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Lateglacial and early-Holocene climate variability reconstructed from multi-proxy records on Andøya, northern Norway

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ABSTRACT

We reconstruct mean July temperature (Tjul) from three sites on the island of Andøya, northern Norway for the period 15 000–9000 cal yr BP using three biotic proxies. A probabilistic indicator species approach (pdf method) was used for plant macrofossil data from all sites (M-Tjul). Reconstructions based on pollen (P-Tjul) (2 sites) and chironomids C-Tjul) (1 site) were done using weighted averaging and weighted-averaging partial least-squares, respectively. A sediment proxy for catchment glacier development was measured at the main site, Lusvatnet. The July temperature reconstructions from all the sites show a similar development through the deglaciation. An initial July temperature of 4 °C increased to a maximum of 7–8 °C during the Allerød at c.13 200 cal yr BP. There was no marked cooling at the start of the Younger Dryas (YD) chronozone, at Lusvatnet, C-Tjul decreased after 12 700 cal yr BP to a low of 6 °C at about 12 550 cal yr BP before increasing markedly around 12 400 cal yr BP. Conversely, P-Tjul rose slowly through the early YD. Both proxies exceeded the Allerød temperatures for around 300 years before decreasing towards a minimum of 6 °C at c. 12 000 cal yr BP. M-Tjul maintained a mean of c. 8 °C throughout the YD. Different sensitivities of proxies are discussed. Their different responses during the YD at the three sites, along with the glacial evidence, highlight the role of aridity. At c. 11 500 cal yr BP, July temperatures increased rapidly over Andøya to about 10 °C, and then rose gradually to maximum values of 12 °C at c. 9700 cal yr BP. The temperature reconstructions are consistent with the flow of Atlantic water into the Nordic Seas except during the YD, when variability in sea ice may have been more important. During the early Holocene there are some differences between sites, resulting from local site factors such as altitude and exposure, soil development, and catchment instability.

1. Introduction

Climate changes in and around the Nordic Seas after the Last Glacial Maximum (LGM) about 20 000 years ago were large and rapid (e.g. Rasmussen et al., 2006). In northern Norway, deglacial warming was mediated both by the northward transport of heat by the thermohaline circulation, that increased gradually until it became fully established in the Holocene, and by fluctuations in the amount of sea ice related to movements of the polar front (e.g. Risebrobakken et al., 2010). However, the pattern of deglacial climate in this region, including the development of the Younger Dryas, is poorly known, especially from terrestrial records. At present some quantitative climate reconstructions are available from northern Norway that cover parts of the deglaciation (Seppä et al., 2002; Birks et al., 2005) and early Holocene (Bjune et al., 2004; Bjune and Birks, 2008; Nichols et al., 2009). Only one, Jansvatnet (Fig. 1, Birks et al., 2012), covers the whole Lateglacial and early-Holocene periods. These records indicate that Lateglacial and early-Holocene temperature and precipitation patterns in northern Norway were different from those in southern Norway (Birks et al., 2005; Birks and Birks, 2013). In the south, the inferred Lateglacial and early-Holocene temperature and precipitation changes conform to the classical Scandinavian Lateglacial pattern,

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particularly in the prominence of the Younger Dryas (YD) cold reversal associated with glacial advance (e.g. Lohne et al., 2013). In the north, a cold Allerød period is little different in temperature from the early part of the Younger Dryas and glacial advances were small. The principal factors driving biotic responses were lack of precipitation in combination with temperature changes (Birks et al., 2012; Aarnes et al., 2012a).

At present the position of the boundary between these two Lateglacial climate zones, related to the position of the polar front, is unknown. The broad-scale temperature and precipitation gradients that existed during the Lateglacial and early Holocene were different from those of today (Birks et al., 2005), and we do not know if the gradients were regular or were step-like. Even on a relatively fine spatial scale, temperature and precipitation gradients were different, reflecting the greater seasonality of the Lateglacial and early Holocene compared to today (Birks and van Dinter, 2010). To refine our knowledge of the palaeoclimate and associated biotic and glacial changes during the Lateglacial and early Holocene in northern Norway, more detailed high-quality reconstructions are required.

Here we present a well-dated multi-proxy temperature record from Lusvatnet, Andøya, based on terrestrial plant macrofossils, pollen, and chironomid records through the Lateglacial and early-Holocene sediment sequence along with evidence of glacier activity in the catchment. This sequence starts around 13 600 calibrated years before present (cal yr BP with 1950 defined as 'present'). We have supplemented our results with records from two other lakes on Andøya to extend the mean July air temperature (Tjul) record back to about 15 000 cal yr BP and to cover an elevational range from sea level to 106 m. We focus on a key period of climate change, the Younger Dryas (YD) stadial, when the temporal resolution of the Lusvatnet record is 10–30 years per sample. To improve the detection of patterns of past climate changes we compare our records to other reconstructions from the region and discuss possible causes and mechanisms for the changes that occurred.

