Memorandum: Disaggregation of Category 1 / Category 2 Commercial Marine Vessel Emissions for 2011

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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC

MEMORANDUM

TO: Laurel Driver/US EPA

FROM: Roger Chang, Heather Perez and Richard Billings/ERG

DATE: November 20, 2013

SUBJECT: Disaggregation of Category 1 / Category 2 Commercial Marine Vessel Emissions for 2011

1.0 Introduction

The Emission Inventory and Analysis Group (EIAG) annually produce the National Emission Inventory (NEI). The NEI compiles comprehensive emissions data for criteria and HAPs for mobile, point, and nonpoint sources. For this project ERG is revising the 2011 version of the commercial marine vessel (CMV) component of the NEI to provide a more detailed emission estimates for marine vessels equipped with Category 1 and 2 propulsion engines. This memo specifically addresses the disaggregation of the Category 1 / 2 emissions into vessel type data. Were additional details could be obtained allocation profiles for categories such as ferries, tugs and towboats and deepwater vessels. This memorandum is a deliverable for Task 7 of Work Assignment 3-01 for EPA Contract No. EP-D-11-006, Work Assignment 3-01.

2.0 Methodology

2.1 Disaggregation into vessel types

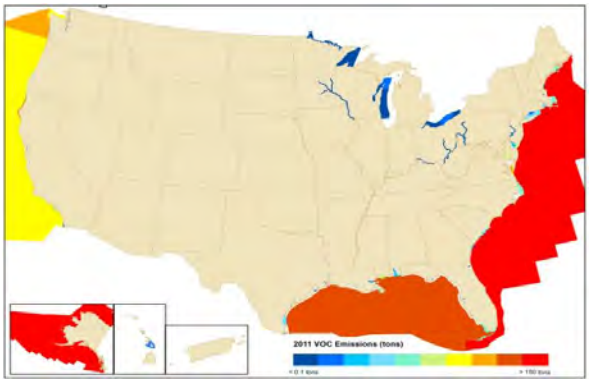
EPA's Office of Transportation and Air Quality (OTAQ) provided 2011 C1/C2 emissions estimates used only two source classification codes (SCCs). The goal of the current project was to disaggregate OTAQ's emissions into individual vessel types including deepwater, ferries, fishing, government, Great Lakers, support (offshore and research) vessels, and tugs.

The report entitled "*Category 2 Vessel Census, Activity, and Spatial Allocation Assessment and Category 1 and Category 2 In-port/At-sea Splits,"* (Census Report) February 16, 2007, developed activity profiles by vessel type that were allocated to underway shapes throughout the United States. That report served as the basis for allocation of emissions by activity data (i.e., kw-hrs) by vessel types in the 2011NEI version 1. Table 1 summarizes the reallocated emissions data by vessel type.

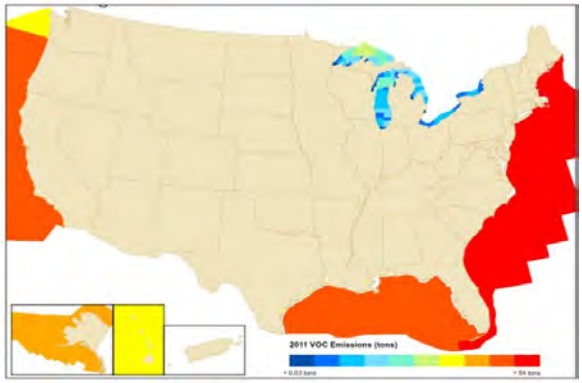
Table 1. Comparing Emission Estimates from Previous to Revised 2011 Emission Inventory

Vessel Type	Pollutant	2280002100	2280002200
		Port	Underway
Previous 2011 Emissions (TPY)			
Total	NO_x	85,214	640,143
Disaggregated 2011 Emissions (TPY)			
Deepwater	NO_x	575	56,819
Ferries	NO_x	20,489	11,032
Fishing	NO_x	3,677	69,793
Government	NO_x	18,274	12,722
Great Lake	NO_x	300	29,692
Support (Offshore & Research)	NO_x	12,892	318,571
Tugs	NO_x	29,007	141,513
Total	NO_x	85,214	640,143

