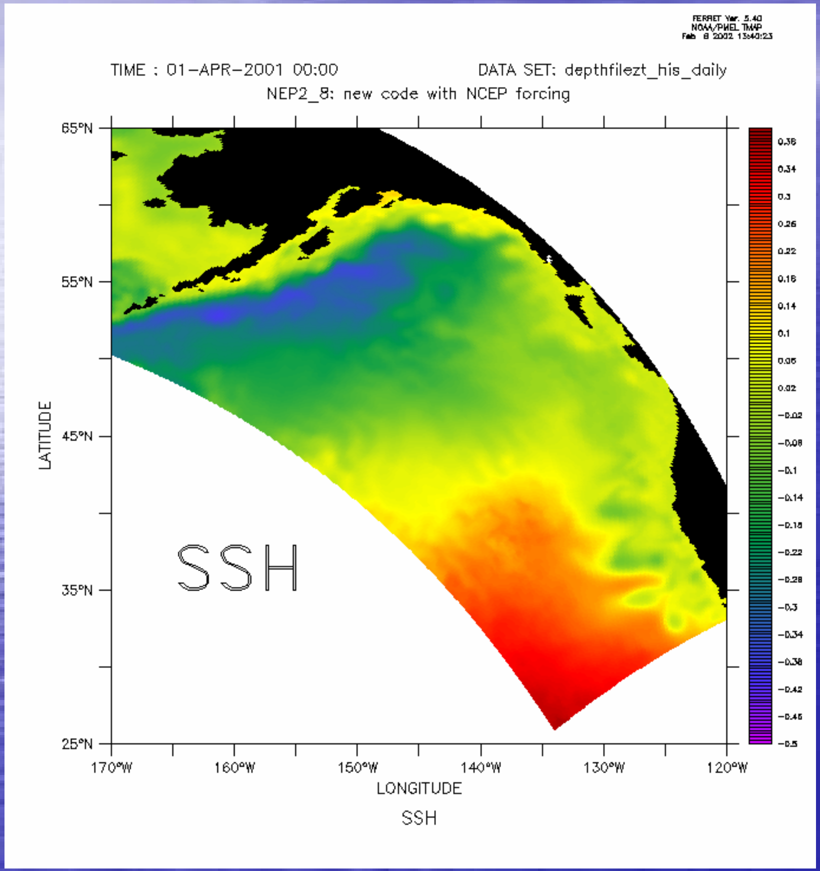
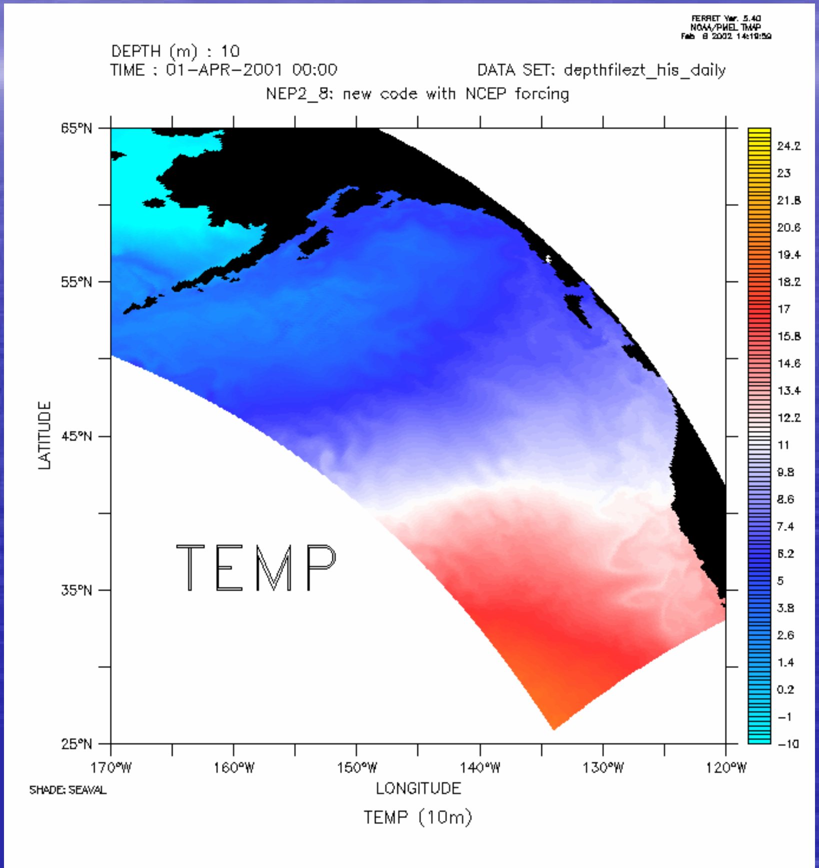
A comparison of different NPZ models for the Northeast Pacific

Albert J. Hermann[1], Thomas M. Powell[2], Elizabeth L. Dobbins[1], Sarah Hinckley[3], Enrique N. Curchitser[4], Dale B. Haidvogel[5] and Kenneth Coyle[6]

1 Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
2 Department of Integrative Biology, U. C. Berkeley
3 Alaska Fisheries Science Center
4 Lamont-Doherty Earth Observatory of Columbia University
5 Institute of Marine and Coastal Sciences, Rutgers University
6 Institute of Marine Science, University of Alaska Fairbanks

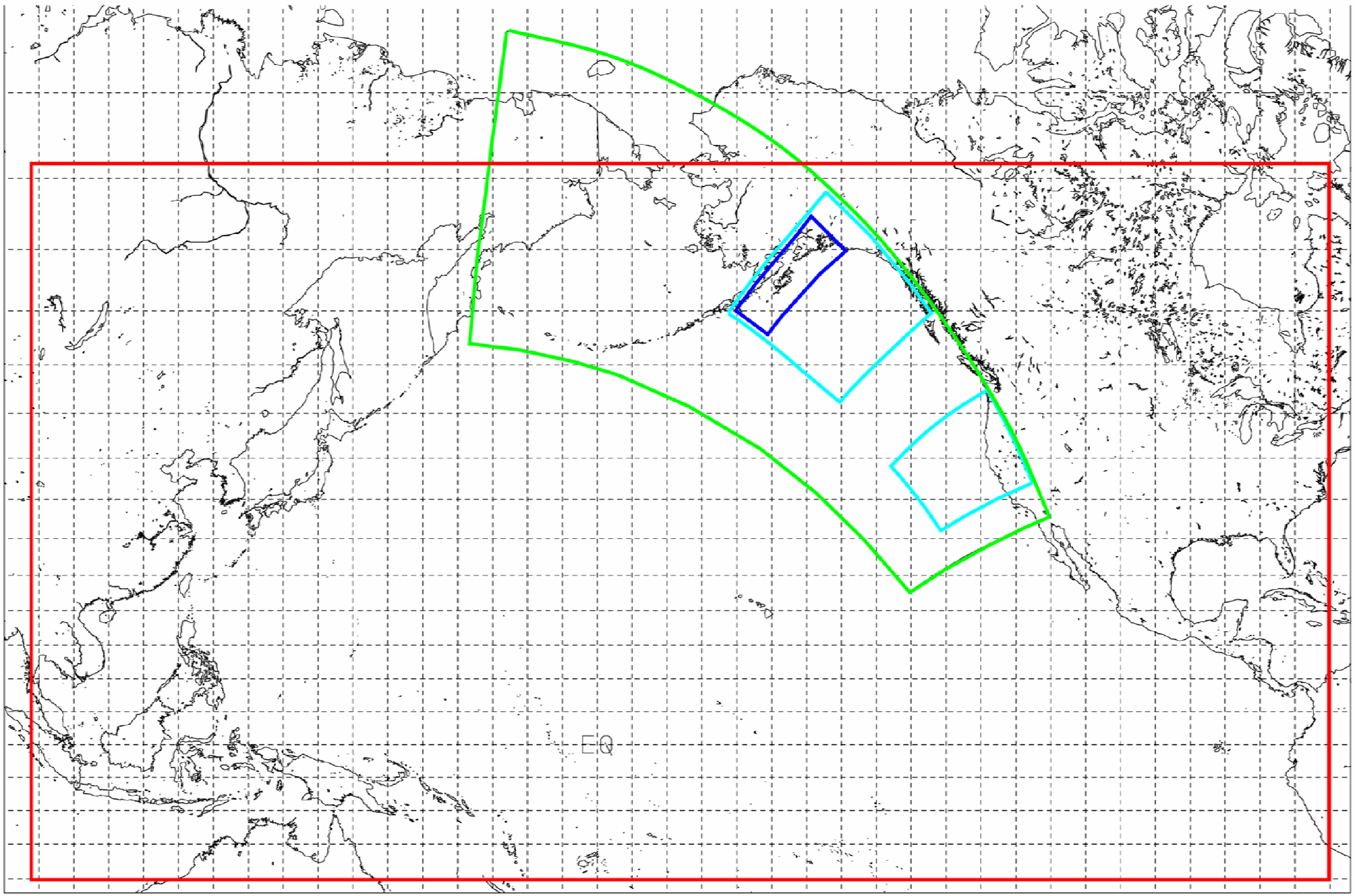
Northeast Pacific GLOBEC (NSF/NOAA)





Do the gyres covary, and does this affect biology?

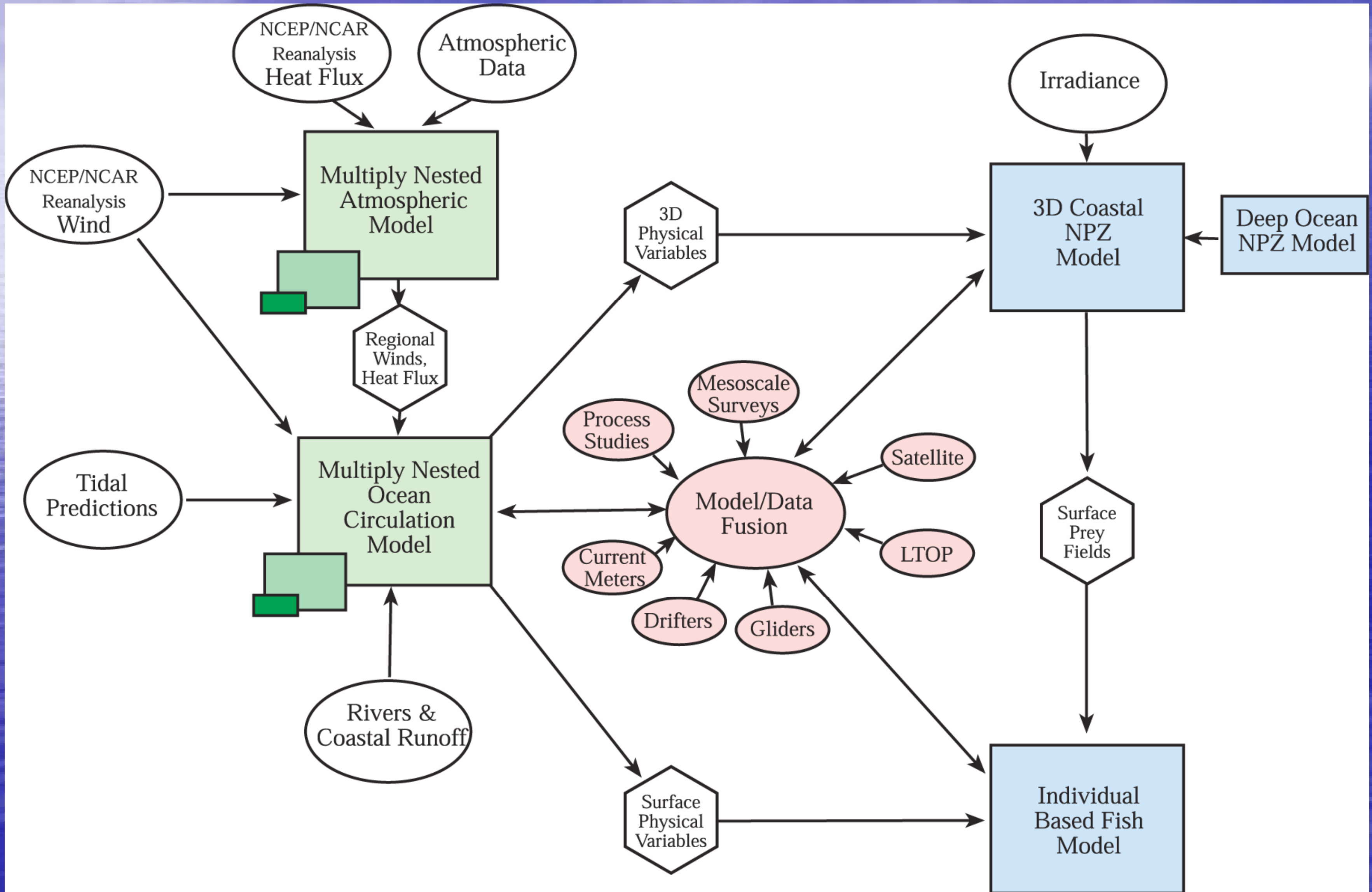
NESTED CIRCULATION MODEL DOMAINS



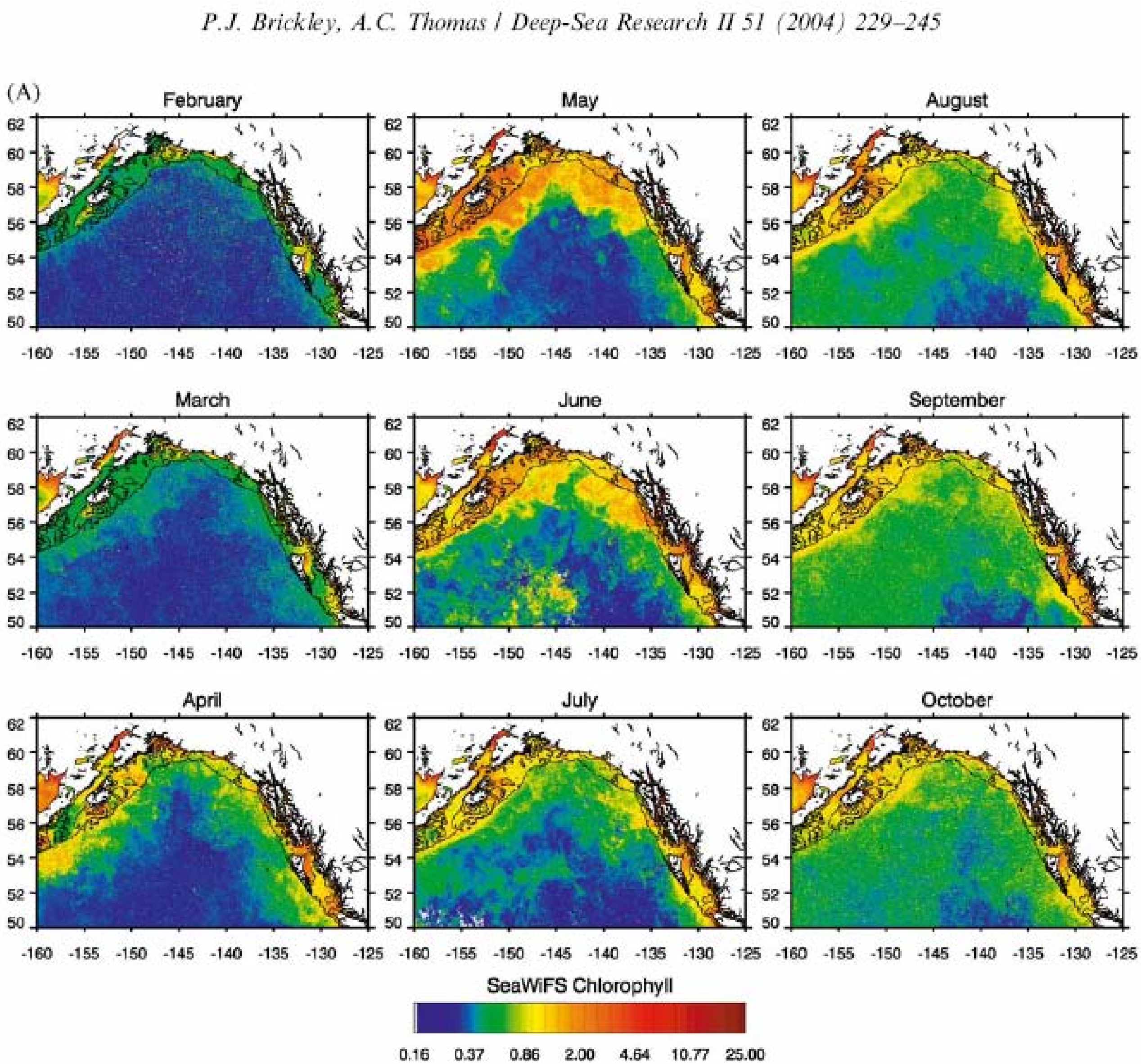
NPac (40 km) NEP (10 km) CCS&CGOA (3 km) PWS (1 km)

