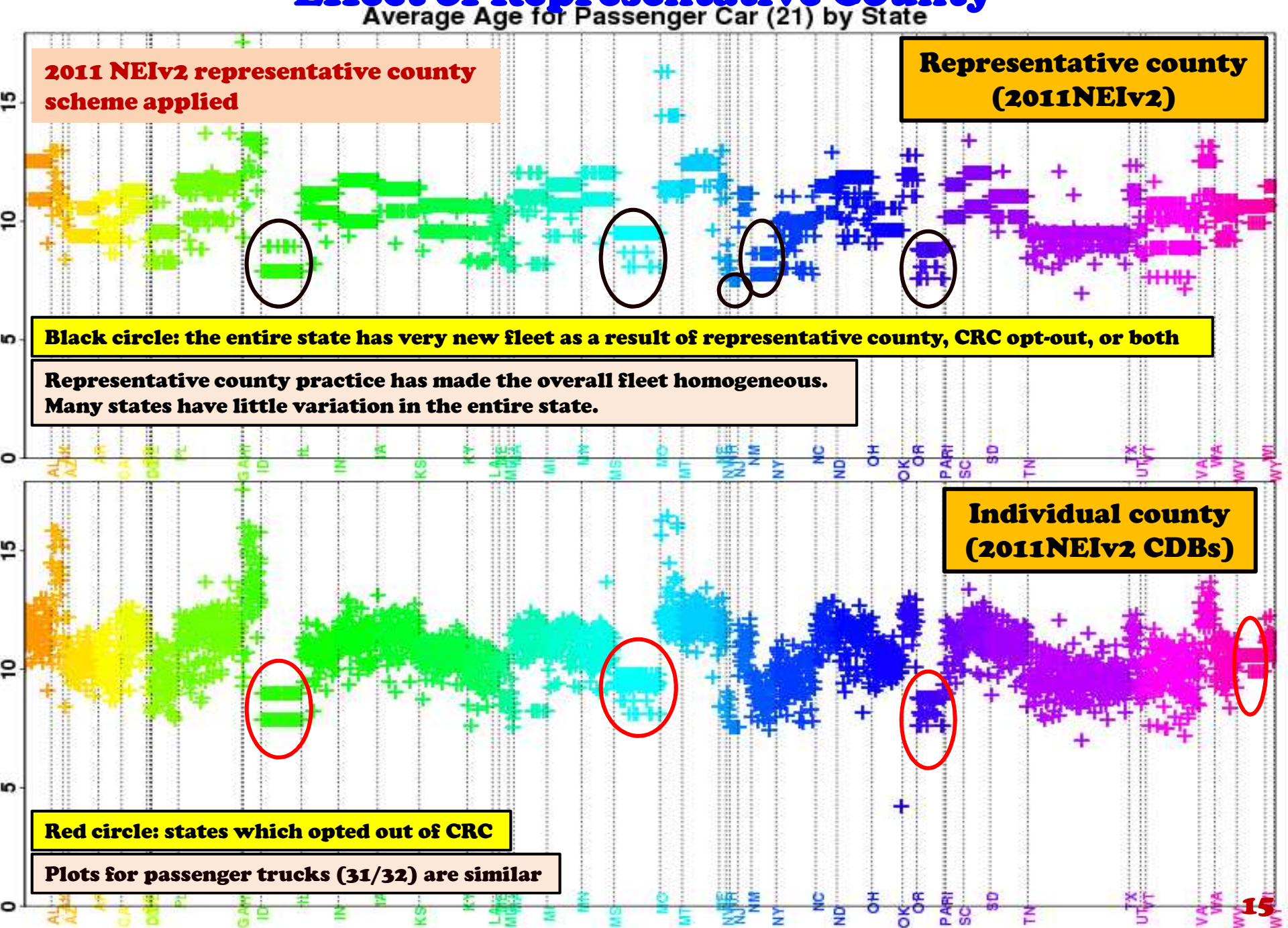
CRC data

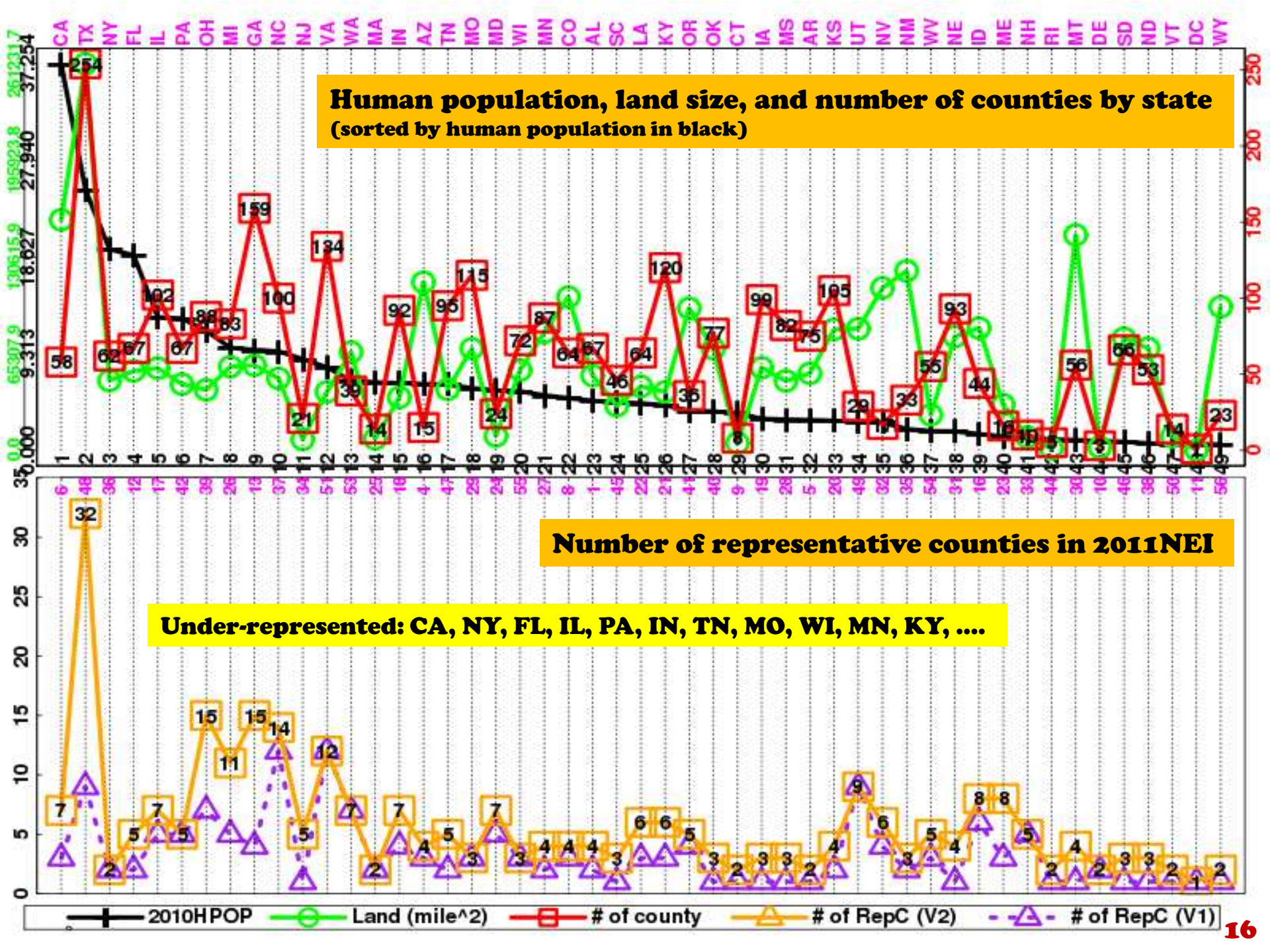


raw CRC data prior to age 30 correction

-- Overall newer vehicles in TX, NY, NH, VT, NJ and FL

Effect of Representative County




Human population, land size, and number of counties by state
(sorted by human population in black)
Number of representative counties in 2011NEI
Under-represented: CA, NY, FL, IL, PA, IN, TN, MO, WI, MN, KY, ...
2010HPOP
Land (mile^2)
# of county
# of RepC (V2)
# of RepC (V1)

