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High-resolution paleoclimatology of the Santa Barbara Basin during the Medieval Climate Anomaly and early Little Ice Age based on diatom and silicoflagellate assemblages in Kasten core SPR0901-02KC

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ABSTRACT

Diatom and silicoflagellate assemblages documented in a high-resolution time series spanning 800 to 1600 (AD) in varved sediment recovered in Kasten core SPR0901-02KC (34°16.845′ N, 120°02.332′ W, water depth 588 m) from the Santa Barbara Basin (SBB) reveal that SBB surface water conditions during the Medieval Climate Anomaly (MCA) and the early part of the Little Ice Age (LIA) were not extreme by modern standards, mostly falling within one standard deviation of mean conditions during the pre anthropogenic interval of 1748–1900. No clear differences between the character of MCA and the early LIA conditions are apparent. During intervals of extreme droughts identified by terrigenous proxy scanning XRF analyses, diatom and silicoflagellate proxies for coastal upwelling typically exceed one standard deviation above mean values for 1748–1900, supporting the hypothesis that droughts in southern California are associated with cooler (or La Niña-like) sea surface temperatures (SSTs). Increased percentages of diatoms transported downslope generally coincide with intervals of increased siliciclastic flux to the SBB identified by scanning XRF analyses. Diatom assemblages suggest only two intervals of the MCA (at ~897 to 922 and ~1151–1167) when proxy SSTs exceeded one standard deviation above mean values for 1748 to 1900. Conversely, silicoflagellates imply extreme warm water events only at ~830 to 860 (early MCA) and ~1360 to 1370 (early LIA) that are not supported by the diatom data. Silicoflagellates appear to be more suitable for characterizing average climate during the 5 to 11 year-long sample intervals studied in the SPR0901-02KC core than diatoms, probably because diatom relative abundances may be dominated by seasonal blooms of a particular year.
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1. Introduction

1.1. Medieval Climate Anomaly and the Little Ice Age

The Medieval Climate Anomaly (MCA) and Little Ice Age (LIA) represent the largest broad-scale deviations of climate change during the last several thousand years prior to the recent, anthropogenically-derived warming (Mann and Jones, 2003; Mann et al., 2009). The MCA was anomalously warm across much of the planet, particularly in the North Atlantic and Europe, with the PAGES (Past Global Changes) 2k Consortium (2013) recently concluding that the period from 830 to 1100 was generally characterized by sustained warmth throughout the Northern Hemisphere. Although the PAGES 2k Consortium (2013) acknowledged that the cooler conditions that marked the LIA did not begin synchronously across the globe, they identified periods of strong volcanic and negative solar forcing of climate at 1310 to 1351, 1431 to 1520, 1581 to 1610, 1641 to 1700, and 1791 to 1820 that resulted in widespread cooling of global climate.

On the other hand, there is evidence that cool La Niña-like conditions in the eastern Pacific were associated with dry conditions over western North America (Kennett and Kennett, 2000; Cobb et al., 2003; Mann and Jones, 2003; Graham et al., 2007). Similarly, Kennett and Kennett (2000), Graham et al. (2007), and others have linked warmer sea surface temperatures (SSTs) in the eastern Pacific during the LIA with an increased expression of more positive El Niño Southern Oscillation (ENSO) conditions and increased precipitation throughout much of western North America.

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Evidence of megadroughts during the MCA and during other periods of extended La Niña-like conditions in western North America comes from many sources (see Graham et al., 2007). Cook et al. (2004) used a network of 835 tree-ring chronologies in a 2.5° grid of 286 points covering most of North America to reconstruct drought histories for North America during the past 1200 years. They documented an epic drought that extended throughout much of the West between 900 and 1300, a period broadly consistent with the MCA. Tree ring records from California to Alberta compiled by MacDonald and Case (2005) and other numerous records of precipitation (summarized by Graham et al., 2007) support the presence of La Niña-like winter Northern Hemisphere circulation patterns during the MCA. Similarly, Herweijer et al. (2006) applied an atmospheric general circulation model to the tree-ring database and the tropical Pacific coral SST record of Cobb et al. (2003) to argue that the epic North American droughts of the MCA were caused by La Niña-like conditions in the tropical Pacific. Recently, however, Emile-Geay et al. (2012) compiled a Niño-3.4 index for the past millennium using various proxy data from the equatorial Pacific that displayed no evidence for systematic change in El Niño character between the MCA and LIA.

The relationships between western drought and La Niña-like conditions largely stem from the association of anomalously low SSTs with anomalously high pressure throughout the eastern Pacific, extending from the tropical Pacific to the Gulf of Alaska (Herweijer et al., 2006). However, there are very few SST records in the eastern Pacific detailed enough to evaluate this hypothesis. In order to evaluate the extent and cause of climate change during the MCA and LIA, well dated, high-resolution records of a wide range of proxies sensitive to seasonal changes in both sea surface temperature (SST), and precipitation are needed.

