

UNDERSTANDING MOVES BY ANALYZING LOOKUP TABLES

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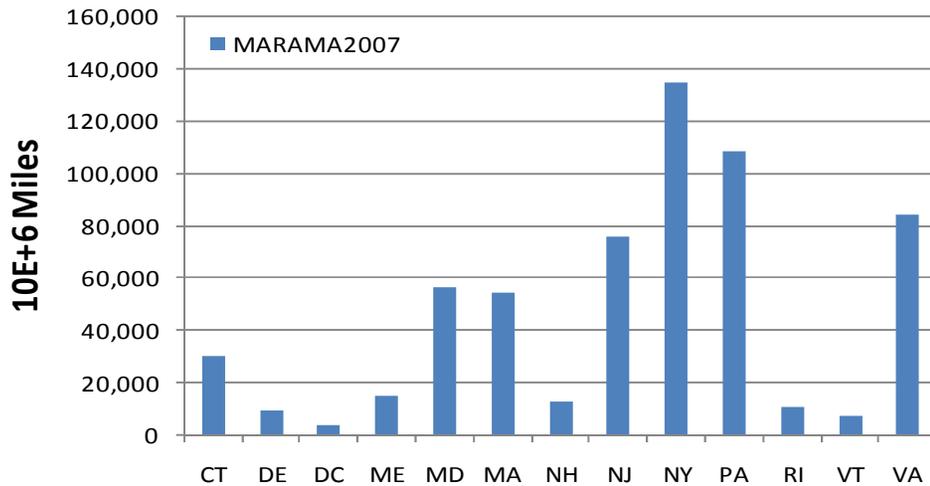
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Background

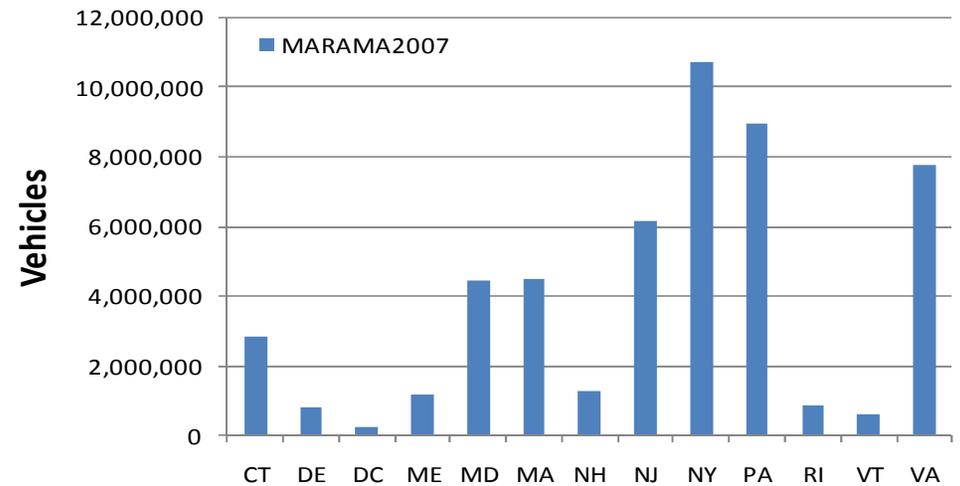
- MOVES can be run in two modes:
 - Inventory mode (county scale, monthly averaged T)
 - Emission rate mode (regional scale, hourly T)
- Emission rate mode generates lookup tables for three sectors:
 - Rate-per-distance (RPD) – in g/mile
 - Rate-per-vehicle (RPV) – in g/vehicle/hr
 - Rate-per-profile (RPP) – in g/vehicle/hr
- Rates are interpolated in SMOKE, multiplied by activities (VMT, VPOP) and summed to obtain hourly emissions for CMAQ
 - $RPD * VMT$ (followed by temporal) and $RPV/RPP * VPOP$, all in mass/hr

2007 Activity and Emission Totals by State (OTR)

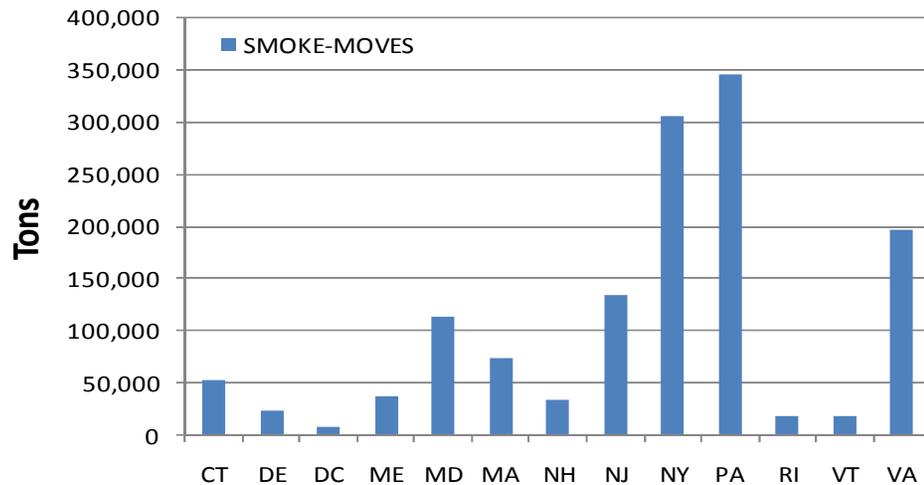
Mobile Source 2007 Annual VMT State Totals



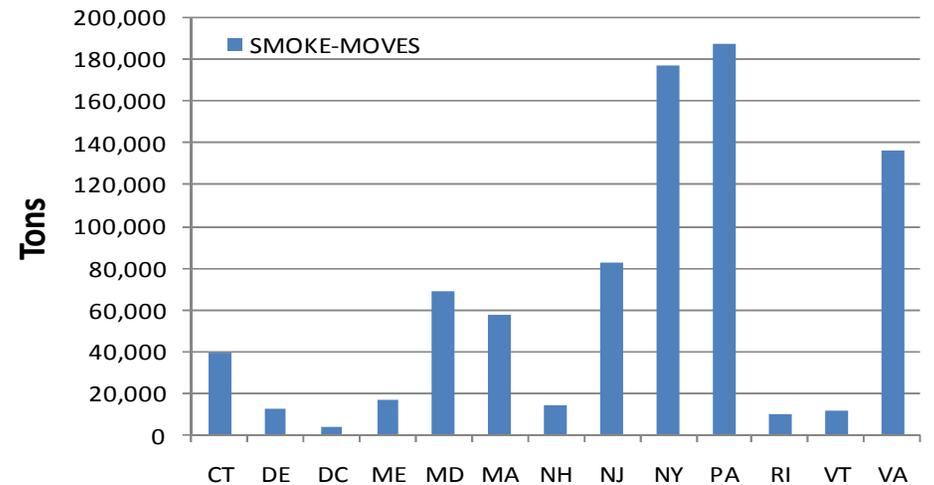
Mobile Source 2007 Annual VPOP State Totals



Mobile Source NOx State Totals, January - December 2007



Mobile Source VOC State Totals, January - December 2007



-- Virginia activity data and total annual emissions are the third highest among OTC states.

Lookup Tables

- Emission rates depend on many parameters
- RPD (g/mile) – function of (SCC, proc, speed bin, T, RH, pollutant, fuel month)
- RPV (g/vehicle/hr) – function of (SCC, proc, T, pollutant, weekday/weekend, hour, fuel month)
- RPP (g/vehicle/hr) – function of (SCC, proc, T, VOC, weekday/weekend, hour, fuel month)
- Tables contain tens of thousands of records
 - One fuel month -- RPD (~40K – 50K), RPV/RPP (~10K – 20K), more for finer resolutions

Approach

- SCC₁₀ is simplified to SCC₇
 - last digit (emission process) and second to last two digits (road type) are grouped together (but not ignored). Differences, if any, will show up in the analysis.
- Plot all parameters while keeping one parameter constant
- Focuses on exhaust (EXH) and evaporative (EVP) emissions (no brake or tire wear) in one representative county
- Because units are in rates, not absolute emissions, conclusions deduced from one representative county could be universal

Speed bin distribution

SCC7 vehicle types

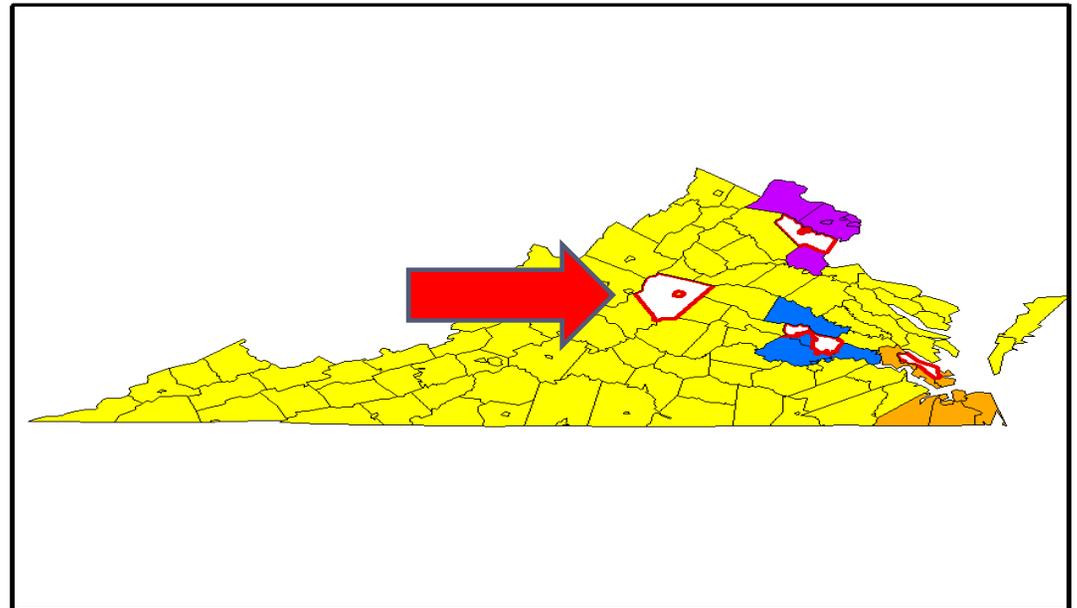
SCC7	Class
2201001	LDGV
2201020	LDGT1
2201040	LDGT2
2201070	HDGV
2201080	MC
2230001	LDDV
2230060	LDDT
2230071	2BHDDV
2230072	LHDDV
2230073	MHDDV
2230074	HHDDV
2230075	BUSES

Speed Bin	Avg.Speed (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

-- There are 12 SCC vehicles types and 16 speed bins.

