Performance of NEMURO with the Regional Ocean Modeling System (ROMS) for the Coastal Gulf of Alaska

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The Problem

- Many different models are being used to anticipate climate-driven change
- Downscaling of climate scenarios involves a transition from general (global) to specific (regional) models
  - How to couple and compare these results?
  - How complex of a model is needed in each case?
- You can be misled by predictions from an overly “stiff” model
  - More region-specific model can be finely tuned to the present but then “stiff” and less relevant to the future
  - More general model can be applied to other times and places but less satisfying fit in the present
  - Both simple and complex models can be overly “stiff”

Why NEMURO + ROMS?

- NEMURO has been incorporated into several 3D circulation models
- Here, we incorporate NEMURO into ROMS
- Why NEMURO/ why ROMS?
  - Both NEMURO and ROMS have a large (and growing) user base
  - Both have been applied successfully to regional issues
  - NEMURO has enough generality to be applicable (after tuning) in many regions
  - ROMS has sophisticated physics, ice, multiple choices for mixing parameterization, etc., and is applicable “worldwide”

NEMURO features

- Multiple size classes of P and Z
- Links to fish models
- Multiple macronutrients (NO3,NH4,SiOH4)
- Iron limitation is being developed by several groups
  - see Fiechter poster for CGOA iron effects in ROMS-NEMURO
  - see Hinckley et al (submitted) for CGOA iron/size class effects in ROMS-CGOANPZ (similar complexity to NEMURO)

ROMS features

- Flexible (curvilinear) grid
- Bottom-following vertical coordinates
  - resolve boundary layers
- Sophisticated advection schemes
  - preserve frontal structures
- Tides
  - resolve some of tidal mixing
- Ice
- Nesting
- KPP, MY and K-E mixing algorithms
- DATA ASSIMILATION for physics and NPZD biology

NEMURO

\+ ROMS =

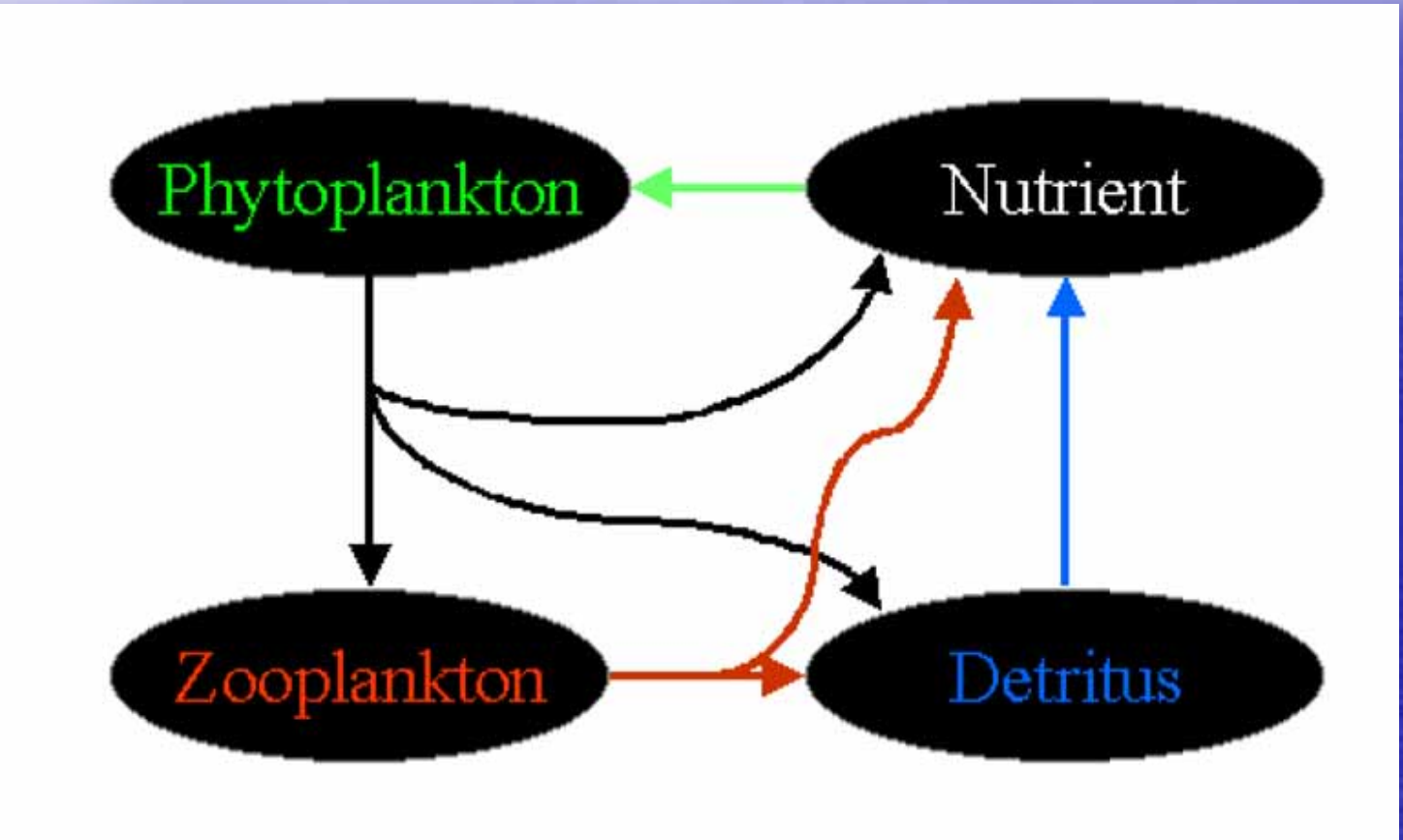
NEMUROMS

(pending approval from Mafia)

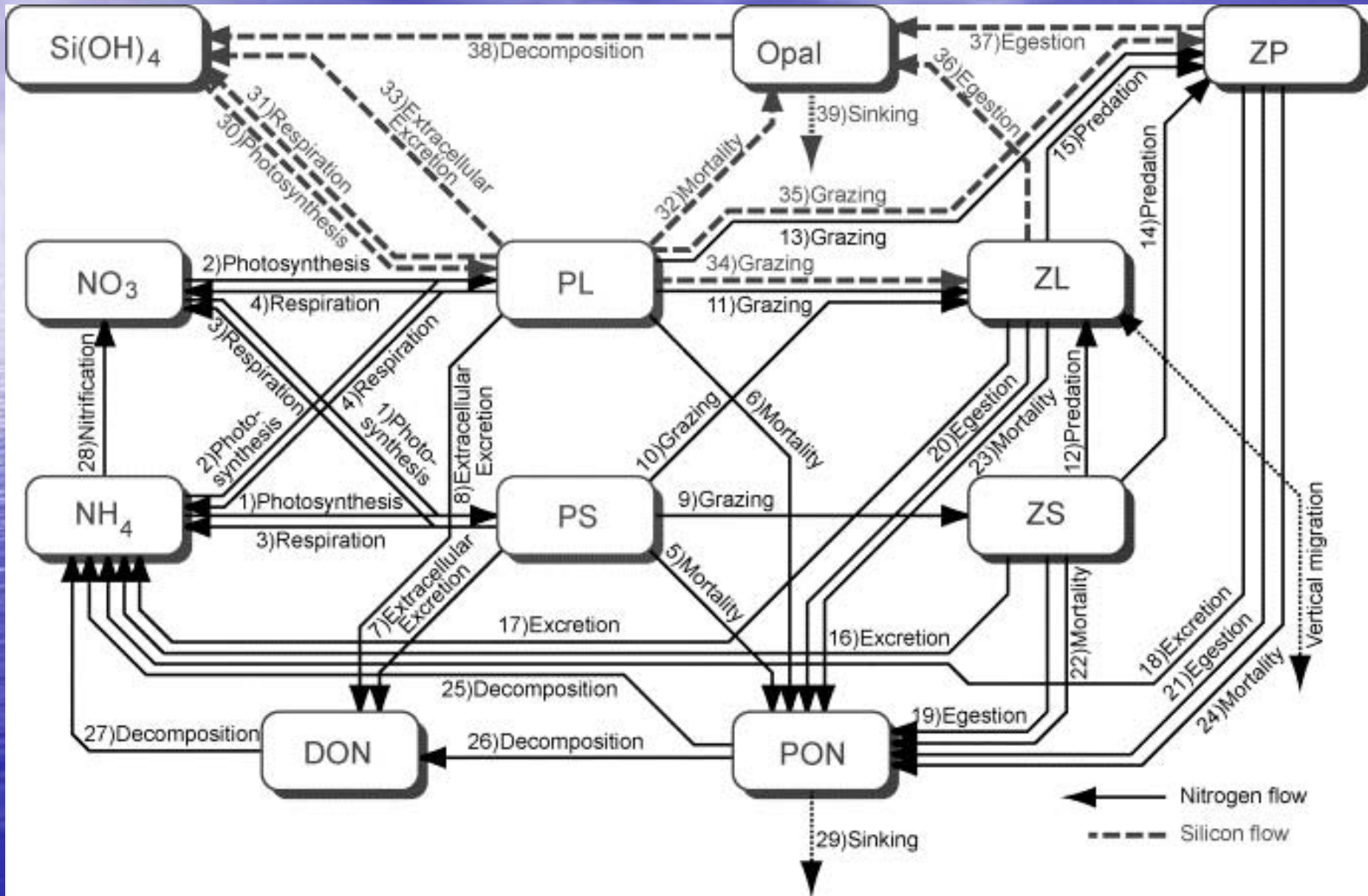
NEMURO is now one of several NPZ models the user can enable in ROMS

- Code is available from ROMS website
- Caveat emptor! Each of the bio models may have hidden bugs
  - erroneous coefficient values
  - conservation issues
- Comparison of results across models can help reveal these bugs

NPZD model structure – simple!



NEMURO model structure



Can we compare NEMUROMS with previous NEMURO benchmarks?

