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Holocene temperature history of northern Iceland inferred from subfossil midges

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Abstract

The Holocene temperature history of Iceland is not well known, despite Iceland's climatically strategic location at the intersection of major surface currents in the high-latitude North Atlantic. Existing terrestrial records reveal spatially heterogeneous changes in Iceland's glacier extent, vegetation cover, and climate over the Holocene, but these records are temporally discontinuous and mostly qualitative. This paper presents the first quantitative estimates of temperatures throughout the entire Holocene on Iceland. Mean July temperatures are inferred based upon subfossil midge (Chironomidae) assemblages from three coastal lakes in northern Iceland. Midge data from each of the three lakes indicate broadly similar temperature trends, and suggest that the North Icelandic coast experienced relatively cool early Holocene summers and gradual warming throughout the Holocene until after 3 ka. This contrasts with many sites on Iceland and around the high-latitude Northern Hemisphere that experienced an early to mid-Holocene "thermal maximum" in response to enhanced summer insolation forcing. Our results suggest a heightened temperature gradient across Iceland in the early Holocene, with suppressed terrestrial temperatures along the northern coastal fringe, possibly as a result of sea surface conditions on the North Iceland shelf.

1. Introduction

A general picture of Holocene climate around the Northern Hemisphere is emerging, and with it recognition that the response of interglacial climate to changing radiative forcing has been neither linear nor spatially homogeneous (e.g., deMenocal et al., 2000; CAPE Project Members, 2001; Kaufman et al., 2004; Kaplan and Wolfe, 2006). Climate is clearly modulated by local- and regional-scale factors that complicate the response to radiative forcing. This presents a challenge for those aiming to predict local and even regional-scale climatic responses to anthropogenic greenhouse forcing. Because it is climate at these scales that matters to society—more so than global or hemispheric climatic averages—it should be a high priority for paleoclimate and modeling studies to understand the factors that modulate local climatic responses to radiative forcings.

Ocean circulation, which plays an important modulatory role in Earth's climate system, has undergone both millennial-scale and abrupt, decadal-scale changes during the Holocene (e.g., Bond et al., 2001; Mayewski et al., 2004; Alley and Ágústdóttir, 2005). Some of these changes probably originated with perturbations in the North Atlantic thermohaline circulation, which has been called the "Achilles heel" of the climate system (Broecker, 1997). Today there is concern that ongoing changes in the freshwater budget of the northern oceans could alter the thermohaline circulation, with potentially severe impacts on society (e.g., NRC (National Research Council Committee on Abrupt Climate Change), 2002; Bryden et al., 2005; Curry and Mauritzen, 2005). Thus the controls on, and impacts of, North Atlantic circulation are important to understand.

As the largest land mass in the central North Atlantic (Fig. 1), Iceland occupies a strategic position: The modern-day

