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Multiproxy fossil comparison reveals contrasting surface ocean conditions in the western Iceland Sea for the last two interglacials

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ABSTRACT

Dinoflagellate cyst (dinocyst), coccolith and planktic foraminiferal assemblages from a core in the western Iceland Sea were used to reconstruct and compare the surface ocean developments of the Holocene and the Last Interglacial (Marine Isotopic Stage or MIS 5e). While increasing subpolar planktic foraminifers from ~10 ka indicate subsurface warming peaking around 7.5 ka, the dinocyst data suggest that the uppermost ocean remained dominated by cold waters until ~6.5 ka. A reduced advection of cold polar waters through the East Greenland/East Icelandic Current thereafter entailed warmest and most saline Holocene conditions between 6.5 and 5 ka, in turn followed by a general cooling trend. By contrast, both planktic foraminifers and dinocysts show an increased presence of Atlantic (-type) waters from ~122 ka onward resulting in a MIS 5e thermal optimum around 120.5 ka. Nonetheless, occasional freshwater input from melting drift ice created stratified but also seasonally variable conditions during this first half of MIS 5e. This stratification signature disappeared at ~120 ka when a marked repositioning of the oceanographic fronts occurred. Slightly colder conditions are indicated by both phyto- and zooplankton from there on until the end of MIS 5e around ~117 ka. A late MIS 5e cooling at the Iceland Plateau is opposite to a late MIS 5e optimum observed in the eastern Nordic seas. This regional difference is likely explained by various feedback mechanisms following the major reorganisation of the oceanic fronts at ~120 ka. The Holocene and MIS 5e interglacial variability is not reflected in the (quasi-monospecific) coccolith assemblages and illustrates the low sensitivity of living coccolithophore communities to subtle temperature changes in the low-temperature regions of the Nordic seas. Overall, quite different surface water properties appear to have characterised both interglacial intervals, with a higher share of warm, Atlantic elements in the planktic communities during MIS 5e. This suggests a higher contribution of Atlantic waters in the southwestern Nordic seas probably due to a more northward expansion of the Irminger Current under weakened polar East Greenland/East Icelandic currents. Such a reduced influence of polar waters in the southwestern Nordic seas may thus explain other evidence for relatively warm conditions in MIS 5e all around southern Greenland.

1. Introduction

Numerous paleoceanographic studies using a wide variety of different proxies have focused on the Nordic seas (i.e. the Greenland, Iceland and Norwegian seas), because of the general sensitivity of the arctic regions to climate fluctuations and the crucial role of the Nordic seas as climate regulator in particular. At present, the Nordic seas have a distinctive surface water mass distribution, with warm waters of Atlantic origin in the east, cold polar water masses in the west, and a mixing zone in the central Nordic seas featuring a variable seasonal sea-ice cover (Blindheim and Østerhus, 2005; Kvingedal, 2005). The repartition of these surface water masses is closely linked with the atmospheric circulation as well as the rate of overturning and deepwater formation, and is thus a determining factor for the northern hemisphere climate (e.g. Blindheim et al., 2000).

Notwithstanding the expected discrepancies in timing and intensity of climatic phases between different sites due to site- and region-specific factors, a fairly consistent picture for the Holocene climatic evolution has emerged from a multitude of studies in the Northern Hemisphere. These generally provide evidence for warmest conditions occurring in line with highest summer insolation roughly between 9.5 and 6 ka, i.e. the Holocene thermal maximum (HTM) (e.g. Ran et al., 2006, and references therein). Nevertheless, conflicting records exist for the eastern Nordic seas, i.e. the area most strongly influenced by the inflow of warm Atlantic water: for instance, while phytoplanktic (-based) records in general register a clear HTM (e.g. Birks and Koç, 2002; Calvo et al., 2002; Marchal et al., 2002; Andersen et al., 2004), zooplanktic records from the same region are more dissimilar (Risebrobakken et al., 2003; Cortese et al., 2005; Bauch and Erlenkeuser, 2008). Inversely, indications

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for an earliest Holocene thermal optimum between 11 and 9 ka were found in zooplanktic records (Sarnthein et al., 2003; Hald et al., 2004; Risebrobakken et al., 2011) but remain undetected in phytoplanktic data. These differences are explained by proxy-dependent responses to different forcing mechanisms (e.g. Hass et al., 2001; Risebrobakken et al., 2011).