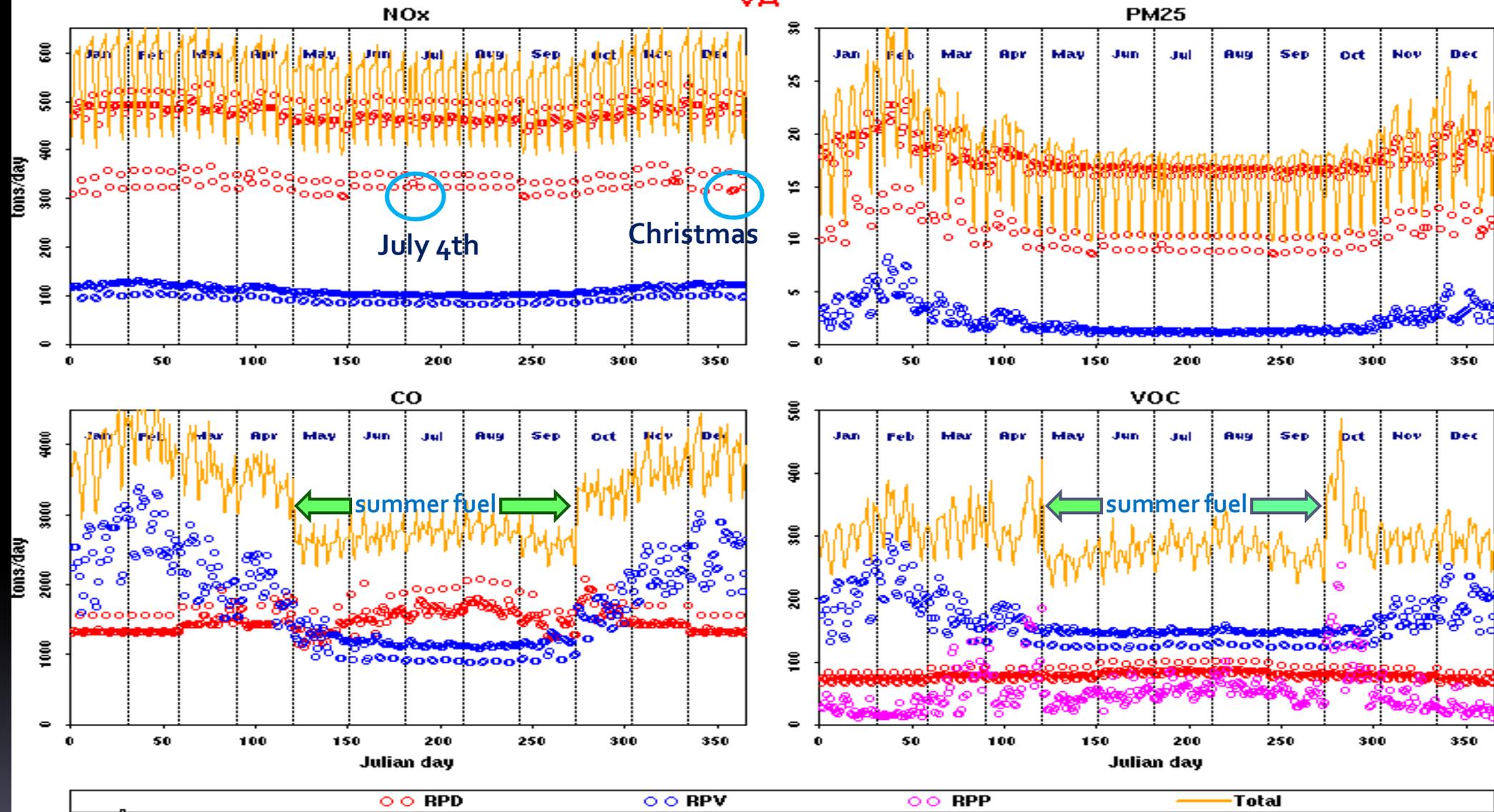
Representative County

- Albemarle, Virginia
- 2007 county localized data
- No missing road-types, state-wide early NLEV, no I/M program
- Represents 106 counties (in yellow)
- The most accurate post-processing script with all bug fixes was used (including fix for repeated rates across T bins) to generate “summed” lookup tables



Example – 2007 MOVES profiles for Virginia

VA

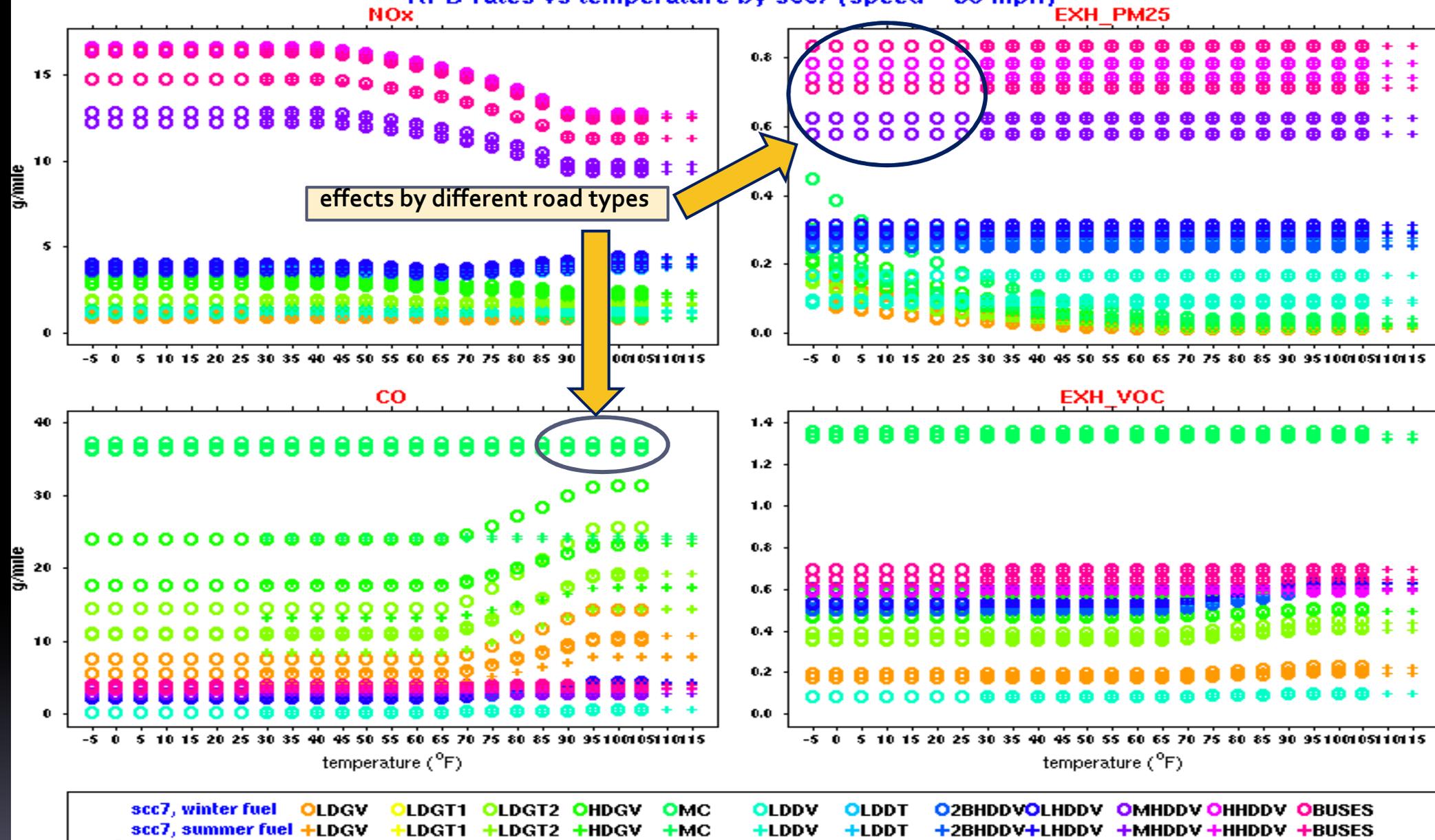


- For NOx and PM2.5, RPD dominates among the three sectors, accounting for >80% of the two pollutants.
- By contrast, for CO and VOCs, RPV is the dominating sector, whereas RPP is the least contributor to VOCs among the three.
- Usage of winter or summer fuel affects CO and VOCs, causing both to have sudden drop and jump in fuel transition months (May and October).
- Emission rates for CO and VOCs are higher with winter fuel than with summer fuel.

