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

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A sensitive environment

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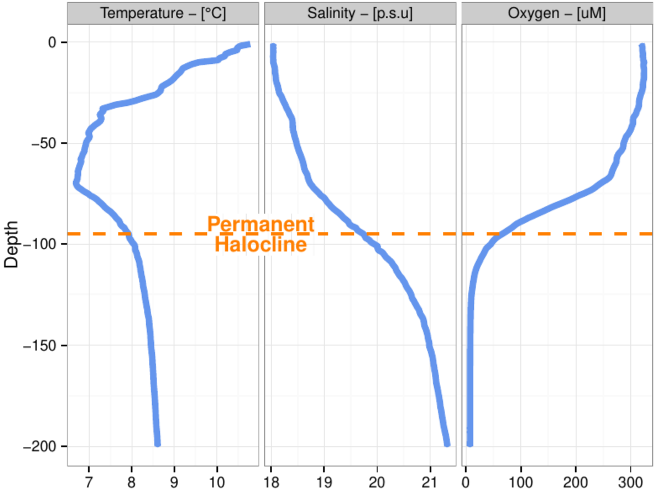

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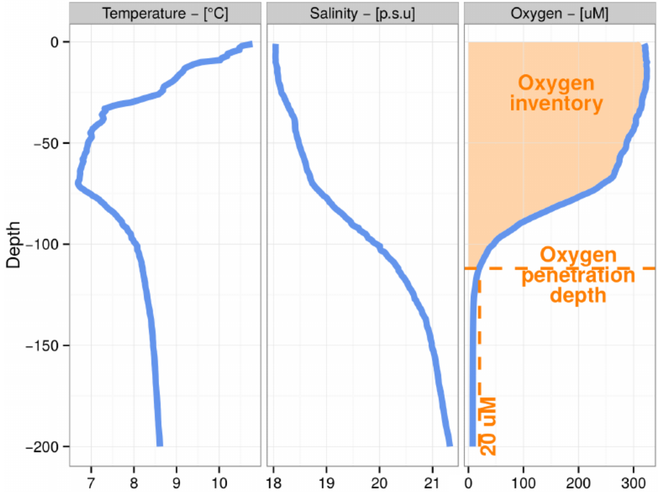

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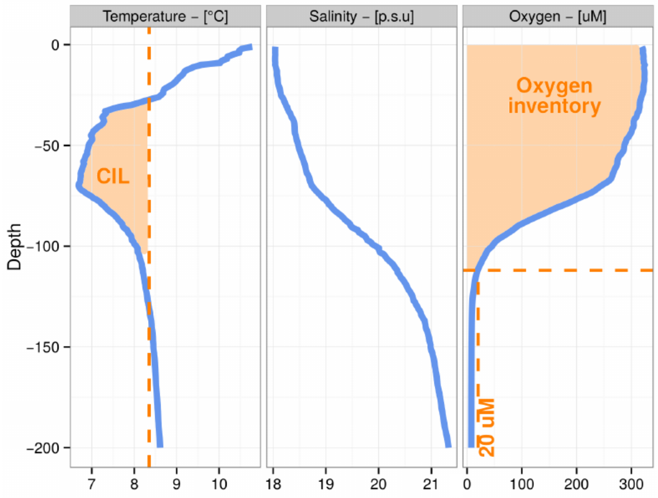
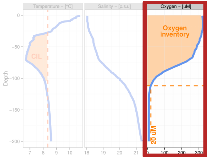
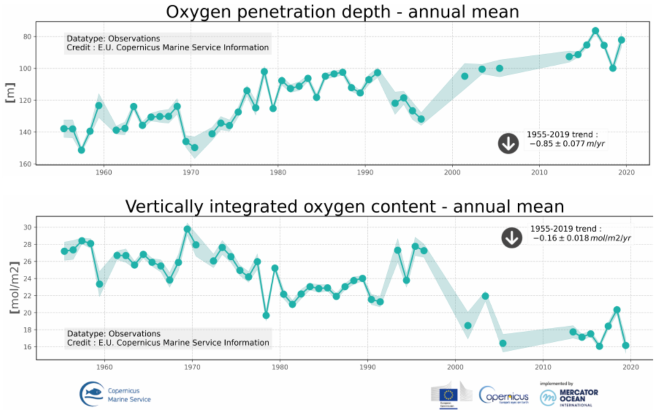


