

Effects of Vehicle Speeds on Criteria Pollutants Emissions

**Jin-Sheng Lin, Kristen Stumpf,
Sonya Lewis-Cheatham, Mike Kiss**
Virginia Department of Environmental Quality

**MARAMA MOVES Workgroup conference call
January 29, 2013**

Background

- **Vehicle speed is considered an important factor affecting emissions**
- **Constant speed is often assumed in SMOKE-MOVES modeling framework**
- **Effects of speed are unknown and rarely explored**

MOVES Speed Bins

Speed Bin	Average (mph)	Ranges
1	2.5	speed < 2.5
2	5	2.5 ≤ speed < 7.5
3	10	7.5 ≤ speed < 12.5
4	15	12.5 ≤ speed < 17.5
5	20	17.5 ≤ speed < 22.5
6	25	22.5 ≤ speed < 27.5
7	30	27.5 ≤ speed < 32.5
8	35	32.5 ≤ speed < 37.5
9	40	37.5 ≤ speed < 42.5
10	45	42.5 ≤ speed < 47.5
11	50	47.5 ≤ speed < 52.5
12	55	52.5 ≤ speed < 57.5
13	60	57.5 ≤ speed < 62.5
14	65	62.5 ≤ speed < 67.5
15	70	67.5 ≤ speed < 72.5
16	75	72.5 ≤ speed

MOVES defines 16 speed bins of an increment of 5 mph except the first bin

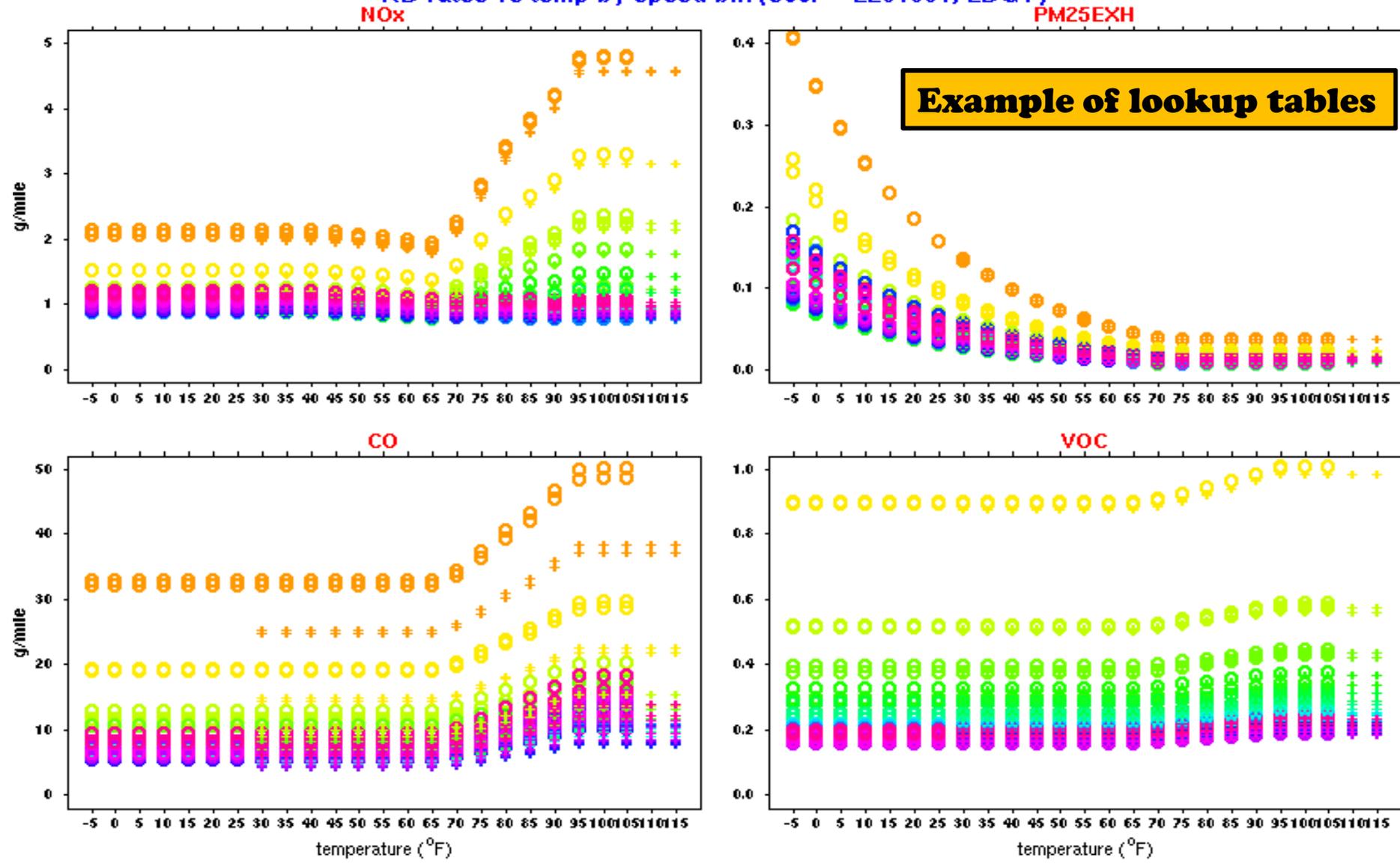
In MOVES, an average speed is re-allocated into 16 speed bins by fractions of traveled time (as **VHT, vehicle hour traveled) (see section 3.6.4 Creating a Distribution from a Single Average Speed in MOVES Technical Guidance).**

