

1 **Structure of the bottom boundary current South of**
2 **Iceland and spreading of deep waters by submesoscale**
3 **processes**

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9 **Key Points:**

- 10 • An intense bottom boundary current originating from the Iceland-Faroe Ridge and
11 the Faroe Bank Channel flows along the Icelandic Shelf.
- 12 • The rough topography and the intensity of the current lead to bottom mixing and
13 sustain a large bottom mixed layer.
- 14 • Submesoscale structures generated locally participate in the spreading of deep
15 water masses in the Iceland Basin.

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16 **Abstract**

17 The northeastern part of the North Atlantic subpolar gyre is a key passage for the
18 Atlantic Meridional Overturning Circulation upper cell. To this day, the precise path-
19 way and intensity of bottom currents in this area have not reached a consensus. In this
20 study, we make use of regional high resolution numerical modeling to suggest that the
21 main bottom current flowing south of Iceland originates from both the Faroe-Bank Chan-
22 nel and the Iceland-Faroe Ridge (with about equal contributions) and then flows along
23 the topographic slope centered on the $1027.75 \text{ kg m}^{-3}$ isopycnal. When flowing over the
24 rough topography, this bottom current generates a bottom mixed layer reaching 200 m
25 height. We further demonstrate that many submesoscale structures are generated at the
26 southernmost tip of the Icelandic shelf, thus spreading water masses in the open Iceland
27 Basin. These findings have major implication in the better understanding of the trans-
28 port of dense water masses in the North Atlantic, but also for the distribution of ben-
29 thic species along the Icelandic shelf.

30 **Plain Language Summary**

31 Water masses formed in the Arctic Ocean overflow into the North Atlantic at the
32 bottom of the ocean, forming the so-called upper cell of the Atlantic Meridional Over-
33 turning Circulation (AMOC). The pathway of the currents carrying these water masses
34 is still under debate due to a lack of observations. In this study, we discuss in details the
35 pathway of these bottom currents in the specific area south of Iceland. We show that
36 a steady current flows along the Icelandic continental shelf, and then divide in smaller
37 structures when reaching the southernmost tip of Iceland. We also show that on its way,
38 the current mixes the bottom layer of the ocean. These findings have major implication
39 in the understanding of heat and carbon transport at depth in this area, which consti-
40 tute an important response of the climate to anthropogenic forcing.

41 1 Introduction

42 The northeastern part of the North Atlantic subpolar gyre is a key part of the At-
43 lantic Meridional Overturning Circulation (AMOC, Buckley & Marshall, 2016). Its so-
44 called "upper cell" ventilates the upper 2 km of the Atlantic Ocean, and it transports
45 heat and carbon at depth from the surface (Kostov et al., 2014; Marshall et al., 2014).
46 It therefore plays a determinant role in the response of the climate to anthropogenic forc-
47 ing (Drijfhout et al., 2012; Winton et al., 2013; Meehl et al., 2014). The main sources
48 of dense water into the upper cell are overflows from the Nordic Seas (Lozier et al., 2019;
49 Chafik & Rossby, 2019; Tsubouchi et al., 2021). There, intense heat loss in winter trans-
50 forms the water into colder and denser water masses that subsequently flow southward
51 through gaps in topography (Brakstad, Gebbie, et al., 2023).

52 While it is the crossroad of this global circulation, the region south of Iceland has
53 been poorly studied in details (see Fig. 1a for the location of the places mentioned be-
54 low). At this place, there is no consensus on the shape and intensity of bottom currents.
55 Studies agree for an overall southwestward flow from the Iceland-Faroe Ridge (IFR) and
56 the Faroe-Bank Channel (FBC) regions toward the Iceland Basin, following the Reyk-
57 janes Ridge, see *e.g.*, Stow & Holbrook (1984); Bianchi & McCave (1999). When look-
58 ing at it more precisely, opinions diverge a lot, due to the lack of available data in the
59 area. Investigators sometimes only consider the IFR, the FBC, include an overflow over
60 the Western Valley, or assume a pathway across the deep waters of the Iceland Basin,
61 see *e.g.*, Bowles & Jahn (1983); Hansen (1985); Perkins et al. (1998); Hansen & Øster-
62 hus (2000, 2007); Beaird et al. (2013); Logemann et al. (2013); Guo et al. (2014); Ull-
63 gren et al. (2014); Daniault et al. (2016); Zou et al. (2017); Zhao et al. (2018); Hansen
64 et al. (2018); Petit et al. (2019); Chafik & Rossby (2019); Semper et al. (2020); Koman
65 et al. (2022); Brakstad, Gebbie, et al. (2023). Understanding the actual properties of lo-
66 cal geophysical processes at depth is therefore timely. It will allow to better target fu-
67 ture *in situ* observations aiming at quantifying water mass transport and mixing by the
68 bottom currents, and thus better assess deep storage of anthropogenic-induced tracers.

