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Additional Thesis
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Pathway classification of Argo floats within the Irminger Sea

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Abstract

The Atlantic Meridonial Overturning Circulation (AMOC) in the North Atlantic Ocean (NAO) plays a major role in earth's climate and climate change. A key element of the AMOC is deep convection, which is still not fully understood. One of the unknowns is where water is exchanged between the boundary current and the regions where deep convection can occur. This is important for models to know where deep waters are formed and where they are transported to. This study focuses on the Irminger Sea (IRS), a sub-sea of the NAO. The interior of this sub-sea is a known area where deep convection can occur. Using data from the Argo Float Program, a analysis was conducted to investigate exchanges of water between the boundary current of the IRS and the area where deep convection can occur. The entries and departure locations of the Argo floats are collected and statically compared. Furthermore, seasonality difference between winter and summer months are compared using the Mann-Whitney U-Test. Lastly, the internal pathways water takes within the interior area are analysed, by tracking where a float enters the interior area and where it afterwards leaves the area. The results show water takes many different pathways in and out of the interior area and the pathways taken within the area show the expected cyclonic pattern. There were no clear differences between summer and winter months, except in the northern part of the interior area, where in winter a clear south-western current is present, but not in summer. Future studies on the exchange between the boundary current and the interior area can use these results as an indication that the exchange happens all around the area, but the water does follow a cyclonic pattern.

1 Introduction

The Atlantic Meridional Overturning Circulation (AMOC) is key to understanding the energy balance of the Atlantic Ocean. The intensity of the AMOC has major effects on global and regional climate, thus essential for climate predictions. A schematic representation of the AMOC is given in figure 1. Overall, the AMOC consists of a northward flow of warm and salty water and a deeper southward flow of cold en fresher water. The AMOC intensity dictates how much warm water is transported northwards and how much cold water is transported southwards in the North Atlantic Ocean. This transport of warm water brings a lot of energy to the Northern Hemisphere, warming it as a whole, but more substantially, the northwest European region. Next to that, the AMOC is responsible for a lot of the CO_2 sink by the ocean. Surface waters take in the CO_2, which is then transported downward to the deep ocean, where it can be stored for centuries (Fröb et al., 2016). This study focuses on the part the Irminger Sea (IRS) has in the AMOC.

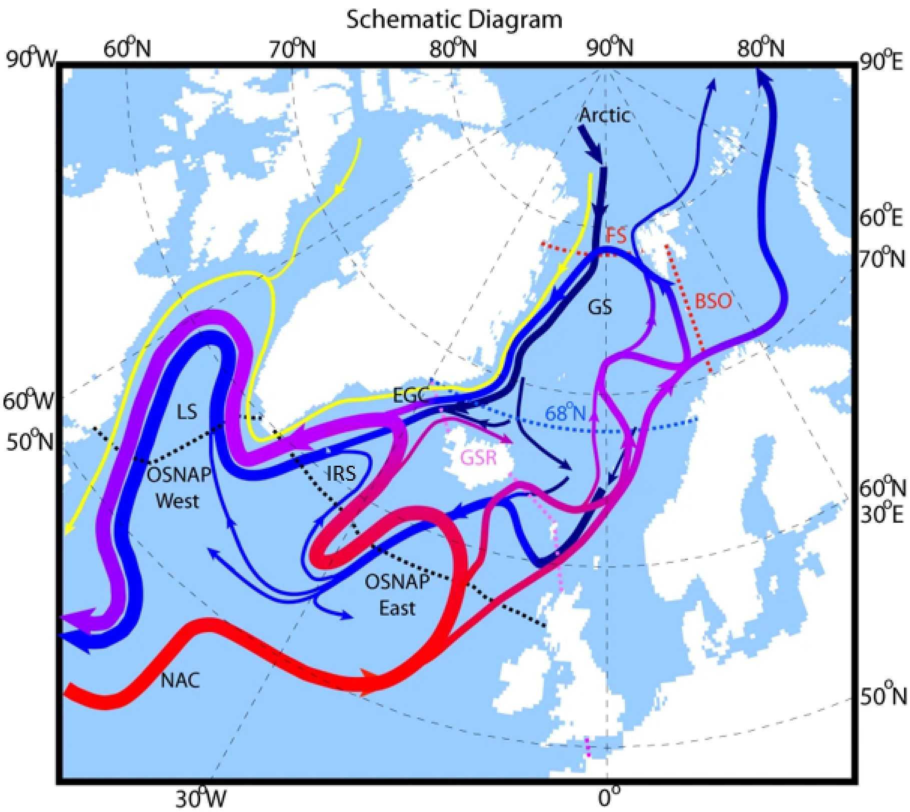

Figure 1: Schematic representation of the AMOC (adapted from Zhang and Thomas (2021)). Acronyms used: Labrador Sea (LS), Greenland Sea (GS), Irminger Sea (IRS), East Greenland Current (EGC), North Atlantic Current (NAC), Greenland-Scotland Ridge (GSR), Fram Strait (FS), Barents Sea Opening (BSO). Warm water flows into the north along the NAC. The flow splits into two parts. One flowing towards the IRS and LS and the other part flowing to the GS. Within these marginal seas the water cools down considerably, indicated by the color change of the currents. The yellow currents are cold, but fresh waters. The density gradient (light to dense) is yellow-red-purple-violet-blue-black.

