D6.6 Crowd-sourcing of ice information

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Document Status

Authors

Name	Organisation
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Document History

Version	Date	Initials	Description
1	2017-10-27	MA	First version
2	2017-10-30	MA	Revised version based on some of the feedback from Henrik Holm (RISE)

Review

Name	Organisation
Henrik Holm	Rise
Scott MacKinnon	Chalmers University of Technology

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Contents

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1 Summary

AIS data analysis of ice in the Baltic Sea has been conducted for EfficienSea2, Task 6.3 (crowd-sourcing of ice information).

The AIS data was provided by the Swedish Maritime Administration. Ice thickness forecasts were provided by the Danish Meteorological Institute (DMI).

The influence of ice has been studied by looking at the ship speed and heading behaviour, of ships in the northern part of the Baltic sea. Attempts have been made to capture the influence of ice by measuring the speed reduction in ice. Two different methods have been tested to capture this. An attempt to capture the influence by analysing the heading variation has also been made.

This study has shown that some speed reduction in ice can be observed with one of the methods, but the method itself has been found to be unreliable. The other method has found no speed reduction in ice. Using ship speed from AIS does therefore not seem to be a good method to investigate the influence of ice.

An increased heading variation in ice has however been observed. Unfortunately, there seems to be no obvious correlation between this increased heading variation and known parameters, such as ship speed, ship beam, ship length etc. There is however a weak correlation with forecasted ice thickness. Finding a reliable method to predict influence of ice based on heading deviation is most likely very difficult.

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2 Introduction

An analysis of AIS-data to study the influence of ice has been conducted. A geographical area in the northern part of the Baltic Sea was defined (Figure 1). The first three months in 2011 were studied. This period was chosen since there was more ice in the defined area than during more recent years.

Ships that have spent some time in this area during the spring and also in the following summer was filtered out. Icebreakers and Tugs where excluded.

Segments from tracks with the selected ships in the defined area and time frame with a ship speed over ground (sog) above 1 knot was included in the study.

Track plots from the first three months in 2011 can be seen in Figure 2. Track plots for the summer with the same ships can be seen in Figure 3. Track plots for the icebreakers during winter can be seen in Figure 4.