SMOKE-MOVES Practice

- **An inventory of constant speed (by county/SCC) is fed into SMOKE in conjunction with VMT of the same resolution**
ex. LDGV at 50mph in Fairfax (51059) on urban freeway/expressway (2201001250)
- **Constant speed --> rates (g/mile) in lookup tables --> multiplied by temporalized VMT --> emissions by hours --> air quality models**
- **A feature accounting hourly speed profiles was introduced in SMOKE after initial release of SMOKE-MOVES**
- **OTAQ released a database of nation-wide hourly speed profiles which supposedly vary by county/SCC and by weekday/weekend**

- **Inventory of constant speed is used as a default.**
- **Constant speeds are usually supplied by states from running MOVES in inventory mode.**
- **Hourly speed profiles serve as an additional input which would overwrite the default.**
- **Constant speed inventory must still always exist even if hourly speed profiles are supplied.**

RD rates vs temp by speed bin (scc7 = 2201001, LDGV)



winter speed bin (avg mph)	○ 2.5	○ 5	○ 10	○ 15	○ 20	○ 25	○ 30	○ 35	○ 40	○ 45	○ 50	○ 55	○ 60	○ 65	○ 70	○ 75
summer speed bin (avg mph)	+ 2.5	+ 5	+ 10	+ 15	+ 20	+ 25	+ 30	+ 35	+ 40	+ 45	+ 50	+ 55	+ 60	+ 65	+ 70	+ 75

- LDGV releases more NOx and CO at higher temperatures, but emits more PM2.5 at lower temperatures.
- **The lower the speed an LDGV travels, the higher the emissions for all pollutants.**
- Winter and summer fuels affect CO only. Summer fuel has lower CO emission rates than winter fuel.

