ENVIRON

June 25, 2012

TECHNICAL MEMORANDUM No. 3: ON-ROAD MOBILE SOURCES

To: Tom Moore, Western Regional Air Partnership (WRAP)

From: James G. Wilkinson and Cyndi Loomis, Alpine Geophysics, LLC
Ralph Morris, ENVIRON International Corporation

Subject: On-Road Mobile Source Emissions

INTRODUCTION

ENVIRON International Corporation (ENVIRON), Alpine Geophysics, LLC (Alpine) and the University of North Carolina (UNC) at Chapel Hill Institute for Environment are performing the West-wide Jump Start Air Quality Modeling Study (WestJumpAQMS) managed by the Western Governors' Association (WGA) for the Western Regional Air Partnership (WRAP). WestJumpAQMS is setting up the CAMx photochemical grid model for the 2008 calendar year (plus spin up days for the end of December 2007) on a 36 km CONUS, 12 km WESTUS and several 4 km Inter-Mountain West modeling domains. The WestJumpAQMS Team are currently compiling emissions to be used for the 2008 base case modeling, with the 2008 National Emissions Inventory (NEI) being a major data source. The Team is preparing 13 Technical Memorandums discussing the sources of the 2008 emissions by major source sector:

1. Point Sources including Electrical Generating Units (EGUs) and Non-EGUs;
2. Area plus Non-Road Mobile Sources;
3. On-Road Mobile Sources that will be based on MOVES;
4. Oil and Gas Sources (in several installments);
5. Fires Emissions including wildfire, prescribed burns and agricultural burning;
6. Fugitive Dust Sources;
7. Off-Shore Shipping Sources;
8. Ammonia Emissions;
9. Biogenic Emissions;
10. Eastern USA Emissions;
11. Mexico/Canada;

12. Sea Salt and Lightning Emissions; and
13. Emissions Modeling Parameters including spatial surrogates, temporal adjustment parameters and chemical (VOC and PM) speciation profiles.

This Technical Memorandum #3 discusses the approach to be used for developing 2008 emissions for the on-road mobile source emissions sector.

ON-ROAD MOBILE SOURCES

Mobile sources describe a wide variety of vehicles, engines, and equipment that under their own power can move from one location to another on paved and un-paved roads. There is a distinction between on-road sources and those sources that are non-road. On-road sources include vehicles used for the transportation of passengers or freight. Non-road sources distinguish between commercial-military marine vessels/railroad (on-rail)/aircraft and all other non-road categories (e.g., construction equipment, recreational equipment, agricultural equipment, etc.).

On-road mobile sources include light-duty vehicles, light-duty trucks, heavy-duty vehicles, buses and motorcycles used for transportation of goods and passengers on established roadways. On-road vehicles may be fueled with gasoline, diesel fuel, or alternative fuels such as alcohol or natural gas.

MOVES and SMOKE EMISSIONS PROCESSING

MOVES

The Motor Vehicle Emissions Simulator (MOVES[1]) is EPA's current tool to construct on-road mobile source emissions estimates for national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile source air toxics from highway vehicles (EPA, 2012a). In addition, MOVES can make projections for energy consumption (total, petroleum-based, and fossil-based). EPA requires that all new regulatory modeling use the MOVES model for mobile source emissions (EPA, 2012c).

The WestJumpAQMS on-road mobile source emission modeling was conducted using MOVES2010a. In April 2012 EPA released MOVES2010b after WestJumpAQMS completed its MOVES modeling. According to EPA's documentation, the primary difference between MOVES2010b and MOVES2010a is related to performance issues (e.g., computing run time) and the emission estimates produced by the two versions of MOVES are nearly identical[2]. EPA's technical guidance for State Implementation Plans (SIPs) and transportation conformity notes that studies that started with MOVES2010a do not have to switch to the new MOVES2010b (EPA, 2012b[3]). Given the near identical emissions, EPA's MOVES modeling guidance and the

1 http://www.epa.gov/otaq/models/moves/index.htm
2 http://www.epa.gov/otaq/models/moves/documents/420f12014.pdf
3 http://www.epa.gov/otaq/models/moves/documents/420b12028.pdf

significant effort WestJumpAQMS has invested in its MOVES modeling to date, rerunning with MOVES2010b is not necessary.

MOVES Modeling Approaches

MOVES2010a can be configured to estimates emissions directly (i.e., emissions inventory mode) or estimates emissions factors (i.e., emissions factor mode). There are three main approaches for using MOVES to generate hourly gridded speciated emission inputs needed for photochemical grid models (e.g., CAMx and CMAQ):

- Run MOVES in emissions inventory mode using county-specific representative hourly temperature, vehicle miles traveled (VMT) and other inputs (e.g., fleet mix and fuel type) to generate hourly county-level on-road mobile source emissions. The Sparse Matrix Operator Kernel Emissions (SMOKE) emissions modeling system is then used to grid and speciate the hourly county-level MOVES emissions.

- Use the SMOKE-MOVES tool that accesses a MOVES emission factor lookup table using gridded hourly meteorological data and representative VMT, fleet mix, fuel type, etc. for the grid cell to generate gridded hourly on-road emission estimates that are then speciated into the appropriate chemical species. The MOVES lookup table is generated by running MOVES multiple times in emissions factor mode for different temperatures, fuel types, etc.

- Use CONCEPT-MOVES that combines link-based VMT data from a Transportation Demand Model (TDM) with hourly meteorological data and a MOVES emissions factor lookup table to generate hourly gridded speciated on-road mobile source emissions.

MOVES Modeling for WestJumpAQMS

For the current study, MOVES2010a was run in emissions inventory mode to estimate hourly emissions at the county level for a representative weekend day and weekday for each month of 2008. CONCEPT-MOVES is limited to locations with TDM data and SMOKE-MOVES would require more resources than available for the study. A modified version of MET4MOVES was run to prepare representative average meteorology for 2008 by month, hour, and county that is suitable for use by MOVES2010a. These new hourly estimates of temperature and relative humidity, based on a 2008 WRF simulation such as the WestJumpAQMS WRF run (ENVIRON, Alpine and UNC, 2012[4]), replaced the current default meteorology that exists in the MOVES2010a (movesdb20100830.zonemonthhour database). MOVES2010a was run using the existing MOVES2010a default data sets, with the replacement meteorology, to estimate emissions (tons per hour) for all PM and OZONE pollutants by county/month/weekend day-weekday/hour by appropriate SCC and MOVES2010a process (e.g., extended idle, running exhaust, etc.). The resulting emissions estimates were converted to SMOKE-ready area source, hourly data sets suitable for processing by SMOKE/SMKINVEN. A modified version of SMKINVEN is used to process the hour-specific emissions estimates.

