ScienceDirect

Quaternary Science Reviews
Volume 46, 16 July 2012, Pages 57-65

A 9170-year record of decadal-to-multi-centennial scale pluvial episodes from the coastal Southwest United States: a role for atmospheric rivers?

Matthew E. Kirby [a], Susan R.H. Zimmerman [b 1], William P. Patterson [c 2], Jose J. Rivera [a 3]

Show more

Share Cite

https://doi.org/10.1016/j.quascirev.2012.05.008
Get rights and content

Abstract

A well-dated, 9170 calendar year before present (cal yr BP) paleohydrologic reconstruction is presented from Lower Bear Lake in the San Bernardino Mountains of the coastal southwest United States. This new multi-proxy record is characterized by alternating organic-rich/carbonate-rich sediment units, interpreted to reflect hydrologically-forced changes in the lake's depositional environment. Our interpretation of the proxy data indicates nine decadal-to-multi-centennial pluvial episodes (PE) over the past 9170 cal yr BP. Of these nine inferred pluvials, five are interpreted as more pronounced based on their combined proxy interpretations: (PE-V) 9170?–8250, (PE-IV) 7000–6400, (PE-III) 3350–3000, (PE-II) 850–700, and (PE-I) 500–476 (top of core) cal yr BP. The Lower Bear Lake record indicates that the San Bernardino Mountains, source region for the Mojave River and its terminal playa, was wet during the same periods (within dating errors), to several of the major pluvials proposed from the lakes in the sink of the Mojave River. Our comparison extends north also to Tulare Lake, which drains the southcentral-western Sierra Nevada Mountains. This temporally and spatially coherent signal indicates that a similar climate forcing acted to increase regional wetness at various times during the past 9170 cal yr BP. As originally proposed by Enzel, Ely, and colleagues (e.g., Enzel et al., 1989; Enzel, 1992; Ely et al., 1994; Enzel and Wells, 1997), we too contend that Holocene pluvial episodes are associated with changing the frequency of large winter storms that track across a broad region at decadal-to-multi-centennial timescales. We build upon their hypothesis through the addition of new and better-dated site comparisons, recent advances in the understanding of atmospheric rivers, and improved knowledge of the ocean–atmosphere dynamics that caused the early 20th century western United States pluvial.

Highlights

► New Holocene lake sediment core from coastal southwest United States. ► Record captures nine centennial scale Holocene pluvial episodes over 9170 cal yrs. ► Validates and Improves Mojave Desert

Holocene lake timing. ► Spatially coherent signal suggests a regional hydrologic change. ► Increase in atmospheric river storm activity proposed for pluvials.

Introduction

Southern California (or the coastal southwest United States) is subject to a variety of natural hazards. Besides the earthquakes, fires, and perennial water shortages, the coastal southwest United States (US) is also impacted occasionally by extreme storms, which promote large floods, coastal erosion, and landslides (Enzel, 1992; Ely et al., 1993; Enzel and Well, 1997; Westerling et al., 2003; Skinner et al., 2008; Dettinger, 2011). So significant is this risk that the USGS has created the ARkStorm Project (Porter et al., 2011). This project aims to prepare California for a future storm(s) on the scale of the disastrous winter of 1861–1862 A.D. Unfortunately, our knowledge of pre-measurement wetter-than-average climate episodes at decadal-to-multi-centennial timescales (i.e., pluvials), including their frequency, timing, and duration, is not well understood for the coastal southwest US, especially into the mid-to-early Holocene (Fye et al., 2004; Hidalgo, 2004; Woodhouse et al., 2005; Cook et al., 2007, 2011; Herweijer et al., 2007). It is now well-documented that the largest flood-producing precipitation events in the coastal southwest are associated with atmospheric river (AR) storms (Ralph et al., 2006; Neiman et al., 2008; Leung and Qian, 2009; Ralph and Dettinger, 2011). The abrupt topography of the coastal southwest enhances the hydrologic impact of AR storms via rapid orographic uplift and consequent moisture release (Neiman et al., 2008). This rapid de-watering generates copious single storm precipitation amounts that are rivaled only by the hurricanes of the American southeast (Dettinger et al., 2011).

