Critical Review of Mobile Emissions from EPA 2011 NEI: Part Three – Extended Idling, Emission Processes, and Ramp Fraction

Jin-Sheng Lin, Kristen Stumpf, and Sonya Lewis-Cheatham
Virginia Department of Environmental Quality

MARAMA MOVES Workgroup conference call
February 3, 2014

Background

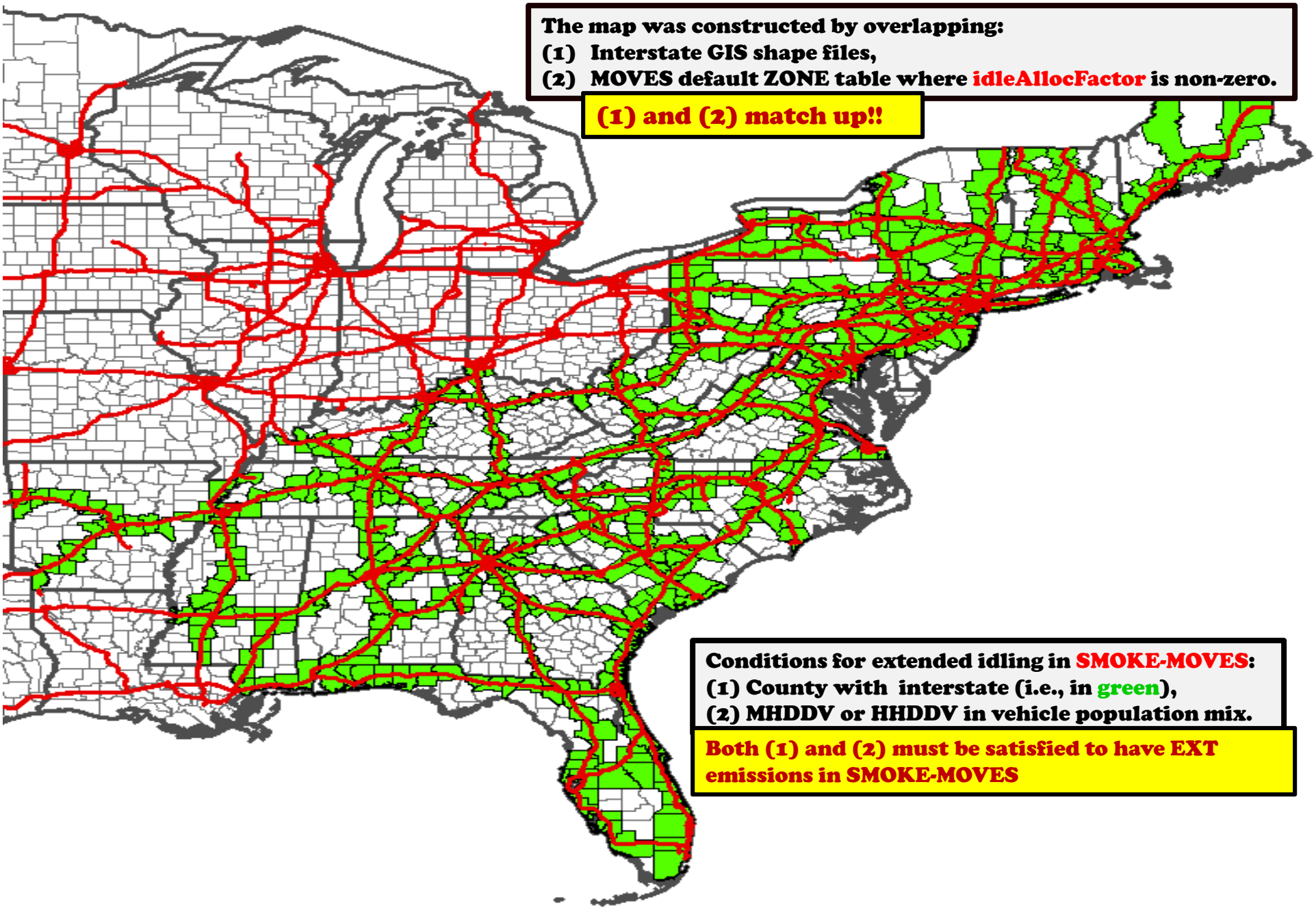
- The 2011 NEI version1 inventory has been under review since it was released in September 2013
- By comparing a state's inventory-mode MOVES and EPA's SMOKE-MOVES:
  - Meteorology has been shown to have only a minor impact on emission estimates
  - Without county grouping, estimates by SMOKE-MOVES and MOVES have been shown to be very close (differences < 10%)
- Other factors identified as possible causes for the difference between the two approaches:
  - Activity aggregation (VMT, VPOP, age distribution)
  - Extended idling
  - MOVES version
  - Control programs
  - Fuel properties

Presentation Outline

- Extended Idling (EXT)
- MOVES Version
- MOVES Emission Processes
- Effects of Ramp Fraction

Following GA approach, replaced extended idling emissions in EPA's SMOKE-MOVES with extended idling emissions in VDEQ's Inventory MOVES

Extended Idling County Map – Eastern United States



The map was constructed by overlapping:
(1) Interstate GIS shape files,
(2) MOVES default ZONE table where idleAllocFactor is non-zero.

(1) and (2) match up!!

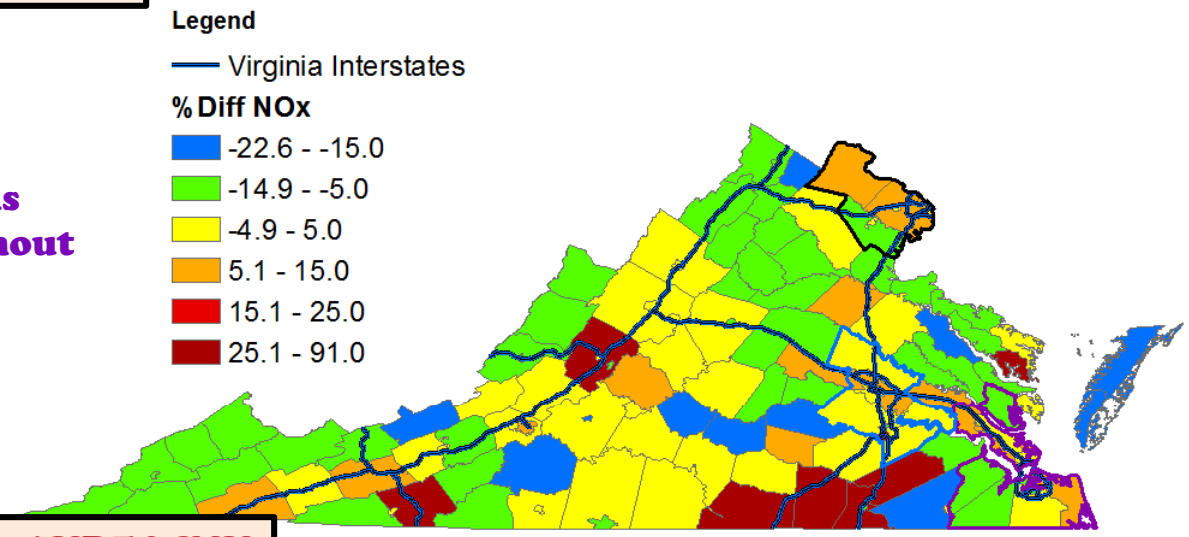
Conditions for extended idling in SMOKE-MOVES:
(1) County with interstate (i.e., in green),
(2) MHDDV or HHDDV in vehicle population mix.

Both (1) and (2) must be satisfied to have EXT emissions in SMOKE-MOVES

EXT Replacement – NOx

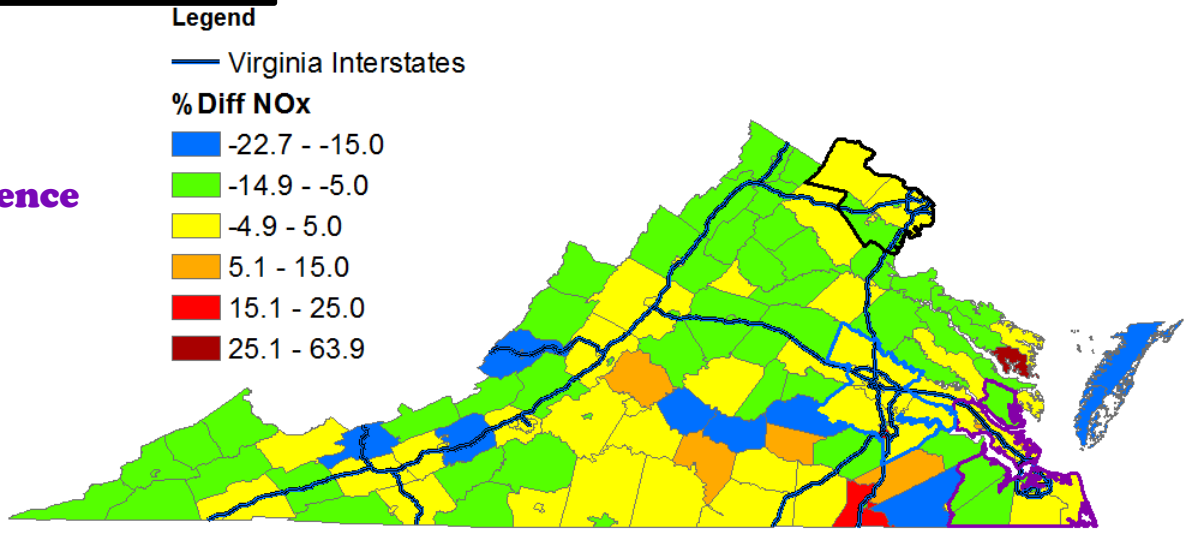
(EPA NEI v1 – VDEQ INV) * 100 / VDEQ INV

Except for a few counties, EPA's NOx is mostly lower than VDEQ INV throughout the Commonwealth.



