Upwelling index along the north-central California Current from 1988-2010 (California Current upwelling modes project)

Website: https://www.bco-dmo.org/dataset/472602
Version: 2013-12-03

Project
» History and Future of Coastal Upwelling Modes and Biological Responses in the California Current (California Current upwelling modes)

Contributors	Affiliation	Role
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Methods & Sampling

Upwelling: Winds and SST
We quantified local upwelling using two variables: 1) an estimate of offshore Ekman transport (Uw) calculated from buoy winds and 2) SST as an integrated estimate of ocean conditions that reflects the shoaling and mixing of deep water in response to upwelling winds, alongshore and cross-shore transport, and air-sea heat fluxes as well as variability in water column characteristics that could impact the upwelling process. Hourly wind data, from 1988 to 2010, were obtained from 12 NOAA buoys located from 34 to 47°N along the continental shelf of the U.S. west coast, available at http://www.ndbc.noaa.gov. Missing data ranged from 4% at buoy 46025 to 26% at buoy 46041, with an average of 15% in all buoys. Gaps were 77 days long on average, with the longest gaps ranging from 4 months at buoy 46025 to 1.8 years at buoy 46011. Data were highly correlated (r > 0.9 for wind and > 0.75 for SST, except for buoy 46025), so neighboring buoys could be used to fill the gaps via linear regressions.

Wind stress was calculated from wind speed following Large and Pond (1981), and the alongshore component was calculated using the orientation of the principal axis of the wind, which largely follows the coastal orientation (details in García-Reyes and Largier 2010). We compared these variables to the upwelling index (UI) provided by NOAA (Schwing and others 1996). The UI quantifies the offshore Ekman transport caused by alongshore wind stress, but is calculated from cross-shore gradients in sea level pressure. While UI data is provided at 3° intervals along the Northeast Pacific coast, the scale of the cross-shore sea level pressure used in its calculation is 6°. Here, we considered data (http://www.pfeg.noaa.gov/products/las.html) from 33 to 48°N across the 1988 to 2010 interval shared by the buoy data.

Data Processing Description

To investigate variability in upwelling with respect to season, we computed the monthly mean, standard deviation and coefficient of variation for each physical variable (Uw, SST, and UI). Subsequently, we conducted a Principal Component Analysis (PCA) to explore shared patterns of variability among these time series, which were extracted and used as multivariate indices of the CCE. Given that upwelling varies among locations, among season and among years (García-Reyes and Largier 2012; Thompson and others 2012), we arranged each physical data variable (Uw, SST and UI) into a three-dimensional matrix consisting of 12 locations x 12 months x 23 years; resulting components were labeled as PCUw, PCSST, and PCUI. Each column was normalized (zero mean and variance equal to 1 standard deviation) before calculating the PCA. Next we ran a PCA that combined Uw and SST data by arranging their data arrays into a single matrix with dimensions: 24 locations (12 Uw locations + 12 SST locations) x 12 months x 23 years. Resulting PCs, labeled as PCenv, captured the dominant and sub-dominant seasonal "modes" or patterns in upwelling and their interannual variability. PCs (scores) from the three physical variables (PCUw, PCSST, and PCUI) were compared to one another as well as to PCenv using Spearman ranked correlations. PCs with Eigenvalues < 1 and explaining < 10% of the variability in the data set were dropped from further analysis (Jolliffe 2002).

The 15 biological indicators included in the study were cross-correlated with one another to generally assess the extent to which they shared common patterns. Subsequently, we conducted a PCA (resulting components labeled as PCbio) using the nine longest (1982-2006) biological indicators. Biological indicators excluded from the PCA were correlated against the PCbio components as a measure of their agreement with dominant patterns in the longer datasets. Those that were significant at the $p < 0.05$ level were retained. To summarize physical-biological interactions, the scores of the environmental PCs (PCUw, PCSST, PCUI and PCenv), the biological indices, and biological PCs (PCbio) were compared using Spearman correlations.

Biological Principal Component Sources and Loading (PDF)

Environmental Principal Component Sources and Loading (PDF)

References, this data:

Reyes, M., W. J. Sydeman, S. A. Thompson, B. A. Black, R. R. Rykaczewski, J. A. Thayer, and S. J. Bograd. 2013. Integrated assessment of wind effects on Central California’s pelagic ecosystem. Ecosystems. DOI: 10.1007/s10021-013-9643-6.

