Estimating biological parameters of a size-dependent NPZD ecosystem model

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Abstract

A new 1-dimensional 4-compartment biogeochemical model is developed by I. Kriest and A. Oschlies within the MERSEA project. Implicitly accounting for phytoplankton different size classes, the new model is one more attempt to describe the dynamics of phytoplankton Ph, zooplankton Z, nutrients N and detritus D under different physics given one (a unique) set of biological parameters. The model is calibrated with and validated against time series data collected at 6 locations of the World Ocean. Here we apply the Sequential Importance Resampling filter (Rubin, 1988) for the parameter optimization problem (Kivman, 2003). Several nonparametrical statistics criteria are presented and used for estimating "goodness" of the model to data fit.

1 Model

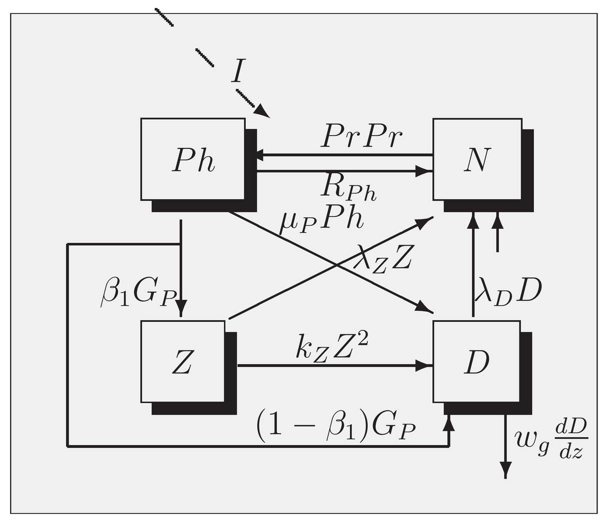

Figure 1. NPZD model schematic diagram.

In the model, phytolpankton is presented by a spectrum of different sizes. Thus, some of the parameterized biogeochemical process- in particular, phytoplankton growth and exudation,- are size-dependent. (We will refer to the model as SD NPZD).

2 Data

The model is constrained by monthly mean data of

- the Bermuda Atlantic Time-series Study (BATS $32^0 N$, $65^0 W$),
- Ocean Weather stationPAPA ($50^0 N$, $145^0 W$),
- Equatorial Pacific Ocean (EqPac, $0^0 S$, $140^0 W$),
- the North Atlantic Bloom Experimen (NABE, $47^0 N$, $20^0 W$),
- the Arabian Sea C station (AS-C, $10^0 N$, $65^0 E$),
- the Ross Sea ($63.2^0 S$, $170^0 W$)

particularly, by measurements of dissolved inorganic nitrogen and chlorophyll concentrations.

3 Model calibration and validation

Nonparametrical (distribution free) rank statistics (based on "rank order") is used as criteria of "goodness" of model-to-data fit:

r_{sp} – Spearman Rank Correlation Coefficient, a measure of the strength of the associations between model components and data

r_{sp} = 1-6 $\sum \frac{d^2}{N(N^2-1)}$,
d are differences in statistical ranks of respective variables

W – Wilcoxon test shows whether the model solution and data are of the same distributions (have same median value)

W = (T - 0.25N(N-1) $\pm$ 0.5)$\sqrt{\frac{24}{N(N-1)(2N+1)}}$,
T is a sum of negative (or positive) ranks,
N is the number of data

MW – Mann-Whitney U criterion tests whether all modes of data distribution and distribution of model results are similar and sampled equally well

U = N^2 + $\frac{N(N+1)}{2}$ - R_1,
MW = (U - 0.5N^2) $\sqrt{\frac{12}{N^2(2N+1)}}$,
R1 is the sum of model (or data) ranks

