D6.9 Part 1
Report on “Comfort Zone”

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Contents

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Summary

The distance between vessels at different locations and the parameters effecting this distance are investigated in this report. The method used in this research is measurement of distance between vessels using the GPS position, which is transmitted using AIS. This research is based on AIS data since AIS positions are the record of what occurred at sea. The tool developed in this research lets the user choose location for the investigation and computes the shape and size of the Normal Zone.

Comfort Zone has been used the last five decades to describe the area that vessels normally want to keep clear from other vessels. The term Normal Zone is introduced to distinguish the result in this research from the term Comfort Zone, since Comfort Zone have had a slightly different meaning in previous research. The Normal Zone is the contour line between the area where it is normal to pass and the area where it is unnormal to pass. Normal in this sentence is defined as the second standard deviation of vessels in each direction.

The Normal Zone differ from location to location and situation to situation, hence, as an example, the Normal Zone in an overtaking situation, in open waters and on a route, is 1900 meters long and 600 meters wide. This is longer and a little bit smaller than Coldwell suggested 1983. The reason why it differs can be that ship today are equipped with AIS, so that the bridge team can take action at an earlier stage. It also suggests that this zone is not static and may change in the future when new systems are installed.

When two fairways meet and the ship are crossing each other's paths, the Normal Zone is changed. At those locations the Normal Zone is more of a circle shape, with a radius of 1500 meters. When ships traffic is dense and constrained, like in Öresund, the Normal Zone decrease to almost half the size, 1350 meters long and 300 meters wide. The size of the Normal Zone is even smaller when the ship is travelling in a narrow fairway, it is then normal to have other ships 100 meters away on either starboard or port side.

The ship size influence the size of the Normal Zone, but the influence is not the dominating factor. In open waters the length of the Normal Zone is typically one nautical mile, with a deviation of roughly two vessel lengths, i.e. there is a slightly greater length when two large ships meet. However, this can be due to that the distance is measured from GPS position to GPS position instead of hull to hull.

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Abbreviations

AIS	Automatic Identification System
Fujii ellipse	An ellipse with the axial radiuses of 8 x LOA and 3.2 x LOA
GPS	Global Position System
L, LOA	Length Over All, the length of the ship
Normal Zone	The distance to the boarded between unnormal and normal passage distance.
NM	Nautical Mile, 1 NM = 1852 meter
Own ship	Own ship is the ship that intersects the investigated location and the ship where the distance is calculated from. The own ship can be the same ship multiple times.
SMA	Swedish Maritime Administration
Target ship	A ship less than 5 000 meter away from the own ship. The target ship must have a speed over 0.3 knots and be of AIS type 60-89.
TSS	Traffic Separation Scheme
VTS	Vessel Traffic Service

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1 Introduction

1.1 Background

To determine the space, required around a ship to navigate safely, the terms *Ship Domain* and *Comfort Zone* have been used since the 1970's. Different researchers, all with a slightly different definition of the zones, have investigated them. In this research a new term is introduced, Normal Zone, the area where a ship normally does not have other ships (further described in chapter 1.2 and 1.3). Three of the earliest research results are presented below, each with their definition of the domain. The source of information of those are manual radar observations.

The Japanese researchers Fujii and Tanaka (1971) used the term *effective domain* which Fujii (1983) later defined as:

"Fujii and others indicated the presence of the effective domain around a ship into which other ships avoid entering. The domain for co-directional encounter is approximately elliptic with a long radius of 8L[1] and short radius of 3.2L under ordinary navigation condition."[2]

There is some contradiction between Fujii´s text and illustration. Fujii may have meant that the domain had the diameter 8 x 3.2 LOA[1] , instead of the radius. The reason why it could be the diameter instead of the radius is that there is an illustration indicating that the diameter of the ellipse is 8 x LOA.

Goodwin (1975) defines in "*A statistical study of ship domains"* the ship domain for ships in the North Sea as a circle with three different sectors; port, starboard and astern sector. The different sectors have different radiuses; 0.7 NM, 0.85 NM and 0.45 NM. In this paper, Goodwin defines the *ship domain* as:

"It has been established that a ship domain, the area completely surrounding a ship required by the navigator for safe and efficient navigation, does exist."[3]

Coldwell (1983) suggested slightly different definition of the ship domain in his paper "*Marine traffic behaviour in restricted waters"*:

"The effective area around a vessel which a typical navigator actually keeps free with respect to other vessel"[4]

[1] L, LOA = Length of the vessel.
[2] FUJII, Y. Integrated study on marine traffic accidents. IABSE Colloquium on Ship Collision with Bridges and Offshore Structures, Copenhagen, 1983. 91-98.
[3] GOODWIN, E. M. 1975. A statistical study of ship domains. *Journal of Navigation,* 28**,** 328-344.

Coldwell had a situation-based ellipse to representing the ship domain. Coldwell investigated overtaking and head-on meeting for three different areas and suggested following:

- 6 x 3.5 cables (1 110 x 650 meter) for overtaking situations
- 6.1 x 5 cables (1 130 x 930 meter) for head-on meetings, with an with offset (1.75 cables to port and 3.25 to starboard)

Hansen et al. (2013) investigated the passing distance between two vessels in the Great Belt and in the Drogden channel. Hansen et al. (2013) defines the comfort ellipse as:

"The comfort ellipse should describe how close a situation we can allow between two ships or a ship and an obstacle while still maintaining a reasonable comfort level."

Hansen et al. (2013) measured the distance to target ships in the unit *ship lengths, LOA.* The result from their analysis was that the comfort zone in the areas where they measured was 8x3.2 LOA.

1.2 Normal Zone

Sine Comfort Zone have had slightly different meanings in earlier research is the term Normal Zone introduced in this report. The Normal Zone, later illustrated in Figure 5, is the area where it is unnormal to be. Unnormal in this report is determined as the distance where less than 5% of the traffic passes, this explained in more detail in chapter *1.3.2 Analysis of the data*.

1.3 Method

The method used in this research is measurement of distance between vessels Automatic Identification System, AIS, Global Positioning System, GPS, position. This research uses AIS data since it is the record of what occurred at sea. The tool developed in this research let the user choose location for the investigation and compiles the shape and size of the Normal Zone.

[4] COLDWELL, T. 1983. Marine traffic behaviour in restricted waters. Ibid.36, 430-444.

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Figure 1 Brief description of the intended method for this project, the method is described in detail in the following chapters.

1.3.1 Assumptions for capturing data

The AIS data used in this research is supplied by Swedish Maritime Administration, SMA, during 2016 (1 January to 31 December). AIS position message is transformed into a line segment format at SSPA in order to do the analysis. This transformation also includes checks that the data is reasonable. In this research the line segments are interpolated to points every second of the journey.

The *own ship* is defined as all segments that intersects an arbitrary defined circle of radius 0.01 degrees (latitudinal and longitudinal degrees, approximate 600 x 1300 meters) and they are either a passenger, cargo or tanker ship (AIS type 60 – 89). *Target ship* is defined as all other segments less than 5 000 meter away from the *own ship* , and also of AIS type 60 – 89.

The distance is measured between the *own ship* and the *target ships* AIS position and rounded to even 100 meter intervals. The relative bearing, between the two vessels is calculated from the AIS positions and then rounded into 5° intervals.

The near ship situations are dived into four different types, see Table 1.

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Table 1 Four types of intersections

Overtaking	intersections with relative position of +/- 15°
Crossing	intersections with relative position of + 90 and 270 +/- 15°
Head-on	intersections with relative position of 180 +/- 15°
All intersection	all relative position are included

1.3.2 Analysis of the data

Every dot in the polar diagrams in this report represent one (or multiple, according to the scale) second(s) that a *target ship* is close to the *own ship*. In Figure 2 the blue (smaller) ship intersects the inner circle, defined as the *own ship*. The green (larger) ship is the target ship.

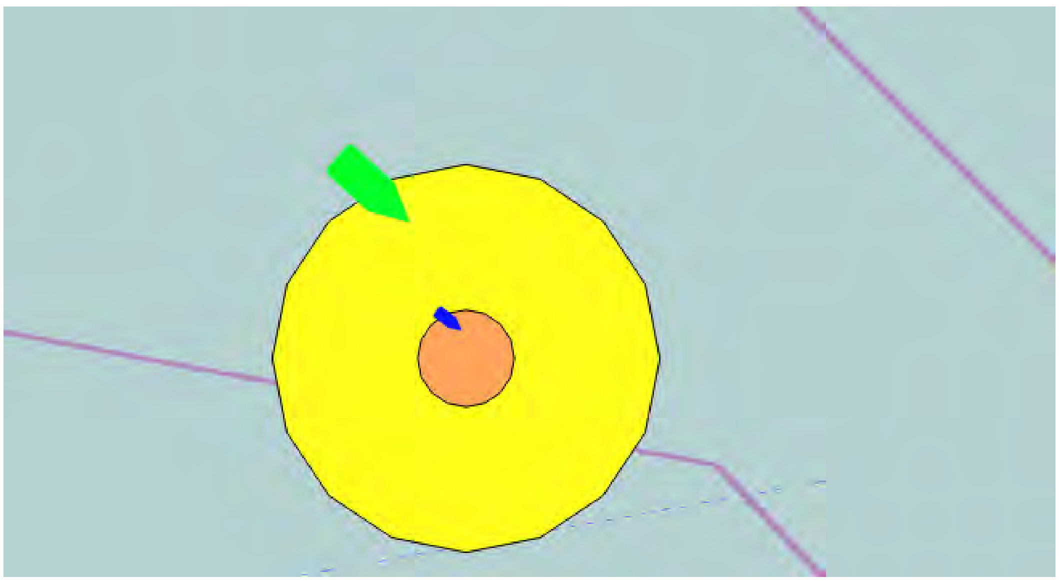

Figure 2 Example of an overtaking situation

The two vessels will generate one dot every second. The blue ship is intersecting the inner circle and the green ship is less than 5000 meter away from the blue ship. The first second that the blue ship enters the inner circle one dot is generated and this is illustrated in Figure 3.

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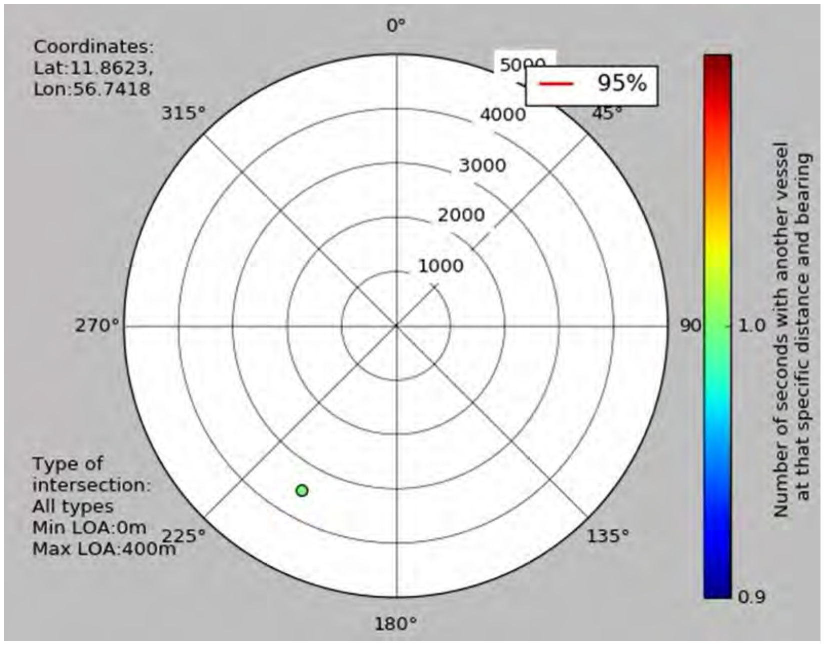

Figure 3 Example of one second plotted in a polar diagram

The own ship, the smaller blue ship, has head up in Figure 3. The dot is placed at approximate 3500 meter and the relative bearing of 210°, if the overtaking has the same distance and relative bearing the next second then the scale will shift and a second dot will be added to Figure 3. The red line (95%) in Figure 3 and Figure 4 is explained after Figure 5. In Figure 4 all the dots that the overtaking in Figure 2 generates are plotted.

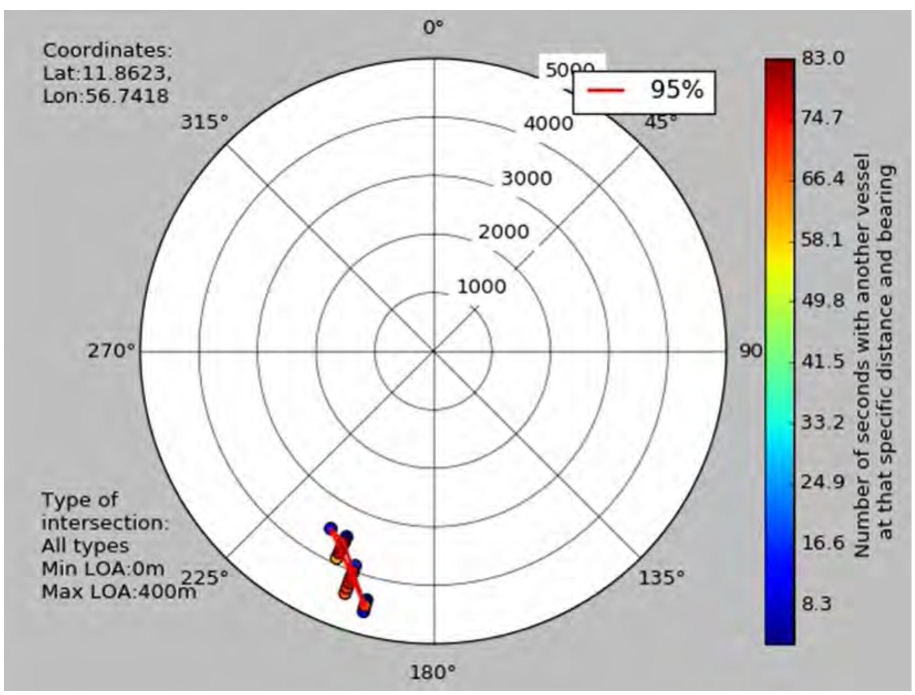

Figure 4 The dots for a "complete" overtaking situation

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The ships in Figure 2 do not pass each other in the selected area, i.e. the overtaking occurred earlier and that's the reason why all the dots in Figure 4 is gathered between 3 000 and 5 000 meters away. The shown situation contains approximately 600 seconds, which is longer than the blue ship is actually within the inner circle. This since the distance from the blue ship's first segment startpoint to its last segment endpoint is larger than the inner circle, but the complete start and end segment is included in the analysis. In practise, this is considered not to influence the results since it, in a big data perspective, just expands the circle. The radius of the circle can be set to an arbitrary size, but it is here set to 0.01 (latitudinal and longitudinal) degrees in order to capture the local differences in specific locations.

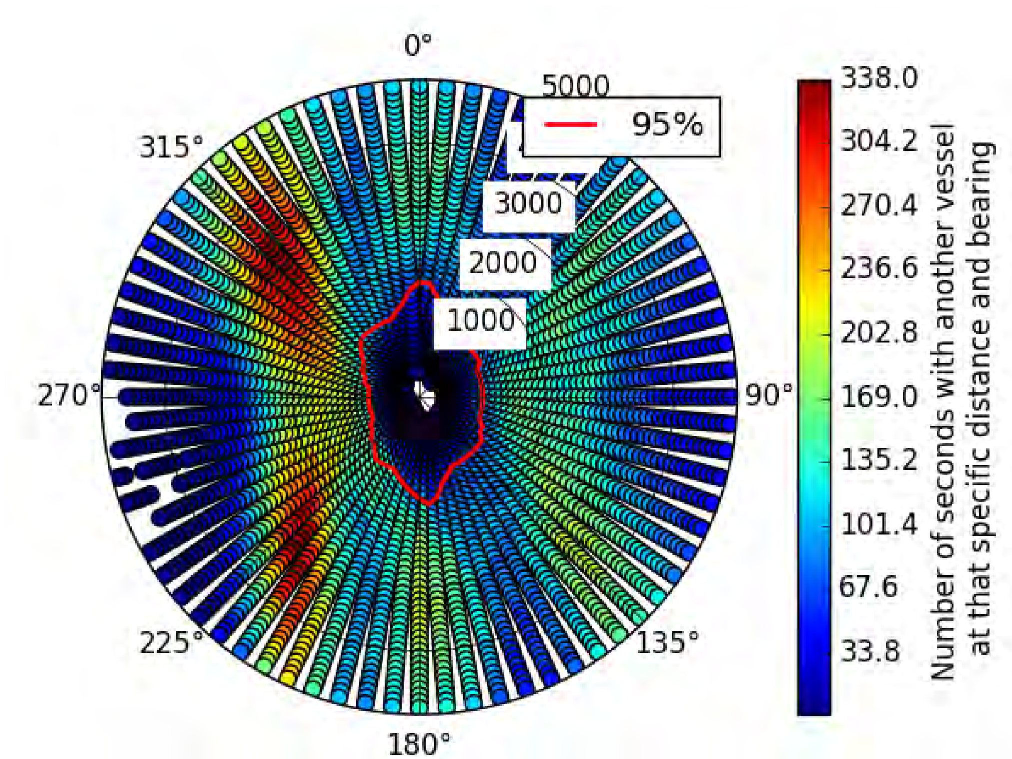

Figure 5 One year of data at the location in Figure 1.

One year in a busy fairway generates much data; the data for 2016 is illustrated in Figure 5. The red line, 95%, indicates the distance where less than 5% of all passages occur inside, seen radially in every 5° direction. Five percent is chosen as the cut off for the Normal Zone, since it represent two σ in a normally distributed unilateral confidence interval. Hansen et al. (2013) made a similar adoption when they plotted the ship domain contour. A lower threshold like 1 % or six sigma's (0.001%) would be possible to use at few locations, hence in many of the investigated locations there are too few *ship near ship* situations to draw valid conclusions.

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The principle of defining a safe contour, where everything that occurs outside is considered to be safe behaviour is well in line with the concept of Safety II, used by Hollnagel (2014) where he focused on what goes right rather than what goes wrong as a measurement of safety.

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2 The developed tool

A tool was developed in order to do this research. The tool is a plugin to the open GIS - Geographical Information System, program QGIS. The source code for the plugin is a combination of code written in c++, python and SQL - Structural Query Language. The plugin is connected to SSPAs internal AIS database, where it filters relevant position messages. The setting tab for the tool is illustrated in Figure 6.

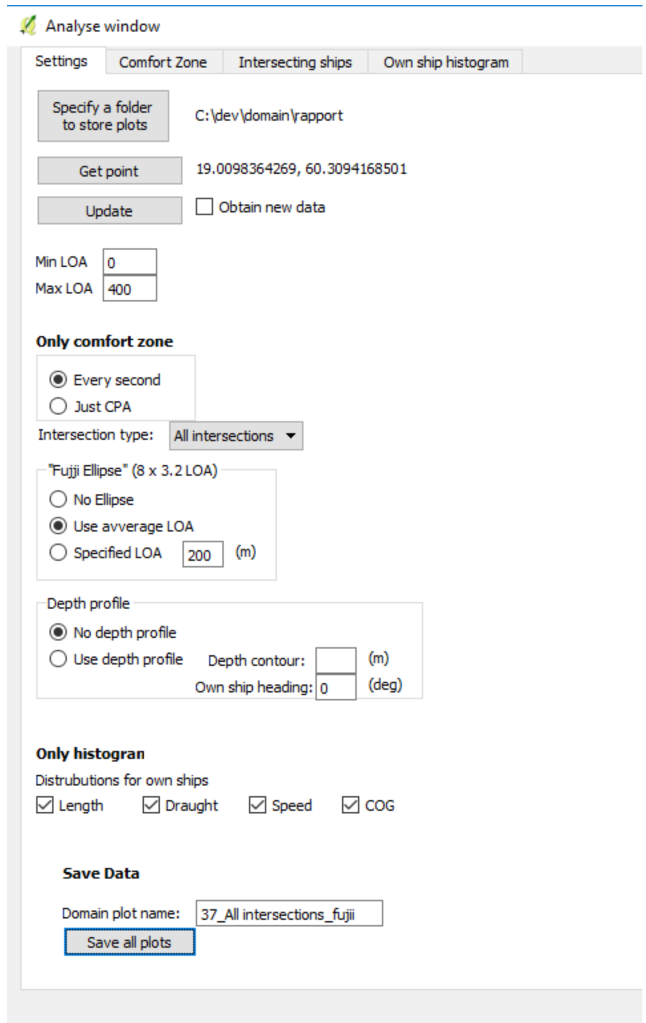

Figure 6 illustration of the tool used in this research.

If the user presses *Get point* he/she is able to capture the coordinates for any point in QGIS. Those coordinates are then used to create the area capturing vectors for the *own ships* and *target ships.*

There is the possibility to choose minimum and maximum sizes of the *own ship.*

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The user can choose whether the plot should plot every second of a meeting or only the closest point between *own ship* and *target ship*.

The intersection type is a combo-box where the user can choose which of the intersections he/she is interested in, the choice is the ones from table 1.

Since some resent studies (Hansen et al., 2013, Hüffmester Johannes, 2012) have proven that the normal behaviour is rather elliptic, an option to add a "Fujii ellipse" was added. The ellipse is plotted into the polar diagram according to equation 1, where *degree* is 0-360 and *LOA* is either the average length of the *own ships* or a user specified value.

Equation 1. Plotting a Fujii ellipse into the polar diagram

$$Distance\ from\ centre\ = \frac{(8 \times LOA) \times (3.2 \times LOA)}{\sqrt{(\sin(degree) \times 8 \times LOA)^2 + (\cos(degree) \times 3.2 \times LOA)^2}}$$

Some initial work has been performed using a *depth profile*, where the depth surrounding the chosen point is gathered. The idea is to see if there is a pattern between available water and spreading of ships. This is further discussed in chapter *6 Suggestion for future work.*

For the *own ships* it is possible to get some histograms with data for the *length-, draught-, speed-* and *Course Over Ground* distributions. The histograms are shown in *Own ship histogram*.

The Normal Zone tab consists of the polar plots shown in the report and Appendix 1.

Ships that are inside the Normal Zone are listed under the *Intersecting ships* tab. This is something that is discussed in chapter 6 Suggestion for future work.

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3 Case studies - Findings area by area

In total 37 different locations were studied, the locations are all near the Swedish coast within SMA's AIS coverage. The locations are chosen randomly where there are potential for near ship situations. In Appendix 1 all figures for the investigated locations are presented.

3.1 The Bornholmgatt

Every year roughly 40 000 ships pass between Sweden and the Danish island Bornholm. The area has been a TSS - Traffic Separation Scheme since 2005 and the traffic is organised in two fairways. Figure 7 illustrate AIS tracks in the Bornholmgatt and the ten different investigated locations. Figure 7 illustrates the investigated locations and the AIS messages from March 2016, hence the calculations are based on the complete year of 2016.

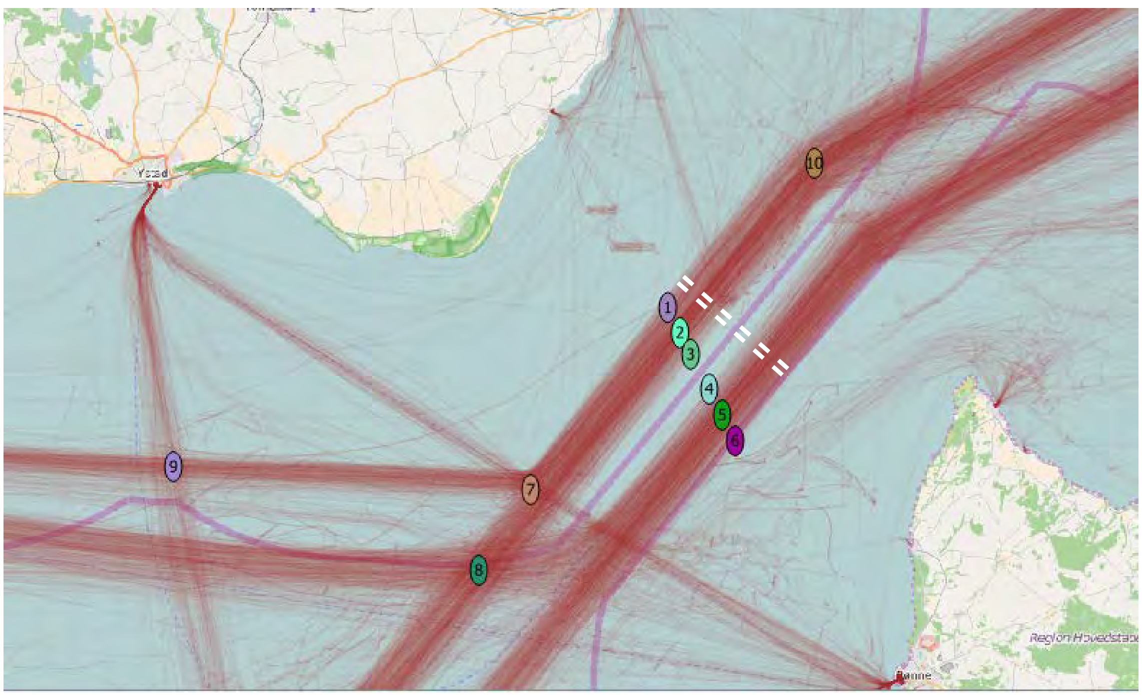

Figure 7 The red lines on the map illustrate AIS data from March 2016 in the Bornholmsgatt, the numbers in the circles referes to a investigated location and the white doted line refers to a passage line shown in the next figure.

The purpose of choosing location one to six is mainly to investigate the sensitivity of the location to the lateral distribution of the fairway. Location 2 and 5 are also chosen to investigate the Normal Zone in overtaking situations. Location 7, 8 and 9 are selected to investigate areas where many crossings occur. The last location, 10, is chosen to investigate the Normal Zone in a bend.

Figure 8 illustrates the lateral distribution of the TSS in the Bornholmsgatt.

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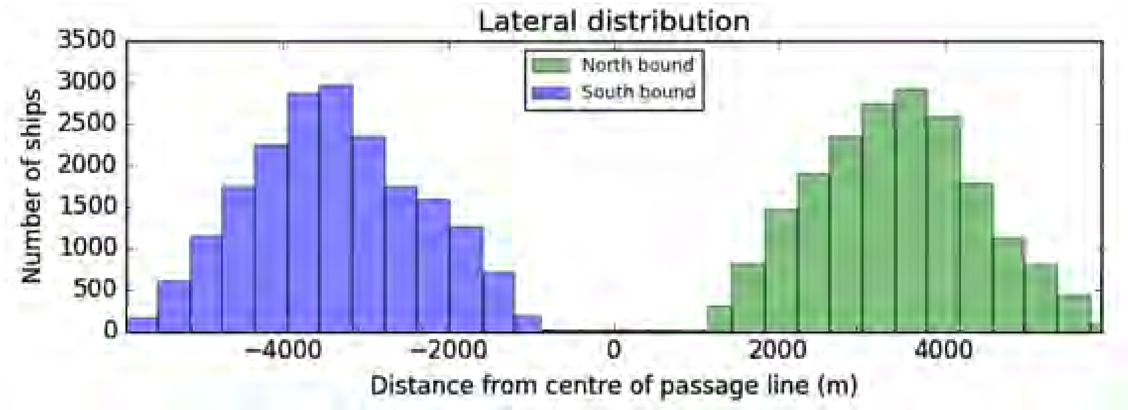

Figure 8 The lateral distribution of the vessels passing the Bornholmsgatt during 2016.

Each fairway (Northeast and Southwest) is approximate 5500 meters wide and according to Figure 8 all vessels do comply with the TSS. Figure 9 illustrates the Normal Zone in location 1, 2 and 3.

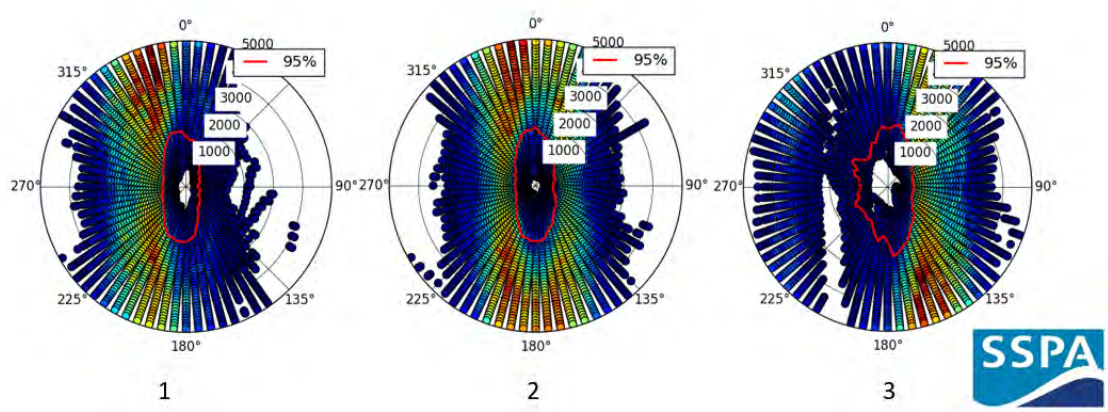

Figure 9 Polar diagram for intersection in area 1, 2 and 3. Own ship has head up, the relative bearing to all target ships are plotted with the distance every second during the investigated area. This is described more in detail in chapter 1.3.2.

The reason that illustration 1 in Figure 9 above have so few *target ships* to the right and illustration 3 have so few *target ship* to the left is due to the fact that ships are sailing southbound in illustration 1 and the *own ship* in the illustration 3 are heading up. The Normal Zone at the three locations are similar, the meeting traffic (north bound) slightly affects the Normal Zone at location 3.

There are multiple ways to describe and investigate the shape of the Normal Zone. In this report the length of A, B, C and D (in Figure 10) are investigated and are not to be confused with the denotation for where the GPS antenna is located on a ship. The length "A" is measured from the *own ships* GPS, position to the average *target ships* GPS position of at the 95% line (described in Figure 5) at relative position of 355°, 0° and 5°.

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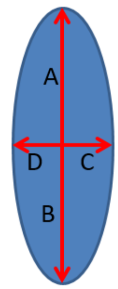

Figure 10 Ellipse with the variables A, B, C and D.

The length “B” is the average distance to the 95% line at 175°, 180° and 185°. The length “C” is the average distance to the 95% line at 85°, 90° and 95°. The length “D” is the average distance to the 95% line at 265°, 270° and 275°.

Figure 11 illustrates the Normal Zone for all ships (average length of 150 meter), only own ships with a length of 160 – 200 meter and only own ships with a length of 60 – 140 meter. The Fujii ellipse is illustrated in the three diagrams by an ellipse with *h* and *k* as 0, *a* as 8 x L and *b* as 3.2 x L in equation 2.

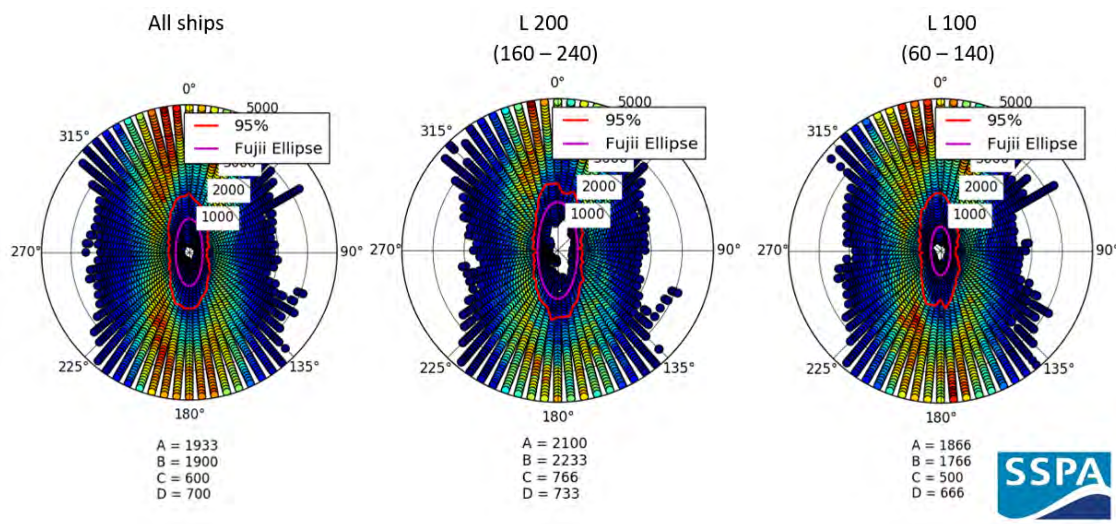

Figure 11 location two with different ship sizes included in the analysis.

Equation 2 the ellipse equation

$$\frac{(x-h)^2}{a^2}+\frac{(y-k)^2}{b^2}=1$$

According to Figure 11 the Normal Zone is not only dependent on the ship length. The Normal Zone for large ships (L200) is approximate 20 percent larger than the Normal Zone for smaller ships (L100).

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In comparison with the well-defined fairway in location 1 – 6, Figure 12 illustrates the intersection at location 7, 8 and 9. These locations are interesting since they have crossing traffic.

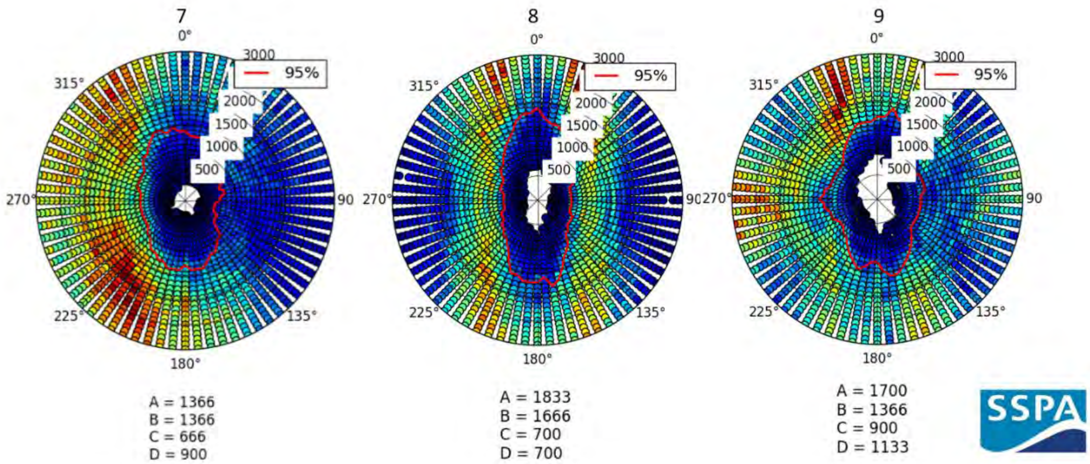

Figure 12 The intersections at location 7, 8 and 9

The ellipses in Figure 12 differ a little bit from Figure 9 and Figure 11. The axial values (A and B) are smaller and the lateral values (C and D) are larger. The reason behind this becomes more clear in Figure 13 where the intersection at location 9 is split into vessels crossing the *own ship´s* path and vessels that are overtaking the *own ship*.

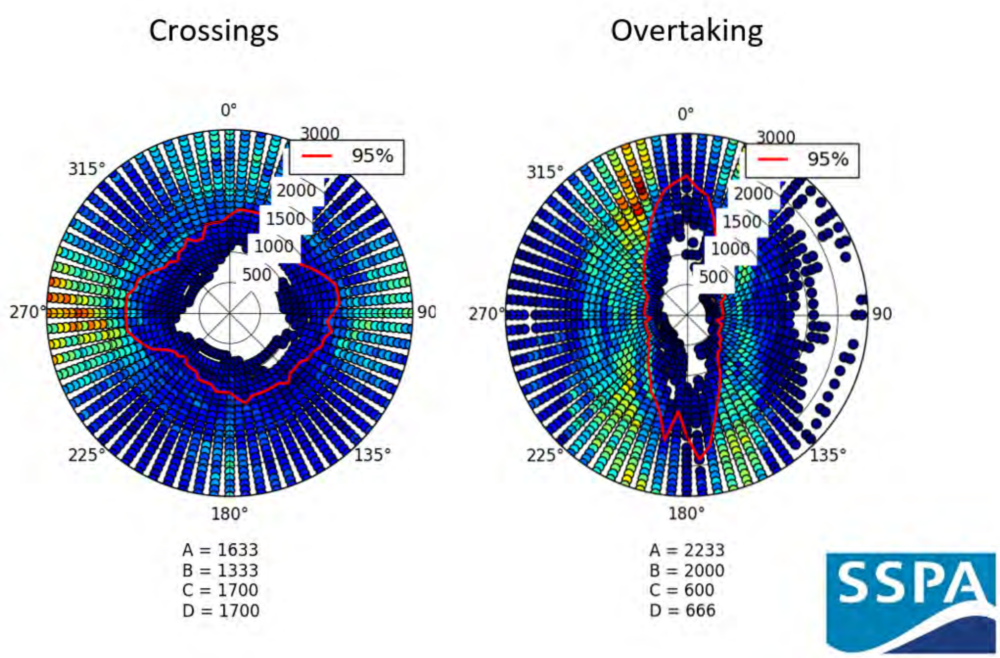

Figure 13 Location 9 divided between crossings intersections and overtaking vessels

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3.2 Öresund

Öresund divides Sweden and Denmark and in these relative shallow waters approximately 28.000 ships pass every year (according to AIS data from ships passing north of Helsingborg during 2016).

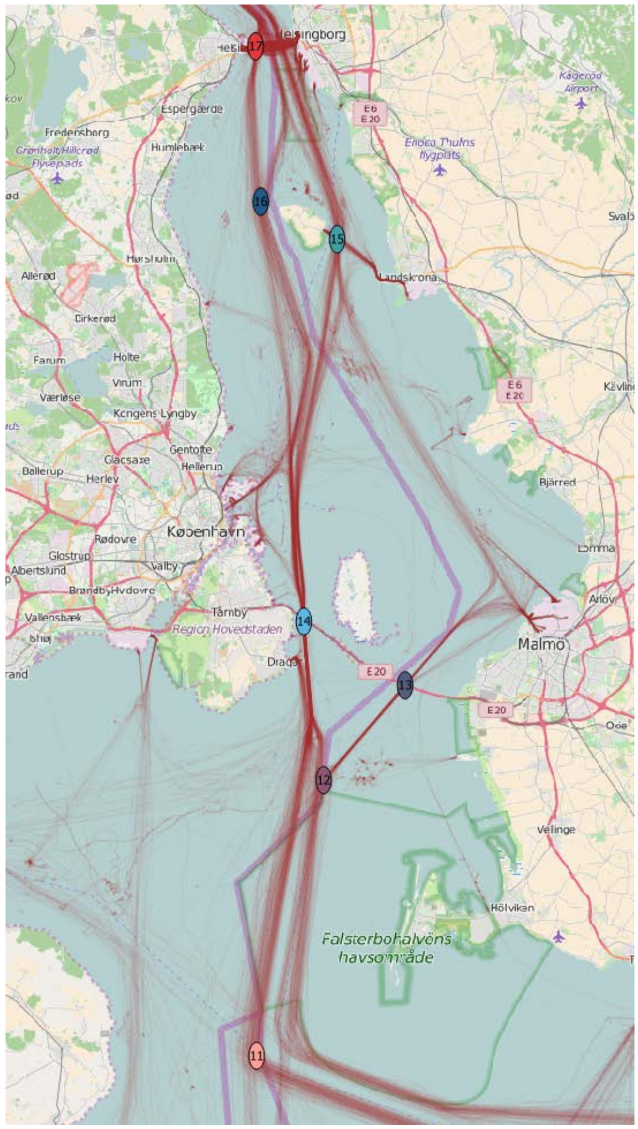

Figure 14 the investigated locations in Öresund.

Three patterns are recognised as interesting in Öresund:

- The decreased size of the Normal Zone compared to Bornholmsgatt , found at location 16, illustrated in Figure 15
- The close passing distances when ferries are frequently passing a traffic lane, found at location 15 and 17 illustrated in Figure 16.
- The behaviour of ships in a narrow fairway, found at location 13 and 14, illustrated in Figure 19.

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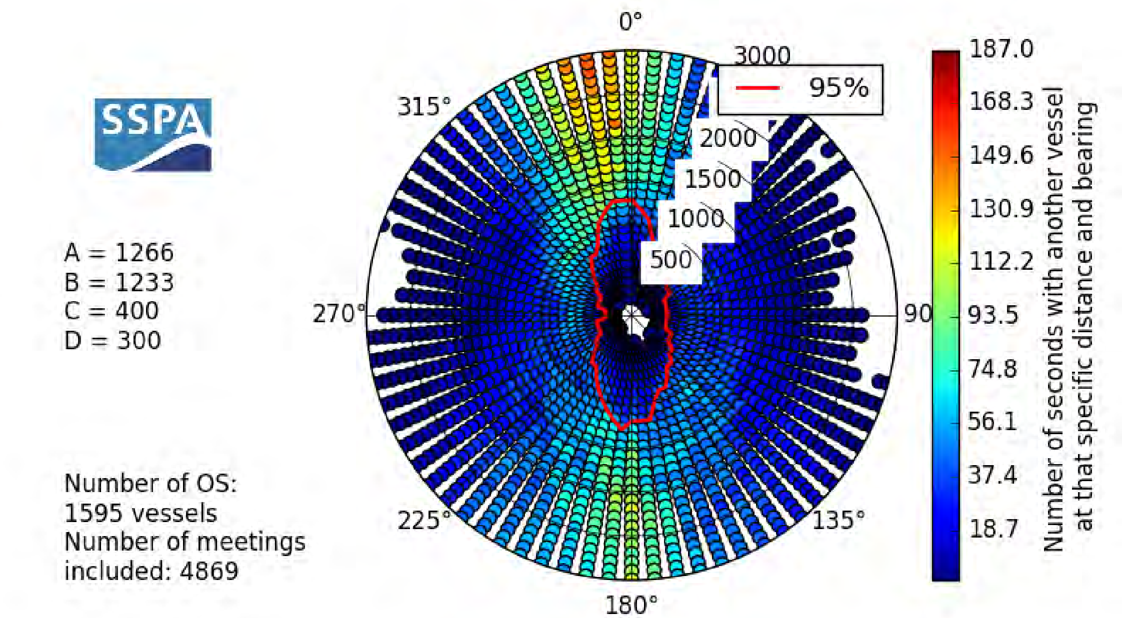

Figure 15 The Normal Zone at location 16 northwest of the island Ven.

The Normal Zone in Figure 15 has a similar elliptic shape as the one found in Figure 9 and Figure 11. The difference is the size of it, from A and B values around 1900 meter to 1250, C and D values from 750 to 350 meters. The reason why the normal behaviour differ this much (a decrease of 65% resp. 50%) is not fully understood, this is further discussed in chapter 4 and 5.

The Normal Zone for crossing traffic at location 15 and 17, illustrated in Figure 16, has an even bigger decrease of size.

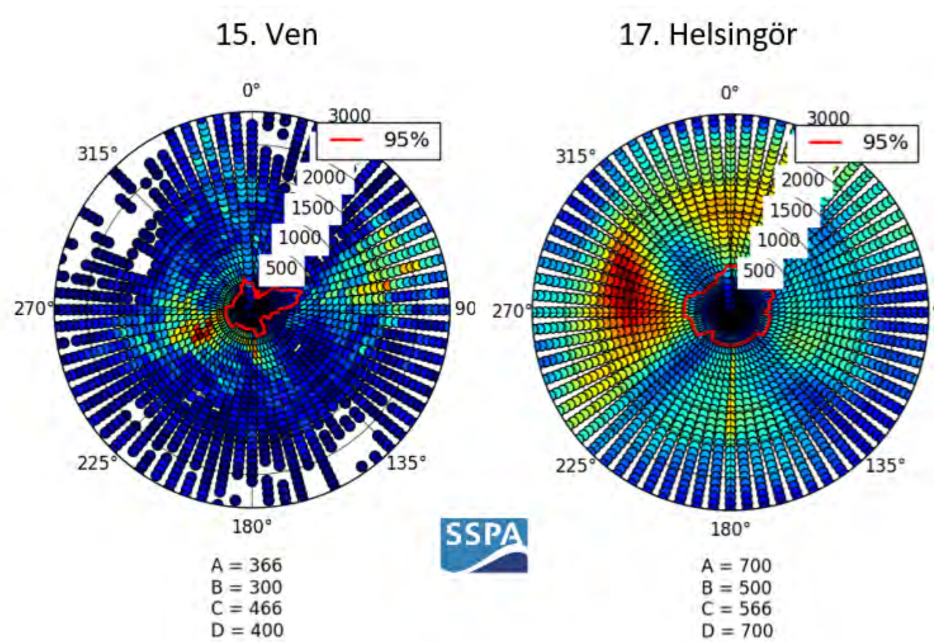

Figure 16 Normal Zone for only crossing situations at location 15 and 17.

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The ferry crossing to the Swedish island Ven impacts the Normal Zone for the crossing traffic with the size less than 25 percent to the ones south of Ystad (se Figure 13). Figure 17 illustrates histograms over the length (LOA), draught, speed and course. How the ship size influence the Normal Zone is discussed in chapter 4 and 5.

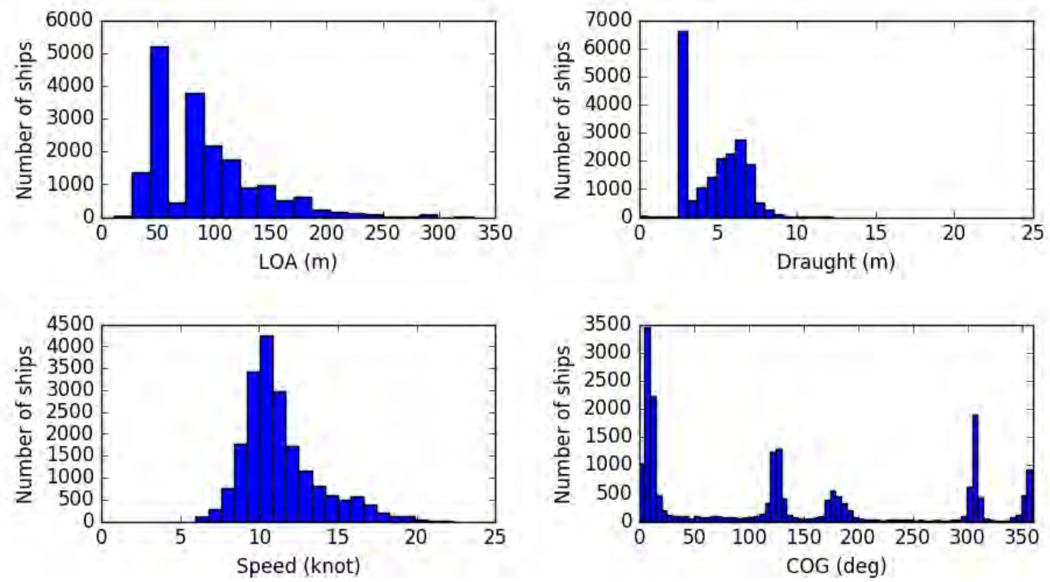

Figure 17 histogram for ship passages east of the Swedish island Ven. Number of ships is the number of own ships included in the analysis i.e. the histogram does not show unique ships.

The most frequent types of ships in the area is less than 100 meters, something that might influence the result. A separate illustration was made in Figure 18 with own ships longer than 100 meter was included in order to see how this influence the Normal Zone.

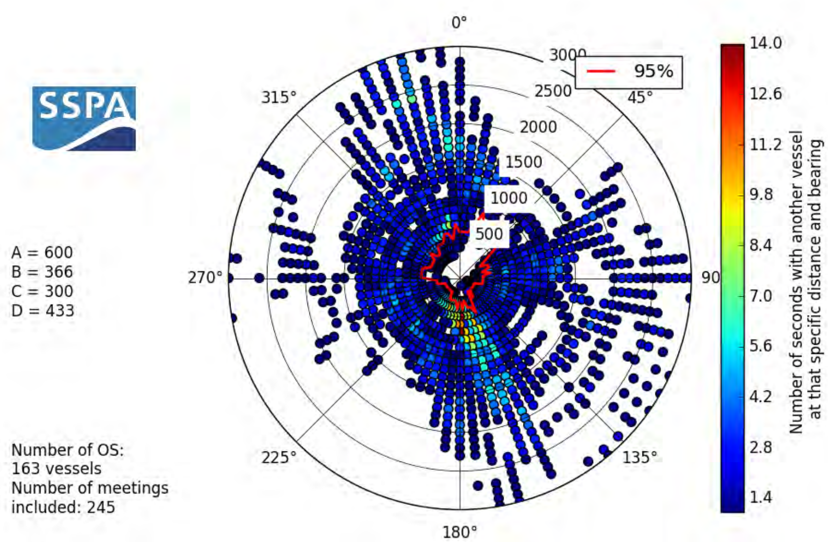

Figure 18 Normal Zone for crossing traffic east of the Swedish island Ven with own ships longer then 100 meter.

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There are two different fairways passing the "Öresund connection". Ships can pass under the bridge in *Flintrännan* (location 13) or over the tunnel in the *Drogden* channel (location 14). Both fairways are rather narrow and well defined, and the Normal Zone is completely different compared to previous locations, see Figure 19.

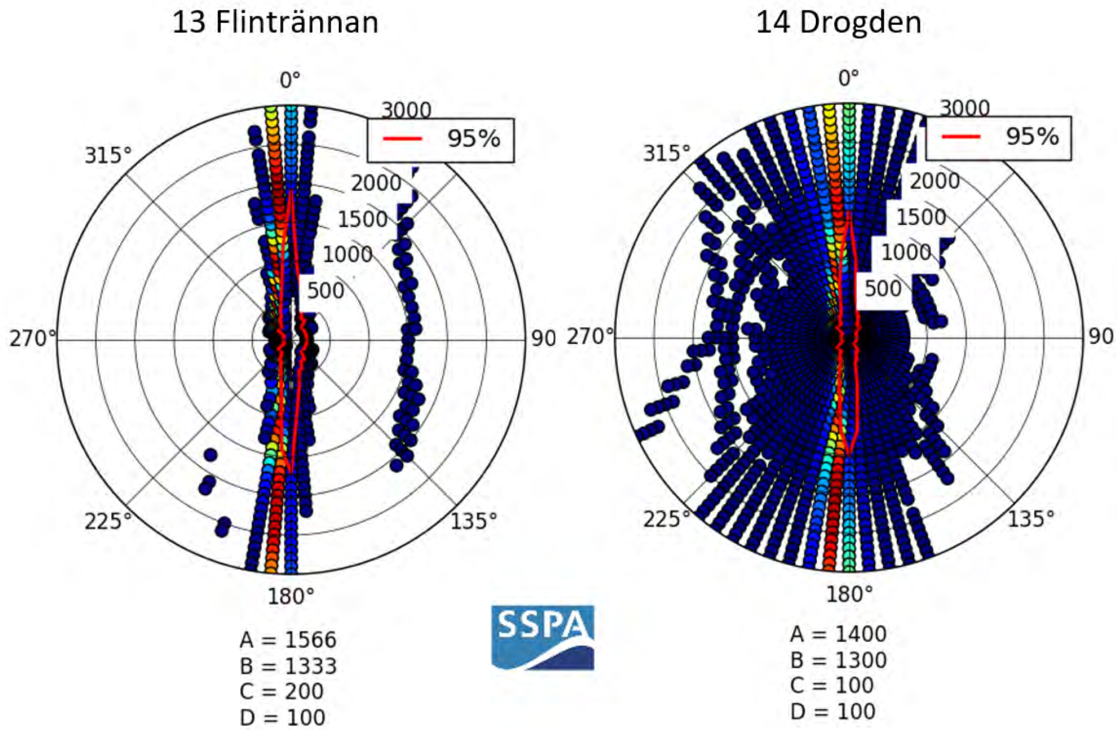

Figure 19 Normal Zone for all situations at location 13 and 14.

The traffic under the Öresundsbridge has the lateral distribution showed in Figure 20.

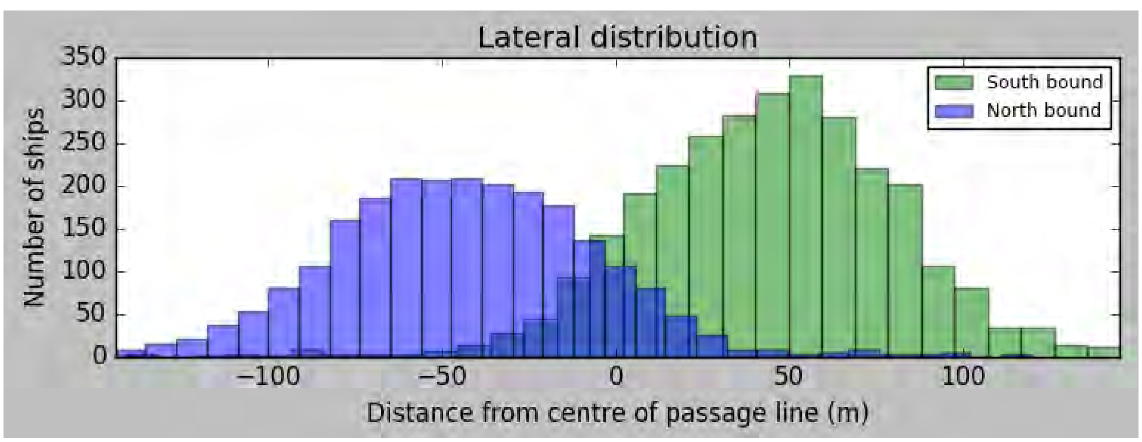

Figure 20 Lateral distribution of ships going north and south under the Öresundsbridge.

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3.3 Skagerrak

Skagerrak is the water south of Norway and north of Denmark. Skagerrak is a rather large area and the traffic is less dense than further south in Kattegatt and in the other investigated areas. In the map bellow, (see Figure 21) the three investigated areas are marked (27, 28 and 29).

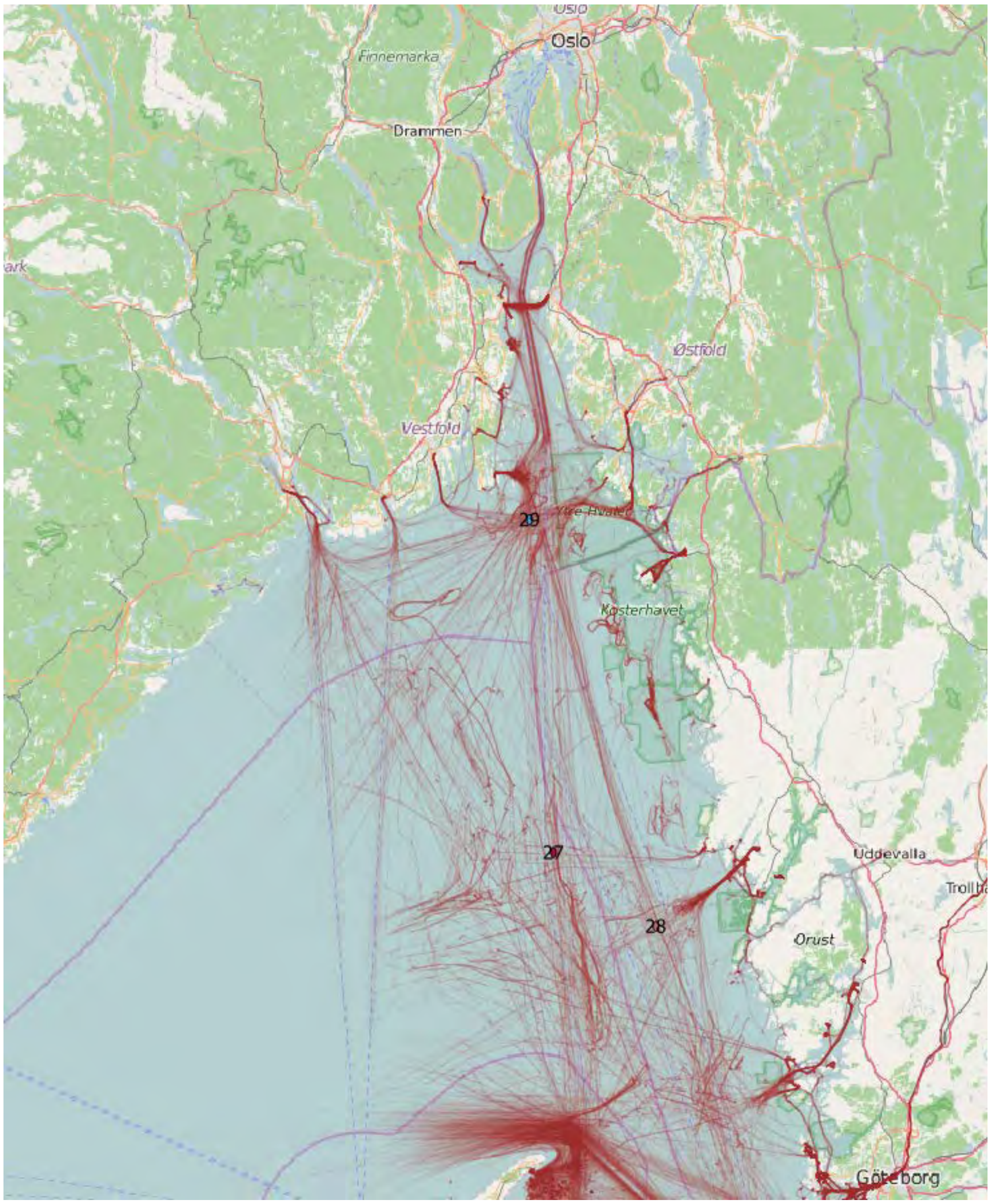

Figure 21 Map over the three investigated location in Skagerrak.

The number of meeting was too few at location 27 and 28 (see Figure 21) in order to get any conclusive results, this is illustrated in Figure 22.

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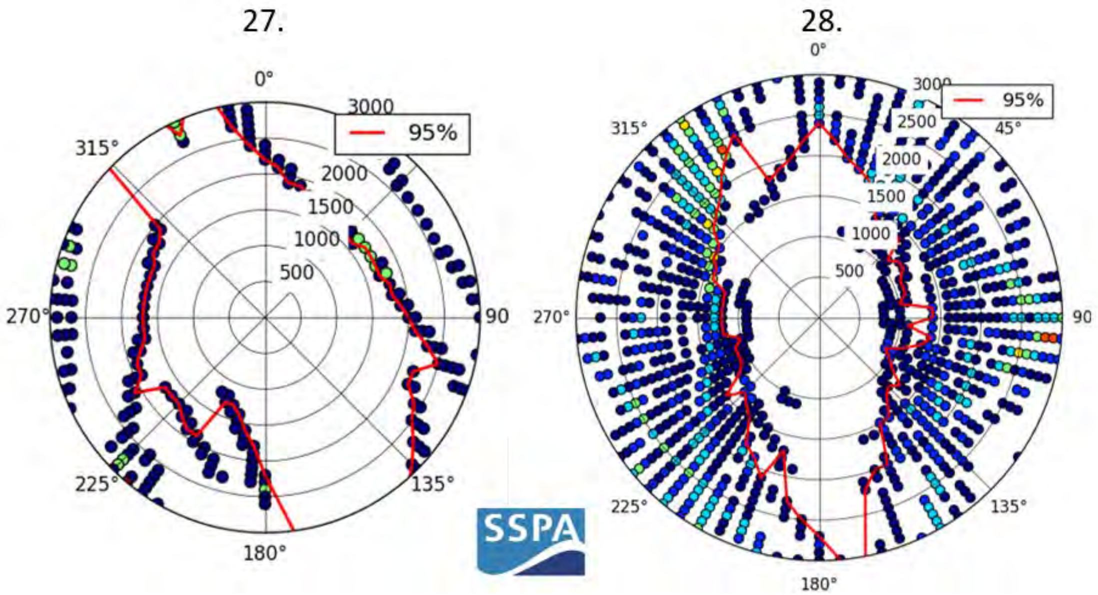

Figure 22 Inconclusive Normal Zones at location 27 and 28.

At location 29 (illustrated in Figure 23) there were more ships intersecting and a similar pattern as the ones found in location 7, 8 and 9.

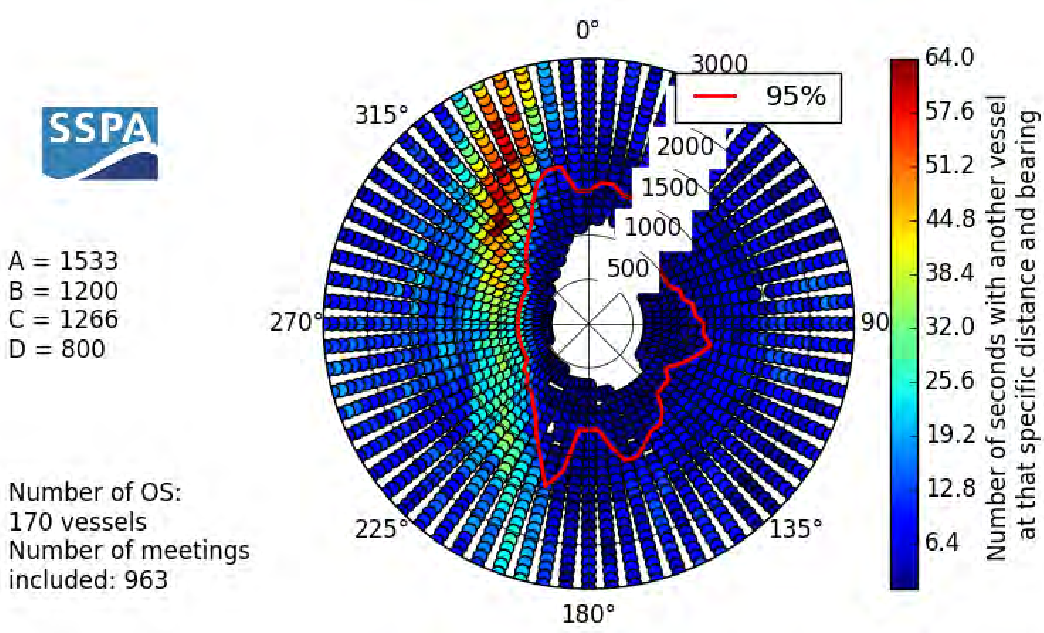

Figure 23 the Normal Zone for all meetings at location 29.

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3.4 Kattegatt

In Kattegatt, located south of Skagerrak, the traffic is more intense. Most of the traffic is sailing in the "T-route" (see Figure 24).

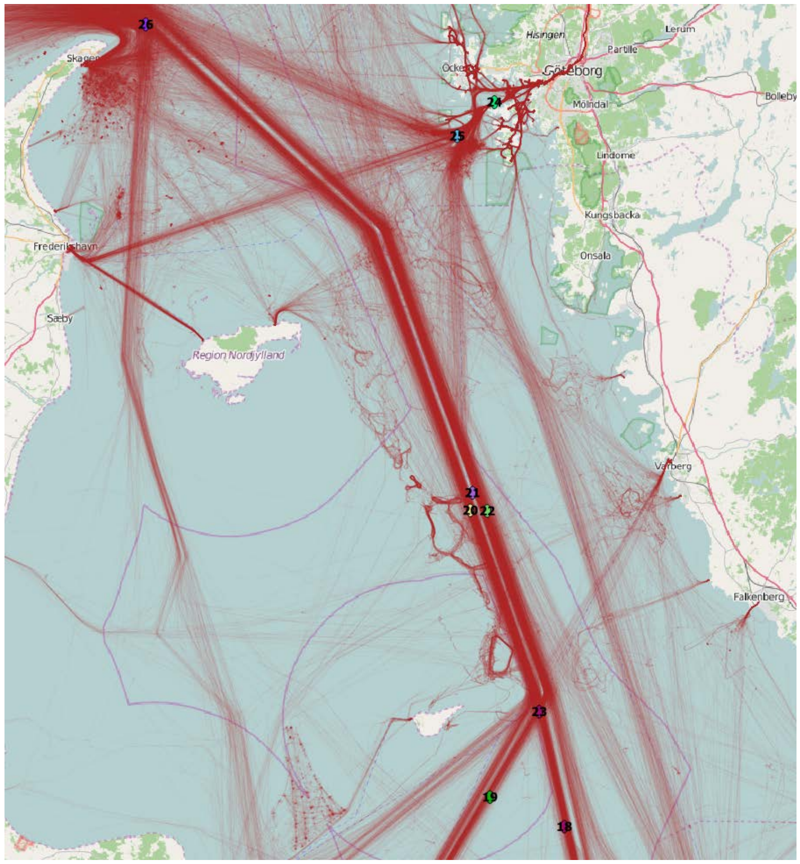

Figure 24 map over Kattegatt with the investigated location 18 – 26.

The Normal Zones in Kattegatt has similar dimensions as the ones identified in the Bornholmsgatt. Location 18, 19, 20 and 22 are very similar to location 2 in the southwest lane in the Bornholmsgatt. Location 23 and 26 has big similarities to the crossing situations in the Bornholmsgatt area (location 7, 8 and 9). At location 24, the approach to Gothenburg, a similar Normal Zone be can identified as the ones found at Flintrännan and Drogden channel in the south Öresund (location 14 and 15). Location 25 has a similar Normal Zone as location 24, hence it is a little bit bigger sine the fairway is wider in this location.

A behaviour that has not been studied that much in the Bornholmsgatt is the head-on meetings. The reason for this is that in the Bornholmsgatt the traffic is designated into a TSS in order to avoid close head-on meetings. In Kattegatt the traffic is a little bit closer to each other and the Normal Zone in location 21 is illustrated in Figure 25.

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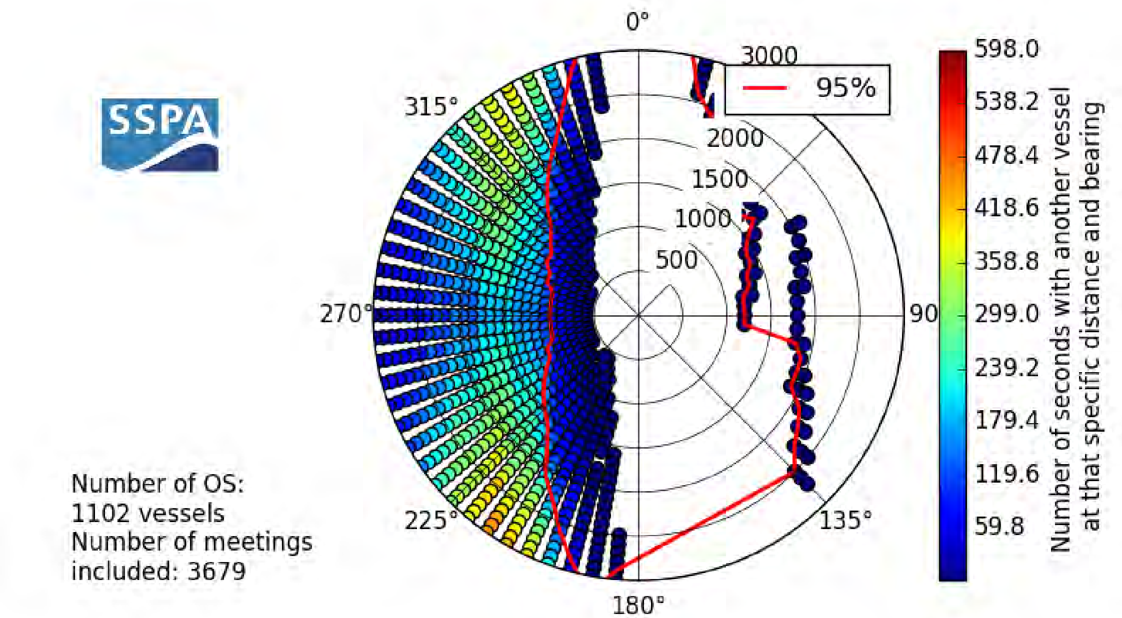

Figure 25 the Normal Zone for head-on meetings at location 21.