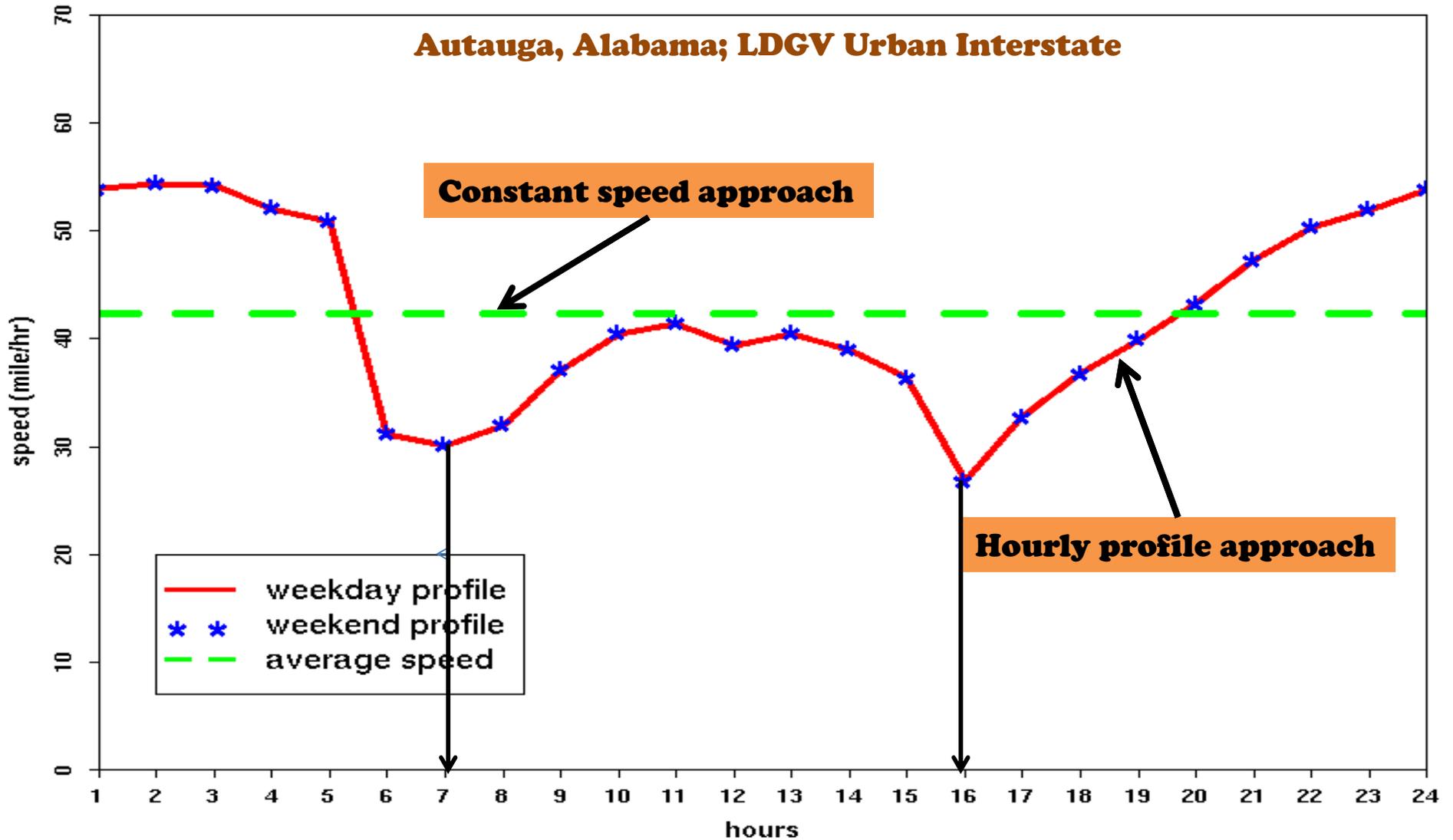
OTAQ Speed Database

- **24-hour speed profiles by county/SCC and by weekday/weekend**
- **A great majority of “profiles” do not vary by hour (i.e. a horizontal straight line of constant speed)**
- **None of the profiles are varied by weekday/weekend**
- **Data appears dated and not in line with average speeds obtained from states MOVES runs in inventory mode**

-- Acting as an overwrite, OTAQ speed profiles should not be used directly without review, else state-supplied inventory of average speeds will be overwritten.

Example OTAQ speed database

hourly speed profile for 01001, 2201001230



-- Morning/evening rush hours show decline in traveling speed; weekday/weekend profiles are identical (which is unrealistic);
-- Average speed = (speed at hr1 + speed at hr2 + + speed hr 24) / 24.

