

September 19, 2019

SPECIFICATION SHEET: CMV_C1C2 2016beta Platform

Description: Category 1 and 2 Commercial Marine Vessel (cmv_c1c2) emissions, for simulating 2016 and future year U.S. air quality

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1. EXECUTIVE SUMMARY

Commercial Marine Vessel (CMV) emissions for ships with Category 1 and Category 2 (i.e., small to medium-sized) engines are modeled in the cmv_c1c2 sector as area sources. The cmv_c1c2 sector includes emissions in U.S. state and federal waters. The 2016 beta platform includes projections of cmv_c1c2 emissions from the 2014 National Emission Inventory version 2 (NEI2014v2) to 2016, 2023, and 2028 based on the Locomotive and Marine rule Regulatory Impact Assessment (RIA)¹. Base and future year inventories were processed for air quality modeling with the Sparse Matrix Operating Kernel Emissions (SMOKE) modeling system version 4.6. National and state-level emission summaries for key pollutants are provided.

¹ <https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-locomotive>

2. INTRODUCTION

This document details the approach and data sources used for developing 2016, 2023, and 2028 emissions for the Commercial Marine Vessel, Category 1 and Category 2 sectors (cmv_c1c2) inventory sector. The 2016 beta platform cmv_c1c2 inventory is projected to 2016 from the U.S EPA 2014NEIv2².

The cmv_c1c2 inventory sector contains small to medium-size engine CMV emissions. Category 1 (C1) and Category 2 (C2) marine diesel engines typically range in size from about 700 to 11,000 hp. These engines are used to provide propulsion power on many kinds of vessels including tugboats, towboats, supply vessels, fishing vessels, and other commercial vessels in and around ports. They are also used as stand-alone generators for auxiliary electrical power on many types of vessels. C1 represents engines up to 7 liters per cylinder displacement. C2 includes engines from 7 to 30 liters per cylinder.³

The cmv_c1c2 inventory sector contains sources that traverse state and federal waters and that are in the 2014NEIv2. Where the Category 3 CMV (cmv_c3) inventory is modeled as point sources with plume rise, the cmv_c1c2 sources are modeled as area sources with emissions that occur only near the Earth's surface.

The cmv_c1c2 sources within state waters are identified in the inventory with the Federal Information Processing Standard (FIPS) county code for the state and county in which the vessel is registered. The cmv_c1c2 sources that operate outside of state waters but within the Emissions Control Area (ECA) are encoded with a state FIPS code of 85. The ECA areas include parts of the Gulf of Mexico, and parts of the Atlantic and Pacific coasts. As the U.S. federal waters around Puerto Rico and Alaska are outside the continental U.S. (CONUS) modeling domain, cmv_c1c2 sources for these regions are not included in the 2016beta inventory. The cmv_c1c2 sources in the 2016beta inventory are categorized as operating either in-port or underway and are encoded using the two source classification codes (SCCs) listed in Table 1.

Table 1. 2016 beta platform SCCs for cmv_c1c2 sector

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2280002100	Mobile Sources	Marine Vessels, Commercial	Diesel	Port emissions
2280002200	Mobile Sources	Marine Vessels, Commercial	Diesel	Underway emissions

² <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>

³ <https://www.epa.gov/sites/production/files/2015-10/documents/fy12-marine-rule-flowchart.pdf>

3. INVENTORY DEVELOPMENT METHODS

CMV_c1c2 emissions from the 2014NEIv2 were projected to 2016 using factors derived from the Regulatory Impact Analysis (RIA) Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder⁴. Emissions projection factors were specified by pollutant and applied nationally, except for vessels registered in California. The 2014NEIv2 cmv_c1c2 emissions were projected to the 2023 and 2028 future years using a similar methodology as was used for 2016. Volatile Organic Compound (VOC) projection factors were applied to both VOC and the VOC Hazardous Air Pollutants (HAPs). Table 2 lists the pollutant-specific projection factors to 2016, 2023, and 2028 that were used for cmv_c1c2 sources outside of California.

Table 2. National projection factors for cmv_c1c2

Pollutant	2014-to-2016	2014-to-2023	2014-to-2028
CO	-1.44%	-2.67%	-1.11%
NOX	-7.44%	-34.56%	-48.73%
PM10	-11.04%	-36.24%	-49.61%
PM2.5	-11.04%	-36.24%	-49.61%
SO2	-60.28%	-86.21%	-86.45%
VOC	-7.96%	-36.96%	-51.41%

For California vessels, CMV inventories that were previously provided by CARB for the years 2014, 2023, and 2028 were used to calculate California-specific projection factors. We applied the county, SCC, and pollutant-specific factors generated from the CARB inventories to the 2014NEIv2 cmv_c1c2 inventory to estimate base and future year emissions for these sources. We linearly interpolated the 2016 cmv_c1c2 projection factor for California vessels from the 2014-to-2023 CARB projection factors. The factors vary by county, SCC, and pollutant. The 2014-to-2023 projection factors were reduced by 2/9 to convert a 9-year growth factor into a 2-year growth factor.

