SMOKE version 4.7 Recent Enhancements

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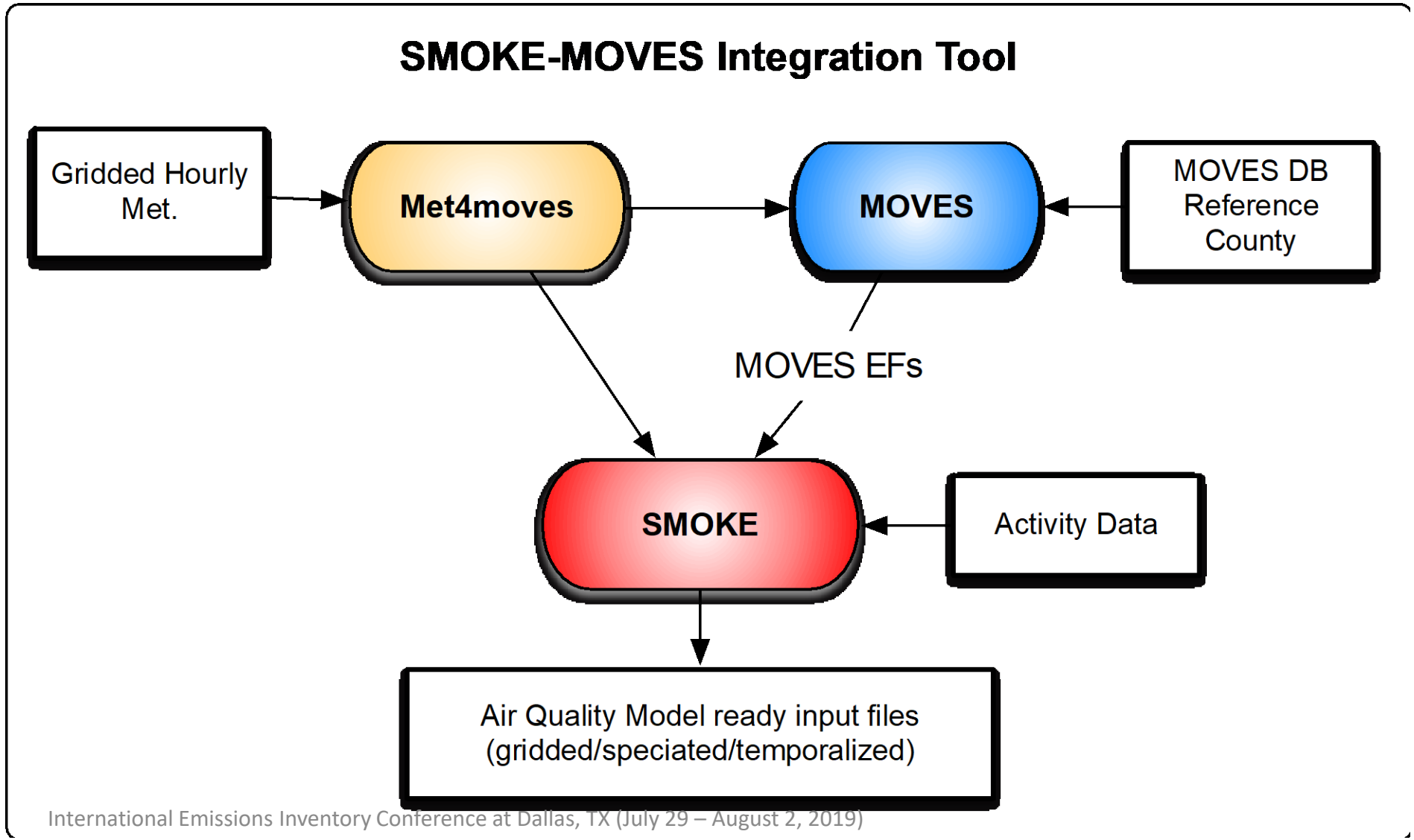
Outline

1. Onroad Mobile Emissions Updates
   - Average Speed Fractions by Distribution (ASD)
   - NOx Humidity Corrections
2. New PostgreSQL/PostGIS Surrogates Tool Development
   - Computationally optimized (Faster and Less memory usage)

Creating Onroad Emissions using SMOKE-MOVES



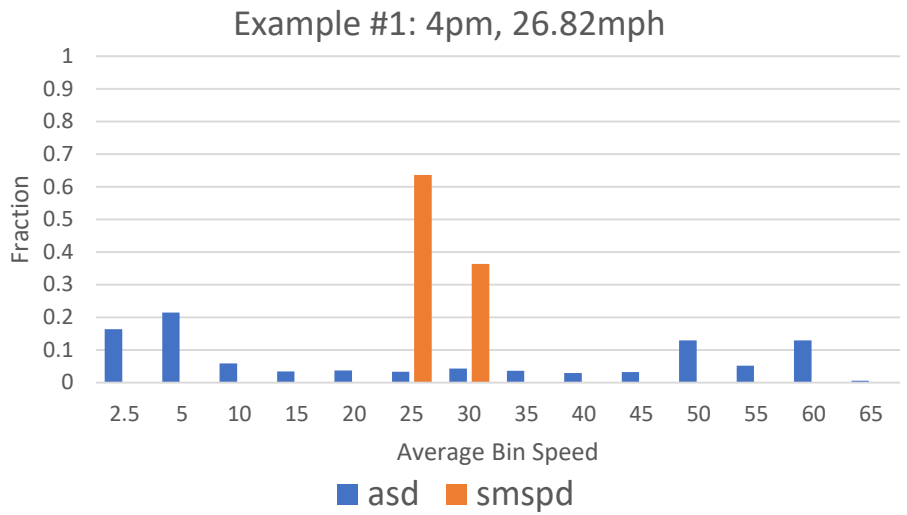
Background on Speeds in MOVES and SMOKE-MOVES

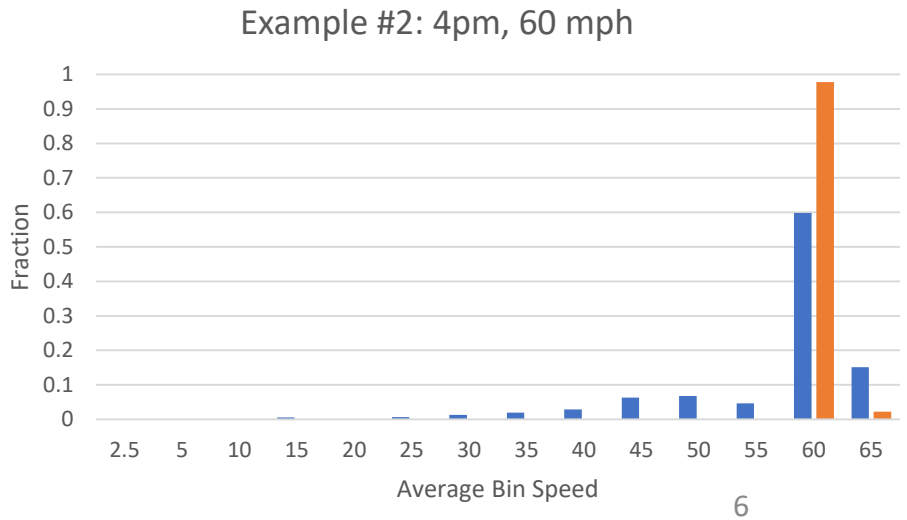
- Speed impacts emission rates and is relevant to MOVES rate-per-distance (RPD) processes
  - Vehicle-miles-traveled (VMT) are used for activity data
  - RPD emissions = RPD emission factor * VMT
- SMOKE-MOVES interpolates between two speed bin MOVES emission factors to estimate the factor for a specific speed value
- Alternatively, MOVES inventory mode uses average speed distributions (ASD) to compute emissions as a weighted sum across all speed bins

Speed Bin	Min Speed	Max Speed
1	0	2.5
2	2.5	7.5
3	7.5	12.5
4	12.5	17.5
5	17.5	22.5
6	22.5	27.5
7	27.5	32.5
8	32.5	37.5
9	37.5	42.5
10	42.5	47.5
11	47.5	52.5
12	52.5	57.5
13	57.5	62.5
14	62.5	67.5
15	67.5	72.5
16	72.5	

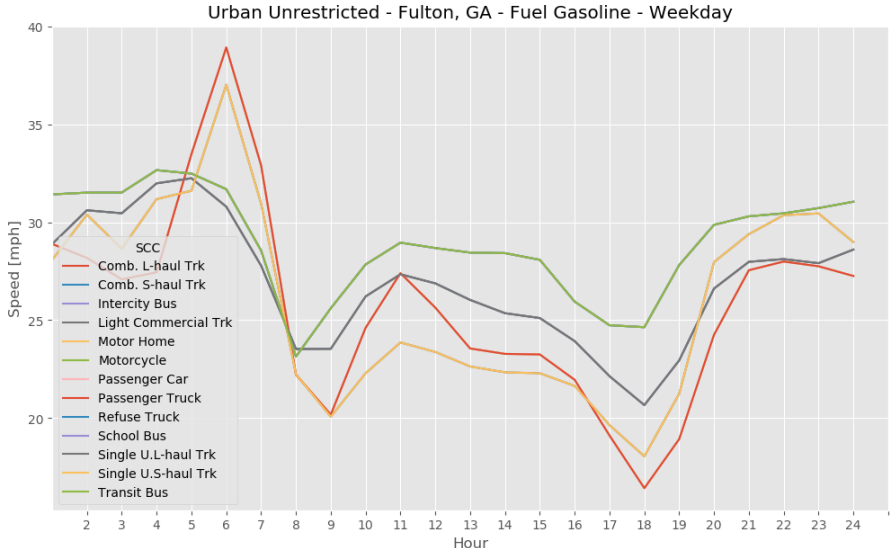
Examples of Average Speed Distributions

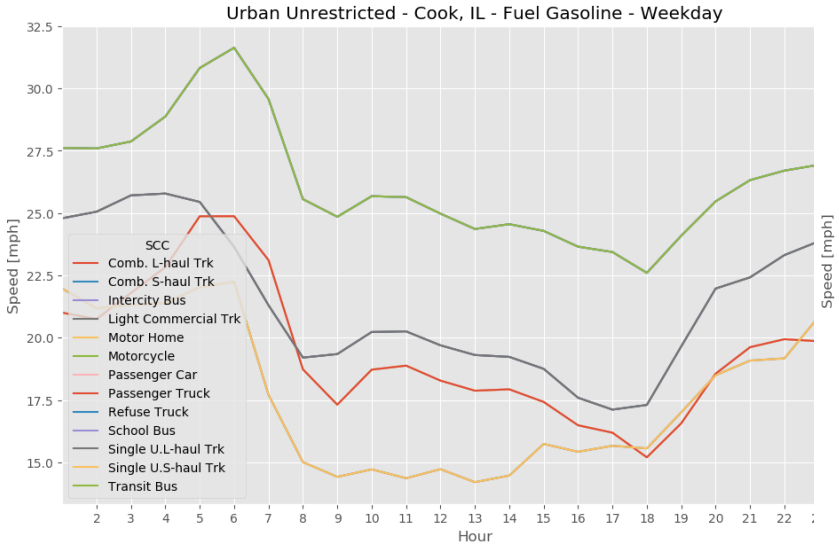
- Two counties ASD for weekdays at 4:00pm
- **Example #1**: Spread-out ASD vs 26.82mph
  - MOVES inventory mode would apply emissions rates from all speed bins and sum the emissions
  - SMOKE-MOVES would interpolate between emissions factors from two speed bins
  - Different emissions would be estimated due to different number of bins involved
- **Example #2**: Compact ASD with a peak at the same bins SMOKE-MOVES would used
  - Similar emissions would be estimated due to similar representation of speed bins

