



A diatom-based sea-ice reconstruction for the Vaigat Strait (Disko Bugt, West Greenland) over the last 5000 yr

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ABSTRACT

A diatom-based sea-ice concentration (SIC) transfer function was developed by using 72 surface samples from west of Greenland and around Iceland, and validated against associated modern SIC. Canonical correspondence analysis on surface sediment diatoms and monthly average of SIC indicated that April SIC is the most important environmental factor controlling the distribution of diatoms in the area, justifying the development of a diatom-based SIC transfer function. The agreement between reconstructed SIC based on diatoms from West Greenland and the satellite and modelled sea-ice data during the last ~75 yr suggests that the diatom-based SIC reconstruction is reliable for studying the palaeoceanography off West Greenland.

Relatively warm conditions with a strong influence of the Irminger Current (IC) were indicated for the early part of the record (~5000–3860 cal. yr BP), corresponding in time to the latest part of the Holocene Thermal Maximum. Between 3860 and 1510 cal. yr BP, April SIC oscillated around the mean value (55%) and during the time interval 1510–1120 cal. yr BP and after 650 cal. yr BP was above the mean, indicating more extensive sea-ice cover in Disko Bugt.

Agreement between reconstructed April SIC and changes in the diatom species suggests that the sea-ice condition in Disko Bugt was strongly influenced by variations in the relative strength of two components of the West Greenland Current, i.e. the cold East Greenland Current and the relatively warm IC. Further analysis of the reconstructed SIC record suggests that solar radiation may be an important forcing mechanism behind the historic sea-ice changes.

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1. Introduction

Sea ice is a major component of the climate system, influencing the earth's albedo, as well as the exchanges of heat, moisture and gases between the ocean and the atmosphere. It is also a key environmental variable when assessing the magnitude and impact of future climate change because of its significant feedback on the planetary energy balance, deep ocean convection and marine biota (Miller et al., 2001), and it is one of the critical parameters in atmospheric and ocean models (Vinnikov et al., 1999). However, observed, reliable data such as satellite images, are only available for the last 30 yr with the exception of records from ship logs (Vinje, 2001), which are sporadic and irregular.

By extending sea-ice time series further back in time, the reconstruction of past sea-ice conditions may help palaeoclimate modellers to constrain boundary conditions and to validate model simulations (de Vernal and Hillaire-Marcel, 2000). Microfossils such as diatoms and dinoflagellate cysts are commonly used as proxies for reconstructing past sea-ice conditions, and a number of such studies have been carried out in the north-western North Atlantic region (De Sève and Dunbar, 1990; Koç Karpuz et al., 1993; Cremer, 1999; de Vernal and Hillaire-Marcel, 2000; Sarntin et al., 2003; Müller et al., 2011; Weckström et al. 2013). However, only a few studies have focused on quantitative reconstructions of sea-ice concentration (SIC) (e.g. de Vernal et al., 2005), with a limited number of them determined using diatoms (Justwan and Koç Karpuz, 2008).

Diatoms are found widely in marine environments and are highly sensitive to ambient ecological conditions. The siliceous cell wall of diatoms is generally well-preserved in marine sediments, and changes in abundance and in species composition in the sediments can be used

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for palaeoenvironmental interpretations. Whereas diatom-based transfer functions for sea ice have been widely developed in the Southern Ocean (Crosta et al., 1998, 2004; Gersonde et al., 2005), the North Pacific (Katsuki and Takahashi, 2005) and the northern North Atlantic (Justwan and Koç Karpuz, 2008), there has been a limited amount of marine diatom research in the north-western North Atlantic region.

The present paper studies the relationship between surface sediment diatoms and SIC in the north-western North Atlantic region and establishes a diatom-based SIC transfer function for this area. In this paper, we present a quantitative SIC record based on high-resolution diatom data for the NW Atlantic, and apply this transfer function to two marine sediment records in order to reconstruct palaeoclimatic and palaeoenvironmental changes off West Greenland during the mid- to late Holocene.

2. Study area

The investigated area extends from 50–75°N and covers the area between West Greenland and the Canadian Arctic Archipelago, which includes the Labrador Sea, Davis Strait and Baffin Bay (Fig. 1A). The Labrador Sea is connected with Baffin Bay through the Davis Strait gateway and with Hudson Bay through the Hudson Strait. A typical feature for West Greenland waters is low sea-surface temperatures all year round and summer air temperatures below 10 °C (Hansen et al., 2004). In the Labrador Sea, surface water temperatures vary between −1 °C in winter and 5–6 °C in summer while in Baffin Bay they are below −1 °C in winter, and vary from 4–5 °C in the southeast to 0 °C and below in the northwest during summer (Tang et al., 2004).

Disko Bugt is a large marine embayment (68°30′–69°15′N, 50°–54°W) in central West Greenland (Fig. 1B), ca. 150 km long and 100 km wide. Water depths generally range from 200 to 400 m, but reach up to 990 m in the deep submarine valley, Egedesminde Dyb, which extends in a south-western direction (Long and Roberts, 2003).

The Vaigat Strait is situated to the north (Fig. 1B) and is bounded by Disko Island to the southwest and the Greenland mainland to the north-east, and acts as a major exit route for the West Greenland Current (WGC) waters entering Disko Bugt, as well as for meltwater and icebergs produced by the major tidewater glaciers, including the Jakobshavn Isbræ, towards the north into Baffin Bay (Long and Roberts, 2003; Andresen et al., 2011). The strait is ca. 130 km long and 20–25 km wide and has maximum water depths of 600 m (cf. Andresen et al., 2011), and is believed that the passage acted as a northern conduit of an ice lobe extending to the mouth of the strait during the last glaciation (Weidick and Bennike, 2007).