4 http://www.wrapair2.org/pdf/WestJumpAQMS_2008_Annual_WRF_Final_Report_February29_2012.pdf

Though MOVES can be run in emissions factors mode and the resulting output combined with VMT, population and speeds data with SMOKE/MOVESMRG to create hourly, gridded on-road mobile source emissions estimates, resource constraints precluded us from following this path. The following is a rough comparison of the MOVES emissions inventory mode and MOVES emissions factor mode approaches:

MOVES emissions inventory mode:

1. Run modified version of MET4MOVES to generate new hourly meteorological profiles by county by month;

2. Substitute in Step 1 into *zonemonthhour* database;

3. Run MOVES2010a;

4. Extract and reformat results from Step 3 to create hourly emissions estimates by county by month for a representative weekend day and weekday; and

5. Run SMOKE.

MOVES emissions factor mode:

1. Unless provided from some external source, extract MOVES2010a default data for counties that cover I/M program, vehicle age distribution by source type, vehicle population by source type, VMT by aggregated source type, fuel supply by county, and fuel formulation data;

2. Unless provided from some external source, examine fuel supply/formulation data coupled with I/M program data in order to determine each representative county and attendant counties;

3. Determine number of fuel seasons to model and what months constitute a fuel season by representative counties;

4. Aggregate vehicle population by source type and VMT by aggregated source type across all attendant counties to create new representative county data sets;

5. Create new vehicle age distribution by source type data set by properly weighting values across all attendant counties;

6. Run MET4MOVES to generate proper meteorological profiles;

7. Run MOVES-SMOKE Tool to generate MOVES2010a XML run scripts;

8. Run MOVES2010a;

9. Run MOVES-SMOKE Tool to extract and summarize emissions factors from Step 8; and

10. Run SMOKE.

In Steps 1 and 2, others can supply this information; however, to the best of available knowledge, the only entity that has run MOVES2010a in the western US who could supply such information is the US EPA, and they indicated that they are in no position to release these data at this time.

As can be observed from the overview of running MOVES in each mode, the emissions factor mode requires more resources.

SMOKE Spatial Allocation

The on-road mobile source emissions estimates will be spatially allocated to the 36/12/4 km modeling domains using the SMOKE emissions model and recent mobile source spatial surrogates developed using the 2010 census and other data. This includes new spatial surrogate categories specific to new source categories in MOVES (e.g., heavy duty truck idling at rest stops). Figure 1 shows the carbon monoxide (CO) emissions by county for April, 2008. Figure 2 shows the total organic gas (TOG) emissions by county for October, 2008. As expected counties with major urban areas, such as Los Angeles, Maricopa (Phoenix) and King (Seattle), tend to have higher emissions, whereas rural counties without major highways have lower emissions.

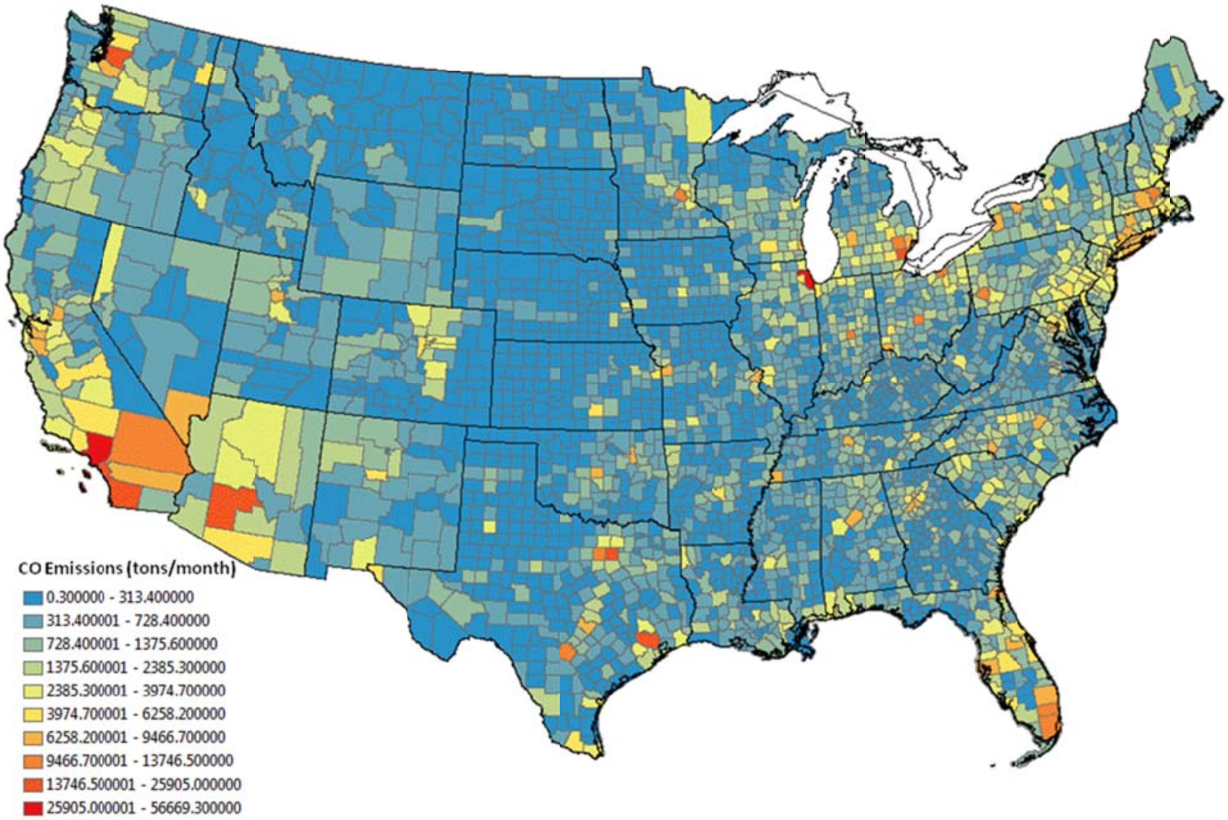


Figure 1. County-level CO emissions by county for April 2008 (tons per month).

