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

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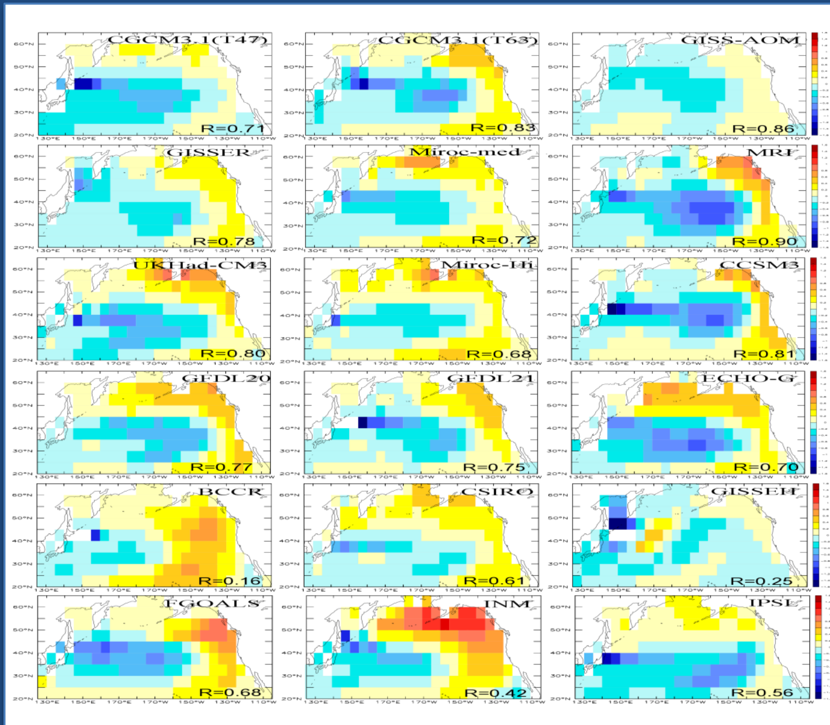
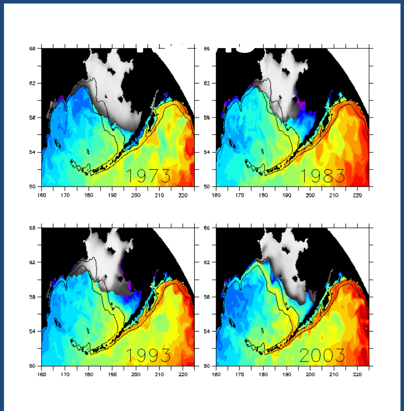
Our method thus far

- 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

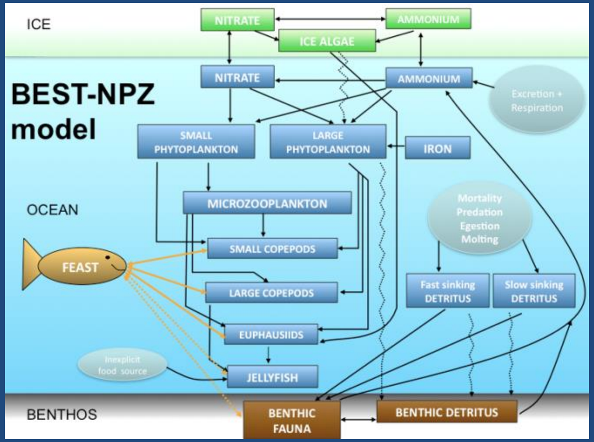
Climate models provide BCs/ICs to ***regional coupled models***



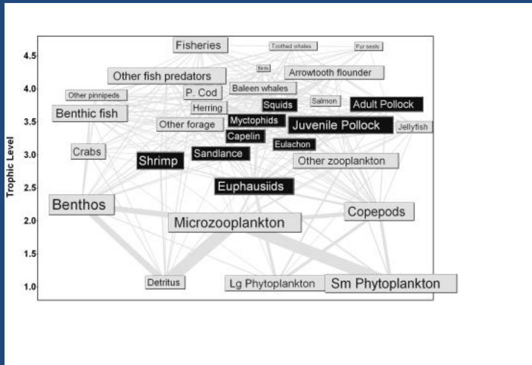
ensemble of runs



NPZ



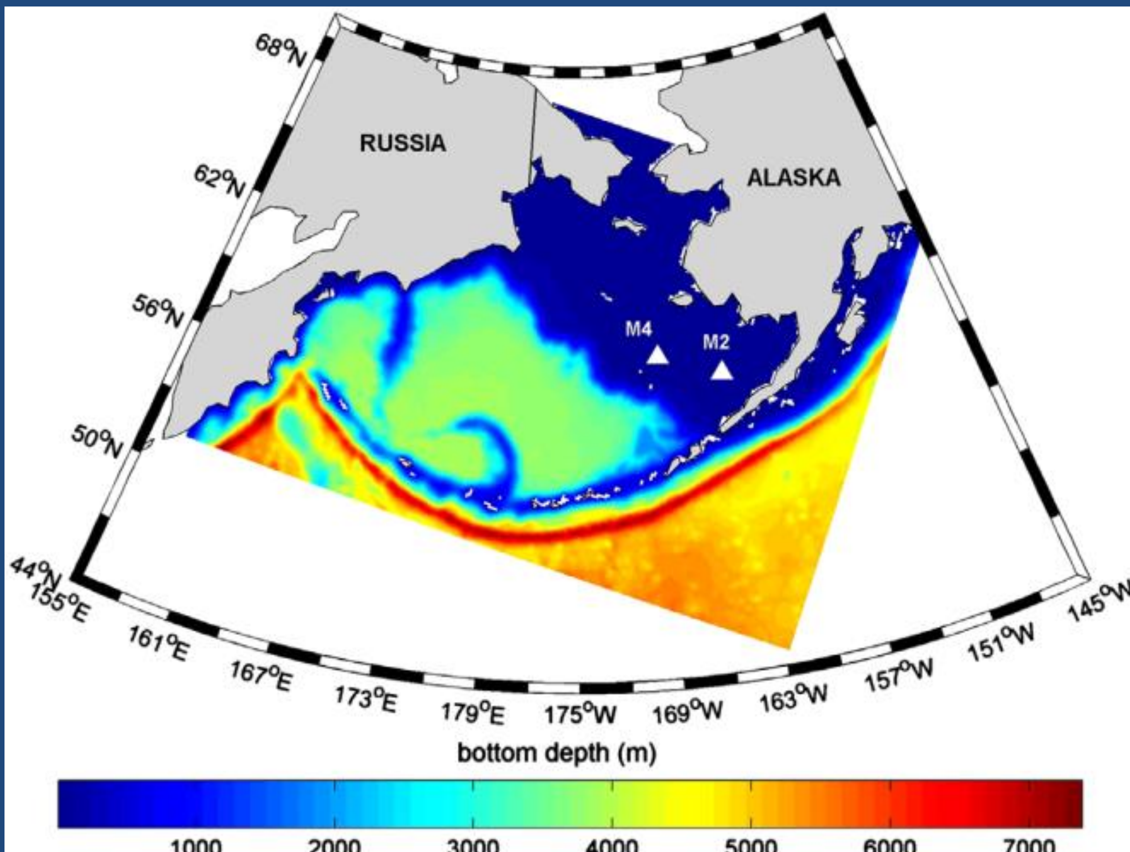
FOOD WEB (FEAST)



