

# **Reviews and Comparisons on Regional Mobile Source Emissions**

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**MARAMA MOVES Workgroup conference call**  
**May 28, 2013**

# Presentation Outline

- **Background**
- **SMOKE-MOVES SCCs**
- **Virginia-specific Comparisons (all pollutants)**
- **Regional NO<sub>x</sub> Comparisons**
- **Regional PM<sub>2.5</sub> Comparisons**
- **Regional VOCs Comparisons**
- **Reviews on EPA Draft 2011 NEI**
- **Issues with Activity Conservation**
- **An Example of Coordinated Efforts**
- **Summary and Recommendation**

# Background

- **States and RPOs conduct MOVES and/or SMOKE-MOVES modeling to generate mobile source emissions**
- **EPA also conducts MOVES and SMOKE-MOVES modeling to generate emissions for air quality modeling**
- **No systematic comparisons have been made on various mobile source emission inventories**

# Data Sources

- **Virginia in-house MOVES and SMOKE-MOVES runs for 2007, 2011, and 2020**
- **MARAMA 2007 and 2020 runs for MANEVU+VA or OTR region (13 states/jurisdictions)**
- **SEMAP 2007 run for Southeast (10 states)**
- **EPA 2005 NEI, 2007, 2008 NEI (3 versions), 2011 NEI (draft), and 2020 covering continental US**
- **Modeling could be conducted in inventory mode, emission rate (lookup table) mode, or hybrids.**
- **Data were jointly collected by NY, VA, and MARAMA**

# Comparison Methodology

- Emissions were sorted by county, by SCC, and by pollutant
- 156 SCCs for SMOKE-MOVES were grouped into either SCC7 (12 vehicle types) or SCC2 (13 road types) for comparison
- MOBILE6 and SMOKE-MOVES have very different SCCs
- SCCs for SMOKE-MOVES were used in all comparisons at the expense of SCCs from MOBILE6

**PM2.5 includes only primary exhaust (i.e., SO4, EC, and OC). Brakewear and tirewear were excluded, except for the two (2007/2011) VA inventory mode runs.**

**SCC example: 2201001110: LDGV Rural Interstate**

**2201001: vehicle type of LDGV**

**11: road type of rural interstate**

**0: emission process (always 0 in SMOKE)**

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# SMOKE-MOVES SCCs

## SMOKE v3.1

### SCC7 vehicle types

SCC7	Class
2201001	LDGV
2201020	LDGT1
2201040	LDGT2
2201070	HDGV
2201080	MC
2230001	LDDV
2230060	LDDT
2230071	2BHDDV
2230072	LHDDV
2230073	MHDDV
2230074	HHDDV
2230075	BUSES

### SCC2 road types

SCC2	Class
11	Rural Interstate
13	Rural Principal Arterial
15	Rural Minor Arterial
17	Rural Major Collector
19	Rural Minor Collector
21	Rural Local
23	Urban Interstate
25	Urban Freeway/Expressway
27	Urban Principal Arterial
29	Urban Minor Arterial
31	Urban Collector
33	Urban Local
00	Off-Network

-- There are 12 vehicles types (SCC7) and 13 road types (SCC2)

# Inconsistent SCCs

**Unknown SCCs were found in EPA's 2008NEI, 2007/2020, and 2011NEI platforms:**

**The 12 unknown SCCs  
are VPOP related**

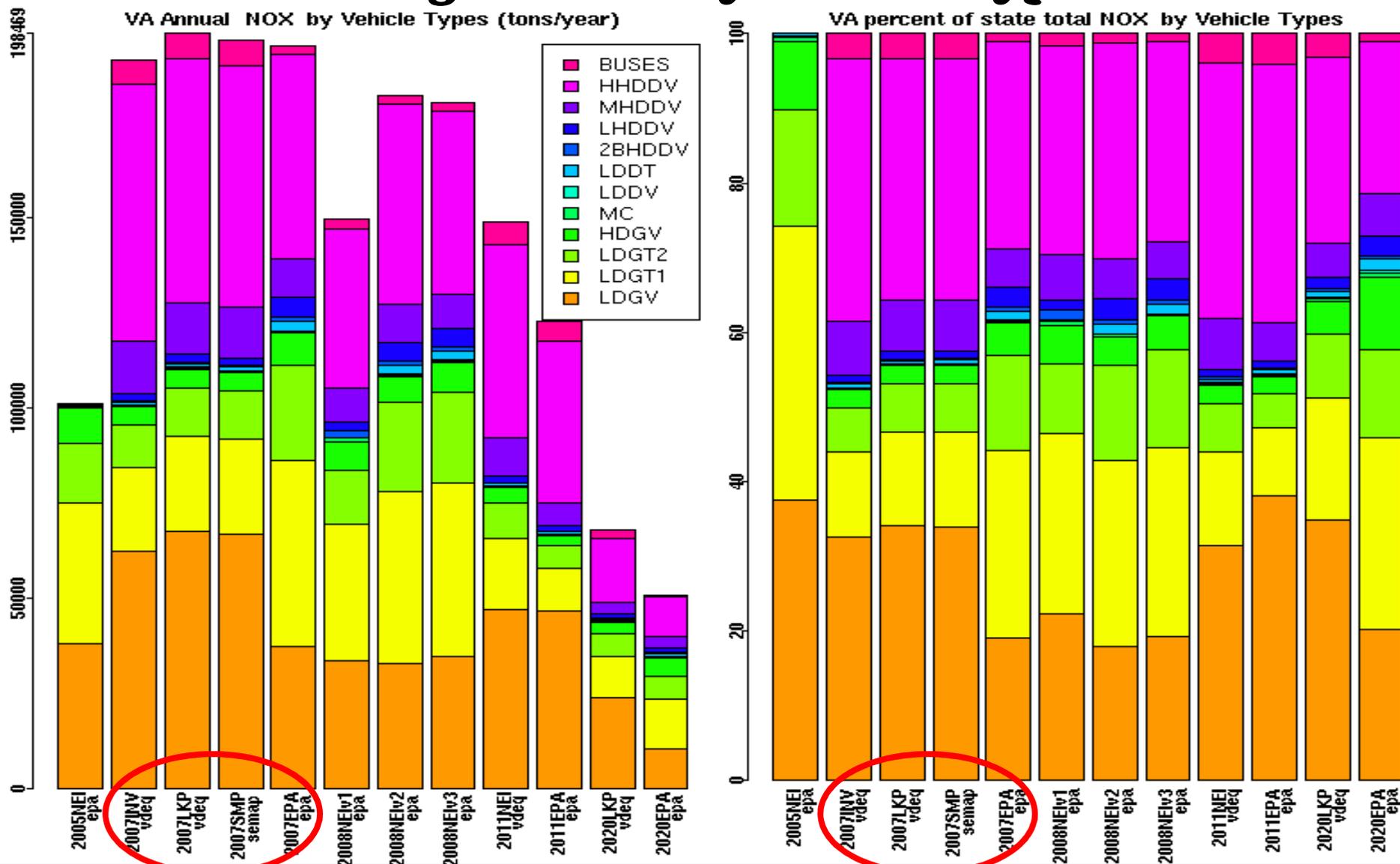
<b>Unknown SCCs</b>	<b>Assumed SCCs</b>
<b>2201001390</b>	<b>2201001000</b>
<b>2201020390</b>	<b>2201020000</b>
<b>2201040390</b>	<b>2201040000</b>
<b>2201070390</b>	<b>2201070000</b>
<b>2201080390</b>	<b>2201080000</b>
<b>2230001390</b>	<b>2230001000</b>
<b>2230060390</b>	<b>2230060000</b>
<b>2230071390</b>	<b>2230071000</b>
<b>2230072390</b>	<b>2230072000</b>
<b>2230073390</b>	<b>2230073000</b>
<b>2230074390</b>	<b>2230074000</b>
<b>2230075390</b>	<b>2230075000</b>

**Unknown SCCs, which appear to be associated with off-network, were translated into assumed SCCs (off-network) of SMOKE-MOVES prior to comparisons**

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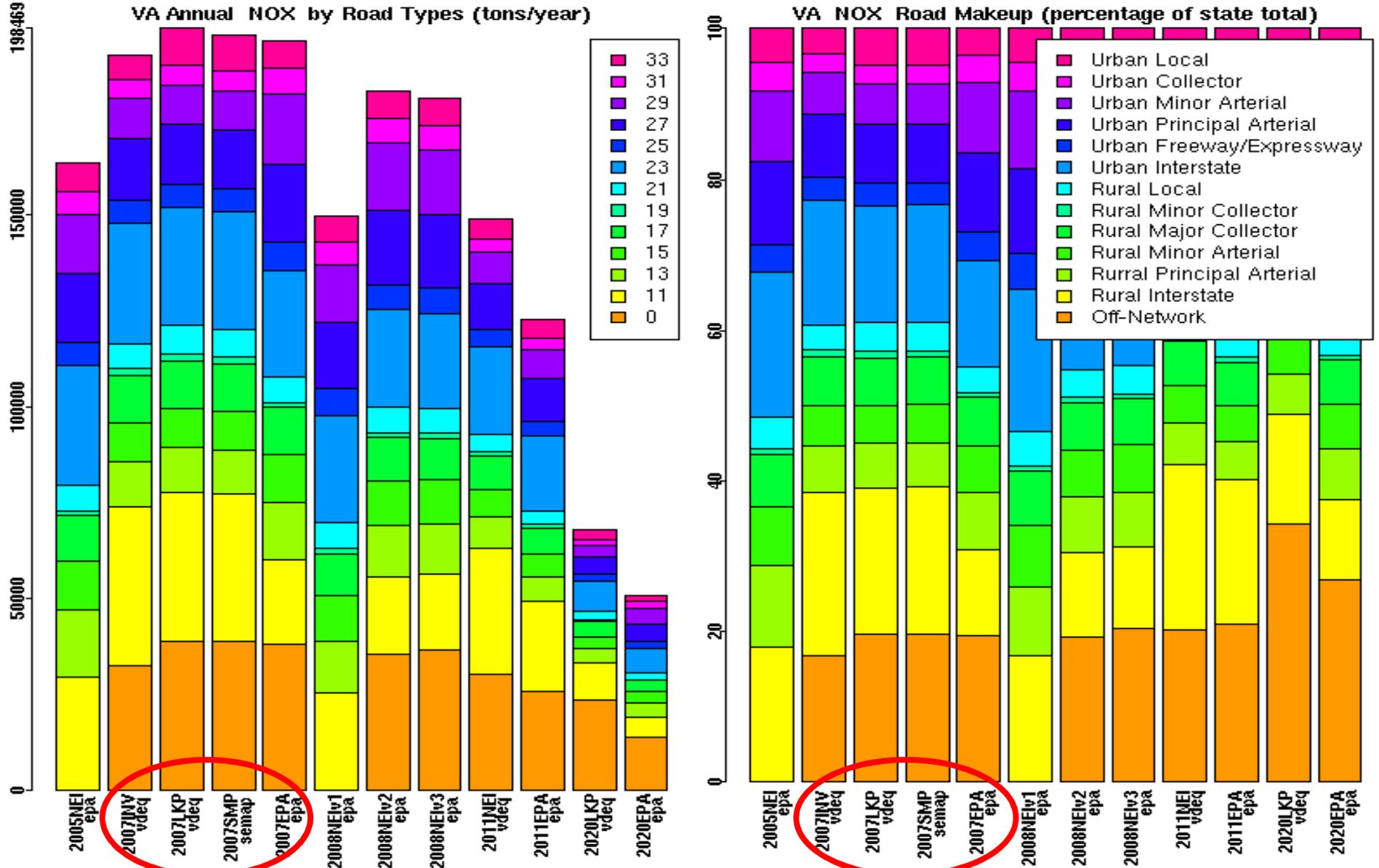
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# Virginia NOx by Vehicle Type



