Interactive comment on “Investigation of gaseous and particulate emissions from various marine vessel types measured on the banks of the Elbe in Northern Germany” by J.-M. Diesch et al.

Anonymous Referee #2
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The paper by Diesch et al. reports on measurements of ambient aerosol and several trace gases on five days in April 2011. These measurements have been carried out on the banks of the lower Elbe close to one of the busiest shipping lanes in Europe. In total 139 ship plumes have been analysed to determine emission factors for the above mentioned quantities depending on vessel classes. In general the paper is an interesting and scientific important piece of work and merits publication in ACP. This is in particular true since only a few studies are available where emission factors of marine vessels have been derived under real conditions. However, like reviewer #1 I have serious concerns about several of the conclusions drawn by the authors due to the very limited data set used. Sections 3.2, 3.3 and 5 should be rephrased, removing all the statements not supported by the data in a statistical proven way.

Detailed comments:

Section 2: Please give information on which days the mobile lab was where. The measurement site in the south is quite close to Glückstadt. Isn’t it possible that local pollution has interfered with ship plumes (in particular for NOx)?

Author: The text was revised as follows: “The measurement sites (2011/04/25: N53° 50' 22" E9° 18' 12"; 2011/04/26 and 2001/04/27: N53° 50' 47" E9° 17' 16"; 2011/04/28 and 2011/04/29: N53° 44' 17" E9° 24' 0"; Fig. 1b) were located near Freiburg/Elbe between Cuxhaven and Hamburg on the banks of the Elbe, chosen to be located directly downwind of the ship tracks. As the wind directions during the study period varied between N-NO (see trajectories in Fig. 1a) three different measurement sites were chosen to prevent local pollution to interfere with the ship plumes. During the study relatively clean air from the Baltic and North Sea was transported to the measurement sites.”
Although regional pollution sources (e.g. Glückstadt or other small cities) cannot be avoided to be measured, they can clearly be distinguished from ship pollution plumes. Ship plumes have been identified as pronounced peaks in the time series of several parameters (Fig. 3) and can be assigned to individual ships using the AIS system. Since the background concentrations have been subtracted from the plume peaks and since the background did not vary strongly over time scales of several minutes (the length of the plume events) we do not expect any interference of the background pollution with our ship plume analysis.

Time resolution of measurements: The airpointer has to my knowledge not a time resolution much better than one minute. This is in particular the case for NO/NO2 since it is measuring these trace gases in a two-step procedure. The data output of the system might be faster but this is not the real time resolution of the detector. Also the results shown in Figure 3 are not supporting the statement that most instruments have a time resolution of 12 s or less.

Author: The time resolution of all instruments is now provided in the new Table 1. The time resolution of most instruments is in the range of a few seconds. The two exceptions are the Aerosol Mass Spectrometer and MAAP, which measure with 60 s time resolution. To clearly distinguish contamination plumes from the background the time resolution of the measured parameter needs to be significantly shorter than the typical length of such an event. The Airpointer is typically operated with internal averaging over a large number of measurement cycles to reduce the noise level. It provides an output of new data every 4 seconds which is recorded by our data acquisition software. The different modules for the different trace gases within the Airpointer have different cycle lengths with the NOx instrument having the longest cycle length and using a two-step cycle of two times 8 seconds to measure NO and NOx as correctly stated by the reviewer. So for this variable the data value is updated only in every other 4-second data point. Laboratory measurements with the Airpointer have shown that while measured averaged concentrations of short-time NO/NOx peaks as observed during the ship emission measurements were affected by the internal sliding window averaging procedure which was set to 10 cycles for the ship measurements. This results in the broadened and flattened peaks in Figure 3, however the actual plume concentrations can be calculated from the total plume peak area correctly.

P22278: Could the authors support their statement, that they have measured only fresh emission plumes with their meteorological observations? Two km distance means that a minimum wind speed of 6 m/s in direction of the lab is needed to cover the distance within 5 minutes.

Author: Indeed, the meteorological observations support the statement that fresh emission plumes were measured. To make this clear we reformulated the sentence in section 2.1: "At the measurement sites, the Elbe is about 2 km wide. For this reason most vessels were probed and identified at a distance of about 0.8 and 1.2 km, reflecting the main shipping lanes (upstream/downstream the Elbe). During the 5 days of sampling similar meteorological conditions existed (no rain, similar temperatures, RH) with an average wind speed of 6 m/s. The plumes were measured directly downwind the Elbe. For this reason, dependent on the meteorological situation and the distance between ship and sampling site the ages of the registered plumes vary between 1-5 minutes."