2. Sites

Andøya, at 69°N 15′E (Fig. 1), is the northernmost island in the Vesterålen archipelago. It has a cool maritime climate influenced by the Norwegian Atlantic current bringing warm water to high latitudes. Mean July temperature is 11 °C, mean January temperature is −2.1 °C, mean annual temperature is 5.5 °C, and mean annual precipitation is 1060 mm at sea level at Andøya meteorological station (E-Klima.no, 2013).

Three lakes were investigated (Fig. 1). The main site is Lusvatnet (69°04′N 15°34′E, 30 m a.s.l.) near the south-west coast. Lusvatnet is a small (0.1 km^2) oval lake with a small and steep catchment in a sheltered valley opening to the north-west towards the sea. Open birch woodland dominated by *Betula pubescens* ssp. *tortuosa* and with a predominantly ericaceous or tall-fern-dominated understory clothes the steep lower slopes. Above the tree-line, the vegetation is composed of ericaceous dwarf-shrubs and grasses on sheltered slopes, open grass-heath on exposed ridges, and cliff vegetation around the head of the lake where several arctic-alpine and montane species occur. A moraine dams the lake and another submerged moraine divides the lake into two basins. Three marginal moraines at the head of the valley mark former front positions

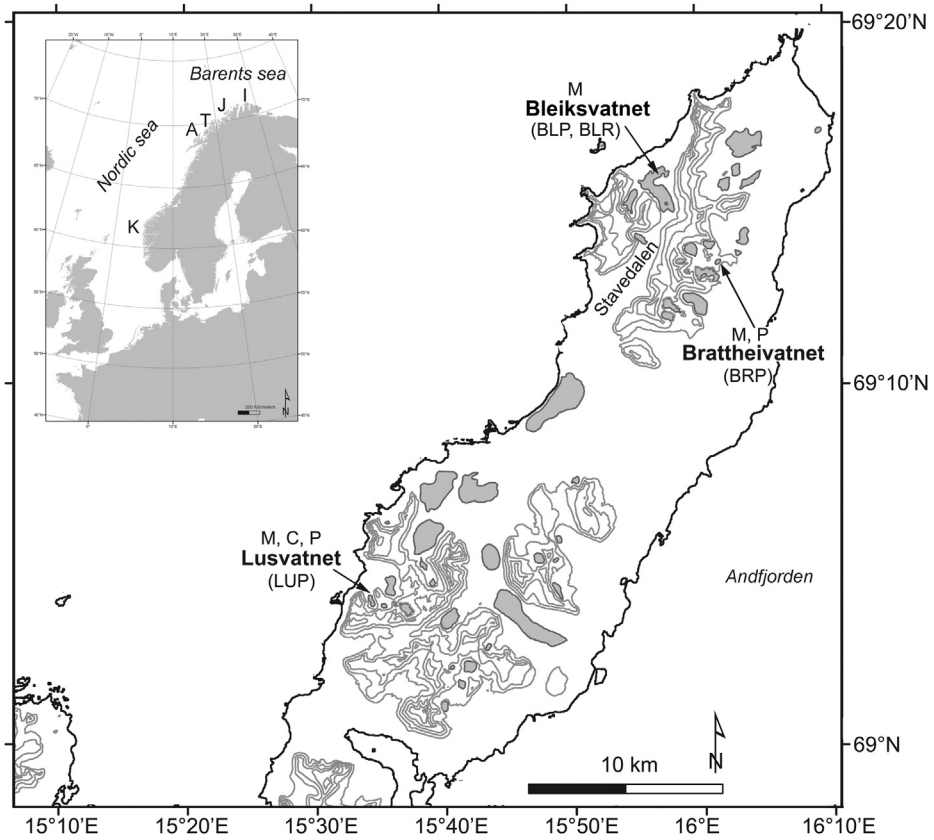

Fig. 1. Andøya (A on the inset map) is situated on the west coast of northern Norway at 69°N, north of the Arctic Circle. Three sites on Andøya were investigated: Lusvatnet (LUP) in the south-west, Bleiksvatnet (BLR, BLP) in the north-west, and Brattheivatnet (BRP) in the north-east. Plant macrofossils (M), pollen (P), and chironomids (C) were analysed at the main site Lusvatnet. Macrofossils were analysed at Bleiksvatnet, and macrofossils and pollen were analysed at Brattheivatnet. Other sites discussed in the text are shown on the inset map: I (Ifjord), J (Jansvatnet), T (Tromsø), and K (Kråkenes).