3-Dimensional coupled physical-biological modelling the North Atlantic: impact of biogeochemical parameters spatial variability

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What is it all about ?

- The coupled model description

  Physical pool

  Strategy for coupling

  Biogeochemical model
- Model validation
- Impact of biological model parameters spatial variability

  Parameter estimation problem
- Conclusions

The Physical Model

- A North Atlantic circulation model, based on the Los Alamos Parallel Ocean Program (POP) (Smith et al. 1992) with an implicit treatment of the Coriolis term and vertical diffusion.
- The K-profile parameterization (Large et al., 1994) is used for vertical mixing.
- 1 horizontal resolution (10S-80N, 99W-20E).
- 23 vertical levels (10, 20, 35, 55, 75, 100, 135, 185, 260, 360, 510, 710, 985,1335, 1750, 2200, 2700, 3200, 3700, 4200, 4700, 5200, 5700).

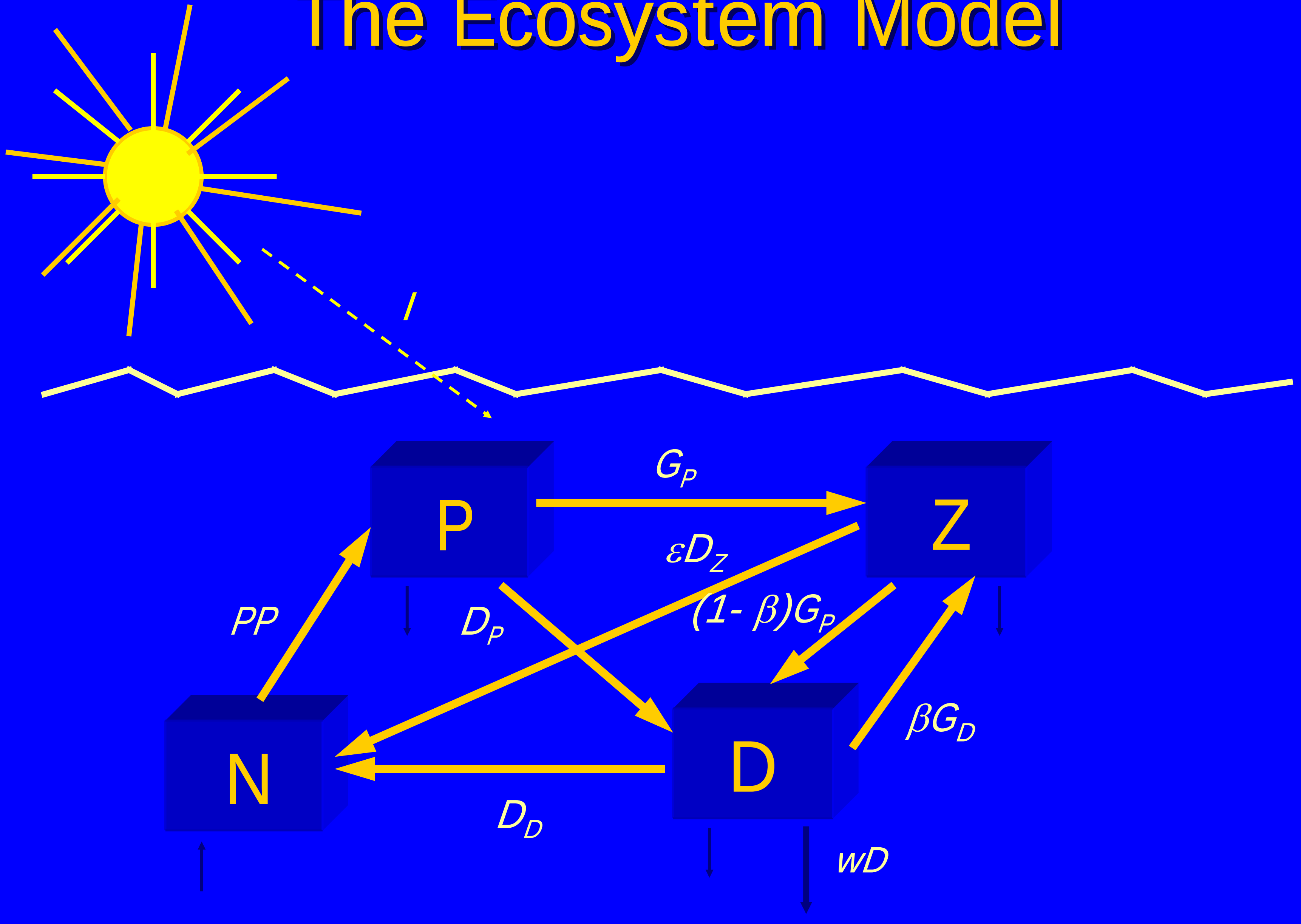
Forcing

- Climatological monthly mean wind stress (da Silva et al., 1994).