GOAL:
mutidecadal
projections of physics and biology in the Bering Sea

ensemble of projected futures

Bering10K model



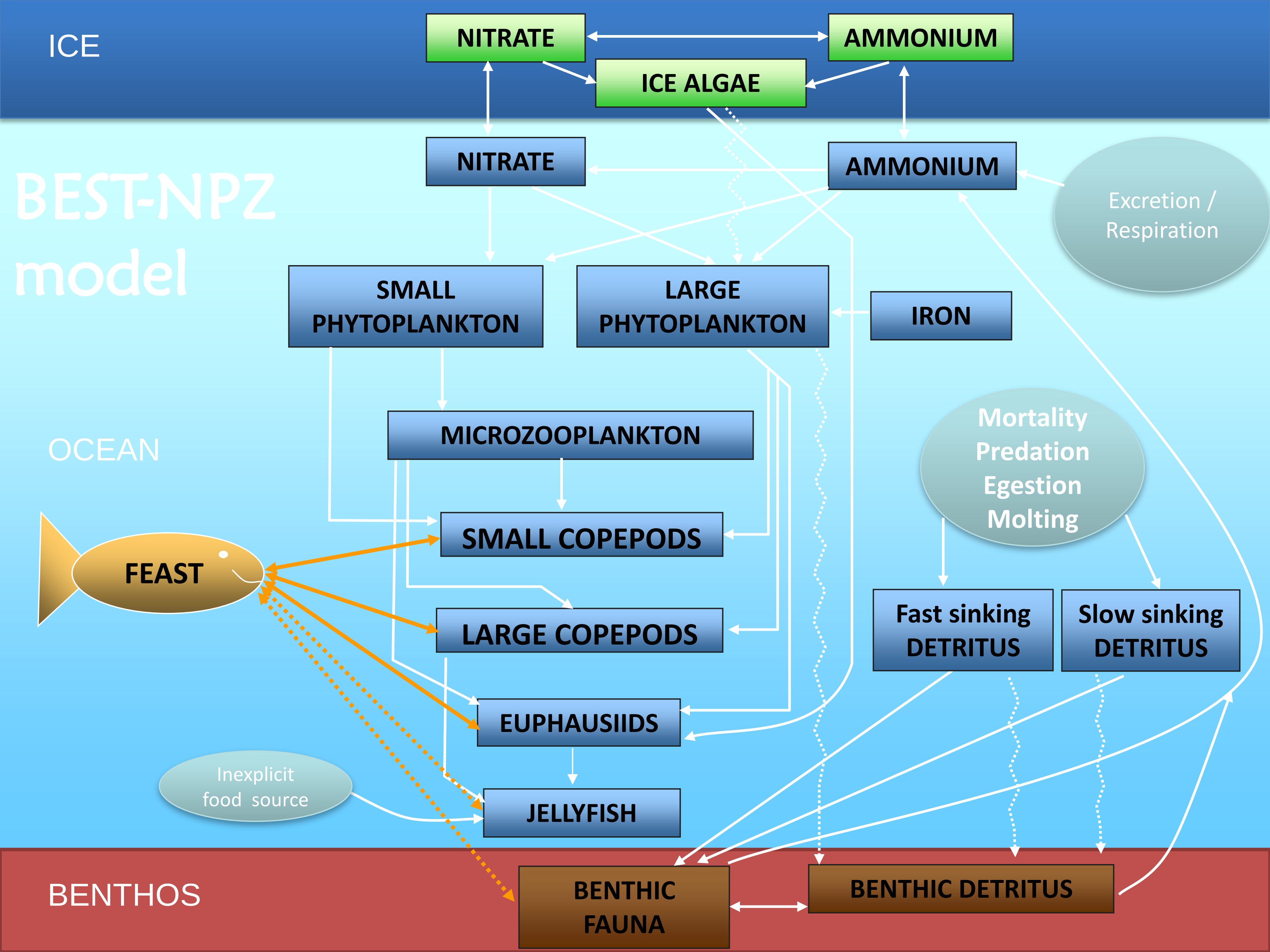
- Descendent of NEP5 (Danielson et al. 2012)
- 10 layers, 10-km grid Includes ice and tides
- CCSM bulk flux
- Details in Hermann et al. (DSR2, 2013)

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?

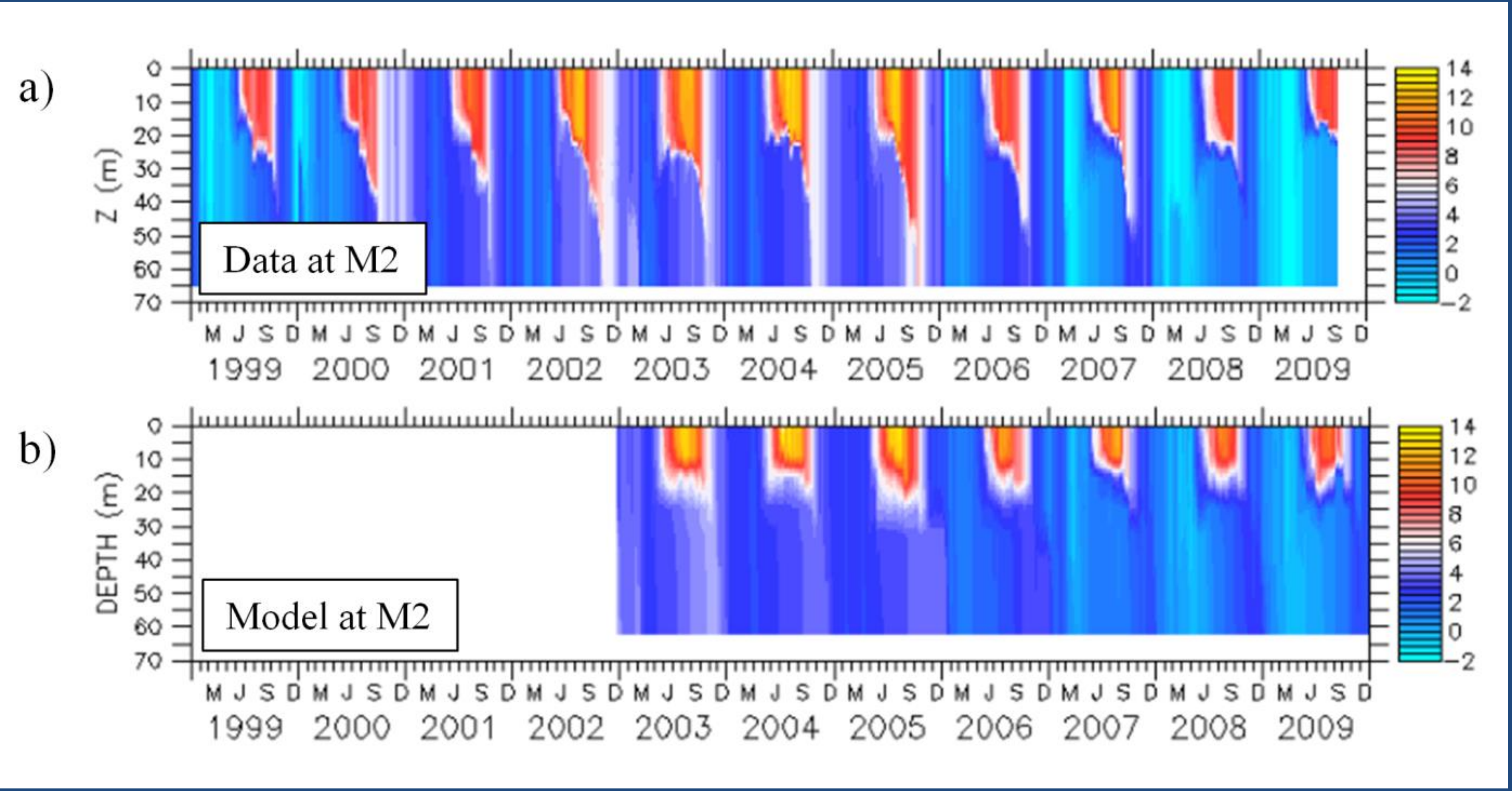
What is unique about the Bering Sea?