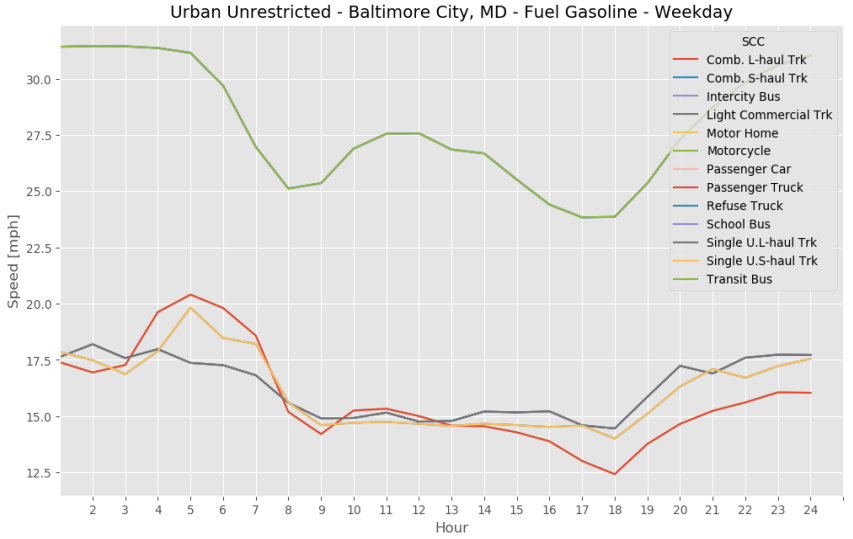


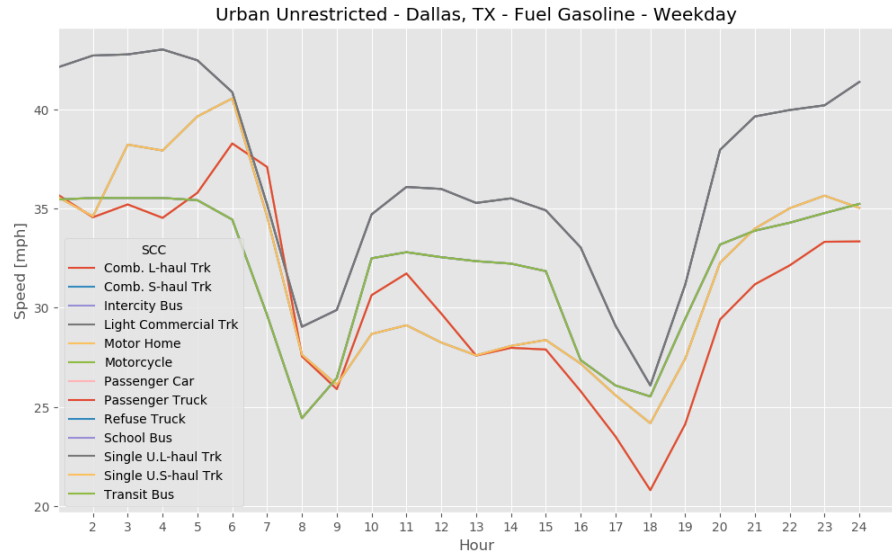


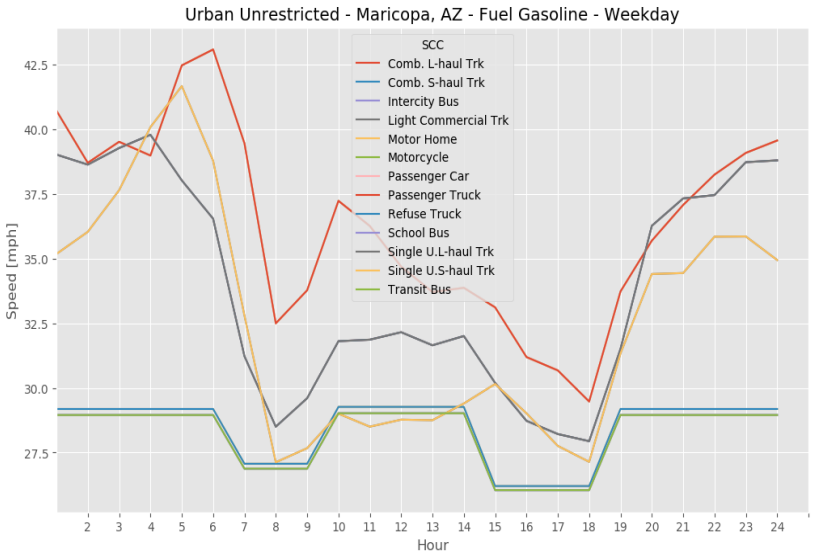
Current 24-hours Speed Profiles by MOVES source type (Gasoline-Urban **Unrestricted**)





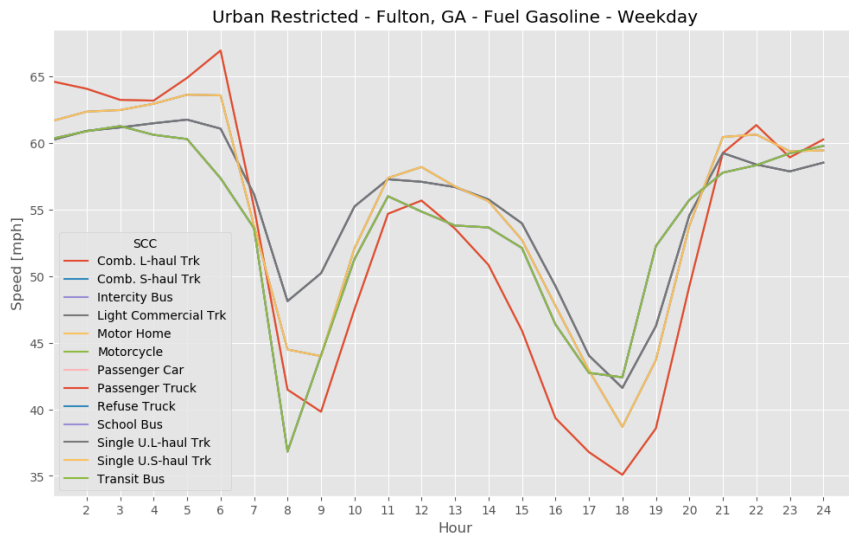


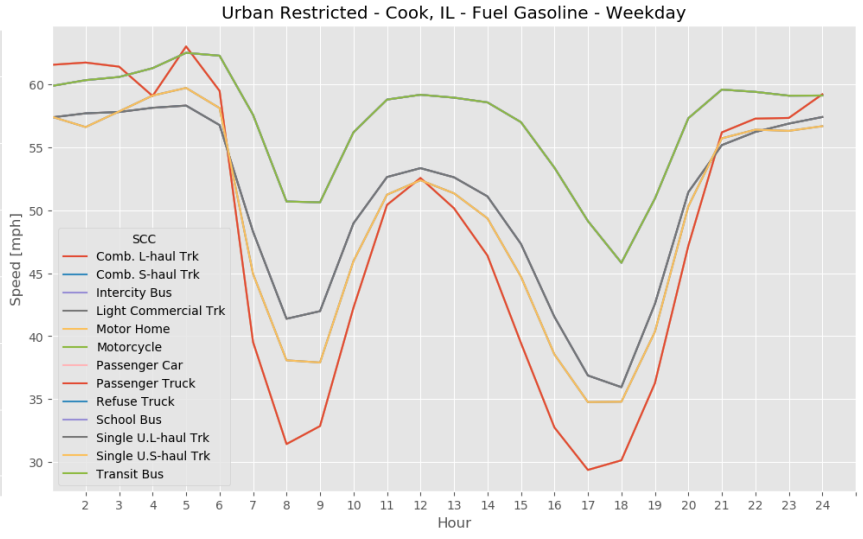


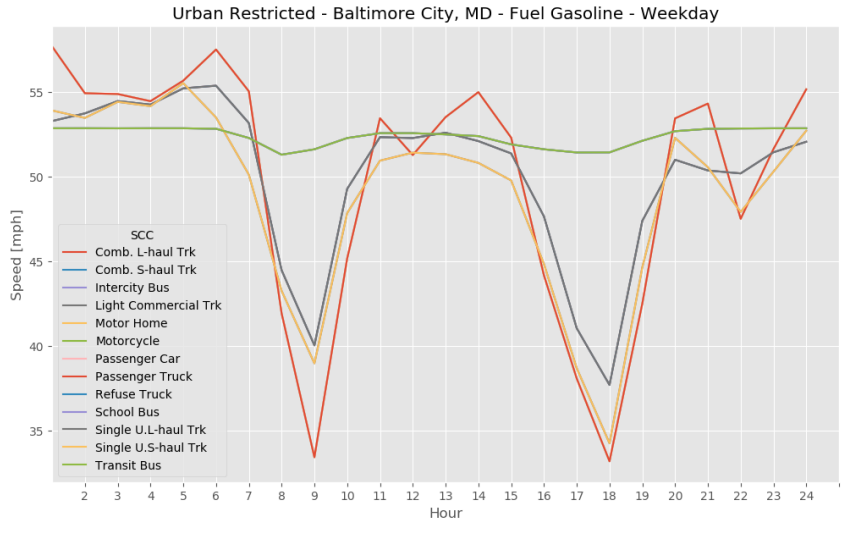


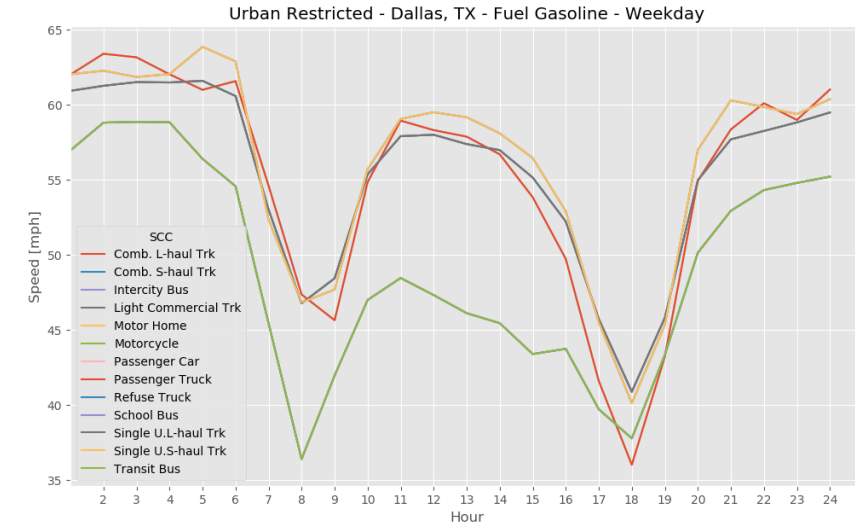
- Atlanta, Chicago, Baltimore, Dallas and Phoenix
- Varies by hour, vehicle, & city
- Slower speed during rush hours and daytime

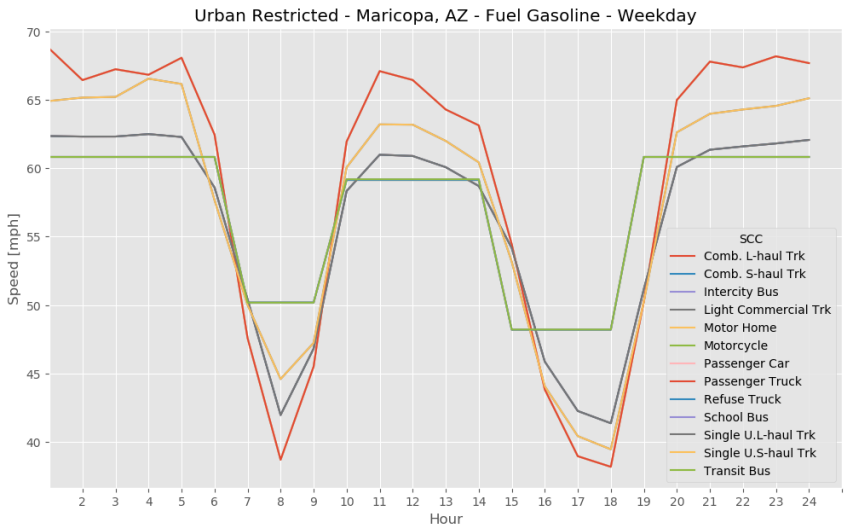
Current 24-hours Speed Profiles by MOVES source type (Gasoline-Urban **Restricted**)







