Limited influence of basalt weathering inputs on the seawater neodymium isotope composition of the northern Iceland Basin

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Highlights

- 1. Icelandic input of radiogenic Nd essentially limited to coastal waters**
- 2. Offshore bottom water Nd isotope signatures consistent with conservative mixing of intermediate and deep water masses**
- 3. Decreased bottom water Nd concentrations likely reflect removal by particle scavenging**

Keywords: Neodymium isotopes; Iceland Basin; seawater; water masses

Abstract

Radiogenic neodymium (Nd) isotopes have been widely used as a proxy for tracing present and past water masses and ocean circulation, yet relatively few data exist for seawater from the important deep water formation area around Iceland. We have analyzed the dissolved seawater Nd isotope compositions (expressed as ϵ_{Nd}) of 71 seawater samples, as well as Nd concentrations [Nd] of 38 seawater samples, collected at full water column profiles from 18 stations in the shelf area off the southern coast of Iceland. The goal of this work was to determine to what extent weathering inputs from Icelandic basalts, which are characterized by a distinctly radiogenic ϵ_{Nd} signature within the North Atlantic, contribute to the Nd isotope and concentration signatures of water masses in the northern Iceland Basin.

Radiogenic ϵ_{Nd} values of up to -3.5 and elevated concentrations of up to 21 pmol/kg compared to nearby open ocean sites were found in surface waters at shallow sites closest to shore and to river mouths of Iceland. This documents partial dissolution of highly radiogenic basaltic particles, which are transported northwards by the coastal currents. A comparable signal is not observed, however, in offshore surface waters likely as a result of the advection of surface currents mainly directed onshore, thus isolating these sites from Icelandic weathering contributions. The dominance of Subpolar Mode Waters and Intermediate Water unaffected by Icelandic contributions in the offshore study area is supported by unradiogenic ϵ_{Nd} signatures between -15 and -12.

In agreement with hydrographic data, highly radiogenic bottom waters at one site on the Iceland-Faroe Ridge ($\epsilon_{\text{Nd}} = -7.5$) reveal the presence of almost pure Iceland Scotland Overflow Water (ISOW) near its formation site further to the east. In bottom waters of all deeper offshore sites, the combination of depleted Nd concentrations and similar ϵ_{Nd} values (averaging at $\simeq -11.75$ for the R/V Poseidon data and $\simeq -11$ for the R/V Thalassa data) confirms the rapid entrainment of Atlantic mid-depth and deep waters into the overflow waters, which is accompanied by near bottom Nd removal via particle scavenging. Overall, our findings demonstrate that at present, apart from the radiogenic isotope signature of ISOW itself, the direct contribution of radiogenic Nd originating from weathering of Iceland basalts to the water column of the Iceland Basin is limited. This supports the reliable application of ϵ_{Nd} values to trace changes in the mixing of open North Atlantic water masses (including ISOW).

1. Introduction

1.1 Neodymium isotopes

Radiogenic neodymium isotopes have been shown to be a valuable proxy for quantifying water mass mixing due to the "quasi conservative" behavior of Nd in seawater (cf. Piepgras and Wasserburg, 1979; Frank, 2002; Goldstein and Hemming, 2003). Overall, Nd isotope signatures of major open ocean water masses broadly depict the signature of the surrounding continents and are influenced by subsequent mixing and particle cycling along the advection pathways (van de Flierdt, 2016; Tachikawa et al., 2017). Radiogenic Nd isotope ratios are generally expressed in the epsilon (ϵ_{Nd}) notation, which represents the deviation of the $^{143}Nd/^{144}Nd$ of a sample from that of CHUR (Chondritic Uniform Reservoir) in parts per 10,000 (Jacobsen and Wasserburg, 1980).

$$\epsilon_{Nd} = \frac{\frac{^{143}Nd}{^{144}Nd}_{sample} - \frac{^{143}Nd}{^{144}Nd}_{CHUR}}{\frac{^{143}Nd}{^{144}Nd}_{CHUR}} \times 10000$$

The Rare Earth Element Nd is primarily introduced into the ocean through rivers, which carry the dissolved and particulate products of continental weathering. Atmospheric dust (Tachikawa et al., 1999; Rickli et al., 2010), marine sediment pore waters (e.g. Abbott et al., 2015), and submarine groundwater discharge (SGD; e.g. Johannesson et al., 2011; 2017; Kim and Kim, 2011) are additional contributors to the Nd budget of the global ocean, whereby the global importance of SGD is not yet clear (Molina-Kescher et al., 2018). Importantly, it has been shown that the exchange between seawater and shelf sediments along continental margins can substantially modify the dissolved seawater Nd isotope composition without significantly altering the seawater Nd concentration, which has been termed "boundary exchange" (Lacan and Jeandel, 2005a; Arsouze et al., 2007; Rempfer et al., 2011). While it has been shown that this process exerts a strong control on the global Nd budget, the exact mechanisms controlling Nd cycling during boundary exchange remain poorly understood.

Nd isotopes preserve distinct signatures along the water mass pathways because the average Nd residence time in seawater of 400 to 1,000 years is short enough to prevent global ocean mixing but long enough for local source signatures to be advected out of and between individual ocean basins (Tachikawa et al., 2003; Siddall et al., 2008; Rempfer et al., 2011). Nd concentrations in the deep ocean are on the order of 10-50 pmol/kg and profiles generally follow a nutrient-type pattern, increasing with depth and with time advected along the global conveyor belt in deep waters (Elderfield et al., 1988; Siddall et al., 2008). Very high Nd concentrations of up to 150 pmol/kg have been measured in coastal surface waters of the North Atlantic, reflecting local inputs; otherwise, Nd concentrations in deep and intermediate waters are generally lowest in the North Atlantic and highest in the North Pacific (Lacan et al., 2012; van de Flierdt et al., 2016; Tachikawa et al., 2017). In contrast, ϵ_{Nd} signatures vary with water mass distribution, particularly when advection is strong and dominant over other vertical Nd cycling processes and diapycnal mixing, thus enabling the distinctive Nd isotopic composition of individual water masses to be conserved. Prompted by the ongoing international GEOTRACES program (Henderson et al., 2007), the available database has expanded greatly over recent years (Mawji et al., 2012; van de Flierdt et al., 2016) and new data for the North Atlantic have been generated (Lambelet et al., 2016; Dubois-Dauphin et al., 2017).