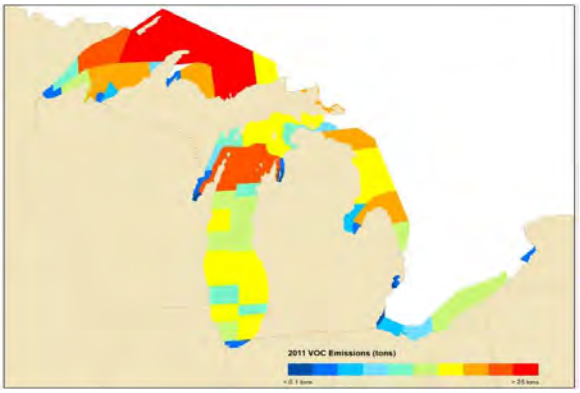
This approach also allows more in-depth investigation in emission patterns across the United States between different vessel types, as shown in Figure 1 (note revised spatial allocations for tugs, ferries, and deep water Category 1 and 2 vessels are presented in the sections to follow).



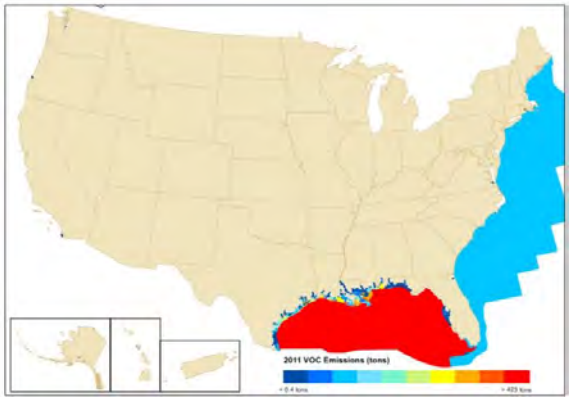
Fishing Vessels



Government Vessels



Great Lakes Vessels



Support Vessels

Figure 1. 2011 Volatile Organic Chemical (VOC) Emissions by C1 /C2 Vessel Type

2.2 Ferries

The report entitled "*Category 2 Vessel Census, Activity, and Spatial Allocation Assessment and Category 1 and Category 2 In-port/At-sea Splits,"* (Census Report) February 16, 2007, developed activity profiles by vessel type that were allocated to underway shapes throughout the United States. This report served as the basis for the 2011 C1 / C2 CMV component of the NEI, this included allocating activity by vessel type to the underway and port shapes currently within EIS.

However, later review indicated that the ferry-related emissions were allocated to a very limited number of ports, resulting in artificially high emissions at some ports and no ferry emissions at other ports. The Bureau of Transportation Statistics' National Census of Ferry Operators (NCFO 2011) database provides ferry operation data from a nationwide census of ferry operators along with other sources of ferry data such as the U.S. Coast Guard and the U.S. Army Corps of Engineers. This relational database format provides for the reporting of the information at various levels, such as by operator, route segment, terminal, or vessel. For this effort, the ferry emissions for underway and port were reallocated to a greater number of ports based on the number of terminals at each port which ferries visit.

The NCFO provides data by individual terminals and includes a terminal name, city, and coordinates to further identify their locations. These terminals were matched to ports within EIS via name matching, GIS mapping, and manual investigation. This process succeeded in assigning 1,370 of the 1,458 terminals total (94%) to a port within EIS. The 88 terminals that remained were further investigated for inclusion in this inventory effort. Some of them lacked important identifying information such as city or coordinate locations, while others had complete location information but appeared to have no activity according to trip count data in the NCFO.

The terminals were assigned to 105 new ports and 113 existing ports. The additional 105 ports were mapped and assigned new ShapeIDs for inclusion in EIS. These additional ports were mapped as small circles with a radius of 0.25 mile using NFCO coordinates as the centroid of the port. They were then spatially adjusted as needed to avoid overlapping with shipping lane areas or other port shapes. Ultimately, 218 ports were selected for use in the ferry emission reallocation, a significant improvement over the 34 ports used in the Census report.

Once the universe of ferry ports was determined, ERG reallocated national emissions to these ports based on the number of terminals at each port. The 218 ports used in this allocation effort represented 1,370 terminals total. National ferry emissions were allocated to each port based on the port's terminal count with respect to the national terminal total of 1,370, as seen in the following equation.

