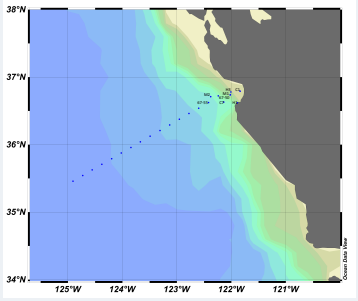
Monterey Bay Time-Series: 23 Years of Measuring Physical, Chemical, and Biological Variables

Marguerite Blum, Reiko P. Michisaki, J. Timothy Pennington, Francisco P. Chavez
7700 Sandholdt Rd. Moss Landing, CA 95039

International Time-Series Methods Workshop, Bermuda, November 27-31, 2012

Abstract

Monterey Bay, CA, USA, is a deep non-estuarine embayment broadly open to the coastal ocean. Its oceanography has been studied since 1936. In 1989, the Monterey Bay Aquarium Research Institute (MBARI) started a program of semi-monthly time-series cruises to several stations within and off-shore of Monterey Bay. Time series parameters at stations in central Monterey Bay are described and shown over the 23 years, 1989-2012, of sampling at this station. Several of the parameters shown are extrapolated from the profiling CTD sensors and samples taken from Niskin bottles, as well as several sensors in the underway surface seawater flow.



Map 1. This is Ocean Data View 4.2 image of the Monterey Bay region using Pre-Bathymetry, Ocean Bathymetry, Pre-coastlines, Coastlines, Pre-Topography, Land Topography, and Post-topography. Positions of time-series stations C1, H1, H3, M1, 67-50, M2, 67-55, and C7 are plotted to show location and reference to land and each other. The unlabeled blues dots represent CalCOFI Line 67 stations.

Methods

Time-series stations:

Shipboard time-series data have been collected twice monthly since mid-1989 aboard the R/V *Point Lobos* on single-day cruises. From 1989 to 1992, four stations were occupied, C1, H1, H3, and C7 (see map). In 1993, these stations were reduced to C1, M1, and M2. Station H3 is 3 km north of station M1; however, they are both in the center of Monterey Bay and over the Monterey submarine canyon. In 1997, the Studies of Ecological and Chemical Responses to Environmental Trends (SECRET) cruise series was begun to occupy 10 CalCOFI Line67 stations to 250km off shore of Monterey Bay. This series occupied C1 and approximated M1 and M2 by Line 67 stations 67-50 and 67-55. The data presented here is the combination of H3, M1, and 67-50.

CTD:

CTD cast were made to at least 200 with a Sea-Bird 911 or 911 + CTD mounted in a General Oceanics 12-place rosette with 5 or 10 liter Niskin bottles (silicon O-rings). Additional sensors, Sea-Bird Electronics 43 and Wet-Star or FLRTD Fluorometer, allow for the collection of the following parameters; temperature, depth, salinity, dissolved O2, and fluorescence (See Figure 1).

Bottle samples:

Rosette Niskin bottles were filled at the surface and 5, 10, 20, 30, 40, 60, 80, 100, 150, and 200 m during each cast. The water was used for a number of measurements; oxygen (O2), dissolved inorganic carbon (DIC), alkalinity (ALK), ammonia (NH4), pH, nitrate (NO3), nitrite (NO2), reactive phosphorus (PO4), reactive silicate (SIO), Chlorophyll a (chl), particulate organic carbon (POC), particulate organic nitrate (PON), primary production using 14C isotope (PP), high performance liquid chromatography (HPLC), flow cytometry (FCM), and quantitative phytoplankton (QP) samples. Figure 2 shows the results of NO3, PO4, SIO, Chl, PP, and Picoeukaryotes from FCM.

Underway Measurements:

On board the ship, another Sea-Bird 21 CTD and a Wet-Star Fluorometer are used to measure the water as the ship travels. A pumping system on the ship takes water from 3m below surface, passes through a de-bubbler and into the Sea-Bird unit. Data collected by the CTD are temperature, salinity, and florescence. In addition to the CTD, a system developed by Gernot Friederich takes pCO2 measurements form the underway seawater. As well as, a Fast Repetition Rate Fluorometer (FRRF) developed by Zbigniew Kolber, which measures chlorophyll a reaction in phytoplankton. The FRRF has been in use for only two years, and the data has not been processed in time for this poster (Figure 3).

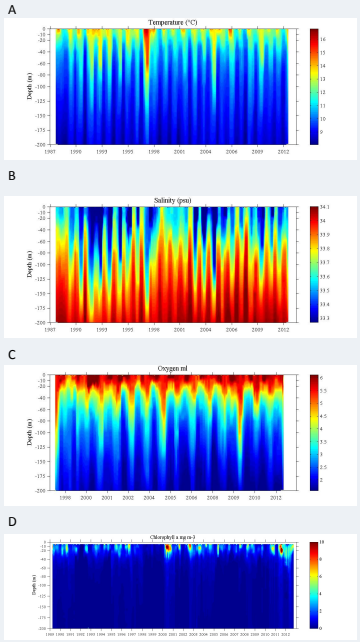
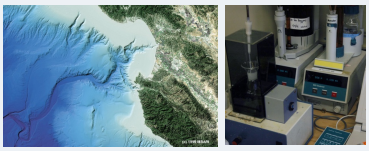


Figure 1. Time-series of profiling CTD measurements: (A) Temperature (degrees C), (B) Salinity (psu), (C) Oxygen (ml), and (D) Fluorescence (volts) at stations H3, M1, and 67-50 to 200m.



