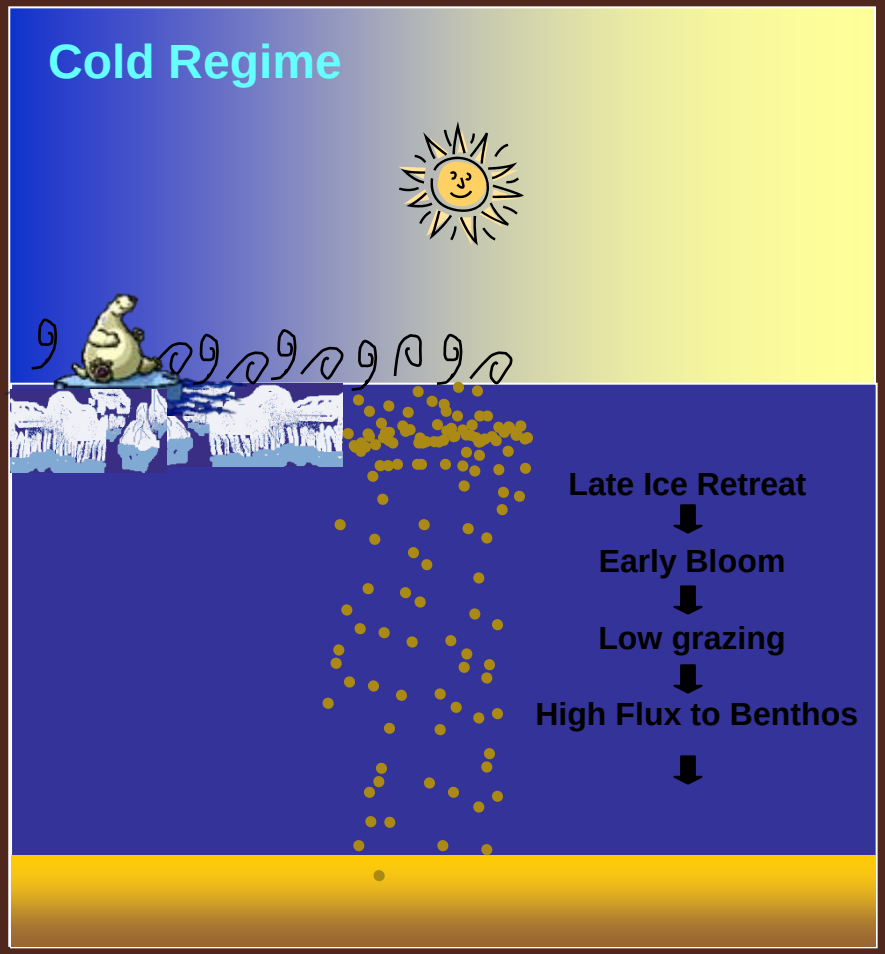
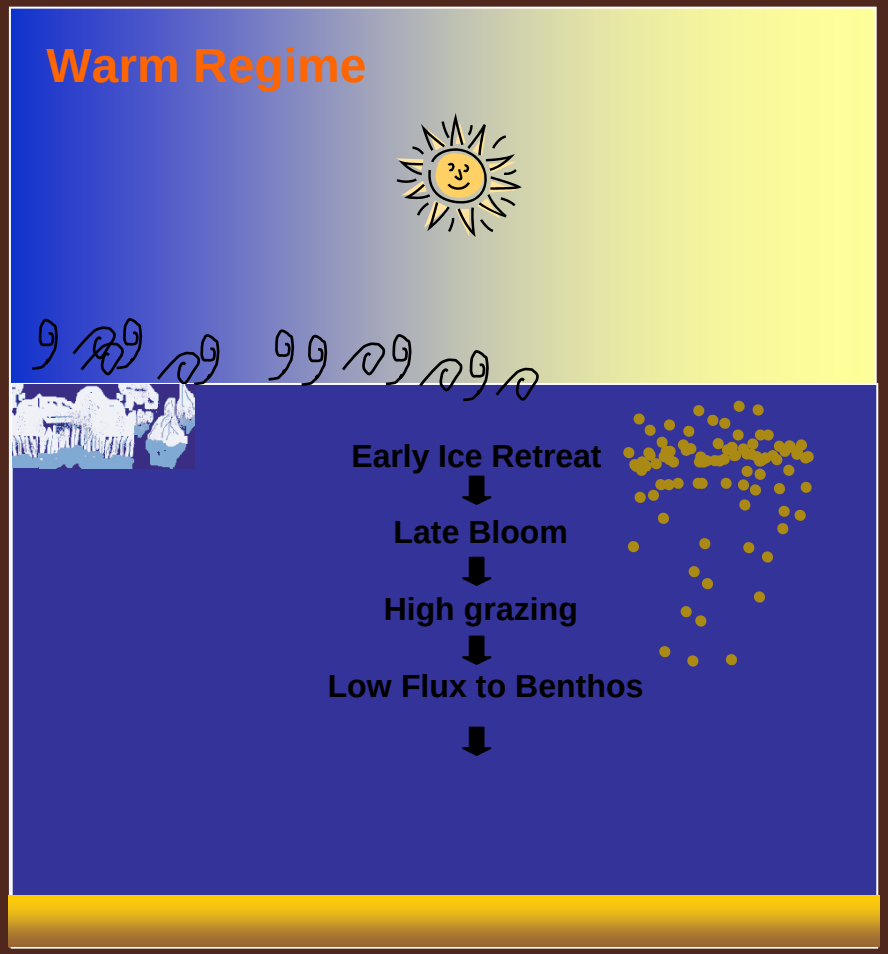
Simulated modes of biophysical variability on the Bering Sea shelf

- A. J. Hermann (UW-JISAO)
- K. Aydin (NOAA-AFSC)
- N. A. Bond (UW-JISAO)
- W. Cheng (UW-JISAO)
- E. N. Curchitser (Rutgers U)
- G. Gibson (UAF-IARC)
- K. Hedstrom (ARSC)
- Y. Ortiz (NOAA-AFSC)
- P. J. Stabeno (NOAA-PMEL)
- M. Wang (UW-JISAO)

Oscillating Control Hypothesis (as of Hunt et al. 2002)





To perform proposed ecosystem projections the NPZ model will need to be able to simulate the dynamics of both cold and warm regimes

Integrated Modeling

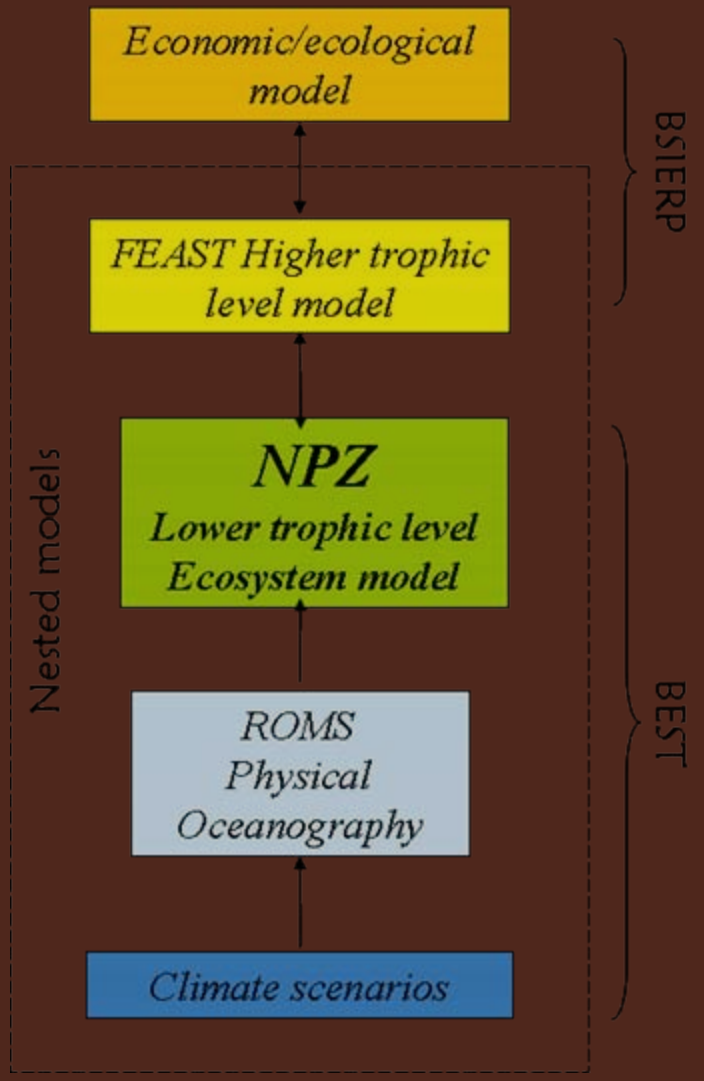
Higher trophic levels
(Pollock etc.)

