NOAA National Air Quality Forecasting Capability (NAQFC)
Community Emissions Testbed (NCET) Project

Meteorology-induced Emissions Coupler, CMAQ-MetEmis, Development

B.H. Baek[1], Siqi Ma[1], Carlie Coats[2], Chi-Tsan Wang[1] and Daniel Tong[1]

[1] Center for Spatial Information Science and System (CSISS), College of Science, George Mason University

[2] Institute for the Environment, University of North Carolina at Chapel Hill

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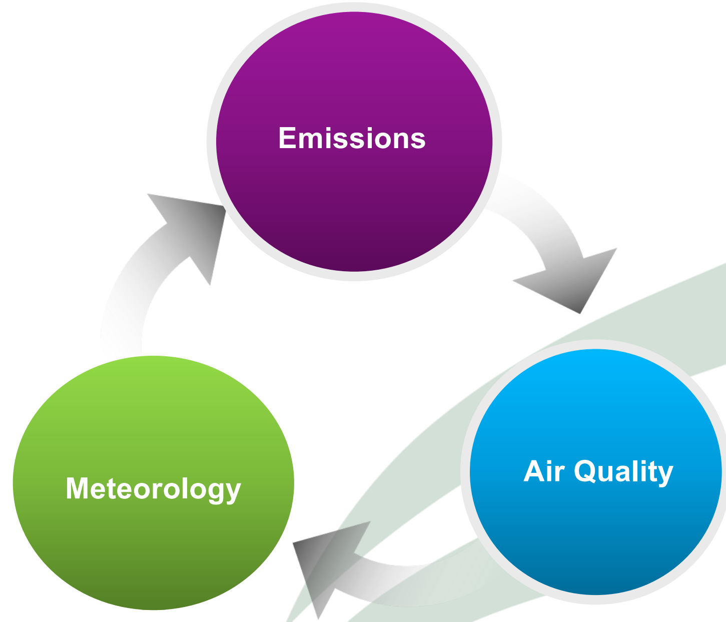
Fully Coupled AQM System

Coupling Meteorology-Induced Emissions with CTM

1. Biogenic
2. NH_3 Bi-directional
3. Lightning NOx
4. Sea salt
5. Windblown Dust
6. Plume Rise for Point
7. **Onroad Mobile**
8. Confined Livestock Wastes
9. Residential Heating



Motivation

Development of fully-coupled Weather-aware Emissions with CTM

- **Meteorology-induced Emissions Sources**:
  - Mobile emissions from MOVES (Motor Vehicle Emission Simulator)
  - Agricultural livestock waste emissions
  - Residential heating-related emissions
- **Technical Challenges:**
  - Complex, Slow and Computationally Expensive
  - Required the detailed meteorological dependency information
- **CMAQ-MetEmis**: Developing the simple and quickest way to process these **Met**eorology-induced **Emis**sions (**MetEmis**) inline with CMAQ for National Air Quality Forecasting Capability (NAQFC).
  - Updated the SMOKE modeling system to generate new pseudo-layered temperature-specific pregridded emissions development
  - Developed a new coupler module [CMAQ-MetEmis] for **MetEmis** sources within CMAQ v5.3.2.

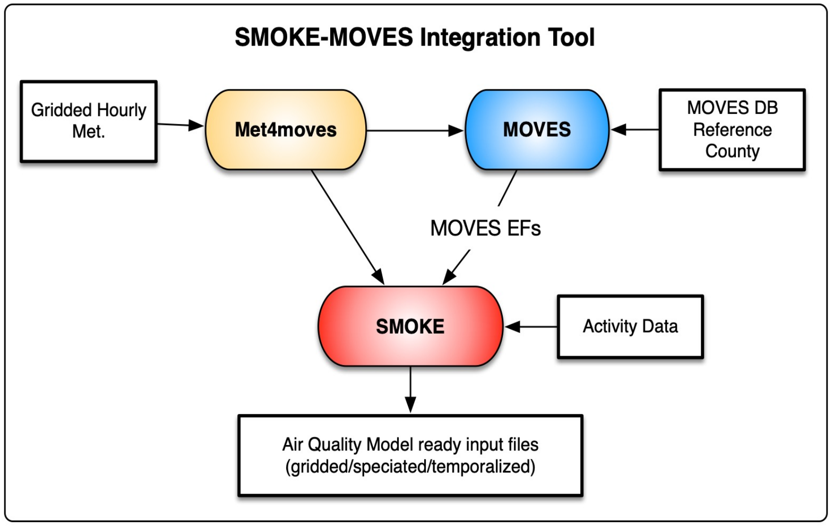
SMOKE-MOVES Integration Tool

: Enabling users to develop offline weather-aware onroad mobile emissions

SMOKE (Sparse Matrix Operator Kerner Emissions) **Modeling System**

MOVES Emission Factors Lookup Tables

- **Rate-Per-Distance** [grams/miles]
  Exhaust and most evaporative emissions that happen on real roadtypes
  Sorted By SCC (=vehicle/road/process), 16 Speed Bins and Ambient Temperature Bins
- **Rate-Per-Vehicle** [grams/vehicle/hour]
  Exhaust and most evaporative emissions that occur off-network
  Sorted By SCC, Hour of day and Ambient Temperature Bins
- **Rate-Per-Hour** [grams/hour]
  APU operation and extended idling processes
  Sorted By SCC, Ambient Temperature Bins
- **Rate-Per-Profile** [grams/vehicle/hour]
  Vapor venting evaporative emissions that occur off-network
  Sorted By SCC, Hour of day and Min/Max Temperatures