- 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



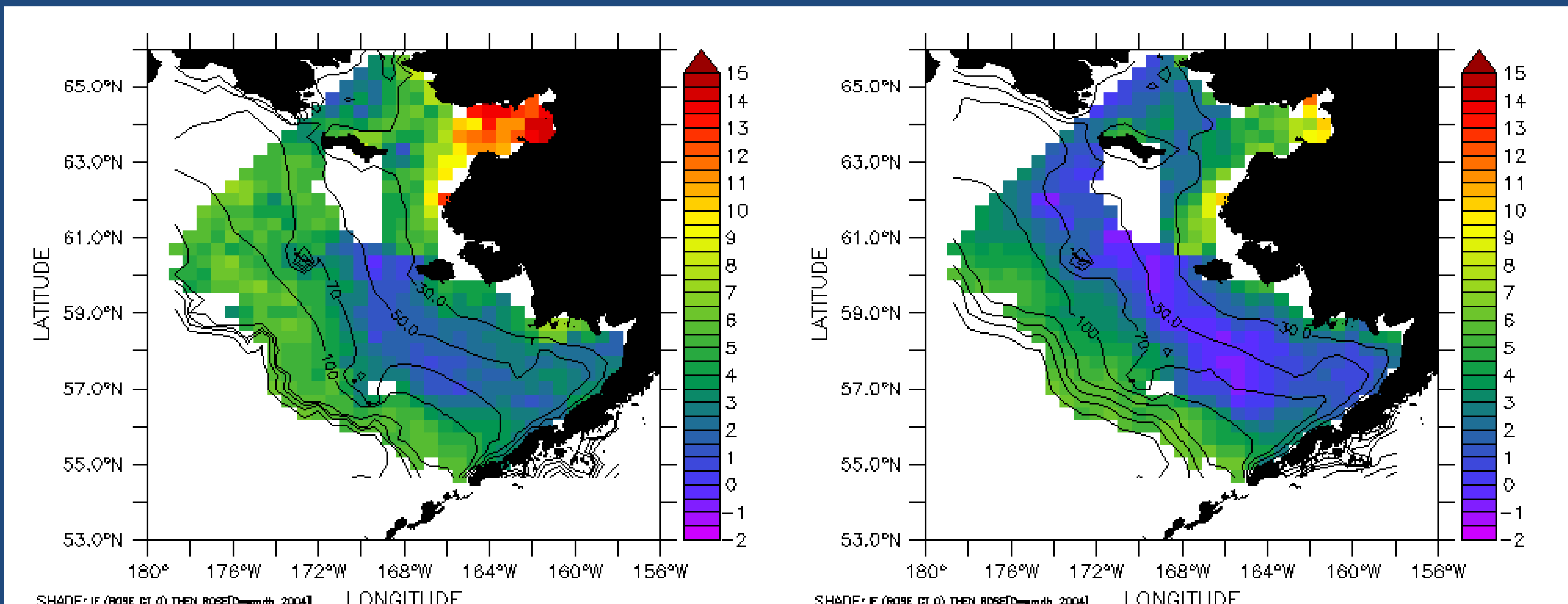
ICE
NITRATE
AMMONIUM
ICE ALGAE
NITRATE
AMMONIUM
BEST-NPZ model
Excretion / Respiration
SMALL PHYTOPLANKTON
LARGE PHYTOPLANKTON
IRON
MICROZOOPLANKTON
OCEAN
Mortality
Predation
Egestion
Molting
SMALL COPEPODS
FEAST
LARGE COPEPODS
Fast sinking DETRITUS
Slow sinking DETRITUS
EUPHAUSIIDS
Inexplicit food source
JELLYFISH
BENTHOS
BENTHIC FAUNA
BENTHIC DETRITUS

Modeled vs observed temperatures at M2



depth-average temperature 2010 (0-40m)

