Northeast Pacific Climate Change Mechanisms

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More Information

www.pfeg.noaa.gov/research/globec/index.html

Salmon Catch and Decadal Changes

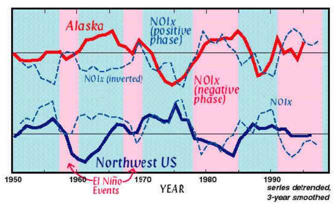

Figure 1. The extratropical Northern Oscillation Index (NOIx) and salmon catch for Alaska (red) and the Pacific Northwest (blue). The NOIx (dashed lines) is the sea level pressure anomaly (SLPA) in the NEP minus the SLPA at Darwin, Australia (see green dots in Figs. 2, 3). The NOIx integrates regional atmospheric variability and tropical-extratropical linkages associated with north Pacific climate change. It is well correlated to a number of physical and biological variables in the NEP, including salmon catch. From the NOIx, we can define decadal climate regimes and regime transitions. Since 1970, the NOIx shows a 15 year cycle which indicates regime shifts around 1990 and 1998. But the timing of regime shifts varies, indicating that climate variations involve several mechanisms and time scales.

Coastal Variations

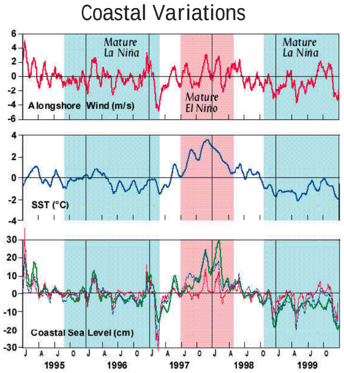

Figure 4. Monthly time series of regional composite anomalies of (a) NDBC coastal buoy wind, (b) NDBC coastal buoy SST, and (c) coastal sea level (CSL) along central California, 1995-99. The green line in c is CSL; the red line is CSL estimated from regression against wind "stress" (daily wind anomaly squared, r=.66); the blue line is CSL estimated from regression against stress and SST anomalies (r=.89). Most of the CSL signal since 1995 was due to coastal Ekman processes and upper ocean warming, as represented by SST. The wind did not track the interannual rise and fall in CSL from early August 1997 to mid-April 1998. Ocean warming, probably due to enhanced poleward transport, was critical in explaining CSL variability. Wind forcing still played an important role by driving intraseasonal perturbations in CSL throughout the 1997-98 El Niño. We hypothesize that CSL anomalies in the CCS are controlled by local winds on intraseasonal scales and by remote ocean-atmosphere teleconnections

Acknowledgements

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Overview

We are investigating mechanisms of climate change in the northeast Pacific (NEP) relevant to variations in marine ecosystems, especially fishery populations. In this research, we are synthesizing and analyzing extensive historical oceanic and atmospheric data sets. Our work uses global, high-resolution, ocean models to simulate processes not adequately represented in observations (see Ocean Model box). We also are using atmospheric models to identify atmospheric processes that lead to climate change in the NEP.

Seasonal cycles of key observed and modeled ocean fields are being related to atmospheric forcing fields, and compared with the mechanisms of interannual and decadal variations, with emphasis on major interannual (e.g., El Niño and La Niña) events, and possible decadal regime shifts around 1990 and 1998. We are comparing basin scale and regional changes to see if similar mechanisms operate at these different spatial scales. From these analyses, biologically relevant indices of climate change are being developed.

The observational and model products we are developing cover a wide range of environmental data sets and indices that define climate change in the NEP and its ecosystem effects. These products are being delivered through the web, principally via the PFEL live access server site: **http://salmonid.pfeg.noaa.gov/las.html.**

Questions

Our research focuses on three overriding questions:

1. To what degree are seasonal to decadal changes in the upper ocean due to mechanical wind forcing, versus thermal forcing?

2. To what degree are ocean anomalies, especially in coastal ecosystems, due to local atmospheric anomalies, versus atmospheric or oceanic teleconnections?

3. Are there dynamical similarities in the patterns and evolution of atmospheric and oceanic anomaly fields on seasonal to decadal scales, and therefore in the mechanisms leading to these oceanic anomalies?

Activities and Results

Development of Data Bases and Data Access Servers

Development of live access server:
http://salmonid.pfeg.noaa.gov/las.html

Creation of convenient community access to COADS & WODB and products

Distribution of oceanic and atmospheric products derived from NCEP reanalyses, including new environmental indices

Creation of global ocean general circulation model output data base

Analysis of Climatological and Anomaly Regime Patterns

Development & analysis of new environmental indices (Fig. 1)

Identification of temporal and spatial variability patterns (Fig. 2)

Characterization of El Nino & La Nina signals in NEP (Fig. 3)
Identification and analysis of multi-year and decadal regime shifts

Diagnosis of dynamical similarity for processes operating on intraseasonal to decadal scales (Fig. 2, 3)

Analysis of non-stationarity of seasonal cycles

Identification of common trends in atmosphere/ocean time series

Analysis of output from global oceanic and atmospheric general circulation models

Diagnosis of Climate Variation Mechanisms

Analysis of atmospheric forcing of upper ocean seasonal cycles

Diagnosis of mechanisms underlying El Niño, La Niña, and decadal regime anomalies (Fig. 3)