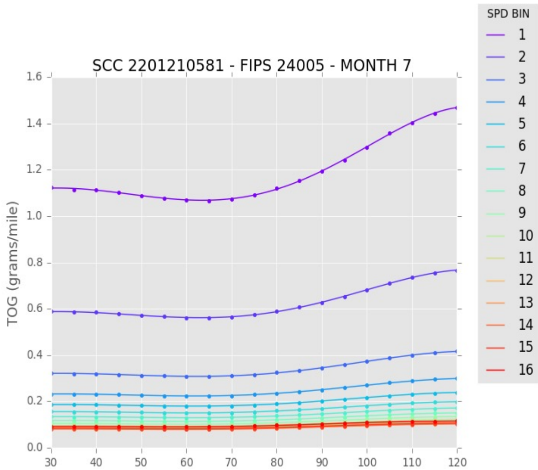
More modes are expected to capture their own process at best:

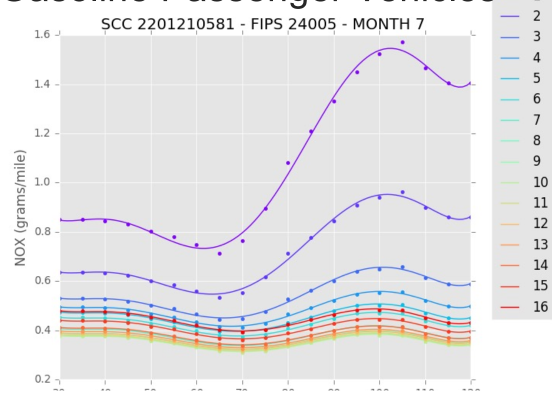
- **RatePerStart [RPS]**: Engine start exhaust emissions
- **Off-Network Idling [ONI]**: Off-network extended idling exhaust emissions