1.a Main currents in the IRS

The IRS is one of the sub-seas of the North Atlantic Ocean. A schematic representation of the sea is shown in figure 2. The IRS is enclosed by Greenland to the west, the Denmark Strait (DS) to the north and the Reykjanes Ridge (RR) to the east. The sea is characterized by relative shallow water, a strong narrow boundary current on the western side and a broad boundary current on the east, due to rough bathymetry of the RR. The boundary current of the IRS can be split up in two components: the surface and deep boundary current. The surface current consists of Irminger Subpolar Mode Water (SPMW), which originates from the North Atlantic Current (NAC), see figure 1. The SPMW flows southward from Iceland on the east side of the RR, until it turns around over the RR and flows back north on the western side of the RR into the IRS (see red current of figure 2). The current follows the bathymetry, due to topographical steering. The northern part of the RR has too shallow waters for the current to flow through, so its pushed southward. Once the RR is less prominent and the waters are deeper, the current crosses over the RR due to the Coriolis force pushing it towards the right. This water is both salty and relative warm, but already cools down considerably when flowing around the RR. Once in the IRS, the current continuous as the Irminger Current (IC) flowing northward. Not depicted in figure 2, but can be seen in figure 1, a fraction of the IC splits of in the north that flows northward through the DS into the GS. The rest of the branches of the current follow the cyclonic rotation around the interior of the IRS southward along the eastern coast of Greenland. As can be seen in figure 2, there is a cyclonic branch that flows into the interior of the basin and rejoins the IC on the western side and forms the Irminger Gyre. The IC further continuous southward and around Greenland at Cape Farewell into the Labrador Sea.

The deep boundary current in the Irminger Sea consists of two parts: The Denmark Strait Overflow Water (DSOW) and the Iceland-Scotland Overflow Water (ISOW), which are the blue current coming from the north and the blue current coming from the east in figure 2 respectively. Because these currents flow deeper, the ISOW has to flow further south around the RR. The current crosses the RR at the Blight Fracture Zone (BFZ) and the Charlie-Gibbs Fracture Zone (CGFZ), where the ridge has gaps, which allows the water the flow through. After the turn around the ISOW follows the same path as the IC around the interior of the IRS. At the DS, the IC is joined by the DSOW coming from the GS flowing along the East Greenland Current. From here it also continues southward around Greenland into the Labrador Sea.

1.b Deep Convection

The surface and deep currents described in the previous section normally have little to no interaction with each other. This is mainly due to density differences of the water, caused by temperature and saline differences. These differences cause a layered system where the light warmer water flows atop the denser cold water. However, within the interior of several sub-seas of the North Atlantic Ocean, interaction between the surface and deep currents is possible under the right conditions in the form of deep convection. During deep convection, deep waters are formed, which are then transported along the deep boundary current to the rest of the Atlantic Ocean (figure 1) One of these seas, where deep convection is possible, is the IRS, where the focus of this study lies.

In figure 3 a schematic representation of such a sub-sea like the IRS is given. In the interior of the IRS is, just as the rest of ocean, build up of layers of water with a different density per layer, separated by isopycnals. Deep convection, vertical mixing of these layers, can occur when the surface layers get more dense and the vertical density gradient disappears. This occurs when surface layers densify to similar densities of the deeper layers. Then there will be almost no density gradient anymore, since all layers have approximately the same density. The density of ocean water is predominantly determined by its temperature (lower is denser) and salinity (higher is denser).

In the sub- and polar region of the North Atlantic Ocean, cold polar winds cool the water and the forming of sea ice increases the salinity. In addition, the IRS experiences a cyclonic (anti-clockwise) ocean current (see figure 2). This cyclonic motion creates upwelling in the interior of the basin via Ekman suction. This pushes the isopycnals upward and the deep dense water with it (figure 3). The combination of the increase in density of the surface layers and the Ekman suction destratifies the upper layers of the ocean, allowing water to mix up to greater depths. The depth the mixing reaches is called the mixed layer depth.

Deep convection within the IRS is not a yearly event. Several factors determine if deep convection occurs.

Starting with the wind in the area, tip jets that blow over Greenland towards the IRS can become very strong due to the high orographic descent because of the height differences between the center of Greenland the IRS. These jets are not only high in velocity, but also very cold. This combination gives rise to a high turbulent heat flux over the IRS, resulting in a strong cooling effect of the surface waters.

Secondly, the Irminger Gyre is prone to preconditioning its waters. The center of the IRS is quite isolated by the gyre. The conditions of the water in the years before can therefore still have influence on the waters current state.

Paquin et al. (2016) studied these effects on the MLD of the IRS from 2004 to 2010. From this study an area was defined where the MLD reached deeper than 800 meters at some point in time (figure 4).

In this figure we can also see that the MLD starts increasing halfway through December and decreases again around half April. In a study by Bras et al. (2020) they also found the MLD depth to be maximum between January and mid-April. In this study they focused on the winters of 2015 and 2016, where also deep convection over 1000 meters was recorded in the same area. Lavender et al. (2000) investigated the flow patterns of the IRS, the LS and the waters in between and around, shown in figure 2. A clear anti-clockwise direction can be seen at the same place Paquin et al. (2016) found the deep convection.