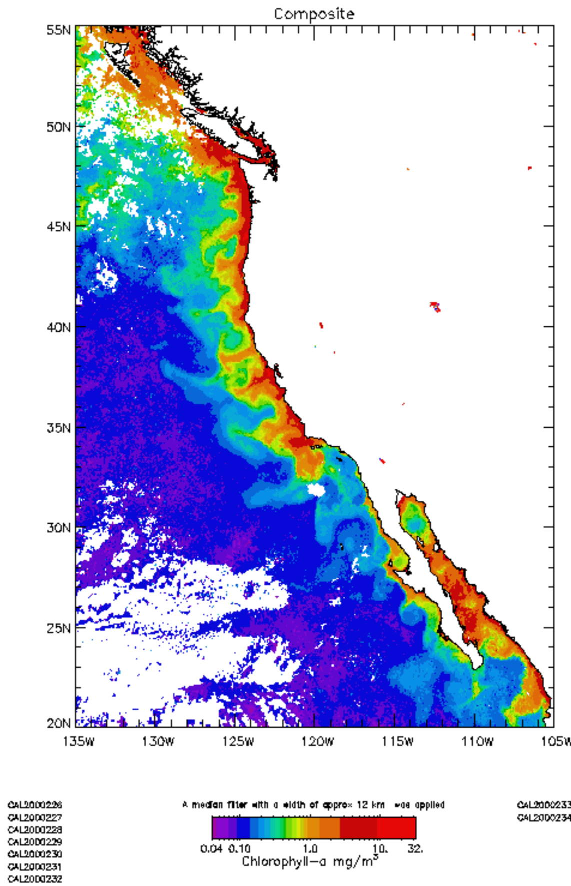
Nested Biophysical Models for GLOBEC:

NCEP/MM5 -> ROMS/NPZ -> IBM



Observed chl (from A. Thomas et al.)

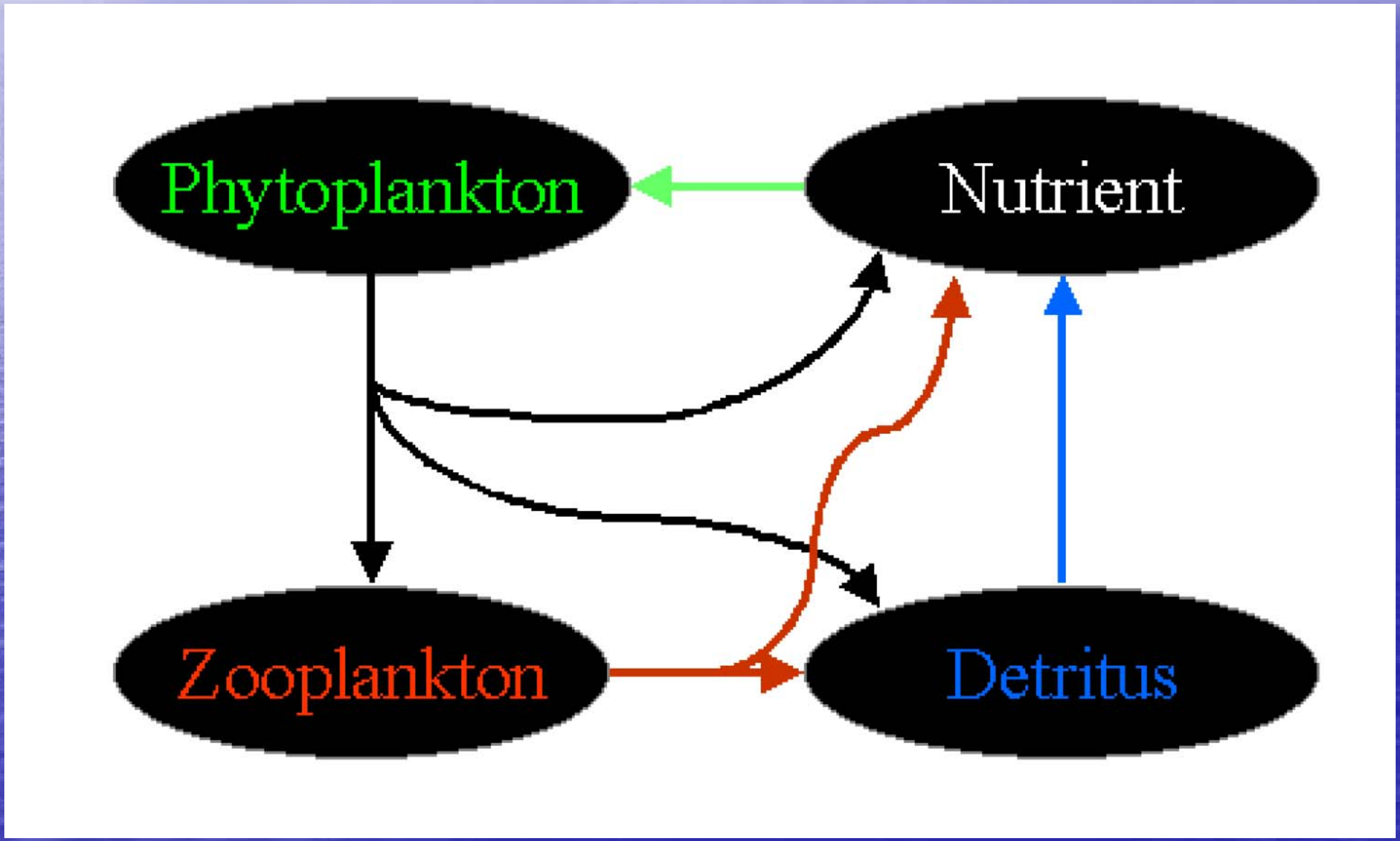




How best to model the NEP?

- Why High Nutrient Low Chl (HNLC) in the GOA?
  - It's the microzooplankton
  - It's the iron
  - It's both!
- What model complexity is required?
  - How many trophic levels?
  - How many size classes?
  - How many nutrients?
- Start simple, get more complex

NPZD model structure – simple!



NPZD model specifics

- Equations similar to Powell et al. (based on Franks et al.)

Governing equations

Nutrient	$\frac{\partial N}{\partial t} = r_d D + e_c G Z + \zeta_{mn} Z - U P$
Phytoplankton	$\frac{\partial P}{\partial t} = U P - G Z - p_m P$
Zooplankton	$\frac{\partial Z}{\partial t} = (1 - g_a) G Z - (\zeta_{md} + \zeta_{mn}) Z$
Detritus	$\frac{\partial D}{\partial t} = p_m P + (g_a - e_c) G Z + \zeta_{md} Z - r_d D + w_s \frac{\partial D}{\partial z}$
Uptake	$U = \frac{v_m N}{k_N + N}$
Grazing	$G = \frac{r_m P^2}{k_P^2 + P^2}$

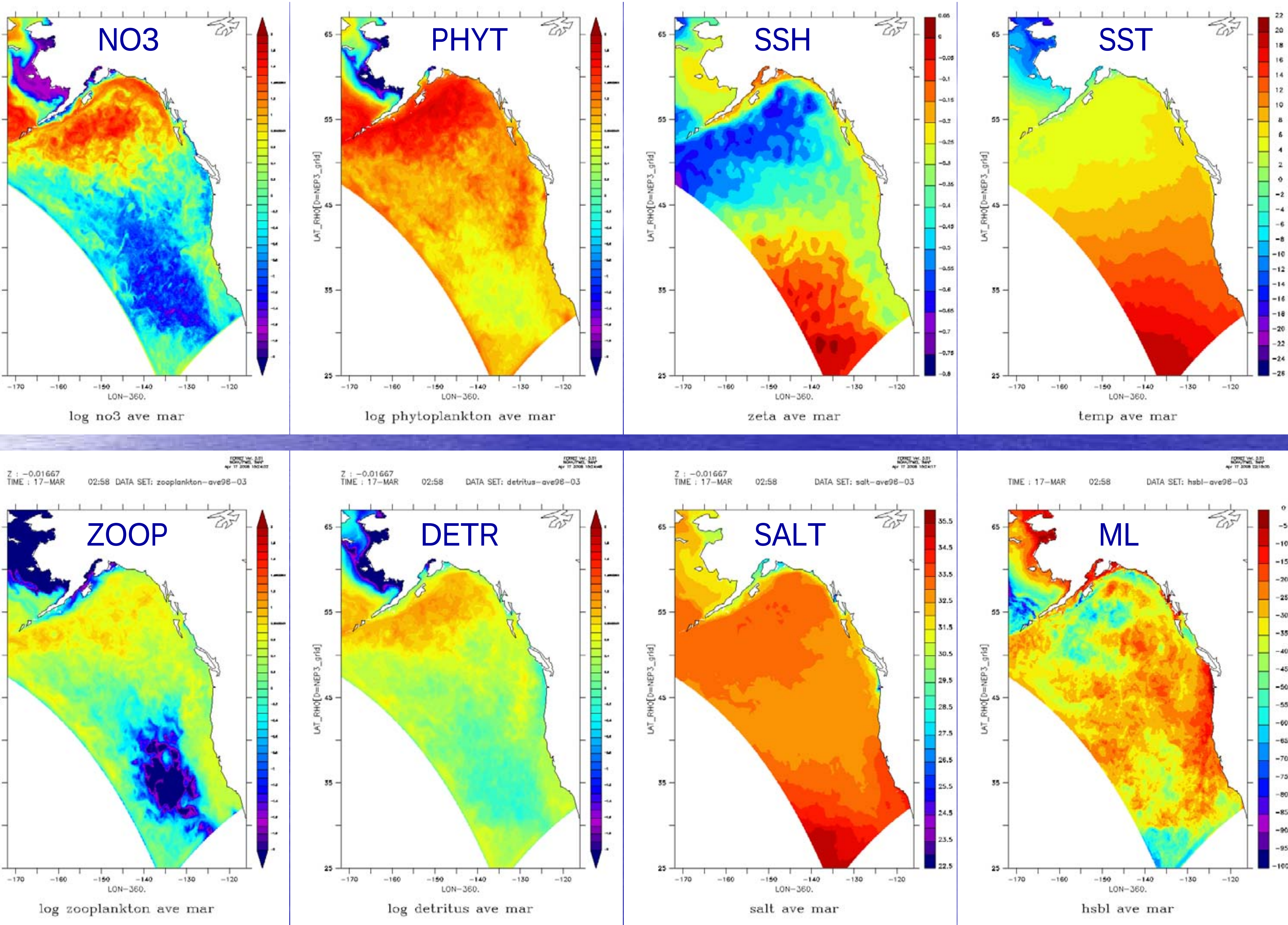
- Light limitation but no self-shading

$$\mathcal{I} = \mathcal{I}_0 e^{k_z z}$$

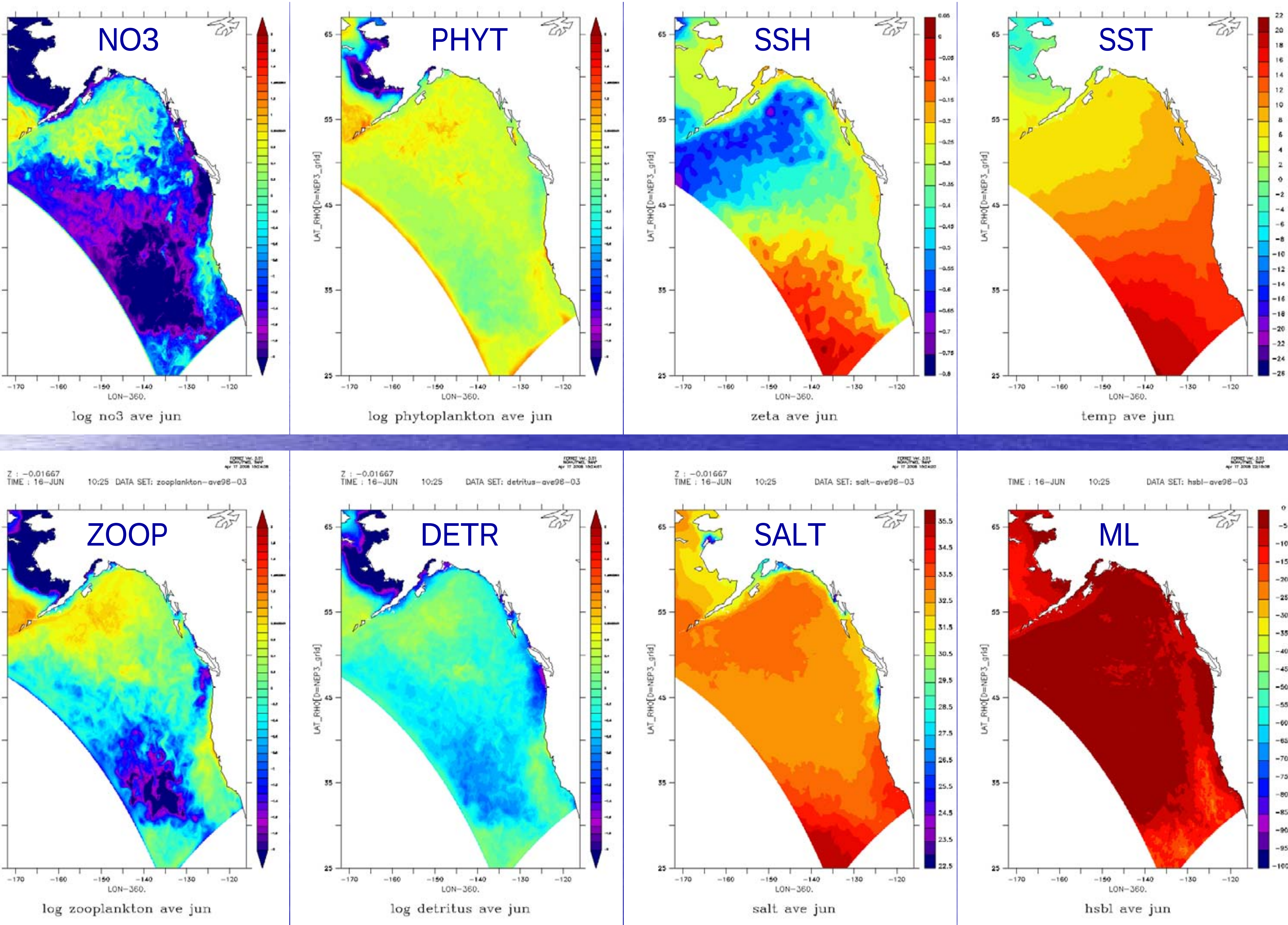
$$\mathcal{U} = \frac{V_m N}{k_N + N} \frac{\alpha \mathcal{I}}{\sqrt{V_m^2 + \alpha^2 \mathcal{I}^2}}$$