Iceland is a uniquely radiogenic Nd source in the Northern North Atlantic due to its location on the Mid Atlantic Ridge. Ninety percent of Iceland consist of basaltic rocks (e.g. Gíslason et al., 1996) characterized by ϵ_{Nd} signatures between +7 and +8.5 (Shorttle et al., 2013). Some of the most important deep water formation areas of the North Atlantic Ocean, which ultimately contribute to the formation of North Atlantic Deep Water (NADW), are located near Iceland. It is thus crucial to constrain if and how basaltic inputs from Iceland contribute to the Nd isotope composition of the surrounding seawater.

1.2 Hydrography of the Iceland Basin

The Iceland Basin is located within the Subpolar Gyre of the North Atlantic, which is a key area of the Atlantic overturning circulation (e.g. van Aken and de Boer, 1995). Interactions between

warm and saline Atlantic waters and colder Arctic waters result in the formation of two major deep water masses in this area which substantially contribute to the formation of NADW: Iceland Scotland Overflow Water (ISOW) and Denmark Strait Overflow Water (DSOW) which originate in the Iceland and Greenland Seas to the north of Iceland (Lee and Ellett, 1967; Swift et al., 1980; Swift, 1984; Fig. 1). Both overflow waters eventually mix with deep waters from other sources in the western North Atlantic basin (most importantly Labrador Sea Water "LSW") to form dense and saline NADW (van Aken and de Boer, 1995). Temporal and spatial changes in these circulation patterns, overflow strength, and water mass distribution are linked to heat and moisture transport in the Northern Hemisphere and are thus impacted by - and influence - regional and global climate (e.g. Rhein et al., 2011).

The hydrography of waters around Iceland is complex due to sea floor topography and admixture of a number of different water masses (van Aken and de Boer, 1995; Malmberg, 2004; Pollard et al., 2004; Logemann et al., 2013; Fig. 1). The Iceland Basin is located to the south of Iceland and is bordered by the Denmark Strait in the west and the Iceland-Faroe Ridge in the east (Fig. 1). Warm and saline subtropical Atlantic Water originating from the Gulf Stream is advected into the Nordic Seas where it mixes with cold and fresh Arctic Water flowing southward. Cooling and freezing processes further transform and subduct these water masses, which are eventually carried back into the Atlantic as overflow waters both across the Iceland-Faroe Ridge into the Iceland Basin, and across the Denmark Strait into the Irminger Basin. The properties and proportions of major water masses in the Iceland Basin vary on inter-annual time scales (van Aken and de Boer, 1995).

As a result, the main water masses found in the Iceland Basin include *Subpolar Mode Water* (SPMW), a modification of Atlantic Water convectively formed in the Subpolar Gyre through mixing of subtropical and polar waters. It has a temperature of $\approx 8^{\circ}\text{C}$ and a salinity of ≈ 35.2 , and is found below the surface mixed layer extending as deep as 1000 meters (McCartney and Talley, 1982; van Aken and de Boer, 1995). *Intermediate Water* (IW) is another modification of Atlantic Water found below SPMW and is primarily identified by a distinct oxygen minimum and temperatures of $\approx 6^{\circ}\text{C}$ (van Aken and de Boer, 1995; Beird, 2016). *Icelandic Slope Water* (ISW)

is a water mass found at deep levels on the Icelandic slope and is comprised of a mixture of SPMW and ISOW, with high salinity and oxygen values (van Aken and de Boer, 1995). *Labrador Sea Water* (LSW) spreads from its source in the Labrador Basin across the Mid-Atlantic Ridge into the Iceland Basin and is one of the important deep water masses contributing to the formation of NADW, with temperatures of $\approx 3\text{-}4^{\circ}\text{C}$, a somewhat variable salinity near ≈ 34.9 , and oxygen content $> 275 \text{ } \mu\text{mol/kg}$ (van Aken and de Boer, 1995; Malmberg, 2004). *Iceland Scotland Overflow Water* (ISOW) is another important deep water mass contributing to NADW which forms by mixing of Atlantic waters and LSW and flows westwards across the Iceland-Faroe Ridge into the Iceland Basin. This water mass is characterized by low temperatures of $\approx 1.75\text{-}3^{\circ}\text{C}$, a salinity of ≈ 35 , and high oxygen concentrations around $300 \text{ } \mu\text{mol/kg}$ (van Aken and de Boer, 1995; Malmberg, 2004; Beaird et al., 2016).

Several studies on the Nd isotope composition of water masses have been performed in this area of the North Atlantic which defined distinctly radiogenic ϵ_{Nd} signatures of ISOW (-7.7 ± 0.6 by Piepgras and Wasserburg, 1987; -8.2 ± 0.6 by Lacan and Jeandel, 2004b) and DSOW (-8.6 ± 0.5 by Piepgras and Wasserburg, 1987; -8.4 ± 1.2 by Lacan and Jeandel, 2004a). Other major water masses have been isotopically characterized in the northern North Atlantic including parts of the southern Iceland Basin. In the northeastern Iceland Basin near the Iceland-Faroe Ridge, SPMW has an ϵ_{Nd} signature of -13 ± 0.6 , and in the southwestern Iceland Basin ϵ_{Nd} signatures of SPMW and LSW are -14.8 ± 0.2 and -14.1 ± 0.4 , respectively (Lacan and Jeandel, 2004c; Lacan and Jeandel, 2005b; Dubois-Dauphin et al., 2017). Overall, however, very few data exist for locations close to Iceland, in particular in shallow waters.

Here we determine to what extent weathering inputs from Icelandic basalts, which are characterized by a distinctly radiogenic ϵ_{Nd} signature within the North Atlantic, modify the Nd isotope and concentration signatures of water masses in the northern Iceland Basin. We have analyzed 71 samples collected at 18 stations off the southern coast of Iceland for seawater Nd isotopic compositions, and 38 of those samples for seawater Nd concentrations. The goal was to further elucidate the Nd isotope signatures of the water masses and their mixing, and therefore the influence of processes such as boundary exchange (Lacan and Jeandel (2005a, b)

and basalt dissolution (e.g Pearce et al., 2013; Fröllje et al., 2016) on the Nd isotope composition of Iceland Basin seawater.

2. Materials and Methods

The entire purification and measurement techniques applied by the GEOMAR and GEOPS laboratories followed approved GEOTRACES protocols and both laboratories successfully participated in the international GEOTRACES intercalibration study (van de Flierdt et al., 2012). In total, 9 nearshore stations at less than 500 m depth (883, 899, 890, 913, and one "surface" sample from cruise P457, and 6, 9, 15, and 16 from cruise ICE-CTD), and 9 offshore stations (889, 903, and 905 from cruise P457, and 5, 10, 11, 13, 18, and 19 from cruise ICE-CTD) were occupied including locations above the Reykjanes Ridge to the southwest of Iceland and above the Iceland-Faroe Ridge to the southeast (Fig. 1).