- Hard to compare 1D NEMUROMS with 0D NEMURO runs
  - 0D had specified temperature, mixing, upwelling
  - None of these can be well represented in ROMS, which has spatially continuous, dynamically evolving fields
  - Instead use 1D case

Testing the new code

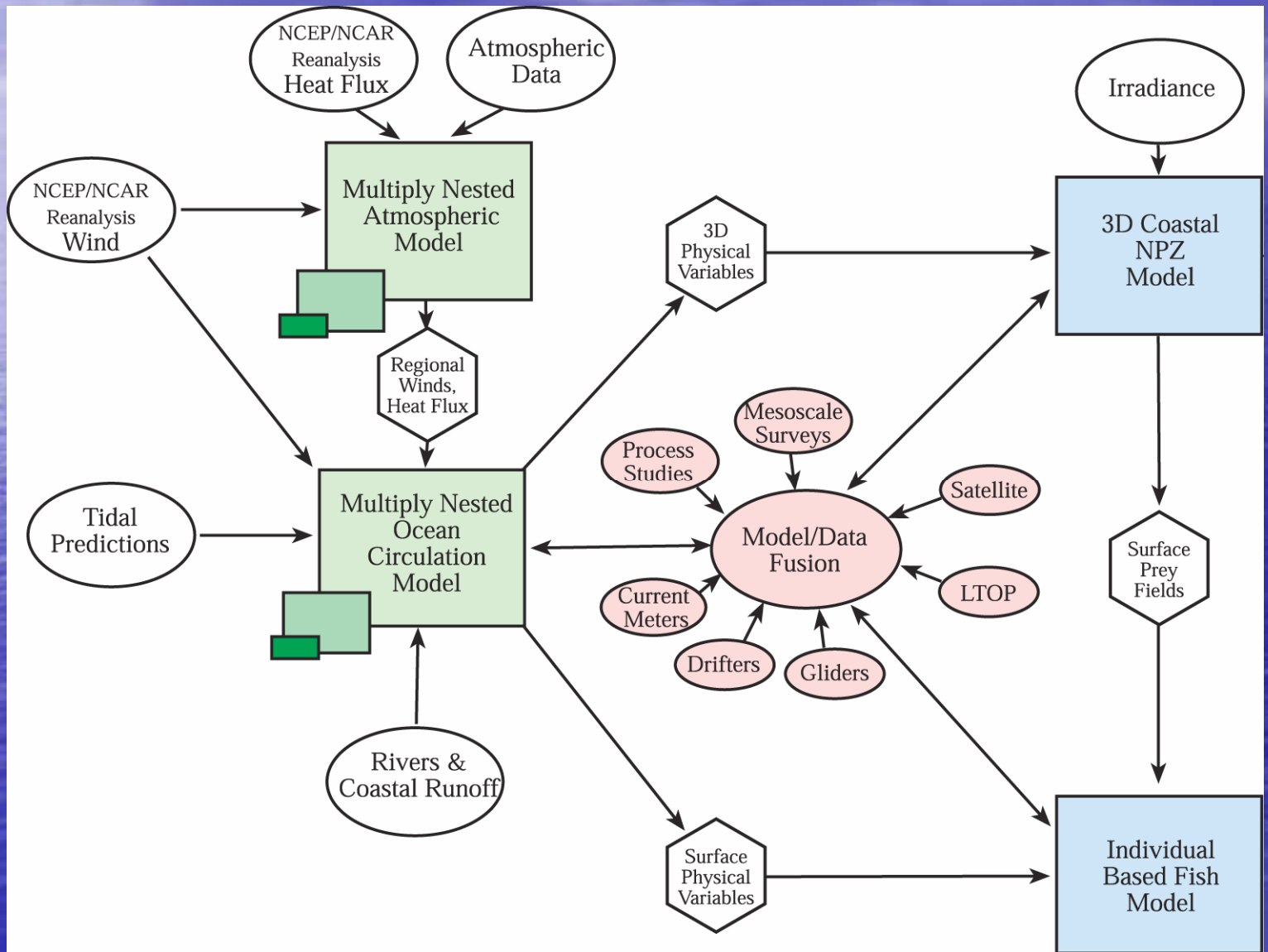
- Look for sensible behavior in **1D** case
- Examine the **total nitrogen** of each model over many years; is it conserved?
- Examine these aspects using a repeating yearly cycle, which includes daily variability
- Use our GLOBEC study region as a testbed

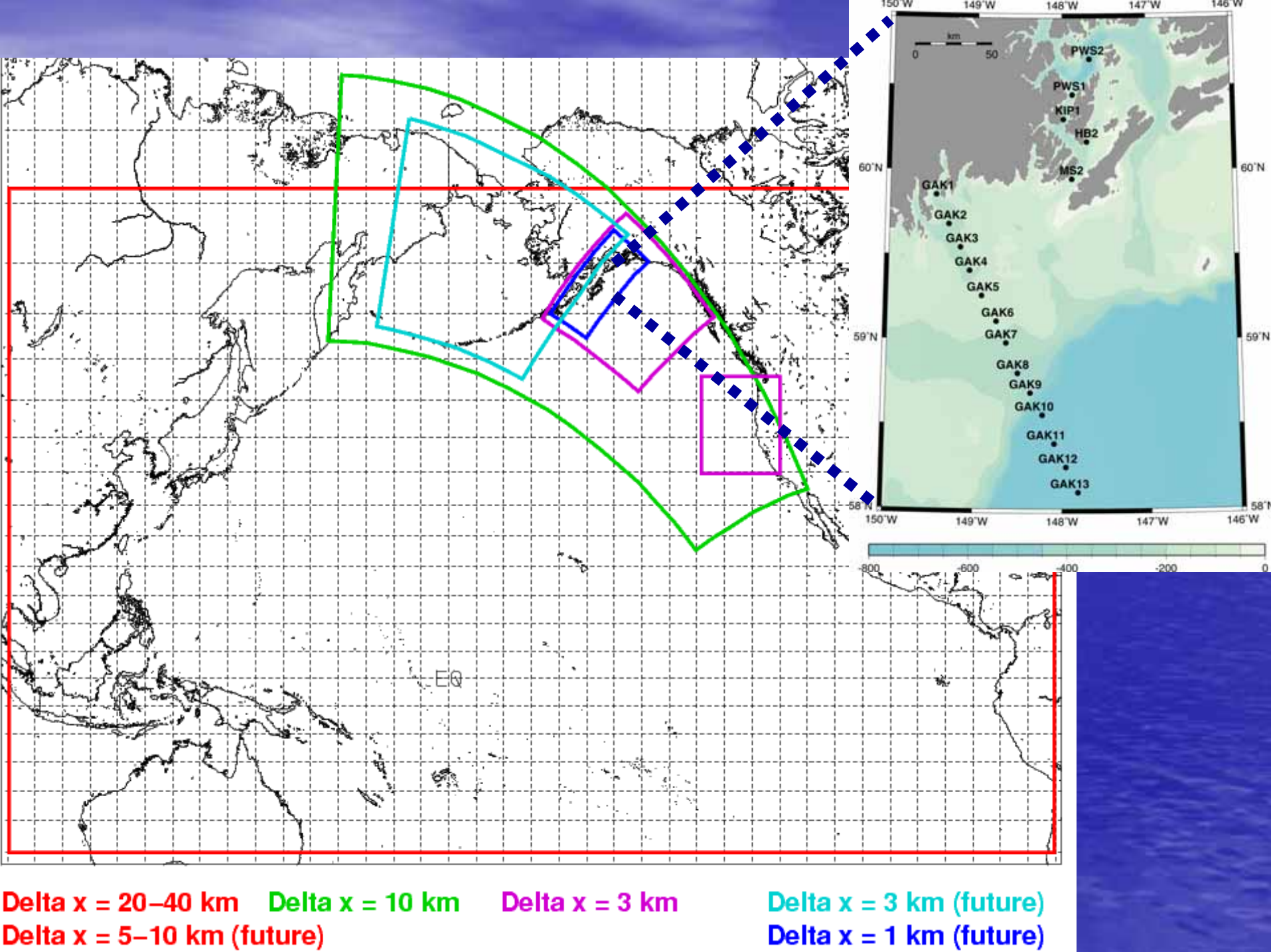
Main results

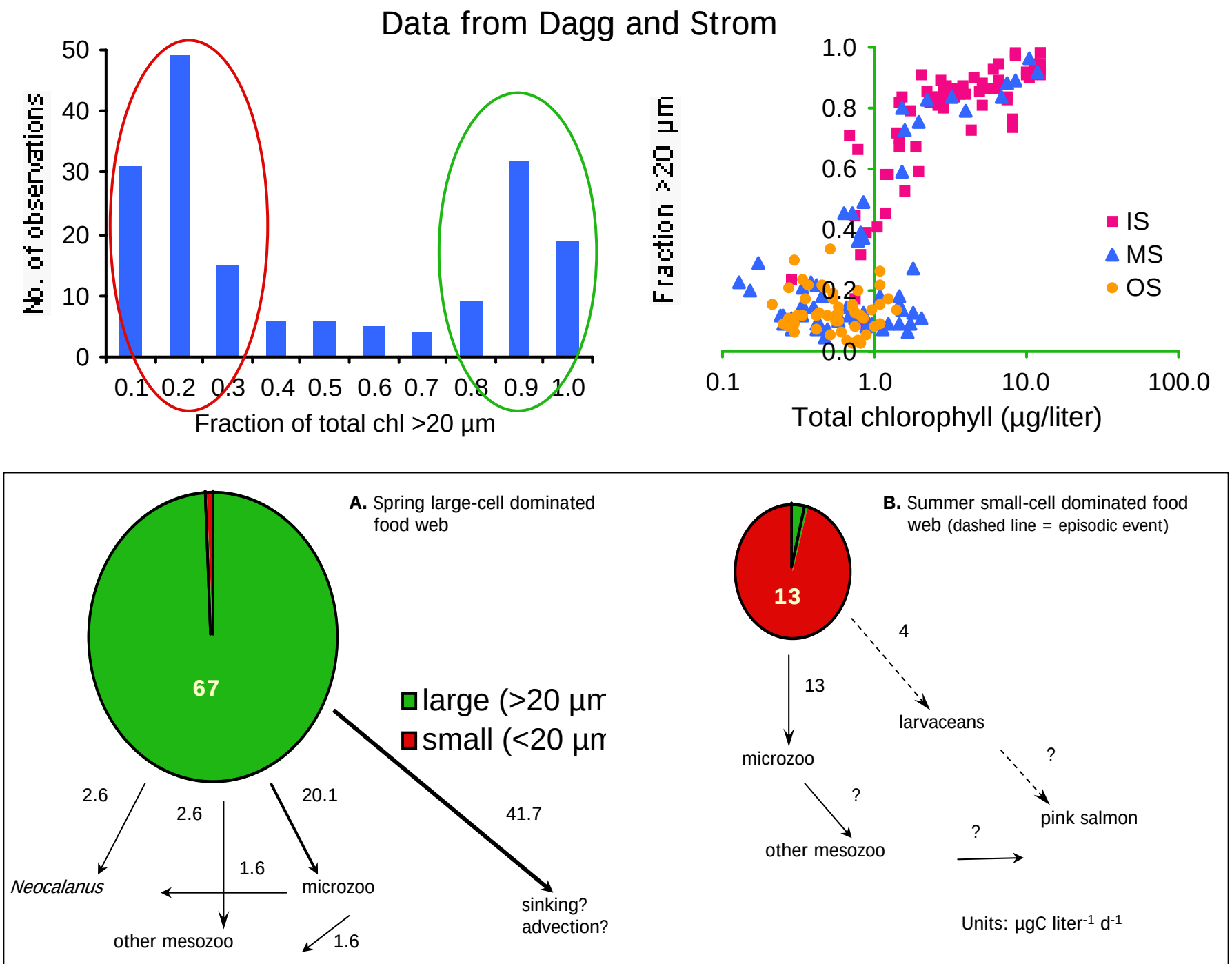
- The code works! Maybe 99% debugged now…
- NPZD model exhibits narrower time window of production
  - Single big bloom of phyt then zoop
- NEMURO exhibits wider time window of production
  - Multiple blooms of P and Z groups

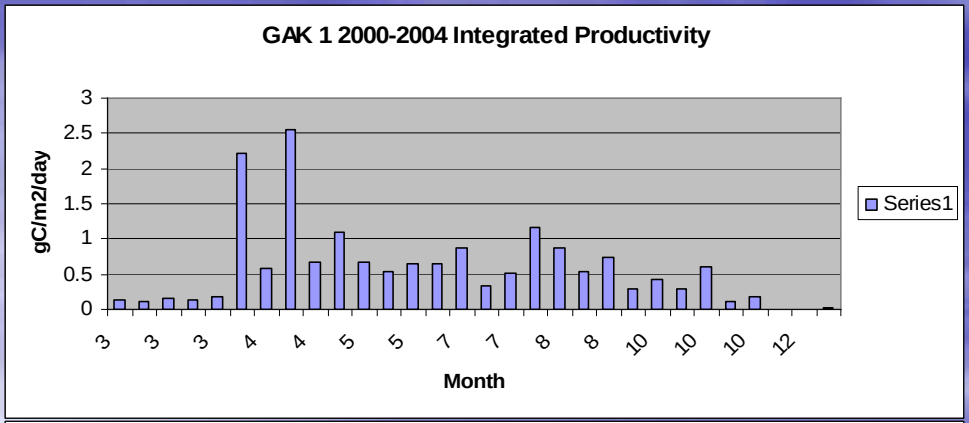
Nested Biophysical Models for **GLOBEC**:

