The North Pacific Gyre Oscillation

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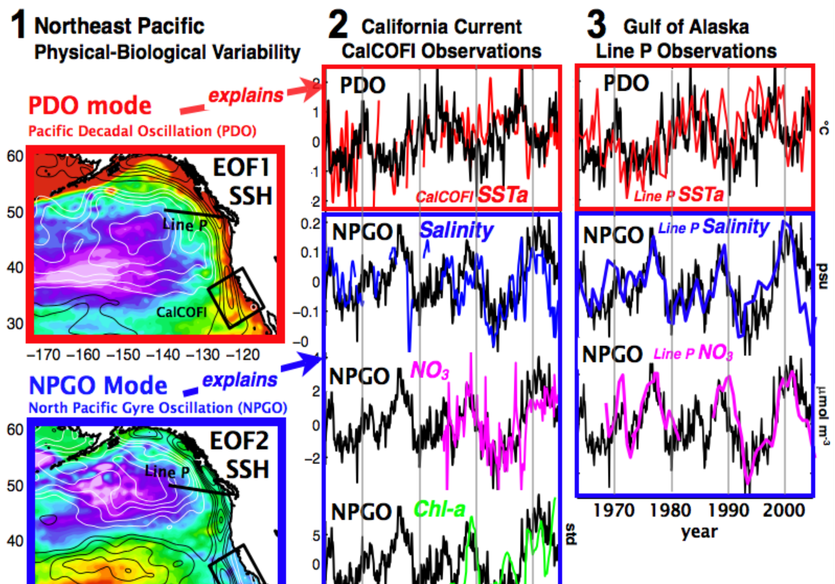
Summary

Decadal variability in the North Pacific is typically described by the Pacific Decadal Oscillation (PDO). While many aspects of Pacific climate anomalies are associated with the PDO, variations of oceanic salinity, nutrients and the ecosystem off the coast of North America are independent of the PDO. A 50+ year ocean hindcast in the North-East Pacific suggests that the North Pacific Gyre Oscillation (NPGO; Di Lorenzo et al. 2008), the second empirical orthogonal function of sea surface height, reproduces these time series in the California Current and Alaskan Gyre. The mode describes a spin-up (or down) of the subtropical and Alaskan gyres, and an acceleration of the North Pacific Current. Associated sea surface temperature patterns are similar to the Victoria Mode, the second EOF of North Pacific surface temperature anomalies. With a lag of a few years, the NPGO is linked to strength of Kuroshio Extension via Rossby wave dynamics. The NPGO is the oceanic expression of the North Pacific Oscillation, a dipole sea level pressure pattern that results from intrinsic atmospheric mid-latitude variability and interactions with the El Nino/Southern Oscillation.

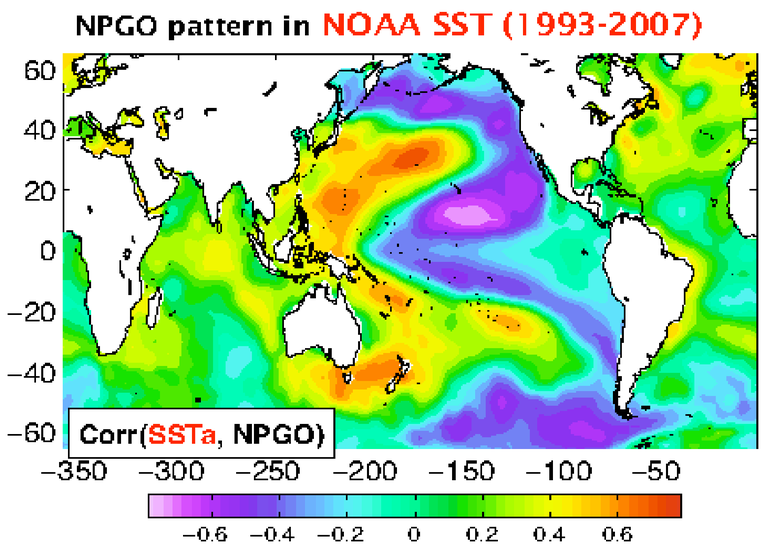
NPGO definition, eastern boundary salinity, nutrients and chlorophyll

