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Labrador Current fluctuation during the last glacial cycle

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ABSTRACT

Records from cores 2011031-059 and 2011031-062 (hereafter 59 and 62) have been used to reconstruct changes in the vigor of the Labrador Current in northern Flemish Pass during the last glacial cycle. Grain size proxies for current speed, planktonic foraminiferal $\delta^{18}O$, X-ray diffraction analysis for dolomite and calcite, and abundance of ice-rafted detritus (IRD) have been determined. An age model back to Marine Isotope Stage (MIS) 5 is based on recognition of seven Heinrich events from total dolomite and calcite, correlated to the IODP U1302/3 record, and confirmed by O-isotope stratigraphy and radiocarbon dates. A straight-line relationship between mean size of sortable silt ($\overline{SS}$) and percent of sortable silt (SS%) and the lack of relationship between $\overline{SS}$ and IRD (> 500 μm) indicate well-sorted sediments in cores 59 and 62, which can be used to reconstruct the paleo-current intensity. Intensified current vigor occurred in MIS 5, 3 and 1, so that warmer periods show faster currents, probably through the Irminger Current component of the North Atlantic subpolar gyre. Low values of $\delta^{18}O$, SS% and $\overline{SS}$ correspond to H events, suggesting a slowdown in the Labrador Current, followed by a rapid return to strong circulation. In some cases current vigor recovery lagged slightly after the H events. Heinrich events with larger amounts of meltwater show higher current vigor. Correlation with deep-water current vigor records in the Iceland Basin show a broad correlation on a multi-millennial scale with Labrador Current variations. As our study is on a shallow sediment drift formed by the Labrador Current, one of the surface currents of the North Atlantic sub-polar gyre, it provides new evidence for a tight connection between surface current vigor fluctuation and the vigor of the deep thermohaline circulation.

1. Introduction

The northwest Atlantic continental margin is swept by the south-flowing Labrador Current (LC) and the Western Boundary Undercurrent (WBUC). The Labrador Current is an important component of the Atlantic Ocean circulation, as it is associated with heat transport to the North Atlantic Ocean and forms the intensified western component of the North Atlantic sub-polar gyre (Hátún et al., 2005). On an observational timescale, fluctuations in Labrador Current speed relate both to changing inputs of freshwater from land (Lazier and Wright, 1993) and variations in the subpolar gyre (Hall et al., 2013).The latter is associated with the Atlantic multidecadal oscillation (Born et al., 2013). Meltwaters from the Greenland and Laurentide ice sheets modify the Labrador Sea water density and favor greater stratification of the upper water masses (Yang et al., 2016), while at the same time increasing LC speed (Lazier and Wright, 1993). During the early to mid-Holocene, the weakening of the Atlantic meridional overturning circulation (AMOC) has been attributed to an increase in freshwater flux from the land-based ice, most likely from the Laurentide ice-sheet (LIS), melted by warmer conditions (Sakai and Peltier, 1996). However, the direct evidence for this linkage between freshwater and AMOC from the Labrador Sea, one of the pivotal sites of the deep-water formation, is lacking. Limited evidence for any relationship in temperature and salinity between the Labrador and Nordic seas during the mid to late-Holocene implies that the Labrador Sea water masses did not influence the subpolar gyres (SPG), which rather were affected by a decrease in wind stress (Thornalley et al., 2009).

During the last glacial cycle, cyclic ice-sheet collapses and surges of the Laurentide Ice Sheet were accompanied by enormous iceberg and meltwater discharges drifting from the Labrador Sea into the North Atlantic, called Heinrich events (Bond et al., 1992; Heinrich, 1988; Hemming, 2004; Jonkers et al., 2012; Rashid et al., 2012). Low values of $\delta^{18}O$ in the foraminifers from H event sediments are usually interpreted as a meltwater signal (Bond et al., 1993). Although H events were originally defined on the basis of increased ice-rafted detritus (IRD) (Heinrich, 1988), in the Labrador Sea they correspond to layers of