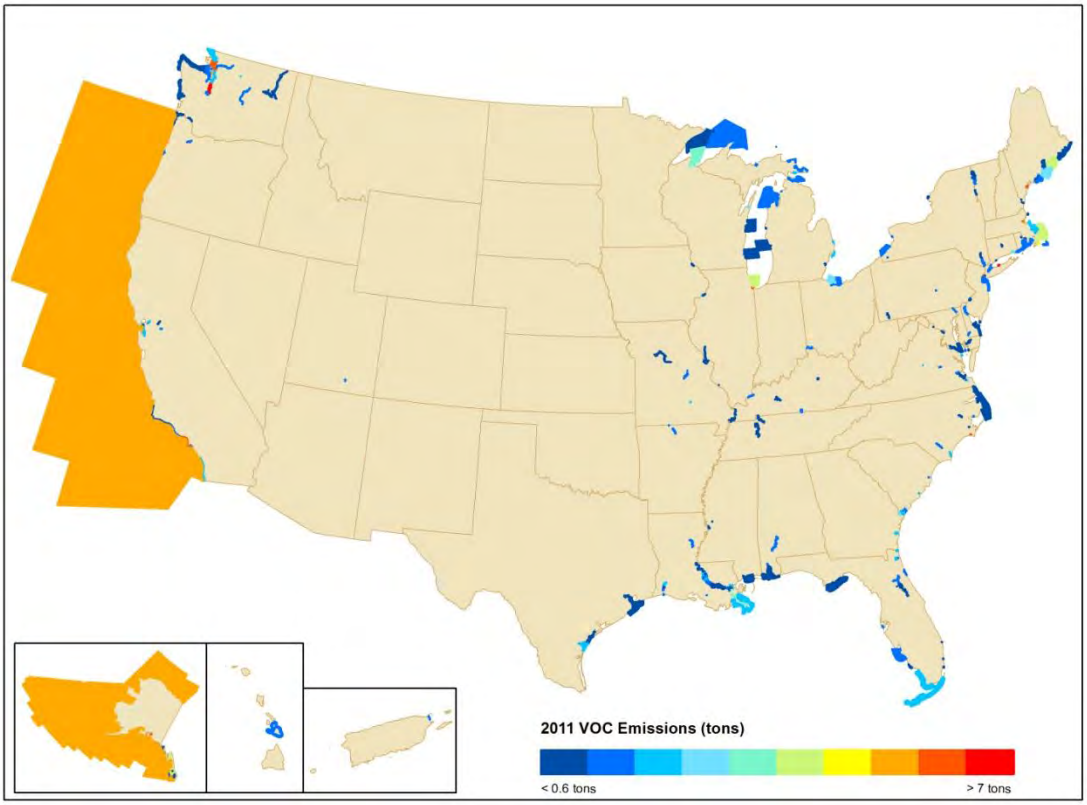
Sample Calculation for VOC Port Ferry Emissions for Cheboygan, MI

Port Emissions = National Emissions × Terminals at this port / Total Terminals Nationwide

0.68 tons = 468.71 ton × 2 / 1,370

In lieu of better underway activity data, the ferry underway emissions followed an allocation method similar to the original census report: underway activity was allocated to the underway shapeID closest to each port using the same proportion derived from the port reallocation above. Activity and fuel were also multiplied by this proportion to ensure activity remains consistent with emissions. Figure 2 shows the revised spatial allocation for ferry activities.

Figure 2. 2011 C1/C2 Ferry Allocation (VOC emissions)



2.3 Tugs and Towboats

Previous tug spatial allocation methods assigned emissions to navigable waterways based on total cargo tonnage as a surrogate for vessel traffic. Additional review indicated that, because this method includes all vessel types, total cargo tonnage is not an appropriate surrogate in some cases. For example, in the Great Lakes cargo tonnage is predominantly from other vessels such as lakers; therefore, the use of total cargo tonnage for spatially allocating underway tug activity nationally assigns activity and emissions in locations where there are no tug operations and under reports activity and emission where there are activities.

Data from the 2011 Waterborne Commerce of the United States (WCUS) (USACE, 2011) has cargo tonnage broken out by three vessel types: tugs, dry cargo, and tankers. The dataset is primarily composed of tug activity data and serves as a better surrogate for spatially allocating national tug underway emissions to waterway segments. Again, the national emissions values and the port emissions do not change; this revision targets only spatial reallocation of tug underway emissions.