Secondary Producers
(Zooplankton)

Primary Producers
(Phytoplankton)

Nutrients
NO_3, $NH_{4...}$

Physical Forcing
(Wind, temp, sun)



Our trophic levels…..

- K. Aydin (NOAA-AFSC)
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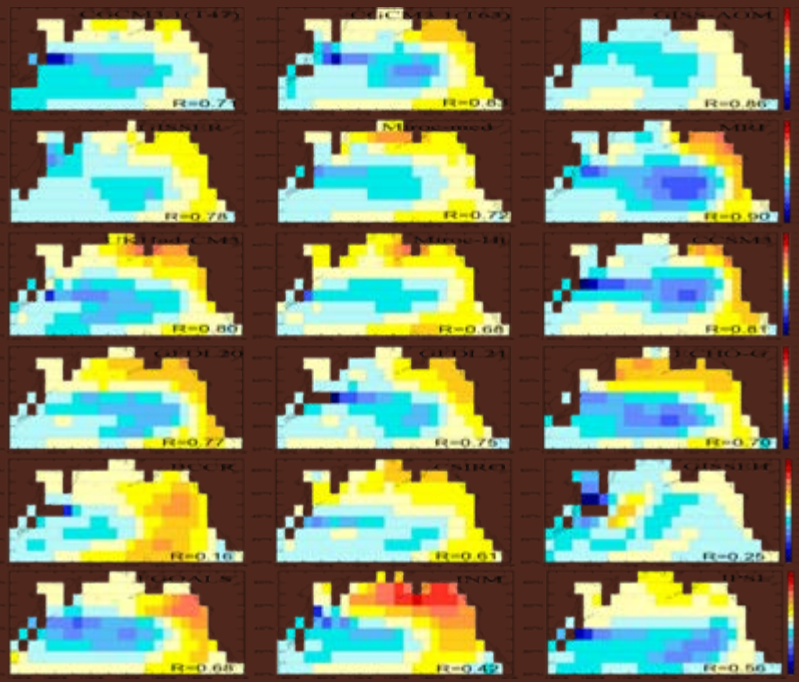
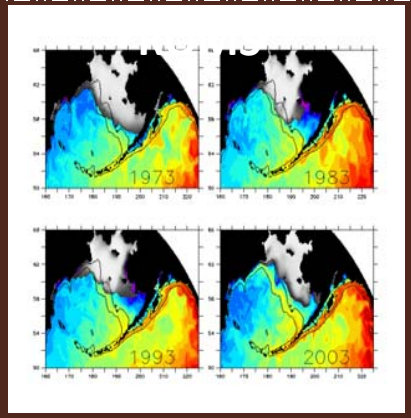
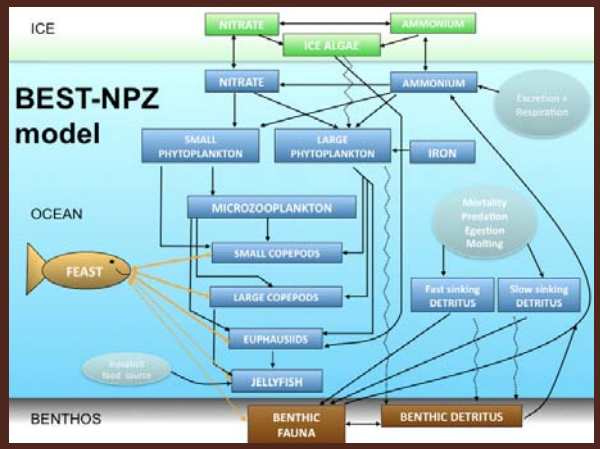
Climate models provide BCs/ICs to *regional coupled models*



ensemble of runs



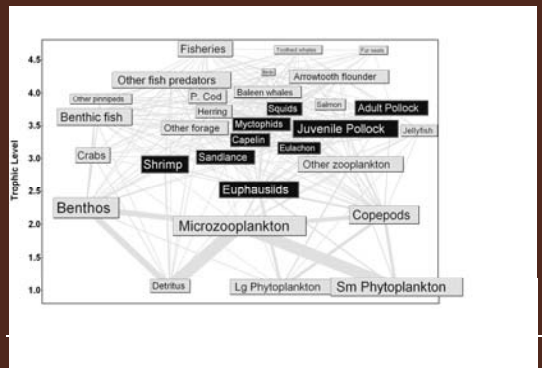
NPZ



FOOD WEB (FEAST)

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

ensemble of projected futures



IPCC global model variables used for regional downscaling

- Monthly values from global ocean models:
  - Ocean Temperature (3D)
  - Ocean Salinity (3D)
  - Surface Height (2D)

- Daily* sea surface values from global atmospheric models:
  - Air Temperature
  - Specific Humidity
  - Sea Level Pressure
  - Surface Wind (u,v)
  - Shortwave Radiation (downward)
  - Longwave Radiation (downward)
  - Precipitation

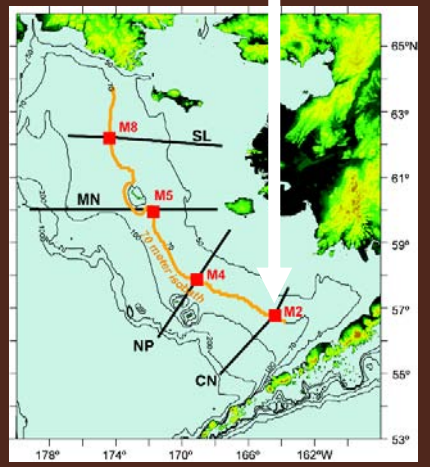
* NOTE: daily values are useful but 6-hourly values are preferable (as they yield better mixing physics in the regional model)

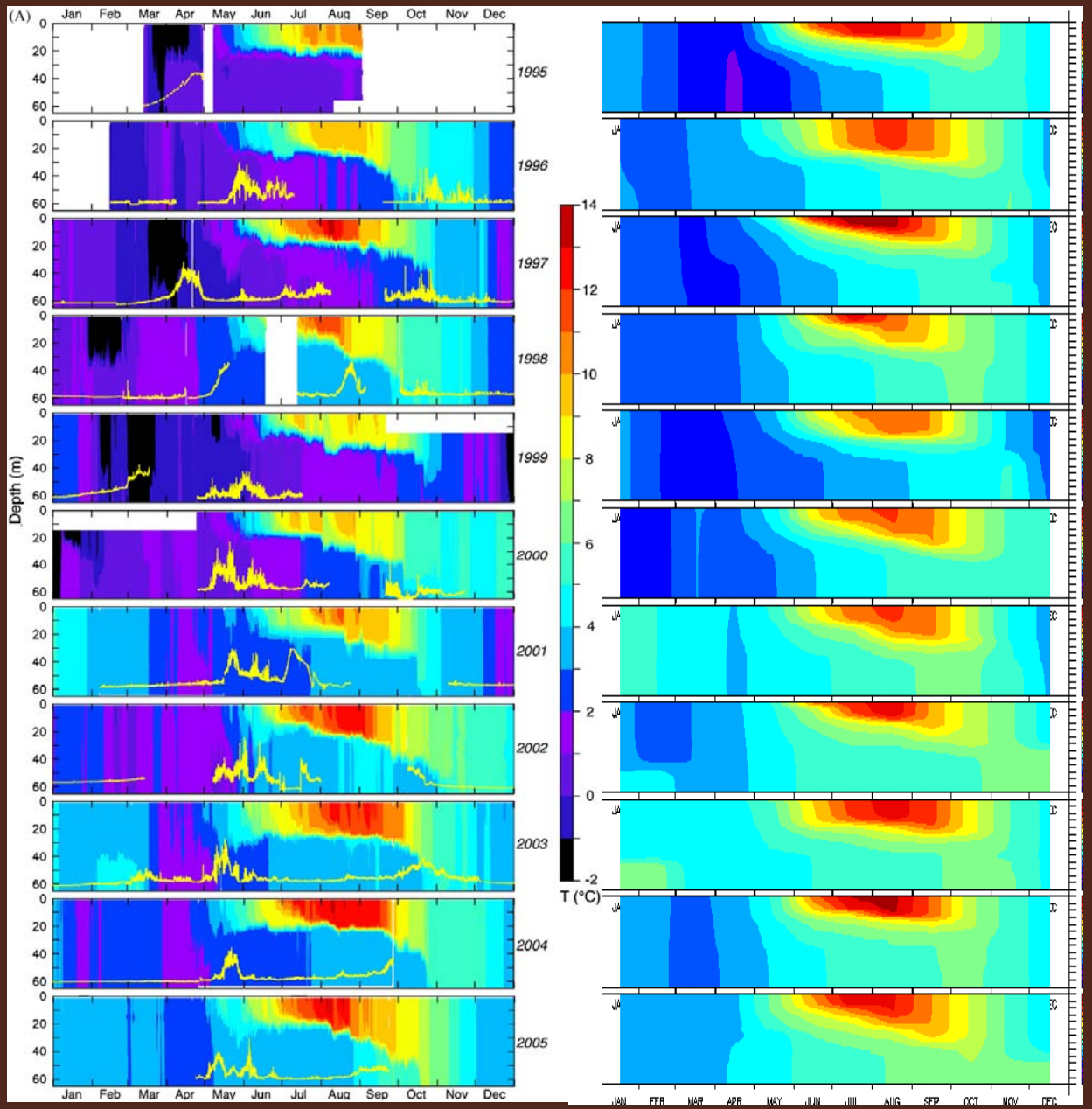
Northeast Pacific (NEP-5) Circulation Model