Rate-per-Distance (RPD)

- Emissions when vehicles are in motion

RPD rates vs temperature by scc7 (speed = 50 mph)

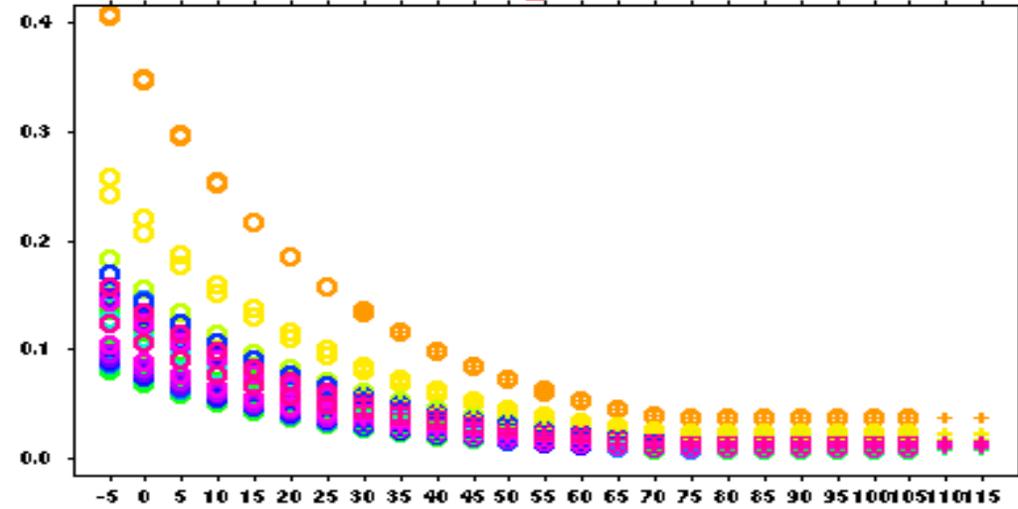
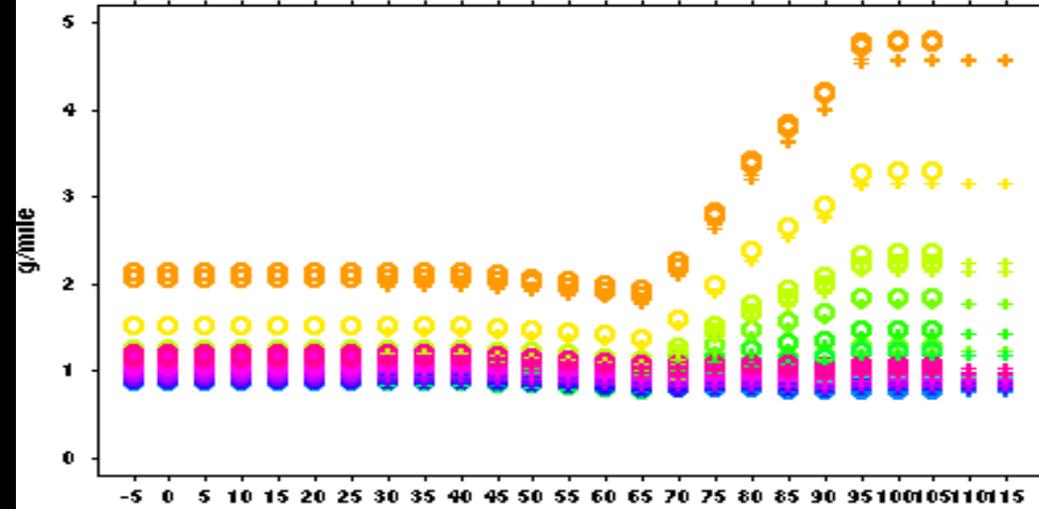


- Higher temperatures decrease NOx for buses and HDDV, while increasing CO for gasoline vehicles. Temperatures have little effect on EXH_VOCs.
- Only gasoline vehicles exhibit PM2.5 temperature dependence with higher PM2.5 at cold temperatures (≤ 72°F).
- Buses and diesel vehicles emit higher NOx and PM2.5 than gasoline vehicles.
- Winter and summer fuels affect CO only. Maximum CO rate using winter fuel is higher than maximum rate with summer fuel.

RPD rates vs temperature by speed bin (scc7 = 2201001, LDGV)

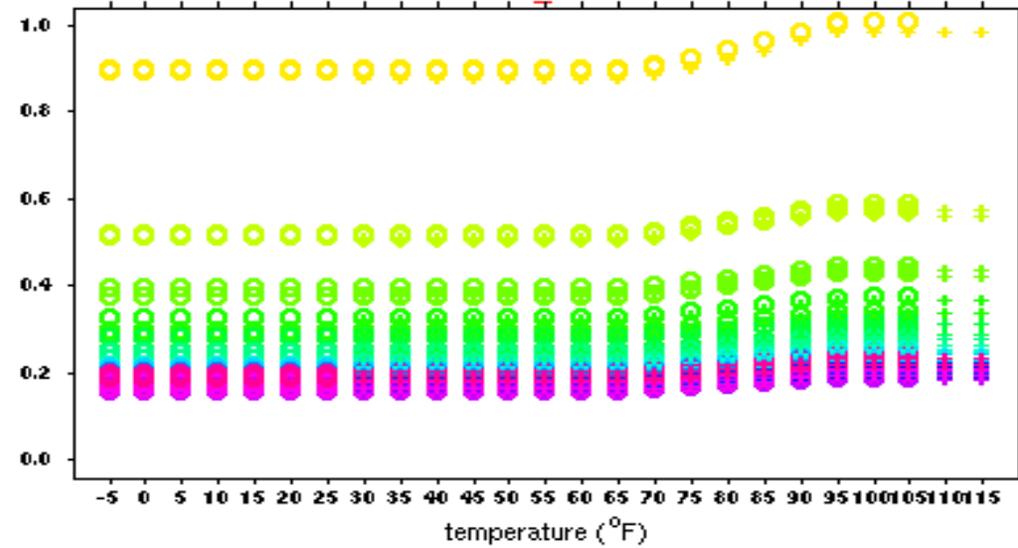
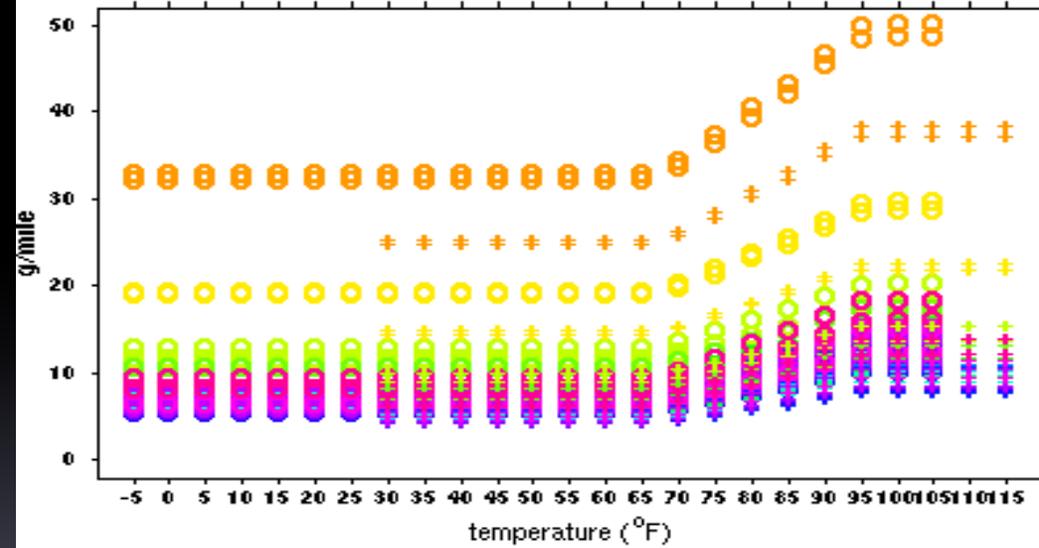
NOx