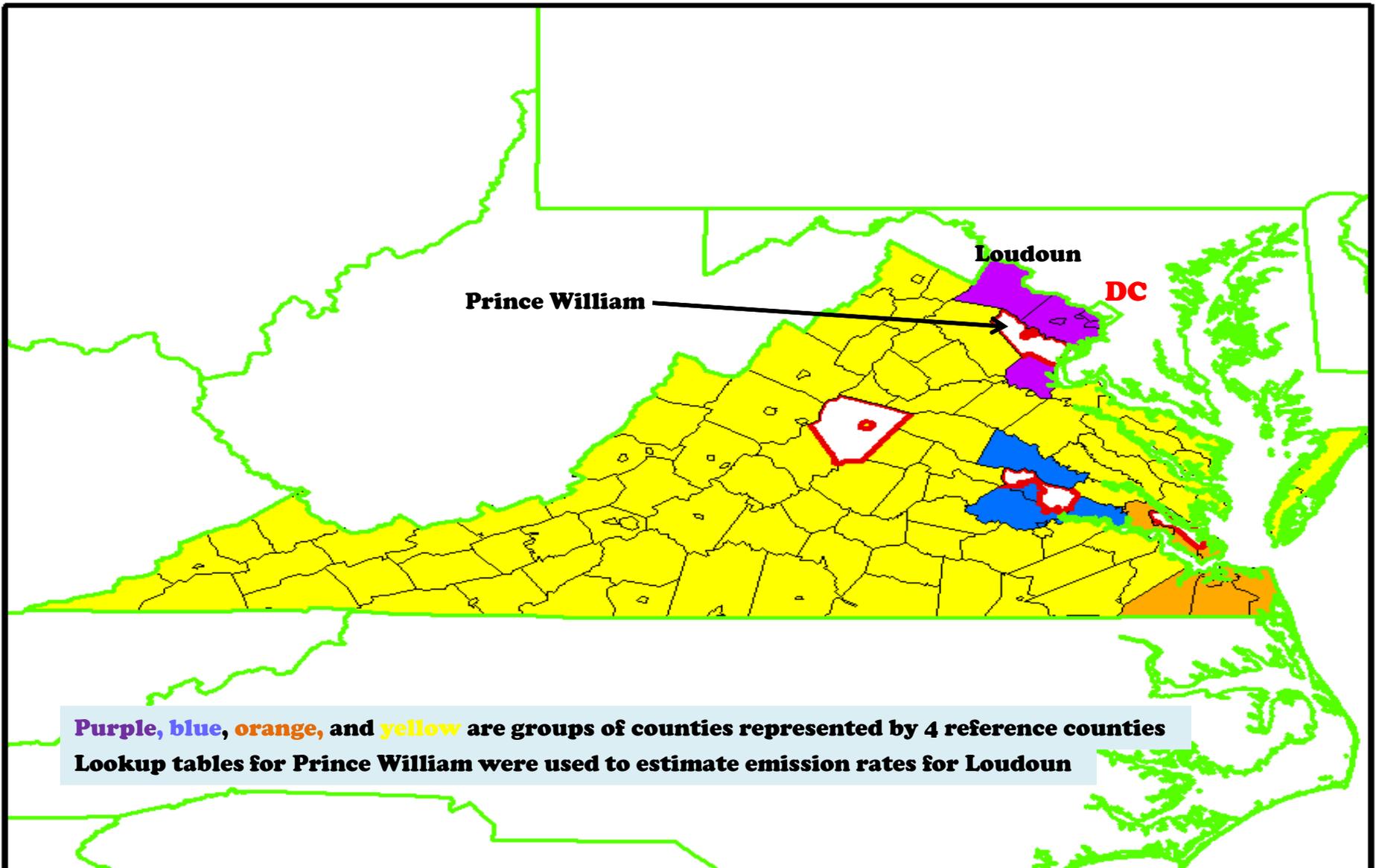
Sensitivity Runs

Sensitivity batch	Speed range (mph)	Intended Effects
(1) one county, one SCC	constant speed (from 10 to 80)	different speeds on emissions
(2) one county, one SCC	hourly profile (from 10 to 80)	constant speed versus hourly profile
(3) one county, group SCCs	constant speed (from 10 to 80)	different speeds on emissions
(4) one county, group SCCs	hourly profile (from 10 to 80)	constant speed versus hourly profile

- County, SCC, and group of SCCs is chosen to be 51107 (**Loudoun**), 2201001270 (**LDGV, urban principal arterial**), and 2201001 (**LDGV on all roads**), respectively.
- Constant speed does not vary by hour, whereas an hourly profile has 24 distinct speeds.
- Hourly profile approach uses the generic (hypothetical) profile of 01001, 2201001230 (shown in previous page) as a basis to adjust/scale a speed in speed range so that resulting profile has similar shape with an average equal to that speed.

Out of 156 SCCs, 144 are associated with “onroad”

Virginia Representative County



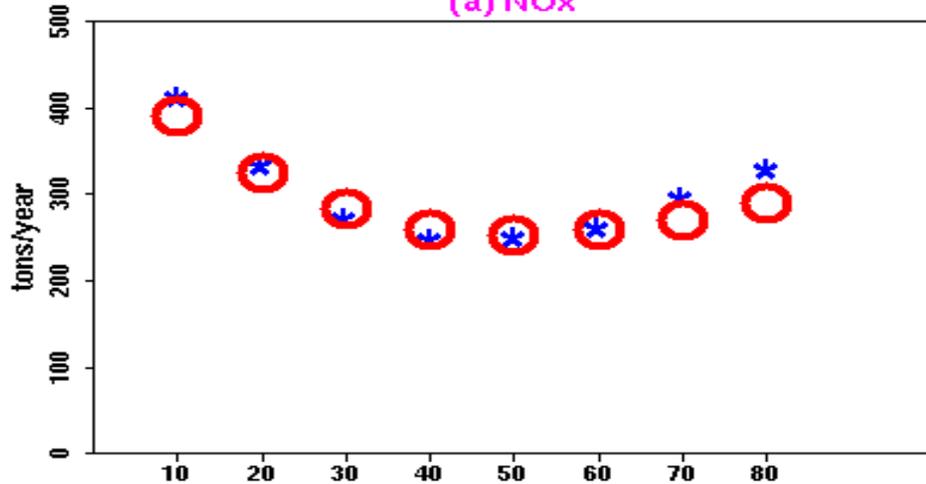
Purple, blue, orange, and yellow are groups of counties represented by 4 reference counties
Lookup tables for Prince William were used to estimate emission rates for Loudoun

- VA SMOKE-MOVES modeling used four representative counties (shown in white with red boundary).
- Loudoun is one of the 10 inventory group counties represented by Prince William.

