Downscaling Climate Model Projections for Marine Ecosystem Applications

Nick Bond, University of Washington/JISAO and NOAA/PMEL

Collaborations featuring ABSILCC, UAF (J. Walsh)
Topics

• Long-term projections from Scenarios Network for Alaska and Arctic Planning (SNAP) and the Bering Sea project

• Seasonal predictions from J-SCOPE for the Pacific Northwest coast
Downscaling of global climate models by SNAP (Scenarios Network for Alaska and Arctic Planning)

- A set of 20+ models were compared with data (1958-2000) for surface air temperature, sea level pressure, and precipitation
- Models that perform best over Alaska have been selected
- Two statistical downscaling methods: one for monthly means by decade, one for changes in extremes
Decadal temperature and precipitation, **A2 scenario**: Attu, AK

**Average Monthly Temperature for Attu, Alaska**

Due to variability among climate models and among years in a natural climate system, these graphs are useful for examining trends over time, rather than for precisely predicting monthly or yearly values. For more information on derivation, reliability, and variability among these projections, please visit www.snap.uaf.edu.

**Average Monthly Precipitation for Attu, Alaska**

Due to variability among climate models and among years in a natural climate system, these graphs are useful for examining trends over time, rather than for precisely predicting monthly or yearly values. For more information on derivation, reliability, and variability among these projections, please visit www.snap.uaf.edu.
Episodic Events: # of days with average temperature > 12ºC
Bering Sea, Jun-Aug 1981-2099, 3 models (RCP 8.5)

-- large increase in summer days warmer than 54ºF
Episodic Events: # of days with average windspeed >10.8 m/sec
Bering Sea, Sep-Oct 1981-2099, 3 models (RCP 8.5)

-- increase in autumn storminess
Dynamical Modeling for the Bering Sea Project

Higher trophic levels (Pollock etc.)
- Secondary Producers (Zooplankton)
- Primary Producers (Phytoplankton)
- Nutrients (NO$_3$, NH$_4$...)
- Physical Forcing (Wind, temp, sun)

Economic/ecological model
- FEAST Higher trophic level model
- NPZ Lower trophic level Ecosystem model
- ROMS Physical Oceanography
- Climate scenarios

BSERP
BEST
Surface Temperature Changes (August) from Present to 2030s

Al Hermann, UW

CCCMA

MIROC
Ice Phytoplankton Concentration

- Date Range: 12/29/2002 04:00 - 12/04/2039 04:00

The modeled concentration of ice algae averaged over time.

Data set

PMEL MIROC Climate Model

NOAA’s Pacific Marine Environmental Laboratory (PMEL) produced downscaled climate forecasts from three global climate models for the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). This product contains one of the models: the Model for Interdisciplinary Research on Climate (MIROC)-M model developed by a consortium of agencies in Japan. Compared to other models tested by PMEL, MIROC-M was intermediate in degree of warming over the Bering Sea shelf for the first half of the 21st century.
Time Series for a Location West of Nunivak Island based on Climate Forcing from MIROC
A Couple of Takeaways

• Dynamical downscaling and empirical approaches are being used with global climate models for various types of applications

• Extreme/episodic events can be a key aspect of the climate forcing of a system, complicating long-term projections

• Check out www.snap.uaf.edu & http://data.aoos.org/maps/search/arctic.php?#search?q=pmel&tagId=null&page=1

Google “AOOS Arctic Data Integration Portal” and Search “PMEL”
J-SCOPE
JISAO’s Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE)

Nick Bond, Al Hermann, Jan Newton, Samantha Siedlecki (UW)
Isaac Kaplan, Phil Levin, Bill Peterson, Greg Williams (NOAA/NWFSC)

1. Brief Description of System

2. Early Results
Salmon returns are linked to conditions encountered by young salmon during their first summer at sea

B. Peterson NOAA/NWFSC

<table>
<thead>
<tr>
<th>Juvenile Migration Year</th>
<th>Adult Return Outlook</th>
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<td>Large- scale ocean and atmospheric indicators</td>
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<td>PDO (May – Sept)</td>
<td>■</td>
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<td>ONI (Jan-Jun)</td>
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<td>Local and regional physical indicators</td>
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<td>Sea surface temperature anomalies</td>
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<td>Coastal upwelling</td>
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<td>Deep water temperature and salinity</td>
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<td>Local biological indicators</td>
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<td>Copepod biodiversity</td>
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<td>Northern copepod anomalies</td>
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<td>Biological spring transition</td>
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<td>Winter Ichthyoplankton</td>
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<td>Spring Chinook Salmon--June</td>
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Key:
- ■: good conditions for salmon
- yellow circle: poor conditions for salmon
- green circle: good returns expected
- orange circle: poor returns expected
- no data
Elements of Forecast System

