March 7, 2019

SPECIFICATION SHEET: CMV_C1C2 2016beta Platform

Description: Category 1 and 2 Commercial Marine Vessel (cmv_c1c2) emissions, for simulating 2016 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 a projection of cmv_c1c2 emissions from the 2014 National Emission Inventory version 2 (NEI2014v2) to 2016 based on the Locomotive and Marine rule Regulatory Impact Assessment (RIA)[1]. Base 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 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.

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 Cylinder[4]. Emissions projection factors were specified by pollutant and applied nationally, except for vessels registered in California. 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 that were used for cmv_c1c2 sources outside of California.

Table 2. National projection factors for cmv_c1c2

Pollutant	2014-to-2016
CO	-1.44%
NOX	-7.44%
PM10	-11.04%
PM2.5	-11.04%
SO2	-60.28%
VOC	-7.96%

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. County, SCC, and pollutant-specific factors generated from the CARB inventories were applied to the 2014NEIv2 cmv_c1c2 inventory to estimate 2016 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) 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. Plots of the 808 and 820 surrogates are shown in Figures 1 and 2, respectively.

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

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

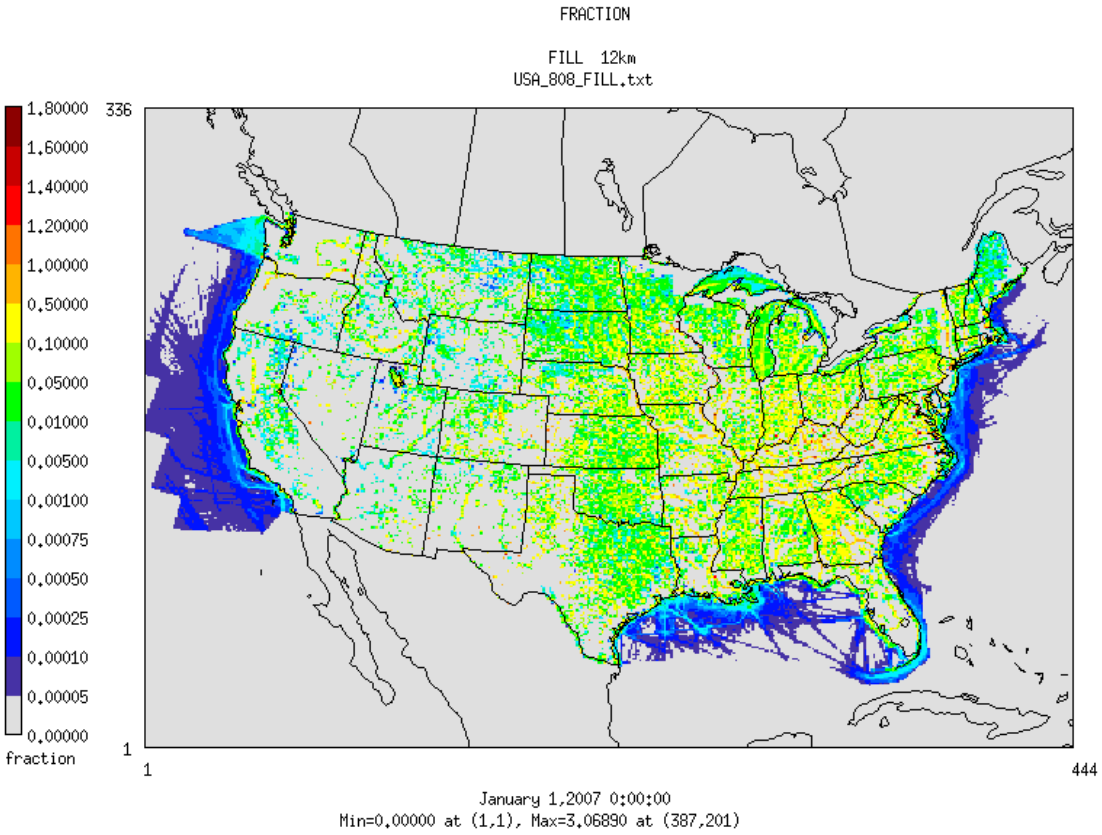

Figure 1. 2013 Shipping Density Surrogate Number 808

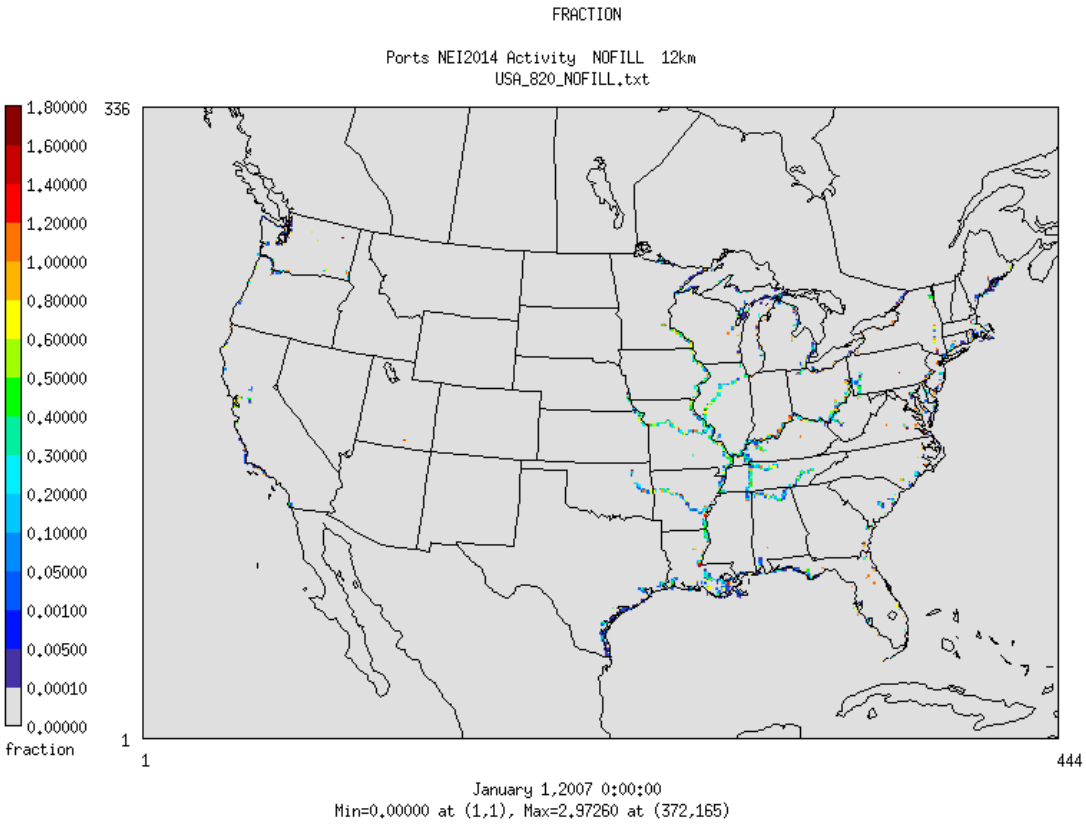

Figure 2. Ports NEI2014 Surrogate Number 820

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 LADCO[5]. 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

[5] Details are available in the workbook TemporalProfiles_byLake_UNC_14Mar2017.xlsx

Monthly Profile	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
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