- We get / from shortwave radiation term of NCEP forcing
- “Meso” parameters (diatoms and copepods)
- When implemented off California coast, spatial statistics (autocovariance scales) match data

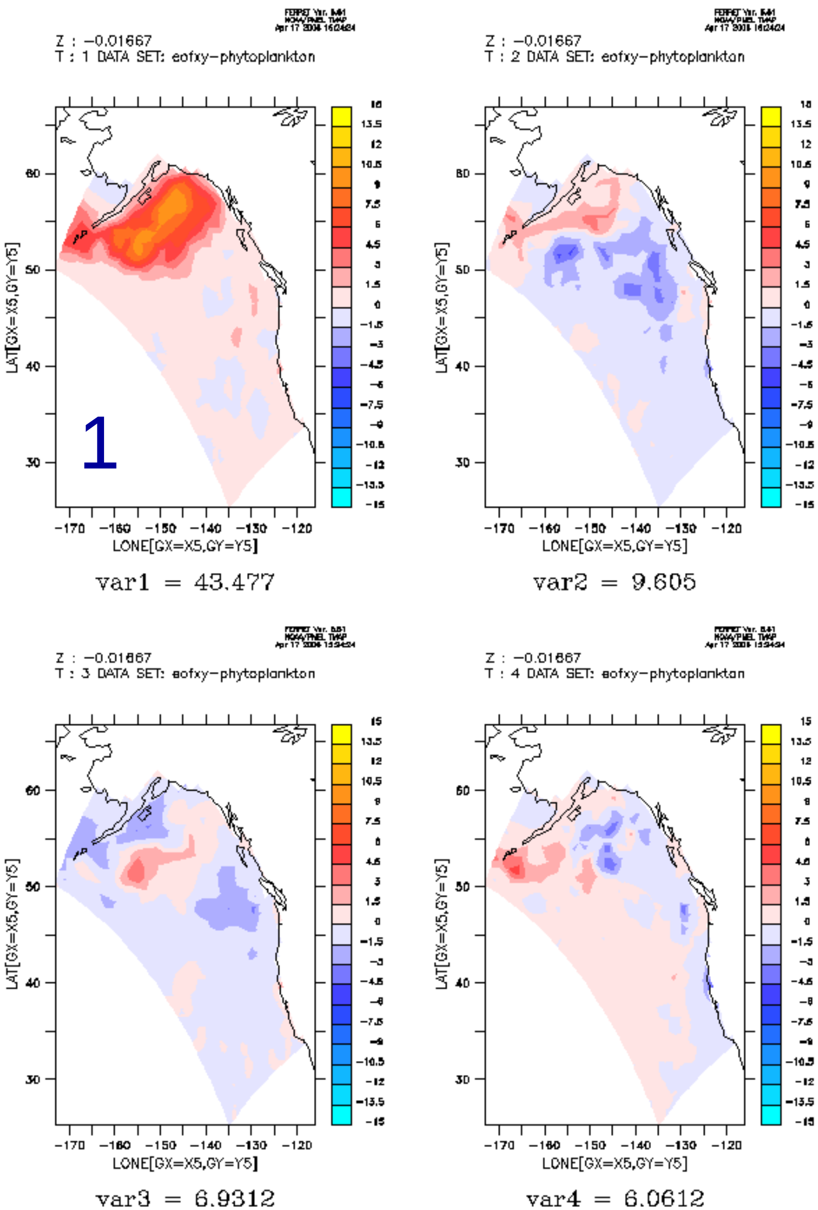
MARCH AVERAGE



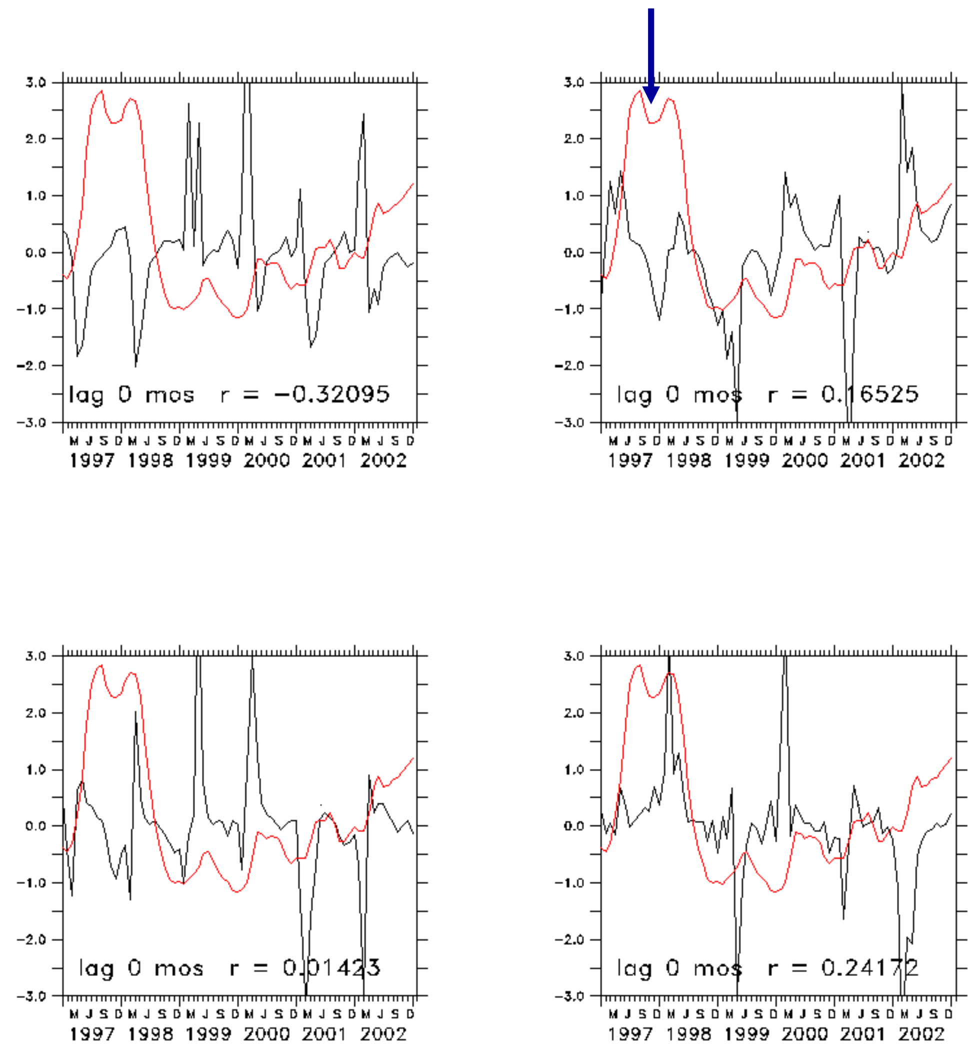
JUNE AVERAGE



Model Phytoplankton spatial modes

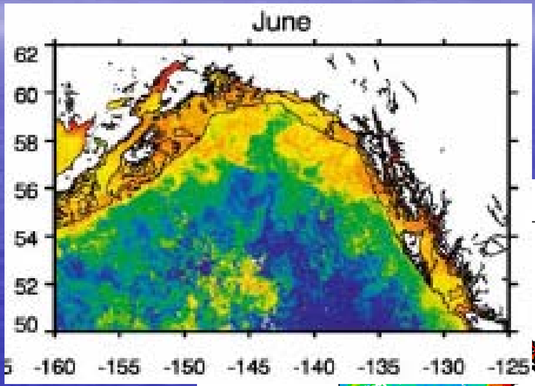


EOF amplitudes vs. *El Nino Index (MEI)*

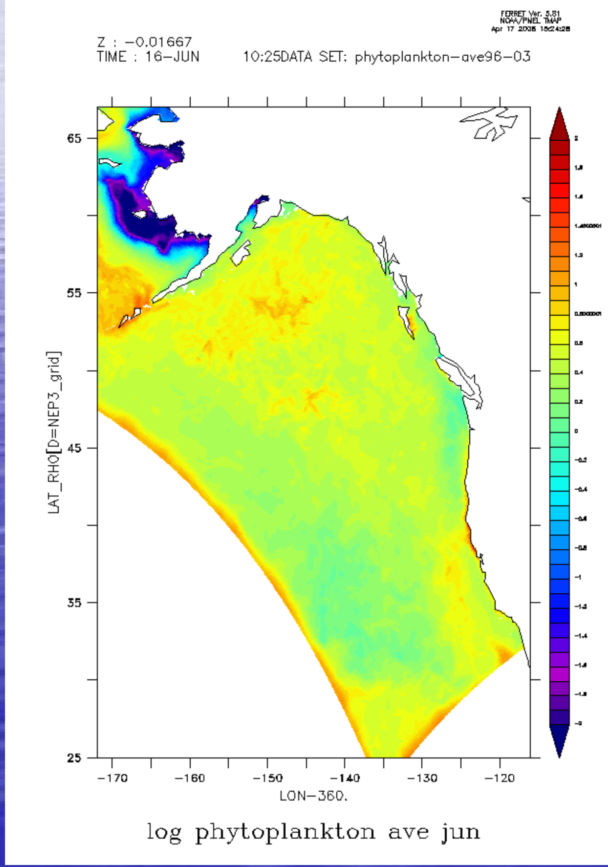


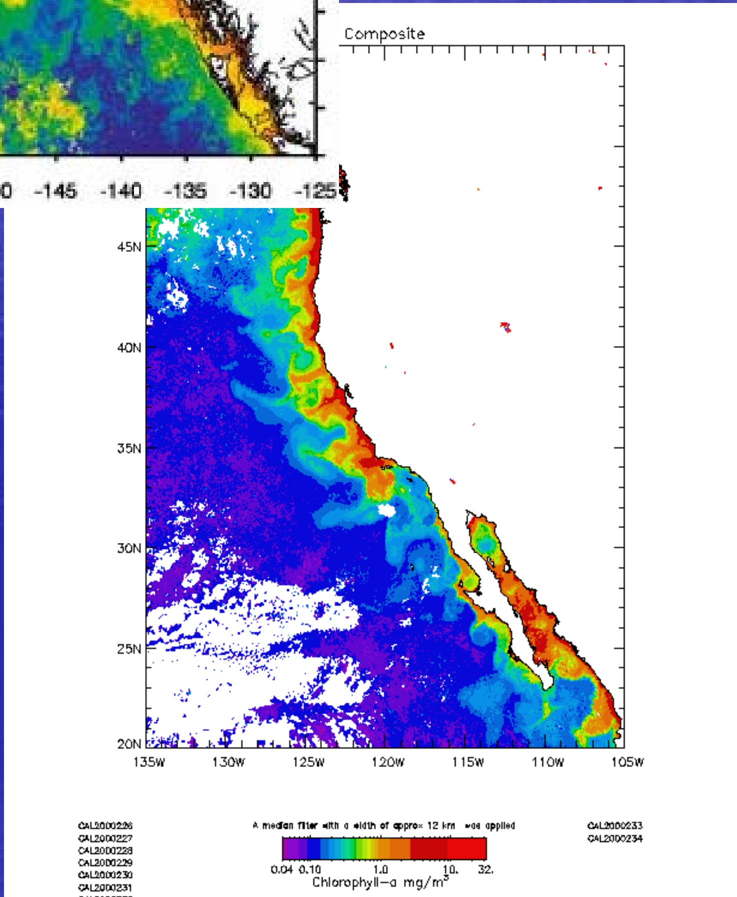
Clearly this is not good for GOA – can a more complex model do better?