4. ANCILLARY DATA

Spatial Allocation

Spatial allocation of CMV emissions to national 36km and 12km modeling grids is accomplished using spatial surrogates. Spatial surrogates map county polygons to the uniformly spaced grid cells of a modeling domain. The cmv_c1c2 sector uses surrogate 820 (Ports NEI2014 Activity)

⁴ <https://nepis.epa.gov/Exe/ZyPDF.cgi/P10023S4.PDF?Dockkey=P10023S4.PDF>

for port emissions and surrogate 808 (2013 Shipping Density) for underway emissions. A summary of the national total cmv_c1c2 emissions assigned to each spatial surrogate is provided in Plots of the 808 and 820 surrogates are shown in Figures 1 and 2, respectively.

Table 3. Plots of the 808 and 820 surrogates are shown in Figures 1 and 2, respectively.

Table 3. 2016 cmv_c1c2 emissions (tons/year) by spatial surrogate, 36US3 domain

Surrogate	Description	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
808	2013 Shipping Density	99,837	297	489,917	13,464	12,963	1,736	8,543
820	Ports NEI2014 Activity	4,754	11	23,996	779	735	1,386	985

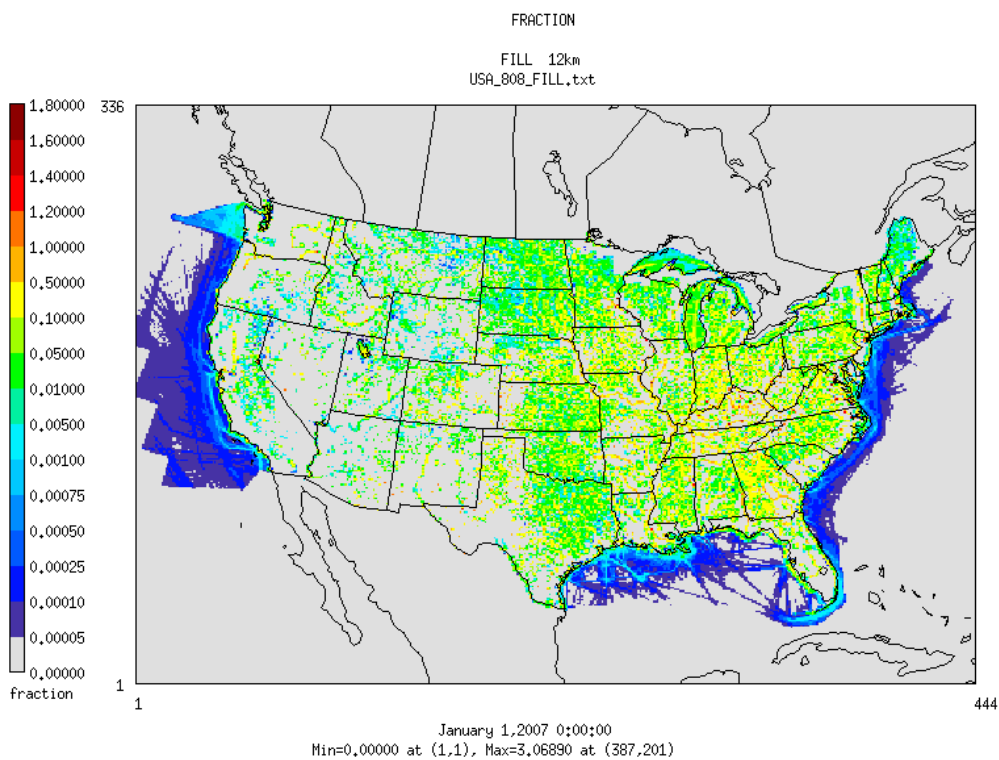


Figure 1. 2013 Shipping Density Surrogate Number 808

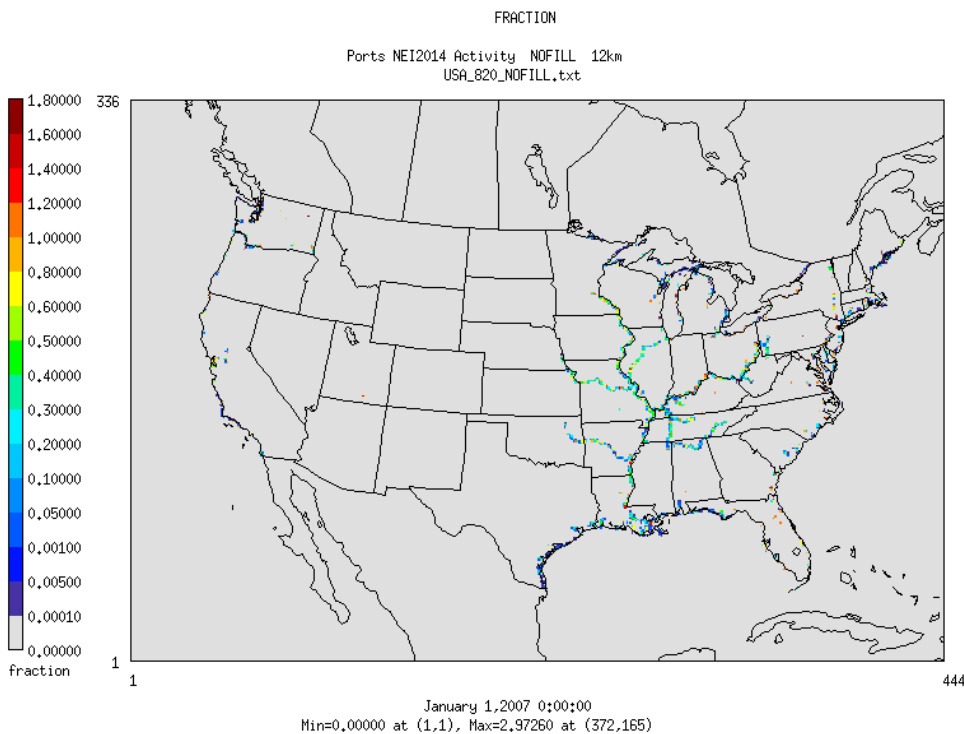


Figure 2. Ports NEI2014 Surrogate Number 820

Temporal Allocation