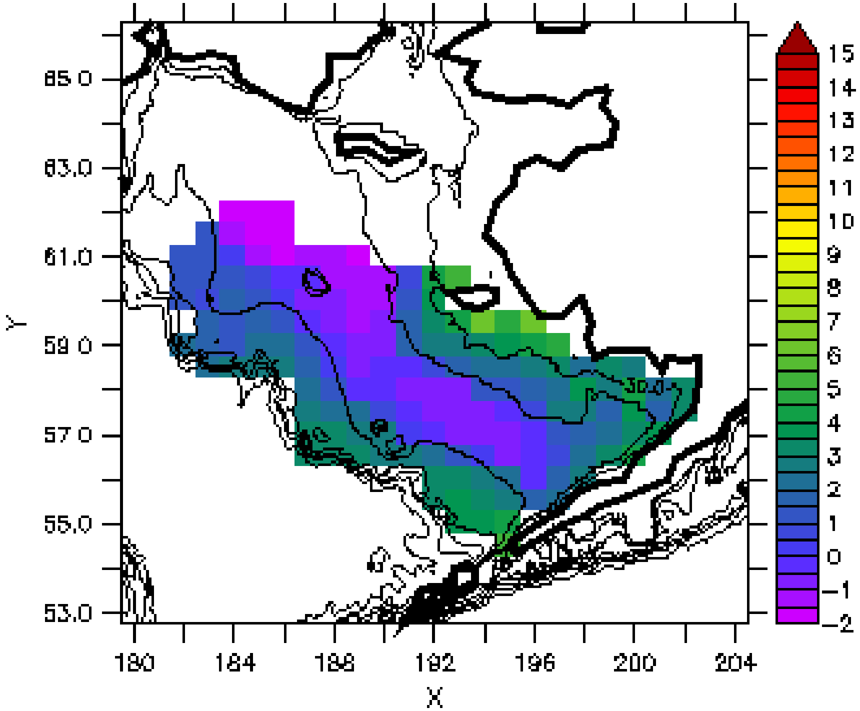
DATA MODEL

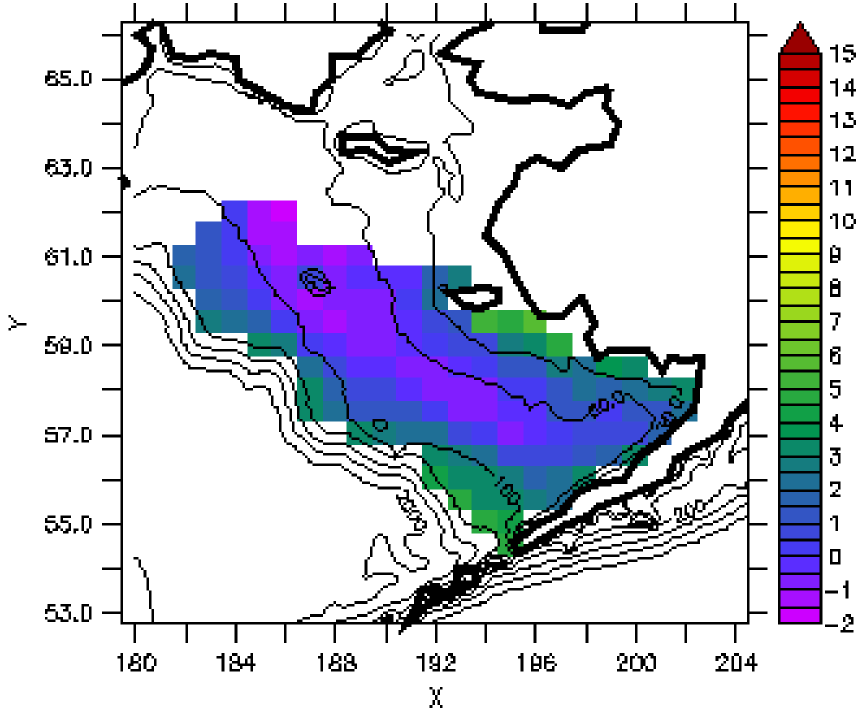


Bottom temperature 2009

DATA

MODEL



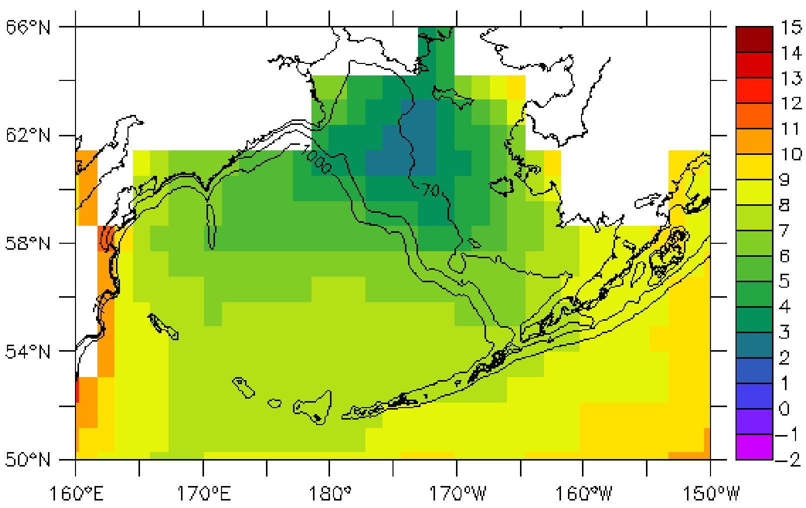


Resolution of AR4-IPCC model output (single A1B scenario realizations)

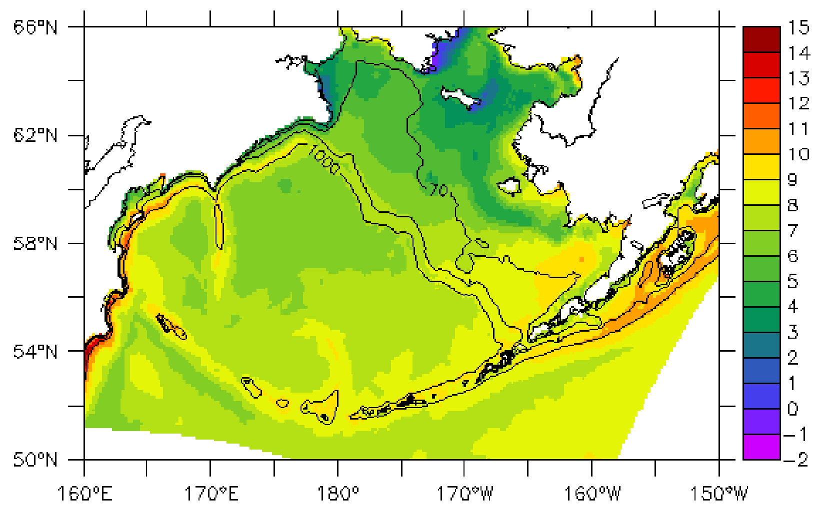
MODEL	CGCM3.1	MIROC	ECHOG
OCEAN	1.85-degree lat 1.85-degree lon monthly	~1.0-degree lat ~0.5-degree lon monthly	~2.8 lat* ~2.8 lon monthly *finer near equator
ATMOSPHERE	3.75-degree lat 3.75-degree lon daily	~2.5-degree lat ~1-degree lon daily	~3.7-degree lat ~3.75-degree lon daily

Bering10K resolves more detail!