Chl data

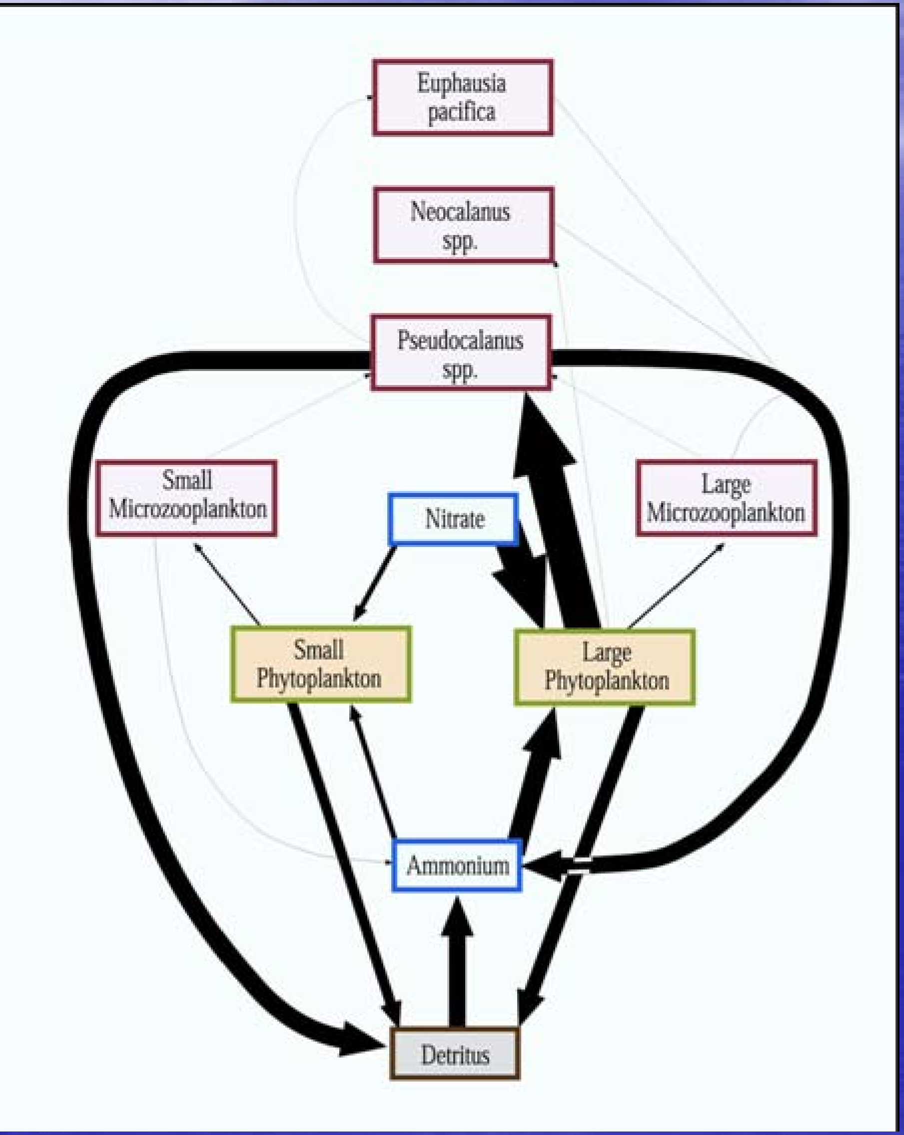


NPZD model



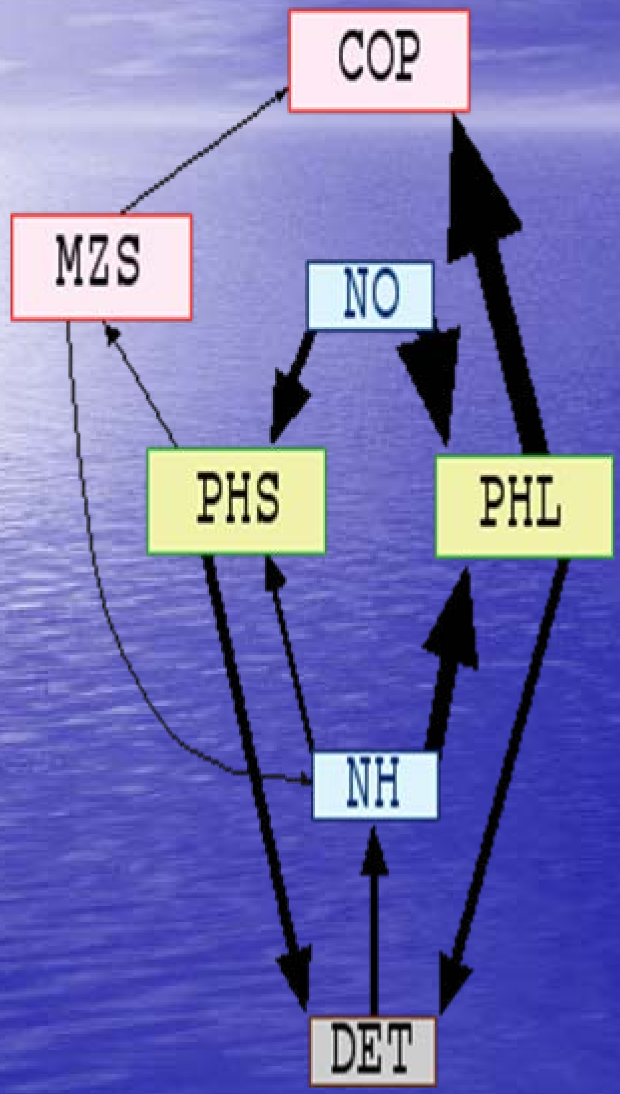


CGOA-NPZ model (arrows indicate coastal nitrogen flux)



- Nutrients (Nitrate, Ammonium, Iron)
- Phytoplankton (Small and Large) w/self-shading
- Microzooplankton (Small and Large)
- Copepods (Small, Large Oceanic)
- Euphausiids
- Detritus

CGOA-NPZ model (arrows indicate coastal nitrogen flux)



- Nutrients (Nitrate, Ammonium, Iron)
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- Euphausiids
- Detritus

Method for iron limitation

- Felim: a multiplicative factor affecting growth of both small and large Phytoplankton. Affects large phytoplankton more strongly
- Michaelis-Menton function (as in Fennel et al. 2003)
- Iron depletion and nudging back to climatology (higher on shelf and at depth)
- Does not follow iron through whole ecosystem

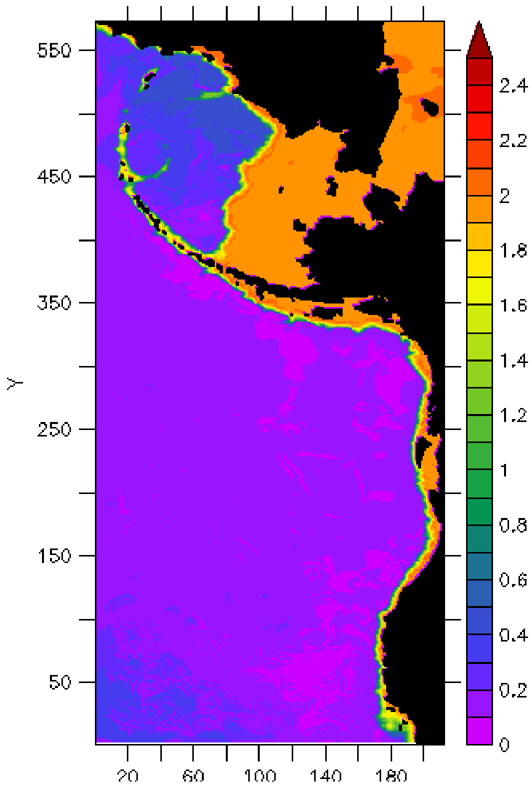
3D Sensitivity test

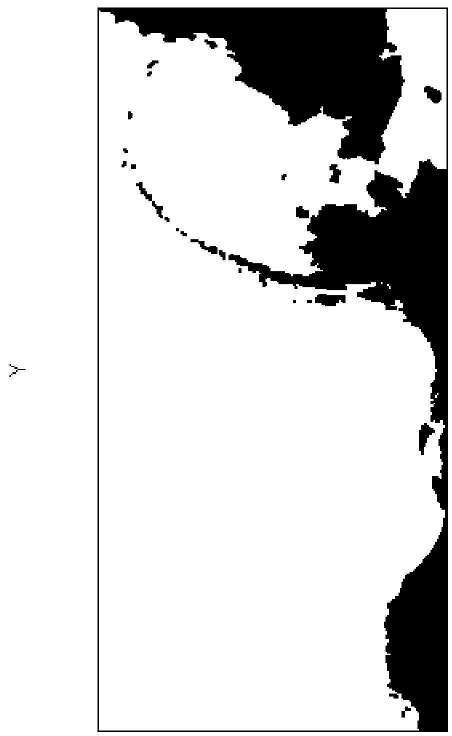
- CGOA-NPZ was designed for CGOA only
- Here, use it as an example of a more complex model for the entire NEP
  - can it do better than simple NPZD
  - what difference does iron make?

March surface Fe – higher on shelf

Model w/ Felim

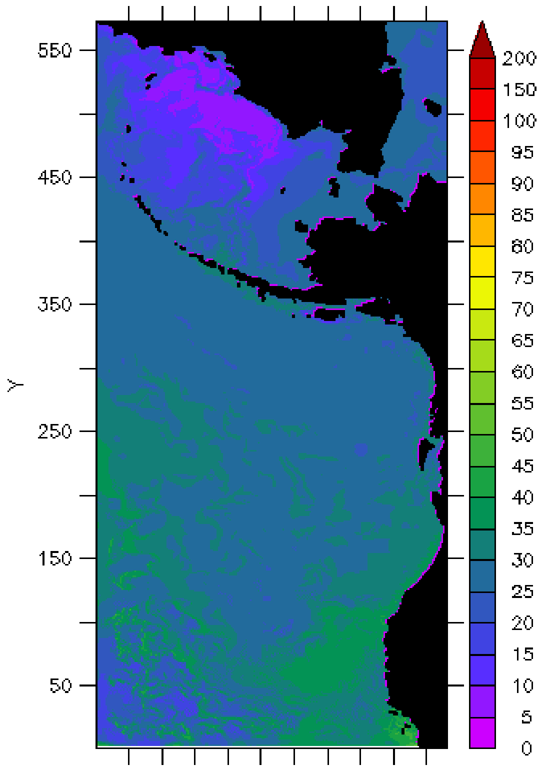
Model w/o Felim



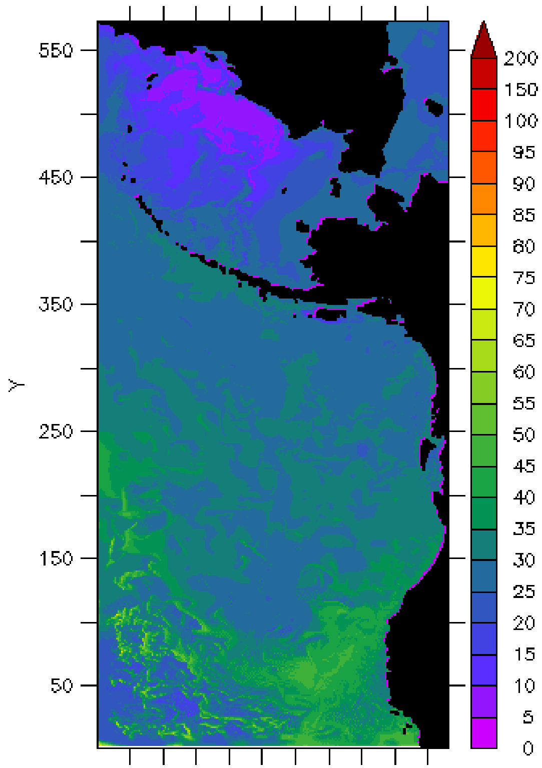


March surface total phytoplankton (PhS+PhL)

