Comparison of Physical-Biological Models of the California Current System and the Coastal Gulf of Alaska

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ABSTRACT

The California Current System (CCS) and the Coastal Gulf of Alaska (CGOA) are both regions of high biological productivity. While the dynamics governing the CCS's upwelling system are fairly well understood, the reasons for high productivity on the CGOA's downwelling shelf are more mysterious. Two biological models, each embedded within the Regional Ocean Modeling System (ROMS), are being used to investigate the differences between these systems; a simple NPZD model is used for the CCS, but for the CGOA, a specialized, 10-compartment model, called GLNPZ, has been developed and tuned to conditions in the Gulf. In order to compare the biological models, independent from the different physical conditions of the regions, a pseudo 1-D test case of ROMS was developed to run with both. We compare the biological results produced by implementations of this test case, and consider the implications for interregional comparisons.

NEP GLOBEC HYPOTHESIS

A core hypothesis in the Northeast Pacific GLOBEC program is that the ecosystem dynamics of the CCS and CGOA are connected by basin-scale physical processes.

CGOA MODELING

- Complex 3-D processes (downwelling, canyons, and eddies) combine with seasonal forcing (PAR, wind mixing, and temperature) to drive productivity
- Specialized biological model tuned to conditions in the coastal Gulf
- Seasonal/interannual time scales

CCS MODELING

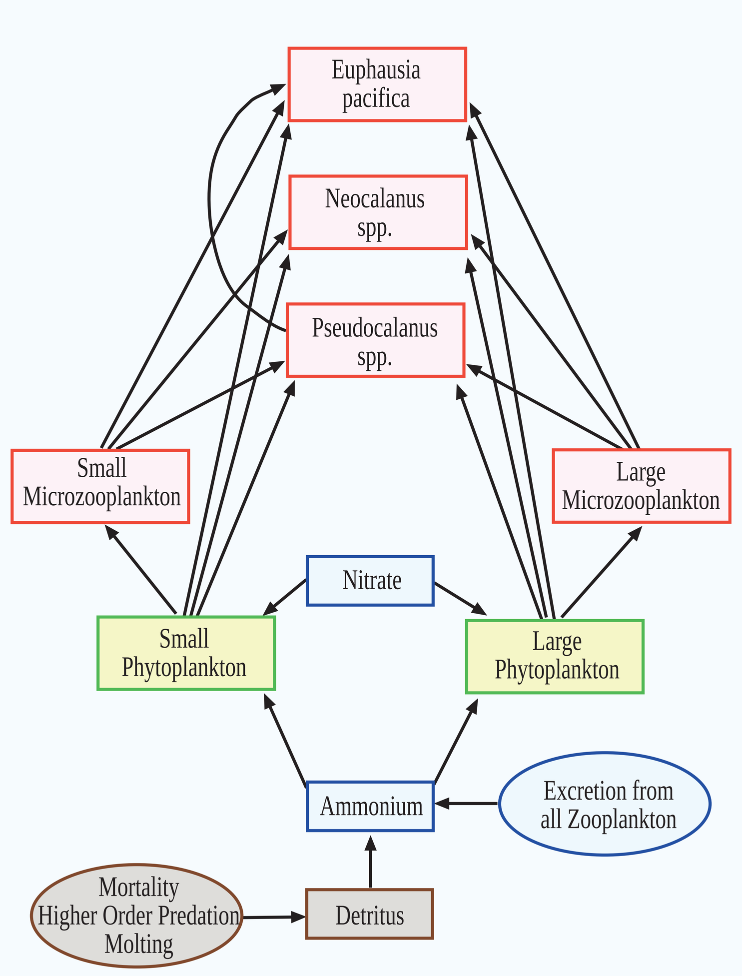
- Relatively well understood physical system - Coastal Upwelling
- Hierarchy of simple, easily configured biological models
- Short time scales (~1 month) defined by upwelling events

