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Reconstructing early Holocene seasonal bottom-water temperatures in the northern North Sea using stable oxygen isotope records of *Arctica islandica* shells

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ABSTRACT

The knowledge of seasonal temperature variability in the ocean is essential for understanding climate and its response to forcing factors. Time intervals with highly dynamic climate and increased seasonal forcing such as the early Holocene are of particular interest. Yet, the temporal resolution of most existing climate records is not sufficient to reconstruct temperature seasonality. Here, we present the first seasonally resolved, early Holocene, bottom-water temperature record from the Viking Bank in the northern North Sea. The reconstruction is based on the stable oxygen isotope data ($\delta^{18}O_{shell}$) of two crossdated, radiocarbon-dated subfossil shells of *Arctica islandica* (Bivalvia). Oxygen isotope data were combined into a 21-year long record, dated at 9593–9573 (±55) cal yr BP The record indicates an early Holocene seasonal temperature amplitude up to ca. 4.5 °C. To estimate changes in the mean state and seasonality of temperature conditions between the present and early Holocene, the record and temperatures inferred thereof are compared with modern $\delta^{18}O_{shell}$ profiles and instrumental temperature data. The results indicate that the seasonal amplitude of $\delta^{18}O_{shell}$ signal in the subfossil shells reflects sea-level changes. The reconstruction suggests that the long-term average and seasonal variability of temperature were similar to modern times when considering changes in the relative sea level. Our data also confirm that $\delta^{18}O_{shell}$ records are reproducible and track seasonal amplitude of bottom-water temperature variability, thus demonstrate the potential for application in reconstructions of past seasonality. Furthermore, our results show that $\delta^{18}O_{shell}$ records can be used to reconstruct seasonal stratification dynamics. This novel application of sclerochronological data has the potential to be used to validate and constrain paleotidal models.

1. Introduction

The early Holocene (ca. 11,500–8000 cal yr BP) climate in the North Atlantic region was highly dynamic and characterized by abrupt climatic fluctuations (e.g., Mayewski et al., 2004; Bakke et al., 2005; Nesje et al., 2005; Hou et al., 2011). A prominent feature of early Holocene marine climate records in the northeastern subpolar North Atlantic is a distinct thermal maximum (Hald et al., 2007). As evidenced in sediment core records from the Barents Sea and Svalbard margin, this was the warmest interval within the entire Holocene (Hald et al., 2004, 2007; Ebbesen et al., 2007). The early Holocene thermal maximum is commonly associated with the Holocene summer insolation maximum in the Northern Hemisphere (Renssen et al., 2009, 2012), which occurred around 12,000–10,000 cal yr BP (Berger and Loutre, 1991) and is connected with an increase in seasonality.

Available marine records from the mid-latitudes do not show a consistent pattern of early Holocene warmth (e.g., Andersson et al., 2010 and references therein) and indicate temperature conditions as warm as, or slightly warmer than the present, depending on the proxy used (Birks and Koç, 2002; Calvo et al., 2002; Dolven et al., 2002; Risebrobakken et al., 2003; Andersen et al., 2004; Hald et al., 2007). The difference in trends between the southern and northern records was

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