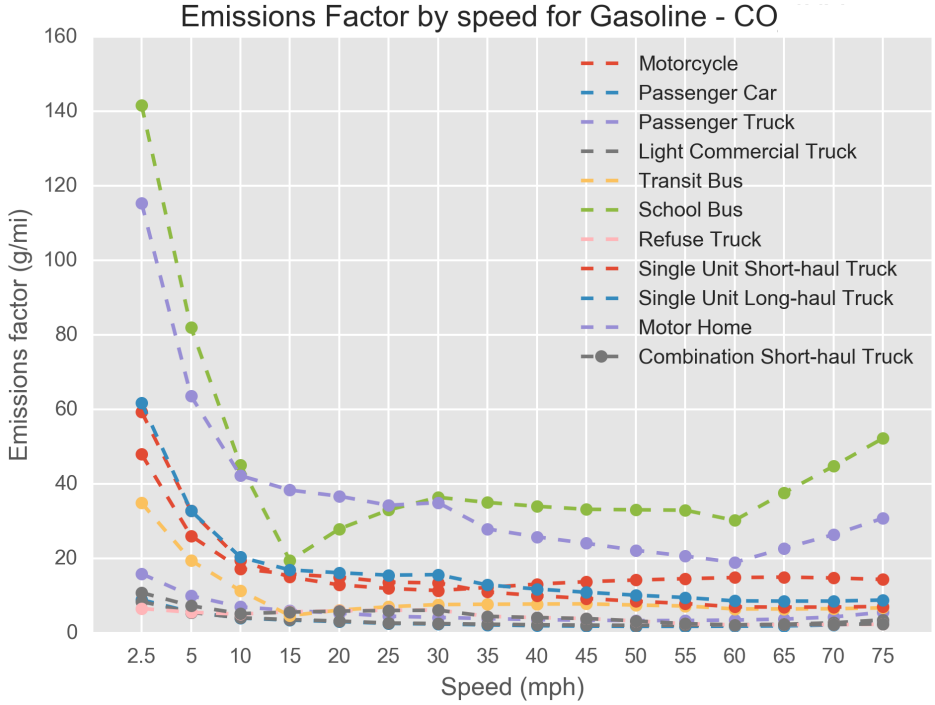


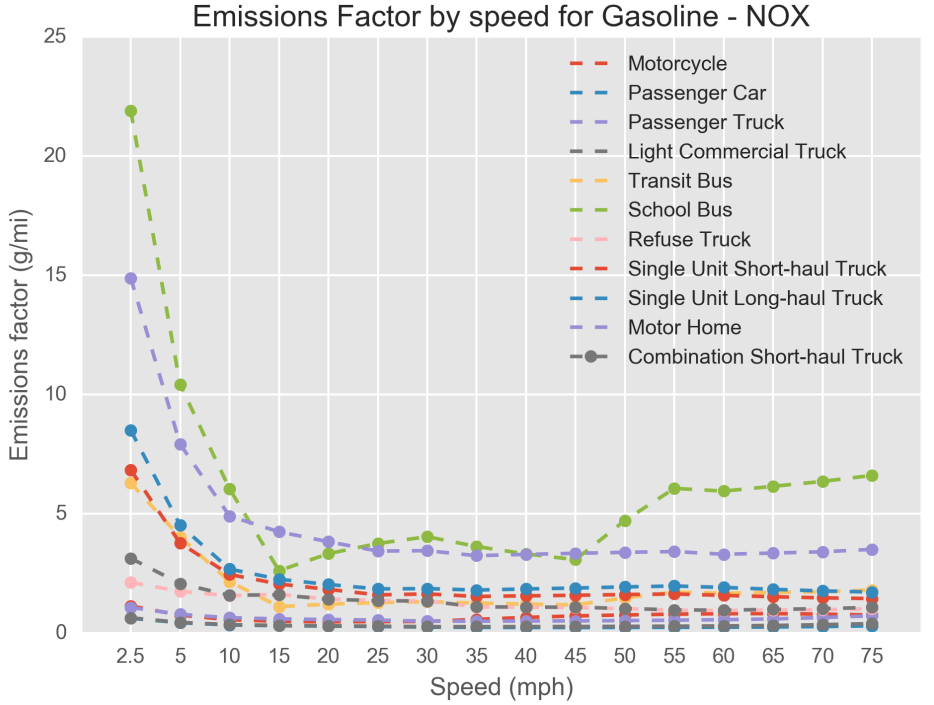


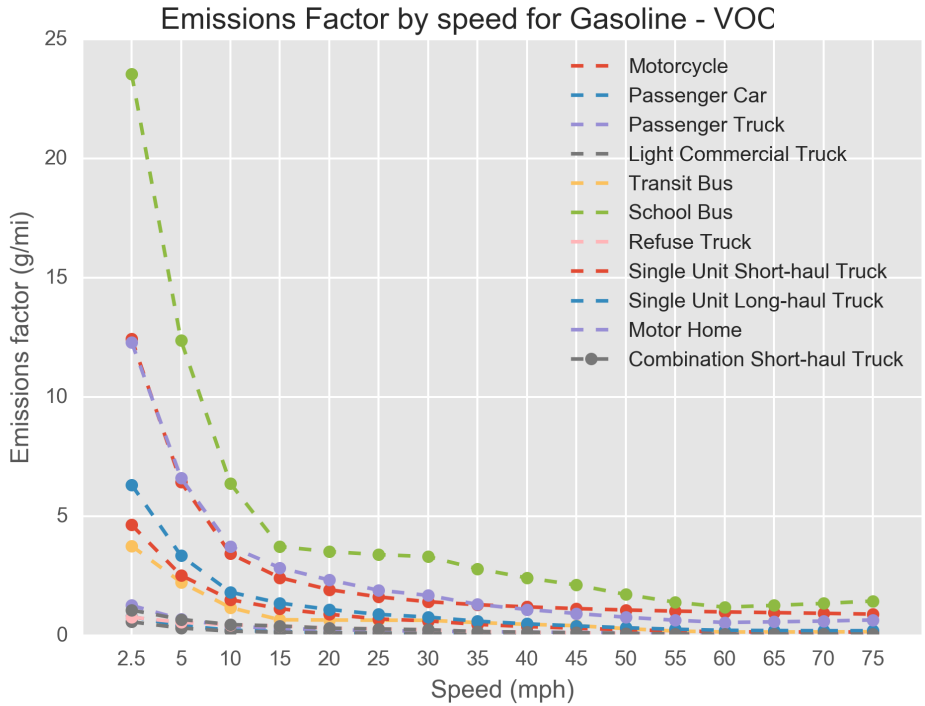
- Restricted road speeds are typically higher than unrestricted road
- Clear lower speed during the rush hours

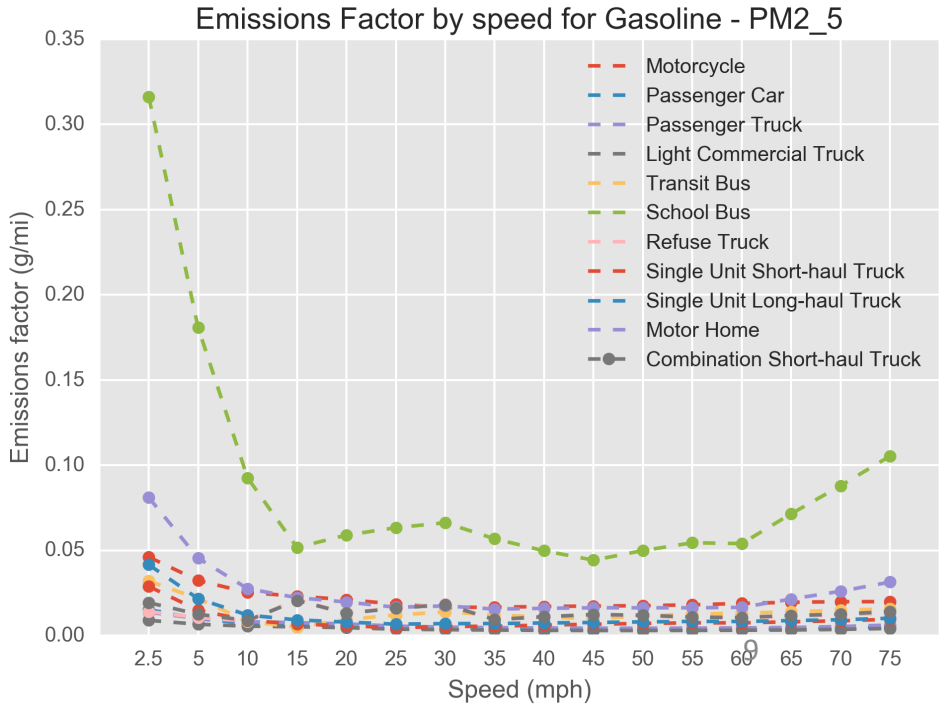
Impact of Speed by Pollutant and Vehicle Type

Fuel: Gasoline



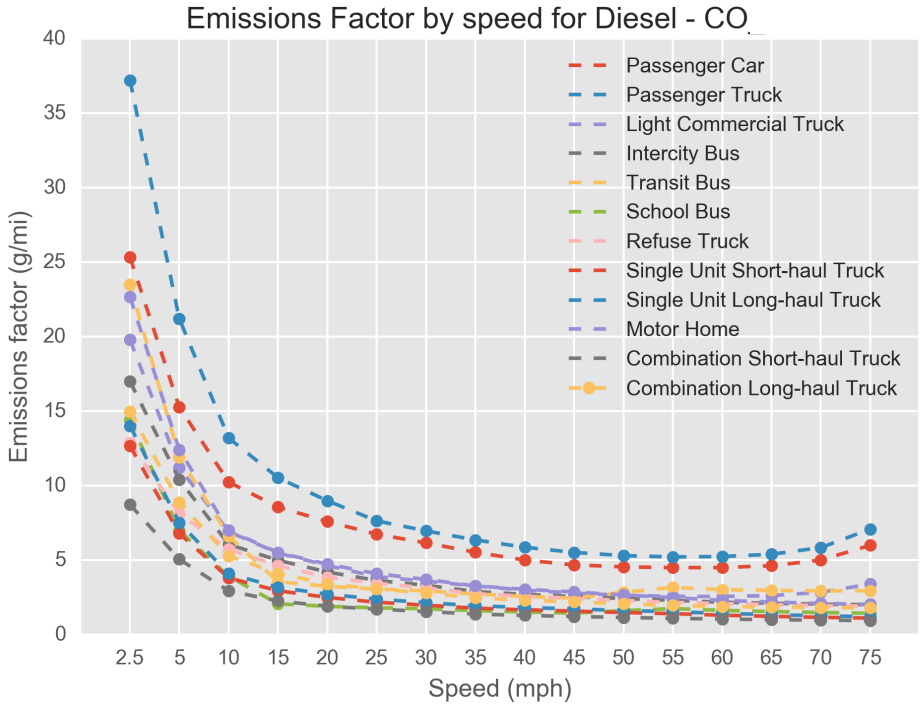


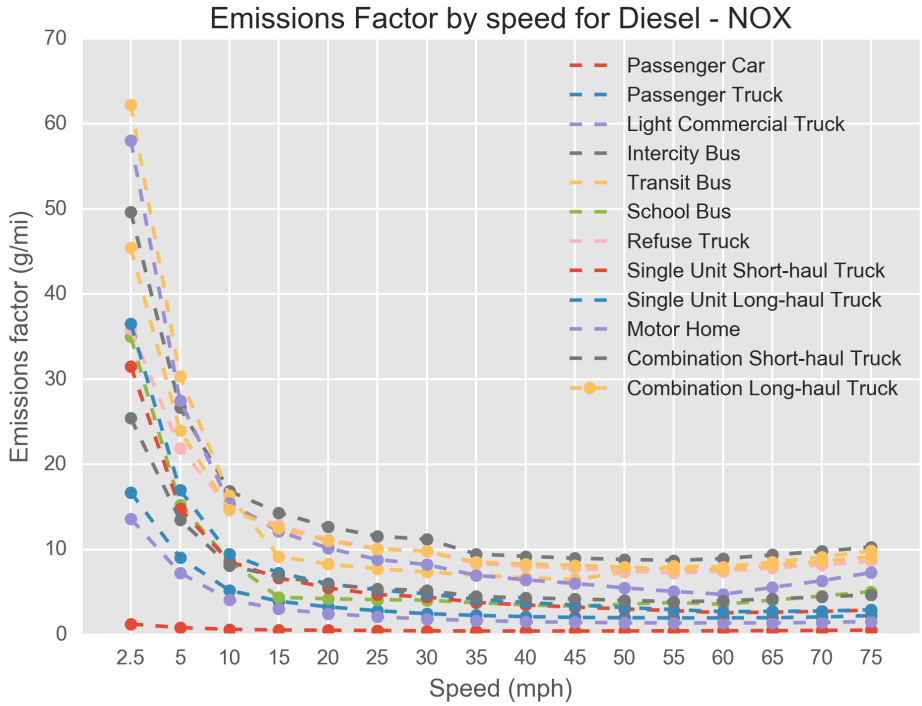


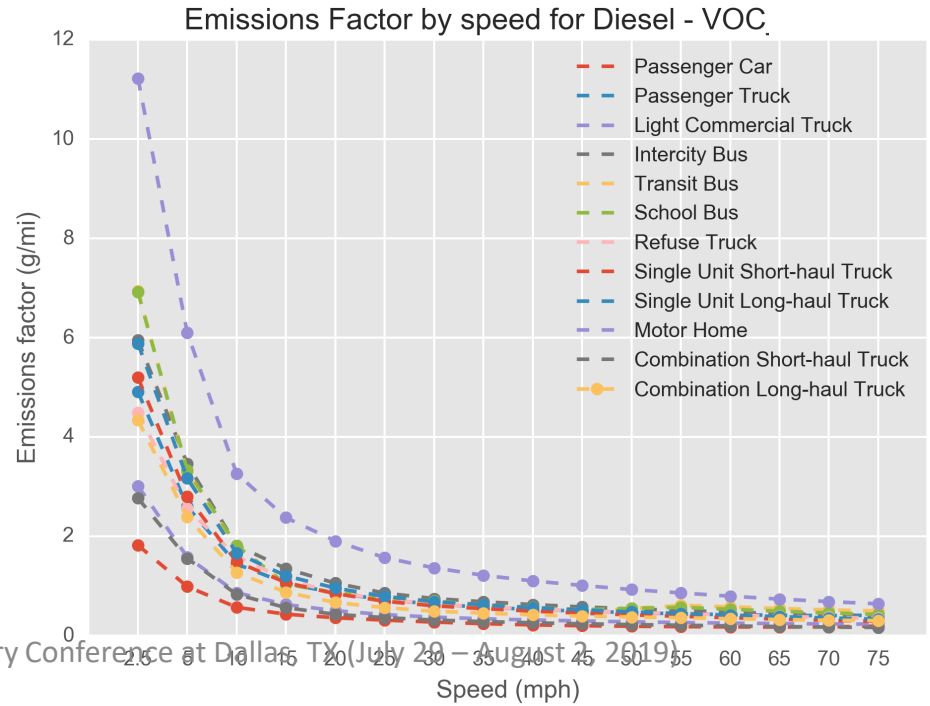


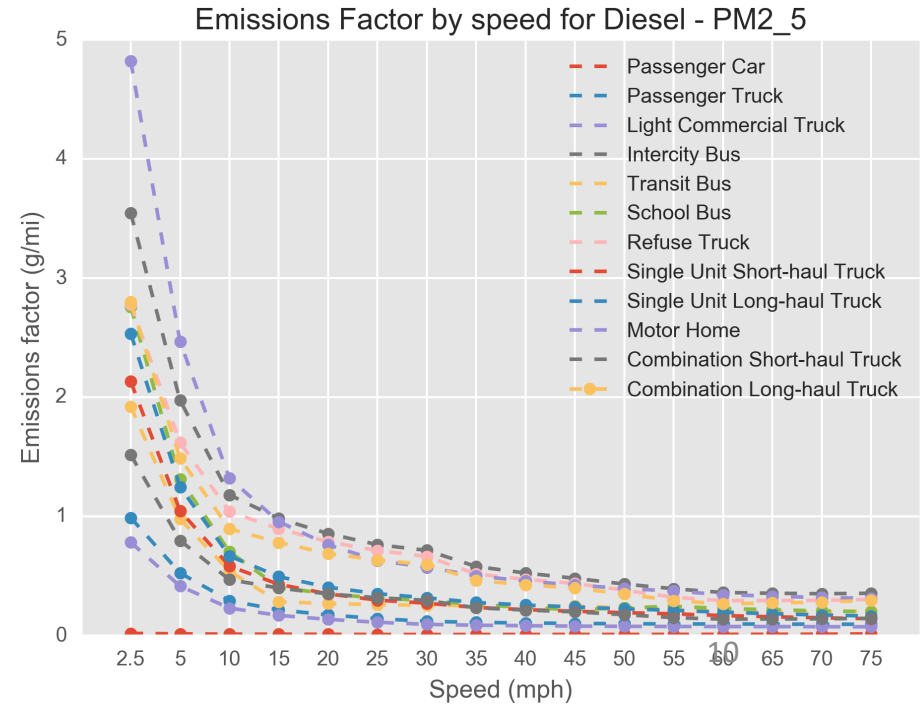
Impact of Speed by Pollutant and Vehicle Type