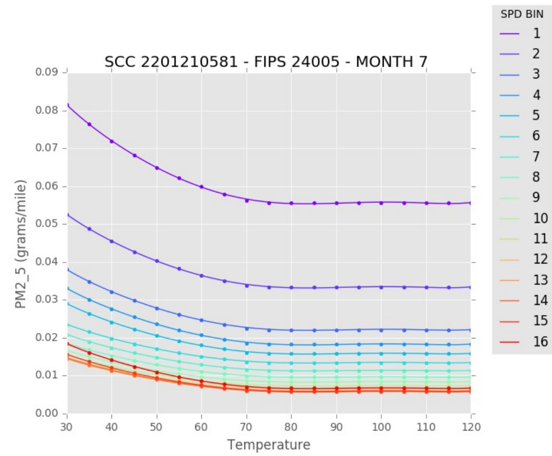
MOVES Emissions Factors Lookup Tables

RPD from Urban Unrestricted Access
All Exhaust, Evaporative, Brake and Tire

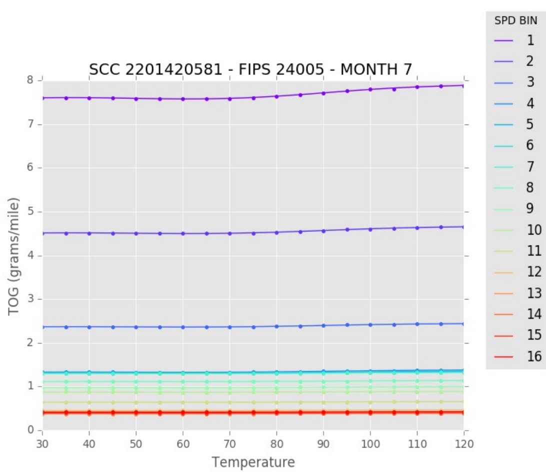
Gasoline Passenger Vehicles

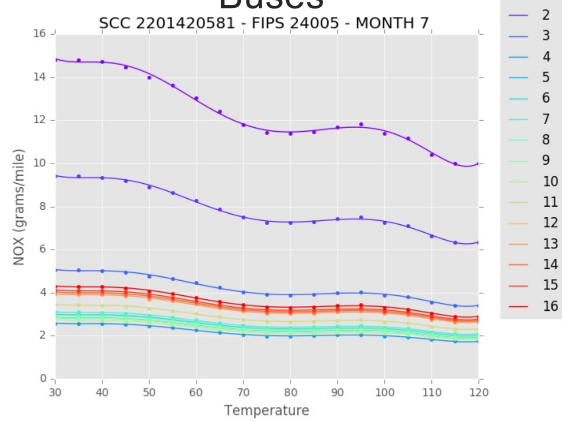


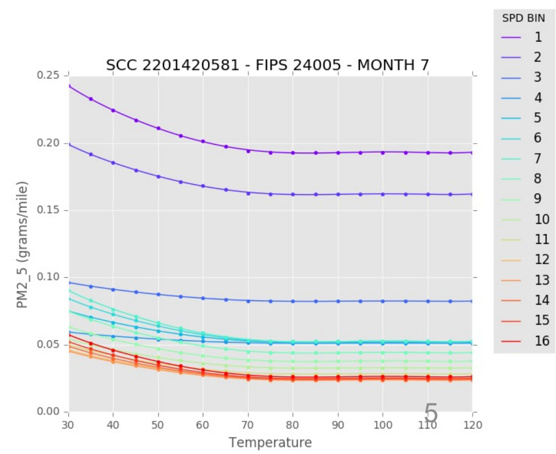




Buses



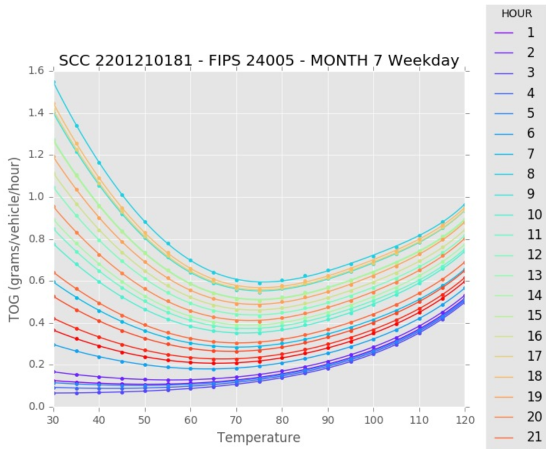


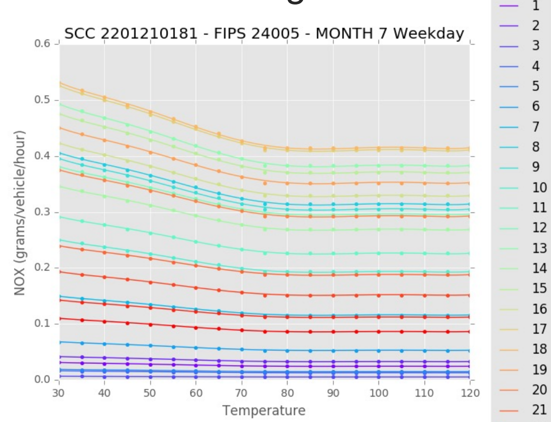


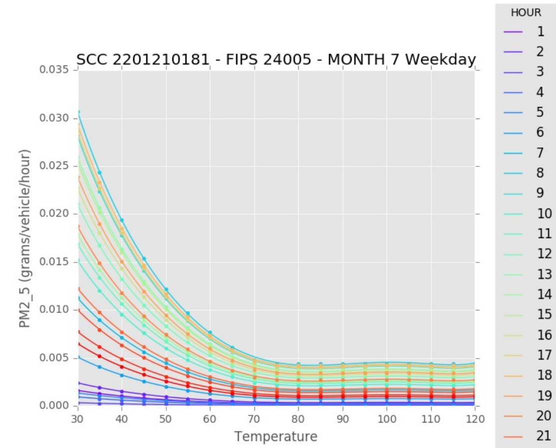
MOVES Emissions Factors Lookup Tables

RPV Off-network : All Exhaust, Evaporative, Brake and Tire

Gasoline Passenger Vehicles







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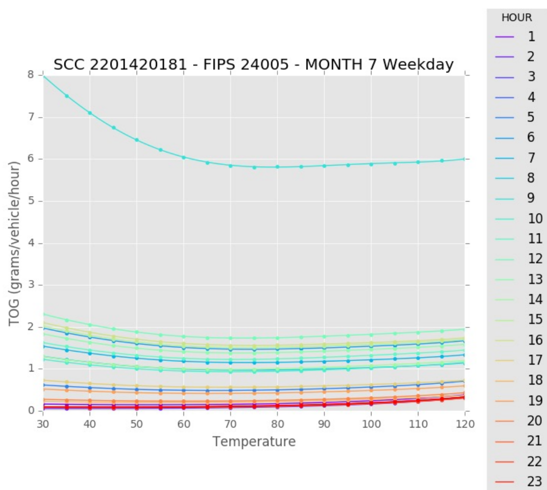
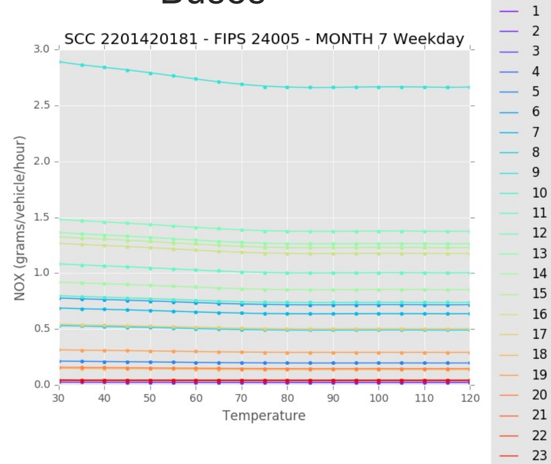
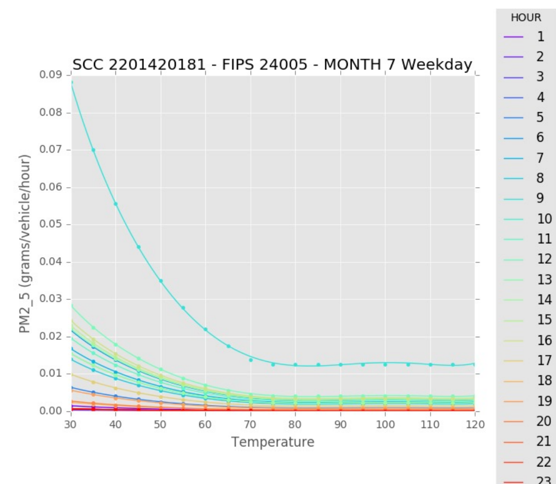






Current SMOKE-MOVES Integration Runs

- **315** Reference Counties for Continental U.S. Modeling Domains with Two Fuel Months per Each Reference County (Based on NEI 2017v1 Modeling Platform)
  - Over 330 MOVES Lookup Tables to process per day
- Size of MOVES Lookup Tables:
  - **RPD: 85-150MB (~66.7GB), RPV: 28-86MB (~36GB), RPP: 15-50MB, PRH: Less than 1MB**
- **Computational Time**