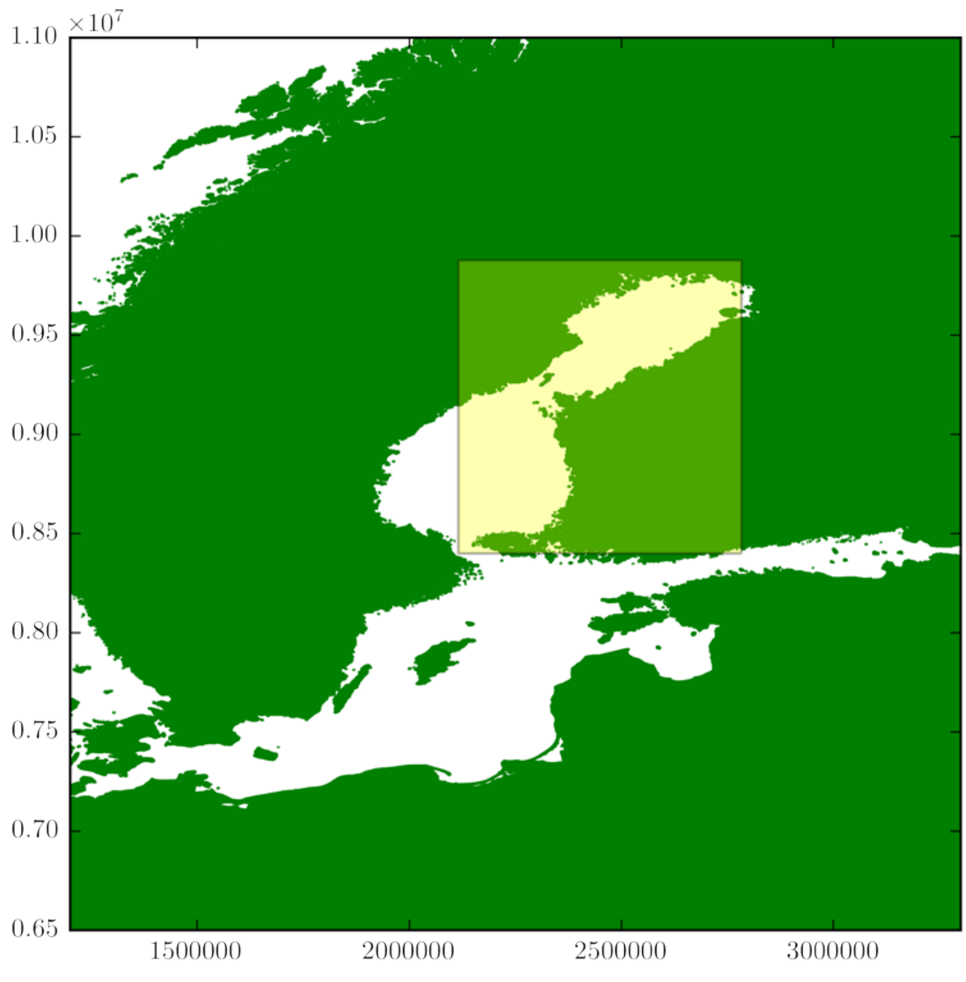

Figure 1, Analyzed area in Northern part of the Baltic sea

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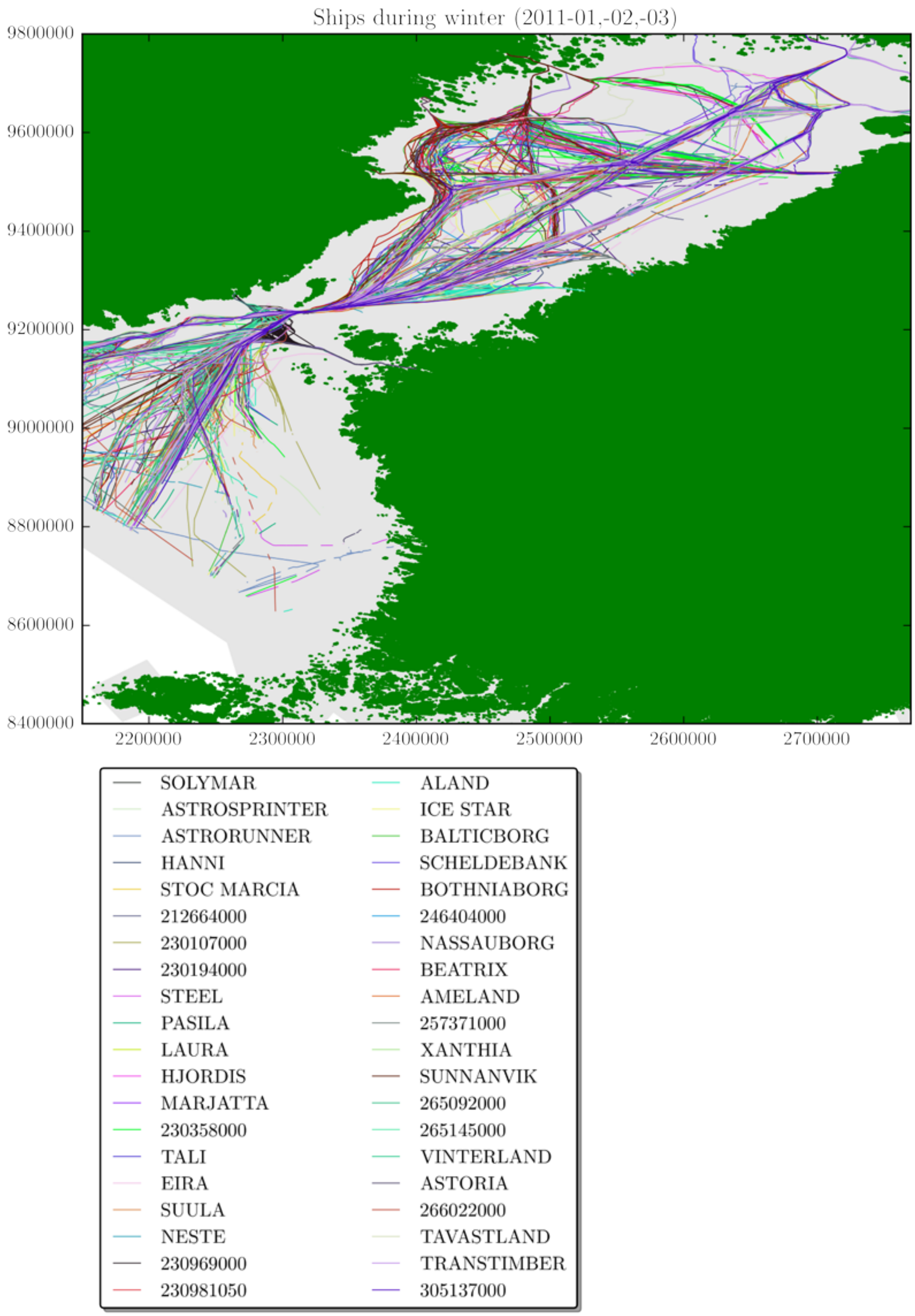