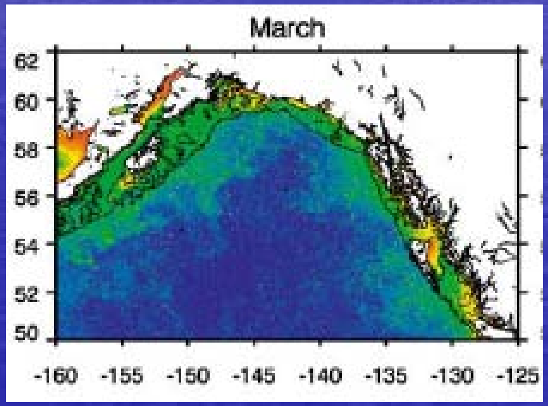
Model w/ Felim



Model w/o Felim



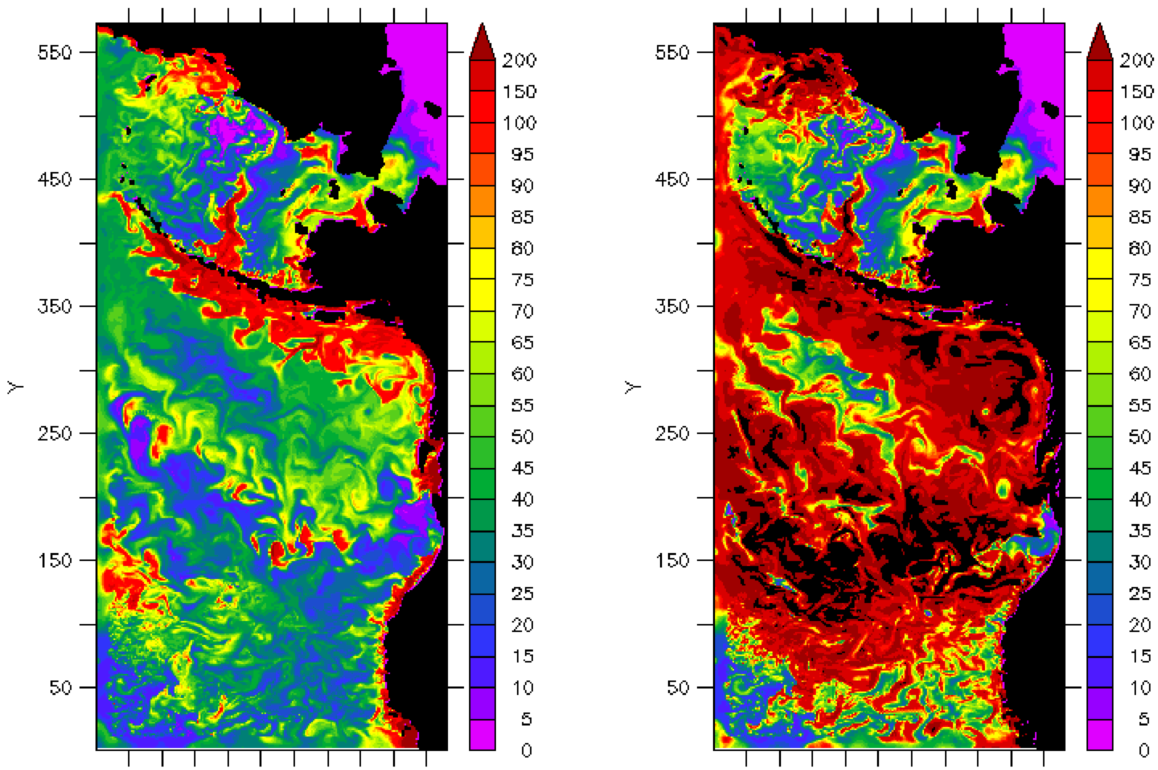
Chl data



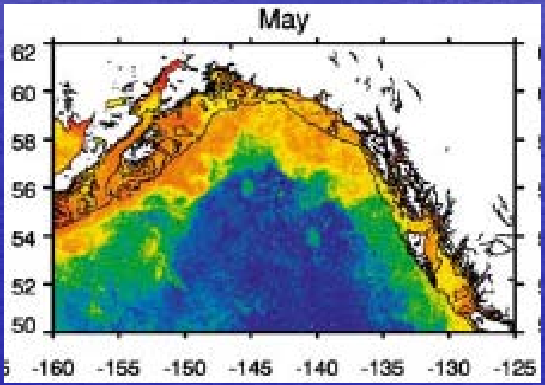
May surface total phytoplankton

Model w/ Felim

Model w/o Felim

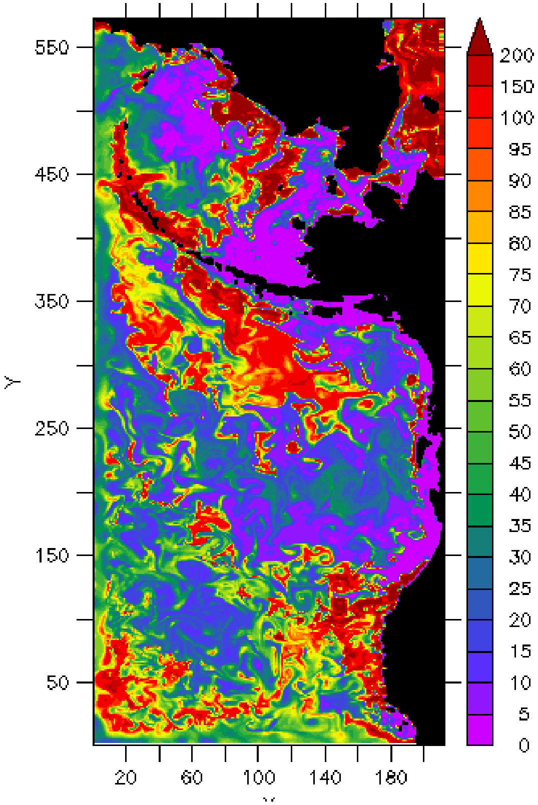


Chl data

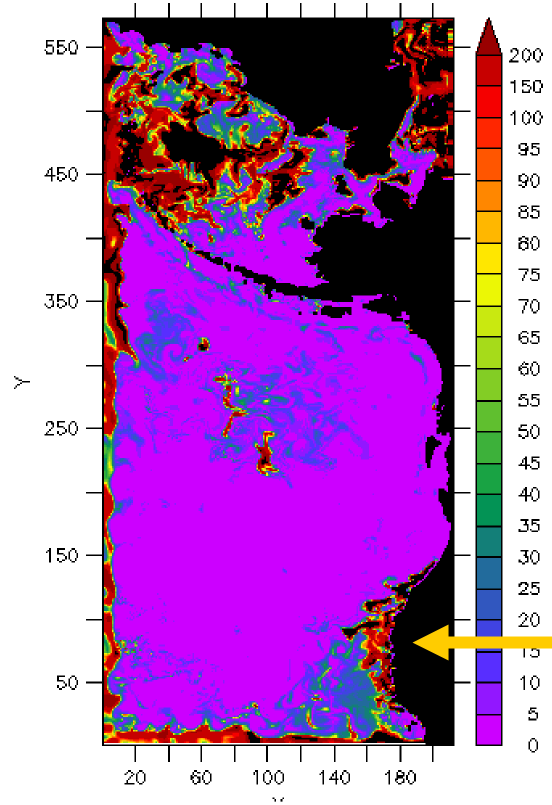


Jul surface total phytoplankton

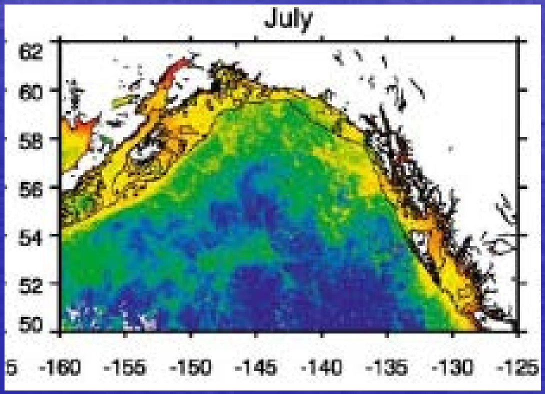
Model w/ Felim



Model w/o Felim



Chl data

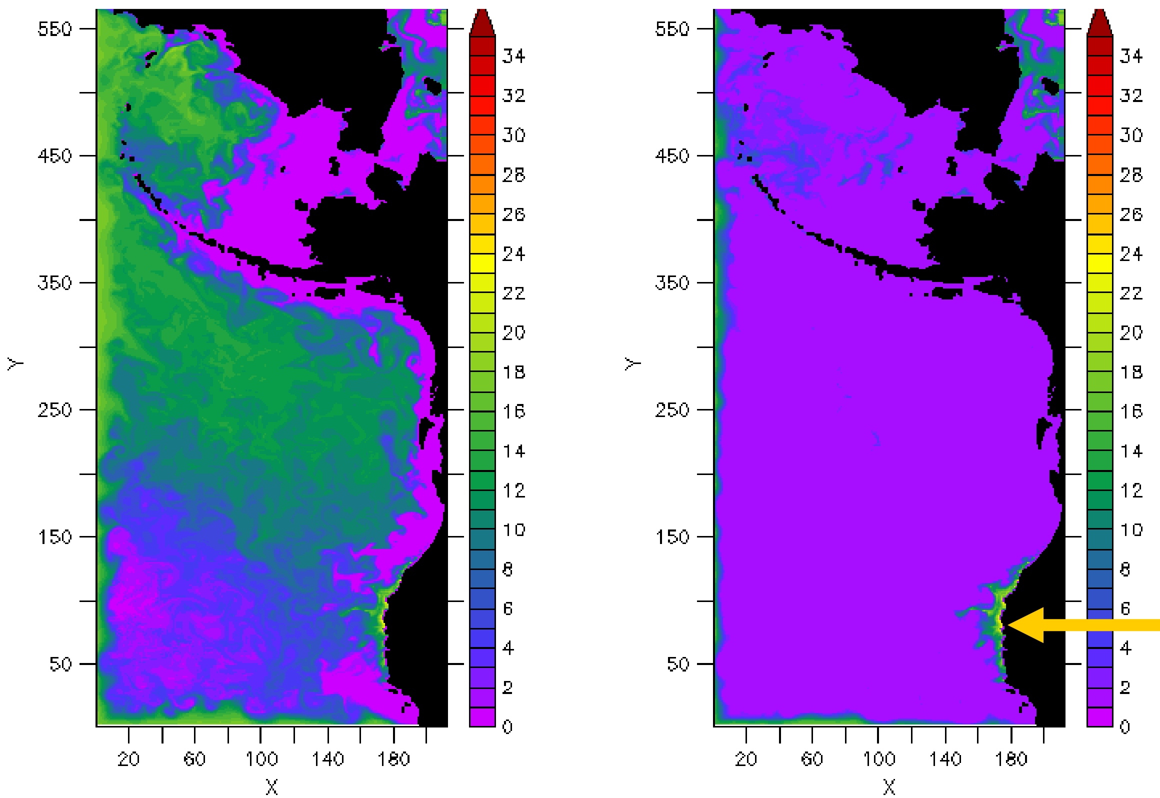


Coastal upwelling

August no3 -> HNLC in the GOA

Model w / Felim

Model w / o Felim



Coastal upwelling

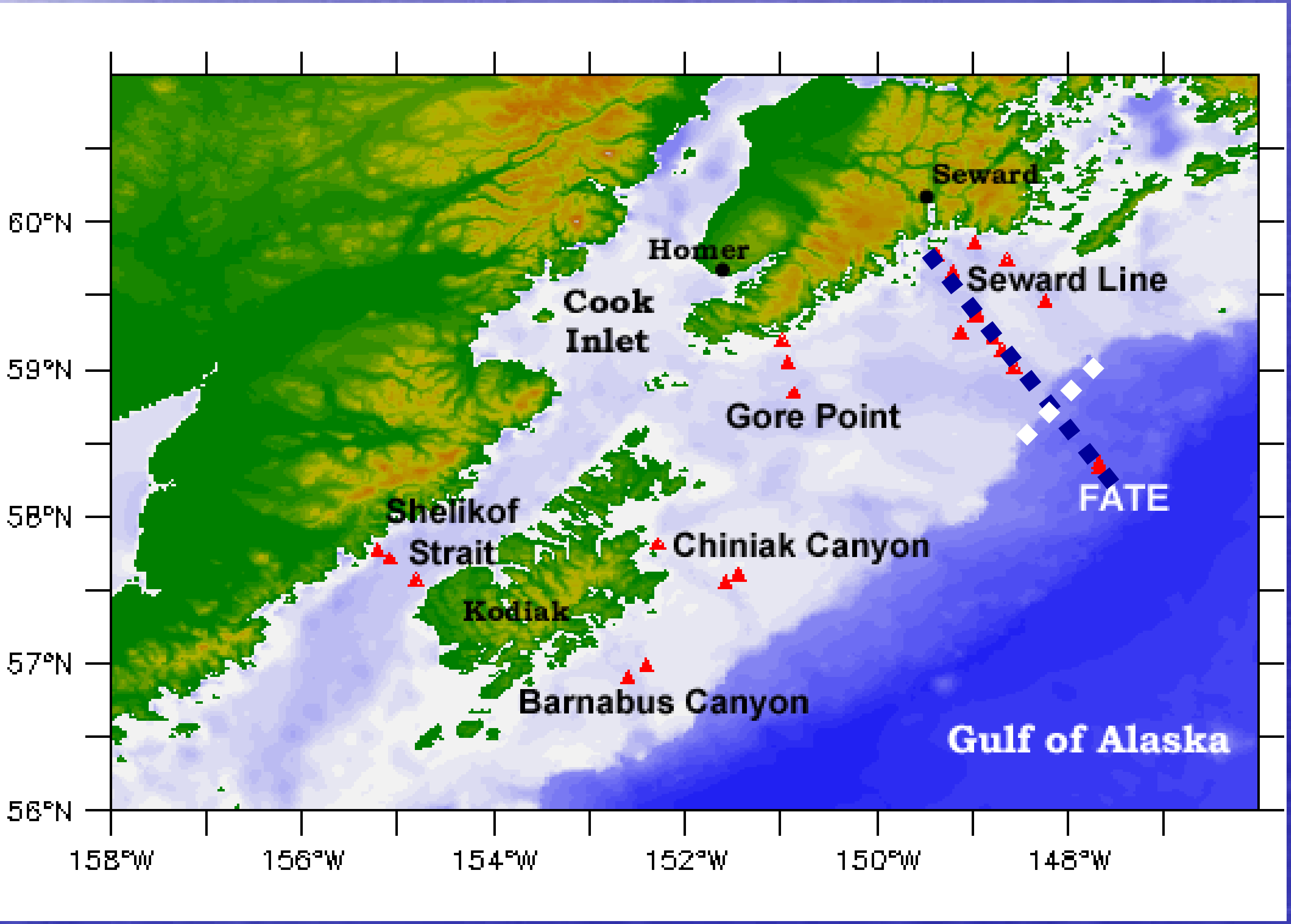
3D runs summary:

- NPZD w/o iron limitation -> fail
- More complex (size classes) but w/o iron limitation -> still fail (works for CC but not for CGOA)
- More complex w/ iron limitation -> much better!

- NPZD with iron limitation, other permutations not yet tried (some in progress). Full exploration expensive!
- Use 1D model for more extensive sensitivity tests
  - retain/remove small (PhL) phyt (NPZD vs NPPZD)
  - Fe limitation vs no Fe limitation

N x 1D sensitivity tests along cross-shelf line

- latest version of CGOA-NPZ model (iron not nudged)
- Physical output from CGOA circulation model



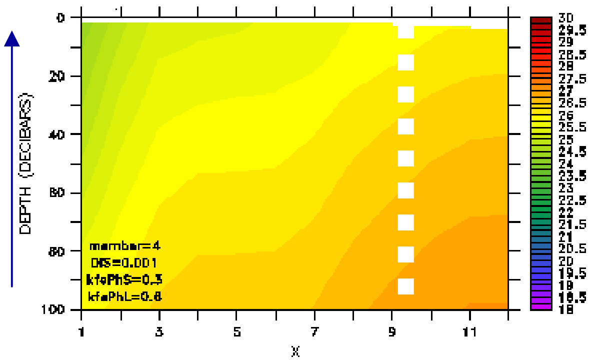
Cross-shelf rho (x-z) Mar-Jun ave:

Model w/ ONLY PhL | **Model w/ PhL + PhS**

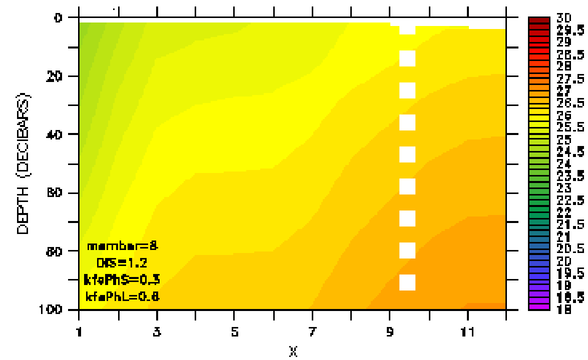
dist offshore

z

Model w/ Felim

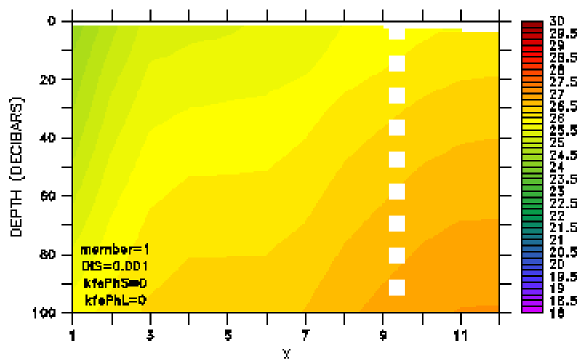


NNPZDFe

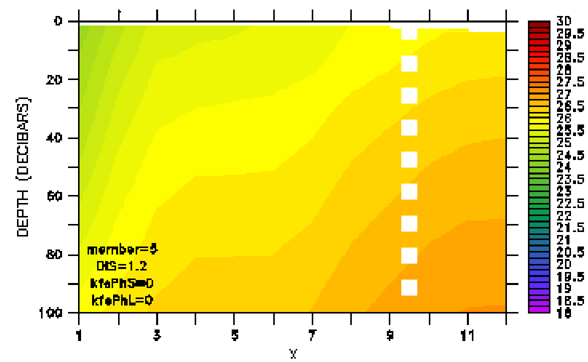


NNPPZZDFe

Model w/o Felim



NNPZD



NNPPZZD

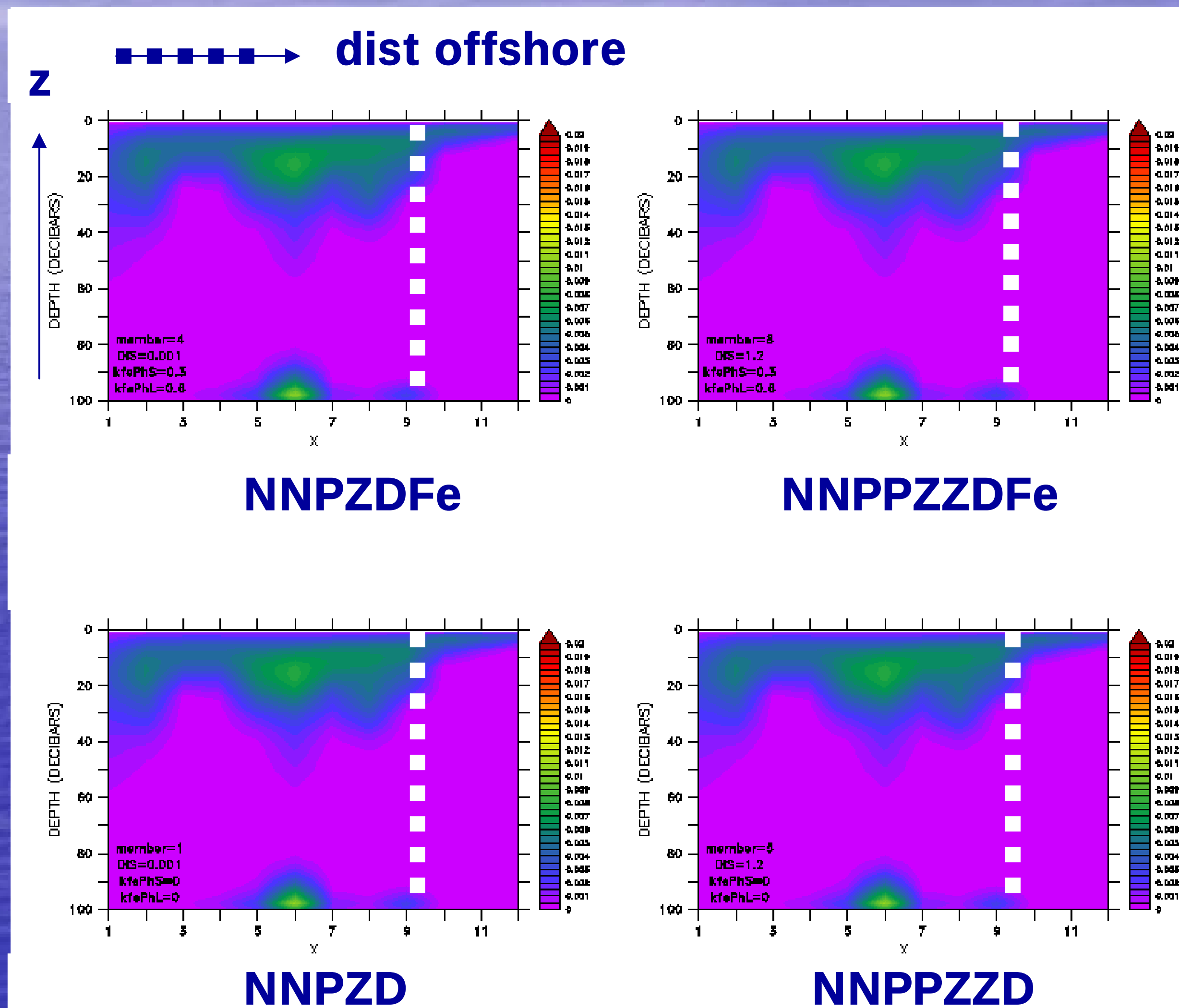
Shelf break

Vertical mixing pattern (x-z) Mar-Jun ave:

