February 27, 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

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 Environment (SMOKE) v4.6. 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 2014NEIv2[2].

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.

[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

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

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 Cylinder[4]. 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. We reduced the 2014-to-2023 factors by 2/9 to convert a 9-year growth factor into a 2-year growth factor.

[4] https://nepis.epa.gov/Exe/ZyPDF.cgi/P10023S4.PDF?Dockey=P10023S4.PDF

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) 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 Table 3.

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

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 LADCO. 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 1 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
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

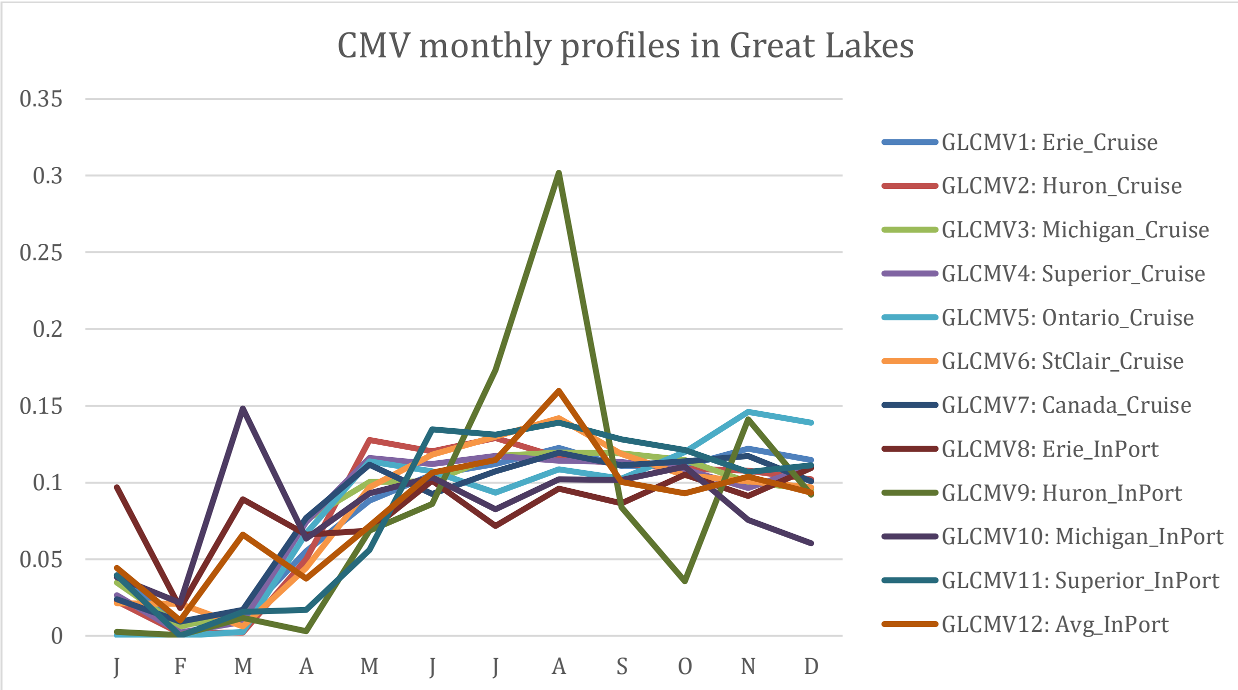

Figure 1. CMV Great Lakes 2014-based monthly temporal profiles

Chemical Speciation

The cmv_c1c2 sector includes emissions for particulate matter < 2.5 μm ($PM_{2.5}$), oxides of nitrogen (NOx), 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 SPECIATE[5] 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 VOC speciation profile 2480 (Industrial Cluster, Ship Channel, Downwind Sample). The cmv_c1c2 NOx emissions were speciated using a 90:9.2:0.8 split for NO:NO2:HONO.

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

[5] https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40

Engines Less than 30 Liters per Cylinder[4]. California sources were projected to 2023 and 2028 using factors provided by CARB.

6. Emissions Processing Requirements

CMV_c1c2 emissions were processed for air quality modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE[6]) 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 5 compares annual, national total cmv_c1c2 emissions for the 2016 beta platform to cmv_c1c2 emissions from previous modeling platforms. Table 6 and Table 7 show similar comparisons for state total cmv_c1c2 NOx and VOC emissions, respectively. Figure 2 and Figure 3 are gridded emissions plots of annual total NOx and SO_2. Figure 4 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 website[7] and the Intermountain West Data Warehouse[8].