Fuel: Diesel









Improved Representation of Speeds in SMOKE-MOVES

- New Feature in SMOKE-MOVES: Average Speed Fraction by Distance (ASD)

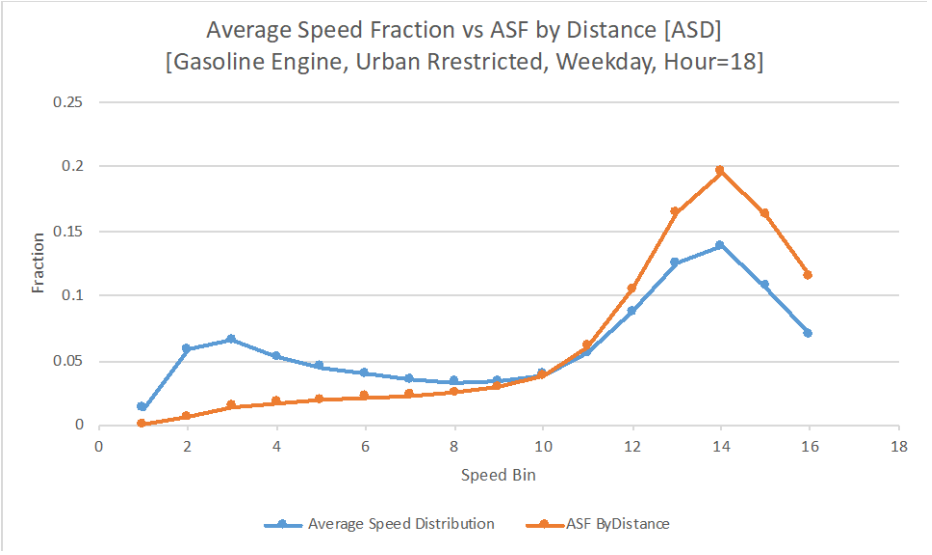
  : Emissions estimated for each of 16 speed bins (SPD)

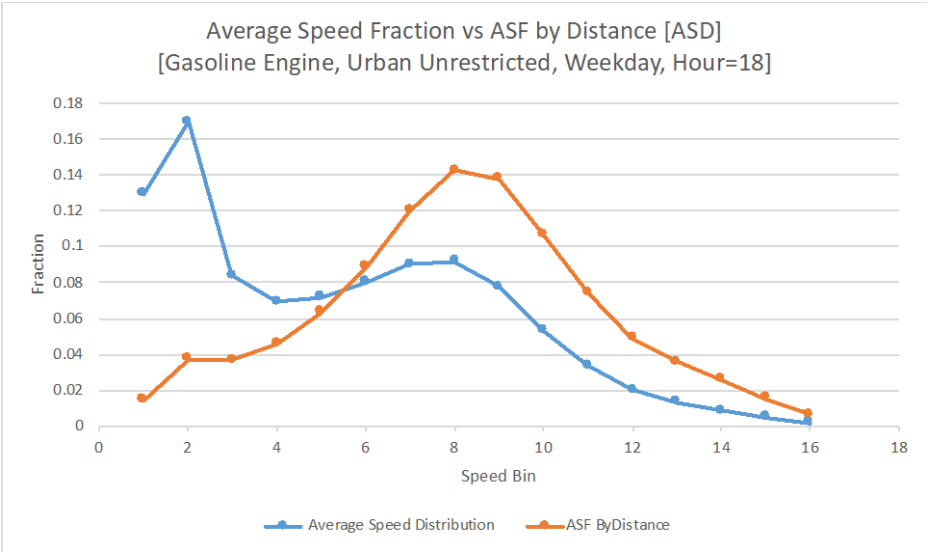
  : Traveled Distance $(TD)_{spd}$ = Speed $(mph)_{spd}$ * ASF_{spd}

  : $ASD_{spd} = TD_{spd}$ / Sums of TD

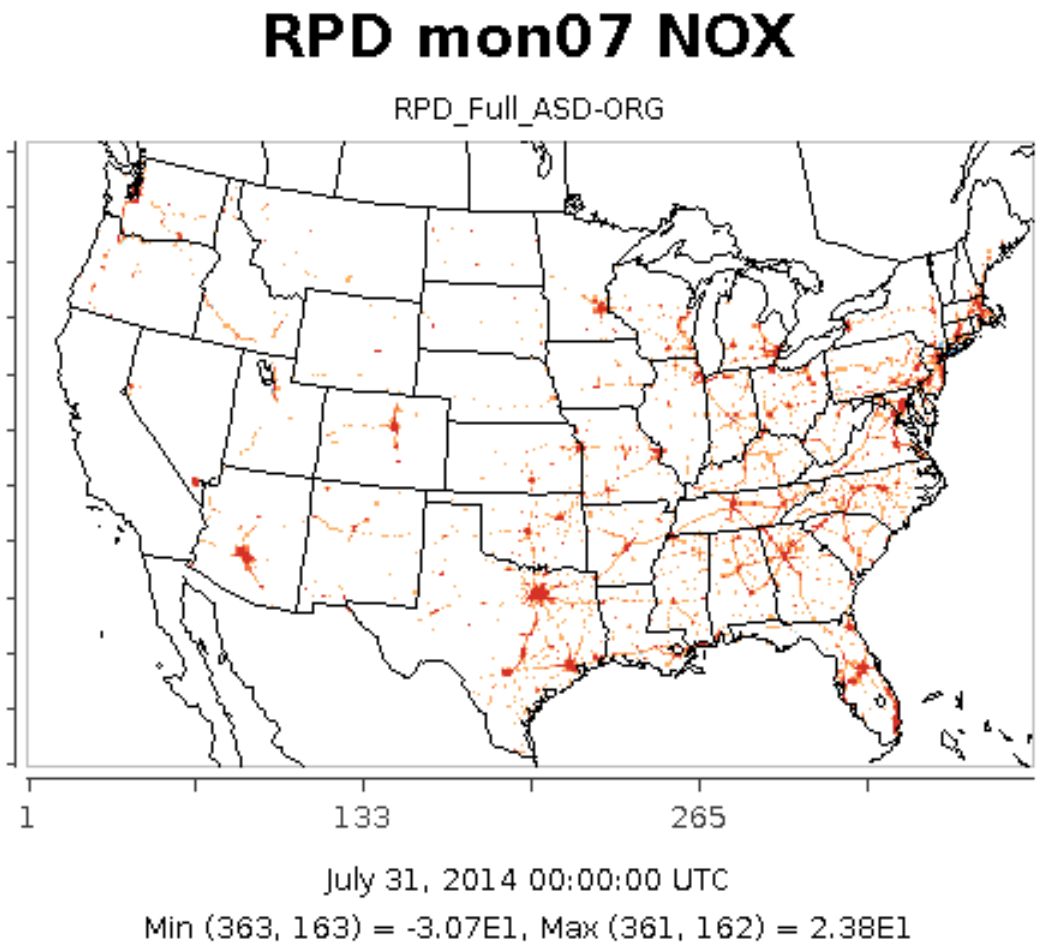
  : ASD is function of

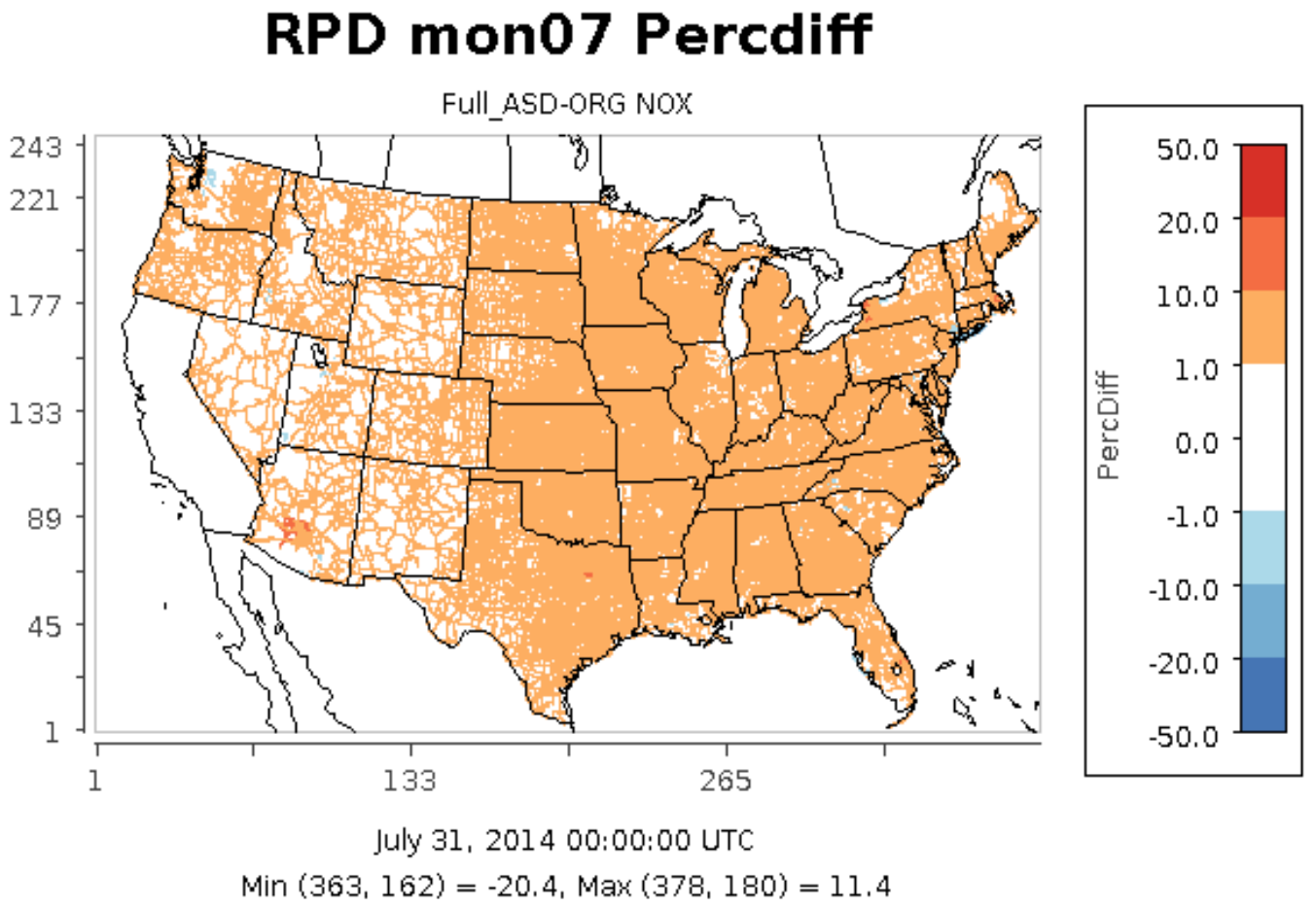
  $\int$ (FIPS, SCC, Weekday/Weekend, Hour of day, Speed)