Figure 25 “miss” values for A, B, C and D, this due to that there are no vessels on a head-on course with a relative bearing in all starboard degrees. Figure 25 illustrates that it is normal to have a vessel on a relative bearing between 190 to 250 degrees. The dots in the polar diagram between 0 and 180 degrees are to be regarded as unnormal.

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3.5 The Baltic Sea

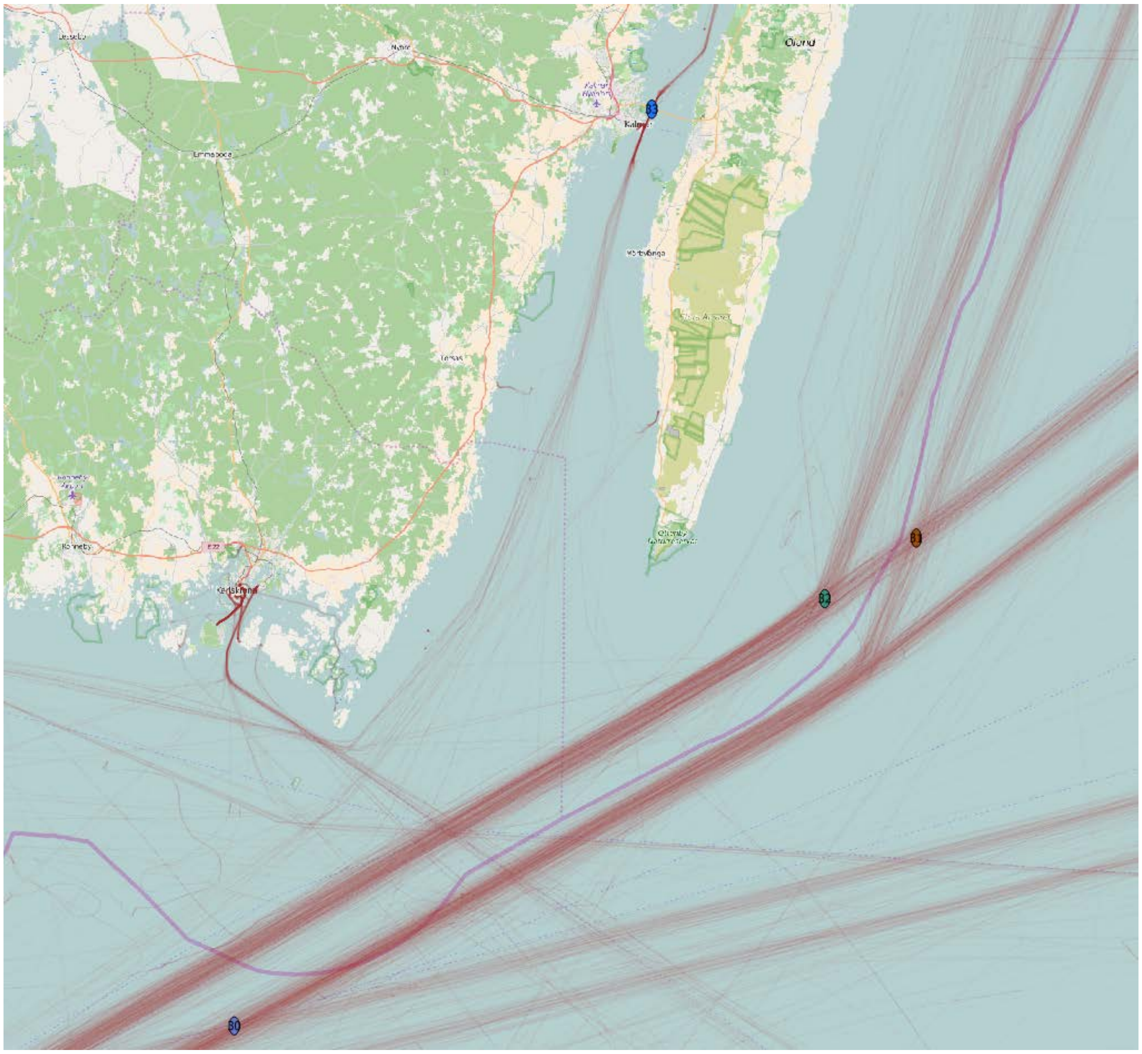

Figure 26 Map over the four investigated location southeast of Sweden.

The Normal Zone in location 30 and 31 in Figure 26 is similar to the ones found in location 2. Location 32 is similar to location 7, 8 and 9. Location 33, near the Ölandsbridge, differ from location 13 (under the Öresundsbridge, at Flintrännan) mainly due to that two ships hardly overtake or meet under the bridge. The polar diagram for *all intersection* at location 33 shows some dots, hence they represent a few crossing intersections.

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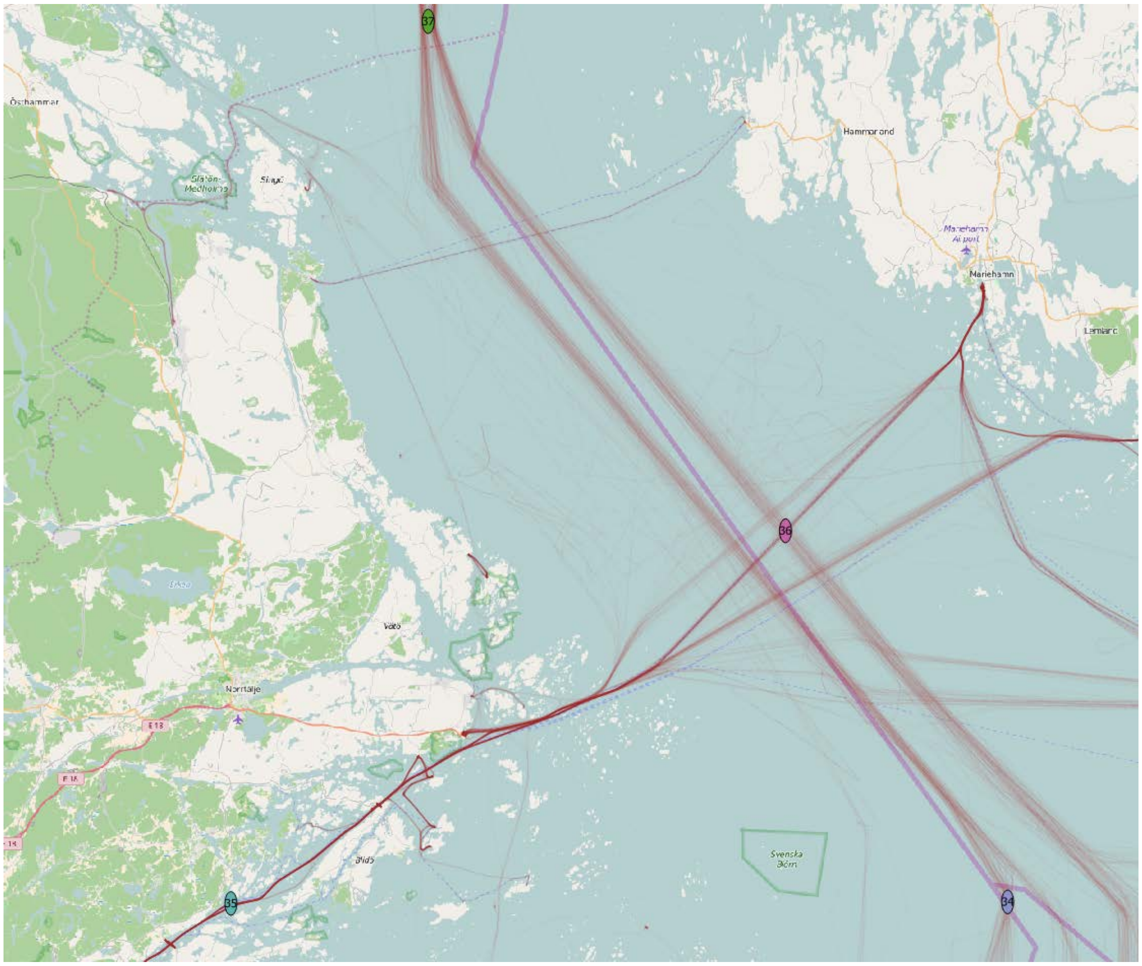

Figure 27 Map illustrating the four investigated locations northeast of Stockholm

Location 35, the inlet to Stockholm, is similar to location 24, the inlet to Gothenburg. The Normal Zone is a little bit wider and shorter than the ones found in Drogden channel and Flintrännan.

Location 36 have similarities to location 32 with crossing traffic, hence in location 36 are there more ships that crosses than overtaking.

Location 34 in the lower right corner of Figure 27 is investigated, it is compared with location 10 (north of the Bornholmsgatt) and location 11 (south of Öresund). They all show the same trend i.e. that the Normal Zone gets shorter compared to other locations in open water, see Figure 28. The Normal Zone at location 34 is even shorter then at location 10, this can be a result of a sharper bend.

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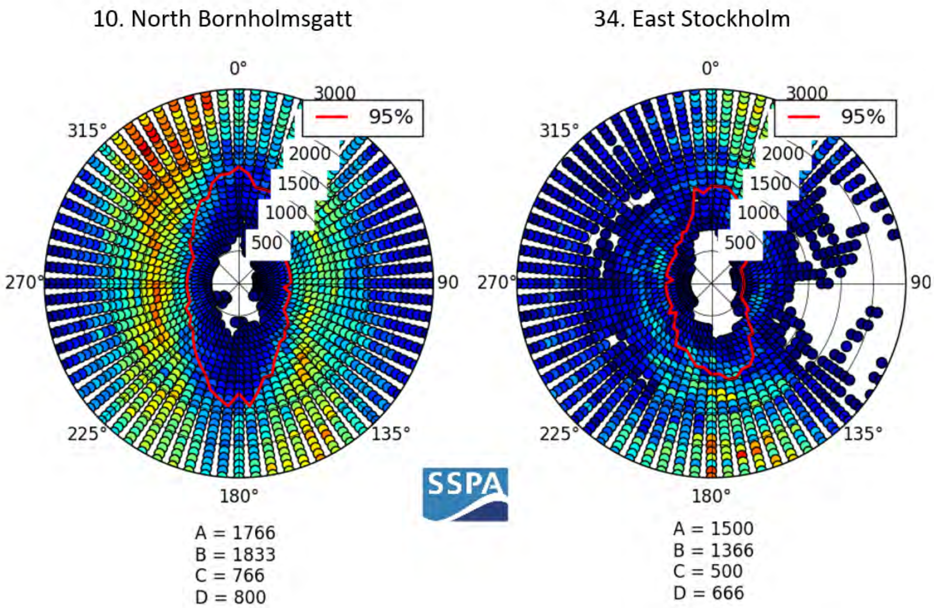

Figure 28 the Normal Zone in a bend for all intersections in location 10 and 34.

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4 Results

There are many different parameters influencing the Normal Zone, and something that is normal in one situation is not necessarily normal in another. This chapter is dived into different scenarios. The elliptic equation 2 is rewritten in equation 3 to include the values A, B, C and D, see Figure 29.

Equation 3 the equation for the Normal Zone based on the values A, B, C and D in this report (x and y may be swifted to get the ellipse head up).

$$1 = \frac{\left(x - (A - B)\right)^2}{\left(\frac{|A| + |B|}{2}\right)^2} + \frac{\left(y - (C - D)\right)^2}{\left(\frac{|C| + |D|}{2}\right)^2}, \qquad A, B, C, D \neq 0$$

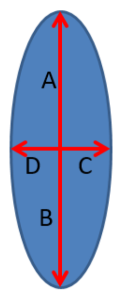

Figure 29 Ellipse with the variables A, B, C and D.

4.1 Overtaking in open waters on a route

Based on the result of the investigated location, most traffic sails on marked routes in sea charts, as opposed to sailing at any available waters. Following locations are considered to represent overtaking on a route in open waters; 2, 5, 10, 22, 18, 19, 30, 32 and 37, their A, B, C and D values are gathered in table 2.

Table 2 Average values for A, B, C and D in overtaking situations in open waters.

	2	**5**	**10**	**18**	**19**	**20**	**22**	**30**	**32**	**37**	**Average**
A	1866	1966	1766	2233	2300	2233	2033	2033	1666	1700	**1980**
B	1866	1933	1833	2000	2200	2100	1933	2133	1666	1500	**1916**
C	600	700	766	600	600	600	600	700	733	400	**630**
D	700	600	800	500	500	500	500	600	800	400	**590**

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On a defined route it is normal that overtaking occurs and they normally occur outside the elliptic zone defined in equation 3, with the average values from table 2.

4.2 The Normal Zone in Öresund

The Normal Zone in Öresund differ from the other location's Normal Zones. They are compiled in table 3. The table have two different average values, "average 1" is all the locations. In "average 2" location 15 and 17 are removed, due to the dense ferry traffic.

Table 3 the Normal Zone in Öresund where traffic is dense, average 1 is all the location, average 2 is the average expect location 15 and 17 where the ferry traffic is dense.

	12	13	14	15	16	17	Average 1	Average 2
A	1300	1566	1400	700	1266	533	**1128**	**1383**
B	1300	1333	1300	666	1233	500	**1055**	**1292**
C	600	200	100	433	400	200	**322**	**325**
D	500	100	100	200	300	200	**233**	**250**

4.3 Overtaking in narrow fairways

The narrow fairways at Drogden, Flintrännan, inlet to Gothenburg and Stockholm is compiled in table 4.

Table 4 Normal Zone for overtaking in narrow fairways, location 35 had not one overtaking in all 72 directions and therefore is the values from all intersection in location 35.

	13	14	24	35*	Average
A	1233	1400	666	900	**1050**
B	1133	1300	633	933	**1000**
C	200	100	100	200	**150**
D	200	100	100	200	**150**

The Normal Zone for location 35 is the one from *all intersection*, hence the size and the shape at *overtaking* is similar to *all intersection.*

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4.4 Bends

Locations close to a bend, near a TSS, have a similar Normal Zone and are gathered in Table 5.

Table 5 Normal Zone for bends with all intersections in open water close to a TSS.

	10	11	34	Average
A	1766	1266	1500	**1511**
B	1600	1233	1366	**1400**
C	800	600	500	**633**
D	800	933	666	**800**

The three locations, gathered in table 5, shows that the sharpness of the bend influences the Normal Zone. The sharpest bend is at location 11 and that location has the shortest zone. Location 10 got the longest Normal Zone and location 10 is where the bend is least sharp of the three locations.

4.5 Normal Zone in crossing situations

Crossing situations with two vessels, at a relative bearing of 90 or 270, close to each other, is relatively unnormal, but at location 8, 9, 23, 26, 29 and 36 there are enough crossing intersections to compile table 6.

Table 6 Normal Zone for crossing situations.

	8	9	23	26	29	36	Average
A	1033	1633	1700	1433	1400	1900	**1517**
B	1166	1333	1366	1200	966	1633	**1277**
C	1700	1700	1500	1300	1466	1933	**1600**
D	1633	1700	1333	1633	1366	1900	**1594**

4.6 Ship size

Fujii (1983) and Hansen et al. (2013) used *ship length* as unit while investigate the comfort zone/ship domain. It is thereby noteworthy that the size of the Normal Zone in relation to the *ship length* has a vague correlation in the investigated locations. The investigated locations were location 2 and 37 and the result is compiled in table 7.

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Table 7 the Normal Zone for different ship length while overtaking. "2" and “37” refers to all ship sizes, small refers to ships between 60 and 140 long and large ships refers to ship between 160 and 240 long.

	2	2 small	2 large	37	37 small	37 large
A	1866	1633	2100	1866	1766	1633
B	1866	1333	1933	1633	1533	1866
C	600	1700	700	400	400	433
D	700	1700	700	700	700	600

4.7 Head on meetings

In the investigated locations head-on meetings on starboard side are considered to be unnormal. It is also unnormal to have another ship in front or directly behind the ship. As a result it is not possible to make an ellipse for head-on meetings. At locations where head-on meetings occur, it is normal that they occur approximately 700 meter to the port side.

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5 Conclusion

Reducing the number of collisions at sea is of highest concern and the term Normal Zone is introduced in this report. The Normal Zone enables the possibility to quantify normal passing distances, when what is normal is known it is possible to determine what is unnormal. A more thorough understanding of suitable passing distances can improve traffic risk analysis and the planning of fairways. Warning systems for collisions can be improved by having a better ratio between true and false alerts and thus gaining higher degree of acceptance and usage by mariners and Vessel Traffic Service, VTS, operators. Also, the mariner education can benefit from a concept of Normal Zone that will adapt to the actual circumstances and give a more realistic awareness of suitable passing distances.

An example of the Normal Zone is 1900 meters long and 600 meters wide in an overtaking situation, in open waters and on a route. This is longer and a little bit smaller than Coldwell suggested 1983. The reason why it differs can be that ship today are equipped with AIS, so that the bridge team can take action at an earlier stage. It also suggests that this zone is not static and may change in the future when new systems are installed.

However the results show that the Normal Zone differ both with regards to location and situation. When two fairways meet and the ship are crossing each other's paths, the Normal Zone is changed. At those locations the Normal Zone is more of a circle shape, with a radius of 1500 meters. When ships traffic is dense and constrained, like in Öresund, the Normal Zone decrease to almost half the size, 1350 meters long and 300 meters wide. The size of the Normal Zone is even smaller when the ship is travelling in a narrow fairway, it is then normal to have other ships 100 meters away on either starboard or port side.

The ship size influence the size of the Normal Zone, but the influence is not the dominating factor as Fujii (1983) suggested and Hansen (2013) concluded. In open waters the length of the Normal Zone is typically one nautical mile, with a deviation of roughly two vessel lengths, i.e. there is a slightly greater length when two large ships meet. However, this can be due to that the distance is measured from GPS position to GPS position instead of hull to full. The difference between this and Fujiis research is that this is based on what is normal compared to Fujiis research which was based on the feeling of what is comfortable.

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6 Suggestion for future work

It would be very interesting to link accidents to this research, to get measurement of how violation of the Normal Zone affects safety. Are ships that intersect the Normal Zone overrepresented in accident statistics?

Other areas can be improved in the future

- Knowledge of intentions. This can be improved by identifying if and where the ships change course or with knowledge of if they have had verbal communication.
- More research can improve the relationship with the Normal Zone and traffic density.
- It was identified that the sharpness of the bends matter, future research can investigate this matter more thoroughly.
- The available depth and the width of the fairway influences the Normal Zone, hence the effect is not studied.
- In this research the distance was measured from GPS to GPS, it would be interesting to measure the distance from shipside to shipside.
- The values of A, B, C and D was calculated as the average of the three values, it might be interesting to use a Gaussian sample average instead.
- A systematic analysis of the governing parameters, this to identify if there are any other inter-ship parameters that influence the situations.
- The effects by weather conditions and light on the Normal Zone.
- Study on ships equipped with route exchange possibilities.

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D6.9 Part 2
Report on Dynamic NoGo Areas

Project no.	636329
Project acronym:	EfficienSea2
	EFFICIENSEA2 – efficient, safe and sustainable traffic at sea
Funding scheme:	Innovation Action (IA)
Start date of project:	1 May 2015
End date of project:	30 April 2018
Duration:	36 months

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Contents

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1 Executive summary

Dynamic NoGo-areas is a visualisation technique in electronic nautical charts that increases the navigator's awareness of available navigable water in the vicinity of the ship. By colouring areas shallower than the vessel's present draught red he or she gains a quicker and more unambiguous understanding of dangers around the vessel. The benefit of this is increased safety as well as increased efficiency.

Increased safety, because it makes the navigator more aware of the available manoeuvre space. Grounding areas will be unambiguously shown, as well as areas available for evasive manoeuvres. Passages through narrow channels will be safer when high resolution bathymetry, real-time tide gauge and sea state data and onboard sensor information of the vessels draught, trim, squat and heel is fused into reliable

The dynamic NoGo areas are shown directly on the electronic chart and display information system (ECDIS) allowing substantial cognitive off-loading compared to the traditional systems where mental arithmetic having to be performed deducting the ship's draught from the depth numbers presented in the chart and on top of that adding the tidal component together with vessel data.

The complexity of carrying out a full under keel clearance (UKC) calculation leads to efficiency losses. Ships tend to travel with greater safety margins than necessary, and taking less cargo than could be possible passing shallow sills like the Sound and the Belt entrances to the Baltic Sea. But because of the complex calculation situation awareness is hampered, and the safety gains one should expect from the greater margins, does not materialize.

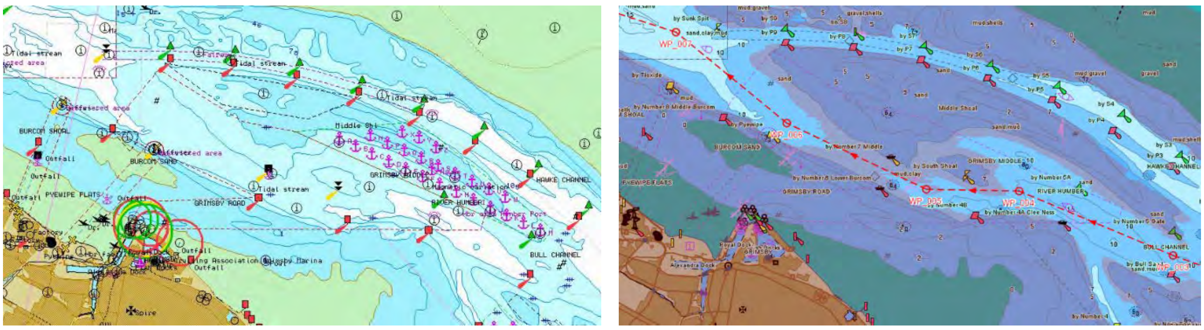

Figure 1. To the left is a modern electronic chart over the Humber Estuary at Immingham in the UK. To the right is the same chart with a Dynamic NoGo area overlay. The transparent red polygons depict areas too shallow for the vessel at present tide and loading conditions.

In Figure 1, left, a detail of a modern electronic chart can be seen (Transas). The depicted area is from the Humber Estuary at Immingham in eastern UK. The chart uses the standard colour coding from the paper charts: Water areas deeper that 10 meters are

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coloured white, while areas with a depth of 10-2 meters are light blue and below 2 meters the darker shade of blue. Areas that dry out during low tide are coloured green. The Chart Datum (the reference surface to which all depth numbers refer) is in the UK case Lowest Astronomical Tide (LAT). But showing the depths at LAT does not give a true picture of the depths because the current tidal level has to be added to the presented depths and these depths must then be compared to the vessel's draught. In Figure 1, right, this calculation has been done and the results are presented in the form of "dynamic NoGo areas", transparent red polygons depicting areas which are too shallow for the vessel. In the Humber case depicted, we can see that the southern channel is closed for this vessel with a draught of 10.5 meters, while the northern, narrow channel is open.

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2 Introduction

2.1 Scope and purpose

This document reports the “Dynamic NoGo Areas” part in the deliverable (D) 6.9, which is one of the outputs of Task 6.4 in Work Package (WP 6) in the EfficienSea2 conducted by Chalmers University of Technology.

By taking a socio-technical perspective and trying to support the human as an integral part of the ship-shore system, Task 6.4 aims to take a holistic view on the information flow and the e-navigation services developed within the project, both the novel services in preceding WPs and advanced solutions in WP6.

Two case studies are conducted with two specific services of relevance to information overload: "comfort-zone" and "no-go" area. These are two different approaches to assist the navigator in keeping a safe passage with regard to all relevant parameters such as other vessels, MSI/NM, bathymetry, off-shore installations, etc.

This is issue 1.0 of the document. An issue 2.0 will be issued after simulator tests, planned in June 2017, have been conducted.

2.2 Background

The dynamic NoGo service allows for merging a variety of data, such as draft, bathymetry and tidal levels, into simpler information indicating where a vessel can operate safely. Dynamic NoGo-areas is a visualisation technique in electronic nautical charts that increases the navigator’s awareness of available navigable water in the vicinity of the ship. By colouring areas shallower than the vessel’s present draught red he or she gains a quicker and more unambiguous understanding of dangers around the vessel. The benefit of this is increased safety as well as increased efficiency.

2.3 Structure of the document

This report is structured as followed:

Chapter 1 this is an introduction containing scope, purpose, background, list of abbreviations.
Chapter 2 gives a background to the need of a dynamic NoGo service and defines UKC.
Chapter 3 describes earlier prototypes and test results together with the EfficienSea2 prototype and tests performed in May and June 2017 (TBC).
Chapter 5 proposes future work
Chapter 4 summaries the main results
Chapter 6 lists references used in this report

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2.4 Abbreviations

B-Max	Baltic Maximum ship
D	Deliverable
ECDIS	Electronic Chart and Display Information System
E	EfficienSea2
EPD	e-Navigation Prototype Display
TBC	To Be Confirmed
TBD	To Be Determined
UKC	Under Keel Clearance
WP	Work Package

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3 Background

3.1 The Danish straits and the entrance to the Baltic Sea

Increased safety is the major intention with the Dynamic NoGo Areas service. However increased transport efficiency is another targeted benefit. More than 82 000 ships passed in 2012 in and out of the Baltic Sea. The depth limitation over the sills in the Danish Straits sets the limit to the size and cargo carrying capacity of each ship. If better bathymetrical surveys, better precision in measuring and predicting water levels and vessel data can be used together with better visualisation techniques, larger ships can pass into the Baltic Sea with the same or better safety.

The Baltic Sea is a mediterranean sea of the Atlantic detached from the North Sea by Denmark, Norway and Sweden. The Baltic Sea is also an important transfer route for shipborne goods, which is over 90 % of the world's trade. Poland, the Baltic countries, Finland, Germany, Denmark and Sweden all have important harbours in the Baltic Sea. However the Sea is only accessible by ships through three channels: From Kattegat, The Sound (between Sweden and Denmark), and The Great Belt (in Denmark), and from the North Sea, the North-Ostsee-Kanal through northern Germany. In 2012, 33 672 ships passed in and out of the Baltic Sea through the Sound, 19 441 through the Great Belt and 29 441 through the Kiel Canal (ACCSEAS, 2015).

The Baltic Sea is a shallow sea with an average depth of 55 meters. The deepest point is the Landsortsdjupet east of Stockholm in Sweden (459 meters) but the sills in the Belt and the Sound sets the limits to maximum draughts entering the Baltic Sea.

"Baltimax" is a naval architecture term for the largest ship measurements capable of entering and leaving the Baltic Sea in a laden condition. It is the Great Belt route that allows the largest ships. The limit is a draft of 15.4 metres (in the Kadet Trench) and an maximum air draft of 65 metres under the east bridge of the Great Belt bridge. The vessel length can be around 240 m and the width around 42 m. This gives a weight of around 100.000 metric ton. The Sound allows only 7.7 meters in the Drogden channel (minimum depth 8.0 meters) and 7.2 meters draught in the Flint channel (minimum depth 8.4 meters). The difference between minimum depth and maximum draught are often pilot regulations to ensure enough safety margin (under keel clearance). Both Sound channels has air draught restrictions, Flint 57 meters due to the fixed bridge, and Drogden 36 meters due to landing airplanes on Kastrup airport. The Kiel Canal (Nord-Ostsee-Kanal) allows 9,5 m draft. Furthermore, many ports limit ship size. The iron ore ports of Luleå (11 m, to be deepened to 13 m) and Kemi (10 m) and the large oil port of Klaipėda (12.5 m) have less draft than Baltimax. The largest oil port is Primorsk which has 15 m draft, similar to Baltimax. The Northern Port in Gdańsk can take the 300.000 ton 15 m draft ships (Wikipedia).

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3.2 What is Under Keel Clearance?

The navigational work performed by the ships's bridge team follows the navigation process, consisting of four elements:

- Appraisal;
- Planning;
- Execution; and
- Monitoring.

It is the master´s responsibility that the ship's voyage is planned in advance and that this plan is monitored and followed. The planning is often conducted by the second officer.

The voyage plan should include the berth-to-berth route together with, among other items, identified hazards along the route. One of the main risks during a voyage is grounding. In the voyage plan no-go areas along the route are highlighted. When defining no-go areas the main parameter to consider is the Under Keel Clearance (UKC) requirement in relation to tidal information. UKC is defined as the vertical distance between the lowest part of the ship's hull and the seabed. The master needs to make sure that a certain UKC is maintained during all phases of the voyage. In some cases, authorities or cargo owners put requirements on minimum UKC. The following factors are affecting the selection of an UKC:

- Uncertainties in charted depth;
- Uncertainties in the vessel's draught, which will change during the voyage;
- Dynamic squat;
- Tidal surge;
- Heavy weather and sea state; and
- Depth information.

Bathometry information is given in the nautical chart. Today, we have two types of nautical charts:

- Paper charts; and
- Electronic charts

This is discussed further in the section below.

3.3 Traditional portrayal of depth information in nautical charts

However, because ships have different draughts, the NoGo areas of one vessel might not be the NoGo areas of another. That is the problem of nautical charts: they describe seabed features, but to be able to tailor those for a particular ship the mariner needs to undertake some arithmetic. For instance, the chart gives a depth of 10 meters. Your ship has a draught of 8.5 meters, but to be on the safe side you want an Under Keel Clearance

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(UKC) of 2 meters. In total a depth of 10.5 meters, which you do not have. However, the tidewater is rising and is at noon +2.5 meters which should give you an encouraging 13 meters of water. However, there is a high pressure and strong westerly winds lowering the sea level -1.3 meters. On top of that, you have a squat of -0.5 meters and waves with a significant wave height of 0.9 meters. Can you pass the area? Of course, these types of calculations are normally done in peace and quite well in advance, but if something happens and the ship needs to make an evasive manoeuvre or gets engine problems and starts drifting, these complex calculations needs to be made on the fly with risks of errors.

In modern electronic charts, a feature called "safety contours" has been added. This feature allows a depth contour (a line connecting similar depths) to be highlighted and the areas inside the contour to be highlighted (in blue). Compare the images in Figure 2 where the safety contour in the same area is set to 2, 5 and 10 meters (left to right).

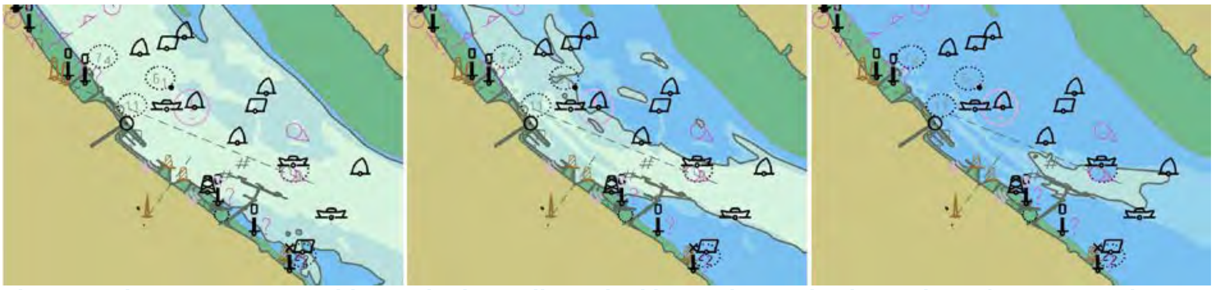

Figure 2. The water area outside Immingham oil terminal in an electronic chart. The safety contour is set to 2 (left), 5 (middle), and 10 meters (right). The contours need to be present in the chart database, so, for instance, a safety contour of 8.5 meters cannot be set: it will instead be the next deeper contour, 10 meters.

The problem with safety contours is that they need to be set manually and several groundings have been partly due to that this feature has not been used to make shallow waters more conspicuous (FBMCI, 2009; MAIB, 2014). The draught today is read from a gauge painted on the bow and sternpost of the ship before leaving port. The general tidal level can be found in tables on-line. They are derived from historical records taking into account geographical features of the coastline, but the wind effect and atmospheric pressure might have significant influence on these predictions. At some places the total tide can be read from gauge buoys in real time. Squat and heel are displacements of the ship's hull that depend on speed, and wind and must be approximated onboard based on tables made up for each individual ship. Heave depends on the sea state, which in turn depends on old swells, wind and bottom topography. The problem is for the officer on the bridge to deal with this complex information. Often rough approximations are done on-the-fly, with risks of error.

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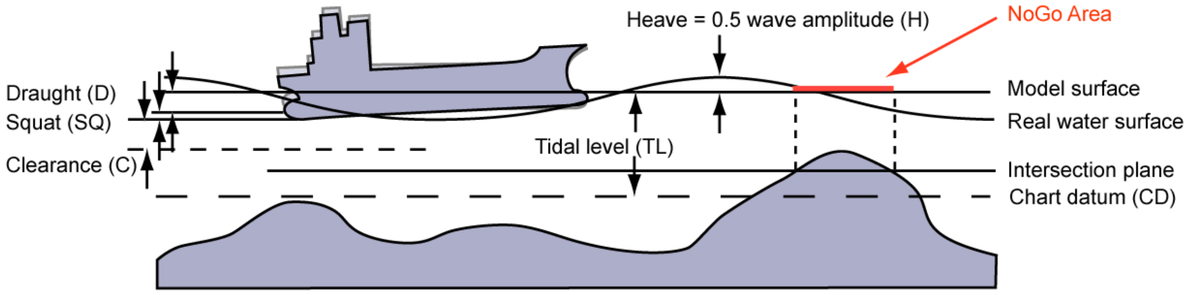
4 Method: Calculation of Dynamic NoGo areas

In 2002 Porathe & Sivetun proposed an automatic feature in electronic nautical charts which would highlight areas too shallow for sailing given the current water level and sea state, and the ships draught and squat (see Figure 3).



Depth of the intersection plane = TL(t) - D(t) - SQ(v) - C - H(t)

Figure 3. A simplified calculation of under keel clearance and generation of Dynamic NoGo areas, in reality the parameters also includes parameters of heel, water density, and date of bottom survey and siltation allowance (Porathe, 2005; AMSA, 2007).

However, this is not enough: the tidal level can change quite drastically on an hourly level, why the mariner needs to monitor not only the present situation, but also plan ahead. Given the economic pressure in the shipping industry, the cost of fuel and the need to keep timeslots in locks and ports the mariner on the bridge is left with a substantial workload managing the voyage.

4.1 Prototype one

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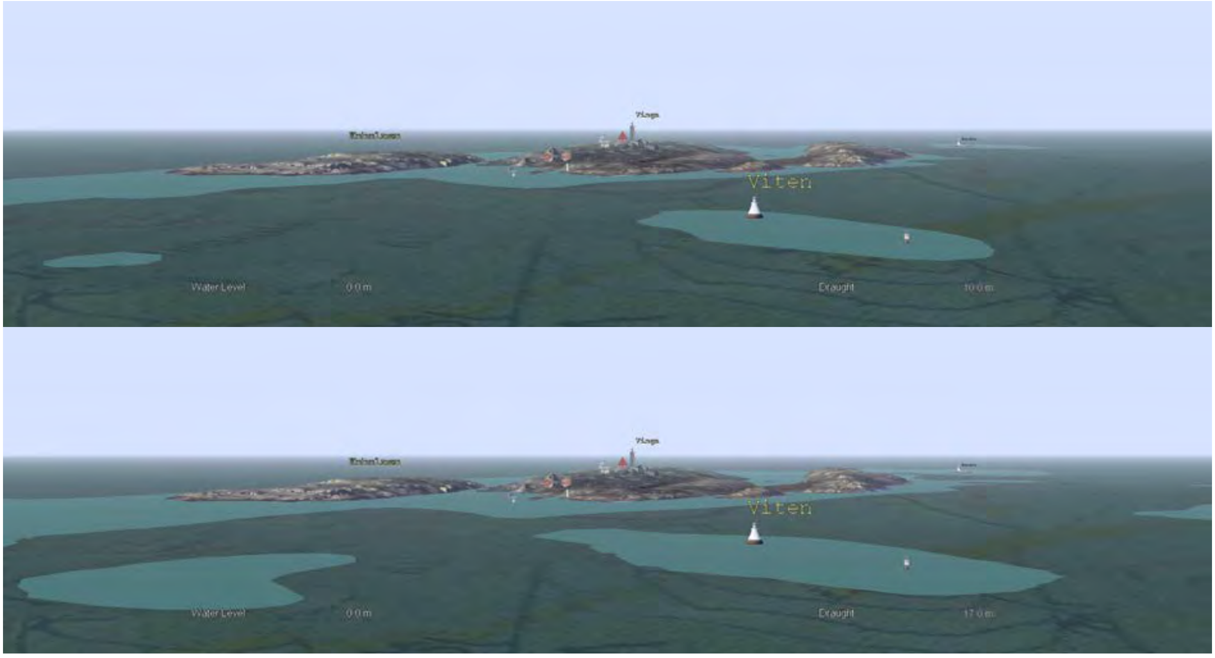

Figure 4 Dynamic NoGo-area visualisation in a 3D nautical chart prototype (Porathe, 2006). From the top the NoGo areas depict areas shallower than 2, 10 and 17 meters

A visualization prototype of the NoGo areas was developed for a 3D chart (Porathe, 2006, see Figure 4). This prototype was however not tested in formal usability tests. A first working prototype of the NoGo areas in an ordinary electronic chart was developed by the Danish Maritime Safety Administration and Chalmers University of Technology in the EU-project EfficienSea (2012, pp. 16-20). This prototype utilized a high resolution bathymetric database for the Danish side of the Sound between Sweden and Denmark provided by the Danish Hydrographic office, but the results of the NoGo area calculation was displayed in a relatively coarse 100 by 100 meter grid. Technical tests were successful but no user tests were carried out at that time either.

4.2 Prototype two

In the EU project, ACCSEAS (2012-2015) the development work continued in a NoGo area prototype of the Humber Estuary. The area was picked out as a testbed area for several e-Navigation services developed in the ACCSEAS project. The Humber Estuary was an excellent place to test the NoGo areas. The tidewater at Hull ranges from +6.9 meters over the chart datum (Lower Low Tide) at spring tide to + 3.5 meters at neap. Due to the heavy siltation, navigation in the river was challenged by shifting sandbanks something that makes the Humber Port authorities to carry out contiguous surveying for water depths. While the cells in the regular electronic nautical charts are only updated on yearly intervals at best, the results of these surveys are published on a bi-weekly basis in

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the form of survey maps downloadable in pdf format from the Humber Estuary Services (2015). For an example, see Figure 5.

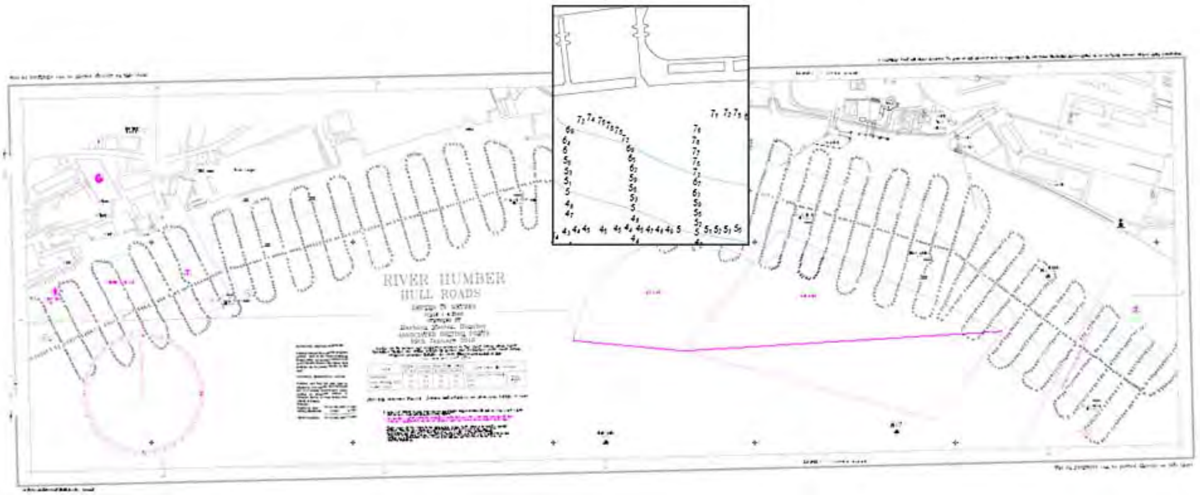

Figure 5. A downloadable survey map from the Humber Estuary Services presenting the results of a survey run along the piers of Hull from 29th of January 2015. In the clos-up the soundings (in meters) is visible. (Curtesy of Humber Estuary Services, 2015)

These survey maps represent very accurate and up-to-date information about the present condition in the river, but from a usability point of view their value are could be questioned: few ships will have large format printers onboard so they need to viewed on a monitor using a pdf reader, a tool that do not have any provisions for measuring bearings and distance and that cannot present own or other ships positions from satellite navigation systems. Instead information needs to carried “in the head” from the PDF screen to the electronic chart system.

For this prototype, the United Kingdom Hydrographic Office agreed to develop a river database based on the up-do-date Humber Estuary Services’ surveys that could be used as basis for the NoGo area service prototyped.

4.2.1 The tested prototype service

Input to the calculations were:

1) Manual input by navigator:
   a) Vessel draught
   b) Wanted Under Keel Clearance; taking into account vessels draught, squat, heave, etc.
2) Automatic:
   a) Detailed bathymetry (from database; 1 centimetre depth intervals in a 50x50 meters grid)
   b) Tidal information: in 10-minute time slices and 1 centimetre intervals for the closest

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Standard Port (Total Tide).

c) Weather information adjusting astronomic tidal level (not tested during ACCSEAS project).

For the tests the No-Go area service has been implemented in the e-Navigation Prototype Display (EPD), a chart display with basic Electronic Chart and Display Information System functionality (see Figures 9 and 10).

4.2.2 Acquisition procedure

Due to restrictions in the data processing capacity of the test implementation, only a limited area could be processed during each request. The procedure for requesting NoGo polygons was as follows:

1) The user right-clicked anywhere in the chart and choose “Request NoGo Area” from a context menu.
2) The Request NoGo dialogue box opened where you set your own ship’s draught (automatically copied from the vessels Automatic Identification System message) and specified an Under Keel Clearance (UKC). If you wanted NoGo areas for different time intervals you needed to specify that. For example, if you choose a time interval of 6 hours and request 6 slices you will get 6 NoGo overlays, one for each 1 hour period. The system will then calculate NoGo areas for the least favourable depth in each time interval.
3) Finally, the user clicks “Select area” and draws a rectangle for the area in question with the cursor on the screen.
4) There is a delay while the query is sent to the database and the requested numbers of slices are sent back. The time delay could be substantial depending on the size of the area and the number of slices requested as well as bandwidth for the communication link. During the test an area of a square mile or so with just one slice would be computed in about 30 seconds.
5) As only one NoGo area slice was visible at a time there was a time slider in the NoGo Area section of the right side bar. This time slider could be pulled back and forward showing the different NoGo areas and the time interval each one was valid for (see Figures 6 and 10).
6) The NoGo polygons could be toggled off and on.

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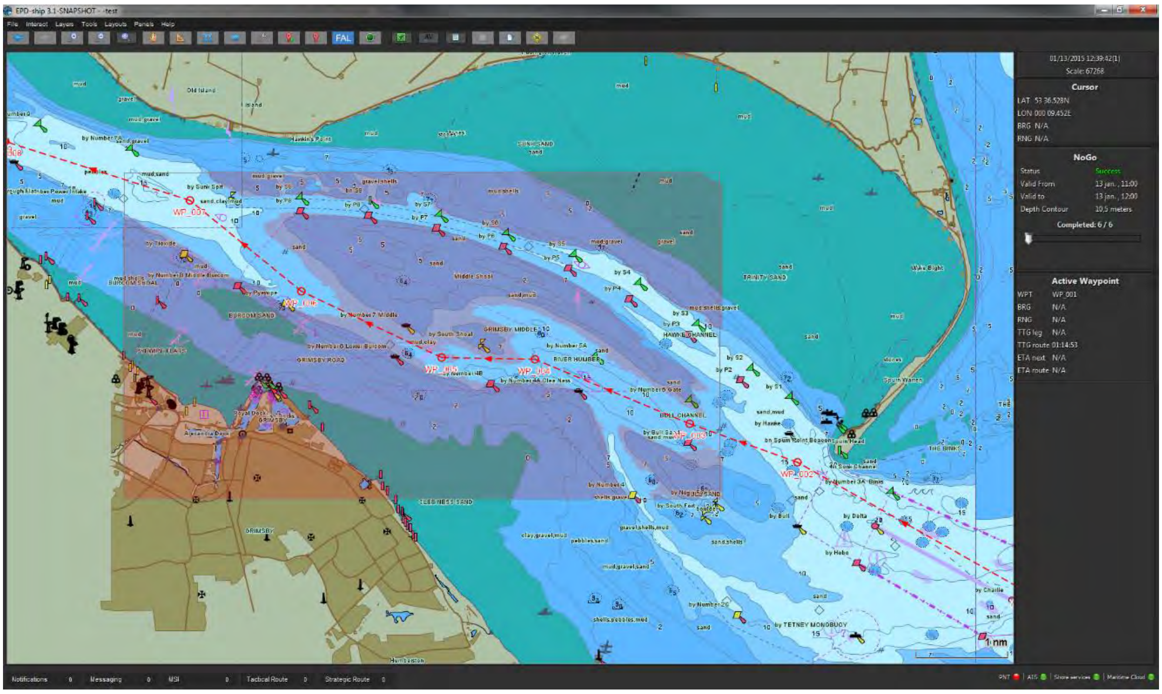

Figure 6. Screen dump from the prototype application. Own ship's planned track is shown as the red dashed line. NoGo polygons for the area within the rectangle drawn on the screen are displayed in a transparent red colour layered on top of the nautical chart. In this case, it is the first time slice (of 6) acquisitioned and shows worst case scenario for the time from 11.00 to 12.00 o'clock. The NoGo polygons show that the southern channel is closed for vessel with a draught, plus UKC of 10.5 meters due to low water. (Image curtesy of Mads Bentzen, Danish Maritime Authority.)

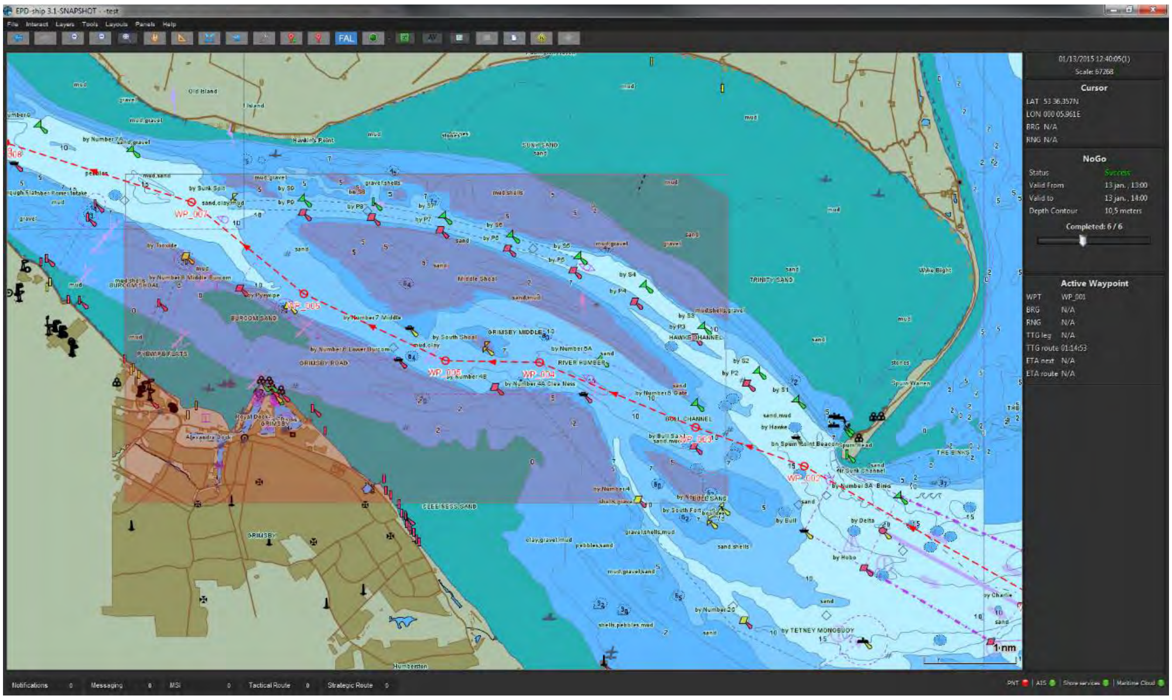

Figure 7. In this screen dump the time handle in the top section of the panel to the right has been moved showing NoGo polygons for the time period 13.00 to 14.00. As the tide is now raising the channel has opened for our vessel. (Image curtesy of Mads Bentzen, Danish Maritime Authority.)

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4.2.3 User test

The NoGo area service was tested during a four-day session in the simulator centre at the Department of Shipping and Marine technology at Chalmers University of Technology in Sweden. A number of different scenarios with ship movements in the Humber estuary were executed. The NoGo area service was tested along with other e-Navigation services. Qualitative data was collected during the simulations with special focus on usability, professional acceptance and unintended consequences of change. Simulation sessions and debriefings were video recorded. The participants were encouraged to think aloud.

4.2.4 Participants

11 professional British, Swedish and Danish bridge officers, harbour masters, pilots and Vessel Traffic Service (VTS) operators with experience from traffic in the Humber area was used for the test. All the participants were male from age 32 to 58, with a mean age of 47 years. They all had a professional experience ranging from 12 to 30 years, mean 22 years.

Each bridge was manned with two bridge officers, which would be realistic considering that the situation was approach to port and constrained waters with heavy traffic.

The Spurn Head simulated VTS was manned with two VTS operators from the actual VTS centre.

4.2.5 Results: Conceptual level

There was an agreement that this service was beneficial, especially for tidal areas as electronic charts today does not take in tidal information. Even if the pilot would know the area at the particular tidal situation it will supply at-a-glance reassurance for the rest of the bridge team. One of the pilots said that “many times I have had captains look over my shoulder pointing at the ECDIS (electronic chart) saying, ‘look my draught is 7 meters, it says 5.5 there’ and I have had to say, ‘don’t worry, captain, we got 3 meters of tide on top of that number’”.

Another benefit mentioned was that even if you have old chart cells that have not been updated for a long time, you will get the NoGo areas based on the latest bathymetrical survey data from the area.

For pilots it is an extra confidence. It is a nice-to-have.

The service is particularly good for foreign ships not known to the area.

4.2.6 Results Procedural level

NoGo areas based on the most current surveys and for the correct tidal situation will make it easier for the VTS to show to vessels that they can actually go a certain way and they will not ground.

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It might lessen the workload for the VTS because they might not need to answer a lot of questions about the tidal level.

4.2.7 Results Functional level

NoGo areas should be delivered automatically along the future route of the ship with right times for future positions along the route.

There should be an alarm for track leading into NoGo areas.

4.2.8 Results HMI level

Several participants agreed that the NoGo area service, in the present stage of development, was too difficult to handle. It involved too many steps and too many windows to get it to work.

“But, off course it was because they were new to the system. It felt a lot more comfortable the second day than it did the first” (comment by one of the captains).

There was also a comment about the colour the needed to be more noticeable.

4.3 Survey

The participants were asked to summarise their impressions about the service in a survey with three questions (the available answer options are seen in Table 1):

1. What is your opinion about the tested NoGo area concept?
2. Do you think a similar NoGo area concept will become reality in the future?
3. What is your professional opinion about the system tested?

Two participants had to leave early and did not take the survey. The results of the 9 remaining participants can be seen in the diagrams in Figure 8.

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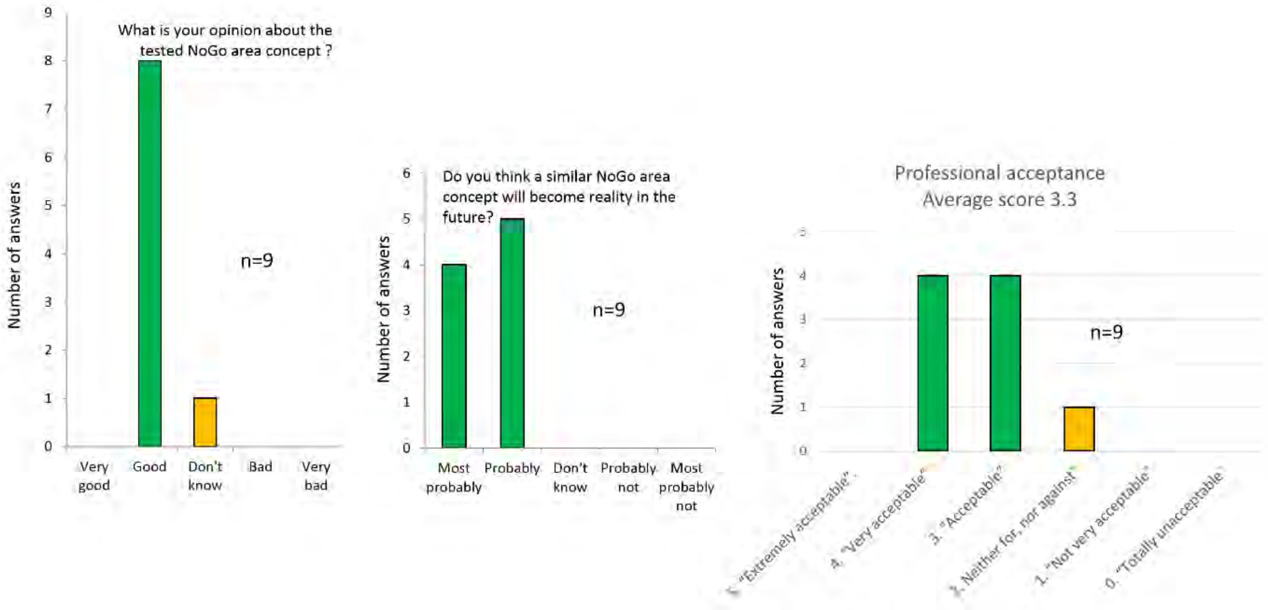

Figure 8. Results from the survey conducted after the simulation tests.

4.4 Prototype three

During the EfficienSea2 project a third prototype was developed based on input and user studies from the ACCSEAS project.

4.4.1 The tested prototype service

Input to the calculations were:

1) Manual input by navigator:
   a) Vessel draught
   b) Wanted Under Keel Clearance; taking into account vessels draught, squat, heave, etc.
2) Automatic:
   a) Detailed bathymetry (from database; 1 centimetre depth intervals in a 50x50 meters grid)
   b) Information on waterlevel which in the Sound mainly depends on air pressure and wind: in 10-minute time slices and 1 centimetre intervals.

For the tests the No-Go area service had been implemented in the BalticWeb portal (see Figures 9 and 10).

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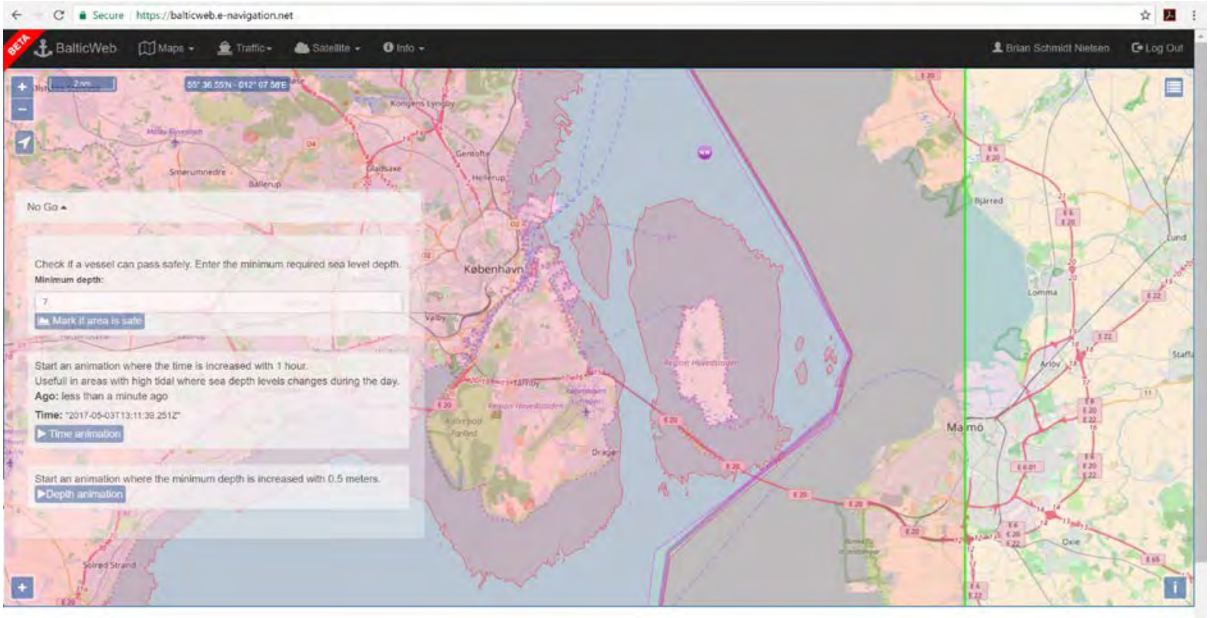

Figure 9. In the prototype the NoGo areas was activated by opening the NoGo tab. It was temporarily placed on the left side of the chart display. By inserting a requested minimum depth (with maximum one decimal) and clicking on the “Mark if area is safe”, NoGo polygons for the visible area of the screen was rendered.

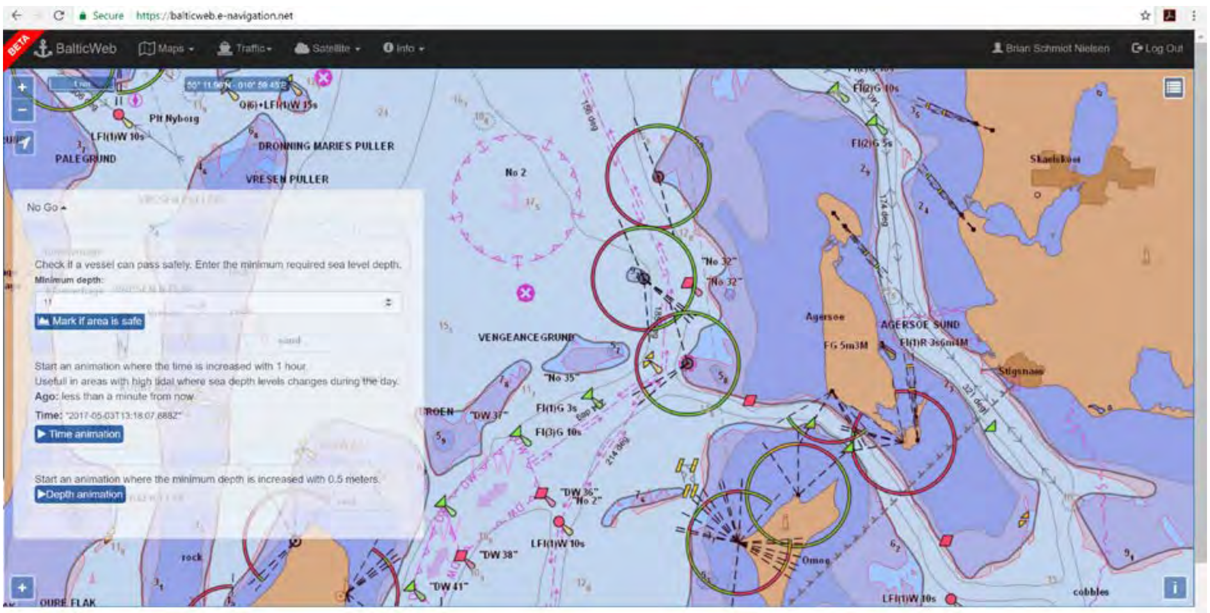

Figure 10. For tidal waters a Time Animation would be played where the time was incremented in 1 hr steps for the next 10 hrs. This function was based on tidal tables and not used for the Sound (as the tide is only a few centimetres). There was also a Depth Animation where the minimum depth was increased in steps of 0.5 meters up to 10 meters.

4.4.2 Acquisition procedure

Due to restrictions in the data processing capacity of the test implementation, only a limited area could be processed during each request. The procedure for requesting NoGo polygons was simplified compared to prototype two where the navigator had to draw a

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bounding box over the area requested. This time the extent of the whole screen was chosen (if within the green rectangle visible in Figure 9 marking the extent of the depth database). Thus, taking away one action from the access process. This was one user want from the usability tests of the ACCSEAS prototype.

The acquisition process was as follows:

1) The user clicked the NoGo Area button provisionally placed on the left side of the screen (see Figure 11).
2) The NoGo dialogue drop-down box opened where you set the requested minimum depth with maximum one decimal, then click the “Mark if area is safe” button. The system would then calculate NoGo areas for the least favourable depth.
3) The NoGo polygons could be turned off by closing the NoGo dialogue.

4.4.3 User test

User tests will be conducted in May and June of 2017 and this report will then be updated on the EfficienSea2 homepage.

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5 Future research

The NoGo area service has still a lot of potential for developing. By showing the minimum depth for future times when the vessel plans to pass a certain point, based on reports from the weather service a safer passage can be achieved. A consecutive visualisation for such time dependant NoGo areas could look something in the line of Figure 11.

By considering the speed induced squat in the calculation the voyage pan can be marked with maximum speed for shallow areas of the voyage.

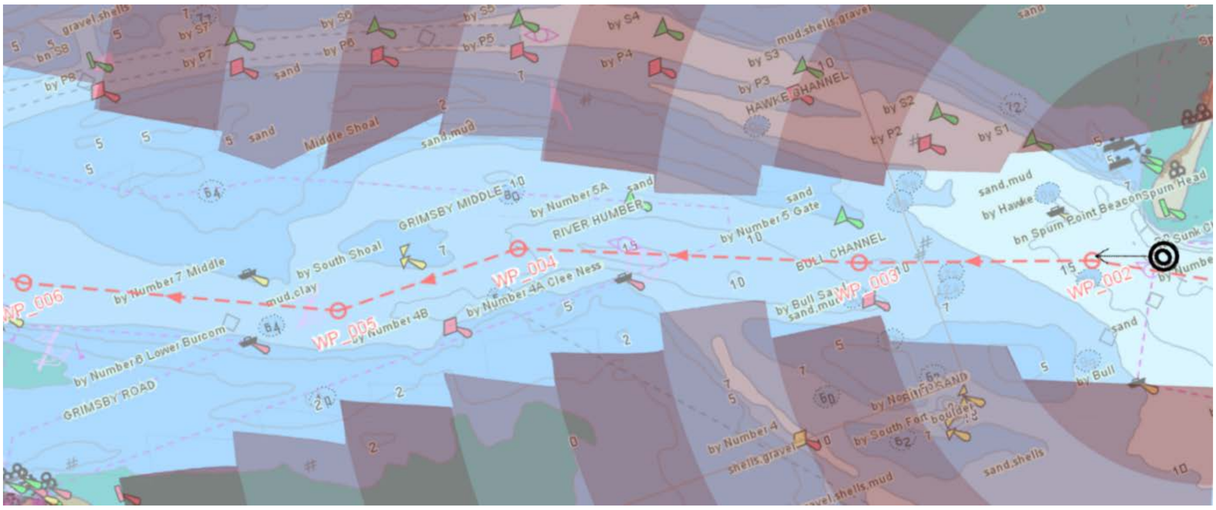

Figure 11. A time dependant NoGo area might look something like this. It is generated automatically in front of the ship and does not only take ships draught into consideration, but also the tidal situation at a particular point along the ships future route at the time the ship will be there. The time segments could for instance be 30 minutes.

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6 Conclusion

In an earlier prototype developed and tested in the ACCSEAS project the NoGo area service was found relevant and professionally acceptable by the participants testing the application. Some of the short comings commented on by the users was then developed further in the EfficenSea2 project. The results of this new prototype will be inserted in a new version of this report once the tests in May and June of 2017 have been done.

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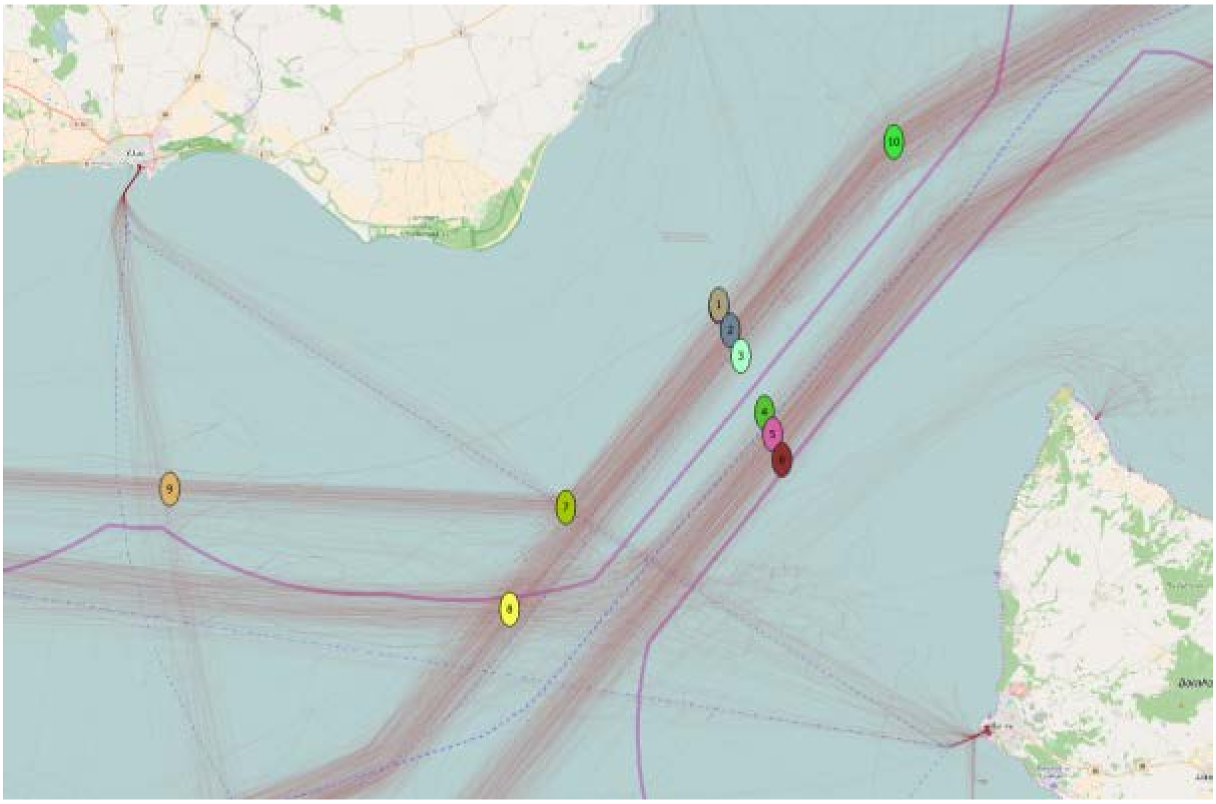
Appendix 1 – Figures for all captured locations and intersections (from Part 1 – Report on Comfort Zones)

In this appendix is all diagrams, that this research is based on, gathered. They diagrams are grouped by their location and all locations have at least one figure for *all intersections,* hence most of them also got a figure for *crossing, head-on meetings* and *overtaking*. Some locations also include a "Fujii ellipse" with different ship sizes.

