Available online at www.sciencedirect.com
ScienceDirect
Marine Micropaleontology 62 (2007) 115–139
MARINE MICROPALEONTOLOGY
www.elsevier.com/locate/marmicro

# Solar forcing of Gulf of California climate during the past 2000 yr suggested by diatoms and silicoflagellates

John A. Barron*, David Bukry

*U.S. Geological Survey, MS910, Menlo Park, CA, 94025 United States*

Received 20 April 2006; received in revised form 3 August 2006; accepted 4 August 2006

**Abstract**

High-resolution records of the past 2000 yr are compared in a north–south transect (28° N to 24° N) of three cores from the eastern slopes of the Guaymas, Carmen, and Pescadero Basins of the Gulf of California (hereafter referred to as the "Gulf"). Evenly-spaced samples from the varved sediments in each core allow sample resolution ranging from ~ 16 to ~ 37 yr.

Diatoms and silicoflagellates capture the seasonal variation between a late fall to early spring period of high biosiliceous productivity, that is driven by northwest winds, and a summer period of warmer, more stratified waters during which these winds slacken and/or reverse direction (monsoonal flow). As these winds decrease, tropical waters enter the Gulf and spread northward. Individual samples represent a composite of 7 to 23 yr of deposition and are assumed to record the relative dominance of the winter vs. summer floral components.

Intervals of enhanced summer incursion of tropical waters, alternating with periods of increased late fall to early spring biosiliceous productivity are recorded in all three cores. Regularly spaced cycles (~ 100 yr duration) of *Octactis pulchra*, a silicoflagellate proxy for lower SST and high productivity, and *Azpeitia nodulifera*, a tropical diatom, occur between ~ A.D. 400 and ~ 1700 in the more nearshore Carmen Basin core, NH01-21 (26.3° N), suggesting a possible solar influence on coastal upwelling.

Cores BAM80 E-17 (27.9° N) and NH01-26 (24.3° N) contain longer-duration cycles of diatoms and silicoflagellates. The early part of Medieval Climate Anomaly (~ A.D. 900 to 1200) is characterized by two periods of reduced productivity (warmer SST) with an intervening high productivity (cool) interval centered at ~ A.D. 1050. Reduced productivity and higher SST also characterize the record of the last ~ 100 to 200 yr in these cores. Solar variability appears to be driving productivity cycles, as intervals of increased radiocarbon production (sunspot minima) correlate with intervals of enhanced productivity. It is proposed that increased winter cooling of the atmosphere above southwest U.S. during sunspot minima causes intensification of the northwest winds that blow down the Gulf during the late fall to early spring, leading to intensified overturn of surface waters and enhanced productivity.

A new silicoflagellate species, *Dictyocha franshepardii* Bukry, is described and illustrated.


*Keywords:* Holocene; Gulf of California; Upwelling; Diatoms; Silicoflagellates; Monsoon; Medieval climate anomaly; Little Ice Age; Solar forcing; Sea surface temperature

## 1. Introduction

### 1.1. Gulf of California climatology

The climate of the Gulf of California region (Fig. 1) is characterized by a mid-latitude winter phase and a

* Corresponding author. Tel.: +1 650 3294971; fax: +1 650 3295203.

*E-mail address:* jbarron@usgs.gov (J.A. Barron).

0377-8398/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.marmicro.2006.08.003