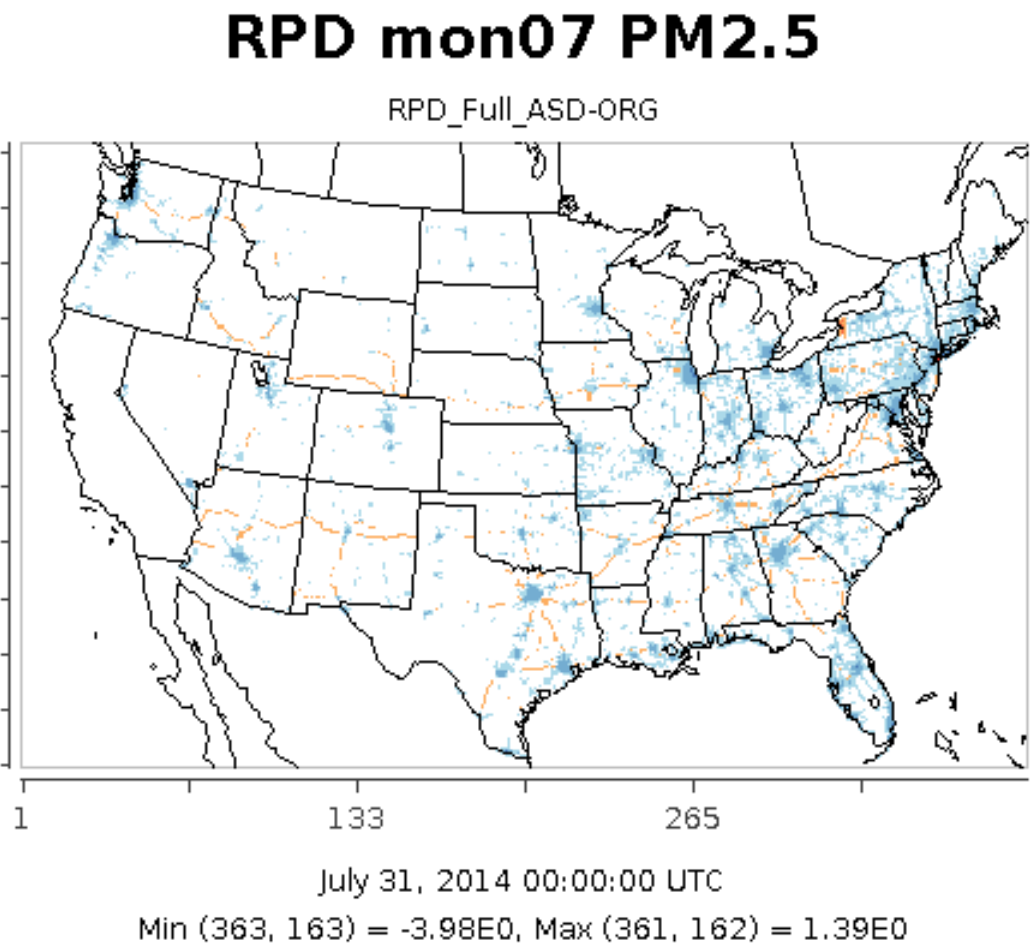


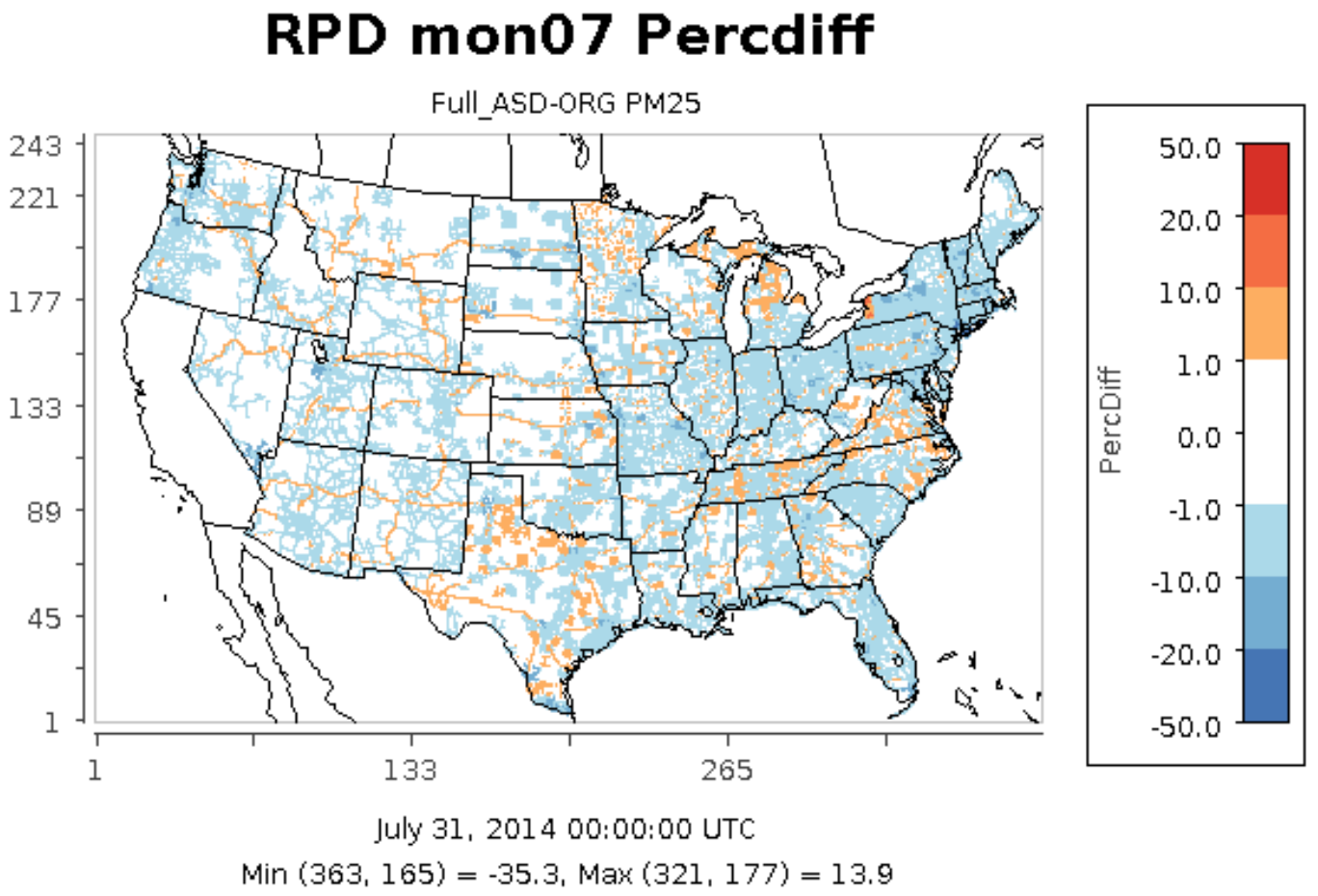
Difference in July NOx



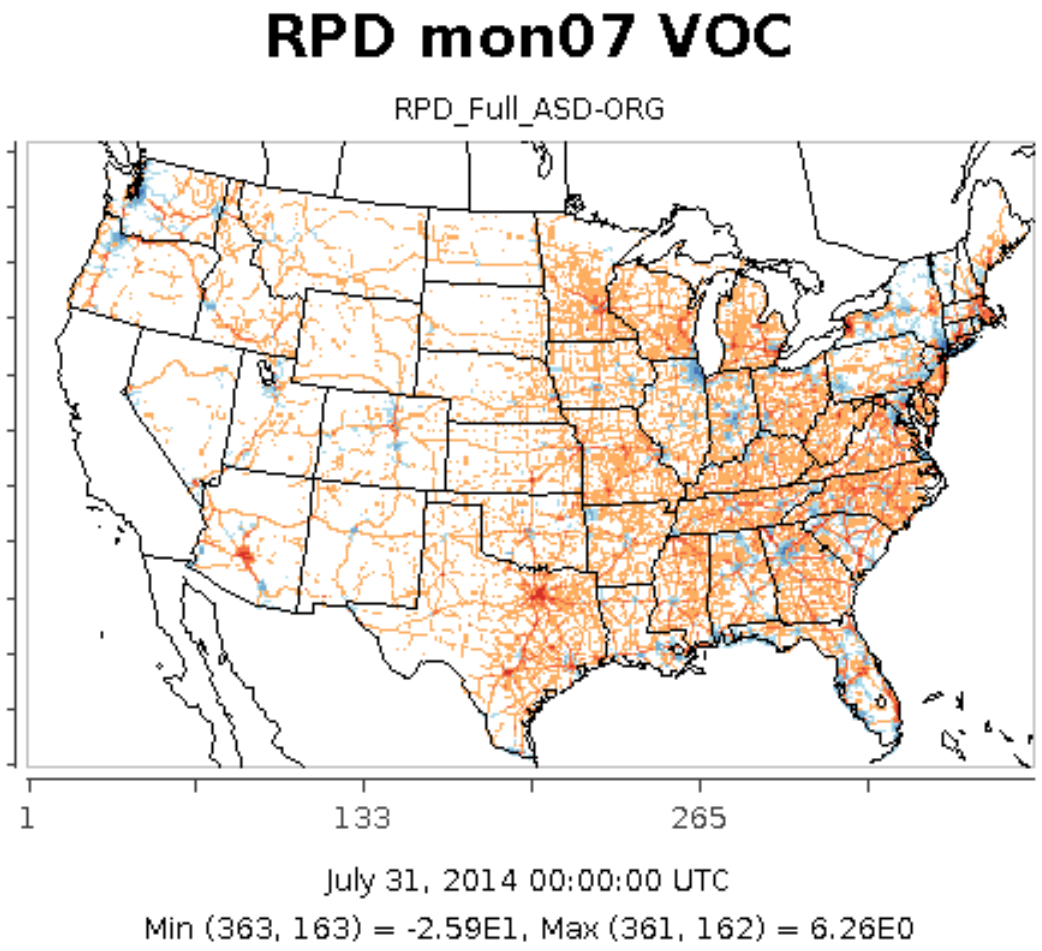


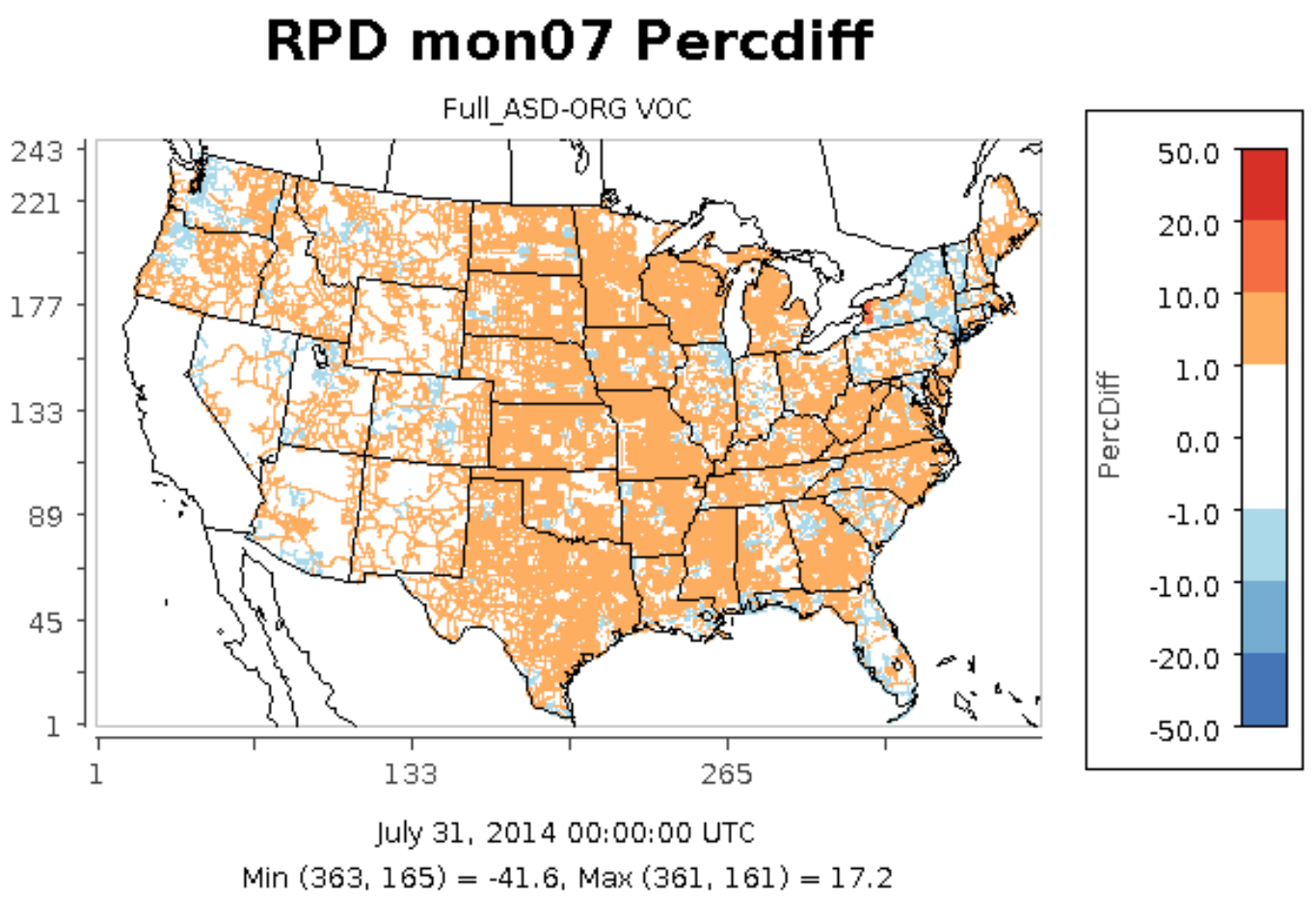
Difference in July $PM_{2.5}$





Difference in July VOC





Comparison between Interpolation vs ASD

- July Monthly Total Emissions Comparison
  - Percent Difference [%]: (ASD – ORG)/ORG * 100
- PM_{10} and $PM_{2.5}$ Model Species: Reduction: -2% ~ -10%
- Gas Model Species: All Increases ranging from 0% to 7%

