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Background

The Finnish Meteorological Institute has made an estimate of exhaust gas emissions from Baltic Sea Shipping in 2016, see the attachment. The emission estimates for the year 2016 are based on over 1.1 billion AIS-messages sent by 23 867 different ships, of which 8 243 had an IMO registry number indicating commercial marine traffic. The AIS position reports were received by terrestrial base stations in the Baltic Sea countries and collected to regional HELCOM AIS data server. Emissions are generated using the Ship Traffic Emission Assessment Model (STEAM) of Jalkanen *et al.* (2009, 2012) and further described in Johansson *et al.* (2013, 2017).

For 2016, the temporal coverage was 99.4% without any significant data gaps. Most of the messages originate from South-Western region of the Baltic Sea near the Danish and southern Swedish sea areas (see Figure 7). For individual vessels however, data gaps occur regularly but the smart routing feature of the STEAM3 model (Johansson et al., 2017) interpolates vessel activities (including berthing activities) between two consecutive AIS-messages and can avoid land masses in such cases.

Emissions from Baltic Sea Shipping in 2015

Total emissions from all vessels in the Baltic Sea in 2016 were 318 kt of NO_x, 10 kt of SO_x, 9 kt of PM, 22 kt of CO and 14.7 Mt of CO_2. The CO_2 amount corresponds to 4792 kilotons of fuel, of which 24% was associated to auxiliary engines. The fuel consumption of inland waterway traffic sending AIS-messages was 49 kilotons.

The most significant contribution to emissions can be associated with RoPax vessels, tankers, cargo ships and container ships. In terms of fuel consumption, the respective shares for these vessel types in the presented order are 1234 (+1.5%), 1073 (+0.9%), 822 (+2.4%) and 776 (+6.9%) kt of fuel consumed.

The emissions of all pollutants have increased by 2.8% (NO_x), 3.1% (SO_x), 3.0% ($PM_{2.5}$), 3.3% (CO), and 3.2% (CO_2) when compared to year 2015. The emissions of CO_2 from non-IMO registered vessels were 3.6% of total CO_2 emitted from ships.

Overall transport work (vessel type dependent fraction of DWT*km) has increased by +2.3% while the total travelling distance of IMO-registered vessels has decreased by 3.3%. The transport work of containership segment increased by +10.6% whereas the transport work of tankers and cargo ships increased by +0.2% and +1.5%. For RoPax vessels a slight increase of +0.4% was observed.

The emissions of particulate matter and sulphur have increased by +3.0%. During the 2016 study period the number of IMO-registered vessels has increased by +0.4%.

More detailed information can be found in the attached report of the Finnish Meteorological Institute.

Action requested

The HELCOM Maritime 17 Meeting is invited to take note of the information.