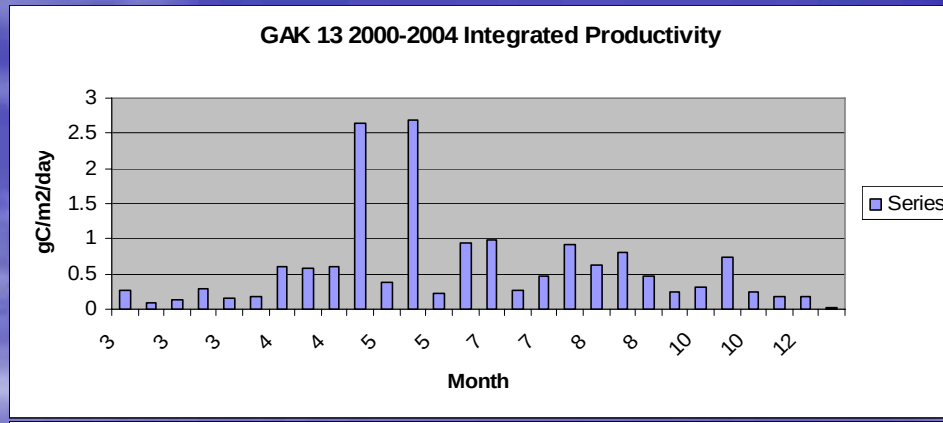
NCEP/MM5 -> ROMS/NPZ -> IBM

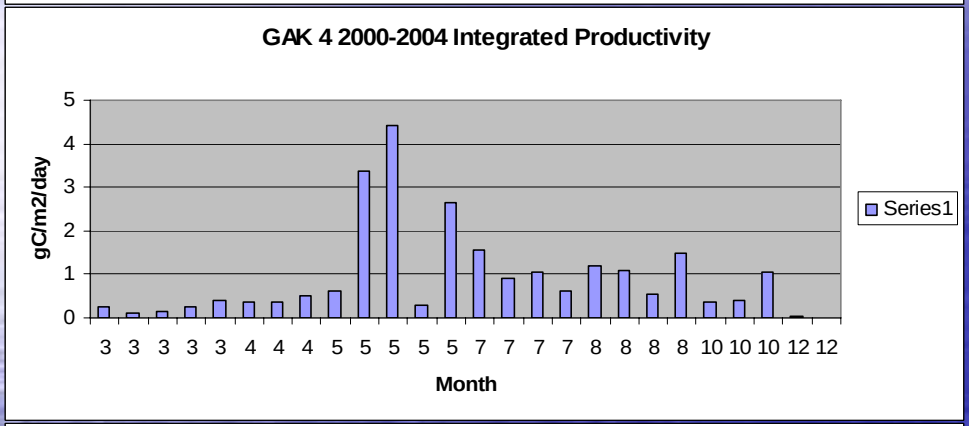


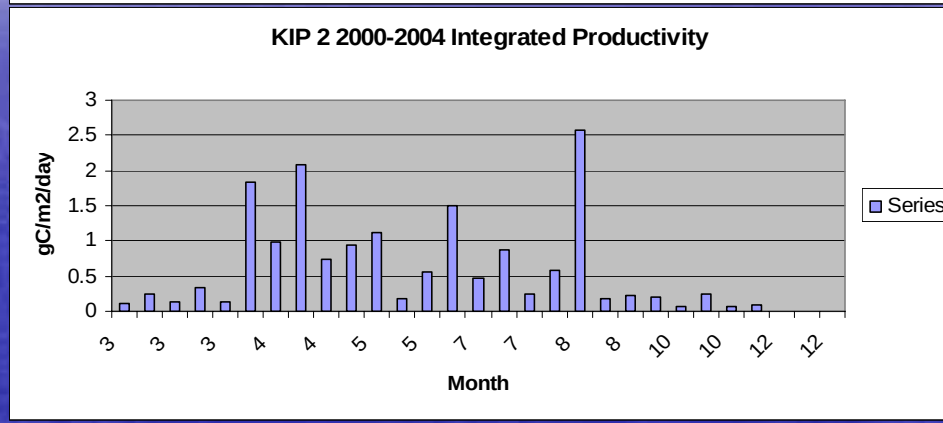

150°W
149°W
148°W
147°W
146°W
km
0
50
PWS2
PWS1
KIP1
HB2
MS2
60°N
GAK1
GAK2
GAK3
GAK4
GAK5
GAK6
GAK7
GAK8
GAK9
GAK10
GAK11
GAK12
GAK13
59°N
58°N
-800
-600
-400
-200
0
EQ
Delta x = 20–40 km
Delta x = 10 km
Delta x = 3 km
Delta x = 3 km (future)
Delta x = 5–10 km (future)
Delta x = 1 km (future)

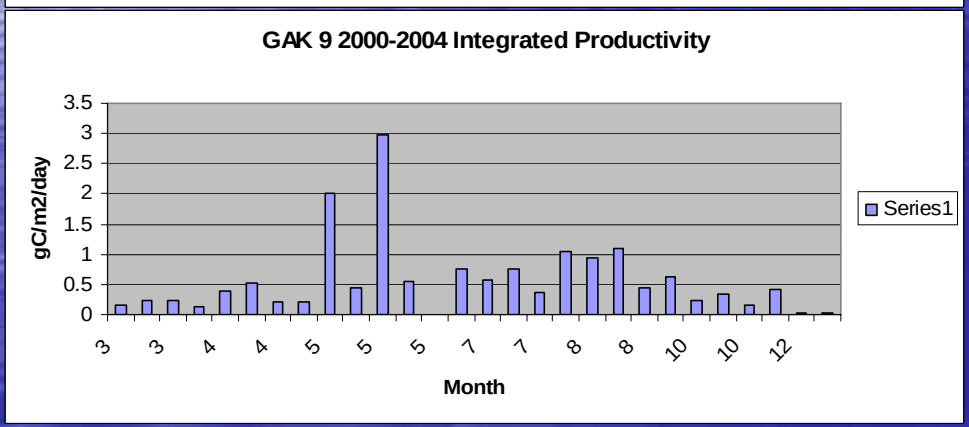

Data from Dagg and Strom
No. of observations
Fraction of total chl >20 µm
Fraction >20 µm
Total chlorophyll (µg/liter)
IS
MS
OS
A. Spring large-cell dominated food web
large (>20 µm
small (<20 µm
67
2.6
2.6
20.1
41.7
1.6
1.6
Neocalanus
microzoo
other mesozoo
sinking?
advection?
B. Summer small-cell dominated food web (dashed line = episodic event)
13
4
13
larvaceans
microzoo
?
?
?
other mesozoo
pink salmon
Units: µgC liter-1 d-1







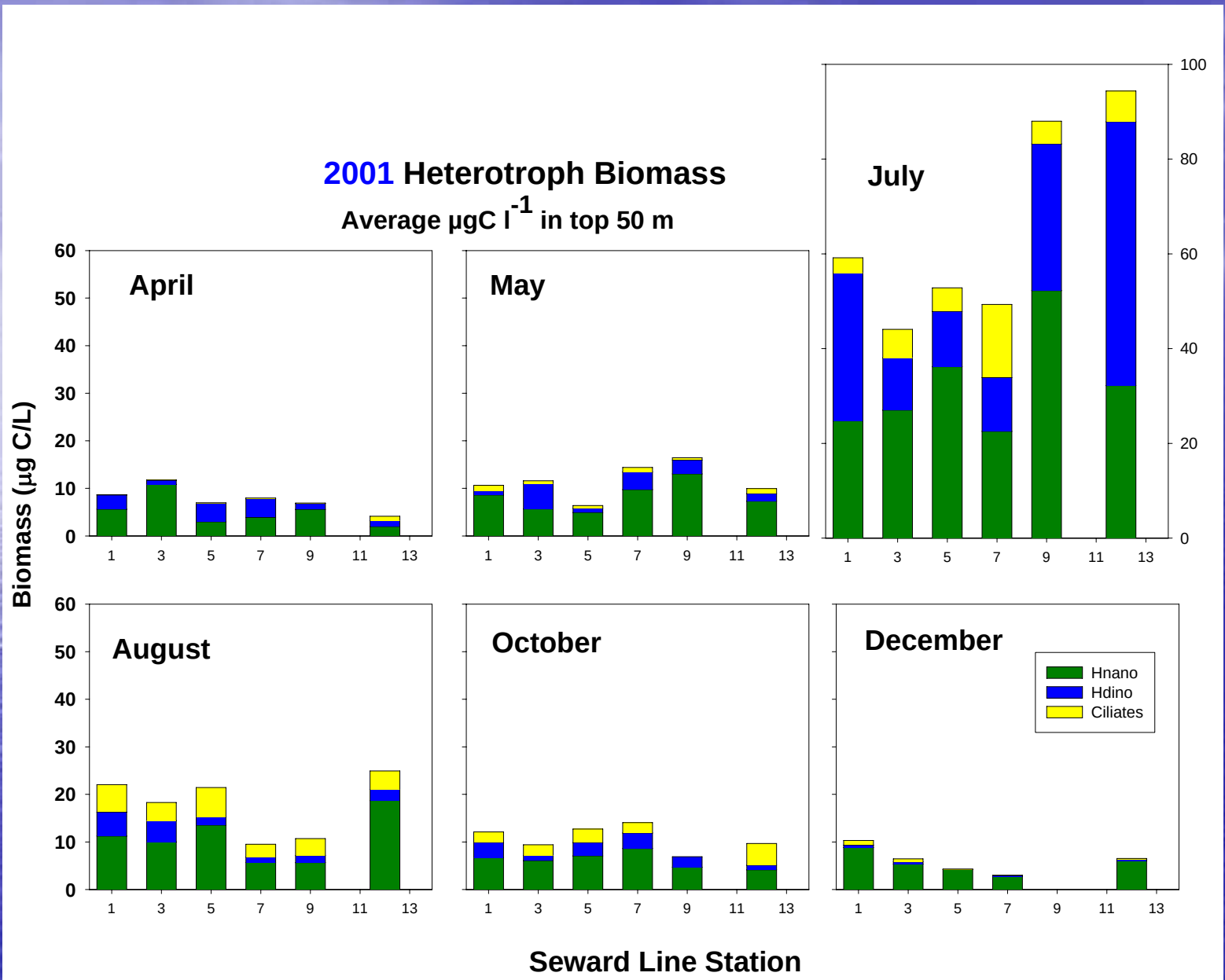




GLOBEC 2000-2004:

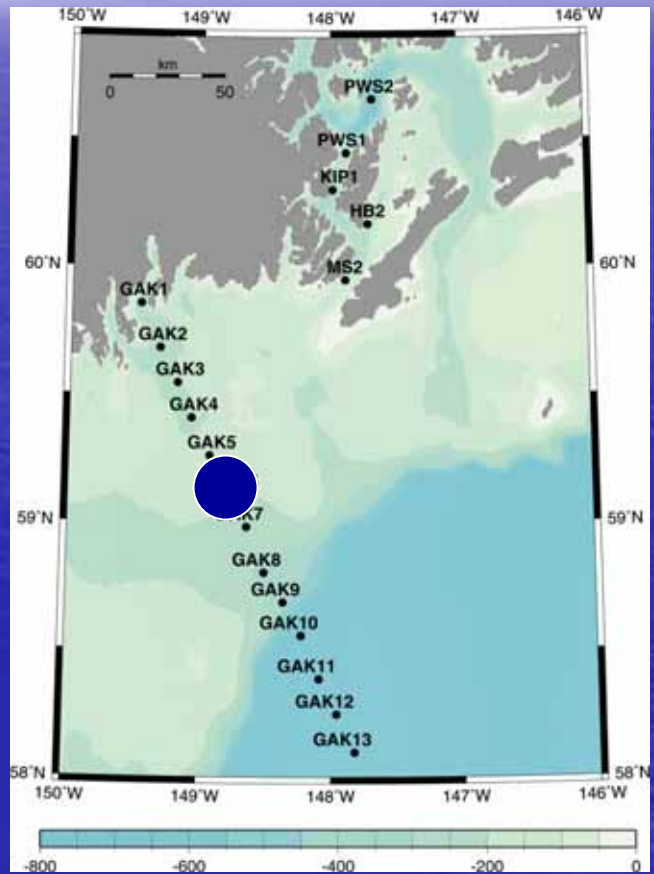
Integrated daily productivity shown for each station by sample month

Primary production measurements; GLOBEC LINE, 2000 – 2004; Whitledge et al.


