SMOKE-MOVES

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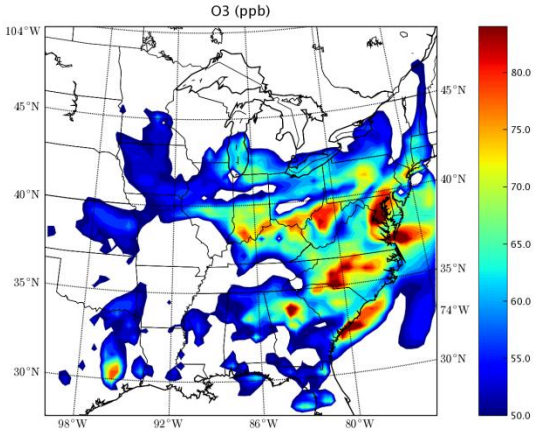
MOVES

SMOKE and Modeling Emissions for AQ

inventory emissions:
ascii
county
inventory pollutants (e.g. NOx, VOC)
annual/monthly

SMOKE

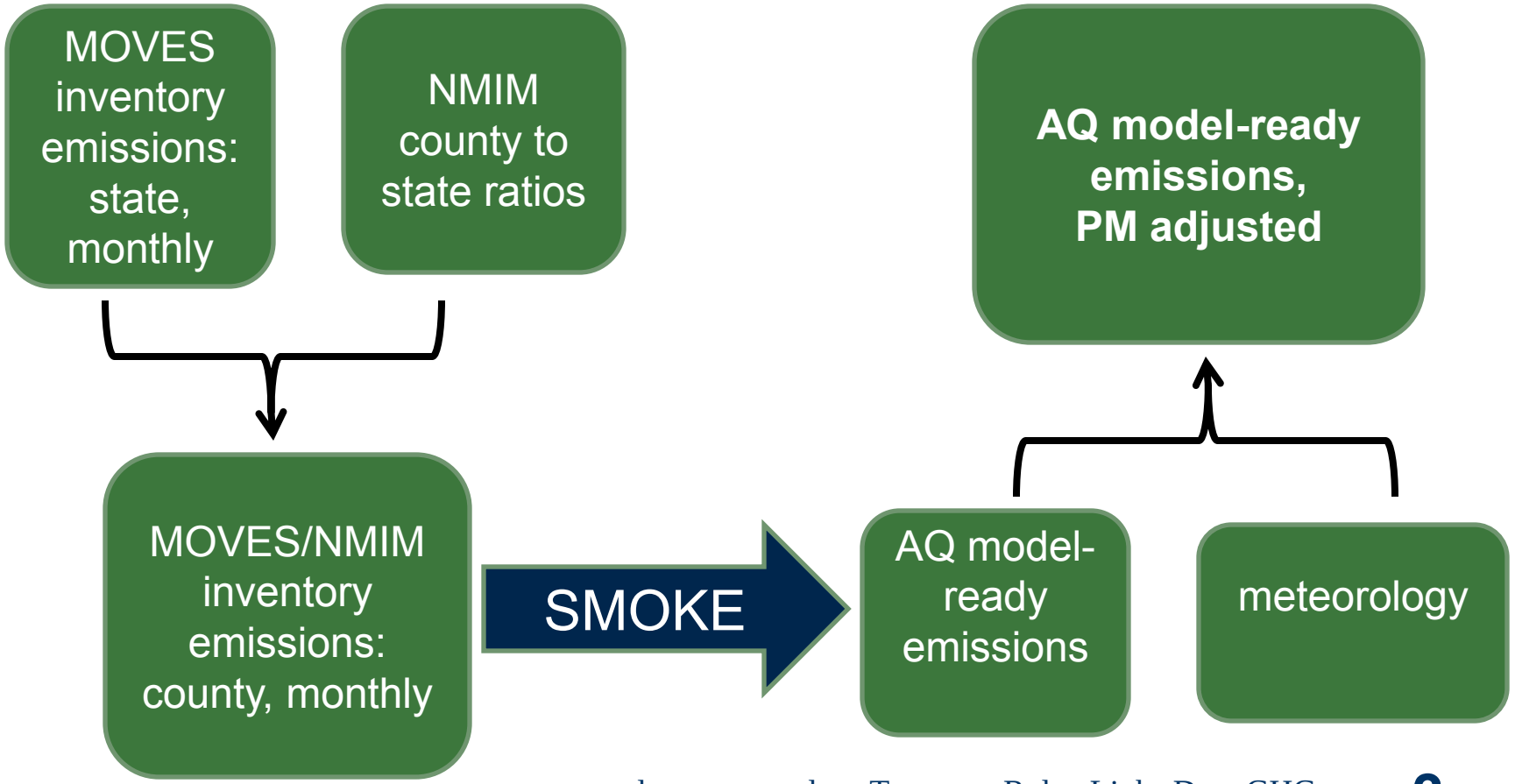
AQ model-ready emissions:
binary
gridded
AQ species (e.g. NO2,NO, HONO, Acetaldehyde, Ethene, ...)
hourly



