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MEMORANDUM

TO: Sarah Roberts, Laurel Driver, Alison Eyth /US EPA

FROM: Isabella Brown, Roger Chang, and Richard Billings/ERG

DATE: September 17, 2019

SUBJECT: 2016 to 2017 Entrance and Clearance Activity Ratios

Summary: EPA requested an adjustment factor that could be applied to the 2017 AIS-based emission estimates to represent 2016 emissions. ERG used the ratio of the known 2016 and 2017 activity levels for various vessel types to derive vessel type-specific adjustment factors. These adjustment factors could be applied to the 2017 AIS-based emission estimates to estimate 2016 emissions for each vessel types. Data indicate that, in aggregate, there is a 2 percent increase in vessel traffic from 2016 to 2017.

Methodology: Records were collected for all ports within the US Army Corps of Engineers (USACE) 2016 and 2017 Entrance and Clearance (E&C) port commerce databases. Ship types were assigned by matching International Maritime Organization (IMO) numbers included in the E&C records to the Clarkson's registry database. The ship types that were assigned to the E&C data were based on the aggregated types compiled for the Category 3 2017 NEI Marine Emissions Model.

The E&C vessel activity was analyzed for six levels of aggregation:

- National level daily
- National level monthly
- National level annual
- Port level daily
- Port level monthly
- Port level annual

National daily vessel activity per ship type was calculated by summing all inbound and outbound calls across all ports per ship type per day. Similarly, national monthly and annual ship type vessel activity was calculated by aggregating the daily values by month and by year. Finally, port-level daily, monthly, and annual vessel activity was calculated by summing inbound and outbound calls per ship type and port ID for each day, month, and year.

For each level of aggregation, the percent ratio between 2016 and 2017 vessel activity of each day, month, or the entire year, for the corresponding aggregation levels, was calculated. For

example, national daily percent ratio between 2016 and 2017 activity were calculated per ship type by dividing the January 1st vessel activity in 2016 by that of 2017, as shown in Equation 1.

$$\frac{2016 \text{ Vessel Activity}_{\text{vessel type, national/port, time period}}}{2017 \text{ Vessel Activity}_{\text{vessel type, national/port, time period}}} \times 100 = \text{Ratio (percent)} \qquad \text{Equation 1}$$

Therefore, this number can be used as a multiplier to approximate 2016 emissions from the 2017 AIS-based emission estimates.

The 2016/2017 annual activity ratios, at the national level, per ship type, are reported in Table 1 as a percentage. Percentage ratios greater than 100% indicate that 2016 activity was greater than 2017 activity for that ship type. Likewise, percentage ratios less than 100% indicate that 2016 activity was less than 2017 activity for that ship type. A 100% percentage ratio indicates no change across the two years. Note that for underrepresented ship types there is considerable uncertainty in the calculated ratio. For example, a ratio was calculated between 2016 and 2017 for yachts. These ship types typically represent pleasure craft which are underrepresented in E&C commerce records. In fact, there were only 6 yachts reported in the 2016 E&C records while 0 were reported for 2017.

Table 1. National Annual Activity Ratios (%)

Ship Type	Annual Activity Ratios (Percent) (2016/2017)National E&C Records
Barge	64.5%
Bulk Carrier	93.7%
Chemical Tanker	97.0%
Container Ship	96.7%
Cruise	99.2%
Ferry Ro Pax	70.0%
General Cargo	112.7%
Liquified Gas Tanker	83.9%
Miscellaneous Fishing	107.3%
Miscellaneous Other	98.5%
Offshore	116.3%
Oil Tanker	90.8%
Other Tanker	96.4%
Reefer	115.3%
Ro Ro	99.3%
Service Tug	93.1%
Yacht	Insufficient Data

The monthly ratios between 2016 and 2017 are presented in Table 2 for each ship type.