Figure 2, Ships during winter 2011

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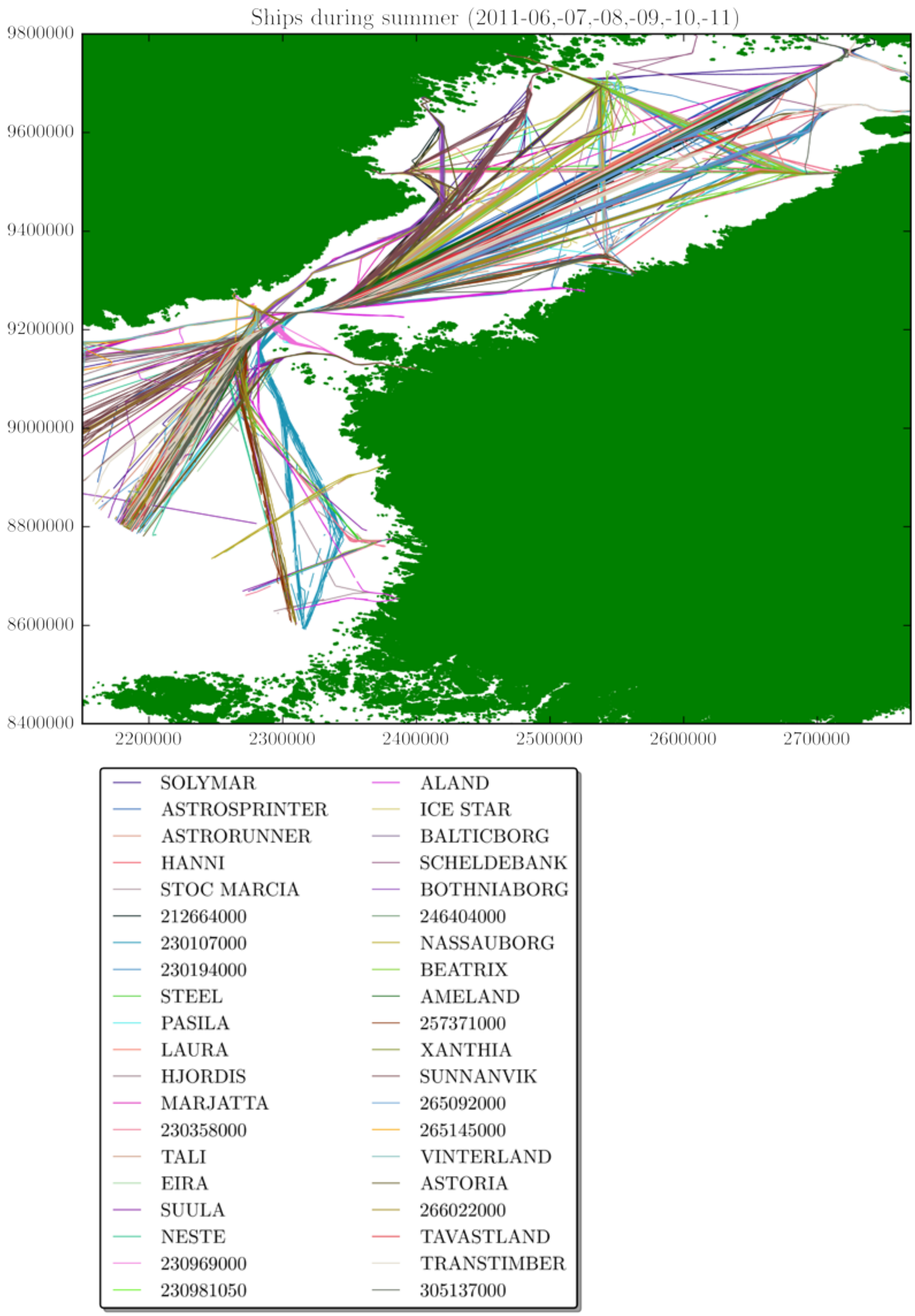

Figure 3, Ships during summer 2011

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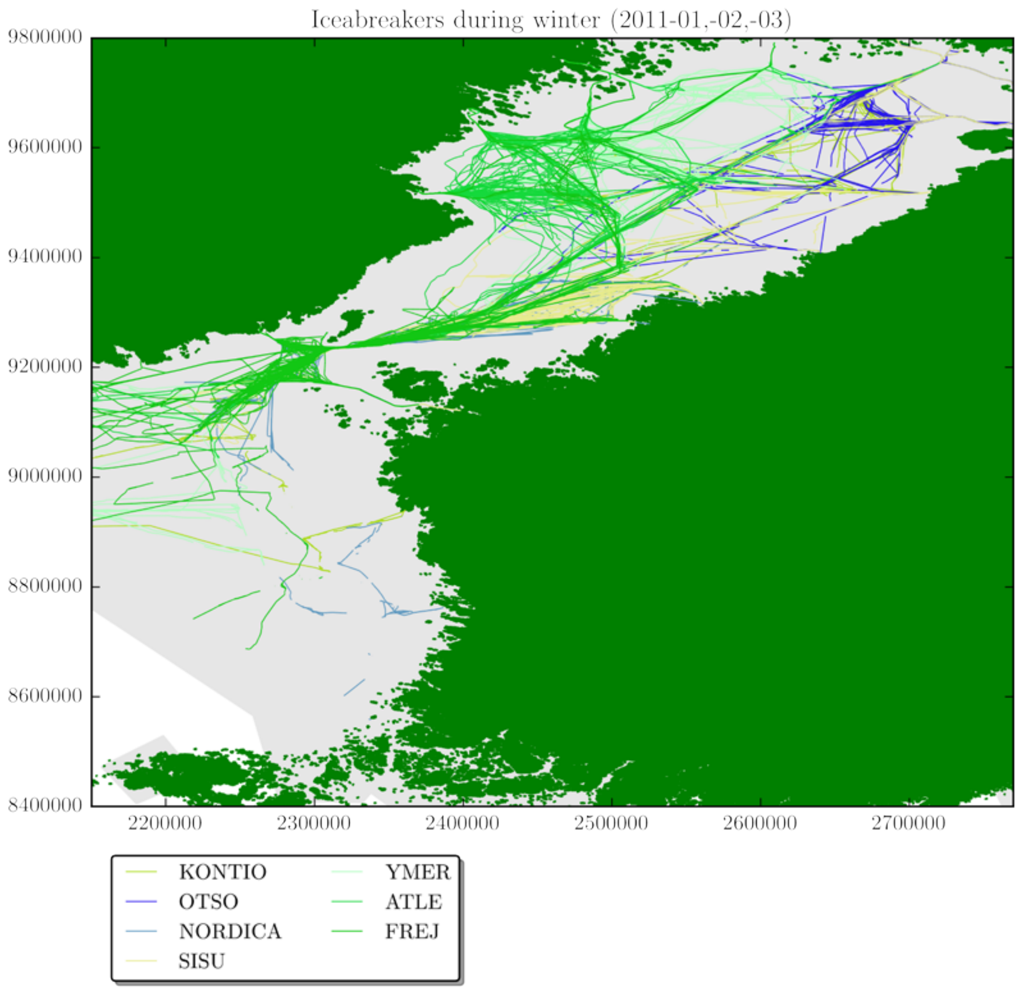

Figure 4, Icebreakers during winter 2011

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3 Speed reduction in ice

The speed of the ships over the selected tracks have been studied. The aim has been to find a speed reduction in ice that can be related to the influence of ice.