1.c Argo Float Program

At the start of the millennium the Argo Program was started. The goal of the program was and still is to map the temperature, salinity and pressure vertical profiles of the entire ocean up to 2000 meters depth. The temperature and salinity can be combined do determine the vertical and horizontal density gradients, which, together with the pressure gradients, allow to investigate the oceans circulation of a much deeper part then before. Since 2017 Argo Floats which can reach depths up to 6000 meters are being deployed. This extends the research domain to almost the entire ocean. At present day there are almost 4000 floats and around 1200 deep floats active all around the worlds oceans. In figure 6 the cycle of standard Argo Float is presented. The floats are dropped into the ocean after which they go on an endless cycle until their batteries run out, which is around 5 years. The majority of the time the float drifts at approximately 1000 meters depth. However, every 10 days the float starts descending to 2000 meters depth from where it starts ascending to the surface to profile temperature, salinity and pressure of the 2000 meter vertical. Once reaching the surface it sends out the gathered data and descends again to 1000 meters. In this study the trajectories of the floats are used. Since they drift at 1000 meters depth the majority of the time, they can give a good indication of the flow patterns at that depth. As can be seen in figure 4, deep convection can also reach up to that depth. Therefore these trajectories can be used to investigate the exchanges between the boundary current and the interior of the IRS, where deep convection is possible. These trajectories are not a perfect representation of the actual currents however. Since the floats need to surface, they come into contact with the surface currents. These currents have much higher velocities (30 cm/s compared to 5-7 cm/s at 700 meter depth) and can also have a different direction. Therefore, once the float is back at drifting depth, it may have been displaced to a different location with a different flow. The float is in the upper 100 meters of the ocean for about an hour, during which it can drift about a kilometer. This can impact the resulting trajectory if the float is displaced into another current during this time. Especially on the border of the boundary current this can have an impact if during the surface interval, the float is pushed out of the boundary current.

1.d Focus of research

This study focuses on the IRS, following a similar more extended research by Georgiou et al. (2021), and will investigate the exchanges between the boundary current and the interior of the sea, where vertical mixing occurs. The following research questions will be addressed in this study: Which different pathways does water take from the boundary current to convection areas in the IRS and back to the boundary current?

To this end, a data analysis using the Argo Float program (Jayne et al., 2017) is performed. Within the IRS basin a area is defined where deep convection can occur. This study investigates the trajectories of Argo Floats where they cross from the boundary current into the area, to analyse the exchanges between the boundary current and the interior.

Chapter 2 will describe the available data that is used from the Argo Program and which method is used to answer the research question. Next, chapter 3 elaborates the results. Lastly, chapter 4 ends the report with a conclusion discussion, where the overall implications of the study are presented and its shortcomings.

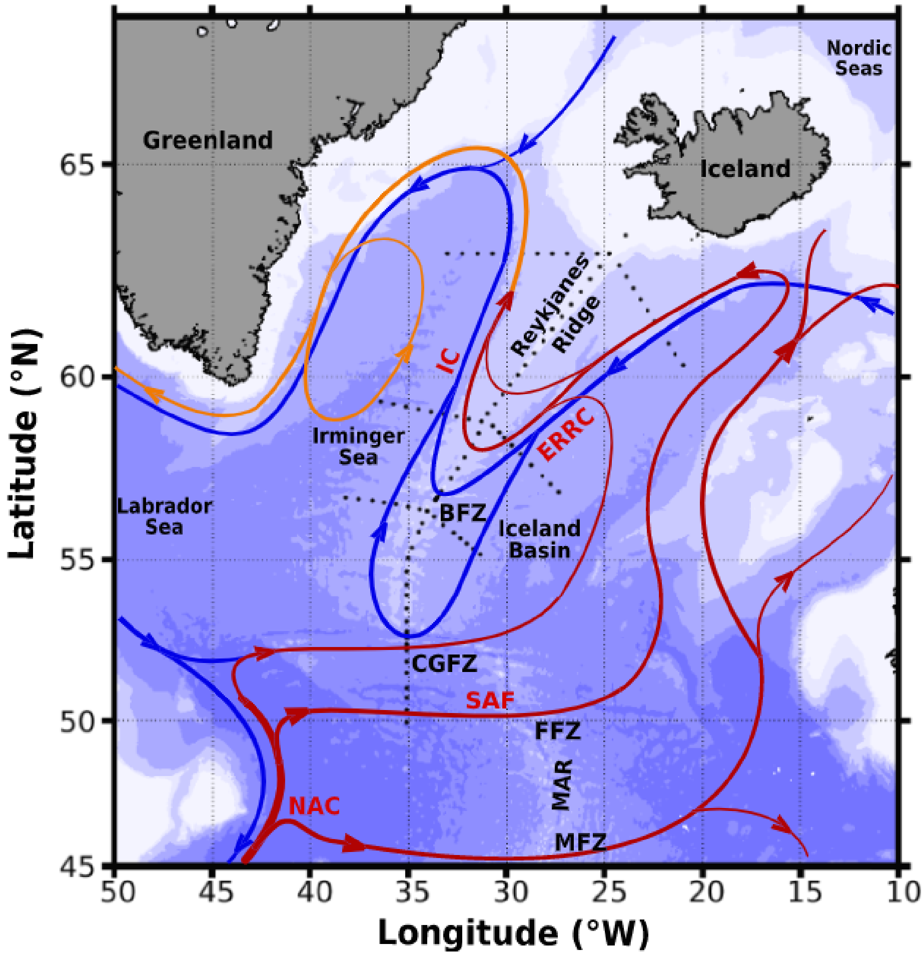

Figure 2: Schematic representation of the main currents the IRS (Petit et al., 2019). Density gradient of the currents, indicated by the color, is from light to dense: red-orange-blue. The black dotted lines are the measurements locations of the study of Petit et al. (2019). Topographical features indicated are: Blight Fracture Zone (BFZ), Charlie-Gibbs Fracture Zone (CGFZ), Faraday Fracture Zone (FFZ), Maxwell Fracture Zone (MFZ), Mid-Atlantic Ridge (MAR). The main currents represented here are the North Atlantic Current (NAC), subarctic front (SAF), East Reykjanes Ridge Current (ERRC) and Irminger Current (IC).