Initial and Boundary conditions

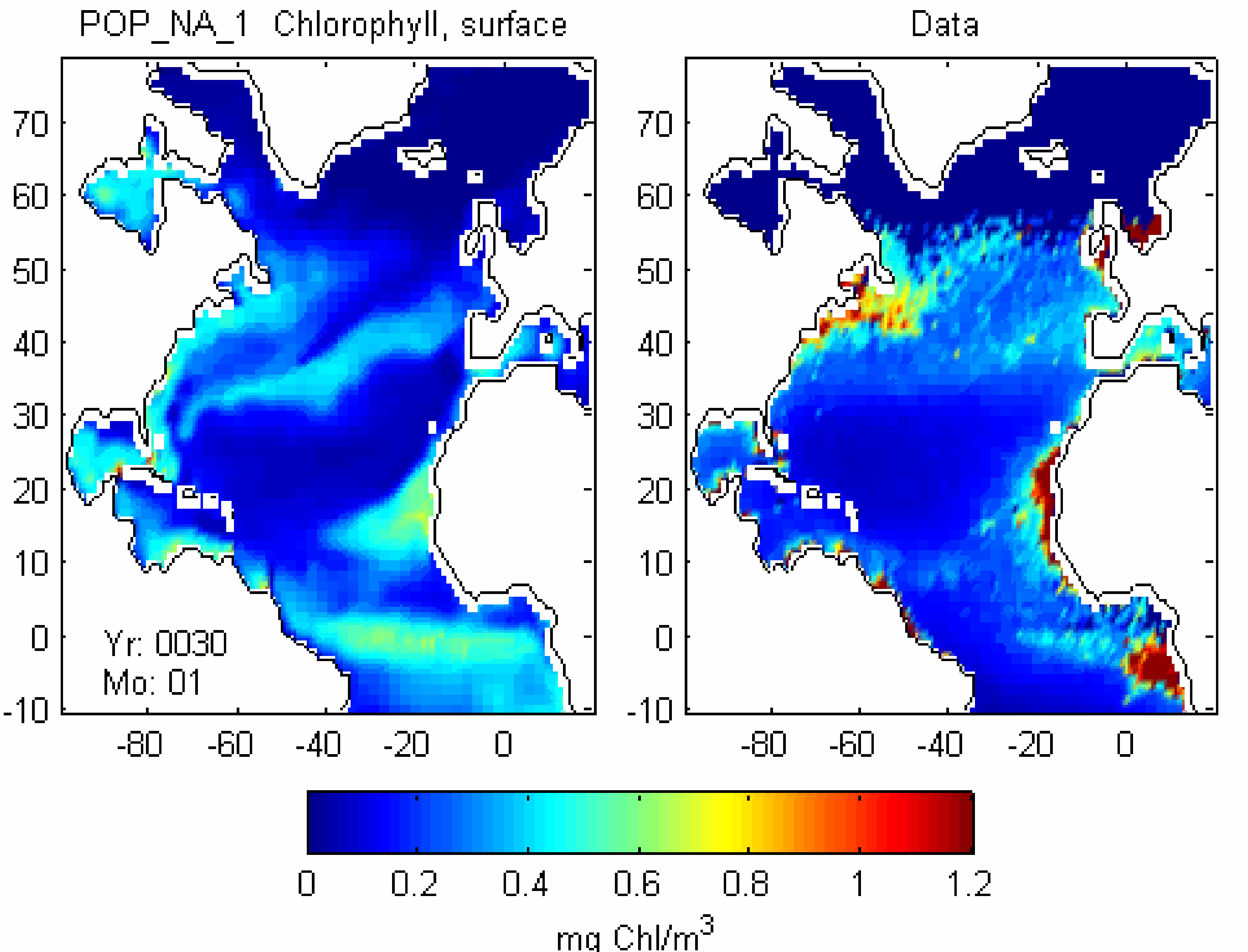
- Climatological monthly mean temperature and salinity (I. Yashayaev, Bedford Institute of Oceanography).
- Northern and Southern boundaries are closed with sponge layers at which the water temperature and salinity are relaxed to climatological values.