Month-of-year temporalization for the cmv_c1c2 sector is flat, except for emissions in the Great Lakes which uses 2014-based monthly profiles provided by LADCO⁵. As the day-of-week and hour-of-day temporal profiles are flat for all cmv_c1c2 sources, air quality model-ready emissions were only prepared for one representative day per month. Table 4 lists the annual total 2016 emissions assigned to different monthly temporal profiles. The Great Lakes vessels use the profiles that include “GLCMV” in the monthly profile name; the rest of the sources in the U.S. use the flat monthly profile (262). Figure 3 is a plot of the Great Lakes monthly temporal profiles used for the 2016beta emissions.

Table 4. 2016 cmv_c1c2 emissions by monthly temporal profile (includes federal waters)

Monthly Profile	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
262 (flat)	107,901	318	526,324	14,730	14,201	2,916	9,604
GLCMV1	479	1	2,675	64	59	0	44
GLCMV10	9	0	47	2	2	2	1
GLCMV11	12	0	65	2	1	0	1
GLCMV12	3	0	26	1	1	3	1

⁵ Details are available in the workbook TemporalProfiles_byLake_UNC_14Mar2017.xlsx

Monthly Profile	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
GLCMV2	1,280	3	7,535	151	139	2	105
GLCMV3	1,685	3	9,283	151	138	228	105
GLCMV4	2,279	5	12,684	205	188	0	143
GLCMV5	788	2	3,828	94	92	1	43
GLCMV6	342	1	1,900	46	42	0	32
GLCMV8	5	0	26	0	0	4	0
GLCMV9	0	0	0	0	0	1	0