2.1 Seawater sample collection

During the R/V Thalassa cruise ICE-CTD in June/July 2012 (carried out by GEOPS), 33 seawater samples were collected at 10 full water column stations (Fig. 1 and Table 1). During this cruise, seawater samples and temperature and salinity data were collected using a standard Sea-Bird SBE 911plus CTD-Rosette system equipped with 24 12-liter Niskin bottles. The samples were then filtered through AcroPak capsule filters at 0.8 - 0.45 μm (the range of pore sizes in the filters), transferred to 10-liter acid-cleaned cubitainers, and immediately acidified to a pH of 2 using distilled concentrated hydrochloric acid. Upon collection on board of the ship, the dissolved REE fraction was extracted by adding an ultrapure FeCl_3 solution (corresponding to 4 mg of Fe per liter seawater) and after equilibration raising the pH to 8 through addition of ammonium hydroxide solution (28%, Optima grade) leading to co-precipitation of the dissolved REEs together with the iron hydroxides (FeOOH).

During the R/V Poseidon cruise P457 in August 2013 (carried out by GEOMAR), 38 seawater samples were collected from 8 different sites (Fig. 1 and Table 1). The seawater samples and water column hydrographic parameters (temperature, salinity, and oxygen) were collected using a CTD-Rosette system equipped with 12 10-liter Niskin bottles and a standard Sea-Bird

SBE 911plus CTD-Rosette system. The samples were then transferred to acid-cleaned 20-liter HDPE containers, were filtered through 0.45 μm Millipore nitrocellulose acetate filters within two hours after sampling, and then each acidified to a pH of 2 using distilled concentrated hydrochloric acid. For seawater samples of R/V Poseidon cruise P457, the co-precipitation step was performed in the laboratory at GEOMAR following a procedure similar to the one used for ICE-CTD cruise samples. A 2 liter aliquot was also separated from each sample in the laboratory for Nd concentration measurements.

2.2 Analytical procedures for Nd isotope and Nd concentration measurements

For samples of the ICE-CTD cruise, the REE co-precipitated fractions were separated from the remaining solution through several centrifugations and careful rinsing with Milli-Q water. The residues were then re-dissolved in 3 N HNO_3 , evaporated to dryness, and finally re-dissolved in 2 ml 8 N HNO_3 and 50 μl of HF to remove any possible hydrated silica residues precipitated during the Fe co-precipitation step. After drying, REEs were separated from the matrix (Fe) using anion exchange columns (AG1-X8 resin, 100–200 mesh size). After loading the solutions onto the columns in 2 ml 6 N HCl, the REEs were eluted in 8 ml 6 N HCl. Nd was extracted and purified by using an Ln-Spec column following the method described in detail by Copard et al. (2010) and Wu et al. (2015). In this method, samples were loaded using 0.7 ml of 0.05 N HNO_3 on preconditioned LN-Spec columns. The unwanted cations were eluted using 3.25 ml of 0.25 N HCl. Nd was then eluted with an additional 2.5 ml of 0.25 N HCl. The total blanks obtained on the present study were 10 pg for methods of pre-concentration with FeCl_3 solution.

Neodymium isotopic measurements were performed on a Thermo Scientific Neptune Plus Multi Collector ICP-MS at the Laboratoire des Sciences du Climat et de l'Environnement in Gif-sur-Yvette. Mass-dependent fractionation was corrected for by normalizing $^{146}\text{Nd}/^{144}\text{Nd}$ to 0.7219 and applying an exponential-fractionation law. The external reproducibility (2σ), defined as 2 standard deviations of repeated measurements of the La Jolla and JNdi-1 standards, was 0.2 ϵ_{Nd} units and all error bars in the text and the figures correspond to this external reproducibility. Samples were analyzed during 4 or 5 sessions of 10-15 standards and every two samples were bracketed with analyses of appropriate Nd standard solutions with accepted $^{143}\text{Nd}/^{144}\text{Nd}$ values

of 0.512115 ± 0.000006 for JNdi-1 (Tanaka et al., 2000) and 0.511858 ± 0.000007 for La Jolla (Lugmair et al., 1983).

For samples of R/V Poseidon cruise P457, the extraction and purification of the dissolved neodymium for the Nd isotope measurements followed the procedure described in detail in Stichel et al. (2012). In brief, 500 μ l iron (III) chloride solution (corresponding to 100 mg of Fe) was added to each 20 liter water sample to co-precipitate neodymium and other elements, and suprapure ammonia was added to raise the pH to around 8. After careful rinsing with Milli-Q water and dissolving the sample in 6M HCl, organic matter was destroyed through the addition of Aqua Regia. Iron was later removed through back-extraction with diethyl-ether. Each sample was run through two column chemistry steps: ion chromatographic columns with 1.4 ml AG-X8 (Biorad) cation exchange resin (200-400 μ m mesh size) to separate REEs from the matrix, and Nd purification columns (2 ml Eichrom LN-Spec, 50-100 μ m mesh size) to purify the Nd from other REEs. Several chemistry blanks covering the entire chemical procedure were run.

Neodymium isotope measurements of the samples from R/V Poseidon cruise P457 were performed on a Thermo Scientific Neptune Plus Multi Collector ICP-MS at GEOMAR. Measured Nd isotope compositions were corrected for instrumental mass fractionation based on Vance and Thirlwall (2002). The external reproducibility (2σ) defined as 2 standard deviations of repeated measurements of the JNdi-1 standard during the different measurement sessions was between 0.08 and 0.21 ϵ_{Nd} units and all error bars in the text and the figures correspond to this external reproducibility. All measured values were normalized to the accepted JNdi-1 $^{143}Nd/^{144}Nd$ of 0.512115 ± 0.000006 (Tanaka et al., 2000).

A $^{150}Nd/^{149}Sm$ spike solution was added to pre-weighed 1 liter seawater aliquots from cruise P457 for isotope dilution measurements of Nd concentrations following Stichel et al. (2012). Briefly, after equilibration for >4 days, the REEs were co-precipitated with $FeCl_3$, organic matter destroyed, and samples run through ion chromatographic columns with 1.4 ml AG50W-X8 (200-400 μ m mesh size) cation exchange resin. Isotope dilution Nd concentration measurements were made on the Nu Plasma High Resolution Multi Collector ICP-MS at GEOMAR. Repeated measurements of samples (including separate spiking, co-precipitation, and purification) with

this technique yielded an external precision of 2% (2SD, $n = 4$). No Nd concentration measurements were performed on the ICE-CTD cruise samples because the samples for these measurements were accidentally lost during chemical treatment in the laboratory.