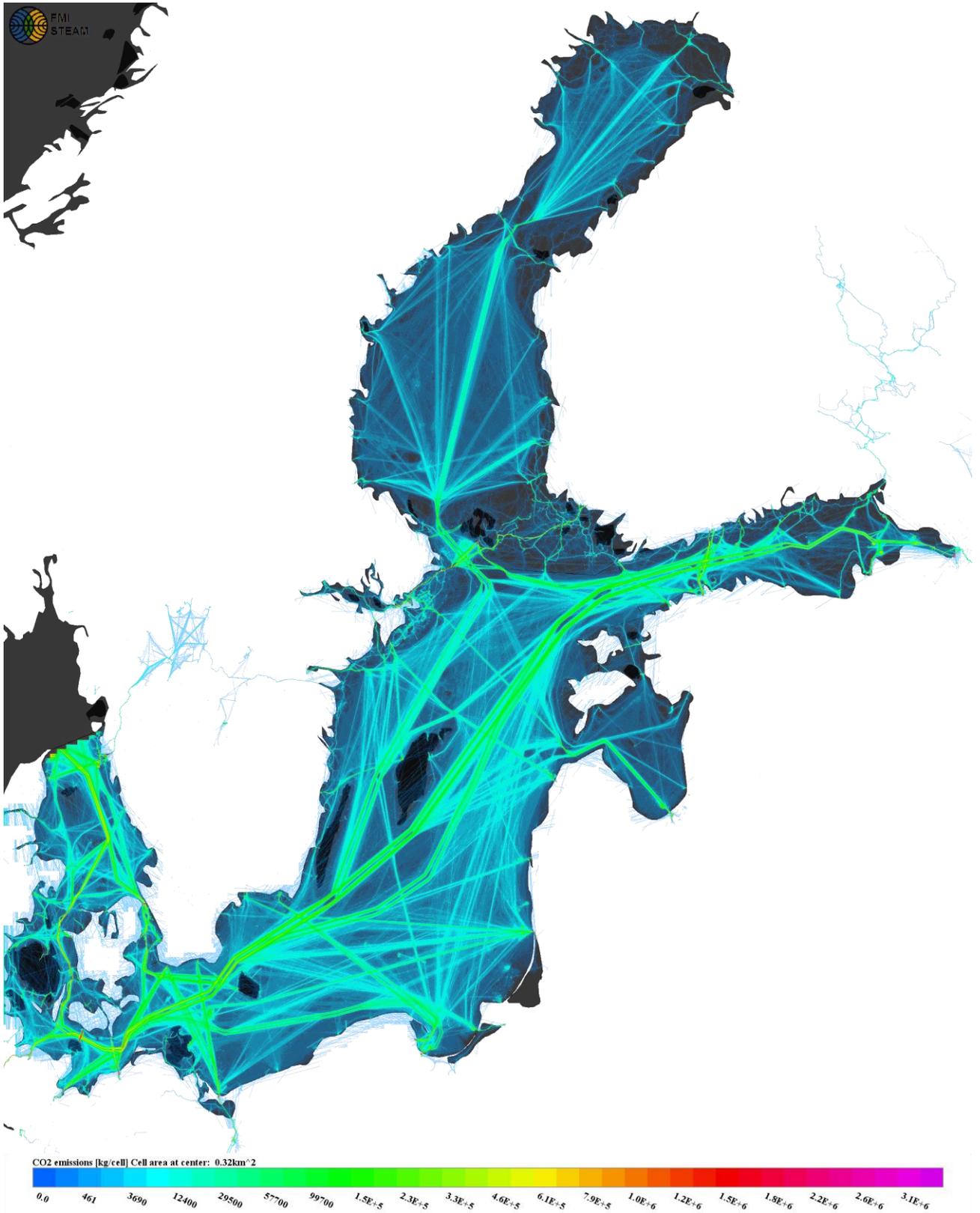# Emissions from Baltic Sea shipping in 2016

Authors: Lasse Johansson, Jukka-Pekka Jalkanen

Finnish Meteorological Institute, Atmospheric Composition Research

P.O Box 503, FI-00101 Helsinki, Finland

Key Messages

1. **Total emissions from all vessels in the Baltic Sea in 2016 were 318 kt of NO_x, 10 kt of SO_x, 9 kt of PM, 22 kt of CO and 14.7 Mt of CO_2.** The CO_2 amount corresponds to 4792 kilotons of fuel, of which 24% was associated to auxiliary engines. The fuel consumption of inland waterway traffic sending AIS-messages was 49 kilotons.

2. **The most significant contribution to emissions can be associated with RoPax vessels, tankers, cargo ships and container ships.** In terms of fuel consumption, the respective shares for these vessel types in the presented order are 1234 (+1.5%), 1073 (+0.9%), 822 (+2.4%) and 776 (+6.9%) kt of fuel consumed.

3. **The emissions of all pollutants have increased by 2.8% (NO_x), 3.1% (SO_x), 3.0% ($PM_{2.5}$), 3.3% (CO), and 3.2% (CO_2) when compared to year 2015.** The emissions of CO_2 from non-IMO registered vessels were 3.6% of total CO_2 emitted from ships.

4. **Overall transport work (vessel type dependent fraction of DWT*km) has increased by +2.3% while the total travelling distance of IMO-registered vessels have increased by -3.3%.** The transport work of containership segment increased by +10.6% whereas the transport work of tankers and cargo ships increased by +0.2% and +1.5%. For RoPax vessels a slight increase of +0.4% was observed.

5. The emissions of particulate matter and sulphur have increased by +3.0%. During the 2016 study period the number of IMO-registered vessels has increased by +0.4%.