2001 Heterotroph Biomass
Average µgC l-1 in top 50 m
Biomass (µg C/L)
April
May
July
August
October
December
Hnano
Hdino
Ciliates
Seward Line Station

Location of our 1D test: GAK6

- Coastal Gulf of Alaska (CGOA)
- mid-shelf location
- 150m depth



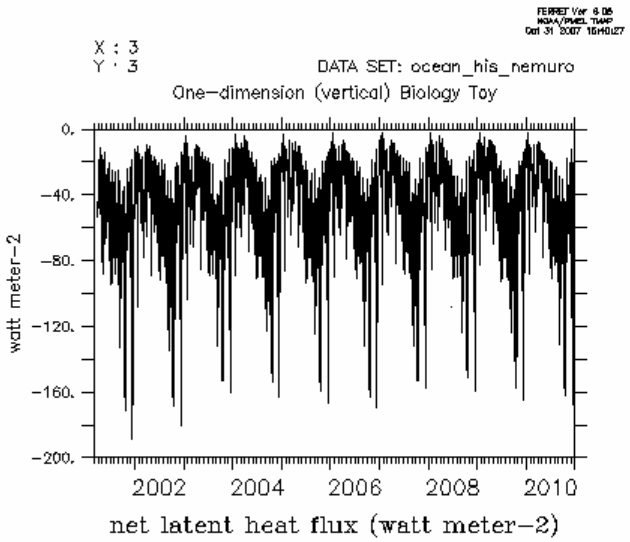
Model configuration

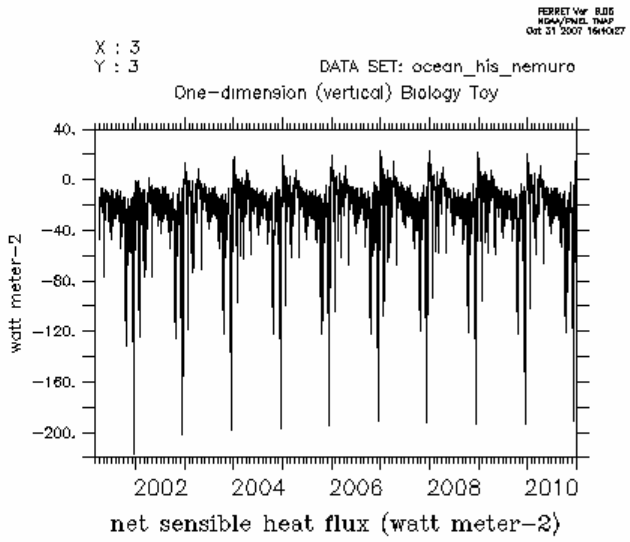
- 1D tests w/KPP mixing
  - remineralize all nutrients at the bottom so no loss
- Ignore salinity for now
  - 1D model cannot capture runoff and advection of salt, which are huge in this area
  - Instead, produce simple seasonal cycle of temp stratification/mixing in summer/winter
- Ignore tides as well! Trying to be really simple here for basic testing.....
- 3D CGOA implementation by Fiecther et al.

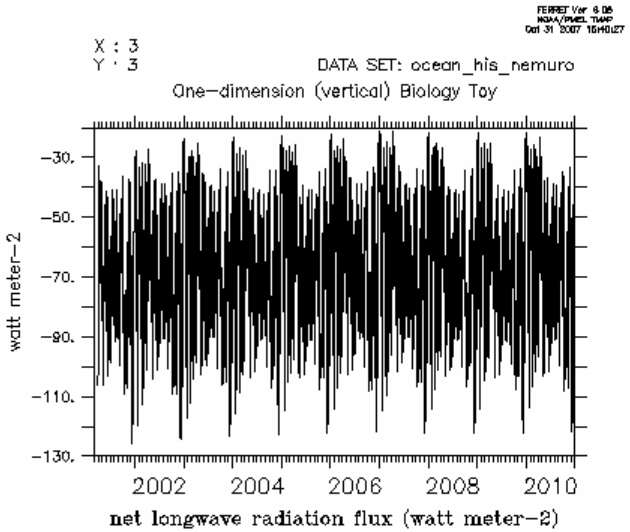
Forcing functions

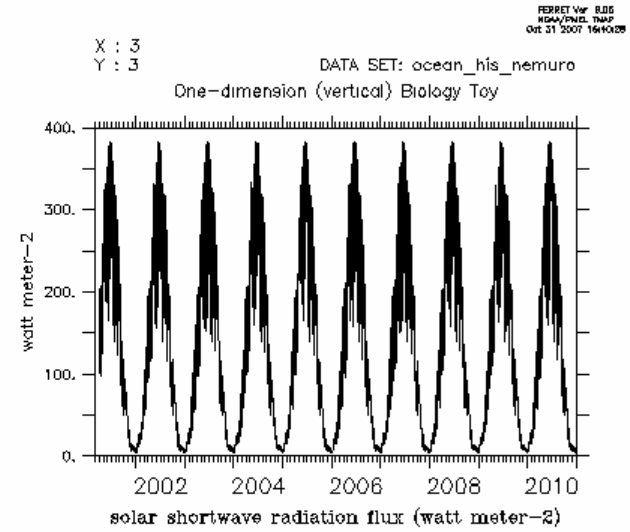
- NCEP forcing downscaled using MM5
  - nested atmospheric model of Bond et al. (2007)
- Bulk flux formulation
  - Analytical shortwave radiation (sunlight), attenuated by clouds
  - Latent heat flux via winds and relative humidity
  - Sensible heat flux via air-T, SST, and winds
  - Longwave radiation specified by atmos model
  - Wind stress from winds and SST
- Repeating 10-year annual cycle based on year 2001
- Look for repeating cycle of physical/biological models

A repeating cycle of forcing is used



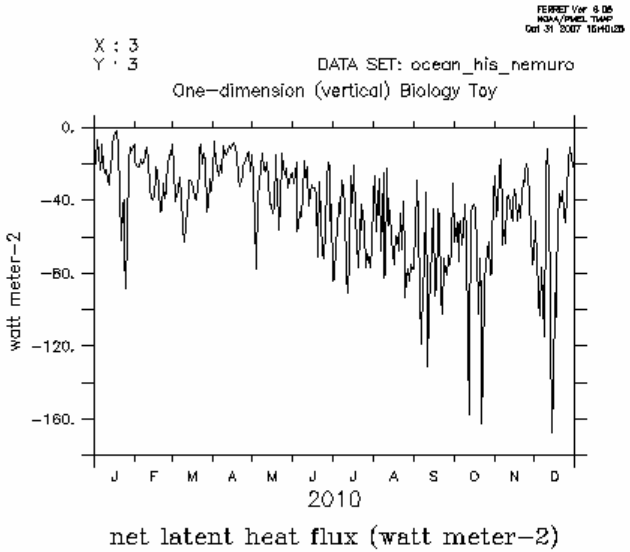




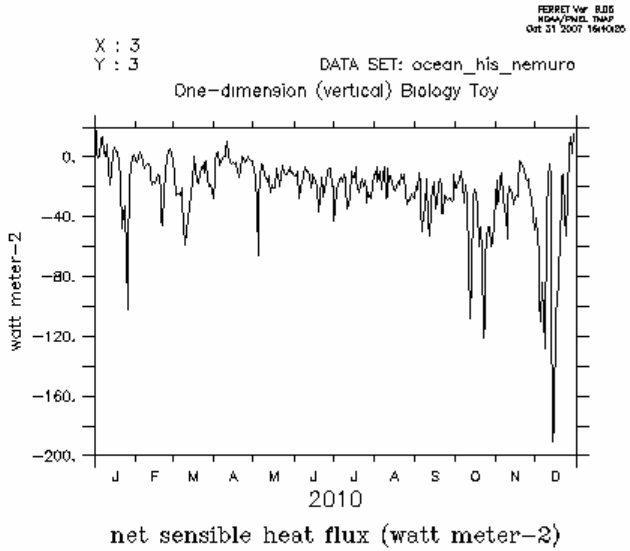


Some fluxes are a function of the ocean as well as the atmosphere

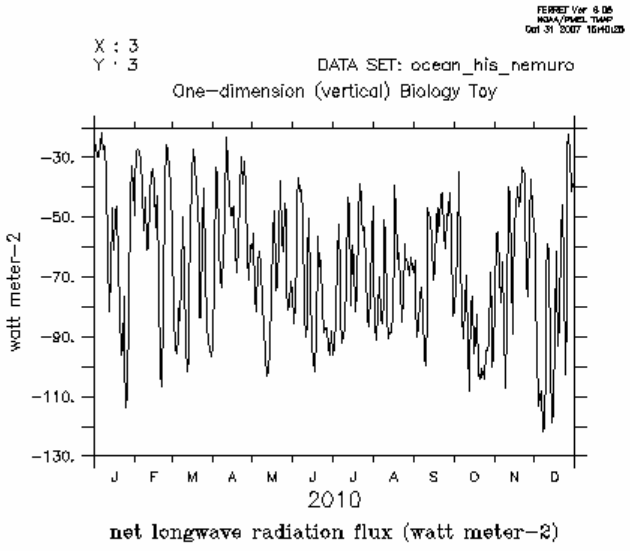
Annual cycle of surface heat flux



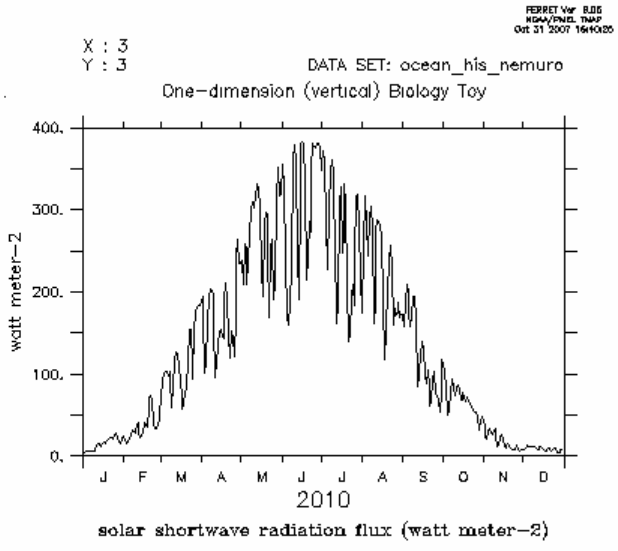
net latent heat flux (watt meter-2)



net sensible heat flux (watt meter-2)