3. Results

Combined temperature, salinity, and oxygen data from both cruises served to characterize the hydrography of the study area (Figs. 2 and 3; temperature distribution shown in Fig. S1). Subpolar Mode Water was identified at all stations by its high temperature and salinity immediately below the surface mixed layer and extended down to depths between 300 m (at station 913) and 750 m (at station 905). At offshore stations, oxygen minima marked the presence of Intermediate Water (IW) below SPMW. Below these two intermediate water masses, deep water masses were identified at offshore sites near the seafloor, including almost pure Iceland Scotland Overflow Water at the bottom of station 913 above the Iceland-Faroe Ridge.

The seawater neodymium isotope compositions show a wide range of values from -16.7 ± 0.2 at station 890 (10 m) to -3.5 ± 0.2 at station 899 (5 m). Nd concentrations are within a relatively narrow range from 13.5 pmol/kg at station 889 (10 m) to 20.7 pmol/kg at station 899 (5 m) (Table 1, Figs. 3 and 4).

Nearshore waters (<500 m water depth):

The four nearshore stations with the most radiogenic surface waters (ϵ_{Nd} averaging -4.6 at stations 883 and 899 in the upper 25 m water depth, -5.7 ± 0.7 at station 15 at 53 m depth, and -8.9 ± 0.1 at station 913 at 15 m depth) also show the highest surface Nd concentrations, where available (between 16.9 and 20.7 pmol/kg). The three most radiogenic stations (all less than 160 m water depth) are located close to river mouths, while station 913 (≈ 480 m water depth) is located farther away from the coast above the Iceland-Faroe Ridge (Figs. 1, 5). In contrast, station 9 (130 m water depth) and the "surface" station of cruise P457 show unradiogenic surface values ($\epsilon_{Nd} = -12.4 \pm 0.3$ and -14.6 ± 0.1 , respectively), which is explainable by the fact that they are not located close to a river mouth (Figs. 1, 5). Bottom waters at station 9,

however, are relatively radiogenic ($\epsilon_{Nd} = -8.2 \pm 0.3$ at 125 m water depth, 5 meters above the seafloor), as well as bottom waters at station 16 (-8.6 ± 0.2 at 150 m water depth, 5 meters above the seafloor) (Figs. 3 and 4). The least radiogenic ϵ_{Nd} value was found in (only) very shallow waters of station 890 above the Reykjanes Ridge ($\epsilon_{Nd} = -16.7 \pm 0.1$ at 10 meters), and similarly unradiogenic values were not observed at any other sites. ϵ_{Nd} signatures in surface waters (shallower than 100 m) of the remaining stations in the study area ranged between -12.6 and -14.6 with an average ϵ_{Nd} of -14.1 ± 0.7 (n=9).

Concentrations at stations 890 and 883 increase by up to 4 pmol/kg within the upper 100 meters depth, whereas they are constant at relatively high values of 17 and 21 pmol/kg at stations 913 and 899. Below 100 m depth they are constant and then show a decreasing trend close to the seafloor (Figs. 3, 4).

Offshore waters:

The offshore stations show distinctly unradiogenic ϵ_{Nd} values throughout the water column including the surface waters (which are all characterized by markedly low Nd concentrations of ≈ 13.5 pmol/kg) and intermediate depths where SPMW and IW prevail (Figs. 2, 3). Cruise P457 data average at $\epsilon_{Nd} \approx -14.0 \pm 0.6$ (n=12) whereas cruise ICE-CTD data are slightly more radiogenic at an average of -12.7 ± 1.4 (n=16). Below these unradiogenic waters, we observe a systematic shift to more radiogenic ϵ_{Nd} values above the seafloor between $\approx -11.6 \pm 0.6$ (n=4) for P457 samples (excluding bottom waters of 913, which likely trace a major influence of ISOW) and $\approx -10.9 \pm 1.0$ (n=7) for ICE-CTD samples of bottom waters at almost all stations (Fig. 4). The depths of these shifts generally match small decreases observed in Nd concentrations near the bottom.

Station 913 and deepest station 905 both have hydrographic properties (potential temperatures less than 3°C and salinities below 35; Fig. 3, Fig. S1), in agreement with a pronounced fraction of ISOW. Station 913 near the Iceland-Faroe Ridge exhibits radiogenic bottom waters (ϵ_{Nd} signature of -7.5 ± 0.1 at 460 m depth), which is accompanied by very high oxygen concentrations just below 300 $\mu\text{mol/kg}$. This isotopic composition and hydrographic

properties at station 913 are consistent with "pure" ISOW as defined by Piepgras and Wasserburg (1987) and Lacan and Jeandel (2004b).

4. Discussion

4.1 Lithogenic inputs to nearshore surface waters (stations < 500 m water depth)

The large variability of Nd isotope compositions and Nd concentrations measured in surface waters off the southern coast of Iceland clearly demonstrates that nearshore waters are influenced by local Nd inputs in addition to conservative water mass mixing (Figs. 5 and 6).

Several of the shallowest nearshore stations (883, 899, and 15) display isotope compositions significantly more radiogenic (up to $\epsilon_{Nd} = -3.5$) than both the deep waters in the rest of the study area and any so far published values from the surrounding areas (Lacan and Jeandel, 2012; Lambelet et al., 2016; Dubois-Dauphin et al., 2017). Importantly, these ϵ_{Nd} signatures are much more radiogenic than the two NADW end-member water masses DSOW and ISOW (Lacan and Jeandel, 2004a; b). Station 883 is located close to Iceland's western coast, while stations 899 and 15 are near the southern coast. These stations were occupied at water depths shallower than 140 meters and are located close to the mouths of rivers (Figs. 1 and 5). The above observations combined with the elevated Nd concentrations at the same stations (Fig. 5, where concentrations are available) reflect continental runoff containing radiogenic basaltic particles from Iceland and their partial dissolution. Given that the river waters from Iceland do not carry large amounts of organic material supporting the solubility of REEs, they are expected to be rapidly removed in the Iceland estuaries (Tepe and Bau, 2016; Merschel et al., 2017; Laukert et al., 2017). It is thus unlikely that there is still a detectable contribution of dissolved riverine Nd at salinities above 34.5. More offshore above the Iceland-Faroe Ridge, the surface waters at station 913 are also highly radiogenic (ϵ_{Nd} of -8.9 ± 0.1) and have higher Nd concentrations than other offshore stations, which is an unusual observation considering that this station is far away from river outflows. However, Iceland is also an important source of basaltic dust deposition on the ocean surface whereby the major dust deposition rates primarily occur in close vicinity to the coastal regions. According to Arnalds (2010) and Waldhauserová (2014), up to $500 \text{ g m}^{-2} \text{ yr}^{-1}$ of dust can be deposited in the nearshore area

along Iceland's southern coastline, but deposition is temporally and spatially variable and dependent on atmospheric conditions. A spatially restricted basaltic dust input event thus may account for the more radiogenic values and higher Nd concentrations observed at station 913 compared to other offshore stations (e.g. unradiogenic surface water signatures are encountered at station 9 and the "surface" station from cruise P457).