Figure 1 The geographical distribution of CO_2 emissions from Baltic Sea shipping in 2016. Emissions are reported in kilograms per grid cell.
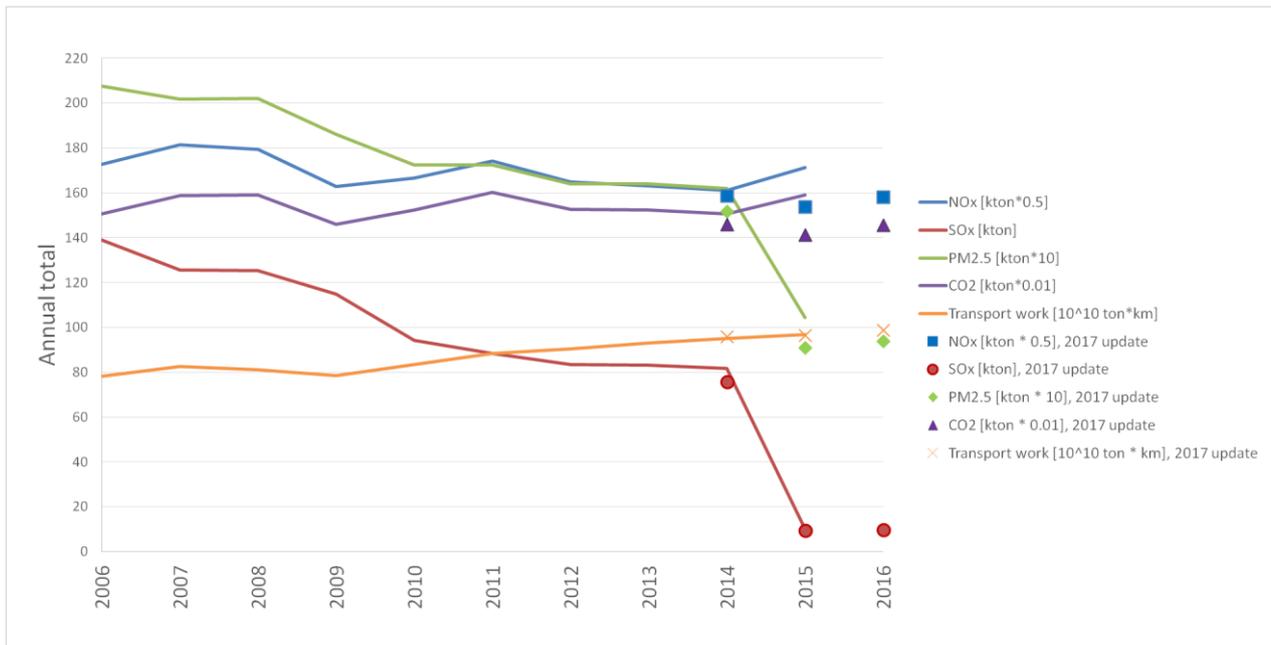
Figure 2 Emissions and the transport work of Baltic Sea shipping during 2006-2016. The colored lines represent NO$_x$, SO$_x$, PM$_{2.5}$, and CO$_2$ emissions and transport work obtained with STEAM2 model for the period 2006-2015. The corresponding color symbols indicate same quantities obtained with a new STEAM3 model version for years 2014, 2015 and 2016.

The long term trend of ship emissions indicates that after the 0.1% sulphur limit for marine fuel entered into force in Jan 1st 2015, the emissions have stabilized to lower levels. There is a slight increase of emissions and transport work compared to previous year. Figure 2 illustrates the annual emission totals with colored lines (old STEAM2 results) and symbols (new STEAM3 model version).

The summary of results for 2016 has been collected to Table 1. In Table 1a, the estimated annual total emissions are shown for different parts of the Baltic Sea and by vessel type. Most of the emissions are produced in the main body of the Baltic Sea although the much smaller areas of Kattegat and the Gulf of Finland constitute a fair share of the total emissions. In Table 1b, the fuel consumption statistics, travel distances, transportation work and the number of ships are shown. The total number of vessels was 23 867 in 2016, of which 21% were unidentified vessels. Over 65% of AIS targets in the Baltic Sea were not IMO-registered.

Table 1a-b: Summary of key results from Baltic Sea shipping in 2015.

Baltic - 2016		NO_x [ton]	SO_x [ton]	$PM_{2.5}$ [ton]	CO [ton]	CO_2 [10^3 ton]
All		318 286	9 779	9 434	21 888	14 657
	IMO	308 181	9 412	9 095	20 753	14 127
Baltic Sea	Baltic Sea	182 826	5 458	5 206	12 103	8 227
	Kattegat	63 684	1 886	1 847	4 417	2 817
	Gulf of Finland	43 687	1 383	1 373	3 180	2 075
	Gulf of Bothnia	21 162	792	774	1 561	1 181
	Gulf of Riga	4 290	154	139	331	207
Other	Other	2 674	108	97	298	151
RoPax_vessels		75 204	2 479	2 221	4 470	3 752
Vehicle_carriers		28 400	867	728	1 821	1 359
Cargo_ships		55 890	1 691	1 683	4 560	2 498
Container_ships		54 712	1 587	1 636	3 815	2 359
Tankers		77 378	2 196	2 281	4 729	3 259
Passenger_ships		1 255	46	40	126	67
Cruisers		8 482	285	251	573	448
Fishing_vessels		2 254	82	75	213	121
Service_ships		2 082	73	73	194	108
Unknown		2 625	110	98	350	160
Misc		10 039	364	348	1 039	528