- Overall mobile emissions show a decreasing trend from 2007, 2008, 2011, to 2020, with the exception of 2008NEIv1, which was MOBILE6-based.
- Regardless of years, about 50-60% of NOx are from light duty gasoline vehicles (LDGV, LDGT1, LDGT2) and MC.
- Differences among four 2007 runs are small with 3.6%, 1.5%, and 0.8% for LKP vs INV, LKP vs. EPA, and LKP vs SEMAP, respectively.
- While 2007 EPA is close to the other three 2007 runs state-wide, its distribution among vehicle types is quite different (EPA has less LDGT1, HHDDV, and BUSES, but more LDGT2)

# Virginia NOx by Road Type



- 2005NEI looks higher than slide 10, due to discontinued SCCs (2230070) in MOBILE6: road types were counted, but vehicle types were not.
- For 2007, NOx road types for EPA run are different from the other runs (INV, LKP, SEMAP) which show similar/comparable distributions.
- For 2020, about 30% NOx is from off-network for both VDEQ and EPA runs. EPA run has less NOx from rural interstate.
- Although its 2007 NOx are close state-wide, EPA's 2020 projection using 2007 platform results in a 33% drop compared to 2020LKP (VADEQ).

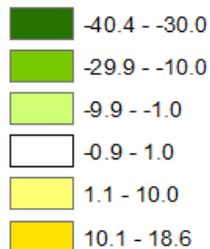
# Inventory Mode versus Lookup Table Mode

$$(2007INV - 2007LKP) * 100 / 2007LKP$$

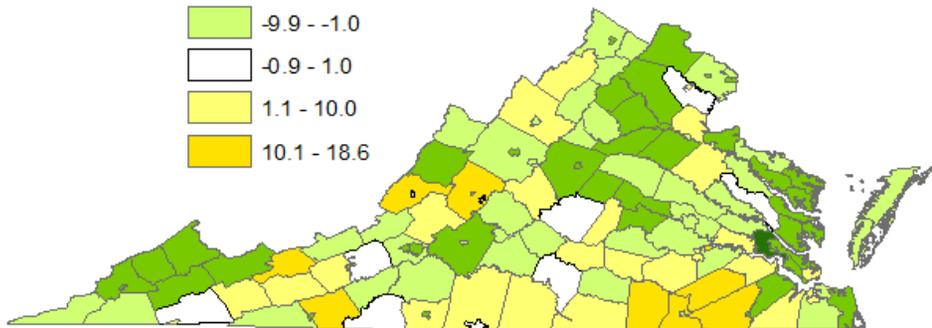
Legend

County

%Diff NOx



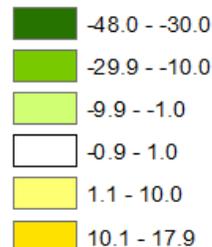
**NOx**



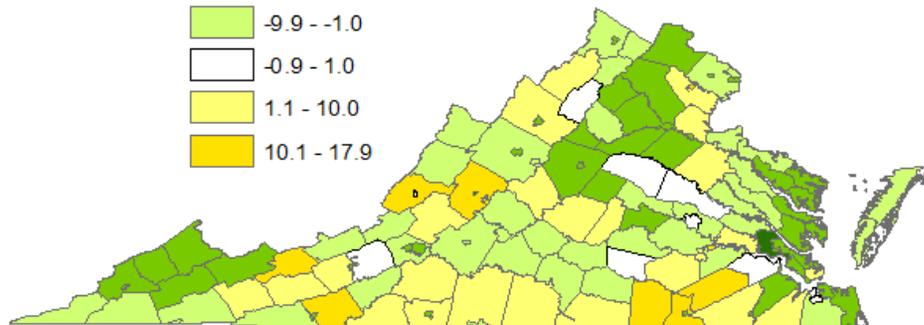
Legend

County

%Diff PM2.5



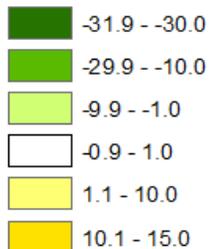
**PM2.5**



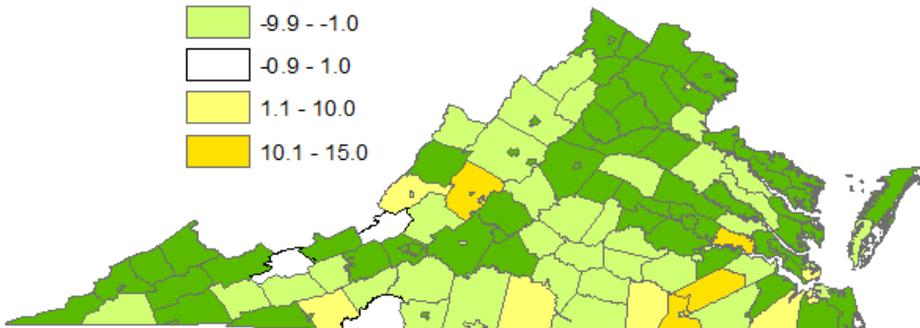
Legend

County

%Diff VOC



**VOCs**



- White color indicates nearly exact agreement between the two modes.
- Positive means higher estimates by inventory mode than by lookup table mode.
- Inventory mode estimates lower emissions around major metropolitan areas (such as northern VA and Richmond).

Inventory mode	Lookup table mode
individual counties	representative counties
monthly average temperatures	hourly temperatures
county-specific activities	aggregated activities

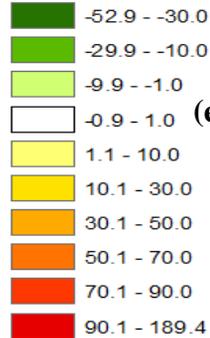
# 2007 VADEQ versus 2007 EPA (both in lookup table mode)