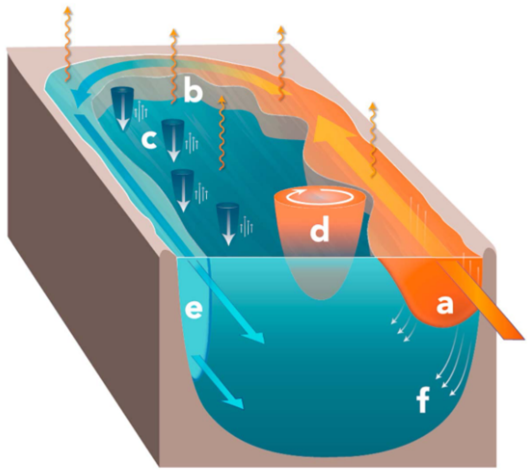

Figure 3: Schematic representation of a sea at high latitudes, like the IRS (Johnson et al., 2019). At (a) warm water flows into the basin, which gradually cools down by the atmosphere (b). The colder water on the left side gives rise to convective plumes at (c), while on the right side, from the still warmer water, buoyant eddies break free from the boundary current (d). (e) represents the colder and deeper outflowing boundary current. At (f) downwelling along the edge of the basin, due to the topography is indicated.

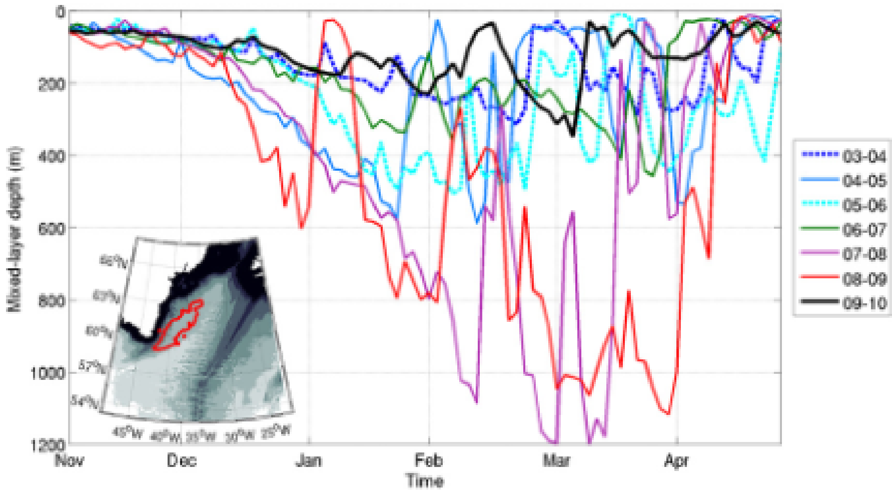

Figure 4: Mixed layer depth in area of Irminger Sea where deepest MLD was observed by Paquin et al. (2016). The different years are represented with different colors. On the left bottom corner the area of this study is shown.

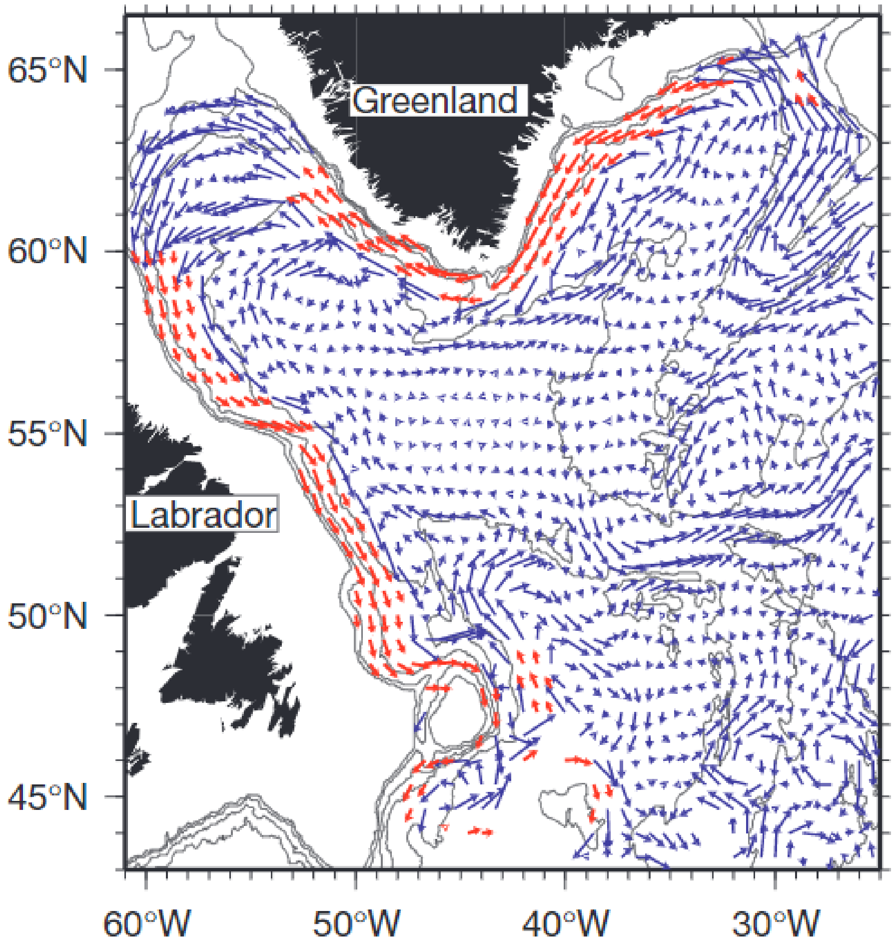

Figure 5: Flow pattern at 700m depth of the IRS, based on observation of direct velocity measurements by floats in the 90's. Blue arrows represent the distance traveled over 30 days with velocities of < 5 cm/s and red arrows the distance traveled over 8 days with velocities of > 5 cm/s over 8 days (Lavender et al., 2000).

