Answers to referee comments on "Contribution of ship traffic to aerosol particle concentrations downwind of a major shipping lane" by N. Kivekäs et al.

We thank both referees for their comments. The comments are valuable and incorporating them to the final ACP manuscript increases the quality and understandability of the manuscript. In several parts of the manuscript we have lost clarity of the text while trying to make it concise, leading to misunderstandings. The reviewers are experts in this field and if they misunderstand something, so will other readers.

As the issues presented in the comments do not require major revisions or restructuring of the manuscript, we go through them one by one here. The comments are in normal font, the answers in *italic*.

Comments by anonymous Referee #1

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Comment on "Contribution of ship traffic to aerosol particle concentrations downwind of a major shipping lane", by Kivekäs et al.

The authors present a methodology for the quantification of the contribution of ship traffic to particle number and mass concentration. The method is intended for use at other on-shore field sites. The method presented is rather simple and allows for a reasonable estimation of the ship contribution. The main sources of error have been included and presented.

Comments:

Pag. 8421, Line 11: "Emissions of SO2 lead to the formation of sulfate aerosol particles, which generally have a cooling effect on the climate. . ."; Remove "generally";

The direct and indirect cooling effects of sulfur aerosol particles take place only at daytime above surfaces that have lower albedo than the particles or clouds. Besides scattering incoming short wave radiation the particles and cloud droplets also inhibit outgoing long wave radiation from leaving the atmosphere. Even though the combined effect is clearly a cooling one on global average, in ice-covered areas (such as Arctic Ocean or Antarctica) the total effect can be a warming one. Therefore we have not removed this word.

Pag. 8421, Line 17: ". . .to 0.5% sulfur. . ."; Remove "sulfur";

We have removed this word from the revised manuscript.

Pag. 8425, Lines 22-24: How were the losses taken into account?

To take into account the drier losses we divided the measured particle concentrations in each size bin by the size dependent fraction of particles surviving through the drier.

Pag. 8426, Lines 13-14: Can the authors say whether there have been rainy days weighting down the calculated mean contributions from ships?
Even though we did not analyze rain or other weather parameters in this study, it is obvious that there are periods when rain has removed a fraction of the particles produced by ships. While the rain removes ship-originated particles, it also removes particles from the background particle population. This is one of the main reasons why we have looked not only the absolute values in particle number concentration (N_e), but also the relative values (R_{Ne}).

Pag. 8427, Lines 3-10: This part of the manuscript is not very clear. The days were classified into 4 categories based on the trajectories. For example a ship day is a day when all trajectories arrive from the sea. Does it mean that all the calculated air masses cross the shipping lane during 24h? Please, clarify this point. A sea day is defined as "a day when all trajectories arrive from the sea (either from south or north)". However, in Figure 4 there are no trajectories arriving from the north during sea day. Moreover, the authors defined a mixed day "if there were more than one type of trajectories". However, the mixed day presented in Figure 4 only shows air masses from the north. Please, clarify this point.
We have rewritten the classification of trajectories and days in order to make it more clear (section 3.1. Trajectory analysis). We have also changed figure 4 and the example days in it to avoid misunderstandings.

Pag. 8427, Line 20-23: How did the authors define the shipping lane? Was it placed in such a way the particles were 1 hour aged at the sampling site? What is the criterion used for placing the shipping line?
The shipping lane is defined by the route ships take passing the measurement site. This is based on ship AIS data revealing the real ship locations during year 2012 (see Figure 1). The age of particles (roughly 1 hour) at the site is based on the location of the shipping lane and the air mass moving speed taken from air mass back trajectories. We have added a discussion about defining of the shipping lane in the measurements section (2.1. Høvsøre field site). We have also added a reference to figure 1 in section 3.2 (Number of ships) and added a sentence in the figure caption (of figure 1) to highlight shipping lanes in the figure.

