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Spatial and temporal distribution of Holocene temperature maxima in the northern Nordic seas: interplay of Atlantic-, Arctic- and polar water masses

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Subsurface and bottom water temperatures on the western shelf of Svalbard at 79°N are reconstructed in order to investigate the relative influence of warm Atlantic water, cold Arctic/polar water and meltwater during the Holocene. The study is based on sediment core NP05-21GC, which has been investigated for the distribution of planktic foraminiferal species, oxygen and carbon isotopes measured in benthic and planktic foraminifera and subsurface and bottom water temperatures calculated from transfer functions. The data are compared to several other records from the western margin of Svalbard. The results indicate that until 9600 years BP the water column west of Svalbard was stratified by a pycnocline situated at a water depth of c. 100 m on the shelf and at c. 30 m on the slope. The water mass above the pycnocline consisted of cold Arctic/polar water and meltwater, whereas the water mass below the pycnocline consisted of warm Atlantic water. After 9600 the supply of Arctic/polar water and meltwater diminished weakening the pycnocline and from 9000 to 6000 years BP warm Atlantic water occupied the entire water column. The upper and deeper water masses experienced different Holocene temperature maxima. In the Atlantic water the temperature maximum occurred during the early Holocene 11,500–8200 years BP, only interrupted by the cold Pre-Boreal Oscillation c. 11,300–10,800 years BP. The maximum was followed by a gradual temperature decrease until c. 5000 years BP. In the upper water masses the temperature maximum occurred from c. 9000–6000 years BP. The timing of the maximum here is influenced by the decreasing supply of cold Arctic/polar water versus the increasing dominance of Atlantic water. The temperatures of both the surface and bottom water decreased to a minimum from c. 5000–2000 years BP. During the last 2000 years conditions have been increasingly unstable although with slightly increasing subsurface temperatures.

1. Introduction

The Norwegian-Atlantic Current transports warm, saline Atlantic surface water from the North Atlantic into the Arctic Ocean (Aagaard et al., 1987). At the northern tip of Norway, the current splits into two branches. The North Cape Current continues to the east into the Barents Sea, while the West Spitsbergen Current carries the Atlantic water further north along the continental margin of the Barents Sea and Svalbard (Fig. 1). South of Svalbard the warm Atlantic water meets the East Spitsbergen Current, which transports cold Arctic surface water out of the Arctic Ocean (Saloranta and Svendsen, 2001; Skogseth et al., 2005) and north along the west coast of Svalbard, where it generally overlies the denser Atlantic water (Fig. 1).

The distribution of water masses of western Svalbard is exposed to frequent changes. Recently, the western shelf and fjords have experienced a stronger inflow of Atlantic water resulting in a year-round increase in surface water temperature and salinity (Cottier et al., 2005; Skogseth et al., 2005; Nilsen et al., 2008; Jernas et al., 2010). Off Kongsfjorden at 79°N pronounced changes in the flow of Atlantic water across the shelf and into the fjord have been observed since 2002. In this area, the Atlantic water normally flows along the bottom below the Arctic water of the East Spitsbergen

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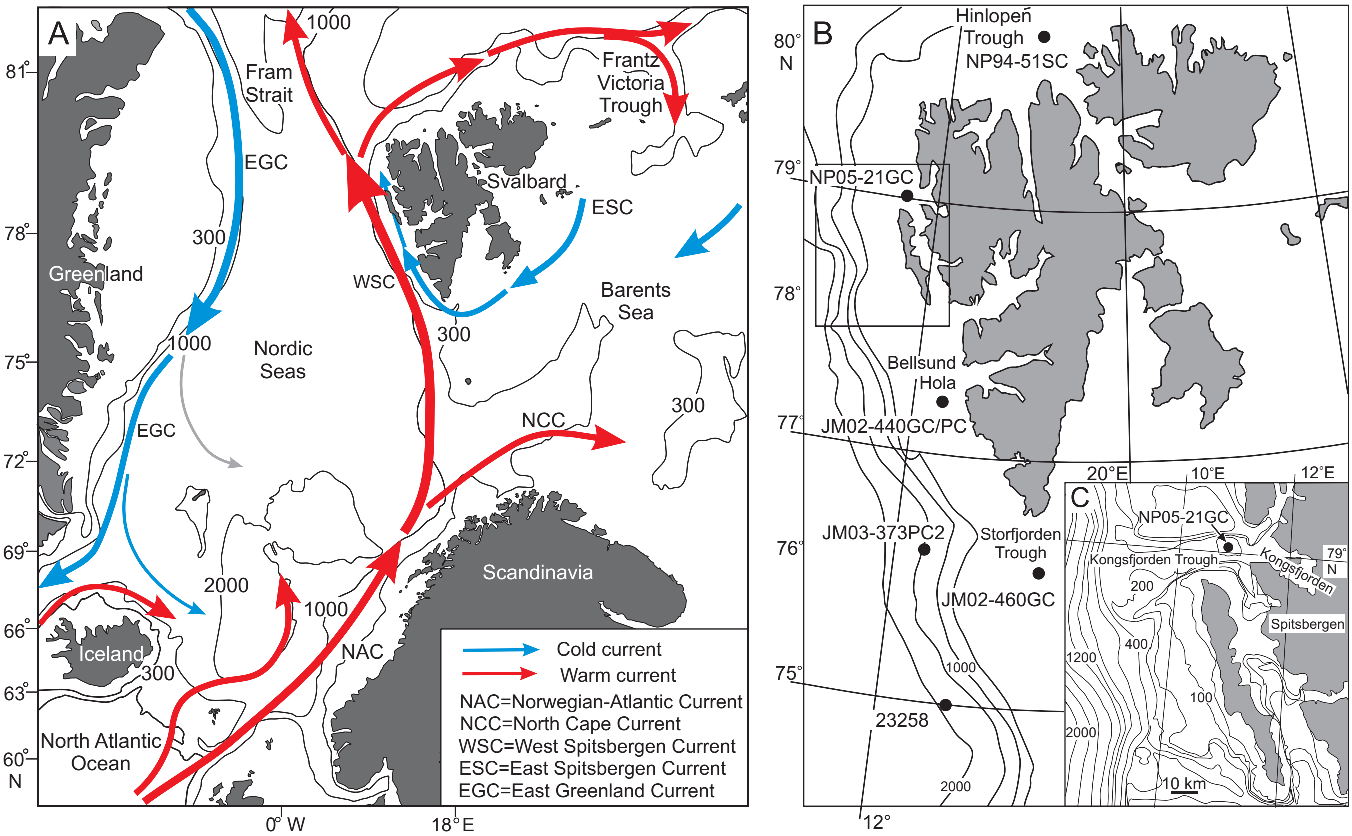

