UPPER OCEAN DYNAMICS RELATED TO THE PACIFIC DECADAL OSCILLATION USING ALTIMETER DERIVED VELOCITY FIELDS

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The principal goal of this study is to resolve the ocean dynamics associated with the climate mode known as the Pacific Decadal Oscillation (PDO). It will apply direct measurements of surface currents from satellite altimeter and vector wind data, which we have developed and refined under prior and ongoing research support, in order to investigate the large scale ocean circulation variability associated with this important climate signal. We will specifically investigate the role of ocean transport of surface properties and the ocean's dynamic response to stochastic wind forcing in governing the observed responses of sea surface temperature (SST) and topography (SSH), and examine leading indices that may provide a measure of predictability.

The surface current product, derived from the SSH dataset, now extends from late 1992 to the present (>15 years), which is long enough to have observed variability associated with this mode. Most significant in the record is the abrupt change that occurred in 1998-1999 that showed many of the PDO-like spatial features. The key scientific questions for this study are as follows:

1. SSH variability: What governs the principal PDO-like SSH signature, and what are the relative roles of stochastic wind forcing, propagating signals, and changes in upper ocean buoyancy?
2. Circulation: What are the basin scale circulation patterns associated with the PDO-scale variations, what role do they have in the SST and SSH changes observed, and do they provide a lead time and predictability?
3. Advection and fluxes: What are the patterns and magnitudes of SST advection, what role do they have in the SST variations relative to net surface fluxes, and what processes explain the coherent variations between SST and SSH?

Figure 1 : The Pacific Decadal Oscillation (PDO) is defined by the first EOF of wintertime SST anomalies in the Pacific basin (colors), shown with related surface wind anomalies (arrows) (from: jisao.washington.edu/pdo/; Mantua et al, 1997).

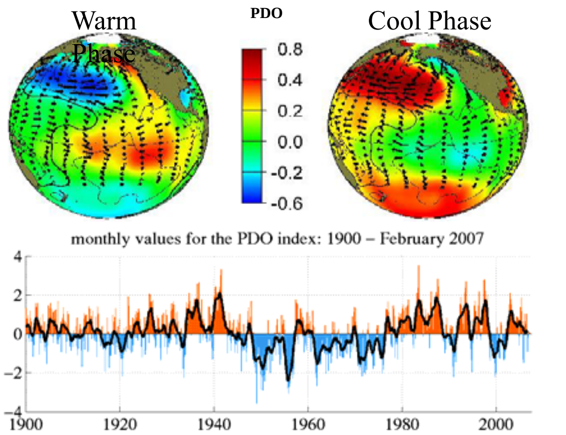


Figure 2: (a) The top panel shows the canonical maps of SSH (blue lines) and SST (red lines) for canonical correlation CCA1. The contour interval is 0.2 and negative contours are dashed. The lower panel gives the temporal components; the canonical correlation is 0.88. CCA1 explains 46% of the SSH variance and 48% of the SST variance. (b) Maps and temporal components (canonical correlation of 0.63) for CCA2, accounting for 12% and 11% of the SSH and SST variance, respectively. From Cummins, Lagerloef & Mitchum (2005).

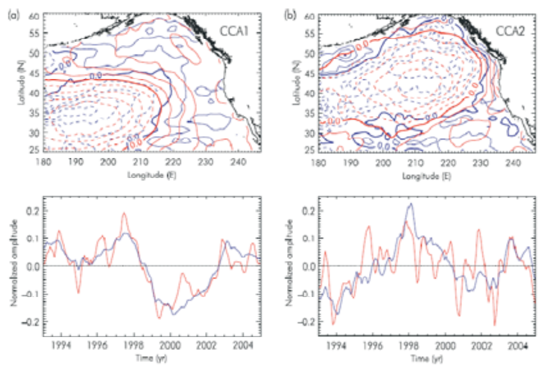


Figure 3 : Our extended sea surface height (SSH) mode timeseries in the NE Pacific (solid curves) and conventional SST PDO index (blue & red bars). The black curve is the Alaska gyre dynamic height EOF (from Lagerloef 1995) and the green curve is the first EOF of satellite altimetry after Cummins, Lagerloef & Mitchum (2005). Note the rapid transition from warm to cool phase after the 1997-98 El Nino. This is updated monthly online at (www.esr.org).