| Baltic - 2016		Main_Eng, [10^3 ton]	Aux_EngFu [10^3 ton]	TRAVEL [10^3 km]	Transport [10^6 ton km]	SHIPS Ships
All		3 686	1 136	141 112	993 235	23 867
	IMO	3 604	1 044	113 536	990 416	8 243
Baltic Sea	Baltic Sea	2 192	515	80 374	581 120	
	Kattegat	662	265	29 267	213 942	
	Gulf of Finland	460	223	13 979	136 790	
	Gulf of Bothnia	312	76	12 591	45 101	
	Gulf of Riga	43	25	2 687	12 081	
Other	Other	17	32	2 218	4 207	
RoPaX		1 067	167	15 885	31 353	222
Passenger_Cruiser		118	30	1 272	0	98
Passengers_Ferry		13	9	3 101	0	396
Service		12	23	1 737	0	442
Cargo		667	155	43 433	321 338	4 137
Container		515	260	12 919	165 453	573
Tanker		752	321	21 539	416 639	2 010
Other		110	64	22 777	0	10 120
Fishing		20	20	5 382	0	666
Vehicle_Carrier		400	47	8 124	58 454	298
Unknown		12	41	4 946	0	4 905

There were 8 243 AIS targets with a valid IMO number and 15 624 targets which transmitted only MMSI information. Searching vessel databases and internet with MMSI codes yielded no data for 4 905 targets and these represented 5.1% of AIS data received in the Helcom 2016 dataset. For the remaining 10 719 MMSI targets closest match (physical dimension, installed engine size, design speed) of the STEAM vessel database was used. Using data from similar, closest matching vessels to fill the gaps in ship technical data should provide a more reliable estimate of the vessel fuel consumption and emissions.
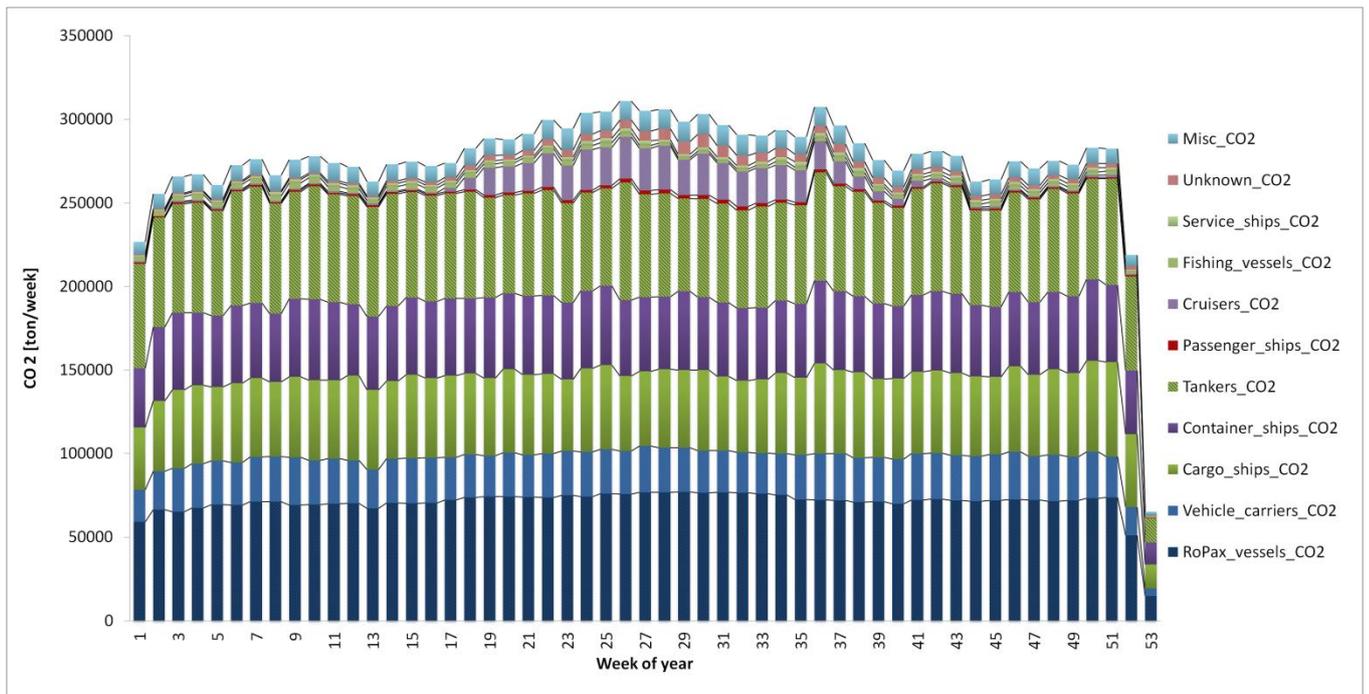
Figure 3 CO_2 **weekly emissions for classified by ship category. Vehicle carriers include RoRo vessels. Category 'Other' includes tugs, dredgers, barges, SAR, ice breakers and law enforcement vessels**

The contribution of RoPax vessels, tankers, cargo ships and container ships remains steady throughout the year (Figure 3). The most significant seasonal variation can be observed with passenger cruisers, which operate almost exclusively during summer.

