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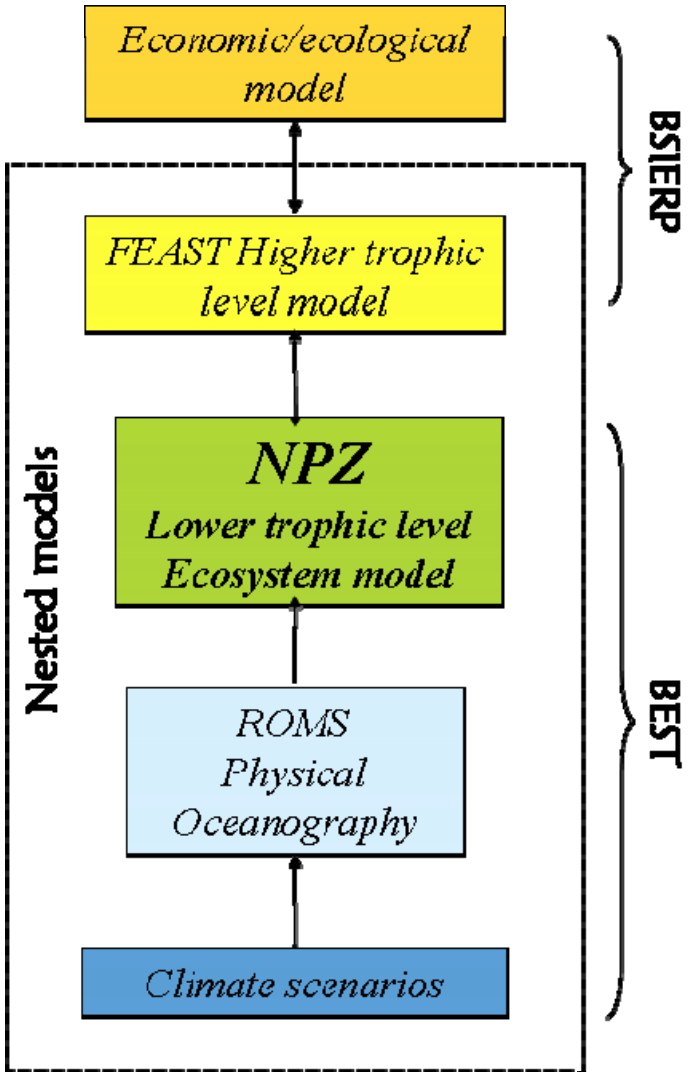
Simulating lower trophic level ecosystem dynamics during 'cold' and 'warm' years:

An ecosystem model for the Bering Sea.

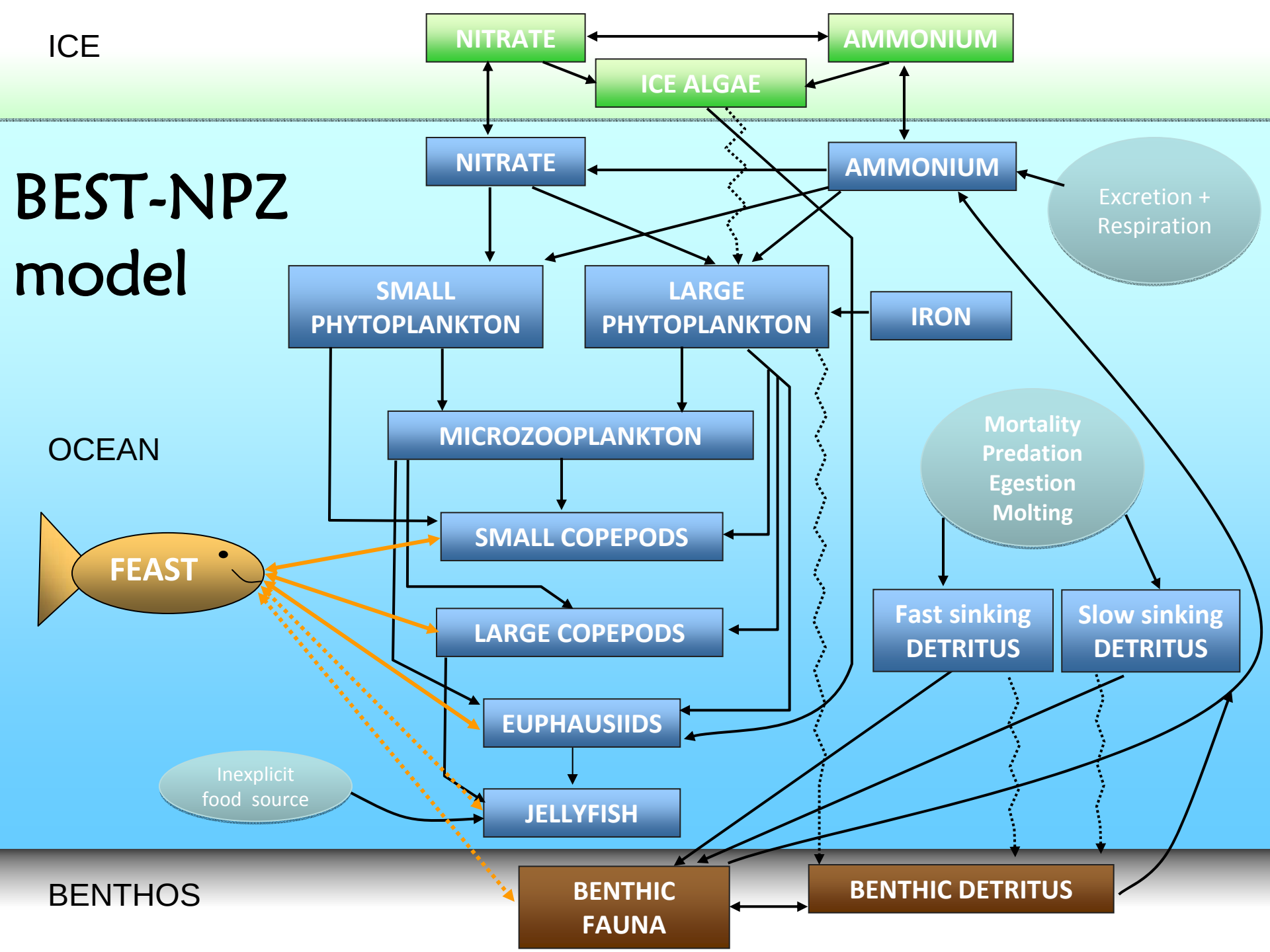
Georgina A. Gibson

Cooperative Institute For Alaska Research

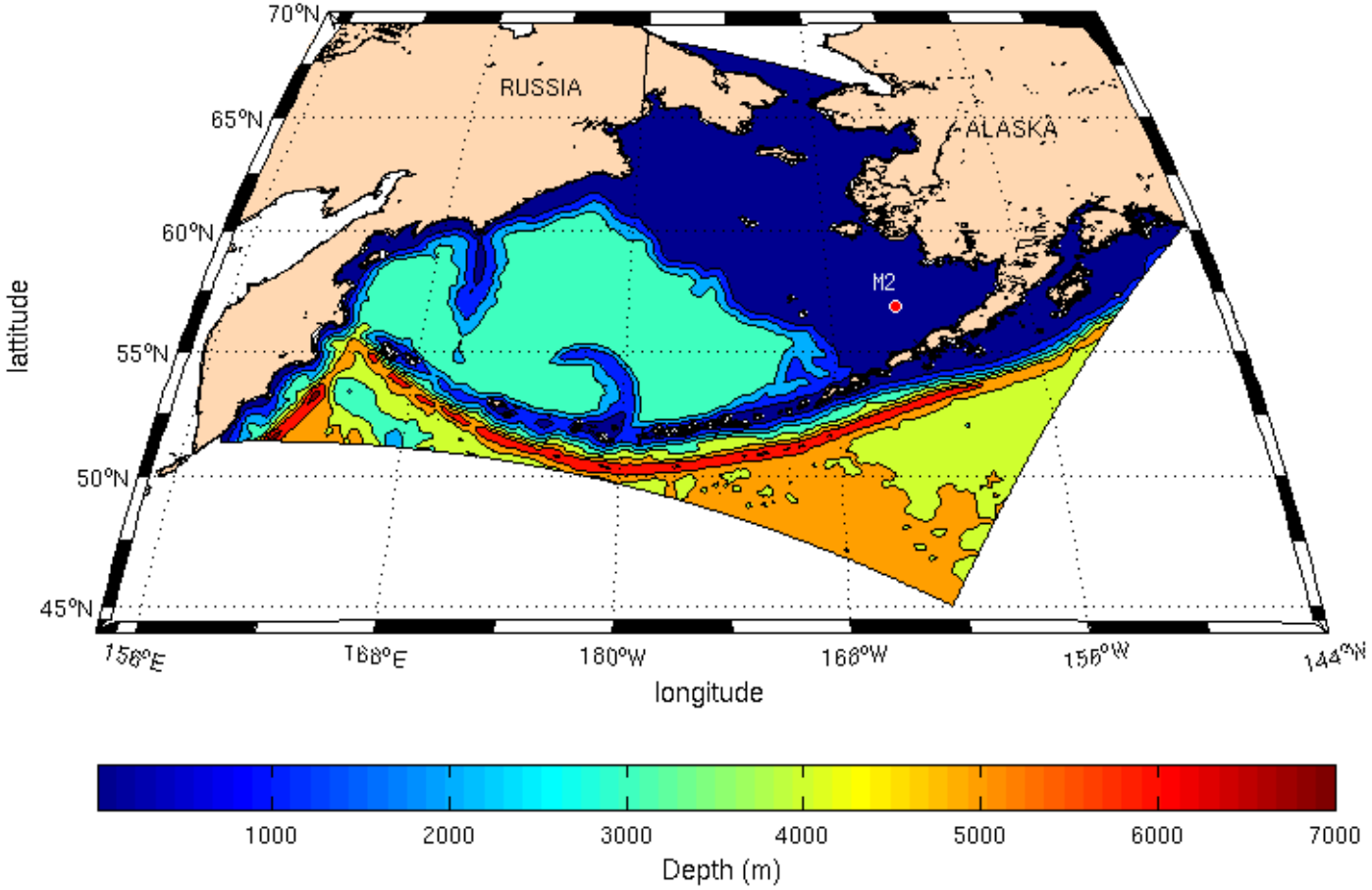
Integrated Modeling



BEST/BSIERP Collaborators: Bond, Curchitser, Hedstrom, Herman, Aydin


ICE
NITRATE
AMMONIUM
ICE ALGAE
BEST-NPZ model
NITRATE
AMMONIUM
Excretion + Respiration
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

The Model Grids



Grid size = 180*256*60

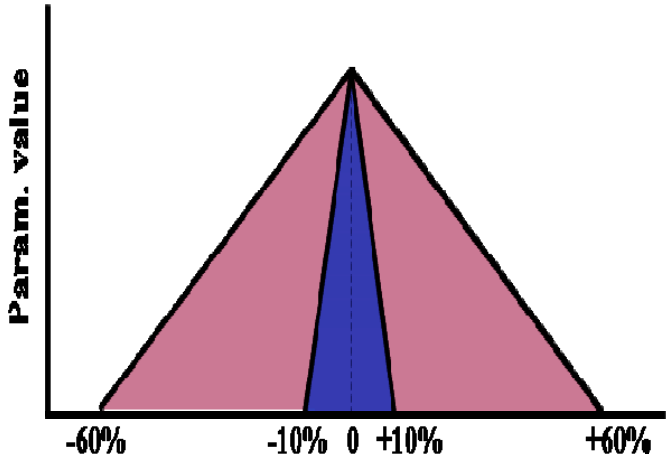
3D grid has 10km resolution

Model Sensitivity Analysis

Monte Carlo analysis was performed to understand model sensitivity to biological input parameters and physical forcing.