Model w/ ONLY PhL | Model w/ PhL + PhS

Model w/ Felim

Model w/o Felim



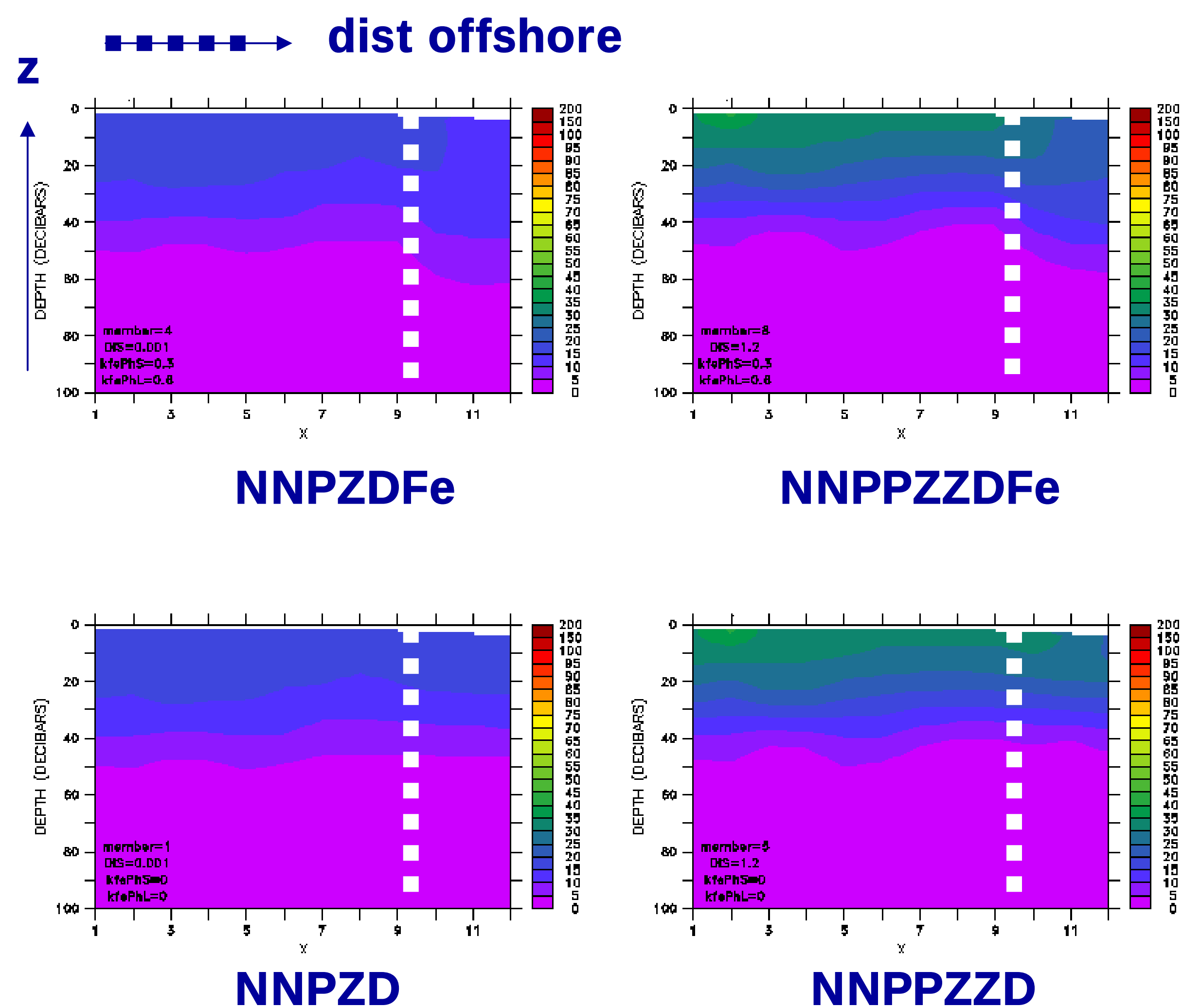
Shelf break

Cross-shelf total phyt (x-z) Mar-Jun ave: w/ Felim *or* PhS -> lower total phyt offshore

Model w/ ONLY PhL | **Model w/ PhL + PhS**

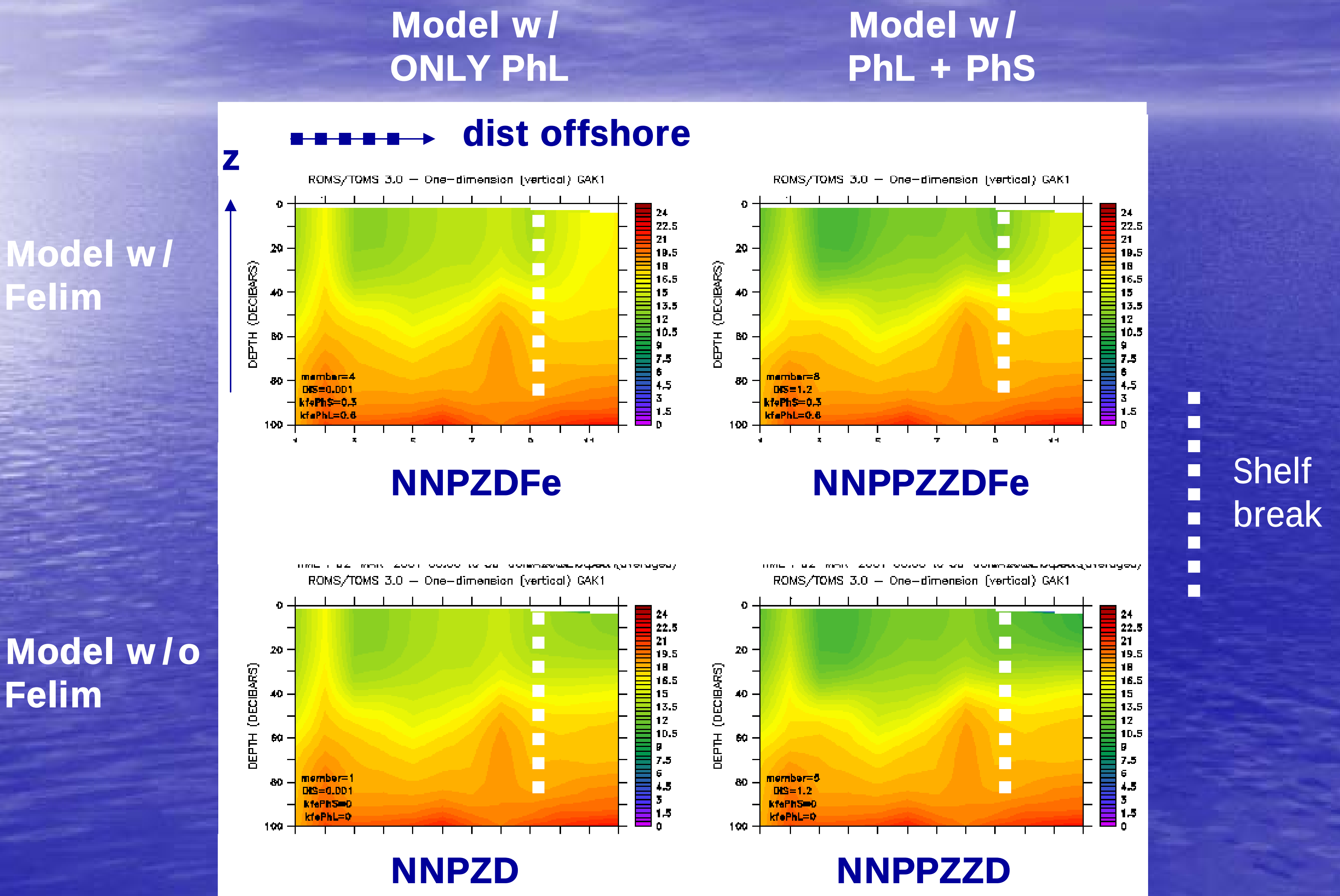
Model w/ Felim

Model w/o Felim



Shelf break

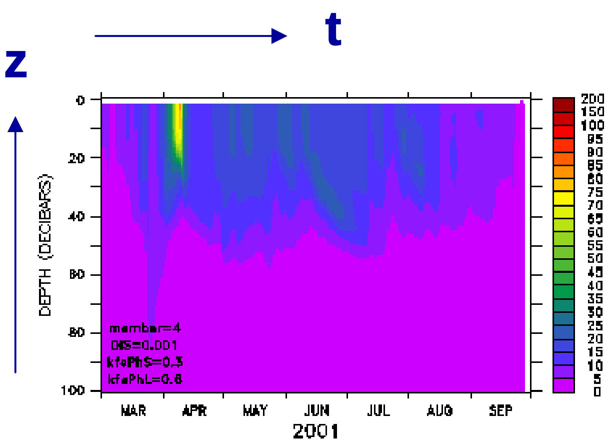
Cross-shelf no3 (x-z time ave):
w/ Felim -> higher no3 offshore



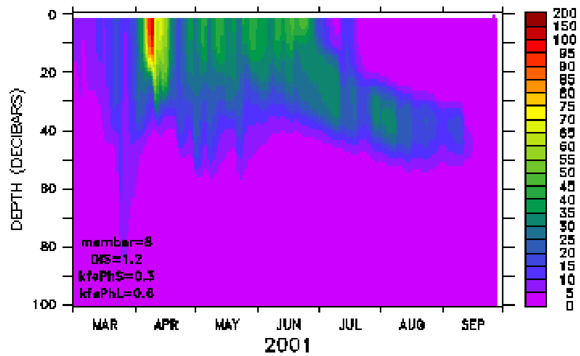
Neashore total phytoplankton (z-t): w/ PhS -> different seasonal progression

Model w/ ONLY PhL | **Model w/ PhL + PhS**

Model w/ Felim

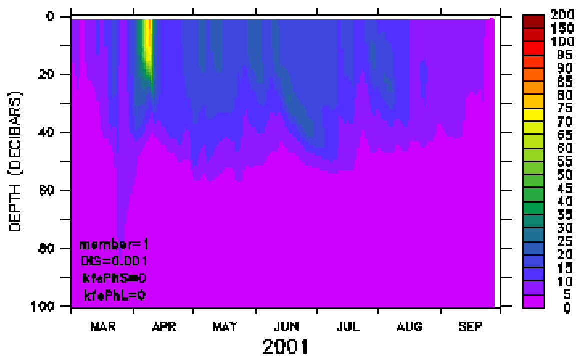


NNPZDFe

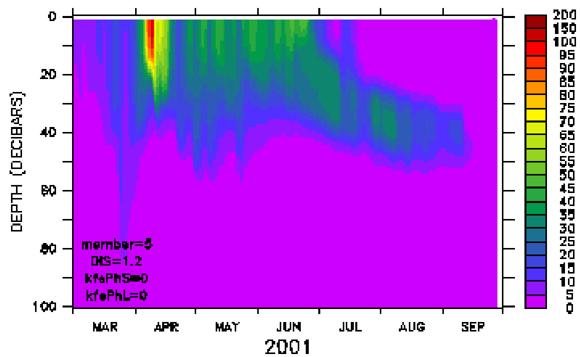


NNPPZZDFe

Model w/o Felim



NNPZD



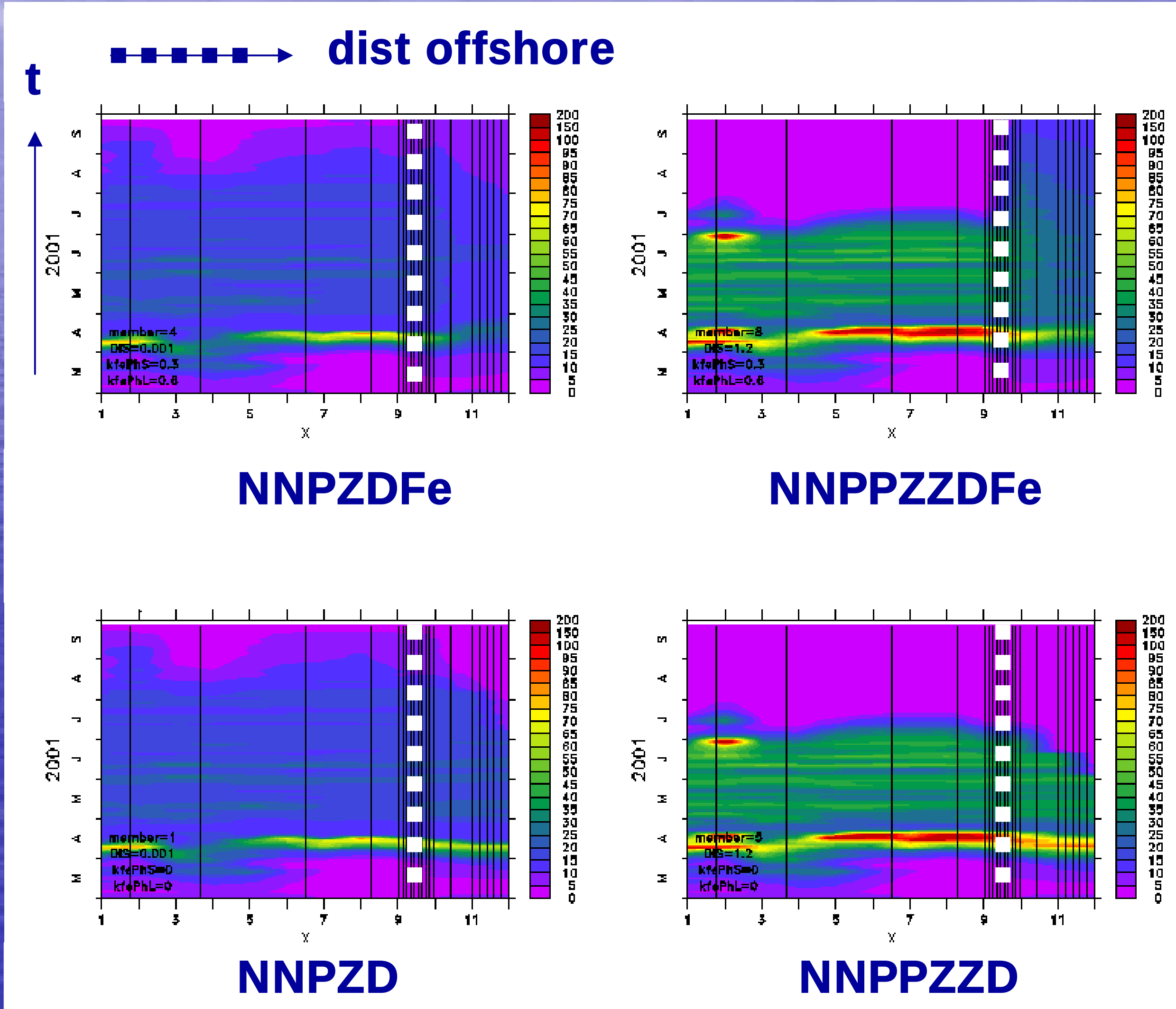
NNPPZZD

Near-surface total phytoplankton (Hovmuller plot): w/ Felim *or* PhS -> lower total phyt offshore