EXH_PM25



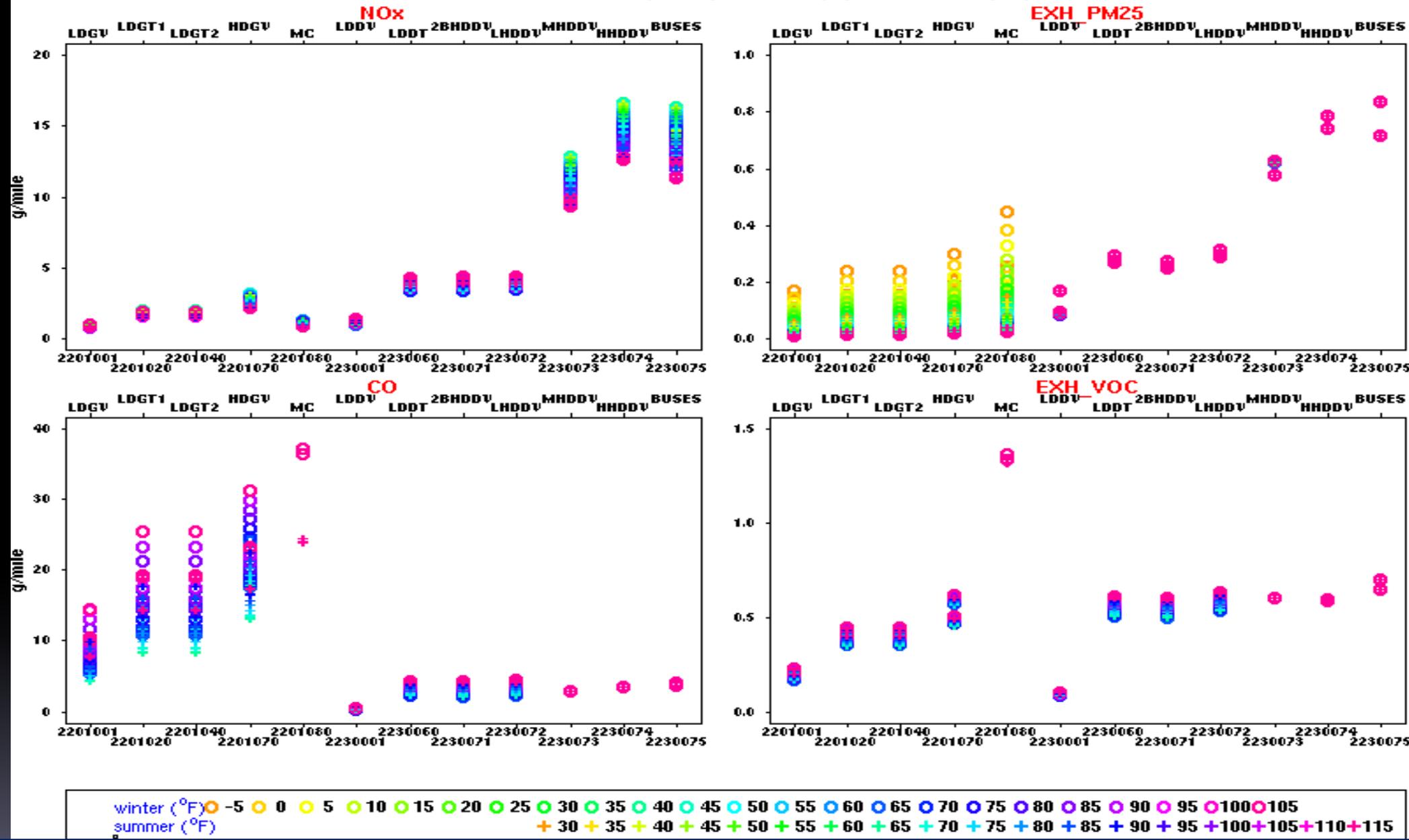
CO

EXH_VOC



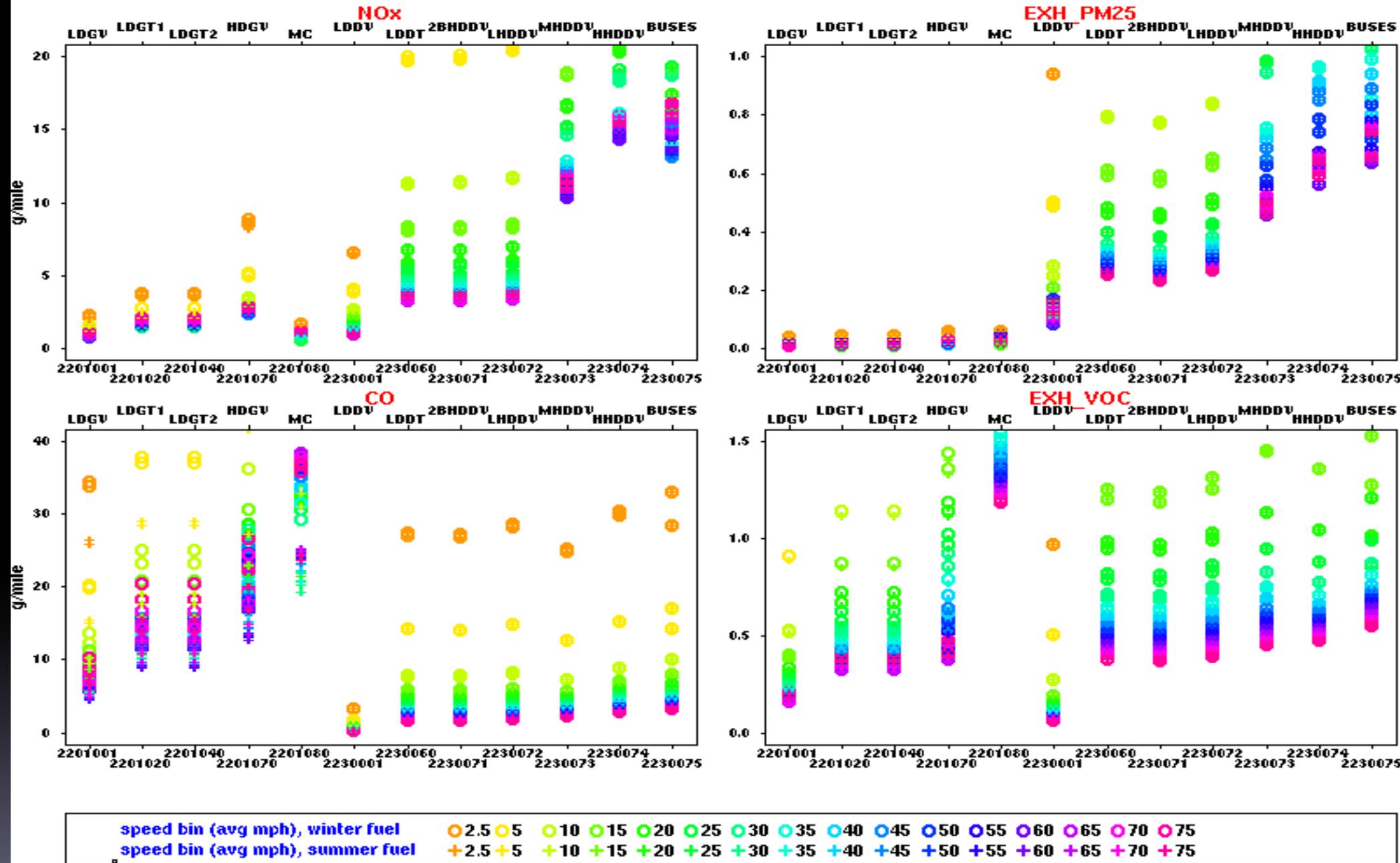
- LDGV releases more NOx and CO at higher temperatures, but emits more PM2.5 at lower temperatures.
- The lower the speed an LDGV travels, the higher the emissions for all pollutants.
- Winter and summer fuels affect CO only. Winter fuel has higher CO emission rates than summer fuel.

RPD rates vs scc7 by temperature (speed = 50 mph)



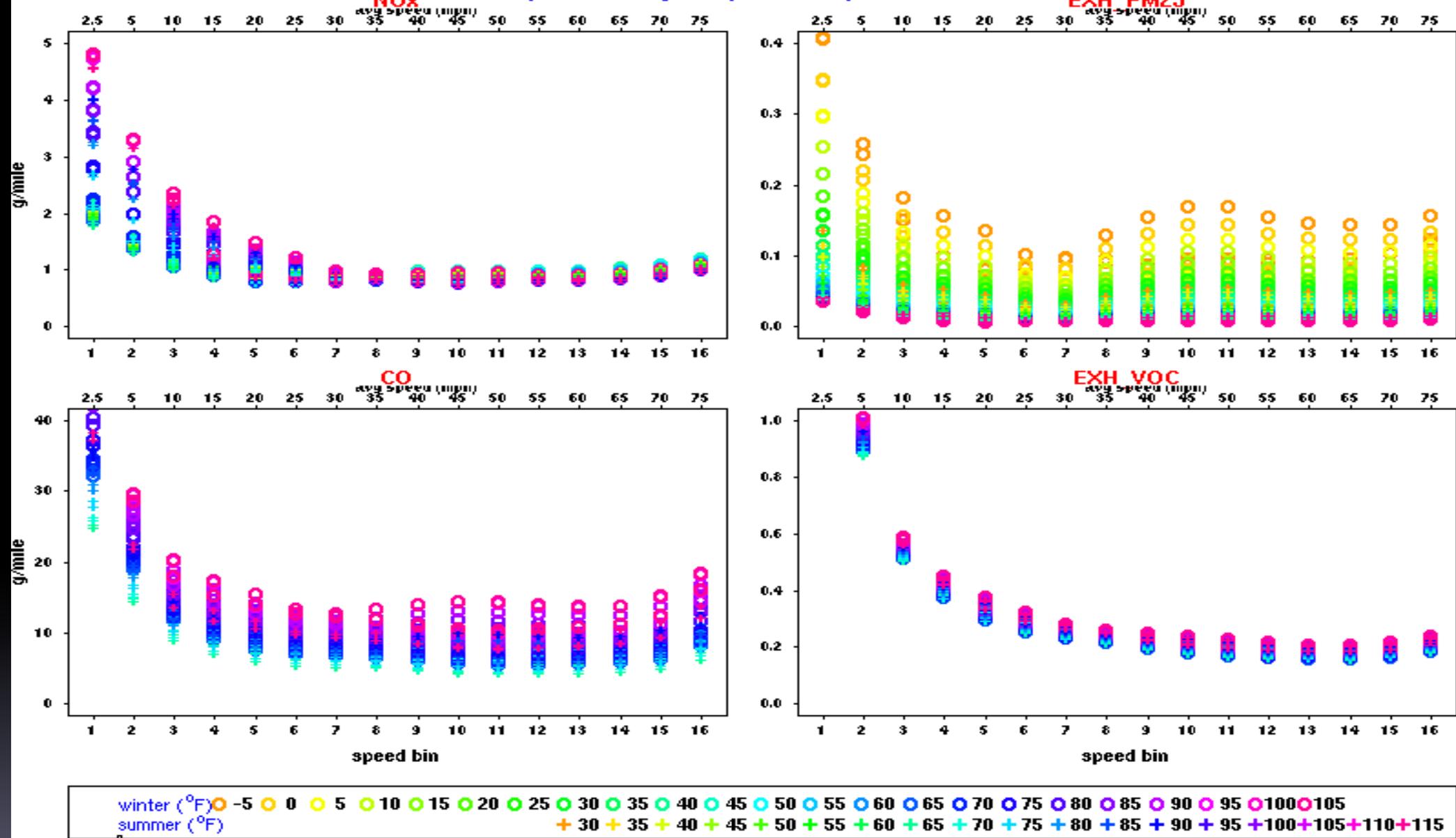
- Traveling at 50mph, buses and heavy/medium duty diesel vehicles emit more NOx and PM2.5 than other vehicles.
- Gasoline vehicles in general have higher CO emissions than other vehicles. Motorcycles emit highest CO and EXH_VOCs among all vehicles.
- Only gasoline vehicles exhibit temperature dependence, and the dependence is on PM2.5 and CO only.