Pearce et al. (2013) demonstrated that the release of Nd from weathered basaltic sediments sampled at two sites on the western coast of Iceland (one river and one estuarine environment) markedly raised the ϵ_{Nd} of seawater in a batch experiment within a short period of time (days). Our more radiogenic Nd isotope signatures and elevated Nd concentrations which are clearly influenced by riverine inputs and/or dust deposition support this interaction between suspended particles and seawater. The glass-like properties of basaltic ashes and the mineralogical composition of basaltic rocks (such as Icelandic basalt), allows them to be easily weathered (Gislason et al., 1994; Stefánsson and Gislason, 2001; Louvat et al., 2008).

The remaining nearshore surface waters which are markedly less radiogenic (station 9 and the "surface" sample from cruise P457; Figs. 3, 4, 5) are more consistent with the ϵ_{Nd} compositions of offshore waters. Available concentration data for the P457 "surface" sample additionally showed much lower Nd concentrations than those of the more radiogenic sites, in agreement with the ϵ_{Nd} data. These stations are both located closer to glaciers than to rivers (Fig 1, 5) and surface waters are therefore less influenced directly by continental runoff. Significantly more radiogenic bottom waters at station 9 and another nearshore station 16 (where only one, bottom water sample was taken), however, indicate exchange with Icelandic shelf sediments. These results show that modification of ϵ_{Nd} seawater signatures towards more radiogenic values by exchange with Icelandic basaltic particles is primarily restricted to nearshore waters.

4.2 Surface waters and circulation patterns

Comparison of our data to the distribution of coastal surface currents around Iceland indicates that current patterns are responsible for restricting the influence of radiogenic particulate material to nearshore waters. From the southern coast these currents move nearshore waters in one of two directions: either clockwise westwards and then north around Iceland, or

eastwards towards the Iceland-Faroe Ridge (Valdimarsson and Malmberg, 1999, Logemann et al., 2013; Fig. 1). Station 913 is located along the latter current pathway, which is consistent with its more radiogenic ϵ_{Nd} and higher surface Nd concentrations despite its distance (approx. 60 miles) from the coast. These currents are the main means to transport the highly variable inputs of radiogenic riverine and aeolian-derived material. Therefore, the current patterns also help to explain why we do not observe radiogenic surface waters at offshore sites in the northern Iceland Basin (excluding station 913). For future studies, it will be clearly be important to sample waters off the northern coast of Iceland to investigate if the near shore surface currents originating south of Iceland supply highly radiogenic waters along the coast to the Nordic Seas where the waters are subducted, and thus contribute to the radiogenic signatures of the overflow waters.

Another common feature of all offshore stations for which Nd concentration data are available (excluding the shallow, highly radiogenic waters) is the increase in [Nd] by up to 4 pmol/kg within the first approx. 150 meters water depth, while ϵ_{Nd} shows little variation in these same samples (Fig. 4). This change in concentration is likely the result of biogenic particle scavenging in shallow waters where primary production is known to be moderately high (Schlüter and Sauter, 2000). The higher Nd concentrations within the subsurface layers are correspondingly ascribed to particle remineralization or desorption processes.

The least radiogenic ϵ_{Nd} values of our study site are found in surface waters at shallow station 890, located on the Reykjanes Ridge to the southwest of Iceland. The cause for such negative signatures is not easily explained given that the hydrographic (T, S, and O_2) properties of this station do not greatly differ from other sites nearby which have more radiogenic ϵ_{Nd} surface values. One of the contributors to Subpolar Mode Water is the unradiogenic Labrador Current, which is characterized by an ϵ_{Nd} value of $\simeq -17$ (Lacan and Jeandel, 2004c). This isotope composition is similar to the unusually unradiogenic value measured in the surface waters at station 890 ($\epsilon_{Nd} = -16.7$), even though the core of the current itself does not reach that far west. Similarly unradiogenic surface values were measured in the Labrador Sea (e.g. Filippova et al., 2017). If these sources were responsible for our observations, there is still a discrepancy in

surface ϵ_{Nd} even between the two stations on the Reykjanes Ridge located in close proximity to each other. Another possibility to explain this value is that highly unradiogenic source waters have been transported into the study area by eddies. Eddies are common in the Iceland Basin and also tend to vary spatially and over time (Shoosmith et al., 2005). The presence of eddies in the Iceland Basin and surrounding the Reykjanes Ridge may be able to redistribute unradiogenic water parcels or continental material contained therein, similar to the situation offshore Alaska (Haley et al., 2014). While the seawater ϵ_{Nd} values in the Denmark Strait (which separates Iceland from Greenland) are distinctly radiogenic (Lacan and Jeandel, 2004a), parts of Greenland and Labrador are characterized by unradiogenic continental material (cf. Filippova et al., 2017), contributing weathering inputs with a wide range of ϵ_{Nd} values in this part of the Atlantic (Fig. 6). In addition, water supplied by the highly unradiogenic Labrador Current (Lacan and Jeandel, 2004c) may also reach this area. Altimetry data for the time period before the samples of our study were taken reveal pronounced eddy activity in the region and particularly extending from the Greenland coast (see Supplementary Movie), which are consistent with the large range of Nd isotope signatures observed on short spatial scales.