Table 2. Monthly Activity Ratios (%) (2016/2017) By Ship Type

Ship Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Barge	57.8%	45.3%	49.1%	54.3%	65.5%	68.6%	80.4%	72.1%	64.5%	68.1%	63.6%	60.9%
Bulk Carrier	87.1%	87.9%	83.8%	90.6%	87.9%	93.5%	90.0%	102.9%	96.0%	98.4%	100.1%	105.3%
Chemical Tanker	85.8%	92.6%	100.5%	105.2%	96.4%	101.8%	97.1%	104.7%	97.4%	91.8%	94.2%	97.6%
Container Ship	94.7%	100.0%	96.1%	99.1%	98.3%	100.5%	97.3%	96.6%	97.2%	92.9%	96.6%	91.7%
Cruise	96.9%	98.7%	100.6%	104.0%	93.2%	97.0%	93.3%	95.8%	90.4%	112.1%	114.2%	105.6%
Ferry Ro Pax	74.7%	89.4%	73.5%	61.8%	61.1%	70.3%	45.4%	59.0%	98.6%	75.3%	81.4%	75.4%
General Cargo	125.0%	123.0%	116.5%	138.5%	122.6%	116.5%	132.0%	107.6%	139.5%	96.9%	83.4%	71.0%
Liquified Gas Tanker	78.1%	86.4%	76.3%	72.8%	87.3%	90.2%	89.7%	94.8%	72.6%	87.0%	89.4%	85.6%
Miscellaneous Fishing	3.7%	42.9%	16.7%	28.6%	88.9%	71.4%	227.3%	280.0%	290.0%	266.7%	141.7%	188.9%
Miscellaneous Other	97.1%	103.0%	94.4%	91.8%	101.7%	100.9%	93.1%	102.1%	98.7%	101.8%	104.5%	94.5%
Offshore	136.6%	141.8%	133.0%	132.7%	119.4%	113.7%	122.6%	126.3%	126.1%	89.9%	87.7%	87.4%
Oil Tanker	150.0%	88.2%	59.1%	36.4%	57.1%	100.0%	57.1%	50.0%	181.8%	158.3%	142.9%	125.0%
Other Tanker	94.6%	95.0%	98.7%	100.3%	87.1%	108.3%	104.9%	113.3%	103.3%	77.2%	84.3%	94.7%
Reefer	98.3%	121.9%	111.1%	109.9%	123.4%	125.9%	124.2%	111.7%	101.1%	107.7%	122.4%	128.1%
Ro Ro	90.9%	108.9%	100.1%	98.8%	101.5%	98.3%	95.9%	93.1%	101.9%	94.9%	103.6%	106.3%
Service Tug	97.0%	97.6%	84.5%	87.8%	101.0%	103.8%	109.8%	91.4%	87.1%	93.8%	85.3%	80.1%
Yacht	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND: No data/insufficient data.

Both annual and monthly national ratio percentages between the two years were plotted in Figure 1. These ratios represent changing activity within a year, rather than the year-to-year variation in activity. As is evident from the plot, the monthly activity level of certain ship types varies more significantly year to year than other ship types. While Container Ship activity remains largely the same between 2016 and 2017, both on a monthly and annual basis; the difference between oil tanker 2016 and 2017 activity varies significantly on a month-to-month basis.