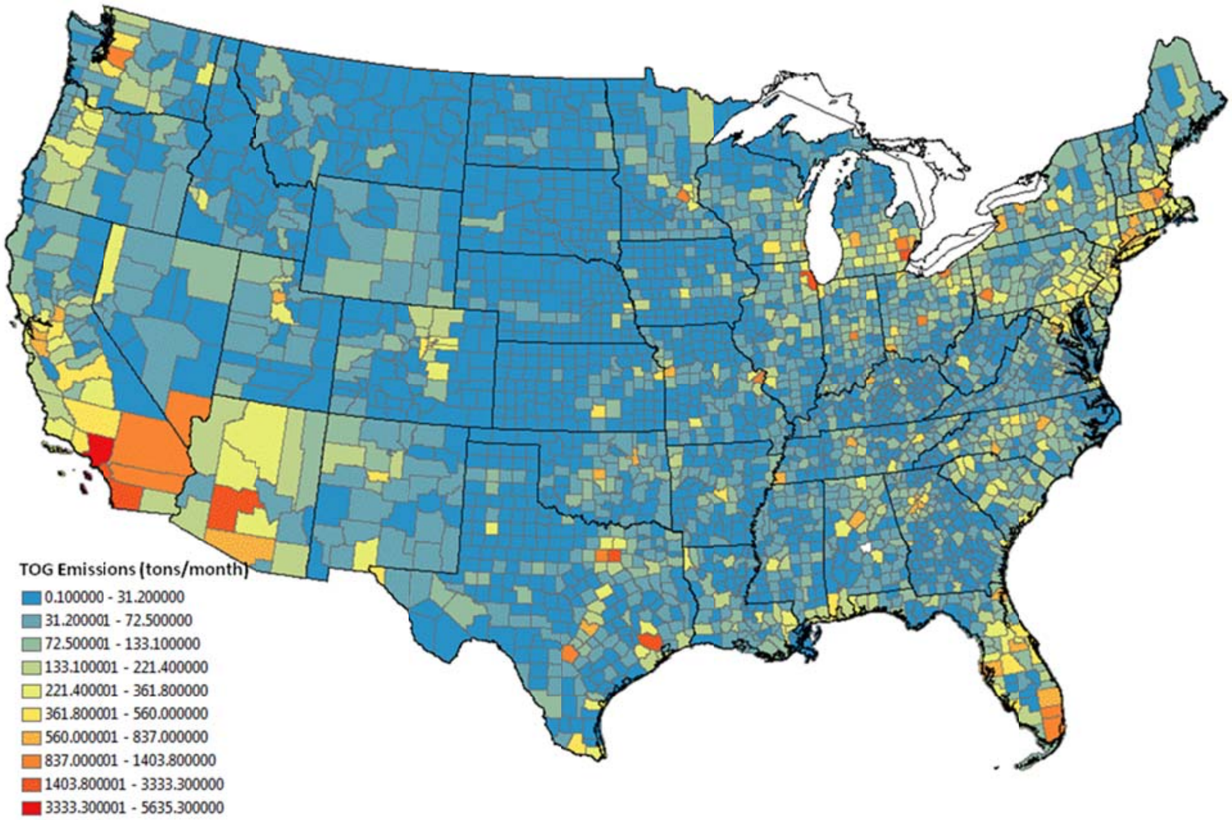
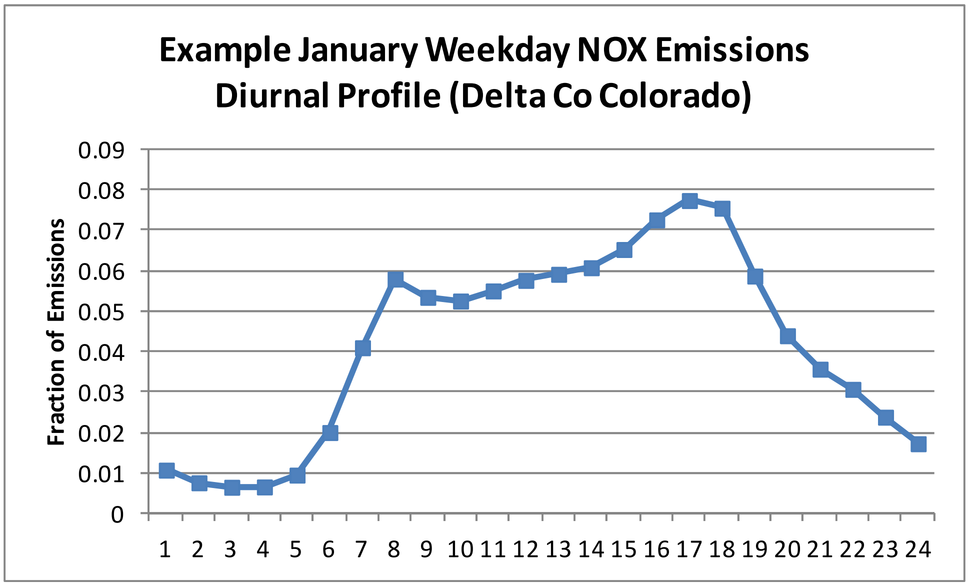


Figure 2. County-level TOG emissions for October 2008 (tons per month).

SMOKE Temporal Allocation

As MOVES2010a estimates hourly on-road mobile source emissions estimates by county by month for a representative weekend day and weekday, there is no need to temporally allocate the emissions using SMOKE. However, in order for SMOKE to properly utilize these hourly emissions estimates, a modified version of SMOKE is required. During a previous study, Alpine Geophysics modified SMOKE to accept county-wide, hourly emissions estimates. Figure 3 presents example diurnal plots for NO_X emissions in Delta County, Colorado for a representative January weekday (top graphic) and a representative January weekend day (bottom graphic). The weekday diurnal profile has the characteristic “batman” diurnal profile that shows higher emissions during the morning and afternoon commute periods; the batman profile would be more pronounced for an urban area county. The weekend day diurnal profile, on the other hand, starts increasing in the morning to a high value at about noon and then creeps a little bit higher until around 5 pm after which the emissions begin to drop.