AQ model

MOVES

SMOKE and MOVES Previous Approach

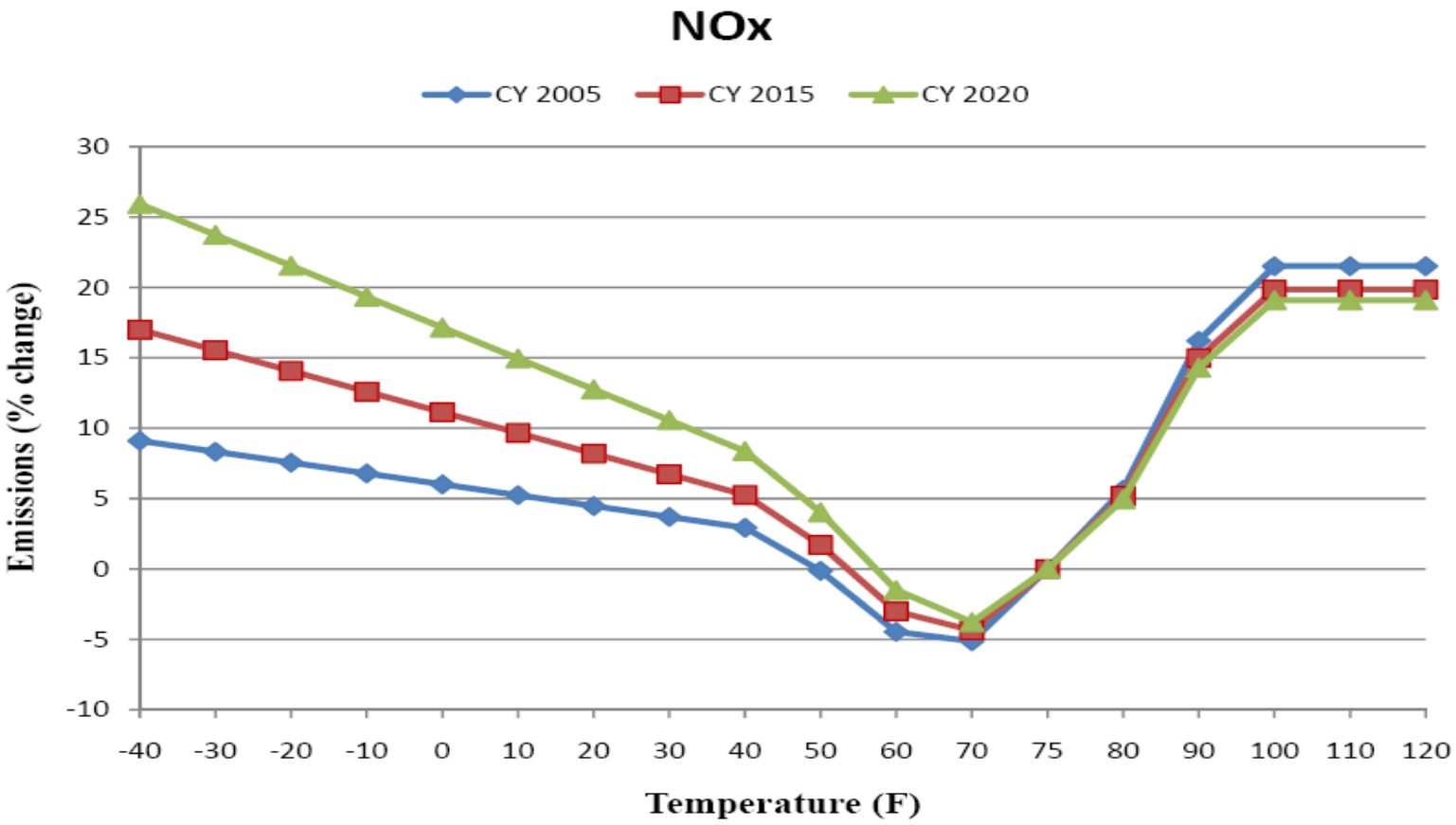


recent regulatory examples: Transport Rule, Light-Duty GHG

Motivation

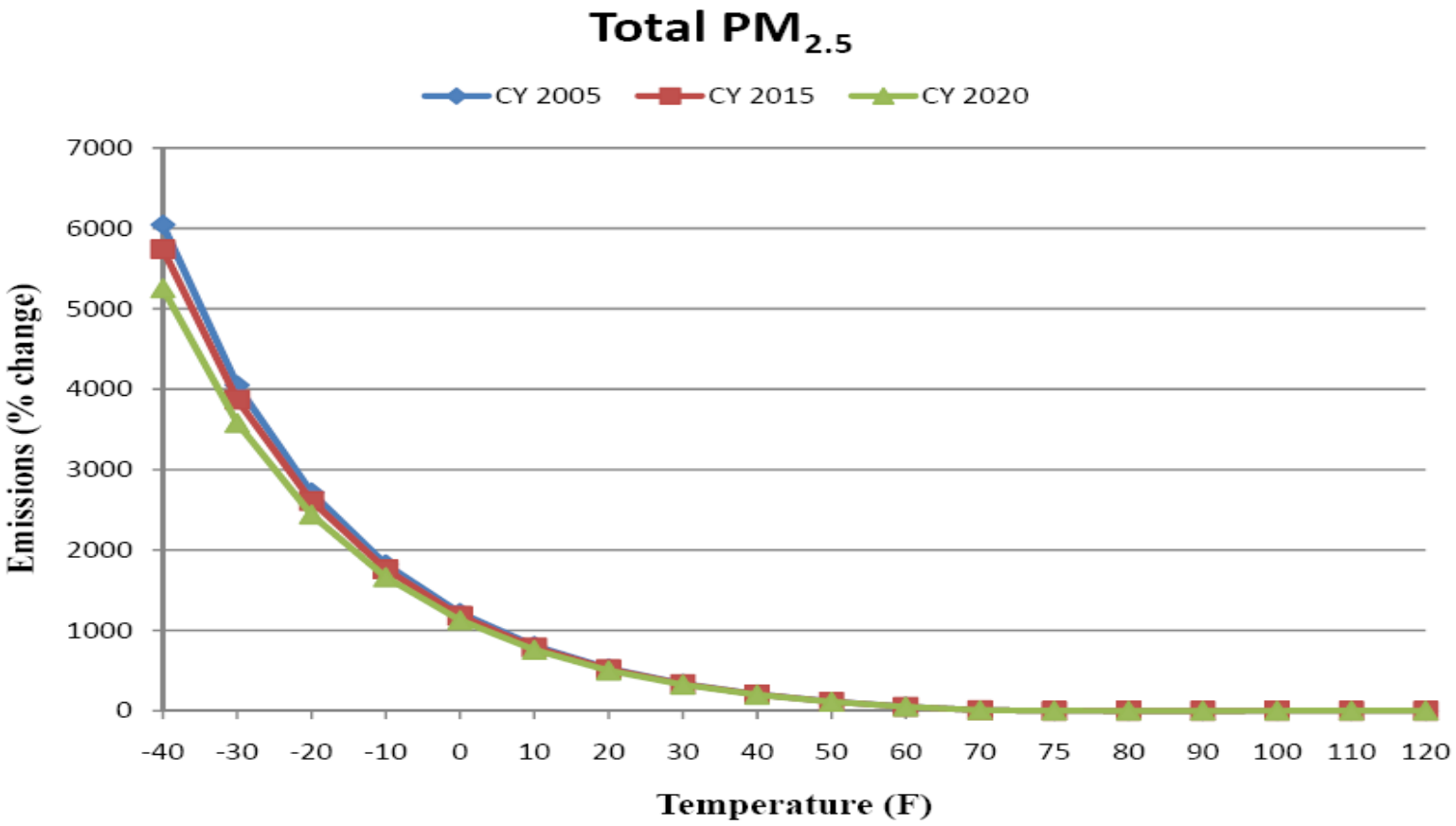
- **More closely integrate MOVES into the emissions modeling process**
  - Automation of the emissions process
  - Previously needed MOVES and NMIM runs for each future year or representative future years
- **Emissions sensitive to temperature**
  - Initially focused on PM
  - See significant T sensitivity for other pollutants
- **Computation considerations**
  - Keep computation demands “reasonable”
  - Representative counties
  - Lookup tables for emission factors