GLNPZ

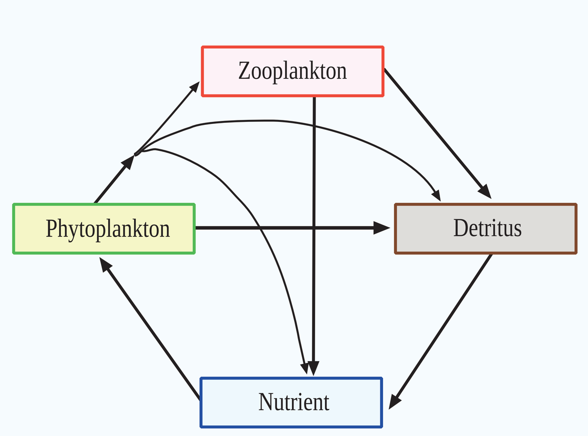
- 10 Boxes with 83 Parameters:
  Nutrients - NO_3 and NH_4
  Phytoplankton - Small (PhS) & Large (PhL)
  Microzooplankton - Small (MZS) & Large (MZL)
  Mesozooplankton - Copepods (Cop) & Neocalanus (NC)
  Euphausiids (Eup)
  Detritus (D)
- P uptake of N and Z growth rates are Temperature Dependent.
- Seasonal Irradiance Curve. Date and latitude dependent Day Length.
- P mortality and sinking increase when NO_3 falls below a critical value.
- P self-shading based on Frost, 1987
- Neocalanus and Euphausiids do not experience vertical diffusivity

NPZD

- 4 Boxes with 12 Parameters:
  Nutrients (N)
  Phytoplankton (P)
  Microzooplankton (μZ) -or- Mesozooplankton (mZ) - Copepods
  Detritus (D)
- No Temperature Dependence.
- No Seasonal Irradiance. Constant Day Length.
- Constant P mortality. No P sinking.
- No P self-shading
- All variables experience vertical diffusivity



Flowchart of GLNPZ.



Flowchart of NPZD.

NO ATTEMPT WAS MADE TO MATCH THE PARAMETERS OF NPZD AND GLNPZ

Even with simplifications to physics and GLNPZ, there are still differences due to different parameters and model structure.

How can the results of differently structured biological models in different physical regimes be compared?

First, compare the models driven by identical, idealized physics

SIMPLIFIED TEST PROBLEM

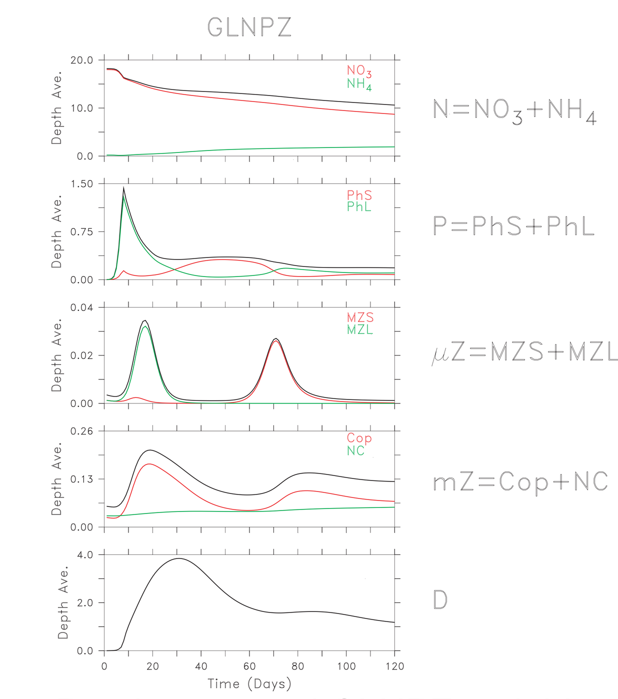
- PHYSICS
  - ROMS v1.8.0
  - Mellor-Yamata 2.5 Vertical Mixing
  - Background Vertical Mixing coefficient = 0.0001 $m^2\ s^{-1}$
- DOMAIN
  - 5x5 domain, doubly periodic simulates 1-D
  - Horizontal Resolution 50 km
  - 100 m deep
  - 20 equally spaced Sigma levels
- ENVIRONMENT
  - Simplify GLNPZ with constant, summer, CGOA values
  - uniform Temperature = 12 °C
  - constant Irradiance = 70 E $m^{-2}\ d^{-1}$
  - constant Day Length = 15.4 hr
- BIOLOGICAL INITIAL CONDITIONS
  - Vertically averaged profiles
  - Background oceanic values
    - Phytoplankton = .00126 mmol N m^{-3}
    - Microzooplankton = .00126 mmol N m^{-3}
  - GLOBEC field studies of CGOA in March, 1999
    - NO3 = 18 mmol N m^{-3}
    - NH4 = 0.2 mmol N m^{-3}
    - Copepods = 0.026 mmol N m^{-3}
    - Neocalanus = 0.030 mmol N m^{-3}
    - Euphausiids = 0.017 mmol N m^{-3}
- WIND MIXING TEST
  - Wind stress applied for 40 days
  - Magnitude (0.8 m s^{-1}) average of spring, CGOA