69 Beyond this slowly-varying and averaged picture, it has been shown in the past years
70 that small-scale processes have an important role in modulating the global ocean prop-
71 erties. This includes submesoscale balanced currents such as Submesoscale Coherent Vor-
72 tices (SCVs), Intrathermocline Eddies, or fronts (McWilliams, 2019). These structures

73 have been shown to be key for the global heat budget (Su et al., 2018) and the distri-
74 bution of marine ecosystems (Lévy et al., 2018) *via* deep-reaching vertical and horizon-
75 tal transports (Zhong & Bracco, 2013; Siegelman et al., 2020). Small-scale processes also
76 include fine-scale vertical mixing, induced by deep-reaching currents and internal tides
77 flowing over the topography (Vic et al., 2019; Gula et al., 2022; Polzin & McDougall, 2022).
78 These processes are of major importance to regulate the transport of heat and biogeo-
79 chemical tracers, and they are suggested to be a good candidate for the closing of the
80 oceanic energy budget (Jayne, 2009; Ferrari & Wunsch, 2009; de Lavergne et al., 2022).
81 The contribution of all these submesoscale processes in the south Icelandic dynamics has
82 yet not been studied. However, it is likely that it plays an important role in the trans-
83 port of water masses there. Note that the submesoscale is defined here as the scale at
84 which processes happen on horizontal scales smaller than the average deformation ra-
85 dius (here $\mathcal{O}(20\text{--}30)$ km (LaCasce & Groeskamp, 2020)), and on vertical scales smaller
86 than the bottom mixed layer (here $\mathcal{O}(100)$ m, see section 3.2).

87 In the present paper, we discuss in details the bottom circulation south of Iceland
88 using regional high resolution numerical modeling. In particular we discuss the shape
89 and intensity of the bottom boundary current flowing at ~ 1000 m depth along the Ice-
90 landic shelf. This current is the connection between Nordic Seas and the northeastern
91 part of the North Atlantic subpolar gyre. In the following, mention to the "bottom bound-
92 ary current" refers to this current. We further show that this latter generates numer-
93 ous submesoscale features on its path and where it overshoots. This processes are shown
94 to be of importance for the distribution of water masses in the area. In section 2 we present
95 the methods used to investigate these processes. In section 3 we present the analysis of
96 the numerical simulations. In section 4 we discuss and conclude on our results.

2 Methods

2.1 Numerical simulation of the North Atlantic

We use outputs of a realistic simulation of the North Atlantic Subpolar Gyre, already used and validated in previous studies, *e.g.*, Le Corre, Gula, Smilenova, & Houper (2019); Le Corre, Gula, & Treguier (2019); de Marez & Le Corre (n.d.); Smilenova et al. (n.d.); de Marez et al. (2021); Wang et al. (2022). It is performed using the Coastal and Regional Ocean COmmunity model (CROCO, Shchepetkin & McWilliams, 2005). This model solves the hydrostatic primitive equations using the full equation of state for seawater (Shchepetkin & McWilliams, 2011). The horizontal advection terms for tracers and momentum are discretized with third-order upwind advection schemes (UP3), see *e.g.* Klein et al. (2008) for a further description. This parameterization considers implicit dissipation and it damps dispersive errors.

A one-way nesting approach is used. A first simulation of the whole North Atlantic is implemented with a $\Delta x \sim 6$ km horizontal resolution and 50 topography-following levels, such that mesoscale eddies are reasonably well resolved. It is initialized and forced at boundaries with the SODA dataset (Carton & Giese, 2008). At the surface, the forcing is obtained from the daily ERA-INTERIM dataset (Dee et al., 2011). The bathymetry is constructed from the SRTM30 PLUS dataset (Becker et al., 2009). Then, this simulation is used as boundary forcing and initialization for a second —child— simulation in the Subpolar region, with $\Delta x \sim 2$ km horizontal resolution and 80 topography-following levels. This higher resolution resolves small scale bathymetric features. In particular, it allows an accurate description of the FBC and the IFR.

We make use of this high resolution simulation in the present study, for the period 2002-2009 (after a 2-years spin up). Reference to time averaged quantities over this period are denoted $\langle \cdot \rangle_t$. The simulation has already been thoroughly validated by Le Corre, Gula, & Treguier (2019) in the Subpolar Gyre, and at the large scale. In our domain of interest, a slight average temperature and salinity offset is seen in the whole water column (constant throughout depth). However, it does not affect the average stratification (see Fig. 2c,d) which is here the main parameter for the study of the dynamical processes. For further details, we refer the reader to Le Corre, Gula, & Treguier (2019)'s description and validation of the simulation, and their Fig. 1 that presents the simulation domain.

129 **2.2 Particulate advection simulations**

130 We perform three offline particle advection simulations, using the velocity field from
131 the numerical simulation on the $1027.75 \text{ kg m}^{-3}$ isopycnal, implementing the set of python
132 classes Parcels (Probably A Really Computationally Efficient Lagrangian Simulator). This
133 tool has been widely used in the past few years and it is fully described in Lange & van
134 Sebille (2017), Delandmeter & van Sebille (2019), and in references therein. The three
135 simulations are designed such that they all are one year long. We arbitrarily chose the
136 year 2005 of the CROCO simulation for the currents.

