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Spatio-temporal patterns in Lateglacial and Holocene vegetation and climate of Finnmark, northernmost Europe

Brian Huntley [a,*], Antony J. Long [b], Judy R.M. Allen [a]

[a] School of Biological and Biomedical Sciences, Durham University, South Road, Durham DH1 3LE, United Kingdom
[b] Department of Geography, Durham University, South Road, Durham DH1 3LE, United Kingdom

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ABSTRACT

Precisely-dated records of palaeovegetation and reconstructed palaeoclimate are presented from three lakes in northernmost Finnmark. The lakes lie adjacent to the southern shore of the Barents Sea and are located along a west–east transect. The three records are used to reconstruct spatial patterns in regional vegetation and climatic history since 13,900 cal yr BP. Longer-term shifts in treeline position and in the position of the *Pinus–Betula* ecotone are recorded. In addition, especially during the regional Holocene thermal maximum, the latter exhibited strong periodic fluctuations. The number and strength of these fluctuations that were recorded at each of the three sites differed systematically, with fewer and weaker fluctuations seen at the easternmost site, in particular. The patterns revealed are used to test the hypothesis that variations in the strength of the North Cape Current have been of primary importance as the proximal driver of climatic variability in the region since deglaciation. The results provide strong support for this hypothesis during the Holocene, the strong periodic fluctuations during the regional Holocene thermal maximum in particular being consistent with the proposed mechanism. During the Lateglacial and earliest Holocene the patterns are less clear, but nonetheless also consistent with the proposed mechanism. Further work on precisely-dated marine sediment cores will be necessary to understand the factors leading to the periodic and longer-term variations in strength of the North Cape Current.

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1. Introduction

Principally as a result of their proximity to the North Cape Current (NCaC, Ingvaldsen, 2005), a warm surface current in the southern Barents Sea that is one of the ultimate branches of the North Atlantic Current (Fig. 1(a)), the northern coastal peninsulas of Finnmark, the northernmost parts of mainland Europe, have an anomalously mild present climate compared to more inland areas of northern Fennoscandia that lie to the south. Holocene palaeoclimate and ecosystems in this coastal region are thus expected to have been particularly sensitive to variations in the strength of these ocean currents, that in turn are sensitive to the varying strength of the Atlantic meridional overturning circulation (AMOC) evident from studies of marine sediments (Bianchi and McCave, 1999). Previous work at a small lake on Nordkinnhalvøya (Fig. 1(b)), in central northern Finnmark (Allen et al., 2007), has provided evidence of millennial variability, both in Holocene palaeoclimate and in the position of the northern limit of *Pinus sylvestris* (Scots Pine) (nomenclature for vascular plants follows Mossberg and Stenberg, 2003), the species of coniferous tree that extends furthest north in Fennoscandia, forming the northernmost taiga in this region (Fig. 1(b)).

Whilst such evidence from a single locality confirms that regional climate and ecosystems exhibited millennial variability throughout the Holocene, it cannot provide evidence of any spatial pattern in this variability. Spatial patterning is to be expected, however, if the underlying cause of the regional variability is varying strength of the AMOC, and hence of the NCaC. Increased strength of the NCaC is likely to result also in increased eastward extension of warm surface water, with the converse happening when the current weakens. If this is the case, and if the variations observed on Nordkinnhalvøya are related to varying strength of the NCaC, then similar evidence of variations in climate and ecosystems is expected at other sites along the Finnmark coast. Furthermore, unless the fluctuations in strength and penetration of the NCaC were of consistent magnitude, the variations in climate and ecosystems seen along the Finnmark coast would not be expected to be consistent in magnitude with longitude. On the contrary, if at some

* Corresponding author.
E-mail address: brian.huntley@durham.ac.uk (B. Huntley).

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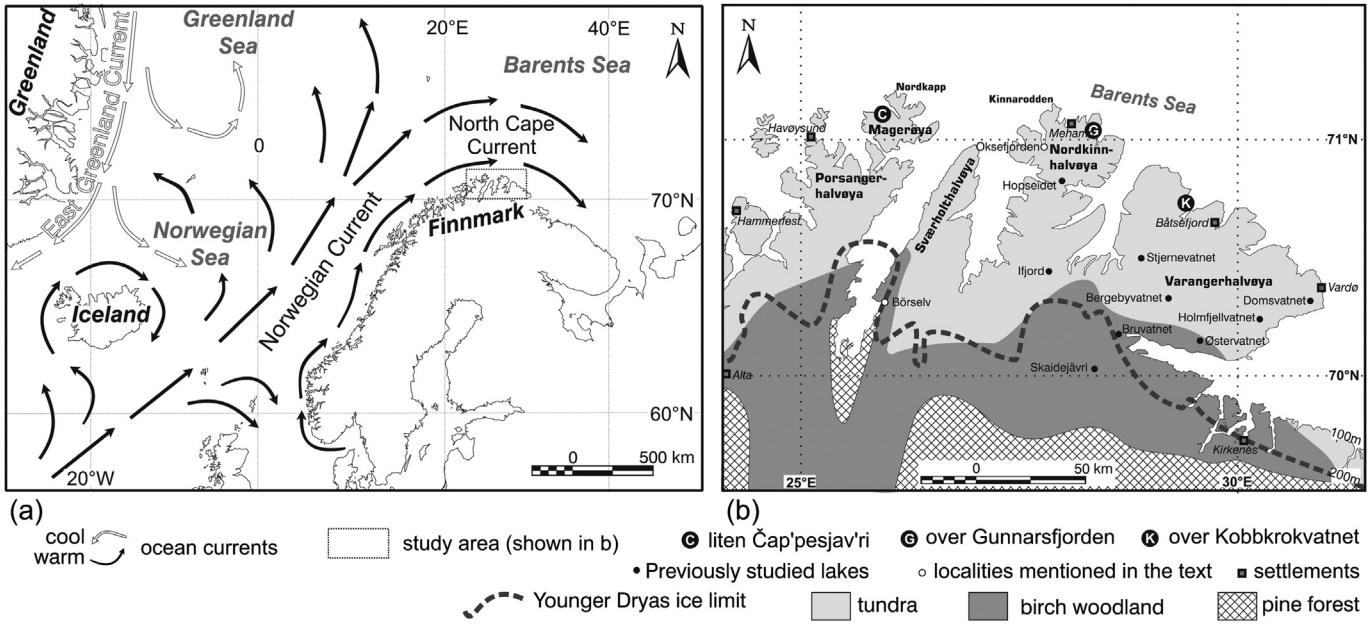