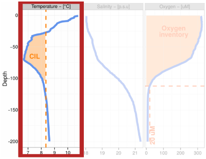
General Context

Oxygen decline

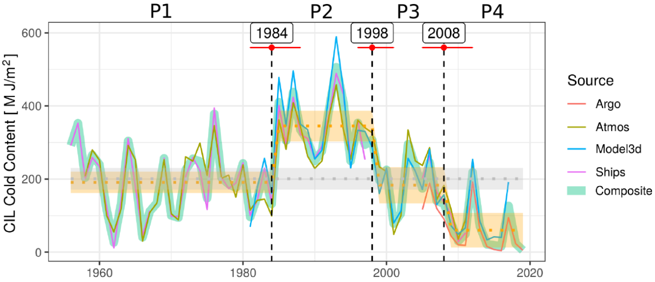




CMEMS OMI, 2020



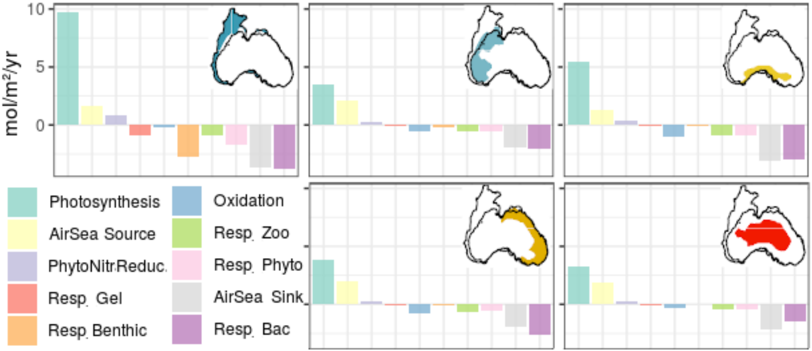
Ventilation by Cold Water formation.



Capet et al. 2016, *Biogeoscience*

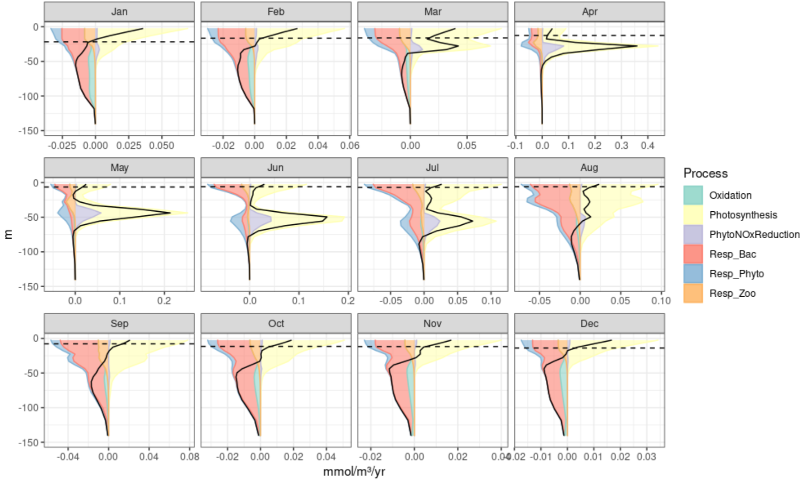
Biogeochemical Sink/Source Terms

- Interface Fluxes
- Photosynthesis
- Respiration
- Oxidation



General Context

Oxygen decline : Processes



Objectives

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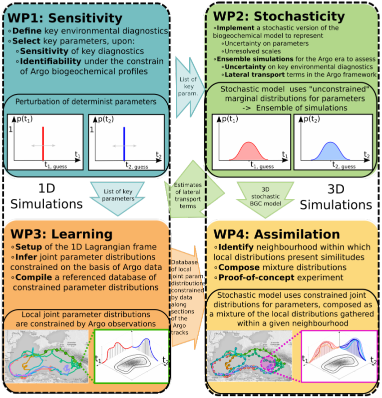
The Albatros Project

- Better constrain BGC terms in the O_2 budget.
- Parameter-based stochastic approach.
- Enable long-term training of paramer local variations.



Given a set of key processes :

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

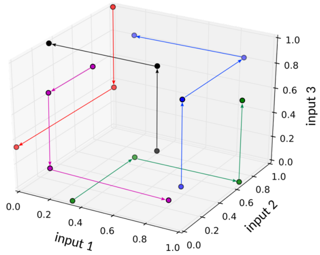
Sensitivity Analysis

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

Grégoire et al. 2008; Capet et al. 2016; CMEMS documentation

Sensitivity Analysis
Parameter perturbation

Global sensitivity analysis
→ Morris Screening
Parameter perturbations (50–150%)



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

Morris, 1991 ; Campolongo et al., 2007

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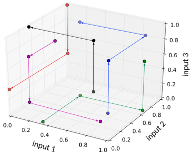

- 188 parameters *x* 40 repetitions → 7440 1D simulations.
- For any model output y :

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

- which is summarized as :