Fig. 1. Map of Svalbard and the Nordic seas showing major surface currents and location of studied core NP05-21GC. Locations of other cores discussed are also indicated.

Current, but in spring 2007 the Atlantic water was also present at the surface (Tverberg and Nøst, 2009) with the consequence that the temperatures of the entire water column increased (Cottier et al., 2007; Jernas et al., 2010). The reason for the inflow of Atlantic surface water is believed to be changes in the density gradient between the Atlantic water of the West Spitsbergen Current and the Arctic water of the East Spitsbergen Current (Tverberg and Nøst, 2009).

In the light of the recent variations in the water mass distribution on the western Svalbard shelf it is important to investigate if similar changes have occurred in the past under different climatic circumstances. The purpose of the present study is to reconstruct the distribution of water masses on the Svalbard shelf and slope during the Holocene, 11,700 years BP to Recent, in comparison to climate changes and meltwater input. The starting point for the investigation is core NP05-21GC taken on the western shelf of Svalbard outside Kongsfjorden at a water depth of 327 m. Planktic foraminiferal species were investigated as indicators of temperature, nutrient supply and productivity in the subsurface water column. Stable oxygen and carbon isotopes were measured in planktic as well as benthic foraminifera as monitors for changes in the chemical and physical properties of the water masses. The results are compared to new temperature reconstructions based on transfer functions from previously published core JM03-373PC2 (Rasmussen et al., 2007) and to several other Holocene records from the Svalbard margin.

1.1. Oceanographic setting

Kongsfjorden Trough is a more than 15 km wide elongate depression stretching from the mouth of Kongsfjorden to the edge of the shelf. The coring site is situated on the shelf in front of the fjord mouth. It receives water from three sources: Relatively warm Atlantic water from the West Spitsbergen Current, colder Arctic water from the East Spitsbergen Current and local polar meltwater from glaciers, rivers, snow melt and other freshwater sources (Svendsen et al., 2002; Cottier et al., 2005) (Fig. 2). The Atlantic water normally enters the site as a subsurface current below the Arctic water (Svendsen et al., 2002; Cottier et al., 2005). During late spring and summer, the glacial meltwater creates a strong pycnocline separating the low salinity surface water from the underlying warmer and saltier Atlantic water. During winter time local basins and depressions on the shelf may be filled with cold dense bottom water (Svendsen et al., 2002; Cottier et al., 2005). Bottom water conditions may therefore switch seasonally from an Atlantic dominated system with bottom water temperatures up to 3 °C to an Arctic/polar dominated system with cold bottom water close to −2 °C (Svendsen et al., 2002; Cottier et al., 2005). Bottom water salinities vary much less (<0.2 psu) (Cottier et al., 2005; Tverberg and Nøst, 2009) (Fig. 2). Because of the relatively small salinity and $\delta^{18}O_{water}$ variations in the bottom water (MacLachlan et al., 2007) we expect that the benthic foraminifera oxygen isotope values primarily reflect bottom water temperatures (see also Lubinski et al., 2001).

2. Material and methods

Gravity core NP05-21GC (Fig. 1) is 515 cm long and has previously been investigated for lithology and benthic foraminifera (Skirbekk et al., 2010). The sediments consist of hemipelagic muds with dropstones in the upper and lower parts.