

Laura Gómez-Rodríguez
Odeya Bay, September 2013

Biogeochemical controls on the Black Sea oxygen dynamics.

Diagnostics, processes and monitoring strategies

Capet Arthur, Luc Vandenbulcke, Marilaure Grégoire

MAST-FOCUS, Liège University

General Context

General Context

Objectives

Sensitivity Analysis

Conclusions

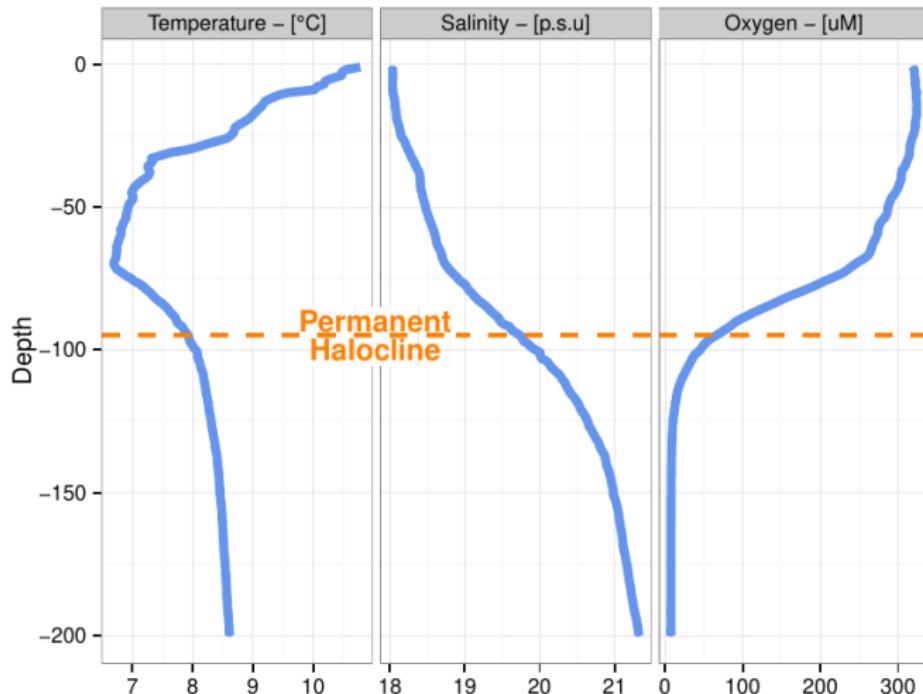
General Context

A sensitive environment



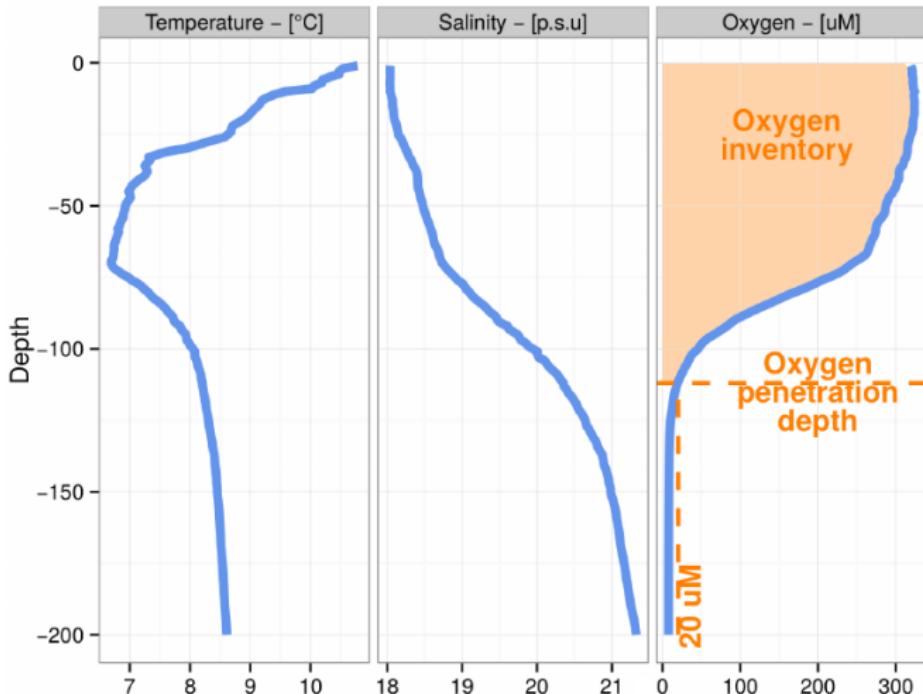
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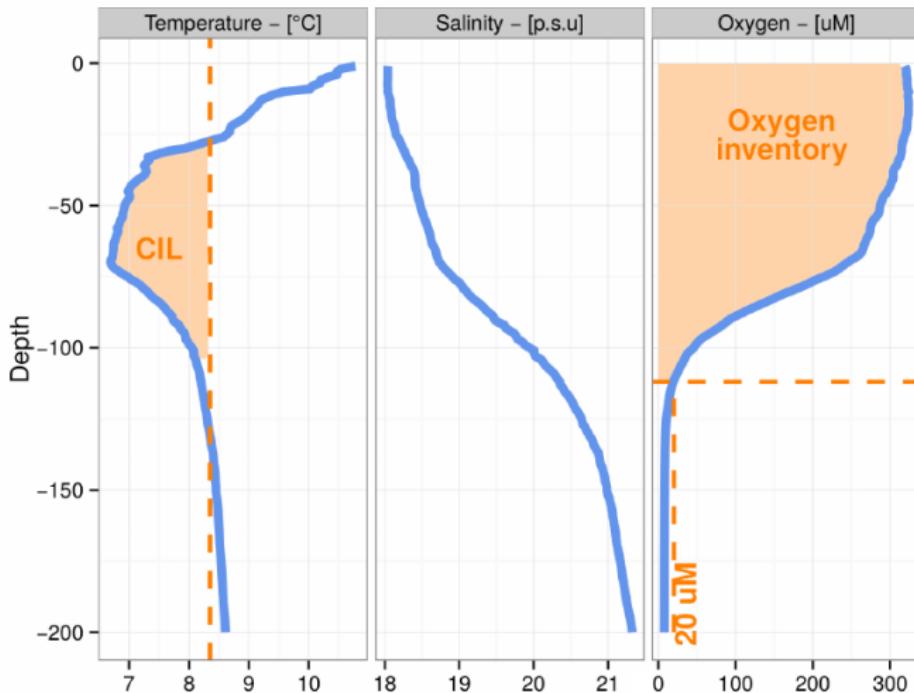
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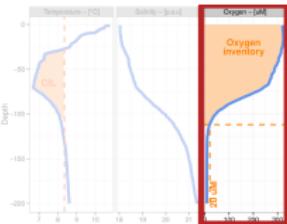
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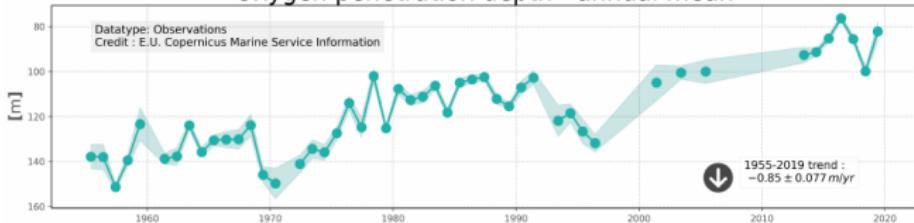


General Context

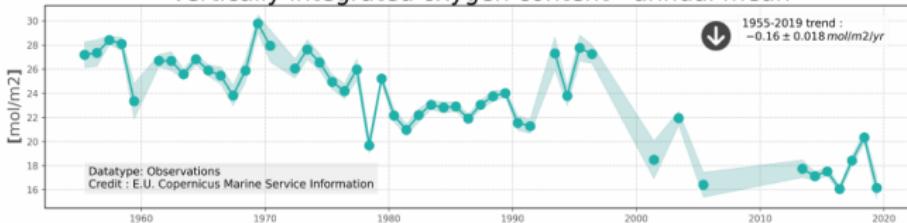
Oxygen decline



Oxygen penetration depth - annual mean



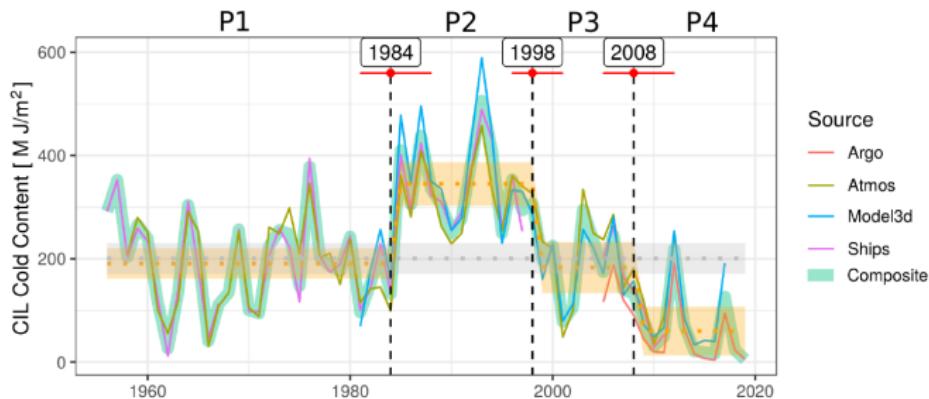
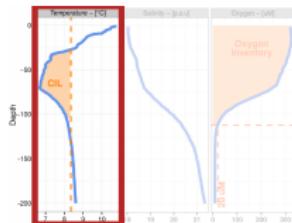
Vertically integrated oxygen content - annual mean



General Context

Oxygen decline : Processes

Ventilation by Cold Water formation.