Sectors	Computing Time	RAM Memory Usages
RPD	90 mins/day	10-20 GB
RPV	40 mins/day	5-10 GB
RPH	5 mins/day	2 GB
RPP	20 mins/day	< 1 GB

SMOKE: Temp-Pregridded Emissions (MetEmis_TABLE)

Pseudo-layered Pre-gridded Hourly Emissions (EMIS_TABLE)

- **SMOKE Movesmrg (MOVES EF Lookup Tables)** Enhancement:

  :Optionally can estimate a temperature-bin gridded hourly emissions (**`METEMIS_TABLE`**) and store them into into pseudo-layers using SMOKE. *Not Applicable for RPP yet.*

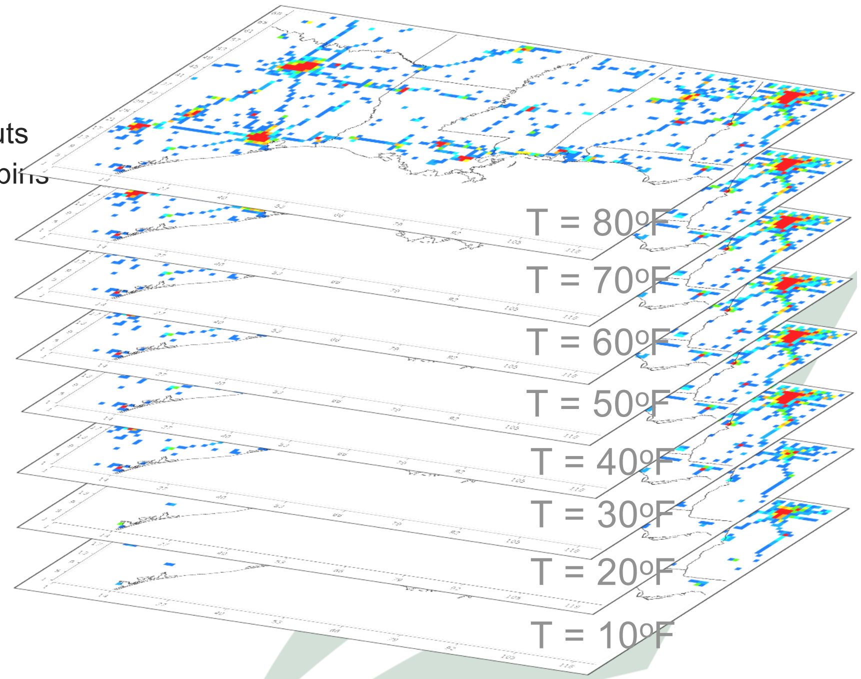
  :Generate **the identical results** with MCIP gridded meteorology inputs using the same liner interpolation method between two temperature bins

- **Advantages:**
  - Monthly MOVES_TABLE files for SMOKE and CMAQ
    - Same weekly pattern of VMT
    - Same seasonal MOVES Emission Factors
    - Time-independent Gridding & Speciation
  - No need of MCIP meteorology files

- **Performance**: Significant improvement on SMOKE Processing: NEI 2017v1 Modeling Platform 12US1 [31 days]
  - Current **Movesmrg**: 31-days RPD outputs

    [~1.5 hours/day | total over 50 hours for 31 days]
  - New **Mrggrid**: **1.5 hours** for 31 days

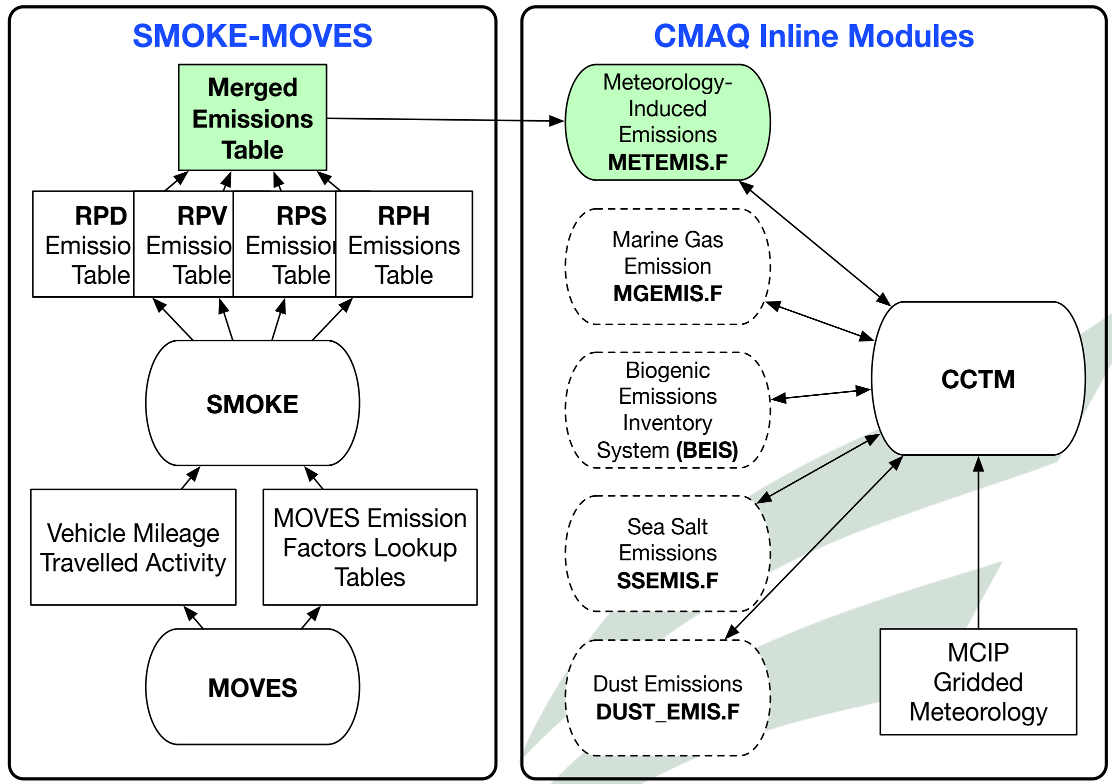
    [**4~5 mins/day**]: Faster with OpenMP Mrggrid



