Available online at www.sciencedirect.com
SCIENCE DIRECT®
Continental Shelf Research 25 (2005) 397–417
CONTINENTAL SHELF RESEARCH
www.elsevier.com/locate/csr

Local wind forcing of the Monterey Bay area inner shelf

Patrick T. Drake[a,*], Margaret A. McManus[b], Curt D. Storlazzi[c]

[a]*Long Marine Lab., University of California, Santa Cruz, CA, USA*
[b]*Department of Oceanography, University of Hawaii at Manoa, Honolulu, HI, USA*
[c]*US Geological Survey, Coastal and Marine Geology Program, Pacific Science Center, Santa Cruz, CA, USA*

Received 18 June 2003; received in revised form 16 September 2004; accepted 1 October 2004

Abstract

Wind forcing and the seasonal cycles of temperature and currents were investigated on the inner shelf of the Monterey Bay area of the California coast for 460 days, from June 2001 to September 2002. Temperature measurements spanned an approximate 100 km stretch of coastline from a bluff just north of Monterey Bay south to Point Sur. Inner shelf currents were measured at two sites near the bay's northern shore. Seasonal temperature variations were consistent with previous observations from the central California shelf. During the spring, summer and fall, a seasonal mean alongshore current was observed flowing northwestward in the northern bay, in direct opposition to a southeastward wind stress. A barotropic alongshore pressure gradient, potentially driving the northwestward flow, was needed to balance the alongshore momentum equation. With the exception of the winter season, vertical profiles of mean cross-shore currents were consistent with two-dimensional upwelling and existing observations from upwelling regions with poleward subsurface flow. At periods of 15–60 days, temperature fluctuations were coherent both throughout the domain and with the regional wind field. Remote wind forcing was minimal. During the spring upwelling season, alongshore currents and temperatures in the northern bay were most coherent with winds measured at a nearby land meteorological station. This wind site showed relatively low correlations to offshore buoy wind stations, indicating localized wind effects are important to the circulation along this stretch of Monterey Bay's inner shelf.

Keywords: Coastal upwelling; Inner shelf; Wind-driven currents; Ekman transport

1. Introduction

The inner continental shelf, defined here as water depths shoreward of 30 m, plays a critical role in both coastal circulation and the dynamics of marine ecosystems. Measurements show wind-driven upwelling on the US west coast, which

*Corresponding author. Long Marine Laboratory, University of California, Santa Cruz, 100 Shaffer Road, Santa Cruz, California 95060, USA.
E-mail address: drake@biology.ucsc.edu (P.T. Drake).

0278-4343/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.csr.2004.10.006

eventually feeds the elevated biological productivity found there, will be strongest over the inner shelf, closest to the shore (Huyer, 1983; Winant et al., 1987). These measurements are consistent with theoretical treatments of coastal upwelling (Allen, 1975), which predict that upwelling will be most pronounced within the baroclinic Rossby radius of the coast, roughly within 10 km of the shoreline. Satellite images (Kosro et al., 1991) reveal the importance of upwelling on the inner shelf to the growth of the larger-scale upwelling front and coastal transition zone further offshore.

To gain a better understanding of the upwelling and wind forcing on the inner shelf, long-term temperature and current measurements made in the Monterey Bay region of the US west coast were studied and compared to a variety of wind measurements. The observations and analysis summarized here were performed at the University of California, Santa Cruz, and were supported by the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a multi-institutional research program. Observations spanned well over 1 year, from 4 June 2001 to 7 September 2002. The spatial extent of the study was approximately 100 km, from a bluff just north of Monterey Bay south to Point Sur.

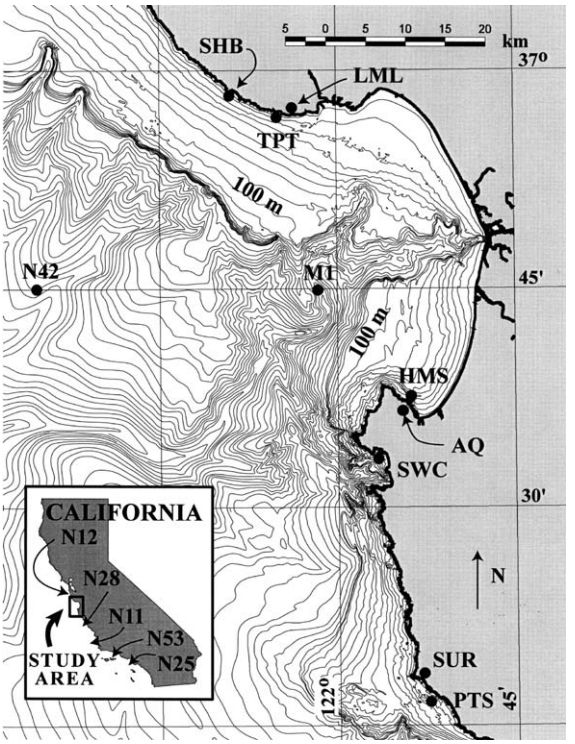

Fig. 1. Study site showing the Monterey Bay area of the California coast and locations of wind stations (N12, LML, N42, M1, AQ, SUR, N28, N11, N53, N25), temperature moorings (SHB, TPT, M1, HMS, SWC, PTS) and ADCP current profilers (SHB, TPT). Water depth of the PISCO inner shelf stations (SHB, TPT, HMS, SWC, PTS) was ~20 m. Isobath contour interval is 10 m for water depths <200 m and 100 m for depths >200 m.

2. Methods

2.1. Instrumentation

The study encompassed five inner shelf moorings north of, inside, and to the south of Monterey Bay (Fig. 1, Table 1). Located in an approximate water depth of 20 m, all five shelf moorings measured temperature at three depths, referred to as bottom, middle, and top. Currents, measured with Acoustic Doppler Current Profilers (ADCPs), were also analyzed at the two northernmost sites (SHB and TPT). All inner shelf moorings were maintained by the UCSC PISCO program. Supplementary temperature data from a deep-water mooring inside Monterey Bay (M1) and a variety of wind data sets were also used to complement the analysis. Maintained by the Monterey Bay Aquarium Research Institute (MBARI), the M1 mooring is located in a nominal water depth of 1600 m in the heart of the Monterey Submarine Canyon. Only temperature from M1's 10 m depth will be presented here, as this depth was available for both calendar years. Wind data from 10 different sites were employed in the analysis (Table 2). Both land (LML, AQ, SUR) and offshore buoy wind stations, including M1, were used. All buoy wind stations, with the exception of M1, were maintained by the National Data Buoy Center. Land-based wind measurements were made available from the Monterey Bay Aquarium (AQ), UCSC's Long Marine Lab (LML) and the Department of Meteorology at the Naval Postgraduate School, which maintains a meteorological station at the Point Sur Naval Station (SUR).