- All biological parameters + 5 environment parameters
- Latin Hypercube Sampling used to randomly generate 1000 input parameter sets drawn from triangular probability distributions.
- Multiple linear regression to rank parameters for the diagnostic model output variables.
- ANOVA to determine R^2

Biological parameters were from within ±10% or ±60% of baseline values.



Model Sensitivity to Environment

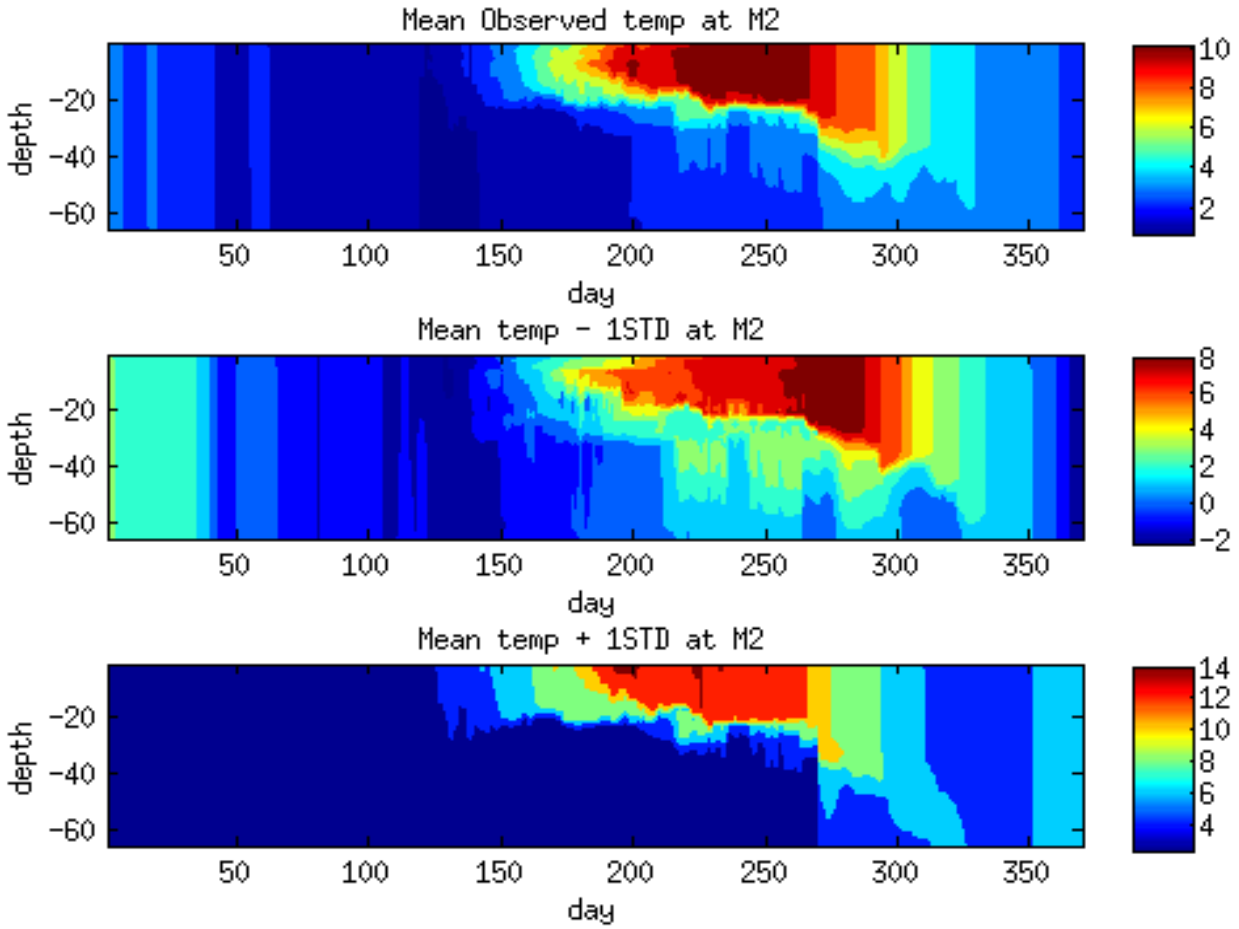
Variable	Formulation	Data Source
Nitrate	N=N+sd*nP	M2 pre-bloom nitrate at 1979,1980,1981,1999, 2007.
Temperature	T =T+sd*tP	M2 oceanographic moorings and CTD observations for 1999 and 2004
Salinity	S=S+sd*sP	M2 oceanographic moorings and CTD observations for 1999 and 2004
Ice thickness	It = It +sd*iP	1999 and 2004 for the NSIDC data
Shortwave radiation	Sw=Sw+sd*lP	M2 atmospheric mooring 1999 and 2004

5 environmental parameters :