WHICH VARIABLES TO COMPARE?

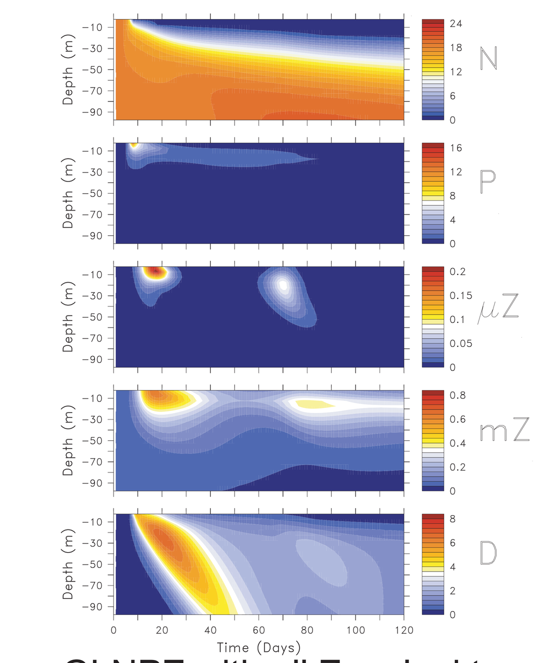
Add GLNPZ's Nutrients, Phytoplankton species, Mesozooplankton species, and Microzooplankton species together.

Since models' parameters / structures / species compositions aren't the same, a more exact comparison is premature.

Some GLNPZ runs performed with zooplankton trophic levels disabled, to assess the impact of complex vs. simple models.



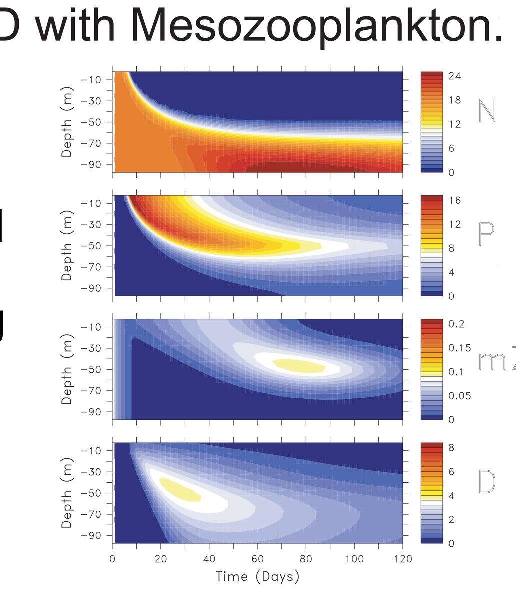
Depth averaged GLNPZ variables and their sums (mmol N m^{-3}).