$(2007LKP - 2007EPA) * 100 / 2007EPA$

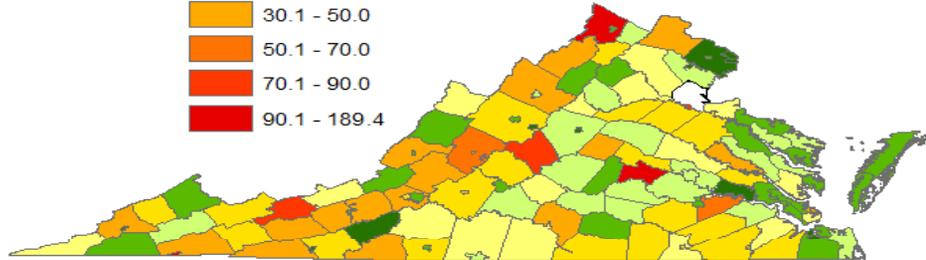
Legend

County

%Diff NOx



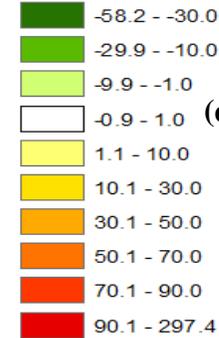
**NOx**



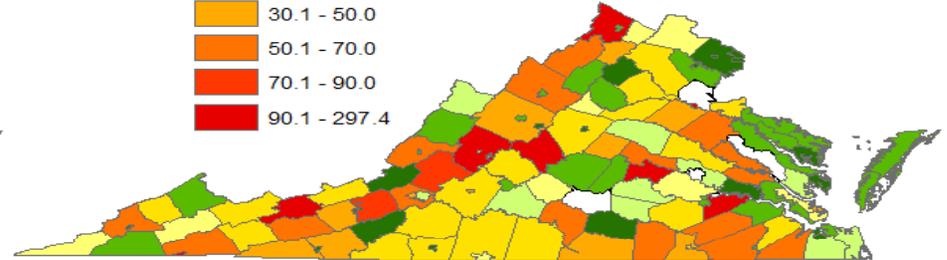
Legend

County

%Diff PM25



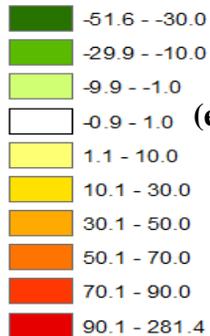
**PM2.5**



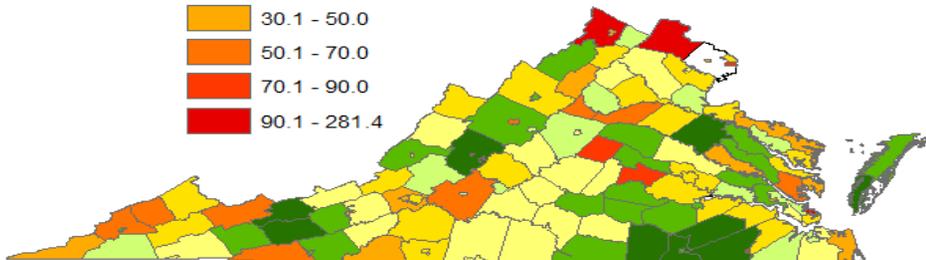
Legend

County

%Diff VOC



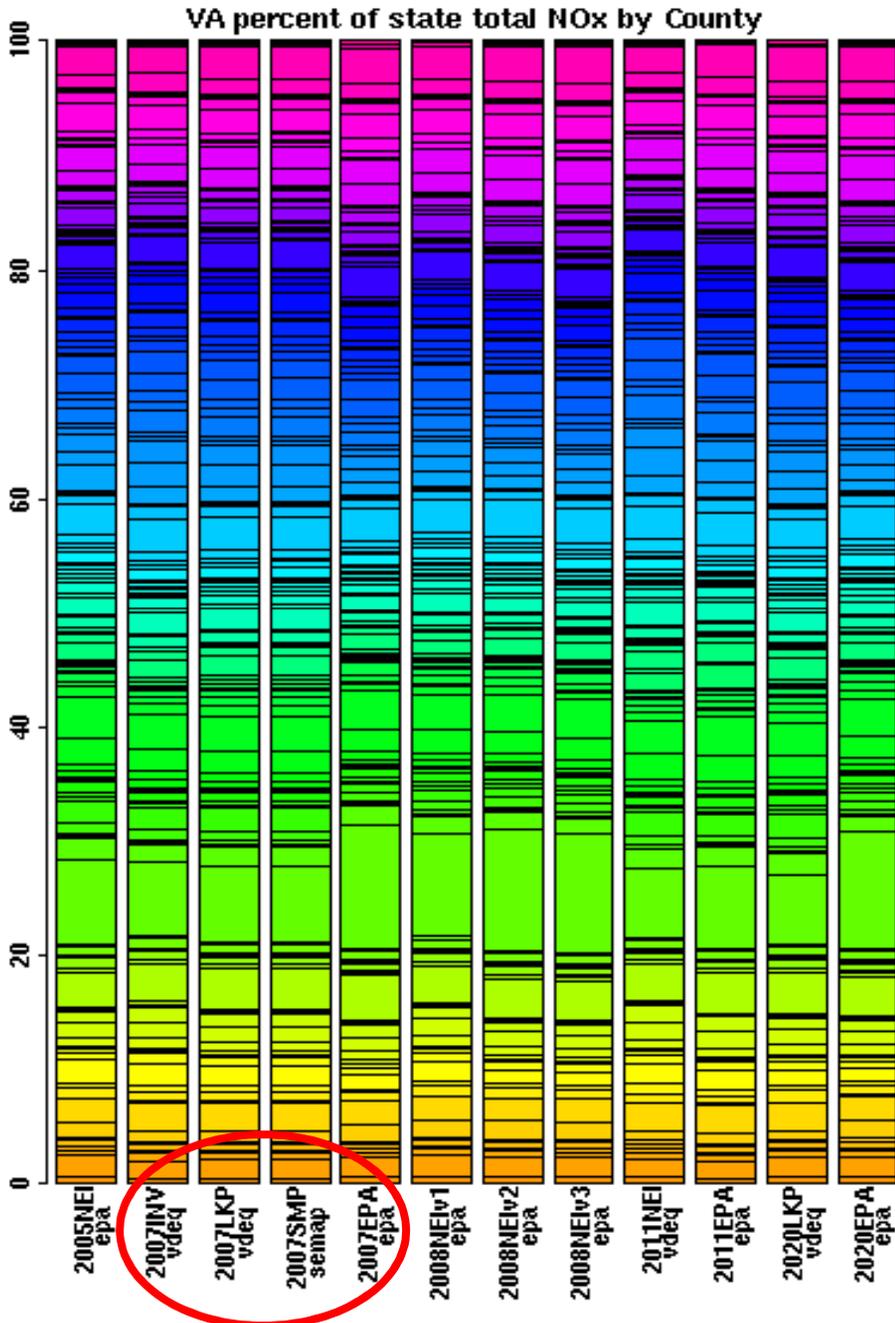
**VOCs**



- Very few counties show exact agreement (in white).
- Positive indicates higher VADEQ estimates than EPA.
- In previous slides, EPA state-wide estimates are shown to be comparable to VADEQ; county-by-county estimates, however, indicate large differences for all pollutants.

**Representative county scheme and activity allocations are possible causes for the large differences**

# Virginia NOx by County



- VA has 134 counties
- Each block in the plot represents NOx (in percentage) from a county
- Of the four 2007 runs, INV, LKP, and SMP show similar county blocks. EPA run, by contrast, shows much different county blocks from the others.
- The two 2020 runs also show very different county makeup. Each is more similar to its “parent” 2007 run.
- **Correct county makeup is crucial, as grid cells in air quality models are much smaller in size than a county.**

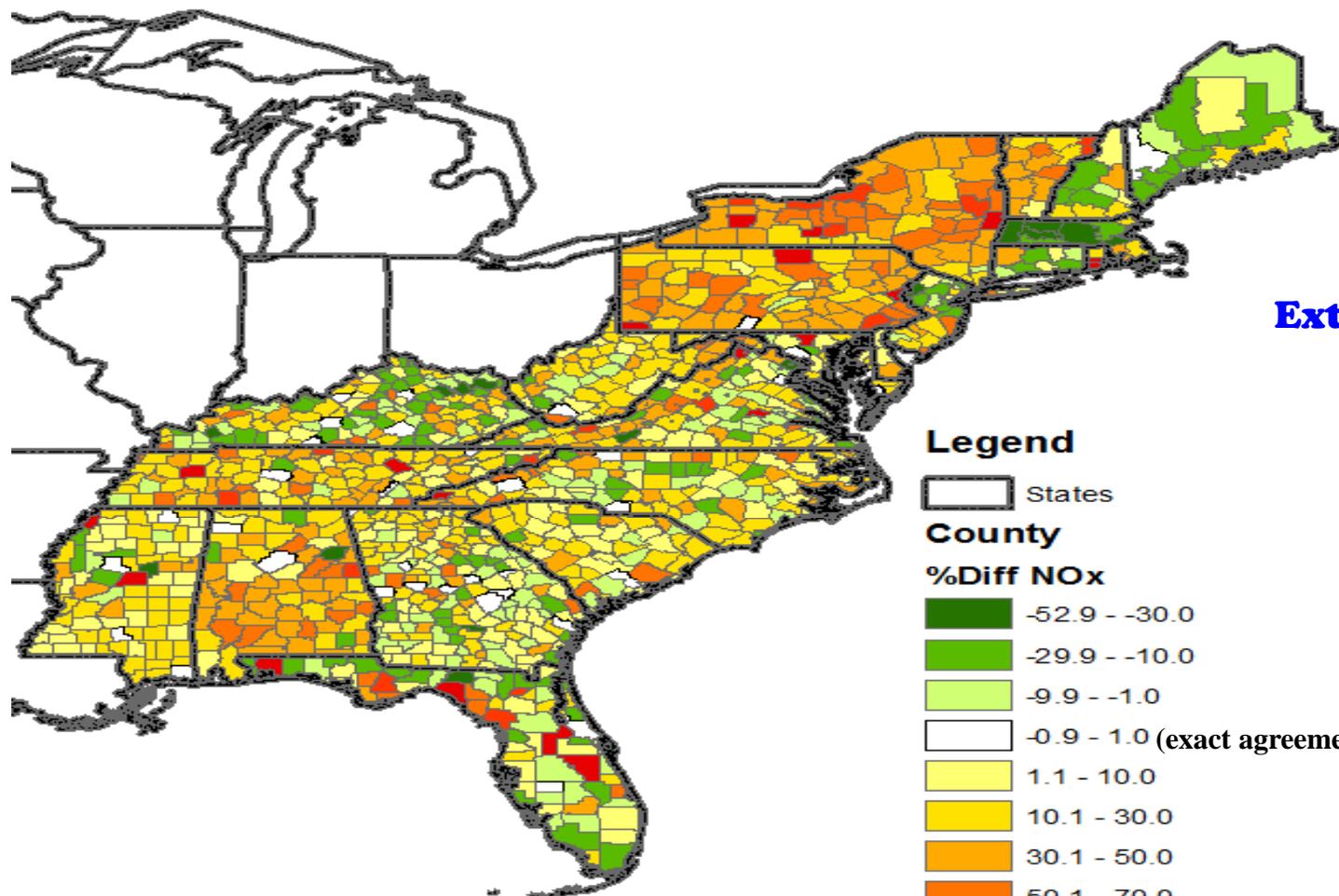
**Comparisons made at state level are very crude, as overestimates and underestimates at county level have been compromised and canceled out**

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# 2007 RPOs versus 2007 EPA for NO<sub>x</sub> (lookup table mode)

