User's Guide for the SMOKE–MOVES Integration Tool

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1 Introduction

1.1 Overview

MOVES is the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator (OTAQ, 2009, also available at http://www.epa.gov/otaq/models/moves/index.htm and). The purpose of MOVES is to provide an accurate estimate of emissions from mobile sources under a wide range of user-defined conditions. It helps the user answer "what if" questions, such as "How would particulate matter emissions decrease in my state on a typical weekday if truck travel were reduced during rush hour?", or "How does the total hydrocarbon emission rate change if my fleet switches to gasoline from diesel fuel?"

In the modeling process, the user specifies vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types to be modeled. The model then performs a series of calculations, which have been carefully developed to accurately reflect vehicle operating processes (such as cold start or extended idle) and provide estimates of bulk emissions or emission rates. Specifying the characteristics of the particular scenario to be modeled is done by creating a Run Specification, or runspec (discussed further in Section 3).

The outputs from MOVES are emissions estimates or emissions factors. These can be used as inputs to larger emissions modeling systems that model many different types of emissions (e.g., stationary point sources, area sources and biogenic sources) and provide results that are used in performing air quality modeling. An example of such systems is the Sparse Matrix Operator Kernel Emissions (SMOKE) model, which is widely used in both the public and private sectors (IE, 2009a). Detailed information about SMOKE is available at http://www.smoke-model.org.

In December 2009, a new version of MOVES was released: the Motor Vehicle Emission Simulator 2010 model (MOVES2010). An important feature of MOVES2010 is that it allows users to choose between (1) the "Inventory" calculation type, which provides emission rates in terms of total quantity of emissions for a given time period; and (2) the "Emission Rate" calculation type, which gives emission rates in terms of grams/mile or grams/vehicle/hour. For large-scale emissions modeling such as that needed for regional- and national-scale air quality modeling projects, it is desirable to use the Emission Rate calculation type, which populates emission rate lookup tables that can then be applied to many times and places, thus reducing the total number of MOVES runs required.

Under Work Assignment (WA) 3-03 of EPA contract EP-D-07-102 to the University of North Carolina at Chapel Hill (UNC), EPA's Office of Transportation and Air Quality (OTAQ) has tasked UNC and ENVIRON with developing tools to facilitate the process of using MOVES to create emissions estimates appropriate for air quality modeling.

The successful use of the MOVES Emission Rate calculation type requires careful planning and a clear understanding of emission rates calculation in MOVES. To reduce the time and effort required of the user for this process, and to help the user obtain more accurate modeling results, UNC and ENVIRON created a new tool called the SMOKE-MOVES integration tool (Figure 1). This tool consists of a set of scripts that automate the proper use of the Emission Rate

calculations for the purpose of estimating mobile-source emissions for air quality (AQ) modeling. The SMOKE-MOVES tool provides three major functions:

1. **Meteorological data preprocessor:**
   - The meteorological data preprocessor program (Met4moves) prepares spatially and temporally averaged temperatures and relative humidity data to set up the meteorological input conditions for MOVES and SMOKE using the Meteorology-Chemistry Interface Processor (MCIP) output files.

2. **MOVES model processing:**
   - The MOVES driver script creates data importer files and the MOVES input file (runspec), which specifies the characteristics of the particular scenario to be modeled.
   - The MOVES postprocessing script formats the MOVES emission rate lookup tables for SMOKE.

3. **SMOKE model processing:**
   - The SMOKE postprocessing program (Movesmrg) estimates emissions from on-road mobile sources based on MOVES-based emission rate lookup tables and meteorology data from Met4moves.
   - Creates hourly gridded speciated air quality model-ready input files.
   - Produces various types of reports for users.

This user's guide describes the major functions of the SMOKE-MOVES integration tool.

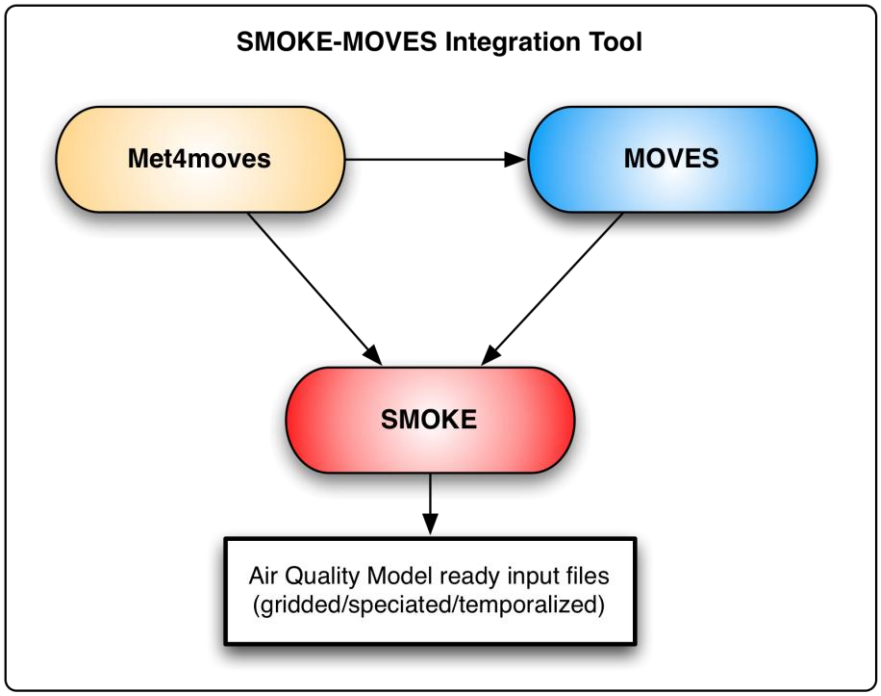

Figure 1. Flow diagram of overall SMOKE-MOVES integration tool.

1.2 Key Concepts and Terminology

Before we provide more information about the tool, this section discusses some key concepts and terminology that will help users in understanding this document.

1.2.1 Reference Counties and Fuel Months

Reference county – The approach for running MOVES for SMOKE relies on the concept of reference counties. These are counties that are used during the creation and use of emission rates to represent a set of similar counties (i.e., inventory counties) called a **county group**. The purpose of the reference county is to reduce the computational burden of running MOVES on every county in your modeling domain. By using a reference county, the user generates key emission rates for the single county in MOVES and then utilizes these factors to estimate emissions for all counties in the county group through SMOKE. The reference county is modeled at a range of speeds and temperatures to produce emission rate lookup tables (grams/mile or grams/vehicle/hour, depending on mobile emission process). The variables that are assumed to be constant across the county group members (and the reference county) are fuel parameters, fleet age distribution and inspection/maintenance (I/M) programs. The variables that can vary within the county group are vehicle miles traveled (VMT), source type vehicle population, roadway speed, and grid cell temperatures. Determining the reference counties and their respective county groups is a key aspect of utilizing the SMOKE-MOVES tool. It is ideal for the user to create each county group based on the similarity between the county characteristics (e.g., urban and rural) and the meteorological conditions (e.g., temperature and relative humidity). The user should avoid grouping counties that have significantly different meteorological conditions.

Fuel month – The concept of a fuel month is used to indicate when a particular set of fuel properties should be used in a MOVES simulation. 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. To determine the fuel month and which months it corresponds to, the user should review the State-provided fuel supply data in the MOVES database for each reference county. If the fuel supply data change throughout the year, then group the months by fuel parameters. For example, if the grams/mile exhaust emission rates in January are identical to February's rates for a given reference county, then use a single fuel month to represent January and February. In other words, only one of the months needs to be modeled through MOVES.

1.2.2 Emissions Processes

When the MOVES model runs as a part of the SMOKE-MOVES tool, it runs for all emissions processes (or modes), including on-road and off-network emissions processes, for the selected pollutants. Off-network emission processes (e.g., parked engine-off, engine starts, and idling, and fuel vapor venting) in MOVES are hour-dependent due to vehicle activity assumptions built into the MOVES model; the emission rate depends on both hour of the day and temperature. On-roadway emission processes (e.g., running exhaust, crankcase running exhaust, brake wear, tire wear, and on-road evaporative), on the other hand, do not depend on hour. In MOVES, these emission processes are categorized into three major groups:

1. **rate-per-distance (RPD)** – The emission rate of vehicles on-network (i.e., driving) from MOVES. The rate is expressed in grams/mile traveled.

2. **rate-per-vehicle (RPV)** – The emission rate of vehicles off-network (e.g., idling, starts, refueling, parked) from MOVES. The rate is given in grams/vehicle/hour.

3. **rate-per-profile (RPP)** – The emission rate of vehicles off-network—specifically, the evaporation from parked vehicles (vapor-venting emissions) from MOVES. The rate is expressed in grams/vehicle/hour.

1.3 Level of Knowledge Expected

This SMOKE-MOVES integration tool user's guide assumes that readers have some experiences using both the MOVES model and the SMOKE model; this type of knowledge is necessary for effective use of the SMOKE-MOVES tool. For detailed information about these models, please check their user's guides (OTAQ, 2009; IE, 2009a).

2 Meteorological Preprocessor: Met4moves

2.1 Preprocessor Description

2.1.1 Met4moves Overview

Met4moves is a meteorological preprocessor that prepares temperature and relative humidity (RH) data for use by both MOVES and SMOKE (see Figure 2). Met4moves produces specific meteorological metrics for the reference county(s) for MOVES and additional meteorological metrics for all inventory counties in the county group for SMOKE. The meteorological metrics are specific to the emissions processes (RPD, RPV, or RPP); this is discussed in more detail below.

The inputs for Met4moves include the reference county cross-reference file (MCXREF), the reference county fuel month cross-reference file (MFMREF) for mapping reference counties to fuels and months, spatial surrogates used to identify grid cells per county (SRGLIST), a list of counties (COSTCY), the grid description (GRIDDESC), and gridded hourly temperatures output from MCIP (ORD, 2009). More information about the inputs for Met4moves is available in Section 2.3.1.

The outputs are (1) a file for MOVES that contains the temperatures and RH for each reference county, and (2) a file for SMOKE that contains the temperatures and RH for each inventory county in the county group(s), supplementing the gridded hourly temperatures from MCIP. More specifically:

- For MOVES, Met4moves creates datasets that provide all minimum/maximum (min/max) temperature combinations for a reference county, reflecting all min/max combinations for all inventory counties in that county group. The associated RH values are also included in these datasets. In addition, the datasets include the 24-hour diurnal

profiles needed for the RPP emission process, and contain user-specified temperature increments for use by MOVES. This is discussed in more detail at Section 2.3.3.1.

- For SMOKE, Met4moves creates datasets that contain the min/max temperatures, and averaged RH associated for each inventory county. More detailed information is available in Section 2.3.3.2.

The key difference between the datasets provided to MOVES and those provided to SMOKE is that the former includes only the reference counties, while the latter includes all of the inventory counties.

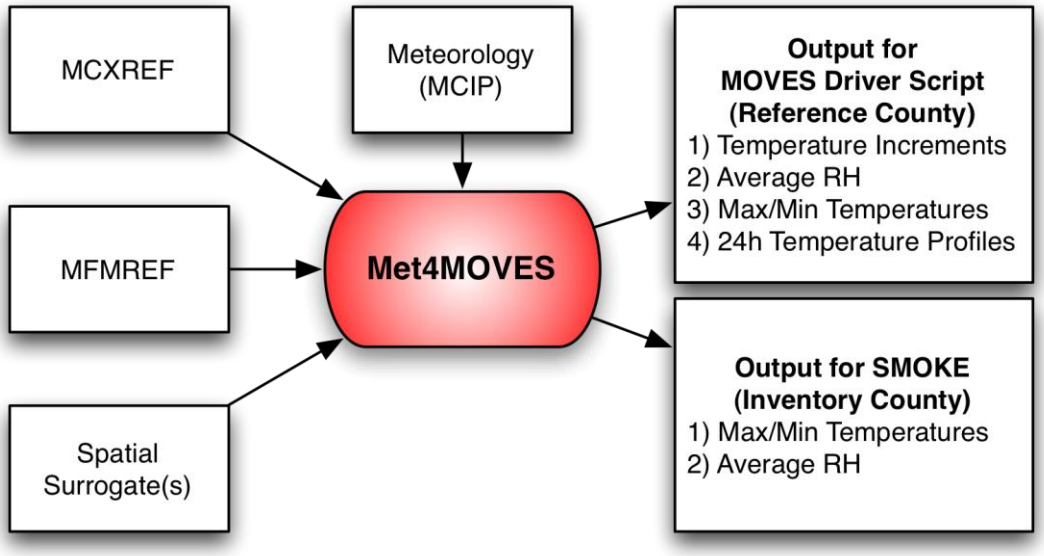

Figure 2. Flow diagram of Met4moves

2.1.2 Reference County Mapping

As described in Section 1.1.1, the SMOKE-MOVES approach is based on reference counties, each one representing a county group that shares the same fuel parameters, fleet age distribution, I/M programs, and meteorological conditions. The use of reference counties allows reductions in the MOVES processing time and in the sizes of the emission rate lookup tables output by MOVES. The reference county cross-reference file (MCXREF) defines the reference counties, and the county group that maps to each reference county. Table 1 provides the format for this input file, while Table 2 gives an example of reference county cross-reference file entries (both of these tables are shown later in Section 2.3.1.4).

2.1.3 Spatial Averaging Method for Temperature and RH Data

In order to combine gridded meteorology data with county-based mobile emissions data, a technique has been developed for calculating spatially averaged meteorology for each reference county. Because not all of the grid cells in a county contain on-road mobile emissions, this technique provides a way to select which cells should be used in determining the min/max

temperatures and 24-hour temperature profiles. Spatial surrogates (see IE, 2009b) are used to select grid cells in each county group where the mobile emissions are located. Based on the definitions of reference counties and county groups, and the specific spatial surrogates, Met4moves selects the appropriate meteorology grid cells across the county groups. It uses the temperatures in the selected grid cells to create the temperature input files for both the MOVES model (using a process described in Section 3) and the SMOKE model (using a process described in Section 4). Details of defining a subset of county grid cells for MOVES modeling include the following:

- The user must specify at least one spatial surrogate for Met4moves processing.
- Using more than one surrogate could provide a proxy for grid cells with higher mobile emission activities.
- To select all grid cells within the county, the user could select a total land area surrogate.
- The grid cells selected will likely vary depending on the choice of spatial surrogate(s).
- Only the selected grid cells are used to estimate the min/max temperatures and 24-hour temperature profiles.
- When selecting the absolute min/max temperatures in any hour that are needed for the reference county, Met4moves considers all the selected grid cells in the reference county and all the selected grid cells from inventory counties in the county group. This approach is needed because the reference county could have a smaller temperature range than one of the counties that is mapped to it. The absolute min/max temperatures are used for computing RPD and RPV emissions processes.
- When calculating the diurnal temperature 24-hour profiles for the reference county, Met4moves considers all the selected grid cells in the reference county and all the selected grid cells from inventory counties in the county group. This approach is needed because the reference county could have a smaller temperature range than one of the counties that is mapped to it. The 24-hour diurnal shape profiles are used for computing various 24-hour diurnal profiles based on min/max temperature combinations for the RPP emissions process.

