Research paper

Decadal climate variability of the North Sea during the last millennium reconstructed from bivalve shells (*Arctica islandica*)

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Abstract

Uninterrupted, annually resolved paleoclimate records are crucial to contextualize the current global change. Such information is particularly relevant for the Europe realm for which weather and climate projections are still very challenging if not virtually impossible. This study presents the first precisely dated, annually resolved, multiregional *Arctica islandica* chronologies from the North Sea which cover the time interval AD 1040–2010 and contain important information on supra-regional climatic conditions (sea surface temperature (SST), ocean productivity, wind stress). Shell growth varied periodically on timescales of 3–8, 12–16, 28–36, 50–80, and 120–240 years, possibly indicating a close association with the North Atlantic Oscillation, ocean-internal cycles of the North Atlantic controlled by ocean–atmosphere couplings, and the Atlantic Multi-Decadal Oscillation. Increased climatic instability, that is, stronger quasi-decadal variability, seems to be linked to the predominance of atmospheric forcings and some significantly decreased insolation phases (e.g. Spörer and Maunder Minima). Increased climatic variability of shorter timescales was also observed during some particularly warm phases or regime shifts (e.g. during the 'Medieval Climate Anomaly' and since *c.* 1970). More stable climatic conditions, that is, extended warm or cold periods ('Medieval Climate Anomaly', 'Little Ice Age'), however, fell together with a predominance of multi-decadal oceanic cycles. Whether the sunspot number and the higher frequency climate variability are causally linked and which processes and mechanisms are required lie beyond this study.

Keywords

annual increment width, Atlantic Meridional Overturning Circulation, bivalve sclerochronology, dendrochronology, North Atlantic Oscillation, sunspot number, wavelet analysis

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Introduction

Uninterrupted, long-term, high-resolution paleoenvironmental proxy data provide an essential means to test and verify numerical climate models (IPCC, 2007; Jones et al., 2001, 2009) and contextualize present climate change. Such data are particularly relevant for Europe and adjacent marine settings for which weather and climate predictions beyond timescales of several days are virtually impossible at present (Woollings, 2010). The difficulty to predict future change in this region results from (1) the dynamic and non-stationary behavior of oceanic and atmospheric circulation patterns that govern European climate (Greatbatch, 2000), that is, the Atlantic Meridional Overturning Circulation (AMOC; Delworth and Mann, 2000; Schlesinger and Ramankutty, 1994; Wei et al., 2012) and the North Atlantic Oscillation (NAO; Hurrell, 1995; Van Loon and Rogers, 1978) and (2) the lack of sufficient long-term, high-resolution paleoclimate datasets.

Numerous terrestrial, annually resolved paleoclimate archives (e.g. tree rings – Briffa et al., 1992; Esper et al., 2002; Grudd et al., 2002; stalagmites – Fohlmeister et al., 2012; Scholz et al., 2012; Vollweiler et al., 2006; varved lake sediments – Sirocko et al., 2012) spanning centuries to millennia have yielded unique insights into the European climate history and highlighted potential links to cultural transformations (Büntgen et al., 2012). However, one major drawback of these records is that they tend to be biased toward summer, whereas environmental variables during other seasons are only indirectly recorded. Furthermore, a more detailed understanding of the European climate also requires knowledge of environmental variability in adjacent oceans, specifically the North Sea, which exerts a direct influence on climate of the littoral states.

As demonstrated by several recent studies, shells of long-lived bivalve mollusks, in particular the ocean quahog, *Arctica islandica*, contain detailed records of decadal to century-scale environmental change in the northern North Atlantic (Schöne et al., 2003; Wanamaker et al., 2012; Witbaard et al., 1997). Based on synchronous changes in shell growth and a common response to environmental fluctuations, increment width time-series of specimens with overlapping life spans can be combined by means of cross-dating (wiggle-matching) into single composite or master

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