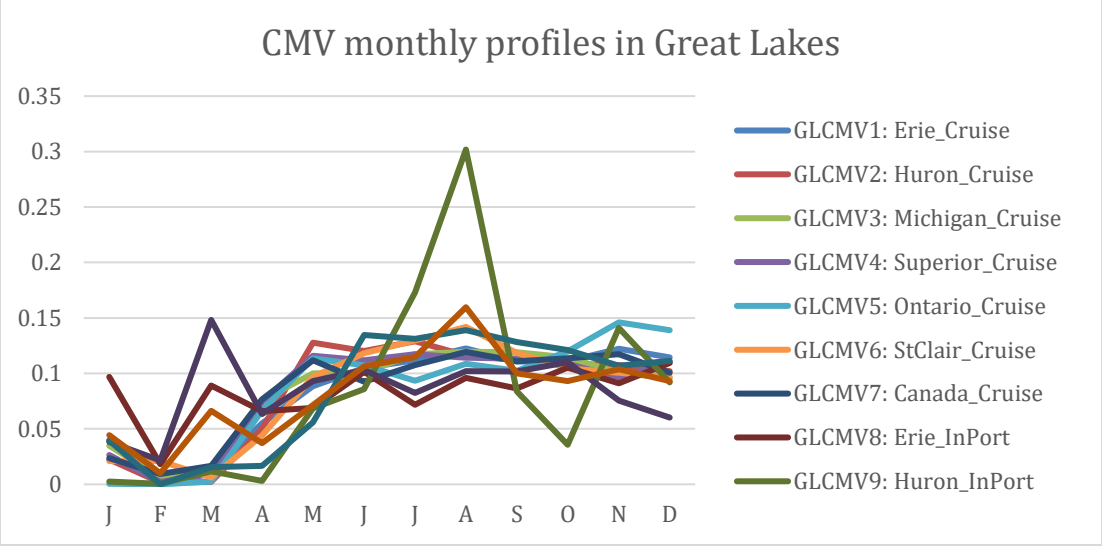

Figure 3. CMV Great Lakes 2014-based monthly temporal profiles

Chemical Speciation

The cmv_c1c2 sector includes emissions for particulate matter < 2.5 µm ($PM_{2.5}$), oxides of nitrogen (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[6] 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

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

instead of the VOC profile. The VOC-to-TOG conversion factor for profiles 2480 is 1.033. In the 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

Future year projections for the 2016 beta platform have not yet been finalized at the time this was written.

6. EMISSIONS PROCESSING REQUIREMENTS

CMV_c1c2 emissions were processed for air quality modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE[7]) 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 7 compares annual, national total cmv_c1c2 emissions for the 2016 beta platform to cmv_c1c2 emissions from previous modeling platforms. Table 8 provides a national comparison by SCC for state and federal waters. Table 9 and Table 10 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 SO_2. Additional cmv_c1c2 plots and maps are available online through the LADCO website[8] and the Intermountain West Data Warehouse[9].

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 = 2016 beta platform

Table 7. Comparison of national total annual CAPS cmv_c1c2 emissions (tons/yr)

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

[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. National total annual CAPS cmv_c1c2 emissions by SCC (tons/yr)

Region	Pollutant	SCC	SCC Description	2016ff
US State Waters	CO	2280002100	Port Emissions	5,769
US State Waters	CO	2280002200	Underway Emissions	46,914
US Federal Waters	CO	2280002200	Underway Emissions	62,099
US State Waters	NH3	2280002100	Port Emissions	13
US State Waters	NH3	2280002200	Underway Emissions	121
US Federal Waters	NH3	2280002200	Underway Emissions	201
US State Waters	NOX	2280002100	Port Emissions	29,043
US State Waters	NOX	2280002200	Underway Emissions	240,590
US Federal Waters	NOX	2280002200	Underway Emissions	294,761
US State Waters	PM10	2280002100	Port Emissions	904
US State Waters	PM10	2280002200	Underway Emissions	5,599
US Federal Waters	PM10	2280002200	Underway Emissions	8,942
US State Waters	PM25	2280002100	Port Emissions	855
US State Waters	PM25	2280002200	Underway Emissions	5,334
US Federal Waters	PM25	2280002200	Underway Emissions	8,674
US State Waters	SO2	2280002100	Port Emissions	1,413
US State Waters	SO2	2280002200	Underway Emissions	851
US Federal Waters	SO2	2280002200	Underway Emissions	894
US State Waters	VOC	2280002100	Port Emissions	1,045
US State Waters	VOC	2280002200	Underway Emissions	3,856
US Federal Waters	VOC	2280002200	Underway Emissions	5,179