Temperature - Gasoline



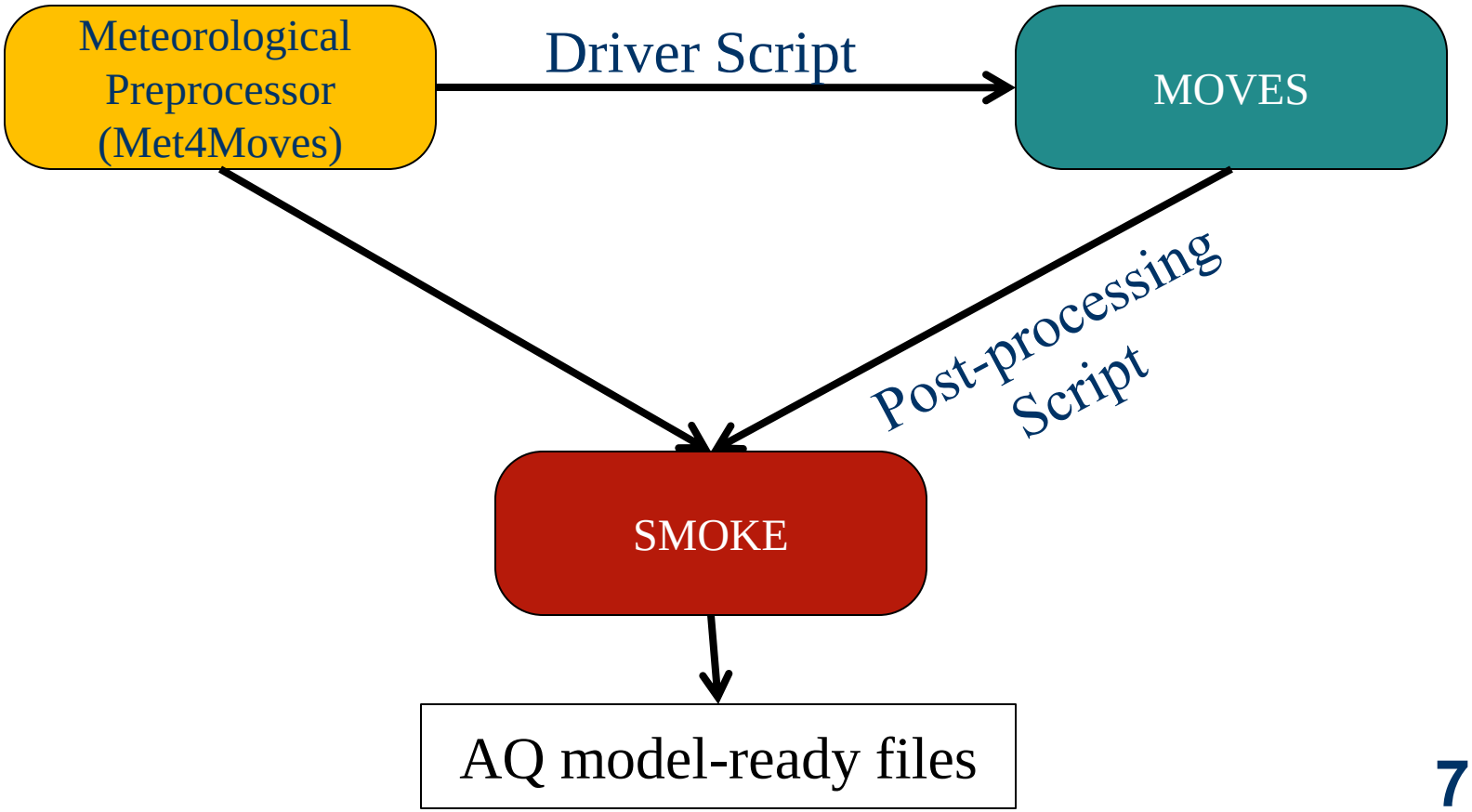
From OTAQ

Temperature - Gasoline



From OTAQ

SMOKE-MOVES Integration Tool



SMOKE-MOVES Overview

- **Met4Moves**
  - Produces temperature ranges, diurnal temperature profiles, and relative humidity (RH) values for specific counties
- **MOVES**
  - Runs series of scenarios for each of the temperature profiles and temperature bins
  - Produces emission factors (EF)
- **SMOKE**
  - Takes EF, activity data (VMT, SPEED, VPOP) and temperature data
  - Produces AQ model-ready emissions

MOVES

Overview: Reference County

- Reduces the computational burden of running MOVES on every county in your modeling domain
- Represent a set of similar counties (i.e., inventory counties) called a county group.
- Key emission rates for the single reference county in MOVES can be utilized to estimate emissions for all counties in the county group through SMOKE.

- *Criteria* : Similar fuel parameters, fleet age distribution and I/M programs.

Overview: Fuel Month

- Similar to the reference county, the fuel month reduces the computational time of MOVES by using a single month to represent a set of months.
- Represent a particular set of fuel properties over the months used in MOVES
- Example: Run MOVES for January, use that run to represent a series of months with similar fuel types (e.g. Oct, Nov, Dec, Jan, Feb, Mar)