Following meta data is included in all the figures:

- Dimension for A, B, C and D.
- Number of Own Ships (OS) and Number of meetings.
- The coordinates for the location.
- Type of intersection.
- Minimum and maximum length of the *own ship* (default values are 0 and 400meter).

The maps



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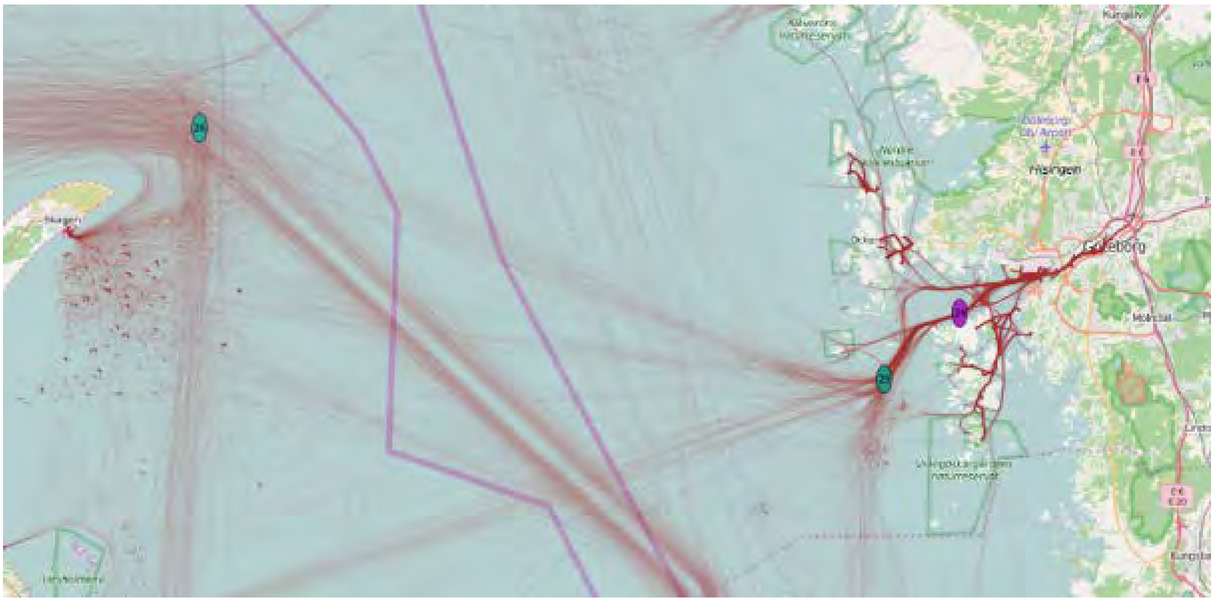

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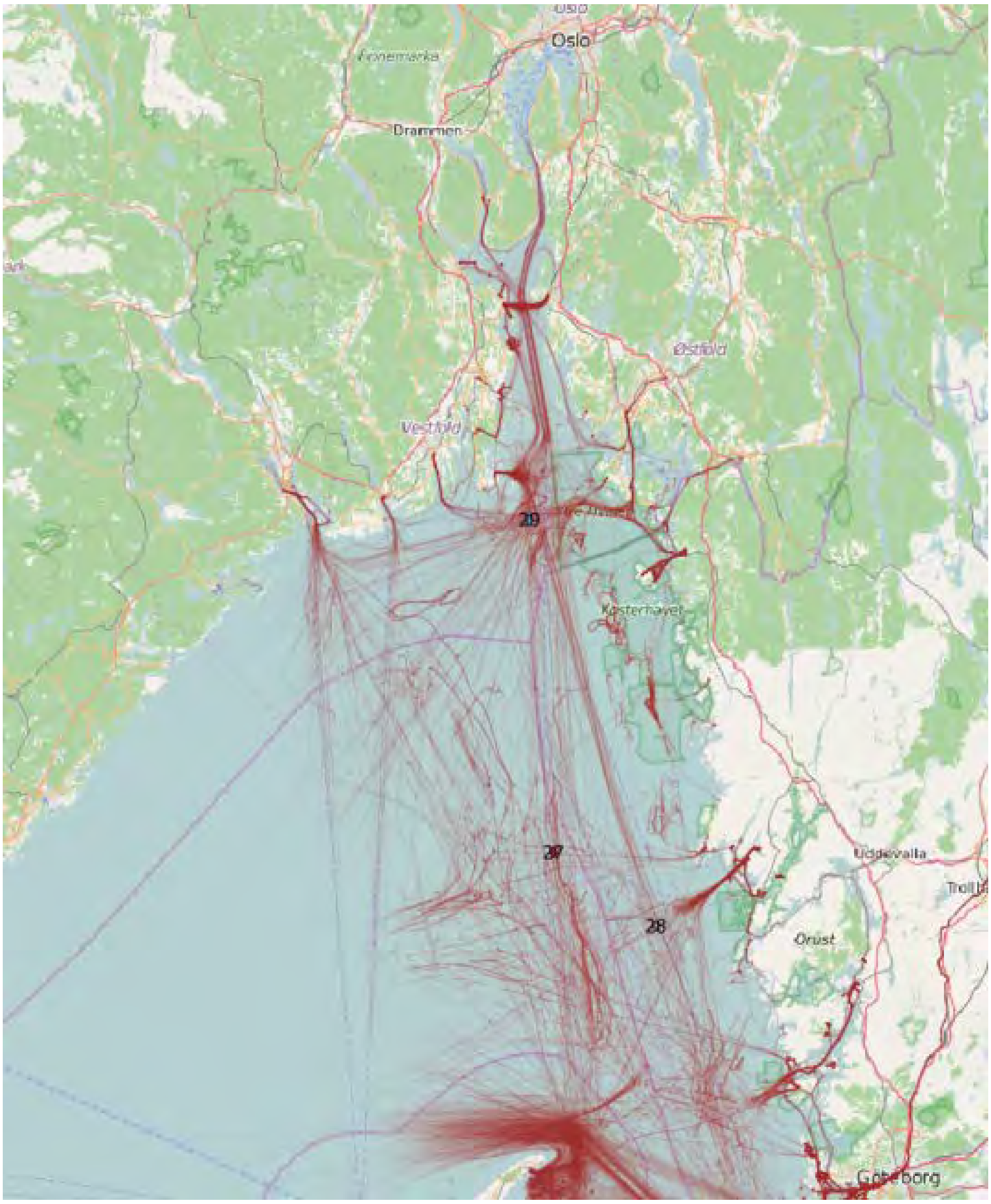

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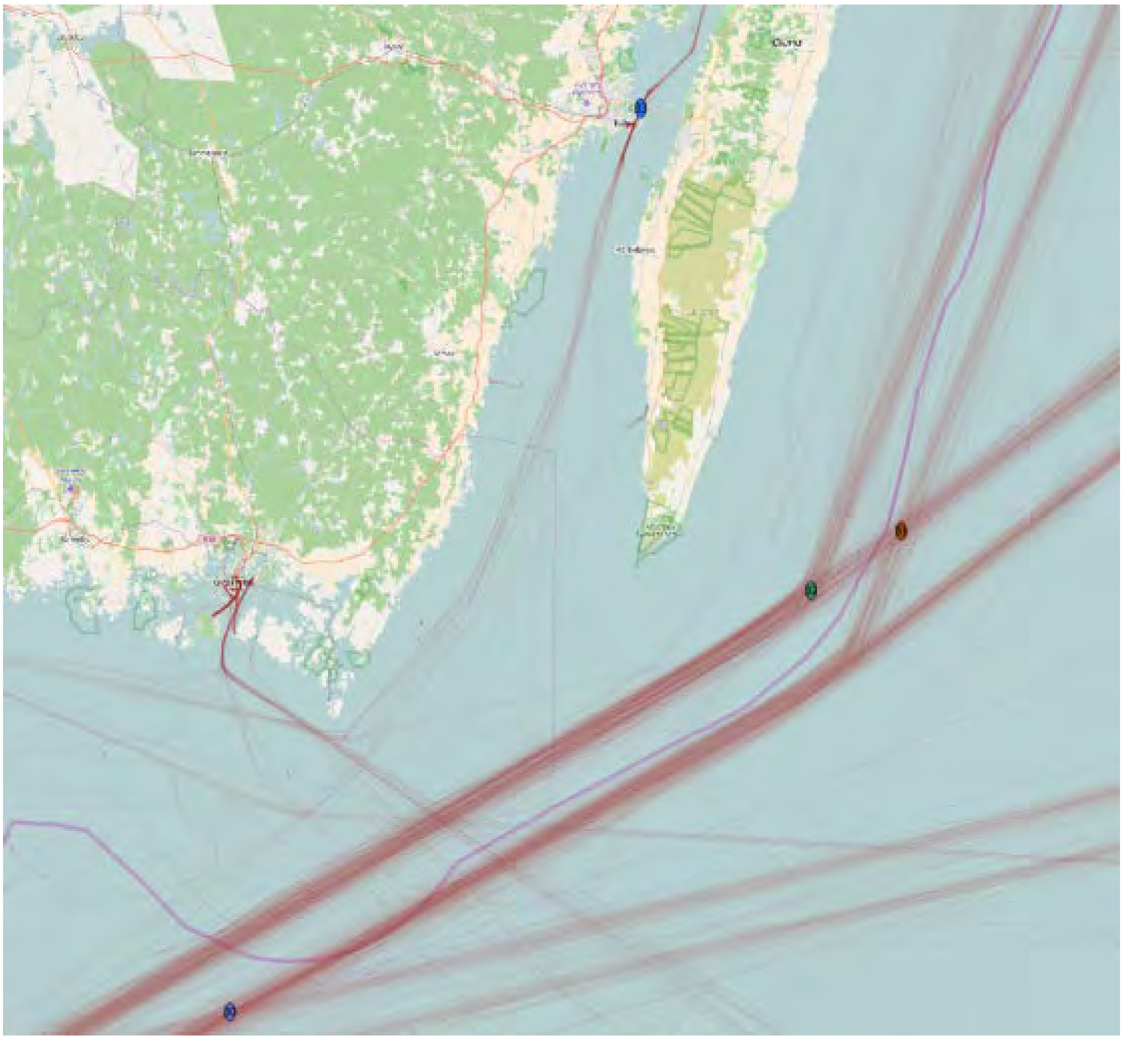

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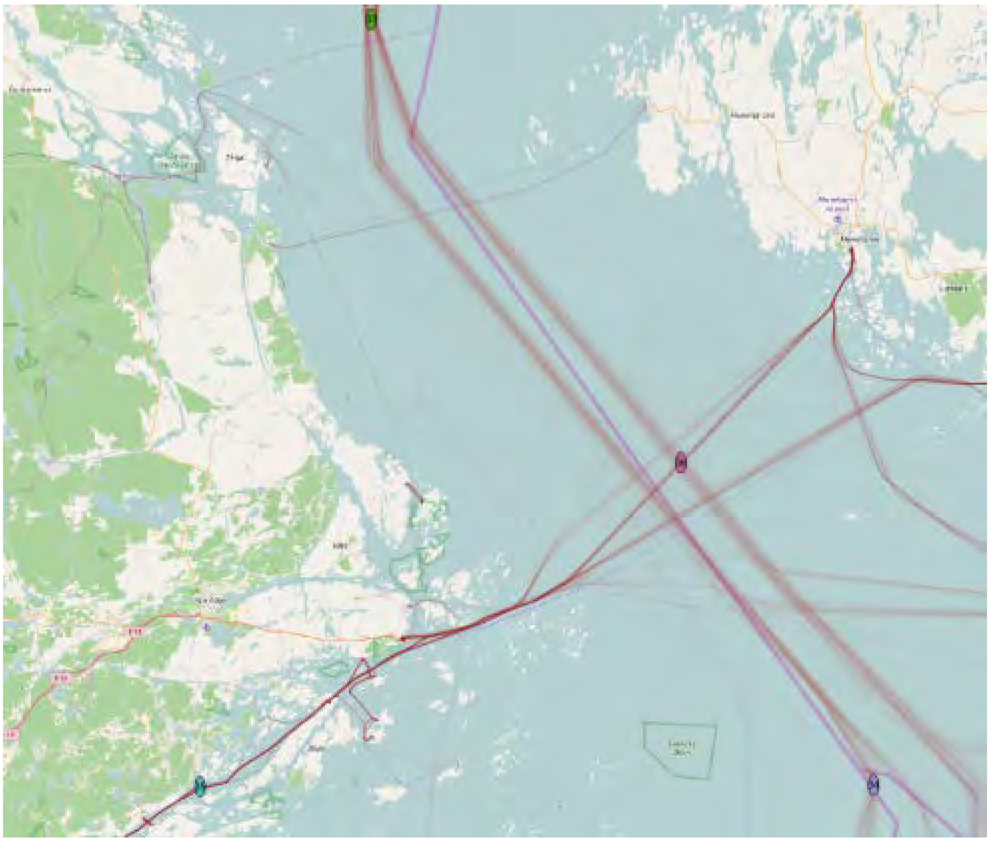

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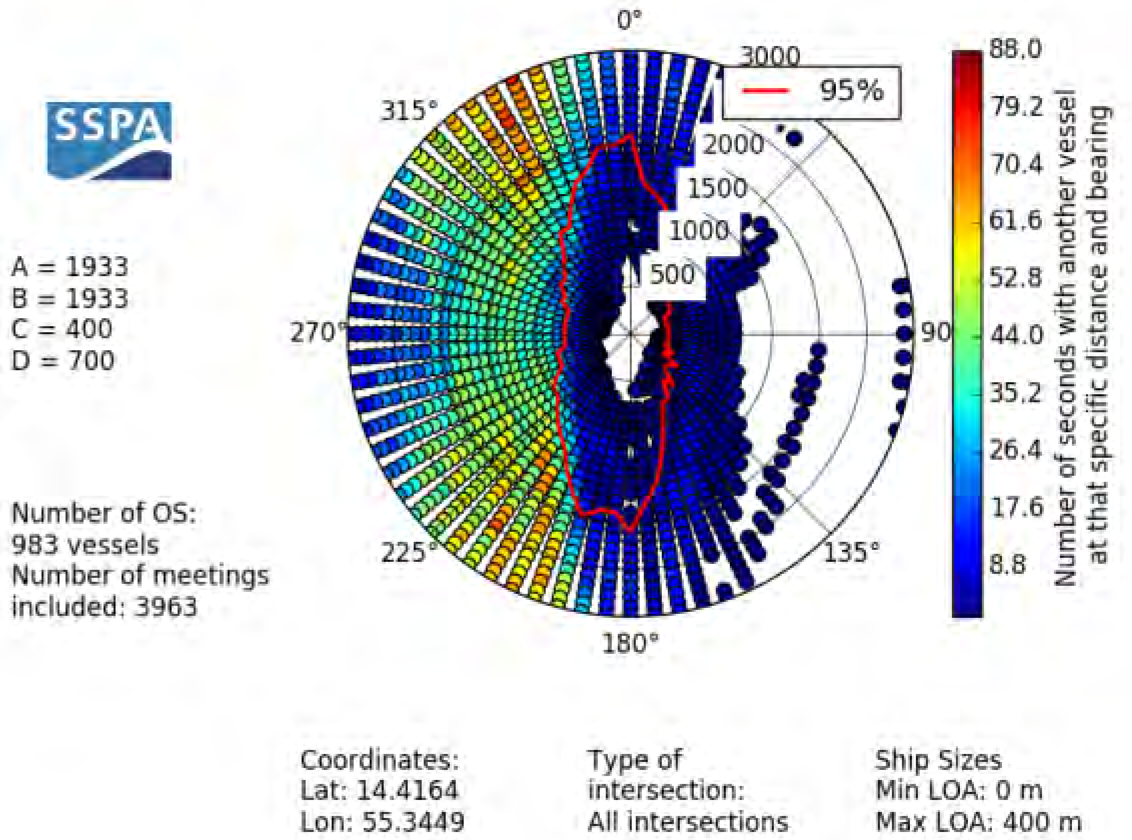
Location 1.



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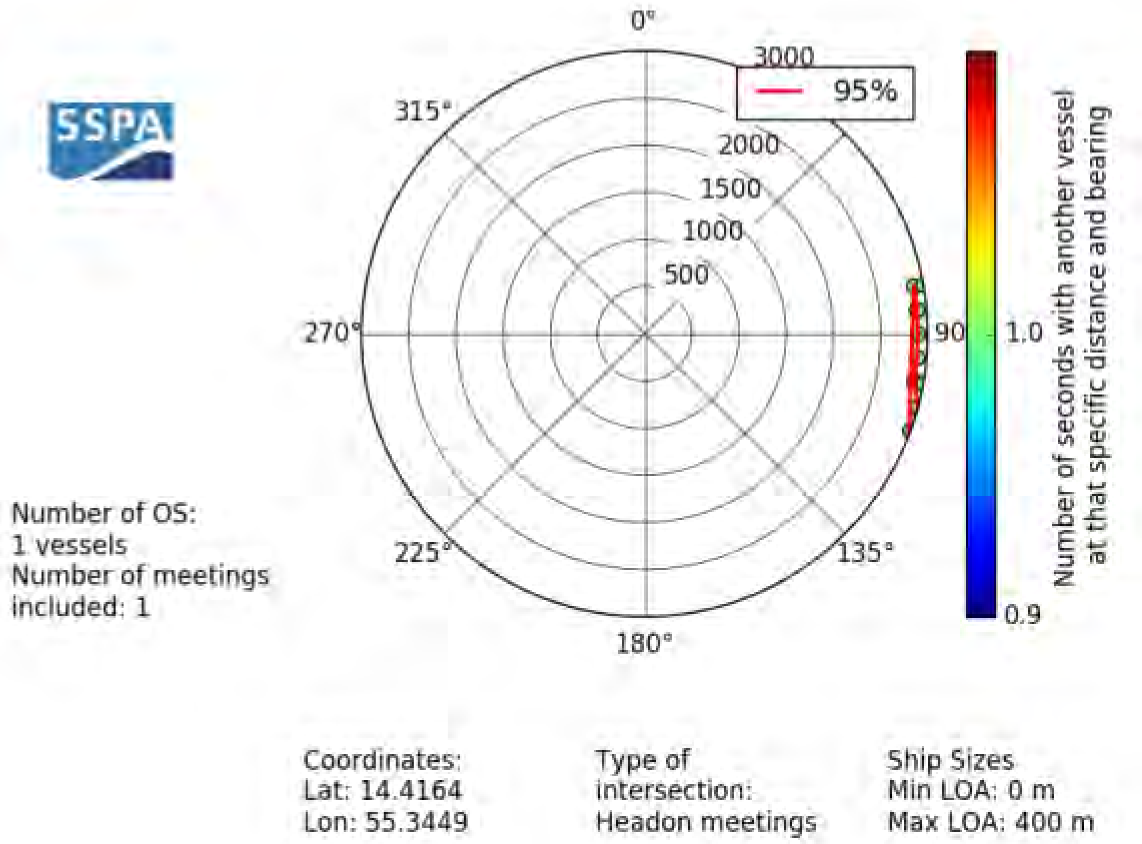

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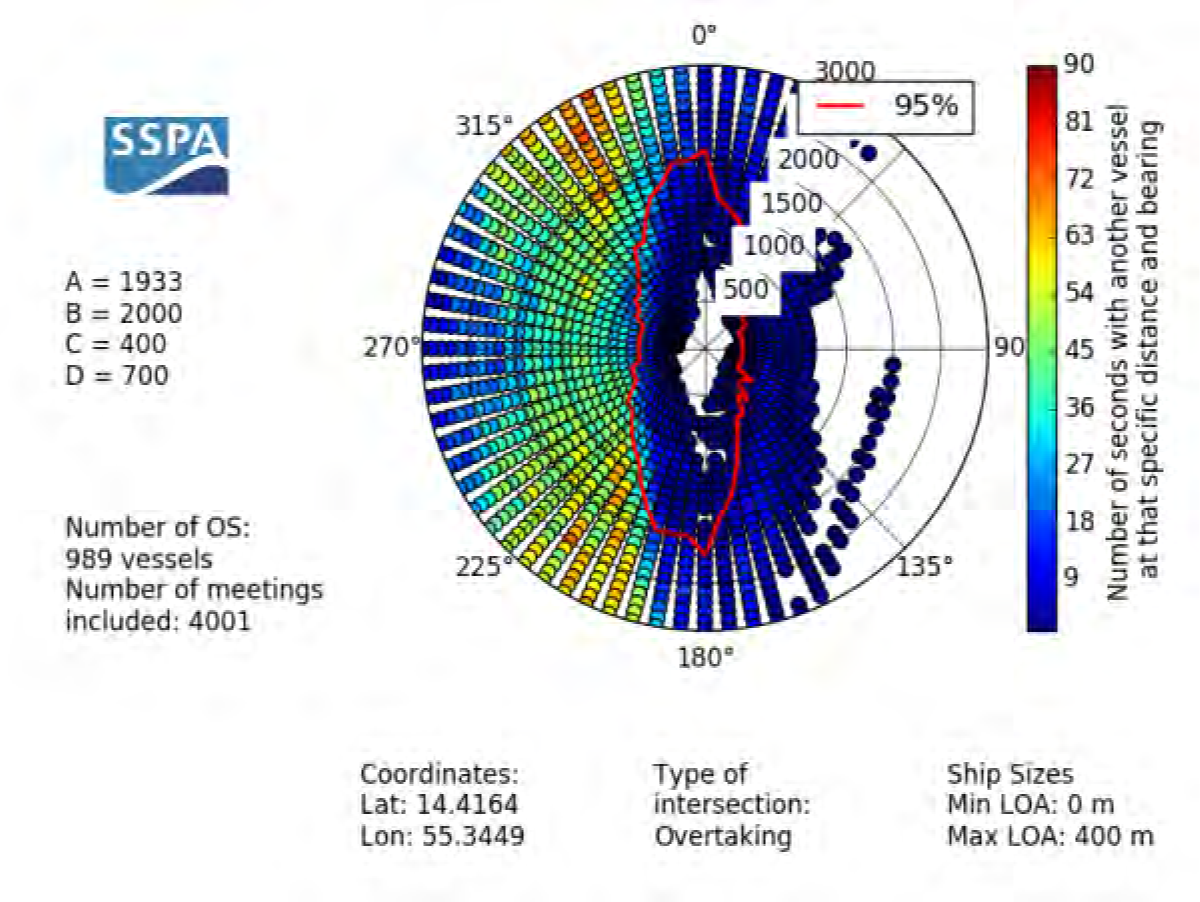

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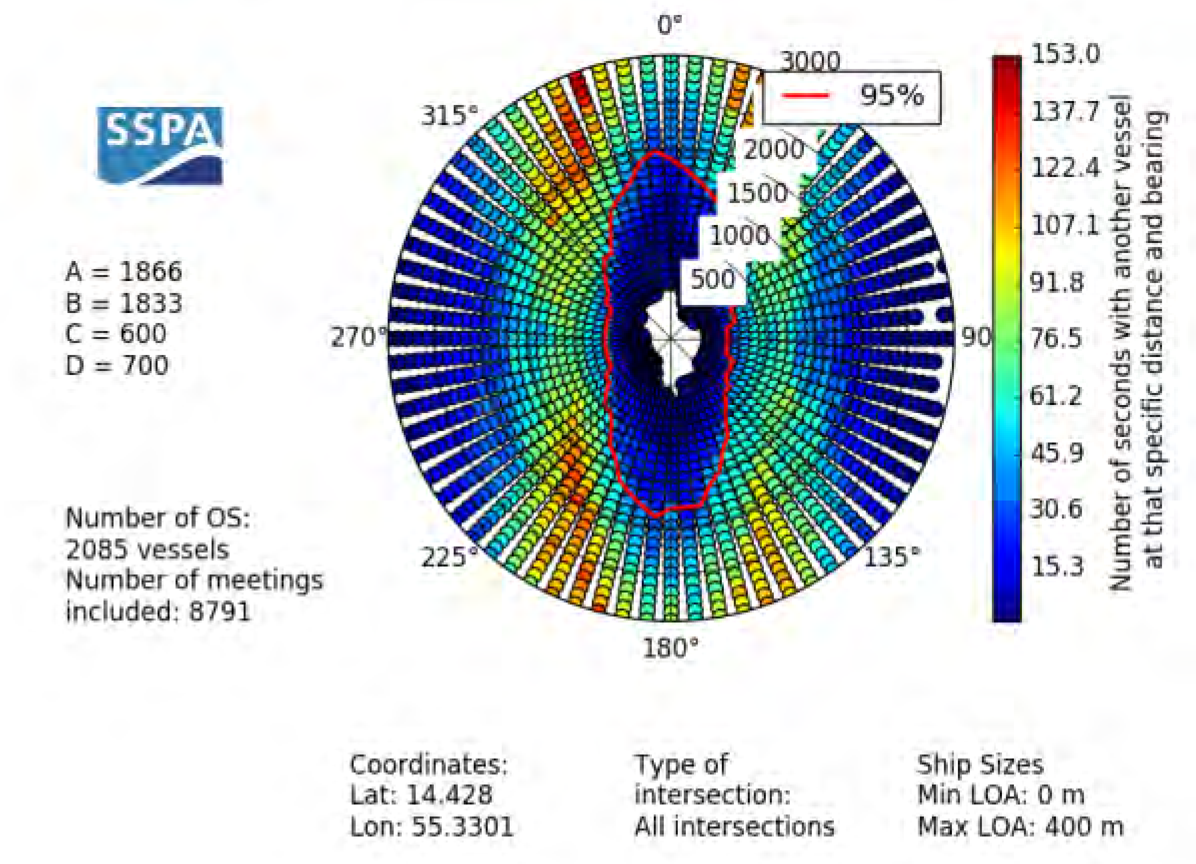
Location 2.



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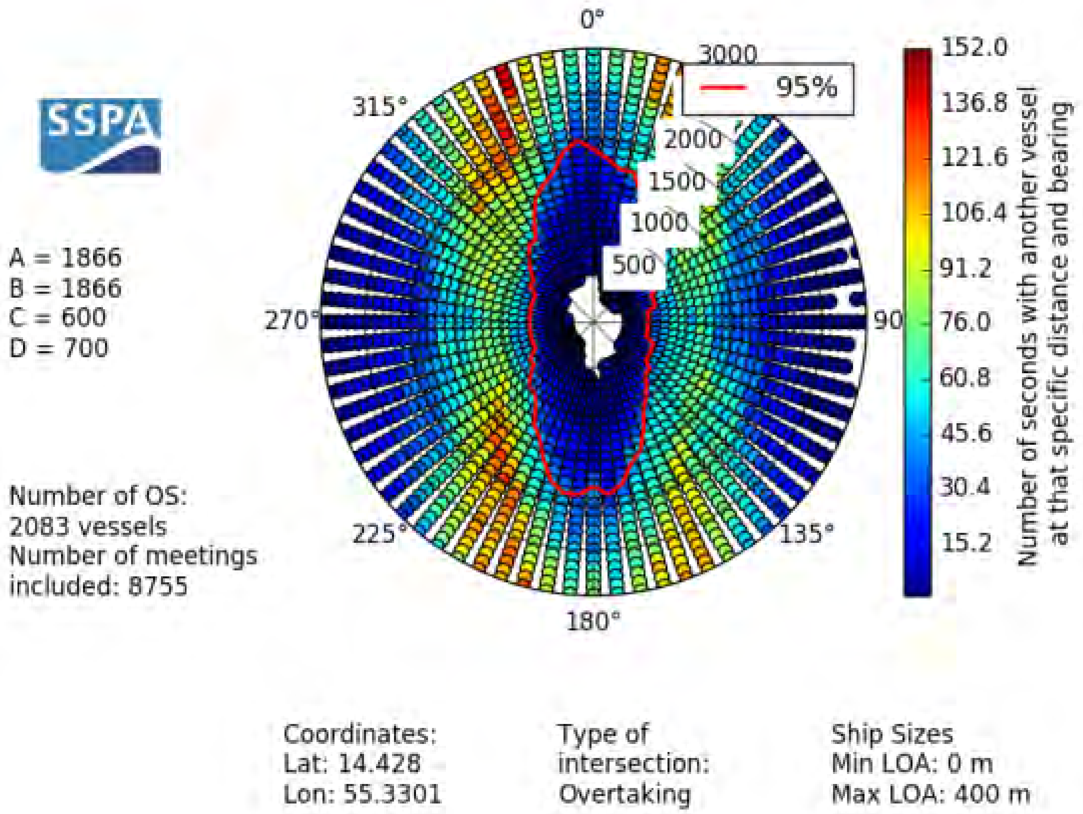

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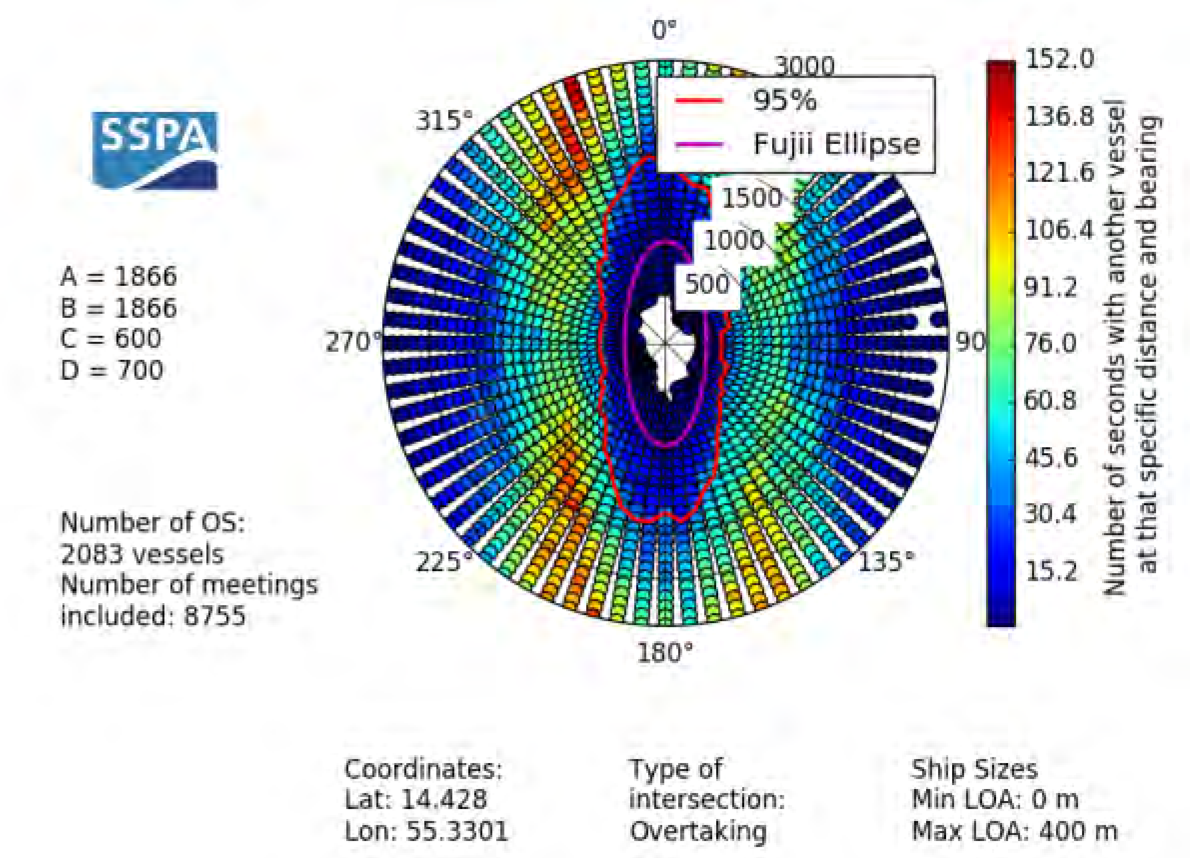

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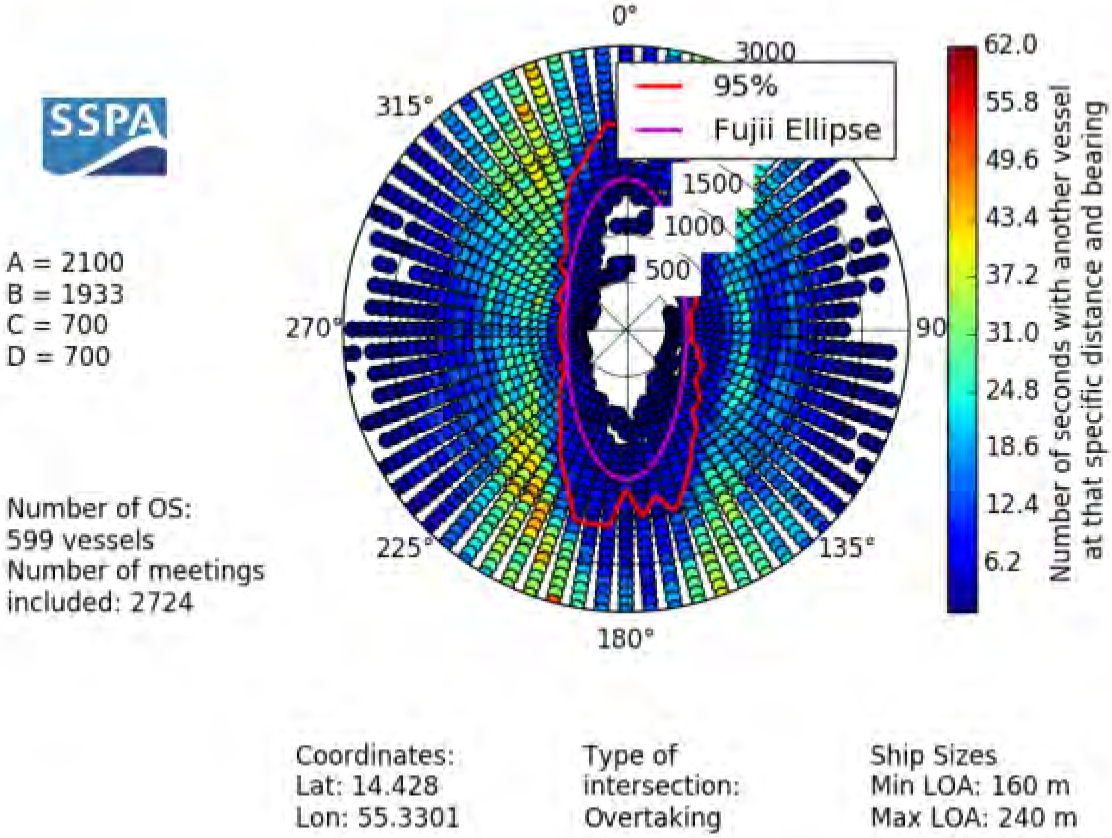

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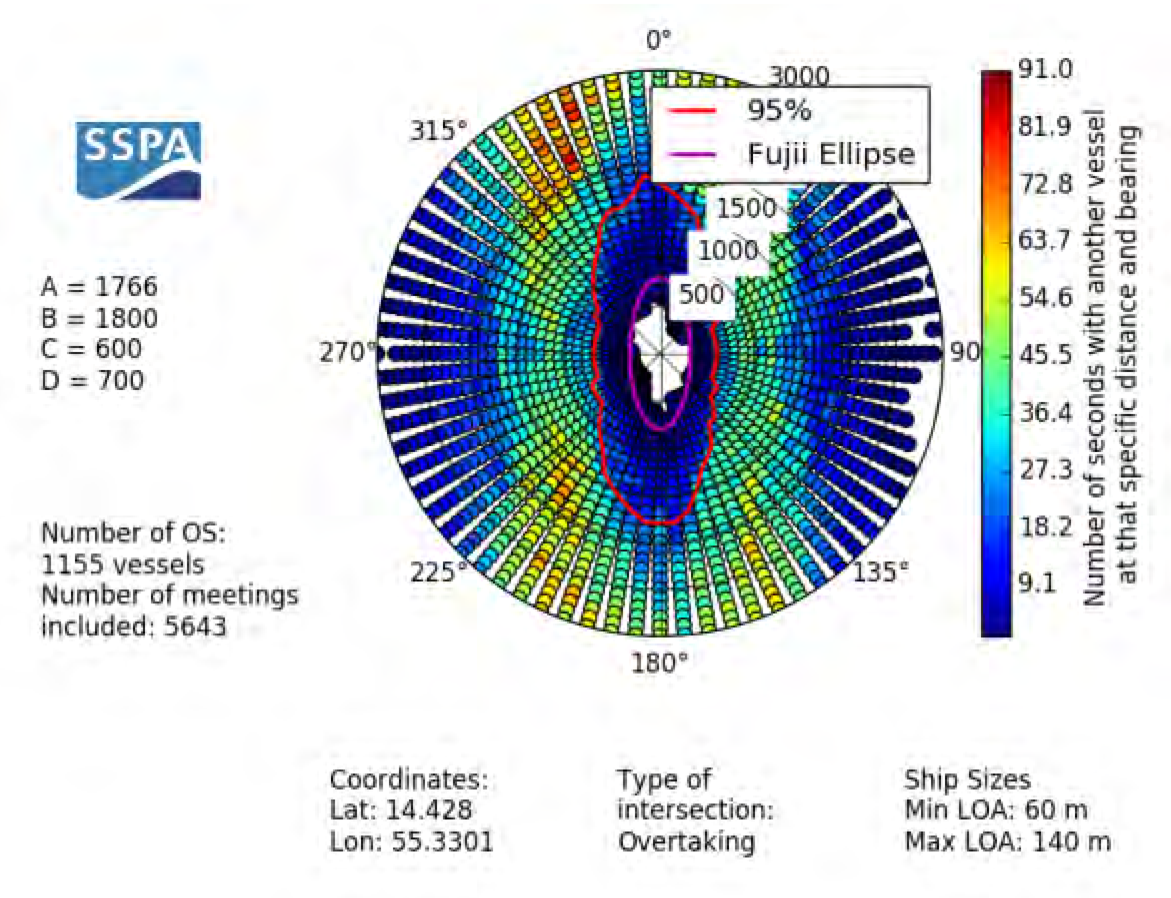

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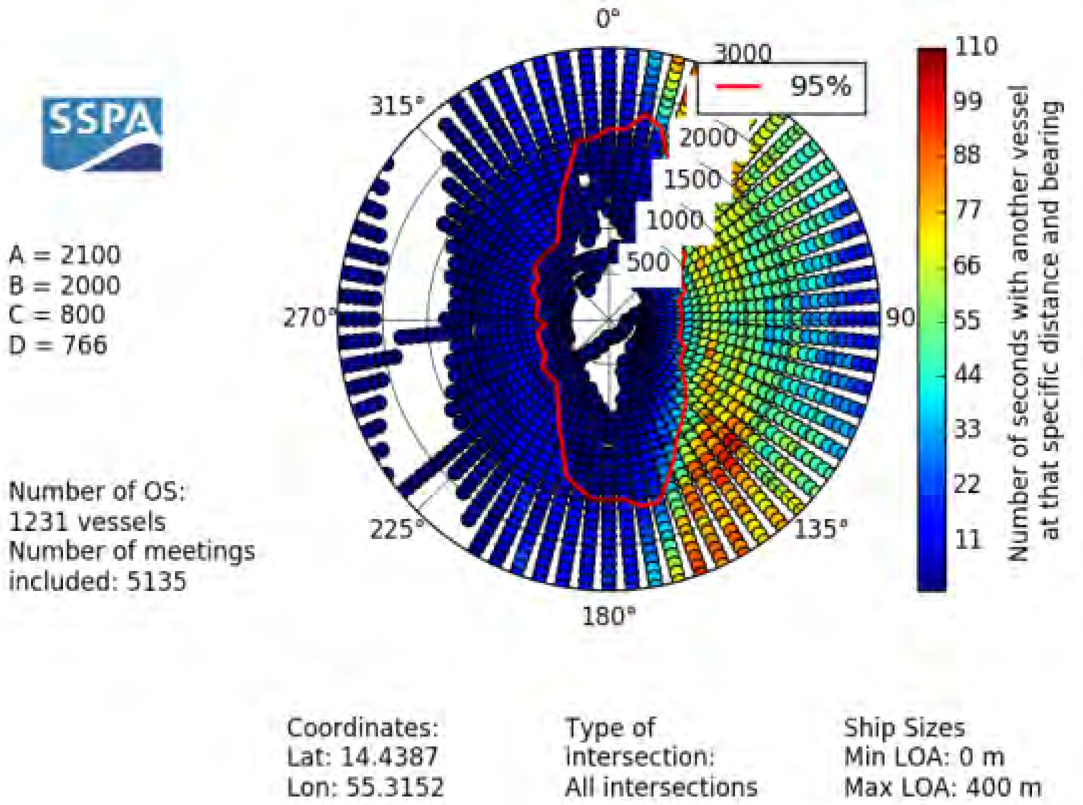

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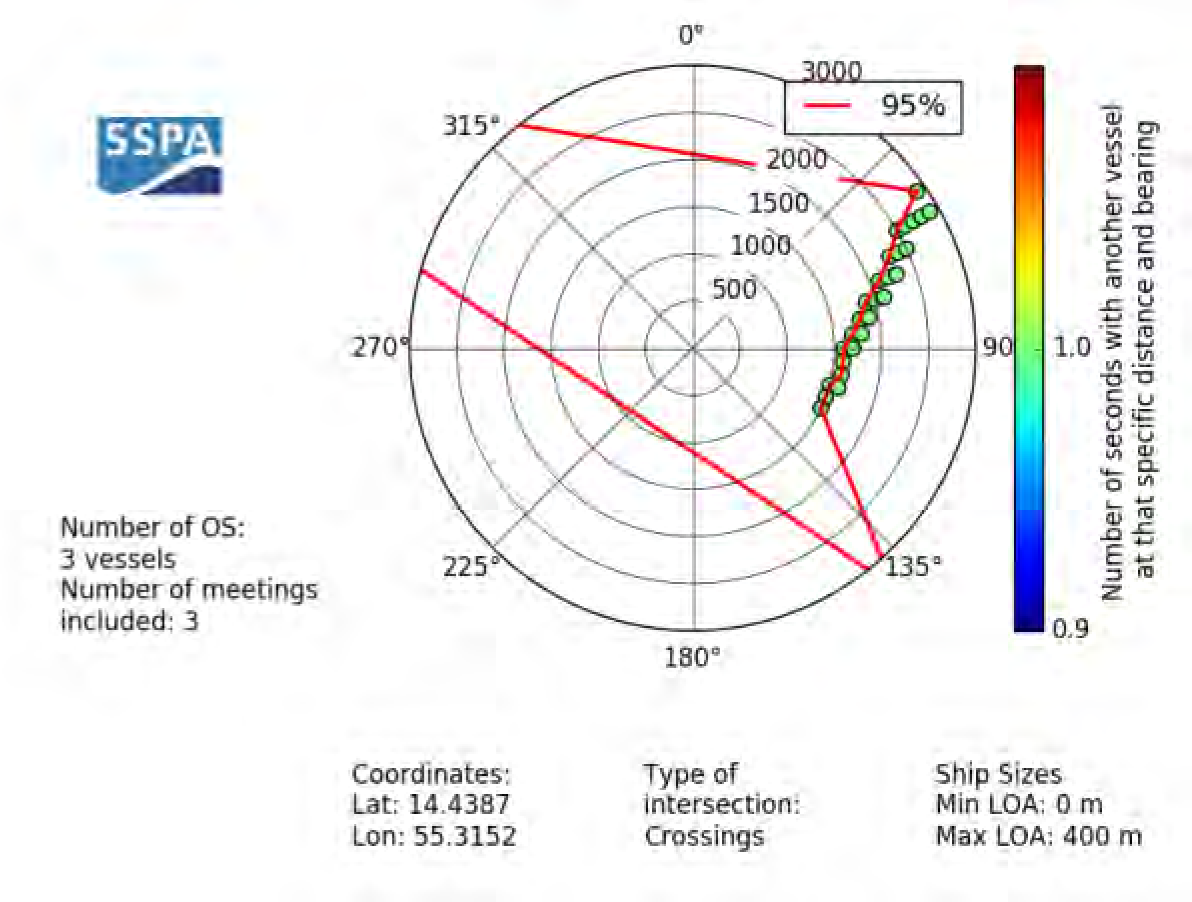

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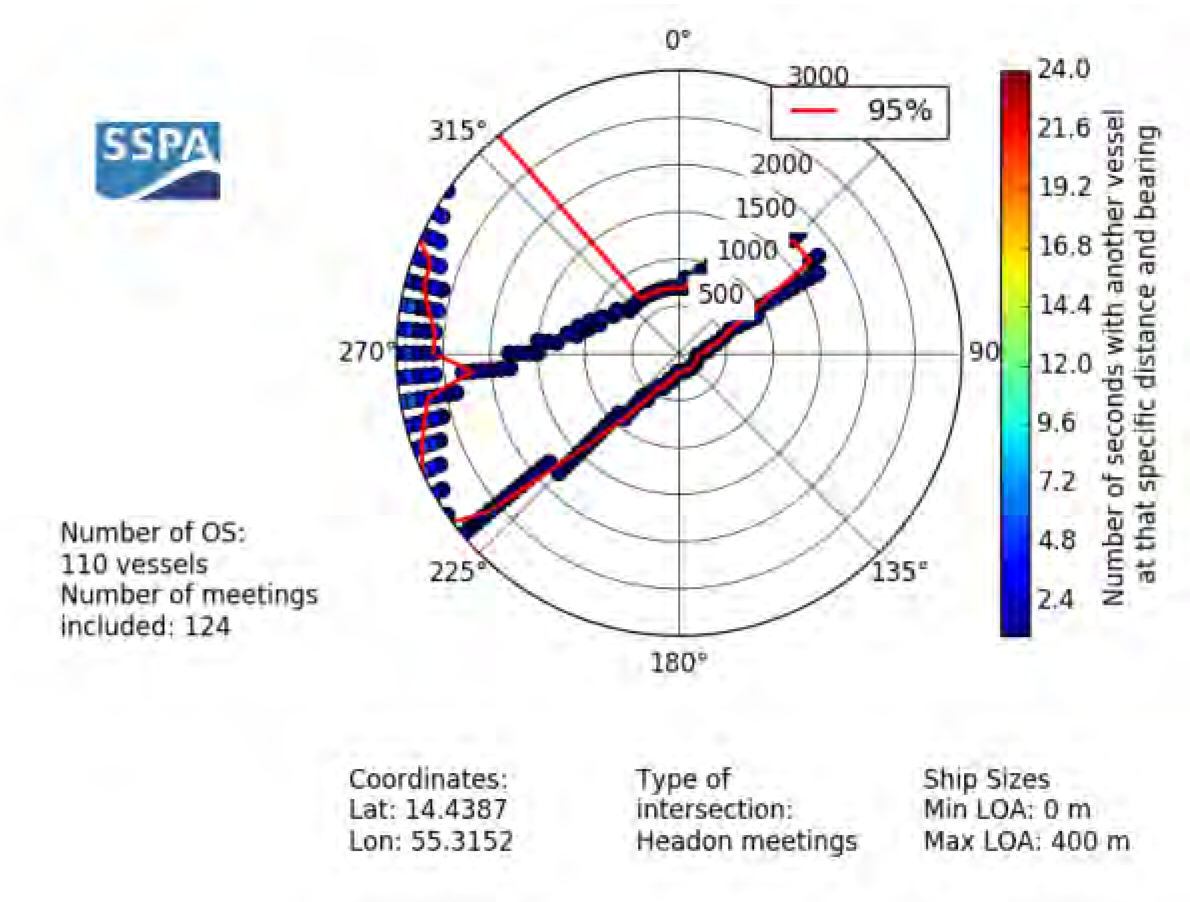

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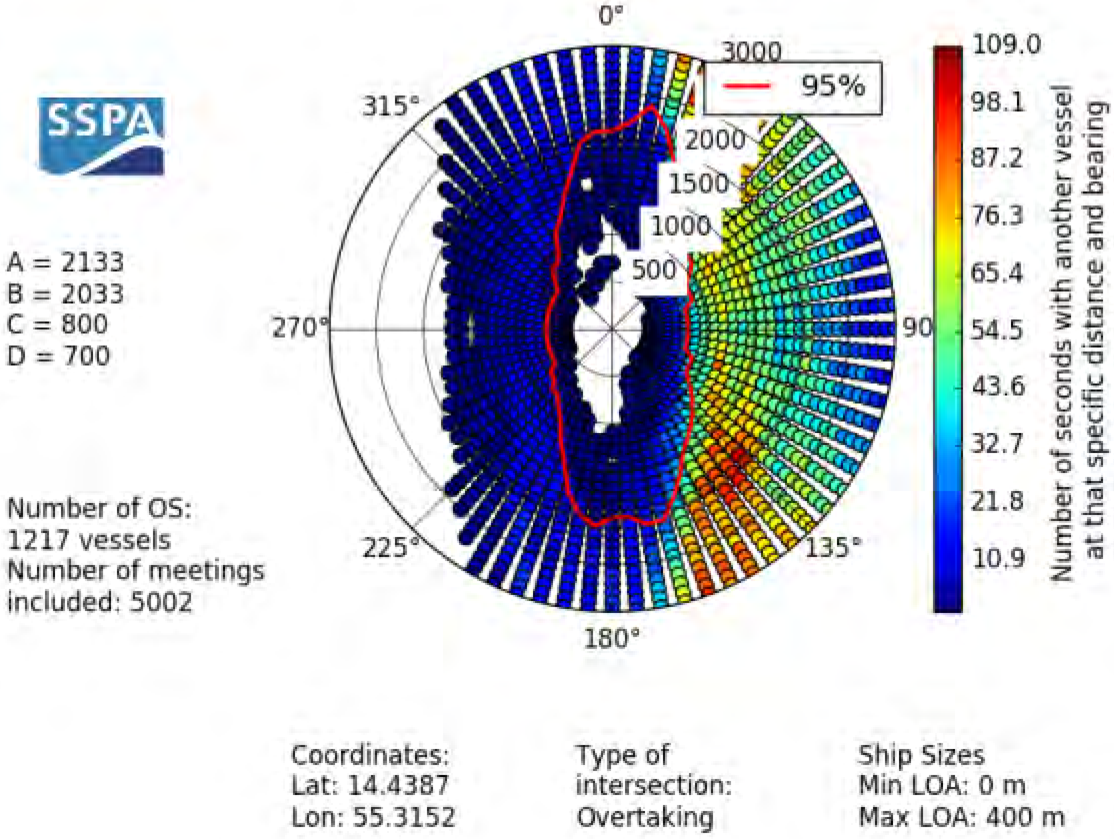

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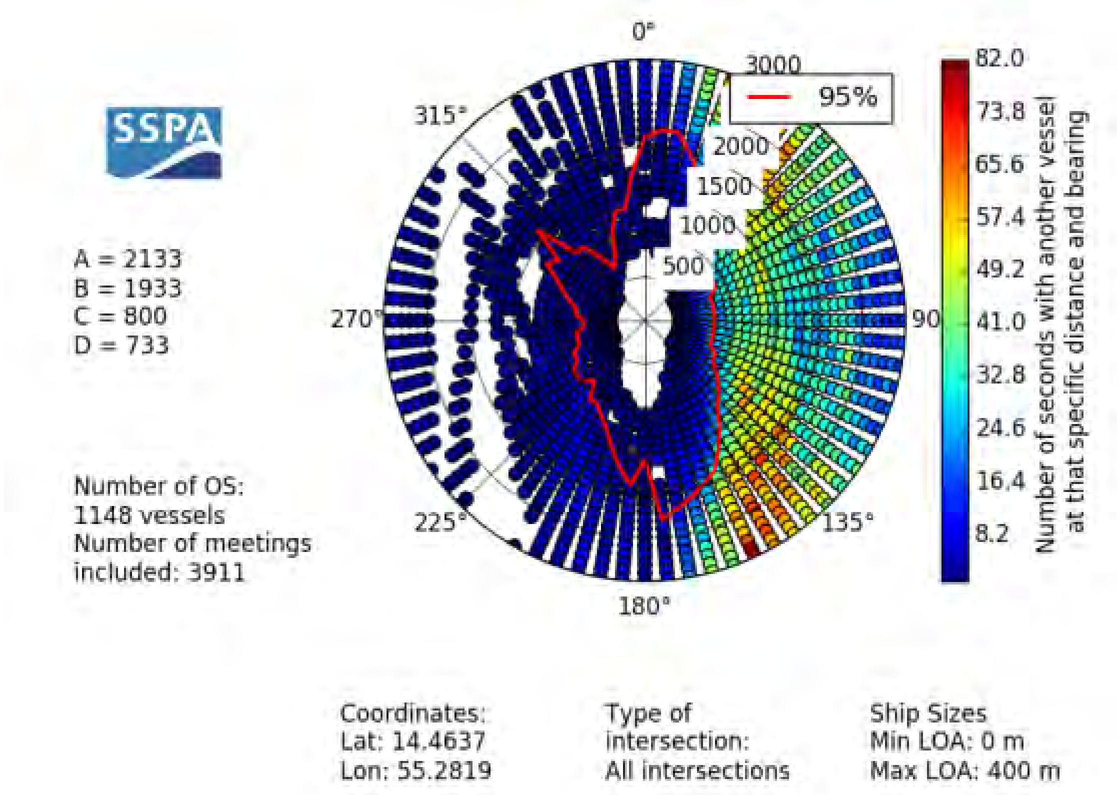
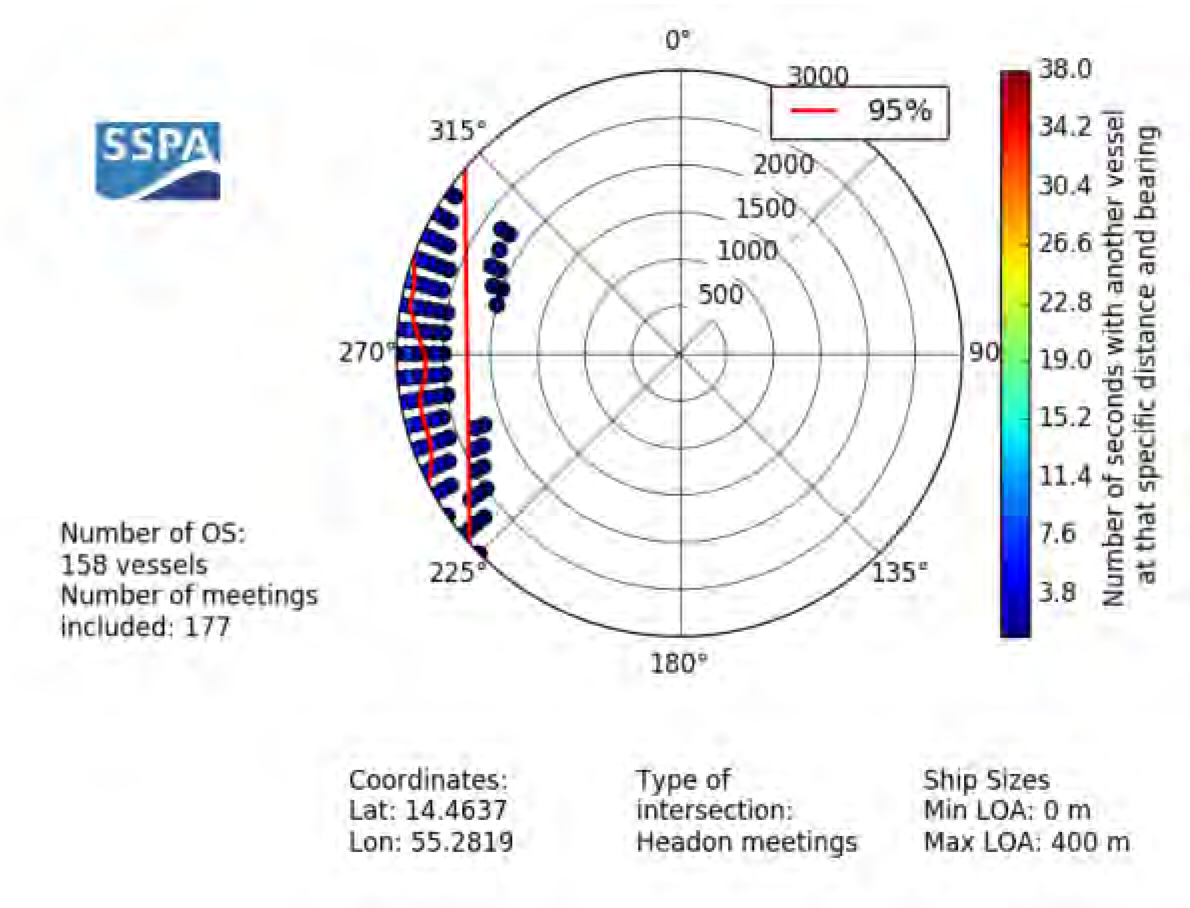
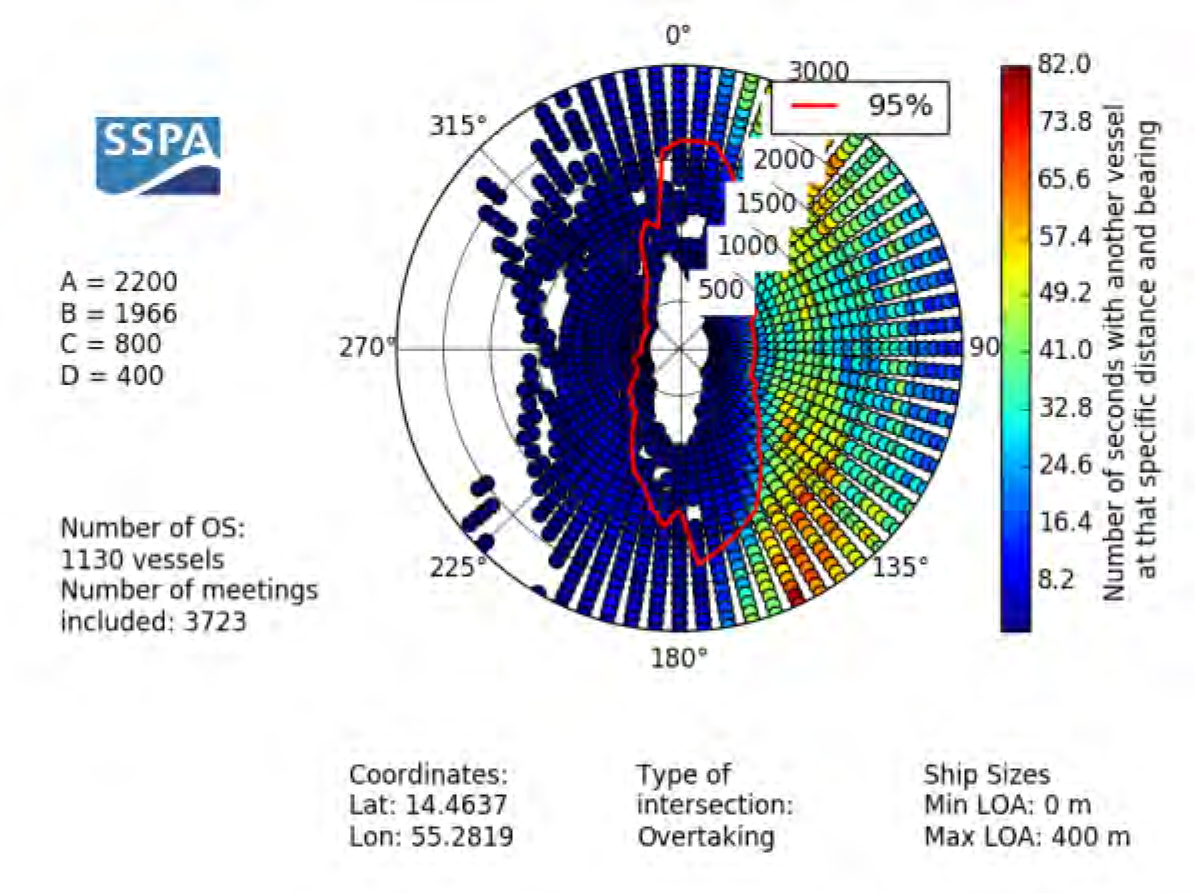
Location 4.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

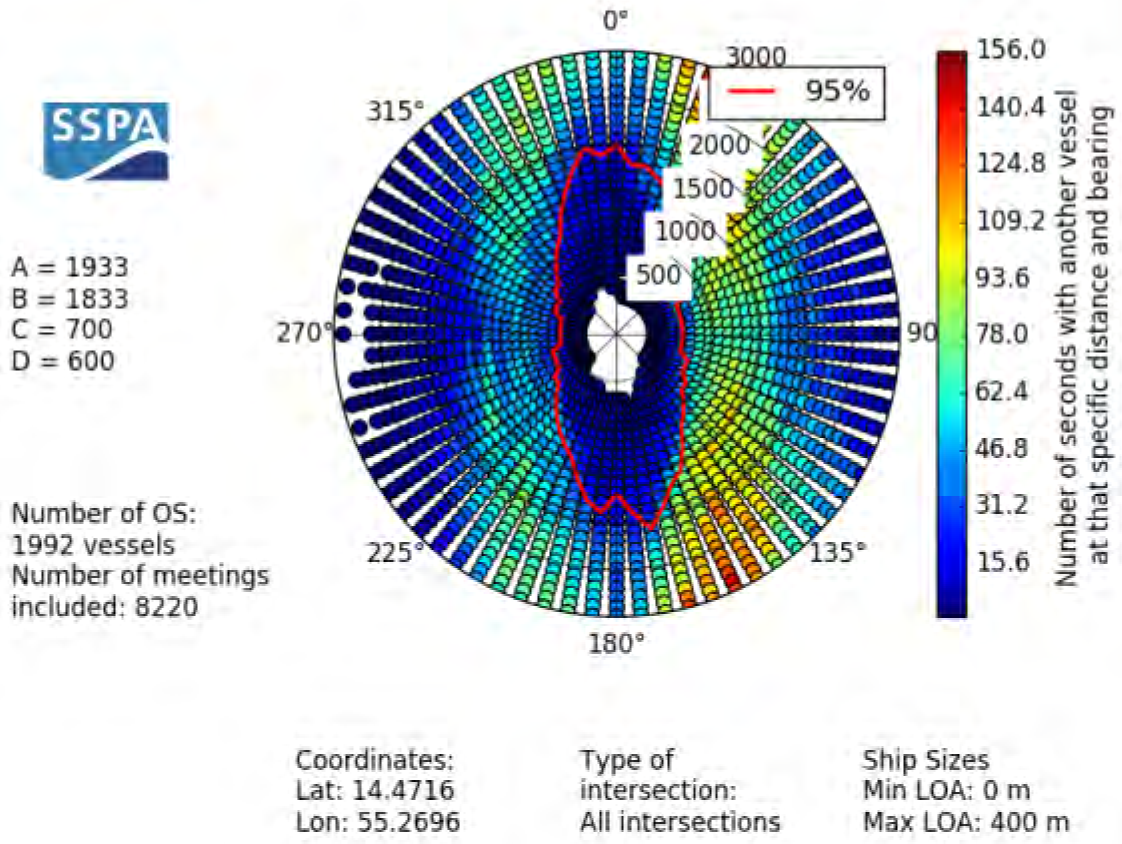


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

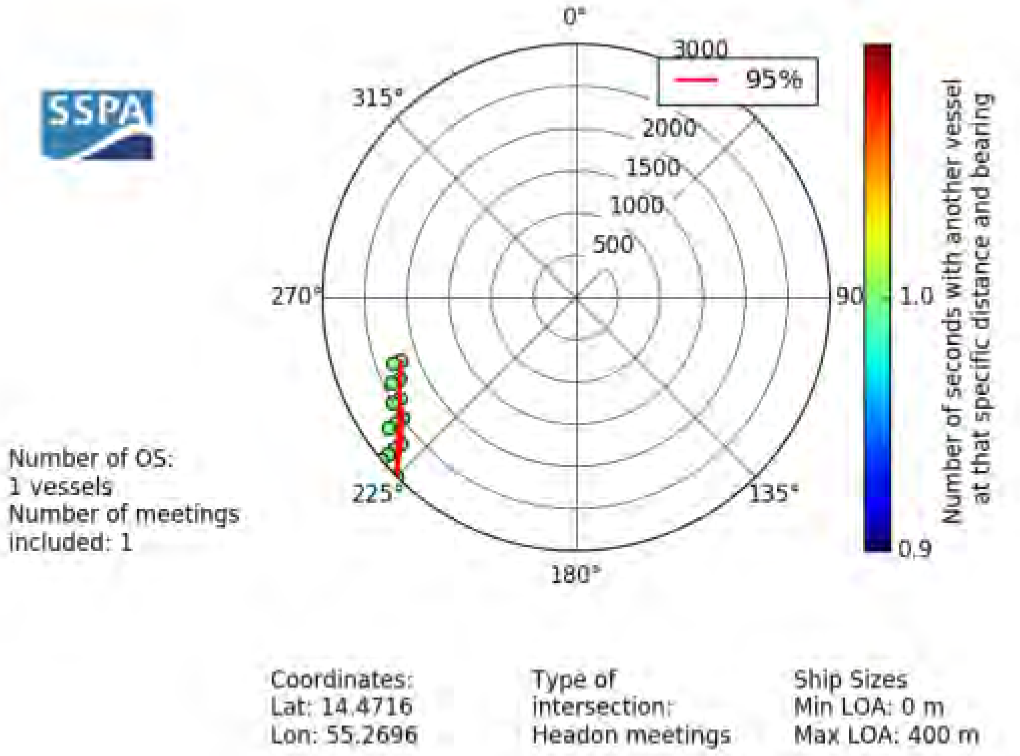


Location 5.