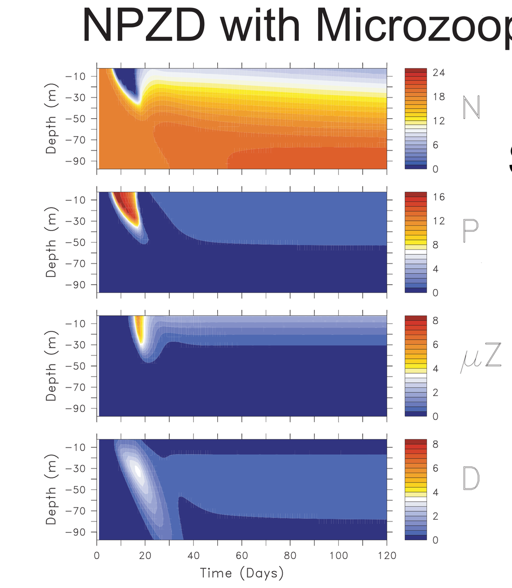
GLNPZ with all Zooplankton.

NPZD with Mesozooplankton.

Minimal Grazing

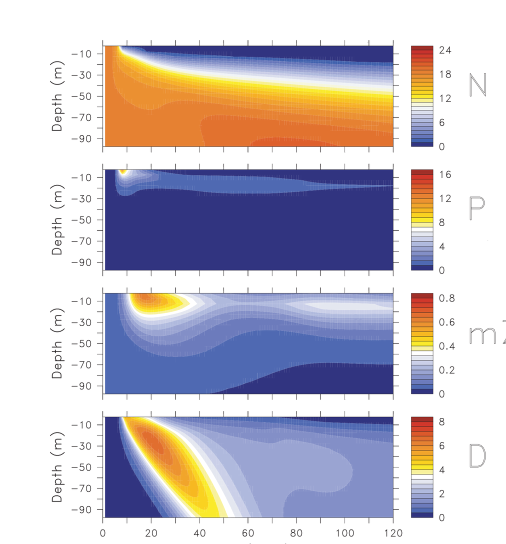


NPZD with Microzooplankton.

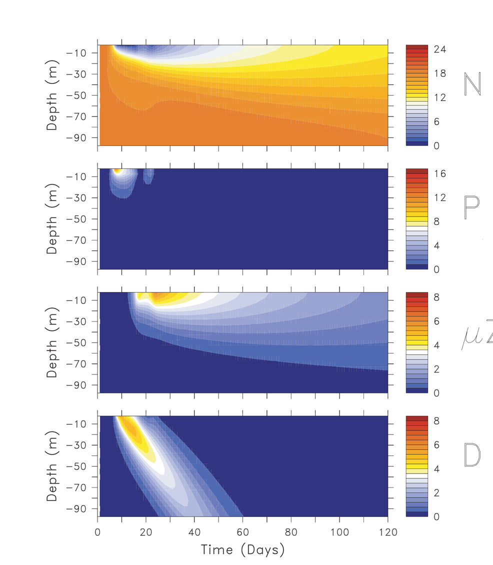


Surface N High After Bloom

Like Full GLNPZ



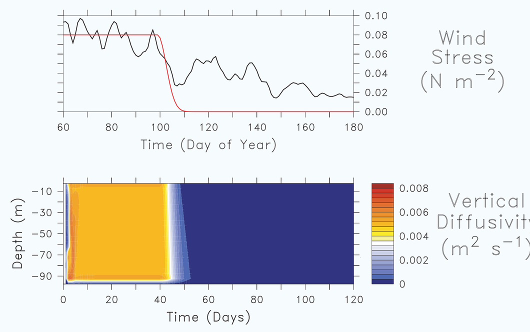
GLNPZ with Mesozooplankton.