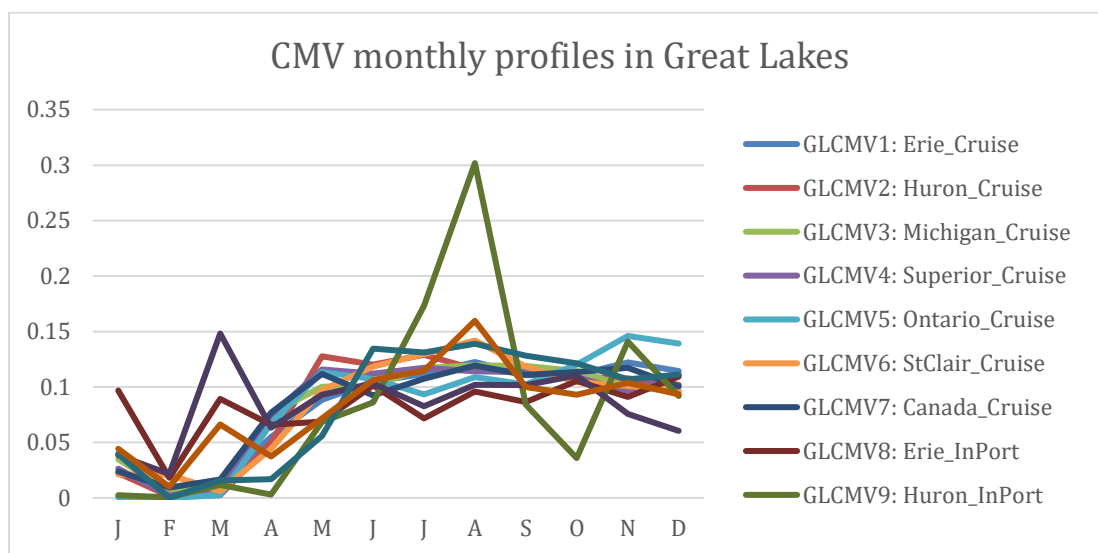


Figure 3. CMV Great Lakes 2014-based monthly temporal profiles

Chemical Speciation

The cmv_c1c2 sector includes emissions for particulate matter < 2.5 μm (PM_{2.5}), oxides of nitrogen (NO_x), and VOC, among other criteria pollutants. These three inventory pollutants must be converted to air quality modeling species through an emissions processing step referred to as “chemical speciation”. The U.S. EPA SPECIATE⁶ database was used to develop factors to map the inventory species to the chemical species required for air quality modeling. All of the emissions in the cmv_c1c2 sector were assigned the PM_{2.5} speciation profile 91106 (HDDV Diesel) and the NONHAPTOG speciation profile 2480 (Industrial Cluster, Ship Channel, Downwind Sample). The components of these profiles are shown in Table 5 and Table 6. Note that because the entire cmv_c1c2 sector is integrated, so the NONHAPTOG profile is used instead of the VOC profile. The VOC-to-TOG conversion factor for profiles 2480 is 1.033. In the

⁶ <https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40>

profile, SOAALK is an extra tracer, so the factors sum to 1.0 if SOAALK is excluded from the sum. The cmv_c1c2 NOx emissions were speciated using a 90:9.2:0.8 split for NO:NO2:HONO.

Table 5. PM2.5 Speciation Profile 91106

Species	Factor
PCA	0.000583
PCL	0.000205
PEC	0.7712
PFE	0.000262
PK	0.000038
PMOTHR	0.004091
PNCOM	0.0439
PNO3	0.001141
POC	0.1756
PSO4	0.00295
PTI	0.000004

Table 6. NONHAPTOG Speciation Profile 2480

Species	Factor	Molecular weight
ETH	0.0149	28.0532
ETHA	0.0321	30.069
ETHY	0.0218	26.0373
IOLE	0.0119	56.2694
ISOP	0.00957	68.117
OLE	0.0308	29.0229
PAR	0.5584	15.0347
PRPA	0.0363	44.0956
SOAALK	0.2244	81.5503
TOL	0.1114	96.4914
UNR	0.0571	16.3928
XYLMN	0.1157	110.2229

5. EMISSIONS PROJECTION METHODS

As described in Section 3, cmv_c1c2 emissions outside of California were projected from the NEI2014v2 to 2023 and 2028 using factors derived from the Regulatory Impact Analysis (RIA) Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder⁴. The specific numbers are shown above in Table 7. California sources were projected to 2023 and 2028 using factors provided by CARB.

Table 7. NONHAPTOG Speciation Profile 2480

Pollutant	2016-2023 factor	2016-2028 factor
CO	-1.3%	0.3%
NOx	-29.3%	-44.6%
PM	-28.3%	-43.4%
SO2	-65.3%	-65.9%
VOC	-31.5%	-47.2%

6. EMISSIONS PROCESSING REQUIREMENTS

CMV_c1c2 emissions were processed for air quality modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE⁷) modeling system. Because day-of-week temporalization is flat for all sources, a single representative day per month was processed. The cmv_c1c2 sector was processed through SMOKE as nonpoint/area sources. This is a 2-D sector in which all emissions are output to a single layer, gridded emissions file.

7. EMISSIONS SUMMARIES

Table 8 compares annual, national total cmv_c1c2 emissions for the 2016 beta platform to cmv_c1c2 emissions from previous modeling platforms. Table 9 provides a national comparison by SCC for state and federal waters. Table 10 and Table 11 show comparisons for state total cmv_c1c2 NOx and VOC emissions, respectively. Figure 4 and Figure 5 are gridded emissions plots of annual total NOx and SO₂. Figure 6 shows county density maps of cmv_c1c2 2016 and 2023 NOx emissions, and comparisons between the 2016 and 2023 emissions. Additional cmv_c1c2 plots and maps are available online through the LADCO website⁸ and the Intermountain West Data Warehouse⁹.