Model w/ ONLY PhL | **Model w/ PhL + PhS**

Model w/ Felim

Model w/o Felim



Shelf break

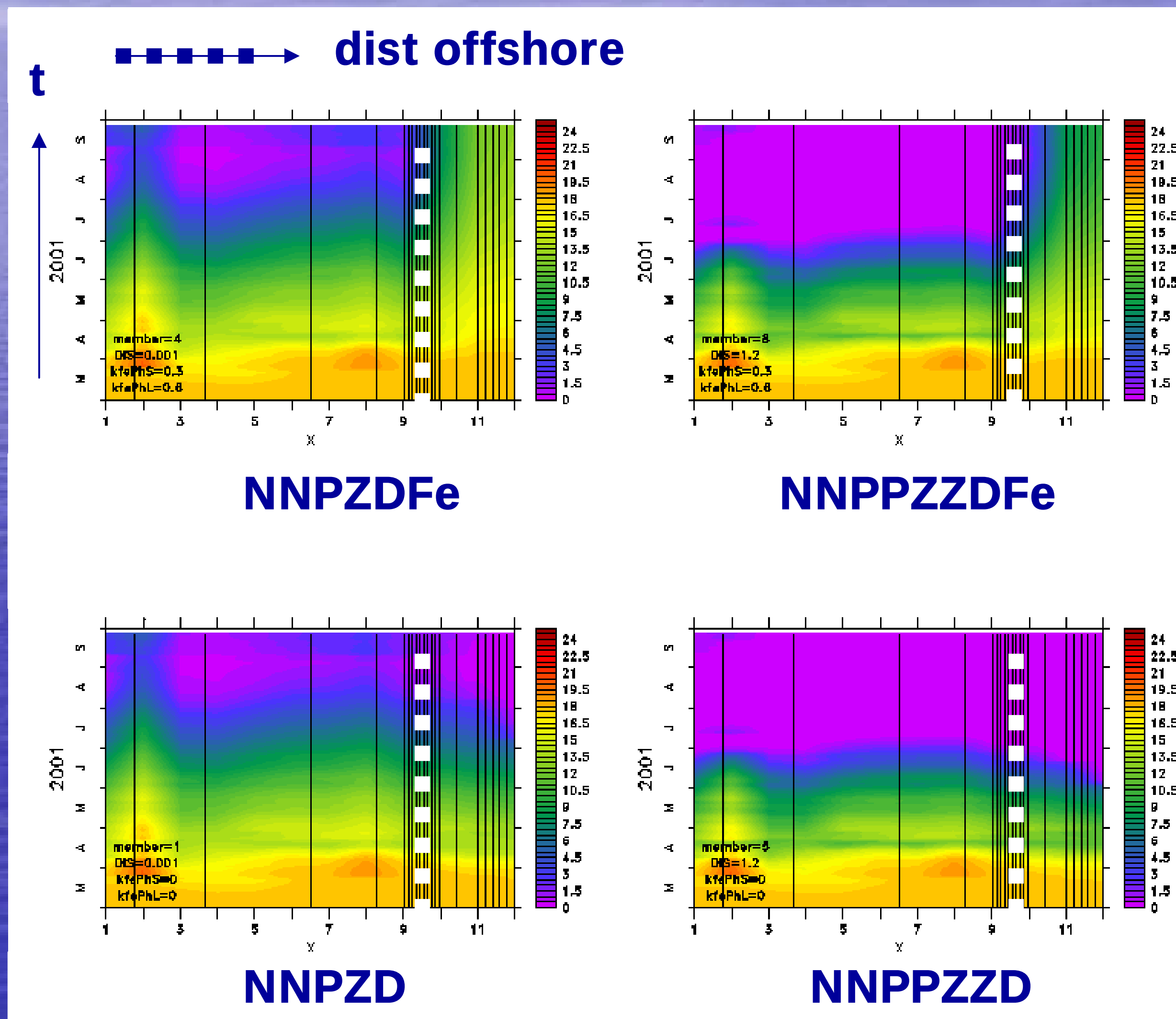
Near-surface no3 (Hovmuller plot): w/ Felim -> higher no3 offshore

Model w/ ONLY PhL

Model w/ PhL + PhS

Model w/ Felim

Model w/o Felim



Shelf break

Conclusion from 1D and 3D tests

- **Both** factors (Fe and size classes) make a difference to phyt and no3
- Two size classes are better than one -> get the LC part of HNLC
- Felim is needed to get the HN part of HNLC
- Multiclass model with iron is probably required to get broad spatial patterns of NEP (*despite* being formally undetermined by data) but still difficult to capture all observed spatial gradients

Next steps

- Further sensitivity tests on 3D CGOA-NPZ model (Coyle et al.) - esp. iron and nudging issues
- Add iron to NEMURO and code into ROMS
- Further 1D tuning of CGOANPZ (genetic algorithm)

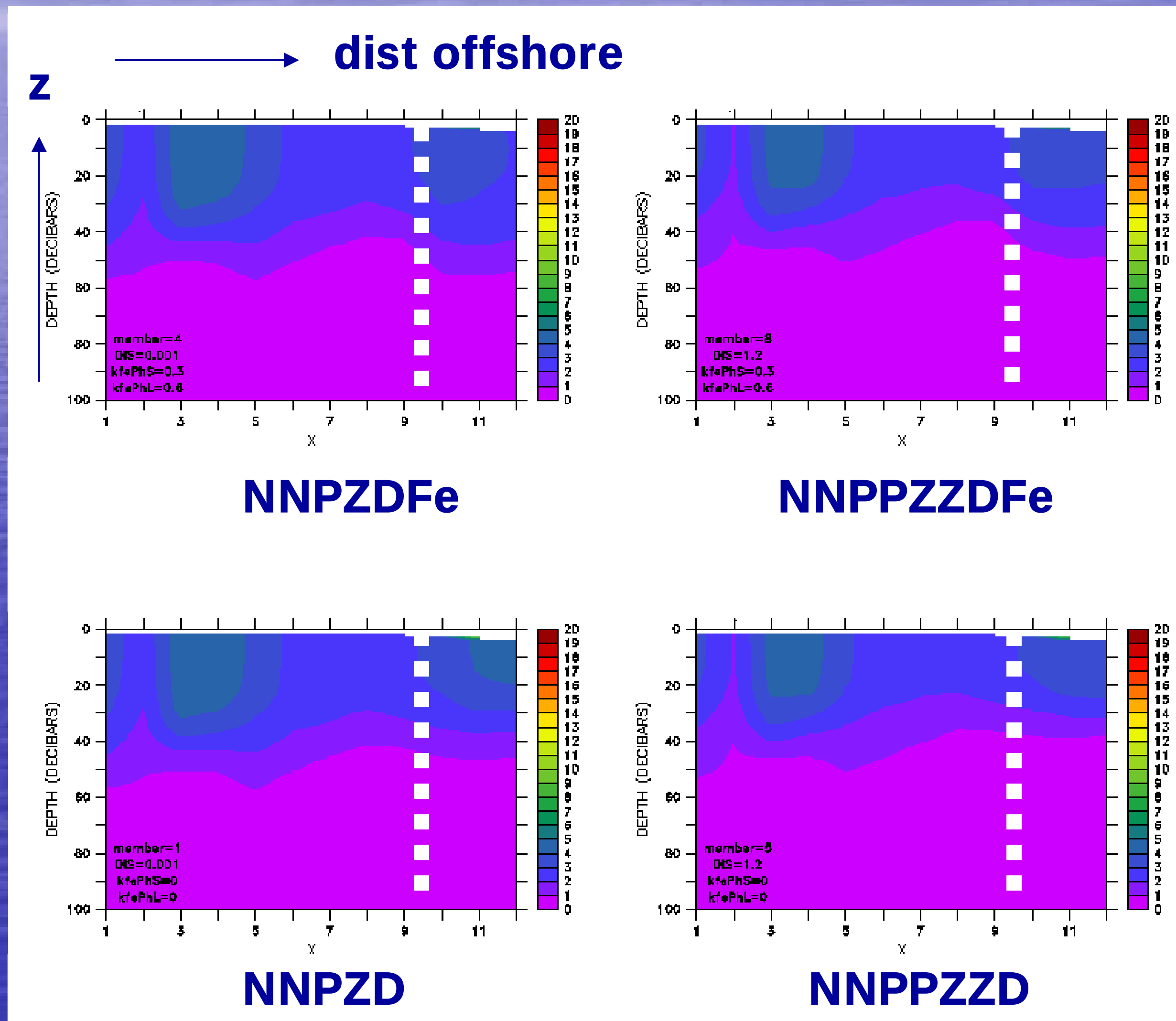
Cross-shelf copepods (x-z time ave)

Model w/ ONLY PhL

Model w/ PhL + PhS

Model w/ Felim

Model w/o Felim



Shelf break

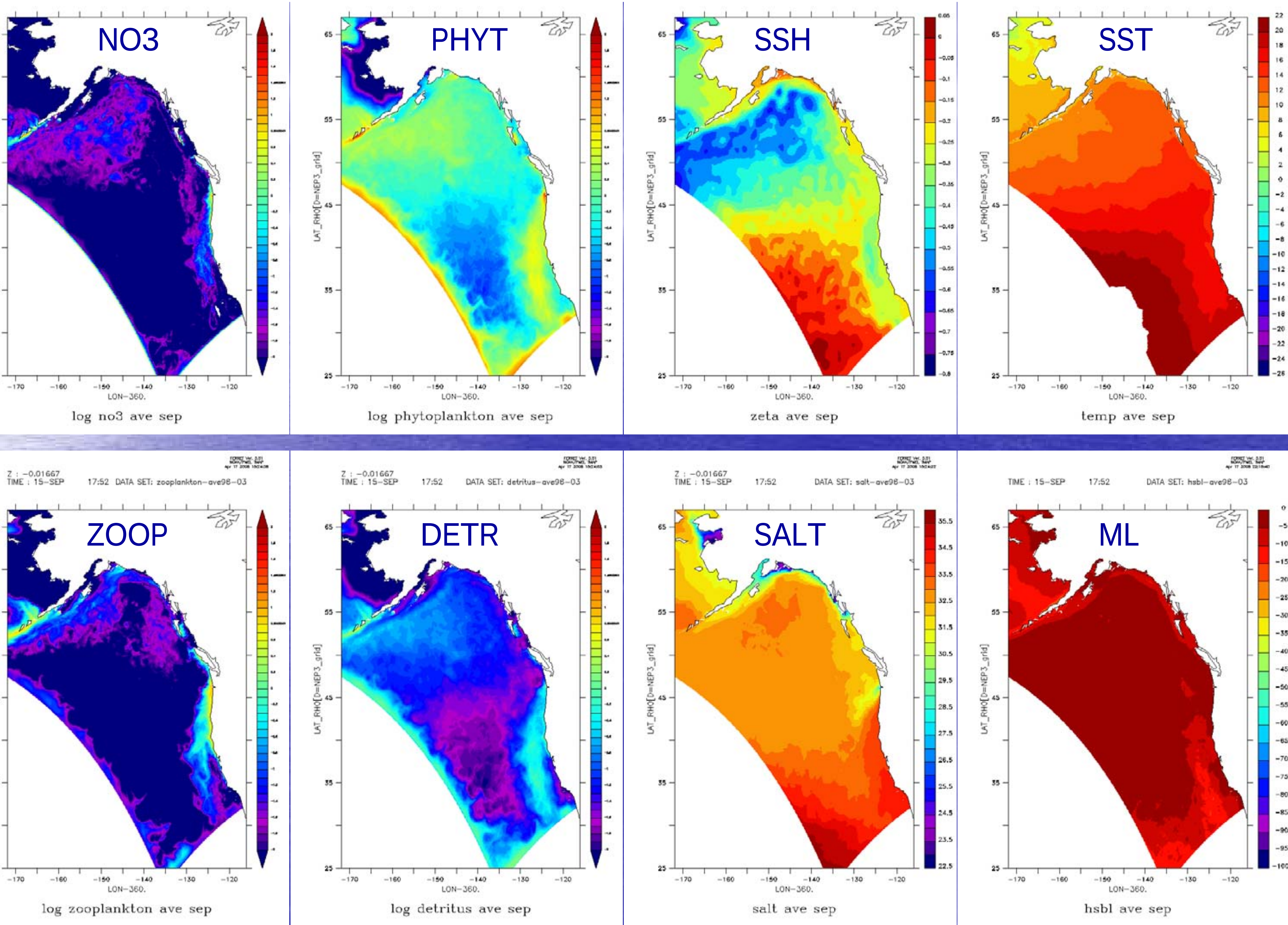
ABSTRACT

- As part of the synthesis phase of the Northeast Pacific US-GLOBEC program, we have begun simulating lower trophic level (NPZ) dynamics of the Northeast Pacific between Baja California and the Bering Strait, out to ~1500 km offshore. As a first step, a “generic” NPZ model, presumed relevant to both the California Current and the Gulf of Alaska under a single set of internal parameters for mesoplankton, was implemented on a 10-km resolution grid (the Northeast Pacific grid; NEP) and simulated over a span of years which includes multiple El Ninos (and the 1997-1998 event in particular). The NEP model is embedded in a larger-scale circulation model of the North Pacific. While some features of the area (e.g. upwelling-driven production off California) were reproduced by the simple NPZ model, others features (e.g. higher production on the Gulf of Alaska shelf relative to the basin, as evidenced by SEAWIFS data) were not well captured. These discrepancies underscore the need for multiple size classes of phytoplankton and zooplankton, and/or the inclusion of iron as a limiting micronutrient. To address these needs, we compare results from more complex NPZ models on the NEP grid, including a multiple size class model initially developed for the Coastal Gulf of Alaska (CGOA-NPZ), both with and without iron limitation. Through EOFs and other spatial analysis, we explore what is gained (and lost) by the use of these more complex models of the Northeast Pacific, relative to the simpler NPZ model.