(EPA w VDEQ EXT – VDEQ INV) * 100 / VDEQ INV

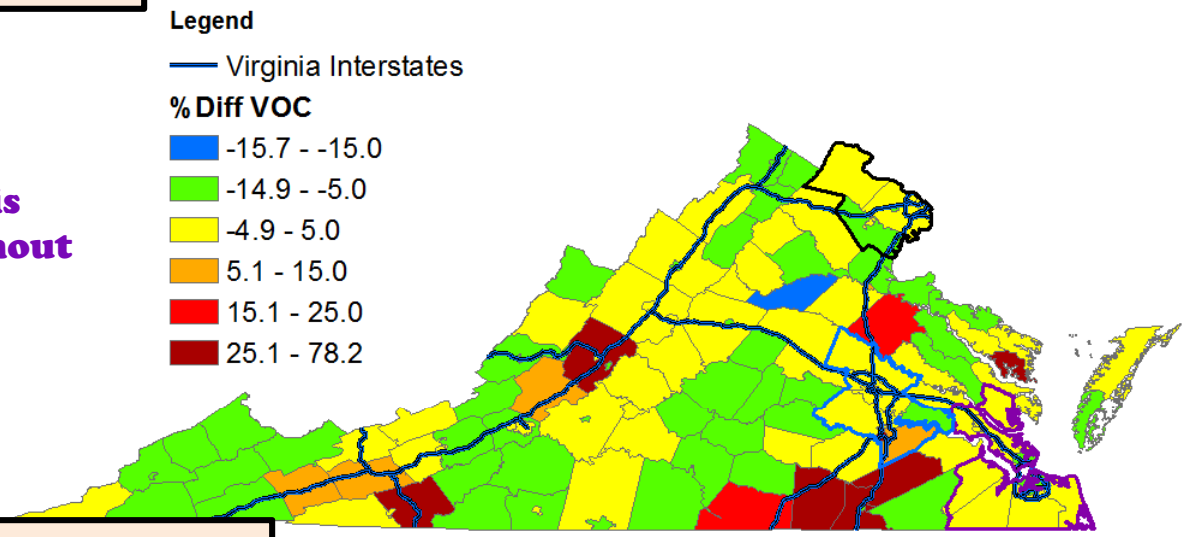
The replacement improves NOx difference along interstates.



EXT Replacement – VOCs

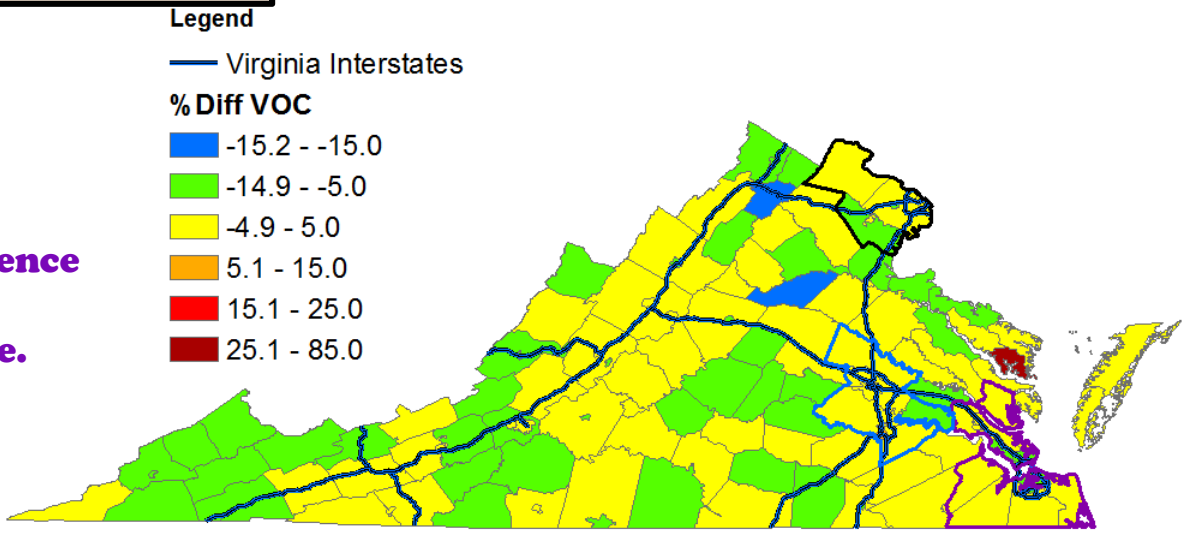
(EPA NEI v1 – VDEQ INV) * 100 / VDEQ INV

Except for a few counties, EPA's VOC is mostly lower than VDEQ INV throughout the Commonwealth.



(EPA w VDEQ EXT – VDEQ INV) * 100 / VDEQ INV

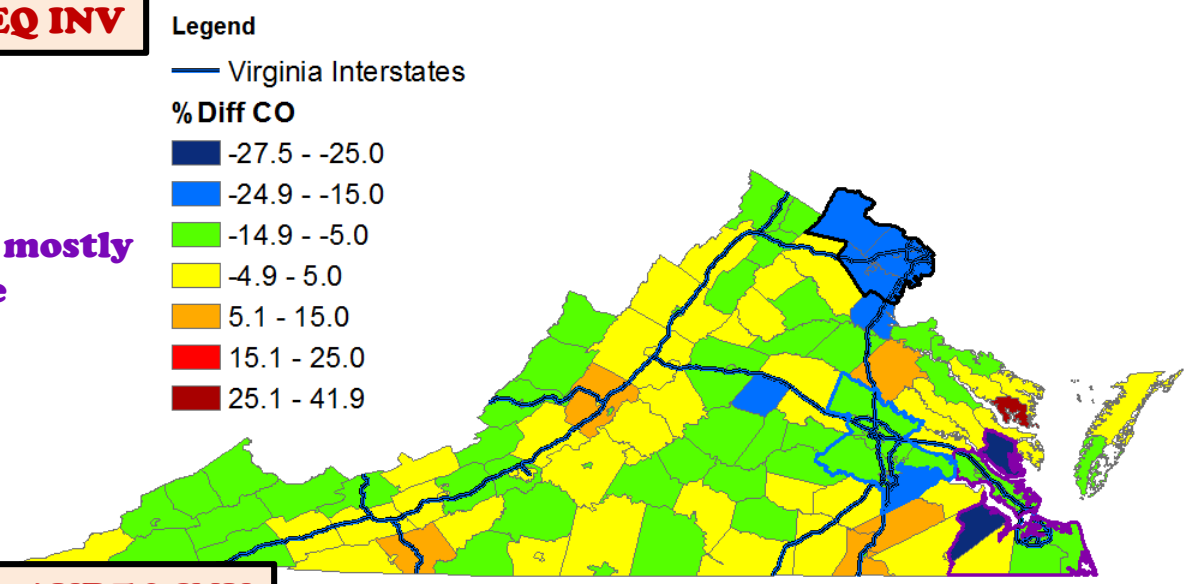
The replacement improves VOC difference along interstates.
EPA's VOC is lower almost everywhere.



EXT Replacement – CO

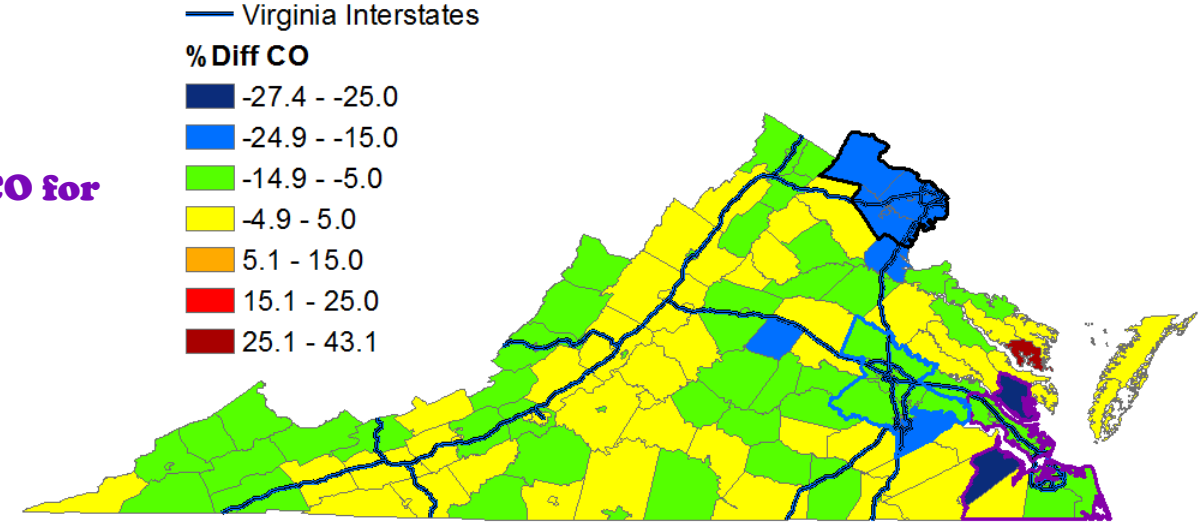
(EPA NEI v1 – VDEQ INV) * 100 / VDEQ INV

Except for a few counties, EPA's CO is mostly lower than VDEQ INV throughout the Commonwealth.



(EPA w VDEQ EXT – VDEQ INV) * 100 / VDEQ INV

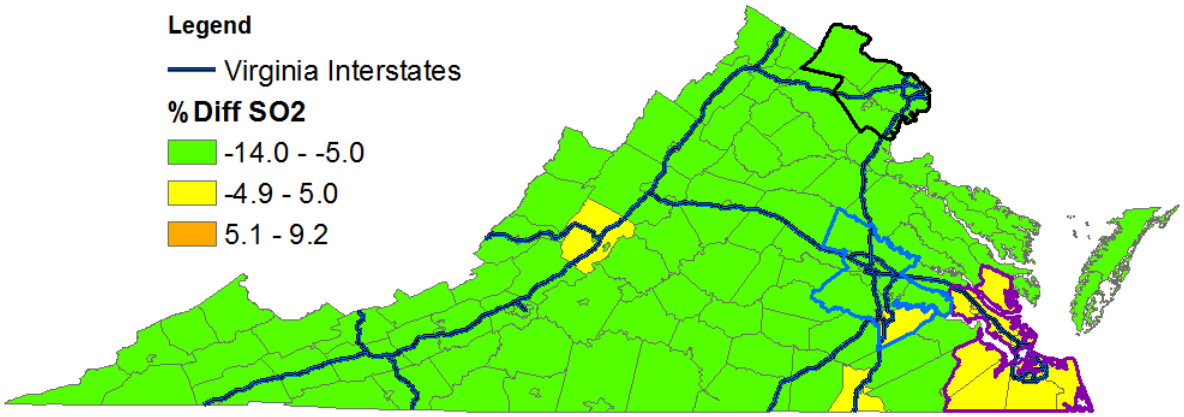
The replacement has some effect on CO for a few counties.