$-1 \leq nP, tP, sP, lP \leq 1$

$-0.7 \leq iP \leq 1$

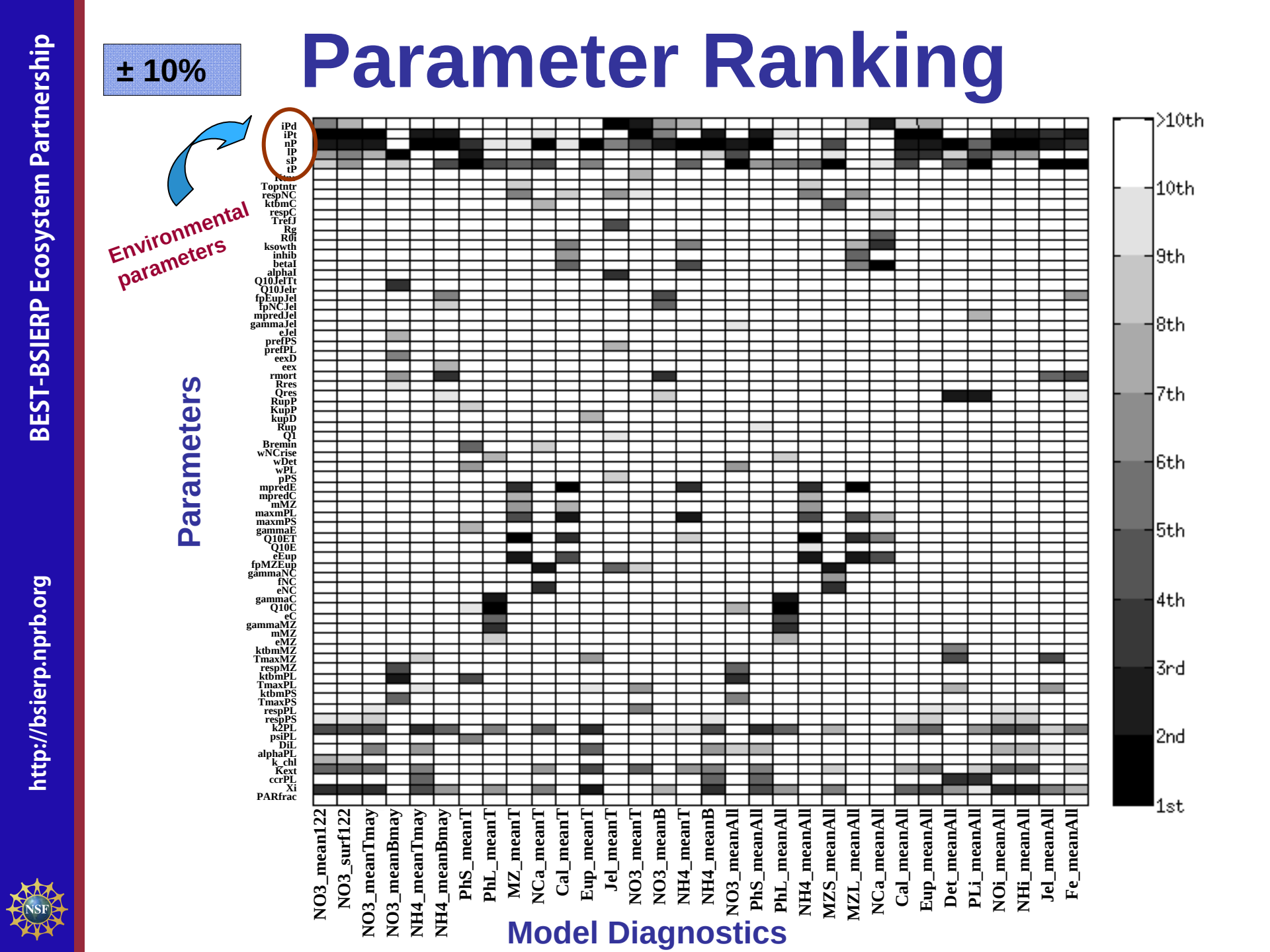
Model Sensitivity to Environment



$$T = T + STD * tP \qquad -1 \leq tP \leq 1$$

Parameter Ranking

± 10%



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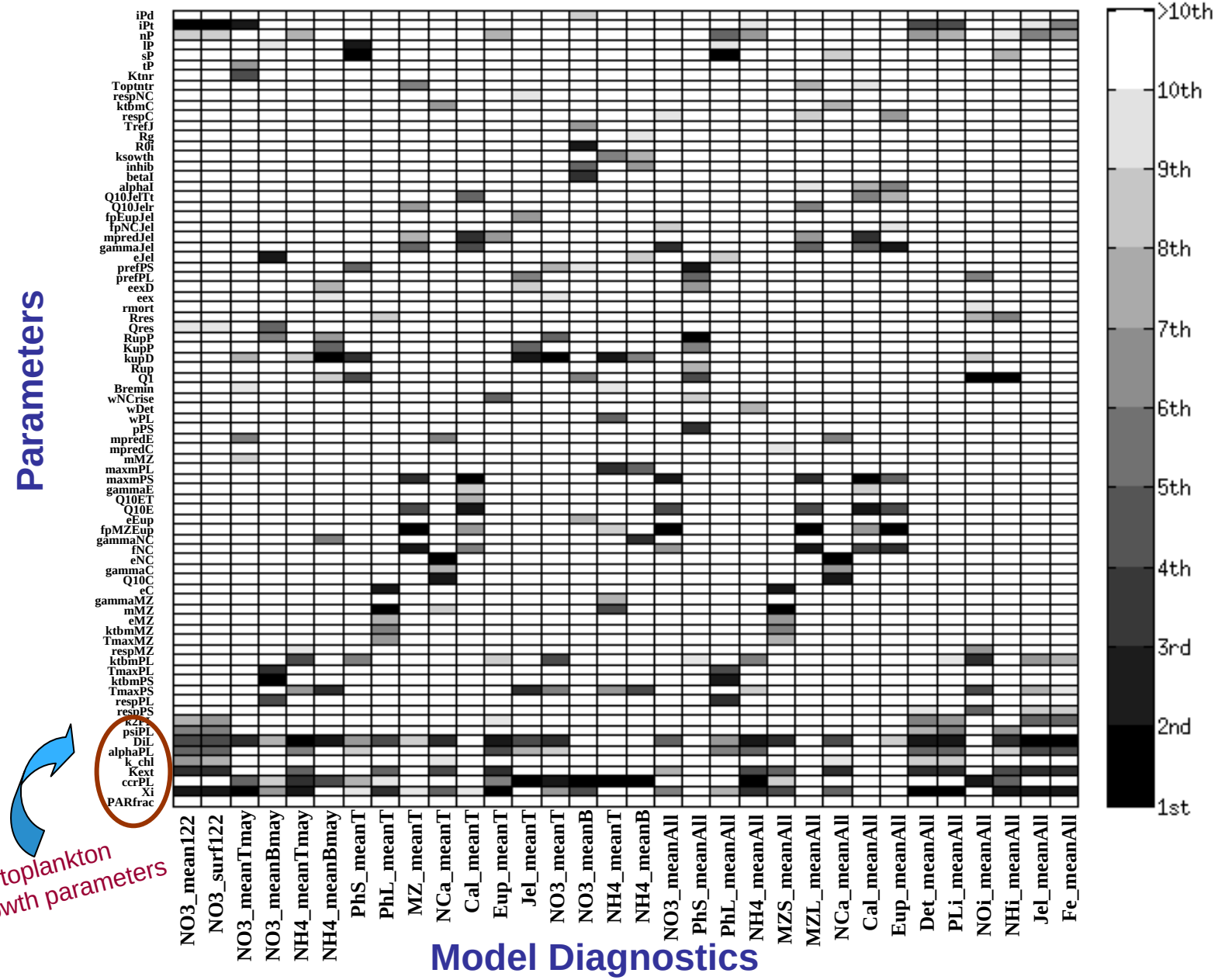
± 60%

Parameter Ranking



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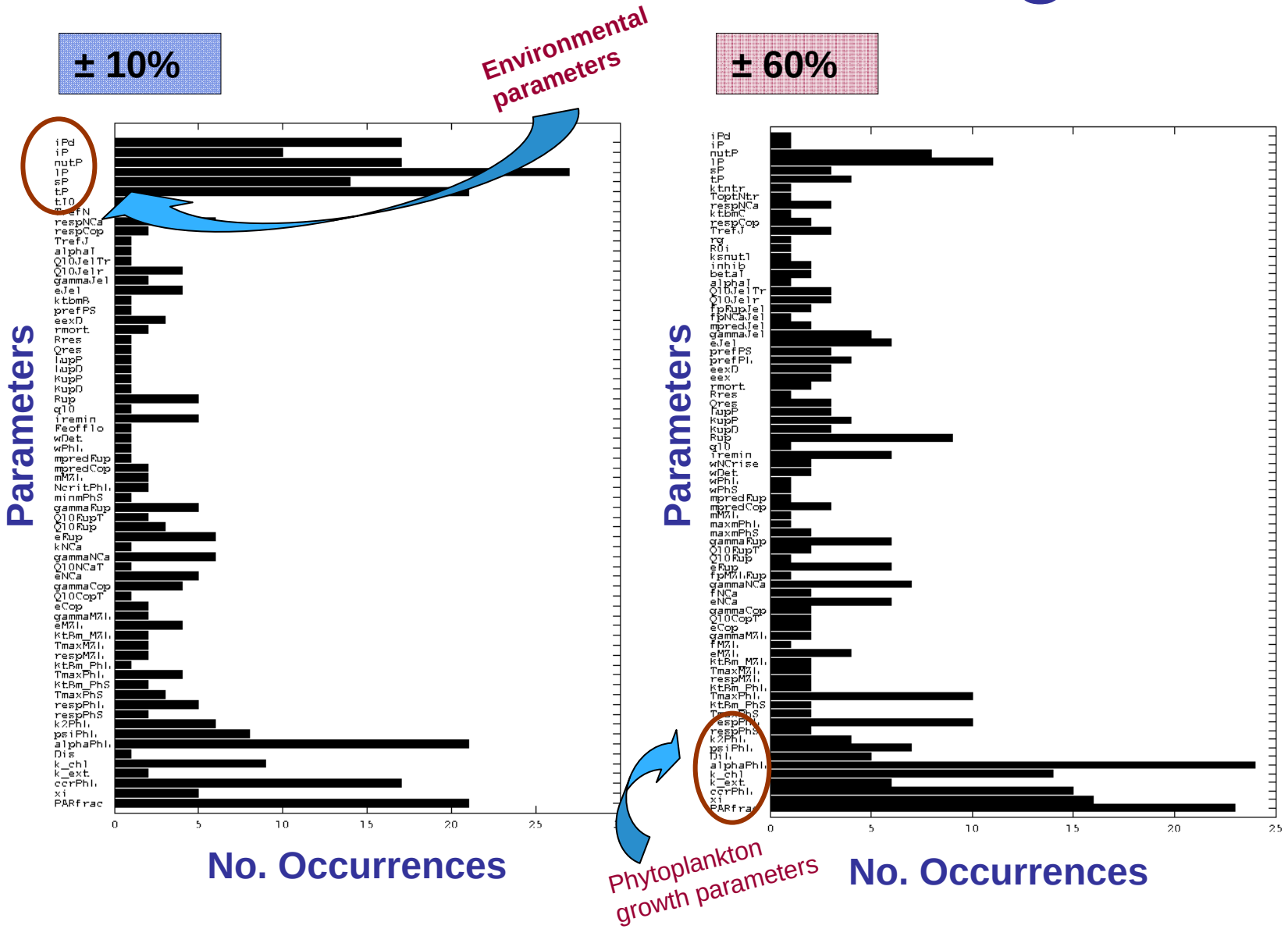
Parameter Ranking



Suggests that model could be simplified

Adjusted R2

	NO3_meanT		PL_meanT		ZL_meanT	
	± 10%	± 60%	± 10%	± 60%	± 10%	± 60%
R2 for top 5	**0.78**	**0.73**	**0.75**	**0.38**	**0.65**	**0.39**
R2 for top 10	**0.90**	**0.83**	**0.87**	**0.44**	**0.72**	**0.48**
R2 for lP only	**0.39**	0.03	**0.32**	0.02	0.00	0.00
R2 for tP only	0.01	0.00	**0.05**	0.00	**0.08**	0.00
R2 for tP and sP	**0.07**	0.01	**0.05**	0.00	**0.08**	0.00
R2 for nP only	**0.13**	0.02	**0.24**	0.01	0.00	0.01

- 5 variables account for large percentage of variability in model diagnostics.
- Controlling influence on model output shifts from physical environment to the biological parameters with increase in biological parameter variability
- Zooplankton were little influenced by environmental variables examined
- Useful info for model tuning and interpretation.

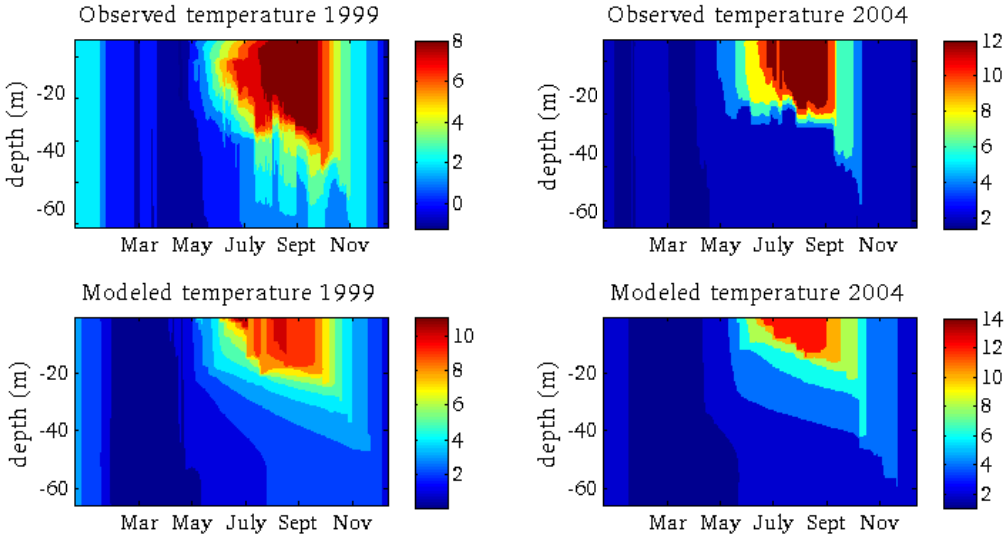
Top ranked parameters

	NO3_meanT		PL_meanT		ZL_meanT	
	± 10%	± 60%	± 10%	± 60%	± 10%	± 60%
1st	lP	alphaPL	lP	xi	gammaNCa	gammaNCa
2nd	nP	PARfrac	nP	alphaPL	eNCa	eNCa
3rd	PARfrac	ccrPL	alphaPhL	PARfrac	gammaEup	gammaEup
4th	alphaPhL	k_chl	PARfrac	ccrPL	eEup	eEup
5th	ccrPhL	psiPL	xi	k_chl	tP	eJel
6th	iPd	lP	ccrPhL	TmaxPL	respNCa	fpEupJel
7th	sP	TmaxPL	tP	lP	Q10Eup	gammaJel
8th	k_chl	respPL	k_chl	wPL	Q10EupT	respNCa
9th	psiPhL	k2PL	iPd	respPL	TrefN	TrefJ
10th	k2PhL	nutP	wPhL	nP	Q10NCaT	Q10JelTr

Top ranked biological parameters correspond well to those found important in the NEMURO model (Yoshie et al 2006).

Useful info for model tuning and interpretation.