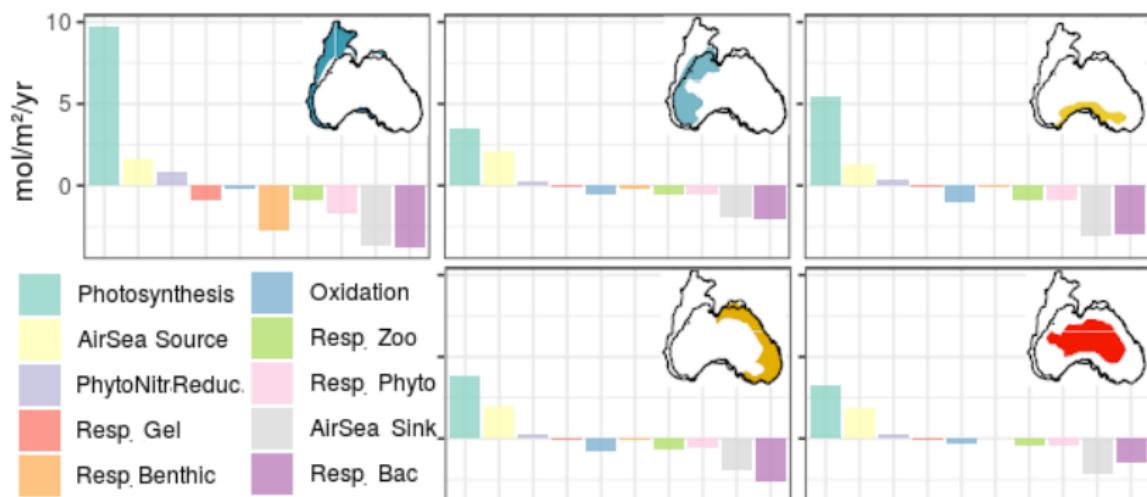


General Context

Oxygen decline : Processes

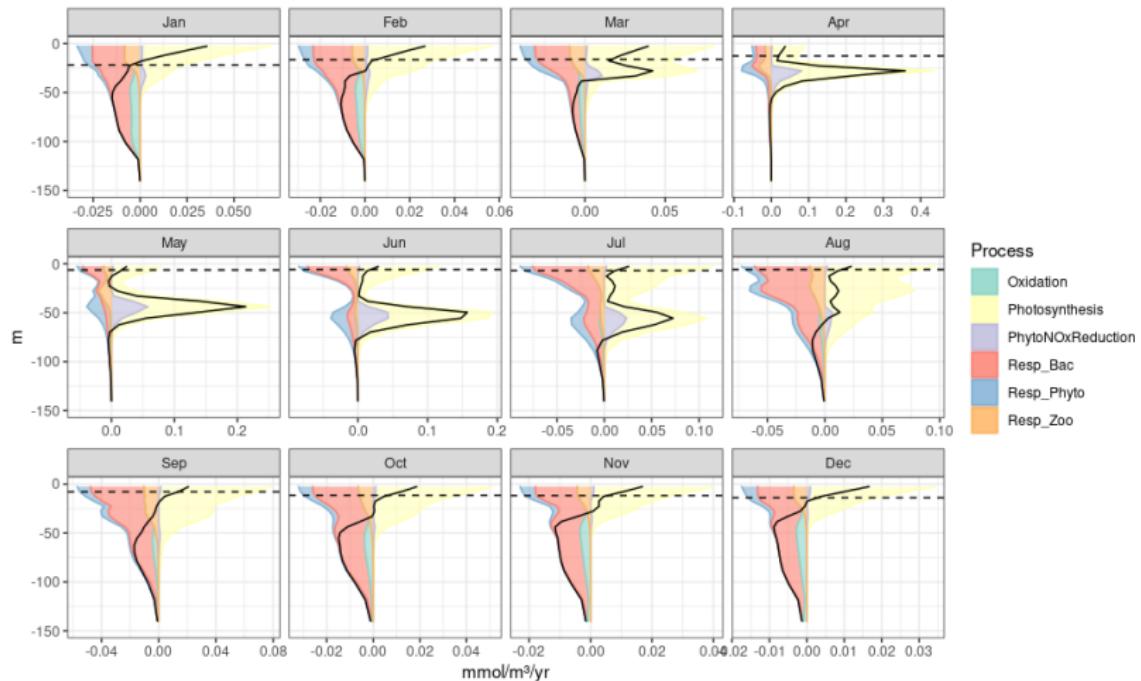
Biogeochemical Sink/Source Terms

- Interface Fluxes
- Photosynthesis
- Respiration
- Oxidation



General Context

Oxygen decline : Processes



Objectives

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Sensitivity Analysis

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Objectives

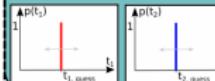
The Albatros Project

- ◊ Better constrain BGC terms in the O₂ budget.
- ◊ Parameter-based stochastic approach.
- ◊ Enable long-term training of parameter local variations.

WP1: Sensitivity

- Define key environmental diagnostics
- Select key parameters, upon:
 - Sensitivity of key diagnostics
 - Identifiability under the constraint of Argo biogeochemical profiles

Perturbation of determinist parameters



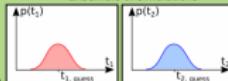
1D Simulations

WP2: Stochasticity

- Implement a stochastic version of the biogeochemical model to represent
 - Uncertainty on parameters
 - Unresolved scales
- Ensemble simulations for the Argo era to assess
 - Uncertainty on key environmental diagnostics
 - Lateral transport terms in the Argo framework

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 - Lateral transport terms in the Argo framework
- Stochastic model uses "unconstrained" marginal distributions for parameters
-> Ensemble of simulations



3D Simulations

WP3: Learning

- Setup of the 1D Lagrangian frame
- Infer joint parameter distributions constrained on the basis of Argo data
- Compile a referenced database of constrained parameter distributions

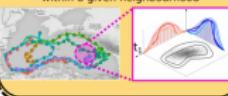
Local joint parameter distributions are constrained by Argo observations



WP4: Assimilation

- Identify neighbourhood within which local distributions present similarities
- Compose mixture distributions
- Proof-of-concept experiment

Stochastic model uses constrained joint distributions for parameters, composed as a mixture of the local distributions gathered within a given neighbourhood



Objectives

First Task : Sensitivity analysis

Given a set of key processes :

- ◊ Which model parameters should we focus on?
Sensitivity
- ◊ Can we constrain these parameters from samplings?
Controlability

Sensitivity Analysis

General Context

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Conclusions

Sensitivity Analysis

Setup

- ◊ 1D simulations of BAMHBI (CMEMS BS-MFC-BIO¹)
- ◊ Fixed position, annual simulation.
- ◊ 3D simulations to
 - Impose physics.
 - Extract IC.
 - Assess 1D framework.
 - Extract pseudos-observations.

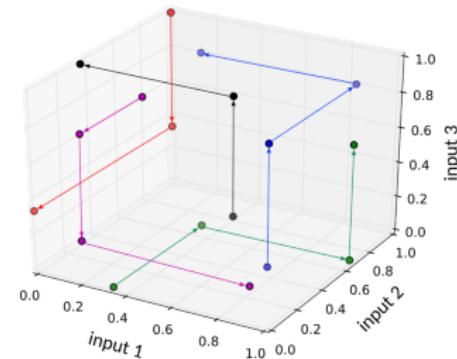
Sensitivity Analysis

Parameter perturbation

Global sensitivity analysis

→ Morris Screening

Parameter perturbations (50–150%)



- ◇ 188 parameters x 40 repetitions → 7440 1D simulations.