Sea level is analyzed in a 1950-2004 hindcast with the ROMS model in the eastern North Pacific, 25N-62N, 180-110W, forced with time dependent NCEP wind stress, heat fluxes and the climatological surface fresh water flux.
The leading empirical orthogonal function of sea level captures variations associated with the Pacific Decadal Oscillation. The second EOF of sea level is highly correlated with observations of surface salinity, nutrients at 150 m depth, and chlorophyll observed during CalCoFI in the California Current and along line P in the Alaskan Gyre. Its sea level pattern in the North-East Pacific is a dipole and is called the North Pacific Gyre Oscillation.



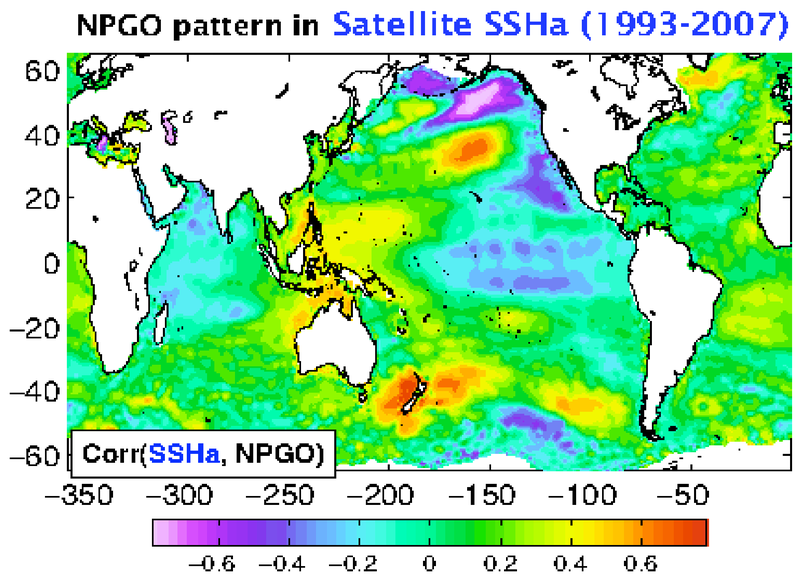
Relationship to sea surface temperature modes

The NPGO mode is highly correlated with the second EOF of North Pacific sea surface temperature, the Victoria mode, that explains more of the North Pacific sea surface temperature anomalies than the PDO mode during 1990-2002.