Descriptions of the emissions platform cases shown in the tables and plots below are as follows:

2011en, 2023en, 2028el = Final 2011, 2023, and 2028 cases from the 2011v6.3 platform

2014fd = 2014NElv2 and 2014 NATA

2016fe = 2016 alpha platform (grown from 2014NElv2)

2016ff, 2023ff, and 2028ff = 2016, 2023, and 2028 cases from the 2016 beta platform

⁷ <http://www.smoke-model.org/index.cfm>

⁸ <https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/>

⁹ <http://views.cira.colostate.edu/iwdw/eibrowser2016>

Table 8. Comparison of national total annual CAPs cmv_c1c2 emissions (tons/yr)

Pollutant	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
CO	129,170	116,080	116,080	114,782	125,160	114,431	127,083	116,593
NH3	394	334	334	335	397	336	399	337
NOX	636,177	609,605	609,605	564,394	384,639	399,745	303,028	315,434
PM10	21,195	17,321	17,321	15,445	11,657	11,113	9,344	8,932
PM2.5	20,433	16,670	16,670	14,864	11,237	10,695	9,004	8,592
SO2	10,487	5,788	579	3,159	2,376	2,208	2,398	2,392
VOC	15,644	10,814	10,814	10,080	9,978	7,406	8,184	6,183

Table 9. Comparison of national total annual CAPS cmv_c1c2 emissions by SCC (tons/yr)

Region	Pollutant	SCC	SCC Description	2016ff	2023ff	2028ff
US State Waters	CO	2280002100	Port Emissions	5,769	5,955	6,194
US State Waters	CO	2280002200	Underway Emissions	46,914	47,156	48,096
US Federal Waters	CO	2280002200	Underway Emissions	62,099	61,321	62,303
US State Waters	NH3	2280002100	Port Emissions	13	14	15
US State Waters	NH3	2280002200	Underway Emissions	121	121	122
US Federal Waters	NH3	2280002200	Underway Emissions	201	201	201
US State Waters	NOX	2280002100	Port Emissions	29,043	21,175	17,638
US State Waters	NOX	2280002200	Underway Emissions	240,590	170,165	134,524
US Federal Waters	NOX	2280002200	Underway Emissions	294,761	208,405	163,272
US State Waters	PM10	2280002100	Port Emissions	904	732	679
US State Waters	PM10	2280002200	Underway Emissions	5,599	3,971	3,188
US Federal Waters	PM10	2280002200	Underway Emissions	8,942	6,410	5,065
US State Waters	PM25	2280002100	Port Emissions	855	692	642
US State Waters	PM25	2280002200	Underway Emissions	5,334	3,785	3,037
US Federal Waters	PM25	2280002200	Underway Emissions	8,674	6,218	4,913
US State Waters	SO2	2280002100	Port Emissions	1,413	1,520	1,694
US State Waters	SO2	2280002200	Underway Emissions	851	377	394
US Federal Waters	SO2	2280002200	Underway Emissions	894	310	305
US State Waters	VOC	2280002100	Port Emissions	1,045	964	990
US State Waters	VOC	2280002200	Underway Emissions	3,856	2,894	2,459
US Federal Waters	VOC	2280002200	Underway Emissions	5,179	3,548	2,734

Table 10. Comparison of state total annual NOx cmv_c1c2 emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Alabama	6,846	9,228	9,228	8,542	4,130	6,039	3,219	4,731
Alaska	18,645	29,294	29,294	27,116	11,246	19,172	8,766	15,020
Arkansas	1,797	1,727	1,727	1,598	1,084	1,130	845	885
California	21,055	20,182	20,182	18,808	14,005	13,999	13,238	13,227
Connecticut	1,310	1,096	1,096	1,015	777	717	609	562
Delaware	1,226	860	860	796	727	563	570	441
D.C.	20	0	0	0	12	0	9	0