$$(2007LKP - 2007EPA) * 100 / 2007EPA$$

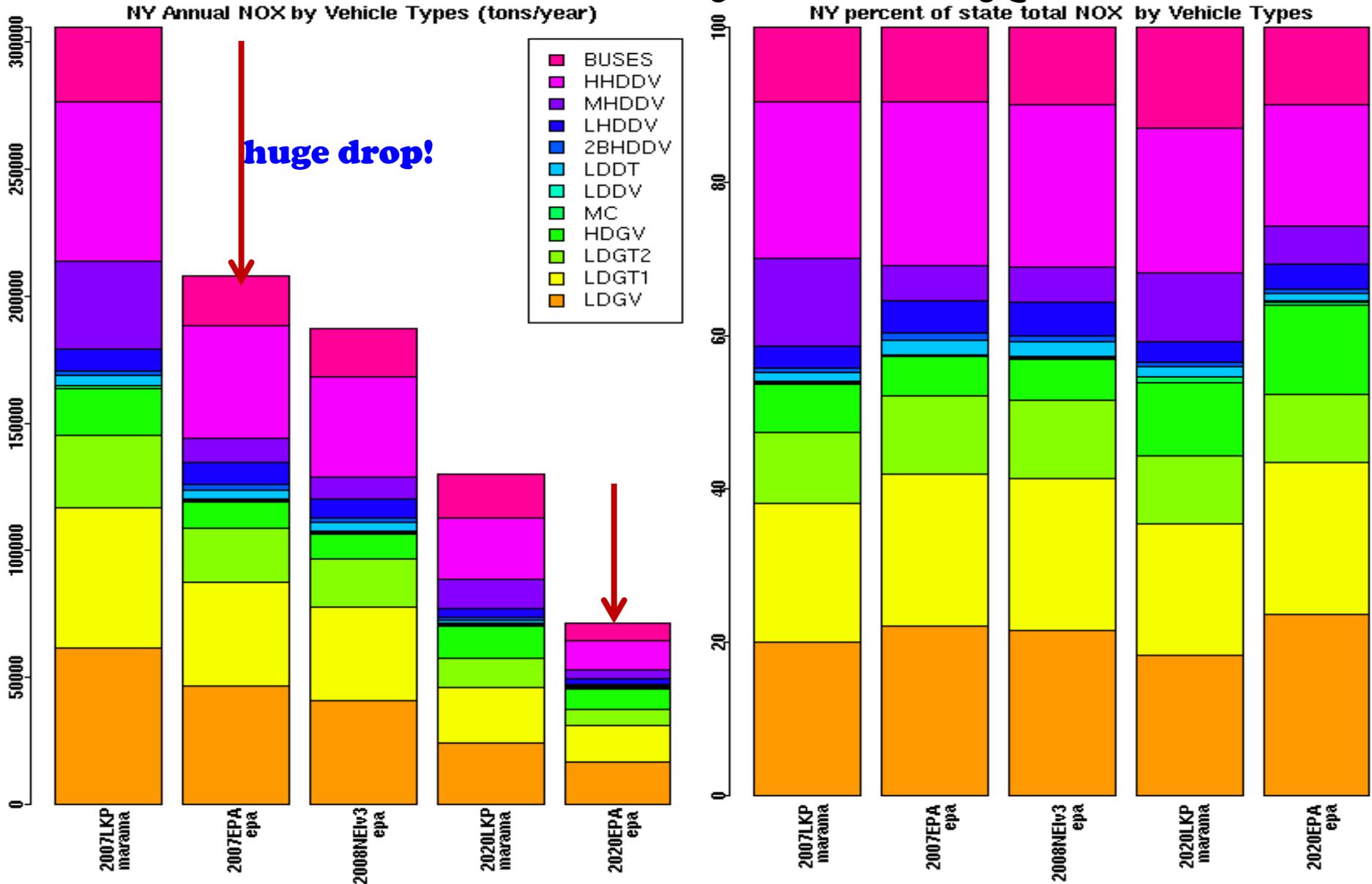


**Extremes:**

**VT**  
**MA**  
**NY**  
**PA**  
**KY**  
**AL**  
**FL**

**Very large variability in NO<sub>x</sub> is seen between RPOs and EPA estimates. Differences range from -50% to +200%.**

# New York NOx by Vehicle Types

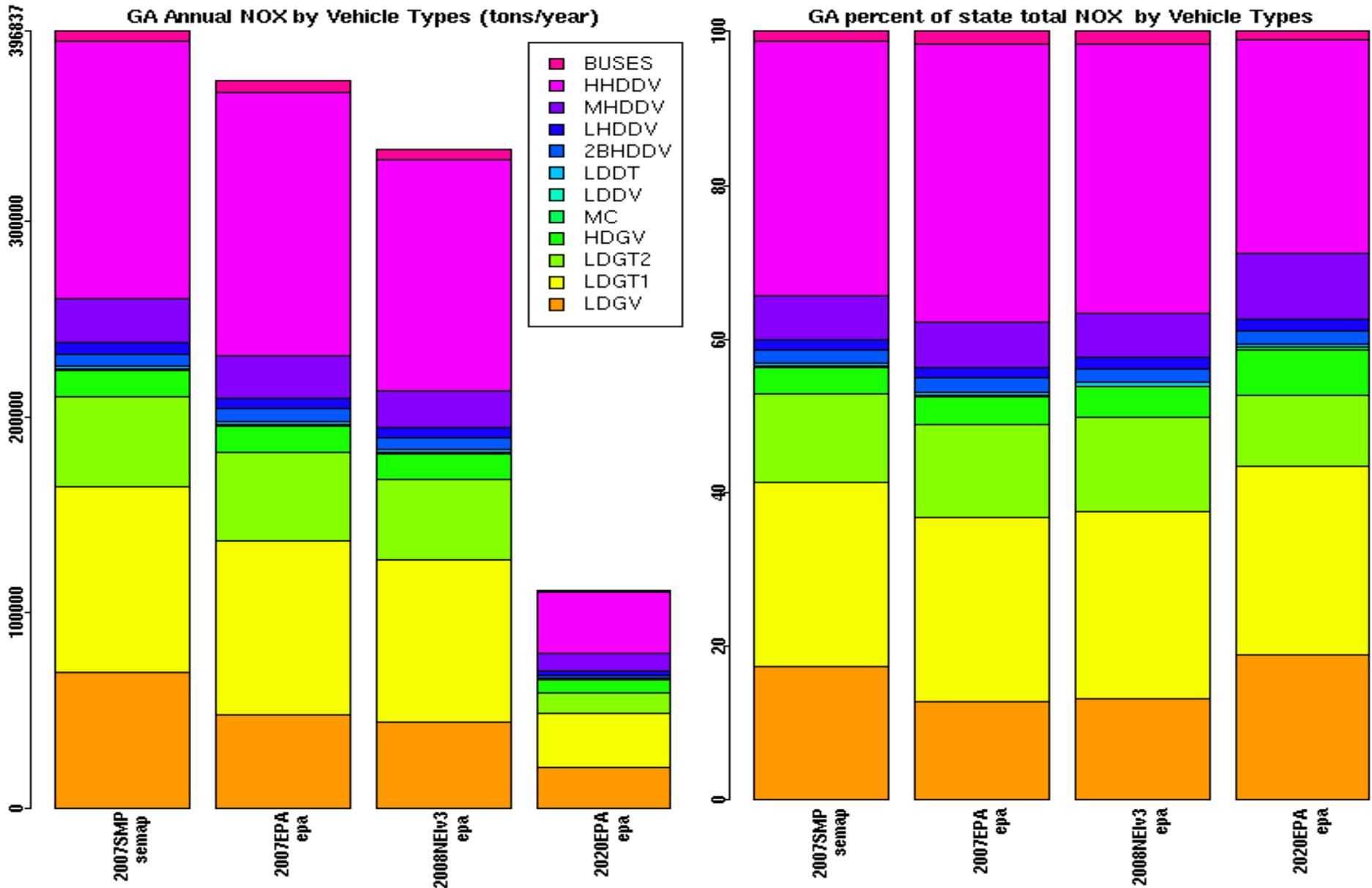


-- Differences in NOx between 2007 MARAMA and 2007 EPA reach 46.3% for state of NY (EPA's estimates are much lower).

-- Similarly, much lower estimates by EPA are projected for 2020 using 2007 platform.

-- Distribution among vehicle types are roughly similar between the two (except MHDDV), suggesting lower emissions across the board by EPA.

# Georgia NOx by Vehicle Types



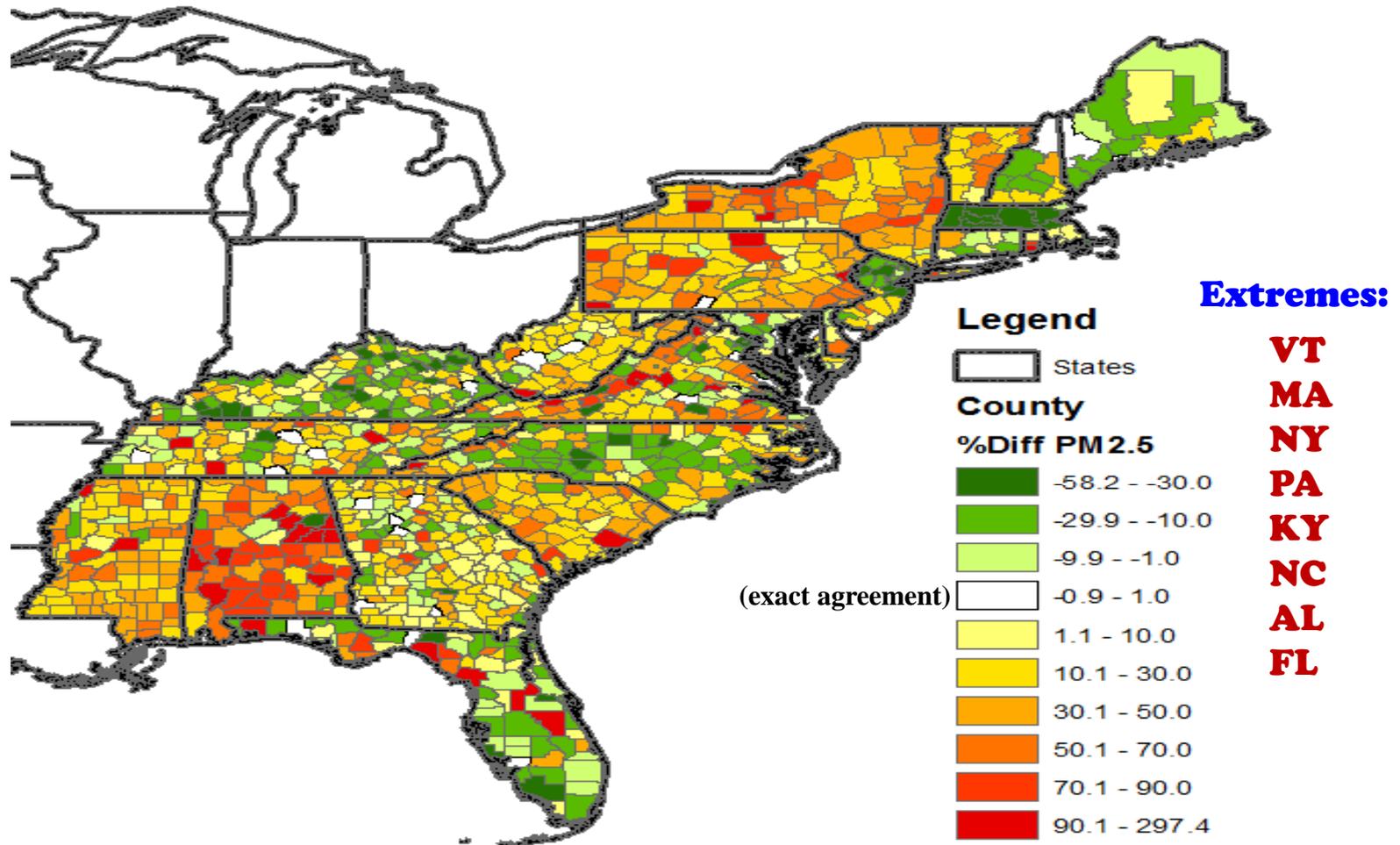
-- 2007 EPA run estimates lower NOx than 2007 SEMAP run for state of GA.  
 -- EPA tends to have lower LDGV emissions.  
 -- Emissions for SEMAP projection year, 2018, are not yet available.