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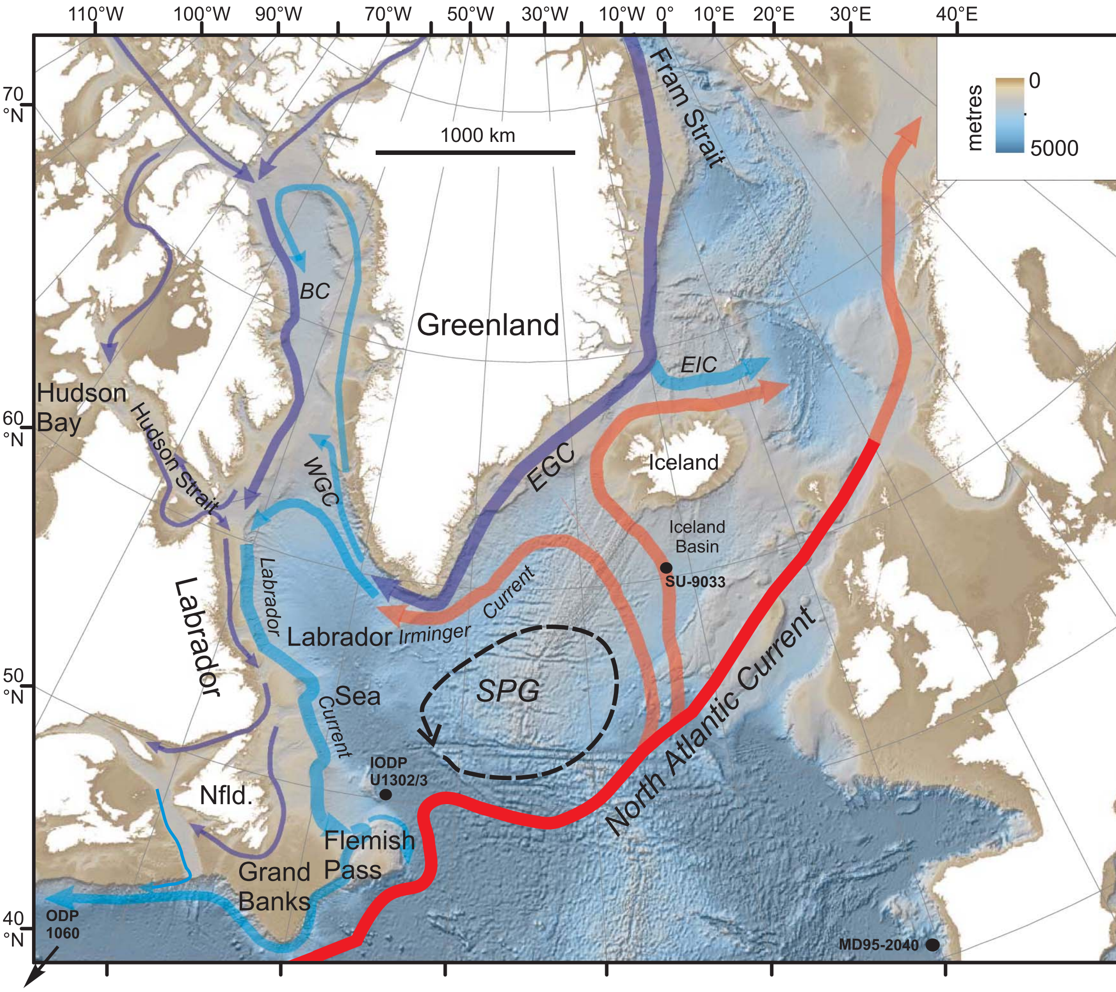

Fig. 1. General map of the North Atlantic subpolar gyre, showing location of the Labrador Current and its relationship to the other surface currents of the North Atlantic Subpolar Gyre. Also shows other North Atlantic cores referenced in the text. Contours at 500 m and 4000 m. Nfld = Newfoundland.

sediment rich in detrital carbonate (Andrews and Tedesco, 1992). The Labrador Current played an important role in the dispersion of ice in Heinrich events and related meltwaters from Hudson Strait to the North Atlantic Ocean system. These events had pronounced impacts on climate changes as they correspond to weakening of the Atlantic Meridional Overturning Circulation (AMOC) (Álvarez-Solas et al., 2011), which resulted in decreasing oceanic pole-ward heat transport and caused fundamental reorganisation of ocean-climate system (Bond et al., 1992; Ganopolski and Rahmstorf, 2001; Jonkers et al., 2010). Recent studies of variation of the Labrador Current vigor have examined the Holocene (Rashid et al., 2017) and the Last Glacial Maximum (LGM) (Marshall et al., 2014), but little is known about the variability of the Labrador Current vigor during an entire glacial cycle and its response to controlling factors on Milankovitch and millennial time-scales.

We present here an analysis of the fluctuation in the Labrador Current during the last glacial cycle (back to ca. 100 ka) with an emphasis on its variation around Heinrich events (H events). Our study is based on a unique high resolution sedimentary record from two long piston cores taken from a shallow contourite drift south of the Labrador Sea at the northern edge of Flemish Cap. Our objectives are: (1) To reconstruct the fluctuation of the Labrador Current vigor during the last glacial cycle; (2) To identify which factors control its variability; and (3) To compare our results with the current knowledge on the North Atlantic Subpolar Gyre during glacial periods.

2. Oceanographic setting of northern Flemish Cap

Flemish Cap is a submarine knoll in the Atlantic Ocean separated from the Grand Banks of Newfoundland by Flemish Pass (Figs. 1 and 2) (Kennard et al., 1990). Flemish Pass is a saddle shaped mid-slope basin, 50 km wide, in approximately 1100 m water depth on the continental slope (Fig. 2) (Piper and Pereira, 1992). It is bounded on its northern end by Sackville Spur, a Neogene-Quaternary sediment drift, which has a gentle slope towards Flemish Pass and a steeper northern flank towards Orphan Basin (Kennard et al., 1990). Other sediment drifts are located on the northern and eastern flanks of the Flemish Cap.

The northwest Atlantic continental margin, Flemish Cap included, is swept by the south-flowing Labrador Current (LC) (Fig. 1) and the Western Boundary Undercurrent (WBUC). The LC moves over the shelf and upper slope and extends down to at least 1000 m water depth, whereas WBUC is a south-flowing contour current that moves at lower slope to upper rise depths, centered at 3000 m water depth (Carter, 1979; Carter and Schafer, 1983; Hall et al., 2013). These two currents were thought to be separated at an estimated depth of about 1200 m (Swallow and Worthingtoln, 1969), although more recent work shows considerable inter-annual variation with at times almost continuous flow down to 3500 m in the central Labrador Sea (Hall et al., 2013). The Labrador Current originates in the northern Labrador Sea adjacent to Greenland and has average annual flow speeds of approximately 25–35 cm s^{-1} (Cuny et al., 2002). The main component of the Labrador Current flows towards the east along the northern slopes of Flemish