Inland from the coastal southwest US is the arid Mojave Desert. Today, the Mojave region is dotted with ephemeral lakes, many of which are fed by the Mojave River – a river sourced in the mountains of the coastal southwest US (i.e., San Bernardino Mountains). A wealth of research using stranded beaches, playa lake cores, and exposed lacustrine sediments from the Mojave Desert has generated important insight to episodes of wetter-than-average Holocene climate interpreted to reflect more frequent Pacific storms and their resultant extreme floods (e.g., Enzel et al., 1989; Enzel and Wells, 1997; Wells et al., 2003; Miller et al., 2010). The length of the transmitting ephemeral channel from its source (the mountains of the coastal southwest US) to its sink (modern playa-lakes fed by the Mojave River) produces a natural filter that excludes records of events below the minimum discharge required to produce and sustain Mojave lakes for more than a few months (Enzel, 1992; Enzel and Wells, 1997). The ocean–atmosphere conditions required to form and sustain lakes in the sink of the Mojave River are associated with more frequent and larger magnitude winter storms as well as their interannual seasonal persistence (Enzel et al., 1989; Enzel, 1992; Ely et al., 1994; Enzel and Wells, 1997; Redmond et al., 2002).

Here, we present a 9170 calendar years before present (hereafter cal yr BP), paleohydrologic reconstruction from Lower Bear Lake in the San Bernardino Mountains of the coastal southwest US. Because Lower Bear Lake is located at the source region for the Mojave River and its terminal playa, Lower Bear Lake presents a unique opportunity to compare and contrast pluvial episode timing, duration, and frequency between source and sink. To evaluate our new record, we compare also the Lower Bear Lake pluvials to comparably dated sites across the coastal southwest US (e.g., Lake Elsinore, Dry Lake, and Tulare Lake).

Section snippets

Setting and background

Lower Bear Lake is located in the east–west trending San Bernardino Mountains within the Big Bear Valley water shed, approximately 160 km northeast of Los Angeles (Fig. 1). For clarity, the term Lower Bear Lake is used in a public land survey in 1857 A.D. for the small lake within Big Bear Valley before the construction of the dam in 1884 A.D. (Leidy, 2003). Modern bathymetry reveals a distinct depression in the near-center of modern Big Bear Reservoir, representing the original Lower Bear Lake …

Methods

A single drive, 4.5 m-long sediment core (BBLVC05-1) was extracted from Lower Bear Lake in 2005. The core was split, described, digitally photographed, and sub-sampled in the CSUF Paleoclimatology and Paleotsunami Laboratory. Mass magnetic susceptibility, LOI 550 °C (% total organic matter), and LOI 950 °C (%total carbonate) were determined at 1 cm contiguous intervals (e.g., 0–1 cm = 0.5 cm, 1–2 cm = 1.5 cm etc.) following the same protocol as Kirby et al. (2007). Counts per 1 g dry sediment…

Results and proxy interpretations

Of the 33 AMS ^{14}C dates obtained from BBLVC05-1, 23 were used to construct an age model (Table 1). All dates were corrected to calibrated years before present using the online CALIB Program version 6.0.0 and the intcal09.14c calibration data set (Stuiver and Reimer, 1993; Reimer et al., 2009). Ten dates were dismissed for several reasons including coupled bulk-discrete samples with different ages (n=2), coupled discrete ages on different materials with different ages (n=4), stratigraphic…

Source to sink

A series of papers by Enzel and others (e.g., Enzel et al., 1989, 1992; Enzel, 1992; Enzel and Wells, 1997) investigate the modern and modeled Holocene atmospheric conditions necessary to create and maintain lakes in the sink of the Mojave River (Fig. 1). Their work is relevant particularly to the Lower Bear Lake record because the San Bernardino Mountains provide the source of water required to form and maintain Holocene lakes in the Mojave River sink (Fig. 1). Specifically, lakes do not form…

Conclusions

We have demonstrated that Lower Bear Lake, in the San Bernardino Mountains of the coastal southwest, experienced several major pluvial episodes over the last 9170 cy BP. These pluvial episodes correspond well (within chronological uncertainties) with pluvials inferred from the lakes in the Mojave River sink, whose source is precipitation (especially wintertime) falling in the San Bernardino Mountains (Fig. 1). In addition, good evidence from several lakes in the coastal southwest US with…

Acknowledgments

Special thanks to the Big Bear Municipal Water District for core acquisition and project funds, especially Erika Saad and Mike Stephenson; thanks to Christine Hiner, Pedro Monarrez, Lauren Mirallegro de Rivera, and Dinka Besic for various lab analyses; thanks to Michael Blazevic for the bathymetric map; the authors also thank two anonymous reviewers for insightful and helpful reviews. This work was performed in part under the auspices of the U.S. Department of Energy by Lawrence Livermore…

Recommended articles

References (63)