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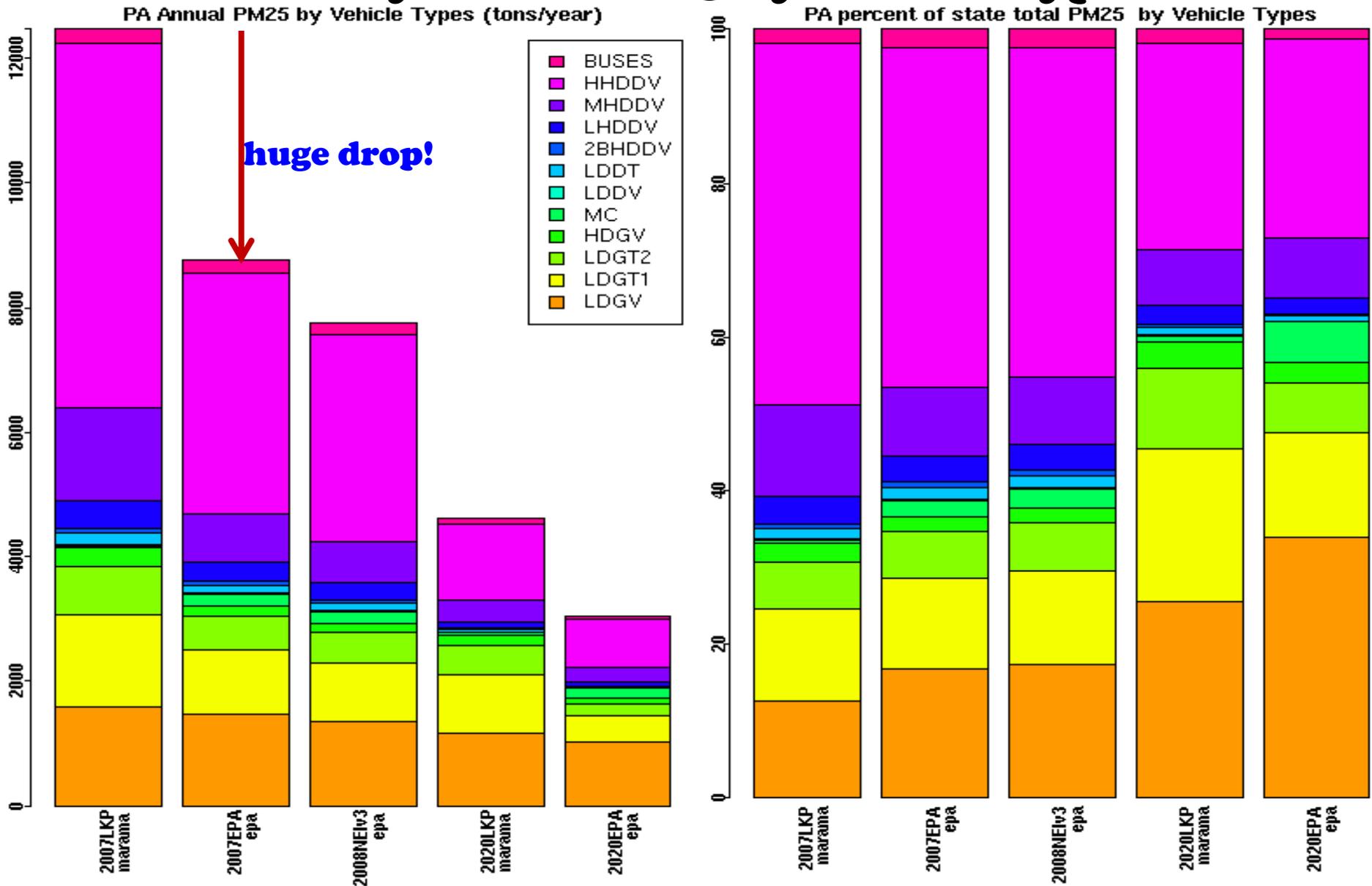
# 2007 RPOs and 2007 EPA for PM<sub>2.5</sub> (lookup table mode)

$$(2007LKP - 2007EPA) * 100 / 2007EPA$$



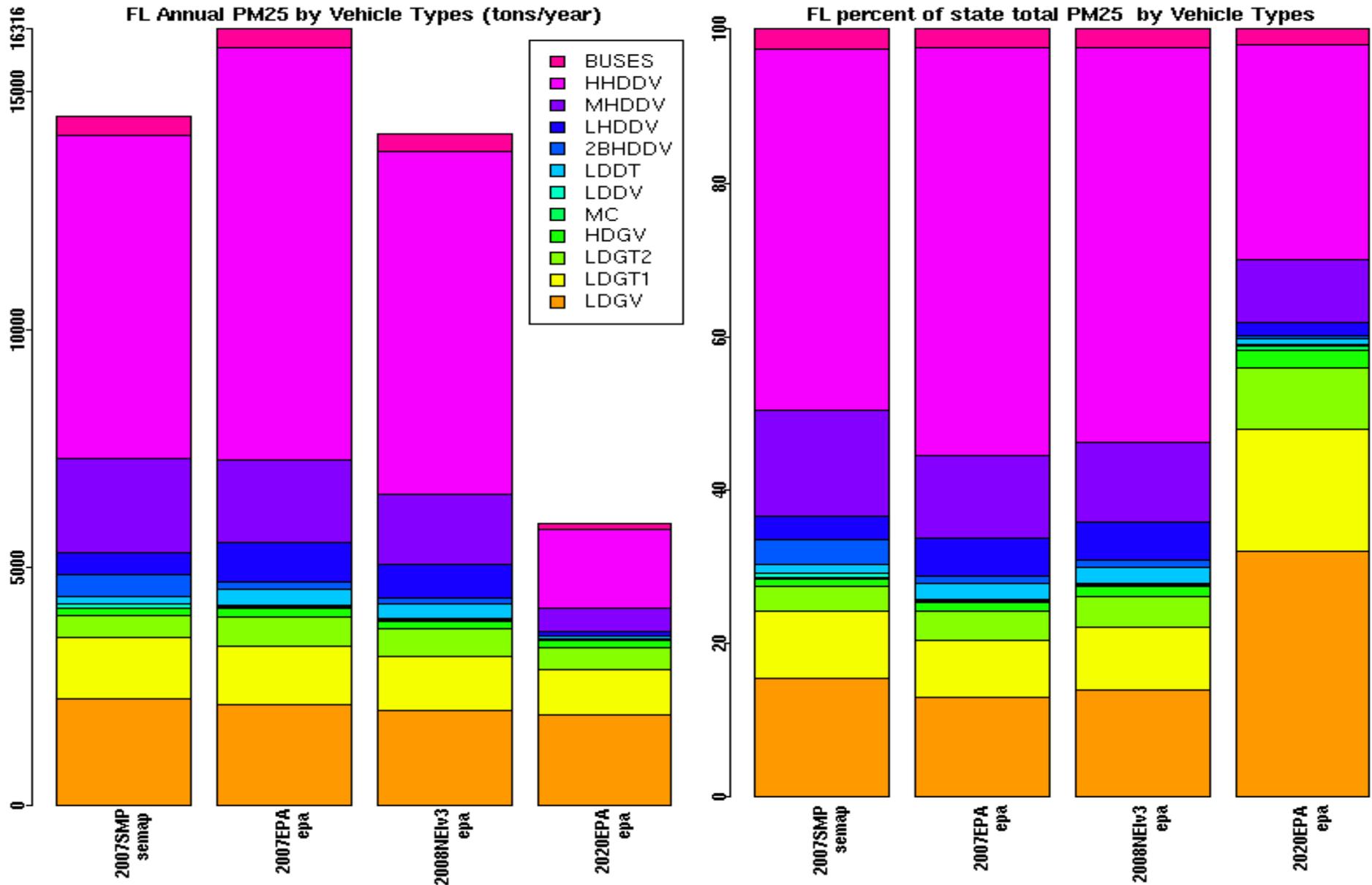
**Similar to NO<sub>x</sub>, variability of PM<sub>2.5</sub> is extremely large between RPOs and EPA estimates. Differences range from -60% to +300%**

# Pennsylvania PM2.5 by Vehicle Types



- Differences in PM2.5 between 2007 MARAMA and 2007 EPA reach 42% for state of PA (EPA's estimates are much lower).
- Similarly, much lower emissions by EPA are projected for 2020 using 2007 platform.
- EPA estimates less HHDDV/MHDDV emissions but more LDGV emissions percentage-wise.