Two methods have been used to measure speed reduction in ice:

- Speed reduction during winter compared to summer
- Speed reduction during the same track

The first method measures the speed reduction in ice by comparing the average speed during winter and summer, for each ship, in the same area. The other method measures the speed reduction in ice by analyzing tracks where ships have experienced both ice conditions and ice-free conditions.

3.1 Speed reduction during winter compared to summer

Speed profiles for winter and summer have been created for each ship. The speed profiles have been created as distance weighted histograms of speed over ground. The speed profiles in Figure 5 show the speed distribution during winter 2011 and summer 2011. Most of the histograms in Figure 5 show that the ships had lower speeds during winter.

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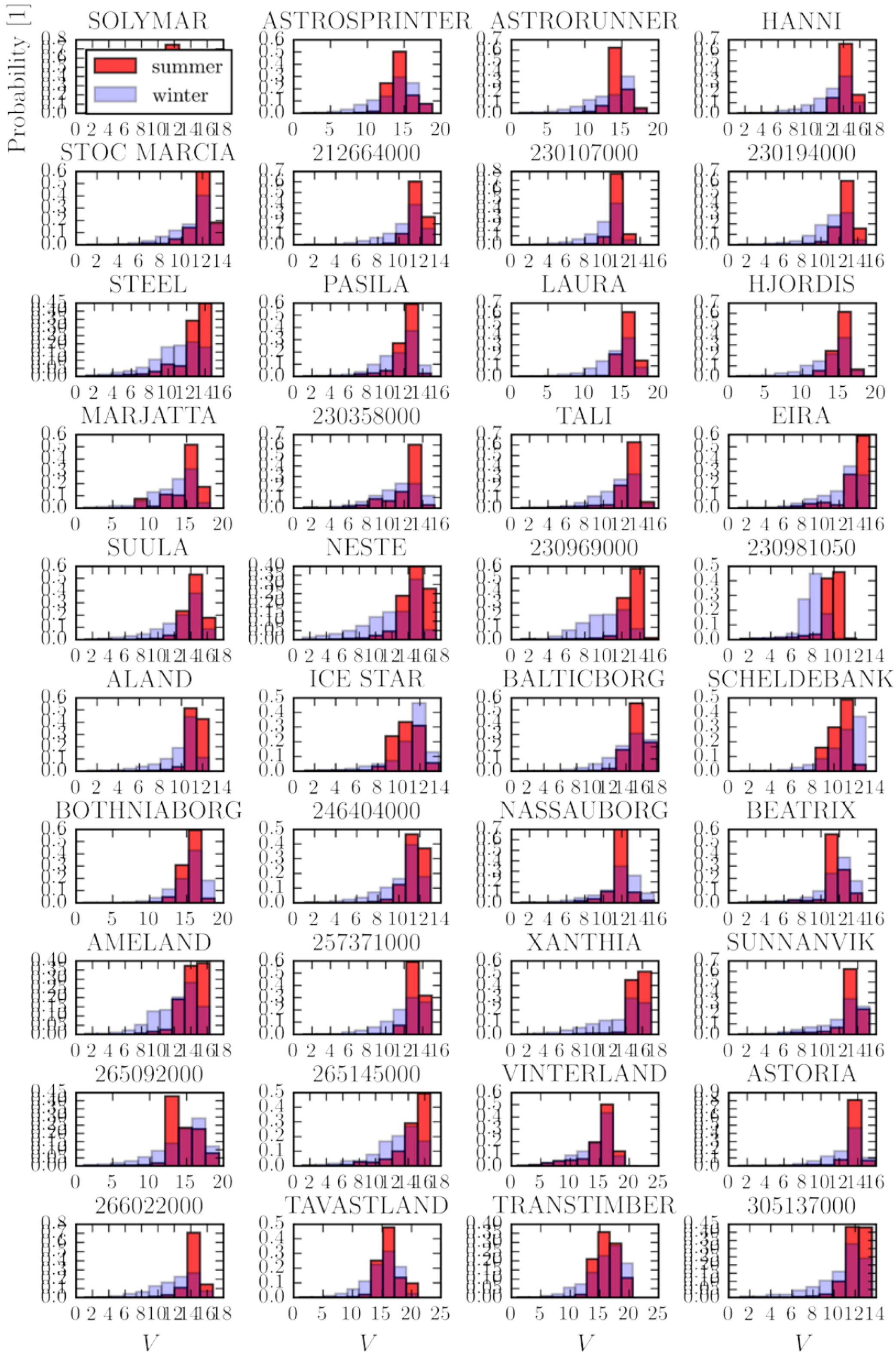

Figure 5, Speed profiles for all ships during summer and winter

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Speed reduction has been calculated as:

$$speed\ reduction\ = \overline{sog_{summer}} - \overline{sog_{winter}}$$

Figure 6 show average speed reduction for all ships. The speed reduction has been calculated for winter 2011 compared to the summers 2011, 2015, 2016. There seems to be a speed reduction during winter 2011 when comparing with summer 2011 of about 1 knot. When comparing with summer 2015 or 2016 there is however almost no speed reduction at all.