137 **2.3 *in situ* data**

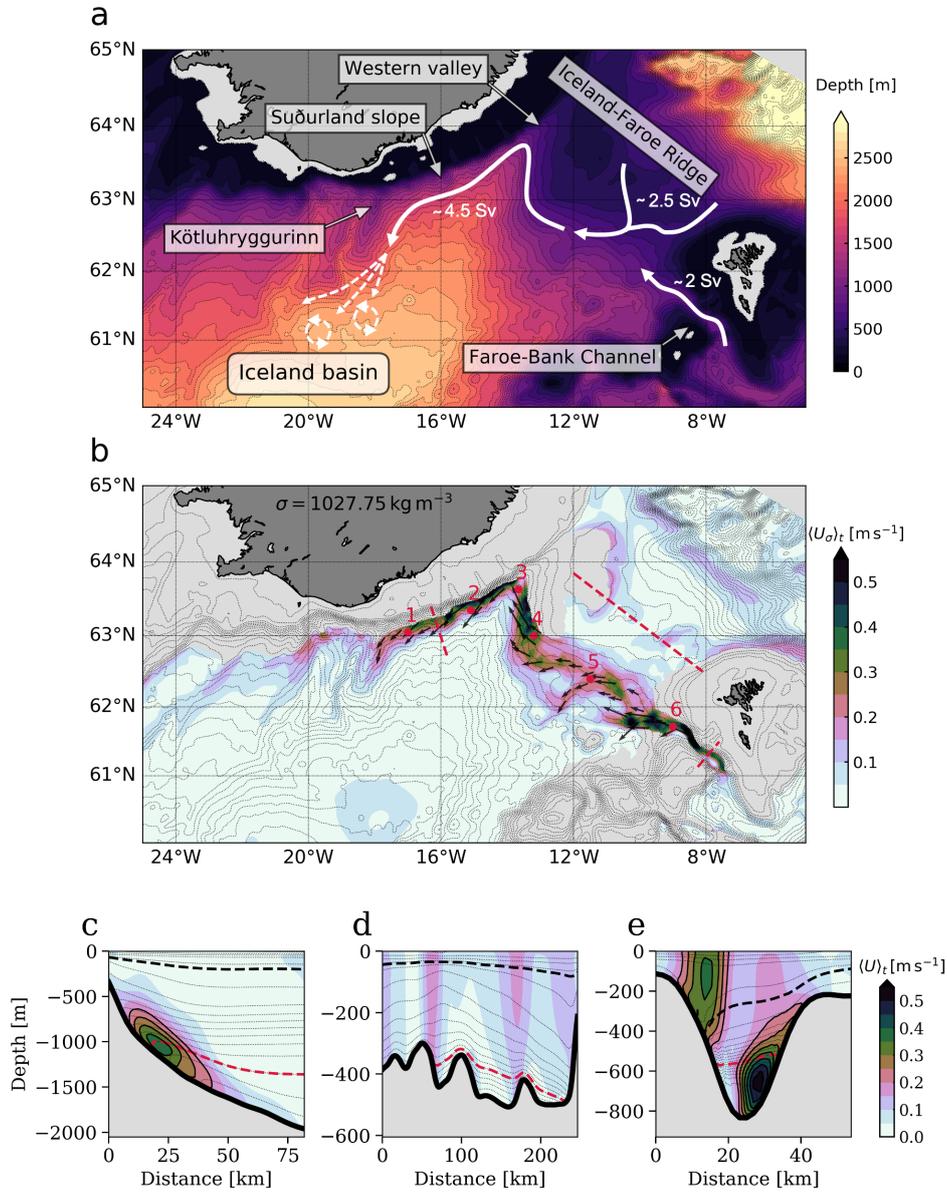
138 The data used for validation and comparison was obtained from SeaDataNet and
139 the Norwegian Marine Data Center (Brakstad, Våge, et al., 2023) for the region south-
140 east of Iceland, corresponding to 80 CTD profiles from 1996 until 2019 covering the 4
141 seasons. Most of the profiles were uploaded to these open source databases by the Hy-
142 drography Observational Programme carried out by the Icelandic Marine and Freshwa-
143 ter Research Institute (Ólafsdóttir et al., 2020). The CTD profiles were used to validate
144 the simulation at the virtual location of 13.7°W and 63.6°N (Stokksnes 5), shown in Fig.
145 1b as the point labeled 3.

146

3 Results

147

3.1 General description of the bottom current



148

Figure 1. a: Region of interest, bathymetry, and schematic path of the bottom current; white

149

numbers indicate the transport through the three sections shown in panels c,d,e. b: Velocity

150

norm on the $1027.75 \text{ kg m}^{-3}$ isopycnal; position of sections shown in panels c,d,e, position of

151

profiles shown in Fig. 2, and bathymetry (thin black lines). c,d,e: Vertical sections of the velocity

152

norm and isopycnals (thin dashed every 0.05 kg m^{-3} , red dashed $1027.75 \text{ kg m}^{-3}$, and thick

153

dashed $\sigma_{\text{top}} = 1027.3 \text{ kg m}^{-3}$).