RPD rates vs scc7 by speed bins (temperature = 70F)



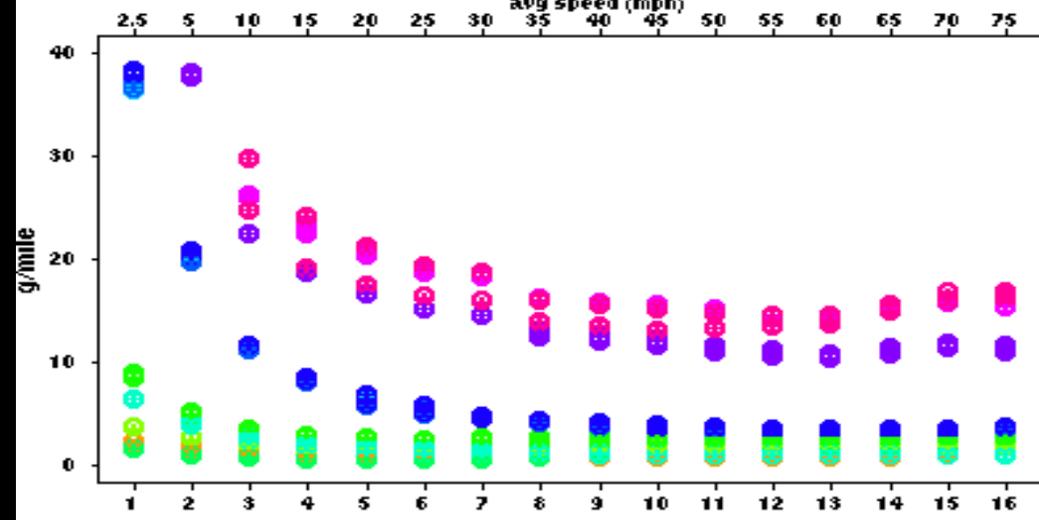
-- At 70F, all vehicles release comparable amount of pollutants, although gasoline vehicles and motorcycles have lowest PM2.5 emissions.
 -- Emissions are higher when vehicles travel at lower speeds.

RPD rates vs speed bin by temperature (scc7 = 2201001, LDGV)

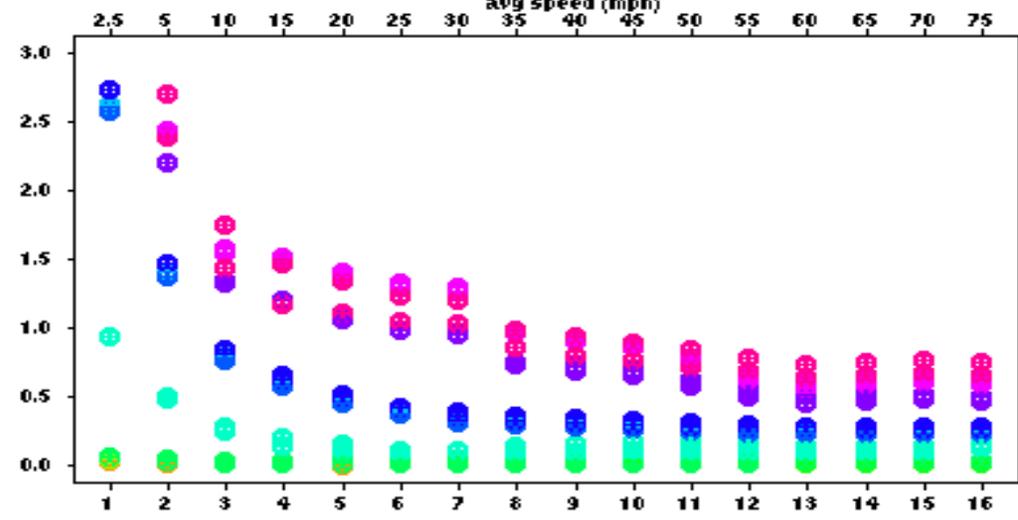


- For LDGV, lower speed in general emit more pollutants. The effect levels out as speed increases.
- The lower the temperatures, the higher the PM2.5 emissions.
- By contrast, effects of temperatures are much smaller for NOx and CO, and almost none for EXH_VOCs.

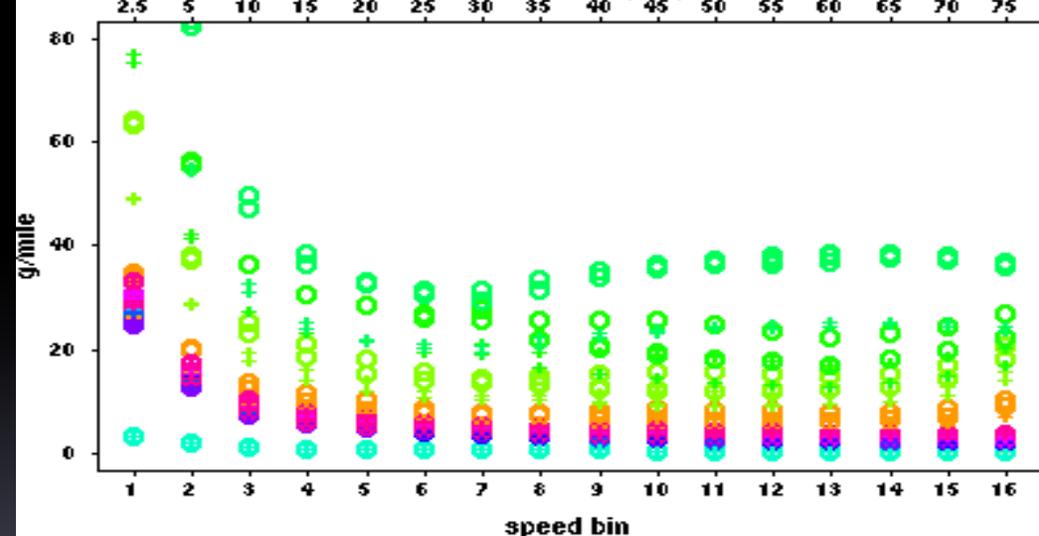
NOx RPD rates vs speed bins by scc7 (temperature = 70F)



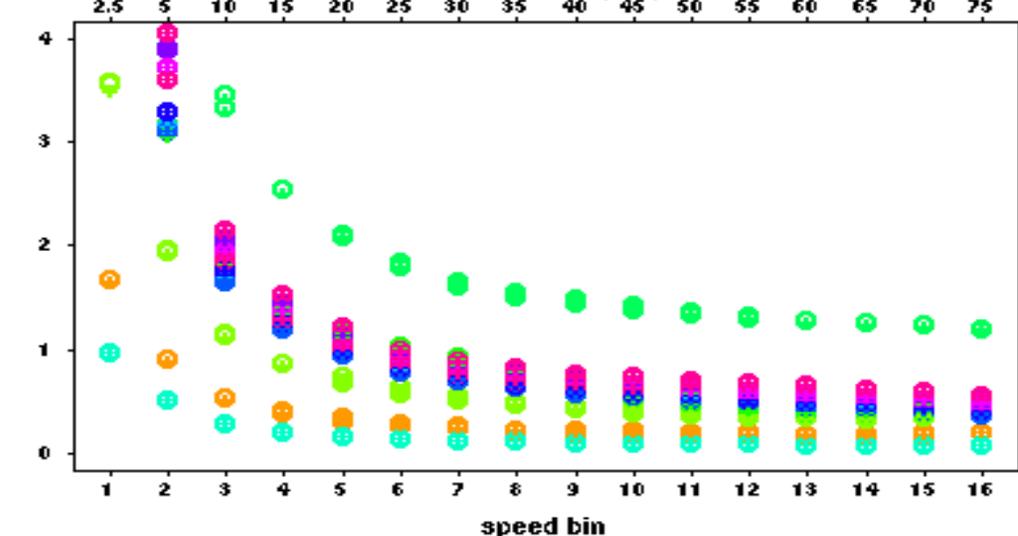
EXH PM25



CO



EXH VOC



scc7, winter fuel	LDGV	LDGT1	LDGT2	HDGV	MC	LDDV	LDDT	2BHDDV	LHDDV	MHDDV	HHDDV	BUSES
scc7, summer fuel	+LDGV	+LDGT1	+LDGT2	+HDGV	+MC	+LDDV	+LDDT	+2BHDDV	+LHDDV	+MHDDV	+HHDDV	+BUSES

- At 70F, vehicles traveling at lower speeds release more pollutants, as expected, but the effect diminishes as speed increases.
- Buses and diesel vehicles emit more NOx and PM2.5 than other vehicles.
- Motorcycles release more CO and VOCs than other type of vehicles.