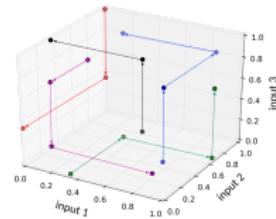
Sensitivity Analysis

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Parameter perturbations (50–150%)



- ◇ 188 parameters x 40 repetitions → 7440 1D simulations.
- ◇ For any model output y :

$$SEE_i^j(y) = \frac{y(x_1, \dots, x_i + \Delta, \dots, x_p) - y(x_1, \dots, x_i, \dots, x_p)}{\Delta} \cdot \frac{\sigma_{x_i}}{\sigma_y}$$

- ◇ which is summarized as :

$$\mu_i^*(y) = \frac{1}{r} \sum_j |EE_{i,j}^k|$$

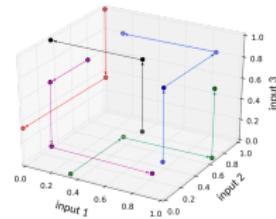
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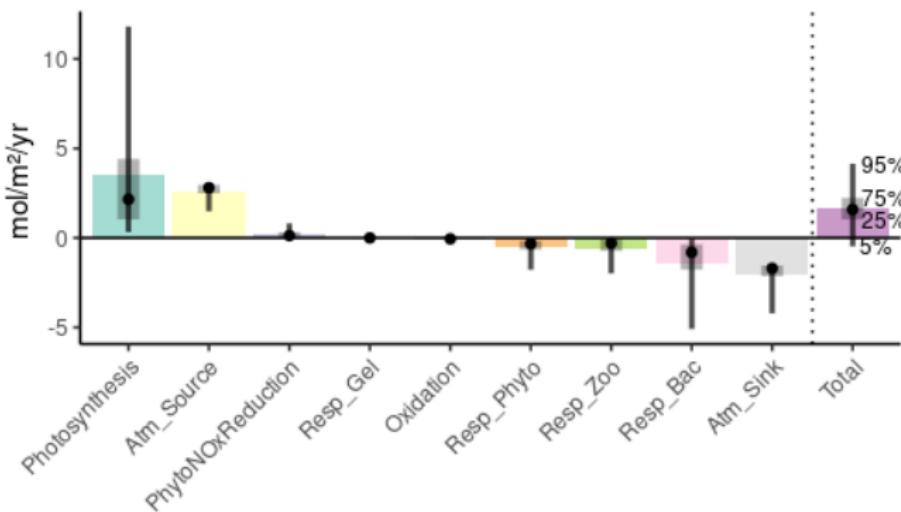
$$\mu_i^*(y) = \frac{1}{r} \sum_j |EE_{i,j}^k|$$

- ◇ Sensitivity and Controlability are addressed with specific y

Sensitivity Analysis

Parameter perturbation

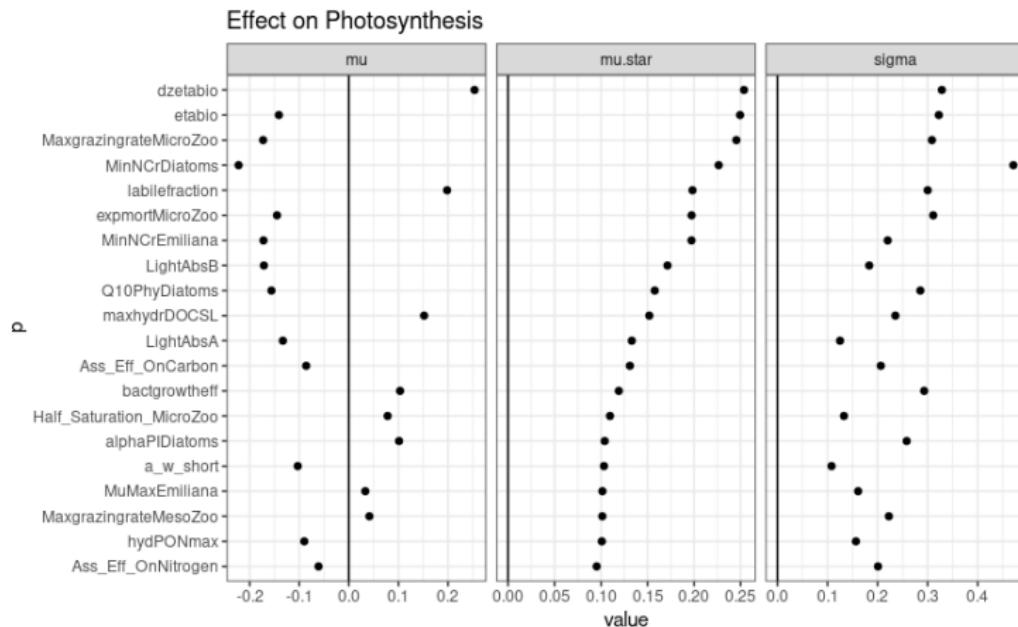
For **Sensitivity** we consider the O_2 sources/sink terms.



Sensitivity Analysis

Parameter perturbation

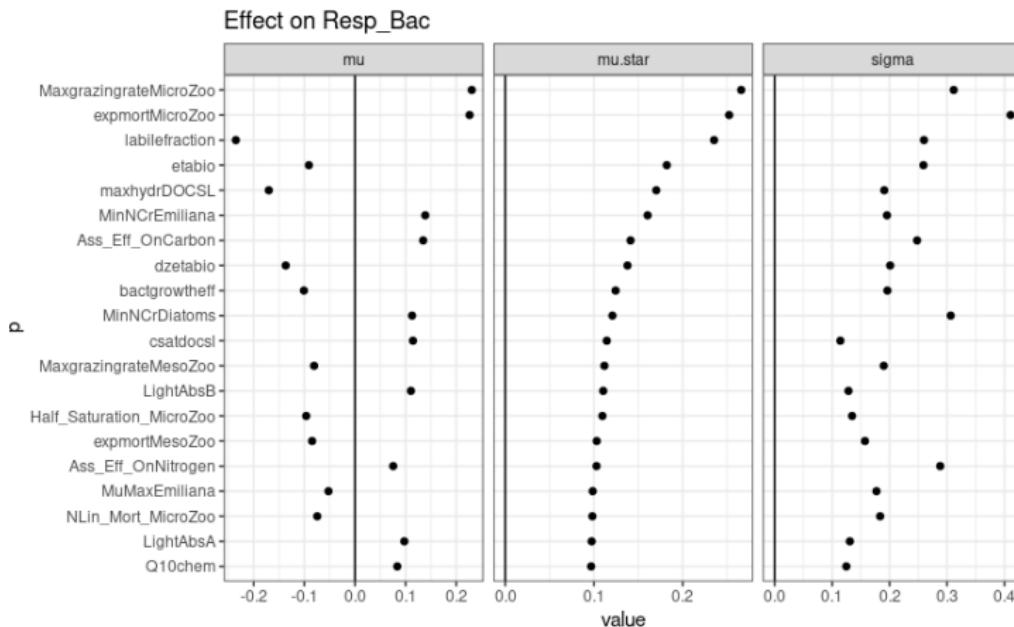
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Sensitivity Analysis

Parameter perturbation

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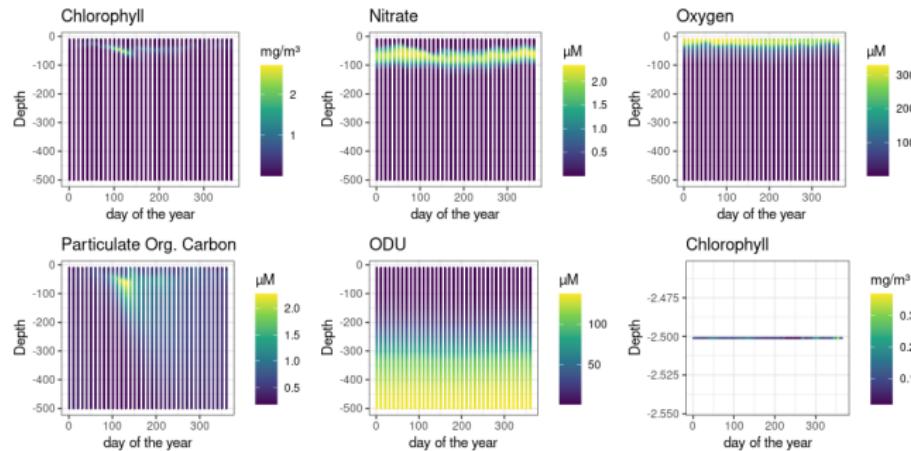


Sensitivity Analysis

Parameter perturbation

For **Controlability** we consider common ocean obs.