Summary on Representative County

- Representative county is generally selected as county in a group with the highest VMT (which is usually more urbanized), making overall fleet newer (lower emissions)
- The approach also makes the entire fleet more homogeneous. Many states have very little variation in average fleet age for the entire state
- The overall fleet in some states is very new, as a result of either representative county scheme, CRC opt-out, or both (IL, MO, NJ, NY, PA)
- Representative county scheme should consider a total of six criteria. How can this approach be realistically implemented in practice?

Fleet Age in SMOKE-MOVES

Fleet Age in SMOKE-MOVES

- Increase in emission rate as vehicles age (shown in page 4 and page 5) is not simulated in SMOKE-MOVES
  - Vehicle model year is set to false in SMOKE-MOVES runspec
  - Lookup tables contain no age info (i.e., rates do not depend on vehicle age)
- SMOKE-MOVES uses average age by representative county
- Step sequence:
  - From age distribution, calculate average age by representative county
  - Average age is used in MOVES runs to generate lookup tables
  - SMOKE-MOVES uses lookup tables to calculate emissions
- What matters is the average age, not age distribution (age distribution is used in other calculations)
- This important input parameter in mobile source emissions is therefore diluted by SMOKE-MOVES

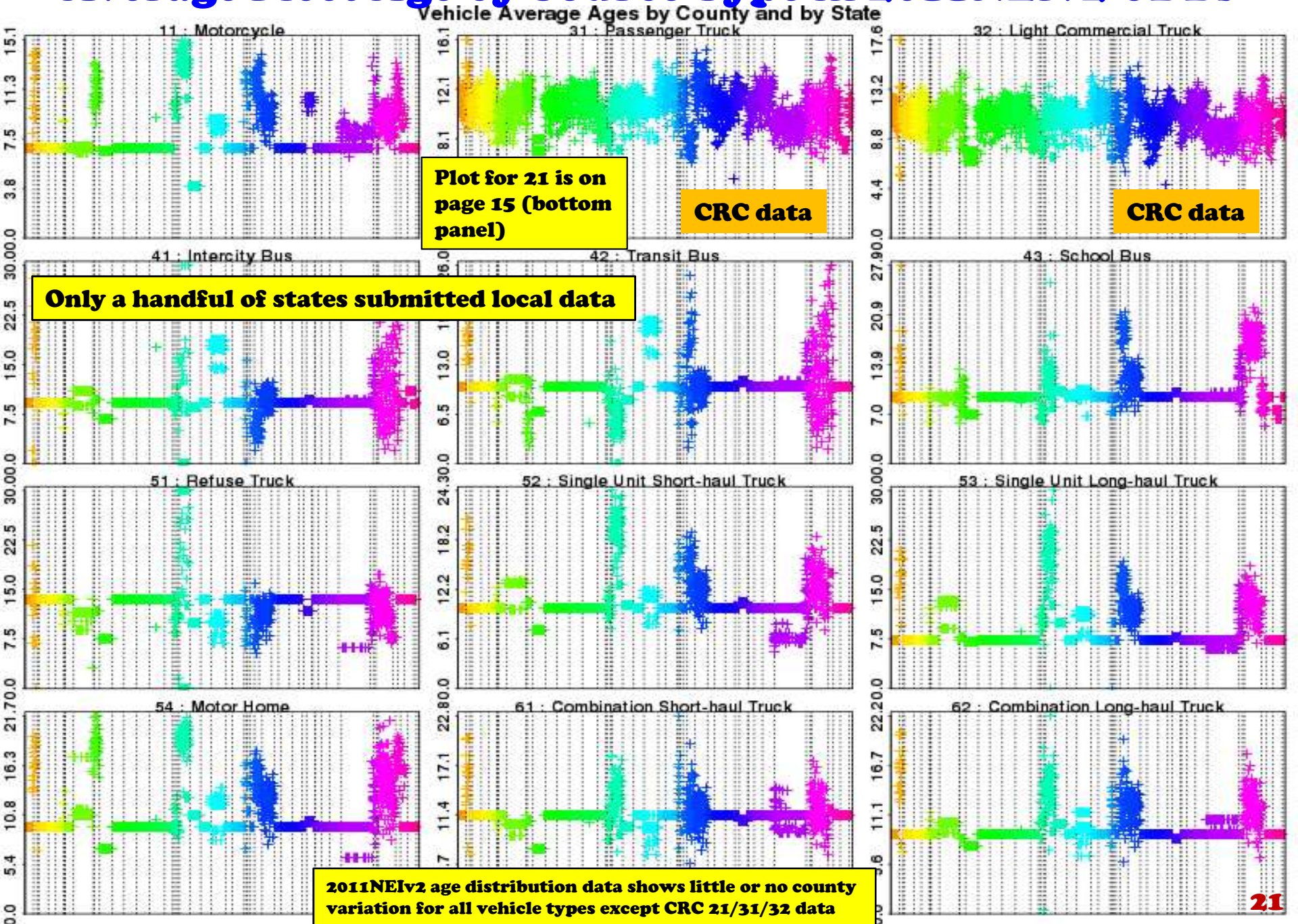
Fleet Age Distribution in 2011NEIv2

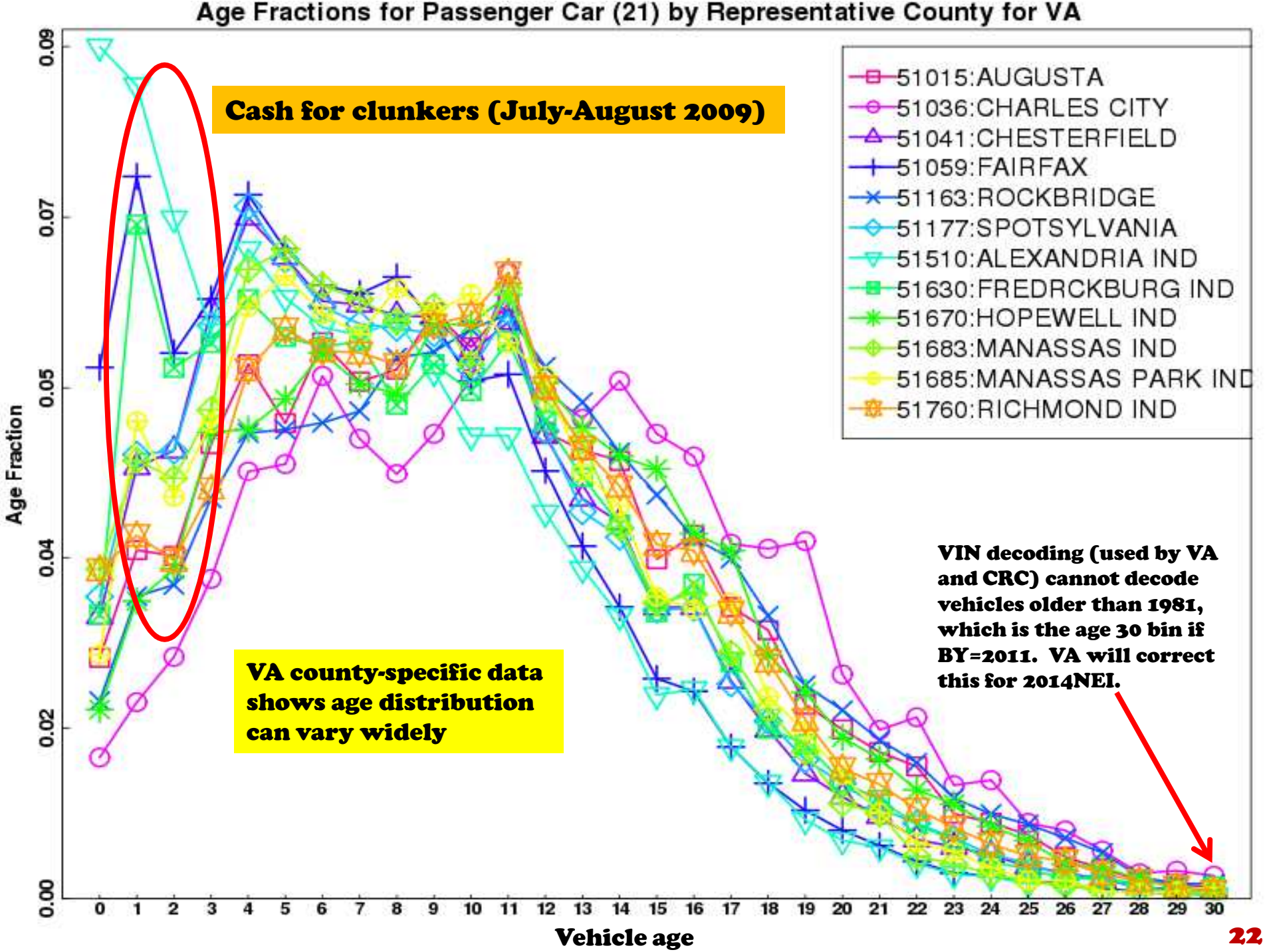
Data source: 2011NEIv2 CDBs as posted by EPA

(a) Average age (queried from CDBs and calculated)

(b) Age distribution (queried from CDBs)

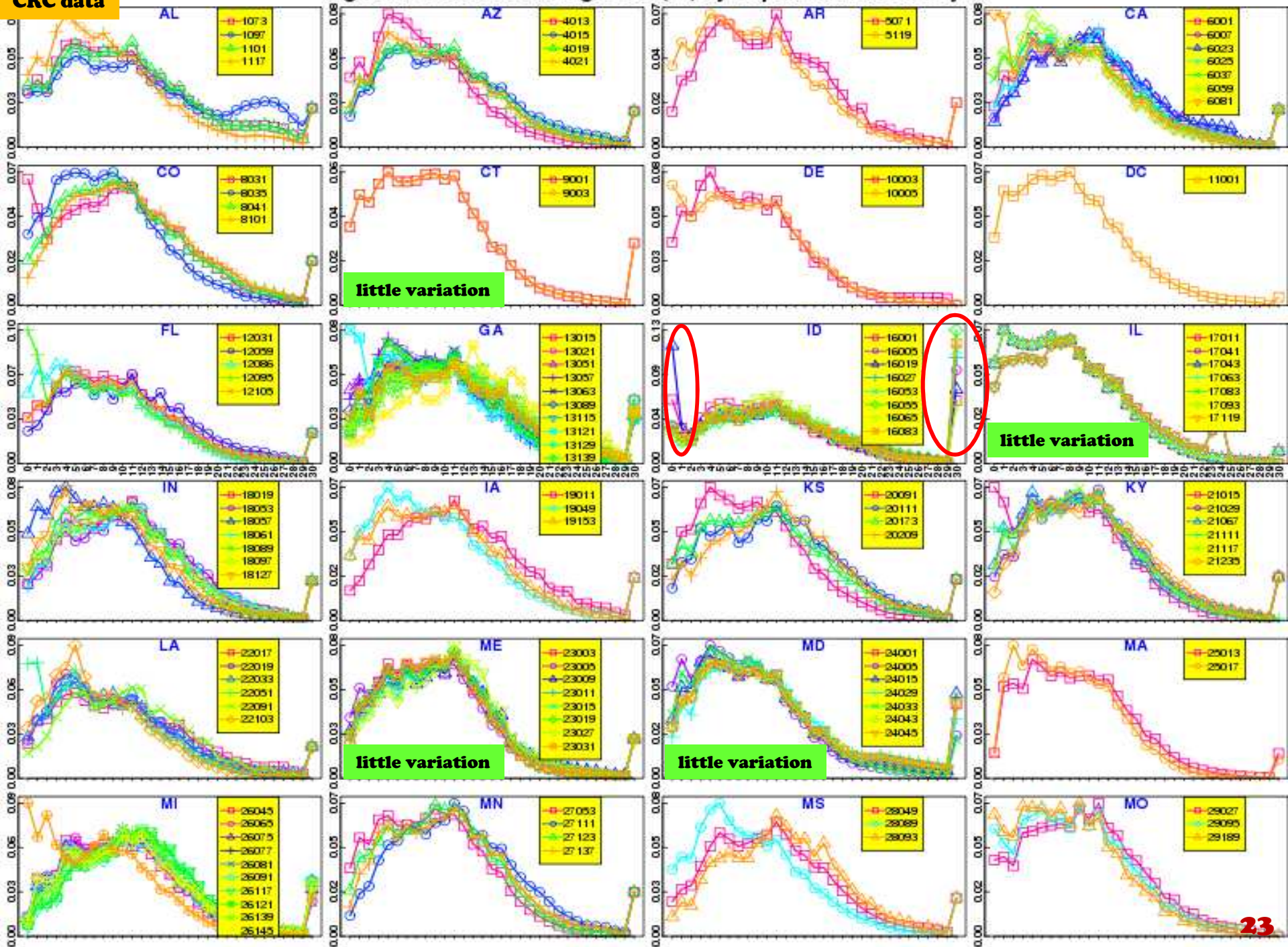
Average Fleet Age by Source Type in 2011NEIv2 CDBs




Age Fractions for Passenger Car (21) by Representative County for VA
Cash for clunkers (July-August 2009)
51015:AUGUSTA
51036:CHARLES CITY
51041:CHESTERFIELD
51059:FAIRFAX
51163:ROCKBRIDGE
51177:SPOTSYLVANIA
51510:ALEXANDRIA IND
51630:FREDRCKBURG IND
51670:HOPEWELL IND
51683:MANASSAS IND
51685:MANASSAS PARK IND
51760:RICHMOND IND
VA county-specific data shows age distribution can vary widely
VIN decoding (used by VA and CRC) cannot decode vehicles older than 1981, which is the age 30 bin if BY=2011. VA will correct this for 2014NEI.
Age Fraction
0.00
0.02
0.04
0.05
0.07
0.09
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
Vehicle age