Figure 4 illustrates the share of transport work done by each size class of vessels. The transport work has been calculated as described in the 2nd IMO GHG study (IMO, 2009). A shift towards larger vessels can be observed, because the share of the transport work of five smallest size categories (under 45 000 GT) has decreased whereas the contribution of the two largest categories has increased. This is indicated by the columns; transport work shares for 2014, 2015 and 2016 are depicted by green, red and blue bars. The share of CO_2 emitted from the different size classes is indicated by black symbols. A vessel class where the black symbol is lower than the blue bar indicates a vessel size class with good energy efficiency.
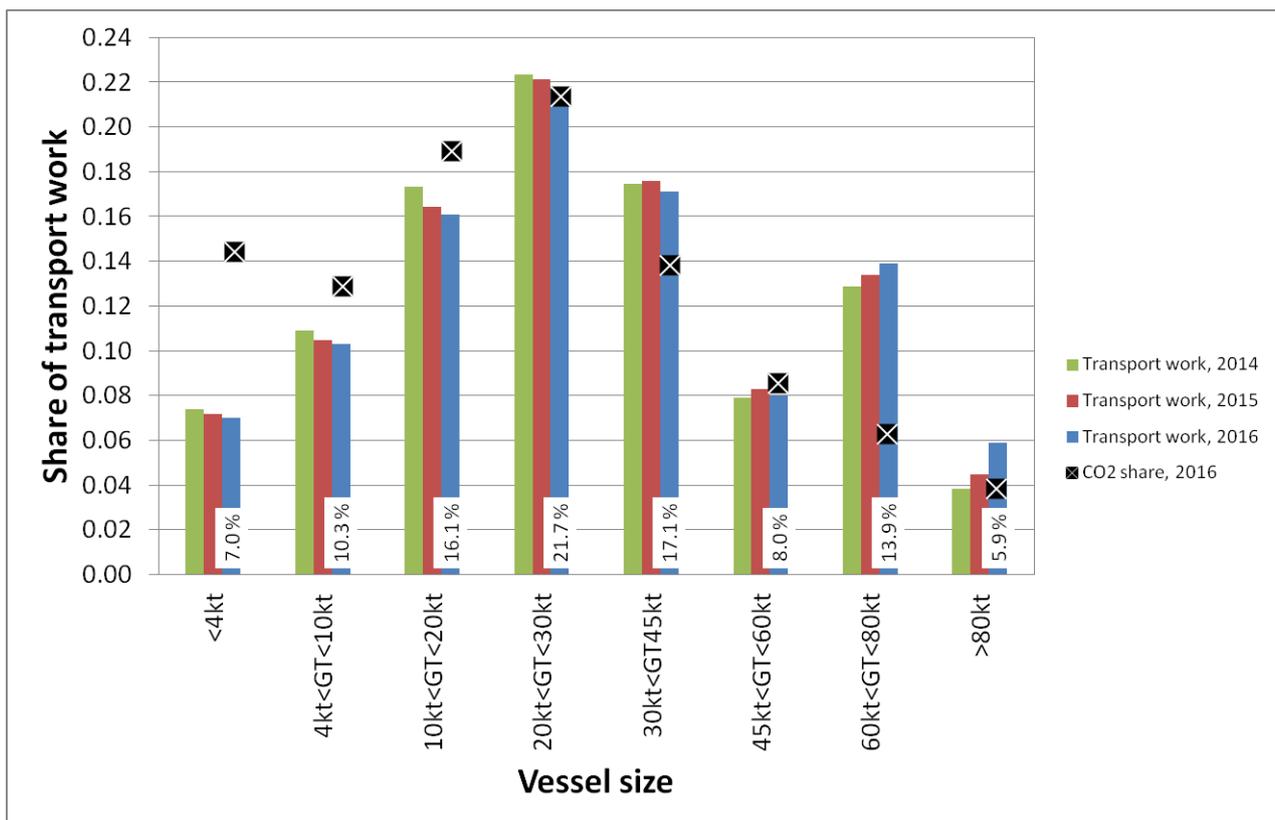

Figure 4. Transport work done by each size category of ships in the Baltic Sea during 2014-2016. Gradual shift towards larger vessels was observed during this period. The percentage values at the base of the 2016 bar report the transport share of each class in numerical form.