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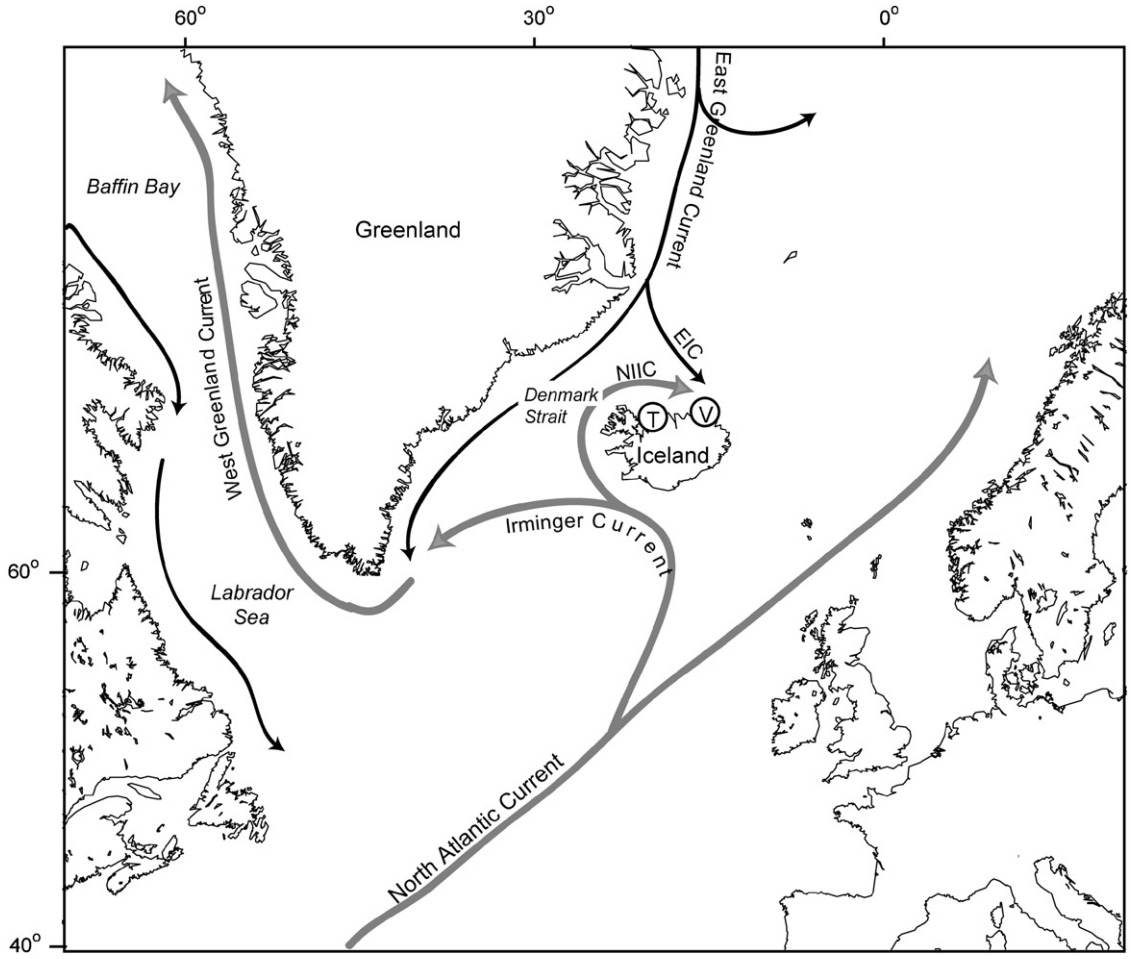

Fig. 1. The North Atlantic region, showing major ocean surface currents around Iceland, and locations of study sites Torfadalsvatn (T) and Stora and Litla Viðarvatn (V). EIC = East Iceland Current; NIIC = North Iceland Irminger Current.

Polar Front between cold, polar ocean surface currents and warm, Atlantic surface currents lies just north of Iceland, creating steep salinity and temperature gradients over the North Iceland shelf and a steep climate gradient across the island. Today Iceland's southern coast is warmed by the Atlantic Irminger Current (IC), which imports heat from the south. The cooler climate of northern Iceland reflects the competing influences of the IC and the cold East Iceland Current (EIC) a branch of the polar East Greenland Current (EGC; Fig. 1; Valdimarsson and Malmberg, 1999). Both the IC and EGC are important players in the global thermohaline circulation (e.g., Curry and Mauritzen, 2005). Changes in the strength and character of the Irminger and East Greenland currents cause dramatic oceanographic changes off northern Iceland (e.g., Ólafsson, 1999; Andrews and Giraudeau, 2003). Thus, Iceland sits in an ideal position to have been influenced by oceanographic changes of global importance, including those associated with changes in the convective strength of the thermohaline circulation.

Marine sediment core studies over the last decade have documented complex paleoceanographic changes off northern Iceland through the Lateglacial and Holocene (e.g., Eiríksson et al., 2000; Andrews et al., 2001; Jiang et al., 2002; Andrews and Giraudeau, 2003; Andersen et al., 2004; Castañeda et al., 2004; Giraudeau et al., 2004; Moros et al., 2004, 2006; Andresen and Björck, 2005; Smith et al., 2005; Ran et al., 2006; Solignac et al., 2006; Bendle and Rosell-Melé, 2007). But the overall pattern of these changes—and whether oceanographic changes were accompanied by simultaneous temperature changes on land, where temperatures are a function of marine conditions, regional wind patterns (Ólafsson, 1999), and solar forcing—remains unclear. A growing number of glacial geologic, pollen, chironomid, and other lake sediment records (e.g., Hallsdóttir, 1991, 1995; Gudmundsson, 1997; Rundgren, 1997, 1999; Stötter et al., 1999; Kirkbride and Dugmore, 2001, 2006; Wastl et al., 2001; Caseldine et al., 2003, 2006; Hallsdóttir and Caseldine, 2005; Wastl and Stötter, 2005; Hannesdóttir, 2006; Holmes, 2006) provide a general picture of terrestrial climate over the Holocene, but the terrestrial record from Iceland remains discontinuous and mostly qualitative.

This study uses subfossil chironomids (Diptera: Chironomidae, or non-biting midges) to reconstruct Holocene paleotemperatures at three lakes in northern Iceland, with