Like NPZD with μZ

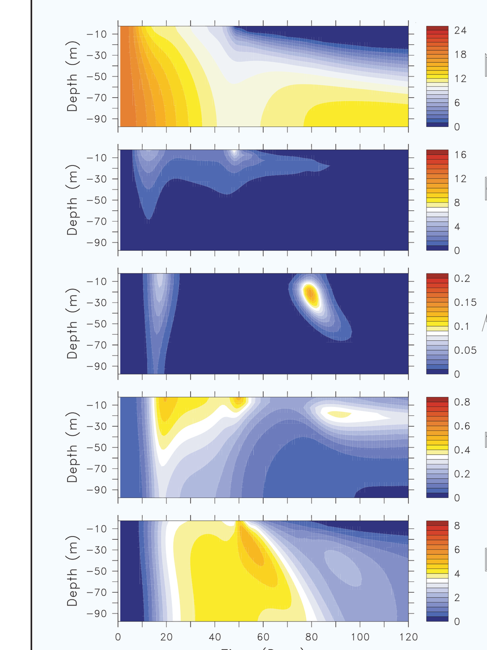
GLNPZ with Microzooplankton.

CESSATION OF SPRING WIND MIXING



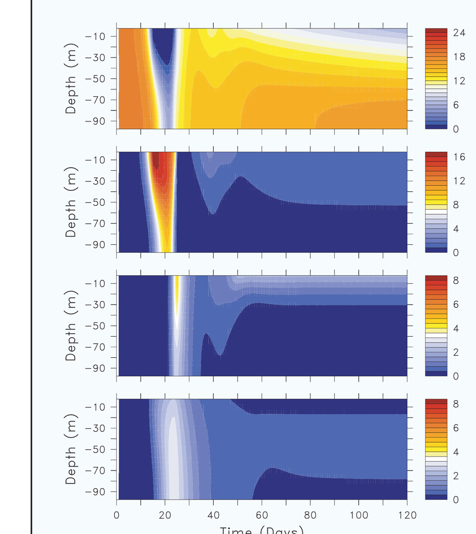
A possible trigger for the spring bloom in the CGOA is decreasing wind mixing, which allows Phytoplankton to remain in the euphotic zone.

CGOA Wind Stress (black line), modelled Wind Stress (red line), and resulting Vertical Diffusivity.



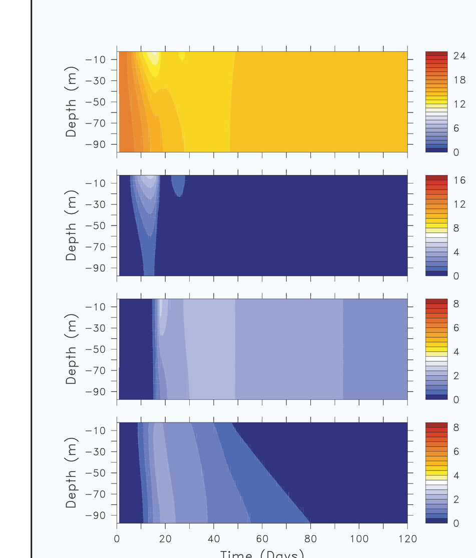
Bloom Delayed

GLNPZ with all Zooplankton and wind mixing.



Bloom Deepened

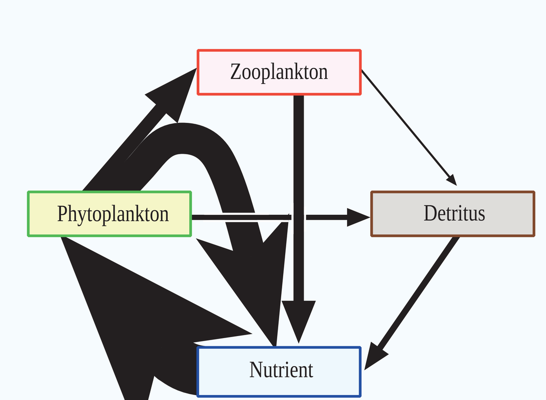
NPZD with Microzooplankton and wind mixing.