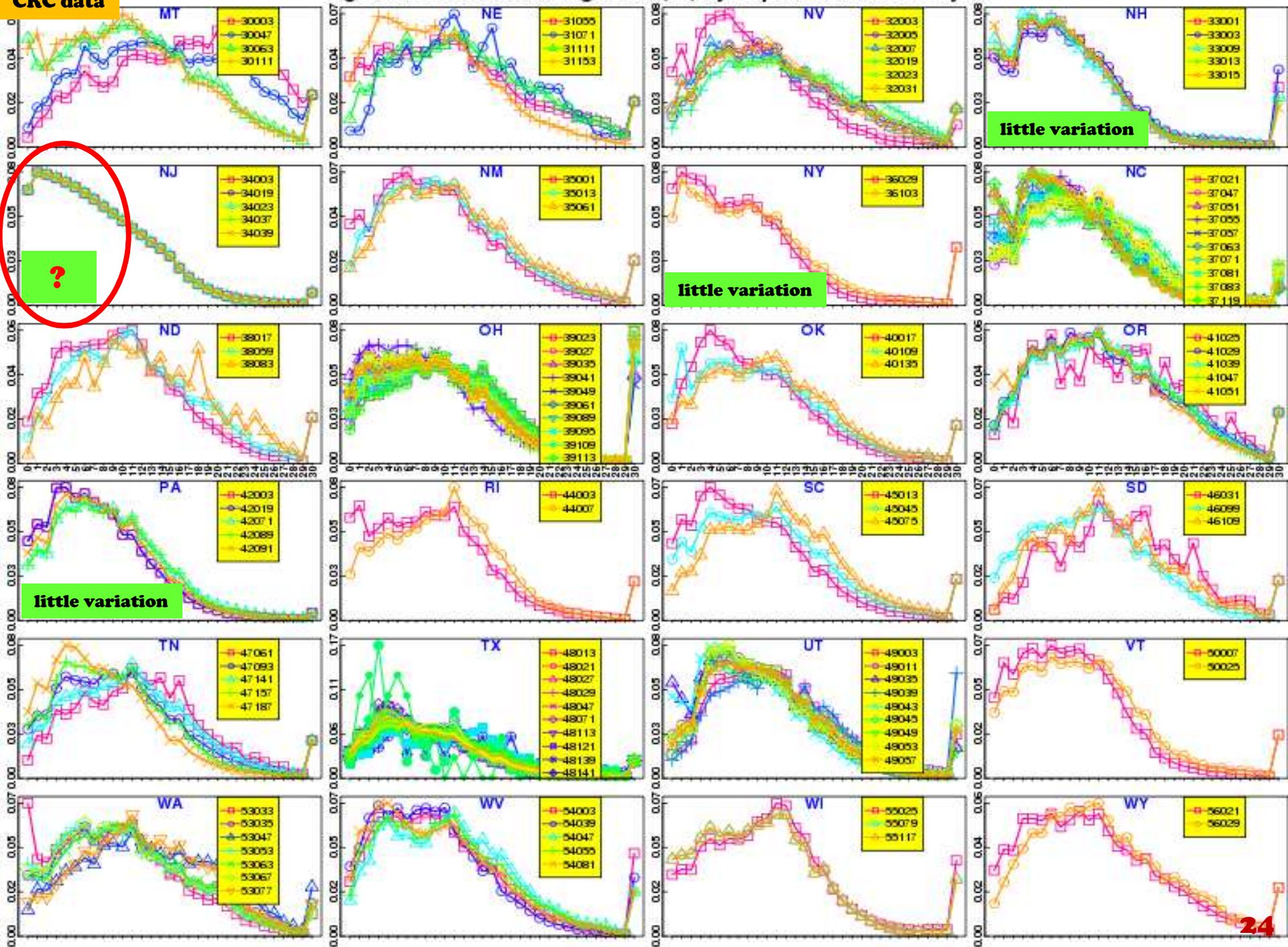
CRC data

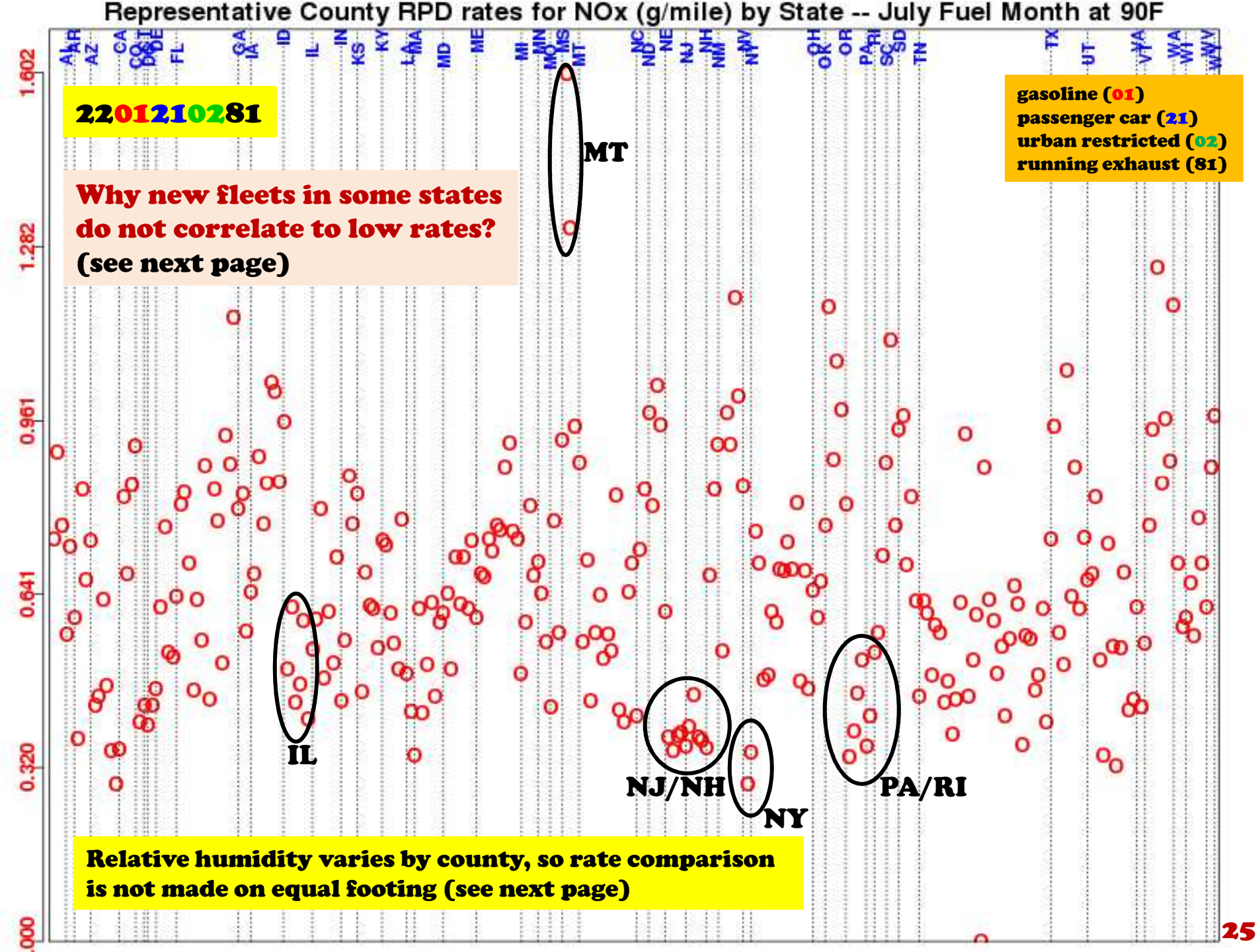
Age Fractions for Passenger Car (21) by Representative County