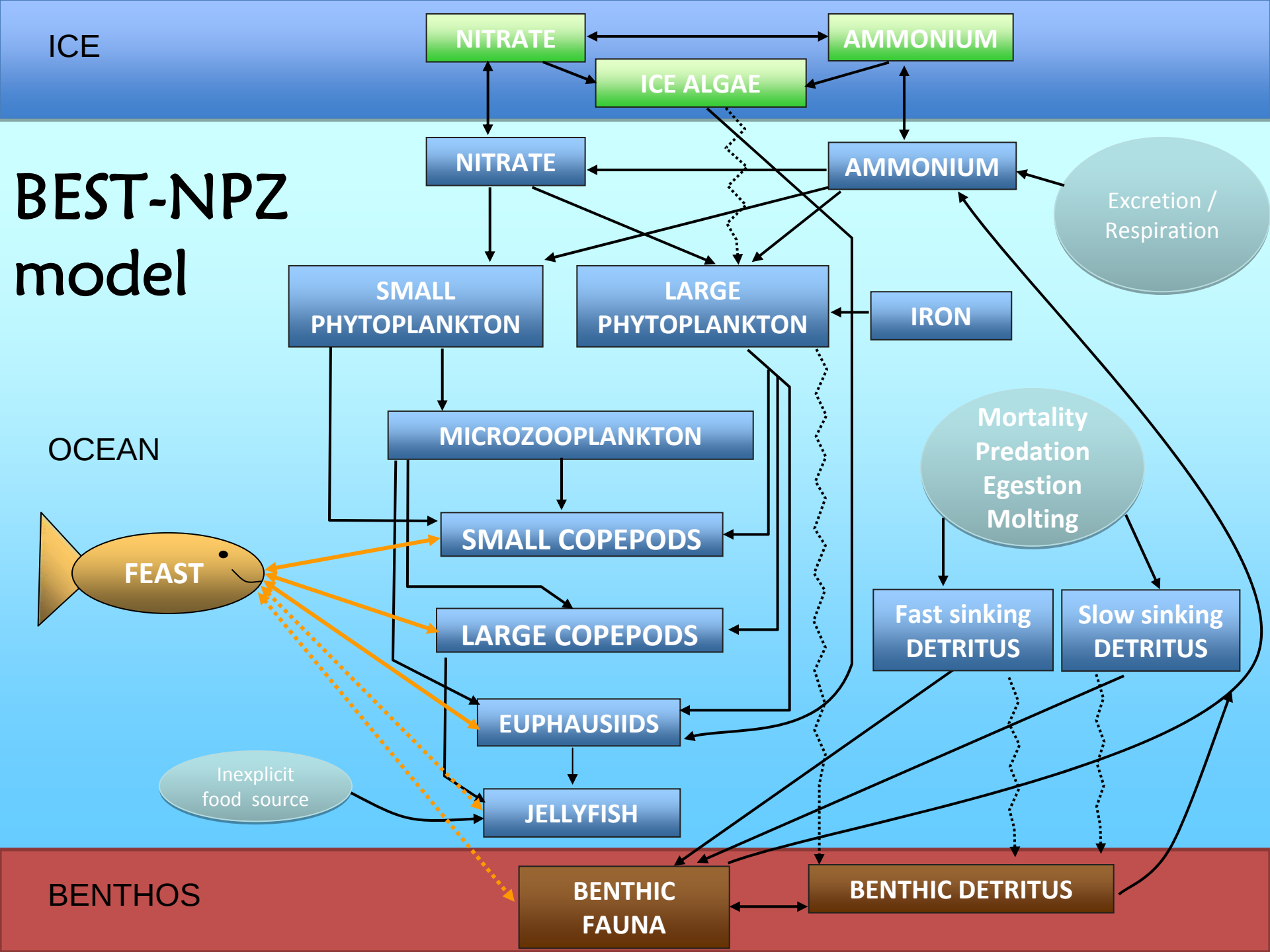
- Regional Ocean Modeling System (ROMS)
- Primitive Equations
- Terrain-following vertical coordinates (60 vertical levels)
- Mixed layer physics: K-Profile Parameterization
- Ice physics
- Vetted IPCC models to be used for
  - initial conditions
  - boundary conditions
  - atmospheric forcing
- Implemented on massively parallel (distributed memory) computers

Data Model

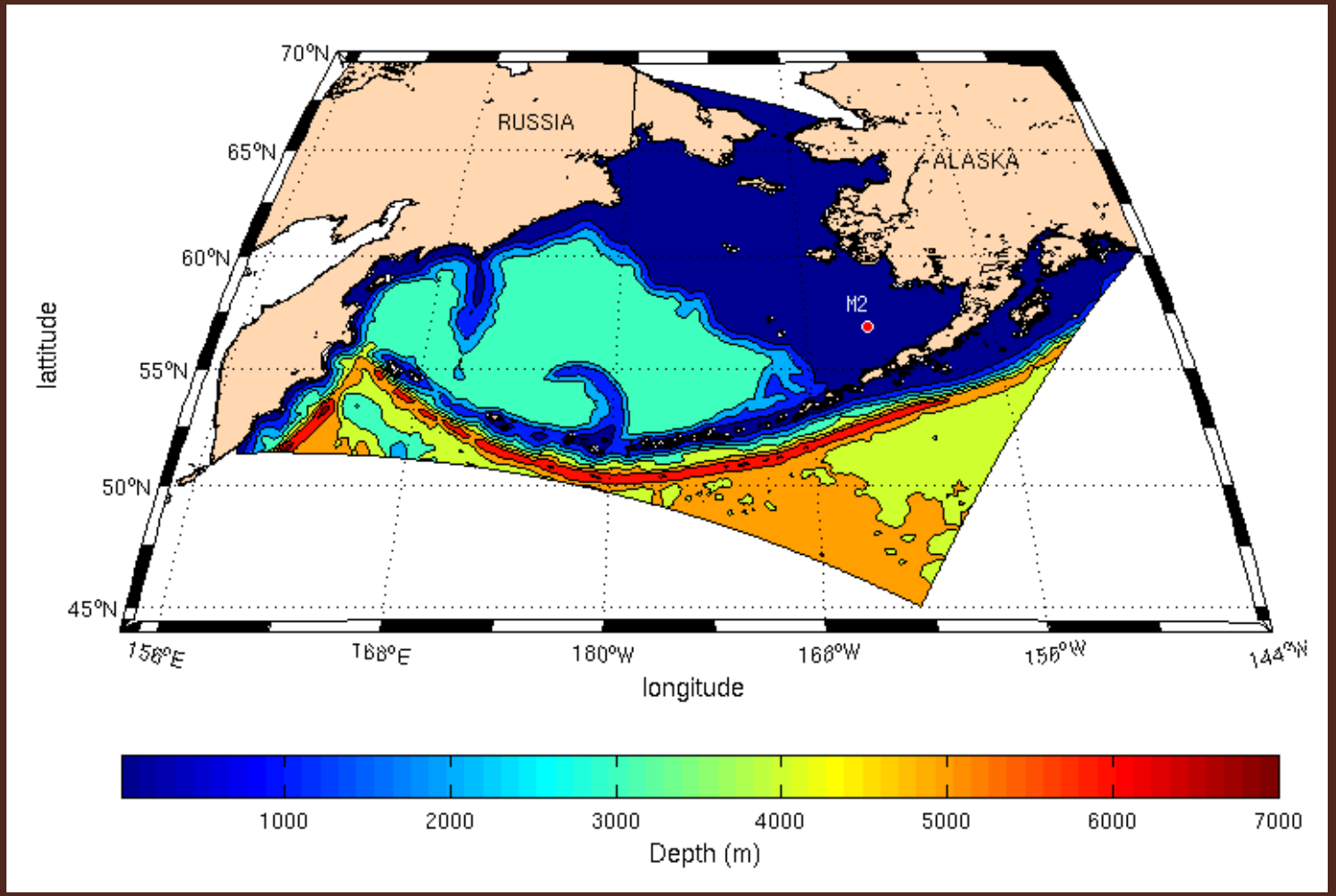
T at M2






ICE
NITRATE
AMMONIUM
ICE ALGAE
NITRATE
AMMONIUM
Excretion / Respiration
BEST-NPZ model
SMALL PHYTOPLANKTON
LARGE PHYTOPLANKTON
IRON
OCEAN
MICROZOOPLANKTON
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

Model Grid for NPZ and FEAST



Grid size = 180*256*60

3D grid has 10km resolution

Model runs for this talk

- Run the BEST-NPZ model on the 3D grid, but with 5 layers only (coarse but fast; retains most basic behaviors)
- Force with some recent years (1999-2004) and some future projections from the CCCMA-t47 model (2010, 2030, 2040)
  - Single-year runs with identical initial conditions
  - Run for 6 months in each case (Jan-June)
- Calculate annual climatologies based on these runs; derive anomaly time series
- Calculate multivariate EOFs from these anomaly time series

Statistical Analysis: Multivariate EOFS

- Typical biological use of Principal Components looks for coupled modes of variability in multivariate samples (these may be timeseries or just scattered samples in space and time)
- Typical physical use of Empirical Orthogonal Functions (EOFS) looks for spatial structure of a *single* variable
- Here, we use *mutivariate* EOFs (space/variable/time) to extract coupled biophysical modes which vary through time (Note: these time series need not be continuous)

Normalize the variables first!