2.1.4 Temporal Averaging Method for County Groups

Met4moves uses hourly min/max temperatures and averaged RH over the spatial region that includes all of the inventory counties in a county group over the user-defined modeling period. The current version of Met4moves supports only the monthly averaging method (versus daily or episodic) to create min/max temperatures and averaged RH for all inventory counties in the county group(s). This means, for example, that if you process an entire year using the monthly averaging method, then Met4moves will produce 12 calendar months of min/max temperatures and averaged RH for all of the inventory counties in the county group for SMOKE.

When computing RH, Met4moves defaults to using only the hours from 6 AM through 6 PM, in order to exclude hours with little traffic that would artificially skew the values. Users can override the default and change the hours of the day to use for this calculation, if desired. Detailed information for this setting is available in Section 2.3.2.

2.1.5 Temporal Optimization for Reference County Fuel Month Groups

As described in Section 1.1.1, the concept of a fuel month is used to indicate when a particular set of fuel properties should be used in a MOVES simulation. To group months by fuel properties, the user must create and input a fuel month file (MFMREF) to Met4moves. The fuel month file is a text file that contains reference county FIPS codes, monthly fuel type identification (ID) codes, and the months that use each fuel type (Tables 3 and 4, shown later in Section 2.3.1.5). If a fuel month file containing more than one fuel month entry is provided to Met4moves, fuel-month-specific temperature outputs will be created for the MOVES model. For example, if a reference county has four fuel months representing the entire year with the monthly averaging method, then Met4moves will produce four sets of temperatures and averaged RH outputs for the reference county, as opposed to 12 calendar months of outputs for the county group. The outputs for the reference county are used as input to the MOVES driver script (Section 3), while the outputs for the county group are used as input for SMOKE processing (Section 4).

2.1.6 Temperature Increments

Temperature increments are used by MOVES to determine the number of emission rates needed in the various lookup tables. The user can define three different temperature increments, which control the RPD, RPV, and RPP emissions processes, respectively. MOVES will calculate emission rates at the various temperatures (determined by the temperature increment) and bounded by the range of absolute min/max temperatures. This provides some control over the number of MOVES runs. Note that all temperatures produced by Met4moves are in ºF.

Examples: If the absolute min/max for an averaging period and reference county is 68/94 ºF, the temperatures associated with the RPD, RPV, and RPP calculations are as follows:

a. For RPD, a temperature increment of 5 ºF would require emission rates at all temperature from 65 ºF to 95 ºF in 5º increments.
b. For RPV, a temperature increment of 10 ºF would require emission rates for each hour at 60, 70, 80, 90, and 100 ºF. (Note that these are needed for each hour because RPV depends on hour of day as well as temperature.)
c. For RPP, with a temperature increment of 10 ºF, Met4moves will create a set of 24-hour temperature profiles based on the normalized 24-hour shape profile. This set of profiles will cover all combinations of min/max values within the absolute min/max range. In this example, the set of profiles (min, max) are: (60, 100), (70, 100), (80, 100), (90, 100), (100,100), (60, 90), (70, 90), (80, 90), (90,90), (60, 80), (70, 80), (80,80), (60, 70), (70,70), and (60, 60) ºF.

2.2 Met4moves Processing

2.2.1 Overview

Using the specified county groups and temporal averaging approach for temperature and RH data (Section 2.1.4), Met4moves determines the min/max grid cell temperatures and associated RH for both SMOKE and MOVES, and computes average 24-hour temperature profiles for use in MOVES.

The 24-hour temperature profiles are averaged over a user-specified time period and grid cells for the reference county. Each profile is assigned to a profile ID code that identifies the combination of minimum and maximum temperatures. Note that there could be several temperature profile IDs used by the MOVES driver scripts (discussed in Section 3) for a single iteration of MOVES.

2.2.2 Met4moves Processing Sequence

Met4moves must be run on a Linux / Unix computer after running MCIP and before running MOVES and SMOKE.

The following are the major processing steps that Met4moves performs:

1. Read the reference county cross-reference file (MCXREF) that contains a list of reference counties and the county groups that map to those reference counties.
2. Read the surrogate description file (SRGDESC) and a list of associated spatial surrogate(s) chosen for use in selecting grid cells.
3. Determine a list of grid cells for each county. Only the selected grid cells are used to estimate the min/max temperatures, 24-hour temperature profiles, and RH over the user-specified modeling period.
4. Set the dates of the modeling episode in local time using the flags STDATE and ENDATE.
5. Determine the averaging method (AVERAGING_METHOD) chosen by the user to create 24-hour temperature profiles (i.e., MONTHLY).
6. Determine the fuel month for the reference county using the MFMREF input file.
7. Read the country/state/county (COSTCY) file to define the time zones for county groups.
8. Read the meteorology data that have been processed by MCIP.
9. Calculate the min/max temperatures hourly and over the modeling period.
10. Calculate average RH for the specified hour range over the modeling period. The default hour range is from 6 AM to 6 PM local time).
11. Once min/max temperatures and averaged RH are estimated for all reference counties and all inventory counties in the county groups, estimate diurnal 24-hour temperature profiles for use by the MOVES driver script (Section 3). The result is a normalized 24-hour shape profile over the user-specified period or fuel month.

2.3 Files and Environment Variables for Met4moves

2.3.1 Input Files

Met4moves requires several input files (Figure 3). This includes the reference county cross-reference file (MCXREF), the reference county fuel month cross-reference file (MFMREF) for mapping reference counties to fuels and months, spatial surrogates used to identify grid cells per county (SRGLIST), a list of counties (COSTCY), the grid description (GRIDDESC), and gridded hourly temperatures MCIP output.

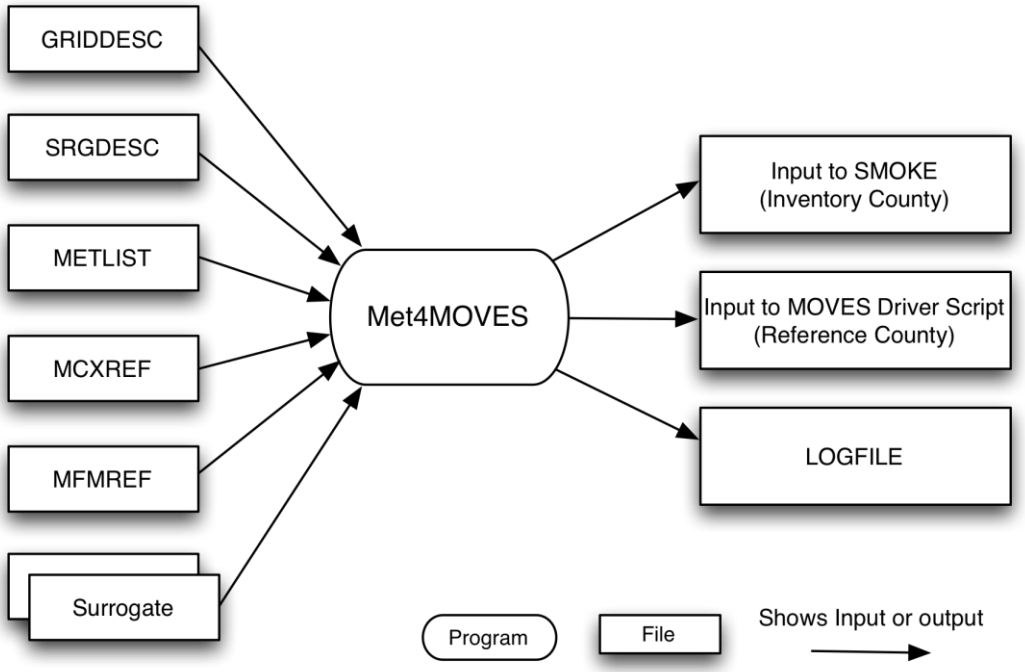

Figure 3. A flow diagram of Met4moves input and output files.

2.3.1.1 GRIDDESC: Grid Description File

The GRIDDESC input file describes the modeling grid. See the SMOKE user's manual (http://www.smoke-model.org) for details.

2.3.1.2 SRGDESC: Surrogate Description File

The SRGDESC input file includes a surrogate list, description, and surrogate file name used in the modeling grid. Note: The user must set SRGPRO_PATH to define the location of the spatial surrogate coefficient file(s). See the SMOKE user's manual for details.

2.3.1.3 METLIST: Spatial Surrogate File

The METLIST input file contains a list of MCIP meteorology files, including their full paths.

2.3.1.4 MCXREF: Reference county cross-reference File

The MCXREF input file defines the reference counties, and the county group that maps to each reference county. In defining the reference counties and county groups, the following guiding principles should be taken into account:

- The members of the county group should have the same fuel characteristics, the same distribution of fuels over the year, the same I/M programs, and the same fleet age distribution.
- Since RH is averaged over a county group, grouping counties with reasonably similar daytime RH is advisable.
- Since min/max temperature and diurnal temperature profiles are calculated over a county group, grouping counties with reasonably similar temperature ranges is advisable. Optionally, the shape of the diurnal temperature distribution can be considered for

defining county groups. The shape of the diurnal temperature profile is created based on intersections with all inventory counties in the county group.

- Optionally, the ratio of VMT to vehicle population can be considered in the definition of county groups, since the ratio affects the off-network emissions factors. This could be a minor factor in the county grouping, but it would be incomplete not to mention it.

The MCXREF file is a comma-separated-values (CSV) file. Table 1 provides the file format, and Table 2 gives an example set of entries for this file. The user can either include or exclude leading zeroes. For example, California could be represented by '06' or '6'.

Table 1. Format of reference county cross-reference file (MCXREF)

Line	Col	Description
1+	A	One-digit country FIPS code for inventory county (Integer)
	B	Two-digit state FIPS code for inventory county (Integer)
	C	Three-digit county FIPS code for inventory county (Integer)
	D	One-digit country FIPS code for reference county (Integer)
	E	Two-digit state FIPS code for reference county (Integer)
	F	Three-digit county FIPS code for reference county (Integer)

Table 2. Example of reference county cross-reference file entries

County Groups			Reference Counties		
Country	State	County	Country	State	County
0	13	101	0	13	121
0	13	102	0	13	121
0	13	103	0	13	121
…	…	…	…	…	…
0	13	121	0	13	121
0	13	123	0	13	217
0	13	125	0	13	217
0	13	127	0	13	217
…	…	…	…	…	…

2.3.1.5 MFMREF: Reference County Fuel Month File

The MFMREF input file serves the purpose of grouping months of the year by fuel parameters. The file specifies representative fuel months (the fuelMonth field in the MOVES database) to assign to the calendar months being simulated (the Month field) for each reference county.

As with MCXREF, MFMREF is a CSV file. Table 3 provides the file format. Table 4 is an example that illustrates a situation in which there are three fuel formulations in a given calendar year to be modeled in SMOKE-MOVES. In this example, reference county 13121 uses the fuel formulation mix in January (1) for modeling months November (11), December (12), January (1) and February (2). The April (4) fuel formulation mix is used for March (3), April (4), and May

(5). The June (6) fuel formulation mix is used for simulating June (6), July (7), August (8), September (9), and October (10). The user can either include or exclude leading zeros for the country codes; for example, USA country code '0' could be excluded.

Table 3. Format of reference county fuel month file (MFMREF)

Line	Position	Description
1+	A	Six-digit county-specific code for reference county (Integer)
	fuelMonth	Reference county fuel month (Integer)
	Month	Month (Integer)

Table 4. Example of reference county fuel month file entries

RefCounty	fuelMonth	Month
013121	1	1
013121	1	2
13121	4	3
13121	4	4
13121	4	5
13121	6	6
13121	6	7
13121	6	8
13121	6	9
13121	6	10
13121	1	11
13121	1	12

2.3.2 Input Environment Variables

Environment variables are used to provide settings to Met4moves that control the functioning of the program. These settings are below.

- `STDATE`: [default: 0]
  Sets the overall episode start date; Julian format (YYYYDDD).

- `ENDATE`: [default: 0]
  Sets the overall episode end date; Julian format (YYYYDDD).

- `AVERAGING_METHOD`: [default: `MONTHLY`]
  Sets averaging method to create 24-hour temperature profiles based on `STDATE` and `ENDATE`

    - `MONTHLY`: Average data and profiles for each month within the user-specified modeling episode. MONTHLY is the only allowable method at this time.

- `MOVES_OUTFILE`: [default: none]
  Defines the output filename for MOVES.

- `SMOKE_OUTFILE`: [default: none]
  Defines the output filename for SMOKE.

- `PD_TEMP_INCREMENT`: [default: 5]
  Defines the temperature increment (in ºF) for RPD lookup table (described in Section 3.1.1.2) to create combinations of min/max temperature bins.

- `PV_TEMP_INCREMENT`: [default: 5]
  Defines the temperature increment (in ºF) for RPV lookup table (described in Section 3.1.1.2) to create combinations of min/max temperature bins.

- `PP_TEMP_INCREMENT`: [default: 10]
  Defines the temperature increment (in ºF) for RPP lookup table (described in Section 3.1.1.2) to create combinations of min/max temperature bins for normalized 24-hour diurnal temperature profile.

- `RH_STR_HOUR`: [default: 60000]
  Defines the start hour in local time for average RH over the user-specified modeling episode.

- `RH_END_HOUR`: [default: 180000]
  Defines the end hour in local time for average RH over the user-specified modeling episode.

- `SRG_LIST`: [default: none]
  Specifies the name(s) of the spatial surrogate(s) to be used in selecting the grid cells for the county (example: setenv SRG_LIST '100, 230').

- `SRGPRO_PATH`: [default: none]
  Defines the location of spatial surrogate coefficient files.

- `TMPVNAME`: [default: `TEMP2`]
  Specifies the variable name for the temperature to extract from MCIP files.

2.3.3 Output Files

Met4moves produces two output files (Figure 3). The main difference between the output files is that the output file created for input to the MOVES driver script (Section 3) includes data for the reference counties only, while the output file created for input to SMOKE includes data for all of the counties within the modeling domain.