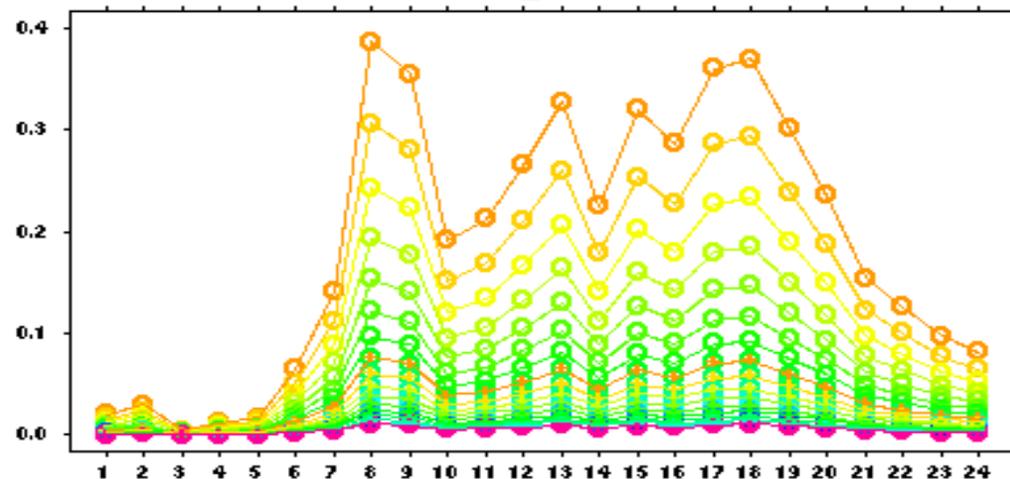
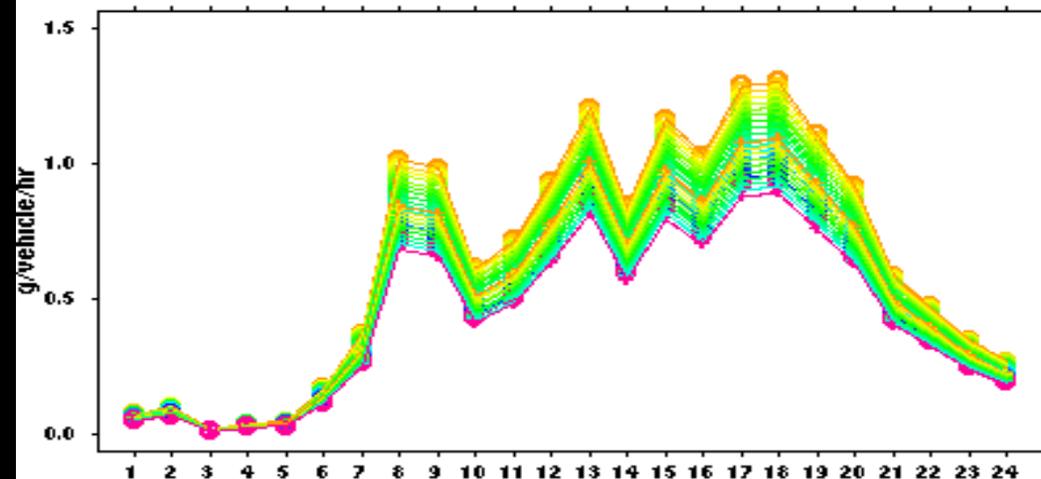
Rate-per-Vehicle (RPV)

- Emissions when vehicles are off-network, such as engine starts, idling, refueling, and parked
- 

weekday hourly RPV rates by temperature (scc7 = 2201001, LDGV)

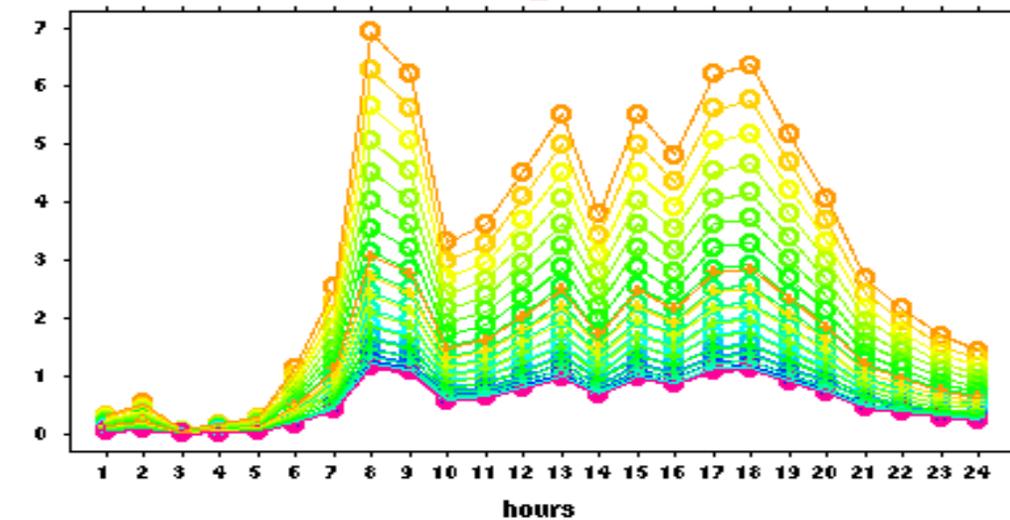
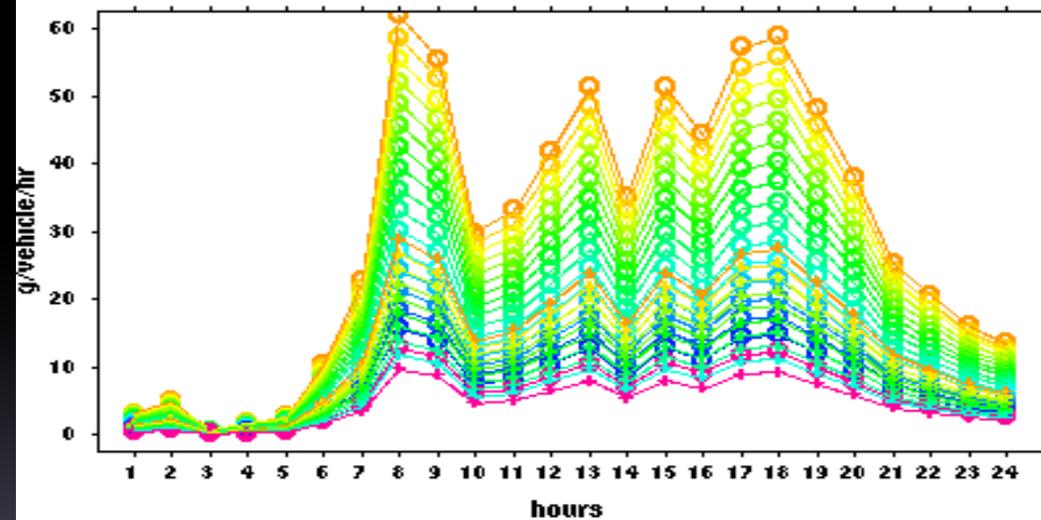
NOx