- Standard EOF analysis uses the covariance matrix of all time series
- For biophysical modes, we wish to give all of the timeseries an equal chance to influence the results
- Normalize each series by its own local mean and variance; this takes care of different units AND emphasizes *relative* change at each location

Bering Sea modes

- Ice has a strong effect on the structure of the ecosystem
- An ice-free Bering is fundamentally different from one with ice cover; expect these "modes" to emerge in the analysis

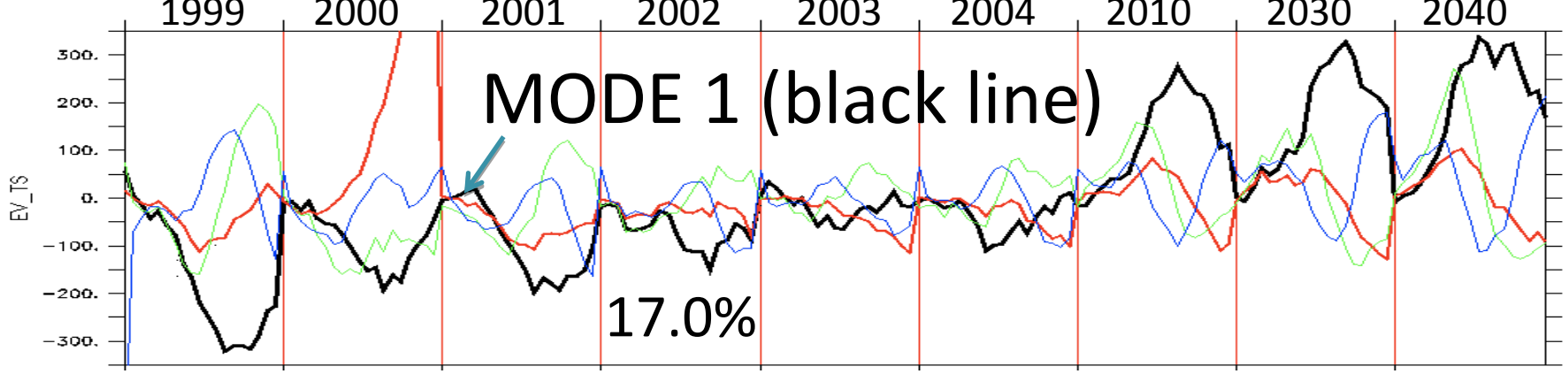
Variables used for 3D model analysis

PHYSICAL (ROMS)

- Surface Temperatue
- Surface Salinity
- Ice (fractional coverage)
- Mixed Layer Depth

BIOLOGICAL (BEST-NPZ)

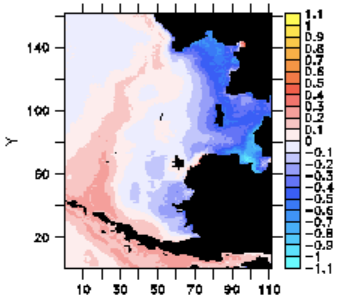
- Nitrate + Ammonium
- Small + Large Phyt
- Copepods
- Euphausiids
- Benthic detritus
- Benthic infauna



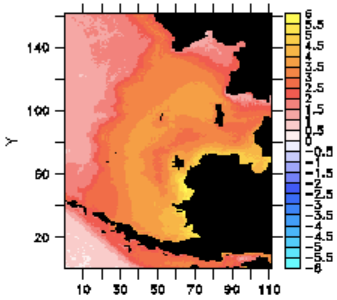
MODE 1 (black line)