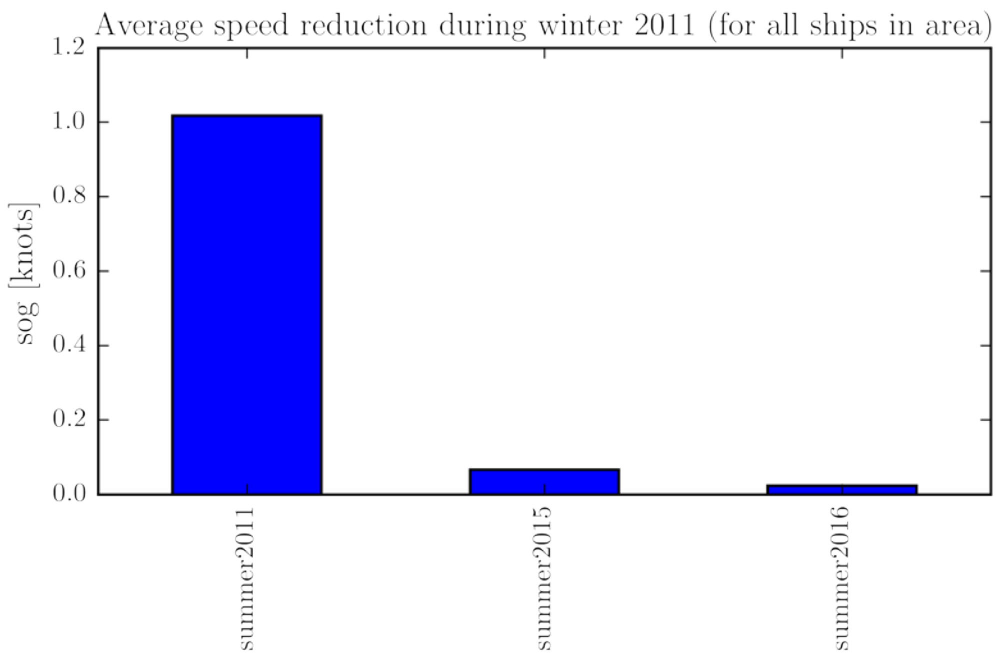

Figure 6, Average speed reduction in ice for all ships when comparing winter 2011 to summer 2011, 2015, 2016.

The predicted speed reduction in ice, with this method seems to be very unreliable,

since it gave different results for different summers.

3.2 Speed reduction during the same track

Tracks where the ships have been partly in ice and partly in ice free conditions have been studied. Figure 7 show these tracks, where the ice part of the tracks is blue and the ice-free part is red.

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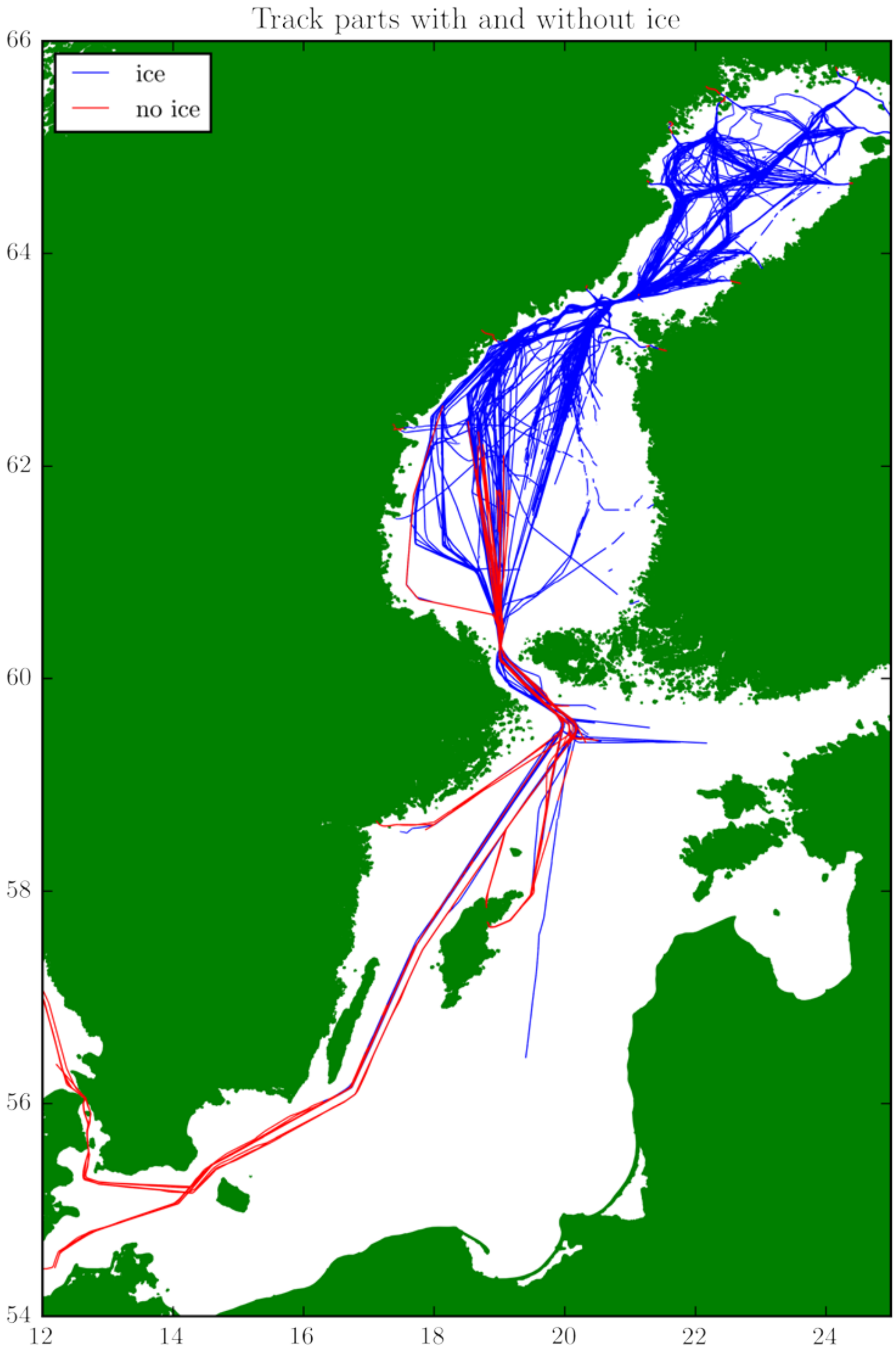

Figure 7, The tracks have been divided into a part with ice and a part without ice.