Optimized model parameters

Symbol	Parameter, P	Initial value	Optimal value	Units
α	Initial slope of the P-I curve	0.025	0.05	$(W\ m^{-2})^{-1}$
μ_P	Phytoplankton mortality	0.03	0.01	day^{-1}
μ_Z	maximum zooplankton grazing rate	2.00	1.05	day^{-1}
k_G	Zooplankton ingestion half-saturation constant	0.50	0.50	$mmol N\ m^{-3}$
k_Z	quadratic zooplankton mortality	0.20	0.42	$mmol N\ m^{-3}$
λ_Z	Zooplankton excretion rate	0.03	0.026	day^{-1}
λ_D	detritus remineralization rate	0.05	0.068	day^{-1}

Parameter optimization method

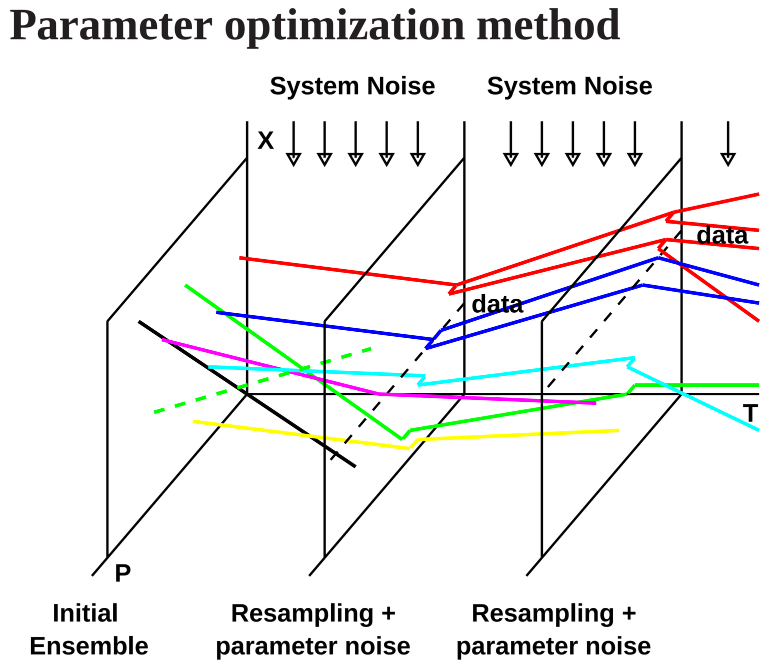

Figure 2. (to the right) SIRF scheme. X = { N, Ph, Z, D}. Probability on the k ensemble $\psi = \{X, P\}$ member to be resampled is equal to $w^k = p(d|\psi_k)/\sum p(d|\psi_k)$, $p(d|\psi_k) = (1 + (X^k - data)^2 \sigma_{data}^{-2})^{-1}$, σ_{data} is the error levels of the observations.

4 Results *of simultaneous tuning the size dependent NPZD model for all the noted locations*

Model forcing: solar radiation is calculated according to Brock (1981); mixing is assumed to be 2592 $m^2 d^{-1}$ in the upper mixed layer (monthly mean upper mixed layer depths are extracted from Levitus, 1994), then decreasing within 10m to 2.592 $m^2 d^{-1}$; nitrate concentrations at the upper boundary of the seasonal pycnocline are taken from Conkright et al (2002).