17.0%

SSS

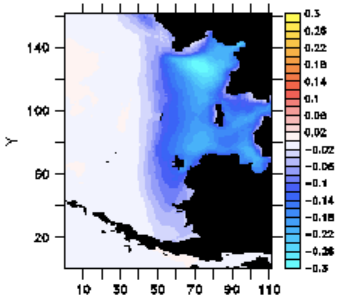


SST



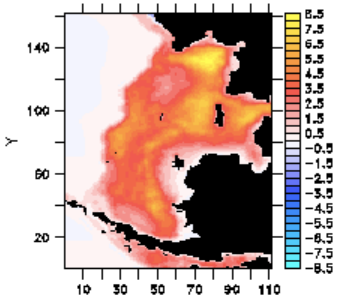
warmer

ICE



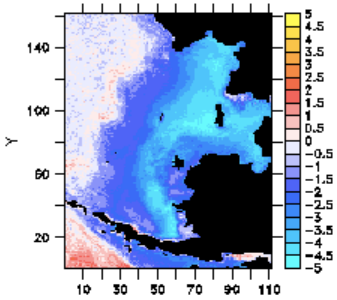
less ice

MLD



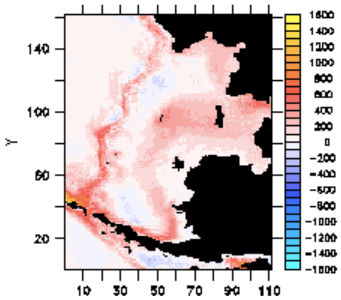
shallower

DIN

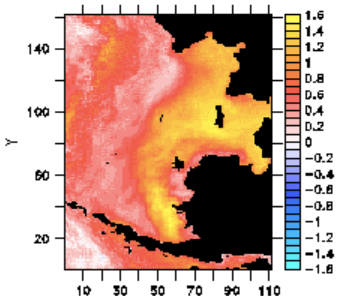


less DIN

PHYT

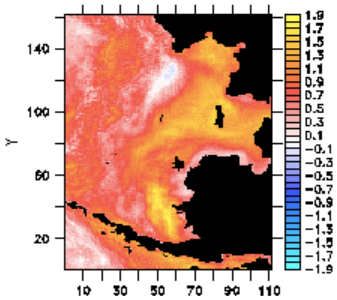


COP

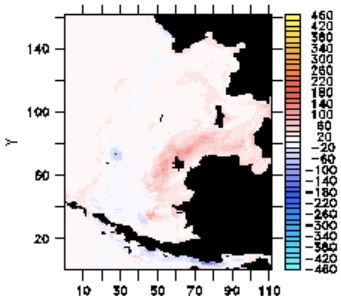


More cops and eups, on inner shelf

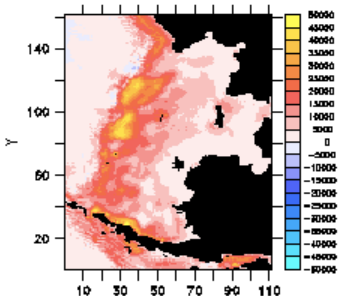
EUP



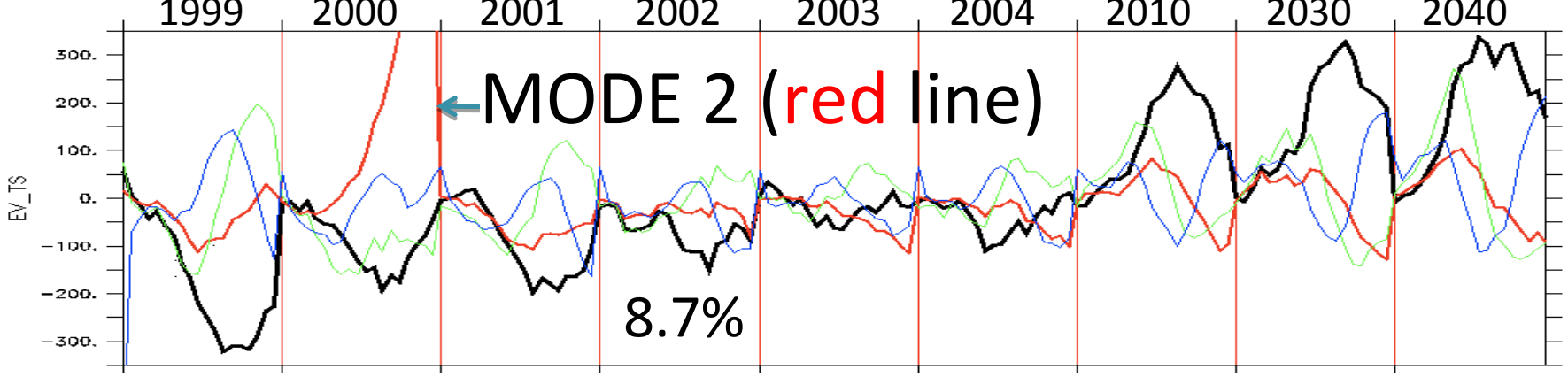
DET



BEN



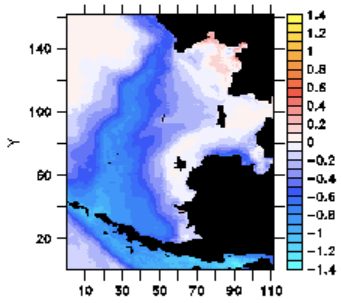
more benthos at outer shelf



MODE 2 (red line)

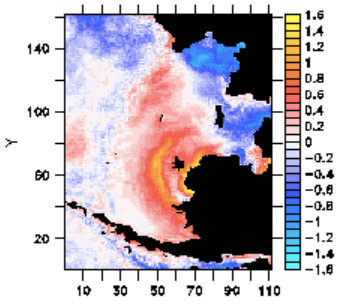
8.7%

SSS

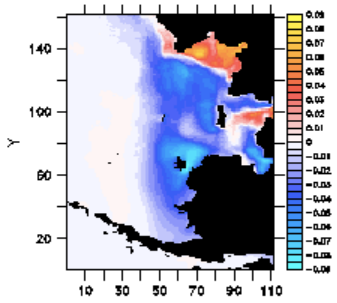


fresher

SST

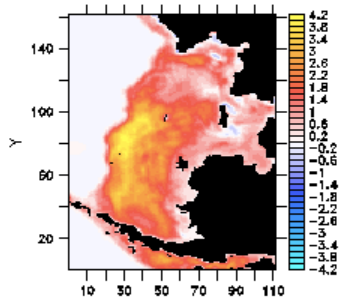


ICE



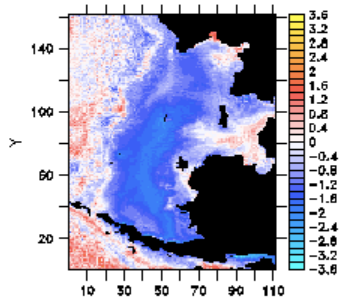
less ice

MLD



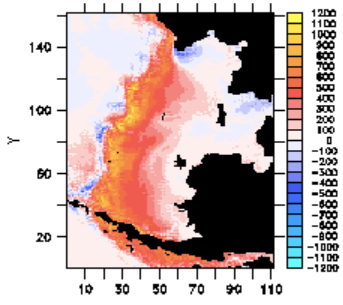
shallower

DIN



less DIN

PHYT



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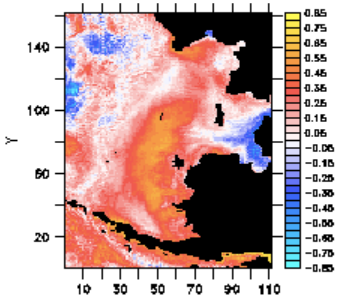
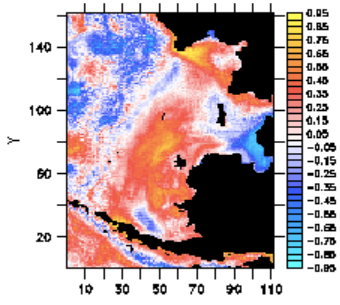


EUP



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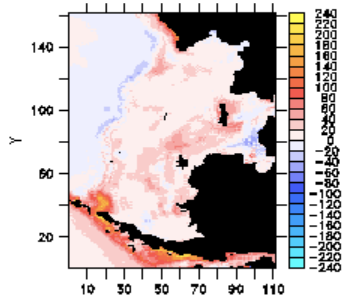
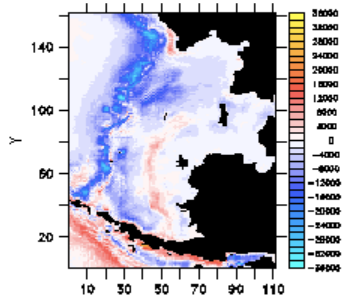


BEN



more phyt at the greenbelt, more cop/eup on the inner shelf

Tentative Conclusions

- Coupled biophysical modes appear from the EOF analysis
- A primary mode of this analysis suggests the following long-term trend:
  - Light-limited response to increased stratification
  - Higher secondary production overall (but what fish will this support?)
  - More **pelagic** food chain on the *inner* shelf
  - More **benthic** food chain on the *outer* shelf

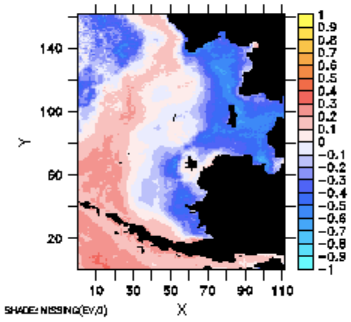
Planned improvements

- Add fish!
- Continuous runs with proper boundary conditions
- Explore other ways of grouping the data before calculating modes
- Higher resolution

FIN!

Mode 1 (normalized): warmer, less ice, pelagic shelf, benthic slope

SSS



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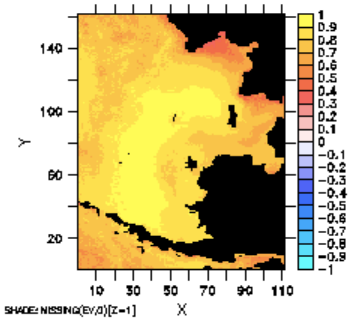

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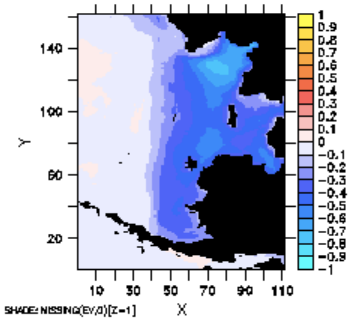
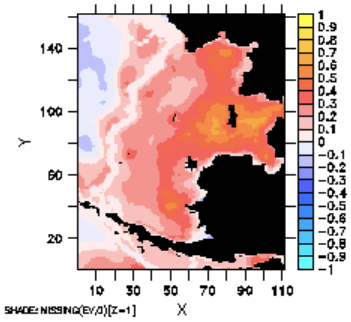


MLD



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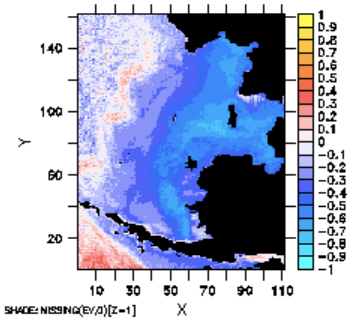
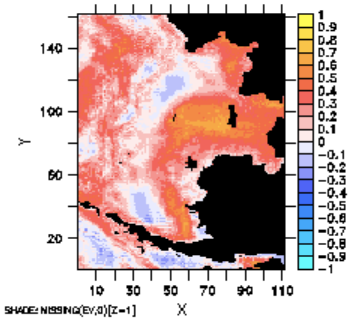


PHYT



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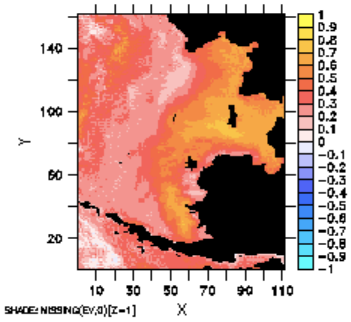

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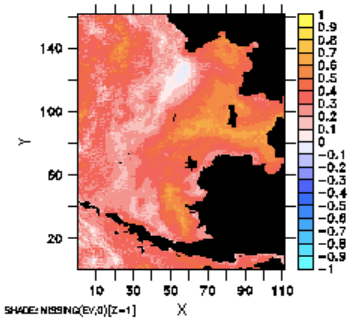

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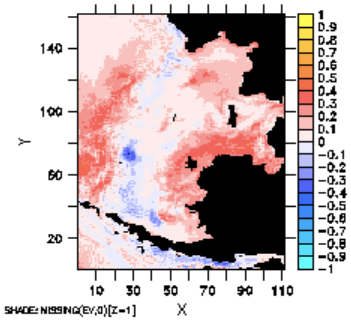