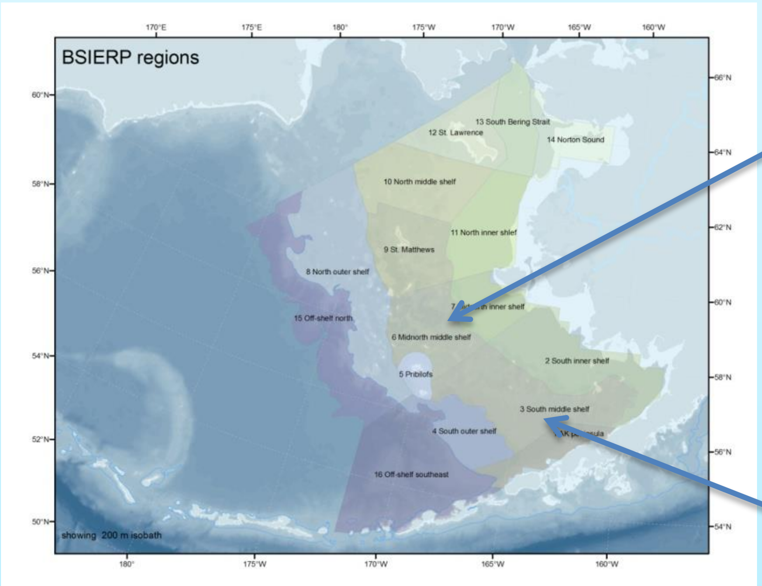
MIROC

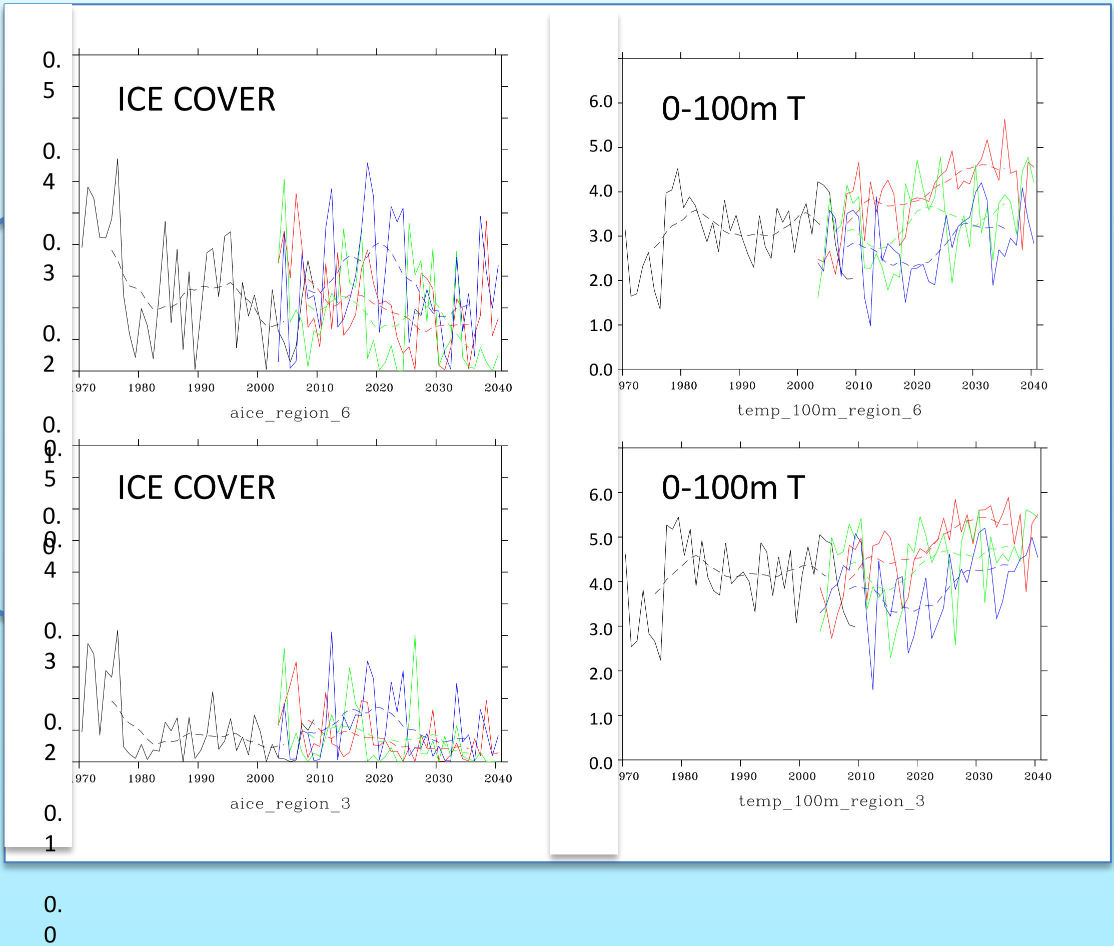


Bering10K



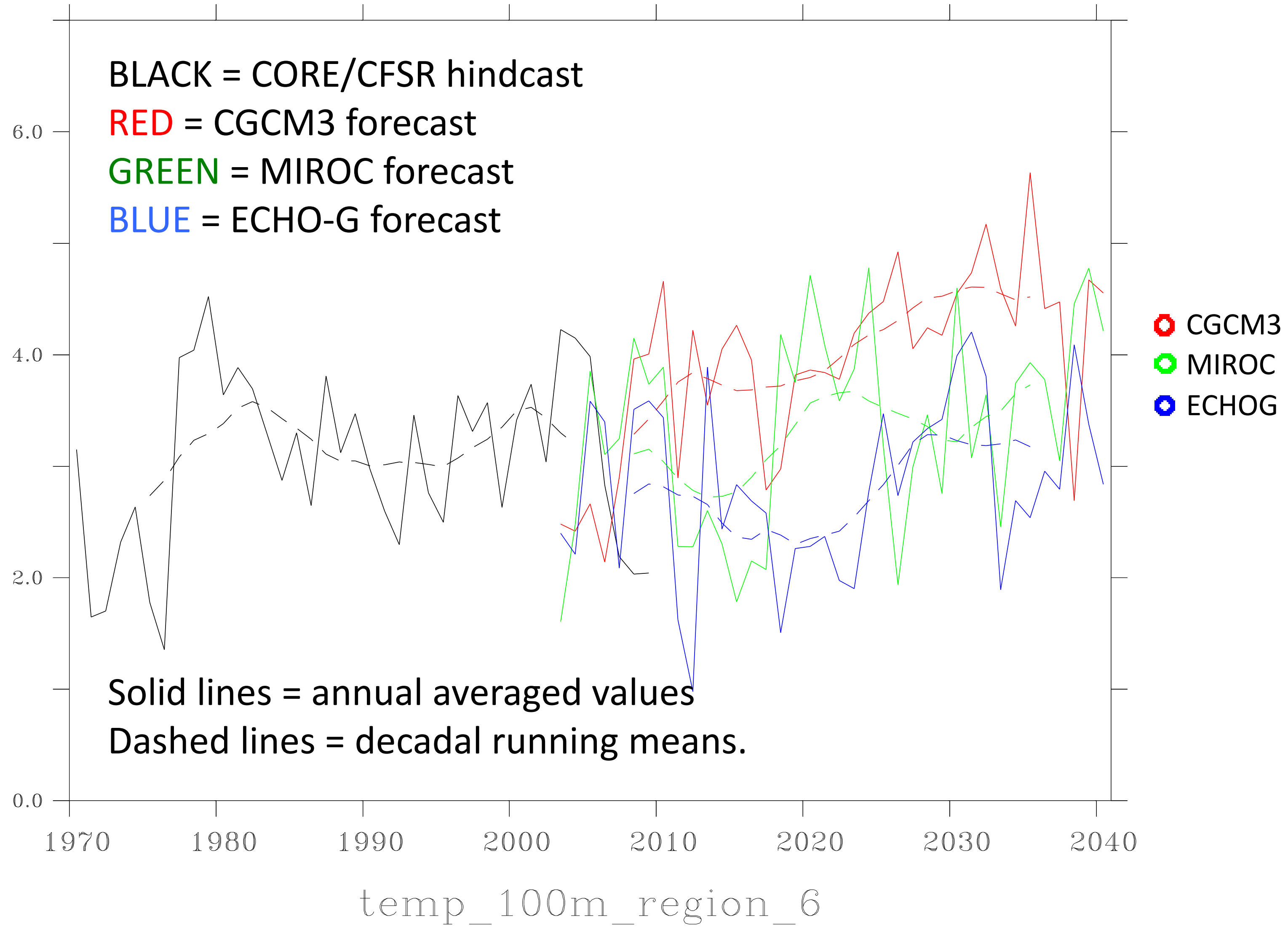
Projected EBS ice cover and vertical average temperature





Standard BEST/BSIERP bioregions of the Bering Sea (Ortiz, 2012)