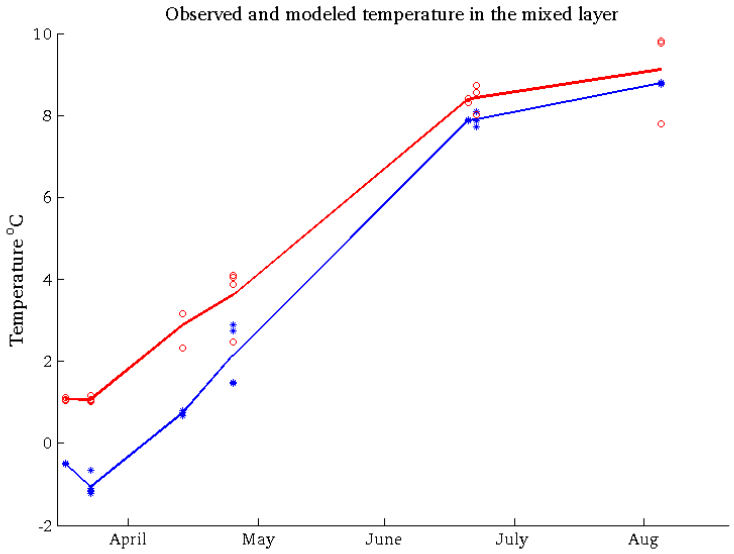
Comparison with data



Temperature

R^2=0.99

MEF =0.78



1D model can capture temperature trends – Initial conditions likely too warm

BS shelf Ecosystem Differences 1999 vs. 2004

NPZ model will need to be able to simulate the dynamics of both cold and warm regimes

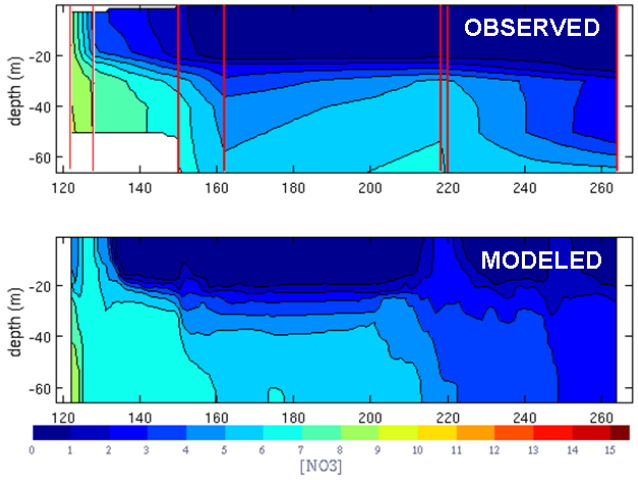
Zooplankton group	Model Component	1999	2004	Reference
Microzooplankton	Small and large microzooplankton	27.8mg.m-3	<20mg.m-3	Strom and Fredrickson 2007; Olson and Strom, 2002
Pseudocalanus sp.	Small copepods	16 $mg{\cdot}m^{-3}$	41 $mg{\cdot}m^{-3}$	Coyle *et. al.*, 2007
Calanus marshallae	Large copepods	510$mg{\cdot}m^{-3}$	0.1 $mg{\cdot}m^{-3}$	Coyle *et. al.*, 2007
Thysanoessa spp.	Euphausiids	6.3 $mg{\cdot}m^{-3}$	0.47 $mg{\cdot}m^{-3}$	Coyle *et al.*, 2007
C. Melanaster	Jellyfish	3$mg{\cdot}m^{-3}$	0.07$mg{\cdot}m^{-3}$	Coyle *et al* ., 2007; Brodeur et al., 2002
Phytoplankton	Small and large phytoplankton	2 ug Chl-a·l-1	0.4 ug Chl-a·l-1 (Surface) 1.2 ug Chl-a·l-1 (20m)	Strom and Fredrickson 2007, Whitledge per. com (FOCI data)

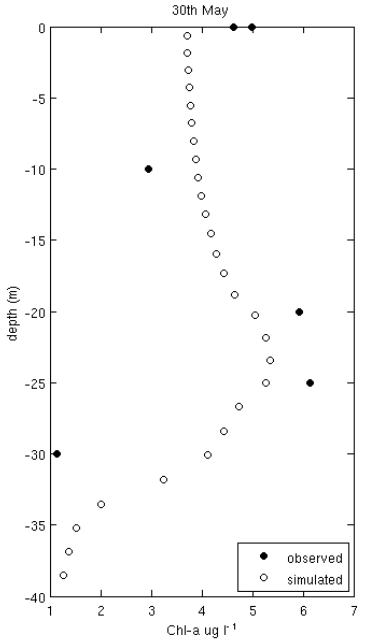
- **Phytoplankton strongly nutrient limited in 2004**
- **Large mesozooplankton biomass in 1999**
- **Biomass dominated by small copepods in 2004**
- **System dynamics controlled by stability (Coyle/Strom)**

Comparison with data

NPZ model was initially tuned to 1999 data…

… model components compared favorably to data …

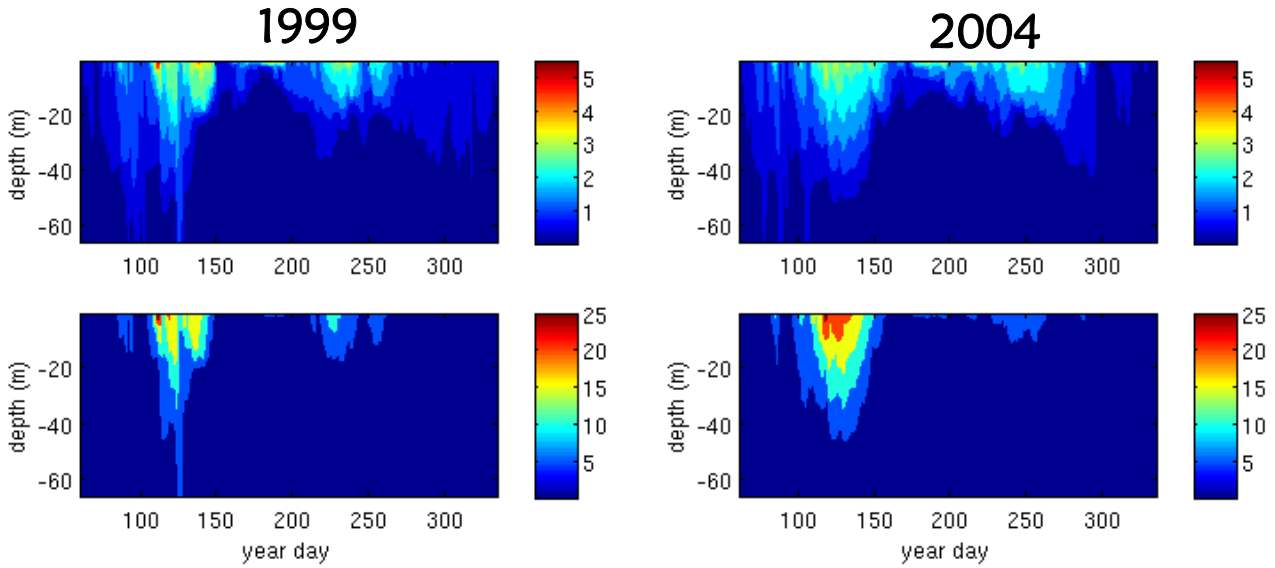




…alas…not capturing the differences observed in 2004

Small phytoplankton

Large phytoplankton



FLUXES

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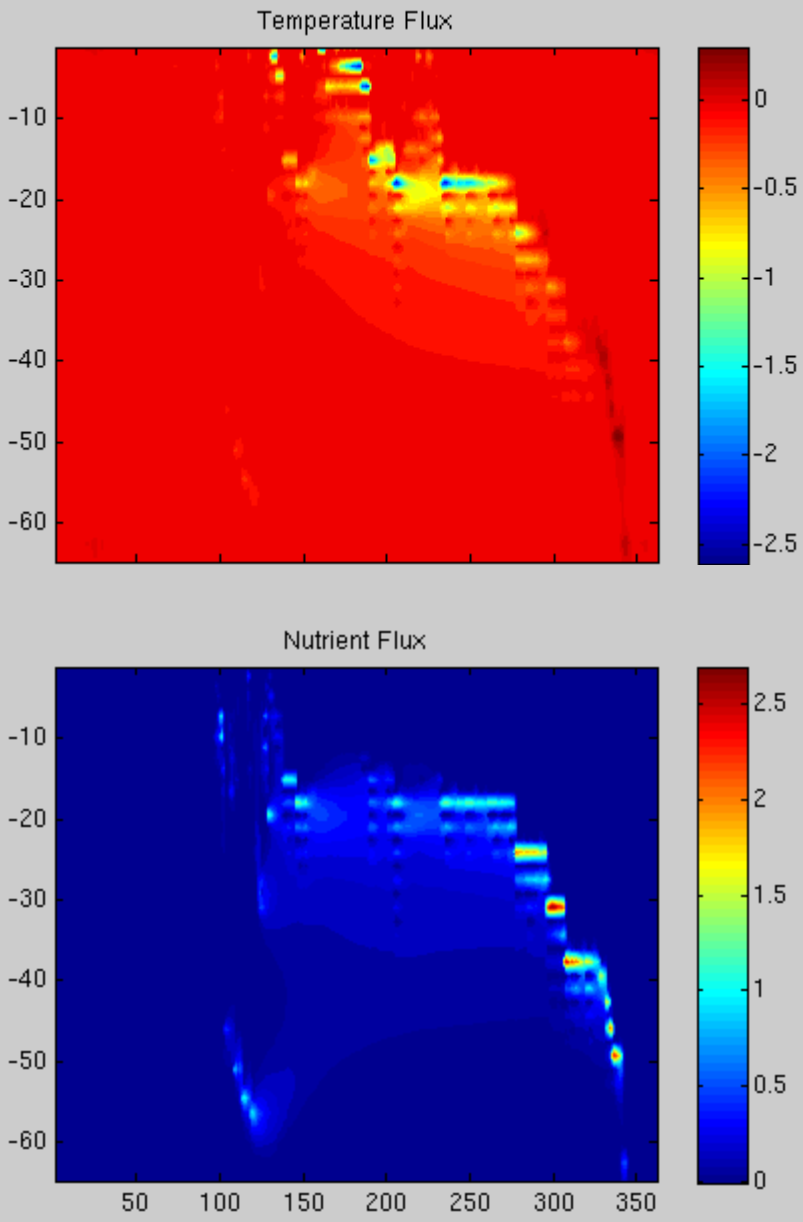
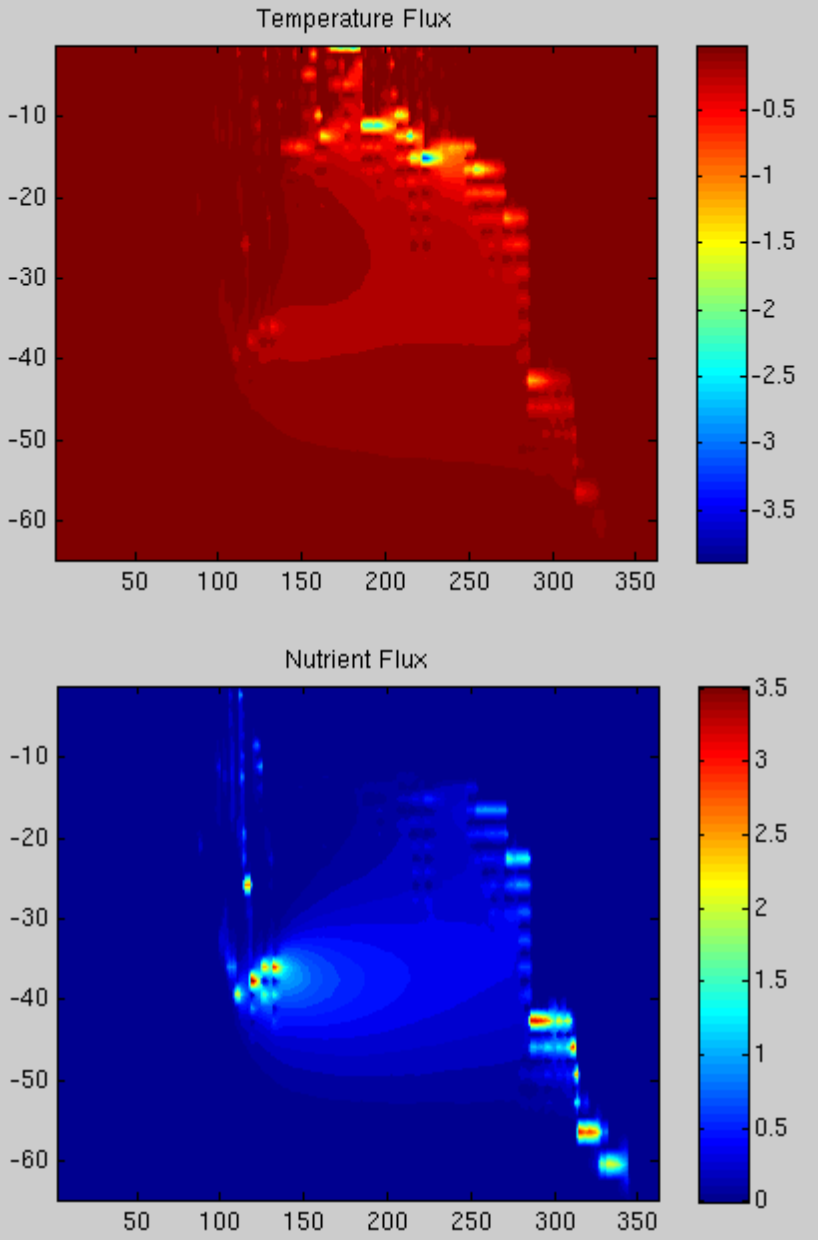
1999