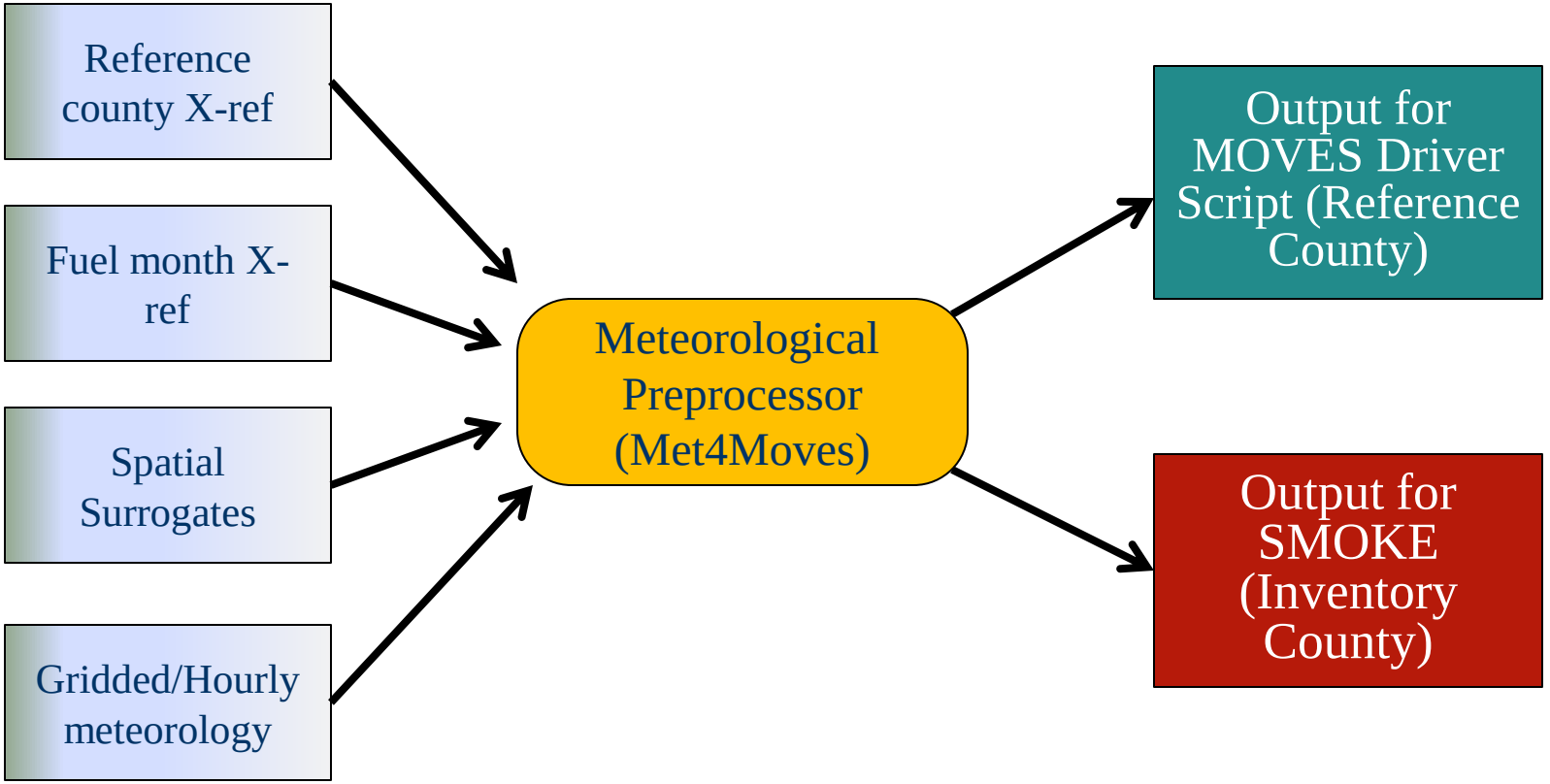
- *Criteria* : Fuel supply data in the MOVES database for each reference county

MOVES

Overview: Emission Processes

- **Rate-per-distance (RPD)**
  - On-roadway emissions
  - Exhaust, evaporative, brake and tire wear
- **Rate-per-vehicle (RPV)**
  - Off-network emissions
  - Exhaust, evaporative
- **Rate-per-profile (RPP)**
  - Off-network emissions
  - Parked vehicles, including diurnal (when the vehicle is parked during the day) and hot soak (immediately after a trip)
  - Evaporative fuel vapor venting

Met4Moves


Reference county X-ref
Fuel month X-ref
Spatial Surrogates
Gridded/Hourly meteorology
Meteorological Preprocessor (Met4Moves)
Output for MOVES Driver Script (Reference County)
Output for SMOKE (Inventory County)

Met4Moves: Output for MOVES

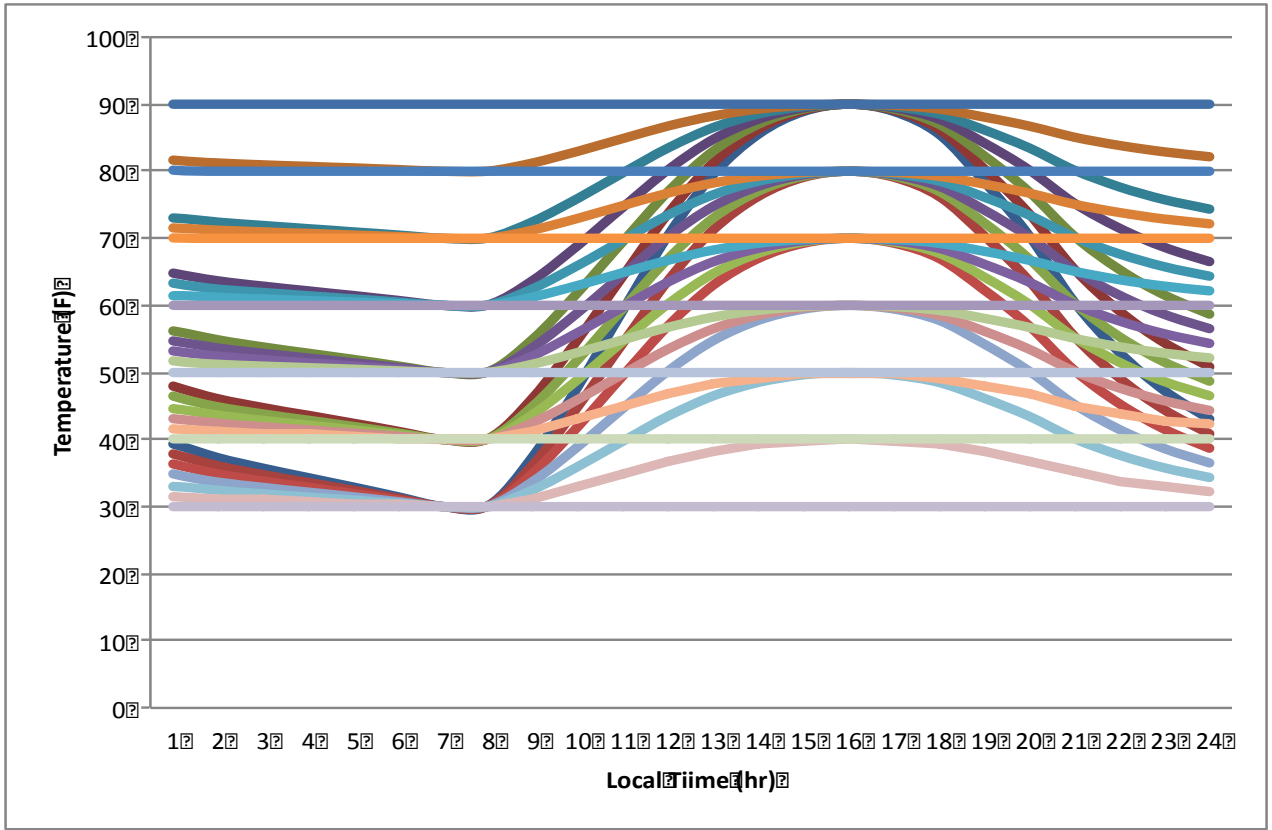
- **Representative counties**
- **Representative months**