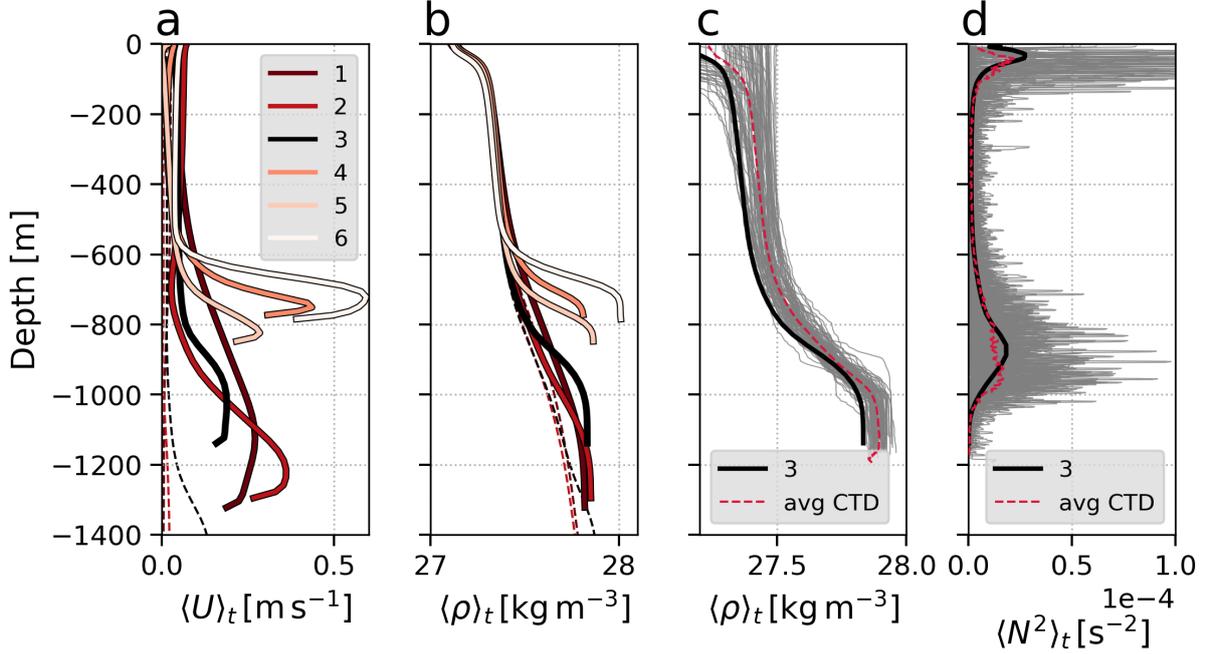
154 Time-averaged simulation outputs show that the bottom boundary current orig-
 155 inates from two branches at the northeast boundary of the Iceland Basin. A first branch
 156 consists of a northwestward flow coming from the FBC. There, an intense current with
 157 average maximum velocity of 0.53 m s^{-1} located below 500 m depth flows along the north-
 158 ern slope of the narrow channel, see Fig. 1b,e. The transport in this channel has been
 159 shown in previous studies to be about 2 Sv (Hansen & Østerhus, 2007; Hansen et al.,
 160 2016). We determine that this transport is satisfied when integrating the crossing cur-
 161 rent between the $\sigma_{\text{top}} = 1027.3 \text{ kg m}^{-3}$ isopycnal and the bottom. A second branch con-
 162 sists of a southwestward flow coming from the IFR. There, two weak currents at $\sim 11^\circ\text{W}$
 163 and $\sim 9^\circ\text{W}$ flow over the ridge. The average maximum velocity of 0.19 m s^{-1} at the bot-
 164 tom is seen at the western most location, see Fig. 1b,d. The crossing overflow transport
 165 between σ_{top} and the bottom is about 2.5 Sv, larger than the FBC transport because
 166 of the wider section.

167 When entering the Iceland Basin, the bottom boundary current stabilizes around
 168 the $1027.75 \text{ kg m}^{-3}$ isopycnal, see Fig. 1b. It flows northward, constrained along the con-
 169 tinental shelf. When reaching the Western Valley, it retroflects following the topogra-
 170 phy. It then flows southwestward along the continental shelf south of Iceland, namely
 171 Suðurland slope, after the name of the Icelandic southern lands. The flow is very well
 172 marked along the slope, with average maximum velocity of 0.38 m s^{-1} on the $1027.75 \text{ kg m}^{-3}$
 173 isopycnal, see Fig. 1c. This finding justifies the choice of this particular isopycnal for the
 174 further investigation of the current made in this study. The transport induced by the
 175 current between σ_{top} and the bottom is about 4.5 Sv, thus satisfying the mass conser-
 176 vation from overflows to the Suðurland slope.