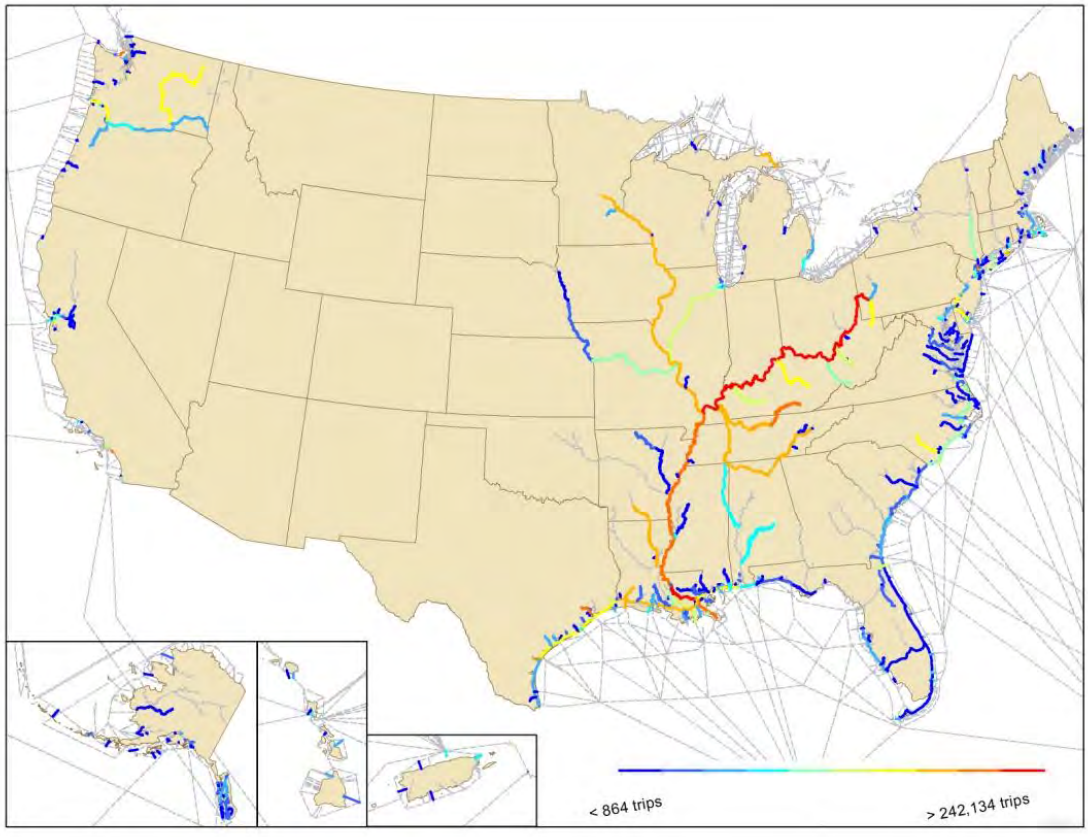


Figure 3. 2011 Waterborne Commerce of the United States Trip Count Data

The WCUS dataset provides vessel trip count per waterway segment. National emissions were assigned to waterway segments based on the proportion of total trips represented by each segment, as shown in the following equation:

WWEm = NatEm × (WWTrips / NatTrips)

Where:

WWEm = Waterway underway emissions
NatEm = National tug underway emissions
WWTrips = Trips associated with the waterway segment
NatTrips = Total trips Nationwide

5.46 tons of VOC = 3,237 Tons of VOC × (9,346 trips on Detroit River, MI waterway/ 5,536,686 national trips)

Waterway segments are associated with one or more underway shapeIDs available in EIS. To apportion the waterway-level emissions to individual shapeIDs, the waterway segments were spatially intersected with the underway shapes, and the length of each segment portion was calculated. Waterway underway emissions were calculated as follows:

$ShapeEm = WWEm \times WWLength / WWLength_{Total}$ *

Where:

WWEm = Waterway underway emissions
ShapeEm = ShapeID Emissions
WWLength = Waterway length per segment within ShapeID
$WWLength_{Total}$ = Total Waterway length

Table 2. Sample Allocation of Waterway Segment-level Emissions to Individual EIS ShapeIDs

Waterway Segment	Waterway Name	EIS ShapeID	Length (Miles)	Percent of Waterway Emissions
3301	DETROIT RIVER, MI	2498	12.91	53.37%
3301	DETROIT RIVER, MI	2496	9.92	41.01%
3301	DETROIT RIVER, MI	2497	1.34	5.54%
3301	DETROIT RIVER, MI	2494	0.02	0.08%
Total			24.19	100.00%

2.91 tons of VOC for ShapeID 2498 = 5.46 tons of VOC * (12.91 miles / 24.21 miles)

The allocation percentages derived for emissions were also applied to activity and fuel data to ensure that the emissions data were consistent with these activity elements at the individual underway shapeID level. After processing, emissions and activity were summed to the shapeID level to provide total emissions per underway shape. The result of this process is a

national allocation that closely resembles the original waterborne commerce data and represents reasonable activity patters across the United States.