DESC Sample Met input file for MOVES Driver script
PD_TEMP_INCREMENT 5
PV_TEMP_INCREMENT 5
PP_TEMP_INCREMENT 10

Ref. County	fuelMonth	temperatureProfileID	RH	Temp1 (Min)	Temp2 (Max)	Temp3	…	Temp24
13121	1	min_max	66.82	31.21	89.98			
13121	1	M2009120001	66.82	37.80	35.69	34.50	…	41.07
13121	1	M2009120002	66.82	46.50	44.75	43.75	…	49.23
13121	1	M2009120003	66.82	55.20	53.80	53.00	…	57.38
…	…	…	…	…	…	…	…	…
13121	4	min_max	66.21	45.21	90.2			
13121	4	M2009180001	66.21	47.88	45.12	44.52	…	51.06
13121	4	M2009180002	66.21	56.51	54.45	53.35	…	59.24
13121	4	M2009180003	66.21	65.94	63.55	63.15	…	67.65
…	…	…	…	…	…	…	…	…

Met4Moves: Output for MOVES

- Diurnal T profiles for RPP
- Normalized 24 hr T profiles based on min/max T of county group



Met4Moves: Output for SMOKE

- **Monthly or Daily temperature ranges for RPP**
- **All counties in domain**

Inventory County	fuelMonth	Month	julianDate	RH	Temp (Minimum)	Temp (Maximum)
13001	1	3	2009060	51.1	25.2	65.1
13002	1	3	2009060	55.2	29.1	58.9
13003	1	3	2009060	52.6	21.4	59.3
13005	1	3	2009060	51.7	25.8	62.1
…	…	…	…	…	…	…
13001	4	4	2009090	61.1	44.2	75.1
13002	4	4	2009090	66.6	39.9	63.7
13003	4	4	2009090	61.1	45.1	80.5
13005	4	4	2009090	56.2	46.2	79.5
…	…	…	…	…	…	…

MOVES Driver Script

- Creates the input data tables for import
- Creates run specification (runspec) XML files to run MOVES for large number of conditions
  - Separate runs for each T bin or T profile and for each reference county and fuel month
- Generates specific T and RH csv files based on Met4Moves output
- Creates scripts to run all the importers and all the MOVES scenarios

MOVES Post-processing Scripts

- **Convert MOVES MySQL tables to SMOKE-ready EF tables**
  - Produces 3 types of EF tables RPD, RPV, RPP EF tables
  - Produces separate set of tables for each reference county and fuel month
- **Maps MOVES PM species to SMOKE PM species**
  - Appropriate for CB05 with SOA
  - e.g. PMC, POC, PNO3, ...
- **Maps MOVES emission processes to SMOKE emission processes**
  - Optionally consolidate down to “typical” SMOKE modes: EVP, EXH, BRK, TIR

MOVES

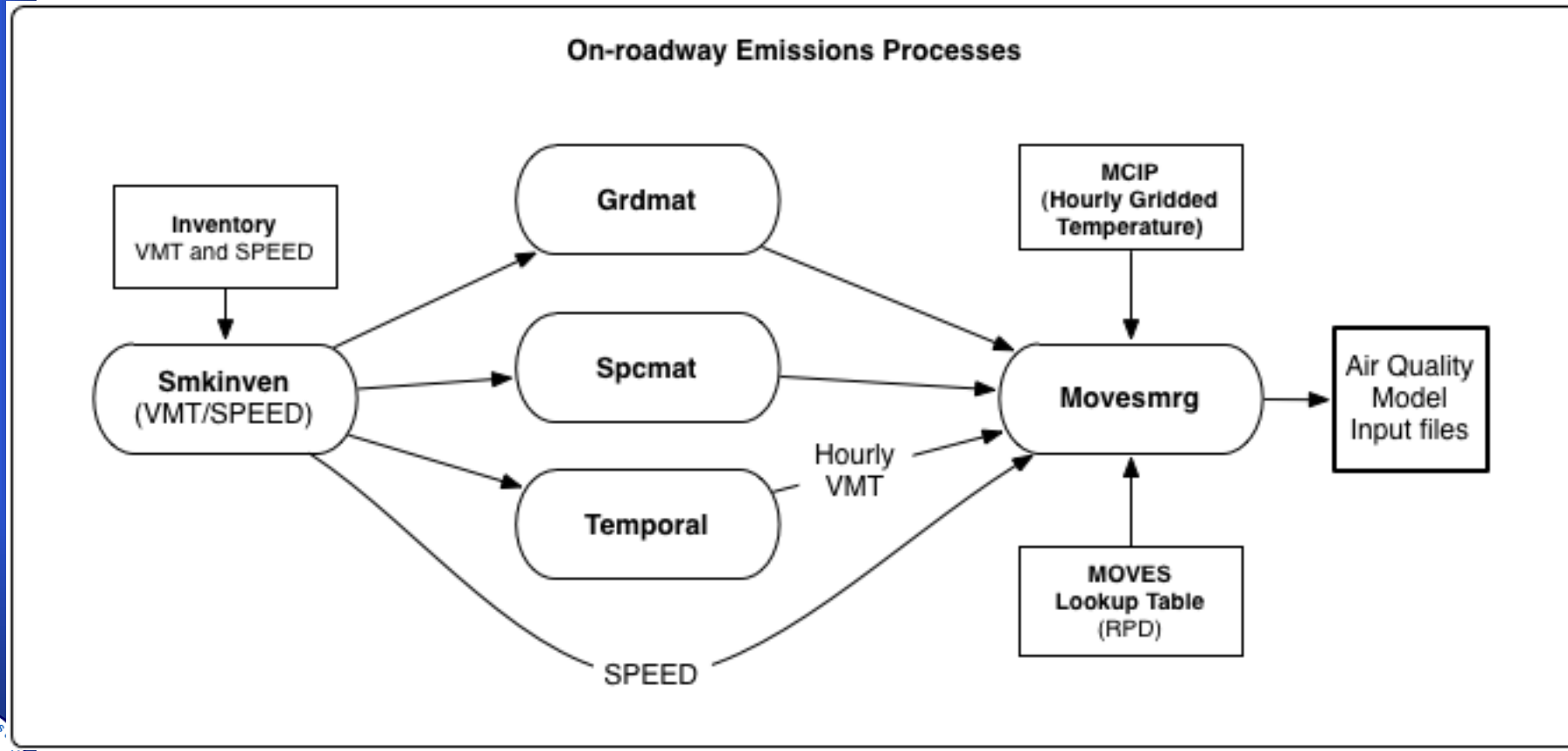
MOVES Post-processing Scripts: Emission Processes