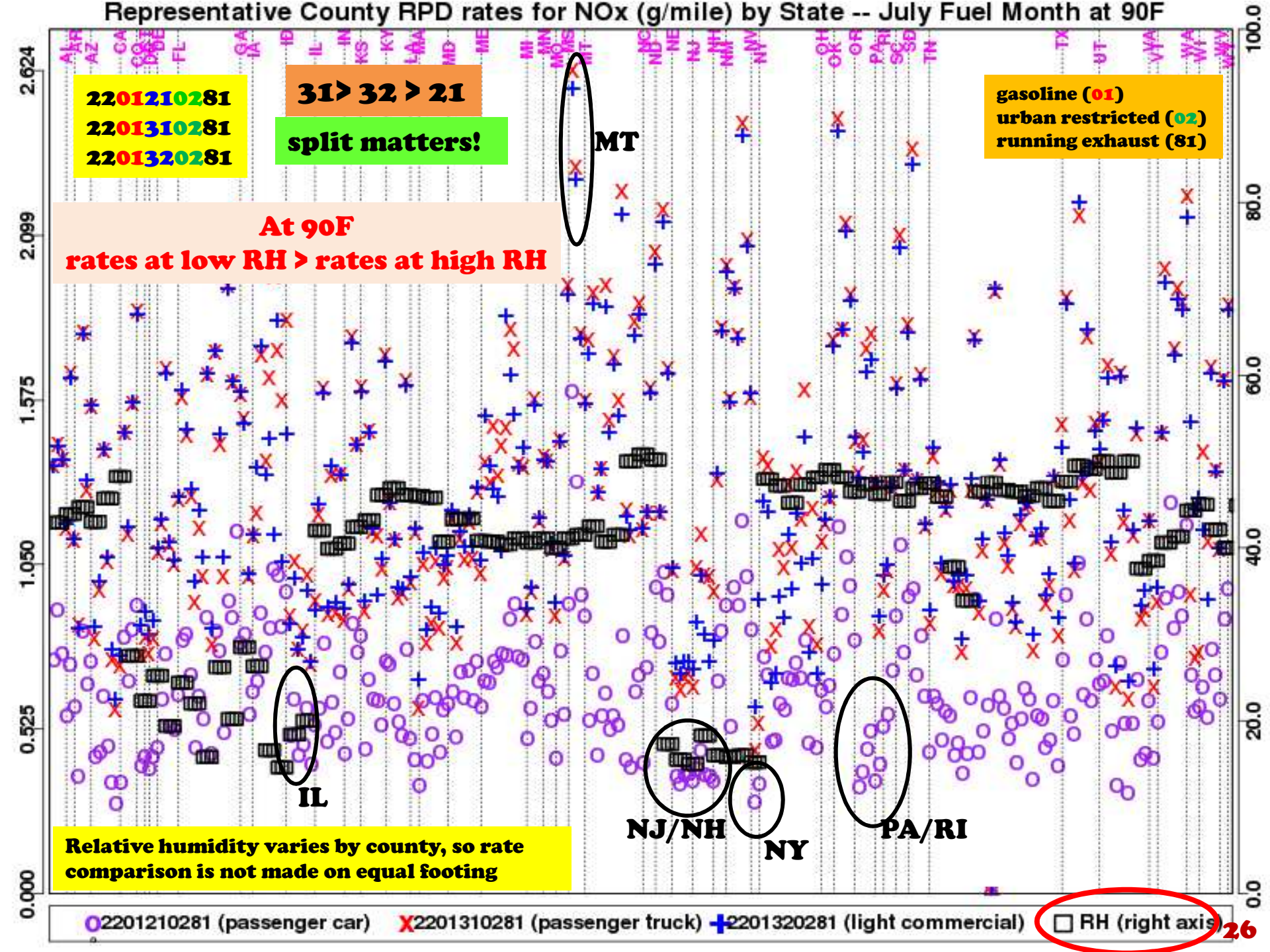


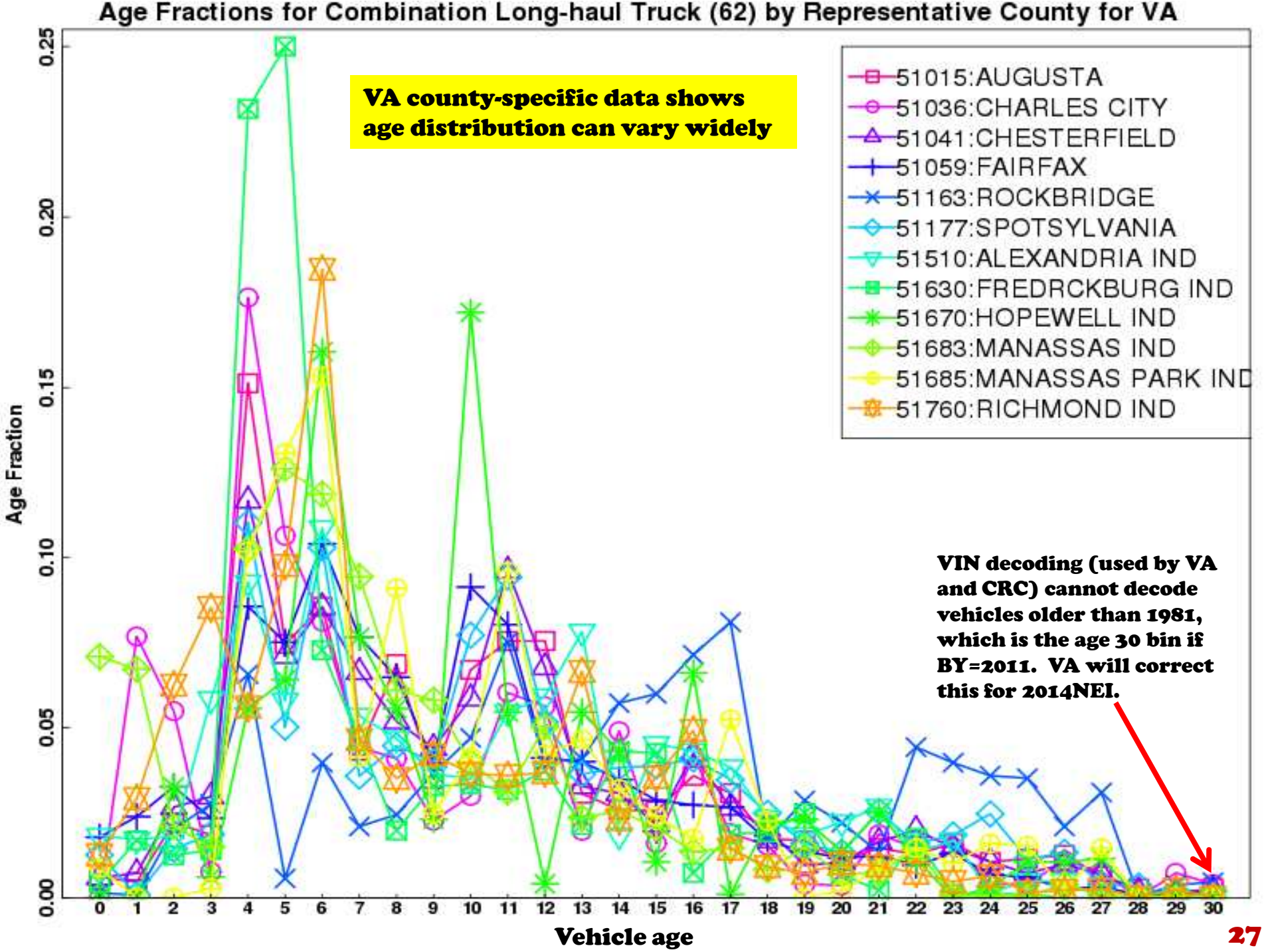
CRC data

Age Fractions for Passenger Car (21) by Representative County




Representative County RPD rates for NOx (g/mile) by State -- July Fuel Month at 90F
1.602
1.282
0.961
0.641
0.320
0.000
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 NJ NH NM NV NY OH OK OR PA RI SC SD TN TX UT VA VT WA WI WV WY
2201210281
Why new fleets in some states do not correlate to low rates?
(see next page)
gasoline (01)
passenger car (21)
urban restricted (02)
running exhaust (81)
MT
IL
NJ/NH
NY
PA/RI
Relative humidity varies by county, so rate comparison is not made on equal footing (see next page)


