PDO-Related Variability in the Northeast Pacific in Altimeter-Derived Velocity Fields

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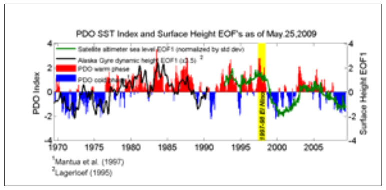
This research is supported by NASA through grants to Earth and Space Research

Motivation

Satellite altimetry encompasses a 17 year record, which is long enough to examine interannual variability in the oceans. Sea surface height (SSH) measurements are now routinely coupled with surface wind stress and sea surface temperature (SST) measurements to estimate sea surface velocities. This study focuses on the role of surface currents in transporting properties, such as temperature, in the evolution of the Pacific Decadal Oscillation (PDO) in the northeast Pacific Ocean. Elucidating the role of surface velocities will enhance our understanding of the dynamics of PDO-like variability and may provide a leading indicator to improve predictability.

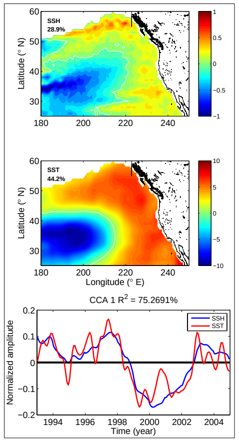
A regional definition of the PDO index

The conventional definition of PDO index (*Mantua et al.,* 1997) is the first EOF of wintertime SST anomalies in the basin-wide north Pacific (colored bars). *Cummins et al.* (2005) defined a regional index (green line). based on SSH in a region bounded on the west by the dateline and on the south by 25ºN

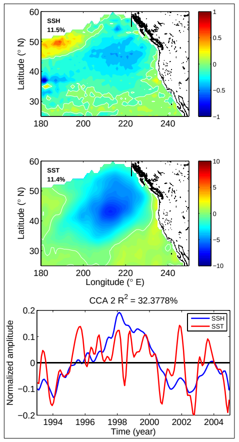


Canonical correlation analysis (CCA) shows that SSH and SST vary coherently at large spatial scales and low frequencies over the northeast Pacific. Attention is focused on the transition from warm to cool phase that occurred at the end of 1998.

CCA 1 (PDO)



CCA 2

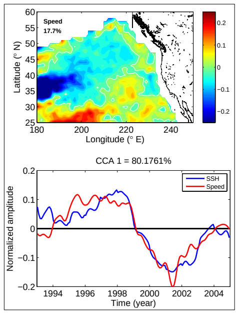


Left column is CCA mode 1 and right column is CCA mode 2. Top row is the canonical map of SSH and middle row is the canonical map of SST. Percent variance explained by map is shown. Bottom row is the temporal variation of the components for SSH (blue) and SST (red) with the canonical correlations shown as percentages.

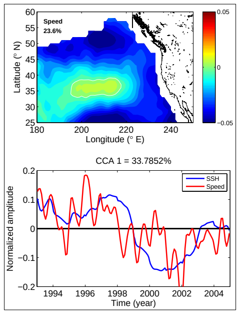
PDO-related changes in surface speeds and temperature advection

Geostrophic and Ekman components of surface velocities were calculated using techniques developed for Ocean Surface Currents Real-time (OSCAR). The resulting surface *speeds* were then subject to CCA with the PDO-related mode of SSH.

Geostrophic speeds (CCA 1)



Ekman speeds (CCA 1)

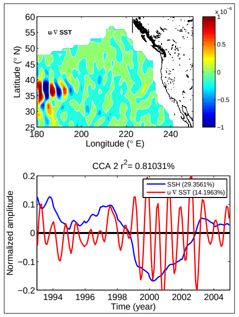


The first mode of geostrophic speeds (left column) is highly correlated with the regional PDO index. The spatial pattern, while not explaining a large amount of variance, is indicative of variations of the Kuroshio extension. Surface Ekman speeds (right column) have considerable high frequency variability and no clear correlation with the PDO index. They are more strongly correlated with the second EOF of SSH (not shown).

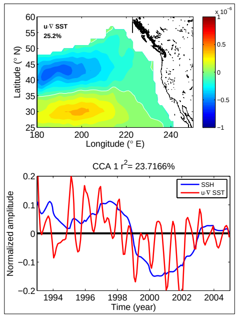
Some theories of the mechanism behind the PDO posit an important role for air-sea interaction. To examine the ocean contribution to changes in SST, the separate geostrophic and Ekman velocities were used to calculate the advection of SST,

$$\vec{u}\cdot\nabla T$$

Geostrophic advection



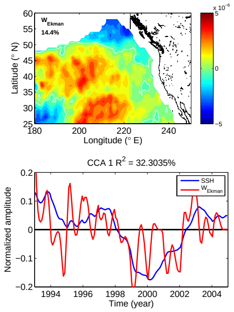
Ekman advection



The spatial pattern of the Ekman advection of SST (right column) contributes to warming of the subpolar gyre and cooling of the subtropical gyre during the cold phase of the PDO. The geostrophic advection of SST is dominated by small spatial scales. Although its temporal correlation is low because of high frequency variation, the *amplitude* of the variability appears to be related to the phase of the PDO index.

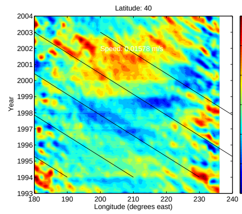
Ekman pumping response: damped or propagating?

Ekman pumping (CCA1)



Low-frequency changes in Ekman pumping are correlated with the PDO index.

SSH along 40º N

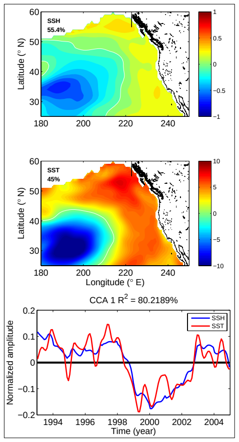


Hovemuller diagram of SSH along 40º N shows some evidence of slow westward propagation in the middle of the domain. Propagating disturbances are more evident near the eastern and western edges of domain

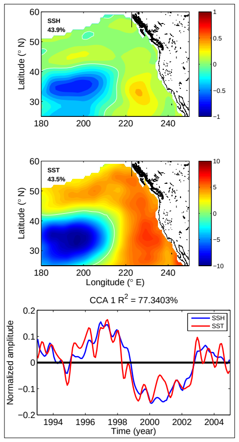
Representation of PDO in ocean reanalysis products

To augment the satellite-observed surface variables with depth-dependent upper ocean quantities like stratification and shear, we also looked at some data-assimilating models. Both ECCO (JPL, left) and GODAS (NOAA, right) provide reasonable representations of the SSH and SST variations associated with the PDO.

CCA 1
(ECCO smoothed wind)



CCA 1
(GODAS)



Summary

- .The first EOF of SSH in the northeast Pacific is a regional PDO index
- SST and geostrophic surface speeds are highly correlated with it.
- Geostrophic advection of temperature shows a role for enhanced eddy activity in the Kuroshio extension region during the cold phase.
- Most of the variation in SSH is due to local Ekman pumping.
- Ocean reanalysis products represent well the SSH and SST of PDO.