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

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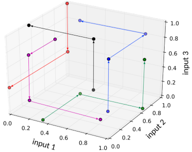

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- Sensitivity and Controlability are adressed with specific y

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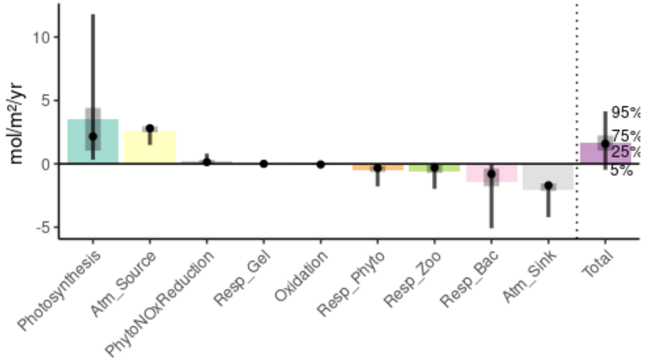
Morris, 1991 ; Campolongo et al., 2007

Sensitivity Analysis
Parameter perturbation

For Sensitivity we consider the O_2 sources/sink terms.



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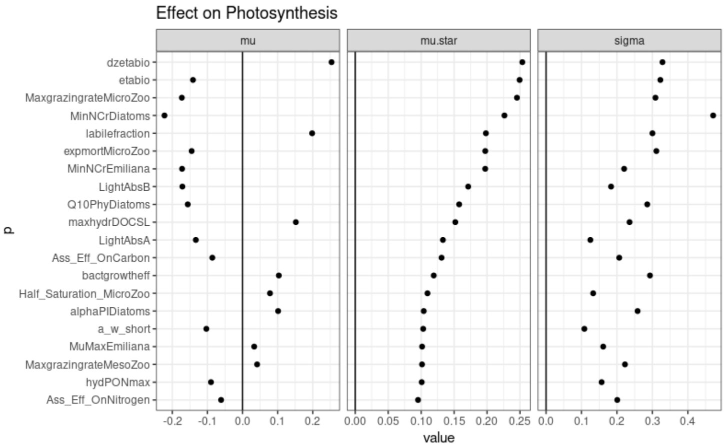

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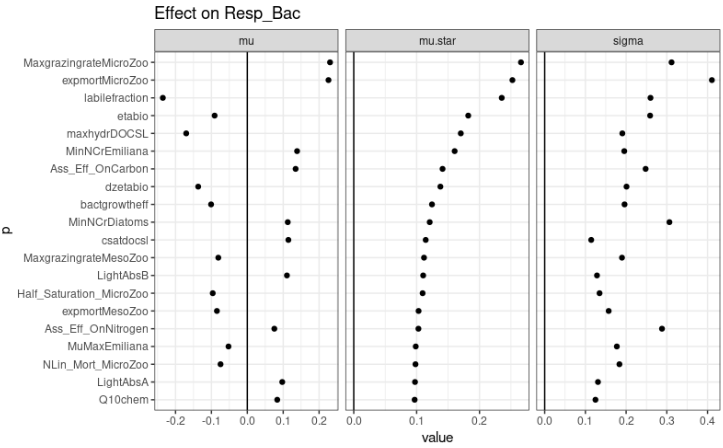
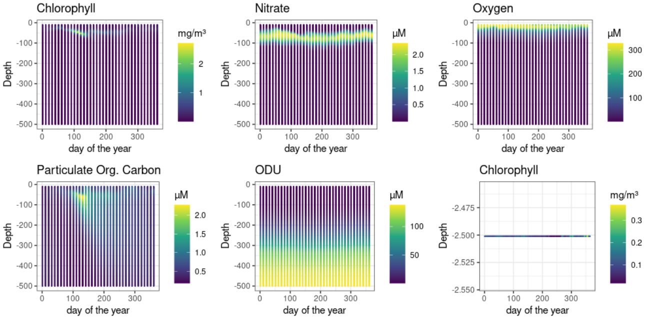


Sensitivity Analysis

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

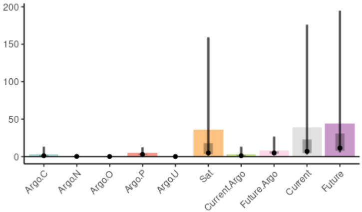
Parameter perturbation

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

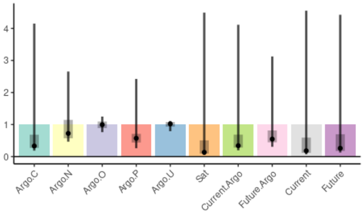
$$c = \sum c_v, \text{ for multivar.}$$

Multi-var. sets :

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



Range of values.



Divided by mean value.