EXT Replacement – SO2

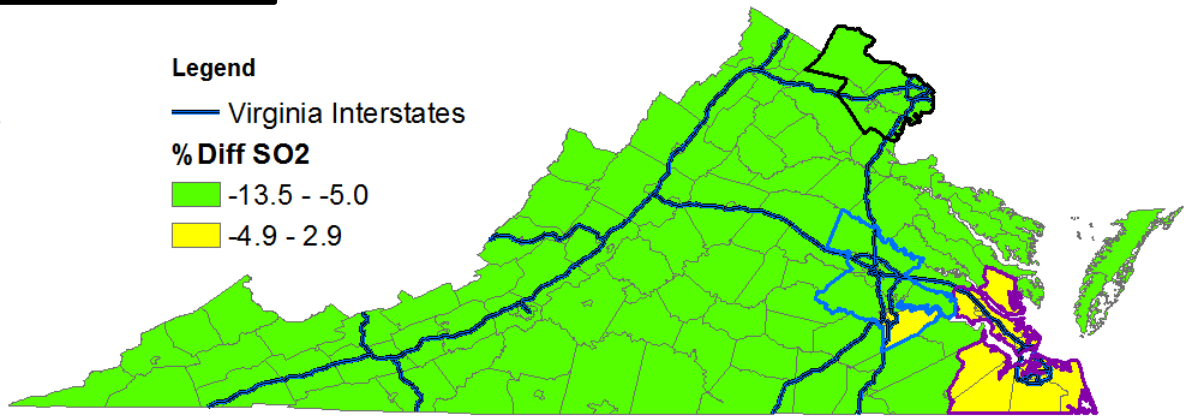
(EPA NEI v1 – VDEQ INV) * 100 / VDEQ INV

EPA's SO2 is lower than VDEQ INV everywhere.



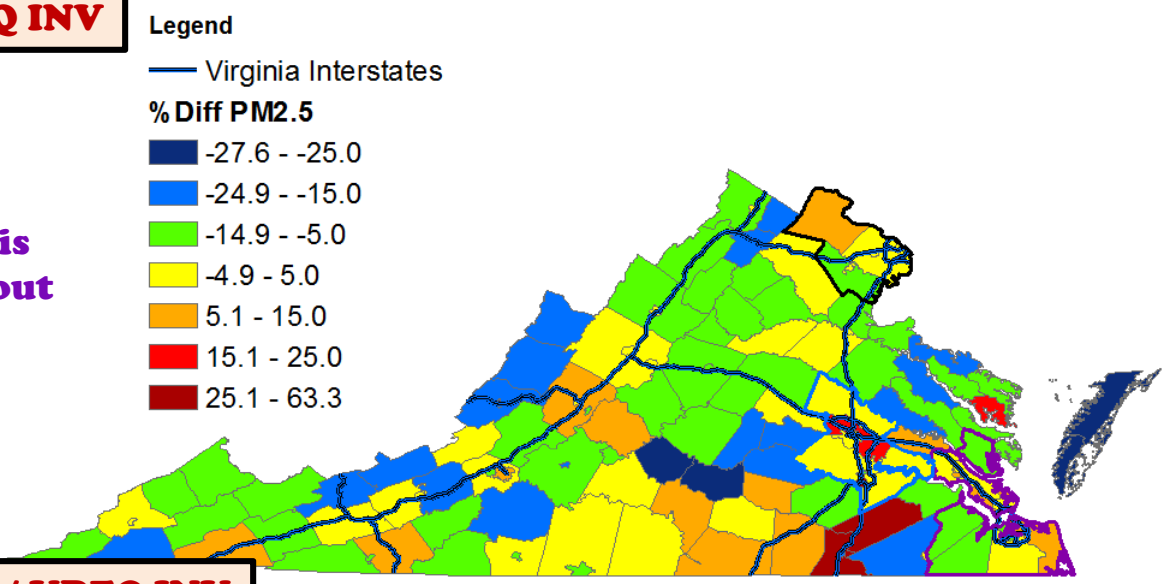
(EPA w VDEQ EXT – VDEQ INV) * 100 / VDEQ INV

The replacement has no effect on SO2.



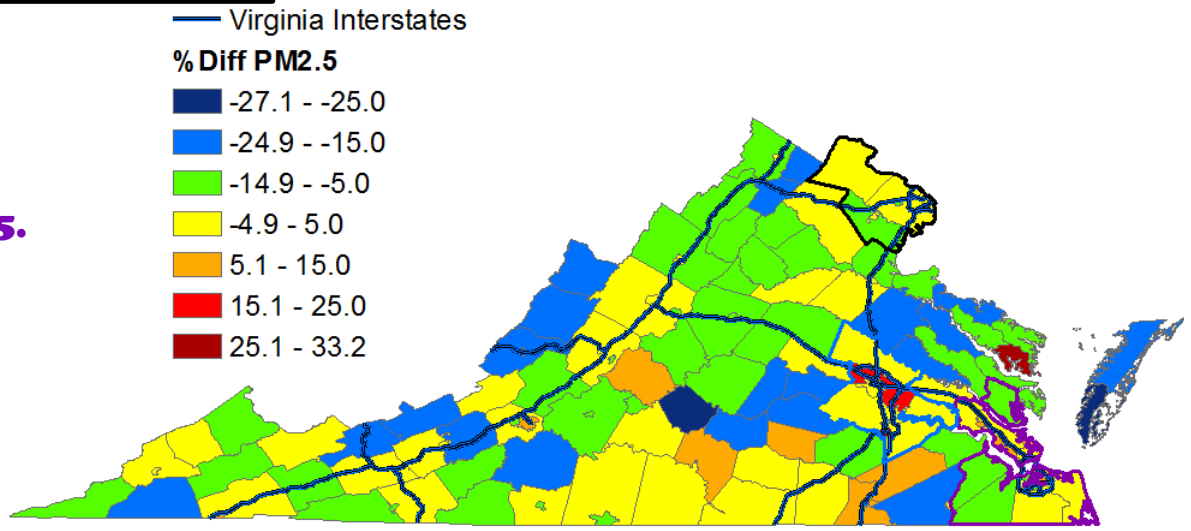
EXT Replacement – PM25

(EPA NEI v1 – VDEQ INV) * 100 / VDEQ INV



Except for a few counties, EPA's PM25 is mostly lower than VDEQ INV throughout the Commonwealth.

(EPA w VDEQ EXT – VDEQ INV) * 100 / VDEQ INV

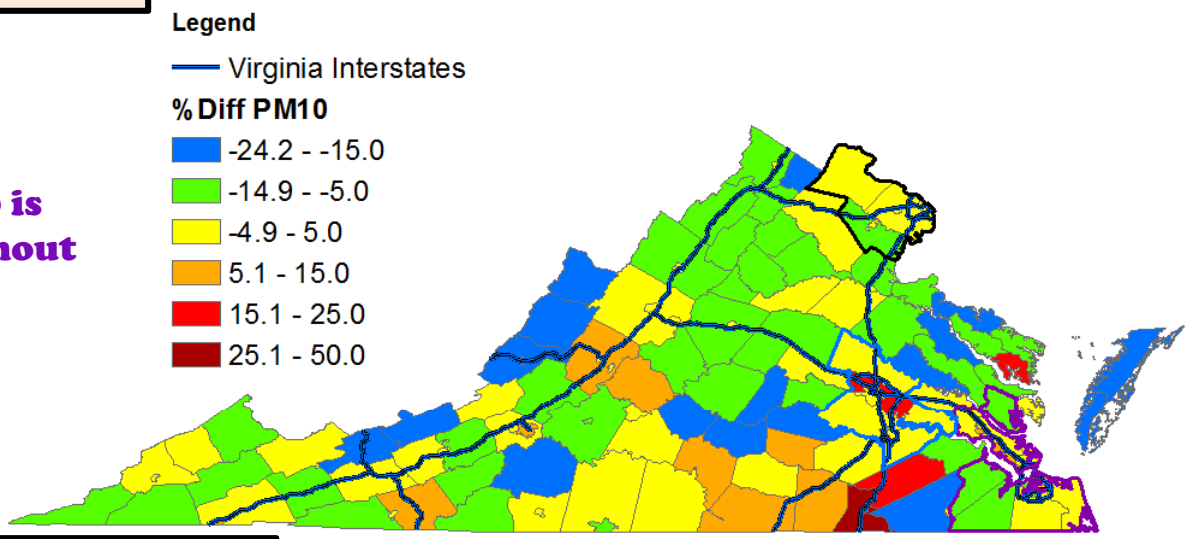


The replacement has no effect on PM25.