Representative County RPD rates for NOx (g/mile) by State -- July Fuel Month at 90F
2201210281
2201310281
2201320281
31> 32 > 21
split matters!
gasoline (01)
urban restricted (02)
running exhaust (81)
At 90F
rates at low RH > rates at high RH
MT
IL
NJ/NH
NY
PA/RI
Relative humidity varies by county, so rate comparison is not made on equal footing
2.624
2.099
1.575
1.050
0.525
0.000
100.0
80.0
60.0
40.0
20.0
0.0
2201210281 (passenger car)
2201310281 (passenger truck)
2201320281 (light commercial)
RH (right axis)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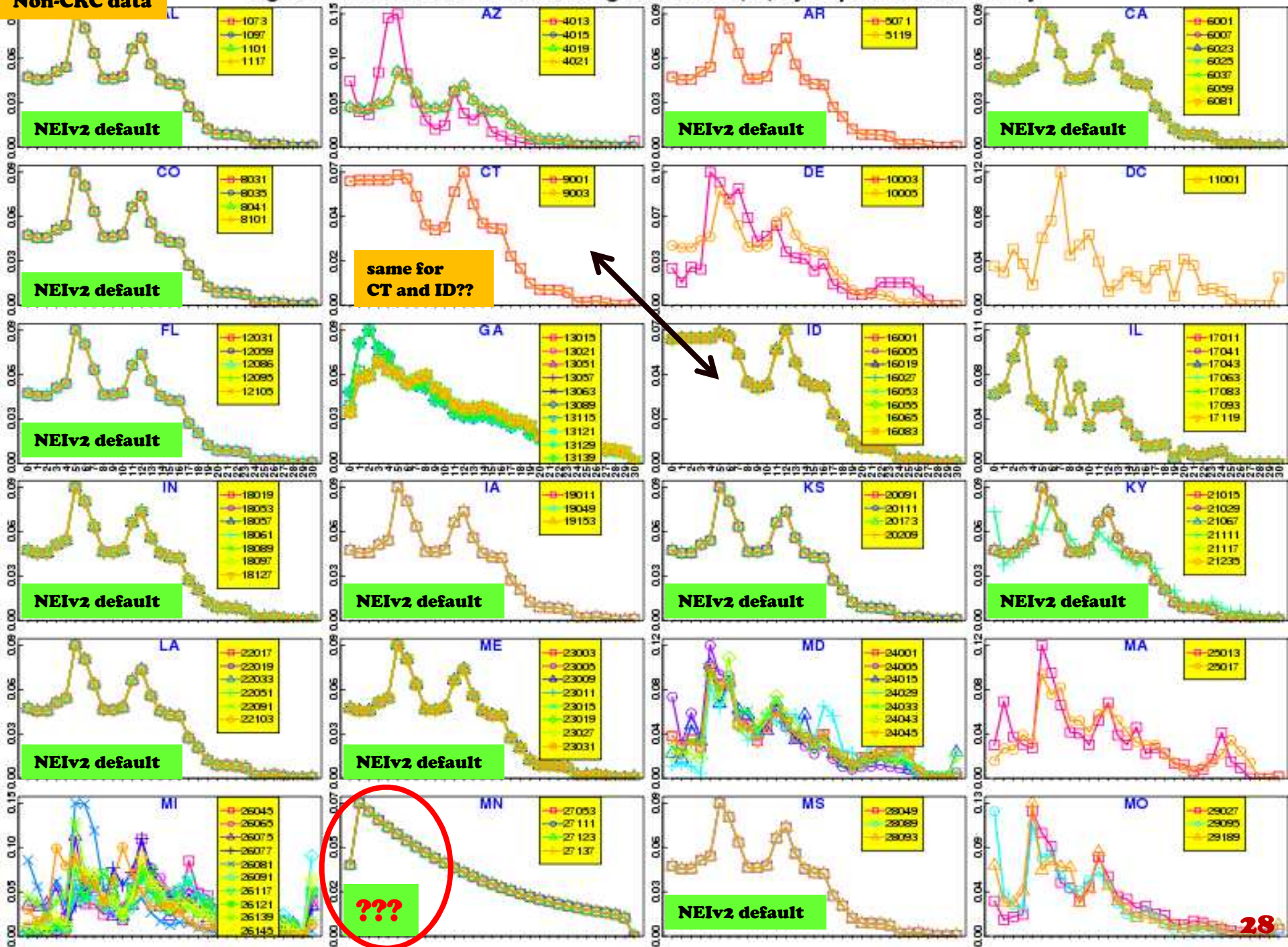
Age Fraction
0.00
0.05
0.10
0.15
0.20
0.25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Vehicle age