Sensitivity Analysis

Parameter perturbation

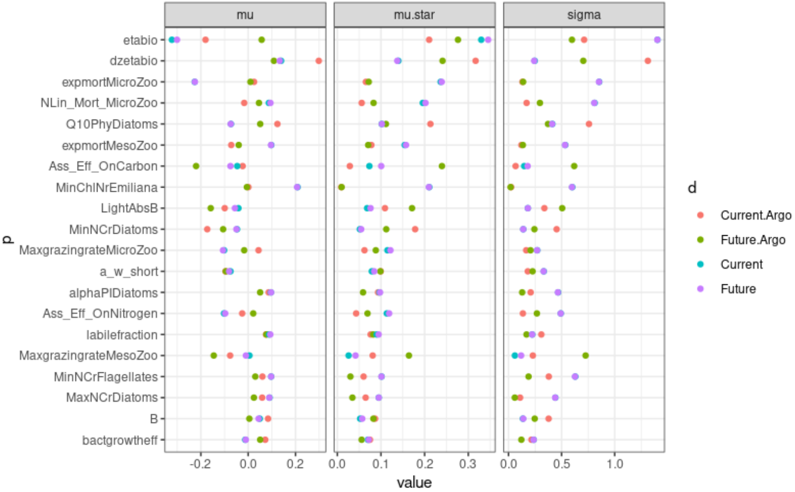
variable	mean.cost	sd.cost	CV.cost	Nobs	mean.sRMS	mean.RMS
Argo.C	3.17	7.60	2.40	18167	1.78	0.26
Argo.N	0.27	0.18	0.67	18167	0.52	0.29
Argo.O	0.04	0.01	0.15	18167	0.19	12.53
Argo.P	5.07	13.92	2.75	18167	2.25	0.63
Argo.U	0.00	0.00	0.15	18167	0.04	2.25
Sat	35.45	111.57	3.15	365	5.95	0.31
Current.Argo	3.21	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 :

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

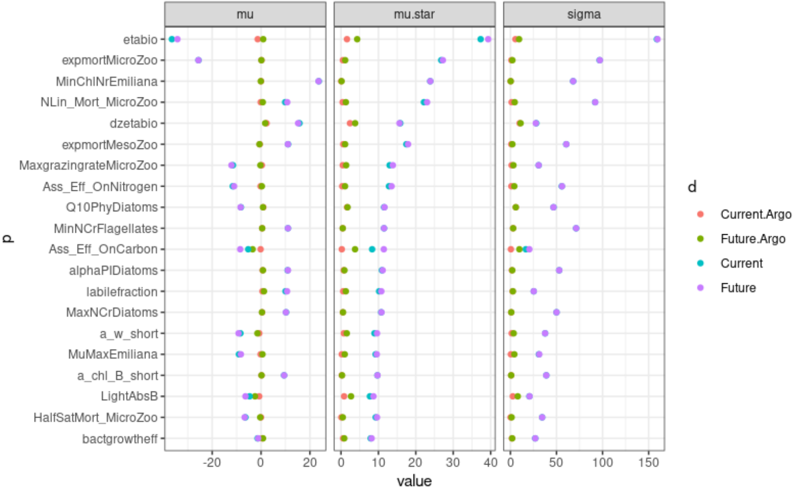


Sensitivity Analysis

Parameter perturbation

Option 2 :

$$SEE_i^j(c_v) = \left.\frac{\partial c_v}{\partial x_i}\right|_j \cdot \frac{\sigma_{x_i}}{1}$$



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 ?

$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^*(Cost_v) \cdot \mu_i^*(Diag_k)$$

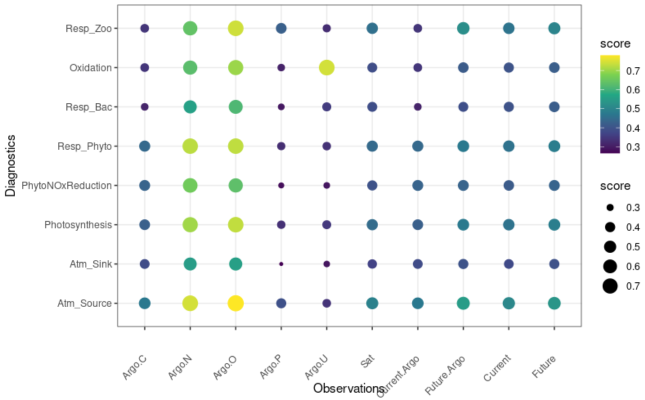
Sensitivity Analysis

Constrain

$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^* (Cost_v) \cdot \mu_i^* (Diag_k)$$

Option 1 :