Table 9. Comparison of state total annual NOx cmv_c1c2 emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2028el
Alabama	6,846	9,228	9,228	8,542	4,130	3,219
Alaska	18,645	29,294	29,294	27,116	11,246	8,766
Arkansas	1,797	1,727	1,727	1,598	1,084	845
California	21,055	20,182	20,182	18,808	14,005	13,238
Connecticut	1,310	1,096	1,096	1,015	777	609
Delaware	1,226	860	860	796	727	570
D.C.	20	0	0	0	12	9
Florida	16,330	16,786	16,786	15,537	9,850	7,678
Georgia	1,264	1,468	1,468	1,359	762	594
Hawaii	1,829	372	372	344	1,103	860
Idaho	3				2	2
Illinois	7,047	16,515	16,515	15,287	4,251	3,314
Indiana	135	5,655	5,655	5,235	81	63
Iowa	770	2,770	2,770	2,564	465	362
Kansas	13	16	16	15	8	6
Kentucky	14,125	13,567	13,567	12,558	8,520	6,641
Louisiana	121,906	30,672	30,672	28,391	73,532	57,317

State	2011en	2014fd	2016fe	2016ff	2023en	2028el
Maine	3,926	2,204	2,204	2,040	2,328	1,824
Maryland	876	598	598	554	519	407
Massachusetts	5,866	13,046	13,046	12,075	3,479	2,725
Michigan	0	28,218	28,218	26,119	0	0
Minnesota	2,312	2,868	2,868	2,655	1,395	1,087
Mississippi	6,406	7,110	7,110	6,581	3,864	3,012
Missouri	3,258	12,912	12,912	11,952	1,965	1,532
Montana		0	0	0		
Nebraska	11	1	1	1	7	5
New Hampshire	15	37	37	34	9	7
New Jersey	4,940	7,644	7,644	7,076	2,929	2,295
New York	16,749	8,995	8,995	8,326	9,932	7,782
North Carolina	5,547	2,718	2,718	2,516	3,468	3,468
Ohio	304	8,055	8,055	7,456	184	143
Oklahoma	23	347	347	322	14	11
Oregon	3,011	1,435	1,435	1,329	1,816	1,415
Pennsylvania	3,554	846	846	783	2,107	1,651
Rhode Island	896	3,473	3,473	3,215	531	416
South Carolina	1,201	1,604	1,604	1,485	724	565
Tennessee	6,115	3,912	3,912	3,621	3,688	2,875
Texas	7,162	15,465	15,465	14,315	4,320	3,368
Utah	60	1	1	1	36	28
Vermont	190	15	15	14	113	88
Virginia	6,957	2,116	2,116	1,959	4,126	3,232
Washington	10,172	7,038	7,038	6,515	6,136	4,783
West Virginia	4,865	3,511	3,511	3,250	2,885	2,260
Wisconsin	459	5,625	5,625	5,206	277	216
Puerto Rico	347	956	956	885	209	163
Virgin Islands		200	200	186		
Offshore to EEZ	326,631	318,444	318,444	294,761	197,021	153,575

Table 10. Comparison of state total annual SO2 cmv_c1c2 emissions (tons/yr)

State	2011en	2014fd	2016fe	2016ff	2023en	2028el
Alabama	84	10	1	4	8	6
Alaska	229	16	2	7	21	16
Arkansas	22	1	0	0	2	2
California	1,827	1,329	133	1,387	1,606	1,803
Connecticut	16	1	0	0	1	1
Delaware	98	84	8	34	7	7
D.C.	0	0	0	0	0	0
Florida	201	85	9	34	18	14
Georgia	16	2	0	1	1	1
Hawaii	22	5	0	2	2	2
Idaho	0				0	0