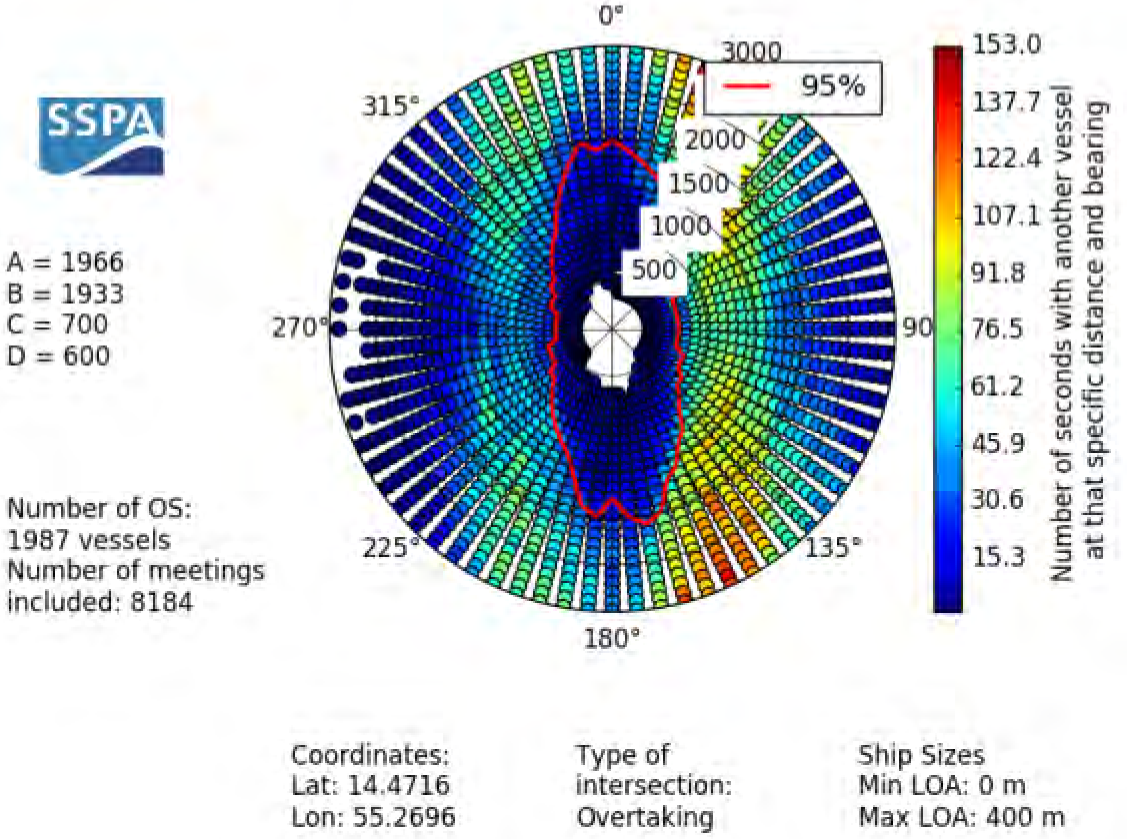
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

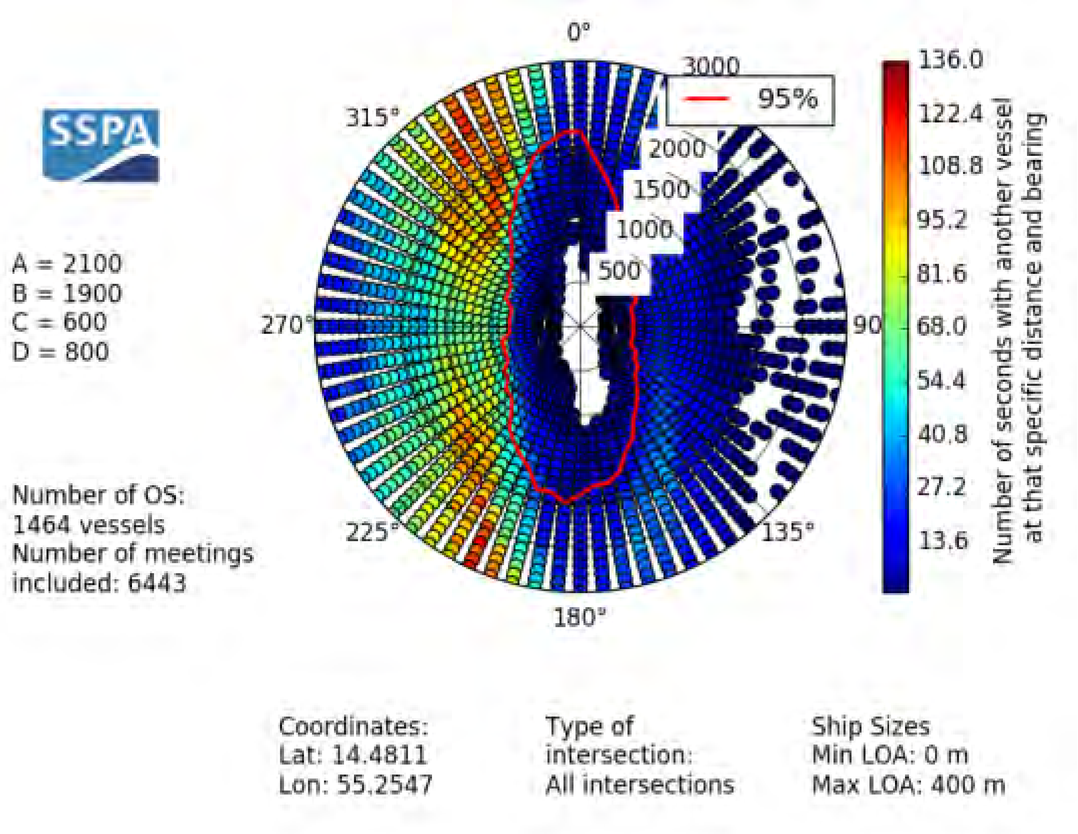


“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

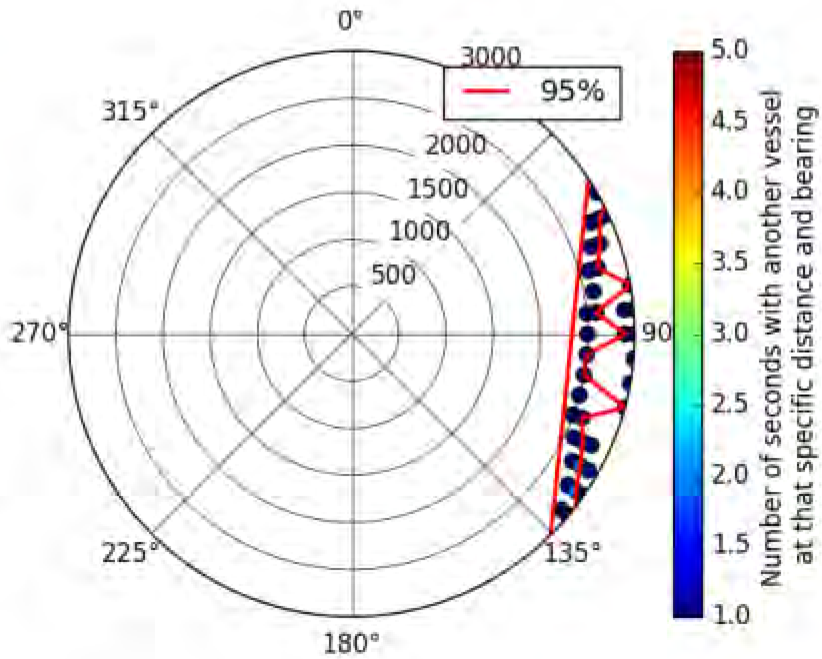


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 6.



“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.



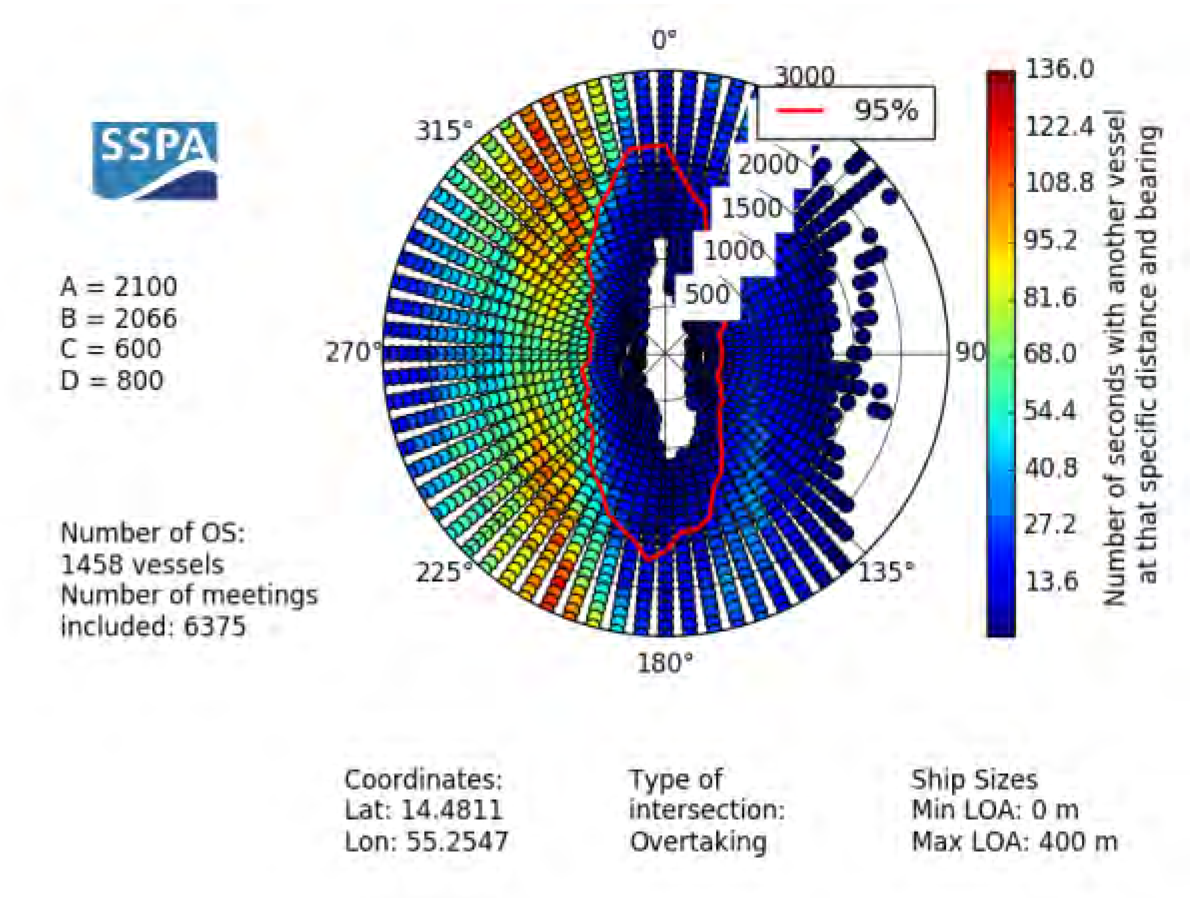
Number of OS:
22 vessels
Number of meetings included: 23

Coordinates:
Lat: 14.4811
Lon: 55.2547

Type of intersection:
Headon meetings

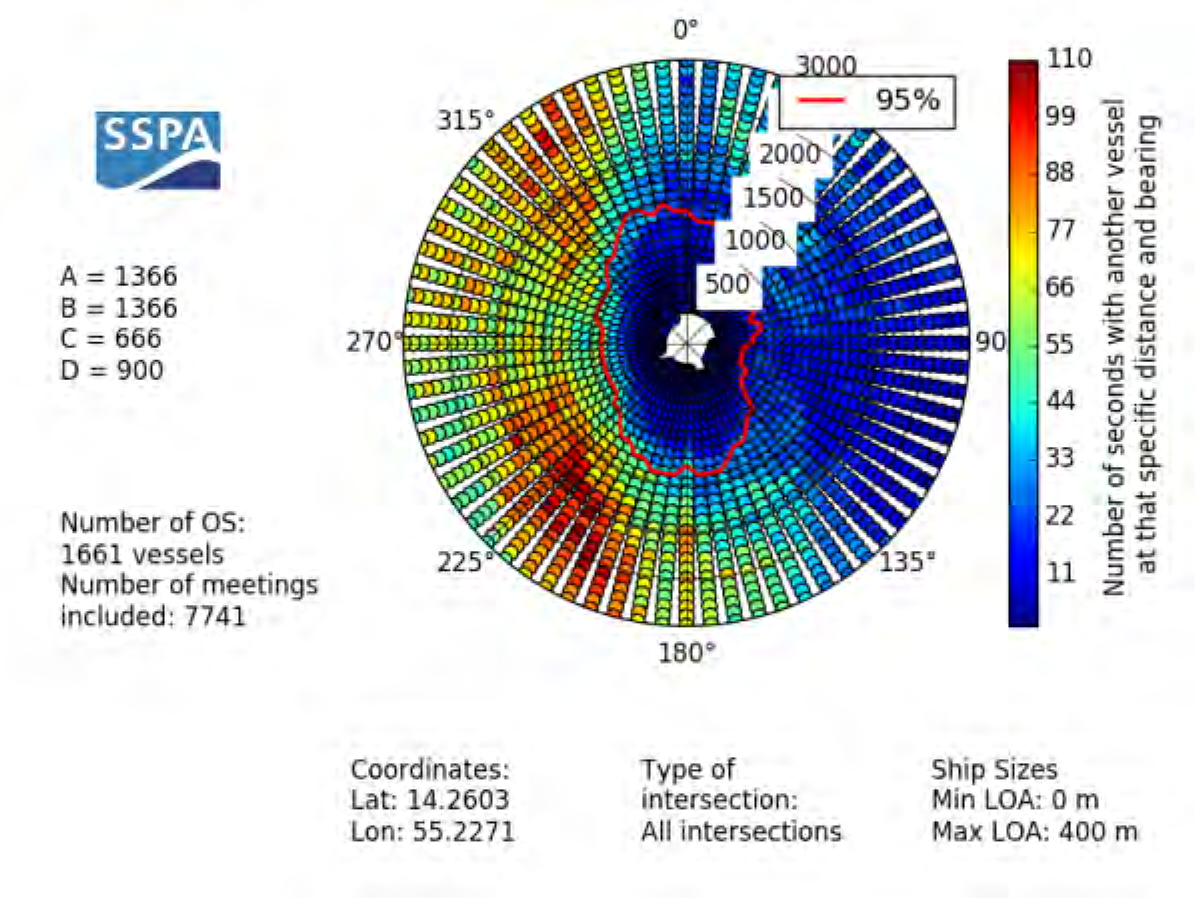
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

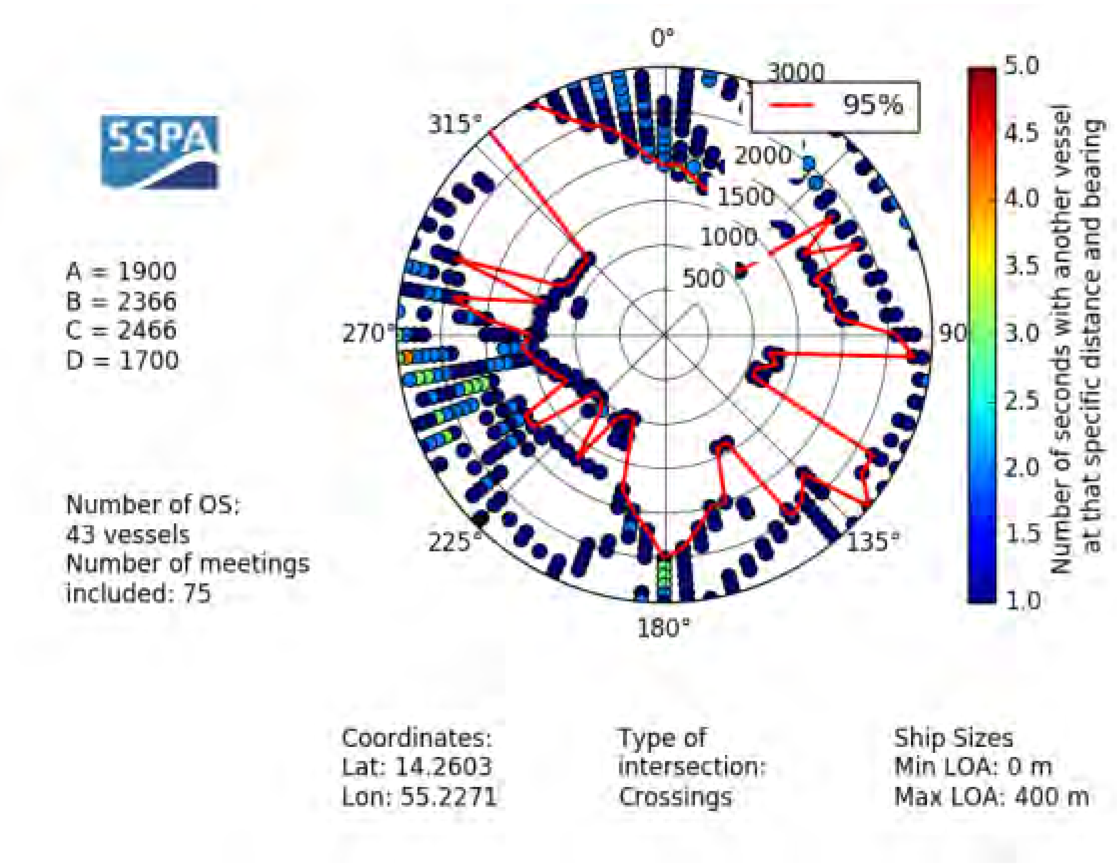


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

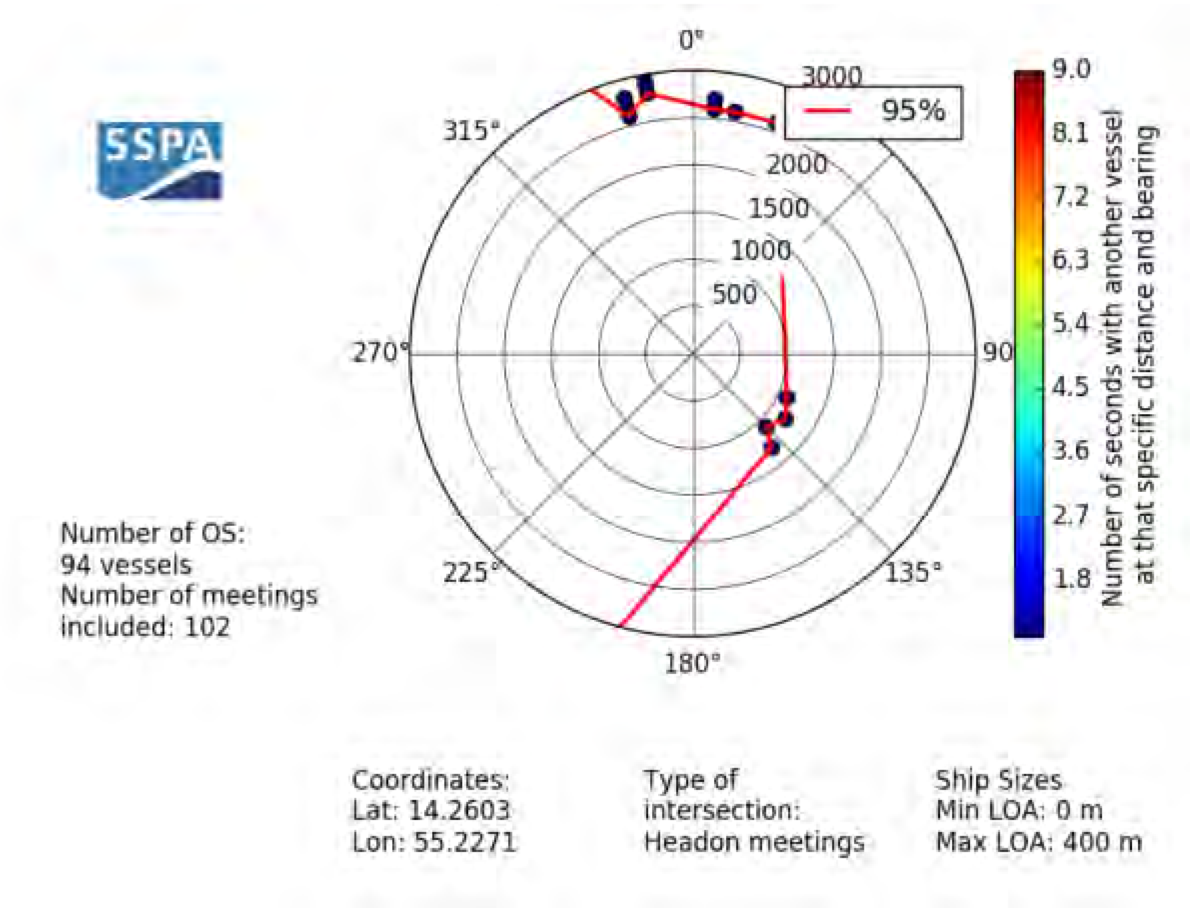
Location 7.



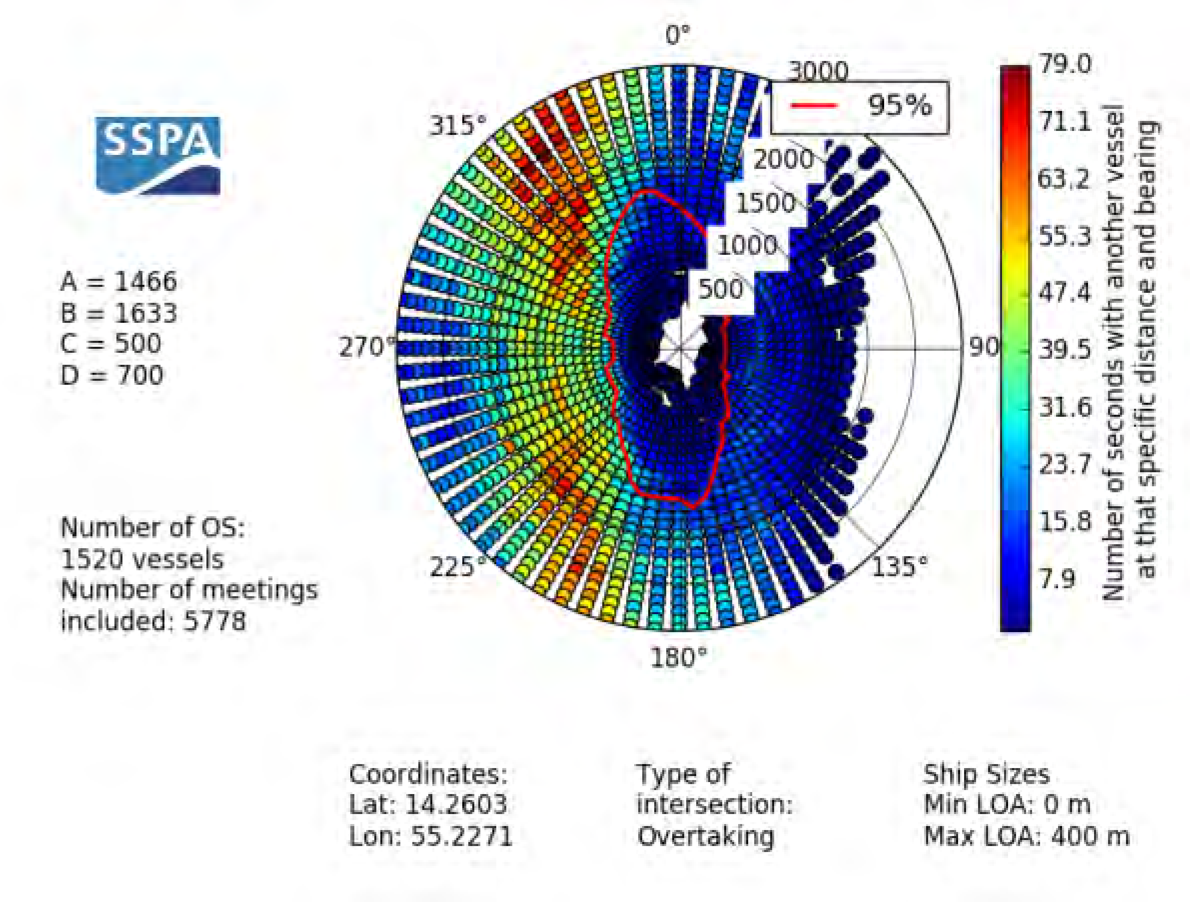
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

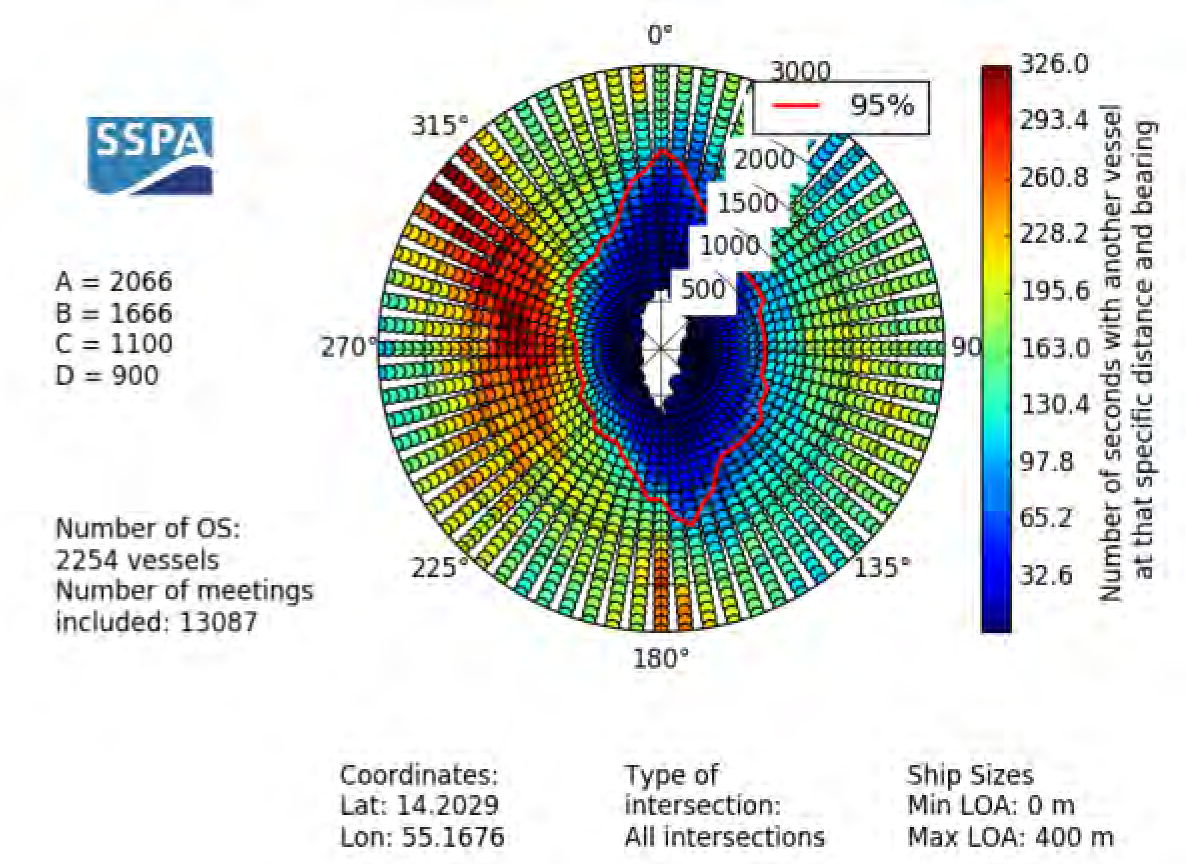


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

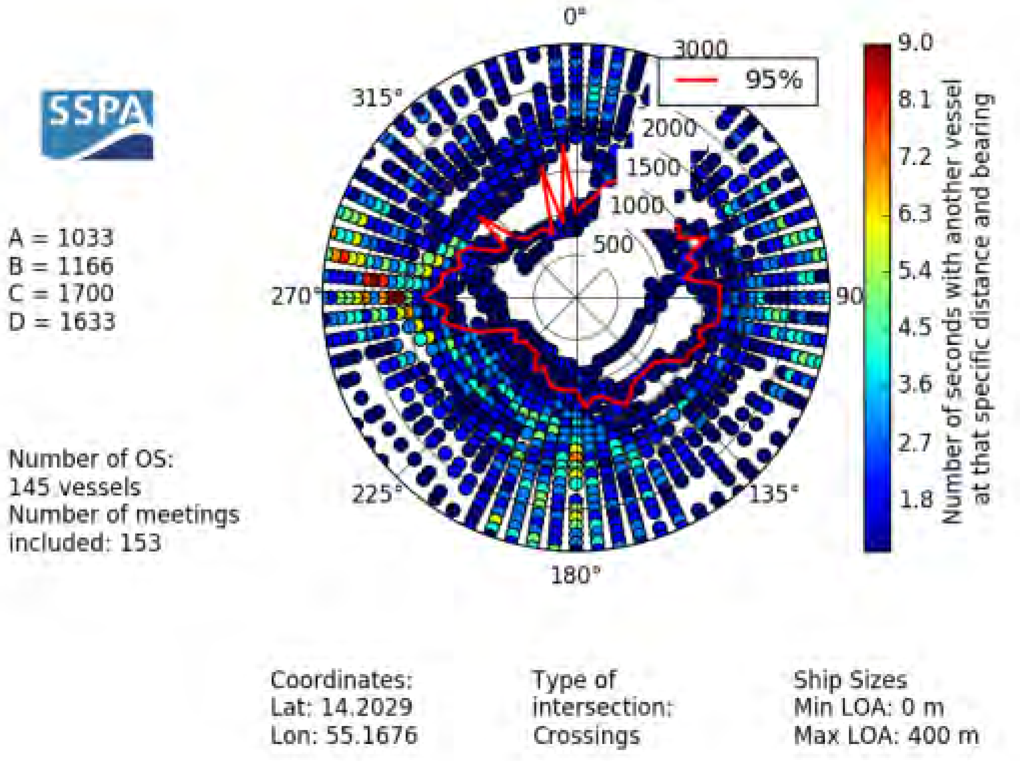


Location 8.

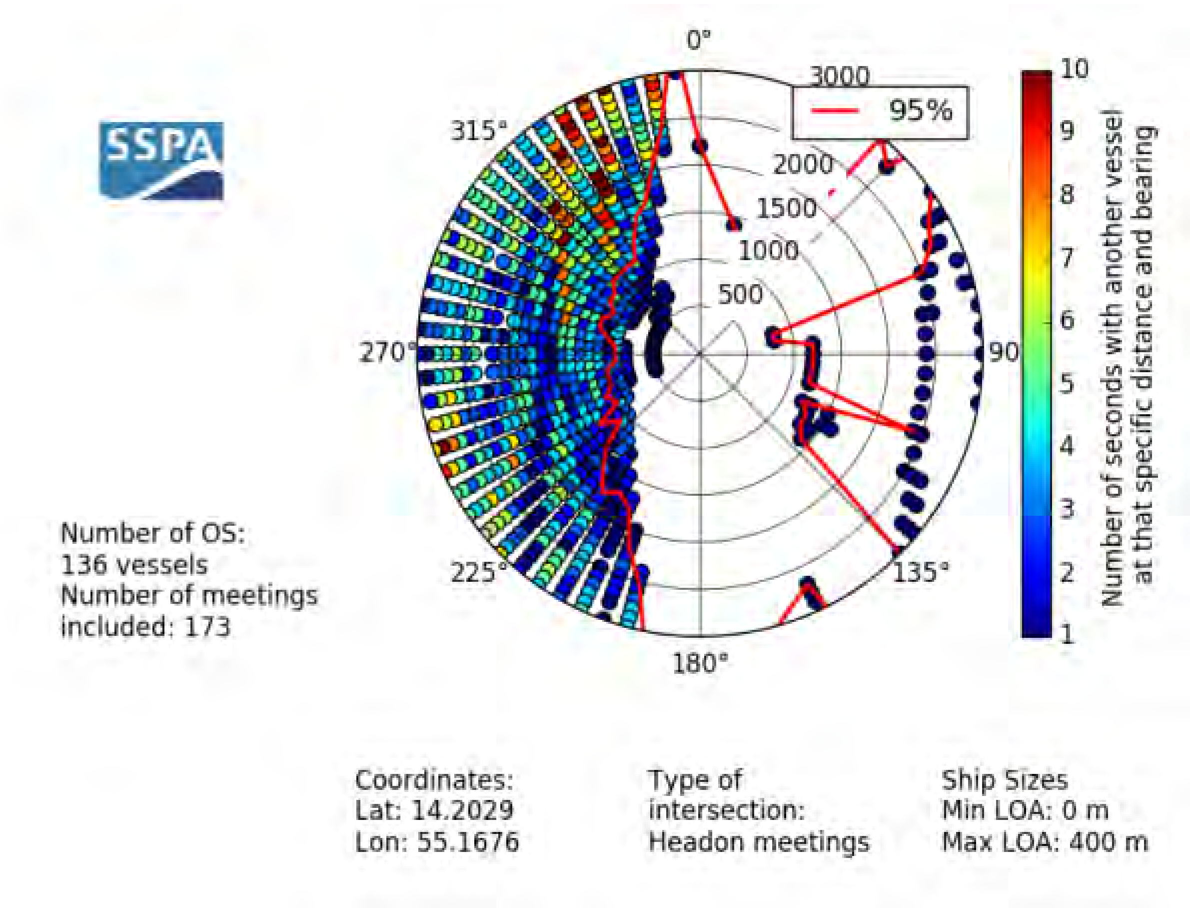
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



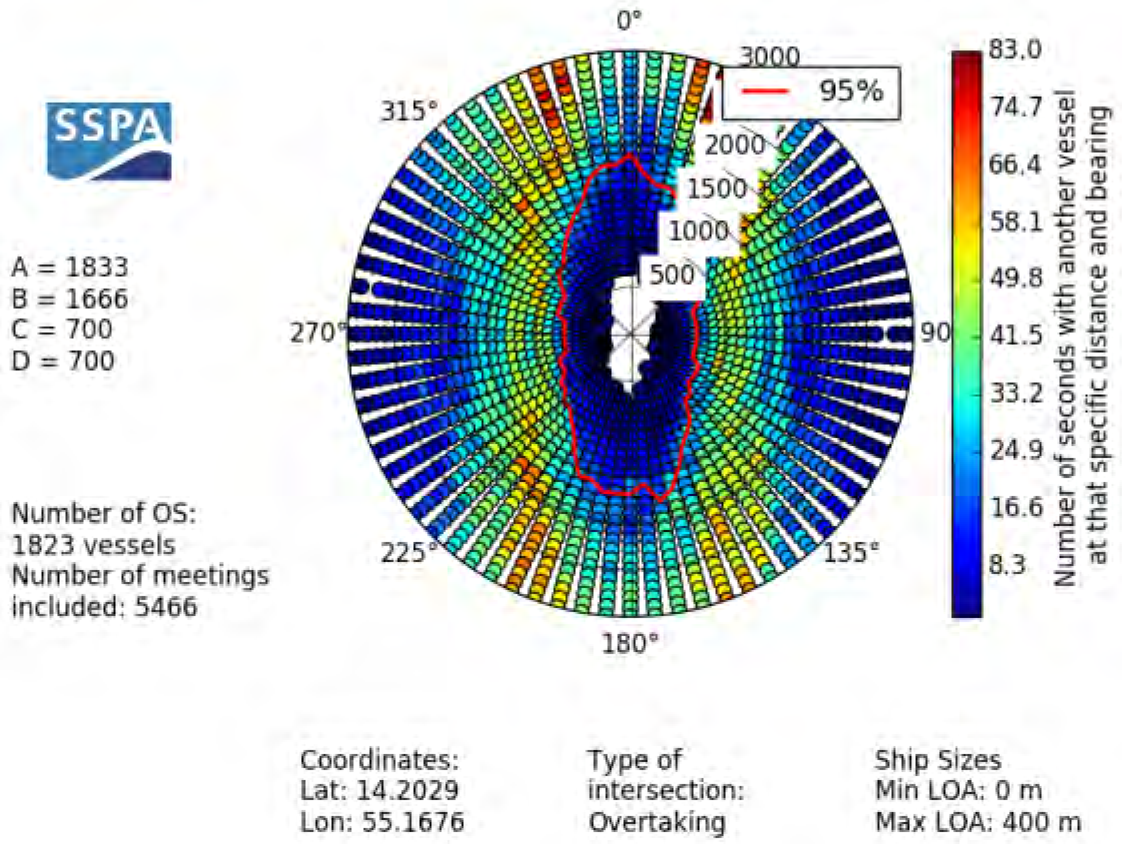
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

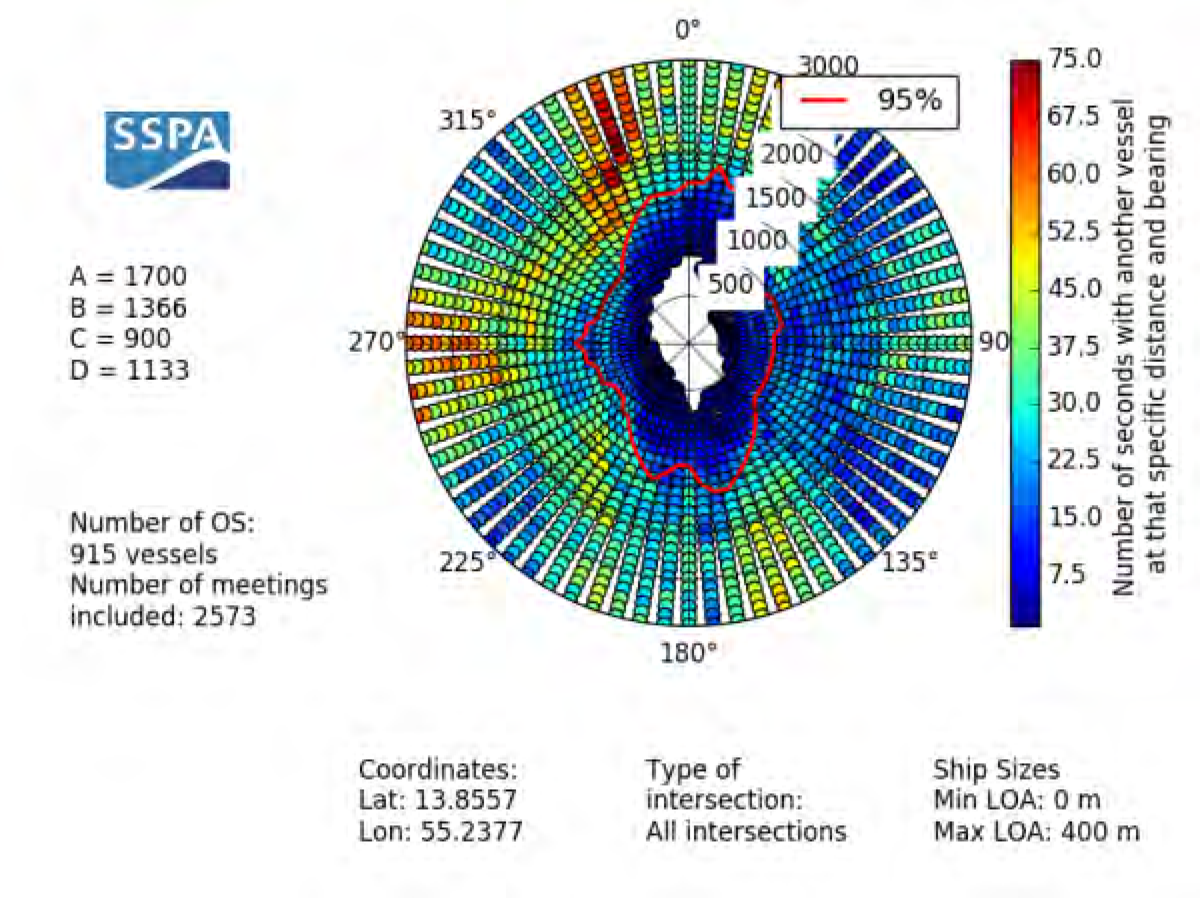


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

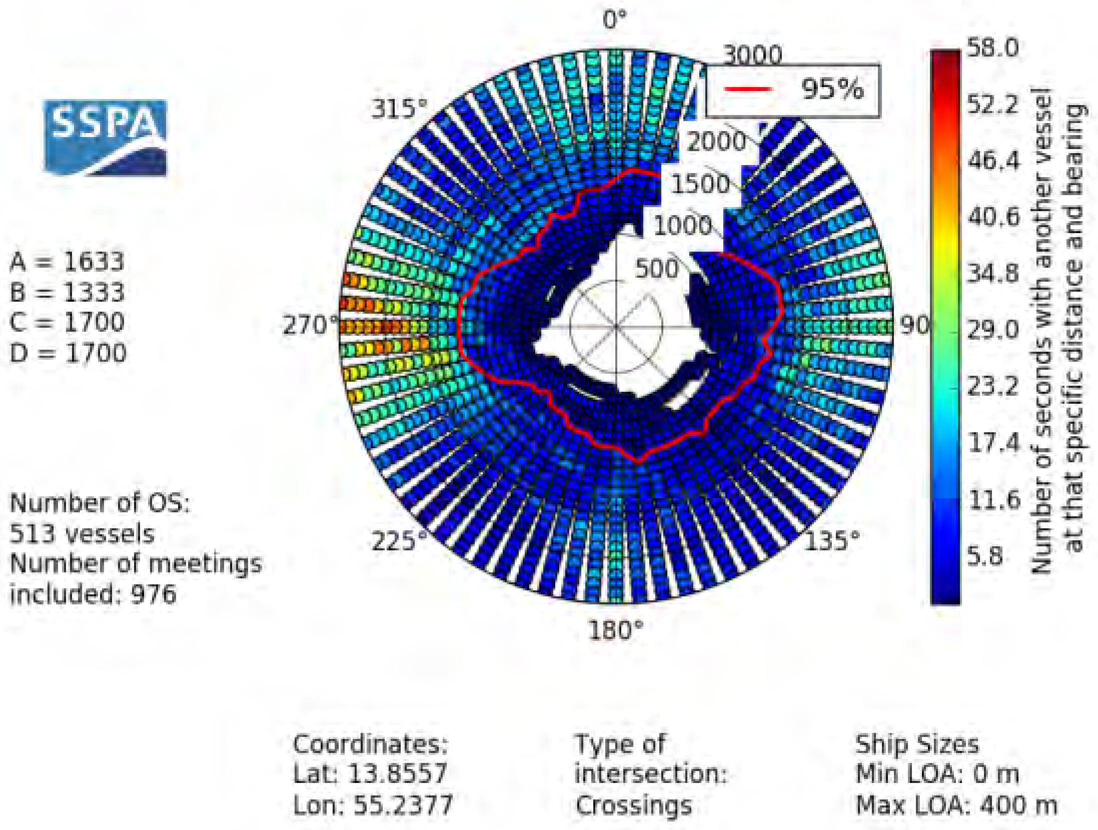


“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

Location 9.

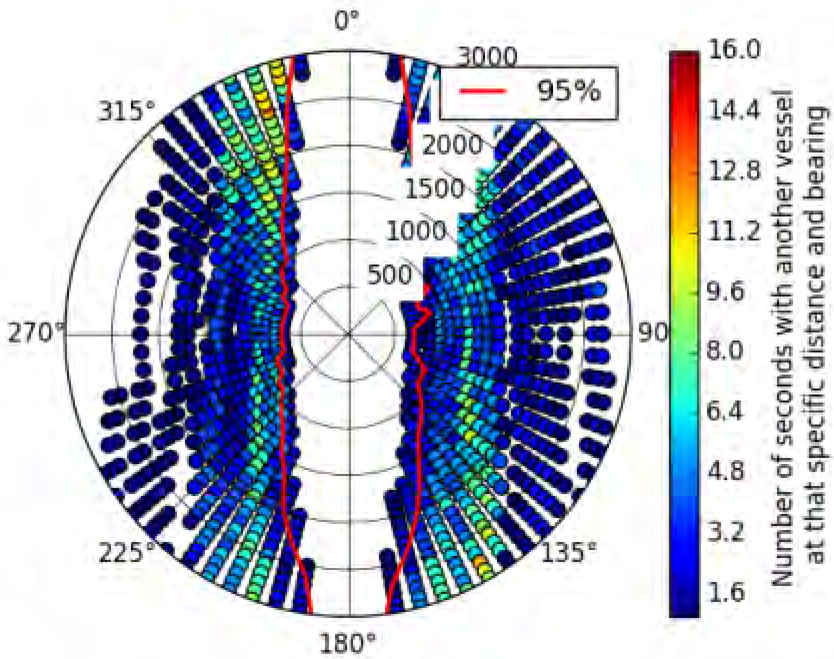


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Number of OS:
18 vessels
Number of meetings
included: 105

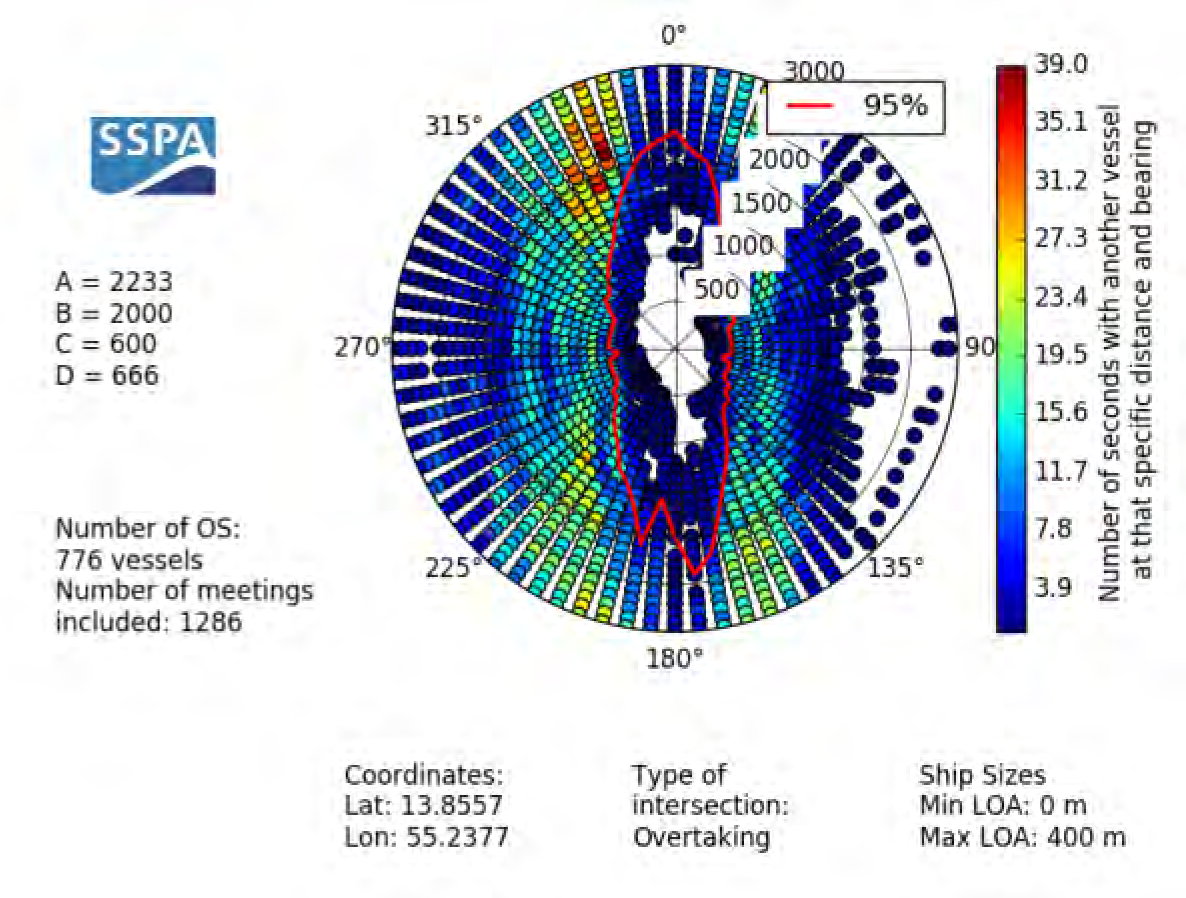


Coordinates:
Lat: 13.8557
Lon: 55.2377

Type of
intersection:
Headon meetings

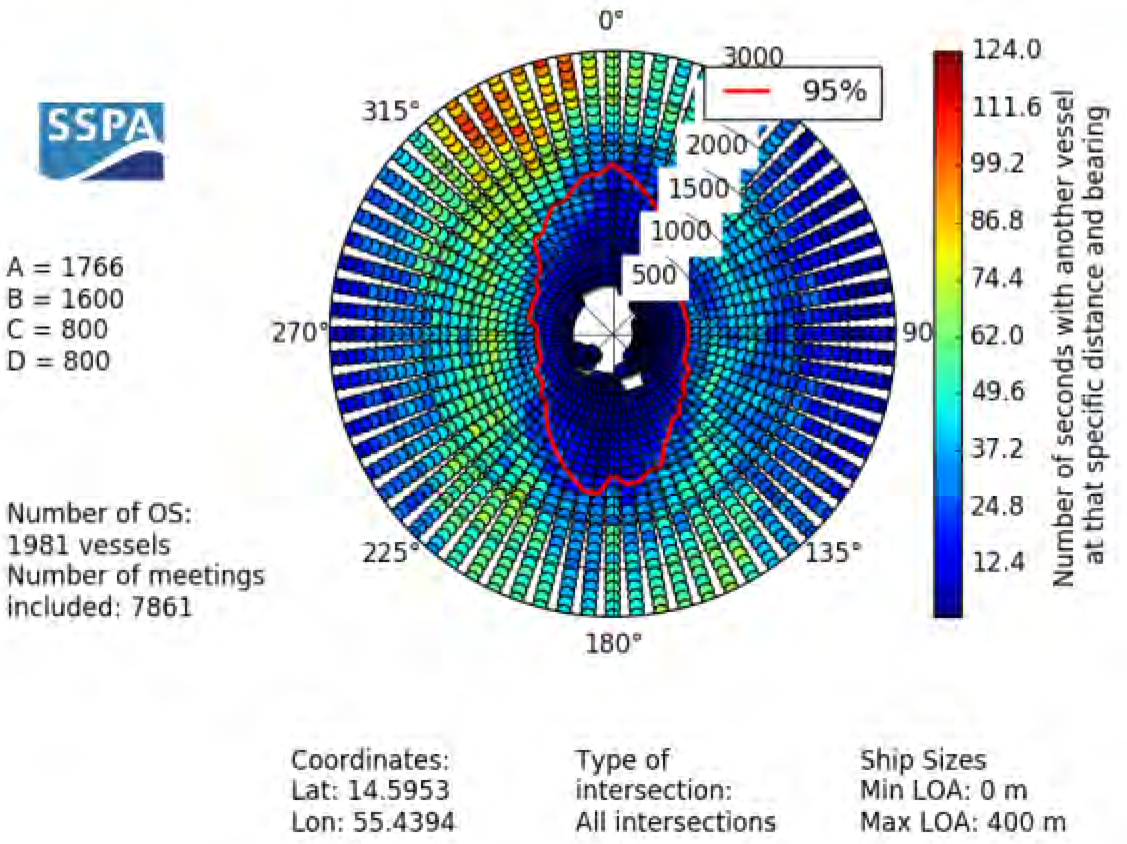
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

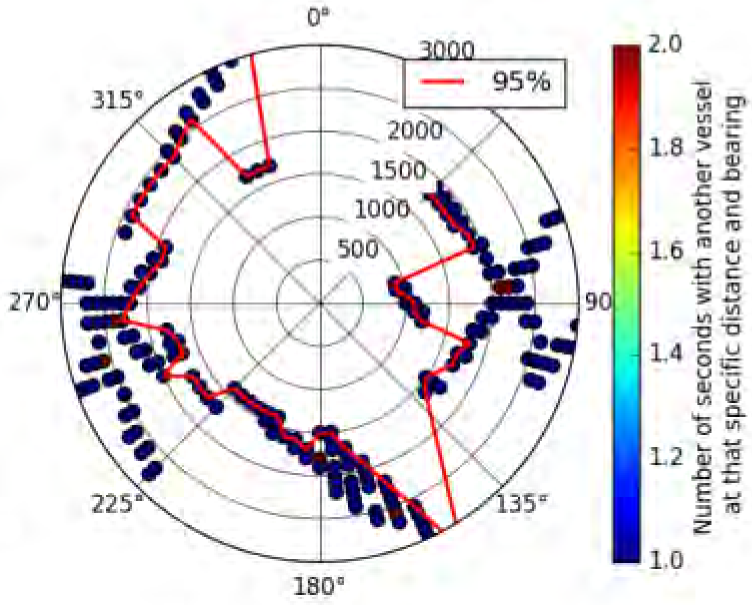


Location 10.

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



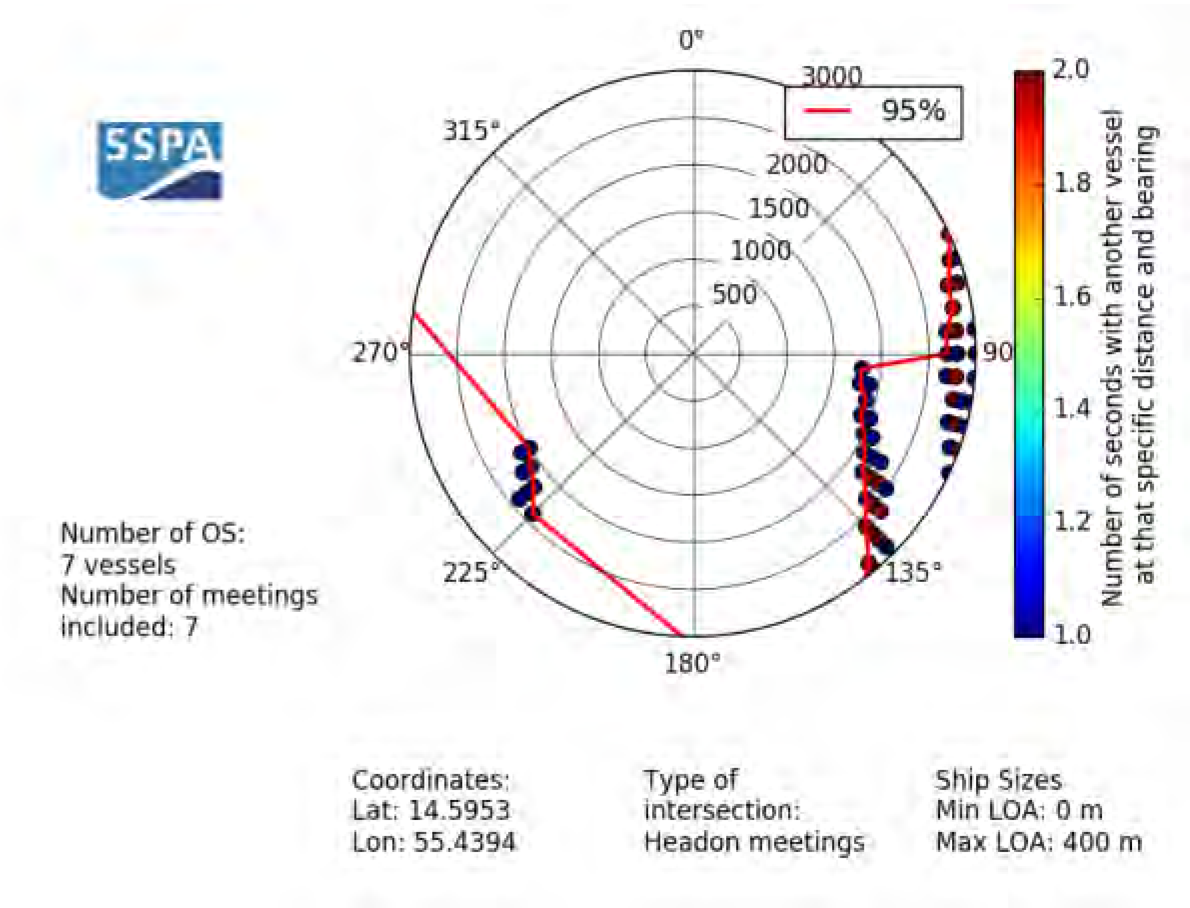
Number of OS:
23 vessels
Number of meetings
included: 22

Coordinates:
Lat: 14.5953
Lon: 55.4394

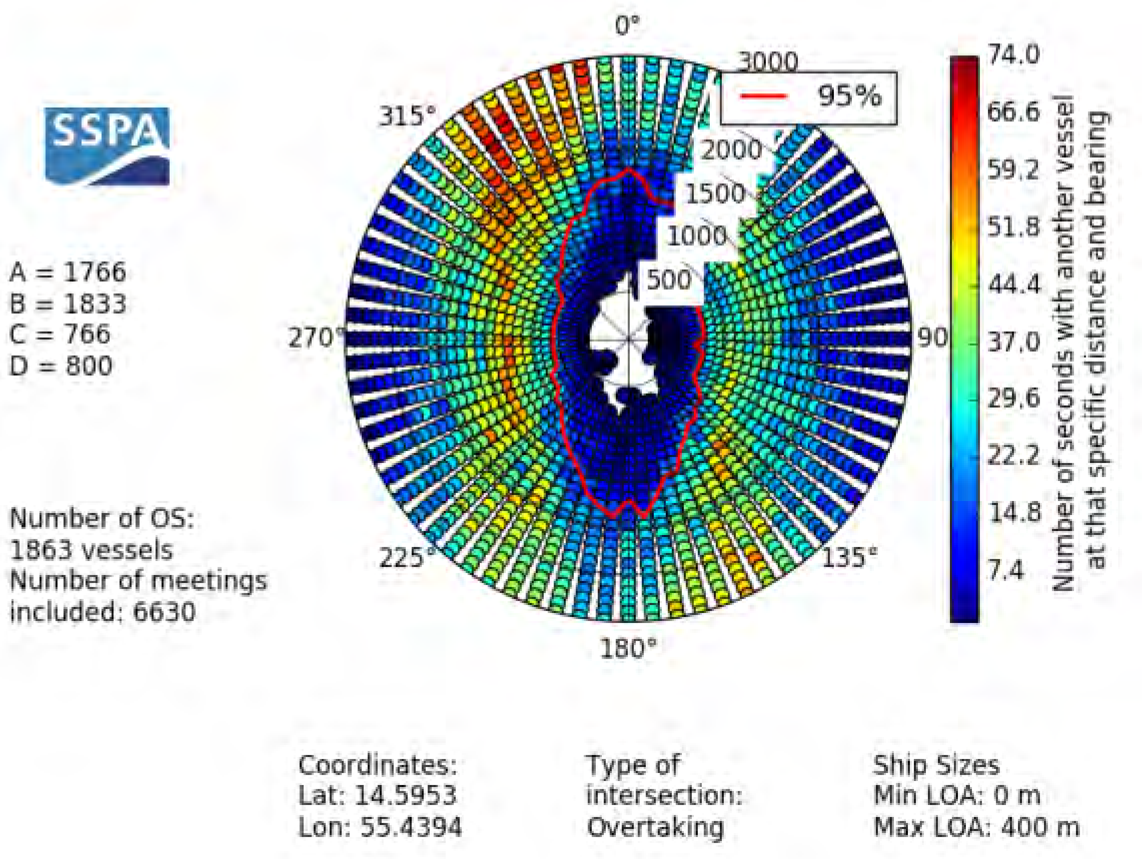
Type of
intersection:
Crossings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

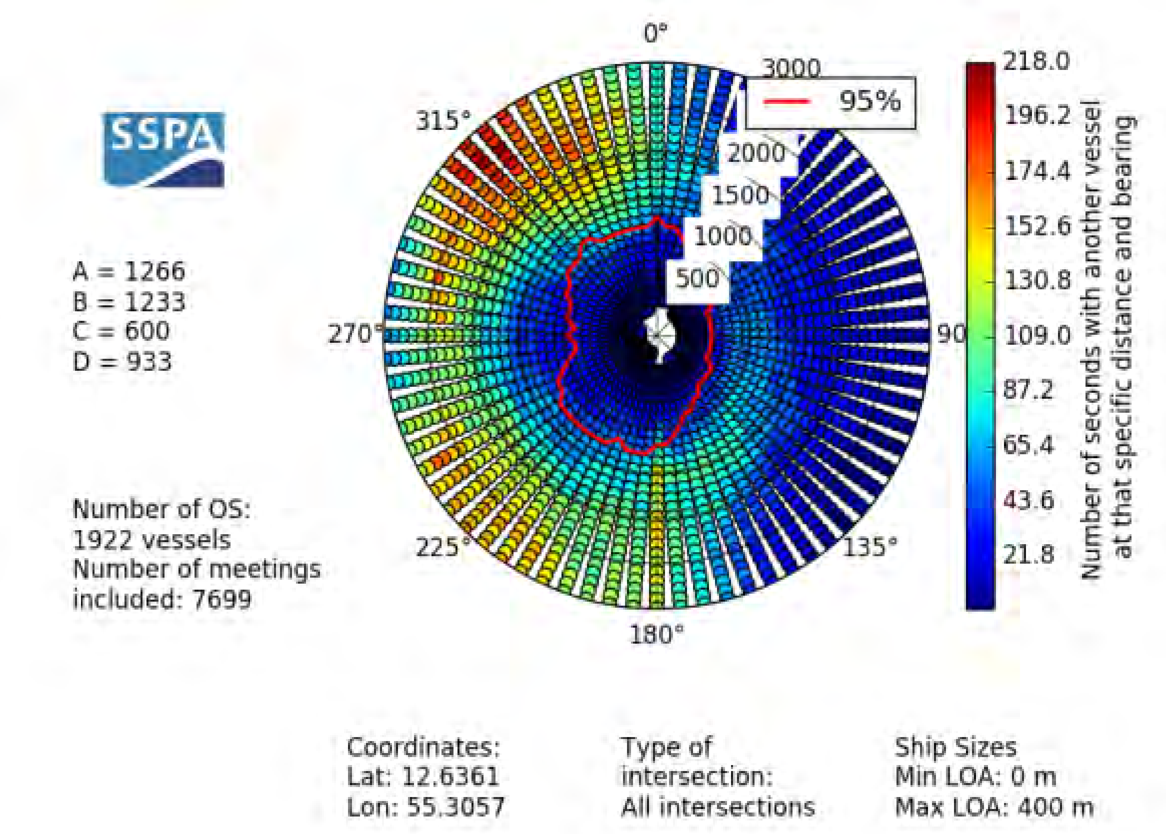


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

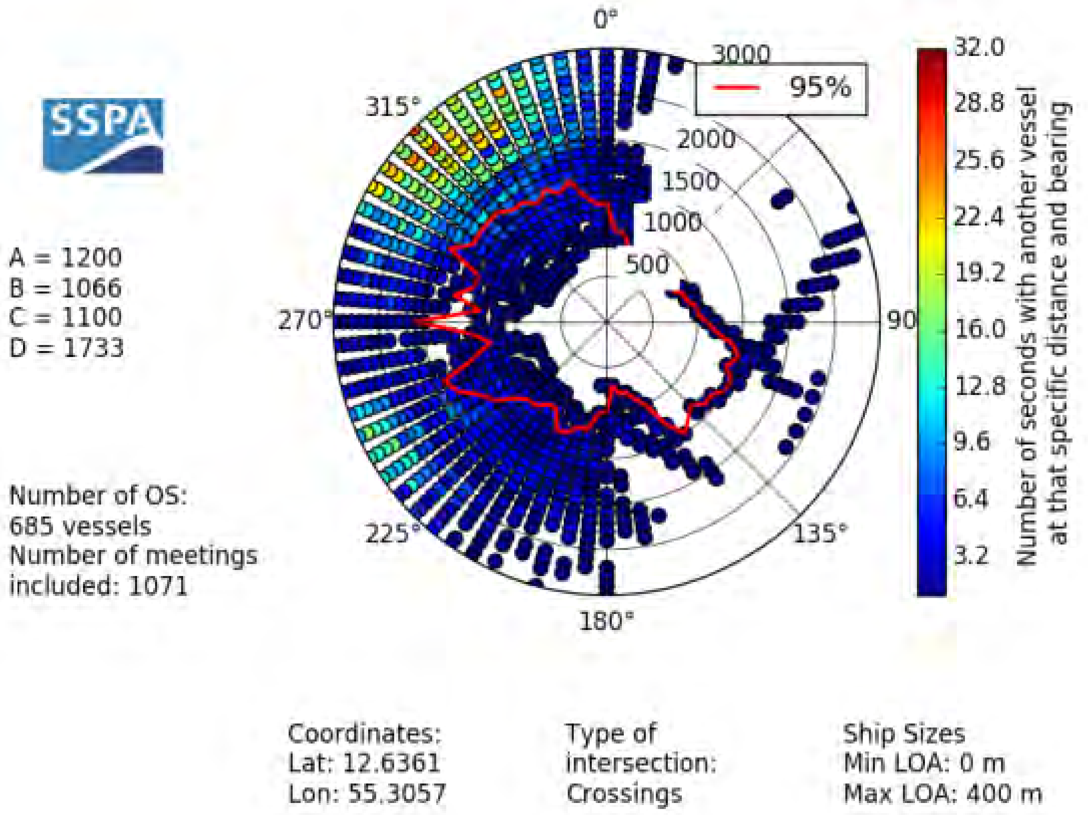


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 11.