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 = 2014NEIv2 and 2014 NATA

2016fe = 2016 alpha platform (grown from 2014NEIv2)

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

[6] http://www.smoke-model.org/index.cfm

[7] https://www.ladco.org/technical/modeling-results/2016-inventory-collaborative/

[8] http://views.cira.colostate.edu/iwdw/eibrowser2016

Table 5. 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 6. 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
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

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
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 7. Comparison of state total annual VOC cmv_c1c2 emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Alabama	157	105	105	96	93	66	72	51
Alaska	427	325	325	299	254	205	196	158
Arkansas	41	20	20	18	25	12	19	9
California	1,375	1,421	1,421	1,435	1,484	1,484	1,620	1,620
Connecticut	30	12	12	11	18	8	14	6
Delaware	31	21	21	19	18	13	14	10
D.C.	0	0	0	0	0	0	0	0
Florida	374	187	187	172	223	118	172	91
Georgia	29	16	16	14	17	10	13	8
Hawaii	42	4	4	4	25	3	19	2
Idaho	0				0		0	
Illinois	155	271	271	249	92	171	71	131
Indiana	3	86	86	79	2	54	1	42
Iowa	18	45	45	42	11	29	8	22
Kansas	0	0	0	0	0	0	0	0
Kentucky	323	154	154	141	193	97	148	75

State	2011en	2014fd	2016fe	2016ff	2023en	2023ff	2028el	2028ff
Louisiana	2,789	348	348	320	1,662	219	1,281	169
Maine	90	24	24	22	53	15	41	12
Maryland	32	7	7	6	19	4	14	3
Massachusetts	134	140	140	129	79	88	61	68
Michigan	0	351	351	323	0	221	0	171
Minnesota	50	35	35	32	30	22	23	17
Mississippi	147	80	80	74	87	51	67	39
Missouri	75	212	212	195	44	134	34	103
Montana		0	0	0		0		0
Nebraska	0	0	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0	0	0
New Jersey	210	204	204	188	123	129	95	99
New York	383	100	100	92	225	63	173	48
North Carolina	127	29	29	27	79	19	79	14
Ohio	7	134	134	123	4	84	3	65
Oklahoma	1	4	4	4	0	2	0	2
Oregon	69	16	16	14	41	10	32	8
Pennsylvania	81	10	10	9	48	6	37	5
Rhode Island	20	37	37	34	12	23	9	18
South Carolina	32	17	17	16	19	11	15	8
Tennessee	140	44	44	41	83	28	64	22
Texas	164	337	337	310	98	212	75	164
Utah	1	0	0	0	1	0	1	0
Vermont	4	0	0	0	3	0	2	0
Virginia	159	23	23	21	93	15	72	11
Washington	324	248	248	228	193	156	149	120
West Virginia	111	40	40	37	65	25	50	19
Wisconsin	10	64	64	59	6	40	5	31
Puerto Rico	8	14	14	13	5	9	4	7
Virgin Islands		4	4	4		3		2
Offshore to EEZ	7,472	5,627	5,627	5,179	4,453	3,548	3,431	2,734