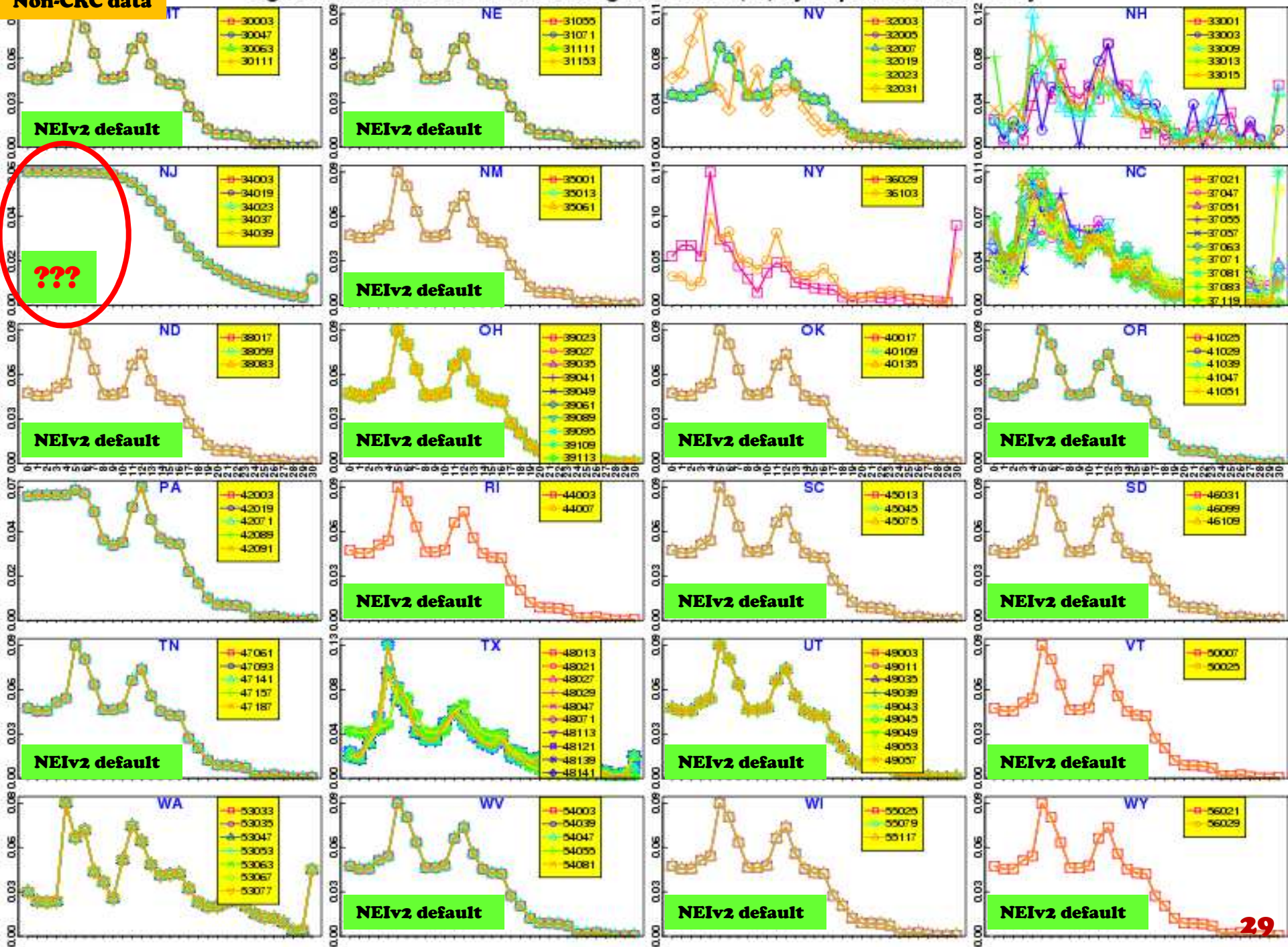
Non-CRC data

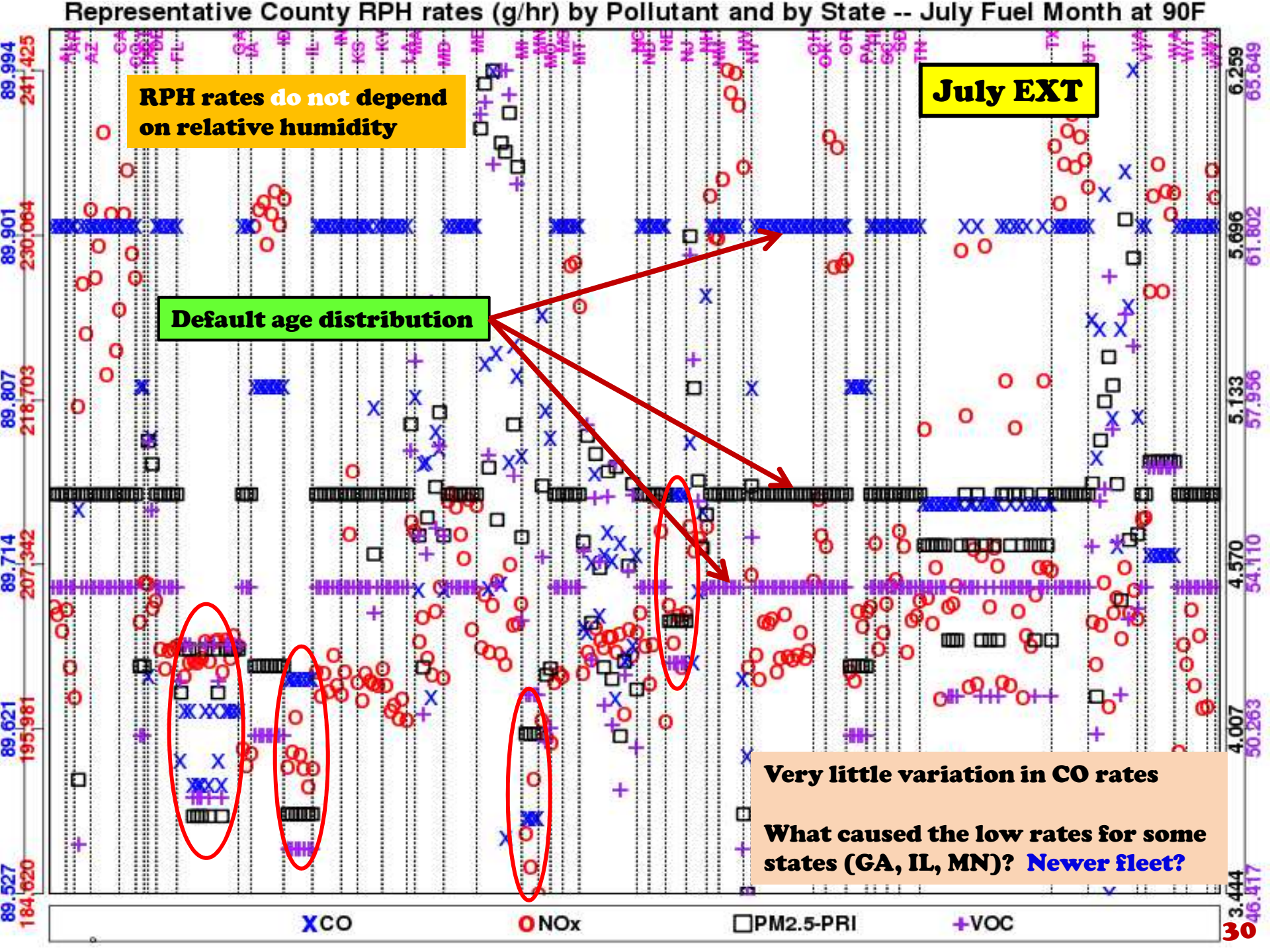
Age Fractions for Combination Long-haul Truck (62) by Representative County



