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Vegetation response to southern California drought during the Medieval Climate Anomaly and early Little Ice Age (AD 800–1600)

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A B S T R A C T

High-resolution studies of pollen in laminated sediments deposited in Santa Barbara Basin (SBB) core SPR0901-02KC reflect decadal-scale fluctuations in precipitation spanning the interval from AD 800–1600. From AD 800–1090 during the Medieval Climate Anomaly (MCA) SBB sediments were dominated by xeric vegetation types (drought-resistant coastal sagebrush and chaparral) implying reduced precipitation in the southern California region. Drought-adapted vegetation abruptly decreased at AD 1090 and was rapidly replaced by mesic oak (*Quercus*) woodlands associated with an increased pollen flux into the basin. After a mesic interval lasting ~100 years, pollen flux and the relative abundance of *Quercus* pollen dropped abruptly at AD 1200 when the rapid rise of chaparral suggests a significant drought similar to that of the MCA (~AD 800–1090). This brief resurgence of drought-adapted vegetation between AD 1200–1270 marked the end of the MCA droughts. A gradual increase in mesic vegetation followed, characterizing cool hydroclimates of the Little Ice Age (LIA) in coastal southern California.

The presence of xeric vegetation in SBB coincides with major drought events recorded in tree rings and low lake levels elsewhere in California except for the brief drought between AD 1130–1160. Correlative diatom and terrigenous sediment input proxy records from SBB are largely supportive of the pollen record predominantly linking the MCA with drought and La Niña-like conditions and the LIA with wetter (more El Niño-like) conditions. Differences between paleoclimate proxies (pollen, diatoms, and terrigenous sediment) in SBB exist, however, possibly reflecting the temporal and spatial differences in the generation of each proxy record, as well as their individual sensitivity to climate change.

1. Introduction

1.1. California vegetation and climate

Ecologically and economically damaging extreme weather events – drought and severe storms – characterize the Mediterranean southern California climate (summer drought/winter wet). Predicted future changes in mean annual precipitation and temperature seasonality will likely severely impact western North America tree populations (McLaughlin and Zaveleta, 2012). Some bioclimate studies suggest that regional-scale shifts in vegetation are already occurring. Future water deficits are projected to result in widespread changes in the distribution and composition of southern California ecosystems – the reduction of oak (*Quercus*) woodlands from their modern range size and displacement, most likely, closer to water (Kueppers, 2005; Sork et al., 2010; McLaughlin and Zaveleta, 2012). However, the distinctive, endemic, drought-adapted vegetation that now characterizes southern California (Axelrod, 1977) has evolved over millions of years of hydroclimate change and may be quite robust in its response to an anthropogenically-forced warmer world.

Regional records of climatically-driven changes in vegetation can serve as templates for the response of southern California ecosystems to future anthropogenic-related climate change. Pollen-based reconstructions of California climate vary in temporal resolution and scope. During the last interglacial (MIS 5e), pollen deposited in the Santa Barbara Basin (SBB; ODP Hole 893A) from drought-adapted, Mediterranean type vegetation was comparable to or even more expansive than present (Heusser, 1995; Friddell

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et al., 2002). Low resolution pollen-based reconstructions (ODP Hole 893B) suggest that drought-adapted vegetation also expanded during the Medieval Climate Anomaly (MCA) and shifted gradually toward more mesic *Quercus/Pinus* woodlands and forests during the Little Ice Age (LIA) at ~ AD 1300–1400 (Heusser, unpublished). Other paleohydrographic proxies from the American southwest also indicate a pattern of long-term drought during the MCA that extended until ~ AD 1360 (Kennett and Kennett, 2000; Cook et al., 2004, 2010; MacDonald and Case, 2005; Graham et al., 2007).

Here we present a high resolution, continuous pollen record from AD 800–1600 for south coastal California from a new core (Kasten core SPR0901-02KC) collected in 2009 from the SBB. Our unique, high (~5-year) resolution, coeval terrestrial and marine climate proxy data reveal a complex MCA-LIA transition (~AD 1100–1300). In coastal southern California from ~AD 1100–1200, mesic conditions interrupted the prevailing drought. We posit that different paleoproxies have contrasting limitations related to the temporal resolution of the resulting paleoclimate record and differing degrees of sensitivity to different aspects of climate such as temperature, seasonality, and mean annual precipitation.