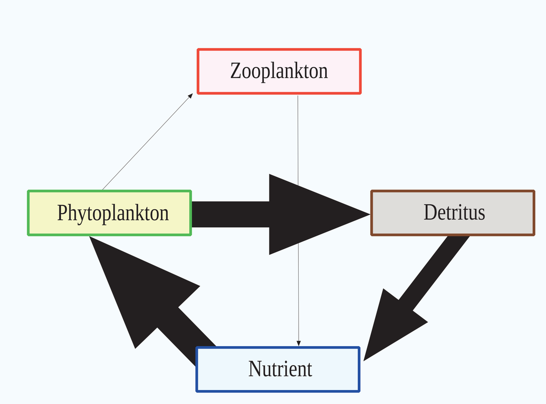
No Bloom

GLNPZ with Microzooplankton and wind mixing.

NITROGEN FLUXES



Fluxes within NPZD with Microzooplankton.



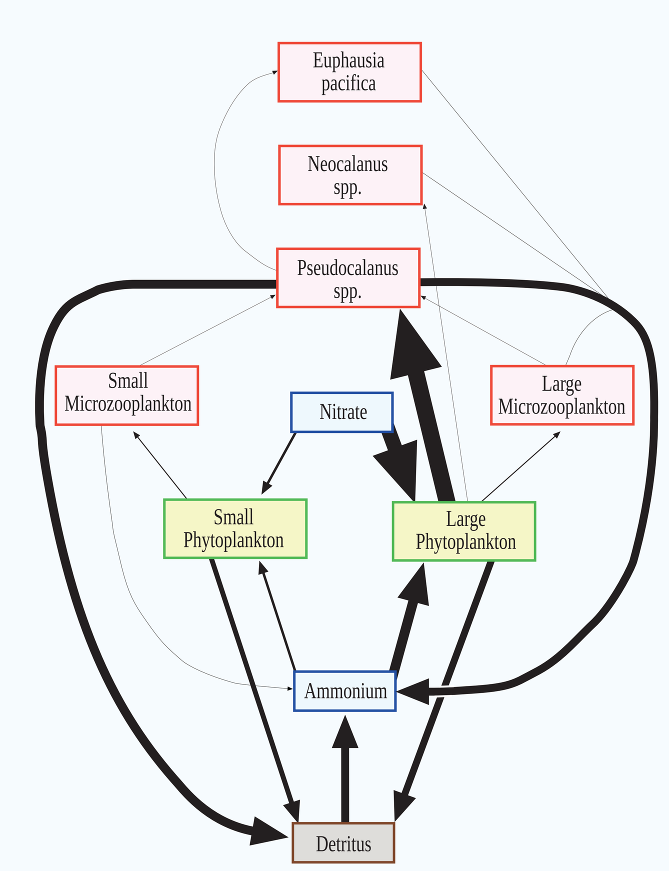
Fluxes within NPZD with Mesozooplankton.

Fluxes between the models' boxes:
- Averaged over depth
- Averaged over 120 day run
- Arrow size is proportional to flux

In NPZD with Microzooplankton, excretion cycles Nitrogen from the Phytoplankton pool to the Nutrient pool.

In NPZD with Mesozooplankton, grazing is minimal, and Nitrogen cycles through Detritus.

GLNPZ is dominated by a loop through Large Phytoplankton and Copepods to Detritus and Ammonium.



Fluxes within GLNPZ. Egestion and excretion losses to grazing are added to Zooplankton fluxes.

SUMMARY

- In GLNPZ, grazing by Copepods reduces the importance of Microzooplankton, as does the sensitivity of Phytoplankton to Nutrient levels. Refined Microzooplankton parameters might alter this.
- Lack of self shading in NPZD results in very deep Phytoplankton blooms, that are only slightly affected by strong vertical mixing.
- Higher trophic levels in GLNPZ affect Phytoplankton and Nutrients, so it will be difficult to compare single trophic levels of a single, complex model to those from a hierarchy of simple models.
- If higher trophic levels and seasonal dynamics are removed from GLNPZ, then results are similar to NPZD - remarkable for models with such different structures.

SPECULATIONS

- Total productivity might be a useful comparative measure (scaled by trophic level?)
- Equalizing parameters will be arduous and ultimately pointless
- Associating specific boxes (i.e. P to either PhS or PhL) is complicated by successional blooms in GLNPZ. This may be clarified by refining the doubling rates of PhS and PhL.