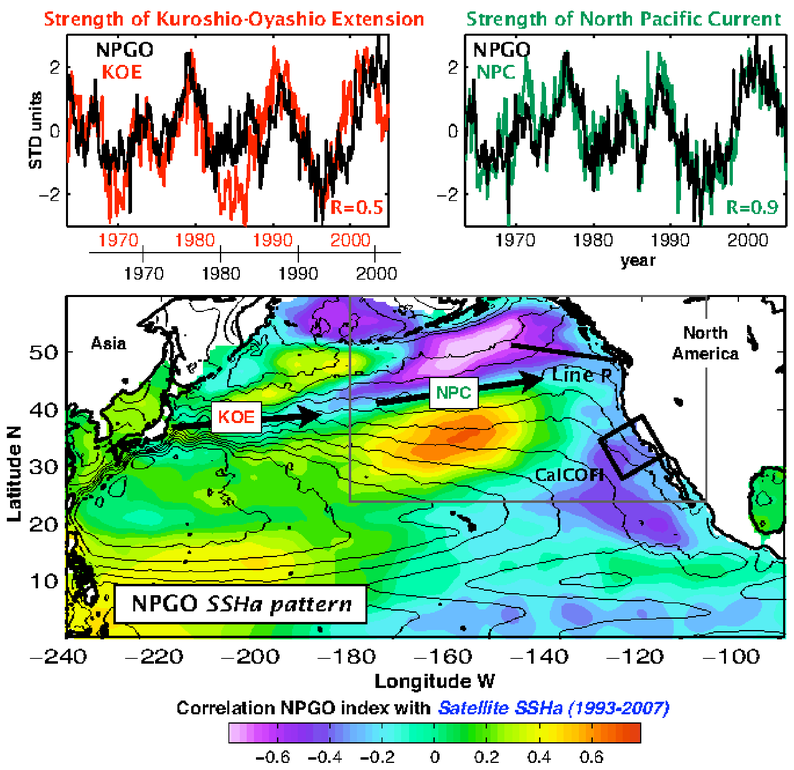
NPGO pattern from altimeter sea level

The correlation of the NPGO index with altimeter sea surface height shows the dipole in the North-East Pacific, and indicates expressions of this mode in the equatorial region and in the southern hemisphere Pacific. This indicates a coupling to the tropics.



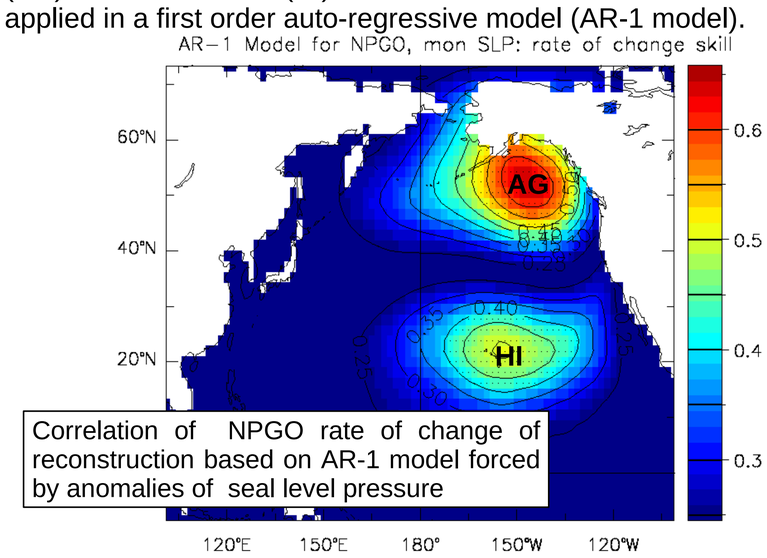
Link to the Kuroshio-Extension

The NPGO links oceanic variations in the eastern and western North Pacific. The NPGO index is related to the strength of the North Pacific Current, with a positive NPGO index corresponding to a stronger eastward flow. An index for the strength of the zonal flow in the North Pacific Kuroshio Extension (Taguchi et al. 2007) is correlated with the NPGO index at a lag of a few years, consistent with Rossby wave propagation (Ceballos et al. 2008).



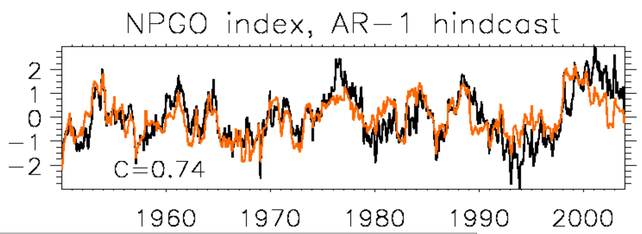
Forcing by the North Pacific Oscillation

The NPGO is the oceanic expression of the North Pacific Oscillation. Sea level pressure anomalies over the Alaskan Gyre (AG) or over Hawaii (HI) recover the NPGO time series when applied in a first order auto-regressive model (AR-1 model).



Fitting the NPGO time-series to an AR-1 model forced by sea level pressure anomalies at AG and HI yields a model with very good hindcast skill and opposite signed loadings, consistent with the North Pacific Oscillation of Walker and Bliss (1932).

