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Gulf of Maine shells reveal changes in seawater temperature seasonality during the Medieval Climate Anomaly and the Little Ice Age

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In this study, we use subannually resolved oxygen isotope values of fossil (dead-collected) and modern (live-caught) bivalve shells (*Arctica islandica* L.) from the northwestern Atlantic (Gulf of Maine, USA) to reconstruct past seasonal changes in seawater temperature. Our results indicate decreased seasonal temperature amplitude of about 1.6 °C (or ~21%) during Medieval times (*ca.* AD 1033–1062) compared to shells from the early Little Ice Age (*ca.* AD 1321–1391) and during the late 19th century (AD 1864–1886). Additionally, seasonal oxygen isotope data suggest that summers were cooler and winters were warmer in the Gulf of Maine during the 11th century compared to summers and winters in the 14th century and the late 19th century. The inferred decreased seasonality during Medieval times likely resulted from increased stratification of the coastal waters due to warmer seawater temperatures. As seawater cooled during the Little Ice Age, we suggest that increased vertical mixing of the coastal surface waters was a major driving factor for the observed increase in the amplitude of the seasonal seawater temperature cycle.

1. Introduction

Small changes in seasonality can have dramatic and rapid effects on the climate system (Denton et al., 2005), terrestrial and marine ecosystems (e.g., Hinzman et al., 2005; Smetacek and Nicol, 2005), and on the health and stability of human populations (e.g., Barlow et al., 1997; Altizer et al., 2006; Patterson et al., 2010). In the current global warming scenario (IPCC, 2007), records of past climate and seasonality from a variety of locations are needed to place recent global changes into context. Although there is a vast network of annually-resolved, terrestrial-based proxies in the northern hemisphere for the last millennium (NRC, 2006) to study climate change, such records are scarce in the marine realm; this problem exists despite the fact that marine-based data are critical to fully capture recent and past climate change. Thus far, much of the existing annually-resolved, marine-based proxy records, mostly from corals and sclerosponges, are biased to the tropical oceans. To some extent, research in the climatically important mid-to-high-latitude oceans has been hindered by a lack of suitable high-resolution marine archives with annual banding for sclerochronological studies (e.g., Halfar et al., 2008).

In this study we attempt to reconstruct past seasonal dynamics of seawater temperature variations in the Gulf of Maine, USA for intervals of the last millennium. The Gulf of Maine is situated in the northwestern Atlantic located along a hydrographic and faunal transition zone that is sensitive to minor climate shifts (Fig. 1) (e.g., MERCINA, 2001, 2003). The Gulf of Maine is an extremely productive ocean environment that supports a rich and dynamic ecosystem. Because of its geographic location, changes in the strength and/or position of slope water currents (Labrador Current and Gulf Stream) are thought to significantly affect the oceanography (e.g., temperature, salinity, productivity) in the Gulf of Maine (Pickart et al. 1999; MERCINA, 2001; Greene and Pershing, 2001; Conversi et al., 2001; Halfar et al., 2008; Wanamaker et al., 2008a, 2009). To date very few studies have investigated the ocean climate and ecosystem dynamics of the Gulf of Maine beyond the relatively short instrumental period. Of these studies, none have characterized the past seasonality of seawater temperature variability in terms of climate (i.e., 30-yr means). Previously, Wanamaker et al. (2008a) showed a long-term increasing trend in annual $\delta^{18}O$ shell values (indicative of 1–2 °C cooling) in the Gulf of Maine during the last millennium using oxygen isotope profiles from *Arctica islandica* shells. In this study, we revisit the work of Wanamaker et al. (2008a) to determine if there were any significant changes in seawater temperature seasonality during the last 1000 years, especially between the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA) intervals.

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