The surface circulation west of Greenland and adjacent areas is dominated by two major currents: the WGC, which flows northward along the west coast of Greenland, and the Baffin–Labrador Current (BLC) that flows southward along the east coast of Baffin Island and Labrador (Fig. 1A). The WGC consists of two components, i.e. the cold low-salinity Polar water from the East Greenland Current (EGC) and the relatively warmer high-salinity Atlantic water from the Irminger Current (IC) (Andersen, 1981a; Buch, 2002; Tang et al., 2004). The two components mix continuously as it flows northwards, but can still be distinguished to the southwest of Disko Bugt (Andersen, 1981b). In western Baffin Bay, Arctic water is driven southward through the Canadian Archipelago, into Baffin Bay and Labrador Sea, and becomes the BLC (Drinkwater, 1996; Stern and Heide-Jørgensen, 2003; Tang et al., 2004).

Present-day observations indicate that in the Labrador Sea sea ice starts to form in November, with the maximum ice extent reached in March (LeDrew et al., 1992). The area off the Southwest Greenland coast, south of Nuuk, is normally free of sea ice, but during late winter or spring, as well as during early summer months it can be ice-covered for short periods by multi-year ice originating from the Arctic Ocean that drifts into the area (Valeur et al., 1997).

In Baffin Bay, sea ice starts to form in open waters in September, and cover increases steadily from the north to the south, reaching a maximum in March, when the entire bay, except for the eastern Davis Strait,

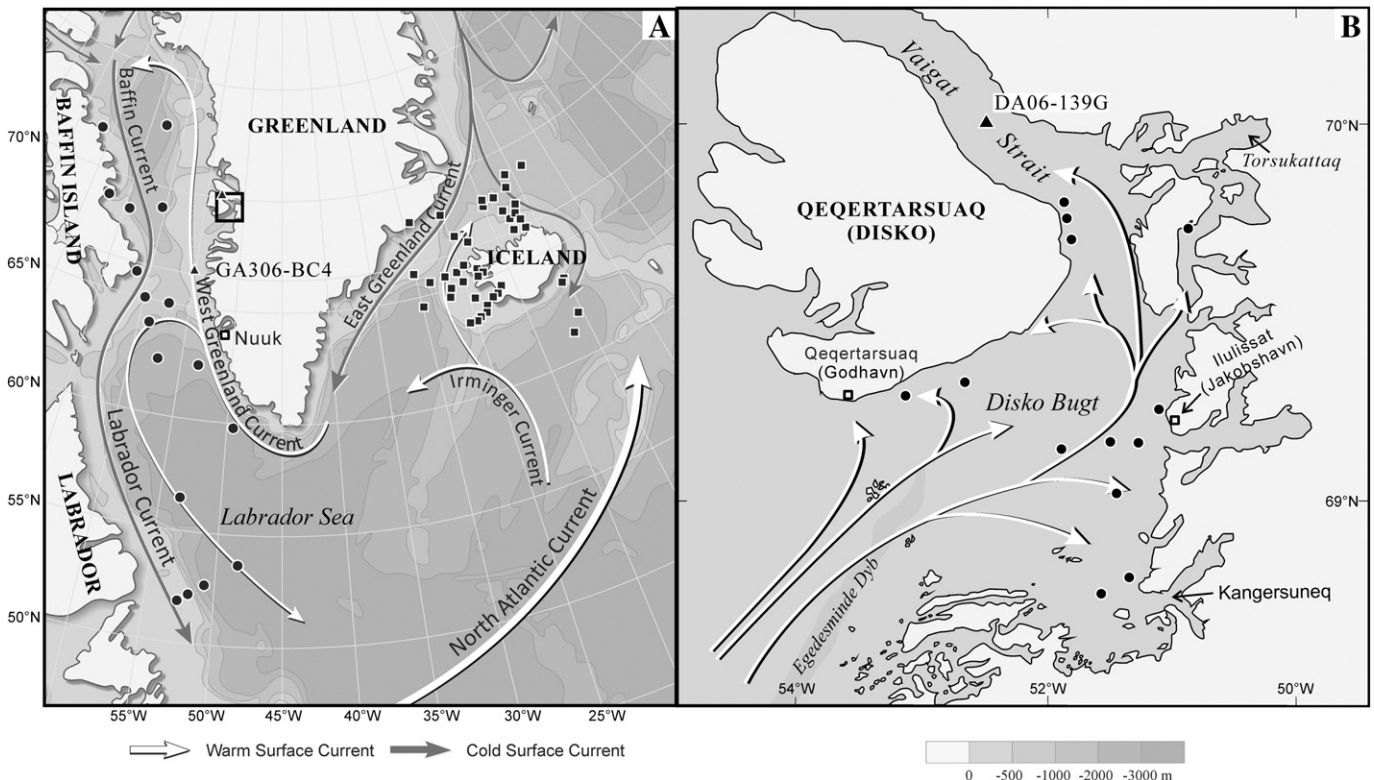


Fig. 1. (A) Surface current pattern in the NW Atlantic and locations of diatom samples in the investigated area. (B) Detailed map of the study area shown as a square on Fig. 1A. Filled circles indicate new samples from off West Greenland. Filled squares represent samples from off East Greenland and Iceland previously published by Jiang et al. (2001).

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