2.3.3.1 MOVES_OUTFILE: Output File for MOVES Driver Script

The output file created for use by the MOVES driver script contains the absolute minimum and maximum temperatures and average RH values associated with each reference county. The scope

of these min/max temperatures extends across the selected grid cells in the county group associated with that reference county. The min/max temperatures determine the MOVES runs that are needed for generating the RPD and RPV emission rates. The temperature increments listed in the header are used to define the temperature bins used to optimize the MOVES runs (Table 5). In addition, the output file prepared for the MOVES driver script contains sets of diurnal temperature profiles based on combinations of min/max temperature bins for each reference county; these are necessary for the MOVES vapor-venting emissions calculation that is performed for the RPP emissions process.

This output file contains all of the temperature and RH values for all reference counties. If, for example, the duration of the episode is annual, there are four fuel months, and the averaging method is monthly, Met4moves outputs four sets of monthly average RH, min/max temperatures, and 24-hour temperature profiles in local time for all reference counties into one output file. An example of this file is provided in Table 5. When each set of fuel month min/max temperatures begins with the record "min_max" in the temperatureProfileID column, the "Temp1" and "Temp2" fields can be referred to as minimum and maximum temperatures, respectively. The remaining records for the specific reference county and fuel month (the records between this "min_max" and the next "min_max") are the 24-hour temperature profiles. The profile names, temperatureProfileID, are a combination of the averaging type (M is for monthly), the last Julian date of the averaging period, and an index of the profiles (e.g., M2009180003 is the third monthly profile for the 2009180 averaging period). For a specific reference county and fuel month, the monthly average RH value is identical for all the records.

Table 5. Format of reference county minimum/maximum temperatures, relative humidity, temperature increments, and temperature profiles used as input to MOVES driver script

# 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
…	…	…	…	…	…	…	…	…

2.3.3.2 **SMOKE_OUTFILE: Output File for the SMOKE Model**

The output file created for use by the SMOKE model contains county-specific min/max temperatures and averaged RH values in local time for every inventory county and averaging

period in the modeling inventory. Table 6 gives an example of this file. SMOKE adjusts the native MCIP time zone (GMT) to local time in order to properly use the Met4moves lookup tables, which are given in local time. This output contains the actual month (Month), the fuel month (fuelMonth) and the Julian date (julianDate) used by MOVES to generate the emission rate lookup tables. If the averaging method is set to monthly, julianDate will contain the last Julian date of the averaging month. There are no 24-hour profiles, since SMOKE does not need them.

Table 6. Format of inventory county-specific minimum/maximum temperatures and temperature profiles used as input to SMOKE.

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
…	…	…	…	…	…	…

3 MOVES Model Processing

The second major component of the SMOKE-MOVES tool is MOVES model processing. This involves two scripts: The MOVES driver script (Section 3.1) creates data importer files and the MOVES input file (runspec), which specifies the characteristics of the particular scenario to be modeled. The MOVES postprocessing script (Section 3.2) formats the MOVES emission rate lookup tables for SMOKE.

Unlike the Met4moves meteorology preprocessor and the SMOKE modeling system, the MOVES driver script is typically run on Windows XP/Vista/7. However, a version that can run on Linux may become available later in 2010 After you finish running Met4moves (Section 2) on Linux, you must copy the Met4moves output file to system on which you are running MOVES (typically a Windows computer). Next, run the MOVES driver script to perform the MOVES runs and the postprocessing script to process the data output from MOVES on that system to create the MOVES-based lookup tables. These tables will be used as inputs to SMOKE that runs on Linux.

When you run the MOVES driver script, it generates the MOVES driver files (both run specifications and data importers) based on the Met4moves output temperature list by reference county, as follows:

- Reads the output file from Met4moves and two other user input files.
- Assembles instructions for MOVES to create MySQL input databases from XML files (data importer).
- Assembles run specification (runspec) XML files to run MOVES for a wide range of conditions.
- Generates the run-specific temperature and humidity CSV file.
- Assembles a batch list of data importer files, runspec files, and also a list of the MySQL. output database names to be postprocessed.

Once the MOVES driver script has completed, the *postprocessor* script extracts the emissions factor tables from the MOVES databases; maps MOVES source, fuel, and road types to Source Classification Codes (SCCs); and formats the emissions factor tables for use as SMOKE inputs, as follows:

- Reads the list of databases created by the MOVES driver script.
- Maps from the MOVES source types, fuel types, and road types to SCC, and aggregates SCC emissions factors over model years.
- Performs operations to drop and add fields and reduce the database size by performing a cross-tab query that places all pollutants on a single row.
- Writes final processed lookup tables to CSV files that are formatted for SMOKE.

3.1 MOVES Driver Script

The MOVES driver script, which is written in Perl, generates outputs for each reference county. The goals of the driver script are (1) to create the MOVES input files called "runspecs"; (2) to create all required MOVES data importer files, which are the instructions to MOVES on how to build county-level MySQL input databases; and (3) to create batch files of MOVES commands that run MOVES from the Windows command prompt. When the user launches the importer batch file though the Windows command prompt, the MOVES model imports data files into MySQL tables, after which the user needs to launch the runspec batch file so that MOVES calculates emission rates for all the conditions specified in the runspecs.

This section of the user's guide describes how to coordinate the use of input data from Met4moves and raw MOVES inputs (e.g., prepared by States or EPA) to create and organize the runspec files, and how to choose some user selections (e.g., calendar year, pollutants of interest) and modify hard-coded features (e.g., inclusion of all required emission processes for a given pollutant).

The MOVES model can be run at any of the three domains/scales: national, county, or project. Refer to the MOVES2010 user's guide for detailed descriptions of the different scales. The SMOKE-MOVES tool always uses the county domain/scale because this level of model detail is required by EPA for SIP and conformity analyses. For this scale, MOVES requires a MySQL input database containing local data for a single county. Every runspec file contains the name of a MySQL input database.

The MOVES driver script requires the following four types of inputs:

1. A run control file containing basic user selections for MOVES (example format in Appendix A)
2. Meteorological outputs from the Met4moves preprocessor for each reference county and fuel month:
   a. Minimum and maximum temperatures
   b. Average daytime relative humidity
   c. Multiple sets of 24-hour temperature profiles
   d. Temperature increments
3. Reference county file indicating the filenames by file type keyword for each of the files specified in item 4 (see example format in Appendix A).
4. Reference county inputs in CSV files formatted for the County Data Manager in MOVES that specify:
   a. Vehicle age distribution
   b. Fuels (parameters and market shares, by month[1])
   c. I/M programs
   d. VMT
   e. Vehicle population

Using the MOVES driver script involves two major processing steps: creation of the runspec files (Section 3.1.1), and user preparation of the data inputs needed for using the driver script to assemble the MySQL input data tables (Section 3.1.2). After the driver script approach is explained, Section 3.2 describes the MOVES postprocessing script that is used with output from a MOVES batch file run to generate the SMOKE-ready lookup table input files.

3.1.1 Creation of Runspec Files

The first action of the driver script is to create runspec files for MOVES that contain all of the selections required to execute a run. The MOVES driver script requires as input two files: a run control file in which the user specifies calendar year, pollutants, and day type (weekday or weekend); and the Met4moves output temperature file for the batch run of MOVES. The user selections in the run control file determine the information printed by the driver script in runspec files for MOVES.

3.1.1.1 Specifying Pollutants

The user must specify in the run control file one or more groups of pollutants to model. There are four groups available: ozone precursors, toxics, PM, and greenhouse gases (GHG). The MOVES pollutants and pollutant groups for the four types of modeling are provided below in Table 7. The choice of pollutant group(s) determines what pollutants are included in the three emission rate lookup tables output by MOVES (RPD, RPV, and RPP), which are described in Section 3.3. The letter 'X' marks the key pollutants for inclusion, and a 'd' signifies that the pollutant is included in the MOVES run because a key pollutant depends on it.

[1] Fuel selections (i.e., fuelFormulationIDs and market shares) should be listed by a single month even though they apply to multiple months. The single month listed must be consistent with the fuelMonth input file to Met4moves.

Table 7. MOVES Pollutants Available for Inclusion in the Lookup Tables Output by MOVES

pollutantID	pollutantName	Pollutant group			
		Ozone	Toxics	PM	GHG
1	Total Gaseous Hydrocarbons	d	d	d	
79	Non-Methane Hydrocarbons	d	d	d	
80	Non-Methane Organic Gases	d	d	d	
86	Total Organic Gases	X	X	X	
87	Volatile Organic Compounds	X	X	X	
2	Carbon Monoxide (CO)	X			
3	Oxides of Nitrogen	X		X	
30	Ammonia (NH3)			X	
32	Nitrogen Oxide	X		X	
33	Nitrogen Dioxide	X		X	
31	Sulfur Dioxide (SO2)			X	
100	Primary Exhaust PM10 – Total		d	X	
101	Primary PM10 - Organic Carbon		d	X	
102	Primary PM10 - Elemental Carbon		d	X	
105	Primary PM10 - Sulfate Particulate		d	X	
106	Primary PM10 - Brakewear Particulate			X	
107	Primary PM10 - Tirewear Particulate			X	
110	Primary Exhaust PM2.5 - Total			X	
111	Primary PM2.5 - Organic Carbon			X	
112	Primary PM2.5 - Elemental Carbon			X	
115	Primary PM2.5 - Sulfate Particulate			X	
116	Primary PM2.5 - Brakewear Particulate			X	
117	Primary PM2.5 - Tirewear Particulate			X	
91	Total Energy Consumption		d	d	X
92	Petroleum Energy Consumption				X
93	Fossil Fuel Energy Consumption				X
5	Methane (CH4)	d	d	d	X
6	Nitrous Oxide (N2O)				X
90	Atmospheric CO2				X
98	CO2 Equivalent				X
20	Benzene		X	X	
21	Ethanol				
22	MTBE		X		
23	Naphthalene		X		
24	1,3-Butadiene		X		
25	Formaldehyde		X		
26	Acetaldehyde		X		
27	Acrolein		X		

3.1.1.2 Driver Script Approach for Organizing Emission Processes

When the MOVES driver script creates the runspec files, it includes all emissions processes (or modes) for the selected pollutants. To optimally implement this design, different emission processes are selected in separate runspecs but sent to the same output database of lookup tables.

The remainder of this subsection explains the grouping of emissions processes (RPD, RPV, RPP).

For RPD lookup tables: Off-network emission processes in MOVES are hour-dependent due to vehicle activity assumptions built into the MOVES model; the emission rate depends on both hour of the day and temperature. On-roadway emission processes, on the other hand, do not depend on hour. Thus, the total MOVES run time can be reduced by implementing the temperatures of interest in hour spots for the on-road running processes. The MOVES driver script therefore groups together the on-roadway emission processes that occur in a single runspec file. Processes that fall into this category include the following:

Running Exhaust
Crankcase Running Exhaust
Tire Wear
Brake Wear
On-road Evaporative Permeation (roadTypeID=2,3,4,5)
On-road Evaporative Fuel Leaks (roadTypeID=2,3,4,5)
On-road Evaporative Vapor Venting (roadTypeID=2,3,4,5)

These processes have in common that they have no dependence on hour of the day and their emission rates are all written to the RPD lookup table in grams/mile traveled. Due to the lack of dependence on hour of the day, individual temperature bins in the min/max temperature range can be placed in hours 1 through 24 sequentially. For emission rate calculation, MOVES automatically generates the emission rates for all 16 speed bins (see Table 9) at every temperature bin. The temperature increment (#PR_TEMP_INCREMENT) used to divide temperature bins between the minimum and maximum is provided through the header of the Met4moves temperature preprocessor (Table 5). Potentially, there could be more than 24 temperature bins, in which case a second runspec file for these processes would be created.

For RPV lookup tables: The second grouping of emission processes occur from parked cars. These are run together in a MOVES runspec file for the same reference county. The emission processes in this grouping are listed below.

Start Exhaust
Crankcase Start Exhaust
Off-network Evaporative Permeation (roadTypeID=1)
Off-network Evaporative Fuel Leaks (roadTypeID=1)
Crankcase Extended Idle Exhaust
Extended Idle Exhaust

The MOVES emission rates for these processes are all written to the RPV lookup table and have units of grams/vehicle/hour. The rates depend on hour for various reasons. Start exhaust depends on engine soak time, which varies by hour. Additionally, the lookup table hourly emission rates already incorporate an assumption about the number of starts per vehicle by hour. Similarly, for off-network evaporative emissions and extended idle exhaust, hourly emission rates contain activity assumptions for parked time and idling time activity. As such, this group of emission

processes must be run at a single temperature for each of the 24 hours of the day, and the entire range of temperatures will be modeled by using a separate runspec file for each temperature. The number of runspec files equals the number of temperature increments (#PV_TEMP_INCREMENT) (Table 5). MOVES does not calculate these processes at different speeds.

For RPP lookup tables: The third and final group of emissions processes needing its own runspec file for the same reference county includes just one process: off-network evaporative fuel vapor venting. This emission rates for this process are written to the RPP lookup table and have units of grams/vehicle/hour. This emission process is unique in that it depends on the full 24-hour diurnal temperature profile. Temperature inputs for these runspec files are based on a period-specific normalized 24-hour profile shape that is spatially specific to the group of inventory counties mapped to the reference county, as described in Section 2.3.3.1. Sets of 24-hour temperature profiles from Met4moves are used for the vapor venting MOVES runs using the number of temperature increment (#PP_TEMP_INCREMENT). The number of runspec files equals the number of unique temperature profiles per reference county, obtained from Met4moves analysis of the county group for a given averaging period (Table 5).

It is important to note that the MOVES hourly emission rates in all three of the lookup tables (RPD, RPV, RPP) are in local time. When SMOKE uses emission rates from these tables (where hour and temperature are key lookup fields), SMOKE scripts need to account for SMOKE's meteorology data time zone (GMT) and adjust to the local time of the actual county in order to properly use the lookup tables.

3.1.1.3 Driver Script Generation of MOVES Runspec Batch File

As each runspec file is created by the MOVES driver script, its filename and path are appended to a text file that becomes the batch file of all the runspec files needed for all reference counties. For logistical reasons, the three groups of emissions processes for a reference county are split in the runspec setup portion of the MOVES driver scripts. The first group of emission processes is set up with a different temperature bin increment at each hour. Splitting out this group saves run time compared to running these emission processes in the same runspec file as the second group of emission processes: starts, idle, off-network evaporatives. Vapor venting requires its own third group due to the uniqueness of the temperature inputs—diurnal 24-hour profiles rather than temperature bins in the min/max range. Temperature and speed bins are not the only inputs required to set up a MOVES county domain scale run; other key inputs include vehicle age distribution, fuels, and I/M programs, which are defined based on the reference county. Temperature is one of the tables in the MySQL input database for a county-level MOVES run that changes by runspec. Therefore, each runspec file requires a unique MySQL input database. The other data sources required for inclusion in a MySQL input database are described in Section 3.1.2.