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



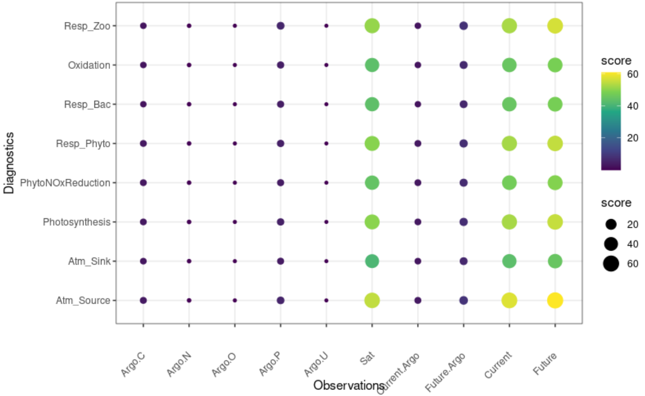
Sensitivity Analysis

Constrain

$$C_{k,v} = \sum_{i \in \mathcal{P}} \mu_i^*(Cost_v) \cdot \mu_i^*(Diag_k)$$

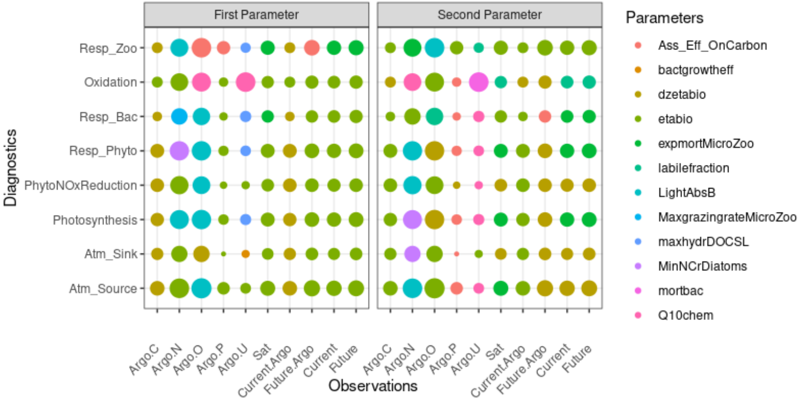
Option 2 :

$$SEE_i^j(c_v) = \left.\frac{\partial c_v}{\partial x_i}\right|_j \cdot \frac{\sigma_{x_i}}{\sigma_1}$$



Sensitivity Analysis
Constrain

Finally, what parameter should we focus on ?



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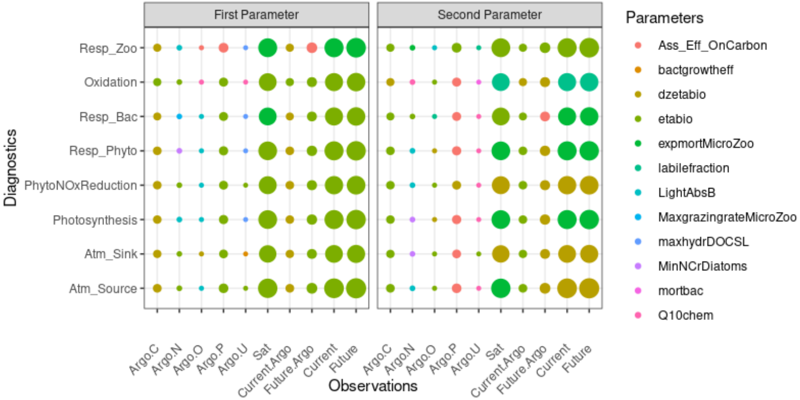

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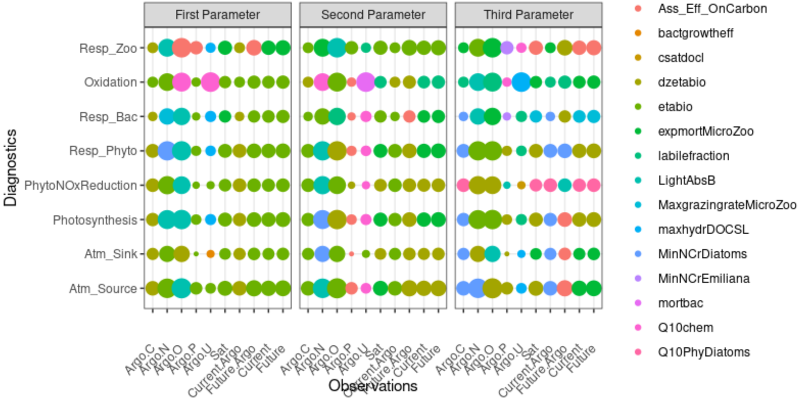