Emission Rate Lookup Table	Units	SMOKE ProcesID	Emissions Process
RatePerDistance	Gram/mile	EXR	Running Exhaust
		CXR	Crankcase Running Exhaust
		TIR	Tire Wear
		BRK	Brake Wear
		EVP	On-road Evaporative Permeation (roadTypeID=2,3,4,5)
		EFL	On-road Evaporative Fuel Leaks (roadTypeID=2,3,4,5)
		EFV	On-road Evaporative Fuel Vapor Venting (roadTypeID=2,3,4,5)
RatePerVehicle	Gram /vehicle /hour	EXS	Start Exhaust
		CXS	Crankcase Start Exhaust
		EVP	Off-network Evaporative Permeation (roadTypeID=1)
		EFL	Off-network Evaporative Fuel Leaks (roadTypeID=1)
		CEI	Crankcase Extended Idle Exhaust
		EXT	Extended Idle Exhaust
RatePerProfile	Gram /vehicle /hour	EFV	Off-network Evaporative Fuel Vapor Venting (roadTypeID=1)

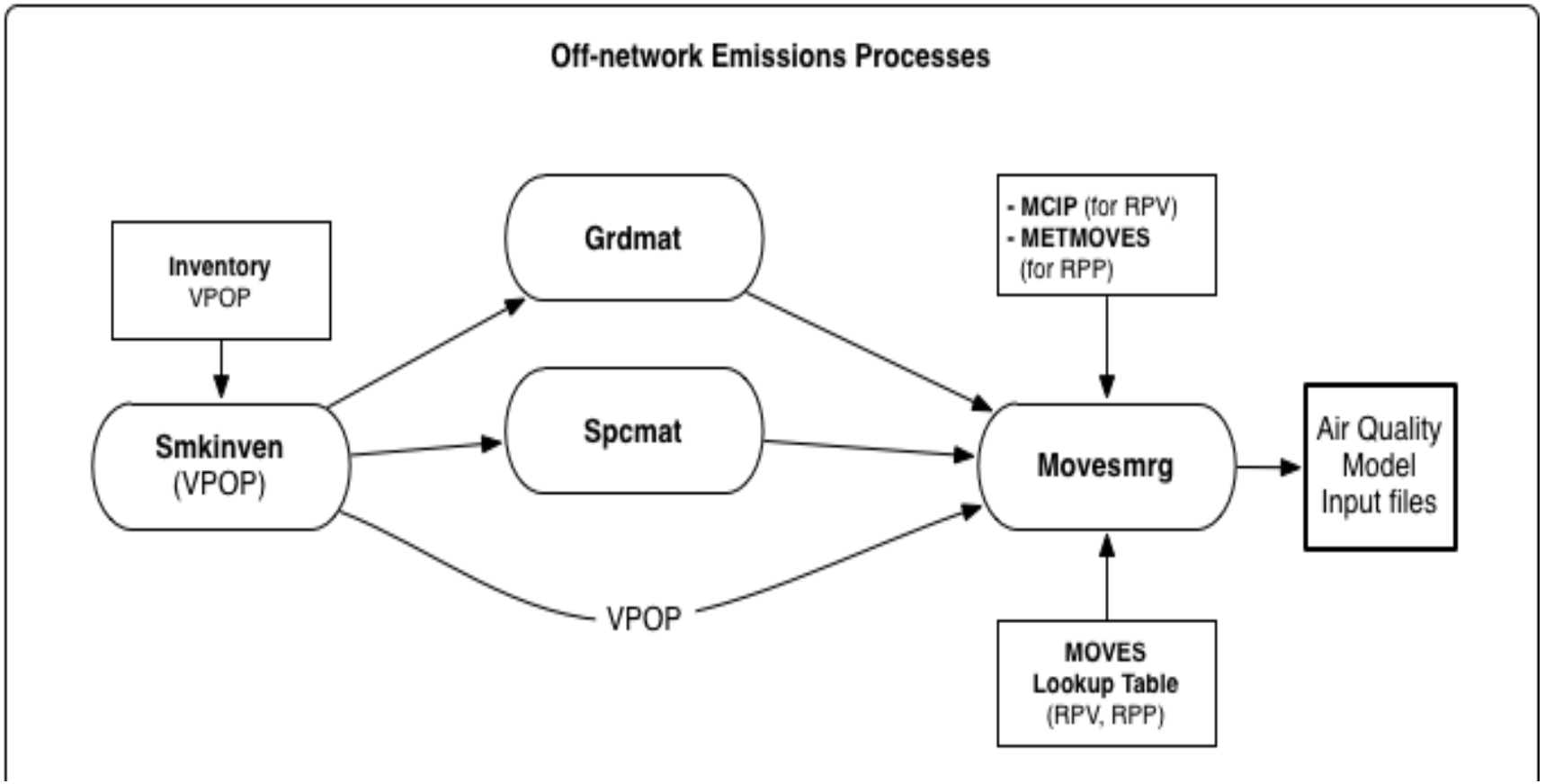
SMOKE Modeling System

- **RPD (grams/miles) : On-roadway Emission Process EFs**
  - Lookup Fields: SCC, speed (optional 24-hr speed profiles), fuel month, and temperature.
- **RPV (grams/vehicle-hr) : Off-network Emission Process EFs**
  - Lookup Fields: SCC, fuel month, temperature, local time (hourID).
- **RPP (grams/vehicle-hr) : Off-network Vapor Venting Evap. EFs**
  - Lookup Fields: SCC, fuel month, temperature profiles, local time (hourID).