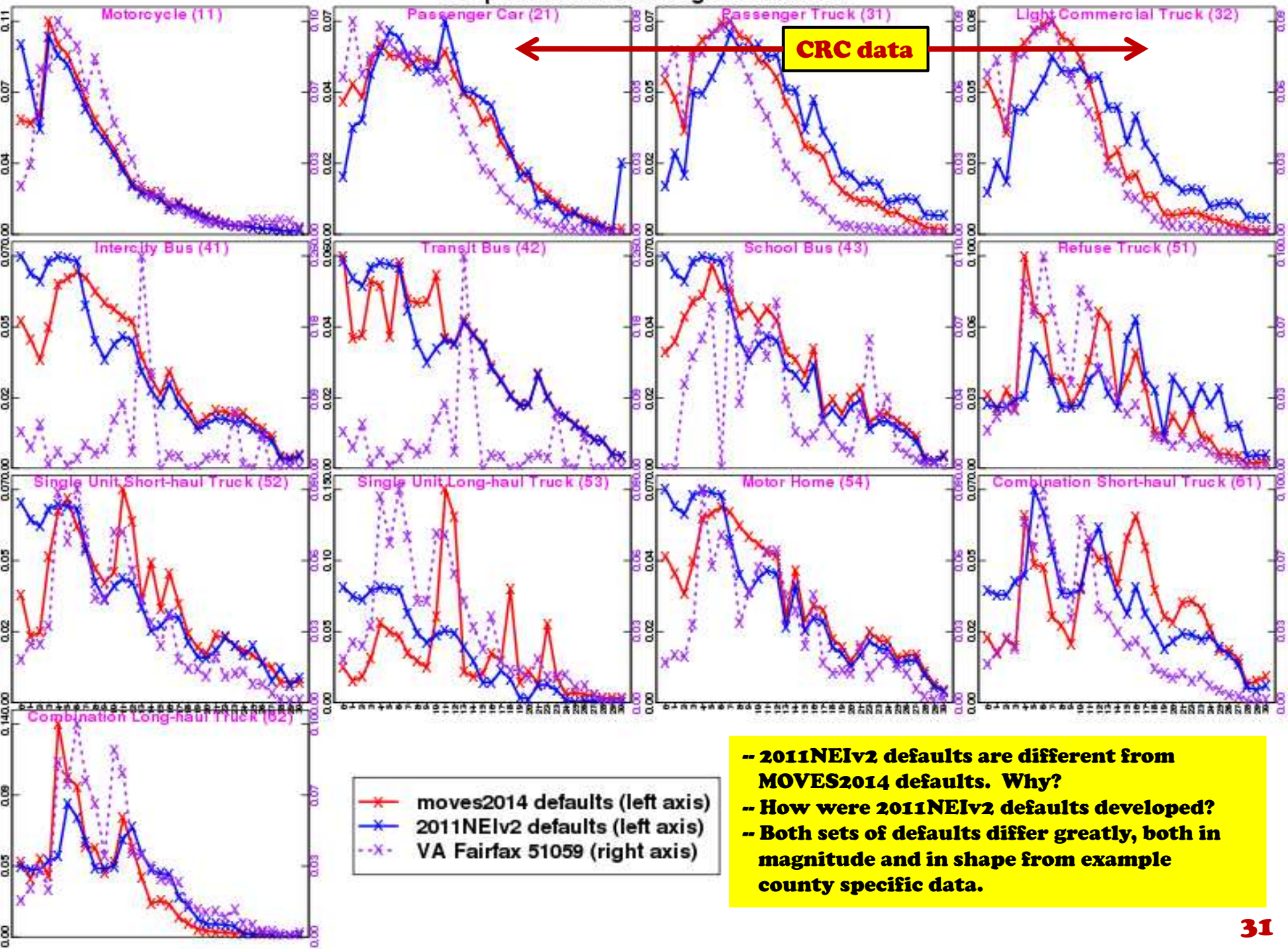
Non-CRC data

Age Fractions for Combination Long-haul Truck (62) by Representative County




Representative County RPH rates (g/hr) by Pollutant and by State -- July Fuel Month at 90F
RPH rates do not depend on relative humidity
July EXT
Default age distribution
Very little variation in CO rates
What caused the low rates for some states (GA, IL, MN)? Newer fleet?
89.994
241,425
89.901
230,064
89.807
218,703
89.714
207,342
89.621
195,981
89.527
184,620
6.259
65.649
5.696
61.802
5.133
57.956
4.570
54.110
4.007
50.263
3.444
46.417
XCO
O NOx
PM2.5-PRI
+VOC

Comparison on Default Age Distributions



-- 2011NEIv2 defaults are different from MOVES2014 defaults. Why?
-- How were 2011NEIv2 defaults developed?
-- Both sets of defaults differ greatly, both in magnitude and in shape from example county specific data.

Data Issues with Fleet Age in 2011NEIv2
Overall Summary

	Category	Effect on Mobile Emissions	Example States
(1)	MOVES defaults for all counties and for all types (except CRC 21/31/32)	Unknown, depends on default	Too many to list
(2)	No variation with representative county	Homogeneous emission rates for the entire state	CT, IL, MN, NJ
(3)	Fewer representative counties	Emissions underestimated	IL, NY, PA
(4)	Smooth age distribution	Overall newer fleet, emissions underestimated	MN, NJ
(5)	No correction for age 30	Newer fleet, emissions underestimated	PA, VA
(6)	Over-corrected age 30 (CRC data only)	Older fleet, emissions overestimated	MI, NH, NC, WA
(7)	Large peaks for particular model years	Effects vary	GA, TX, ...

Roughly in order of significance

-- See next page for a detailed overall summary table by state
-- Default (in the table) = 2011NEIv2 default

State	11	21	31	32	41	42	43	51	52	53	54	61	62
AL	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
AR	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
AZ	Default (except 1)				Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)
CA	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
CO	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
CT	No variation				No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation
DC													
DE													
FL	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
GA	Year 11 spike				Little variation	High spikes	Little variation	Little variation	Little variation	Year 30 spike	Year 30 spike	Little variation	Little variation
IA	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
ID					High spikes	High Spikes		High spike	No variation	No variation	Year 30 spike	No variation	No variation
IL	No variation				No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation
IN	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
KS	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
KY	Default (except 1)				Default (except 1)	Default (except 1 - High)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)
LA	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
MA	No variation												
MD													
ME	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
MI					High spikes	High spikes		Year 30 spike	Year 30 spike	Year 30 spike	Year 30 spike		
MN	Year 11 spike				No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation
MO													
MS	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
MT	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
NC													
ND	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
NE	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
NH					High spikes					Year 0 spike			
NJ	No variation				No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation
NM	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
NV	Default (except 2)				Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)	Default (except 1)
NY					High spike	Year 30 spike	Year 30 spike						
OH	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
OK	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
OR	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
PA					No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation	No variation
RI	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
SC	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
SD	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
TN	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
TX					Little variation	Little variation	Little variation	Little variation	Little variation	Little variation	Little variation		Little variation
UT												Default	Default
VA					High spike	High spikes	High spike						
VT	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default
WA					High spike	High spike	High spike		No variation	No variation	Year 30 spike	No variation	No variation
WI	Default					Default		Default	Default	Default	Default	Default	Default
WV	Default (except 2)				Default	Default	Default	Default	Default	Default	Default (except 2)	Default	Default
WY	Default				Default	Default	Default	Default	Default	Default	Default	Default	Default

CRC data

Summary on Fleet Age Data in 2011NEIv2

- Most states show no data variation for the entire state for all vehicle source types (except CRC data for vehicle types 21/31/32)
- Some states opted out of using CRC data, but the data used are homogeneous with very little variation for the entire state
- Methods adopted by states are inconsistent, creating "biased" mobile source inventory (age distribution very smooth or vehicle fleet very new)
- Widespread use of defaults for source types other than 21/31/32
- Representative county approach in SMOKE-MOVES magnifies the issues

Overall Summary

- Several data issues are found in mobile source inventory for 2011NEI version2
- Nearly two thirds (2/3) of US did not supply county-specific data and relied on model defaults
- Effects of defaults have not been examined
- Methods adopted by states and EPA are inconsistent
- Issues are magnified by representative county scheme used in SMOKE-MOVES
- Due to representative county scheme and widespread use of defaults, the mobile source inventory in 2011NEI has very coarse resolution
- 2011NEI is ill-suited for a contribution-to-monitor type of analysis or assessment
- Development of quality mobile source inventory is a critical component in air quality modeling

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- URL: http://www.arc.vt.edu