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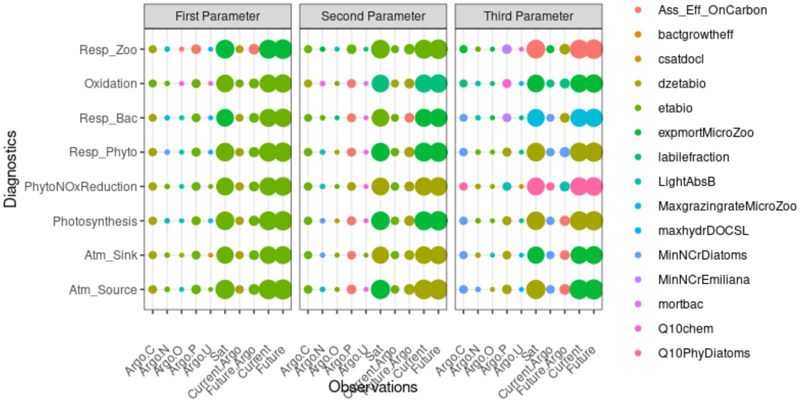

Sensitivity Analysis

- 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.

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

Diagnostics - Sensitivity

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

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

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

Cost functions - Controlability

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

$$c = \sum c_v, \text{ for multivar.}$$

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

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

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

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.

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- Autonomous samplings of POM and nitrate will largely help in that regard.
- Meanwhile, we should focus on chlorophyll samplings.

Thank you for your attention ..

.. and questions !

MAST

acapet@uliege.be

Biogeochemical Sink/Source Terms

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- Photosynthesis
- Respiration
- Oxidation

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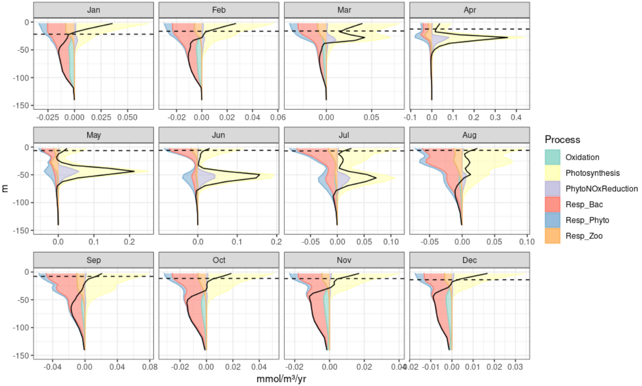
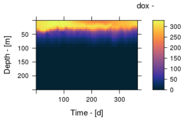
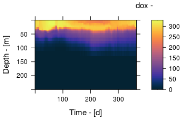


Testing vertical advection. Oxygen

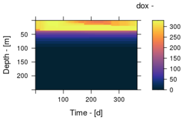
3D



1D-Vert. Adv.

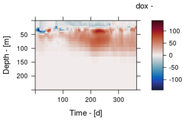


1D-No Vert. Adv.



Map

BIAS -Vert. Adv.



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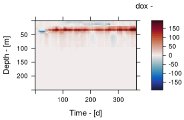
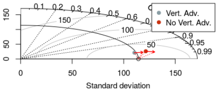
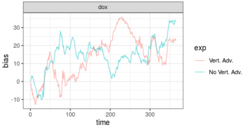


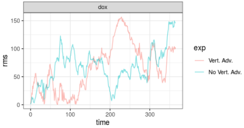
Stats



BIAS(upper 200m)

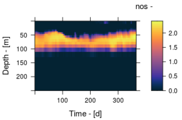


RMS(upper 200m)

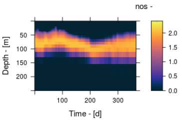


Testing vertical advection. Nitrate

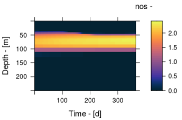
3D



1D-Vert. Adv.



1D-No Vert. Adv.



Map

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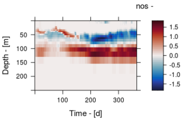

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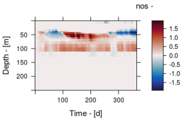

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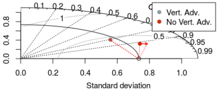
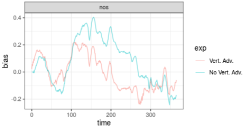
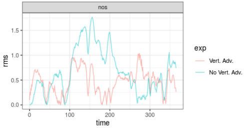