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Ice thickness from DMI forecasts have been collected for all tracks. This data has been plotted in Figure 8. The forecasted ice thickness was used when the tracks where divided into ice and ice-free parts.

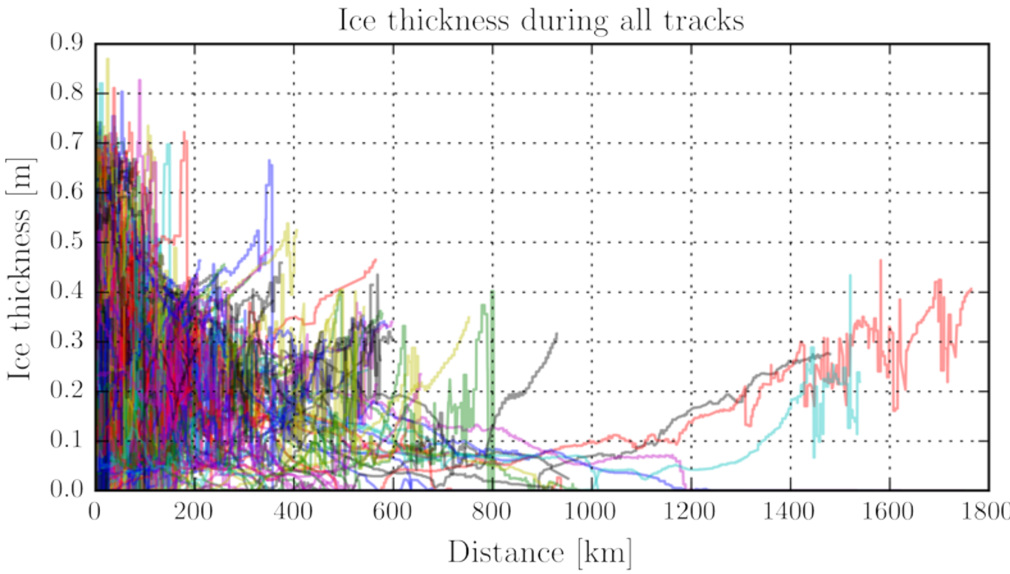

Figure 8, Ice thickness for all tracks

The speed reduction in ice has been calculated for each ice segment by comparing the speed to the average speed of the ice-free part of the journey, according to:

$$speed\ reduction = \frac{\overline{sog_{no\ ice}} - sog_{ice}}{\overline{sog_{no\ ice}}}$$

Figure 8 shows a weighted histogram of the speed reduction for all segments in ice (The distance of the segments have been used as weights).

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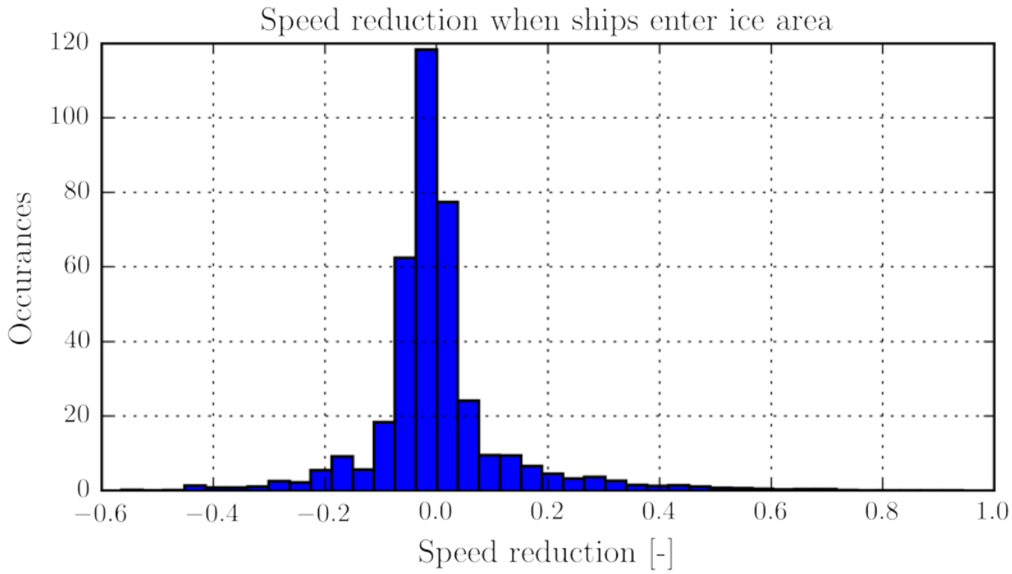

Figure 9, Speed reduction when ships enter ice area

Figure 8 show that average speed reduction is 0.0, which means that the ships do not change their speed when they enter ice. The calculated speed reduction with this method can therefore not be used to predict the influence of ice.

4 Heading variation in ice

The heading variations of the ships have been investigated to see if it can be used as an indication of ice influence. The heading of the ships seems to vary more when they are operating in ice, which can be seen when comparing Figure 2 with Figure 3. Can this be used in some way to study the influence of ice?