In order to further our general understanding of the “operating mode” of warm climates, the paleoceanographic community has also been focussing on the Last Interglacial, Marine Isotopic Stage (MIS) 5e. Where at first it was believed that MIS 5e is a good analogue for the Holocene and possible future climate development (e.g. Kellogg, 1980), more recent investigations have shown that MIS 5e developed quite differently in the Nordic seas: in contrast to the Holocene, a more zonal circulation was suggested to have been the dominant circulation mode during MIS 5e (e.g. Bauch et al., 1999), and warmer than Holocene conditions existed on and along south(east)ern Greenland (Bennike and Böcher, 1994; Funder et al., 1998; de Vernal and Hillaire-Marcel, 2008; Irvali et al., 2012) resulting in a strongly reduced southern Greenland ice sheet (Fig. 1; Colville et al., 2011, and references therein). Furthermore, optimal thermal conditions with most intense northward Atlantic surface water advection through the eastern Nordic seas developed only late in MIS 5e and at times when northern hemisphere insolation was already significantly decreased (e.g. Rasmussen et al., 2003; Bauch et al., 2011; Van Nieuwenhove et al., 2011). This delayed development has been linked to the specific deglacial history of the larger Saalian, relative to the Weichselian, ice sheet (Van Nieuwenhove et al., 2011; Govin et al., 2012), as indeed it has been suggested that interglacial climate development is partly controlled by the northern hemisphere ice sheet configuration (Renssen et al., 2009).

Here, we present a new multi-fossil investigation of the Holocene and MIS 5e on a core located in the western Nordic seas (northern Iceland Plateau). Three planktic groups (i.e. coccoliths, dinoflagellate cysts (dinocysts), and foraminifera) are used, supported by stable isotope and ice-rafted detritus (IRD) data. Coccoliths are the skeletal calcareous remains of coccolithophores, primary producers that in the subarctic live nearly exclusively in the upper 30 m of the water column (Honjo and Okada, 1974). Dinocysts, as referred to here, are the fossilisable organic remains produced at a specific stage in the life cycle of some dinoflagellates. These algae are directly (autotrophic species) or indirectly (heterotrophic species) dependent on the availability of light and therefore obligatorily reside in the euphotic zone (Matthiessen et al., 2005, and references therein). In contrast, planktic foraminifera thrive at greater water depths in the Nordic seas than phytoplankton and are therefore rather representatives of the water masses within and below the pycnocline (Simstich et al., 2003). The distribution of these three fossil groups in relation to surface water parameters in the Northern Hemisphere is well documented (e.g. Braarud, 1979; Samtleben and Schröder, 1992; Samtleben et al., 1995; Jensen, 1998; Rochon et al., 1999; Baumann et al., 2000; Marret and Zonneveld, 2003; de Vernal et al., 2005; Solignac et al., 2008, 2009; Bonnet et al., 2012) which allows for their widespread use in numerous paleoceanographic studies. Thus, through combining features revealed by each single plankton group at its specific habitat depth, a more refined and complete insight into the upper ocean development can be provided (cf. Hass et al., 2001). By applying this multi-proxy approach to a core located in the presently seasonally ice-covered mixing zone of warm Atlantic and cold polar (sub-) surface water masses, we try to reconstruct past fluctuations in the distribution of these water masses in the western Nordic seas.