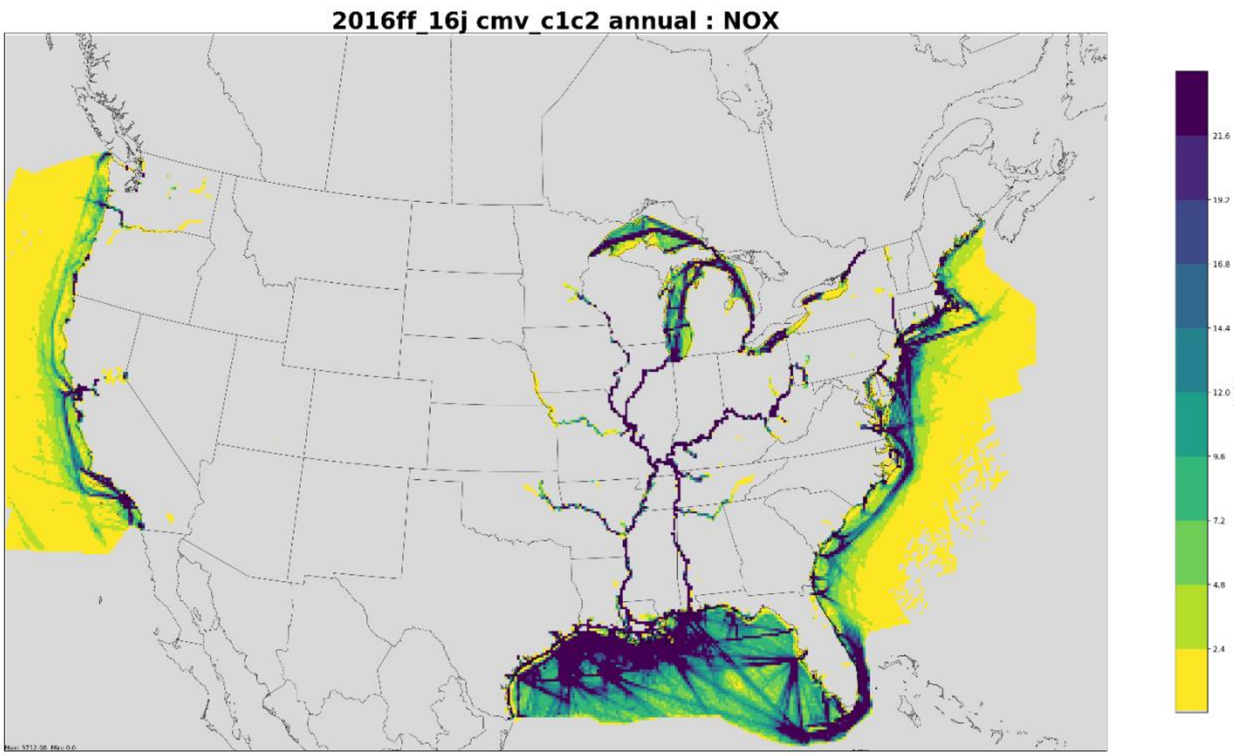

Figure 2. Gridded 2016 NOx emissions from cmv_c1c2

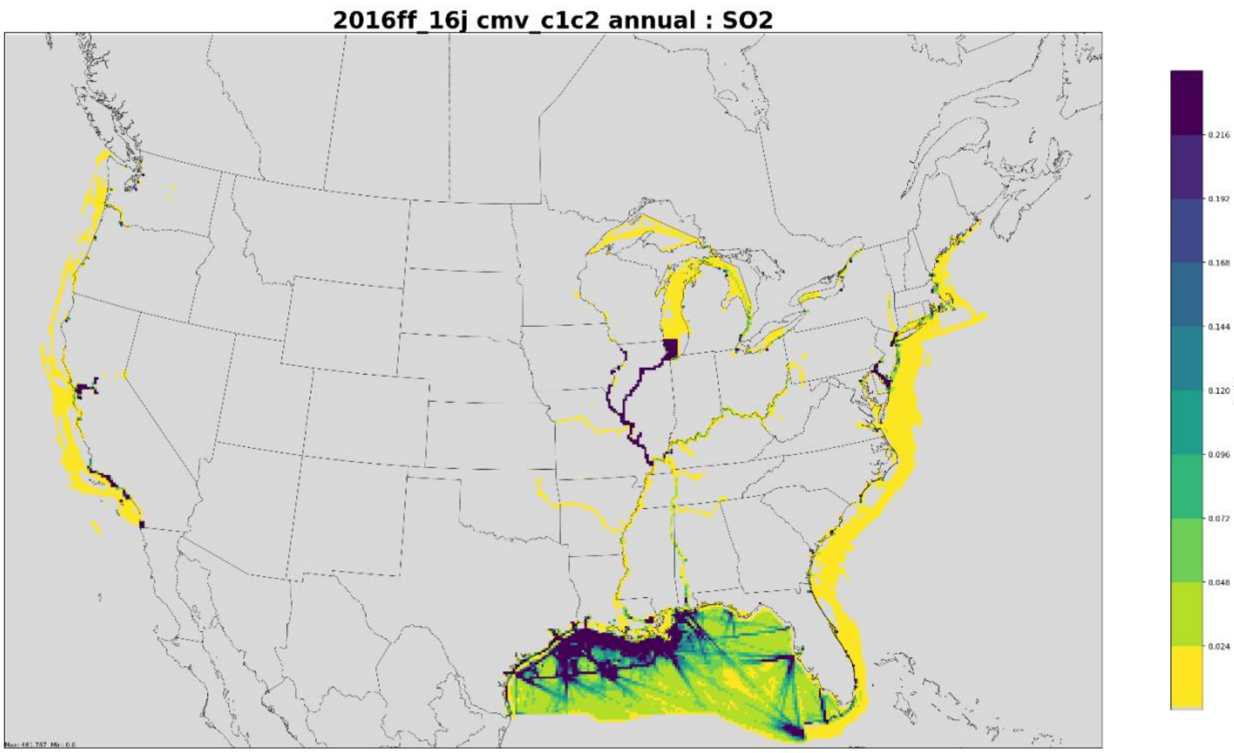