The Ecosystem Model

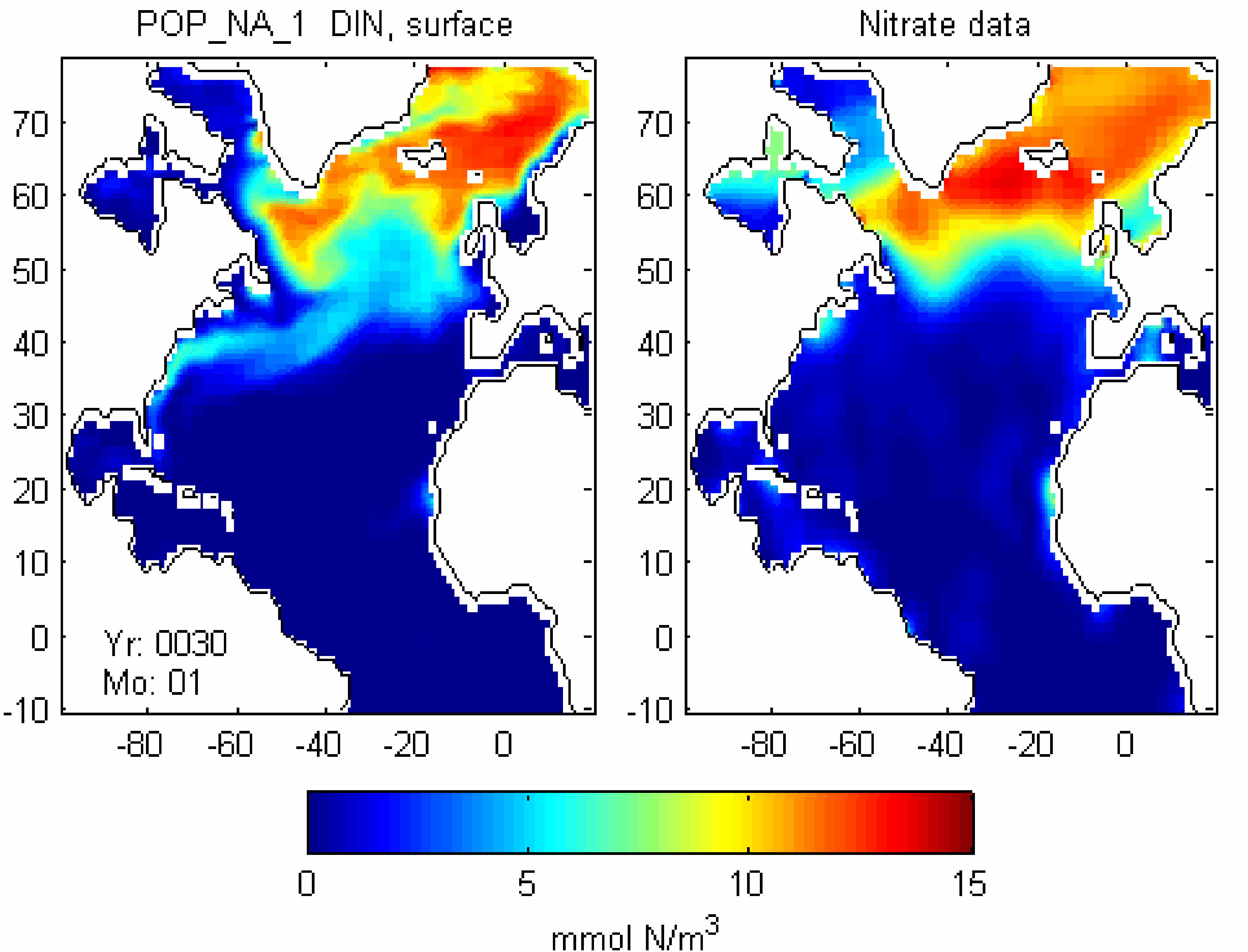


Biological boundary and initial condition

- Climatological seasonal mean nitrate estimates (World Ocean Database, 1998)
- Climatological monthly mean chlorophyll estimates obtained by averaging SeaWiFS data over the period 1997-2003.
- Z_{init} = 0.02 and decreases exponentially with the depth.
- D_{init} = 0.1



POP_NA_1 Chlorophyll, surface
Data
70
60
50
40
30
20
10
0
-10
-80
-60
-40
-20
0
Yr: 0030
Mo: 01
0
0.2
0.4
0.6
0.8
1
1.2
mg Chl/m3