# Florida PM2.5 by Vehicle Types



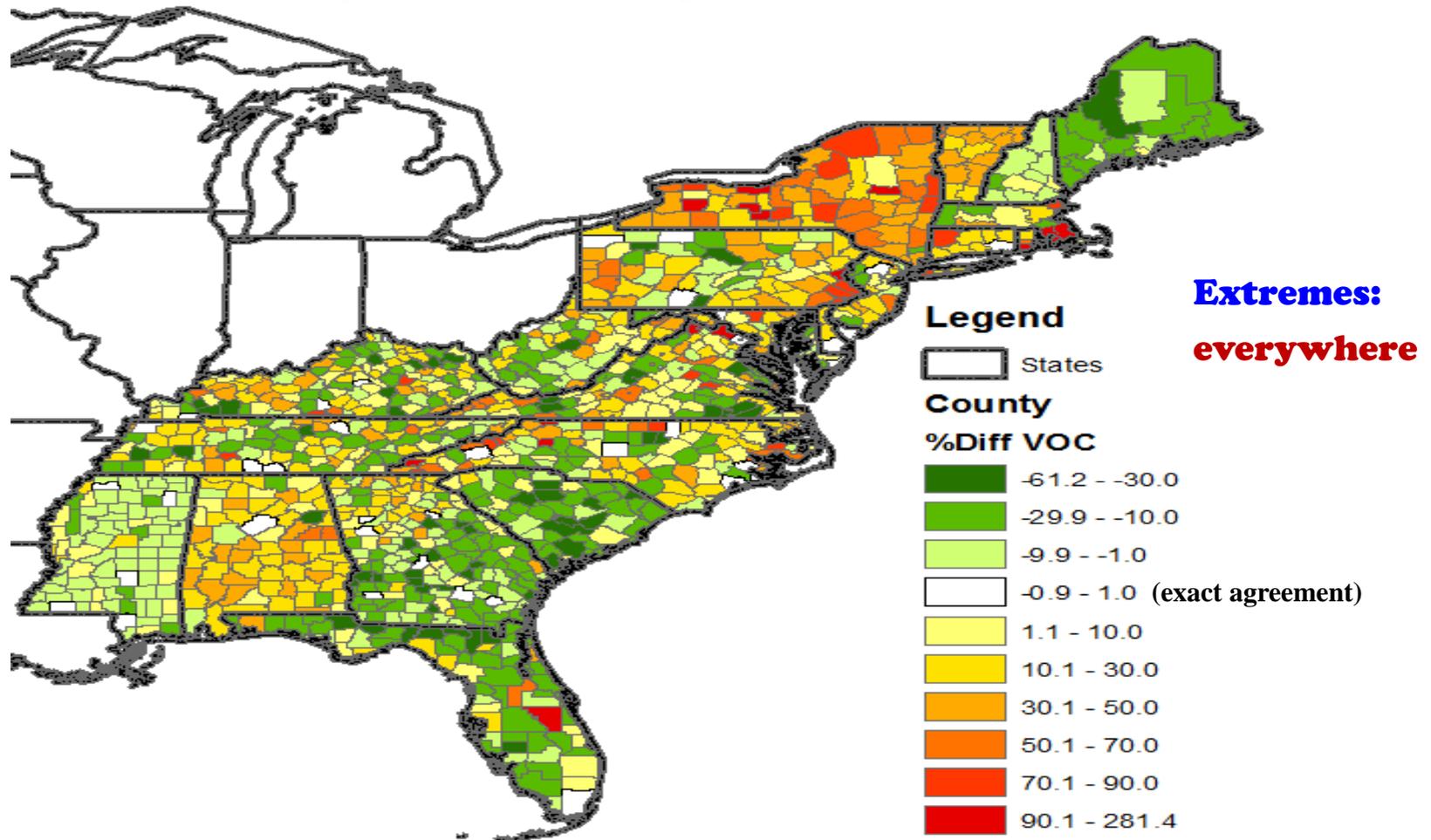
-- 2007 EPA run estimates more PM2.5 in comparison to 2007 SEMAP run for state of FL.  
 -- EPA estimates more PM2.5 in HHDDV category.  
 -- Emissions for SEMAP projection year, 2018, are not yet available.

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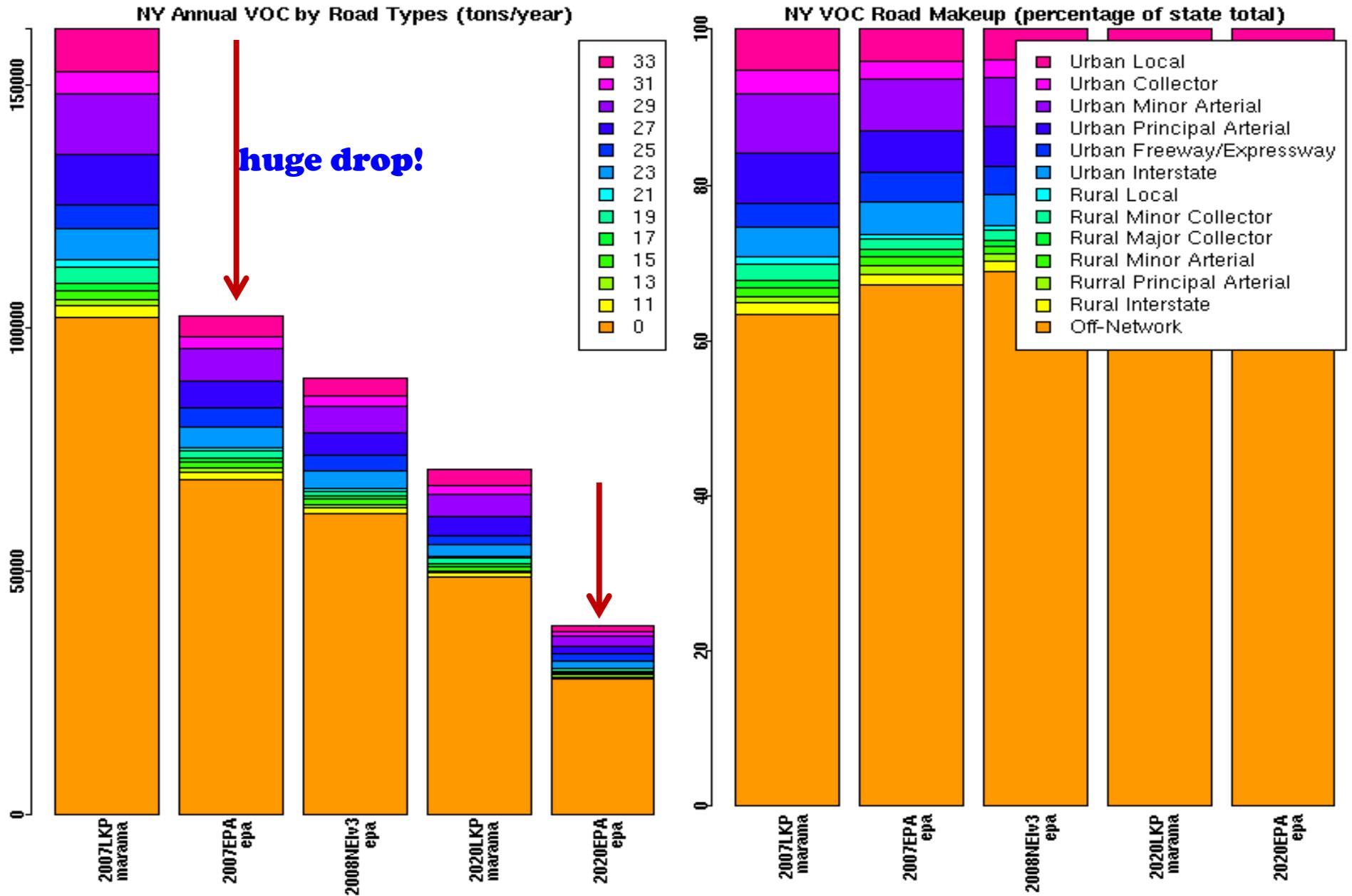
# 2007 RPOs versus 2007 EPA for VOC (lookup table mode)

$$(2007LKP - 2007EPA) * 100 / 2007EPA$$



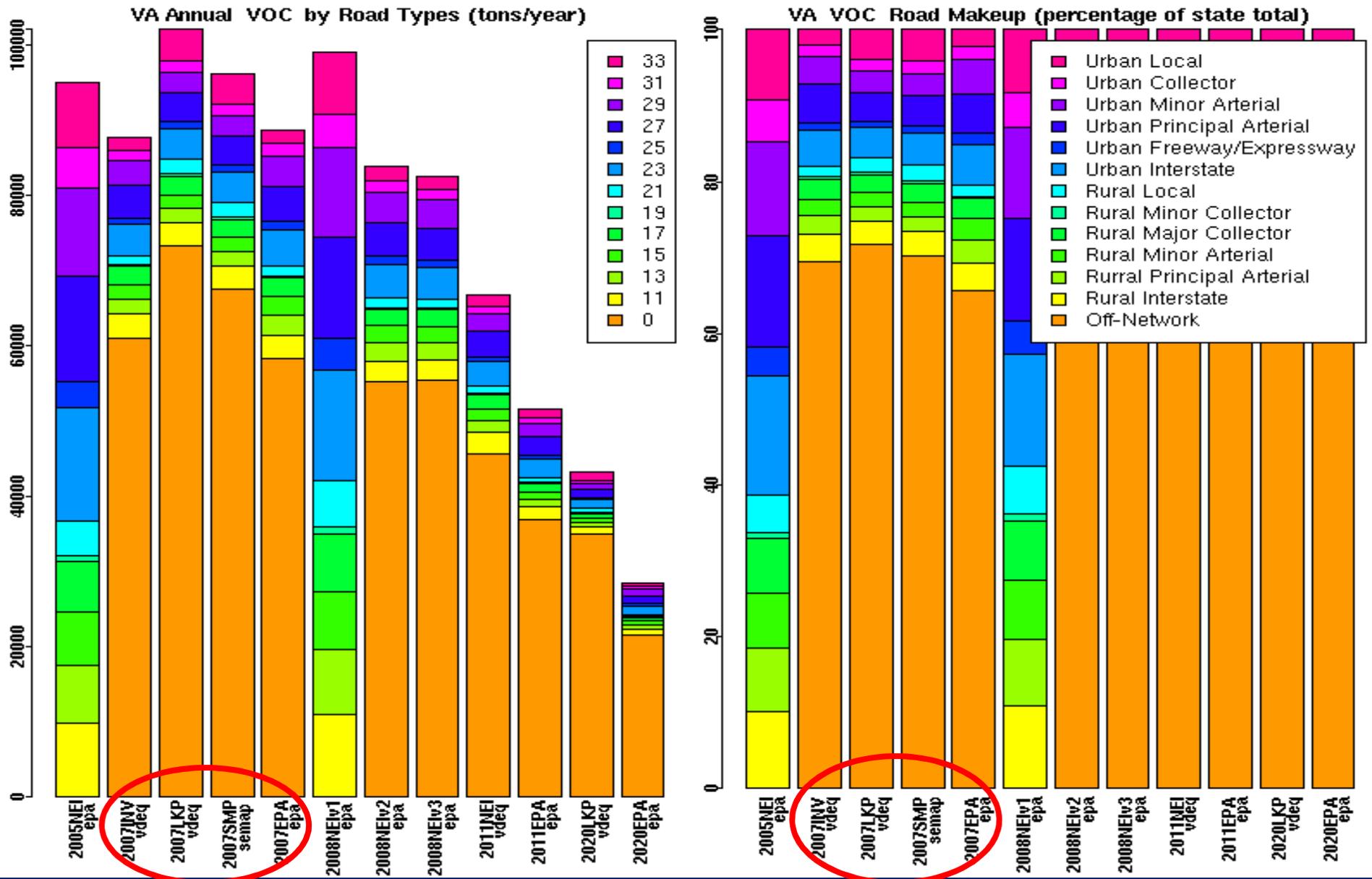
**Similar to NO<sub>x</sub> and PM<sub>2.5</sub>, variability of VOC is all over the place between RPOs and EPA estimates. Differences range from -60% to +300%**

# New York VOC by Road Types



-- Off-network makes up the largest share for mobile VOC emissions.  
 -- 2007 EPA has significantly less VOC emissions in comparison to 2007LKP (MARAMA) for state of NY.