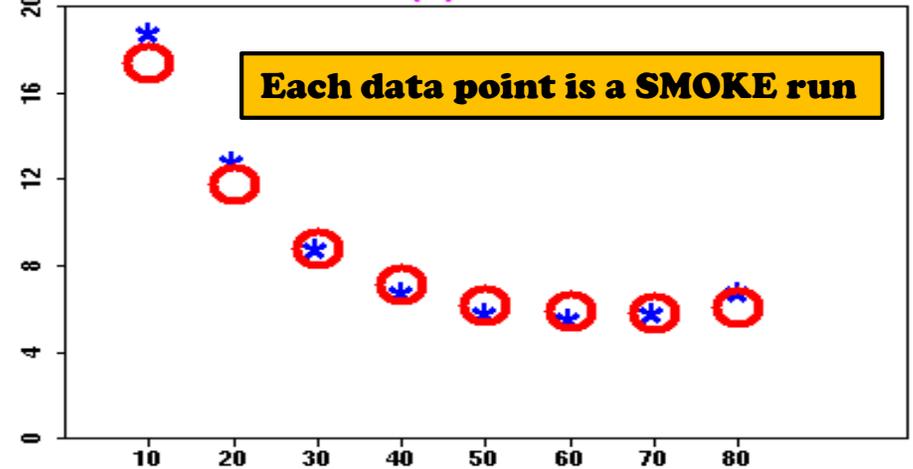
Sensitivity – one county, one SCC

criteria pollutants emissions by vehicle speed (FIPS=51107, SCC=2201001270)