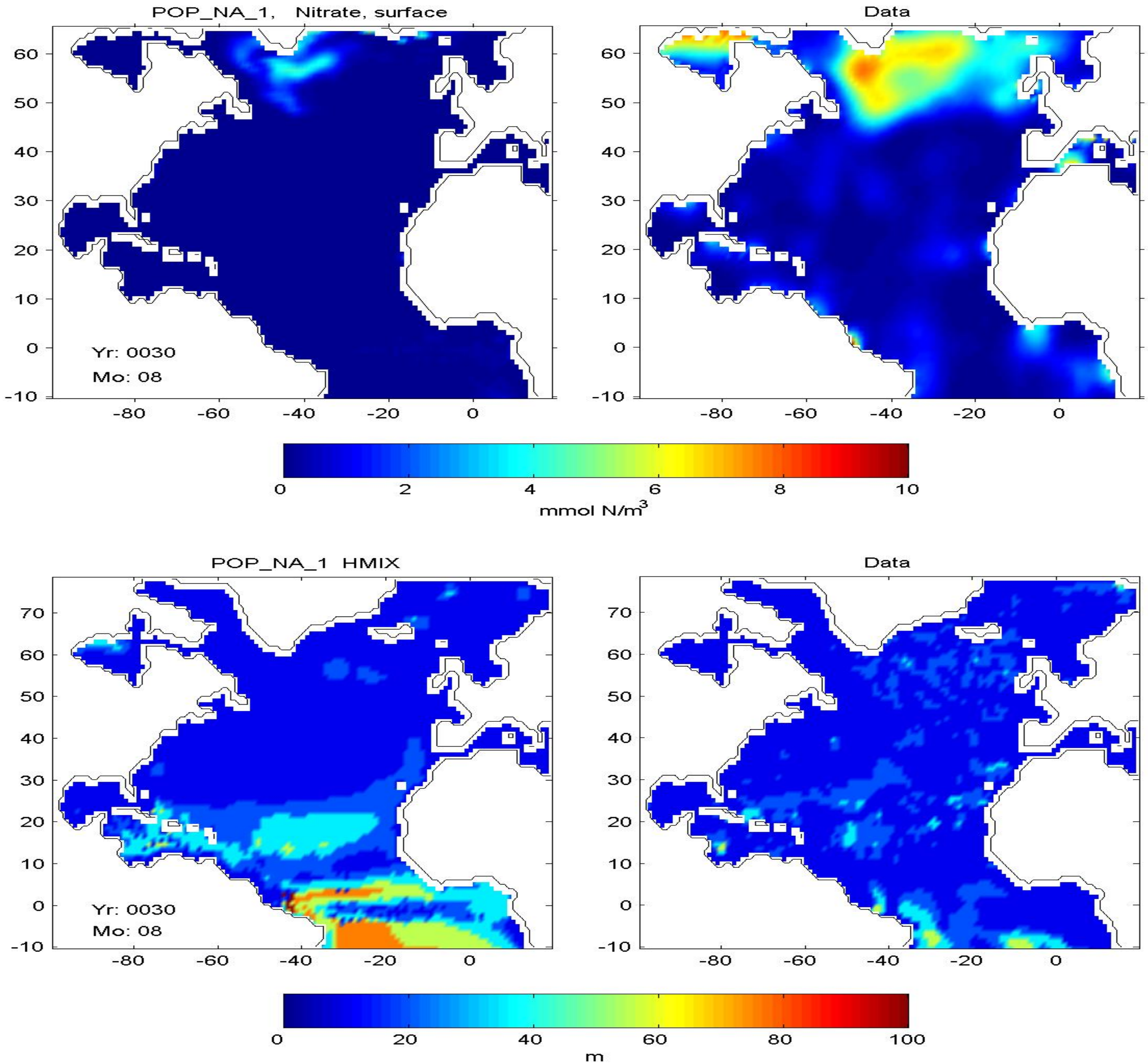


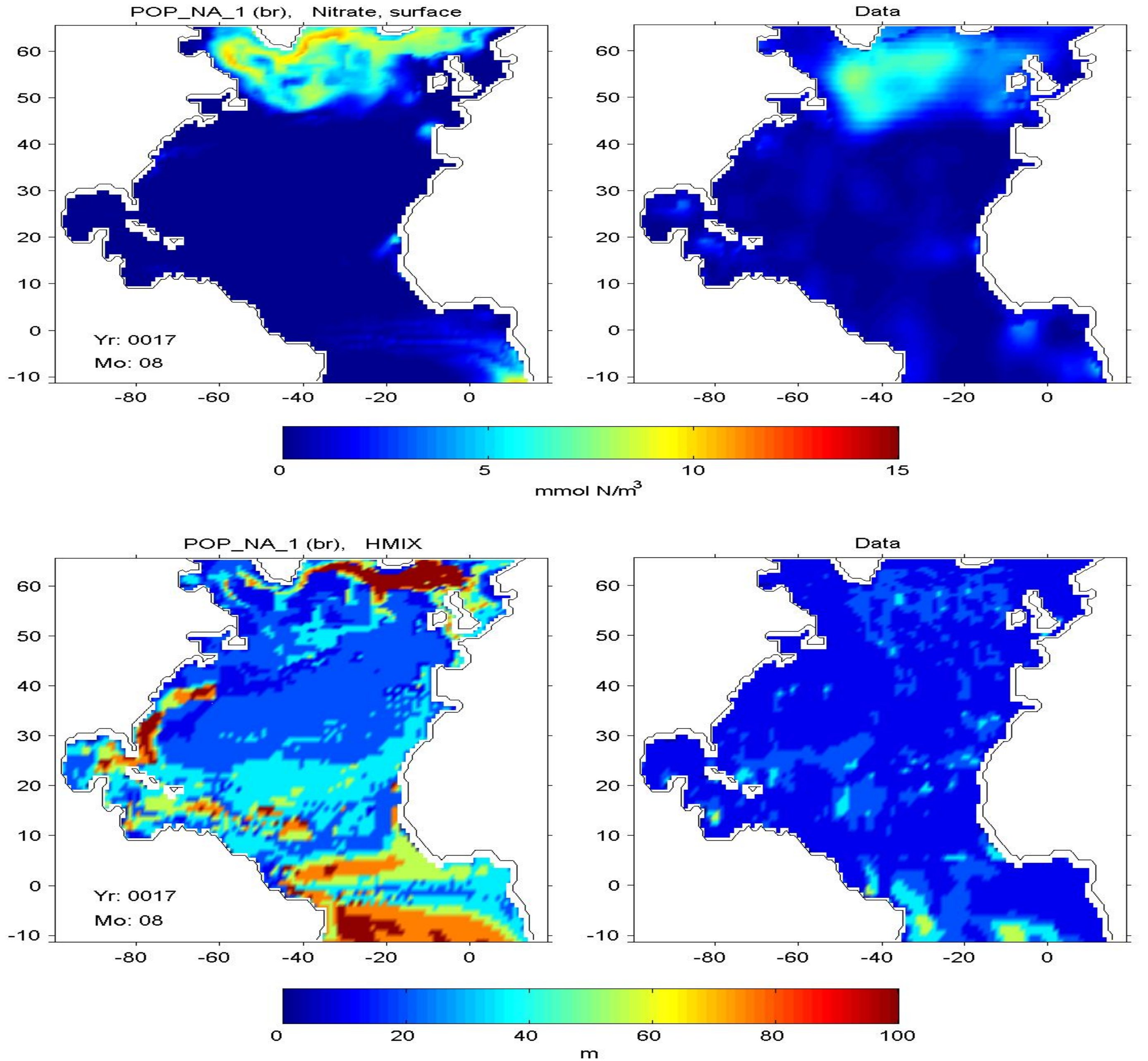
POP_NA_1 DIN, surface
Nitrate data
70
60
50
40
30
20
10
0
-10
-80
-60
-40
-20
0
Yr: 0030
Mo: 01
0
5
10
15
mmol N/m3

The model has captured essential features of the ocean phytoplankton dynamics:

- a strong seasonal cycle in biological productivity in the mid- to high latitudes in the N. Atlantic;
- phytoplankton biomass remains low and relatively invariant year-round in the subtropical to equatorial parts of the basin (except for regions of elevated biomass along west Africa and the equator);
- subsurface chlorophyll maximum.

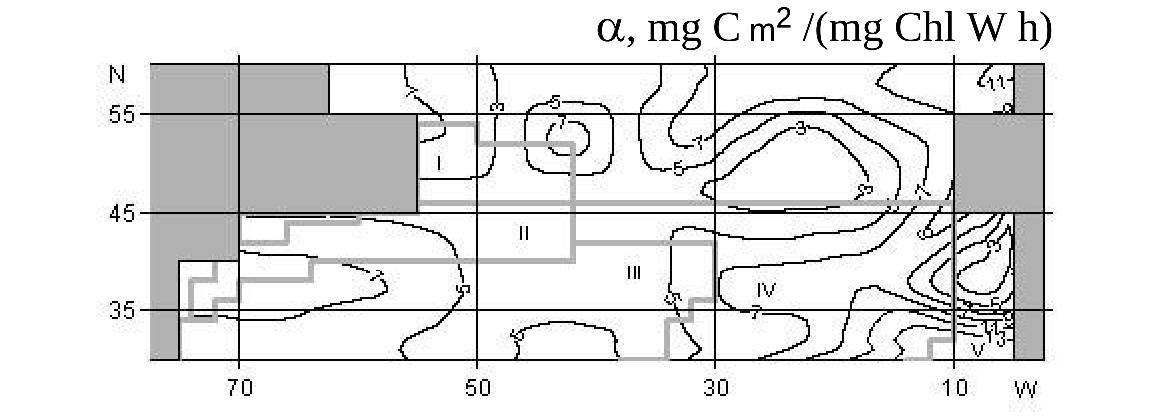
The coupled model had difficulty simulating the nitrate seasonal cycle.