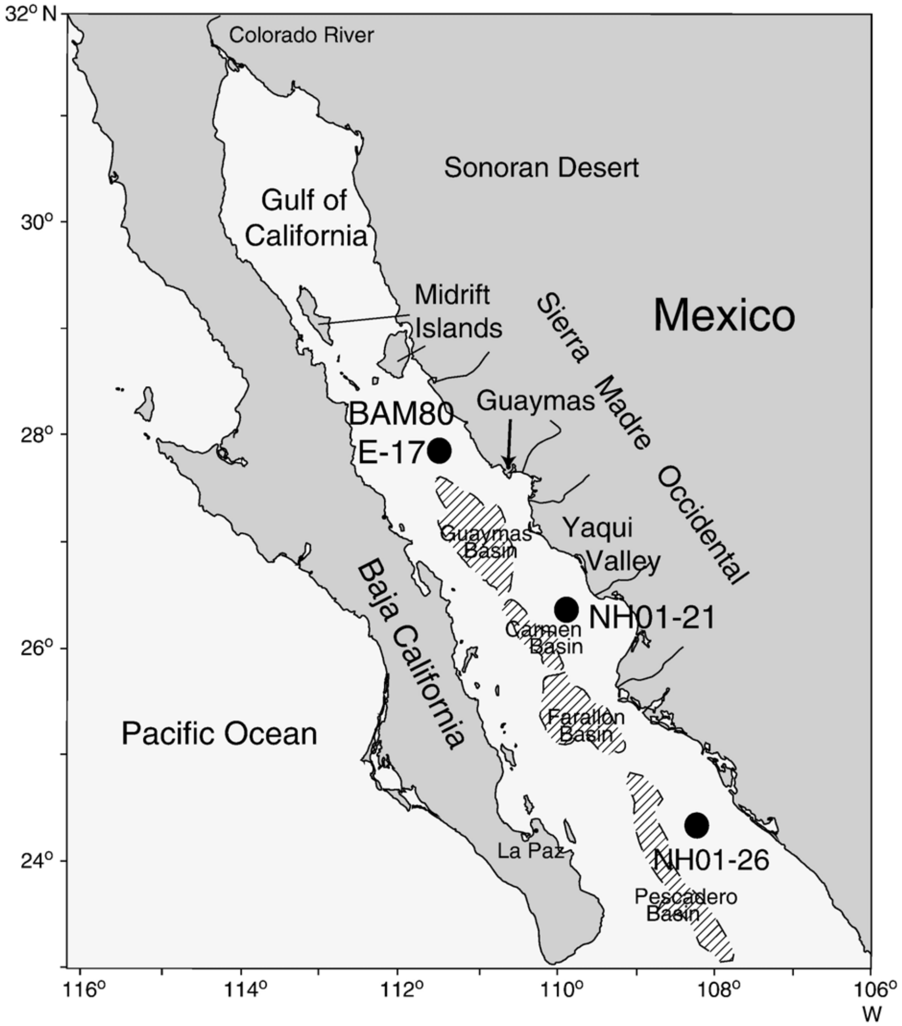


Fig. 1. Location of cores BAM80 E-17, NH01-21, and NH0-26 in the Gulf of California. Areas marked by diagonal lines represent closed basins below the 1500 m depth contour.

subtropical summer or monsoonal phase (Mitchell et al., 2002). During late fall to early spring (November to March), prevailing surface winds are from the northwest, blowing down the axis of the Gulf and causing an overturn of the water column. The resulting upwelling of nutrients leads to enhanced phytoplankton production, mainly on the eastern (mainland) side of the Gulf (Bandon-Dangon et al., 1991). During the winter, sea surface temperatures (SST) typically range from ~ 18 °C in the northern Gulf to ~ 23 °C in the southernmost Gulf (Soto-Mardones et al., 1999), a strong north–south gradient. Late spring to early fall (May to October) are characterized by a weakening of the winds and an influx of tropical surface waters from the Pacific, (Soto-Mardones et al., 1999; Pares-Sierra et al., 2002). Sea surface temperatures typically rise to >28 °C throughout the Gulf, as tropical waters move northward up the eastern (mainland) side of the Gulf (Marinone, 2003).

During El Niño events, there is a greater advection of tropical waters into the Gulf, as northwest winds slacken earlier (March) in the spring and resume later in the fall (November) (Thunell, 1998; Soto-Mardones et al., 1999).

Kahru et al. (2004) studied 6 yr (1997–2003) of satellite-generated chlorophyll *a* data and concluded that chlorophyll *a* concentration and phytoplankton primary production showed variability on a multitude of scales. Although the annual cycle was the dominant mode of variability, a semiannual cycle with chlorophyll maxima during the spring and fall transitions was also apparent. Douglas et al. (in press) observed that except in summer, pigment concentrations measured on the eastern side of