In this Author Comment #1 the original comments by Reviewer #1 are written in black while the authors' responses are written in blue.

We thank the reviewer for his/her detailed review and for the time s/he spent on it. Nearly all of the comments will be implemented in the revised version, including a change of the main focus from estimation of transport (*F*) when *q* (fresh water flux which is a proxy for lateral mixing with the surrounding fresher water) is unknown to the estimation of *q* itself when *F* is known (from SODA velocity fields). This change of focus results from the direct transport calculations suggested by the reviewer that yielded values of *F* east and west of Greenland and which have greatly streamlined the sermon of the paper. A discussion of the physical meaning of $q=F/L$ and its application to the two branches of the IC will be added in the revision. This will give the robust determinations of the values of *L* an easy to grasp physical meaning based on Eq. (1) for known values of *F* and will focus the sermon of the paper on a quantification of the lateral mixing (entrainment) of the IC east and west of Greenland.

Summary of review

This study presents a diagnostic, which is referred to as Freshening Length, to infer along-track changes in the Irminger Current transport around the South-Greenland coast. Based on the Freshening Length, the authors conclude that 20% of the original water mass in the Irminger Current at the eastern side are transported along the southern coast of Greenland to the western side, while 80% are dispersed into the ambient ocean.

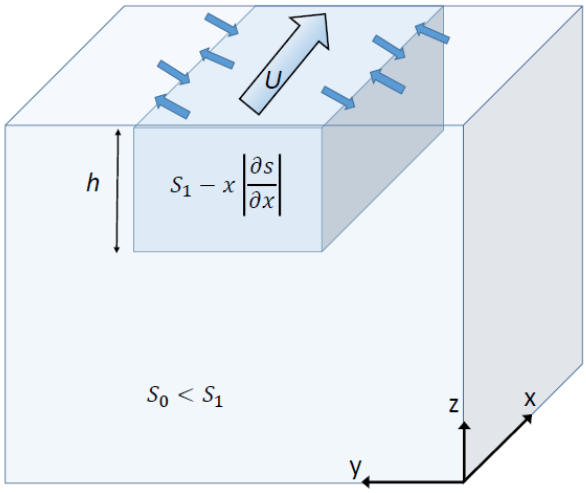
Overall, I find this study quite thin. Further analyses may be needed to justify publication. From the current version, I am not able conclude that the study represents a substantial contribution to the journal.

Indeed, our paper has a well-defined focus: The application of the new Freshening Length diagnostic/schema to the Irminger Current. Applying this new schema to climatological reanalyzed sea surface salinity data yields the noted robust and reliable estimate of the changes in *L* along the Current. No other oceanographic diagnostic yields a similarly confident/reliable estimates. With the new direct transport estimations (*F*) based on SODA's velocity fields (that will be presented in a new table) the application of Eq. (1) to the IC east and west of Greenland will yield quantitative estimates of lateral mixing (entrainment) in the two branches of the IC.

For instance, the manuscript includes four figures and only two of these are original. Figure 1 contains maps adapted from other studies and Figure 2 shows climatological fields of the sea surface temperature and salinity from the publicly available SODA dataset, along with the points at the locations that were used to diagnose the transport changes.

Figure 1 will be eliminated from the revised version and all the figures and the new table (that shows the ratio between the transports east and west of Greenland) will contain original calculations based on SODA's salinity and velocity fields. A new figure (see below) will be added to explain the adaptation of the Evaporation Length schema (which was developed in Berman et al., 2019 and which will be discussed in more

details in the Introduction of the revised version) to the Freshening Length schema employed in this study.



I would recommend publication only if (1) additional analyses are added, or (2) the authors can demonstrate more clearly what the overall value of their analysis is.

Additional analyses could include an exploration of the processes along the current section by which the transport exchanges occur, such as eddies, or further dynamical implications of their study, or temporal changes over or the investigated period and links to larger-scale ocean or atmospheric variability. In any case, I would recommend that the authors further demonstrate the potential information that can be gained from the Freshening Length.

In line with the reviewer's alternative (2), the revised version will demonstrate how the Freshening Length together with direct transport calculations yield a proxy for the rate of horizontal mixing via the value of *q*. Our results imply that the rate of entrainment must change when the IC negotiates Cape Farewell since the transports (calculated from SODA's velocity fields) vary only slightly between the east and west branches of the IC. The application of Eq. (1) will take the form of $q = F/L$ when the RHS is known. The revision will also include a detailed account of the physical meaning of *q*.

General comments

1) The scientific writing could be improved. Some paragraphs are difficult to follow. In particular, many paragraphs could be shortened and the sentences could be written in a more concise way. Phrases like *"it appears"* (line 31) do not sound scientific. Overall, I think the amount of text is not in proportion to the amount of information it includes. Therefore, I would recommend shortening of the text.

The text will be shortened by eliminating points that are tangential to the paper's new main sermon.

2) I did not understand why the Freshening Length is important. The climatological map of the sea surface salinity (Figure 2b) already shows there is a gradual freshening along the

current. This is expected since freshwater from the Greenland coastal currents is gradually added along its path. Given that the results are expected already from the climatology map what information is gained from the additional quantification by the Freshening Length?

Other diagnostics, like the freshwater column, which is the integrated freshwater anomaly over depth relative to a pre-defined reference salinity, or the freshwater volume, have been used in numerous earlier studies. These diagnostics have been applied to distinct scientific questions. I am not convinced of the overall value of the Freshening Length unless the authors can demonstrate a clear use or application of the Freshening Length that other diagnostics or just visual inspection of the climatological sea surface salinity map are not able to provide.