CMAQ-MetEmis Coupler Development

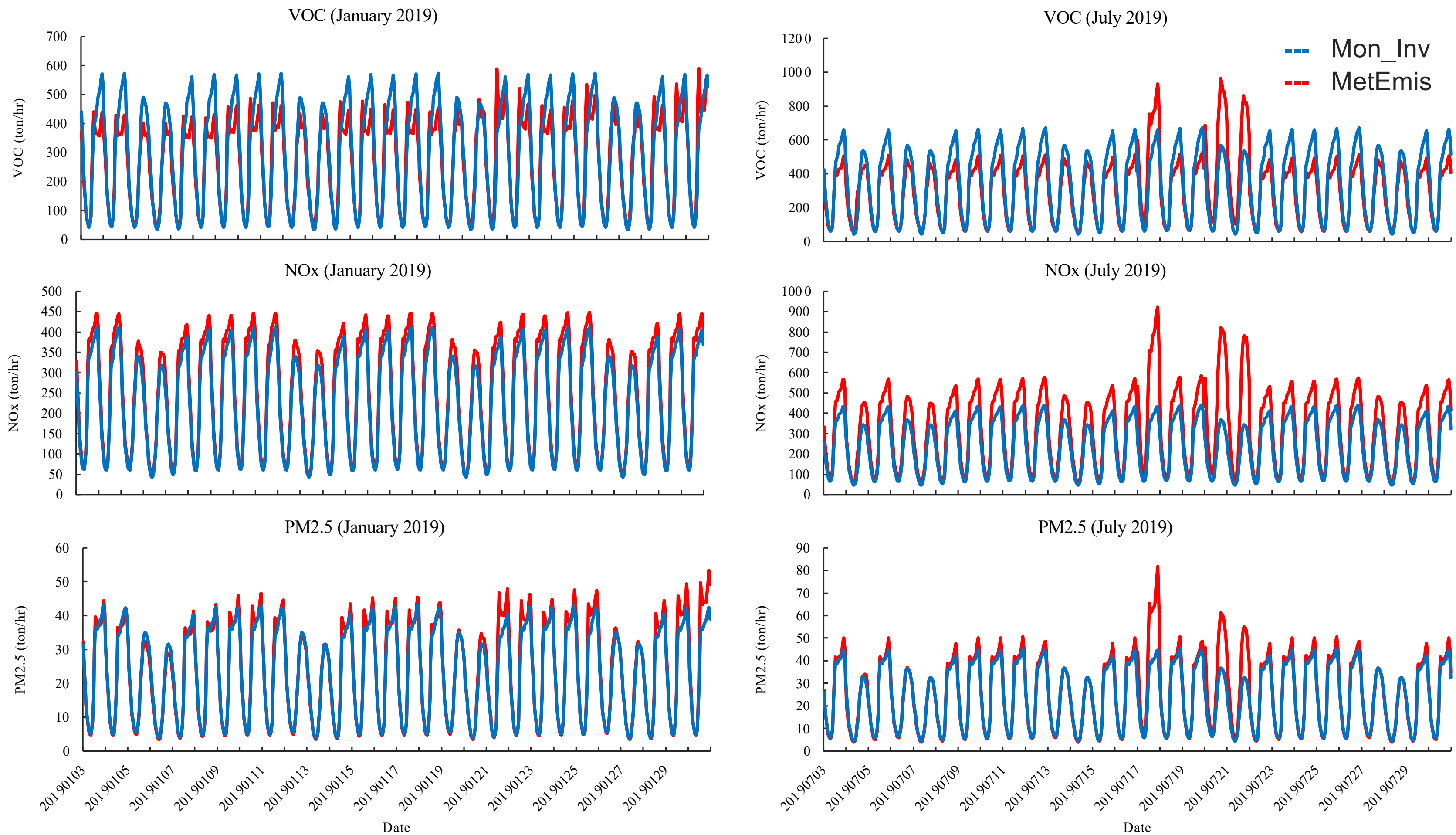
Direct Coupling between SMOKE and CMAQ

- **No need to run multiple mobile sectors (RPD, RPV, RPH) but the merged METEMIST_TABLE is all needed**
- Linear interpolation between temp-bins emissions based on a gridded temperature at 2 meter from METCRO_2D.
- Meteorology-induced Emissions Coupler [**MetEmis.F**] module applications
  - Onroad mobile sources
  - Livestock waste NH_3 sources (future)



Meteorology Impacts on Emissions

- Temporal Allocation Profiles used in SMOKE-MOVES define the majority of temporal hourly emissions