This batch file of all the MOVES runspec files needed for all reference counties resides in the output directory specified in the run control file. The user can review this file before launching the script via the Windows command prompt. However, prior to submitting the MOVES runspec files, the user must first generate the MySQL input databases required for each runspec. This is our next topic of discussion.

3.1.2 Data Sources for Both the MOVES Driver Script and the MOVES Model

This section begins with some background on the data required for a county-level MOVES run. Manually, a user can import county-level data from Excel® or an ASCII format using the MOVES County Data Manager in the Geographic Bounds panel of the MOVES graphic user interface (GUI). The County Data Manager importer tool transforms these data into a MySQL input database that is named in the MOVES runspec file. As an alternative to using the GUI, a user can manually create an XML file that lists the directory path and filenames of the county-level data. The user can then launch that XML file using a MOVES java command at the Windows command prompt, and the data importer tool included in the MOVES model will build the MySQL input database to be used by MOVES.

The approach of the MOVES driver script is to build the input databases and to create the XML data importer files at the same time it generates the runspec files. The driver script also generates a batch file of the data importer XML files. This batch file must be executed, and the log file reviewed, prior to submitting the MOVES runspec batch file. The XML file identifies the filename and path of required input data (in Excel® or CSV format). Table 8 lists all of the data types required as input to the MOVES driver script for running MOVES for a reference county. The rightmost column names the sources of the data. Where the data source listed is "Dummy data," the user does not need to provide this information; the MOVES driver script handles those inputs to MOVES by calling a file that applies for all runs. Meteorology, speeds, vehicle age distribution, fuels, inspection/maintenance (I/M) programs, population, and VMT are discussed individually below.

Table 8. Inputs for MOVES at the County Domain Scale, Emission Rate Calculation

Data Type	MOVES Table Name	Description	Source of Data
Temperature bins	*Zonemonthhour*	Temperature and relative humidity inputs by hour	Met4moves run by user
Speed bins	*Avgspeeddistribution*	Speed bin distribution by roadway type and vehicle class	Dummy data
Vehicle age distribution	*sourceTypeAgeDistribution*	Age distribution by source type over 30 vehicle model years	User
Fuel properties	*fuelSupply (required)* *fuelFormulation (optional)*	Fuel properties and their market shares	User
I/M programs	*IMcoverage*	Inspection & maintenance program inputs	User
Population	*sourceTypeYear*	Vehicle population by MOVES source type	User

Data Type	MOVES Table Name	Description	Source of Data
VMT	*HPMSVTypeYear*	Annual VMT by Highway Performance Monitoring System (HPMS) vehicle type	User
	roadTypeDistribution	Fractions allocating annual VMT to the five MOVES roadway types	Dummy data
	monthVMTFraction	Fractions allocating annual VMT to individual months	Dummy data
	dayVMTFraction	Fractions allocating month VMT to day type (weekday or weekend)	Dummy data
	hourVMTFraction	Fractions allocating day-type VMT to individual hours	Dummy data

The MOVES driver script assembles a text file in the format needed for the County Data Manager import tool in MOVES to create the *zonemonthhour* MySQL table for the input database. The *zonemonthhour* table contains temperature and RH data from the Met4moves meteorological preprocessor (Section 2). Relative humidity is a single value averaged over the time period selected by the user in Met4moves (default 6 AM to 6 PM local time) and averaged over the entire group of inventory counties that map to a reference county.

To create the *avgspeeddistribution* MySQL table, the MOVES driver script assembles dummy inputs in the format needed for the County Data Manager import tool in MOVES. This input is meaningful only for the Inventory calculation type, where the fraction of VMT at each of the 16 speed bins described in Table 9 would need to be specified. For the SMOKE-MOVES tool, however, MOVES is run using the Emission Rate calculation type where, by default, MOVES calculates for every speed bin (Table 9) at every hour.

Table 9. MOVES Default Speed Bins

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

The next category of inputs in Table 8 includes the three inputs that define a reference county: vehicle age distribution, fuel properties, and I/M programs. These inputs are expected to be provided by the user in the exact formats discussed below. Tables 10 through 13 list the field descriptions of required user-provided data for a county-level MOVES run.

Table 10. Field Descriptions of MOVES Age Distribution Inputs

MOVES Table Name	Field Heading
sourceTypeAgeDistribution	sourceTypeID
	yearID
	ageID
	ageFraction

Table 11. Field Descriptions of MOVES Fuels Inputs

MOVES Table Name	Field Heading
fuelSupply	countyID
	fuelYearID
	monthGroupID*
	fuelFormulationID
	marketShare
	marketShareCV

*monthGroupID is not currently a supported feature in MOVES

Table 12. Field Descriptions of a Second (Optional) MOVES Fuel Inputs

MOVES Table Name	Field Heading
fuelFormulation	fuelFormulationID
	fuelSubtypeID
	RVP
	sulfurLevel
	ETOHVolume
	MTBEVolume
	ETBEVolume
	TAMEVolume
	aromaticContent
	olefinContent
	benzeneContent
	e200
	e300
	bioDieselEsterVolume
	cetaneIndex
	PAHContent

Table 13. Field Descriptions of MOVES I/M Program Inputs

MOVES Table Name	Field Heading
IMCoverage	polProcessID
	stateID
	countyID
	yearID
	sourcetypeID
	fuelTypeID
	IMProgramID
	inspectFreq
	testStandardsID
	begModelYearID
	endModelYearID
	useIMyn
	complianceFactor

Tables 11 and 12 show the fuel input formats, which are two separate input tables. The *fuelSupply* table allows users to specify a fuelFormulationID corresponding to a list of nearly 9,000 predefined fuels in MOVES. If the user decides that none of the MOVES fuels describes the local fuel for the reference county of interest, then the user has to modify an existing, or define a new, fuelFormulationID, and list all of the properties (except the last three) shown in the *fuelFormulation* table fields (Table 12). Users should refer to the MOVES2010 user's guide for additional information on how to populate these input tables in the format for the County Data Manager importer tool in MOVES. In the *fuelSupply* table (Table 11), users share the same fuel month in the monthGroupID field for different fuelFormulationIDs with the fuelMonth in the Met4moves output file in Table 5 (Section 2.3.3.1). The same fuel month must be specified in both places.

Tables 14 and 15 list the required fields for population and VMT inputs, respectively. Note that VMT inputs are input by HPMSVType, rather than by MOVES sourceType. Users should refer to Table 3.3 of the MOVES2010 technical guidance document (http://www.epa.gov/otaq/models/moves/420b10023.pdf) to understand the relationship between HPMSVType and sourceType (OTAQ, 2010).

Table 14. Field descriptions of MOVES Population Inputs

MOVES Table Name	Field Heading
sourceTypeYear	yearID
	sourceTypeID
	sourceTypePopulation

Table 15. Field descriptions of MOVES VMT Inputs

MOVES Table Name	Field Heading
HPMSVTypeYear	HPMSVtypeID
	yearID
	HPMSBaseYearVMT
	baseYearOffNetVMT

The remainder of the MOVES input tables in Table 8 relate to VMT fractions by month, day, hour, and road type. All of these are irrelevant to MOVES emission rate outputs as long as they sum to 1, yet these are still required inputs to MOVES. Users do not need to specify the dummy values. The MOVES driver script uses a default file that contains default distributions.

3.2 MOVES Postprocessing Script

Once a MOVES batch file run completes, MOVES will have populated the three output lookup tables. Table 16 lists the field format of the raw tables as they are output by MOVES, prior to any postprocessing steps.

Table 16. Columns Included in the Three MOVES2010 Emission Rate Lookup Tables (RPD, RPV, RPP) before Postprocessing

rateperdistance (grams/mile)	**ratepervehicle** (grams/vehicle/hour)	**rateperprofile** (grams/vehicle/hour)
MOVESScenarioID	MOVESScenarioID	MOVESScenarioID
MOVESRunID	MOVESRunID	MOVESRunID
yearID	yearID	temperatureProfileID
monthID	monthID	yearID
dayID	dayID	dayID
hourID	hourID	hourID
linkID	zoneID	pollutantID
pollutantID	pollutantID	processID
processID	processID	sourceTypeID
sourceTypeID	sourceTypeID	fuelTypeID
fuelTypeID	fuelTypeID	modelYearID
modelYearID	modelYearID	Temperature
roadTypeID	Temperature	ratePerProfile
avgSpeedBinID	ratePerVehicle	
Temperature		
relHumidity		
ratePerDistance		

Part of the SMOKE-MOVES tool is the MOVES postprocessing script, which transforms the tables output by MOVES into new tables, as described in this section. The modifications to the raw tables are necessary to remove unnecessary information, create fields that are missing, and reduce the overall table size. The postprocessing changes enable SMOKE to more easily use the MOVES emission rate results. The following list shows the input and output table names for this postprocessing:

- rateperdistance → rateperdistance_smoke
- ratepervehicle → ratepervehicle_smoke
- rateperprofile → rateperprofile_smoke

The following postprocessing steps will be performed:

- Create a new field for 'SCC' and aggregate emission rates (Section 3.2.1).
- Create a new field for 'countyID' (Section 3.2.2).
- Cross-tab pollutantID to reduce output table size. (Section 3.2.3)
- Augment the speciated PM emissions factors to reflect the PM species needed for modeling (Section 3.2.4).
- Create final emissions rate lookup tables (Section 3.2.5).

3.2.1 Postprocessing an SCC Field

The SMOKE model processes county-level emissions by Source Classification Code (SCC). Currently in MOVES2010, output detail by SCC is not available when running MOVES for the Emission Rate calculation tables. For Emission Rate calculation, emission rates are stored in the lookup tables by source type, fuel parameters, road type, and emission process. ENVIRON and EPA OTAQ agreed on an approach for mapping from these parameters to SCC. The approach mirrors the methodology used in the MOVES Inventory calculation with output by SCC. There are 156 different SCCs; they are described in Appendix B.

The MOVES default database (MOVES20091216) table *scc* decodes SCC as SCCRoadTypeID, SCCVtypeID, and SCCProcID (OTAQ, 2010). For example, the MOVES SCC 223000127X corresponds to SCCRoadTypeID=27 (Urban Principal Arterial), SCCVtypeID=6 (Light Duty Diesel Vehicles), and SCCProcID=X (exhaust emission processes). The MOVES postprocessor script does not use SCCProcID in the construction or of SCCs. Instead "processName" is listed in a separate field from SCC.

Mapping MOVES roadway and emission process to SCC classification requires disaggregation from the 5 MOVES roadway types to 13 SCC roadway types. The fractions for disaggregation are found in the *sccroadtypedistribution* table in MOVES20091216. Fractions are applied at the county level. An example set of disaggregation factors for Wayne County, Michigan, is presented in Table 17 to illustrate the mapping. Per communication with OTAQ, these factors allocate both the emissions and the activity.

Table 17. Example Mapping of MOVES roadTypeID to SCCRoadTypeID
(Example fractions are specific to countyID 26163.)

roadTypeID	roaddesc	SCCRoadTypeID	SCCRoadTypeDesc	SCCRoadTypeFraction
1	Off-Network	1	Off-Network	1
2	Rural Restricted Access	11	Rural Interstate	1
3	Rural Unrestricted Access	15	Rural Minor Arterial	0.270
		21	Rural Local	0.139
		17	Rural Major Collector	0.520
		13	Rural Principal Arterial	0
		19	Rural Minor Collector	0.072

4	Urban Restricted Access	25	Urban Freeway/Expressway	0.215
		23	Urban Interstate	0.785
5	Urban Unrestricted Access	33	Urban Local	0.181
		29	Urban Minor Arterial	0.287
		31	Urban Collector	0.061
		27	Urban Principal Arterial	0.471

Mapping MOVES vehicle types and fuel types to SCCvtypeID requires that the MOVES emission rate output be disaggregated into the 31 vehicle model years in MOVES. Fractions that map MOVES sourceTypeID by model year and fuelTypeID to SCCVtypeID are found in the *sccvtypedistribution* table of MOVES20091216 (OTAQ, 2010). Table 18 illustrates an example of how source type, model year, and fuel map to SCCVtype.

Table 18. Example mapping of MOVES sourceType and fuelType to SCCVtype for model year 2000 and 2001 Single Unit Short-Haul Trucks

sourceType ModelYearID	fuelTypeID	fueltypedesc	SCCVtypeID	part5sccvtypedesc	SCCVtypeFraction
522000	1	Gasoline	4	HDGV	1
	2	Diesel Fuel	10	MHDDV	0.757
			11	HHDDV	0.243
	5	Placeholder Fuel Type	4	HDGV	1
	9	Electricity	4	HDGV	1
522001	1	Gasoline	4	HDGV	1
	2	Diesel Fuel	10	MHDDV	0.778
			11	HHDDV	0.222
	5	Placeholder Fuel Type	4	HDGV	1
	9	Electricity	4	HDGV	1

As noted earlier, SCCVtypeID (Table 18) and SCCroadtypeID (Table 17) are the only components needed to determine the applicable SCC. The postprocessing script maps the SCC value to each emission rate.

After the process of mapping the columns of the emission rate tables to SCCs based on Tables 17 and 18, the lookup table emission rates are listed by SCC and model year. The final step of the SCC mapping portion of the postprocessing script is to aggregate those SCC emission rates over model years using travel fraction. Travel fractions are simply weighting factors that sum to 1 over all model years; they are used to aggregate emission rates over model years to produce a single SCC-wide emission rate instead of a rate for each of the 31 vehicle model years. Travel fractions are based on mileage accumulation by model year and/or age distribution by model year. Travel fractions for the RPD table use Equation (1a), while travel fractions for the RPV and RPP tables use Equation (1b).

Equation (1a): $$f_{travel,MY} = \frac{\left(p_{MY} \times relMAR_{MY}\right)}{\sum_{MY}\left(p_{MY} \times relMAR_{MY}\right)}$$ (gram/mile emission rates)

Equation (1b): $$f_{travel,MY} = \frac{p_{MY}}{\sum_{MY} p_{MY}}$$ (gram/vehicle emission rates)

where:

$f_{travel,MY}$ is the travel fraction by vehicle class for model year MY (sums to 1 over all model years)

p_{MY} is the fractional population in model year MY from the vehicle age distribution for the reference county

$relMAR_{MY}$ is the relative mileage accrual for a vehicle of model year MY from the MOVES2010 default table *MOVES20091216.sourcetypeage*

Equation (2) shows how the travel fractions are then used to weight each model year emission rate to compute emission rates for each vehicle class. The calculation is simply a weighted sum of emission rates over all model years using the travel fractions as the weights.