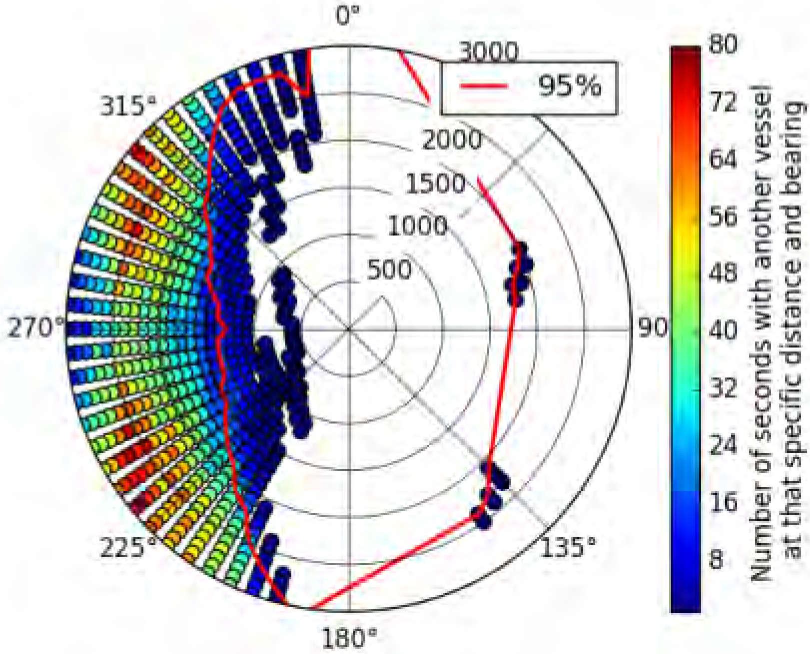


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

Number of OS:
773 vessels
Number of meetings
included: 1388

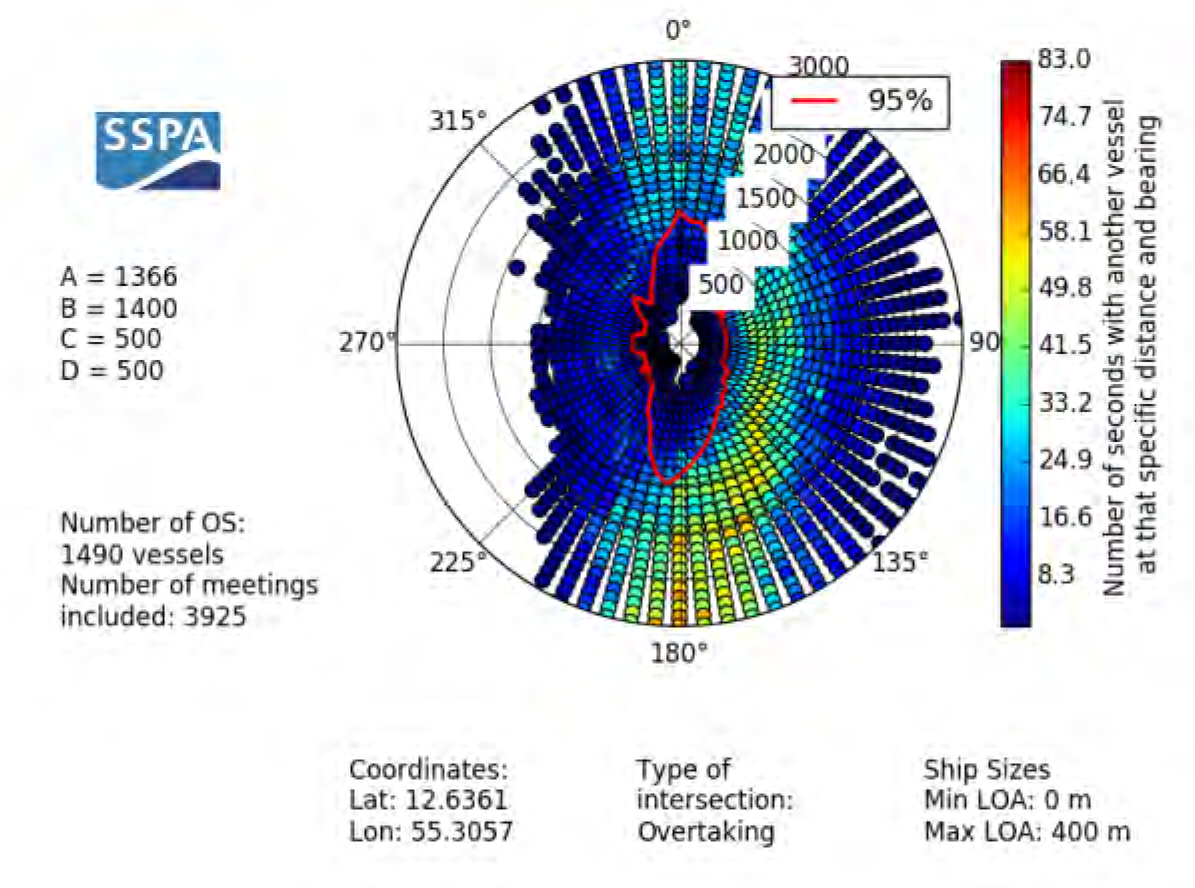


Coordinates:
Lat: 12.6361
Lon: 55.3057

Type of
intersection:
Headon meetings

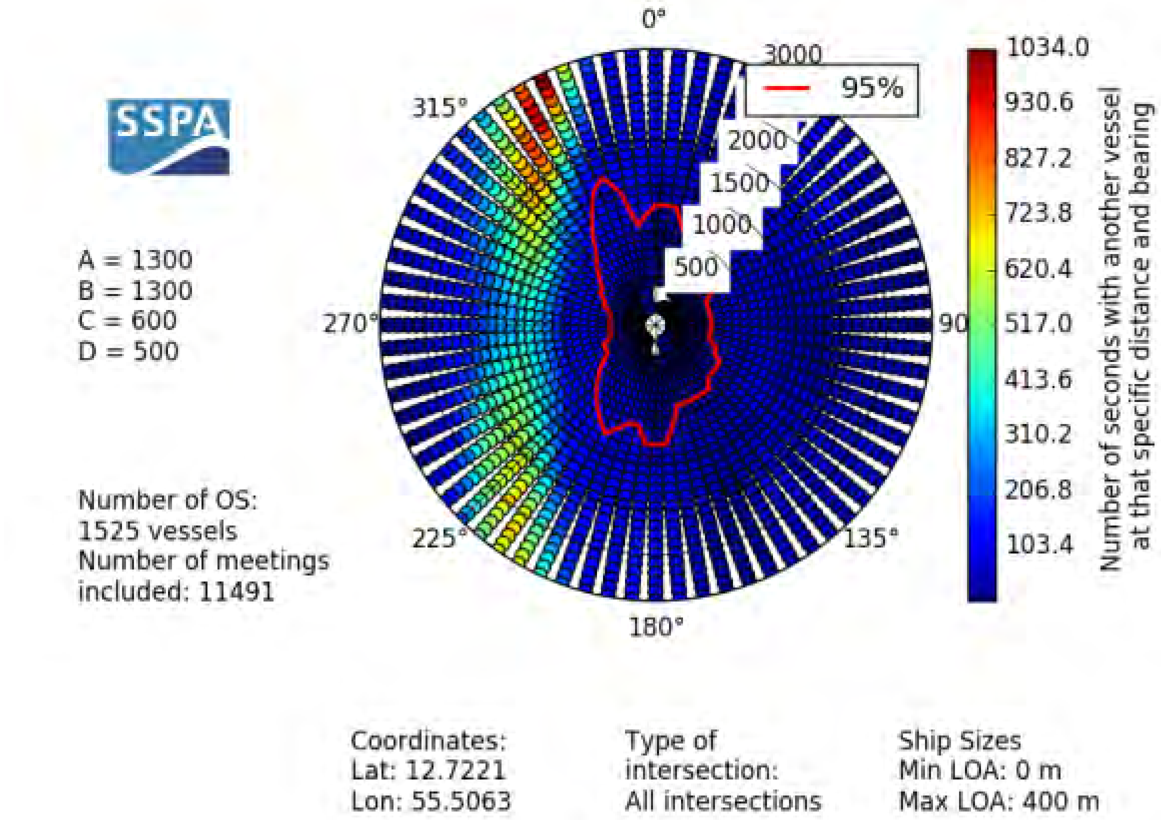
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

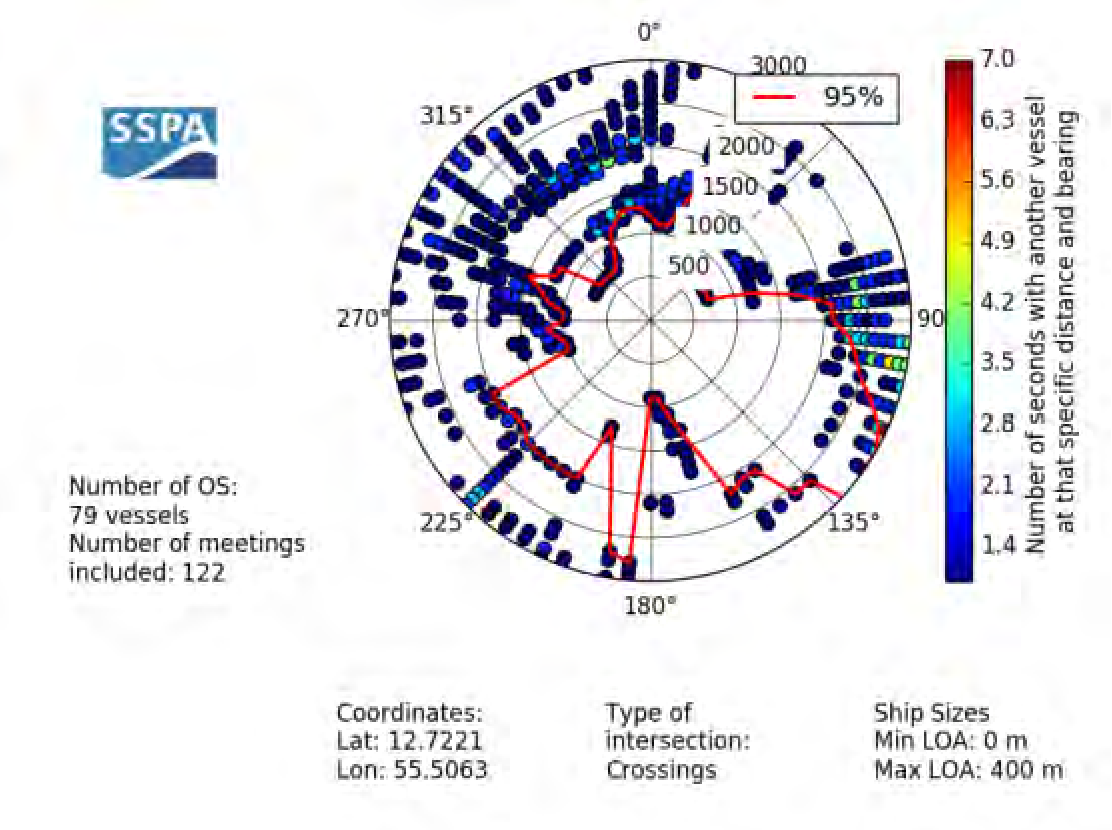


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

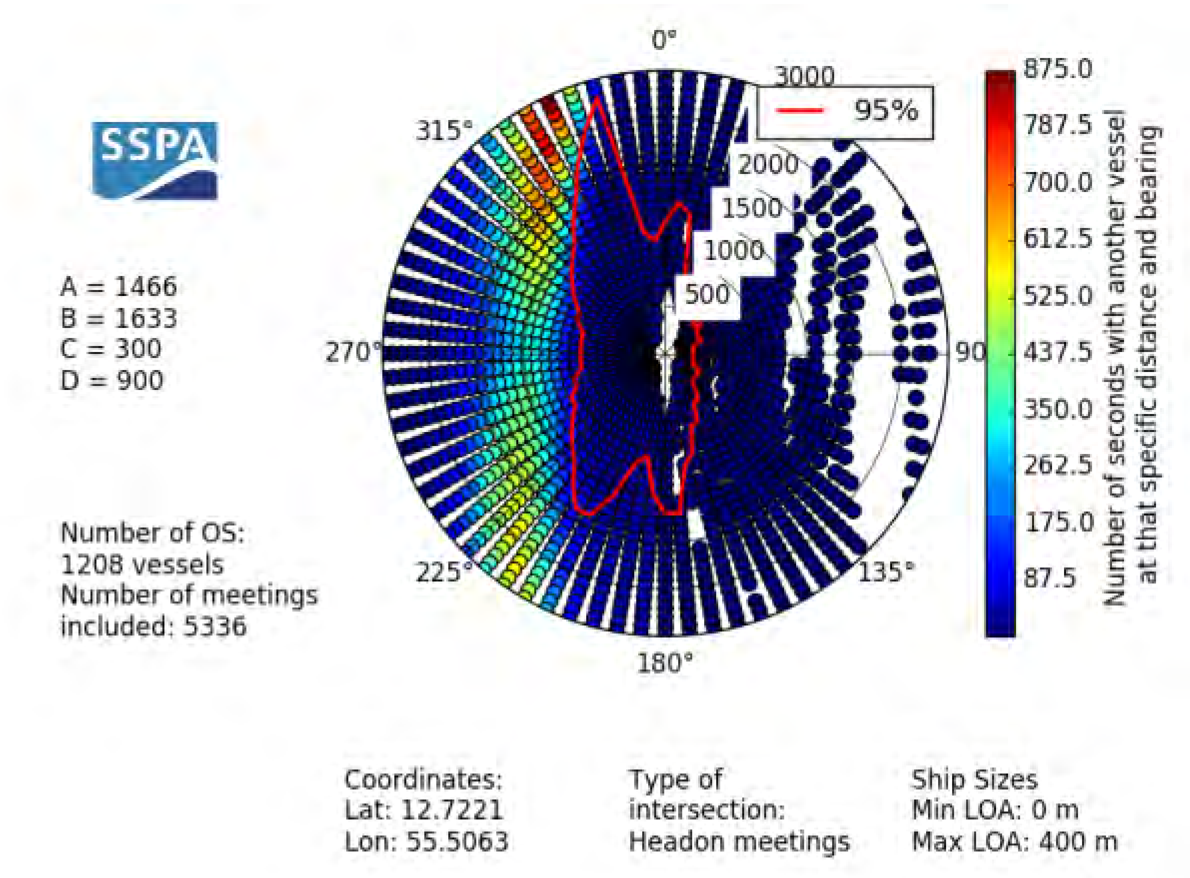
Location 12.



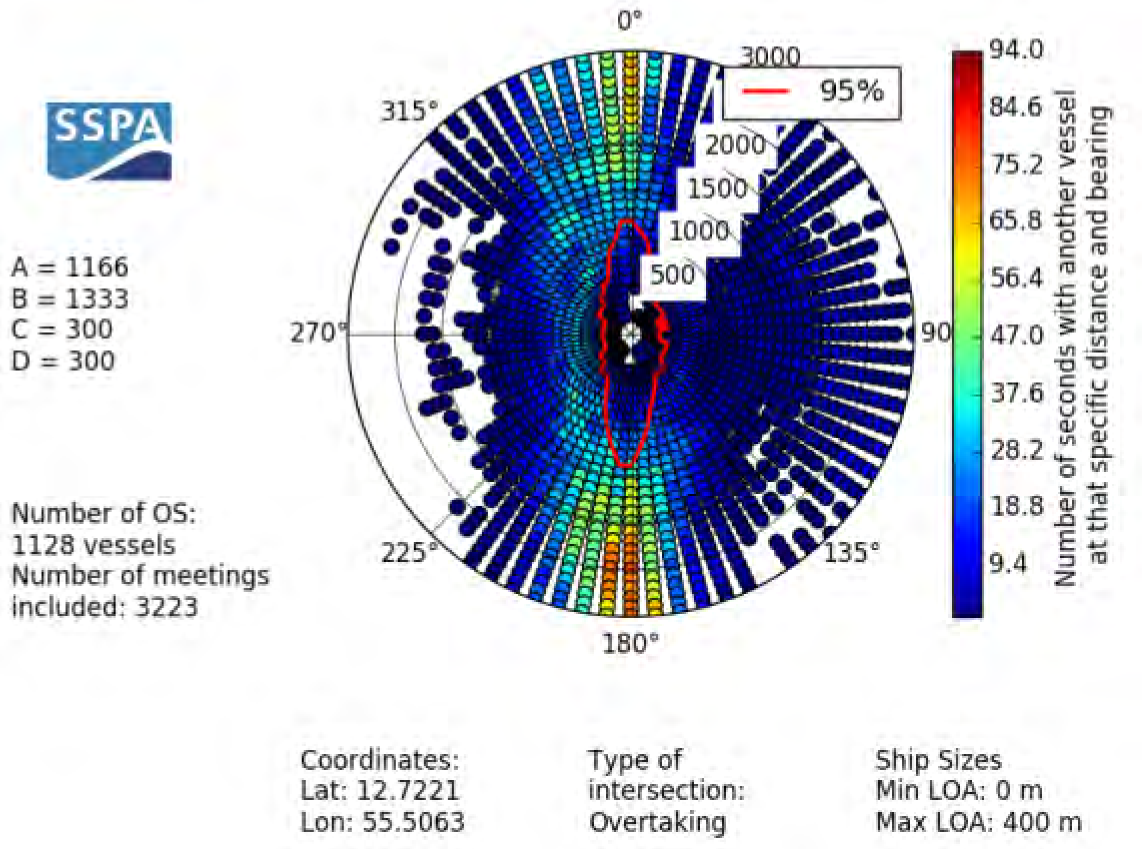
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

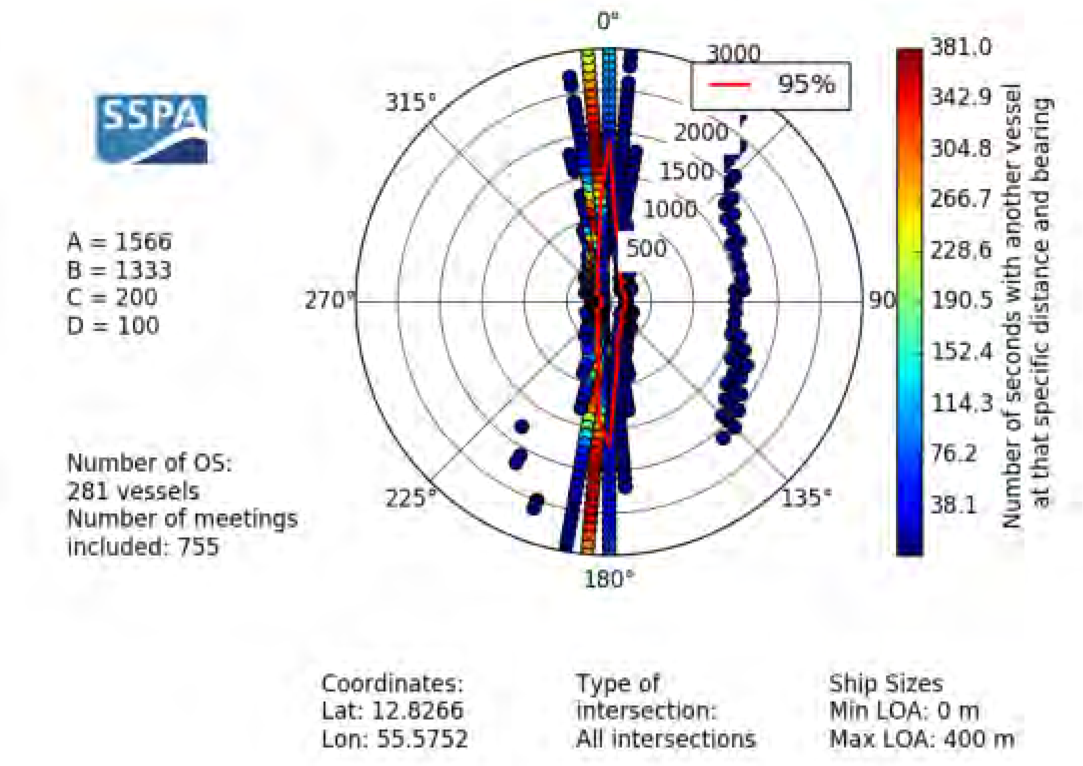


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 13.



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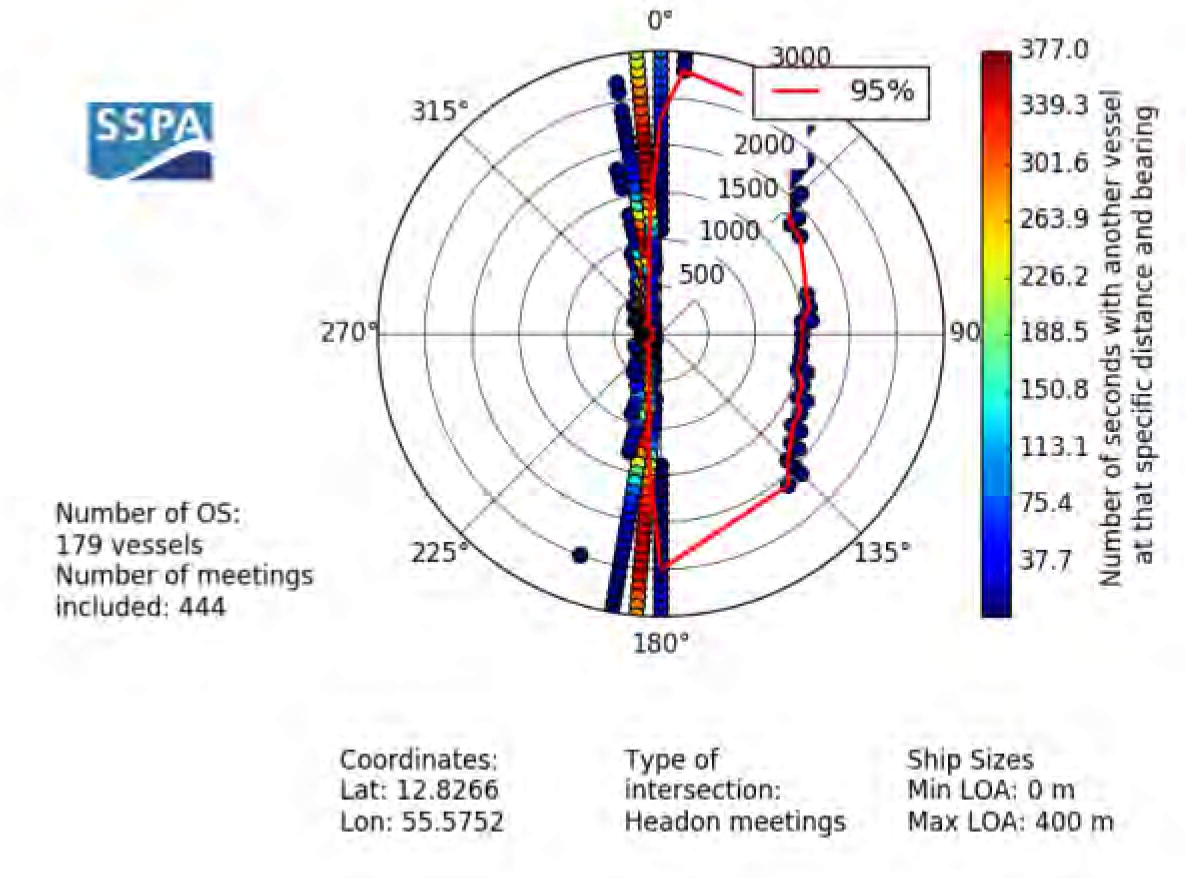
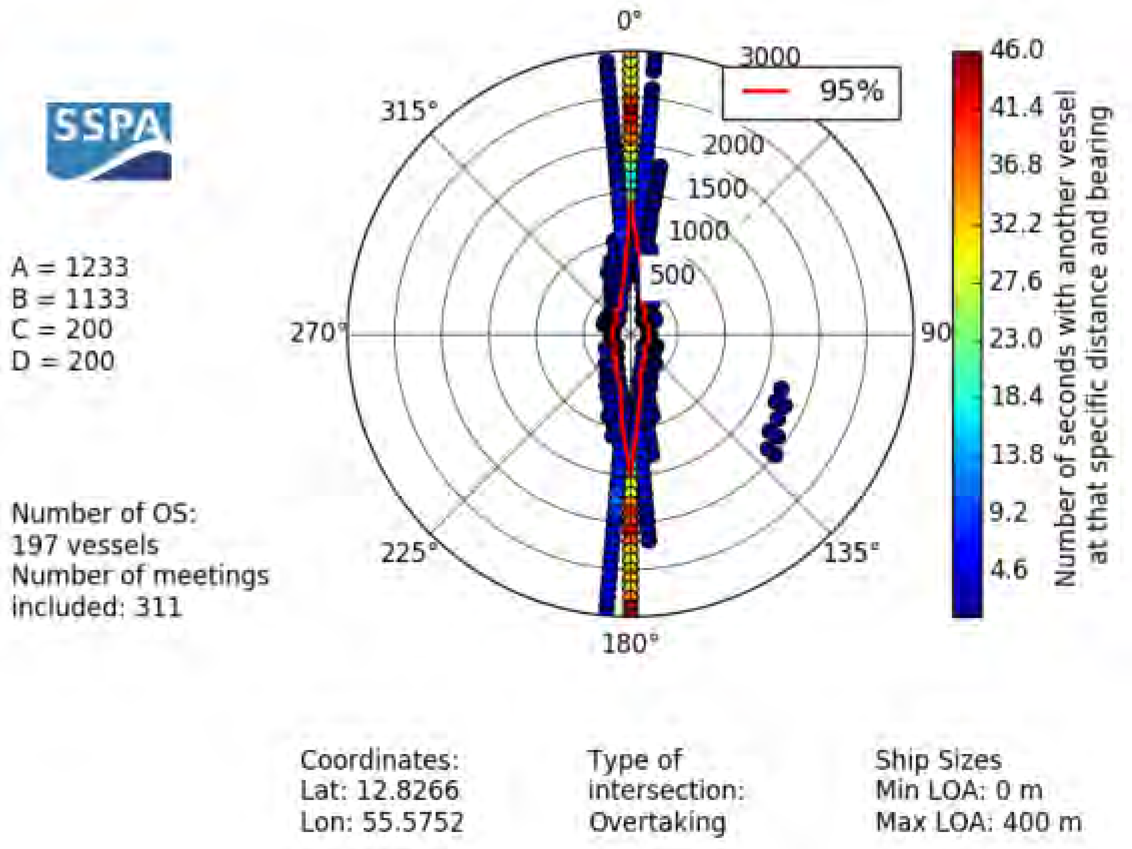
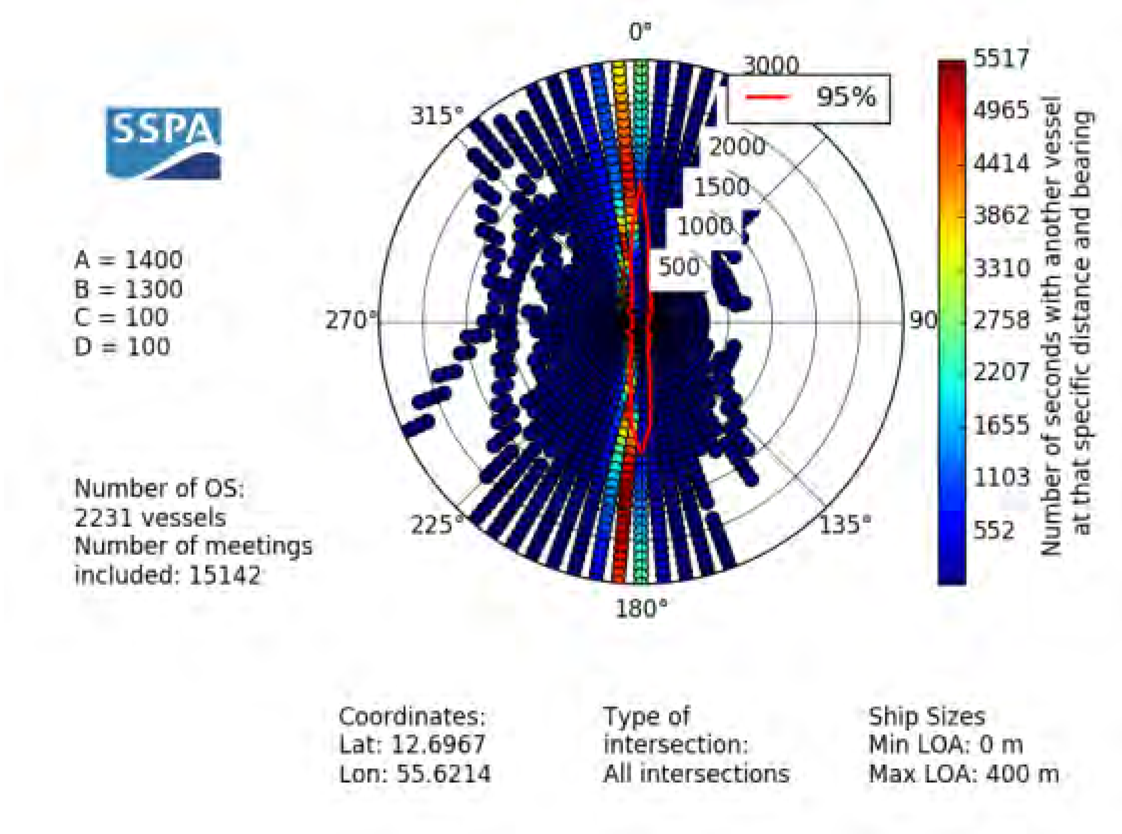


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

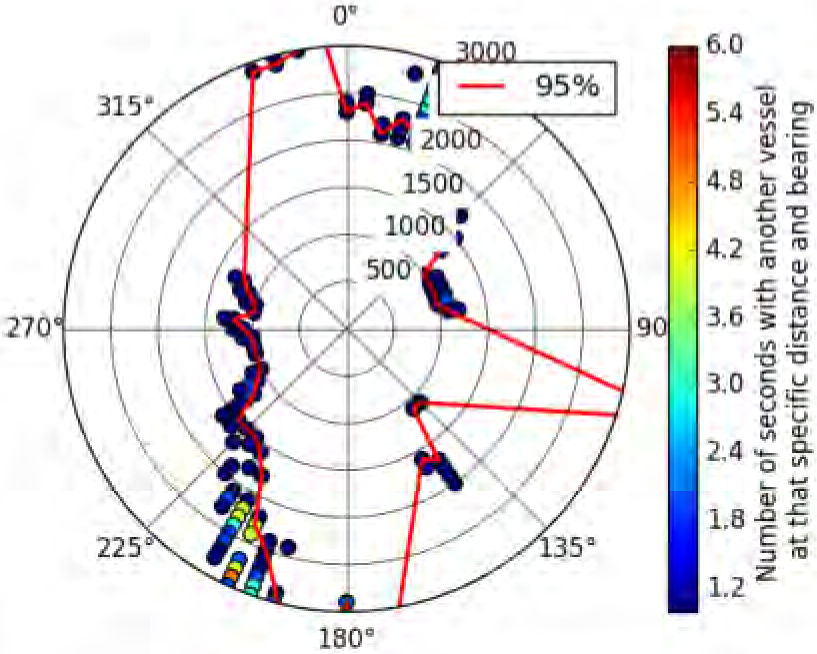


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 14.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



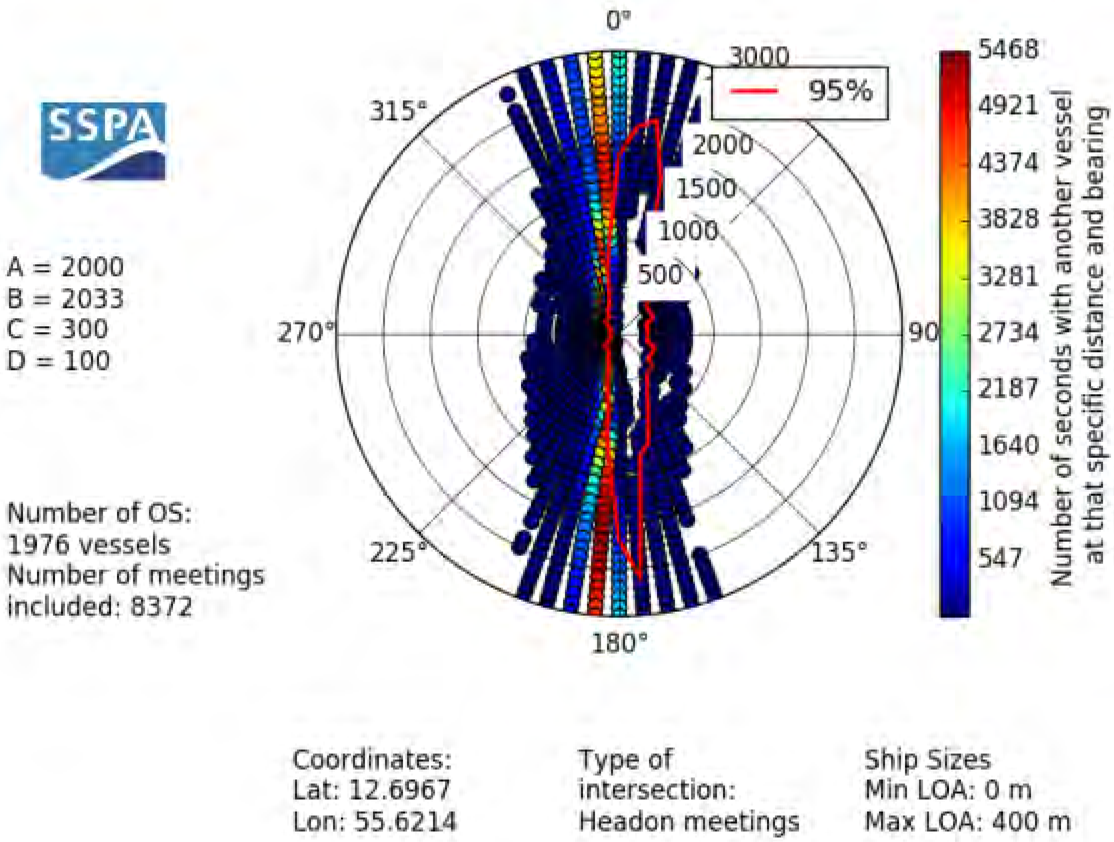
Number of OS:
95 vessels
Number of meetings included: 97

Coordinates:
Lat: 12.6967
Lon: 55.6214

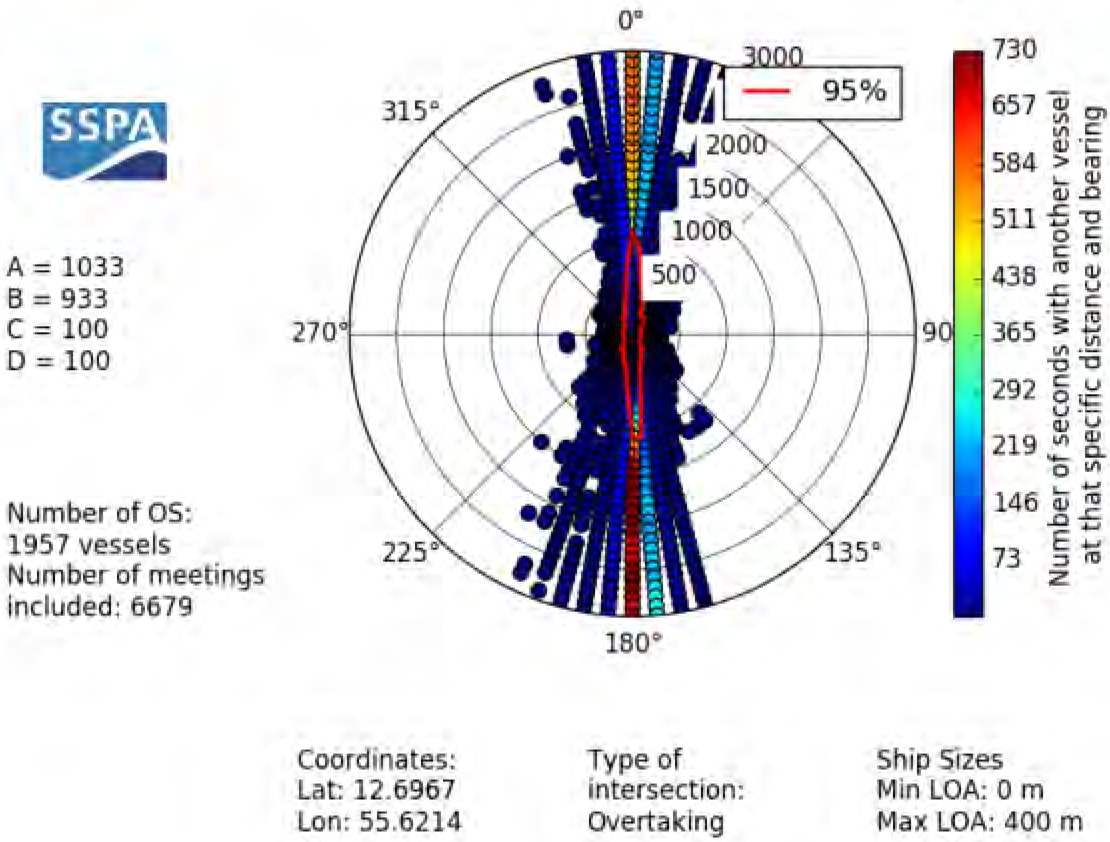
Type of intersection:
Crossings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

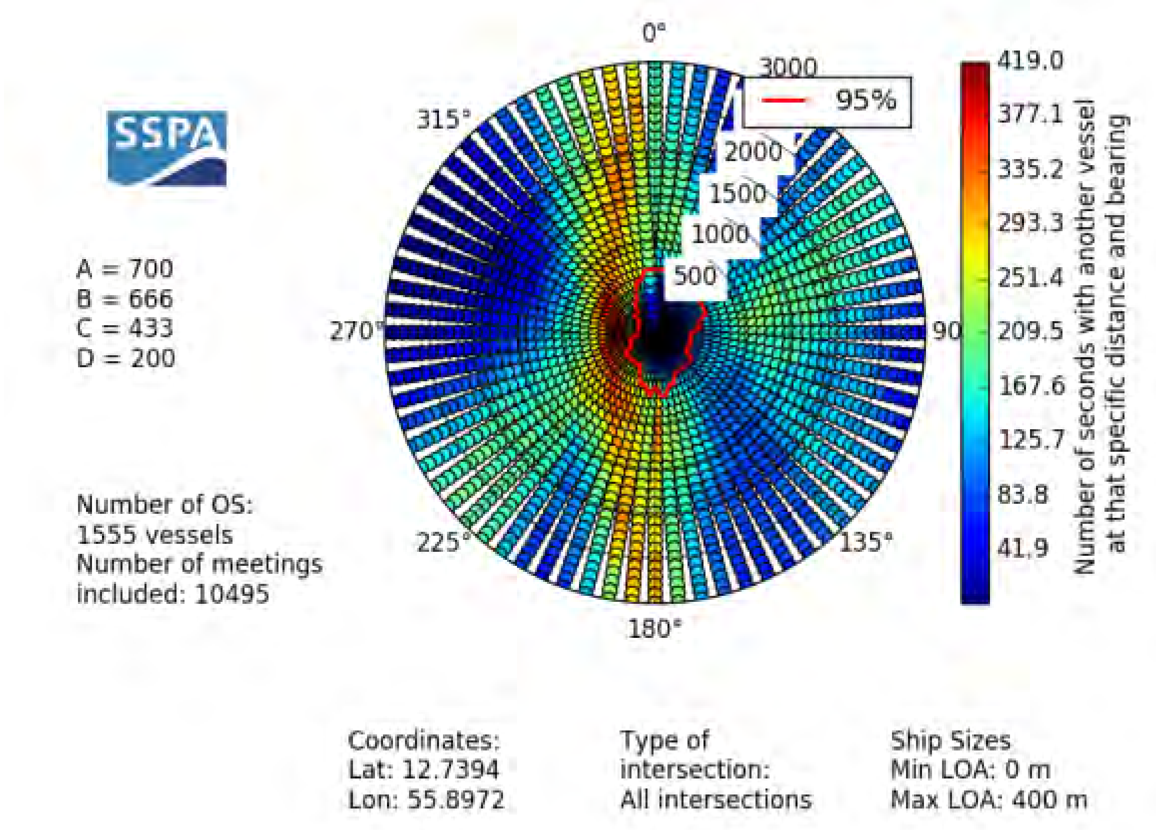


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



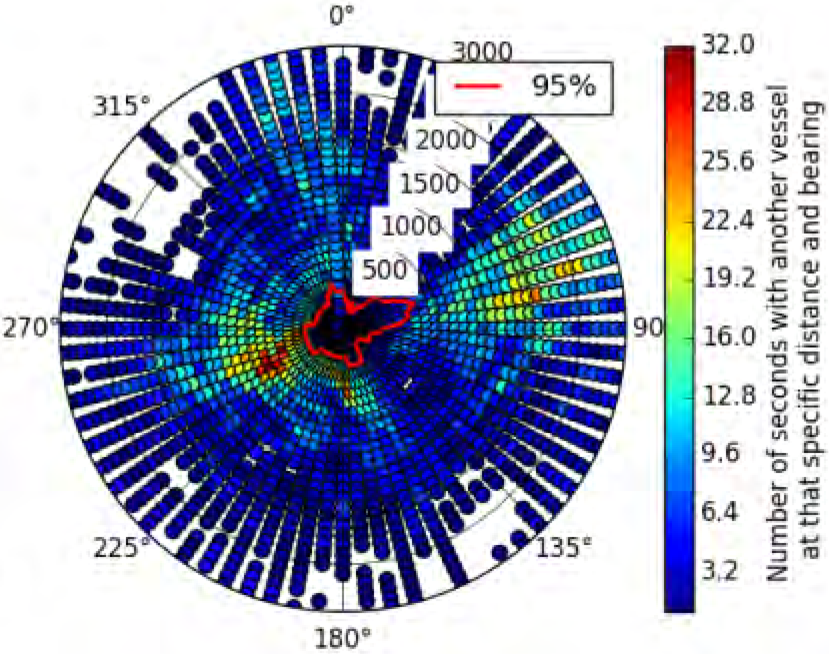
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 15.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

A = 366
B = 300
C = 466
D = 400



Number of OS:
390 vessels
Number of meetings included: 1003

Coordinates:
Lat: 12.7394
Lon: 55.8972

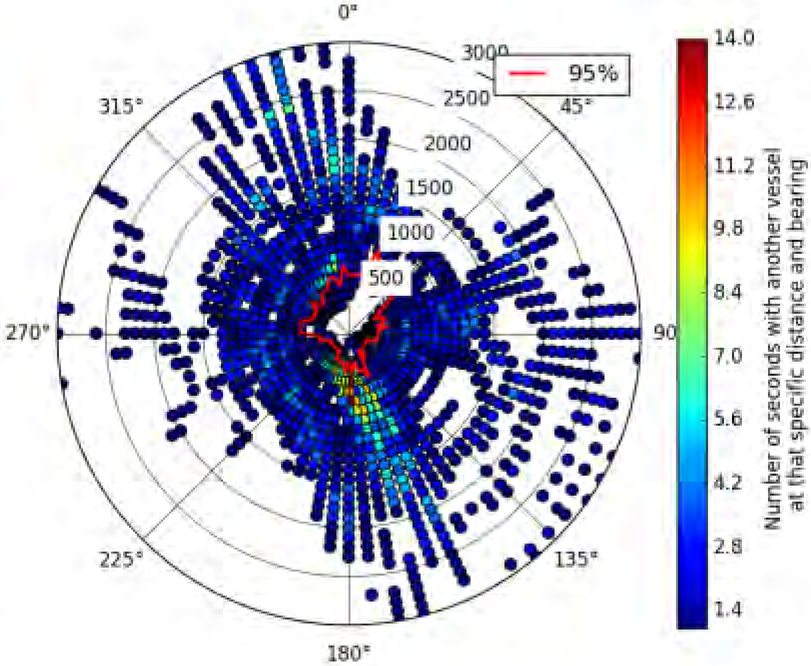
Type of intersection:
Crossings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

SSPA

A = 600
B = 366
C = 300
D = 433



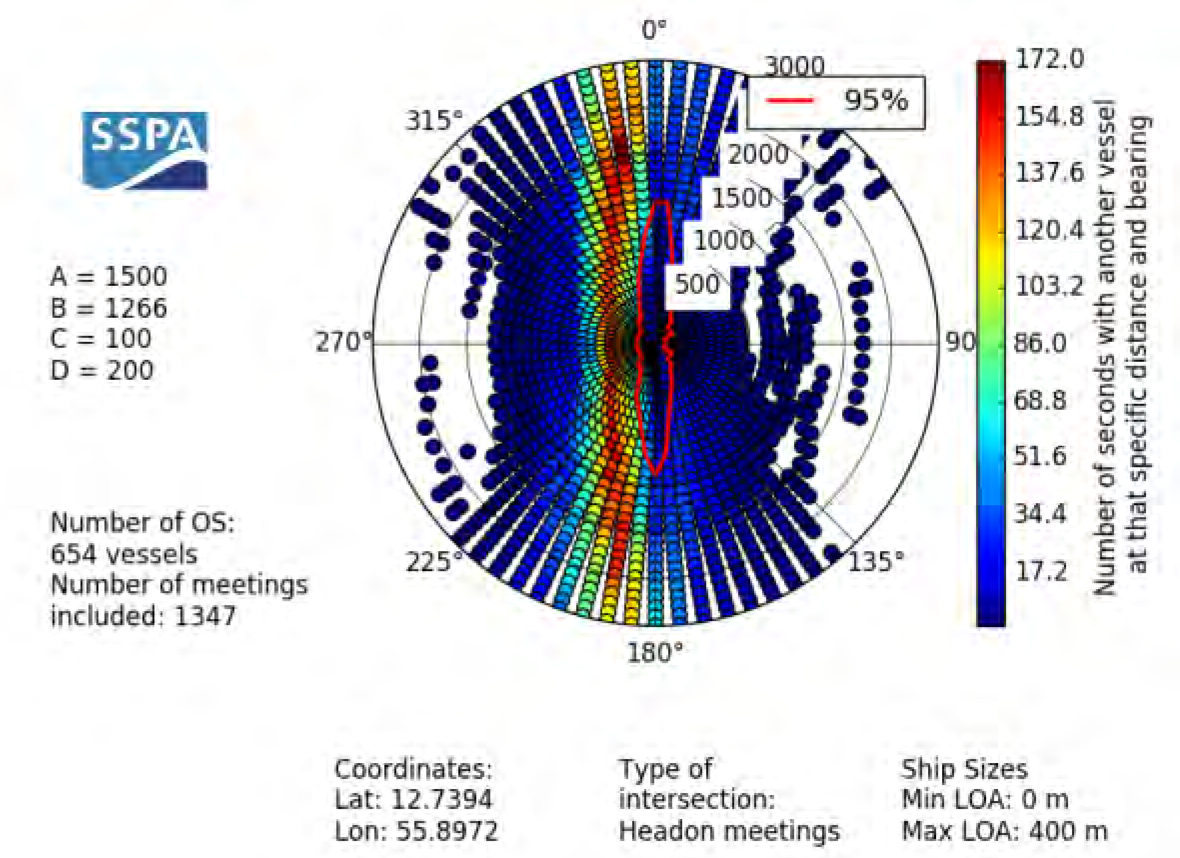
Number of OS:
163 vessels
Number of meetings included: 245

Coordinates:
Lat: 12.739
Lon: 55.8975

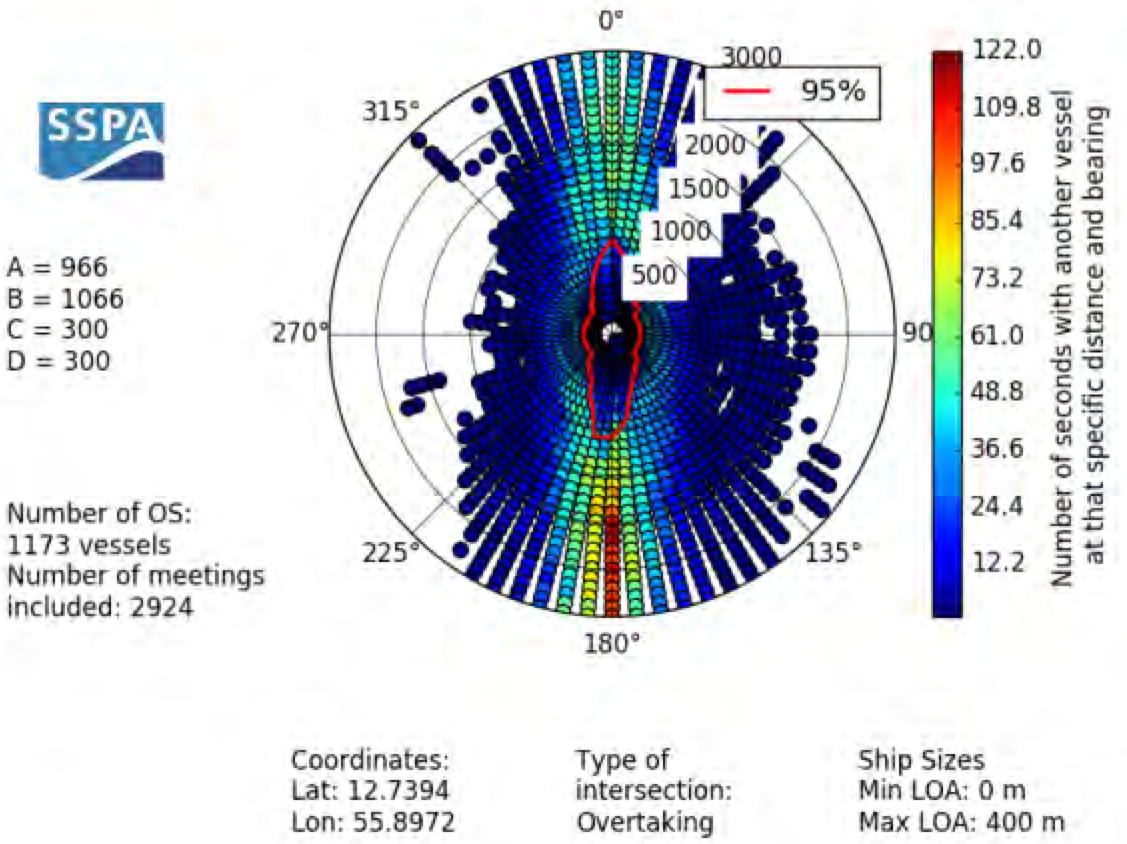
Type of intersection:
Crossings

Ship Sizes
Min LOA: 100 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



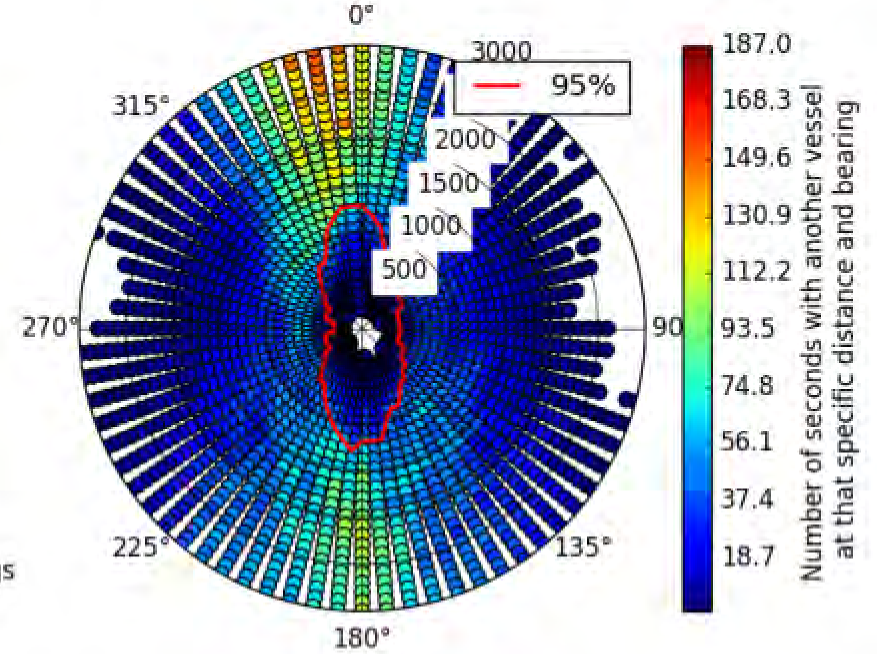
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 16.

A = 1266
B = 1233
C = 400
D = 300



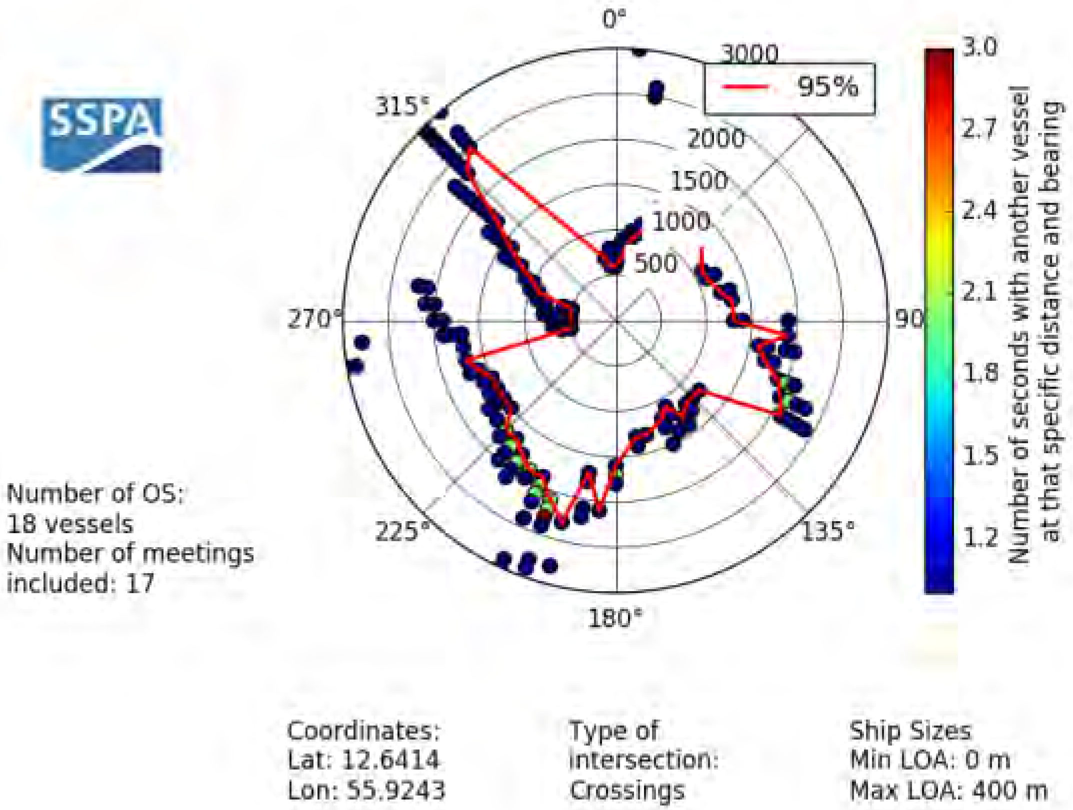
Number of OS:
1595 vessels
Number of meetings included: 4869

Coordinates:
Lat: 12.6414
Lon: 55.9243

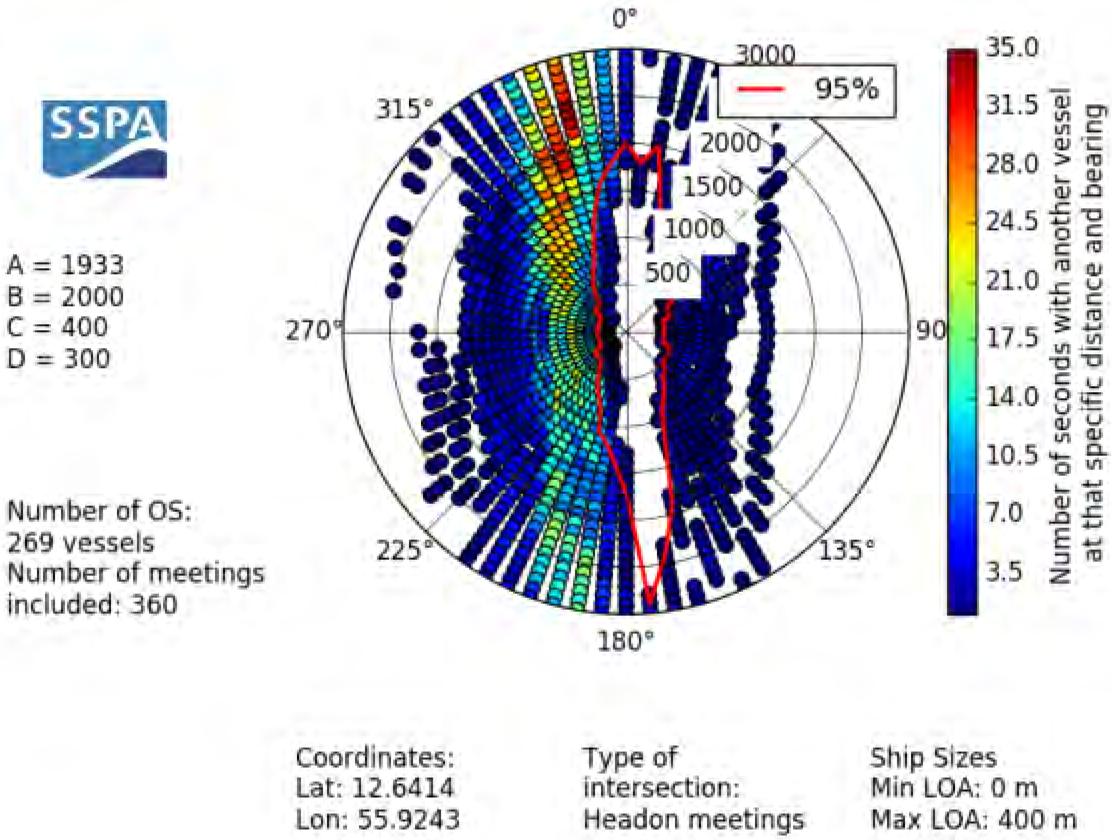
Type of intersection:
All intersections

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

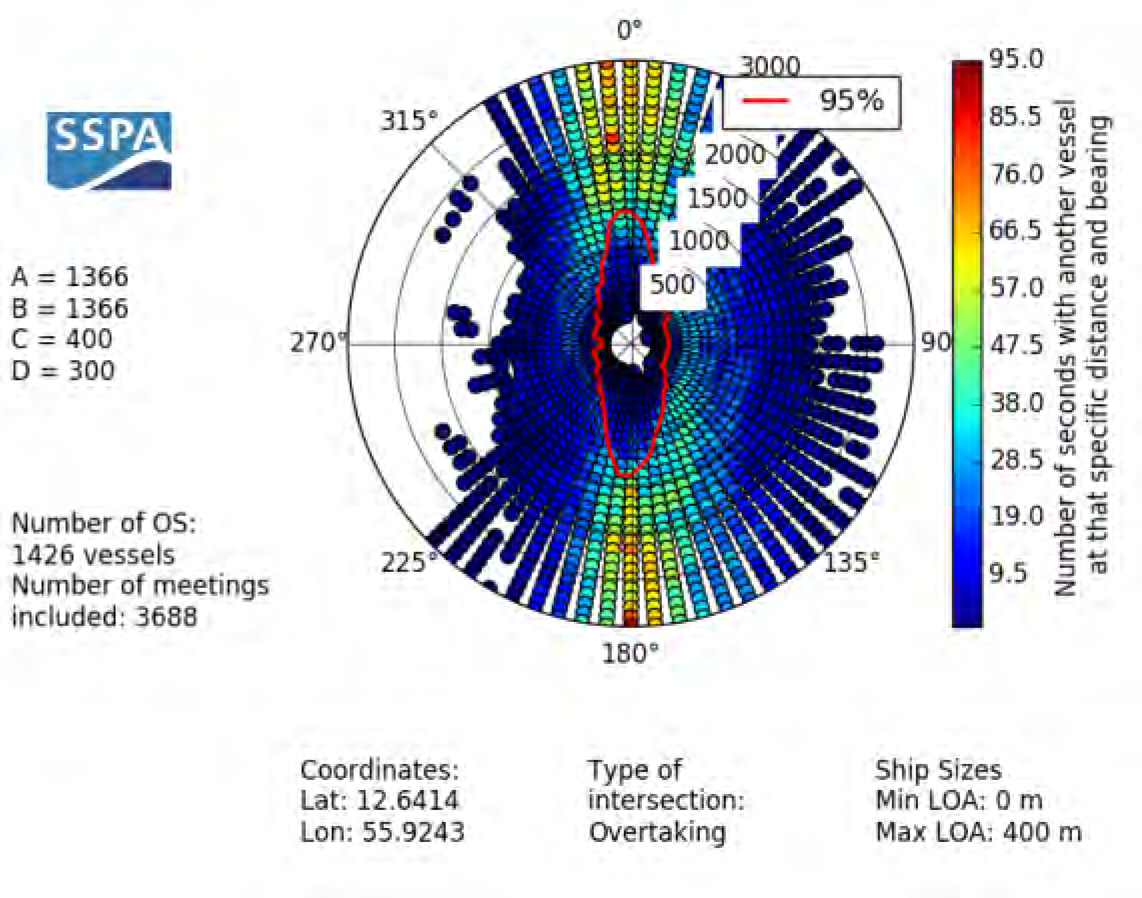
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

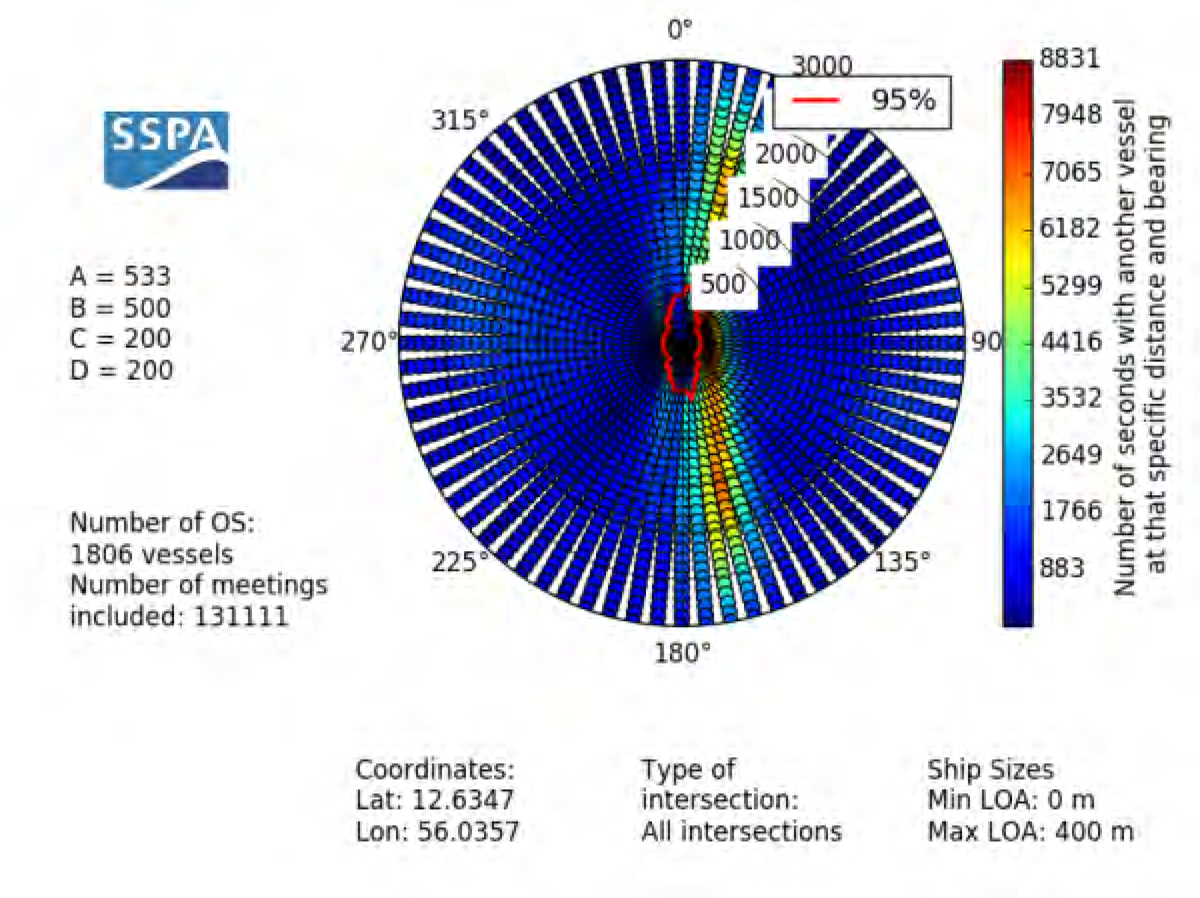


“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

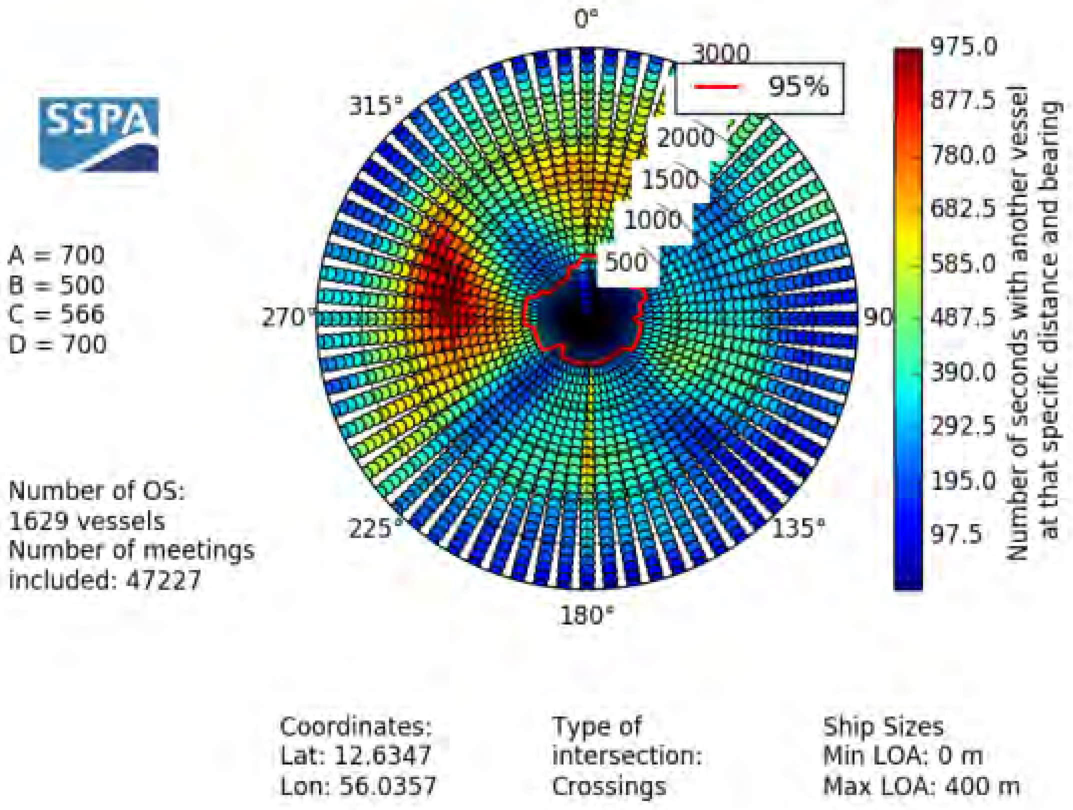


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

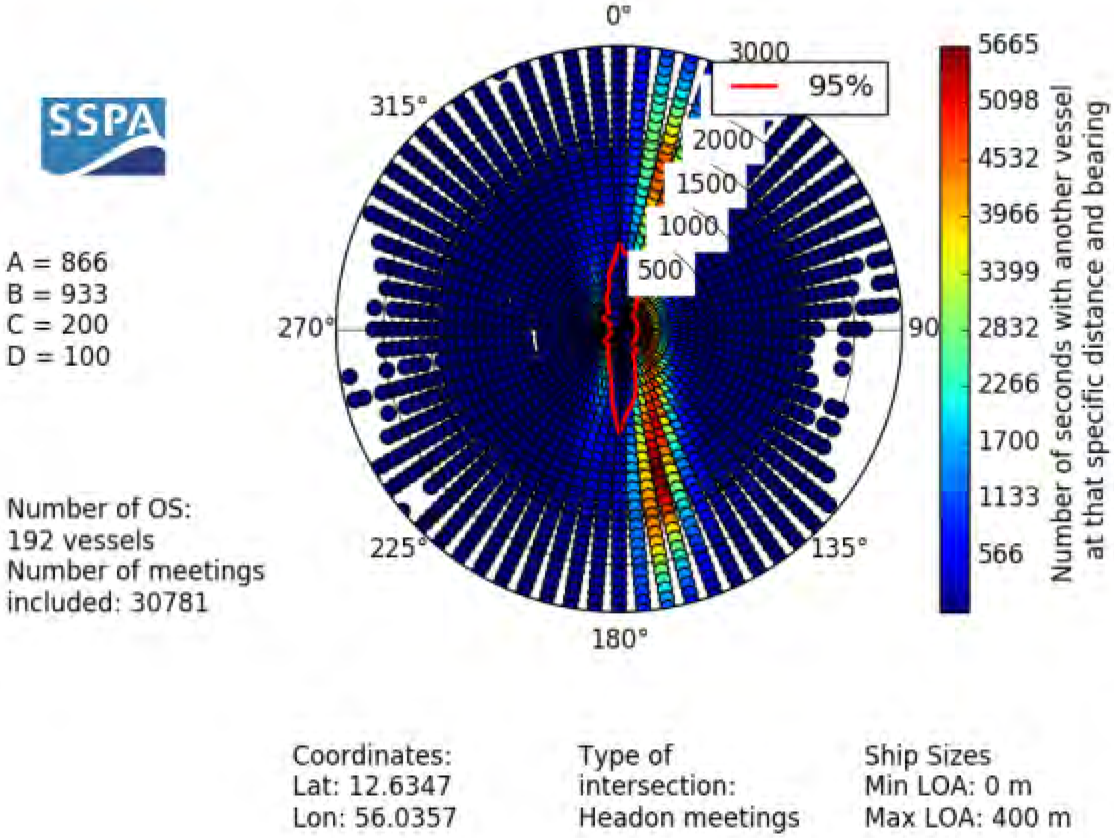
Location 17.