Some of the course variations are of course due to pure navigational changes and some might be due to that the ship is struggling in ice. An attempt has been made to filter out the heading changes that might be due to ice from changes due to navigation. This has been done by applying a High pass Butterworth Filter to the heading signal, in order to filter out the faster heading variations from slower varying variations (which are assumed to be navigational). A High pass Butterworth Filter with order 3 and border frequency 0.03 [1/deg] has been used. Figure 10 shows an example of this filtering for one of the tracks.

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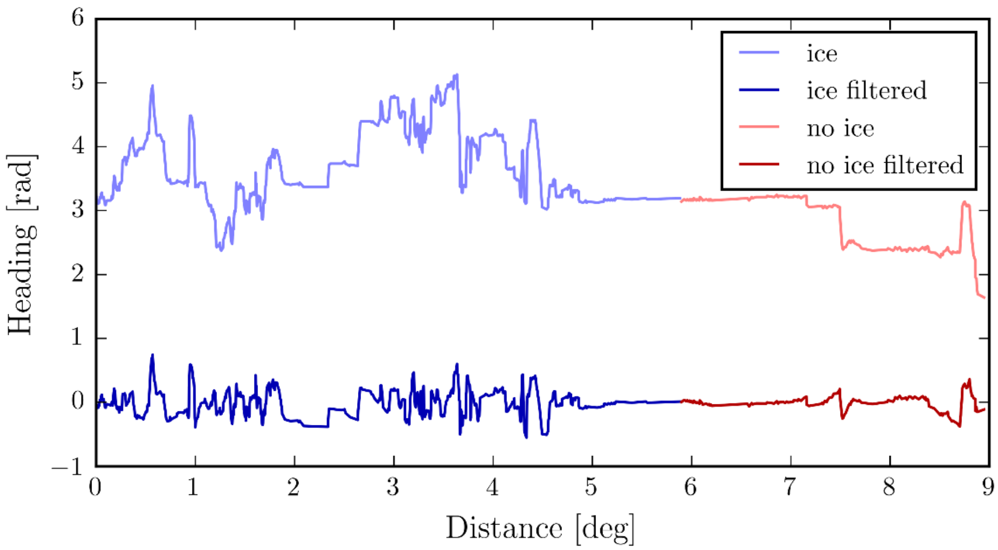

Figure 10, High pass filtering of ship heading.

The standard deviation of the filtered heading signals, of the ice-free part from this example is 0.14 rad and the standard deviation of the ice part is 0.21 rad. So, this method seems to capture the difference in heading variation.

A heading deviation increase in ice was defined as:

$$heading\ deviation\ increase = \frac{std(highpass(heading_{ice}))}{std(highpass(heading_{no\ ice}))}$$

Figure 11 shows heading deviation increase in ice for all of the tracks. There seems to be a variation in heading deviation increase with a maximum value of 2.7. The heading deviation increase has been plotted in Figure 11 against ship beam, speed over ground and ice thickness, but there does not seem to be any correlation, or a very weak relationship.

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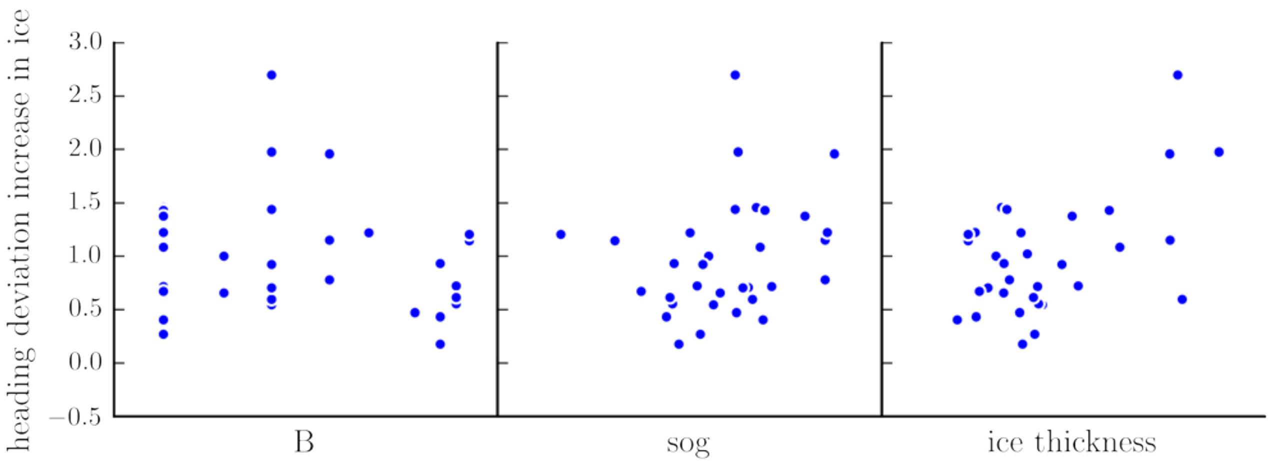

Figure 11, Heading deviation increase in ice.

4.1 Correlation

The correlation between known parameters was calculated using the *Pearson correlation coefficient*. Figure 12 shows a heat map of these coefficients. A value of 1 or -1 means that here is a perfect correlation. A value of 0 means that there is no correlation. The heat map shows that there is low correlations between the parameters. *Heading deviation increase in ice* and *ice thickness* have the highest correlation.