1.2. Regional setting

Waters off the coast of California lie near the modern-day boundary between the subarctic and subtropical gyres of the North Pacific, where they are influenced by the strength and character of the California Current (Huyer, 1983). During much of the spring and summer, juxtaposition of the North Pacific High (NPH) and the North American Low results in strong, persistent northwesterly winds, which induce coastal upwelling and lead to high biologic productivity (Hood et al., 1999). Winters are influenced by a southward migration of the NPH from ~40°N to ~30°N, and the southward migration of the jet stream from ~48°N to an average position of 38°N due to a strengthening of the Aleutian Low (Bograd et al., 2002). Winters are typically mild, wet, and stormy, with an alternation of southwesterly winds and upwelling-favorable northwest winds (Huyer, 1983; Harms and Winant, 1998). El Niño events and positive Pacific Decadal Oscillation (PDO) phases are associated with an enhanced Aleutian Low and strengthened cyclonic circulation in the North Pacific that result in greater poleward heat transport, higher SSTs, and a depression of isotherms throughout the eastern Pacific.

Santa Barbara Basin (SBB), just southeast of Point Conception, is located on the inshore side of the low salinity core of the California Current (Fig. 1). The combination of the geostrophic flow of the California Current offshore and upwelling favorable winds result in a shallow thermocline and high productivity year round. Strong northerly winds associated with intensification of the offshore California Current induce coastal upwelling throughout the year as well, but these are most intense in spring and summer. During other seasons of the year, the combination of upwelling favorable wind events and the Southern California Countercurrent result in cyclonic circulation over the basin (Harms and Winant, 1998). This cyclonic mixes warmer waters from the south with recently upwelled waters. During the summer and early fall, warm waters from the south are transported into the SBB by the Southern California Countercurrent. The northward-flowing Davidson Current is a coastal countercurrent extending northward to ~40°N (Hendershott and Winnant, 1996; Di Lorenzo, 2003) that is active in the winter. Average SSTs in the SBB range from about 13 °C in the spring to 18 °C in the late summer, although higher (or lower) SSTs can occur seasonally during El Niño (La Niña) events (California Cooperative Oceanic Fisheries Investigations database http://www.calcofi.org/newhome/data/database/database.htm).

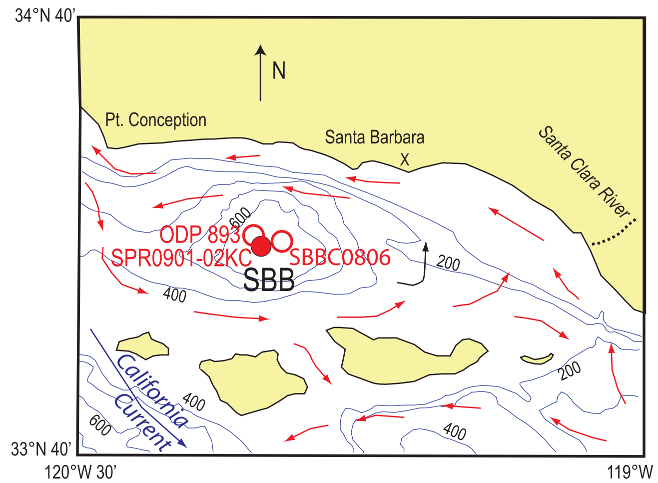

Fig. 1. Location map of the Santa Barbara Basin (SBB) showing the cores studied, bathymetry in meters, and general surface circulation.

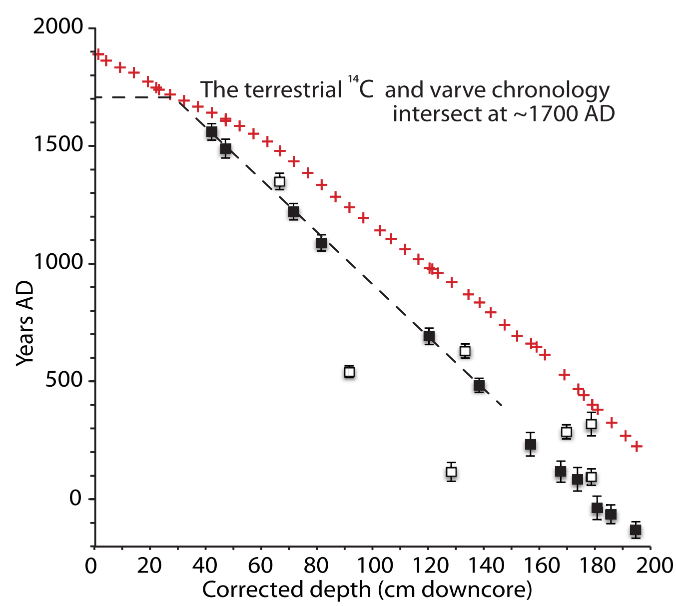

Fig. 2. Chronology of the SBB record has been refined by a high-resolution ^{14}C study that resolved the varve and radiocarbon chronology differences of the last 2000 years (Hendy et al., 2013). Comparison of traditional varve-count (red crosses, Schimmelmann et al., 2006) and terrestrial ^{14}C dates (squares, calibrated using Intercal09) generated from seeds, leaves, twigs and charcoal demonstrates inaccuracies in the varve chronology. Closed squares represent samples used in the new age model. Open squares display samples that fall off the age-depth line and were removed from the age model. Core depth has been corrected by the removal of instantaneous sedimentary events such as turbidites and flood layers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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