Sampling	Variable	Depth	Day of year	Mean	Std.	Coef. Var.
Sat	Chl	Surface	1d	0.10	0.05	0.50
Argo.C	Chl	10:1:500	10d	0.03	0.14	4.76
Argo.N	NOx	10:1:500	10d	0.22	0.56	2.57
Argo.O	O2	10:1:500	10d	21.76	65.28	3.00
Argo.P	POC	10:1:500	10d	0.51	0.28	0.55
Argo.U	ODU	10:1:500	10d	59.64	53.08	0.89

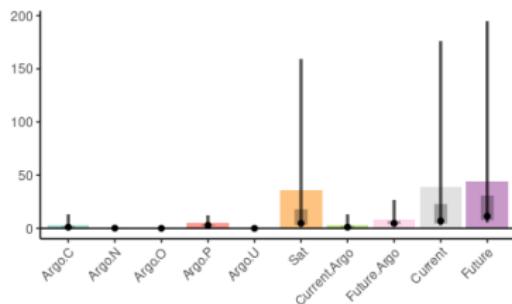


Sensitivity Analysis

Parameter perturbation

$$C_V = \frac{1}{N_v} \sum_{i=1}^{N_v} \left(\frac{V_i^O - V_i^M}{\sigma_{v^O}} \right)^2$$

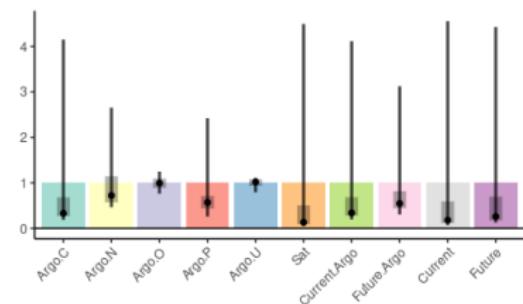
$c = \sum C_V$, for multivar.



Range of values.

Multi-var. sets :

	Argo.C	Argo.N	Argo.O	Argo.P	Argo.U	Sat
Current.Argo	X					
Current	X					
Future.Argo		X	X			X
Future	X	X	X	X	X	X



Divided by mean value.

Sensitivity Analysis

Parameter perturbation

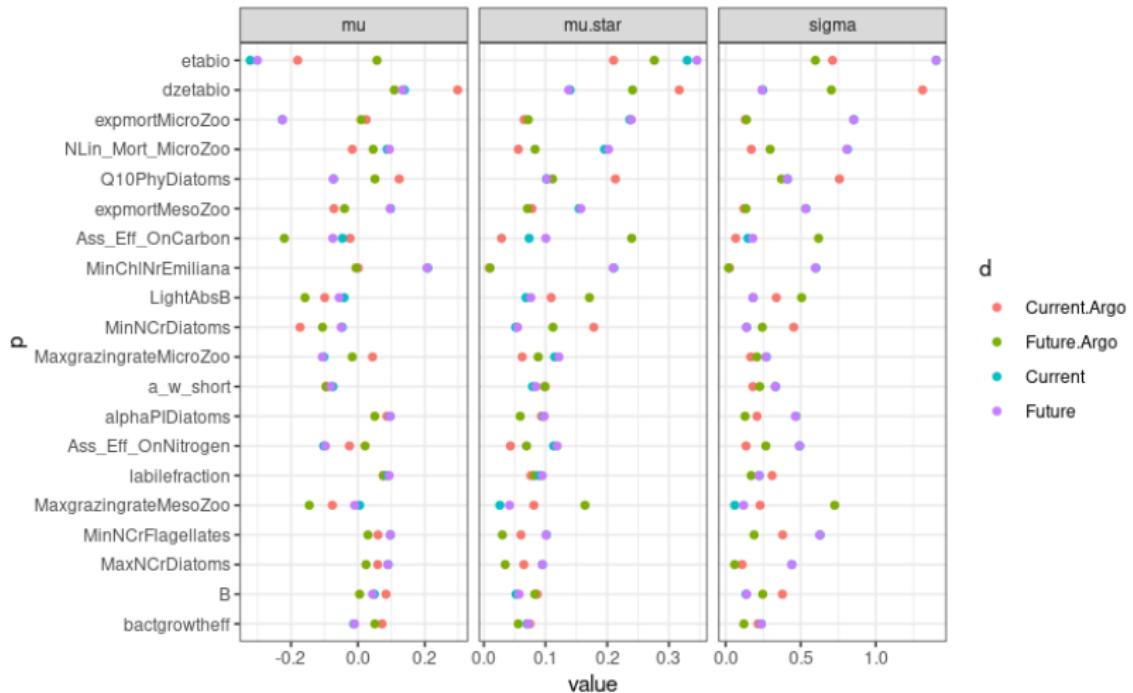
variable	mean.cost	sd.cost	CV.cost	Nobs	mean.sRMS	mean.RMS
Argo.C	3.17	7.60	2.40	18167	1.78	0.26
Argo.N	0.27	0.18	0.67	18167	0.52	0.29
Argo.O	0.04	0.01	0.15	18167	0.19	12.53
Argo.P	5.07	13.92	2.75	18167	2.25	0.63
Argo.U	0.00	0.00	0.15	18167	0.04	2.25
Sat	35.45	111.57	3.15	365	5.95	0.31
Current.Argo	3.21	7.60	2.37			
Future.Argo	8.55	15.66	1.83			
Current	38.66	113.23	2.93			
Future	44.00	113.85	2.59			

Sensitivity Analysis

Parameter perturbation

Option 1 :

$$SEE_i(C_V) = \frac{\partial C_V}{\partial x_i} \Big|_j \cdot \frac{\sigma_{x_i}}{\sigma_{C_V}}$$

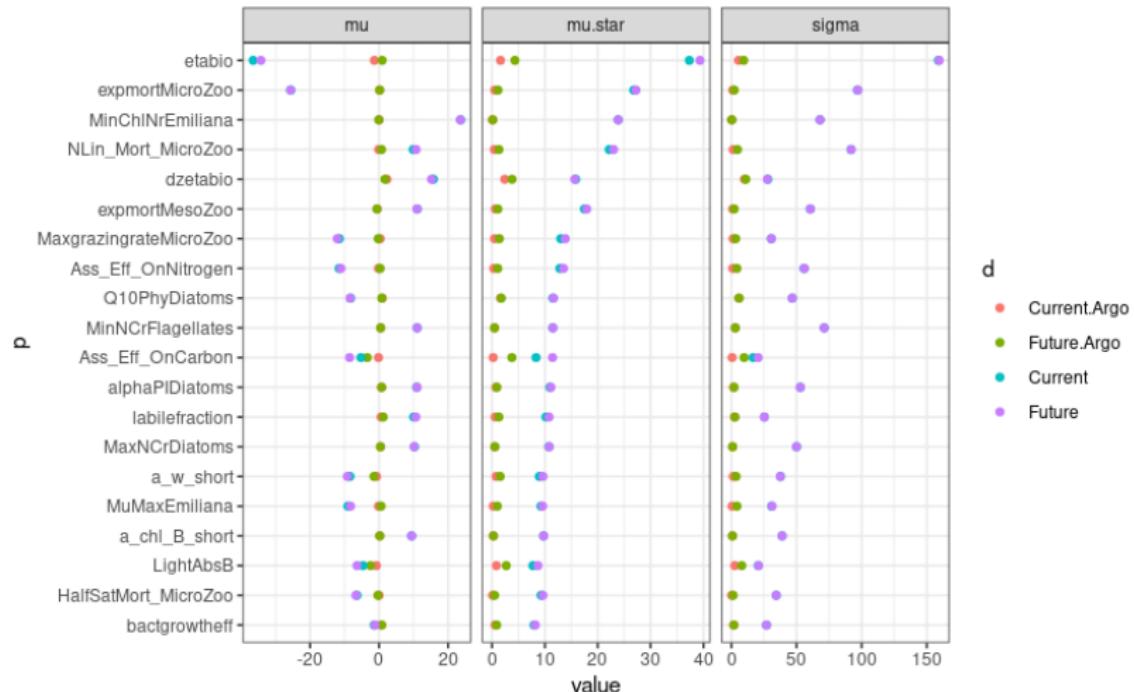


Sensitivity Analysis

Parameter perturbation

Option 2 :

$$SEE_j^i(C_V) = \frac{\partial C_V}{\partial x_i} \Big|_j \cdot \frac{\sigma_{x_i}}{1}$$



Sensitivity Analysis

Constrain

Combining Sensitivity and Controlability results we define a Constrain Score

→ How relevant is a given sampling set for constraining the simulation of a given diagnostic ?