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Florida	16,330	16,786	16,786	15,537	9,850	10,985	7,678	8,606
Georgia	1,264	1,468	1,468	1,359	762	961	594	753
Hawaii	1,829	372	372	344	1,103	244	860	191
Idaho	3				2		2	
Illinois	7,047	16,515	16,515	15,287	4,251	10,808	3,314	8,468
Indiana	135	5,655	5,655	5,235	81	3,701	63	2,900
Iowa	770	2,770	2,770	2,564	465	1,813	362	1,420
Kansas	13	16	16	15	8	10	6	8
Kentucky	14,125	13,567	13,567	12,558	8,520	8,879	6,641	6,956
Louisiana	121,906	30,672	30,672	28,391	73,532	20,073	57,317	15,726
Maine	3,926	2,204	2,204	2,040	2,328	1,443	1,824	1,130
Maryland	876	598	598	554	519	391	407	307
Massachusetts	5,866	13,046	13,046	12,075	3,479	8,538	2,725	6,689
Michigan	0	28,218	28,218	26,119	0	18,467	0	14,468
Minnesota	2,312	2,868	2,868	2,655	1,395	1,877	1,087	1,471
Mississippi	6,406	7,110	7,110	6,581	3,864	4,653	3,012	3,645
Missouri	3,258	12,912	12,912	11,952	1,965	8,450	1,532	6,620
Montana		0	0	0		0		0
Nebraska	11	1	1	1	7	1	5	0
New Hampshire	15	37	37	34	9	24	7	19
New Jersey	4,940	7,644	7,644	7,076	2,929	5,003	2,295	3,919
New York	16,749	8,995	8,995	8,326	9,932	5,887	7,782	4,612
North Carolina	5,547	2,718	2,718	2,516	3,468	1,779	3,468	1,394
Ohio	304	8,055	8,055	7,456	184	5,272	143	4,130
Oklahoma	23	347	347	322	14	227	11	178
Oregon	3,011	1,435	1,435	1,329	1,816	939	1,415	736
Pennsylvania	3,554	846	846	783	2,107	554	1,651	434
Rhode Island	896	3,473	3,473	3,215	531	2,273	416	1,781
South Carolina	1,201	1,604	1,604	1,485	724	1,050	565	822
Tennessee	6,115	3,912	3,912	3,621	3,688	2,560	2,875	2,006
Texas	7,162	15,465	15,465	14,315	4,320	10,121	3,368	7,929
Utah	60	1	1	1	36	0	28	0
Vermont	190	15	15	14	113	10	88	8
Virginia	6,957	2,116	2,116	1,959	4,126	1,385	3,232	1,085
Washington	10,172	7,038	7,038	6,515	6,136	4,606	4,783	3,609
West Virginia	4,865	3,511	3,511	3,250	2,885	2,298	2,260	1,800
Wisconsin	459	5,625	5,625	5,206	277	3,681	216	2,884
Puerto Rico	347	956	956	885	209	626	163	490
Virgin Islands		200	200	186		131		103
Offshore to EEZ	326,631	318,444	318,444	294,761	197,021	208,405	153,575	163,272

Table 11. Comparison of state total annual SO2 cmv_c1c2 emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Alabama	84	10	1	4	8	1	6	1

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Alaska	229	16	2	7	21	2	16	2
Arkansas	22	1	0	0	2	0	2	0
California	1,827	1,329	133	1,387	1,606	1,593	1,803	1,788
Connecticut	16	1	0	0	1	0	1	0
Delaware	98	84	8	34	7	12	7	11
D.C.	0	0	0	0	0	0	0	0
Florida	201	85	9	34	18	12	14	12
Georgia	16	2	0	1	1	0	1	0
Hawaii	22	5	0	2	2	1	2	1
Idaho	0				0		0	
Illinois	664	1,591	159	632	61	219	45	215
Indiana	12	0	0	0	1	0	1	0
Iowa	9	1	0	0	1	0	1	0
Kansas	0	0	0	0	0	0	0	0
Kentucky	174	6	1	3	16	1	12	1
Louisiana	1,498	52	5	20	137	7	103	7
Maine	48	6	1	2	3	1	3	1
Maryland	122	1	0	1	9	0	8	0
Massachusetts	72	8	1	3	5	1	5	1
Michigan	0	15	2	6	0	2	0	2
Minnesota	203	1	0	0	19	0	14	0
Mississippi	79	4	0	2	7	1	5	1
Missouri	40	1	0	0	4	0	3	0
Montana		0	0	0		0		0
Nebraska	0	0	0	0	0	0	0	0
New Hampshire	2	2	0	1	0	0	0	0
New Jersey	179	68	7	27	12	9	12	9
New York	206	12	1	5	14	2	14	2
North Carolina	68	2	0	1	7	0	7	0
Ohio	27	10	1	4	2	1	2	1
Oklahoma	0	0	0	0	0	0	0	0
Oregon	37	3	0	1	3	0	3	0
Pennsylvania	44	1	0	0	3	0	3	0
Rhode Island	11	2	0	1	1	0	1	0
South Carolina	12	1	0	1	1	0	1	0
Tennessee	75	2	0	1	7	0	5	0
Texas	88	92	9	37	8	13	6	13
Utah	1	0	0	0	0	0	0	0
Vermont	2	0	0	0	0	0	0	0
Virginia	85	3	0	1	6	0	6	0
Washington	94	51	5	20	9	7	6	7
West Virginia	60	2	0	1	4	0	4	0
Wisconsin	40	2	0	1	4	0	3	0
Puerto Rico	4	38	4	15	0	5	0	5
Virgin Islands		24	2	9		3		3