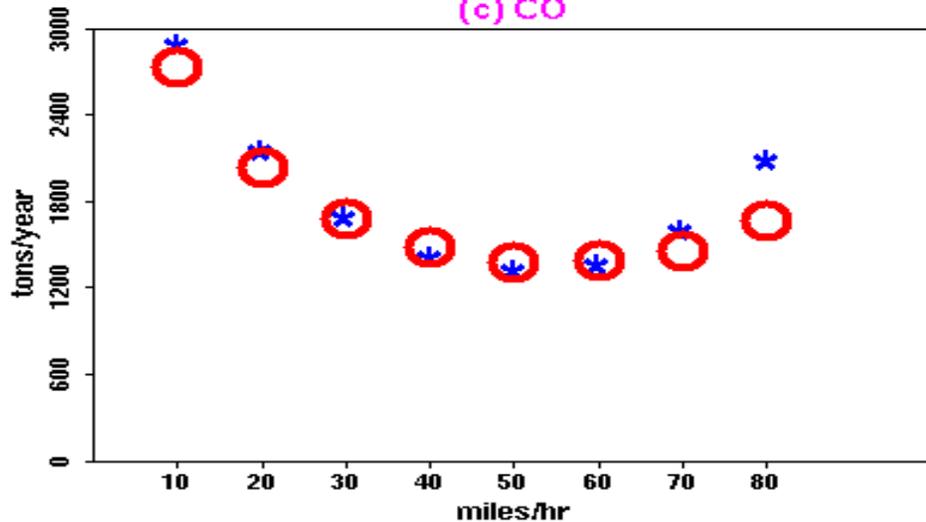
(a) NOx



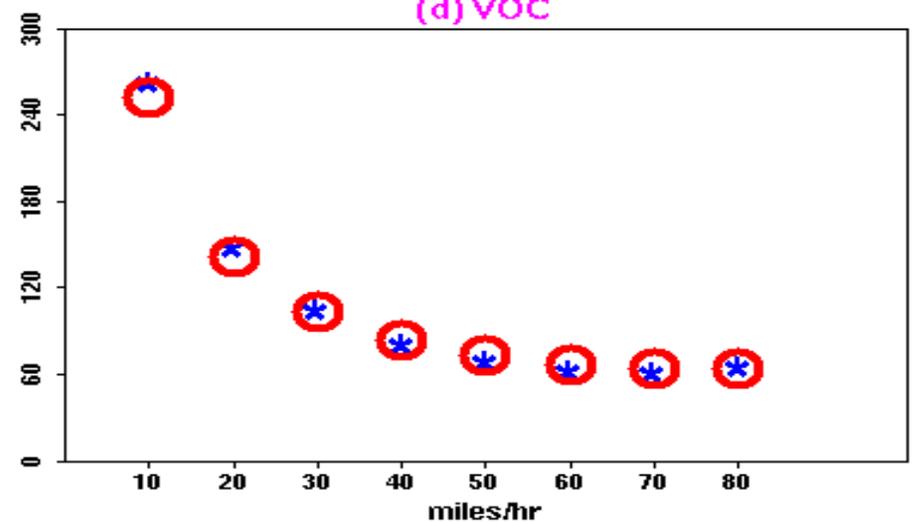
(b) PM25



(c) CO



(d) VOC



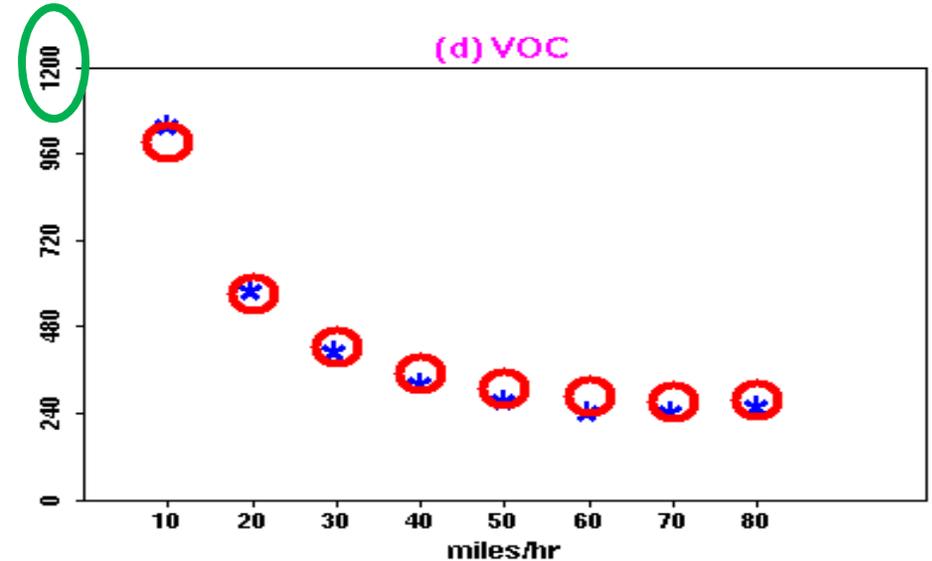