4.3 Offshore and Subsurface waters

Unradiogenic values dominate most of the water column at offshore stations (Figs. 3, 4), and ϵ_{Nd} signatures of major intermediate depth water masses are within the range of published values for this area (Lacan and Jeandel, 2012; Dubois-Dauphin et al., 2017; Fig. 6). The average ϵ_{Nd} of Subpolar Mode Water for offshore stations (including 913 above the Iceland Faroe Ridge) is -13.5 ± 1.1 and is fully consistent with data from the literature: SPMW is known to have an ϵ_{Nd} of -13 ± 0.6 near the Iceland-Faroe Ridge, and of -14.8 ± 0.2 in the southern part of the Iceland Basin, where the influence of the unradiogenic Labrador Current ($\epsilon_{Nd} = -17$) is larger (Lacan and Jeandel 2004c). In subsurface waters down to 700 m depth where intermediate waters are present (primarily SPMW), the ϵ_{Nd} values south of Iceland are consistently unradiogenic and geographically similar (Fig. 6). There are only two data points of station 18 above the Reykjanes Ridge, and the surface of station 903, that are slightly more radiogenic and indicate a small Icelandic influence, likely originating from exchange with suspended particles. Near the bottom of some shallow offshore profiles, the presence of more radiogenic waters is

the result of the admixture of Denmark Strait and Iceland Scotland overflow waters with potential small contributions from exchange with radiogenic sediments. A gradual westward shift to less radiogenic values closer to sources in the Labrador Sea is also observed. This indicates typical mixing of the water masses advected in the northern Iceland Basin, and in contrast to the nearshore waters, illustrates the limited influence of radiogenic Icelandic sediments on the Nd isotope composition of these major intermediate depth water masses.

At the majority of offshore stations we observe increases to more radiogenic ϵ_{Nd} signatures below the intermediate waters (SPMW and IW) and close to the seafloor. These are consistently accompanied by slight decreases in Nd concentrations where available and occur regardless of the water masses prevailing at those depths (Fig. 4). Two examples of this occurrence are: 1) bottom waters at station 890 at 280 m depth (the shallower station on the Reykjanes Ridge), which show this increase to more radiogenic waters even though the deepest water mass identified at that location was SPMW, which should exhibit much less radiogenic values; and 2) hydrographic data from bottom waters (≈ 1500 m) at deep station 905 indicate the presence of Iceland Scotland Overflow Water (Figs. 2 and 3), which should exhibit more radiogenic values than were measured (Piepgras and Wasserburg, 1987; Lacan and Jeandel, 2004b), but obviously already contains a significant fraction (approx. 60%) of entrained LSW (see Fig. 7).

The majority of bottom waters are too radiogenic for LSW and too unradiogenic for ISOW, and most stations are far too shallow, warm, and saline for the presence of either, and as discussed above, their more radiogenic signatures are a result of exchange with the Icelandic sediments. It is only the deepest parts of stations 905 and 913 that have hydrographic properties close to these deep water masses (Figs. 2 and 3). Of these locations, station 913 on the Iceland-Faroe Ridge (despite its shallower depth) has radiogenic bottom waters ($\epsilon_{Nd} = -7.5 \pm 0.1$ around 460 m) and hydrographic properties (T, S, and O_2) consistent with essentially pure ISOW based on published values. As ISOW overflows westward into the Iceland Basin, it entrains North Atlantic waters resulting in an initial ϵ_{Nd} signature between -7.7 ± 0.6 ($[Nd] = 21.4$) and -8.2 ± 0.6 ($[Nd] = 21.5$) (Piepgras and Wasserburg, 1987; Lacan and Jeandel, 2004b, respectively).

Bottom waters from stations deeper than 900 m (from R/V Poseidon P457 cruise, for which Nd concentration data are available) are plotted in a mixing diagram (Fig. 7). They are compared to a hypothetical mixing line between published values for the deeper, more radiogenic "pure" ISOW (see end of last paragraph) and the shallower, less radiogenic LSW (Filippova et al., 2017). Except for almost pure ISOW at station 913, almost all our samples show depleted Nd concentrations compared to expected values for conservative mixing between these water masses. At the same time, bottom water ϵ_{Nd} signatures are in good agreement with what may be expected for entrainment of shallower, less radiogenic water masses (either LSW or SPMW depending on the respective stations) into the deeper, more radiogenic ISOW along its flow path across the basin. These observed ϵ_{Nd} values of the bottom waters accompanied by decreases in Nd concentration, where available, additionally suggest a net removal of Nd by particles along the flowpaths of LSW and ISOW without substantially affecting the Nd isotope compositions. A relatively high particulate matter concentration has been measured close to the seafloor in the waters south of Iceland (between 100-200 $\mu\text{g/l}$), and nepheloid layers up to 400 meters thick have been found (Gardner et al., 2018). This is supported by beam attenuation data along a N-S section across the Iceland basin (Gardner et al., 2018; see Supplementary Figure 2). These data clearly indicate higher particle concentrations within the uppermost 100 m. This mainly reflects biogenic particles and higher particle concentrations near the bottom which indicates the presence of a nepheloid layer and of resuspended material. In further support, a recently published study by Crockett et al. (2018) documented the presence of nepheloid layers at several locations in the northeastern Atlantic near Iceland, some of which showed elevated Nd levels whereas others were accompanied by low Nd concentrations. Therefore, the most likely explanation for the observed depleted concentrations is scavenging of Nd from the water column onto particles within benthic nepheloid layers.

5. Conclusions

We present the first systematic study of the Nd isotope exchange between the radiogenic rocks and sediments of Iceland and adjacent seawater. Close to shore and to the mouths of rivers, ϵ_{Nd} values of near surface waters are overall significantly more radiogenic, and Nd concentrations are higher than in surface waters offshore (>500 m water depth). This documents exchange

with riverine and/or aeolian basaltic particles from Iceland. These seawater signatures are also modified by water mass mixing and are advected within surface currents. The ϵ_{Nd} signal from Iceland does at present not influence the major surface and intermediate depth water masses in the open northern Iceland Basin. This is shown by 1) the restriction of radiogenic values to nearshore waters, and 2) offshore water mass ϵ_{Nd} signatures that are consistent with those of prior studies from the surrounding North Atlantic area.

Increases towards more radiogenic ϵ_{Nd} values in bottom waters at offshore stations agree with the patterns expected from mixing between the deep, highly radiogenic ISOW and overlying, unradiogenic Atlantic intermediate and deep water masses, resulting in isotopically relatively homogenous bottom waters throughout the study area. An exception to this is the dense bottom waters present above the shallow Iceland-Faroe Ridge which have hydrographic and Nd isotope compositions indicative of undiluted ISOW. Depleted concentrations in bottom waters likely reflect removal of Nd by particle scavenging within nepheloid layers. Overall, the results of this study help to better constrain water mass mixing based on ϵ_{Nd} signatures which are advected through the basin, and show that the influence of radiogenic weathering inputs from Iceland in the northern Iceland Basin is predominantly local and restricted to the shallowest nearshore sites.