Middle shelf 0-100m temperature

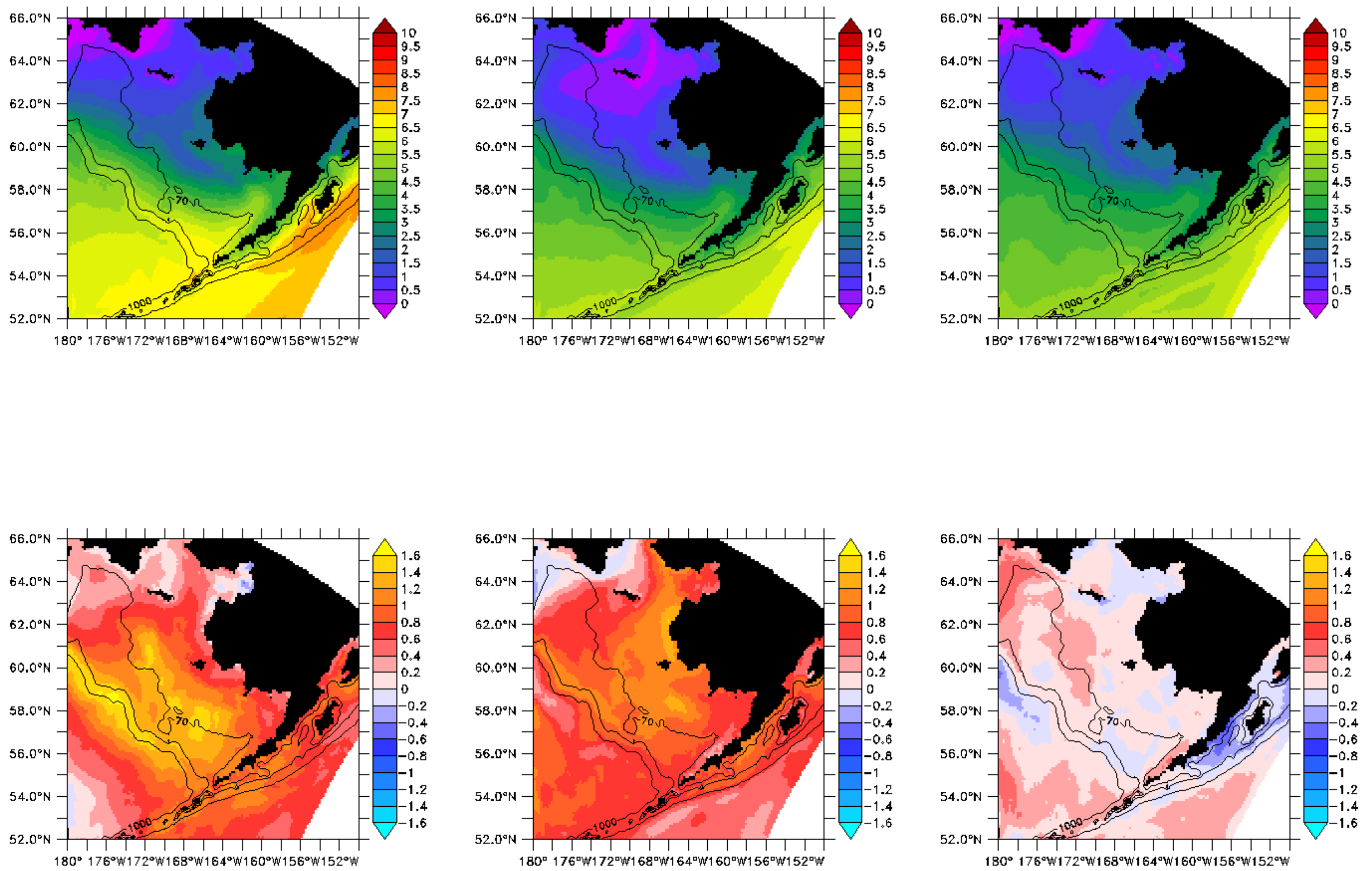


SST (deg C)

CGCM3 | MIROC | ECHOG

“Present”
(2003-2012)

“Future”
(2031-2040)
w.r.t. present

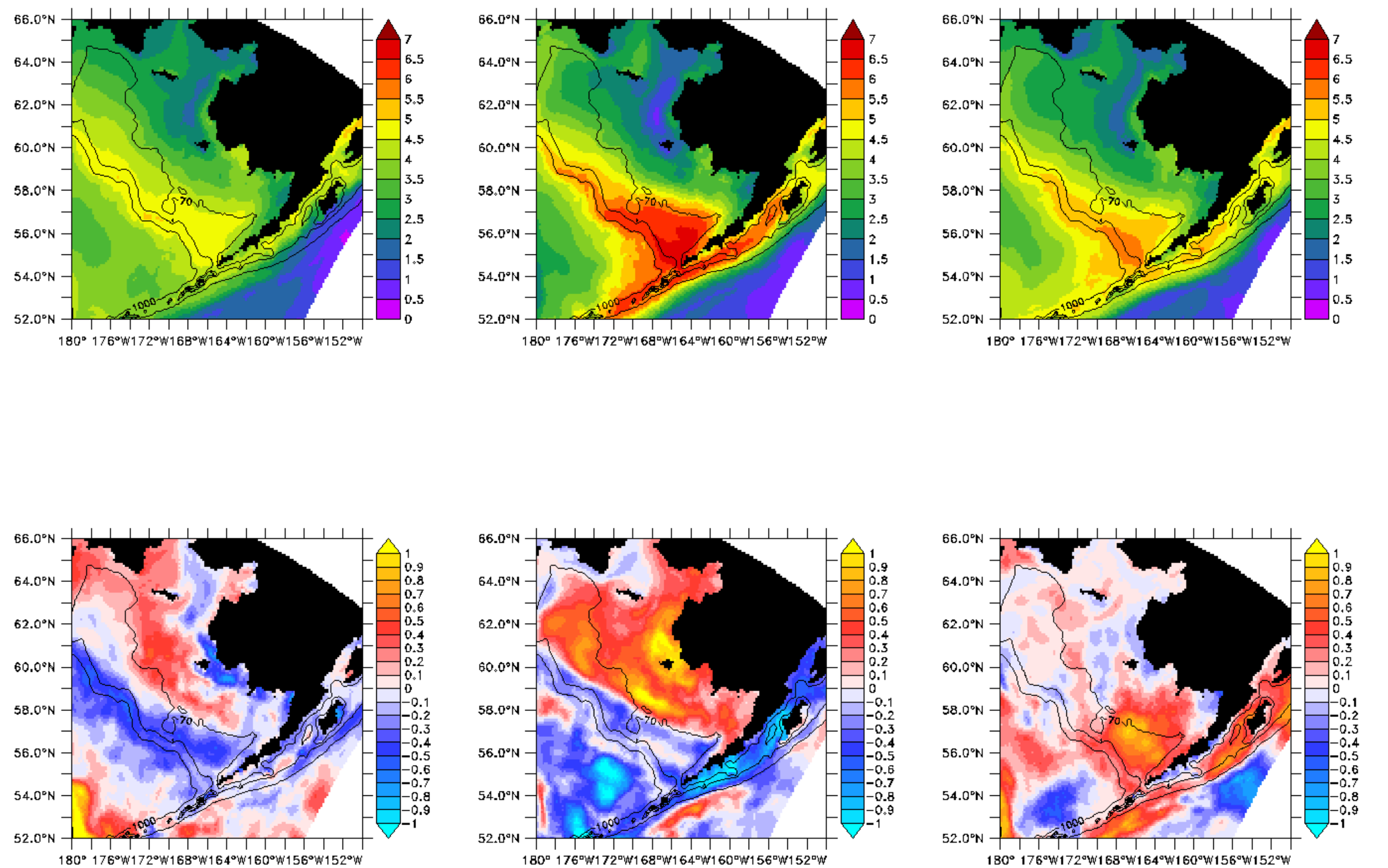


Large Crustacean Zooplankton (mgC m^{-3})