$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^*(\text{Cost}_v) \cdot \mu_i^*(\text{Diag}_k)$$

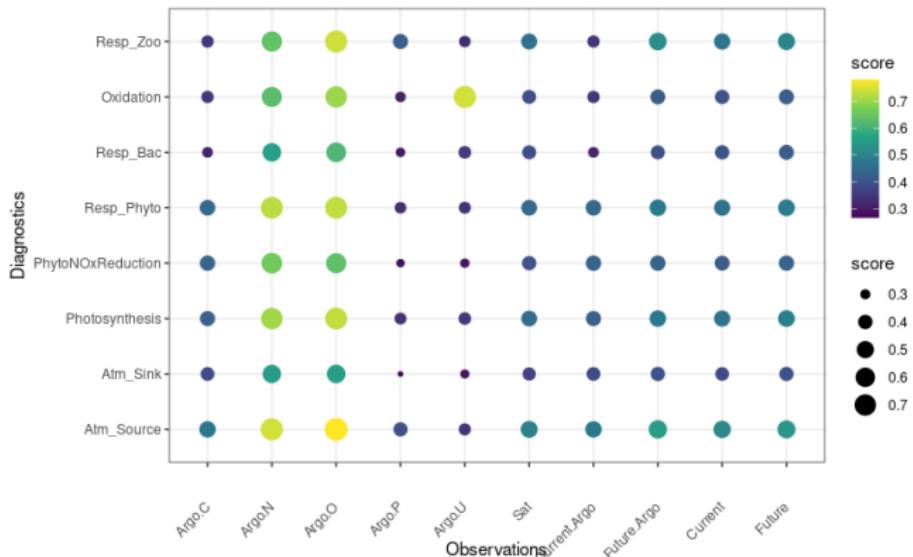
Sensitivity Analysis

Constrain

$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^*(\text{Cost}_v) \cdot \mu_i^*(\text{Diag}_k)$$

Option 1 :

$$SEE_i^j(c_v) = \frac{\partial c_v}{\partial x_i} \Big|_j \cdot \frac{\sigma_{x_i}}{\sigma_{c_v}}$$



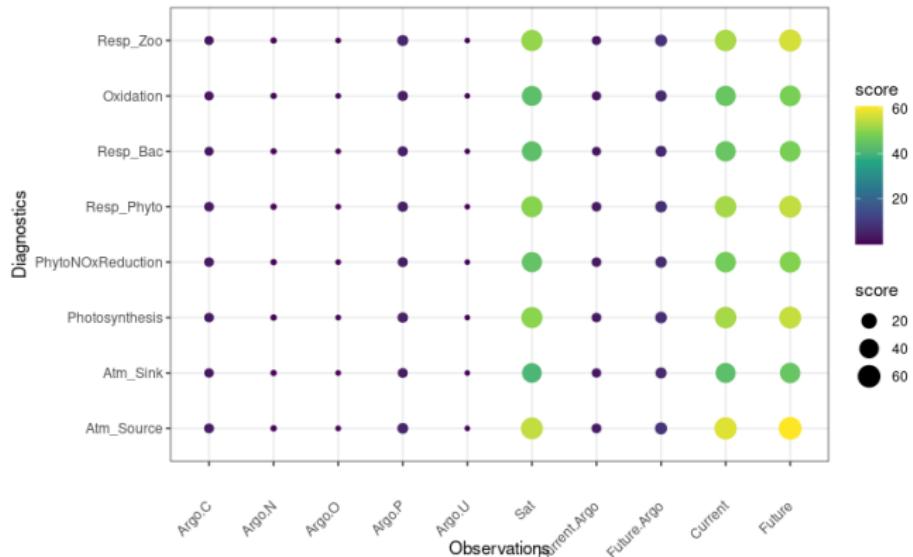
Sensitivity Analysis

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$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^*(\text{Cost}_v) \cdot \mu_i^*(\text{Diag}_k)$$

Option 2 :

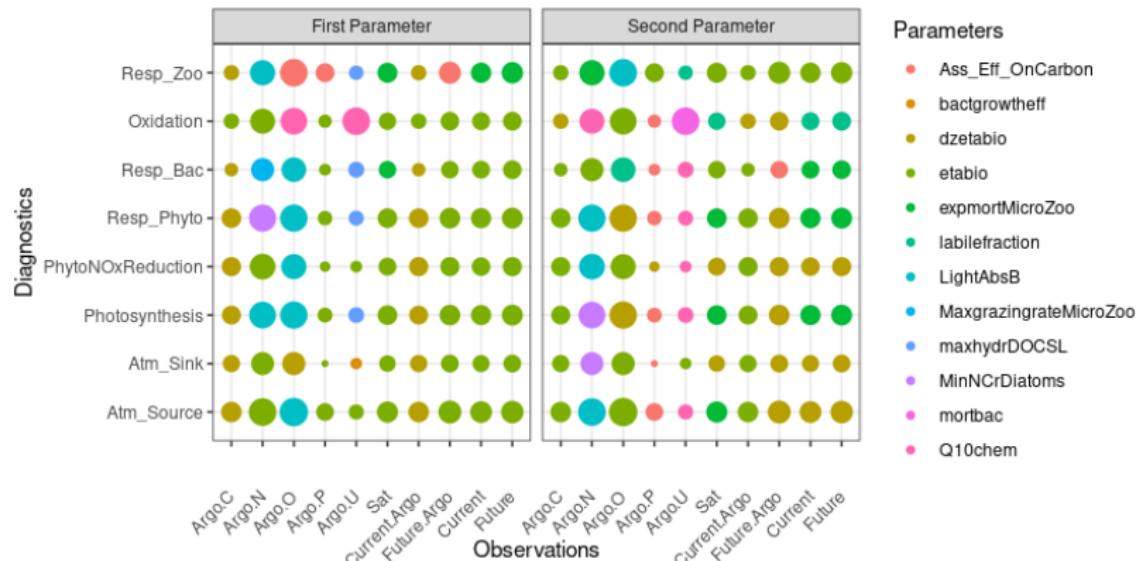
$$SEE_i^j(c_v) = \frac{\partial C_v}{\partial x_i} \Big|_j \cdot \frac{\sigma_{x_i}}{\sigma_1}$$



Sensitivity Analysis

Constrain

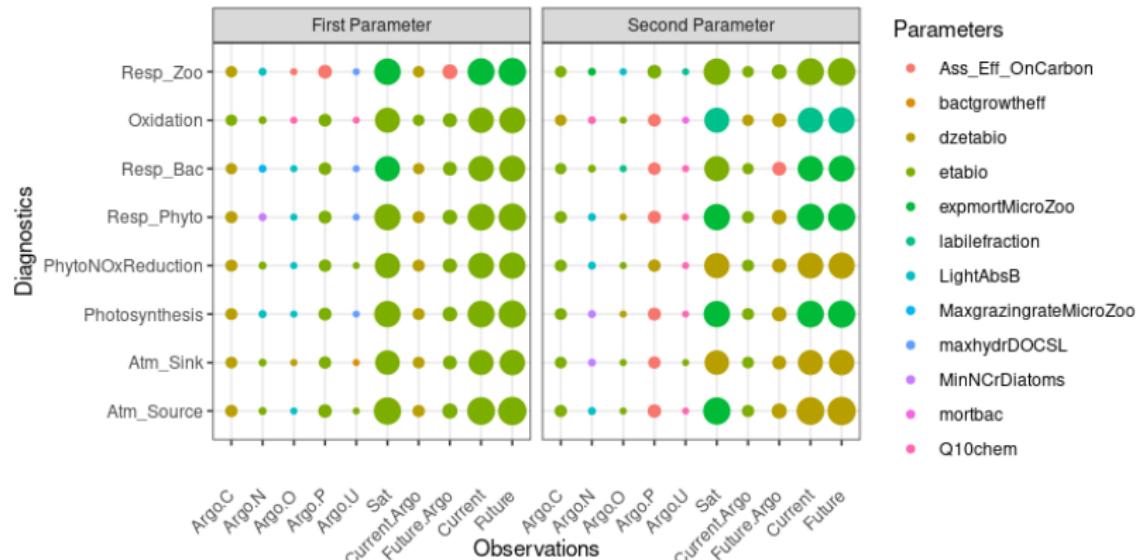
Finally, what parameter should we focus on ?