POP_NA_1, Nitrate, surface
Data
Yr: 0030
Mo: 08
mmol N/m3
POP_NA_1 HMIX
Data
Yr: 0030
Mo: 08
m


POP_NA_1 (br), Nitrate, surface
Data
Yr: 0017
Mo: 08
mmol N/m^3
POP_NA_1 (br), HMIX
Data
Yr: 0017
Mo: 08
m

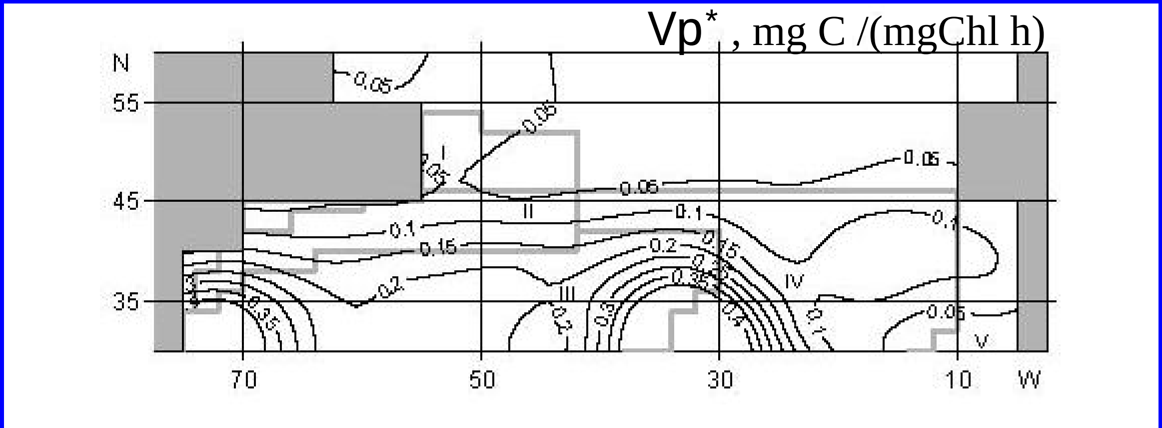
Horizontal distribution of optimized model parameters

(Losa, Kivman and Ryabchenko/Journal of Marine System, 2004)



Kyewalyanga et al., 1998

	I	II	III	IV	V
spring	3.30 +- 2.63	6.01 +- 2.35	6.88 +- 3.30	8.23 +-2.62	6.64 +-3.37
autumn	2.24 +- 1.56	4.51 +- 2.09	4.58 +- 2.32	4.43 +-2.68	4.88 +-1.28