	CO	NOx	NH3	SO2	TOG	PM2.5	PM10
	(tons/month)	(tons/month)	(tons/month)	(tons/month)	(tons/month)	(tons/month)	(tons/month)
Original	1,501,013.41	327,310.36	8,665.32	2,430.10	169,334.73	11,379.31	22,991.43
ASD (Gasoline)	1,571,406.72	331,528.95	9,154.95	2,453.14	169,686.71	11,046.51	21,198.54
ASD (All Fuels)	1,575,032.49	338,725.40	9,229.94	2,471.60	170,290.36	10,881.81	20,808.59
	CO	NOx	NH3	SO2	TOG	PM2.5	PM10
ASD (Gasoline)	4.69%	1.29%	5.65%	0.95%	0.21%	-2.92%	-7.80%
ASD (Others)	0.24%	2.20%	0.87%	0.76%	0.36%	-1.45%	-1.70%
ASD (All Fuels)	4.93%	3.49%	6.52%	1.71%	0.56%	-4.37%	-9.49%

Findings on Using ASD

- **Why are NOx emissions increased with ASD application?**
  - More lower speed bins are included when computing emissions with the ASD approach
- **Why are $PM_{2.5}$ emissions decreased with ASD in cities while increased in highways?**
  - The single NEI average speed assigned for urban roads was relatively lower than used in ASD
  - The single NEI average speed assigned for rural roads was relatively higher than ASD
- **Why do VOC emissions show different patterns between Dallas and Phoenix?**
  - Most of metro cities show relatively lower estimated VOC while Dallas, TX and Phoenix, AZ show increases.
  - Higher average speed for urban unrestricted roads from Dallas and Phoenix
  - Higher contribution of urban unrestricted roads from Dallas and Phoenix
  - Contributions of road and vehicle types by region, and/or average speed played a key role

*** ASD approach is a better representation of actual driving patterns by road type**

NOx Humidity Correction

Humidity impacts NOx emissions

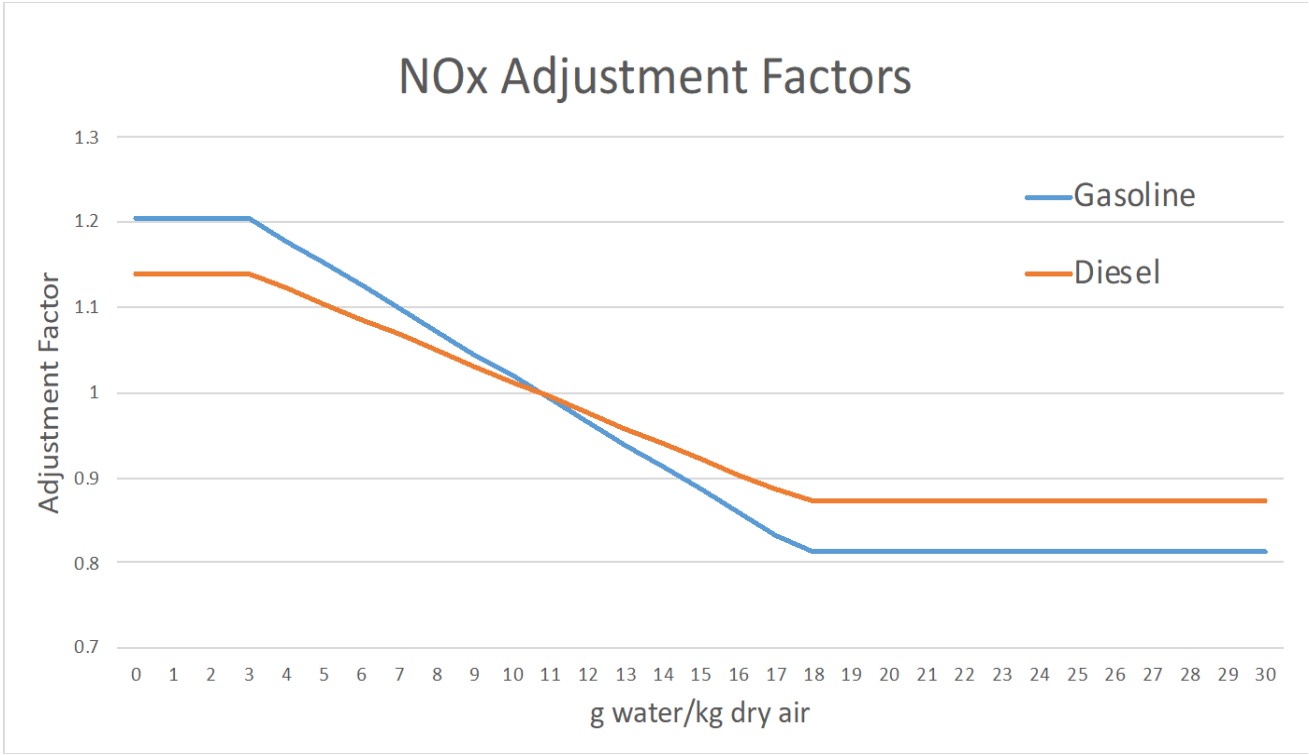
- Spark-Ignition engines
- Compression Ignition Diesel

The NOx Humidity Correction Equation differs by fuel Type:

1. Gasoline, Ethanol and CNG
2. Diesel

Compute the Correction Using:

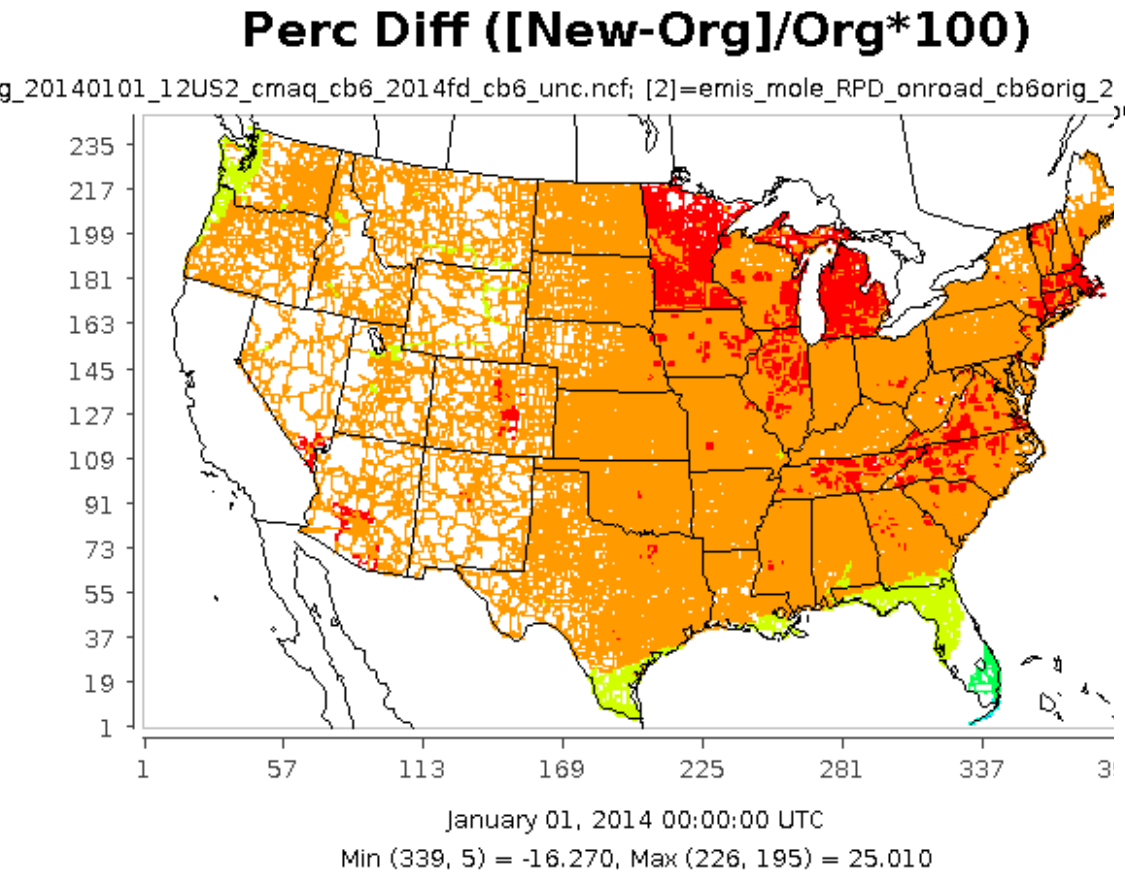
1. MOVES Model (Month-humidity/county)
2. SMOKE-MOVES Integration Tool



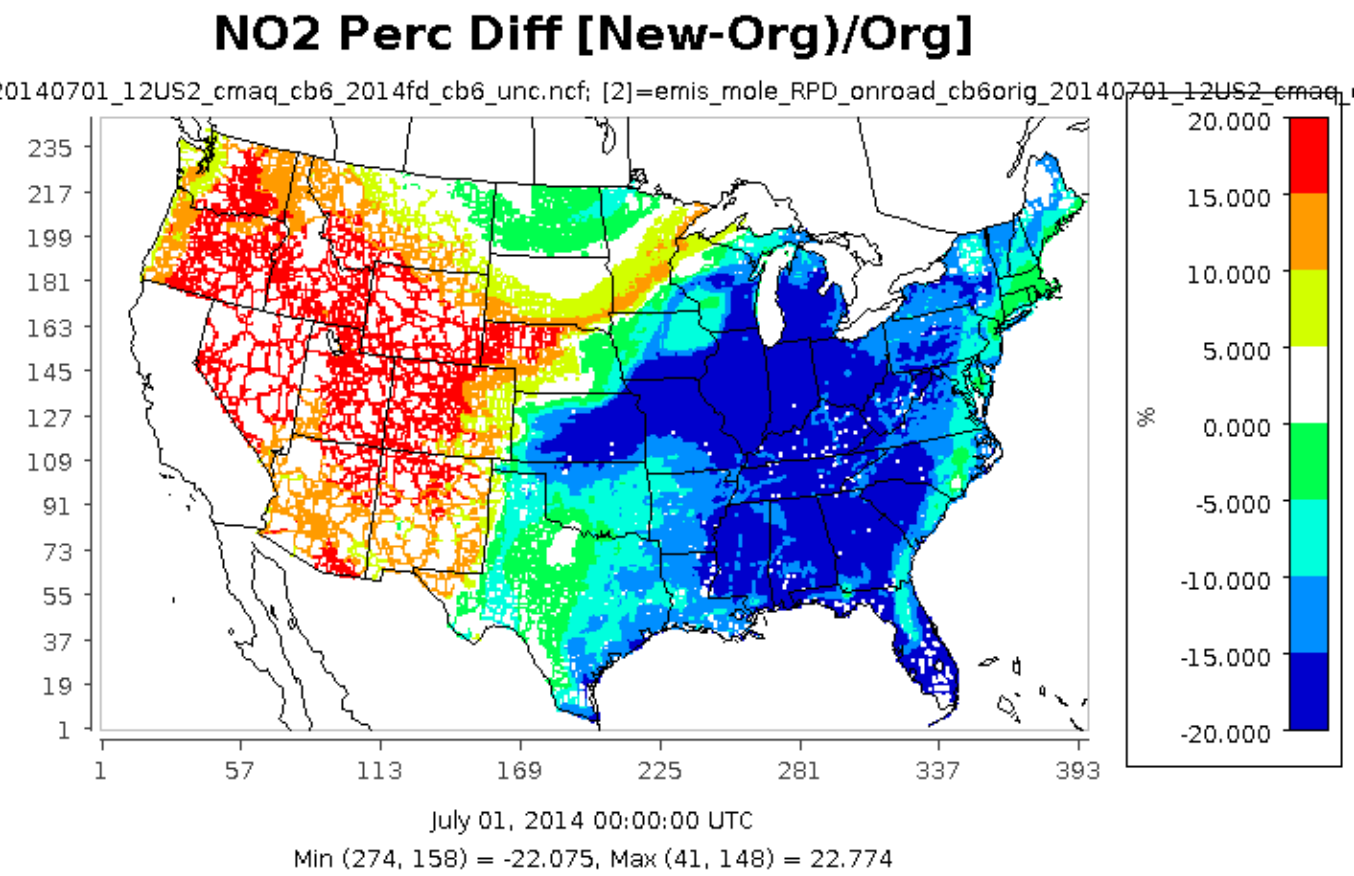
The humidity correction equation has been coded into the latest version of SMOKE-MOVES, thus allowing the adjustment to be applied according to hourly changes in humidity instead of seasonal averages