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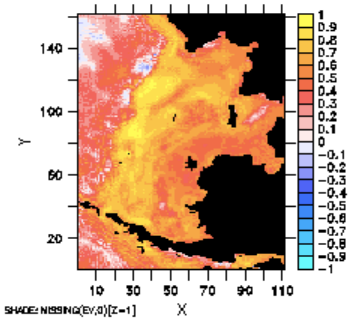
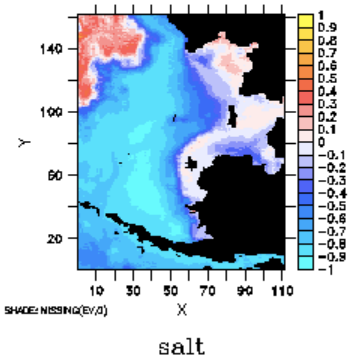
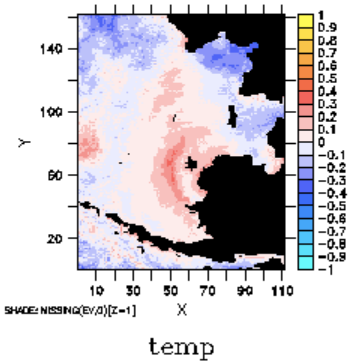


Mode 2 (normalized): fresher shelf/slope, more phytoplankton

SSS



SST



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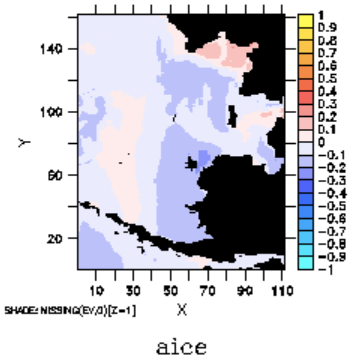
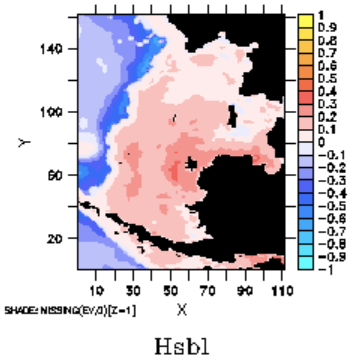
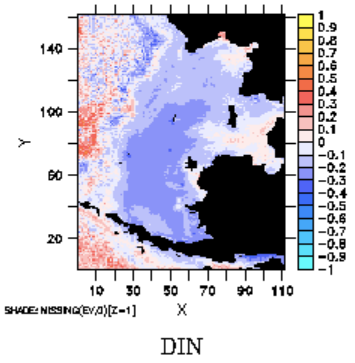


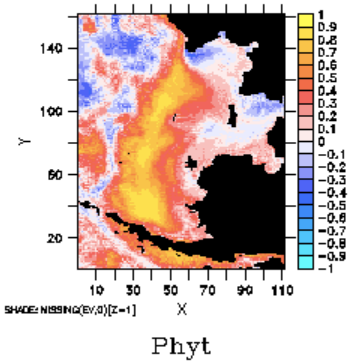
MLD



DIN



PHYT



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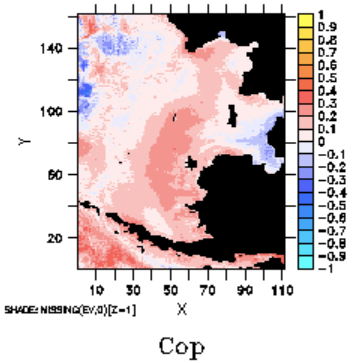

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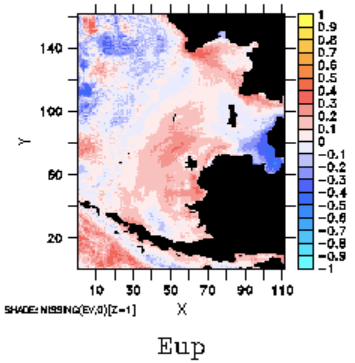

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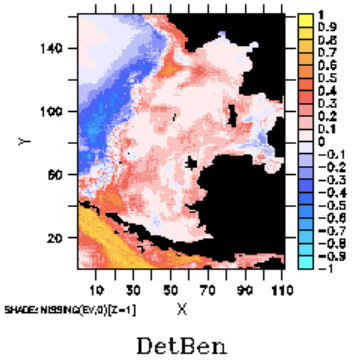

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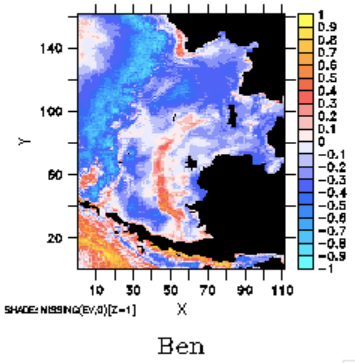
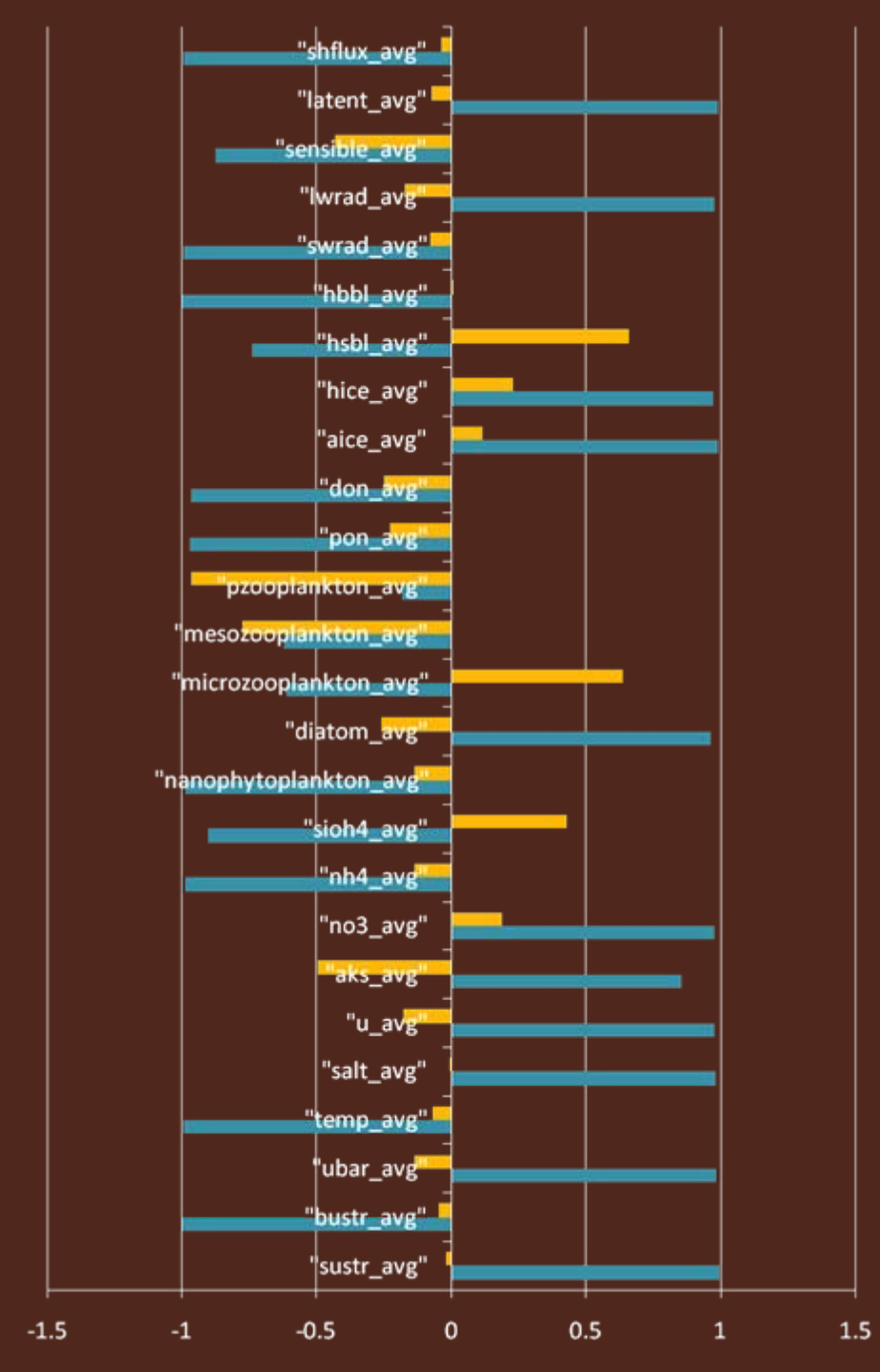
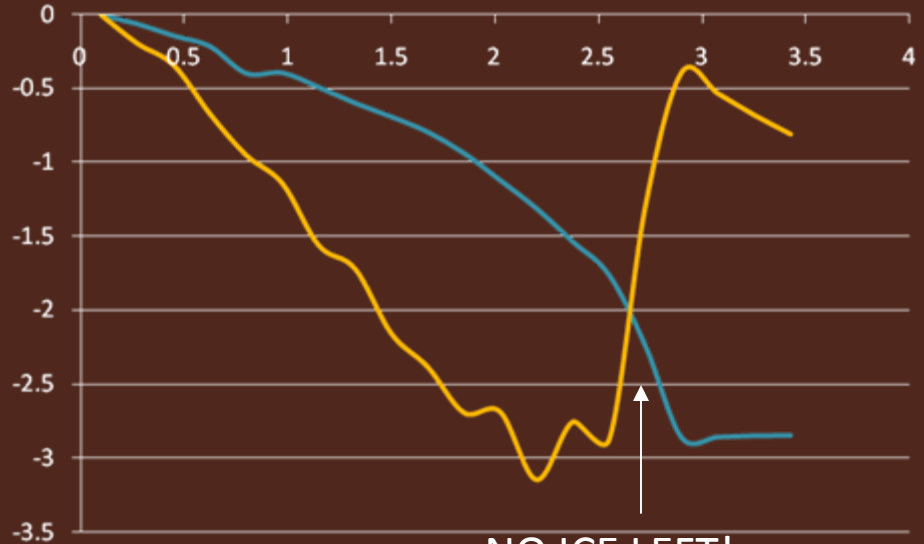
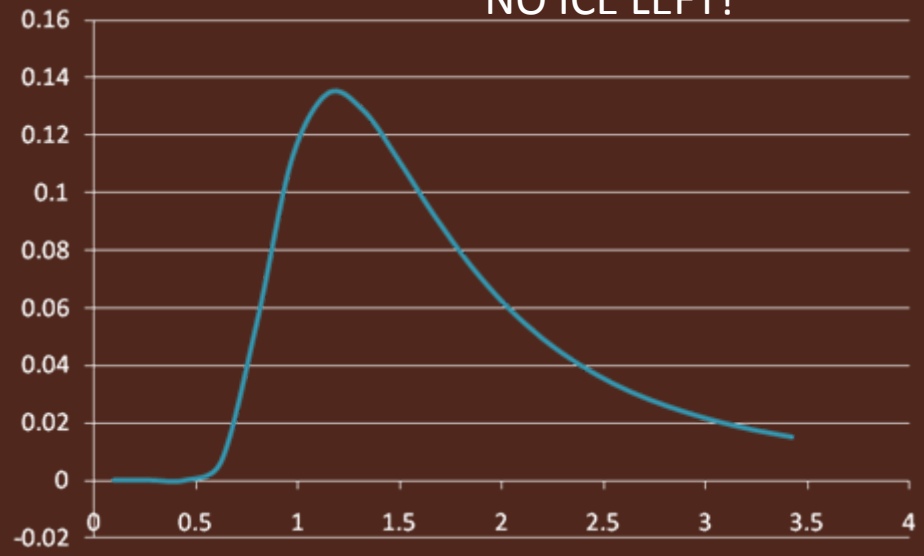