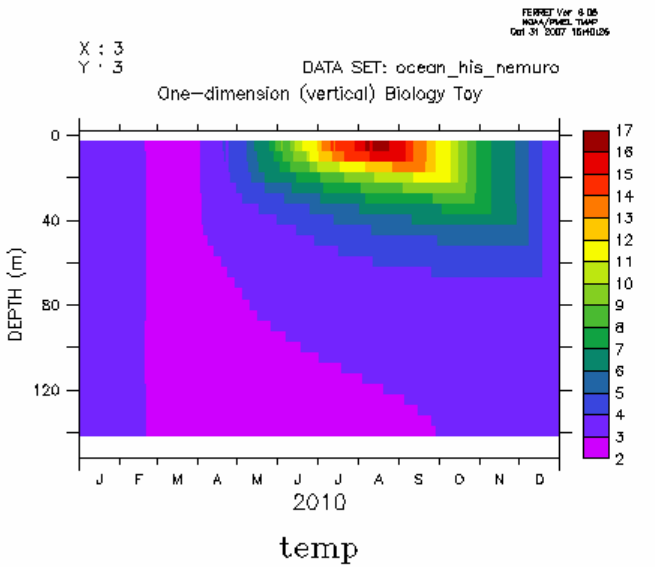
net longwave radiation flux (watt meter-2)

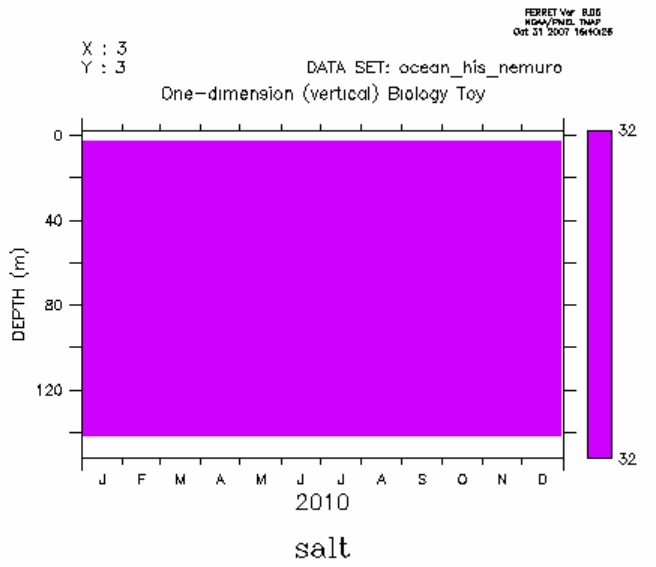


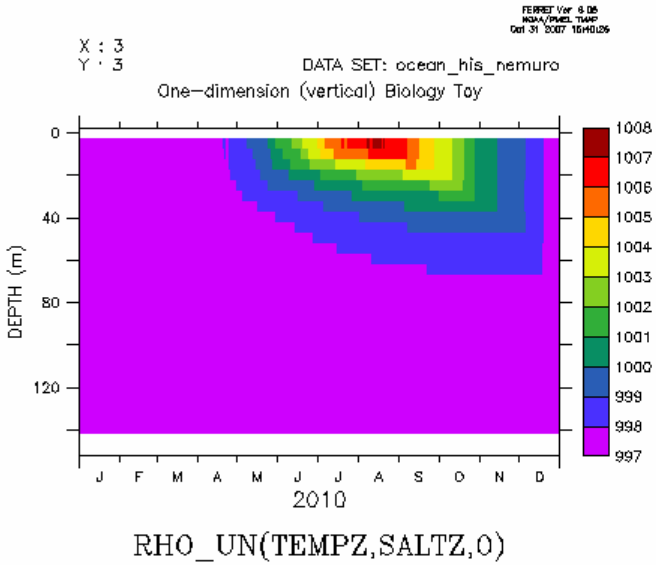
solar shortwave radiation flux (watt meter-2)

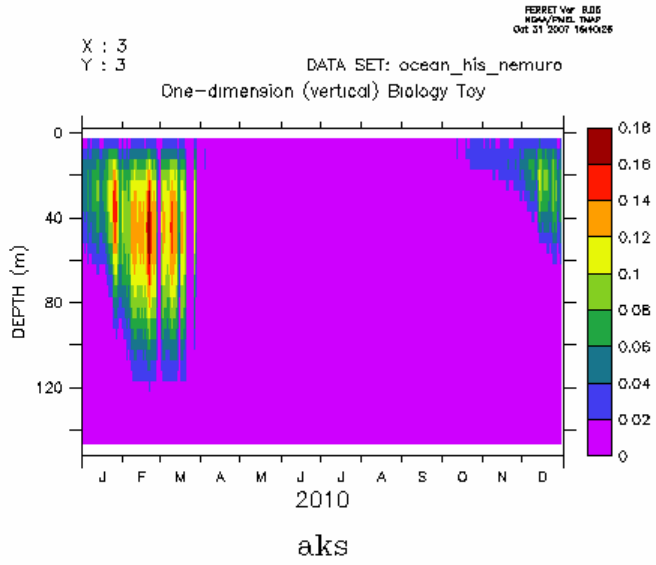
Note daily variability, which is important in mixing events

Annual cycle of physics









Stratification in summer

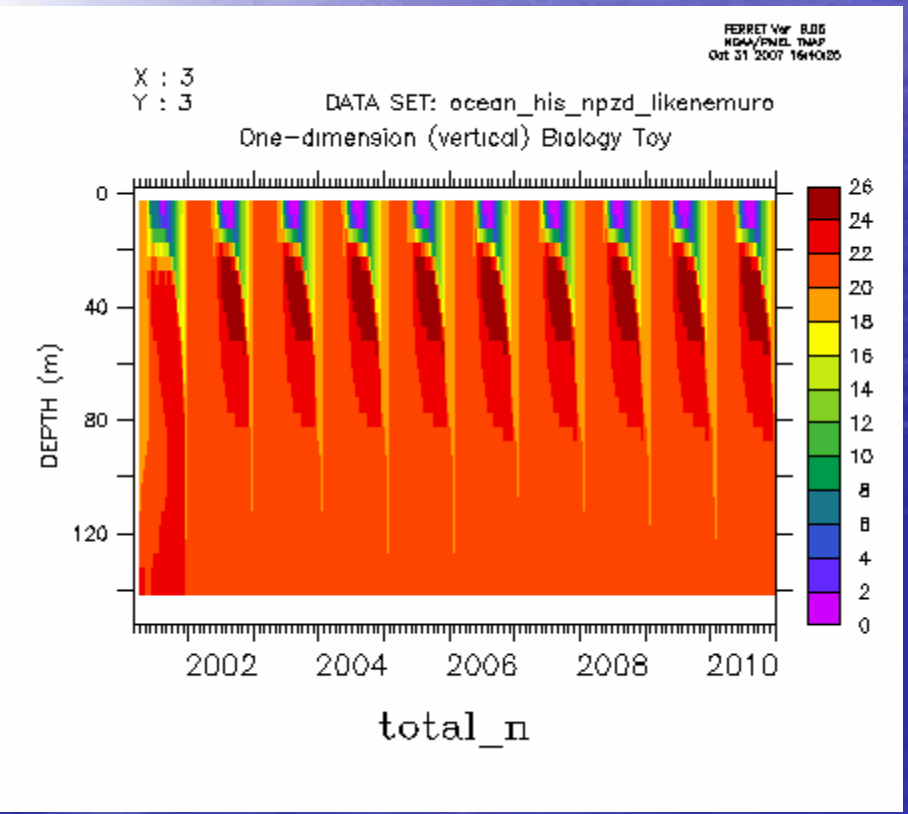
Strong mixing in winter

Model comparisons

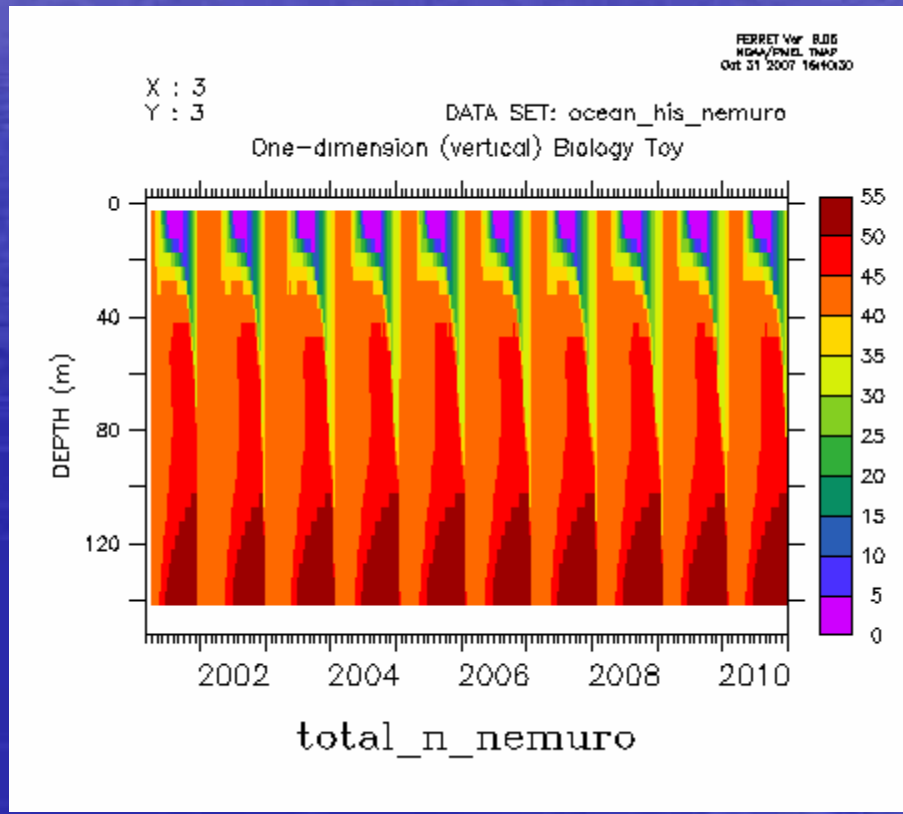
- NEMURO
  - Standard coefficient values from Kishi et al. (2007)
- NPZD
  - Standard coefficient values from Powell et al. (2006)
  - NEMURO-like coef values used for
    - Ivlev constant (was *very* different)
    - Self-shading
    - NO3 half-saturation
    - Intrinsic growth rate