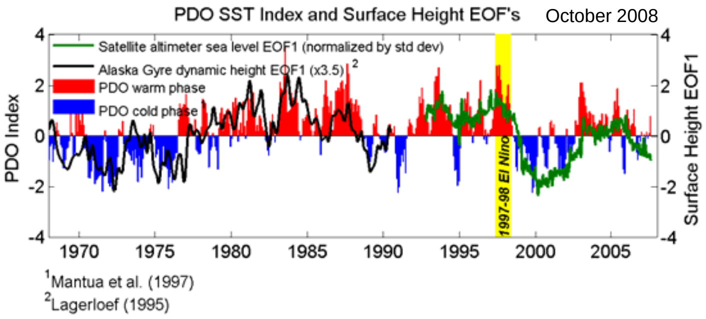


Figure 4 : (Left) Northeast Pacific satellite SSH difference between multi-year averages after minus before 1998, resembling the principal PDO pattern. A north-south CTD transect is shown near the southern perimeter of the SSH anomaly pattern. (Right) Yearly CTD transects before and after the 1998 transition, showing extensive changes to the upper ocean heat content and thermocline structure (courtesy J.Polovina and M.Seki, NOAA/NMFS, Honolulu).

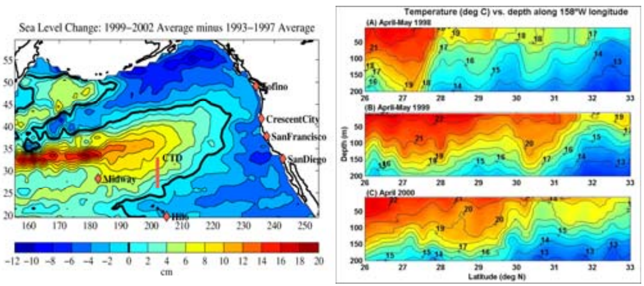


Figure 5 The sequence of yearly average SSH and OSCAR current anomalies before, during an after the 1998-1999 transition.

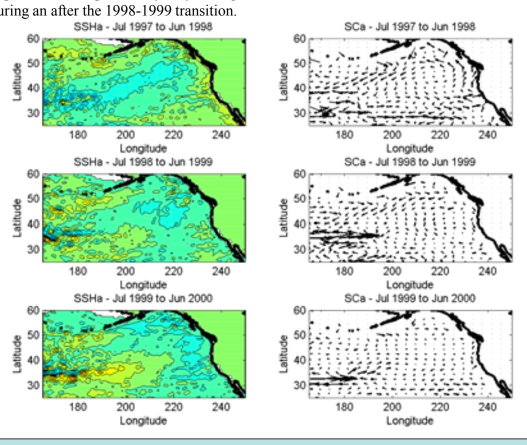
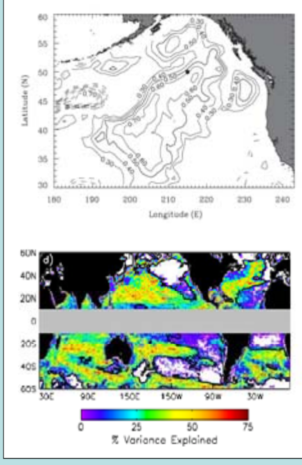
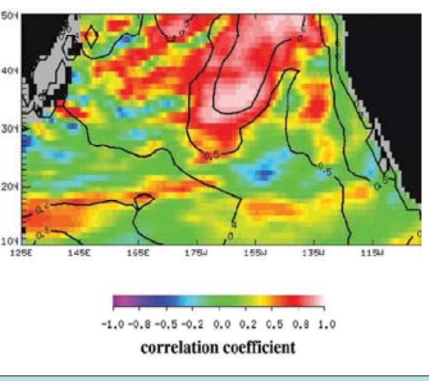


Figure 6: Stochastic wind forcing of SSH hindcast comparisons relative to altimeter data: (Upper Left panel), From Cummins and Lagerloef (2004), contours of hindcast skill metric using Equation (1) with damping time scale (λ^{-1} = 2 years) and with no Cx term (i.e. no Rossby wave dynamics). (Right panel), From Fu and Qiu (2002), hindcast correlation using the full Equation (1) and with weaker damping (λ^{-1} = 6 years). Note that both models have similar skill in the same general region of the north central basin, and similar poor skill in other regions to the southwest and southeast. (Lower Left panel) From Chelton et al (2007), the % SSH variance explained by mesoscale eddies. Note the white area of very low eddy variance in the central North Pacific encompasses the region of better hindcast skill of the stochastic forcing models.

$$\frac{\partial \eta}{\partial t} - C_x \frac{\partial \eta}{\partial x} = -\frac{\Delta \rho}{\rho} We - \lambda \eta \qquad (1)$$





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