Figure 3. Gridded 2016 SO_2 emissions from cmv_c1c2

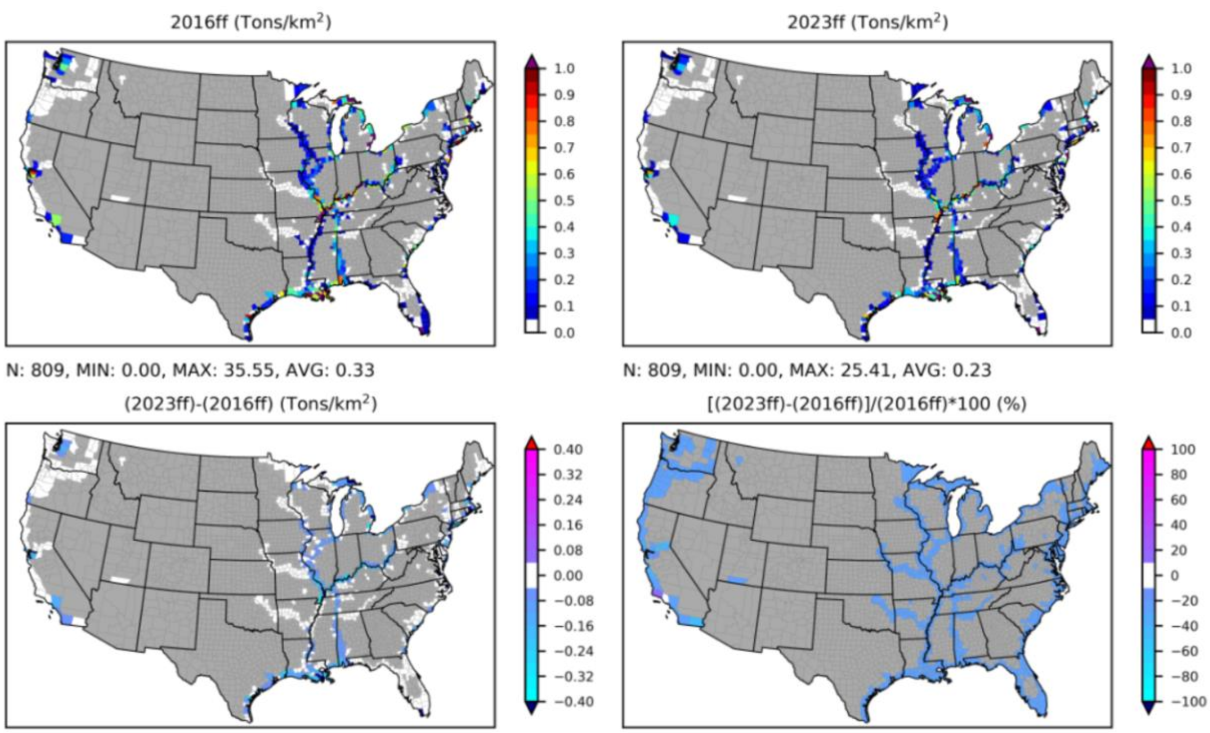

Figure 4. 2016 and 2023 NOx Density from cmv_c1c2