Total N is conserved in both models

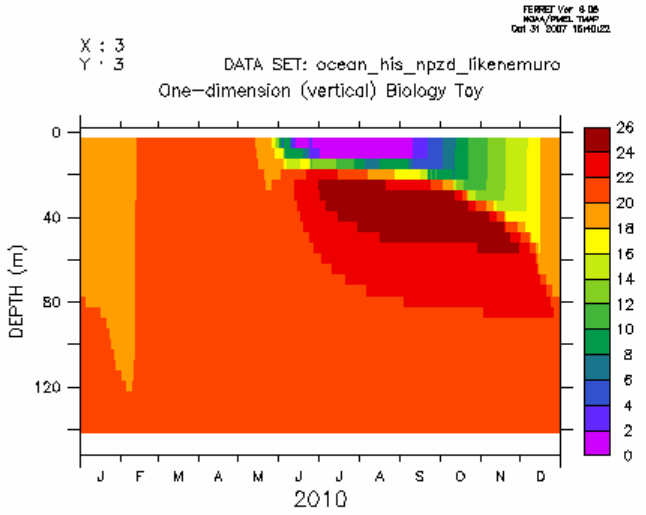
NPZD



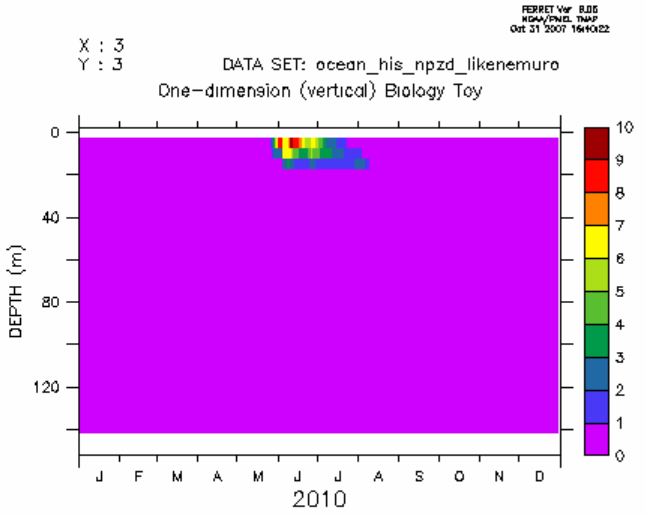
NEMUROMS



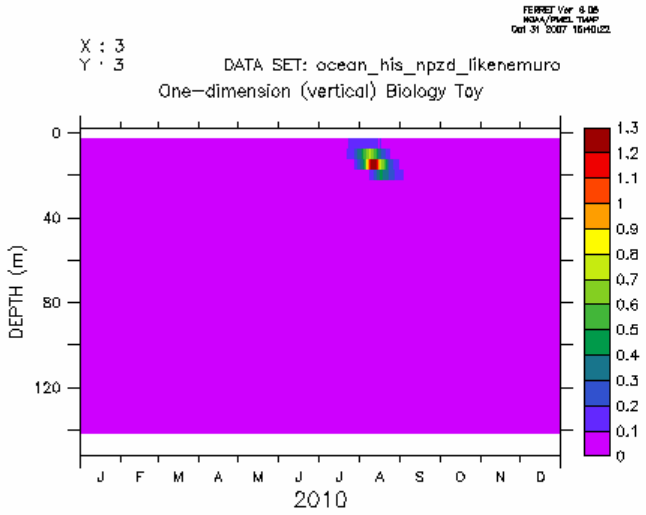
NPZD annual cycles



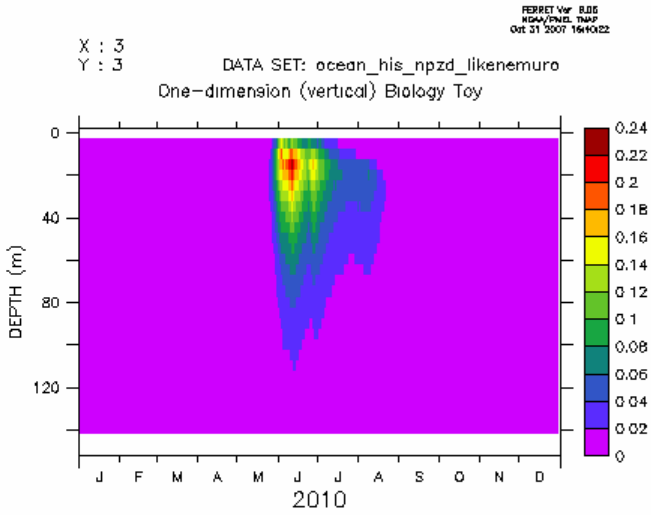
no3



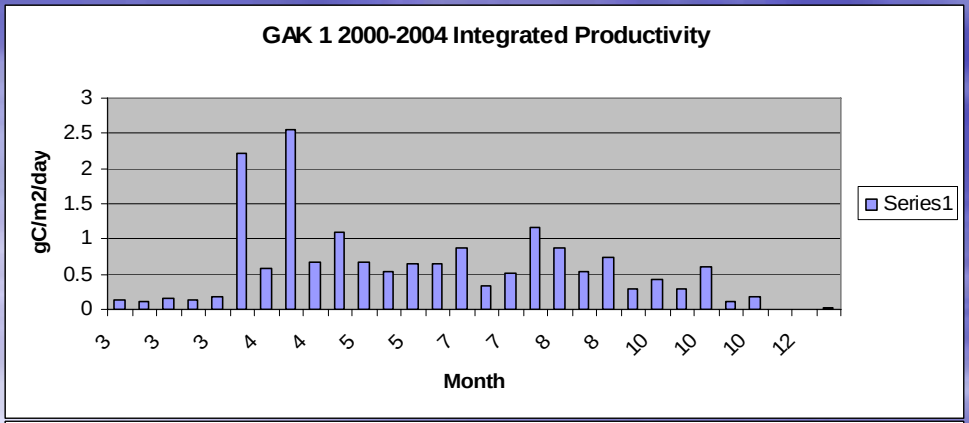
phytoplankton

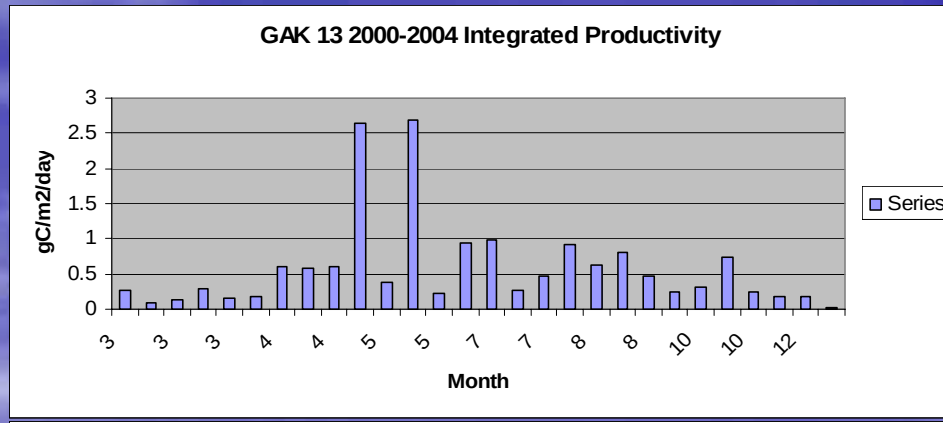


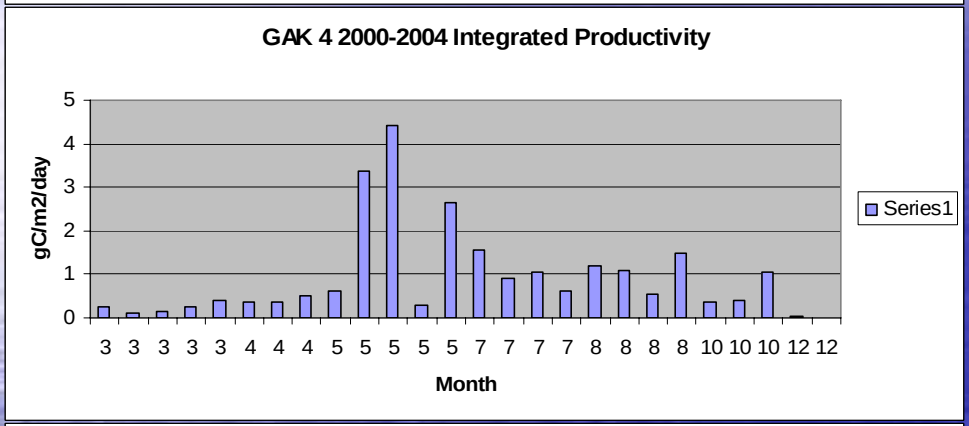
zooplankton

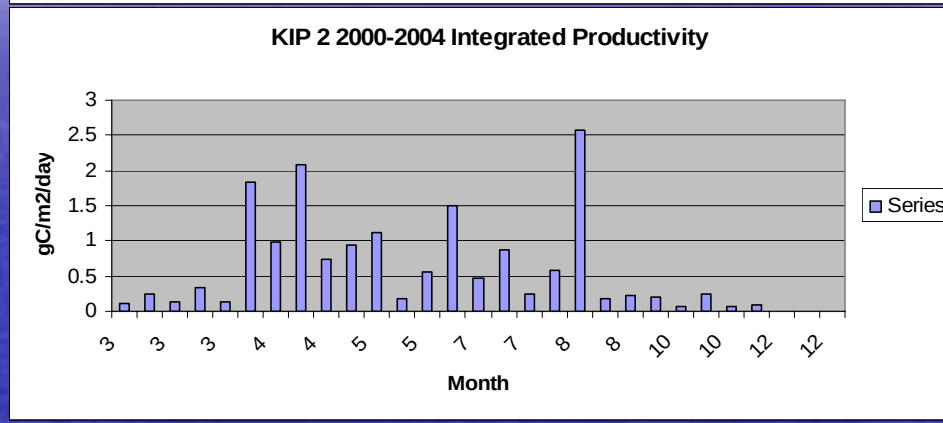


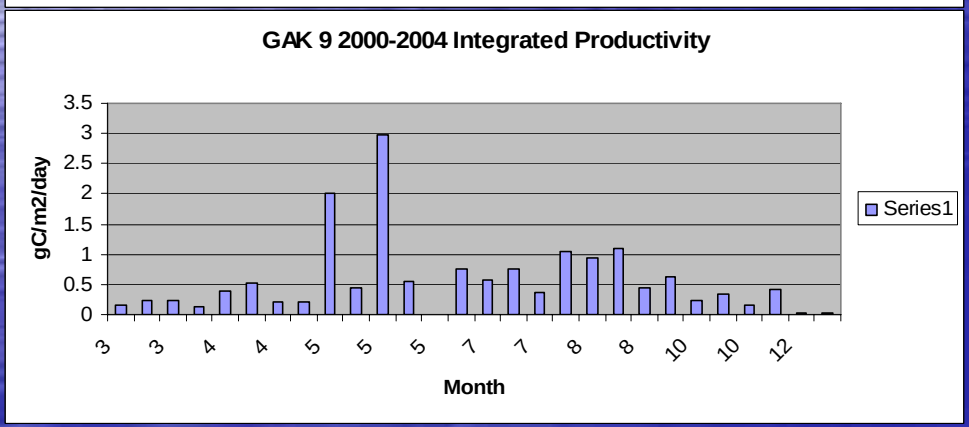
detritus











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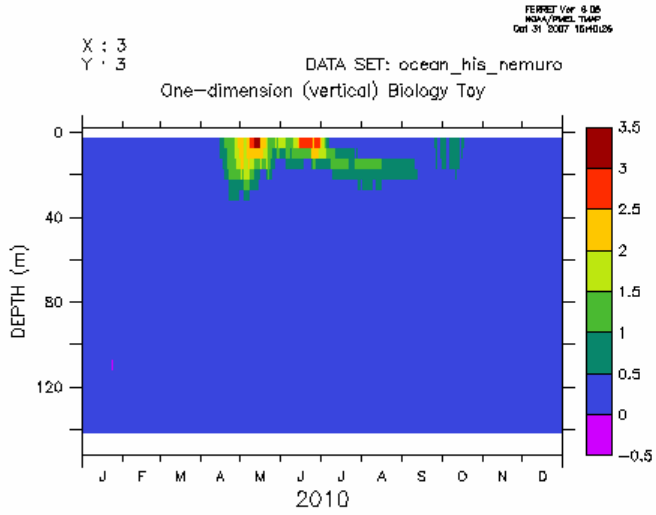
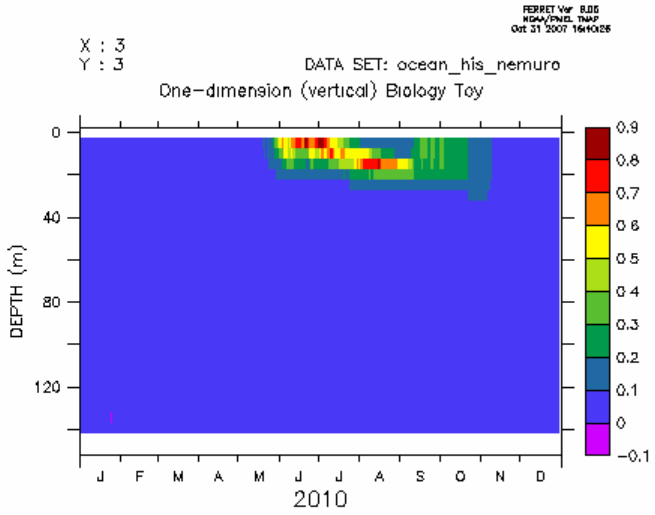
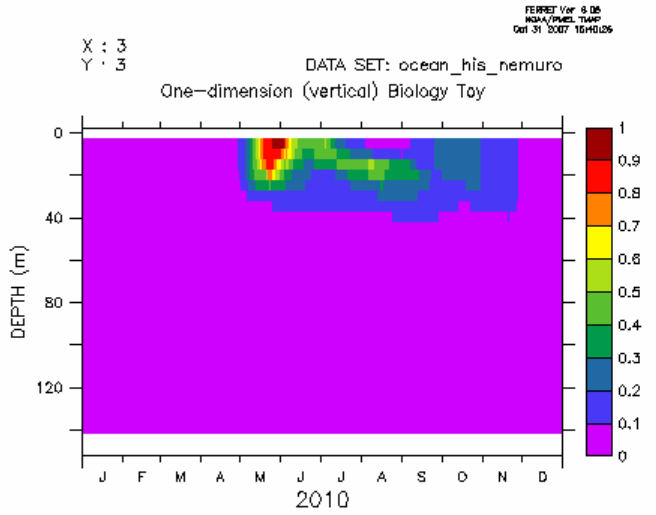
