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Northeast Pacific Climate Change Mechanisms

Murphree, Tom

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Project Participants
Pacific Fisheries Environmental Laboratory (NMFS/NOAA/SWIFSC), Pacific Grove, CA
Frank Schwingham (lead PI)
Roy Mendelssohn (co-PI)
Richard Parrish (co-PI)
Lynn vanDriest (co-PI)
Phaadr Green (oceanographer)
Chris Moore (oceanographer)

Naval Postgraduate School, Monterey, CA
Tom Murphy (lead PI)
Robin Tomakian (co-PI)
Bert Seltmann (co-PI)
Bruce Ford (oceanographer/meteorologist)
Phaedra Green (oceanographer)
Lynn deWitt (co-PI)
Richard Parrish (co-PI)
Pacific Fisheries Environmental Laboratory

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

Salmon Catch and Decadal Changes

Figure 1. The extratropical Northern Oscillation Index (NOI) and salmon catch for Alaska (red) and the North Pacific Northwest (blue). The NOI (dashed lines) is the sea level pressure anomaly (SLPA) in the NPO minus the SLP at Darwin, Australia (see green dots in Figs. 2, 3). The NOI integrates and spatially 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 NOI, we can define decadal climate regimes and regime transitions. Since 1970, the NOI 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.

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

Overview
We are investigating mechanisms of climate change in the northeast Pacific (NEP) related to variations in marine ecosystems, especially fish populations. In this research, we are synthesizing and analyzing extensive historical ocean and atmospheric data sets. Our work uses global, high-resolution, ocean models to simulate processes not adequately represented in current models (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.

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Activities and Results
Development of Data Bases and Data Access Servers
http://salmonid.pfeg.noaa.gov/las.html

1. Atollkreis of convenient access to COADS and WOCE products
2. Distribution of oceanic and atmospheric products derived from NCEP reanalyses, including new environmental indices
3. 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 intra-annual to decadal scales (Fig. 2, 3)
Analysis of non-stationary of seasonal cycles
Identification of common trends in atmospheric/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: ENSO processes in upper ocean (Fig. 4)
Air-sea fluxes
Ocean advection
Planetary waves in the ocean and atmosphere (Fig. 5)
Atmospheric teleconnections (Fig. 5)
Hypothesis testing with ocean/atmosphere models (Fig. 6)

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 mechanisms 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.

North Pacific Decadal Anomalies

Figure 2. Composites of sea surface temperature (°C) and surface wind 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 oppositely, 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 NOIs 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.

Figure 4. Monthly time series of regional composite anomalies of (a) NOBC coastal buoy wind, (b) NOBC coastal buoy SST, and (c) coastal sea level (CSL) along central California, 1995-99. The red line in (c) is CSL, the red line is CSL estimated from regression against wind stress (daily wind anomaly trend r=0.89), the blue line is CSL estimated from regression against stress and SST anomalies (r=0.89). Most of the CSL signal since 1995 is due to coastal El Niño processes and upper ocean warming, as represented by SST. The wind did not track the interannual rise and fall in CSL from early August 1995 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 to interannual scales and by remote ocean-atmosphere teleconnections.

Figure 5. The anomalies 200 mb vertical wind field (m) for September-January of 1970-1976, during a positive phase of the NOIs (Fig. 1), a period of generally negative ocean temperature anomalies in the NEP (Fig. 2). Alternating patches of red and blue arcing from east Asia to the north Pacific indicate a quasi-stationary atmospheric wave train. The wave train extends down 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 arrows indicate 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 Arctic monsoon region and the northwestern Atlantic. Understanding the mechanisms that affect the NEP may also help explain variations in the other US GLOBEC region.

Figure 6. Comparison of output from Parallel Ocean Model and observed fields at 40N, 152W. Fields are modeled sea surface height (SSH), model heat content (upper and lower isotherm height), SSH from two climatology fields (upper and lower steric height), SSH from two climatology fields. 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.

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