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Shifts in precipitation during the last millennium in northern Scandinavia from lacustrine isotope records

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ABSTRACT

Here we present $\delta^{18}O_{diatom}$ data from two high-latitude lakes; one has short residence time and a water isotopic composition ($\delta^{18}O_{lake}$) that fluctuate due to seasonal variations in precipitation and temperature, and the other has $\delta^{18}O_{lake}$ that is influenced by longer lake water residence times and evaporation. The $\delta^{18}O_{diatom}$ records reveal common responses to precipitation forcing over the past millennium. Relatively wet summers are inferred from $\delta^{18}O_{diatom}$ between 1000 and 1080 AD, 1300 and 1440 AD, and during the early 19th century, coincided with periods of high cloud cover inferred from tree-ring carbon isotopes, and other data for high Arctic Oscillation index. While relatively dry summers with increasing influence of winter snow are indicated between 1600 and 1750 AD. The co-response between carbon isotopes in trees and oxygen isotopes in diatoms strengthens the relationship between cloud cover and precipitation and the hypothesis that these changes were the result of significant regional shifts in atmospheric circulation.

1. Introduction

The atmospheric circulation over northern Scandinavia is governed by the balance between Arctic and North Atlantic air masses (Hurrell et al., 2003; Sutton and Hodson, 2005). Shifts in this balance at interannual–interdecadal time scales have been attributed to variations in the Arctic Oscillation (AO) and the associated North Atlantic Oscillation (NAO) (Thompson and Wallace, 1998; Rigor et al., 2002; Hurrell et al., 2003). A wet and mild summer climate is a consequence of positive AO conditions (high index), a dry and cold climate the consequence of negative AO conditions (low index). Perturbations associated with NAO have the largest impact on regional winter climate which becomes mild and moist during positive phases and cold and dry during negative phases (Hurrell et al., 2003). A positive phase of summer NAO is characterized by anticyclonic summer conditions in northern Scandinavia, resulting in a warm and dry climate (Folland et al., 2009). Past variation in the summer climate as a consequence of AO and NAO shifts has previously been reconstructed using tree-rings (D'Arrigo et al., 2003; Folland et al., 2009; Young et al., 2010, 2012).

The Arctic and Atlantic derived air masses that impact Northern Europe have characteristic seasonal patterns of temperature and precipitation and distinct oxygen and hydrogen isotope compositions (Bowen and Wilkinson, 2002). The oxygen isotopic composition of lacustrine diatoms/carbonates and aquatic cellulose have previously been used to reconstruct past changes in the oxygen isotopic composition of lake water ($\delta^{18}O_{lake}$) and precipitation ($\delta^{18}O_P$) in northern Sweden (Hammarlund et al., 2002; Rosqvist et al., 2004, 2007; Jonsson et al., 2009, 2010a,b; Andersson et al., 2010; St. Amour et al., 2010). Many of these records show a Holocene depletion trend which has been explained in terms of long term circulation and temperature changes forced by the decrease in summer insolation at this latitude (Shemesh et al., 2001;

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Hammarlund et al., 2002, 2004; St. Amour et al., 2010). Isotopic shifts on millennial-centennial time scales have been associated with North Atlantic atmospheric and oceanic circulation changes over the last 3000 years (Rosqvist et al., 2004, 2007; St. Amour et al., 2010).

Our aim is to determine past changes in seasonal variability in precipitation and moisture availability through analyses of the oxygen isotopic composition in lake water and preserved diatom silica. The results are used to infer past changes in dominant atmospheric circulation modes. While high-latitude lakes with short residence times have water isotopic compositions ($\delta^{18}O_{lake}$) that fluctuate due to seasonal variations in precipitation and temperature (Jonsson et al., 2009), this variation is mainly produced by the input of isotopically depleted snowmelt (winter precipitation) in May/June and to a lesser extent the subsequent influence of relatively more enriched summer precipitation. In contrast the $\delta^{18}O_{lake}$ of semi-closed lakes, even at high latitudes, is influenced by longer lake water residence times and evaporation (Leng and Marshall, 2004; Jonsson et al., 2009). Here we present two $\delta^{18}O_{diatom}$ records that allow us to infer changes in seasonality and amount of precipitation at much higher resolution than has been previously achieved from Northern European lakes, down to a sub decadal (in part) time scale.

