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Research Paper

Arctic planktic foraminiferal assemblages: Implications for subsurface temperature reconstructions

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A R T I C L E I N F O

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A B S T R A C T

Earlier reconstructions of the inflow of Atlantic Water to Arctic and Subarctic oceans based on foraminiferal proxy data have been obstructed by uncertain quantitative reconstructions of sea-surface and subsurface temperatures. In this study surface sediment samples with undisturbed sediment-water interface from Polar North Atlantic and Barents Sea were retrieved and prepared at the size fractions from 100 μm to 1000 μm. The foraminiferal analyses show that *Neogloboquadrina pachyderma* constitutes 96–99% of the fauna in Arctic and Polar surface water masses the same result is obtained when investigating the >150 μm size fraction. However, in Arctic areas influenced by Atlantic Water, additional faunal information is obtained when using the smaller >100 μm size fraction. In these areas, *N. pachyderma* is reduced to about 50%, and the relatively small species *Turborotalita quinqueloba* becomes very frequent. This also applies to the Coastal Water masses, which are dominated by *Neogloboquadrina incompta* and *Globigerinita uvula*. Transfer functions using the current dataset based on the >100 μm size fraction were developed and assessed. Different statistical models were tested, using both seasonal and annual temperature data from 0 m, 10 m, 50 m, and 100 m water depth. The most precise reconstructions of subsurface temperatures were found when using summer temperatures from the 100 m depth level. The transfer function was tested on Holocene foraminiferal records and compared to previous reconstructions. The results show that our new transfer function based on the >100 μm fraction generally yields lower temperatures at both 10 and 100 m water depth than earlier reconstructions (e.g. Hald et al., 2007). This could be due to the increased number of samples containing both small species and/or the presence of more small specimens representing cold conditions.

1. Introduction

In order to understand natural climate change and its interactions with ocean circulation, it is essential to obtain reliable and quantitative environmental data. It is also crucial to establish paleoceanographic records that go further back in time, beyond the instrumental data series, in order to establish the full range of natural climate evolution. Reliable quantitative environmental data are also a prerequisite when modelling and predicting future climate change (e.g. IPCC, 2007). Since the pioneer work by Imbrie and Kipp (1971) paleoceanographers have developed and applied different methods in order to obtain robust quantitative reconstructions of marine environmental parameters. Dinocysts and diatoms have been used to reconstruct variations of temperature, salinity and the duration of sea ice cover (e.g. Koç et al., 1993; de Vernal et al., 2005), benthic foraminifera have been used to calculate sea level, bottom water temperature and salinity (e.g. Sejrup et al., 2004; Leorri et al., 2011), and planktic foraminifera have been used to reconstruct sea-surface temperatures (Hutson, 1980; Prell, 1985; Pflaumann et al., 1996; Waelbroeck et al., 1998; Malmgren et al., 2001; Pflaumann et al., 2003; Kucera et al., 2005). However, subpolar and polar reconstructions of sea-surface and subsurface temperatures based on planktic foraminifera have been hampered in different ways. First of all the databases have been based on sediment samples from core tops that might cover several thousand years not representing modern conditions (e.g. Kucera et al., 2005). Palaeoceanographic studies from subpolar and polar regions have also suffered from a relatively poor geographical coverage from the region meaning that not all environmental gradients of the region are represented (e.g. Kucera et al., 2005). Further, it has been observed that subpolar and polar foraminifera are generally small, and when using the larger size fractions, such as >125 μm or >150 μm, much faunal information is lost (Carstens and Wefer, 1992; Bauch, 1994; Carstens et al., 1997). The effects of loss of the smaller size fractions on paleotemperature reconstructions have been studied by Hald et al. (2007). Their study showed that there were no apparent effects for sea-surface temperatures higher than higher than 4 °C, but for colder temperatures the sea-surface temperature estimates were

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1–2 °C higher when smaller size fractions were not considered (Hald et al., 2007). In this study we have investigated only surface sediment samples from the upper 2 cm of the sea floor. These surface sediment samples represent modern conditions and a continuous sedimentation until today (e.g. Kucera et al., 2005). We have investigated a smaller size fraction (>100 μm) than most previous studies, which includes small sized specimens of *Turborotalita quinqueloba* characteristic of subpolar and polar environments (Bauch, 1994; Carstens et al., 1997). In earlier studies, it has been observed that planktic foraminifera migrate through the water column, and that polar foraminifera have a rather deep depth habitat with maximum occurrence from 50 to 150 m (Carstens et al., 1997; Volkmann, 2000; Jonkers et al., 2010). In order to find out for what water depth paleotemperature can be estimated most accurately (e.g. Pflaumann et al., 1996) we have used seasonal and annual temperature data from four different water depths (0 m, 10 m, 50 m, and 100 m).

