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A low seasonality scenario in the Mediterranean Sea during the Calabrian (Early Pleistocene) inferred from fossil *Arctica islandica* shells

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ABSTRACT

Understanding past seasonal temperature variability in the ocean is essential to evaluate the effects of future climate change on marine ecosystems. Here, we estimate seasonal water temperature amplitudes from stable oxygen isotope ($\delta^{18}O_{shell}$) values of fossil shells of *Arctica islandica* (assuming $\delta^{18}O_{water} = +0.9 \pm 0.1$‰ V-SMOW). Specimens were collected from three Pleistocene successions (Emilian and Sicilian substages of the Calabrian) in Central and Southern Italy (i.e., Rome, Lecce and Sicily). Biostratigraphic analyses from Rome Quarry deposits indicate an age between 1.6 and 1.2 Ma, whereas Sicily and Lecce successions are slightly more recent (between 1.1 and 0.62 Ma). Prior to carbonate geochemical analysis, we checked the shells for potential diagenetic alterations (e.g., from aragonite to calcite) using confocal Raman microscopy. $\delta^{18}O_{shell}$ transects indicate an annual temperature amplitude of about 3 °C during the Early Pleistocene. This is in sharp contrast to reconstructions based on faunal assemblages, according to which the simultaneous occurrence of boreal and warm-water species in the Calabrian Mediterranean Sea suggests a much higher seasonality (ca. 10 °C). The low seasonality and the relatively cold water (9–10 °C) indicate the outcrops represent colder climatic conditions compared to modern times, and suggest the occurrence of a maximum glacial phase.

1. Introduction

Understanding of the feedback between ecosystems, climate variability and changing environmental conditions are a prerequisite for forecasting ecosystem responses to long-term climate fluctuations (e.g., Gian-Reto, 2010; Huntley and Scarponi, 2012, 2015; Kowalewski et al., 2015; Wittmer et al., 2014). For instance, temperature variations of 1 °C are reported to shift ecological zones latitudinally by 160 km (Thuiller, 2007). These shifts, in turn, are expected to cause modifications in the community structure and the possible formation of non-analogous communities resulting in extirpation/extinction and migration of taxa (e.g., Keith et al., 2009).

In addition, assessing past dynamics of seasonality and temperature through phases of strong natural climate change (as the Pleistocene epoch) is important because global climate changes are often paced by seasonality changes "related to periodicities in the Earth's orbital elements" (Broecker, 2000). Furthermore, high-resolution (seasonal) climate data of the past are also essential for climate-system modeling. As models used to predict future climate trends have to be tested against already documented past climate dynamics to provide more accurate and reliable future projections. Hence, to improve reliability of model climate forecast about the effects and timing of global change in the future is pivotal to understand the natural long-term variability of environmental and climatic variables such as temperature and seasonality in the past. So far, less has been done on high-resolution Mediterranean climate (seasonality and ocean water temperatures) reconstructions during the Early Pleistocene (e.g., Thunell, 1979a; Crippa et al., 2016). The easily accessible marine macrobenthic fossil record, accumulated during Pleistocene astronomically-driven climate oscillations, represents a valuable archive to investigate past climates and its influence on marine settings.

The Mediterranean basin is a key area within the global change context (Giorgi and Lionello, 2008), as it is "one of the most important hotspots in future climate change projections" (Giorgi, 2006). According to Bethoux et al. (1999), the Mediterranean represents "a miniature ocean in relation to climate" and therefore it is well suited to facilitate our understanding of global climatic patterns. Moreover, the Mediterranean Sea provides valuable services to mankind (e.g., coastal habitats, fisheries) and plays a significant role in modern atmosphere dynamics (e.g., North Atlantic Oscillation, NAO).

Through the Pleistocene (2.58 Ma to 11.7 ka) - the most recent glacial period - the progressive climatic deterioration (i.e., global cooling) responsible for southward migration of the arctic polar front to mid

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