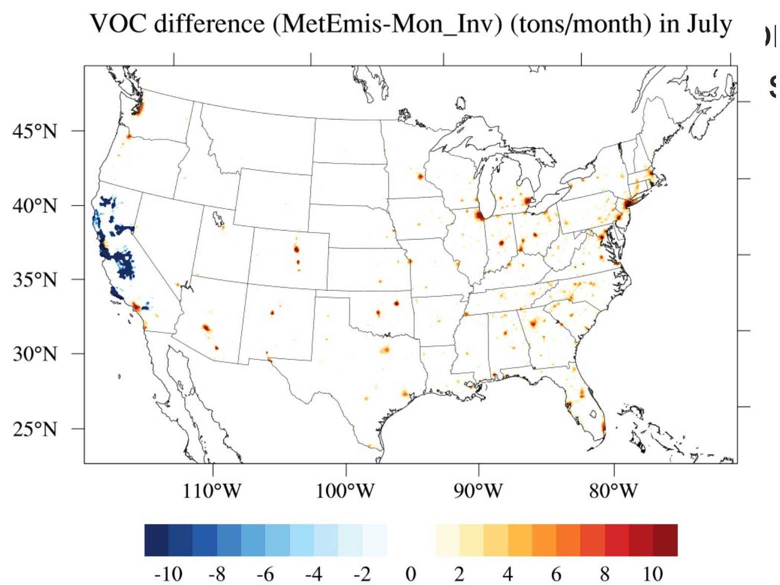
Meteorology Impacts on Emissions

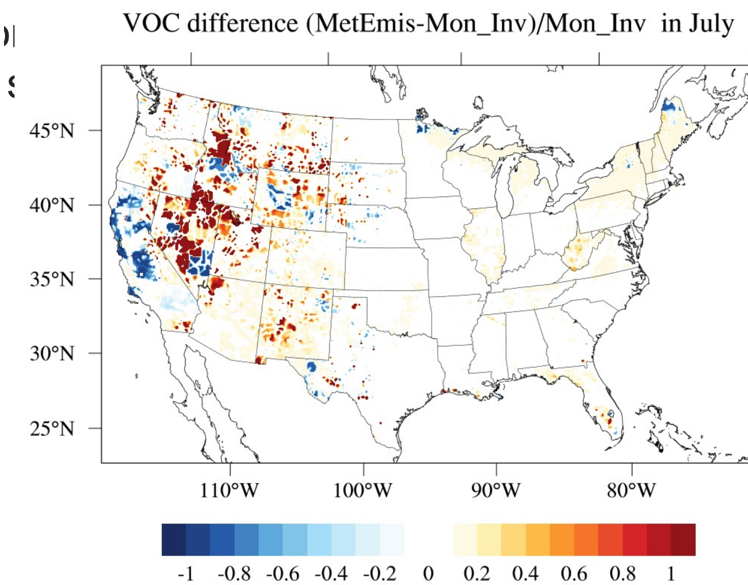
MOVES Monthly Inventory vs. SMOKE-MOVES MetEmis

(U.S. EPA NEI 2017 v1 Emission Modeling Platform)

AbsDiff : MetEmis-Mon_Inv

Ratio = (MetEmis-Mon_Inv)/Mon_Inv





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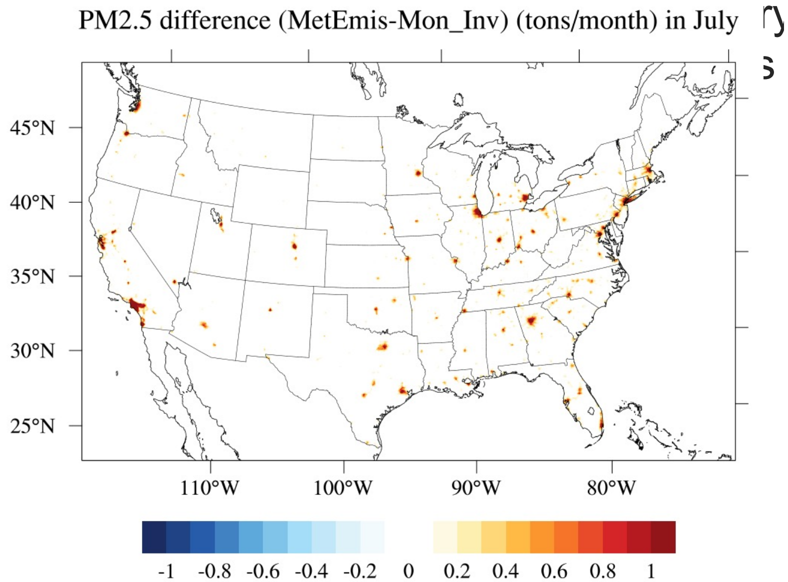