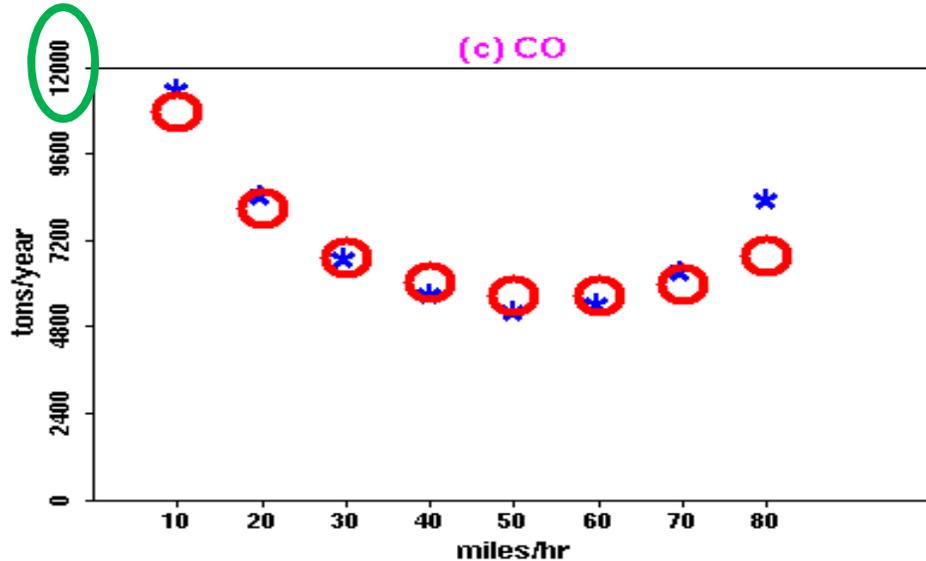
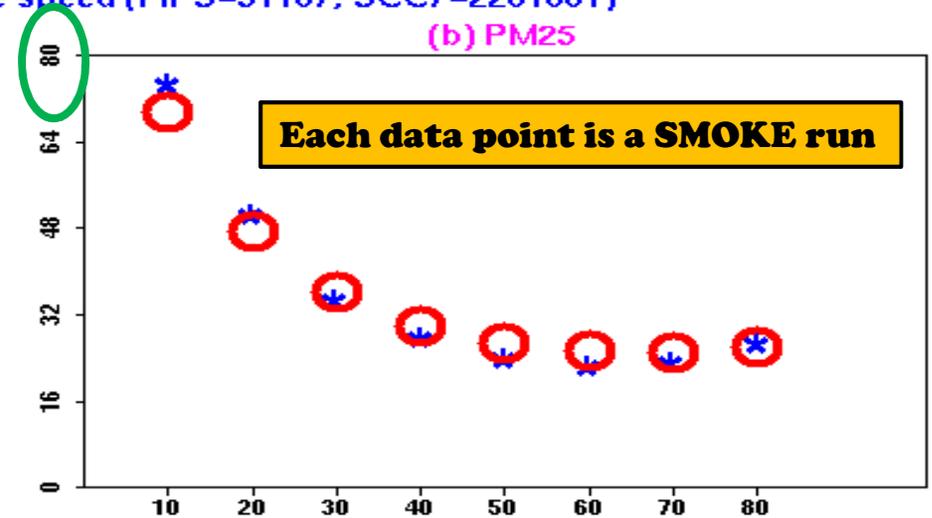
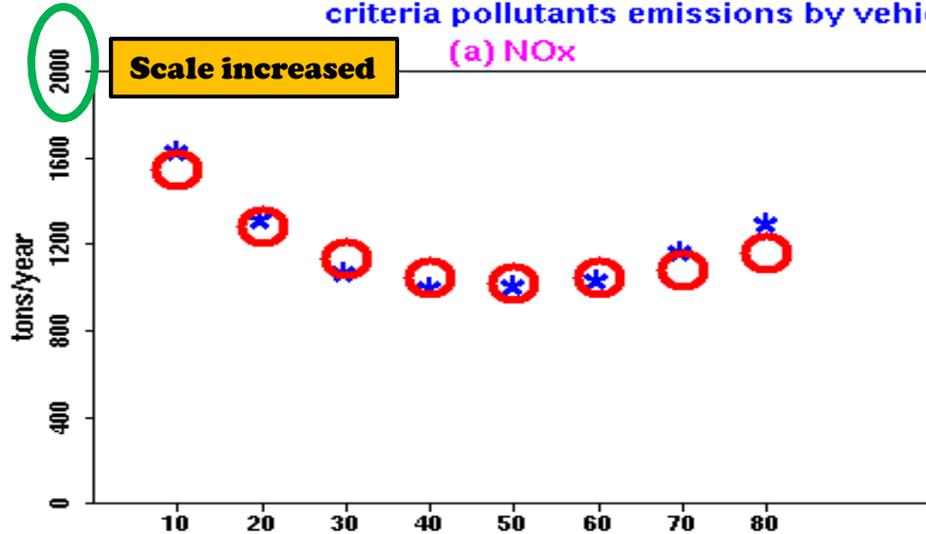
* constant speed over 24 hours