2004



FLUXES

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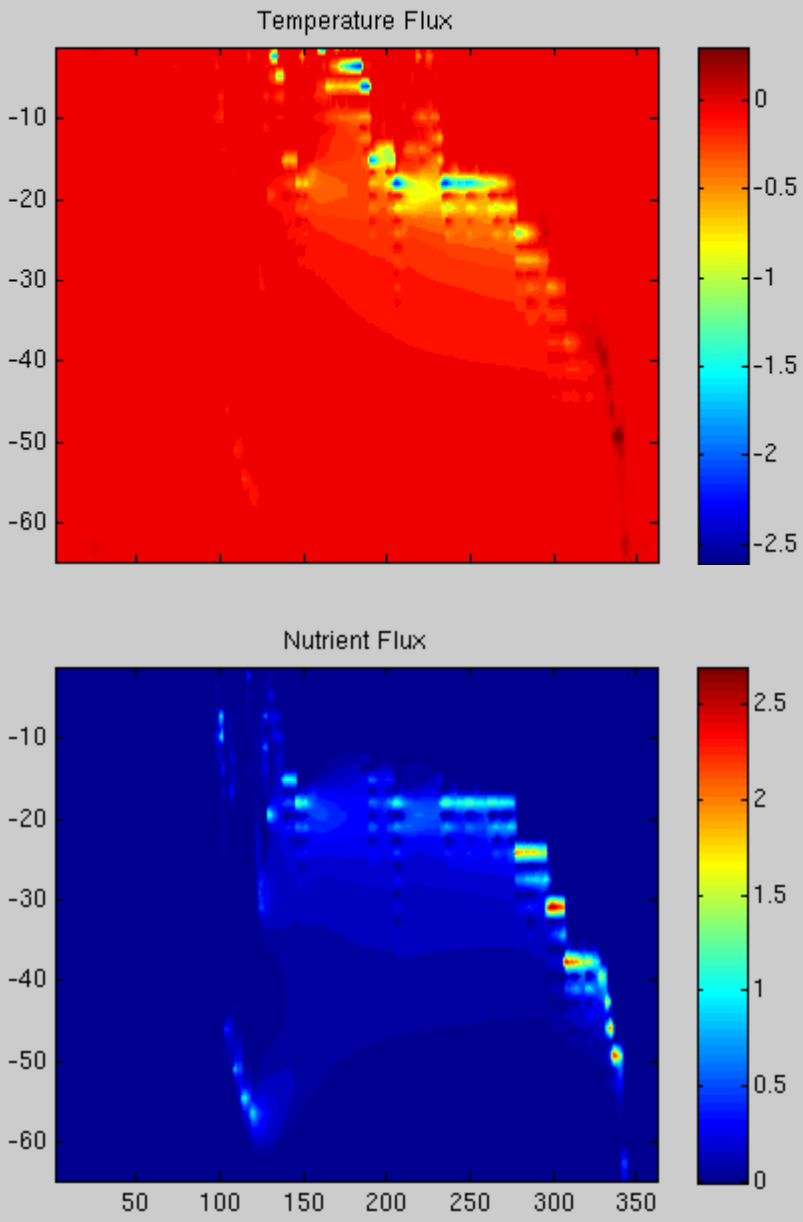
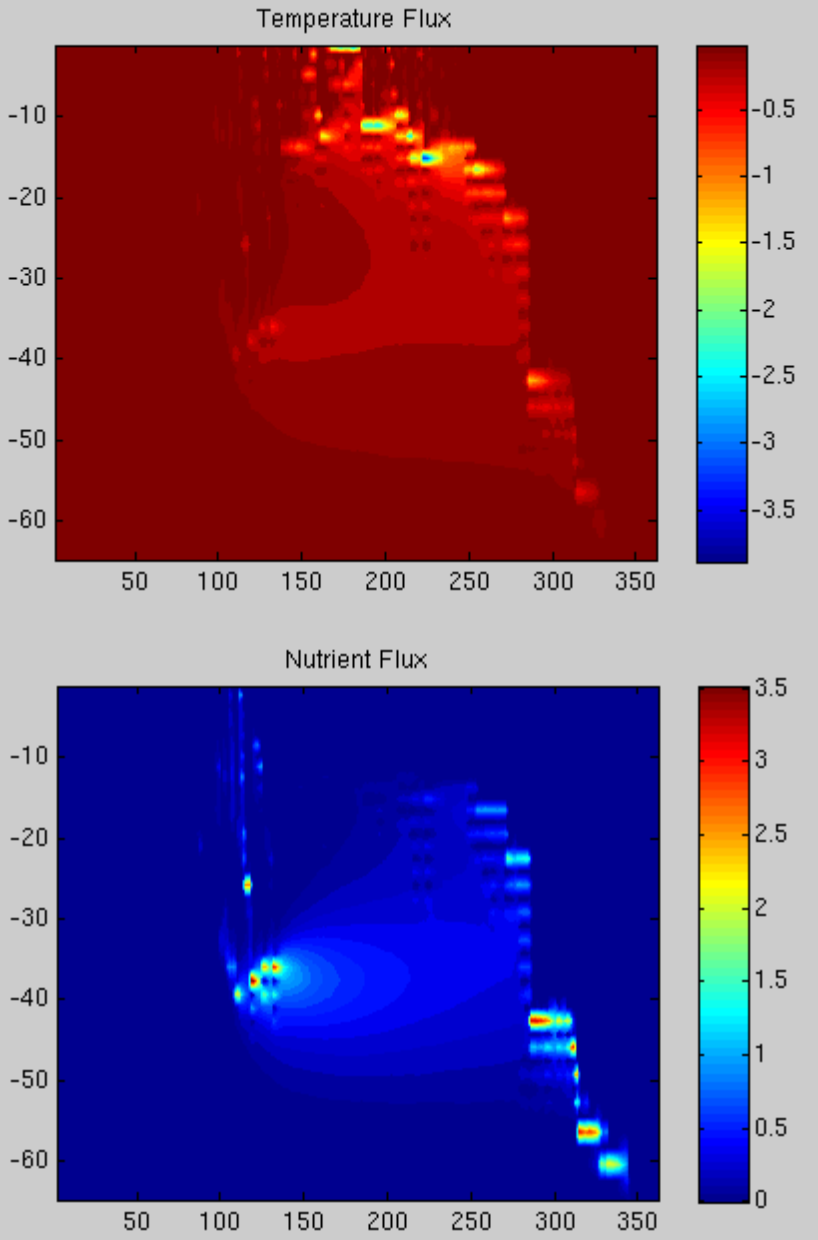
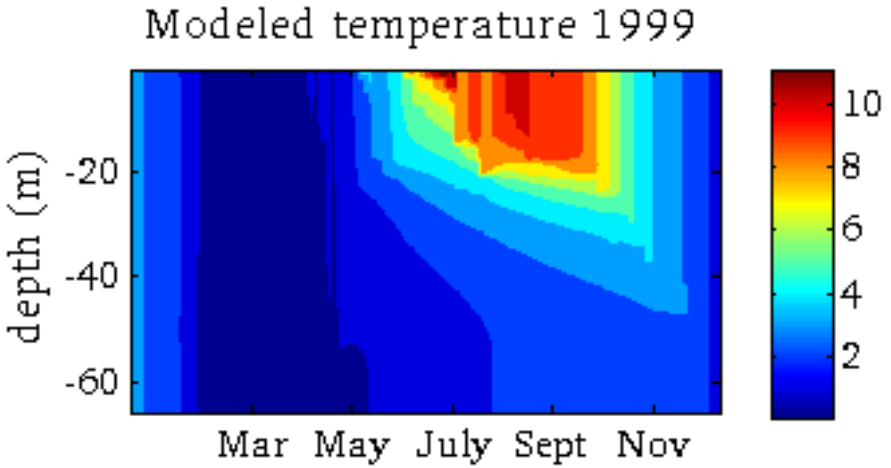
1999