Equation (2): $$EF_{veh} = \sum_{MY}\left(f_{travel,MY} \times EF_{MY}\right)$$

where:

EF_{veh} is the SCC-specific emissions factor of a particular pollutant (grams/mile)

$f_{travel,MY}$ is the SCC-specific travel fraction for model year MY (sums to 1 over all model years)

EF_{MY} is the emissions factor for an SCC of model year MY of a particular pollutant, in units of grams/mile or grams/vehicle/hour, depending on lookup table

The relative mileage accumulation rate (Relative MAR) is listed for each MOVES sourceTypeID and ageID in the *sourcetypeage* table in MOVES20091216. The SourceType age distribution reflects the fraction of the vehicle fleet population in a particular model year. Both Relative MAR and the reference county's *sourcetypeagedistribution* will need to be mapped to SCCVtypeID using the procedure illustrated by example in Table 18. Relative MAR and the age distribution for SCCVtype are then used to aggregate all the SCC emission rates over model year. There are 156 different SCCs described in Appendix B.

3.2.2 Creating a County Field

None of the MOVES2010 lookup tables (refer back to Table 16) contain a countyID field solely dedicated to a state-county FIPS code, but SMOKE needs this information. For this reason, the MOVES postprocessing script creates a county field by extracting it from other fields that include county codes as part of their value. The RPD table has a linkID field that contains countyID in the leading five digits followed by more numbers to allow for future implementation of link modeling. The RPV table has a zoneID field that is countyID with a trailing zero. The RPP table has a TemperatureProfileID field, which also leads with countyID and is trailed by other numbers to indicate month and other identification. The postprocessing script parses countyID from linkID, zoneID, and TemperatureProfileID and stores it as a separate field.

3.2.3 Cross-tabbing the pollutantIDs

Each of the three MOVES2010 lookup tables contains a pollutantID field (refer to Table 16), and associated emission rates for each are listed in the ratePerDistance field or ratePerVehicle field (depending on lookup table). This table structure repeats the leftmost fields (e.g., MOVESRunID, yearID, monthID) for each pollutantID, which greatly increases the total number of rows. The cross-tabbing postprocessing step replaces the column for 'ratePerDistance' (or 'ratePerVehicle', 'ratePerProfile') with additional pollutant-specific columns containing values of emission rates. For example, new field headings would include 'CO_ratePerDistance', 'NOX_ratePerDistance', 'BENZENE_ratePerDistance', etc. Performing this cross-tab on the pollutant emission rates significantly reduces the size of the tables for use by SMOKE.

3.2.4 Adjusting PM species Emission Rates for Modeling

The following information developed by OTAQ and OAQPS to speciate the partially speciated PM2.5 exhaust emissions from MOVES2010. The advantage of using this approach over the approach used for speciating total PM2.5 is that it allows the speciated emissions from MOVES; i.e., elemental carbon and particulate sulfate to be retained and only the remainder of the PM2.5 to rely on speciation profiles.

The MOVES pollutants of interest for this section are summarized in Table 19, which was provided by OTAQ. We need to further disaggregate the MOVES species "PM25OM" into the CMAQ model species.

MOVES species are related as follows:

$$PM25\_TOTAL = PM25EC + PM25OM + PSO4$$

The five CMAQ species Primary or Particulate Organic Carbon (POC), Primary Elemental Carbon (PEC), Primary Nitrate (PNO3), Primary Sulfate (PSO4), and other primary 2.5 particulate matter (PMFINE) also sum to total PM2.5:

$$PM2.5 = POC+PEC+PNO3+PSO4+PMFINE$$

Table 19. MOVES PM species

MOVES PollutantId	Data Transfer PollutantCode
101	PM10OM
102	PM10EC
105	PM10SO4
111	PM25OM
112	PM25EC
115	PM25SO4

The purpose of the equations given above is to fully speciate the MOVES2010 partially speciated exhaust PM2.5 to create the model species needed for CMAQ model. These equations are used only when there are any exhaust-related emissions (e.g., *Running Exhaust, Start*

Exhaust, Crankcase Start/Running Exhaust, and Idle Exhaust). The equations utilize the following MOVES 2010 outputs:

- PM25EC, which is identical to the element carbon portion of PM2.5, or PEC
- PM25SO4, which is identical to the sulfate portion of PM2.5, or PSO4
- PM25OM, which contains all components of PM2.5 other than PEC and PSO4(PM25OM=POC+PNO3+PMFINE)

For gasoline vehicles, MOVES applies a temperature adjustment factor that accounts for the impact of cold temperatures on PM25OM and PM25EC with decreasing temperature below 72 °F. At 72 °F or higher, there is no dependency of any component of PM2.5 on temperature. There is also no dependency of any component of PM2.5 on temperature for diesel vehicles. At temperatures lower than 72 °F, the temperature dependence is different for start emissions (including crankcase starts) versus running emissions (including crankcase running).

For gasoline vehicles, the unadjusted PEC is needed to compute the five components of PM2.5 that are not impacted by temperature. We denote unadjusted PEC as: PEC_72.

There are two ways to determine PEC_72:

1. Run MOVES at 72 °F or higher
2. Calculate it by "backing out" the temperature adjustment from the adjusted MOVES PEC. This is done by dividing PEC by the MOVES cold-temperature adjustment factor, PEC_T_{adj}: $PEC\_72 = PEC / PEC\_T_{adj}$

The option #2 "backing out" is chosen for the SMOKE-MOVE tool to eliminate the need to specify a temperature bin for the MOVES runs that is greater than or equal to 72 °F. To compute PEC_72, the cold temperature adjustment factor (PEC_T_{adj}) can be calculated based on type of exhaust and temperature (Table 20). For diesel vehicle, PEC_T_{adj} is constant to 1.0 since there is no dependency of any component of PM2.5 on temperature for diesel vehicles.

Table 20. The MOVES temperature adjustment factors (PEC_T_{adj}) to PEC.

Vehicle Type	Temperature (°F)	Temperature Adjustment Factor (PEC_T_{adj})	
		Start Exhaust / Crankcase Start Exhaust	Running Exhaust / Crankcase Running Exhaust
Gasoline Vehicles	72 °F > T	28.039 * exp(-0.0463*T)	9.871 * exp(-0.0318*T)
	T ≥ 72 °F	1.0	1.0
Diesel Vehicles	All temperature	1.0	1.0

The equations are as follows:

(1) PEC = PM25EC
(2) PSO4 = PM25SO4
(3) $PNO3 = (PEC / PEC\_T_{adj}) \times FNO3 / FEC$
(4) $METAL = (PEC / PEC\_T_{adj}) \times FMETAL / FEC$

(5) NH4 = (PNO3/62.0049 + 2×PSO4/96.0576) × 18.0383
(6) POC = 5/6 × (PM25OM – METAL – NH4 – PNO3)
(7) PMFINE = METAL + NH4 + 0.2 × POC
(8) PMC = ($R_{PM10\text{-}to\text{-}PM25}$*-1)* × (PMFINE + PEC + POC + PSO4 + PNO3)

where

Gasoline SCCs	All SCCs begin with "2201"
Diesel SCCs	All SCCs begin with "2230"
PEC	Mass of primary elemental carbon, a species needed for CMAQ
PM25EC	Mass of primary elemental carbon provided by the MOVES model
PM25SO4	Mass of primary sulfate provided by the MOVES model
PSO4	Mass of primary sulfate, a species needed for CMAQ
PNO3	Mass of primary nitrate, a species needed for CMAQ
PEC_72	Mass of primary elemental carbon when MOVES runs at 72°F or higher temperature; calculated by "backing out" the temperature adjustment factor, PEC_T_{adj}
PEC_T_{adj}	The MOVES cold-temperature adjustment factor to PM25EC from gasoline vehicles.
FNO3, FEC, FMETAL	Percentages of nitrate, elemental carbon, and metal derived from the vehicle-type-specific speciation profile; values are provided in Table 21
METAL	Mass of metal component of PM2.5, which is a component of PMFINE
NH4	Mass of ammonium component of PM2.5, which is a component of PMFINE
62.0049	Molecular weight of nitrate
96.0576	Molecular weight of sulfate
18.0383	Molecular weight of ammonium
POC	Mass of primary organic carbon, a species needed for CMAQ
PM25OM	Mass of organic material provided by the MOVES model;this actually includes more than organic matter: it includes the mass of all components of PM2.5 other than PEC and PSO4
PMFINE	Mass of other primary PM2.5 not accounted for in PEC, POC, PSO4, and PNO3; this is a species needed for CMAQ. This mass includes the ammonium, metals, water, and the mass of the noncarbon material, i.e., hydrogen, oxygen, and other atoms attached to the organic carbon
PMC	Mass of the coarse fraction of PM10; defined as PM10 – PM2.5; this is a species needed for CMAQ
$R_{PM10\text{-}to\text{-}PM25}$	Ratio of PM10-to-PM2.5, which is a constant that is dependent upon fuel type; values are provided in Table 21

Table 21 gives the values for *FNO3*, *FEC* and *FMETAL* and $R_{PM10\text{-}to\text{-}PM25.}$ They are based on the vehicle type (first seven digits of the SCC), except that $R_{PM10\text{-}to\text{-}PM25}$ is based solely on fuel type.

Table 21. Values and basis for fractions used to compute PNO3, METAL, and PMC

Vehicle Type	SCC list	*FEC (%)*	*FNO3 (%)*	*FMETAL (%)*	$R_{PM10\text{-}to\text{-}PM25}$
LDDV	All SCCs that begin with: 2230001, 2230002, 2230003, 2230004, 2230005, 2230006	57.4805	0.2300	0.6513	1.0309
HDDV	All SCCs that begin with: 223007	77.1241	0.1141	0.2757	1.0309
LDGV HDGV	All SCCs that begin with 2201	20.8011	0.1015	2.2256	1.0860

3.2.5 Final Postprocessed Emission Rate Lookup Tables

In addition to the changes specified in Section 3.2.1 to 3.2.4, a few minor cosmetic changes (described in this section) are made to each table. The three postprocessed tables named rateperdistance_smoke, ratepervehicle_smoke, and rateperprofile_smoke are exported from MySQL into ASCII files for their use in SMOKE. The fields are listed by lookup table type in Table 22.

Table 22. Fields included in the three MOVES2010 Emission Rate Lookup Tables after Postprocessing

rateperdistance_smoke (RPD) (grams/mile)	**ratepervehicle_smoke (RPV)** (grams/vehicle/hour)	**rateperprofile_smoke (RPP)** (grams/vehicle/hour)
MOVESScenarioID	MOVESScenarioID	MOVESScenarioID
yearID	yearID	yearID
monthID	monthID	monthID
FIPS (countyID)	dayID	dayID
SCC	hourID	hourID
smokeProcID	FIPS (countyID)	FIPS (countyID)
avgSpeedBinID	SCC	SCC
temperature	smokeProcID	smokeProcID
relHumidity	temperature	Temperature
TOG	TOG	TOG
CO	CO	CO
NOX	NOX	NOX
…	…	…

The cosmetic changes made to the raw table formats shown in Table 16 in creating the formats in Table 22 are detailed in the list below, followed by a paragraph of explanation.

- rateperdistance_smoke (RPD lookup table):
  - Dropped MOVESRunID, dayID,hourID, sourceTypeID, fuelTypeID, modelYearID, roadTypeID fields
  - Mapped MOVES linkID to FIPS
  - Moved the ratePerDistance field. It is now specified for each listed pollutantID (ie. TOG, CO, NOX)

  - Mapped MOVES processID to SMOKE smokeProcID
  - Added SCC

- ratepervehicle_smoke (RPV lookup table):
  - Mapped MOVES processID to SMOKE smokeProcID
  - Dropped MOVESRunID, sourceTypeID, fuelTypeID, modelYearID
  - Mapped MOVES zoneID to FIPS
  - Moved the ratePerVehicle field. It is now specified for each listed pollutantID.
  - Added SCC

- rateperprofile_smoke (RPV lookup table):
  - Postprocessed a monthID field from the raw table's temperatureProfileID field
  - Dropped MOVESRunID, temperatureProfileID, processID, sourceTypeID, fuelsTypeID, and modelYearID fields
  - Moved the retePerProfile field. It is now specified for each listed pollutantID.
  - Mapped MOVES MOVESRunID to SMOKE smokeProcID

In the RPD table, dayID and hourID are not fields used for lookup and do not have any meaning; therefore, they are dropped. In the raw RPP table, monthID is embedded within a field called temperatureProfileID. In the final rateperprofile_smoke table, monthID is extracted into its own field from temperatureProfileID, and temperatureprofileID is then dropped, since it contains no other pertinent information. In all three tables, MOVES processID is relabeled with a three-character string for SMOKE (smokeProcID), shown in the rightmost column of Table 23.

Table 23. MOVES processID, corresponding processName and associated emission rate lookup tables for SMOKE

processID	Description	smokeProcID	Associated Lookup Tables
1	Running Exh	EXR	RPD
2	Start Exh	EXS	RPV
15	Crank Run Exh	CXR	RPD
16	Crank Start Exh	CXS	RPV
17	Crank Ext Idle	CEI	RPV
90	Ext Idle Exh	EXT	RPV
11	Evap Permeation	EVP	RPD, RPV
12	Evap Fuel Vent	EFV	RPD, RPP
13	Evap Fuel Leak	EFL	RPD, RPV
18	Refuel Disp Vap	RFV	N/A
19	Refuel Spillage	RFS	N/A
9	Brakewear	BRK	RPD
10	Tirewear	TIR	RPD

4 SMOKE Model Processing

4.1 Overview

Now that we have covered the Met4moves meteorology preprocessor (Section 2) and the MOVES model processing that results in the SMOKE-formatted emissions factor lookup tables (Section 3), we address the remaining major component of the SMOKE-MOVES tool: the SMOKE model processing step. The goals of this step are (1) to estimate emissions from on-road mobile sources based on MOVES-based emissions lookup tables and meteorology data from Met4moves, (2) to create hourly gridded speciated air quality model-ready input files, and (3) to produce various types of reports for the user.

As some readers are aware, MOBILE6 and MOVES are both vehicle emissions modeling systems used with SMOKE. However, they differ in their approaches to calculating off-network evaporative emissions. In MOBILE6, off-network emissions processes are calculated as emission factors in grams/mile, which is related to VMT. MOVES, on the other hand, uses the source (vehicle) type population (VPOP) to calculate start and off-network evaporative emissions, which are assigned to off-network emissions processes; these processes are hour-dependent due to VPOP (activity) assumptions built into the MOVES model. Thus, compared to the SMOKE-MOBILE6 approach, the SMOKE-MOVES approach requires additional vehicle population inventory data as input for estimating mobile-source emissions from off-network emissions processes. This requirement is reflected in the discussion below.