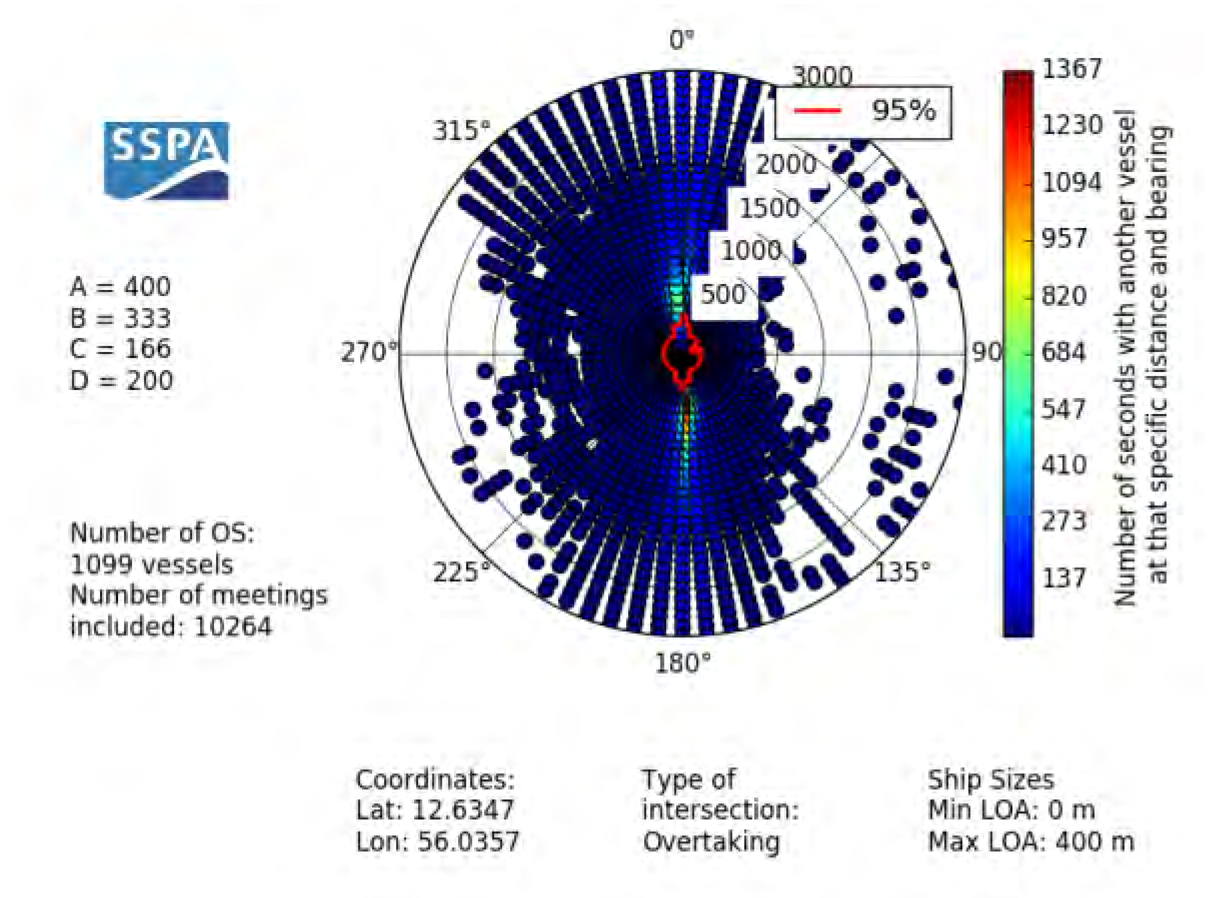
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

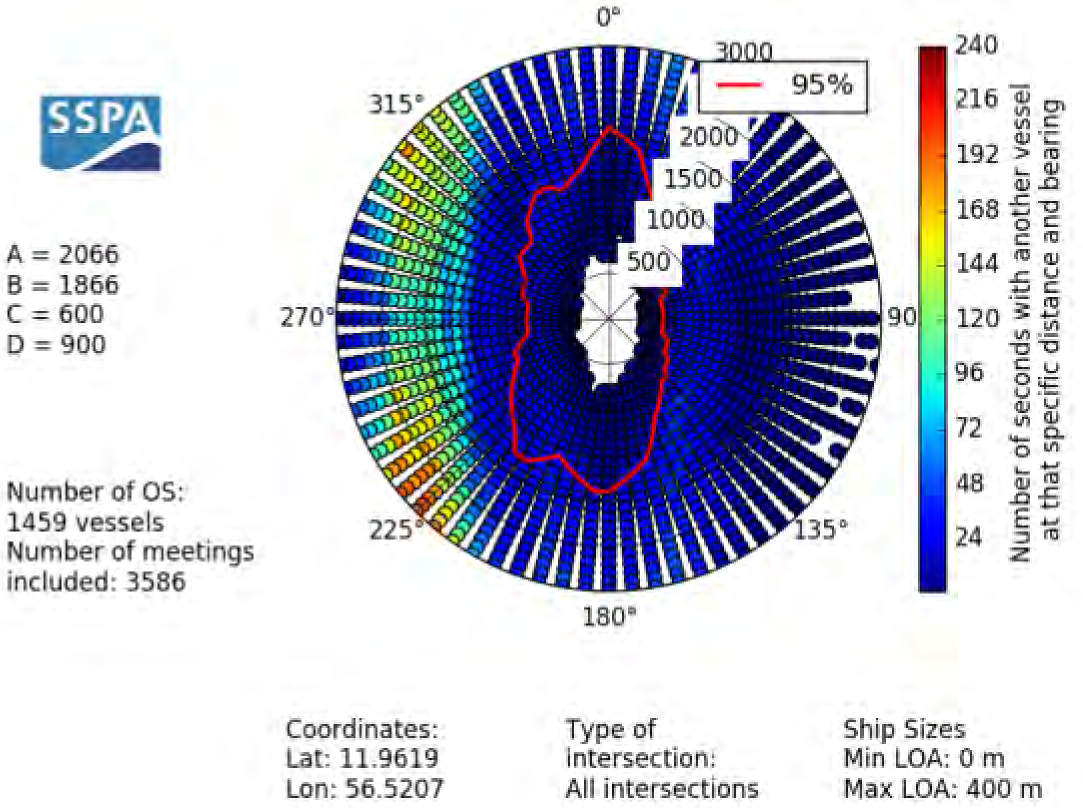


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

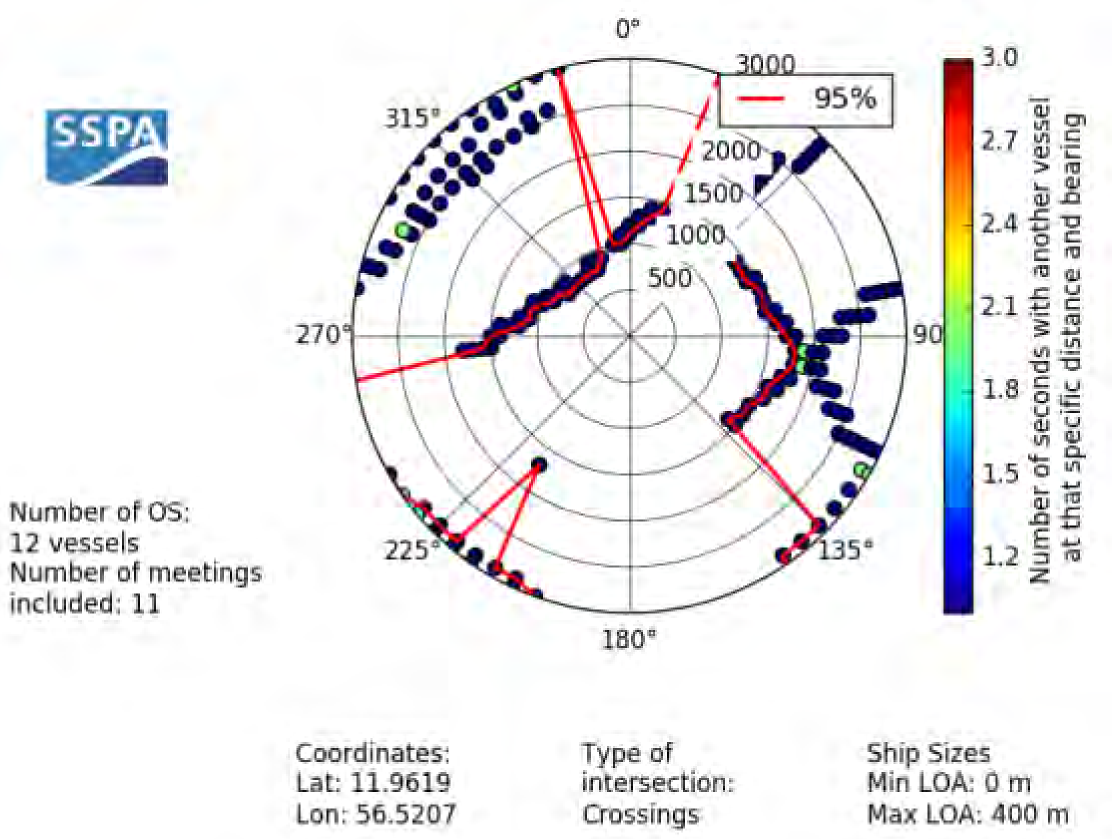


Location 18.

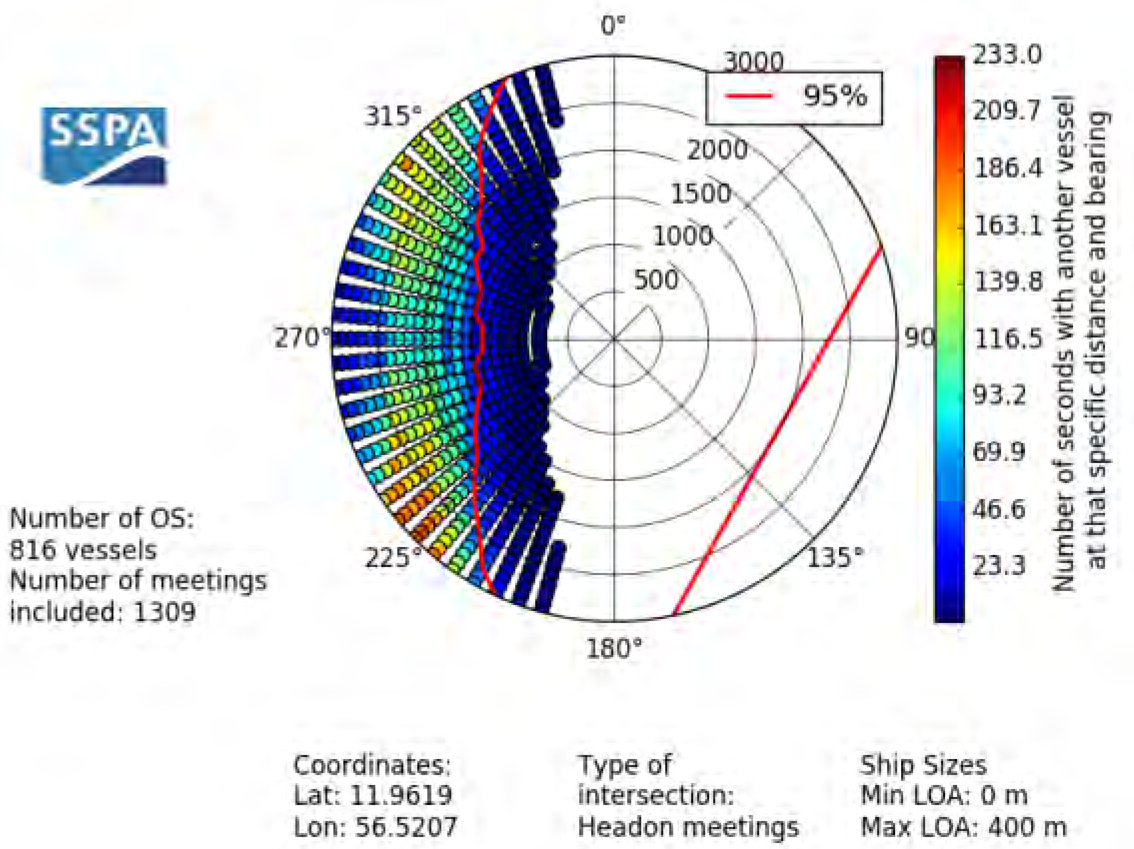
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



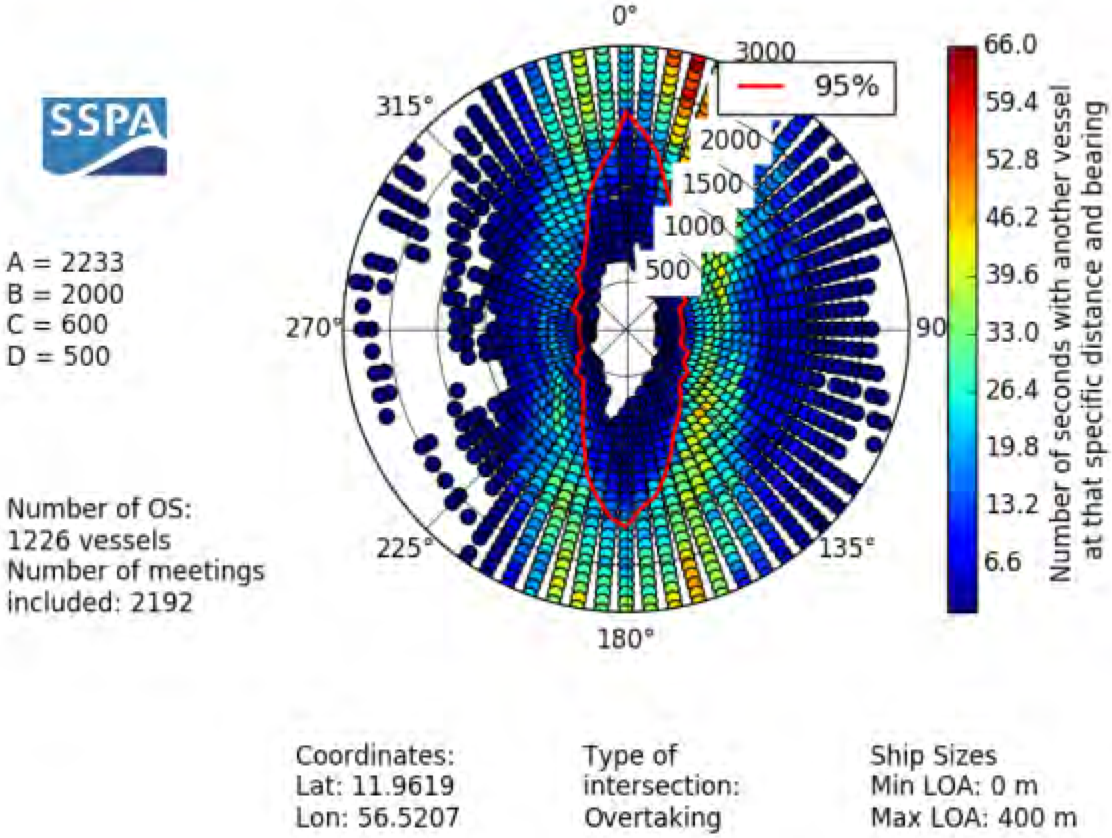
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

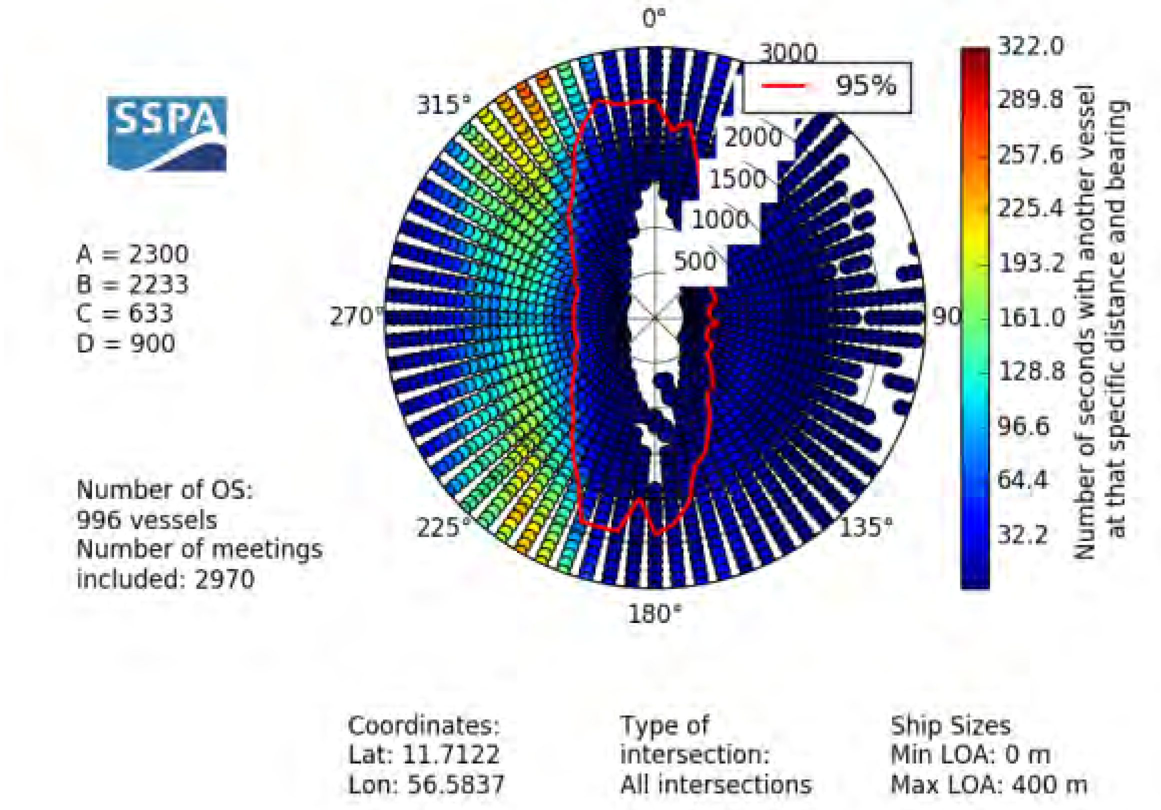


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

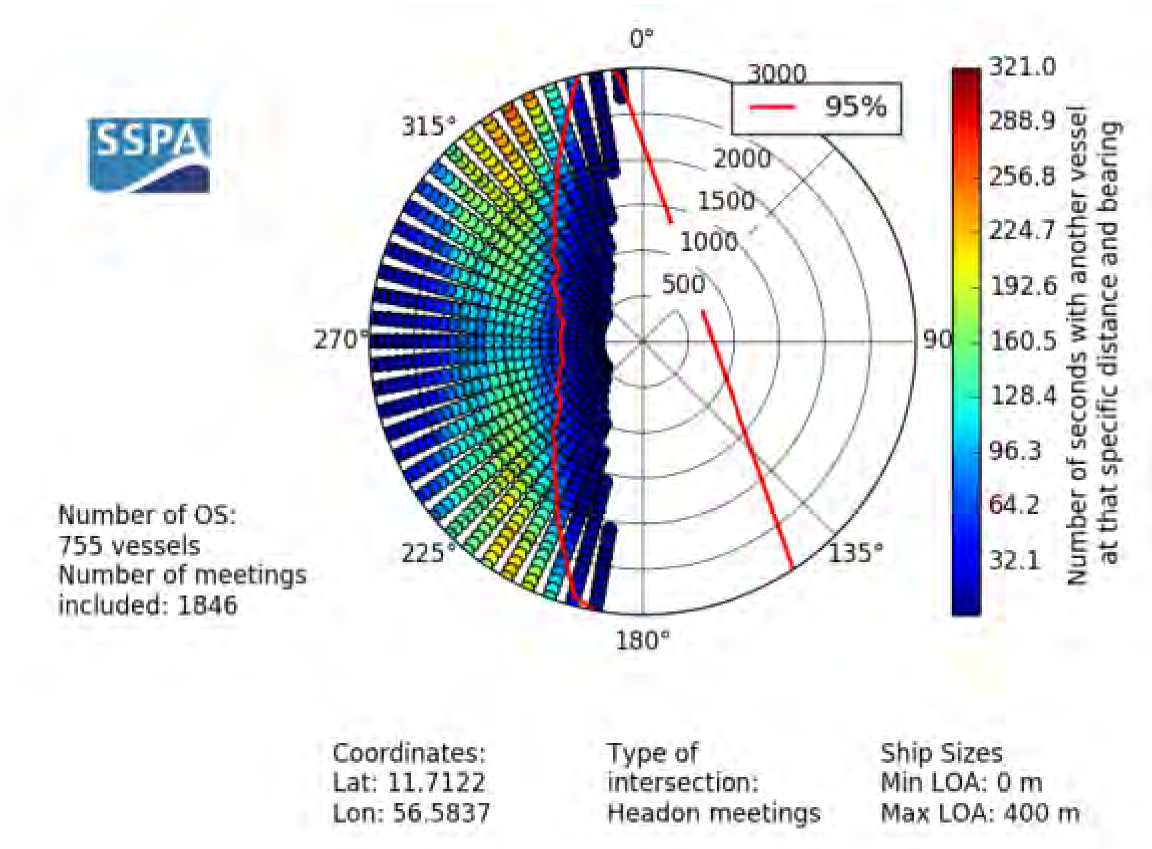


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

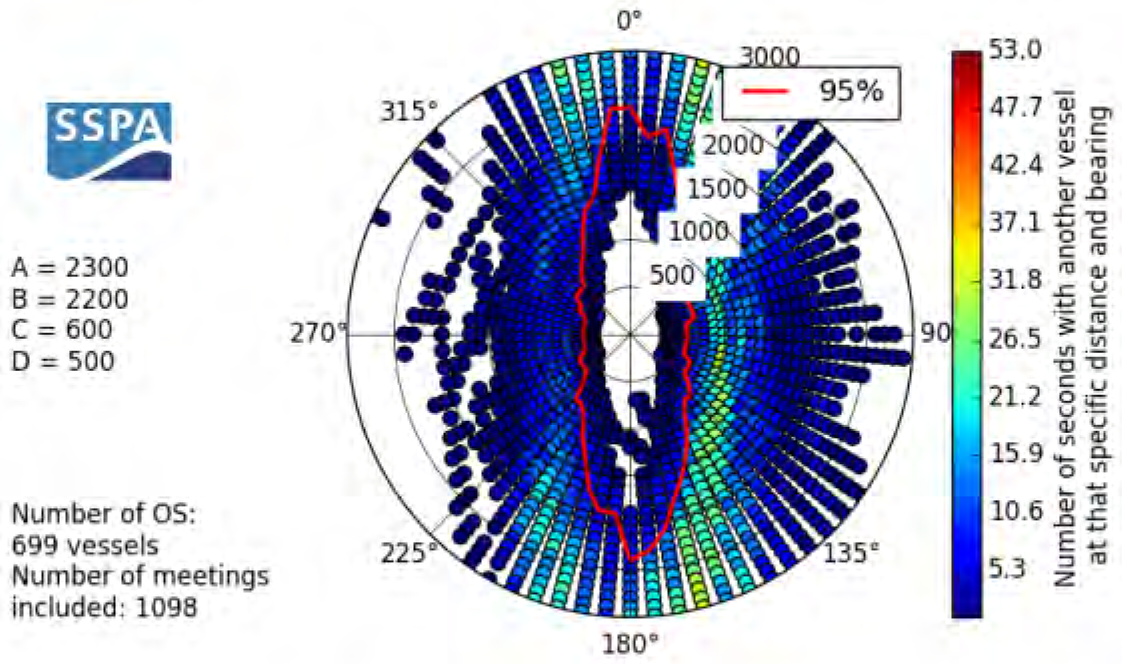
Location 19.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



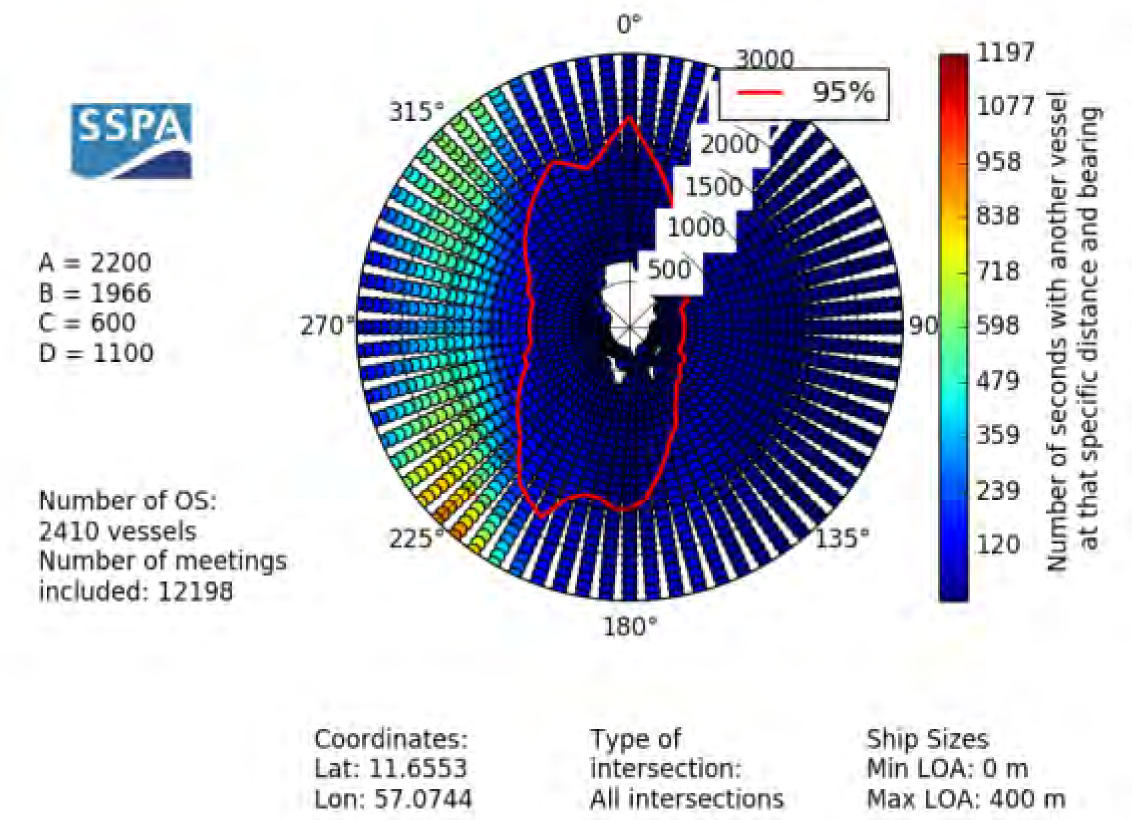
Coordinates:
Lat: 11.7122
Lon: 56.5837

Type of
intersection:
Overtaking

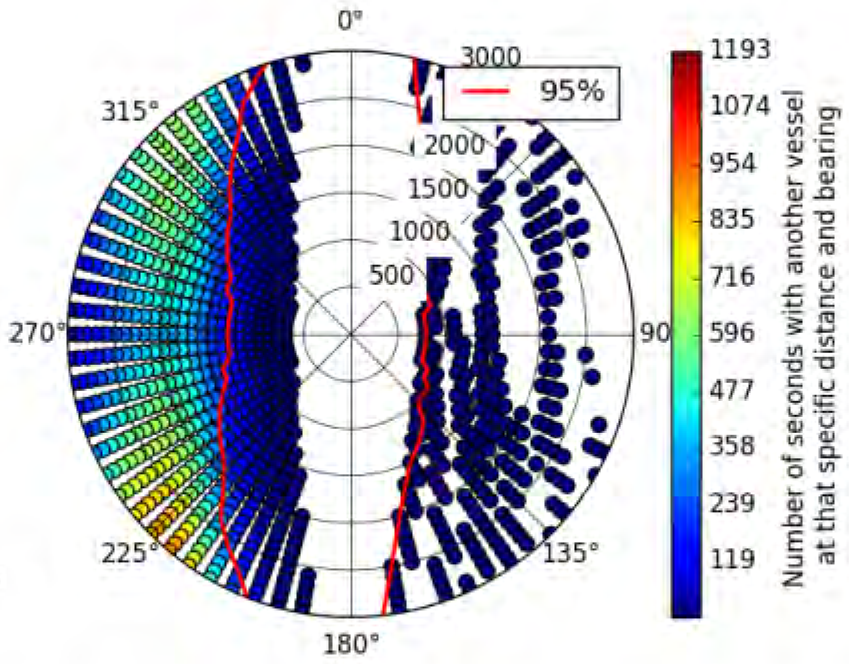
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 20.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



Number of OS:
2005 vessels
Number of meetings included: 6930

Coordinates:
Lat: 11.6553
Lon: 57.0744

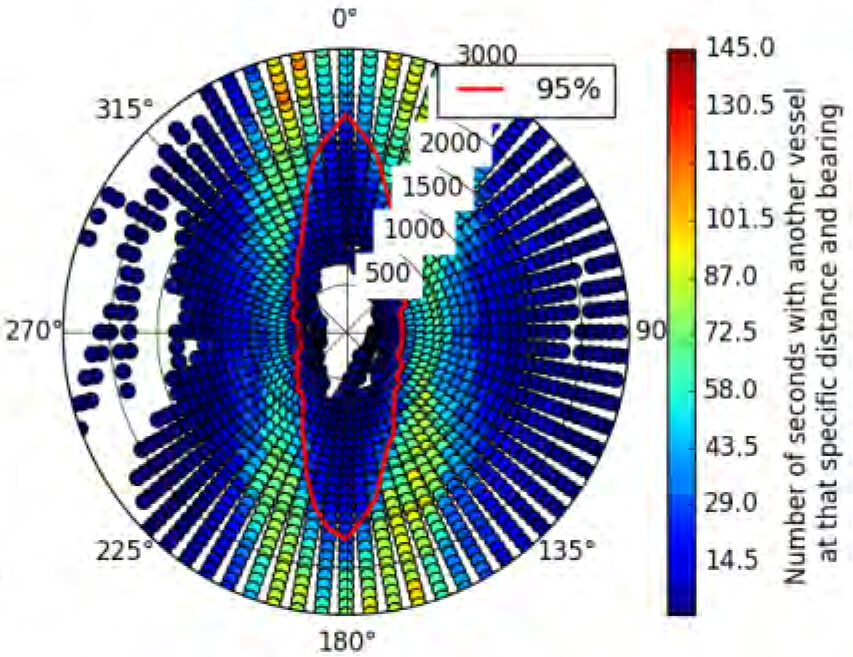
Type of intersection:
Headon meetings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

A = 2233
B = 2100
C = 600
D = 500

Number of OS:
1996 vessels
Number of meetings
included: 5095



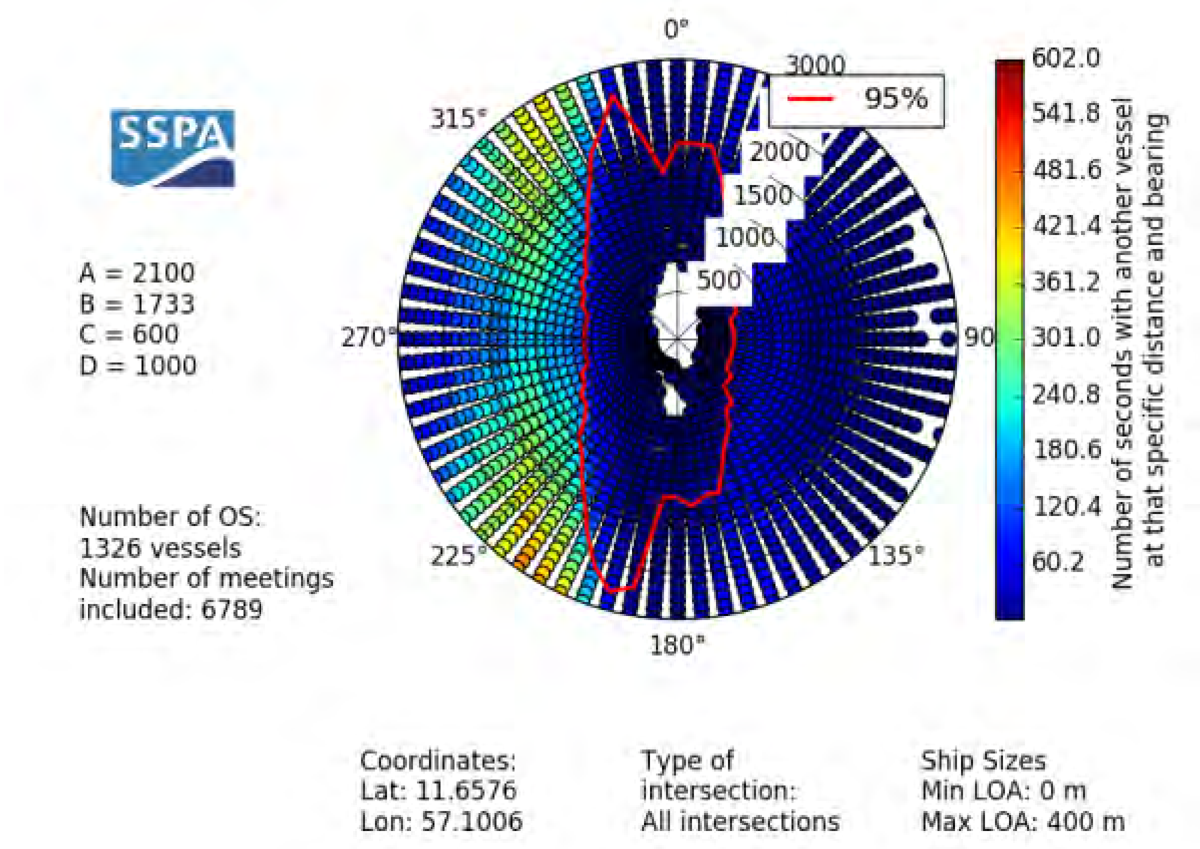
Coordinates:
Lat: 11.6553
Lon: 57.0744

Type of
intersection:
Overtaking

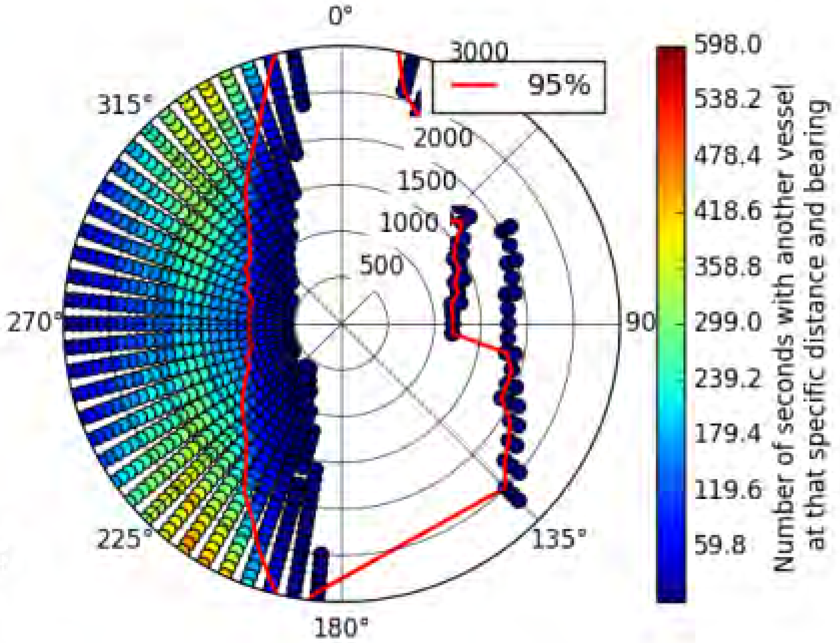
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 21.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



Number of OS:
1102 vessels
Number of meetings included: 3679

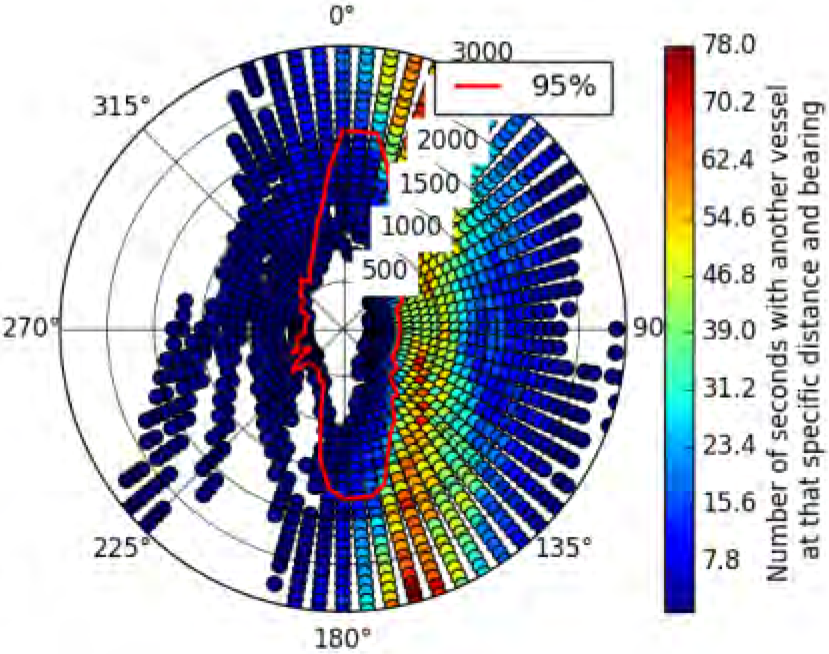
Coordinates:
Lat: 11.6576
Lon: 57.1006

Type of intersection:
Headon meetings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

A = 2100
B = 1766
C = 600
D = 400



Number of OS:
1071 vessels
Number of meetings included: 2928

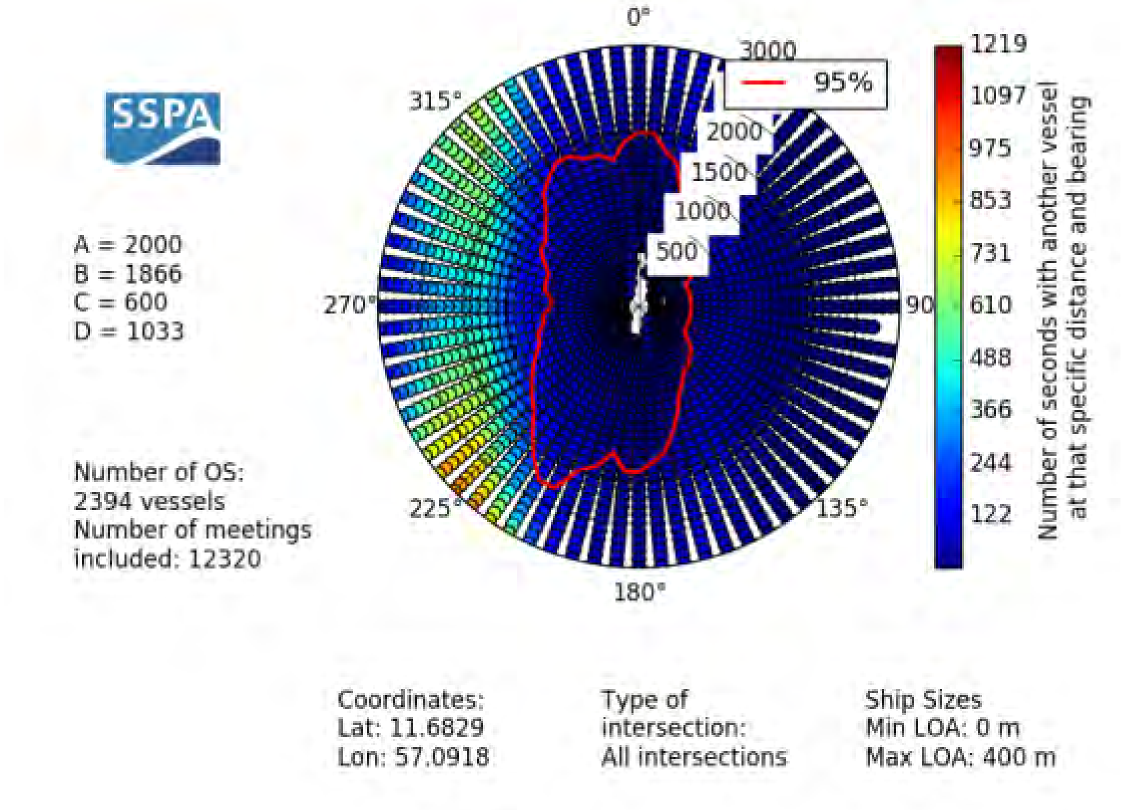
Coordinates:
Lat: 11.6576
Lon: 57.1006

Type of intersection:
Overtaking

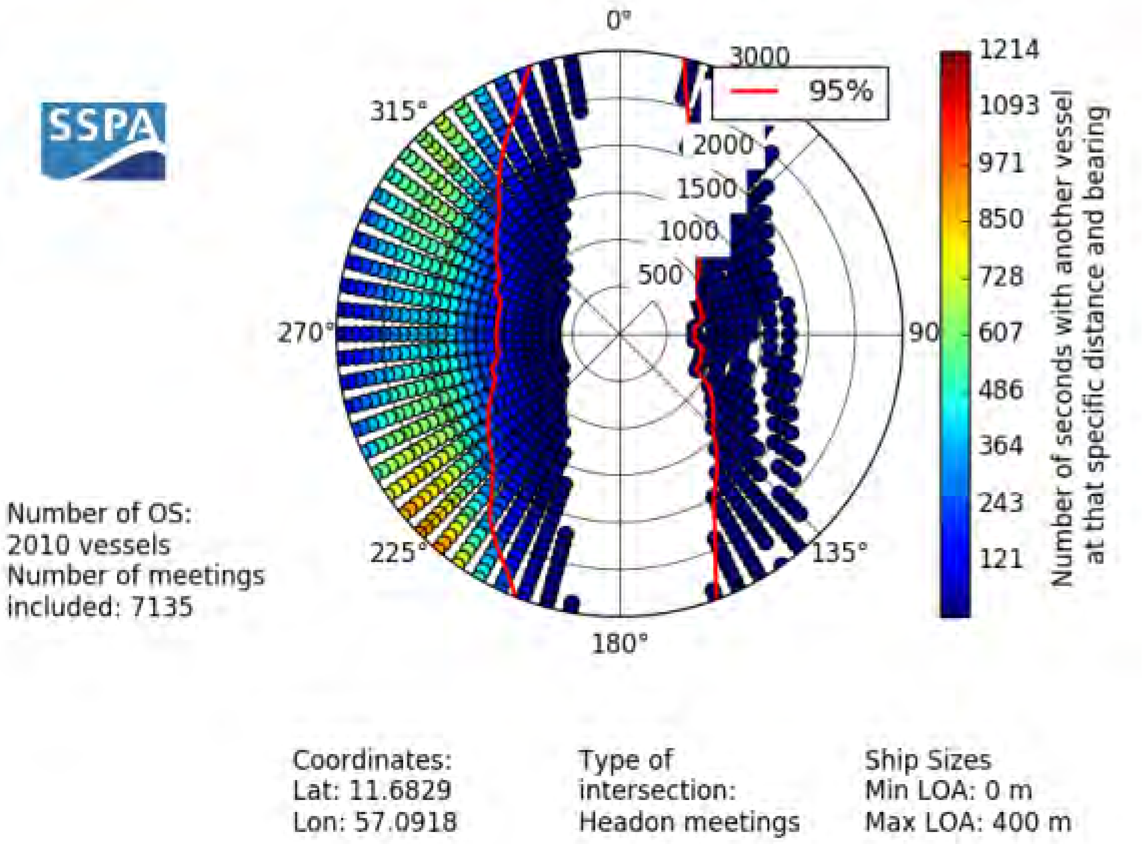
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

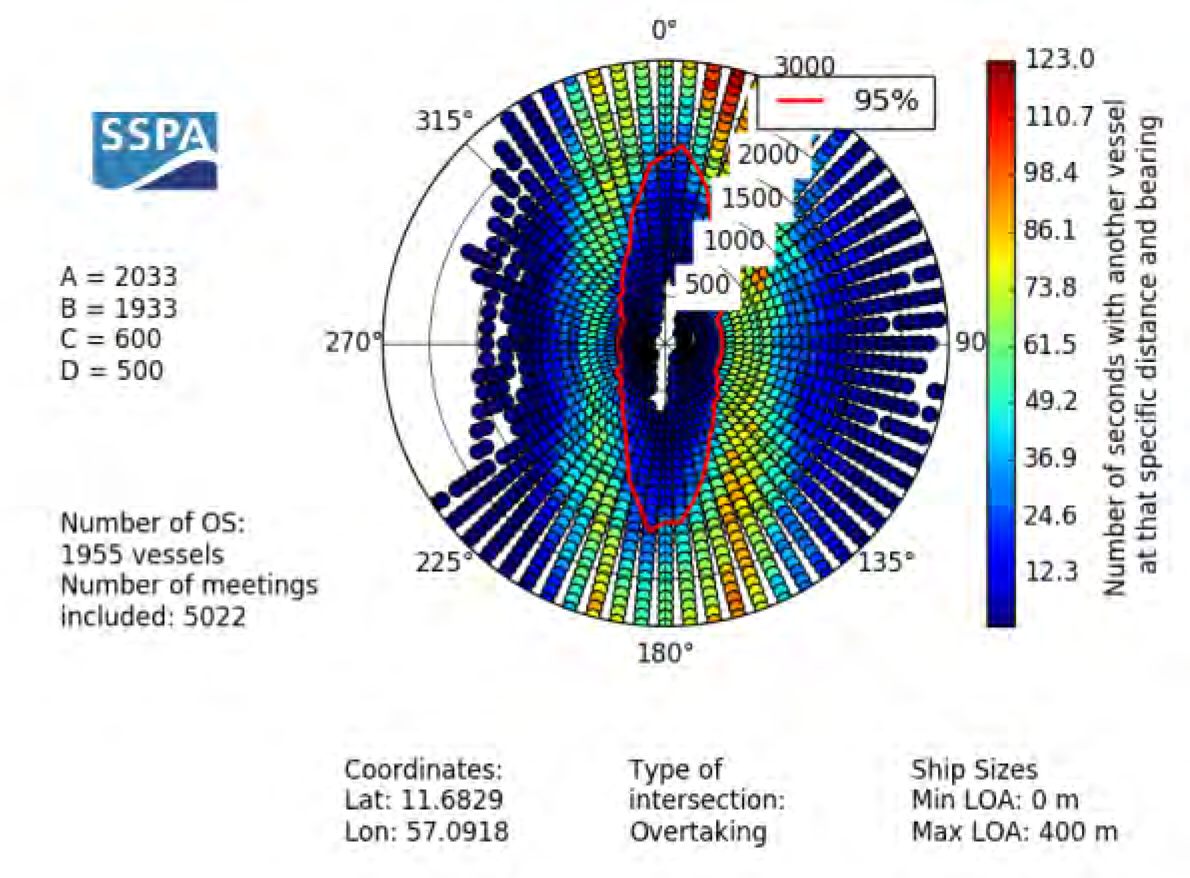
Location 22.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



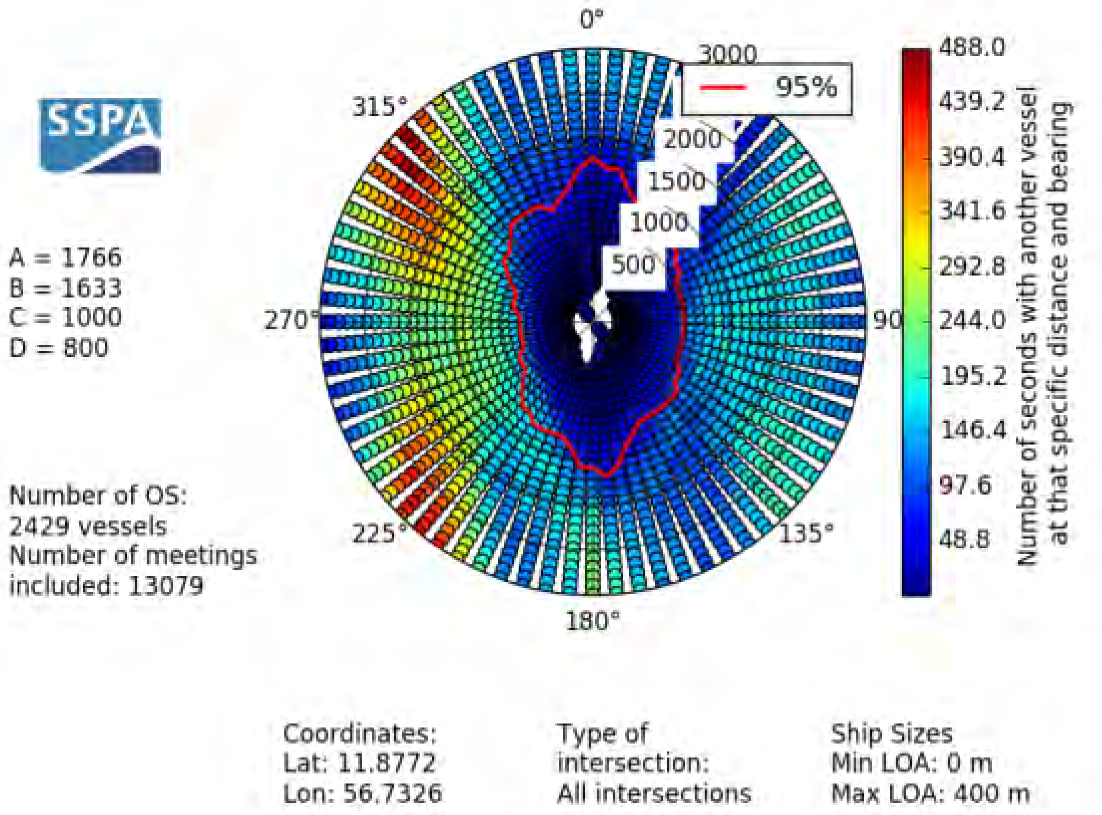
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



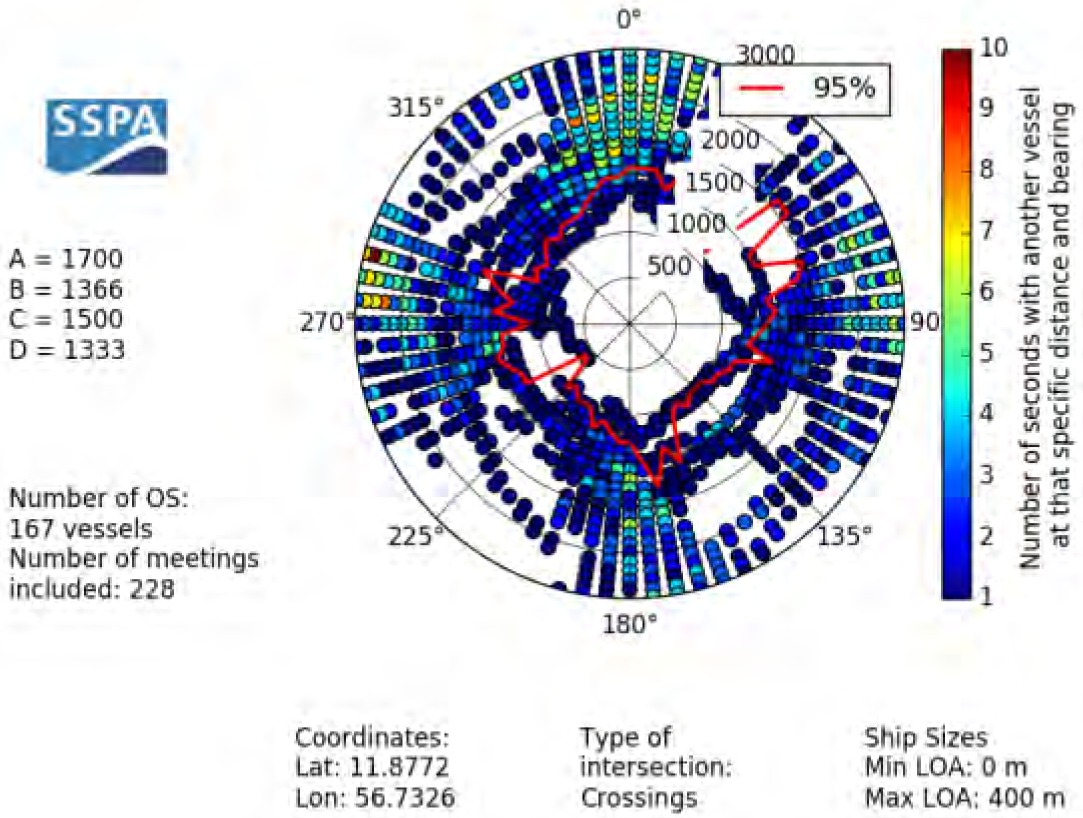
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 23.

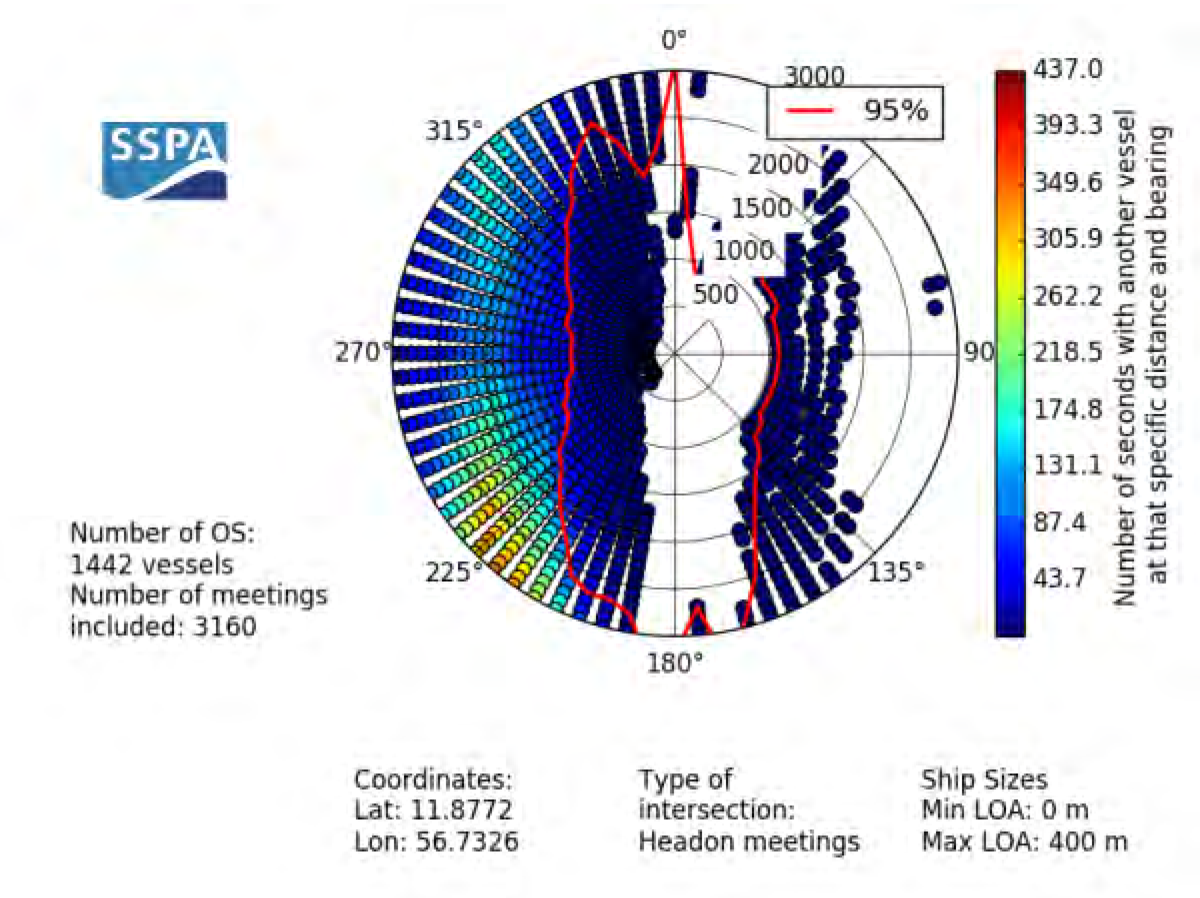
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



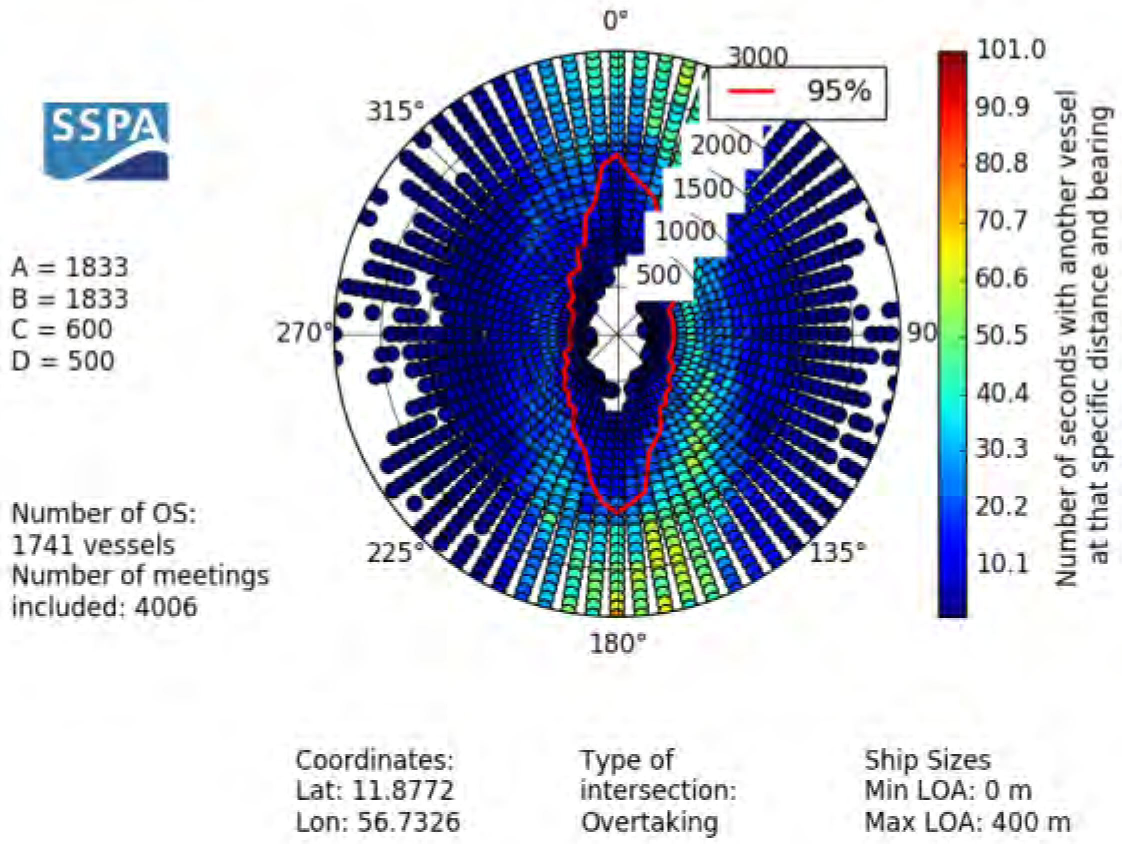
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



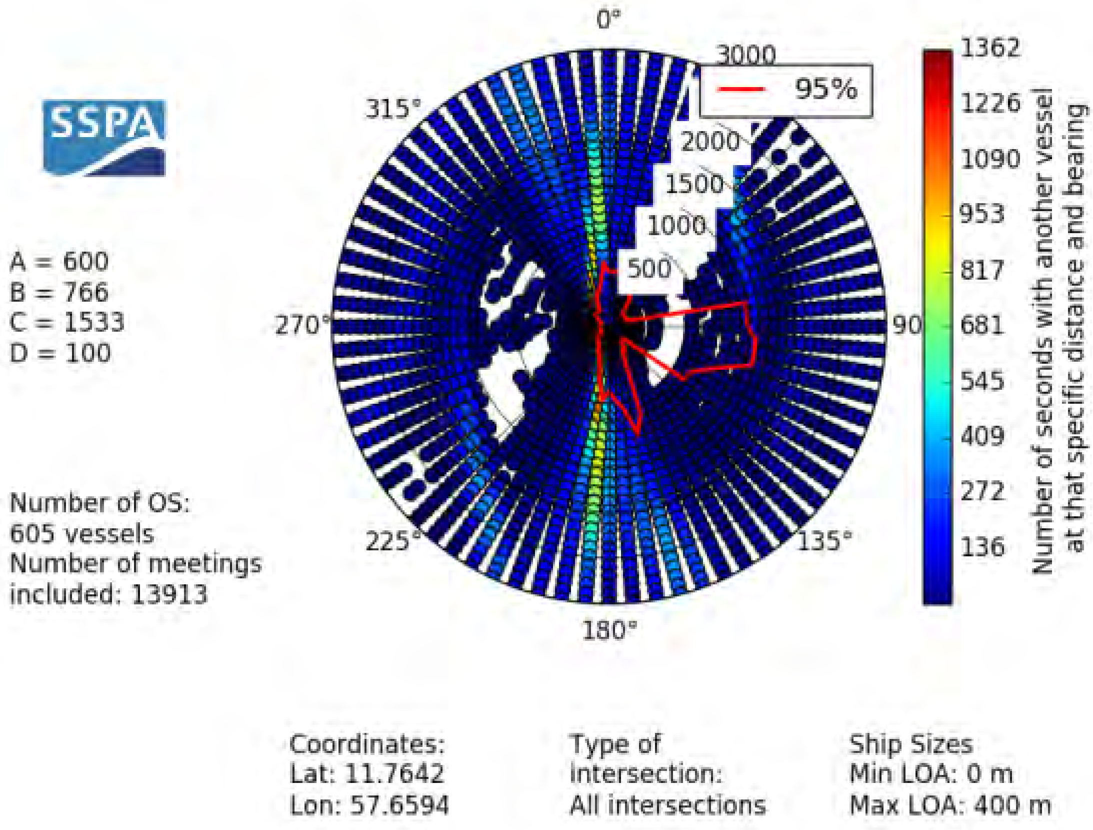
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



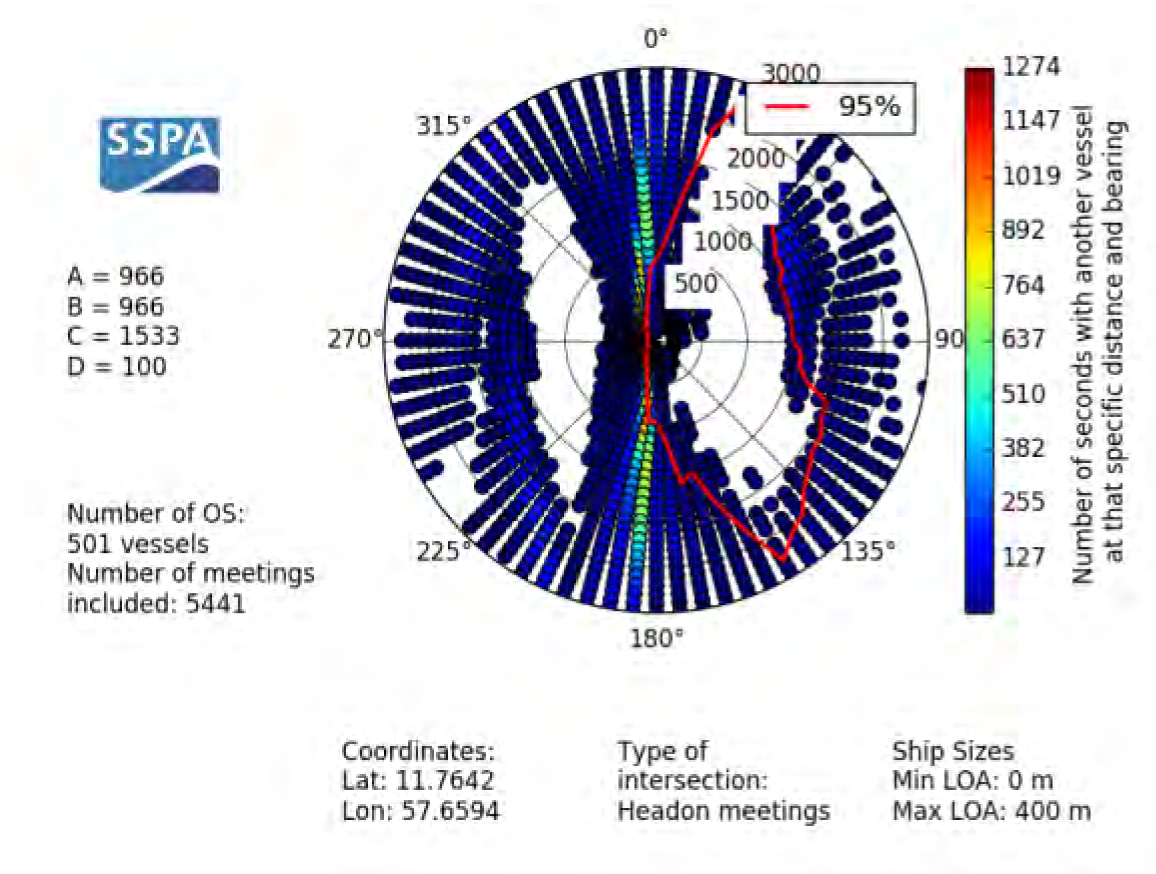
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 24.