In Figure 5 the share of emissions are shown for the top 16 flag sates (based on CO_2 output). It can be seen from the figure that vessels under the flag of Finland contribute the most of all the flag states in 2016.
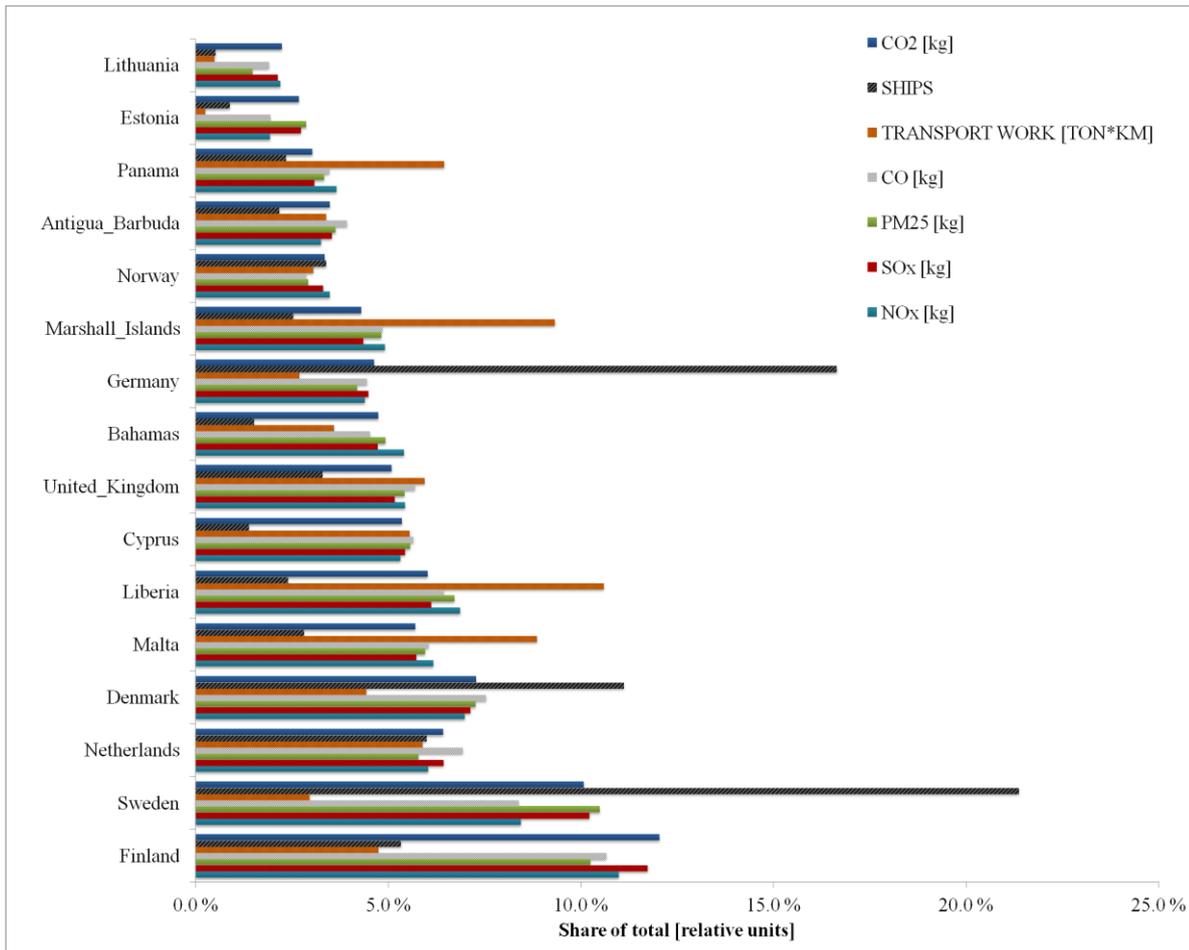
Figure 5 Share of emissions, transport work and the number of ships of the Baltic Sea total in 2016, classified by flag state.

Unit emissions and total CO_2 emissions were calculated for each vessel type (see Figure 6). Cargo oriented fleets (Liberia, Cyprus , Marshall Islands, Panama) have lowest unit emissions. It should be noted, that passenger carrying capacity has no effect on the unit emission calculation, because only DWT of vessels is considered. In this study, the exclusion of passenger carrying capacity during the unit emissions calculations will favor cargo oriented fleets. The net weight of the cargo transport onboard was evaluated with a method described in the 2nd IMO GHG study (IMO, 2009).