SMOKE: On-roadway Processing (RPD)



SMOKE: Off-network Processing (RPP, RPV)



SMOKE: Final Merging

- Run separately (RPD, RPV, RPP)
- RPD, RPV are run for every day using hourly gridded MCIP files
- RPP could be run for average day (representative day per month) using monthly averaged meteorological output from Met4Moves OR could be run every day using daily meteorological output from Met4Moves

National Run

- **103 reference counties, 2 fuel months**
- **MOVES was run using cloud computing**
- **12km national domain for SMOKE**
  - Post-processed to 36km national domain and 2 12km domains (East and West U.S.)
- **Using separate permeation mode (5th SMOKE mode, EPM) – new speciation profiles**
- **Some of the toxics and the NOx components (NO, NO2, HONO) were modeled directly**

National Run: Timing

- **Initial computational approach**
  - 13 minutes/model day for 1 representative county (RPD)
  - Scaled almost linearly with representative counties
  - Estimated timing for our national domain: **1 year**
  - Profiled the code
    - Majority of the time was in reading/processing the EF tables
    - EF tables were being processed every hour
    - Another significant process is generating the reports: 2x per day loop
- **Enhanced computational approach**
  - Moved reading EF tables to outer loop & added header to EF tables
  - Limited reports to once per day loop
  - 20 seconds/model day for 1 representative county (RPD)
  - Estimated timing for our national domain: **9 days**

Recent Developments

- **Improved computational efficiency of Movesmrg**
- **Updates to post-processor script**
  - New header for EF tables
  - Extended idle
  - PMC for Brake and Tire modes
- **Met4moves averaging period**
  - Daily vs. Monthly ranges (SMOKE output)
  - New header
- **QA reports from Movesmrg**
  - Source level reports
  - Speciated reports

Recent Developments

- **Support for weekday/weekend hourly speed profiles (RPD)**
- **Support for monthly activity data in FF10 format**
- **Updated Emission Processing Input Data**
  - Chemical speciation profiles and cross-reference input files
  - Temporal profiles and cross-reference files
  - Surrogates

References

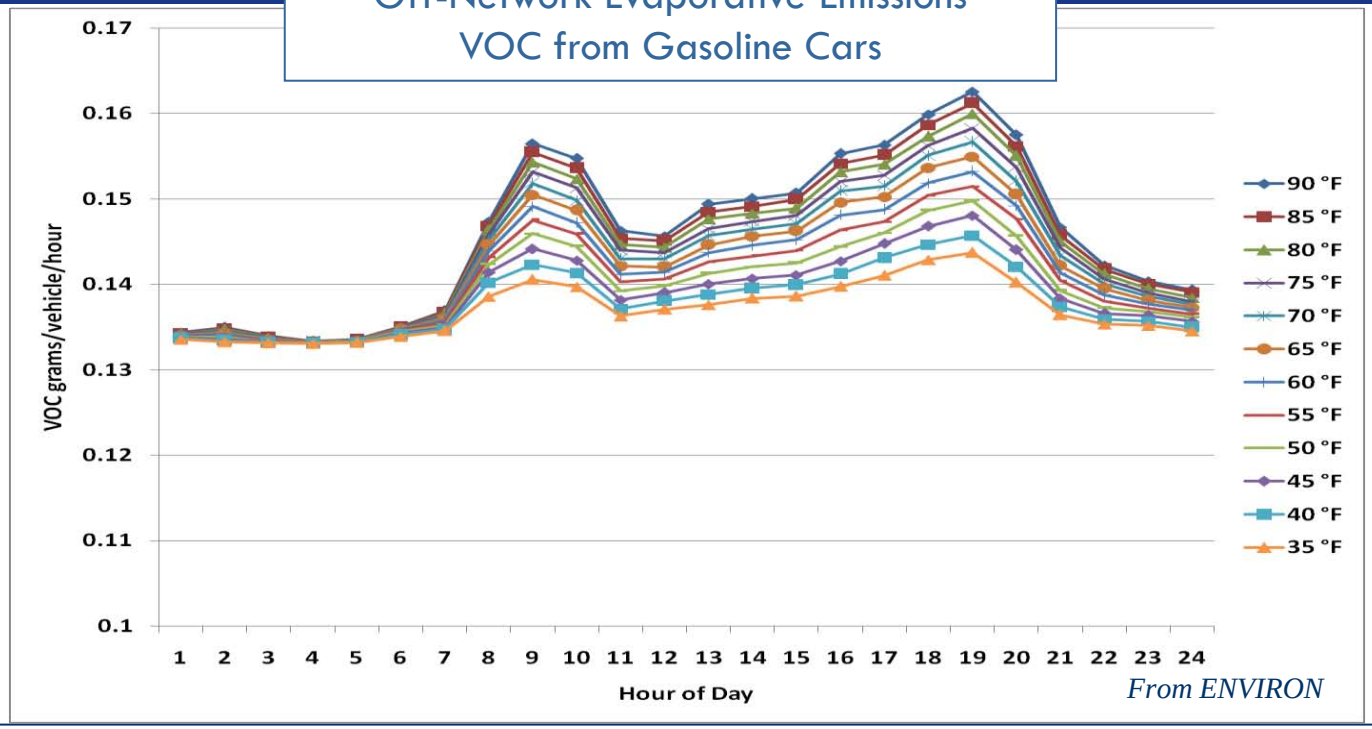
- **SMOKE:** http://www.smoke-model.org/
- **SMOKE-MOVES User's Guide:** http://www.smoke-model.org/smoke_moves_tool/SMOKE-MOVES_Tool_Users_Guide.pdf

Acknowledgement

- OTC, NESCAUM, MARAMA, SESARM
- ENVIRON International Corporation
- US EPA Office of Transportation and Air Quality (OTAQ)