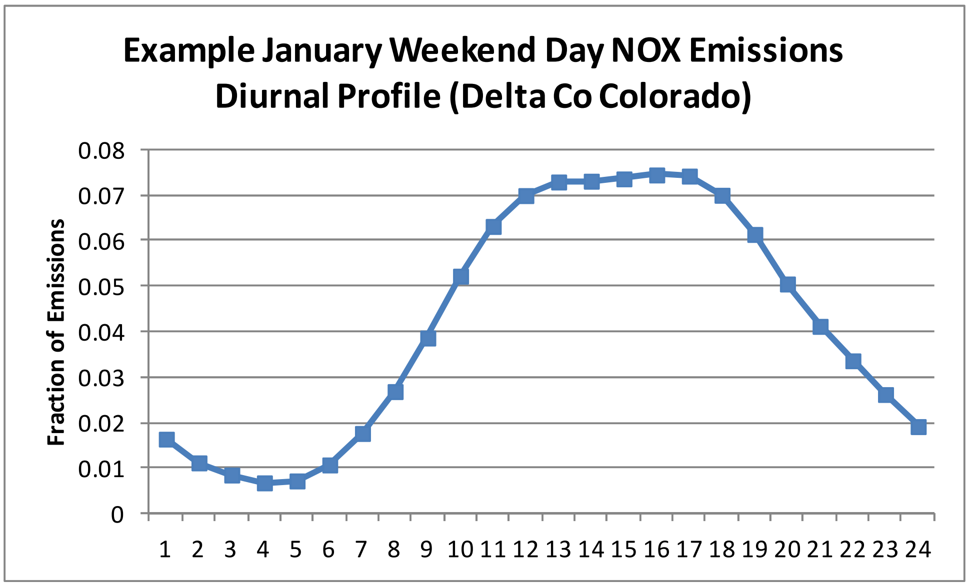


Figure 3. Example diurnal profiles of MOVES2010a NOX emissions estimates.

Input Emissions Summaries

Table 1 shows a summary of the on-road mobile source emissions estimates by state for the month of July 2008. Table 2 shows a similar summary for the 2008 annual period. And Table 3 displays the percent deviations of the July mobile sources from the annual average values. With four notable exceptions, in general the "states" July on-road mobile source emission estimates are within ±20% of the annual average values. The four outlier "states" are Alaska (AK), Hawaii (HI), Puerto Rico (PI) and Virgin Islands (VI) whose on-road emissions in July tend to be 100% to 200% greater than the annual average value.

There are many factors that affect on-road mobile source emissions that can cause the July emissions to deviate from the annual average values including activity, such as Vehicle Miles Travelled (VMT), temperature, humidity and fuels. Tirewear and brakewear PM emissions will depend on VMT and the fact that emissions for these two categories are 100% to 200% greater for the four outlier states (AK, HI, PR and VI) explains why these four states are different and have July average on-road mobile source emissions that are more than double the annual average values. These four states have large tourism components that increase their VMT in the summer. Alaska also has weather conditions that inhibit vehicle travels in the winter. For the other states, the tirewear and brakewear PM emissions in July tend to be ~10% greater than annual average indicating that July VMT is ~10% greater than annual average. So all things being equal, we would expect on-road mobile emissions in July to be ~10% greater than annual average. However, there are other offsetting factors that affect on-road mobile source emissions that are described next.

Temperature has offsetting effects on on-road mobile source emissions. Hotter temperatures tend to increase running exhaust TOG, NO_X and CO emissions as well as evaporative TOG emissions. Hot temperatures also result in the use of air conditioners (AC) that can dramatically increase running exhaust TOG, NO_X and CO emissions. However, colder temperatures will increase TOG, CO, and to a lesser extent, NO_X, start emissions as it will take longer for the catalyst to warm up and be an effective control device. Higher humidity tends to reduce NO_X emissions as it reduces temperatures in the combustion chamber. Some areas, mainly ozone nonattainment areas, may also use different cleaner burning fuels during the summer (e.g., low RVP gasoline)

Given these offsetting effects, it is difficult to explain all of the changes between July and annual average emissions, but the trends among the different states tend to make sense. For example, for most states the July CO emissions tend to be lower than annual average reflecting the lower start emissions. For cold weather states (e.g., MN, MT, ND, WI, etc.) the July CO emissions tend to be much lower than annual average (-20% to -30%). However, for warmer states the higher exhaust CO emissions and use of AC results in less CO reductions in July compared to annual average to even higher CO emissions in July than annual average for very hot states such as AZ (+10%) and TX (+6%). July NO_X and TOG emissions tend to be within ±10% of the annual average, with the exception of the four outlier states. The ammonia and SO_2 emissions tend to be related directly to activity (VMT) so the July average emissions tend to be ~10% greater than the annual average.

On-road mobile PM emissions tend to be lower in July than the annual average. One significant change between MOVES and MOBILE6 is the inclusions of temperature effects for PM emissions. In particular, MOVES produces much higher PM emissions from light duty gasoline vehicles (LDGV) under cold temperatures. This effect explains why the July average on-road mobile source emissions are lower than the annual average values.

Table 1. Example emissions summary for July, 2008 (tons/month). WRAP region States are highlighted in yellow.