○ hourly variable speed profile with "equivalent" average of inventory constant speed

- In general, emissions decrease for all pollutants as speed increases. Emissions are high both at very low and at very high speeds.
- Constant speed approach and hourly profile approach generate roughly similar emissions annually.
- At very low and very high speeds, constant speed approach overestimates emissions in comparison to hourly profile approach.

Sensitivity – one county, group of SCC

criteria pollutants emissions by vehicle speed (FIPS=51107, SCC7=2201001)



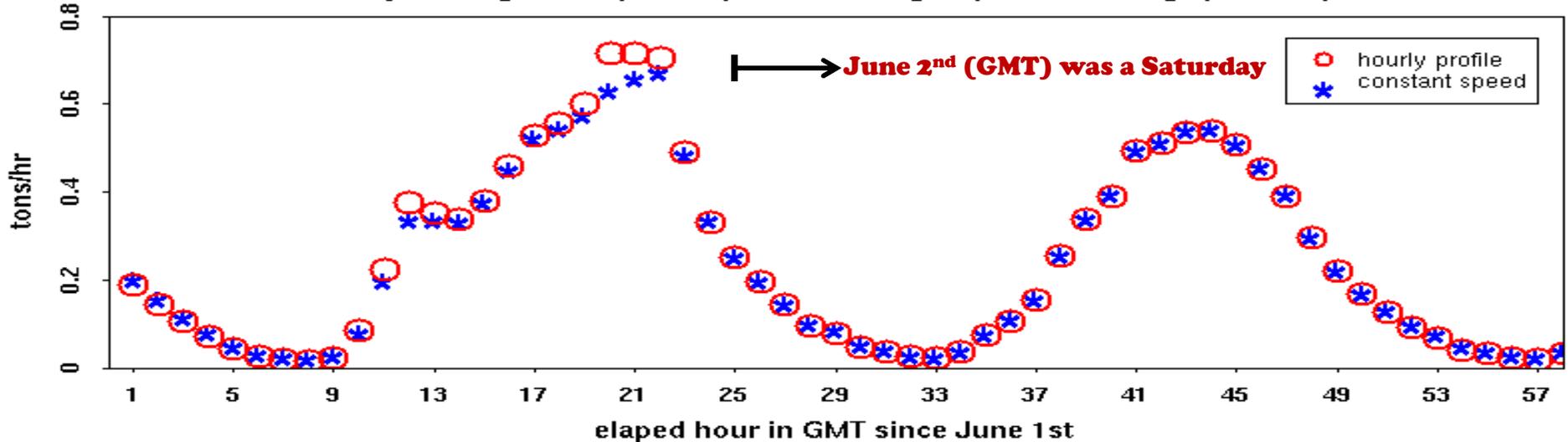
* constant speed over 24 hours

○ hourly variable speed profile with "equivalent" average of inventory constant speed

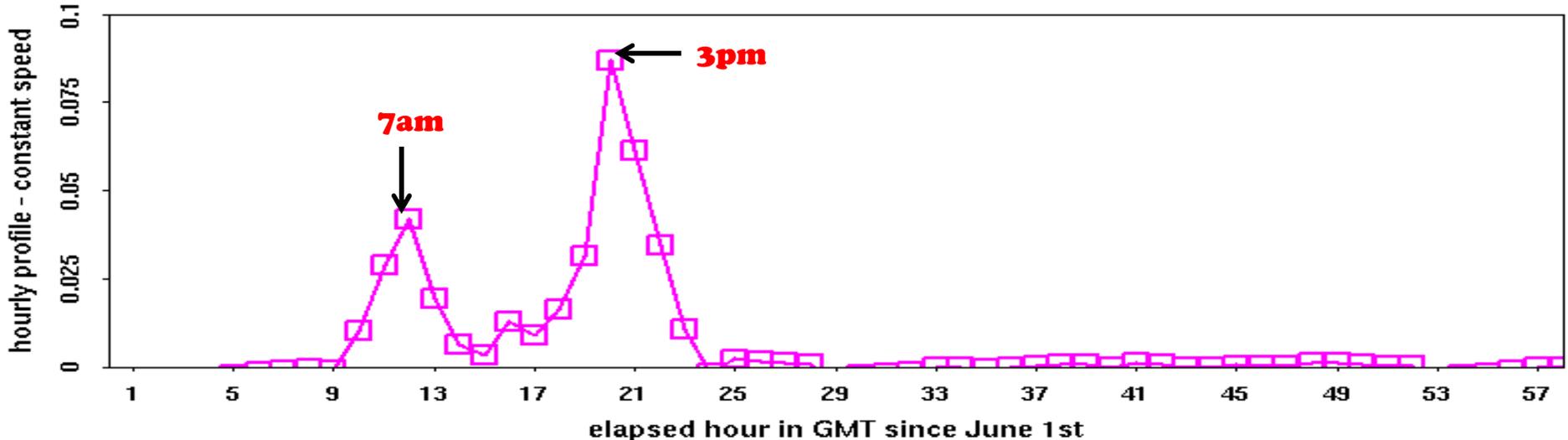
- Changing speed in a group of SCC increases emissions, exacerbating the differences and compounding the problem.
- Constant speed approach and hourly profile approach once again generate roughly similar emissions annually.
- However, detailed resolutions in space and time may tell a different story.

Emissions at a Grid Cell

hourly CO at grid cell (116, 81) – Loudoun, group of SCCs, avg spd=50 mph



hourly CO differences between two approaches at grid cell (116, 81)



- Emissions for both approaches show diurnal oscillation due to the fact that VMT is temporalized.
- Constant speed always pulls the same rate in lookup tables; therefore, it fails to capture emissions peaks at the rush hours.
- CO differences between the two approaches occurred at rush hours and are consistent with speed profiles used in the sensitivity.

Concluding Remarks

- **Vehicles traveling at lower speeds emit more pollutants**
- **Constant speed practice cannot capture emission peaks during morning and evening rush hours**
- **Accurately characterizing speed distribution (for all counties and all SCCs) will improve emission estimates**
- **Hourly profiles in SMOKE can be used to quantify effects of speed on pollutant emissions**