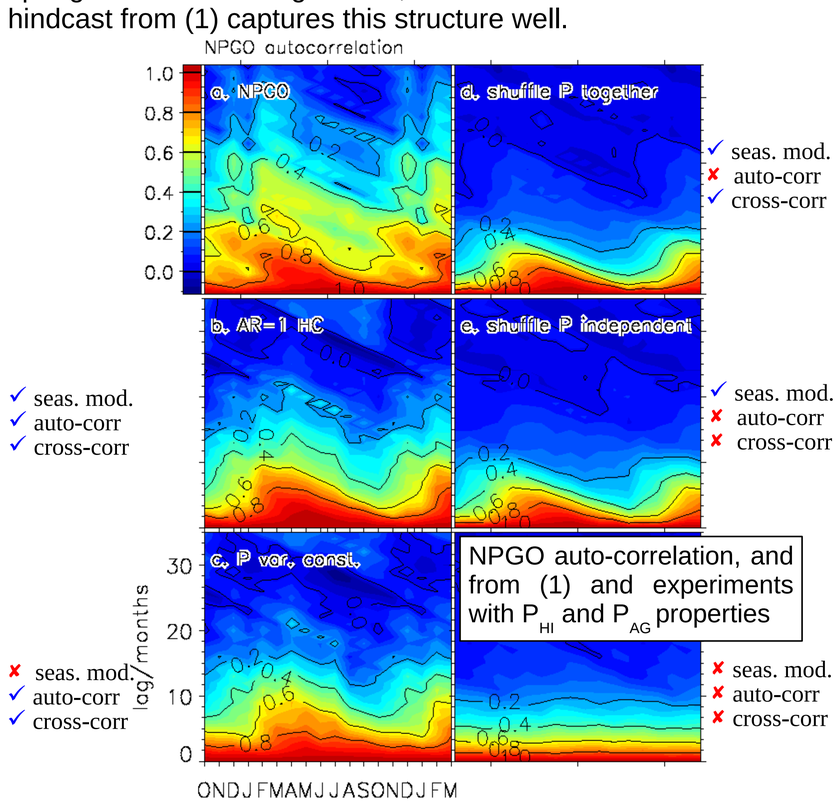
$$NPGO(t) = 0.85\,NPGO(t-1) - 0.21\,P_{AG} + 0.14\,P_{HI} \qquad (1)$$



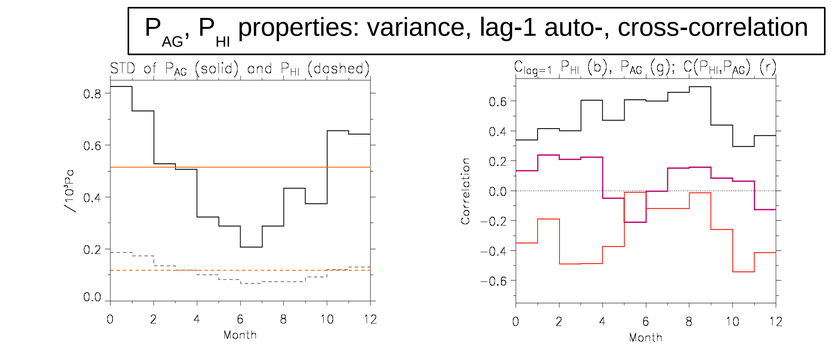
NPGO timeseries and hindcast from (1)

NPGO properties

The auto-correlation function of the NPGO index shows a pronounced seasonal modulation with high correlations from spring to the following winter, similar to ENSO indices. The hindcast from (1) captures this structure well.