EXT Replacement – PM10

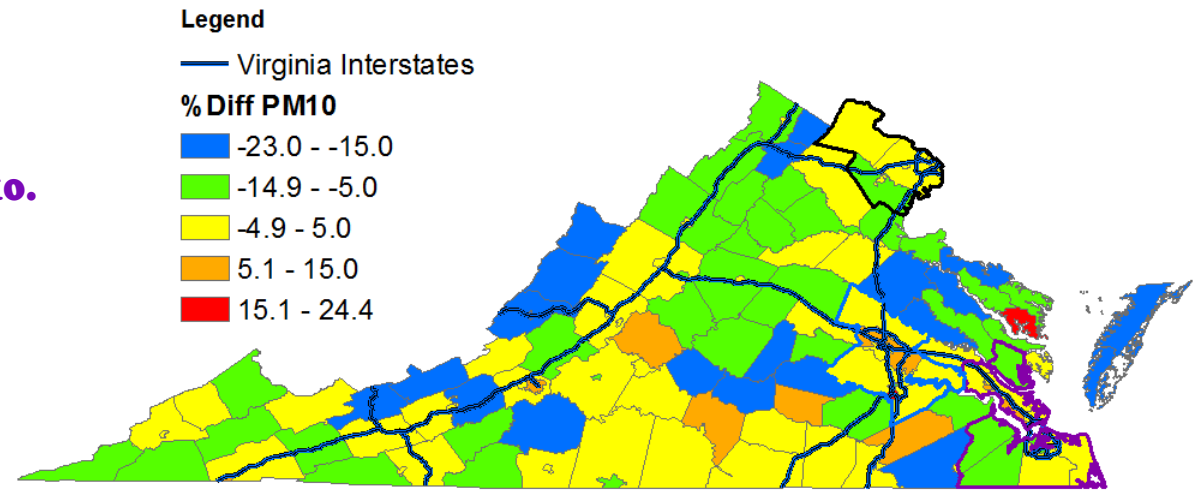
(EPA NEI v1 – VDEQ INV) * 100 / VDEQ INV

Except for a few counties, EPA's PM10 is mostly lower than VDEQ INV throughout the Commonwealth.



(EPA w VDEQ EXT – VDEQ INV) * 100 / VDEQ INV

The replacement has no effect on PM10.



Summary on EXT Replacement

- **Replaced extended idling emissions in EPA's NEI SMOKE-MOVES with extended idling emissions in VDEQ's Inventory MOVES:**
  - **-- NOx and VOC have become closer**
  - **-- Minimal impact on other pollutants, indicating other factors are affecting the differences**
  - **-- Estimates in 2011NEI are consistently lower than VDEQ's inventory for all pollutants across the state**

Presentation Outline

- Extended Idling (EXT)
- MOVES Version
- MOVES Emission Processes
- Effects of Ramp Fraction

Could other factors such as MOVES model version account for the differences?

Two Versions of 2011 NEI

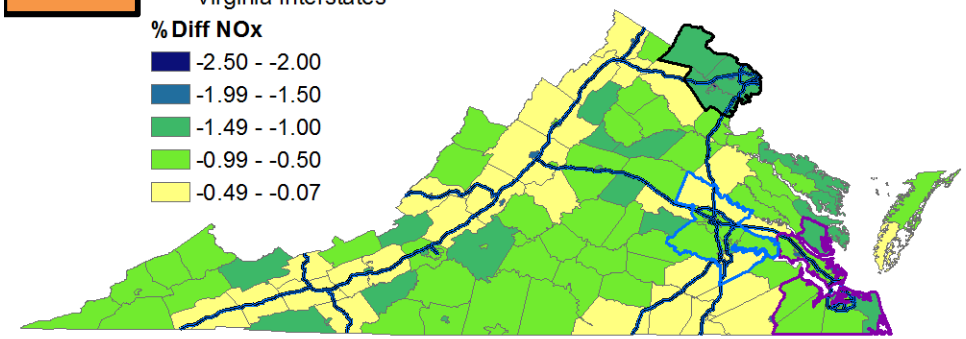
- **2011NEI version1**: Released on September 30, 2013 (the night before the government shutdown). MOVES version was MOVES2010b
- **2011NEI modeling platform**: Released in December 2013. MOVES version used has incorporated new updates (new controls such as Tier3?)

Extended Idle replacement used the NEI modeling platform instead of NEI v1

EPA Modeling Platform vs. EPA NEI v1

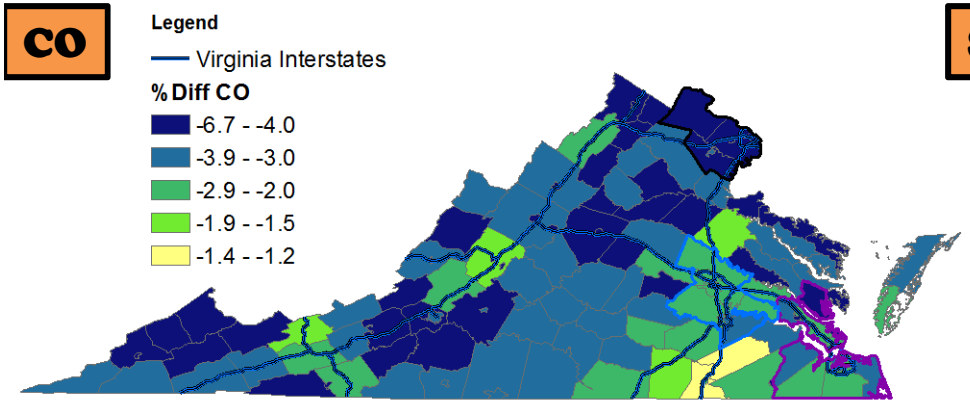
(EPA NEI MP – EPA NEI v1) * 100 / EPA NEI v1

NOx

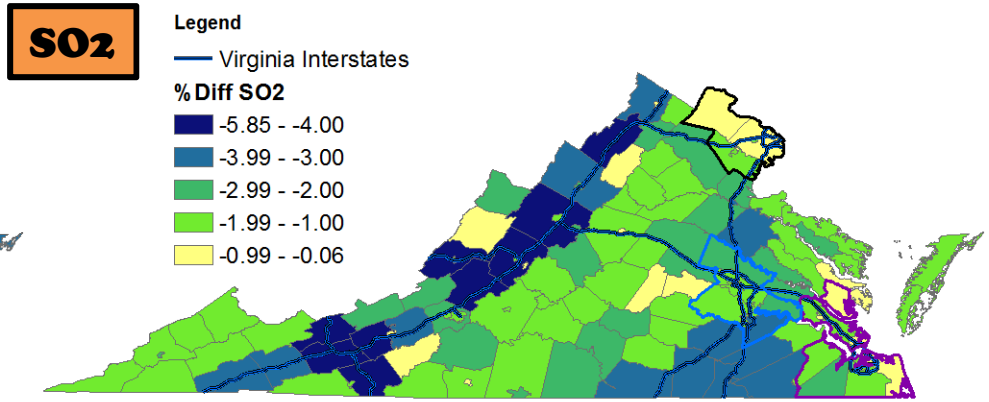


- -- plots have different scales
- -- colors closer to yellow indicate less difference
- -- EPA NEI MP < EPA NEI v1
- -- differences in CO and SO2 are greater than other pollutants
- -- wide-spread spatial differences in NOx range between -0.5 % and -2.0%

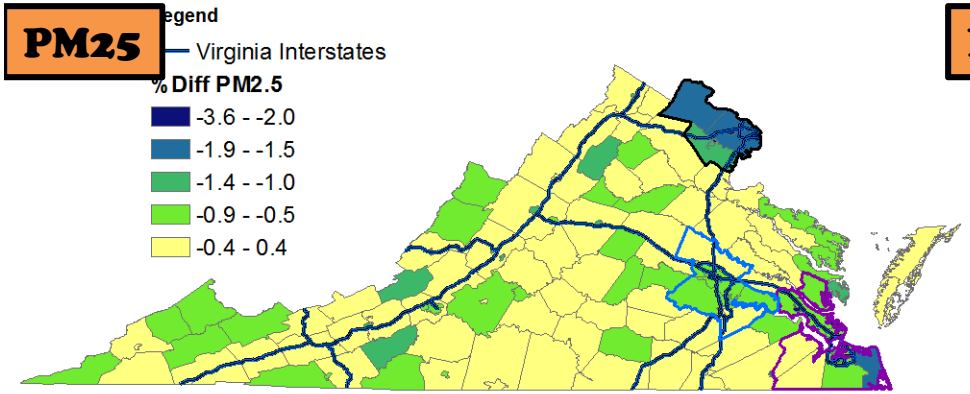
CO



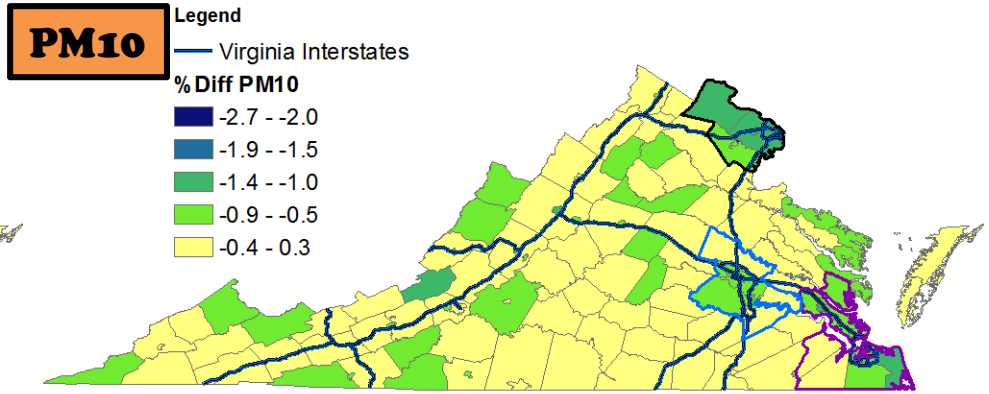
SO2



PM25



PM10



Summary on two EPA NEI versions

- Emissions in 2011 NEI modeling platform are lower than emissions in 2011 NEI version1 for all pollutants
- New updates and/or controls implemented in 2011 NEI modeling platform have further lowered its emission estimates in comparison to 2011 NEI version1 which used MOVES2010b
- Changes between MOVES versions are much less and thus cannot account for the differences between EPA estimates and VDEQ estimates

Presentation Outline

- Extended Idling (EXT)
- MOVES Version
- MOVES Emission Processes
- Effects of Ramp Fraction

Which emission processes could have caused the differences, and how would the differences affect emission processes?