Sensitivity Analysis

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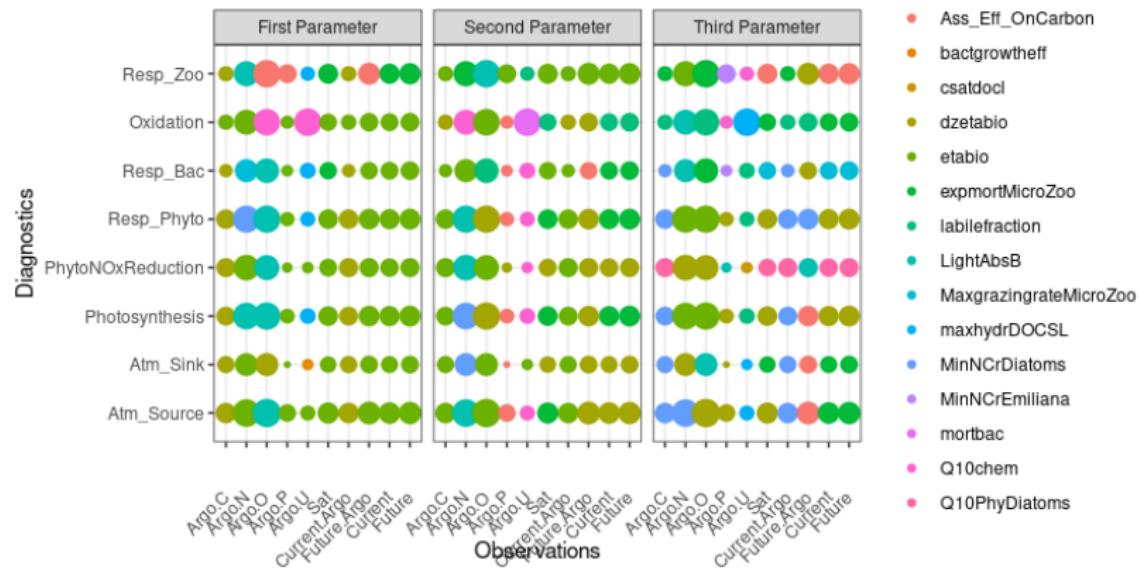
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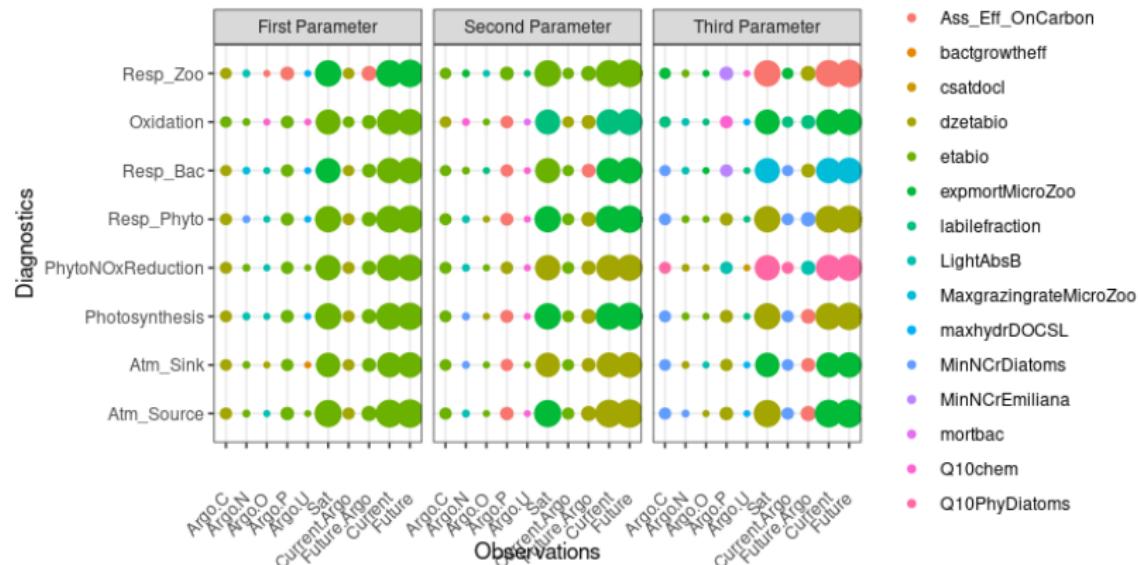
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Sensitivity Analysis

Constrain

Finally, what parameter should we focus on ?



Sensitivity Analysis

Constrain

- ◊ Photosynthesis
 - params. involved in the sedimentation rate of particulate matter.
 - Minimum N:C ratio in Coccolithophores.
 - Mineralisation rate for dissolved organic matter.
- ◊ Bacterial Respiration
 - Grazing rate of zooplankton groups.
 - Fractionation of irradiance in spectral bands.
 - Fraction of excretion in labile/semi-labile pools.

Sensitivity Analysis

Summary

$$\frac{\partial y}{\partial x_i} \sim \frac{y(x_1, \dots, x_i + \Delta, \dots, x_p) - y(x_1, \dots, x_i, \dots, x_p)}{\Delta x_i}$$

Cost functions - Controlability

Diagnostics - Sensitivity

d_k : vert. & annual int. of BGC terms
 $\text{mol m}^{-2} \text{yr}^{-1}$

$$SEE_i^j(d_k) = \left. \frac{\partial d_k}{\partial x_i} \right|_j \cdot \frac{\sigma_{x_i}}{\sigma_{d_k}}$$

$$\mu_i^*(d_k) = \frac{1}{r} \sum_j |SEE_i^j(d_k)|$$

$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^*(\textcolor{red}{c_v}) \cdot \mu_i^*(\textcolor{orange}{d_k})$$

$$c_v = \frac{1}{N_v} \sum_{i=1}^{N_v} \left(\frac{v_i^O - v_i^M}{\sigma_{v^O}} \right)^2$$

$c = \sum c_v$, for multivar.

$$SEE_i^j(c_v) = \left. \frac{\partial c_v}{\partial x_i} \right|_j \cdot \frac{\sigma_{x_i}}{\sigma_{c_v}}$$

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Conclusions

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- ◇ Oxygen profiles only poorly helps in constraining BGC oxygen processes (in a parameter-based approach).

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- ◊ Autonomous samplings of POM and nitrate will largely help in that regard.

Conclusions

- ◊ Oxygen profiles only poorly helps in constraining BGC oxygen processes (in a parameter-based approach).
- ◊ Autonomous samplings of POM and nitrate will largely help in that regard.
- ◊ Meanwhile, we should focus on chlorophyll samplings.

Low Salinity Flora
Odega Bay, Sonoma, CA

Thank you for your attention ..
.. and questions !



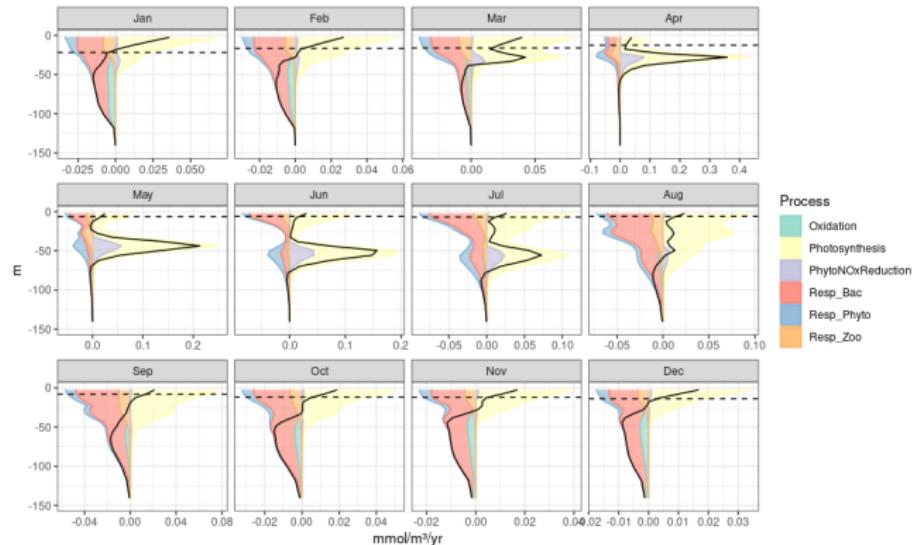
acapet@uliege.be

Biogeochemical Sink/Source Terms

- ◊ Interface Fluxes
- ◊ Photosynthesis
- ◊ Respiration
- ◊ Oxidation

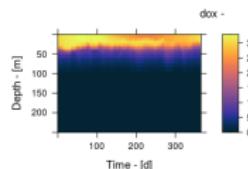
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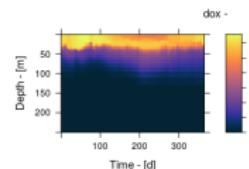


Testing vertical advection. Oxygen

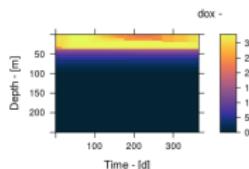
3D



1D-Vert. Adv.



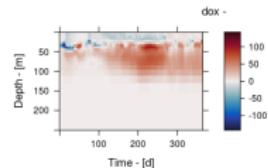
1D-No Vert. Adv.



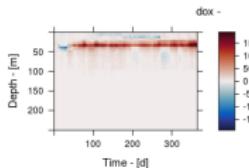
Map



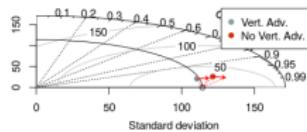
BIAS -Vert. Adv.