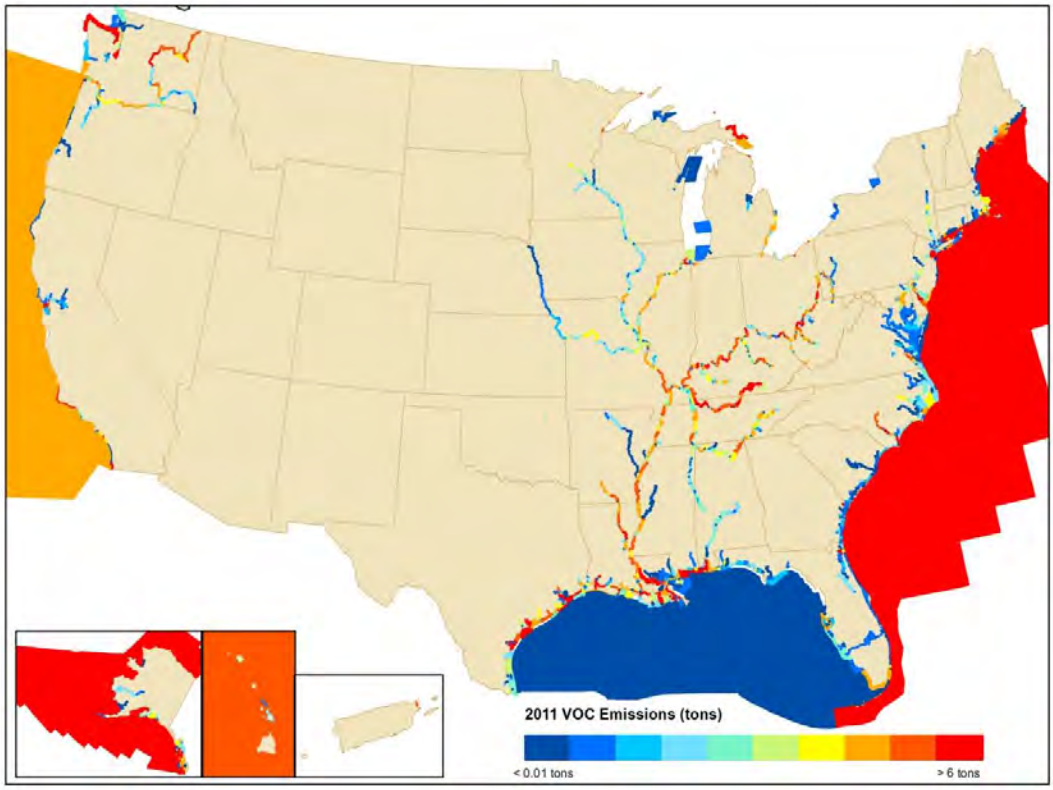


Figure 4. 2011 C1/C2 Tug VOC Emissions

2.4 Deepwater Vessels

Previous deepwater spatial allocation methods assigned emissions to navigable waterways based on total cargo tonnage as a surrogate for vessel traffic. Additional review indicated that, because this method includes all vessel types, total cargo tonnage is not an appropriate surrogate in some cases. For example, in the Great Lakes cargo tonnage is predominantly from other vessels such as lakers; therefore, the use of total cargo tonnage for spatially allocating underway tug activity nationally assigns activity and emissions in locations where there are no tug operations and under reports activity and emission where there are activities.

Army Corps of Engineers' Entrance and Clearance (E&C) data (USACE E&C, 2011) has individual vessel movements for each port visited in the U.S.; this included 1,859 foreign ports and 199 U.S. ports. To streamline the process, trips were grouped by origination and destination (O/D) pairs; and for foreign trips, the busiest port in each country was used as surrogate for all traffic to and from that country. Canada and Mexico-bound trips were aggregated into east coast, west coast, and Great Lakes routes.