MOVES Emission Processes

Process ID	Abbreviation	Process Name
1	EXR	Running Exhaust
2	EXS	Start Exhaust
9	BRK	Brakewear
10	TIR	Tirewear
11	EPM	Evap Permeation
12	EFV	Evap Fuel Vapor Venting
13	EFL	Evap Fuel Leak
15	CXR	Crankcase Running Exhaust
16	CXS	Crankcase Start Exhaust
17	CEI	Crankcase Extended Idle Exhaust
18	RFV	Refueling Displacement Vapor Loss
19	RFS	Refueling Spillage Loss
90	EXT	Extended Idle Exhaust
99		Well-to-Pump

EXR/CXR: running exhaust
EXS/CXS: start exhaust
EXT/CEI: extended idling

EPM, EFV, EFL, EFV, EFS:
VOC related processes

BRK, TIR:
PM related processes

NOx Additive Mechanism

RPD: rate-per-distance
RPV: rate-per-vehicle
RPP: rate-per-profile

RPD: vehicle in motion
RPV: vehicle motionless
RPP: parked vehicles (no NOx)

- **NOx in MOVES :**
  RPD = (EXR + CXR)
  RPV = (EXS + CXS) + (EXT + CEI)

- **NOx in SMOKE-MOVES:**
  RPD = EXH
  RPV = EXH + EXT

Total NOx = Running Exhaust + Engine Starts + Extended Idling

Numbers were extracted from EPA 2011NEI and VDEQ MOVES inventory for comparison

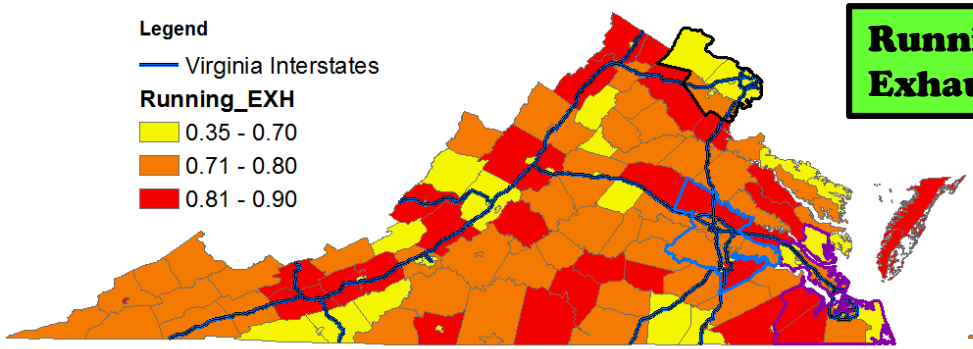
The above equations apply to NOx only.

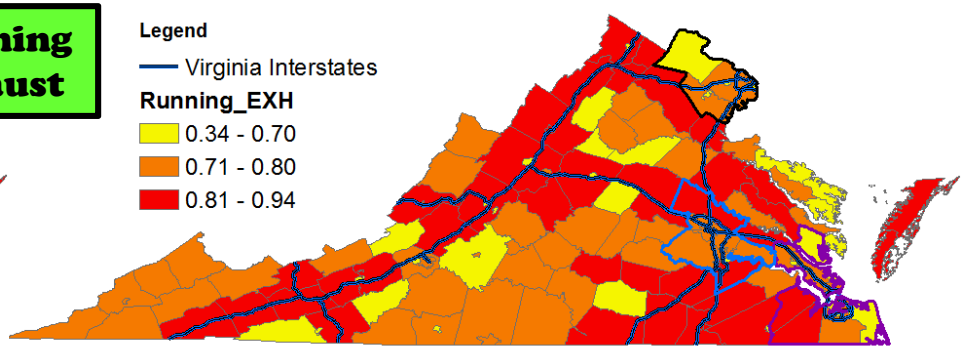
Fractional NOx Emissions

EPA 2011NEI

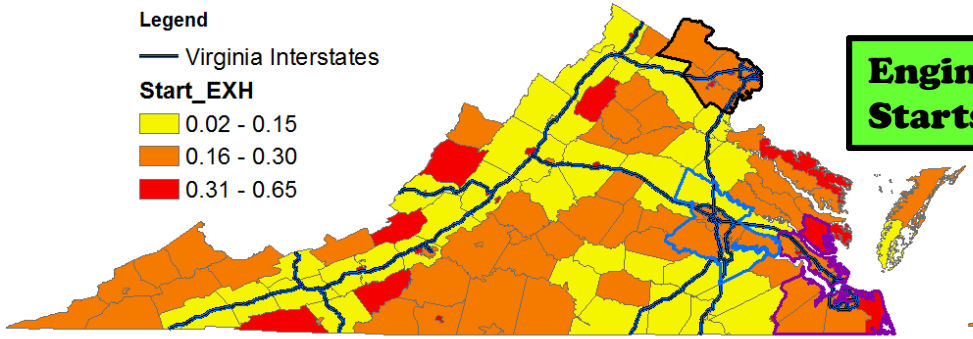
VDEQ Inventory MOVES

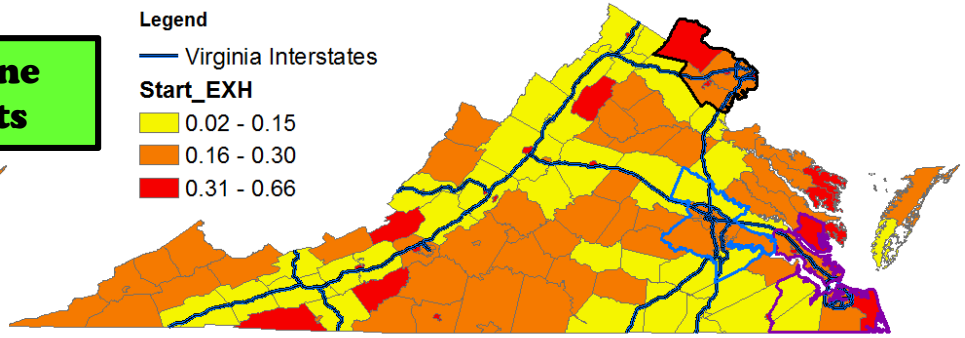
Running Exhaust



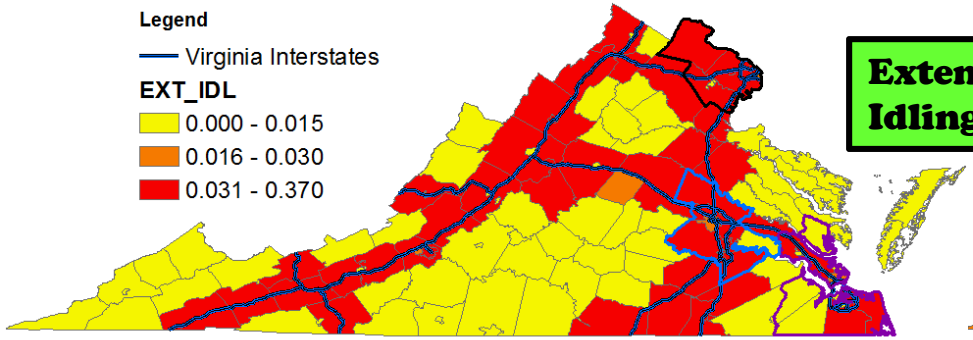


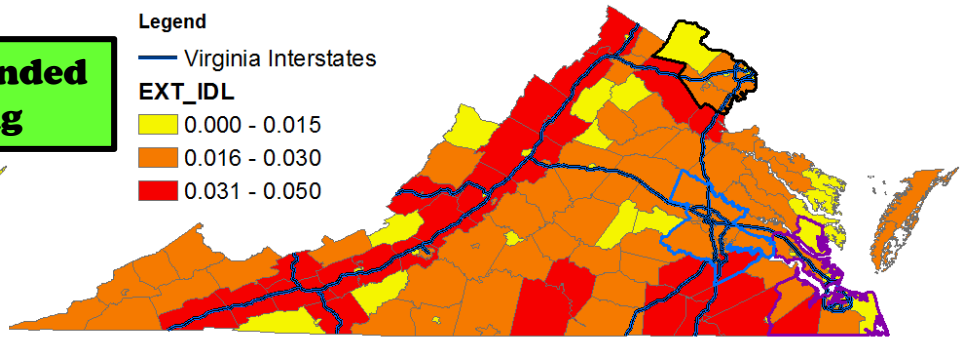
Engine Starts





Extended Idling





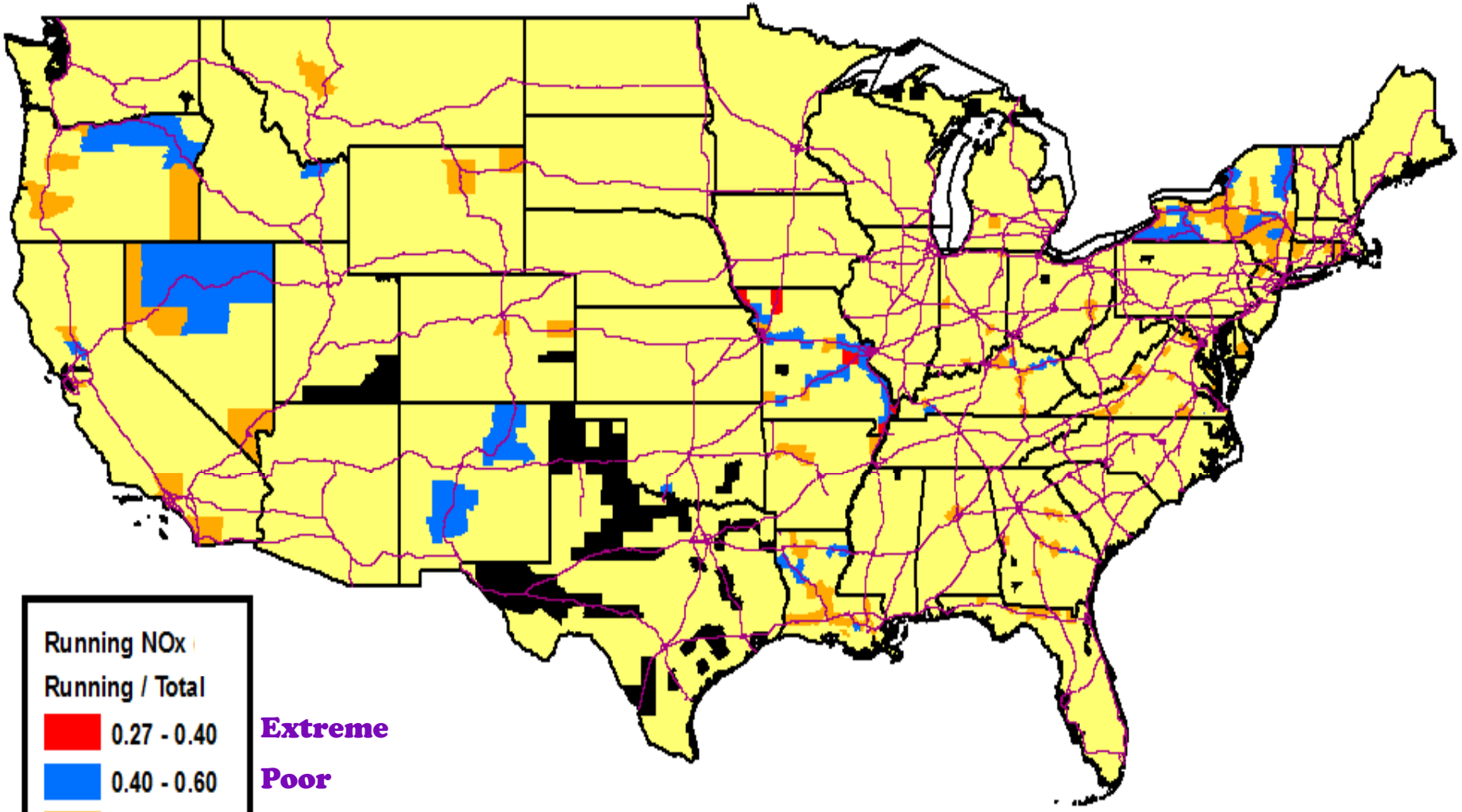
-- Running exhaust contributes a great majority of total NOx (~80%), whereas extended idling is a miniscule portion of total NOx (<5%).
-- VDEQ inventory exhibits distinct (and reasonable) spatial patterns for all three contributing sectors (running, start, idling).
-- EPA 2011NEI greatly exaggerates extended idling along interstates, and also shifts running exhaust away from the interstates.