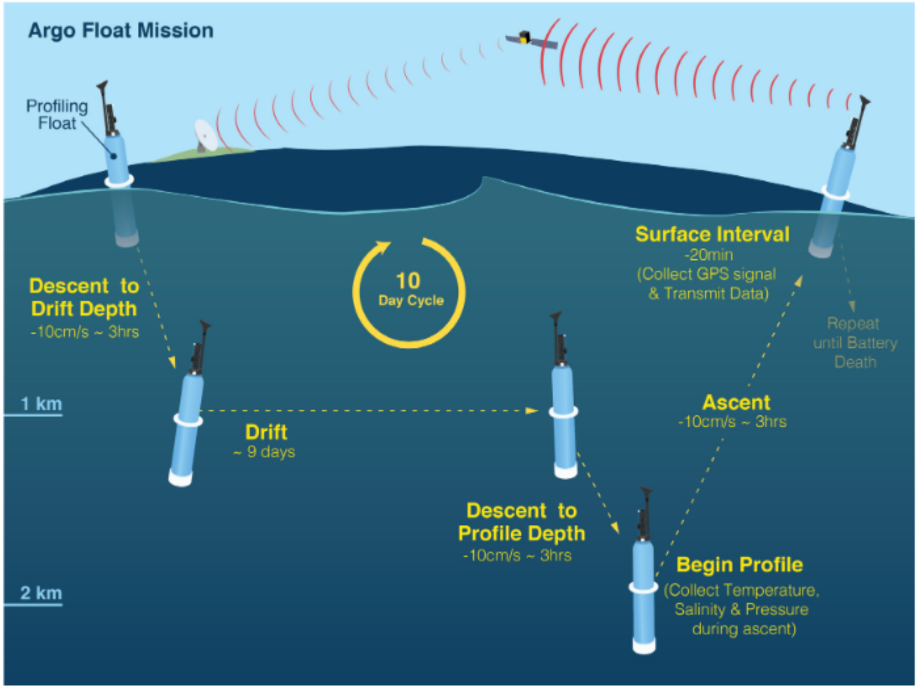

Figure 6: Cycle of an Argo float. After dropped into the sea, the float descends to approximately 1km depth, where it drifts for 9 days. Afterwards it descends to 2km to initiate the profiling and then ascending to the surface to transmit all data collected (Jayne et al., 2017)

2 Method

In order to investigate the IRS, the domain was defined as 50°N to 72°N and 48°W to 20°W (see figure 7). This area includes the IRS basin plus a margin, to include all areas of interest. Within this domain, an area in the interior of the basin is defined based on figure 5 and 4, where deep convection is possible. To investigate the exchanges between the boundary current and interior area, floats that have been in the interior area for at least 5 consecutive cycles are selected. The entry and departure locations of these floats are collected and analysed as discussed below.

2.a Seasons

To start the analysis, the floats data was separated into winter and summer months based on figure 4. The winter months are selected to be the months where the MLD is the deepest., whilest also taking account the months are evenly divided between summer and winter months. The winter months are defined from December to May. In hindsight, this selection was not entirely correct see chapter 4 for more information.

To statistically analyse if there are differences between the summer and winter months, the Mann-Whitney U-test is used. This test compares the winter and summer data and gives a p-value between 0 and 1. If the p-value is below 0.05, a significant difference between the two seasons may be assumed.

2.b Polygon

For the analysis a polygon is defined, where deep convection has occurred in the past (figure 4) and there is a cyclonic rotation (figures 2 and 5). This polygon is shown in figure 7 and its corner coordinates are as follows: (-42, 58.5), (-37, 62.5), (-35, 62.5), (-40, 58.5) (xx°W, yy°N). Next, the cross-section of floats entering and leaving this area are collected and separated between the northern, eastern, southern and western border. They are presented in a histogram for each border, also indicating if the cross-section was in winter or summer.

Next the pathways floats take within the region are analysed. For this purpose, the eastern and western border are separated in two equal sections, creating six borders in total (figure 7): North (N), North-East (NE), South-East (SE), South (S), South-West (SW) and North-West (NW). The floats are sorted by connecting their entry and departure border. This is defined as an internal pathway of a float. The 6 borders were chosen to get a general idea of the internal pathways in the region, but not splicing the data into too small parts.

During the aforementioned analyses, floats are considered to be in the defined area if they have at least 5 consecutive cycles (dt=5) in the area. To investigate the difference dt has on the results, dt is increased from 2 up to 10 and the respective results are analysed.

2.c Expected results

In the results (chapter 3), it's expected the northern border won't have many cross-sections, since the general flow is curving around that border (figure 5 and 7). At the eastern border more interactions are expected, the flow is generally northward along the border, but looks to have some interaction with the interior area. The southern border is likely to have more incoming floats than outgoing, since the flow is more northward at the southern border. The western border has the strong boundary current to its West. This can either take most of the floats with it, not letting any into the interior area. Or, due to the faster flowing current, eddies may form, which can transport floats towards the interior. The South-West corner can be a crucial place, where the boundary current starts flowing westward around Greenland.

For the pathways floats take within the interior region, the floats are expected to follow the cyclonic rotation of the area (figure 5).