NEMUROMS annual cycles



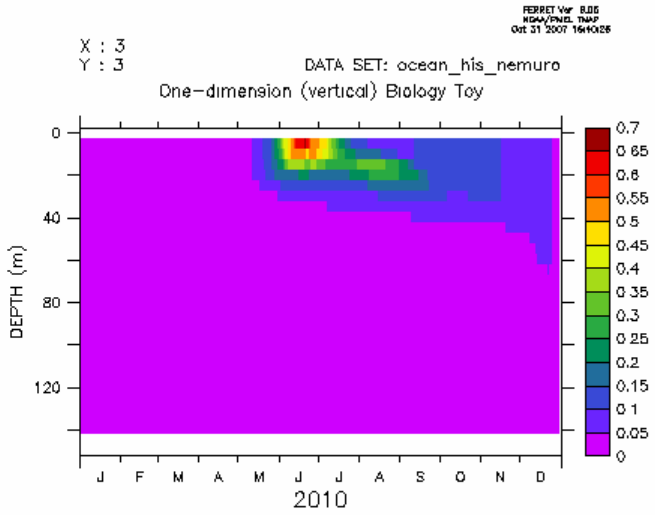
nanophytoplankton



diatom

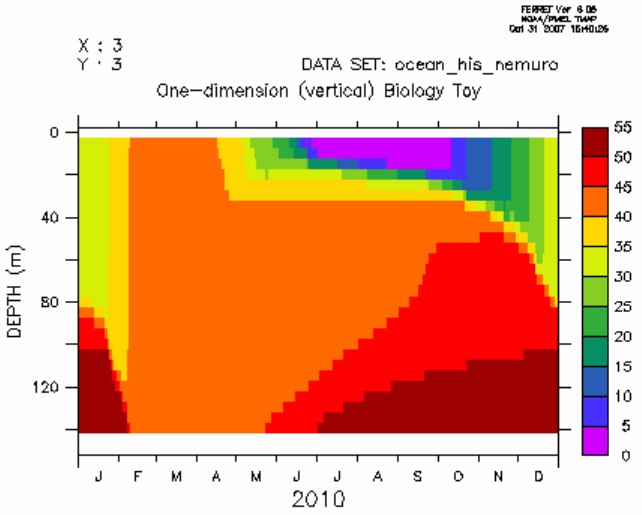


microzooplankton



mesozooplankton

NEMUROMS annual cycles



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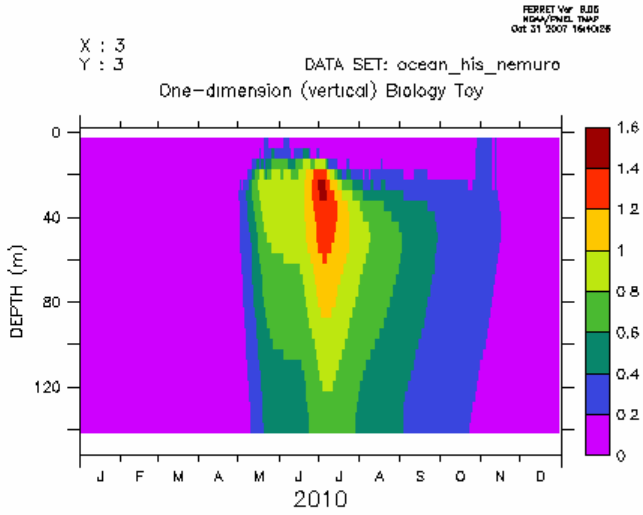
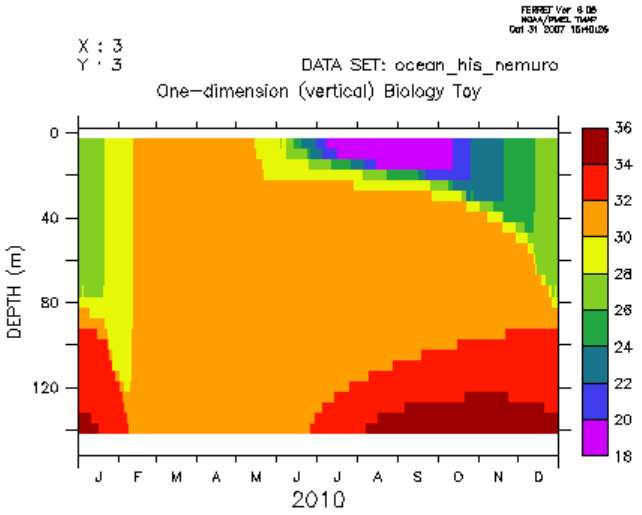
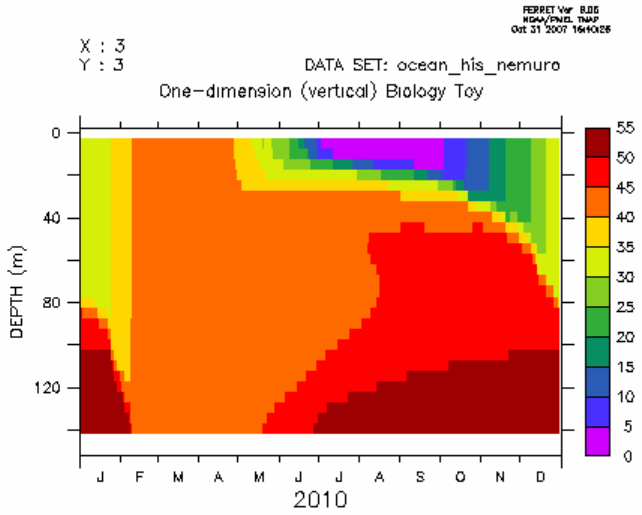


nh4

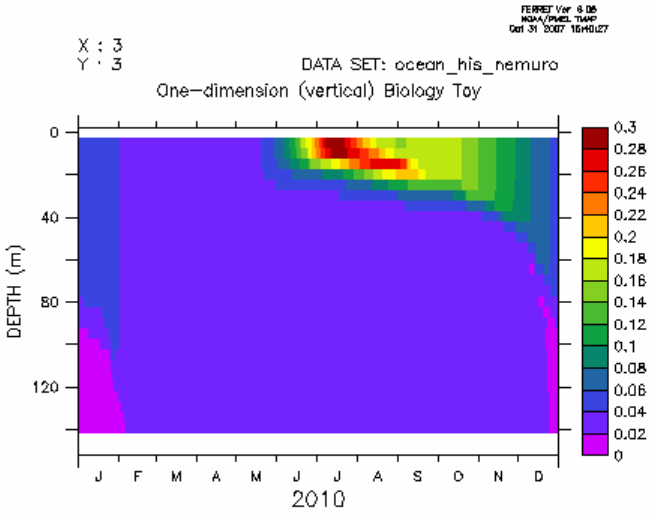


sioh4

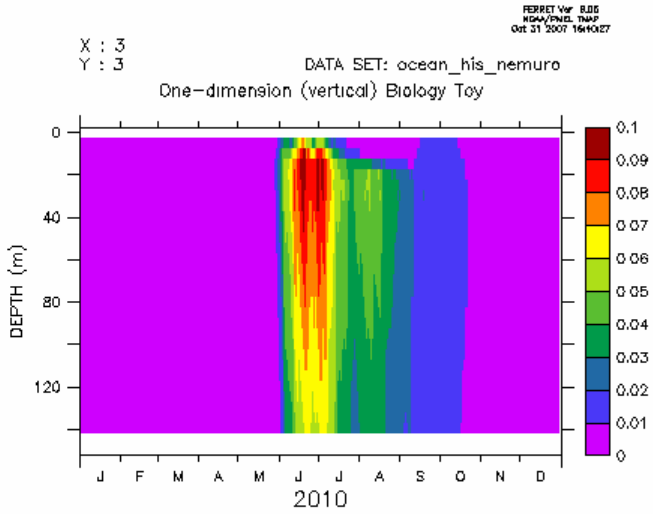


total_n_nemuro

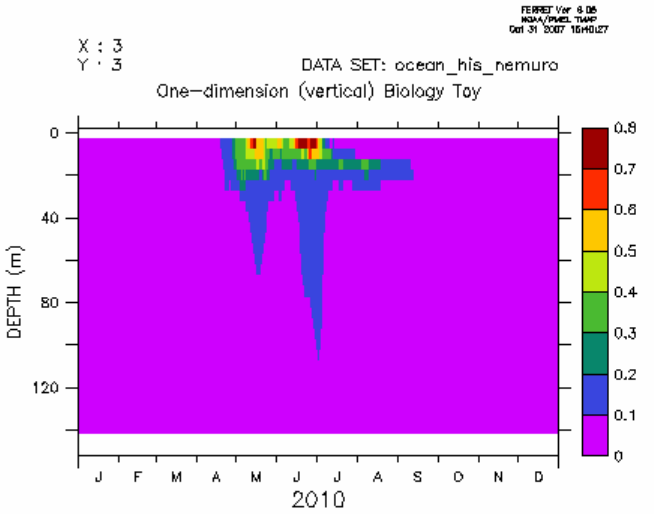
NEMUROMS annual cycles



pzooplankton



opal



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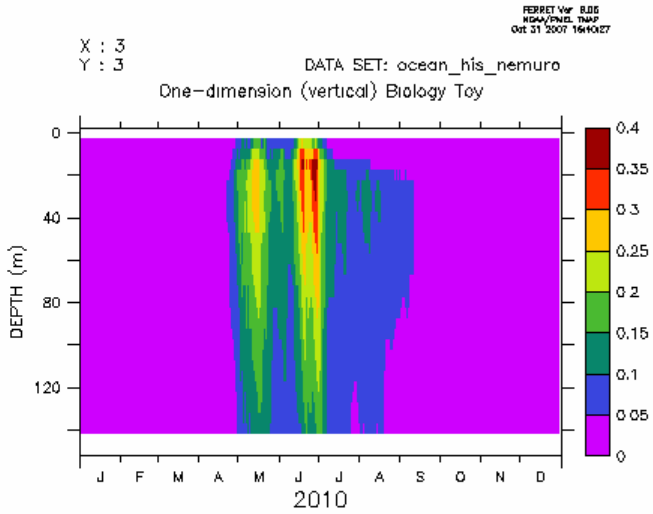