EXH_PM25



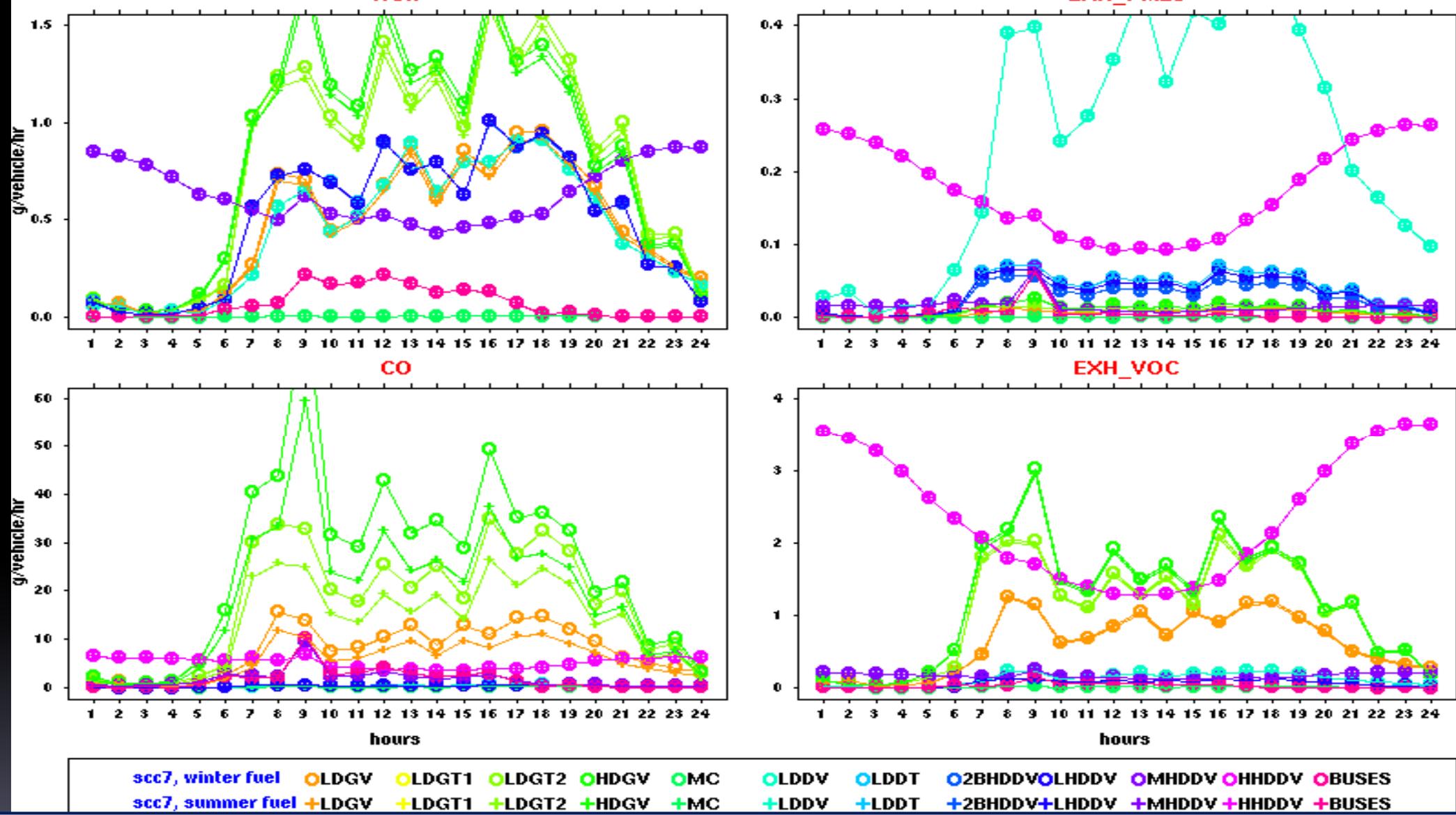
CO

EXH_VOC



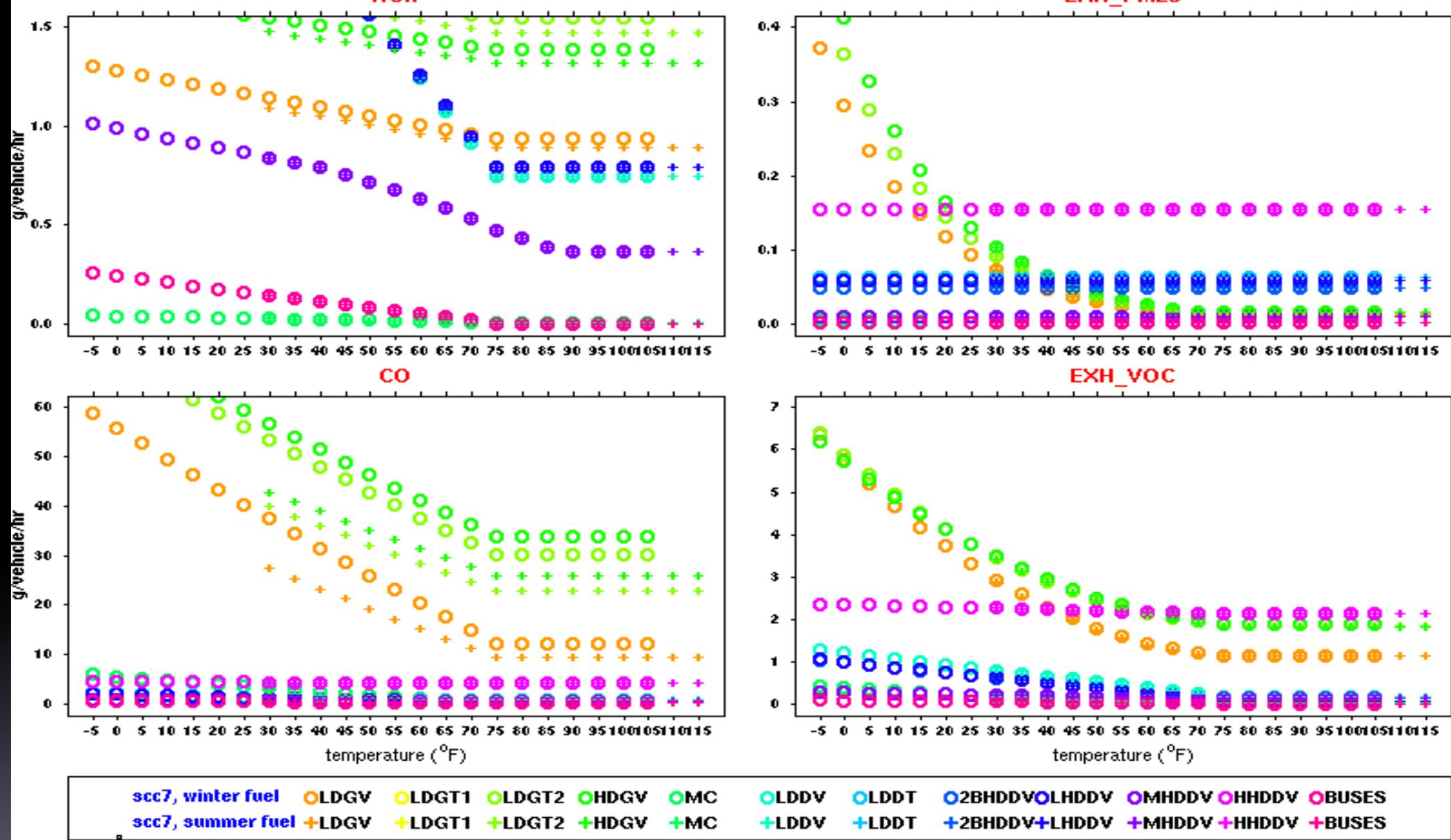
- Diurnal RPV profiles show four emission rate peaks (preset by MOVES) at 8am, 1pm, 3pm and 6pm. Rates are lower at off-peak hours.
- The lower the temperatures, the higher the emissions for all pollutants, including EXH_VOCs.
- Effect of temperatures on NOx is much smaller than on other pollutants.

weekday hourly RPV rates by scc7 (temperature = 70F)



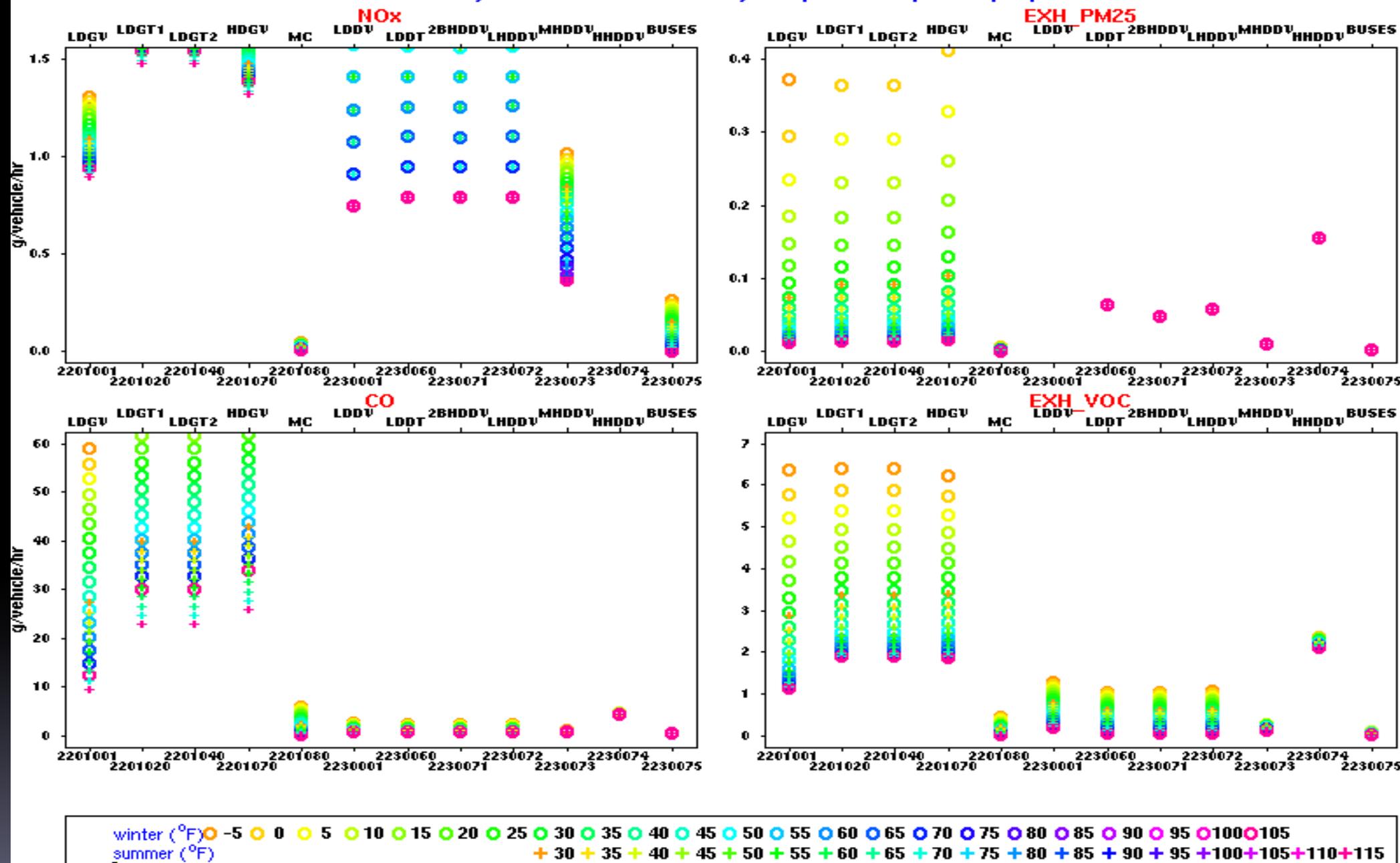
- At 70F, all vehicles but HHDDV show similar four emission peak hours.
- HHDDV release high EXH_VOCs and PM2.5 at off-peak hours; MHDDV exhibits similar off-peak hourly emission pattern for NOx.
- LDDV release unusually high PM2.5 compared to other vehicles (although all rates are low).
- Gasoline vehicles generally have greater diurnal variations in EXH_VOCs, CO, and NOx than diesel vehicles.

weekday RPV rates vs temperature by scc7 (hr = 6pm)



- At 6pm, gasoline vehicles emit more pollutants at colder temperatures, including EXH_VOCs.
- Diesel vehicles show no temperature dependence.
- Winter and summer fuels affect CO only and the effects are primarily on gasoline vehicles.

weekday RPV rates vs scc7 by temperature (hr = 6pm)