In comparison, a plot with the national daily ratios, in addition to the monthly and annual values presented in Figure 1, are plotted in Figure 2, noting the large variance in the daily ship type activity between 2016 and 2017.
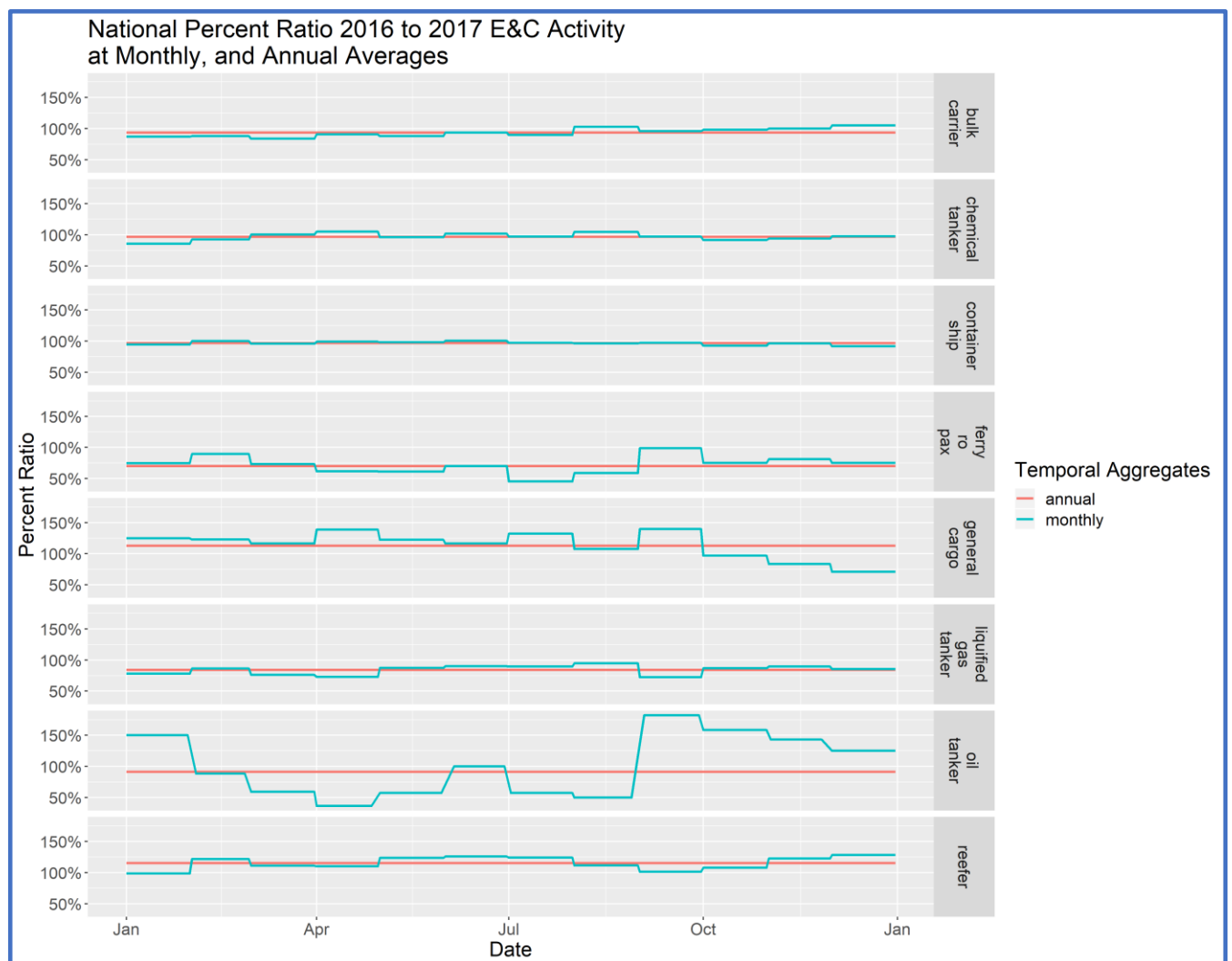