Related References:

García-Reyes M, Largier JL. 2012. Seasonality of coastal upwelling off central and northern California: new insights, including temporal and spatial variability. J Geophys Res 117:C03028.

Jolliffe IT. 2002. Principal component analysis. 2nd ed. Springer series in statistics. ISBN 0-387-95442-2.

Large WG, Pond S. 1981. Open ocean momentum flux measurements in moderate to strong winds. J Phys Oceanogr 11:324-36.

Thompson SA, Sydeman WJ, Santora JA, Black BA, Suryan RM, Calambokidis J, Peterson WT, Bograd SJ. 2012. Linking predators to seasonality of upwelling: using food web indicators and path analysis to infer trophic connections. Prog Oceanogr 101:106–20.

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Data Files

File
upwell_index2.csv(Comma Separated Values (.csv), 6.20 KB) MD5:a0ac20d08411999d69e160180f53c52f Primary data file for dataset ID 472602

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Parameters

Parameter	Description	Units
lat	latitude	decimal degrees
month	month - local time	integer 1 to 12
year	year	YYYY
temp_ss	sea surface temperature	degrees Celsius

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Deployments

Black_model

Website	https://www.bco-dmo.org/deployment/472783
Platform	OSU
Start Date	2011-09-01
End Date	2013-05-31
Description	climate reconstruction model

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Project Information

History and Future of Coastal Upwelling Modes and Biological Responses in the California Current (California Current upwelling modes)

Coverage: North-central California Current between approx 36N, 122W and 39N, 125W

From NSF award abstract:

Climate variability on multiple temporal scales is increasingly recognized as a major factor influencing the structure, functioning, and productivity of the California Current Ecosystem (CCE). Yet, despite many long-term and integrative studies, a detailed understanding of climatic impacts on upwelling and biological processes is still lacking, compromising our abilities to assess important concepts such as ecosystem "health" and "resilience." To address these issues in the central-northern CCE, the PIs have recently collated and analyzed records of rockfish and salmon growth and seabird reproductive success with respect to upwelling variability (NSF award #0929017). These diverse, multi-decadal time series revealed the importance of wintertime upwelling on ecosystem structure and function, even though upwelling, a principal driver of productivity in the CCE, is largely a summertime process. This research led to an unexpected discovery that winter and summer upwelling vary independently of one another in distinct seasonal "modes", with some biological processes affected by the winter mode and others by the summer mode. This is of significance because the summer mode shows a long-term increase (despite inter-decadal variability) while the winter mode does not.

In this new project, the PIs will test the overarching hypothesis that upwelling modes are forced by contrasting atmospheric-oceanographic processes, exhibit contrasting patterns of low- and high-frequency variability, and will be differentially impacted by global climate change with corresponding impacts on biology. To address this hypothesis the PIs propose a three-tiered approach to better understand seasonal upwelling modes and their differential impacts on biology of the CCE. First, they will examine the responses of an entirely new suite of species to upwelling modes, including Pacific sardine (recruitment), black rockfish (growth), rhinoceros auklet and Brandt's cormorant (survival), and coho salmon (survival). Previously, coarsely resolved upwelling indices were used in these analyses, but the PIs now will integrate winds and temperatures from local buoy data to better capture climate variability on finer timescales. Second, they will derive a more mechanistic understanding of seasonal upwelling modes and use this information in combination with global climate models to forecast upwelling responses under various climate-change scenarios. Third, preliminary results indicate that tree-ring data co-vary with the fish and seabirds and are similarly sensitive to a driver of winter upwelling, the Northern Oscillation Index (NOI). The PIs will use tree-ring data to provide a 300-400 year reconstruction of the winter NOI to assess the historical range of variability in upwelling mean and variance. This study will reveal the past, present forcing, and potential future of upwelling and its biological consequences in the California Current.

Related Publications:
García-Reyes, M., W. J. Sydeman, S. A. Thompson, B. A. Black, R. R. Rykaczewski, J. A. Thayer, and S. J. Bograd. 2013. Integrated assessment of wind effects on Central California's pelagic ecosystem. Ecosystems. DOI: 10.1007/s10021-013-9643-6.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1130125

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