CGCM3 | MIROC | ECHOG

"Present" (2003-2012)

"Future" (2031-2040) *w.r.t.* present

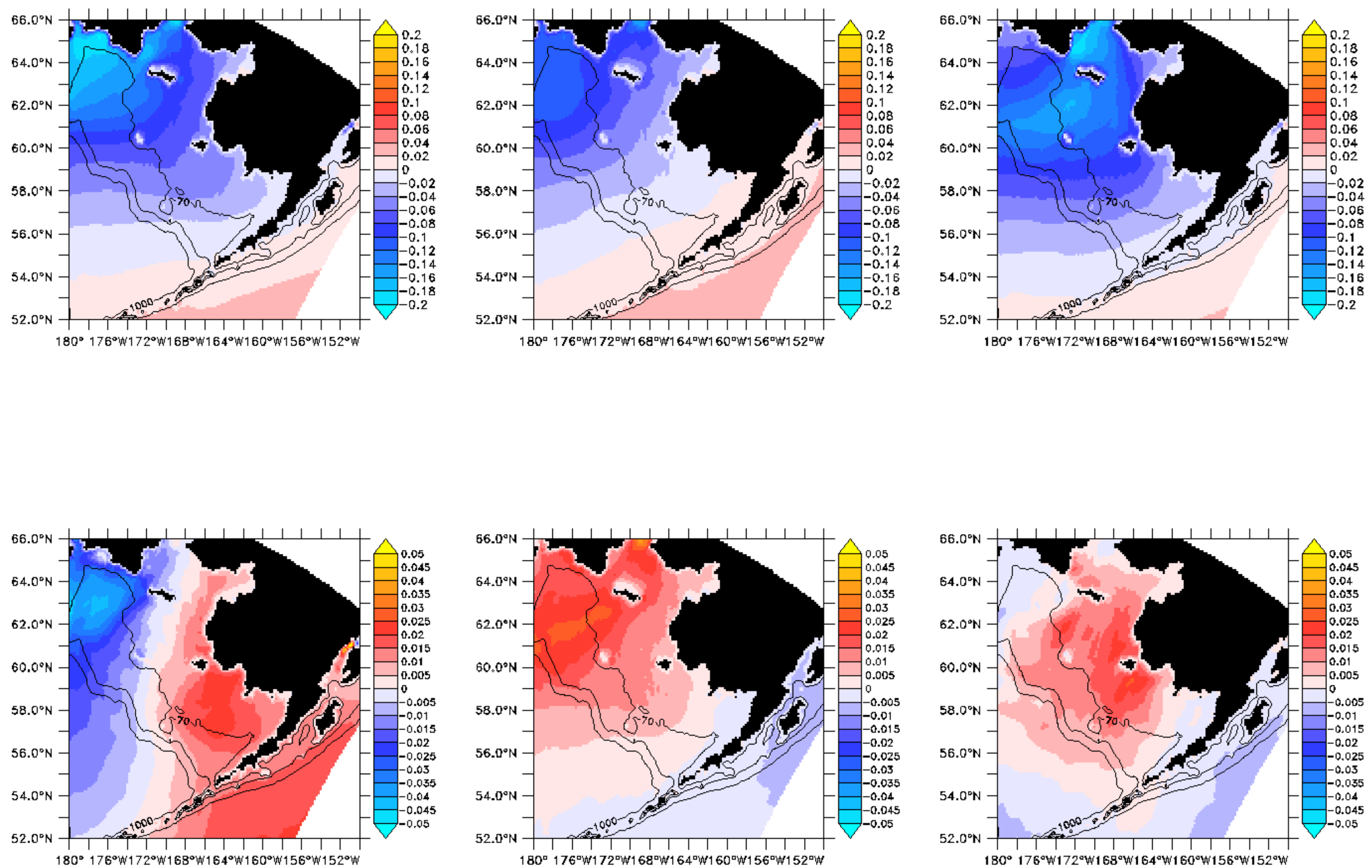


Northward wind stress (N m^{-2})

CGCM3 | MIROC | ECHOG

"Present" (2003-2012)