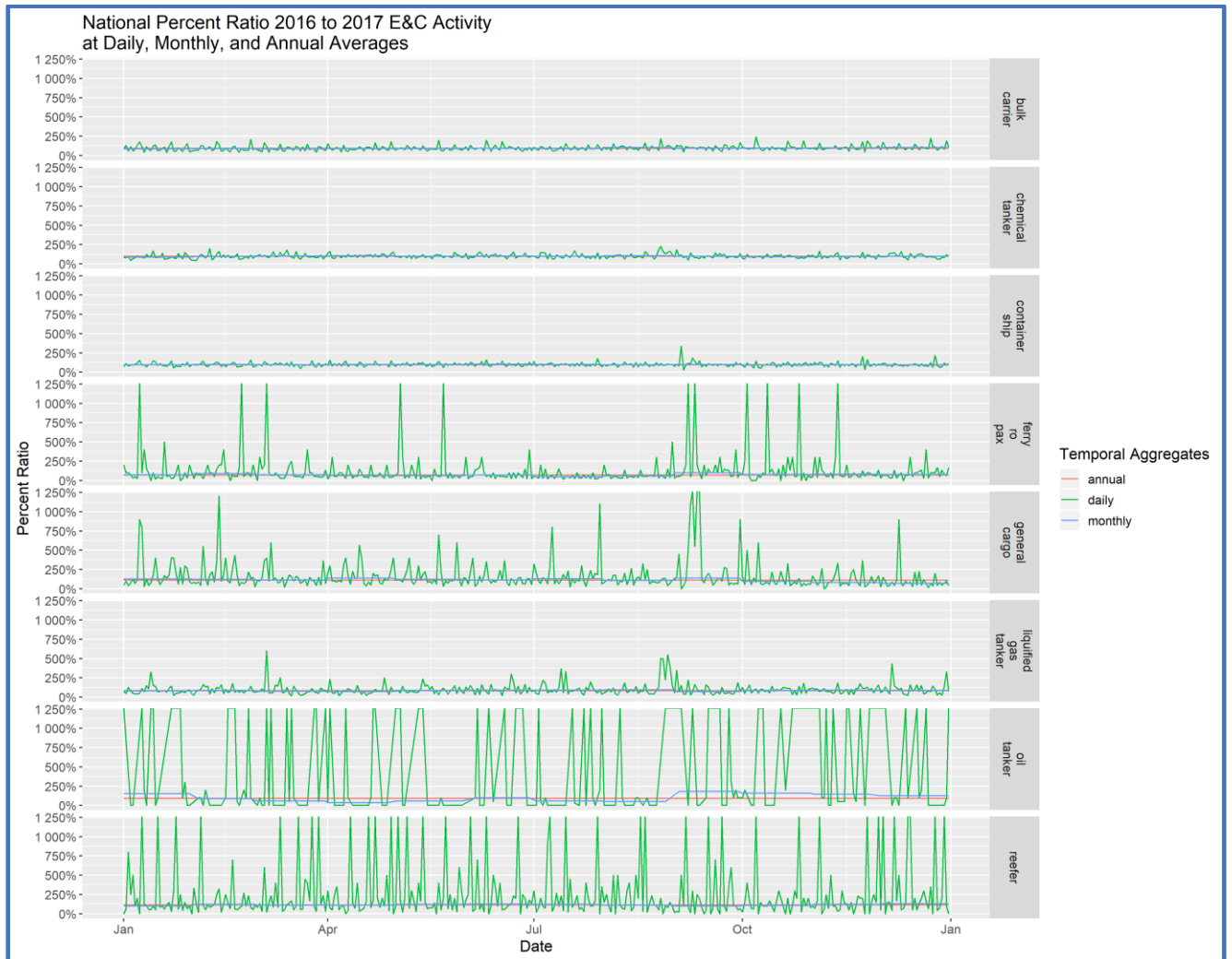**Figure 1. National Monthly, and Annual 2016 to 2017 Activity Ratios, By Ship Type**

Figure 2. National Daily, Monthly, and Annual 2016 to 2017 Activity Ratios, By Ship Type

