

Response to Anonymous Referee#3 comments for “The circulation of Icelandic waters – a modelling study” by K. Logemann et al.

K. Logemann et al.

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We would like to thank the anonymous reviewer for the thoughtful comments which contributed to a substantial improvement of the manuscript. The reviewer’s comments are displayed with a bold/italic font.

This is a comprehensive study of the waters surrounding Iceland, describing and explaining the currents flowing through the region. It is well written and deserves publishing after some revisions as detailed below.

Main comments

The text is well written and informative, but also prohibitively long. Not being a modeller, it is not quite clear to me, how much of section 2.1 is novel, but it seems very general and one wonders whether it could not have been replaced by a reference to previous work with a few comments on special features.

Section 2.1 has been considerably shortened. Equations (1) to (6) were removed, and the section became part of the introduction of chapter 2.

There is also considerable repetition, especially between sections 3 and 5 and, in some cases, too much detail. As an example, the discussion on groundwater in section 3.1.1 seems excessively detailed.

We have considerably shortened also section 3.1.1

I suggest that the authors go through the whole text with the aim to remove details that are not necessary and remove excessive repetition. It is always tempting to "discuss" results as they are presented, but when there is a "Discussion and conclusions" section, the "discussion" presented in the results sections should be limited.

Section 3.2.1: We removed the discussion of seasonal FW thickness variability, the effect of AW flushing and the dynamical explanation of the ICUC.

Section 3.2.3: We removed the discussion about the oNIIC variability, the NIJ validation, NIJ water properties

Section 3.2.4: We removed the discussion of the SIC/FC relationship

Section 3.2.5: We removed the discussion about a possible NIIC/NIJ correlation, and about the SIC stability, also the discussion of the causes of temporal variability

Section 4: We removed the discussion of the NIJ reduction within the reference run

Section 4.1: We removed the last paragraph, discussion of the NIIC/SIC forcing

When discussing the driving of the currents investigated, the text becomes sloppy in several instances. On page 767, it says: "A discrete coastal current, driven by a freshwater induced coastal density front". This implies that the coastal density front causes the coastal current by generating a force that accelerates the water into motion and maintains the motion against frictional effects. Such a force should be present on the right-hand side of Equations (1) and (2). In general, a coastal current may be driven by several forces such as wind, tidal rectification, or a barotropic pressure gradient induced by freshwater addition from land, and it may be affected by other forces such as the Coriolis force and cross-flow pressure gradients. The coastal density front is clearly also generated by the run-off and associated with the coastal current, but I cannot see, how a coastal density front could be the primary cause of the forces responsible for this surface-near flow.

We have replaced the formulation with "...driven by the barotropic pressure field related to a freshwater induced coastal density gradients"

Similar statements about driving by density gradients are found in many other places in the manuscript, some of them more reasonable than others. For the (very nice) experiment illustrated in Fig. 15, horizontal density variations are said (page 788) to cause the flow.

Now, we explain in detail that the density gradient causes a hydrostatic pressure gradient, which causes a southward flow, which causes a sea level rise, which causes a barotropic pressure gradient, which causes a northward flow, which balances the southward flow. That finally two geostrophic flows parallel to the front set up.

We also made according changes in chapter 3.2.1 ("We define the ICC as a near-shore ocean current being driven by the barotropic pressure gradients due to a runoff induced coastal density reduction, therefore directed clockwise around the island.")

Also in chapter 4: "The ICC and ICUC (...) are primarily driven by pressure gradients due to coastal density reduction caused by river runoff." And "The EGC in Denmark Strait is mainly driven by barotropic pressure gradients related to the Polar Front."

Chapter 5: "We found the NIJ to be forced by local baroclinic pressure gradients."

As seen in Fig. 15d (when magnified on the screen; not on the paper),

The vectors were enlarged

they cause a southward deep flow (overflow) on both sides of Iceland. This removes water from the northern half of the region, which sets up north-south sea level gradients (Fig. 15b). The barotropic pressure gradients generated by this then force the surface-near flow (Fig. 15c), which includes a net northward transport in the upper layers, compensating for the overflow. Thus, I agree that horizontal density variations are the ultimate causes of the flow, but the force driving the surface-near currents in this case is the pressure gradient generated by a sloping sea surface (the second to last terms in Equations (1) and (2)). I am not saying that the text in lines 10-15 on page 788 is wrong, but it could be more informative and, elsewhere, such as at the bottom of page 786, I find the text misleading.

We have re-written the part about the results of the sensitivity experiments, added more details and also graphics. Now, we do not state any longer that currents are driven by density gradients. This is valid for the whole document.

More generally, if the authors wish to use terms such as "driven by", then the text should be comprehensible in terms of basic Newtonian physics and consistent with Equations (1) and (2). One solution, which also could reduce the degree of repetition, would be to move most of the discussion on "driving" to a coherent part of section 5. For the abstract, the sentence: "Both currents are driven by topographically induced distortions of the Arctic Front's barotropic pressure field" seems rather obscure. It would be clearer to say e.g.: "Both currents are driven by barotropic pressure gradients induced by a sea level slope across the Greenland-Scotland Ridge"

We have adopted this formulation.