Pag. 8430, Line 23: Where 1.5 gcm-3 comes from? Is there any reference for this value?
We have no measurements of the density of these particles. We assume the moderately aged ship-induced particles to be soot agglomerates coverer with ammonium sulfate and organics, and therefore we have used a value that is roughly in line with measurements by Rissler et al (2014) for aged particles in the area. We have added more description and a reference for this (Section 3.4. Defining and extracting the ship plumes from the data).

Pag. 8430, Lines 25-26: “The total daily number and volume concentrations of particles were extrapolated to cover also the unanalyzable periods”. Please, clarify how this was done.
We did that by dividing the daily values by the daily analyzable fraction of day. We have clarified this sentence in the revised manuscript.

Pag. 8431, Par. 3.5: These simple formulas allow for a reasonable estimation of “low” and “high” ship plume contributions. I would remove the zero term in formula (4).
We have removed the zero-term and thereby made the formula (4) a bit more user friendly.

Pag. 8433. Par. 4.1 It is not clear how the authors use the information about the number of ships in their manuscript. Please, clarify.
The daily number of ships and the daily number of larger ships (gross weight > 10 ktons) are used as comparison values for the daily number of observed ship plumes. They are also a validity check for our method. If the number of plumes was larger than the number of ships, it would mean that our method is creating false ship plumes. There was not a single day in our analysis when this happened. This information has now been added in the end of section 4.2.(Characteristics of the ship plumes). The comparison between the number of ships and number of observed ship plumes is in section 5.(Discussion) and has not been changed.

Pag. 8436, Lines 1-3. Remove the sentence. Is a repetition.
We have removed this sentence from the revised manuscript, and modified the next sentence slightly.

Figure 1: This map does not show the coordinates (latitude and longitude).
The map (without the star marking the measurement site and the red and black lines) was provided by the Norwegian Coastal Authorities as is. Unfortunately there were no coordinates or scales.

Figure 4. Does this figure show all the hourly backtrajectories calculated for the 4.5 months study period?
No, it doesn’t. We have clarified this in the new figure 4 and its caption in the revised manuscript.

Figure 6 (Bottom). A) Y-axis should report the % values (+/- 10%). B) It seems that the smoothed absolute Nb change rate never exceeds the defined threshold of 56 cm-3 (cf. Pag. 8429, Lines 27-29). Please, clarify this point. C) Is there any reason why the points around 72.3 were considered as analyzable? The relative change exceeded the selected threshold.
We have modified the figure to make it clearer.

A) We have changed the Y-axis to percentage values.

B) *What the referee points out is true. During this individual day the +-56/cm3 threshold value was not exceeded at any time. There are, however, other days when the absolute threshold value is exceeded but the relative threshold value is not. We have used this day in figure 6 because it was also used in figure 5 and figure 7.*

C) *The smoothed relative change rate does not exceed the 5% threshold value around time 72.3, but it is so close to it that the upper edge of the marker in the figure was above the threshold line. In the revised version of the figure we have replaced the markers with a plain line to remove this problem.*

Comments by M. Kaasik (Referee)

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I still do n0t understand, why double ship counts should be avoided (subsec. 3.2, lines 27 - 28, see also my first review), as any ship that passes and then returns, makes a new plume that naturally contributes to daily pollution statistics. However, this peculiarity of method is explained and should be understood by any reader, who then can then ask authors, why they did that. This is a minor issue and I don0t see any obstacles to publish the paper as it is.

The ship position data consists of data points with a pair of ship position coordinates attached to a certain time point. As these time points have 6 minute intervals, we needed to include some area north and south from the line the ships need to pass in order to make sure that we have at least one data point for every ship passing the line. This meant that we could get two or three data points for a slower moving ship for one passing (leading to one pollution plume). We have eliminated these multiple counts leaving only one ship count per passing, but this also meant that a ship passing the line twice the same day and therefore creating two plumes was counted only once, as the referee points out. This leads to a slight underestimation of the number of ship passing tracks, as is stated in the Results section (4.1. Number of ships).

To clarify why we have eliminated the multiple counts we have slightly modified this part of the Methods section (3.2. Number of ships).