These same values were calculated on the port level as well. Ratios cannot be calculated for small ports because they may report no calls for a given ship type one year and only a few of that ship type another year, likely because of low traffic load. The monthly and annual port percentage ratios are plotted in Figure 3 for a sample of ports, identified by their E&C port ID. Plots where the lines do not extend across the entire year signify those for which ratios could not be calculated.
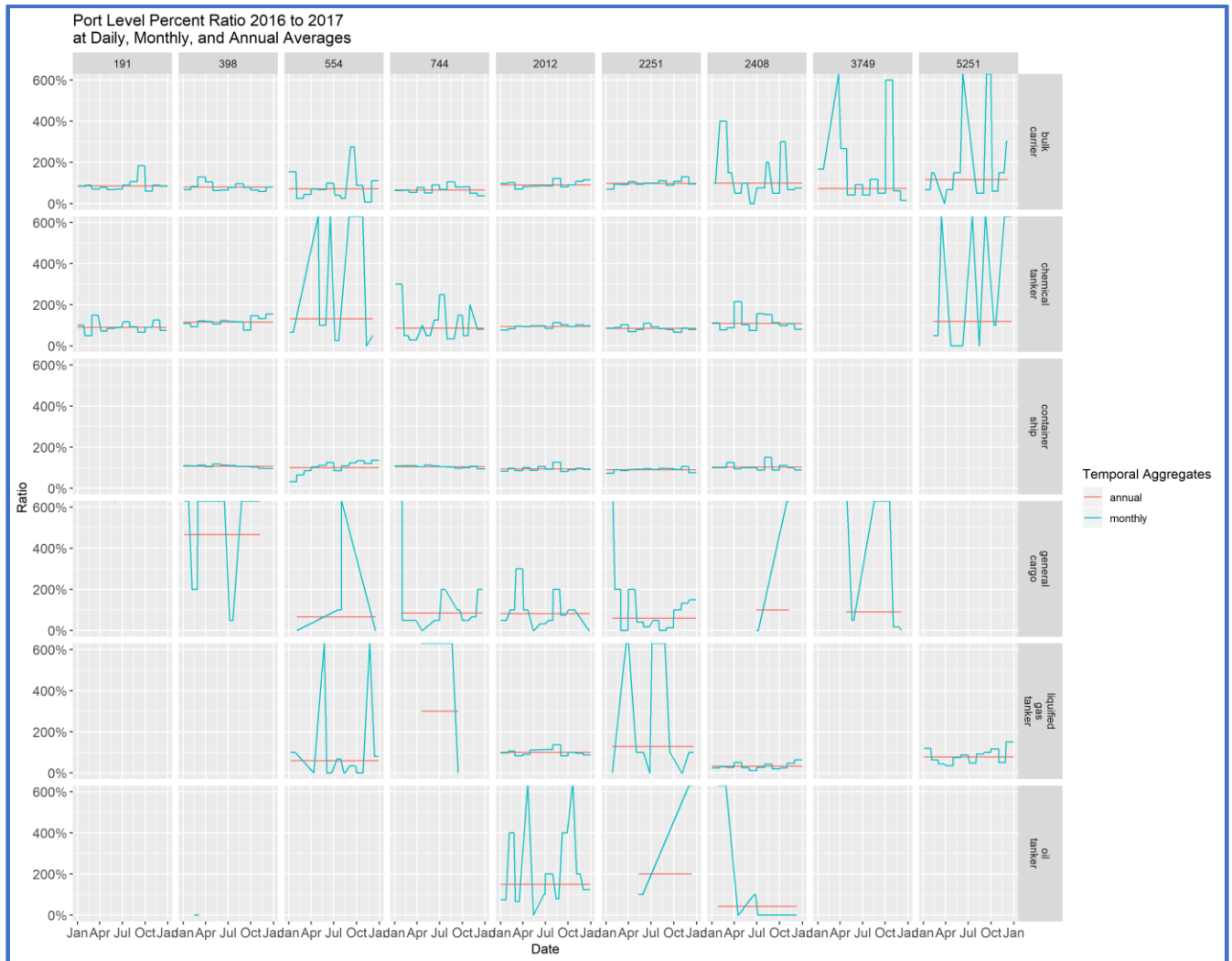
Figure 3. Monthly and Annual 2016 to 2017 Activity Ratios, By Port and Ship Type

The daily variations between 2016 and 2017 activity is added to the below plot in Figure 4 and shows the same issue in daily activity ratios noted in Figure 2.

Figure 4. Daily, Monthly, and Annual 2016 to 2017 Activity Ratios, By Port and Ship Type

Recommendations

We recommend using the national vessel type activity ratios, as presented in Table 1, to derive 2016 emissions data from the 2017 AIS-based emissions data. The 2016 and 2017 E&C port activity data are a good surrogate for capturing regional differences; but to extrapolate those port differences to underway operations would be complex and resource intensive. We further recommend that emissions from barges, fishing boats, tugs and yachts be excluded from consideration. E&C is not a good source of activity data for these vessels as it tends to underrepresent these operations as these vessels are not generally involved in internationals shipments of cargo. We recommend using a national default value of 98% for these vessels as well as all Category 1 / 2 vessels.