Fig. 1. Location of the study area and sites sampled. (a) Shows the location of the study area in northern Norway and how it is related to the principal present ocean surface currents. (b) Shows the locations of the three sites examined in relation to a schematic representation of the present major vegetation patterns, previously studied sites and principal settlements.

times the NCaC reached only to western Finnmark, then only at sites on the western peninsulas would its influence be likely to be apparent, whilst if at other times it penetrated beyond eastern Finnmark, then its influence is likely to be apparent at sites east to Varangerhalvøya, the easternmost peninsula of the Finnmark coast.

In order to explore whether there is evidence of such longitudinal variability in the magnitude and spatial extent of Holocene variations in climate and ecosystems, further comparable records are required from sites at locations to the west and/or east of the previously studied site. Comparison of these records with that from Nordkinnhalvøya will provide evidence of the extent to which the variability observed at the central site also is apparent at other sites in the region, and hence of the extent to which this variability is, as was argued previously, a regional rather than a local signal. More importantly, such comparisons may also provide evidence of fluctuations observed at the Nordkinnhalvøya site that are not seen further east and/or of additional fluctuations seen to the west that are not recorded by the site on Nordkinnhalvøya. Critical for any such comparisons, however, will be that each record has its own independent high-resolution chronology. Only in this way can comparisons be made objectively and without recourse to 'wiggle matching' and its associated hazard of circular reasoning.

We present here the results of pollen analyses at two further lakes, one in western Finnmark on the island of Magerøya and one in the east on Varangerhalvøya (Fig. 1(b)). Together with the site examined on Nordkinnhalvøya, these sites form a west–east transect extending for > 150 km and spanning most of the Finnmark coast. We also present new high-resolution age–depth models for all three sites. These provide the basis for investigating the extent to which the three records exhibit coincident fluctuations in ecosystems and reconstructed climate, and also allow us to explore the extent to which the records show evidence of periodicity in these fluctuations. The results are used to infer spatial and temporal patterns in regional Holocene climate and ecosystems and to explore the extent to which these are consistent with fluctuations in the strength of the AMOC and hence of the NCaC.

2. Methods

2.1. Sites and sampling

The western site is located on the island of Magerøya, best known because its northernmost point, Nordkapp (71° 10′ 21″ N, 25° 47′ 40″ E), is often considered to be the northernmost point in Europe, as well as marking the boundary between the Norwegian and Barents Seas. The lake is unnamed on the 1:50,000 topographic map (Topografisk Hovedkartserie—M711, Blad 2037 II 'Nordkapp'; Statens Kartverk, N-3500 Hønefoss); we refer to it as liten Čap'pesjav'ri. It is located near the west coast of Magerøya, *ca* 2.5 km south of the hamlet of Gjesvær (Fig. 1(b) and 2(a); 71° 4′ 28″ N, 25° 22′ 5″ E, 41 m above sea level (a.s.l.)) and has a surface area of *ca* 2.5 ha. It is one of several small lakes linked by a small stream flowing from Čap'pesjav'ri (56 m a.s.l.) to the sea. The local bedrock is principally metamorphosed Late Proterozoic to Cambrian age sandstones, with quartzite, amphibolite and conglomerate layers (Siedlecka and Roberts, 1996). The eastern site lies close to the north coast of Varangerhalvøya, near the western shore of Kongsfjord and *ca* 2.5 km south of the eponymous hamlet (Figs. 1(b) and 2(b); 70° 41′ 57″ N, 29° 17′ 41″ E, 51 m a.s.l.). It too is unnamed on the 1:50,000 topographic map (Topografisk Hovedkartserie—M711, Blad 2336 II 'Kongsfjord'; Statens Kartverk, N–3500 Hønefoss); we refer to it as over Kobbkrokvatnet. It has a surface area of *ca* 1.7 ha and is one of three small lakes, the uppermost at 64 m a.s.l., connected by a small stream flowing into Kobbkrokvatnet at 48 m a.s.l. The local bedrock is mostly dark grey sandstone, alternating with layers of grey-black mudstone and shale, assigned to the Barents Sea group and marginal to the rocks of the Caledonian orogeny (Siedlecka and Roberts, 1996). The central site, referred to as over Gunnarsfjorden (Allen et al., 2007), is located close to the east coast of Nordkinnhalvøya, the peninsula that extends to the northernmost mainland point in Europe at Kinnarodden (71° 8′ 2″ N, 27° 39′ 0″ E), *ca* 4.0 km south of the hamlet of Gamvik (Fig. 1(b) and 2(c); 71° 2′ 18″ N, 28° 10′ 7″ E, 78 m

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