The main point in the revised version is that Figure 3 (the T-S diagram) only provides a qualitative comparison between the changes in SSS and SST east and west of Greenland while the values of *L* yield a quantitative measure for these changes. In the revised version, accurate determination of both L and F yield an estimation of *q*, the parameter that parameterize horizontal mixing with the surrounding fresher water.

3) Based on my understanding of this study, the main result is the statement that 20% of the water in the Irminger Current travel around the southern tip of Greenland. Yet, why is it important to know how much water travels around the southern tip of Greenland as a coherent current? I do not think that the analysis provides meaningful information about the AMOC since the loss of transport that is calculated may be compensated for by other currents and eddies. I cannot see a clear connection to the AMOC from this analysis.

The revised version will focus on the entrainment of surrounding water by the IC on both sides Greenland.

4) The analysis is focused on grid point averages around selected points along the salinity maximum. Yet, the current may be broader at some locations than at others, in which case the diagnostic does not describe the transport in the Irminger Current but is sensitive to how the current is defined. A considerable fraction of the transport could also occur in eddies or in the boundary currents like the Greenland Coastal Currents. These are not captured by focusing on a narrow current with pre-defined width.

True. That's why we emphasize transport per unit length in the cross-stream direction where the current's direction is determined by the local salinity maximum. The new direct transport estimates are also conducted over the same cross-sections (five grid points centered on the point of maximum salinity) so eddies moving independently of the IC are not included in *F* (but the eddies do not necessarily move parallel to the IC)

5) The analysis only considers the climatological mean over a 37-year period. I do not think there is a substantial gain in such an analysis. It would be more interesting to look at the time variability of the transport and investigate the involved dynamical processes.

The advantage of averaging 37 years of data is that it filters out seasonal, annual and even decadal changes. In the paragraph between lines 184-194 (of the old version) we

note the results of short-period analyses and highlight their consistency with previous studies.

6) Part of the freshwater transport around Greenland's coast occurs as sea ice. I am not sure if the authors accounted for this. Melting of sea ice along the way may also influence the salinity and hence the Freshening Length.

Melting sea ice a one of the contributors to *q* and hence it is included in our calculation.

Specific comments

Title: I find the title misleading and difficult to understand. The study does not investigate *"changes in the surface salinity gradient"*. It should either read *"changes in the sea surface salinity along the current"* or *"the sea surface salinity gradient along the current"* but not *"changes in the gradient"* (which would correspond to the second rather than a first derivative). This mistake is repeated later, for instance in the abstract.

Also, I am not sure what is meant by *"the climate perspective"* in the title.

Title will be modified to it the new focus.

line 4, "surprising": I do not find it surprising that the Irminger Current can be identified based on salinity maxima, given that it represents a saline current system around the fresher subpolar gyre.

The “surprise” is associated with the climatological data i.e. that the salinity maximum is not masked by the massive averaging. This clarification will be added in the text.

line 12: *"A temperature-salinity analysis shows that the Irminger Current east of Greenland is characterized by a compensating isopycnal exchange of temperature and salinity, while west of Greenland the horizontal convergence of less dense surface water is accompanied by downwelling/subduction."*

This sentence is misleading and confusing. It suggests that less dense water is subducted beneath denser water.

The confusion will be clarified in the revised version.

line 79: The SODA data set contains very irregular measurements in time. Thus, it is likely biased towards the recent period.

On periods shorter than the complete 37 year record our analysis does not show any biases in SODA’s SSS data. See also our response to general comment #5 above.

line 120: The title and figures refer to the sea surface salinity but the Freshening Length itself seems to be integrated over the full current depth. I find this confusing. To avoid misunderstandings, it would be great if the authors could clarify this in the text and if necessary, adjust the title.

No, the Freshening Length is evaluated solely from surface salinity values.

In case the analysis is restricted to the surface, the Freshening Length would not be a meaningful indicator of the transport fraction that travels around Greenland, as part of the freshwater could be mixed down to depth.

The mixing “down to depth” (i.e. subduction) implies a balancing horizontal convergent flow at the surface. This balancing horizontal flow from the surrounding fresher water is precisely the cause of decrease in salinity of the salty IC

line 178: The conclusion, that the transport loss occurs in eddies is not supported by the preceding sentence. It is not clear from the sentence or the paragraph why the transport loss should occur in eddies. The writing here could be more precise.

The point will not appear in the revision where the transport will be evaluated directly.

line 193: I understand that the Freshening Length is only robust on climatological mean data. However, considering the large interannual and decadal variability in the subpolar region, it is questionable if the application of the Freshening Length to only the climatological average contains meaningful information.

No. As was shown in Berman et al. (2019) the application of the schema to data collected in particular field campaigns yields similar results to that of climatological data provided the data quality is high enough.

line 195: *"...the Freshening Length estimate of the transport is much more robust and informative than direct estimates based on velocity profiles..."*

I strongly disagree with this sentence and the entire paragraph. Of course, the method used always depends on the question that needs to be answered. Still, I would argue that direct estimates based on velocity profiles are generally preferred to calculate transports.

Following the change of focus and the new direct calculations of the transport the entire paragraph will be eliminated from the revision.

Figure 1: in panel b, the labels are difficult to read

Panel b will be deleted from the revised version.

Figure 4: I am not sure why the red and blue lines are fitted to the points. What information is gained from doing this?

Thanks. The graphical issues of Fig. 4 will be corrected in the new version.