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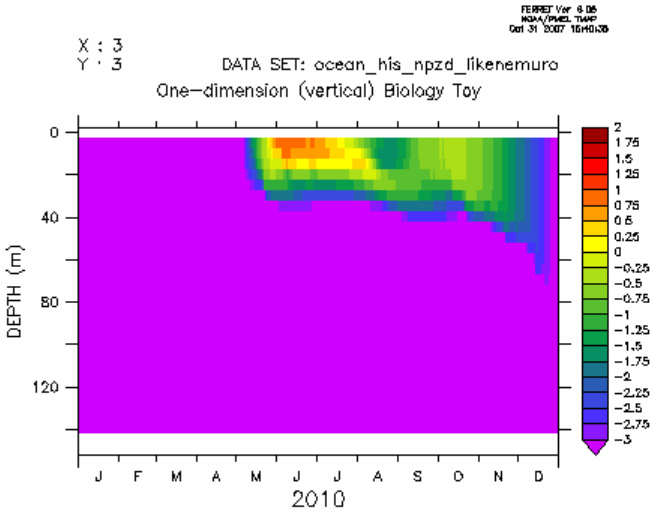
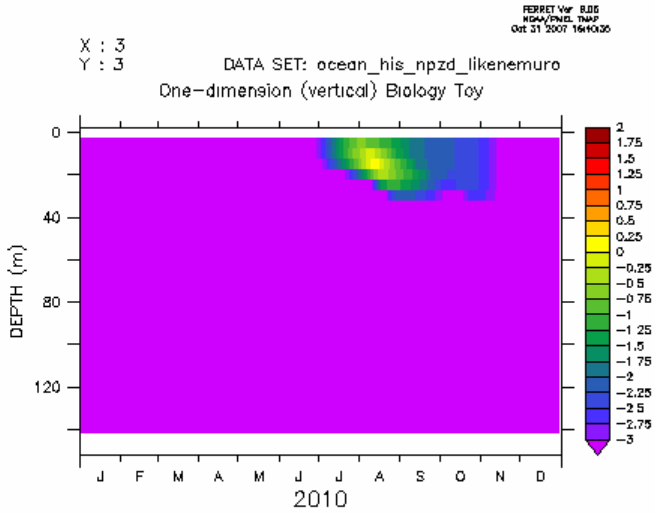
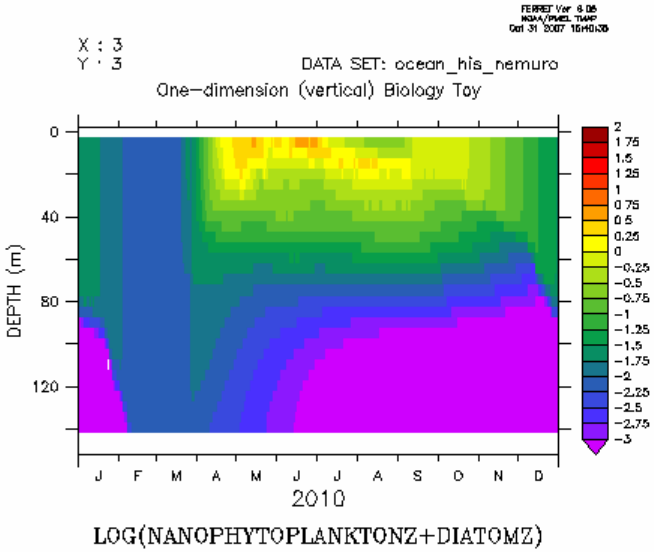
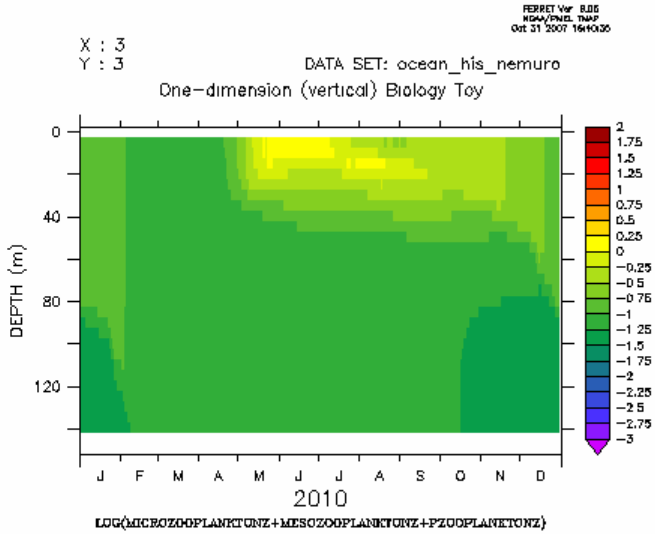
Compare NEMUROMS with NPZD

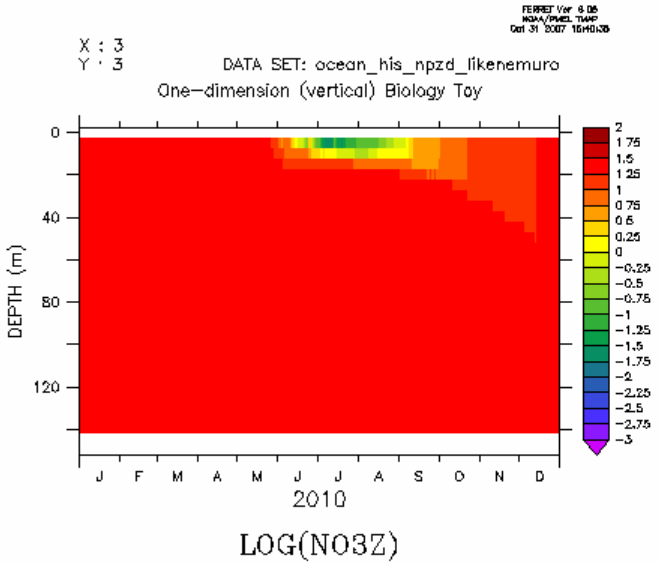




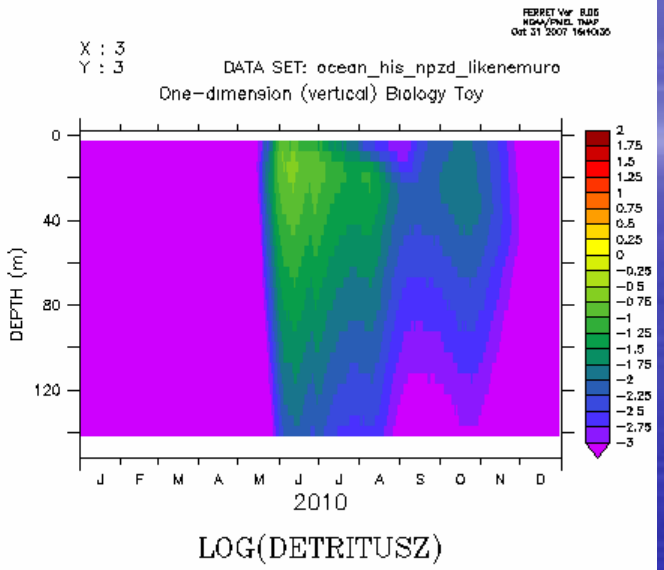




Compare NEMUROMS with NPZD



LOG(NO3Z)



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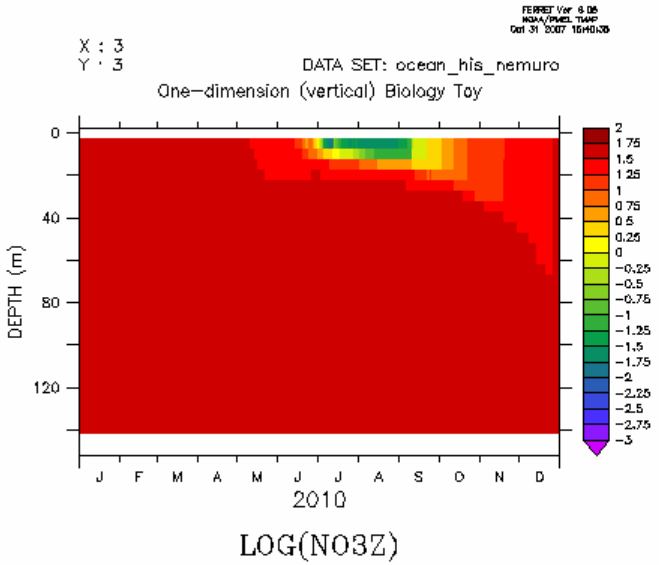

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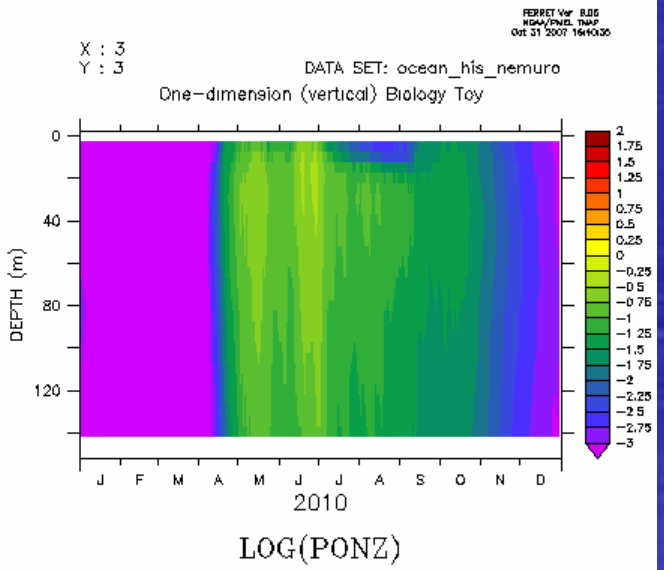

LOG(PONZ)

Conclusions

- The code works!
  - Maybe 99% debugged now...
  - download from ROMS website in a few weeks
- NPZD model has narrower time window of production
  - Single big bloom of phyt then zoop
- NEMUROMS has wider time window of production
  - Multiple blooms of P and Z groups
  - enhanced export of new production to depth

Interpretation/Speculation

- **More niches are exploited by the more complex model**
  - nature has evolved many strategies to exploit potential energy
  - models of the future should reflect this diversity of strategies as conditions change
  - overly simple models may be too stiff to predict the future
  - overly specific models (tightly tuned to a specific space/time domain) may be too stiff as well
  - IDEAL: a diverse model which can adapt to new conditions, whatever they may be.....

Ongoing/Future work

- J. Fiecther has added Fe to NEMUROMS
- Apply NEMUROMS in more places!
- Compare future projections using different models: NEMURO/NPZD/CGOANPZ
- Develop metrics for comparison (e.g. total production measures by trophic level)

Suggestion to PICES

- An **adjoint version** of NEMUROMS would be a very powerful tool for sensitivity analysis of regional ecosystems!

FIN!