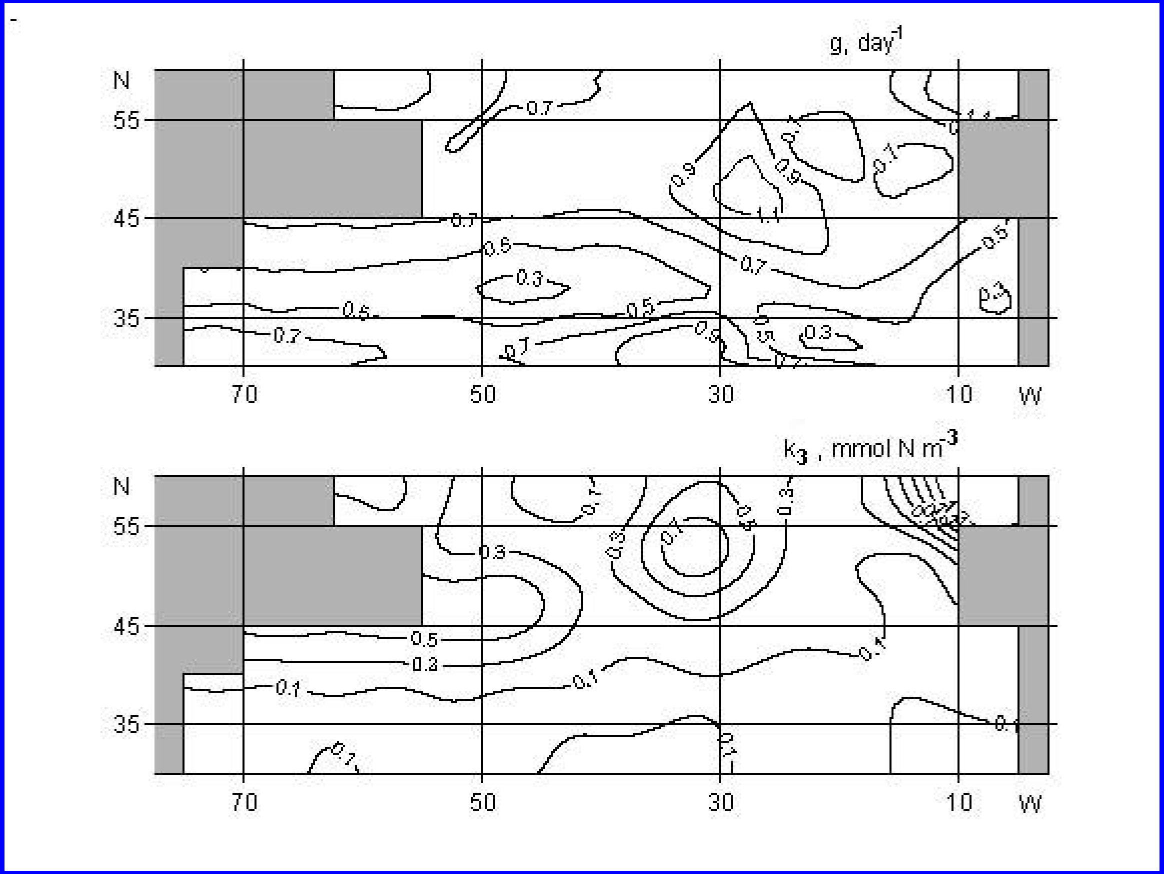


Kyewalyanga et al., 1998

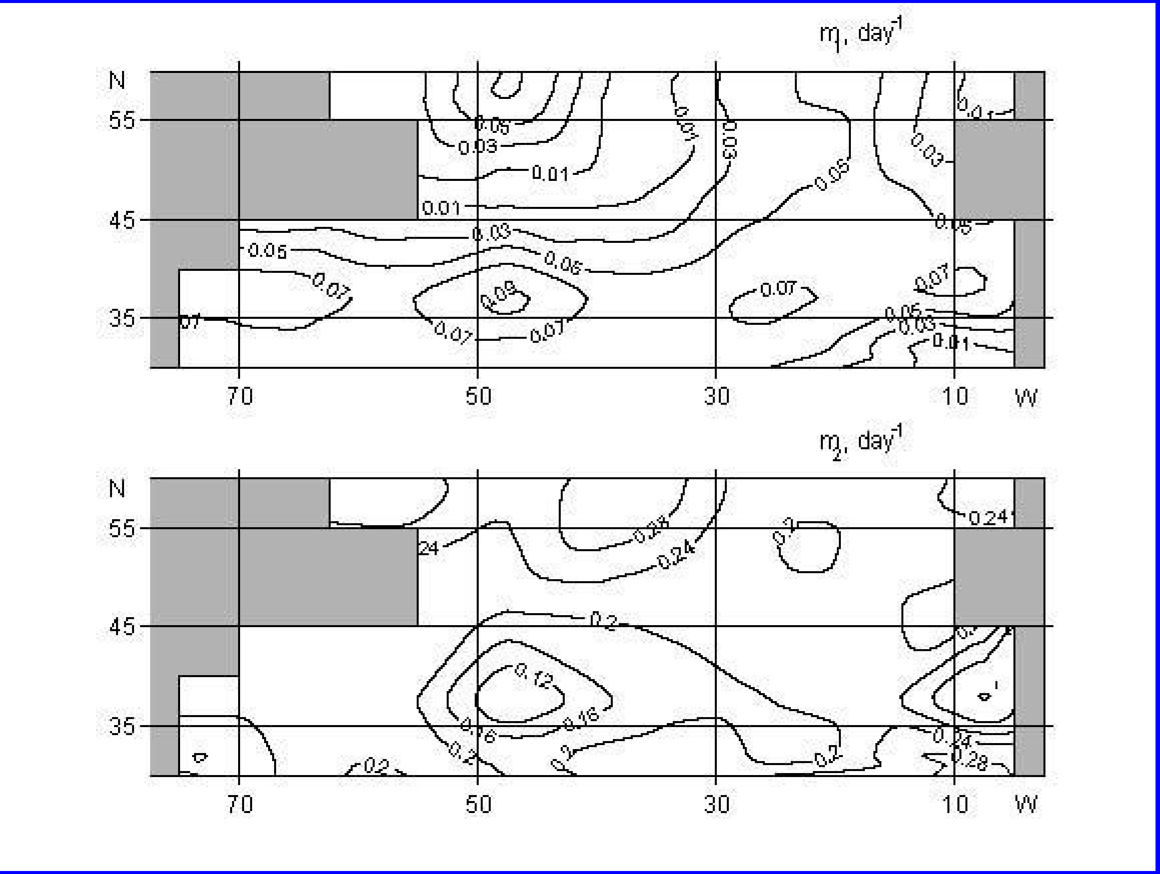
	I	II	III	IV	V
spring	0.073 +- 0.048	0.100 +- 0.045	0.075 +- 0.028	0.078 +-0.025	0.069 +-0.032
autumn	0.019 +- 0.007	0.040 +- 0.020	0.037 +- 0.006	0.049 +- 0.037	0.023 +-0.008

