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# Oceanographic changes through the last millennium off North Iceland: Temperature and salinity reconstructions based on foraminifera and stable isotopes

Karen Luise Knudsen [a,*], Jón Eiríksson [b], Helga Bára Bartels-Jónsdóttir [a,b]

[a] Department of Earth Sciences, Aarhus University, DK-8000 Aarhus C, Denmark
[b] Earth Science Institute, Askja, University of Iceland, IS-101 Reykjavik, Iceland

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ABSTRACT

Temperature and salinity reconstructions for two 1000-year high-resolution sedimentary records, located at the boundary between Atlantic and Arctic surface waters on the North Icelandic shelf, are based on transfer functions and oxygen isotopes for planktonic and benthic foraminifera. There is a general increase of Arctic Water indicator species at the transition from the Medieval Warm Period into the Little Ice Age (LIA) and a subsequent return of Atlantic Water indicator species towards the end of the LIA and in the 20th century. The timing of the reconstructed temperature changes, both at the beginning and at the end of the LIA, appears to be slightly different for the different water masses. The earliest temperature change is seen in the bottom and subsurface waters, where a cooling is reconstructed as early as AD 1150–1200 at both locations, whereas previously published diatom-based and alkenone-based sea-surface temperature reconstructions show a change at AD 1300, coinciding with the air temperature shift in the area. Our results show the need of a thorough understanding of the oceanography in the study area, as well as the different living habitat for the biological proxies used for the temperature estimates.



## 1. Introduction

Continental shelf areas provide important archives for palaeoceanographic and palaeoclimatic studies, especially where mud-dominated basins with extremely high sedimentation rates are available for the study of sedimentary and fossil records in high time resolution (Johnsson and Baldwin, 1998; Leeder, 1999). Strong climatic gradients between the Arctic and North Atlantic realms that traverse the North Icelandic shelf at the present position of the oceanographic and atmospheric Polar fronts (Johannessen, 1986; Ólafsson, 1999) enhance the significance of this key area for the study of oceanographic changes through the last millennium.

Off North Iceland, the oceanographic Polar Front separates cold, low-salinity Polar and Arctic surface waters of the East Greenland and East Icelandic currents from branches of the relatively warm, high-salinity North Atlantic Current (Fig. 1A). The sedimentary and fossil record, which is sensitive to past oceanographic and climatic changes in this boundary region, shows that the position of the Polar Front has been very dynamic through the last millennium.

The relative strength of the Irminger Current and the East Icelandic Current, as well as the composition of the Arctic Surface Water of the East Icelandic Current, is important for the environmental conditions off North Iceland. Relatively warm, high-salinity and high-productivity conditions characterise periods with a relatively strong Irminger Current, whereas cold, low-salinity and low-productivity conditions prevail, when the East Icelandic Current is dominant (cf. Johannessen, 1986; Johannessen et al., 1994). As the Atlantic Water flows northwards in the northern North Atlantic, it becomes gradually cooled down and is denoted modified or chilled Atlantic Water (cf. Steinsund, 1994; Hald and Steinsund, 1996; Jennings et al., 2004). The modified Atlantic Water is, however, still relatively warm and has a higher salinity than the Arctic Water in the area.

At present, the Atlantic surface water mass occupies water depths down to about 3–400 m off North Iceland (e.g. Stefánsson, 1962; Knudsen et al., 2004). During summer months, there is a vertical stratification of the water column, which disintegrates during winter cooling (Stefánsson, 1962).

The present distribution of water masses on the North Icelandic shelf is partly determined by the landward extension of the submarine Kolbeinsey Ridge, which is a mid-ocean ridge between Iceland and Jan Mayen (Perry, 1996). This ridge appears to act as an oceanographic barrier in the region (cf. Stefánsson, 1962), as also confirmed by Rytter et al. (2002) on the basis of the modern benthic foraminiferal distribution on the North Icelandic shelf.

It has been demonstrated that atmospheric circulation plays a crucial part in the relative volumes of the contrasting water masses north of Iceland (e.g. Jónsson, 1992), and the extreme advection of fresh and cold Arctic Water carrying sea ice to the North Iceland shelf during the Great Salinity Anomaly (GSA) of the 1960s (Dickson et al.,

* Corresponding author.
*E-mail address:* karenluise.knudsen@geo.au.dk (K.L. Knudsen).