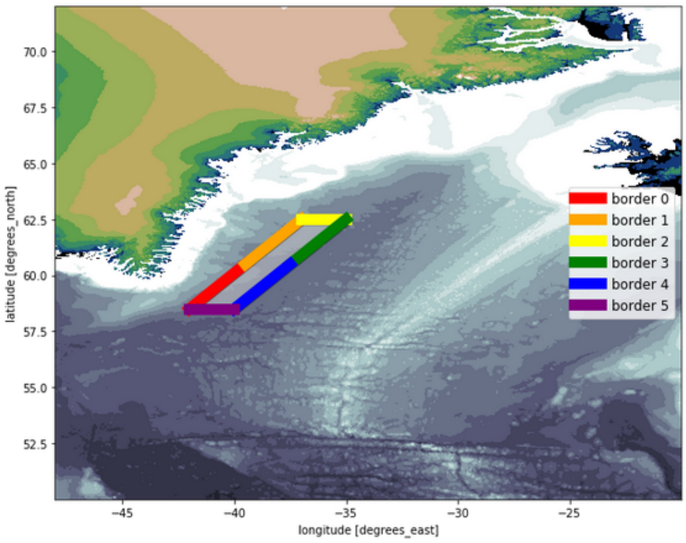

Figure 7: Study area and the defined convection area, which corner coordinates are: (-42, 58.5), (-37, 62.5), (-35, 62.5), (-40, 58.5) (XX°W, YY°N). The borders are colored and called, as in the legend: North (N), North-East (NE), South-East (SE), South (S), South-West (SW) and North-West (NW).

3 Argo float pathways between interior and boundary current

Within this chapter, the exchanges between the interior area, defined in figure 7, and the boundary current of the IRS are presented. For this purpose, floats were selected that have been in the interior area for at least 5 consecutive cycles (dt=5). This resulted in a total of 64 floats, with 97 incoming trajectories and 110 outgoing trajectories. From these floats, all points of entry and departure are selected and are presented in figures 8 and 9 for each border. They are split between summer (orange) and winter (blue) months and are sorted in 0.5° sized bins. The x-axis represents the longitudinal coordinate of the borders and the y-axis represent the amount of incoming floats. In table 1 the p-values of the Mann-Whitney U-test are given, which statistically indicates the difference between the summer and winter months at each border. Next, the pathways all floats take within the interior region are presented in table 2. Lastly, the sensitivity of the results to the amount of cycles dt are explored.

3.a Incoming floats

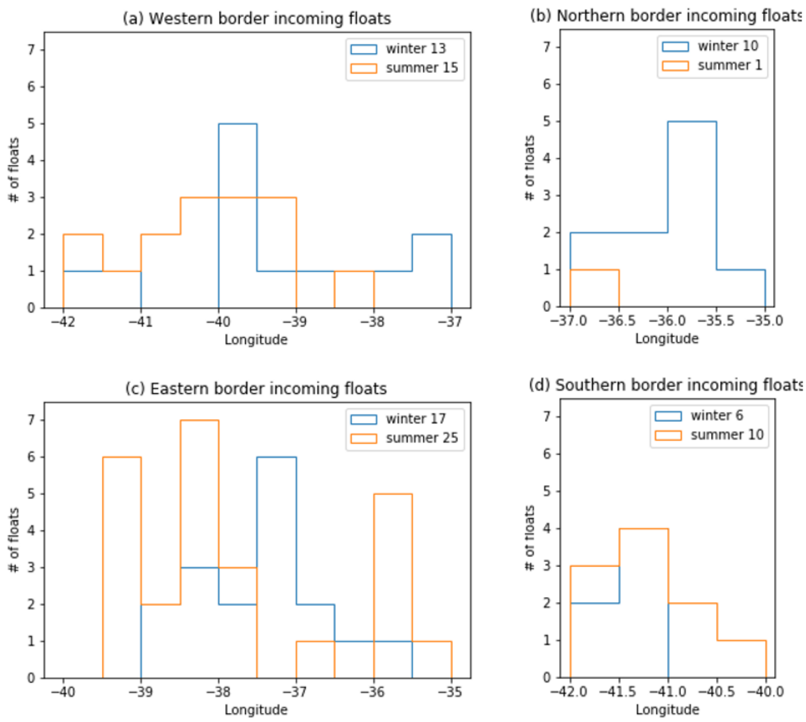

Figure 8: All incoming floats at the interior area with dt=5. The borders used are the same as in figure 7, where the NW and SW together are here represented as the western border. The same goes for the eastern border. The data is split between summer (Jun-Nov, in orange) and winter (Dec-May, blue) months. The total amount of incoming floats in winter and summer is given the legend of each figure.

First at the western border (figure 8a), there was a total of 28 incoming trajectories, with 13 during winter and 15 during summer. Most floats entered the interior region between -40.5° and -39° latitude, with a total of 54%, of which 46% of the entries of the winter months and 60% of the summer months. This indicates this region has increased chances of water being transported from the boundary current into the interior region. Overall, the difference between winter and summer months is quite small. The winter months have more entries between -40° and -37° longitude (85%) and summer months have more entries between -42° and -39° longitude (93%). Although, as shown by the Mann-Whitney U-test (table 1) with a p-value of 0.3, the difference is not significant. This is mainly because the sample size is not very large and, as said before, most floats are concentrated between -40.5° and -39° for both periods.

The northern border (8b) proved to be predominately used as an entry point during winter, with 10 (91%) incoming floats during winter and only 1 (9%) during summer. The Mann-Whitney U-test 1 also shows a significant difference between the winter and summer with a p-value of 0.02. This indicates a flow pattern shift, where in summer water tends to follow the boundary current and in winter the current is more unstable, allowing more floats to enter the interior area. This could mean a higher presence of eddy activity during winter, which transports water to the interior area.

Next, the eastern border (figure 8c) has a total of 42 incoming floats, with 17 (40%) during winter and 25 (60%) during summer. Similar to the western border, between -38.5° and -37° longitude are the most entries, with a total of 21 (50%) floats, whereof 64% of the entries of the winter months and 40% of the summer months. This region shares the same latitude with the area on the western border, which had 54% of incoming floats. The difference between the winter and summer months resulted to be not significant with a p-value 0f 0.34 (1).