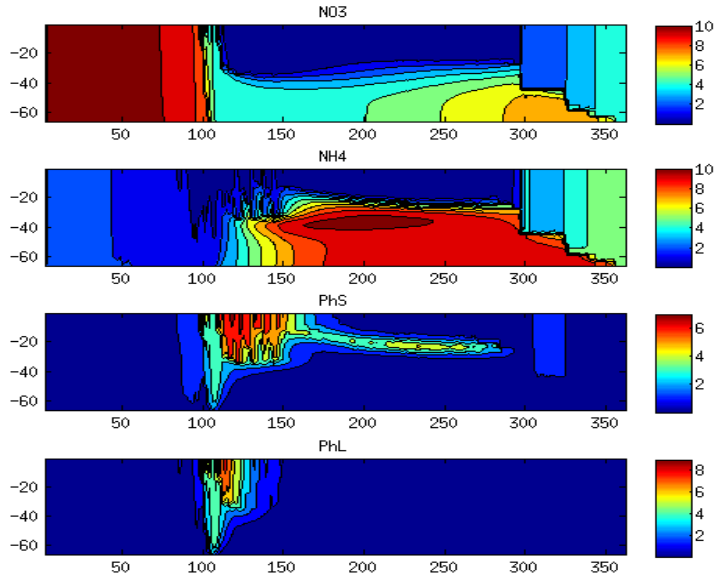


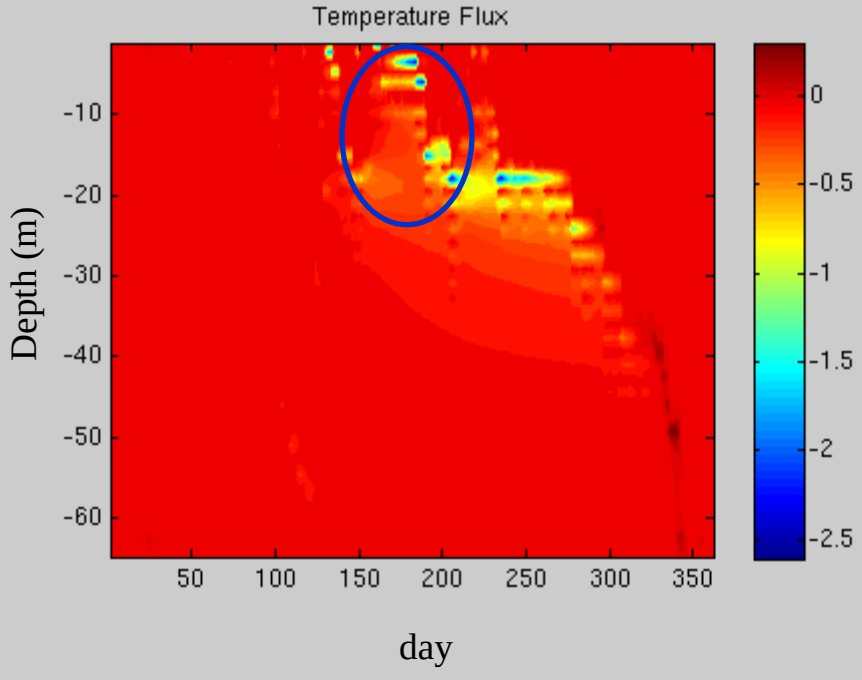
2004

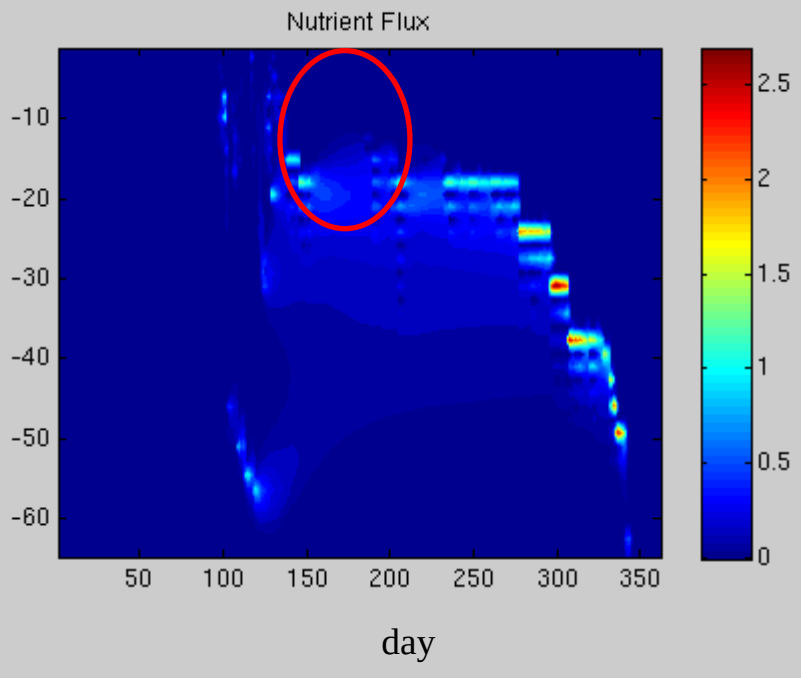


FLUXES





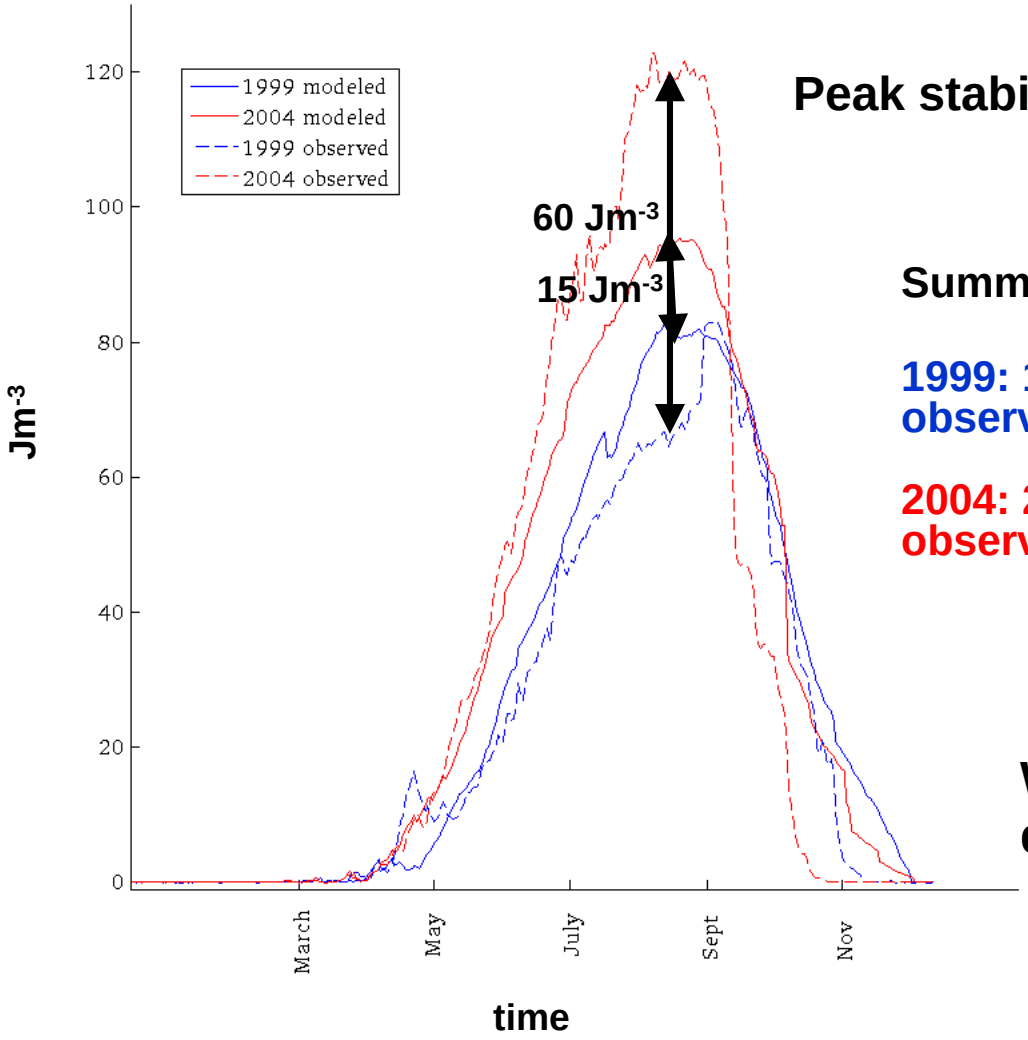




Missing nutrient flux in summer ?

- Could get a simulation that looked good for 1999
- 2004 simulation didn't look much different – indicate that had incorrect parameterization
- Ran models simultaneously progresively introducing mode components
- Didn't see difference in the phytoplankton between the 2 years – this is the driver of the ecosystem difference.
- Is it the stability ? – adjsuted sw forcing and now have good stability.
- Problem. 1999 should have higher production in the surface in summer.
- NH4 in the surface is under estimated by the model.
- Either insufficeitn NH4 is being mixed up into surface from below the pycnocline or the 1D model fails to capture advection of the NH4 – hypothesised by Rho.
- Tried incrementing the mixing – an approached used by coyle in the 1D model. Still had same response in the 2 years.
- Must be advective???
- Could be CCSM inability to capture storm events