The reference to the instrumental description of Drewnick et al. is missing in the reference list.

Author: Thank you – it was added to the reference list.

Drewnick, F., Böttger, T., von der Weiden-Reinmüller, S.-L., Zorn, S. R., Klimach, T., Schneider, S., and Borrmann, S.: Design of a mobile aerosol research laboratory and data processing tools for effective stationary and mobile measurements, Atmos. Meas. Tech. Discuss., 5, 2273-2313, doi: 10.5194/amtd-5-2273-2012, 2012.

Section 2.5: The description of the vessel types is needless since it is never used in the analysis of the data. Instead I would like to have the classification from section 3.3 here.

Author: As proposed, we removed the classification of the different vessel classes from chapter 3.3 and revised section 2.5 as follows:

"2.5 Different types of ships studied and classification into vessel classes

Ship information including ship name, commercial type, length, breadth, deepness, speed, position, gross tonnage and engine power was collected from Automated Identification System (AIS) broadcasts. AIS is a globally implemented identification system mandatory in all vessels larger than 20 m length or gross tonnage larger than 300. Specific data of each vessel are broadcasted continuously and serve for the prevention of collisions between vessels. The system allows identification of the individual ships passing the measurement site and thus assigning the specific ship characteristics to each of the registered plumes and to classify the measured vessels into different types.
Using AIS, the vessels were separated into 7 types (container ships, tankers, ferries & RoRos, cargo ships, reefer & bulkcarriers, riverboats and others). However, the characteristics of the individual vessels (size, speed, gross tonnage and engine power) within each of the classified ship types differ strongly resulting in large variations of the emissions. By detailed analysis, we found the gross tonnage which is a measure for the ships volume to be the most distinct factor in grouping different kinds of vessels. For this reason, vessels were classified in
- “Type 1” vessels which exhibit gross tonnages less than 5000,
- “Type 2” vessels are characterized by gross tonnages from 5000 up to 30,000 and
- “Type 3” vessels exhibit a gross tonnage level larger than 30,000.
Additionally, two vessel types were identified according to their particle number and black carbon EFs as follows (see Fig. 4):
- “high PN emitters” represent those vessels which correspond to the 10% highest particle number emitters (grey box) while
- “high BC emitters” are characterized being one of the 10% highest black carbon polluters (brown box).”

Sections 3.2 and 3.3: As pointed out above and also shown by reviewer #1 several statements are not supported by the results. E.g. “higher NO/NO2 ratio was found with increased engine power”. Or: “the majority of plumes exhibit a bimodal size distribution”. My interpretation would be that this the case only for Type 1 vessels.

Author: We revised sections 3.2 and 3.3 regarding those statements which are not proven by the results and removed several correlations e.g. NO/NO2 and engine power.

Figure 1: For which altitude the trajectories have been calculated. In general, this figure is in my opinion not very helpful. Either one has to zoom in to see the trajectories with the sites or the authors just plot wind speed and direction from their own observation, which I clearly prefer.

Author: The 48 h back trajectories at 5 m arrival height above ground level were calculated for every hour during the whole campaign using the HYSPLIT (HYbrid Single Particle Lagrangian Integrated Trajectory) model (Draxler and Rolph, 2003). As the roof inlet was installed at 5 m height above ground level and since the terrain in this area is very flat, also the trajectories were calculated for this height. We decided not to change Figure 1 because we think that the combination of Figure 1a and 1b provides a good overview over both, the local and the regional conditions: In Fig. 1a, the map shows the location around the measurement site including the trajectories as they present the long range transport direction in contrast to wind speed and direction measured using the mobile lab. A zoom-in is presented in Fig. 1b where all measurement locations and the shipping lanes on the Elbe are presented together with the local wind direction measured on the respective days.

Figure 2: Panel A of this figure needs a zoom in.

Author: The insert box in Fig 2a was increased.

Figure 5: Please use the same scale for SO2 EFs.

Author: Done.

Figure 7: It is almost impossible to get any useful information from the overlapping error bars. It might be improved by shifting the lines a bit within the size bins.

Author: We improved the readability of Figure 7 by removing the error bars for most of the traces and showing them only exemplarily for the “all plumes” size distribution. Shifting the lines a bit within the size bins would have made the graph even busier, further decreasing readability.