E.R. Cook *et al.*
North American drought: reconstructions, causes, and consequences
Earth-Science Reviews (2007)

O.K. Davis
Pollen analysis of Tulare lake, California: great basin-like vegetation in central California during the full-glacial and early Holocene
Review of Palaeobotany and Palynology (1999)

Y. Enzel *et al.*
Short-duration Holocene lakes in the Mojave river drainage basin, southern California
Quaternary Research (1992)

Y. Enzel *et al.*
Extracting Holocene paleohydrology and paleoclimatology information from modern extreme flood events: an example from southern California
Geomorphology (1997)

M.E. Kirby *et al.*
Mid-Wisconsin sediment record from Baldwin Lake reveals hemispheric climate dynamics (Southern CA, USA)
Palaeogeography, Palaeoclimatology, and Palaeoecology (2006)

P.A. Meyers *et al.*
Lacustrine organic geochemistry – an overview of indicators of organic matter sources and diagenesis in lake sediments
Organic Geochemistry (1993)

D.M. Miller *et al.*
Holocene landscape response to seasonality of storms in the Mojave Desert
Quaternary International (2010)

R.A. Minnich
Snow levels and amounts in the mountains of Southern California
Journal of Hydrology (1986)

R.M. Negrini *et al.*
The Rambla highstand shoreline and the Holocene lake-level history of Tulare Lake, California, USA
Quaternary Science Reviews (2006)

L.A. Owen *et al.*
Numerical dating of a Late Quaternary spit-shoreline complex at the northern end of Silver Lake playa, Mojave Desert, California: a comparison of the applicability of radiocarbon, luminescence, terrestrial cosmogenic nuclide, electron spin resonance, U-series and amino acid racemization methods
Quaternary International (2007)

View more references

Cited by (58)

Temporal and geographic extent of the late Holocene dry period in the central Great Basin, USA

2023, Quaternary Science Reviews

Show abstract

High-resolution interannual precipitation reconstruction of Southern California: Implications for Holocene ENSO evolution

2021, Earth and Planetary Science Letters

Show abstract

Holocene paleoclimate change in the western US: The importance of chronology in discerning patterns and drivers

2020, Quaternary Science Reviews

Show abstract

Late Holocene hydroclimate changes in the eastern Sierra Nevada revealed by a 4600-year paleoproduction record from June Lake, CA

2020, Quaternary Science Reviews

> *Citation Excerpt :*
> …The LHDP is also well represented in many of these basins (e.g., Benson et al., 2002; Mensing et al., 2004; Osleger et al., 2009; Mensing et al., 2013, Zimmerman et al., accepted). The Neopluvial and LHDP have also been observed in meadows of the eastern Great Basin (e.g., Mensing et al., 2013; Wahl et al., 2015), and in lake records from southern California (Kirby et al., 2010, 2012, 2014; Dingemans et al., 2014) (Fig. 9). All these records from across California and Nevada are consistent with our interpretations that the Neopluvial is represented at June Lake by Zone 1, and that Zone 2 encompasses the LHDP.…

Show abstract

Clay minerals in the late Quaternary sediment of Tulare Lake, California: Implications for climate change, weathering, and erosion processes

2019, International Journal of Sediment Research

> *Citation Excerpt :*
> …To better understand and predict the future change, of particular significance is insight into the past hydroclimatic variation. By investigating the sediment in the widespread lakes of the southwestern U.S., numerous palaeoclimate studies have been done over the last few decades with the aim of reconstructing climate changes since the last glacial period (Anderson et al., 2016; Bacon et al., 2006; Benson, 1999; Birks & Birks, 2006; Blunt & Negrini, 2015; Kirby et al., 2006; Kirby et al., 2007; Kirby et al., 2012; Kirby et al., 2013; Kirby et al., 2015; Negrini et al., 2006; Noble et al., 2016; Reheis et al., 2015; Street et al., 2012). Due to the geological and tectonic complexity in California, however, climate records revealed different temporal moisture patterns.…

Show abstract

Retention of alluvial sediment in the tidal delta of a river draining a small, mountainous coastal watershed

2019, Continental Shelf Research

Show abstract

View all citing articles on Scopus

1 Tel.: +1 925 422 8462.

2 Tel.: +1 306 966 5691.

3 Tel.: +1 657 278 3303.

View full text

Copyright © 2012 Elsevier Ltd. Published by Elsevier Ltd. All rights reserved.

ELSEVIER

All content on this site: Copyright © 2024 Elsevier B.V., its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the Creative Commons licensing terms apply.

RELX™