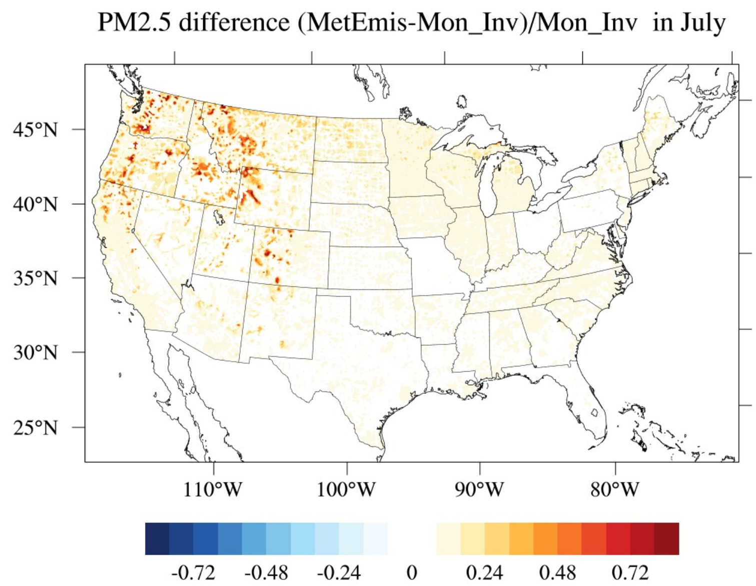

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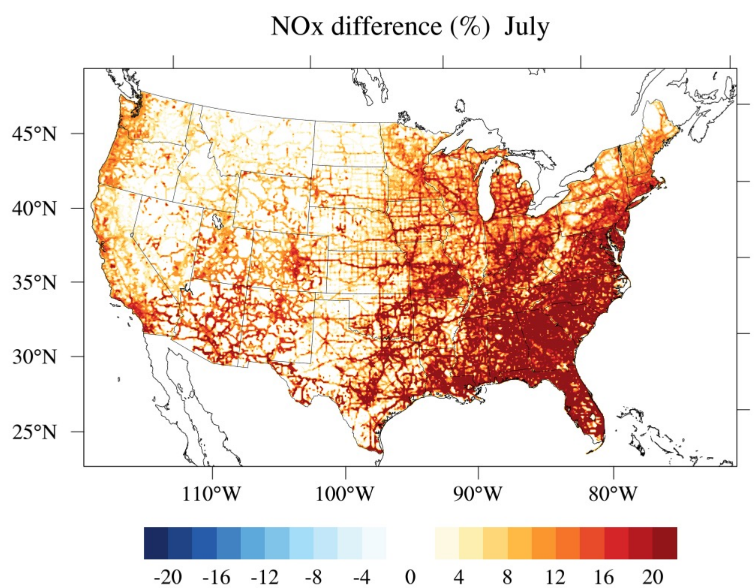

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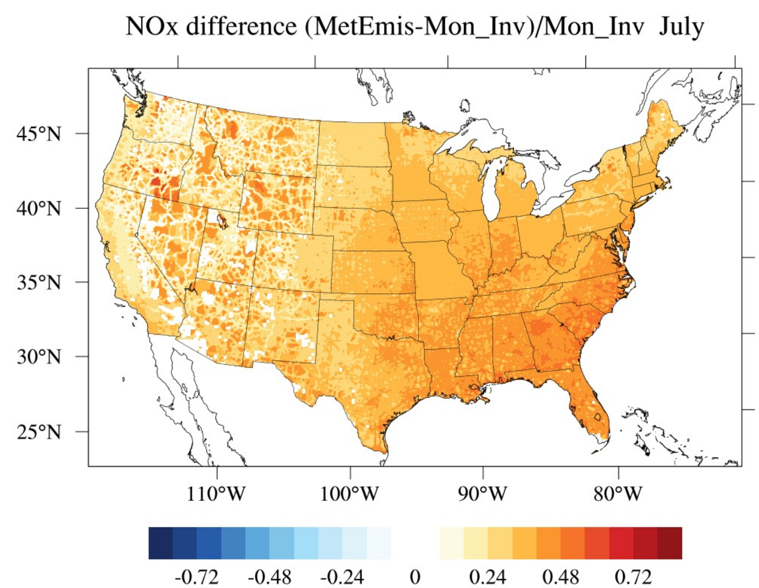
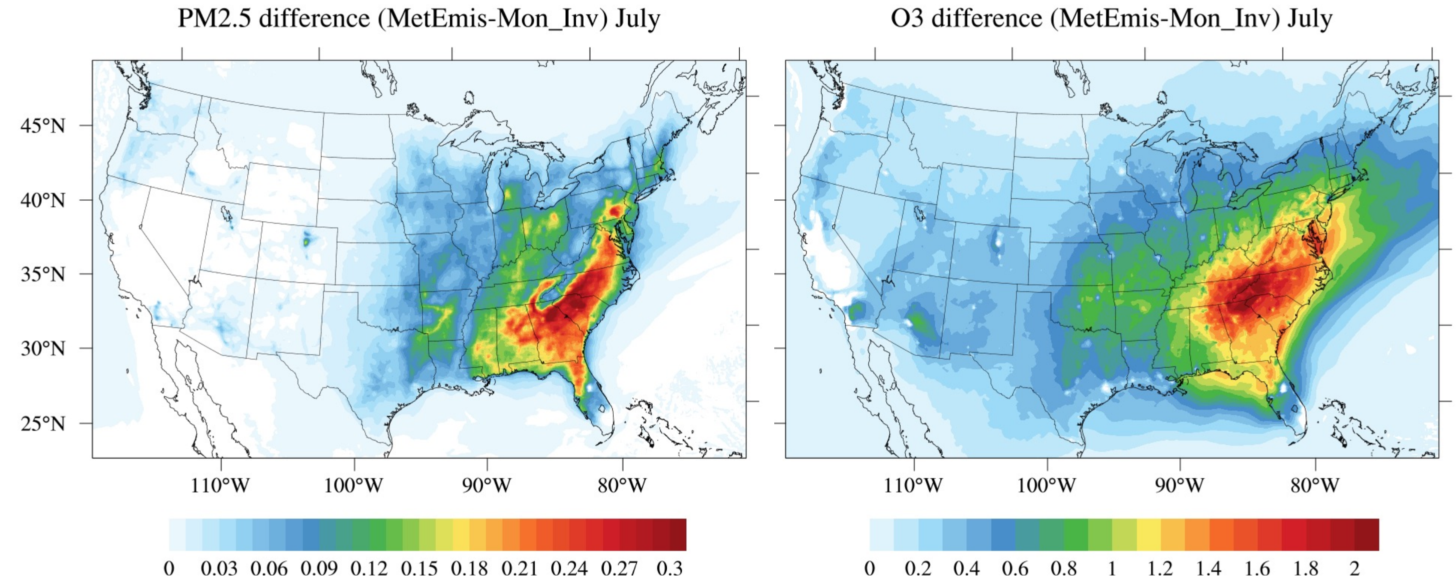
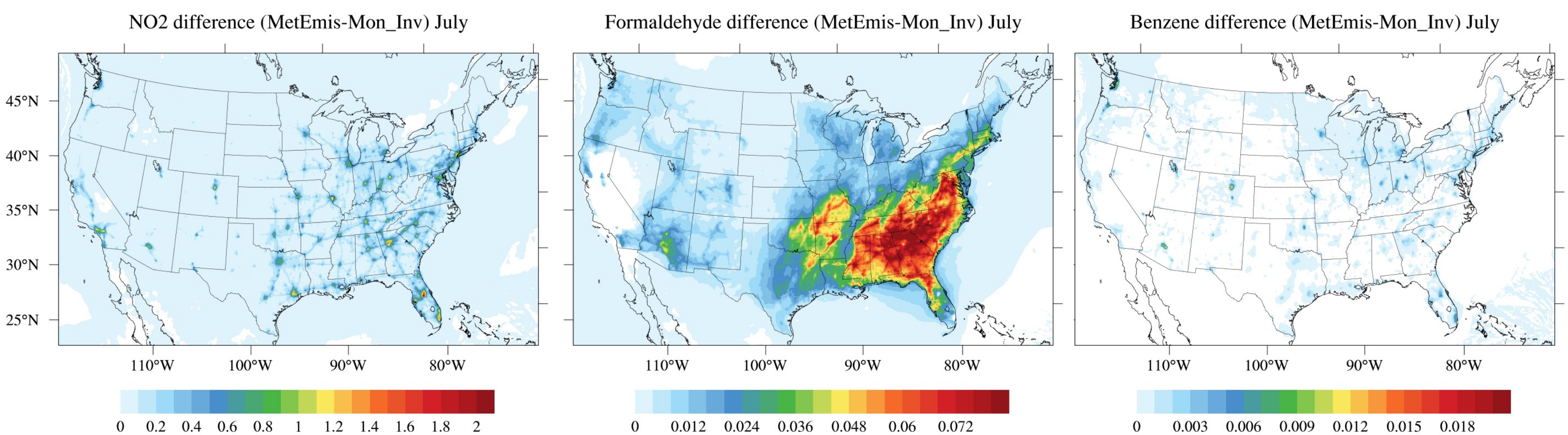