For this C1/C2 allocation of deepwater vessels emissions and activities the E&C data were matched with vessel characteristics data to remove Category 3 vessels. The remaining

C1/C2 O/D pairs were mapped using network analyst tools in a GIS to determine route paths along navigable shipping lanes from the USACE waterway network (USACE, 2013). For foreign trips, ERG extended the waterway network to generate paths to major foreign ports. A portion of the route network is shown in Figure 5.

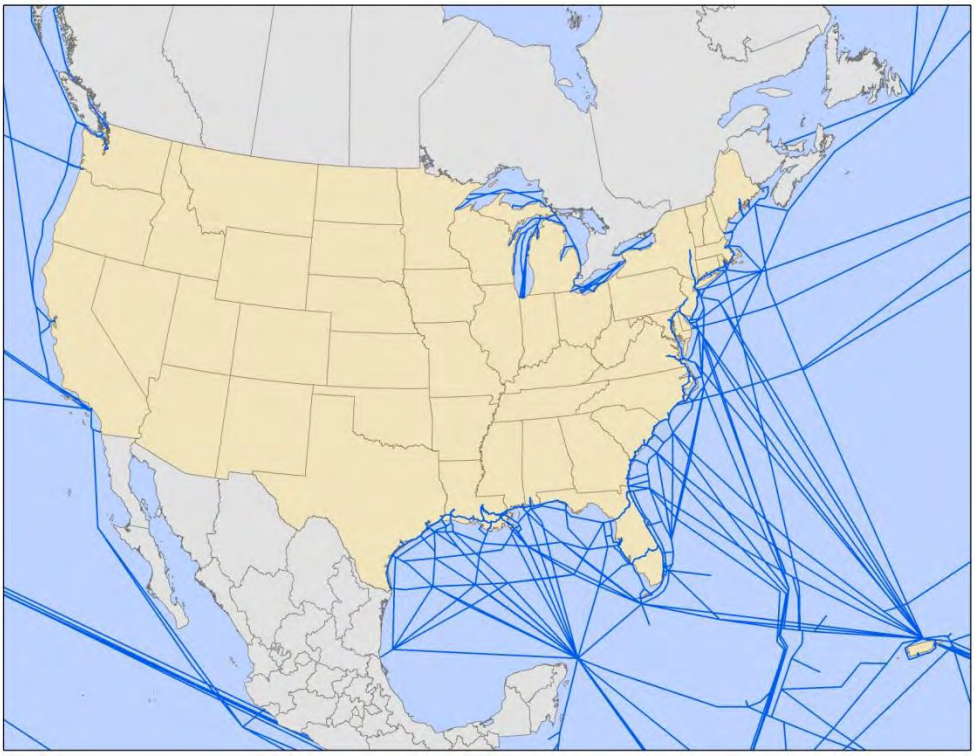


Figure 5. C1/C2 Routes Derived from 2011 Entrance and Clearance Data

Again, the national emissions values did not change; this revision targets only spatial reallocation of deepwater underway emissions. The E&C dataset provides vessel trip count per route for both domestic and foreign routes. The domestic route trip counts are adjusted for double counting by dividing vessel trip counts by two. Due to the nature of the E&C dataset, each domestic route appears in the dataset twice: once as a departure from the originating port and again as an arrival at the destination port. Each foreign route, however, only appears in the dataset once, with a domestic port of origination or a foreign destination. The adjustment to the domestic trip counts per route corrects the discrepancy between domestic and foreign routes. It should be noted that the E&C data is being used as a surrogate for C1/C2 traffic patterns and may not include of all possible C1/C2 vessel trips.

Routes are associated with one or more underway shapeIDs available in EIS. The routes were spatially intersected with the underway shapes, and the length of each segment portion was calculated. The total distance traveled along each route and shapeID segment was calculated by multiplying the number of vessel trips along each route by the length of each route. National deepwater underway emissions were assigned to routes based on the proportion of the national distance traveled represented by each segment, as shown in the following equation:

$$REm = NatEm \times ((Length R_i S_j \times Trip R_i S_j) / \Sigma (*Length R_i S_j \times Trips R_i S_j))$$

Where:

REm	= Underway emissions by shapeID (tons/year)
NatEm	= National deepwater underway emissions (tons/year)
$Trip R_i S_j$	= Trips associated specified Route i and segment shapeID j
$Length R_i S_j$	= Length of segment for shapeID j for specified Route I (km)

