Models linking climate to lower trophic levels: Status and future – Bering Sea

Albert J. Hermann

University of Washington JISAO
NOAA Pacific Marine Environmental Laboratory
Our method thus far

• Apply a subset of AR4-IPCC models as *physical* forcing to a regional model

• NPZ dynamics embedded in the regional model use climatological IC/BC
Climate models provide BCs/ICs to regional coupled models.


NPZ FOOD WEB (FEAST)
Bering10K model

- Descendent of NEP5 (Danielson et al. 2012)
- 10 layers, 10-km grid
- Includes ice and tides
- CCSM bulk flux
- Details in Hermann et al. (DSR2, 2013)
Other regional projection models for the Bering Sea

• Curchitser et al. NEP5-NEMURO
• Zhang and Banas et al. BESTMAS regional model with “Lagrangian” biology
• Others?
What is unique about the Bering Sea?

– Physical
  • Seasonal ice with advection to the south
  • Tidal mixing sets up distinct biophysical regimes

– Biological
  • Ice plankton may be a major food source to higher trophic levels
  • Benthic food chain is a major player
Modeled vs observed temperatures at M2
depth-average temperature 2010 (0-40m)

DATA

MODEL
Bottom temperature 2009

DATA

MODEL
Resolution of AR4-IPCC model output (single A1B scenario realizations)

<table>
<thead>
<tr>
<th>MODEL</th>
<th>CGCM3.1</th>
<th>MIROC</th>
<th>ECHOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCEAN</td>
<td>1.85-degree lat</td>
<td>~1.0-degree lat</td>
<td>~2.8 lat*</td>
</tr>
<tr>
<td></td>
<td>1.85-degree lon</td>
<td>~0.5-degree lon</td>
<td>~2.8 lon</td>
</tr>
<tr>
<td></td>
<td>monthly</td>
<td>monthly</td>
<td>monthly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~finer near equator</td>
<td></td>
</tr>
<tr>
<td>ATMOSPHERE</td>
<td>3.75-degree lat</td>
<td>~2.5-degree lat</td>
<td>~3.7-degree lat</td>
</tr>
<tr>
<td></td>
<td>3.75-degree lon</td>
<td>~1-degree lon</td>
<td>~3.75-degree lon</td>
</tr>
<tr>
<td></td>
<td>daily</td>
<td>daily</td>
<td>daily</td>
</tr>
</tbody>
</table>
Bering10K resolves more detail!

MIROC

Bering10K
Projected EBS ice cover and vertical average temperature

Standard BEST/BSIERP bioregions of the Bering Sea (Ortiz, 2012)
Middle shelf 0-100m temperature

BLACK = CORE/CFSR hindcast
RED = CGCM3 forecast
GREEN = MIROC forecast
BLUE = ECHO-G forecast

Solid lines = annual averaged values
Dashed lines = decadal running means.
SST (deg C)

“Present” (2003-2012)

“Future” (2031-2040) w.r.t. present

CGCM3

MIROC

ECHOG
Large Crustacean Zooplankton (mgC m\textsuperscript{-3})

CGCM3  MIROC  ECHOG

“Present” (2003-2012)

“Future” (2031-2040) w.r.t. present
Northward wind stress (N m$^{-2}$)

CGCM3

MIROC

ECHOG

“Present” (2003-2012)

“Future” (2031-2040) w.r.t. present
Ice coverage (fraction)

“Present”
(2003-2012)

“Future”
(2031-2040)

w.r.t. present
Projected EBS July bottom temperatures

- Ensemble average cold year
- Ensemble average medium year
- Ensemble average warm year
Approach thus far: Individual realizations of global model applied to regional model.

- this generates a regional forecast ensemble which retains all of the nonlinear processes in both global and regional simulations.
- However, *computational and human resources* presently limit the size of this ensemble, since the regional models typically utilize a finer spatial grid, a smaller time step, and more biological detail than their global counterparts.
Alternative approach: reduce dimensionality with multivariate statistics

• Summarize covarying modes of behavior in large- and small-scale models
• Convolve the large-scale patterns with multiple realizations of the large-scale forecast
• Interpret resulting time series as realizations of the covarying small-scale phenomena. Get mean trajectory and spread of small-scale “forecast”
Idealized examples

• Hit a bell (forcing) -> it rings (response)
  – Space/time pattern of impact is the forcing: normal modes of the bell are the response
  – Look for coupled mode of hitting and ringing
  – Convolve the hitting pattern with a forecast of hits to get a forecast of rings

• Large-scale winds (forcing) -> upwelling (response)
  – Look for coupled mode which has large-scale pattern associated with fine-scale coastal conveyor belt response (upwelling -> nutrients -> phytoplankton -> zooplankton)
  – Convolve that large-scale pattern with a single global forecast realization to infer upwelling “realization”
  – Repeat for many forecasts to get many “realizations” of the future upwelling response
How to improve our regional biological boundary conditions?

• Take values directly from ESMs.
• Use linear mapping of state variables between the global and regional NPZ models
• Enforce conservation of basic currencies (e.g. N and C) across the boundaries
• Where necessary, modulate annual averages from IPCC output using present phenology
Conclusions

• Bering Sea has unique features which benefit from both spatial and trophic downscaling:
  – Ice advection and ice plankton
  – Tidal mixing
• Forecasts suggest continued interannual variability on top of a warming trend
• Consider possibilities for multivariate downscaling
• Enforce conservation of basic currency when mapping from global to regional model