177 Finally, the current overshoots at a submarine cape located $\sim 18^\circ\text{W}, 62.5^\circ\text{N}$. It is
 178 called Kötluhryggurinn, "the Katla ridge", after the Katla volcano south of Iceland (Shor,
 179 1980). A slight part of the current overflows west over Kötluhryggurinn, creating weak
 180 branches of current further west, see Fig. 1b. Further examination of the current using
 181 particle advection simulations show that these branches have few impact (section 3.3).
 182 Note that neither seasonal nor inter-annual variability of the bottom boundary current
 183 position/intensity/depth are noticed (not shown), thus justifying the use of 7-years over-
 184 all time averages.

185

3.2 Vertical variations and mixing at the bottom



186 **Figure 2.** a (resp. b): Time-averaged velocity norm (resp. potential density) profiles at the
 187 locations shown in Fig. 1b; thin dashed profiles show profiles ~ 50 km off-shore of the same-color
 188 profiles. c (resp. d): Comparison of potential density (resp. Brunt-Väisälä frequency) profiles
 189 between simulation (thick black) and CTD station (thin gray and thick dashed red) at location 3
 190 (Fig. 1).

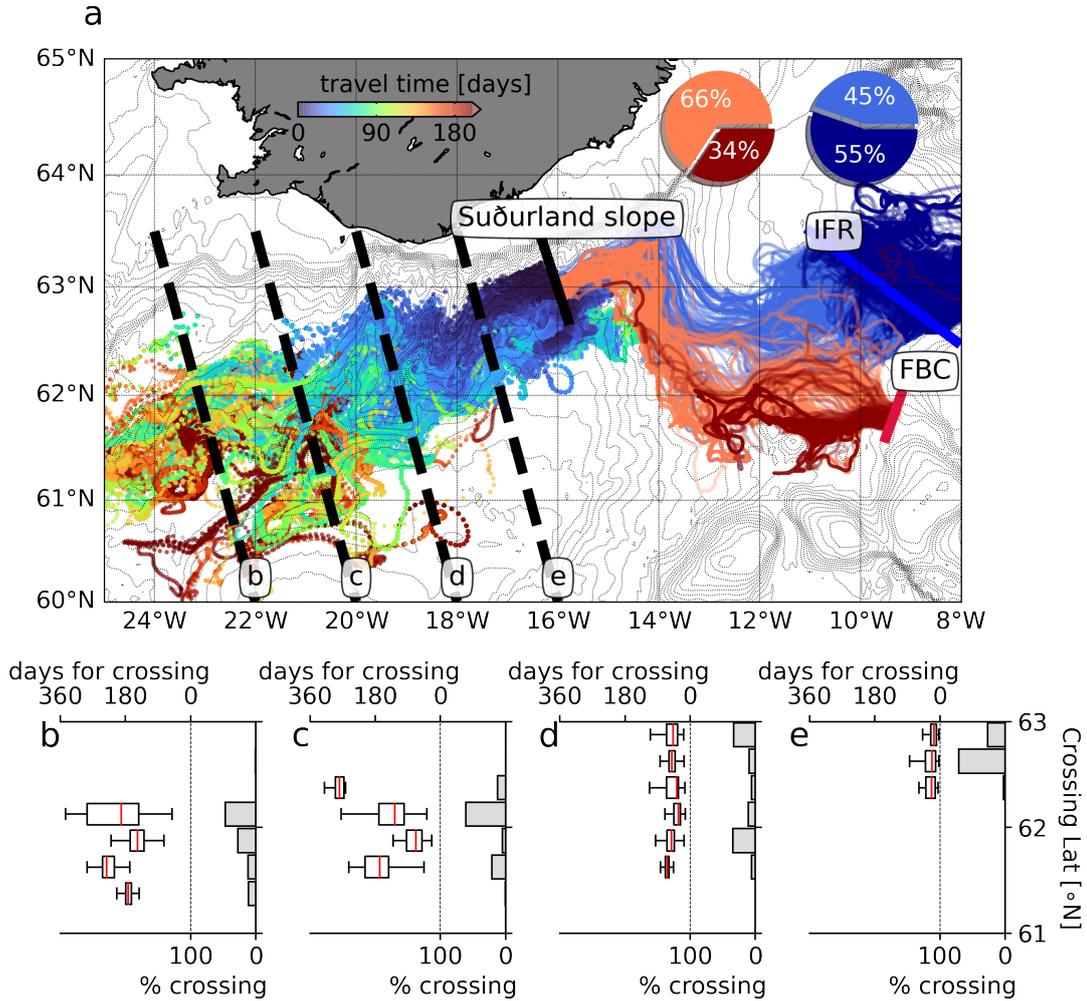
191 Along its path from the FBC to the Suðurland slope, the current has a Gaussian-
 192 like vertical distribution, with average maximum velocity varying between ~ 0.2 and ~ 0.6 m s^{-1} ,
 193 and average thickness varying between ~ 100 m and ~ 500 m, see Fig. 2a. It dives from
 194 ~ 700 m depth at the FBC mouth (profile 6) to ~ 1200 m depth at Kötluhyggurinn (pro-
 195 file 1).