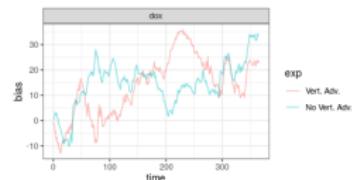
BIAS -No Vert. Adv.



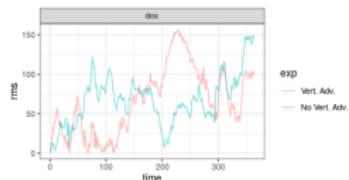
Stats



BIAS(upper 200m)

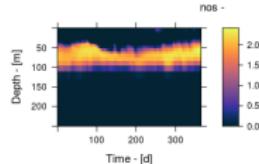


RMS(upper 200m)

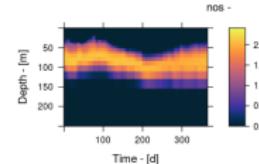


Testing vertical advection. Nitrate

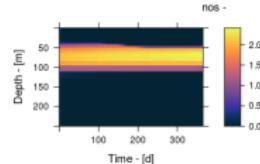
3D



1D-Vert. Adv.



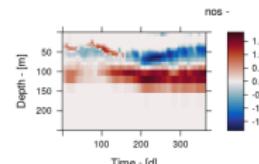
1D-No Vert. Adv.



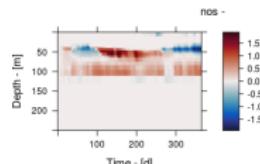
Map



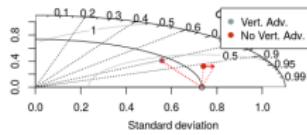
BIAS -Vert. Adv.



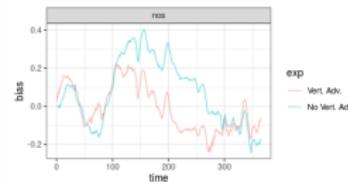
BIAS -No Vert. Adv.



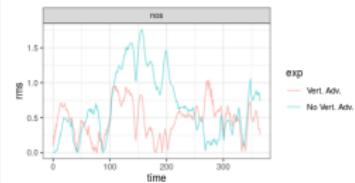
Stats



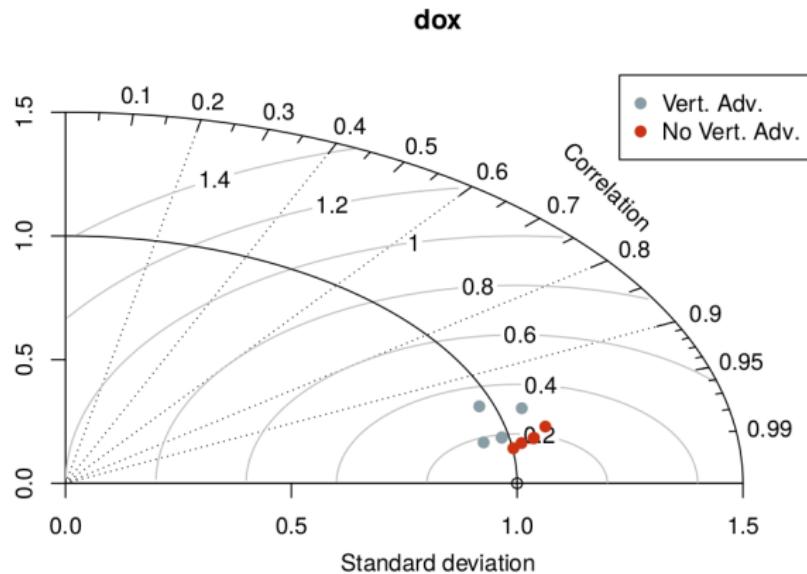
BIAS(upper 200m)



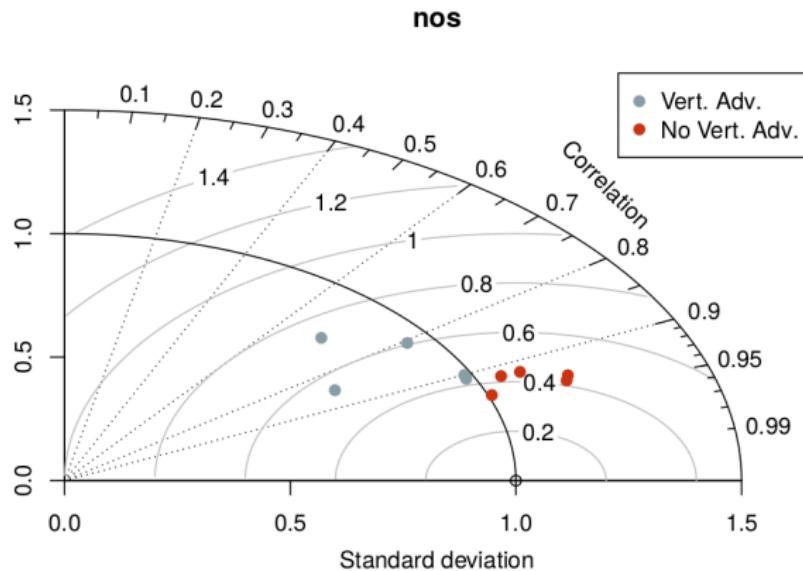
RMS(upper 200m)



Testing vertical advection. Oxygen

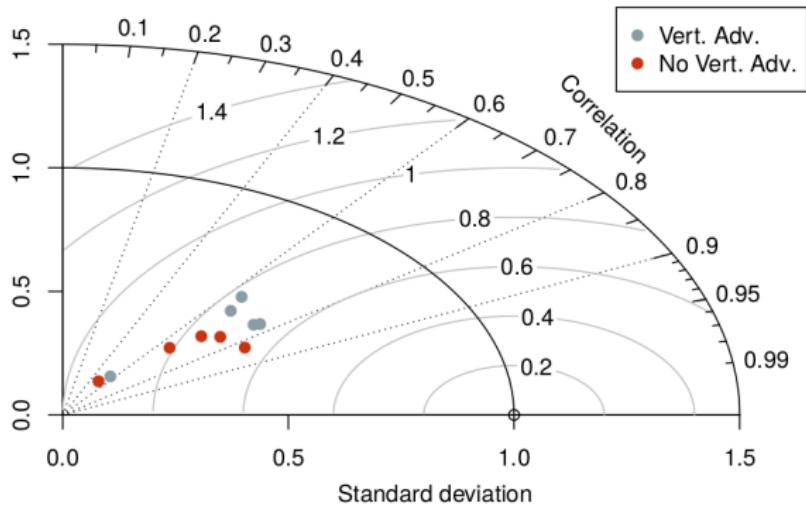


Testing vertical advection. Nitrate



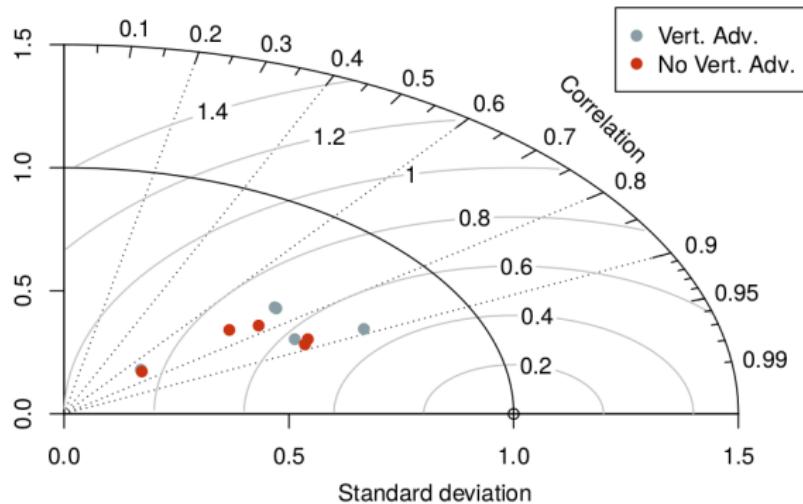
Testing vertical advection. Photosynthesis