Water column stability



Peak stability at M2 is in late August

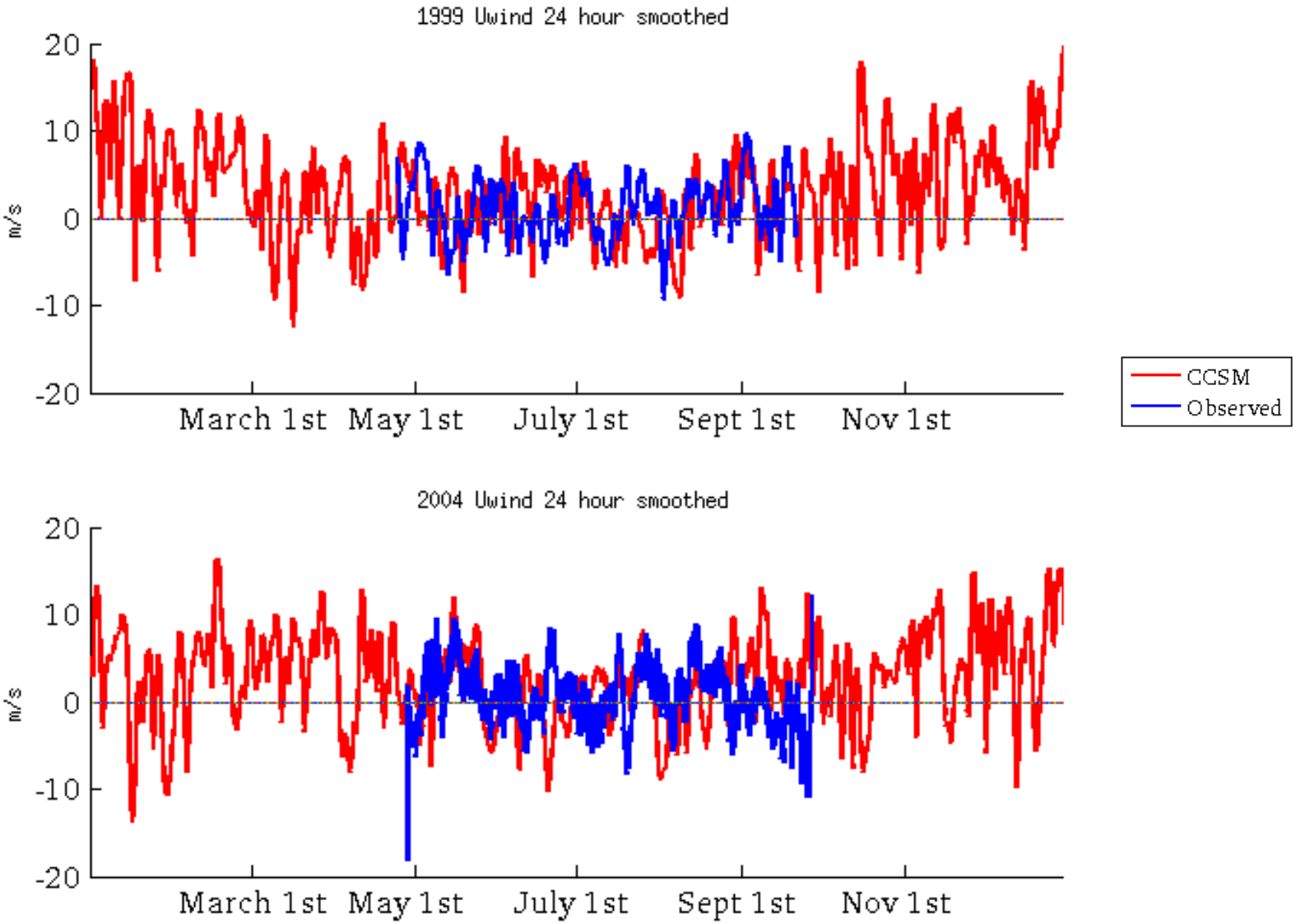
Summer Stability

1999: 15 Jm^{-3} more stable than observed

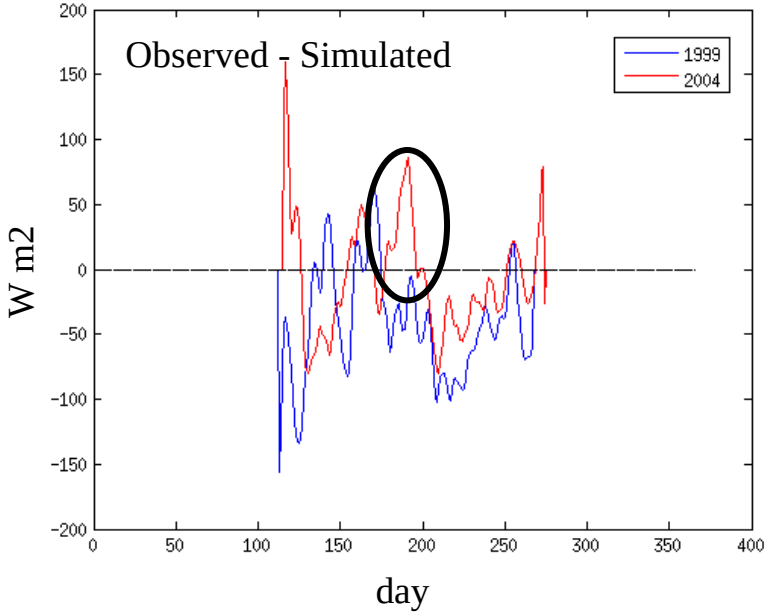
2004: 25 Jm^{-3} less stable than observed

Why is model not capturing differences in stability?

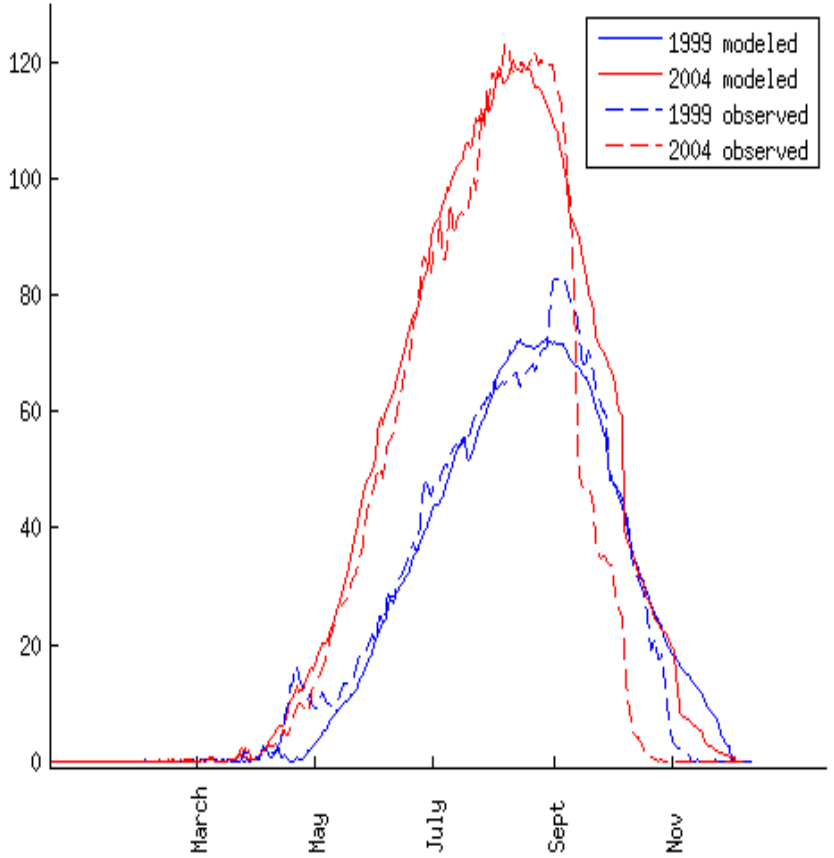
Wind


1999 Uwind 24 hour smoothed
20
10
0
-10
-20
m/s
March 1st
May 1st
July 1st
Sept 1st
Nov 1st
CCSM
Observed
2004 Uwind 24 hour smoothed
20
10
0
-10
-20
m/s
March 1st
May 1st
July 1st
Sept 1st
Nov 1st

Shortwave Radiation



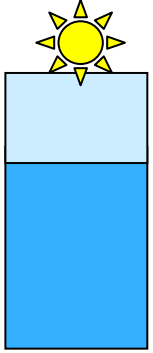
On average CCSM short wave radiation is too high relative to observation at M2 but was 35W too low in summer 2004



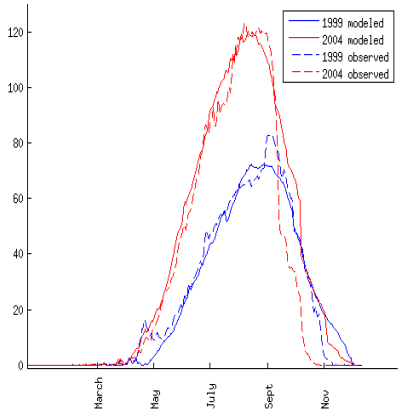
If short wave radiative forcing modified to match observations ROMS can capture observed stability

Stability?

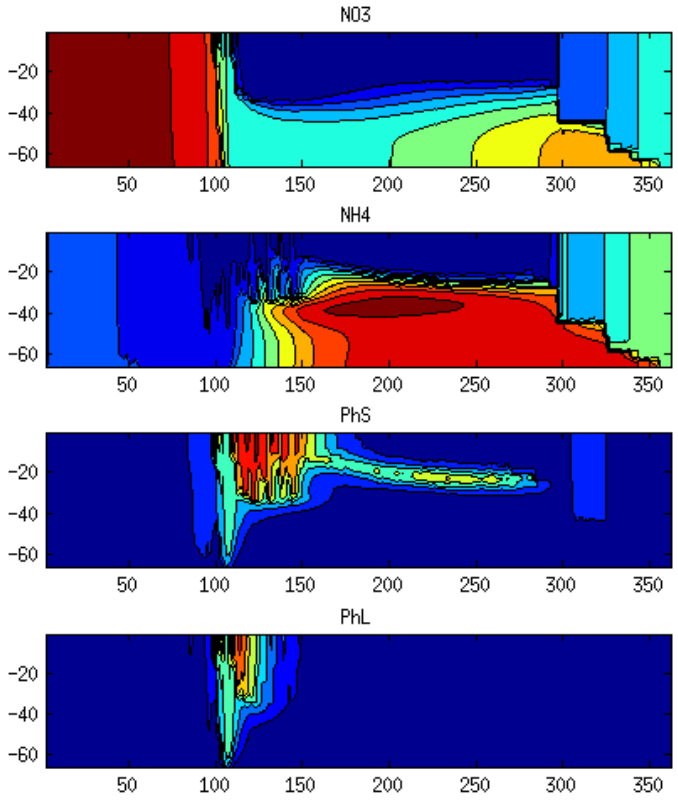
Stability alone could not account for observed differences



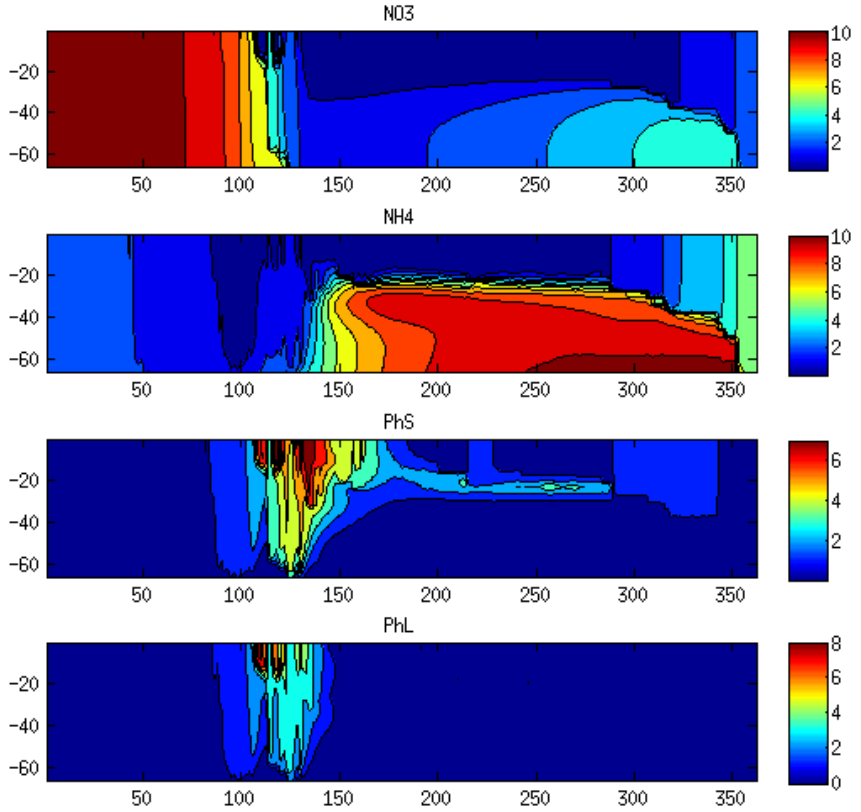
Adjust SW rad.