Summary on Emission Processes
VA Example

- Spatial patterns for start exhaust are similar between EPA 2011NEI and VDEQ inventory (middle two panels)
- EPA 2011NEI places extended idling exclusively along interstates, while zeroing out extended idling in counties without interstates (bottom two panels)
- Running exhaust has been shifted away from the interstates in EPA 2011NEI, breaking the continuity of spatial pattern (top two panels)

Running exhaust remains the most significant cause for the differences between EPA estimates and VDEQ estimates

Fractional Running EXH NOx in 2011NEI



Extreme

Poor

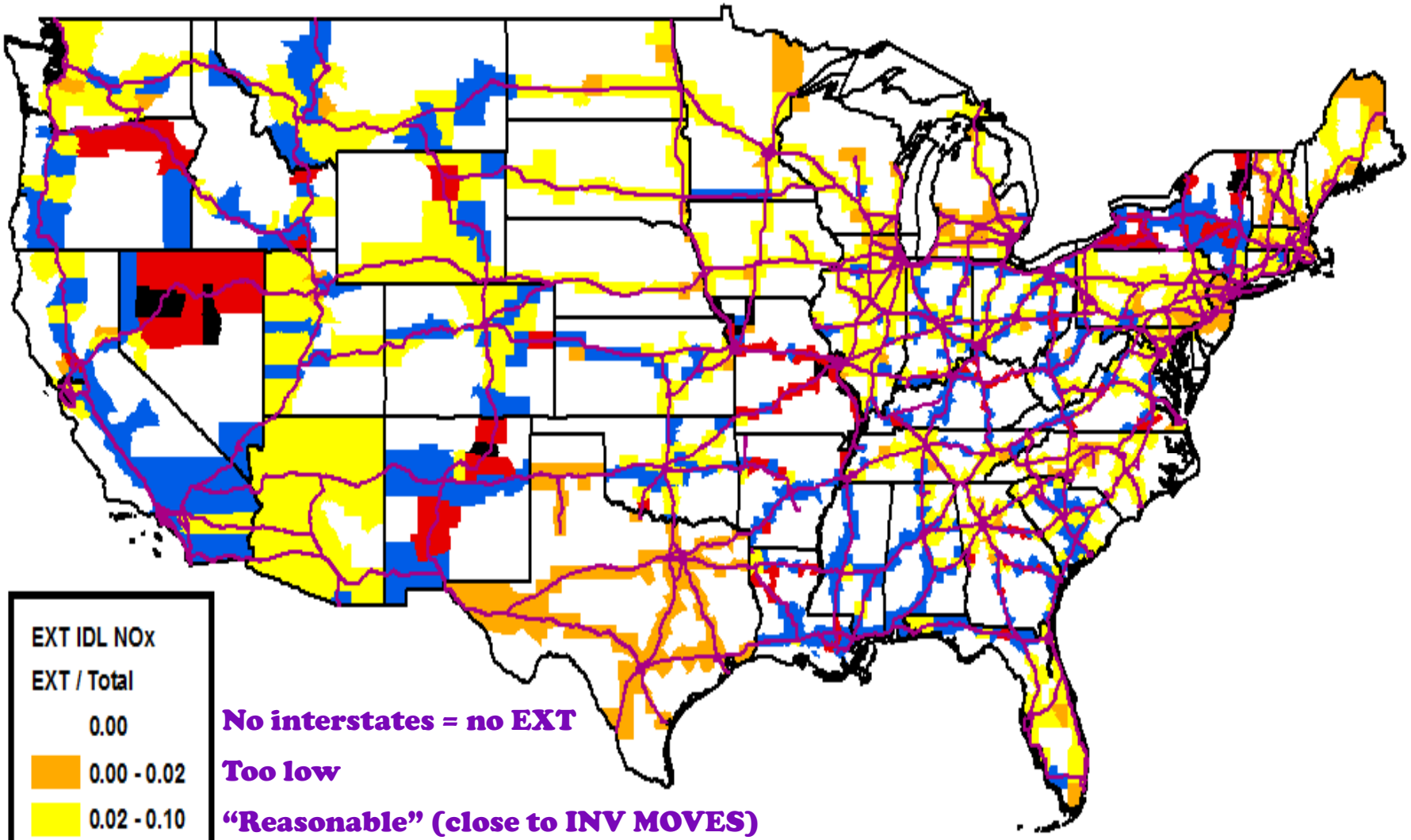
Fair (a little low)

"Reasonable" (close to INV MOVES)

Too high

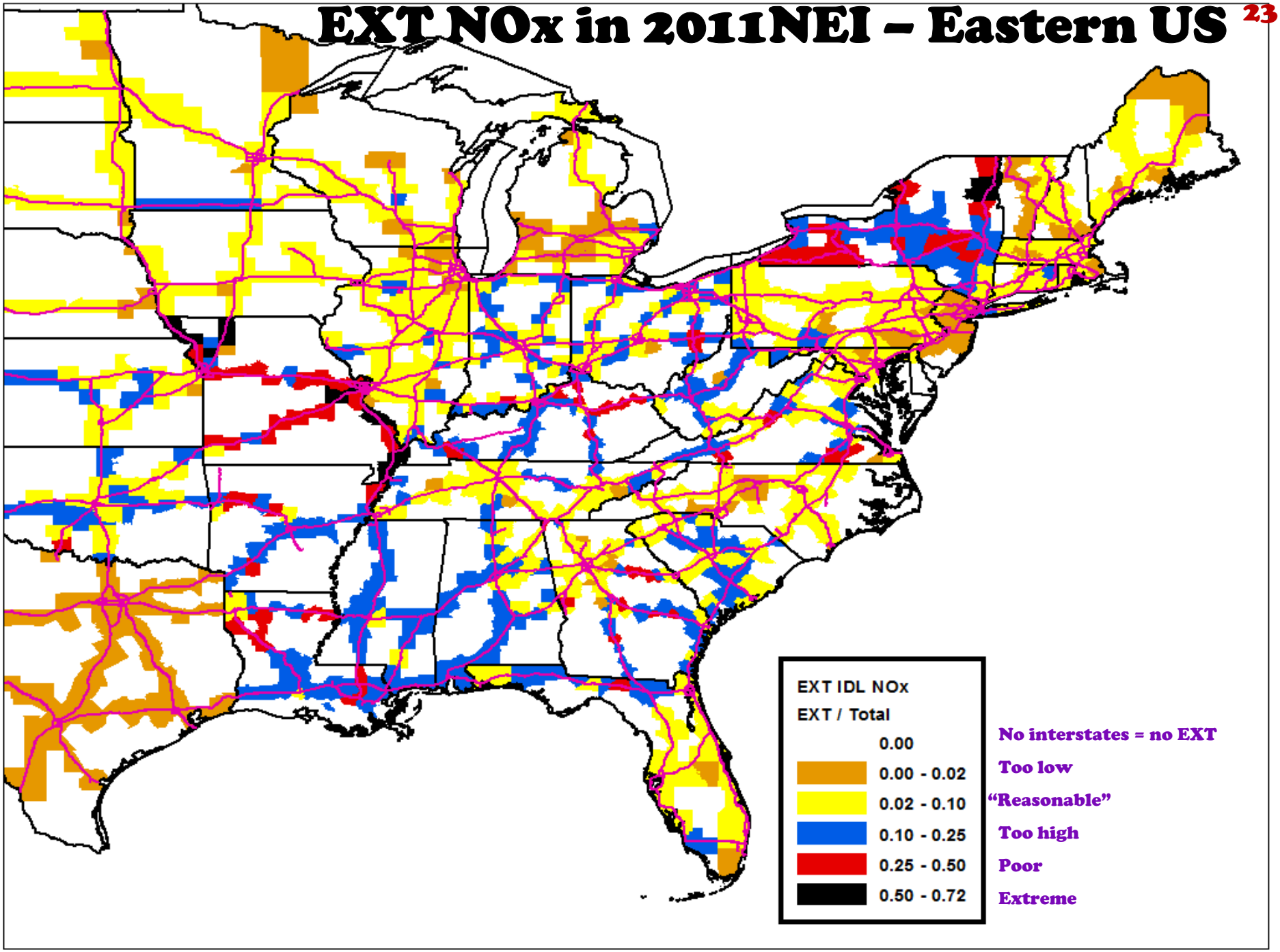
Many states have unusually low percentage for running exhaust (<50%) along interstates.