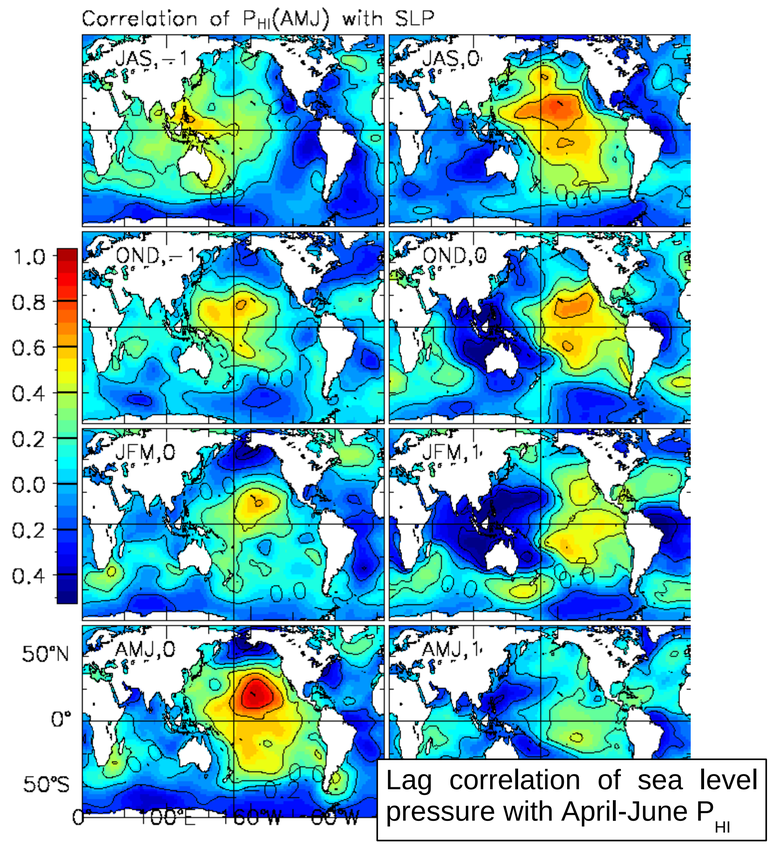
The NPGO auto-correlation reflects the properties of the AG and HI sea level pressure anomaly time series. Their variance is largest in the winter season. The AG sea level pressure has a weak lag-1 auto-correlation and is consistent with white noise. HI sea level pressure anomalies have a considerable non-zero in spring and summmer, lag-1 auto-correlation, and are therefore more 'red' in character. The cross-correlation of HI and AG is weak but largest in winter.



Experiments with the AR-1 model that alter the properties of the sea level pressure time series show that the seasonal variance modulation and 'red' character of the Hawaii sea level pressure pole are largely responsible for the auto-correlation of the NPGO index.

Interaction of with El Nino/Southern Oscillation

Interactions with El Nino underly the auto-correlation of the HI pole of sea level pressure. Its spring values are correlated with a Southern Oscillation sea level pressure pattern in the following winter. This interaction is consistent with the footprinting mechanism (Vimont et al. 2003, Anderson 2003).



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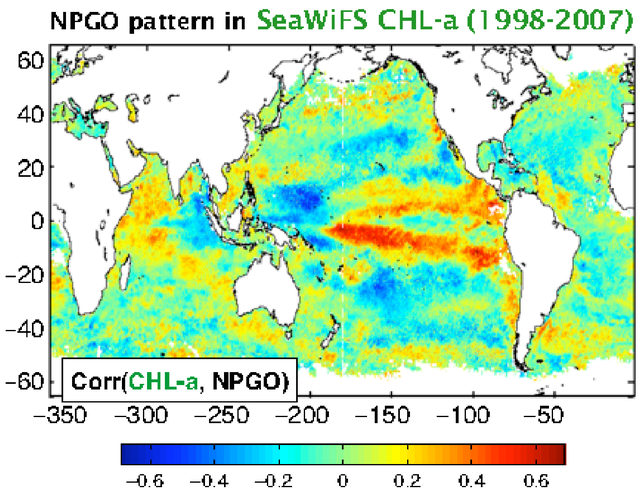
NPGO pattern in SeaWiFS CHL-a (1998-2007)
60
40
20
0
-20
-40
-60
Corr(CHL-a, NPGO)
-350
-300
-250
-200
-150
-100
-50
-0.6
-0.4
-0.2
0
0.2
0.4
0.6