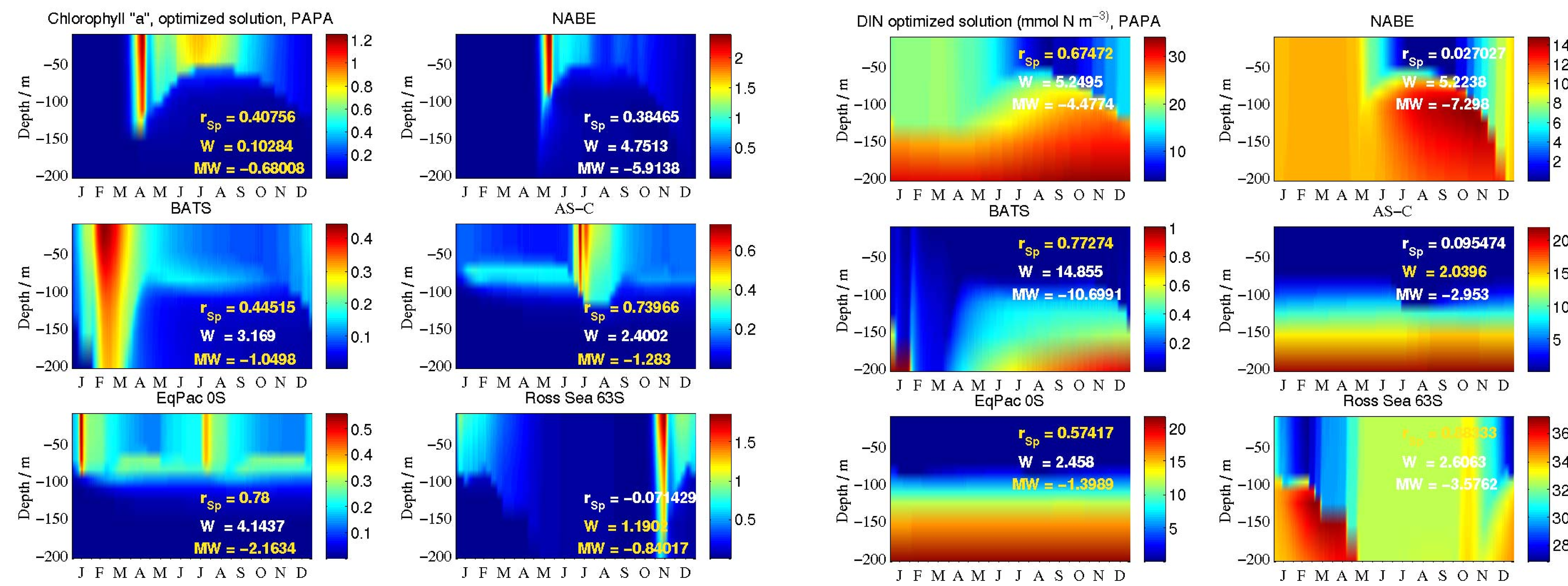

Figure 3. Chlorophyll "a" and dissolved inorganic nitrogen simulated by the size-dependent NPZD eco model at 6 sites.

The statistics criteria values of yellow color indicate sufficient agreement between model and observed concentrations, with respect to a certain criterion.

Comparing the quality of SD NPZD ecosystem model performance against a similar experiment carried out with a simple (not account for phytoplankton size structure) NPZD model version.

Table 1. Agreement between model (simple and SD versions) and observed chlorophyll "a"

Stat. criteria	PAPA		NABE		BATS		AS-C		EqPac.		Ross Sea	
	simple	*SD*	*simple*	*SD*	*simple*	*SD*	*simple*	*SD*	*simple*	*SD*	*simple*	*SD*
r_{sp}	0.72	0.41	0.88	0.38	0.05	0.45	-0.19	0.74	0.79	0.78	-0.07	-0.07
MW	-3.98	-0.68	-6.65	-5.91	-18.58	-1.05	-1.95	-1.29	-0.16	-2.16	-0.84	-0.84
W	2.92	0.10	4.77	4.75	11.97	3.17	1.77	2.4	1.53	4.14	0.91	1.19
notes					*improved*		*improved*					

Table 2. Agreement between model (simple and SD versions) and observed DIN concentrations

Stat. criteria	PAPA		NABE		BATS		AS-C		EqPac.		Ross Sea	
	simple	*SD*	*simple*	*SD*	*simple*	*SD*	*simple*	*SD*	*simple*	*SD*	*simple*	*SD*
r_{sp}	0.52	0.67	0.51	0.027	0.59	0.77	-0.60	0.095	0.56	0.57	-0.90	-0.90
MW	-9.15	-4.47	-7.30	-7.30	-9.85	-10.7	-4.55	-2.95	-2.41	-1.40	-3.50	-3.57
W	7.77	5.25	5.22	5.22	10.30	14.85	3.28	2.04	6.27	2.45	2.60	2.60
notes	*improved*						*improved*		*improved*			

5 Conclusions

Even with the slightly improved version of the biogeochemical model, it is still hardly, if ever, possible to reproduce the observed ecosystem dynamics under different environmental conditions given just one biological parameter set.

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