Percent Change on RPD NO_2

January 1, 2014

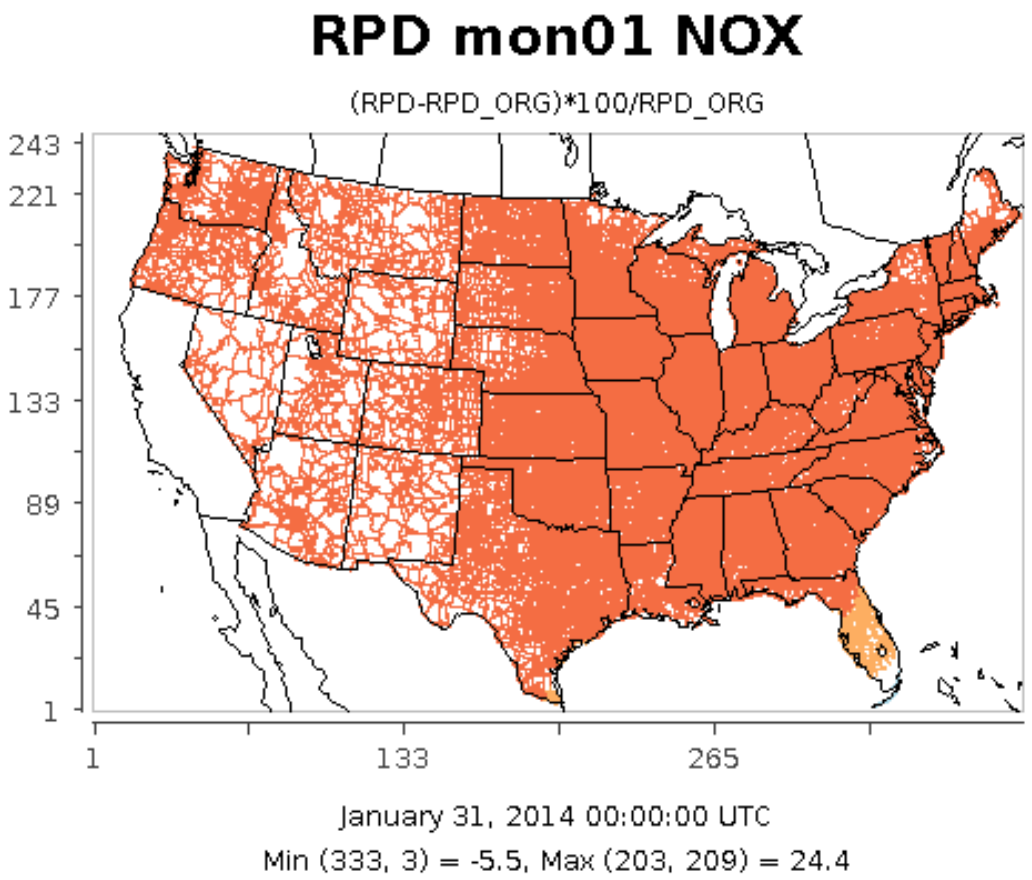


July 1, 2014

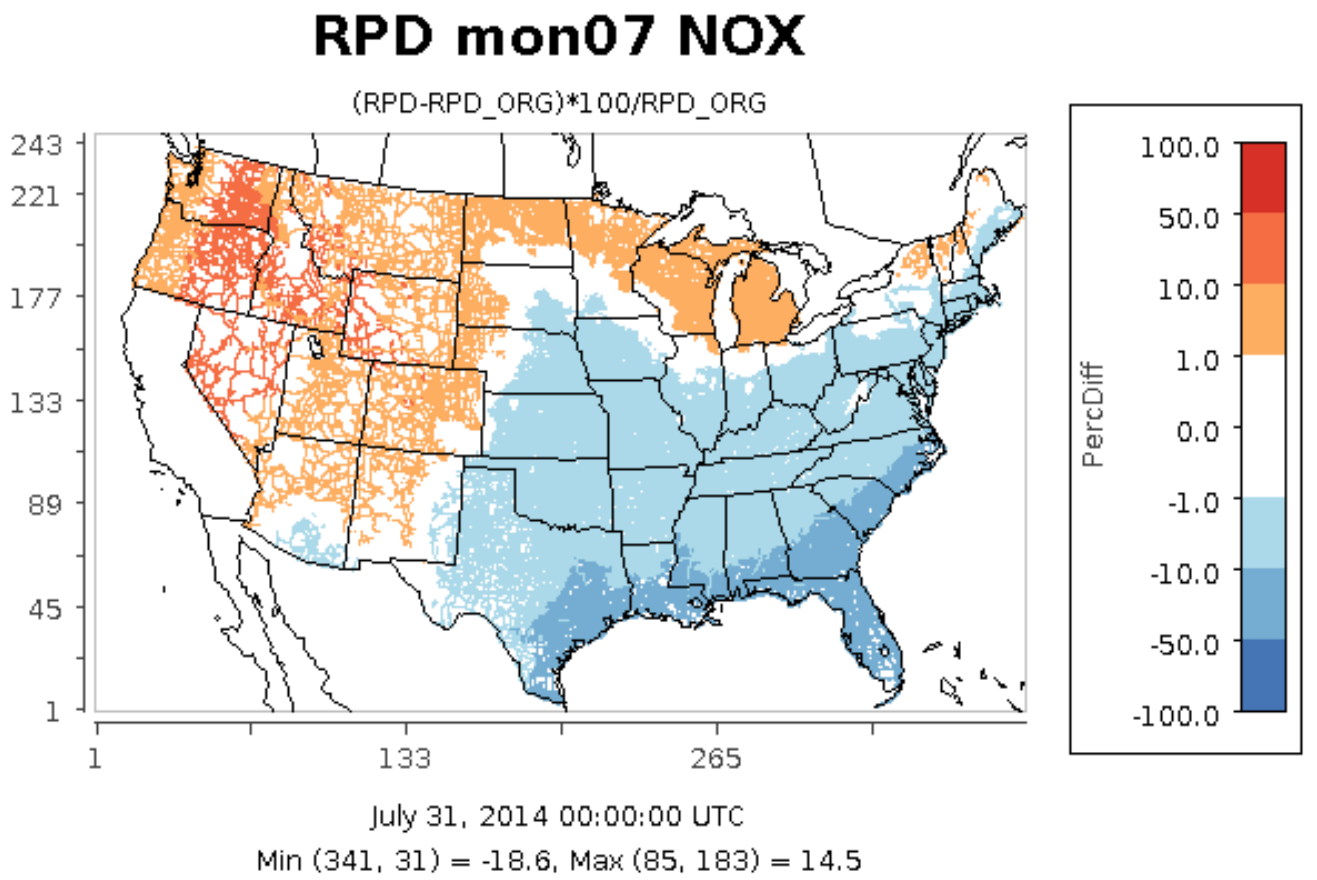


Percent Change in Monthly Total NOx (January and July)

January



July



New Jersey NOx Correction Sensitivity Runs

To assess the true impacts of NOx humidity correction, perform the sensitivity runs based on the following MOVES EFs:

1. **MOVES**

   : Native MOVES EFs without NOx Correction

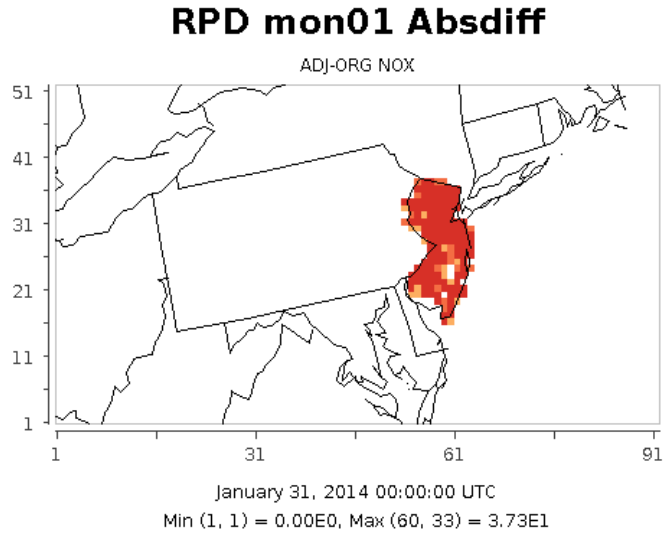
2. **MOVES-NOx**

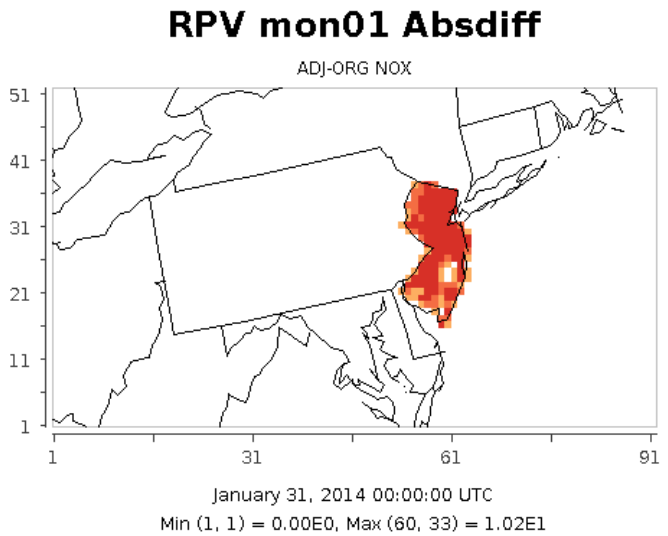
   : MOVES EFs with NOx Correction applied by MOVES

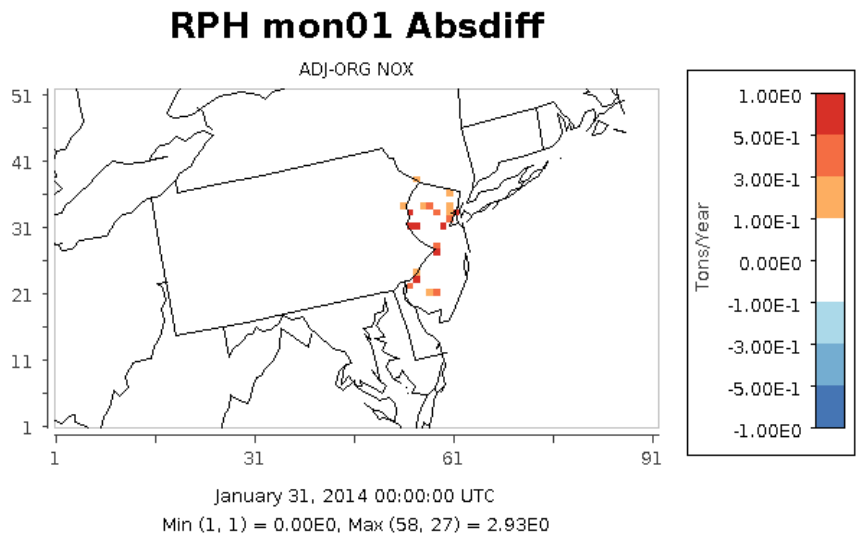
3. **SMOKE-MOVES**

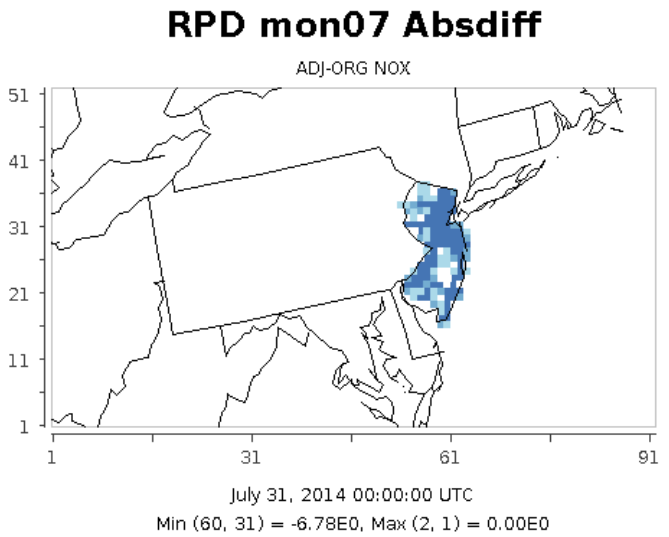
   : MOVES EFs with NOx Correction applied by SMOKE-MOVES

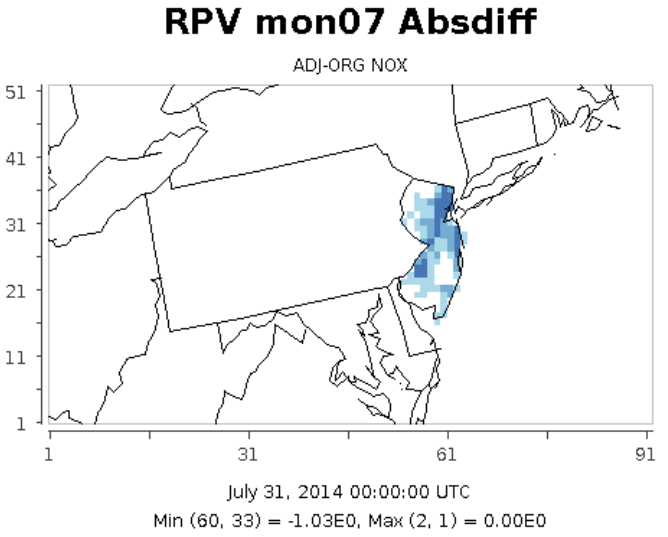
New Jersey NOx Adjustment Sensitivity: (MOVES – SMOKE-MOVES)