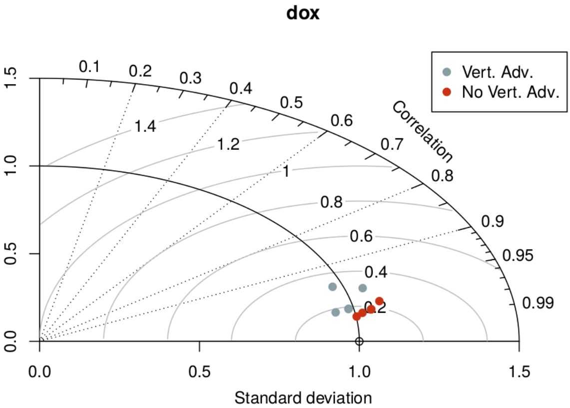
BIAS(upper 200m)



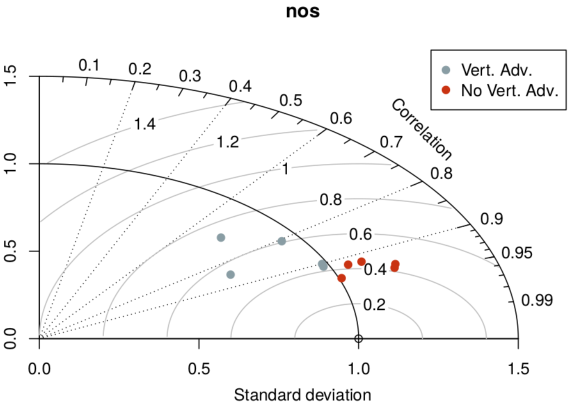
RMS(upper 200m)



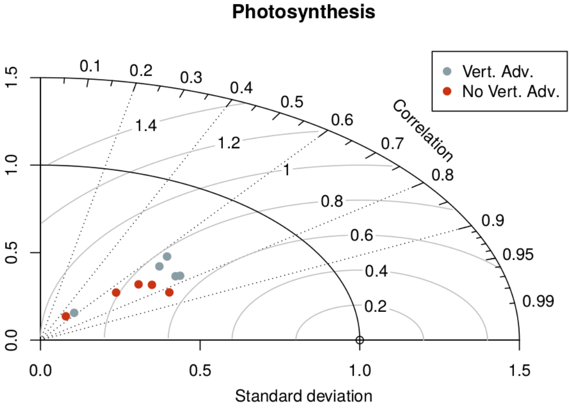
Testing vertical advection. Oxygen



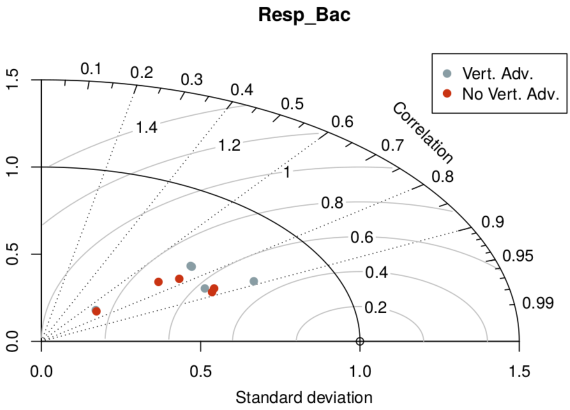
Testing vertical advection. Nitrate



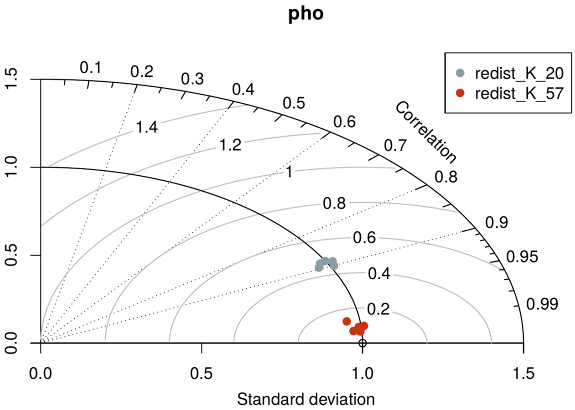
Testing vertical advection. Photosynthesis



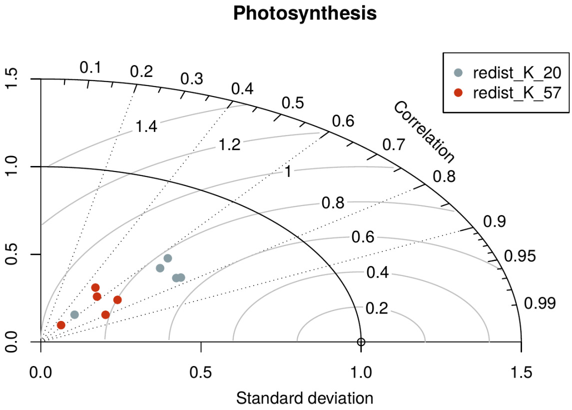
Testing vertical advection. Bacterial Respiration