Fractional EXT NOx in 2011NEI



-- SMOKE-MOVES has greatly changed EXT spatial patterns;
-- Many states have unusually high EXT percentage (>25%) along interstates.

EXT NOx in 2011NEI – Eastern US



Summary on Emission Processes Region-wide

- SMOKE-MOVES has changed spatial pattern of EXT
- EXT in some states makes up greater than 25% of total NOx along the interstates
- Running exhaust (EXH) in some states makes up less than 50% of total NOx along the interstates
- Breakdown of EXT and EXH have been reversed in many counties

Presentation Outline

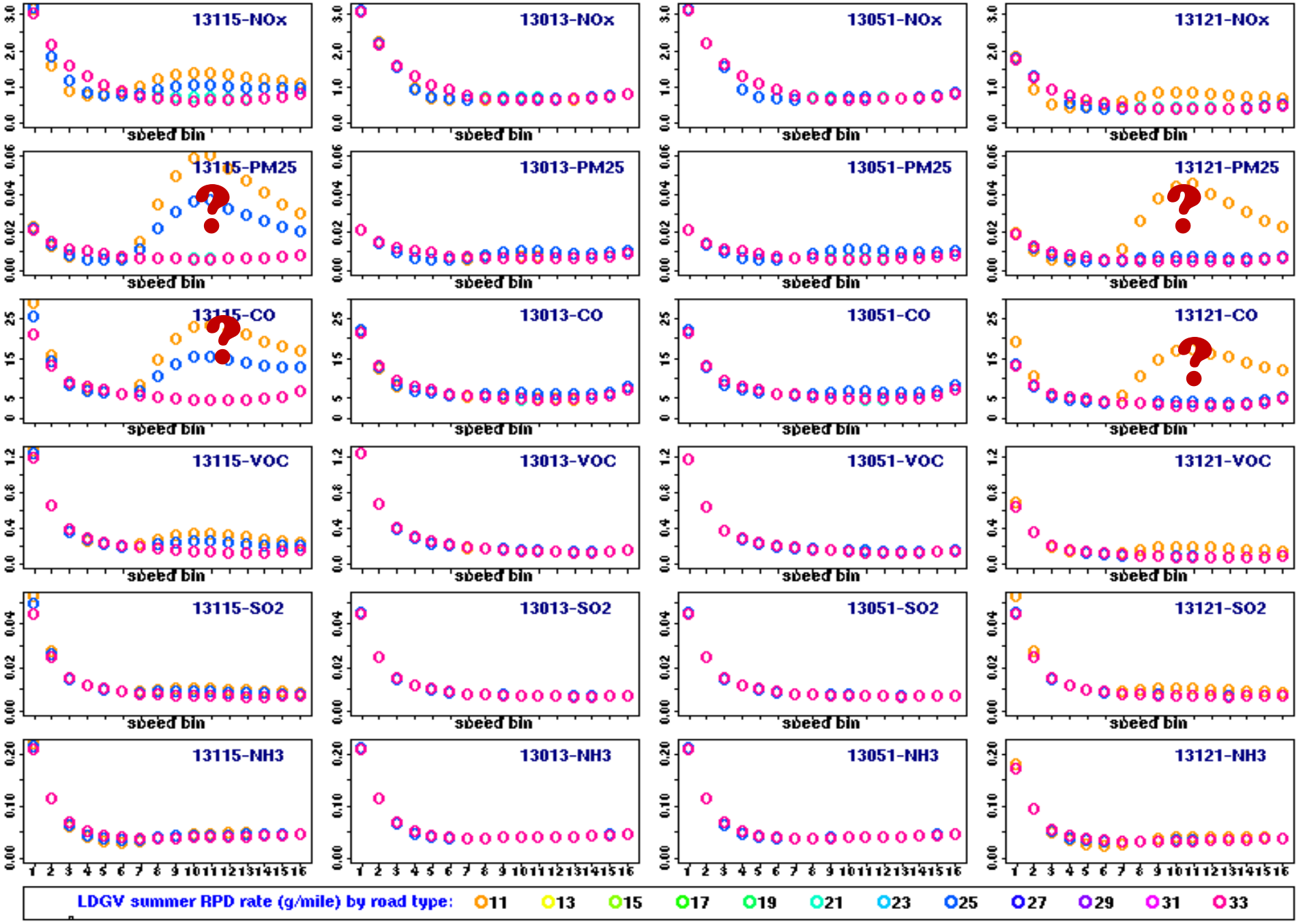
- Extended Idling (EXT)
- MOVES Version
- MOVES Emission Processes
- Effects of Ramp Fraction

A sensitivity study on the effect of ramp fraction

Motivation

- GA found odd profiles of emission rates in two of its four representative counties
- Ramp fraction was identified by EPA as the cause
- How does ramp fraction effect emissions?
- Current SMOKE-MOVES cannot simulate ramp effects (importing of ramp fraction has been disabled)

RPD EXH rates by road types for GA's representative counties (T=90F)



Approach

- "Turn on" RAMP in RunSpec generator (i.e., one of the three perl scripts in SMOKE-MOVES)
- In RepCounty.in, add a variable "RAMP" and associate it with a file path pointing to an input file "rampfraction.csv" with desired ramp fractions
- The minor changes allow SMOKE-MOVES to automate generation of desired ramp fraction inputs in all importing xml files for use in MOVES
- Conduct a series of MOVES sensitivity runs of varying ramp fractions for one county
- Analyze emission rates tabulated in SMOKE-MOVES lookup tables

MOVES Defaults

Default ramp fractions in roadtype table of movesdb20121030

roadTypeID	roadDesc	rampFraction
1	Off-Network	0
2	Rural Restricted Access	0.08
3	Rural Unrestricted Access	0
4	Urban Restricted Access	0.08
5	Urban Unrestricted Access	0

According to MOVES, only roadID 2 and 4 (restricted roads) have ramp fractions of 8 percent; Unrestricted road types have no ramp

Sensitivity Runs

Range of ramp fraction in the analysis

Sensitivity Run	roadTypeID	rampFraction
Trial-1	2	0.00
	4	0.00
Trial-2	2	0.08
	4	0.08
Trial-3	2	0.20
	4	0.20
Trial-4	2	0.40
	4	0.40
Trial-5	2	0.60
	4	0.60
Trial-6	2	0.80
	4	0.80

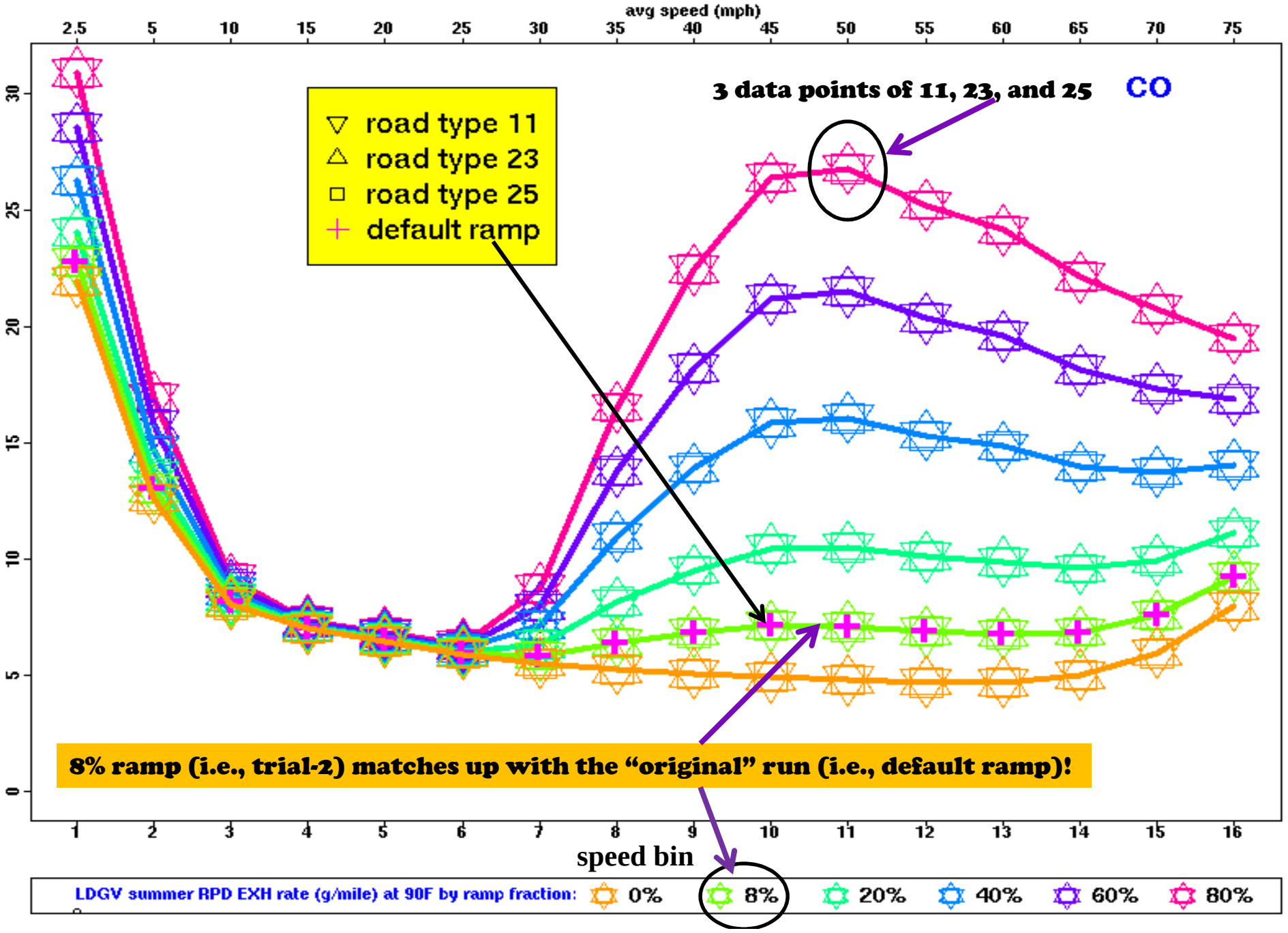
The 6 sensitivity runs were analyzed along with the "original" run which provided no ramp