Lastly, the southern border (figure 8d), had 16 incoming floats. The summer months had more entries, 10 (63%), compared to the 6 (37%) during winter. Most floats (81%) enter the interior area on the western half of the southern border. The winter entries are more concentrated on the western side, but there was no significant difference. The Mann-Whitney U-test resulted in a p-value of 0.23.

border	W	N	E	S
incoming	0.30	0.02	0.34	0.23
outgoing	0.26	0.25	0.48	0.21

Table 1: Mann-Whitney U-Test p-values of the winter versus summer incoming and outgoing floats, using the same data as in figure 8 and 9.

3.b Outgoing floats

The major difference between the incoming and outgoing floats are the northern (figure 9b) and southern border (figure 9d), which have almost no outgoing trajectories as expected. With a total of 110 outgoing floats, only 4 (3.4%) leave at the northern border and 5 (4.5%) at the southern. The rest is almost equally divided between the western and eastern border, with 51 (46%) and 50 (47%) respectively. This was expected, since at the southern border there is a north-western flow (figure 5). At the northern border, the flow curves around the border, resulting in floats rather leaving the area at the northern parts of the western and eastern border.

At the western border (figure 9a), most visible are the 18 floats (60% of winter departures) leaving the interior area between -38.5° and -37° longitude during winter, but only 2 (9.5% of summer departures) during summer. This could indicate a more westward flow in the northern part of the interior area during winter. This is supported by the incoming floats at the northern border (figure 8b), where much more floats enter the area in winter compared to summer. The northern part of the eastern border (figure 8c) does not show an increase of incoming floats during winter. This suggests the flow in the northern part of the interior area is more South-West oriented during winter.

The eastern border (figure 9c) shows a peak of a total of 23 (46%) total floats leaving the interior area between -38° and -37° longitude. Also the incoming data (figure 8c) showed activity in that region as discussed in before. This indicates the flow has no clear direction in this area, which implies the presence of eddies which can both transport water into and out of the interior area.

Both the western and eastern border overall showed no significant difference between summer and winter over the entire border, with a p-value of 0.26 and 0.48 respectively (table 1). The northern and southern border do not have enough data to be able to have significant differences. Also shown by the p-values of 0.25 and 0.21 for the respective borders (table 1).

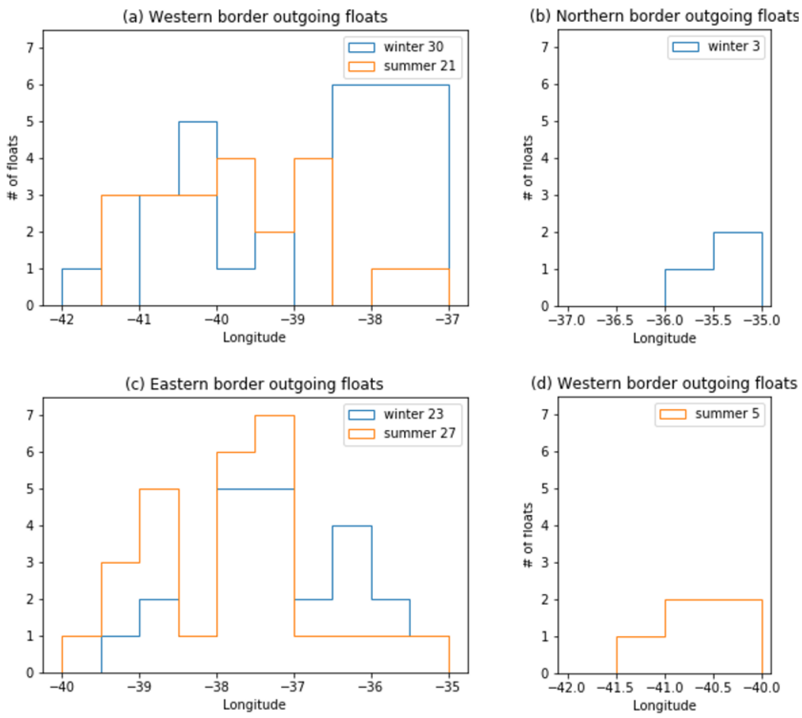

Figure 9: All outgoing floats at the interior area with dt=5. The borders used are the same as in figure 7, where the NW and SW together are here represented as the western border. The same goes for the eastern border. The data is split between summer (Jun-Nov, in orange) and winter (Dec-May, blue) months. The total amount of outgoing floats in winter and summer is given the legend of each figure.

3.c Internal pathways

To get an indication of the internal pathways floats take within the region, the western and eastern border were split in two equal parts, creating a total of 6 borders (figure 7), also explained in chapter 2.b. The results are shown in table 2, with on the left the border where the floats enter and on the top the border where they leave. Here floats of all months are taken together, which resulted in a total of 94 pathways.

	SW	NW	N	NE	SE	S
SW	**8**	2	0	0	7	1
NW	2	**6**	0	2	0	0
N	0	7	**2**	2	0	0
NE	2	6	2	**5**	0	0
SE	3	5	0	6	**9**	1
S	5	0	0	6	4	**1**

Table 2: Table of the internal pathways floats take within the interior region with dt=5. The border names at the top and left side correspond to the borders in figure 7. The entry border of the pathway are on the left side and the border where they leave are at the top.

It was expected the floats would follow a cyclonic rotation around the region, as is seen in figure 5. This is mainly shown by the underlined pathways. These represent all the pathways that leave the area either 1 or 2 borders removed from the entry point in cyclonic direction, which is a total of 41 pathways (42% of all).

The diagonal has a total of 31 pathways (33 % of all), which enter and leave the interior area at the same border. These pathways are probably in the cyclonic direction along the border, but that can't be said for sure.