In the beginning of section 3.2.4 (page 783), the SIC is said to be "less than 5 km south of the coastline" and this is consistent with Fig. 12 top panel, which has a core labeled "SIC" very close to the coast, but according to the bottom panel of Fig. 12, most of that water is fresher than 35.0 and thus inconsistent with the definition of SIC. If there is no other conflicting evidence, it would seem more reasonable to identify the SIC on Fig. 12 as the core between appr. 45 and 60 km from the coast.

We assume that the reviewer has accidentally misinterpreted the colors of the salinity graphic of Fig. 12. This clearly shows that a vast majority of the waters of the current near the coast has a salinity clearly above 35. Hence, it does not contradict our SIC definition. However, pointing to the other branch further offshore is, of course, highly warrantable. Obviously the SIC, like the NIIC, has an inner and an outer branch. Therefore, we have labeled the outer branch with "SIC" as well in Fig. 12 and mentioned this structure in chap. 3.2.4.

Further on, it is stated that the SIC contributes a "major part" of the Faroe Current (FC) (page 783, line 20-21),

Any discussion of the SIC/FC relation was removed. Instead, we have added: "The FC volume flux north of the Faroes was simulated to be 2.1 Sv. (We have added the computation of this value in order to compare it to the observed value of 3.5 Sv.) Hence, we conclude that, within our model, 15%, 33% and 81% of its water stem from the SIC crossing section 14, 13 and 12 respectively."

that the FC originates off the south coast of Iceland (page 783, line 21-22),

These lines were deleted.

and that the SIC is a "major source" of the FC and its "preform" (page 792, line 20-21). For one thing, this illustrates the repetitive character of the text, but it is also inconsistent with other parts of the text.

"major" was replaced by "substantial". We think that "a substantial source" and "preform" are justified formulations to describe our results. However, the repetitive character was removed by deleting the former parts (mentioned above).

According to Table 2, the volume flux of the SIC is less than 10% of the FC (3.5 Sv) on section 14, 20% on section 13. Only on section 12, has it acquired 50% of the volume flux of the FC (and increased slightly in salinity).

Like stated above, we think the simulated SIC should be compared with the simulated FC. Hence the fractions are 15, 33 and 81%

To me this implies that according to the model, half of the FC crosses the ridge over the Icelandic part of it, but only a small fraction "originates off the south coast of Iceland". Most of it could well have followed the flow path sketched in Fig. 16c. Again, I suggest removing these discussions from the "results" sections and combining them into a more balanced description in section 5.

Now, we state in chap. 5, referring to the numbers above, that 33% of the FC water north of the Faroe Islands stem from the SIC west of 17°W. We have also added another reference to Fig. 6 (the simulated mean 15 m flow field) when saying that within our simulation the u-turn structure of Fig. 16c does not exist within the upper layers.

Page 784, line 20, states: "The NIJ across Sect. 5 is negatively correlated to the NIIC". This is stated without any correlation coefficients quoted and no statistical significance analysis. Later on (same page, line 25-26), a positive correlation is stated. Explanations for these "correlations" are speculated, but without any corroborative evidence. The same goes for the rest of section 3.2.5. I suggest deleting all the text from page 784, line 20 to page 785, line 9.

We have removed the all the text except the statement about the SIC stability and its high volume flux from 1992-1999.

Details

Page 765, line 13: "is sub-tropical in origin" -> "has a sub-tropical components" (there are also contributions from the sub-polar gyre"

Corrected

Page 765, line 14 and elsewhere: To my knowledge, salinities should be stated without unit (psu), but this is, of course, up to the editor.

Now, salinity is stated without a unit in the entire manuscript.

Page 766, line 7: "convective cooling" -> "atmospheric cooling"

Corrected

Page 766, line 8: "precipitation" -> "freshwater addition"

corrected

Page 766, line 13: "volume flux volume flux" -> " volume flux"

corrected

Page 766, line 14: "flows eastwards along" -> "continues towards"

corrected

Page 766, line 26: "not more than nine years ago" -> "only in 2004"

corrected

Page 771, line 8: "mean" ???

The word "mean" refers to the sea level, and should indicate that we used "mean sea level pressure" (MSLP) data, i.e. the atmospheric pressure reduced to sea level. However, we agree that it is redundant here and have removed the "mean".

Page 772, line 20: "implicitly" -> "implicit"

done

Page 782, line 10: "whereas" -> "where"

corrected

Page 783, line 2: "vertical heat flux" -> "entrainment"

done

Page 783, line 16: delete "vertical"

done

Page 789, line 1: Fig. 17 is referred to before Fig. 16 (page 793)

The corresponding paragraph was removed (the discussion moved to chapter 5).

Page 791, line 2: delete "there"

done

Page 794, line 7: delete "dynamic" (it is the variation in actual sea level that generates barotropic pressure gradients; not the mathematical construct "dynamic height")

done

Page 794, line 18: "neither" -> "none of" ??

Yes, meant was "none of" - corrected

Page 815: "winterly" -> "winter", "summerly" -> "summer"

done