- Large-scale atmospheric and oceanic conditions provided by NCEP’s Coupled Forecast System (CFSv2) model
- Dynamical downscaling (~1.5 km grid) with the Regional Ocean Modeling System (ROMS) with a lower-trophic level (NPZD2) module
- ROMS output used in an integrated ecosystem assessment
- Projections publically available on the NANOOS website
Regional Ocean Modeling System (ROMS)

1.5 km grid spacing

Tides

Climatological freshwater runoff

NPZD module from Banas et al. (2009) with additional detrital and oxygen sub-model

Algorithms using oxygen and temperature to derive pH and aragonite undersaturation

Nitrate and oxygen values for initial and boundary conditions based on CFSv2 salinity and observed relationships

Phytoplankton and zooplankton set as seed stocks at ROMS boundary
Focus on the biogeochemistry (pH, pCO$_2$, pO$_2$); Banas et al. (2009)
Welcome to NANOOS, the Pacific Northwest regional ocean observing system of IOOS (Integrated Ocean Observing System). NANOOS is creating customized information and tools with these areas of emphasis:

Maritime Operations  Ecosystem Assessment  Fisheries & Biodiversity

Coastal Hazards  Climate

Data Exploration
NVS (NANOOS Visualization System) is a web app that provides easy access to observations, forecasts, data, and visualizations.

Ocean Acidification in the Pacific Northwest
The marine waters of the Pacific Northwest are particularly vulnerable to ocean acidification. NANOOS, with its partners, is collecting and making available ocean acidification related water quality data from sensitive areas along the coast and within Puget Sound.

Visit the OA Page
NANOOS and the Shellfish Industry
Mean January Meridional Wind

6 month forecasts (initialized previous July) for 43-49 N, 128-124 W
Oxygen Concentrations off the Washington Coast
Surface Chl Climatology

Venegas et al, 2008

May–June 2014

July–August 2014

Sept–Oct 2014

Nov–Dec 2014

Sept 2014 is higher than average but closer to the coast
Too Warm

Too Much Primary Productivity

Systematic Errors from ROMS Simulations
Predicted vs. Observed Presence of Sardines in 2009 based on ROMS re-forecasts of T, Salinity, Chl, O2 (Kaplan et al.)

Simple Model

Complex Model
An ecosystem is: "The functional unit of a biological organization interacting with the physical environment such that the flow of energy and mass leads to a characteristic trophic structure and material cycles." ~ Odum, 1969.

NOAA further defines the environment as "the biological, chemical, physical, and social conditions that surround organisms. When appropriate, the term environment should be qualified as biological, chemical, and/or social" (Murawski and Matlock 2006).

The J-SCOPE forecasts are developed to support the California Current Integrated Ecosystem Assessment. Integrated Ecosystem Assessments (IEAs) are a framework for informing ecosystem-based management, which aims to take into account interactions among ecosystem components and managed sectors, as well as cumulative impacts of a wide spectrum of ocean-use sectors (Rosenberg and McLeod 2005). IEAs are a synthesis and quantitative analysis of information on relevant natural and socioeconomic factors, in relation to ecosystem management objectives (Levin et al. 2005).

In the context of the California Current IEA, JSCOPE provides short term (six to nine month) forecasts of ocean condition that are testable and relevant to management decisions for fisheries, protected species and ecosystem health. Results will directly inform the IEA process, and will forecast indicators requested by the Pacific Fishery Management Council.
Final Remarks

• Downscaling from global climate models has been undertaken under the auspices of the SNAP and Bering Sea projects
• A seasonal prediction system (J-SCOPE) has been developed for the coastal waters of the PNW
• A similar effort is beginning for the Bering Sea
Euphausiids
Large copepods
Microzooplankton
Small phytoplankton
Large phytoplankton
Nitrate
Ammonium
Iron
Excretion + respiration
Mortality
Predation
Egestion
Fast sinking detritus
Slow sinking detritus
Inexplicit food source
Feast
Benthic fauna
Benthic detritus
Water
ICE