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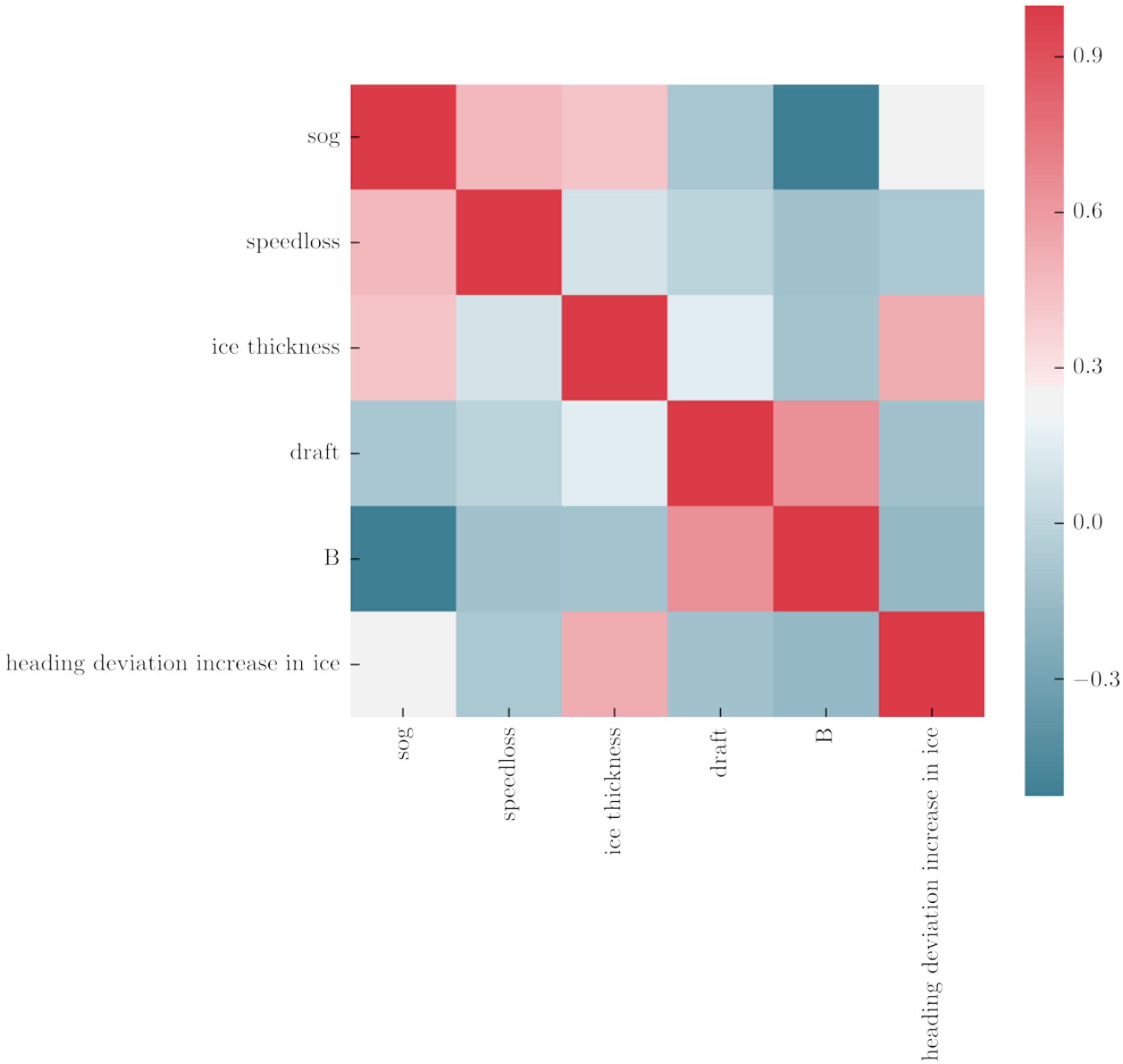

Figure 12, Heat map showing Pearson correlation between the parameters.

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5 Conclusions

- Some speed reduction in ice can be observed when using the method: *Speed reduction during winter compared to summer*, but it is very difficult to say if this speed reduction can be related to the influence of ice, since different summers give so different results.
- No speed reduction in ice can be observed when using the method: *Speed reduction during the same track* which makes the results with the first method even more unreliable.
- An increased heading variation in ice has been observed which has a weak relationship with forecasted ice thickness.

6 Further work

Most of the tracks are in an area with a lot of icebreaking activity, which has not been accounted for in this study. The icebreaking activity and its influence on the ship traffic could be further investigated.

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Appendix 1. Review procedure

No°	Reviewer Initials	Reference in document (General or Paragraph, Figure …)	Type (editorial, structural, formulation, error)	Reviewer's Comments, Question and Proposals	Editor's action on review comment.
1	HH	Figure 2, Figure 3	Editorial	Change map projection to ESPG:3857	Projection has been changed
2	HH	1 Summary	Editorial	Where does AIS-data come from?	AIS data was provided by the Swedish Maritime Administration
3	HH	Figure 5	Editorial	Histogram bins of 2 knots seems to sparse	Will not be considered
4	HH	1 Summary	Editorial	Explain why was 2011 was chosen	Fixed
5	HH		Editorial	Explain in more detail how the data for mean value has been choosen.	Fixed
6	HH	Figure 5	Editorial	Ship “Solymar” is covered by the legend.	Not fixed yet (SNM comment… difficult to do!!!)
7	HH		Editorial	Heading variation. What does “navigational changes” mean?	Fixed.
8	HH		Editorial	Use Pearson correlation coefficient to quantify correlation.	Fixed.
9	HH	Figure 11	Editorial	No axes…	Fixed.

10					