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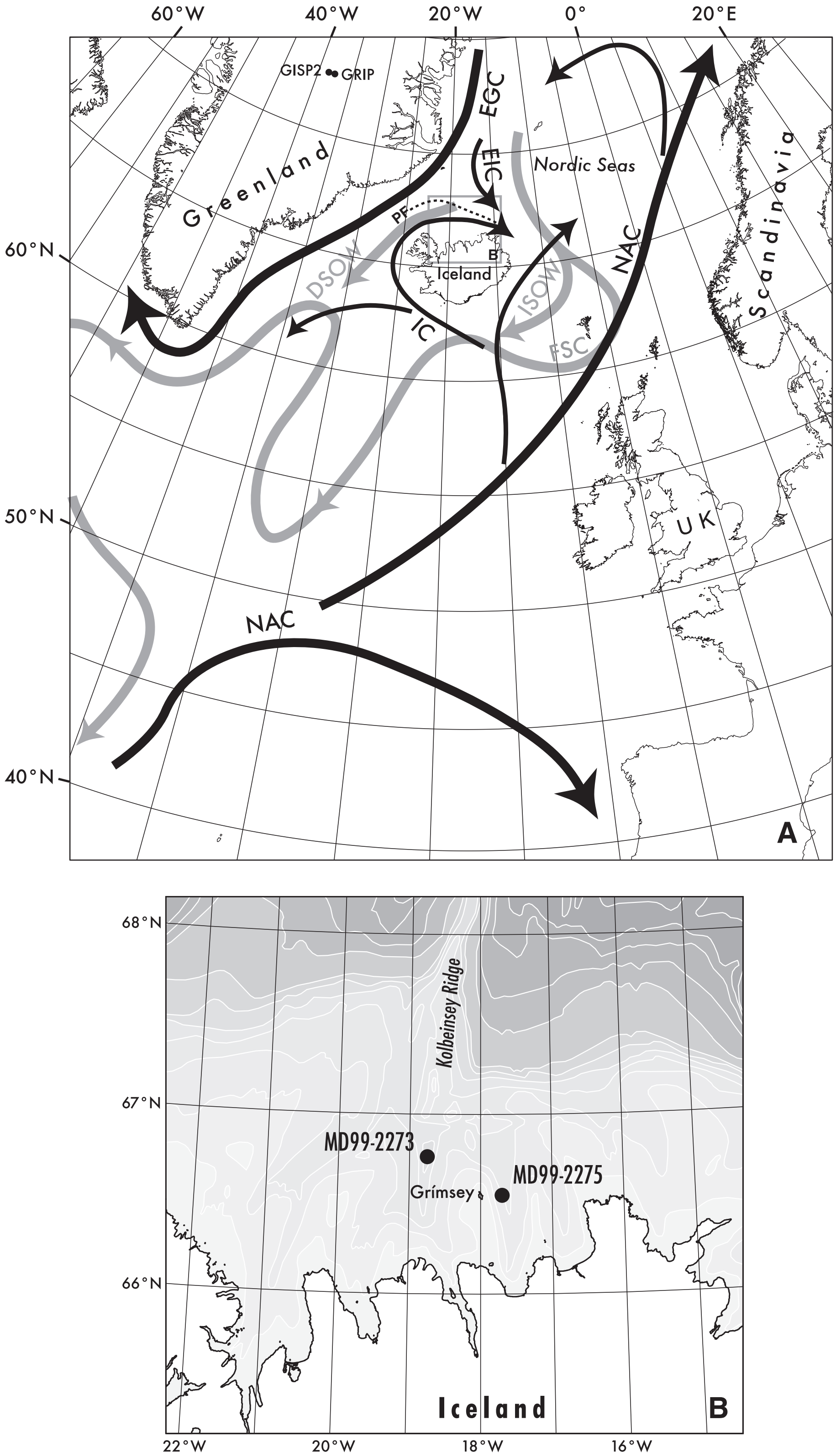


**Fig. 1.** A. Modern oceanographic system in the northern North Atlantic, with the surface water currents (black; modified after Hurdle, 1986) and bottom water overflow currents (grey; after Hansen and Østerhus, 2000; Jónsson and Valdimarsson, 2004). NAC = North Atlantic Current; IC = Irminger Current; EGC = East Greenland Current; EIC = East Icelandic Current; DSOW = Denmark Strait overflow water; ISOW = Iceland–Scotland overflow water; FSC = Faeroe–Shetland overflow water. B. Location of the two studied core sites, MD99-2275 and MD99-2273 on the North Icelandic shelf.

1988), which was associated with a strongly negative winter NAO index, is a well-known example of a combined oceanographic and climate change event in the region. The subsequent gradual freshening of both intermediate and deep waters after the GSA event is considered to be related to reduction of sea ice and fresh water in the Arctic (Drange et al., 2005).

Recent studies of links between the NAO winter index and the temperature and salinity of the subpolar intermediate and deep