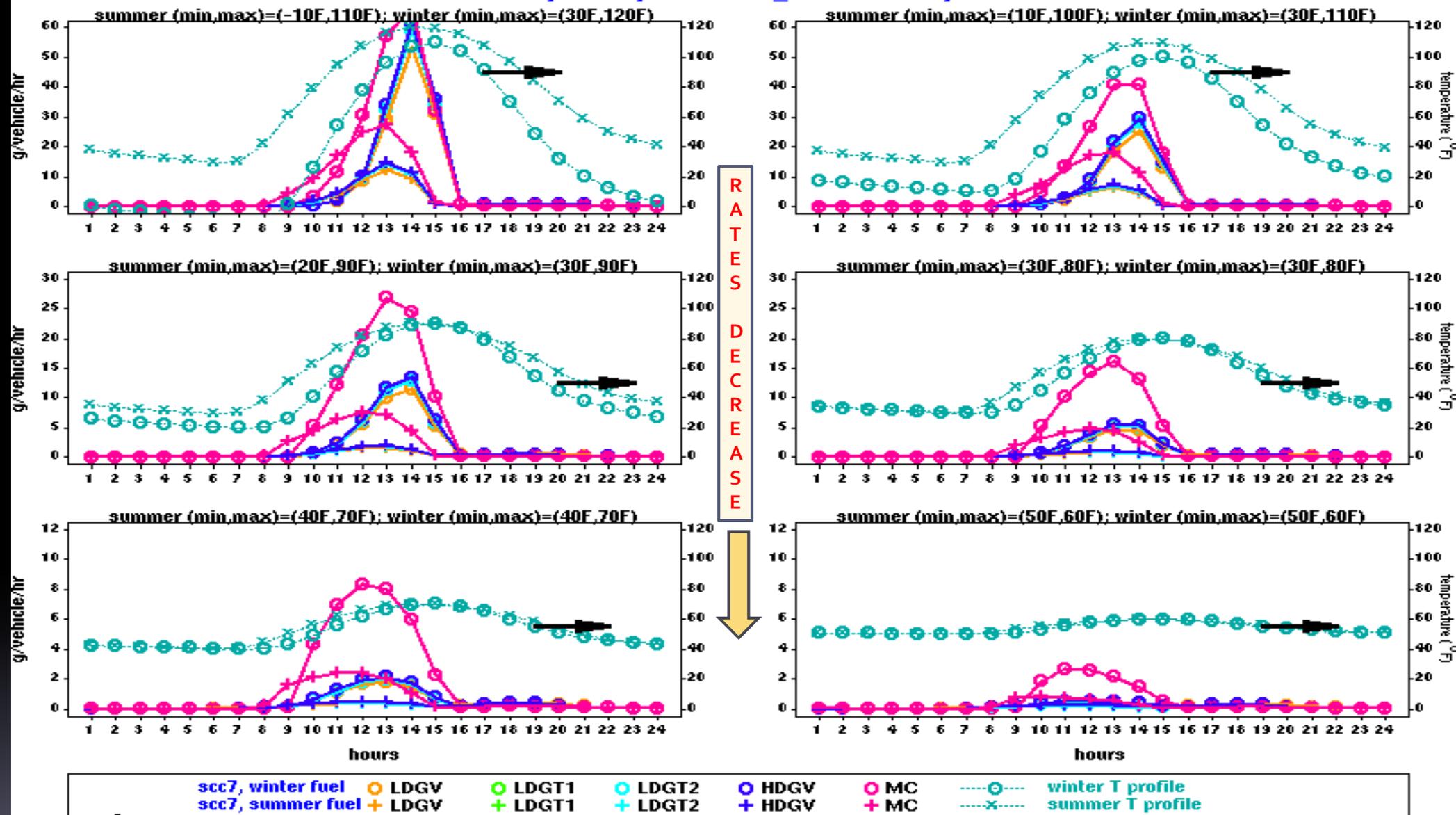


- Gasoline vehicles in general release more pollutants than buses and diesel vehicles.
- Temperatures have a greater effect on gasoline vehicles than on diesel vehicles with the exception of NOx.

Rate-per-Profile (RPP)

- Emissions from off-network parked vehicles
- This sector emits only EVP_VOC (and no other pollutants)
- The process depends on the rate of rise in temperature and the max temperature achieved during the day

weekday hourly RPP EVP_VOC rates by scc7

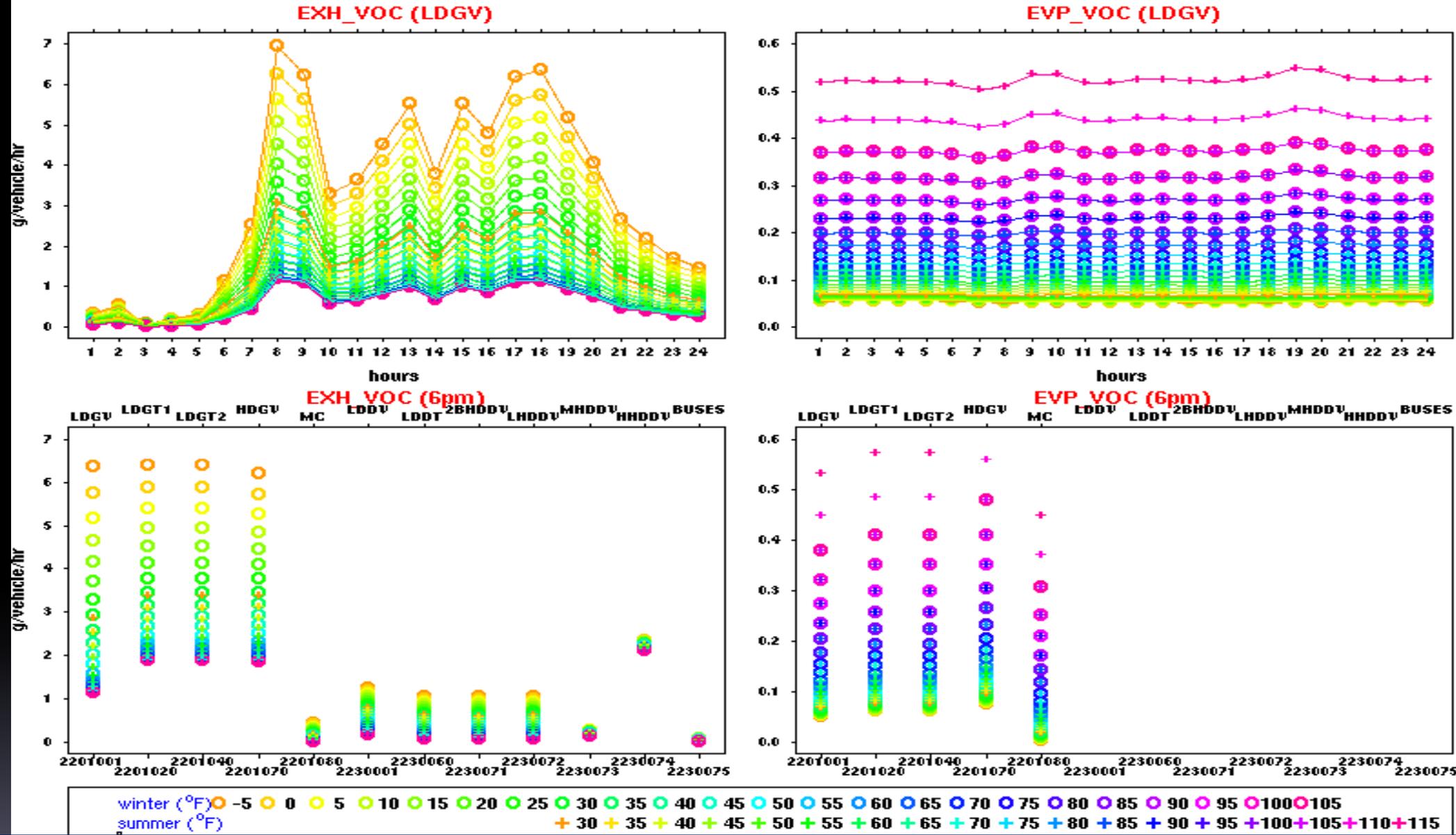


- EVP_VOCs emissions by RPP sector come from gasoline vehicles only. Diesel powered vehicles release no such emissions.
- RPP rate depends on full 24 hour of temperature profiles -- wider temperature swing yields higher EVP_VOCs emissions.
- For the same temperature swing (panel 4 – panel 6), winter fuel emits more EVP_VOCs than summer fuel.
- Amount of VOCs emissions among five vehicles types are MC, HDGV, LDGT2, LDGT1, and LDGV, in that order.

Exhaust VOCs and Evaporative VOCs

- Use RPV sector to illustrate temperature dependence

weekday hourly VOC (EXH VOC and EVP VOC) for RPV sector – temperature dependence



- The lower the temperatures, the higher EXH_VOCs. By contrast, the higher the temperatures, the higher the EVP_VOCs.
- EXH_VOCs come from all types of vehicles. On the other hand, EVP_VOC come from gasoline vehicles only.
- Diesel powered vehicles have no EVP_VOCs emissions.
- EXH_VOCs (RPV) rates are much higher than EVP_VOCs (RPV) rates both on per hour and on per vehicle basis.

Conclusion

Vehicles in motion (RPD)

- Diesel vehicles and buses release higher NO_x and PM_{2.5} than gasoline vehicles
- Gasoline vehicles in general release higher CO than diesel vehicles
- Motorcycles emit the highest CO and EXH_VOCs among all vehicle types and all speed bins
- Vehicles of all types traveling at slower speeds emit higher emissions for all pollutants. The effect levels out as speed increases

Conclusion

Engine starts or idling (RPV)

- MOVES presets temporal and diurnal profiles with four emission rate peaks at 8am, 1pm, 3pm, and 6pm
- HHDDV release high PM_{2.5} and EXH_VOCs at off-peak nighttime and early hours when drivers turn on the engines and sleep in the trailers
- LDDV emit unusually high PM_{2.5} compared to other vehicles
- Gasoline vehicles generally have higher emission rates than diesel vehicles for all pollutants
- EXH_VOCs dominate over EVP_VOCs

Conclusion

Parked vehicles (RPP)

- EVP_VOCs is the only pollutant emitted
- Only gasoline (but not diesel) vehicles release EVP_VOCs
- Amount of EVP_VOCs depends on entire 24-hour temperature profile – a wider range in diurnal temperatures results in higher EVP_VOCs
- $MC > HDGV > LDGT_2 > LDGT_1 > LDGV$

Conclusion

Fuel month

- Use of winter or summer fuel primarily affects CO and VOCs. Emission rates are higher with winter fuel than with summer fuel.

Temperature effects

- Whether in motion or idling, diesel vehicles show little to no temperature dependence for PM_{2.5}, CO, and EXH_VOCs.
- Temperature effects on gasoline vehicles are pollutant and sector dependent: (1) higher PM_{2.5} (RPD/RPV), CO (RPV) and EXH_VOCs (RPV) at lower temperature, (2) higher CO (RPD) and EVP_VOCs at higher temperatures, (3) little to no effects on EXH_VOCs (RPD).

Future Work

- Effect of different road types
- Unusual data points
- Original un-summed tables (resolution of emission processes in summed tables could be lost)
- Differences in data between counties or states