Sources

Chavez, F.P., Barber, R.T., Huyer, A., Kosro, P.M., Ramp, S.R., Stanton, T., and Rojas de Mendiola, B. (1991) Horizontal advection and the distribution of nutrients in the coastal transition zone off northern California: effects on primary production, phytoplankton biomass and species composition. *Journal of Geophysical Research,* 96: 14833-14848.

Pennington, J.T. and F.P. Chavez. (2000) Seasonal fluctuations of temperature, salinity, nitrate, chlorophyll and primary production at station H3/M1 over 1989-1996 in Monterey Bay, California. *Deep Sea Research Part II,* 47: 947-974.

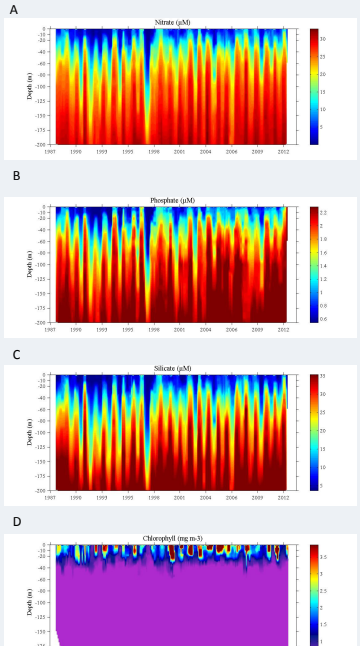


Figure 2. Time-series of chemical and biological measurements: (A) Nitrate (NO3 uM), (B) Phosphate (PO4 uM), (C) Silicate (SIO uM), (D) Chlorophyll a (mg m-3), (E) Primary Production (mg m-3), and (F) Picoeukaryotes from FCM (cells ml) at stations H3, M1, and 67-50 to 200m.

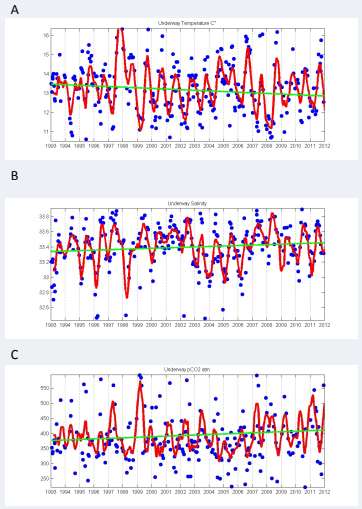


Figure 3. Time-series of underway surface measurements of (A) Temperature (degrees C), (B) Salinity (psu), and (C) pCO2 (atm) at stations H3, M1, and 67-50 to 200m. The blue dots are daily averaged data, red line are the interpolated and smoothed values, where the data are gridded to 14 day intervals using the Stineman interpolation and a 9 point moving average is applied. The green line is the linear regression.

Table 1. Sample list for time-series stations. Samples listed under "complete series" were obtained over the full time period of the series, while samples under "partial series" have been obtained over some of the portion of the series. Several underway mapping systems were also run on the time-series cruises.

Complete series	Partial series	Underway mapping
CTD cast (≥ 200 m) plus downwelling PAR, fluorescence, dissolved oxygen, and transmissivity	Dissolved inorganic carbon profile (0-1000m)	CTD cast plus fluorescence and in air PAR
Chlorophyll profile (0-200 m)	A* and HPLC pigments	ADCP
Nutrient profile (0-1000m) including ammonium, reactive phosphorus , silicate, nitrate, and nitrite	Total alkalinity profile (0-1000m)	Nitrate
	Spectroradiometer casts (PRR)	pCO2
	Hyper-spectral profiling casts	FRRF
	Flow cytometery cell counts (0 m)	AC-9
	Stable isotope ratios	
Total production profile (14C; 100-0.1% LPD)		
New production profile (15N; 100-0.1% LPD)		
Epifluorescence microscopy cell counts (0 m)		
Particulate organic carbon (0 m)		
Particulate organic nitrate (0 m)		

Acknowledgements

I would like to thank the Southwest Fisheries, NOAA, SCRIPPs, and UCSC for all the ship time, equipment, collaboration on all research cruises and for their on going devotion to ocean research. I would also thank all the interns and volunteers, who spend their time out at sea with me showing enthusiasm and wonderment. Also, I would like to thank my mother for watching the weather while I am so far out to sea during the cruises. And I lastly thank all the research vessels and the crews of R/V *Point Lobos,* R/V *Point Sur,* R/V *John Martin,* and R/V *Fulmar*.