1D Bering biophysical modes

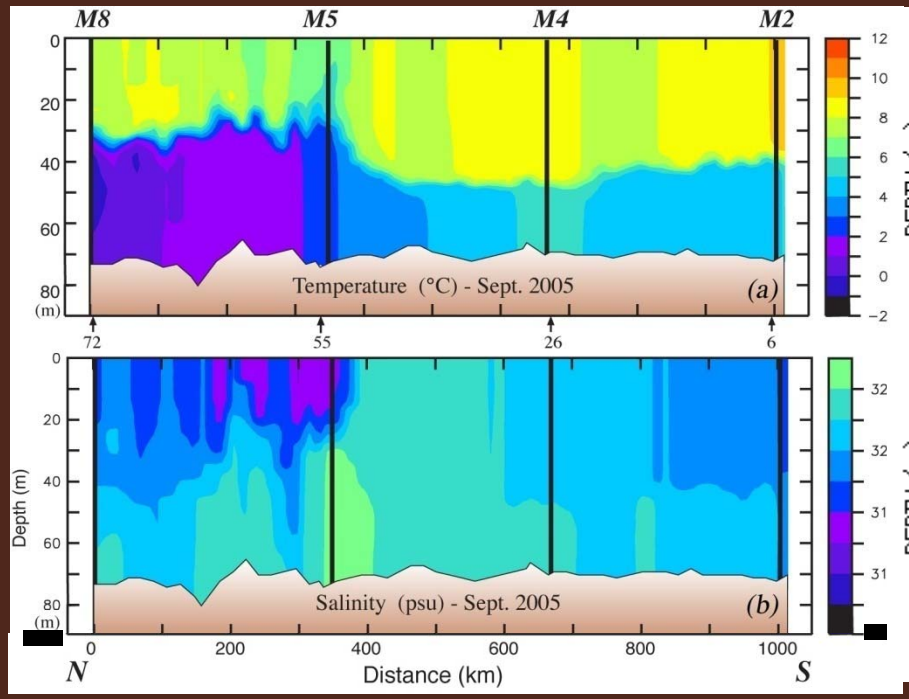


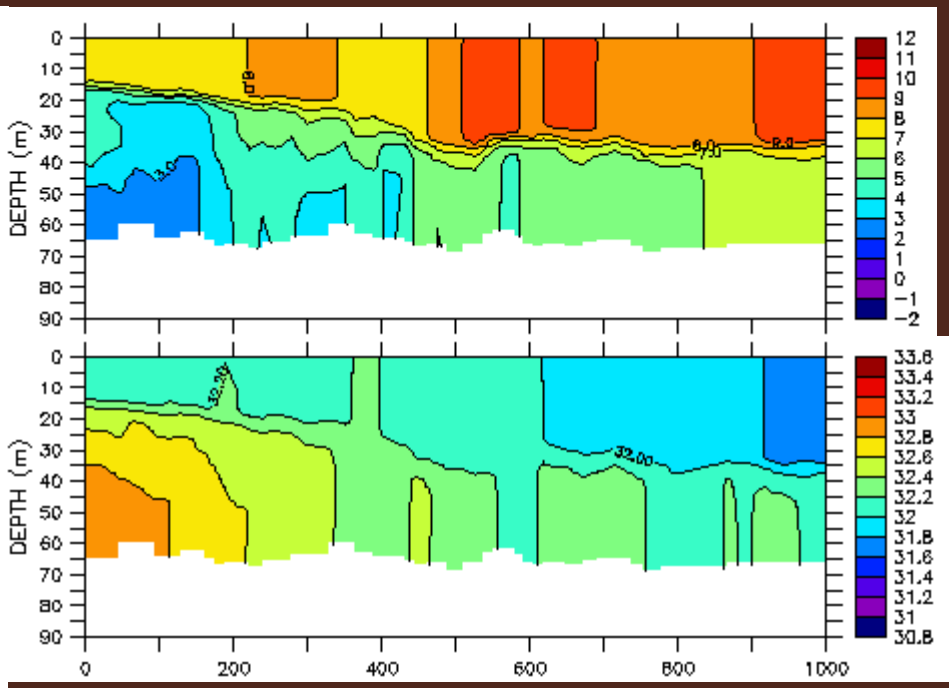




70 m isobath Sep 2005

DATA MODEL



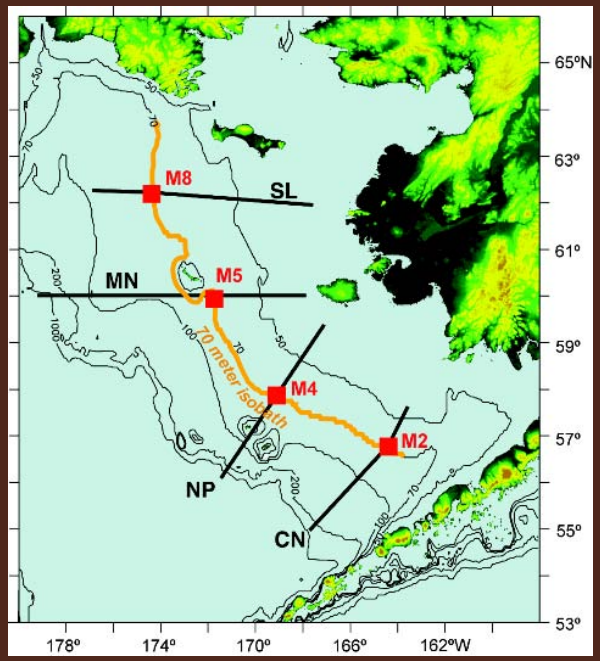


Based on talks here

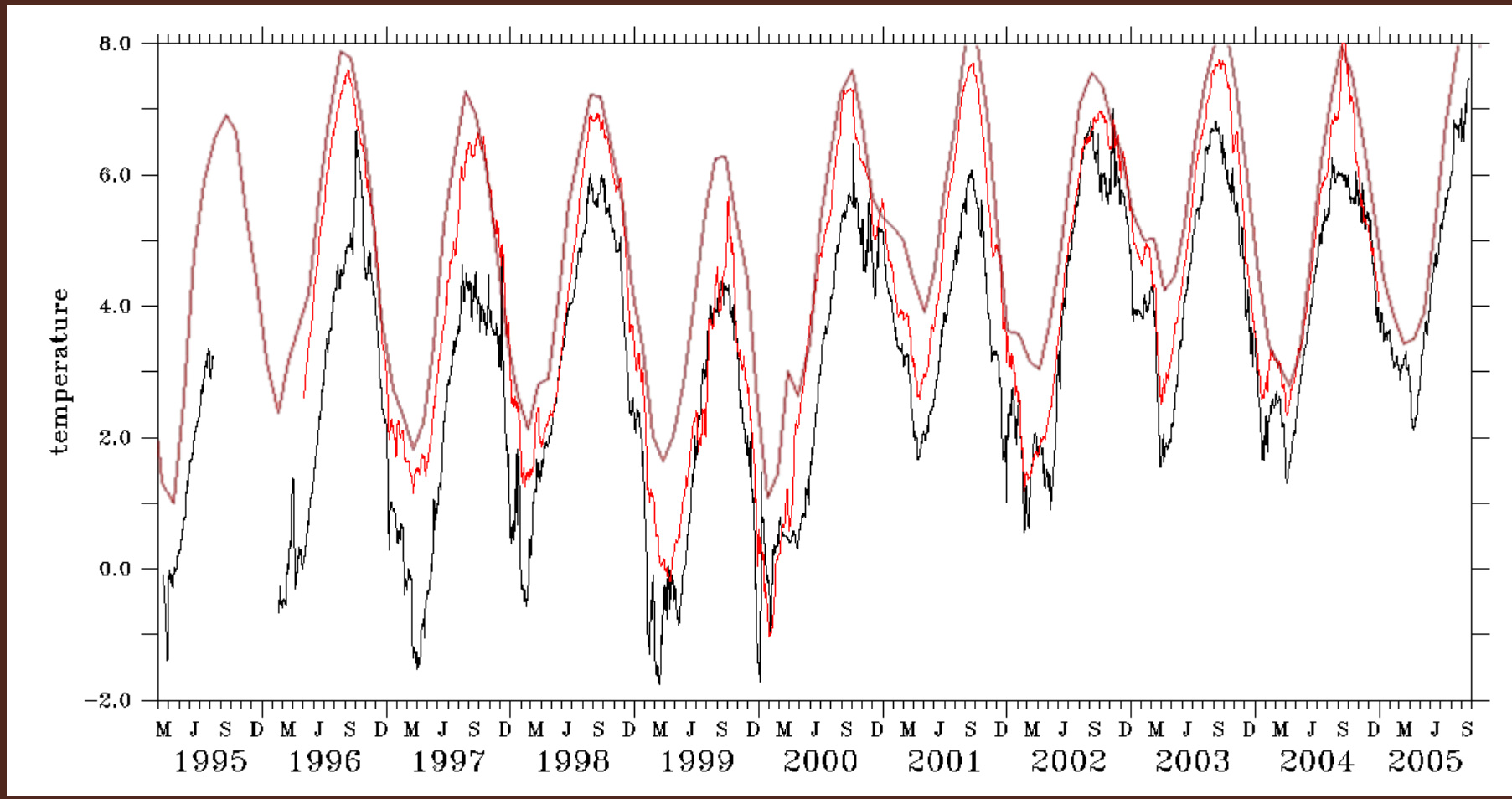
- May need more precise BCs; advective changes alter the community (Napp et al.)
- Reconsider the OCH (Hunt et al, Napp et al) – does warmer mean less food?