When processing mobile-source emissions, SMOKE performs the following basic steps. (For more information on these SMOKE programs, please see the SMOKE user's manual.)

1. Smkinven imports county-total VMT and average speed data by SCC and county-total vehicle population (VPOP) by vehicle type.

2. Spcmat computes the chemical speciation factors for each county, source (=vehicle) type, road type, emission process, and pollutant, and stores the necessary factors for the VMT-to-species and VPOP-to-species transformations.

3. Grdmat allocates the county sources to grid cells and uses spatial surrogates to allocate county-total VMT and VPOP to grid cells, storing the factors needed for these allocations.

The way the MOVES-generated emissions factor lookup tables are used varies according to whether SMOKE is modeling on-roadway emission processes or off-network emissions processes.

On-roadway emission processes: When estimates of on-roadway emission processes (e.g., exhaust running, on-road evaporative, tire and brake wear) are needed, SMOKE requires county-total VMT and average hourly speed (SPEED) inventory data as inputs to a new SMOKE postprocessor called "Movesmrg," which is part of the SMOKE-MOVES tool. Movesmrg uses the MOVES-based rate-per-distance (RPD) table (Section 3.2.5) to estimate on-road sources

emission. The key lookup fields for the factors are gridded hourly temperature and average hourly speed from the avgSpeedBinID field. SMOKE interpolates in the RPD table (in unit of grams/mile) based on gridded hourly temperature and average speed. Figure 4a shows processing steps for on-roadway emissions processes in the SMOKE system using VMT and SPEED inventory input data.

Off-network emission processes: When estimates are needed for off-network emissions processes, including the off-network vapor venting emissions process, SMOKE uses county-total VPOP by vehicle type as input to Movesmrg together with the rate-per-vehicle (RPV) and rate-per-profile (RPP) lookup tables (Figure 4b). A significant difference in the processing steps between the on-roadway emissions processes (RPD table) and the off-network emissions processes (RPV and RPP tables) is that off-network emissions processing does not require the Temporal step because vehicle population (VPOP) does not need to be temporally allocated. In the RPV table, gridded hourly temperature and hour of the day are the key lookup fields SMOKE uses to estimate hourly off-network emissions in unit of grams/vehicle/hour. For the evaporative fuel off-network vapor venting emissions process only, Movesmrg uses the RPP lookup table to estimate the emission rates based on the minimum and maximum temperatures computed by Met4moves (Section 2.3.3.2, Table 6).

The SMOKE system requires the following inputs to process MOVES-based lookup tables:

- **MBINV**: VMT, VPOP, and SPEED inventories in the flat file 2010 (FF10) activity file format (Section 4.3.3.1)
- **MCXREF**: Reference county cross-reference file (Section 2.3.1.4)
- **MEPROC**: A list of MOVES emission processes and associated pollutants for Spcmat (Section 4.3.3.2)
- **MFMREF**: Reference county fuel month file (Section 2.3.1.5)
- **MRCLIST**: A list of MOVES lookup tables by reference county (Section 4.3.3.3)
- MOVES-based emission rate lookup tables (RPD, RPV and RPP) (Section 3.2.5)
- Met4moves output file for SMOKE (Section 2.3.3.2)
- Other ancillary input files needed for mobile-source emissions modeling, including spatial surrogates, surrogate cross-reference file, temporal profile, temporal cross-reference file, speciation profile, and speciation cross-reference file.

For all three emission rate lookup tables (RPD, RPV, RPP), SMOKE performs linear interpolation when using them.

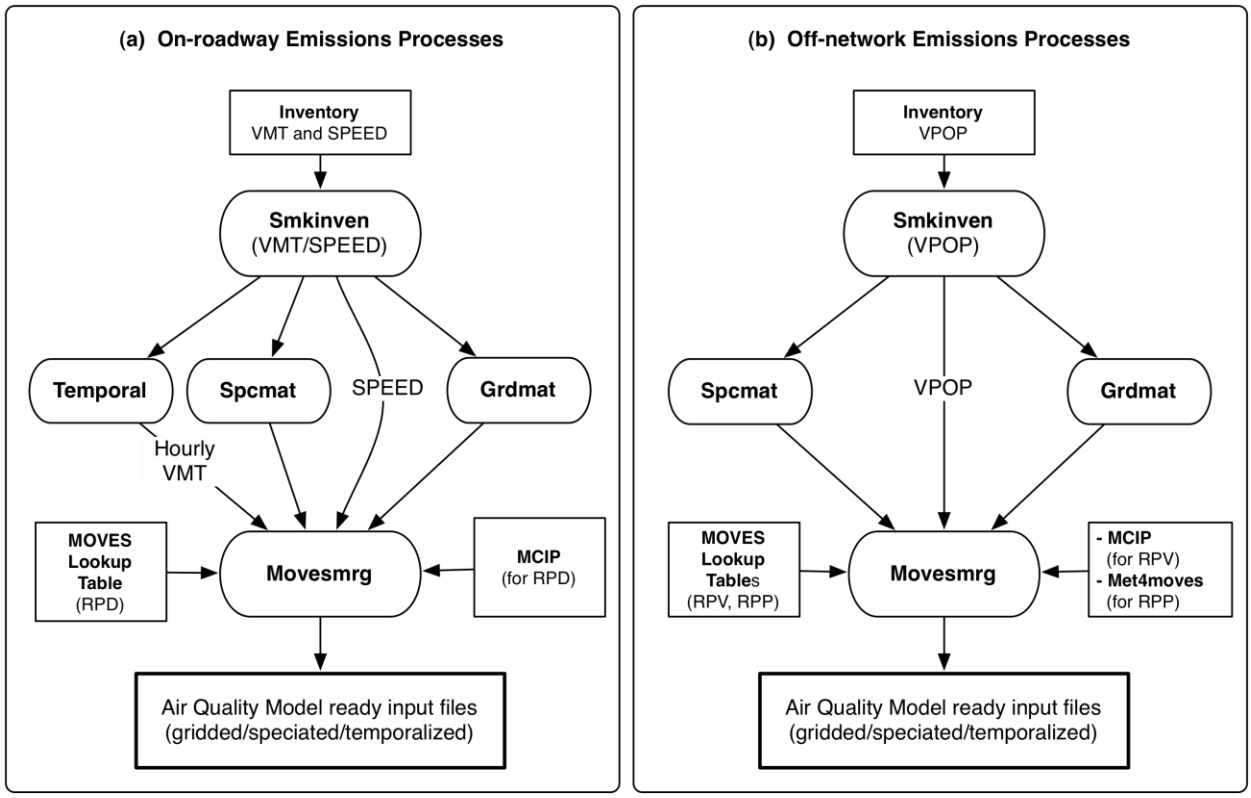

Figure 4. Flow diagrams of SMOKE-MOVES processing by emission processes.

4.2 MOVES-based Lookup Tables

4.2.1 On-roadway Emissions Processes Emissions Factors (RPD)

The Rate Per Distance (RPD) lookup table (see Table 22) is used to provide estimates of on-roadway emissions processes from mobile sources, using a separate file for each reference county. The on-road running processes that appear in this table include running exhaust (EXR), crankcase running exhaust (CXR), brake wear (BRK), tire wear (TIR), on-road evaporative permeation (EVP), on-road evaporative fuel leaks (EFL), and on-road evaporative vapor venting (EFV). The units of the emission rates in this table are grams/mile. The lookup fields for the factors are temperature and average speed. There are 16 set speed bins defined in Table 9 (i.e., avgSpeedBinID 1=2.5mph, 2=5mph, 3=10mph, …16=75mph). The avgBinSpeed is used for interpolation in the RPD table.

4.2.2 Off-network Emissions Processes Emissions Factors (RPV)

The Rate Per Vehicle (RPV) lookup table (see Table 22) is used to provide estimates of off-network emission processes (parked engine-off, engine starts, and idling), except for the evaporative off-network vapor venting emissions process (addressed in Section 4.2.3). A separate file is provided for each reference county. The off-network emission processes include start exhaust (EXS), crankcase start exhaust (CXS), off-network evaporative permeation (EVP), off-network evaporative fuel leaks (EFL), extended idle exhaust (EXT), and crankcase extended idle exhaust (CEI). Fuel month, temperature, and local hourID are the lookup fields in this table,

and hours are in the local time of the countyID. The units of the emission rates are grams/vehicle/hour.

Note: Although the units are grams/vehicle/hour, the number of vehicles (i.e., population) should not be temporally allocated to hours in SMOKE. Instead, a county total of vehicle population should be multiplied by emission rates at any given hour. The number of starts per vehicle by hour is already accounted for in the MOVES lookup table.

4.2.3 Off-network Vapor Venting Emissions Processes Emissions Factors (RPP)

The Rate Per Profile (RPP) table (see Table 22) is used only to estimate emissions for off-network fuel vapor venting (EFV) when the vehicle is parked. This process type includes diurnal (when the vehicle is parked during the day) and hot soak (immediately after a trip when the vehicle parks) emissions types. The process depends on the rate of rise in temperature and the maximum temperature achieved during the day for the diurnal emissions type, and on the hourly temperatures for the hot soak emission type. The lookup fields for this table are fuel month and hour of day. As with the RPV table, the units of the emission rates are grams/vehicle/hour. The estimated emissions rates need to be multiplied by the county vehicle population.

The reference county lookup tables contain 24-hour emission rates per hour per vehicle using a reference-county temperature profile with different minimum and maximum temperatures. The average day county emissions are determined by interpolating between the minimum and maximum temperatures for the county listed in the Met4moves output file for SMOKE listed in Section 2.3.3.2. (Table 6).

4.3 SMOKE Postprocessing Program: Movesmrg

4.3.1 Description

Movesmrg is a new, mobile-sources-only program, loosely based on the SMOKE program Smkmerge, that combines the intermediate files produced by the other SMOKE programs (i.e., Grmdat, Spcmat, Temporal). Similar to Smkmerge, the main goal of Movesmrg is to create (1) gridded, speciated, hourly air quality model-ready input files and (2) county-level SCC summaries. The primary difference between Movesmrg and Smkmerge is that Movesmrg uses the MOVES emission rate lookup tables to compute emissions on the fly, by multiplying the emissions factors by hourly VMT (for RPD) or by monthly or annual vehicle populations (for RPV or RPP).

Movesmrg must be run three times to compute on-roadway and off-network (including vapor venting) emissions processes individually, since the emission rate calculation methods in SMOKE for these categories are quite different. Once all three emissions processes have been computed, the emission output files can be merged (optionally along with other 2-D sectors separate from onroad) using Mrggrid, which combines any number of 2-D or 3-D hourly, gridded, and speciated emission data files. See the SMOKE user's manual for more details on the above programs.

4.3.1.1 Rate-Per-Distance (RPD) and Rate-Per-Vehicle (RPV) Emission Calculations

For its RPD and RPV (but not RPP) lookup table calculations, Movesmrg uses the gridded hourly temperatures in GMT, and then adjusts the hour of the RPD and RPV lookup tables from local time to GMT to get the emission rates for the reference county for the appropriate month. The key lookup fields for the factors are hourly temperature and average speed for the RPD lookup table calculation, and hourly temperature and hour of the day in local time for the RPV table calculation.

4.3.1.2 Rate-Per-Profile (RPP) Emission Calculations

For its RPP (but not RPD or PPV) lookup table calculations, Movesmrg uses the RPP lookup table as an input file for the emission rates that depend not on the gridded hourly temperatures, but on the temperature profiles output by the Met4moves program (Section 2.3.3.2). The emissions estimates based on the RPP table are computed for the temporal averaging period specified for the temperature profiles, rather than using hourly gridded meteorology.

4.3.1.3 List of Processing Pollutants Associated with Processing IDs

Table 24 gives the list of available MOVES pollutants and associates them with emissions processes (i.e., processIDs or smokeProcIDs) from MOVES model, which were shown earlier in Table 23. The information is used to create the MEPROC input file that contains a list of MOVES emission processes and associated pollutants for Spcmat.

For your information, on May 15, 2010, a MOVES2010 Errata/Information sheet was prepared (http://www.epa.gov/otaq/models/moves/420b10026.pdf). It describes several issues with the current version of MOVES. Two issues in particular (#12 and #14) could be very important to some users:

- *Issue #12:* MOVES does not produce output for acrolein, benzene, 1,3-butadiene, and formaldehyde for diesel vehicles if you request processes other than the running exhaust process. This problem does not affect gasoline vehicles.
- *Issue #14:* The extended idle process does not produce records for benzene, formaldehyde, 1,3-butadiene, acetaldehyde, or acrolein even though there are check boxes for these pollutants in the Pollutants and Processes Panel.

Therefore, these toxics will not be available for diesel vehicles in the MOVES driver script. All diesel vehicle SCCs star with "2230". See Appendix B for more detail.

Table 24. List of pollutants associated with emissions processes.