196 A marked Bottom Mixed Layer (BML) is observed along the current path, see Fig.
 197 2b,c,d, and is confirmed by 24 years of *in situ* data. This BML is less than 50 m thick
 198 at the FBC mouth. It then becomes thicker along the IFR reaching over 200 m in the
 199 Western Valley and along the Suðurland slope. The profile 3 position coincides with the
 200 position of CTD casts performed during a 24 years period in the Western Valley (Stokksness
 201 5, Ólafsdóttir et al., 2020). Average vertical profile of potential density from the simu-
 202 lation matches with *in situ* observations. The slight offset in density is homogeneous on

203 the vertical and is mainly due to a $\sim 0.5^\circ\text{C}$ temperature offset. Nevertheless, this does
204 not change the dynamics as the stratification (N^2) closely matches thus proving the oc-
205 currence of this deep BML in the current path, and additionally validating one of the
206 main feature of the simulated current.

207 The evolution of this BML suggest the combination of frictional and arrested bot-
208 tom Ekman layers (Brink & Lentz, 2010). The FBC is a narrow-steep-smooth channel
209 which allows the BML to be tightly confined (~ 10 km) against the slope; there, the ve-
210 locity is maximum and the density contrast between the BML and the interior is also
211 the greatest. This bottom boundary current remains confined to the slope throughout
212 the path presented here. First evidence is that this BML is not seen ~ 50 km off-shore,
213 outside of the current path, see Fig. 2b. Along the path the BML thickness increases
214 coincidentally with the increase in roughness on bottom topography just after the Suðurland
215 slope, which is most likely due to submesoscale viscous processes happening at the bot-
216 tom, when the current flows over the topography (Polzin et al., 2021).

3.3 The faith and spreading of carried waters



218 **Figure 3.** a: Trajectories of particles released from the IFR (blue), the FBC (red), and the
 219 Suðurland slope (rainbow color that indicates the travel time) sections; darker blue (resp. red)
 220 show trajectories of particles released from the IFR (resp. FBC) location that dit not cross the
 221 Suðurland slope section; for clarity only 1 out of 4 trajectory is shown; pie charts indicate the
 222 percentage of trajectories that crossed the Suðurland slope section when released from either
 223 the IFR or the FBC locations; black dashed lines indicate the sections used to compute the his-
 224 tograms shown in bottom panels. b,c,d,e: Percentage of particles crossing the sections shown in
 225 panel a, and time for the crossing, as a function of latitude.

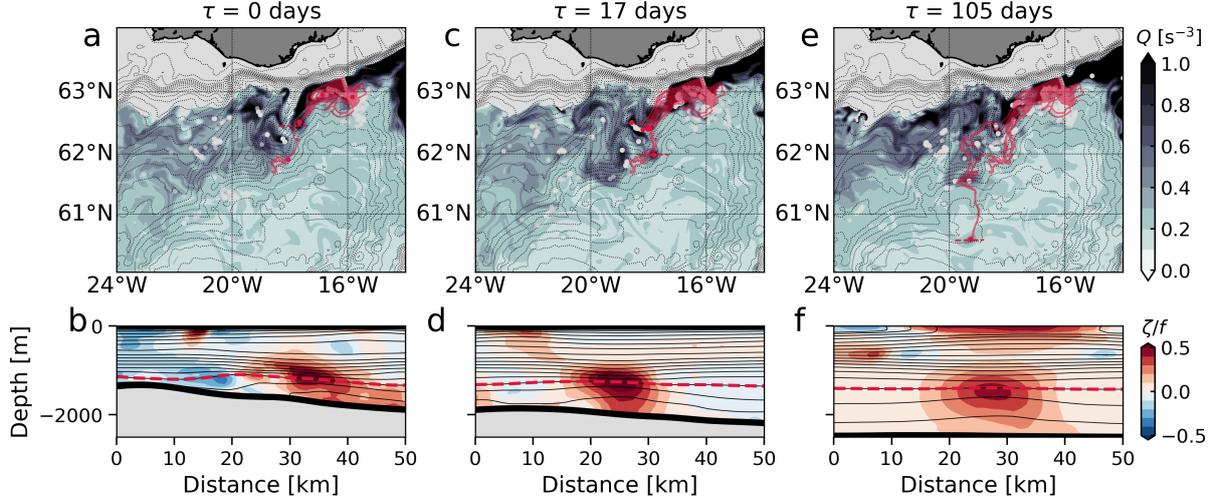
226 Two first particle advection simulations confirm that the bottom current originates
 227 from both the IFR and the FBC overflows. A total of 6 (resp. 26) particles are released
 228 everyday during 300 days along a straight line located in the FBC (resp. on the IFR)
 229 on the $1027.75 \text{ kg m}^{-3}$ isopycnal, see Fig. 3a. Remarkably, all particles overflowing in the

230 Iceland Basin eventually get trapped along a very narrow path along the Suðurland slope.
231 We then measure the number of particles from each simulation that cross a section per-
232 pendicular to the Suðurland slope, see Fig. 3a. Some particles do not reach this region
233 at the end of the simulations (34% and 55%); those particles were either advected too
234 slowly or flowing east of the IFR (see dark blue and dark red trajectories in Fig. 3a).
235 Nevertheless, when particles released at both locations get trapped in the bottom cur-
236 rent they always travel north toward the Western Valley before retroreflecting to the west
237 and crossing the Suðurland slope section. Note that an additional backward advection
238 simulation described in Supplementary Information confirms these findings.