- General conformance to the Doney Idea of light limited response

Latest NEP-5 results vs data

- Tides
- Hydrography
  - At M2
  - Along the 70-m isobath
  - Along the NP cross-shelf line

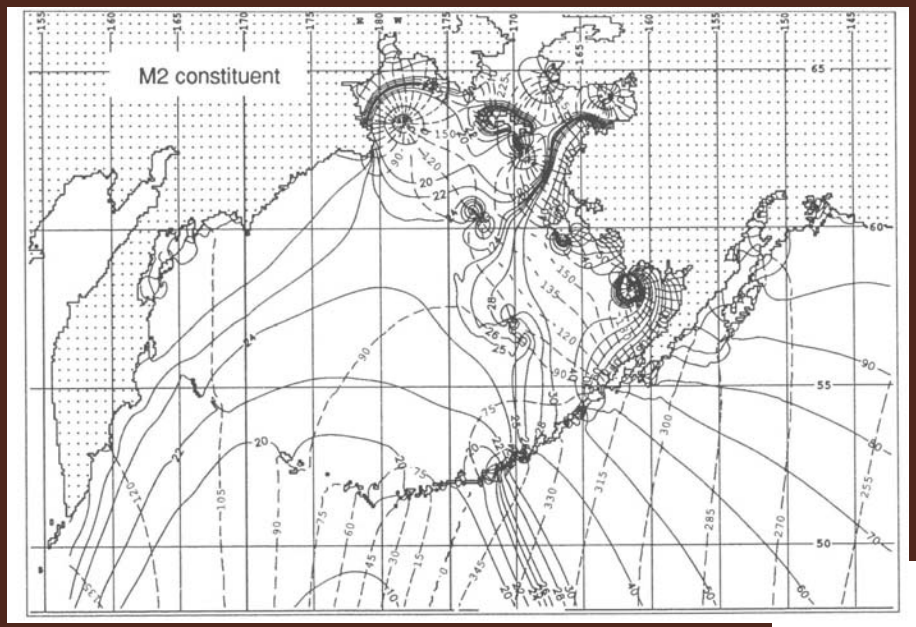


Depth-averaged T at station M2



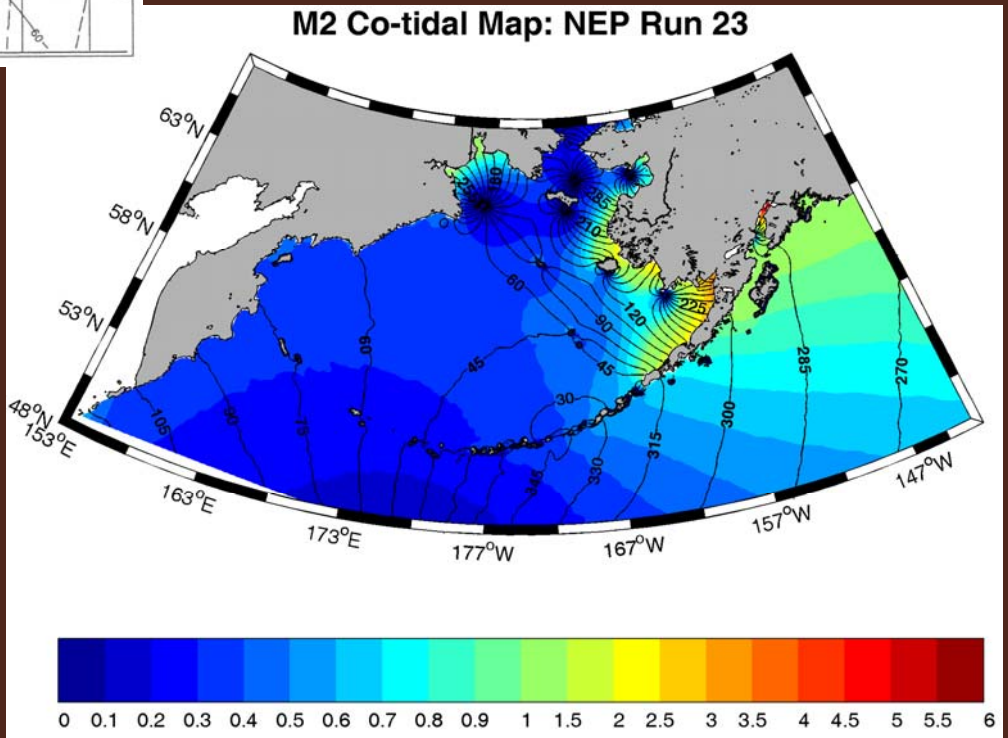
Data (black) vs NEP-4 (red) and NEP-5 (blue)

Tidal model



Tidal ampitude and phase

ROMS



Coupled mode “time series” from the 3D multivariate analysis