MOVES Pollutant Name	SMOKE Name	Process Y/N	smokeProcIDs												
			EXR (1)	EXS (2)	CXR (15)	CXS [16]	CEI [17]	EXT [90]	EVP [11]	EFV [12]	EFL [13]	BRK [9]	TIR [10]	RFV [18]	RFS [19]
Total Gaseous Hydrocarbons	THC	**N**	√	√	√	√	√	√	√	√	√			√	√
Non-Methane Hydrocarbons	NMHC	**N**	√	√	√	√	√	√	√	√	√			√	√
Non-Methane Organic Gases	NMOG	**N**	√	√	√	√	√	√	√	√	√			√	√
Total Organic Gases	**TOG**	**Y**	√	√	√	√	√	√	√	√	√			√	√
Volatile Organic Compounds	**VOC**	**Y**	√	√	√	√	√	√	√	√	√			√	√
Carbon Monoxide (CO)	**CO**	**Y**	√	√	√	√	√	√							
Oxides of Nitrogen	**NOX**	**Y**	√	√	√	√	√	√							
Ammonia (NH3)	**NH3**	**Y**	√	√	√	√	√	√							
Nitrogen Oxide	**NO**	**Y**	√	√	√	√	√	√							
Nitrogen Dioxide	**NO2**	**Y**	√	√	√	√	√	√							
Sulfur Dioxide (SO2)	**SO2**	**Y**	√	√	√	√	√	√							
Primary Exhaust PM10 - Total	**PM10OM**	**Y**	√	√	√	√	√	√							
Primary PM10 - Elemental Carbon	**PM10EC**	**Y**	√	√	√	√	√	√							
Primary PM10 - Sulfate PM	**PM10SO4**	**Y**	√	√	√	√	√	√							
Primary PM10 – Brakewear PM	**PM10BRAKE**	**Y**										√			
Primary PM10 - Tirewear PM	**PM10TIRE**	**Y**											√		
Primary Exhaust PM2.5 - Total	**PM25OM**	**Y**	√	√	√	√	√	√							
Primary PM2.5 - Organic Carbon	**PM25OC**	**Y**	√	√	√	√	√	√							
Primary PM2.5 - Elemental Carbon	**PM25EC**	**Y**	√	√	√	√	√	√							
Primary PM2.5 - Sulfate Particulate	**PM25SO4**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Organic Carbon	**POC**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Elemental Carbon	**PEC**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Sulfate	**PSO4**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Nitrate	**PNO3**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Ammonium	**NH4**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Other PM	**PMFINE**	**Y**	√	√	√	√	√	√							
Calculated PM2.5- Coarse PM	**PMC**	**Y**	√	√	√	√	√	√							
Primary PM2.5 - Brakewear PM	**M25BRAKE**	**Y**										√			
Primary PM2.5 - Tirewear PM	**PM25TIRE**	**Y**											√		
PMethane (CH4)	CH4	**N**	√	√	√	√	√	√	√	√	√			√	√
Nitrous Oxide (N2O)	N2O	**N**	√	√	√	√									
Atmospheric CO2	Atmos. CO2	**N**	√	√				√							
CO2 Equivalent	CO2 Equivalent	**N**	√	√				√							
Benzene	**BENZENE**	**Y**	√	√	√	√	√	√	√	√	√			√	√
Ethanol	Ethanol	**N**	√	√	√	√	√	√	√	√	√			√	√
MTBE	**MTBE**	**Y**	√	√	√	√	√	√	√	√	√			√	√
Naphthalene	**NAPHTH**	**Y**	√	√	√	√	√	√	√	√	√			√	√
1,3-Butadiene	**BUTADIE**	**Y**	√	√	√	√	√	√							
Formaldehyde	**FORMALD**	**Y**	√	√	√	√	√	√							
Acetaldehyde	**ACETALD**	**Y**	√	√	√	√	√	√							
Acrolein	**ACROLEI**	**Y**	√	√	√	√	√	√							

4.3.2 Processing Sequences

SMOKE must be run after Met4moves and after MOVES. Once all output files from Met4moves and MOVES processing scripts are ready, SMOKE programs Smkinven, Spcmat, Grdmat, and optionally Temporal for the RPD mode must be run before Movesmrg runs (Figure 4a and 4b).

Movesmrg begins by reading environment variables and opening input files (these are discussed in detail in Section 4.3.3). Environment variables include the source category (which must be set to "M") and flags that indicate the Movesmrg mode to be run. Movesmrg can run in only one of three emissions processes (or modes) at a time: (1) RPD, which calculates rate-per-distance emissions; (2) RPV, for rate-per-vehicle emissions; or (3) RPP, for rate-per-profile emissions. Therefore, to process these three MOVES-based lookup tables, SMOKE system including Movesmrg has to run three times.

Input files used by Movesmrg include the grid description, processed inventory, and gridding and speciation matrices. In RPD mode, output files from Temporal are opened so that hourly VMT data can be read. While opening the input files, Movesmrg reads inventory characteristics, including FIPS and SCC codes for each source. In addition, Movesmrg checks for consistent grid information and a consistent number of sources across the files. Movesmrg also opens several auxiliary files, including the inventory data table file, the emission processes file (to determine which emission processes and pollutants should be output), and several cross-reference files relating to reference counties and other information.

Once the environment variables and input files are checked/opened, Movesmrg performs several setup steps, including reconciling pollutant and species names between the MEPROC file, the INVTABLE file, and the speciation matrix (SMAT_L) from Spcmat. Movesmrg also determines unit conversion factors for each output species, and reads in county and state data corresponding to the FIPS codes in the inventory.

Movesmrg uses the gridding matrix (GMAT) to determine a list of grid cells associated with each source. Because the gridding matrix is read into contiguous memory that mixes integer and float storage, a special routine is used to split the gridding matrix into separate arrays. These arrays are used during the main processing loop to calculate the fraction of each source that should be allocated to the various grid cells.

Movesmrg reads the reference county information file (MCXREF) and builds data structures so that it can easily access a list of sources for each reference county and can find emission rates files for each reference county. Additionally, Movesmrg determines the fuel month mapping used for each reference county based on the fuel month input file (MFMREF).

After Movesmrg's setup steps are complete, it opens the Movesmrg output files (MGTS_L or MGSTS_S). Depending on the environment variable settings (described in Section 4.3.3.4), Movesmrg can output model-ready emissions (i.e., gridded, speciated, hourly emissions) and/or state and county daily emissions totals for each species.

Differences between RPD and RPV modes:

- RPD mode reads average speed data from the inventory and hourly VMT data output from Temporal
- RPV mode reads VPOP data from the inventory
- RPD mode processes pollutants and emission processes associated with VMT from the MEPROC file
- RPV mode processes pollutants and emission processes associated with VPOP
- RPD mode interpolates the emission rates by speed bin and hourly temperature
- RPV mode interpolates the emission rates by hourly temperature, using the local hour

Differences between RPD/RPV and RPP modes:

- RPP mode uses Met4moves output file (does not use hourly meteorological data as the RPD and RPV modes do)
- RPP mode interpolates the emission rates by temperature profile, instead of using hourly temperature as the RPD and RPV modes do

4.3.3 Files and Environment Variables

4.3.3.1 MBINV: FF10 Activity Inventory Input File for Smkinven

Smkinven requires as input a new inventory file, MBINV. MBINV is an FF10 activity inventory format for VMT, SPEED, and VPOP inventory data. The FF10 format is list-directed and uses the header described in Table 25. Sample header records are shown below:

```
#FORMAT=FF10_ACTIVITY
#COUNTRY US
#YEAR 2008
```

Table 25. FF10 format for MBINV

Line	Posi-tion	Name	Type	Re-quired?	Description
+1	A	COUNTRY_CD	Char(2)	Y	Two-digit country code; default to "US"
	B	REGION_CD	Char(5)	Y	Five-digit FIPS code for state and county
	C	TRIBAL_CODE	Char(3)	N	Leave blank if not applicable
	D	CENSUS_TRACT_CD	Char(20)	N	
	E	SHAPE_ID	Char(20)	N	
	F	SCC	Char(12)	Y	12-character SCC
	G	ACT_PARM_TYPE_CD	Char(10)	N	
	H	ACT_PARM_UOFMSR	Char(20)	N	
	I	ACTIVITY_TYPE	Char(16)	Y	Activity variable names are VMT, VPOP, and SPEED
	J	ANN_PARM_VALUE	Real	Y	Activity values in unit of "miles/yr" for annual VMT and "miles/hr" for SPEED
	K	CALC_YEAR	Int	N	
	L	DATE_UPDATED	Char(8)	N	From LAST_UPDATED_DT, YYYYMMDD format
	M	DATA_SET_ID	Int	N	

Line	Posi-tion	Name	Type	Re-quired?	Description
	N	JAN_VALUE	Real	N	Filled in only if data were provided for January in unit of "miles/day" for monthly VMT. " if val < 1000, write as #.####E##, else write as #.##
	…	…	…	…	…
	Y	DEC_VALUE	Real	N	Same as above
	Z	COMMENT	Char	N	Comment

4.3.3.2 MEPROC: List of MOVES Emission Processes and Associated Emission Pollutants for Spcmat

The MEPROC file, used by Spcmat, lists the emission processes and pollutants that will be generated by MOVES for modeling on-road mobile sources. The format of the MEPROC file is shown in Table 26. You can create your own MEPROC file using a master list of pollutants associated with emission processes (Table 24).

Table 26. Format of MEPROC

Line	Position	Description
1+	A	Activity name (up to 16 characters)
	B	Mobile emissions process (up to 6 characters)
	C+	Associated pollutant name(s) for activity and process combination (Character)

Example of MEPROC for MOVES

```
VMT    EXR    CO NOX TOG SO2 PM25OC PM25EC PM25SO4 NH3 BENZENE MTBE BUTADIE \
              FORMALD ACETALD ACROLEIN
VPOP   EXS    CO NOX TOG BENZENE MTBE BUTADIE FORMALD ACETALD ACROLEI
VMT    EVP    TOG PM25OM PM10OM
VPOP   EVP    TOG
VMT    EFL    TOG PM25OM PM10OM
VPOP   EFL    TOG
VMT    EFV    TOG PM25OM PM10OM
VPOP   EFV    TOG
VMT    CXR    TOG PM25OM PM10OM
VPOP   CXS    TOG
VPOP   CEI    TOG
VMT    BRK    PM25 BRAKE PM10BRAKE
VMT    TIR    PM25 TIRE  PM10TIRE
```

4.3.3.3 Input/Output Files and Environment Variables for Movesmrg

Figure 5 shows the input and output files for the Movesmrg program. The inputs include the country, state, and county codes file (COSTCY), the grid description file (GRIDDESC), the inventory data table (INVTABLE), the reference county fuel month file (MFMREF), the list of emission process and associated pollutants file (MEPROC), the reference county cross-reference file (MCXREF) (Table 1), the list of emission factors files by reference county file (MRCLIST, which is discussed in more detail below Figure 5), the meteorology files (MET_CRO_2D), the gridding matrix from Grdmat (MGMAT), the inventory file output from Smkinven (MOBL), the speciation matrix from Spcmat (MSMAT), the Met4moves output file for SMOKE (METMOVES), the MOVES-based lookup tables (RPD, RPV, and RPP), and the daily hour

VMT files from Temporal (MTMP_(day)). Note that MET_CRO_2D, METMOVES, and MTMP_(day) are optional files that are included only in certain situations, as shown in Figure 5.

Movesmrg outputs a model-ready emissions file (MGTS_L or MGTS_S), a report file (REPMGTS_S), and a log file (LOGFILE).

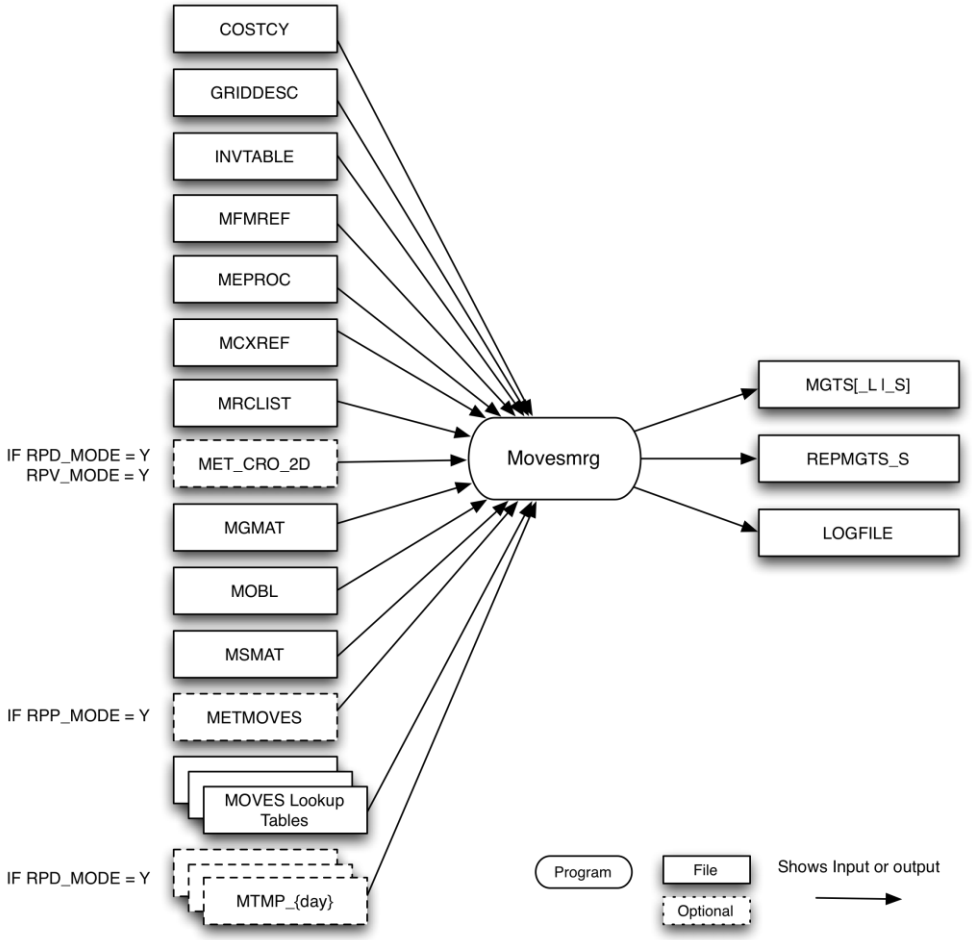

Figure 5. Movesmrg input and output files for mobile sources.

4.3.3.3.1 MRCLIST: List of MOVES Lookup Tables for Movesmrg

The MRCLIST file is an input file for Movesmrg that contains the list of MOVES-based lookup tables from the MOVES postprocessing script associated with reference county and fuel month. The format of the MRCLIST file is shown in Table 27. The user must define the location of the lookup tables using the SMK_MVSPATH environment variable in order for Movesmrg to find these lookup table files.

Table 27. Format of MRCLIST

Line	Position	Description

1+	A	Reference County (Integer)
	B	Fuel Month (Integer)
	C+	Associated MOVES-based lookup table filename (Character)

Example of MRCLIST file for MOVES RPD lookup tables

```
13121 4 rateperdistance_13121_apr.txt
13121 7 rateperdistance_13121_jul.txt
```

Example of MRCLIST file for MOVES RPV lookup tables

```
13121 4 ratepervehicle_13121_apr.txt
13121 7 ratepervehicle_13121_jul.txt
```

Example of MRCLIST file for MOVES RPP lookup tables

```
13121 4 rateperprofile_13121_apr.txt
13121 7 rateperprofile_13121_jul.txt
```

4.3.3.3.2 Input Environment Variables for Movesmrg

The following environment variables control the functioning of Movesmrg.

- `MRG_BYDAY`: [default: blank]
  String code that specifies which source category is to use a by-day approach for the hourly input files. It must be set to "M" for a Movesmrg run to create an output file for each day.

- `MRG_GRDOUT_YN`: [default: N]
  Determines whether Movesmrg produces a gridded output file.
  - Y: Read the gridding matrix produced by the Grdmat program
  - N: Do not read the gridding matrix

- `MRG_SPCOUT_YN`: [default: N]
  Determines whether Movesmrg produces a speciated output file.
  - Y: Read the speciation matrix produced by the Spcmat program
  - N: Do not read the speciation matrix

- `MRG_REPSTA_YN`: [default: N]
  Determines whether Movesmrg produces a report of emission totals by state.
  - Y: Produce the report
  - N: Do not produce the report

- `MRG_REPCNY_YN`: [default: N]
  Determines whether Movesmrg produces a report of emission totals by county.
  - Y: Produce the report
  - N: Do not produce the report

- `MRG_GRDOUT_UNIT`: [default: file units]
  String code that permits user to change the unit of the gridded output file.