State	CO	NOX	TOG	NH3	SO2	PM25	PMC	TIREWEAR	BRAKEWEAR
AK	6,735	1,264	504	22	13	77	42	3	9
AL	59,813	12,682	5,724	246	105	735	397	39	103
AR	35,158	7,402	3,189	134	59	439	237	21	57
AZ	49,206	12,086	4,827	222	78	683	368	35	93
CA	221,454	58,243	21,900	1,277	150	3,256	1,762	194	508
CO	42,700	11,627	4,464	212	92	650	351	33	88
CT	27,404	6,484	2,599	139	47	380	206	21	56
DC	3,139	644	271	16	6	33	18	2	6
DE	8,098	1,766	717	39	15	97	52	6	16
FL	157,888	30,838	13,727	653	277	1,716	927	100	263
GA	107,177	22,160	9,304	461	164	1,364	736	72	191
HI	8,712	1,838	851	38	14	94	51	6	15
IA	29,319	7,501	3,198	134	60	446	240	21	57
ID	15,477	4,137	1,515	66	32	222	120	11	28
IL	92,146	22,970	9,448	476	191	1,333	720	73	194
IN	70,268	17,638	7,510	328	143	1,012	546	52	138
KS	30,393	6,991	3,051	127	57	395	213	20	53
KY	49,809	11,964	4,905	225	91	719	388	36	95
LA	48,792	10,230	4,476	194	80	613	330	31	82
MA	43,144	10,045	3,955	241	77	610	330	36	96
MD	45,188	10,901	4,233	228	90	639	345	35	93
ME	14,324	3,641	1,339	64	28	226	122	10	28
MI	100,714	22,794	9,971	443	210	1,249	676	68	181
MN	50,185	12,711	5,469	237	96	710	384	37	98
MO	69,603	15,866	6,759	309	140	928	500	48	128
MS	41,261	8,928	3,951	164	72	528	285	26	70
MT	11,217	2,924	1,004	45	22	173	93	7	20
NC	99,997	20,591	8,606	411	180	1,209	652	64	170
ND	7,282	2,023	789	33	15	118	64	5	15
NE	18,379	4,607	2,002	82	37	270	145	13	35
NH	11,314	2,916	1,049	55	21	182	98	9	23
NJ	56,489	13,113	5,305	304	105	754	408	46	120
NM	24,094	6,265	2,464	105	48	371	200	17	46
NV	18,078	4,729	1,950	81	29	234	126	13	33
NY	106,822	26,670	10,331	597	226	1,599	865	91	241
OH	102,318	25,152	10,177	494	223	1,452	784	77	204
OK	50,163	11,029	4,938	198	90	598	322	31	83
OR	34,578	8,910	3,219	160	62	507	274	25	67
PA	100,698	23,806	9,219	476	197	1,427	770	74	198
PR	21,143	3,726	1,791	78	34	210	113	12	32
RI	6,795	1,588	628	39	13	96	52	6	15
SC	53,576	11,288	4,570	204	94	701	377	33	88
SD	8,276	2,353	916	38	18	143	77	6	17
TN	68,776	15,839	6,585	300	134	935	504	47	126
TX	227,956	47,452	20,310	974	389	2,686	1,450	150	396
UT	22,425	5,951	2,185	101	48	318	172	16	42
VA	78,277	17,247	6,943	338	141	1,005	542	53	140
VI	523	90	43	2	1	5	3	0	1
VT	6,783	1,764	620	32	14	111	60	5	14
WA	51,793	12,665	4,644	244	94	719	389	38	100
WI	53,345	13,782	5,610	262	107	806	435	41	110
WV	19,622	5,029	1,920	85	39	311	168	14	37
WY	8,478	2,478	831	36	18	146	78	6	16
Total	2,697,302	627,336	256,504	12,470	4,781	36,238	19,564	1,934	5,134

Table 2. Example emissions summary for year 2008 (tons/year). WRAP region States are highlighted in yellow.

State	CO	NOX	TOG	NH3	SO2	PM25	PMC	TIREWEAR	BRAKEWEAR
AK	38,559	6,278	2,629	102	59	396	216	16	44
AL	714,311	147,978	65,960	2,684	1,096	8,591	4,660	419	1,117
AR	421,010	85,472	36,043	1,461	614	5,215	2,829	232	624
AZ	539,205	136,915	53,193	2,425	809	7,996	4,336	380	1,012
CA	2,714,218	651,336	254,848	13,954	1,686	38,513	20,972	2,115	5,555
CO	620,565	134,009	57,372	2,317	999	8,819	4,843	362	962
CT	366,872	79,164	33,341	1,523	548	5,035	2,762	233	616
DC	40,275	7,390	3,314	177	63	431	238	26	67
DE	108,799	20,872	8,850	427	162	1,237	678	64	170
FL	1,760,447	349,860	155,129	7,135	2,915	19,145	10,364	1,088	2,867
GA	1,288,237	260,149	109,197	5,020	1,742	16,011	8,690	782	2,080
HI	44,143	8,856	4,222	180	67	450	244	27	72
IA	463,894	91,022	41,377	1,456	643	6,100	3,346	232	623
ID	220,457	45,758	19,311	723	344	2,986	1,637	115	309
IL	1,371,976	274,475	122,867	5,198	2,077	18,158	9,975	800	2,116
IN	1,080,546	210,035	93,759	3,577	1,531	13,186	7,214	561	1,497
KS	391,704	81,500	35,684	1,382	601	5,013	2,735	217	581
KY	672,580	141,213	58,803	2,446	988	8,886	4,840	386	1,036
LA	557,631	117,225	49,887	2,111	892	6,960	3,763	333	892
MA	633,489	123,840	52,877	2,634	839	8,291	4,562	398	1,045
MD	540,039	127,247	51,125	2,483	991	8,071	4,409	383	1,013
ME	217,498	43,763	17,820	694	307	2,990	1,637	112	301
MI	1,502,126	270,654	132,208	4,837	2,278	17,357	9,554	745	1,973
MN	844,695	150,954	74,478	2,587	991	10,770	5,958	403	1,072
MO	924,278	191,256	82,321	3,402	1,509	11,931	6,515	531	1,415
MS	479,883	102,577	43,931	1,781	748	6,098	3,301	282	759
MT	170,677	33,265	13,980	491	244	2,428	1,286	80	217
NC	1,284,228	241,145	103,038	4,478	1,901	14,471	7,867	697	1,856
ND	127,313	24,081	11,281	363	163	1,761	971	59	158
NE	265,449	55,443	24,706	896	394	3,596	1,969	142	382
NH	168,581	35,128	14,066	599	220	2,417	1,324	95	255
NJ	823,760	172,873	69,400	4,314	1,289	13,609	7,461	658	1,735
NM	316,189	74,317	29,829	1,144	515	4,557	2,478	184	497
NV	215,090	50,711	21,038	887	305	2,964	1,619	137	364
NY	1,589,543	320,170	136,148	6,520	2,499	21,557	11,845	996	2,627
OH	1,627,251	297,926	130,626	5,387	2,404	19,155	10,497	836	2,222
OK	625,383	124,371	54,476	2,159	936	7,191	3,909	338	901
OR	496,793	100,373	40,540	1,744	672	6,369	3,482	274	731
PA	1,457,756	283,229	118,431	5,190	2,107	18,552	10,154	809	2,153
PR	104,179	17,998	8,872	372	161	1,001	541	57	150
RI	100,341	19,497	8,290	421	135	1,287	708	64	166
SC	656,365	131,582	53,129	2,219	990	8,123	4,395	356	959
SD	126,209	27,950	11,834	408	188	1,952	1,070	67	181
TN	968,607	186,545	78,836	3,269	1,419	11,279	6,132	514	1,371
TX	2,586,452	539,735	230,312	10,625	4,075	30,980	16,804	1,634	4,324
UT	315,265	66,157	27,737	1,099	515	4,273	2,343	173	460
VA	989,053	201,472	83,106	3,689	1,508	12,327	6,714	575	1,527
VI	2,554	432	210	9	4	24	13	2	4
VT	105,640	21,110	8,520	347	153	1,505	825	56	150
WA	793,049	144,607	61,203	2,662	1,024	9,373	5,145	411	1,088
WI	855,151	164,416	76,166	2,858	1,172	11,506	6,339	447	1,193
WV	276,053	59,204	23,508	923	415	3,828	2,082	150	406
WY	126,903	28,068	11,122	392	197	1,971	1,079	65	176
Total	35,731,266	7,281,598	3,110,944	136,177	51,102	456,691	249,326	21,115	56,067