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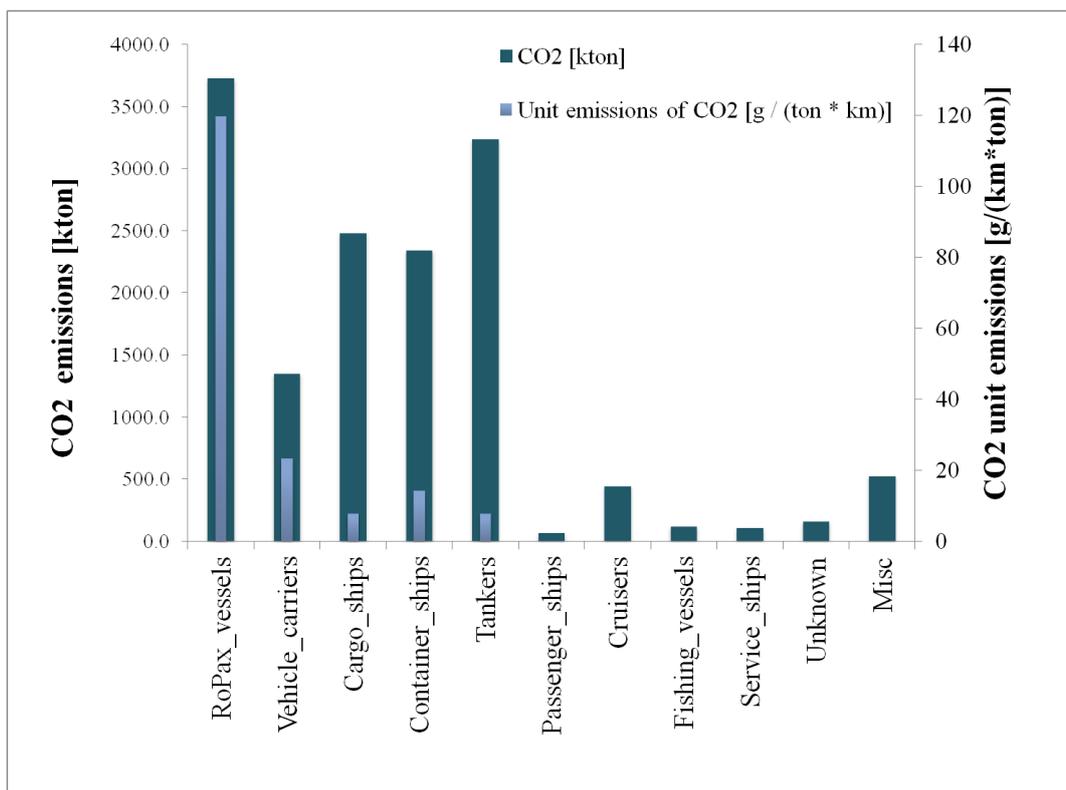
Figure 6 Emissions of CO₂ and unit emissions classified according to vessel type. All CO₂ emission are reported as thousand tons, whereas the unit emissions are in grams per ton km. Unit emissions are not generated for smallest vessel categories because of incomplete data concerning the cargo carrying capacity.

References

International Maritime Organization, Second IMO GHG Study 2009, London, UK, April 2009; Buhaug, Ø., Corbett, J.J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., Pålsson, C., Winebrake, J.J., Wu, W., Yoshida, K.

Jalkanen, J.-P., Brink, A., Kalli, J., Pettersson, H., Kukkonen, J. and Stipa, T., "A modelling system for the exhaust emissions of marine traffic and its application to the Baltic Sea area", *Atmospheric Chemistry and Physics*, **9** (2009) 9209-9223.

Jalkanen, J.-P., Johansson, L., Kukkonen, J., Brink, A., Kalli, J., and Stipa, T., "Extension of assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide", *Atmospheric Chemistry and Physics*, **12** (2012) 2641-2659.

Johansson L., Jalkanen J.-P., Kalli J. and Kukkonen J., "The evolution of shipping emissions and the costs of recent and forthcoming emission regulations in the northern European emission control area", *Atmospheric Chemistry and Physics*, **13** (2013) 11375-11389.

Johansson L., Jalkanen J.-P., and Kukkonen J., " Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution", *Atmospheric Environment*, 167 (2017) 403-415.

Data

The emission estimates for the year 2016 are based on over 1.1 billion AIS-messages sent by 23 867 different ships, of which 8 243 had an IMO registry number indicating commercial marine traffic. The AIS position reports were received by terrestrial base stations in the Baltic Sea countries and collected to regional HELCOM AIS data server. Emissions are generated using the Ship Traffic Emission Assessment Model (STEAM) of Jalkanen et al. (2009, 2012) and further described in Johansson et al. (2013, 2017).