2. Oceanography

The study area is mainly dominated by three water masses: Atlantic Water; Arctic Water, and Polar Water. In the eastern part of the study area, the SW Barents Sea, there also is the Norwegian Coastal Water. The warm (>2 °C) and salty (>35 PSU) Atlantic Water flows into the northern North Atlantic with the North Atlantic Current (NAC). It continues into the Arctic Ocean with the West Spitsbergen Current (WSC) and into the Barents Sea with the North Cape Current (NCC) (Fig. 1). The Atlantic Water sinks below Polar Water north of Svalbard and continues as a subsurface (>100 m deep) current into the Arctic Ocean (Hopkins, 1991). From the Arctic Ocean ice-loaded, cold (<5 °C) and less saline (<34 PSU) Polar Water is carried with the East Greenland Current (EGC) toward south (Fig. 1). The Atlantic Water mixes with the Polar Water and forms the Arctic Water, which is seasonally covered by sea-ice (Hopkins, 1991). The Arctic Water flows from the north-eastern Barents Sea into the study area with the East Spitsbergen Current (ESC) and continues northwards along the inner shelf of western Svalbard (Fig. 1). The boundary between Arctic Water and Atlantic Water may form abrupt changes of ocean temperatures and sea ice distribution, and is termed the Arctic Front (cf. Hopkins, 1991). This also applies to the boundary between Polar Water and Arctic Water which is termed the Polar Front (cf. Hopkins, 1991). Norwegian Coastal Water is transported along the Norwegian coast in the Norwegian Coastal Current (NCC). The Coastal Water is influenced by fresh water runoff from the Norwegian mainland and from the Baltic Sea and thus characterized by reduced salinities (<35 PSU). The Coastal Water typically overlies the Atlantic Water as a westwards thinning wedge; however the two water masses mix more northwards (Sætre, 2007). The boundary between Coastal Water and Atlantic Water is termed the Coastal front (Fig. 1).

3. Material and methods

This study is based on seventy-one surface sediment samples covering a restricted area from ca. 70° – 79° N and from 22° W to 29° E. Thirty-three surface sediment samples were retrieved from the Barents Sea in the period 1983–1991 using a box corer, and the remaining thirty-eight surface sediment samples were retrieved from the Fram Strait and Greenland–Norwegian Seas during 2006–2008 using a multi corer (Fig. 1, Appendix 1). All surface samples were carefully evaluated and samples were left out if they did not represent an undisturbed sediment surface.

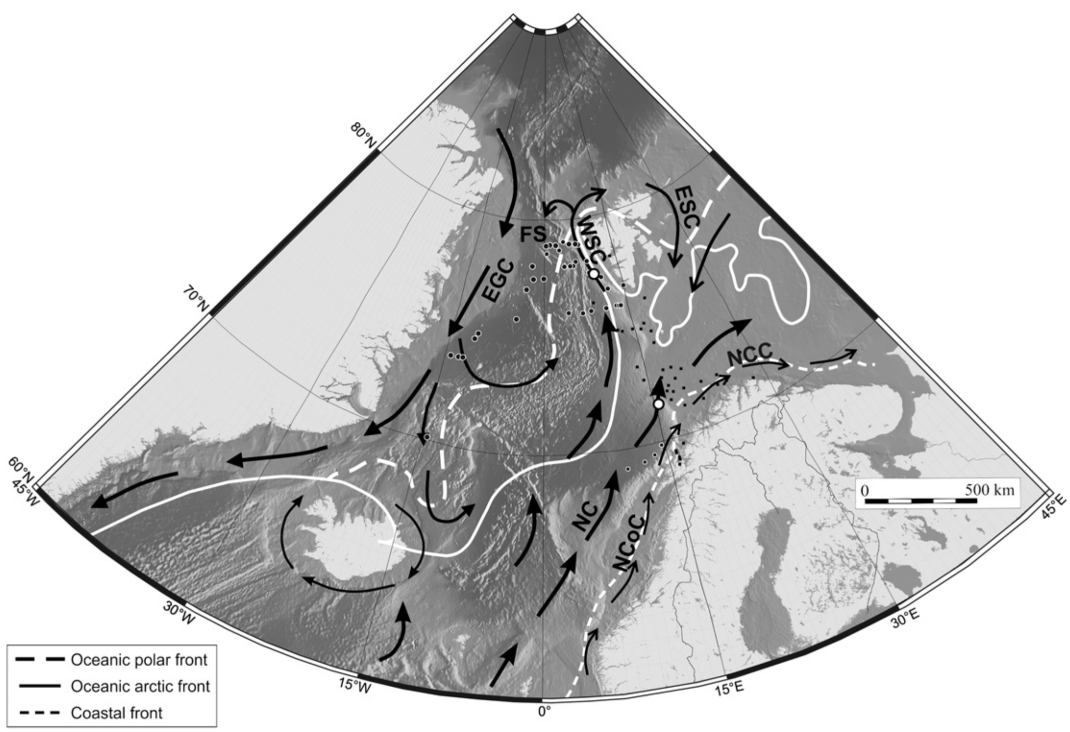

Fig. 1. Bathymetric map showing oceanographic fronts in the northern North Atlantic and adjoining seas modified from Mosby (1968). Main surface currents are also shown: North Atlantic Current (NAC), Norwegian Coastal Current (NCoC), North Cape Current (NCC), East Greenland Current (EGC), West Spitsbergen Current (WSC), East Spitsbergen Current (ESC). Squares are sites sampled 1983–1991 and filled circles were sampled in 2006–2008 from surface sediments. White filled circles show the position of the two Holocene records from core T88-2 (Hald and Aspeli, 1997; Ebbesen, 2004), and core MD99-2304 (Hald et al., 2004; Ebbesen et al., 2007) for which the subsurface temperatures are reconstructed. The location of the Fram Strait (FS) is also indicated.