239 Then, a third simulation is designed in which 15 particles are released everyday dur-
240 ing a year along a straight line perpendicular to the the Suðurland slope on the $1027.75 \text{ kg m}^{-3}$
241 isopycnal, *i.e.*, the same section as the one mentioned previously, see Fig. 3a. Particle
242 trajectories from this simulation shows that when reaching Kötluhryggurinn, the waters
243 carried by the bottom current spread out in the Iceland Basin. We measure the latitude
244 and the travel time at which particles cross four different sections, parallel to the launch-
245 ing section, each spaced of 2° in the longitudinal direction, see Fig. 3. Particles cross the
246 first section (e) in a few weeks and are concentrated north of 62.5°N , see Fig. 3e. Af-
247 ter passing Kötluhryggurinn, and as they travel southwestward, they detach from the
248 continental slope, and they cross sections with a large spreading, see Fig. 3b,c,d. Par-
249 ticles crossing section b are all located south of 62.25°N , and some particles even crossed
250 the 60th parallel North. The spreading is due to turbulent processes, with short time scales,
251 as revealed by the large standard deviations of crossing times. This is also highlighted
252 by the fact that particles are advected by a flow with high values of relative vorticity.
253 In particular, most of the particles have a cyclonic vorticity reaching $\zeta/f > 0.5$ due to
254 the generation of submesoscale structures at Kötluhryggurinn (see Fig. 2 of Supplemen-
255 tary information). These processes are described in the following section.

256

3.4 Submesoscale generation at Kötluhryggurinn



257 **Figure 4.** a,c,e: Snapshots of Potential Vorticity (divided by 10^9) on the $1027.75 \text{ kg m}^{-3}$
 258 isopycnal; position of particles trapped (resp. don't trapped) by the SCV at $\tau = 105$ days is
 259 shown by the red (resp. white) dots. b,d,e: vertical section of normalized relative vorticity at the
 260 position shown by the red dashed lines in top panels; isopycnals are shown in thin black lines; the
 261 $1027.75 \text{ kg m}^{-3}$ isopycnal is shown by the thick dashed red line.

262 Water masses are spread out in the Iceland Basin by submesoscale structures prop-
 263 agating from Kötluhryggurinn. The mechanism is as follows. The bottom current flows
 264 along the Suðurland slope, concentrated around the $1027.75 \text{ kg m}^{-3}$ isopycnal. Viscous
 265 interactions (parameterized in the model, see Le Corre, Gula, & Treguier (2019)) with
 266 the topography leads to a frictional injection of Potential Vorticity (PV) on this isopy-
 267 cnal. This in turn generates a change of sign of the cross-current PV gradient both hor-
 268 izontally and vertically (see Fig. 3 of Supplementary Information). These are the nec-
 269 essary conditions for Barotropic and Baroclinic instabilities to occur. This results in a
 270 highly turbulent flow along the Suðurland slope, as reflected by the high values of Eddy
 271 Kinetic Energy (EKE) and Eddy Available Potential Energy (EAPE) on this isopycnal
 272 (see Fig. 3 and 4 of Supplementary Information). The flow overshooting at Kötluhryg-
 273 gurinn thus does not follow the slope but meanders south in the Iceland Basin. Water
 274 masses are stirred and spread out offshore by intense fronts and rapidly varying flows
 275 with —mainly cyclonic— values of vorticity reaching $\zeta/f > 0.5$ (see Fig. 2 of Supple-
 276 mentary Information). Occasionally, the tongue of potential vorticity wraps onto itself,
 277 generating cyclonic SCVs on the $1027.75 \text{ kg m}^{-3}$ isopycnal.

278 The cyclonic SCVs generated at Kötluhryggurinn enhance the spreading of water
279 masses. A particular event of SCV generation is shown in Fig. 4. This structure was gen-
280 erated following the mechanism discussed in the previous paragraph. It then traveled
281 south, hundreds of kilometers, carrying water masses offshore. At $\tau = 105$ days (Fig.
282 4e,f), 175 particles (out of 5464 released in total during the simulation) are trapped in
283 its core and travel southward. This represents more than 3% of the total amount of par-
284 ticles present along the Suðurland slope during a year, that have been spread out by this
285 single event. Counting the number of such events is arduous because most of the time
286 generated SCVs merge between each other making the tracking of single structures haz-
287 ardous. Nevertheless, we report 15-20 events in the year 2005 of the simulation. This sug-
288 gests that $\mathcal{O}(50)\%$ of water masses present along the Suðurland slope could be spread
289 in the basin by locally generated SCVs.