Table 3. Differences in July and annual average 2008 emissions (percent). WRAP region States are highlighted in yellow.

State	CO	NOX	TOG	NH3	SO2	PM25	PMC	TIREWEAR	BRAKEWEAR
AK	110%	142%	130%	159%	164%	133%	133%	125%	145%
AL	0%	3%	4%	10%	15%	3%	2%	12%	11%
AR	0%	4%	6%	10%	15%	1%	1%	9%	10%
AZ	10%	6%	9%	10%	16%	3%	2%	11%	10%
CA	-2%	7%	3%	10%	7%	1%	1%	10%	10%
CO	-17%	4%	-7%	10%	11%	-12%	-13%	9%	10%
CT	-10%	-2%	-6%	10%	3%	-9%	-10%	8%	9%
DC	-6%	5%	-2%	8%	14%	-8%	-9%	-8%	7%
DE	-11%	2%	-3%	10%	11%	-6%	-8%	13%	13%
FL	8%	6%	6%	10%	14%	8%	7%	10%	10%
GA	0%	2%	2%	10%	13%	2%	2%	10%	10%
HI	137%	149%	142%	153%	151%	151%	151%	167%	150%
IA	-24%	-1%	-7%	10%	12%	-12%	-14%	9%	10%
ID	-16%	8%	-6%	10%	12%	-11%	-12%	15%	9%
IL	-19%	0%	-8%	10%	10%	-12%	-13%	10%	10%
IN	-22%	1%	-4%	10%	12%	-8%	-9%	11%	11%
KS	-7%	3%	3%	10%	14%	-5%	-7%	11%	9%
KY	-11%	2%	0%	10%	11%	-3%	-4%	12%	10%
LA	5%	5%	8%	10%	8%	6%	5%	12%	10%
MA	-18%	-3%	-10%	10%	10%	-12%	-13%	9%	10%
MD	0%	3%	-1%	10%	9%	-5%	-6%	10%	10%
ME	-21%	0%	-10%	11%	9%	-9%	-11%	7%	12%
MI	-20%	1%	-9%	10%	11%	-14%	-15%	10%	10%
MN	-29%	1%	-12%	10%	16%	-21%	-23%	10%	10%
MO	-10%	0%	-1%	9%	11%	-7%	-8%	8%	9%
MS	3%	4%	8%	10%	16%	4%	4%	11%	11%
MT	-21%	5%	-14%	10%	8%	-14%	-13%	5%	11%
NC	-7%	2%	0%	10%	14%	0%	-1%	10%	10%
ND	-31%	1%	-16%	9%	10%	-20%	-21%	2%	14%
NE	-17%	0%	-3%	10%	13%	-10%	-12%	10%	10%
NH	-19%	0%	-11%	10%	15%	-10%	-11%	14%	8%
NJ	-18%	-9%	-8%	-15%	-2%	-34%	-34%	-16%	-17%
NM	-9%	1%	-1%	10%	12%	-2%	-3%	11%	11%
NV	1%	12%	11%	10%	14%	-5%	-7%	14%	9%
NY	-19%	0%	-9%	10%	9%	-11%	-12%	10%	10%
OH	-25%	1%	-7%	10%	11%	-9%	-10%	11%	10%
OK	-4%	6%	9%	10%	15%	0%	-1%	10%	11%
OR	-16%	7%	-5%	10%	11%	-4%	-6%	9%	10%
PA	-17%	1%	-7%	10%	12%	-8%	-9%	10%	10%
PR	144%	148%	142%	152%	153%	152%	151%	153%	156%
RI	-19%	-2%	-9%	11%	16%	-10%	-12%	13%	8%
SC	-2%	3%	3%	10%	14%	4%	3%	11%	10%
SD	-21%	1%	-7%	12%	15%	-12%	-14%	7%	13%
TN	-15%	2%	0%	10%	13%	-1%	-1%	10%	10%
TX	6%	6%	6%	10%	15%	4%	4%	10%	10%
UT	-15%	8%	-5%	10%	12%	-11%	-12%	11%	10%
VA	-5%	3%	0%	10%	12%	-2%	-3%	11%	10%
VI	146%	150%	146%	167%	200%	150%	177%	-100%	200%
VT	-23%	0%	-13%	11%	10%	-11%	-13%	7%	12%
WA	-22%	5%	-9%	10%	10%	-8%	-9%	11%	10%
WI	-25%	1%	-12%	10%	10%	-16%	-18%	10%	11%
WV	-15%	2%	-2%	11%	13%	-3%	-3%	12%	9%
WY	-20%	6%	-10%	10%	10%	-11%	-13%	11%	9%
Total	-9%	3%	-1%	10%	12%	-5%	-6%	10%	10%