1.2. Regional setting

Tied to large-scale changes in northeast Pacific atmospheric and oceanographic circulation, the Mediterranean climate of the southern California margin is highly seasonal. Precipitation typically occurs in winter when the North Pacific High (NPH) is relatively weak, allowing the subpolar low-pressure systems to migrate southward from the northwest toward California (Haston, 1997). Extreme regional rainfall events, on the other hand, are associated with 'atmospheric rivers' produced by a strong southern branch of the polar jet that tracks warm moist air from the tropics near Hawaii (Browning and Pardoe, 1973; Dettinger, 2011). These extreme precipitation conditions are more prevalent during El Niño events (Andrews et al., 2004) and play an important economic role by filling regional reservoirs. Rainfall is highly coherent throughout the region, as almost all the annual precipitation is produced during large, winter storms. The Santa Barbara coastal region (Fig. 1) receives relatively high rainfall (mean annual precipitation is ~389 mm, but ranges from 250 to > 750 mm). This creates an initial brief, intense, sediment-laden discharge to Santa Barbara Channel from the short, steep, coastal watersheds (Nezlin and Stein, 2005) that is followed by delivery of high amounts of suspended sediment from the readily-eroded, weak sedimentary rocks of the Santa Clara and Ventura River drainage basins in the western Transverse Ranges. Dry atmospheric conditions are generally associated with upper level ridging and above normal pressures as the NPH strengthens and migrates poleward in spring-summer (Haston, 1997).

Surface ocean waters of SBB are primarily influenced by the strength and character of equatorward-flowing California Current (CC). Seasonal poleward movement of the NPH pressure system results in northwesterly winds that induce coastal upwelling and associated fog, which are accompanied by moderate coastal air temperatures and increased effective moisture onshore during spring and summer (Fischer et al., 2009). Additionally shade from persistent clouds near the coast reduces annual drought stress by 22–40% (Fischer et al., 2009). By late summer-early fall surface ocean waters reach their highest temperatures in SBB, as the sea surface height gradient from San Diego to Point Conception, north of SBB, increases driving the Southern California Countercurrent (Lynn and Simpson, 1987). Thus ocean surface temperatures in the SBB do not follow the typical seasonal temperature cycle ranging from ~13 °C in the spring to ~18 °C in late summer (Thunell, 1998; Hendy, 2004; Barron et al., 2010).

On the coastal plain up to ~300 m elevation, average air temperature ranges from ~20 °C in summer to ~9° C in winter. At higher elevations in the Santa Ynez Mountains, summer air temperatures average ~10 °C and winters are mild (7 °C). Average annual precipitation increases upslope from ~451 mm in Santa Barbara to ~550 mm in chamise chaparral, ~650 mm in lower montane oak woodland/forest, and ~1200 mm on montane peaks (~1200–1400 m elevation; Wahl, 2003). Furthermore, fog drip at these higher elevations can reduce drought stress by 20–36% (Fischer et al., 2009). On the highest peaks, winter precipitation may fall as snow, with snowfields lasting until early June (Elford, 1974) providing a spring-early summer source of moisture for vegetation.

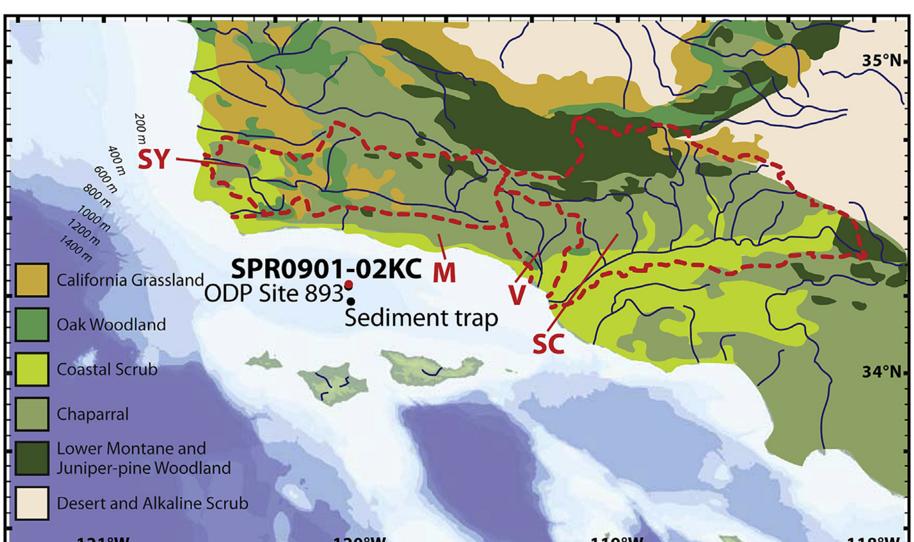

Fig. 1. Map of the Santa Barbara Basin (SBB) showing the location of core SPR0901-02KC, the dominant vegetation types in nearby coastal regions (http://www.californiaherps.com/images/vegetationmapjeaster.jpg; see shading in key), and the drainage basins of rivers emptying into the SBB outlined by red dashed lines (M = Santa Ynez Mountain Range streams; SY = Santa Ynez River, V = Ventura River; SC = Santa Clara River). Shaded bathymetry is in 200 m increments.