"Future" (2031-2040) *w.r.t.* present

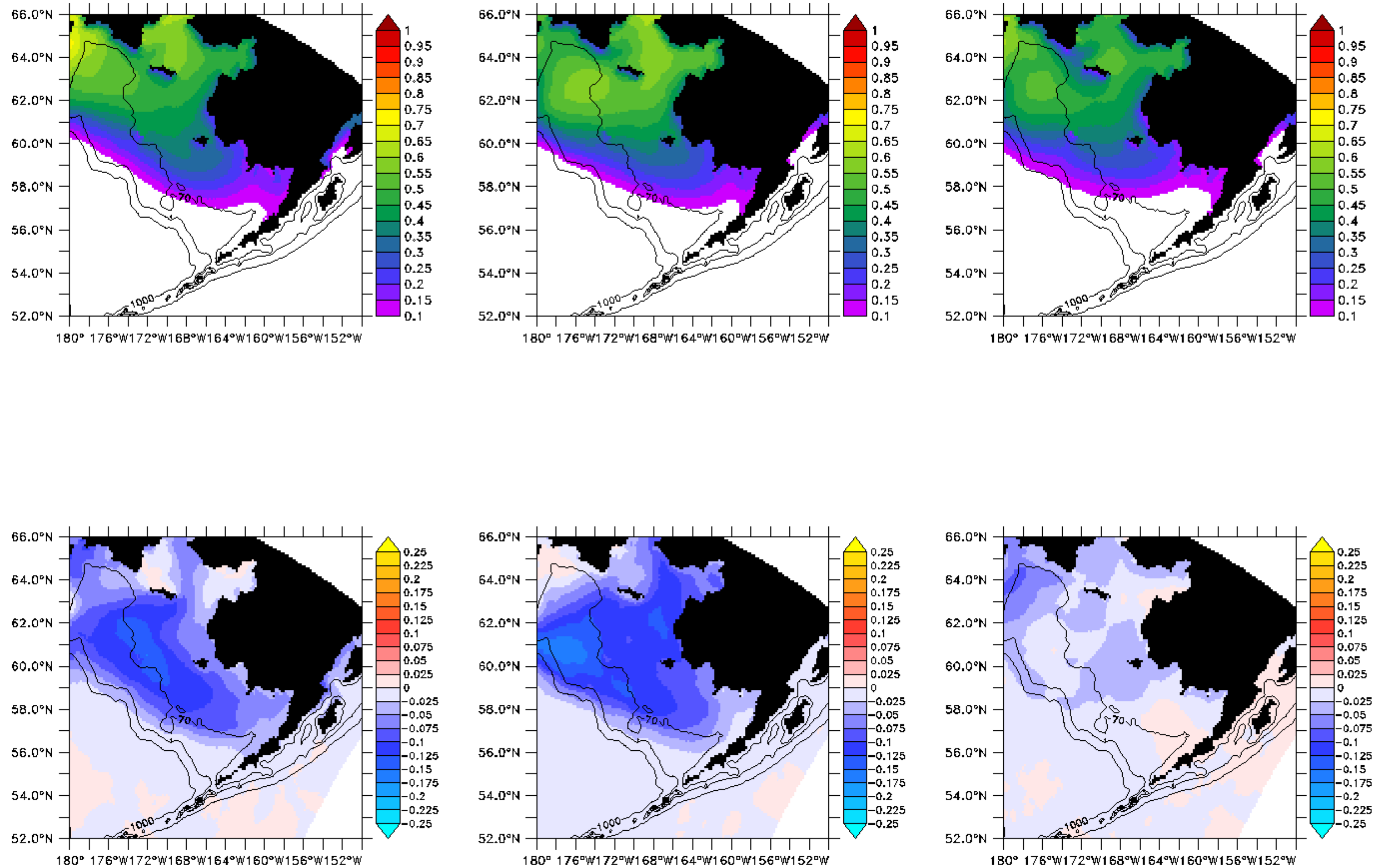


Ice coverage (fraction)

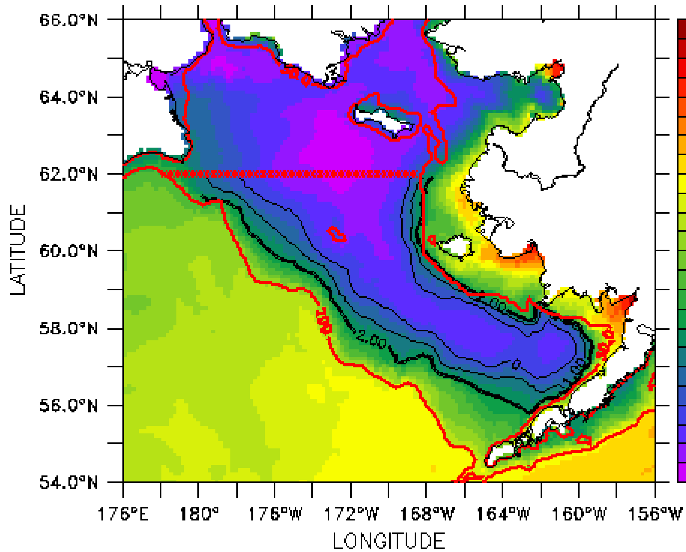
CGCM3 MIROC ECHOG

"Present" (2003-2012)

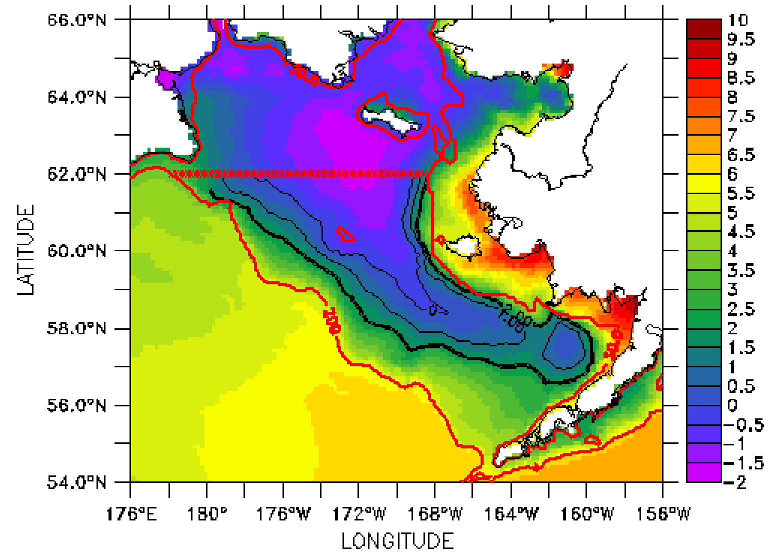
"Future" (2031-2040) *w.r.t.* present



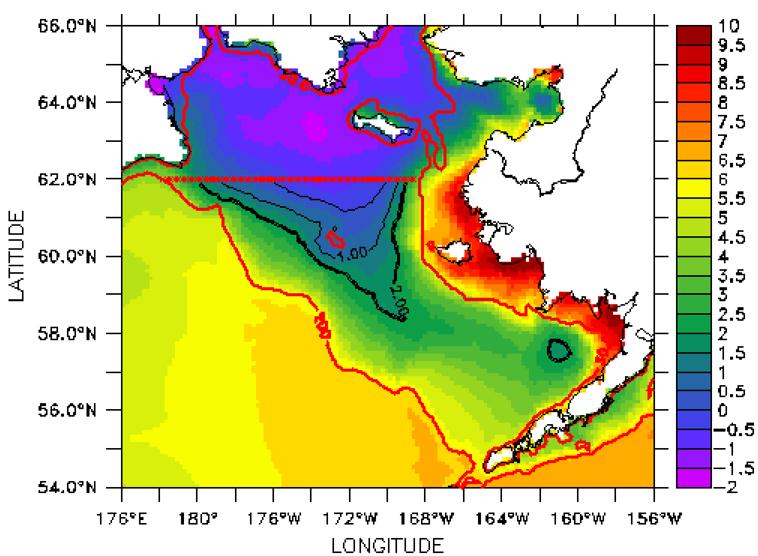
Projected EBS July bottom temperatures



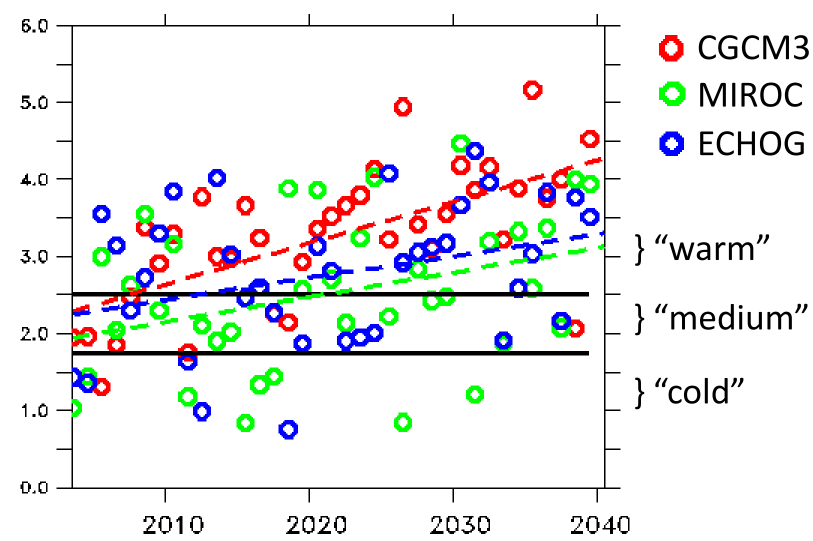
ensemble ave cold year



ensemble ave medium year



ensemble ave warm year



mean EBS bottom temperature

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