State	2011en	2014fd	2016fe	2016ff	2023en	2028el
Illinois	664	1,591	159	632	61	45
Indiana	12	0	0	0	1	1
Iowa	9	1	0	0	1	1
Kansas	0	0	0	0	0	0
Kentucky	174	6	1	3	16	12
Louisiana	1,498	52	5	20	137	103
Maine	48	6	1	2	3	3
Maryland	122	1	0	1	9	8
Massachusetts	72	8	1	3	5	5
Michigan	0	15	2	6	0	0
Minnesota	203	1	0	0	19	14
Mississippi	79	4	0	2	7	5
Missouri	40	1	0	0	4	3
Montana		0	0	0		
Nebraska	0	0	0	0	0	0
New Hampshire	2	2	0	1	0	0
New Jersey	179	68	7	27	12	12
New York	206	12	1	5	14	14
North Carolina	68	2	0	1	7	7
Ohio	27	10	1	4	2	2
Oklahoma	0	0	0	0	0	0
Oregon	37	3	0	1	3	3
Pennsylvania	44	1	0	0	3	3
Rhode Island	11	2	0	1	1	1
South Carolina	12	1	0	1	1	1
Tennessee	75	2	0	1	7	5
Texas	88	92	9	37	8	6
Utah	1	0	0	0	0	0
Vermont	2	0	0	0	0	0
Virginia	85	3	0	1	6	6
Washington	94	51	5	20	9	6
West Virginia	60	2	0	1	4	4
Wisconsin	40	2	0	1	4	3
Puerto Rico	4	38	4	15	0	0
Virgin Islands		24	2	9		
Offshore to EEZ	4,014	2,252	225	894	366	275