# Virginia VOC by Road Types



- Once again, off-network makes up the largest share for mobile VOC emissions.
- EPA estimates more rural VOC but less urban VOC in comparison to VADEQ and SEMAP.
- Differences in VOC among four 2007 runs are mostly due to off-network.

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## **Initial Reviews on EPA draft 2011NEI**

- **A wide range of differences in VMT allocation to county-level SCCs was found between EPA and VA in-house runs**
- **Local VPOP data has **not** been used**
- **National speed database has no variations by hours or by weekday/weekend, and most of its data entries are contradictory to state-supplied speeds**
- **FF10 for VPOP contains 12 parking-related SCCs (see page 8) which are not listed in MOVES2010b**
- **Previous error of extended idling has been corrected in MOVES2010b by county. 2011NEI, however, is run by representative county and thus will need adjustments in SMOKE-MOVES. States have no way (tools) of doing the adjustments**
- **Is EPA using a different model from publicly-released version?? Please clarify.**

# 2011 VADEQ (inventory mode) versus 2011 EPA (lookup table mode)

$$(2011INV - 2011EPA) * 100 / 2011EPA$$

Legend

County

%Diff NO<sub>x</sub>

-3.7 - -1.0

-0.9 - 1.0 (exact agreement)

1.1 - 10.0

10.1 - 30.0

30.1 - 50.0

50.1 - 70.0

70.1 - 90.0

90.1 - 124.4

**NO<sub>x</sub>**

Legend

County

%Diff PM<sub>2.5</sub>

-3.5 - -1.0

-0.9 - 1.0 (exact agreement)

1.1 - 10.0

10.1 - 30.0

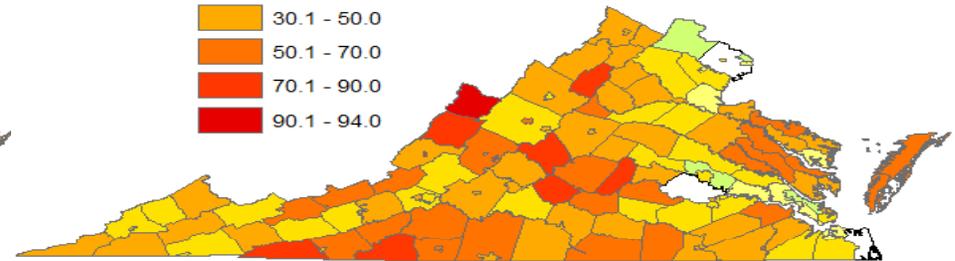
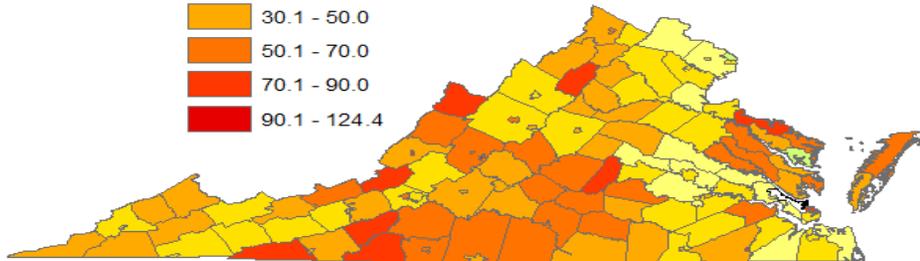
30.1 - 50.0

50.1 - 70.0

70.1 - 90.0

90.1 - 94.0

**PM<sub>2.5</sub>**



Legend

County

%Diff VOC

-19.4 - -10.0

-9.9 - -1.0

-0.9 - 1.0 (exact agreement)

1.1 - 10.0

10.1 - 30.0

30.1 - 50.0

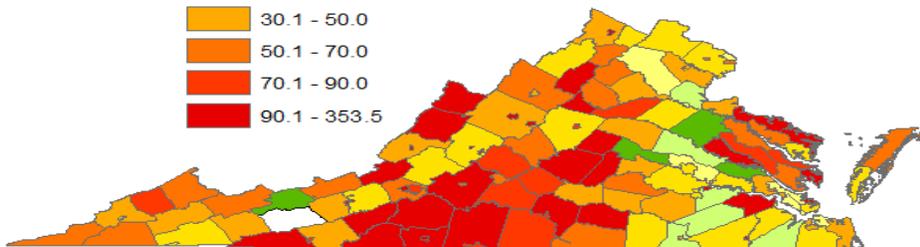
50.1 - 70.0

70.1 - 90.0

90.1 - 353.5

**VOCs**

- Positive indicates higher VADEQ estimates than EPA.
- VADEQ run is in inventory mode; lookup table mode is in progress
- EPA estimates much lower emissions for all pollutants than VADEQ
- PM<sub>2.5</sub> were treated differently. VADEQ included primary, brakewear, and tirewear. EPA included only primary.



**Differences are too significant to ignore!**

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# Conservation of Activities

**MOVES violates basic principle of conservation**



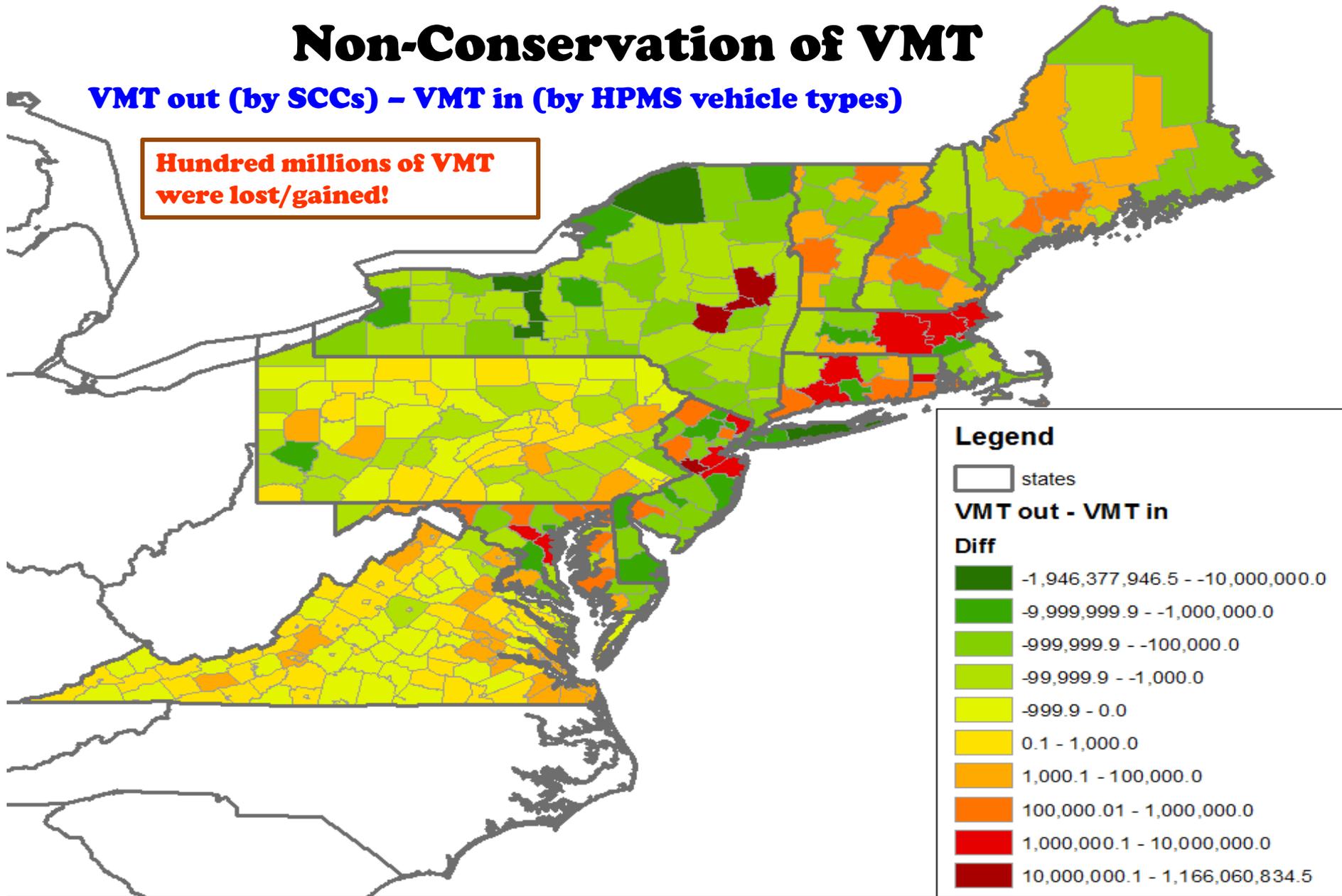
County/State	VMT (% change)	Loss/Gain	Notes
York, VA	minimal	gain	after adjustments
Fairfax, VA	0.01%	loss	no adjustment
Mercer, NJ	0.6%	gain	no adjustment

- Activities by SCCs from MOVES outputs get fed into SMOKE;  **Important!**
- None of the counties modeled conserve activities (either gain or loss);
- Adjustments can be made to recover some VMT and VPOP losses;
- e.x., adding CNG will recover almost all loss of VPOP, but VMT loss cannot be fully recovered;
- **Question: are the loss “real”? If inventory mode outputs are used as SMOKE inputs, then loss is real and SMOKE emission estimates are questionable.**
- VMT loss/gain has not been resolved since the issue was first brought up in April 2011.