Identification of the role played by:
- Ekman processes in upper ocean (Fig. 4)
- Air-sea fluxes
- Ocean advection
- Planetary waves in ocean and atmosphere (Fig. 5)
- Atmospheric teleconnections (Fig. 5)
- Hypothesis testing with ocean/atmosphere models (Fig. 6)

North Pacific Decadal Anomalies

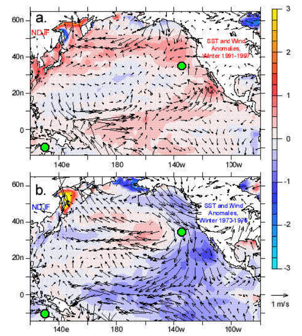

Figure 2. Composites of sea surface temperature (°C) and surface wind anomalies during November-February for two decadal periods, (a) 1991-96 and (b) 1970-76. The latter (earlier) period corresponds to a negative (positive) phase of the NOIx (Fig. 1) associated with a cyclonic (anticyclonic) wind anomaly and generally warm (cool) SSTs in the NEP. The magnitude of the anomalies are not uniform over the entire region (cf. Gulf of Alaska and Baja California). Anomalies for the negative and positive NOIx periods are roughly opposite, and similar to anomalies seen during El Niño and La Niña events, respectively (Fig. 3).

El Nino and La Nina Anomalies

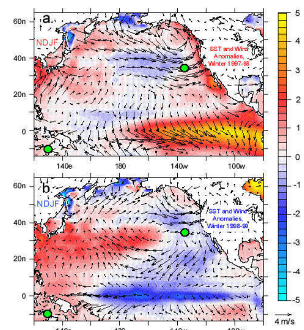

Figure 3. Composites of anomalous sea surface temperature (°C) and surface wind during November-February for the (a) 1997-98 El Niño and (b) 1998-99 La Niña events. Anomalies for the two periods are roughly opposite, and similar to the anomalies seen during decadal periods in which the NOIx is negative (Fig. 2a) and positive (Fig. 2b), respectively. Thus the mechanisms for interannual and decadal climate change in the NEP are dynamically similar. For ecosystem management, it is important to monitor the evolution of decadal anomalies and recognize when decadal regime shifts have occurred.

Atmospheric Wave Trains and Teleconnections

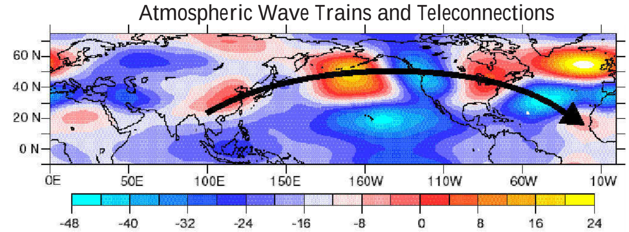

Figure 5. The anomalous 200 millibar height field (m) for September-January of 1970-1976, during a positive phase of the NOIx (Fig.1)**, a period of generally negative ocean temperature anomalies in the NEP** (Fig. 2)**.** Alternating patches of red and blue arching from east Asia to the north Atlantic indicate a quasi-stationary atmospheric wave train. The wave train extends down to the surface, with positive and negative height anomalies corresponding to anticyclonic and cyclonic surface wind stress anomalies. The wave train was initiated by anomalous atmospheric heating in the southeast Asian-western tropical Pacific region. The arrow indicates the direction of wave energy propagation. These atmospheric teleconnections are one example of how climate variations in the NEP are linked to those occurring in remote regions, including variations in the Asian monsoon region and in the northwest Atlantic. Understanding the mechanisms that affect the NEP may also help explain variations in the other US GLOBEC region.

Three Research Components

1. **Vertical Component-** focuses on NEP variations in vertical fluxes between the atmosphere and upper ocean. We are examining how regionally confined, vertically oriented mechanical and thermal interactions explain seasonal to decadal scale climate change.

2. **Horizontal Component-** identifies the role of advection and propagation in the ocean and atmosphere in creating climate change in the NEP. This encompasses oceanic and atmospheric teleconnection processes.

3. **Dynamical Similarity Component-** compares processes described in the other components to identify their dynamical similarities across time scales.

Ocean Model

Primitive equation level model (based on the numerics of Cox, Bryan, and Semtner), allowing a free surface

Average horizontal resolution: 0.25 degree; 20 vertical levels

Model domain: near-global, extending from 73S to 65N

Model relaxed to Levitus climatology at the northern boundary (the Bering Sea in the north Pacific)

An extended run of one version of the model (the Parallel Ocean Climate Model, POCM 4C) has been made for 1979-1998 using realistic momentum, heat, and freshwater fluxes created from ECMWF reanalysis fields. The model gives realistic simulations of major features that are important for understanding climate change in the NEP (Fig. 6).

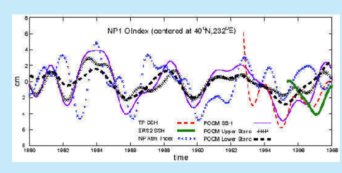

Figure 6. Comparison of output from Parallel Ocean Climate Model and observed fields at 40N, 152W. Fields are model sea surface height (SSH), model heat content (upper and lower steric height), SSH from two altimeters, and the North Pacific Index (SLP at 30N-65N, 160E-140W, Trenberth and Harrel, 1994). The similarities between the model and observed fields indicate the model simulates much of the observed interannual variability. The model's interannual variations are due to the wind forcing.