4 Discussion

In this study, we investigated the bottom boundary current flowing in the north of the Iceland Basin. We showed that it originates from both the Faroe-Bank Channel and the Iceland-Faroe Ridge. It then follows the topography on the $1027.75 \text{ kg m}^{-3}$ isopycnal where it induces bottom mixing creating a large Bottom Mixed Layer. It finally overshoots at K tluhryggurinn, where submesoscale structures are generated and spread water masses in the open Iceland Basin.

In the past decades, circulation in the northern Iceland Basin has been investigated due to its role in the Atlantic Meridional Overturning Circulation, and numerous schematized views of the bottom circulation have emerged. The present paper aims at suggesting that the bottom circulation of the North Iceland basin is as schematized as in Fig. 1a, with a current coming from both the Faroe-Bank Channel and the Iceland-Faroe Ridge (with about equal contributions) and flowing along the topographic slope. More importantly, our study put forth the fact that when overshooting at K tluhryggurinn, the bottom current somehow disappears and let place to a submesoscale processes-driven spreading of the water masses in the Iceland basin, thus making obsolete the view of a current steadily flowing along the Reykjanes Ridge. In particular, a significant amount of water is spread out by locally generated cyclonic SCVs. Even if only a few *in situ* experiments succeeded in measuring SCVs with a sufficient horizontal resolution (see *e.g.*, L'H garet et al., 2016; Meunier et al., 2018; Gula et al., 2019, and references therein), only a few observations of *cyclonic* SCVs were reported (*e.g.*, Bosse et al., 2016; de Marez et al., 2020), suggesting that anticyclonic SCVs are predominant in the deep ocean. Our findings thus further suggest that K tluhryggurinn is an efficient generation spot for deep intense *cyclonic* SCVs. This result is to be confirmed by *in situ* measurements in the area to allow further analysis of these peculiar submesoscale structures.

The region described in this manuscript is of great importance for the future of the AMOC. Indeed, the dense water carried by the bottom current has enormous importance as it significantly contributes to the lower limb of the AMOC. Moreover, the winter convection there can create surface mixed layer depths over 700 m (Brakstad, Gebbie, et al., 2023), which in some regions allows the exchange of surface waters with dense bottom waters. The upper ocean in this region is warming up and IPCC projections suggest this will continue at even higher rates than other basins (Shu et al., 2022). South

322 of Iceland, the combination of deep mixed layers with warmer surface waters, and thick
323 bottom boundary currents with cold-dense waters may exchange this excess of heat re-
324 sulting in changes of these dense waters in a warming climate.

325 The bottom boundary current described in this study also appears to be a key phe-
326 nomenon to sustain biological activity in the area. Indeed, the distribution of several Cold
327 Water Coral species, in particular *Lophelia pertusa*, strongly correlates with the position
328 of the bottom current we described (see Fig. 4 of Buhl-Mortensen et al., 2015). It has
329 been shown in the past that the presence of benthic species, such as Cold Water Coral,
330 is strongly correlated to the physical and chemical properties of seawater. In particular,
331 they rely on a renew of suspended food sources and oxygenated waters, *i.e.*, feeding cur-
332 rents (Mienis et al., 2019). The bottom current described here has the potential to act
333 as a enhancement-nutrient-supply current. Its strong intensity efficiently renews the bot-
334 tom water. The interaction of the current with the topography south of Iceland induces
335 strong vertical gradients, locally enhancing vertical mixing of cold nutrient-rich bottom
336 water to the upper layers. The bottom mixing induced by the current also enhances this
337 water flushing, and contributes in increasing the bottom temperature, necessary condi-
338 tion for this species to survive. This current may have implication to a broader spectrum
339 of benthic species, but more investigation in this direction, and a better sampling of physical-
340 biology-related quantities at the bottom is needed to pursue this question.

341 Finally, even if it is mainly speculations, it is interesting to draw the question of
342 Kötluhryggurinn formation. Studies have discussed the fact that "The Katla Ridges are
343 smooth features with accumulation of sediment beneath the crests in excess of 1.5 kilo-
344 meters. Their mode of formation is inferred to result from the rapid denudation of Ice-
345 land during the Neogene, sediment transport to the base of the slope by turbidity cur-
346 rents and subsequent entrainment and transport southwestward by the flow of Iceland-
347 Scotland Overflow Water." (Shor, 1980). Even if some other exchanges from the shelf
348 into the canyons may contribute to the sediments, several sources (see *e.g.*, Bowles &
349 Jahn, 1983), suggest that the bottom current has lead to the formation of this bathy-
350 metric feature. Taking a step back, this suggests that the bottom current formed Kötluhryg-
351 gurinn topographic anomaly, which in turn contributed to the generation of submesoscale
352 at this particular place. This could be the signature of geological-timescale forced sub-
353 mesoscale process.

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364 **Open Research**

365 CTD data were provided through SeaDataNet Pan-European infrastructure for ocean
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367 as part of the SDC_ARC_DATA_TS_V2 dataset Due to the large size of simulation
368 outputs, they are available upon request. A script to reproduce particle advection sim-
369 ulations can be obtained online (<https://zenodo.org/doi/10.5281/zenodo.3824499>).

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