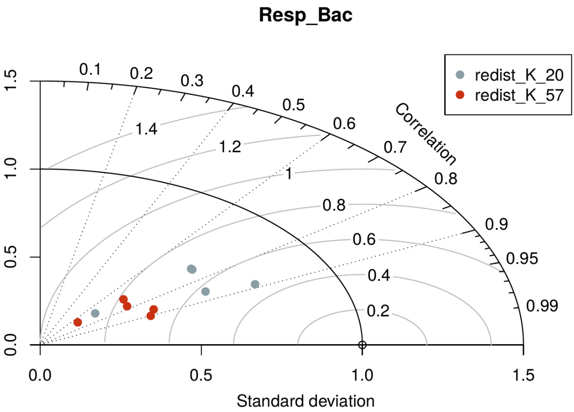
Phosphate Testing redistribution of sinking material.

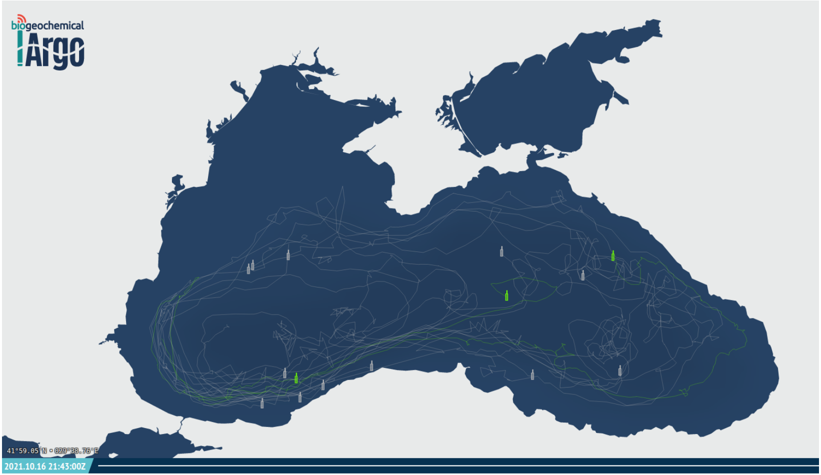


Photosynthesis Testing redistribution of sinking material.

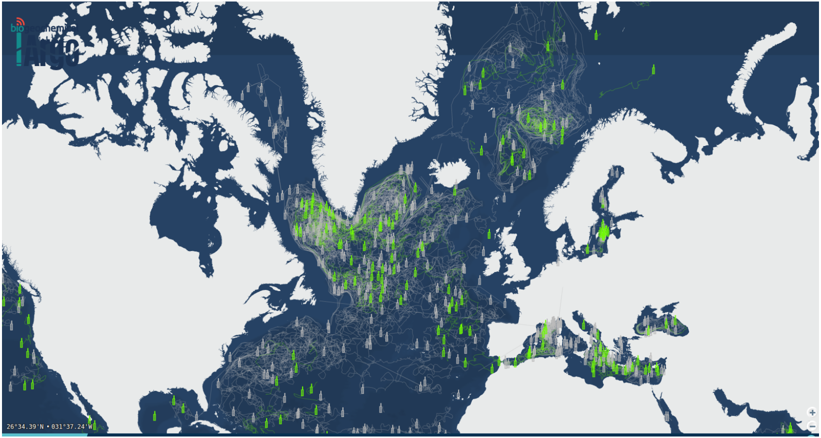


Bacterial Respiration Testing redistribution of sinking material.





https://maps.biogeochemical-argo.com/bgcargo/



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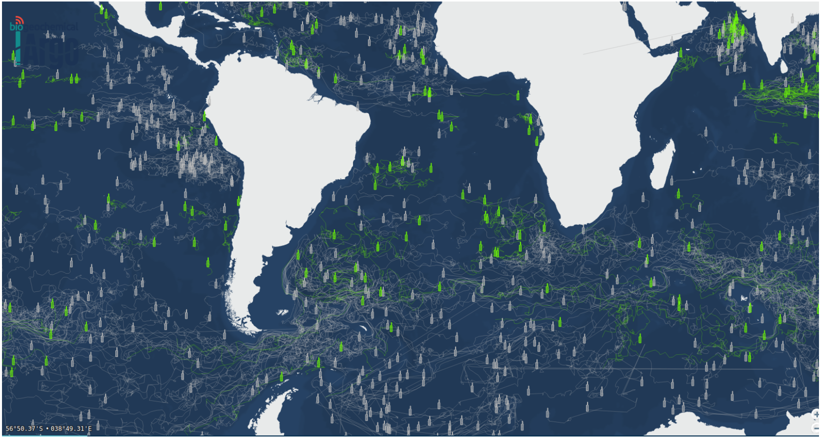

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