2. Regional setting

Lake Stuor Guossasjavri (hence forth called Guossasjavri) (67°50′47″N, 19°40′48″E) is located ca ∼30 km west of Kiruna, and 60 km east of Kebnekaise, the highest summit in Sweden at 2101 m above sea level (m. a. sl.) (Fig. 1a, b). The flat lake catchment covers 3.7 km^2 between 780 and 620 m a. sl. The modern lake surface area is 0.3 km^2 and maximum water depth is 6.5 m. The mean water depth is only 2.2 m and about 10% of the present day lake area is deeper than 4 m (Karlsson and Byström, 2005). Guossasjavri is a semi-closed lake as it only has one semi-permanent inlet and outlet, both of which are active during snowmelt. The water

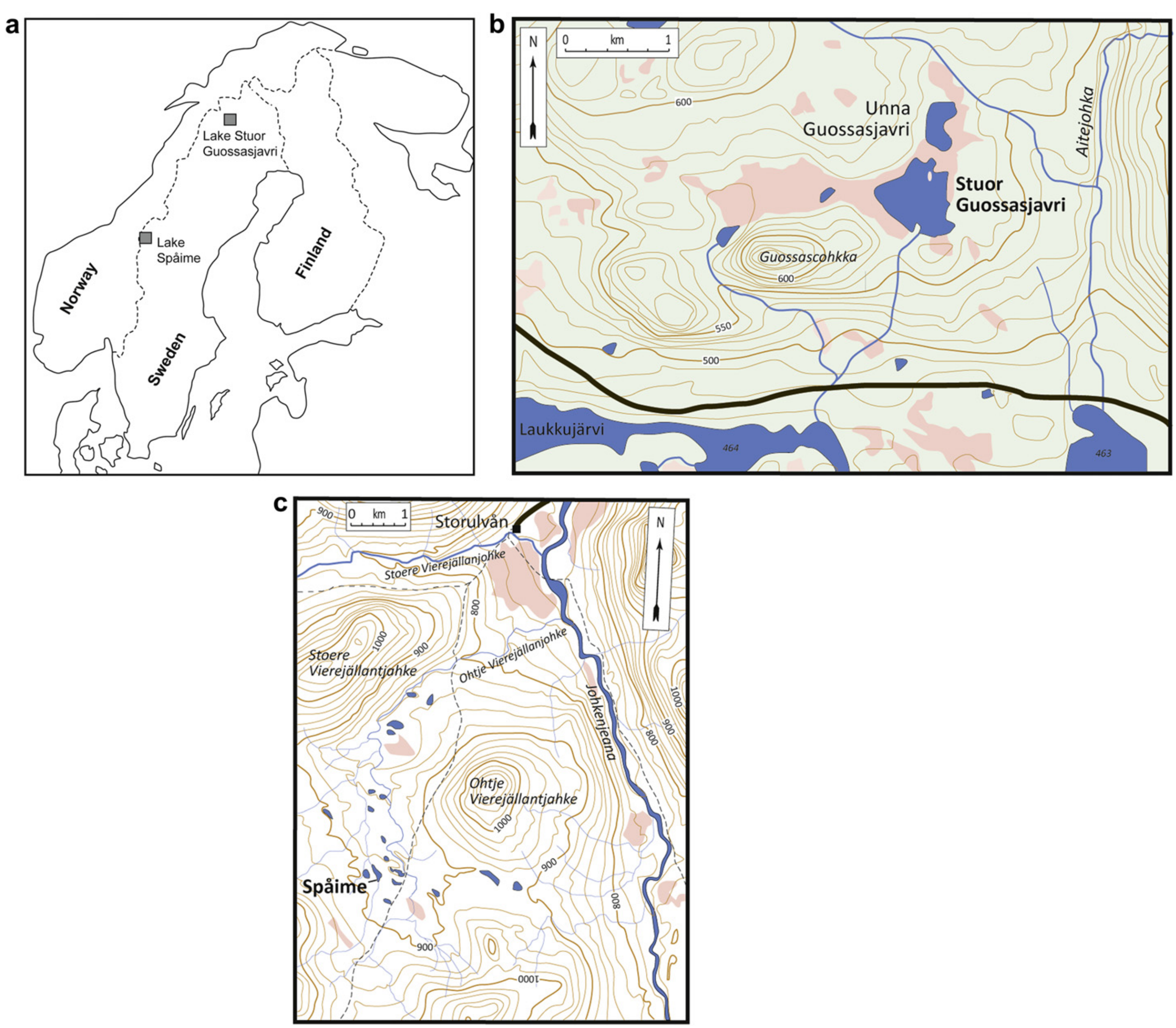

Fig. 1. Map of Scandinavia (a), and the catchments of Lake Stuor Goussasjavri (b) and Lake Spåime (c).