# Non-Conservation of VMT

VMT out (by SCCs) – VMT in (by HPMS vehicle types)

**Hundred millions of VMT were lost/gained!**



- The map was constructed by **2007** platform (MOVES2010a) for MANEVU region, and **2011** platform (MOVES2010b) for Virginia.
- None of the counties have the same VMT as in the original input. Counties have either VMT loss or VMT gain.
- Conservation problem exists in both MOVES2010a and MOVES2010b.
- **The issue has not been resolved since it was first brought up in April 2011.**

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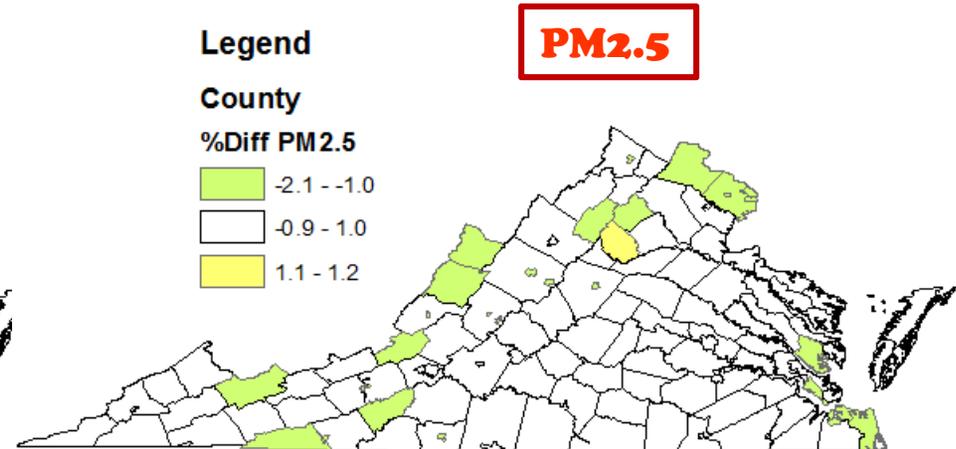
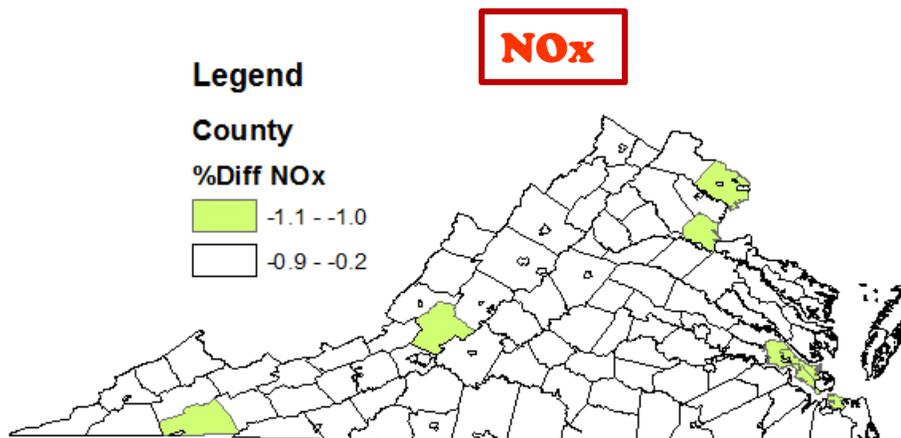
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# **An Example of Coordinated Efforts**

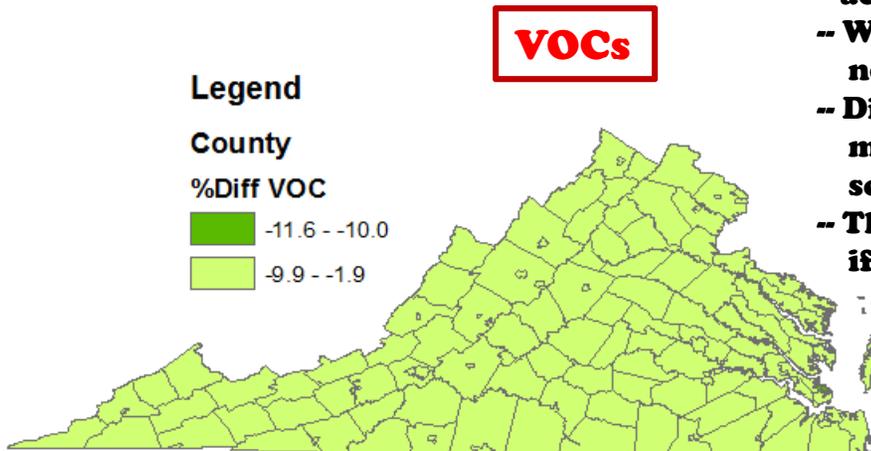
- **Virginia belongs to both MARAMA and SEMAP groups**
- **MARAMA 2007 MOVES modeling was completed before SEMAP**
- **Initial 2007 SEMAP MOVES run jointly conducted by Alpine Geophysics and UNC showed very large differences from MARAMA run for Virginia**
- **VA MOVES settings and input files were reviewed carefully, and SMOKE-MOVES procedure was scrutinized**
- **I/M programs and VMT/VPOP allocations were found to cause significant differences in emissions**
- **Efforts were made to use best possible and consistent inputs. Large differences were eventually erased (see next page)**
- **The differences can now be attributed to different WRF meteorology between two PROs**

# Coordinated Efforts -- Effect of Meteorology

(2007SMP - 2007LKP) \* 100 / 2007LKP



**VOCs are more sensitive to temperature than other pollutants**



- LKP run was conducted by VADEQ, whereas SMP run was jointly conducted by Alpine Geophysics and UNC.
- MOVES settings (representative county) and inputs (including activities) of SMP run were carefully reviewed by VADEQ.
- With the exception of only a few counties, the two runs yielded nearly identical NO<sub>x</sub>/PM<sub>2.5</sub> for all counties.
- Differences between two runs are solely due to WRF meteorology, which shows a very **minor** impact on mobile source emissions.
- The role meteorology plays may change and become important if RH issue in SMOKE-MOVES is fixed in the future.

**Lookup tables (generated from suitable MOVES settings and localized inputs) along with activity allocations are the most important factors determining emissions.**

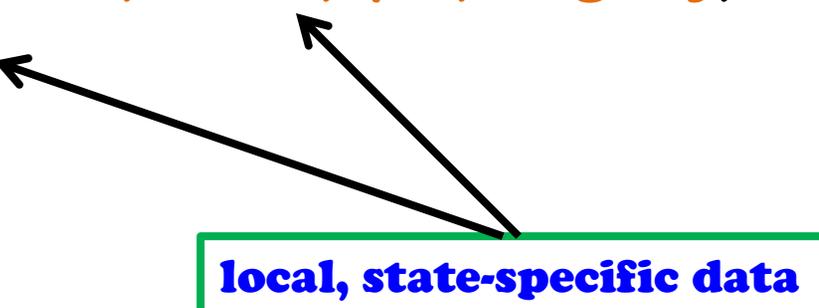
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- **Regional PM<sub>2.5</sub> Comparisons**
- **Regional VOCs Comparisons**
- **Reviews on EPA Draft 2011NEI**
- **Issues with Activity Conservation**
- **An Example of Coordinated Efforts**
- **Summary and Recommendation**

# Summary – Representative County

- **MOVES can be conducted in two operating modes:**
  - (a) **inventory mode (output in emissions, tons);**
  - (b) **lookup table mode (output in rates, g/mile or g/car/hr)**
- **Representative county approach is used in both modes because of excessively long run time if modeled by individual counties**  
**(examples: VA has 134 jurisdictions. GA has 159 counties.)**
- **County grouping criteria:**
  - (a) **control programs (CALEV, NLEV, I/M, stageII);**
  - (b) **fleet age distribution;**
  - (c) **fuel parameters**

**local, state-specific data**



# Summary -- Lookup Tables

- **Lookup tables contain millions of data records of emission rates for a variety of modeling conditions:**  
**example: 0.8 g/mile of NO<sub>x</sub> for LDGV travels at 50 mph on urban freeway (SCC = 2201001250) at ambient temperature of 60F**
- **Emission rates vary widely if conditions (county, fuel month, SCCs, speed, temperature) change**
- **Rates are small numbers (in unit activity of g/mile or g/car). They are the building blocks for emissions and must be accurately generated prior to combination with activity. The accuracy hinges on MOVES runs using local, state-supplied inputs of surrogated counties**

**building blocks: small numbers**

$$\begin{aligned} \text{Emissions (tons)} &= \text{rate (g/mile)} * \text{VMT} * \text{conversion factor} \\ \text{Emissions (tons)} &= \text{rate (g/car)} * \text{VPOP} * \text{conversion factor} \end{aligned}$$

**very large numbers**

## Summary -- Activity Allocation

- **For lookup table mode, activity data (VMT, VPOP, and speed) requires special handling to allocate them into 144 SCCs (VMT) and 12 SCCs (VPOP) so that SMOKE can accurately calculate emissions**
  - (a) There are many ways to allocate activity. Which one is correct?**
  - (b) MOVES can do the allocation but a separate MOVES run in inventory mode is required (i.e., users end up having to conduct both inventory mode and lookup table mode runs);**
  - (c) The end product by MOVES allocation violates basic principle of conservation**

# Issues with EPA MOVES platform

- **Representative county scheme is too crude -- 3200+ counties are represented by 146 counties, many of which are not even in home states (improvements being made)**
- **MOVES inputs of surrogated counties have not been closely examined prior to usage**
- **Fleet age distribution of surrogated county should not be used directly to represent the entire group. The input needs additional processing to obtain “averaged” fleet ages**
- **Activity (VMT and VPOP) was not allocated into MOVES internal SCCs**
- **National speed database is contradictory to state-specific speeds**
- **Many adjustments made by EPA to inputs and outputs make it impossible to replicate or verify emissions using publicly-released models**

**Comparisons made at state level are very lenient, as overestimates and underestimates at county level have been canceled out**

# Recommendations

- **Nation-wide MOVES runs for each individual county in inventory mode**
- **Eliminate SMOKE-MOVES and treat mobile sector as area sources in SMOKE**
- **MOVES mysql CDB (county database) inputs, as submitted by states to EIS as part of 2011 NEI, are ready for immediate usage**
- **Representative county scheme is not necessary (~3200 counties can be completed in 60-90 days using multiple nodes)**
- **Region-wide consistency can be achieved . Process is simple and transparent.**
- **Simple inventory mode encourages states to participate and verify their numbers**
- **No benefit for running MOVES in lookup table mode. Currently, meteorology cannot be simulated correctly due to issues with relative humidity and fuel month**
- **SCC-related problems must be corrected soon**
- **Both emission and air quality modeling must go through rigorous performance evaluations prior to using them for policy decisions**