Horizontal distribution of optimized model parameters

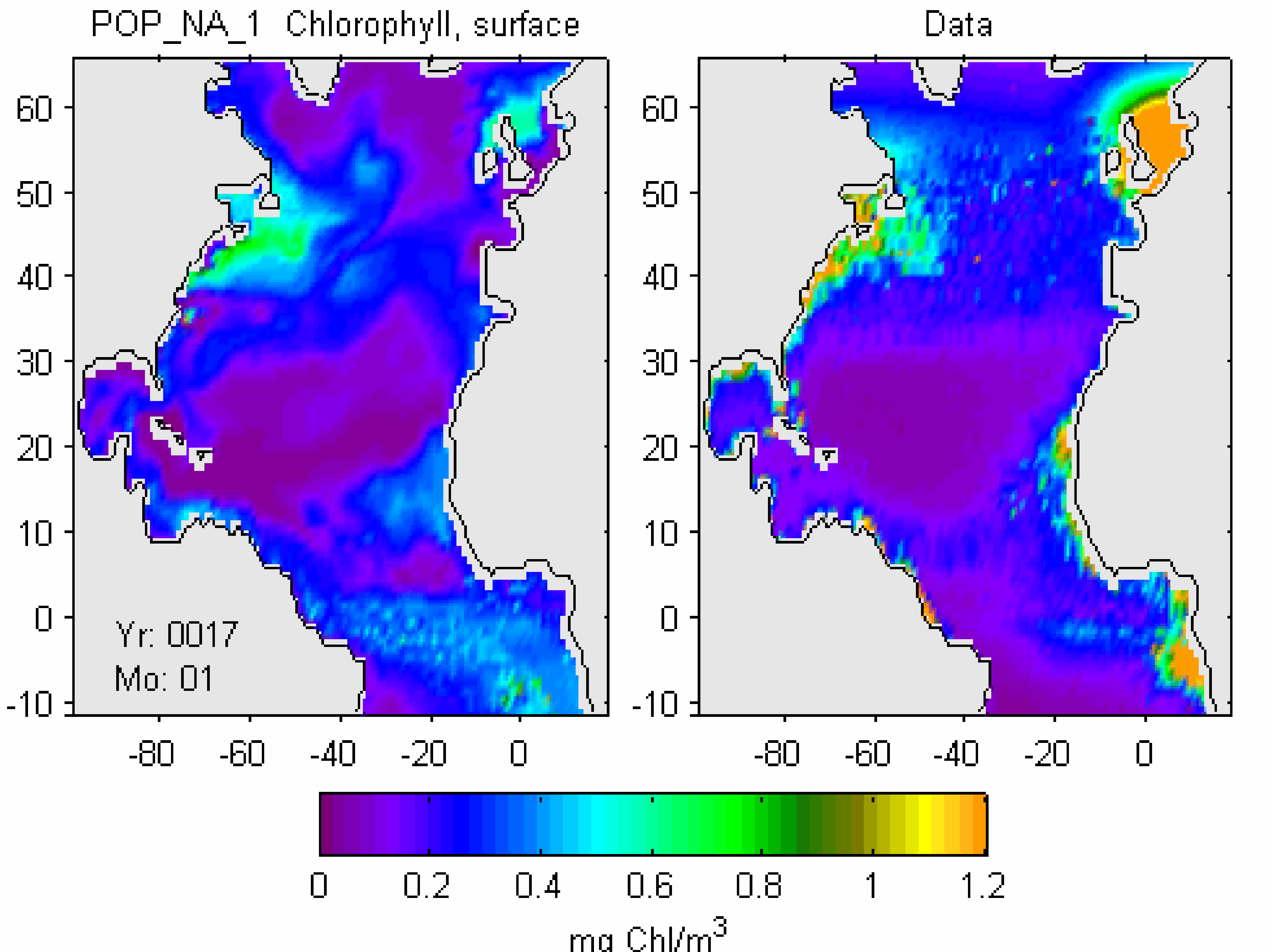
(Losa, Kivman and Ryabchenko/Journal of Marine System, 2004)



Horizontal distribution of optimized model parameters
(Losa, Kivman and Ryabchenko/Journal of Marine System, 2004)



The spatial distribution of the parameters is, obviously, a result of a combined effect of several factors such as solar irradiance, temperature, etc., which may affect latitudinal changes of chemical conditions and plankton species composition. However, it is rather difficult to distinguish which of the physical and biological factors, and in which region, contributes more to the spatial varyability of the physiological model parameters.