This leaves a total of 22 pathways (23 % of all). These pathways leave the interior area more than two borders removed from the entry point in cyclonic direction. This can mean the floats were in the interior area for an extended amount of time, allowing them to traverse a great distance, but still travelling in the cyclonic direction.

table of pathways from left to top

3.d Sensitivity

A crucial parameter of this study, the number of consecutive cycles (dt) the floats have to be in the interior area to be selected, was chosen to be dt=5. Here it is explored how sensitive the results of the internal pathways were to this choice, and if similar results are obtained with higher or lower values for this parameter. For this purpose, dt was taken from a range of 2 to 10. Here the results of dt=2 and dt=10 are presented.

Starting with dt=2, the results are shown in table 3. The amount of pathways that enter and leave at the same border or one over in cyclonic direction has increased the most in this table. For dt=2 these pathways amount to a total of 71% of the total, compared to the 56% for dt=5. This is mainly because floats are now also selected if they are in the area for shorter amounts of time.

In the results for dt=10 (table 4), were relatively almost no changes. The total pathways that leave the area 1 or 2 borders removed from the entry point in cyclonic direction are here 44% of the total pathways, compared to the 42% for dt=5. The diagonal with pathways that enter and leave the area at the same border is here 32% compared to the 33% for dt=5. And lastly, the remaining pathways amount to 26% compared to the 23% for dt=5. These percentages match very well with the earlier presented results of dt=5. Thus increasing the dt higher then 5 did not give any different results, whilst lowering the dt did have an impact on the pathway fractions.

Overall, the floats indicate there are several pathways water takes in and out of interior region and there are not much differences between the summer and winter months, expect in the northern part. The cyclonic rotation presented in figure 2 is also visible in the pathway analysis.

	SW	NW	N	NE	SE	S
SW	**29**	5	0	1	14	1
NW	3	**23**	5	7	0	0
N	0	27	**5**	5	0	0
NE	2	16	5	**41**	0	0
SE	10	6	0	18	**39**	4
S	8	0	0	6	21	**8**

Table 3: Table of the internal pathways floats take within the interior region with dt=2. The border names at the top and left side correspond to the borders in figure 7. The entry border of the pathway are on the left side and the border where they leave are at the top.

	SW	NW	N	NE	SE	S
SW	**5**	0	0	0	3	0
NW	1	**1**	0	1	0	0
N	0	1	**0**	1	0	0
NE	1	2	0	**3**	0	0
SE	0	3	1	2	**2**	0
S	3	0	0	2	3	**0**

Table 4: Table of the internal pathways floats take within the interior region with dt=10. Same layout as the table on the left.

4 Conclusion & Discussion

This study investigated pathways water takes from the boundary current in and out of the interior of IRS, where deep convection can occur. The results from the analysis using the Argo Program floats showed the intricate structure of the flow patterns of the IRS, where not one clear pathway was found, but water takes many different paths.

Entry into the defined interior region (figure 7) occurred from all directions (figure 8). At the western border more entries were expected, due to the high velocities of the boundary current, creating possible eddies transporting water inward. However, the northern, southern and eastern border proved to have many entries as well. The north and south border are about a third of the length of the east and west border. When normalizing the amount of entries by the border size, the western border actually has the least incoming floats and the eastern and southern borders have the most. The middle region of the interior area had the most incoming floats, as discussed in chapter 3.a. This region also had a relative high amount of outgoing floats, as discussed in chapter 3.b. Indicating this region is not just a part where water comes in, but there is exchange between the interior area and boundary current both ways.

The difference between the winter and summer months was highest at the northern part of the interior area. The northern and western border showed a pattern, where the northern had 91% of incoming floats during winter and the northern part of the western border had 60% of outgoing floats during winter. This indicates a more distinguished south-western current in the northern part of the interior area during winter, compared to summer. This flow pattern is also confirmed by the internal pathway analysis 3.c. This showed 64% of incoming floats at the northern border leave the area at the north-western border.

Furthermore, the internal pathway analysis indicated the floats generally followed the expected cyclonic rotation as was presented in chapter 1.b and figure 2. There were some pathways (23%) that did not clearly follow the cyclonic rotation. However, the exact pathways were not examined, only the points of entry and departure. So, further examination has to be done to be sure these floats did not follow the cyclonic rotation.

During this study, assumptions and shortcuts needed to be taken, since there was limited time. First of all, all winters were used, while not every winter had deep convection. When selecting only the years with recorded deep convection (2007, 2008, 2009, 2015, 2016 and 2017), only 10 incoming and 16 outgoing floats remained. This is not enough for any significant statistics. Therefore it was assumed flow patterns from the boundary current to the interior of the basin did not change, whether there was deep convection or not.

Additionally, the winter months chosen in this study were from December to May, which was done to get an even spread of months between winter and summer. However, the MLD has only reached the ocean layer where the floats drift (1000 meters) during February and March (figure 4).

Another issue with the floats is that they're inconsistent over time. Not every year has the same amount floats. This could mean some years are over presented, which may result in skewed outcomes.

As mentioned in part 2, floats have to surface where they come into contact with the much faster and different surface currents. These currents can push them of course, relative to their initial trajectory, pushing them into another path, which would not have happened if they did not need to surface. It was not investigated if the floats used in this study were effected by this, but should be considered when moving forward with this study.

Lastly, the convection area is chosen quite coarsely and may need some adjustments.

In the end, the analysis showed some consistent results compared to the known flow patterns, showing a cyclonic rotation. There was not a main path found that water takes in and out of the interior area, but many different pathways around the area. For future studies, these results from the Argo floats can probably be used to get an indication on the exchanges between the boundary current and the interior area of the IRS, but first further examination is required if the data is representative enough. In the distant future their should also be more available data from the Argo Program, which should enable better results using this analysis.

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