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Offshore to EEZ	4,014	2,252	225	894	366	310	275	305

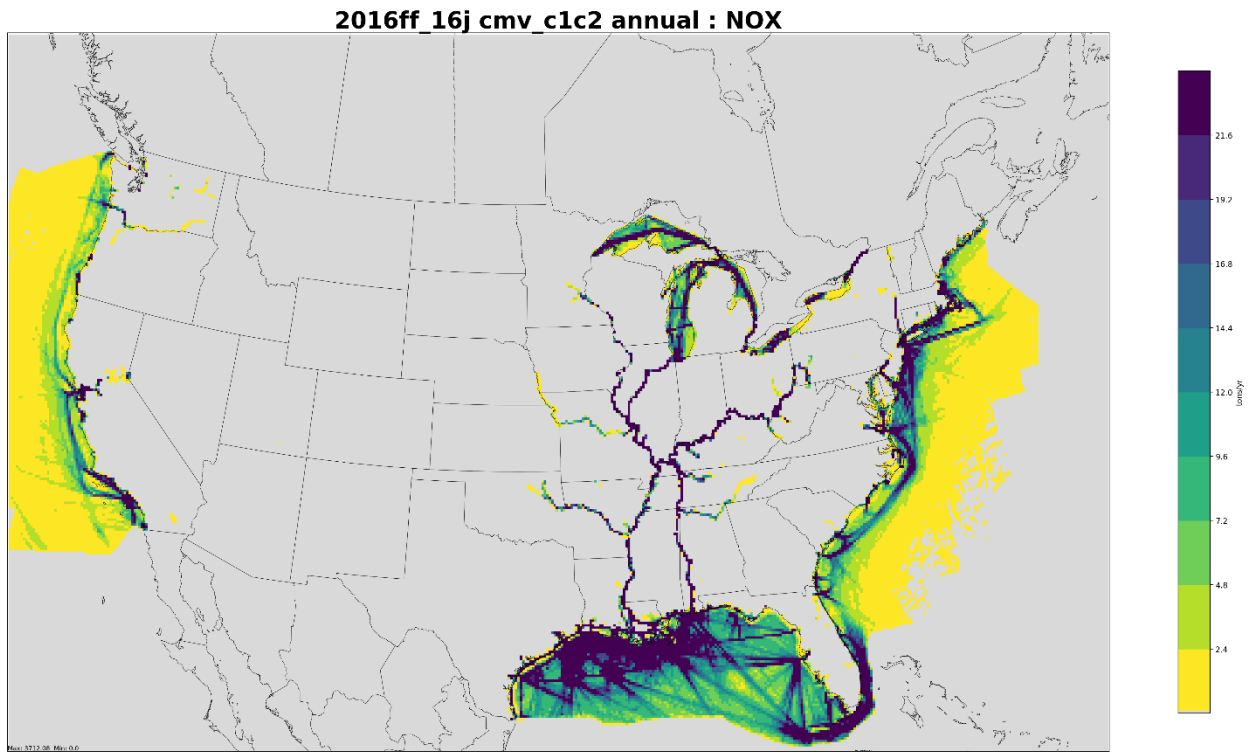


Figure 4. Gridded 2016 NOx emissions from cmv_c1c2