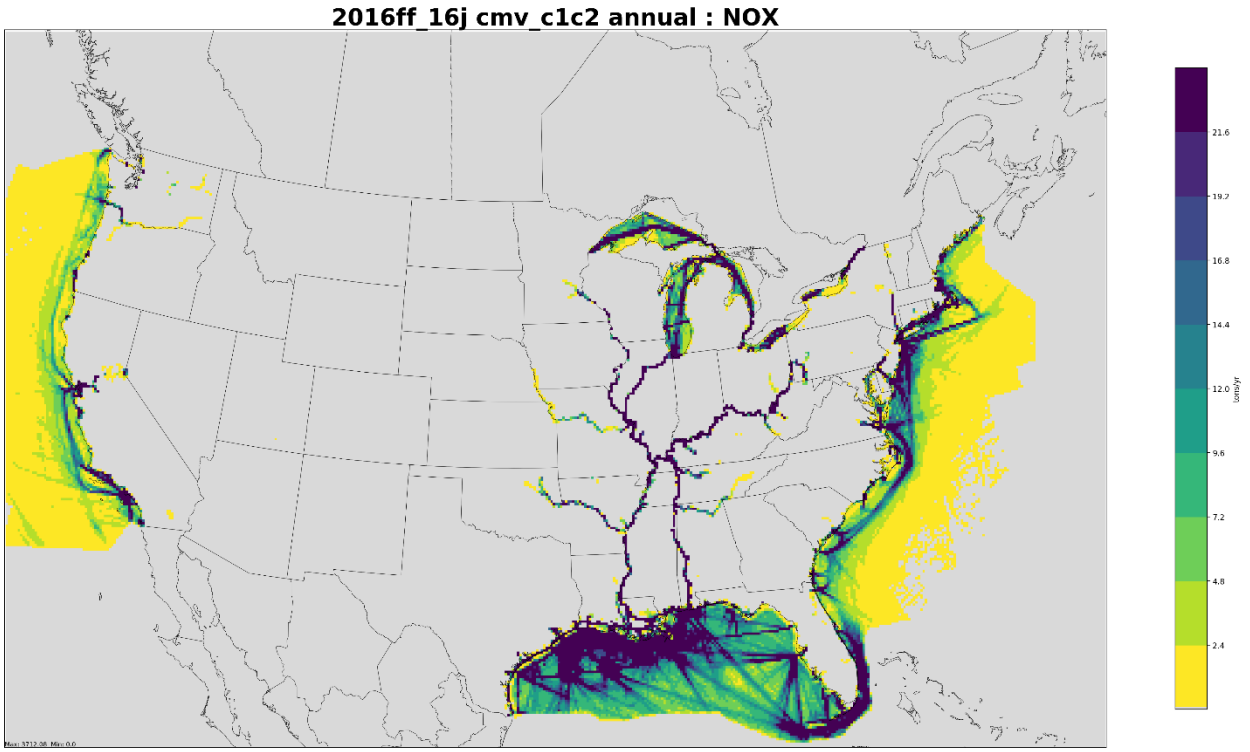

Figure 4. Gridded 2016 NOx emissions from cmv_c1c2

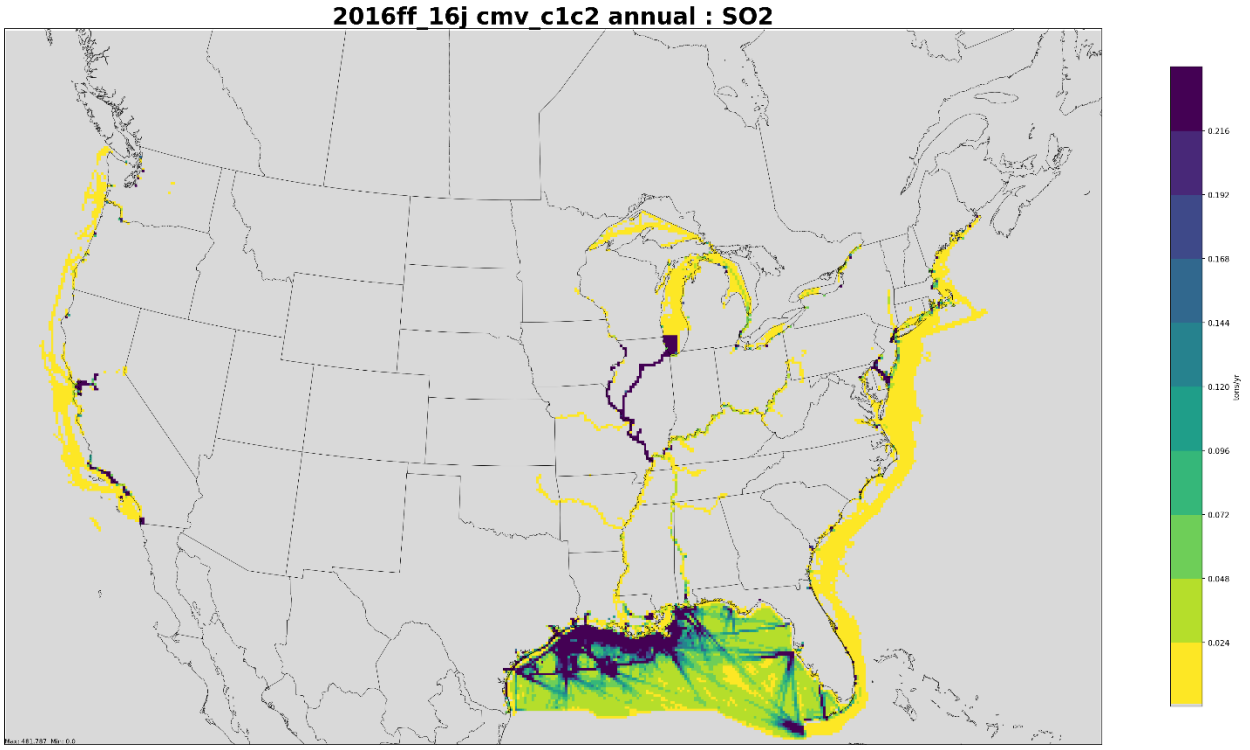

Figure 5. Gridded 2016 SO_2 emissions from cmv_c1c2