1999



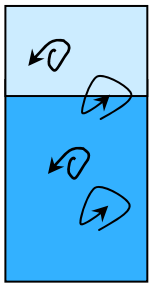
2004



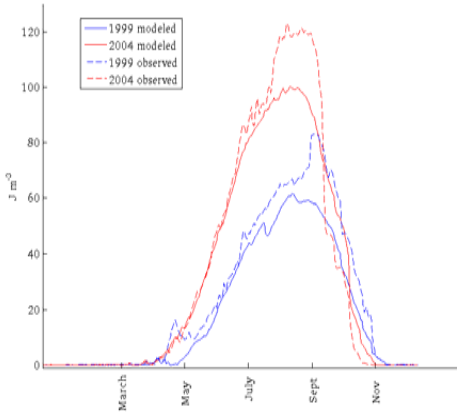
Should see surface maximum in summer 1999

Vertical Mixing ?

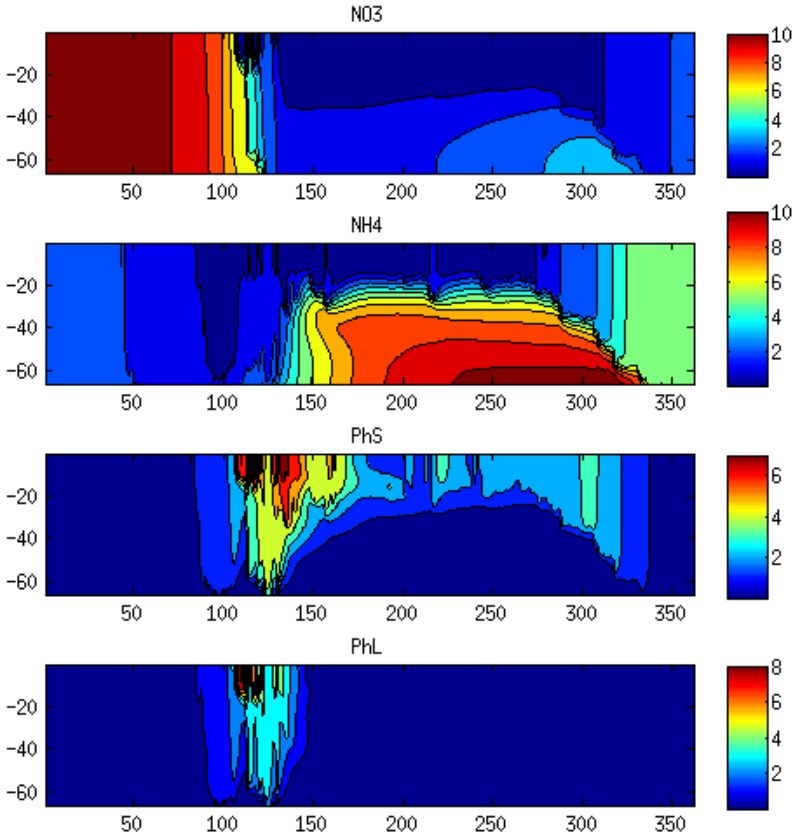
- Incrementing ROMS vertical mixing reduced the stability of the water column in both years so did not help in capturing the differences between 1999 and 2004



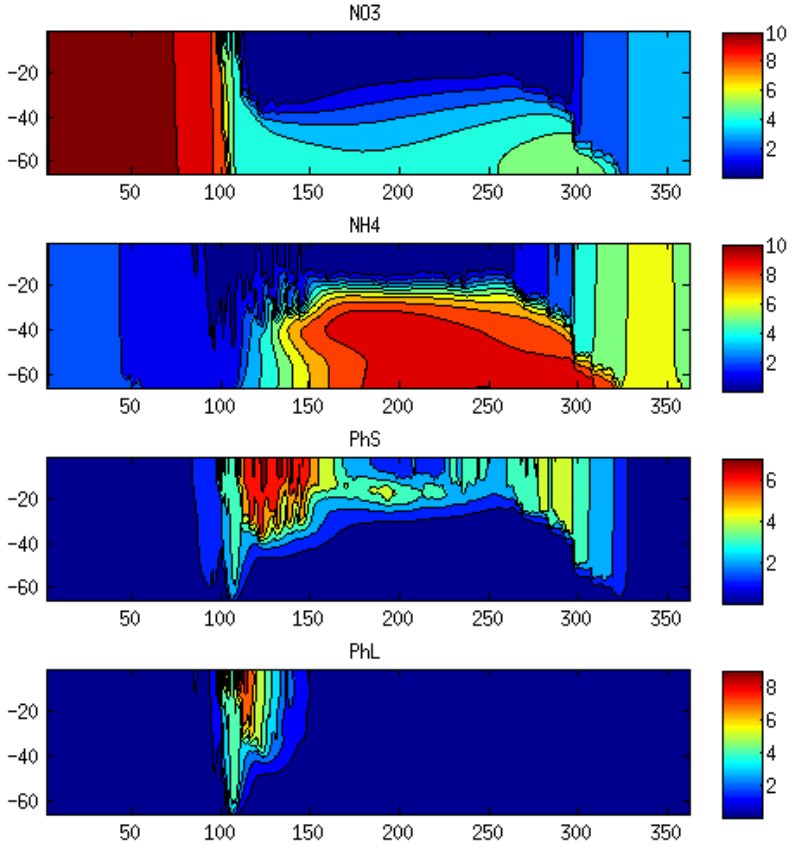
Increased mixing



1999

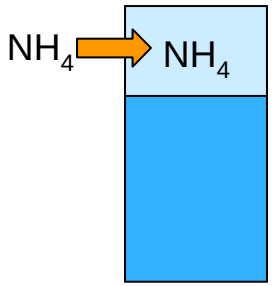


2004



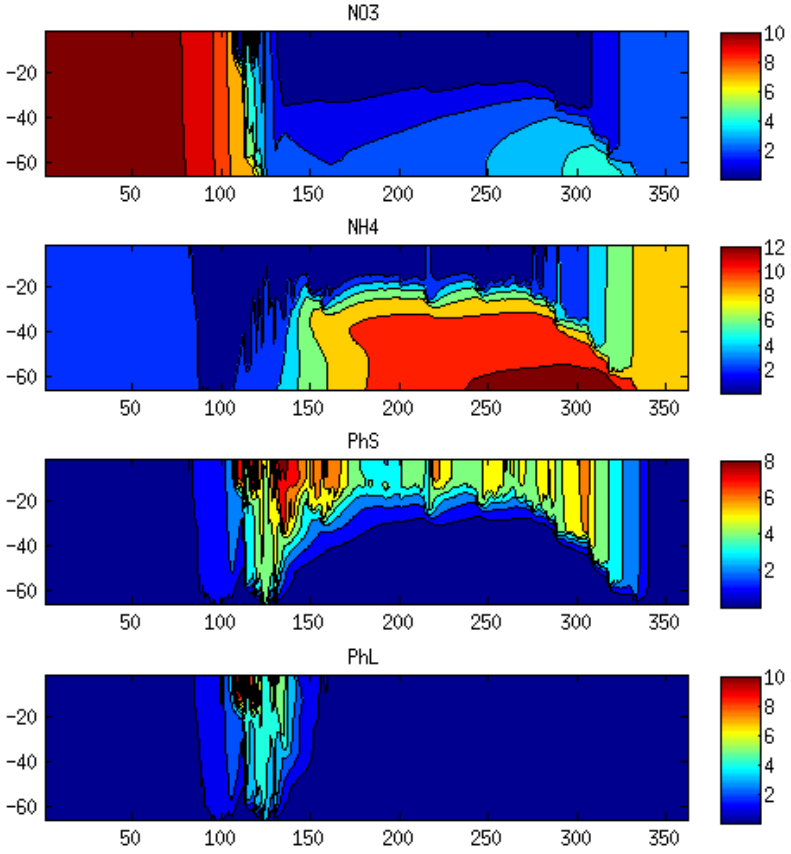
Horizontal Flux?

- Rho et al (2005) – In situ processes at M2 cant account for observed nutrients.
- Adding a source of nutrients to the upper mixed layer enabled differences in the lower trophic level dynamics to be simulated.

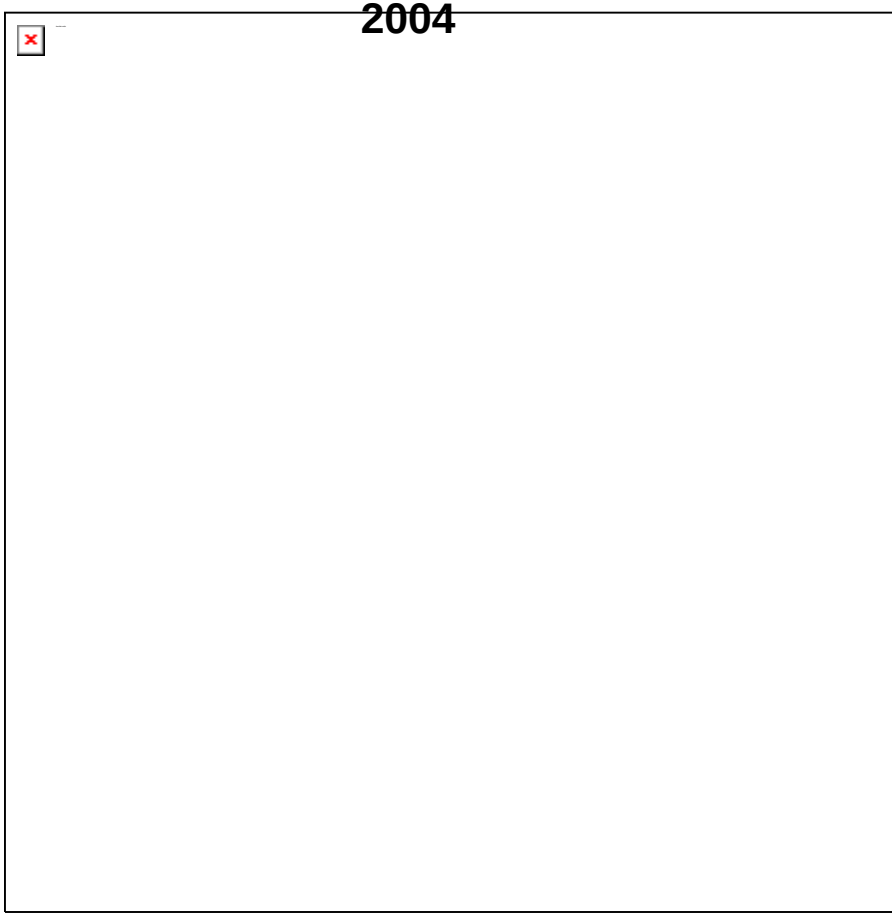


Nutrient Source

1999



2004



Summary

- With small variability in biological parameters NPZ model output dependent on environment.
- If variability in biological parameters is larger their parameterization controls the system.
- Will the climate forcing data simulate short wave radiation well enough to observe stability driven biological differences ?

Summary

- ROMS model does a good job of capturing temperature and stability – is it getting nutrient flux right ?
- To get model right need to consider extremes simultaneously.
- 1999 vs. 2004 - water column stability not the whole story – likely that on shelf nutrient flux important.
- It appears that M2 cannot be modeled well in 1D due to 3D advective processes.

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Questions ?

…….Answers ?