Example: The segment of the route from Juneau, AK to Skagway, AK that intersects with shapeID 152 is 50.6 kilometers long. C1/C2 deep water vessels traveled this route 20 times in 2011. The total national kilometer-trips traveled in 2011 is 2,422,139 kilometers. The proportion of the national deepwater underway VOC emissions assigned to this segment is calculated below:

0.54 Tons of VOC = 1,299 Tons of VOC × ((50.6 km × 20 trips) / 2,422,139 km-trips)

The allocation percentages derived for emissions were also applied to activity and fuel data to ensure that the emissions data were consistent with these activity elements at the individual underway shapeID level. After processing, emissions and activity were summed to the shapeID level to provide total emissions per underway shape. The result of this process is a national allocation that represents reasonable activity patterns across the United States, shown in Figure 6. Total C1/C2 VOC emissions for all vessel types are shown in Figure 7.

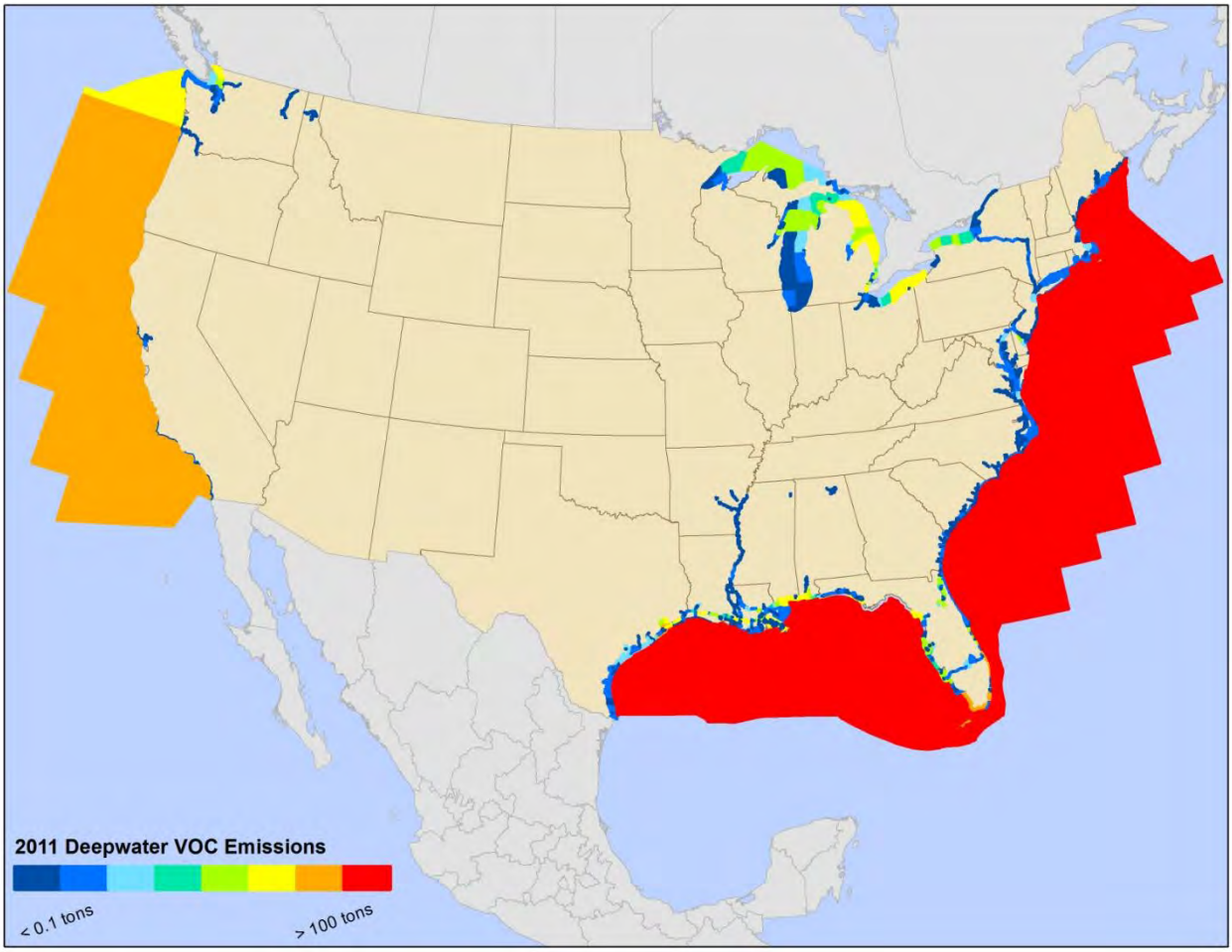


Figure 6. 2011 Deepwater C1/C2 Underway VOC Emissions

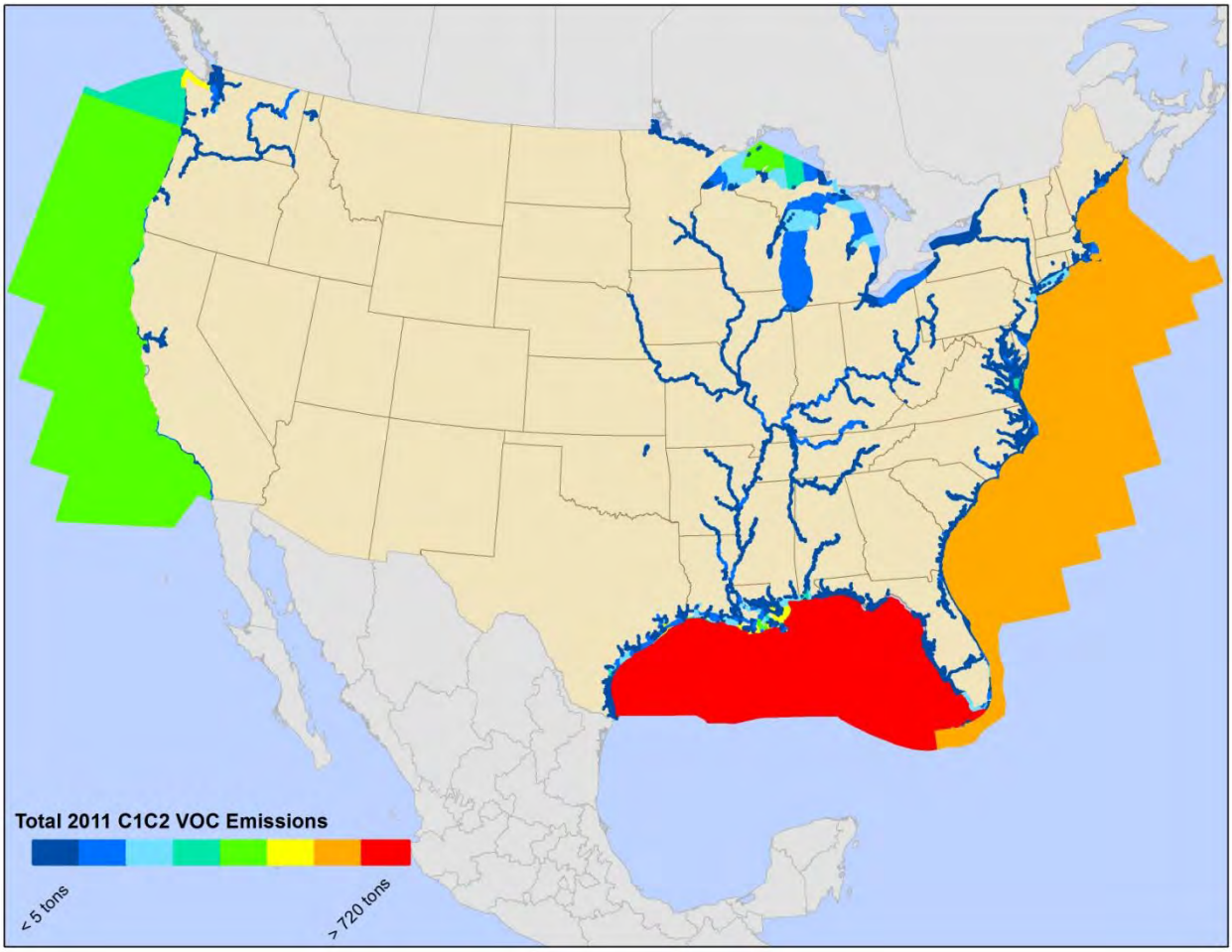


Figure 7. Total 2011 C1/C2 Underway VOC Emissions

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