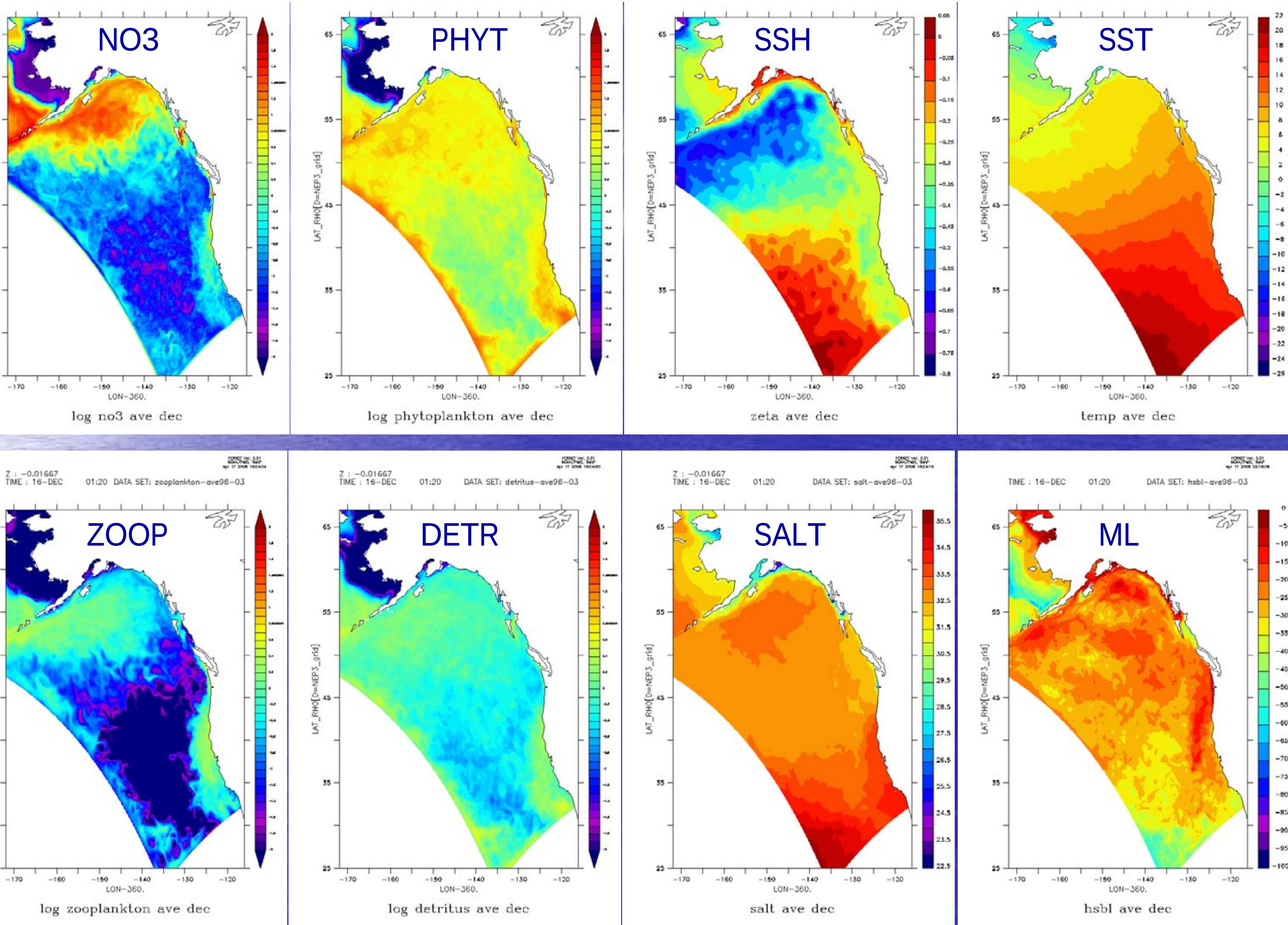
Modes of variability

- vertical structure as a function of parameter variations
- EOFs operate in space and time, typically
- Can also use space and paramter values
- OR could use EOFs in space/time for different params
- OR could use no3 phyt cop etc as SPACE variables, different parameter choices as the time variables. Cocatenate using netcdf tool then calculate EOF. Get basic modes; see who wins
- eddies are they captured – do we get production around the edges with each of these

SEPTEMBER AVERAGE

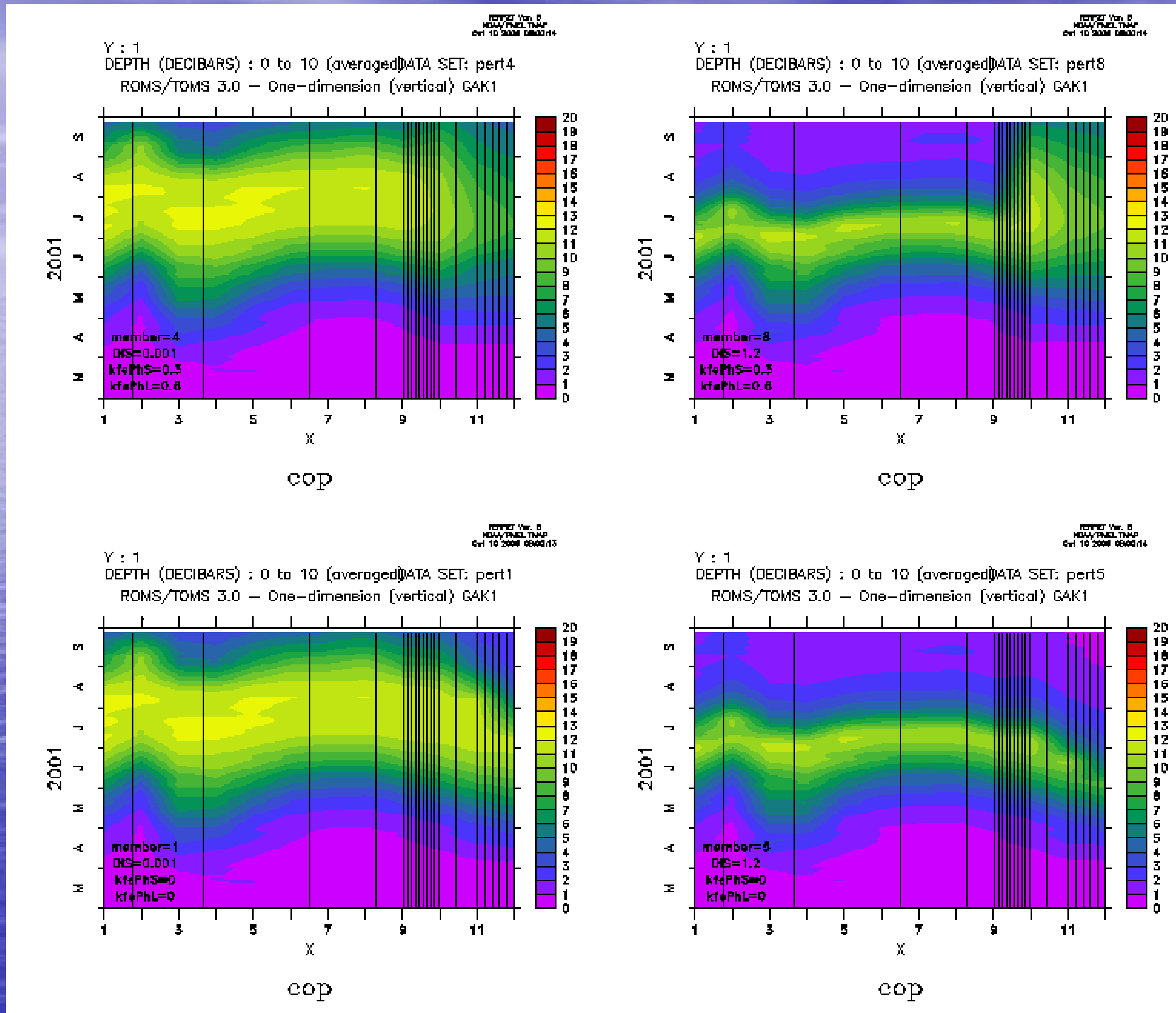


DECEMBER AVERAGE



Data

- Thomas satellite data
- General HNLC ideas
- GAK profiles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DEPTH (DECIBARS) : 0 to 10 (averaged)DATA SET: pert4
ROMS/TOMS 3.0 – One-dimension (vertical) GAK1
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kfePhL=0.6
2001
X
cop
Y : 1
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X
cop
Y : 1
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ROMS/TOMS 3.0 – One-dimension (vertical) GAK1
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X
cop
Y : 1
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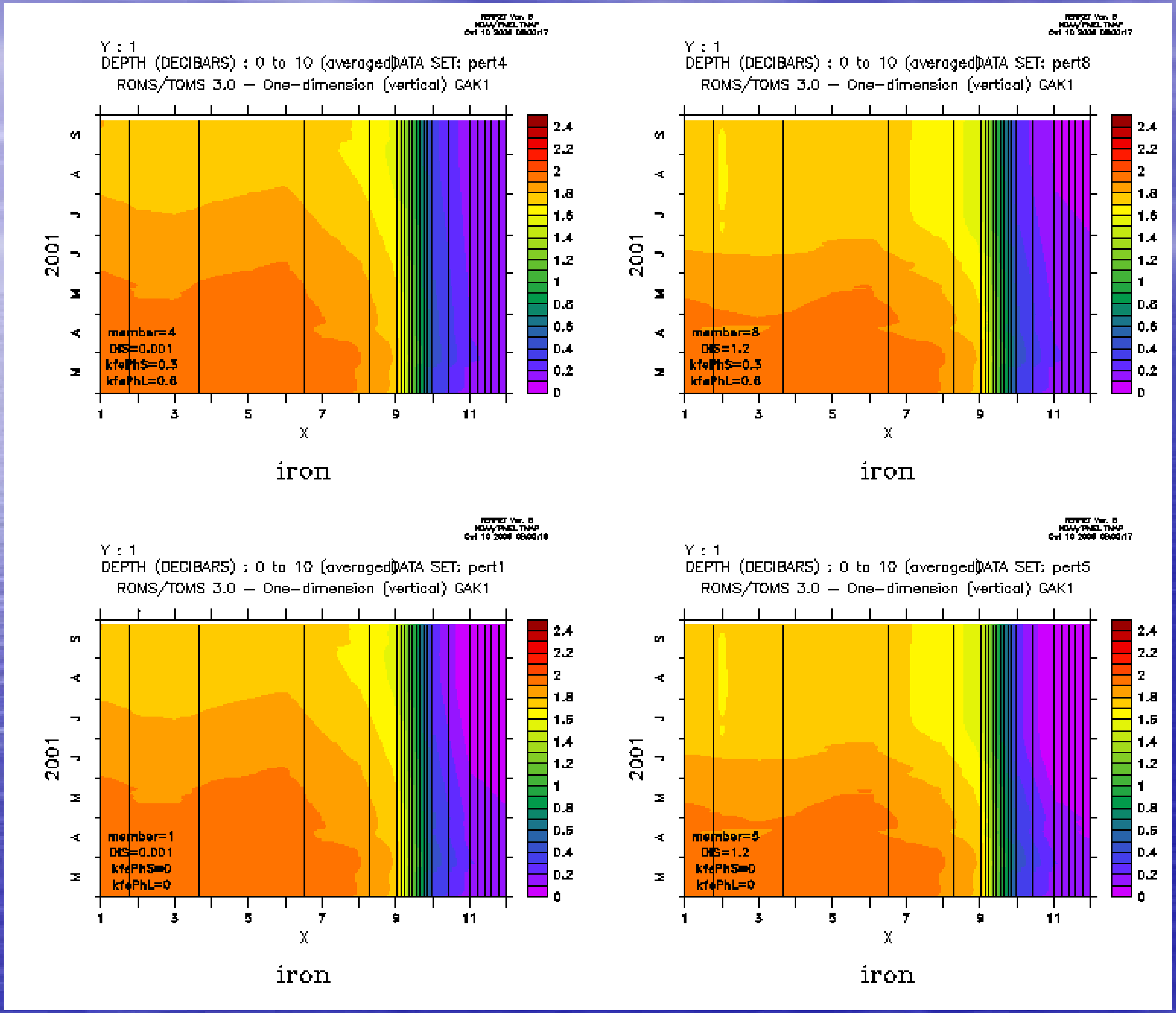
X
cop



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ROMS/TOMS 3.0 – One-dimension (vertical) GAK1
2001
M A M J J A S
1 3 5 7 9 11
X
2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
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DMS=0.001
kfePhS=0.3
kfePhL=0.6
iron
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ROMS/TOMS 3.0 – One-dimension (vertical) GAK1
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M A M J J A S
1 3 5 7 9 11
X
2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
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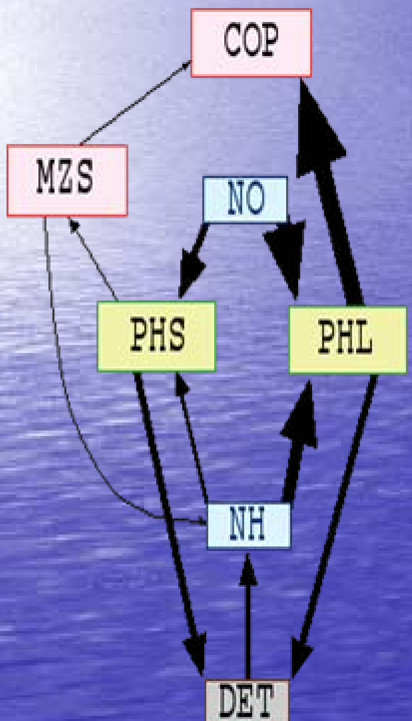
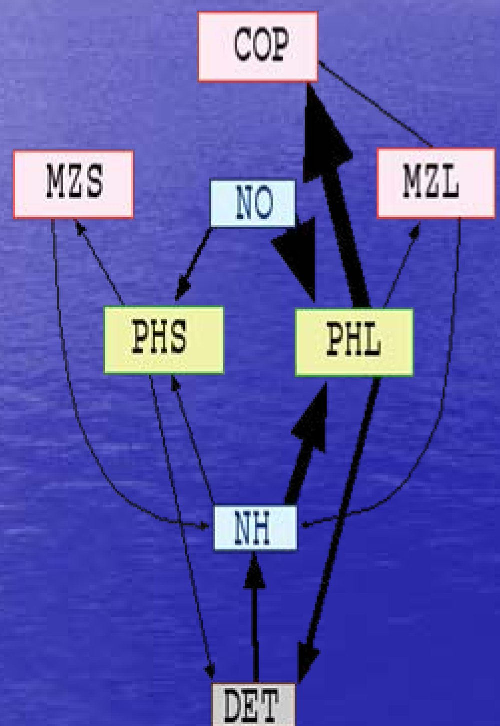
DMS=1.2
kfePhS=0.3
kfePhL=0.6
iron
Y : 1
DEPTH (DECIBARS) : 0 to 10 (averaged) DATA SET: pert1
ROMS/TOMS 3.0 – One-dimension (vertical) GAK1
2001
M A M J J A S
1 3 5 7 9 11
X
2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
member=1
DMS=0.001
kfePhS=0
kfePhL=0
iron
Y : 1
DEPTH (DECIBARS) : 0 to 10 (averaged) DATA SET: pert5
ROMS/TOMS 3.0 – One-dimension (vertical) GAK1
2001
M A M J J A S
1 3 5 7 9 11
X
2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
member=5
DMS=1.2
kfePhS=0
kfePhL=0
iron

Nitrogen Fluxes

Coastal



Oceanic
No FeLim



Oceanic
FeLim