Comparisons with WRAP region 2002 Emissions

Table 3 compares the current state-wide 2008 MOVES2010a inventory mode on-road mobile source emissions with the WRAP 2002 Base02b on-road mobile source emissions estimated using MOBILE6.2 (Pollack et al. 2006[5]) for TOG, NO_X, SO_2, CO, NH_3 and $PM_{2.5}$ emissions. There are numerous changes between the WRAP Base02b 2002 and MOVES2010a 2008 mobile source emissions that affect the differences shown in Table 3:

- Activity data, such as VMT with 2008 having higher activity than 2002;
- Fleet mix, with 2002 having a higher emitting fleet average emission than 2008;
- Methodology, 2002 was based on MOBILE6 (except California that used EMFAC) whereas 2008 was based on MOVES2010a; and
- Fuel use, with 2008 using cleaner fuels

The changes between the 2002 and 2008 on-road mobile source emissions in Table 3 reflects the offsetting effects, with the increases in activity and MOBILE6 to MOVES2010a methodology changes generally resulting in increases in emissions, and the fleet turnover and cleaner fuels resulting in decreases in on-road mobile source emissions.

TOG emissions are estimated to be reduced from -14% to -70% between 2002 and 2008 across the WRAP region (Table 3a). The lowest reductions (-14%) occurs in ND and SD and the highest reductions (-68% and -70%) occur in AK and MT. Because of all of the offsetting effects it is difficult to explain the causes of these differences. There are smaller differences in the NO_X emissions between 2002 and 2008. Alaska has the largest reduction in NO_X emissions between 2002 and 2008 (-61%) with the changes in the remaining states ranging from a 12% increase to a 39% decrease (Table 3b). The largest reductions in on-road mobile emissions between 2002 and 2008 occur for SO_2 emissions that are reduced from -33% to -91%. This is due in part to the use of lower sulfur diesel fuel with a diesel fuel sulfur content of ~500 ppm in 2002 being reduced to 15 ppm in 2008 (Table 3c).

CO emissions are reduced by -17% to -74% between 2002 and 2008 (Table 3d). With NH_3 emissions being reduced by -27% to -56% (Table 3d). Unlike the other pollutants, on-road mobile $PM_{2.5}$ emissions increase from 12% to 391% between 2002 and 2008, with an average increase of 200% (Table 3f). This is because MOVES2010a has much higher $PM_{2.5}$ emissions than MOBILE6. This is especially true under colder conditions where MOVES2010a has a substantial increase in $PM_{2.5}$ emissions under colder temperatures; MOBILE6 had very little temperature effect on its PM emissions under cold temperatures.

5 http://www.wrapair.org/forums/ef/UMSI/0606_WRAP_Mobile_Source_EI_Final_Report.pdf

Table 3a. Comparison of 2008 MOVES and WRAP 2002 Base02b MOBILE6.2 on-road mobile source TOG emissions for WRAP region states.

TOG Emissions [tpy]	On-Road Mobile Sources			
State	2008 MOVES	2002 MOBILE6 Base02b	Difference	% Difference
Alaska	2,629	8,666	-6,037	-70%
Arizona	53,193	111,259	-58,067	-52%
California	254,848	324,955	-70,107	-22%
Colorado	57,372	100,910	-43,538	-43%
Washington	61,203	140,184	-78,981	-56%
Oregon	40,540	89,056	-48,516	-54%
Idaho	19,311	26,981	-7,670	-28%
Montana	13,980	43,575	-29,595	-68%
Wyoming	11,122	14,254	-3,132	-22%
North Dakota	11,281	13,119	-1,838	-14%
Nevada	21,038	36,266	-15,228	-42%
New Mexico	29,829	40,266	-10,437	-26%
South Dakota	11,834	13,729	-1,896	-14%
Utah	27,737	49,063	-21,326	-43%
TOTAL	**615,916**	**1,012,283**	**-396,367**	**-39%**

Table 3b. Comparison of 2008 MOVES and WRAP 2002 Base02b MOBILE6.2on-road mobile source NO_X emissions for WRAP region states.

NO_X Emissions [tpy]	On-Road Mobile Sources			
State	2008 MOVES	2002 MOBILE6 Base02b	Difference	% Difference
Alaska	6,278	16,197	-9,919	-61%
Arizona	136,915	179,715	-42,800	-24%
California	651,336	581,144	70,192	12%
Colorado	134,009	141,959	-7,950	-6%
Washington	144,607	201,981	-57,374	-28%
Oregon	100,373	112,840	-12,467	-11%
Idaho	45,758	44,592	1,166	3%
Montana	33,265	54,355	-21,090	-39%
Wyoming	28,068	38,557	-10,489	-27%
North Dakota	24,081	25,062	-981	-4%
Nevada	50,711	41,083	9,628	23%
New Mexico	74,317	69,733	4,583	7%
South Dakota	27,950	29,206	-1,257	-4%

Utah	66,157	77,352	-11,195	-14%
TOTAL	**1,523,824**	**1,613,776**	**-89,951**	**-6%**

Table 3c. Comparison of 2008 MOVES and WRAP 2002 Base02b MOBILE6.2 on-road mobile source SO_2 emissions for WRAP region states.

SO_2 Emissions [tpy]	On-Road Mobile Sources			
State	2008 MOVES	2002 MOBILE6 Base02b	Difference	% Difference
Alaska	59	655	-596	-91%
Arizona	809	2,739	-1,930	-70%
California	1,686	4,034	-2,348	-58%
Colorado	999	4,149	-3,150	-76%
Washington	1,024	5,539	-4,515	-82%
Oregon	672	3,448	-2,776	-81%
Idaho	344	1,590	-1,246	-78%
Montana	244	1,786	-1,542	-86%
Wyoming	197	960	-763	-79%
North Dakota	163	776	-613	-79%
Nevada	305	455	-150	-33%
New Mexico	515	1,951	-1,436	-74%
South Dakota	188	873	-685	-78%
Utah	515	1,777	-1,262	-71%
TOTAL	**7,720**	**30,733**	**-23,013**	**-75%**

Table 3d. Comparison of 2008 MOVES and WRAP 2002 Base02b MOBILE6.2 on-road mobile source CO emissions for WRAP region states.