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Figure 1: Bathymetric map with sampling locations of cruises P457 and ICE-CTD south of Iceland including land topography, rivers, glaciers (gray), major currents, and water masses. The North Atlantic Current (red arrow) dominates the surface circulation. Also shown are the schematic flow paths of the major overflow waters DSOW (Denmark Strait Overflow Water - blue) and ISOW (Iceland Scotland Overflow Water - violet) (Curry and Mauritzen, 2005). Green dotted lines indicate coastal currents (Valdimarsson and Malmberg, 1999; Logemann et al., 2013). Black diamonds mark previously published data (van de Flierdt et al., 2016; Dubois-Dauphin et al., 2017). The figure was generated using ODV (Schlitzer, 2014).

Figure 2: Potential temperature versus salinity for all stations. SPMW = Subpolar Mode Water, IW = Intermediate Water, LSW = Labrador Sea Water, ISW = Icelandic Slope Water, ISOW = Iceland Scotland Overflow Water. The figure was generated using ODV (Schlitzer, 2014).

Figure 3 (a, b, c): Oxygen, salinity, and ϵ_{Nd} data of stations from both cruises, represented on composite E-W section maps outlined in the inset of b). Temperature for this section is shown in Figure S1 (see supplementary material). Black lines indicate sampled stations. Temperature and salinity data are compiled from both cruises, while the oxygen data is only from cruise P457. Characterization of water masses is based on hydrographic properties provided in van Aken and de Boer (1995), Malmberg (2004), and Beird (2016). SPMW = Subpolar Mode Water, IW = Intermediate Water, LSW = Labrador Sea Water, ISW = Icelandic Slope Water, ISOW = Iceland Scotland Overflow Water. The figures were generated using ODV (Schlitzer, 2014).

Figure 4: Depth profiles of Nd isotope compositions (for both cruises) and Nd concentrations (for cruise P457 only) for nearshore and offshore stations, with water depths of the seafloor indicated by slash lines.

Figure 5: Surface water salinity, ϵ_{Nd} , and Nd concentrations ([Nd] only available for cruise P457). Land topography, rivers, and glaciers (gray) are also shown. Black dots represent sampling locations. The figures were generated using ODV (Schlitzer, 2014).

Figure 6: Comparison of offshore stations from this study with data from the literature for the surrounding North Atlantic region: station SGN 12 is from Lacan and Jeandel (2004c, 2005a: note that these are unfiltered samples), stations Pelagia 2.3, 5.1, and 6.1 are from Lambelet et al. (2016), stations ICE 04 and 21 are from Dubois-Dauphin et al. (2017), and stations 903, 889, and 18 are from this study. Error bars (2 SD) are only plotted for the station from this study for clarity (see Materials and Methods for details).

Figure 7: Mixing diagram between ISOW and LSW, with ϵ_{Nd} and [Nd] signatures of the deep water samples of this study plotted along the line. Endmember ϵ_{Nd} and [Nd] values are taken from Piepgras and Wasserburg (1987) and Filippova et al. (2017). The fraction of ISOW in the theoretical mixture is shown in italics.

Table 1: Hydrographic data, Nd isotope compositions (including the 2 S.E. standard internal error of the individual measurements and the 2σ external error of each run), and Nd concentrations. No concentration data are available for cruise ICE-CTD.

Supplementary Figure 1: Potential temperature data of stations from both cruises, represented on a composite E-W section map. Black lines indicate sampled stations. Characterization of water masses is based on hydrographic properties provided in van Aken and de Boer (1995), Malmberg (2004), and Beaird (2016). The figure was generated using ODV (Schlitzer, 2014).

Supplementary Figure 2: Beam attenuation data along a N-S section (section map shown as inset) across the Iceland basin. Plotted data was extracted from Gardener et al., 2018.

Supplementary movie: Sea level anomalies for the period between May 1 and August 31, 2013, for the area between 60° and 70° N and between 10° and 40°W (courtesy of Rena Czeschel, GEOMAR). Delayed-time “all-sat-merged” reference dataset of SLA was used, and the images were mapped on a $\frac{1}{4}^\circ \times \frac{1}{4}^\circ$ Cartesian grid with a temporal resolution of one day. The Copernicus Marine and Environment Monitoring Service (CMEMS), (<http://marine.copernicus.eu>) has taken over the whole processing and distribution of the products formerly distributed by AVISO with no changes in the scientific content.

Figure 1:

Figure 2:

Figure 3:

Figure 4:

Figure 5:

Figure 6:

Figure 7:

Latitude	Longitude	Cruise name, date	Station No., "text ref."	Station Depth (m)	Depth (m)	Potential Temperature θ (°C)	Salinity (psu)	Oxygen ($\mu\text{mol/kg}$)	Water Mass	ϵ_{Nd}	2 S.E.	2 σ	$^{143}\text{Nd}/^{144}\text{Nd}$ normalised	[Nd] pmol/kg
64°30'N	23°29'W	P457 8.7.2013	883_2 "883"	156	10	10.6	34.52	270.39	Surface	-3.6	0.09	0.08	0.512451	16.89
					25	10.39	34.6	269.59	Surface	-5.8	0.13	0.17	0.512339	17.7
					75	8.19	35.11	248.55	SPMW	-6.6	0.14	0.17	0.512299	19.75
					120	7.49	35.14	244.8	SPMW	-8.2	0.13	0.17	0.512219	18.16
63°2'N	23°22'W	P457 8.11.2013	889_3 "889"	970	10	11.1	35.08	268.92	Surface	-14.6	0.15	0.17	0.511882	13.52
					100	8.19	35.17	255.57	SPMW	-14.7	0.08	0.08	0.511887	18.2
					350	7.66	35.17	255.84	SPMW	-13.9	0.16	0.17	0.511927	18.49
					600	6.44	35.13	225.66	IW	-13.5	0.12	0.17	0.511945	18.26
					800	5.23	35.06	244.17	IW	-12.5	0.13	0.17	0.512	17.84
					952	4.62	35.03	252.71	LSW/ISW	-11.9	0.11	0.08	0.512027	16.85
63°9'N	22°40'W	P457 8.11.2013	890_1 "890"	312	10	11.1	35.08	268.87	Surface	-16.7	0.13	0.17	0.511781	13.96
					25	10.8	35.09	268.2	Surface	-15.6	0.14	0.17	0.511838	14.38
					75	8.59	35.15	257.45	SPMW	-15	0.13	0.17	0.51187	17.13
					180	7.98	35.19	255.46	SPMW	-14.4	0.07	0.08	0.5119	18.46
					287	7.67	35.19	248.8	SPMW	-11.6	0.08	0.08	0.512042	17.48
63°20'N	17°56'W	P457 8.13.2013	899_1 "899"	156	5	11.5	34.84	281.28	Surface	-3.5	0.16	0.17	0.512352	20.69
					20	11.1	35.02	272.79	Surface	-5.6	0.08	0.21	0.51246	20.01
					75	8.2	35.19	252.07	SPMW	-10.1	0.09	0.08	0.512121	20.38
					136	7.99	35.2	247.42	SPMW	-10.9	0.14	0.17	0.512079	18.06
63°0'N	17°29'W	P457 8.13.2013	903_1 "903"	1186	10	11.8	35.05	276.79	Surface	-12.6	0.08	0.08	0.51199	13.57
					100	8.69	35.21	256.09	SPMW	-14.6	0.12	0.17	0.511891	18.06
					350	8.26	35.22	255.09	SPMW	-14.5	0.13	0.17	0.511894	17.59
					700	7.03	35.17	228.27	IW	-13.8	0.08	0.08	0.511929	18.19
					950	4.91	35.07	249.23	LSW/ISW	-12.3	0.12	0.17	0.512006	17.25