Road Type Mapping

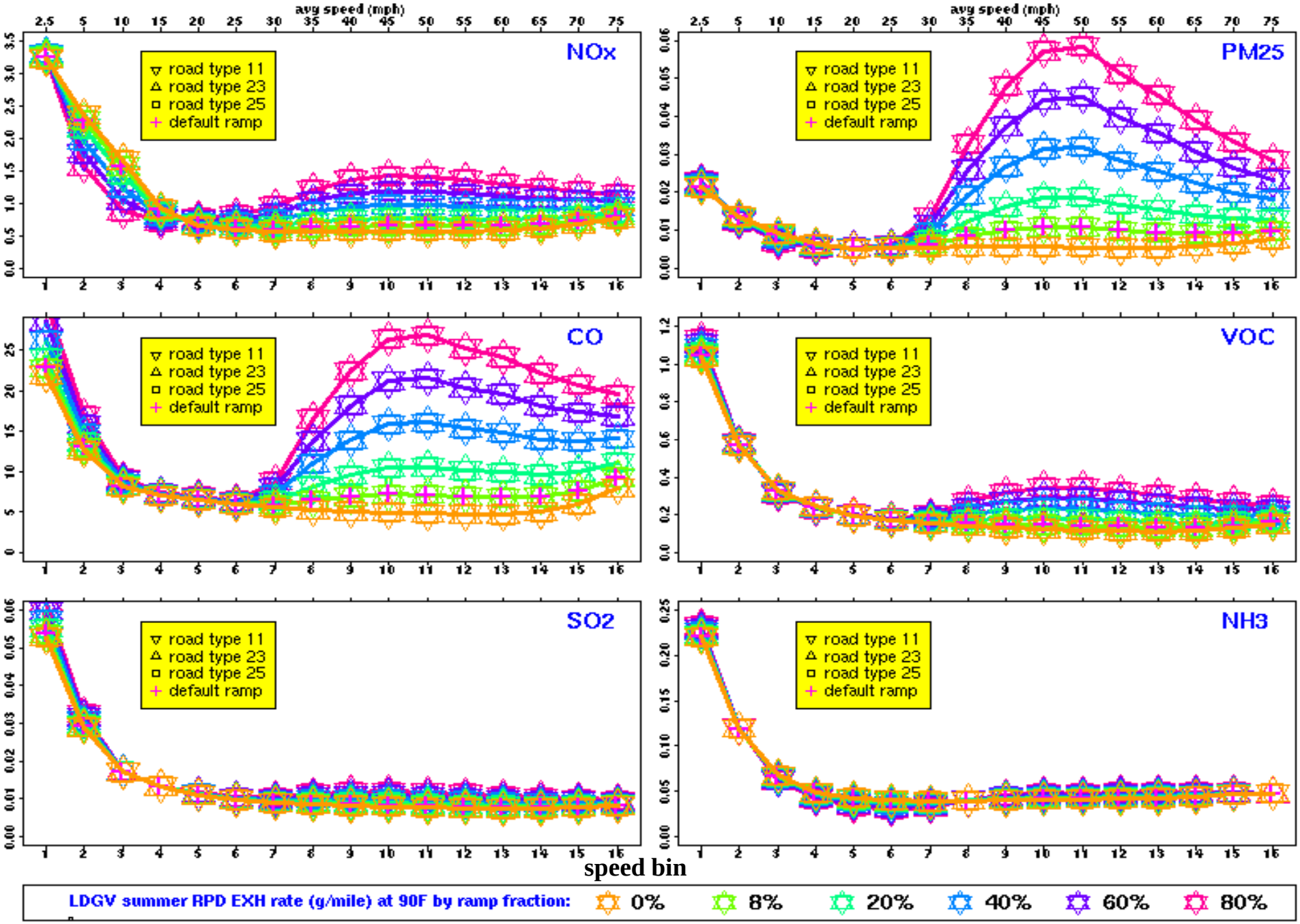
MOVESRoadID	MOVESRoadType	SCCRoadTypeID	SCCRoadTypeDesc
1	Off-Network	00	Off-Network
2	Rural Restricted Access	11	Rural Interstate
3	Rural Unrestricted Access	13	Rural Principal Arterial
	Rural Unrestricted Access	15	Rural Minor Arterial
	Rural Unrestricted Access	17	Rural Major Collector
	Rural Unrestricted Access	19	Rural Minor Collector
	Rural Unrestricted Access	21	Rural Local
4	Urban Restricted Access	23	Urban Interstate
	Urban Restricted Access	25	Urban Freeway/Expressway
5	Urban Unrestricted Access	27	Urban Principal Arterial
	Urban Unrestricted Access	29	Urban Minor Arterial
	Urban Unrestricted Access	31	Urban Collector
	Urban Unrestricted Access	33	Urban Local

Only roadtype 11, 23, and 25 are expected to be affected

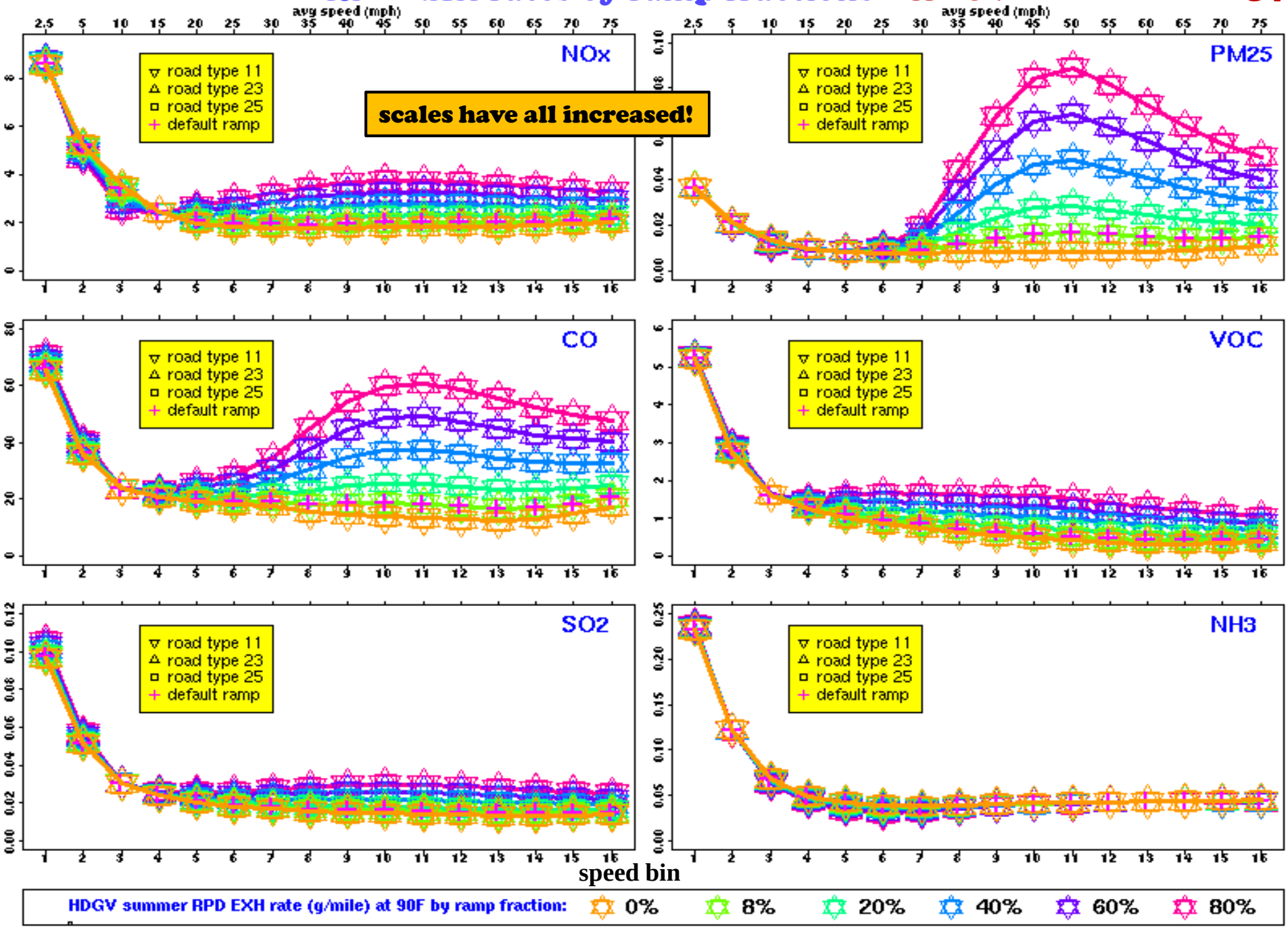
RPD EXH CO rates by ramp fractions – LDGV



RPD EXH rates by ramp fractions – LDGV



RPD EXH rates by ramp fractions – HDGV



Summary on Ramp Sensitivity

- SMOKE-MOVES has been revised to simulate ramp effects
- If ramp inputs are not supplied, MOVES uses default fraction of 8%
- Roadtype 2 and 4 have identical rates if same fraction is used
- Resolution of road type can be increased by providing different ramp fractions for various road types
- Higher fractions yield higher emissions for all pollutants
- Pollutant-wise, PM2.5 is the most sensitive to ramp fraction, followed by CO, NOx, VOC, SO2, and NH3 (in that order)
- Different source types are affected differently (ex, HDGV > LDGV)
- If local data is available (from state DOT/MPO), states are encouraged to supply ramp fraction to adjust defaults
- Concepts are similar, be it SMOKE-MOVES or MOVES

  Caution: representative county approach in SMOKE-MOVES will unilaterally apply the same ramp fraction for all group counties
- To save the environment, an optimal speed of 10 - 25 mph is recommended when approaching ramp ☺