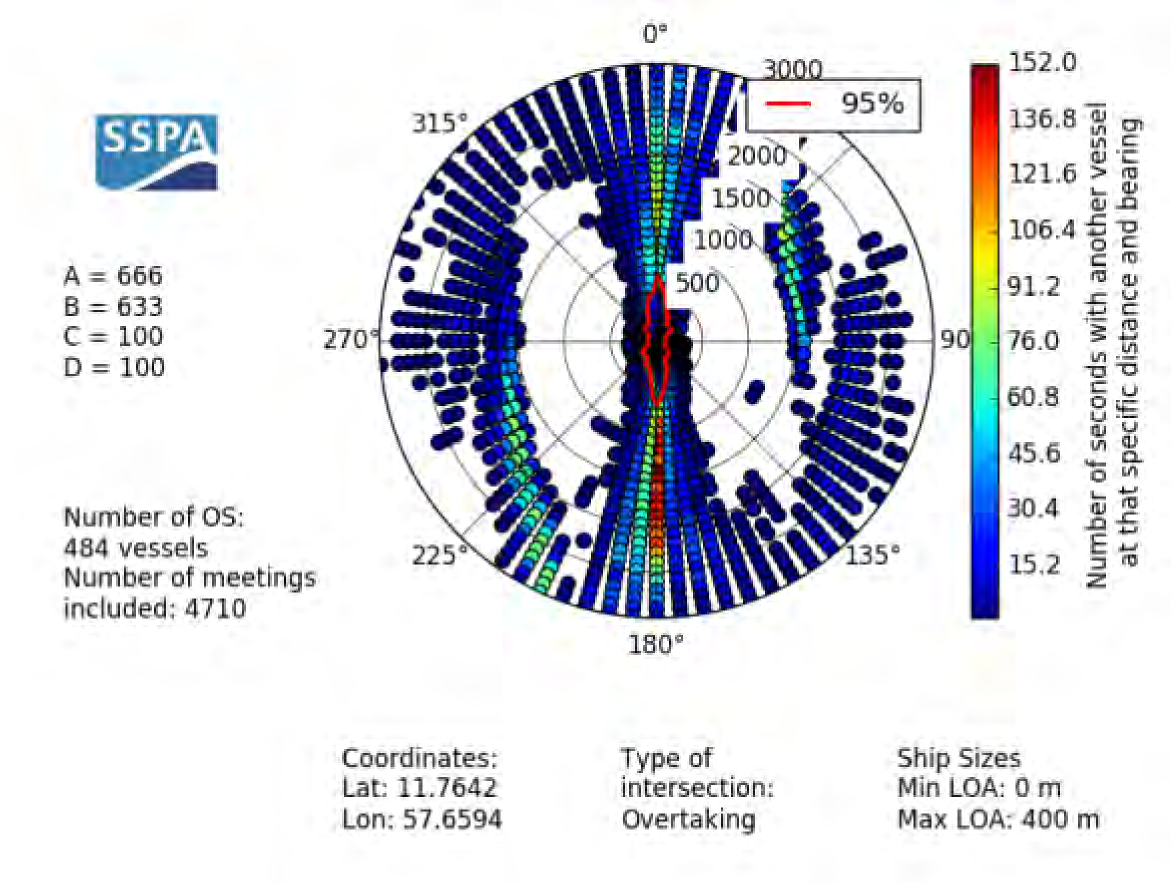
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

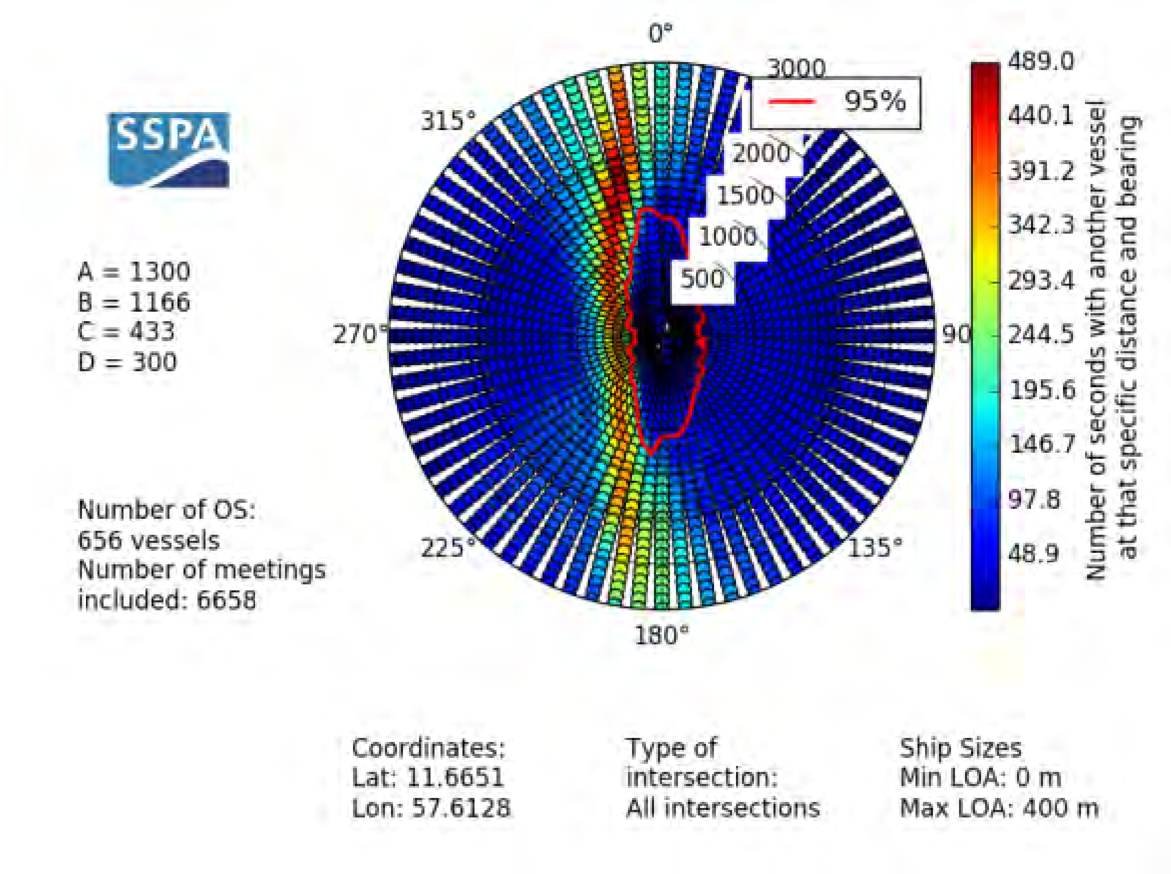


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

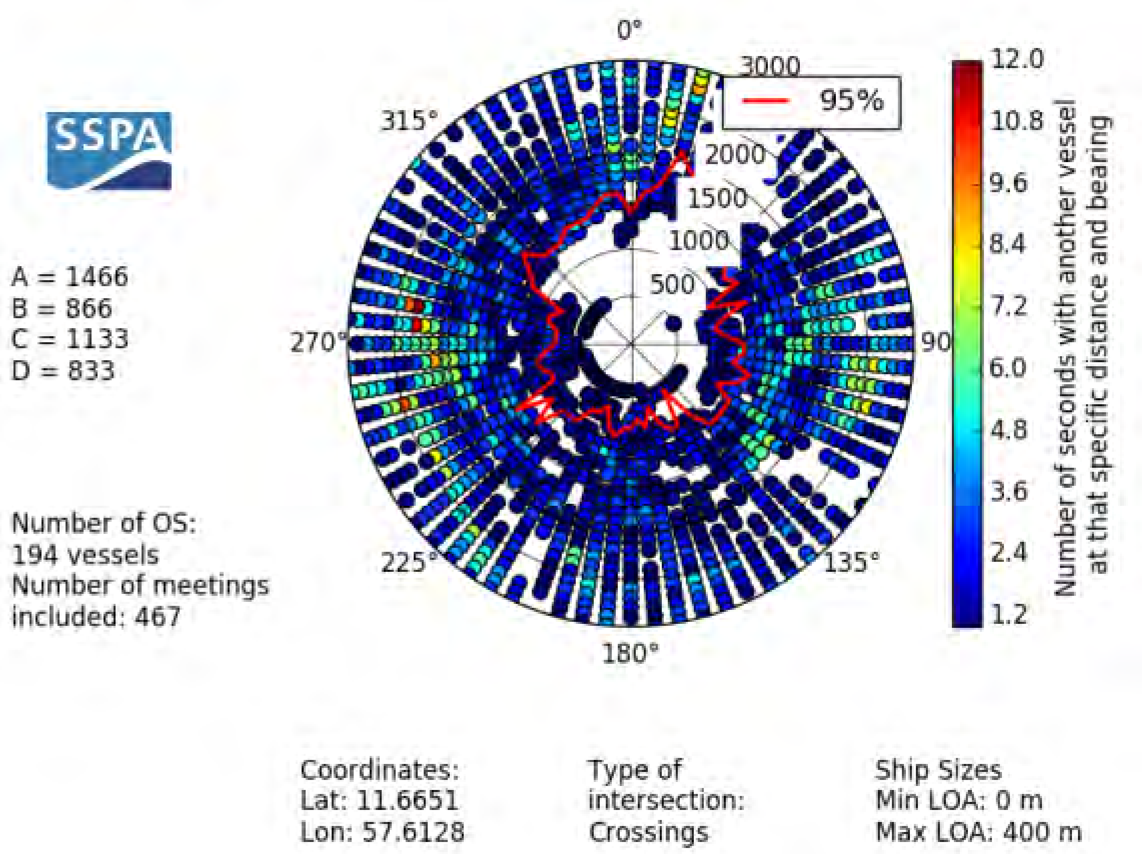


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

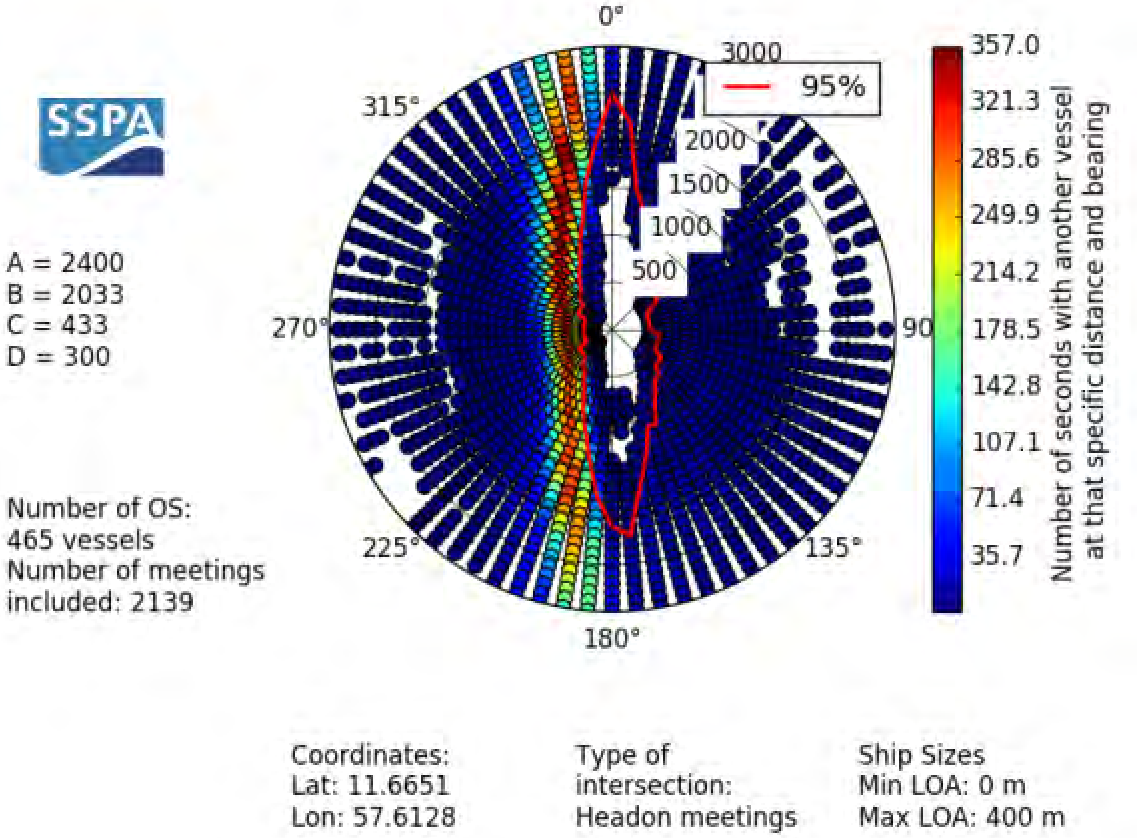
Location 25.



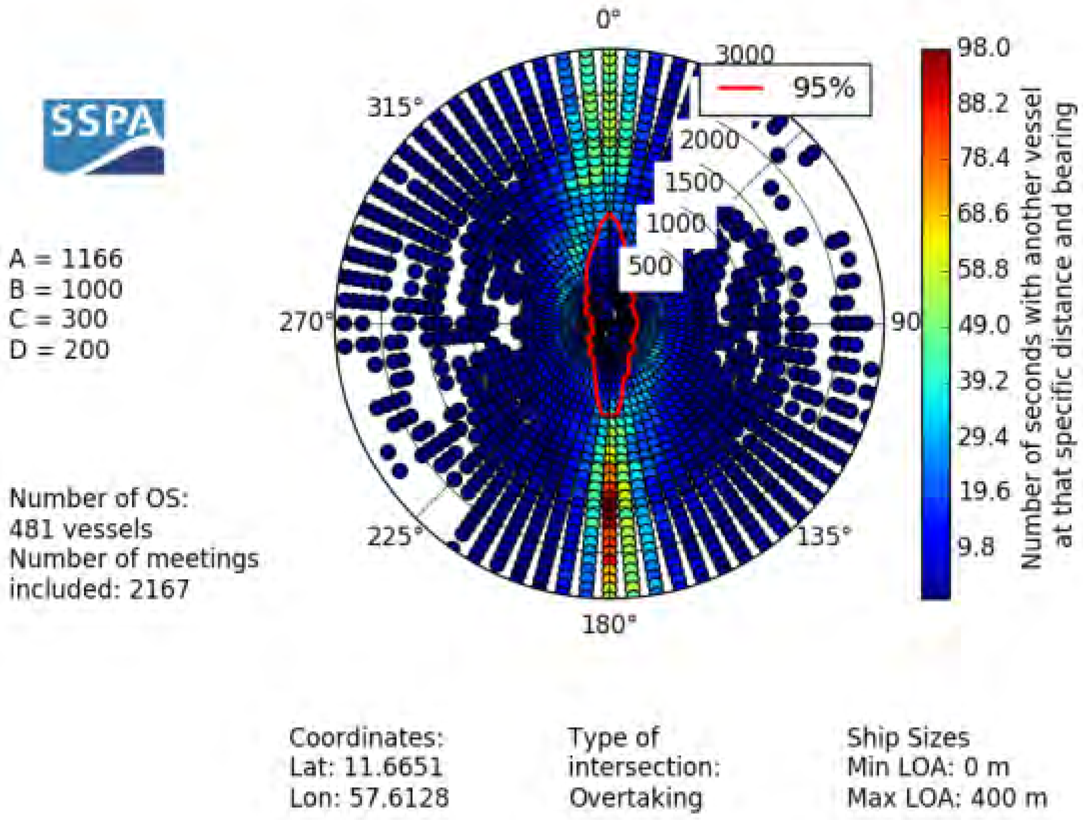
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

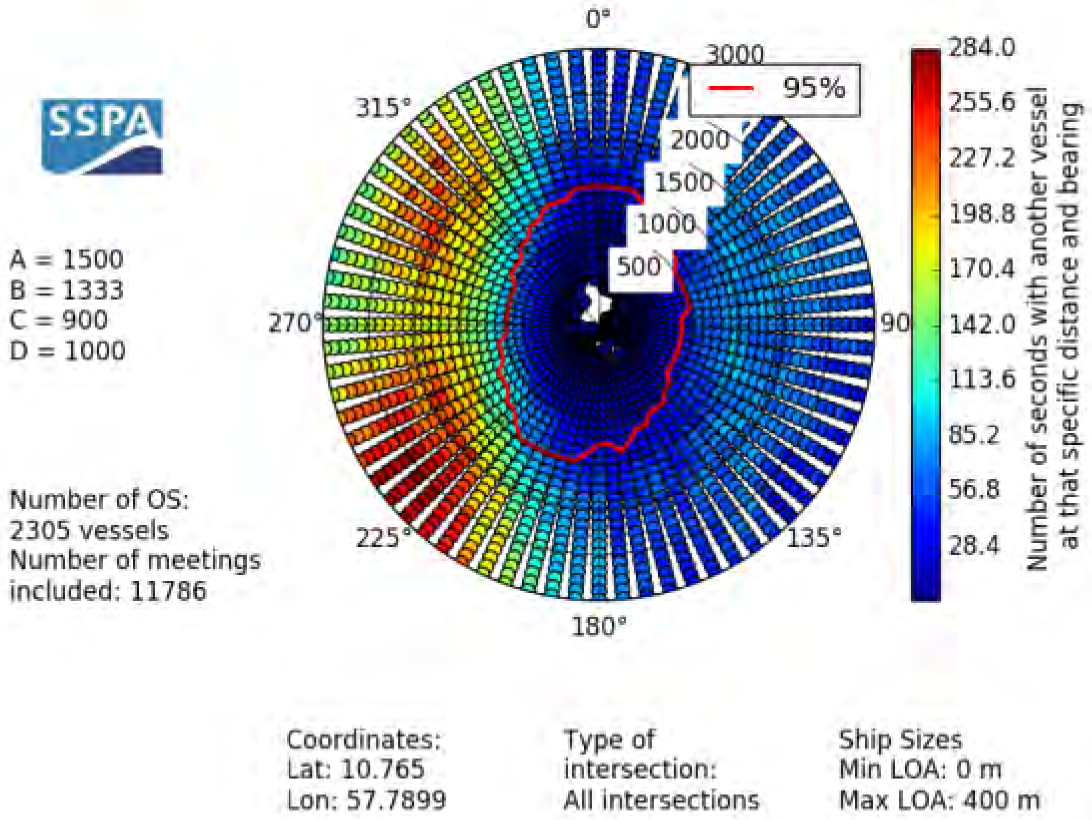


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

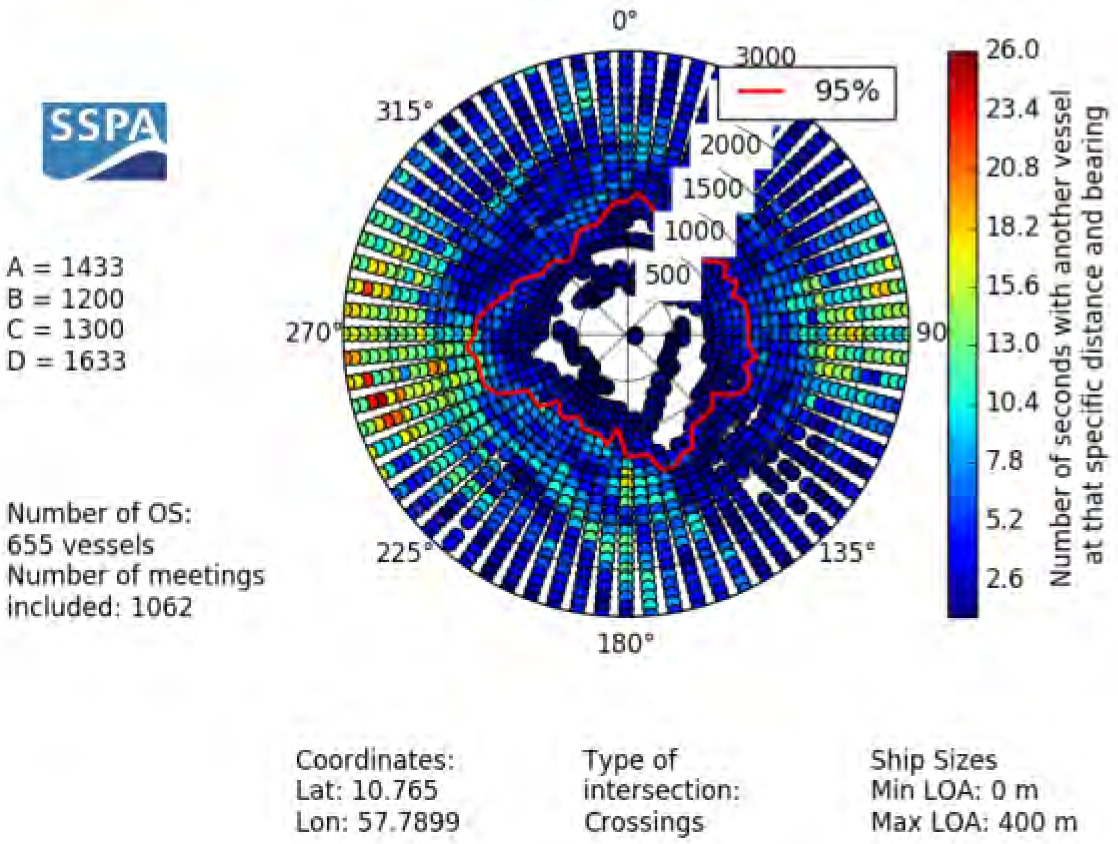


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

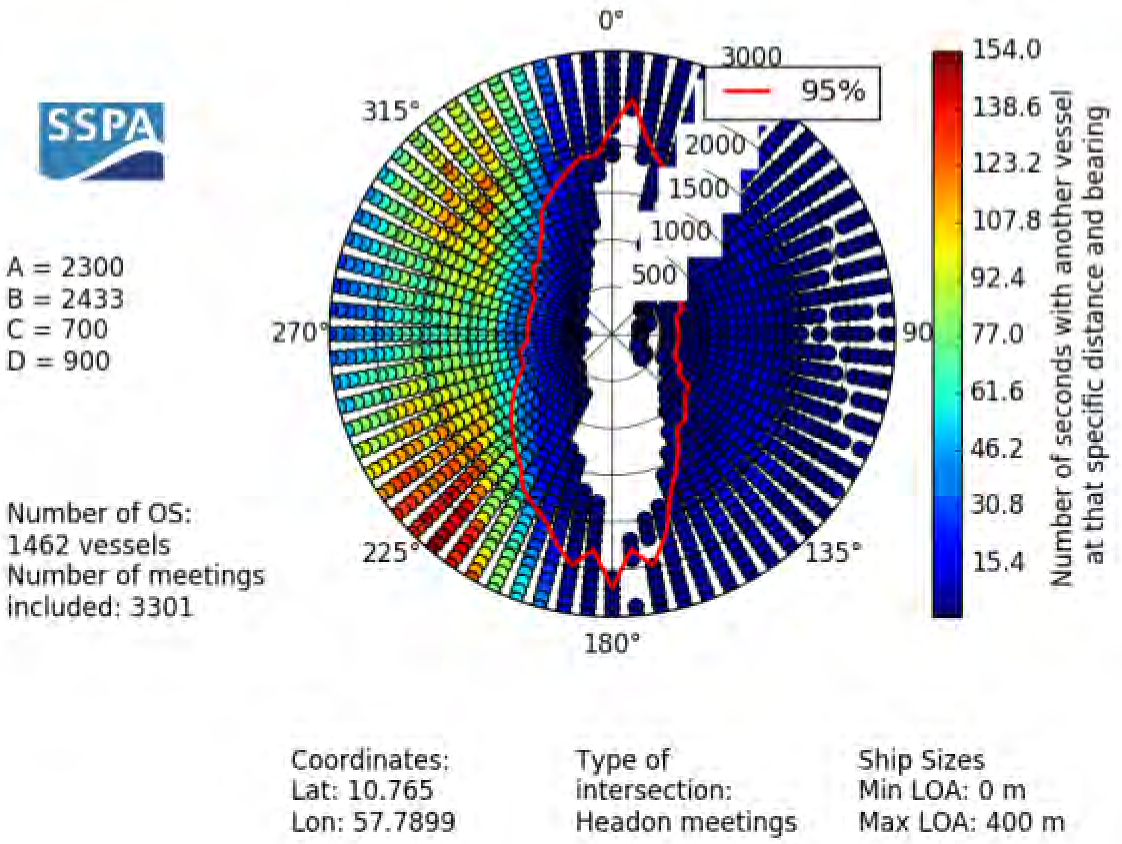
Location 26.



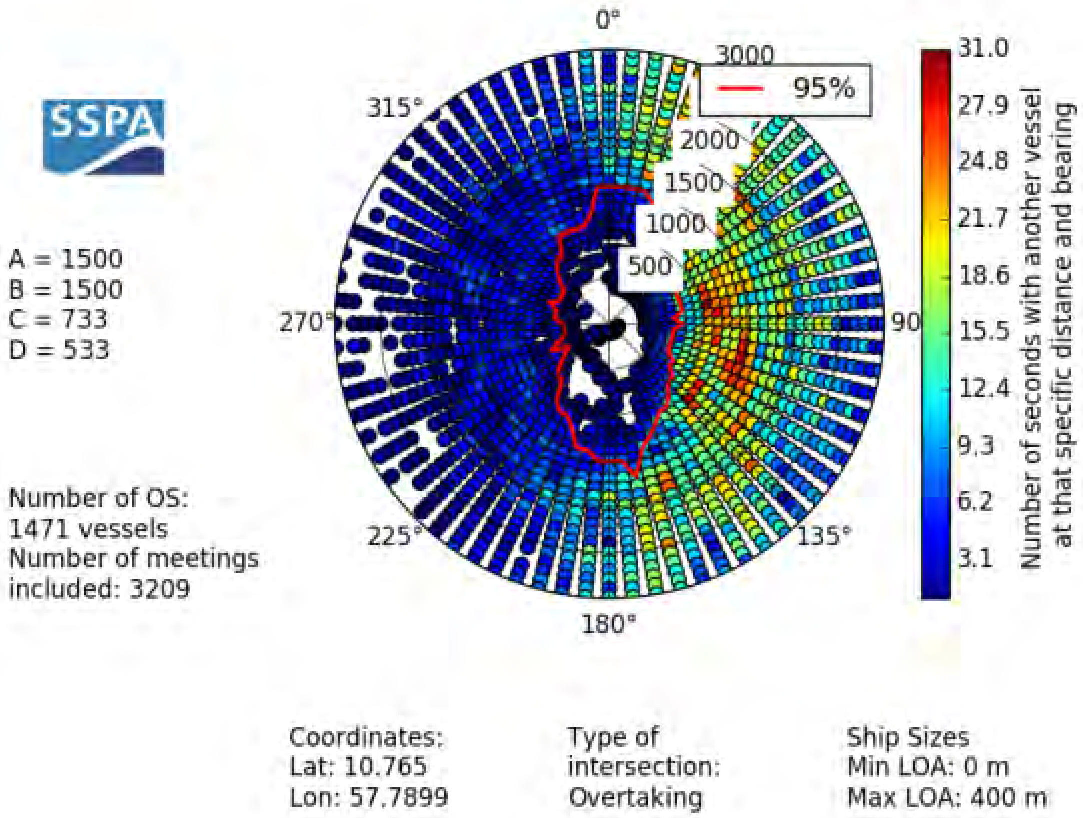
“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

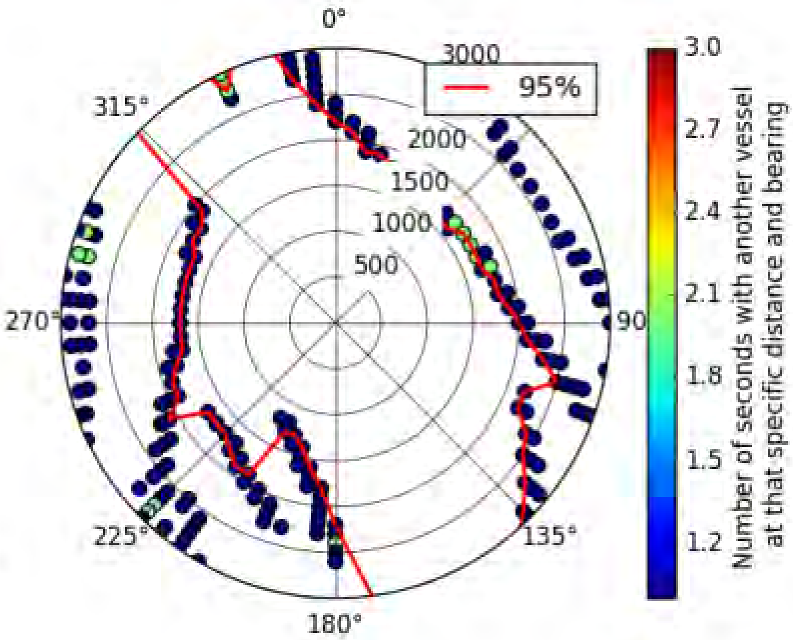


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 27.



Number of OS:
11 vessels
Number of meetings included: 18

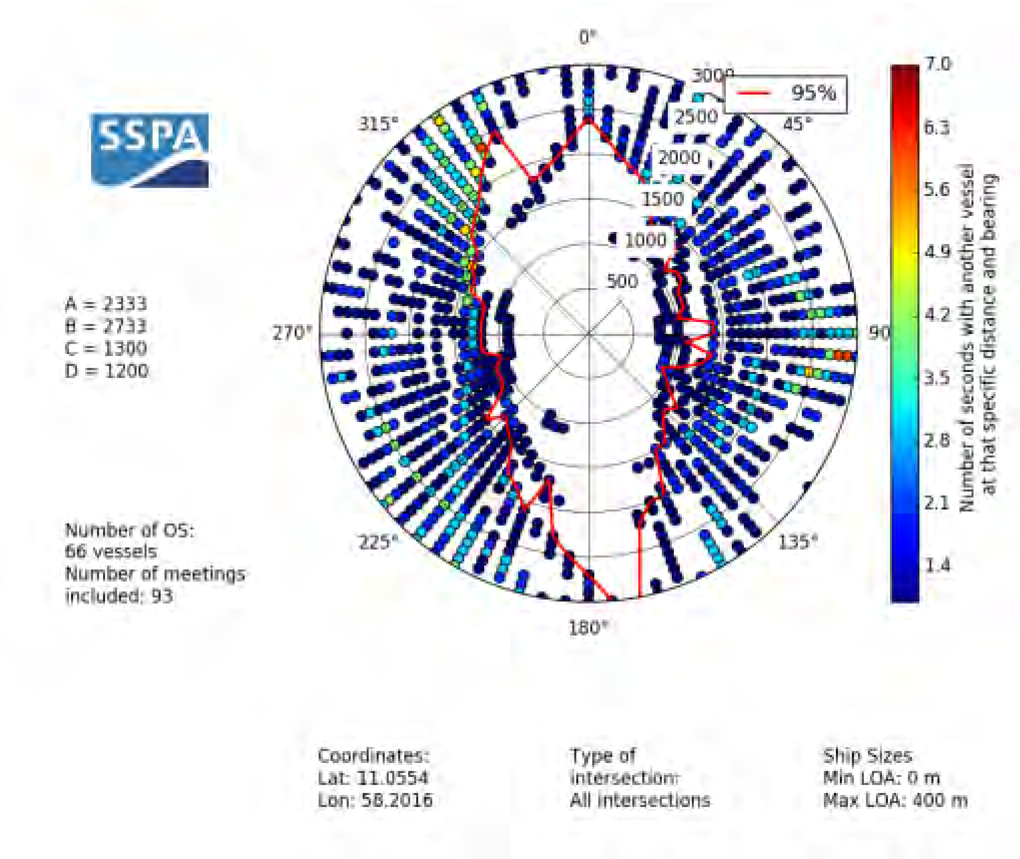
Coordinates:
Lat: 10.7375
Lon: 58.3527

Type of intersection:
All intersections

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

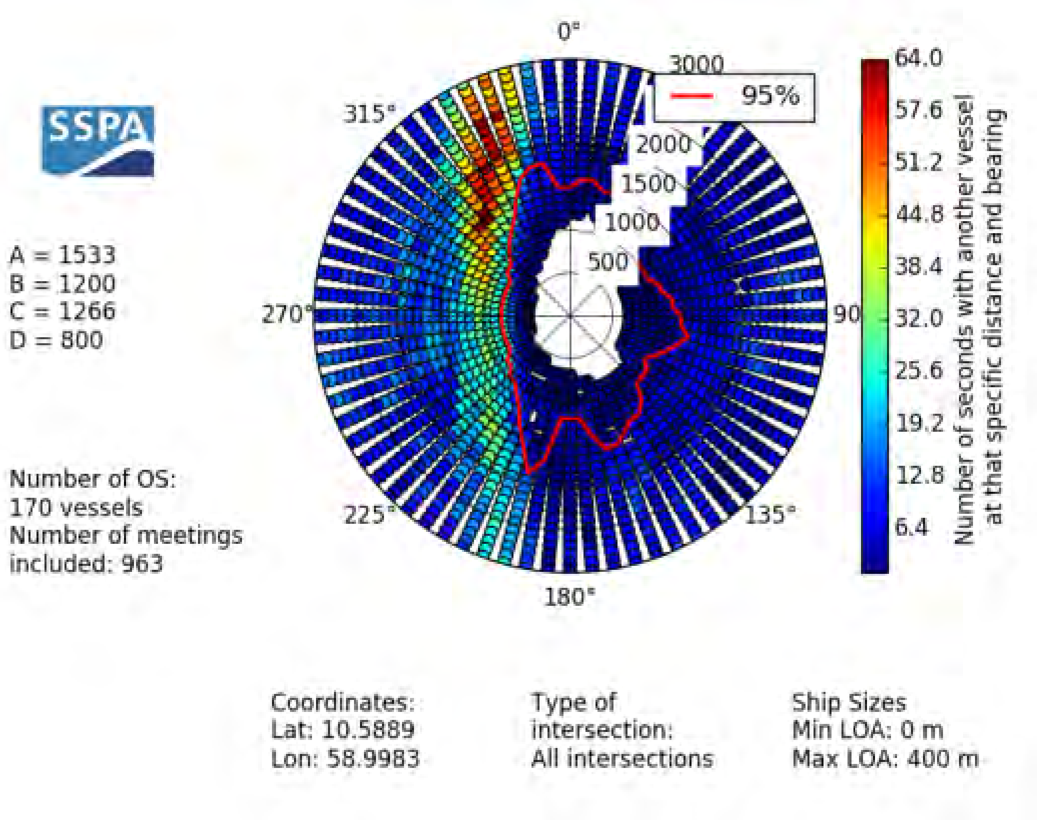
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 28.



Location 29.

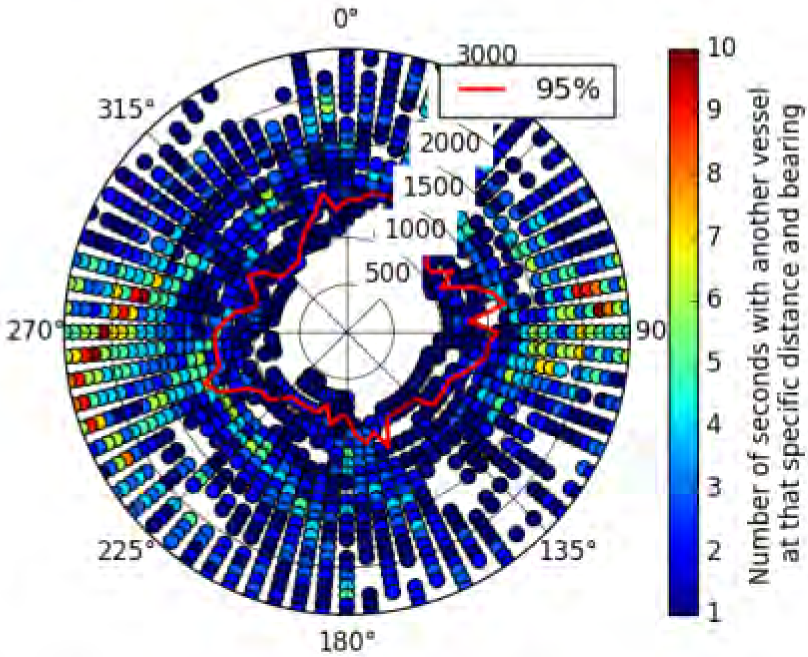
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

A = 1400
B = 966
C = 1466
D = 1366

Number of OS:
65 vessels
Number of meetings
included: 199

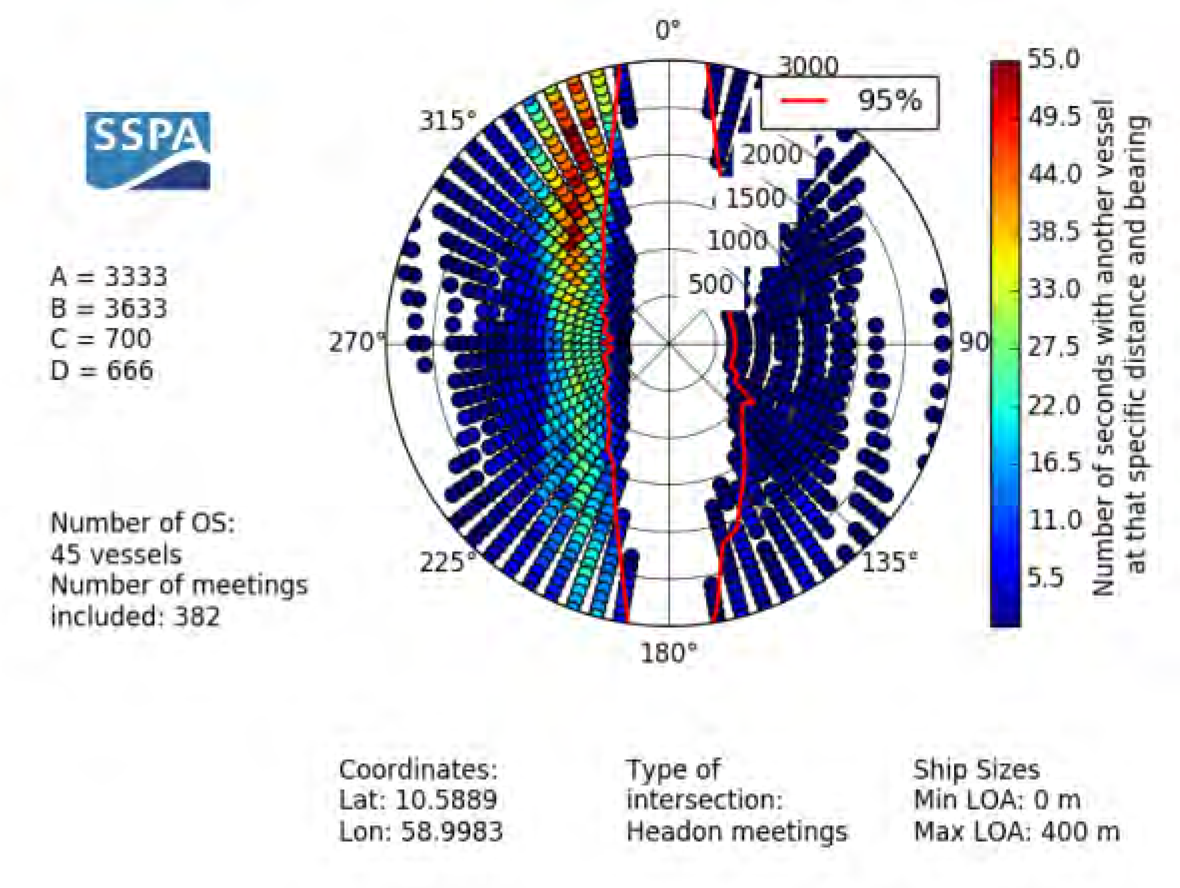


Coordinates:
Lat: 10.5889
Lon: 58.9983

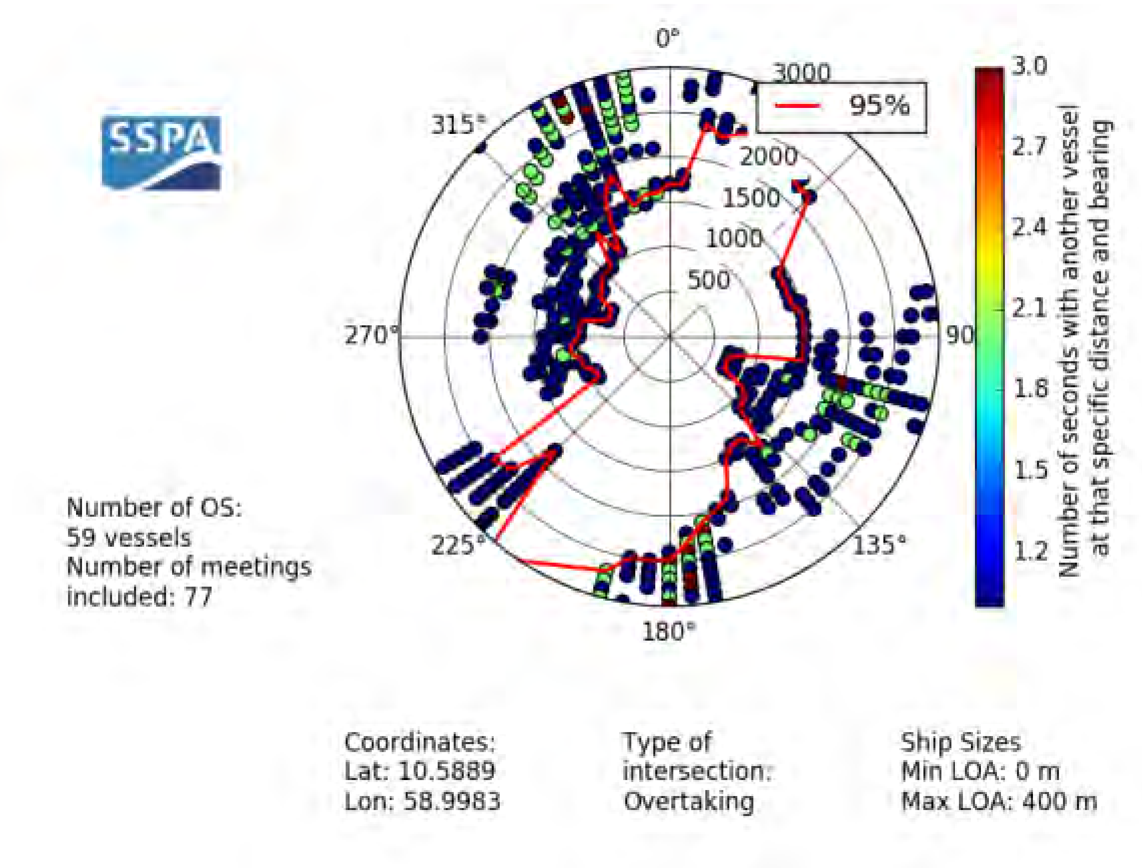
Type of
intersection:
Crossings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

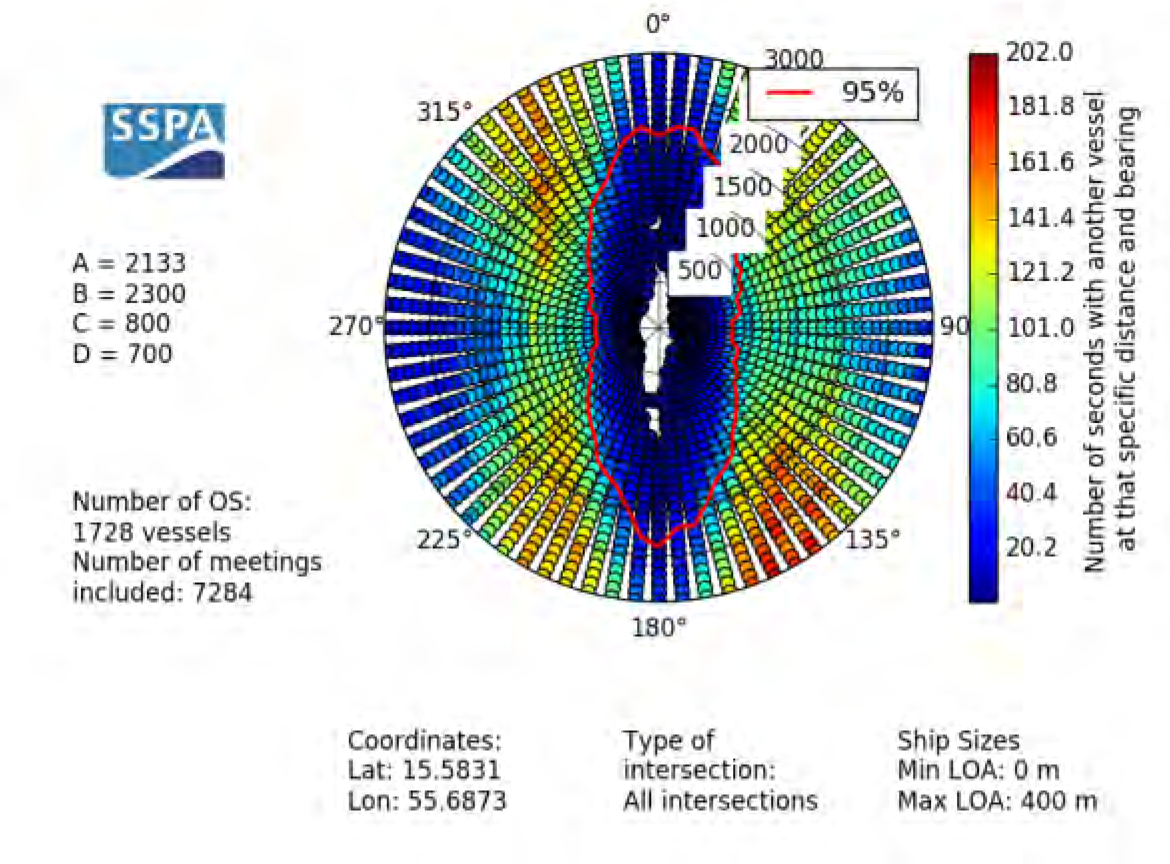


“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

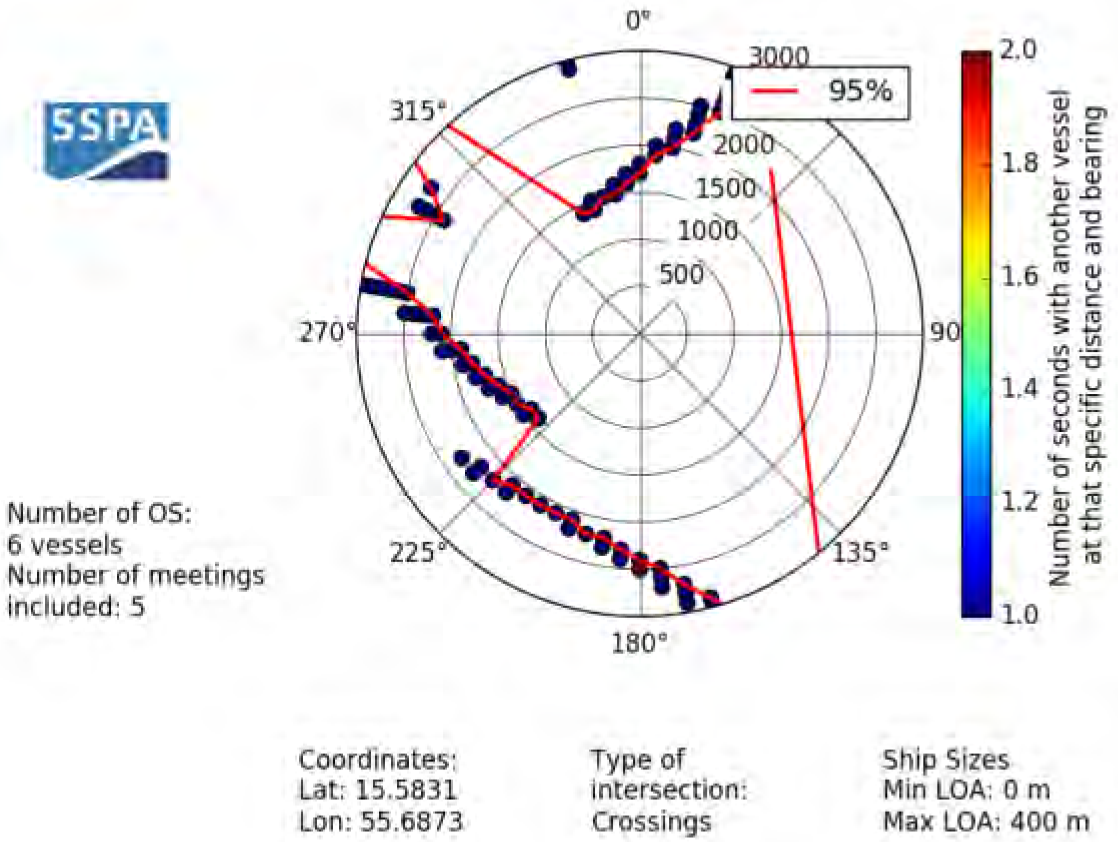


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

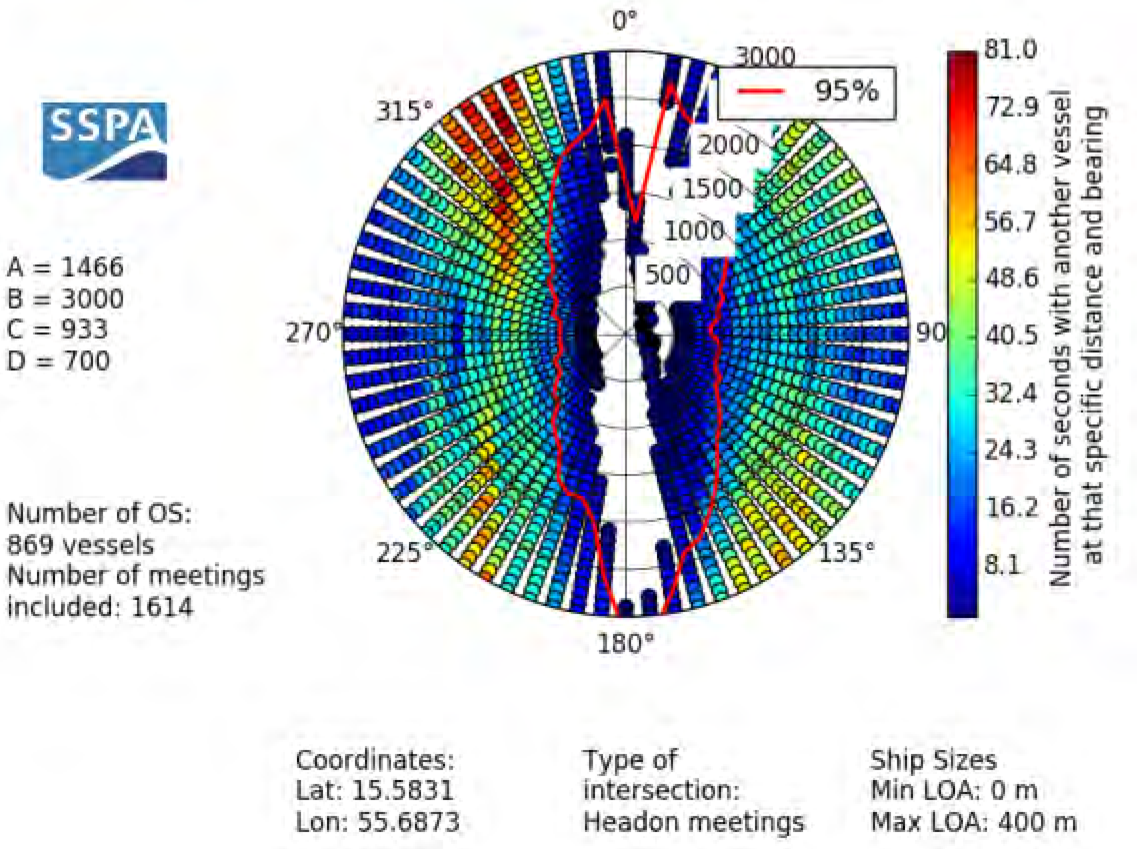
Location 30.



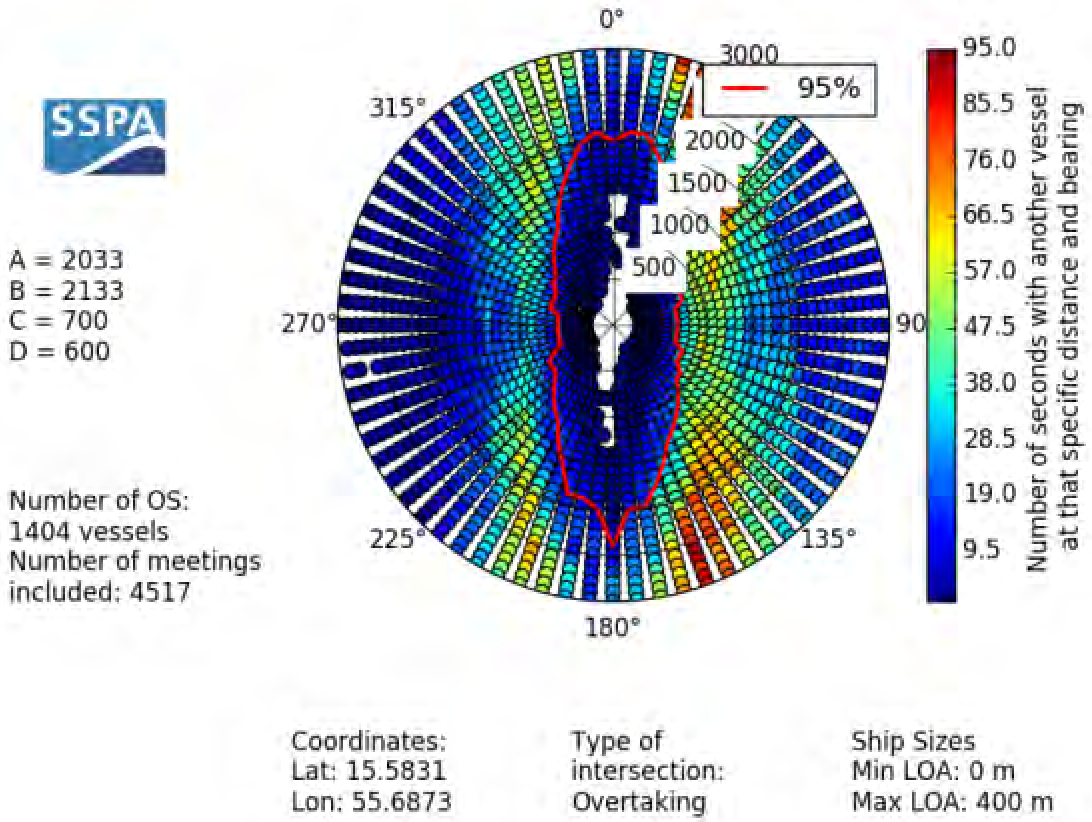
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

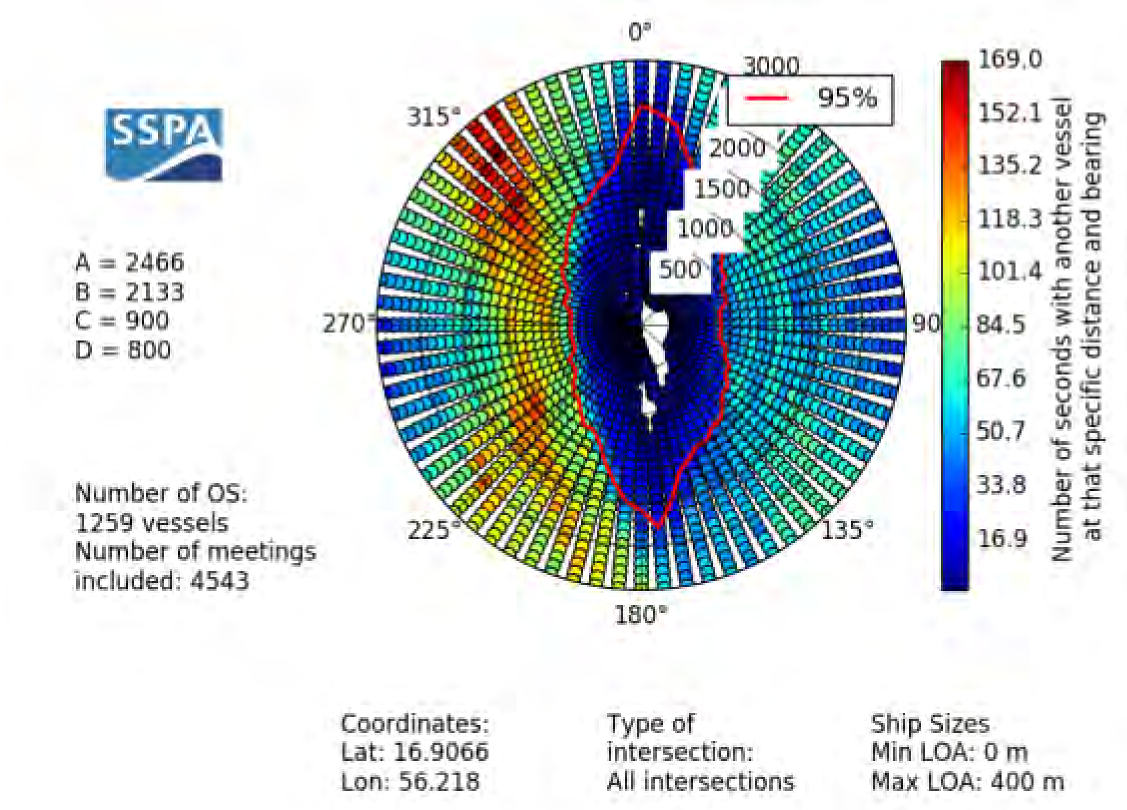


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

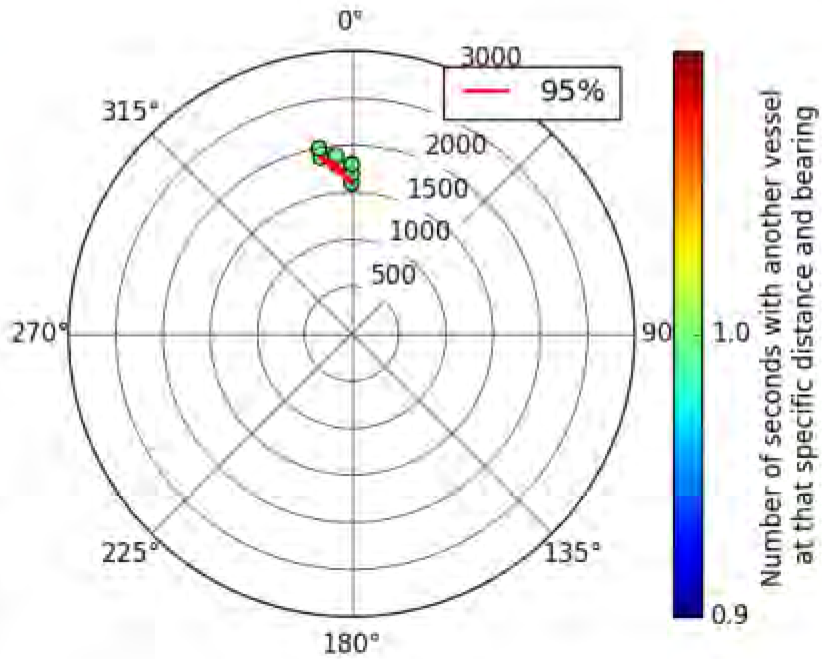


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 31.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



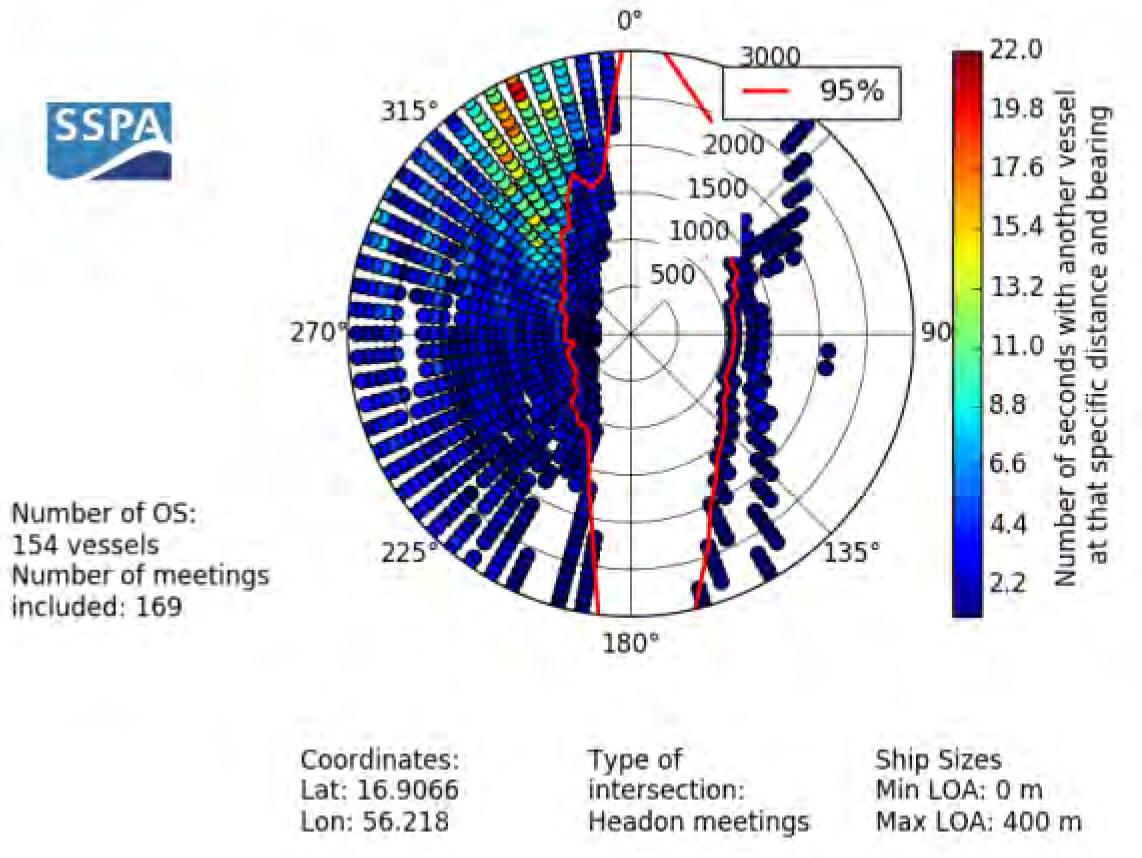
Number of OS:
1 vessels
Number of meetings
included: 1

Coordinates:
Lat: 16.9066
Lon: 56.218

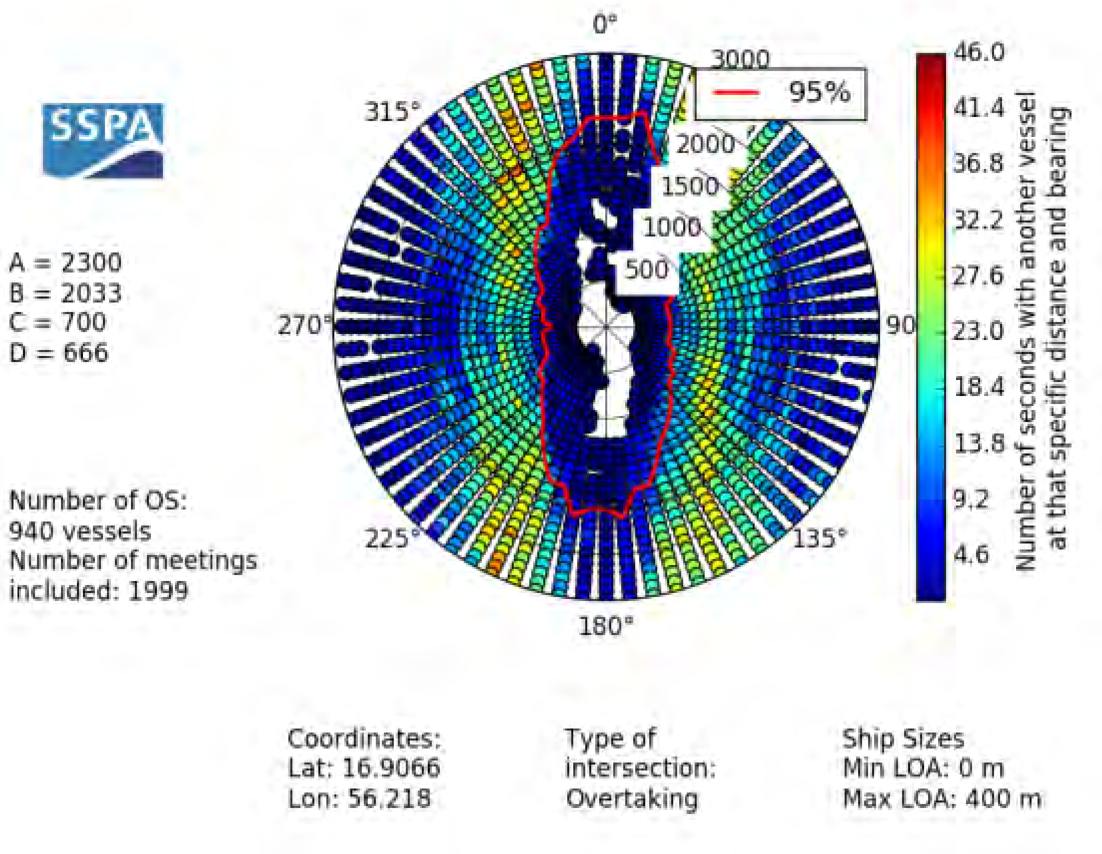
Type of
intersection:
Crossings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

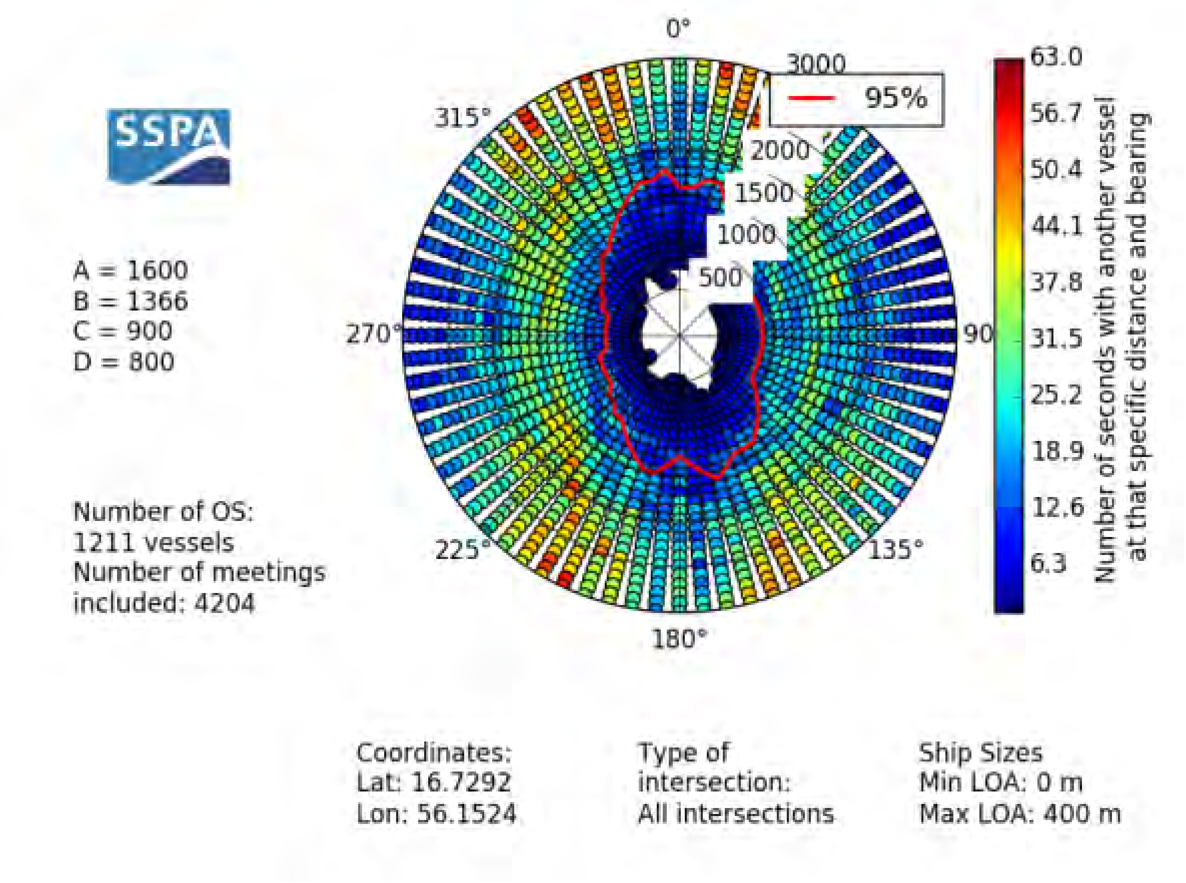


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

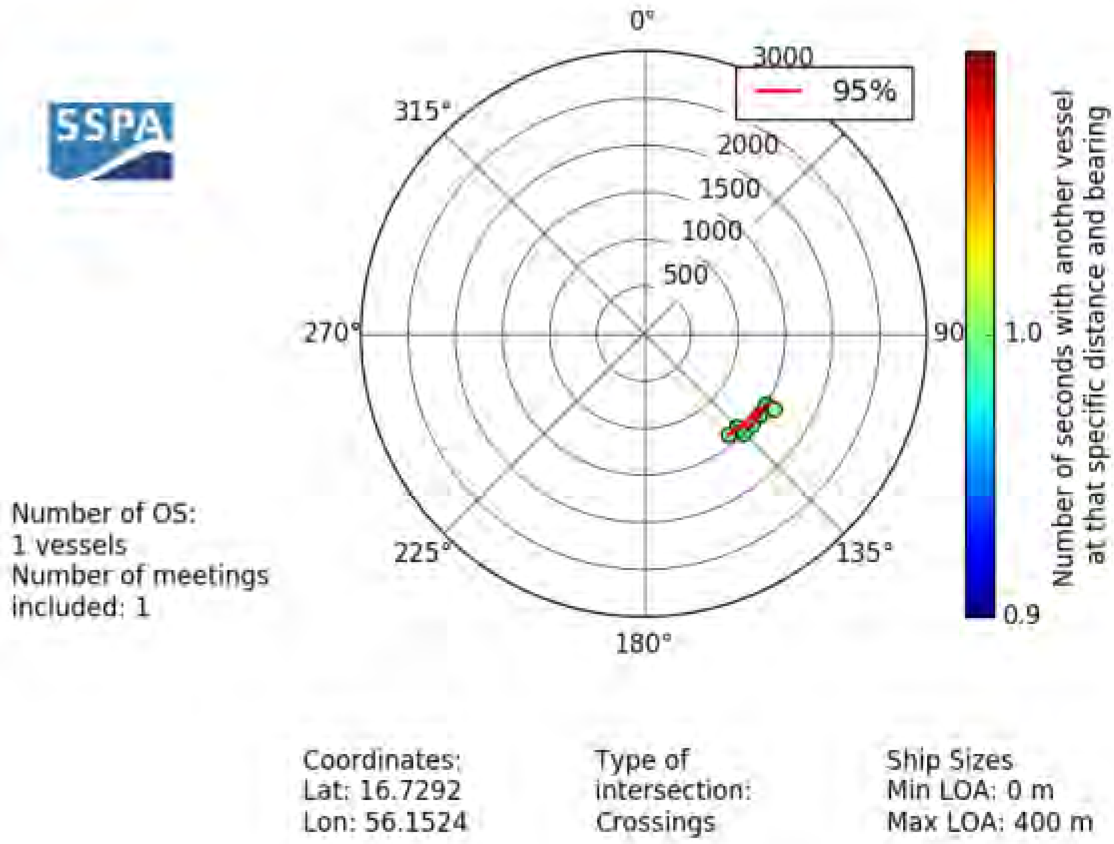


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

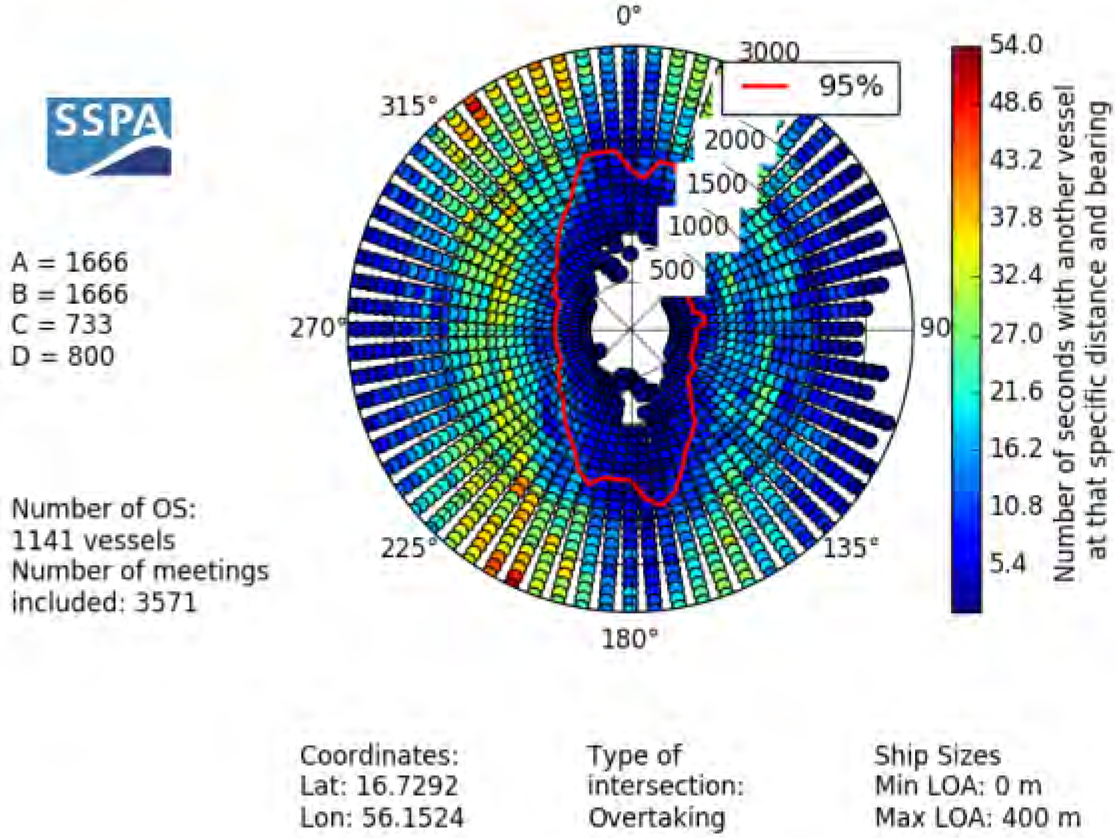
Location 32.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



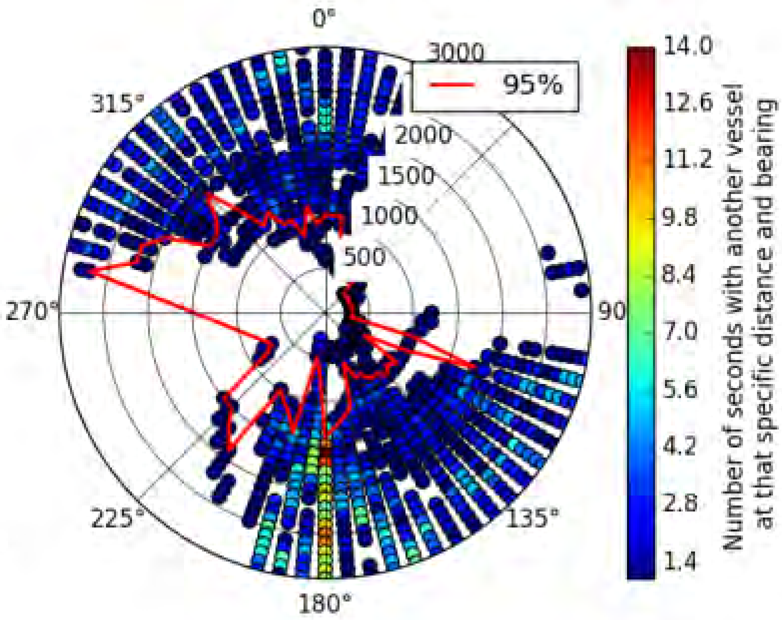
"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



“This project has received funding from the *European Union’s Horizon 2020 research and innovation programme* under grant agreement No 636329”.