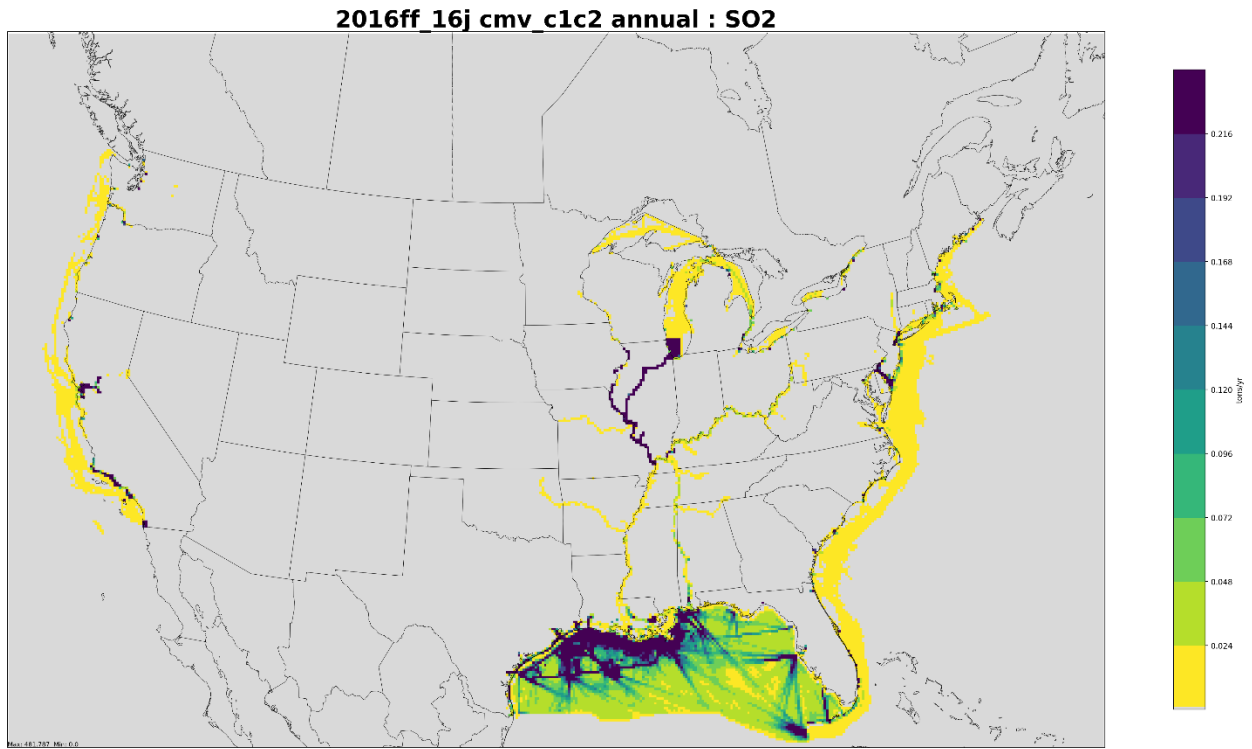


Figure 5. Gridded 2016 SO₂ emissions from cmv_c1c2

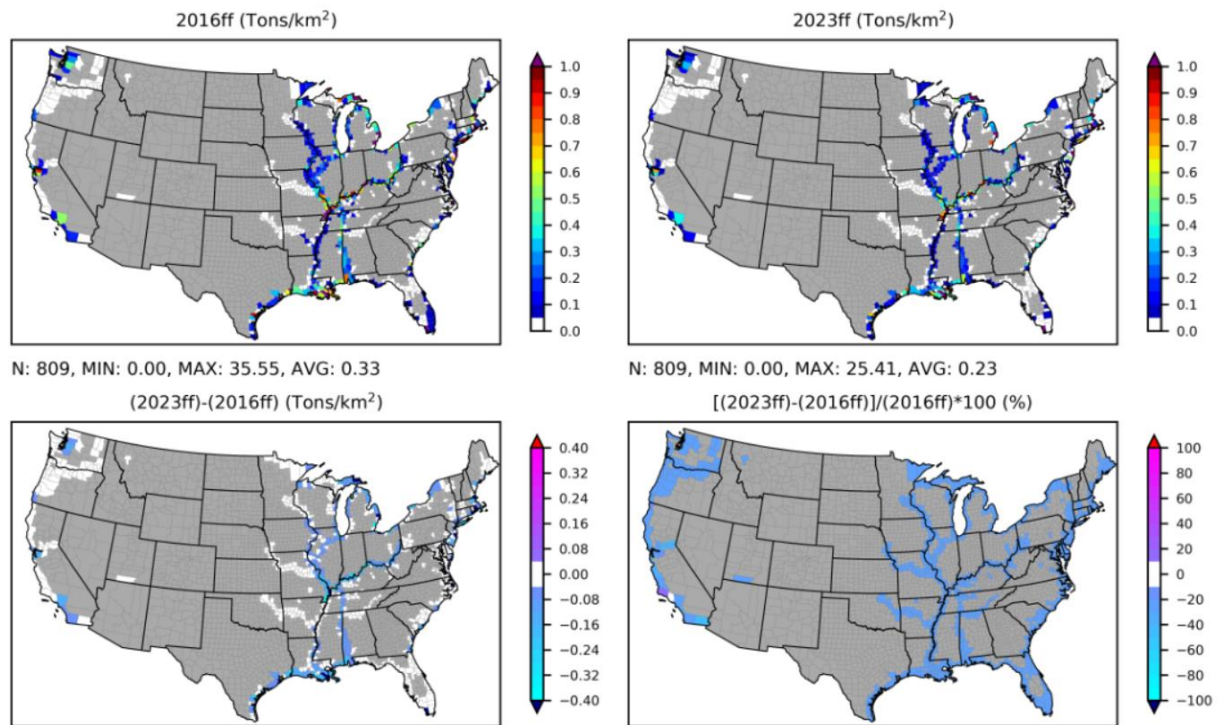


Figure 6. 2016 and 2023 NO_x Density from cmv_c1c2