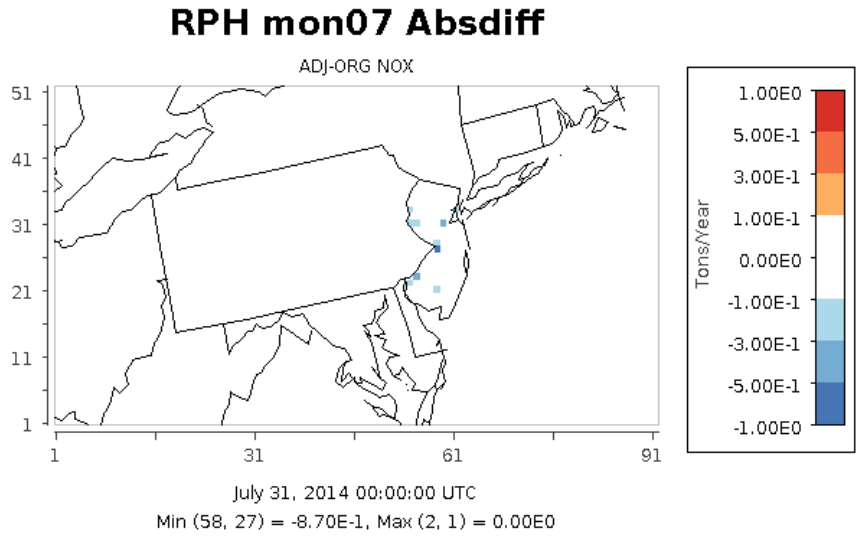












NJ Monthly Total NOx Changes between the Methods

RPD	MOVES (tons/month)	MOVES-NOx (tons/month)	MOVES-NOx Perc. Diff. (%)	SMOKE-MOVES (tons/month)	SMOKE-MOVES Perc. Diff. (%)
January	3,590	4,701	31%	4,252	18%
July	4,517	4,961	10%	4,354	-4%

RPV	MOVES (tons/month)	MOVES-NOx (tons/month)	MOVES-NOx Perc. Diff. (%)	SMOKE-MOVES (tons/month)	SMOKE-MOVES Perc. Diff. (%)
January	1,127	1,115	-1%	1,390	23%
July	870	866	0%	832	-4%

RPH	MOVES (tons/month)	MOVES-NOx (tons/month)	MOVES-NOx Perc. Diff. (%)	SMOKE-MOVES (tons/month)	SMOKE-MOVES Perc. Diff. (%)
January	100	114	14%	115	15%
July	128	128	-1%	124	-3%

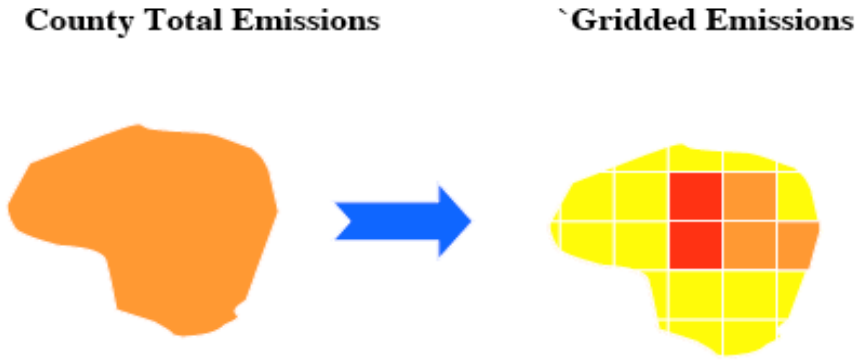
Findings from the NJ NOx Humidity Adjustment

- Significant Impacts to NOx emissions for RPD, RPV and RPH processes
- US western regions with lower humidity will see an increase of NOx
- US eastern regions with higher humidity will see a decrease in NOx
- The Winter drier season (January) shows the significant increases of NOx from all processes
- Summer season (July) shows up to 4% decrease of NOx from all processes
- RPD NOx: MOVES-NOx case shows higher impacts compared to SMOKE-MOVES case
- These findings are limited to New Jersey state

Spatial Allocation using Spatial Surrogates

- Spatial allocation is the process of mapping county-level emissions inventory data to modeling grid cells
- We do this using spatial surrogates - each has a unique code (ID)
  - There are more than 60 surrogates currently used – e.g., Population (100), Total agriculture (310), Railroad Density (261), Offshore shipping (806), Urban unrestricted daily VMT (222), Gas well count (698)
- Surrogates have been created using the Surrogate Tool (from www.cmascenter.org)

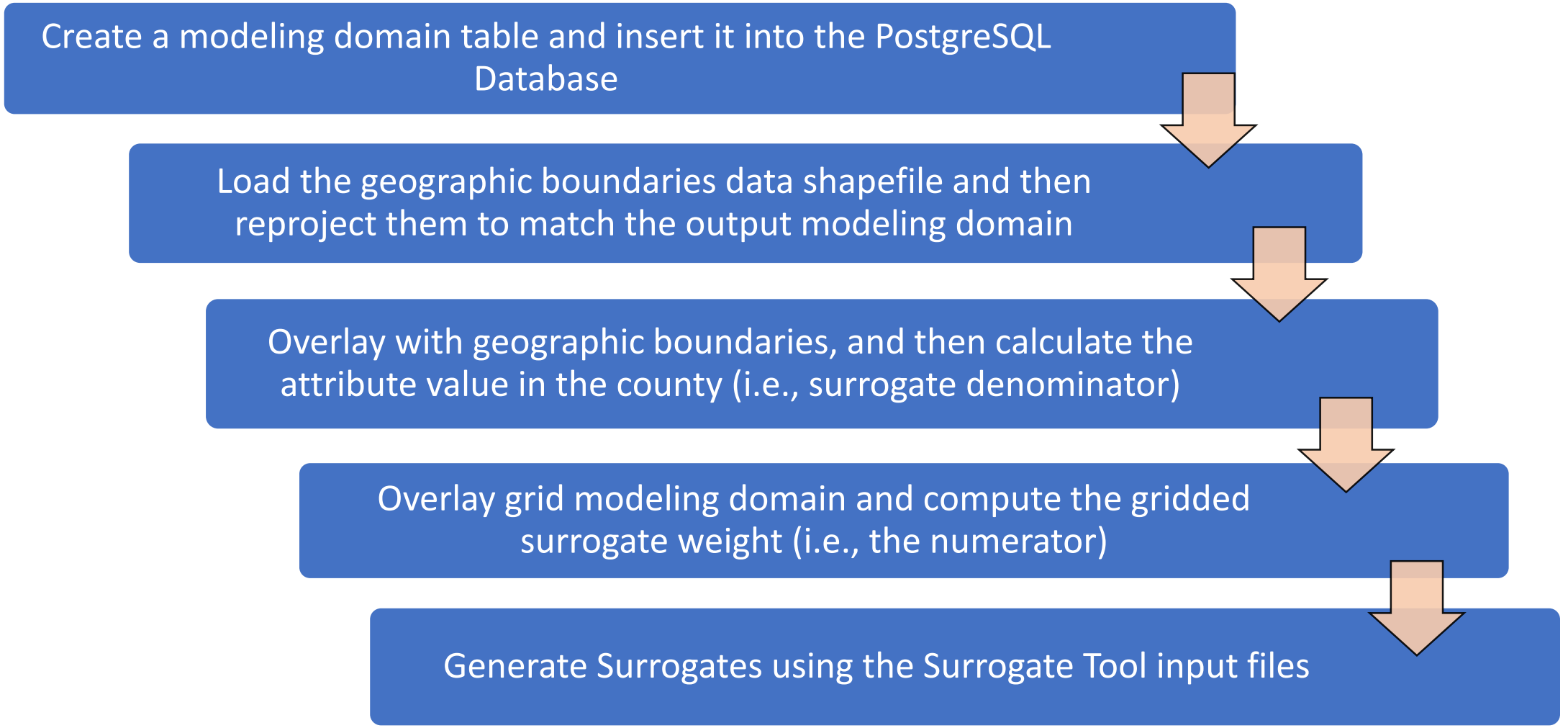
- Value = $\frac{\text{sum of attribute in } \textbf{grid cell}}{\text{sum of attribute in county}}$
- *Values sum to 1 for each county / province*



New: Postgres Spatial Surrogate Tool

- Written in the PostgreSQL and PostGIS database language
- Released on June 30, 2019
- Download from CMAS Center Spatial Allocator Github Repository
  https://github.com/CMASCenter/Spatial-Allocator
- PostgreSQL uses a 3-tier hierarchy for data storage: database, schema, and table. A single query can access multiple tables and multiple schemas, but only one database.
- Requires Read/Create/Update/Insert access for databases
- Supports multicore-Processing for Multiple Jobs running in parallel

Steps performed in the PG Surrogate Tool



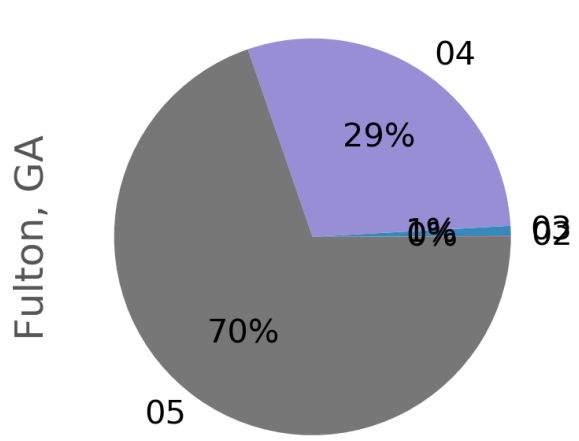
SMOKE v4.7 Public Release

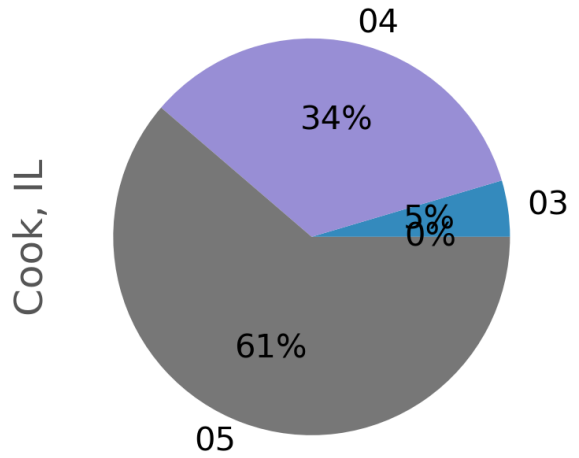
- Plan to release in 2019
- Average Speed Distribution
- NOx Humidity Correction
- A few bug fixes and minor updates
- Future Updates
  - New Rate-Per-Start (RPS) Process
  - New Off-network Idling (ONI) Process

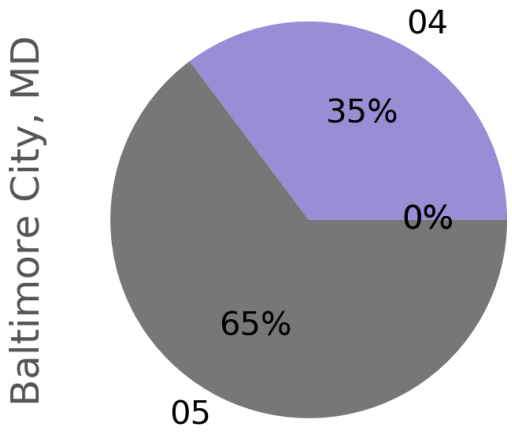
Acknowledgement

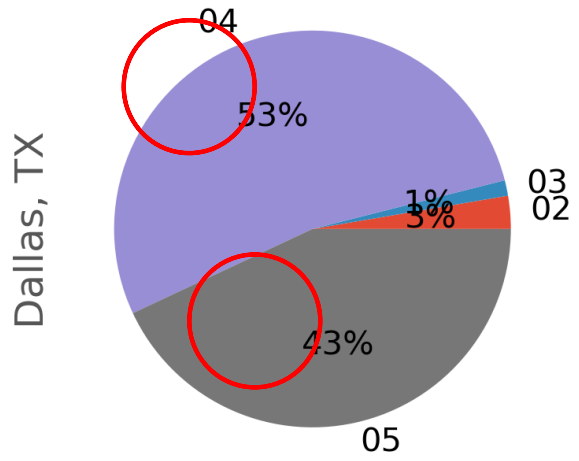
- U.S. EPA Office of Air Quality Planning and Standard (OAQPS)
- U.S. EPA Office of Transportation Air Quality (OTAQ)
- U.S. EPA Office of Research Development (ORD)

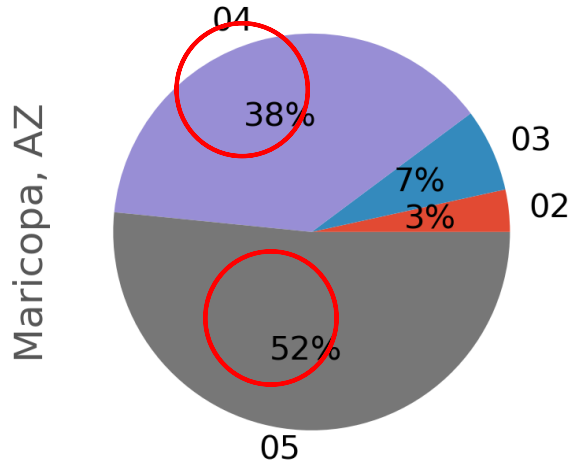
Road Types Distribution by Region

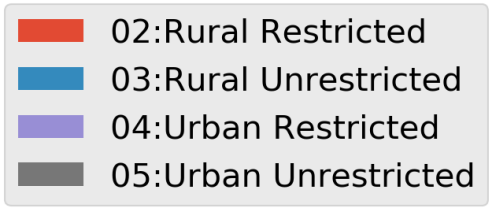












Average Speed by Road type

Urban Unrestricted ASD by SCC (Weekday=5; Hour =18)