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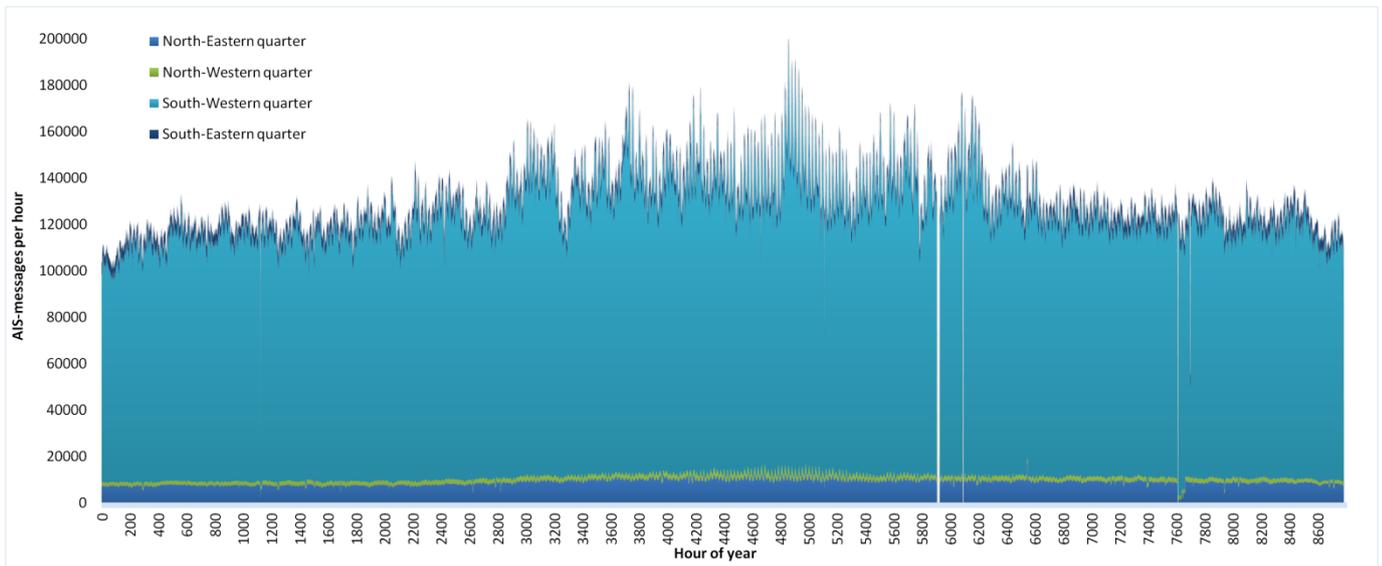
Figure 7 **AIS-data hourly coverage in different parts of the modelling region for 2016.**

Metadata

Fuel and vessel operational procedures can have a large impact on exhaust emissions. Emission factors for ships are in accordance with the latest literature and are believed to represent a reasonable estimate of the resulting emissions. Marine currents, fouling and sea ice can have a significant impact on emissions, but these effects have not been accounted for in this study.

Some uncertainty in predicted emissions arises from the large number of small vessels for which technical details are unavailable or incomplete. However, the internet contains some basic vessel characteristics even for such small and unknown ships [1] and by using an automated vessel characteristics extraction routine, it has been verified that the group of unknown ships are in fact small vessels and as such do not cause significant margins of error for the modelled annual emission totals. Nevertheless, only a fraction of recreational boating activity can be studied with AIS. According to a recent estimate [2], there exists over 250 000 boats in more than 3 000 locations in the Baltic Sea area which are not required to carry AIS onboard. It is likely that the total number of AIS targets observed during the year 2016 represents about 20% of the total waterborne vessels, but describes the activity of commercial ship traffic very well because AIS is mandatory for large vessels.

The STEAM3 model code has been updated. This means that several features of the model have been changed. For this fact sheet, the period 2014-2016 were rerun with new model version to indicate relative changes within this time period (see Figure 2). However, the numerical results of the current work are not directly comparable with previous fact sheets. The changes made to the new model version include advanced path finding of shipping routes in cases where AIS coverage is less than complete, bug fixes to auxiliary engine Tier II emission factor allocation and gap filling of technical data with values from most similar vessels.

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[1] For example, www.marinetraffic.com and www.vesselfinder.com usually yield the ship type and physical dimensions for vessels that have no IMO-number..

[2] Sustainable Shipping and Environment of the Baltic Sea region (SHEBA) project, Deliverable 1.3 "Activity data for the Baltic pleasure boats".