CMAQ O_3 & $PM_{2.5}$

- NOx increase (due to humidity correction) and VOC increase over Southeastern U.S. impacts the most to O_3 and $PM_{2.5}$





CMAQ O_3 & $PM_{2.5}$ Hourly Conc. Difference

Metropolitan (Boston, NYC, Philadelphia, D.C., Atlanta, Dallas, Houston, LA)

O_3 (ppb)	Month	Boston	NYC	PHL	D.C.	Atlanta	Dallas	Houston	LA
Min	January	-0.59	-0.27	-0.52	-0.39	-0.73	-0.40	-0.42	-0.73
Max	January	0.78	0.81	0.78	0.77	0.36	0.31	0.26	0.12
Average	January	-0.05	0.03	0.00	-0.01	-0.05	-0.01	-0.05	-0.15
Min	July	-1.01	-1.02	-0.55	-0.57	-0.79	-1.19	-0.54	-0.83
Max	**July**	**2.77**	**2.65**	**2.98**	**3.32**	**4.31**	**2.13**	**1.98**	**0.40**
Average	July	0.47	0.74	0.95	1.02	1.25	0.48	0.33	-0.10

$PM_{2.5}$ (ug/m^3)	Month	Boston	NYC	PHL	D.C.	Atlanta	Dallas	Houston	LA
Min	January	-0.11	-0.06	-0.05	-0.12	-0.15	-0.02	-0.04	-0.32
Max	January	0.57	0.44	0.52	0.67	0.70	0.32	0.21	0.86
Average	January	0.08	0.08	0.08	0.09	0.09	0.05	0.03	0.01
Min	July	-0.12	-0.12	-0.05	-0.07	-0.11	-0.05	-0.10	-0.23
Max	July	0.70	0.53	0.52	0.45	0.78	0.23	0.44	0.30
Average	July	0.10	0.05	0.09	0.12	0.19	0.04	0.04	-0.03

Preliminary Results

- Successfully coupled the complex onroad mobile emissions that are sensitive to local meteorology with CMAQ for NAQFC applications.
- Applicable for other meteorology-sensitive emission sources like confined livestock wastes and residential heating
- Most temporal allocations of onroad mobile emissions are driven by the VMT temporal allocations and minor impacts by local meteorology.
- No significant local meteorology-induced onroad mobile emissions impacts on local O_3 and $PM_{2.5}$ concentrations.
  - Summer: > 4 ppb O3 and <1 ug/m^3 $PM_{2.5}$ changes
  - Winter: < 1ppb O3 and <1 ug/m^3 $PM_{2.5}$ changes
- **Hypothesis**: Finer grid cell over urban area where mobile emissions contributions are the biggest could show the most sensitive to the local meteorology-induced emissions.
- **Next step**: NAQFC meteorology-induced emissions impact studies based on a combination of onroad mobile, confined livestock wastes (NH_3 and VOC) and residential heating (CO, VOC and $PM_{2.5}$).

Acknowledgement

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