Photosynthesis

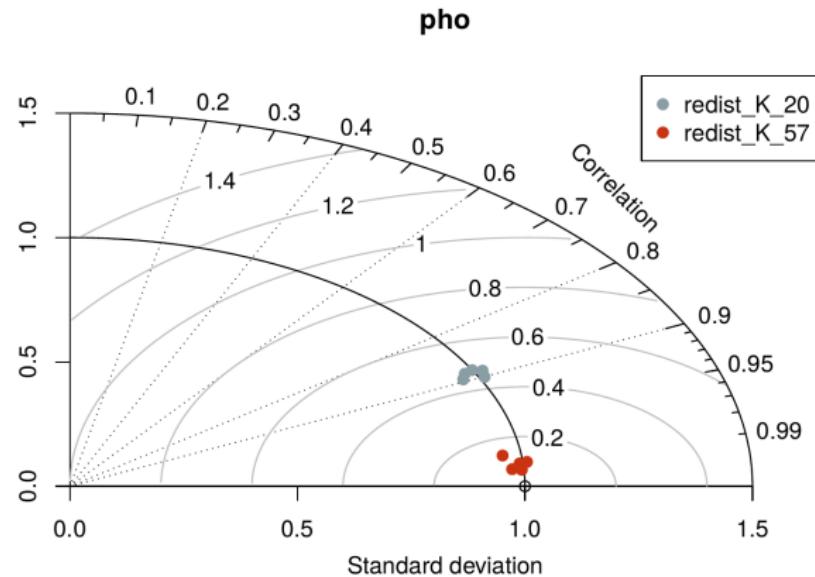


Testing vertical advection. Bacterial Respiration

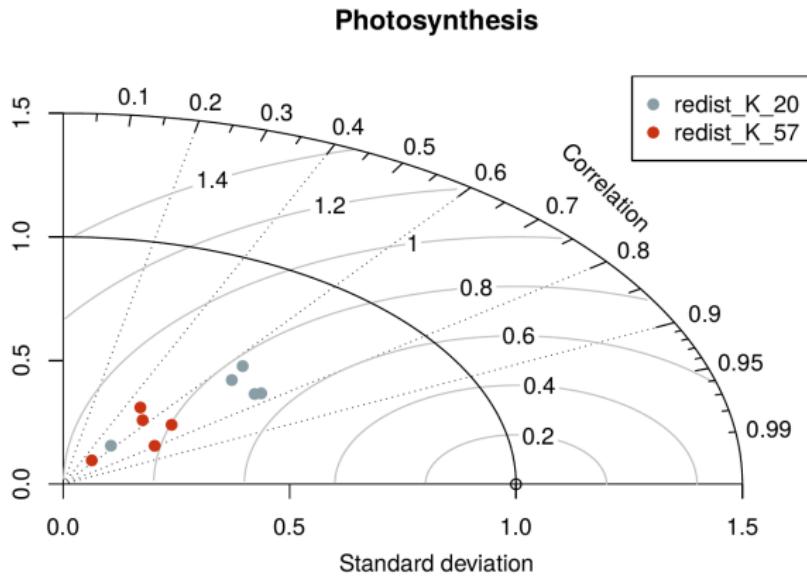
Resp_Bac



Phosphate Testing redistribution of sinking material.

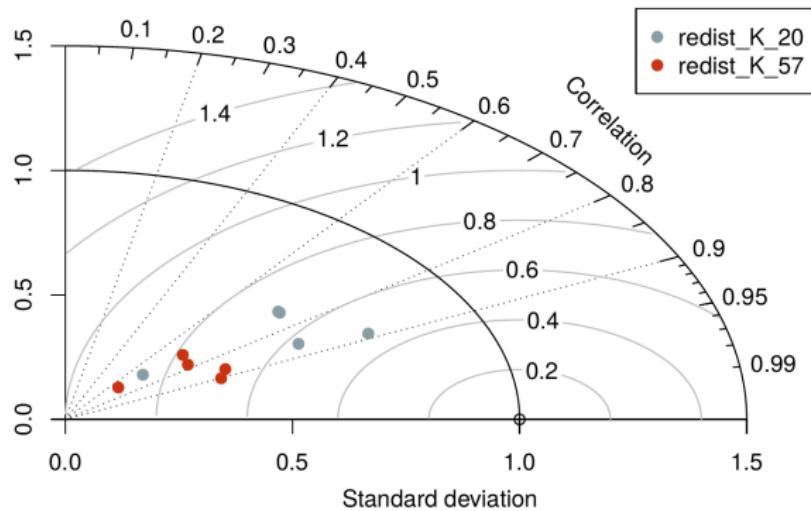


Photosynthesis Testing redistribution of sinking material.



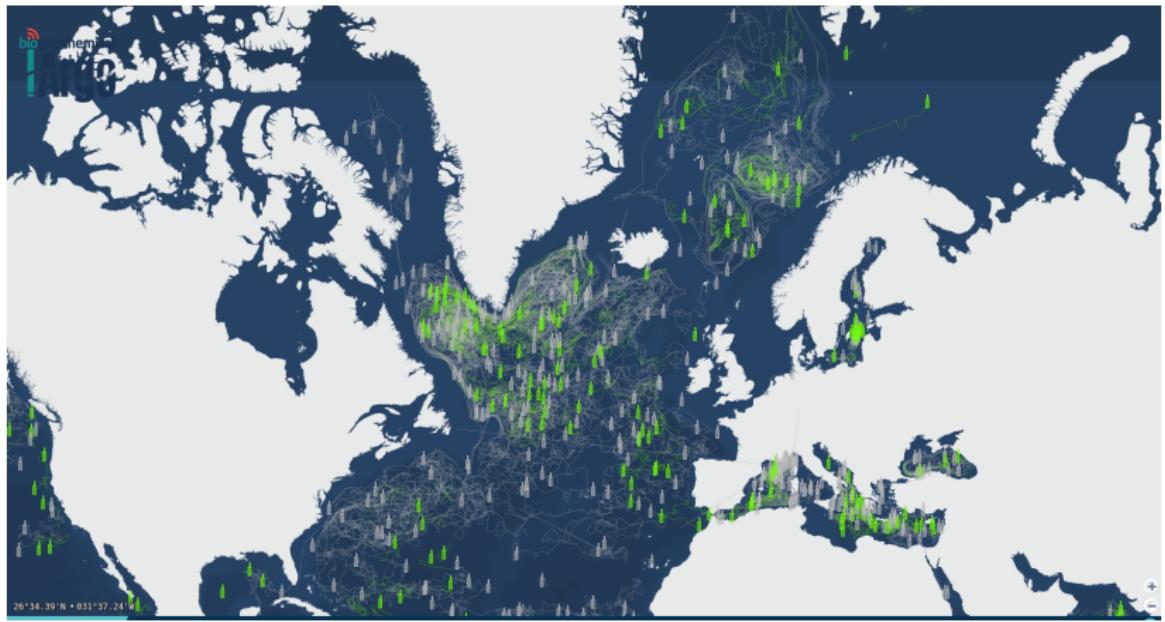
Bacterial Respiration Testing redistribution of sinking material.

Resp_Bac

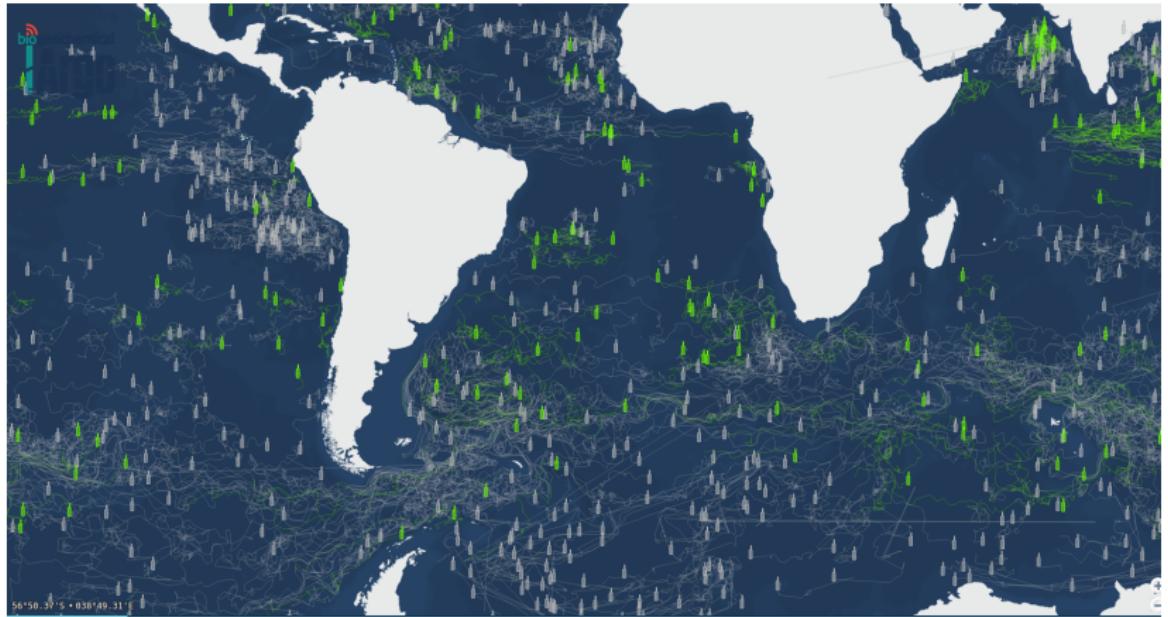




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