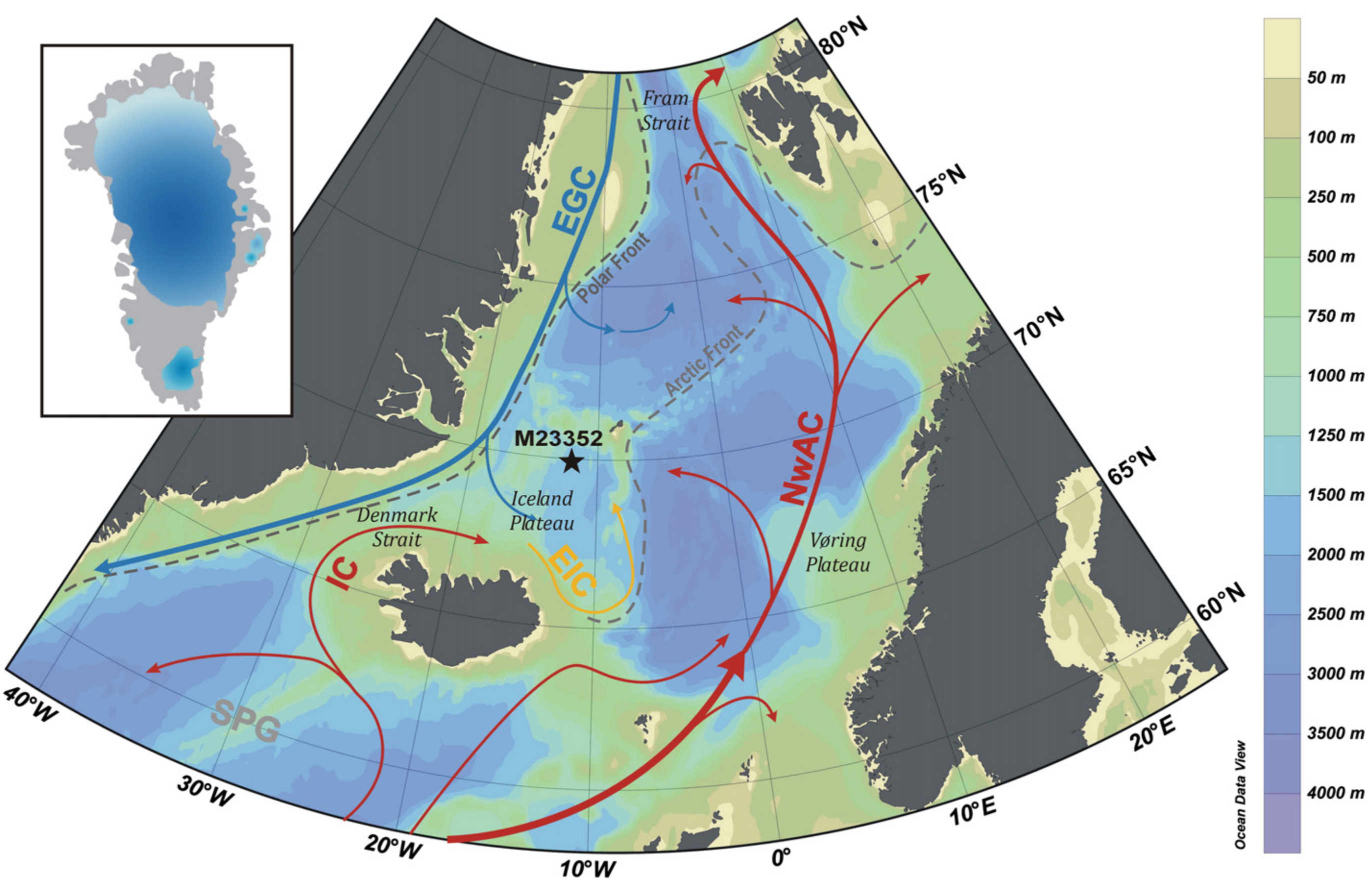

Fig. 1. Map showing the major surface currents in the Nordic seas and the location of core M23352. EGC = East Greenland Current; EIC = East Icelandic Current; IC = Irminger Current; NwAC = Norwegian Atlantic Current; SPG = subpolar gyre. The inset shows the modelled MIS 5e Greenland ice sheet configuration for an Arctic sea-level rise contribution of 3.4 m from Otto-Bliesner et al. (2005).