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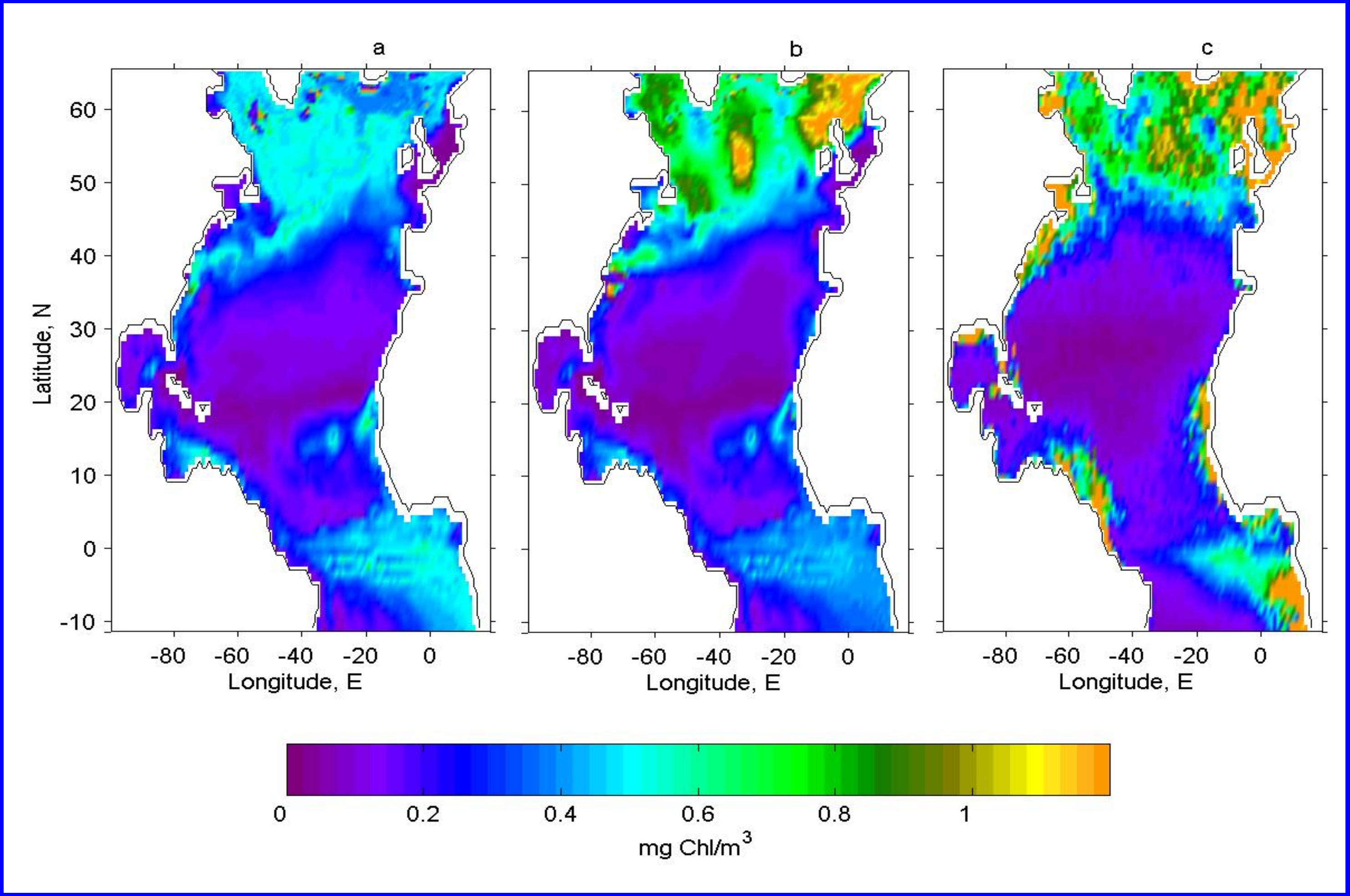
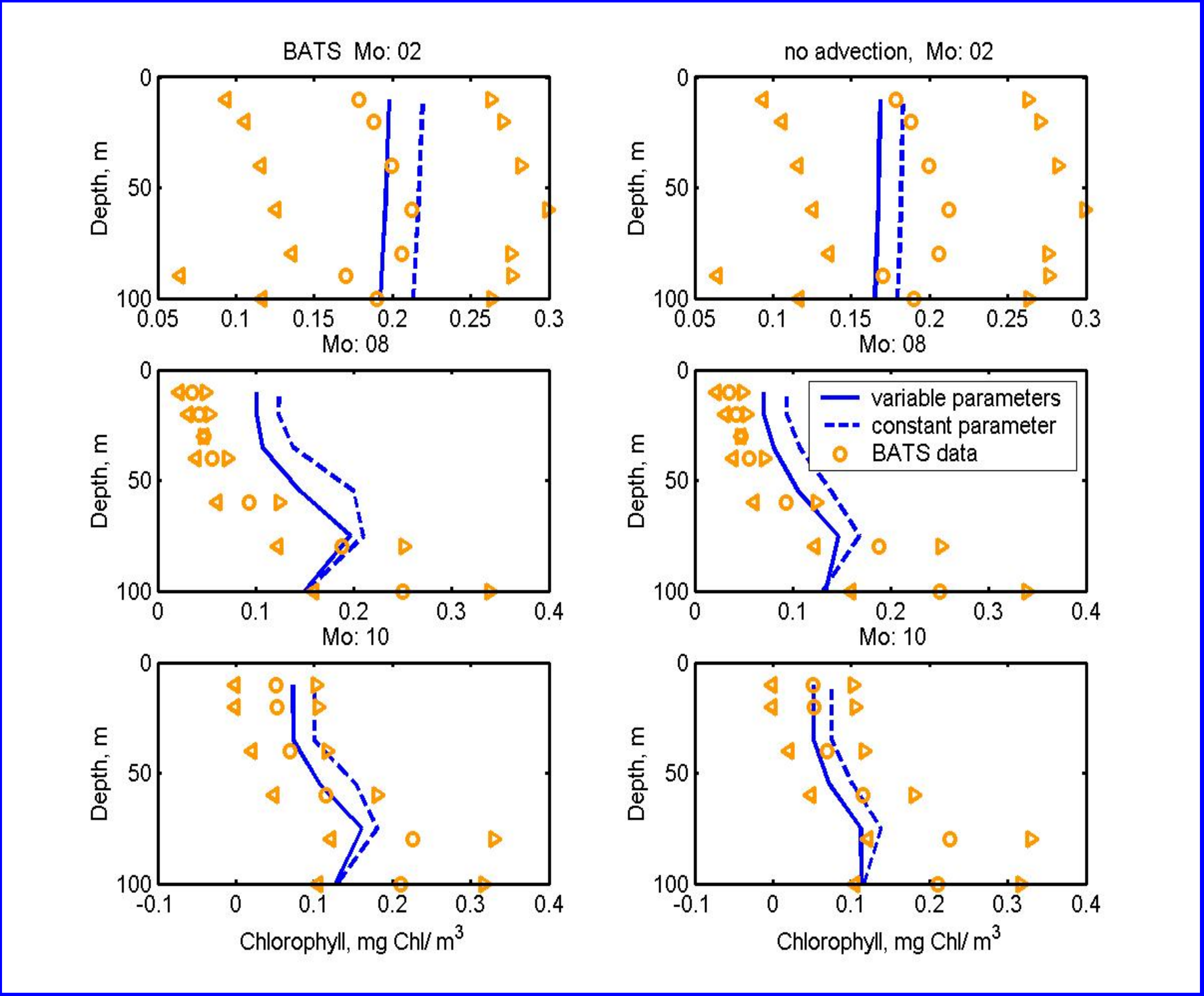
August horizontal distribution of the surface chlorophyll "a" concentration (mgChl m^{-3}) in the North Atlantic



a) the model solution obtained with constant biological parameters; b) the model solution obtained with spatially variable biological parameters and c) SeaWiFS (http://seawifs.gsfc.nasa.gov/SEAWIFS.html) data averaged over 1997-2003.

Chlorophyll vertical profiles



Conclusions

Using some of the biological parameters, - previously considered as constants, - spatially variable allows to get a significant improvements in the model-data agreement

- Relationships between physical and biological patterns appears to be different in physically distinct regions.
- Parameterization of the different biological respond to the variability in physics, under different environmental conditions, still remains of a real challenge.
- Correct formulation of data assimilation problem for biology is a powerful tool for investigating mentioned above problem, as well as for forecasting purposes.