Climate variability and change: time series observations from a coastal ocean

Francisco Chavez and collaborators

Monterey Bay Aquarium Research Institute

Two things never to do with a time series:
1) Start one; 2) End one
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Past

2018 OCB Workshop

Future
The concept of “process” time series

Process: Propagating disturbances observed in sea level have biological impacts that can be measured.

1. Galapagos
2. Paita

El Niño

Normal
The concept of “process” time series

Depth of thermocline/nutricline a fundamental property in upwelling ecosystems and globally

Process: Propagating disturbances observed in sea level have biological impacts that can be measured
Monterey Bay Time Series

• Since 1989 combines ship, mooring, AUVs/gliders, satellite and modeling
• Resulted in over 300 publications
• Generates new ideas and process studies
• Provides a natural laboratory for technology development
• Studies biological response to climate variability and global change
Station M1/H3 observed in situ since early 1920s

Chavez et al., 2017, Oceanography
Station M1/H3 observed in situ since early 1920s

Chavez et al., 2017, Oceanography
Space and time are intertwined especially for biology

Chavez et al., 2017, Oceanography
Strong relations between T and climate, less so for biology

El Niño impacts low productivity winter season
Measurements of PP in California Current

![Graph showing data points related to chlorophyll and primary production.](image)
Space and time lead to nonlinear relations, and low correlations between physics/chemistry and biology.

Diatoms rule the coastal ocean, only taxa will relation to PP.
Temperature decreasing, Salinity increasing, Nitrate increasing, Primary productivity Chlorophyll increasing, PP faster than Chl and P biomass, faster growth

Pennington and Chavez, 2017
Greening correlated with cooling and increase of nutrients at depth.

Monterey Bay Temperature at Depth

Monterey Bay Nitrate at Depth

Monterey Bay Surface Chlorophyll

1984 to 2005
Greening correlated with cooling and increase of nutrients at depth.
A. SST

B. Nitrate 60m

C. Chlorophyll

D. Oxygen at 26.8

E. Dosidicus gigas Sightings

F. Underway pCO2

G. Underway pH

Temperature

Nitrate

Chlorophyll

Oxygen

Jumbo squid

pCO2

pH
Rate of oxygen decline off central California, shallow maxima at 75 m (25.5 isopycnal), deep maxima at 300 m (26.7-26.8 isopycnal)

2018 OCB Workshop
A 4 umol (Redfield) increase in TCO₂ (at 12 C) increases pCO₂ by 8 ppm per year, 4 times greater than “ocean acidification”
A 4 umol (Redfield) increase in TCO$_2$ (at 12 C) driven by respiration increases pCO$_2$ by 8 ppm per year, 4 times greater than “ocean acidification”. Because nitrate also increasing (stimulating PP) effect felt mostly inshore during strong upwelling.
Integrating surface, midwater and benthic time series (Messie et al. in prep) – relating community composition to climate/upwelling

PCA mode 1 = changes in biomass/density
Autonomous surface vehicle measurements of pCO₂ and pH

Wave Glider equipped with the same mooring sensors

Chavez et al., 2018 DSRII
Fleets of Long Range AUVs with ESPs
(and other samplers, instruments)

A new window for observing the sea

5 Cartridge Prototype

ESP AND LRAUV TEAMS

Sequence onboard in the future
eDNA detection of increased anchovy abundance

Monterey Bay, CA, station C1

Preserved DNA samples allow the eDNA analysis of long time series – where other methods of analysis may be unavailable.

Comparison of anchovy eDNA detection from archived samples, whale watching boat sightings, and SST anomaly. Consequence – increased whale entanglements with crab pots.

Whale sightings Fall 2015
Automating the Monterey Bay Time Series
A future of “process” time series?