- `MRG_TOTOUT_UNIT`: [default: file units]
  String code that permits user to change the unit of the state/county total report file.

- `RPD_MODE`: [default: N]
  Determines whether Movesmrg processes rate-per-distance emissions.
  - Y: Process rate-per-distance emissions
  - N: Do not process rate-per-distance emissions

- `RPV_MODE`: [default: N]
  Determines whether Movesrg processes rate-per-vehicle emissions.
  - Y: Process rate-per-vehicle emissions
  - N: Do not process rate-per-vehicle emissions

- `RPD_MODE`: [default: N]
  Determines whether Movesmrg processes rate-per-profile emissions.
  - Y: Process rate-per-profile emissions
  - N: Do not process rate-per-profile emissions

- `SMK_EF_MODEL`: [default: MOBILE6]
  Name of the emission rate model to use. To use the MOVES model, it must be set to "MOVES".

- `SMK_MVSPATH`: [default: blank]
  Location of MOVES-based emissions output files.

- `SMK_SOURCE`: [default: blank]
  Sets the types of source category. It must be set to "M" for a Movesmrg run.

- `TVARNAME`: [default: TEMP2]
  Name of temperature variable to read from the meteorology files for a Movesmrg run.

References

Office of Transportation and Air Quality (OTAQ), "Motor Vehicle Emission Simulator (MOVES) 2010: User Guide," EPA-420-B-09-041, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 2009.

Office of Transportation and Air Quality (OTAQ), "Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity" EPA-420-B-10-023, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 2010.

Office of Research and Development (ORD), "Meteorology-Chemistry Interface Preprocessor Release Notes," U.S. Environmental Protection Agency, Research Triangle Park, NC, October 2009.

Institute for the Environment (IE), "Sparse Matrix Operator Kernel Emissions (SMOKE) version 2.6 User's Manual," University of North Carolina, Chapel Hill, NC, 2009a.

Institute for the Environment (IE), "Emissions Modeling Framework Surrogate Tool: User's Guide," University of North Carolina, Chapel Hill, NC, 2009b.

Appendix A. Design Detail on the Run Control File and Example Formats

User Input: Run Control File

The following is a list of parameters that a user must provide to the MOVES driver script, which generates the runspec and data importer files. These data are independent of reference county; they apply to all runs that will be generated based on the contents of the reference county file and temperature file.

DBHOST	Database hostname
MOVESHome	Full pathname of MOVES installation directory
BATCHRUN	Character string that is the name for the MOVES batch files
OUTDIR	Full pathname where all output files will be written; batch files, MOVES runspec files, MOVES data importer files
ModelYear	Episode modeling year
Pollutants	One or more keywords: PM, OZONE, TOXICS, GHG
DayofWeek	Keywords WEEKDAY and/or WEEKEND. Optional input. If not specified, then both weekday and weekend estimates will be generated.
Met data file	Full pathname of input meteorological data (output from Met4moves processor).

Example Run Control File:

DBHOST	= localhost
MOVESHOME	= C:\Program Files\MOVES20091214
BATCHRUN	= CENRAP
OUTDIR	= C:\Program Files\MOVES20091214\runspec_files\testmjscript\
MODELYEAR	= 2005
POLLUTANTS	= OZONE
DAYOFWEEK	= WEEKDAY, WEEKEND
METFILE	= c:\movesdata\cenrap\2005\2005_repcounty_met.in

Repcounty file

Each reference county is defined by a FIPS code and the MOVES required input data files. The specifications for a single reference county are within a packet that begins with <REPCOUNTY> and ends with <ENDREPCOUNTY>. The keywords description are as follows:

FIPS =	Standard FIPS state/county FIPS code.
AGE =	Full pathname of age distribution data.
POP =	Full pathname of population data.
HPMSVMT =	Full pathname of VMT data.
IM =	Full pathname of inspection/maintenance data.
FUELSUPPLY =	Full pathname of fuel supply data.
FUELFORM =	Full pathname of fuel formulation data. This file is required only if the fuel supply file specifies a nonstandard fuel formulation.

If an input file is erroneously omitted, the MOVES data importer file will not have the required information and the MOVES data importer logfile will indicate the errors.

Example Repcounty File

```
# This is an example of the reference county file for MOVES2010 driver script
#

<REPCOUNTY>
FIPS = 48201
AGE = c:\movesdata\cenrap\2005\2005_age_distribution_48201.csv
POP = c:\movesdata\cenrap\2005\2005_population_48201.csv
HPMSVMT =c:\movesdata\cenrap\2005\vmt_2005_48201.csv
IM = c:\movesdata\cenrap\2005\IM_2005.csv
FUELSUPPLY = c:\movesdata\cenrap\2005\2005_summer_houston_fuelsupply.csv
FUELFORM =
<ENDREPCOUNTY>

<REPCOUNTY>
FIPS = 48001
AGE = c:\movesdata\cenrap\2005\2005_age_distribution_attain.csv
POP = c:\movesdata\cenrap\2005\2005_population_48attain.csv
HPMSVMT =c:\movesdata\cenrap\2005\vmt_2005_48attain.csv
IM = c:\movesdata\cenrap\2005\IM_2005_48attain.csv
FUELSUPPLY = c:\movesdata\cenrap\2005\2005_summer_attain_fuelsupply.csv
FUELFORM =
<ENDREPCOUNTY>
```

Appendix B. MOVES SCC List and Descriptions

SCC	SCCRoadTypeID	SCCRoadTypeDesc	SCCVTypeID	PART5SCCVtypeDesc
2201001110	11	Rural Interstate	1	LDGV
2201001130	13	Rural Principal Arterial	1	LDGV
2201001150	15	Rural Minor Arterial	1	LDGV
2201001170	17	Rural Major Collector	1	LDGV
2201001190	19	Rural Minor Collector	1	LDGV
2201001210	21	Rural Local	1	LDGV
2201001230	23	Urban Interstate	1	LDGV
2201001250	25	Urban Freeway/Expressway	1	LDGV
2201001270	27	Urban Principal Arterial	1	LDGV
2201001290	29	Urban Minor Arterial	1	LDGV
2201001310	31	Urban Collector	1	LDGV
2201001330	33	Urban Local	1	LDGV
2201001000	1	Off-Network	1	LDGV
2201020110	11	Rural Interstate	2	LDGT1
2201020130	13	Rural Principal Arterial	2	LDGT1
2201020150	15	Rural Minor Arterial	2	LDGT1
2201020170	17	Rural Major Collector	2	LDGT1
2201020190	19	Rural Minor Collector	2	LDGT1
2201020210	21	Rural Local	2	LDGT1
2201020230	23	Urban Interstate	2	LDGT1
2201020250	25	Urban Freeway/Expressway	2	LDGT1
2201020270	27	Urban Principal Arterial	2	LDGT1
2201020290	29	Urban Minor Arterial	2	LDGT1
2201020310	31	Urban Collector	2	LDGT1
2201020330	33	Urban Local	2	LDGT1
2201020000	1	Off-Network	2	LDGT1
2201040110	11	Rural Interstate	3	LDGT2
2201040130	13	Rural Principal Arterial	3	LDGT2
2201040150	15	Rural Minor Arterial	3	LDGT2
2201040170	17	Rural Major Collector	3	LDGT2
2201040190	19	Rural Minor Collector	3	LDGT2
2201040210	21	Rural Local	3	LDGT2
2201040230	23	Urban Interstate	3	LDGT2
2201040250	25	Urban Freeway/Expressway	3	LDGT2
2201040270	27	Urban Principal Arterial	3	LDGT2
2201040290	29	Urban Minor Arterial	3	LDGT2
2201040310	31	Urban Collector	3	LDGT2
2201040330	33	Urban Local	3	LDGT2
2201040000	1	Off-Network	3	LDGT2
2201070270	27	Urban Principal Arterial	4	HDGV
2201070290	29	Urban Minor Arterial	4	HDGV
2201070310	31	Urban Collector	4	HDGV
2201070330	33	Urban Local	4	HDGV
2201070110	11	Rural Interstate	4	HDGV

2201070130	13	Rural Principal Arterial	4	HDGV
2201070150	15	Rural Minor Arterial	4	HDGV
2201070170	17	Rural Major Collector	4	HDGV
2201070190	19	Rural Minor Collector	4	HDGV
2201070210	21	Rural Local	4	HDGV
2201070230	23	Urban Interstate	4	HDGV
2201070250	25	Urban Freeway/Expressway	4	HDGV
2201070000	1	Off-Network	4	HDGV
2201080110	11	Rural Interstate	5	MC
2201080130	13	Rural Principal Arterial	5	MC
2201080150	15	Rural Minor Arterial	5	MC
2201080170	17	Rural Major Collector	5	MC
2201080190	19	Rural Minor Collector	5	MC
2201080210	21	Rural Local	5	MC
2201080230	23	Urban Interstate	5	MC
2201080250	25	Urban Freeway/Expressway	5	MC
2201080270	27	Urban Principal Arterial	5	MC
2201080290	29	Urban Minor Arterial	5	MC
2201080310	31	Urban Collector	5	MC
2201080330	33	Urban Local	5	MC
2201080000	1	Off-Network	5	MC
2230001270	27	Urban Principal Arterial	6	LDDV
2230001290	29	Urban Minor Arterial	6	LDDV
2230001310	31	Urban Collector	6	LDDV
2230001330	33	Urban Local	6	LDDV
2230001110	11	Rural Interstate	6	LDDV
2230001130	13	Rural Principal Arterial	6	LDDV
2230001150	15	Rural Minor Arterial	6	LDDV
2230001170	17	Rural Major Collector	6	LDDV
2230001190	19	Rural Minor Collector	6	LDDV
2230001210	21	Rural Local	6	LDDV
2230001230	23	Urban Interstate	6	LDDV
2230001250	25	Urban Freeway/Expressway	6	LDDV
2230001000	1	Off-Network	6	LDDV
2230060110	11	Rural Interstate	7	LDDT
2230060130	13	Rural Principal Arterial	7	LDDT
2230060150	15	Rural Minor Arterial	7	LDDT
2230060170	17	Rural Major Collector	7	LDDT
2230060190	19	Rural Minor Collector	7	LDDT
2230060210	21	Rural Local	7	LDDT
2230060230	23	Urban Interstate	7	LDDT
2230060250	25	Urban Freeway/Expressway	7	LDDT
2230060270	27	Urban Principal Arterial	7	LDDT
2230060290	29	Urban Minor Arterial	7	LDDT
2230060310	31	Urban Collector	7	LDDT
2230060330	33	Urban Local	7	LDDT
2230060000	1	Off-Network	7	LDDT
2230071110	11	Rural Interstate	8	2BHDDV

2230071130	13	Rural Principal Arterial	8	2BHDDV
2230071150	15	Rural Minor Arterial	8	2BHDDV
2230071170	17	Rural Major Collector	8	2BHDDV
2230071190	19	Rural Minor Collector	8	2BHDDV
2230071210	21	Rural Local	8	2BHDDV
2230071230	23	Urban Interstate	8	2BHDDV
2230071250	25	Urban Freeway/Expressway	8	2BHDDV
2230071270	27	Urban Principal Arterial	8	2BHDDV
2230071290	29	Urban Minor Arterial	8	2BHDDV
2230071310	31	Urban Collector	8	2BHDDV
2230071330	33	Urban Local	8	2BHDDV
2230071000	1	Off-Network	8	2BHDDV
2230072110	11	Rural Interstate	9	LHDDV
2230072130	13	Rural Principal Arterial	9	LHDDV
2230072150	15	Rural Minor Arterial	9	LHDDV
2230072170	17	Rural Major Collector	9	LHDDV
2230072190	19	Rural Minor Collector	9	LHDDV
2230072210	21	Rural Local	9	LHDDV
2230072230	23	Urban Interstate	9	LHDDV
2230072250	25	Urban Freeway/Expressway	9	LHDDV
2230072270	27	Urban Principal Arterial	9	LHDDV
2230072290	29	Urban Minor Arterial	9	LHDDV
2230072310	31	Urban Collector	9	LHDDV
2230072330	33	Urban Local	9	LHDDV
2230072000	1	Off-Network	9	LHDDV
2230073110	11	Rural Interstate	10	MHDDV
2230073130	13	Rural Principal Arterial	10	MHDDV
2230073150	15	Rural Minor Arterial	10	MHDDV
2230073170	17	Rural Major Collector	10	MHDDV
2230073190	19	Rural Minor Collector	10	MHDDV
2230073210	21	Rural Local	10	MHDDV
2230073230	23	Urban Interstate	10	MHDDV
2230073250	25	Urban Freeway/Expressway	10	MHDDV
2230073270	27	Urban Principal Arterial	10	MHDDV
2230073290	29	Urban Minor Arterial	10	MHDDV
2230073310	31	Urban Collector	10	MHDDV
2230073330	33	Urban Local	10	MHDDV
2230073000	1	Off-Network	10	MHDDV
2230074110	11	Rural Interstate	11	HHDDV
2230074130	13	Rural Principal Arterial	11	HHDDV
2230074150	15	Rural Minor Arterial	11	HHDDV
2230074170	17	Rural Major Collector	11	HHDDV
2230074190	19	Rural Minor Collector	11	HHDDV
2230074210	21	Rural Local	11	HHDDV
2230074230	23	Urban Interstate	11	HHDDV
2230074250	25	Urban Freeway/Expressway	11	HHDDV
2230074270	27	Urban Principal Arterial	11	HHDDV
2230074290	29	Urban Minor Arterial	11	HHDDV

2230074310	31	Urban Collector	11	HHDDV
2230074330	33	Urban Local	11	HHDDV
2230074000	1	Off-Network	11	HHDDV
2230075110	11	Rural Interstate	12	BUSES
2230075130	13	Rural Principal Arterial	12	BUSES
2230075150	15	Rural Minor Arterial	12	BUSES
2230075170	17	Rural Major Collector	12	BUSES
2230075190	19	Rural Minor Collector	12	BUSES
2230075210	21	Rural Local	12	BUSES
2230075230	23	Urban Interstate	12	BUSES
2230075250	25	Urban Freeway/Expressway	12	BUSES
2230075270	27	Urban Principal Arterial	12	BUSES
2230075290	29	Urban Minor Arterial	12	BUSES
2230075310	31	Urban Collector	12	BUSES
2230075330	33	Urban Local	12	BUSES
2230075000	1	Off-Network	12	BUSES