					1174	4.4	35.06	259.98	LSW/ISW	-11	0.13	0.17	0.512073	16.69
62°41'N	14°21'W	P457 8.14.2013	905_1 "905"	1602	15	11.5	35.21	267.12	Surface	-14.7	0.15	0.17	0.511884	13.55
					100	8.99	35.23	253.65	SPMW	-14.7	0.11	0.17	0.511886	17.36
					500	8.45	35.25	253.24	SPMW	-14.2	0.14	0.17	0.511909	17.75
					950	6.41	35.14	218.21	IW	-13.8	0.09	0.08	0.511932	17.86
					1300	4.19	34.97	251.84	LSW/ISW	-13.6	0.15	0.08	0.511941	17.1
					1582	2.29	34.99	265.18	ISOW?	-11.2	0.11	0.17	0.512063	15.52
64°10'N	12°43'W	P457 8.16.2013	913_2 "913"	481	15	10.3	35.04	263.51	Surface	-8.9	0.07	0.08	0.51218	17.29
					100	8.79	35.26	256.02	SPMW	-13.9	0.13	0.17	0.511925	17.79
					230	8.28	35.25	254.61	SPMW	-14	0.11	0.08	0.511921	17.78
					360	4.37	34.99	276.5	ISOW?	-8.2	0.07	0.08	0.512219	17.32
					430	3.37	35.03	270.87	ISOW?	-9.8	0.12	0.17	0.512135	16.01
					463	1.87	34.92	293.77	ISOW	-7.5	0.13	0.17	0.512255	16.34
63°20'N	20°41'W	P457 8.12.2013	Surface "sfc"		0	-	-	-	Surface	-14.6	0.11	0.17	0.511887	14.63
63°47'N	13°56'W	ICE-CTD 6.17.2012	5	710	30	9.02	35.25	-	SPMW	-14.2	0.18	0.18	0.511912	-
					350	7.82	35.25	-	SPMW	-13.6	0.17	0.17	0.511941	-
					550	5.54	35.11	-	IW	-10.9	0.21	0.21	0.512079	-
					630	5.22	35.09	-	IW	-10.2	0.17	0.17	0.512113	-
					700	4.12	35.02	-	LSW/ISW	-9.1	0.23	0.23	0.51217	-
63°52'N	14°0'W	ICE-CTD 6.17.2012	6	256	100	8.06	35.22	-	SPMW	-11.1	0.18	0.18	0.512071	-
					210	7.71	35.23	-	SPMW	-13.4	0.31	0.31	0.511953	-
63°58'N	16°0'W	ICE-CTD 6.20.2012	9	130	24	8.71	35.22	-	SPMW	-12.4	0.3	0.47	0.512003	-
					65	7.96	35.22	-	SPMW	-11.7	0.83	0.83	0.51204	-
					125	7.64	35.21	-	SPMW	-8.2	0.33	0.33	0.512216	-
63°21'N	16°0'W	ICE-CTD	10	830	40	8.51	35.24	-	SPMW	-14.2	0.16	0.16	0.511909	-
					250	7.91	35.25	-	SPMW	-12.3	0.19	0.19	0.512006	-

		6.20.2012			550	6.41	35.18	-	SPMW	-11.9	0.21	0.21	0.512027	-
					700	4.97	35.11	-	IW	-10.9	0.3	0.3	0.512077	-
					817	4.12	35.07	-	IW?	-10.1	0.25	0.25	0.512119	-
63°0'N	16°0'W	ICE-CTD 6.21.2012	11	1539	50	9.06	35.2	-	SPMW	-14.6	0.54	0.54	0.51189	-
					450	7.77	35.26	-	SPMW	-12.5	0.27	0.27	0.511998	-
					800	6.3	35.17	-	IW	-11.5	0.21	0.21	0.512047	-
63°14'N	19°30'W	ICE-CTD 6.23.2012	13	999	50	9.06	35.2	-	SPMW	-13.2	0.58	0.58	0.51196	-
					150	7.88	35.22	-	SPMW	-14.1	0.31	0.31	0.511914	-
					450	7.03	35.19	-	SPMW	-11.1	0.41	0.41	0.512067	-
					800	4.78	35.07	-	IW?	-11.3	0.84	0.84	0.512058	-
					950	4.13	35.03	-	LSW/ISW	-11.6	0.34	0.34	0.512042	-
63°23'N	20°41'W	ICE-CTD 6.24.2012	15	105	53	8.63	35.13	-	Surface	-5.7	0.65	0.65	0.512348	-
63°17'N	20°36'W	ICE-CTD 6.24.2012	16	155	150	7.6	35.2	-	SPMW	-8.6	0.23	0.23	0.512198	-
62°35'N	24°55'W	ICE-CTD 6.26.2012	18	782	40	8.38	35.08	-	Surface	-14.1	0.24	0.24	0.511916	-
					120	7.43	35.14	-	Surface?	-11.7	0.19	0.19	0.512039	-
					350	7.02	35.18	-	SPMW	-13.7	0.51	0.51	0.511938	-
					600	5.82	35.12	-	IW	-11.5	0.54	0.54	0.512046	-
					771	4.98	35.08	-	IW?	-12.2	0.35	0.35	0.512015	-
62°40'N	25°7'W	ICE-CTD 6.26.2012	19	658	75	8.08	35.17	-	Surface?	-13.7	0.28	0.28	0.511934	-
					600	5.95	35.13	-	IW	-11.4	0.61	0.61	0.512053	-
					650	5.74	35.12	-	IW	-11	0.26	0.26	0.512076	-