Location 33.

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



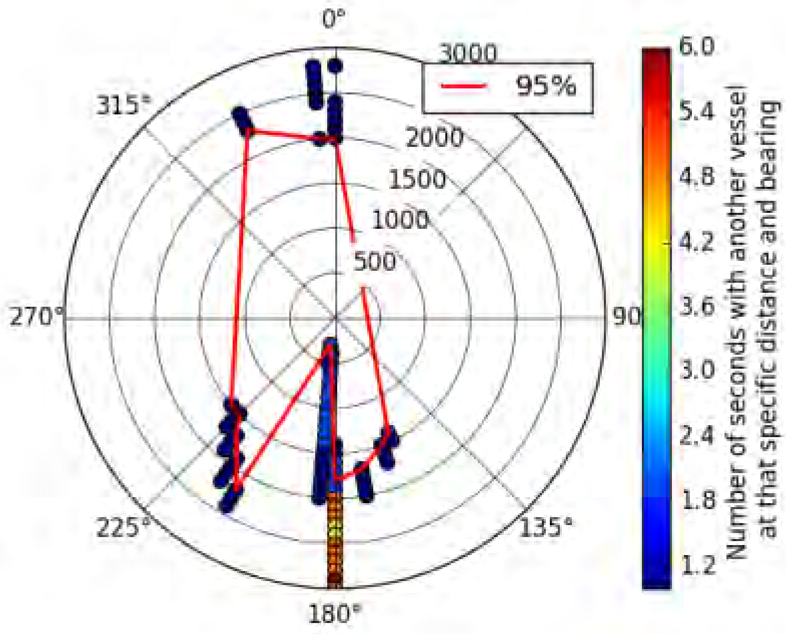
Number of OS:
48 vessels
Number of meetings included: 115

Coordinates:
Lat: 16.3935
Lon: 56.6783

Type of intersection:
All intersections

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



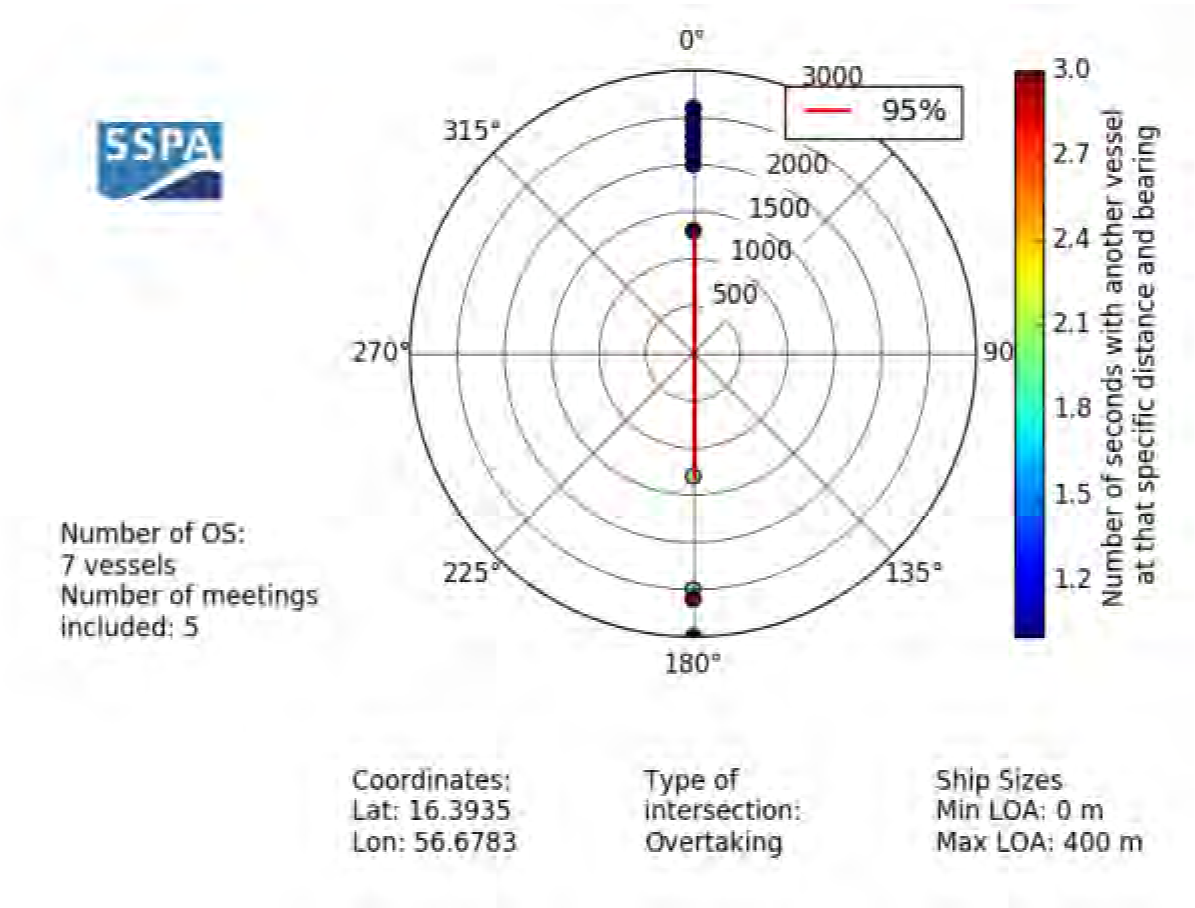
Number of OS:
8 vessels
Number of meetings included: 7

Coordinates:
Lat: 16.3935
Lon: 56.6783

Type of intersection:
Headon meetings

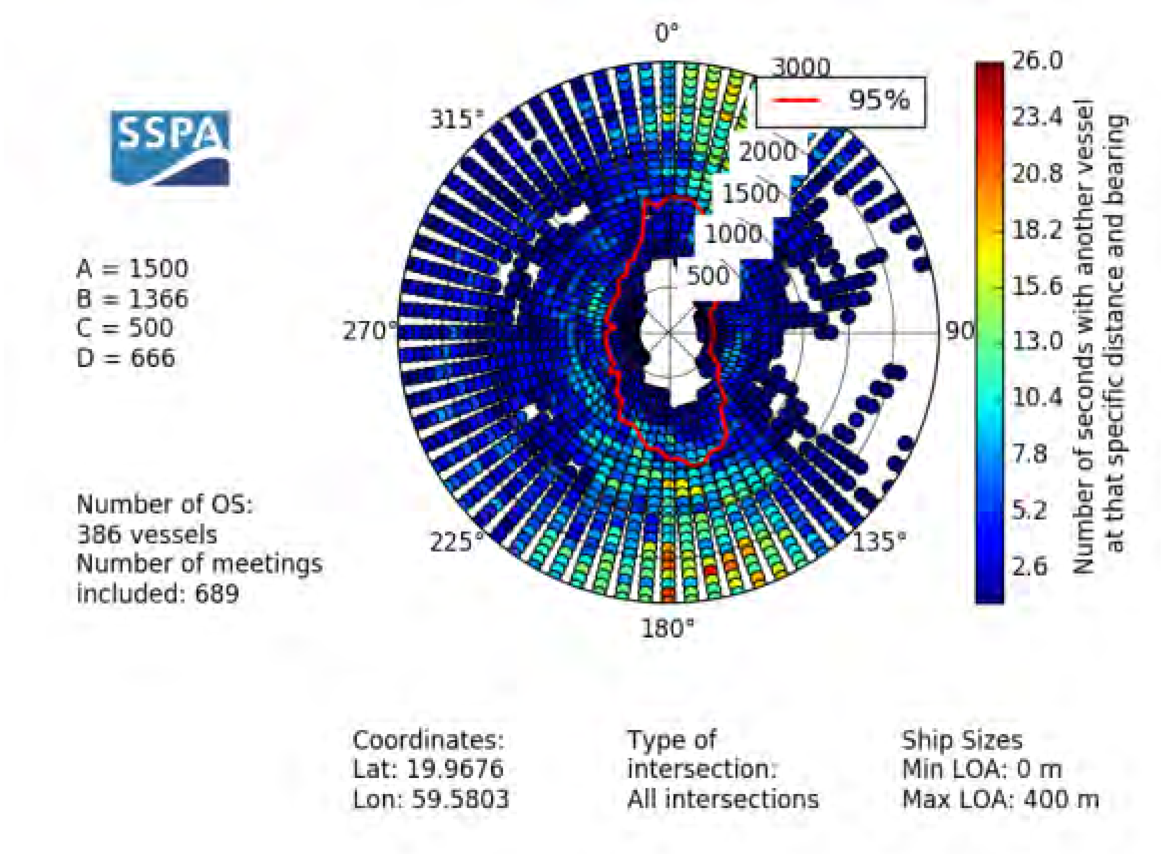
Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

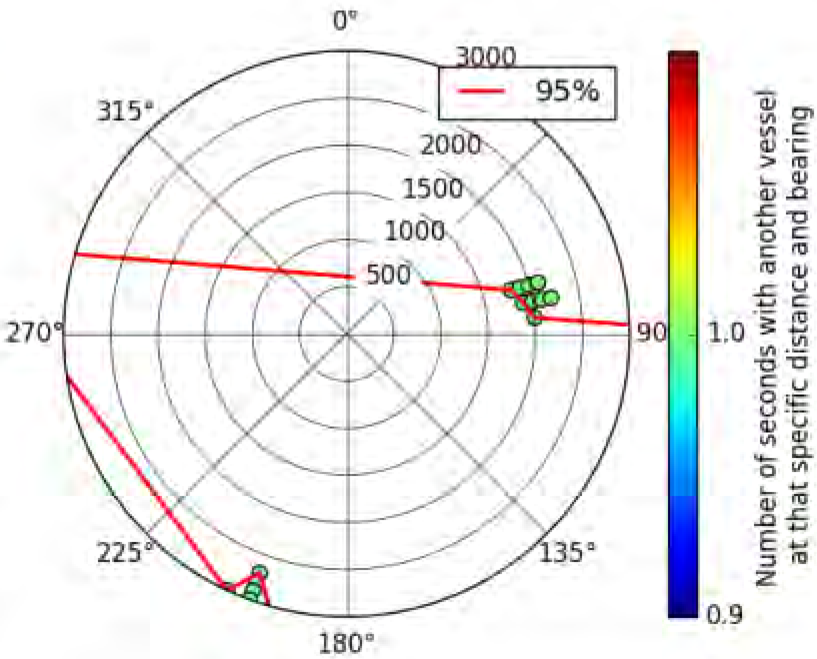


"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".

Location 34.



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



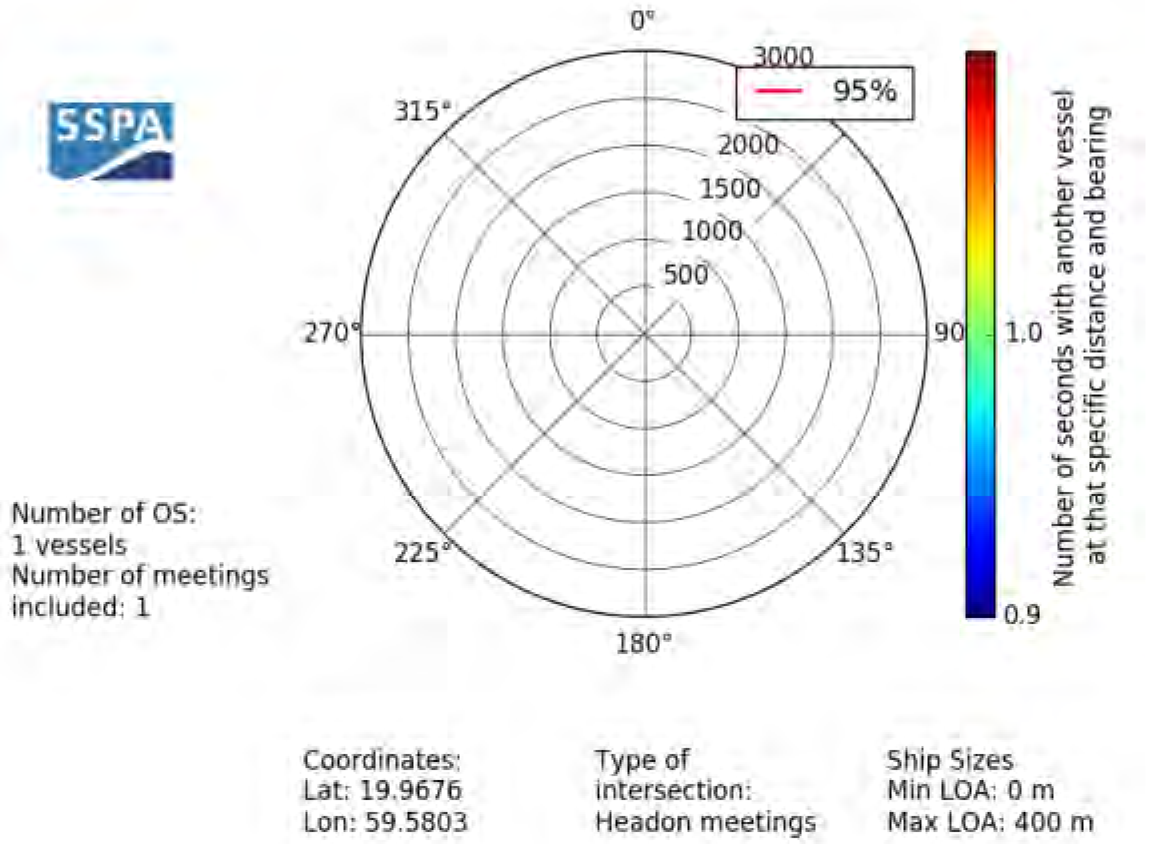
Number of OS:
4 vessels
Number of meetings included: 3

Coordinates:
Lat: 19.9676
Lon: 59.5803

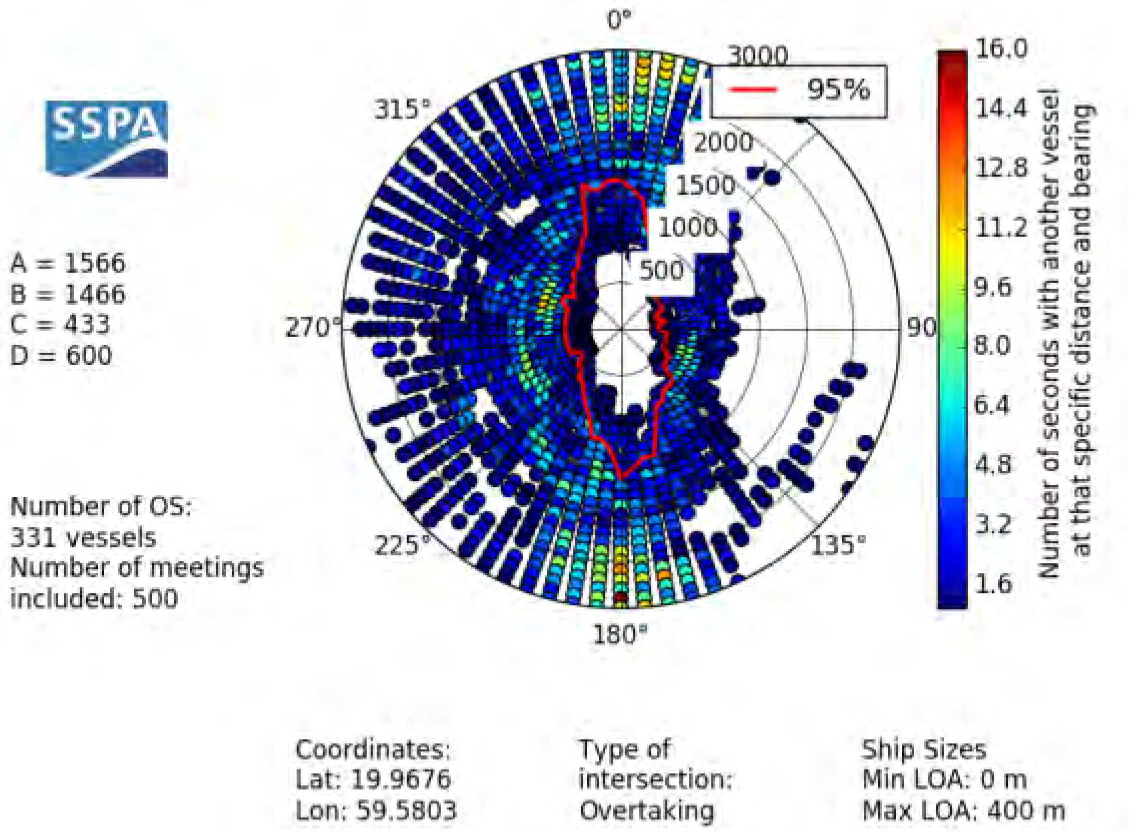
Type of intersection:
Crossings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



"This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 636329".



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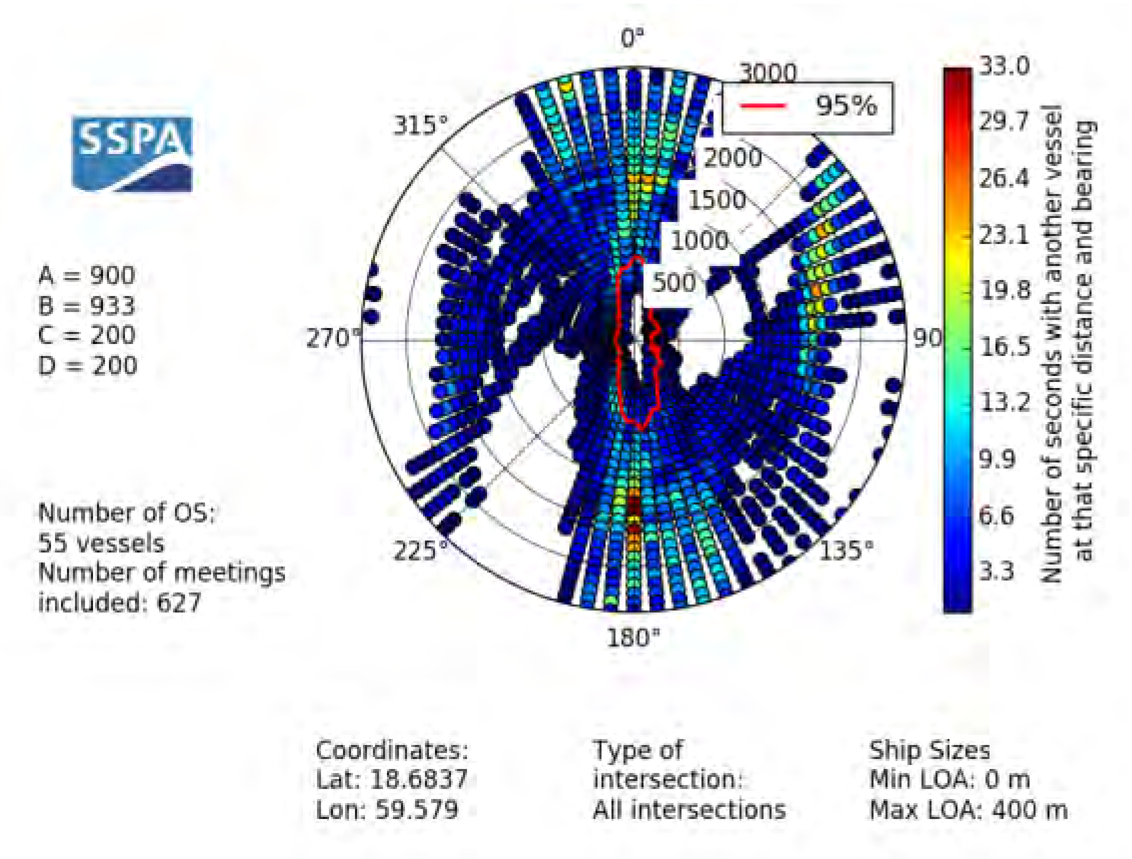
Location 35.



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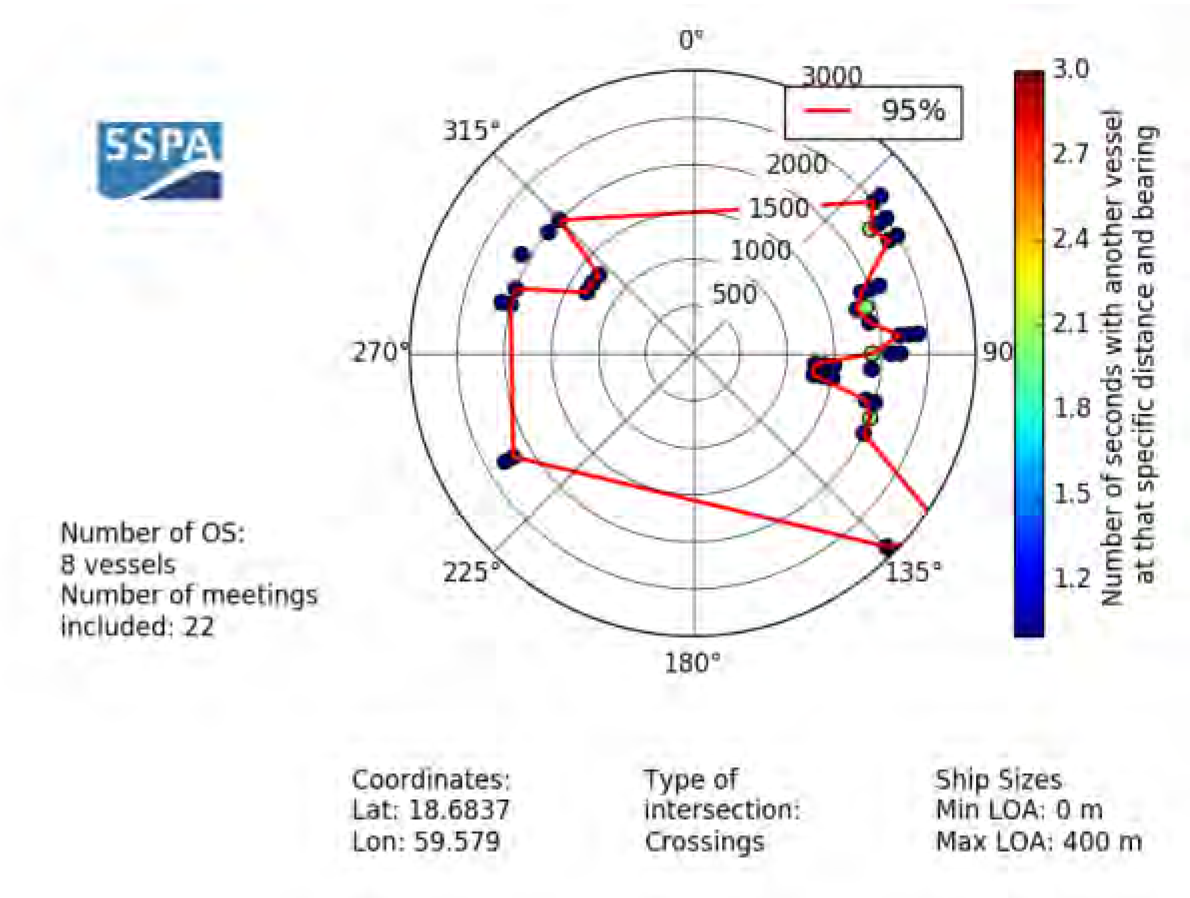

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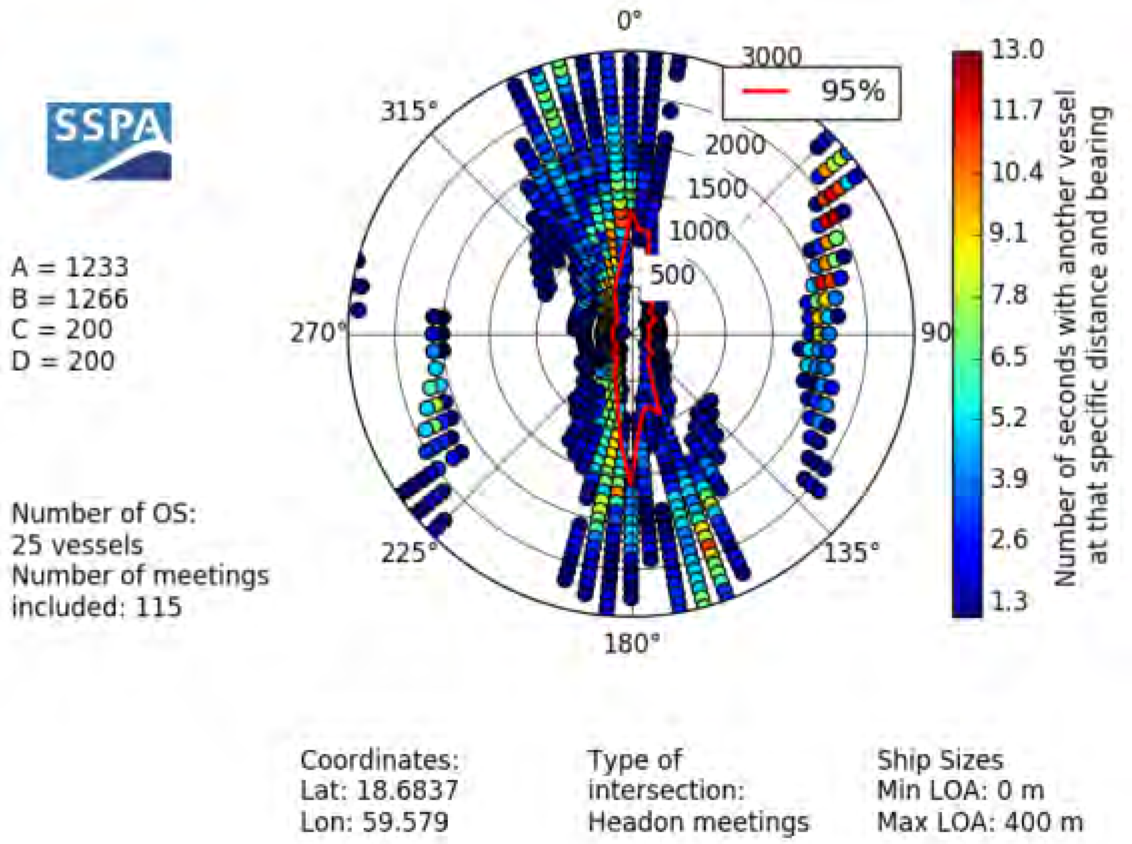

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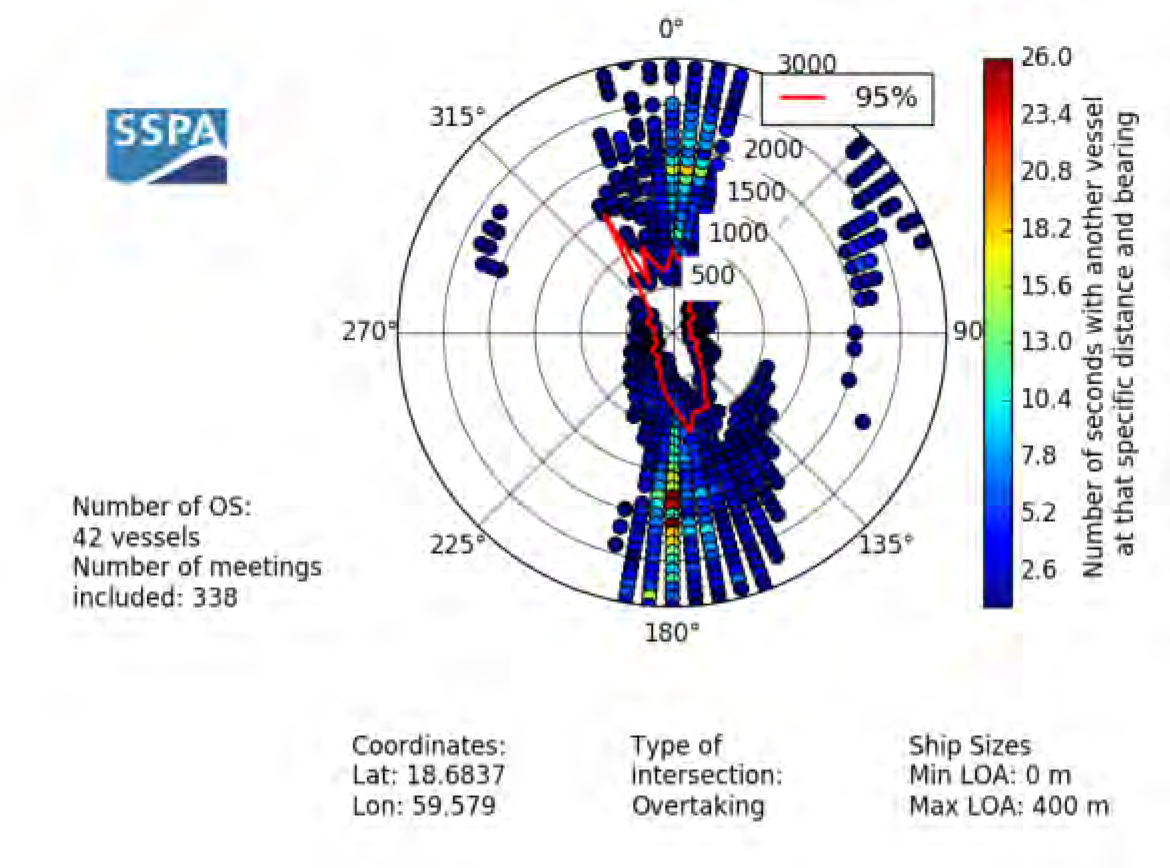

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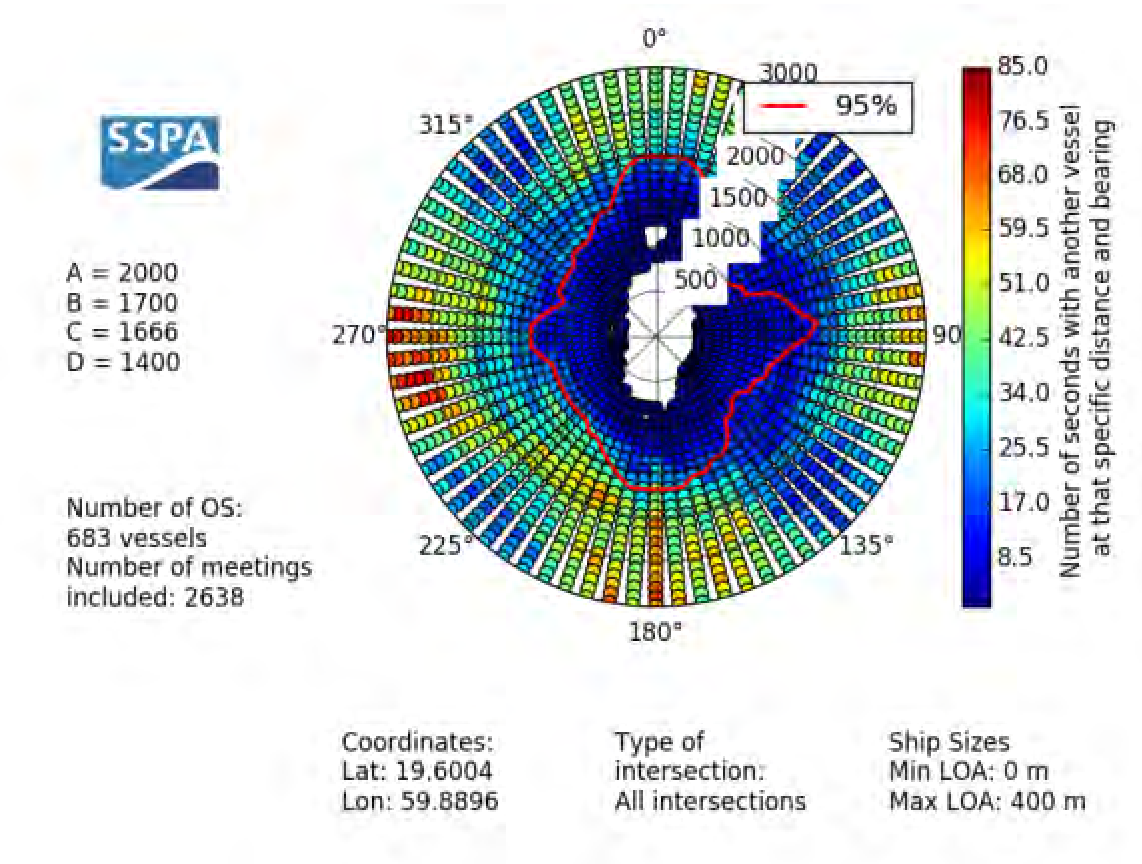
Location 36.



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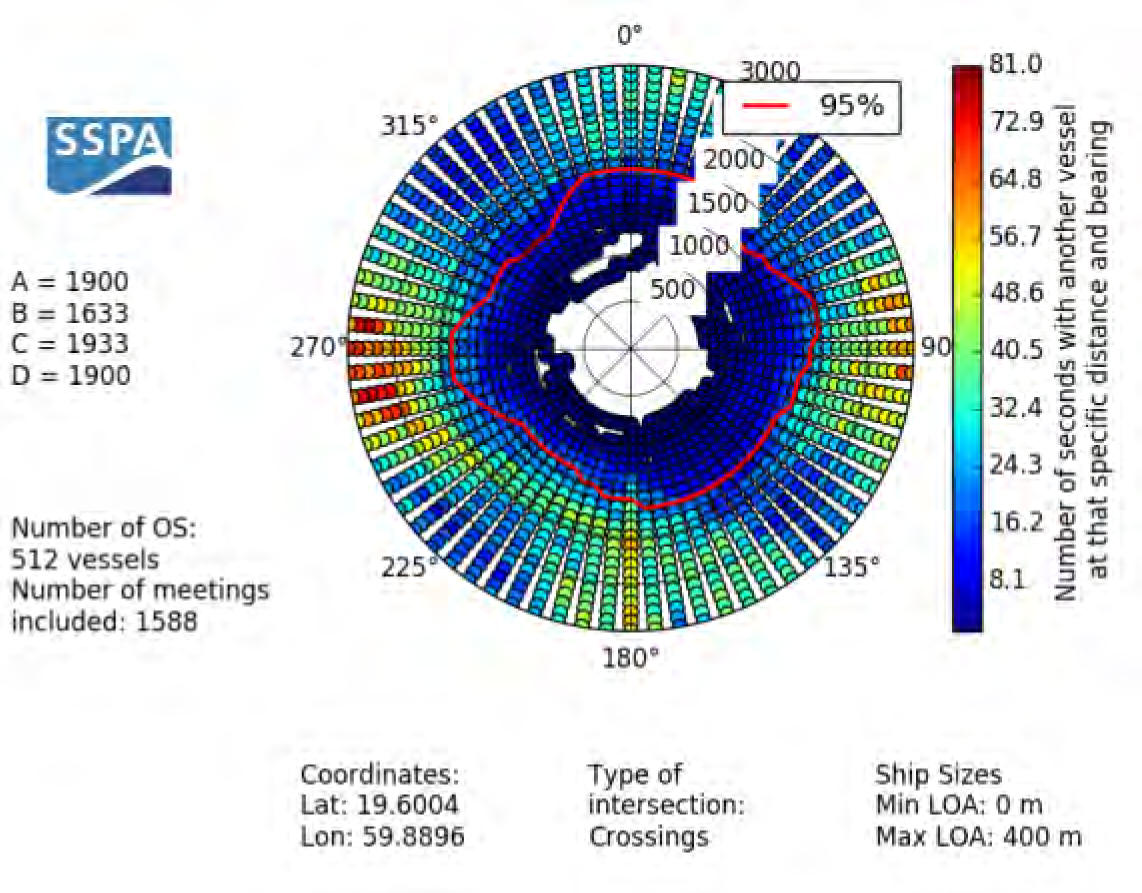

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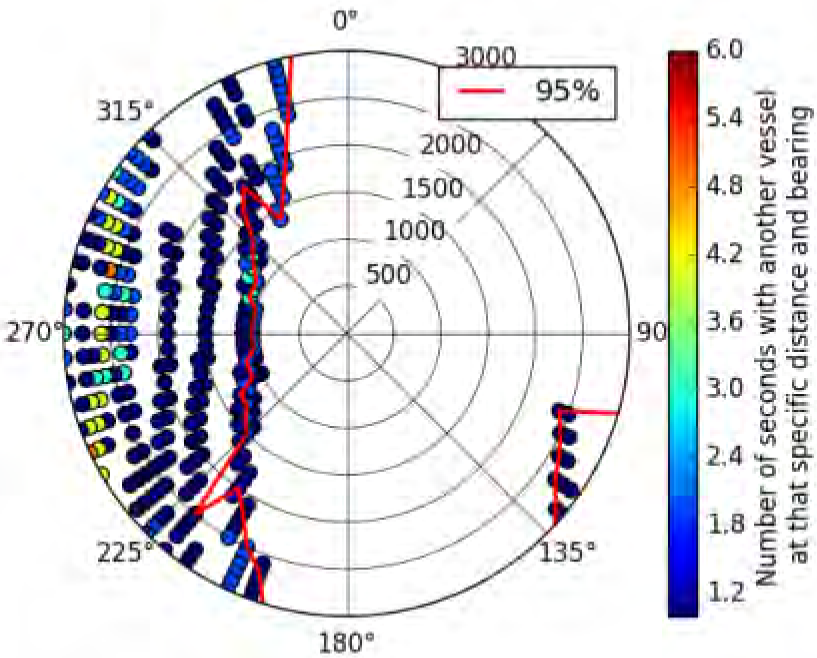

Number of OS:
11 vessels
Number of meetings included: 38

Coordinates:
Lat: 19.6004
Lon: 59.8896

Type of intersection:
Headon meetings

Ship Sizes
Min LOA: 0 m
Max LOA: 400 m

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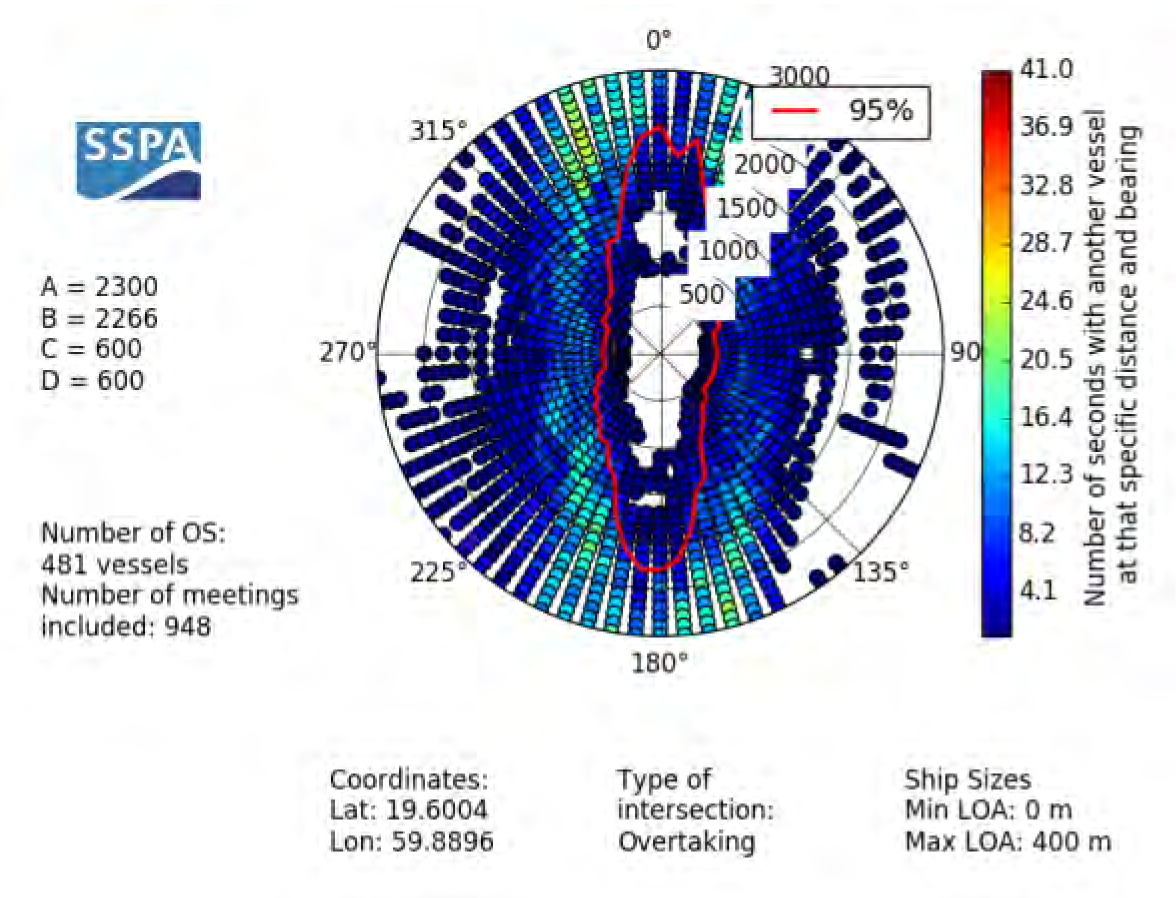

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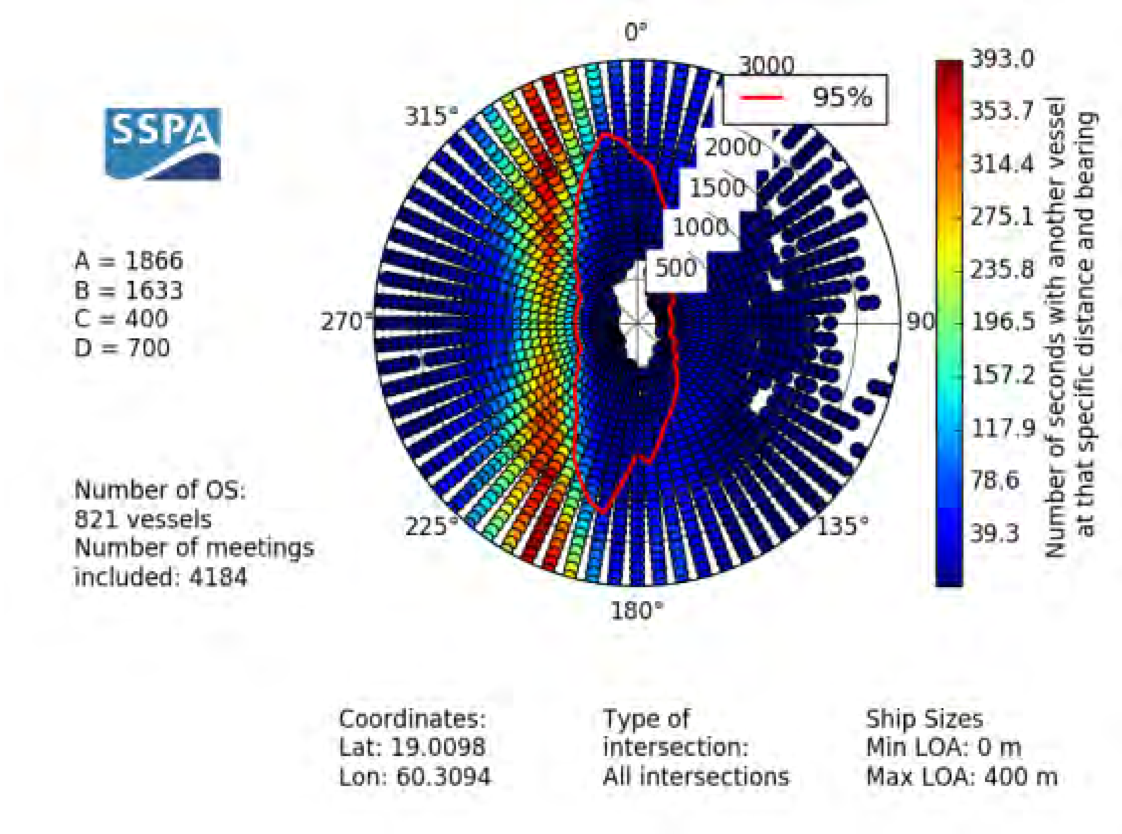
Location 37.



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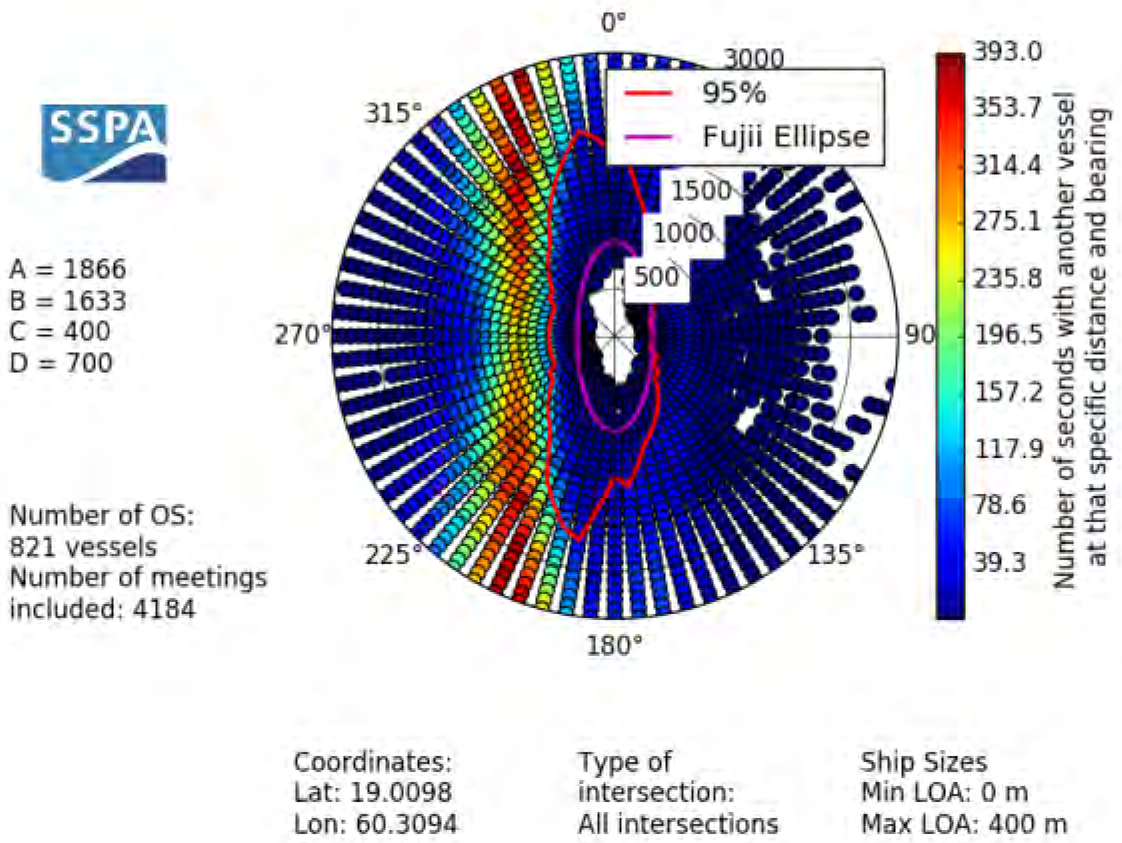

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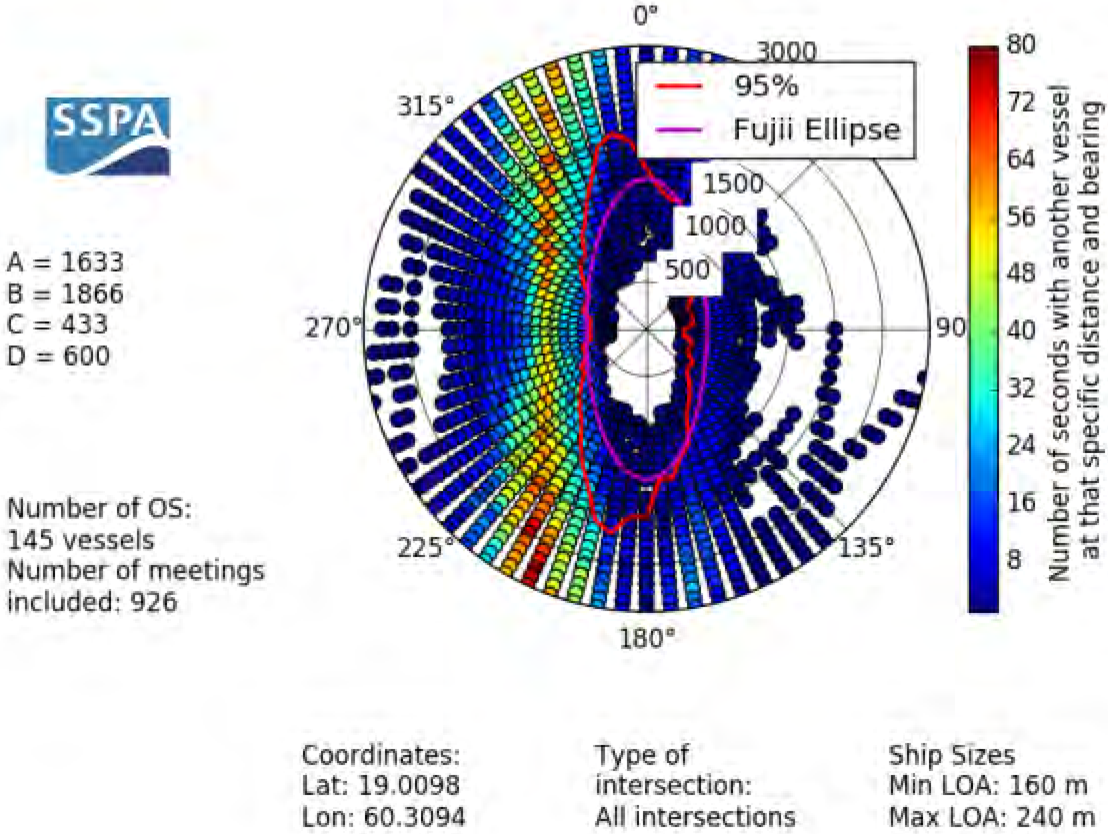

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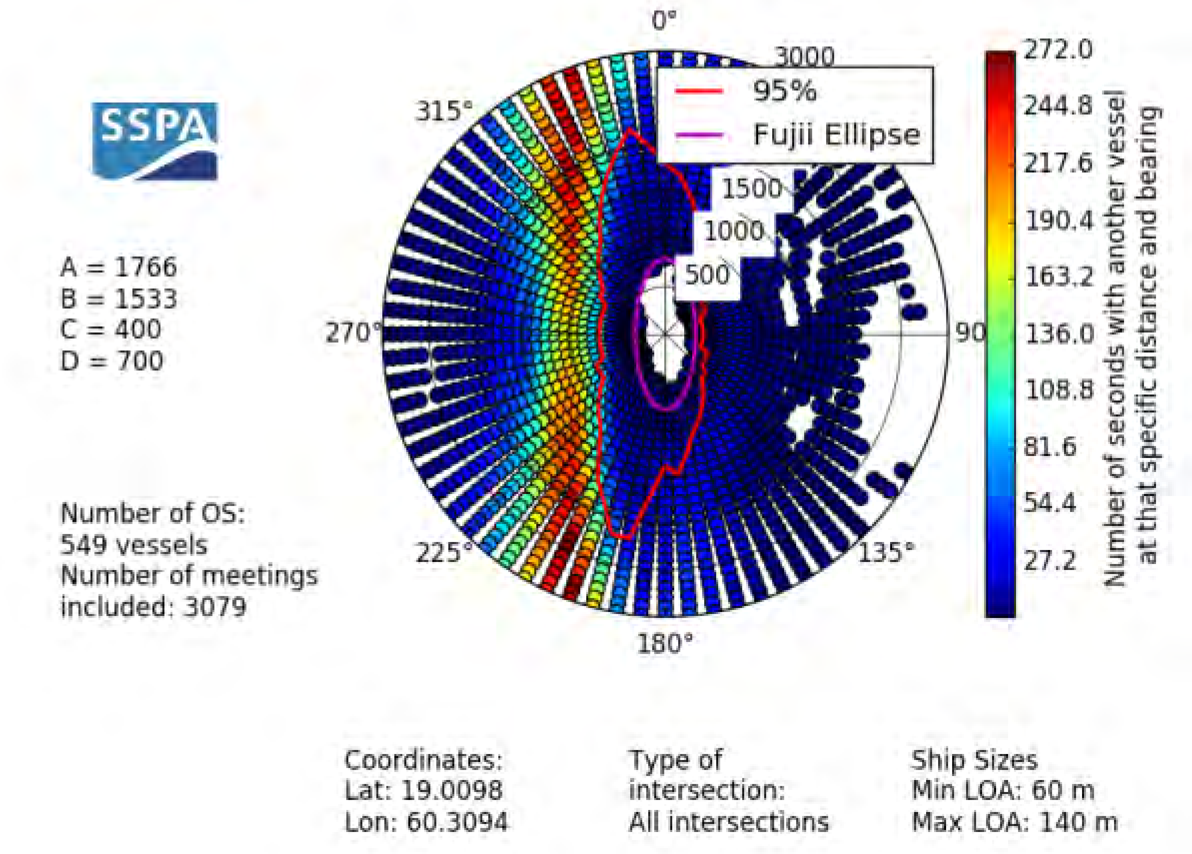

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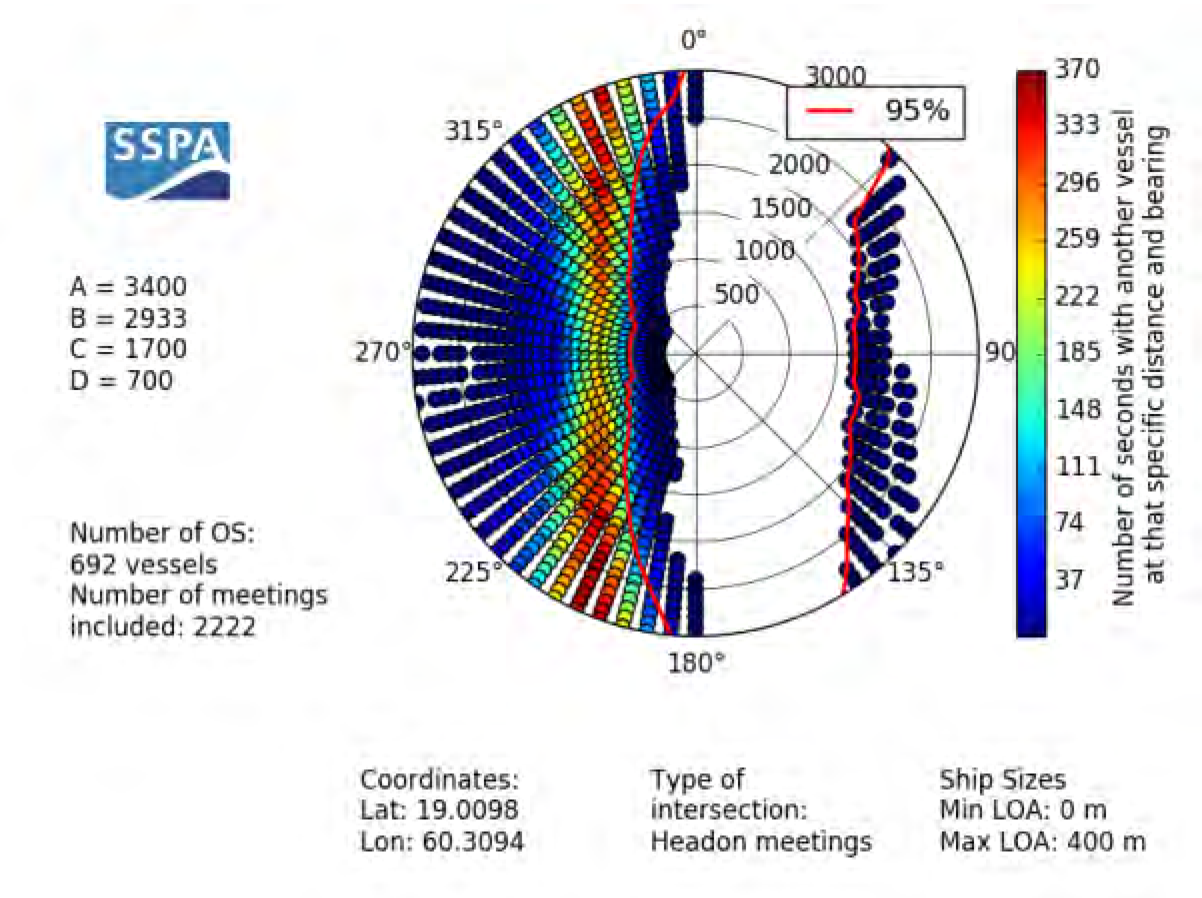

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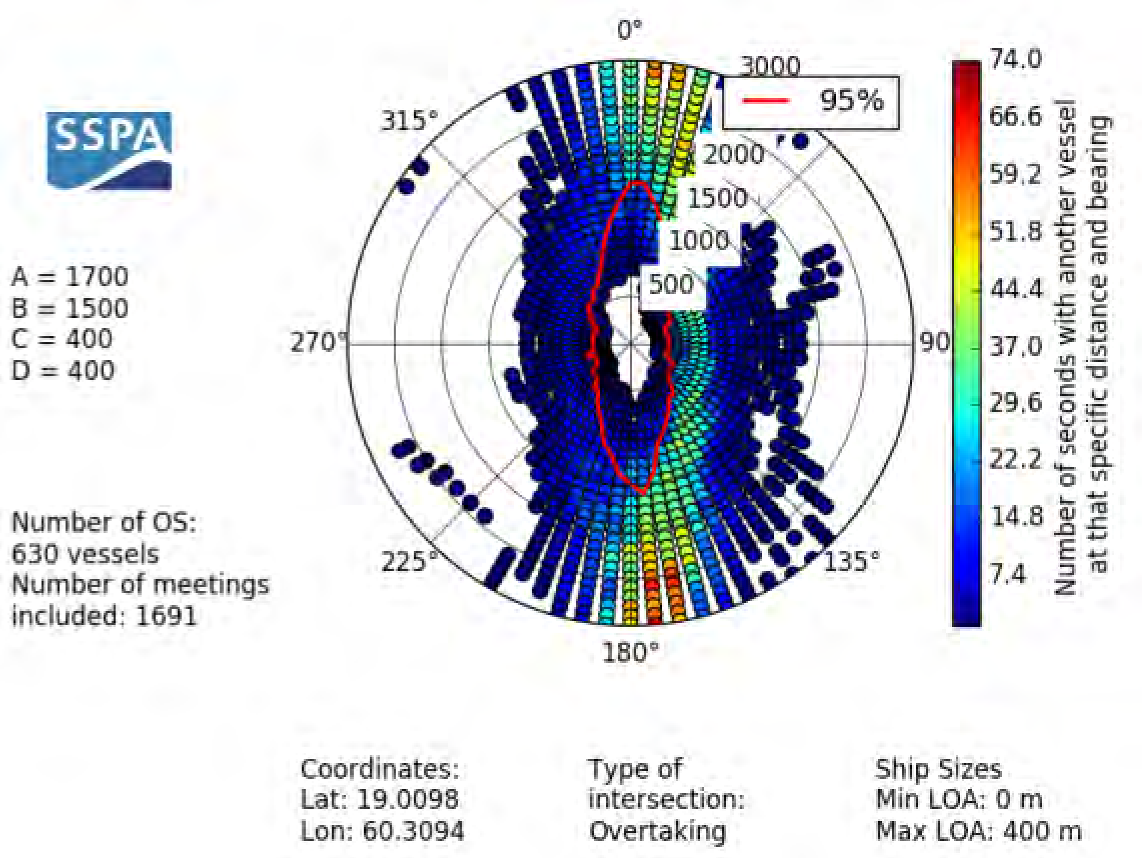

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