CO Emissions [tpy]	On-Road Mobile Sources			
State	2008 MOVES	2002 MOBILE6 Base02b	Difference	% Difference
Alaska	38,559	149,418	-110,859	-74%
Arizona	539,205	1,210,554	-671,349	-55%
California	2,714,218	3,262,928	-548,709	-17%
Colorado	620,565	1,400,289	-779,724	-56%
Washington	793,049	1,721,867	-928,818	-54%
Oregon	496,793	1,087,462	-590,668	-54%
Idaho	220,457	427,091	-206,634	-48%
Montana	170,677	595,833	-425,157	-71%
Wyoming	126,903	235,882	-108,979	-46%
North Dakota	127,313	214,216	-86,904	-41%
Nevada	215,090	401,590	-186,499	-46%
New Mexico	316,189	581,054	-264,866	-46%
South Dakota	126,209	221,263	-95,054	-43%

Utah	315,265	745,499	-430,234	-58%
TOTAL	**6,820,491**	**12,254,945**	**-5,434,454**	**-44%**

Table 3e. Comparison of 2008 MOVES and WRAP 2002 Base02b MOBILE6.2 on-road mobile source NH_3 emissions for WRAP region states.

NH_3 Emissions [tpy]	On-Road Mobile Sources			
State	**2008 MOVES**	**2002 MOBILE6 Base02b**	**Difference**	**% Difference**
Alaska	102	492	-390	-79%
Arizona	2,425	5,034	-2,609	-52%
California	13,954	22,118	-8,163	-37%
Colorado	2,317	4,317	-2,000	-46%
Washington	2,662	5,213	-2,552	-49%
Oregon	1,744	3,263	-1,519	-47%
Idaho	723	1,430	-708	-49%
Montana	491	1,294	-802	-62%
Wyoming	392	538	-146	-27%
North Dakota	363	732	-369	-50%
Nevada	887	2,030	-1,143	-56%
New Mexico	1,144	2,132	-989	-46%
South Dakota	408	842	-435	-52%
Utah	1,099	2,453	-1,354	-55%
TOTAL	**28,711**	**51,889**	**-23,178**	**-45%**

Table 3f. Comparison of 2008 MOVES and WRAP 2002 Base02b MOBILE6.2 on-road mobile source $PM_{2.5}$ emissions for WRAP region states.

$PM_{2.5}$ Emissions [tpy]	On-Road Mobile Sources			
State	**2008 MOVES**	**2002 MOBILE6 Base02b**	**Difference**	**% Difference**
Alaska	396	355	41	12%
Arizona	7,996	3,605	4,391	122%
California	38,513	10,519	27,994	266%
Colorado	8,819	2,971	5,849	197%
Washington	9,373	4,163	5,210	125%
Oregon	6,369	2,378	3,991	168%
Idaho	2,986	845	2,140	253%
Montana	2,428	1,072	1,355	126%
Wyoming	1,971	800	1,172	146%

North Dakota	1,761	545	1,216	223%
Nevada	2,964	604	2,360	391%
New Mexico	4,557	1,525	3,031	199%
South Dakota	1,952	666	1,286	193%
Utah	4,273	1,416	2,857	202%
TOTAL	**94,357**	**31,464**	**62,894**	**200%**

Quality Assurance

Quality assurance (QA) will be performed following the emissions quality assurance protocol developed during WRAP (Adelman, 2004[6]). These procedures include systematic procedures for:

- Modeling QA – accuracy assurance and problem identification.
- System QA – software and data tracking.
- Documentation – tracking QA issues, recording the QA process and report writing.

An emissions QA checklist is developed that delineates each step of the QA process and allows a systematic approach to the QA process to assure critical steps are not overlooked. The completed QA checklists and templates include:

- Model configuration settings.
- Inventory file log.
- Ancillary input file log.
- Model execution log.

A series of QA products are produced that are compared to other studies and the expected outcomes:

- Spatial plots of emissions by source category.
- Annual time series plots of emissions for subregions.
- Diurnal time series plots.

The emissions QA officer is required to generate, review and distribute the QA products to the modeling team and buy off on the results prior to execution of the air quality model.

6 http://www.epa.gov/ttnchie1/conference/ei13/qaqc/adelman_pres.pdf

REFERENCES

Adelman, Z. 2004. Emissions Modeling Quality Assurance Protocol. Presented at 13th Annual Emissions Invnetory Conference, Clearwater, Florida. (http://www.epa.gov/ttnchie1/conference/ei13/qaqc/adelman_pres.pdf).

EPA. 2003. User's Guide to MOBILE6.1 and MOBILE 6.2 Mobile Source Emissions Factor Model. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. EPA 420-R-03-010. August. (http://www.epa.gov/OMSWWW/models/mobile6/420r03010.pdf).

EPA. 2012a. Motor Vehicle Emissions Simulator (MOVES) – User Guide for MOVES2010b. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. EPA 420-B-12-001b. June. (http://www.epa.gov/otaq/models/moves/documents/420b12001b.pdf).

EPA. 2012b. Using MOVES to Prepare Emissions Inventories in State Implementation Plans and Transportation Conformity. Technical Guidance for MOVRS2010, 2010a and 2010b. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Assessment and Standards Division. EPA 420-B-12-028. April. (http://www.epa.gov/otaq/models/moves/documents/420b12028.pdf).

EPA. 2012c. Policy Guidance on the Use of MOVES2010 and Subsequent Minor Revisions for State Implementation Plan Development, Transportation Conformity and Other Purposes. U.S. Environmental Protection Agency, Office of Transportation and Air Quality, Transportation and Climate Division. EPA 420-B-12-010. April. (http://www.epa.gov/otaq/models/moves/documents/420b12010.pdf).

Pollack, A.K., L. Chan, P. Chandraker, J. Grant, C. Lindhjem, S. Rao, J. Russell and C. Tran. 2006. WRAP Mobile Source Emission Inventories Update. ENVIRON International Corporation, Novato, CA. May. (http://www.wrapair.org/forums/ef/UMSI/0606_WRAP_Mobile_Source_EI_Final_Report.pdf).