Appendix

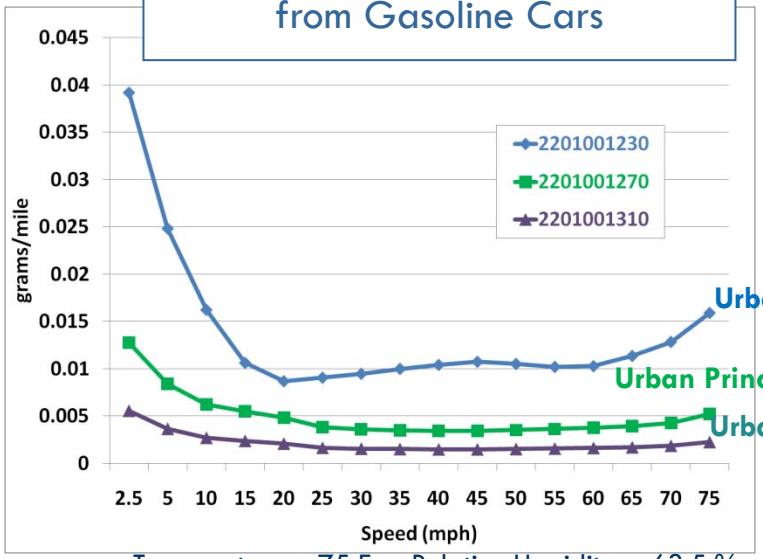
MOVES: RatePerVehicle (RPV) Approach



- Assigns **each binned temperature** to **all hours** of a run day
  - RatePerVehicle emission rates depend on
    - Temperature - Humidity - Hour - Day type

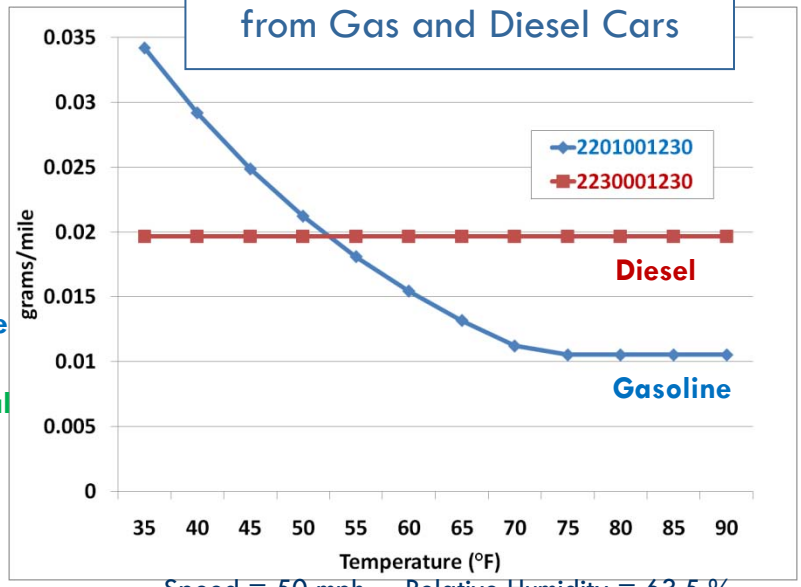
MOVES: RatePerDistance (RPD) Approach

Running Exhaust PM2.5 OC from Gasoline Cars



Temperature = 75 F Relative Humidity = 63.5 %

Running Exhaust PM2.5 OC from Gas and Diesel Cars



Speed = 50 mph Relative Humidity = 63.5 %

From ENVIRON

- Assigns **binned temperatures** to **hours** of the day
  - RatePerDistance emission rates depend on:
    - Temperature - Speed - Humidity

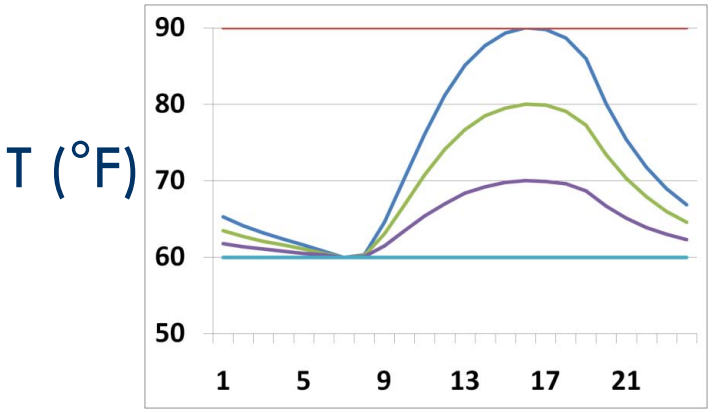
MOVES: RatePerProfile (RPP) Approach

- **Evaporative Fuel Vapor Venting emissions affected by temperatures in <u>previous hours</u>**
  - When the vehicle is parked Including diurnal (when the vehicle is parked during the day) and hot soak (immediately after a trip when the vehicle parks) emissions types

(min, max) temperatures:

(30, 30) (40, 40) (50, 50) **(60, 60)** (70, 70) (80, 80) **(90,90)**
(30, 40) (40, 50) (50, 60) **(60, 70)** (70, 80) (80, 90)
(30, 50) (40, 60) (50, 70) **(60, 80)** (70, 90)
(30, 60) (40, 70) (50, 80) **(60, 90)**
(30, 70) (40, 80) (50, 90)
(30, 80) (40, 90)
(30, 90)

From ENVIRON



MOVES

SMOKE: Movesmrg RPD

- Stores EFs by SCC, speed bin, temperature value, process, and pollutant
- Map every county to corresponding reference counties for appropriate EF
- Map actual date to corresponding fuel month for appropriate EF
- Estimates hourly emissions for every grid cell in the domain using hourly gridded MCIP files

- *Gridded/hourly/speciated Emission = EF * hourly VMT * Grid cell fraction * Speciation fraction*

MOVES

SMOKE: MOVESMRG RPV and RPP

- RPV mode : Store EFs by weekday/weekend, SCC, local hour, temperature value, process, and pollutant
- RPP mode : Store EFs by weekday/weekend, SCC, local hour, temperature profile, process, and pollutant
- RPV estimates hourly emissions for every grid cell in the domain using hourly gridded MCIP files
- RPP estimates emissions by inventory county using appropriate temperature profile based on Met4Moves profiles
- Map every county to corresponding reference counties for appropriate EF
- Map actual date to corresponding fuel month for appropriate EF

- *Gridded/hourly/speciated Emission = EF * Vehicle populations * Grid cell fraction * Speciation fraction*